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Detector description conversion and visualization in Unity for high energy physics experiments

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Abstract: While visualization plays a crucial role in high-energy physics (HEP) experiments, the existing detector description formats face compatibility limitations with modern visualization platforms. This paper presents a universal interface that automatically converts four kinds of detector descriptions into FBX, an industry standard 3D model format which can be seamlessly integrated into advanced visualization platforms like Unity. This method enables HEP experiments to harness rapid technological advancements, and lays the groundwork for the future development of more visualization applications.

Introduction

We have significant demands for detector visualization including detector design, assembly and commissioning, experiment operation, data quality monitoring, simulation and reconstruction, as well as physics analysis. Moreover, detector visualization implies the possibility of achieving event display, which holds significant implications for physics analysis.

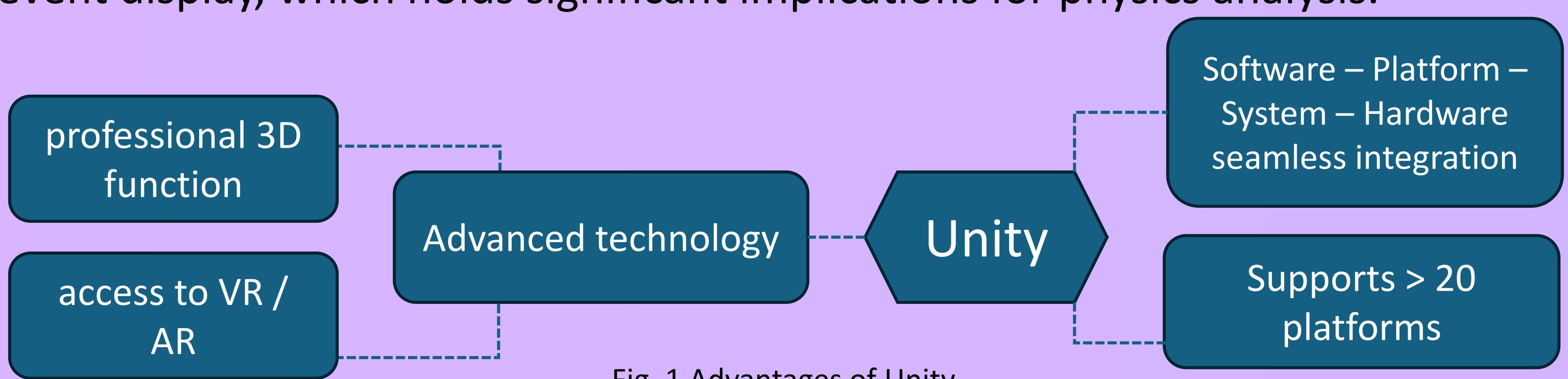


Fig. 1 Advantages of Unity.

Currently, there are several platforms for visualization in HEP experiment field. But visualization technology from industry has more advantages. **Unity** is a professional video and game production engine, which can help to visualize HEP detectors. Although several HEP experiments have made targeted visualization software, such as ELAINA for JUNO and CAMELIA for ATLAS, based on Unity, we hope to complete the HEP experiment detector universal visualization interface.

