LHAASO Gamma-ray

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on behalf of the LHAASO collaboration

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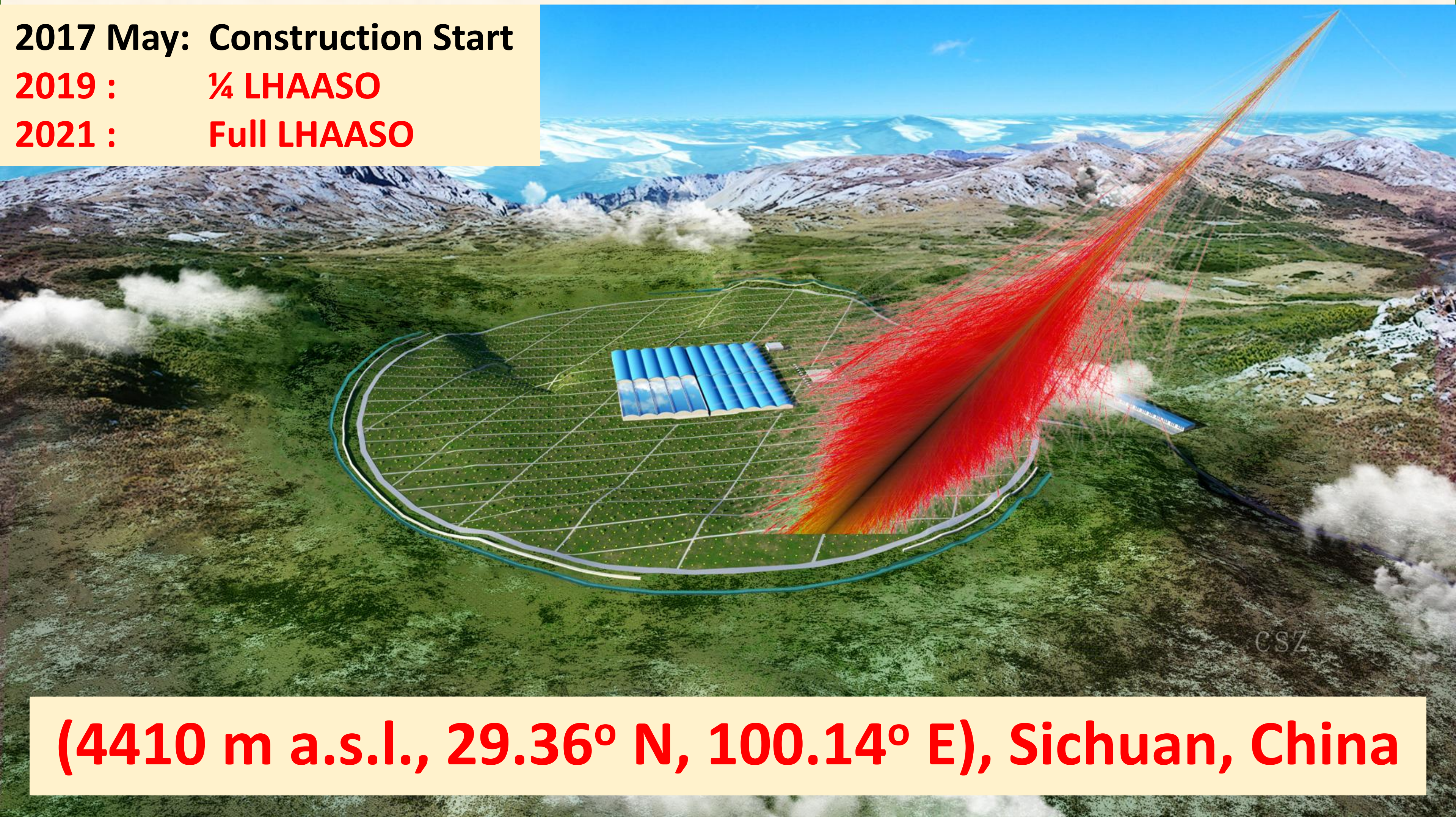
Outline

- 1. Introduction
- 2. Galactic gamma-ray sources
- 3. Extra-galactic gamma-ray sources
- 4. Summary

1. Introduction

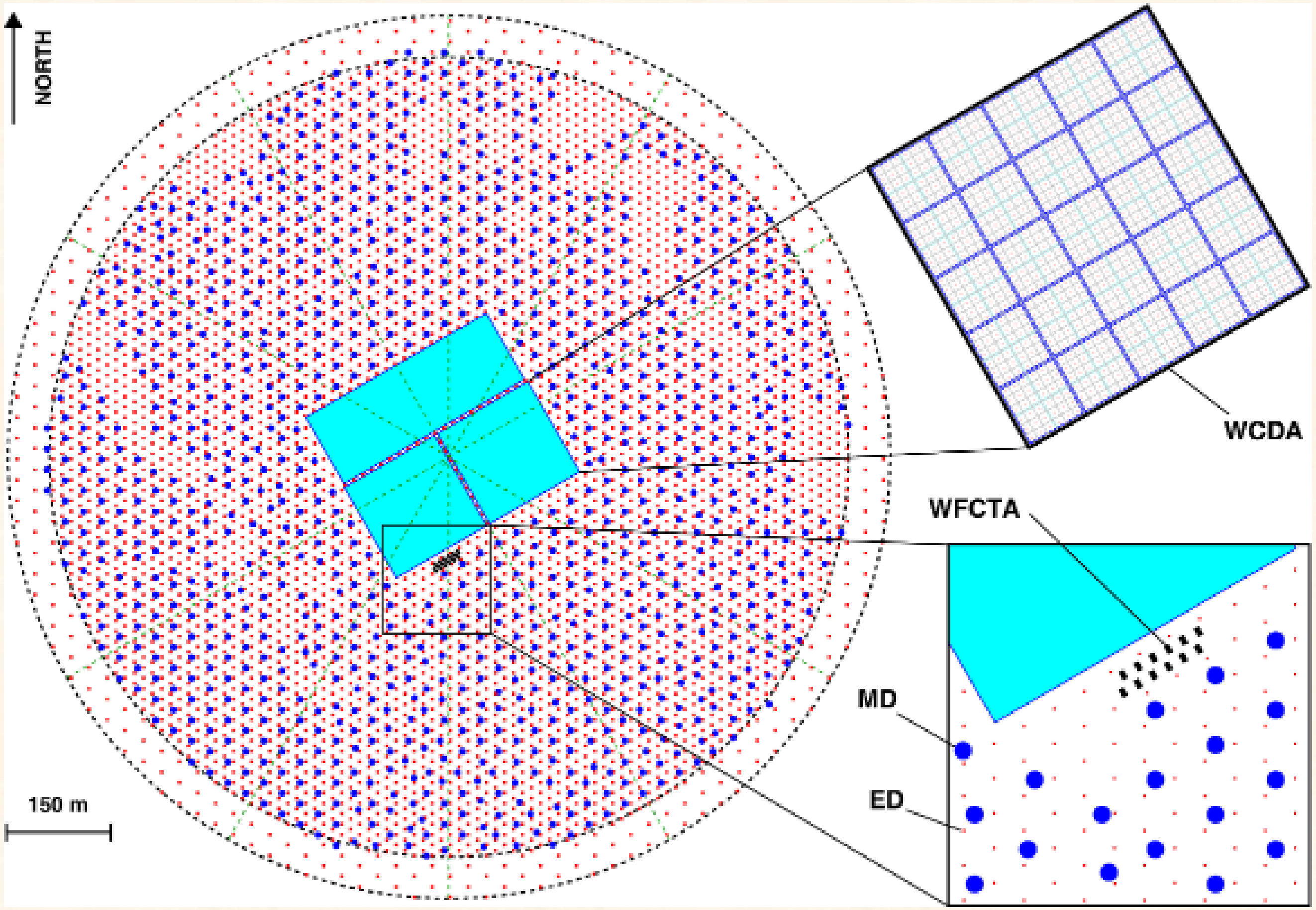
LHAASO: Large High Altitude Air Shower Observatory

2017 May: Construction Start
2019 : ¼ LHAASO
2021 : Full LHAASO



(4410 m a.s.l., 29.36° N, 100.14° E), Sichuan, China

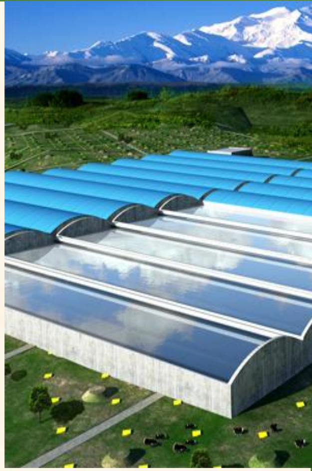
LHAASO detectors

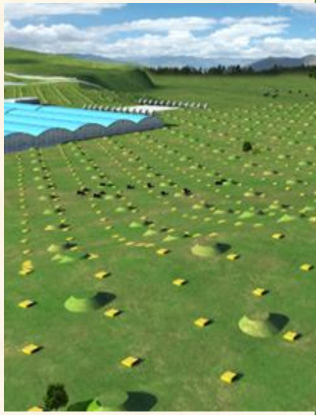


- **5195 EDs**
  - $1\ m^2$ each
  - 15 m spacing
- **1171 MDs**
  - $36\ m^2$ each
  - 30 m spacing
- **3120 WCDs**
  - $25\ m^2$ each
- **12 WFCTs**

Main goals of LHAASO

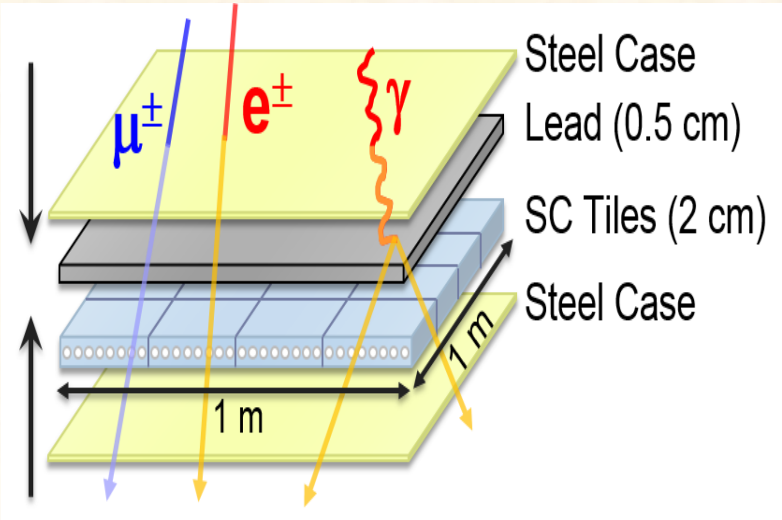
- TeV gamma-ray survey → **WCDA** (100 GeV-30 TeV)
  - AGN, GRB, survey new source, …
- >20 TeV gamma-ray survey →**KM2A** (10TeV-1PeV)
  - SNR, PWN, Superbubble, diffuse around 100TeV, …
- Individual nuclei spectra →**WFCTA** (10TeV to EeV)
  - Different configures
  - Combined with WCDA, WCDA++, KM2A
- Benefit regions:
  - Anisotropy, Solar physics, dark matter, EBL, IGMF, Lorentz invariance, hadronic interaction, …



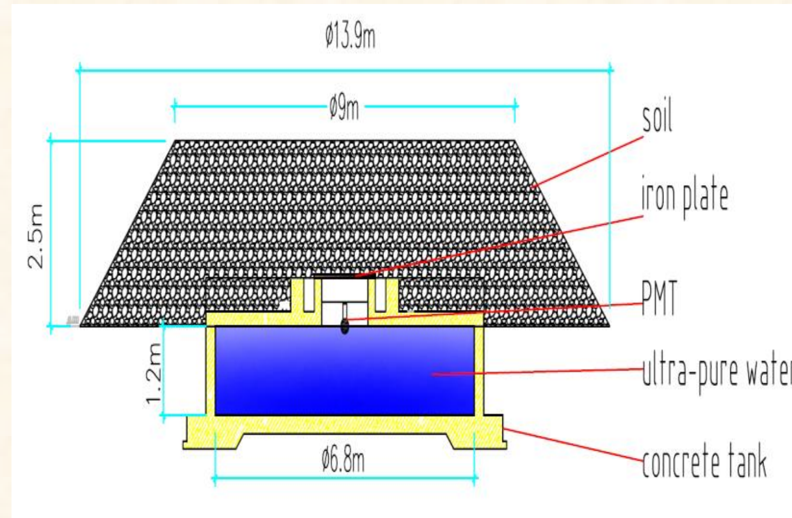


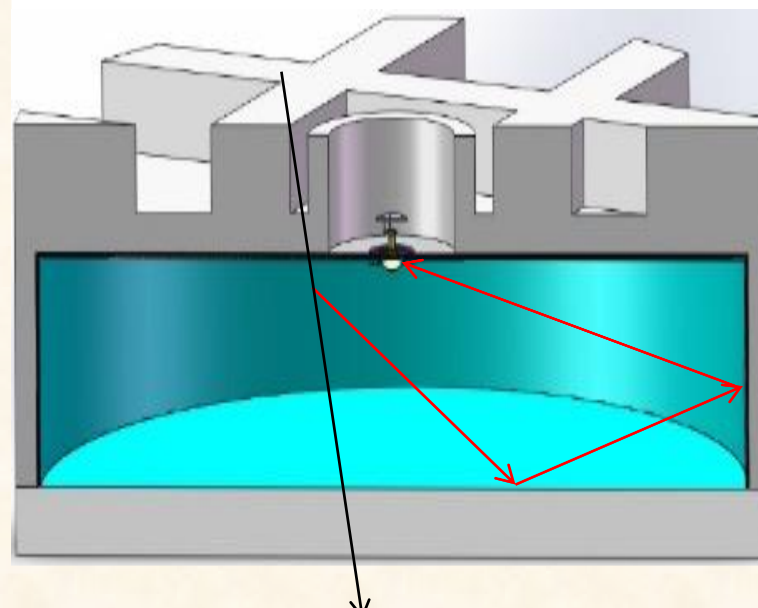
KM2A

ED


Steel Case
Lead (0.5 cm)
SC Tiles (2 cm)
Steel Case
$\mu^{\pm}$
$e^{\pm}$
γ
1 m
1 m

