Ultra-high Energy Particle Astrophysics with the Probe Of Extreme Multi-Messenger Astrophysics (POEMMA)‡

Science Goals:

- **Discover the origin of Ultra-High Energy Cosmic Rays**
  - Measure the full-sky distribution, spectrum, and composition for $E_{CR} \gtrsim 20$ EeV
- **Observe Very-high Energy Neutrinos from Transient Astrophysical Events**
  - Measure beamed Cherenkov light from upward-moving EAS from τ-leptons produced by ν_τ interactions in the Earth for $E_\nu \gtrsim 20$ PeV

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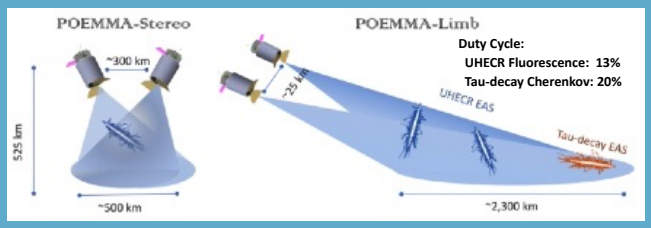
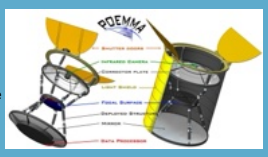
POEMMA Concept of Operation: Ref: JCAP 2021, 06, 007



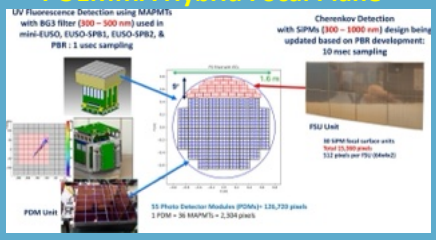
POEMMA is an observatory comprised of two large-area (A_{COLL} = 6 m²) Schmidt telescopes with large FoV that orbit in a loose formation at 525 km altitude and measures the air fluorescence from extensive air showers (EAS) induced by UHECR while also being able to slew to measure the beamed Cherenkov radiation produced by upward-moving EAS generated from Earth-emergent τ-leptons sourced by tau neutrinos from extremely energetic astrophysical transient events.

POEMMA Instrument

Schmidt Telescopes:
- 45° full FoV
- 4 m diam. Prim. Mirror
- 3.3 m diam. Cor. Lens
- 1.6 m diam. Focal Plane
- 3×3 mm² Pixel Size
- 0.084° Pixel iFoV



POEMMA Hybrid Focal Plane

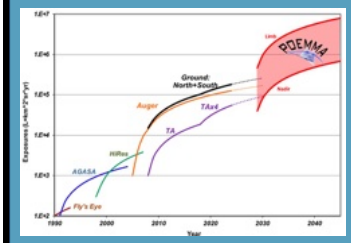


POEMMA Mission

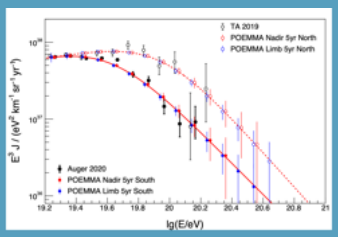
Mission Lifetime: 3 years (5 year goal)
Orbits: 525 km, 28.5° Inc
Orbit Period: 95 min
Satellite Separation: ~25 km – 1000+ km
Satellite Position: 1 m (knowledge)
Pointing Resolution: 0.1°
Pointing Knowledge: 0.01°
Slew Rate: 8 min for 90°
Satellite Dry Mass: 1550 kg
Satellite Wet Mass: 3860 kg
Power: 1250 W (w/contig)
Data: < 1 GB/day
Data Storage: 7 days
Communication: S-band
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 if desired
- Flight Dynamics: 300 km -> 25 km SatSep to put both telescopes in event Cherenkov light pool.
- Propulsion allows: 90 (10) maneuvers for Δt = 24 (3) hr

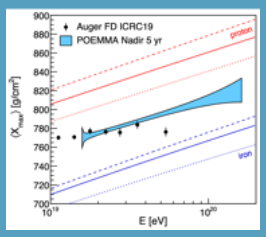
Simulated POEMMA UHECR Performance: Refs: JCAP 2021, 06, 007; PhysRevD.101.023012



