THE PERFORMANCE OF THE HALF DENSITY ALPACA

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   - 100 TeV gamma-ray observation in the northern hemisphere
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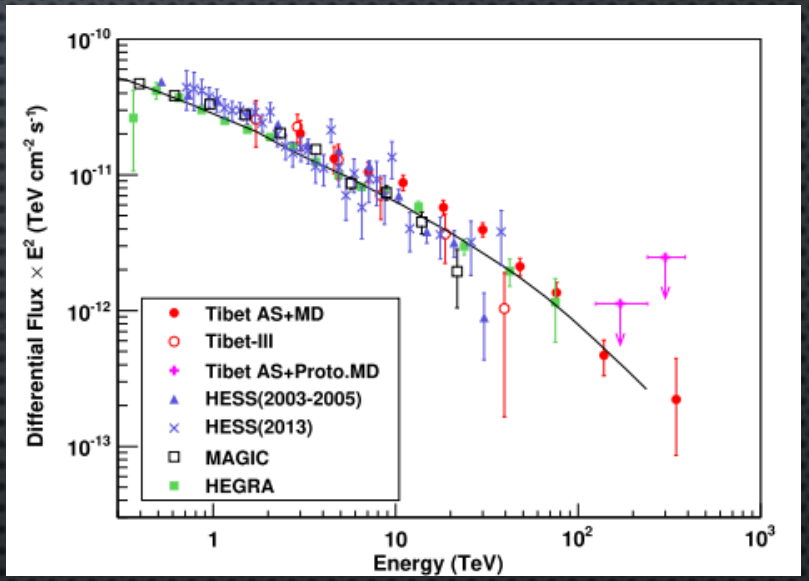
4. Conclusion

100 TeV gamma-ray observations in the northern hemisphere.

・ Photons with energy beyond 100 TeV (>300TeV) was detected in the northern hemisphere by Tibet AS γ experiment in 2019 for the first time.(Crab nebula)

・Following the Tibet AS γ observation, HAWC , LHAASO detected photons beyond100 TeV from several sources.



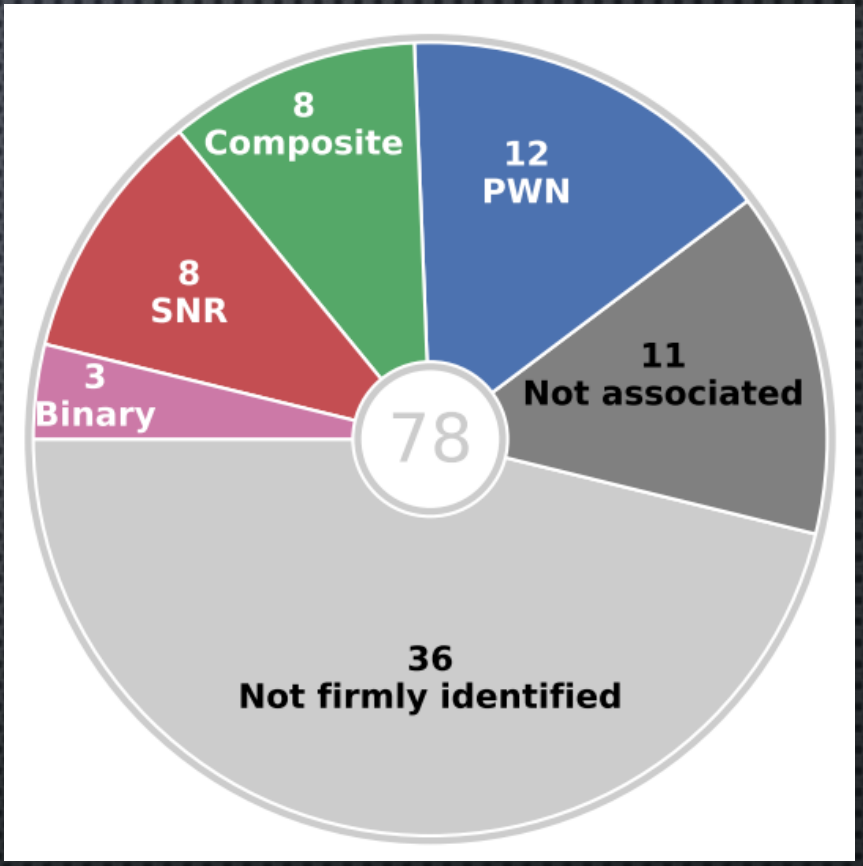
Tibet AS γ experiment

100TeV gamma-ray observation is developing recent years.

First Detection of Photons with Energy beyond 100 TeV from an Astrophysical Source, M.Amenomori et al,(2016)

Importance of the southern hemisphere

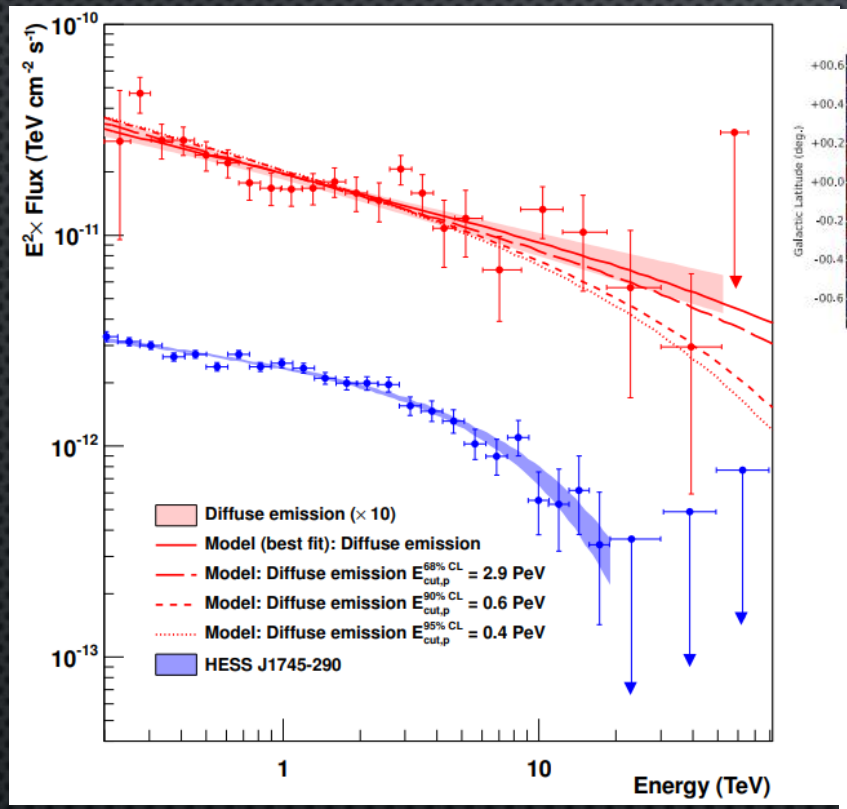
・H.E.S.S. released a Galactic plane survey catalog in 2018. The catalog contains 78 very high energy gamma-ray sources, including PeVatron like sources.

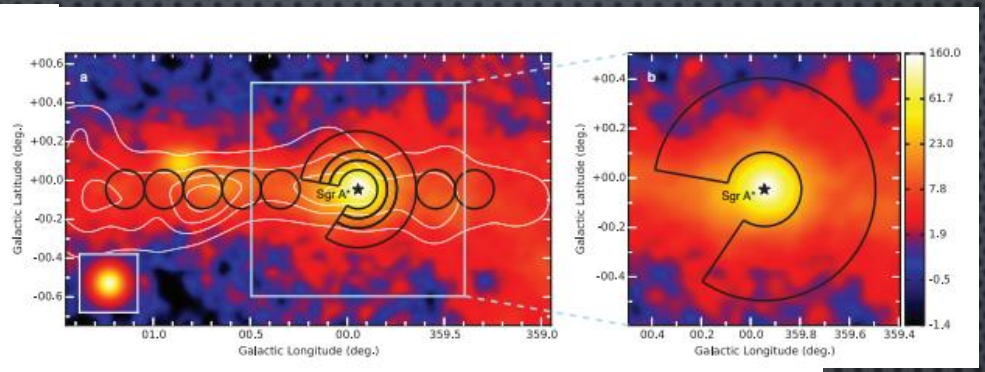


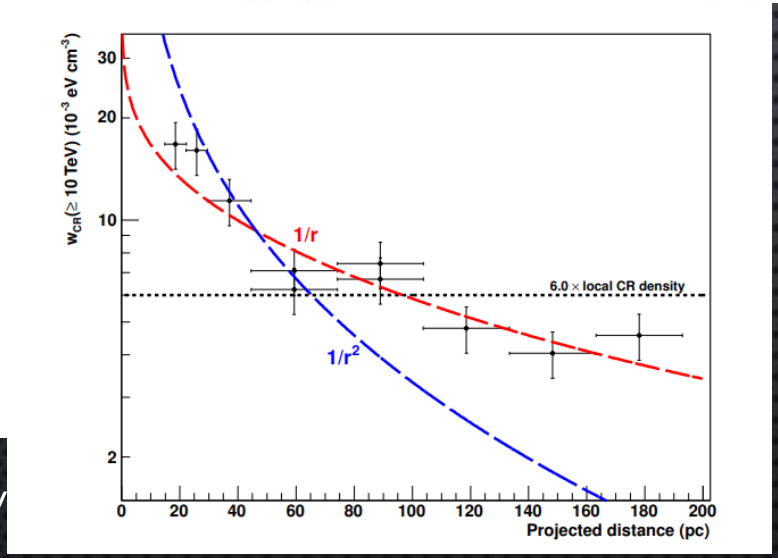
The high energy gamma-ray sources on the H.E.S.S catalog

