



中国科学技术大学
University of Science and Technology of China



LHAASO status and recent results

Ruizhi Yang

**University of Science and Technology of China
On behalf of LHAASO collaborations**

1. Intro of LHAASO

2. Highlights of LHAASO results

3. Summary and prospect



• **274 Scientists**

• **32 institutions**
• **from 5 countries**

Zhen Cao^{1,2,3}, F. Aharonian^{4,5}, Q. An^{6,7}, Axikegu⁸, L. X. Bai⁹, Y. X. Bai^{1,3}, Y. W. Bao¹⁰, D. Bastieri¹¹, X. J. Bi^{1,2,3}, Y. J. Bi^{1,3}, H. Cai¹², J. T. Cai¹¹, Zhe Cao^{6,7}, J. Chang¹³, J. F. Chang^{1,3,6}, B. M. Chen¹⁴, E. S. Chen^{1,2,3}, J. Chen⁹, Liang Chen^{1,2,3}, Liang Chen¹⁵, Long Chen⁸, M. J. Chen^{1,3}, M. L. Chen^{1,3,6}, Q. H. Chen⁸, S. H. Chen^{1,2,3}, S. Z. Chen^{1,3}, T. L. Chen¹⁶, X. L. Chen^{1,2,3}, Y. Chen¹⁰, N. Cheng^{1,3}, Y. D. Cheng^{1,3}, S. W. Cui¹⁴, X. H. Cui¹⁷, Y. D. Cui¹⁸, B. D'Estorre Piazzoli¹⁹, B. Z. Dai²⁰, H. L. Dai^{1,3,6}, Z. G. Dai⁷, Danzengluobu¹⁶, D. della Volpe²¹, X. J. Dong^{1,3}, K. K. Duan¹³, J. H. Fan¹¹, Y. Z. Fan¹³, Z. X. Fan^{1,3}, J. Fang²⁰, K. Fang^{1,3}, C. F. Feng²², L. Feng¹³, S. H. Feng^{1,3}, Y. L. Feng¹³, B. Gao^{1,3}, C. D. Gao²², L. Q. Gao^{1,2,3}, Q. Gao¹⁶, W. Gao²², M. M. Ge²⁰, L. S. Geng^{1,3}, G. H. Gong²³, Q. B. Gou^{1,3}, M. H. Gu^{1,3,6}, F. L. Guo¹⁵, J. G. Guo^{1,2,3}, X. L. Guo⁸, Y. Q. Guo^{1,3}, Y. Y. Guo^{1,2,3,13}, Y. A. Han²⁴, H. H. He^{1,2,3}, H. N. He¹³, J. C. He^{1,2,3}, S. L. He¹¹, X. B. He¹⁸, Y. He⁸, M. Heller²¹, Y. K. Hor¹⁸, C. Hou^{1,3}, H. B. Hu^{1,2,3}, S. Hu⁹, S. C. Hu^{1,2,3}, X. J. Hu²³, D. H. Huang⁸, Q. L. Huang^{1,3}, W. H. Huang²², X. T. Huang²², X. Y. Huang¹³, Z. C. Huang⁸, F. Ji^{1,3}, X. L. Ji^{1,3,6}, H. Y. Jia⁸, K. Jiang^{6,7}, Z. J. Jiang²⁰, C. Jin^{1,2,3}, T. Ke^{1,3}, D. Kuleshov²⁵, K. Levochkin²⁵, B. B. Li¹⁴, Cheng Li^{6,7}, Cong Li^{1,3}, F. Li^{1,3,6}, H. B. Li^{1,3}, H. C. Li^{1,3}, H. Y. Li^{7,13}, J. Li^{1,3,6}, K. Li^{1,3}, W. L. Li²², X. R. Li^{1,3}, Xin Li^{6,7}, Xin Li⁸, Y. Li⁹, Y. Z. Li^{1,2,3}, Zhe Li^{1,3}, Zhuo Li²⁶, E. W. Liang²⁷, Y. F. Liang²⁷, S. J. Lin¹⁸, B. Liu⁷, C. Liu^{1,3}, D. Liu²², H. Liu⁸, H. D. Liu²⁴, J. Liu^{1,3}, J. L. Liu²⁸, J. S. Liu¹⁸, J. Y. Liu^{1,3}, M. Y. Liu¹⁶, R. Y. Liu¹⁰, S. M. Liu⁸, W. Liu^{1,3}, Y. Liu¹¹, Y. N. Liu²³, Z. X. Liu⁹, W. J. Long⁸, R. Lu²⁰, H. K. Lv^{1,3}, B. Q. Ma²⁶, L. L. Ma^{1,3}, X. H. Ma^{1,3}, J. R. Mao²⁹, A. Masood⁸, Z. Min^{1,3}, W. Mitthumsiri²¹, T. Montaruli²¹, Y. C. Nan²², B. Y. Pang⁸, P. Pattarakijwanich³⁰, Z. Y. Pei¹¹, M. Y. Qi^{1,3}, Y. Q. Qi¹⁴, B. Q. Qiao^{1,3}, J. J. Qin⁷, D. Ruffolo³⁰, V. Rubev²⁵, A. Sáiz³⁰, L. Shao¹⁴, O. Shchegolev^{25,31}, X. D. Sheng^{1,3}, J. Y. Shi^{1,3}, H. C. Song²⁶, Yu. V. Stenkin^{25,31}, V. Stepanov²⁵, Y. Su³², Q. N. Sun⁸, X. N. Sun²⁷, Z. B. Sun³³, P. H. T. Tam¹⁸, Z. B. Tang^{6,7}, W. W. Tian^{2,17}, B. D. Wang^{1,3}, C. Wang³³, H. Wang⁸, H. G. Wang¹¹, J. S. Wang²⁸, L. P. Wang²², L. Y. Wang^{1,3}, R. N. Wang⁸, W. Wang¹⁸, W. Wang¹², X. G. Wang²⁷, X. J. Wang^{1,3}, X. Y. Wang¹⁰, Y. Wang⁸, Y. D. Wang^{1,3}, Y. J. Wang^{1,3}, Y. P. Wang^{1,2,3}, Z. H. Wang⁹, Z. X. Wang²⁰, Zhen Wang²⁸, Zheng Wang^{1,3,6}, D. M. Wei¹³, J. J. Wei¹³, Y. J. Wei^{1,2,3}, T. Wen²⁰, C. Y. Wu^{1,3}, H. R. Wu^{1,3}, S. Wu^{1,3}, W. X. Wu⁸, X. F. Wu¹³, S. Q. Xi^{1,3}, J. Xia^{7,13}, J. J. Xia⁸, G. M. Xiang^{2,15}, D. X. Xiao¹⁶, G. Xiao^{1,3}, H. B. Xiao¹¹, G. G. Xin¹², Y. L. Xin⁸, Y. Xing¹⁵, D. L. Xu²⁸, R. X. Xu²⁶, L. Xue²², D. H. Yan²⁹, J. Z. Yan¹³, C. W. Yang⁹, F. F. Yang^{1,3,6}, J. Y. Yang¹⁸, L. L. Yang¹⁸, M. J. Yang^{1,3}, R. Z. Yang⁷, S. B. Yang²⁰, Y. H. Yao⁹, Z. G. Yao^{1,3}, Y. M. Ye²³, L. Q. Yin^{1,3}, N. Yin²², X. H. You^{1,3}, Z. Y. You^{1,2,3}, Y. H. Yu²², Q. Yuan¹³, H. D. Zeng¹³, T. X. Zeng^{1,3,6}, W. Zeng²⁰, Z. K. Zeng^{1,2,3}, M. Zha^{1,3}, X. X. Zhai^{1,3}, B. B. Zhang¹⁰, H. M. Zhang¹⁰, H. Y. Zhang²², J. L. Zhang¹⁷, J. W. Zhang⁹, L. X. Zhang¹¹, Li Zhang²⁰, Lu Zhang¹⁴, P. F. Zhang²⁰, P. P. Zhang¹⁴, R. Zhang^{7,13}, S. R. Zhang¹⁴, S. S. Zhang^{1,3}, X. Zhang¹⁰, X. P. Zhang^{1,3}, Y. F. Zhang⁸, Y. L. Zhang^{1,3}, Yi Zhang^{1,13}, Yong Zhang^{1,3}, B. Zhao⁸, J. Zhao^{1,3}, L. Zhao^{6,7}, L. Z. Zhao¹⁴, S. P. Zhao^{13,22}, F. Zheng³³, Y. Zheng⁸, B. Zhou^{1,3}, H. Zhou²⁸, J. N. Zhou¹⁵, P. Zhou¹⁰, R. Zhou⁹, X. X. Zhou⁸, C. G. Zhu²², F. R. Zhu⁸, H. Zhu¹⁷, K. J. Zhu^{1,2,3,6}, and X. Zuo^{1,3}

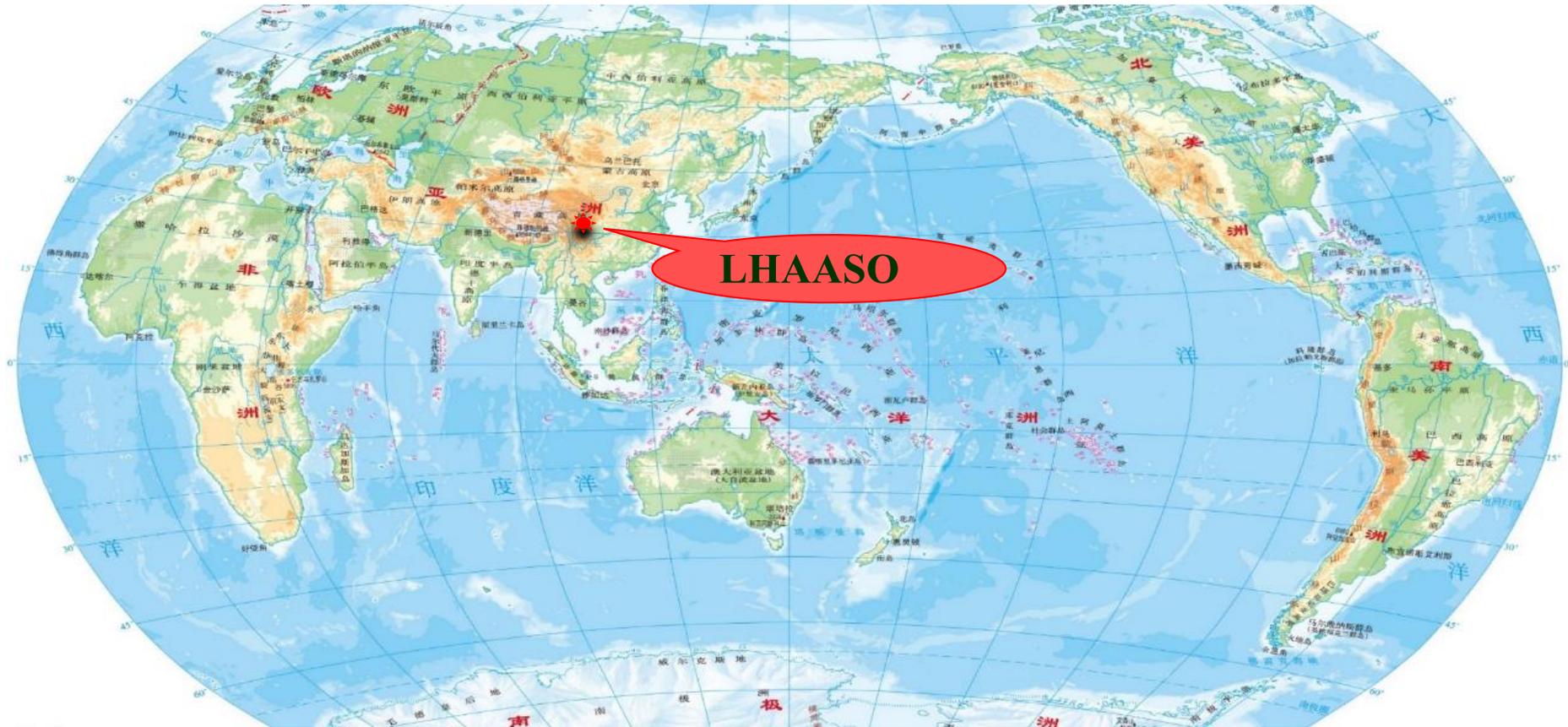
- ¹ Key Laboratory of Particle Astrophysics & Experimental Physics Division & Computing Center, Institute of High Energy Physics, Chinese Academy of Sciences, 100049 Beijing, People's Republic of China; licong@ihep.ac.cn, chensz@ihep.ac.cn, wusha@ihep.ac.cn
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- ¹⁴ Hebei Normal University, 050024 Shijiazhuang, Hebei, People's Republic of China
- ¹⁵ Key Laboratory for Research in Galaxies and Cosmology, Shanghai Astronomical Observatory, Chinese Academy of Sciences, 200030 Shanghai, People's Republic of China
- ¹⁶ Key Laboratory of Cosmic Rays (Tibet University), Ministry of Education, 850000 Lhasa, Tibet, People's Republic of China
- ¹⁷ National Astronomical Observatories, Chinese Academy of Sciences, 100101 Beijing, People's Republic of China
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- ²¹ D'epartement de Physique Nucléaire et Corpusculaire, Faculté de Sciences, Université de Genève, 24 Quai Ernest Ansermet, 1211 Geneva, Switzerland
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- ²⁴ School of Physics and Microelectronics, Zhengzhou University, 450001 Zhengzhou, Henan, People's Republic of China
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- ³⁰ Department of Physics, Faculty of Science, Mahidol University, 10400 Bangkok, Thailand
- ³¹ Moscow Institute of Physics and Technology, 141700 Moscow, Russia
- ³² Key Laboratory of Radio Astronomy, Purple Mountain Observatory, Chinese Academy of Sciences, 210023 Nanjing, Jiangsu, People's Republic of China
- ³³ National Space Science Center, Chinese Academy of Sciences, 100190 Beijing, People's Republic of China

LHAASO site



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- Haizi Mountain, Sichuan province, China
- Location: $29^{\circ}21' 27.6''$ N, $100^{\circ}08' 19.6''$ E
- Altitude: 4410 m a.s.l.
- 10 km from Yading Airport

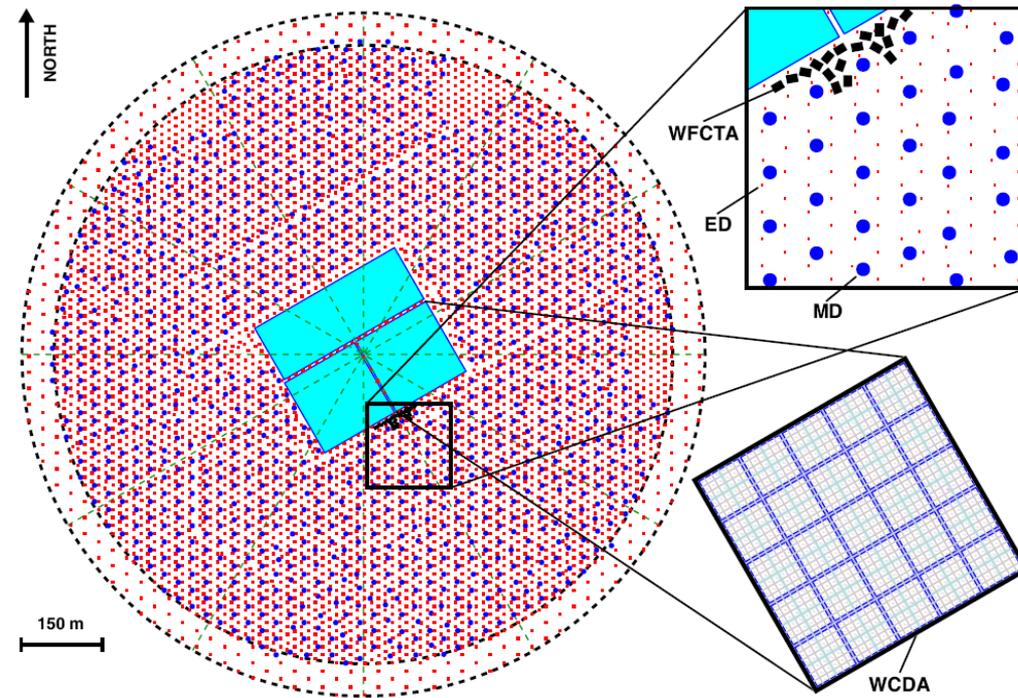


LHAASO layout



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All detectors are in DAQ since 2021-7-19



1.3 km²

- **5195 EDs**
 - **1 m² each**
 - **15 m spacing**
 - **1188 MDs**
 - **36 m² each**
 - **30 m spacing**
 - **3120 WCDA**
 - **18 WFCTAs**
- KM2A**
- WCDA**
- WFCTA**

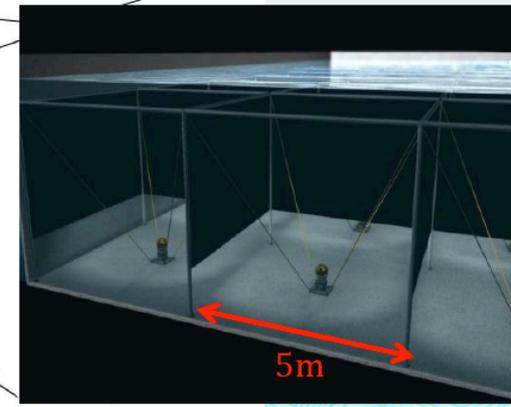
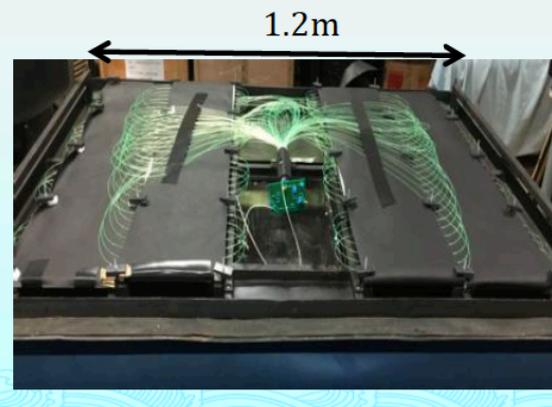
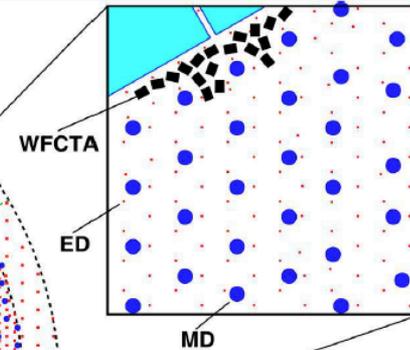
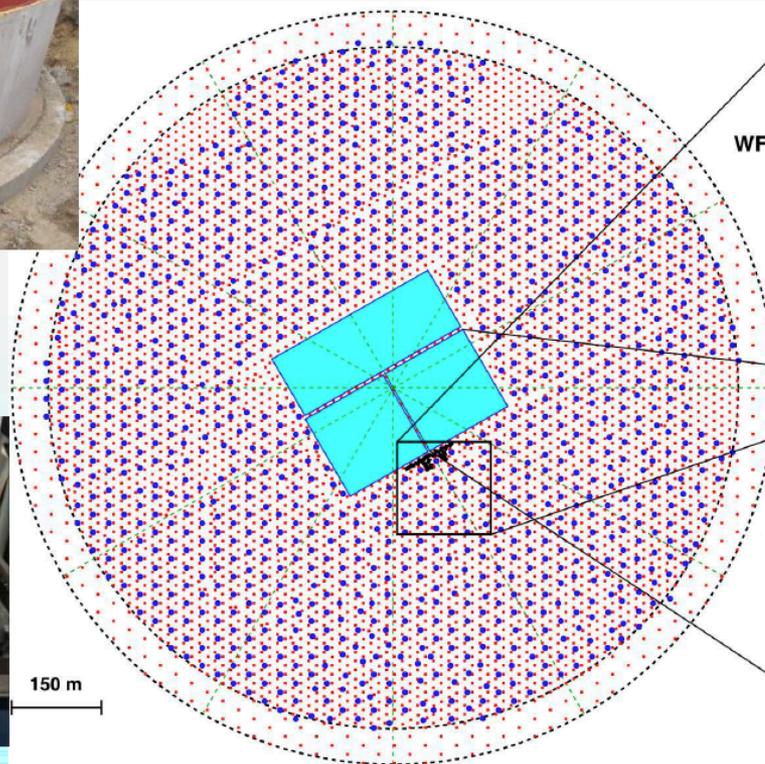
LHAASO layout



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LHAASO Layout

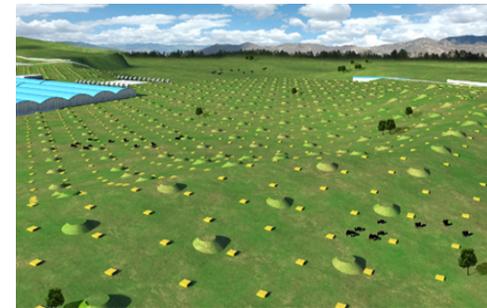
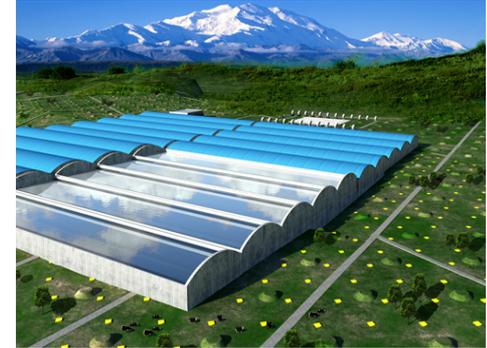


