Probing Extreme PeVatron Sources (PEPS)

Project status and near future plans

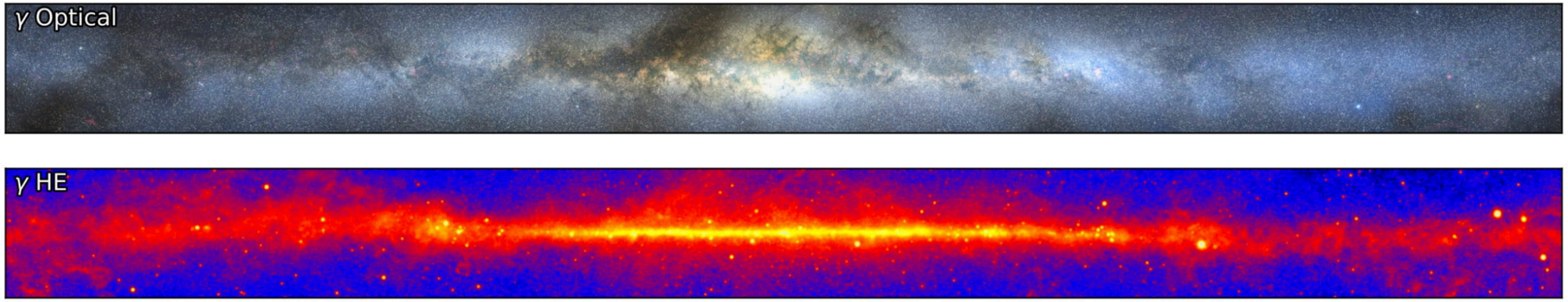
Mateo Fernández Alonso for the PEPS collaboration
Université Libre de Bruxelles

CRISMAC, Sorrento Italy, July 2026

*Image: SS 433, K. Golap, M. Goss; NASA's Wide Field Survey Explorer (WISE)

PEPS: Exploring the highest-energy gamma rays from the Galaxy

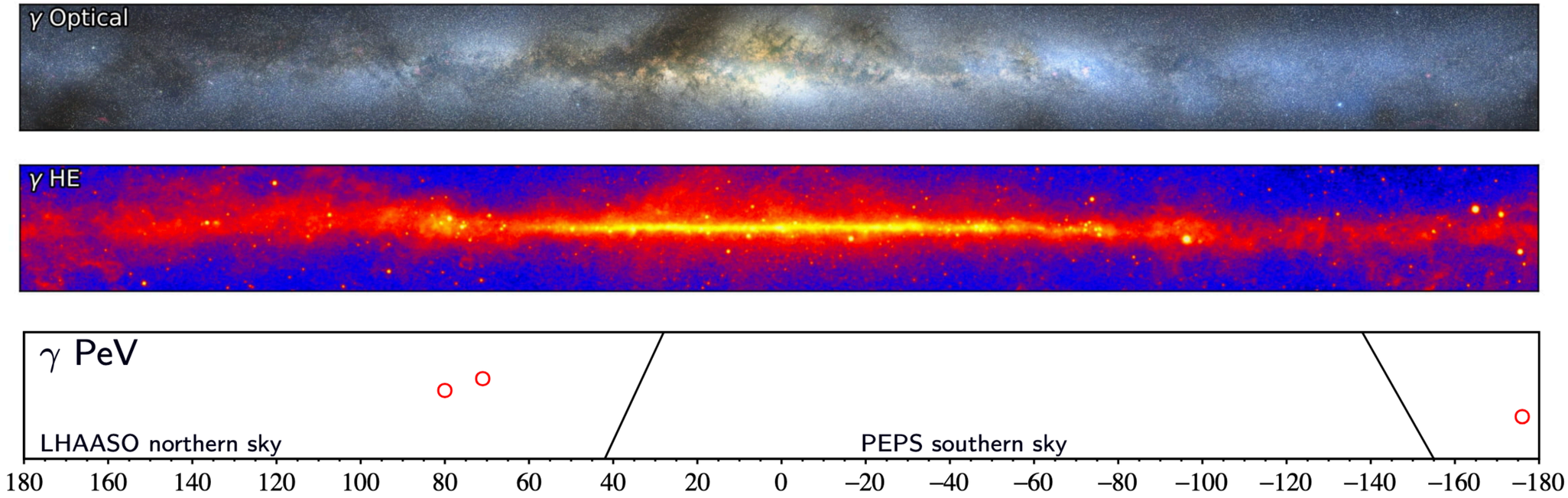
PeV landscape: LHASSO results anticipate an increase in PeVatron (> PeV) detection in the next years.



PEPS in the Southern hemisphere: 10 km^2 array designed to measure gamma rays above 2 PeV

PEPS: Exploring the highest-energy gamma rays from the Galaxy

PeV landscape: LHASSO results anticipate an increase in PeVatron (> PeV) detection in the next years

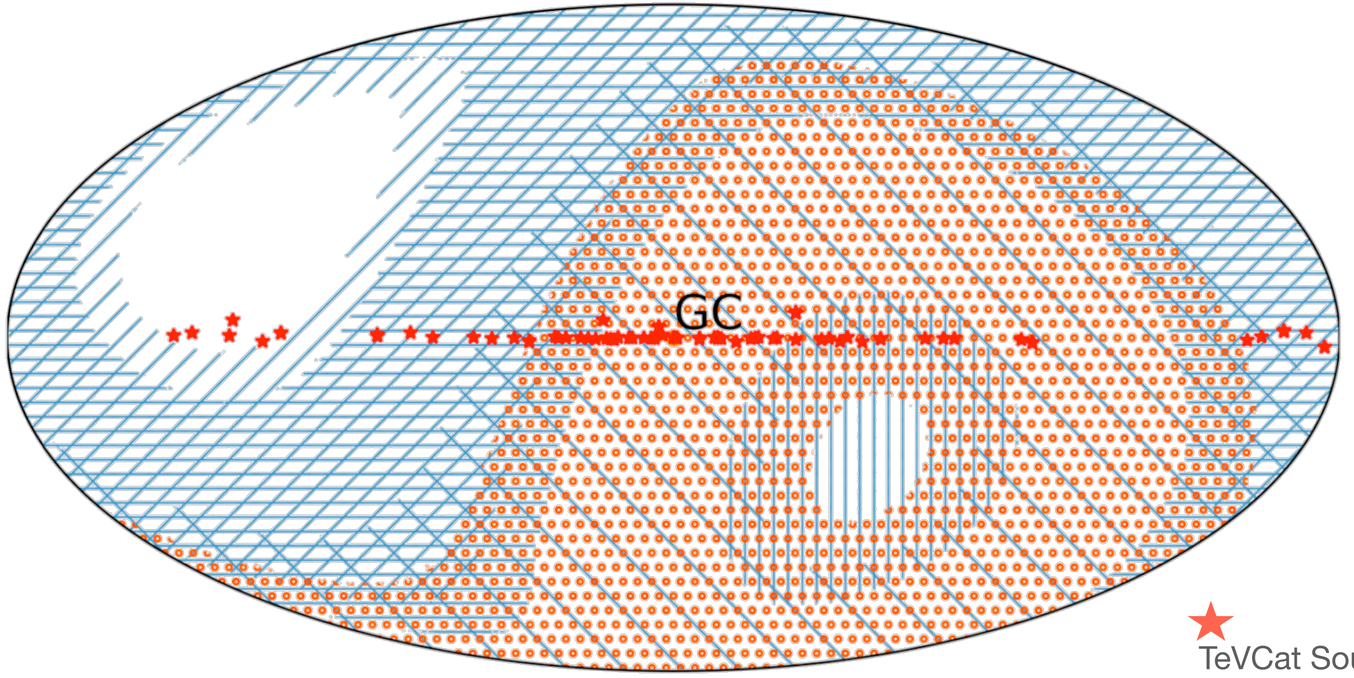


PEPS in the Southern hemisphere: 10 km^2 array designed to measure gamma rays above 2 PeV

