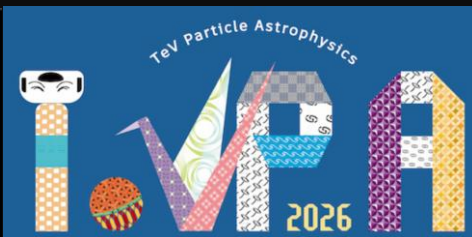
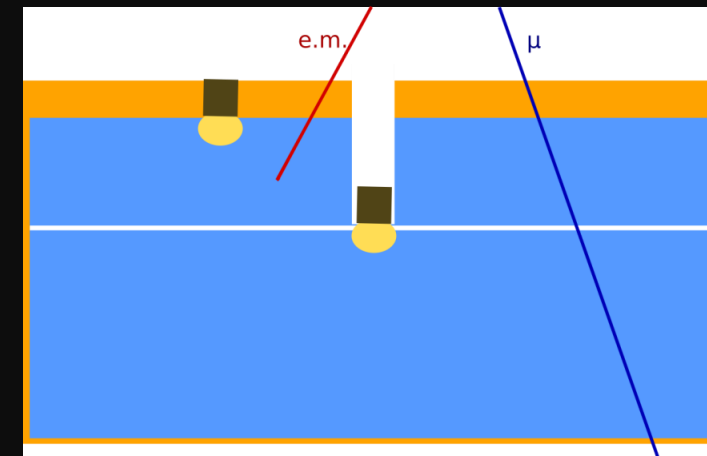
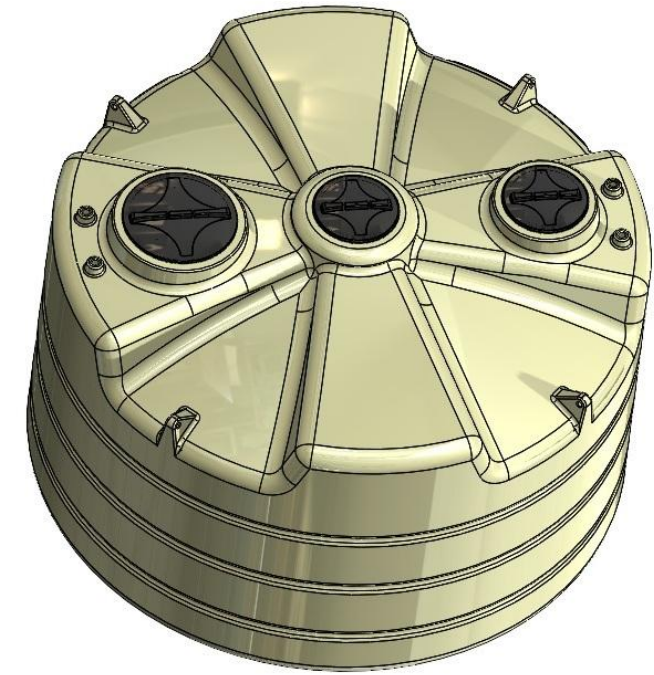




Probing the PeV Gamma-Ray Sky with PEPS (Probing Extreme PeVatron Sources)

E. Kido^{1,2} on behalf of the PEPS Collaboration
ICRR Univ. of Tokyo¹, ABL RIKEN²

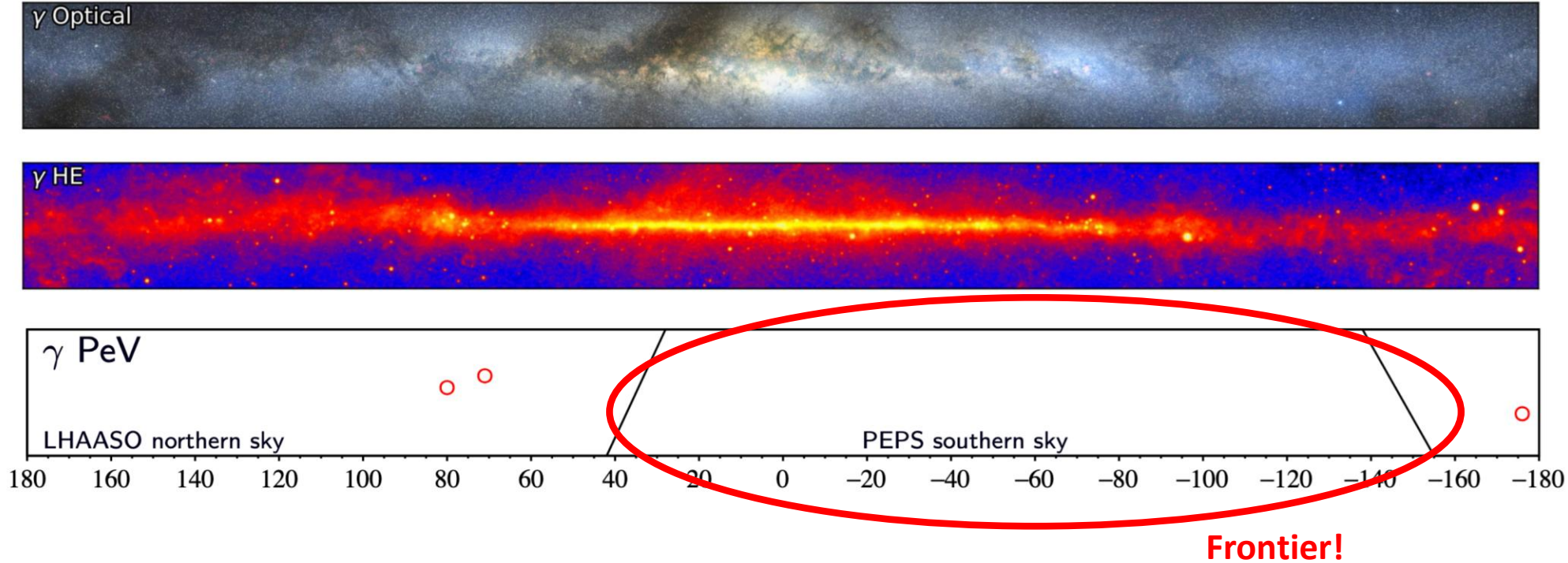


TeVPA2026 August 30 - September 4, 2026

Outline

- Concept of the experiment and the performance simulations
- Prospects of physics cases
 - Expected event rate
 - Dark matter search and cosmic ray measurements
- Hardware developments
- Summary and prospects