LHAASO sub-arrays



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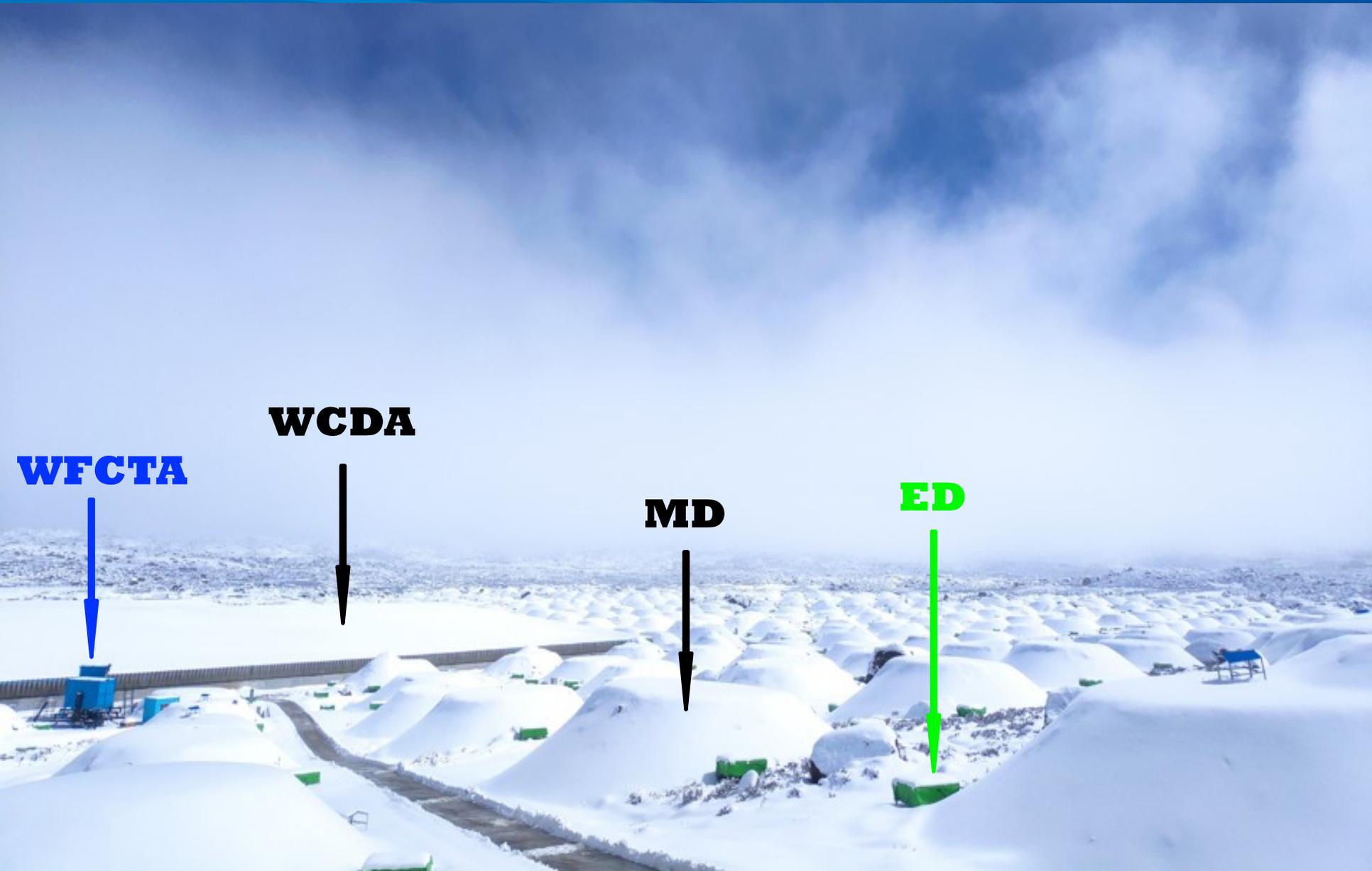
- **WCDA (100 GeV-30 TeV)**
 - VHE ($>0.1\text{TeV}$) γ -ray astronomy
- **KM2A (10 TeV-10 PeV)**
 - UHE ($>0.1\text{PeV}$) γ -ray astronomy
- **WFCTA (10TeV to 1 EeV)**
 - Combined with WCDA, and KM2A
 - Individual nuclei spectra



LHAASO sub-arrays



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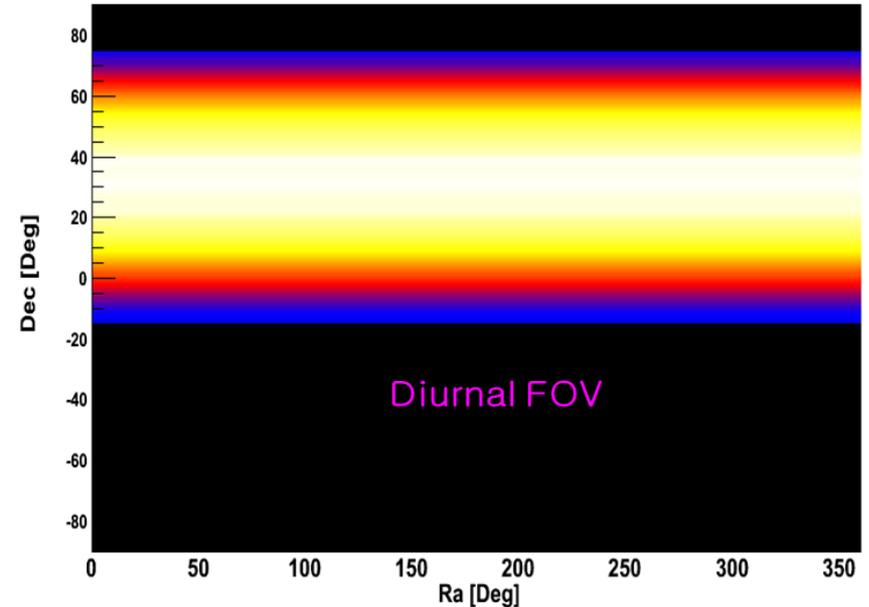
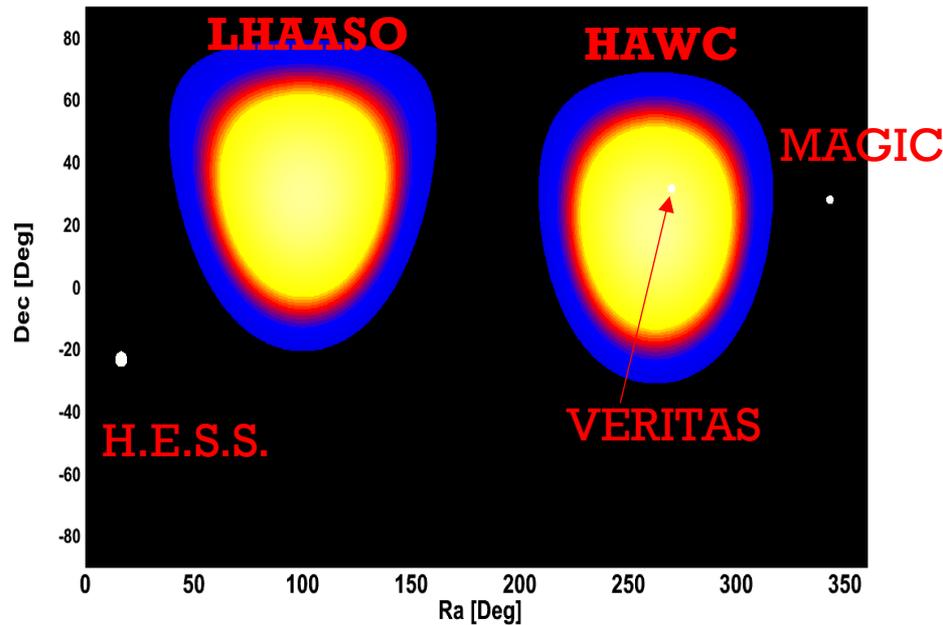


LHAASO FOV



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- **High duty cycle: ~100% running time**
- **Large FOV:**
 - **1/7 of the sky at any time**
 - **60% of the sky in a diurnal observation**

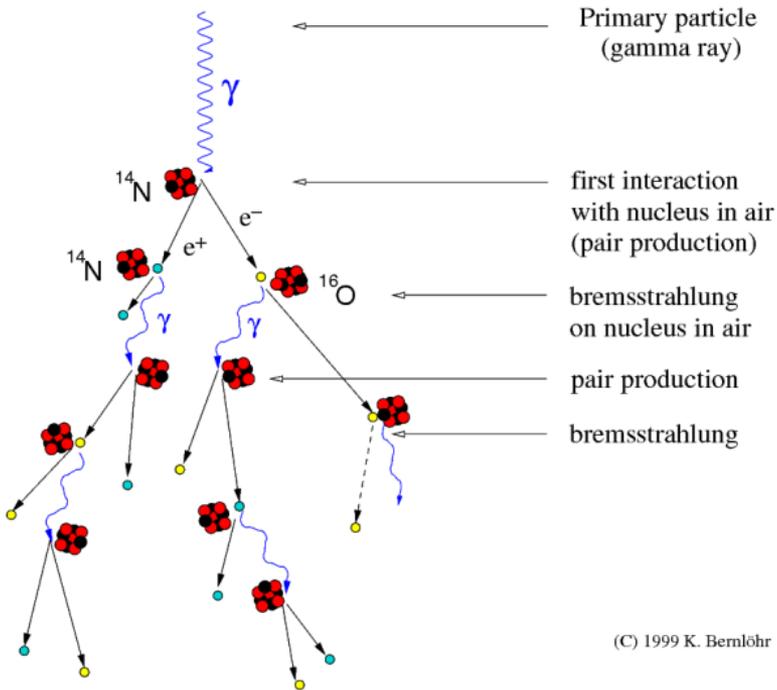


Extensive air shower

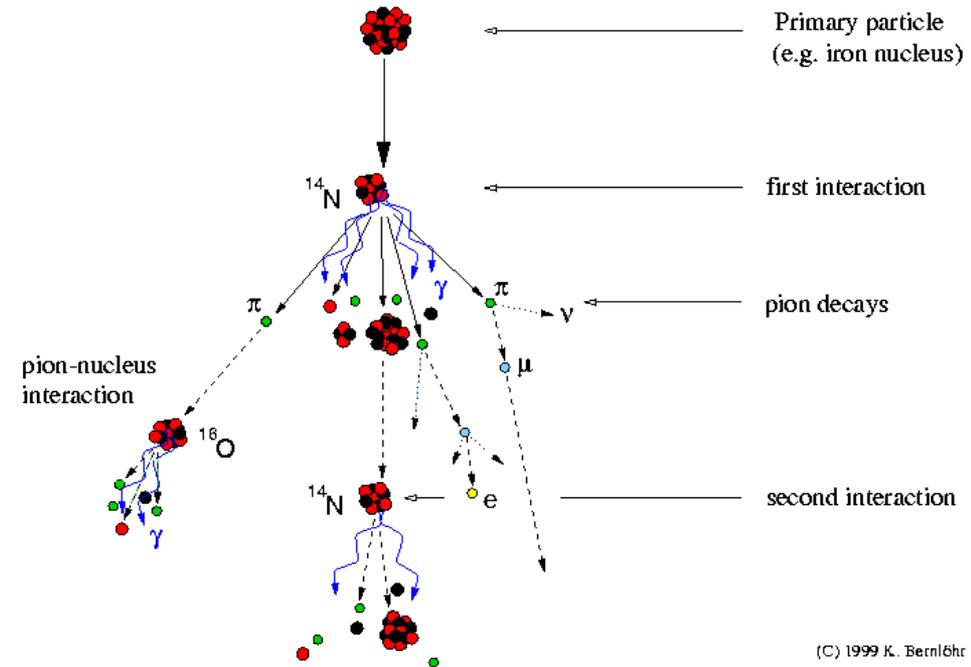


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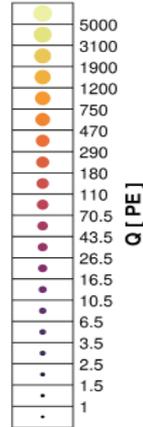
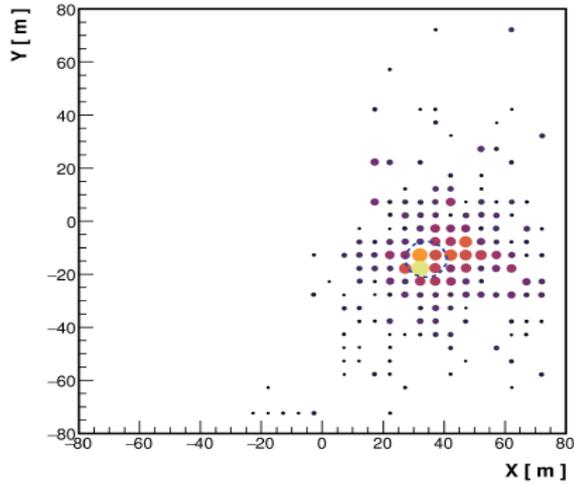
Development of gamma-ray air showers



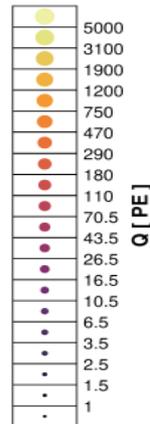
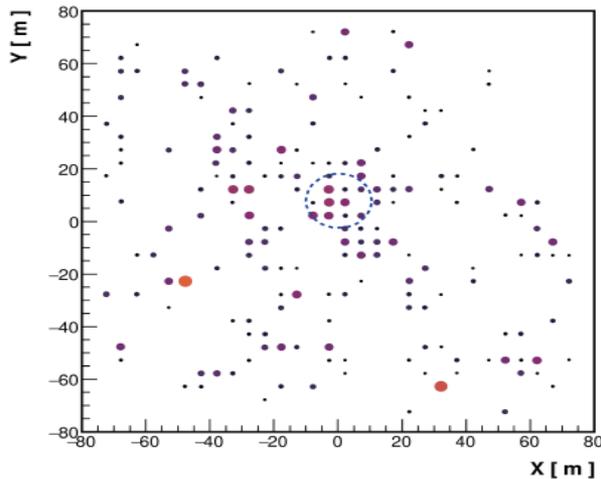
Development of cosmic-ray air showers



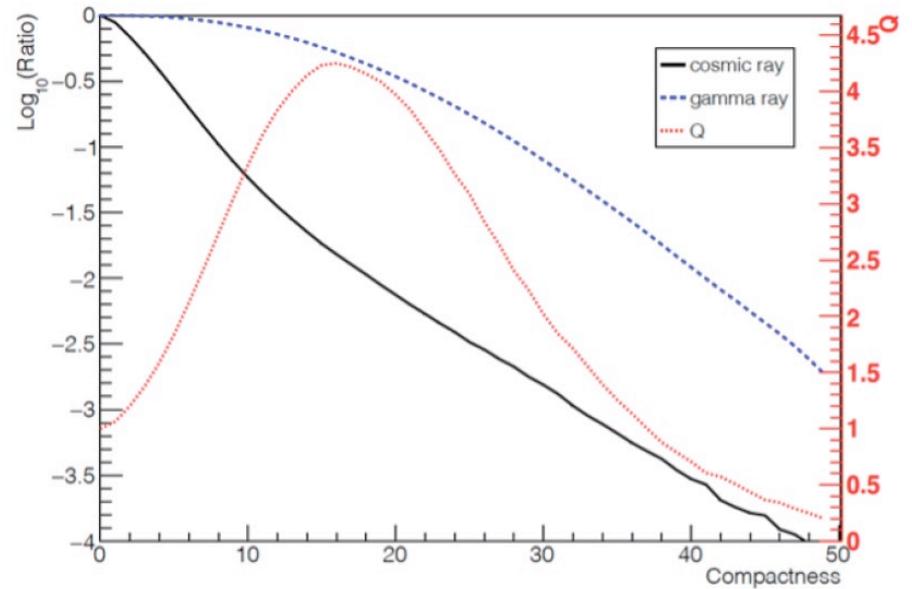
20190703/055515/0.486267626: nHit=165, $\theta=23.35\pm 0.18^\circ$, $\phi=160.18\pm 0.30^\circ$



20190704/024216/0.477409113: nHit=189, $\theta=28.53\pm 0.11^\circ$, $\phi=3.78\pm 0.19^\circ$



WCDA γ /P separation



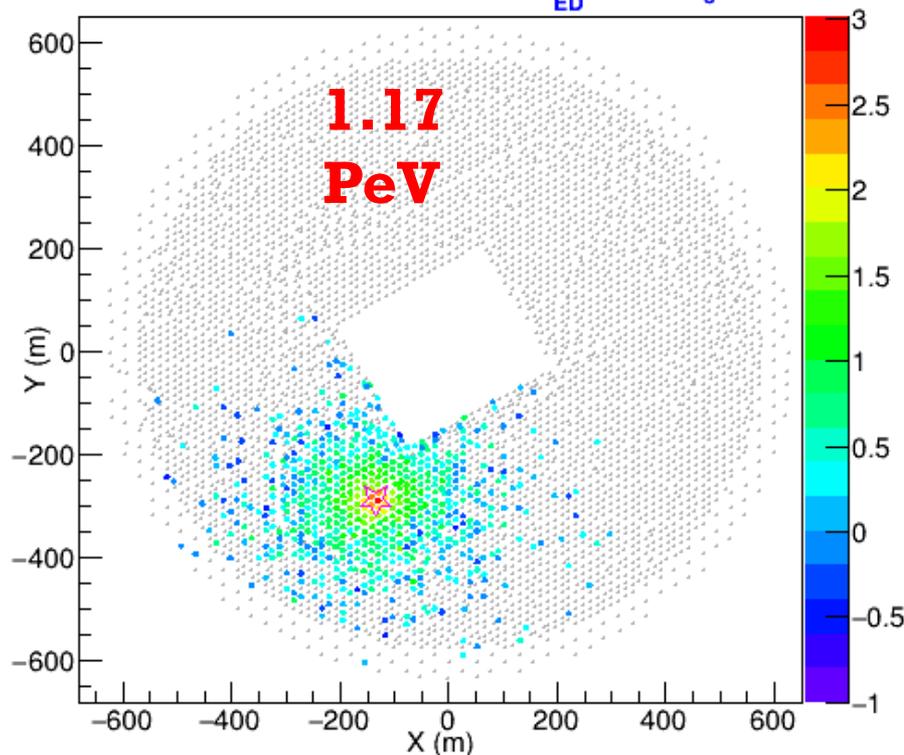
Chinese Physics C 45: 085002 (2021)

KM2A γ /P separation

ED array

Reconstruct the direction,
core, energy of events

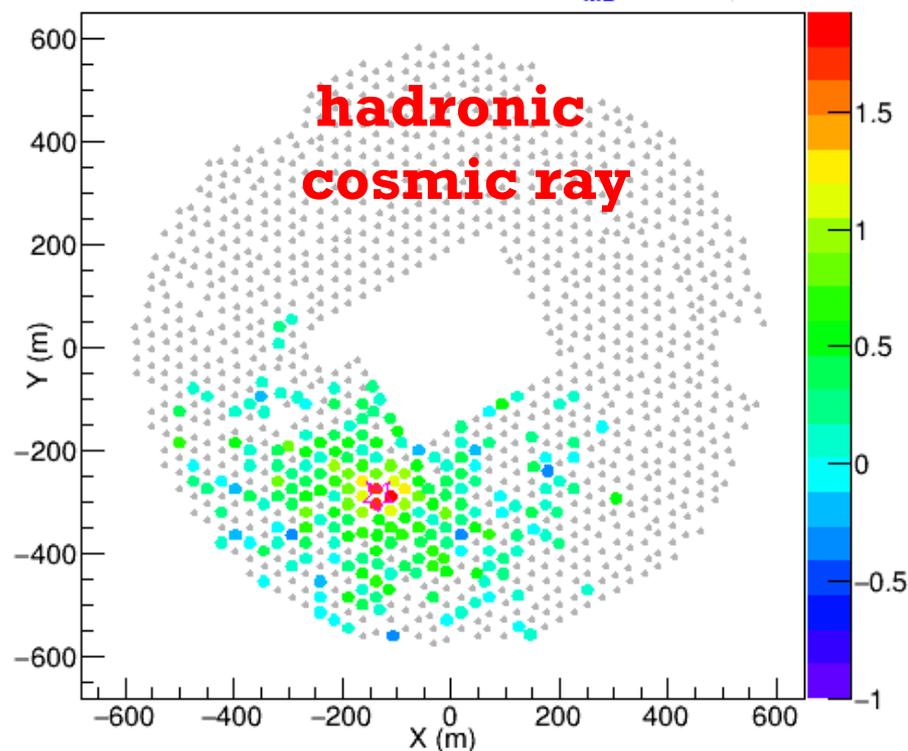
ED: $E=1167$ TeV, $\theta=27.6^\circ$, $N_{ED}=653$, $N_e=5588.9$



