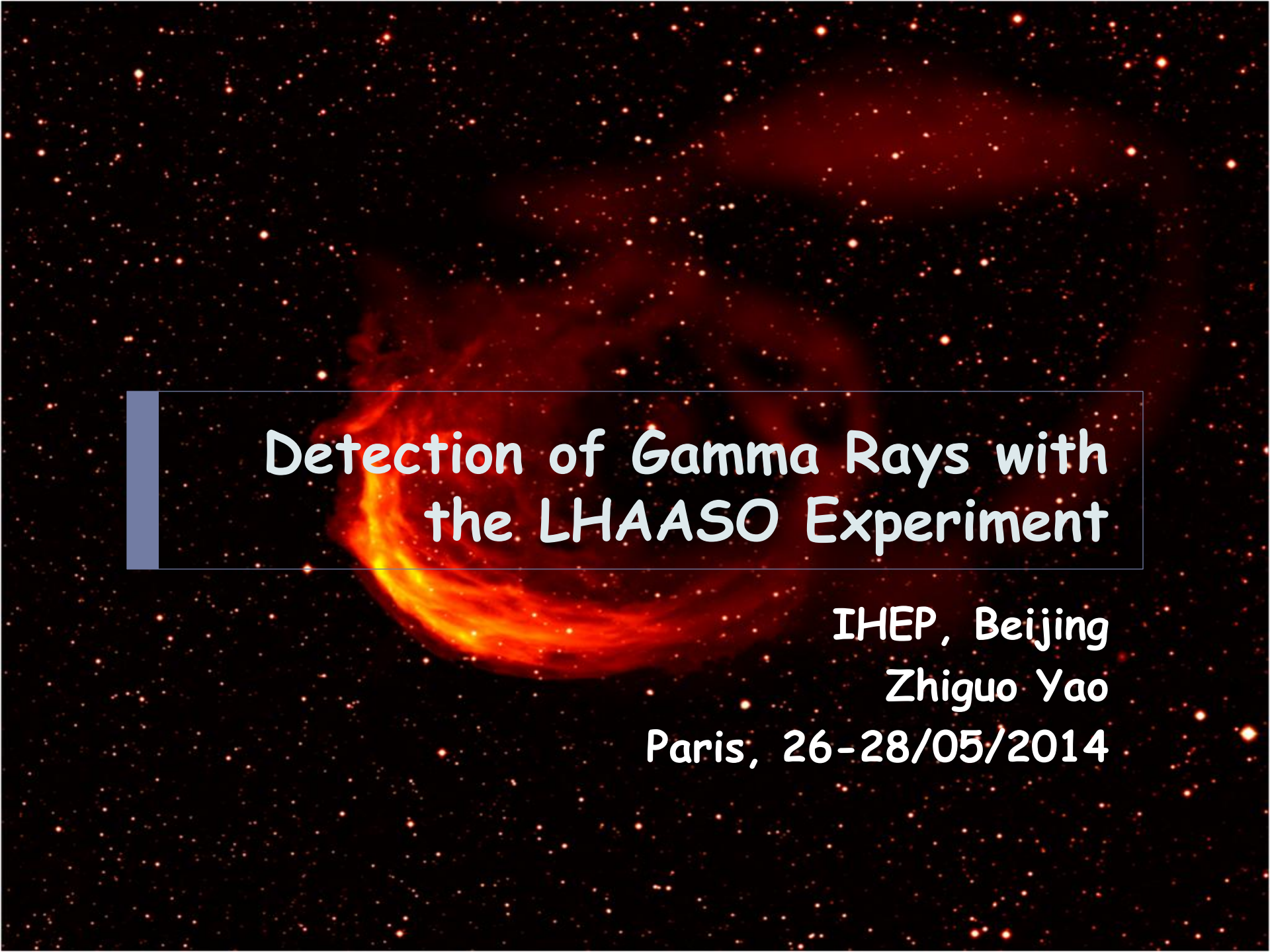


Detection of Gamma Rays with the LHAASO Experiment

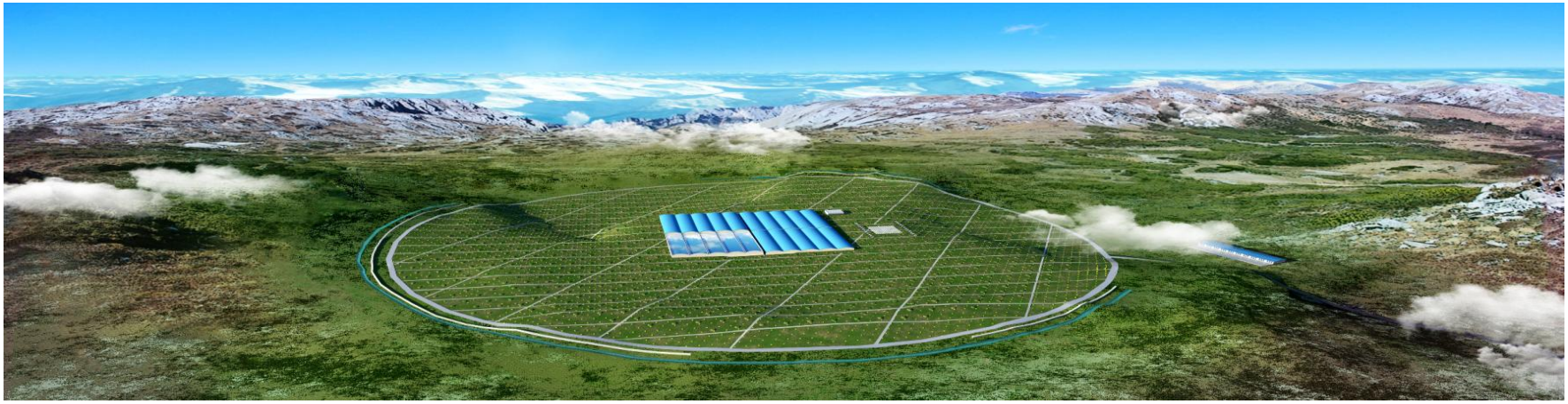
IHEP, Beijing
Zhiguo Yao

Paris, 26-28/05/2014

Outline

- LHAASO & Gamma Ray Detectors
- Physics & Competition
- Gamma/Proton Discrimination
- Performances
- On Flares & Extended sources
- On Known & Unknown Sources
- Summary

LHAASO site



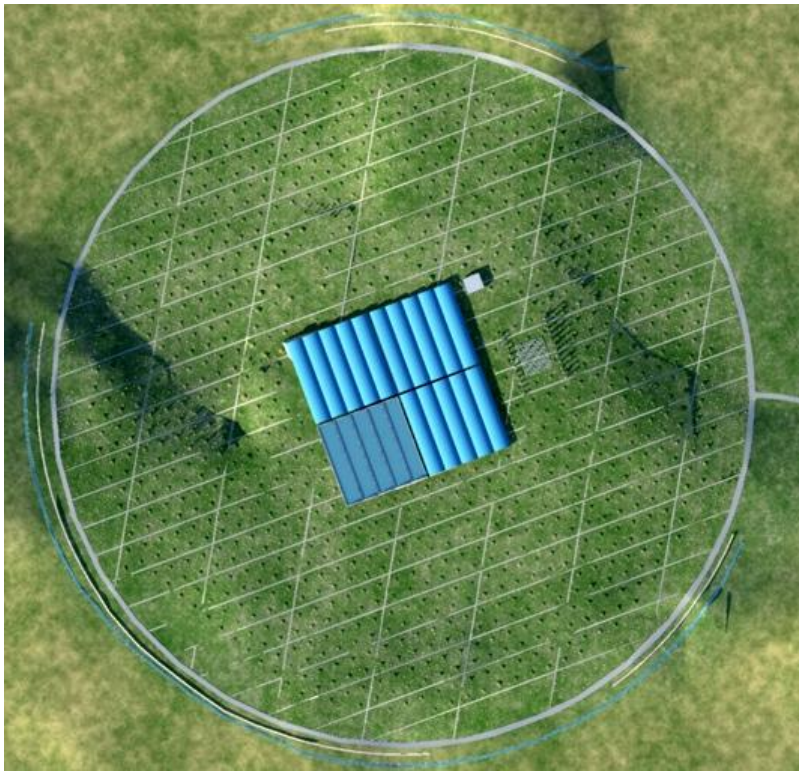
LHAASO for Gamma Astronomy

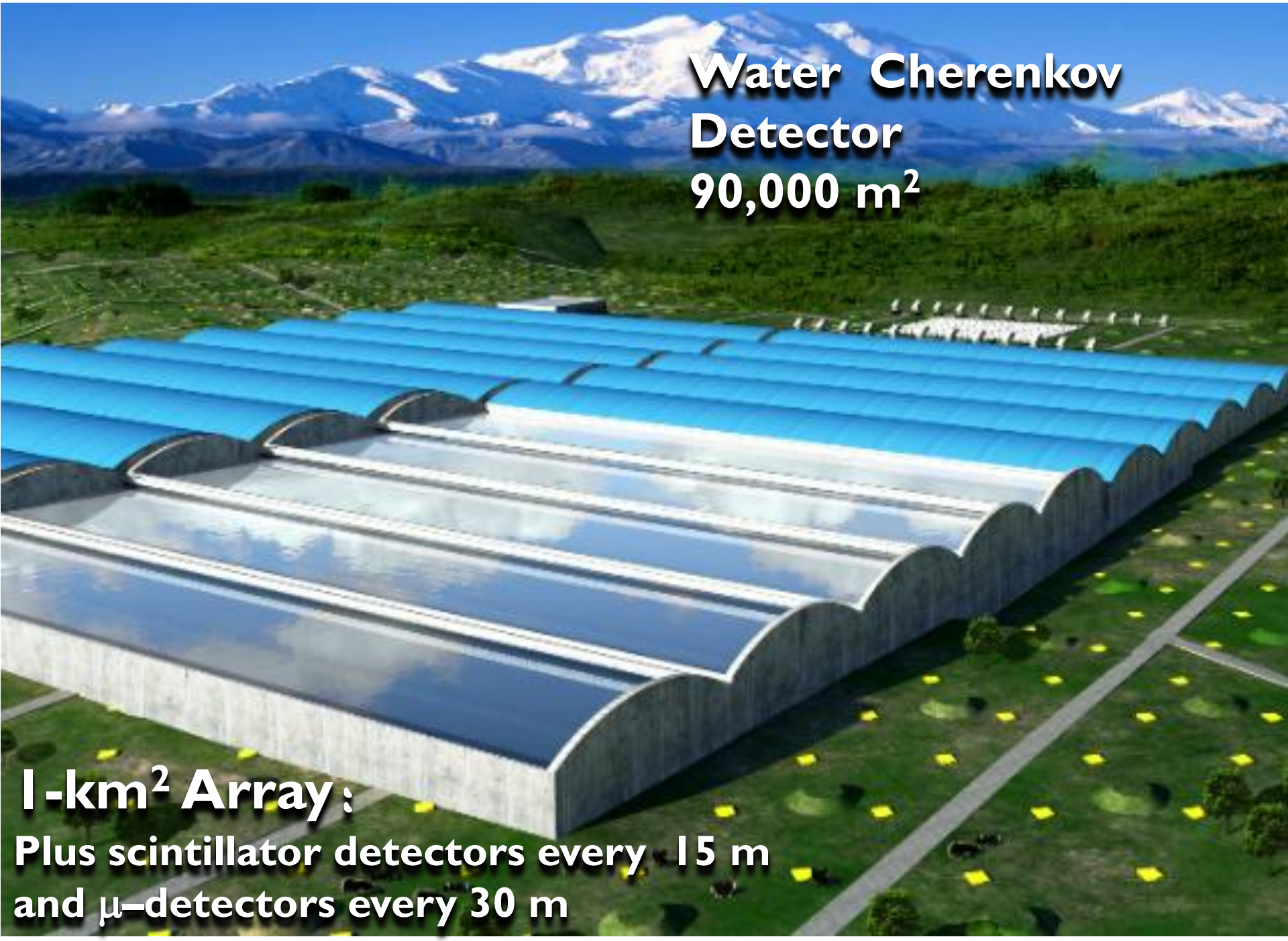
- Two Gamma Ray Astronomic Devices
  - A Wide FOV Survey Facility
  - A Spectrometer for Interesting Sources

WCDA

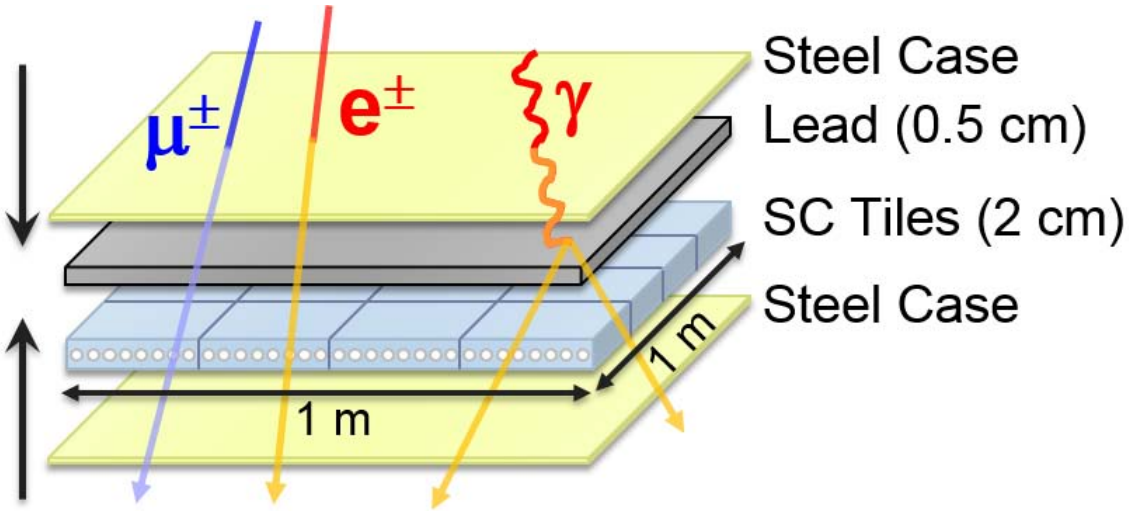
+

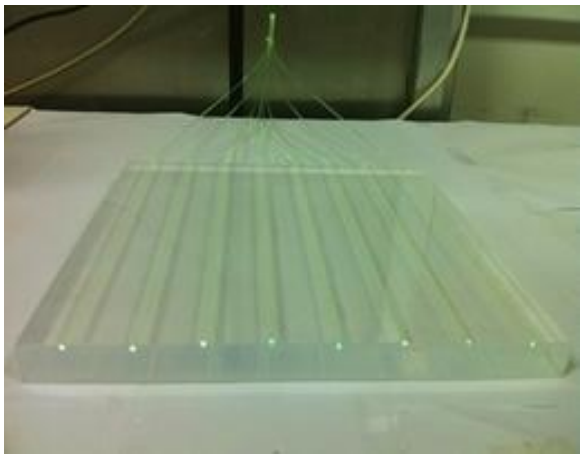
KM2A

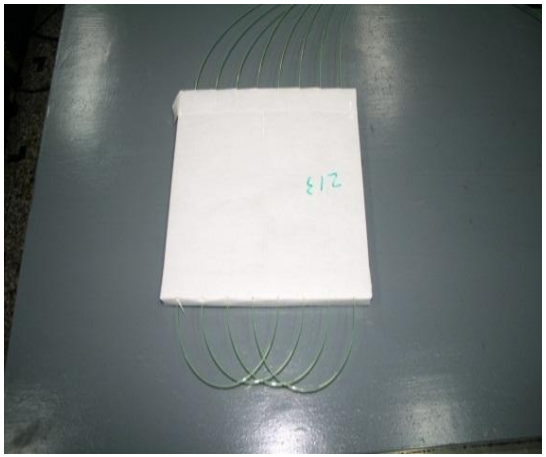



Water Cherenkov
Detector
90,000 m²
1-km² Array:
Plus scintillator detectors every 15 m
and μ–detectors every 30 m

