

The **Quantum Wave Interference** simulation lets students explore how quantum objects produce interference patterns and how particle type, wavelength, slit geometry, and measurement affect them.

Experiment Screen

Fire quantum particles through a slitted barrier and onto a detector screen. Change particle properties and the experiment setup to investigate what affects interference patterns and when interference occurs.

ADJUST source wavelength and intensity

CHOOSE the source particle

CONFIGURE the slits and experiment

OBSERVE detections forming a pattern

CAPTURE snapshots for comparison

GRAPH the detector screen

High Intensity Screen

Visualize the wave as it travels through the slits and forms an interference pattern at the detector. Use this view to connect wave behavior and interference with the resulting detector pattern.

VISUALIZE waves passing through the slits and onto the detector screen

COMPARE how changing the barrier configuration affects the results

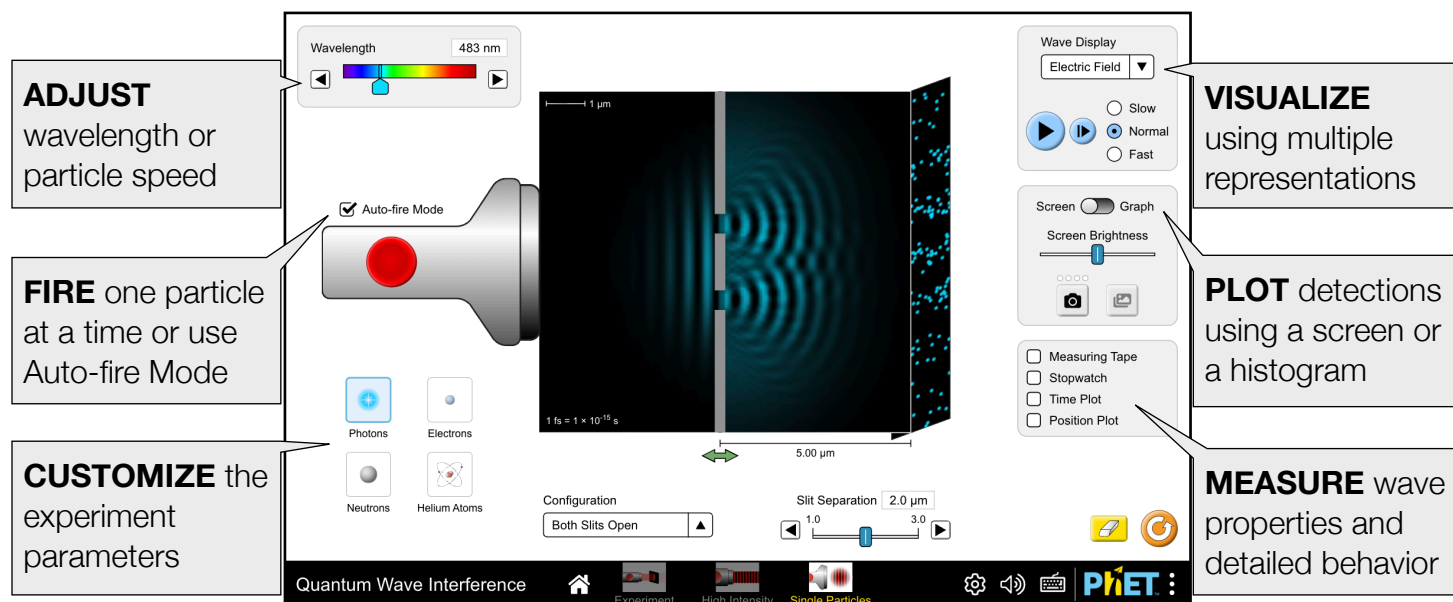
CHANGE the wave display representation

TOGGLE between screen and graph modes

UTILIZE tools to gain insight into wave behavior

Single Particles Screen

Follow one quantum wave packet at a time as it travels through the slits and produces a localized detection. Repeat the experiment to see an interference pattern emerge from many individual hits.