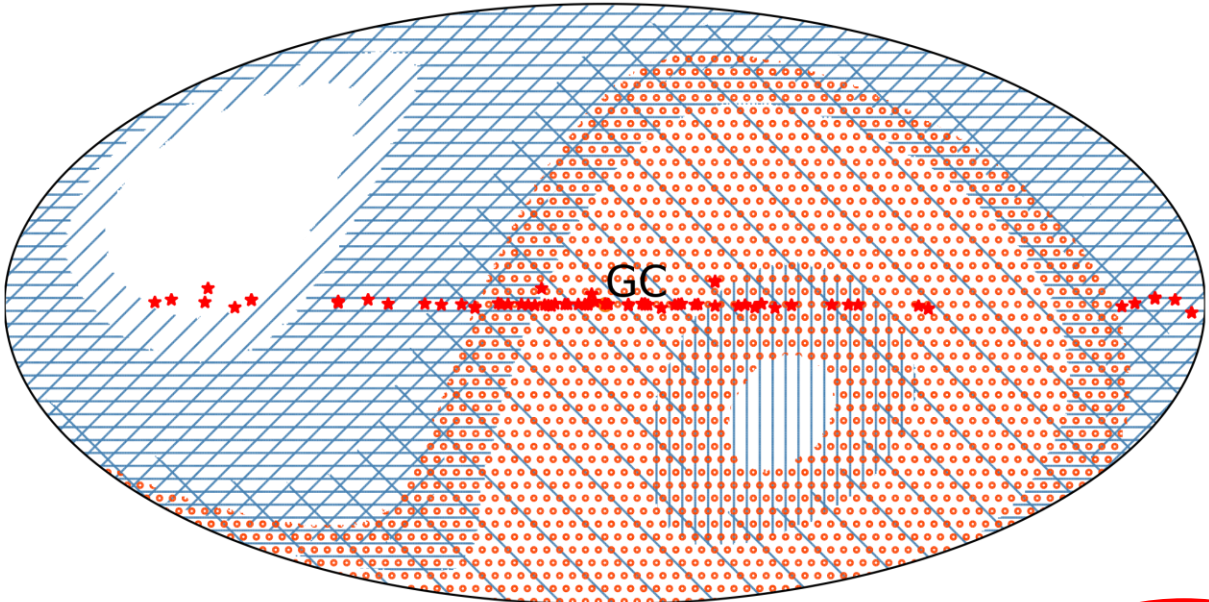
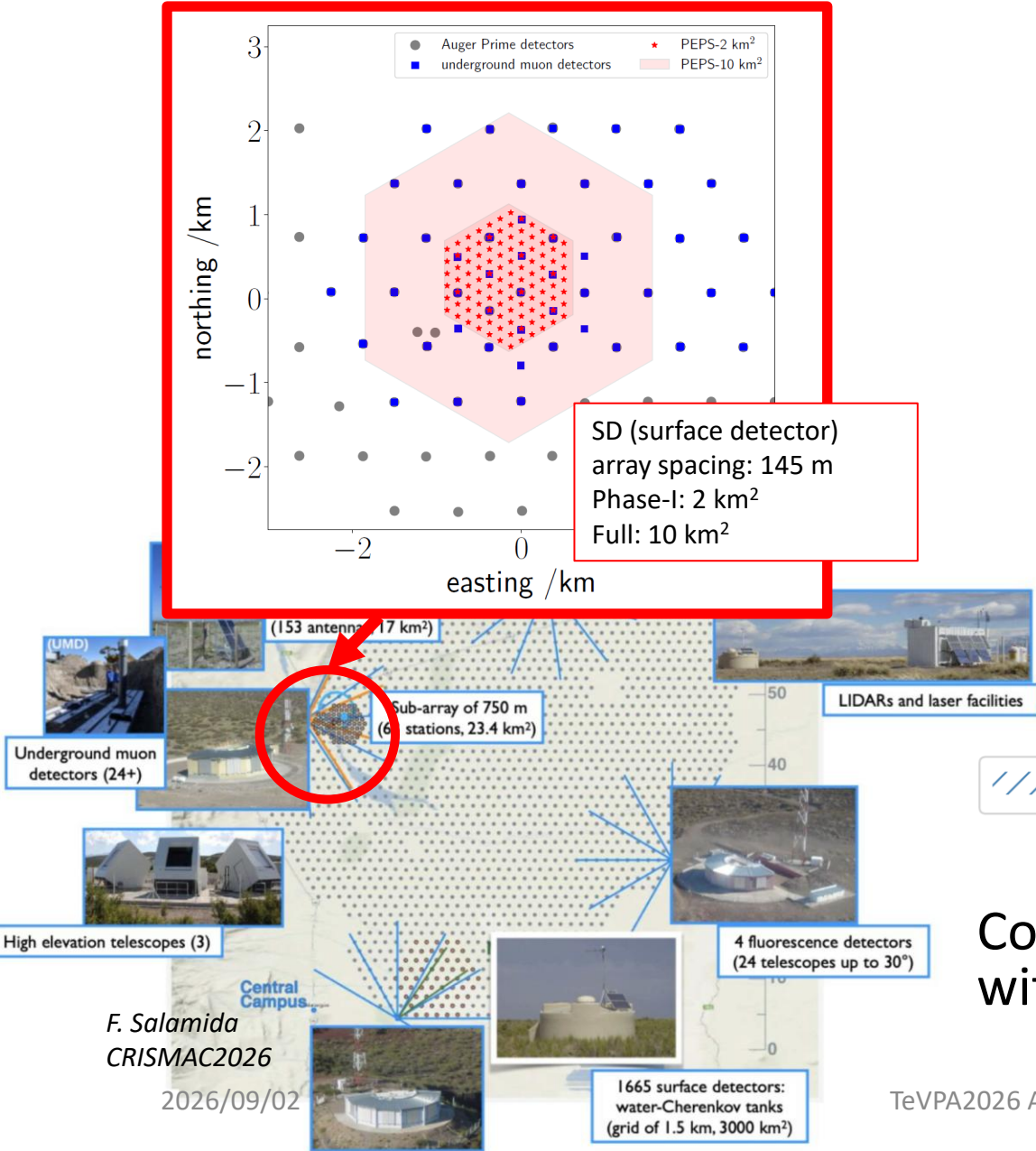
Explore the highest-energy gamma-rays from Galactic sources



