XXXII International Conference on Neutrino Physics and Astrophysics

# Visualization and Virtual Reality Framework for Neutrino Detectors

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## Motivation

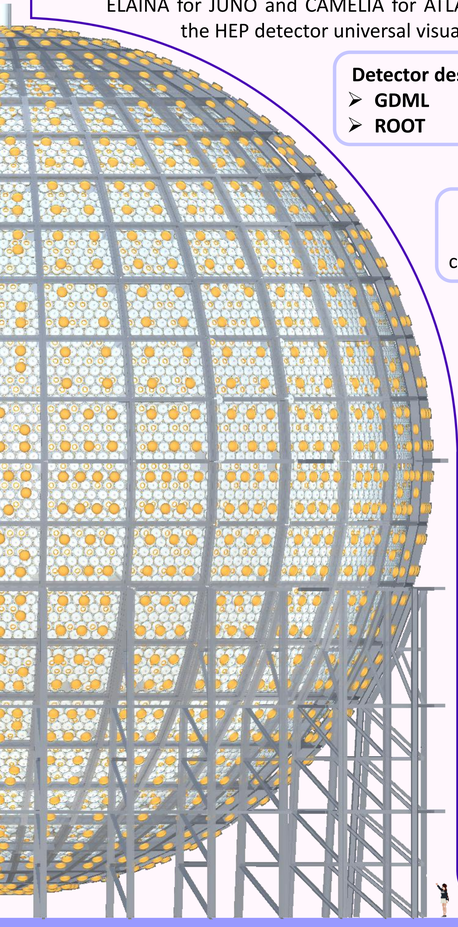
**Detector visualization** is essential for geometry inspection, detector design, simulation validation, event display, and operation monitoring. However, HEP detector descriptions such as GDML, ROOT, Geant4, and DD4hep are not directly compatible with industrial 3D engines. This gap limits interactive visualization and VR-based detector exploration. By importing HEP detector geometry into Unity, the same framework can support both conventional 3D visualization and immersive VR exploration.

**Why Unity?**

**Unity** is a professional video and game production engine, which can help to visualize HEP detectors.

| Requirement in HEP visualization | Unity capability |
|---|---|
| Large detector geometry | Mature 3D rendering engine |
| Interactive inspection | Real-time scene control |
| Cross-platform deployment | Desktop / Web / VR / AR |
| Event display | Dynamic objects and UI |
| Outreach and operation | Immersive visualization |

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 detector universal visualization interface.



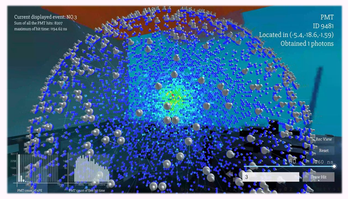
**Detector description in HEP:**
- GDML
- ROOT
- DD4hep
- Geant4

Format & geometry conversion gap

impossible to reconstruct each detector in Unity

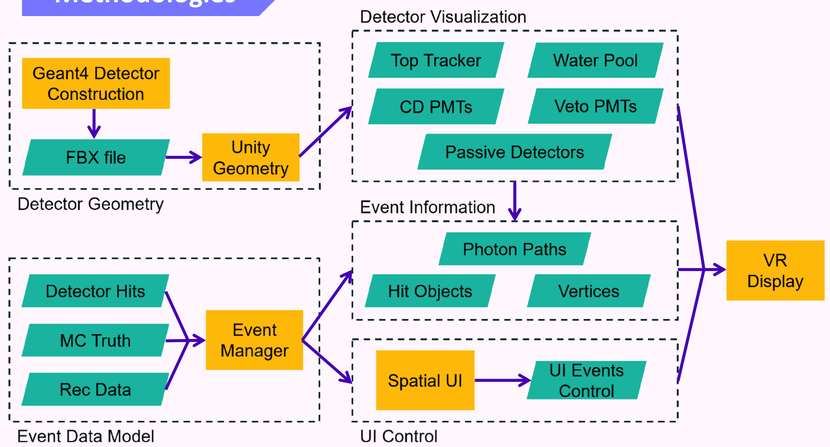
**Develop a method for automatic detector transformation!**

Game developed by Unity



JUNO event display - ELAINA

## Methodologies



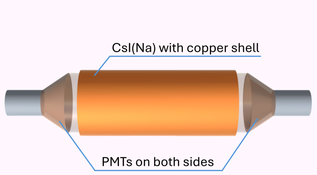

- Converts HEP detector geometry into Unity-compatible 3D models (.fbx files) via an automatically interface.
- Preserves geometry hierarchy and visual properties.
- Supports large-scale detector visualization with large number of complex and intricate subdetectors/structures.
- Enables both desktop and VR interaction.