MD array

Discriminate gamma-ray/
cosmic ray

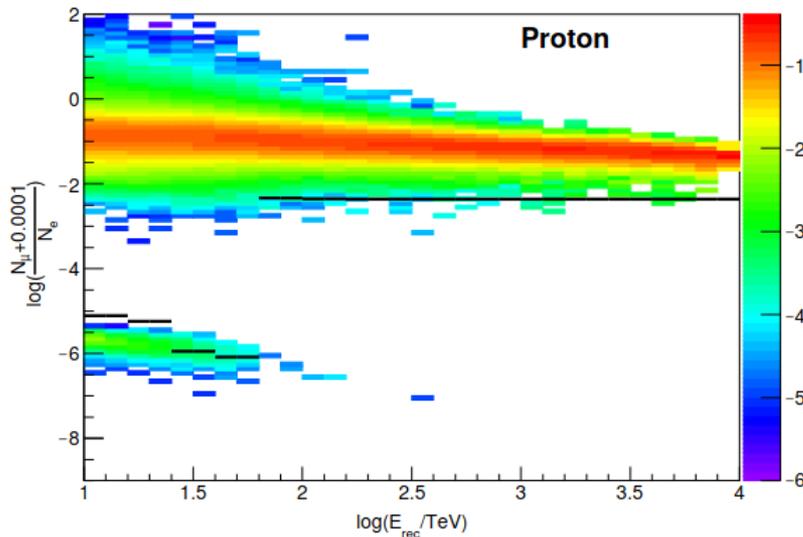
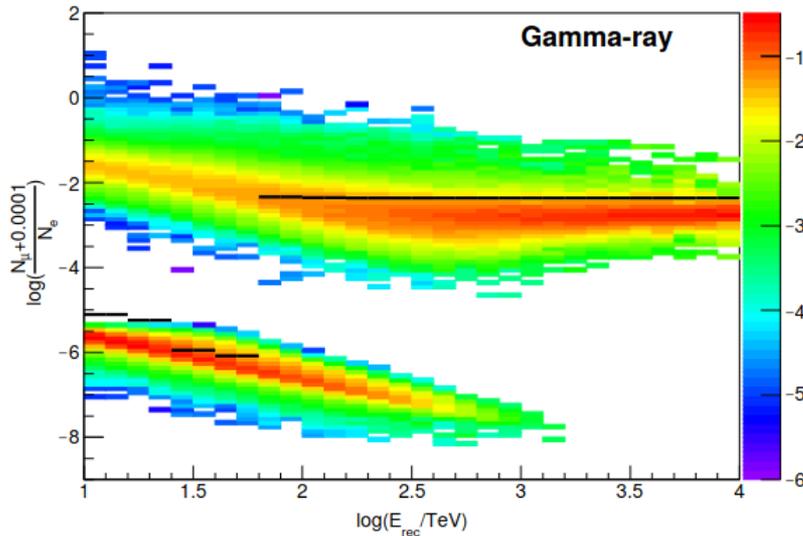
2021-8-11 15:52:42 MD: Ratio=-0.92, $N_{MD}=211$, $N_u=676.7$



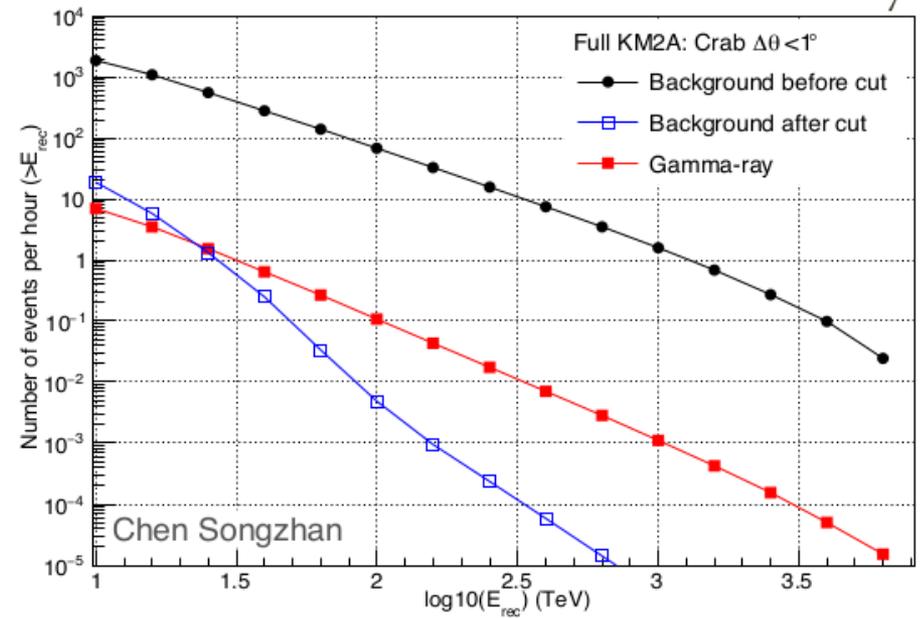
γ -ray/cosmic ray discrimination



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detection rate of the full KM2A array

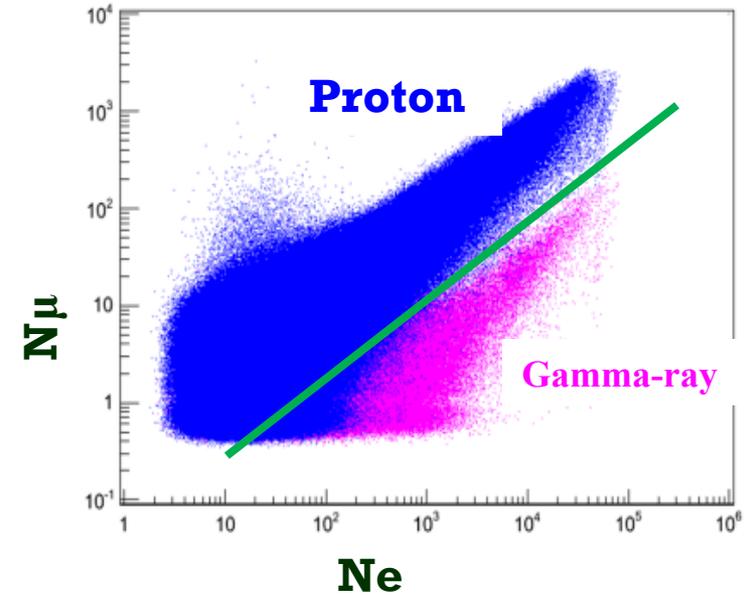
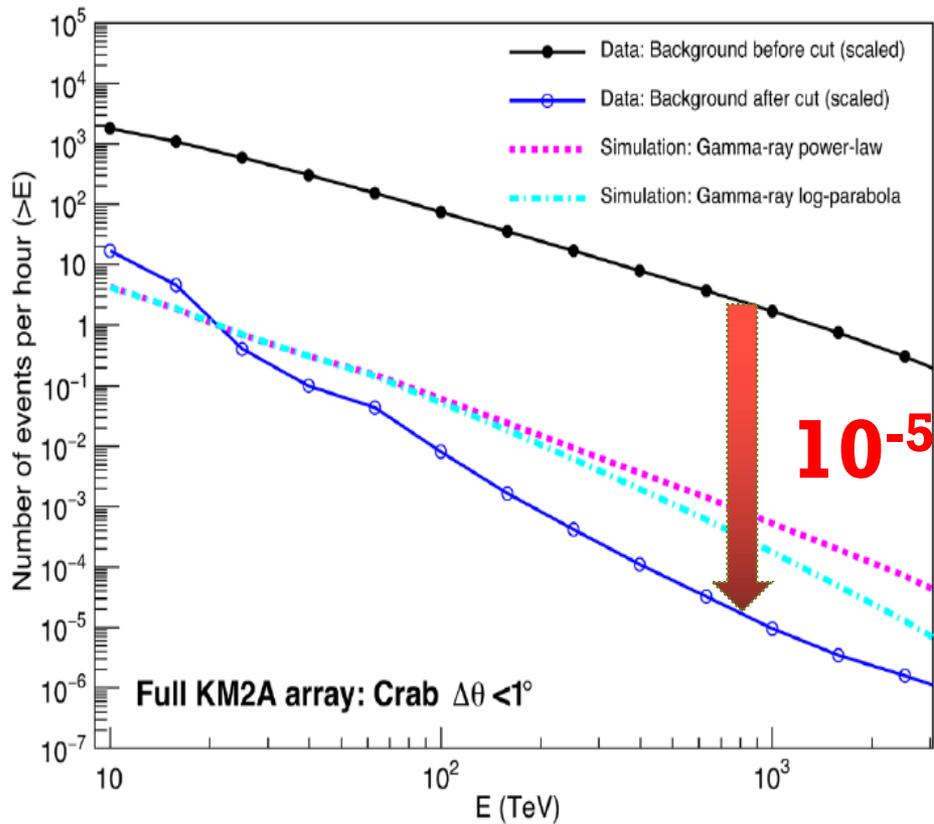


- Large effective area
- efficient background rejection (gamma-proton separation)

γ -ray/cosmic ray discrimination



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**Cosmic ray
rate before cut**

Gamma-ray rate

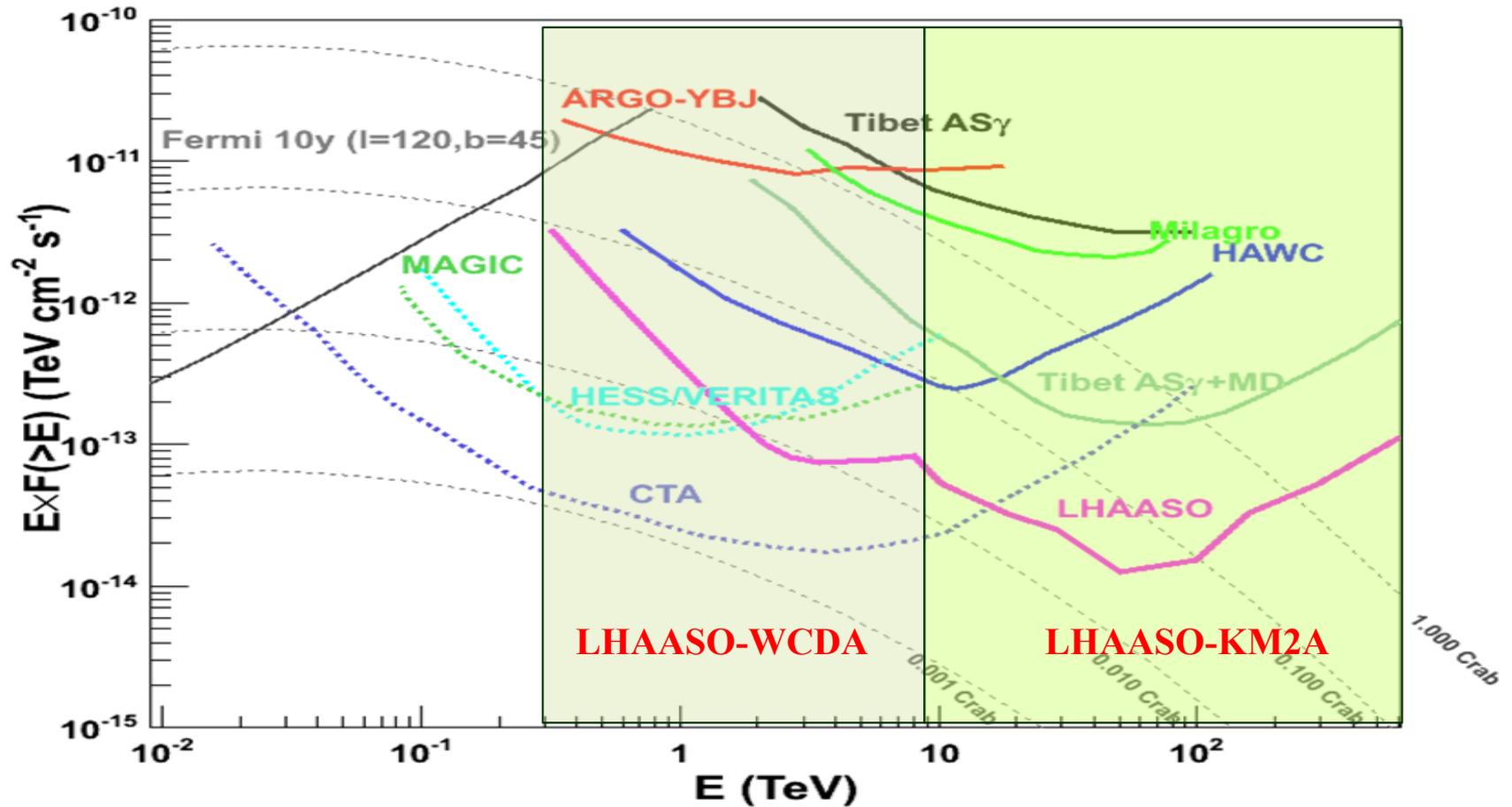
**Cosmic ray rate
after cut**

10⁻⁵

LHAASO Sensitivities

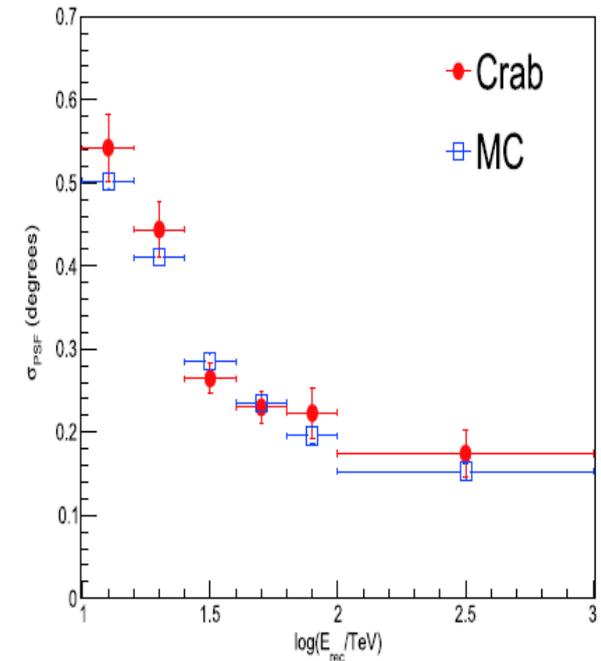
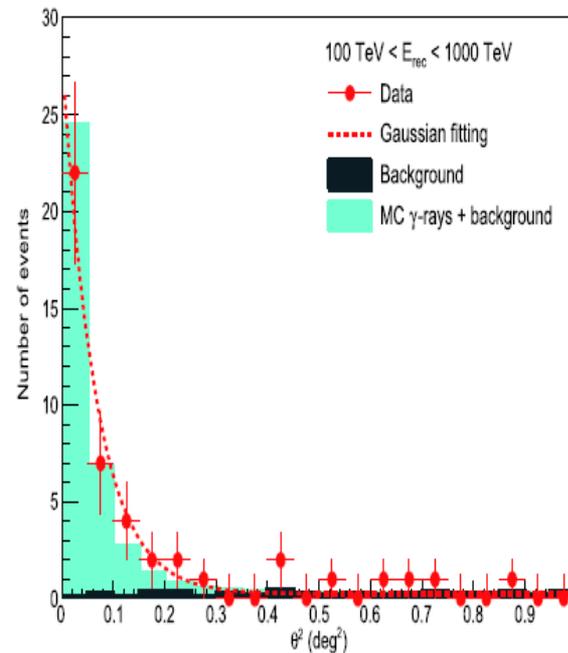
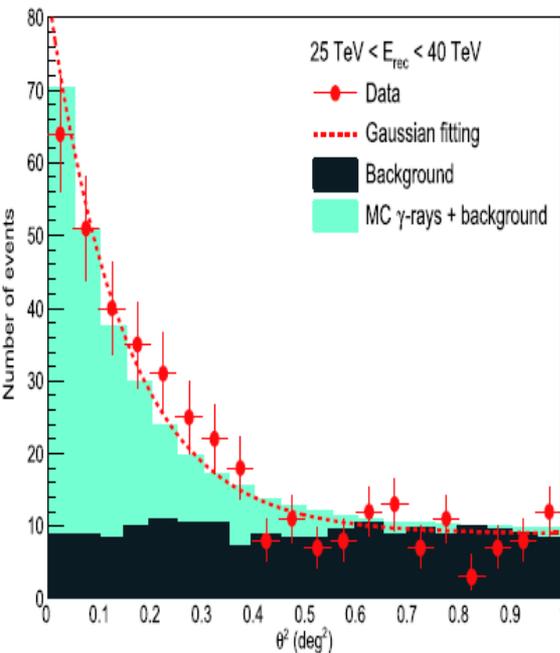


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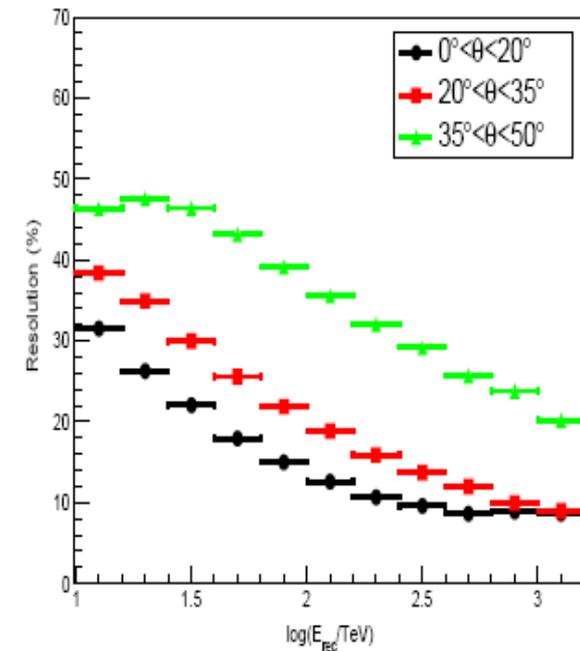
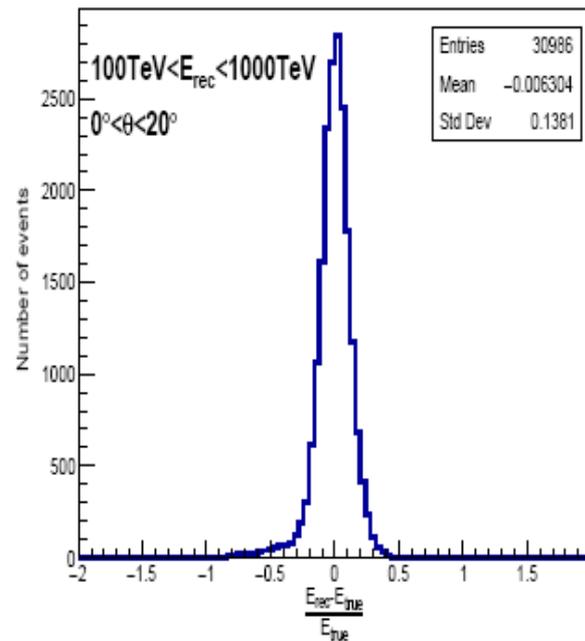
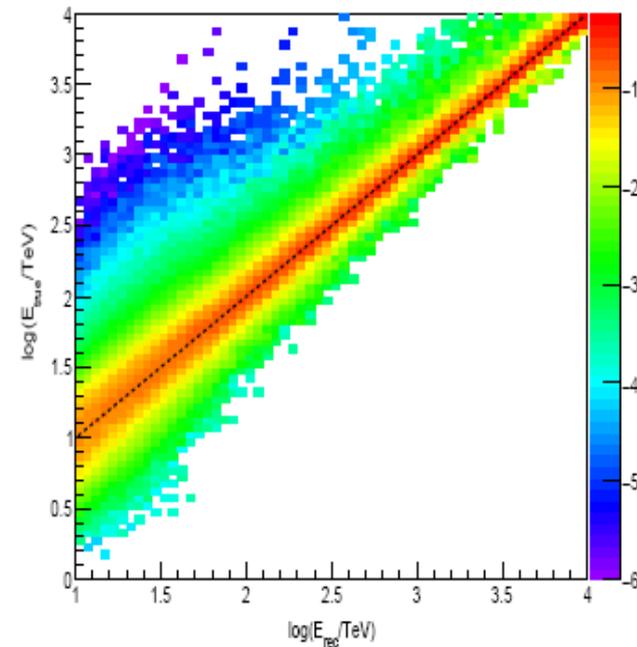


Unprecedented sensitivities above 20 TeV

- **The angular resolution measured using standard candle **Crab Nebula** is consistent with MC prediction.**



