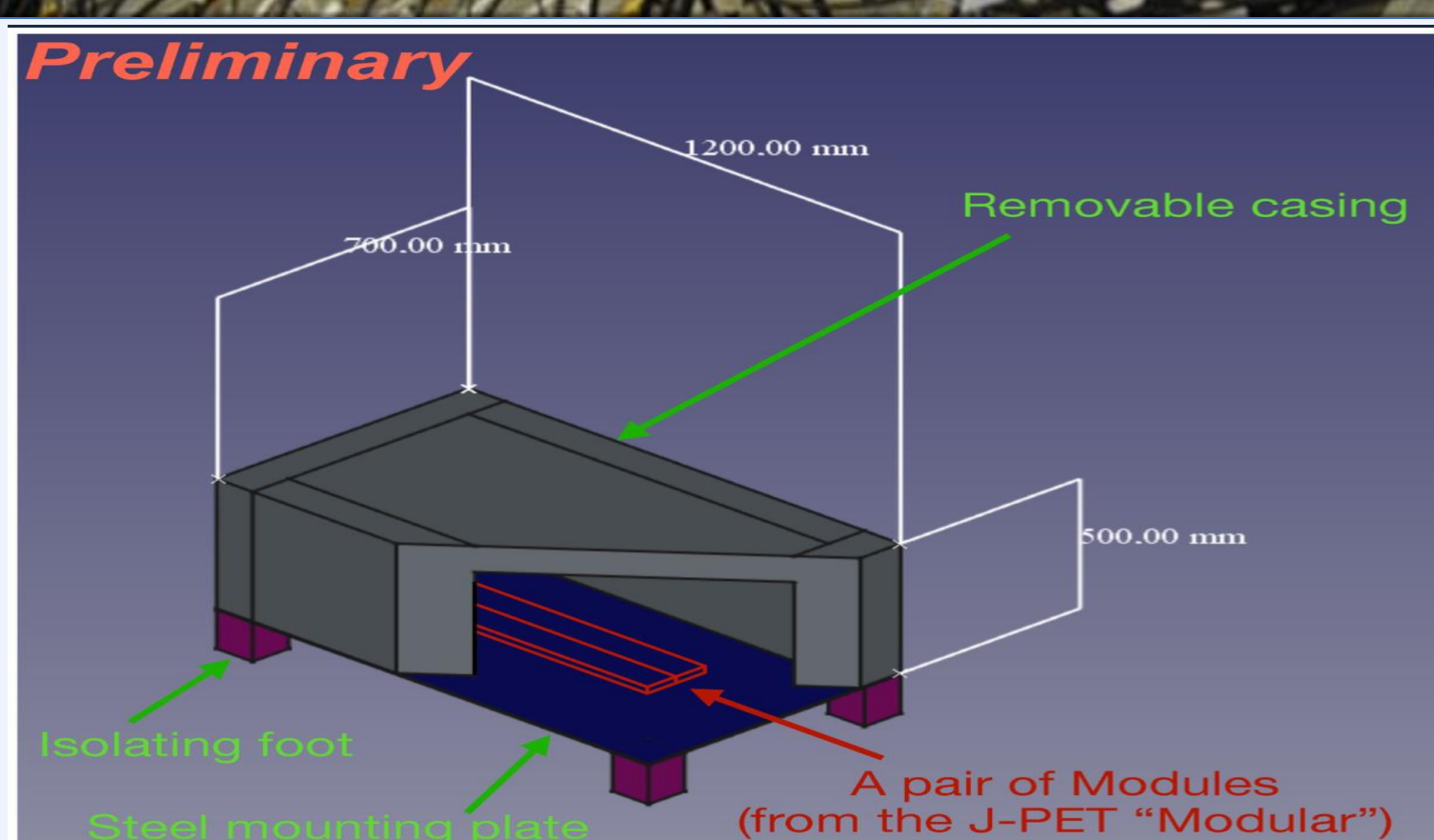
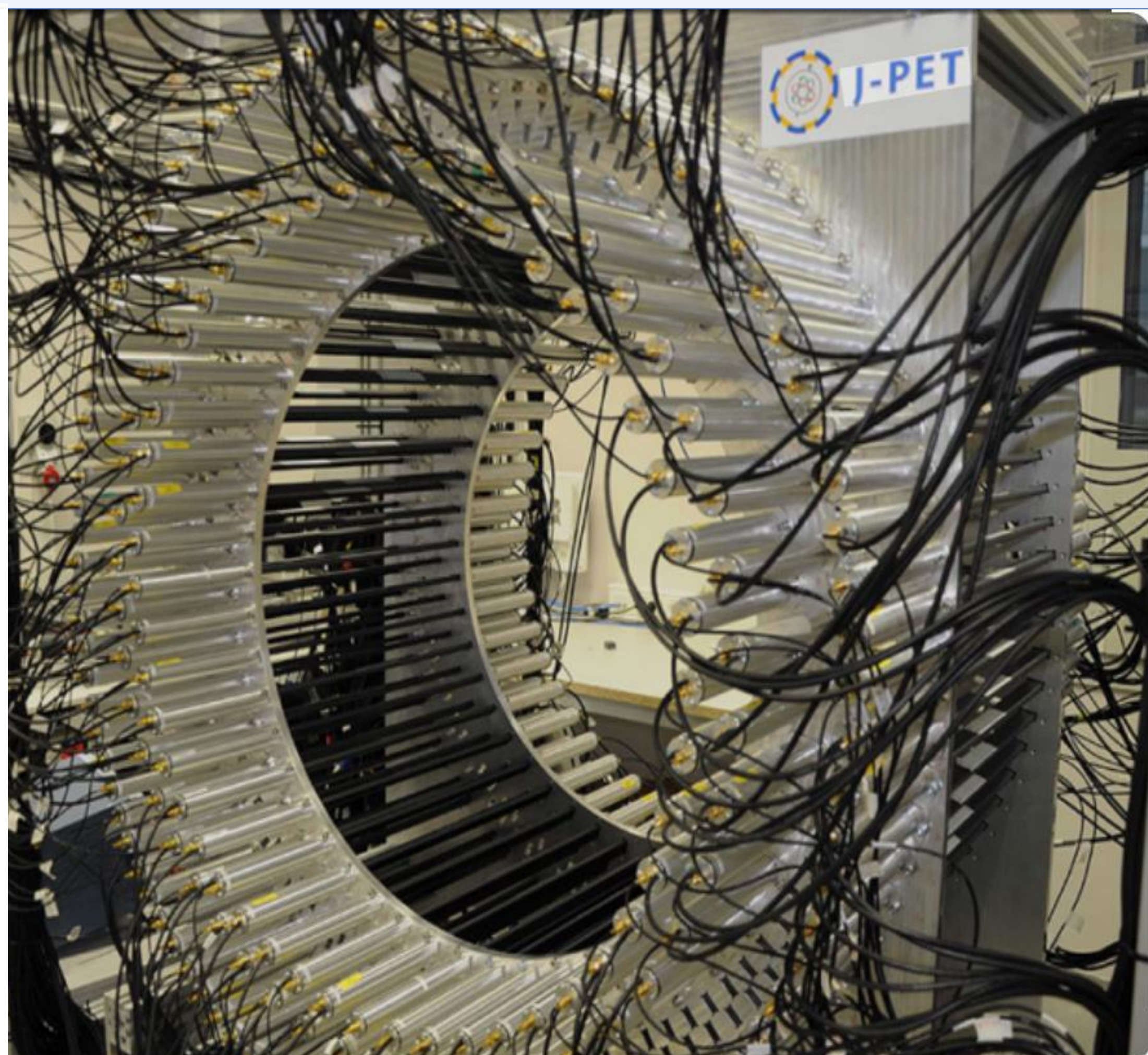