Explore the >2 PeV
gamma-ray sky in the
Southern Hemisphere

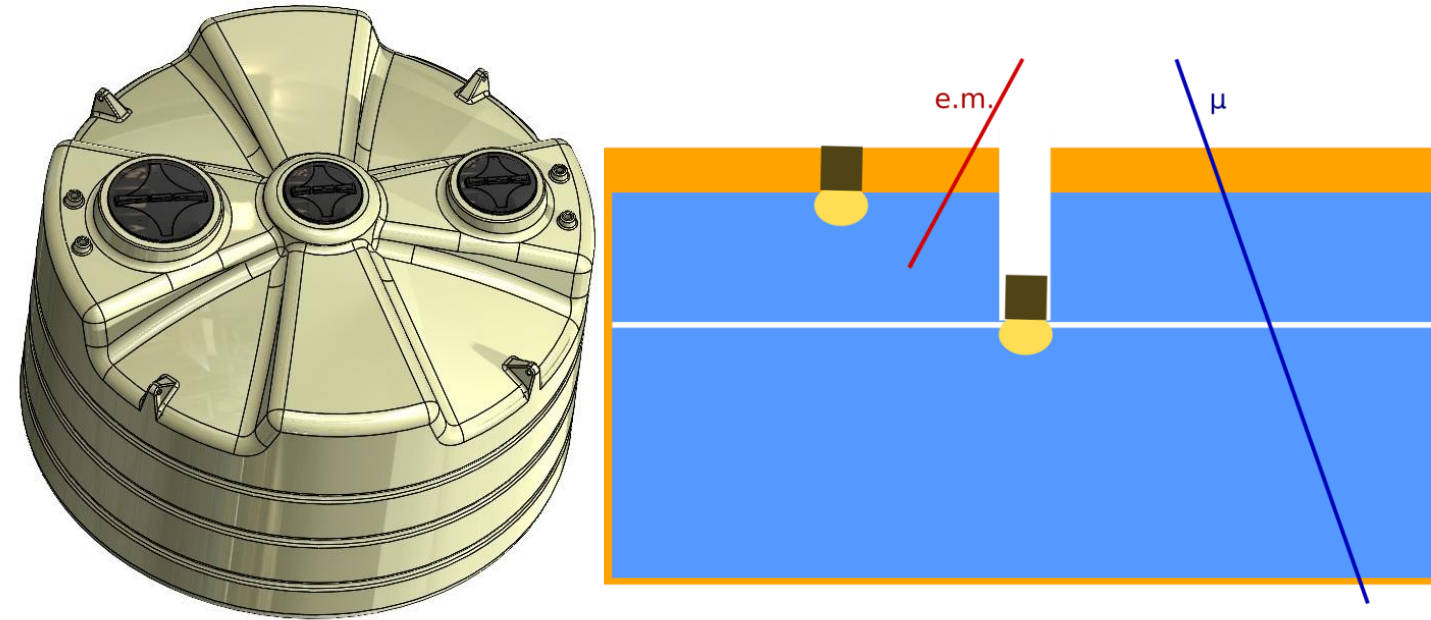
Pierre Auger Observatory site in the Southern hemisphere:
Malargue, Mendoza, Argentina

Observation site and the field of view



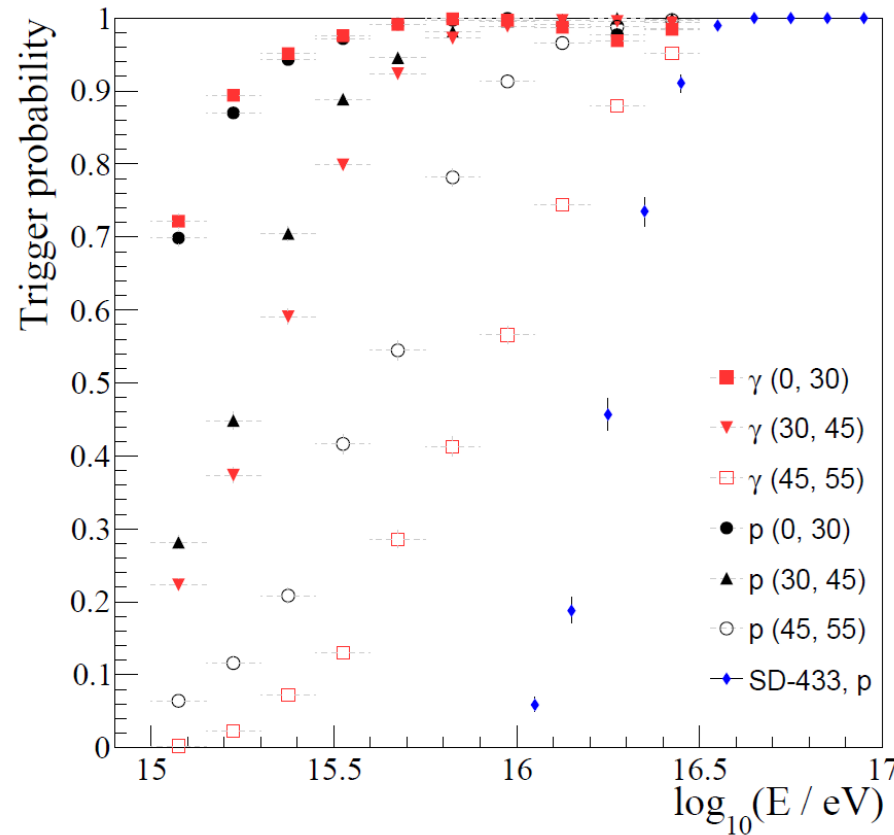
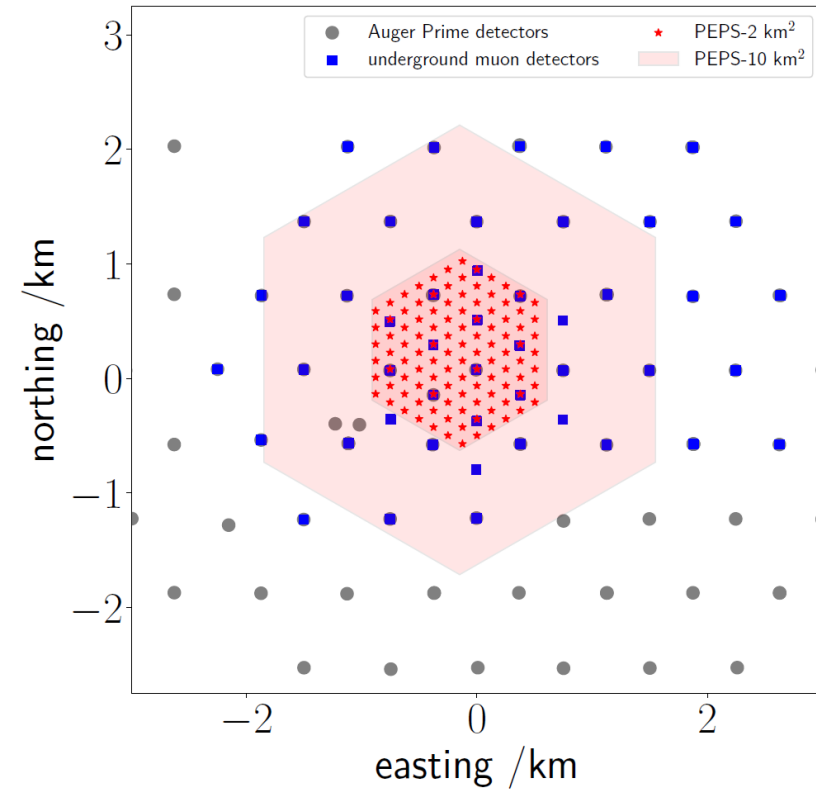
Complementary to Northern-Hemisphere experiments,
with overlapping FoV in the Southern Hemisphere