Excellent coverage of the Southern Sky

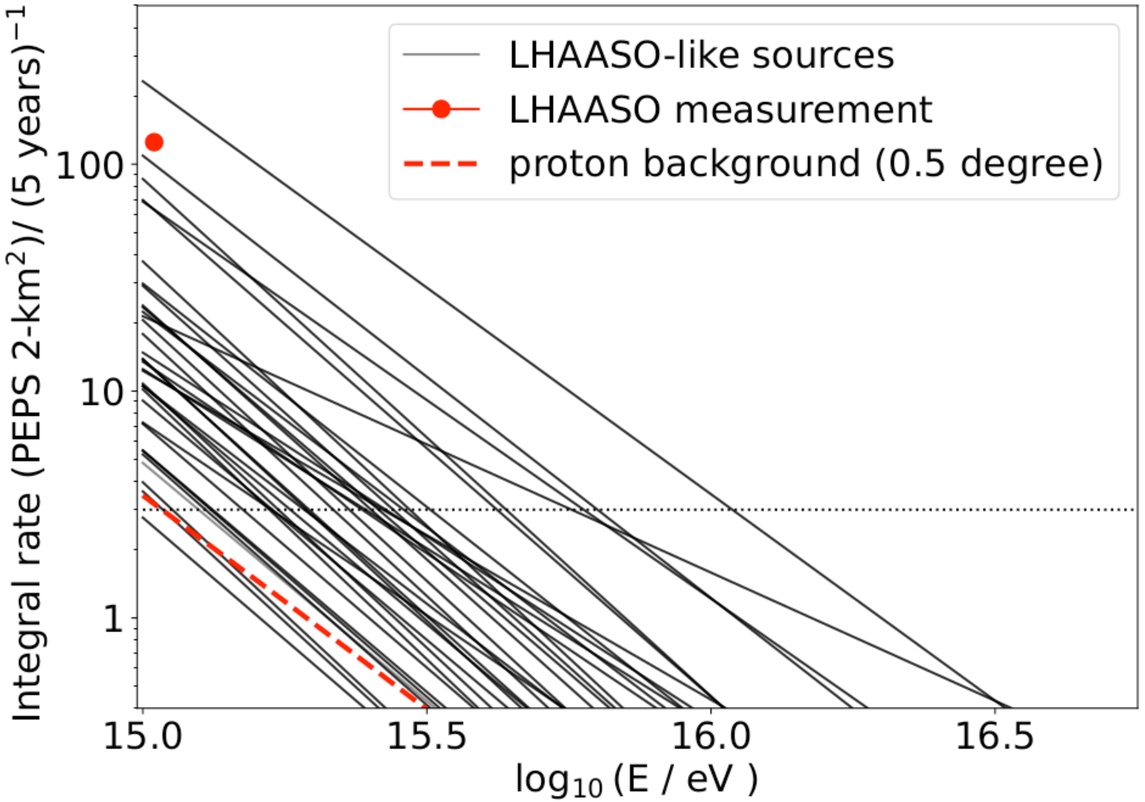
- To be deployed at the Pierre Auger Observatory site in Mendoza, Argentina
- **FoV**: excellent coverage of the Galactic Center & Galactic Plane
- Complementary with LHAASO/HAWC with an overlap with future projects aimed at lower energies like CTA-S, SWGO and ALPACA

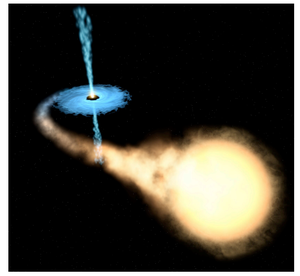




How many gamma rays we expect to detect? Where from?

LHAASO measures about 25 events / km² / year above 1 PeV, with a highest energy of 3.7 PeV





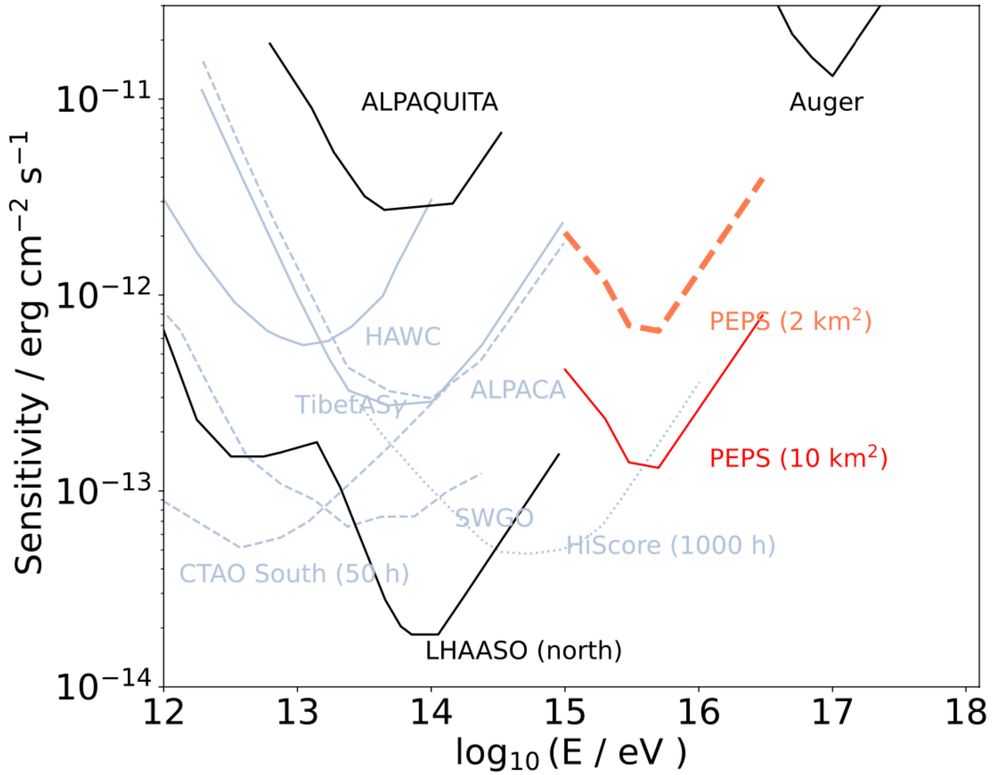
Micro-quasars



Young Stellar Clusters



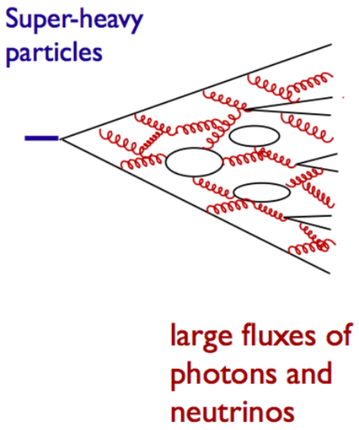
Galactic Center



Flux attenuation at 2 PeV less than 30% for source distances < 5 kpc

Background suppression depends on the angular resolution (expected between 0.3° to 1°) and separation power (this plot, 3e-4).