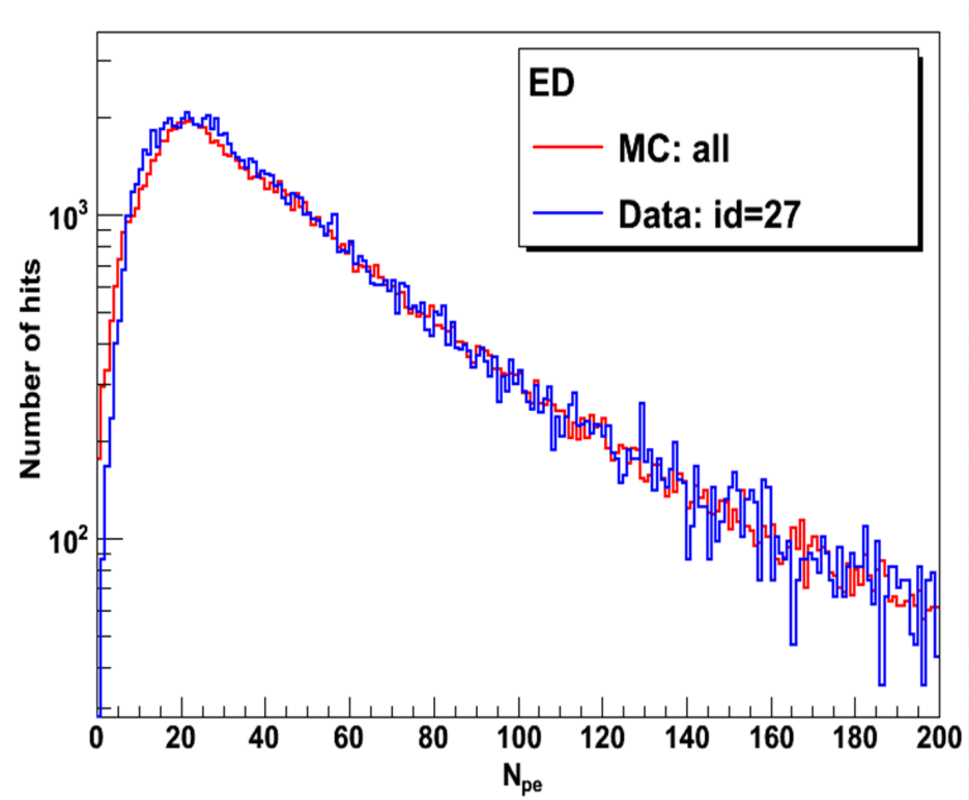
MD

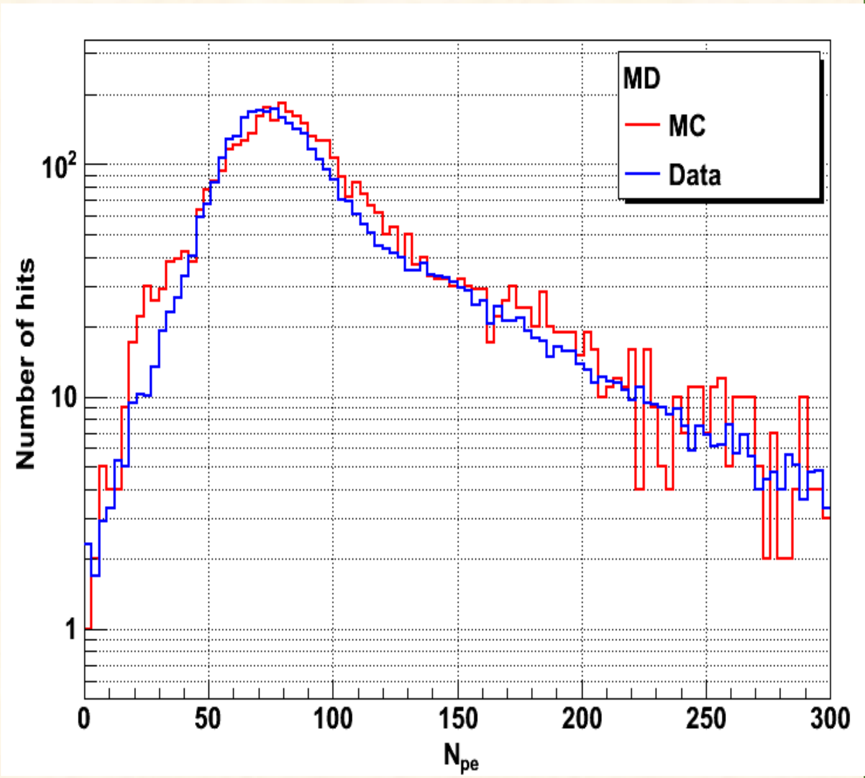

ø13.9m
ø9m
soil
iron plate
2.5m
PMT
1.2m
ultra-pure water
ø6.8m
concrete tank



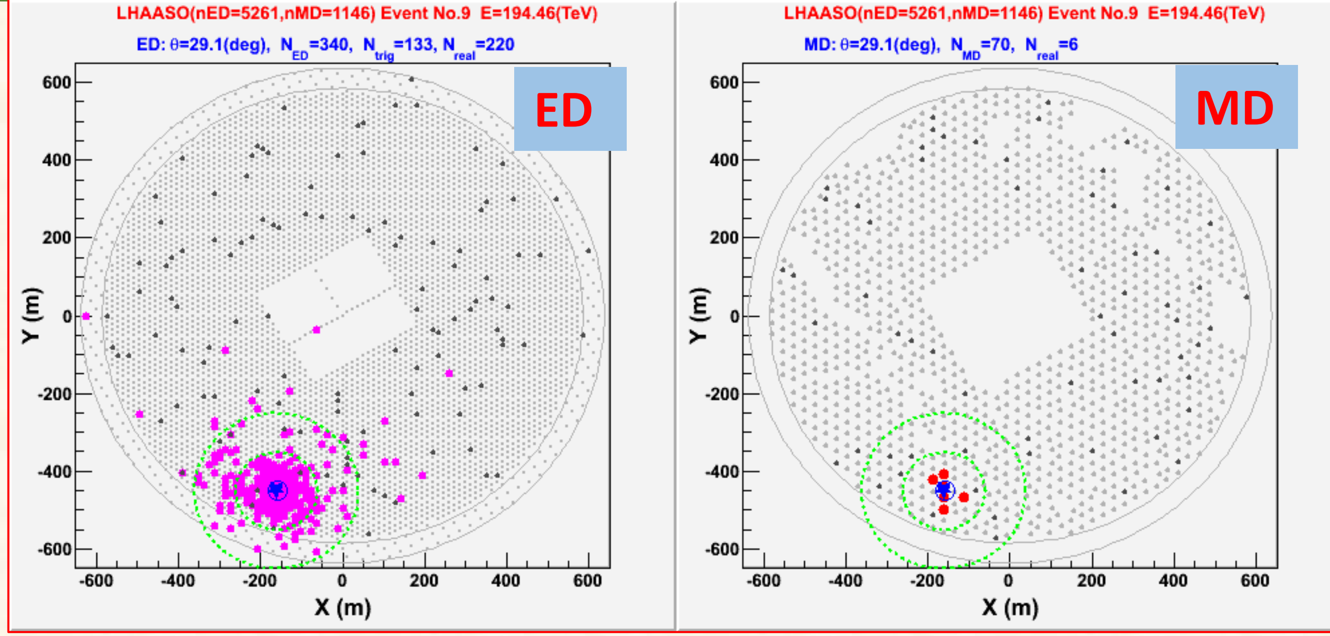
MC vs Data

- $N_{e/r}$=Npe/20. N_u=Npe/70.





