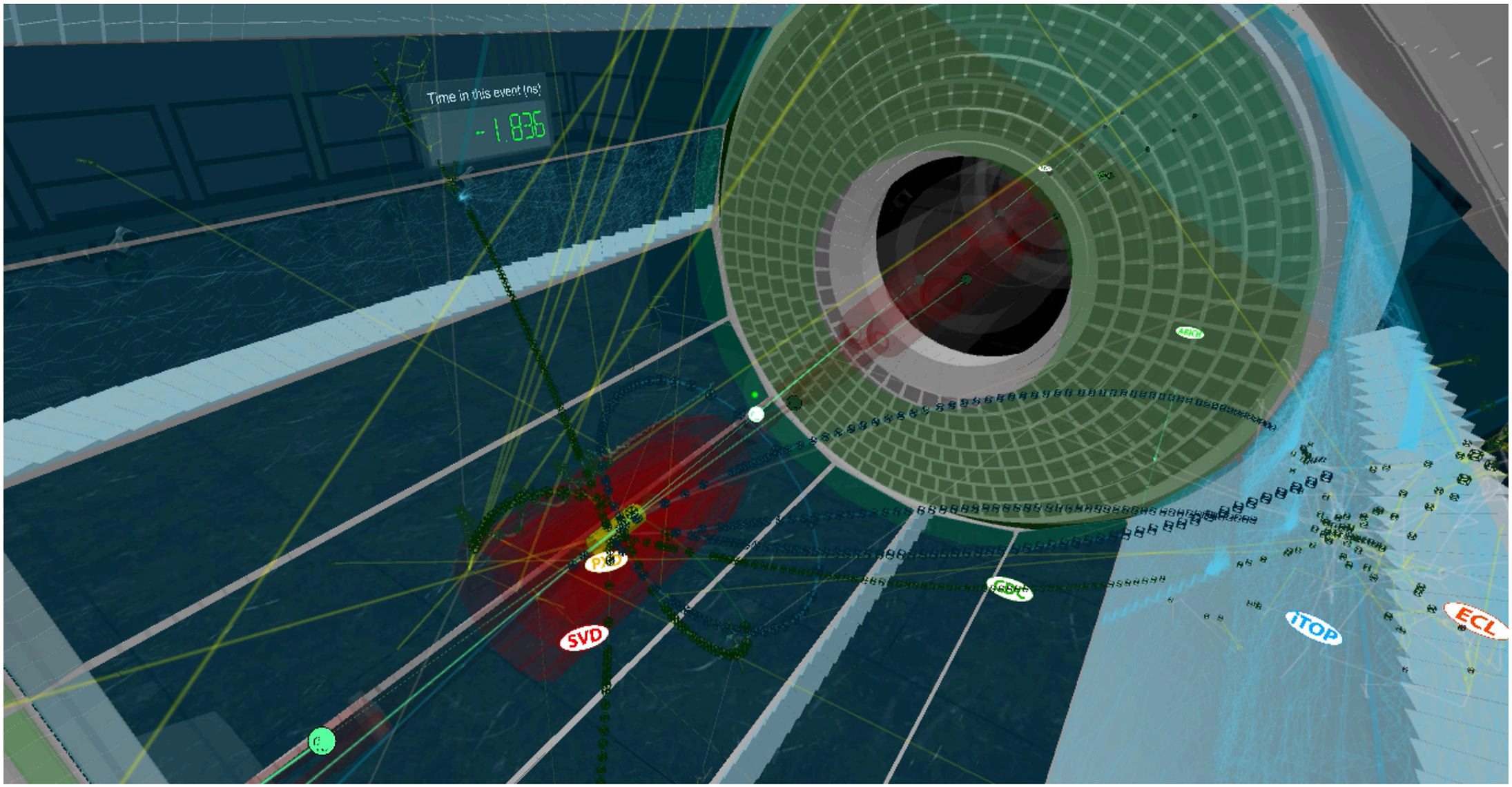
Belle2VR: An interactive virtual reality visualization of GEANT4 event histories

Leo Piilonen, Virginia Tech
on behalf of the Belle II Collaboration's Outreach Group



ACAT 2019 *March 2019*

History

In 2016–2017, we received a $25K grant from Virginia Tech's Institute for Creativity, Arts and Technology (icat.vt.edu) to develop a virtual reality model of Belle II. **Project participants:**

Zach Duer
formerly ICAT Staff
→ now SOVA faculty

Tanner Upthegrove
ICAT Staff
Media Engineer

Jesse Barber
Physics Major
(graduated)

Samantha Spytek
Physics Major
(graduated)

Christopher Dobson
Physics Major
(graduated)

Leo Piilonen
Dept of Physics

George Glasson
School of Education

Nicholas Polys
Computer Science

Dane Webster
School of
Visual Arts

Todd Ogle
TLOS

Platform

Choose Unity (unity3d.com) as the software-development platform *(free for non-commercial use)*

✓ the associated scripts in C# look familiar to any C++ user

✓ Unity itself is written in C++ ➠ provides C# ↔ C++ interface

Display targets:

✓ VR headsets: Oculus Rift, Oculus Go, HTC Vive

✓ computer screen: Windows, Mac OSX, Linux

✓ web browser

✓ smartphones: iPhone, Android

[not distributed in stores; no user interaction is possible]

GEANT4 detector geometry (1)

Export detector geometry from Belle II's basf2 framework

- ✓ In GEANT4, each volume element can be rendered as polygons of its surface, using GetPolygon(), before exporting
- ✓ write two new basf2 modules to export to FBX or VRML2
  - geometry/modules/fbxWriter
  - geometry/modules/vrmlWriter

