# A Multi-purpose Cosmic Ray Experiment

# LHAASO Project

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*On behalf of LHAASO collaboration*

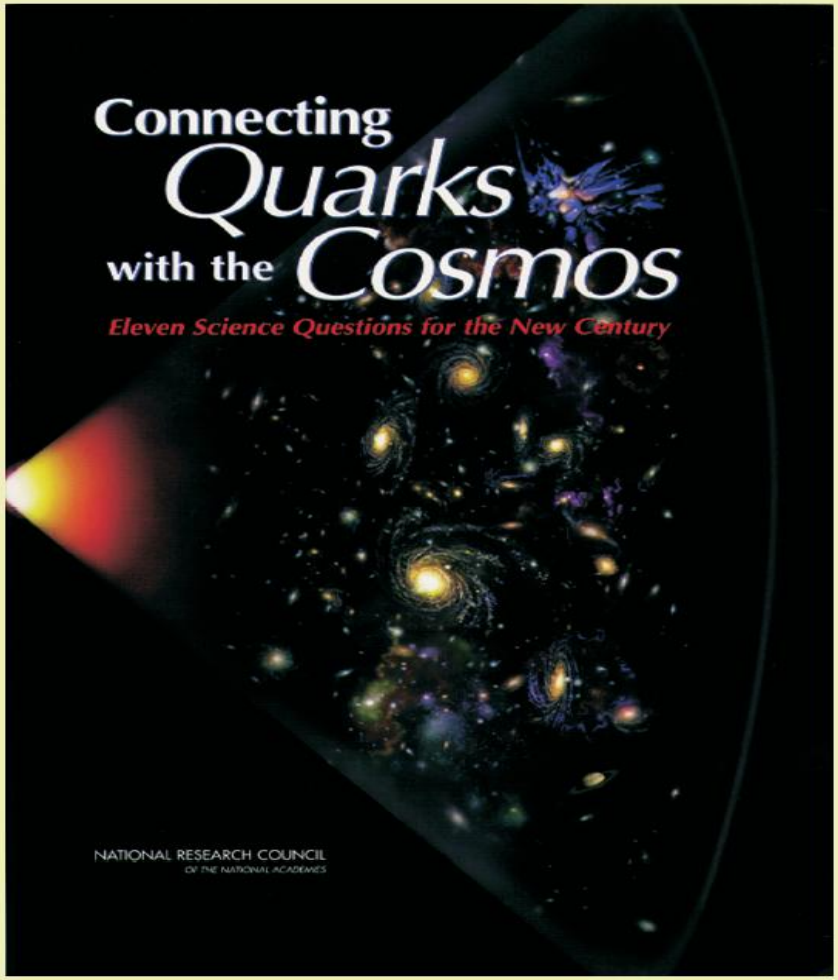
SciNeGHE 2012, Lecce, Italy, June 20-22

**Outline**

- Introduction
- What's LHAASO
- Prospects of LHAASO
- Status of LHAASO
- summary

# Scientific Cases

The Eleven Questions Identified by the C




How do Cosmic Accelerators Work and What are They Accelerating?

Status and Perspective of Astroparticle Physics in Europe

What is the origin of cosmic rays ?

**Mysteries of Astronomy**

***Science ,1 June 2012***

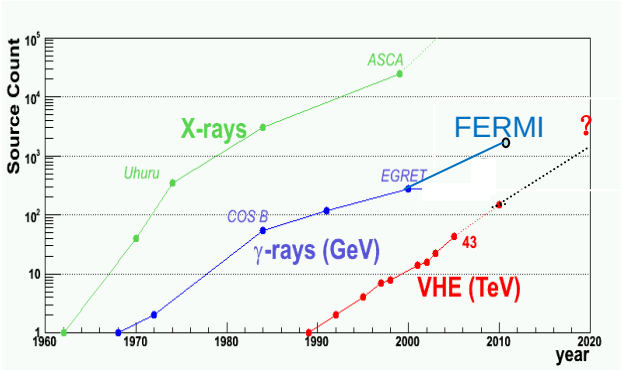
……..1/8

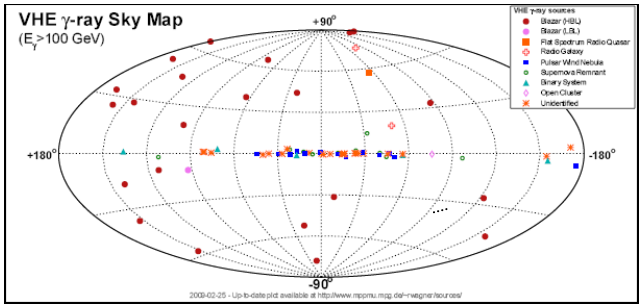
**What's the Source of the Most Energetic Cosmic Rays?**

