STACEX

RPC-based detector for a multi-messenger observatory in the Southern Hemisphere

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STACEX proposal:

STACEX: RPC-based detector for a multi-messenger observatory in the Southern Hemisphere

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Extensice Air Shower (EAS) arrays are survey instruments able to monitor continuously all the overhead sky. Their wide field of view (about 2 sr) is ideal to complement directional detectors by performing unbiased sky surveys, by monitoring variable or flaring sources, such as AGNs, and to discover transients or explosive events (GRBs). With an energy threshold in the 100 GeV range EAS arrays are transient factories. All EAS arrays presently in operation or under installation are located in the Northern hemisphere. A new survey instrument located in the Southern Hemisphere should be a high priority to monitor the Inner Galaxy and the Galactic Center.
STACEX is the proposal of a hybrid detector with ARGO-like RPCs coupled to Water Cherenkov Detectors (WCDs) mainly to lower the energy threshold at 100 GeV level.

arXiv:1907.06686

STACEX proposal:

- Locate a particle detector at high-altitude ~(4.5-5) km a.s.l

- Combined a hybrib detector:

  - RPC carpet 150x150 m^2, with a 0.5 mm lead layer above

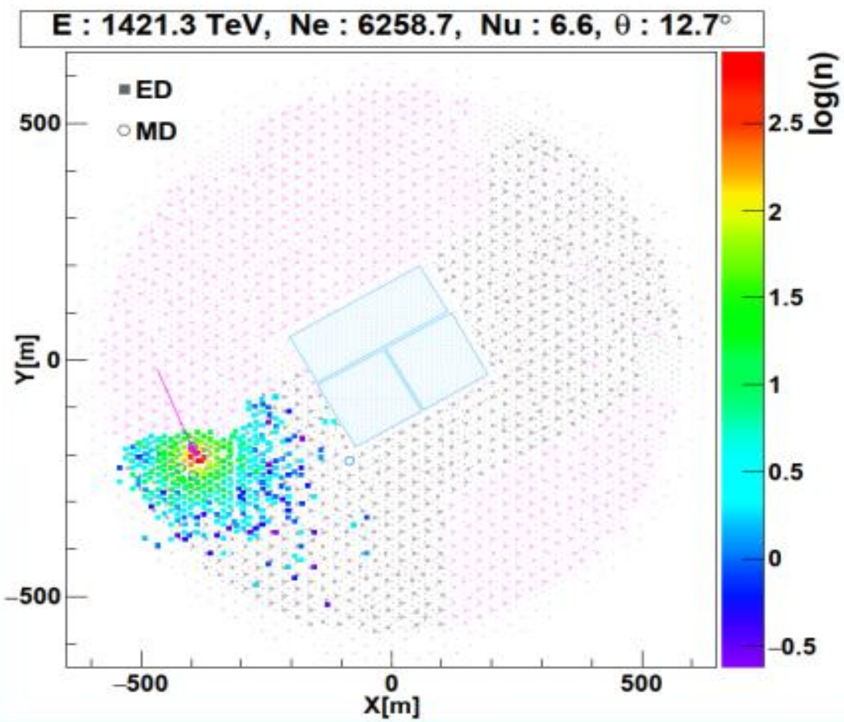
    - Dense sampling for a very low energy threshold (~100 GeV);
    - Dynamical range from 100 GeV to 10 PeV.
    - High granularity of the read-out to have:
      - Good energy resolution (20% or better) above a tens of TeV
      - Good angular resolution (~ 0.2°)

  - Water Cherenkov detector below the carpet to exploit good background discrimination above tens of TeV.