The H.E.S.S. Galactic plane survey, H.E.S.S. collaboration, (2018)

The Galactic Center observations -1







The Galactic Center gamma-ray Observation by H.E.S.S. (2016)

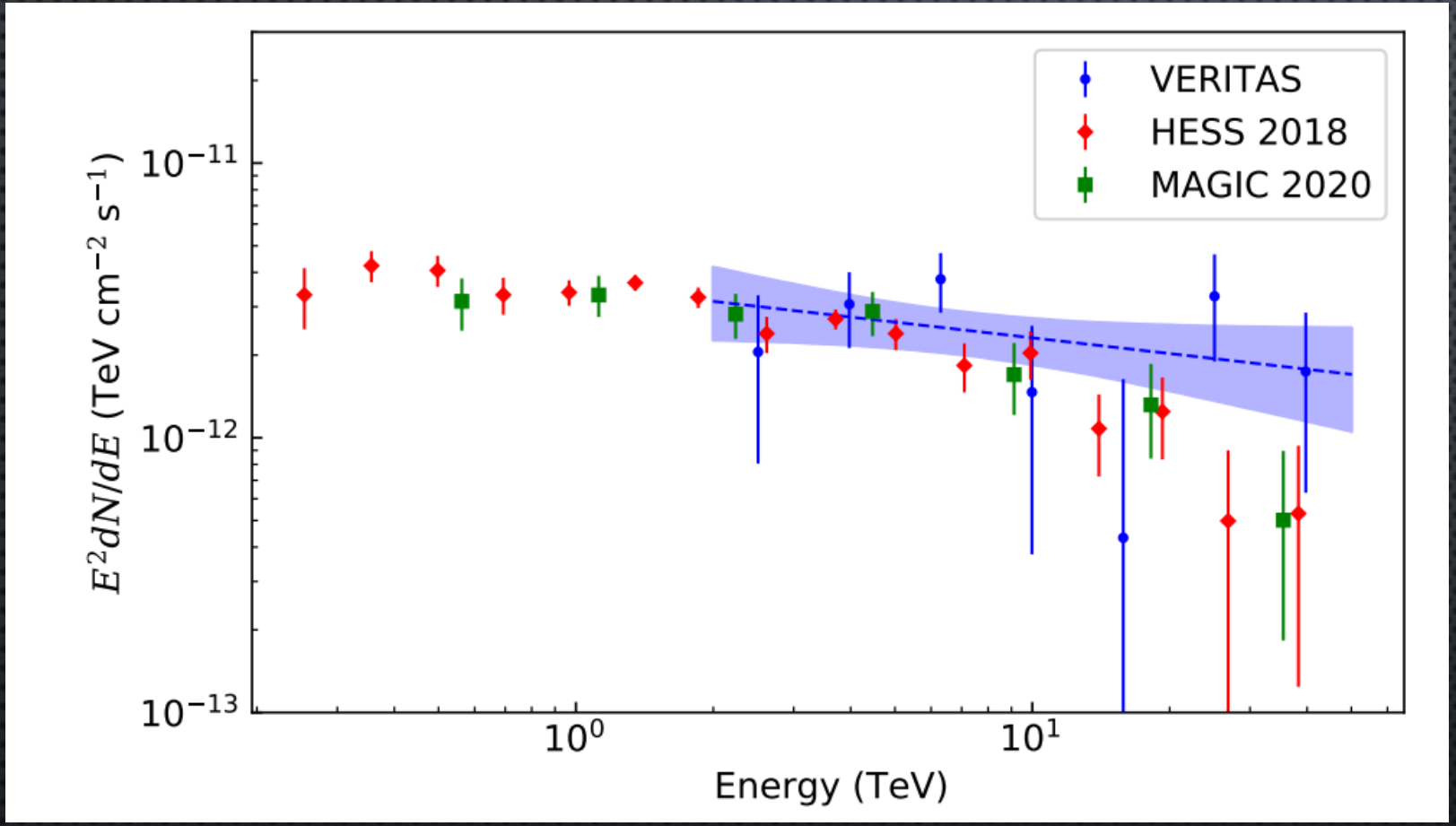
- H.E.S.S. observed diffuse gamma rays from around the Galactic Center in 2016 and 2018.
- Both observations indicate existence of the PeVatron around the Galactic Center.

H.E.S.S collaboration

Acceleration of petaelectronvolt protons in the Galactic Centre(2016)

Characterising the VHE diffuse emission in the central 200 parsecs of our Galaxy with H.E.S.S(2018)

The Galactic Center observations -2



- VERITAS and MAGIC observed the diffuse gamma rays from around the Galactic Center in 2021 and 2020 after H.E.S.S. observation.

- These data estimate that there is PeVatron around the Galactic Center.

MAGIC collaboration
MAGIC observations of the diffuse γ-ray emission in the vicinity of the Galactic Centre(2020)
VERITAS collaboration
VERITAS Observations of the Galactic Center Region at Multi-TeV Gamma-Ray Energies(2021)

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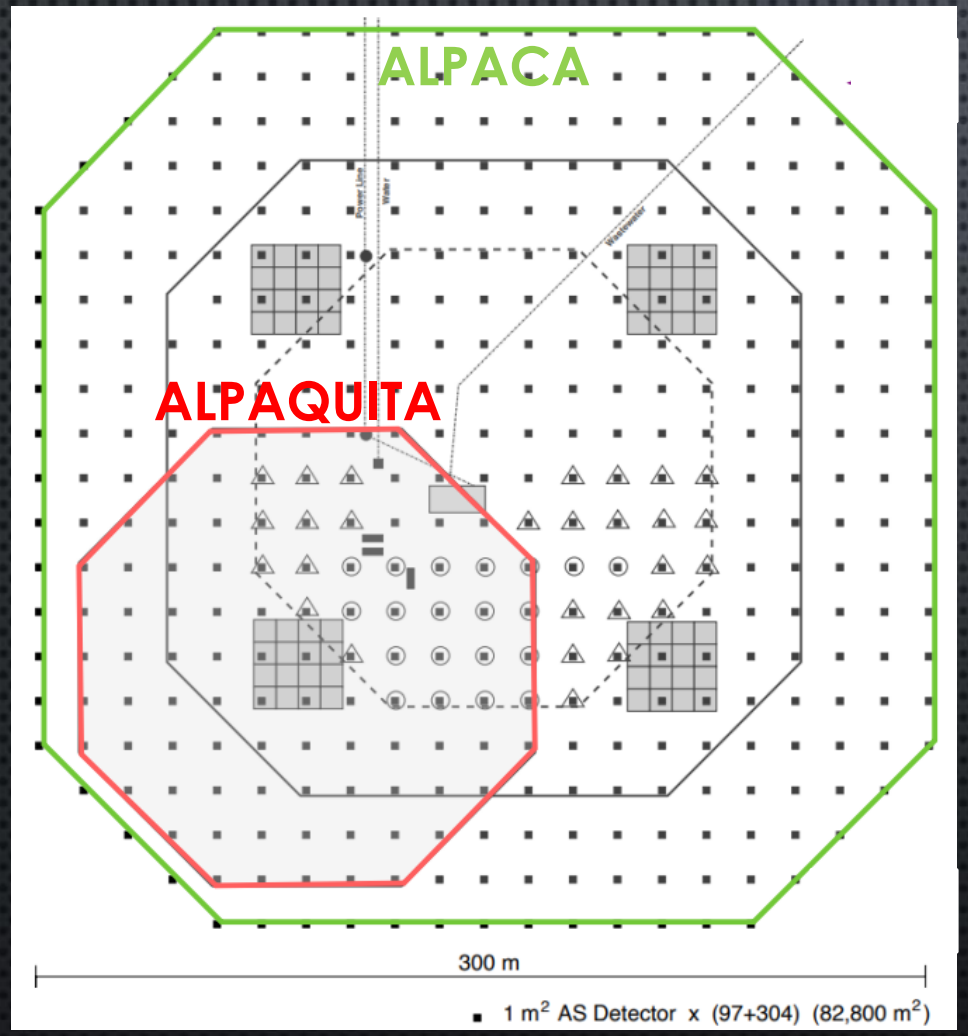
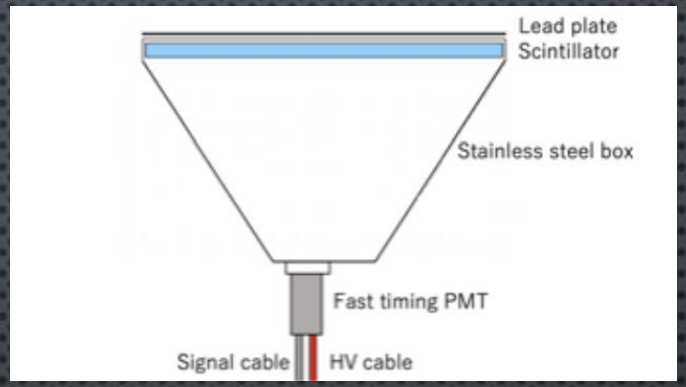
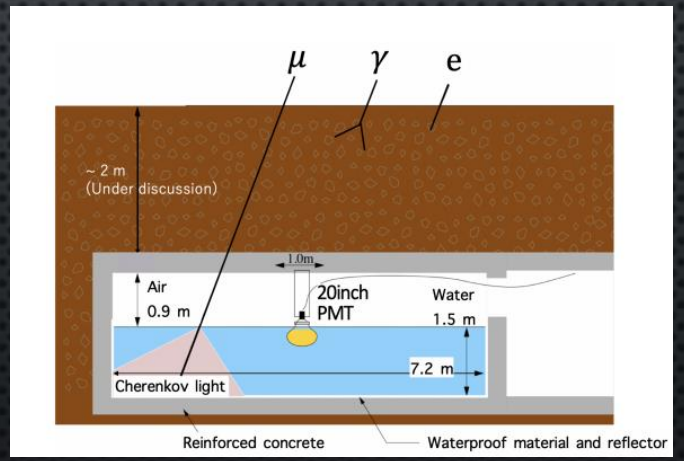
ALPACA & ALPAQUITA



