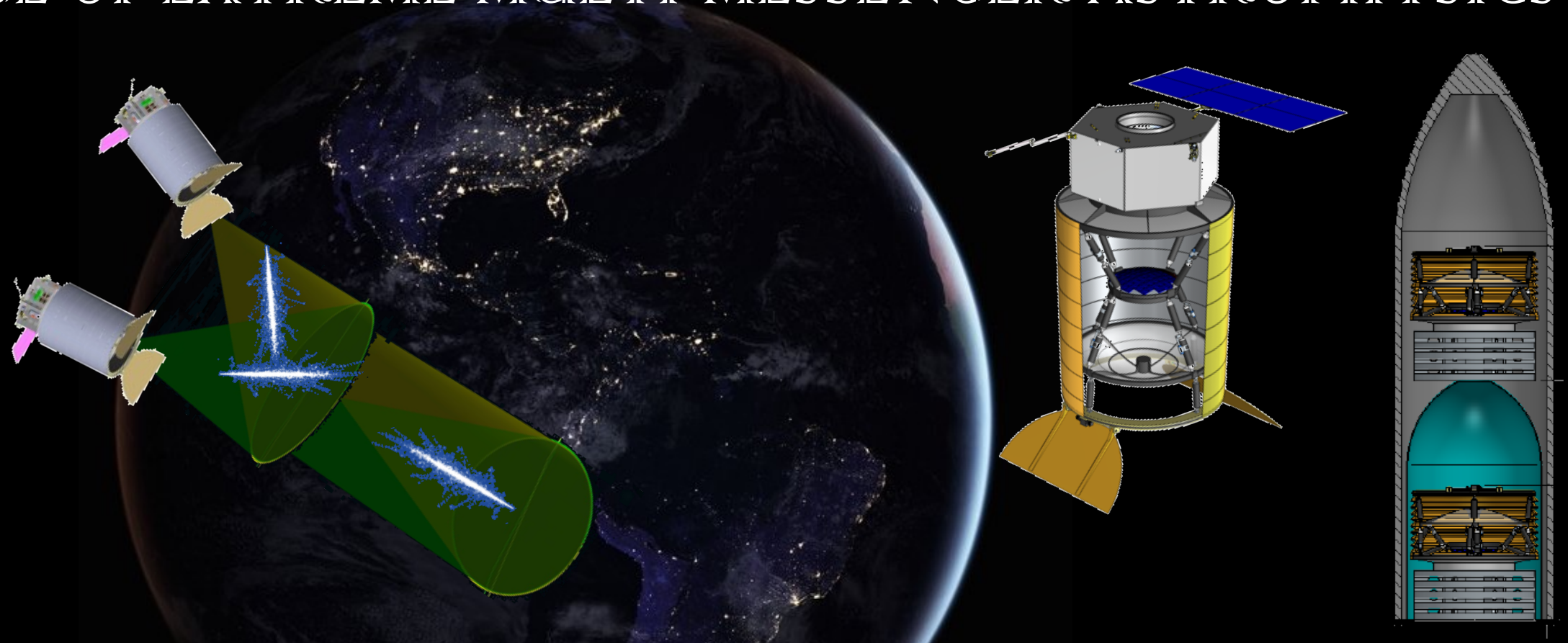




The Roadmap to the POEMMA Mission

PROBE OF EXTREME MULTI-MESSENGER ASTROPHYSICS



THE UNIVERSITY OF CHICAGO



UNIVERSITY of MARYLAND BALTIMORE



Angela V. Olinto,

John F. Krizmanic + the POEMMA Collaboration



POEMMA Collaboration



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DENMARK: NBI: M. Bustamante

FRANCE: APC Univerite de Paris 7: E. Parizot, G. Prevot; IAP, Paris: C. Guepin

GERMANY: KIT: R. Engel, A. Haungs, R. Ulrich, M. Unger;

ITALY: Universita di Torino: M. E. Bertaina, D. Barghini, M. Battisti, F. Bisconti, F. Fenu, H. Miyamoto, Z. Plebaniak; Gran Sasso Science Institute: R. Aloisio, A. L. Cummings, I. De Mitri; INFN Frascati: M. Ricci, INFN Tor Vergata: M. Casolino, L. Marcelli, U. of Rome Tor Vergata: P. Picozza; INFN, Catania: A. Anzalone, INFN, Bari: F. Cafagna, Univ. Catania: R. Caruso, INFN, Napoli: G. Osteria,

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NORWAY: NTNU: F. Oikonomou

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RUSSIA: MSU: P. Klimov, M. Zotov

SLOVAKIA: IEP, Slovak Academy of Science: S. Mackovjak

SWITZERLAND: University of Geneva: A. Neronov

**76 scientists from 38 institutions and 13 countries
OWL, JEM-EUSO, Auger, TA, Veritas, CTA, Fermi, Theory**



Astroparticle Physics Questions:

What are the sources of the **Ultra-High Energy Cosmic Rays (UHECRs)**?

Measure Spectrum, Composition, Anisotropies $E > 10^{19}$ eV = 10 EeV

What are the sources of **Astrophysical Neutrinos**?

Multi-Messenger coincidence gamma-ray, gravitational waves, and neutrinos with $E > 10^{16}$ eV = 10 PeV

What is the **physics and astrophysics** at energies \gg “ground-based” accelerators?

Are there **New Interactions or Dark Matter** signatures (e.g., Secret Neutrino Interactions, Supermassive Dark Matter, Macroscopic Dark Matter)?

[arXiv:2012.07945](https://arxiv.org/abs/2012.07945) [arXiv:1907.03694](https://arxiv.org/abs/1907.03694) [arXiv:1906.07209](https://arxiv.org/abs/1906.07209) [arXiv:2104.05131](https://arxiv.org/abs/2104.05131)

ICRC21 Proceeding: <https://pos.sissa.it/395/406/>; [/419/](https://pos.sissa.it/395/419/); [/437/](https://pos.sissa.it/395/437/); [/519/](https://pos.sissa.it/395/519/); [/551/](https://pos.sissa.it/395/551/); [/977/](https://pos.sissa.it/395/977/); [/1201](https://pos.sissa.it/395/1201/)

By T. Venters, C. Guépin, A. Cummings, M.H. Reno, T. Paul, M. Bertina, plus JEM-EUSO, NuSpaceSim,...



POEMMA



Tau Neutrinos \rightarrow Tau-lepton decay
Upgoing EAS Cherenkov (>10 PeV)

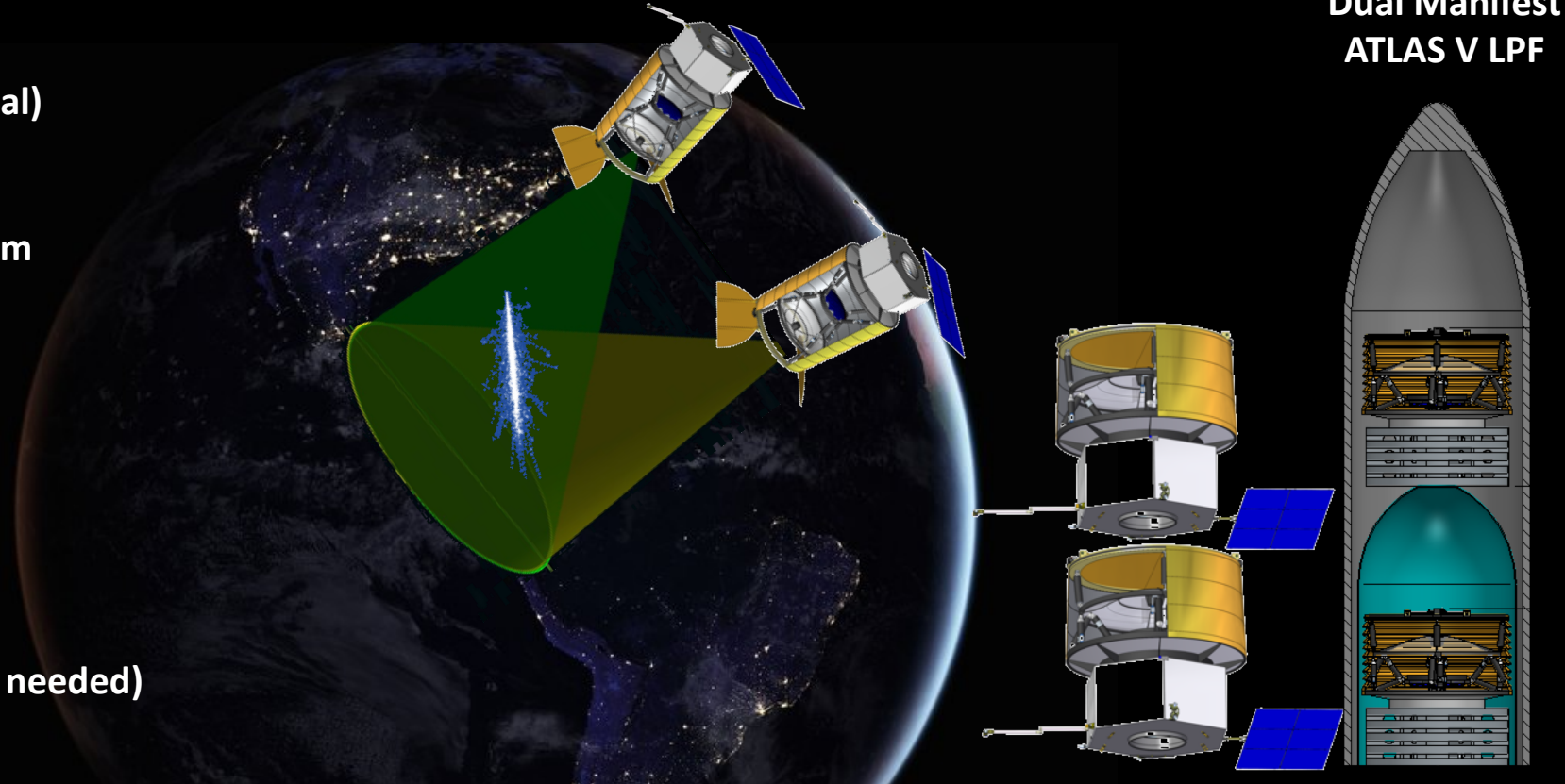
UHECRs + UHENS
Fluorescence
(>10 EeV)

Probe Of Extreme Multi-Messenger Astrophysics
Ultra-High Energy Cosmic Rays and Cosmic Neutrinos



POEMMA Mission

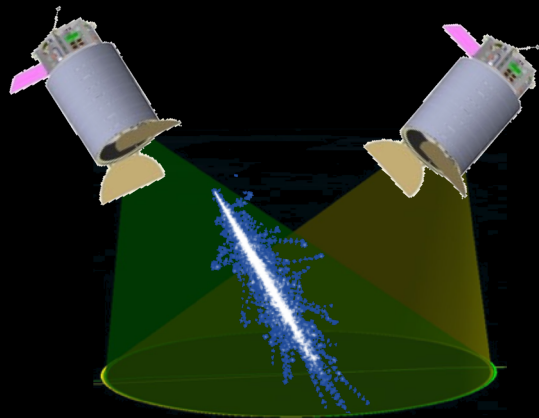
Mission Lifetime: 3 years (5 year goal)
Orbits: 525 km, 28.5° Inc
Orbit Period: 95 min
Satellite Separation: ~25 km – 1000+ km
Satellite Position: 1 m (knowledge)
Pointing Resolution: 0.1°
Pointing Knowledge: 0.01°
Slew Rate: 8 min for 90°
Satellite Wet Mass: 3860 kg
Power: 2030 W
Data: 1 GB/day
Data Storage: 7 days
Communication: S-band (X-band if needed)
Clock synch (timing): 10 nsec