LHAASO: Gamma-rays up to PeV

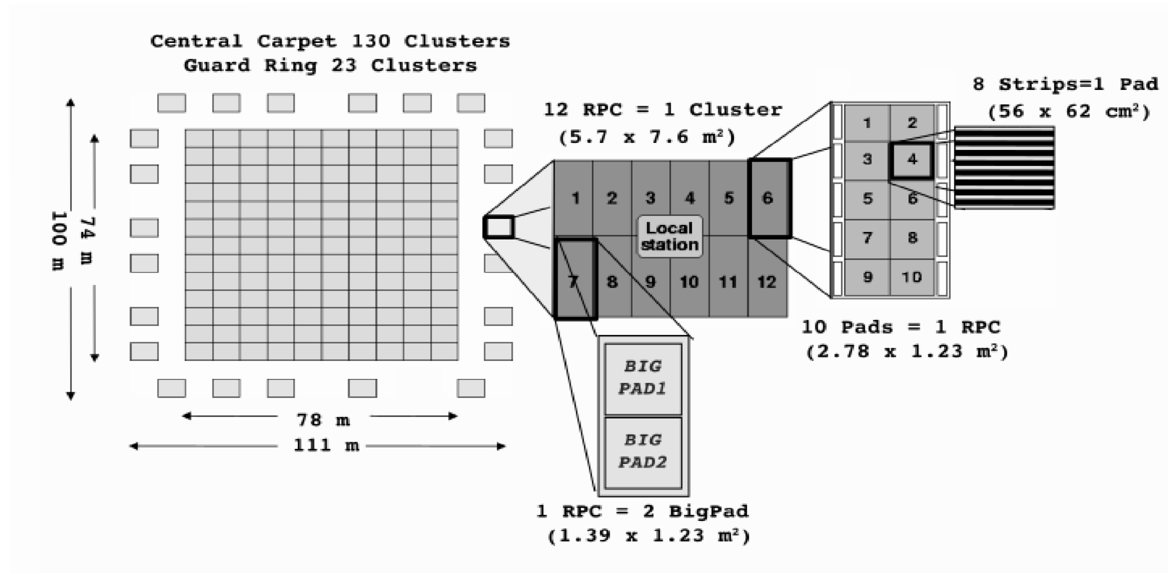
Table 1 | UHE γ-ray sources

Source name	RA (°)	dec. (°)	Significance above 100 TeV (×σ)	E_{max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	83.55	22.05	17.8	0.88 ± 0.11	1.00(0.14)
LHAASO J1825-1326	276.45	−13.45	16.4	0.42 ± 0.16	3.57(0.52)
LHAASO J1839-0545	279.95	−5.75	7.7	0.21 ± 0.05	0.70(0.18)
LHAASO J1843-0338	280.75	−3.65	8.5	$0.26 - 0.10^{+0.16}$	0.73(0.17)
LHAASO J1849-0003	282.35	−0.05	10.4	0.35 ± 0.07	0.74(0.15)
LHAASO J1908+0621	287.05	6.35	17.2	0.44 ± 0.05	1.36(0.18)
LHAASO J1929+1745	292.25	17.75	7.4	$0.71 - 0.07^{+0.16}$	0.38(0.09)
LHAASO J1956+2845	299.05	28.75	7.4	0.42 ± 0.03	0.41(0.09)
LHAASO J2018+3651	304.75	36.85	10.4	0.27 ± 0.02	0.50(0.10)
LHAASO J2032+4102	308.05	41.05	10.5	1.42 ± 0.13	0.54(0.10)
LHAASO J2108+5157	317.15	51.95	8.3	0.43 ± 0.05	0.38(0.09)
LHAASO J2226+6057	336.75	60.95	13.6	0.57 ± 0.19	1.05(0.16)

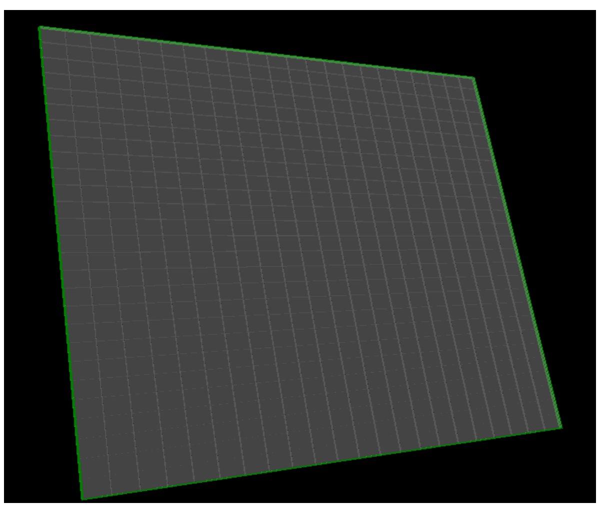


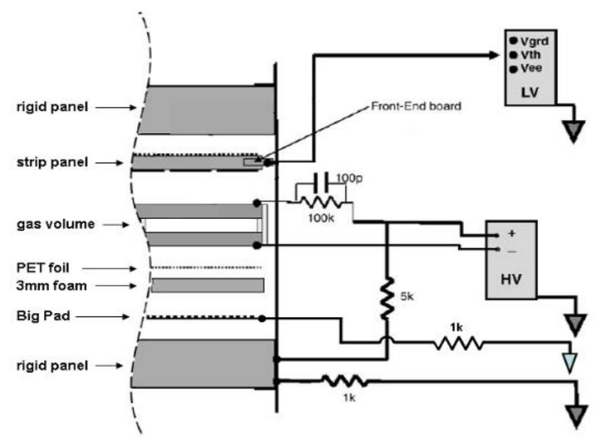
- 12 gamma-ray source that emits up to PeV energies discovered
- High Standard: significance >7σ
- BG-free: Cosmic Ray background rejection rate of 10^{-5}