ALPACA experiment



Air shower array detector



Under ground muon detector

The site is in Chacaltaya plateau, Bolivia (16° 03' S, 68° 08' W).

The altitude is 4,740m.
Total area is 83,000 ㎡.

1 ㎡ scintillation detectors are used as the air shower array detectors.

Underground muon detectors area is 3,700 ㎡.

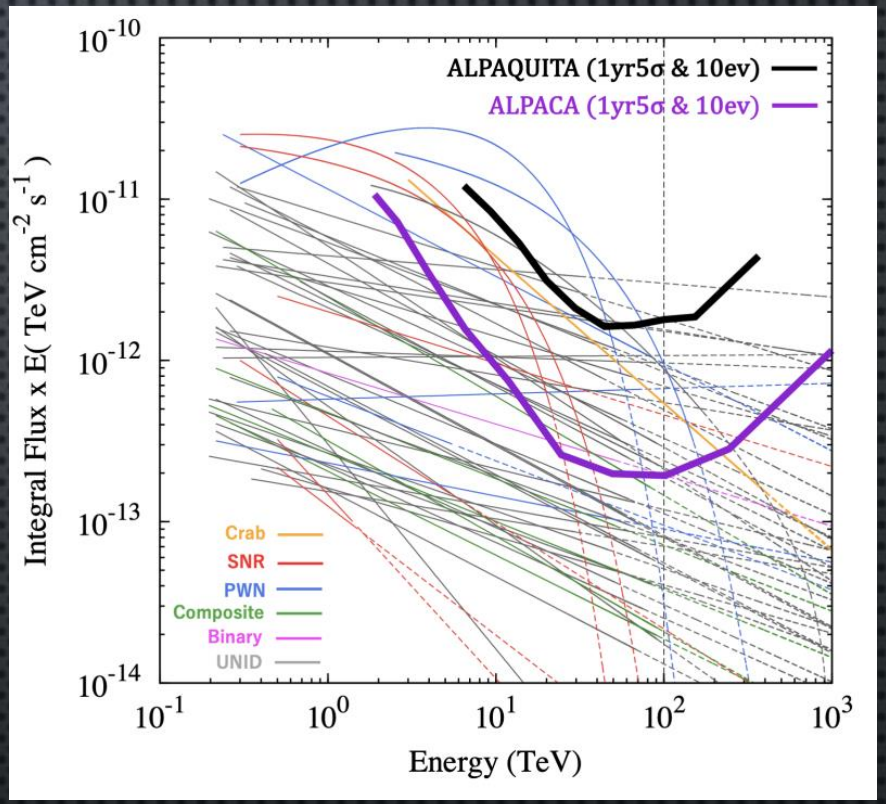
Muon detectors having 2m soil layer above the roof make us enable to eliminate the CR background events.

For the details about the ALPACA project, please refer to the talk by Dr. Marcos (Wed. 27th 16:15～)

Sensitivity of ALPACA & ALPAQUITA

・One of the promising experiment in the Southern hemisphere, ALPAQUITA, having the best point of sensitivity curve at 100 TeV region, will start taking data in August 2022.

・The construction of the half density ALPACA , next stage of ALPAQUITA, will be completed in 2023.

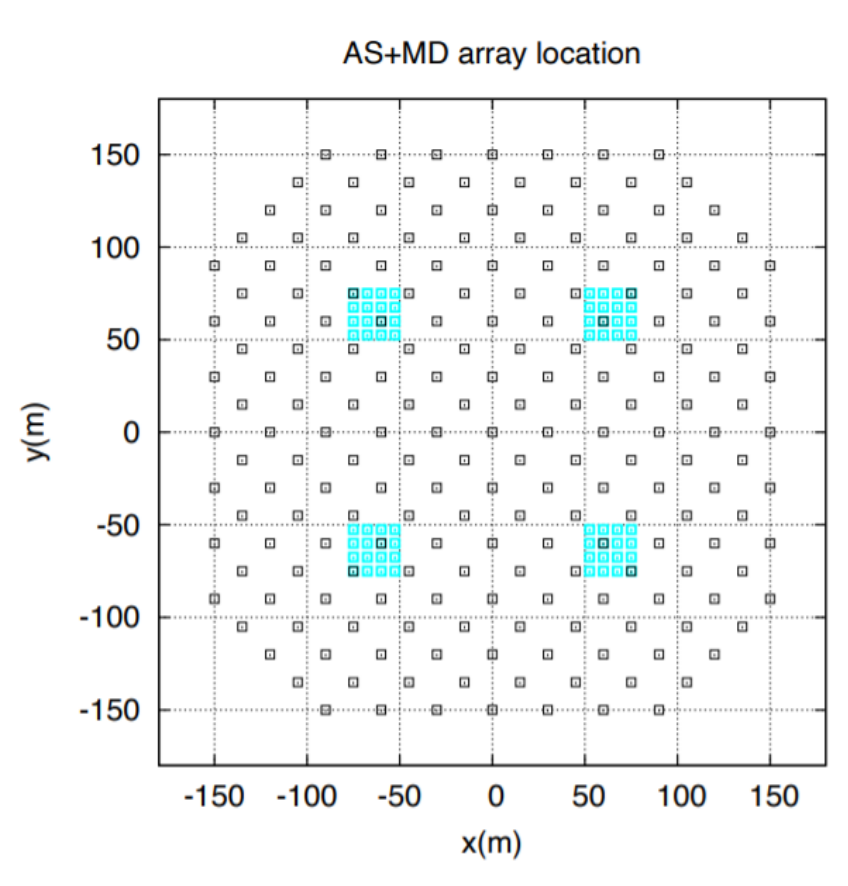


ALPAQUITA sensitivity curve

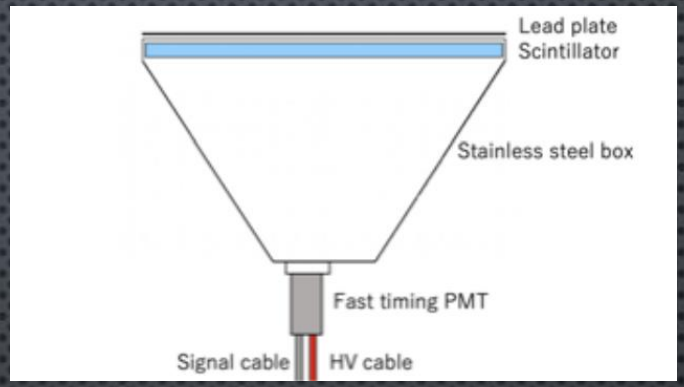
Detectability of southern gamma-ray sources in the 100 TeV range with ALPAQUITA, the prototype experiment of ALPACA, S.Kato et al, (2021)

The H.E.S.S. Galactic plane survey, H.E.S.S. corabollation, (2018)

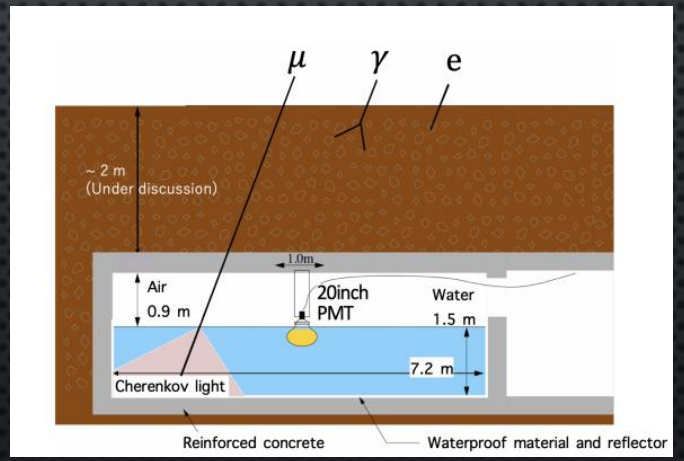
Half Density ALPACA experiment



Half Density of ALPCA experiment



Air shower array detector



Under ground muon detector

Total area is 83,000 ㎡.
(same as ALPACA)
Using 200 air shower detectors with 21m interval distance.
(half density ALPACA)
Underground muon detectors area is 3,700 ㎡.
(same as ALPACA)

Half density ALPACA will start data taking in 2024.

