Application of high energy physics detector description transformation for visualization in Unity

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Abstract: Visualization is integral to high-energy physics (HEP) experiments, spanning from detector design to data analysis. Presently, depicting detectors within HEP is an intricate challenge. Professional visualization platforms like Unity offer advanced capabilities, and also provide promising avenues for detector visualization. This work aims to develop an automated interface facilitating the seamless conversion of detector descriptions from HEP experiments, formatted in GDML, DD4hep, ROOT, and Geant4, directly into 3D models within Unity. The significance of this work extends to aiding detector design, HEP offline software development, physical analysis, and various aspects of HEP experiments. Moreover, it establishes a robust foundation for future research endeavors, including enhancements in event display.

Introduction

The visualization of detectors is an integral aspect throughout the entire process of HEP experiments. We have significant demands for detector visualization in various aspects including detector design, assembly and commissioning, experiment operation and maintenance, data quality monitoring, simulation and reconstruction, as well as physics analysis. Moreover, detector visualization implies the possibility of achieving event display, which may hold significant implications for physics analysis. The HEP Software Foundation Community White Paper Working Group has also outlined guidelines for research directions in visualization.

Fig. 1 Advantages of visualization technology from industry

Currently, there are several software and platforms for detector visualization in HEP experiment field. But in comparison, visualization technology from industry has more advantages. **Unity** is a professional video and game production engine, which can help to visualize HEP detectors.

- Professional 3D software.
- Provide access to VR or AR.
- Supports more than 20 platforms.

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

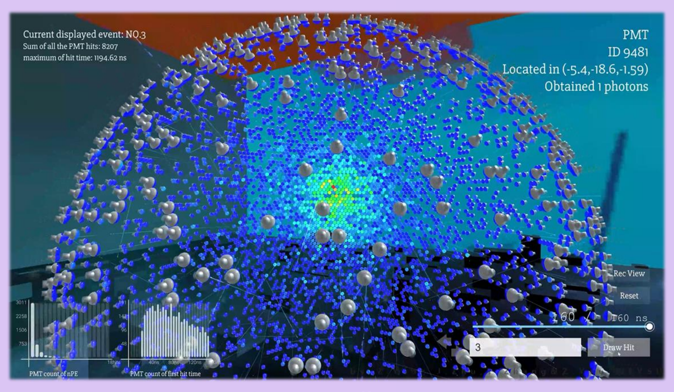


Fig. 3 JUNO event display - ELAINA

Detector Description

HEP experiment detectors are usually large-scale, complex and precise detection instruments, and 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 and accurate model for each HEP detector in Unity.

Detector description in HEP now:

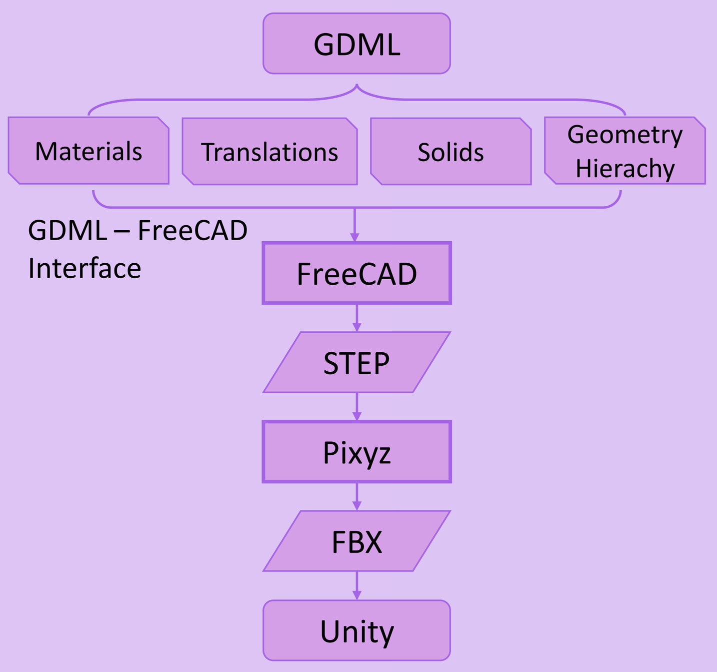
- **GDML**
- **DD4hep**
- **ROOT**
- **Geant4**

None of them can be directly imported into Unity → **Develop a method for automatic detector transformation!**

The method should work for all detectors and all formats, while keeping consistency.

