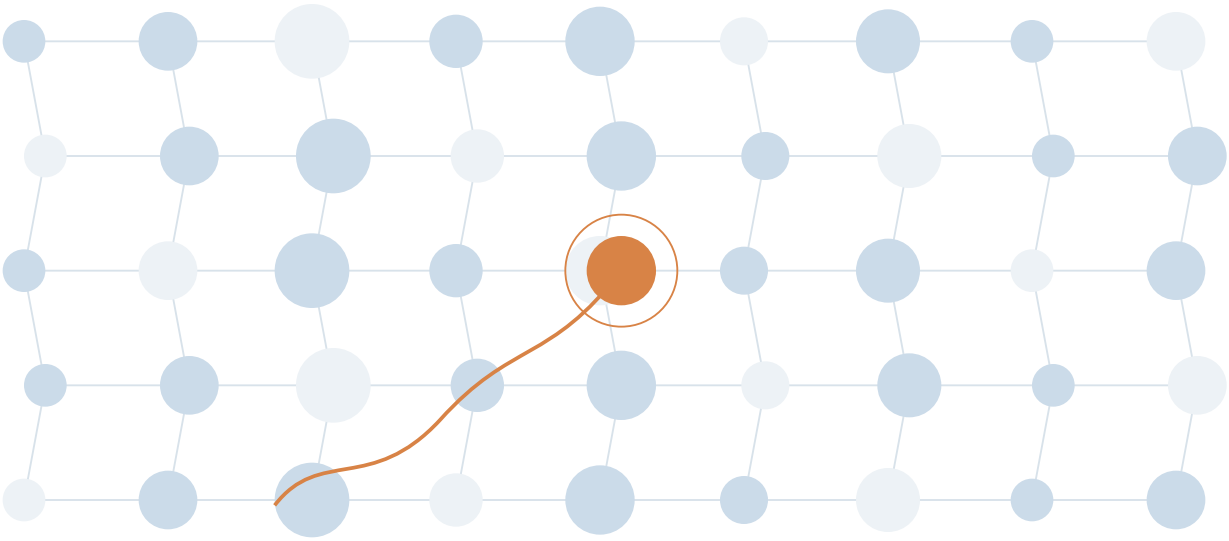
A NATIVE LABORATORY FOR PARTICLE SYSTEMS

Granular LAB

User Manual

VERSION 2.0 / macOS



Explore motion. Measure locally. Compare systematically.

Granular systems and active matter

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English edition / October 2026

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01 Start here

A laboratory you can explore

Granular LAB brings particle simulations, live measurements and reproducible experiments into a native macOS workspace. Start with a physical question, choose a preset, and move between the motion of individual grains and the response of the whole system.

Version 2.0 adds a closer connection between simulation and measurement: four Inspect tools, a family of active-matter experiments, live comparisons, parallel batch studies and native .glab projects.

Choose a way into the manual

If you want to...	Begin with...
Understand the screen	The workspace
Run a short experiment	A first measured run
Follow a particle or measure a region	Inspect
See fields, contacts and force networks	Analysis
Compare parameter values	Run Comparison
Save work for later	Projects and recordings
Export figures or numerical data	Choose an export
Find an experiment	Preset reference

What this edition covers

This English manual describes Granular LAB 2.0.0. It follows the current public preset catalog and the controls available in the app. Some capabilities depend on the selected preset or simulation backend; a disabled control is not a promise that the feature is available elsewhere in that experiment.

The app requires macOS 14 or later. Simulations, projects and this manual work locally without a network connection. Website and literature links require internet access.

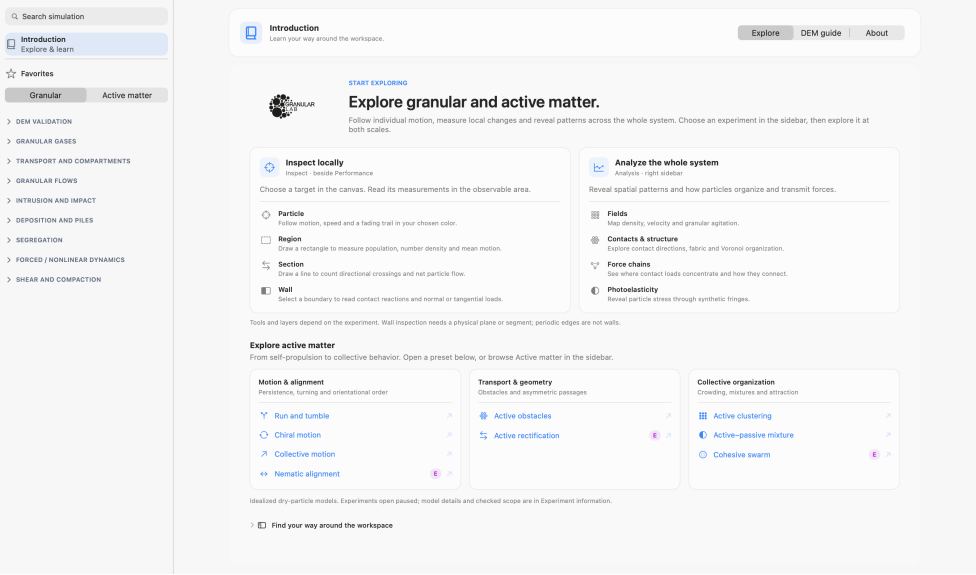
Open **Help > User Manual (PDF)** at any time. Use your PDF reader's outline, the linked contents, or text search to find a control. Menu paths and control names in this book use the English interface. Numerical formatting may follow your Mac's locale.

> A runnable preset is not automatically a calibrated material model. Read its assumptions and numerical notes before treating an observation as a scientific result.

01 Start here

Explore before you run

The Introduction page offers three entry points: **Explore**, **DEM guide** and **About**. Explore connects the app's measurement tools with experiments you can open directly.



Explore introduces local inspection, whole-system analysis and the active-matter family. This native view capture shows the navigation structure.

Two complementary scales

Inspect asks a local question: what is this particle doing, how many grains occupy this rectangle, how many cross this line, or what load reaches this wall?

Analysis asks a spatial question about the current simulation: where is the material dense, how does velocity vary, which contacts carry force, and how is the contact network organized?

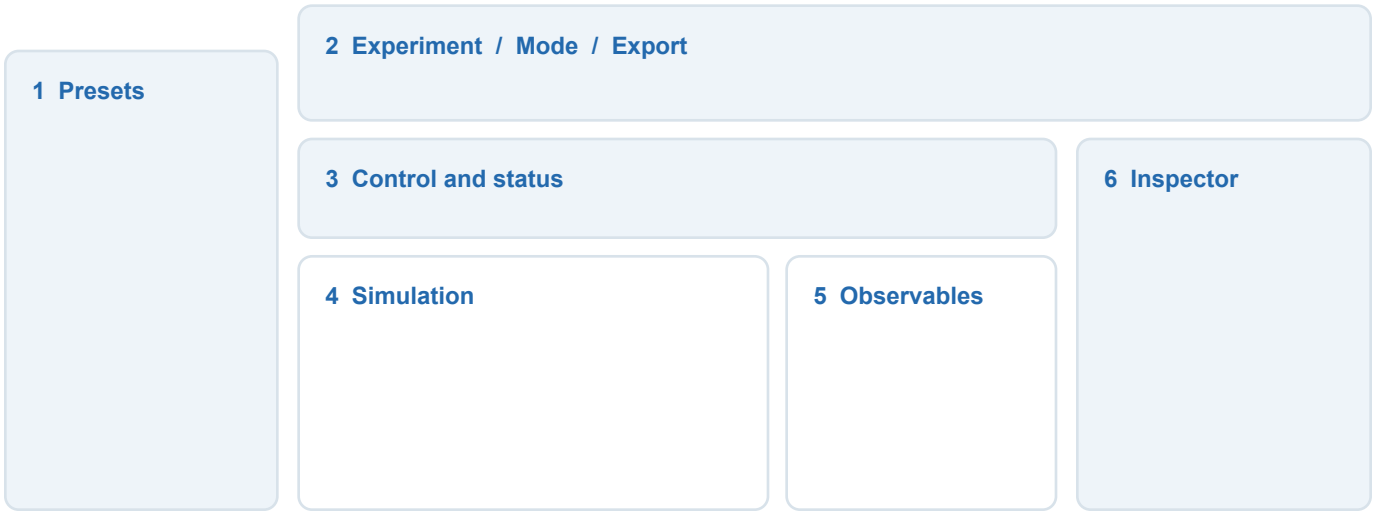
The active-matter section groups motion and alignment, transport through geometry, and collective organization. These are starting points for exploration, not a claim that all nine experiments model the same physical system.

Expand the workspace guide for a tour of navigation, controls and outputs. Open the DEM guide for equations, assumptions and references. About provides app identity, development information and scope.

01 Start here

The workspace

The main window has a stable visual hierarchy. Experiment selection is on the left, the simulation and its measurements occupy the center, and configuration stays on the right.



Workspace map - schematic, not a screenshot

Zone	What you do here
1. Preset sidebar	Search experiments, open a family, choose a preset or mark a favorite.
2. Workspace toolbar	Identify the experiment; switch Mode; export; change appearance or show the inspector.
3. Control and status	Play, pause, step, reset and prepare; inspect color scaling, numerical health and performance.
4. Simulation canvas	Observe physical motion, geometry, time, particle count and scale. Select local instruments here.
5. Observable cards	Choose measured quantities and read their histories. Inspect reuses this space when active.
6. Configuration inspector	Change the experiment, particle properties, forcing, appearance, analysis and numerical settings.

The arrangement of observable cards depends on the experiment and available space. Some sit beside the canvas; others form a row below it. A smaller window can change label placement and chart arrangement without changing the physical domain.

> Resizing or zooming the view does not resize the experiment. Read the scale bar and geometry controls to determine physical lengths.

01 Start here

Find the right experiment

1. Choose **Granular** or **Active matter** in the sidebar.
2. Expand a group to see its presets. Granular experiments are organized by physical theme, such as transport, deposition or shear.
3. Click a preset name. The app constructs its initial state and exposes the appropriate controls and observables.
4. Read **Experiment information** below the workspace. Its physical question, assumptions and references explain what the preset represents.
5. Use the star beside a preset to add it to **Favorites**. Use the search field to locate names without opening every group.

Read the signals beside a name

Signal	Meaning
No special maturity badge	The preset is implemented; this does not certify every parameter regime.
Validated	Explicit automated evidence supports a stated validation question.
Experimental / E	The preset runs, but its physical scope or long-run acceptance remains incomplete.
In development / Dev	A development feature that should not be treated as a validated scientific experiment.
Speed symbol	A guide to expected computational cost. Green, amber and red tones suggest relative speed, not numerical validity.

Use numerical health for stability and the performance readout for measured speed. A fast experiment can be under-resolved; a slow experiment can be numerically sound.

Keep changes intentional

Selecting a different experiment changes the active setup. Save numerical results or create a project before leaving work you want to retain. A favorite records your navigation preference; it is not a saved simulation result.

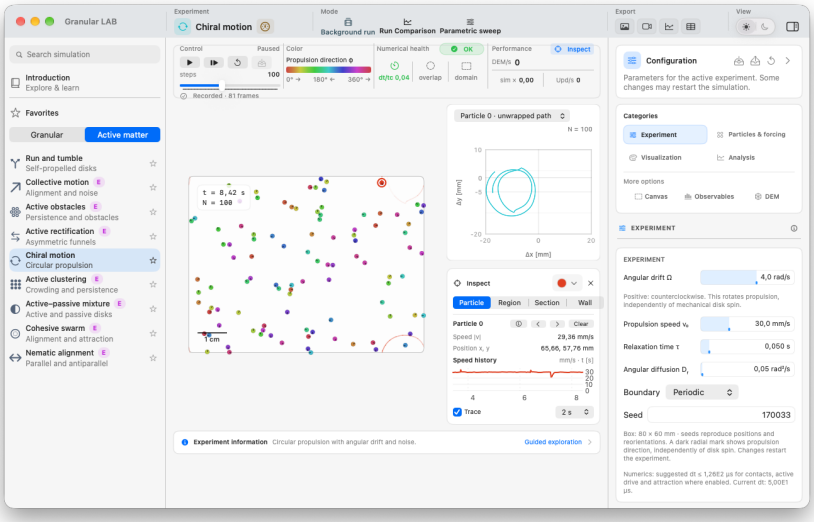
The preset reference covers every visible preset, its principal controls, recommended observables and the comparison or sweep parameters currently exposed.

02 Run and control

A first measured run

Use **Chiral motion** for a short example with a clear trajectory and inexpensive default population. This exercise takes only a small number of particles and does not need a settling stage.

1. Choose **Active matter > Chiral motion**. Start with its default 100 particles and periodic boundaries.
2. Read **Experiment information**. The angular drift rotates the propulsion direction; it is separate from mechanical disk spin.
3. Press **Play**. Watch simulation time advance and inspect **Numerical health**. Pause if a diagnostic needs attention.
4. Click **Inspect** beside Performance and choose **Particle**. Click a disk, or use **Select first particle**.
5. Choose a contrasting highlight color and enable **Trace**. Let the simulation advance for roughly 1-2 seconds of physical time.
6. Pause. Compare the visible path with **Speed history**. Change neither the timestep nor the initial condition merely to make the animation appear faster.
7. Close Inspect to restore the observable layout. Create a project or export an image if you want to keep this exploration.



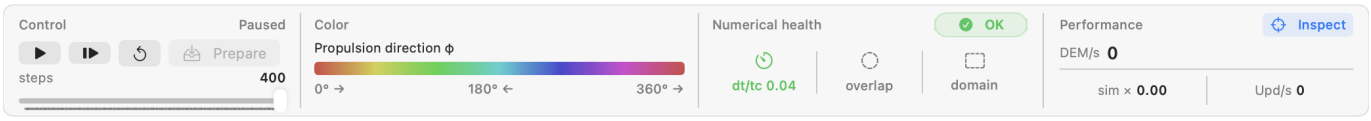
A native Chiral motion workspace with the Particle instrument. The periodic cell, direction colors, measured speed and selected trajectory are visible together.

> A periodic trajectory wraps visually at an edge. The active-matter MSD uses unwrapped displacement; a short path across the screen is not the same measurement as total traveled displacement.

02 Run and control

Control time deliberately

Control	Effect
Play / Pause	Advance the active simulation, or hold its current state for inspection.
Step	Advance a controlled batch while paused. The batch size follows the steps control.
Reset	Rebuild the experiment from its configured initial condition and clear the live histories.
Prepare	Construct or settle a suitable initial sample for presets that support preparation.
steps	Set DEM steps per displayed update. This changes the work between updates, not the physical timestep.



The actual control strip: execution, color, numerical health and Performance. Inspect has its own place at the right.

Three different clocks

Simulation time t is physical time, in seconds. **Wall time** is the time your Mac spends calculating. **Playback** controls how quickly recorded simulation time appears in a movie. These are distinct quantities.

In Performance, **DEM/s** reports integration steps per wall-clock second. **sim x** is the simulated-time rate relative to real time. **Upd/s** reports display updates. Changing steps per update can trade smooth interaction for throughput, while dt remains the physical integration interval.

Rebuilds and live edits

Geometry, population, particle size and some physical parameters require a new initial state. Other controls update the current system. Read the local note before editing during a run. Visualization and color choices are display controls and do not inject energy or modify contact laws.

A small mark identifies a parameter changed from the preset. Double-click its label, or use its context menu, to restore that parameter where supported. Point at supported geometry controls to highlight the corresponding dimension in the canvas.

When comparing experiments, set the input parameters first, then reset or prepare consistently. Changing parameters halfway through a run defines a different protocol and should be recorded as such.

02 Run and control

Prepare an initial condition

Preparation separates construction of the sample from the experiment you want to measure. A silo may need a closed temporary outlet while grains settle; a driven bed may need a rest stage before forcing begins.

1. Choose the preset and set its geometry, particle properties and contact parameters.
2. Click **Prepare** when available. Some protocols route their start through a dedicated preparation procedure.
3. Wait for preparation to finish. The app reports its status and pauses at the end.
4. Verify the arrangement and numerical indicators. Experimental time returns to **t = 0**.
5. Press **Play** to begin measurement with the experiment's intended gates, gravity or drivers restored.

Stopping rules

The Simulation section of Settings controls preparation duration and its stopping rule: fixed time, until quiet, or the combination. Quiet detection uses an RMS-velocity threshold in m/s. A quiet criterion is a numerical preparation rule, not proof of mechanical equilibrium for every material.

Preparation samples are excluded from the experiment's scientific histories. Metadata records the preparation summary where that export supports it. In studies, each parameter value can take a different actual settling time even when the same rule is used.

Protocol-specific behavior

Compaction, tapping, impact and grain-by-grain avalanches can use dedicated protocols rather than the generic Prepare button. Consult the preset notes. A source-driven deposition preset can start with few or no grains and add them during the experiment; this is not necessarily a failed initialization.

> Reset and Prepare are not interchangeable. Reset recreates the configured start; Prepare advances a construction or settling stage before resetting experimental time.

02 Run and control

Read numerical health

The status strip combines a summary with separate checks. Click a highlighted check for its measured values and guidance. Read the reason before changing a parameter.

Check	How to interpret it
dt / tc	Timestep relative to an estimated contact time. A smaller value resolves contact dynamics more finely; it is not a universal guarantee.
overlap	Compression of soft DEM contacts, usually reported relative to the smaller radius. Excessive overlap may indicate overly strong forcing, poor initial packing or insufficient resolution.
domain	Whether particles satisfy the active domain policy. Periodic wrapping, open outlets and soft-wall compression require different interpretations.
Non-finite state	NaN or infinite values invalidate the numerical state. Restart from a corrected setup.
Energy warning	A context-dependent check. Driven and active systems have energy sources; energy need not decrease.

When a run stops

1. Pause or keep the stopped state visible. Open the diagnostic details.
2. Note the preset, time, dt, particle sizes, forcing and the largest reported overlap.
3. Check that particles fit the geometry and that boundary choices match the intended experiment.
4. Reduce dt or forcing when the diagnostic and model justify it; reconstruct and prepare the initial state.
5. Repeat a short test and compare the quantity of interest at a finer timestep before increasing the duration.

An **OK** indicator means the implemented checks did not flag the current state. It is not a substitute for timestep, size or statistical convergence studies.

Finite unforced experiments may stop after becoming quiet. This can be an expected completion condition. It should not be interpreted in the same way as a numerical instability or a user cancellation.

03 Appearance and configuration

Know where a setting belongs

The right inspector keeps physical configuration separate from visual choices. The available controls change with the preset.

Category	Typical controls	Consequence
Experiment	Geometry, source, outlet, boundary arrangement, loading protocol, active-drive model	May rebuild or restart
Particles & forcing	Particle number, diameter, density, polydispersity, gravity, vibration or rotation where applicable	May rebuild or change forcing
Visualization	Particle colors, palettes, zoom, traces, marks and display appearance	Visual only
Analysis	Fields, Contacts and Photoelasticity	Derived measurements and overlays
Canvas	Time/N labels, scale bar, gravity arrow and annotations	Visual only
Observables	Preset quantities and diagnostic controls	Measurement and presentation
DEM	Contact law, friction, stiffness, restitution and numerical controls	Physical or numerical behavior

Canvas, Observables and DEM are grouped under **More options**. Inside a category, advanced settings are often folded to keep the common controls visible.

Saved configurations

The Configuration header provides actions for saving, loading and restoring preset settings. Use their tooltips to identify the actions. A saved configuration preserves inputs; it does not preserve an entire evolving particle state or all measured histories. Use a .glab project for acquired study results and recorded exploration.

If an imported configuration changes geometry or particle properties, inspect the reconstructed state before pressing Play. Keep an exported metadata file with research results so that visual appearance is not the only record of your inputs.

03 Appearance and configuration

Connect controls to the physics

Open **Configuration > Experiment > Physics of this experiment**. This quiet entry opens a separate, scrollable panel for the selected preset. The controls stay in their usual categories; opening the explanation does not run, reset or change the experiment.

The panel connects the model to what you can measure. Read the summary, review the equations, then follow **Connect controls to motion** to choose a parameter and an observable. Expand **Contact model** for the base normal and tangential laws. Finish with **Scope and assumptions** before interpreting the result.

Equation label	How to read it
Motion law	A force or orientation rule used by the model.
Protocol	An imposed boundary motion, loading or injection rule.
Definition	A way of measuring or describing a quantity, not a force.
Limiting case	A reference valid only under the assumptions stated beside it.

A model is not the same as a macroscopic result

In a silo, gravity and contacts determine the trajectories. The discharge rate is measured; an empirical flow-rate curve is not imposed. Likewise, pile slope, mixing, segregation and clustering emerge from the chosen particles, forces, geometry and protocol.

In active matter, propulsion direction and particle velocity are distinct. The polarity rule steers the drive, while inertia, drag and contacts determine how velocity responds. Compare both before treating orientational order as coherent particle motion.