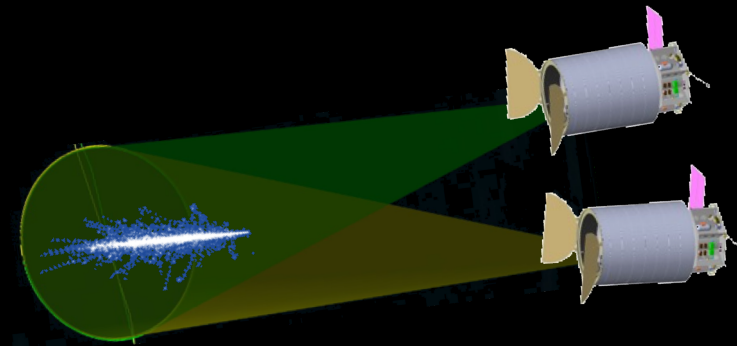
Operations:

- Each satellite collects data autonomously
- Coincidences analyzed on the ground
- View the Earth at near-moonless nights, charge in day and telemeter data to ground
- ToO Mode: dedicated com uplink to re-orient satellites

Observation Modes	Telescope Separation	Pointing	Science Goals (section)
POEMMA-Stereo (mode-2)	~300 km	down close to Nadir; overlapping atmospheric volumes	UHECR fluorescence (2.2, 2.3) precision stereo reconstruction UHECR lower energies 10s EeVs
POEMMA-Limb (mode-3)	~25 km	towards the Limb; azimuth follows ToO target overlapping volume at Limb	Neutrino Cherenkov (2.4, 2.5, 2.6) ToO-stereo
	~300 km	towards the Limb; overlapping volume nearby non-overlapping at Limb	UHECR fluorescence (2.2, 2.3) stereo reconstruction 10s EeV monocular for 100s EeVs
	~300 km	fast slew towards the Limb from POEMMA-Stereo mode azimuth follows ToO target	Neutrino Cherenkov (2.4, 2.5, 2.6) ToO-dual



Observing Modes

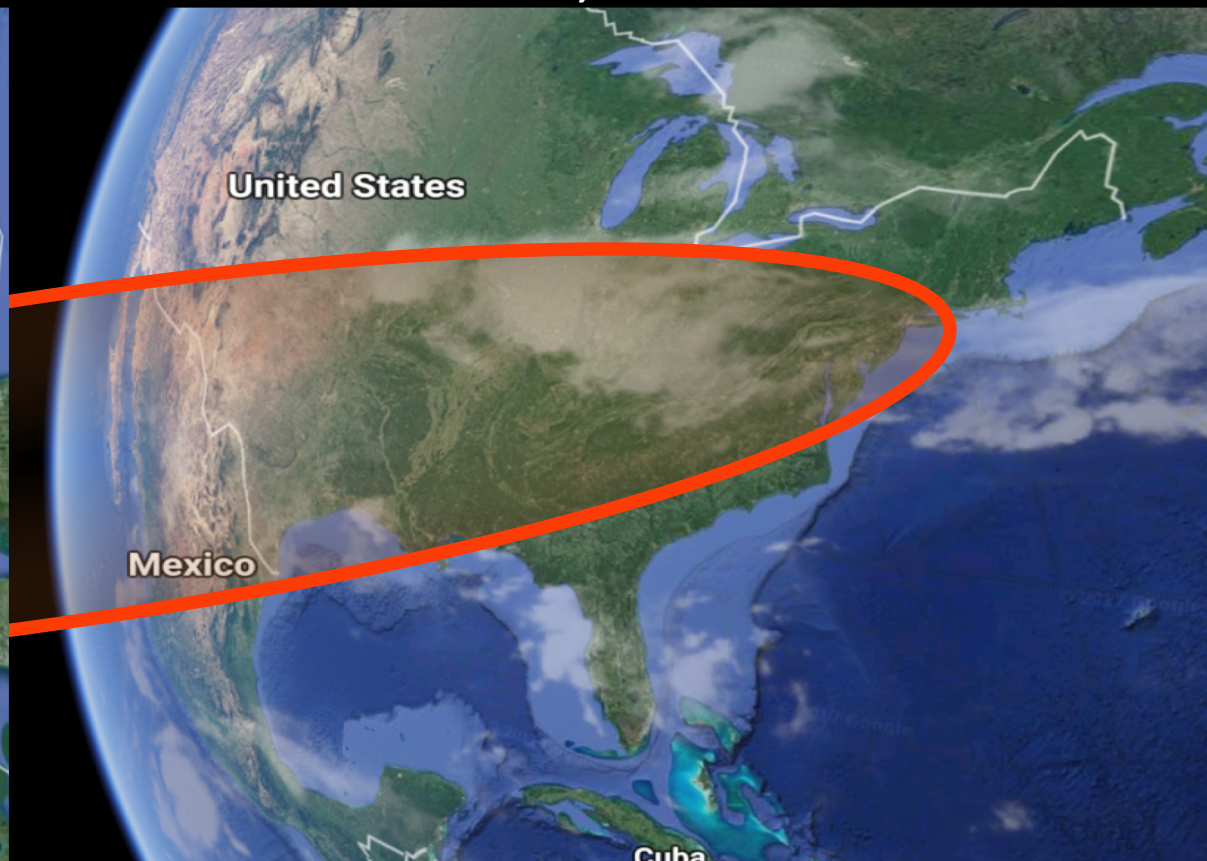
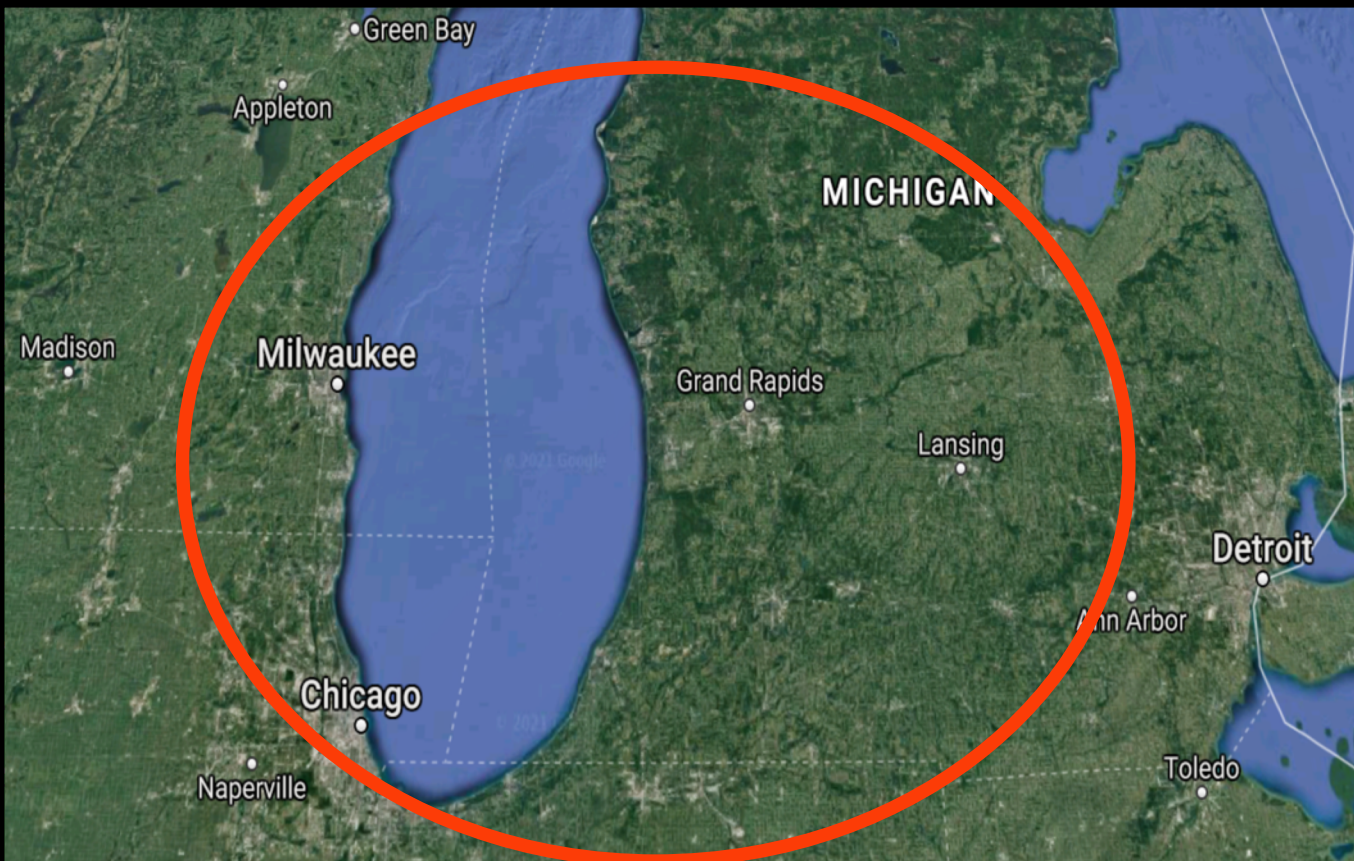


Nadir for UHECR:

Radius 200-400 km; Area $\sim 3 \cdot 10^5 \text{ km}^2$

Limb for Neutrinos & UHECRs:

Radius $3 \cdot 10^3 \text{ km}$; Area $\sim 10^7 \text{ km}^2$



POEMMA

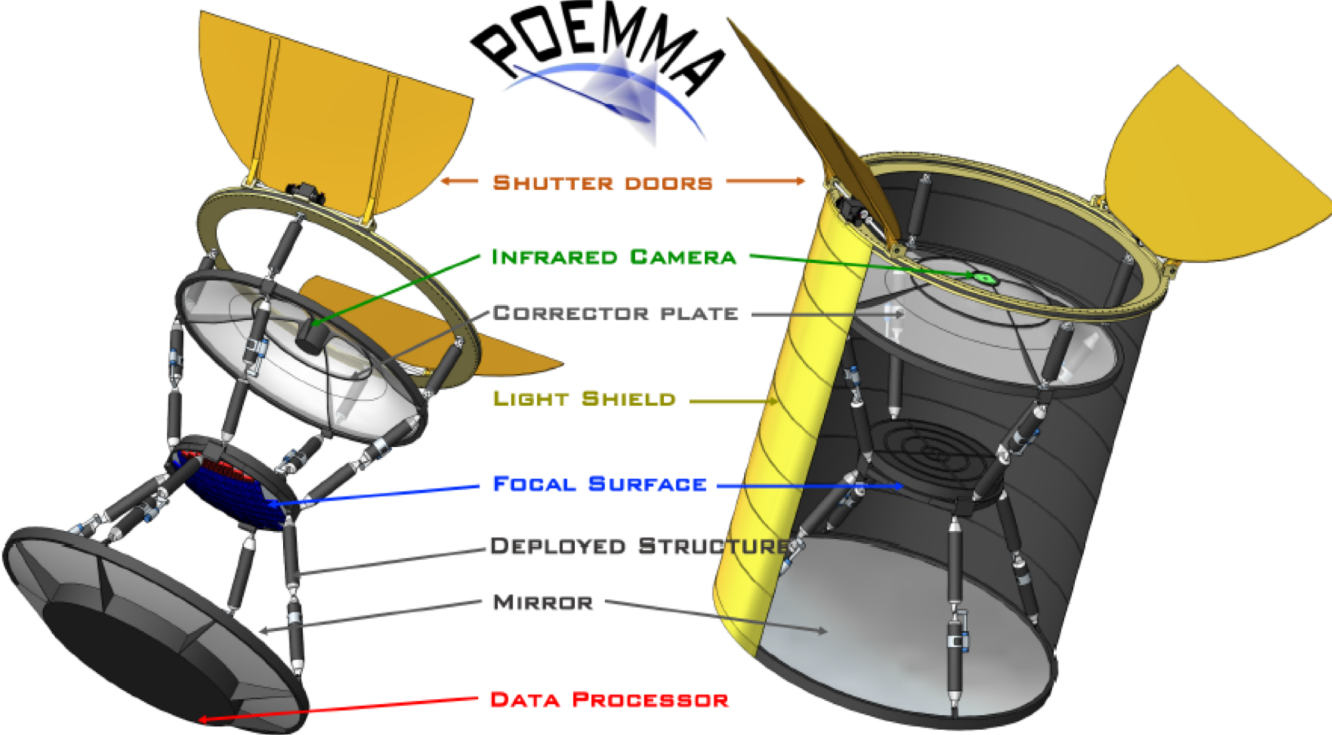


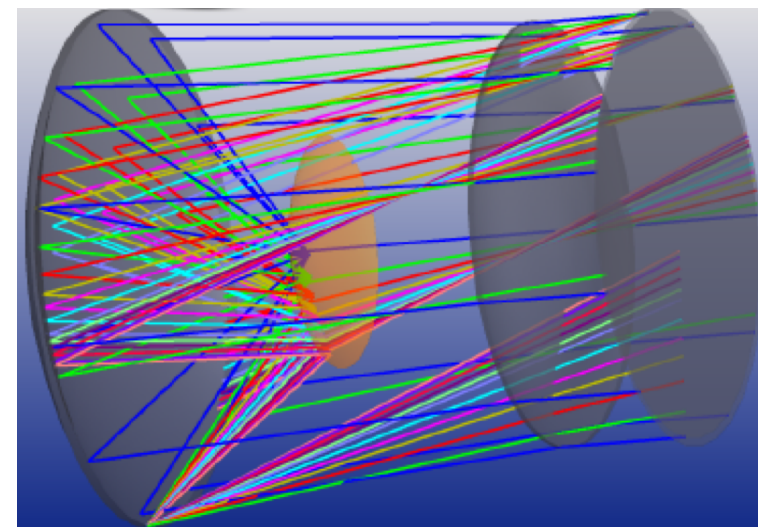
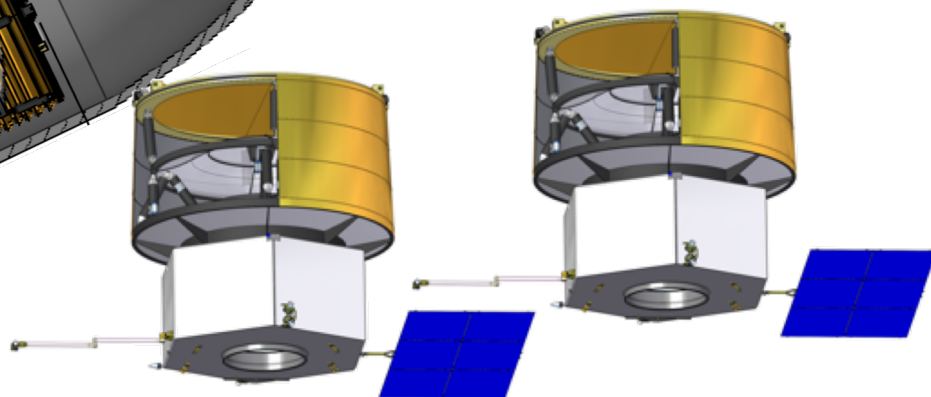
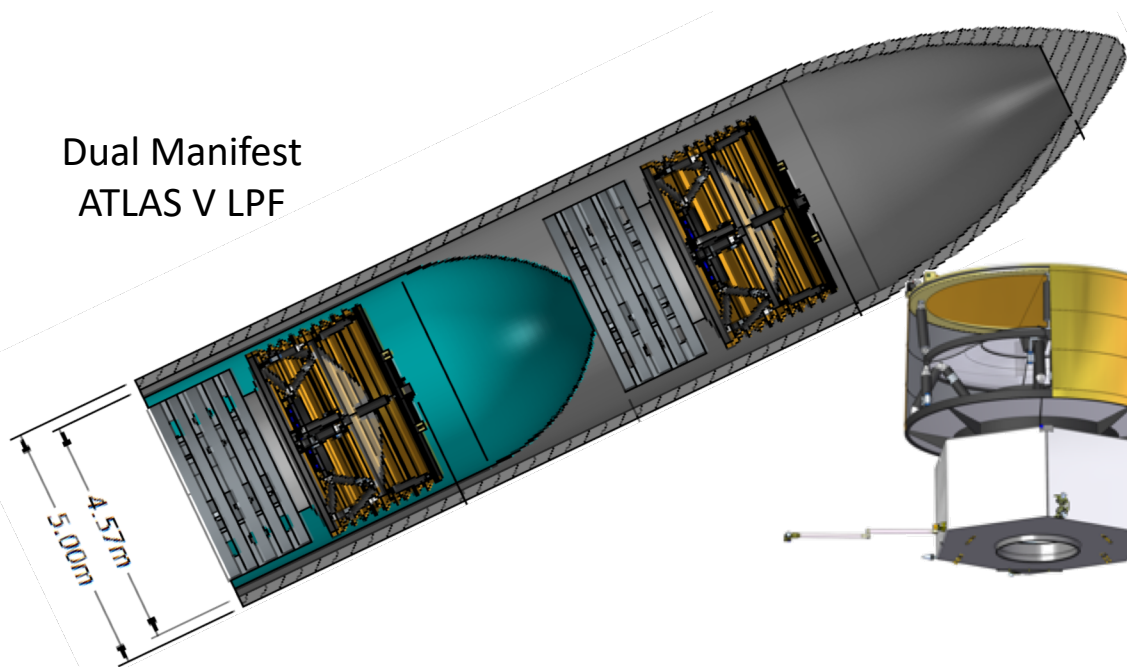
TABLE I: POEMMA Specifications:

Photometer Components		Spacecraft		
Optics	Schmidt	45° full FoV	Slew rate	90° in 8 min
	Primary Mirror	4 m diam.	Pointing Res.	0.1°
	Corrector Lens	3.3 m diam.	Pointing Know.	0.01°
	Focal Surface	1.6 m diam.	Clock synch.	10 nsec
	Pixel Size	3 × 3 mm ²	Data Storage	7 days
	Pixel FoV	0.084°	Communication	S-band
PFC	MAPMT (1μs)	126,720 pixels	Wet Mass	3,450 kg
PCC	SiPM (20 ns)	15,360 pixels	Total Power	880 W
Photometer (One)		Mission (2 Observatories)		
Mass	1,550 kg	Lifetime	3 year (5 year goal)	
Power	590 W	Orbit	525 km, 28.5° Inc	
Data	< 1 GB/day	Orbit Period	95 min	
		Observatory Sep. ~25 - 1000+ km		

Each Observatory = Photometer + Spacecraft; POEMMA Mission = 2 Observatories

optical collecting area ~ 6.4 m²

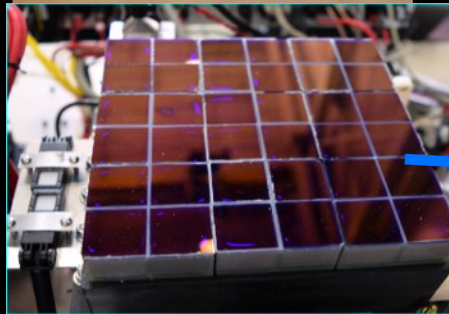
Dual Manifest
ATLAS V LRF



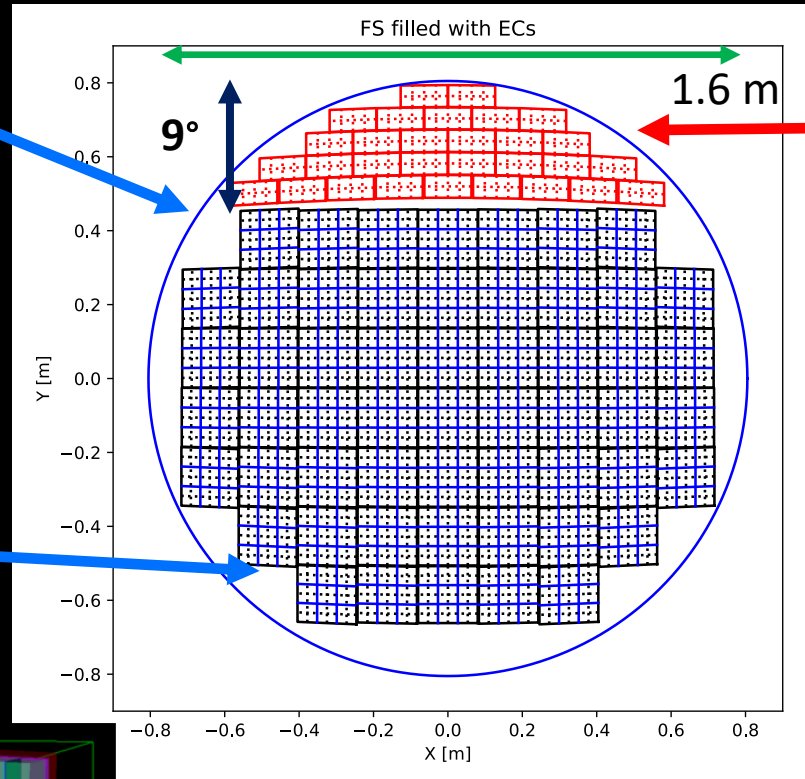
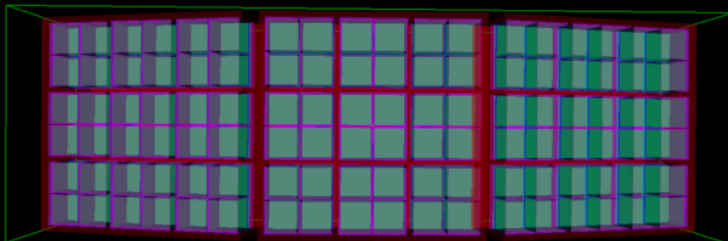
Hybrid Focal Surface

UV Fluorescence
MAPMTs with BG3 filter:
1 usec sampling

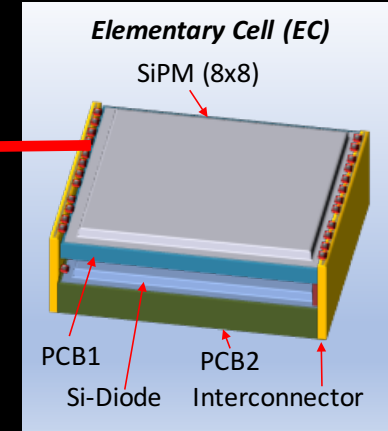
Cherenkov Detection
SiPMs:
20 nsec sampling



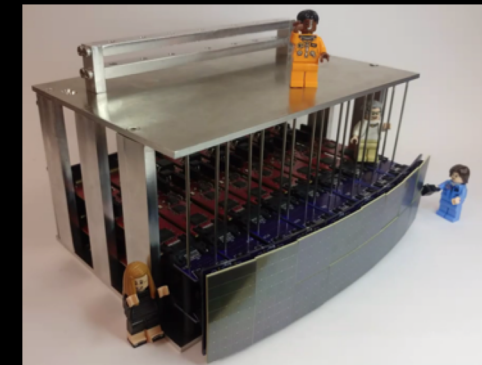
EUSO-SPB2
3 PDMs



55 Photo Detector Modules (PDMs)
TOTAL 126,720 pixels
(1 PDM = 36 MAPMTs = 2,304 pixels)



30 SiPM focal surface units
Total 15,360 pixels
512 pixels per FSU (64x4x2)



EUSO-SPB2
Cherenkov
Camera

Fluorescence Capabilities

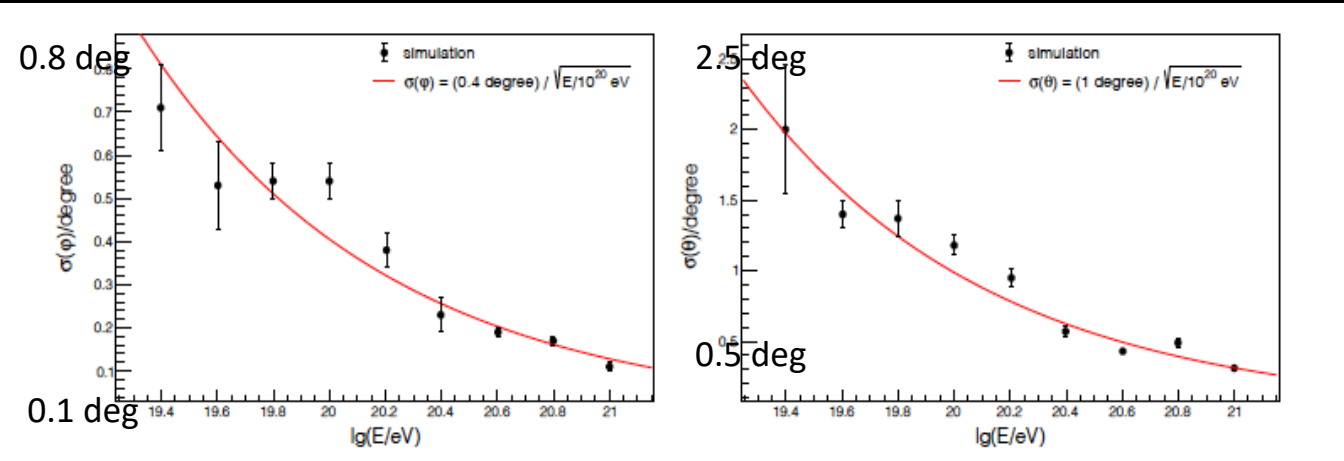


FIG. 5: POEMMA's simulated stereo-reconstructed angular resolution versus UHECR energy. Left: Azimuth angle, right: zenith angle.