Geant4 mass model for STACEX

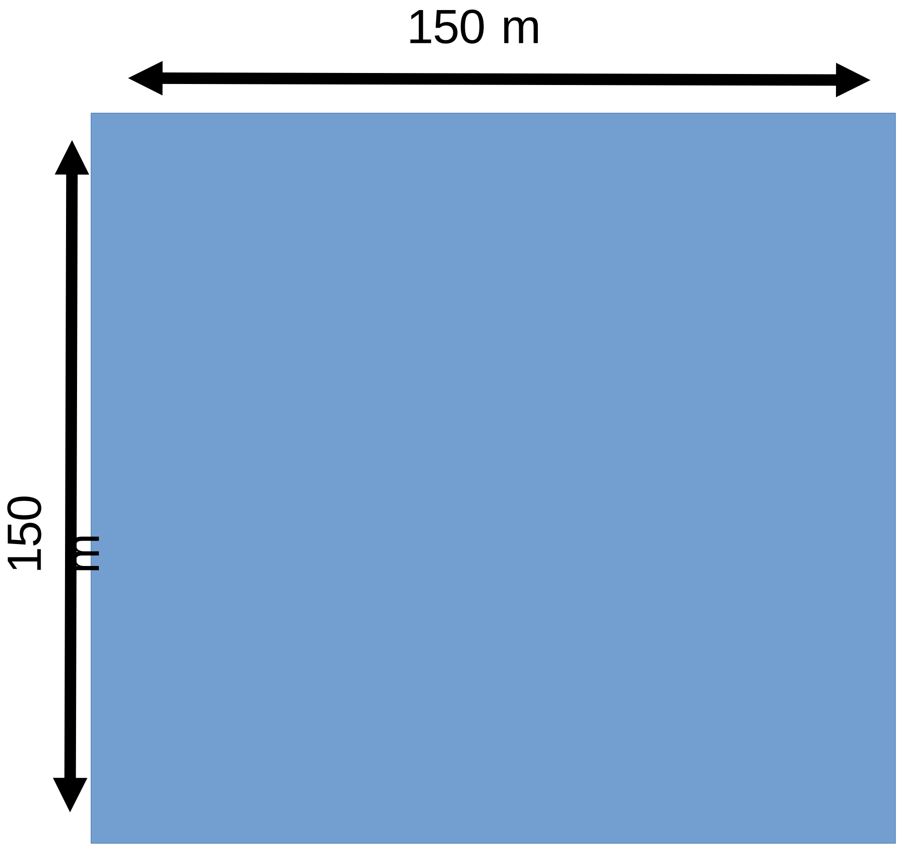


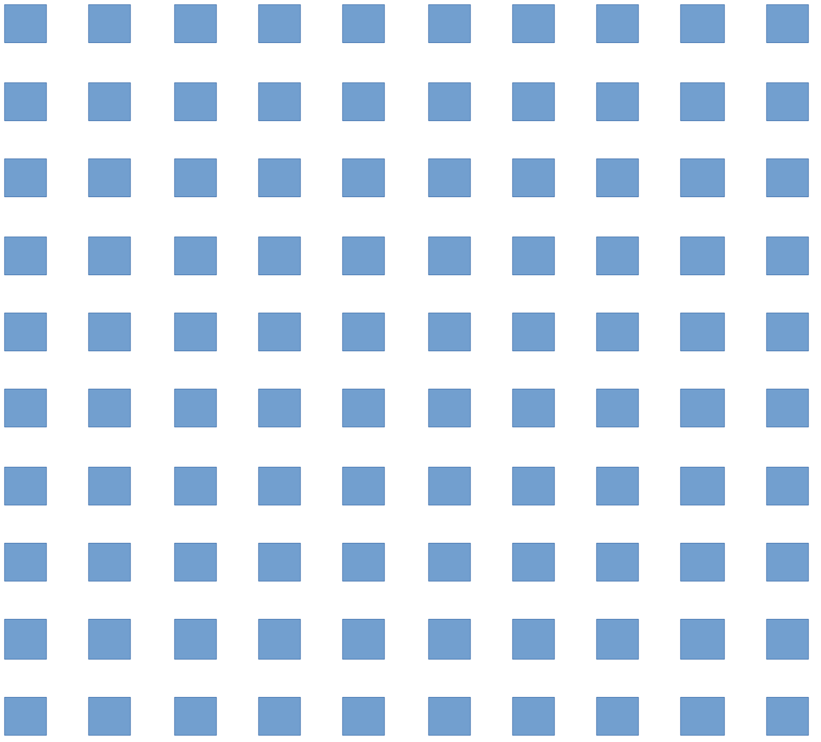
Argo RPCs
0.5 mm of Pb above carpet
Array Muon Detector below



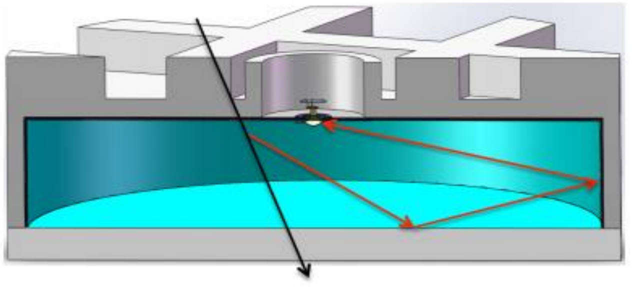


Muon layouts



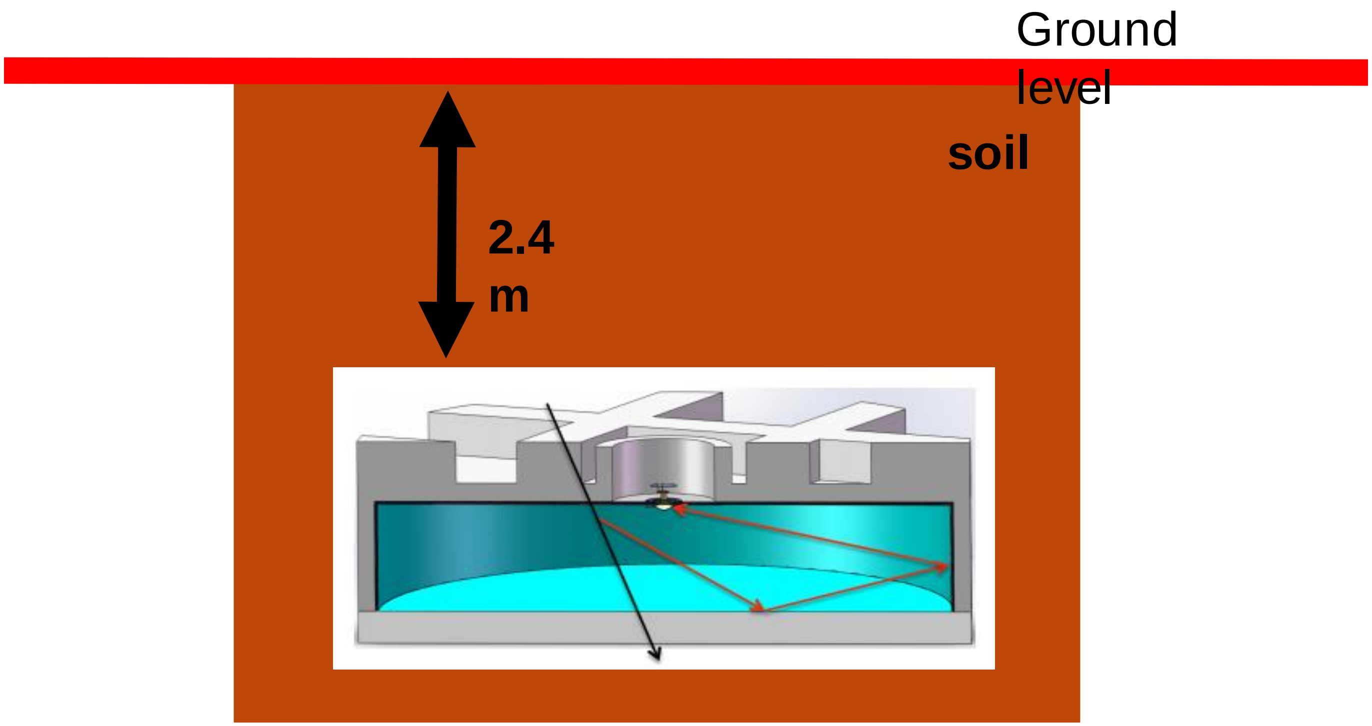


water Cherenkov tanks
LHAASO-like
buried under 2.4m of soil



10x10 detectors
6 x 6 m^2
Separation=15m

Muon Detector



Array of 10x10 MD detectors:

Each MD is a cilindrical LHAASO-like water Cherenkov detector with area 36 m^2 and height 1.2 m