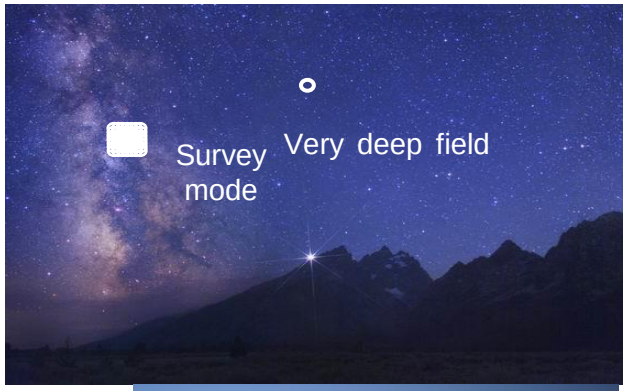
……

# Big Victory !

- >100 VHE γ sources are iscovered in 20 yrs
  - 16 papers in Nature or Science
    - 14 of them are associated with discovery
  - HESS, MAGIC and VERITAS are major players



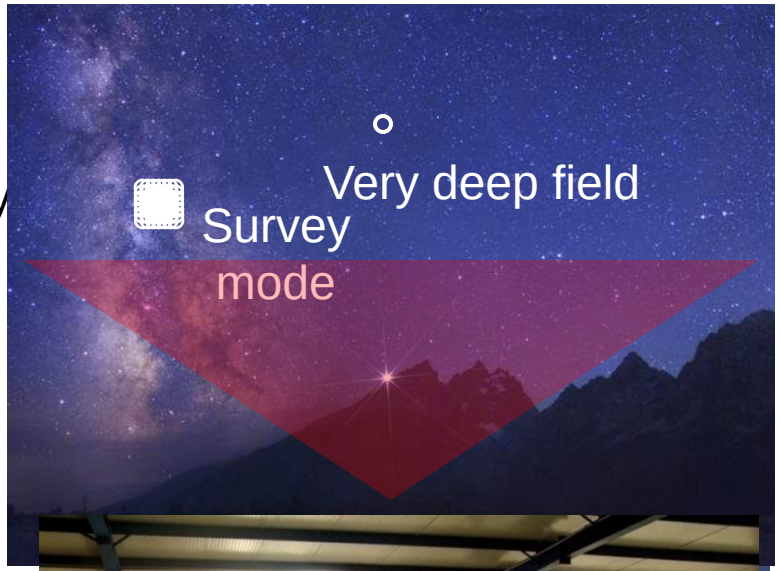



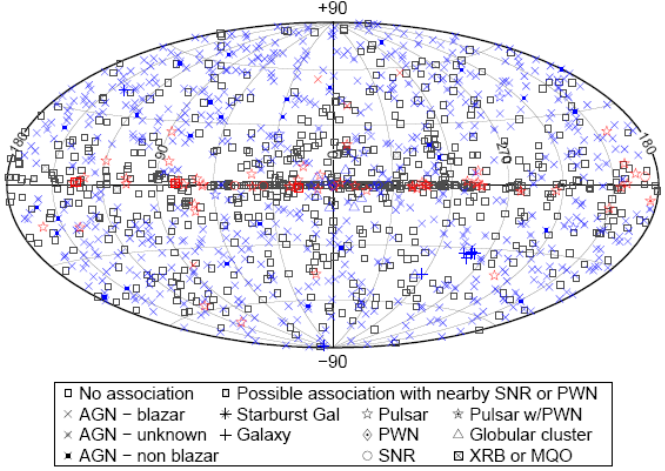


# Big Victory !

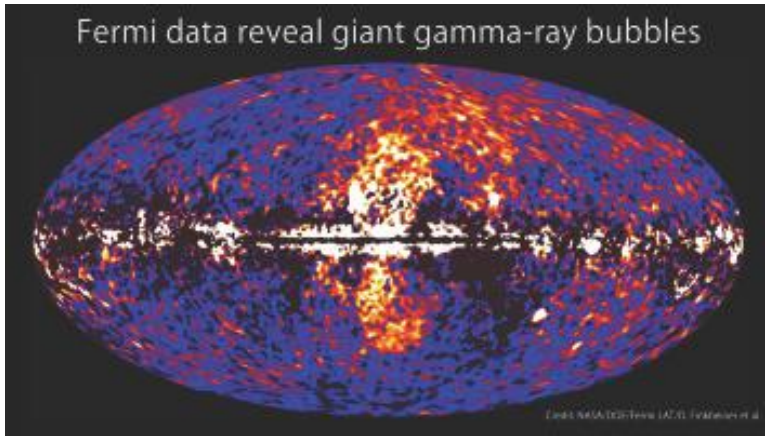
- >100 VHE γ sources are is covered in 20 yrs