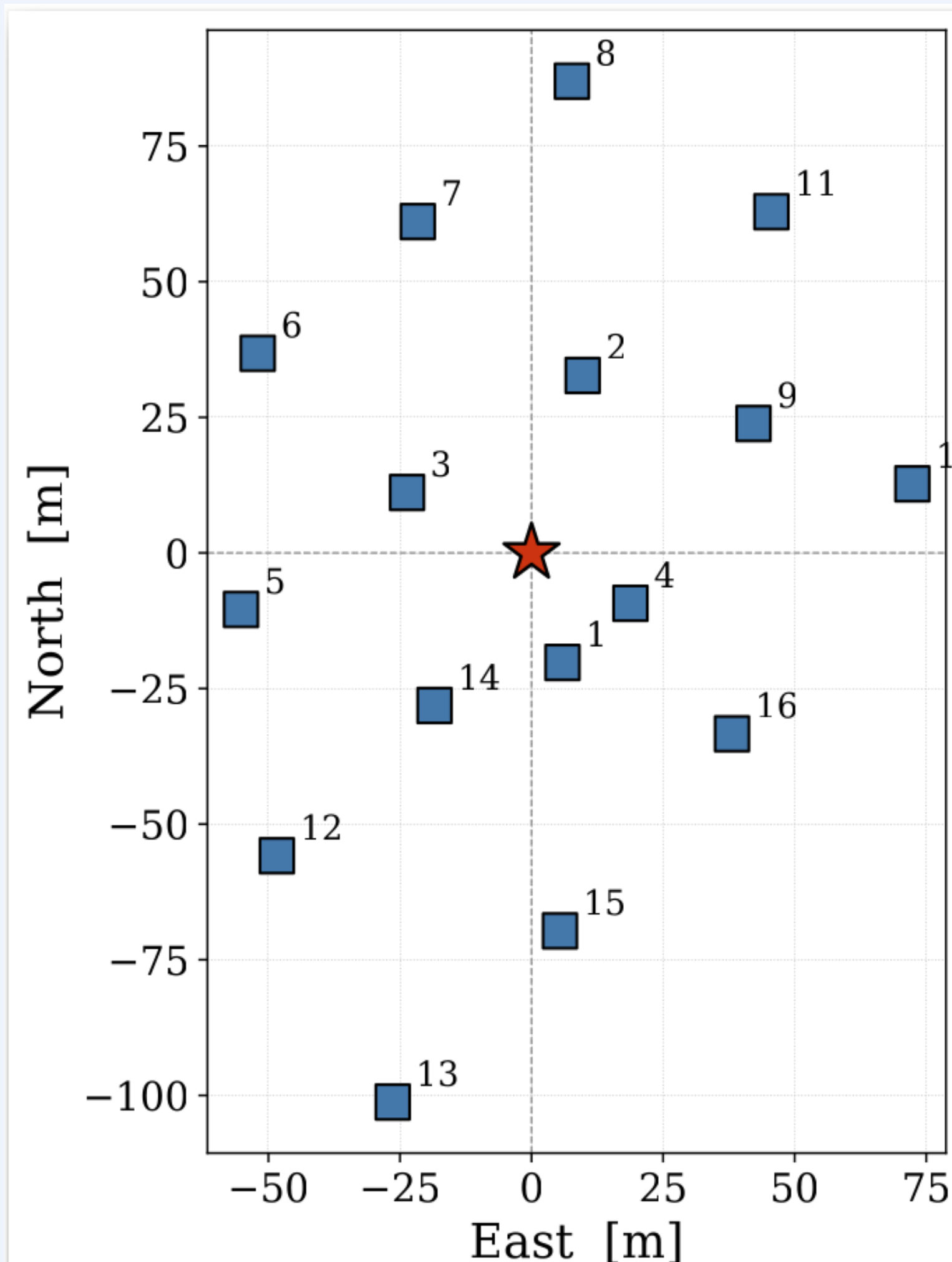