Electromagnetic Particle Detector (ED)

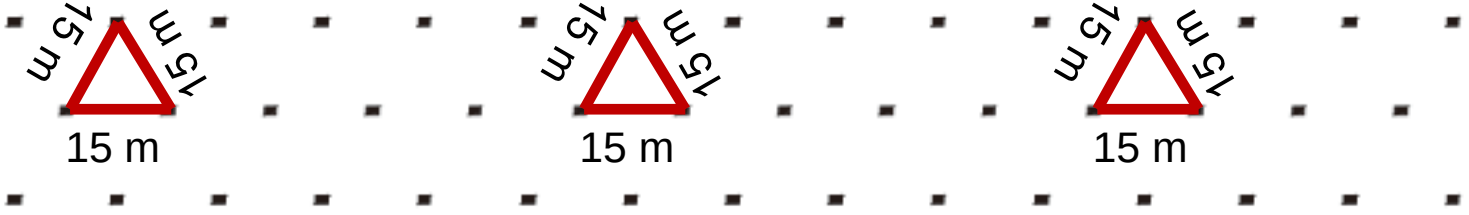




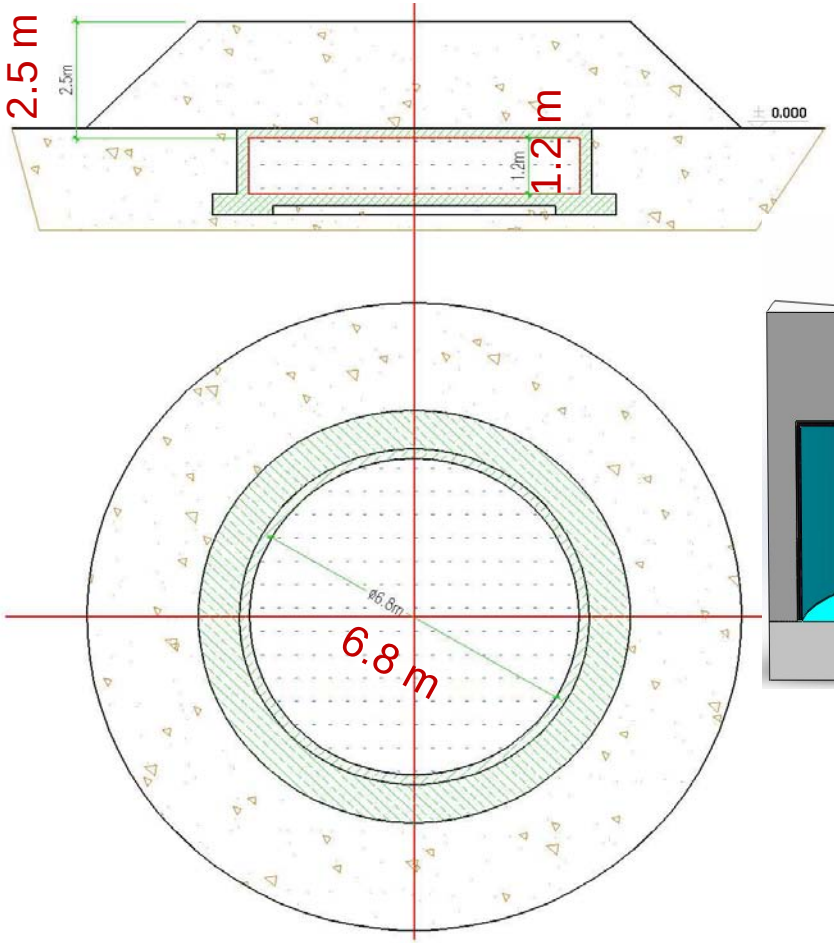


ED Specifications

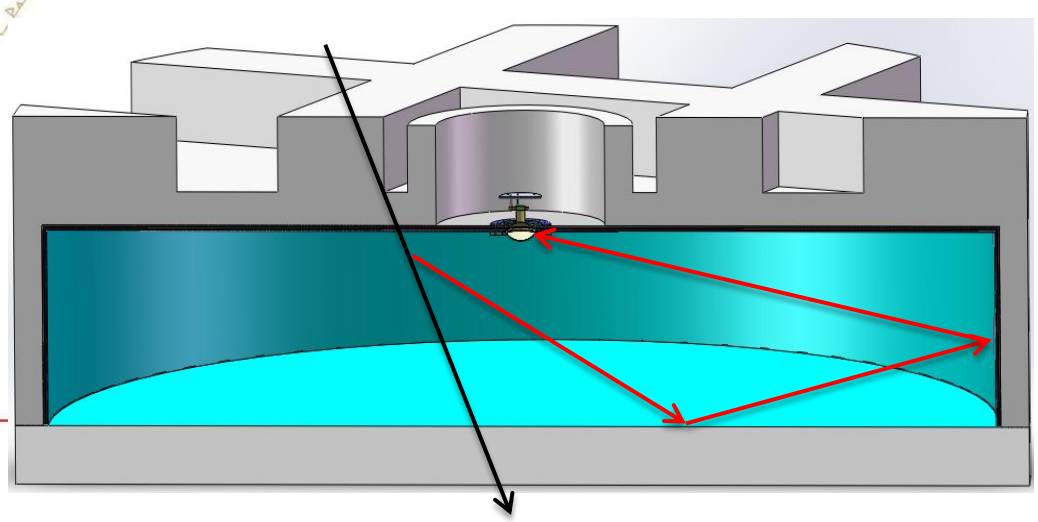
Item	Value
Effective area	1 m^2
Thickness of tiles	2 cm
Number of WLS fibers	8/tile×16 tile
Detection efficiency (> 5 MeV)	>95%
Dynamic range	1-10,000 particles
Time resolution	<2 ns
Particle counting resolution	25% @ 1 particle 5% @ 10,000 particles
Aging	>10 years
Spacing	15 m
Total number of detectors	5635

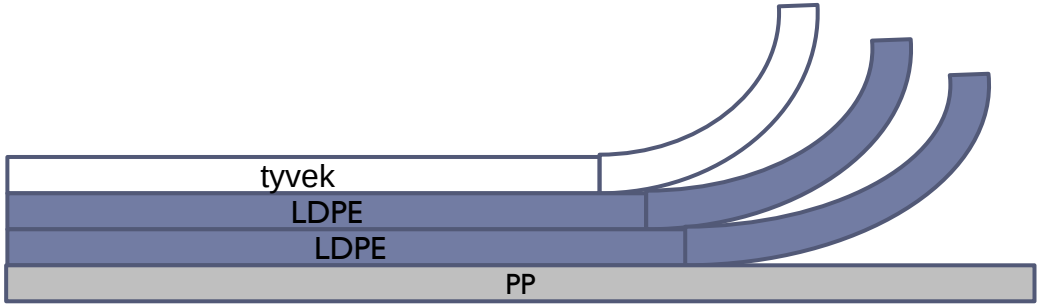


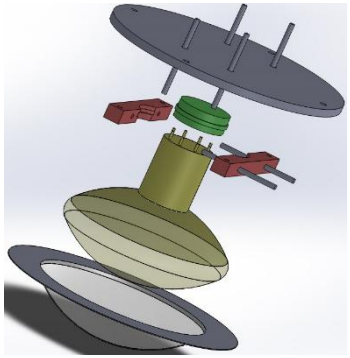
Muon Detector (MD)



PMT: 8” or 9”



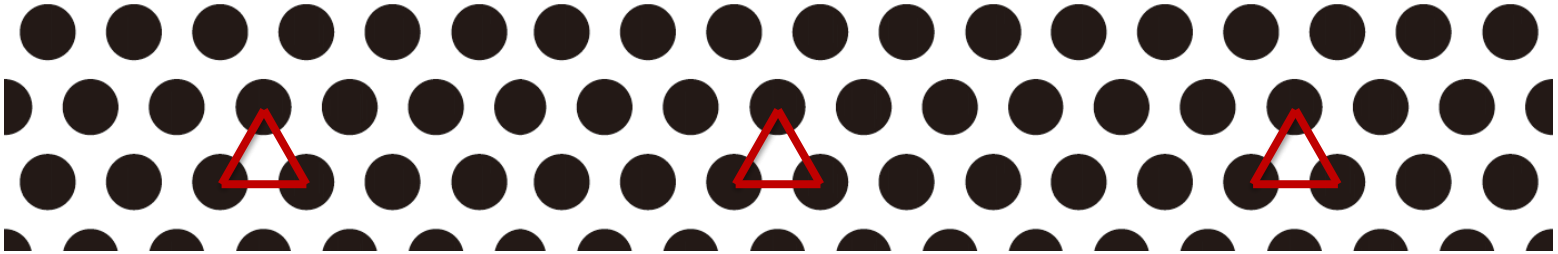

tyvek
LDPE
LDPE
PP



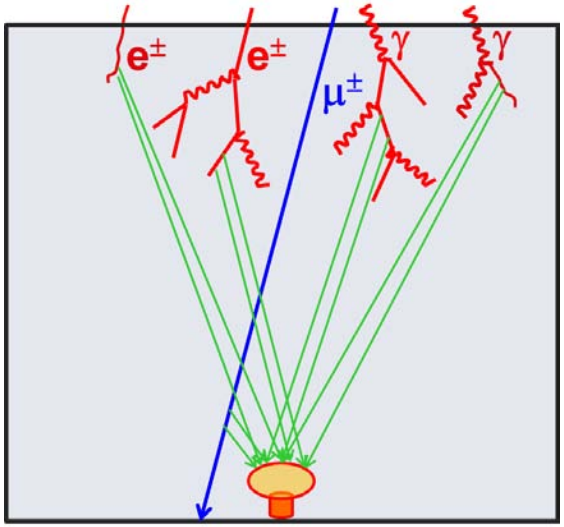

8 m

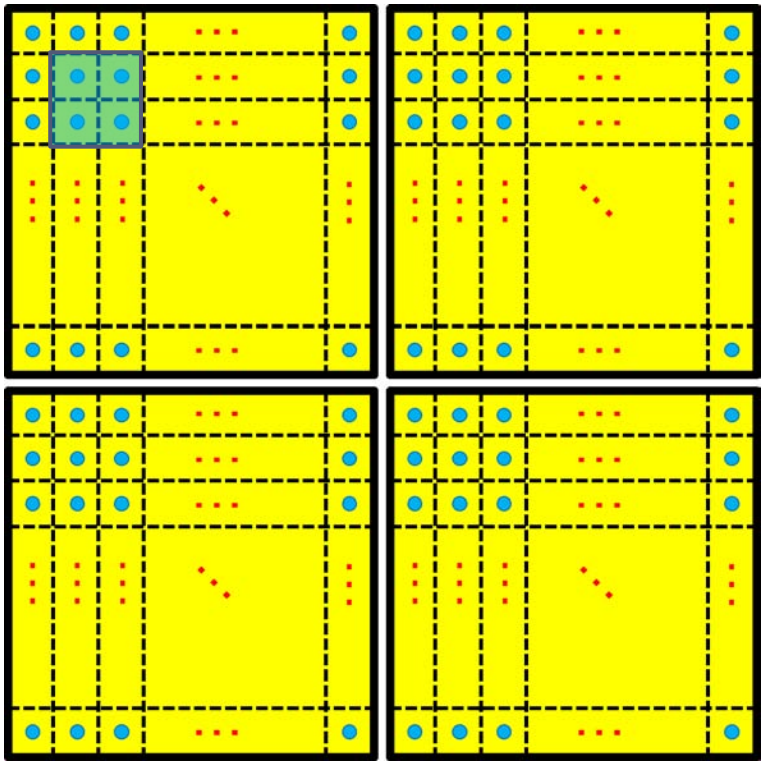
MD Specifications

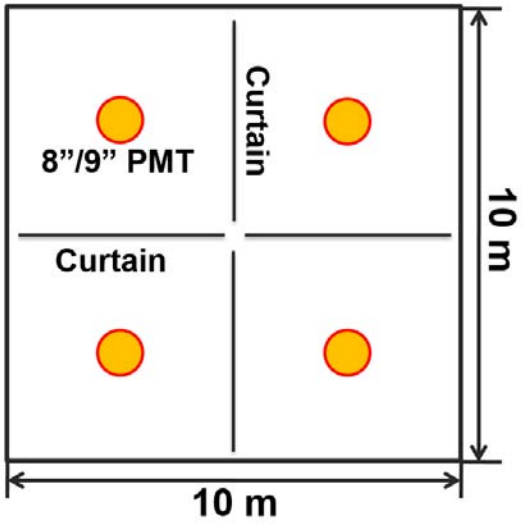
Item	Value
Area	36 m^2
Depth	1.2 m
Molasses overburden	2.5 m
Water transparency (att. len.)	> 30 m (400 nm)
Reflection coefficient	>95%
Time resolution	<10 ns
Particle counting resolution	25% @ 1 particle 5% @ 10,000 particles
Aging	>10 years
Spacing	30 m
Total number of detectors	1221