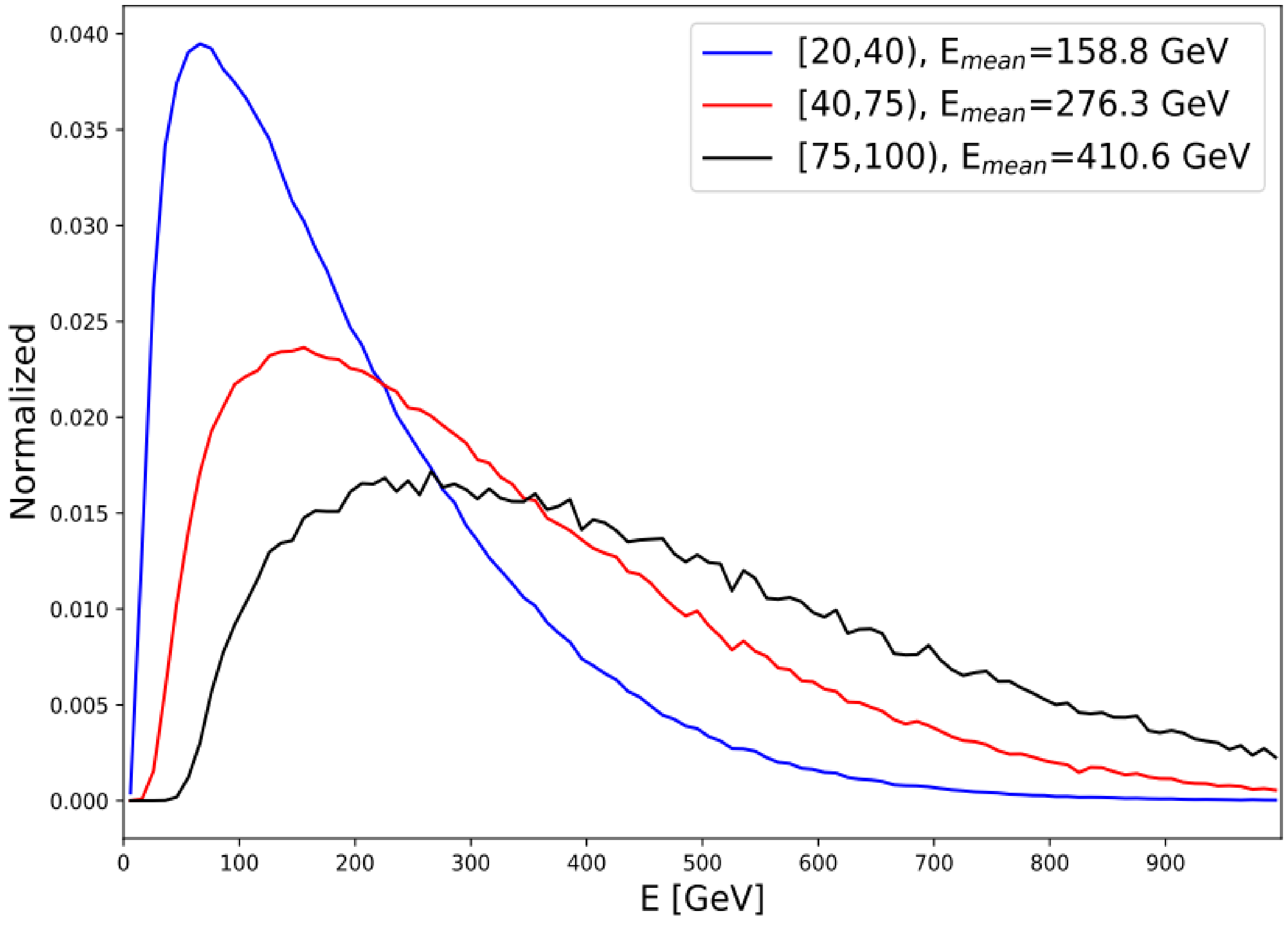
With one downward 8” or 20” PMT (Energy thershold 1 GeV)

Corsika simulation sample:

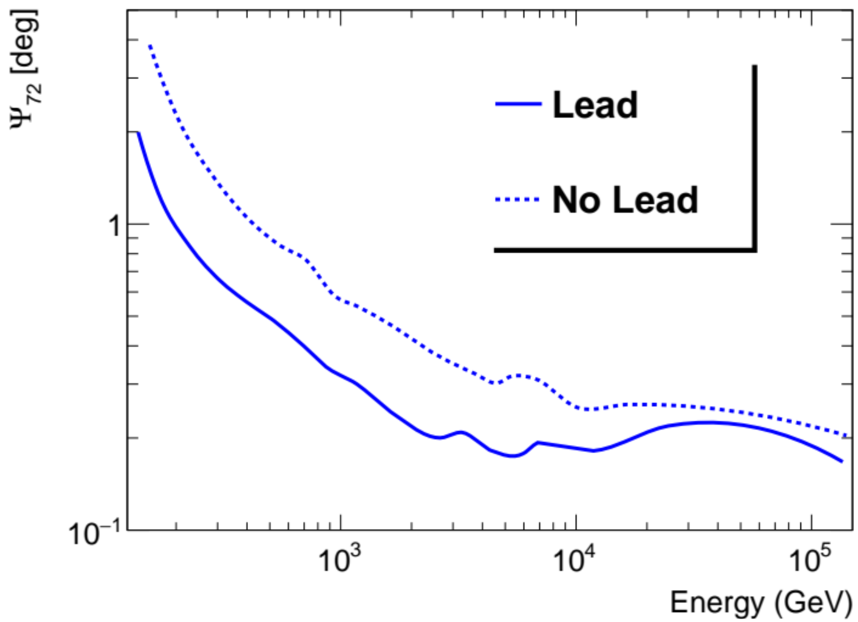
- Primary: Gamma, Proton
- Obs Levels: 5 km
- Zenith: [20] deg.
- Azimuth: [0,360] deg
- Crab Simulations: γ=-2.41
- Proton Background: γ=-2.7
- Energy range: 10 – 10^6 GeV
- Number of primaries (γ & p) = $6x10^8$

- Layout & mass model is simulated using Geant4 framework
- Core sample area 600x600 m^2
- We have used ROOT for the reconstruction algorithms