Methodologies

- **A feasible transformation method provided by other works:**

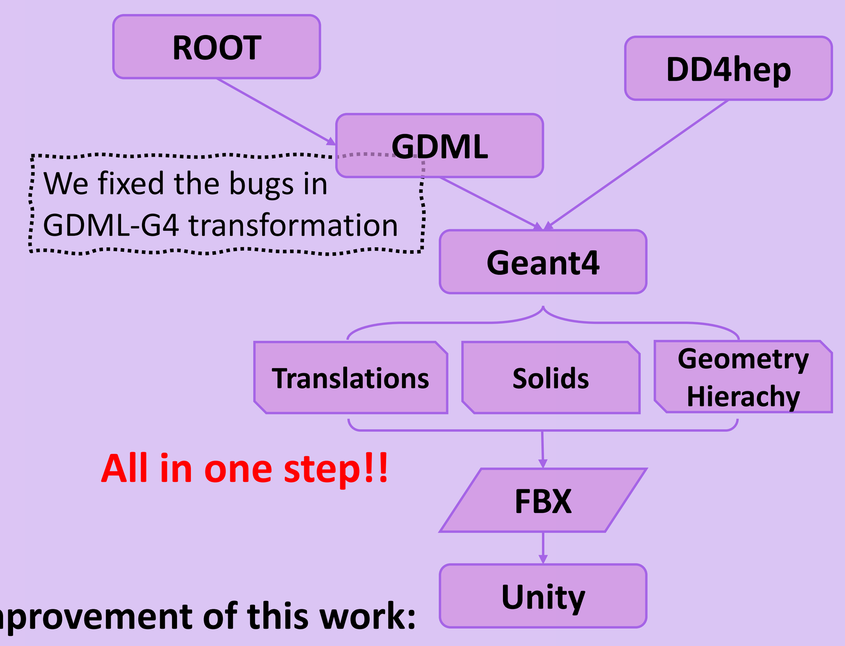


Result of previous work:

- Maintain the unique identifier of each detector unit.
- Provides richer visualization properties.

BUT: Too complicated & time consuming.

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



Improvement of this work:

- 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

Visualization 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 in this part.

1. ROOT to Unity with EicC detector

The Electron-Ion Collider in China (EicC) is a proposed high-energy 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.

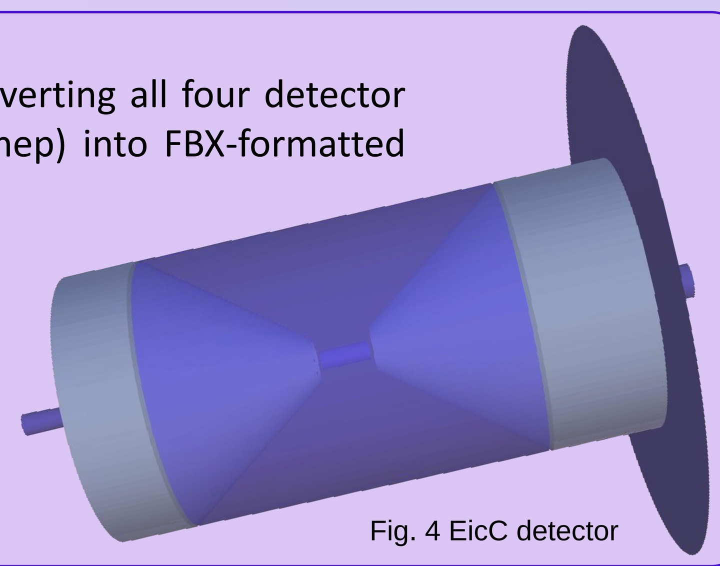


Fig. 4 EicC detector

Visualization in Unity

2. GDML to Unity with BESIII detector

The Beijing Spectrometer Experiment (BESIII detector) at the BEPCII accelerator is a major upgrade of BESII at the BEPC for the studies of hadron physics and τ-charm physics with the highest accuracy achieved until now.