Tests of super-heavy dark matter (SHDM)

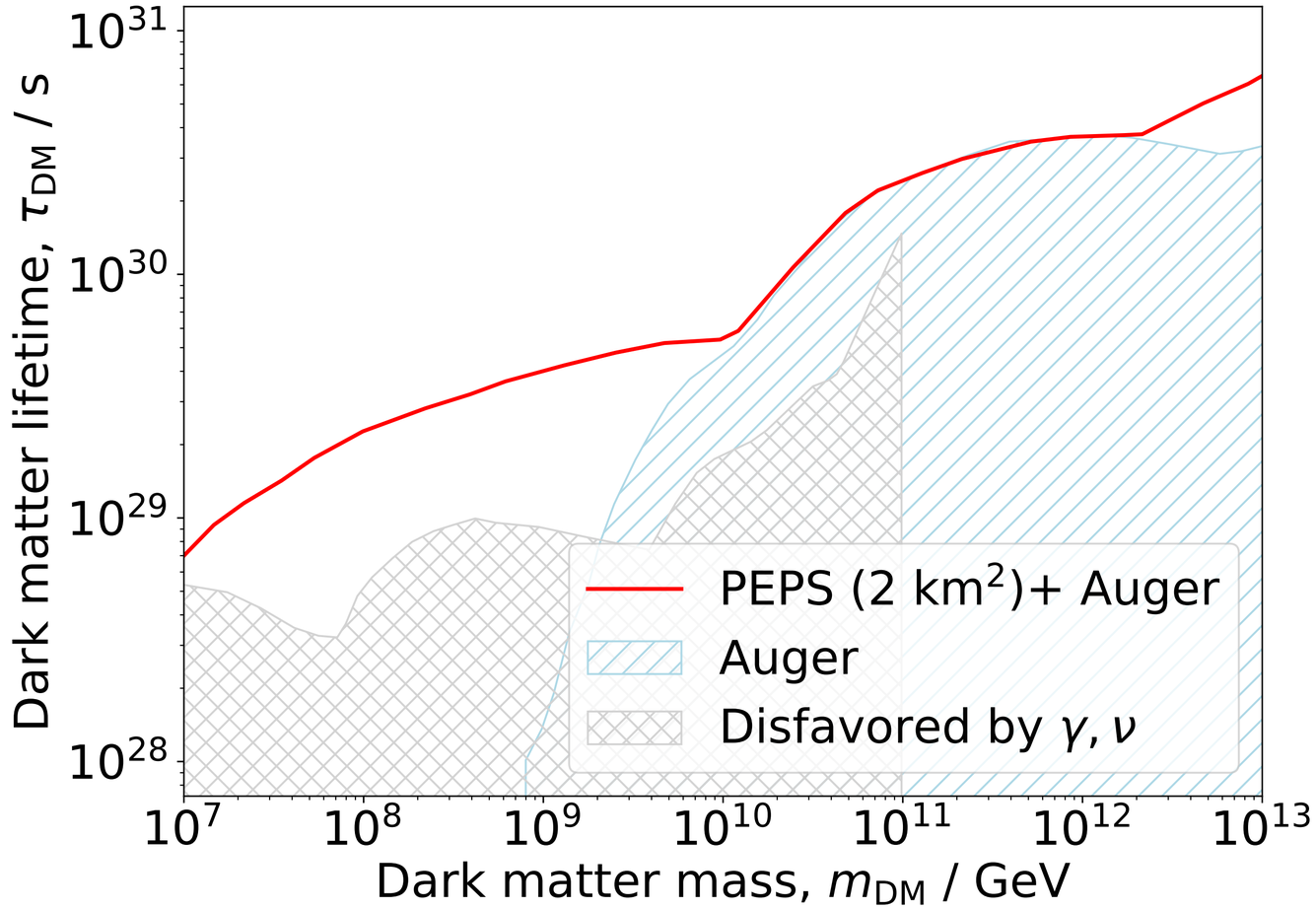


Super Heavy Dark Matter is a viable alternative to WIMPs

UHE gamma rays are expected from the decay of Super Heavy particles

Probing the multi-PeV regime —> Constrains on the lifetime of SHDM

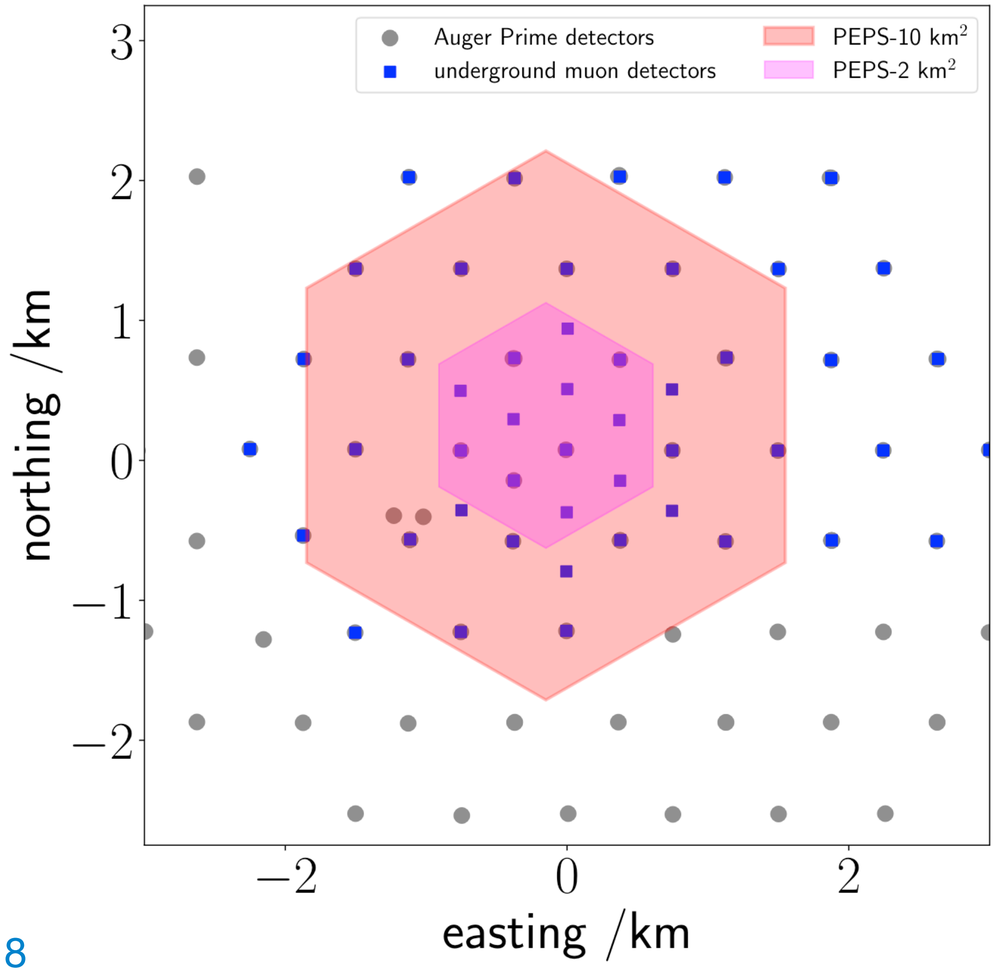
Improvement with respect to current limits at low and high mass