Energy distribution

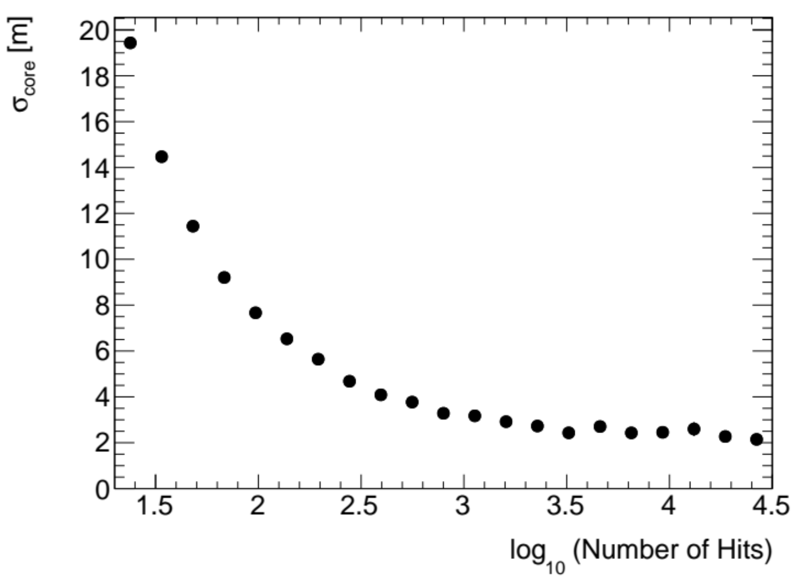


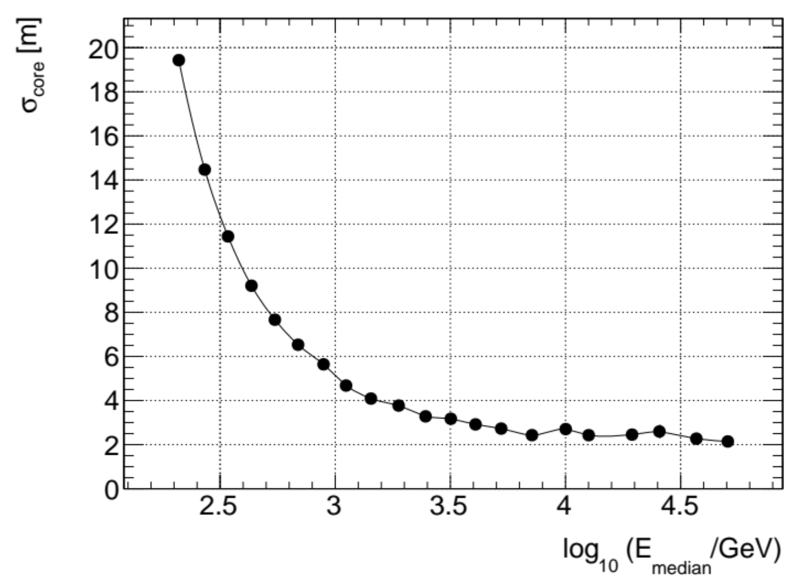
Angular & Core Resolution



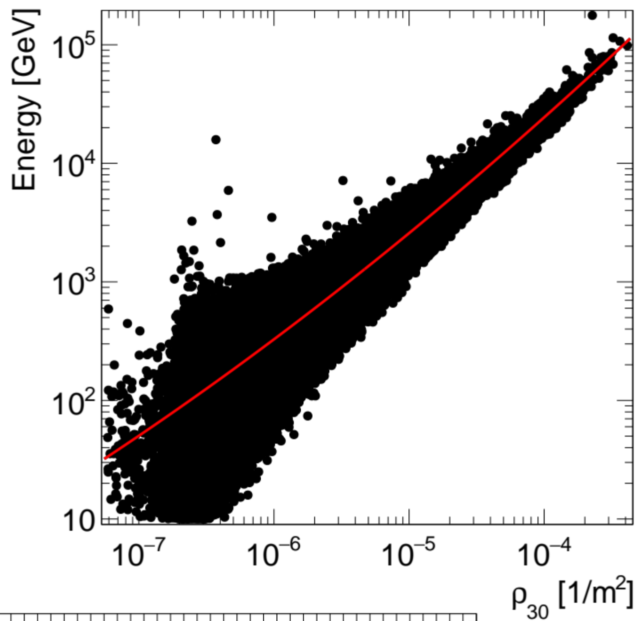
Lead effect:
At 100 GeV → 5.7º to 2.9º
At 1 TeV → 0.57º to 0.32º

Arrival direction: resolution of 0.26° @1 TeV
Shower core location: resolution of 2 m @10 TeV