The performance of the half density ALPACA is calculated with Monte Carlo simulation.

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Simulation condition of the gamma ray source

(CORSIKA7.7100)

- Flux (the diffuse gamma rays from around the G.C.)

$$\frac{dN}{dE} = F_0 \left(\frac{E}{1\mathrm{TeV}}\right)^{-\Gamma} \quad (\mathrm{TeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1})$$

$F_0 = 1.92 \times 10^{-12}$ $(\mathrm{TeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1})$ Γ=2.32

- Source position(the G.C.)

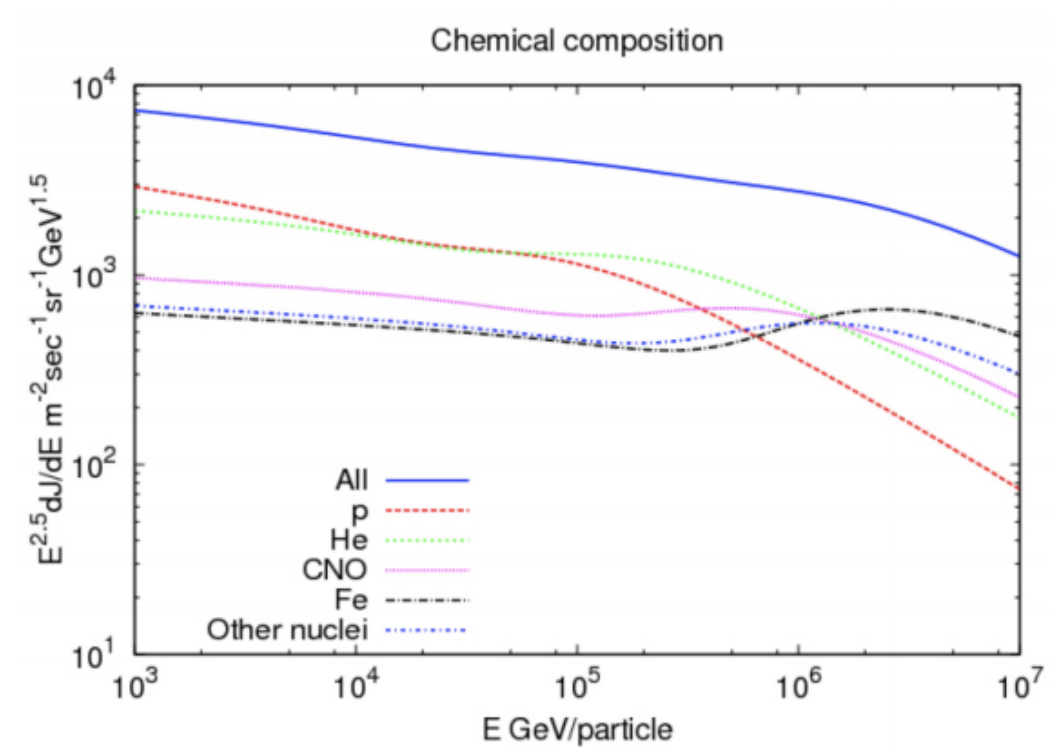
$(\alpha, \delta) = (266.42, -19.01)$

- Point Source

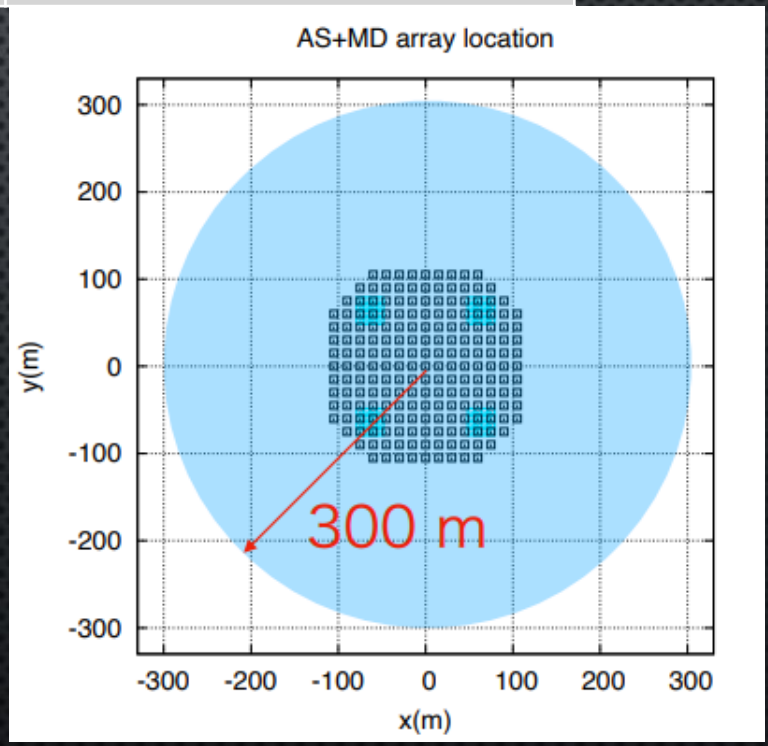
H.E.S.S collaboration
Acceleration of petaelectronvolt protons in the Galactic Centre(2016)[13]

Simulation condition of gamma rays and CRs

	Gamma rays	Cosmic rays
Energy (TeV)	$0.3 \leq E < 10000$	$0.3 \leq E < 10000$
The number of events	1.1×10^8	4.3×10^9
Spectrum	Power law spectrum ($\Gamma = -2$)	Lower left figure

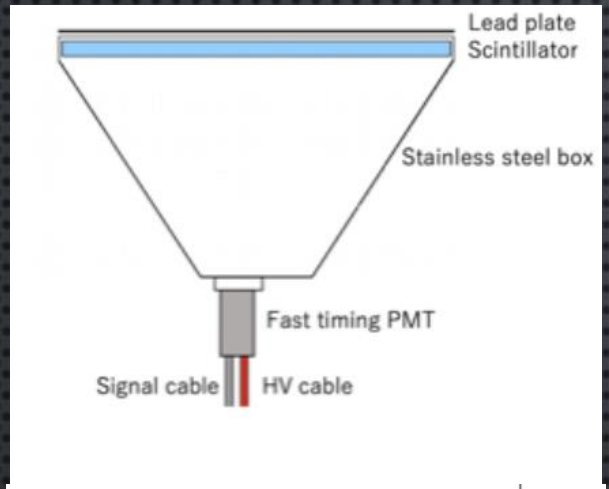


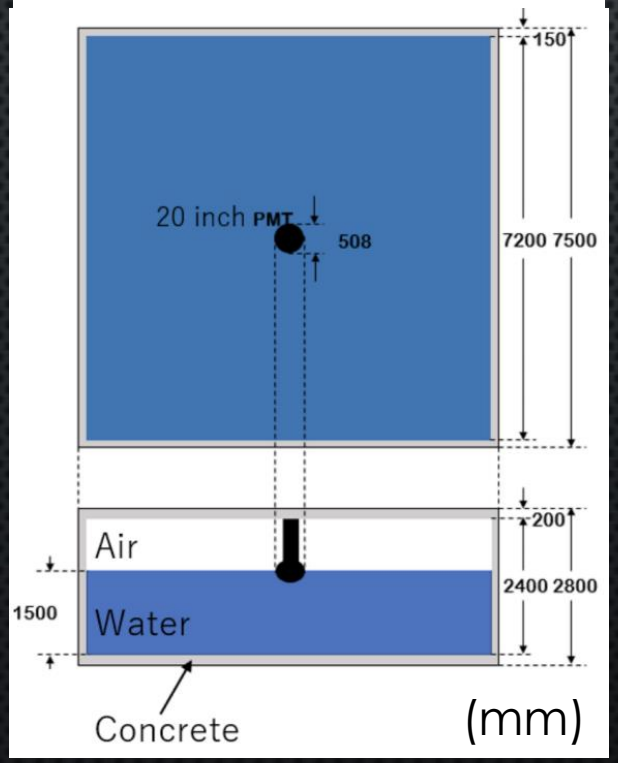
Assumed cosmic ray spectrum



The air shower generation area

Simulation condition of detectors





(Geant4.10.06)

Trigger condition: the number of air shower detectors which detected over 0.5 is over 4.