  - 16 papers in Nature or Science
    - 14 of them are associated with discovery
  - HESS, MAGIC and VERITAS are major players
- All sky survey is other way to play

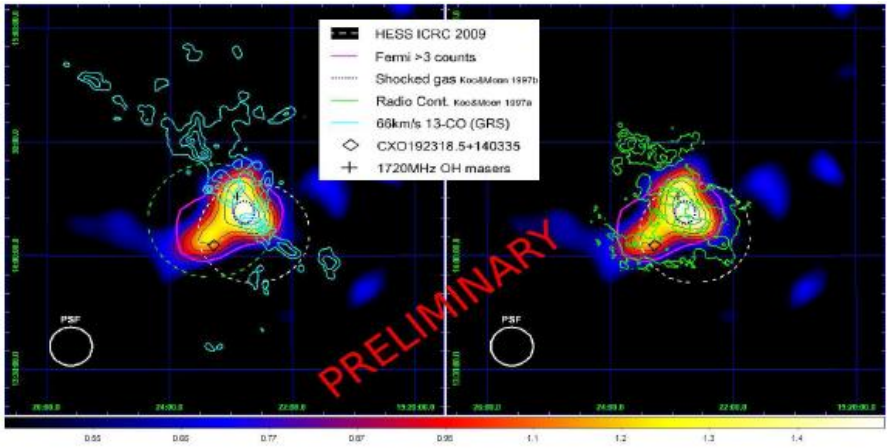



# All sky survey



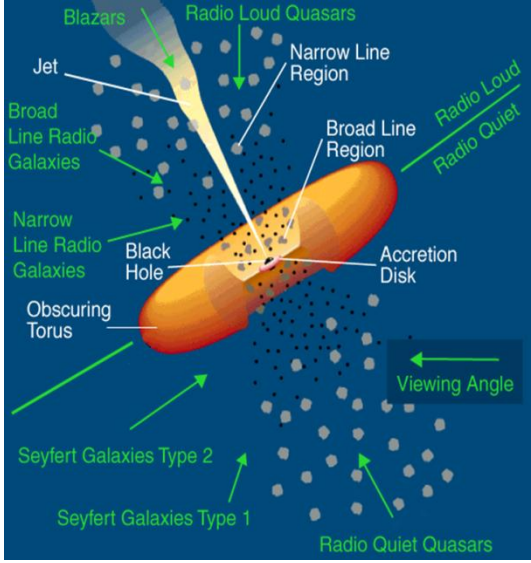

- For wide FOV detector, like LHAASO, all sources brighter than 2%Crab will be seen in a single year
- Great advantage for very extended sources