Angular Resolution: **~0.4 deg azimuth, ~1 deg zenith at 100 EeV**

Energy Resolution: **~17% at 100 EeV**

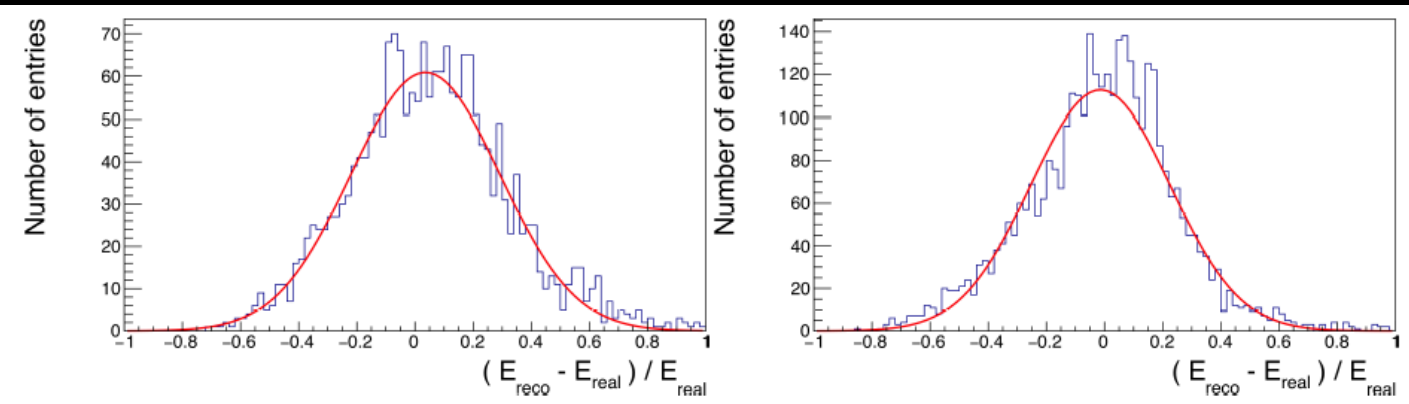


FIG. 36: ESAF simulated energy resolution assuming 1° zenith and azimuth angular resolution. Left: 50 EeV results, right: 100 EeV results.

X_{max} Resolution:
<30% at 100 EeV

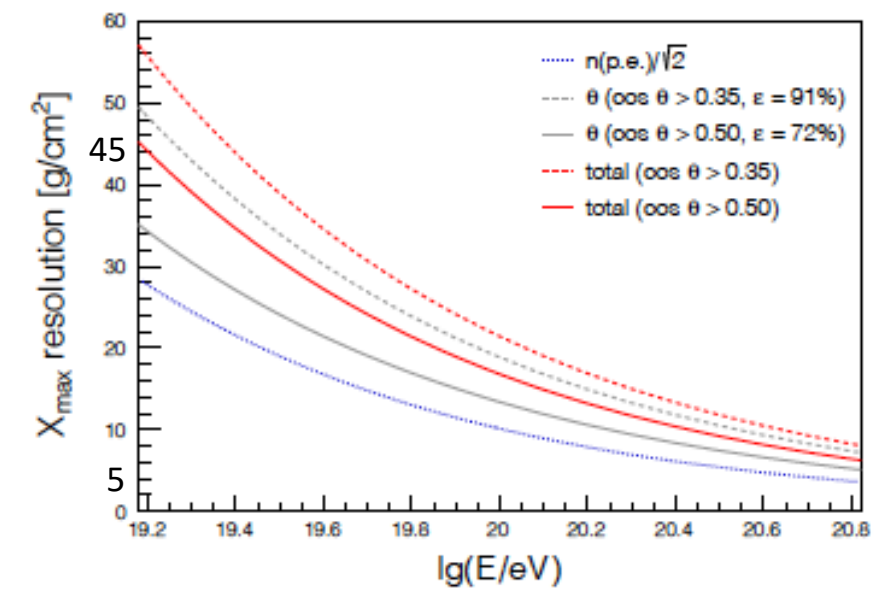
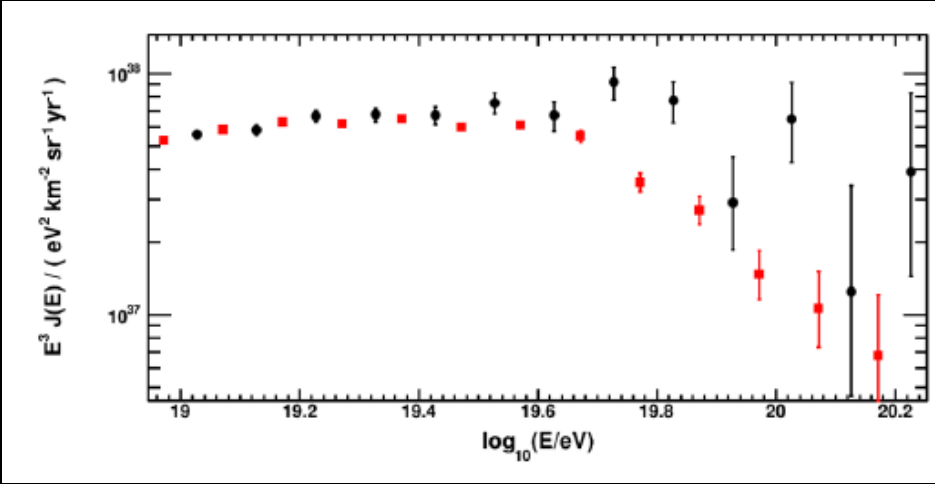


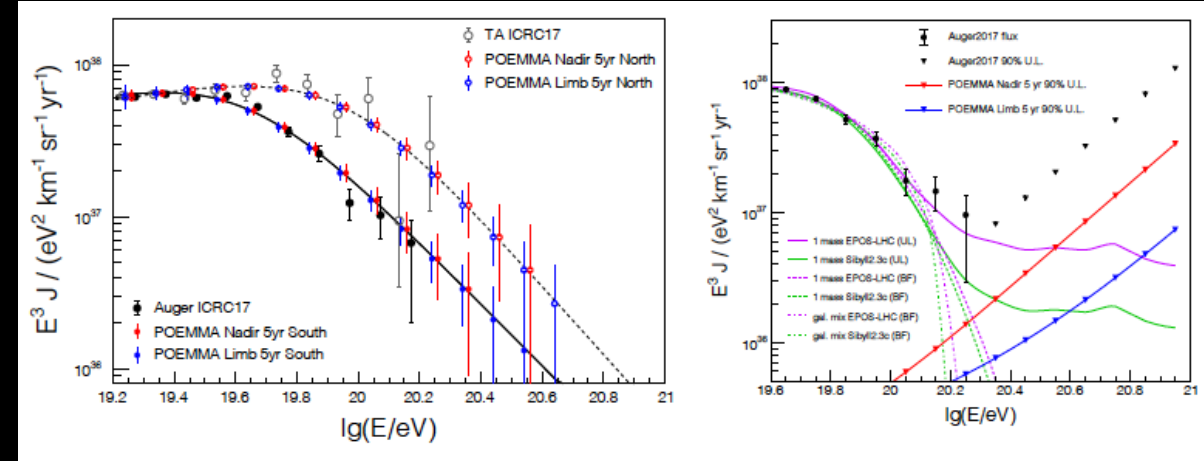
FIG. 17: Preliminary estimate of the X_{\max} resolution of POEMMA in stereo mode. The contributions from the photoelectron statistics and angular resolution are shown in blue and gray respectively. The total resolution, obtained by adding both contributions in quadrature is shown in red for two cuts on the maximum zenith angle.