● $\theta < 20^\circ$: 24% @ 20 TeV, 13% @ 100 TeV

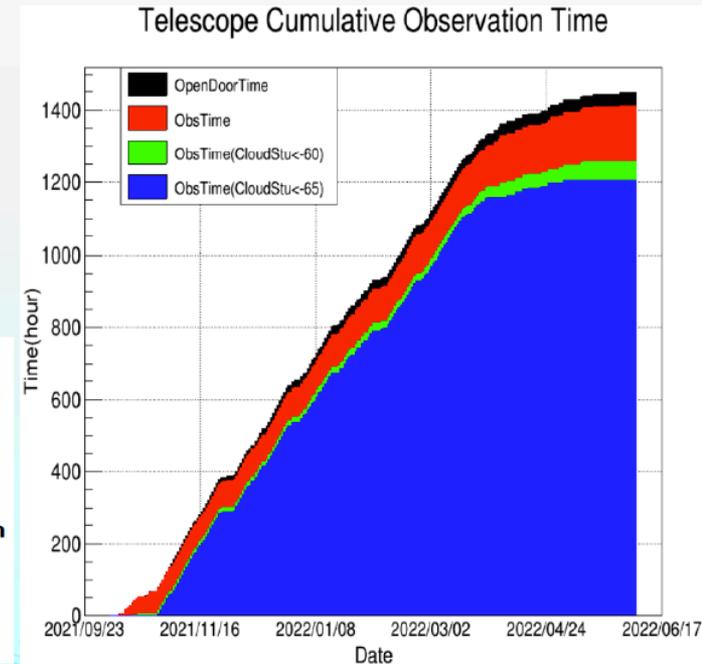
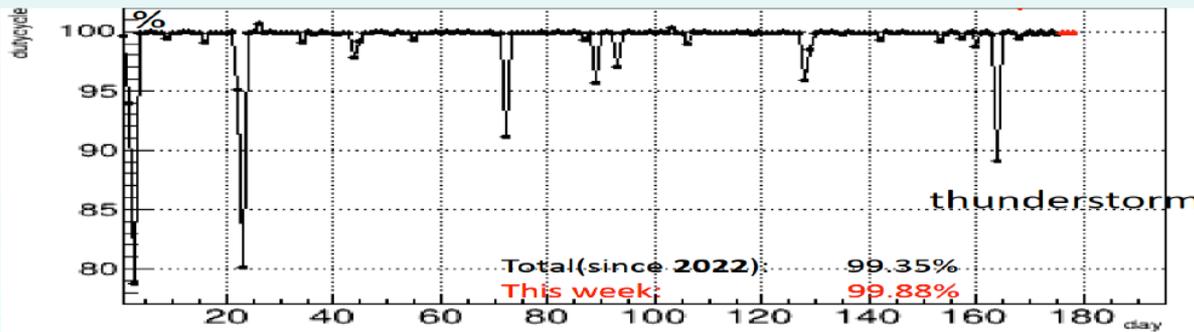
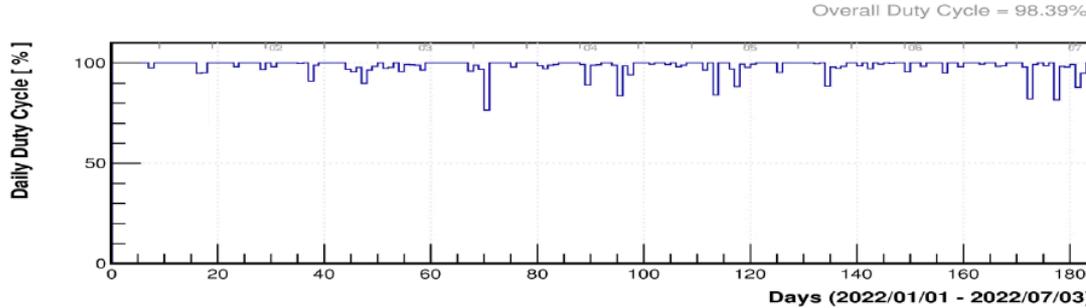


Operation of LHAASO



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- ❖ KM2A is operated with **>99.4% duty cycle** and event rate **2×10^8 /day**
- ❖ WCDA is operated with **98.4%** and event rate **3×10^9 /day**
- ❖ Data acquisition time of WFCTA **>1400 hrs** and number of matched events **~70 million**



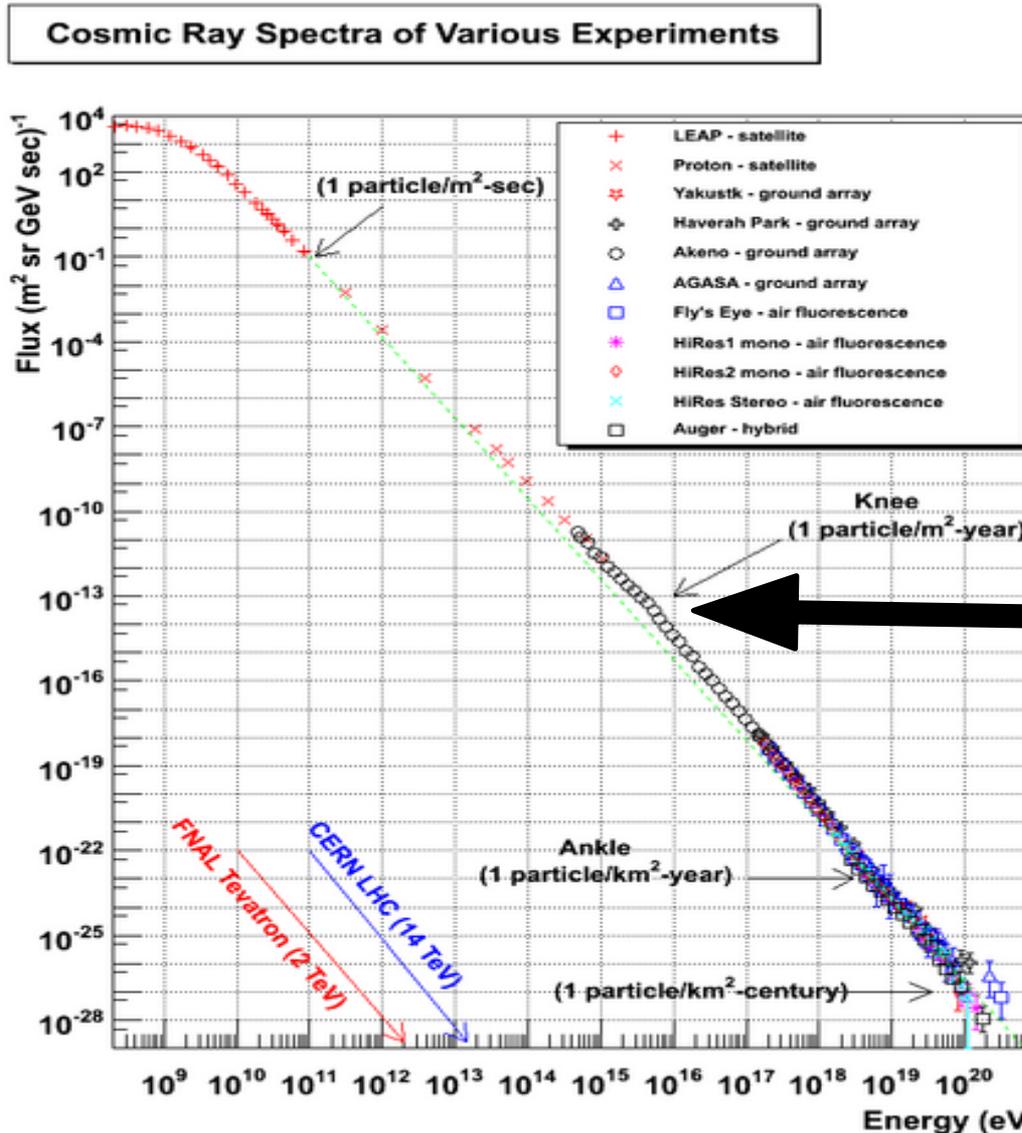


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Highlights on recent results

Scientific objective: PeVatron hunting



← Knee: GCR at least to PeV

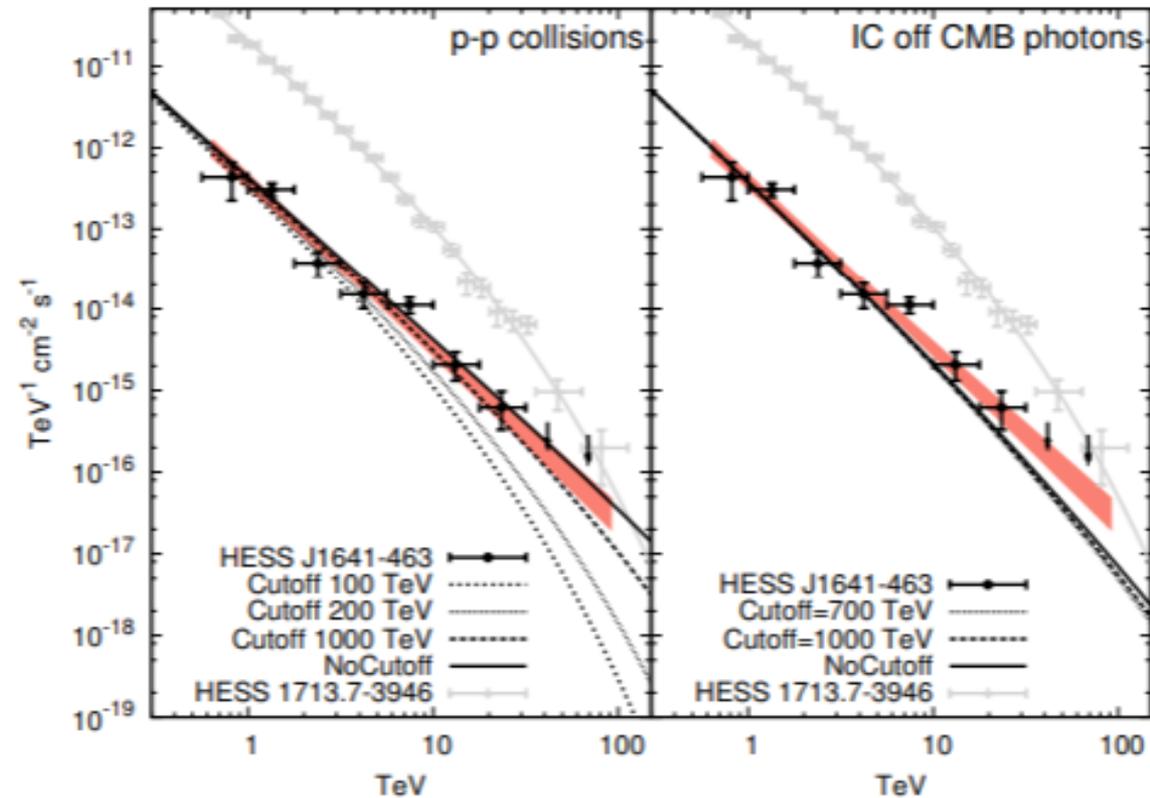
**Searching for
(proton) PeVatron**

PeVatron identification



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- **Hard gamma-ray spectrum without cutoff can hardly be addressed in leptonic model (cooling and KN effects).**
- **no-cutoff in the gamma-ray spectrum up to 25 TeV => no-cutoff in the parent proton spectrum up to ~ PeV.**



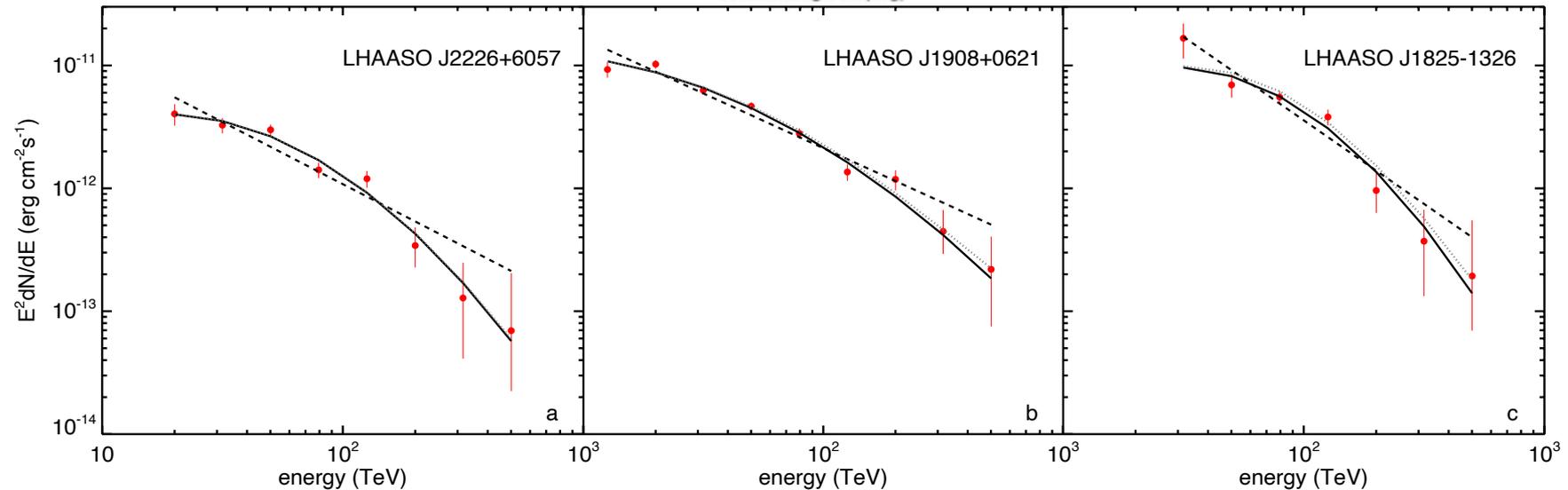
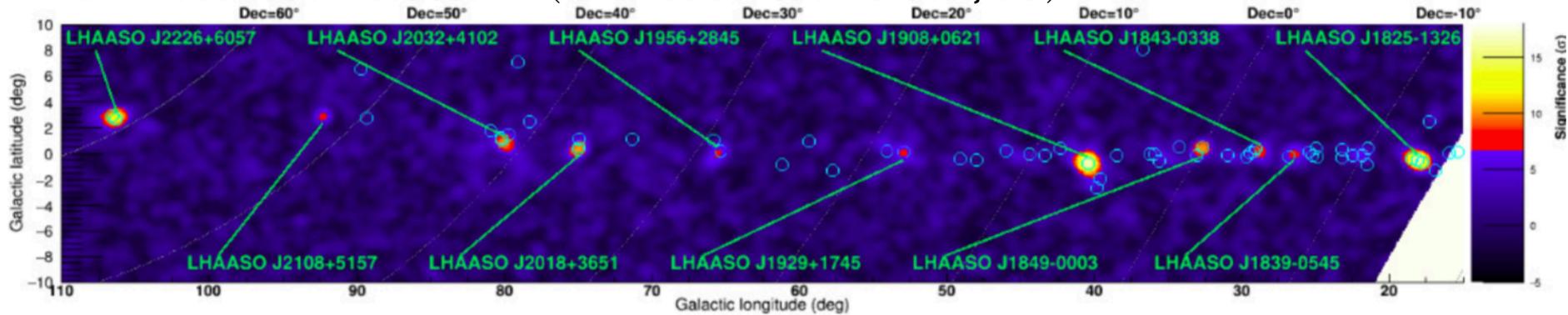
Hess J1641-463
(H.E.S.S collaboration 2016)

Galactic plane survey



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12 UHE sources detected (Cao et.al Nature 594, 33)



11 Months data of Half KM2A-array
Definitely PeVatrons (hadronic or leptonic)
The Galaxy full of powerful accelerators

Source name	RA (°)	dec. (°)	Significance above 100 TeV ($\times\sigma$)	E_{\max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	83.55	22.05	17.8	Update: 1.1 PeV ← 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			Cygnus region ← 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)

Celestial coordinates (RA, dec.); statistical significance of detection above 100 TeV (calculated using a point-like template for the Crab Nebula and LHAASO J2108+5157 and 0.3° extension templates for the other sources); the corresponding differential photon fluxes at 100 TeV; and detected highest photon energies. Errors are estimated as the boundary values of the area that contains $\pm 34.14\%$ of events with respect to the most probable value of the event distribution. In most cases, the distribution is a Gaussian and the error is 1σ .

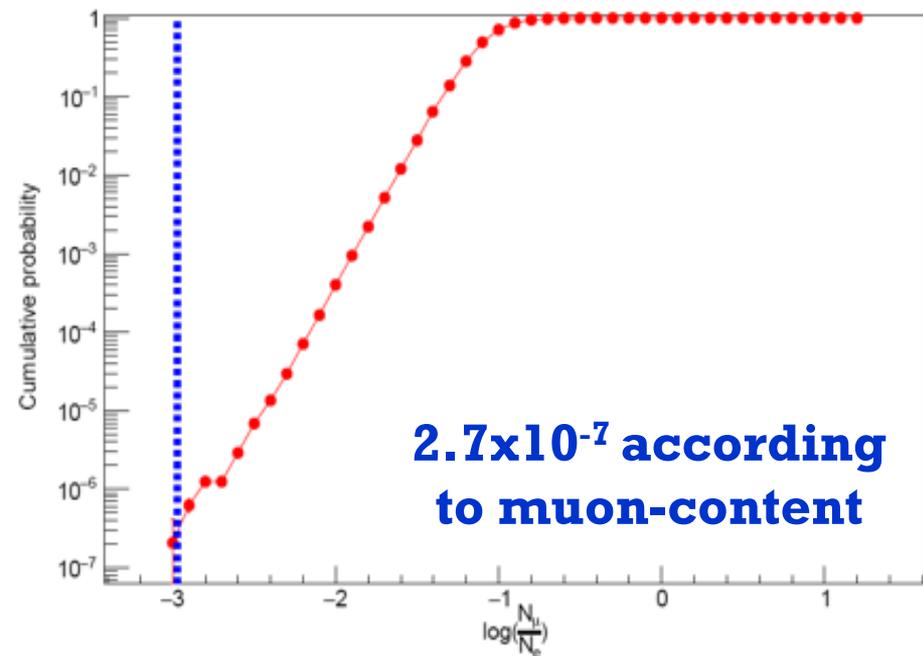
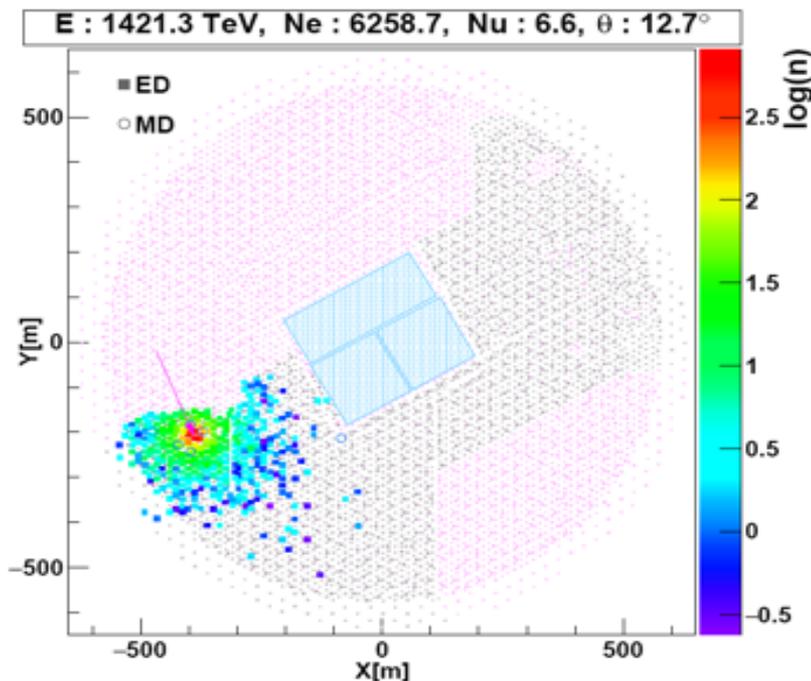
LHAASO Source	Possible Origin	Type	Distance (kpc)	Age (kyr) ^a	L_s (erg/s) ^b	Potential TeV Counterpart ^c
LHAASO J0534+2202	PSR J0534+2200	PSR	2.0	1.26	4.5×10^{38}	Crab, Crab Nebula
LHAASO J1825-1326	PSR J1826-1334	PSR	3.1 ± 0.2^d	21.4	2.8×10^{36}	HESS J1825-137, HESS J1826-130,
	PSR J1826-1256	PSR	1.6	14.4	3.6×10^{36}	2HWC J1825-134
LHAASO J1839-0545	PSR J1837-0604	PSR	4.8	33.8	2.0×10^{36}	2HWC J1837-065, HESS J1837-069,
	PSR J1838-0537	PSR	1.3 ^e	4.9	6.0×10^{36}	HESS J1841-055
LHAASO J1843-0338	SNR G28.6-0.1	SNR	9.6 ± 0.3^f	$< 2^f$	—	HESS J1843-033, HESS J1844-030, 2HWC J1844-032
LHAASO J1849-0003	PSR J1849-0001	PSR	7 ^g	43.1	9.8×10^{36}	HESS J1849-000, 2HWC J1849+001
	W43	YMC	5.5 ^h	—	—	—
LHAASO J1908+0621	SNR G40.5-0.5	SNR	3.4 ⁱ	$\sim 10 - 20^j$	—	MGRO J1908+06, HESS J1908+063,
	PSR 1907+0602	PSR	2.4	19.5	2.8×10^{36}	ARGO J1907+0627, VER J1907+062,
	PSR 1907+0631	PSR	3.4	11.3	5.3×10^{35}	2HWC 1908+063
LHAASO J1929+1745	PSR J1928+1746	PSR	4.6	82.6	1.6×10^{36}	2HWC J1928+177, 2HWC J1930+188,
	PSR J1930+1852	PSR	6.2	2.9	1.2×10^{37}	HESS J1930+188, VER J1930+188
	SNR G54.1+0.3	SNR	$6.3^{+0.8}_-0.7^d$	$1.8 - 3.3^k$	—	—
LHAASO J1956+2845	PSR J1958+2846	PSR	2.0	21.7	3.4×10^{35}	2HWC J1955+285
	SNR G66.0-0.0	SNR	2.3 ± 0.2^d	—	—	—
LHAASO J2018+3651	PSR J2021+3651	PSR	$1.8^{+1.7}_-1.4^l$	17.2	3.4×10^{36}	MGRO J2019+37, VER J2019+368,
	Sh 2-104	H II/YMC	$3.3 \pm 0.3^m/4.0 \pm 0.5^n$	—	—	VER J2016+371
LHAASO J2032+4102	Cygnus OB2	YMC	1.40 ± 0.08^o	—	—	TeV J2032+4130, ARGO J2031+4157,
	PSR 2032+4127	PSR	1.40 ± 0.08^o	201	1.5×10^{35}	MGRO J2031+41, 2HWC J2031+415,
	SNR G79.8+1.2	SNR candidate	—	—	—	VER J2032+414
LHAASO J2108+5157	—	—	—	—	—	—
LHAASO J2226+6057	SNR G106.3+2.7	SNR	0.8 ^p	$\sim 10^p$	—	VER J2227+608, Boomerang Nebula
	PSR J2229+6114	PSR	0.8 ^p	$\sim 10^p$	2.2×10^{37}	—

Highest energy photon



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- 1.42 ± 0.13 PeV from the Cygnus region
- Chance probability due to cosmic ray background 0.028%.