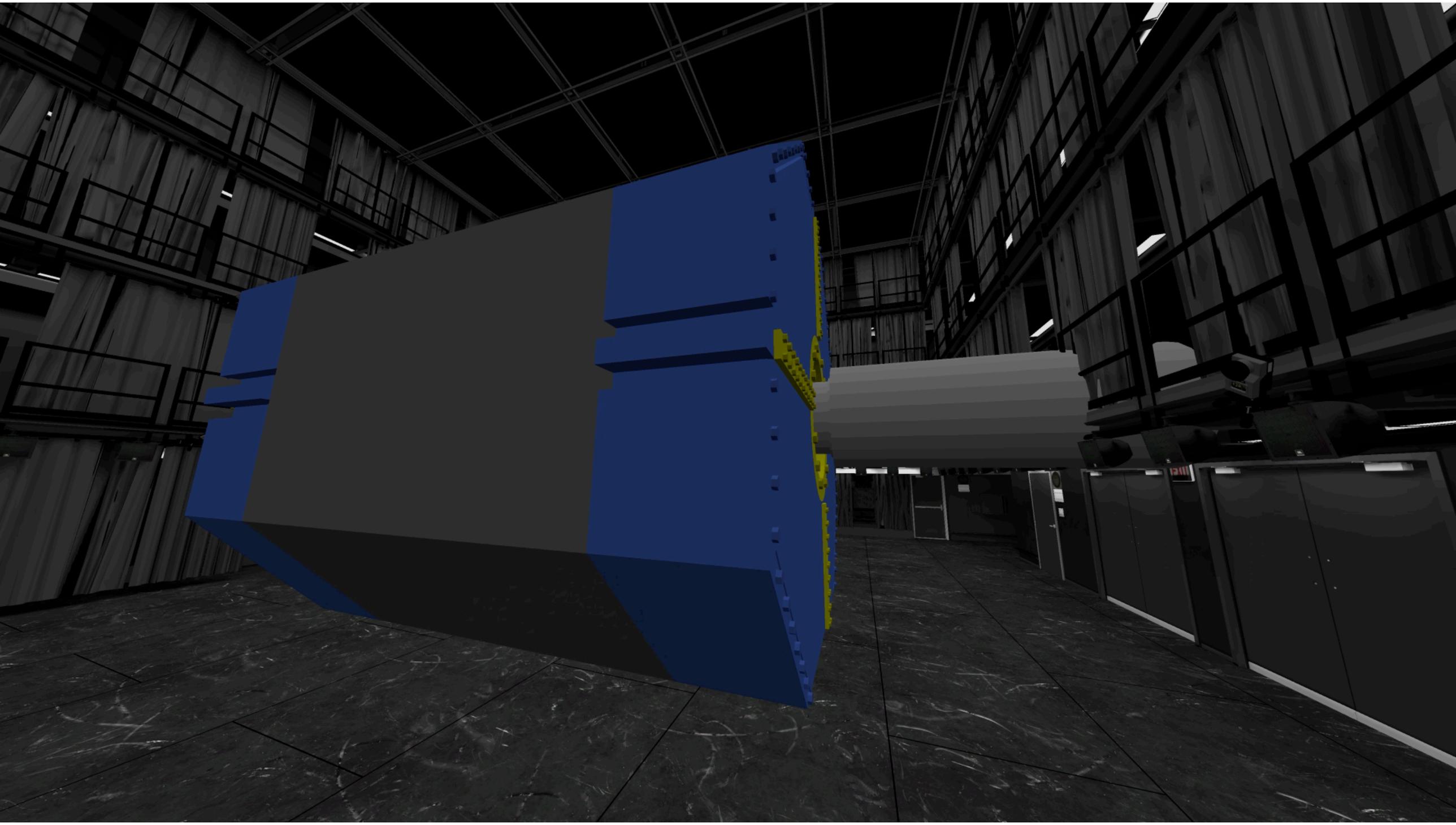
  } ⇢ *structured text files*
  - *you may download from github.com/HSF/Visualization*

Examine the FBX geometry file(s)

- FBX Review: www.autodesk.com/products/fbx/fbx-review
- Cheetah3D: cheetah3d.com (for Mac)
- LynX 3D: ozone3d.net (for Windows)

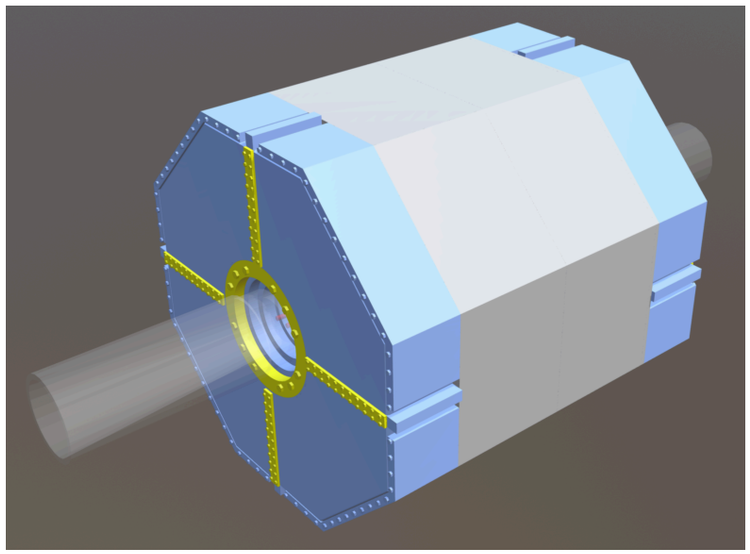
Import the FBX geometry into Unity

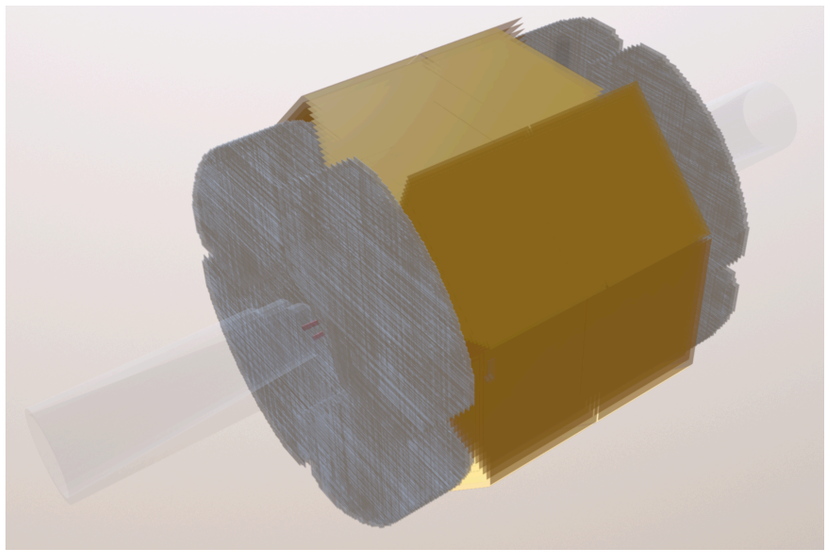
GEANT4 detector geometry (2)

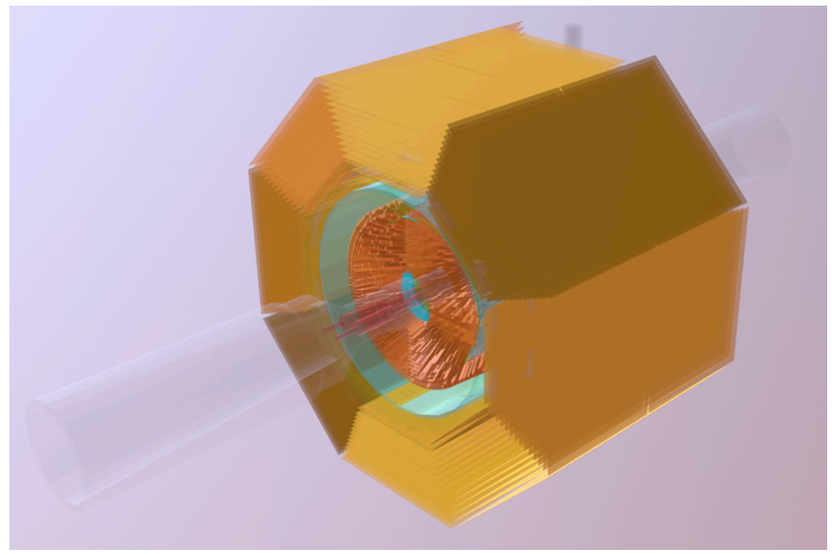


Detector Geometry *… an aside*

Unity can then export the geometry to the glTF™ format (www.khronos.org/gltf/)







sketchfab.com → search for **belleii**

(can be viewed on smartphones)

GEANT4 event histories (1)