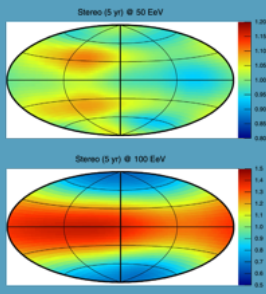
Exposure Evolution



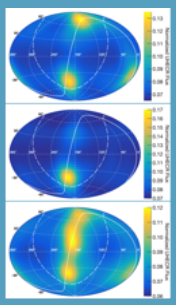
Spectrum (Auger vs TA)



Composition (model)



Sky Coverage (variation)



UHECR Source Model

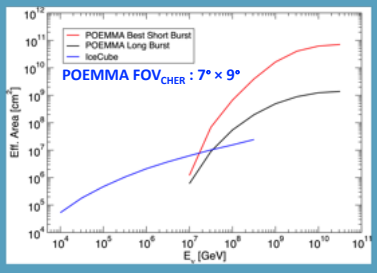
Starburst Galaxies:
11% anisotropy
15% angular spread

Swift-BAT AGNs:
8% anisotropy
15% angular spread

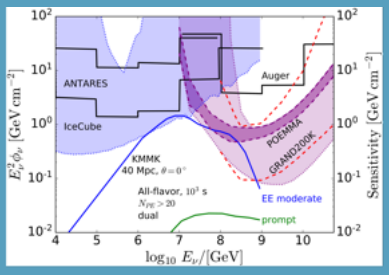
2MRS Galaxies:
19% anisotropy
15% angular spread

Science (interpretation)

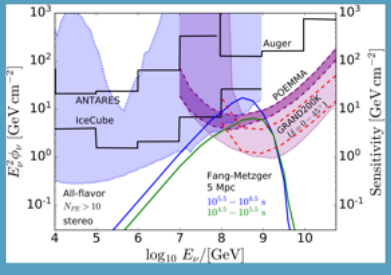
Simulated POEMMA VHE Neutrino Performance: Refs: JCAP 2021, 06, 007; PhysRevD.102.123013



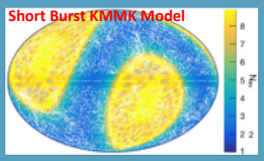
Transient ν Source A_{EFF}

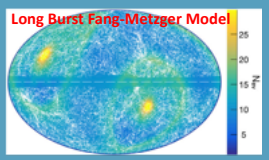


All-flavor 90% CL sensitivity per energy decade for short-burst observations in ToO-dual mode (N_{PE} > 20).



All-flavor 90% CL sensitivity per energy decade for long-burst observations in ToO-stereo mode (N_{PE} > 10).

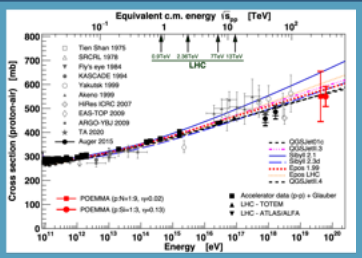




Sky Plot of Event Count

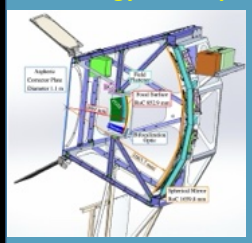
Secondary Science Goals:

- Study Fundamental Physics with the most energetic cosmic particles: √s ≈ 450 TeV @ 100 EeV Ref: PhysRevD.101.023012
- Search for Signatures of super-Heavy Dark Matter using VHE neutrinos and photons Ref: PhysRevD.104.083002
- Study Atmospheric Transient Events (Elves, Sprites, …), survey Meteor Population, … Ref: JCAP 2021, 06, 007



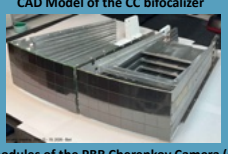
The UHE proton-air cross section as a function of proton energy and the projected UHE proton-air cross section measurement with POEMMA.

Technology Development with PBR Ref: JCAP 2026, 07, 001



PBR Schmidt Telescope and the Hybrid Focal Plane

CAD Model of the CC bifocalizer



2 modules of the PBR Cherenkov Camera (CC)

References: JCAP 2021, 06, 007; PhysRevD.105.055013; Europhysics Letters 135, id.51001; PhysRevD.104.083002; NIM A 985, id. 164614; PhysRevD.104.063029; PhysRevD.103.043017; PhysRevD.102.123013; PhysRevD.101.023012; PhysRevD.100.063010; JCAP 2019, 03, 021