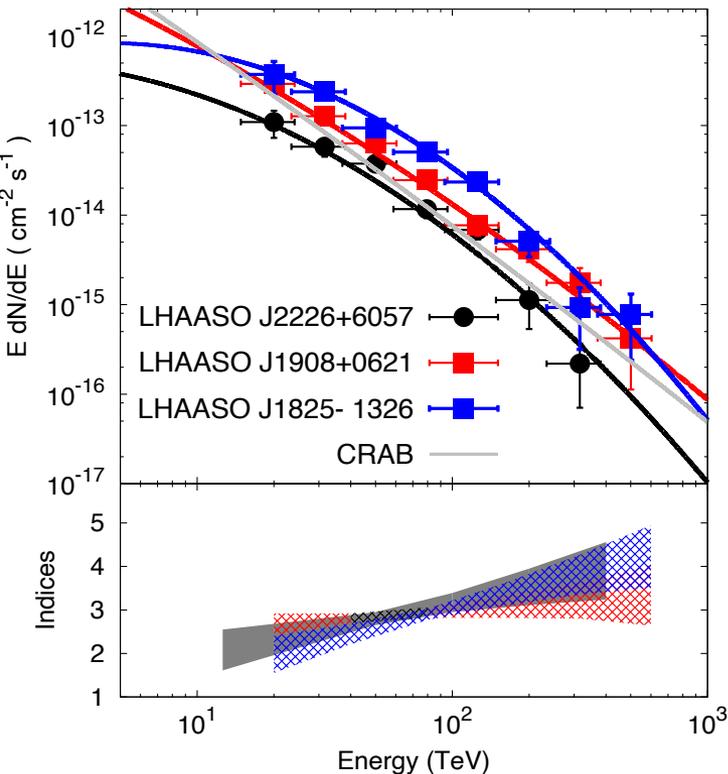


Nature 594:33-36 (2021)

Three brightest sources



			distance	age	power
LHAASO J2226+6057	SNR G106.3+2.7	SNR	0.8^p	$\sim 10^p$	—
	PSR J2229+6114	PSR	0.8^p	$\sim 10^p$	2.2×10^{37}
LHAASO J1908+0621	SNR G40.5-0.5	SNR	3.4^i	$\sim 10 - 20^j$	—
	PSR 1907+0602	PSR	2.4	19.5	2.8×10^{36}
	PSR 1907+0631	PSR	3.4	11.3	5.3×10^{35}
LHAASO J1825-1326	PSR J1826-1334	PSR	3.1 ± 0.2^d	21.4	2.8×10^{36}
	PSR J1826-1256	PSR	1.6	14.4	3.6×10^{36}

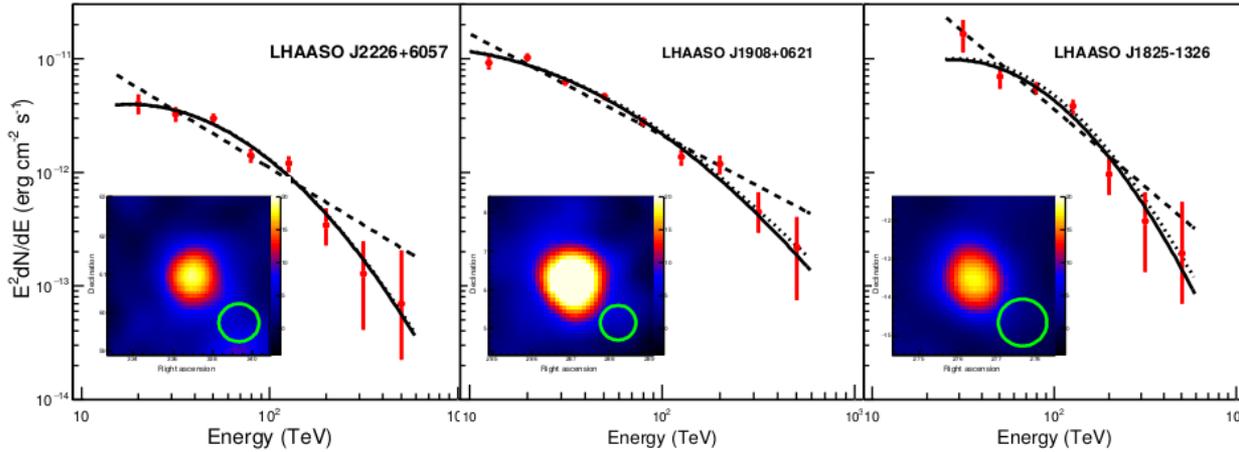


- spectral softening above 100 TeV
- No significant cutoff
- extended sources

Three brightest sources



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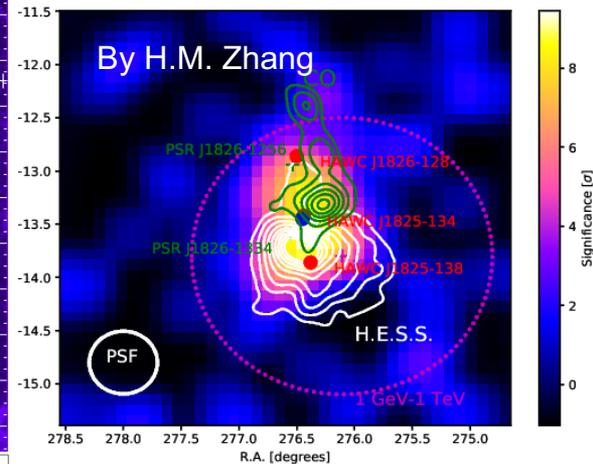
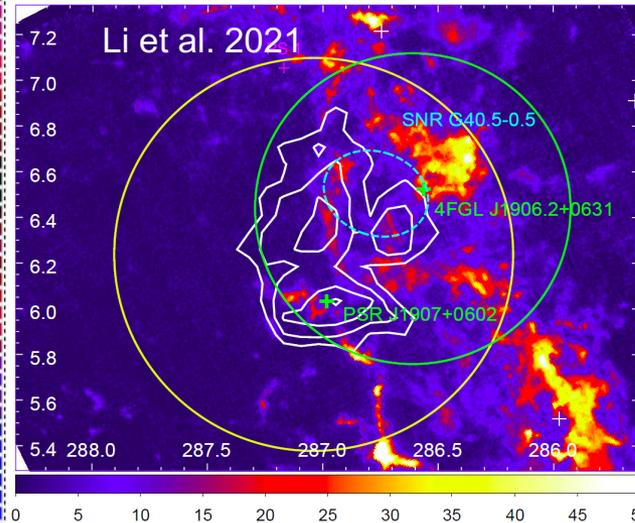
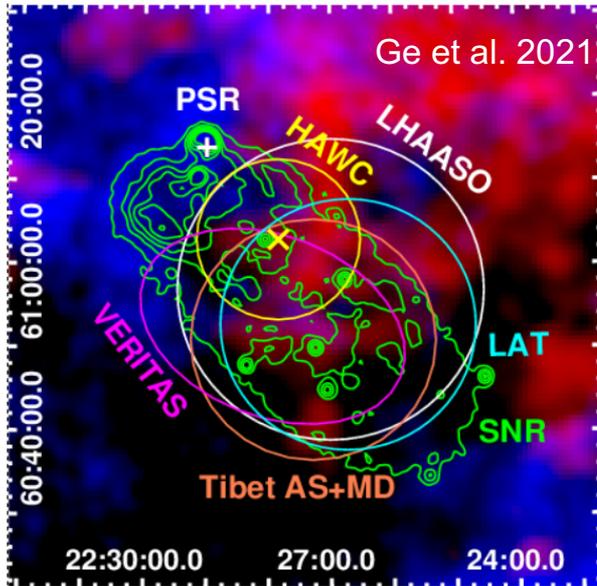


J2226+6057

J1908+0621

J1825-1326

Complex regions

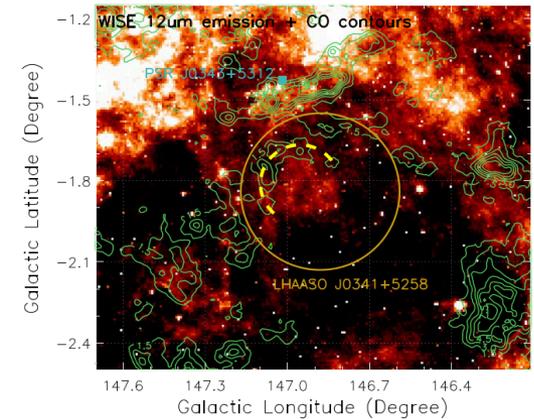
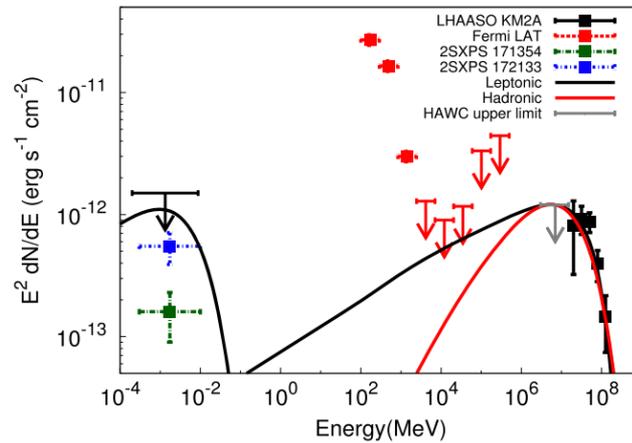
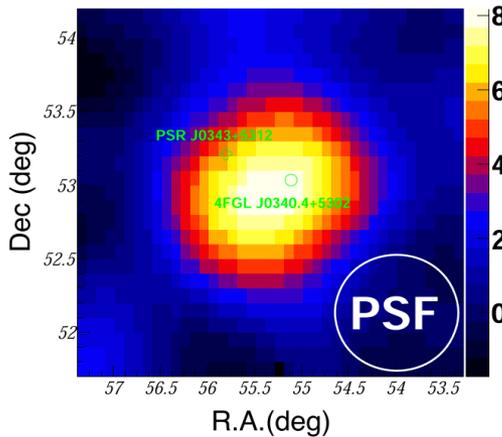


Two New sources

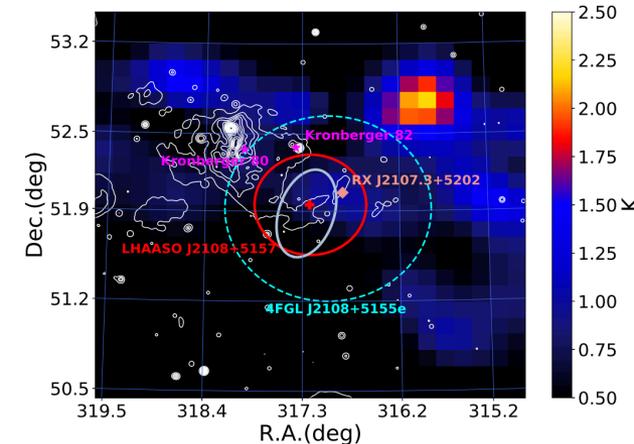
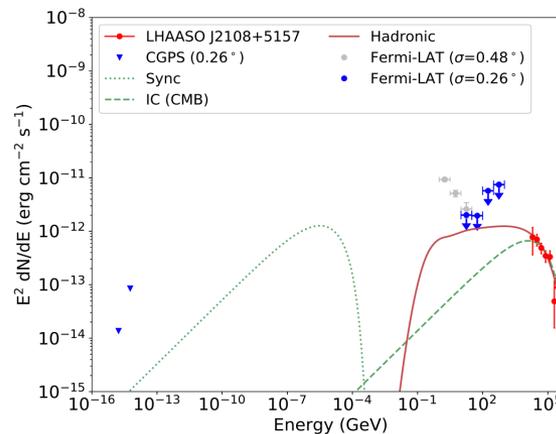
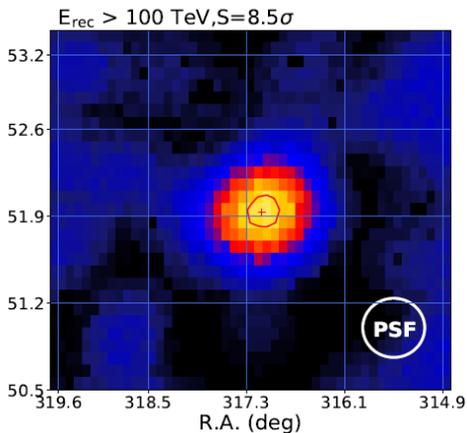


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LHAASO J0341+5258 (ApJL 917, L4)



LHAASO J2108+5157 (ApJL 919, L22)

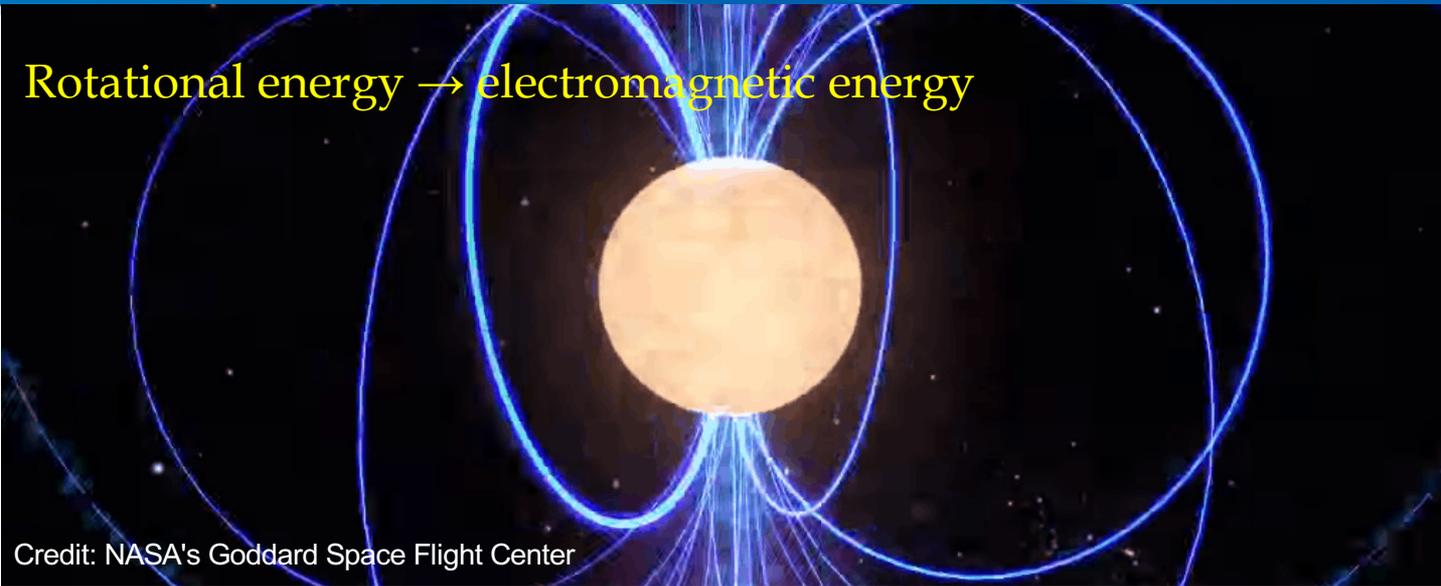


Pulsar related sources

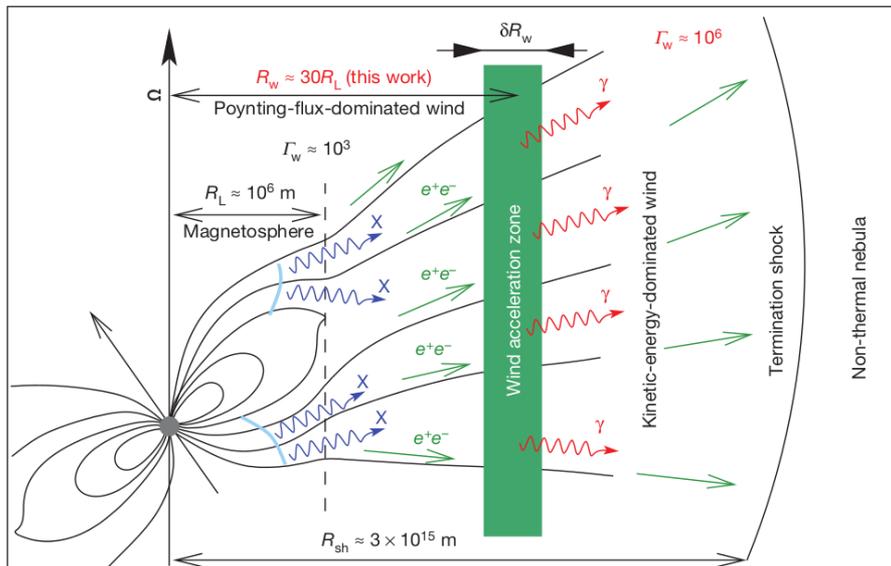


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Rotational energy \rightarrow electromagnetic energy



Credit: NASA's Goddard Space Flight Center

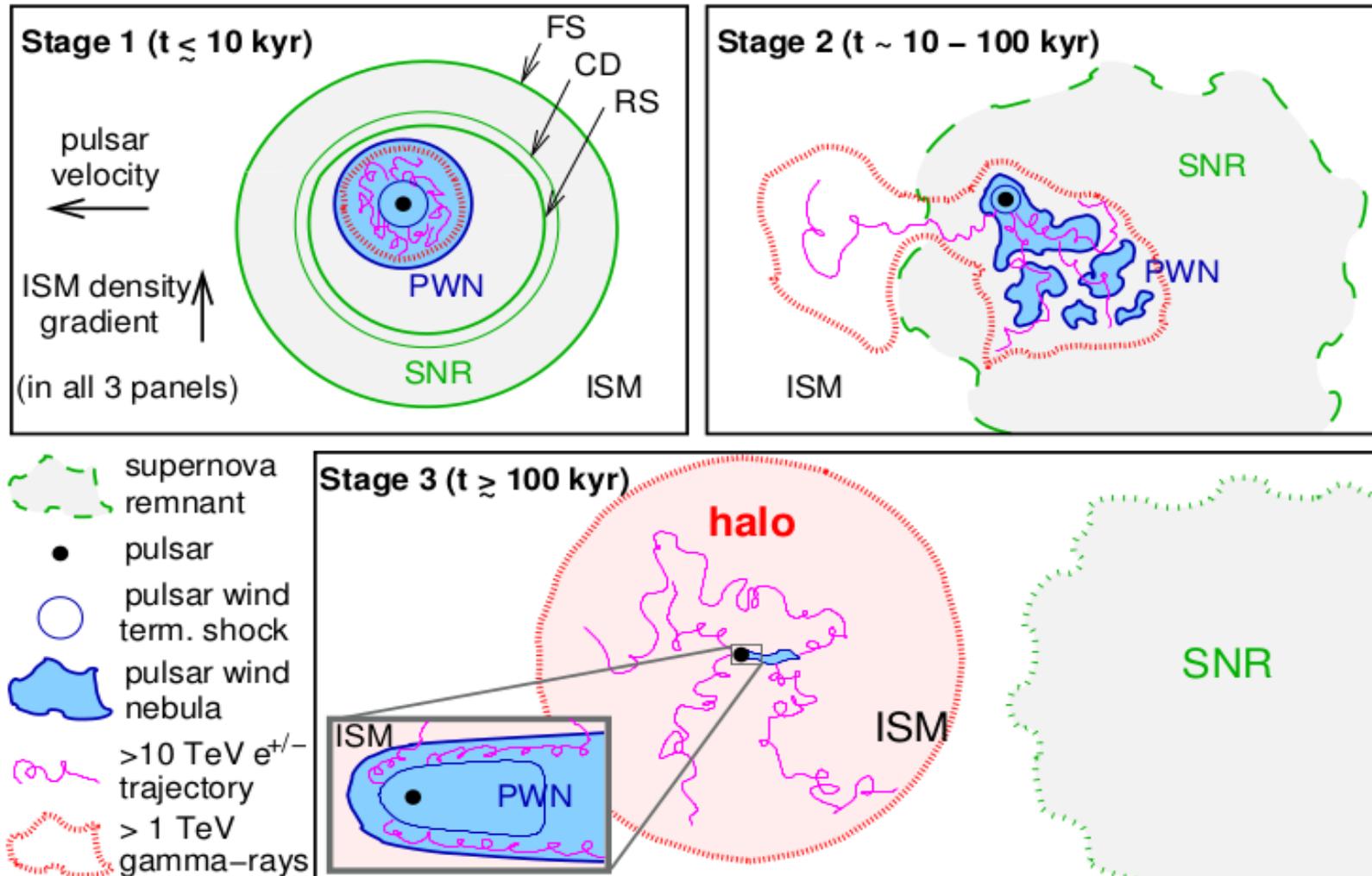


- Pulsar can produce GeV emission through curvature radiation
- Pulsed emission also found up to 1 TeV, possible IC emission of cold wind (Aharonian 2012)