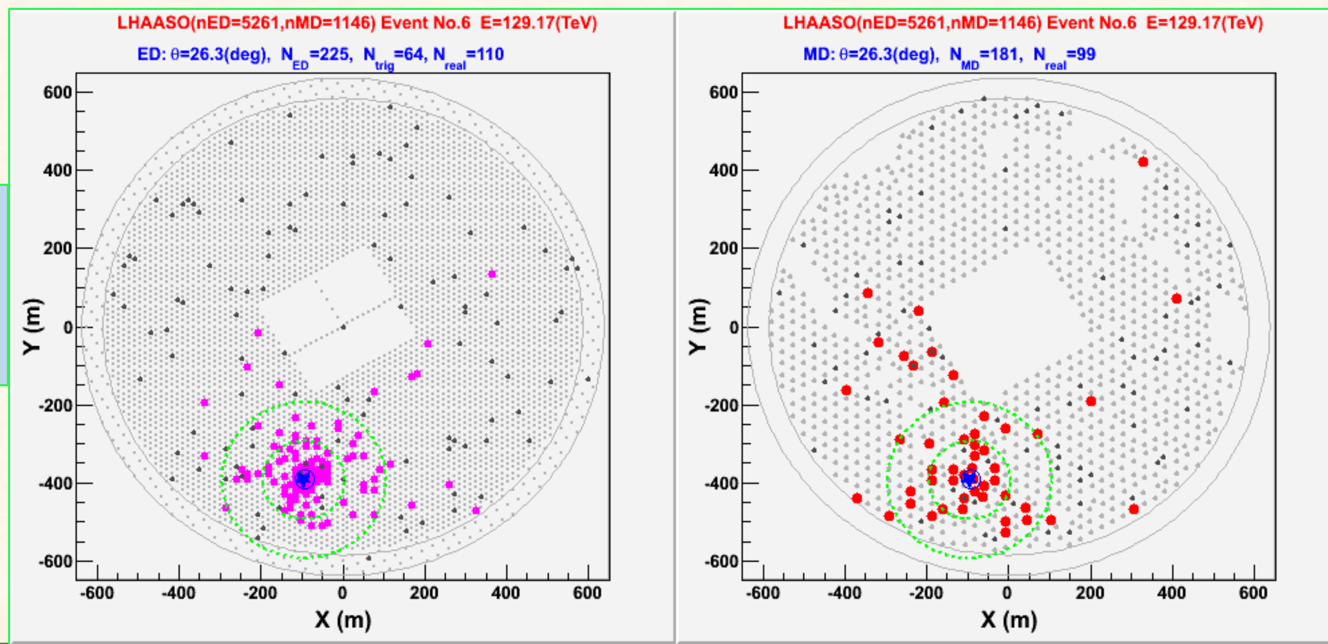
Gamma-ray
E=194 TeV



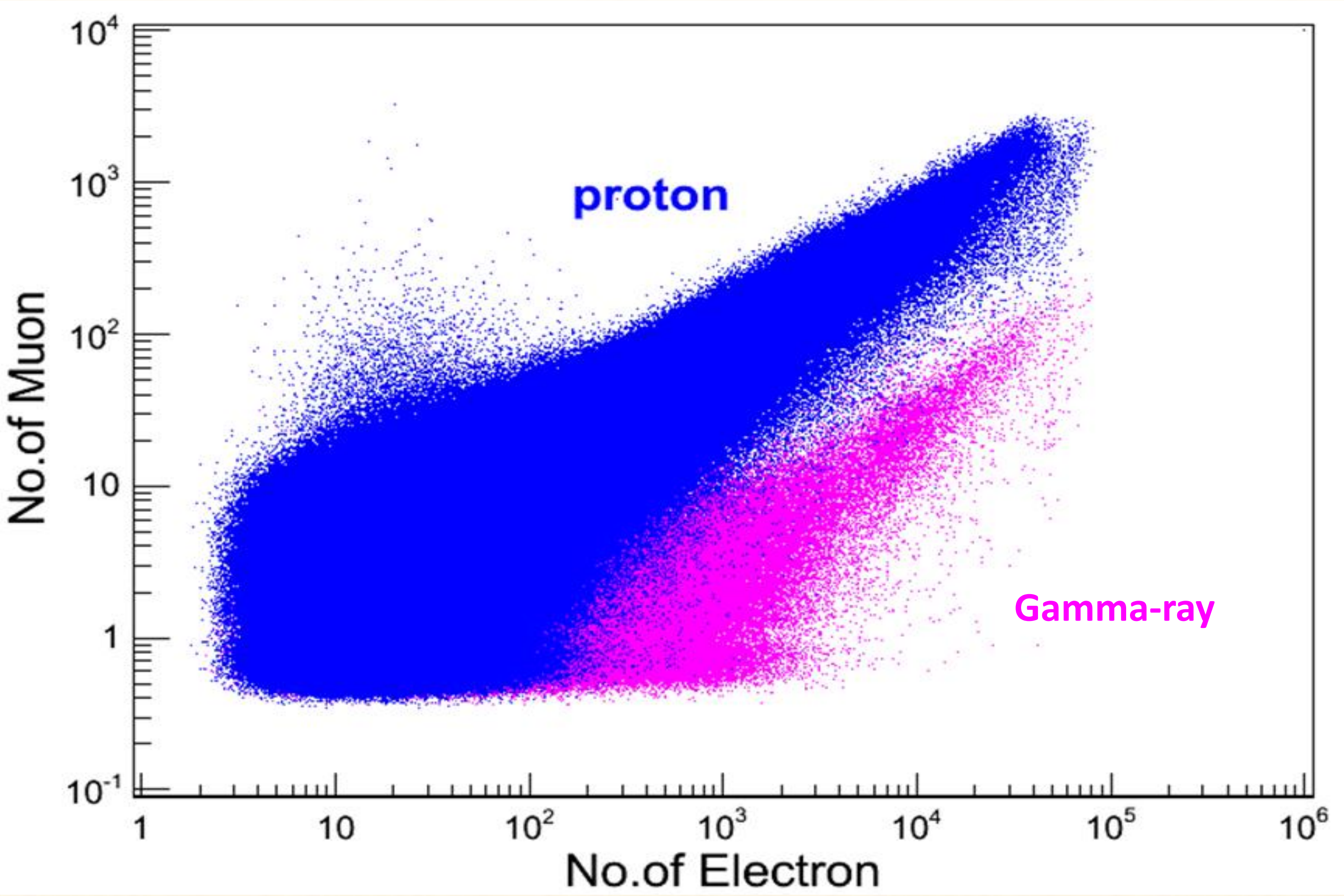
Geant4 based

γ/P discrimination

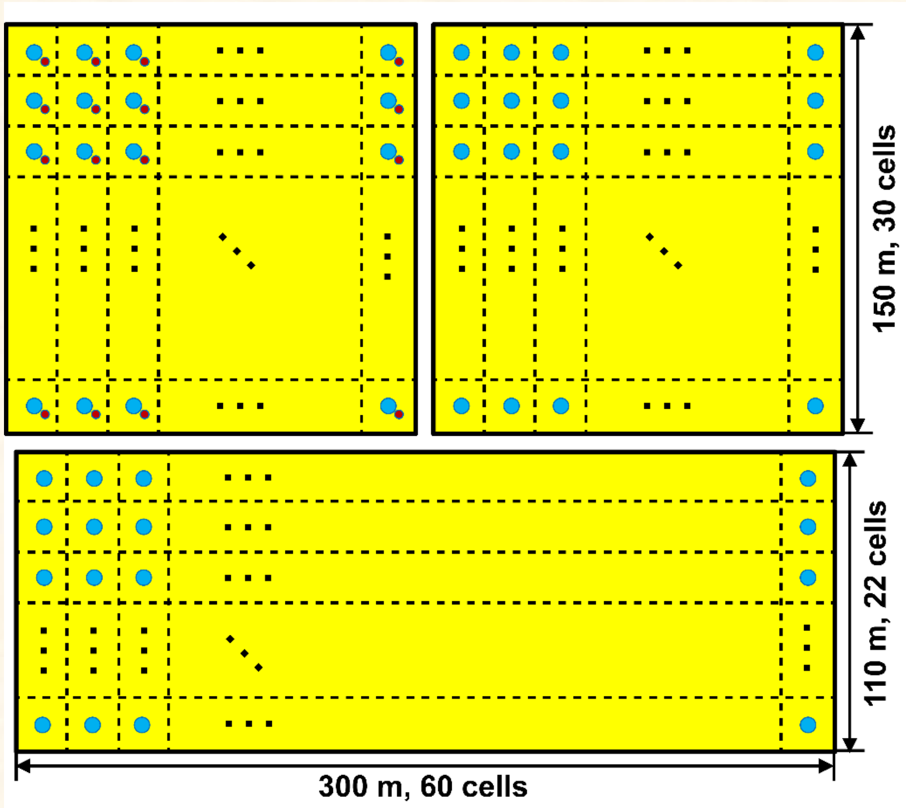
Proton
E=129 TeV

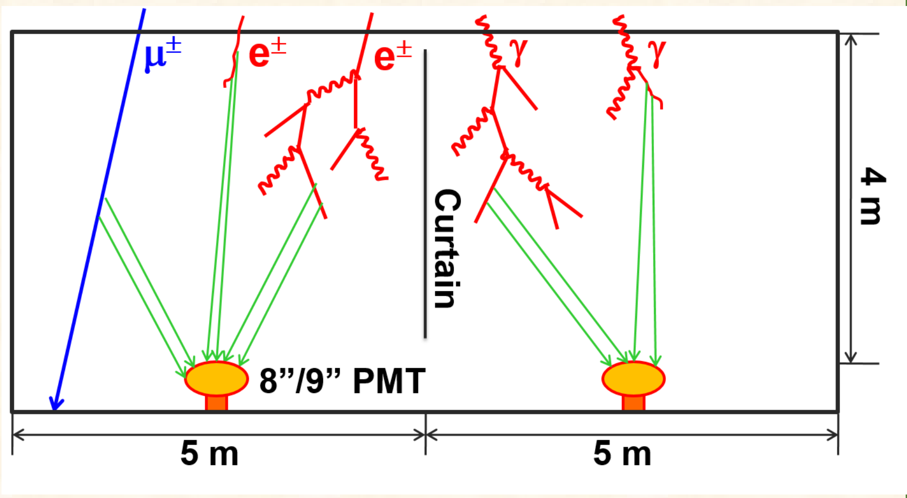


γ/P discrimination

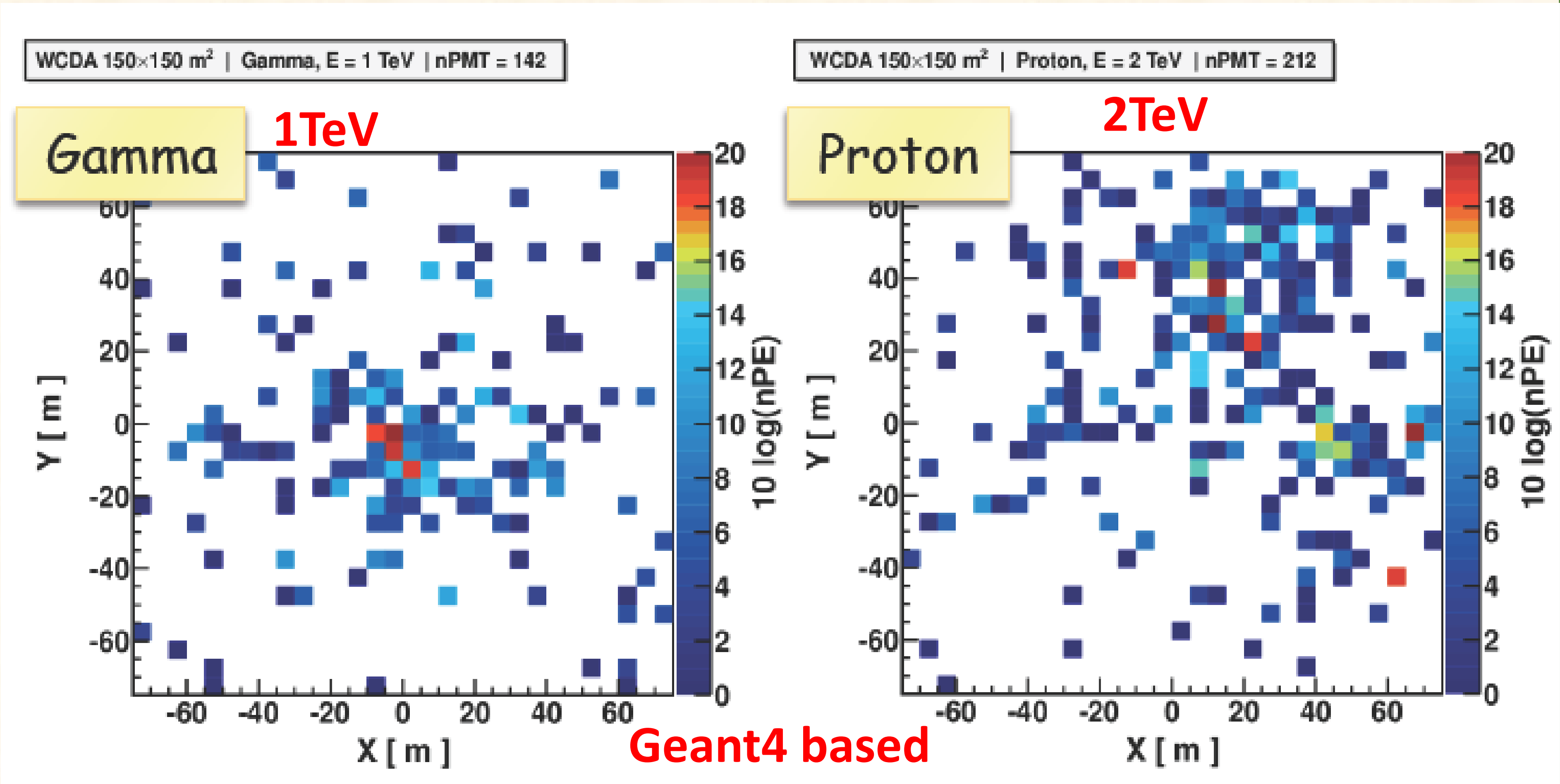


WCDA:Water Cherenkov Detector Array

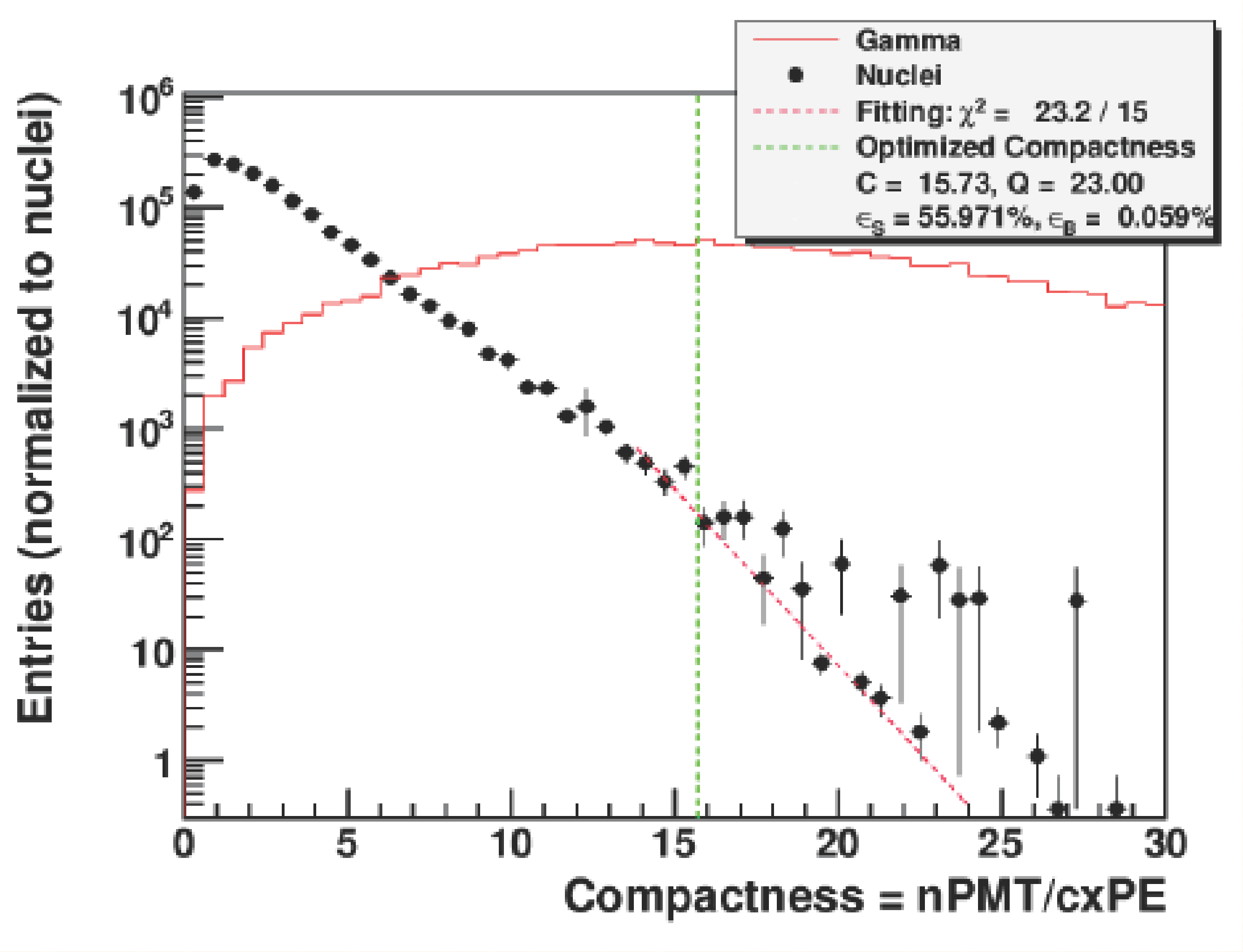




γ/P discrimination

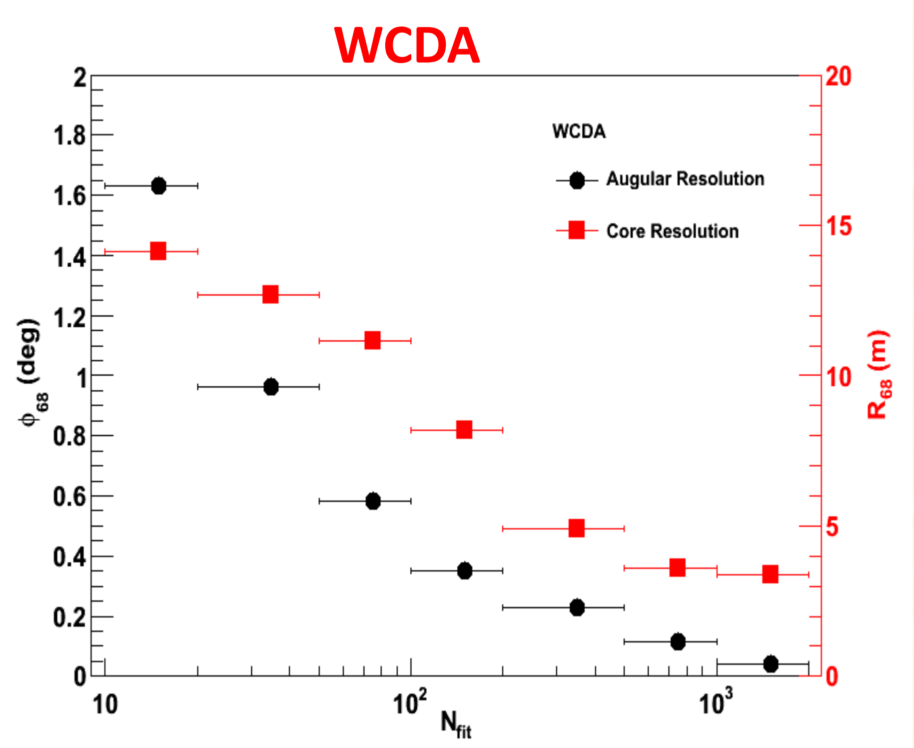


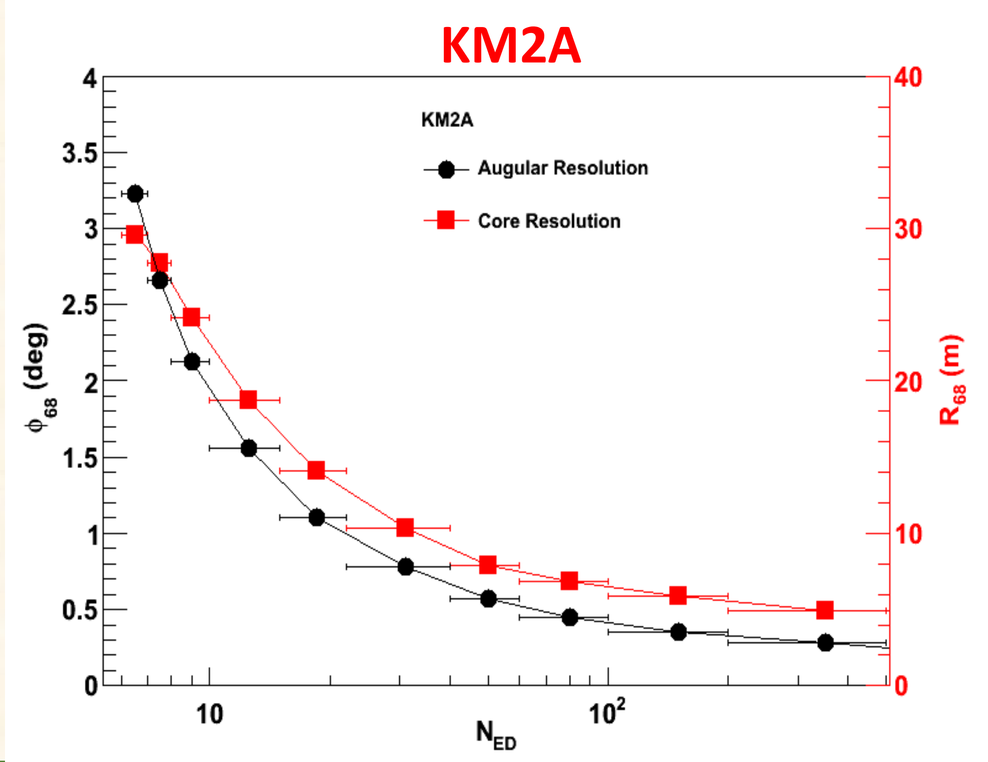
γ/P discrimination



Angular and core resolution

- WCDA: 0.6 deg, 11m (68% containing) @1 TeV
- KM2A: 0.5 deg, 6m @100 TeV

