

Probing Extreme PeVatron Sources PEPS

Ioana C. Mariş

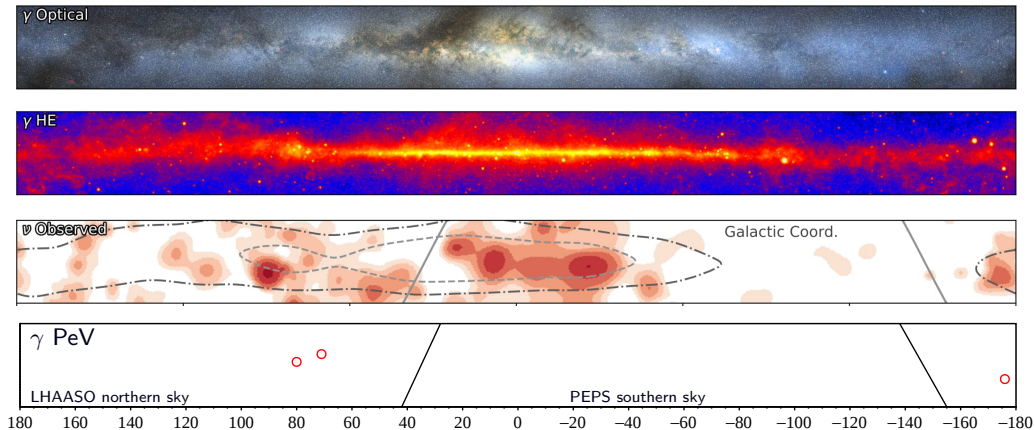
Université Libre de Bruxelles

TeVPa, Valencia, November 3, 2025



PEPS: Breaking the energy frontier

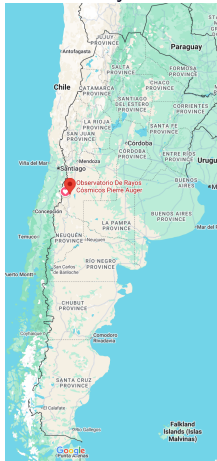
10 km² detector to measure gamma-rays between 1 PeV and 50 PeV



Discovery potential in the new energy range with
a unique view of the Galactic Center and southern galactic sky!

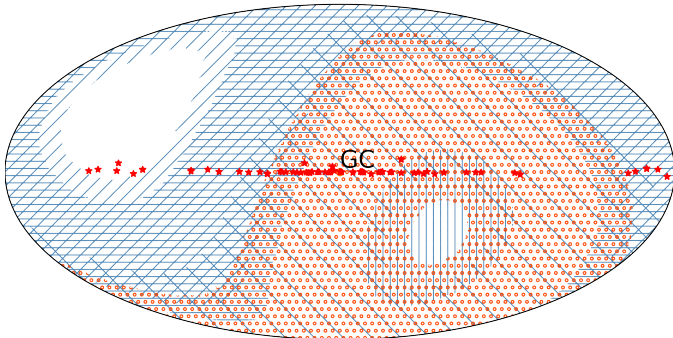
Looking at the southern sky for extreme galactic sources

At the Pierre Auger Observatory



Complementary with LHAASO/HAWC and a good coverage of the Galactic plane and Galactic Center.

Good sky overlap with SWGO/ALPACA (measuring at lower energies)



LHAASO



IceTop



SWGO



HAWC

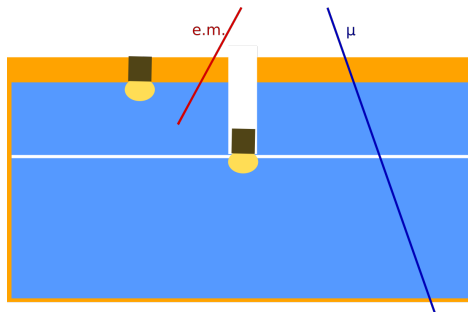
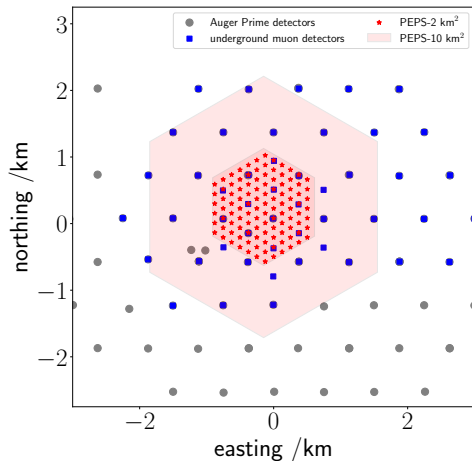


PEPs

red points: TeVCat sources (tevcat.org)