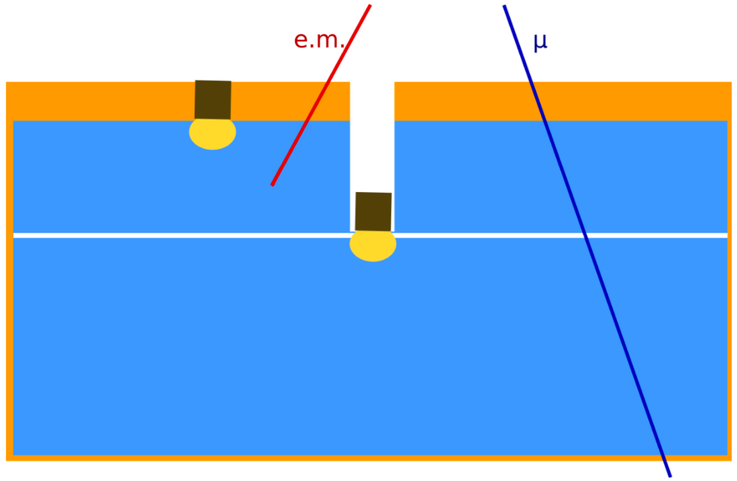
Detection Approach

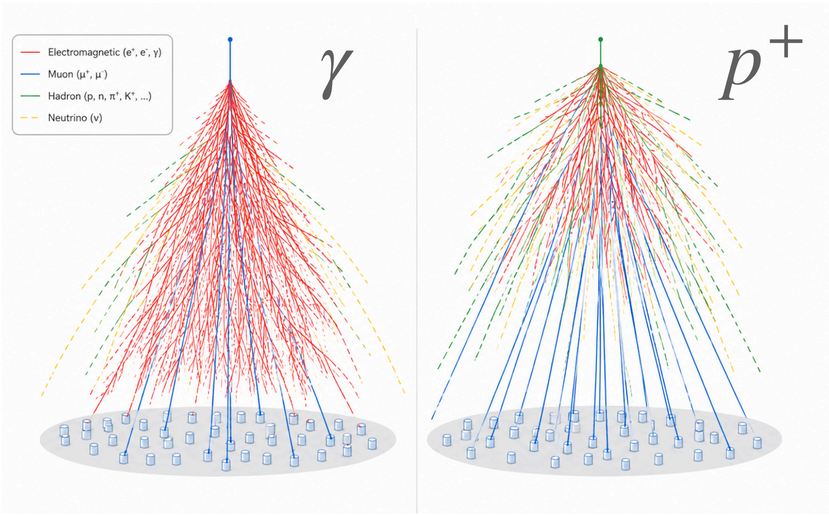
Detector and array layout

PEPS Phase I: a 2-km2 surface detector of water-Cherenkov detectors



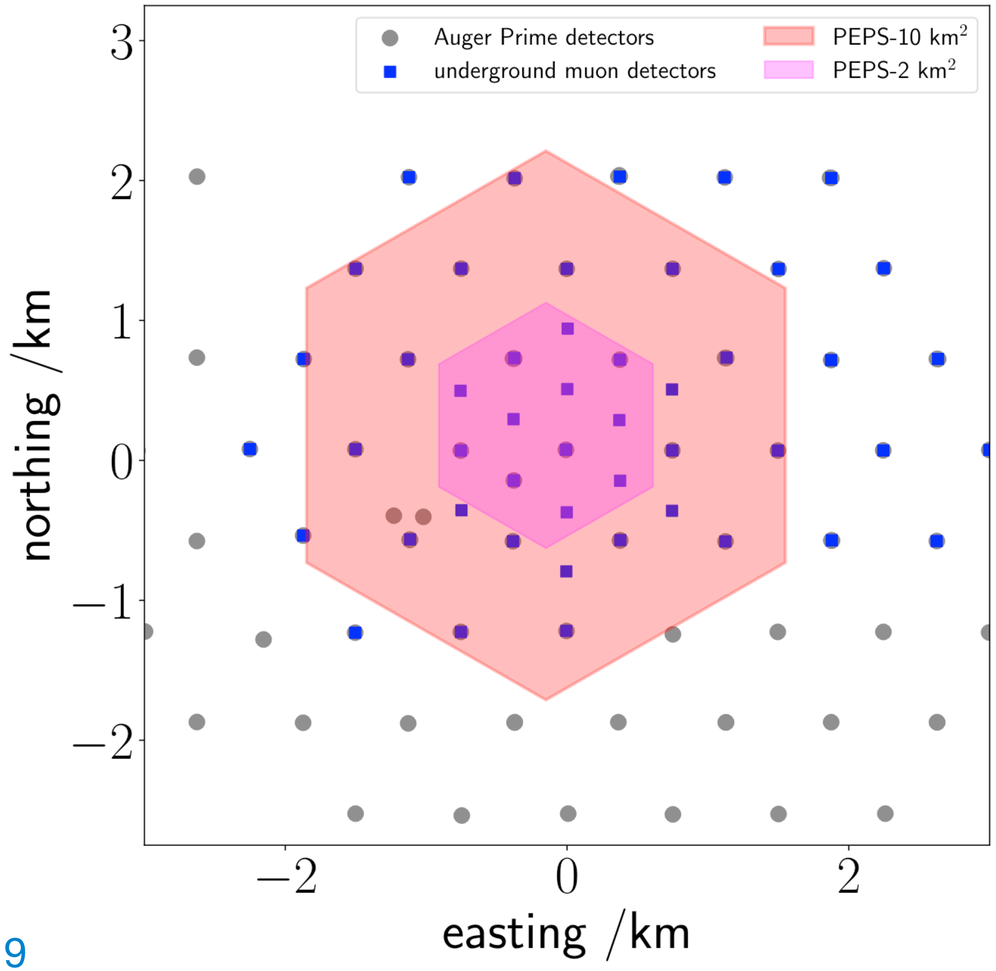
Segmented tanks: separate muonic and EM components

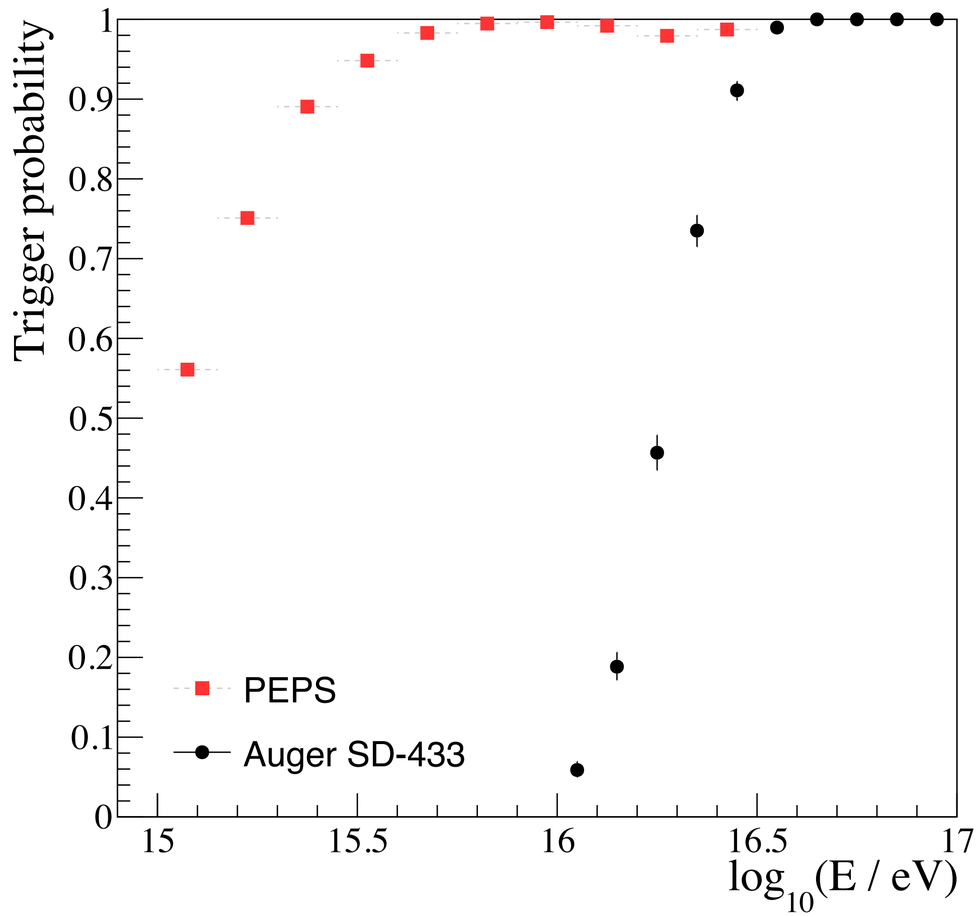




Detector and array layout

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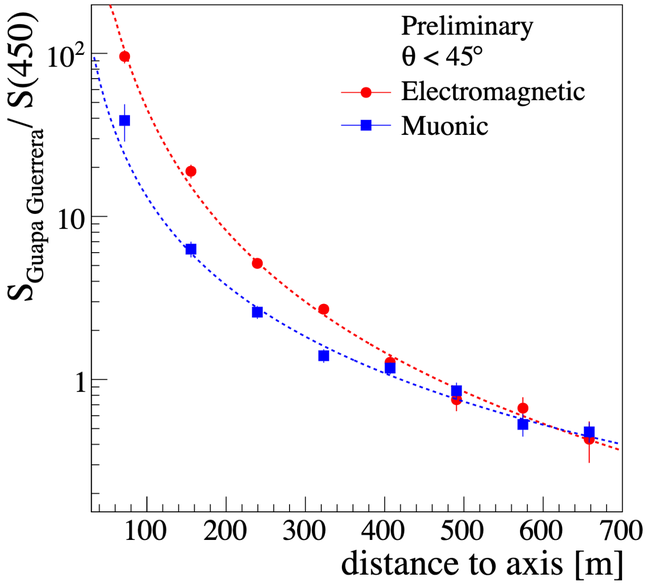