Fig. 2 Platforms Unity supports

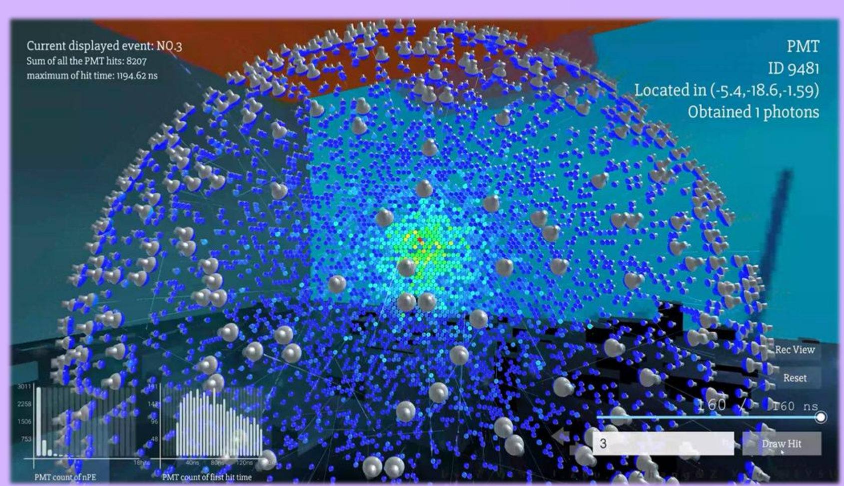


Fig. 3 JUNO event display - ELAINA

Detector Description

HEP experiment detectors are usually large-scale, complex and precise. Their internal detection units often need to be optimized and upgraded. As a result, if we want to implement the detector visualization based on Unity, it is almost impossible to reconstruct a complete model for each HEP detector in Unity.

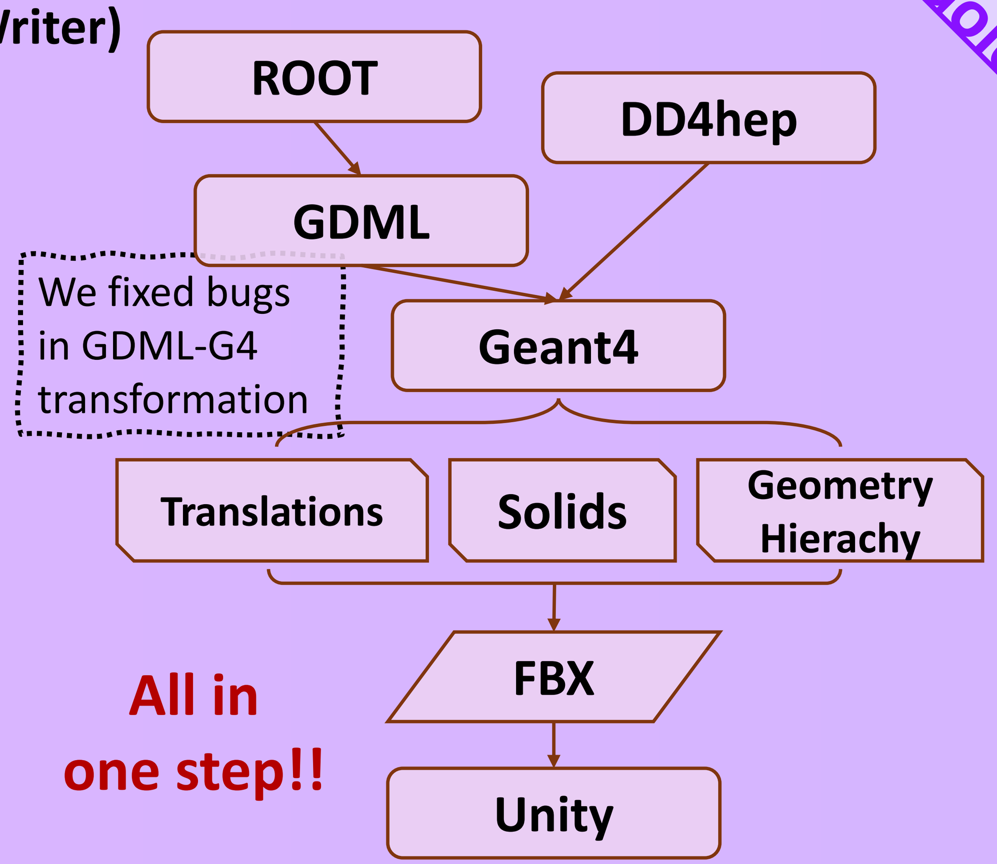
Detector description in HEP now:

- **GDML**
- **ROOT**
- **DD4hep**
- **Geant4**

⇨ Cannot import to Unity ⇨ **Need a method for automatic detector transformation!**

Methodologies

- **A method provided by this work (develop based on HSF Geometry Writer)**



- Fine tuning of configuration to solve crash caused by complicated geometry.
- Support self-defined shapes and geometry classes
- The steps are easier and faster.
- Is able to assist all four detector descriptions.
- Running in Geant4, it's totally free

References

[1] Nuclear Science and Techniques, 2022, 33(11): 142.
[2] https://github.com/HSF/Visualization
[3] https://github.com/gttcz/FBXWriter.git
[4] arXiv:1811.10309, 2018.
[5] arXiv:2507.10261
[6] arXiv:2406.12495

Visualization results in Unity

The interface provided in this work is capable of converting all four detector descriptions (including ROOT, GDML, Geant4 and DD4hep) into FBX-formatted files, and we will show them in Unity.

1. ROOT to Unity with EicC detector

The Electron-Ion Collider in China (EicC) is a proposed HEP facility, aims for precision studies of nucleon structure, partonic interactions in nuclei, and exploration of exotic heavy quark states, supported by an advanced detector system.

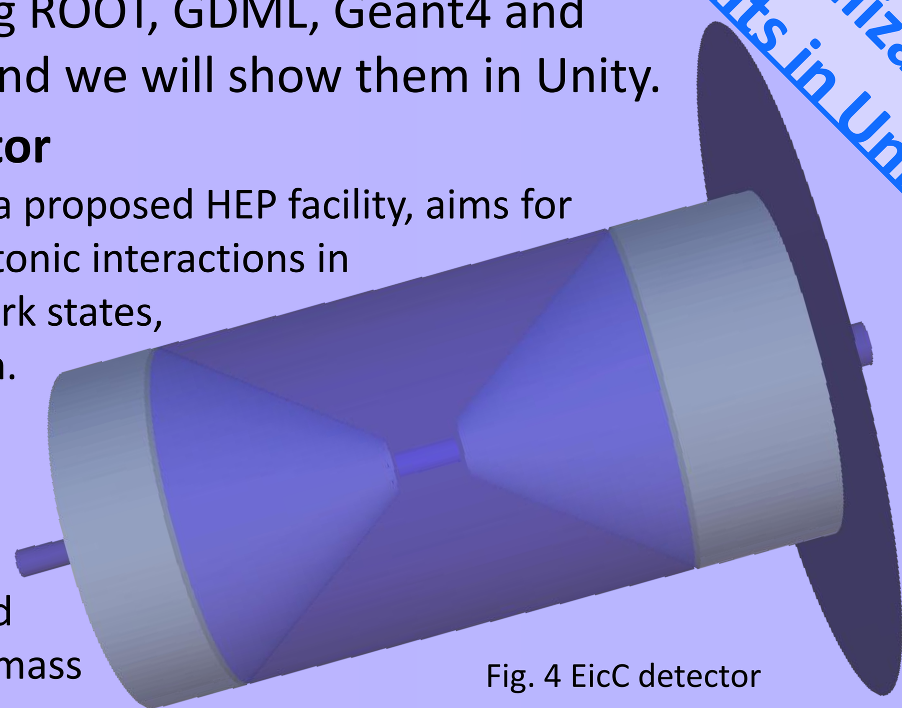


Fig. 4 EicC detector

2. GDML to Unity with BESIII detector

The Beijing Spectrometer (BESIII) detector records symmetric e^+e^- collisions provided by the BEPCII storage ring in the center-of-mass Energy range from 1.84 to 4.95 GeV, enabling precision studies of tau-charm physics.