Using a segmented water-Cherenkov detector

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

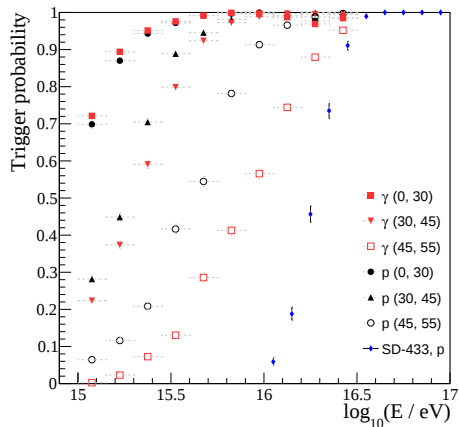


Layered Water Cherenkov detectors optically separated

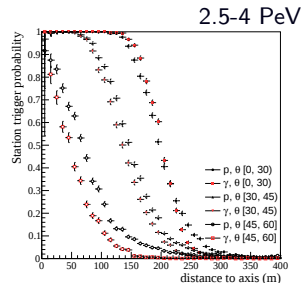
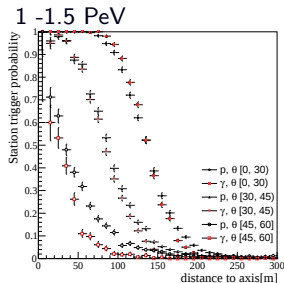
(A. Letessier-Selvon, P. Billoir, M. Blanco, IM, M. Settimo, NIM A767 (2014),
arxiv:1405.5699)

Trigger efficiency

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



Corsika/EPOS-LHC, Geant4

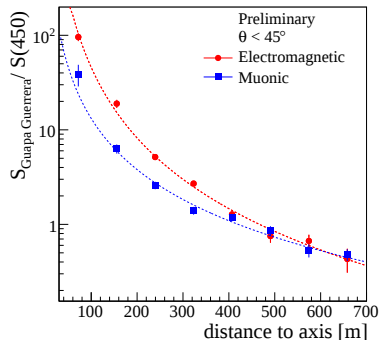


An array with a spacing of 145 m between the detectors

prod. of simulations by N. Gonzalez and E. Santos

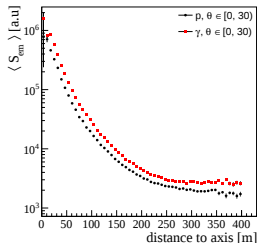
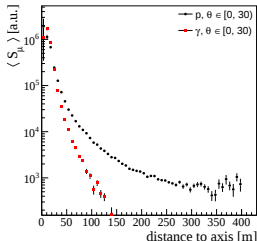
Photon-proton separation

Data from prototypes

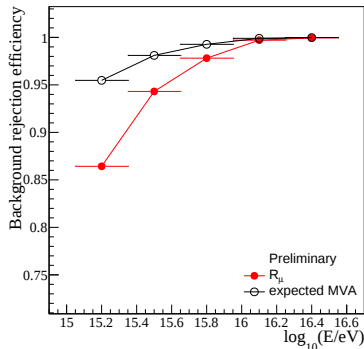


Average LDFs with two months of data in 2014 ($E > 10$ PeV)

simulations



at 50% photon efficiency

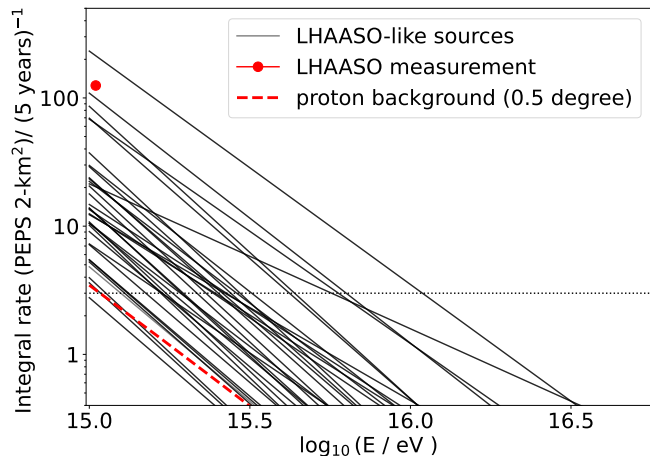


Basic separation variables, summed over N stations:

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

Discovery of extreme PeVatrons in the Southern sky?

What is the maximum available energy in our Galaxy?



Extrapolations of the LHAASO sources.