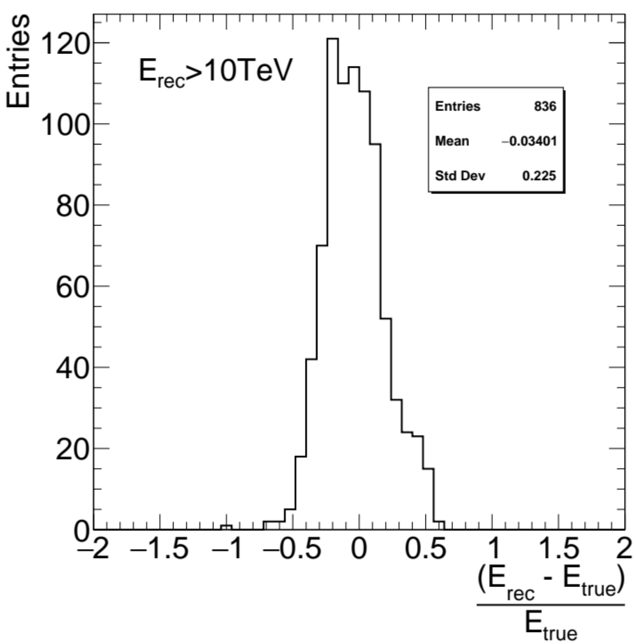


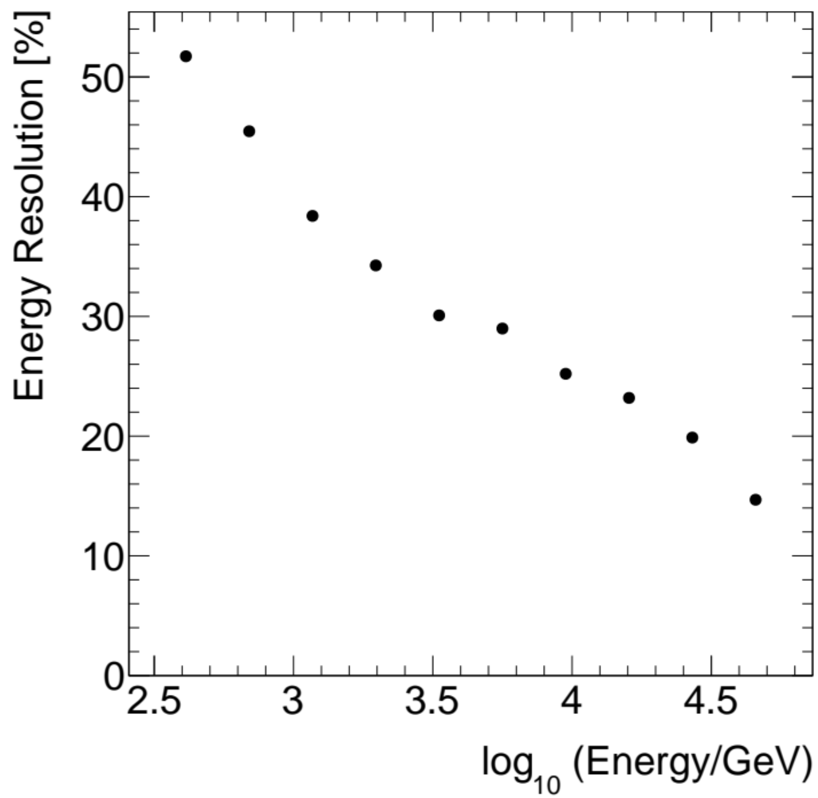


Shower Energy Reconstruction

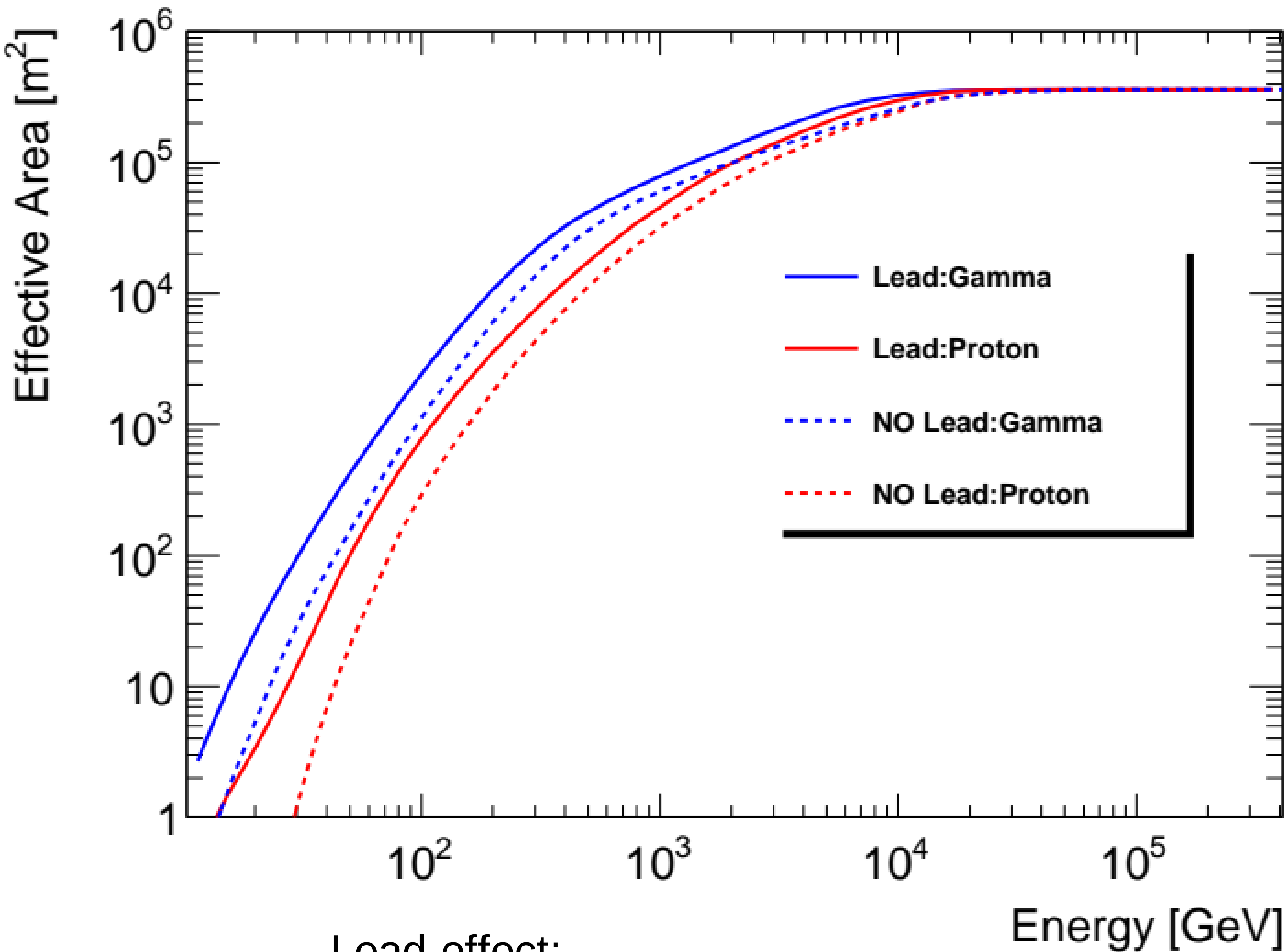


- Lateral distribution: NKG function
- Energy estimator: density at 30m
- Gaussian Resolution function >10 TeV:22%
- Linear response function