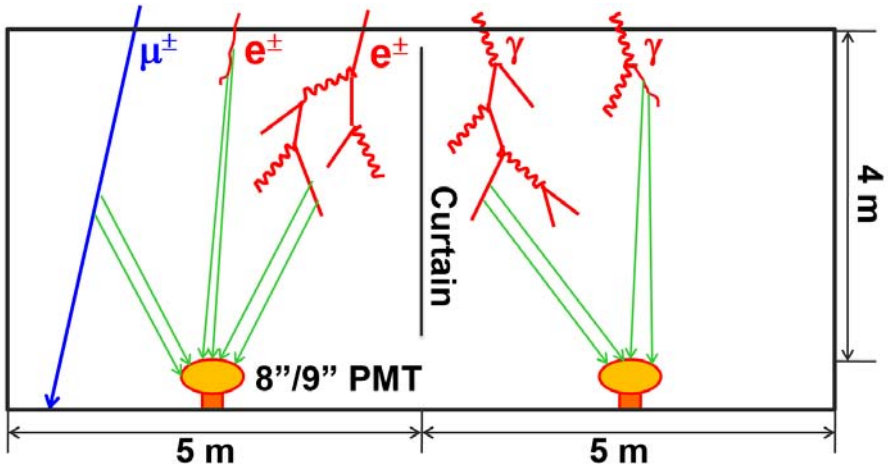


WCDA


e±
e±
μ±
γ
γ



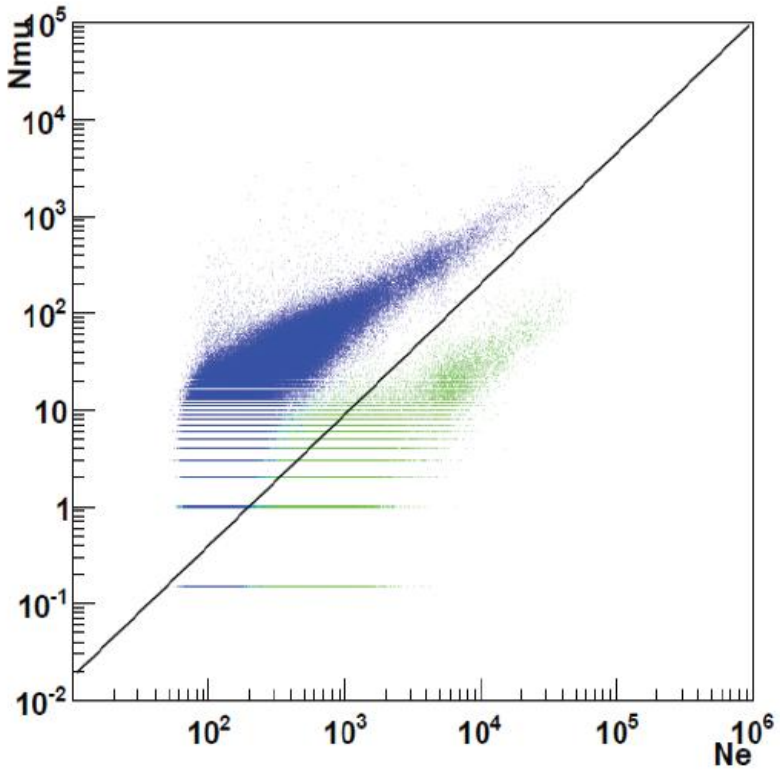

8"/9" PMT
Curtain
Curtain
10 m
10 m


μ±
e±
e±
γ
γ
Curtain
8"/9" PMT
4 m
5 m
5 m

WCDA Specifications

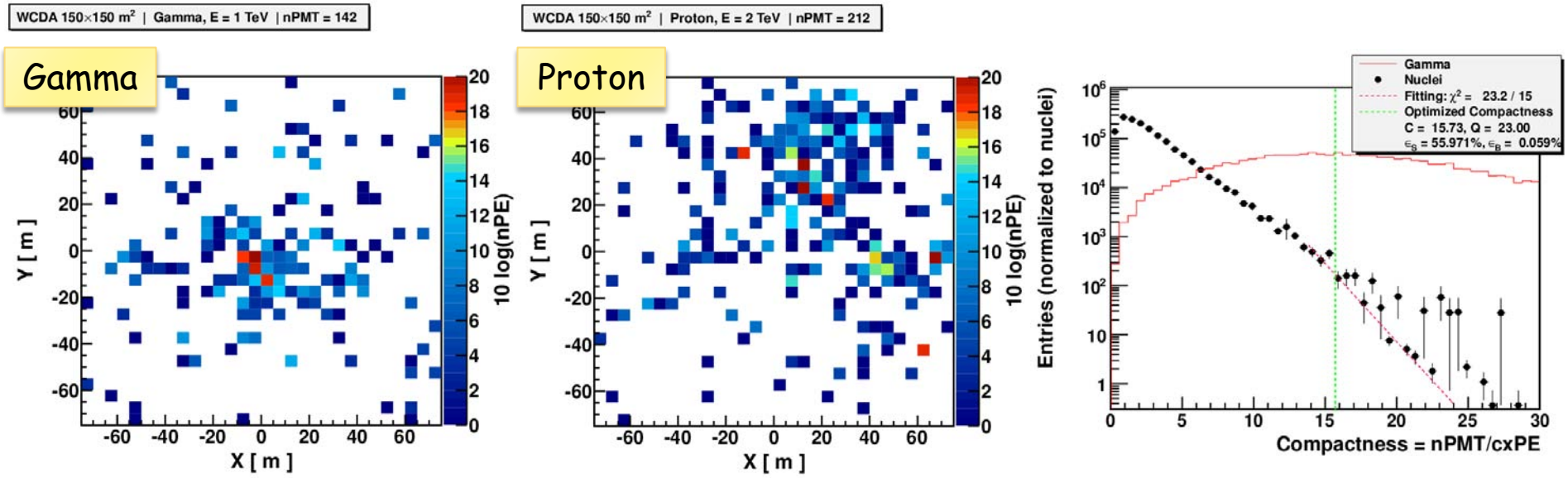
Item	Value
Cell area	25 m^2
Effective water depth	4 m
Water transparency	> 20 m (400 nm)
Precision of time measurement	0.5 ns
Dynamic range	1-4000 PEs
Time resolution	<2 ns
Charge resolution	40% @ 1 PE 5% @ 4000 PEs
Accuracy of charge calibration	<2%
Accuracy of time calibration	<0.2 ns
Total area	90,000 m^2
Total cells	3600

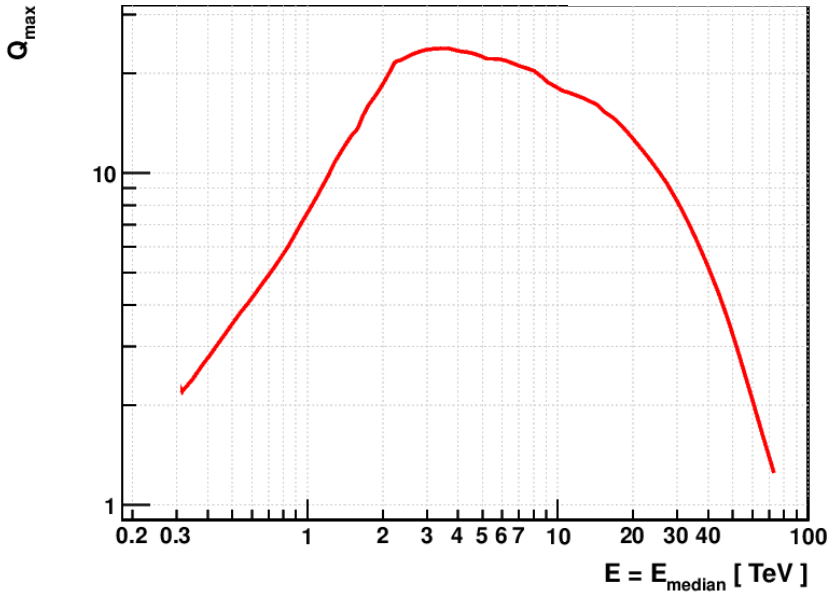
Gamma/proton Discrimination – KM2A



nHit	$\log_{10}$(E) GeV	Q-factor
20-30	3.60	2.67
30-45	3.87	5.62
45-65	4.12	11.9
65-90	4.35	20.7
90-120	4.55	46.4
120-180	4.76	86.6
180-260	5.03	backgroud free
260-360	5.28	backgroud free
360-500	5.53	backgroud free
500-700	5.82	backgroud free
700-1000	6.11	backgroud free

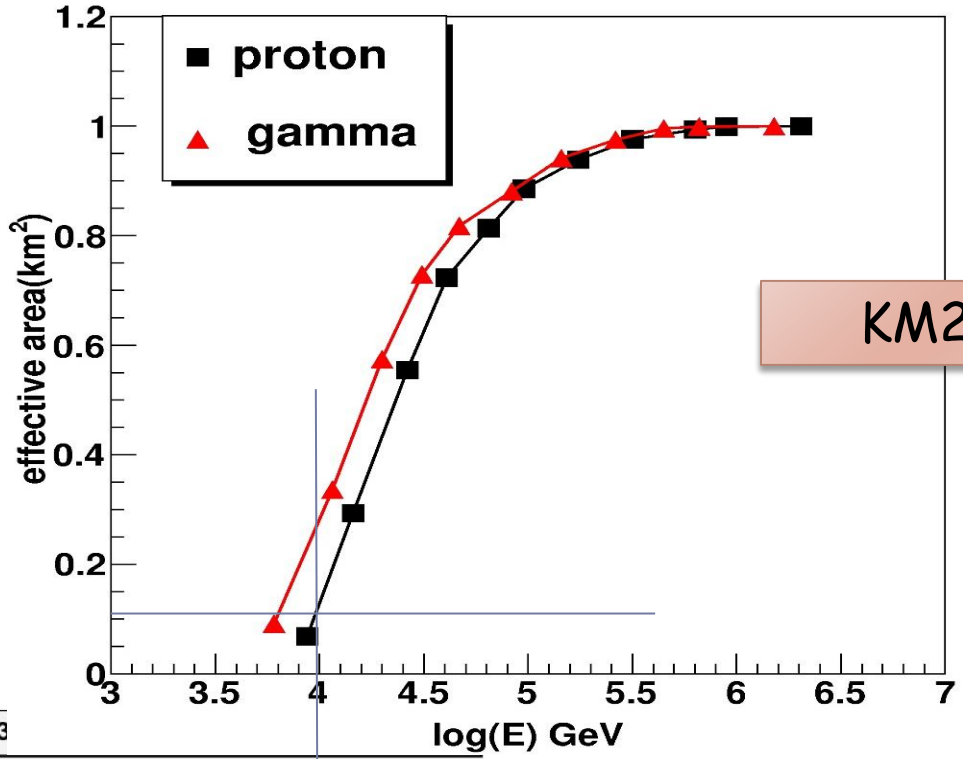
Gamma/proton Discrimination - WCDA



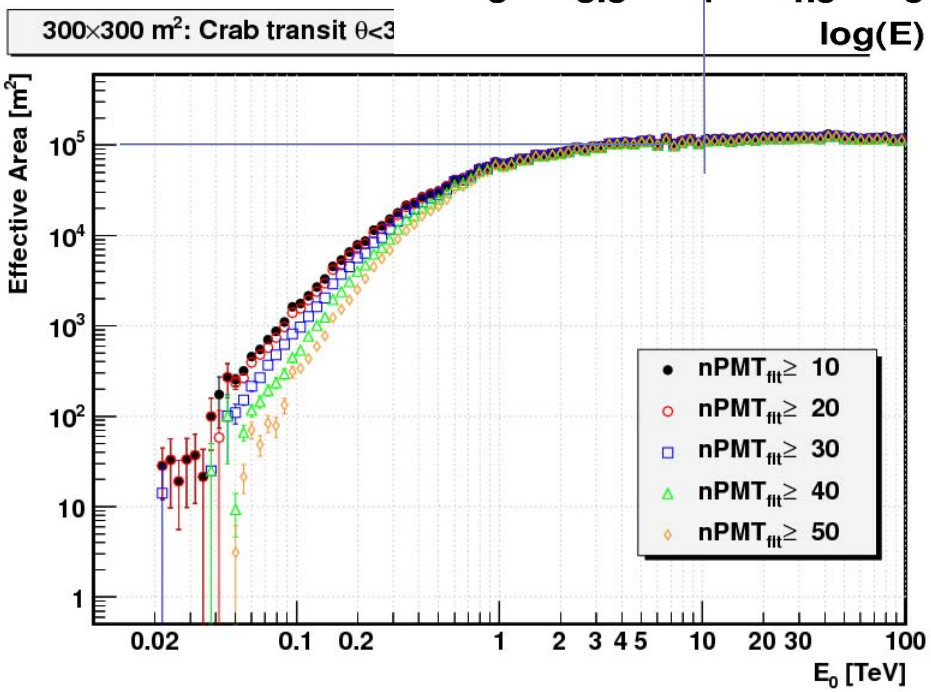


- Brightest "sub-core":
  - Signal of the brightest PMT outside the shower core region (e.g., 45 m);
- "Compactness" can be employed to reject cosmic ray background efficiently.