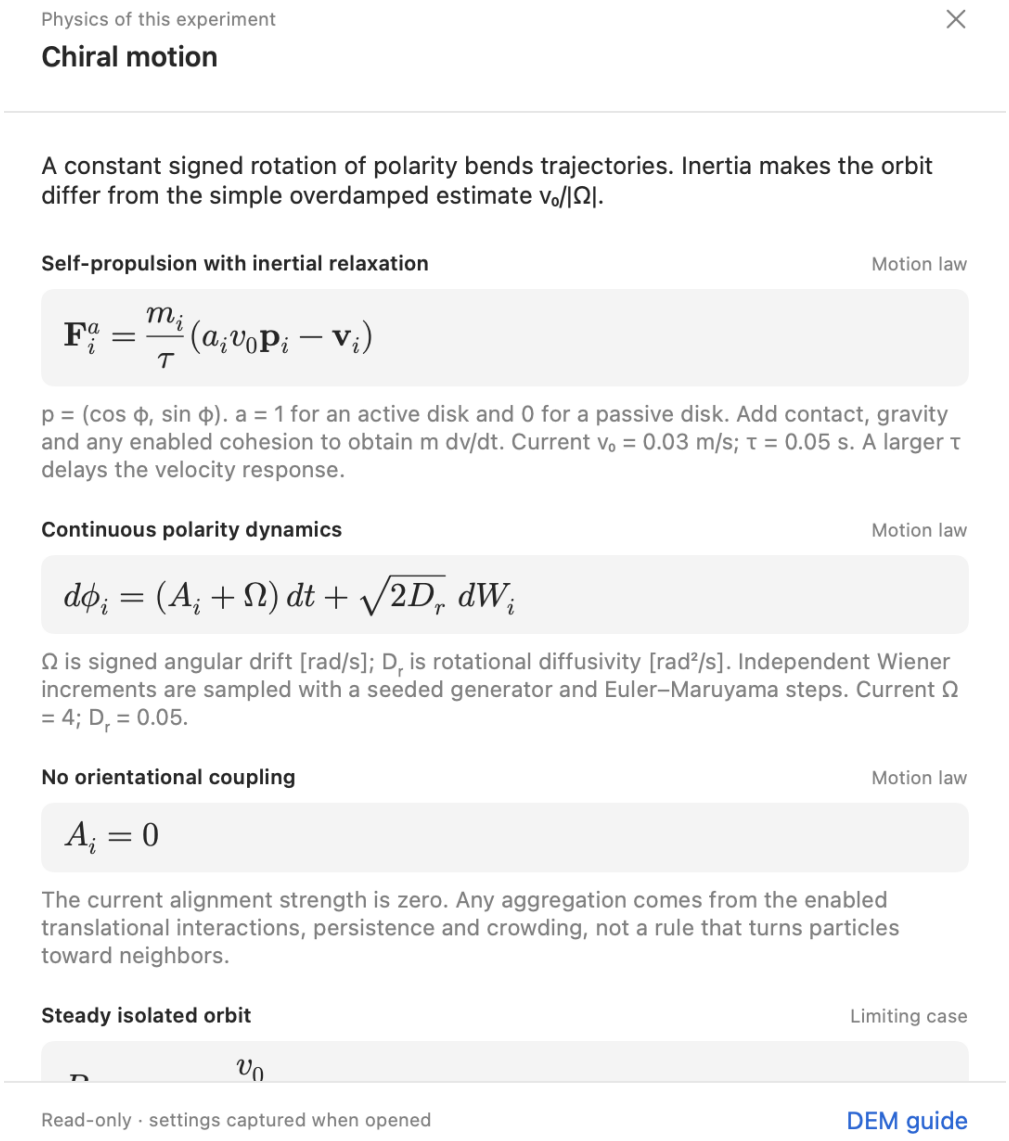
Read the units and limits

Equations use SI units. For 2D disks, mass uses areal density in kg/m² and wall line load is N/m. The quasi-2D experiments use confined 3D spheres with volumetric density; their displayed projection is not their force-calculation geometry.

The panel captures settings when opened. Close and reopen it after an edit. **DEM guide** opens the broader theory reference. A model explanation does not change the preset's scientific maturity or replace timestep, seed and convergence checks.

03 Appearance and configuration

Read a model beside its controls



The real Chiral motion physics panel separates the implemented drive and polarity dynamics from the isolated-orbit limit further down the scroll view. Settings are captured when the panel is opened.

Try it: choose Chiral motion, open this panel, then inspect one particle with a trace. Compare opposite signs of angular velocity. For a quantitative orbit-radius check, use one particle, zero angular noise, no other forcing and allow the velocity transient to relax. The limiting expression is undefined at zero angular velocity.

Scroll to connect each control with a measurement and to review assumptions. Expand Contact model for friction and damping. Press Escape, click outside the panel or use its close button to return to the workspace.

03 Appearance and configuration

Make color explain a quantity

Choose a particle color mode under **Visualization**. The Color group in the status strip identifies the active scale. Use one encoding at a time when preparing a figure.

Mode	Meaning
Single color	A common color for mobile particles; special objects retain their identity.
Color by speed	Instantaneous speed magnitude. Check both the palette and its numerical maximum.
Color by size d	Physical diameter. Equal-sized particles should share a color.
Color by type/material	Material or population identity, when present. In active-passive mixtures this separates driven and passive disks.
Color by bands	The band of each particle's initial position; useful for following mixing.
Speed threshold	A visual split between slow and faster particles at a chosen threshold.
Color by propulsion direction	A cyclic orientation scale for active matter: 0 degrees points right, 90 degrees up.
Color by deposition order	Permanent insertion order in Granular avalanches, not elapsed time.

Automatic or fixed scaling

An automatic speed scale adapts to the current state. It is useful for exploration, but the same color can then represent different speeds at different times. Use a fixed scale when comparing images or runs. Values beyond a fixed display maximum saturate visually; the underlying numerical values are not clipped by the palette.

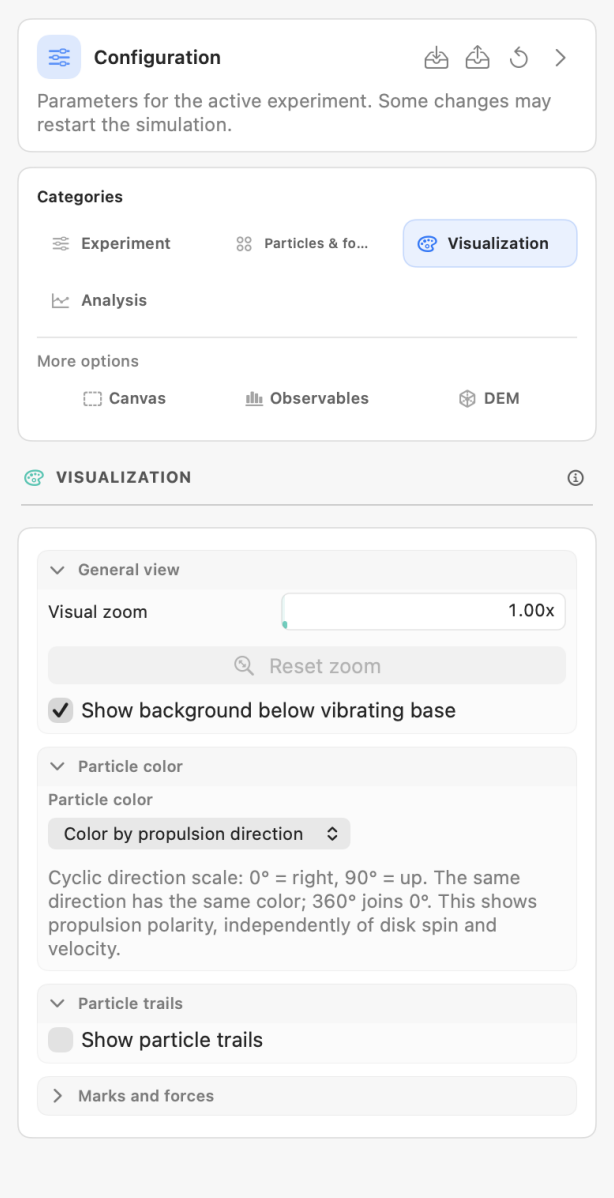
Settings includes palette inversion and a preference for colorblind-safe palettes. Use labels, units, symbols and line patterns as well as color. Inspect highlight colors are independent of the background particle encoding.

> Propulsion direction is not velocity direction and is not disk spin. Collisions and inertia can make these three directions different.

03 Appearance and configuration

Find the visual controls

This is the app's **Visualization** category in an active-matter experiment. The right inspector keeps visual choices together while particle number and physical size remain in Particles & forcing.



Actual Visualization inspector. General view, particle color and trails are separate disclosures; a visual choice does not alter the force law.

Choose the encoding first, then its range and palette. Use the trails disclosure when a path is more informative than a single position. Available choices depend on the preset.

03 Appearance and configuration

Keep the canvas readable

Use Visualization for visual zoom, background and particle marks. Canvas controls handle annotations such as physical time, particle count, gravity and the scale bar. The View area of the toolbar provides appearance and inspector visibility controls.

A useful order of operations

1. Set the physical geometry in Experiment.
2. Fit the view with the visual zoom controls. Use **Reset zoom** if you lose the domain.
3. Choose a color quantity and a meaningful scale.
4. Enable only the marks or analysis layer needed to explain the observation.
5. Position supported labels inside the canvas, clear of the particles you want to discuss.
6. Check the export inclusion controls before creating a figure or video.

The gravity arrow describes the physical gravity direction where applicable. A periodic active system without gravity need not display one. The scale bar follows physical coordinates; changing the window size or visual zoom should not alter the physical length it represents.

Traces and transient history

Visualization > Particle trails can display fading paths for a selected number of particles and a chosen duration. Keep the number modest in dense systems. The Particle Inspect tool provides a separate trace for the selected tracer.

Trails are a bounded visual history, sampled from displayed states. They are not a complete per-step trajectory file. At periodic seams, paths must not be read as a straight segment crossing the whole cell. Use an appropriate recorded quantity or particle export for quantitative displacement analysis.

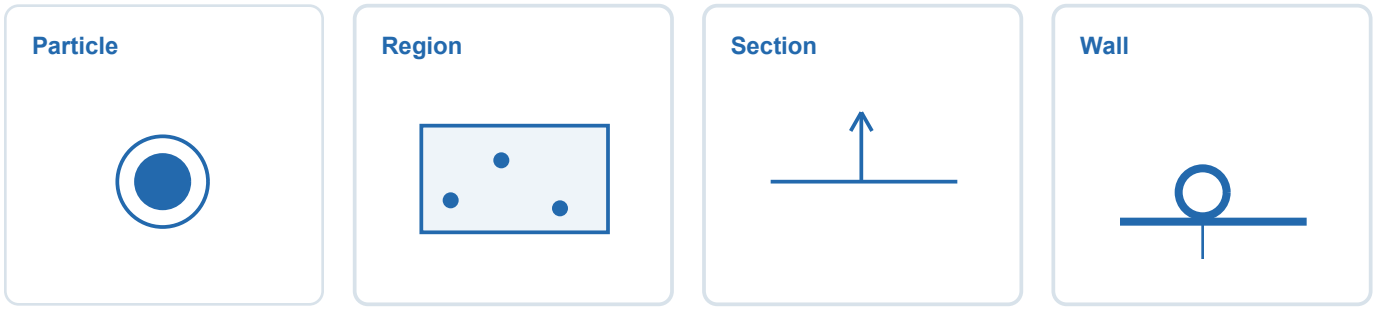
Light and dark appearance

Check contrast in the appearance you will use for a presentation. A clear white simulation background often works well for printed figures. A dark interface can remain useful for interaction without implying that exported figures must use the same composition.

04 Inspect locally

Four instruments, one place

Click **Inspect** in the Performance area to open a measurement card in the observable space. Choose **Particle**, **Region**, **Section** or **Wall**. The tool's highlight color is selected in the same card.



Selection geometries - explanatory diagrams

Instrument	Selection	Primary question
Particle	Click a disk or choose an adjacent ID	How does this particle move?
Region	Drag a rectangle	What occupies this fixed part of space?
Section	Drag an oriented line	How many particle centers cross it, and in which direction?
Wall	Click an available plane/segment or choose its ID	What contact reaction reaches this boundary?

The layout stays organized

With two vertical observable cards, Inspect occupies one card. In a horizontal row it can combine the final two slots into a wider instrument. Closing it restores the observable layout and its retained selections. Configuration categories remain in the right inspector.

Start while paused if selecting a small object is difficult, then resume to see the history develop. Choose a highlight color that is distinct from the particle palette. Tool definitions and histories can reset when you replace an instrument or rebuild the experiment.

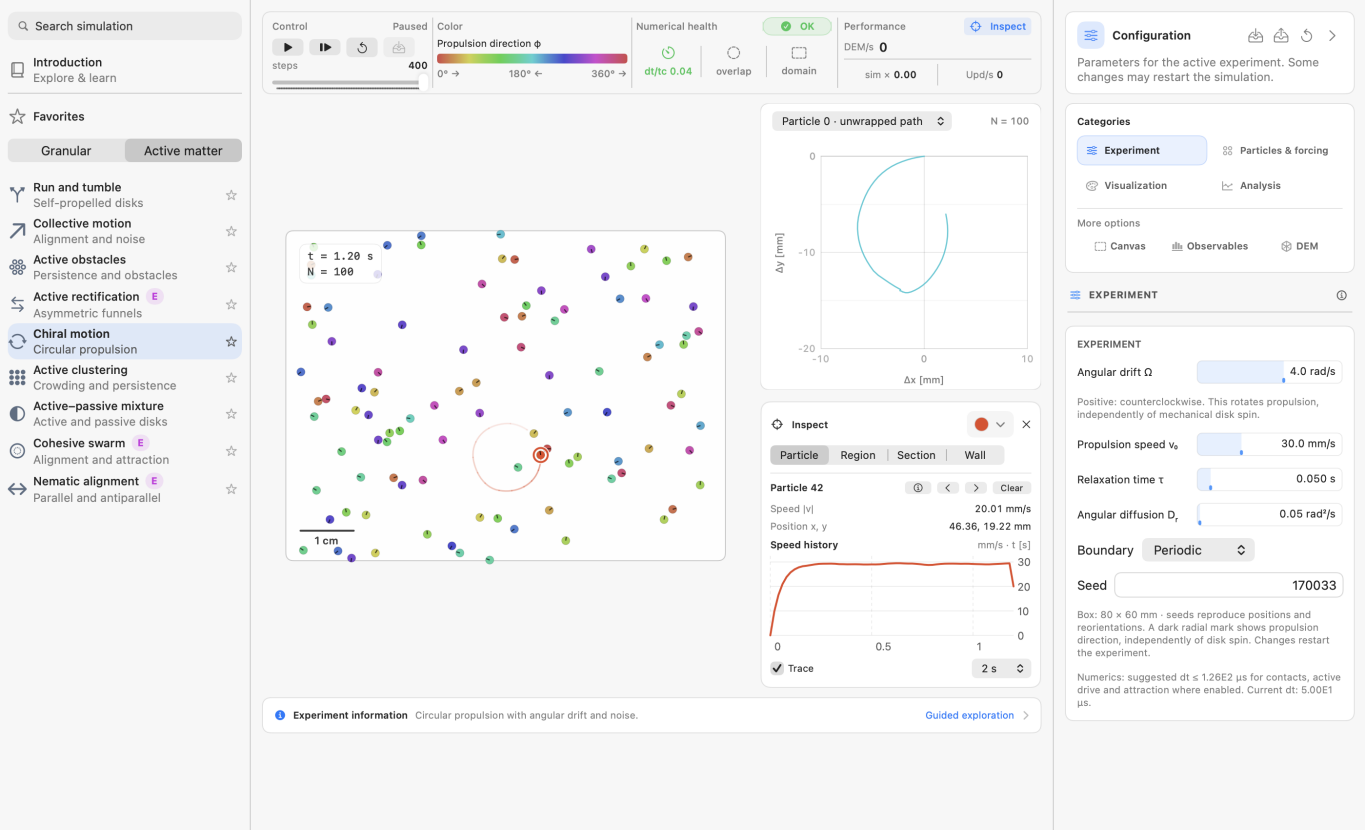
Measurement and acquisition

Particle, region and wall readings use published simulation frames. Section crossing counters are updated inside the DEM stepping path. The distinction matters: a rapidly varying force can peak between displayed frames. Record Exploration preserves acquired samples with their actual timestamps, not unsampled motion.

04 Inspect locally

Follow motion without losing context

In this actual **Chiral motion** run, particle 42 is highlighted in orange. Its fading trace reveals a curved path while the Inspect card reports the same particle's speed and position.



Actual interactive workspace after 1.2 s. Inspect occupies the lower observable card; the upper chart follows particle 0, a different identity. The right inspector remains available for configuration.

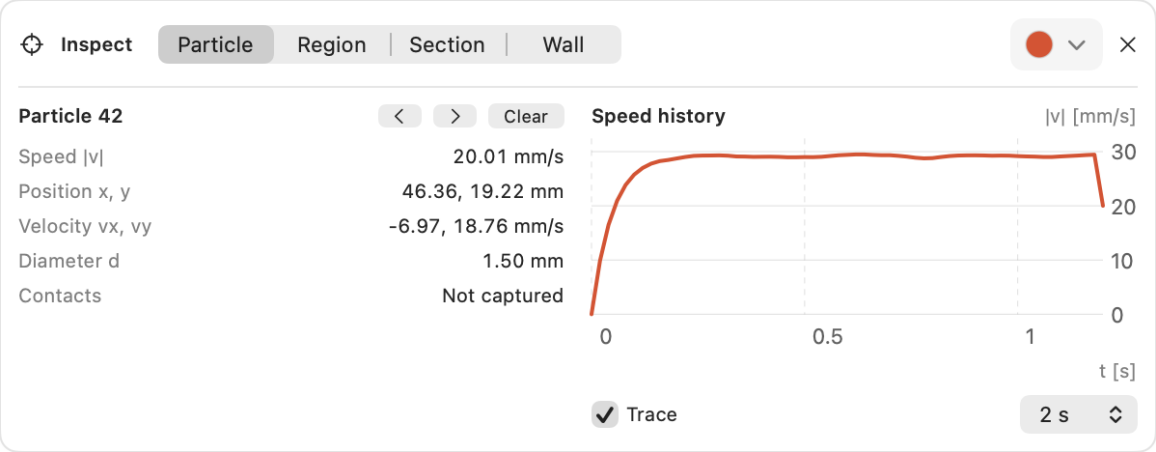
1. Find **Inspect** at the right end of the status strip.
2. Choose Particle and click a disk. Check its ID in the card.
3. Choose a contrasting highlight and enable Trace.
4. Read the chart title before relating an observable to the selected tracer: different instruments can follow different particles.

The close-up on the following page shows the same instrument in its wider horizontal layout. Its placement adapts to the available observable space.

04 Inspect locally

Particle: follow one identity

1. Open Inspect and choose **Particle**.
2. Click a disk in the simulation. If needed, choose **Select first particle**, then use the previous/next controls.
3. Read the particle ID, speed and position. Open the information control for the additional properties available in that frame.
4. Set a contrasting highlight color. The tracer combines a distinctive fill with the selection marker.
5. Enable **Trace** and choose its duration. Press Play to accumulate a speed history and a fading path.
6. Use **Clear** to release the selection, or close Inspect to restore the observable card.



The actual Particle card after a short Chiral motion run. Identity and current readings are on the left; measured speed history and Trace are on the right.

What the history means

Speed is the magnitude of translational velocity, commonly displayed in mm/s; positions use mm. Check units before comparing with a CSV in SI. History uses published frames and a bounded retention interval.

A stable ID follows the same particle, not a screen location. If that particle leaves an open system or becomes unavailable, it must not be silently replaced by another grain.

Try it

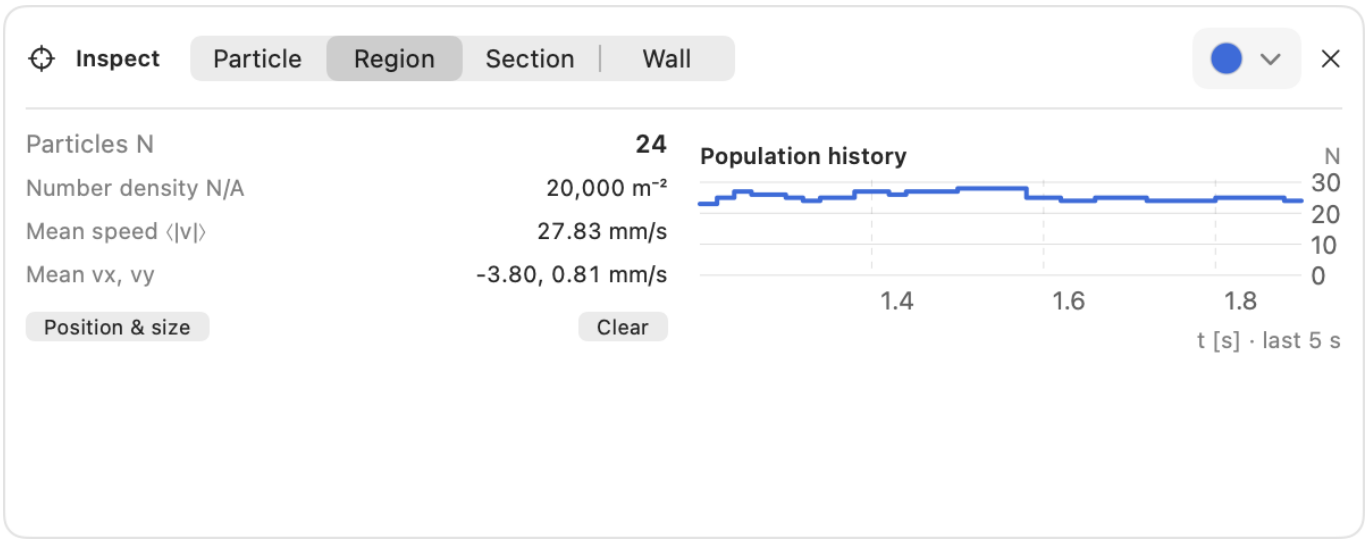
In **Chiral motion**, follow a disk, then compare a fresh run with opposite angular drift. Watch the curvature reverse. Inertia affects both speed and radius: v0/|Omega| is an overdamped limiting radius, not an exact formula for every setting.

> The trace is an aid to seeing motion. To retain measurements, start an exploration recording or choose a suitable numerical export before the interval you want to study.

04 Inspect locally

Region: measure a fixed area

1. Choose **Region** in the Inspect card.
2. Drag a rectangle inside the physical domain, or choose **Create central region**.
3. Read particle count N, number density N/A, mean speed and mean velocity components.
4. Open **Population history** where it is folded. Run the system to watch particles enter and leave.
5. Use **Position & size** for precise coordinates and dimensions in mm, then **Apply region**.
6. Redraw to replace the region, or choose **Clear**.



The actual Region card: population, geometric number density and velocity readings belong to the selected fixed rectangle.

Count centers, not disk intersections

A disk is counted by its center. A grain partly overlapping the rectangle does not contribute a fractional particle. Density is the count divided by the rectangle's full geometric area, including any obstacles inside it. It is a number density in m^{-2}, not mass density or solid area fraction.

Mean speed and the magnitude of mean velocity are different. Opposite motions can cancel in mean velocity while mean speed remains positive. If the region is empty, the mean velocity is undefined; an unavailable reading is not a measured zero.