Layered water Cherenkov detector (WCD) concept



- Layered WCD surface detector (SD)
A. Letessier-Selvon et al., NIM A767 (2014).
 - Diameter: 3.2 m*
 - Water depth: 50 cm (up), 80 cm (low)*
 - 2 PMTs: one per water volume
- Two layered WCDs have been operating at the Auger site since 2014.
- EM/muon discrimination using the different responses of the two layers
→ **gamma-ray detection**

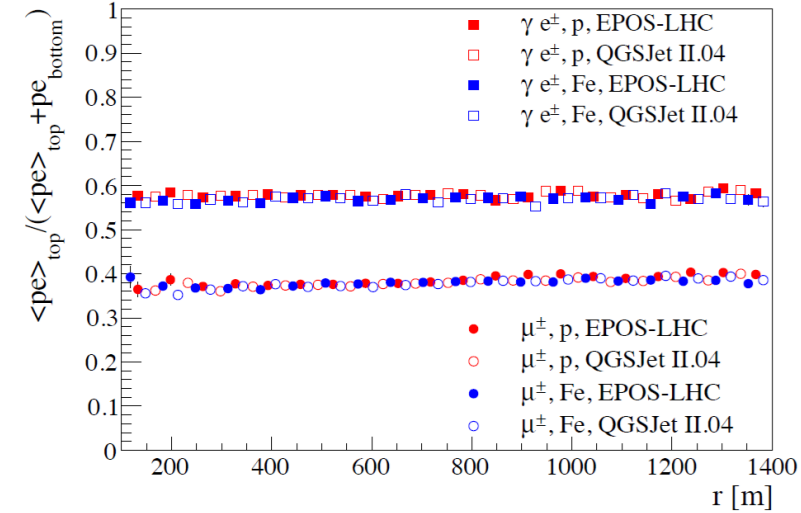
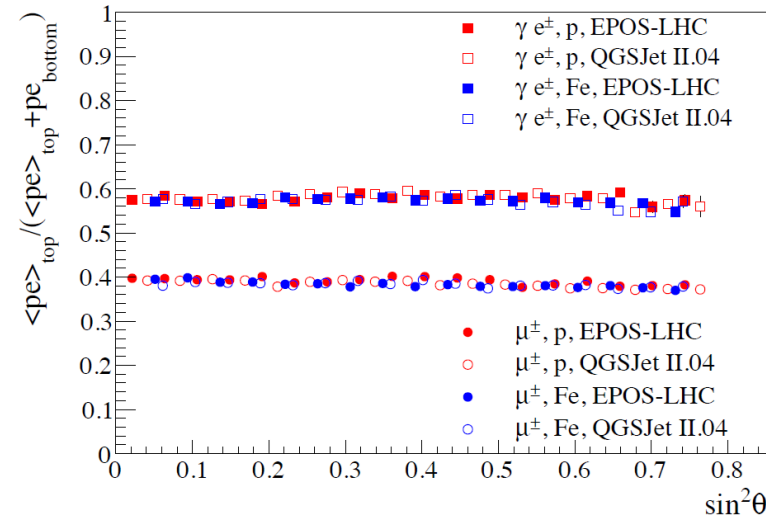
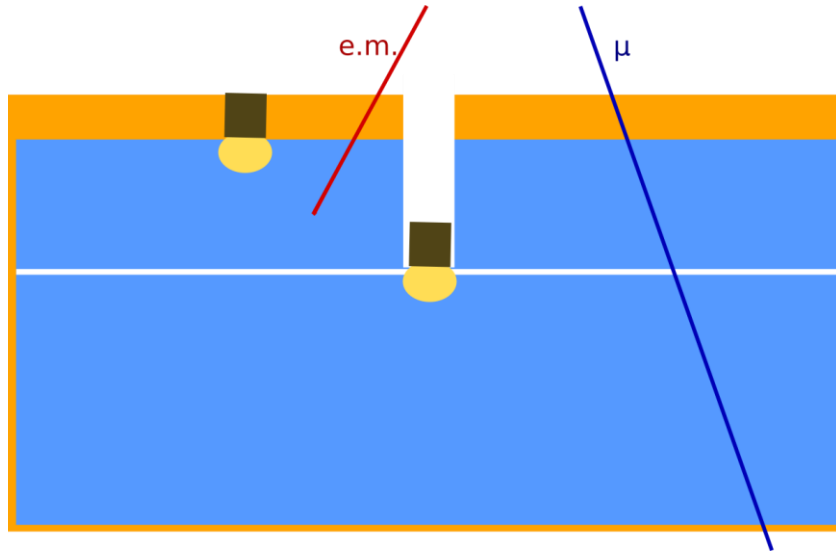
Performance simulations: array design and trigger efficiency



CORSIKA sim. w/ EPOS-LHC model
by N. Gonzalez and E. Santos

- Array spacing: 145 m
- High trigger efficiency for gamma rays **above 2 PeV**
- ~ 125 stations for a 2 km² array
- ~ 550 stations for a 10 km² array

EM/muon separation with a layered WCD



A. Letessier-Selvon et al., NIM A767 (2014).

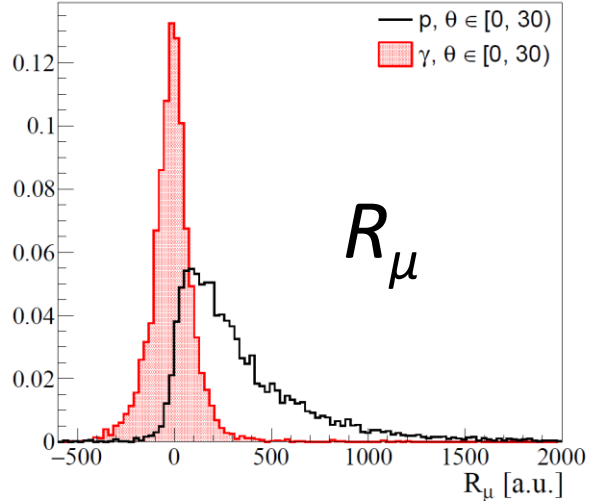
- Muon signal reconstruction with a layered WCD
- Different responses to shower components
 - EM: mainly absorbed in the upper layer
 - Muons: penetrate both layers
- Universality of the response matrix
 - a and b are nearly independent of shower properties
 - S_μ can be reconstructed event by event from the top/bottom signals

$$\begin{pmatrix} S_{top} \\ S_{bot} \end{pmatrix} = \begin{pmatrix} a & b \\ 1-a & 1-b \end{pmatrix} \begin{pmatrix} S_{EM} \\ S_\mu \end{pmatrix}$$