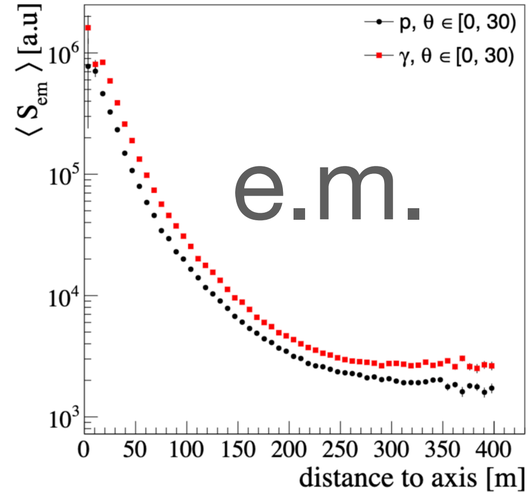
Array spacing 145 m ➡️ **Optimal efficiency above 2 PeV**

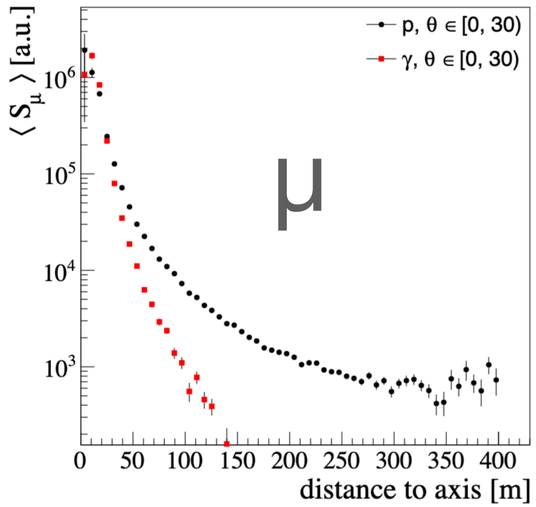
(Corsika + EPOS-LHC + Fluka2011.2)

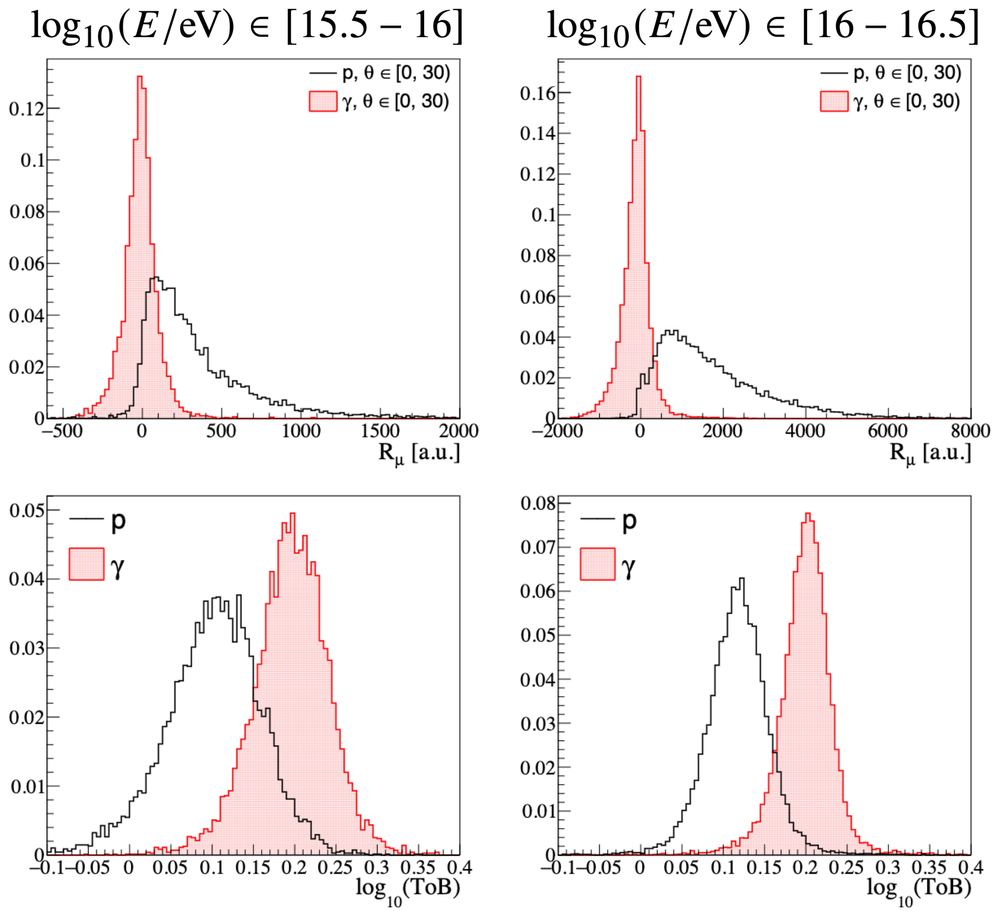
Gamma-hadron separation

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









Separation variables = S_{top}/S_{Bottom} + LDF

$$\log_{10}(\mathrm{ToB}) = \log_{10}\left(\frac{1}{N}\sum_{i}^{N}\frac{S_{\mathrm{top}}}{S_{\mathrm{bottom}}}\right) \qquad R_{\mu} = \frac{1}{N}\sum_{i}^{N} S_{\mu}\cdot r^{1.5}$$

Separation power @ 50% signal efficiency

10^{-3} above 2 PeV

10^{-4} above 10 PeV

Not optimized, expected improvements with NN and UMD measurements

Hardware developments

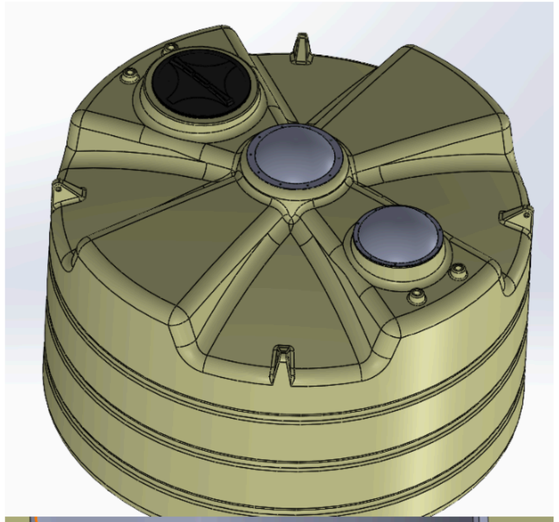
Detector design and construction

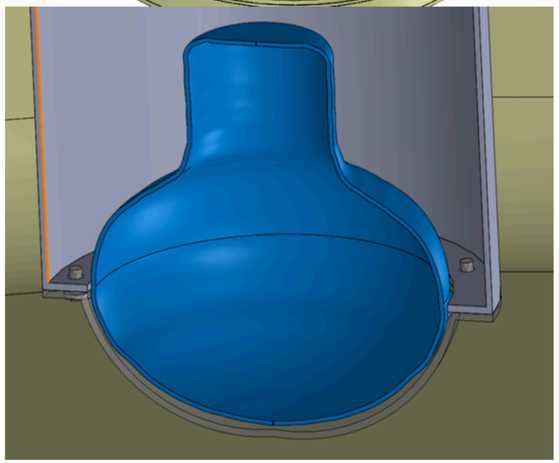
Design based on segmented detectors, leveraging expertise with 2 detectors operating @ Auger since 2014

Considering using reflective material instead of bladders

For the new prototypes: re-utilize decommissioned equipment: Auger solar panels and Unified Boards