Try it

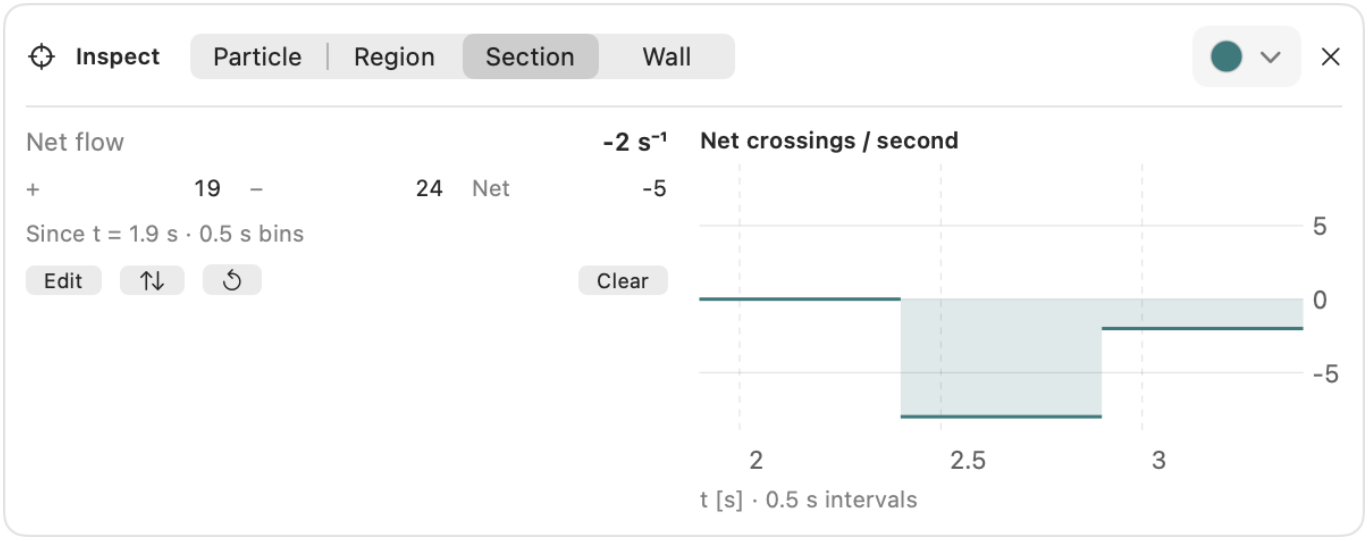
In a silo, place a rectangle above the outlet and compare its population with the preset's discharge observable. In active matter, place a region near an obstacle and compare it with a similarly sized region farther away. Keep the rectangle, duration and particle parameters fixed between runs.

The rectangle stays fixed in physical space. It is not a particle-following camera or a periodic region that automatically straddles both sides of the displayed cell.

04 Inspect locally

Section: measure crossings

1. Choose **Section**. Drag a line across the path you want to measure, or choose **Create central section**.
2. Read the **+ arrow**. It defines the positive crossing direction.
3. Press Play. Positive and negative counters accumulate from the section's creation time.
4. Wait for a complete **0.5 s interval of simulation time** before interpreting Net flow.
5. Use **Edit** for endpoints, **Reverse section direction** to change the sign convention, or **Restart section measurement** to begin again.



The actual Section card after a seeded active-particle run. Positive and negative crossings are accumulated separately; Net flow uses completed physical-time bins.

What is counted

The instrument counts disk-center crossings at every DEM step, including recrossings and individual disk members of rigid bodies. Net count is positive minus negative crossings. Net flow is that difference divided by the completed 0.5 s bin duration, in s^{-1}.

The chart's bins represent their actual physical-time intervals. A high particle count is not necessarily a high mass flux when particle masses differ. This instrument is **number flow**, not kg/s.

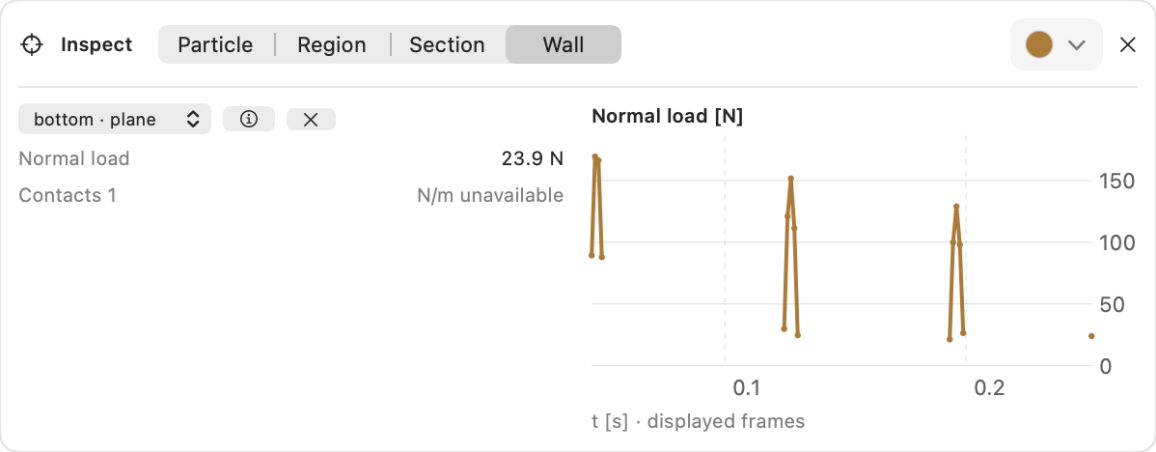
Editing endpoints, reversing the direction or restarting the instrument clears the counters. A new measurement should not be spliced into an old history as if the section had remained unchanged.

Some protocols do not expose this instrument. When the card reports it unavailable, use the preset's own supported transport observable or another inspection tool.

04 Inspect locally

Wall: read boundary reactions

1. Choose **Wall** in Inspect.
2. Click a plane or segment wall, or choose its stable name from the Wall selector.
3. Read **Normal load**, contact count and, where a physical length is defined, load per unit length.
4. Open the information control for signed Fx/Fy, tangential load and wall length.
5. Run the experiment to build the normal-load history. Pause when you want to compare the load with the current contact network.



The actual Wall card in Simple bounce. Its load history comes from published contact records, so missing intervals remain gaps.

Signs and units

Fx and Fy are the signed contact reaction on the wall in world axes, opposite to the force on the particle. Normal and tangential loads sum contact magnitudes. Normal load divided by a finite wall length gives **linear load in N/m**.

This 2D measurement is not pressure in pascals without a defined thickness and conversion. Linear load is unavailable for unbounded planes without a physical length.

Which boundaries can be selected?

The instrument supports plane and segment walls. Periodic edges and fixed roughness disks are not selectable wall probes. If a selected wall disappears after a geometry change, its reading becomes unavailable.

History uses the latest contact evaluation per published frame, not a maximum or average over intervening steps. Missing records appear as gaps. With Euler integration, force evaluation can precede the displayed state by one DEM step.

> Use a finer acquisition strategy for short collision peaks. A smooth-looking wall history alone does not demonstrate that those peaks have been resolved.

05 Analyze the whole system

Analysis: from grains to structure

Open **Analysis** in the right inspector. Its main areas are **Fields**, **Contacts** and **Photoelasticity**, with shared appearance settings and additional disclosures for advanced controls.

Question	Tool
Where is material concentrated?	Area-fraction field; Voronoi density where supported
How does it move?	Mean-velocity field, velocity arrows and fluctuation field
Where is contact load transmitted?	Force links, contact stress and wall/section probes where supported
Is the contact geometry directional?	Contact fabric and force-weighted angular distributions
Is the network organized into strong paths?	Thresholded force network, node metrics and exploratory communities
What would a qualitative stress-fringe image look like?	Synthetic photoelasticity

Build a readable analysis view

1. Pause on an informative state.
2. Select one analysis area and enable the quantity of interest.
3. Read the legend and units. Set averaging length, threshold or color maximum deliberately.
4. Reduce particle opacity or competing layers if necessary.
5. Resume for dynamics, watching both numerical health and performance.
6. Export the corresponding numerical data when available; a colored image alone is not a measurement table.

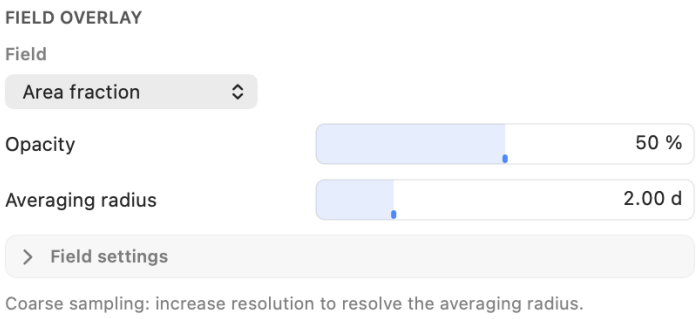
Analysis operates on the active simulation. **Run Comparison** is a separate Mode for comparing independently evolved parameter variations. A .glab recording supports a smaller, explicitly defined set of analyses from stored frames; it does not reconstruct every live Analysis layer.

05 Analyze the whole system

Fields and velocity maps

In **Analysis > Fields**, select a field, adjust opacity and averaging radius, and open **Field settings** for grid resolution and fixed color range. Use **Fit color range to current field** to fit a representative snapshot, then keep the range fixed for a comparison.

Field	Meaning and units
Area fraction	Nominal disk area per unit area; dimensionless
Mean velocity x / y	Components of mass-weighted local velocity in the laboratory frame, m/s
Mean speed	Magnitude of the local mean velocity, m/s; not mean particle-speed magnitude
Fluctuation / agitation	Half the local velocity variance, m^2/s^2; not kelvin
Contact stress yy	Contact contribution, compression positive, N/m; only supported protocols



Actual Fields controls for an area-fraction overlay. Opacity controls appearance; averaging radius controls the spatial measurement scale. Field settings contains further options.

Averaging is part of the measurement

Ordinary fields use a 2D Lucy kernel, with radius relative to configured mean diameter d. A small radius reveals detail but can be noisy; a large radius smooths structure and mixes velocity gradients. Field data also carry 2D mass density in kg/m^2, though it is not a separate Field color choice.

Grid resolution samples the field; it differs from both physical averaging length and DEM neighbor cells. More pixels cannot restore detail removed by a broad kernel. The pictured warning asks for finer sampling relative to the averaging radius.

There is no automatic wall renormalization: near boundaries or free surfaces, part of a kernel lies outside the material. Nominal area fraction can exceed one with fine smoothing or soft-contact overlap.

Velocity arrows can represent individual, binned or coarse-grained velocities. Read the method: binned known velocities are not experimental image-based PIV.

05 Analyze the whole system

Contacts and force networks

Use **Analysis > Contacts** to display contact points and force links. Open the network controls only when you need more than a simple view of load transmission.

1. Enable **Show contacts** to locate contacts in the current state.
2. Choose a force-link representation. Set its threshold and appearance while keeping the physical scale in view.
3. Compare strong links with particle geometry and boundary reactions.
4. Enable node or network diagnostics only when needed; dense graphs can add substantial computation.

Read a network correctly

Particles form nodes and contacts form edges. Force weighting can emphasize the contacts carrying larger loads. A visual threshold changes which links are shown or analyzed; it does not remove those contacts from DEM.

Strong components are connected groups above a chosen threshold. Communities are an exploratory partition of a weighted graph. Modularity Q summarizes the selected partition, while a bottleneck or betweenness measure describes graph connectivity. These are different measurements, not interchangeable definitions of a force chain.

The interface can group small communities into **Other** for visual clarity. That presentation does not redefine the underlying communities or their modularity. Repeat a graph analysis with different thresholds before attributing physical significance to a visually striking partition.

Geometry is not load

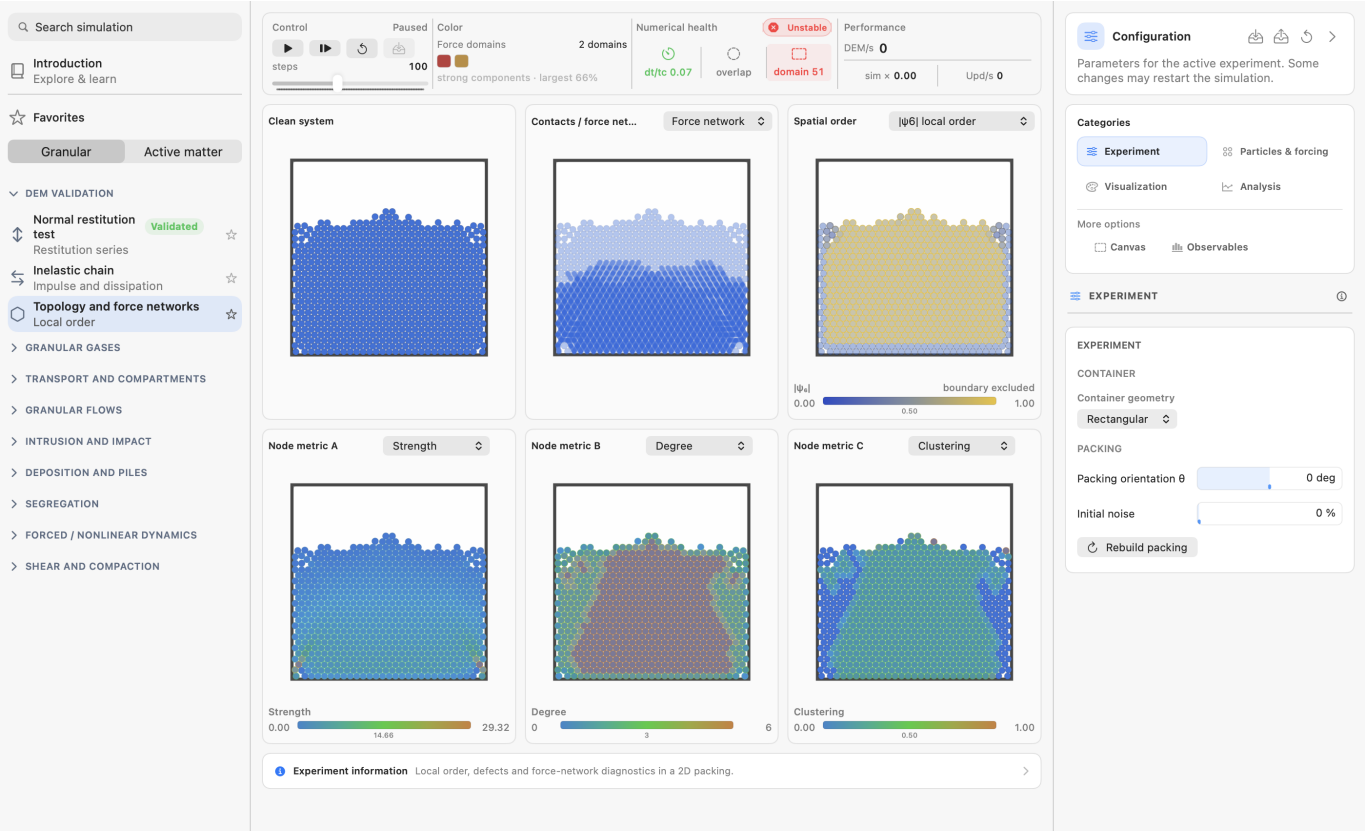
Voronoi cells describe local space around particle centers. Cell area and inverse area are geometric density proxies. A small cell need not carry a large contact force. Boundary clipping and approximate construction affect edge cells; use the documented domain and exclude unsuitable boundary regions when making quantitative comparisons.

The **Topology and force networks** preset puts synchronized structural views side by side. It is useful for learning which patterns come from geometry and which come from contact forces.

05 Analyze the whole system

Read structure in context

The **Topology and force networks** preset presents synchronized structural views. Compare the same packing across views before assigning a physical meaning to a colorful region or connected path.



Actual Topology and force networks workspace. Each panel uses the same constructed packing; geometric, contact and network descriptions answer different questions.

1. Read each panel's selected quantity and scale.
2. Compare particle geometry with the contacts that transmit force.
3. Change one network threshold or display mode at a time.
4. Keep the same state when exporting views for comparison.

The pictured state also reports a domain warning. Check its boundary contacts and numerical health before interpreting the network. A visible structure still depends on the measurement definition and threshold.

05 Analyze the whole system

Contact angles and texture

Contact fabric describes the distribution of contact orientations. It complements a force network by asking whether contacts preferentially align along a direction, even when individual links are hard to distinguish.

1. Open a supported dense-packing or wall-loading experiment, such as **Granular pile**, **Biaxial compression** or **Isotropic compaction**.
2. Prepare the sample, then examine the contact/fabric observables available for that protocol.
3. Read the angular convention and normalization on the plot or information panel.
4. Compare contact counts with the force-weighted distribution. A common direction in the first need not dominate the second.
5. Compare initial, loaded and relaxed states using consistent bins, contact selection and preparation.

Fabric and stress are related, not identical

An undirected contact normal has the same axis after a rotation of 180 degrees. A contact orientation distribution therefore differs from the 360-degree propulsion-direction palette used in active matter.

Contact fabric weights the geometry of a contact set. Force-weighted fabric adds information about load carried along those directions. A stress tensor also depends on contact forces and branch vectors. Do not interpret the longest lobe of an angular plot as a complete stress measurement.

The current fabric and contact-stress pipeline is scoped to the wall-loading protocols and Granular pile. The same menu name elsewhere does not imply that all specialized measurements are available. Read the available selectors and the preset's numerical notes.

> Compare like with like: contact population, angular convention, weighting and time sampling all belong in the caption of a quantitative texture figure.

05 Analyze the whole system

Contact stress and photoelasticity

Contact stress maps

Where supported, select the **contact stress yy** field. In this 2D app, y is the vertical coordinate used by the displayed component; a reference paper using z for vertical may call its analogous component sigma_zz.

The map averages particle-particle and particle-boundary contact branches with a Gaussian kernel. **Gaussian width w** is the standard deviation. Compression is positive and the unit is N/m. The map does not include kinetic stress or automatic wall renormalization.

Use the available stress probes to compare a line profile or finite sampling scale. Change w to assess resolution sensitivity. A larger width can dilute loads near an edge or free surface; a finer grid alone does not solve that problem. Use **Export field CSV** to retain field coordinates, values and context where supported.

Synthetic photoelasticity

Open **Analysis > Photoelasticity** to visualize a synthetic fringe response to the simulated stress state. Adjust the optical/display gain and appearance while observing the same mechanical experiment.

The fringes are a visualization, not a calibrated photograph of a photoelastic material. Gain changes the image response; it does not change stiffness, friction or contact forces. Dense fringes can be visually compelling but should not be converted into physical forces without the required calibration and model assumptions.

A useful cross-check

In a wall-loaded sample, compare the stress pattern with the boundary reaction and the contact network. Each is a different view of the same load transmission. Do not expect a coarse field, a frame-sampled wall history and a single strong-contact image to have identical spatial or temporal resolution.

06 Compare and run in the background

Run Comparison

Choose **Mode > Run Comparison** to vary one parameter across several independent simulations. The central area prioritizes charts; the original interactive simulation is retained separately.

1. Configure the interactive preset, including particles, contact settings, dt and seed.
2. Enter Run Comparison. Use **Use current simulation setup** if you need to recapture an edited setup.
3. In **Study setup**, select a parameter and enter **2-8 distinct values separated by semicolons**. Use the displayed units.
4. Set **Duration per run [s]**. Enable **Prepare each initial condition** when supported and appropriate.
5. Choose Execution, then **Start study**. Curves appear as the independent runs advance.
6. Select the observables for the two charts. Optionally enable **Simulation preview**.
7. Click a run in the legend to inspect its status and diagnostics. Finish or stop the study before saving or exporting it.

What stays fixed

The captured configuration supplies the other material, forcing and numerical inputs. Geometry is rebuilt consistently with the chosen parameter. The same preparation rule can produce different actual preparation durations. Shared seeds improve controlled comparisons but do not remove the need to study statistical variation.

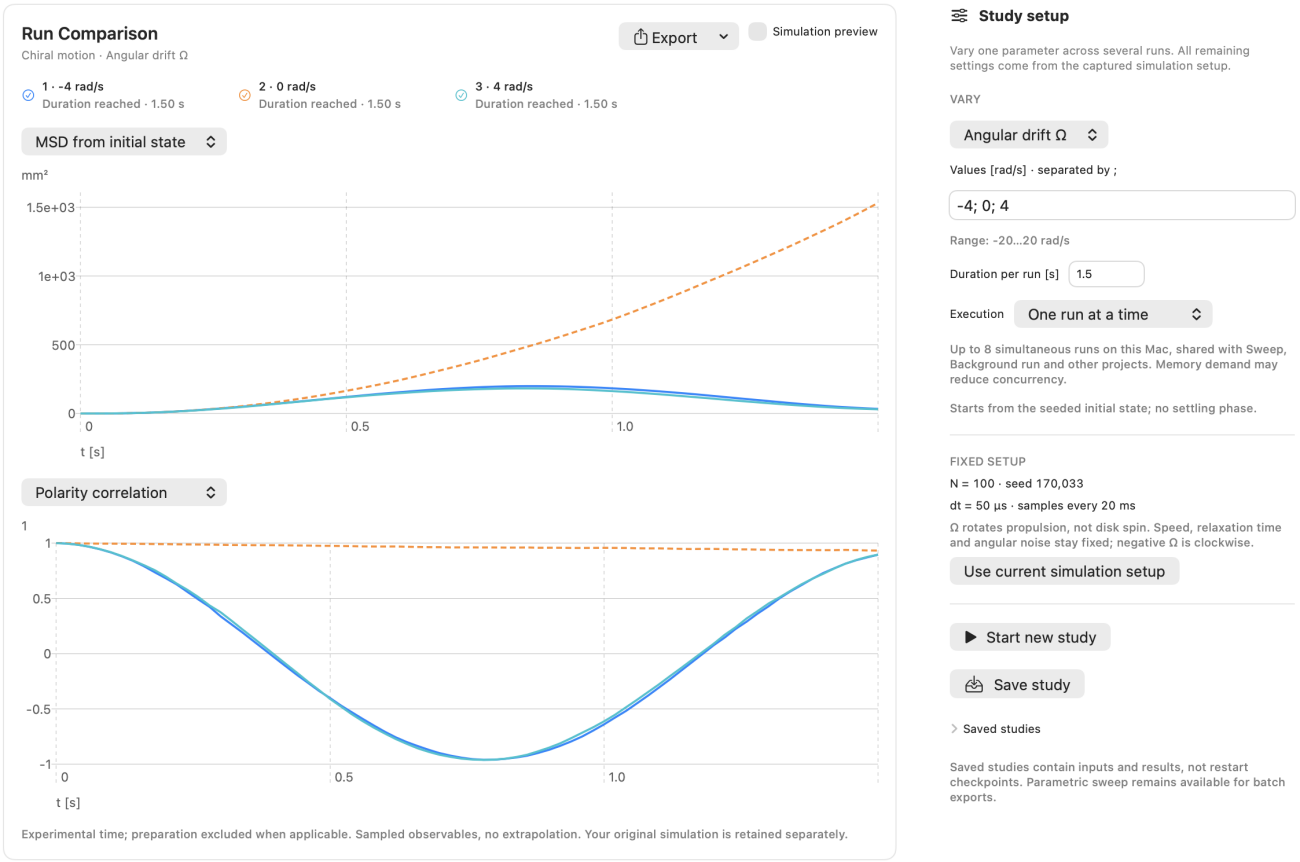
Samples are normally acquired every 20 ms of simulation time. This is not the DEM timestep. Specialized quantities can have longer measurement intervals, such as silo flow over completed 0.5 s bins.

Use the preset reference to see which controls are exposed for comparison. Some presets provide general energy and mean-speed curves while their specialized observables remain in the interactive workspace.