Effective Area

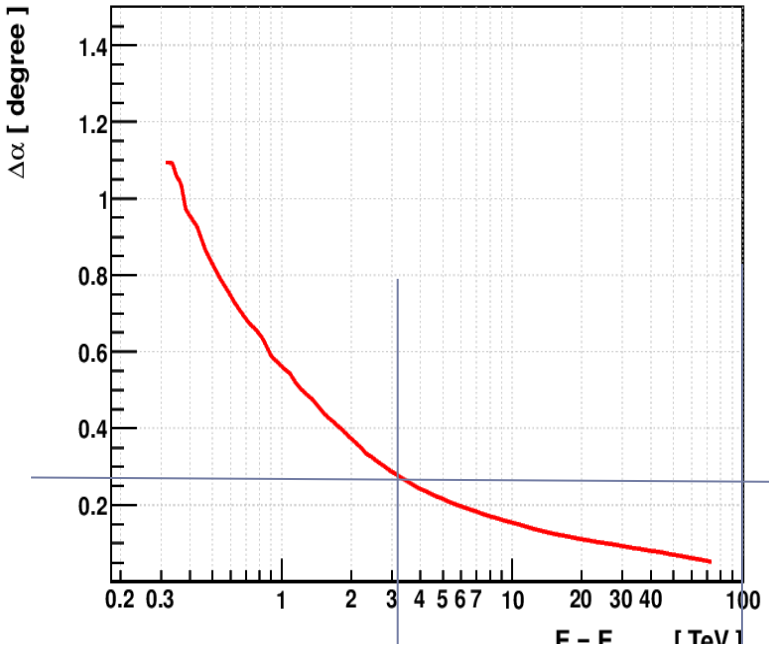


KM2A



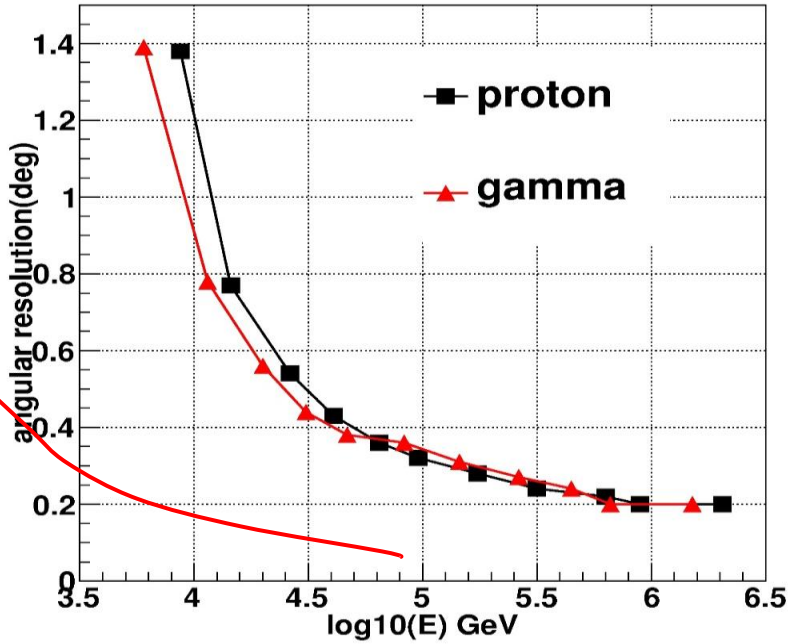
WCDA

Angular Resolution

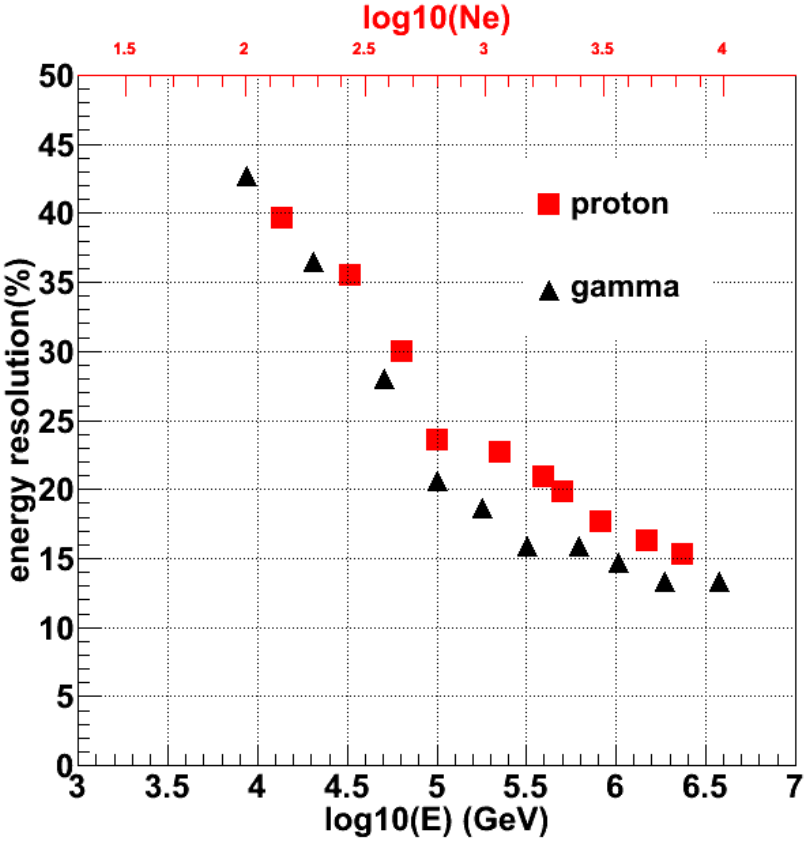


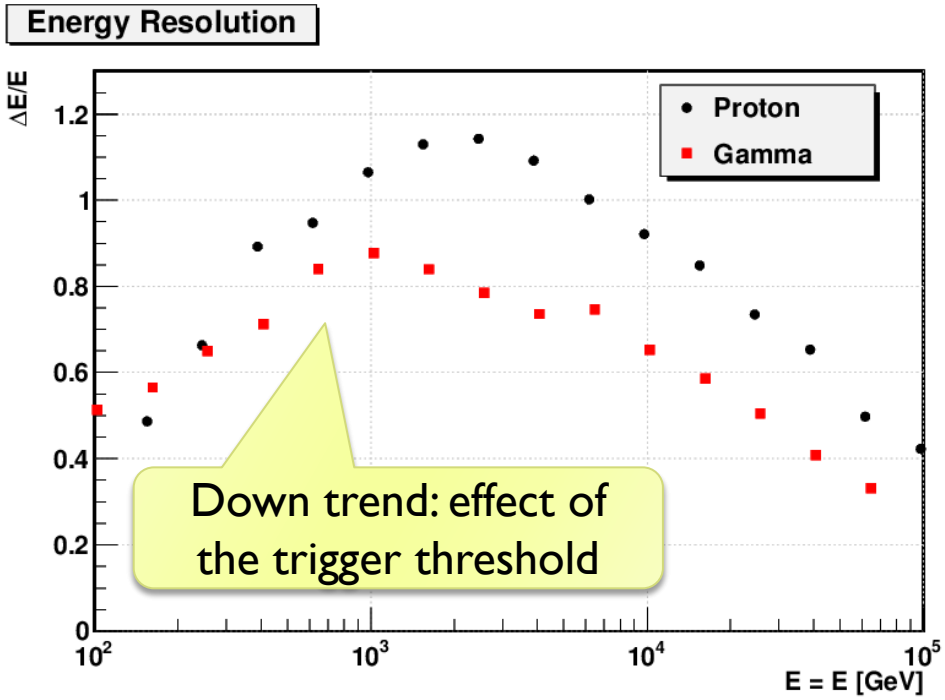
KM2A

WCDA



Energy Resolution

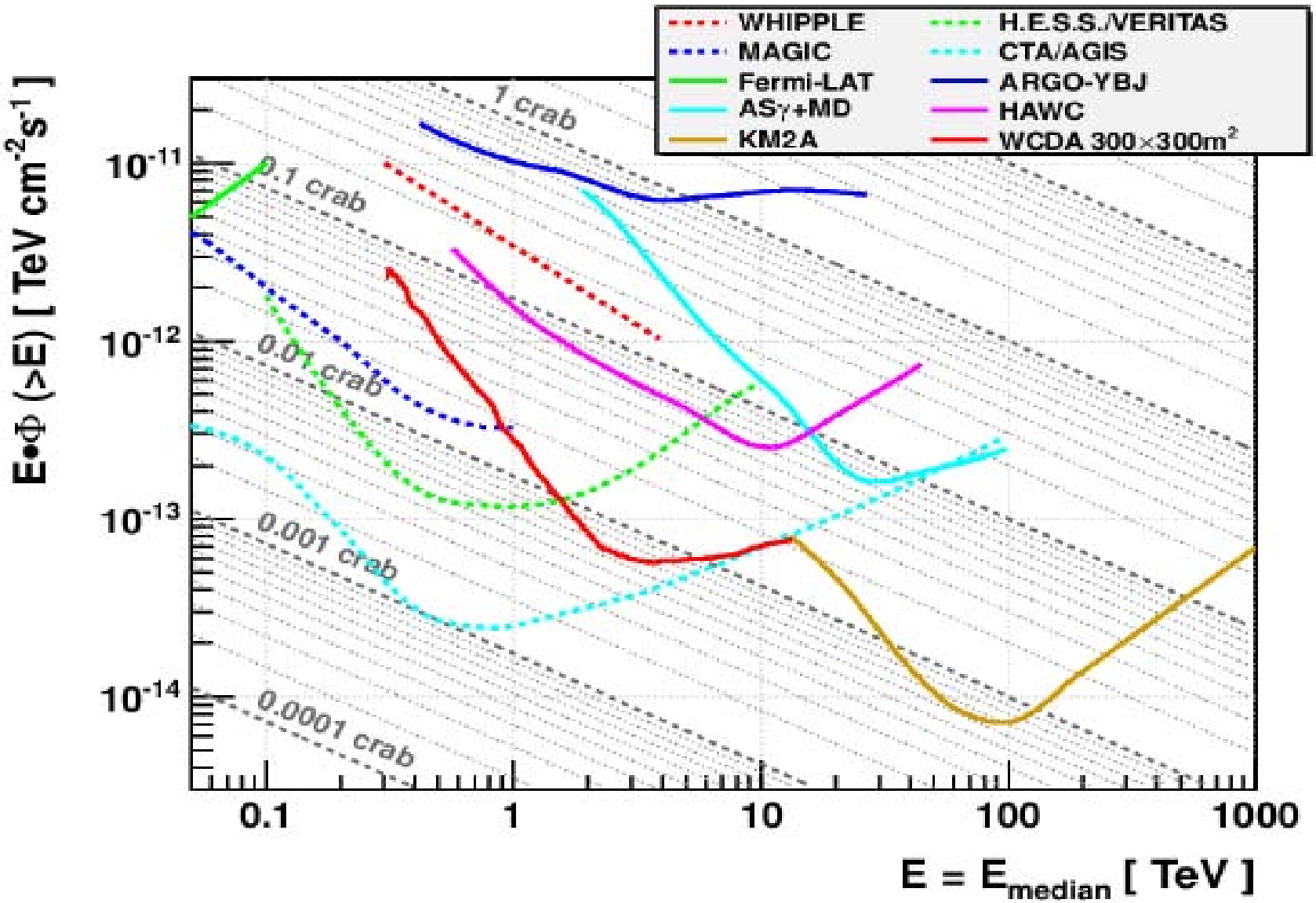




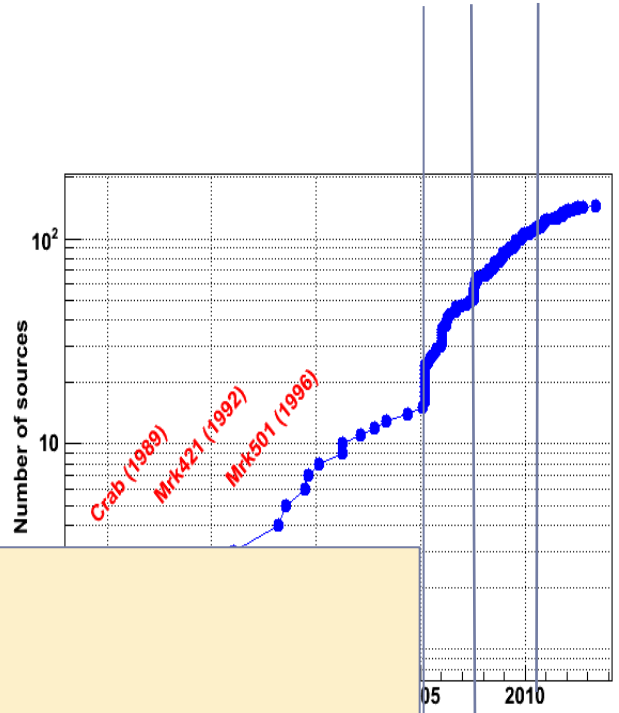
- Take notice that KM2A can reach the background free above 100 TeV, so the spectrum can be well measured…

- WCDA aims to be well calibrated, so that the spectrum can be well fitted if assuming it obeys a power law…

Integral Sensitivity



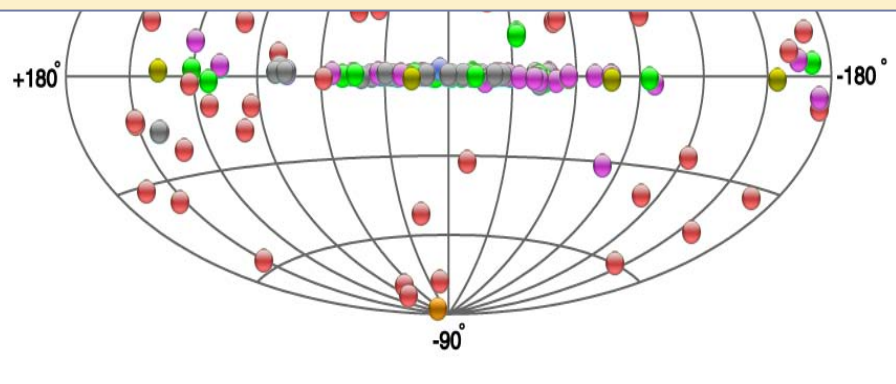
Map and number of the γ ray sources



Two directions

1. Survey for more sources

2. Deep study on interesting sources: spectroscopy & morphology



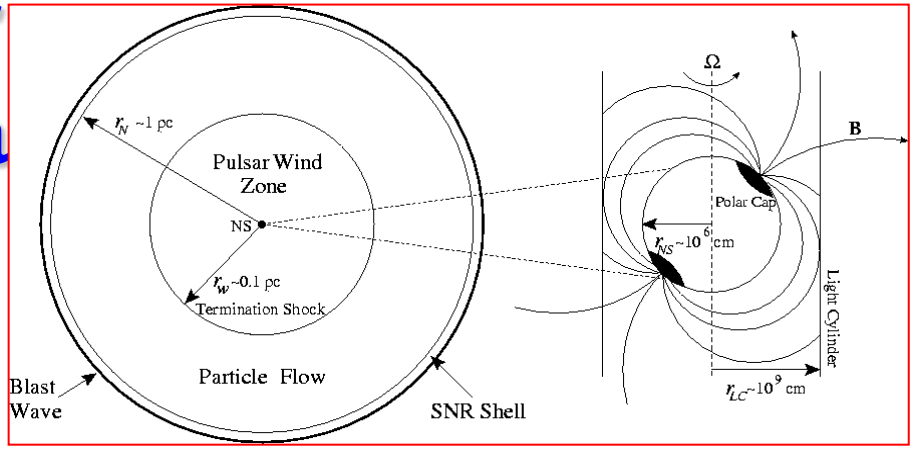
FERMI
Catalog
releasing

MAGIC
Switched

HESS
Switched o

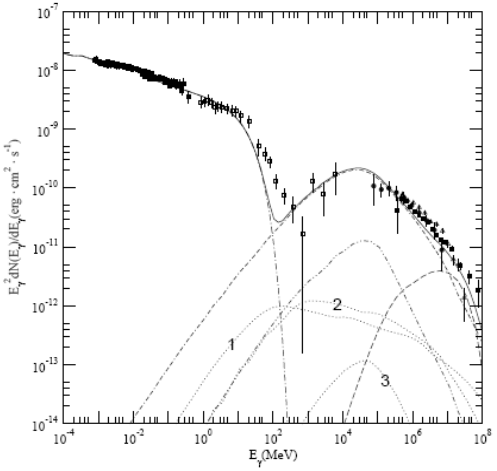
A. 34 Pulsar Wind Nebula

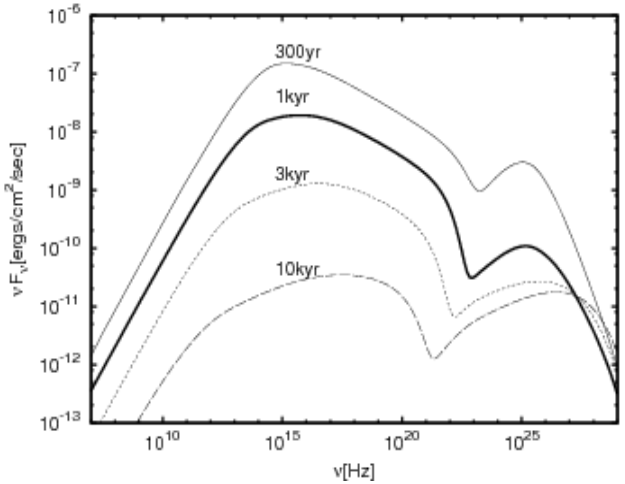
Standard Candle Crab Nebula

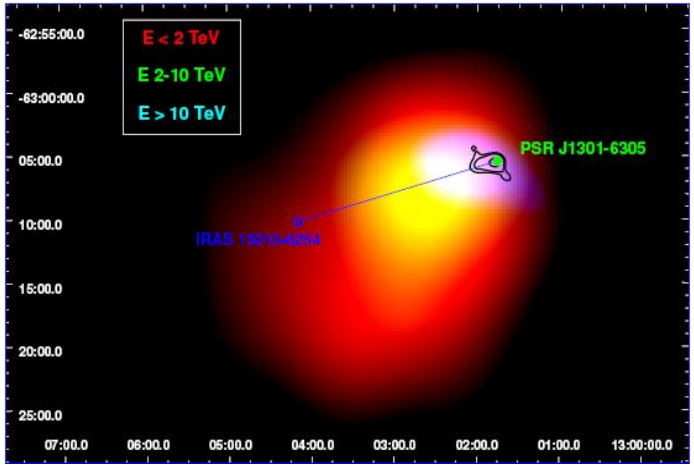


Evolution

Spatial drifting





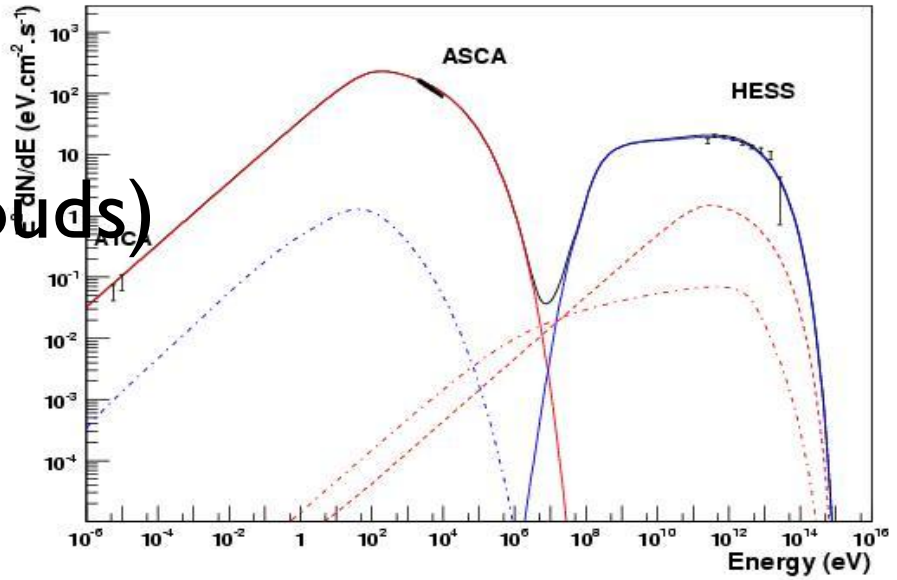


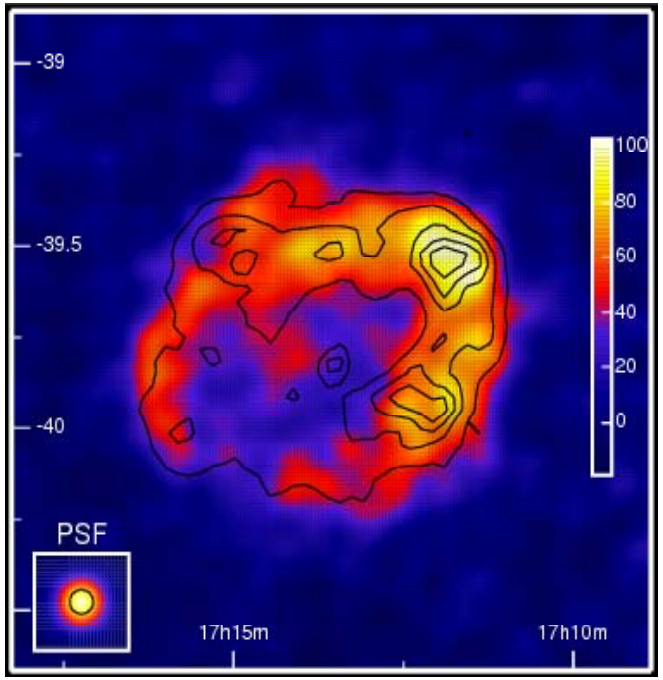
A&A 548, A46 (2012)