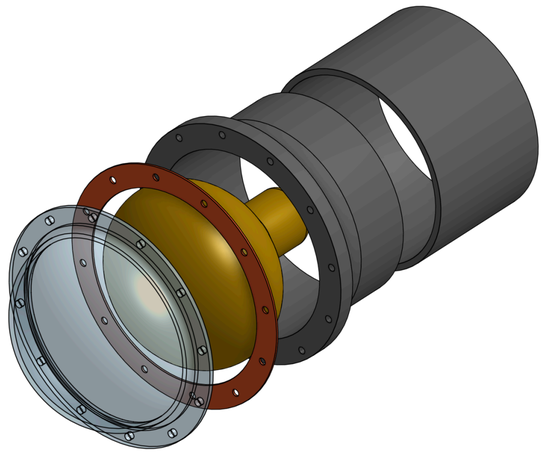
One PMT in each water volume surrounded by UV transparent optical windows





drawings by L. Mendez

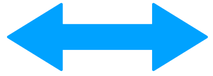


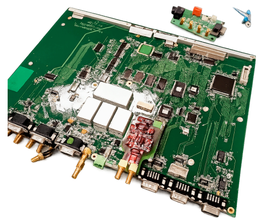


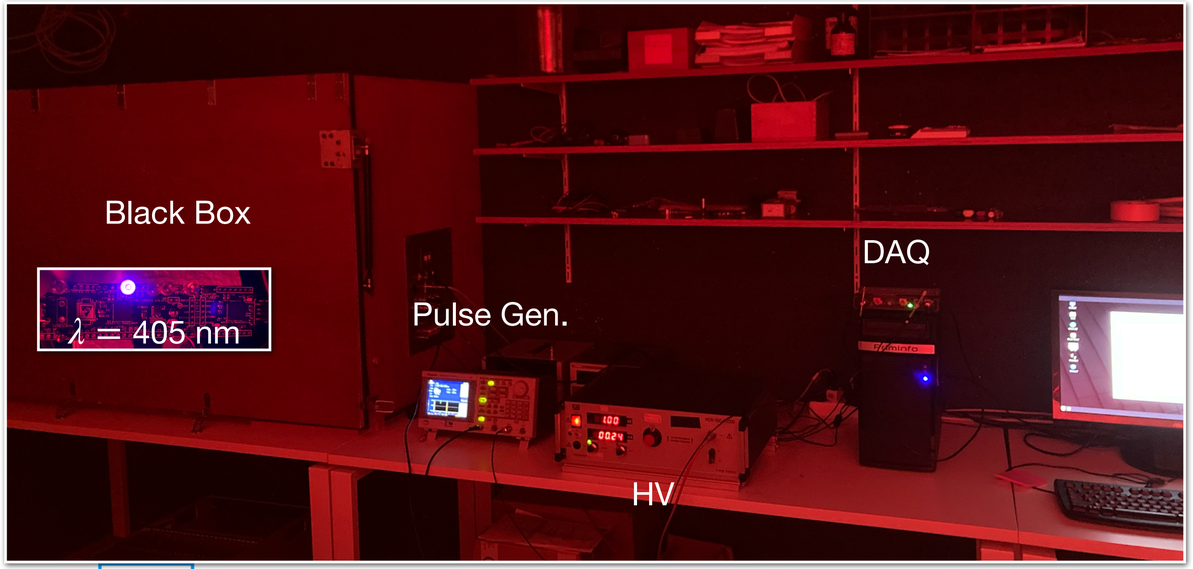
PMT testing @ FZU - Prague & ULB - Brussels

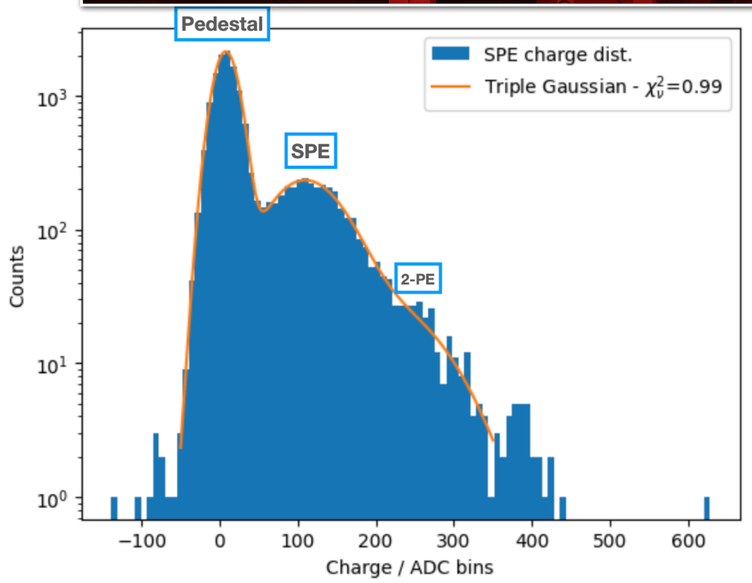
- Are Hamamatsu R5912 suitable for PEPS?
- Six PMTs were tested at FZU (Prague), current crosschecks in Brussels
- Tests:
  - Single Photo Electron spectrum
  - Gain VS high voltage
  - Non-linearity
  - Afterpulse analysis
  - Dark rate
- Adapting the PMT-Base-UB interface and acquisition