Export the GEANT4 simulation event histories from basf2

- ✓ in human-readable format → Excel csv file (one per event)
- ✓ add print statement to the inherited G4UserSteppingAction hook that is called by Geant4 for each step in the history
  - write a record to the csv file for *almost* each step
    PreStepPoint (position, time, momentum, energy),
    PostStepPoint (position, time, momentum, energy),
    volumeName, trackID, parentID, PDGcode, etc
  - *… but no heavy nuclei (A > 4: they don't move, typically)*
  - *… and cut off after 100 ns (neutron walk, late decays)*

Post-process the csv file

- ✓ perl script adds beam-line particles then sorts the records by ParticleName, then TrackID, then StepNumber
- ✓ *[optional]* compress using gzip

GEANT4 event histories (2)

Import the events into Unity

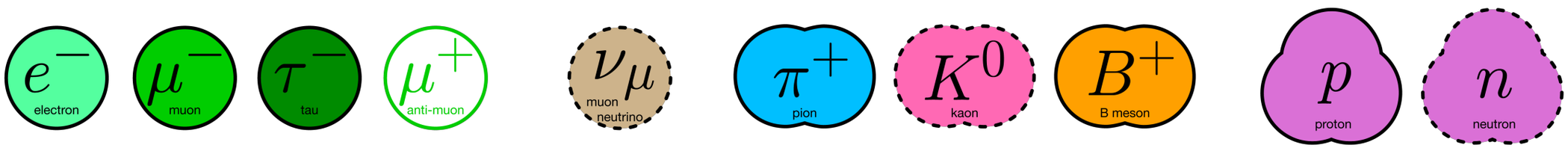
✓ C# scripts in Unity read `csv` file, parse the records, then store the information in internal structures

Animate the event history

✓ persistent faint lines show the entire simulation history

✓ sprite shows each particle during the animation

- colour-coded and shape-coded



- de-emphasis *[faded]* after particle's history ends

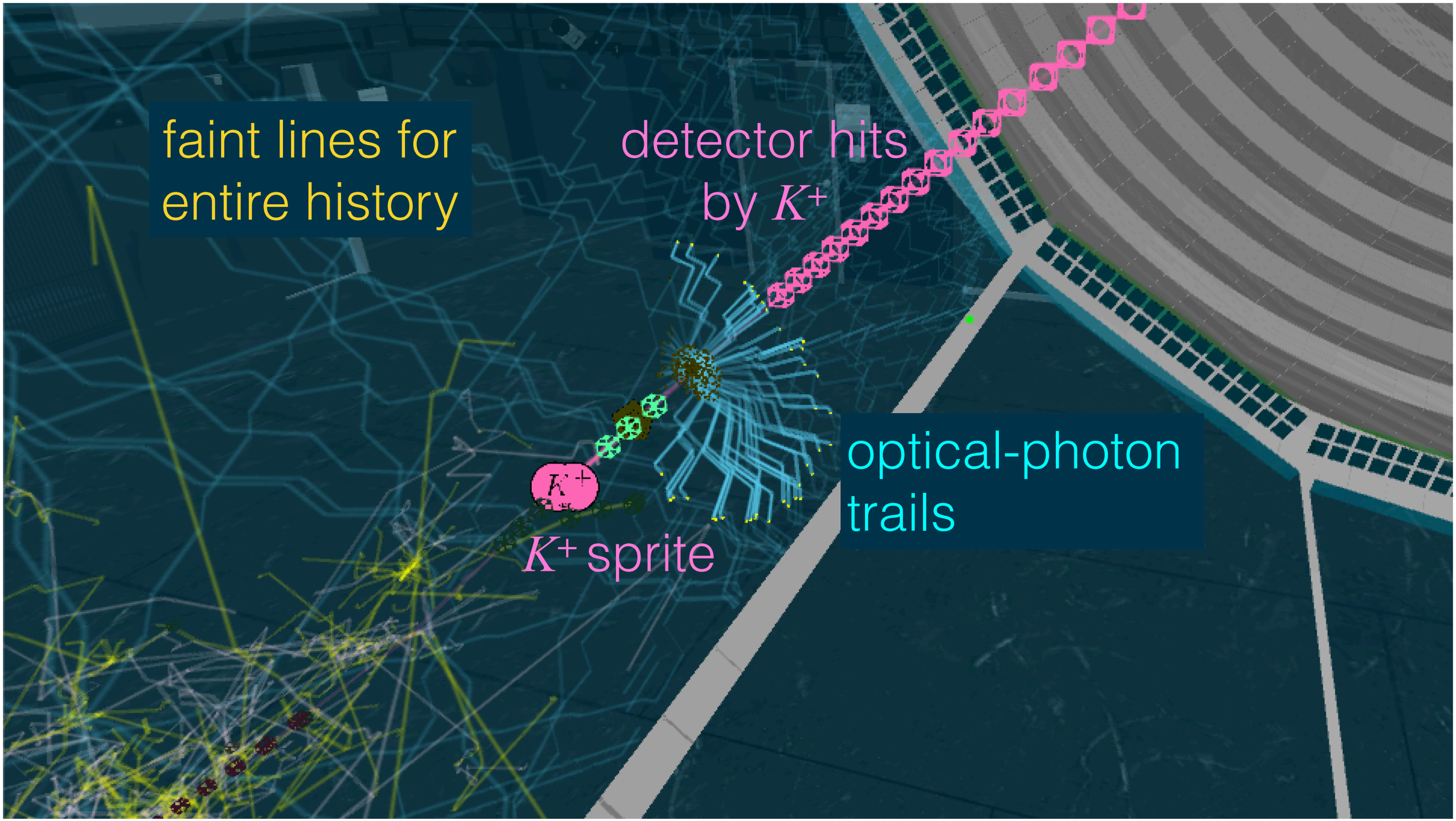
✓ dynamic trails highlight particle motion during animation