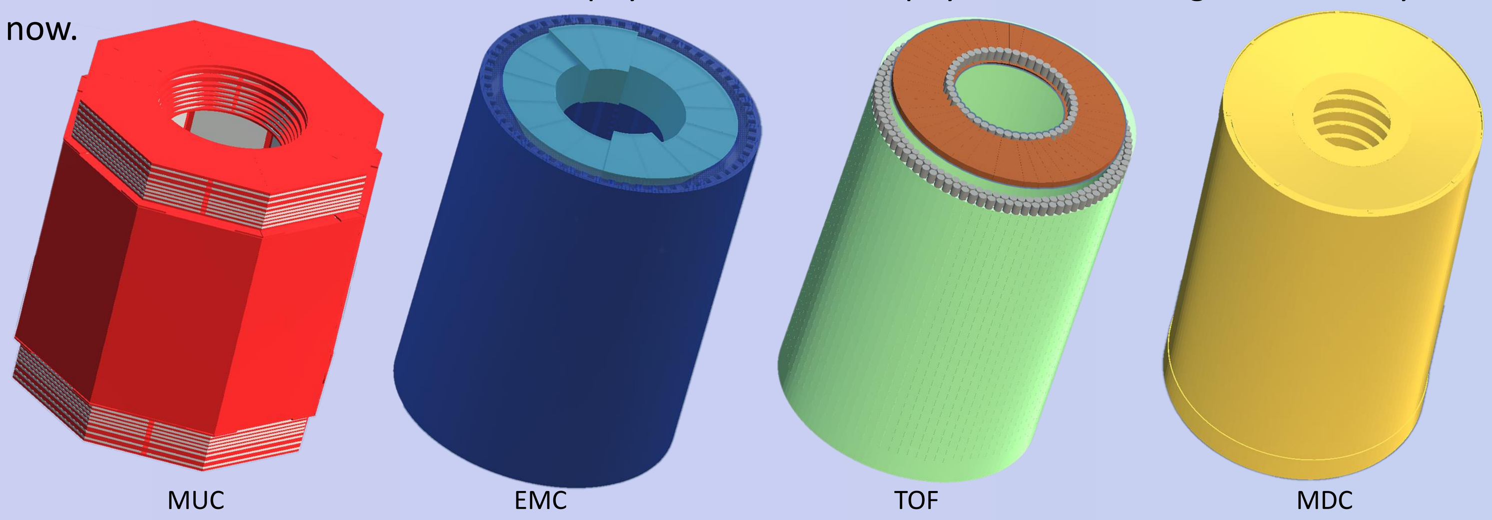


Fig. 5 BESIII Subdetectors

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.