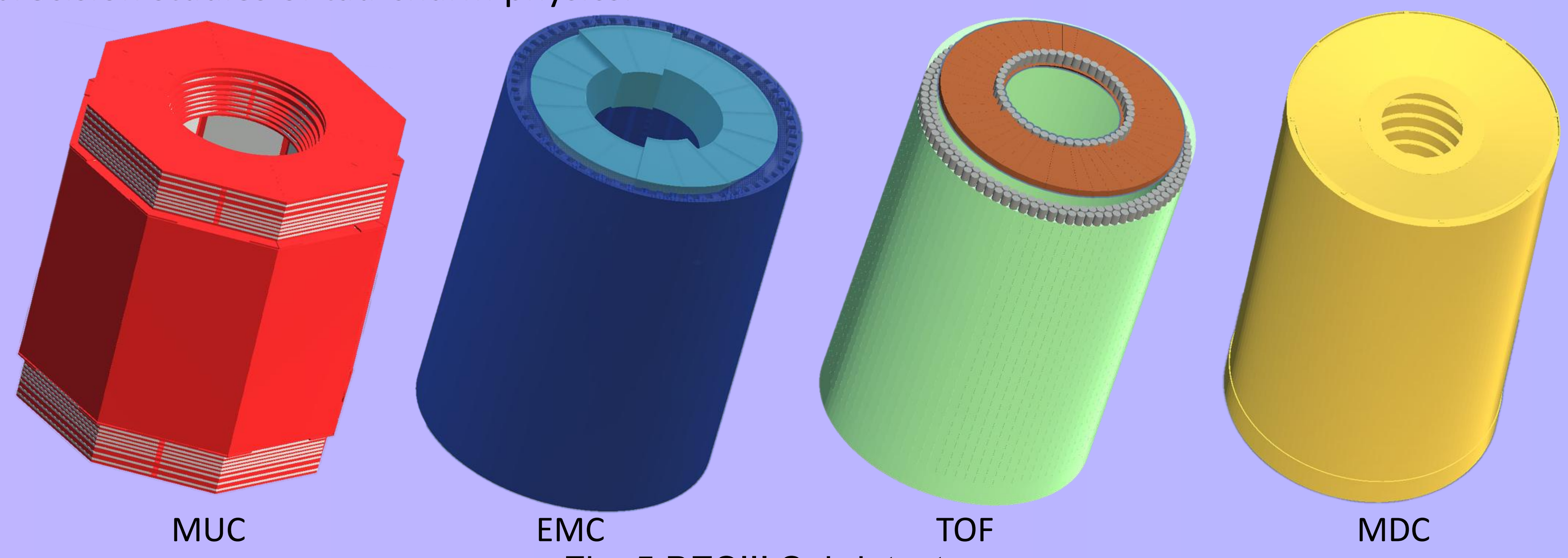


Fig. 5 BESIII Subdetectors

3. Geant4 to Unity with JUNO detector

The Jiangmen Underground Neutrino Observatory (JUNO) is an neutrino experiment station, aimed at determining the neutrino mass hierarchy, precisely measuring neutrino mixing parameters, and conducting various cutting-edge scientific research.