✓ sensitive-detector hits, with detector-specific sound

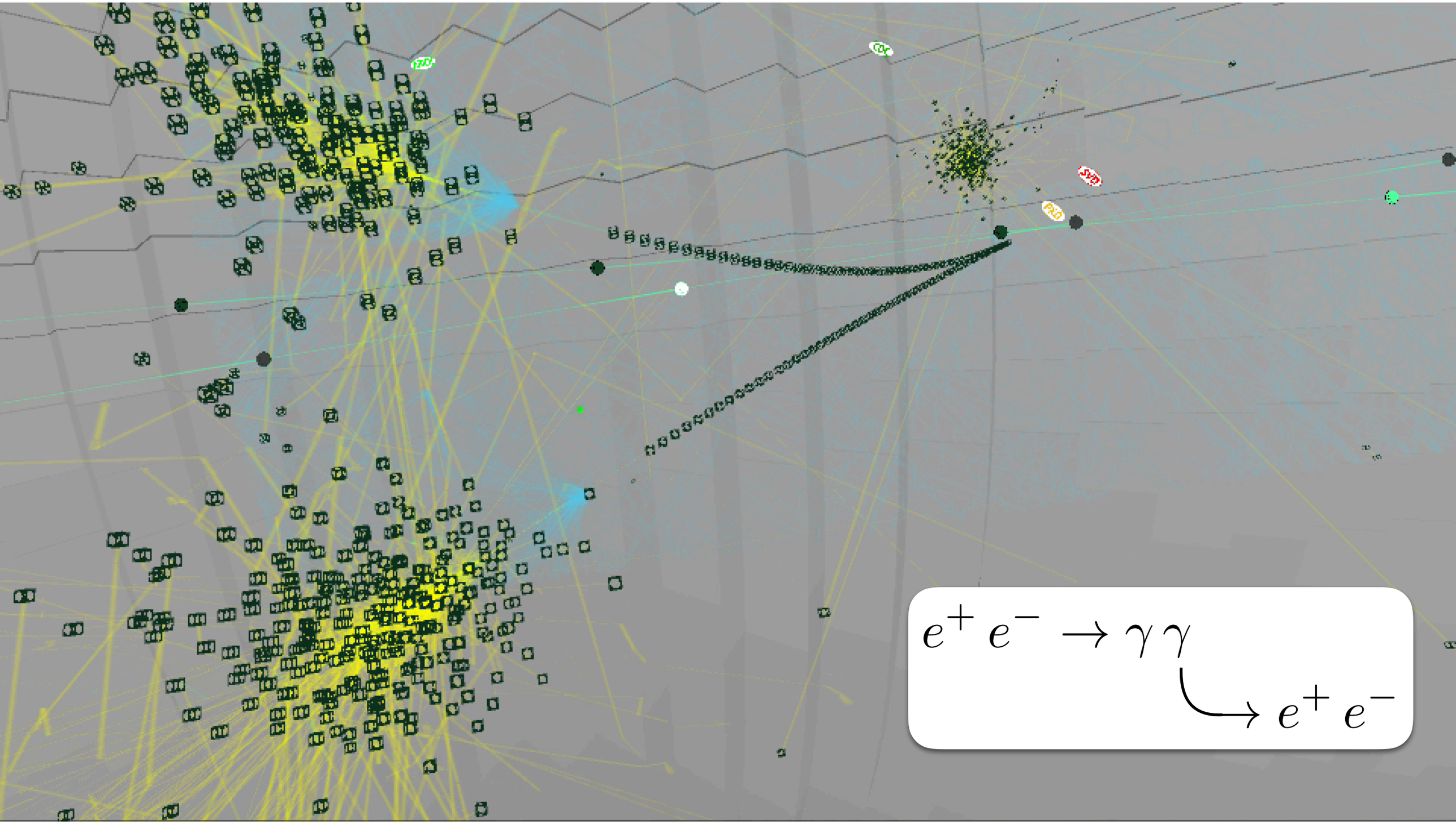
✓ last few seconds of animation: show only the detector hits

✓ ***for VR headset, must run at 90 fps at all times***

GEANT4 event histories (3)

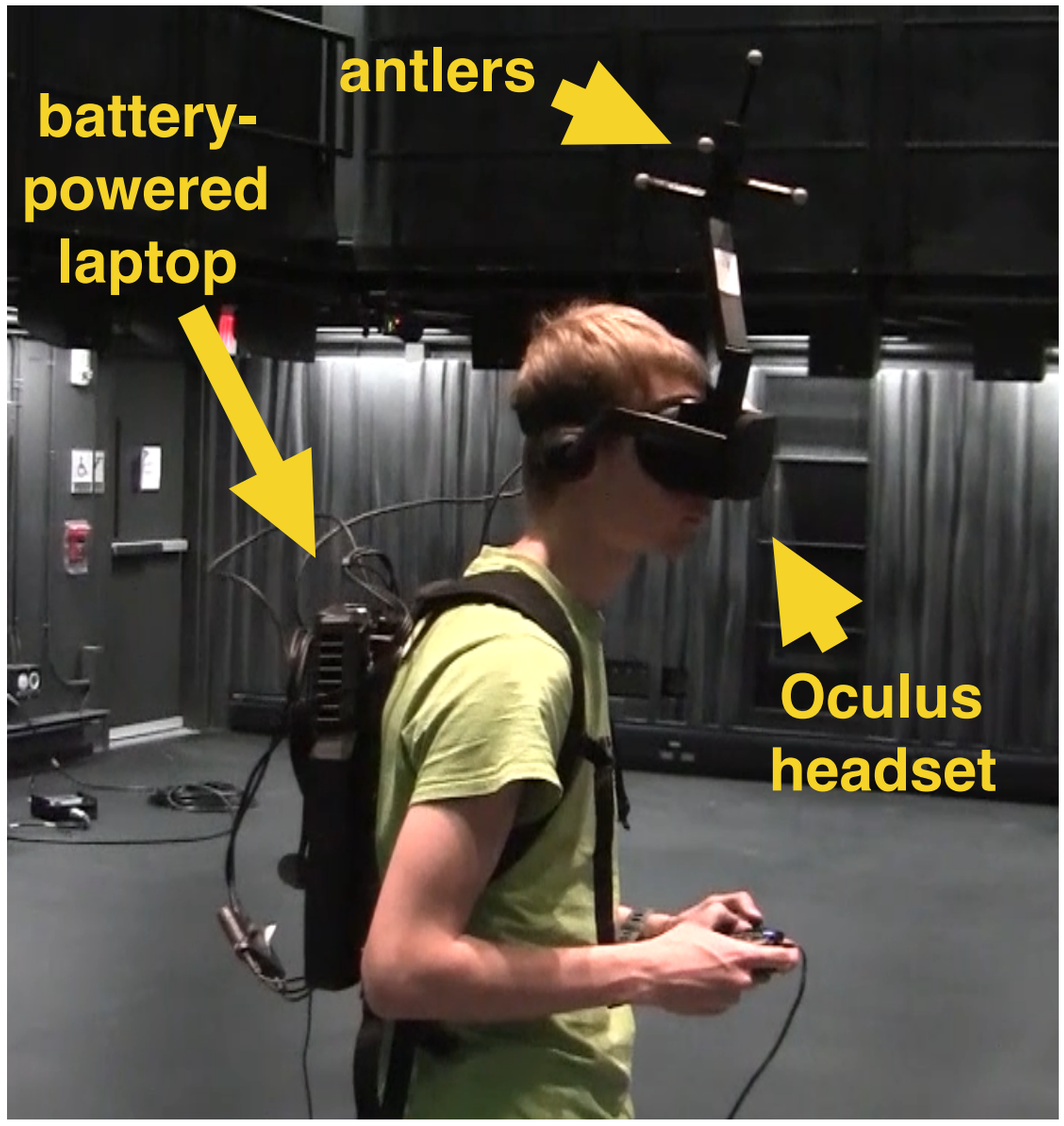


GEANT4 event histories (4)



Belle2VR operation: in CUBE Facility at Virginia Tech

- ✓ In VR world, detector and beam line appear within the CUBE at Virginia Tech to accommodate N students' physical location *(also avoids vertigo experienced with a context-free detector)*
- ✓ Students see each others' avatars in the VR world
- ✓ Untethered movement in CUBE with backpack laptop + headset
- ✓ User-specific antlers provide 3D position and orientation via CUBE's motion-capture system
- ✓ Can be projected onto a huge cylindrical screen ("Cyclorama") in the CUBE for large audiences
  - youtu.be/LxIW6Zv9uTM
  - www.elumenati.com/projects/virginia-tech-cyclorama/