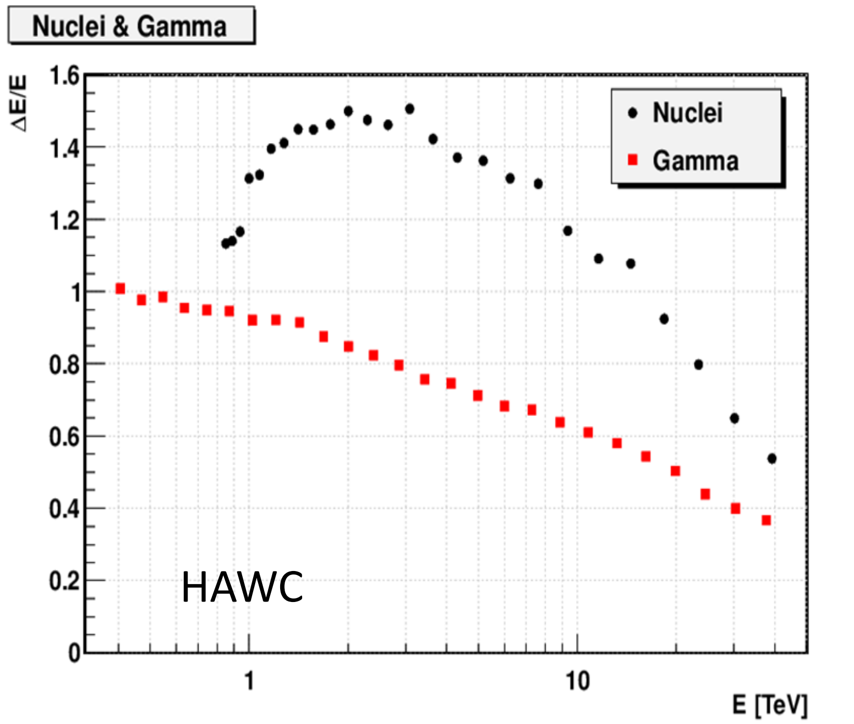


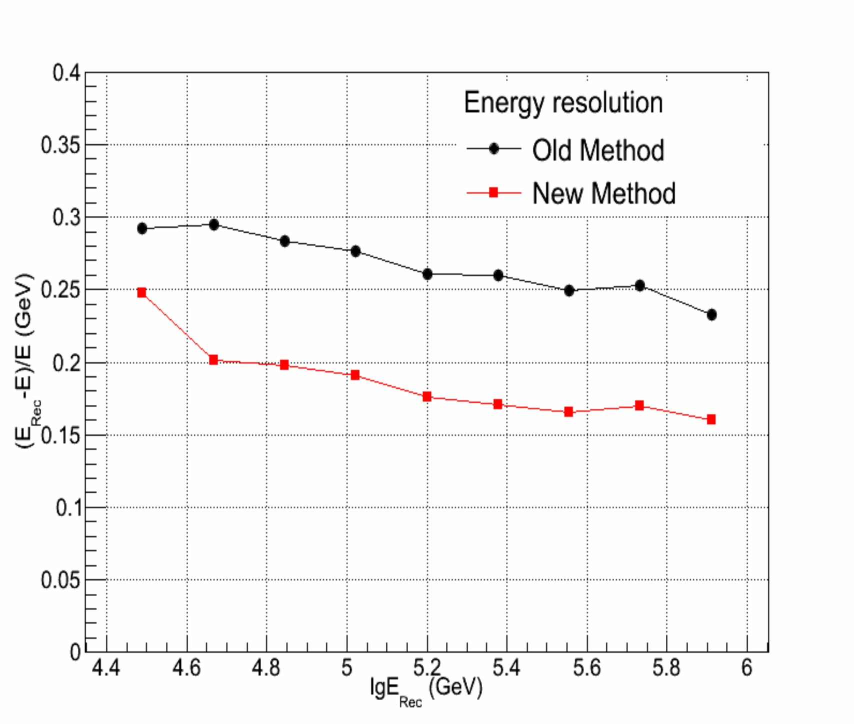


Energy resolution

WCDA:~100%

KM2A: ~20%

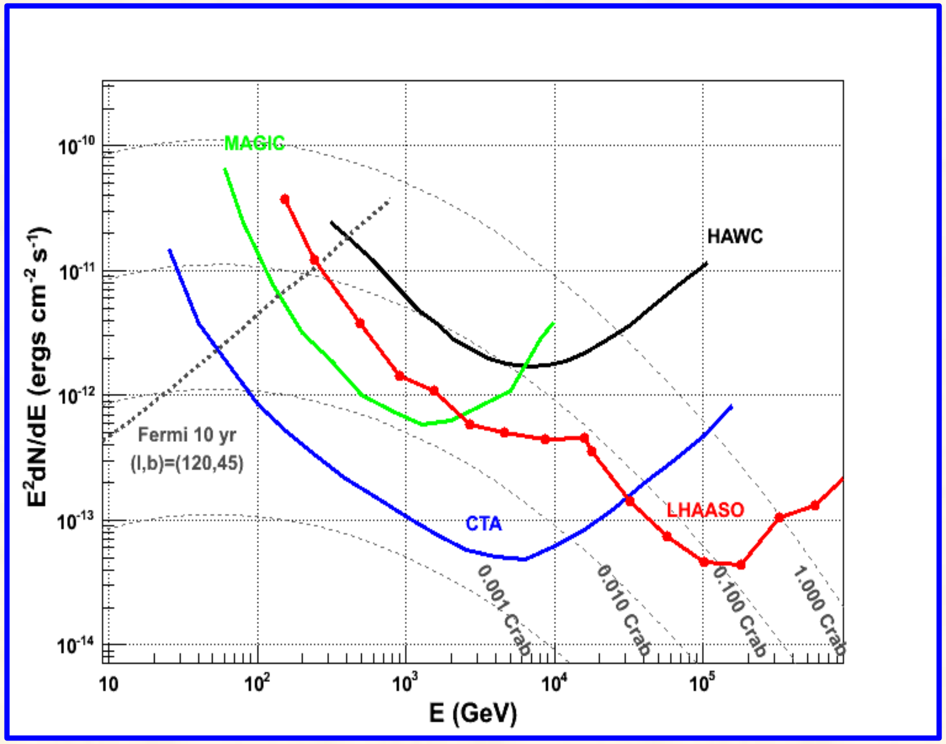




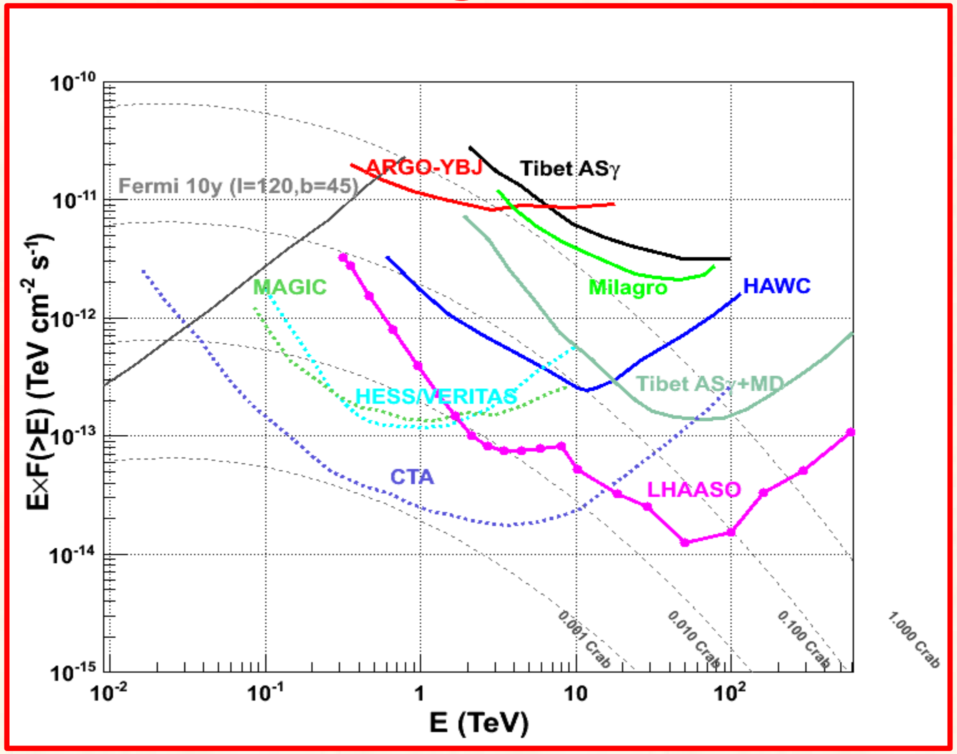
Gamma-ray sensitivity

- **WCDA: 1% Crab unit at 2 TeV**
- **KM2A: Unprecedented sensitivity at energy above 20TeV.**

Differential

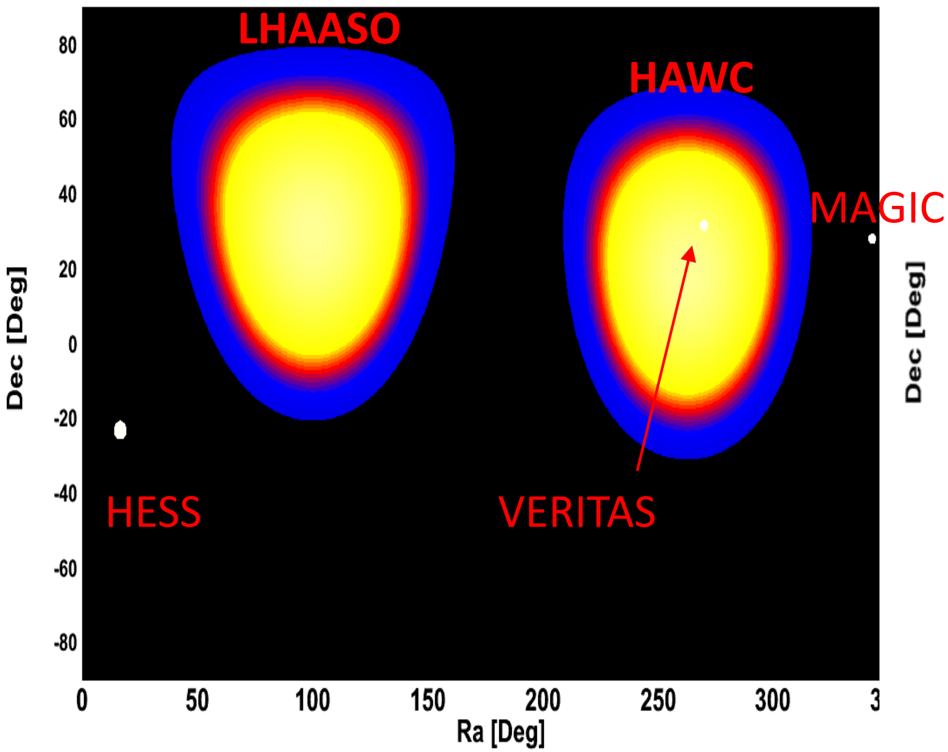


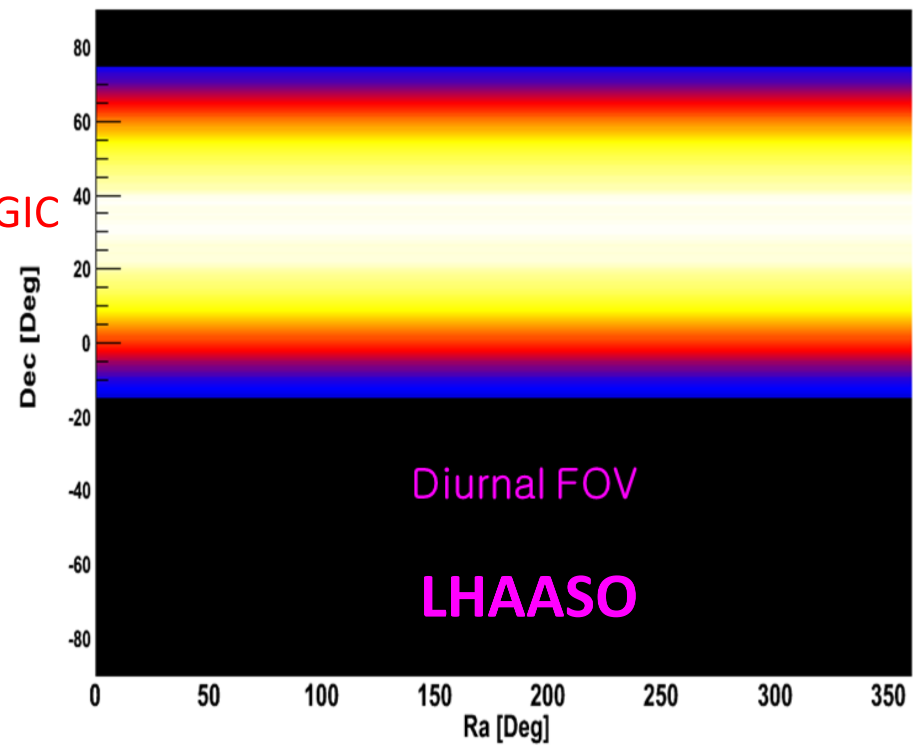
Integral



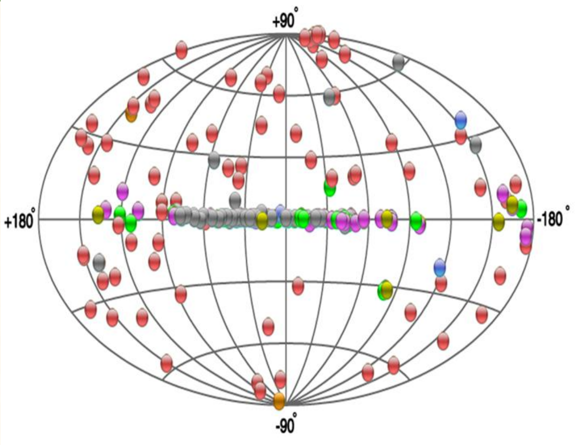
LHAASO:FOV

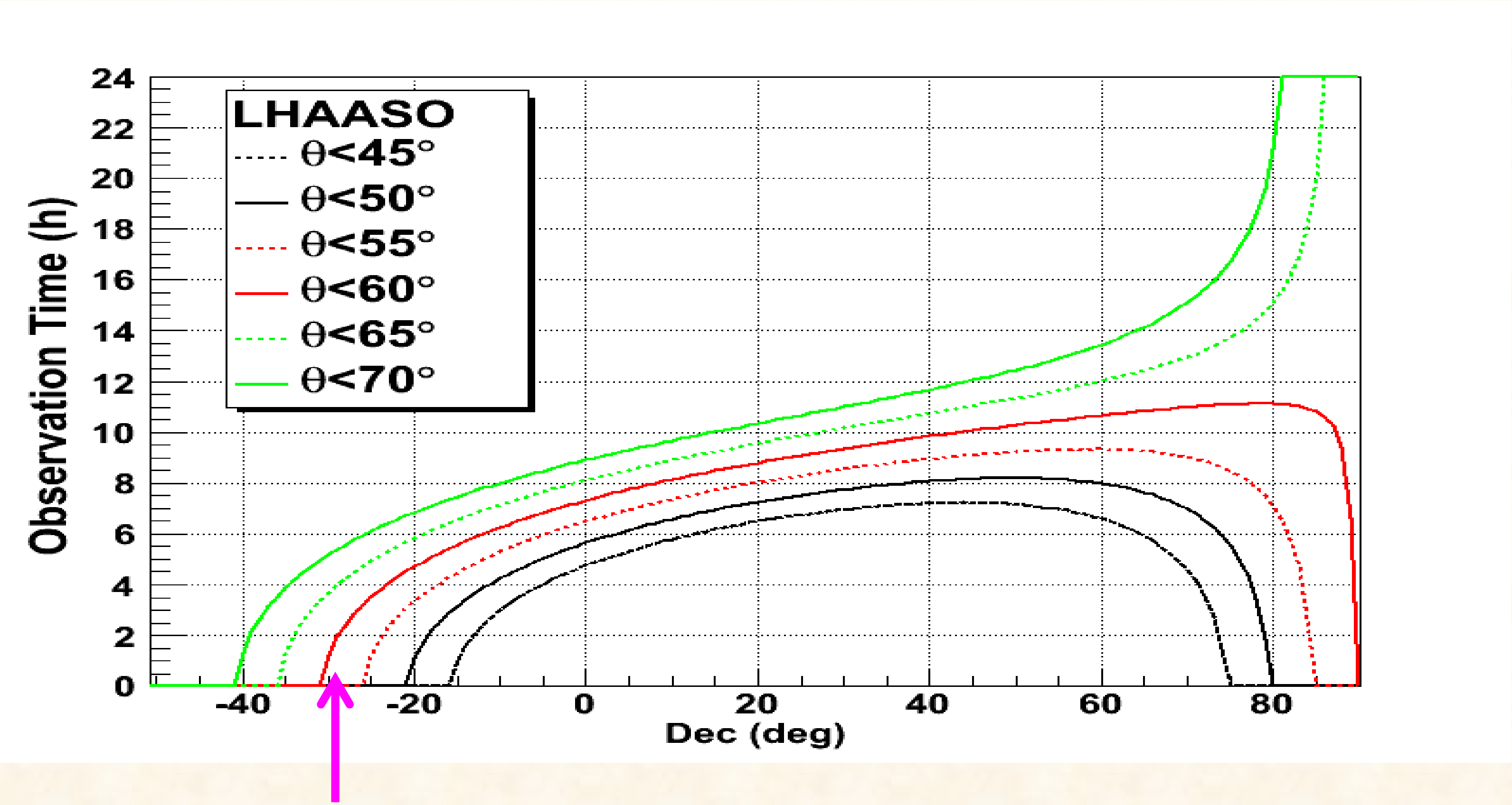
- **1/7 of the sky at each moment**
- **60% of the sky every day**