Pulsar related sources



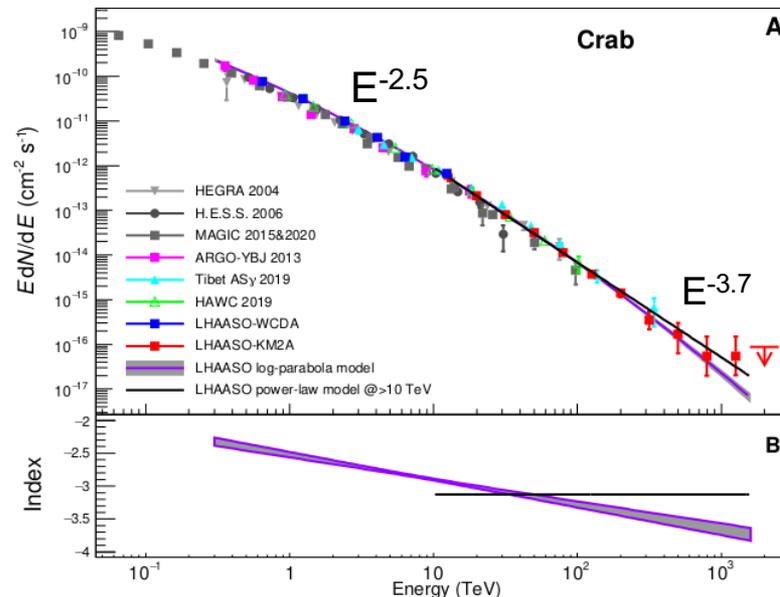
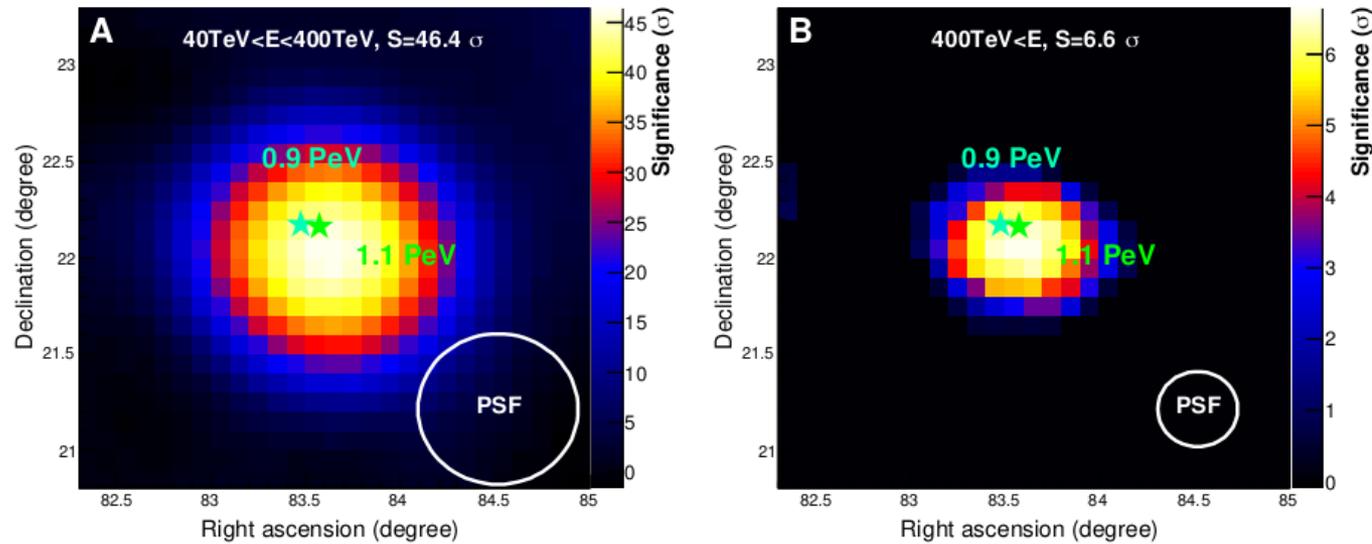
- Pulsar wind nebular (PWN) and Pulsar halo



Crab as electron PeVatron

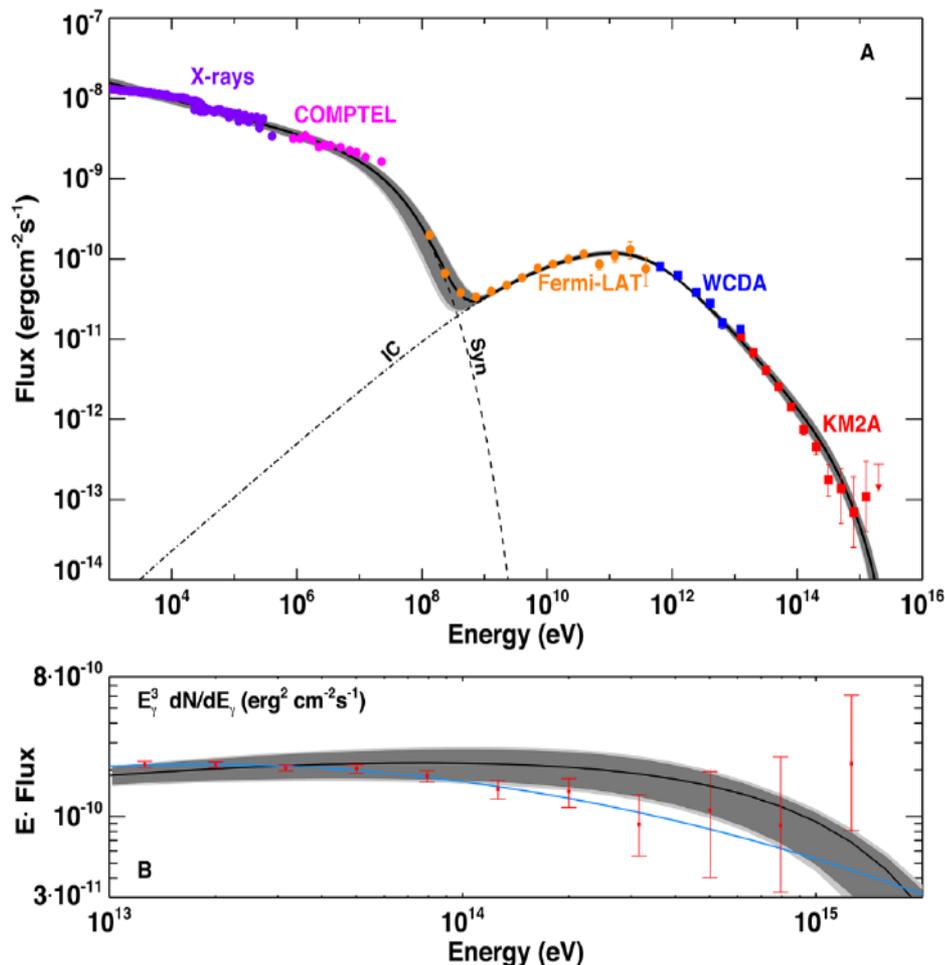


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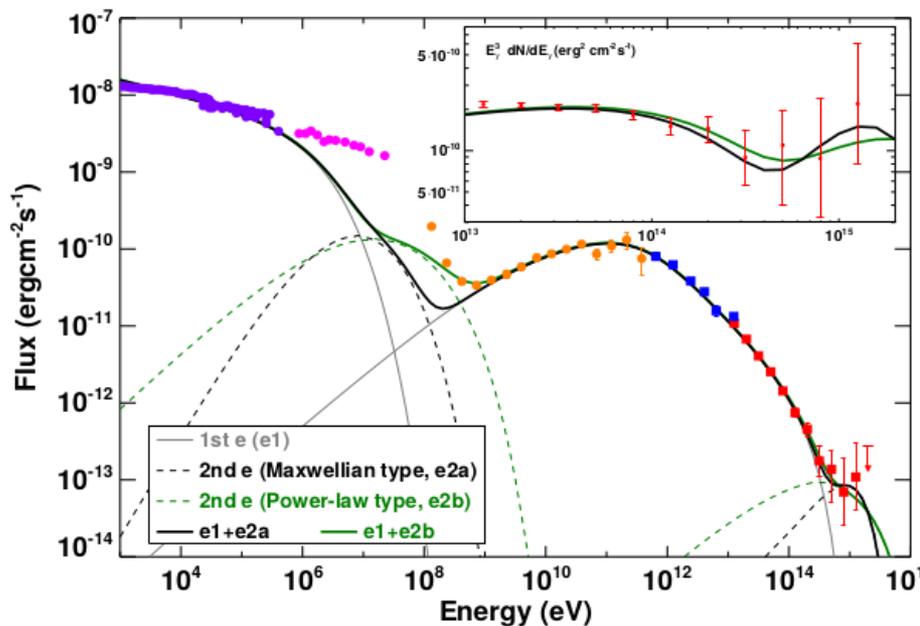
LHAASO collaboration
Science 373, 425

- **An extreme e-accelerator:**
 - **2.3 PeV electrons**
 - **In 0.025—0.1 pc core region**
 - **accelerating efficiency of 15% (1000×SNR shock)**
- **Perfect interpretation of one-zone model up to 50 TeV, while a deviation of 4σ at higher energy.**
- **1~2 PeV photon per year.**

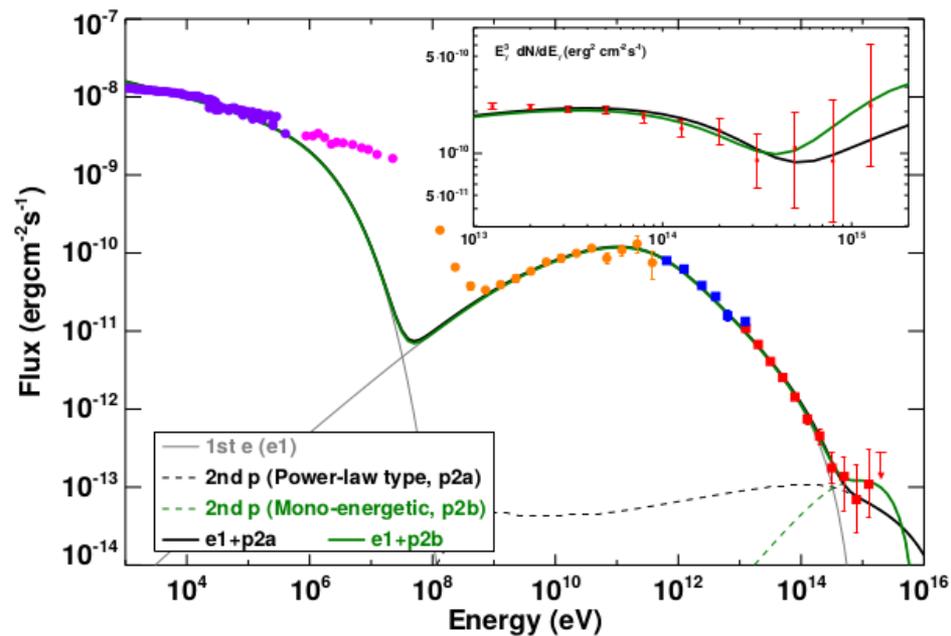


Science 373:425-430 (2021)

2 Leptonic components



Leptonic+Hadronic component

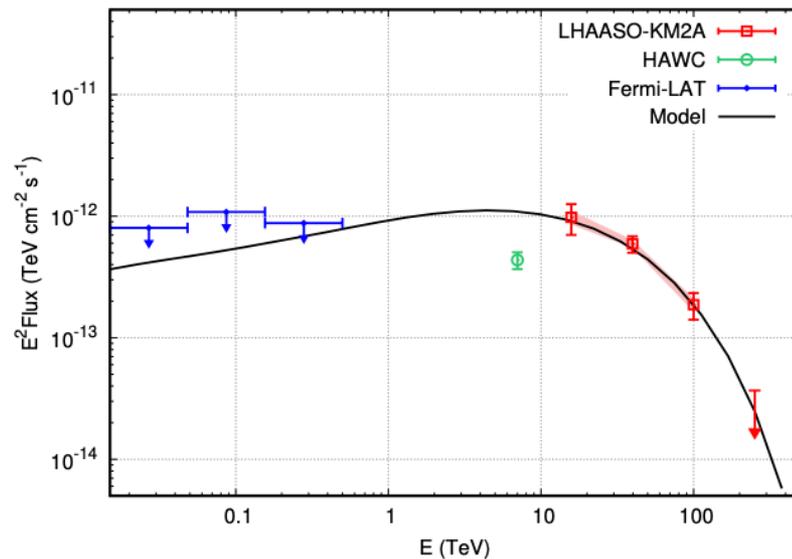
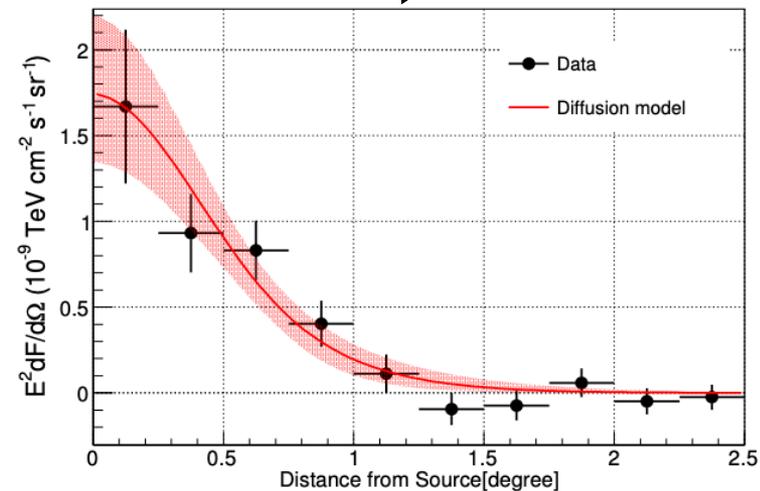
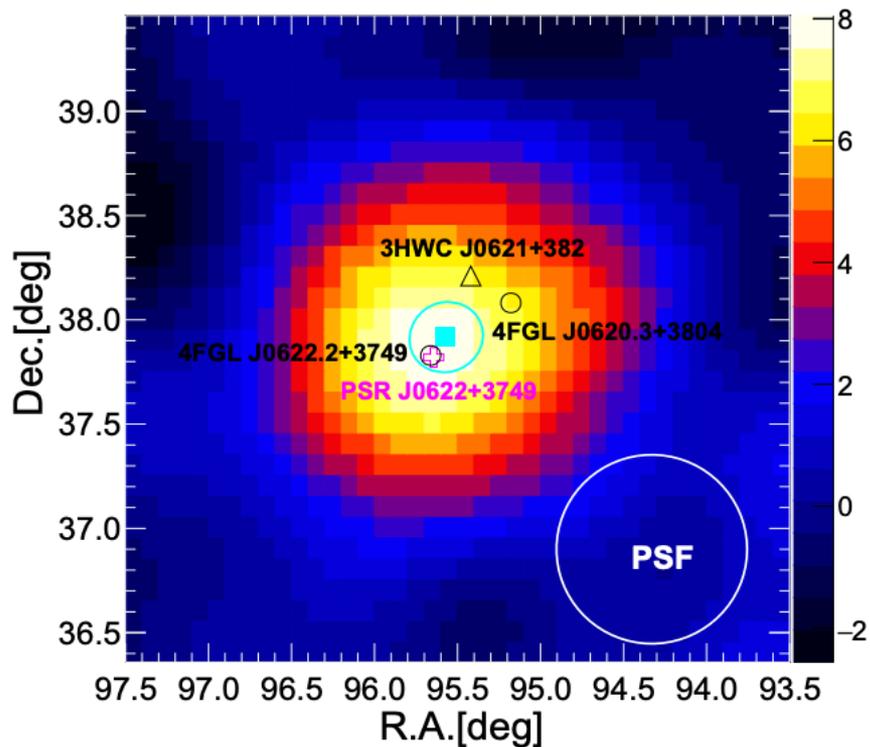


New pulsar halo



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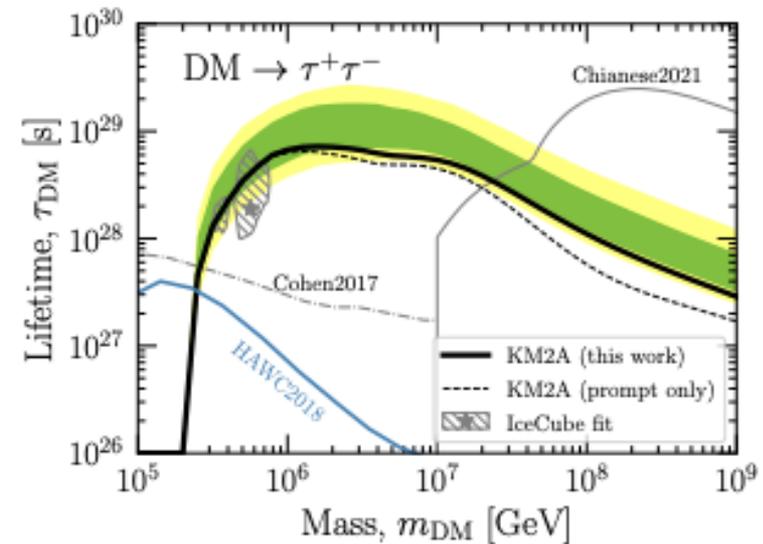
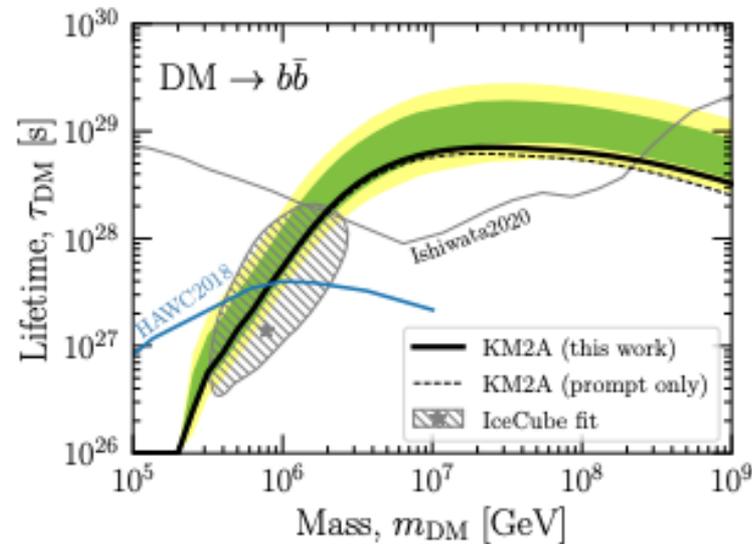
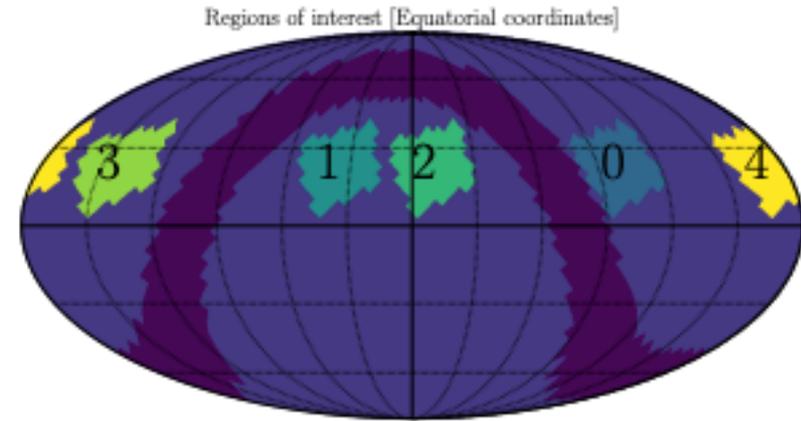
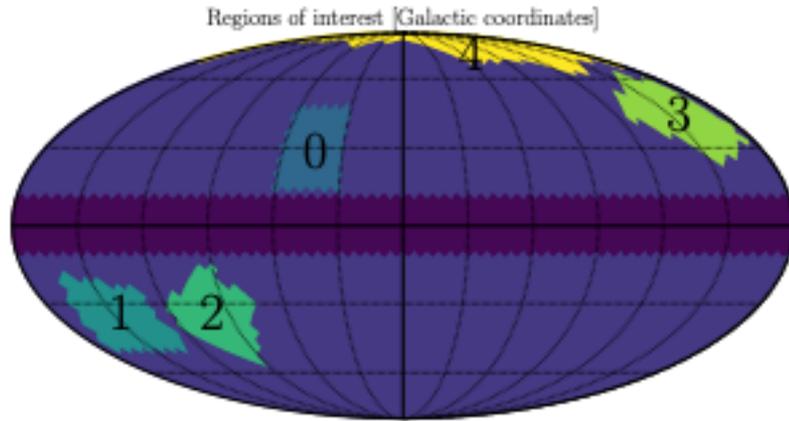
LHAASO J0622 + 3749 (PRL 126, 241103)