Belle2VR operation: in CUBE Facility at Virginia Tech

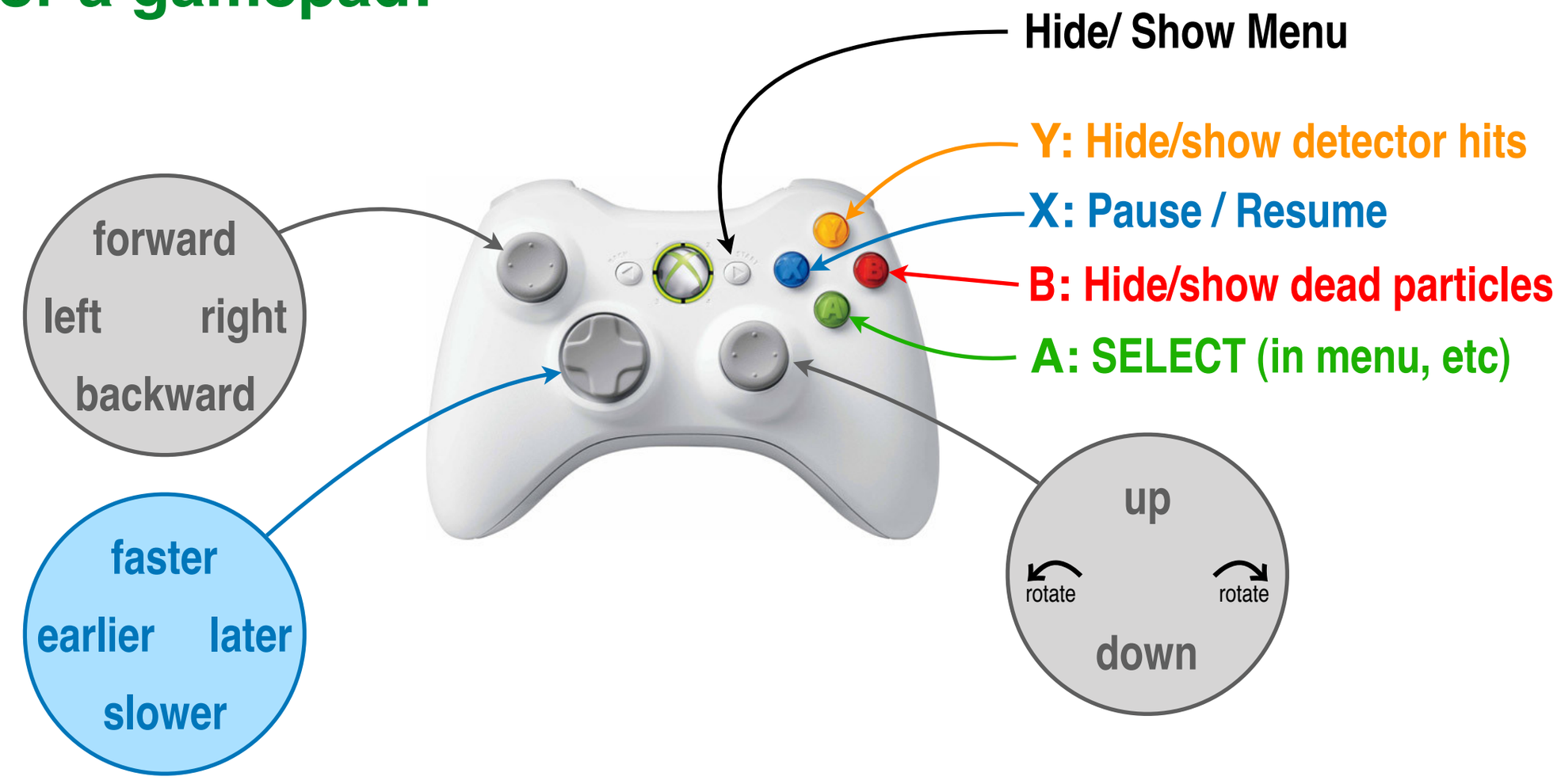
Belle2VR operation: standalone

- ✓ In VR world, the detector and beam line still appear within the CUBE at Virginia Tech *since we don't yet have a 3D model of the Tsukuba experimental hall at KEK* 😐
- ✓ Use Oculus Rift/GO or HTC Vive for immersive 3D experience
- ✓ Use your computer screen for 2D projection of the VR world *(no need for 3D hardware)*
- ✓ Run WebGL app in web browser
- ✓ Control the animation via
  - tethered or Bluetooth gamepad
  - Oculus Touch hand controllers
  - HTC Vive hand controllers
  - keyboard/mouse

VR world user controls (1)

- ✓ Your gaze is always indicated by a green dot in front of you.
- ✓ Turn your head to move the gaze dot.
- ✓ You interact with the in-world features with this gaze dot and your preferred hand controls.

For a gamepad:



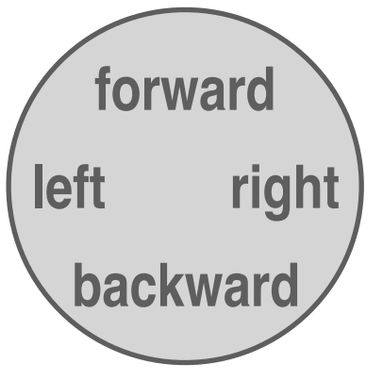
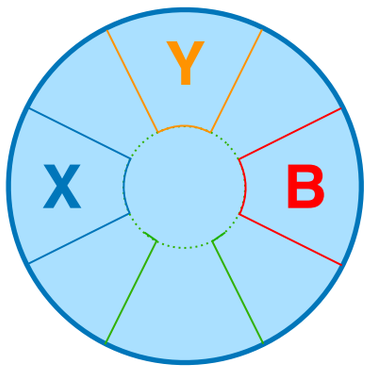
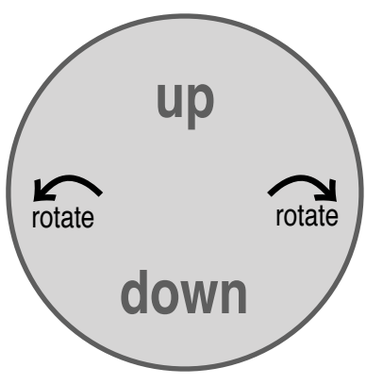
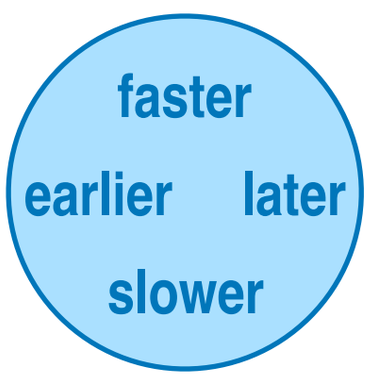
(some controls are omitted here)

VR world user controls (2)

✓ Your gaze is always indicated by a green dot in front of you.