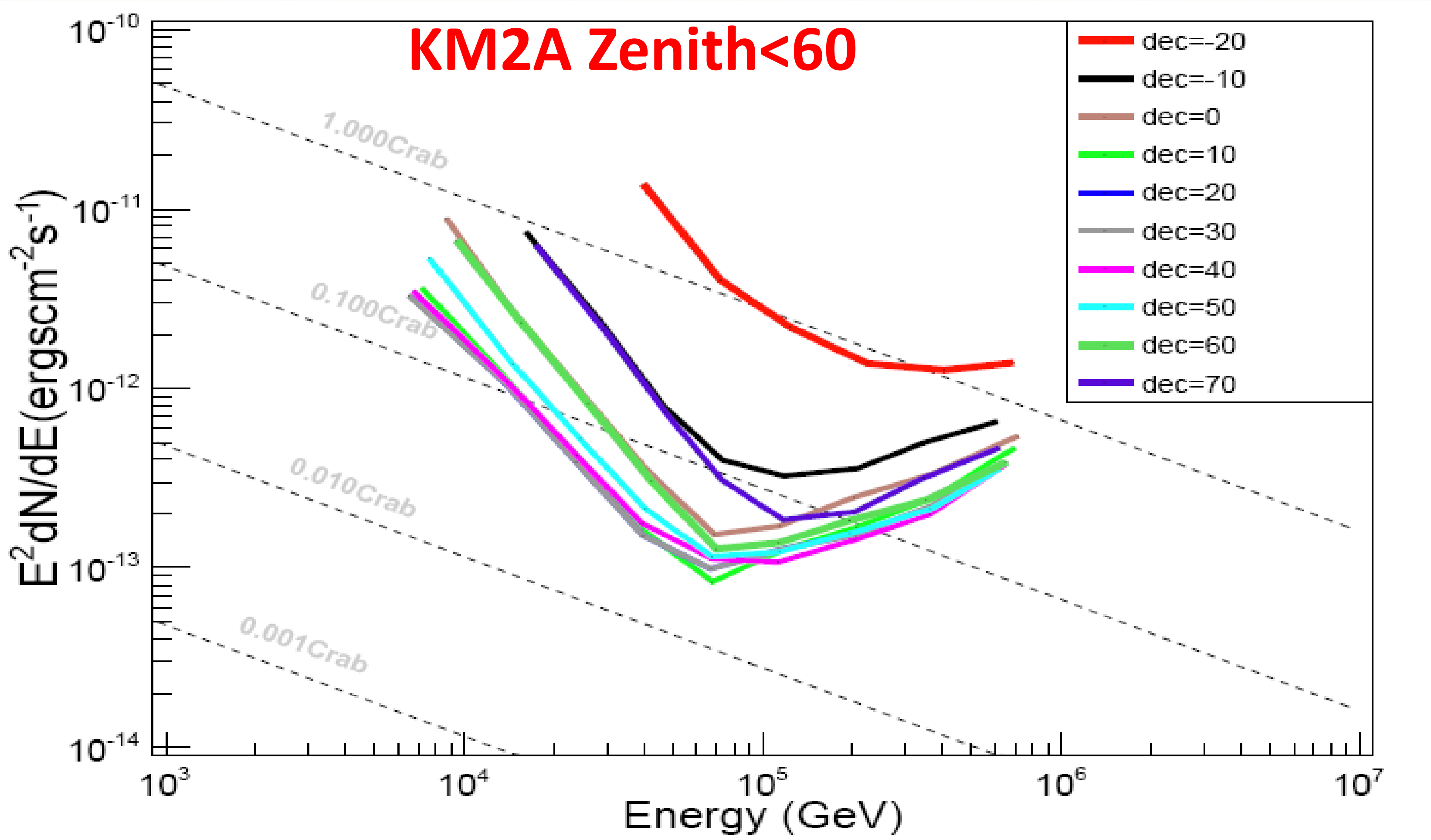
Source Observation time





Galactic center

Sensitivity for different sources

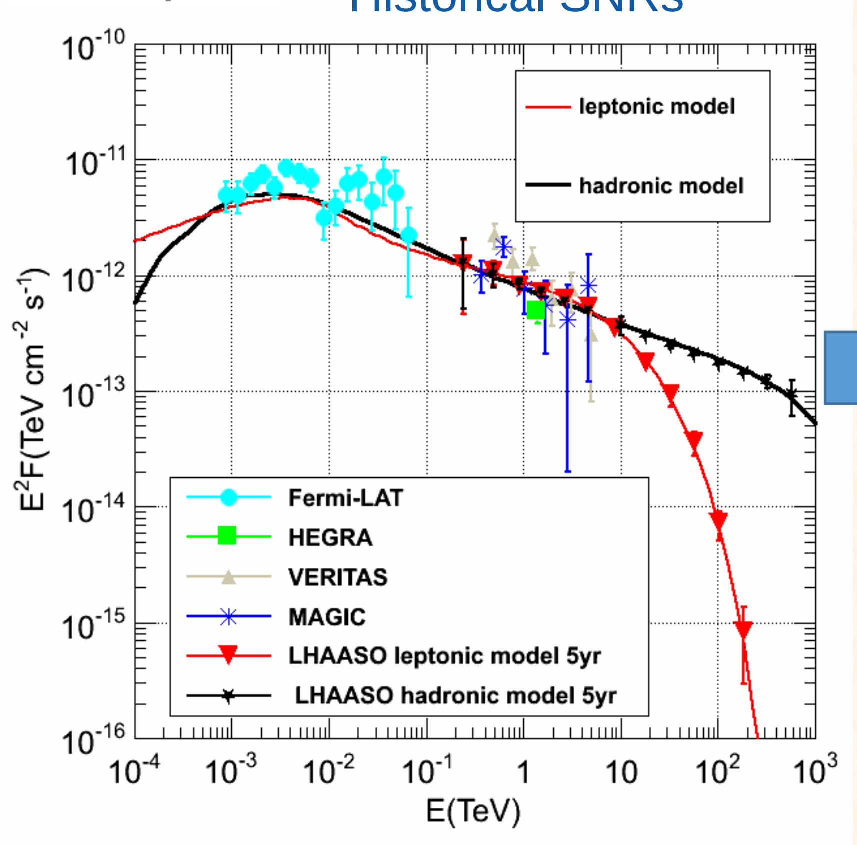


Galactic gamma-ray sources

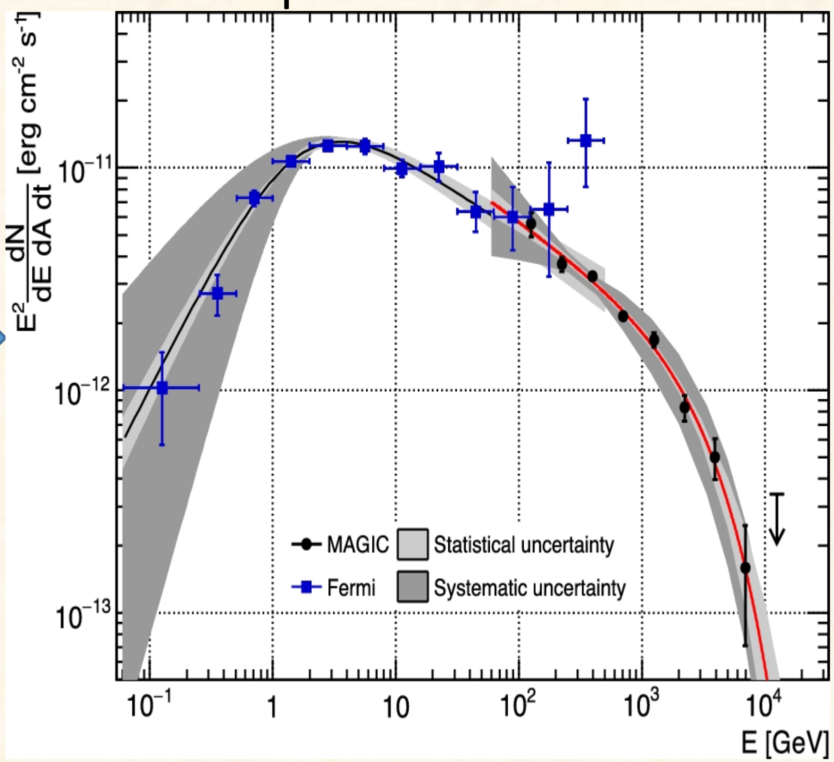
SNR: PeVatron?

Can we find evidence for PeVatron?

Historical SNRs



E_{pcut}~10TeV



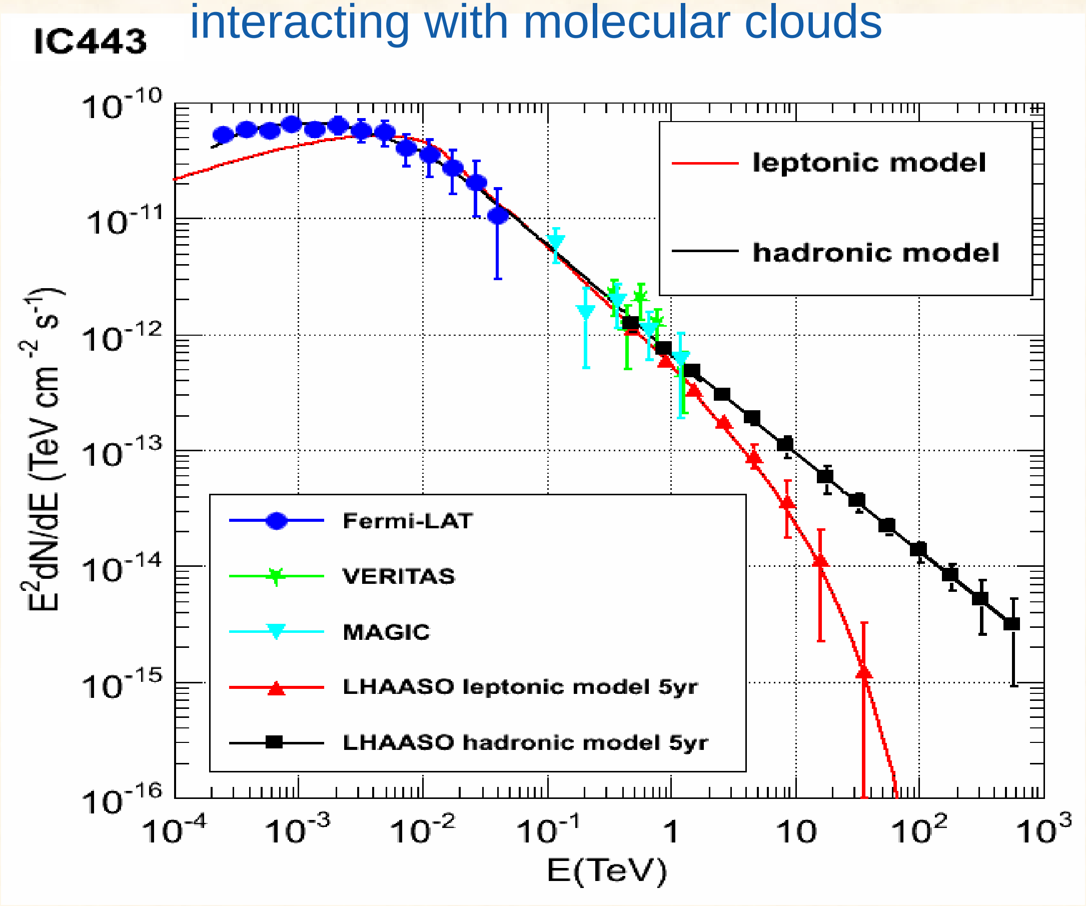
Liu, et. al. 2016

MAGIC coll. 2017

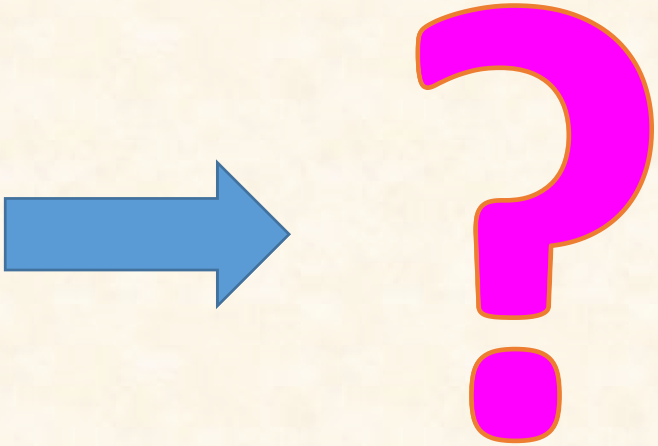
SNR: PeVatron?

Can we find evidence for PeVatron?

interacting with molecular clouds



Liu, et. al. 2016



Significance of SNR and UNID TeV Sources

Table 1

Selection of Known GeV–TeV and TeV SNRs Shown with the Expected Significance above 10 TeV using 5 yr Monte Carlo Simulation Data of LHAASO, Assuming That the Sources Are Under the Specific Hypotheses for the Energy Spectrum

Name	Classification	R.A.	Decl.	α	J_0 ($\mathrm{TeV^{-1}\,cm^{-2}\,s^{-1}}$)	σ (E_{cut} = 100 TeV)	σ' (E_{cut} = 30 TeV)	References
Tycho(a)	GeV–TeV	$00^h25^m18^s$	$+64°09'$	2.92 ± 0.46	2.2×10^{-13}	-	-	1
Tycho(b)	GeV–TeV	$00^h25^m18^s$	$+64°09'$	1.95 ± 0.51	1.70×10^{-13}	11.62	5.20	2
IC 443	GeV–TeV	$06^h17^m00^s$	$+22°30'$	2.99 ± 0.38	8.38×10^{-13}	5.46	-	3
W49B	GeV–TeV	$19^h11^m08^s$	$+09°06'$	3.1 ± 0.3	2.3×10^{-13}	-	-	4
HESS J1912-101	TeV	$19^h12^m49^s$	$+10°09'$	2.7 ± 0.2	3.5×10^{-12}	59.63	28.02	5
W51C	GeV–TeV	$19^h23^m50^s$	$+14°06'$	2.58 ± 0.07	9.7×10^{-13}	31.44	14.87	6
G106.3+2.7	TeV	$22^h27^m59^s$	$+60°52'$	2.29 ± 0.33	1.42×10^{-12}	57.43	21.10	7
Cassiopeia A	GeV–TeV	$23^h23^m26^s$	$+58°48'$	2.3 ± 0.2	7.3×10^{-13}	26.51	10.20	8

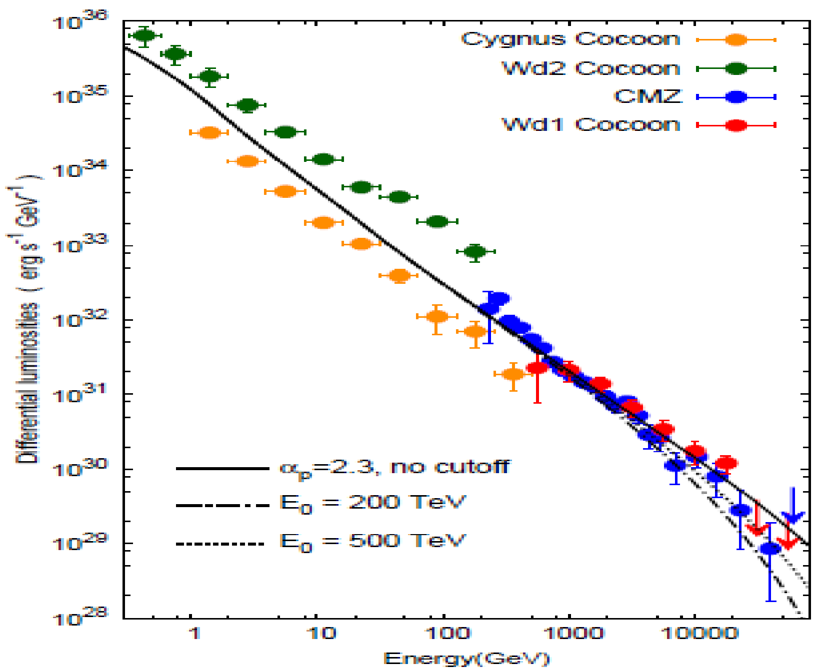
Table 4

Selection of Unidentified TeV γ-ray Sources and a Supperbubble (Cygnus Cocoon) Shown with the Expected Significance above 10 TeV using 5 yr Monte Carlo Simulation Data of LHAASO, Assuming That the Sources Are under the Specific Hypotheses for the Energy Spectrum

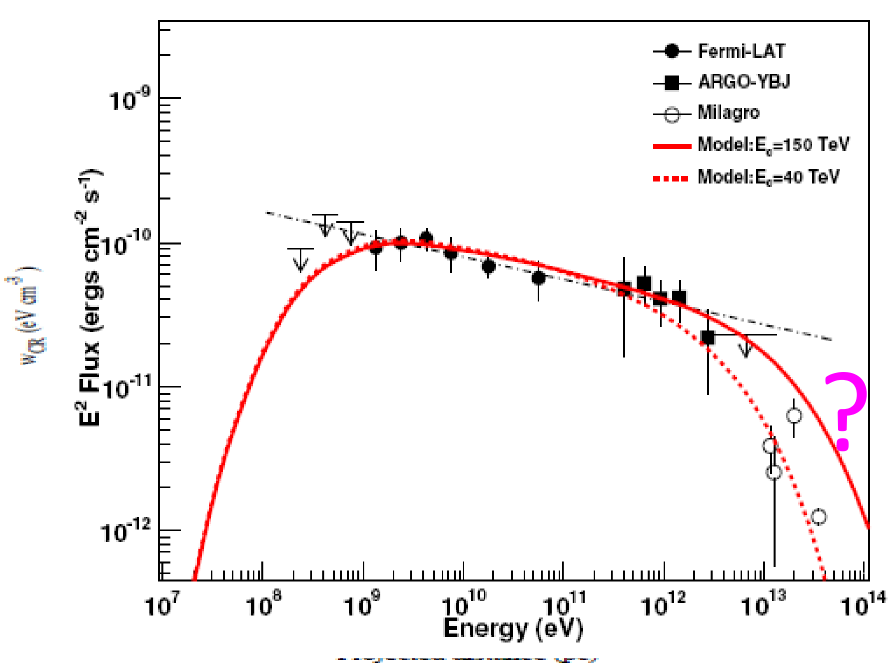
Name	R.A.	Decl.	α	J_0 ($\mathrm{TeV^{-1}\,cm^{-2}\,s^{-1}}$)	σ_{ext} (°)	σ (E_{cut} = 100 TeV)	σ' (E_{cut} = 30 TeV)	References
MAGIC J0223+403	$02^h23^m12^s$	$+43°00'$	3.1 ± 0.31	4.07×10^{-13}	0	-	-	1
HESS J1832-093	$18^h32^m50^s$	$-09°22'$	2.6 ± 0.3	4.8×10^{-13}	0	15.27	5.15	2
HESS J1834-087	$18^h34^m45^s.6$	$-08°45'$	2.5 ± 0.2	3.7×10^{-12}	0.1	21.73	7.15	3
HESS J1841-055	$18^h40^m55^s$	$-05°33'$	2.32 ± 0.23	3.76×10^{-11}	0.4	699.27	234.89	4
HESS J1857+026	$18^h57^m11^s$	$+02°40'$	2.16 ± 0.07	5.37×10^{-12}	0.17	205.63	76.95	5
HESS J1858+020	$18^h58^m20^s$	$+02°05'$	2.17 ± 0.12	6.0×10^{-13}	0.08	20.10	7.45	6
MGRO J1908+06	$19^h07^m54^s$	$+06°16'$	2.54 ± 0.36	2.06×10^{-11}	0.49	220.80	97.13	7
VER J2016+371	$20^h16^m02^s$	$+37°11'$	2.3 ± 0.3	3.1×10^{-13}	0	9.76	5.00	8
VER J2019+368	$20^h19^m25^s$	$+36°48'$	1.75 ± 0.08	1.35×10^{-12}	2.0	58.36	22.40	9
VER J2019+407	$20^h20^m04^s.8$	$+40°45'$	2.37 ± 0.14	1.5×10^{-12}	0.23	38.74	17.89	10
ARGO J2031+4157	$20^h31^m12^s$	$+42°30'$	2.6 ± 0.3	3.05×10^{-12}	2.0	10.86	5.3	11

Massive Stars as Major Factories of Galactic Cosmic Rays?