POEMMA UHECR Science

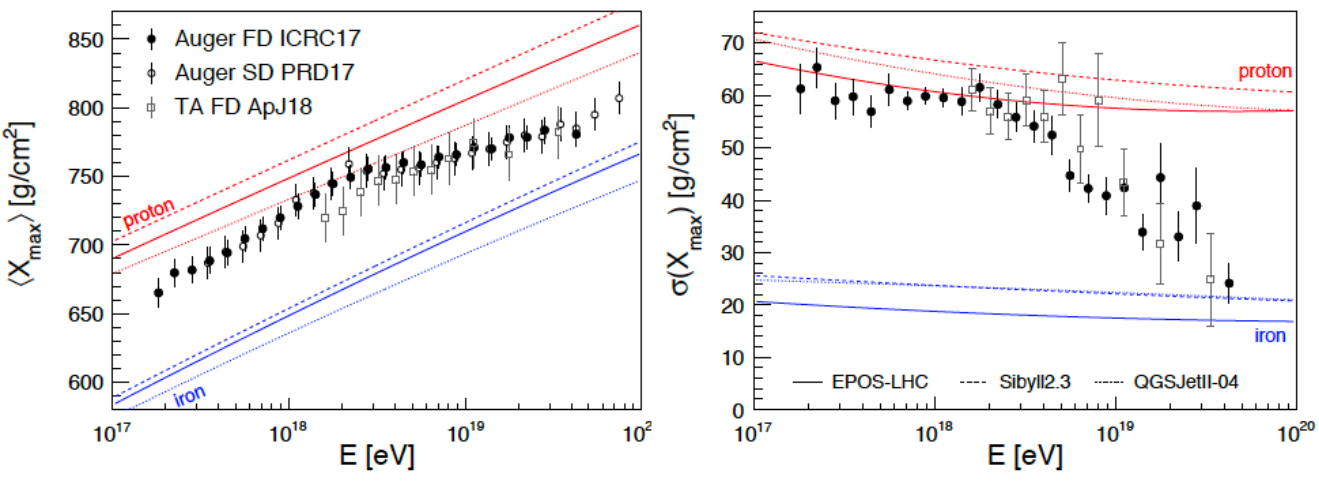
Current UHECR Spectrum



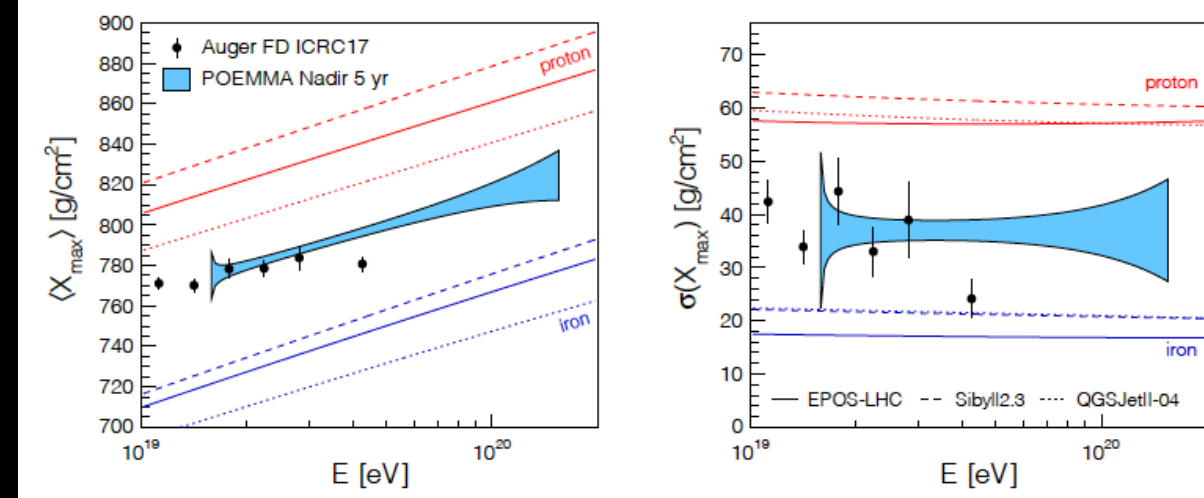
POEMMA UHECR Spectrum



Current UHECR Composition

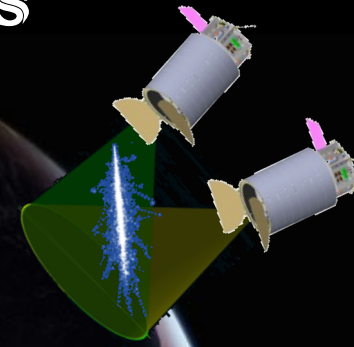


POEMMA UHECR Composition

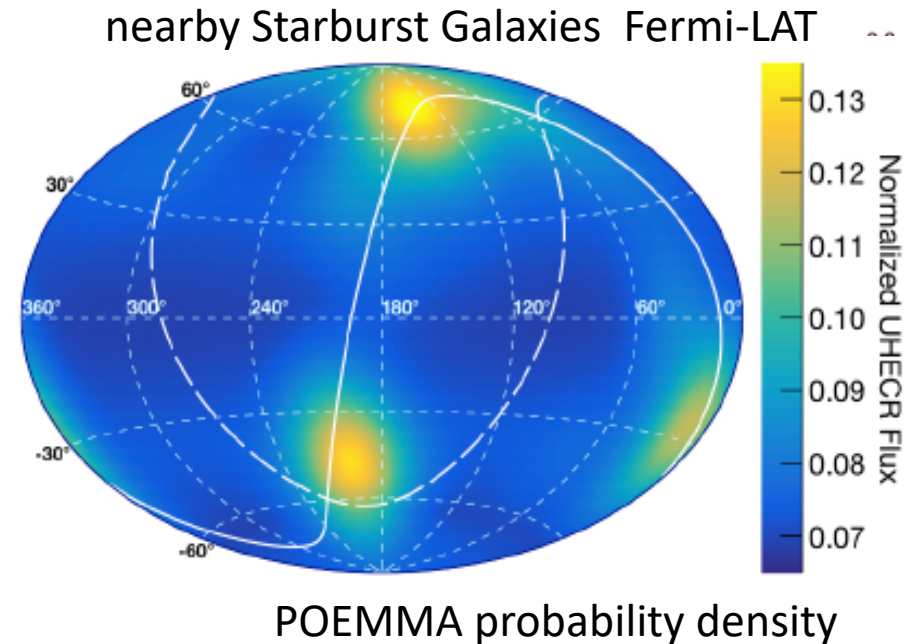
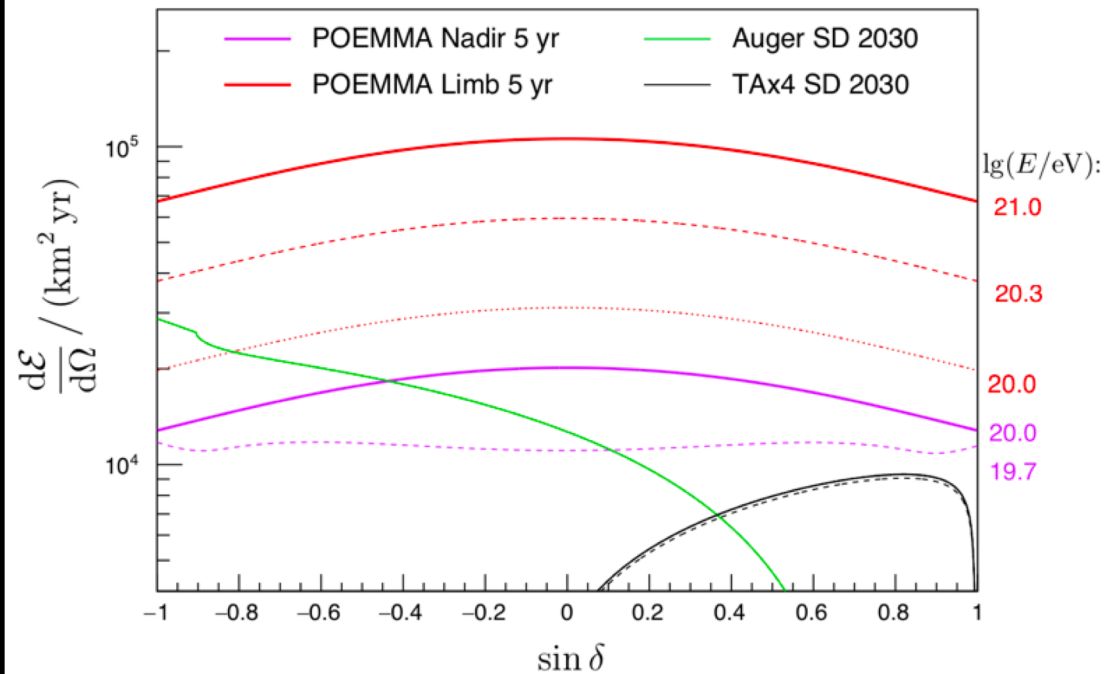




POEMMA: UHECRs



Significant increase in exposure $E > 50 \text{ EeV}$
good energy, angular, and shower maximum resolutions,
accurately measure Composition, Spectrum, Anisotropies
Uniform sky coverage to discover of UHECR sources





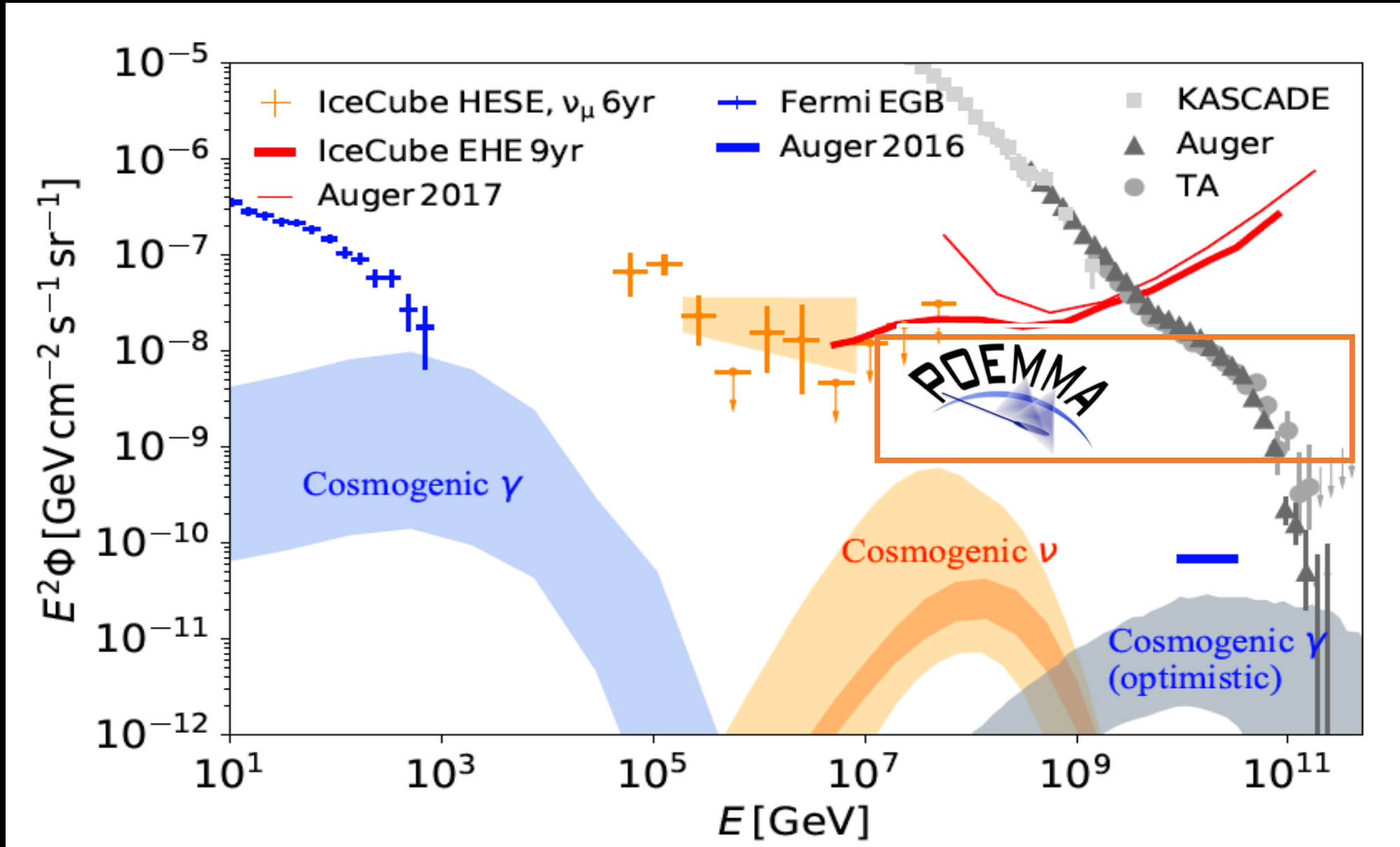
POEMMA: Neutrinos



POEMMA designed to observe neutrinos with $E > 20$ PeV through Cherenkov signal of tau decays.

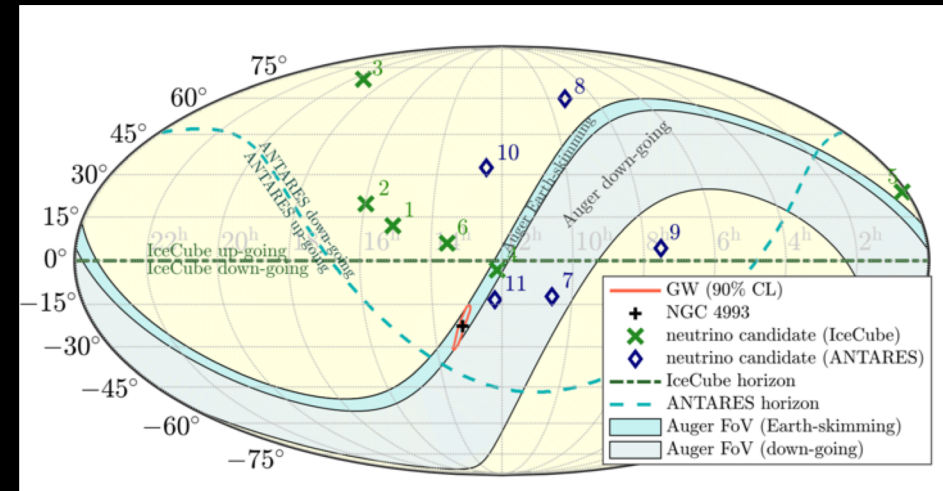
High-Energy Astrophysical Events generates neutrinos (ν_e, ν_μ) and 3 neutrino flavors reach Earth (Oscillations). Tau neutrinos generate tau leptons on their way out of the Earth's surface which decay producing up-going showers, detected by POEMMA