06 Compare and run in the background

Read a live study

This actual study compares **Chiral motion** at angular drifts of -4, 0 and +4 rad/s for 1.5 s per run. The curves were calculated by the app from independent initial states; they are an illustration, not an acceptance benchmark.



Actual Run Comparison workspace. The study setup remains at the right while the legend and two observable plots receive most of the space.

1. Check the varied parameter and units in Study setup.
2. Match each curve to its run in the legend; read status as well as color.
3. Inspect diagnostics before interpreting a difference between curves.
4. Save or export the completed study with its fixed inputs.

Short transients can be useful for learning the controls. A scientific comparison may require longer runs and multiple seeds.

06 Compare and run in the background

Keep a comparison interpretable

Status is part of a result

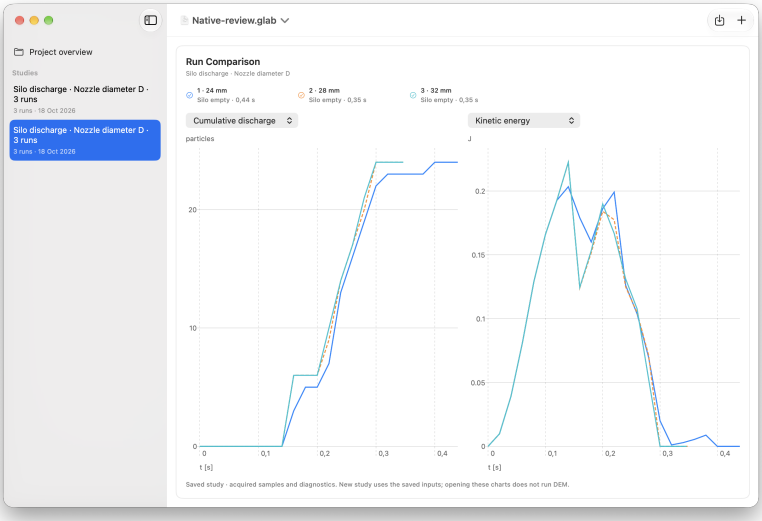
Each run records its parameter value and completion state. A run can finish, stop quietly, be cancelled or fail a numerical check. Do not compare a short failed record with a completed record as if both covered the same physical interval.

Click a legend entry to inspect maximum observed overlap, speed and recorded diagnostic events. These checks are sampled at batch boundaries, with preparation checked at its end. They do not certify that every between-sample extremum was captured.

Save and export

Save study stores the acquired study in the local study library. **Saved studies** reopens those results. In a project window, **Add to project** incorporates the study into the document instead.

Use **Export > Data & charts** or **Data only** after the study finishes or stops. The exported inputs, samples and diagnostics preserve the context needed to interpret the curves. Chart selection affects the figure; it does not change the saved simulations.



A saved study reviewed in a native .glab project. Opening the charts reads acquired results without running the DEM engine.

> A saved study contains inputs and results, not a restart checkpoint. Starting a new study repeats simulations from the saved setup; it does not continue each old curve from its final state.

06 Compare and run in the background

Parametric sweep

A sweep is designed for systematic output across a range of values and repeated seeds. It uses the same supported physical controls as the experiment rather than arbitrary changes to hidden parameters.

1. Choose **Mode > Parametric sweep** on a supported preset.
2. Select **Parameter** and read its unit. Sweep units can differ from the display units in Run Comparison: for example, m instead of mm.
3. Set the minimum, maximum and number of values. Choose linear or logarithmic spacing; logarithmic ranges require valid positive values.
4. Set duration, sampling interval, repetitions and any warm-up offered by the form. Choose initial-condition preparation when appropriate.
5. Select Execution. Begin with one run or the recommended concurrency until you understand the memory demand.
6. Choose the files: observables, metadata, particle data and optional final snapshot. Particle histories can dominate storage.
7. Choose an output folder and click **Start sweep**. Inspect the summary after completion, including partial or failed runs.

Read the output as a study

The sweep folder contains **sweep_metadata.json**, **sweep_summary.csv** and individual **run_###** folders. Keep the complete directory together. Each value and repetition has its own run identity and deterministic seed assignment.

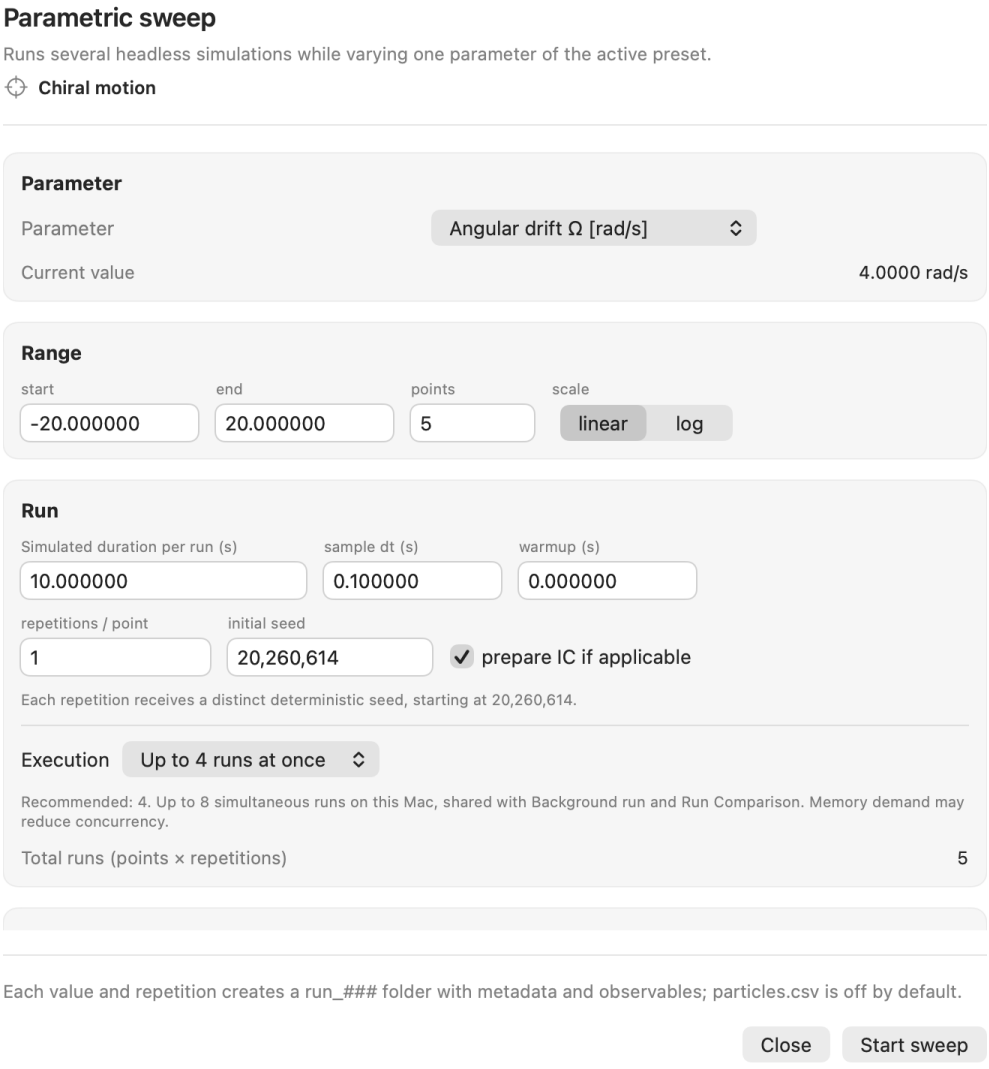
Use repetitions to examine variability. Do not infer a phase boundary from one seed or from a single noisy endpoint. Keep duration, warm-up, dt, analysis convention and stopping rules consistent across the parameter range.

The current sweep varies one parameter at a time. For a multidimensional experiment, plan separate sweeps and label their fixed settings explicitly.

06 Compare and run in the background

Read the sweep form

Work from top to bottom: parameter, range, run protocol, execution and output. The form below is the app's native Parametric sweep view for Chiral motion.



Actual sweep form. Range spacing, repetitions, seed and execution belong to one study definition. Scroll within the form to inspect export choices and the output folder.

Check the estimated total runs before starting. The number of concurrently admitted runs can be smaller than the selected limit when other jobs or memory pressure use shared capacity.

06 Compare and run in the background

Background run

Background run makes an independent copy of an experiment for longer calculation and saved outputs. Its subtle workspace tint and configuration workflow distinguish it from the interactive simulation.

1. Select a preset and choose **Background run**.
2. Configure the copied setup in the right inspector. Choose duration or the experiment-completion condition where offered.
3. Select outputs. **Video only** is the default; **Video + observables** supports replay with synchronized plots. Particle data and Initial image are separate choices.
4. Set Playback and, if needed, a separate data-sampling interval.
5. Choose **Preview**. Inspect the prepared initial condition and any warnings.
6. If settings change, prepare a new preview. **Save & run** starts from the accepted prepared state and asks for a destination.
7. Return to Interactive mode or select another preset while the calculation proceeds. Keep the app open.

Duration, playback and data

Duration is physical simulation time. Playback controls its rate in the movie. A slower-looking movie is not a smaller DEM timestep. Data sampling can be configured separately; short force peaks need adequately fine sampling regardless of the movie frame rate.

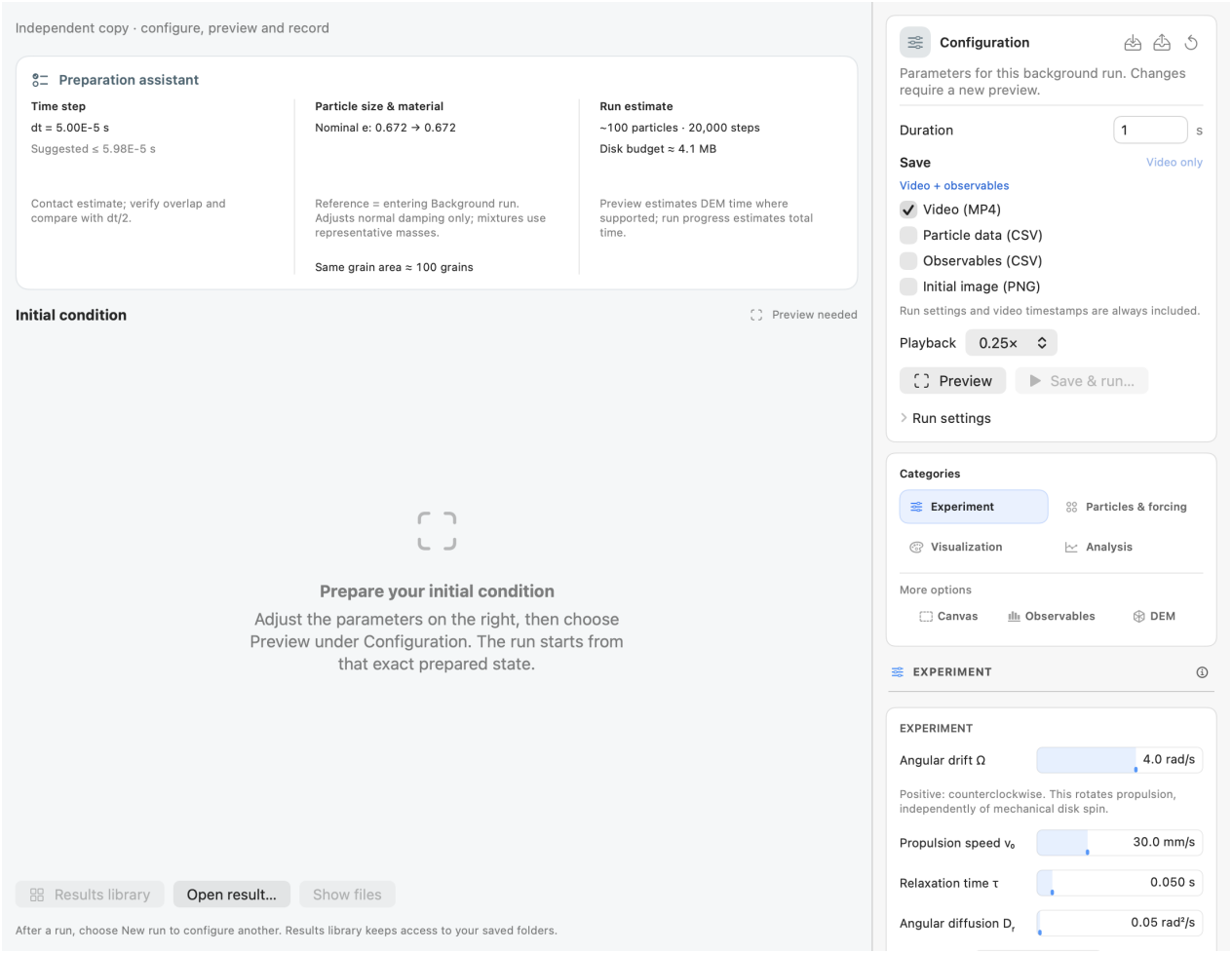
Background video uses MP4 at 1280 x 720 and 30 fps. This workflow is distinct from the configurable MOV Video Export dialog. The output list in Configuration shows which companion files the chosen options will create.

Recording is bounded: up to 108,000 video frames or 1,000,000 data samples. A limit preserves a partial result rather than promising unlimited recording. Run a short pilot to estimate storage and runtime before requesting a long experiment.

06 Compare and run in the background

Configure an independent run

Background run uses an independent configuration. Its preview and output choices describe the run that will be saved, while the interactive workspace remains separate.



Actual Background run workspace before preview. Configure the experiment and outputs, inspect Preview, then use Save & run after preparation is accepted.

The right column is the configuration for this copy. A preview is a check of the initial condition; it is not the final result. Keep the app open during calculation unless a supported recovery point explicitly reports that it is safe to close.

06 Compare and run in the background

Replay, recover and share resources

Results library

After a background calculation, open **Results library** to review saved runs. **Show files** reveals the output folder. The library stores references and thumbnails, not a duplicate of all the data. Removing an entry keeps its files; deleting a folder in Finder removes the actual output.

Keep movie timestamps and observables with the video so replay can synchronize physical time and charts. If a folder moves, use **Open result** to reconnect it. A plain video player does not have the app's associated scientific context.

Pause versus durable recovery

Pause and Resume can work while the app remains open. Closing the app is safe for later continuation only when the supported recovery workflow explicitly says so.

Durable recovery is currently limited to **Thermal box, Periodic gas and Free cooling**, with Cell linked list neighbors. Enable **Save recovery points** before launch. Before closing, pause and wait for **Recovery saved**. Resume from Results library using the same app version and build. A recovery point is saved at launch, periodically during calculation and on pause; an interruption can lose work since the last saved point.

Parallel work

Run Comparison, sweeps, background work and projects share a scheduler. The maximum is hardware-dependent, capped at eight simultaneous jobs while reserving capacity for interaction where possible. The recommended concurrency is at most four. Memory demand can reduce how many jobs start together.

These are independent DEM worlds running concurrently, not a promise that one contact calculation uses every CPU core. A queued job can be healthy and waiting for capacity. Increasing concurrency beyond the useful limit can reduce responsiveness or throughput.

07 Projects and recorded exploration

Keep work in a .glab project

A native project brings together a captured setup, instrument definitions, recorded exploration, study results and notes. It is a document you can reopen independently of the interactive workspace.

1. In the simulation workspace, choose **File > New Project from Workspace** to capture the supported setup and available acquired content.
2. Review **Project overview**. Check the preset, seed, dt and capture time; add notes about the question and protocol.
3. Use **File > Save** and choose a .glab filename and location.
4. Reopen the file with File > Open or Finder. Check the expected studies or recorded frames before discarding the original work.

Work inside the project

Choose a study in the left sidebar to review its charts. **Import study** brings a saved study JSON into the project. **New study** uses an available captured or selected-study setup for a new comparison; it does not automatically launch when you open the document.

New Project creates an empty document. If it has no setup, import a study or capture a supported workspace before expecting a new simulation study to be available.

What a project does not promise

The capture time describes the context of the saved setup. It does not mean that opening the project resumes all particles, contact histories, random streams and numerical state from that instant. A .glab document is a container for inputs and acquired results, not a general DEM checkpoint.

Saving a copied recording does not make it a live link to the original workspace. Frames acquired later remain outside that saved copy unless you capture them again.

07 Projects and recorded exploration

Record an exploration

Recording makes local inspection and selected live observables available after the run. It acquires bounded particle positions, velocities, diagnostics and the instrument definitions selected when recording starts.

1. Configure the simulation and set up the Particle, Region, Section or Wall selections you want to retain.
2. Choose **File > Record Exploration**.
3. Select a **Minimum interval (simulation time)**: 0.01, 0.05, 0.1, 0.5 or 1 s.
4. Click **Start recording**. Use Play and Inspect normally while the app acquires published frames.
5. Reopen the recording panel or use its status control to **Stop recording**.
6. Choose **New Project from Recording**, then save the .glab document.
7. Reopen it and select **Recorded exploration** to review the acquired interval.

Sampling and limits

The requested interval is a minimum spacing, not a guarantee of that sampling rate. Actual simulation timestamps are stored. If the app publishes frames more slowly, samples are farther apart.

The current limit is **1,200 frames or 200,000 particle states**, whichever is reached first. At 1,500 particles this permits up to 133 complete frames. The recording stops at a limit rather than silently dropping earlier frames to imitate an unlimited trajectory.

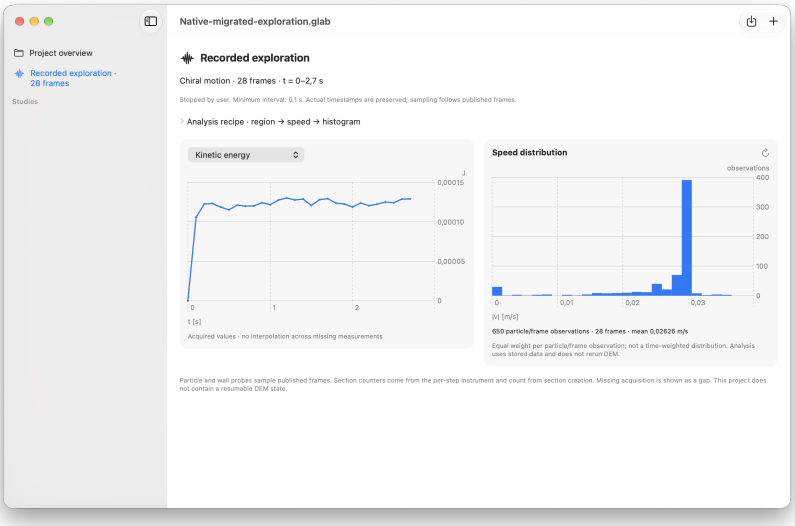
Instrument definitions are fixed at Start. Unavailable measurements remain gaps. A Section counter originates from its per-step instrument, while its values are retained at recorded frame times. Particle and wall histories do not reconstruct peaks between frames.

> Data remain in memory until you create and successfully save a project. Discard removes the in-memory acquisition; it does not delete an already saved .glab copy.

07 Projects and recorded exploration

Analyze stored frames

Recorded exploration displays acquired quantities and a speed distribution computed from stored particle data. Reviewing a project does not rerun DEM.



A recorded exploration with a time history and a speed distribution. The recipe selects stored data; it does not alter or continue the original simulation.

1. Select **Recorded exploration** in the project sidebar.
2. Choose a history observable. Its axis identifies units; missing measurements remain gaps rather than interpolated values.
3. Open the analysis recipe. Choose the entire domain, central half, recorded inspection region or explicit rectangle bounds.
4. Set the time interval and histogram bins, then **Apply**.
5. Use **Reset** to return to the default selection, or **Recalculate** to bypass a cached result.

The current recipe is **region > speed > histogram**. Each particle/frame observation has equal weight. It is not a residence-time-weighted or time-weighted distribution, and it cannot recover unsampled positions or velocities.

Caching avoids repeating the same derived work. The stored source frames remain unchanged. Changing a recipe recomputes its result from the available data; it does not turn the recording into a general analysis pipeline with every live contact or stress field.

07 Projects and recorded exploration

Save, reopen and protect results

A practical project routine

1. Name files by question, parameter set and date rather than only by preset.
2. Add notes explaining preparation, seed choices, sampling and any warnings.
3. Save explicitly after adding a study, recording or important note.
4. Reopen the project and verify its content before moving or deleting source outputs.
5. Keep a separate backup when the work matters.

Project content is limited to **256 MiB including its index**, with up to **64 studies** and the recording limits described earlier. Large particle histories should be planned around numerical exports or shorter acquisitions, rather than assuming a project stores unlimited frames.

If saving fails

Keep the document window open. Free disk space or choose another writable location. Hold Option in the File menu to use **Save As** where macOS offers it, then save again. Only a successful save confirms that the current data reached disk.

Do not manually edit files inside the .glab package. Its versioned structure and indices belong together. Copy or move the project as a single document through Finder.

Four kinds of persistence

Item	Preserves
Saved configuration	Input settings for reconstructing an experiment
Saved study	Parameter plan, acquired samples and diagnostic context
.glab project	Setup, studies, bounded recording, instrument definitions and notes
Recovery point	Supported background execution state, subject to strict version/build restrictions

Choose the format for what you need to do later: inspect a result, repeat a protocol, or resume a supported calculation.

08 Export and reproduce

Choose an export

The toolbar's Export controls and the File menu expose different products. Hover over an icon to read its action. Availability depends on the preset and dimensional backend.

Output	Use it for	Important distinction
Image / PNG	The current supported simulation view	A figure, not numerical state
Particle snapshot CSV	Particle properties at one instant	No earlier trajectory
Time series CSV	Acquisition from the current state onward	Not a retrospective dump of all on-screen history
Video Export / MOV	A headless animation with selected composition	Simulation duration and movie duration differ
Background result	Video and selected companion data	Keep the complete result folder
Comparison export	Multi-run data, inputs, diagnostics and optional charts	Stop or finish the study before exporting
Field CSV	The current supported coarse-grained field	Grid samples have an averaging convention
.glab	Native review of setup and acquired work	Not a general restart checkpoint

Match output to the question

For a presentation, combine a readable image with its scale and legend. For particle kinematics, record particle data at a suitable interval. For parameter studies, use comparison or sweep outputs with metadata. For local explorations you want to reopen, use a recording inside a project.

A screenshot of the entire window includes interface chrome; the app's Image export targets the supported simulation view. Do not expect every inspector, temporary popover or local tool history to be included in a canvas export.

Read the destination dialog carefully. Outputs with companion files use a newly created run folder; a CSV-only export can use a single file.

08 Export and reproduce

Export particle and time-series data

One state: Particle snapshot CSV

1. Pause at the instant you want to retain.
2. Choose **Particle snapshot CSV** in Export or the corresponding File command.
3. Select particle columns and companion files in the options dialog.
4. Keep **Export metadata** enabled for scientific work. Choose derived observables or a final PNG when useful.
5. Select the destination. With companions, the app creates a fresh child folder to keep related files together.