Simulation condition of air shower detectors

	Density(g/cm^(-3))	Size(cm) (l × w × h)
Lead plate	1134	100 × 100 × 0.5
Steel plate	7.82	103.3 × 103.3 × 0.1
Scintillator	1.032	100 × 100 × 5

Simulation condition of under ground muon detectors

	Density(g/cm^(-3))	Thickness(cm)
Soil	2.1	200
Concrete	2.3	20

Reflectivity at the floor : 80% (diffuse reflection)

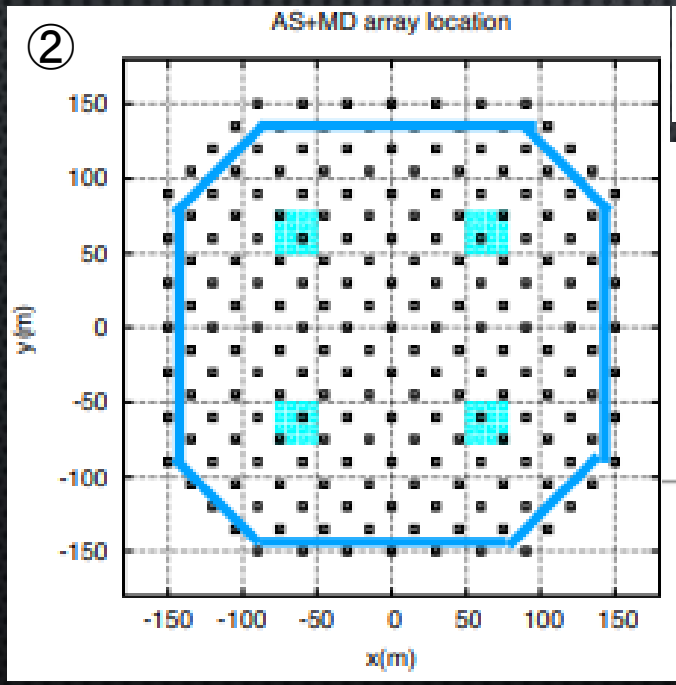
Analysis condition (same as ALPAQUITA) I need the optimization for the half density ALPACA

① Any 4 scintillation detectors detect more than 0.8 particles.
② 3 out of the 4 detectors that record the largest particle densities are inside the inner area
③ The residual error(χ^2) is smaller than 1.0 m.
④ The reconstructed zenith angle is within 40 deg.
⑤ The position of a gamma-ray source is inside the analysis window(r:analysis window radius) opened for each event,

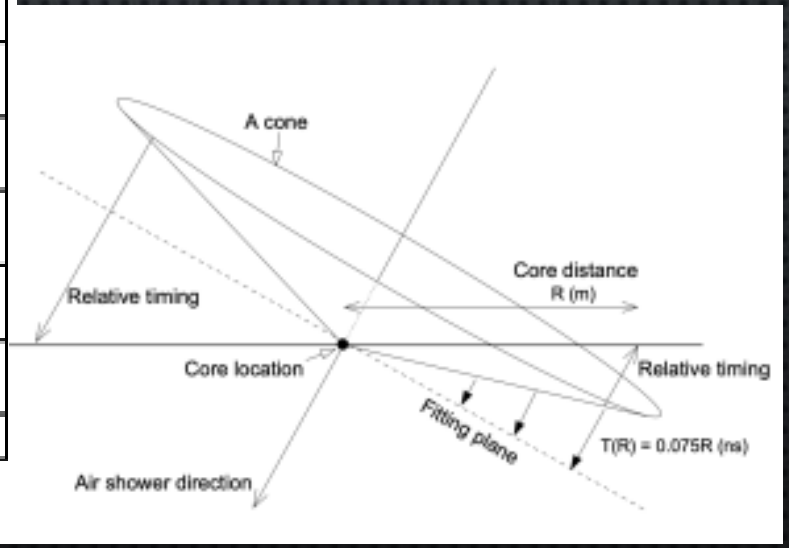
(r>1.5)r=1.5

(1.5>r>0.5)r= $\frac{5.8^\circ}{\sqrt{\Sigma\rho}}$

(r<0.5)r=0.5

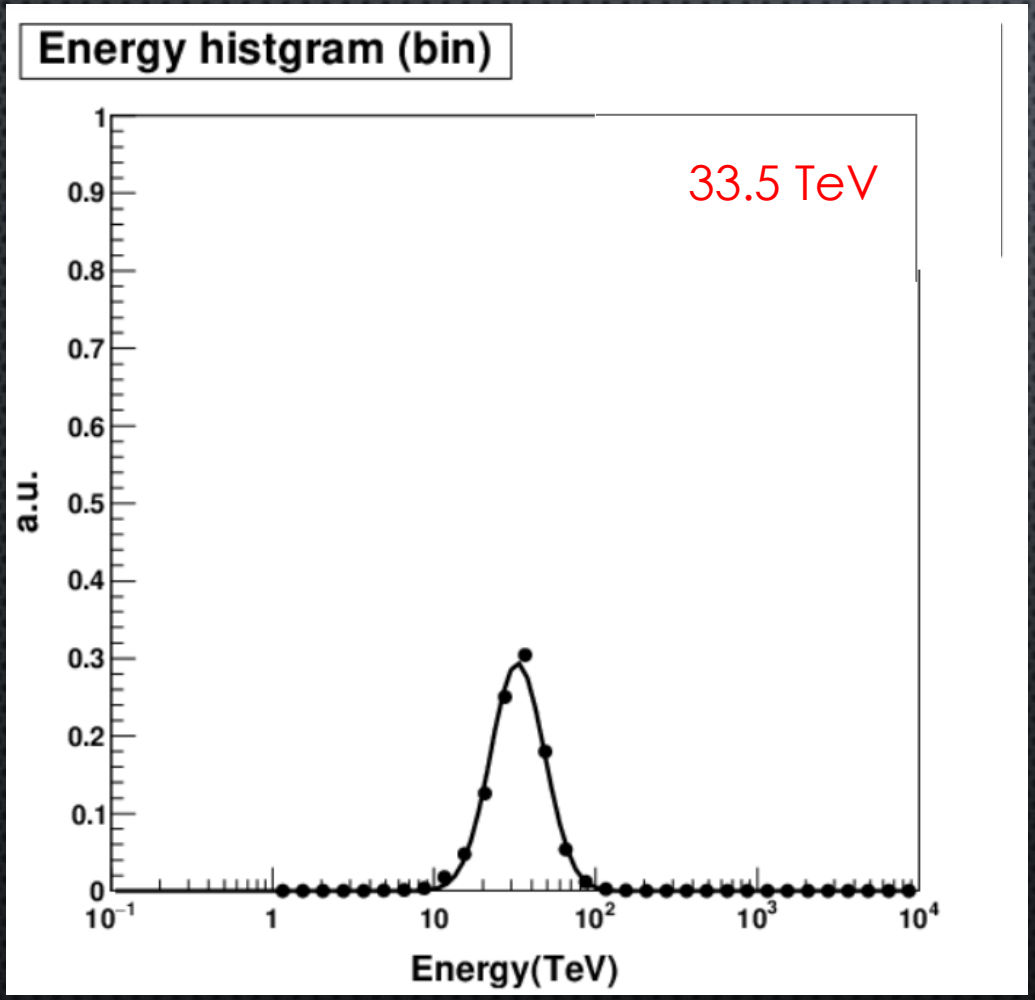


③ : $\chi^2 = \Sigma_i w_i \left(\mathbf{x_i}\cdot\mathbf{l} + c(t_i - t_0)\right)^2 \; w_i = \frac{\rho_i}{\Sigma_i \rho_i}$