- The analysis of gamma-ray data show that the hard energy spectra of parent protons continue up to ~ 1 PeV.
- The population of young massive stars can provide production of CRs at a rate of up to 10^{41} erg/s, **which is sufficient to support the flux of Galactic CRs without invoking other source populations**.



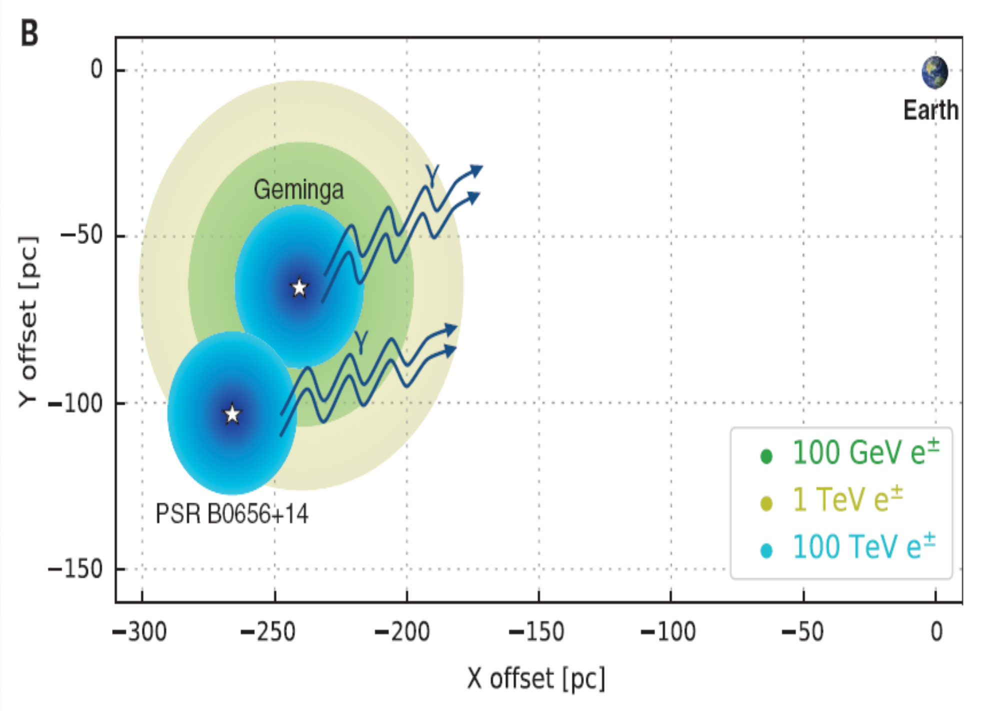
Aharonian et al. 2018

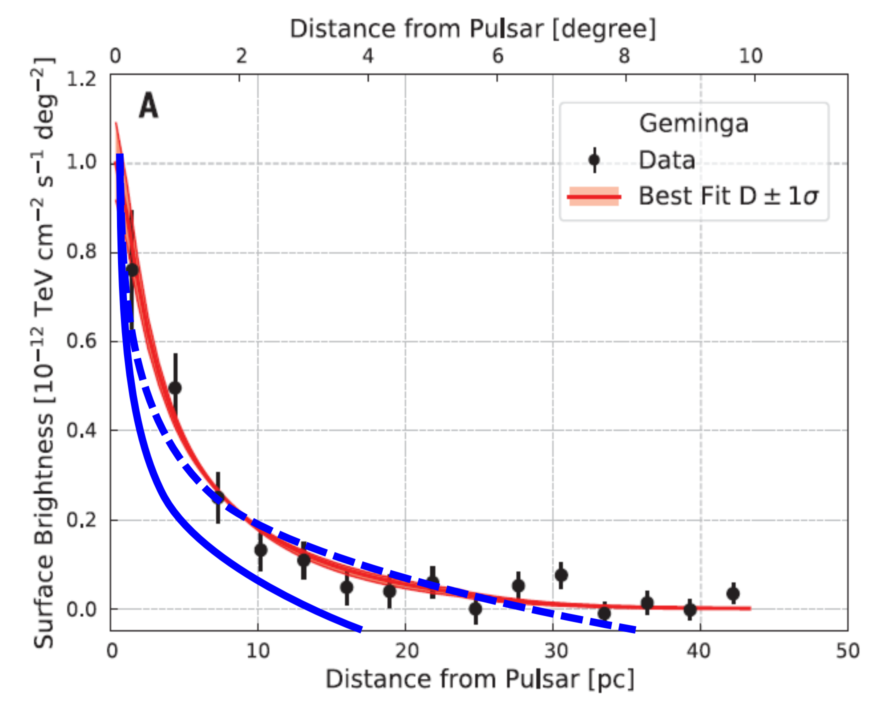


ARGO-YBJ coll. 2014

PWN: the origin of the excess positrons?

LHAASO could provide more information using the extension at different energies.

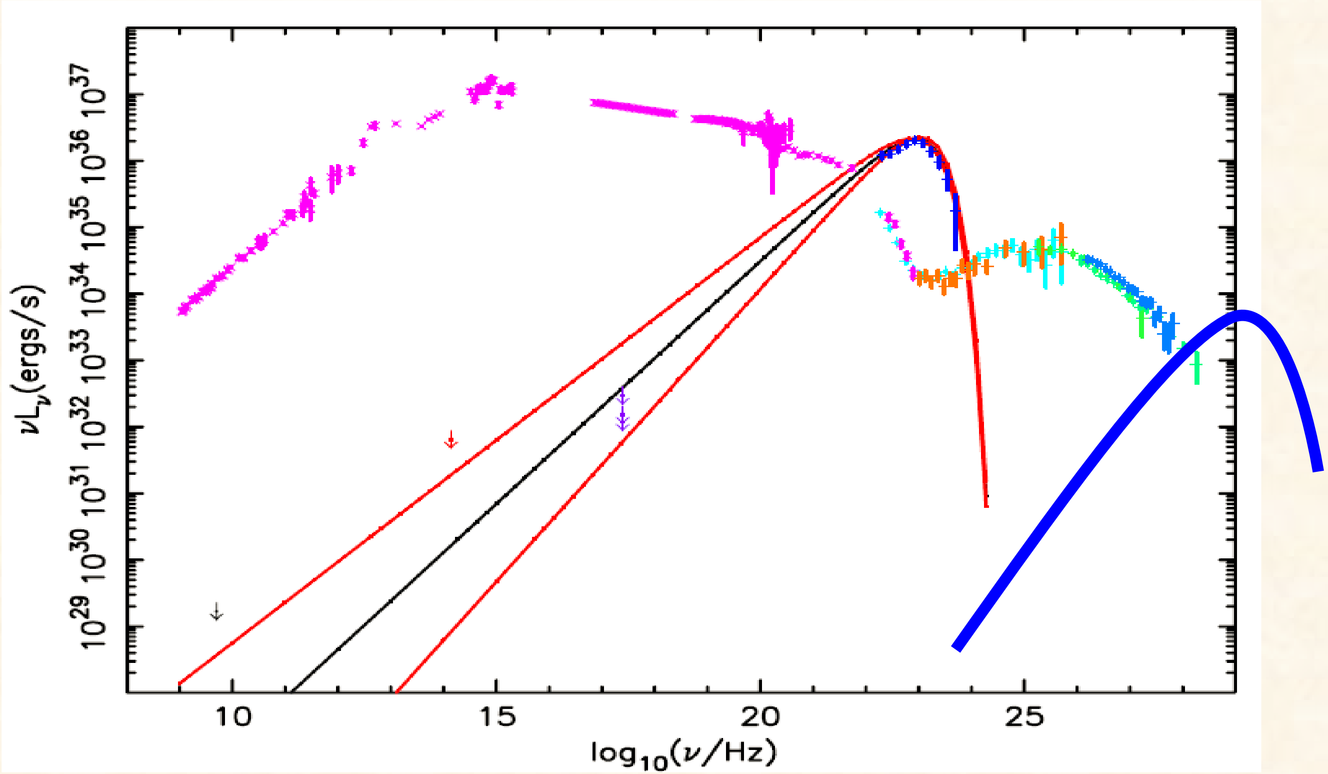




Abeysekara, et. al. 2017

Crab flare: around 100TeV?

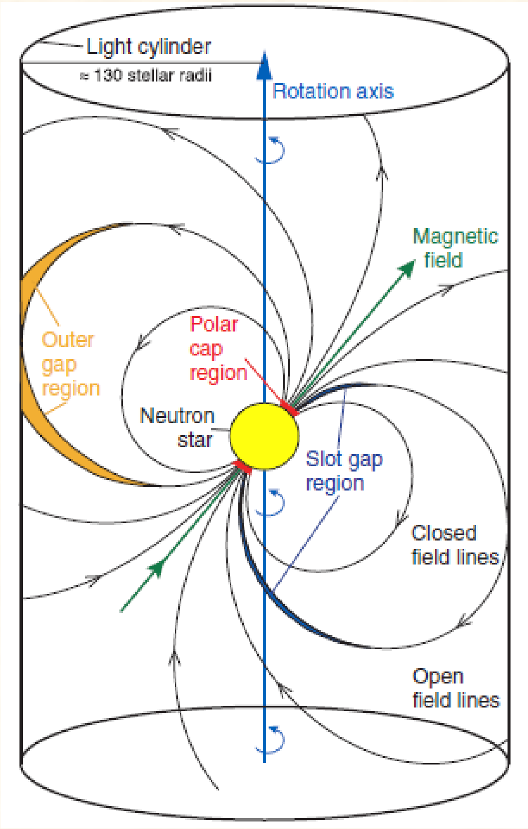
- Is there counterpart flare at higher energy can be observed by LHAASO?

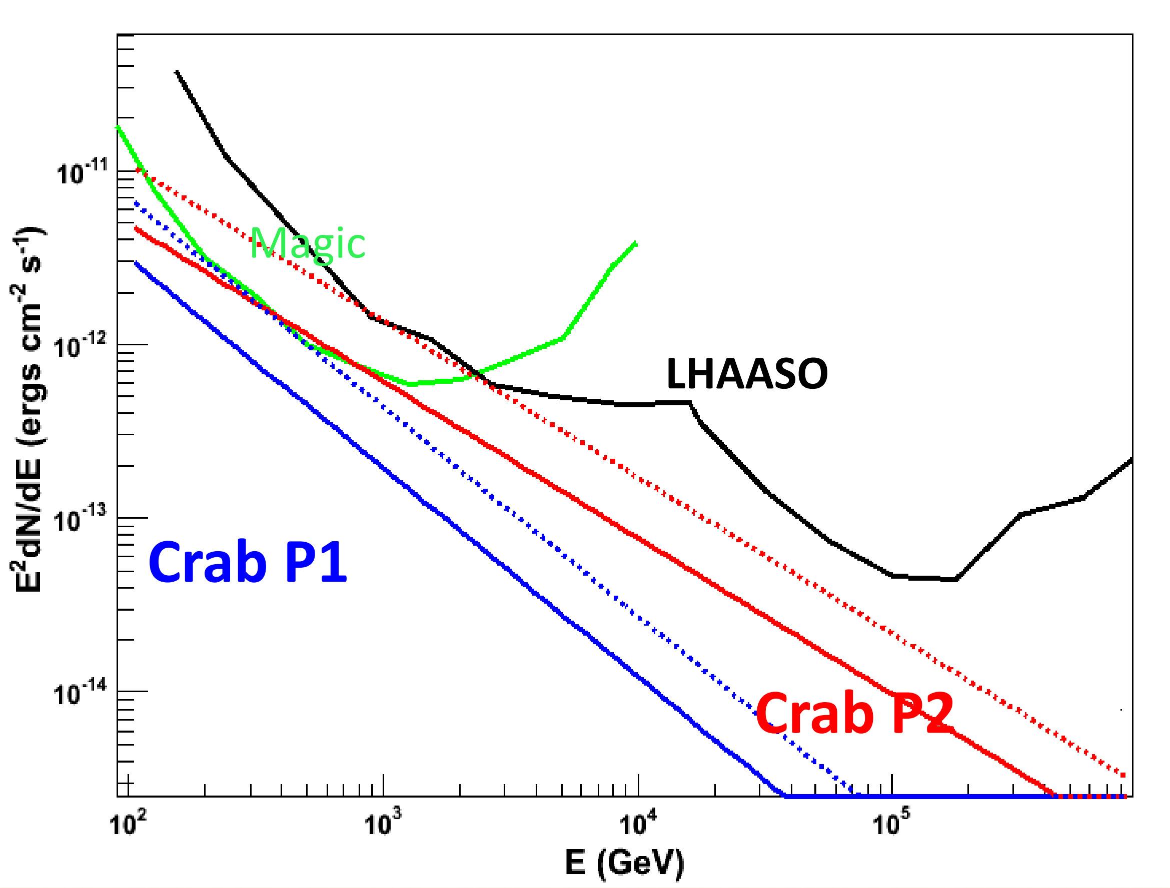


Weisskopf et al., 2013

Crab Pulsar: where is the cutoff energy?

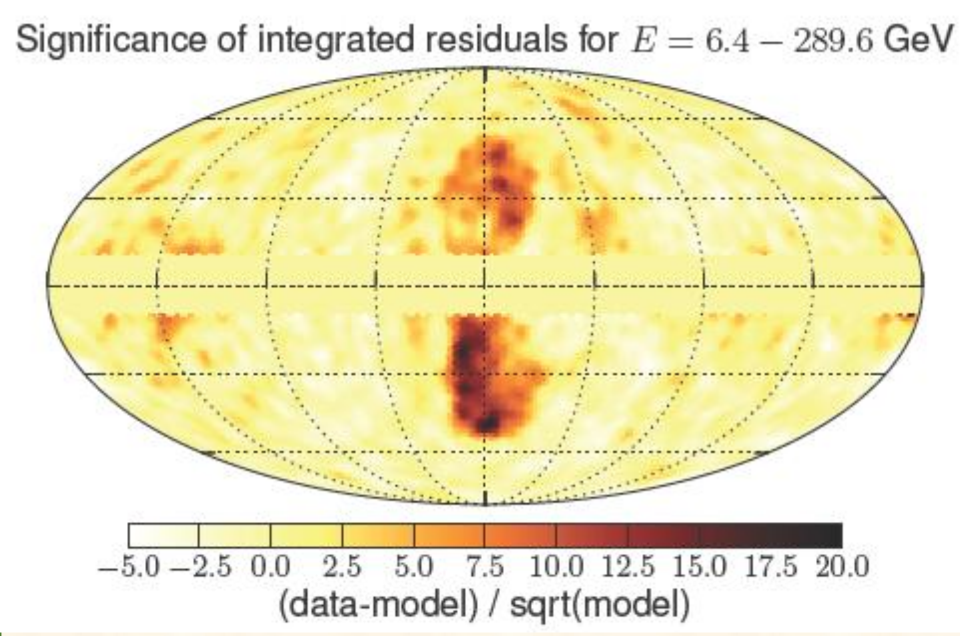
LHAASO have the ability to observed the Crab Pulsar using 5 years data.

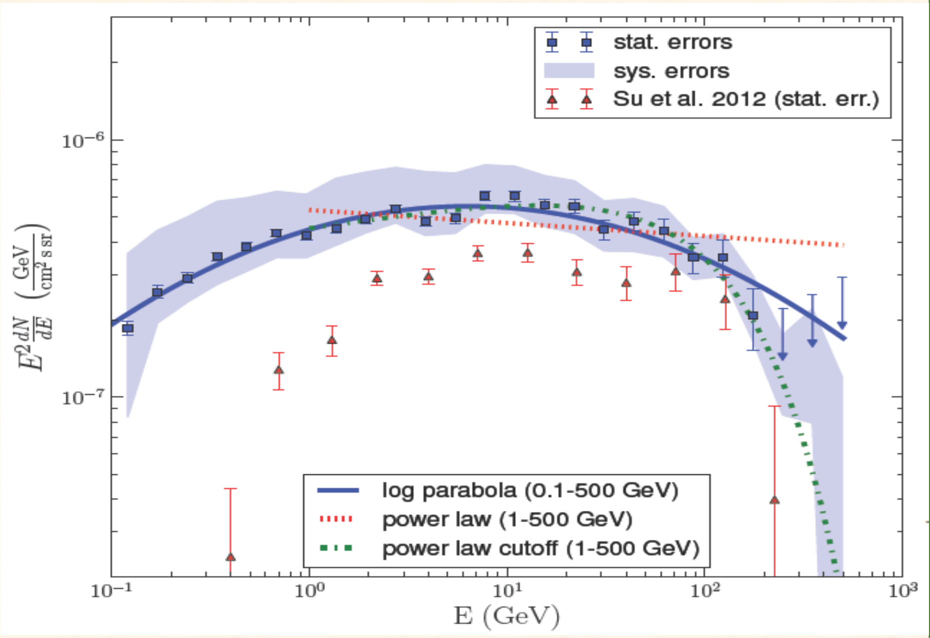




Fermi Bubble: Gamma-ray >1TeV?