The Muon Puzzle & μPPET

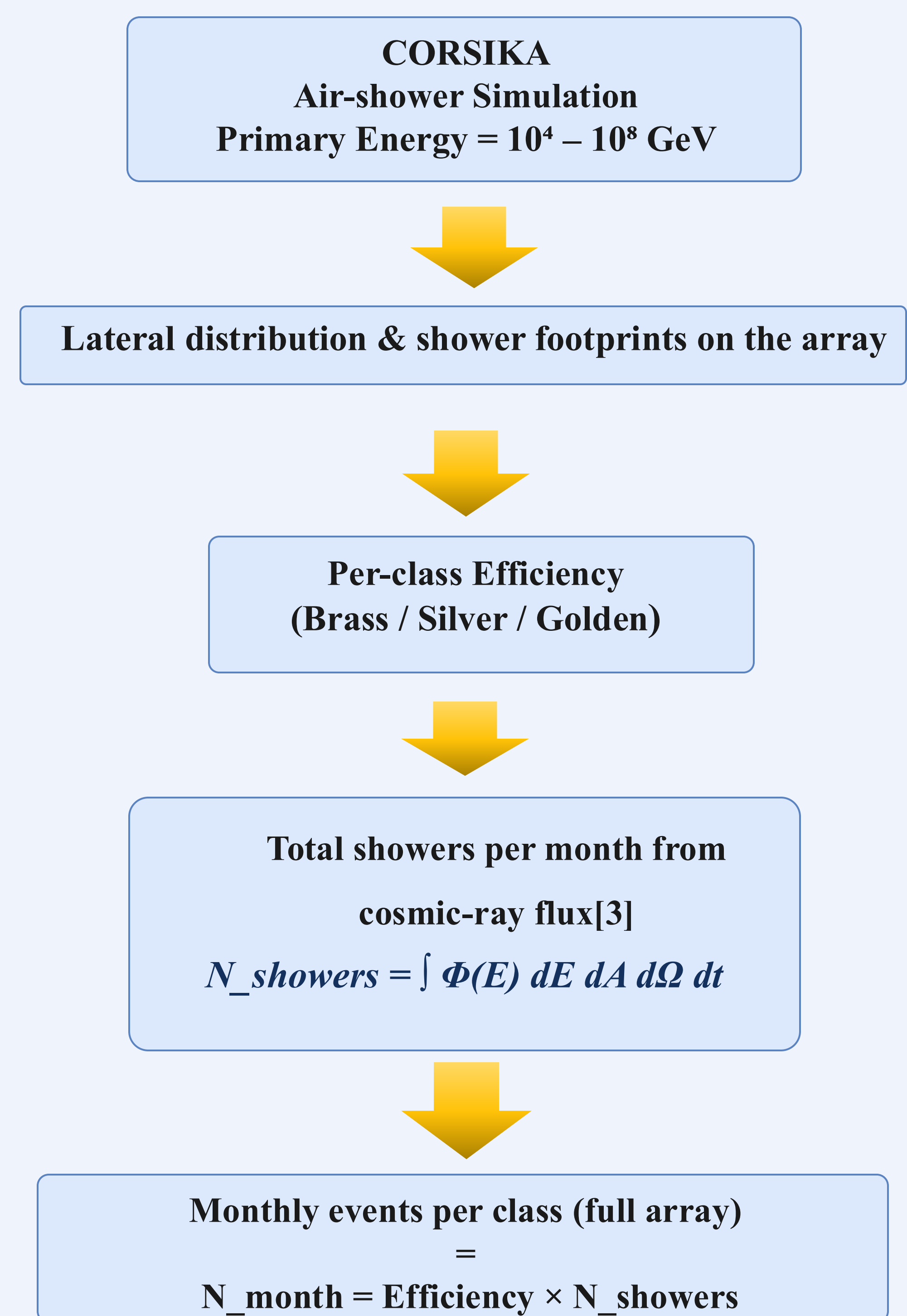
μPPET [1] is a cosmic-ray experiment at Jagiellonian University, Kraków, dedicated to the muon puzzle — a long-standing discrepancy between model predictions and measurements of the ground-level muon count, seen consistently across many experiments over the past fifteen years [2,3]. To probe it, μPPET repurposes J-PET detectors [4,5], originally developed for medical imaging. The apparatus combines two systems. The Big Barrel (BB), housed in a Faraday cage at ground level, reconstructs muon trajectories. The Modular Array (MA), reconfigurable and spread across a rooftop, reconstructs the arrival direction of the primary cosmic ray. By comparing predicted and measured muon fluxes, μPPET aims to shed light on the origin of the puzzle.