Insights into Student Use

- Students may focus on the localized detector hit and overlook that the wave is spread out before detection. Encourage them to compare what happens in the wave region with what appears on the detector screen.
- An interference pattern is difficult to recognize from only a few detections. Auto-fire and Fast speed can help students see the statistical pattern emerge from many individual events.
- Students may interpret a single detector hit as evidence that the particle followed one definite path. Comparing both slits open with a which-path detector can help distinguish detection location from knowledge of the particle's path.

Complex Controls

- **Wave Display:** For photons, students can view Amplitude or Electric Field; for matter particles, they can view Amplitude or the Real Part of the wave function. Probability is related to the magnitude of the wave function, not its instantaneous positive or negative phase.
- **Detector Probe:** With no barrier selected, the detector probe measures the probability of detecting the particle within its circular region. A successful measurement detects the particle there; an unsuccessful measurement changes the remaining wave and allows it to continue.
- **Screen Brightness:** The brightness slider changes only how the detector pattern is displayed. It does not change the underlying detection probabilities.
- Settings and detector data are stored separately for photons, electrons, neutrons, and helium atoms, so students can switch particle types and return to an earlier setup.

Suggestions for Use

See all [published activities](#) for Quantum Wave Interference.

- Begin with both slits open and fire particles individually. Ask students to predict where the next particle will be detected, then use Auto-fire to investigate what becomes predictable after many trials.
- Compare one slit open with both slits open. Ask students to describe what changes in the wave before comparing the accumulated detector patterns.
- Take snapshots of detector patterns for different slit configurations or slit separations and compare them side by side.
- Add a which-path detector and ask students to predict whether the detector pattern will change before running the experiment.
- For electrons, neutrons, or helium atoms, vary particle speed and ask students to connect the resulting wavelength to changes in the interference pattern.
- Compare the physical scale shown for different particle types. Ask why experiments with photons and matter waves require very different slit dimensions.

Sample Challenge Prompts

- How can individual particles produce an interference pattern? What evidence in the simulation supports your explanation?
- With both slits open, can you predict where the next particle will be detected? Can you predict where many particles are most likely to be detected?
- What changes when you determine which slit a particle passes through? What stays the same?
- How does increasing slit separation affect the spacing between interference bands? Explain your observation.
- For a matter particle, how does increasing speed affect wavelength? How does this change the detector pattern?
- What does the wave tell you about where a particle may be detected? What does it not tell you?

Simulation Details

See this sim's [Model Documentation](#) for more details.

- On the Single Particles screen, each emitted particle is represented by a Gaussian wave packet that spreads as it travels. When detection occurs, one localized hit is added to the detector screen and that wave packet ends.
- With both slits open and no which-path measurement, the wave packet can pass through both slits as one coherent quantum state. Repeated particles build up a double-slit interference pattern from individual detections.
- Detector-screen hits are sampled according to the probability predicted by the wave function. Increasing the number of detections makes the underlying probability pattern easier to see.
- For photons, wavelength is controlled directly. For electrons, neutrons, and helium atoms, changing particle speed changes the de Broglie wavelength, with faster particles having shorter wavelengths.
- Which-path detectors are an idealized representation of measurement. Obtaining path information removes coherent interference and changes the accumulated detector pattern.
- The simulation uses idealized coherent sources, slits, detectors, and wave propagation to emphasize interference, diffraction, probability, and measurement rather than experimental imperfections.

Inclusive Features

See the [simulation page](#) for all supported inclusive features.

Alternative Input and Touchscreen Devices

- This simulation supports interaction with focused-based alternative input methods, a built-in feature, that makes the simulation fully operable with a keyboard using standard key presses and some custom keyboard shortcuts. See the Keyboard Shortcuts dialog  in the navigation bar for more details.
- TAB key navigation moves keyboard focus through simulation interactions in a meaningful order. It starts with the source emitter then moves to controls that adjust experimental parameters and configurations, then moves onto interactions for data collection and analysis, data representations, and finally additional custom lab-like measurement tools.