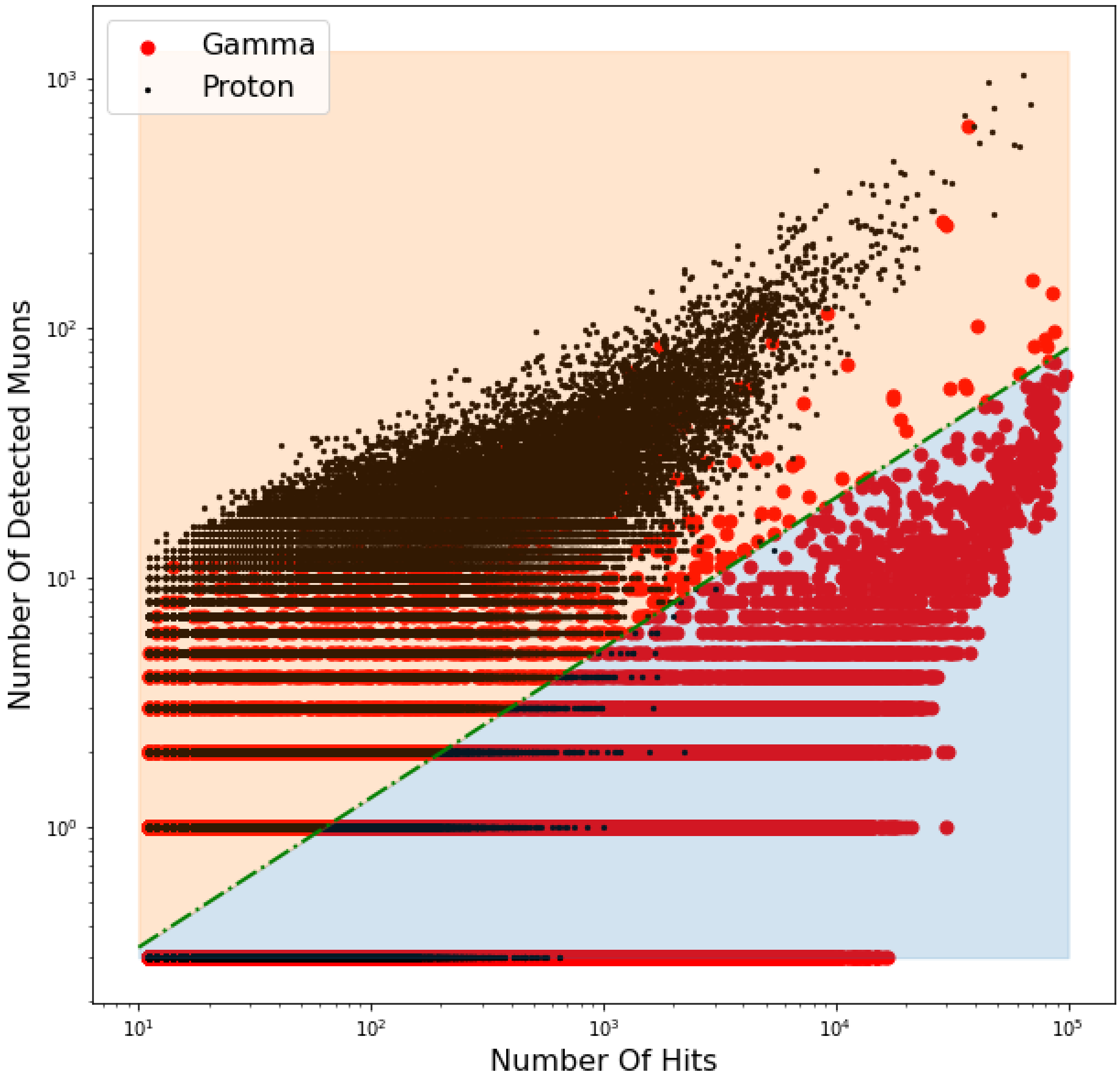


Effective Area at to PeV



Lead effect:
At 100 GeV → increase 50%
At 1 TeV → increase 23%

Gamma-hadron discrimination



We apply a binary classification
using a logistic regression.