The μPPET Apparatus & Event Classes

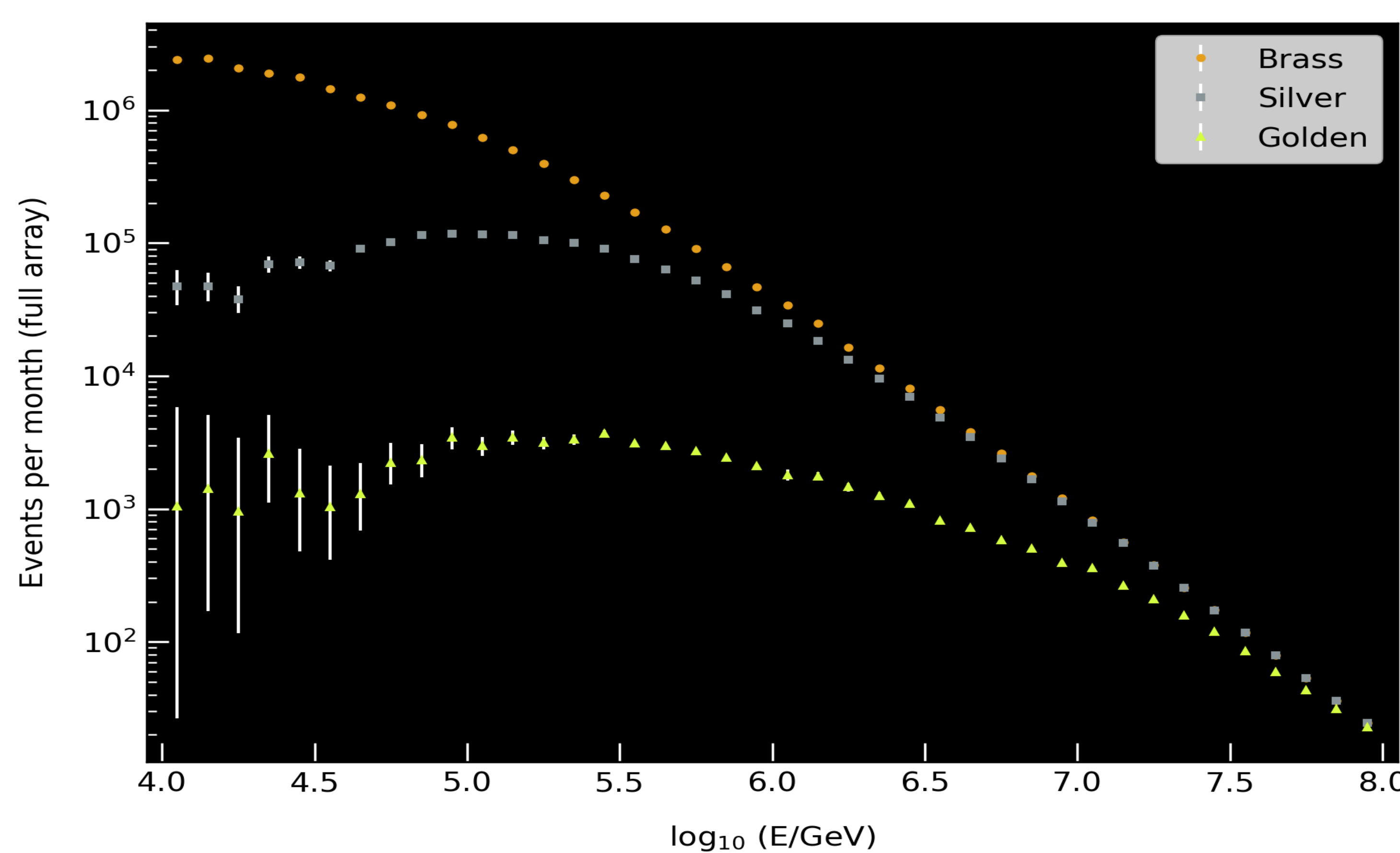