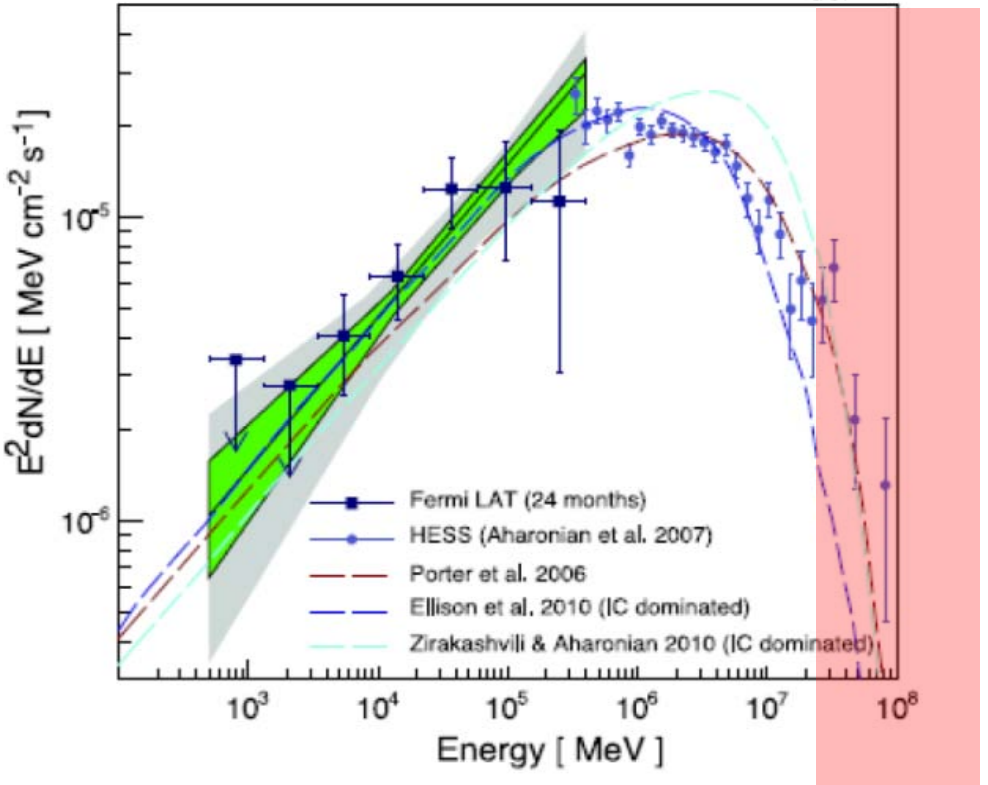
B. 23 SNRs

(Shell or Composite w/clouds)

RXJ 1713.7−3946
Morphology is important,
Spectroscopy is even more

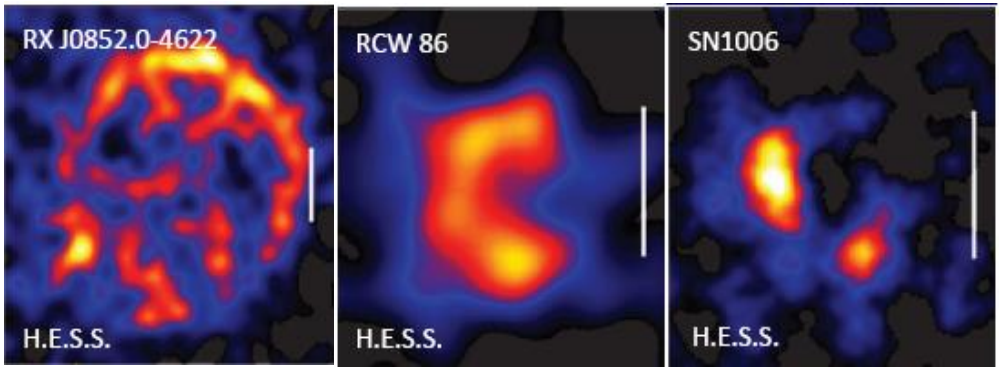


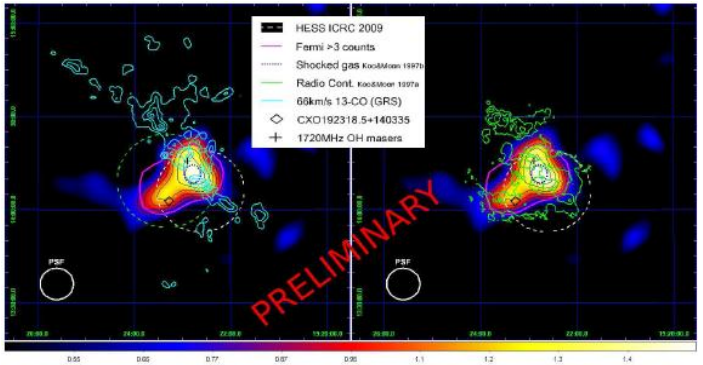




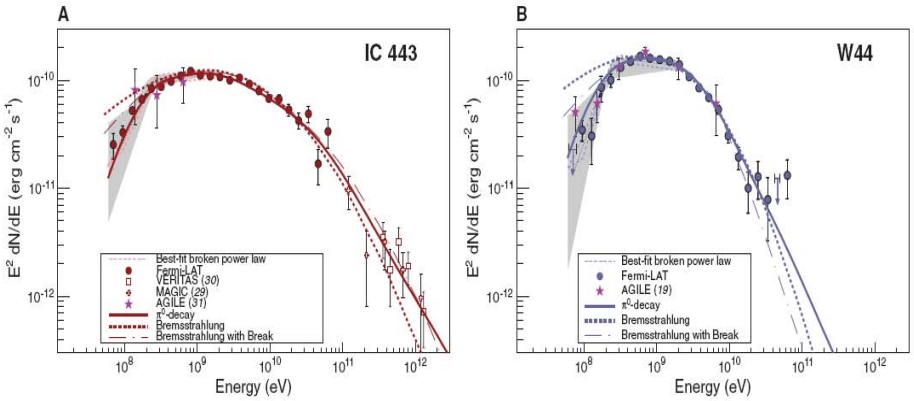
SNRs

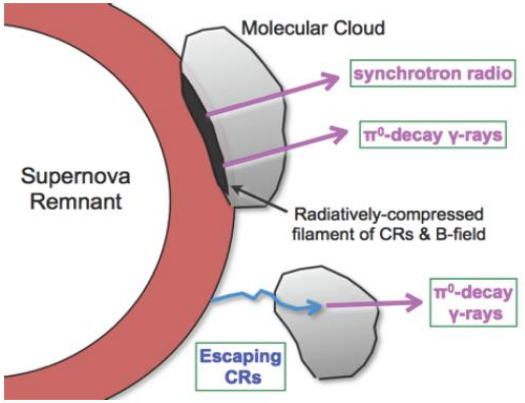
Young SNRs





Old SNRs



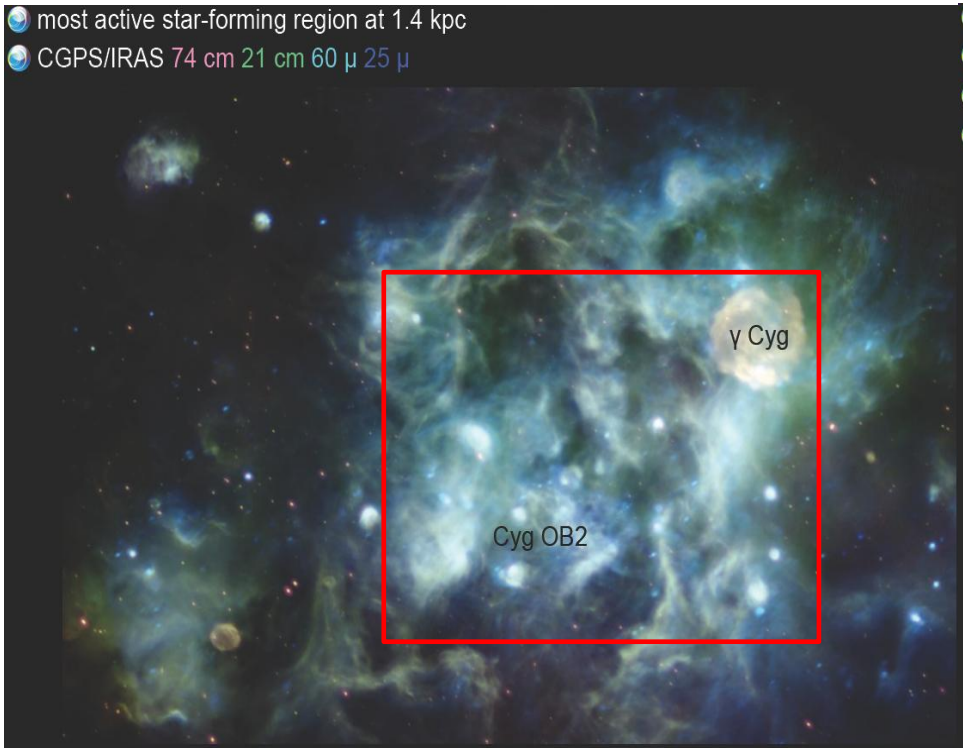


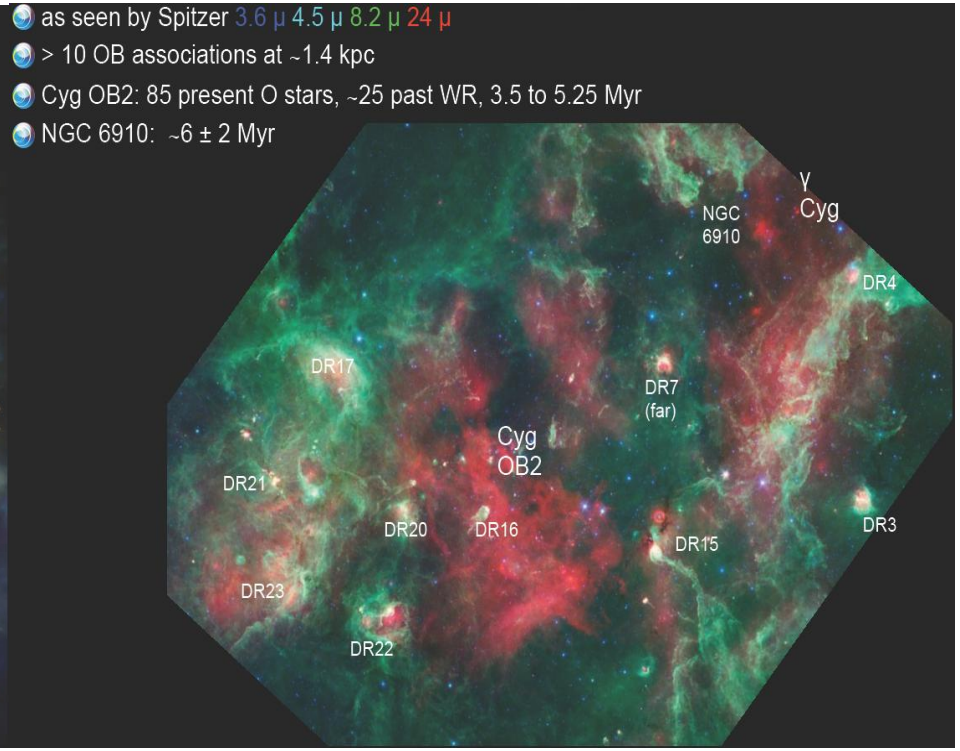
Science 339, 807 (2013)

CR sources?

C. Big objects (regions) in the sky

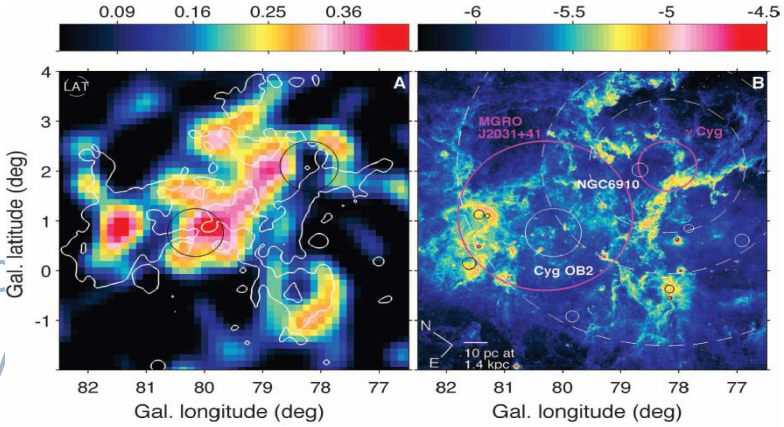
The most active region in the northern sky



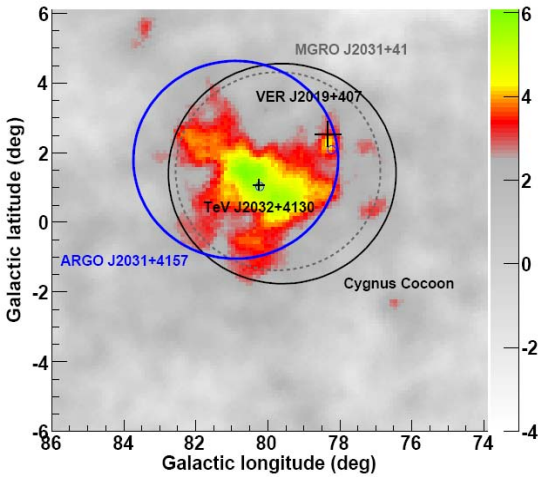


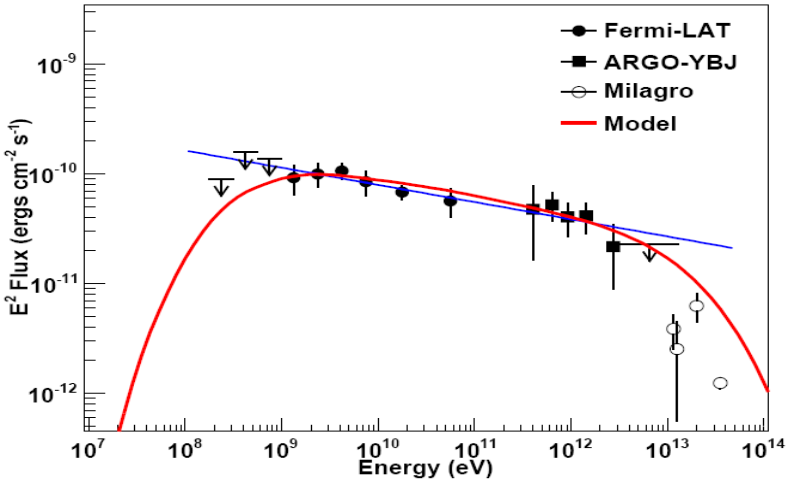
Cygnus Cocoon (FERMI Cocoon)