Interactive Description

This simulation supports learners who rely screen reader software through our [Interactive Description feature](#). See the [Introduction to Interactive Description video](#) for more info on how to best use screen reader software with PhET sims.

- State descriptions name interactions, provide gentle guidance where needed, and maintain access to an accurate description of the current state of the experiment and changes to the wave and detector screen or graph. Snapshots of collected data are also fully described, so learners can compare snapshot details non-visually.
- Responsive Descriptions describe relevant changes in real time as they happen, ensuring students can actively explore and makes changes independently using screen reader software and make sense of identified learning goals. Custom “lab-like” measurement tools are operable and provide some information. They do not provide live updates as they are moved. Blind students will need a learning partner who can see in order to take measurements.
- Because a lot can happen in the simulation, students who rely on the Interactive Description feature may want to start with the slowest available sim speed as they get familiar with the simulation.
- Teachers can [access the Accessibility \(A11y\) View](#) to review the descriptions that are available to screen reader users to ensure blind students will have access to the information needed for planned activities. *Please note: The A11y View is not intended for student use and will not provide a good experience for learners using screen reader software.*

Additional Inclusive Features

- This sim also has *Basic Sounds*, *Pan and Zoom*, and *Interactive Highlights* - features that can support many learners in diverse ways. Make sure learners are aware of available inclusive features.

Customization Options

Option 1: Use [PhET Studio](#) to configure a sim exactly how you want students to see it, save your preset, then send the preset link to your students. This is a premium product. Start a [free trial](#) today!

Option 2: Query parameters allow for customization of the simulation, and can be added by appending a '?' to the sim URL, and separating each query parameter with a '&'. The general URL pattern is:

```
...html?queryParameter1&queryParameter2&queryParameter3
```

For example, if you only want to include the 1st and 2nd screens (`screens=1,2`), with the 2nd screen open by default (`initialScreen=2`) use:

https://phet.colorado.edu/sims/html/quantum-wave-interference/latest/quantum-wave-interference_all.html?screens=1,2&initialScreen=2

To run this in Spanish (`locale=es`), the URL would become:

https://phet.colorado.edu/sims/html/quantum-wave-interference/latest/quantum-wave-interference_all.html?locale=es&screens=1,2&initialScreen=2

⚙ Indicates this customization can be accessed from the Preferences menu within the simulation.

Query Parameter and Description	Example Links
<code>screens</code> - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center .	<code>screens=1</code> <code>screens=2,1</code>
<code>initialScreen</code> - opens the sim directly to the specified screen, bypassing the home screen.	<code>initialScreen=1</code> <code>initialScreen=3</code>
<code>interactiveHighlightsInitiallyEnabled</code> - opens the sim with interactive highlights enabled.	<code>interactiveHighlightsInitiallyEnabled</code>
⚙ <code>locale</code> - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab . Note: this only works if the simulation URL ends in “_all.html”.	<code>locale=es</code> (Spanish) <code>locale=fr</code> (French)
<code>audio</code> - if muted, audio is muted by default. If disabled, all audio is permanently turned off.	<code>audio=muted</code> <code>audio=disabled</code>
<code>allowLinks</code> - when <code>false</code> , disables links that take students to an external URL. Default is <code>true</code> .	<code>allowLinks=false</code>
<code>supportsPanAndZoom</code> - when <code>false</code> , disables panning and zooming using pinch-to-zoom or browser zoom controls. Default is <code>true</code> .	<code>supportsPanAndZoom=false</code>

Additional PhET Resources

See [PhET's Inclusive Design](#) page to learn more about each Inclusive Feature and how to use them with your students.

For more tips on using PhET sims with your students, see [Teaching with PhET](#).

To learn more about ways to create and facilitate sim-based lessons, visit our free [Virtual Workshops](#).