Astrophysical neutrinos > 20 PeV

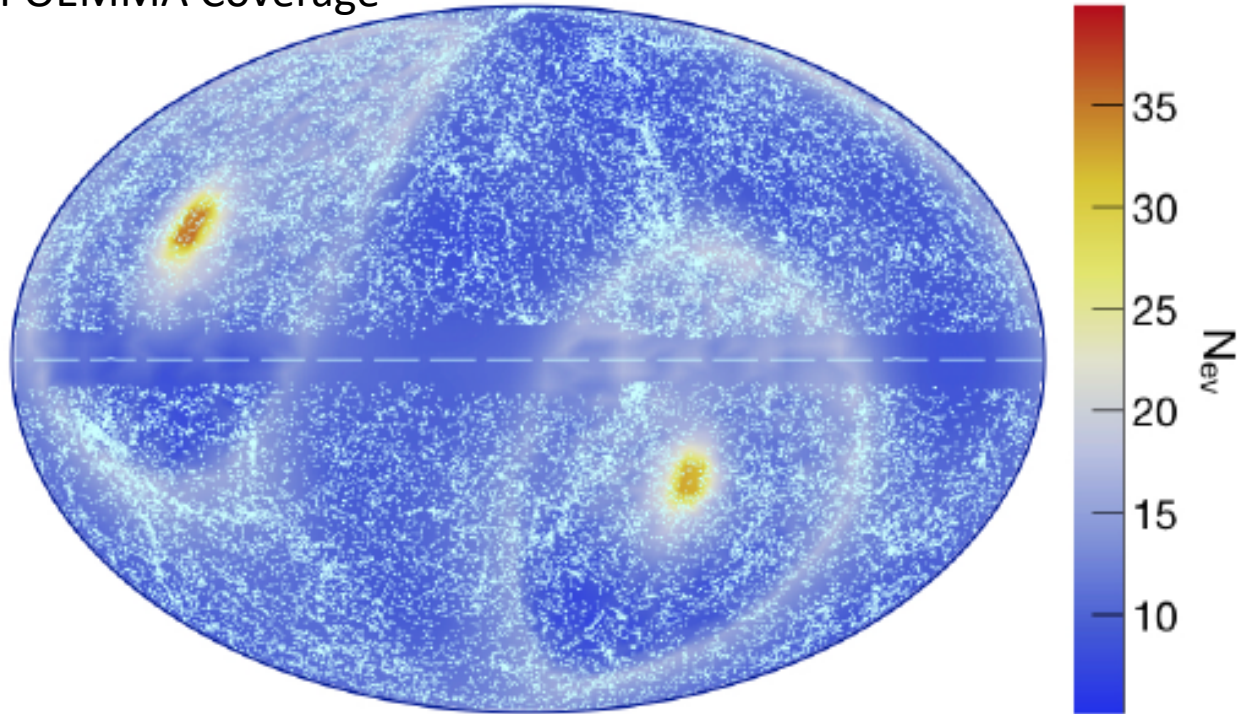




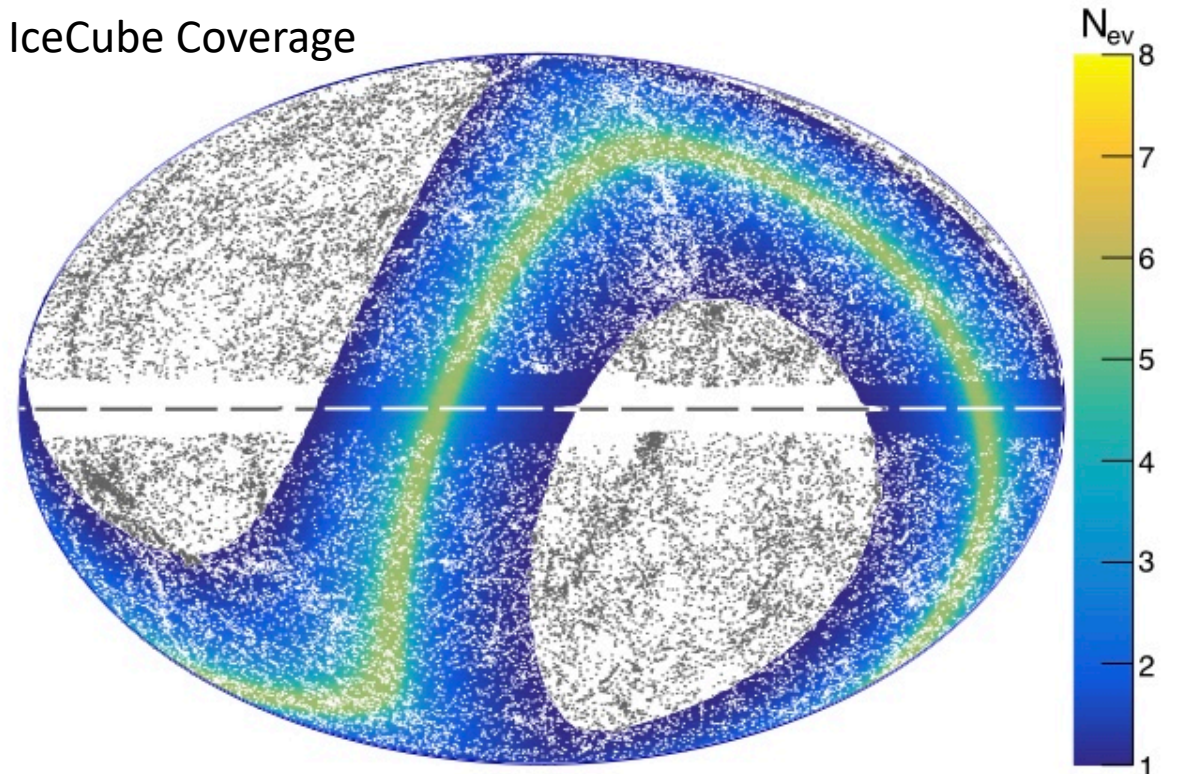
Full Sky Coverage VHE-UHE Neutrinos



POEMMA Coverage



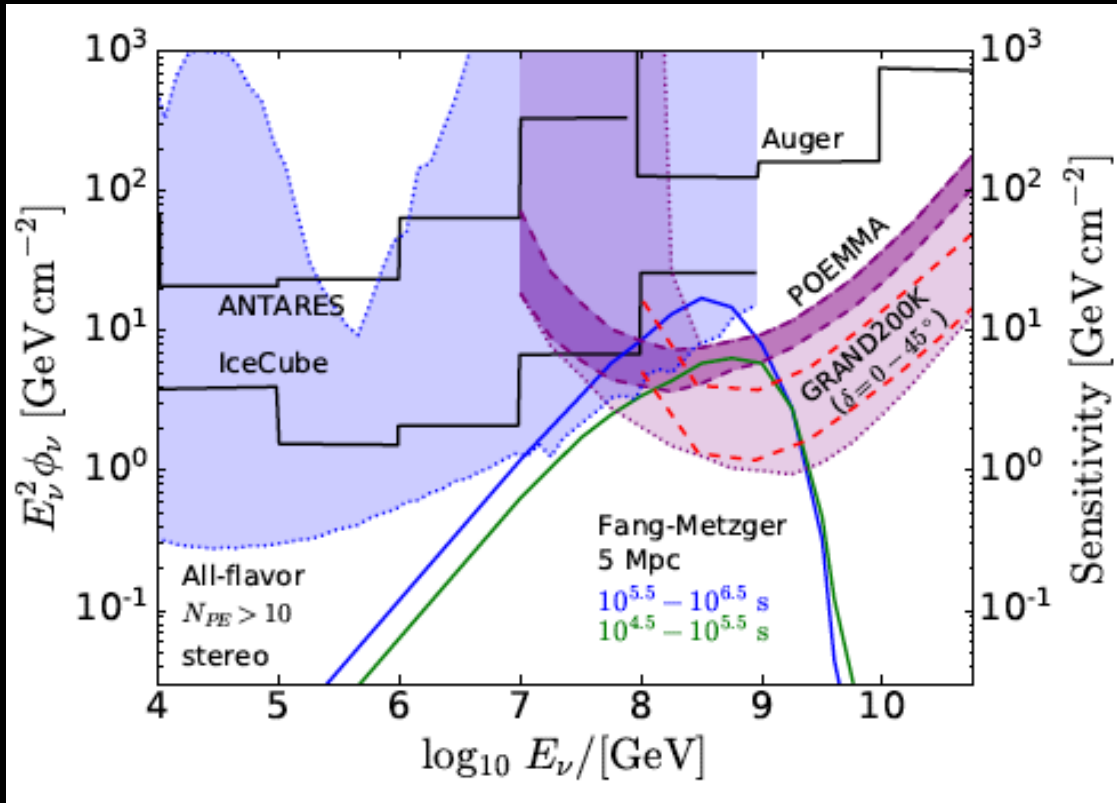
IceCube Coverage





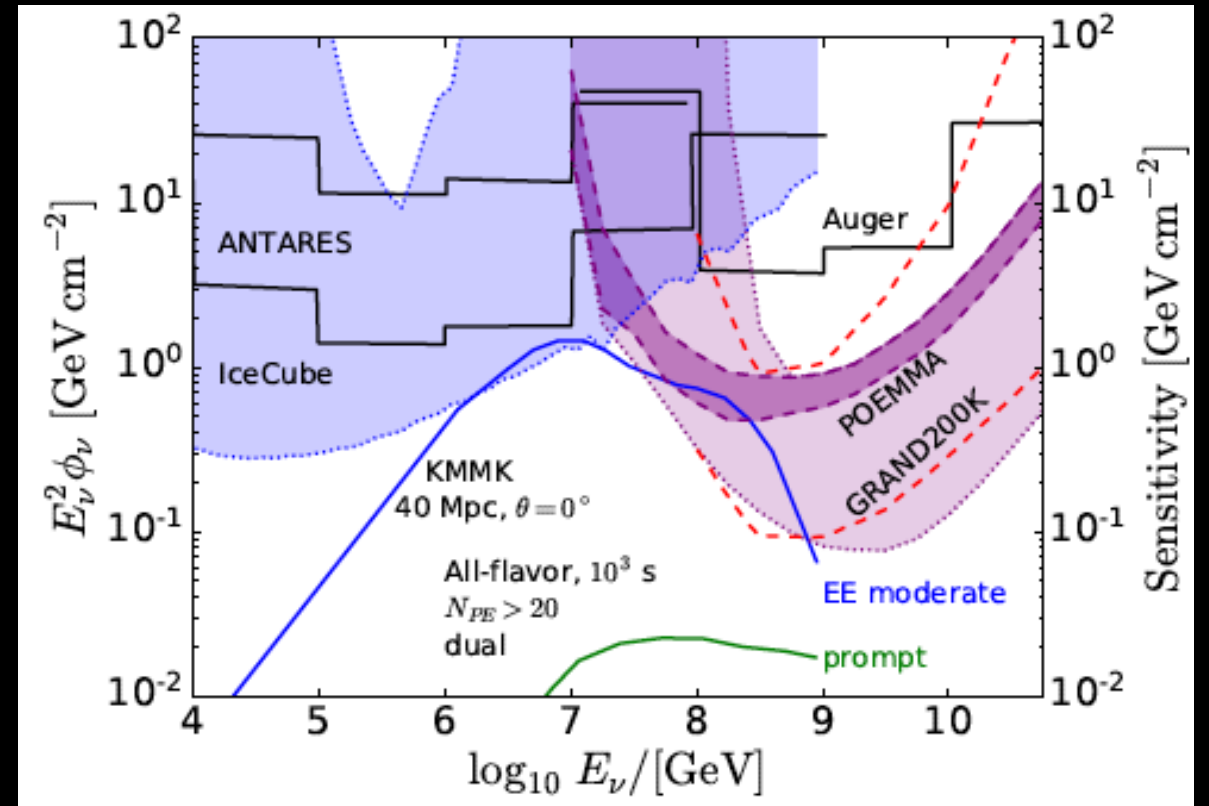
Transient Neutrino Point Source Sensitivity

Long Bursts



Fang & Metzger, arXiv:1707.04263

Short Bursts (<100 s)