Indirect search for DM



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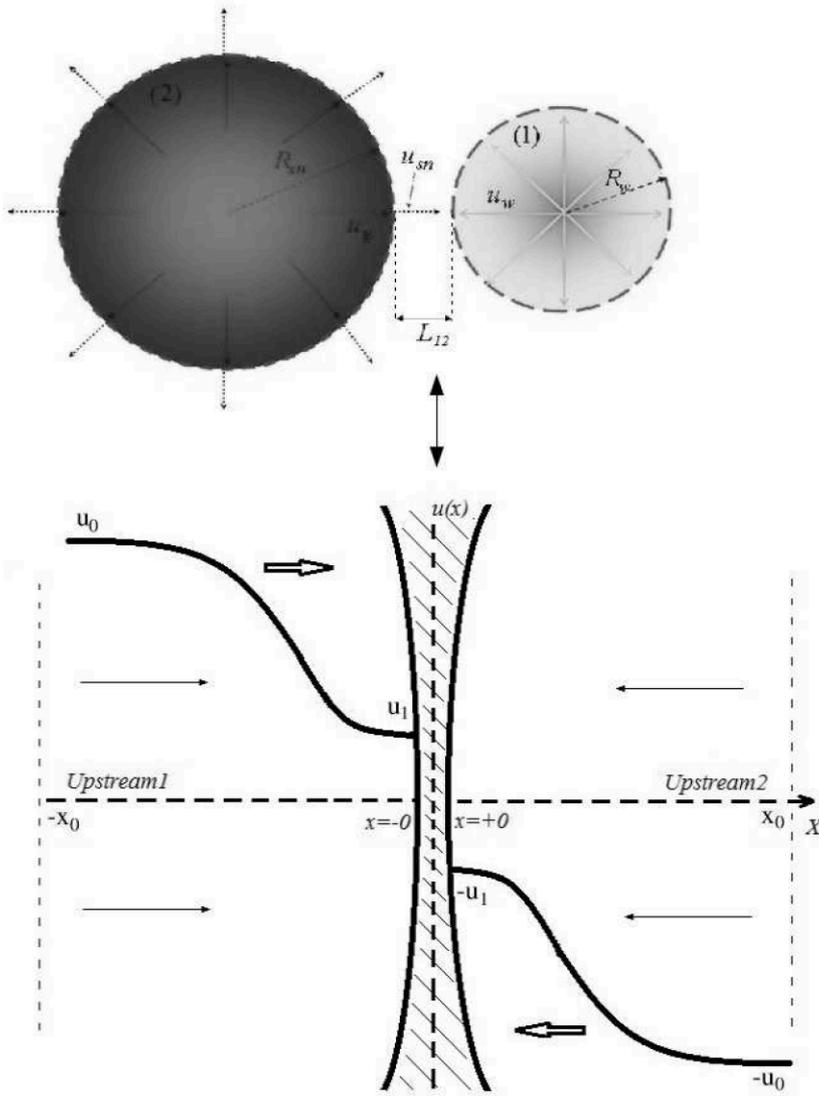


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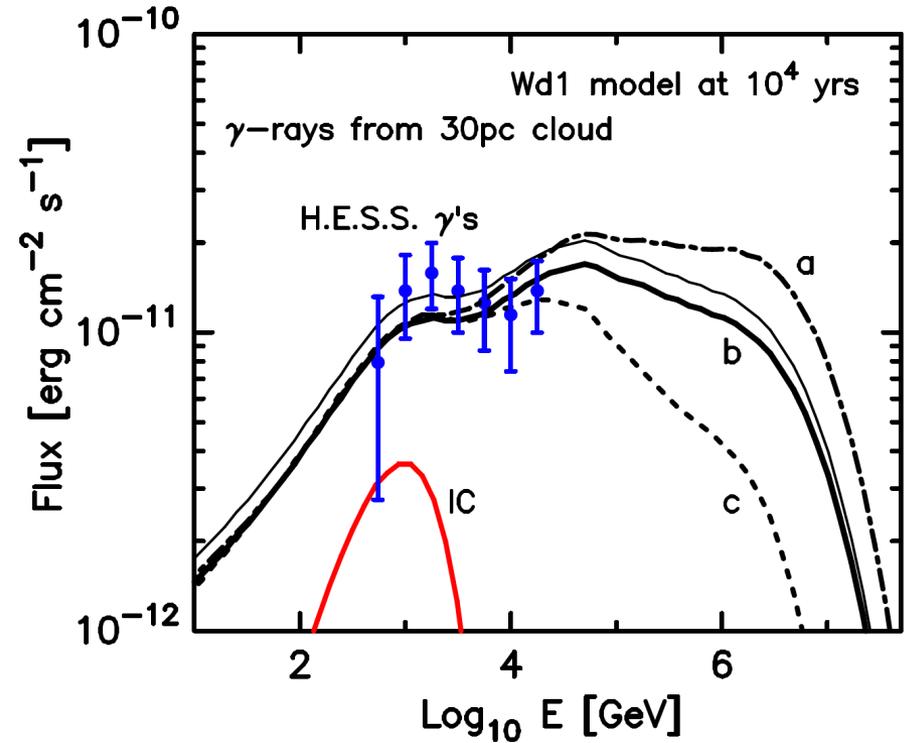
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Prospect

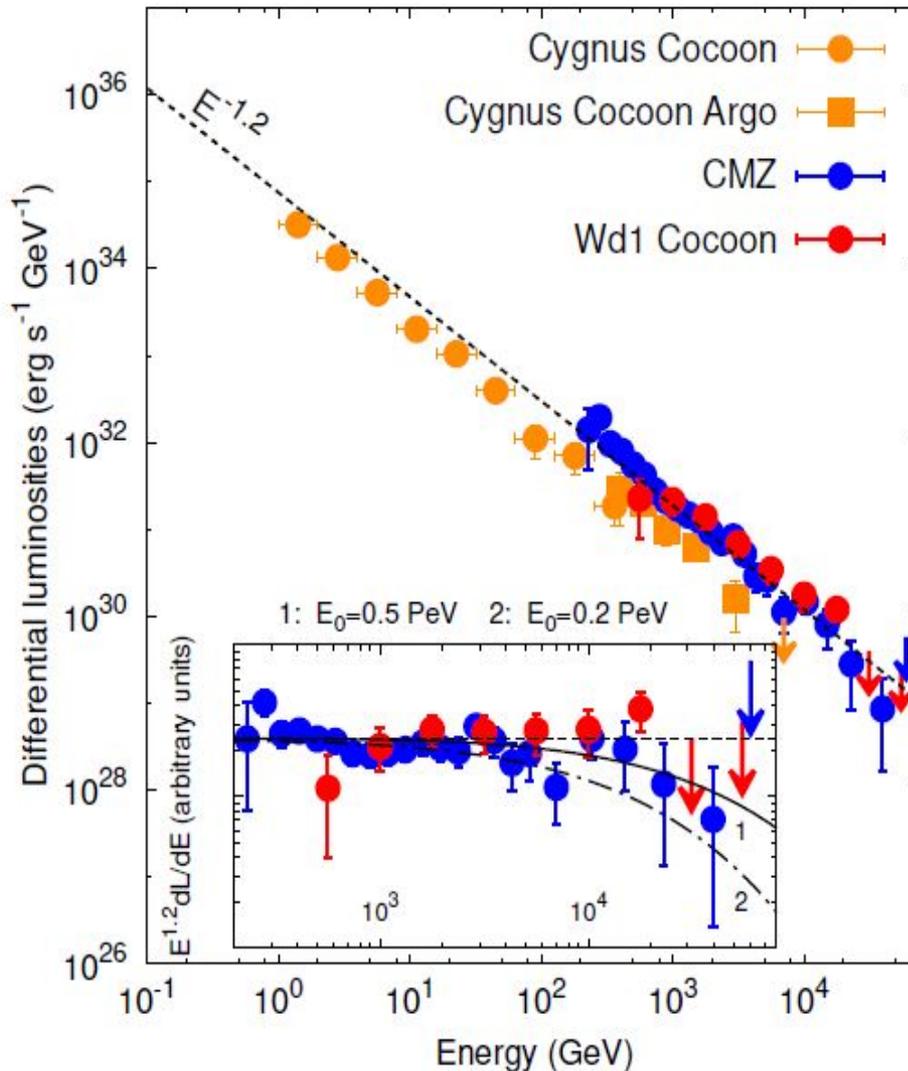
PeVatron hunting: Cygnus region



Bykov et al 2014



- One promising site: SNR shock colliding with wind termination
- Can accelerate to PeV

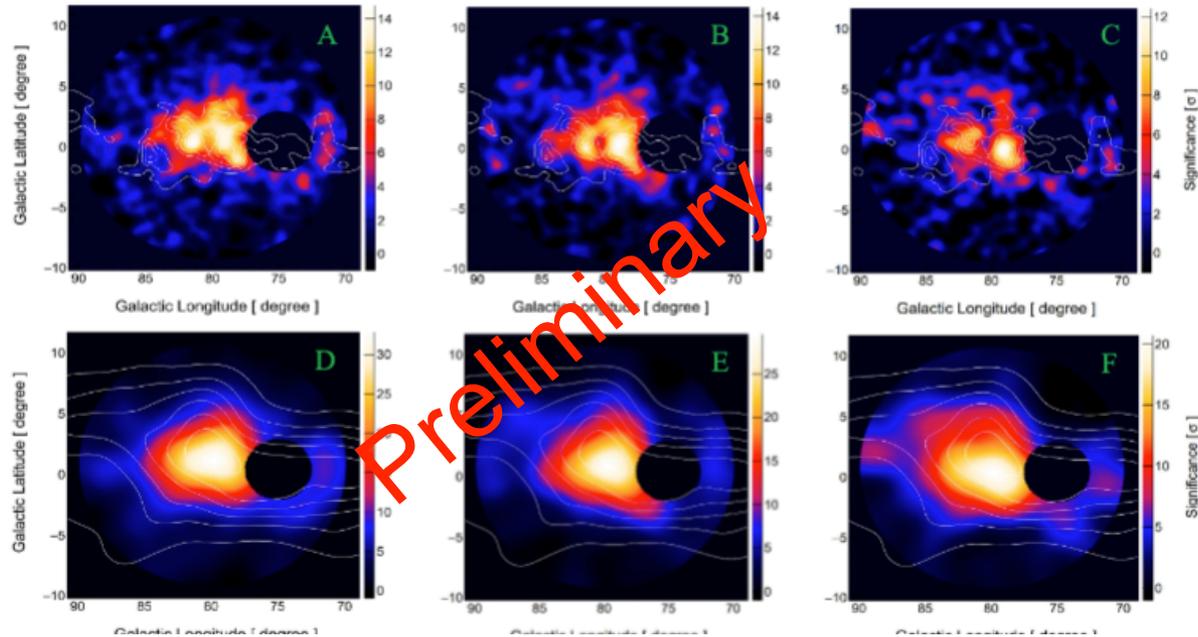


- 1.4 PeV photons from Cygnus region, most promising Proton PeVatron!
- Spectrum extended from GeV to PeV

PeVatron hunting: Cygnus region



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A huge bubble extends more than 100 pc

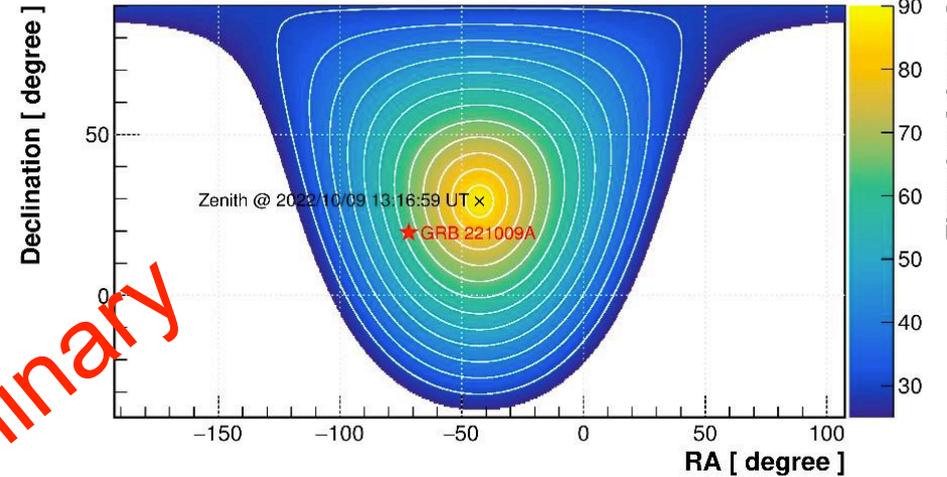
Gamma-ray spectrum extends to more than 1 PeV: hint for super PeVatron

GRB 221009A



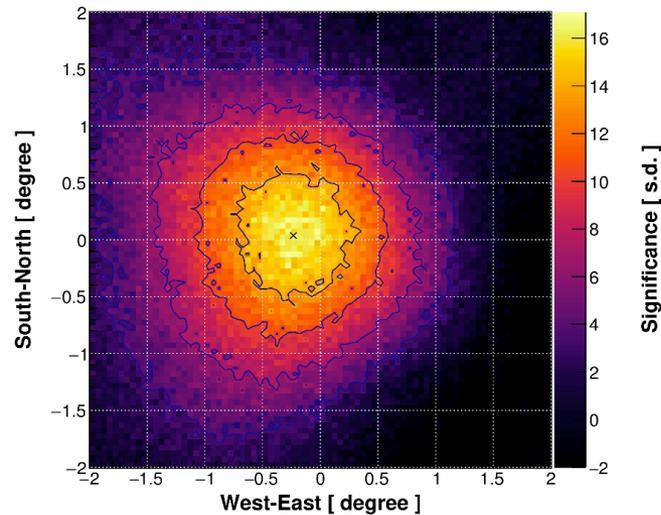
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**LHAASO detected the brightest
GRB in last 60 years**
**>50,000 photons recorded
above 300 GeV**
Significance >131 σ
Photon energy: E_{\max} > 18 TeV

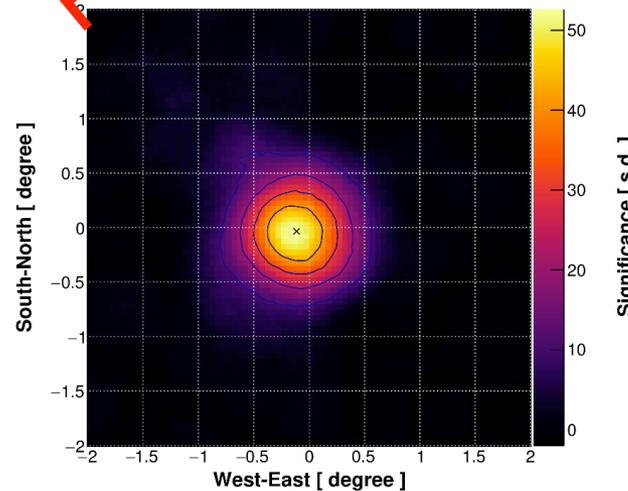


Preliminary

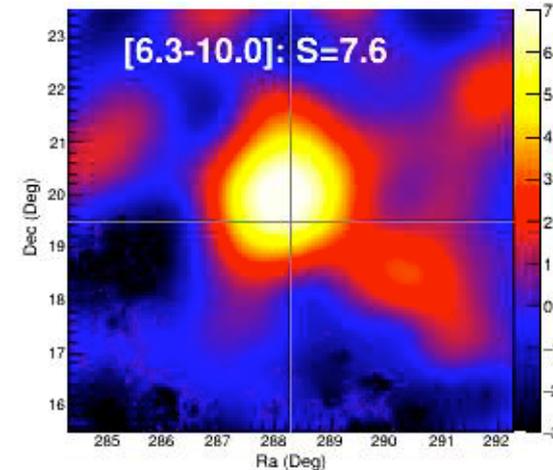
E=0.5 TeV



E=3 TeV



E=8 TeV



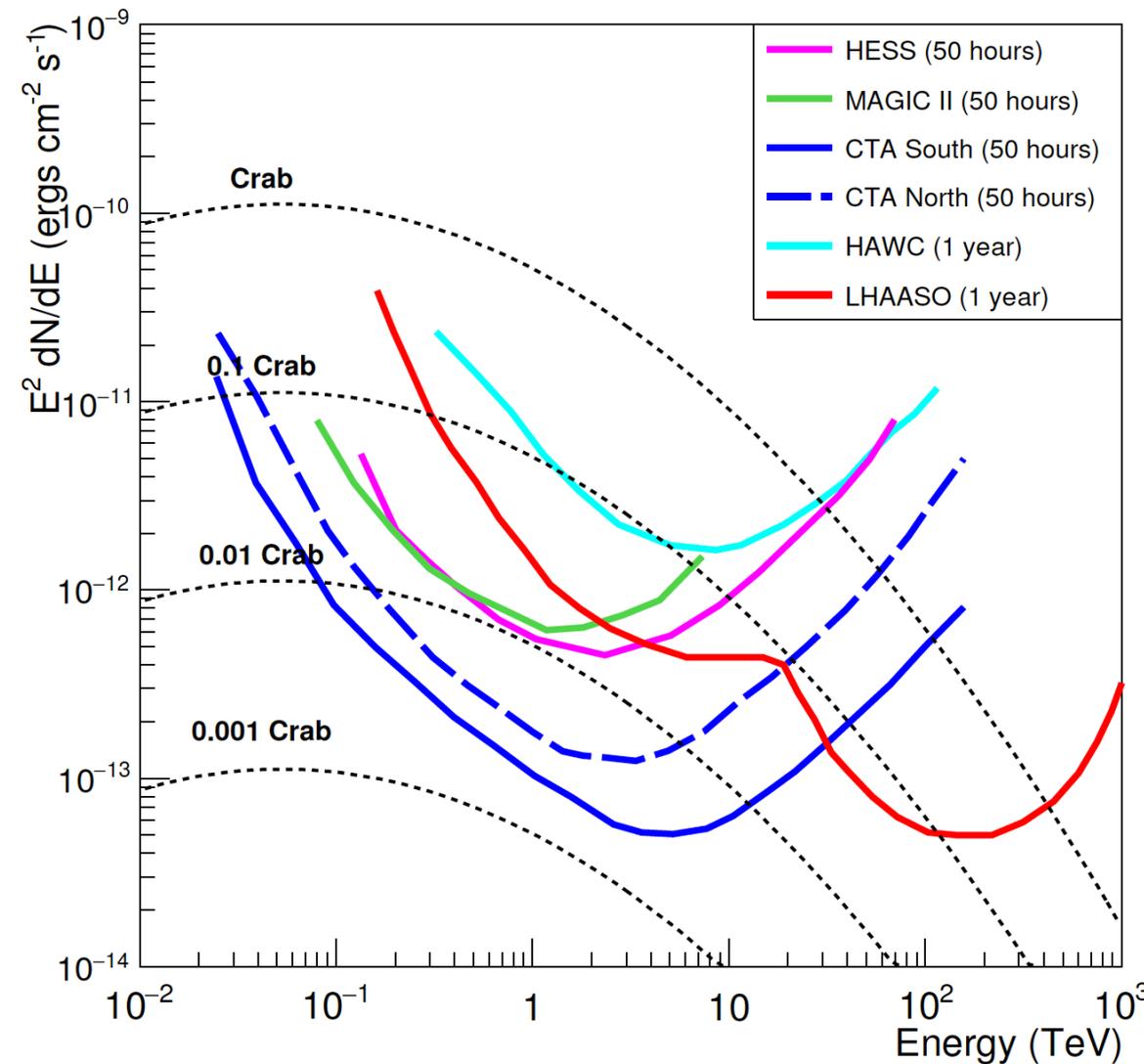
Other on-going work



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- KM2A and WCDA source catalog
- Charged CR spectrum and mass composition
- Diffuse gamma-ray emission from TeV to PeV
- detailed data analysis for other PeVatrons.....

future of LHAASO



Data accumulation of LHAASO and Multi-wavelength observations

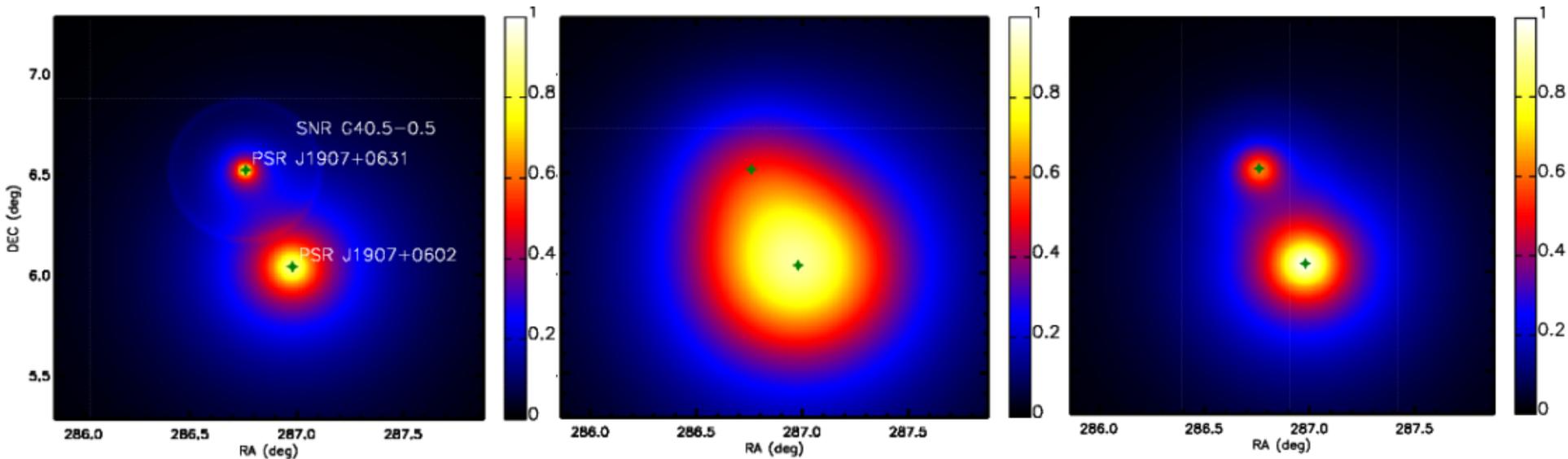
Unprecedented above 20 TeV

ideal PeVatron hunter

But limited angular resolution

(Imaging Air Cherenkov telescope arrays) IACTs can provide angular resolutions as good as 0.05 degree

Important in crowded environment



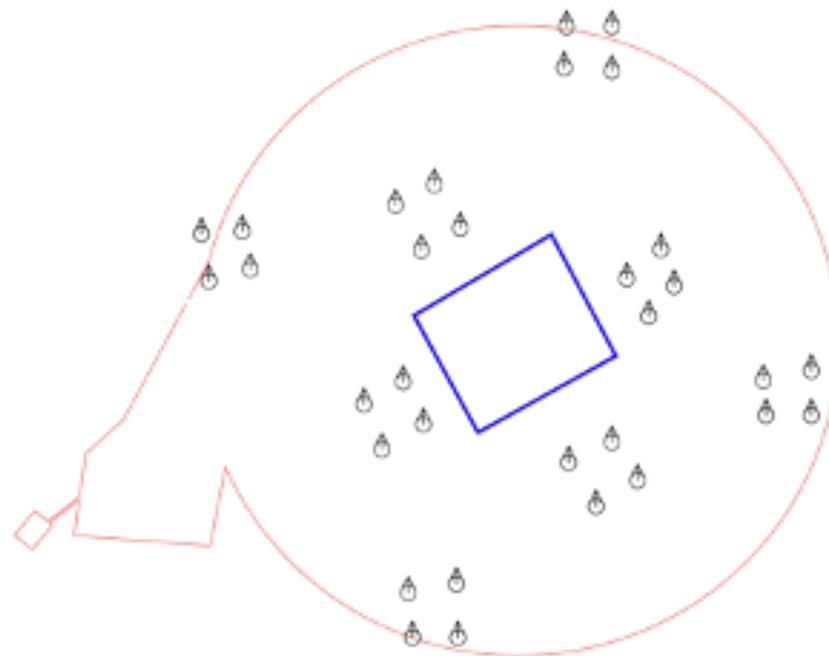
Intrinsic distributions

Observation by LHAASO

Observation of IACTs



6m telescope



8 X 4 arrays in LHAASO site

First light soon!