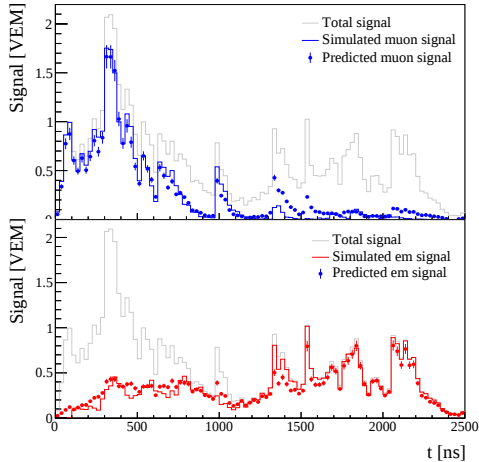
LHAASO measures about 25 photon-like events above 1 PeV / year

Expected between 1 and 10 events/ year above 3 PeV

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

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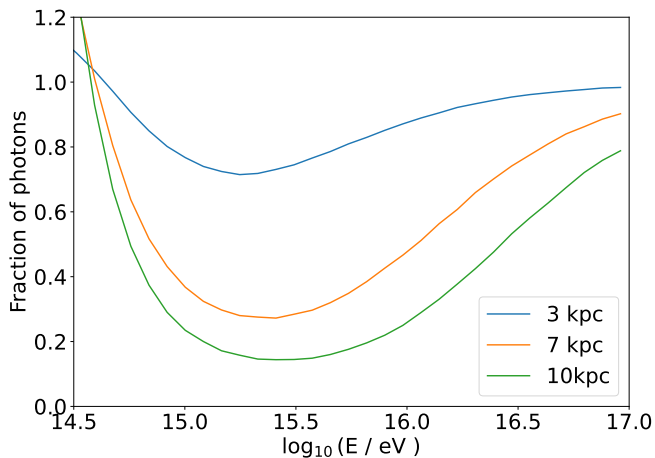
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RNN expected to improve sensitivity (O.Zapparata, PhD thesis, Auger coll.,

JINST 16 (2021) P07016)

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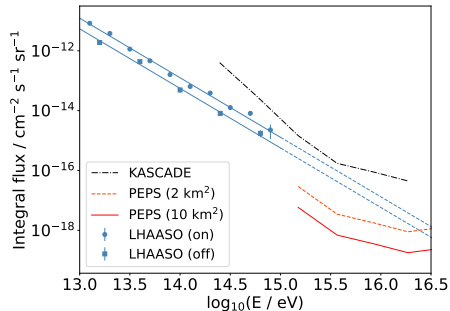
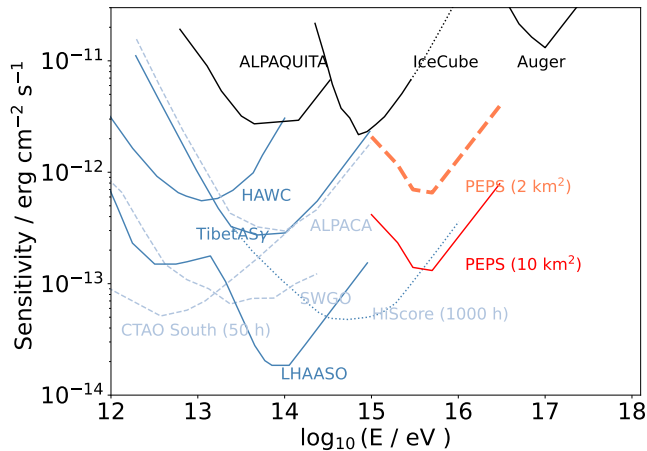
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γ - γ interactions important at distances larger than 5 kpc

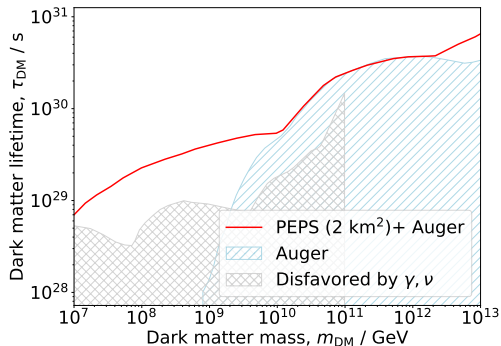
PEPS Sensitivity to point sources and diffuse flux



Discovery potential above 1-3 PeV from the Southern Hemisphere

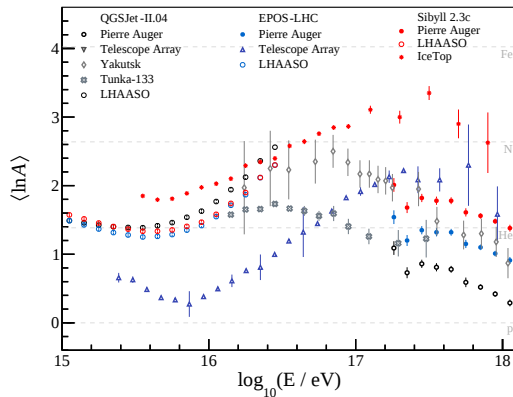
Is there an extra high-energy component in the diffuse flux?