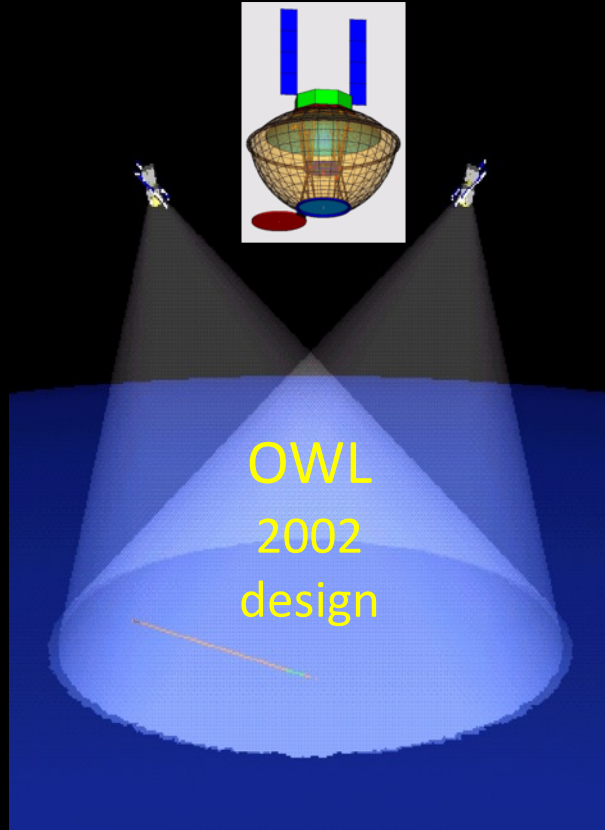
Kimura et al, arXiv:1708.07075

Venters et al. arXiv:1906.07209 and AVO et al. arXiv:2012.0794

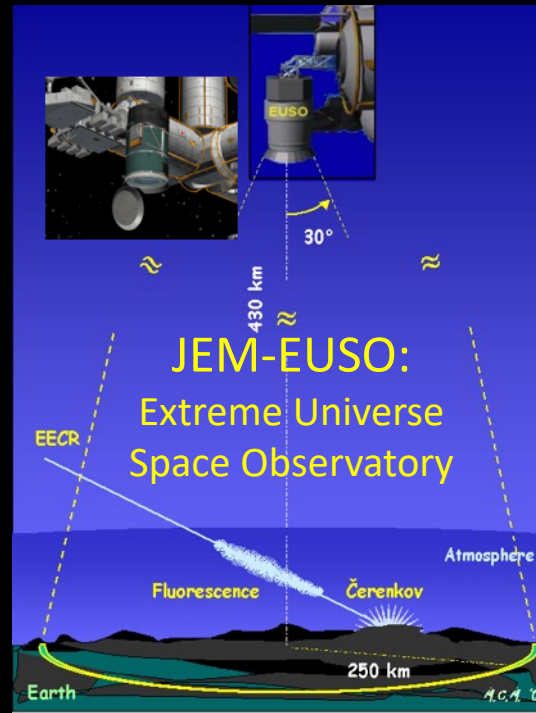
T. Venters ICRC: <https://pos.sissa.it/395/977>; M.H. Reno, <https://pos.sissa.it/395/1201> 15

POEMMA Predecessors

Based on OWL 2002 study, JEM-EUSO, EUSO balloon & SPB experience, and CHANT proposal



TUS, KLYPVE-EUSO



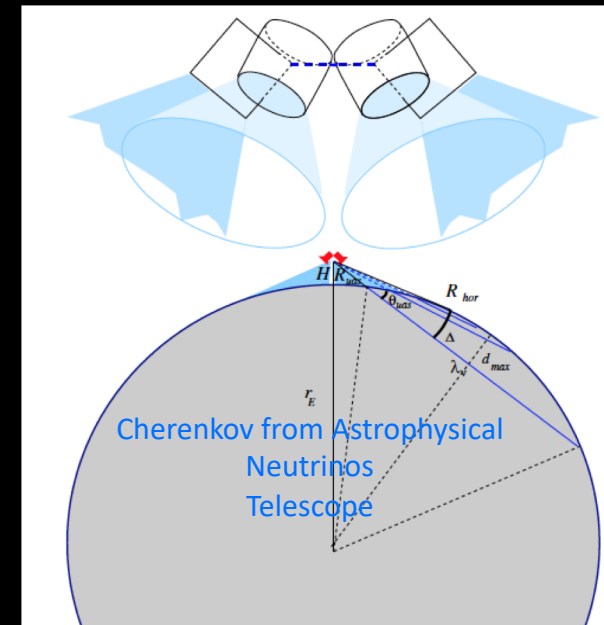
EUSO-Balloon
EUSO@TA
Mini-EUSO

EUSO-SPB1



EUSO-SPB2

CHANT





JEM-EUSO program Joint Experiment Missions Extreme Universe Space Observatory

M. Bertina <https://pos.sissa.it/395/406>

EUSO-TA (2013-)

EUSO-Balloon (2014)

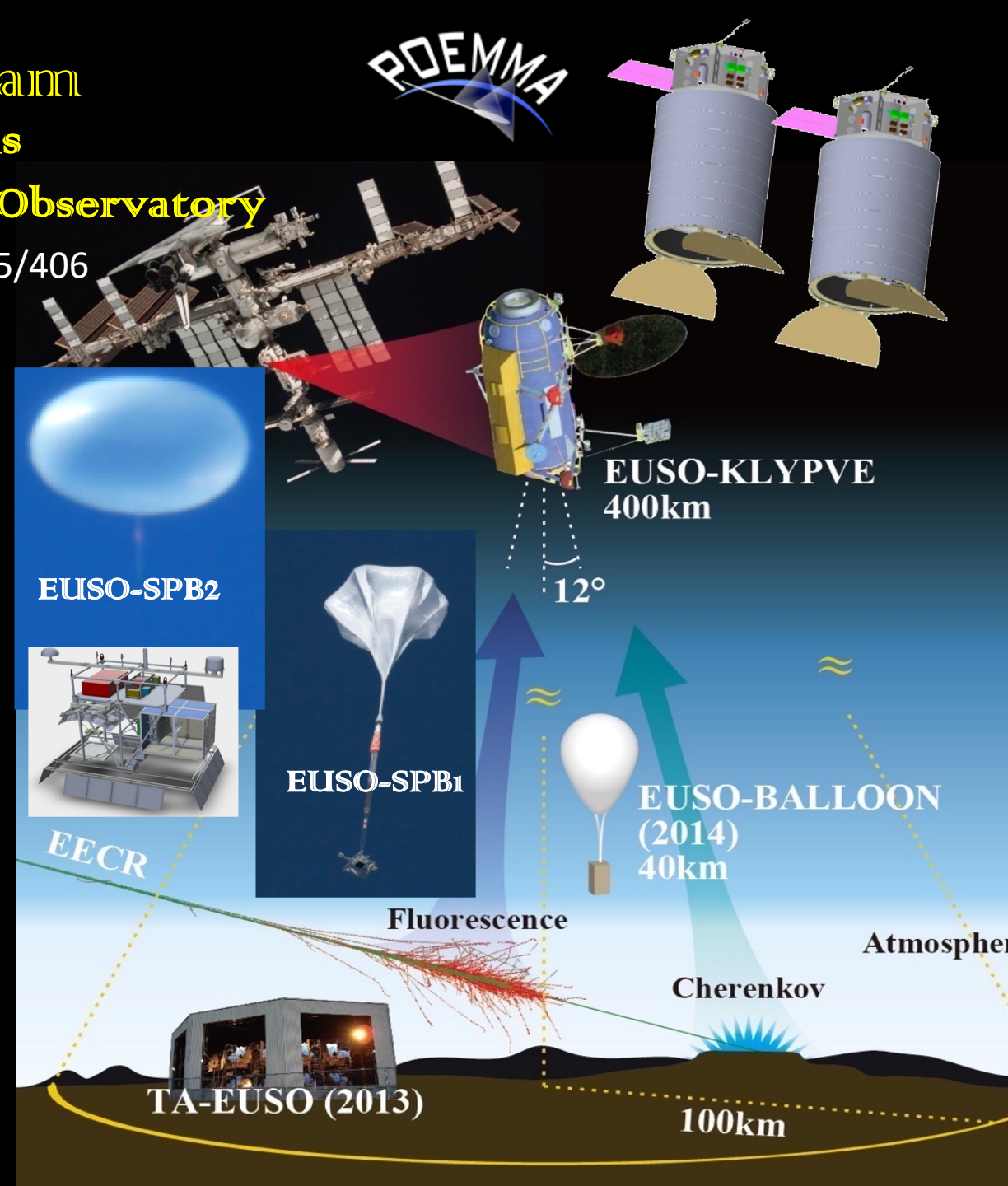
EUSO-SPB1 (2017)

Mini-EUSO (2019)

EUSO-SPB2 (2023)

K-EUSO (2024+)

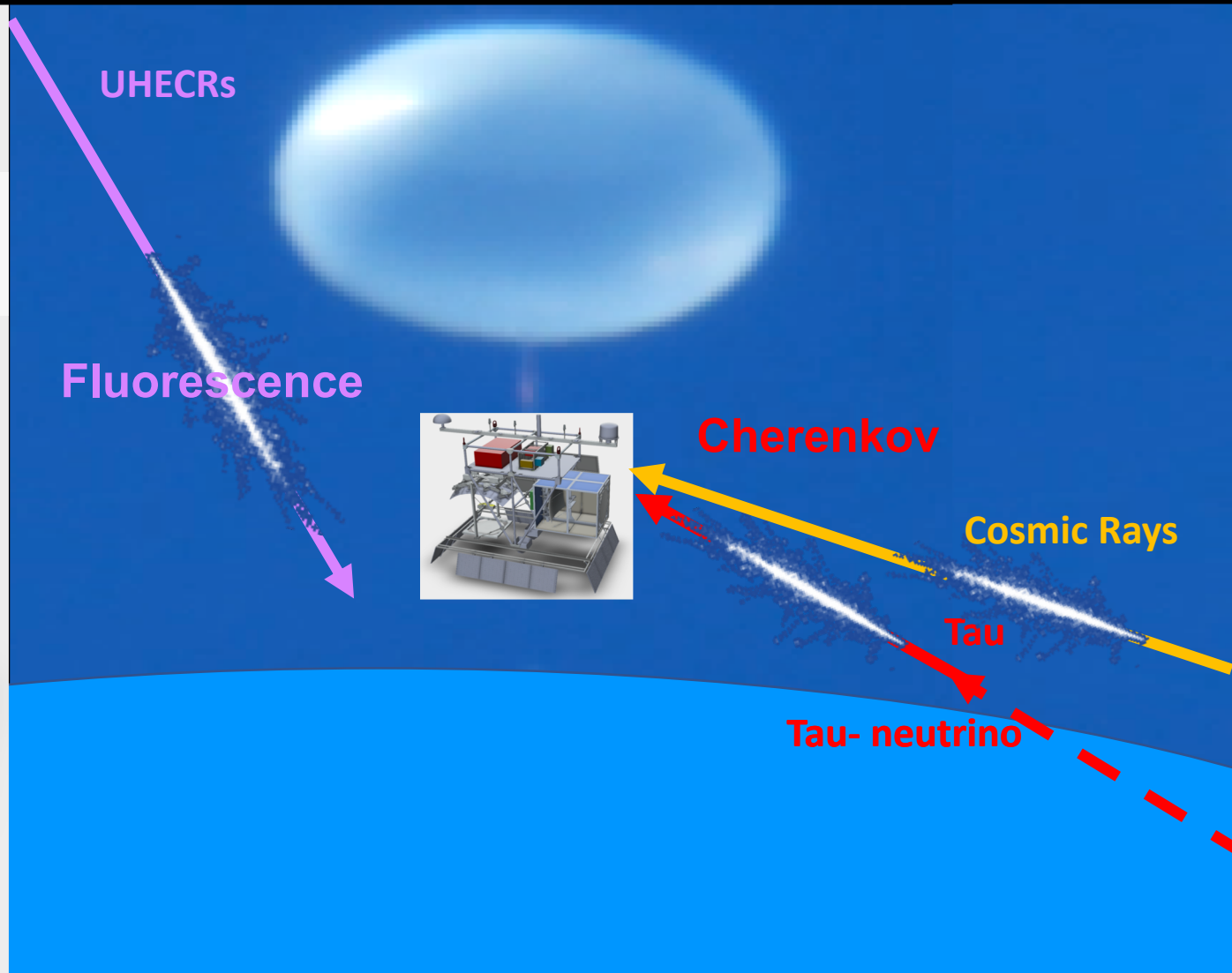
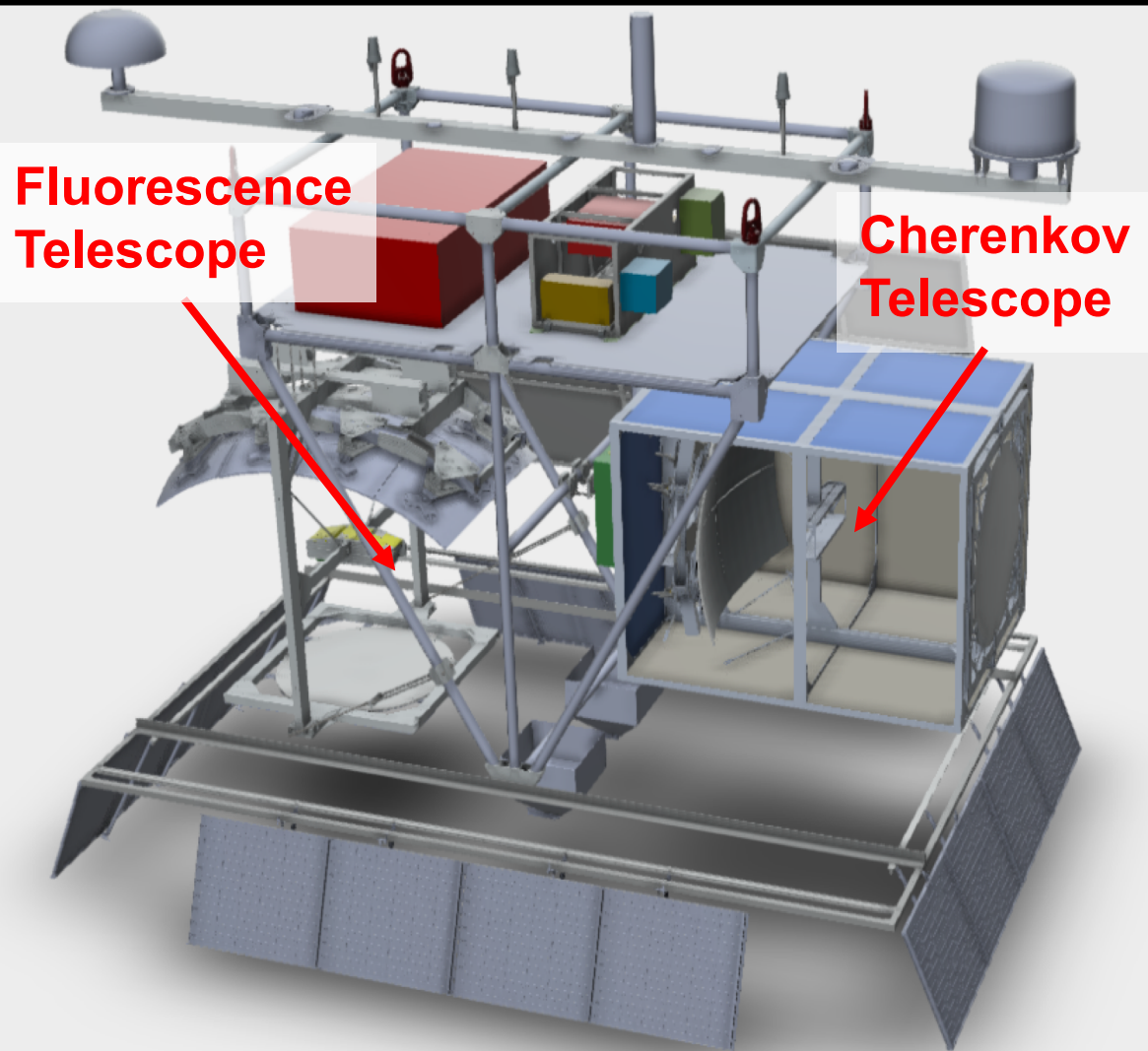
POEMMA (2028+)





