ROBAST 3

https://robast.github.io
https://github.com/ROBAST
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What is ROBAST?

ROOT-based simulator for ray tracing (ROBAST) is an open-source C++ project [1] that has been used for non-sequential ray-tracing simulation in several cosmic-ray (CR) telescope projects since 2007. Utilizing the ROOT geometry library and its particle tracking engine, complex CR telescopes can be easily built, allowing users to simulate multiple reflections, refraction, and scattering of individual photons. In addition to the ROOT primitive geometry classes, ROBAST has its own geometry classes to simulate aspherical surfaces (Fig. 1a) and light concentrators [2], with which most cosmic-ray telescopes can be modeled.

Applications in Future Projects

Fig. 1 demonstrates ROBAST applications in future gamma-ray and cosmic-ray telescopes; the Small-sized telescopes (SSTs) of the Cherenkov Telescope Array (CTA) [3], Trinity [4], and the Cosmic Ray Air Fluorescence Fresnel lens Telescope (CRAFFT) [5]. Complex telescope beams, aspherical primary and secondary mirrors, and a 2048-ch silicon photomultiplier camera are modeled in Fig. 1a. Fresnel lens simulation in CRAFFT is also shown in Fig. 1c.

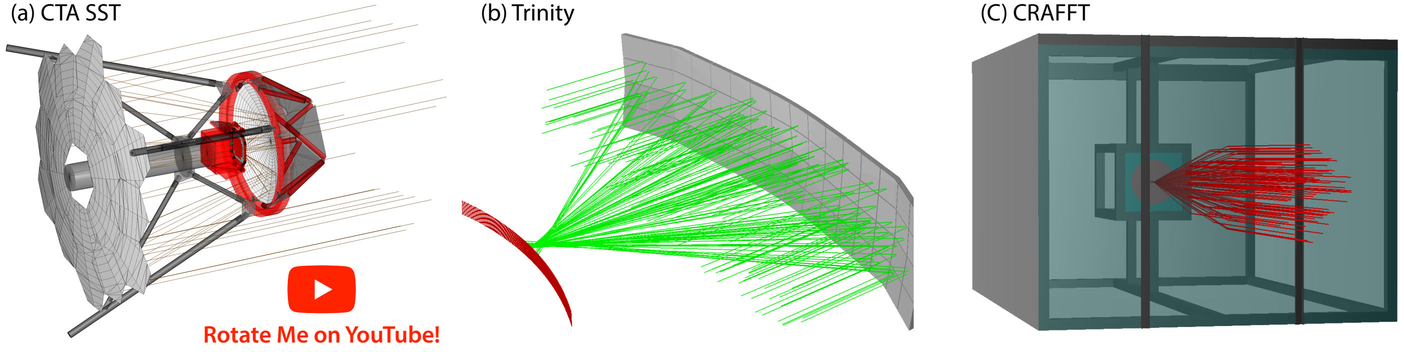

Figure 1: ROBAST 3D models and simulated photon tracks. (a) Aspherical two-mirror system (Schwarzschild–Couder configuration) of CTA SST. The original 3D CAD file was provided by the CTA SST optics team. (b) Wide spherical mirror simulation of the Trinity optical system. Image credit: the Trinity collaboration. (c) Fresnel lens simulation for the CRAFFT optical system. Image credit: Yuichiro Tameda.

Multilayer Coating Simulation (New Functionality in ROBAST 3)

Cherenkov and fluorescence observations using UV-sensitive photodetectors suffer from the night-sky background (NSB) and moonlight. To mitigate the NSB contamination or to increase the effective area of optical systems, multilayer coating on mirrors, light concentrators, and camera protection windows is studied in many projects. In ROBAST 3, the latest major version, multilayer coating on media boundaries can be simulated.

Fig. 2 compares collection efficiency curves of a Winston cone for six different colors. Multilayer coating to reduce the NSB contamination is taken into account in this simulation, and thus lower collection efficiency in long wavelengths and peaks and valleys due to multilayer interference are seen. An example code snippet of multilayer coating in ROBAST is shown in Fig. 3.

This new functionality is also used to simulate strong wavelength and angular dependence of the photon detection efficiency of silicon photomultipliers, which is caused by interference in SiO2 and SiN layers. Please see the proceedings paper for the detail.

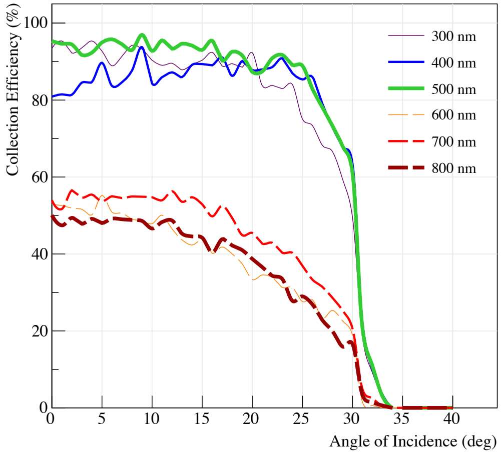

Figure 2: Simulation of the collection efficiency of a Winston cone, the surface of which is coated by multilayer bandpass filter. Six different colors are compared, where many peaks and valleys are due to interference in the coating.

```
auto coating = std::make_shared<AMultilayer>(air, ABS);
coating->InsertLayer(SiO2, 37.7 * nm);
coating->InsertLayer(Ta2O5, 37.5 * nm);
coating->InsertLayer(SiO2,  41.1 * nm);
...
```

Figure 3: A multilayer object example in ROBAST

References

(1) A. Okumura, K. Noda, and C. Rulten. ROBAST: Development of a ROOT-based ray-tracing library for cosmic-ray telescopes and its applications in the Cherenkov Telescope Array. Astropart. Phys. 76 38–47 (2016)
(2) A. Okumura, et al.. Prototyping hexagonal light concentrators using high-reflectance specular films for the Large-Sized Telescopes of the Cherenkov Telescope Array. Journal of Instrumentation, 12 P12008 (2017)
(3) E. Giro, et al. First optical validation of a Schwarzschild couder telescope: the ASTRI SST-2M Cherenkov telescope. Astron. Astrophys. 608 A86 (2017)
(4) A. N. Otte, et al. Trinity: An air-shower imaging system for the detection of ultrahigh energy neutrinos. In Proceedings of 36th International Cosmic Ray Conference, PoS(ICRC2019) (2019)
(5) Y. Tameda, et al. The status and performance of Cosmic Ray Air Fluorescence Fresnel lens Telescope (CRAFFT) for the next generation UHECR observatory. In Proceedings of 36th International Cosmic Ray Conference PoS(ICRC2019) (2019)

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