For the Oculus GO remote:

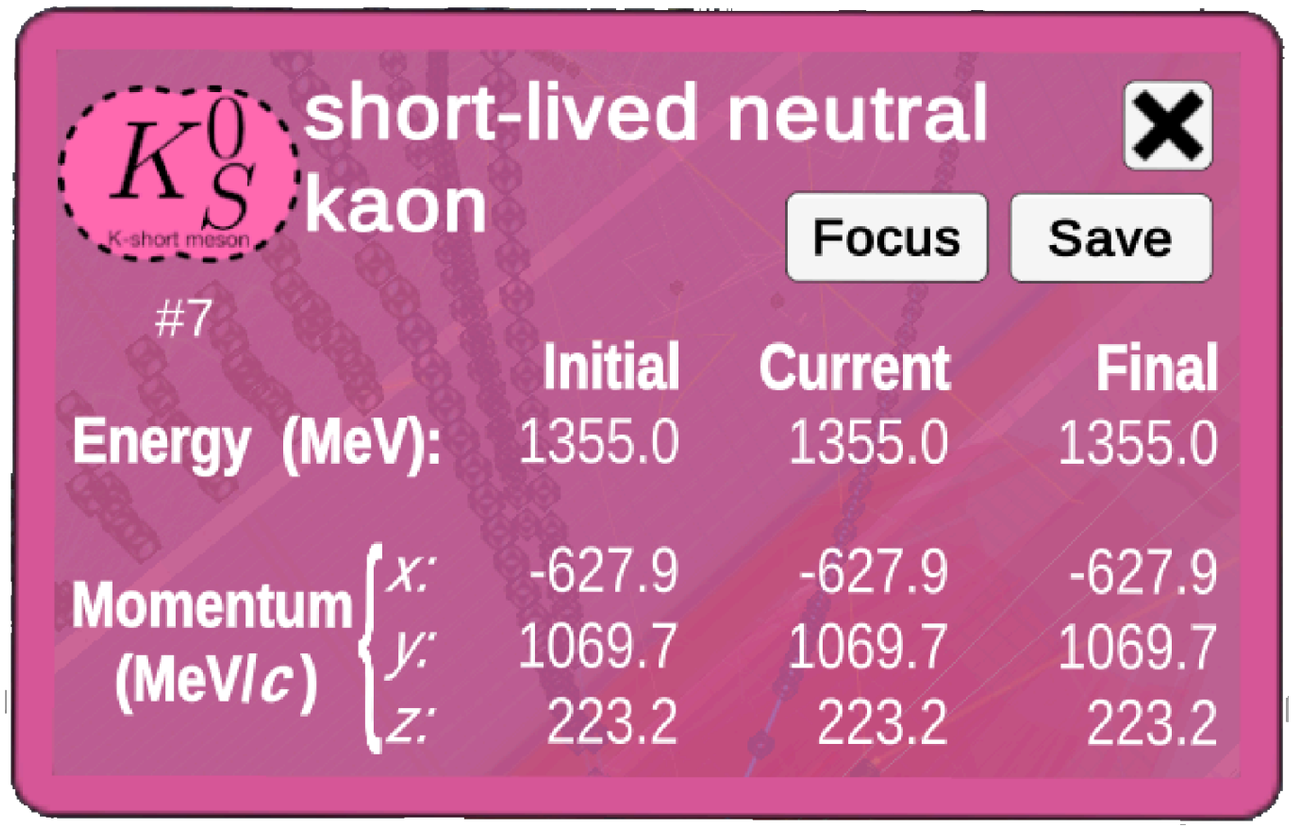
Click to SELECT (in menu, etc)
Double-click to show/hide menu
Hold to modify trackpad action

	not holding the trigger	while holding the trigger
pointing horizontally		
pointing vertically		

Y: Hide/show detector hits
X: Pause / Resume
B: Hide/show dead particles

VR world features (1)

✓ If you gaze at a particle and **SELECT**, an information panel appears.



✓ The panel's border is black if the particle is dead.

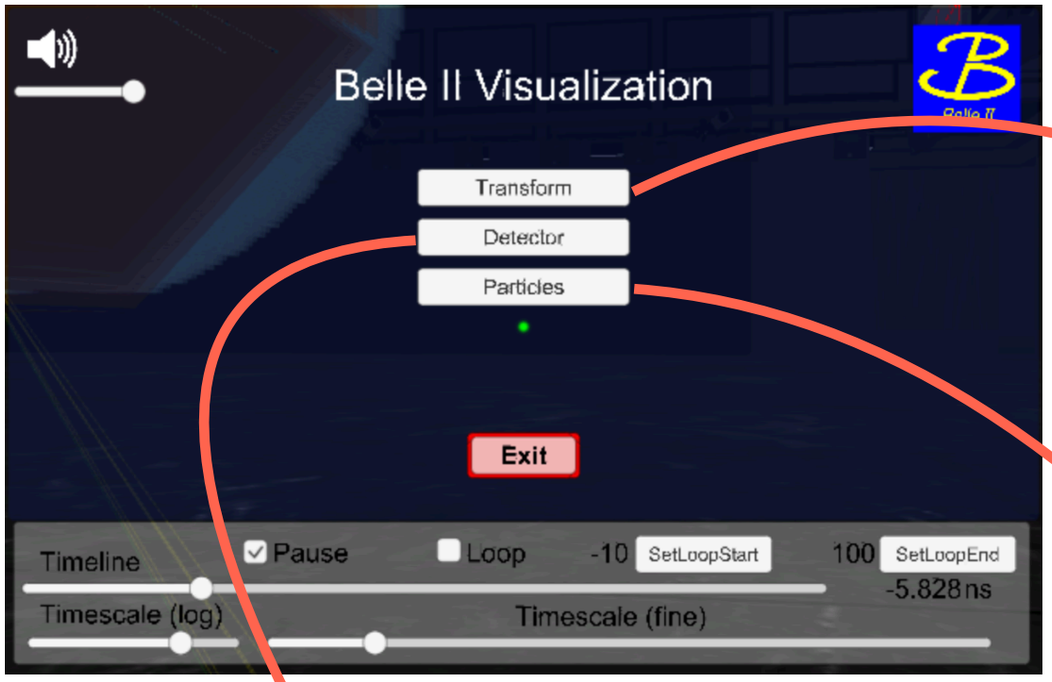
✓ If you gaze at **Focus** and **SELECT**, only this particle and its relatives are shown. *(Then, you can "Unfocus" to show all particles.)*

✓ If you gaze at **Save** and **SELECT**, this particle's information is saved to a row of the panel on one wall of the room.

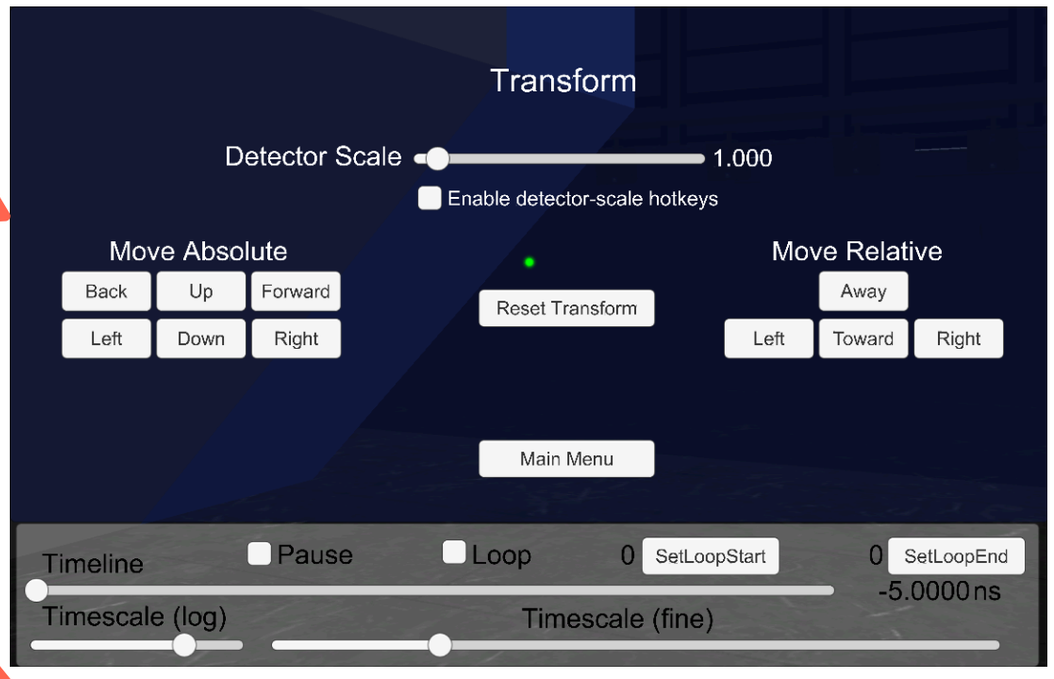
✓ You can sum selected entries on the wall display panel to test conservation of energy and momentum.