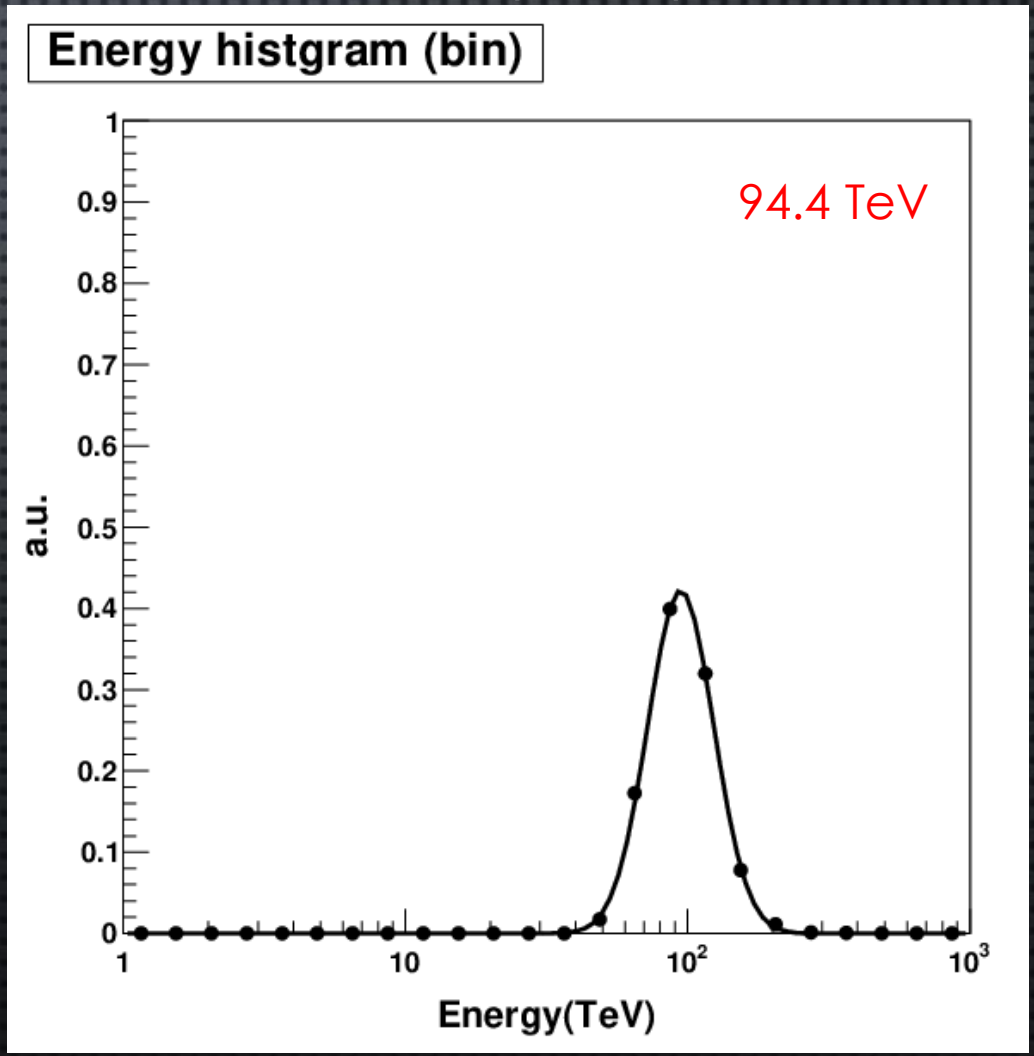


Energy resolution

+41% -34% @ 33.5 TeV

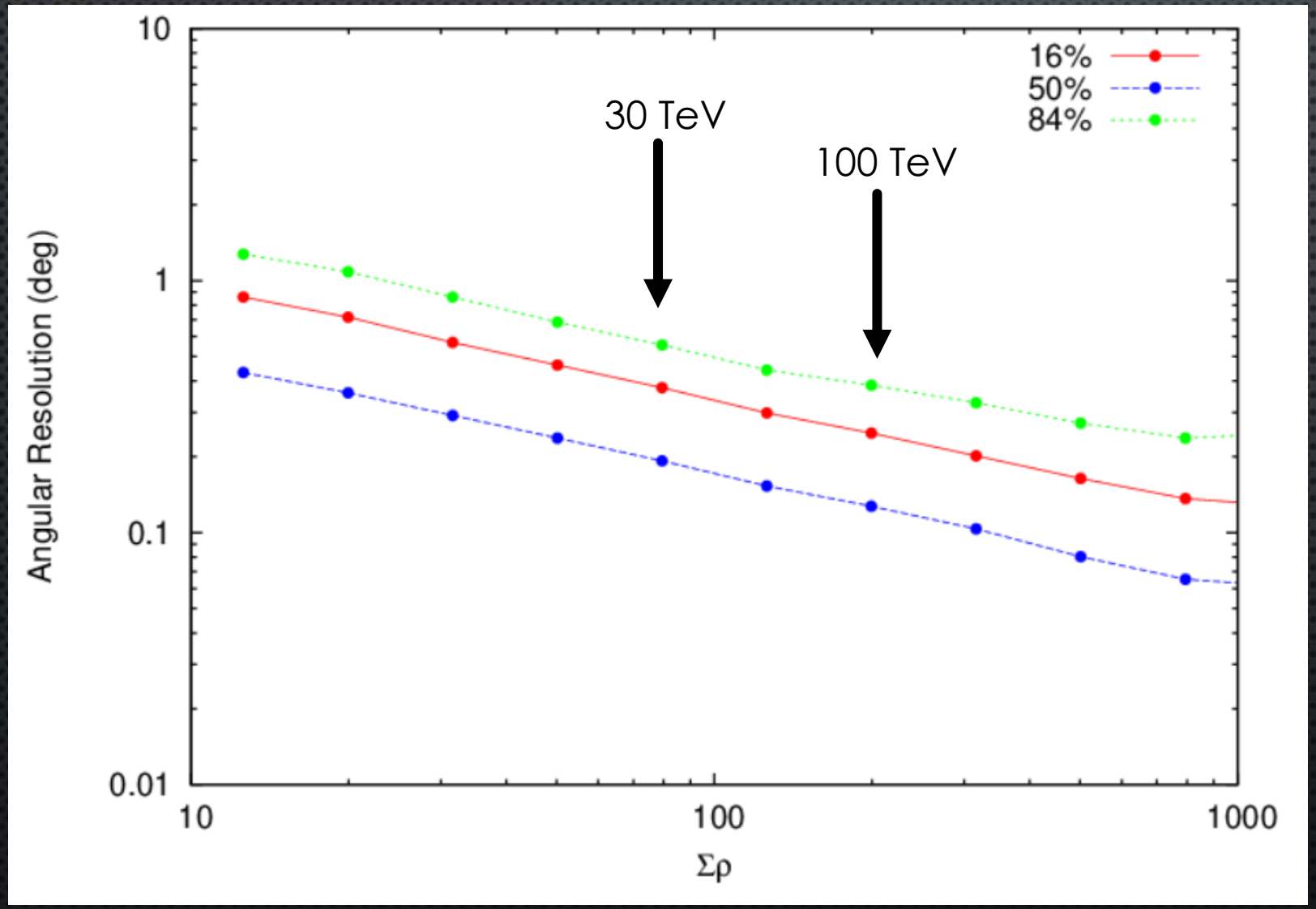


+29% -22% @ 94.4 TeV



The relation between

Angular resolution



0.4 deg @ 33.5 TeV

0.3 deg @ 94.4 TeV

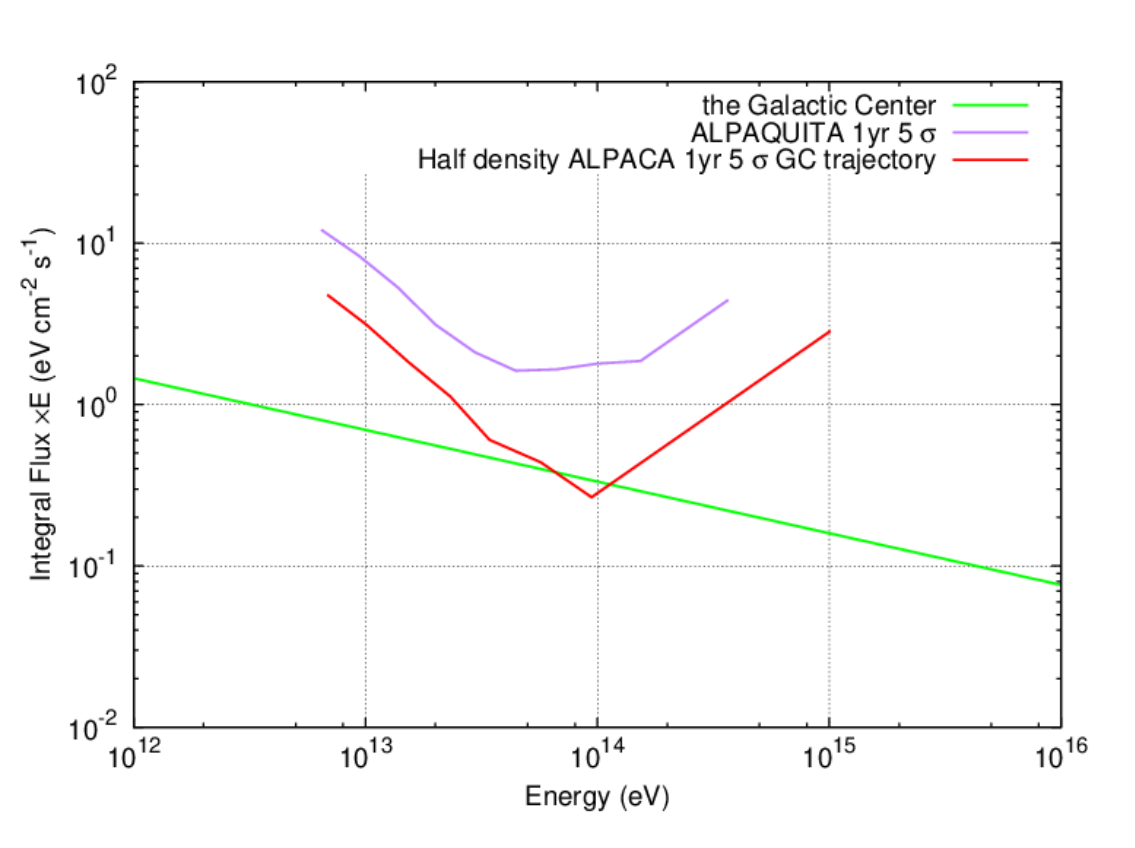
50% point

Angular resolution

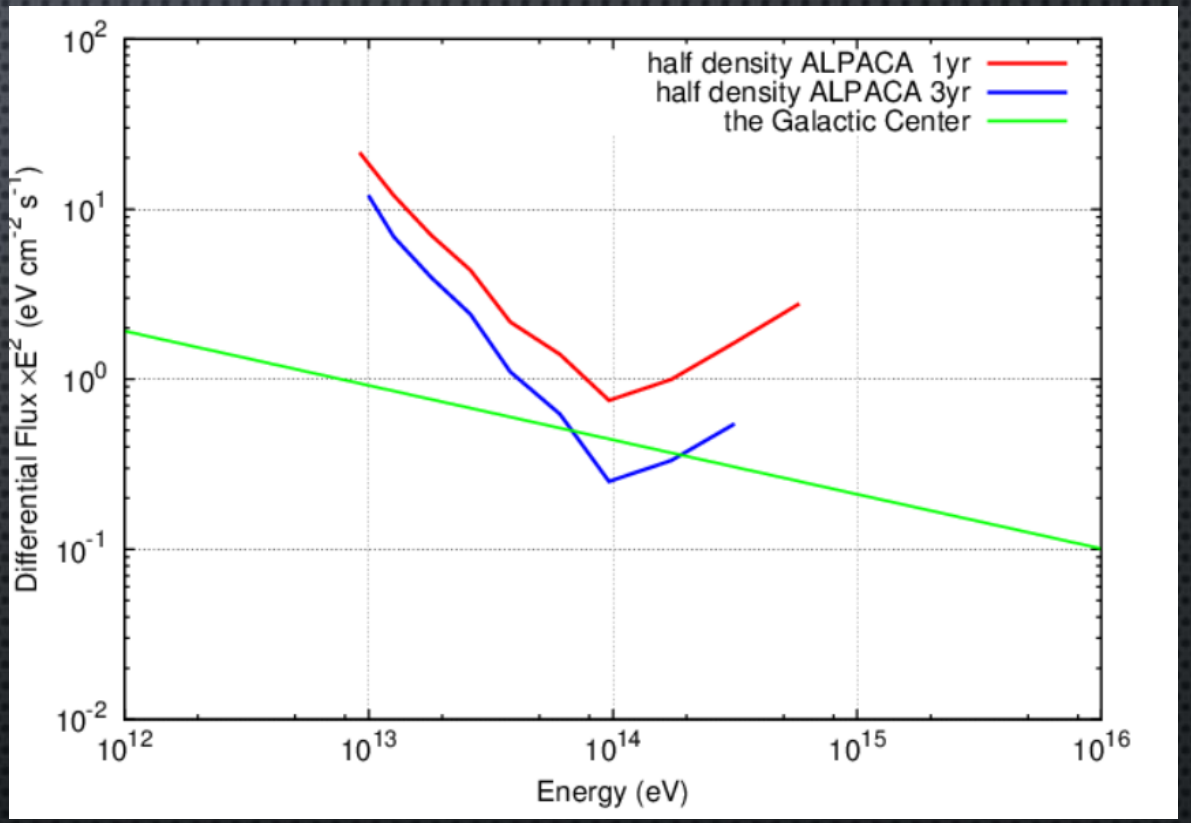
$\sum \rho$:the total number of detected particles

Sensitivity curve