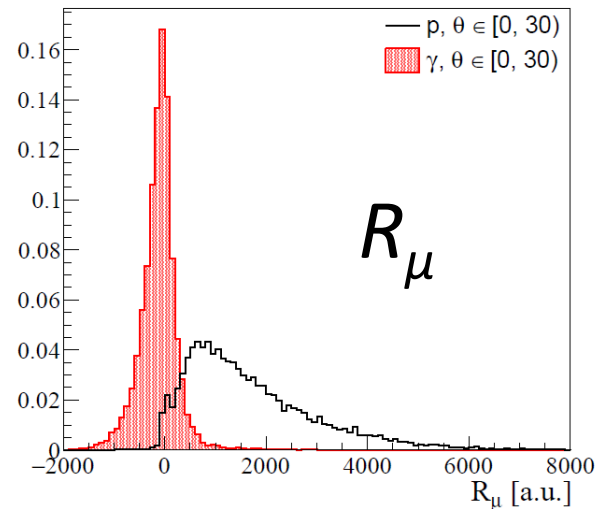
$$S_{top}, S_{bottom} \Rightarrow S_{EM}, S_\mu$$

Performance simulations: gamma/proton discrimination

$\log_{10}(E/\text{eV}) \in [15.5 - 16]$



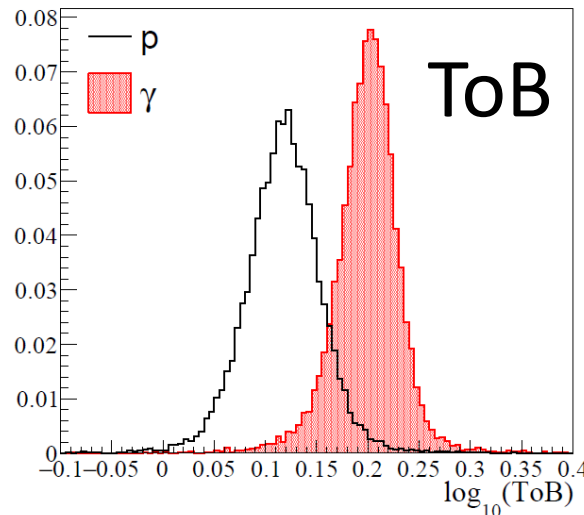
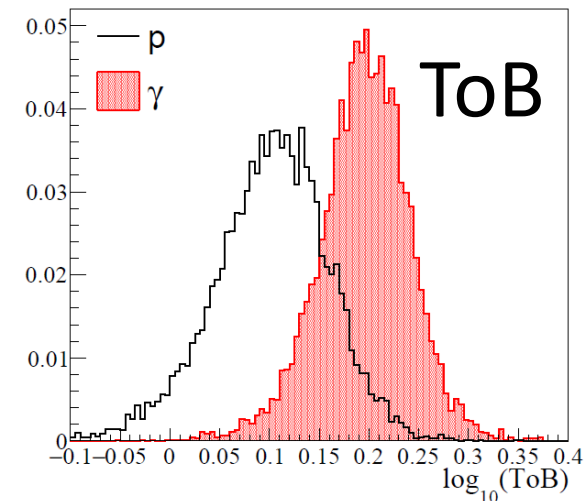
$\log_{10}(E/\text{eV}) \in [16 - 16.5]$



$$R_\mu = \frac{1}{N} \sum_i S_\mu \cdot r^{1.5}$$

$$\log_{10}(\text{ToB}) = \log_{10} \left(\frac{1}{N} \sum_i \frac{S_{\text{top}}}{S_{\text{bottom}}} \right)$$

Two separation variables



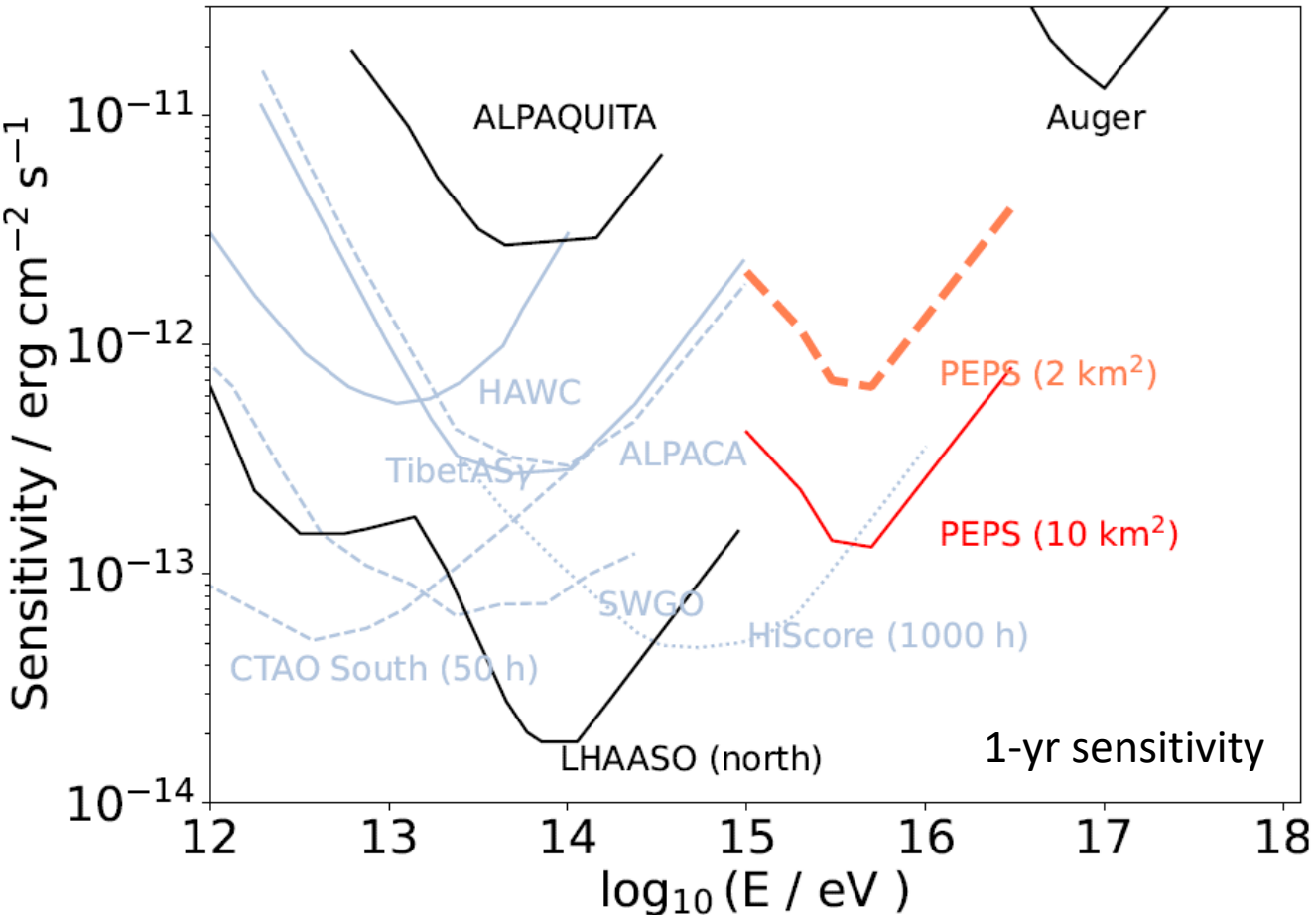
- At 50% gamma efficiency, combination of the two separation variables →
 - Proton leakage decreases rapidly with energy
 - $< 5 \times 10^{-3}$ around 1 PeV
 - $< 10^{-4}$ above 10 PeV
- The gamma/proton separation has not yet been optimized. **Neural-network**-based methods are under development.