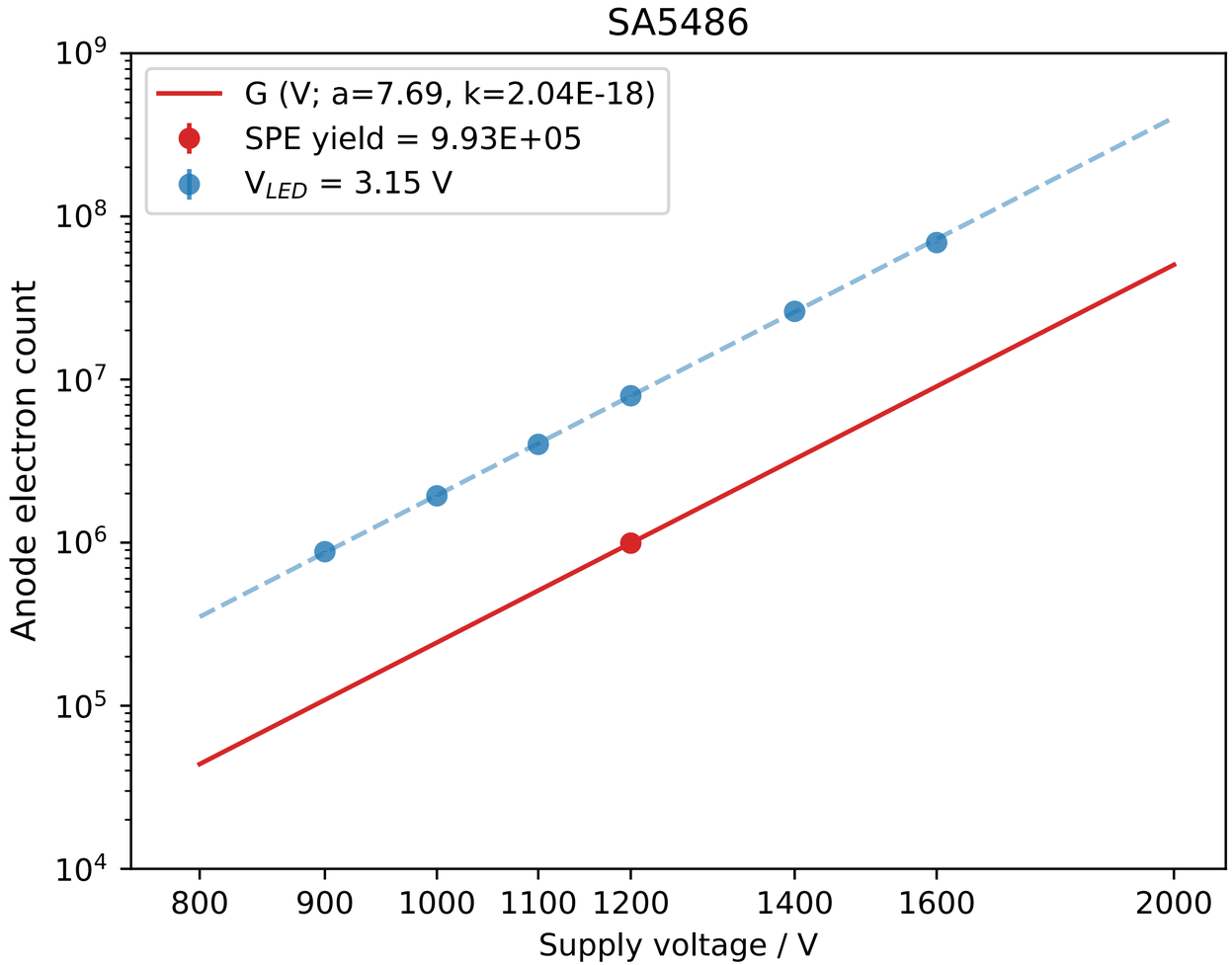


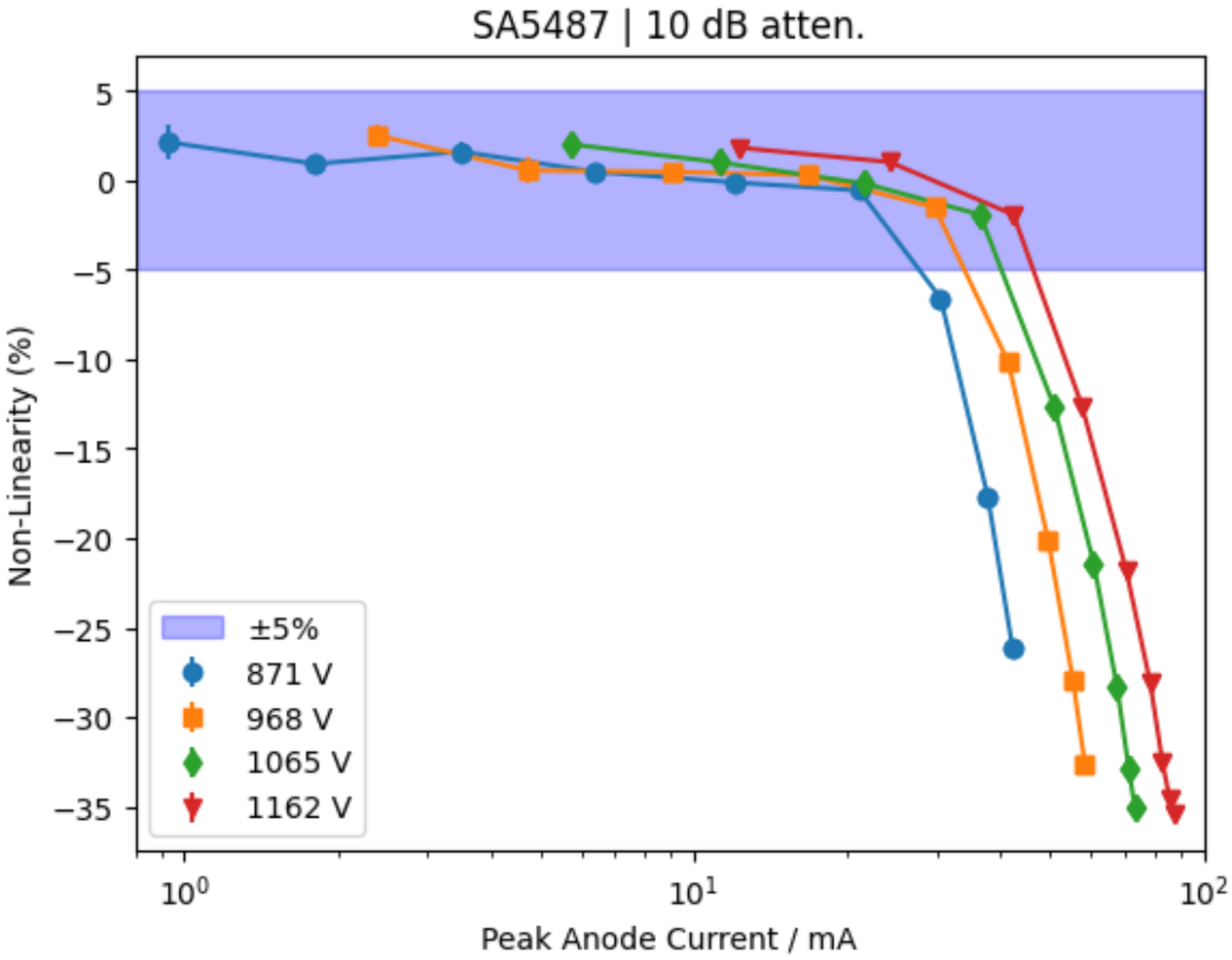






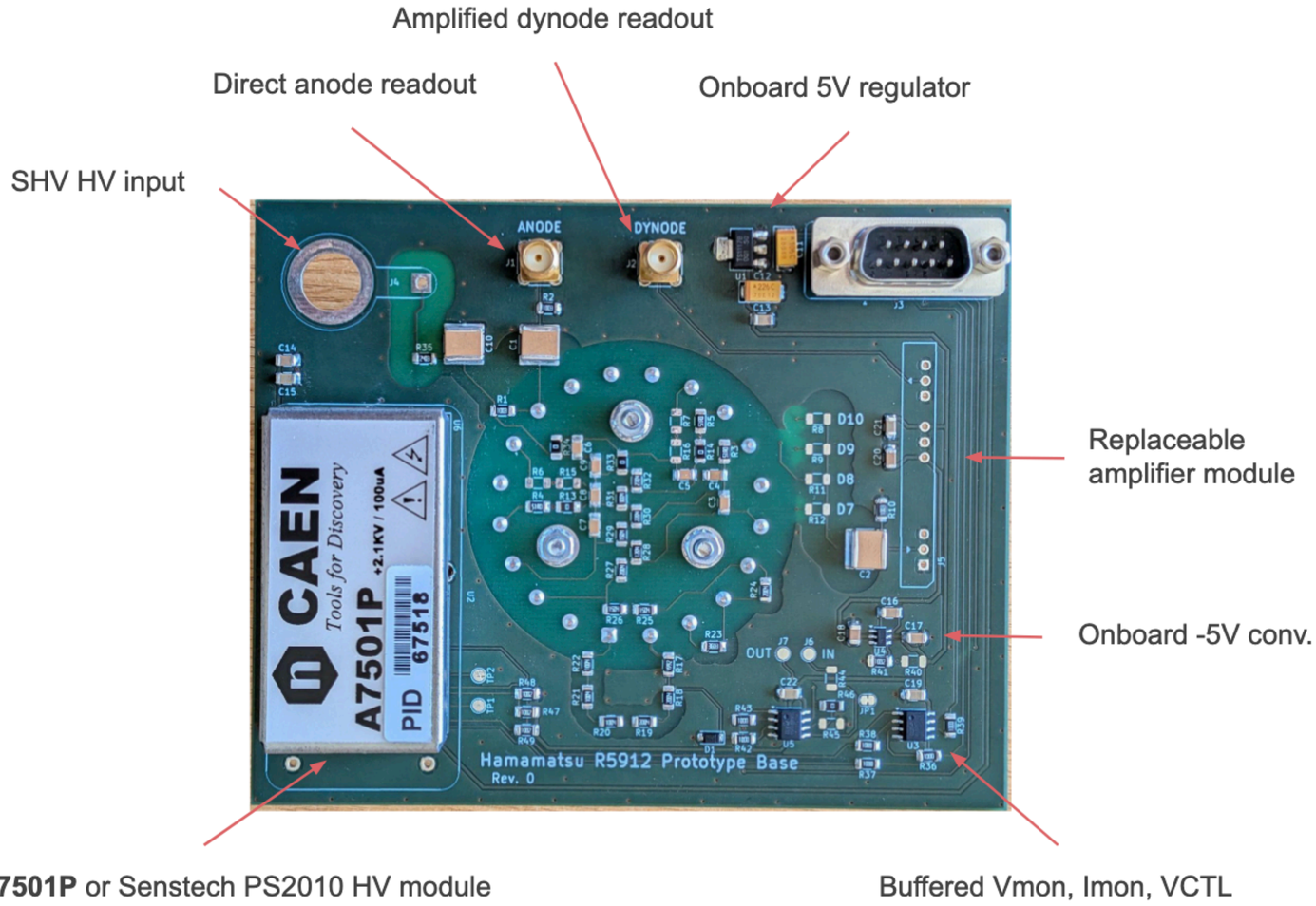
PMT gain and linearity measurements





PMT base development

- Developed at FZU, Prague.
- Based on the Auger-base model
- Works with R5912 / R5912-03
- Compatible with UB / UUB (tested)
- Power: 1.5 W stby, 4.5 W @ 2000V
- Optimization/integration still ongoing