Extreme Universe Space Observatory on a Super Pressure Balloon 2

J. Eser <https://pos.sissa.it/395/412>



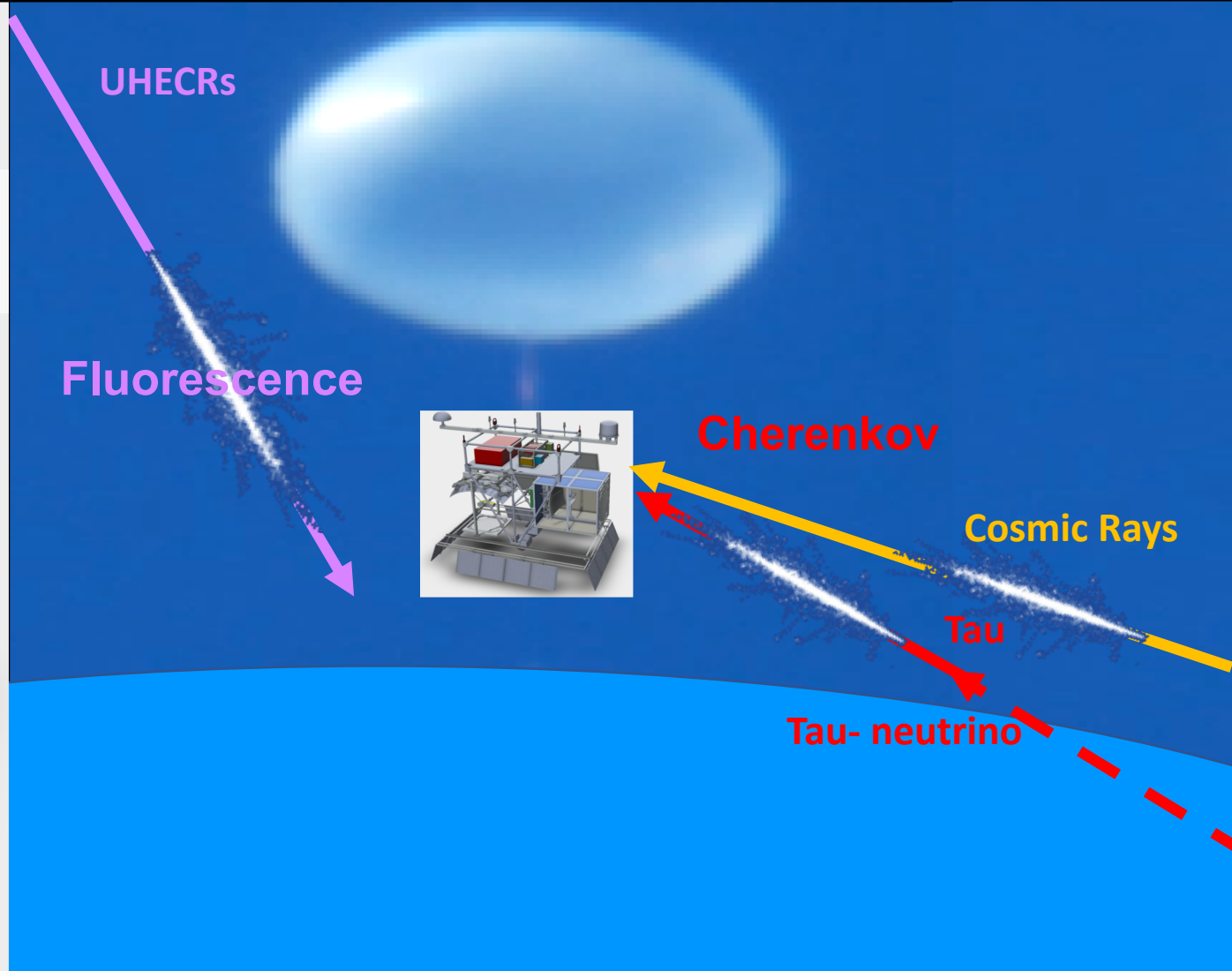
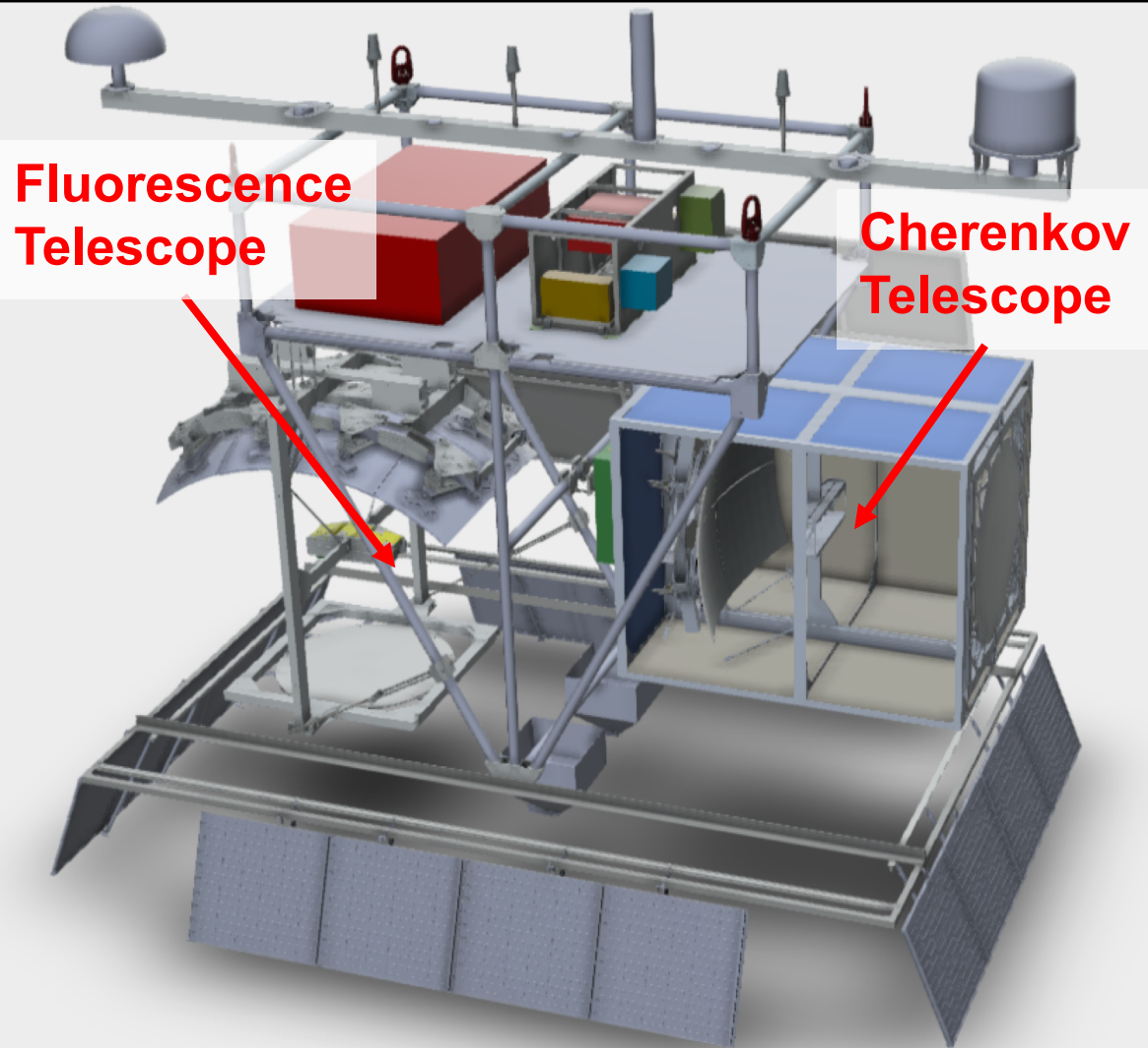


EUSO-SPB2

J. Eser <https://pos.sissa.it/395/412>

Cherenkov Technique:

A. Cummings <https://pos.sissa.it/395/437>
M.H. Reno, <https://pos.sissa.it/395/1201>
Terzina SmallSat mission
Trinity project on ground
A. Brown <https://pos.sissa.it/395/1179>





POEMMA

UHECR and Neutrino Observations

Earth's Atmosphere = Particle Observatory to discover
the Origin of the Highest Energy Cosmic Rays ($E > 10^{19}$ eV);
Very High Energy Neutrino Emission ($E > 10^{16}$ eV) from Astrophysical Events; and
Study New Astro/Physics



23 Oct 2017 16:00:10.000 Time Step: 10.00 sec