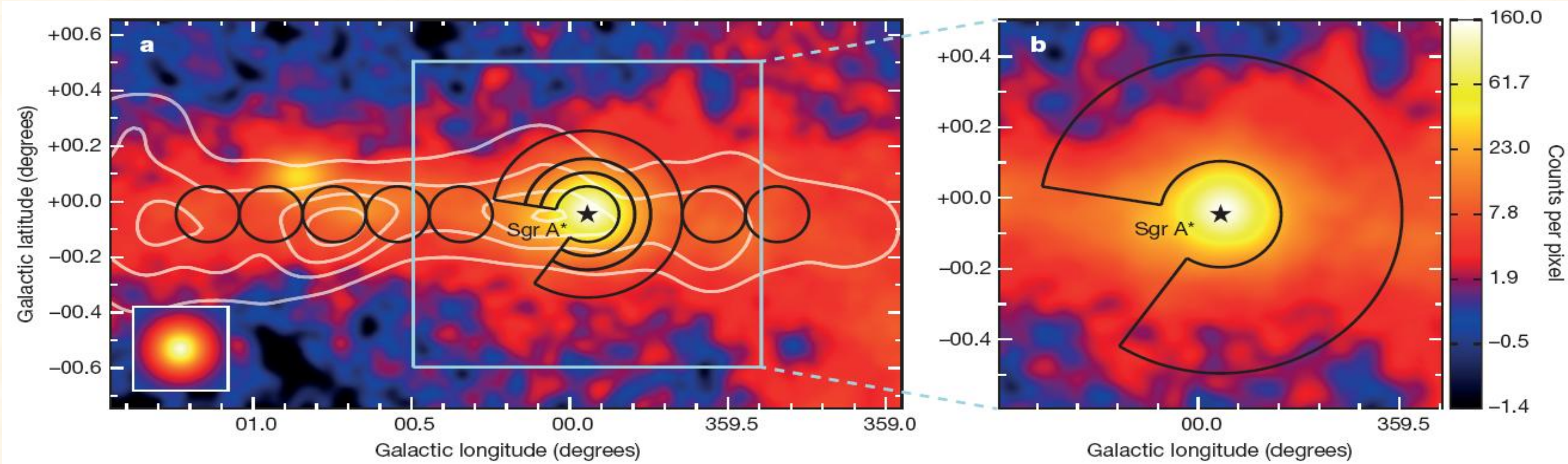
- **The north part of Fermi Bubble is partly covered by LHAASO. LHAASO could give some information for its high energy emission.**

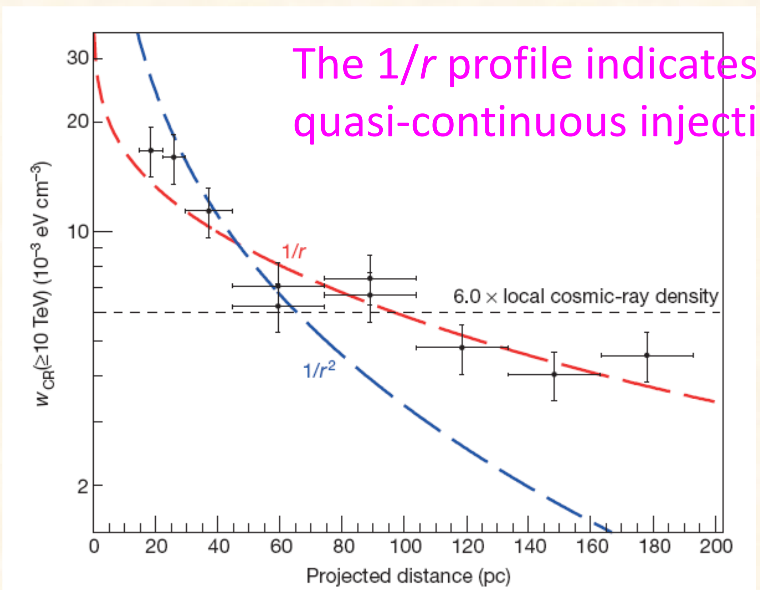


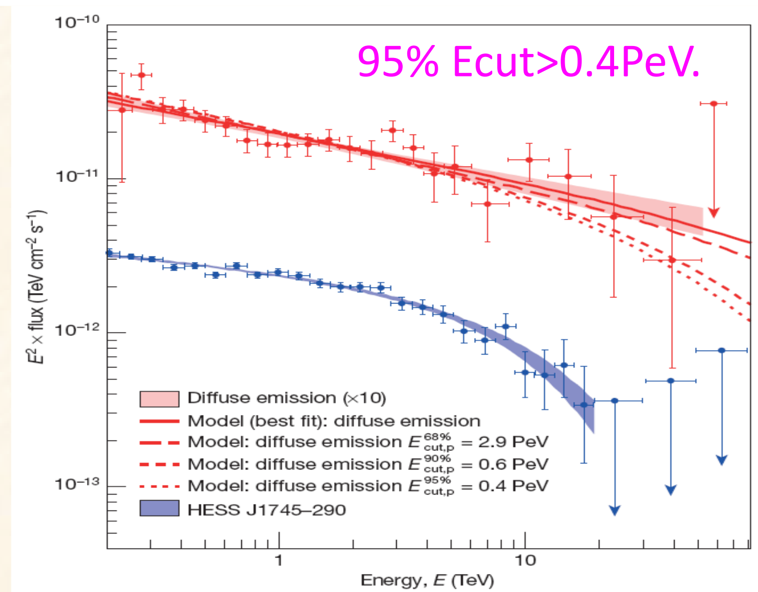


Ackermann et al., 2014

Galactic Centre: Acceleration of PeV protons！ ？



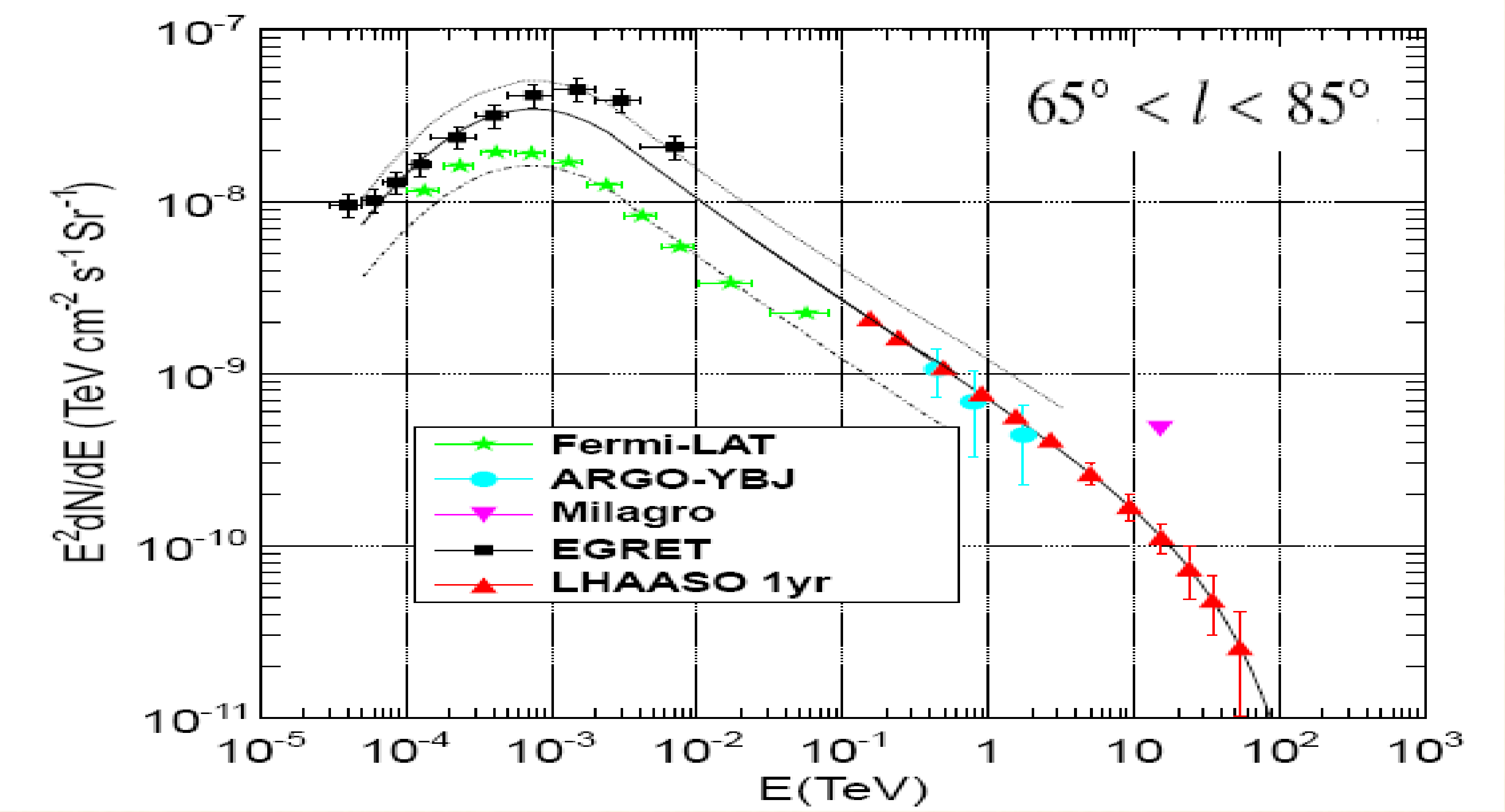




HESS coll. 2016, Nature

Galactic plane diffuse: where is the cutoff energy?

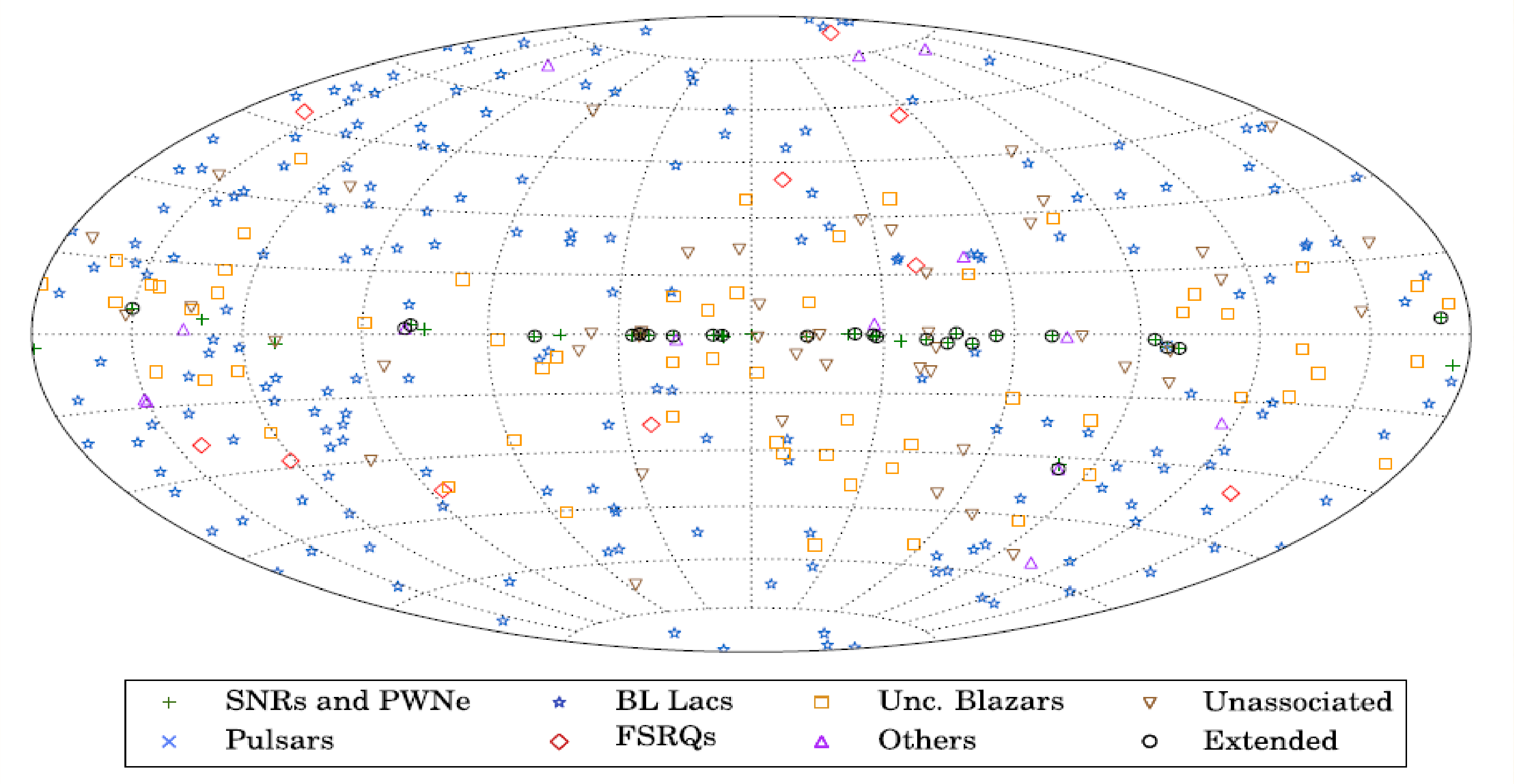
The determination of the cutoff energy will provide important information for the cosmic ray and its propagation!



Extra-galactic gamma-ray sources

2FHL: 50GeV-2 TeV

- 360 sources, AGNs are dominated

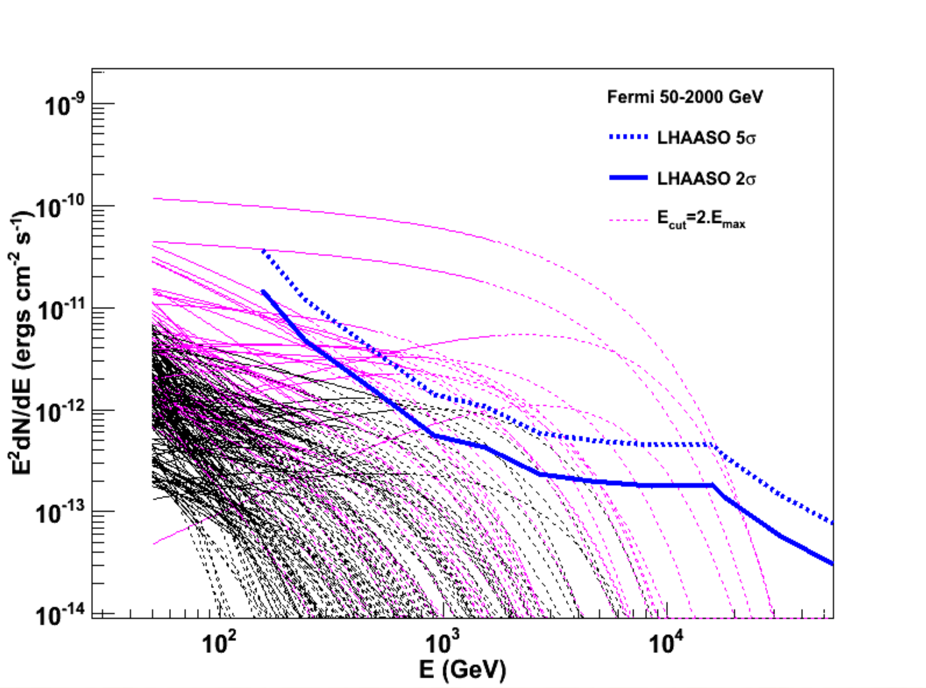


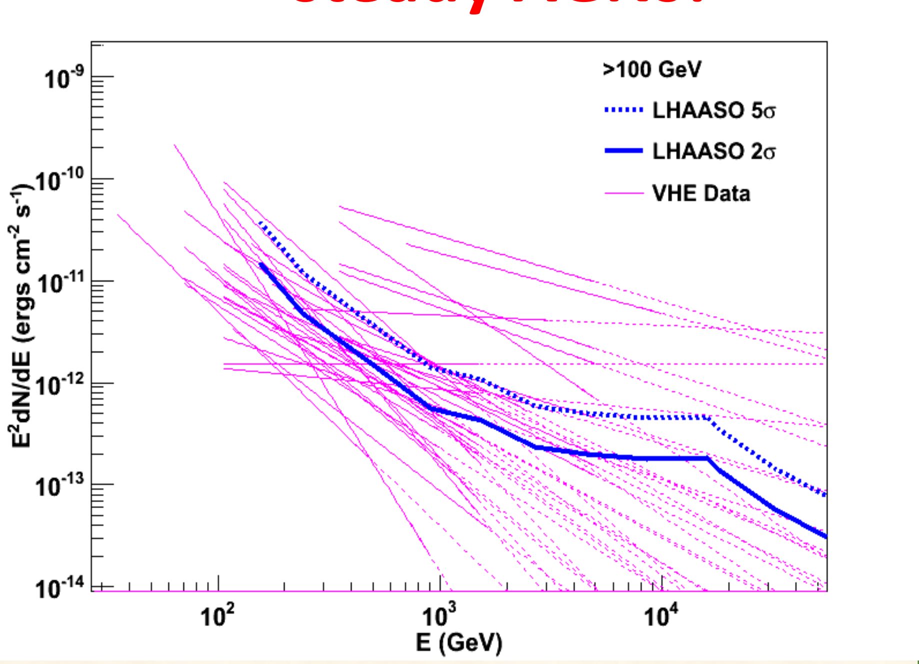
Ackermann, et. al. 2016

AGN: Expectation of LHAASO

- 2FHL: 21 AGNs, where 17 are known AGNs.
- >100GeV catalog: 23 AGNs
- 13 AGNs are overlapped!