The standard 2D snapshot records selected per-particle quantities at one time. The shallow-3D backend has a separate **Quasi-3D particle snapshot CSV**, including three-dimensional position, velocity and angular velocity.

An interval: Time series CSV

1. Set or prepare the starting state before opening the export.
2. Choose **Time series CSV**. Select **Duration (s)** and **Sample delta t (s)**.
3. Choose **Export particle data**, **Include derived observables**, metadata and optional final image as needed.
4. Select the output location. If the simulation was paused, press Play to advance the acquisition; an already running simulation can resume after setup.
5. Let it reach the requested interval, or use **Cancel Time Export** to stop acquisition. Treat an interrupted output as partial.

This records future states beginning at the current simulation time. The live charts are not an unlimited archive from which any past particle trajectory can be reconstructed.

Particle output can grow quickly: storage scales with particle count, number of samples and selected columns. An observable-only run is often enough for a macroscopic question. Sampling too coarsely can miss a collision or transport event even when dt is adequately small.

08 Export and reproduce

Export images and movies

A still image

1. Pause at a representative state and choose the desired particle encoding and analysis layer.
2. Check the legend, physical scale and annotation positions.
3. Review export inclusion settings for time/N, scale and gravity where offered.
4. Choose **Export Image** and save the PNG.
5. Open the result and check that it contains the expected view and readable units.

A headless video

1. Choose **Video Export** on a supported preset.
2. Select **Canvas only** or **Canvas + observables**.
3. Set simulated duration, frame interval, video frame rate and resolution.
4. Review the frame count, estimated movie duration and output size.
5. Keep **Stop if unstable** enabled for a pilot. Decide whether to load the final state where the dialog offers that option.
6. Choose a file and start. Inspect the result after completion.

The MOV writer emits frames progressively rather than retaining the entire film in memory. The headless workflow advances a simulation for the selected interval; it is not a recording of past screen activity.

Frame interval versus frame rate

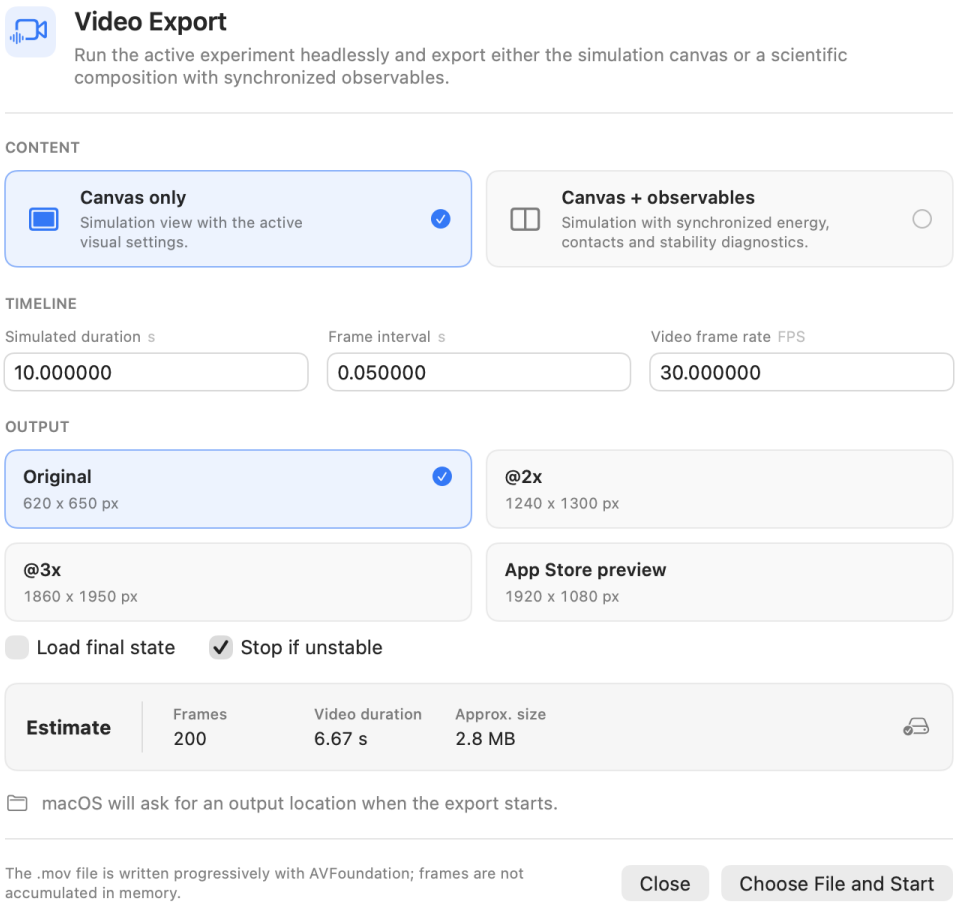
For a fixed physical duration, a smaller sampling interval creates more frames. The movie frame rate determines how many of those frames are displayed per playback second. For example, 10 physical seconds sampled every 0.1 s produce roughly 100 intervals; at 25 frames/s those intervals occupy roughly 4 playback seconds, apart from endpoint-frame conventions.

Always distinguish physical time from playback time in a presentation. Use Background run when you want its dedicated output-folder, replay and recovery workflow rather than the standalone video dialog.

08 Export and reproduce

Read the video export dialog

The native video dialog separates composition, numerical duration and playback. These settings answer different questions and should be checked together before writing a movie.



Actual Video Export dialog. The Canvas/Observables choice controls composition; the estimated frames, duration and size help plan the export.

Read the simulation-time interval and the movie frame rate independently. A visually smooth movie does not demonstrate that DEM contacts were temporally resolved.

08 Export and reproduce

Keep the numerical context

Preserve configuration and metadata alongside every data file. A graph without dt, particle size, boundaries, seed and preparation can be visually clear yet difficult to reproduce.

A compact record for each experiment

• App version and build; preset name and maturity.

• Particle count, size distribution, mass or 2D density, and geometry.

• Contact model, friction, restitution or damping, stiffness and dt.

• Boundary conditions, forcing and any time-dependent protocol.

• Seed, initial-condition construction and preparation summary.

• Physical duration, warm-up, sampling interval and termination reason.

• Observable definition, units, averaging length, threshold and analysis selection.

• Numerical warnings and a short resolution or repeatability check.

Compare quantities with the same definition

Mean speed is not the magnitude of mean velocity. Number flow is not mass flow. Wall load in N/m is not 3D pressure. A velocity-variance field in m^2/s^2 is not the same quantity as a gas temperature observable expressed as fluctuation energy in joules.

CSV column names and metadata identify the exported convention. Do not infer units from a screen value alone: the interface often uses mm or mm/s while files retain SI quantities. Preserve the original values during spreadsheet import, including decimal separators and scientific notation.

A small convergence check

Repeat a short run with the same seed and a smaller dt, holding the physical sampling interval fixed. Compare the observable you actually use, not just whether both runs finish. For stochastic or collective behavior, compare several seeds and sufficient duration; chaotic trajectories need not agree particle by particle to have converged statistics.

09 Preset reference

A catalog organized by questions

The following reference covers all **47 visible presets** in version 2.0: 38 in the Granular family and nine in Active matter. Each profile is grounded in the app's current experiment and capability catalogs.

How to use a profile

Question and model describe the physical idea. **Controls** identify the main inputs. **Observe** suggests measurements. **Try a controlled variation** gives a simple starting task. **Scope and numerics** explain assumptions that affect interpretation.

Comparison and sweep lists show the parameters currently exposed by those workflows. Their units may differ because Run Comparison can use display units while Sweep follows its descriptor units. Blank support means that workflow is not currently offered for the preset.

Family	What to explore
DEM validation	Contact resolution, restitution, impulse transmission and structural diagnostics
Granular gases	Driving, collisions, cooling and fluctuations
Transport and compartments	Exchange, discharge, obstacles and filtering
Granular flows	Inclines, plowing, heaps and falling streams
Intrusion and impact	A projectile entering a prepared bed
Deposition and piles	Construction history, slopes, avalanches and base geometry
Segregation	Size and material differences under driving
Forced / nonlinear dynamics	Impacts, vibration, compaction, drift and rotating beds
Shear and compaction	Boundary loading, force transmission and jamming
Active matter	Self-propulsion, alignment, geometry and collective organization

> Preset defaults are useful starting conditions. A profile does not validate arbitrary combinations of extreme parameters. Use the experiment's current notes and numerical indicators when exploring outside its tested scope.

09 Preset reference

Understand the active-matter family

These presets describe idealized dry active disks with inertia, drag, contact forces and a propulsion direction. They do not solve a surrounding fluid or reproduce the full sensing and locomotion of a bird, fish or biological swimmer.

All nine start with **100 particles and periodic outer boundaries**. Internal obstacles and funnel segments remain physical geometry inside that periodic cell. Changing the outer boundary does not remove them. Closed boundaries remain selectable where supported, and a loaded configuration can retain its own boundary choice.

Common controls

Parameter	Interpretation
Propulsion speed v0	Target speed scale of the active drive
Relaxation time tau	Inertial response time against drag
Tumble rate lambda	Rate of random reorientation events
Angular diffusion Dr	Strength of random angular wandering
Alignment kappa	Rate of alignment with nearby propulsion orientations
Perception radius R	Center-to-center neighborhood distance for alignment
Angular drift Omega	Rotation rate of propulsion direction in chiral motion

The physical box stays fixed when particle diameter or number changes. The occupied area fraction changes instead. This is particularly important in Active clustering and Active-passive mixture: fewer or smaller disks can make a dense collective effect disappear without indicating a malfunction.

Evidence and maturity

Run and tumble, Chiral motion, Collective motion, Active obstacles, Active clustering and Active-passive mixture are implemented within documented tested scopes. Active rectification, Cohesive swarm and Nematic alignment remain experimental because specific statistical acceptance questions are still open.

A large connected cluster is not sufficient evidence of motility-induced phase separation. Neighbor composition alone is not proof of segregation. Polar and nematic order, and finite-time versus stationary behavior, must be distinguished.

09 Preset reference

Normal restitution test

Granular / DEM validation / **Validated**

Question and model

How does the first rebound height follow the effective normal restitution measured in a particle-wall impact?

This preset compares nominal and effective normal restitution. The measured rebound height follows $h1/h0 \approx e_eff^2$, where e_eff is obtained from the velocity ratio before and after the first impact. For strongly dissipative impacts, e_eff may differ from the target value because of the discrete soft-sphere contact implementation.

Main controls

Number of particles N; Mean diameter d; Initial free height h0; Restitution range e_min...e_max; Horizontal spacing; 2D density ρ; Gravity g.

Observe

Particle height y_i(t); Running maximum height h_max,i(t); First rebound height h1; h1/h0 vs e_target^2; h1/h0 vs e_eff^2; e_eff vs e_target; Estimated restitution sqrt(h1/h0).

Try a controlled variation

Keep the free drop height and disk size fixed. Compare target restitution values with the measured velocity ratio and rebound-height ratio. Repeat with dt/2 before attributing their difference entirely to material dissipation.

Scope and numerics

- h0 is the free height between the disk bottom and the base, not the center coordinate.
- e_eff is measured from the vertical velocity ratio before and after the first base impact.
- Particles are spaced horizontally to avoid particle-particle collisions in the reference setup.
- The DEM contact law is unchanged; only gammaN is selected per particle for particle-base contacts.
- For low target restitution, the discrete linear soft-sphere contact can produce an effective restitution above the nominal value.
- e_n = 1 is accepted in the UI and metadata, while the contact-model helper applies its existing numerical clamp internally.
- Monitor maximum overlap and dt/tc when increasing stiffness or gravity.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Initial height h0 [m]; Restitution min e_min [1]; Restitution max e_max [1]; Mean diameter d [m]; Gravity g [m/s2].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Inelastic chain

Granular / DEM validation / **Implemented**

Question and model

How does an impulse travel to a wall and return through a dissipative chain?

A collinear system isolates momentum transfer, restitution and repeated impacts. Choose one-wall impact or a seeded cooling gas between two walls. There is no gravity, friction or background drag. Two lower plots offer trajectories, energy, cumulative collisions and a number-density histogram. Restitution applies to isolated impacts; simultaneous contacts remain genuine DEM dynamics.

Main controls

Particle count N; Diameter d and surface density ρ; Surface gaps / d; Initial speed v0; Particle restitution e and wall restitution e_w; Normal stiffness k_n and steps per contact.

Observe

Trajectories x_i(t); Velocities v_i(t); Kinetic and contact energy / E0; Energy deficit (E0 - K - U) / E0; Momentum P_x / (m v0); Cumulative contact episodes C(t): total, pairs, walls; Number density n(x), particles per metre.

Try a controlled variation

Begin with a short chain in one-wall impact mode. Vary restitution while keeping spacing and launch speed fixed. Compare trajectories, energy and cumulative collision counts; simultaneous soft contacts need not follow an instantaneous binary-collision approximation.

Scope and numerics

- Choose a one-wall impulse or a cooling gas between two walls. Changing physical parameters rebuilds the chain and pauses it; there is no settling stage that consumes the initial impulse.
- Particle label i corresponds to ID i - 1; label 1 is the rightmost striker. Disk mass is $\rho\pi d^2/4$. Pair damping uses reduced mass m/2; wall damping uses m.
- The two-pass analytical estimate assumes a specified sequence of binary collisions. Its sign is not an exact collapse criterion. Finite-duration DEM contacts regularize instantaneous-collision idealizations; reducing dt does not remove finite stiffness.
- The plot window can change from 0.5 to 30 s without resetting dynamics. Large systems display 30 representative trajectories, while CSV retains all particles.
- The density histogram counts particle centers over the initial observation interval; its integral is the in-range count. Escaped particles are separate. This is number per metre, not material density.
- Check overlap and timestep convergence. Energy deficit includes numerical error; spring energy is displayed separately. Contact episodes are counted every DEM step; sustained contact counts once until separation.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Restitution e [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Topology and force networks

Granular / DEM validation / **Implemented**

Question and model

How do local order, coordination defects and force-network structure coexist in a 2D granular packing?

This preset presents one DEM packing through six synchronized structural views: a clean system view, contacts or force network, spatial order, and three independently selectable node-metric panels. The force-network panels use particle-particle contacts only; strong components remain the default domain method, while communities and betweenness are exploratory opt-in diagnostics.

Main controls

Particles N; Mean diameter d; Polydispersity; Packing orientation; Initial noise; Gravity g.

Observe

Mean coordination; Number of particles with Z=5; Number of particles with Z=6; Number of particles with Z=7; Defect fraction; Boundary particles; Mean |psi6|; Standard deviation of |psi6|; Force-network mean degree; Force heterogeneity; Strong-force domain count; Community count and modularity Q when communities are enabled; Voronoi cells; Approximate Delaunay-like neighbor network.

Try a controlled variation

Compare the clean packing, coordination and strong-contact views of the same state. Change only a visualization threshold first. Then test a separately prepared packing with a different seed or initial disorder.

Scope and numerics

- Boundary particles have fewer neighbors and are excluded from structural averages.
- |psi6| is computed from an approximate cutoff-based near-neighbor network; it is not an exact Delaunay triangulation or a full KTHNY classification.
- Force-network diagnostics use particle-particle contacts as weighted edges. Wall contacts remain excluded from V1/V2 network analysis.
- The default dashboard enables lightweight strong-force contacts and domains; communities and betweenness remain off until selected.
- For polydisperse particles, classical Voronoi may be insufficient; radical Voronoi remains a future improvement.
- Gravity is enabled by default so the packing rests on the container base.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Particle count N [1]; Mean diameter d [m]; Polydispersity [%]; Container radius R [m]; Initial noise [%]; Packing orientation theta [deg]; Angular speed [rpm]; Seed [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Thermal box

Granular / Granular gases / **Implemented**

Question and model

How does a dissipative granular gas reach a steady state when energy is supplied by thermal walls?

Confined two-dimensional granular gas. The walls reinject energy and partially compensate dissipation from inelastic collisions. The velocity distribution may deviate from a Maxwellian because of dissipation, density and the energy-injection mechanism.

Main controls

Particles N; Mean diameter d; Size dispersion; Thermal-wall speed; Friction μ; Damping γ_n/γ_t; Color scale.

Observe

T_g; Total kinetic energy; P(|v|); P(vx); P(vy); Contacts; Tx/Ty anisotropy.

Try a controlled variation

Vary wall thermal speed at fixed particle number and restitution. Compare temperature components and the velocity distribution after the initial transient. Use the same physical sampling interval in each run.

Scope and numerics

- Avoid severe initial overlaps and inspect dt/tc when changing particle size or stiffness.
- Granular temperature is a fluctuation-energy observable, not thermodynamic temperature in kelvin. Compare its components and distribution after the initial transient.

Available study controls

Run Comparison: Wall thermal speed [mm/s].

Parametric sweep: Wall thermal speed [m/s]; Particle count N [1]; Mean diameter d [m]; 2D density rho [kg/m2]; Normal restitution [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Periodic gas

Granular / Granular gases / **Implemented**

Question and model

How stable is the mechanical energy of a nearly elastic granular gas without walls?

Granular gas in a periodic domain. Removing walls and external sources makes the experiment a test of approximate conservation and numerical integrator stability.

Main controls

Particles N; Area density; Normal restitution e_n / damping γ_n; Friction μ; Step dt; Periodic condition.

Observe

Total energy; Contact energy; T_g; P(|v|); Contacts; delta max/R.

Try a controlled variation

Run a short periodic control and watch energy and speed statistics. Compare dt and dt/2 with identical inputs. Separate a velocity-squared initial-temperature control from the energy-based temperature observable.

Scope and numerics

- Systematic energy growth should not appear without a physical source.
- Use this preset as a control for integrator and contact changes.
- Gravitational potential energy is zero when gravity is absent.

Available study controls

Run Comparison: Initial temperature [m2/s2].

Parametric sweep: Particle count N [1]; Mean diameter d [m]; Normal restitution [1]; Initial temperature [m2/s2].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Free cooling

Granular / Granular gases / **Implemented**

Question and model

How does granular temperature decay when a dissipative gas receives no external energy?

Free cooling in a periodic domain. The system loses energy through inelastic collisions and shows collective cooling without wall effects.

Main controls

Particles N; Initial density; Normal damping γ_n; Friction μ; Step dt; Periodic condition.

Observe

T_g(t); E_tot(t); Contacts; P(|v|); delta max/R.

Try a controlled variation

Compare restitution values at fixed initial temperature and seed. Plot the cooling history over the same physical interval. Repeat seeds before interpreting density fluctuations as a collective instability.

Scope and numerics

• Energy should decay when dissipation is present.

• Avoid an overly dense initial packing.

• Compare dt/tc before interpreting cooling rates.

Available study controls

Run Comparison: Initial temperature [m2/s2].

Parametric sweep: Normal restitution [1]; Initial temperature [m2/s2]; Particle count N [1]; Mean diameter d [m].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Fluidized instability

Granular / Granular gases / **In development**

Question and model

How can upward gas flow, contacts and binary stratification be explored qualitatively?

This preset preserves the experimental GasGrid2D, permeability-channeling and pressureSOR infrastructure for future exploration. It should not be interpreted as a validated reproduction of McLaren et al. 2019 or as full CFD; Granular LAB's immediate priority remains robust DEM presets.

Main controls

N_L and N_H; d_L and d_H/d_L; rho_H/rho_L; U/Umf_L; Vibration Gamma; GasGrid resolution.

Observe

Interface A(t); Dominant lambda; channeling; F_gas/W by species; overlap and dt/tc.

Try a controlled variation

Treat this as a development demonstration. Inspect its gas-field controls and compare a zero-drive case, without interpreting a qualitative pattern as validated CFD or a calibrated fluidization experiment.

Scope and numerics

• Paused experimental-development preset; keep results as qualitative diagnostics only.

• The gas is porous/coarse-grained: it does not resolve turbulence or bubbles.

• The ug,z velocity is row-normalized and clamped to avoid numerical jets.

• With U = 0, the external gas force should vanish for stationary particles.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: not currently offered for this preset.

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Run and tumble

Active matter / **Implemented**

Question and model

How does persistence change the motion of self-propelled disks?

An inertial run-and-tumble model: m dv/dt = F_contact + m(v_0 p - v)/τ. Polarity p resets to a uniform random angle at Poisson-distributed times. It is independent of mechanical disk rotation.

Main controls

Propulsion speed v_0 [m/s]; Relaxation time τ [s]; Tumble rate λ [1/s]; Particles N, diameter d, box size; Seed.

Observe

Single-origin ensemble MSD [m²]; Polarity correlation C_p(t); Mean speed [m/s]; Particle 0 unwrapped trajectory.

Try a controlled variation

Compare a low and a higher tumble rate at fixed propulsion speed, relaxation time, box and seed. Follow a particle, then examine unwrapped MSD over a sufficiently long interval. Exclude the startup transient when discussing diffusion.

Scope and numerics

• No thermal noise, aligning torque or hydrodynamic interactions. This is not an overdamped bacterial model.

• Changing a parameter resets the experiment. Reuse the seed for comparisons.

• Use dt ≤ 0.02 min(τ, 1/λ) as well as the contact-time limit; compare with dt/2.

• MSD includes startup and collective drift; do not infer a diffusion coefficient from the initial transient.

Current evidence

Checked scope: inertial relaxation, Poisson reorientation, free-particle MSD, timestep refinement and periodic/closed operation. This does not calibrate a biological swimmer.

Available study controls

Run Comparison: Tumble rate λ [1/s].

Parametric sweep: Tumble rate λ [1/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Collective motion

Active matter / **Implemented**

Question and model

When does local alignment produce collective motion?

Inertial active disks with DEM contacts: m dv/dt = F_contact + m(v_0 p - v)/τ. Polarity follows $d\varphi_i = \kappa \langle \sin(\varphi_j - \varphi_i) \rangle \, dt + \sqrt{(2D_r)} \, dW_i$, averaging other centers within R. All orientations update simultaneously. An isolated disk undergoes angular diffusion without alignment.

Main controls

Propulsion speed v_0 [m/s] and relaxation τ [s]; Alignment κ [1/s]; Perception radius R [m]; Angular diffusion D_r [rad²/s]; Particle count, diameter and seed.

Observe

Polarity order |〈p〉|; Velocity order |Σv|/Σ|v|; Mean speed; Orientation color and unwrapped trajectory.

Try a controlled variation

Compare low and high angular diffusion at fixed alignment and perception radius. Read polar order together with velocity order and mean speed. Repeat several seeds before describing a statistically persistent flock.