- FERMI Cocoon
- ARGO J3031+4157
- **The first γ ray Superbubble**
- **it is too big to IACT**
- Could be a possible hadronic source w/ total hadronic energy 1.5×10^{50} erg， E_{cut}=150TeV



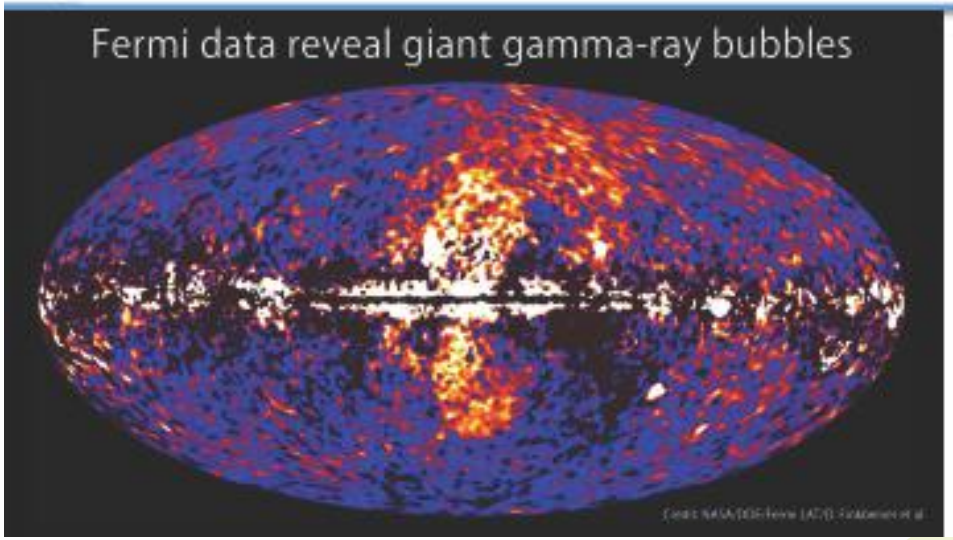
Science 334, 1103 (2011)

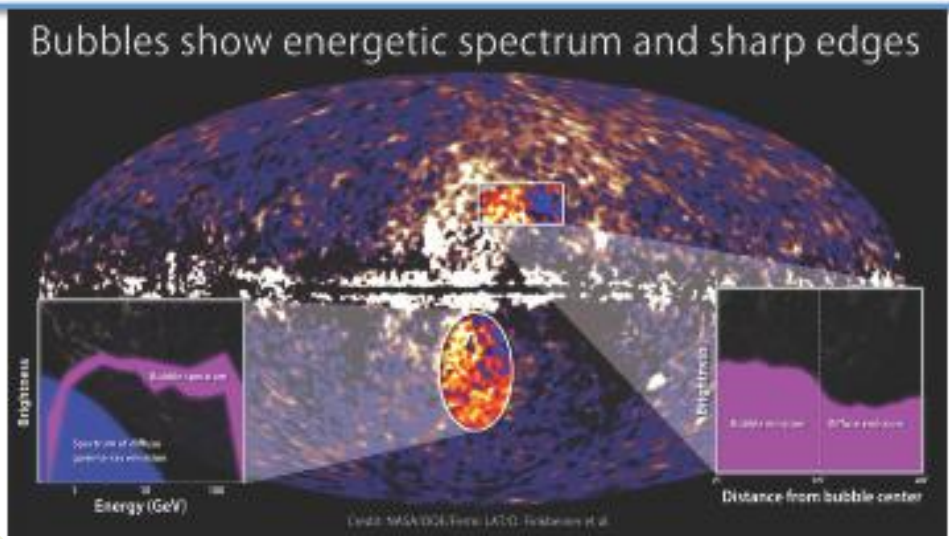


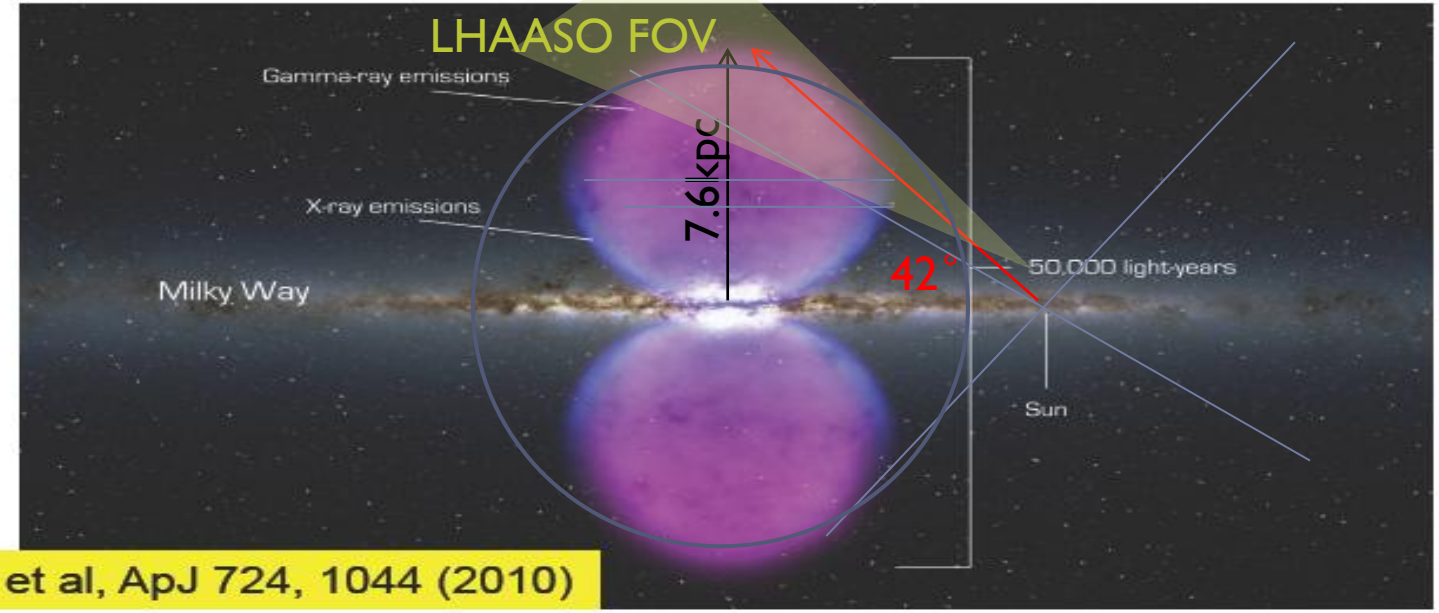


To be submitted to ApJ

Energetic *bubbles* in our galaxy

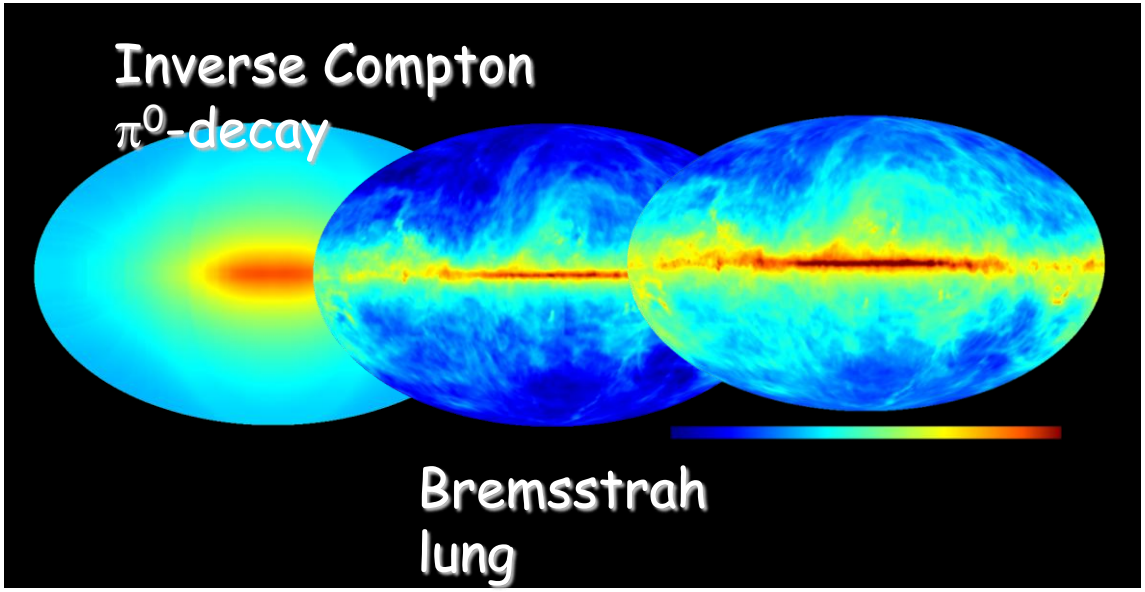






Meng Su et al, ApJ 724, 1044 (2010)

D. Galactic plane diffuse gamma-ray

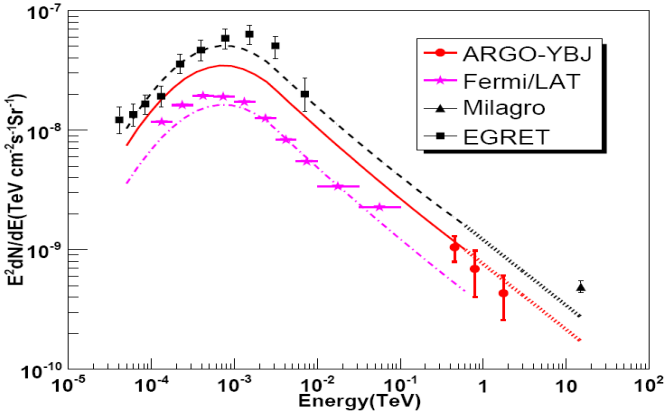


- Diffuse gamma rays produced by interactions of cosmic rays with the interstellar medium and radiation fields. They can be used to probe the cosmic ray spectrum and density throughout the whole Galaxy.

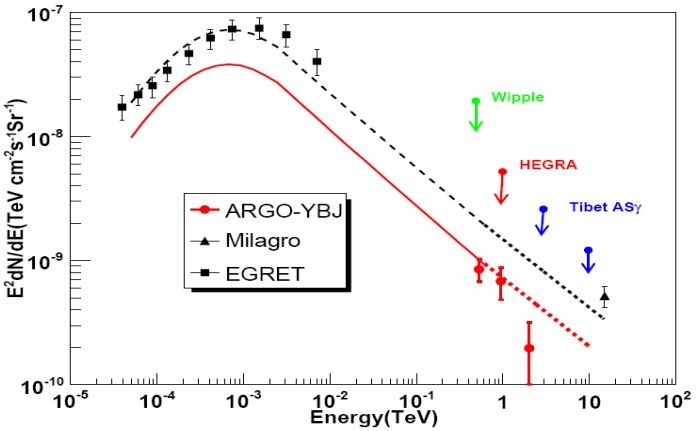
Diffuse γ rays: EGRET, FERMI, ARGO-YBJ and MILAGRO

Cygnus region

$65° < l < 85°, |b| < 5°$



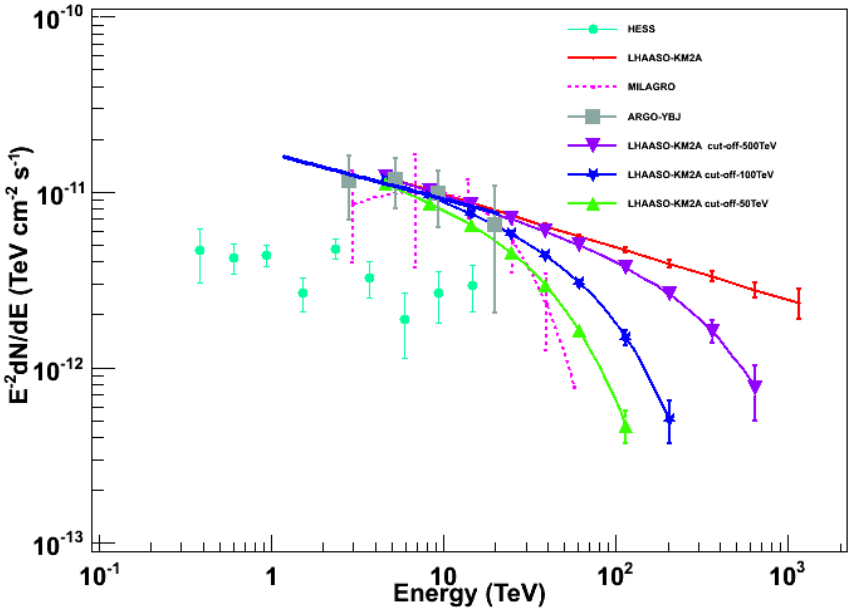
$25° < l < 65°$ and $85° < l < 100°, |b| < 5°$

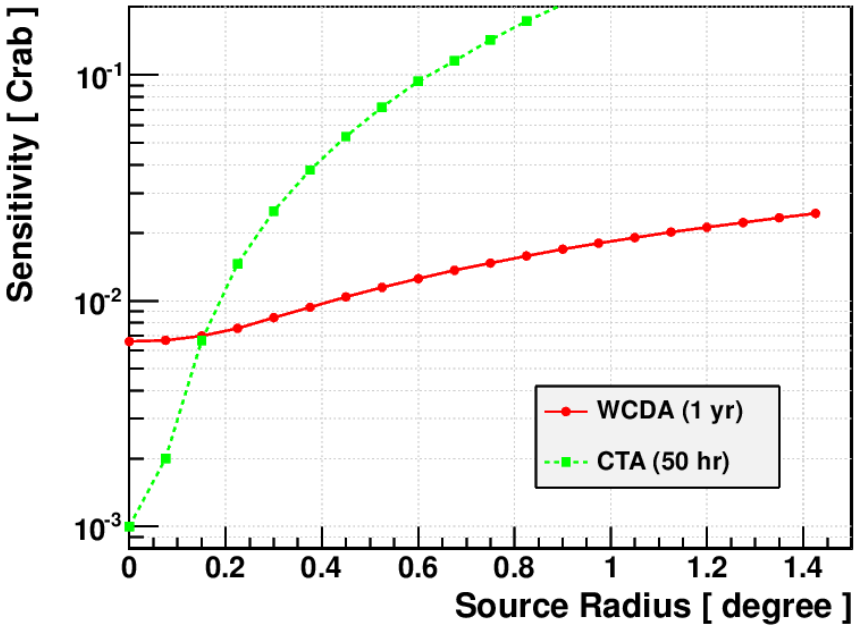


From 30MeV to 20TeV, traces CR propagation well.