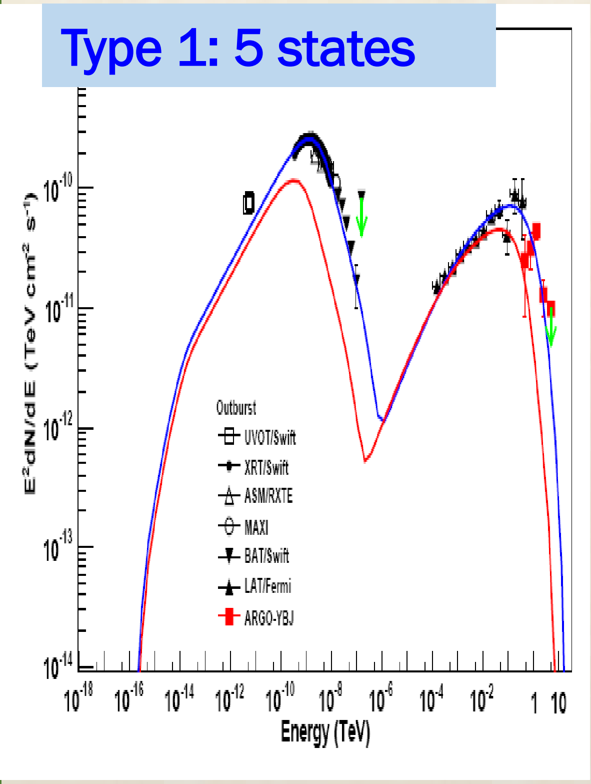
Only for steady AGNs!

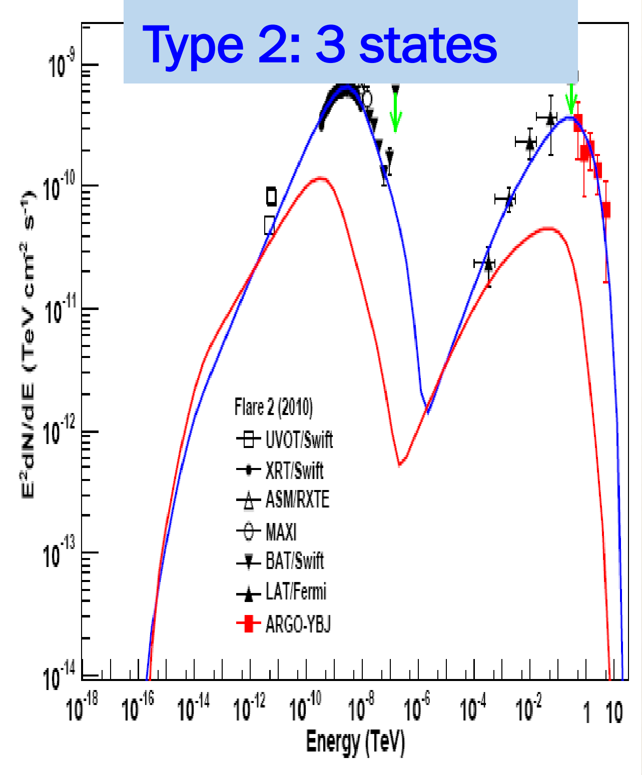


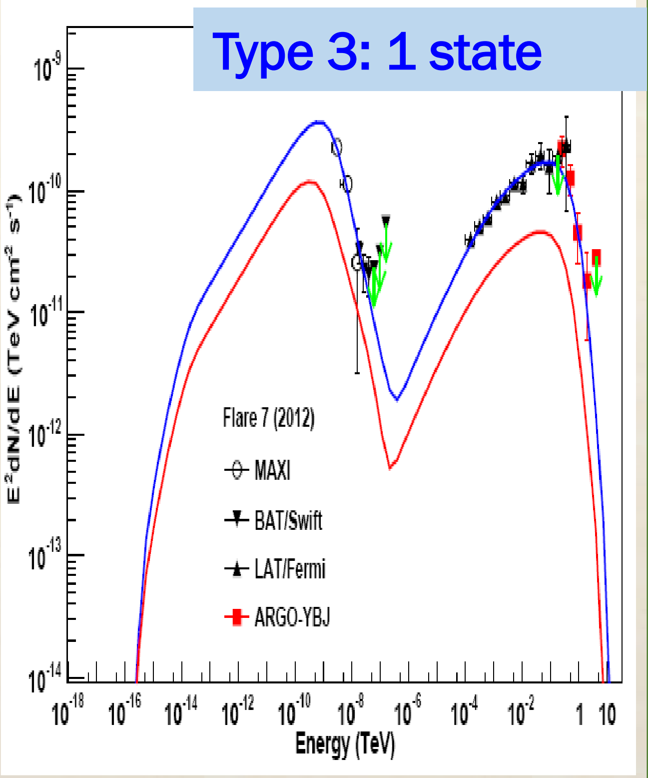


AGN: long-term continue observation

Long-term MWL monitor is essential to systematic study the flares of AGNs







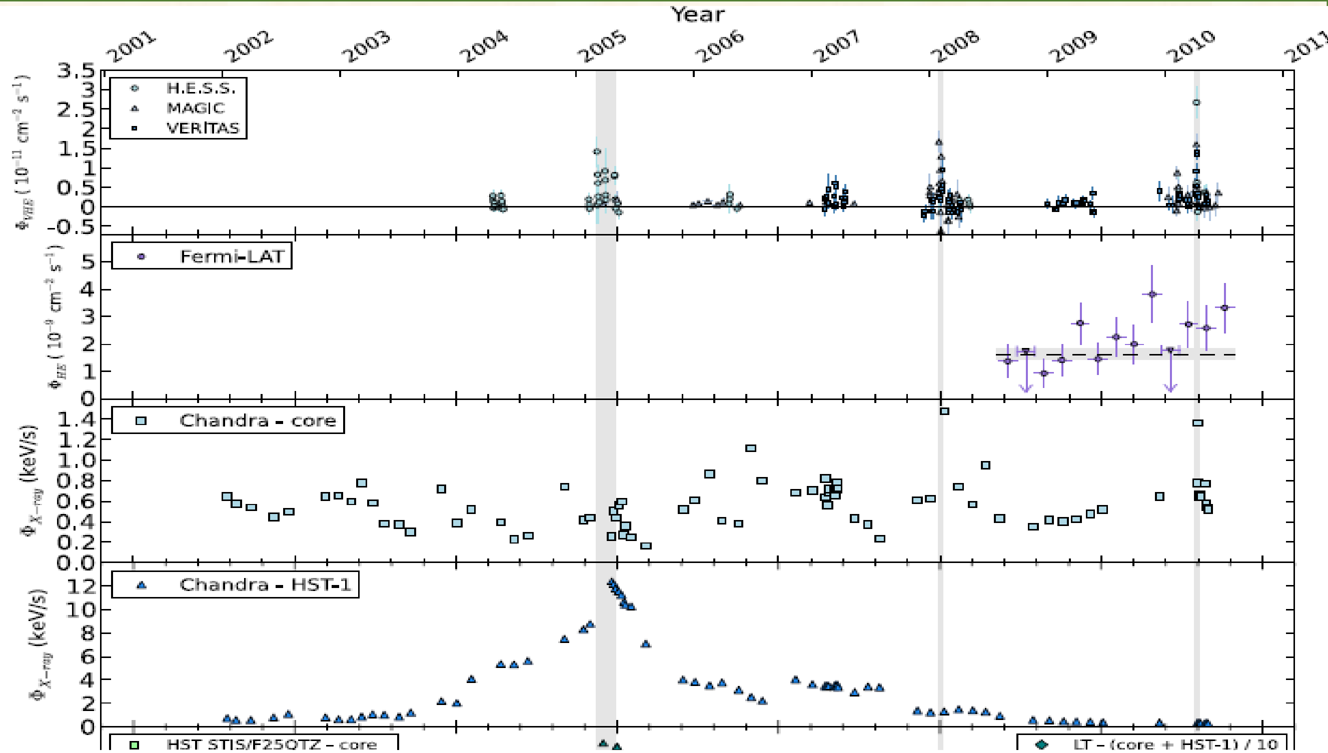
ARGO-YBJ coll., ApJS, 222:6, (2016)

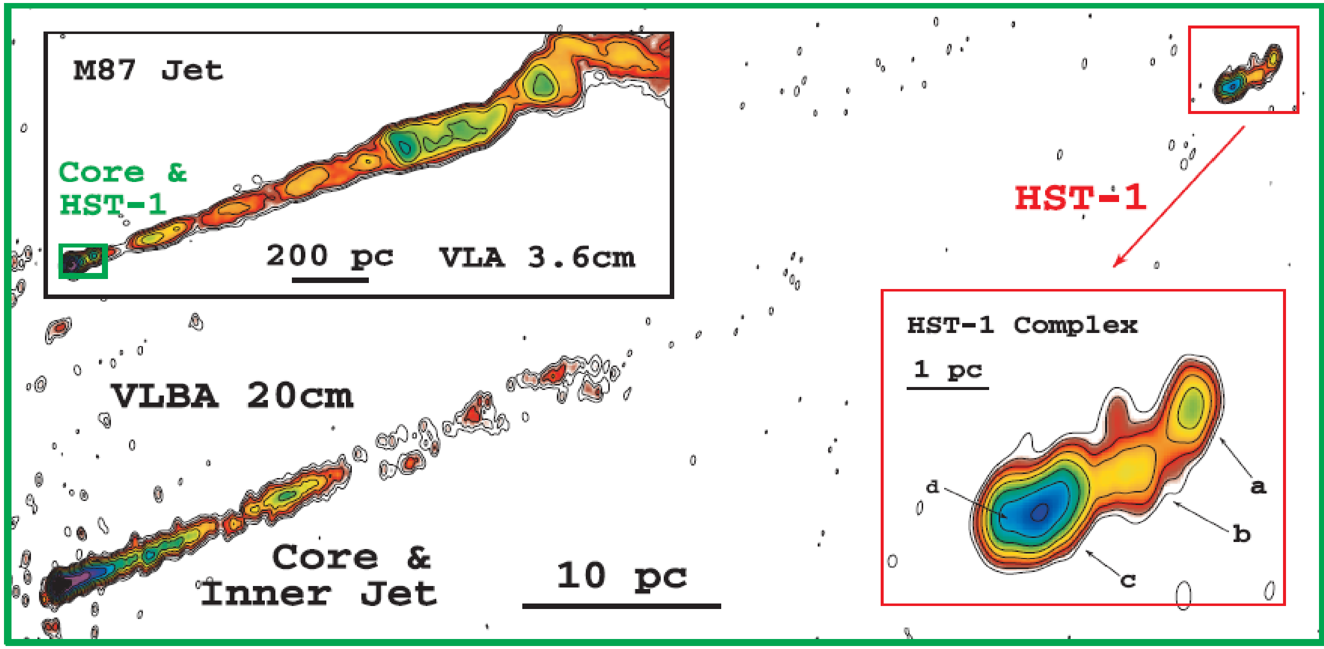
Radio AGN

- **LHAASO may detect more events for such correlation study.**

Abramowski et al., 2012

Cheung et al., 2007



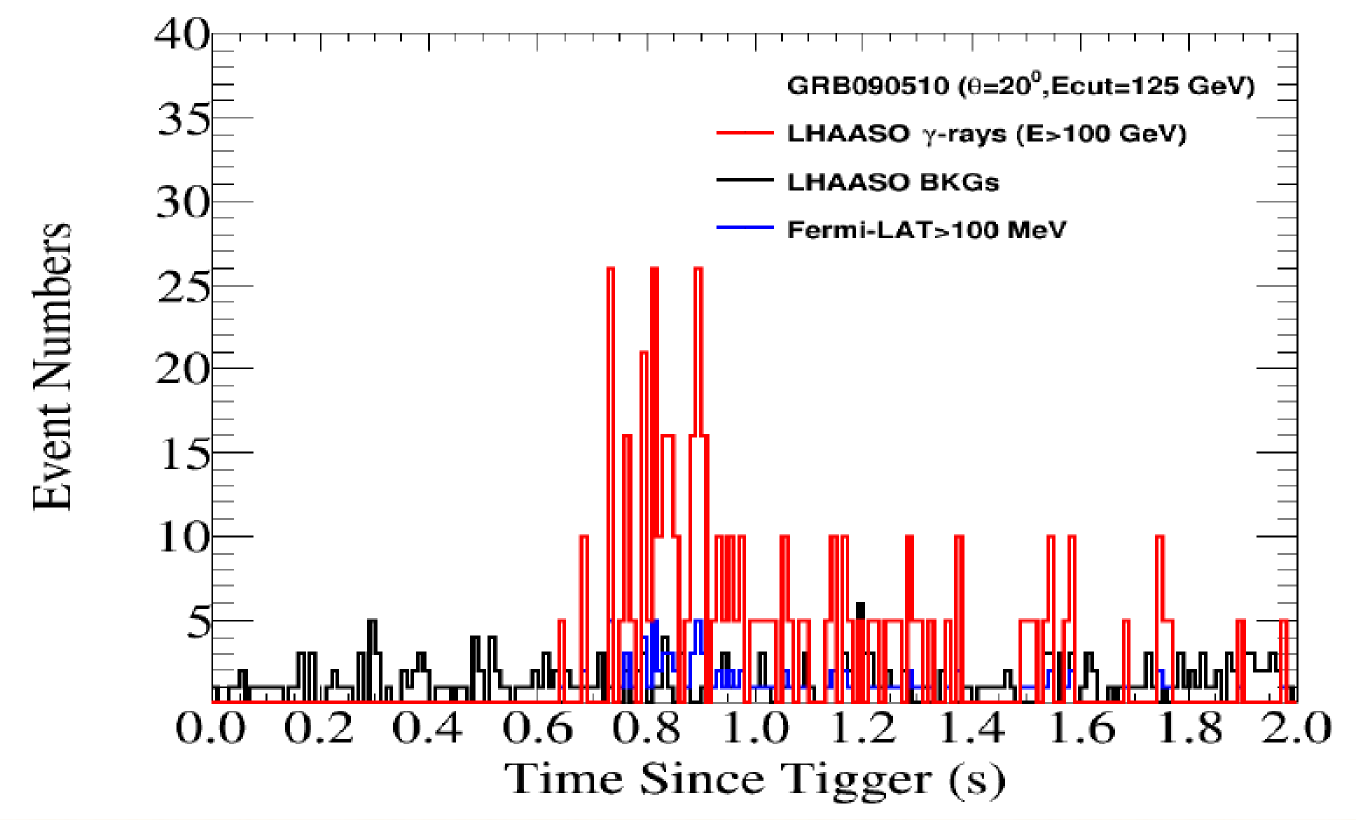


GRB: lucky enough?

LHAASO have the sensitivity to detect very bright GRBs.

This will be important to determine many things: GRB Ecut, EBL, LIV.

While this need us lucky enough!



Summary

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- **LHAASO will certainly improve the sensitivity of wide field sky survey up to 1% Crab unit.**
- **LHAASO will deeply extend the gamma-ray astronomy from about 10 TeV to 100TeV or higher.**
- **LHAASO results around 100 TeV on specific sources may be millstone, like SNR,PWN, GP diffuse and so on.**