VR world features (2)

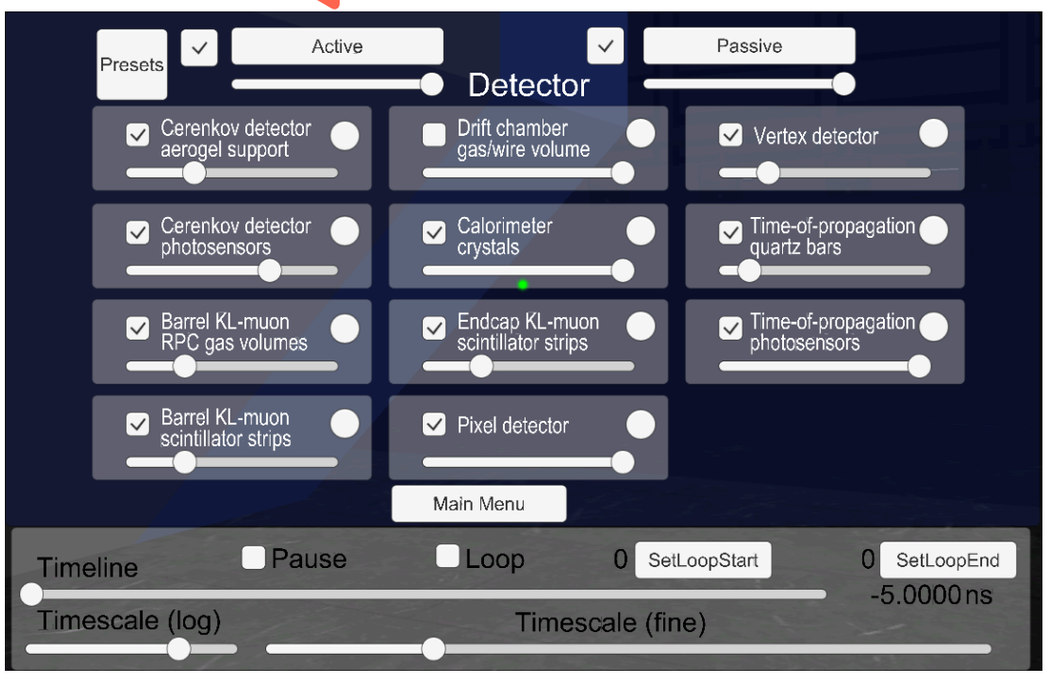
- ✓ Show the **in-game menu** by pressing the **Start button**.
- ✓ Move your gaze to place the green dot on a menu item then press **SELECT**.