To be submitted to ApJ

Sensitivity to Extended Sources

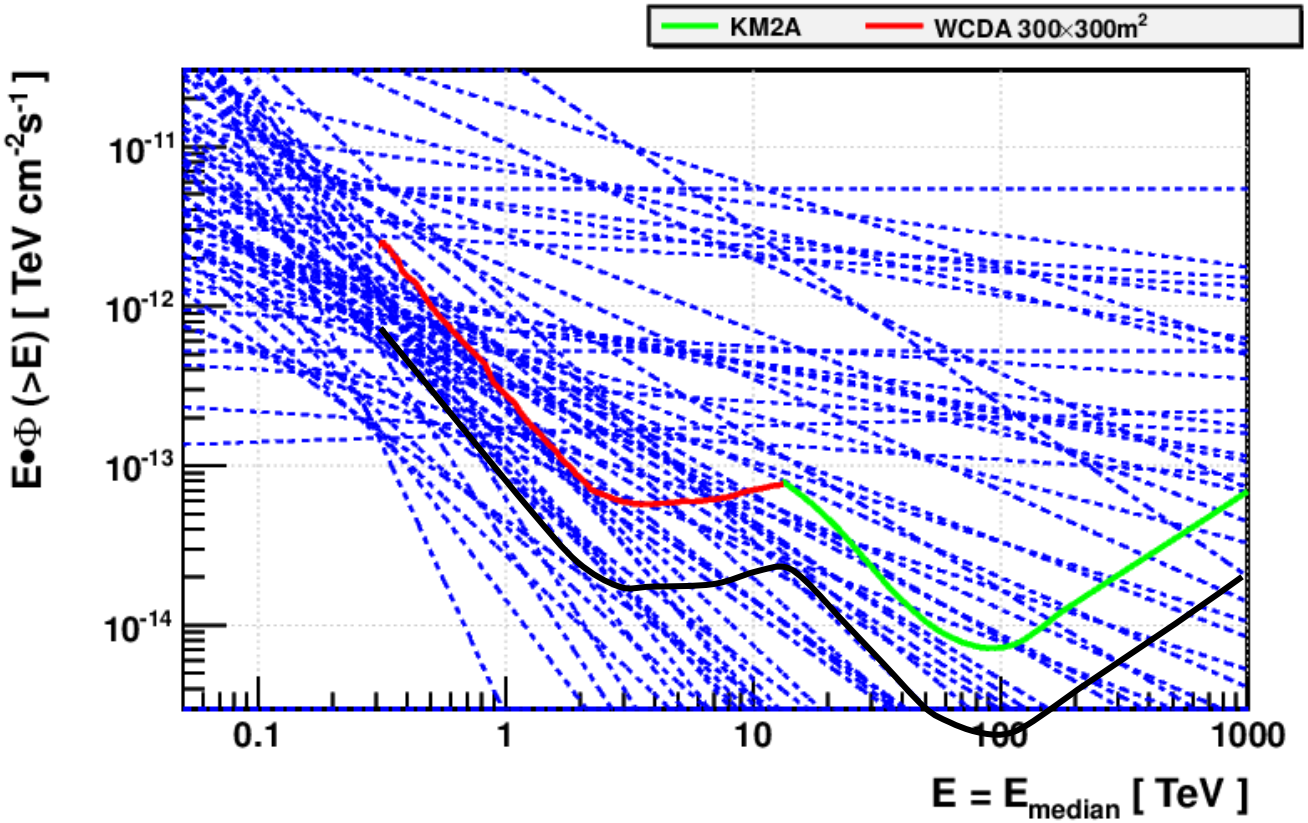




- MGRO J1908+06 spectrum – can be measured well by KM2A, under assumption of different cutoff values. (Xinhua Ma et al., APP, 2014)

- Sensitivity of WCDA to extended sources as a function of size. The angular bin is optimized for the WCDA only.

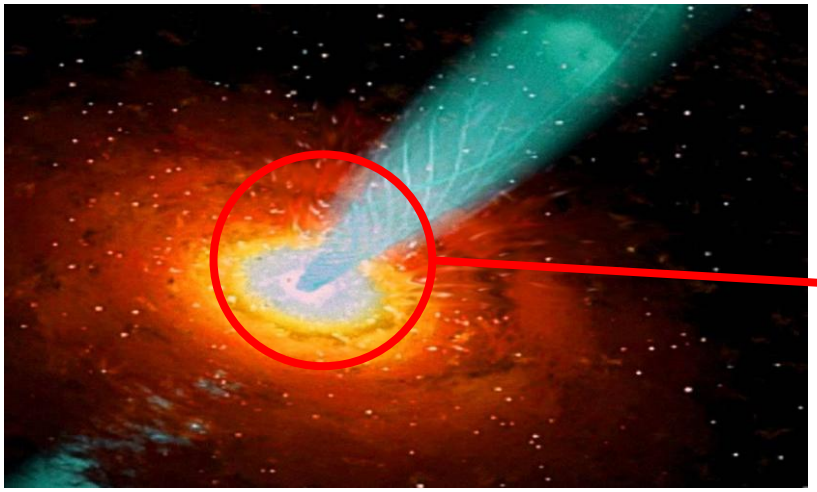
TeVCat Sources

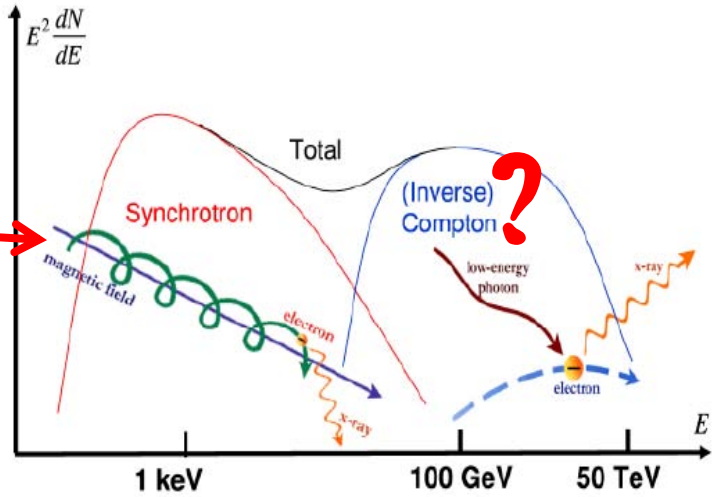


- 67 of 148 known TeVCat sources are in the LHAASO FOV;
- For a very simple estimation, the EBL absorption and the spectrum cut-off is ignored;
- 80% of these sources can be detected by LHAASO in 1-2 year's operation.

E. AGNs

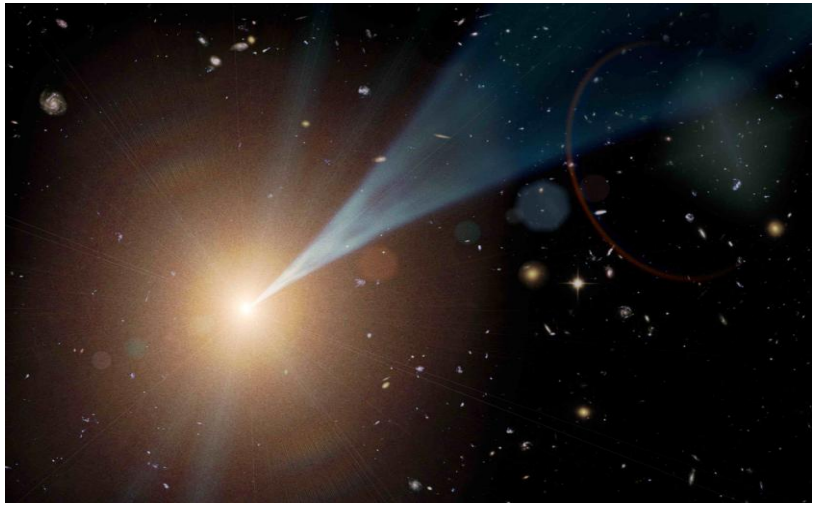
Leptonic SSC, EC? Hadronic?



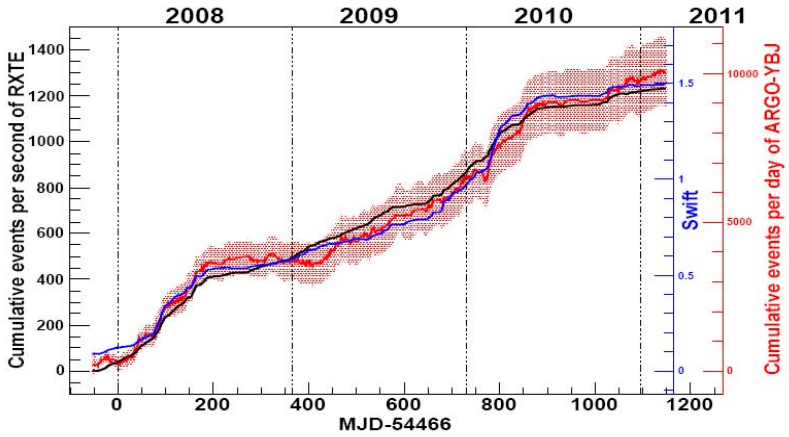


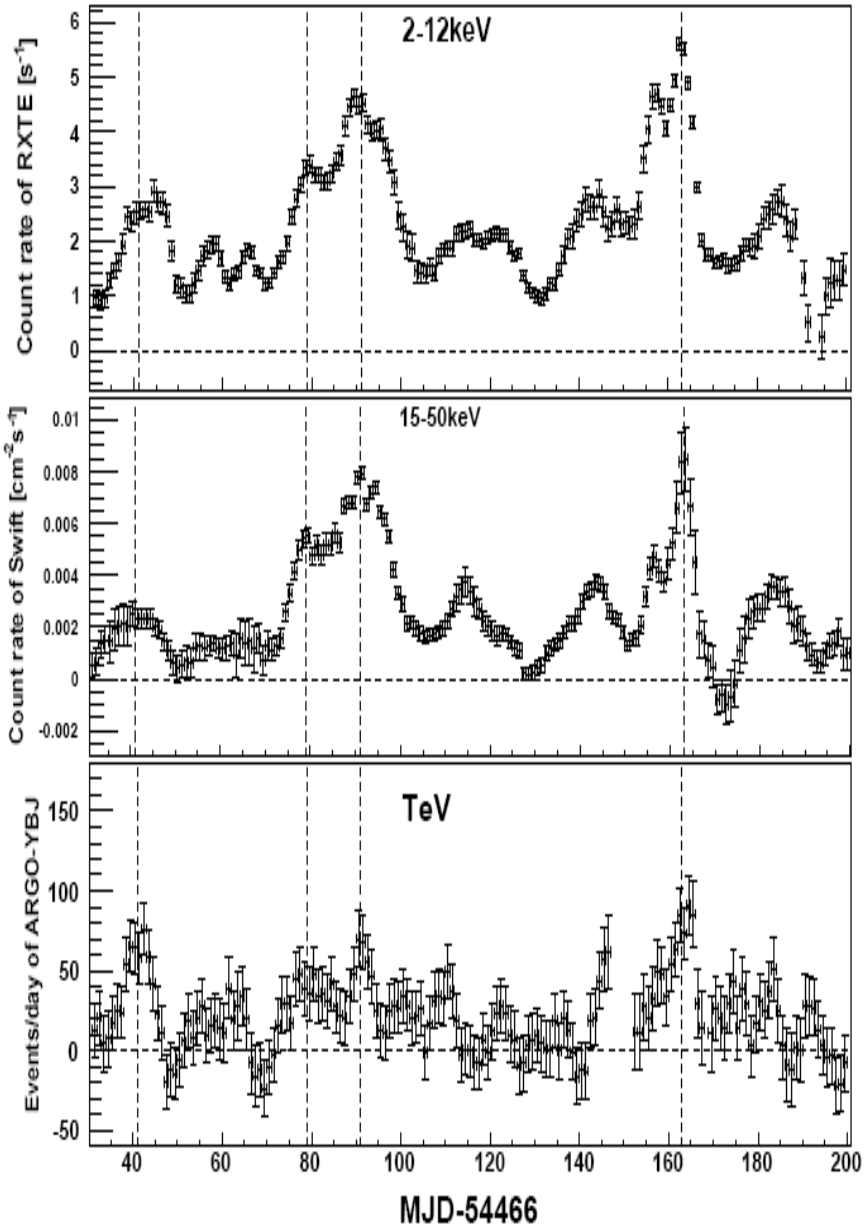
Different models will predict different correlations between low and high energy components. Thus, **long-term continuously multi-wavelength observations, especially at X-ray and TeV band,** are crucial to understand the emission mechanisms and underline processes of the outbursts.

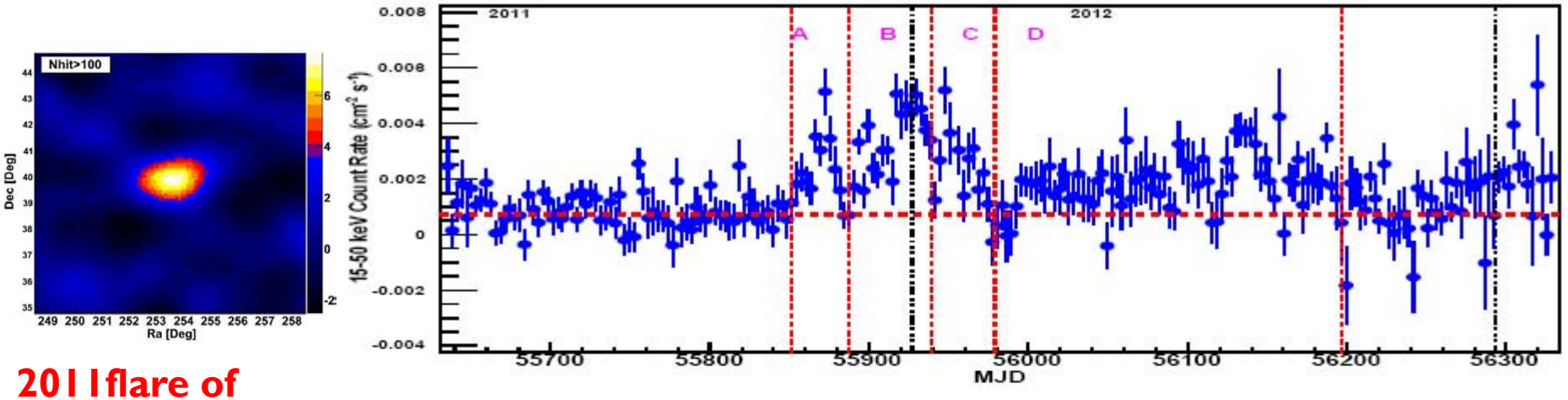
Survey of transient AGNs



Transient AGNs: Mrk421







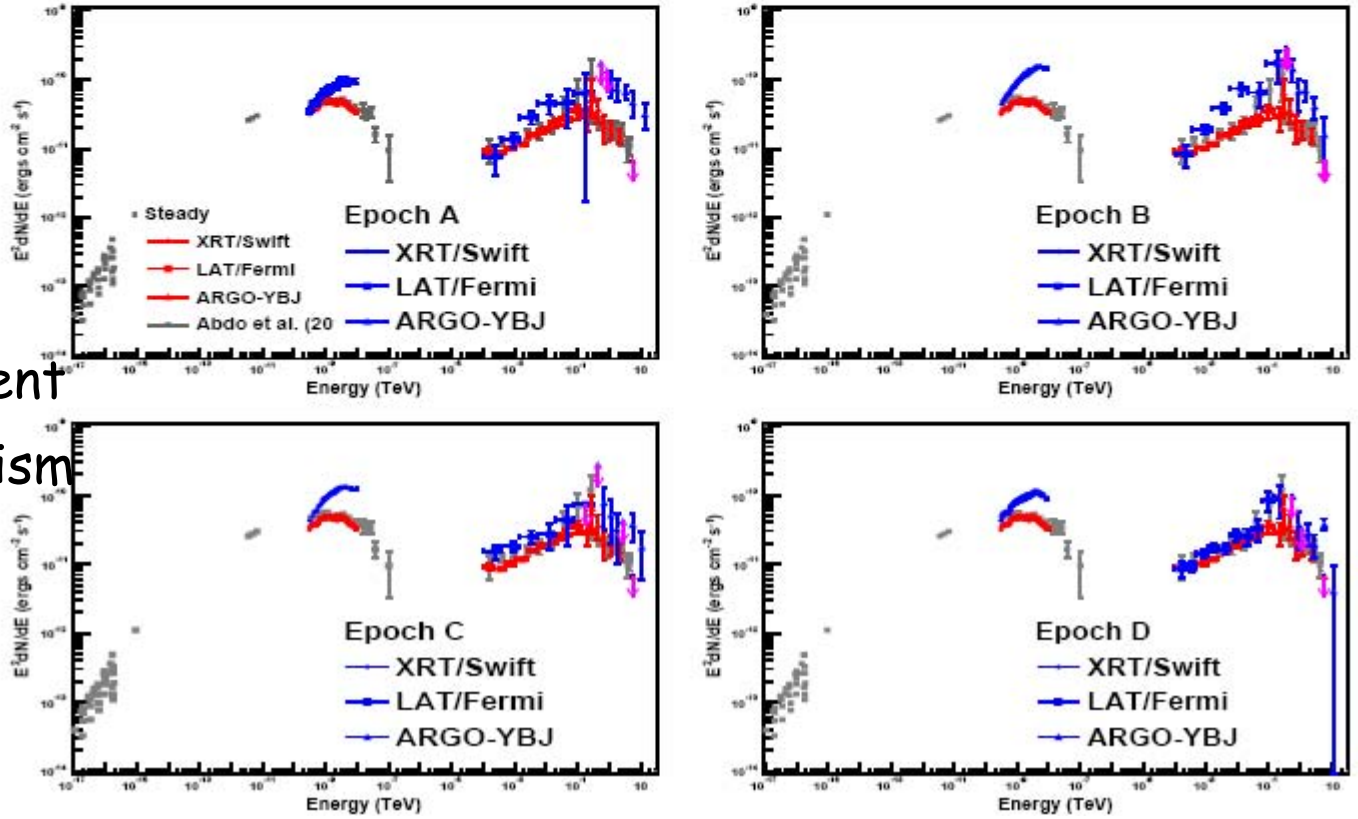
2011flare of Mrk501 S=7.7σ

Fig. 3: Three day-averaged light curve of Mrk 501 at 15–50 keV measured by BAT/*Swift*. The vertical dashed lines indicate the four epochs analyzed in this paper. All the errors are statistical at 1 σ.