Divide a single digit of $\sum \rho$ into 5 bins



Sensitivity curve (Integral)



Sensitivity curve (Differential)

We need the 1yr observation to detect the diffuse γ rays from around the Galactic Center as integral flux.
If we want to detect it as differential flux, 3yrs observation is necessary.

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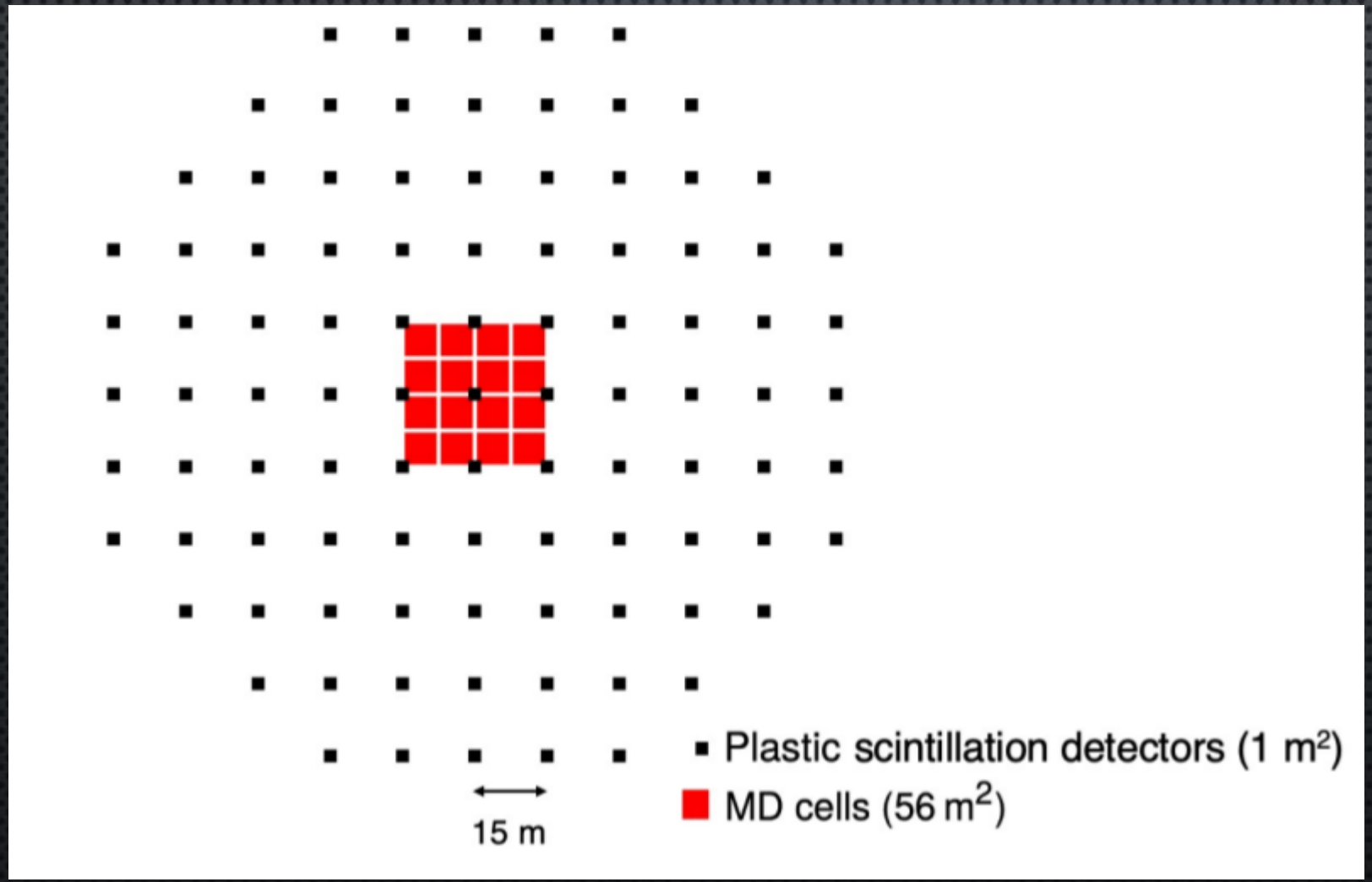
Conclusion