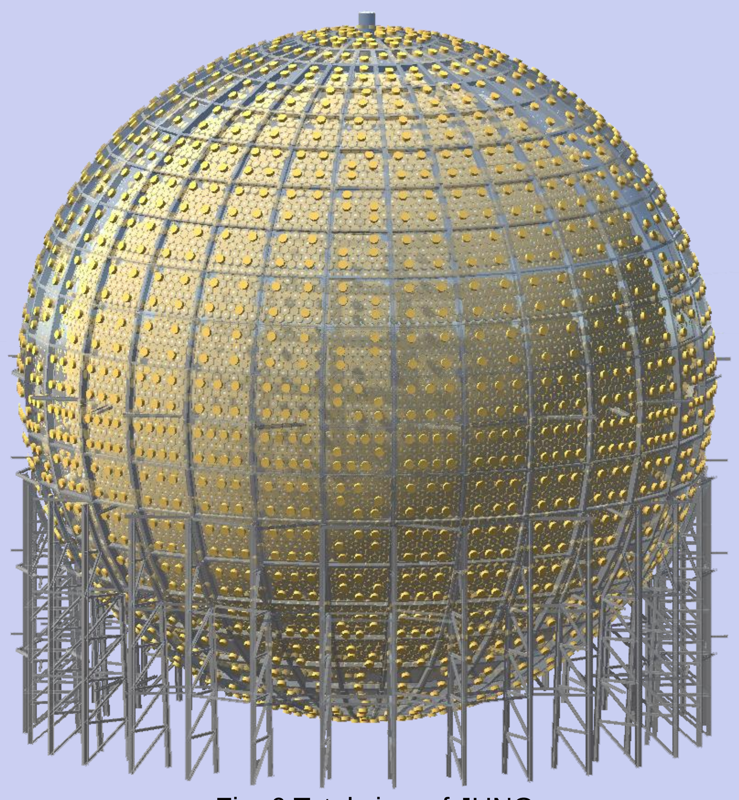


Fig. 6 Total view of JUNO

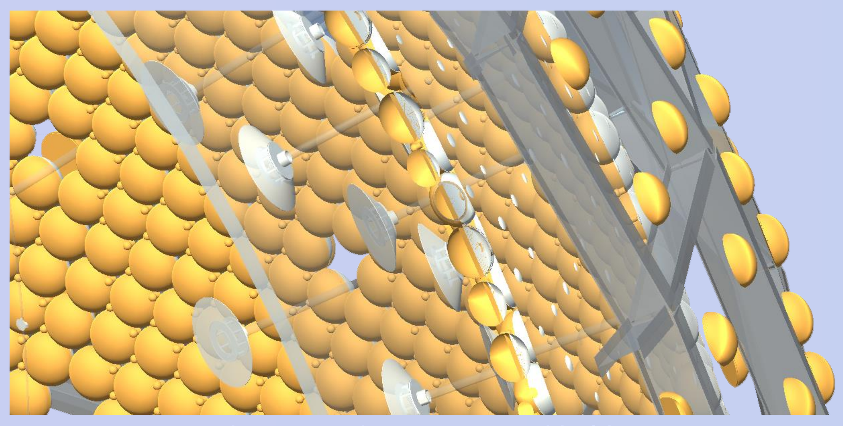


Fig. 7 Inner/outer PMT and holder

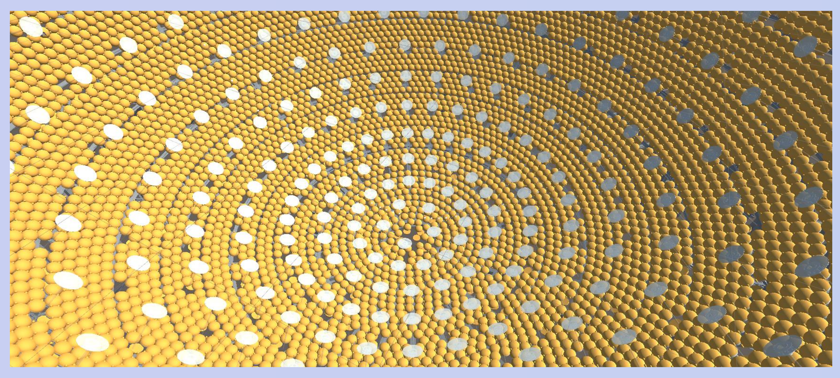


Fig. 8 Inner view of JUNO

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.