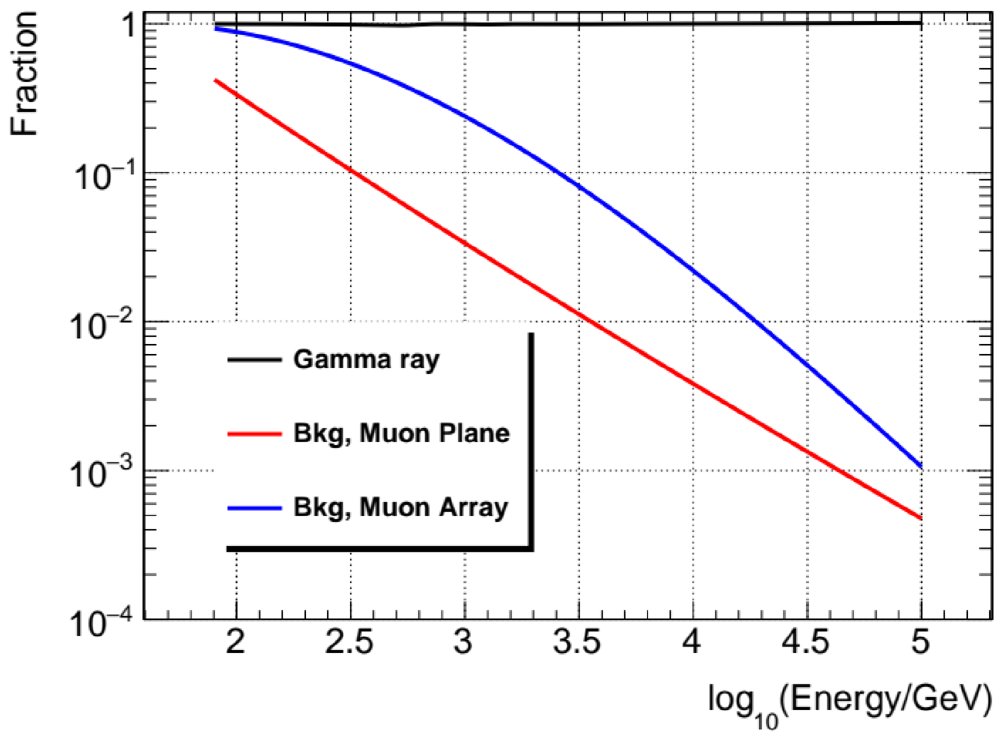
$$y = 1/(1 + e^{-x})$$

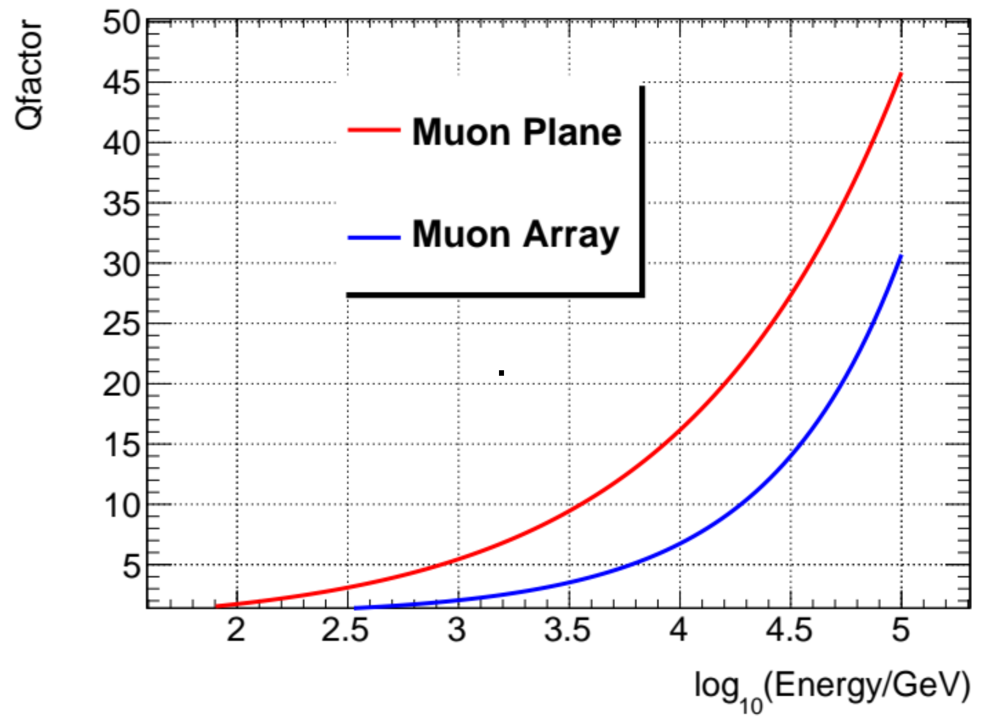
As a result we obtain a surface that separate g/h as a function of number oh hits

Q-Factor VS Energy

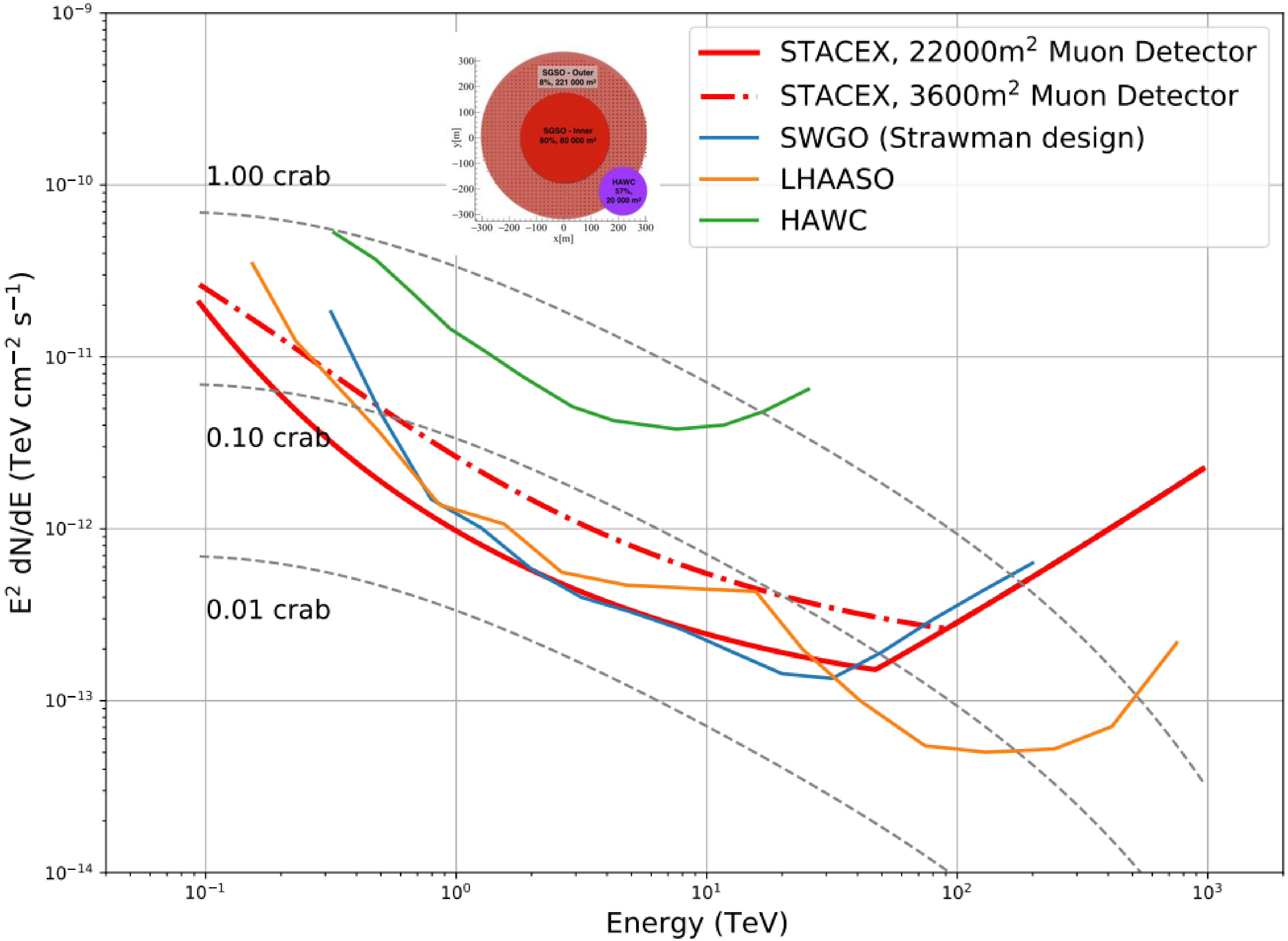
Q-Factor

$$Q = \frac{Survival\ Ratio\ of\ \gamma}{\sqrt{Survival\ Ratio\ of\ proton}}.$$





Differential Sensitivity WITH LEAD



Summary and NEXT

- We have simulate a particle detector at high-altitude ~(4.5-5) km a.s.l
- Combined a hybrib detector:
  - RPC carpet 150x150 m^2, with a 0.5 mm lead layer above.
  - Muon array at 2.4 m below RPCs (under ground)

TO BE DONE:

- Migrate the RPC simulation into SWGO software framework
  - What layout?
- Migrate the angular and energy reconstruction algorithms