Scope and numerics

- Vicsek-inspired alignment with inertia and soft contacts, not the classical fixed-speed Vicsek model. No attraction, fluid coupling or biological calibration.
- The perception search is separate from contact detection and uses periodic minimum-image distances. R is a center-to-center distance, independent of diameter.
- Euler-Maruyama polarity updates; dt ≤ 0.02 min(τ, 1/κ, $1/D_r$), ignoring zero rates, plus the contact limit. Compare statistical results across seeds and with dt/2.
- Velocity order is speed-weighted and defined as zero at rest. High polarity order does not guarantee high speed or a cohesive flock.

Current evidence

Checked scope: local polar alignment and angular noise in inertial disks, independent order measurements and low/high-noise controls. High-noise P meets both refinement margins over 24 s across 12 seeds. Six N=400 runs characterize finite-time order; they do not establish a stationary phase or a critical point.

Available study controls

Run Comparison: Alignment strength κ [1/s]; Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [mm/s].

Parametric sweep: Alignment strength κ [1/s]; Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Active obstacles

Active matter / **Implemented**

Question and model

How do obstacles slow and redirect persistent motion?

Dry inertial disks with run-and-tumble propulsion and repulsive DEM contacts. The default box is periodic in both directions; internal obstacles and funnels repeat with it. Contacts change velocity without resetting propulsion direction. A closed box is optional.

Main controls

Single, regular or disordered obstacles; Obstacle count, diameter and geometry seed; Propulsion speed, relaxation time and tumble rate; Particles N, diameter and motion seed.

Observe

MSD from initial state; Mean speed; Particle 0 path; Contacts and overlap.

Try a controlled variation

Compare a regular and a seeded disordered obstacle layout at fixed N, diameter and activity. Record obstacle count and radius because they change available area. Examine MSD and speed, not only a visually trapped particle.

Scope and numerics

- No fluid solver or bacterial calibration. Default friction is zero so a persistent particle can slide along a wall. Contact laws and the inertial active drive are shared with Run and tumble.
- Initial positions use reproducible, collision-free shuffled hexagonal sites. Geometry and motion have separate seeds. The UI permits up to 400 particles with 1-2 mm diameters.
- Disordered means bounded, seeded offsets from a regular grid, not a Poisson process. MSD uses unwrapped displacement across periodic edges. Selecting a closed box instead can produce long-time saturation.
- Compare layouts at fixed N, diameter and activity. Changing obstacle count or size also changes available area; compare multiple geometry seeds.
- Use the active accuracy bound and DEM contact-time bound. Monitor overlap, finite state and confinement; compare statistical observables when halving dt.

Current evidence

Checked scope: periodic transport with single, regular and bounded-disordered obstacles; 100 disks, obstacle radii of 3 and 4 mm, populations of 1, 9 and 16 obstacles, 20 s and three timesteps across 12 seeds. Mobility and surface-band occupancy meet the stated refinement margins. Other parameter regimes still require resolution checks.

Available study controls

Run Comparison: Tumble rate λ [1/s]; Propulsion speed v_0 [mm/s].

Parametric sweep: Tumble rate λ [1/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Active rectification

Active matter / **Experimental**

Question and model

Can asymmetric barriers bias persistent transport?

Dry inertial disks with run-and-tumble propulsion and repulsive DEM contacts. The default box is periodic in both directions; internal obstacles and funnels repeat with it. Contacts change velocity without resetting propulsion direction. A closed box is optional.

Main controls

Funnel direction or symmetric openings; Throat gap, depth and number of funnels; Propulsion speed, relaxation time and tumble rate; Particles N, diameter and motion seed.

Observe

Occupancy bias (N_R - N_L)/N; Cumulative L→R and R→L crossings; Net crossings; Mean speed and MSD.

Try a controlled variation

Compare opposite funnel orientations and a symmetric control. Read net crossings as well as left/right occupancy. In a periodic box, account for crossings at the outer seam when interpreting the population balance.

Scope and numerics

- Dry run-and-tumble disks with repulsive DEM contacts; no fluid solver or bacterial calibration. Zero default friction permits sliding without resetting propulsion direction.
- Geometry and motion use separate seeds. Initial particles are placed without collisions; N and diameter remain in Particles & forcing.
- Counts use wrapped centers: equality at the midline belongs to R. Recrossings are included. In a periodic box, ΔN_R = net midline crossings - net positive x-seam crossings. Both counters are exported.
- Occupancy bias is not a current. Compare the slope of net crossings for mirrored funnels and symmetric openings across seeds and dt/2. A closed box permits redistribution, not a permanent net current.
- Use the active-drive and DEM contact-time bounds. Check overlap, finite state and confinement.

Current evidence

Experimental: mirrored funnels reverse transport and the periodic population balance is exact. Two of six occupancy-refinement intervals in the 12-seed, 30 s campaign extend beyond the ±0.05 margin. The symmetric control also needs more statistical precision; the same seeds have a small free-drive drift. This is not a confirmed contact failure, but the acceptance criterion remains open.

Available study controls

Run Comparison: Tumble rate λ [1/s]; Propulsion speed v_0 [mm/s].

Parametric sweep: Tumble rate λ [1/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Chiral motion

Active matter / **Implemented**

Question and model

How does rotating propulsion bend a disk's path?

Dry inertial disks with repulsive DEM contacts, linear drag and independently evolving propulsion direction. There is no fluid solver or thermal translational noise.

Main controls

Signed angular drift Ω [rad/s]; Angular diffusion D_r [rad²/s]; Propulsion speed v_0 and relaxation τ; N, diameter and seed.

Observe

Particle 0 unwrapped path; Polarity correlation; MSD and mean speed.

Try a controlled variation

Compare negative, zero and positive angular drift with the same speed and relaxation time. Trace one particle in a dilute, low-noise case. Then add noise and compare an ensemble correlation rather than matching individual paths.

Scope and numerics

- $d\varphi/dt = \Omega + \sqrt{(2D_r)}\,\xi(t)$. Positive Ω is counterclockwise. This is propulsion rotation, not mechanical disk spin.
- For one isolated noiseless disk, the inertial steady orbit radius is $v_0 / (|\Omega| \sqrt{(1 + \Omega^2\tau^2)})$; $v_0/|\Omega|$ is only the small-inertia limit. Ω = 0 restores straight propulsion with relaxation.
- The ensemble polarity reference $\exp(-D_r t)\cos(\Omega t)$ applies to independent orientations. Collisions change motion, not polarity.
- Use SI units internally. Orientation uses simultaneous Euler-Maruyama updates. dt obeys active-relaxation, angular-rate and DEM contact limits. Check overlap and finite state; compare dt/2 and several seeds.
- This exploratory finite inertial system does not establish a phase diagram or reproduce a calibrated experimental swimmer. Persistent aggregates alone are not proof of motility-induced phase separation.

Current evidence

Checked scope: inertial circular motion with positive, negative and zero polarity rotation, noisy correlation, work/drag and boundary operation. Mechanical disk spin is a separate quantity.

Available study controls

Run Comparison: Angular drift Ω [rad/s].

Parametric sweep: Angular drift Ω [rad/s]; Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Active clustering

Active matter / **Implemented**

Question and model

Can persistence and crowding create dense groups without attraction?

Dry inertial disks with repulsive DEM contacts, linear drag and independently evolving propulsion direction. There is no fluid solver or thermal translational noise.

Main controls

Nominal area fraction φ; Propulsion speed v_0, relaxation τ and angular diffusion D_r; N, diameter and seed; Cluster distance threshold.

Observe

Largest cluster fraction; Particle-weighted cluster size; Spatial number variance / mean; Mean speed.

Try a controlled variation

Hold box size fixed and compare two number densities by changing N or diameter. Then vary angular noise at fixed density. Read largest-group fraction together with speed and the documented connectivity threshold; a cluster alone does not establish phase separation.

Scope and numerics

- No aligning torque or attractive force. The initializer shuffles a nonoverlapping periodic triangular lattice; let the transient relax before interpreting clusters.
- $\varphi = N\pi(d/2)^2/A$ is nominal, without subtracting overlaps. Box dimensions are fixed. Changing N or diameter changes φ; the displayed value is derived from the actual configuration.
- Groups join centers at distance ≤ threshold × (r_i+r_j), using minimum images. Weighted size is $\Sigma s^2/N$, including isolated grains. Spatial variance uses a fixed 8×8 grid; it is not a temporal fluctuation measurement.
- Use SI units internally. Orientation uses simultaneous Euler-Maruyama updates. dt obeys active-relaxation, angular-rate and DEM contact limits. Check overlap and finite state; compare dt/2 and several seeds.
- This exploratory finite inertial system does not establish a phase diagram or reproduce a calibrated experimental swimmer. Persistent aggregates alone are not proof of motility-induced phase separation.

Current evidence

Checked scope: periodic repulsive active disks, independent connectivity measurements and density/noise controls. The dense N=100 case meets the connectivity and speed refinement margins over 24 s across 12 seeds. One-second membership retention permits mergers and is not a cluster lifetime; a large connected group alone does not establish phase separation.

Available study controls

Run Comparison: Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [mm/s].

Parametric sweep: Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Active-passive mixture

Active matter / **Implemented**

Question and model

How does an active population transport passive neighbors?

A minimal dry, inertial active-particle model on the shared DEM engine. All quantities use SI internally. There is no CFD, solvent momentum field or calibrated biological response.

Main controls

Active fraction: round(f × N) particles of species A; Total N and derived area fraction φ in a fixed box; Propulsion speed, relaxation and angular diffusion; Diameter and seed.

Observe

MSD by activity; Mean speed by activity; Unlike neighbor fraction; Largest cluster fraction.

Try a controlled variation

Compare active fractions at fixed total population and diameter. Read the two species' MSD separately and monitor unlike-neighbor fraction. A missing species is not a measured diffusive population.

Scope and numerics

- A is propelled; B has zero propulsion. Both have the same mass, diameter, drag and repulsive contacts. Passive disks are athermal: without active collisions they relax to rest.
- Species labels occupy independently shuffled lattice sites. Their fixed IDs, displacement and species survive snapshots. Active and passive mobility use their own population counts. An absent species exports count zero and mobility zero; its plotted series is omitted.
- Unlike neighbor fraction is the number of A-B edges divided by all edges at the cluster distance threshold, with minimum images. It is zero when no edges exist. This is a structural comparison, not a calibrated segregation index.
- Orientations update simultaneously with Euler-Maruyama, independently of mechanical spin. Seeds reproduce the same timestep and configuration; noisy trajectories need not match when dt changes.
- Compare several seeds, system sizes and dt/2. Check overlap, finite state and confinement. A finite cluster or ordered configuration does not establish a phase diagram.

Current evidence

Checked scope: periodic active/passive disks with equal mass, diameter and drag; passive particles receive motion through contacts. The 50/50, N=100 case meets connectivity and both species-speed refinement margins over 24 s across 12 seeds. Neighbor composition is a geometric measurement, not by itself evidence of segregation.

Available study controls

Run Comparison: Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [mm/s].

Parametric sweep: Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Cohesive swarm

Active matter / **Experimental**

Question and model

How do attraction and alignment compete with active spreading?

A minimal dry, inertial active-particle model on the shared DEM engine. All quantities use SI internally. There is no CFD, solvent momentum field or calibrated biological response.

Main controls

Attraction F_0 [N] and range / d; Alignment κ and perception radius R; Propulsion speed, relaxation time and angular diffusion; N, diameter, derived area fraction φ and seed.

Observe

Largest cluster fraction; Polarity order; Particle-weighted cluster size; Mean speed.

Try a controlled variation

Compare attraction enabled and disabled while keeping alignment and noise fixed. Examine group size and membership retention separately. Do not use the generic mechanical-energy curve alone to close the attraction-energy balance.

Scope and numerics

- Attraction is central and equal/opposite. Let $d = r_i+r_j$, ℓ = (rangeFactor-1)d and $s = (r-d)/\ell$. Its magnitude is $F_0 \sin(\pi s)$ for $0 < s < 1$ and zero otherwise. Repulsion is ordinary DEM.
- The attraction potential is $-F_0\ell(1+\cos(\pi s))/\pi$ within range, $-2F_0\ell/\pi$ below contact and zero beyond cutoff. Force and potential are continuous at both joins.
- Attraction range, perception radius and cluster threshold are independent. $F_0 = 0$ removes attraction but retains alignment. A bound pair may lie outside the cluster threshold.
- The generic mechanical-energy diagnostic omits attraction potential, and DEM force chains omit attraction. A slope-based timestep bound supplements contact and active-drive limits.
- Orientations update simultaneously, independently of disk spin. Compare several seeds, sizes and dt/2; identical noisy paths are not expected when dt changes. Finite clusters do not establish a phase diagram.

Current evidence

Experimental: pair attraction and energy accounting are checked. In the 12-seed, 12 s reference campaign, polar order and one-second membership retention meet the refinement margin, but both largest-group intervals extend beyond ±0.05. Without attraction, membership-retention precision also remains unresolved. Retention permits mergers and is not a cluster lifetime.

Available study controls

Run Comparison: Alignment strength κ [1/s]; Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [mm/s].

Parametric sweep: Alignment strength κ [1/s]; Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Nematic alignment

Active matter / **Experimental**

Question and model

Can orientational order exist without a common direction of travel?

A minimal dry, inertial active-particle model on the shared DEM engine. All quantities use SI internally. There is no CFD, solvent momentum field or calibrated biological response.

Main controls

Alignment κ [1/s]; Perception radius R [m]; Angular diffusion D_r [rad²/s]; Propulsion speed, relaxation, N and seed.

Observe

Nematic order S = $|\langle \exp(2i\varphi) \rangle|$; Polarity order P = $|\langle \exp(i\varphi) \rangle|$; Velocity order; MSD.

Try a controlled variation

Vary noise at fixed alignment radius and strength. Read nematic order S and polar order P together. Parallel and antiparallel headings can share a nematic axis even when their polar average cancels.

Scope and numerics

- $d\varphi_i/dt = \kappa \, \mathrm{mean}_j \sin(2(\varphi_j - \varphi_i)) + \sqrt{(2D_r)}\, \xi_i$. Perception excludes self and uses minimum-image distances within R. κ is not divided by two.
- Parallel and antiparallel headings share a nematic axis. An equally split antiparallel population has S = 1 and P = 0. Each disk still propels along its own polar heading.
- These are circular DEM disks with nematic steering. They are not rods, do not acquire steric rod alignment, and do not model wet active-nematic defects or hydrodynamics. The cited rod experiment motivates the distinction in order, not quantitative agreement.
- Orientations update simultaneously with Euler-Maruyama, independently of mechanical spin. Seeds reproduce the same timestep and configuration; noisy trajectories need not match when dt changes.
- Compare several seeds, system sizes and dt/2. Check overlap, finite state and confinement. A finite cluster or ordered configuration does not establish a phase diagram.

Current evidence

Experimental: head-tail symmetry and nematic order S are checked. Secondary polar order P varies strongly between seeds; both P refinement intervals remain wider than the ±0.05 acceptance margin in the 12-seed, 24 s campaign. Finite-size ordering and transients must be distinguished from a stationary phase.

Available study controls

Run Comparison: Alignment strength κ [1/s]; Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [mm/s].

Parametric sweep: Alignment strength κ [1/s]; Angular diffusion Dr [rad²/s]; Propulsion speed v_0 [m/s].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Maxwell compartment

Granular / Transport and compartments / **Implemented**

Question and model

How does the population evolve between two compartments connected by an aperture?

Two cells separated by a wall with a central opening. It supports studying transport, mixing and sensitivity to opening size/position.

Main controls

Particles N; Opening height; Opening position; Gravity g or no gravity; Friction μ; Damping γ_n.

Observe

Particles per compartment; Flow through the opening; Energy; Contacts; delta max/R.

Try a controlled variation

Compare opening heights at fixed particle size, population and forcing. Watch compartment populations and transport through the divider. Avoid initial states that place particle centers inside the divider.

Scope and numerics

• The wall must repel from both accessible faces.

• Do not seed particles inside the divider.

• Avoid openings so small that they compress particles during rebuild.

Available study controls

Run Comparison: Opening height [mm].

Parametric sweep: Opening width [m]; Particle count N [1]; Wall thermal speed [m/s].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Silo discharge

Granular / Transport and compartments / **Implemented**

Question and model

Why can the discharge rate of a granular silo be approximately constant and independent of column height?

Grain column discharging through a lower opening. The cumulative discharged particle count N_out(t) reveals the steady regime; an approximately linear region indicates a nearly constant particle discharge rate.

Main controls

Particles N; Mean diameter d; Dispersion; Outlet width; Box width; Box height; Bottom angle; Gravity g; Friction μ; Global damping; Silo geometry.

Observe

N_out(t); Particle discharge rate q_N = dN_out/dt; Base load F_base(t); Lateral load F_lateral(t) and p_lateral,2D(t); Particles inside the silo; Clogging events.

Try a controlled variation

Prepare the same sample for several outlet diameters. Compare cumulative discharged count and the complete-bin particle flow rate. Keep d fixed so that D/d is interpretable, and distinguish a quiet clogged state from a numerical stop.

Scope and numerics

• Initialize without severe overlaps.

• Use initial relaxation if needed.

• Avoid particles trapped at the outlet.

• Discharged particles are captured as a diagnostic without drawing a physical receiving container.

Available study controls

Run Comparison: Nozzle diameter D [mm].

Parametric sweep: Orifice diameter D [m]; Mean diameter d [m]; Friction [1]; Fill particles N [1]; Obstacle size [m]; Obstacle height above outlet [m]; Obstacle x offset [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Multi-orifice silo discharge

Granular / Transport and compartments / **Implemented**

Question and model

How does a granular column split its discharge among multiple lower outlets?

Rectangular silo with a flat bottom and several centered orifices. It tracks total discharged mass M_out(t), per-orifice mass M_out,i(t), flow Q_i and outlet balance.

Main controls

Number of orifices n; Mean diameter d; Dispersion; Orifice diameter D; Center spacing s; Box width W; Box height H; Initial fill height H_fill; Gravity g; Friction μ; Global damping.

Observe

N_out,total; N_out,i; M_out,total; M_out,i; Q_total; Q_i; Outlet balance; Maximum overlap ratio.

Try a controlled variation

Compare centered layouts with different outlet spacing while holding number and diameter of outlets fixed. Examine per-outlet discharge and total flow; equal total discharge does not imply equal sharing among outlets.

Scope and numerics

- Orifices are centered and clamped to fit inside W with a minimum solid ligament.
- Discharged particles are counted only when x falls inside an orifice interval.
- Captured particles are discarded below the visible domain and do not create a lower receptacle.
- Use fixed seeds when comparing outlet balance across layouts.

Available study controls

Run Comparison: Orifice diameter D [mm].

Parametric sweep: Number of orifices n [1]; Orifice diameter D [m]; Orifice spacing s [m]; Mean diameter d [m]; Friction [1]; Obstacle size [m]; Obstacle height above outlet [m]; Obstacle x offset [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Galton board

Granular / Transport and compartments / **Implemented**

Question and model

How does a lateral outlet distribution emerge when particles fall through a periodic obstacle array?

Disks falling under gravity through a pin array. Each collision changes the trajectory and the ensemble produces an outlet distribution in the lower bins. It supports discussion of diffusion, dispersion and granular mixing.

Main controls

Particles N; Mean diameter d; Pin radius; Horizontal spacing; Vertical spacing; Number of rows; Friction μ; Normal restitution e_n / damping γ_n; Board width; Bin geometry.

Observe

Histogram by bin; Lateral outlet distribution; Fall time; Collisions per particle; Particles outside domain; Maximum overlap; Mixing by species when applicable.

Try a controlled variation

Keep grain size and release conditions fixed while varying pin spacing. Compare the captured-bin distribution only after enough grains have arrived. Verify clearances before making pins larger.

Scope and numerics

• Avoid overlaps with pins or walls.

• Inject particles gradually.

• Ensure side walls.

• Lower bins must detect particles without generating artificial contacts.

Available study controls

Run Comparison: Pin spacing [mm].

Parametric sweep: Pin spacing [m]; Pin radius [m]; Mean diameter d [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Mesh filtration

Granular / Transport and compartments / **Implemented**

Question and model

How do filtration and size segregation develop along an inclined mesh?

A grain assembly flows over a perforated inclined mesh. The historical settled-release protocol starts from a column resting on the mesh; funnel feed retains the material between two inclined walls and releases it through a horizontal gate above the solid lead-in. The Particles panel can prepare either one size distribution or a bilayer: species A is placed below species B with independent diameters and a controlled number fraction. The gate height and opening set the initial fall and feeding width before the perforated section. The collector composition then reveals how filtration and segregation depend on the size-to-aperture ratio.

Main controls

Particles N; Initial layering: single size or bilayer; Mean diameter d; Lower/upper diameters d_A and d_B; Lower-layer number fraction; Feed condition; Gate opening G; Funnel opening D_f; Funnel gate height h_f; Aperture D; Ratio chi=d/D; Relative thickness delta/D; Inclination angle; Number of compartments below the perforated zone; Friction μ; Gravity g.

Observe

Filtered mass by compartment; Fraction mu_i; Profile mu(x); Filtration length ell; Remaining survival mass M(x); Local filtration rate k(x); Asymptotic rate k_0 and development length x_s; Local filtration length ell_local=1/k_0 versus global ell_fit; Residual mass; Total filtered fraction; Species-filtered fractions F_A and F_B; Species-B fraction by collector x_B,i; Collector segregation index S_bins; Vertical separation S_y of uncollected grains.

Try a controlled variation

Compare aperture at fixed diameter and inclination, recording chi = d/D. For a bilayer, examine each species' filtered fraction and collector composition. Do not fit a filtration length when too few bins contain meaningful mass.

Scope and numerics

- Finite segments represent the solid mesh; openings must remain open. Filtered particles are counted once and remain dynamic inside the collectors.
- Filtration-length and local-rate estimates require populated bins and adequate remaining mass. Missing or rejected fit values should remain unavailable.
- The survival profile is derived from classified outcomes, including residual mass at the mesh end. Local rates use a smoothed spatial derivative and omit unsuitable bins.
- The collector segregation index compares the collected-bin distributions of A and B. Vertical separation describes the uncollected population. These are different measurements.

Available study controls

Run Comparison: Mesh opening [mm].

Parametric sweep: Mesh opening [m]; Mean diameter d [m]; Inclination angle [deg]; Friction [1].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Inclined plane

Granular / Granular flows / **Implemented**

Question and model

How do inclination and an optional obstacle change a granular release?

A finite sample is prepared behind a hopper gate and released onto a continuous inclined base. Explore angle, friction and gravity, then optionally add one fixed circular obstacle tangent to the plane. Its diameter and centre distance from the start of the plane are adjustable. This two-dimensional cross-section allows grains to pass over the obstacle, without transverse side-wall effects. Contacts use the same grain-boundary DEM model as the base.

Main controls

Particles N; Mean diameter d; Polydispersity; Plane angle; Optional obstacle diameter and position; Grain-grain friction μ; Grain-boundary friction μ; Damping γ_n/γ_t; Gravity g.