I. Maris and N. Gonzalez
PoS(ICRC2023)718

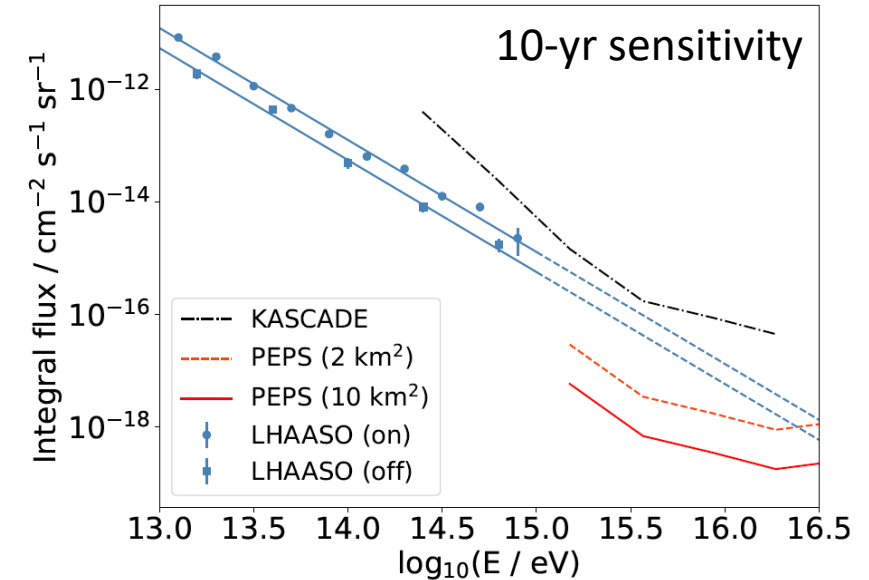
September 4, 2026

PEPS sensitivity in the PeV γ -ray range

Point-source sensitivity

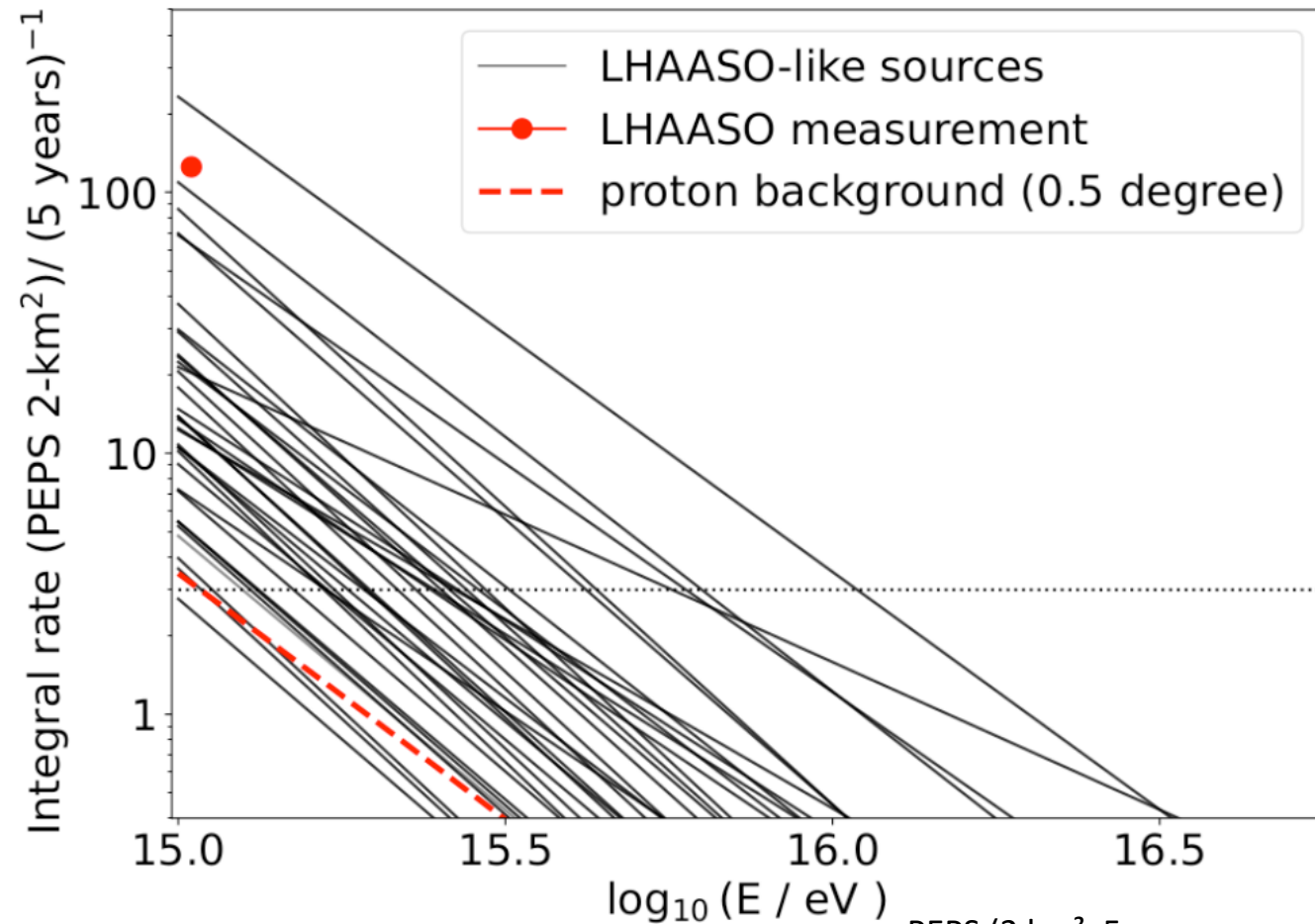


Diffuse-flux sensitivity



- Point-source sensitivity (1 yr):
PEPS extends γ -ray measurements beyond ~ 1 PeV, where **current coverage is limited**.
- Diffuse-flux sensitivity (10 yr):
PEPS will test whether diffuse flux extends to higher energies. **PEPS could probe the diffuse Galactic emission** beyond 1 PeV, even allowing for attenuation around 2 PeV.

Expected event rate for PEPS