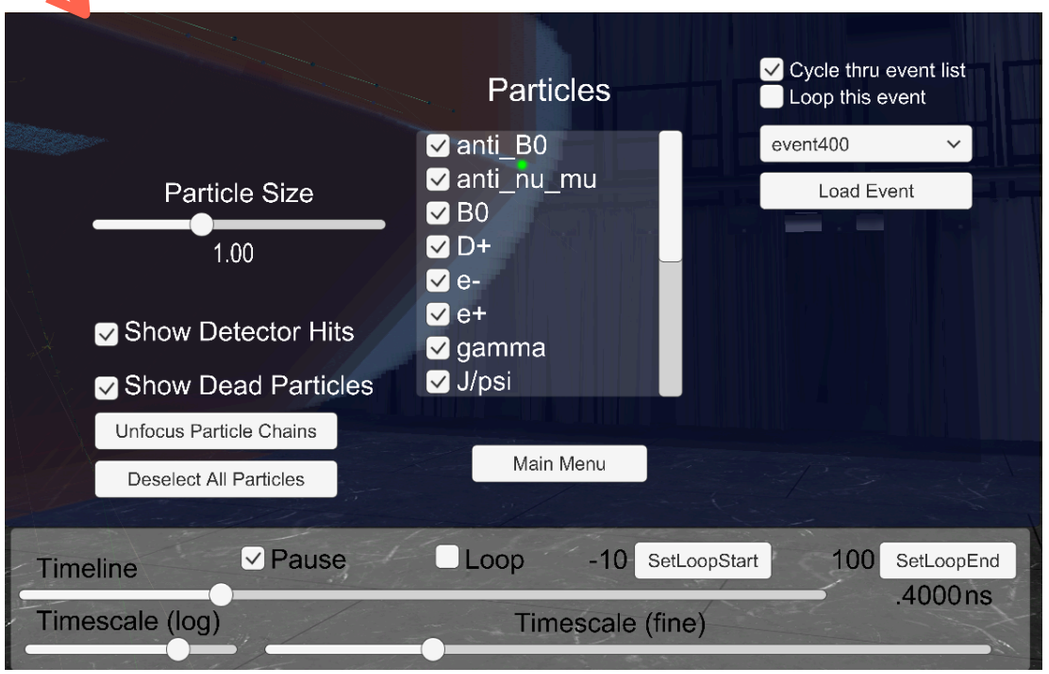
Main menu



Transformation menu



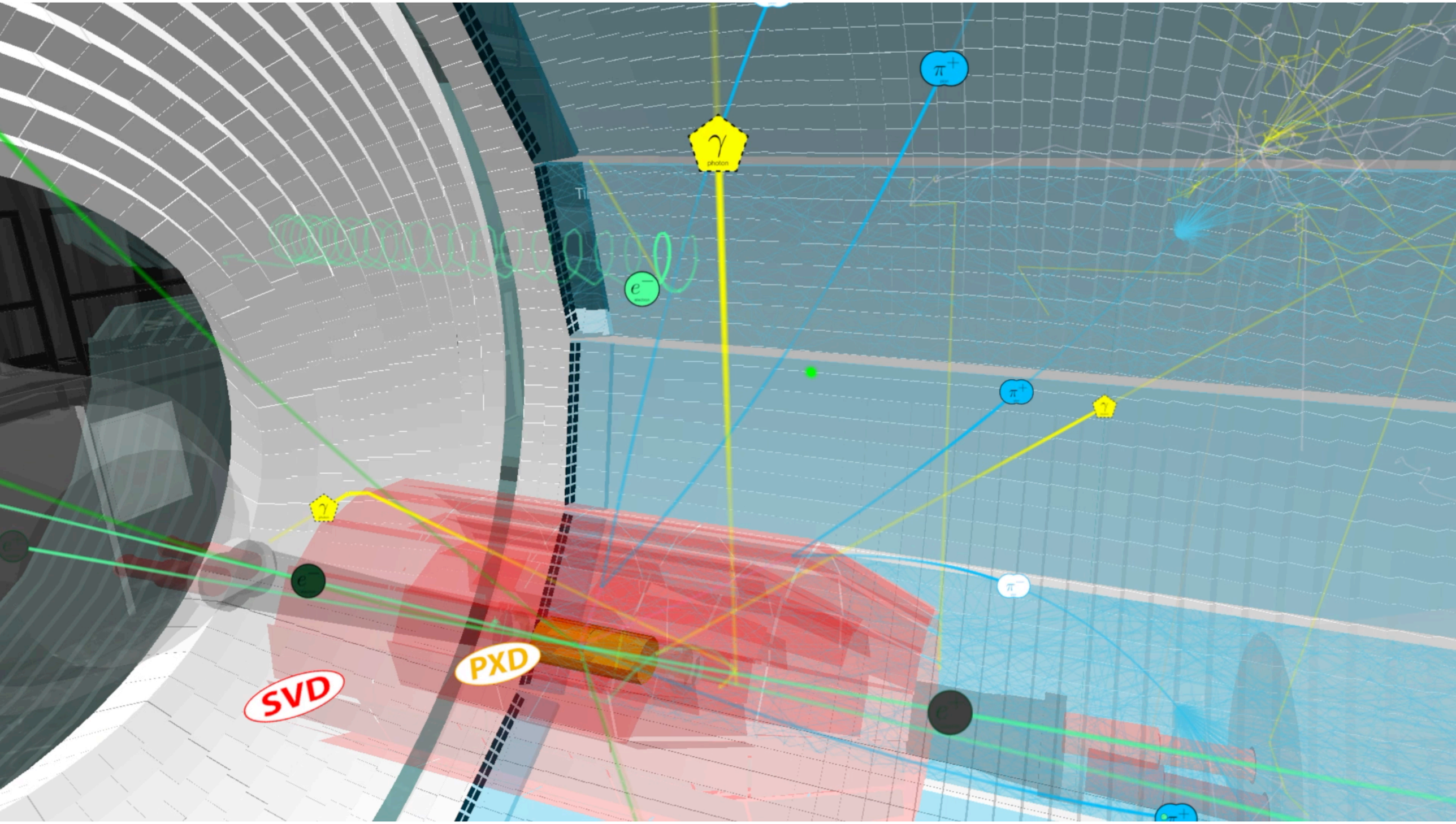
Detector visibility menu



Particles and events menu

User-interaction examples

GEANT4 event-history animation examples

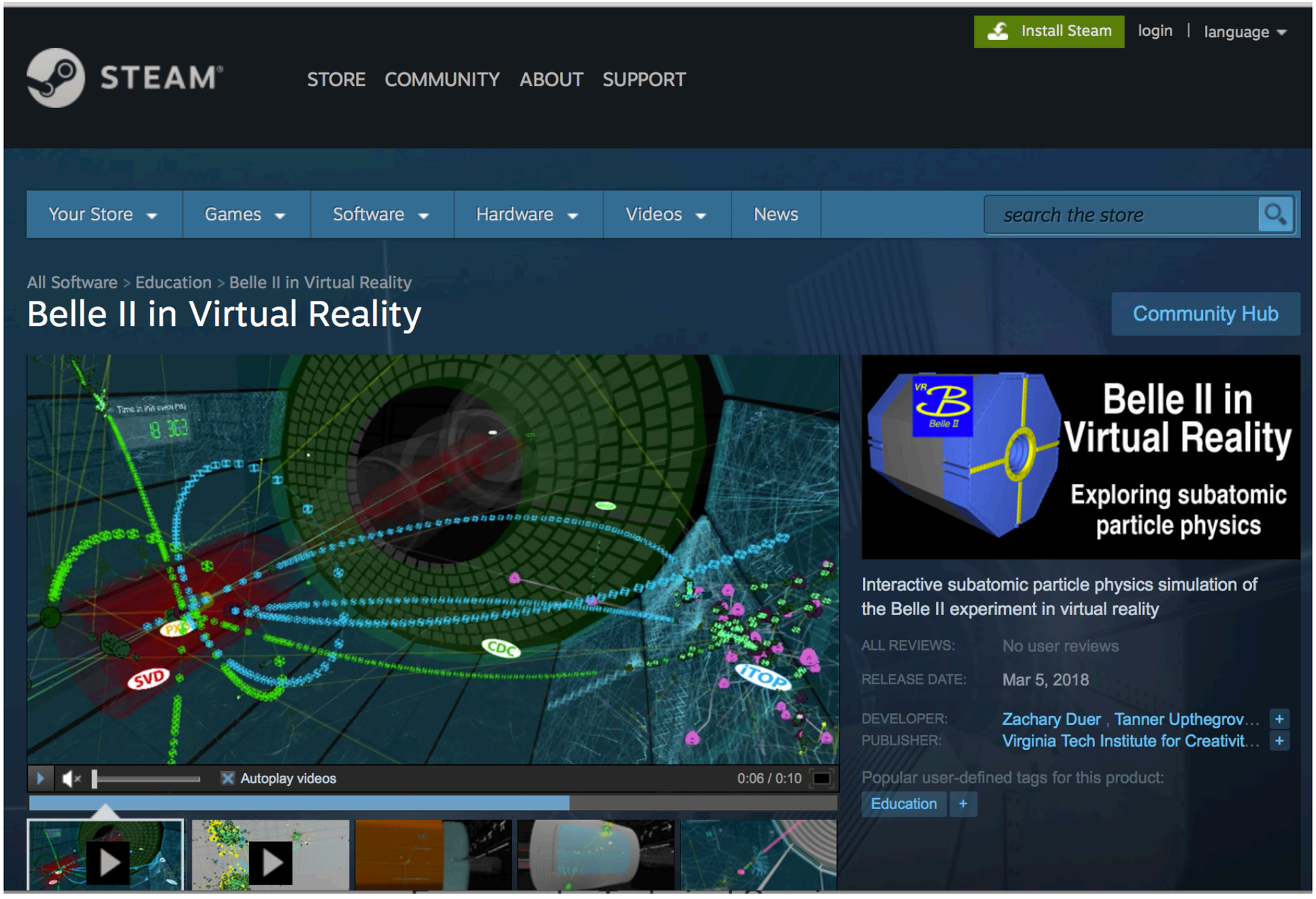


Publicity

- ✓ Development process:
  - vimeo.com/220004044 *(narrated)* & 214899668 *(captioned)*
- ✓ Presentations:
  - IEEE Visualization in Practice *including paper* www.visinpractice.rwth-aachen.de (2017)
  - Virginia Association of Science Teachers www.vast.org (2017)
  - HEP Software Foundation (2018) indico.cern.ch/event/658060/
  - ICHEP 2018 and CHEP 2018
  - ACAT 2019
- ✓ **Public displays and outreach:**
  - many! used by ~40 institutions
  - Belle II MasterClasses in 2019 with versions in French, German, Italian, Slovenian, . . .

App (free) is available on Steam

store.steampowered.com/app/810020/



and on the Oculus store (for the GO)

secure.oculus.com/my/gear-vr-go → “Redeem code” *(ask me for a code)*

Going forward

- ✓ Seeking new funding to continue this development, particularly as a pedagogical tool in undergraduate physics (university) and high school science education

For more information and downloads
www.phys.vt.edu/~piilonen/VR/

Thank you for your attention!