Observe

Mean velocity parallel to the plane; Center of mass; Parallel displacement; Kinetic energy; Contact count; Maximum overlap.

Try a controlled variation

Prepare the hopper and compare nearby inclinations at fixed friction. Read velocity parallel to the plane and displacement. Add the optional obstacle only in a separate comparison so its effect is not confused with the angle change.

Scope and numerics

- Avoid high initial overlaps between the layer and base.
- The base is continuous. Obstacles is off by default; enabling it adds one fixed disk without adding basal roughness.
- Velocity and displacement average active grains, including those in the hopper; they are not local flow profiles. Base-force plots exclude the obstacle reaction.
- Monitor particles outside the domain at large angles.
- Measure velocities in coordinates parallel/normal to the plane.
- Use Velocity Verlet for dense flow and persistent contacts.

Available study controls

Run Comparison: Inclination angle [deg].

Parametric sweep: Inclination angle [deg]; Friction [1]; Mean diameter d [m]; Particle count N [1].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Inclined plow

Granular / Granular flows / **Implemented**

Question and model

How do drag and lift forces scale for an inclined plate pushing a granular bed?

2D preset inspired by Percier et al. An inclined plate advances at constant speed over a settled bed and records boundary forces and mass in a measurement zone ahead of the plate.

Main controls

Particles N; Mean diameter d; Polydispersity; Bed height; Plate length; Attack angle; Plow speed; Travel distance; Finite/periodic X condition.

Observe

F_D(t); F_L(t); M_zona(t); F_D/(M_zona g); F_L/(M_zona g); mu_eff.

Try a controlled variation

Prepare the bed, then vary plate speed with the same penetration and angle. Compare drag and lift with the mass in the measurement zone. That zone is a geometric diagnostic, not a new physical boundary.

Scope and numerics

• Use Prepare to settle the bed before activating the plow.

• Periodic-x mode is opt-in for long/headless runs.

• M_zone is a geometric estimate in an ahead-of-plate measurement window; it is not a physical boundary.

• The plow is a kinematic segment: plate degrees of freedom are not resolved.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Plow speed [m/s]; Plow angle [deg]; Plow penetration [m]; Friction [1]; Mean diameter d [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Heap flow

Granular / Granular flows / **Implemented**

Question and model

How do surface avalanches and outflow develop when grains are continuously deposited onto an L-shaped heap?

Heap flow is an educational DEM preset inspired by the heap-flow surface geometry discussed by GDR MiDi. It uses a controlled particle source and an L-shaped cell to form a heap; grains discharge when they fall from the open right edge of the base. It is not a calibrated quantitative replica.

Main controls

Mean diameter d; Active-particle limit N; L wall height H; L base length W; Base roughness diameter; Source width; Source x; Source height; Source-surface gap; Deposition rate; Friction μ.

Observe

Surface angle θ_surface(t); Avalanche activity A(t); Surface map h(x,t); Discharged count N_out(t); Mass flow rate Q_out(t); Dimensionless 2D flow proxy Q*_2D(t); Avalanche count and duration.

Try a controlled variation

Compare deposition rates at fixed base length and particle size. Read surface angle, activity and discharged mass flow after the heap forms. Keep a record of the active-particle limit and source position.

Scope and numerics

- The source reuses inactive particle slots before appending new particles and respects a hard slot capacity.
- Discharged grains are detected after falling below the base at the open right edge; they are marked inactive and removed from contacts.
- The surface angle is fitted only when enough finite surface bins are available.
- Q*_2D is a 2D proxy Q_mass/(rho_2D d sqrt(gd)); it is not a calibrated Hele-Shaw flow rate.
- Force-network analysis is available but disabled by default.

Available study controls

Run Comparison: L base length W [mm].

Parametric sweep: L base length W [m]; Deposition rate [1/s]; Source width [m]; Source-surface gap [m]; Base roughness diameter [m]; Mean diameter d [m]; Friction [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Free-fall stream

Granular / Granular flows / **Implemented**

Question and model

How do the center of mass and shape of a freely falling granular segment evolve when vacuum, uniform air and shielded drag are compared?

2D granular column without walls or cohesion. The visualization can follow the center of mass, while observables report fall, deformation, connectivity and geometric exposure to air.

Main controls

Particles N; Mean diameter d; Polydispersity; Initial width D0; Initial height L0; External medium; Air damping γ_air; Shielding length; Laboratory/center-of-mass camera.

Observe

Y_cm(t); V_cm(t); A_cm(t); Radius of gyration R_g(t); Aspect ratio L_y/W_x; Instantaneous contacts and clusters; Mean exposure and drag force.

Try a controlled variation

Compare no external medium with uniform linear drag, then inspect the geometric shielding option separately. Use the center-of-mass camera for readability while retaining laboratory-frame quantities for dynamics.

Scope and numerics

- This preset has no cohesion, so cohesive stream clustering is outside its scope.
- Shielded air is a geometric model of differential drag, not CFD or capillary cohesion.
- The comoving camera is visual and does not change physical positions or velocities.
- Uniform linear air uses F_drag = -m γ_air v through ExternalMedium.
- There are no walls or floor; particles can fall indefinitely in the laboratory frame.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Source width [m]; Mean diameter d [m]; Particle count N [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Granular impact · 2D

Granular / Intrusion and impact / **Implemented**

Question and model

How does a granular bed stop an intruder and transmit its momentum?

Prepare the bed, release the intruder, then compare penetration, downward speed and upward contact force. Recorded run calculates an independent recorded run for playback and export. This is a two-dimensional disk model, not a quantitative model of a sphere in 3D sand.

Main controls

Number of bed grains; Reference grain diameter d; Projectile D/d and 2D density ratio; Launch speed (not contact speed); Bed width / d; Friction, reference restitution and stiffness; Preparation seed.

Observe

Penetration below the initial bed surface; Projectile downward velocity; Upward resultant contact force; Contact network; Maximum overlap and kinetic energy.

Try a controlled variation

Prepare a small bed and vary launch speed with fixed projectile size and density ratio. Compare penetration, downward velocity and upward contact force. Check width, depth, dt and seed sensitivity before fitting a penetration law.

Scope and numerics

- Disk mass is $\rho\pi r^2$ and rotational inertia is $mr^2/2$; ρ has units kg/m^2. Linear spring-dashpot contacts, tangential history and Coulomb friction provide the stopping force.
- Restitution is calibrated for a reference pair. Effective restitution can differ for walls, other grain sizes and the projectile because reduced masses differ.
- The projectile is absent during preparation, then inserted one grain diameter above the settled surface. Gravity raises its speed before contact.
- The top is open. Sidewalls and bottom are physical. Check sensitivity to bed width, depth, packing seed and timestep.
- Recorded run integrates impulse every DEM step and saves interval means and peaks separately from video frames. Live plots and standard CSV are instantaneous samples.
- This 2D model excludes air, cohesion, fracture and high-speed cratering physics. More grains alone do not demonstrate convergence.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: not currently offered for this preset.

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Angle of repose

Granular / Deposition and piles / **Implemented**

Question and model

How does an effective angle of repose emerge when grains are deposited from a localized source and form a pile?

Gravitational deposition on a rough base. Grains fall from a localized source and accumulate into a pile whose slope depends on friction, roughness and dissipation.

Main controls

Particles N; Mean diameter d; Source width; Deposition height; Deposition rate; Base roughness; Gravity g; Friction μ; Global damping.

Observe

Pile height; Basal width; Estimated angle of repose; Kinetic energy; Contacts; delta max/R.

Try a controlled variation

Deposit a modest pile and wait until kinetic activity is low before reading its slope. Compare friction while keeping source width, insertion rate and base roughness fixed. A slope measured during a falling avalanche is a different observable.

Scope and numerics

• Deposit grains progressively from the source, without physical hopper walls.

• Adjust deposition rate to avoid severe initial overlaps.

• Monitor kinetic energy before measuring a stationary slope.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Deposition rate [1/s]; Source width [m]; Source-surface gap [m]; Mean diameter d [m]; Friction [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Granular pile

Granular / Deposition and piles / **Implemented**

Question and model

How does the basal load profile change when a granular pile is built by a localized source or by homogeneous rain?

2D granular pile inspired by the construction-history memory experiments of Vanel et al. The preset compares two initial conditions and measures the basal normal load with discrete sensors.

Main controls

Construction mode; Particles N; Mean diameter d; Polydispersity; Basal width; Basal sensors; Friction μ.

Observe

q_y(x) [N/m]; q_y/(Mg/L); Central dip index; F_base/Mg; Kinetic energy; Contacts.

Try a controlled variation

Prepare a pile from each construction mode using the same total mass and base. Compare the basal linear-load profile, central dip and total basal reaction. Source and rain construction are separate runs.

Scope and numerics

- Use Prepare to relax the pile before measurement.
- Basal load is reported as 2D line pressure in N/m.
- Source/rain comparisons are made in separate runs.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Deposition rate [1/s]; Source width [m]; Source-surface gap [m]; Mean diameter d [m]; Friction [1].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Granular avalanches

Granular / Deposition and piles / **Implemented**

Question and model

How does a pile respond to the addition of just one grain?

A reproducible disordered rough base with open ends. The next grain is released only after the entire pile has remained quiet, including particle rotation.

Main controls

Additions; Grain diameter; Base width; Release height above base; Random gaps; Rest tolerance and duration.

Observe

Avalanche size S(n); P(S), including S = 0; Escaped grains; Relaxation time; Voronoi shape factor ζ.

Try a controlled variation

Use a short sequence of additions and inspect settled states before and after each grain. Compare the avalanche-size sequence including zero events. Increase the number of additions only after verifying that the rest criterion is achieved.

Scope and numerics

- 2D disk analogue; glass-plate friction and 3D sphere inertia are not represented. No power law is imposed.
- S counts old centres without a centre within d/7 in the next settled state. The new grain is excluded. ID displacement is reported separately.
- A timeout stops deposition; it never releases another grain into a moving pile.
- Voronoi is optional and evaluated only at rest. Cells touching the 4d local boundary and centres within 2d of the base are excluded; retained cells use exact half-plane clipping.
- The compact demo is not the paper geometry. The paper uses L = 600 mm, d = 4 mm, h = 280 mm and 55,000 additions. Its arXiv version excludes the first 4,500 events; configure the transient for your study.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: not currently offered for this preset.

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Curved-base deposition

Granular / Deposition and piles / **Implemented**

Question and model

How do pile shape and stability change when deposition occurs over a non-flat rough base?

Gravitational deposition from a localized source over a static rough boundary with flat, concave, convex or wavy geometry.

Main controls

Base type; Base amplitude or curvature; Wavelength; Particles N; Mean diameter d; Source width; Source height or adaptive distance; Deposition rate; Base roughness.

Observe

Apparent angle of repose; Surface profile h(x); h(x,t) map; Residual activity.

Try a controlled variation

Compare flat, concave and convex bases with the same source and particle properties. Observe the surface profile and residual activity. The adaptive source changes insertion position, not the force law.

Scope and numerics

• The base is a static DEM boundary made of segments and rough disks.

• The adaptive source only changes insertion position; it does not add forces.

• Control deposition rate and roughness to avoid initial overlaps.

Available study controls

Run Comparison: Base amplitude [mm].

Parametric sweep: Base amplitude [m]; Base wavelength [m]; Source-surface gap [m]; Deposition rate [1/s]; Mean diameter d [m].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Brazil nut

Granular / Segregation / **Implemented**

Question and model

Under what conditions does a large intruder rise inside a vibrated granular bed?

Vibrated bed with a larger intruder particle. It supports studying segregation, percolation, convection and sensitivity to density and friction.

Main controls

Small-grain radius; Intruder radius; Intruder density ρ; Initial height; Base agitation; Gravity g; Friction μ.

Observe

Intruder height; Kinetic energy; Contacts; Rise time; delta max/R.

Try a controlled variation

Prepare a bed with one intruder and vary its size or density in separate experiments. Follow intruder height while checking wall effects and agitation. A short upward excursion is not a converged rise-time statistic.

Scope and numerics

- Initialize the intruder without overlaps.
- Control agitation amplitude to avoid numerical ejection.
- Separate physical segregation from boundary effects.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Intruder diameter [m]; Density ratio [1]; Gamma Γ [1]; Base frequency [Hz]; Mean diameter d [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Granular mixing

Granular / Segregation / **Implemented**

Question and model

How does mixing evolve between two initially separated granular populations?

Two granular species are placed initially separated inside a rotating drum. Rotation produces a surface active layer and a passive region that can mix or segregate particles depending on size, density, fill level and angular speed. This preset supports studying the competition between mixing and segregation.

Main controls

Species fraction; Initial condition; RPM; Size ratio; Densities ρ_A/ρ_B; Friction μ; Drum radius; Gravity g; Roughness.

Observe

Mixing index M; Local concentration by species; Center of mass by species; Mean diameter by species; Kinetic energy; Granular activity.

Try a controlled variation

Start with two separated species and compare rotation rates at fixed fill level. Use a mixing grid with enough particles per cell, then compare equal-size species with a size-contrast case.

Scope and numerics

- Use nonoverlapping initial conditions and consistent mass, density and radius for both species.
- Mixing statistics need enough particles in each analysis bin. Sparse-bin fluctuations are not by themselves evidence of segregation.

Available study controls

Run Comparison: Rotation rate [rpm].

Parametric sweep: Rotation rate [rpm]; Size ratio [1]; Density ratio [1]; Particle count N [1]; Friction [1].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Simple bounce

Granular / Forced / nonlinear dynamics / **Implemented**

Question and model

How is the effective restitution of a particle bouncing on a rigid wall measured?

A minimal experiment of one particle under gravity colliding with a base. Use it to examine rebound height, kinetic and potential energy, damping and effective restitution.

Main controls

Teaching material; Radius; 2D density ρ; Initial height; Initial velocity; Normal restitution e_n; Friction μ.

Observe

Maximum height; Kinetic energy; Potential energy; Total energy; Effective restitution; Time between bounces.

Try a controlled variation

Compare two restitution settings at the same drop height and initial velocity. Read the rebound, energy and impact sequence. Use the dedicated Normal restitution test for its explicit validation comparison.

Scope and numerics

- The measured contact response depends on timestep, stiffness and damping as well as the requested restitution.
- Monitor overlap when increasing drop height. For a dissipative impact on a stationary base, compare pre-impact and post-impact mechanical energy, allowing for transient contact storage.

Available study controls

Run Comparison: Normal restitution e [1].

Parametric sweep: Initial height [m]; Initial velocity [m/s]; Normal restitution [1]; Gravity g [m/s2].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Vibrated base

Granular / Forced / nonlinear dynamics / **Implemented**

Question and model

How do periodic orbits, subharmonics and chaos appear in a particle bouncing on a vibrating base?

A particle falls under gravity and collides with a vertically oscillating base. Energy is injected at each impact according to base phase and relative particle-wall velocity. Changing amplitude, frequency and restitution can produce periodic responses, period doubling and chaos.

Main controls

Amplitude A; Frequency f; Gravity g; Normal restitution e_n; Friction μ; Initial height; Initial velocity; Mass/radius.

Observe

y(t); vy(t); Phase space vy vs y; Impact phase; Post-impact velocity vs phase; Maximum height; Time between bounces; Effective restitution.

Try a controlled variation

Hold restitution and initial conditions fixed while changing vibration amplitude. Compare the trajectory and impact phase. Record amplitude and frequency separately even when reporting the derived acceleration Gamma.

Scope and numerics

- Energy transfer depends on relative particle-wall velocity and the phase of the moving base at impact.
- Phase is 2 pi f t modulo 2 pi. A trajectory with a few impacts is insufficient to establish a statistically stationary or chaotic regime.

Available study controls

Run Comparison: Gamma Γ [1].

Parametric sweep: Gamma Γ [1]; Base amplitude [m]; Base frequency [Hz]; Normal restitution [1]; Concave base curvature [1/m]; Wavy amplitude [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Vibrating ratchet

Granular / Forced / nonlinear dynamics / **Implemented**

Question and model

How can an asymmetric vibrating base rectify particle motion and produce lateral transport?

The preset explores how geometry, vibration intensity, forcing direction and particle size control activation, directional bias and mean lateral displacement. This version uses circular particles and supports vertical, horizontal or circular vibration with a 90-degree phase shift between x and y.

Main controls

Tooth height h; Period w; Asymmetry length y; a = y/w; Number of teeth; Amplitude A; Frequency f; Forcing direction; Acceleration Γ; Particle radius; Friction μ and normal restitution e_n.

Observe

x(t); y(t); Delta x total; Intraperiod residual; Inter-tooth events; p_event; Directional bias; Drift velocity; Relative phase xi; Physical tooth jumps P(n_i); Time-lag displacement and drift-corrected variance; Effective diffusion D_eff (single particle).

Try a controlled variation

Compare tooth asymmetries with the same forcing direction and vibration. Inspect unwrapped displacement and drift, then reverse the asymmetry. Long-time diffusion estimates require a stationary interval and repeated evidence.

Scope and numerics

- Contact events are based on DEM-step minima of height relative to the base near a contact. Tooth-index differences define physical jumps; rounded displacement and the initial-tooth histogram are different measurements.
- Diffusion uses one particle, unwrapped laboratory-frame displacements and overlapping time origins sampled at 50 Hz, retaining up to 900 s. The 2-20 s fit begins after 100 s and assumes stationary increments. D_eff is not a convergence claim.
- Domain width must be an exact multiple of tooth period w. Horizontal periodicity preserves accumulated displacement separately from wrapped position.
- Horizontal and circular forcing move the base rigidly; contacts use relative wall velocity. In circular mode A is the trajectory radius and $\Gamma = A(2\pi f)^2/g$.
- The linear-contact, periodic model is not calibrated to a finite experimental cell or to a different contact law.

Available study controls

Run Comparison: Gamma Γ [1].

Parametric sweep: Gamma Γ [1]; Base amplitude [m]; Base frequency [Hz]; Ratchet asymmetry [1]; Mean diameter d [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Vibrated bed

Granular / Forced / nonlinear dynamics / **Implemented**

Question and model

How does a granular bed fluidize when it receives energy from a vibrating base?

A vertically vibrated grain bed can show fluidization, compaction, saltation, convection and collective patterns. The key parameter is Γ, the maximum base acceleration normalized by gravity.

Main controls

Particles N; Mean diameter d; Polydispersity; Amplitude A; Frequency f; Acceleration $\Gamma = A(2\pi f)^2/g$; Gravity g; Friction μ; Damping γ_n/γ_t.

Observe

Mean bed height; Vertical center of mass; Granular temperature; Kinetic energy; Airborne particle fraction; Contact count; Maximum overlap.

Try a controlled variation

Prepare the bed, then compare amplitude or frequency one at a time. Read center-of-mass height and airborne fraction as well as the color map. Monitor overlap and the open upper boundary as forcing increases.

Scope and numerics

- The base uses relative particle-wall velocity. The top remains open rather than imposing an artificial elastic ceiling.
- Large Gamma can require finer resolution. Check overlap, finite state and lateral confinement.
- Read amplitude and frequency as well as Gamma. Similar maximum acceleration does not imply identical displacement or velocity forcing.

Available study controls

Run Comparison: Base amplitude [mm]; Base frequency [Hz].

Parametric sweep: Gamma Γ [1]; Base amplitude [m]; Base frequency [Hz]; Particle count N [1]; Mean diameter d [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Tapped compaction

Granular / Forced / nonlinear dynamics / **Implemented**

Question and model

How does a gently deposited two-dimensional packing densify under repeated discrete taps separated by relaxation?

This preset is an educational two-dimensional soft-disk DEM adaptation of tapped-compaction experiments. Prepare deposits grains gradually under gravity and lets the bed relax before the first tap. The base and lateral walls then translate together during a raised-cosine pulse and remain still until the next tap. The reported packing fraction is nominal: the sum of disk areas divided by the rectangular bed envelope.

Main controls

Particles N; Mean diameter d; Polydispersity; Peak cell rise A; Pulse frequency f; Tap period T; Peak acceleration $\Gamma = 2\pi^2 A f^2/g$; Gravity g; Friction μ.

Observe

Settled nominal packing fraction $\varphi_{pile}(n)$; Bed height $H_{pile}(n)$; Granular temperature after each tap; Tap index n; Dimensionless acceleration Γ; Amplitude ratio A/d.

Try a controlled variation

Prepare the bed and run a short tap sequence. Read packing fraction during the rest interval after each tap. Compare peak rise at fixed pulse frequency; the raised-cosine pulse has its own Gamma convention.

Scope and numerics

- The raised-cosine pulse starts and ends with zero displacement and velocity, avoiding a discontinuous wall velocity.
- The default gentle tap uses A/d = 0.20 and $\Gamma \approx 1.45$; limiting A/d alone does not limit acceleration when frequency increases.
- Colors follow initial horizontal bands. A fixed gray copy of the initial free surface is drawn behind the mobile grains; it has no mass, contacts or effect on observables.
- Prepare uses gradual gravity deposition followed by a rest stage; it is a reproducible 2D analogue rather than a literal nitrogen-fluidization replica.
- The tracker records one sample per tap during the rest interval, rather than sampling while the container is moving.
- φ_{pile} is a nominal 2D area fraction; soft-disk overlaps and boundary-layer corrections are not subtracted.
- This is a 2D educational model, not a quantitative reproduction of the original three-dimensional experiments.
- The inverse-log compaction law is useful as a phenomenological comparison, but it is not automatically fitted or asserted by this preset.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Tap Gamma Γ [1]; Tap amplitude [m]; Tap frequency [Hz]; Tap period [s]; Particle count N [1]; Mean diameter d [m]; Friction [1].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

V-shaped bed

Granular / Forced / nonlinear dynamics / **Implemented**

Question and model

How does base geometry modify agitation, order and fluidization in a vibrated granular bed?

A grain bed is confined in a vertical cell whose V-shaped base vibrates sinusoidally. Changing the base angle breaks packing symmetry, which can promote defects, increase disorder and modify granular temperature at comparable injected energy.

Main controls

Particles N; Mean diameter d; Polydispersity; Amplitude A; Frequency f; Acceleration $\Gamma = A(2\pi f)^2/g$; Gravity g; V-base angle; Friction μ; Damping γ_n/γ_t.

Observe

Acceleration Γ; Mean bed height; Vertical center of mass; Granular temperature; Kinetic energy; Flight fraction; Contact count; Velocity field; Maximum overlap.

Try a controlled variation

Prepare separate beds for two base angles while keeping vibration fixed. Compare left/right response, center position and flight fraction. Changing the angle rebuilds geometry and packing, so record that difference in the protocol.

Scope and numerics

- The V-base moves as a rigid boundary with two synchronized inclined walls.
- Contacts with moving walls must use relative particle-wall velocity.
- Large angle changes rebuild the initial packing.
- Monitor high overlap, NaN and particles outside the domain.
- Topological observables such as psi6, defects and solid/fluid fraction remain future work.