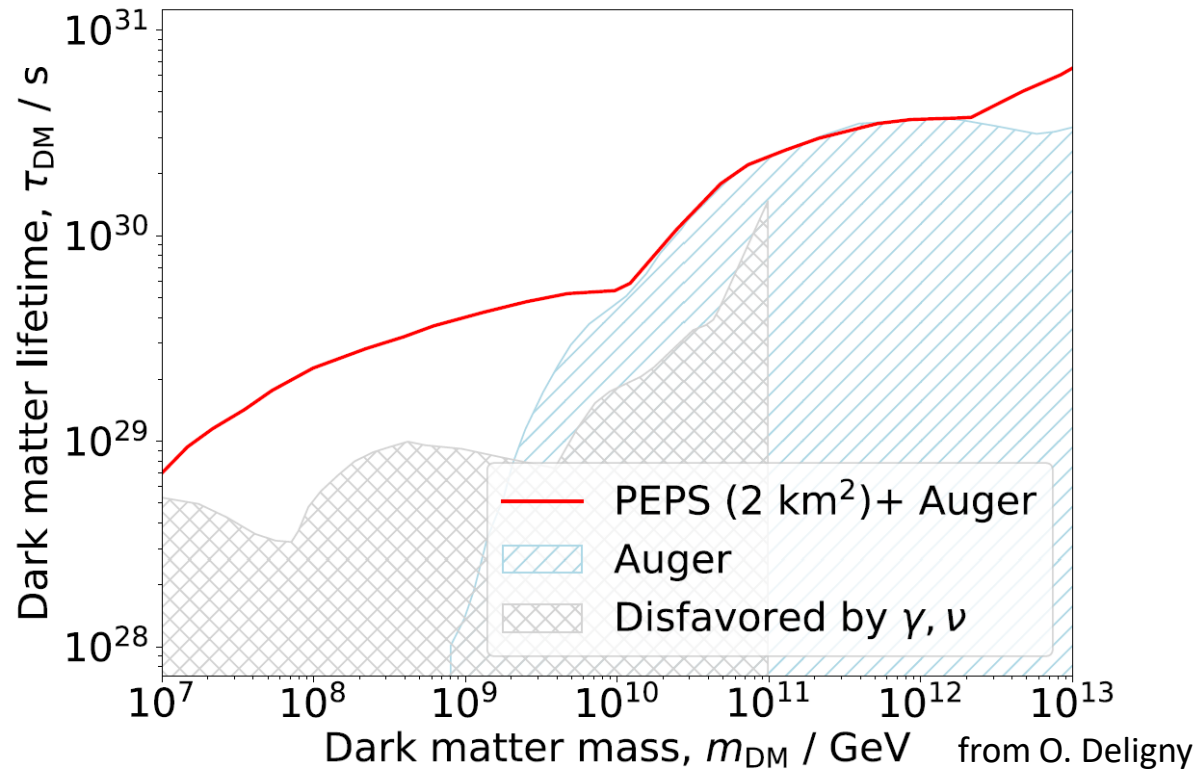


- Representative bright LHAASO source:
 $\sim 25 \text{ events km}^{-2} \text{ yr}^{-1}$ above 1 PeV
- Highest-energy LHAASO event: $3.73 \pm 0.41 \text{ PeV}$ from Cygnus X-3.
- “LHAASO-like sources”: benchmark sources with fluxes/spectral shapes similar to bright sources measured by LHAASO
- Simple extrapolation to higher energies, assuming no attenuation and no intrinsic cutoff
- A 2 km^2 PEPS array **can collect measurable samples** from bright LHAASO-like sources over several years.

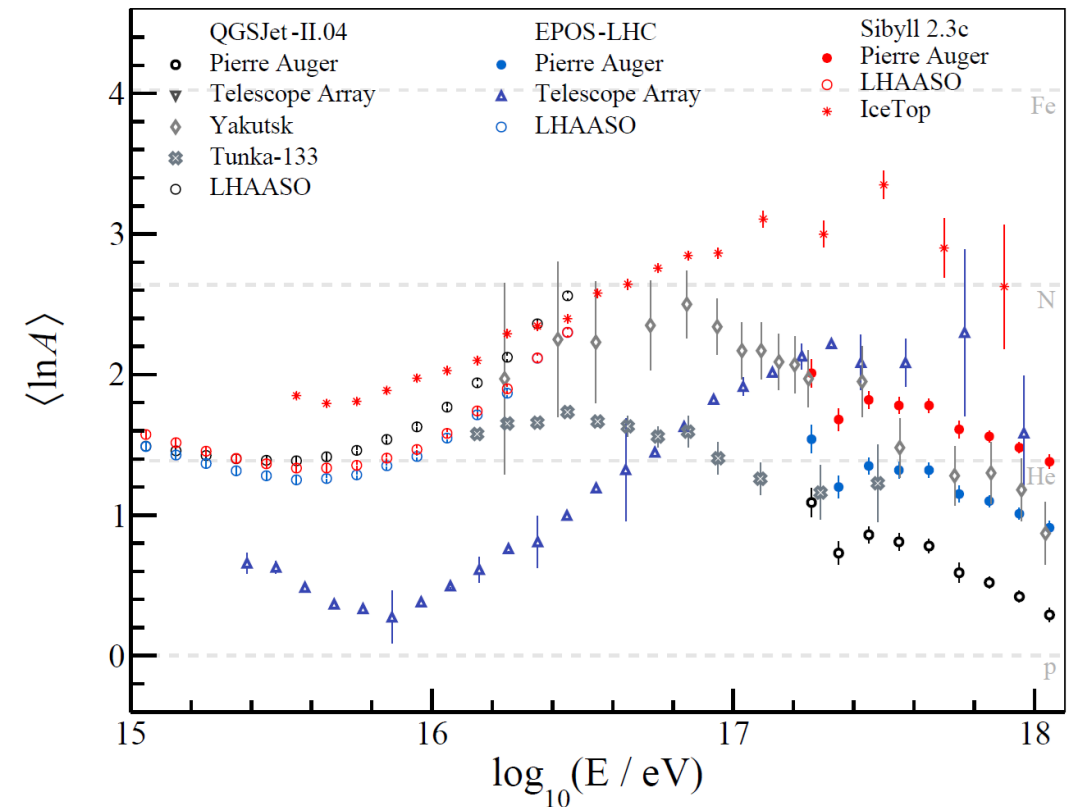
PEPS (2 km^2 , 5 years exposure)