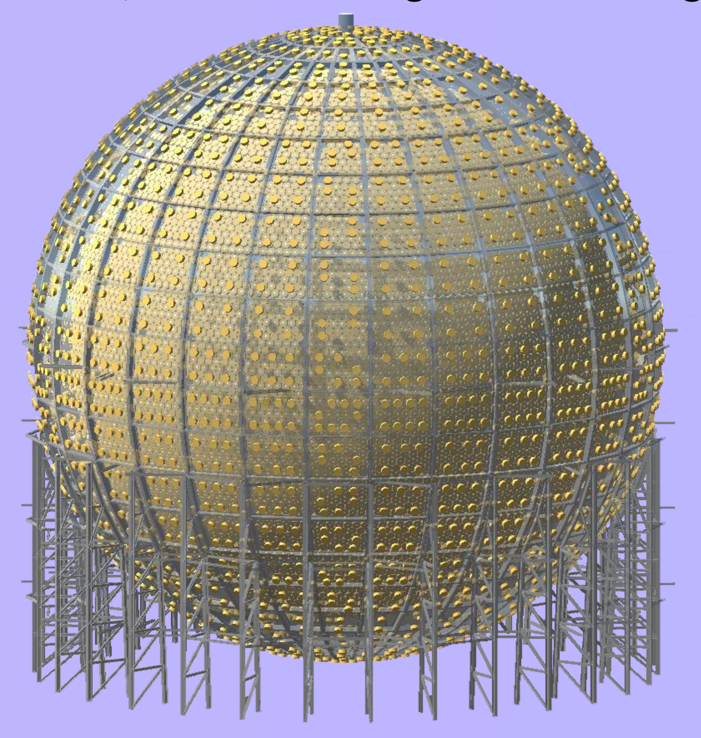


Fig. 6 Total view of JUNO

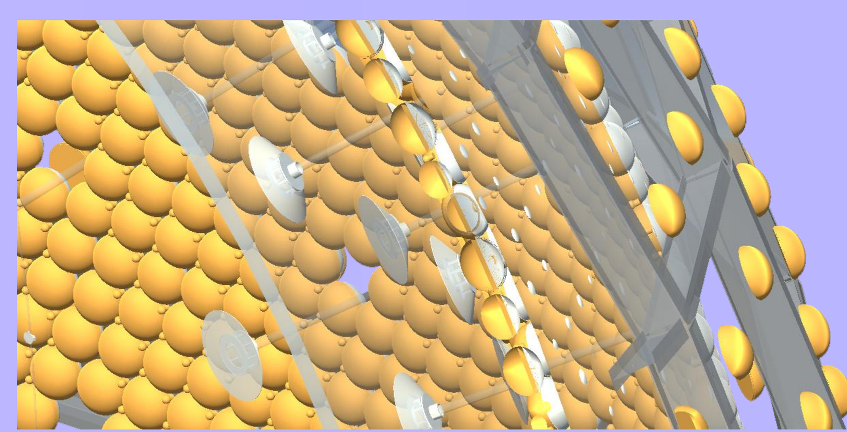


Fig. 7 Inner/outer PMT and holder

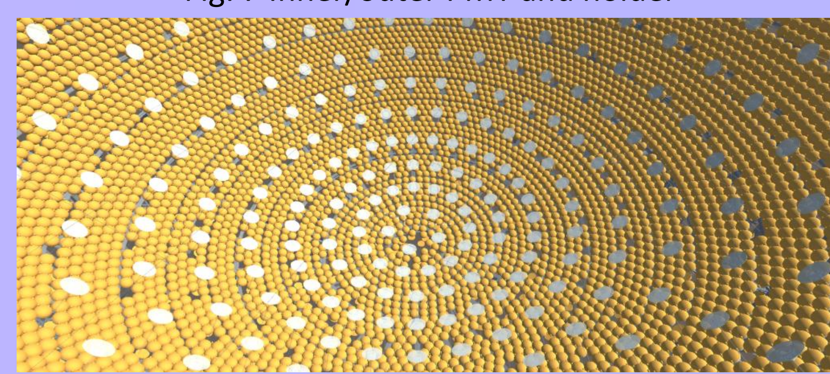


Fig. 8 Inner view of JUNO

4. DD4hep to Unity with CEPC

The CEPC (Circular Electron-Positron Collider) is a proposed high-energy particle accelerator for precision Higgs boson and physics beyond the Standard Model research.