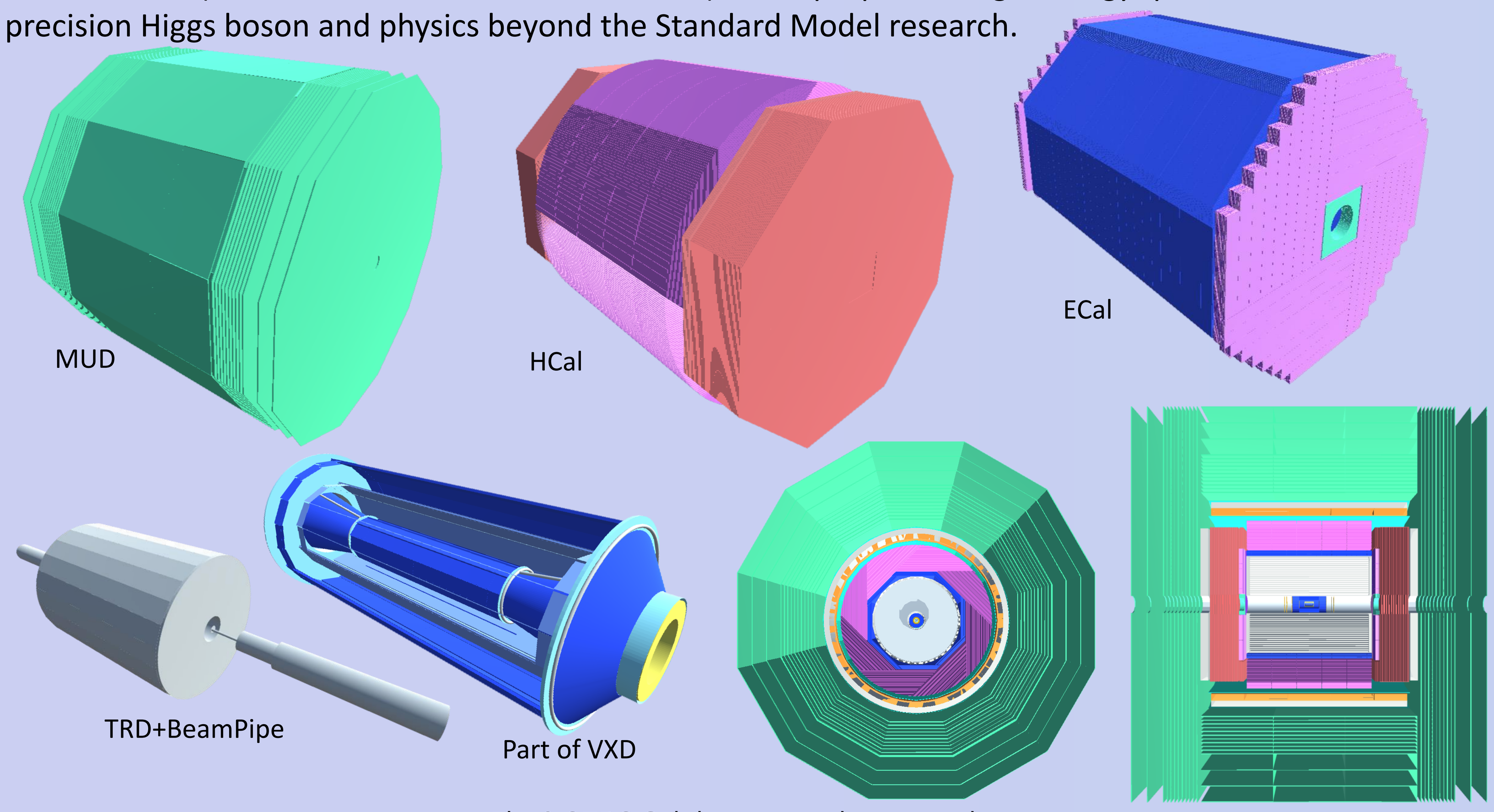


Fig. 9 CEPC Subdetectors and cross section

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:

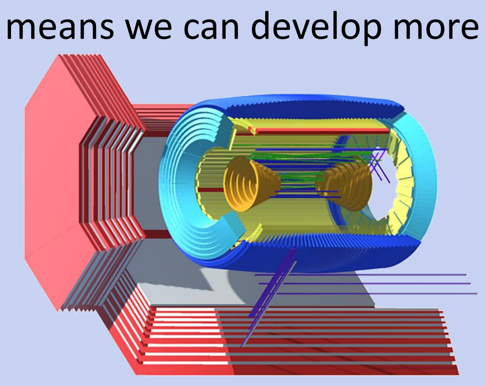


Fig. 3 Visualization result of BESVIS

- **Event display**

This figure is the event display shown in Besvis, which is based on ROOT. In the future, we can develop event display software for various detectors based on Unity more conveniently. In addition, we can develop real-time event display, 3D example display video production technology, which can further enrich our operation monitoring and physics analysis.

- **Virtual Reality (VR) / Augmented Reality (AR)**

Unity provides a direct interface to AR or VR, where we can upgrade to more and richer interactive content. This content can be done based on hardware such as HTC Vive, Oculus Quest2, Apple Vision Pro and so on. The figure on the left shows how the JUNO detector behaves in VR interactions, which can assist in the design, assembly and operational supervision of the detector.

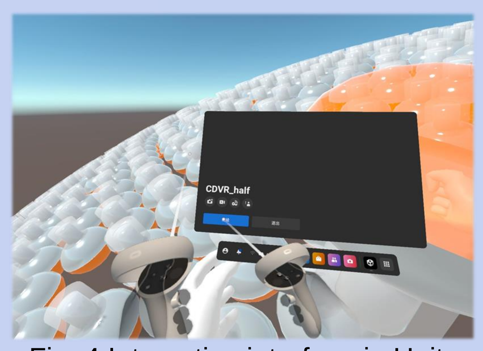


Fig. 4 Interactive interface in Unity

Reference

[1] HEP Software Foundation Community White Paper Working Group---Visualization[J]. Bellis M, Bianchi R M, Binet S, et al., arXiv:1811.10309, 2018.
[2] Method for detector description transformation to Unity and application in BESIII[J]. Huang K X, Li Z J, Qian Z, et al., Nuclear Science and Techniques, 2022, 33(11): 142.
[3] Ric-bianchi, tpmccauley, et al., (2018) Visualization[source code].https://github.com/HSF/Visualization.

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