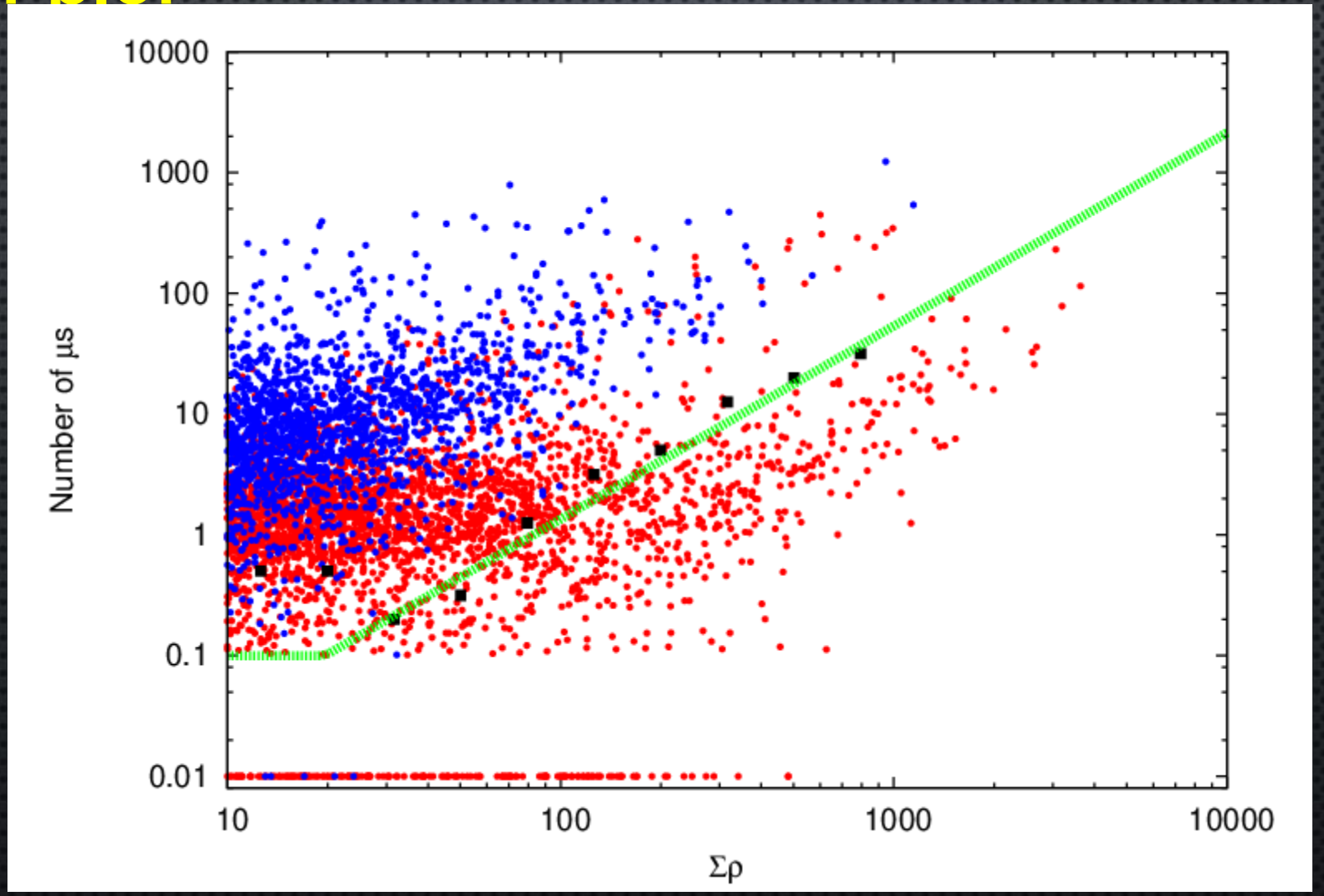
- 100TeV gamma-ray observation is developing recent years.
- The exisitence of PeVatron around the Galactic Center is estimated by various experiment results.
- ALPAQUITA will start data taking in August 2022.
- The construction of the half density ALPACA will be completed in 2023.
- The Energy resolution of the half density ALPACA is from 20 to 30 % at 100 TeV.
- The half density ALPACA has 0.3 deg angular resolution at 100 TeV.
- We can hope that the detection of the diffuse gamma rays from around the Galactic Center at 100 TeV region in 1 year observation as integral flux and 3 years observation as differential flux.

END

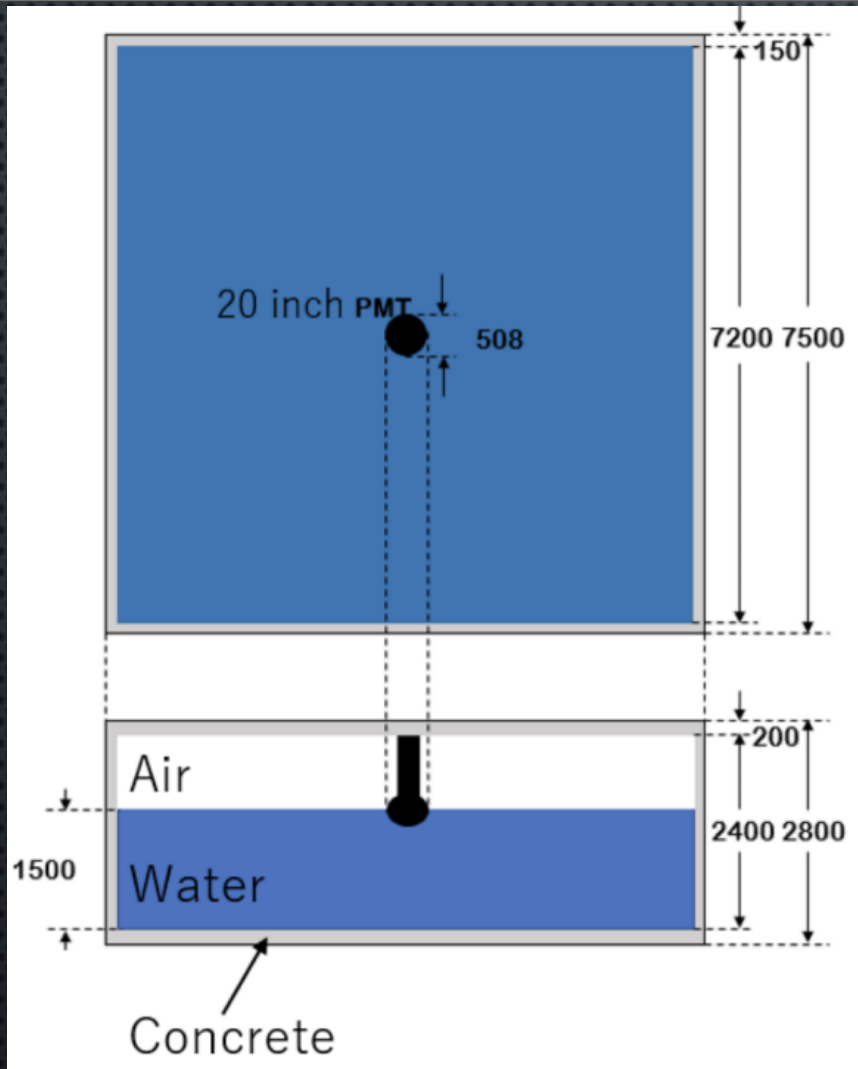
ALPAQUITA experiment



Scatter plot



シミュレーション（４）（Geant4.10.06）



・Detction area : 50 m^2

・Locate at 2.0 m underground

・Density : soil : 2.1 $g/cm^3 \times 2$ m

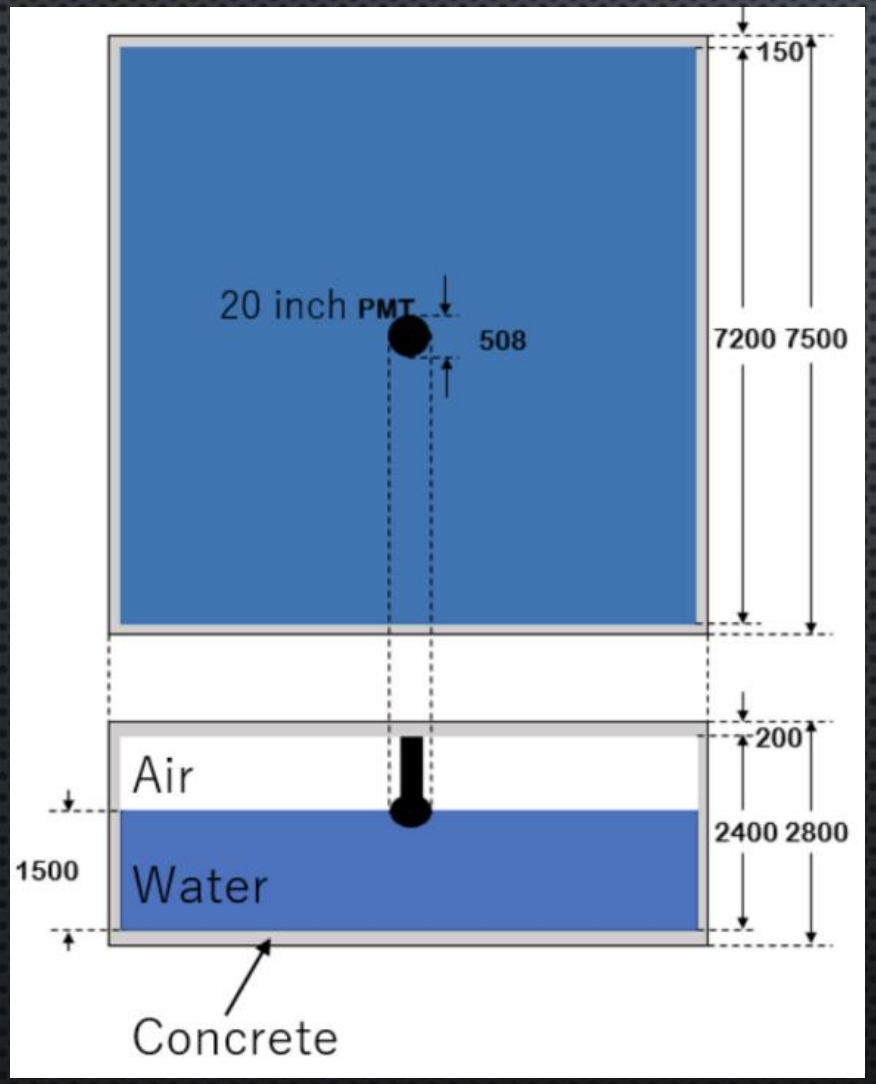
concrete : 2.3 $g/cm^3 \times 20$ cm

→ 470 g/cm^2 equiv. to 16 radiation length ($e^{-16} \sim 10^{-7}$)

・Reflectivity at the floor : 80%　(diffuse reflection)

→470g/㎠(16放射長)

・床と壁面の反射率　80%


150
20 inch PMT
508
7200 7500
200
Air
2400 2800
1500
Water
Concrete