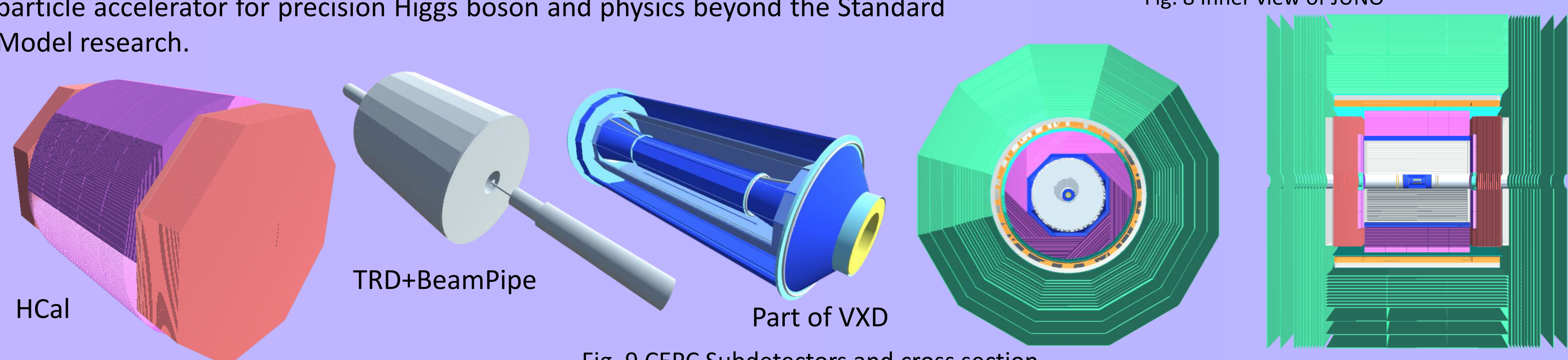


Fig. 9 CEPC Subdetectors and cross section

Further applications

With the FBX files converted from GDML, we can visualize detectors in Unity directly, Which means we can develop more technology based on Unity. Which is promising for us in the future:

- **Event display:** Event display software, real-time event display, and even 3D example display can be developed more conveniently on Unity, further enriching the operation monitoring and physics analysis.
- **Virtual Reality (VR) / Augmented Reality (AR):** Unity provides a direct interface to AR/VR, so we can upgrade to more interactive content. This can be done based on hardware such as HTC Vive, Oculus Quest2, and Apple Vision Pro. This function can assist in the design, assembly and operational supervision of the detector.

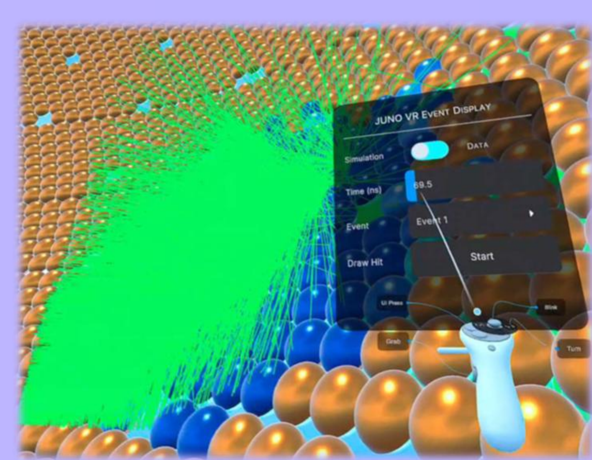


Fig. 10 Interactive interface in Unity

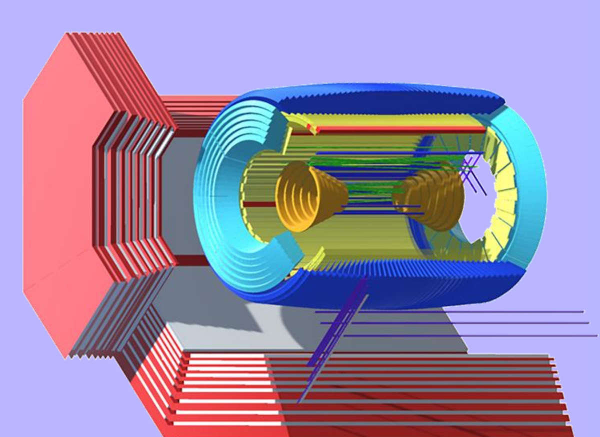


Fig. 11 BESIII detector in BESVIS

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