Super-heavy dark matter and charged cosmic rays



from O. Deligny

Probes of meta-stable super-heavy dark matter
 Models with the SHDM decaying into
 low-multiplicity (e.g. sterile neutrinos, spin 3/2
 particles)



Extend down in energy the Auger measurements
 (allows for a cross-calibration between fluorescence
 and surface detectors)

Detector design and construction

First PEPS workshop took place in Brussels last week

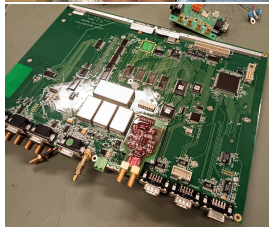
Design based on robust segmented detectors, leveraging previous expertise and similarities to SWGO
(2 detectors operating since 2014)

Cost effective: Use decommissioned components for non-critical parts
(Pierre Auger Observatory unified boards and solar panels)

Prototypes are currently built to be deployed in 2026 in Malargue
(Brussels, Prague and Osaka)



(2014)



(2024)

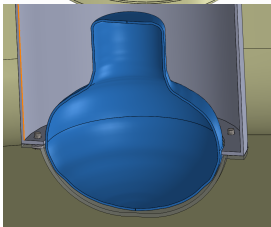
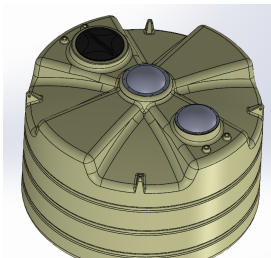
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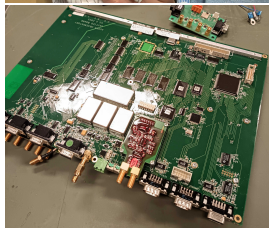
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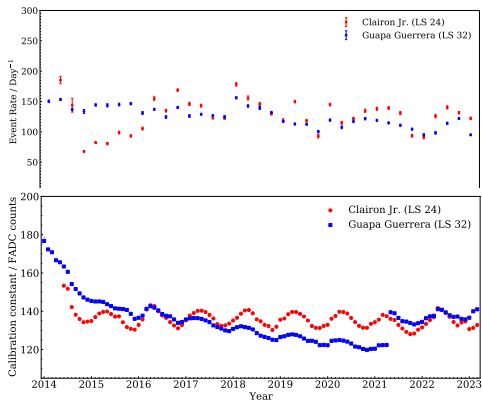


drawings by L. Mendez



(2024)

Stability and calibration of the detector



Use existing infrastructure of the Auger Observatory for assembling, water purification, and deployment

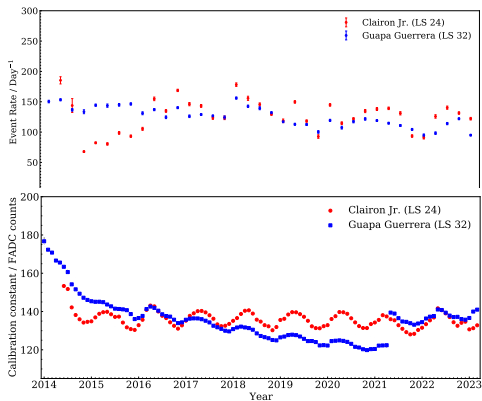
Optimisation of the PEPS geometry

PEPS can be fully operational in 2.5 years



Deployment in 2014

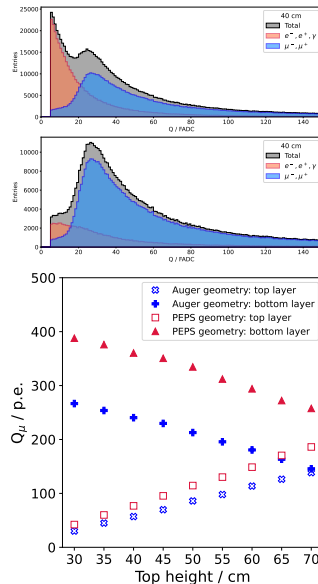
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Probing Extreme PeVatron Sources (PEPS)



- The world's largest observatory for gamma-rays in the energy range 1-50 PeV
- First observation of the most energetic gamma-rays in the Milky Way Galaxy as seen from the Southern sky
- PEPS 2-km²: A pioneering first step towards a future 10-km² array

Interested in PEPS? Join mailing list: <https://listserv.vub.be/mailman/postorius/lists/peps.listserv.vub.be/>