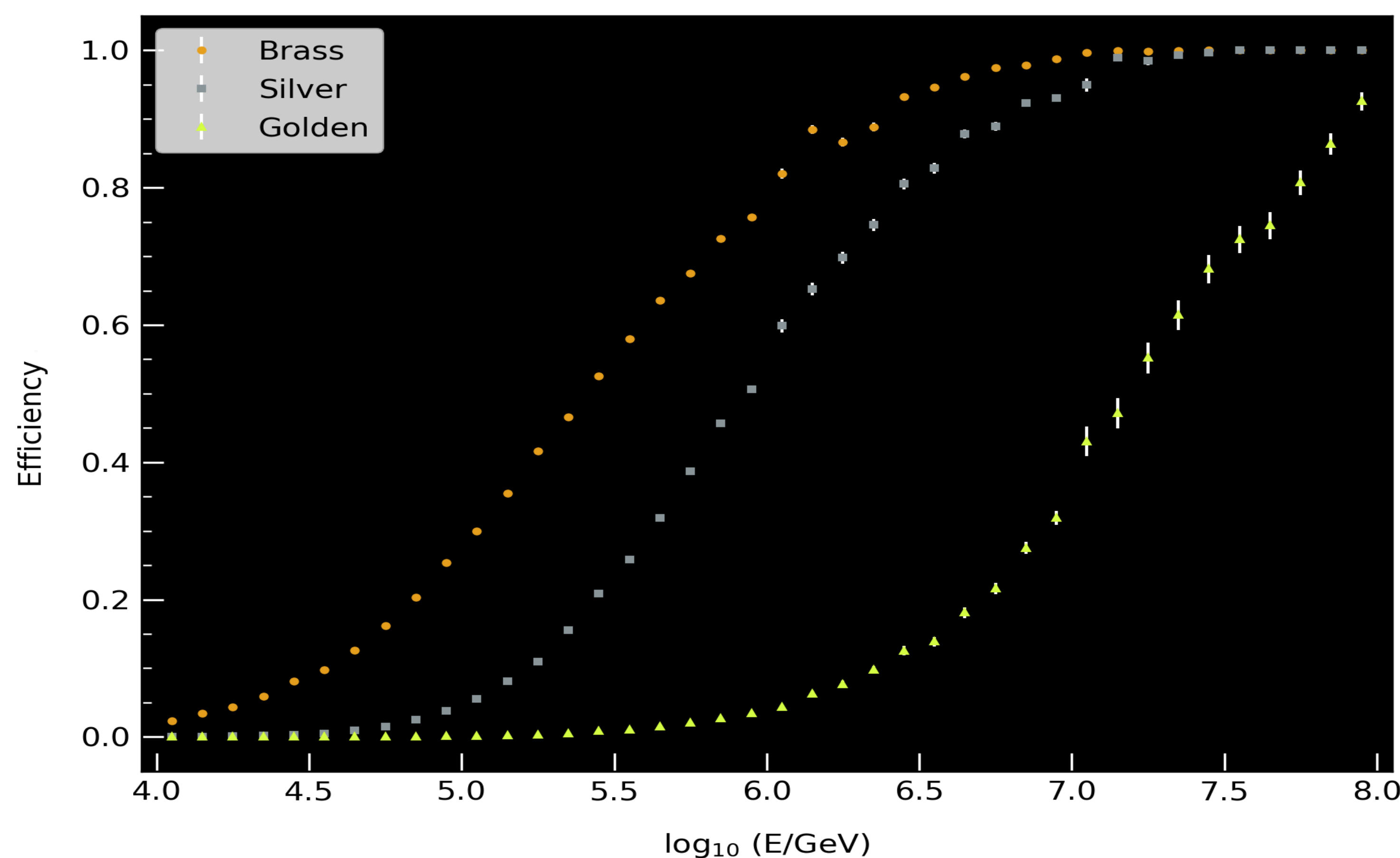