Proton background efficiency: 3×10^{-4}

Dark matter search and cosmic ray measurements

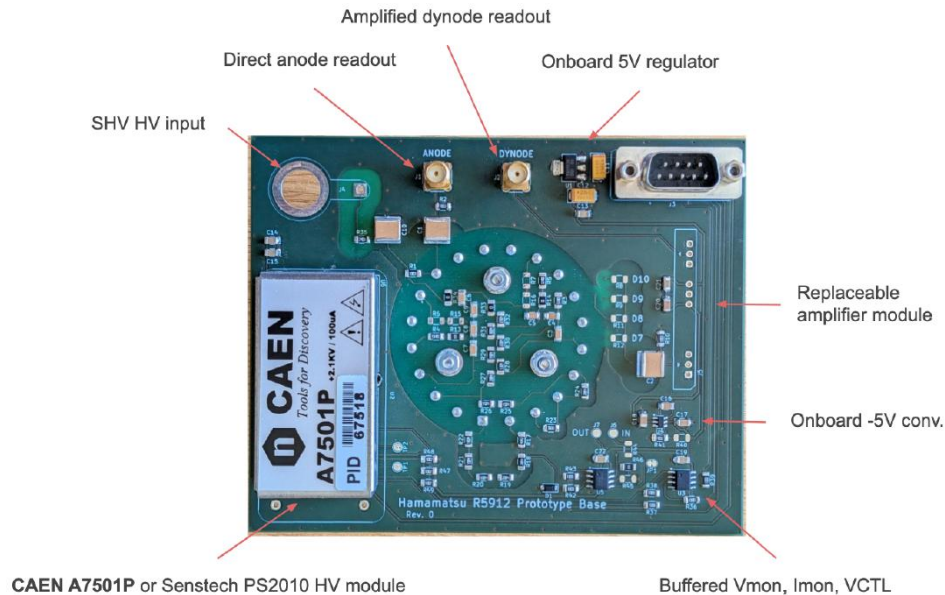


UHE gamma rays from super-heavy dark-matter decay
 → constraints on the dark-matter lifetime

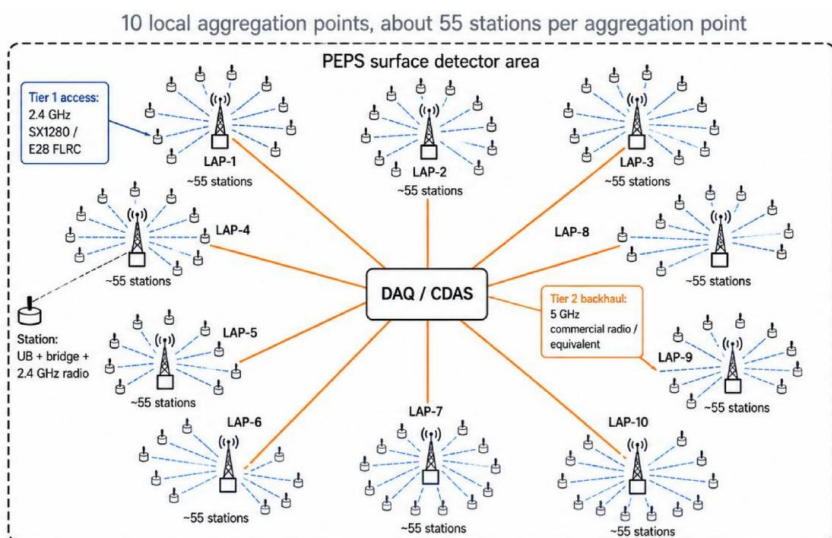


Cosmic-ray composition measurements with layered WCDs
 → comparison with existing measurements

Hardware developments



- FZU Prague and ULB Brussels
- Hamamatsu R5912 PMTs are being tested
 - Single-photoelectron response
 - Linearity
 - Afterpulse
 - Dark rate
- PMT base
 - Adjustment for the PMT and front-end electronics
- Reuse existing Auger equipment
 - Solar panels
 - Unified boards
- Wireless communication
 - The proposed wireless communication does not overlap with the frequencies currently used by the Auger DAQ.

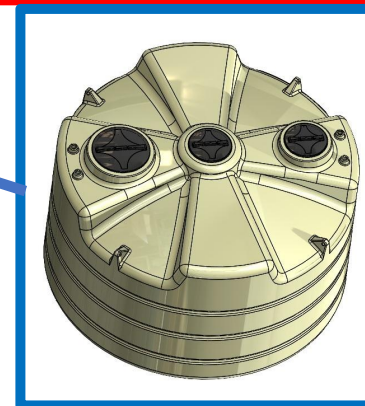


Topology of wireless communication for the data acquisition

Blue: 2.4 GHz wi-fi

Orange: 5 GHz wireless comm.

Hardware development at the Akeno Observatory



- A PEPS station will be constructed at the Akeno Observatory.
- Nine ALPACA SDs are also planned for installation on the rooftop.
- Coincident air-shower events will be measured with the PEPS and ALPACA detectors.

Summary and prospects

- PEPS: Probing Extreme PeVatron Sources
- Concept: a dense array of layered water-Cherenkov detectors
→ a **large-area gamma-ray observatory** in the Southern Hemisphere, targeting energies above **2 PeV**
- Hardware developments are ongoing.
- An 8-station prototype array (PEPSino) is planned for deployment in 2026–2027.



Interested? Join us!



Probing Extreme PeVatron Sources (PEPS)