PEPS communications system

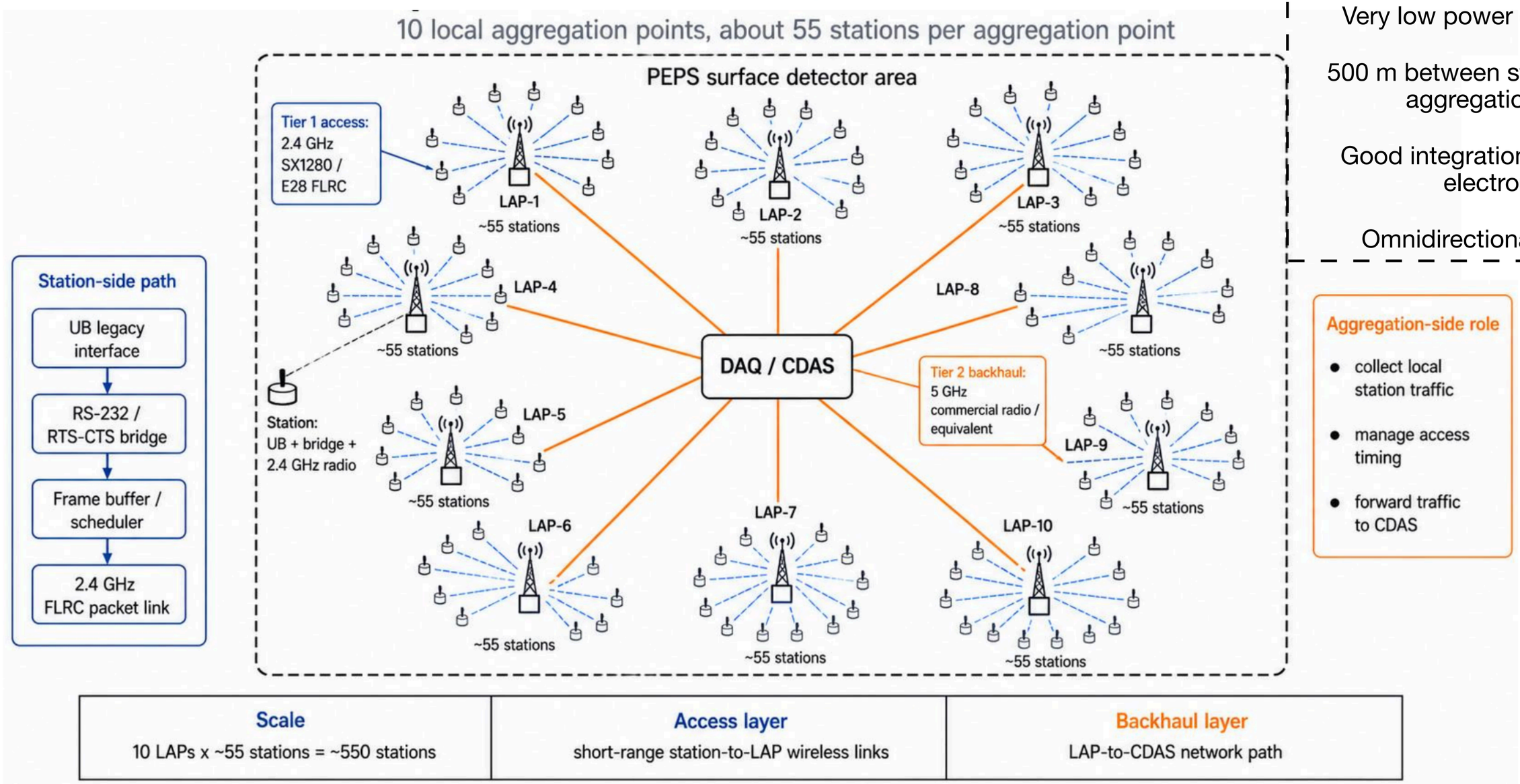
Wireless 2.4 GHz two tier system

Very low power consumption

500 m between stations in local aggregation point

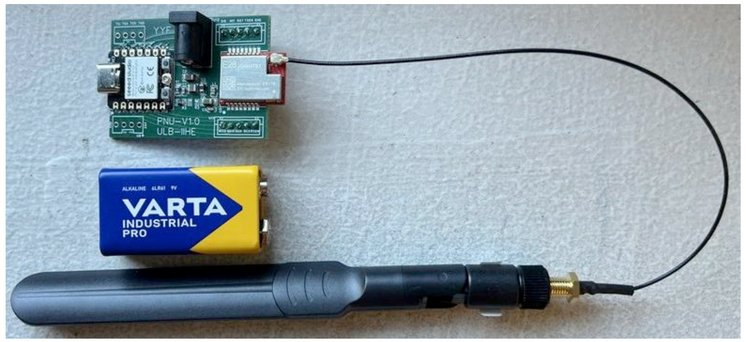
Good integration with current electronics

Omnidirectional antennas



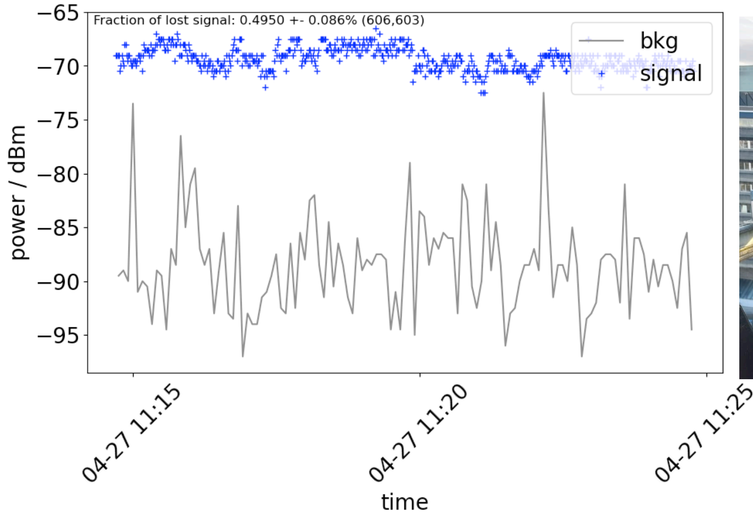
Scale	Access layer	Backhaul layer
10 LAPs x ~55 stations = ~550 stations	short-range station-to-LAP wireless links	LAP-to-CDAS network path

PEPS communications system



Greluma 2x8dBi 2.4/5/5.8GHz Double Bande WiFi RP-SMA Antenne
Freq.= 2.4 + 5 GHz
Power Cons. = < 3 W
Range >~ 1 km

Ubiquity airMax Rocket-Bullet 5AC Lite BaseStation
Freq.= 2.4 + 5 GHz
Power Cons. = > 6-8 W
Range = 5-15 km





- Currently adapting and testing different off-the-shelf communication systems.
- UB compatibility
- Investigating data transfer performance, power consumption, operating range, overall cost, etc.

~ 700 m



PEPS workshops

Brussels, October 2025







Osaka, May 2026





Next one to be held in Brussels beginning 2027.

Conclusions and outlook

- Probing Extreme PeVatron Sources: planned as the largest gamma-ray experiment deployed at the Pierre Auger Observatory to observe the Southern hemisphere sky above 2 PeV

- Cost-effective design based on segmented water Cherenkov detectors using decommissioned equipment from the Pierre Auger Observatory

- Hardware developments are progressing: characterization of PMT and its base, adaptation of communications systems and mechanical parts

- Plans to deploy a small 8-station array in 2026/2027 (PEPSino)

Interested? Join us!

Special thanks to the Pierre Auger Collaboration!

Back-up

Gamma absorption (CMB - IR)