The evolution of the Spectrum during flares

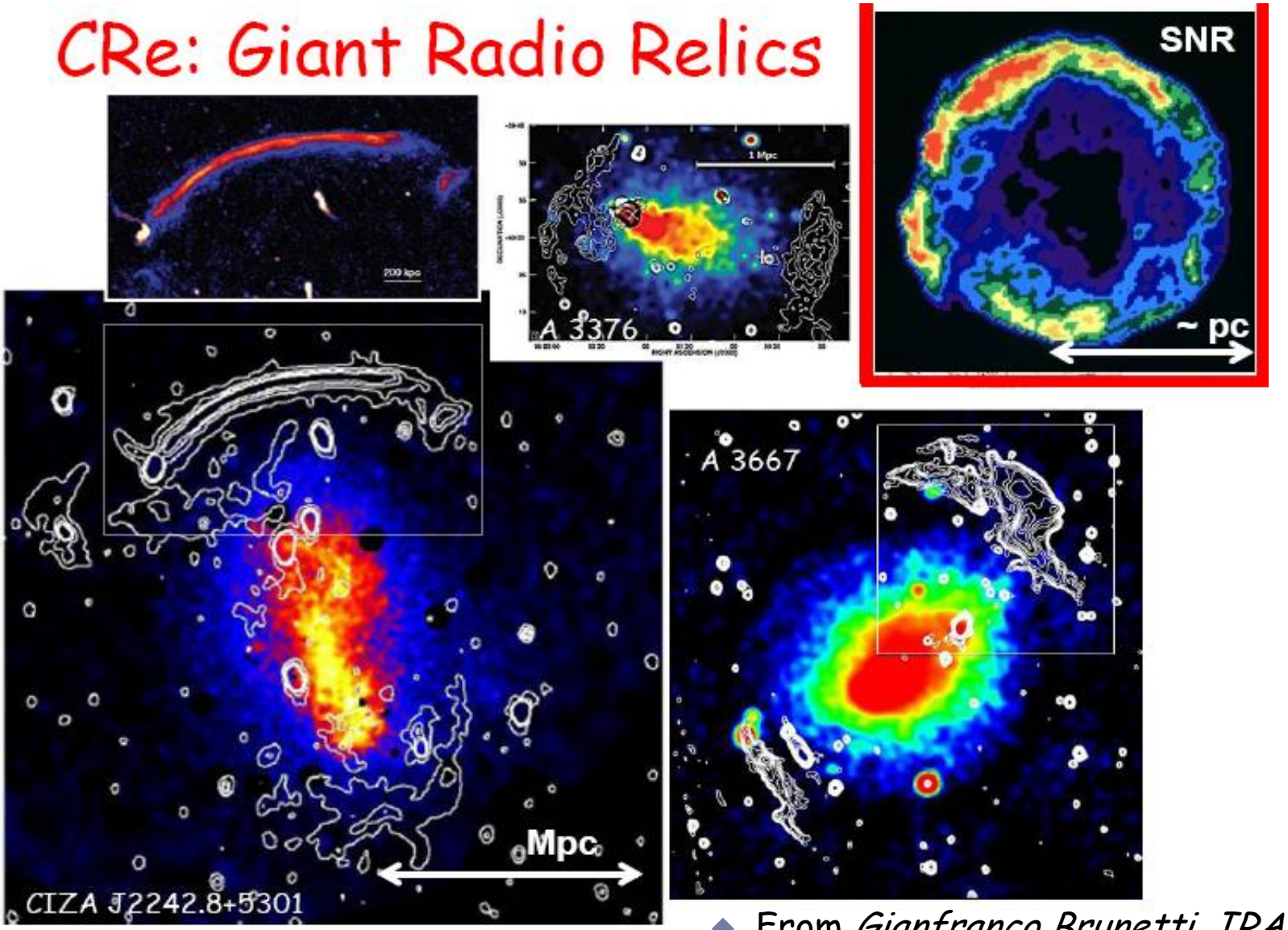
IGMF measurement

Emitting Mechanism



Extra-galactic CR accelerators

CRe: Giant Radio Relics



- From *Gianfranco Brunetti, IRA , INAF*

From radio to high energies

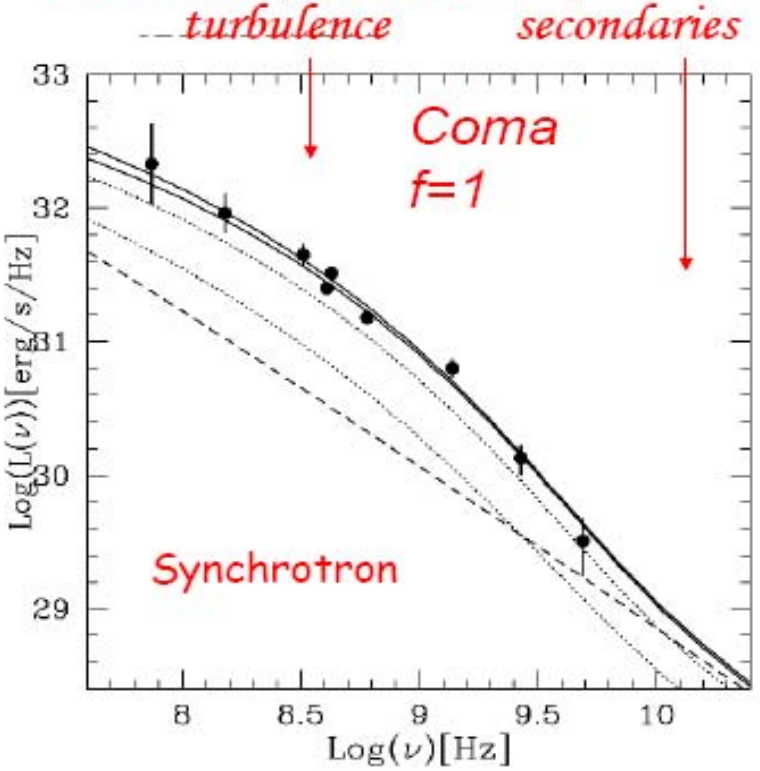
(Brunetti & Lazarian 11)

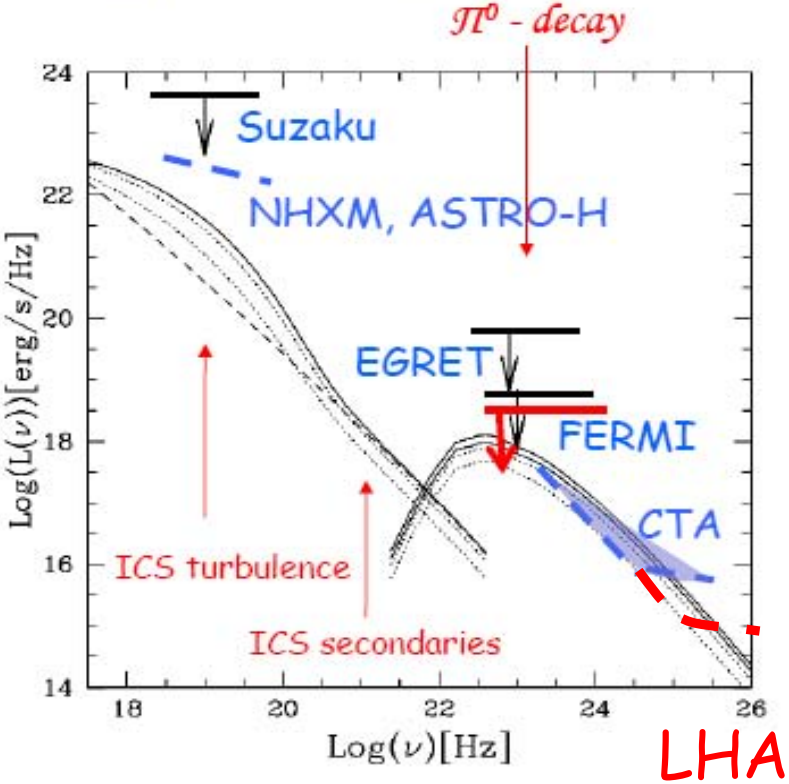
Calculations that consider the general case where both primaries (CRp,CRe) and secondaries (CRe) interact with Turbulence (reaccelerated)

$$f = \frac{PRIMARY\, e^{\pm}}{SECONDARY\, e^{\pm}} + 1$$

$E_{tur} \approx 10\ \%\ E_{th}$ @k^{-1}~100 kpc

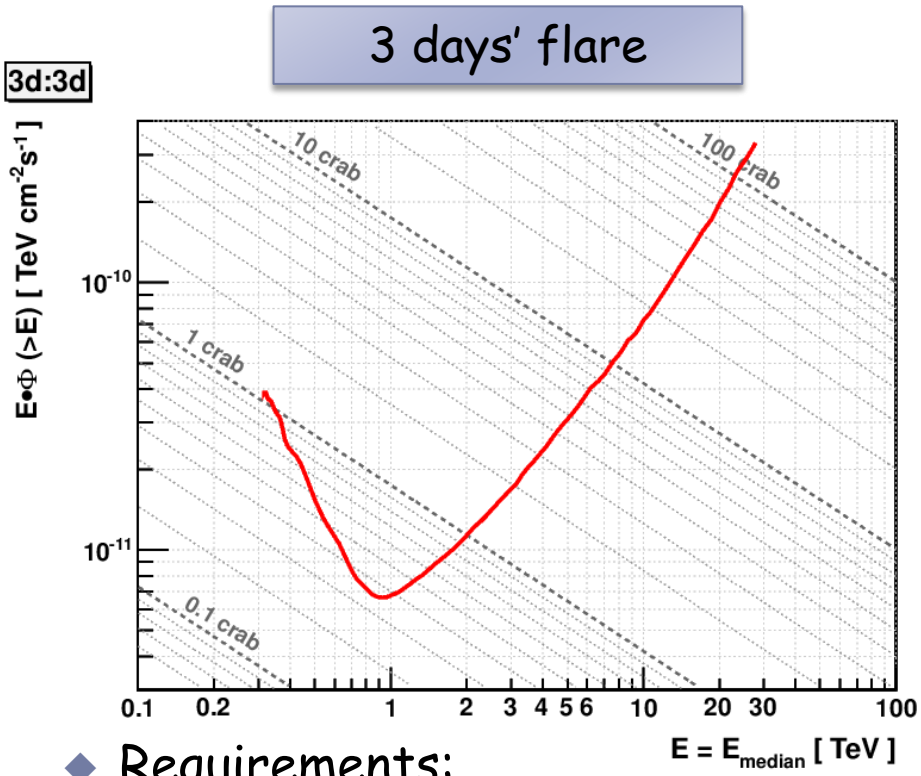
$E_{CRp} = \sim\ \%\ E_{th}$





LHAASO

Sensitivity to Flares / GRBs - WCDA

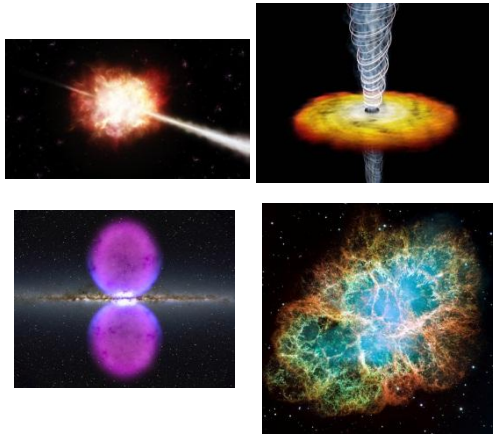


- Requirements:
  - 30 events;
  - 5 s.d.;
  - Calculation based on a power law spectrum (λ=-2.62).
- Partly limited by statistics.

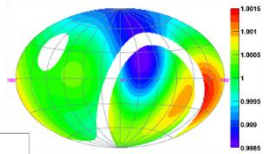
Duration	Sensitivity (Crab)
1 year	0.0066
6 months	0.0094
3 months	0.013
1 month	0.039
10 days	0.10
3 days	0.36
1 day	1.0
2 hours	3.5
1 hour	5.4
30 minutes	13
10 minutes	67
3 minutes	410
1 minute	2100

Physics on Gamma Astronomy

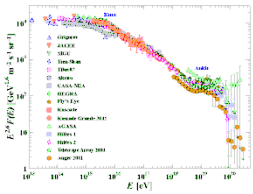
- VHE gamma sky survey (100 GeV-1 PeV):
  - Galactic sources;
  - Extragalactic sources & flares;
  - VHE emission from Gamma Ray Bursts;
  - Diffused Gamma rays.

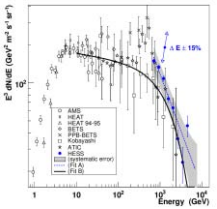


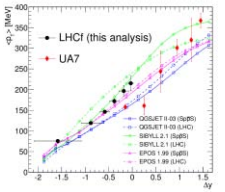
- Spectrum measurement at the high end:
  - Nature of the acceleration: leptonic or hadronic;
  - Origin of cosmic rays – 100 years' mystery.



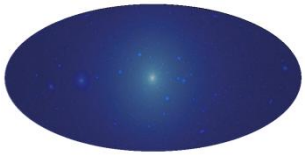
- Cosmic rays
  - Anisotropy of VHE cosmic rays;
  - Cosmic electrons / positrons;

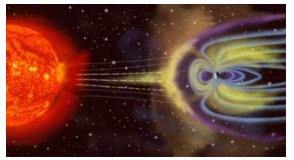






- Miscellaneous:
  - Gamma rays from dark matter;
  - Sun storm & IMF.





Summary

- LHAASO is going to be built soon (in a year) at Haizishan, Sichuan Province;
- Two detector arrays (KM2A & WCDA) of the LHAASO project will mainly focus on Gamma astronomy;
- The sensitivity of the two arrays can reach to 1% Crab flux at ~1 TeV and ~100 TeV, respectively;
- LHAASO will play an important role in surveying, detecting, observing and measuring various VHE Gamma ray sources.