Available study controls

Run Comparison: V-base angle [deg].

Parametric sweep: Gamma Γ [1]; V-base angle [deg]; Base amplitude [m]; Base frequency [Hz]; Mean diameter d [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Vibrated quasi-2D layer

Granular / Forced / nonlinear dynamics / **Experimental**

Question and model

How do vertical confinement and vibration redistribute kinetic energy between horizontal and vertical motion in a shallow granular layer?

This exploratory preset uses an isolated three-dimensional sphere backend because projected particle overlap does not imply physical contact in a shallow cell. It is inspired by quasi-2D vibrated-layer experiments and is not yet a quantitatively calibrated reproduction.

Main controls

Box width Lx; Box depth Ly; Gap ratio h/d; Particles N; Particle diameter d; Material density rho; Vibration amplitude A; Frequency f; Normal restitution; Normal stiffness.

Observe

Mean vertical position; Vertical layer occupancy; Horizontal granular temperature Txy; Vertical granular temperature Tz; Anisotropy Tz/Txy; Top and bottom wall contacts.

Try a controlled variation

Start with a small population and compare the top projection with a finite side slab. Read the gap and any displayed vertical magnification. Projected overlaps are not automatically three-dimensional contacts.

Scope and numerics

- The current default uses Cundall-Strack tangential history and particle rotation. Normal-only contacts remain available as an experimental comparison.
- Projected overlaps do not create contacts. The force network uses actual sphere-sphere contacts in three dimensions.
- Amplitude and frequency are primary inputs; Gamma and A/d are derived. N is primary and projected filling fraction is derived.
- The finite side slab is a projection, and Fit gap can magnify the vertical axis. Q4/Q6 thresholds and same-phase clusters are exploratory diagnostics.
- Use the dedicated Quasi-3D particle snapshot CSV. Do not assume compatibility with the standard 2D CSV, inspection or study workflows.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: not currently offered for this preset.

Other catalog capabilities: Observables.

09 Preset reference

Granular Brownian motion

Granular / Forced / nonlinear dynamics / **Experimental**

Question and model

When does a large tracer on a vibrated granular layer exhibit horizontal diffusion?

Contacts drive the tracer without added random forces. The initial transient is excluded from statistics. Mass and inertia follow solid-sphere geometry; at equal density the default 3d tracer (4.5 mm) has 27 times the bath-grain mass. A Brownian regime is not guaranteed.

Main controls

Bath N and d; Tracer D/d and density ratio; A and f; Friction and restitution; Transient and sampling interval.

Observe

Drift-centered horizontal MSD versus lag; Horizontal velocity correlation; Tracer height; Unwrapped trajectory.

Try a controlled variation

Follow the large tracer after the initial transient, comparing its MSD at several lag times. Repeat seeds before estimating diffusion. The bath drives it through contacts; there is no added random tracer force.

Scope and numerics

- SI units; CPU/Double/Velocity Verlet. Check overlap and dt/2 convergence.
- Positions are in the moving-base frame; horizontal coordinates are unwrapped for statistics.
- Multiple overlapping time origins are correlated. Repeat seeds and box sizes before interpreting diffusivity.
- Background observables include tracer.csv and diffusion.csv; particle dumps remain optional.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: not currently offered for this preset.

Other catalog capabilities: Observables.

09 Preset reference

Rotating drum

Granular / Forced / nonlinear dynamics / **Implemented**

Question and model

How do surface avalanches form in a granular material inside a slowly rotating drum?

A set of grains is confined in a circular drum rotating under gravity. At low rotation speeds, the material can remain nearly solid until the free surface reaches a critical angle and an avalanche occurs. Increasing rotation speed can move the system from intermittent avalanches to continuous flow.

Main controls

Particles N; Grain size; Polydispersity; Drum radius; Angular speed in rpm; Grain-grain friction μ; Grain-wall friction μ; Gravity g; Wall roughness.

Observe

Center-of-mass angle; Free-surface angle; Minimum and maximum angles; Kinetic energy; Avalanche frequency; Granular activity; Contact count; Force chains and synthetic photoelasticity.

Try a controlled variation

Prepare the same filling and compare low rotation rates. Read energy and the available surface/angle observables together with the visible moving layer. Use a fixed color scale if comparing activity images.

Scope and numerics

- Contact motion is relative to the rotating boundary. Prepare a packing without excessive overlaps and monitor the domain checks.
- Energy peaks and rapid surface-angle changes can help identify avalanches; the definition and sampling of an event must remain consistent between runs.
- Photoelasticity and force-network capture add computation. Enable them when their measurements are needed.

Available study controls

Run Comparison: Rotation rate [rpm].

Parametric sweep: Rotation rate [rpm]; Friction [1]; Particle count N [1]; Mean diameter d [m].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Granular stick-slip

Granular / Shear and compaction / **Implemented**

Question and model

When does spring-driven granular friction produce intermittent slip instead of smooth motion?

Prepare a polydisperse bed under a constant normal load, then drive the spring anchor at constant speed. The guided upper plate responds dynamically to the spring and the grains, and can rise as the layer dilates. Loading and slip emerge from frictional DEM contacts; the plate velocity is not prescribed.

Main controls

Drive speed V [m/s]; Drive stiffness k [N/m]; Total normal load W [N]; Plate mass M [kg]; Grain friction μ; Initial layers, columns and mean diameter [m]; Disordered or regular rough surfaces; random seed.

Observe

Spring force and contact resistance [N]; Plate velocity and drive speed [m/s]; Dilation from prepared height [mm]; Grain, plate and spring energy [J].

Try a controlled variation

Prepare the loaded bed, then compare drive speeds while keeping spring stiffness, load and initial layers fixed. Read spring force, plate resistance and plate velocity together; they differ during plate acceleration.

Scope and numerics

- This is a 2D analogue of spring-driven granular friction, not a calibrated 3D experiment. The layer is periodic horizontally above a rough fixed base; the upper plate translates without rotation.
- Roughness can be regular or independently seeded and disordered. Glued boundary disks overlap to close the surface. Grain radii vary by ±20%.
- The plate obeys $M\ddot{x} = k(Vt-x) + F_{contact,x}$ and $M\ddot{y} = F_{contact,y} - W$. W is the total applied normal force, independent of plate inertia. Grain gravity is 9.81 m/s².
- Prepare holds the spring anchor and adds damping; it preserves contact history and preload. Preparation damping is removed and the experiment clock/dilation reference begin afterward.
- Spring force and contact resistance differ during acceleration. The energy plot separates plate/grain kinetic energy and spring storage; it is not a closed-system balance.
- Plate height is the gap between rough-surface envelope planes; dilation is displacement from the prepared state. Width is columns × 1.22 × mean diameter. Thin layers need not represent thick beds.
- No static/dynamic friction switch or universal transition speed is imposed. Vary speed, stiffness and load separately, allowing transients; check overlap and dt refinement.

Available study controls

Run Comparison: Drive speed [mm/s].

Parametric sweep: Drive speed [m/s].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Simple shear cell

Granular / Shear and compaction / **Implemented**

Question and model

How do contacts and stress anisotropies organize during granular shear?

Rectangular simple-shear cell at fixed height. A grain band is confined between a fixed rough lower wall and a rough upper wall that moves horizontally; synthetic photoelasticity is an optional Analysis layer.

Main controls

Number of grains; Mean diameter d; Particle-size distribution and polydispersity; Target area fraction phi; Packing method; Top-wall speed; Ramp time; Friction μ; Normal stiffness k_n / k_t/k_n ratio; Photoelastic sensitivity.

Observe

Shear strain gamma and strain rate; Tangential and normal 2D wall stress [N/m]; Effective friction |tau|/sigma_n; Profile vx(y); Solid fraction phi(y); Coordination Z and fabric anisotropy; Optional force chains and synthetic fringes.

Try a controlled variation

Prepare the reproducible packing before applying shear. Compare top-wall speeds at fixed height and friction. Then change the photoelastic display gain without changing the mechanical setup to separate optics from physics.

Scope and numerics

- Cell height is fixed; compression-positive stresses assume unit out-of-plane thickness.
- Top and bottom roughness are fixed to avoid geometric coupling with dMean.
- Use periodicity only in x.
- The default size-aware triangular lattice inserts the requested population whenever the available site capacity permits; use Prepare to relax this reproducible initial state before shear.
- The bidisperse option uses a discrete 50:50 number mixture with exact dL/dS = 1.40 through the structured initializer. It is a reproducible ordered initial condition, not a direct sample of a random steady state.
- Activate the top wall with a smooth ramp.
- Monitor overlaps near roughness.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Top wall velocity [m/s]; Cell height [m]; Friction [1]; Photoelastic gain [1].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

09 Preset reference

Biaxial compression

Granular / Shear and compaction / **Implemented**

Question and model

How does a dense granular packing develop strength and dilatancy under axial compression at controlled lateral stress?

A centered specimen is enclosed by four fitted walls, prepared isotropically to p0, then compressed vertically at prescribed strain rate while a bounded wall servo maintains sigma3 near p0.

Main controls

Preparation pressure p0 [N/m]; Axial strain rate [1/s]; Lateral servo gain [m2/(N s)]; Maximum servo speed [m/s]; Friction and contact stiffness.

Observe

q/p versus axial strain; Volumetric strain and dilatancy; Packing fraction phi; Coordination Z; Fabric anisotropy; Maximum overlap.

Try a controlled variation

Wait for the isotropic pressure/energy preparation criteria before axial loading. Compare strain rates at fixed target lateral load. Inspect both the servo response and stress-strain curve rather than only the final packing.

Scope and numerics

- Compression is positive and stresses are 2D line loads in N/m for unit thickness.
- The preparation servo remains active during relaxation and requires both pressure and kinetic-energy stability before axial loading.
- Indigo wall lines show the instantaneous cell; arrows identify walls that are moving.
- The lateral controller is proportional, speed-limited and paused above the overlap guardrail.
- The preset stops at the declared maximum axial strain.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Target lateral pressure [N/m]; Axial strain rate [1/s]; Lateral servo gain [m2/(N s)]; Friction [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Isotropic compaction

Granular / Shear and compaction / **Implemented**

Question and model

How do pressure, coordination and fabric evolve as a soft-disk assembly approaches jamming?

Four fitted planar walls advance symmetrically at equal strain rate in small increments; each increment is followed by kinetic-energy relaxation before compression resumes.

Main controls

Target packing fraction phi; Wall speed [m/s]; Strain increment; Relaxation energy threshold [J/particle]; Friction and contact stiffness.

Observe

p(phi) [N/m]; Z(phi); Fabric anisotropy; Maximum overlap; Kinetic and contact energy.

Try a controlled variation

Compare target area fractions using the same initial packing and relaxed-increment protocol. Read pressure and kinetic relaxation. A low target can correctly finish at negligible pressure.

Scope and numerics

- The four walls remain symmetric and the geometric center is invariant.
- The default target phi = 0.84 crosses the expected 2D soft-disk jamming region; lower targets may correctly finish with negligible pressure.
- Indigo wall lines show the instantaneous cell; arrows identify walls that are moving.
- Wall motion pauses when the overlap guardrail is exceeded.
- Bulk modulus estimates require enough relaxed p(phi) samples and are not inferred from a single increment.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Target area fraction [1]; Wall speed [m/s]; Friction [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Periodic isotropic jamming

Granular / Shear and compaction / **Implemented**

Question and model

How do coordination, force residual and contact-force statistics evolve during quasi-static isotropic compression toward jamming?

A periodic polydisperse soft-disk packing is compressed affinely in small isotropic increments and relaxed after every increment until a force-residual criterion is met.

Main controls

Particles N and mean radius r; Target area fraction φ_target; Compression increment strain Δε; Force-residual tolerance R_F; Maximum relaxation steps; Friction μ and stiffness ratio k_t/k_n; Deterministic seed.

Observe

Packing fraction φ; Force residual R_F; Coordination number Z; Mean overlap ratio; P(f_n/<f_n>) and its moments; P(|f_t|/<|f_t|>); Coulomb mobilization P(η).

Try a controlled variation

Compare compression increments at the same final area fraction and seed. Require both target fraction and force-residual tolerance. Treat an iteration-limit stop as incomplete relaxation, not a jammed success.

Scope and numerics

- Both directions are periodic; gravity and physical walls are absent.
- Compression is affine and alternates with force relaxation, rather than moving four walls.
- Success requires the target φ and final R_F tolerance; safety or iteration limits terminate with a reported failure reason.
- R_F is dimensionless and must be interpreted together with maximum overlap and finite-state diagnostics.
- The preset is a finite educational analogue of Boberski et al.; the reference study used approximately 14,200 disks.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Target area fraction [1]; Compression strain increment [1]; Particle count N [1]; Mean diameter d [m]; Friction [1].

Other catalog capabilities: Observables, Time-series CSV, Headless, Video.

09 Preset reference

Couette cell

Granular / Shear and compaction / **Implemented**

Question and model

How does a dense annular packing reach a reproducible steady shear state before velocity and force statistics are measured?

A rough-wall annular Couette cell with an exploratory mode and a Howell et al. (1999) validation mode using a quasi-static drive and an explicit preshear protocol.

Main controls

Inner radius R_i; Outer radius R_o; Particles N; Mean diameter d; Polydispersity; Angular speed Ω; Study mode and preshear rotations; Friction μ; Normal stiffness k_n / k_t/k_n ratio.

Observe

Radial profile v_theta(r); Inner/outer wall contacts; Kinetic energy; Maximum overlap; Particles inside the annulus; Clearance against rough walls; Preshear progress and stationarity; P(f_n/<f_n>), P(|f_t|/<|f_t|>) and P(η).

Try a controlled variation

Begin with the exploratory protocol and compare inner angular speeds at fixed gap and filling. If using the reference-inspired mode, retain its preparation and preshear rules and interpret optical proxies separately from contact forces.

Scope and numerics

- C1 uses wall disks as rough boundaries, not smooth circular walls.
- The inner wall uses RotatingFixedDisk2D drivers paired by ID with real disks.
- The outer wall remains fixed.
- Packing uses reproducible polar rejection and validates overlap against real wall disks.
- Howell mode uses the published bidisperse geometry and quasi-static angular-speed range as a validation reference.
- Its preshear stationarity criterion is an operational DEM criterion; the experimental optical force proxy G^2 is not identified with a single contact force.

Available study controls

Run Comparison: not currently offered for this preset.

Parametric sweep: Inner angular speed [rad/s]; Annular gap [m]; Particle count N [1]; Target area fraction [1]; Friction [1].

Other catalog capabilities: Preparation, Observables, Time-series CSV, Headless, Video.

10 Settings and troubleshooting

Tune the workspace, not the result

Open **Granular LAB > Settings** for global preferences. The sections cover General, Simulation, Visualization, Interface, Export and Advanced controls.

Section	Typical use
General	Local app preferences and general behavior
Simulation	Control limits and initial-condition preparation defaults
Visualization	Palettes, speed scaling, particle and boundary colors, overlays
Interface	Appearance, descriptive text and visual density
Export	Default behavior and information about user-selected destinations
Advanced	Neighbor-search choices and advanced numerical/performance settings

Use the **Restore defaults** action only when you intend to replace those preferences. Restoring a single modified preset parameter is a more focused operation and is available from that parameter's label or context menu where supported.

Make dense views lighter

Reduce costly analysis overlays, field resolution or the number of visible trails. Increase independent-run concurrency only after checking throughput and memory. Reducing particle number changes the physical sample, so document that choice when comparing scientific results.

The stable neighbor-search baseline is **Cell linked list**. Experimental auto/Verlet-skin behavior is an advanced opt-in choice; inspect its effective method and fallback metadata before claiming a particular optimization was used.

Useful native commands

Use the Simulation menu to navigate experiments. **Command-1** returns to Introduction. The standard **Command-?** opens Granular LAB Help; **Help > User Manual (PDF)** opens this bundled document in the Mac's PDF application. File commands expose projects and supported exports. Native document shortcuts follow the active window.

10 Settings and troubleshooting

When something looks wrong

Symptom	Check and next action
Play seems slow	Compare DEM/s, sim x and Upd/s. Dense contacts, small dt and analysis layers can be expensive. Start with a small representative pilot.
Chart is empty	Run long enough to acquire data. Check the selected observable, required preparation and whether its population exists. Some rates require a complete time bin.
Inspect shows a dash or a gap	The measurement is unavailable or undefined, not necessarily zero. Check selection, empty region, missing wall or protocol support.
A periodic disk appears at the opposite edge	This is wrapping. Use unwrapped displacement observables for transport rather than screen-coordinate differences.
A region density seems too low near an obstacle	N/A uses the full rectangle area, including the obstacle.
Colors change while motion looks similar	Check automatic scaling. Use a fixed maximum for comparisons.
Export button is disabled	Check backend support and whether another conflicting operation is active. A quasi-3D backend needs its own dimensional export.
Time-series export has not advanced	A paused simulation must advance after acquisition starts. Check its requested duration and sampling interval.
A parallel job says Queued	Shared CPU/memory capacity may be occupied. It can start automatically when resources become available.
Saved result cannot be found	Keep complete folders together. Reconnect a moved background result with Open result.
Project will not save	Keep it open, check space and write access, then save to another location. Reopen before closing the working copy.

For an unstable run, follow numerical health rather than hiding the warning or merely slowing the animation. If a failure is reproducible, use **Help > Contact / Report Issue** and include a small configuration, app version/build and the exact action that triggered it.

11 Model, units and scope

What is being simulated?

The standard granular backend is a soft-contact 2D discrete-element model. Translational and rotational motion respond to contact forces, gravity and enabled external driving. The standard contact description includes normal elasticity and damping, tangential contact history and a Coulomb friction limit.

The baseline integration is explicit Verlet-type integration on the CPU. Physical timestep dt is distinct from display update rate. Contact detection, force evaluation and time integration are numerical operations whose settings matter for stability and reproducibility.

2D means more than a flat picture

Ordinary particles are disks. Mass derived from 2D density uses area, with density in kg/m^2. Boundary loads normalized by length are in N/m. A 2D cross-section can help explore mechanisms, but it is not automatically quantitatively equivalent to a three-dimensional bulk material.

Vibrated quasi-2D layer uses a distinct shallow-3D sphere model. Its side slab is a projection of a finite slice and can display explicit vertical magnification. **Granular Brownian motion** has its own experimental tracer context. Read their individual profiles and export restrictions instead of assuming every standard 2D tool transfers unchanged.

A focused workstation

Granular LAB emphasizes prepared experiments, immediate visual feedback, local probes, spatial diagnostics and a traceable desktop workflow. General-purpose DEM frameworks such as LIGGGHTS or YADE address a broader model-building and scripting landscape. Similar contact-model terminology does not establish numerical equivalence between implementations.

Use the app to explore and test a defined physical question. For quantitative research, specify the model, validate it for the regime, study resolution and statistics, and retain input/output context. The DEM guide and Experiment information provide the relevant starting references.

11 Model, units and scope

Units and quantities at a glance

Quantity	Typical display or output convention
Position, diameter, geometric length	Often mm in the inspector; m in SI configuration and exports
Velocity or speed	Often mm/s in Inspect; m/s in SI data
Time / timestep	Physical s; dt can be displayed in microseconds
Mass / force / energy	kg / N / J
2D mass density	kg/m^2
Number density	Particle-center count per geometric area, m^{-2}
Area fraction	Dimensionless nominal disk area fraction
Wall linear load and 2D contact stress	N/m, not Pa
Vibration frequency	Hz; angular rates can use rad/s or rpm as labeled
Sinusoidal vibration acceleration	Gamma = A $(2 \pi f)^2$ / g; tapping uses its own pulse convention
Restitution and friction coefficient	Dimensionless
Angular diffusion	rad^2/s
Section number flow	Crossings/s, signed by the section arrow
Field agitation	Half a local velocity variance, m^2/s^2
Gas temperature observable	Fluctuation-energy convention in J, as defined by the gas tracker

Notation is contextual

N may denote requested particles, currently living particles or the population of an instrument. Read its location and label. The canvas count can differ from the requested total during insertion, escape or deposition.

The initial-temperature control of a gas can use a velocity-squared scale while its measured granular-temperature observable uses a mass-weighted energy convention. Likewise, normalized forces and densities can be dimensionless even when their underlying variables have SI units.

Keep explicit units when transferring values to another tool. A display conversion is not a change to the physical model, and a visual zoom is not a change to particle diameter.

11 Model, units and scope

A short glossary

Term	Meaning in this manual
DEM	Discrete element method: contact-based evolution of individual particles.
Preset	A defined experiment with focused inputs, geometry, protocol and measurements.
Preparation	Construction or settling before experimental time begins.
Observable	A defined measured quantity, such as energy, population or discharge.
Contact fabric	Statistical geometry of contact orientations.
Force chain	A useful description of load-bearing paths; its visualization depends on the selected network rule.
Coarse graining	Averaging discrete particle/contact information over a specified spatial scale.
Polar order	Alignment with a preferred direction, distinguishing head from tail.
Nematic order	Axis alignment that treats parallel and antiparallel orientations equivalently.
MSD	Mean-square displacement; periodic transport requires an unwrapped convention.
Seed	Input to a reproducible random sequence. It does not eliminate finite-sample variation.
Physical time	Time advanced by the simulation, distinct from calculation and movie time.
Checkpoint	State sufficient to resume a supported numerical execution, subject to compatibility rules.
Recording	Acquired frames and measurements at actual timestamps; not an exact checkpoint.
Cache	Reusable derived results that can be recalculated from unchanged stored data.
Convergence	Evidence that a relevant result is stable under a defined refinement or longer statistical sampling.

11 Model, units and scope

Continue exploring

Built-in references

Use **Introduction > DEM guide** for the model overview, equations, fields and bibliography. **Experiment information** provides the references and assumptions associated with a particular preset. **Help > Preset Guide** lists capabilities and maturity from the app's own catalog.

The literature provides hypotheses and comparison targets. A cited experiment does not mean a preset reproduces every part of that experiment, especially when dimensionality, boundaries or material calibration differ.

Support and privacy

The app's official website is Granular LAB. Use **Help > Contact / Report Issue** to contact the developer. Include a short sequence of actions, app version/build, preset settings and numerical diagnostics when reporting a problem.

Granular LAB stores preferences locally and does not require a login for simulation. Exports are written to user-selected destinations. Review **Help > Privacy Policy** for the current policy, and About for third-party acknowledgments.

About this manual

Prepared for Granular LAB 2.0.0, October 2026. The reference catalog is generated from the app's visible presets. Figures are native app/view captures or explicitly labeled explanatory diagrams. Their displayed values illustrate a workflow; they are not independent validation data.

The DataGraph manual supplied as a reference informed the organization into overview, procedures and detailed reference. Its prose and artwork are not reproduced here.

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