Predicted sensitivities

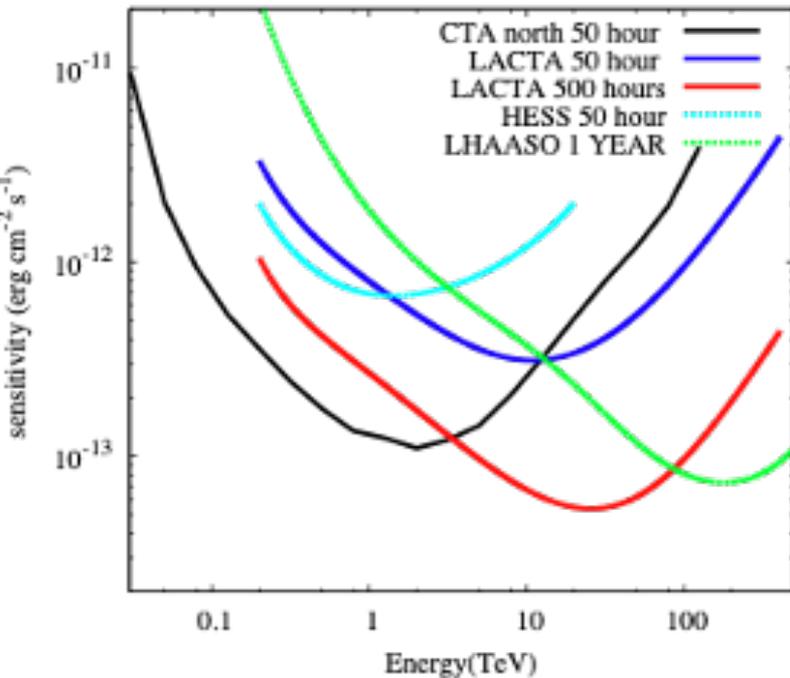


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Synergy with LHAASO

Use MD to improve the gamma/p separation

Detailed morphology study of PeVatrons, TeV halo, PWN...



target	R.A	DEC	Exposure per year	Photon number above 50 TeV	Photon number above 100TeV
Crab	83.55	22.05	1090	400	100
LHAASO J1908	287.05	6.35	913	800	110
Cygnus Cocoon	308.05	41.05	1190	200	100
LHAASO J1825	276.45	-13.45	600	1000	350
LHAASO J2226	336.75	60.95	1267	600	140
W43	282.35	-0.05	833		75



Conclusion



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- LHAASO already show great power in gamma-ray astronomy, especially in PeVatron study and time domain astronomy
- A lot of future tasks for LHAASO: GRB light curve, Cygnus region, diffuse gamma-ray, high energy transients, direct measurement of CRs, indirect dark matter search.....
- Further project: Imaging Air Cherenkov array in LHAASO site

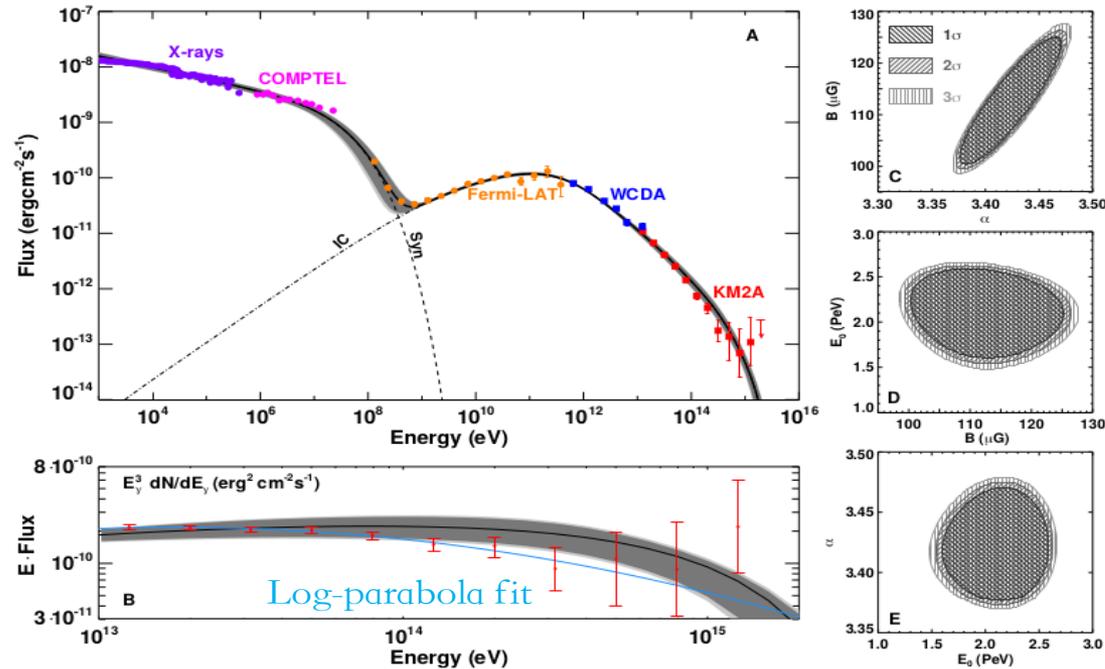


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Thanks!

Standard One-Zone Model



$$E_e = 2.15 (E_\gamma / 1 \text{ PeV})^{0.77}$$

Inverse Compton scattering on CMB

$$\dot{E}_e = e\mathcal{E}c = \eta eBc$$

$\eta = \mathcal{E}/B$ acceleration efficiency

$$\dot{E}_{e,\text{syn}} = \sigma_T (E_e / m_e c^2)^2 B^2 c / 6\pi$$

Synchrotron loss rate

Extreme acceleration efficiency

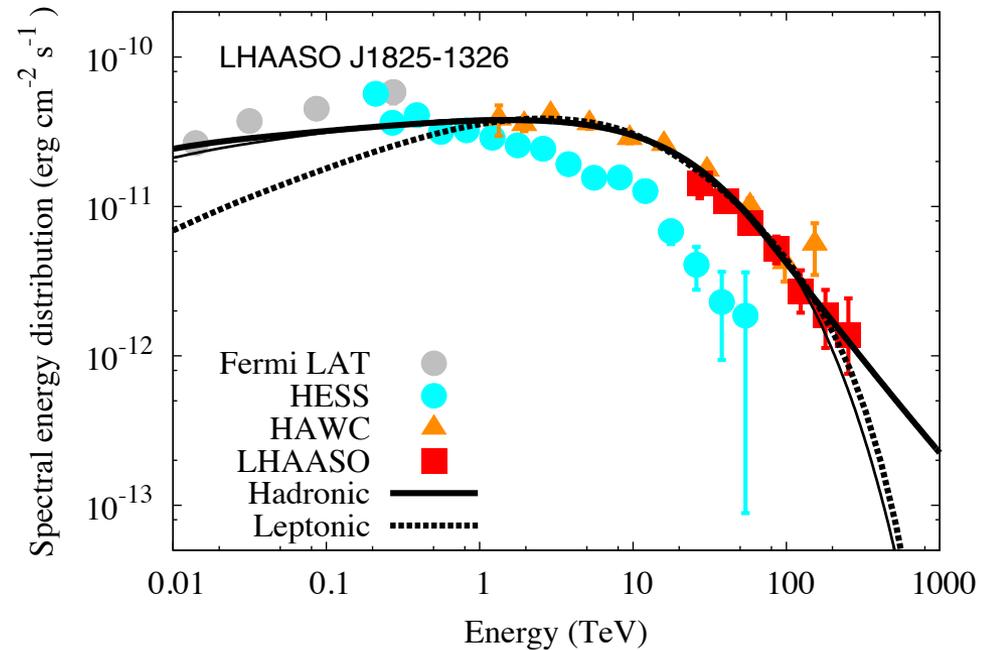
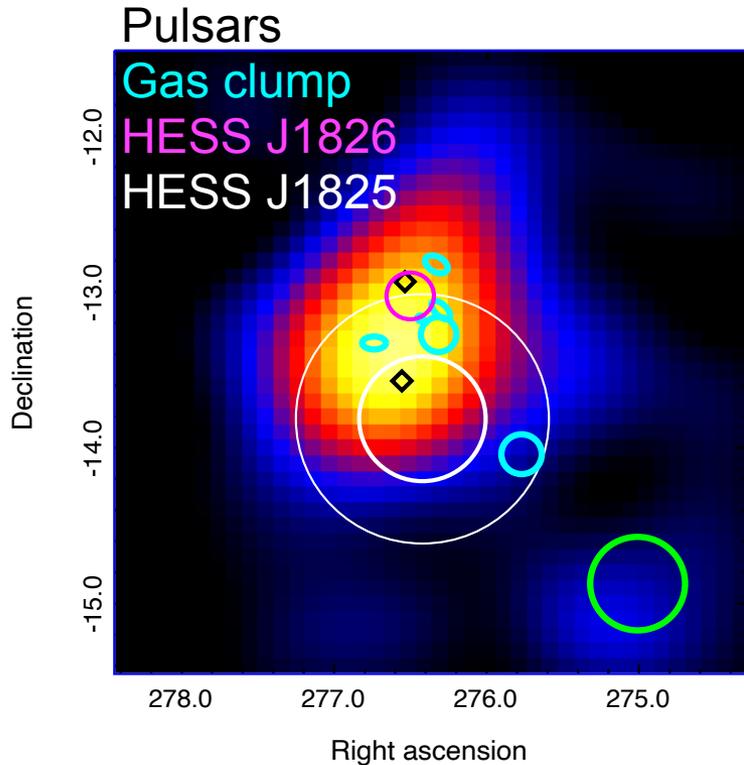
$$\eta = 0.14 (B / 100 \mu\text{G}) (E_\gamma / 1 \text{ PeV})^{1.54}$$

$$\dot{W}_{e,\text{PeV}} = 2 \times 10^{36} (B / 100 \mu\text{G})^2 \text{ erg/s}$$

LHAASO J1825



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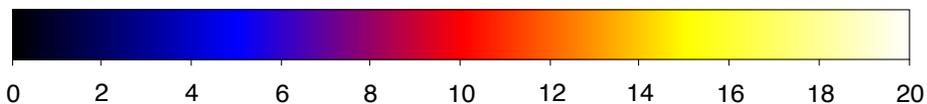
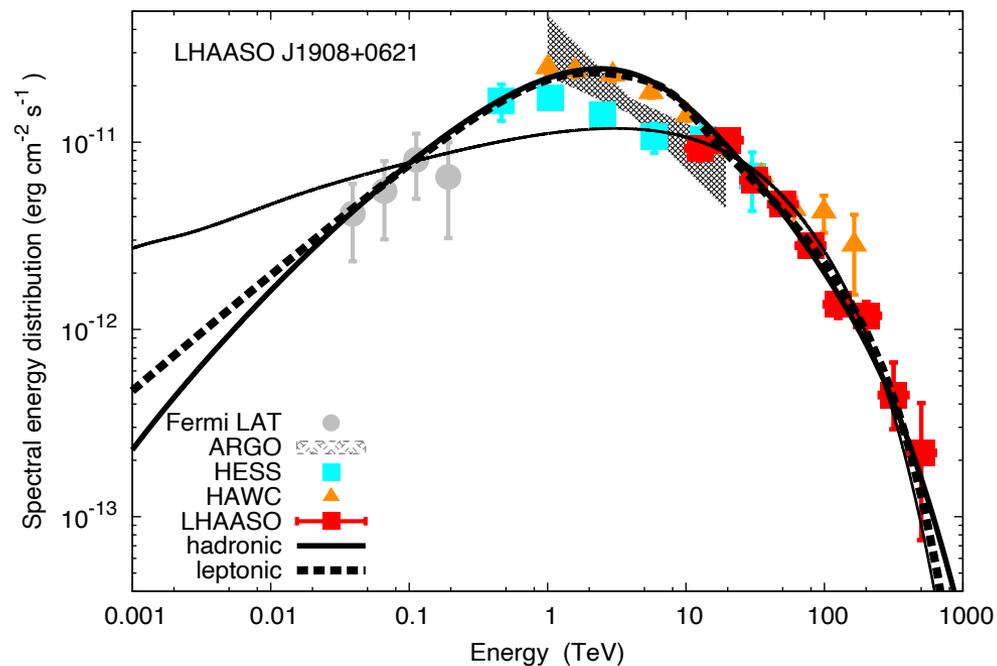
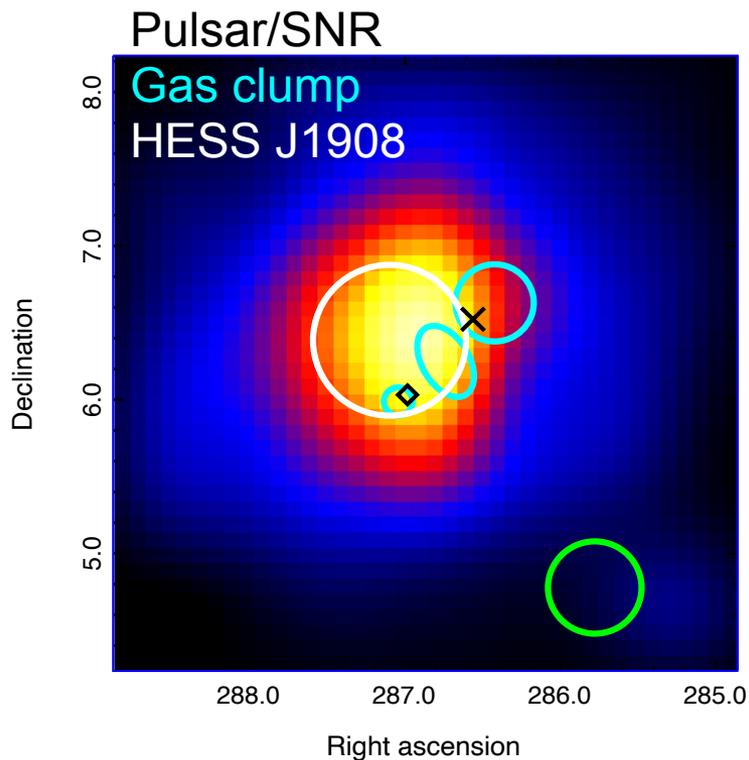


- BPL for protons : index 2.0 and 3.4 below and above 120 TeV
- PLEC for electrons: injection index of 2.07 cutoff ~ 600 TeV

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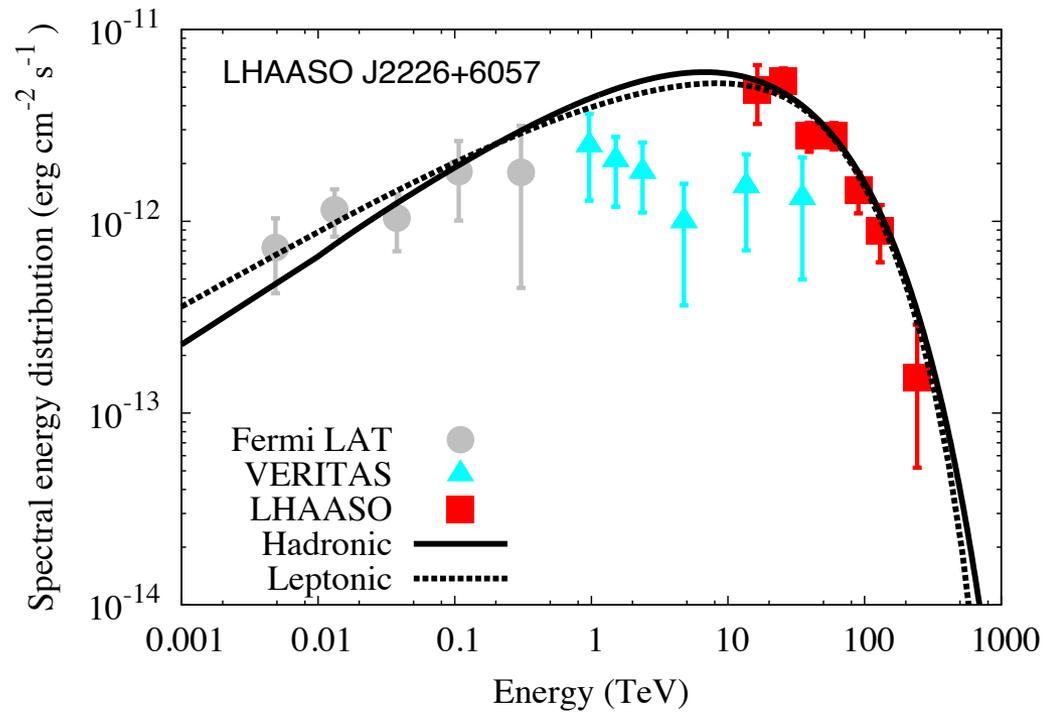
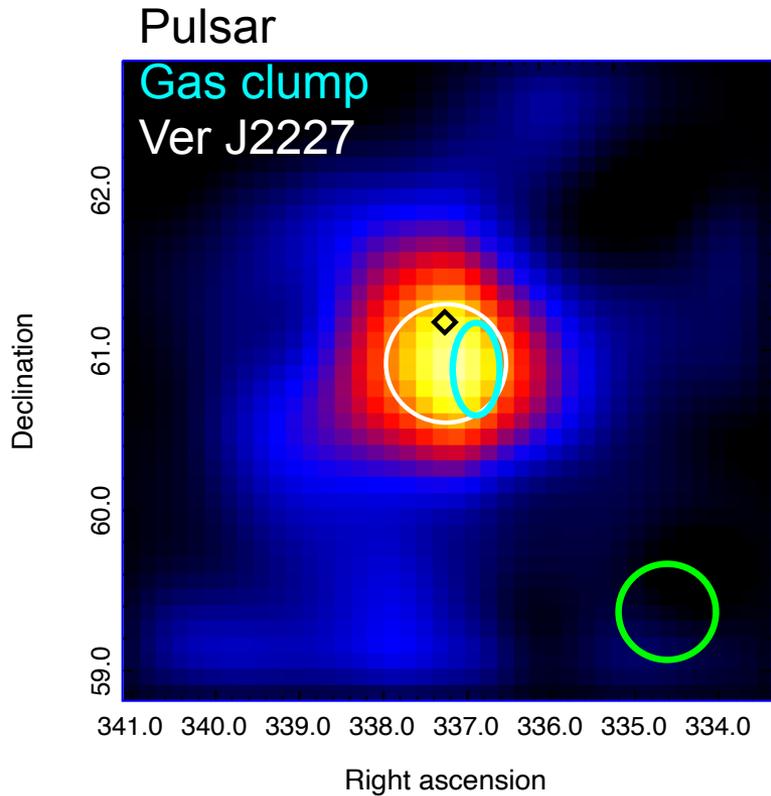
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Need to understand the discrepancy
between IACT and EAS