Class	Trigger condition
Brass	at least 1 MA module
Silver	at least 3 MA modules
Golden	at least 2 MA modules + BB

Simulation & Analysis Chain



Efficiency & Monthly Rate vs. Energy



Conclusions & Outlook

- Brass fires on almost every shower — array highly sensitive
- Silver, Golden rarer; more sensitive at higher energies (stricter requirements)
- Golden = muon channel needs Big Barrel (BB → μ⁺/μ⁻), while MA sees shower electrons (MA → e⁺/e⁻)
- Golden is the only class requiring the Big Barrel, tagging the muonic component
- Golden events observed across the full range, smaller at low energies (10⁻⁴ - 10⁻⁵)
- Larger uncertainties in the efficiency at high energies are due to smaller statistics
- Efficiency shown is Trigger-Level only; scintillator detection efficiency not yet folded in
- Next: fold scintillator efficiency; train physics-informed neural network for muon identification

References & Acknowledgments

References

[1] A. Porcelli et al., Universe, 11(6), 180, 2025, DOI: 10.3390/universe11060180

[2] J. Albrecht et al., Astrophys. Space Sci., 2022, 367: 27.

[3] S. Baur et al., Phys. Rev. D., 2023, 107: 094031.

[4] P. Moskal et al., Science Advances, 2025, 1(18):ead3046, DOI: 10.1126/sciadv.adp3046

[5] P. Moskal et al., Science Advances 2024, 10(37):eadp2840, DOI: 10.1126/sciadv.adp2840.

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