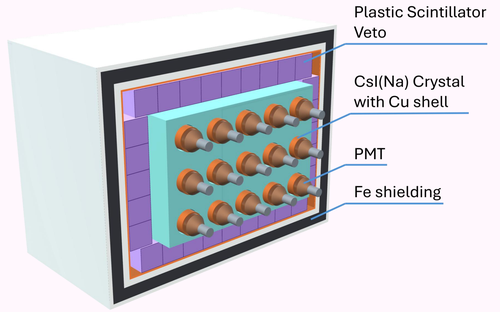
## Visualization on desktop

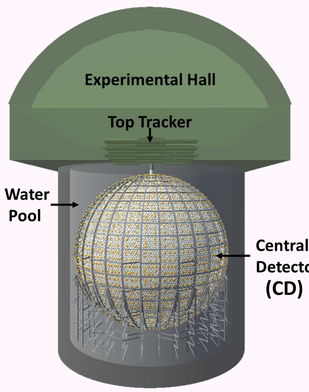
**1. CICENNS (CsI detector for Coherent Elastic Neutrino-Nucleus scattering)**

A compact neutrino scattering detector.

This detector is presented in another poster “CICENNS experiment: A 300kg CsI(Na) detector for CEvNS measurement” in detail.

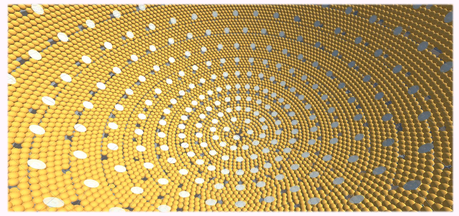



**2. JUNO detector**

Large liquid scintillator neutrino detector with complex spherical geometry and massive PMT arrays.



## Visualization in VR

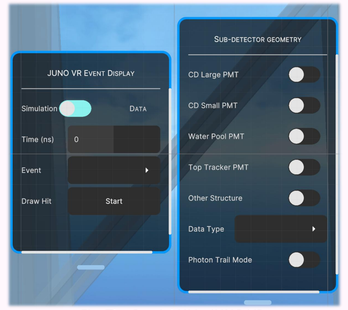



Fig. The Spatial UI in JUNO VR.

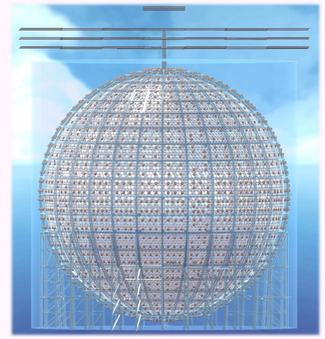
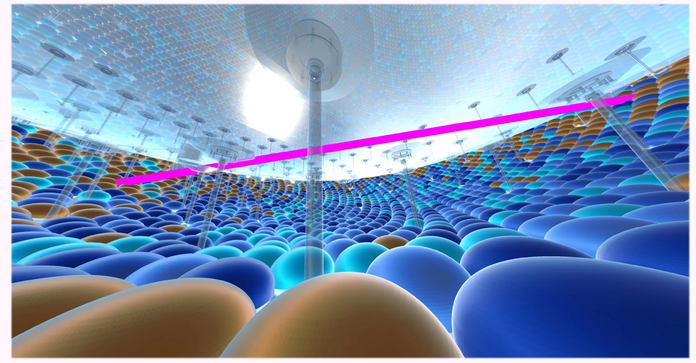


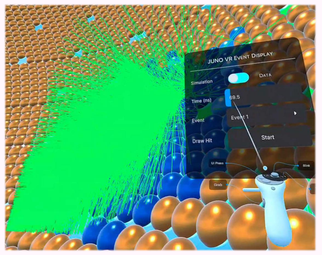
Fig. JUNO detector in the VR application.

| Interactive module | Function |
|---|---|
| Geometry display | Toggle different sub-detectors. |
| Event display | Switch data/simulation, select event type, control event timeline. |
| Immersive interaction | Navigate inside the detector, switch viewpoints, drag/hide panels, and interact with UI elements using controller rays. |



**Event information visualized**
- Hit time and charge of PMTs
- MC photon trajectories and vertices
- Reconstructed vertex and muon track
- Simulated and Data Challenge events

**Potential applications**
- Detector operation monitoring
- Reconstruction validation
- Physics analysis and outreach



## Reference

[1] Huang, KX., Song, TZ., Su, YN. et al. Unity-based virtual reality for detector and event visualization in JUNO experiment. NUCL SCI TECH 37, 74 (2026).

[2] Tian-Zi Song, Kai-Xuan Huang, Yu-Jie Zeng, Ming-Hua Liao, Xue-Sen Wang, Yu-Mei Zhang, Zheng-Yun You. Detector description conversion and visualization in Unity for high energy physics experiments. Front. Phys., 2026, 21(2): 026201

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