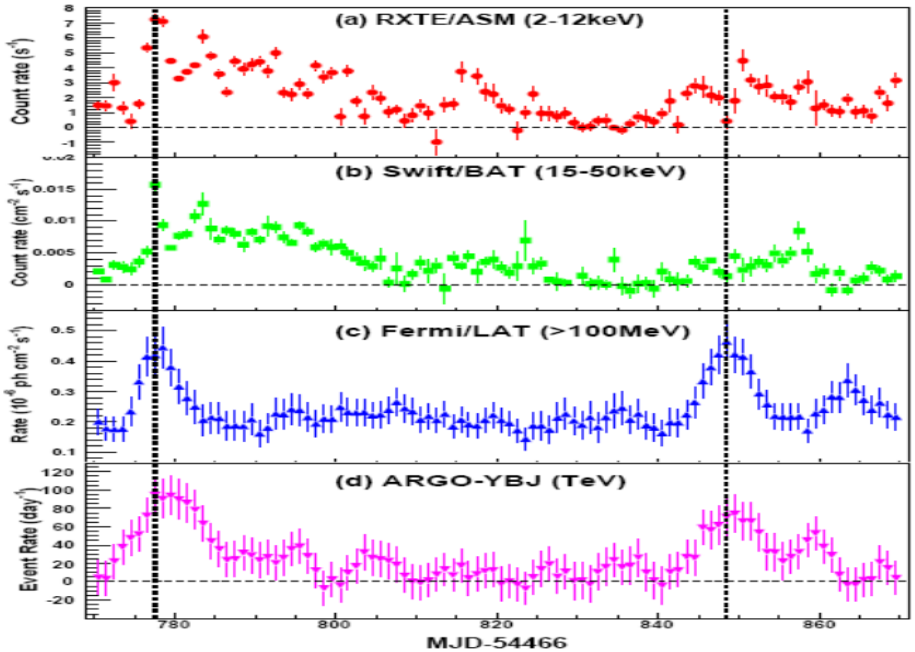



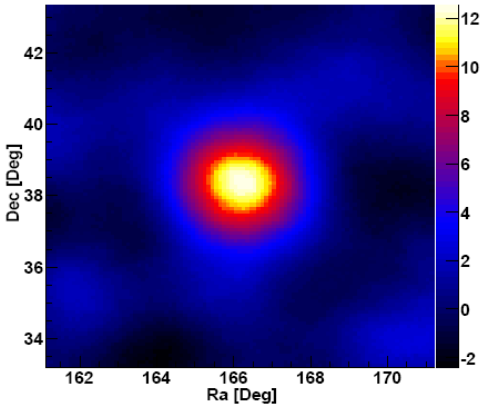

- For variables, most story of variability will be recoded

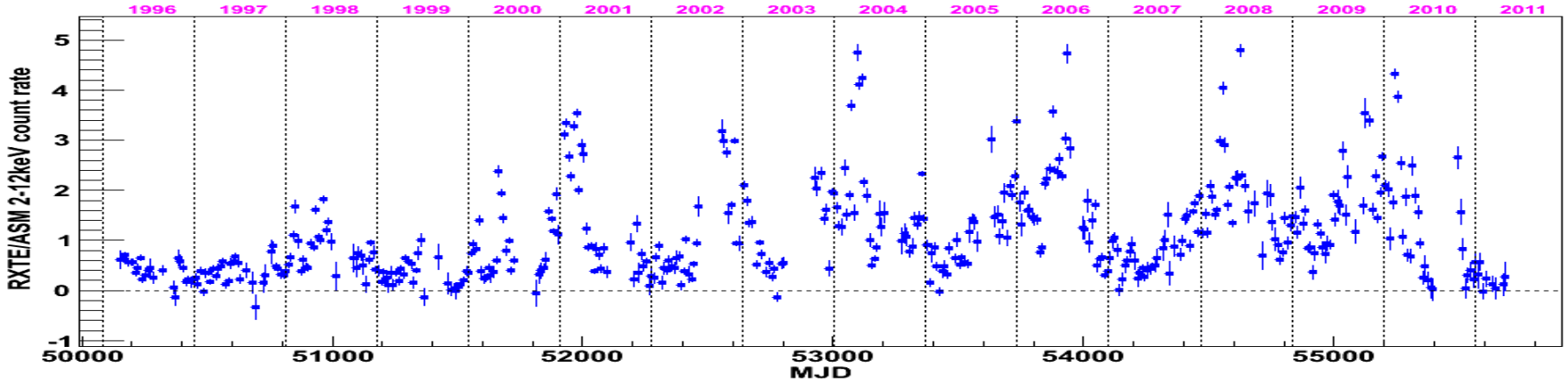
# Extragalactic Variables




Mulit-wavelength analysis



# Three major scientific goals of LHAASO

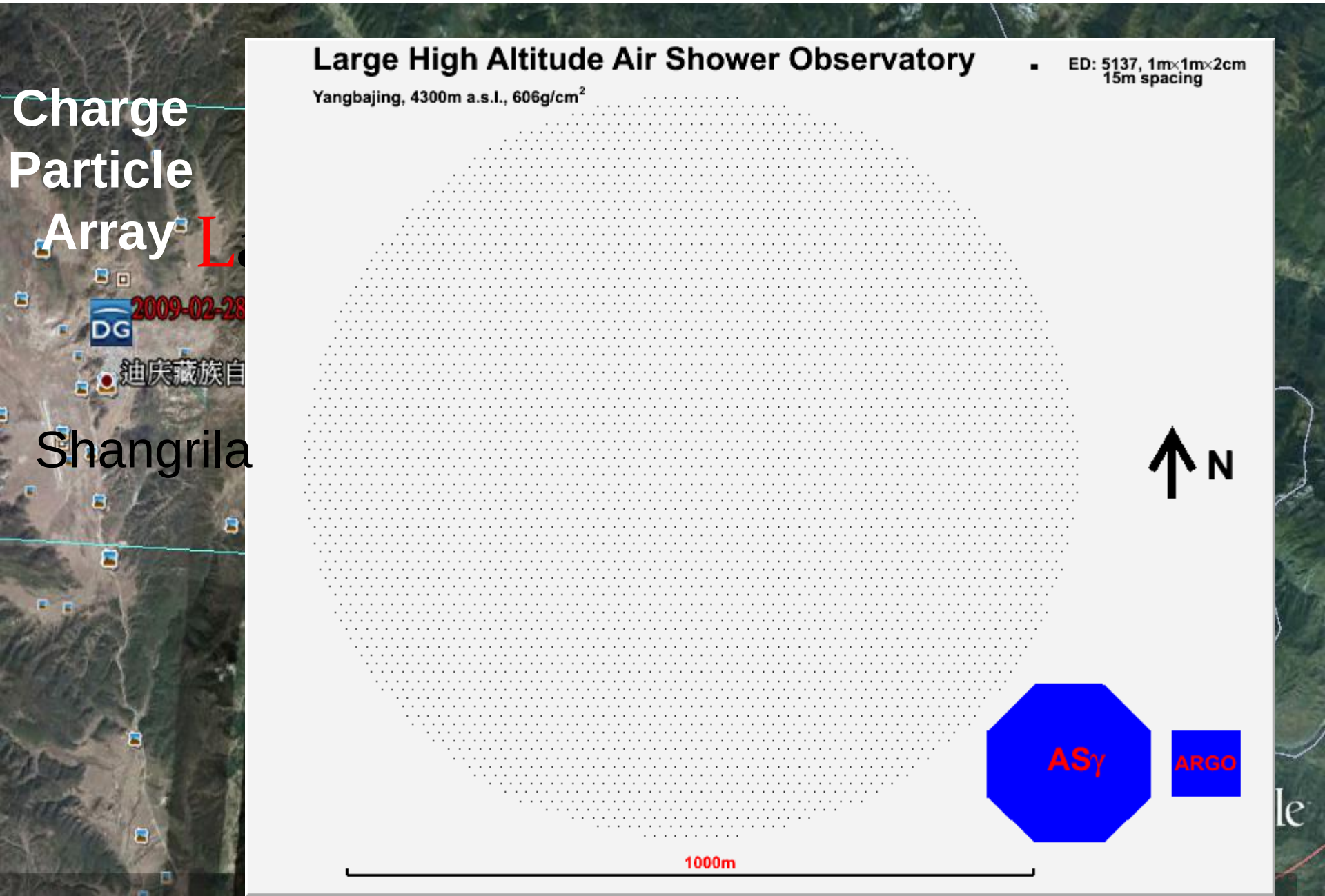
- TeV γ ray observation has an opportunity of finding CR origin: 108+ sources discovered
  - All-sky survey for γ source population is necessary (full duty cycle, wide FOV and sufficient sensitivity )
  - 50+ galactic sources: γ at high energy (>30TeV) is crucial (high sensitivity and high energy resolution)
- Exploring for new physics frontier
- PeV CR spectra of individual composition

# The Current Design of the Complex Detector Array

Three major components

- 90k $m^2$ water Cerenkov detector for $\gamma$>100GeV
- 1$km^2$ complex array for $\gamma$ >30TeV
  - Array of 5000 scintillation detectors
  - Array of 1200 μ detectors buried water C detectors
- Cosmic Ray Detector Array for CRs >30TeV
  - Array of 24 WFV C-telescopes
  - Extension using TUNKA-technique by Russian Collaborators
  - Array of 400 burst detectors or PRISMA (neutron detector array)

# LHAASO Project: γ astronomy and origin of CR

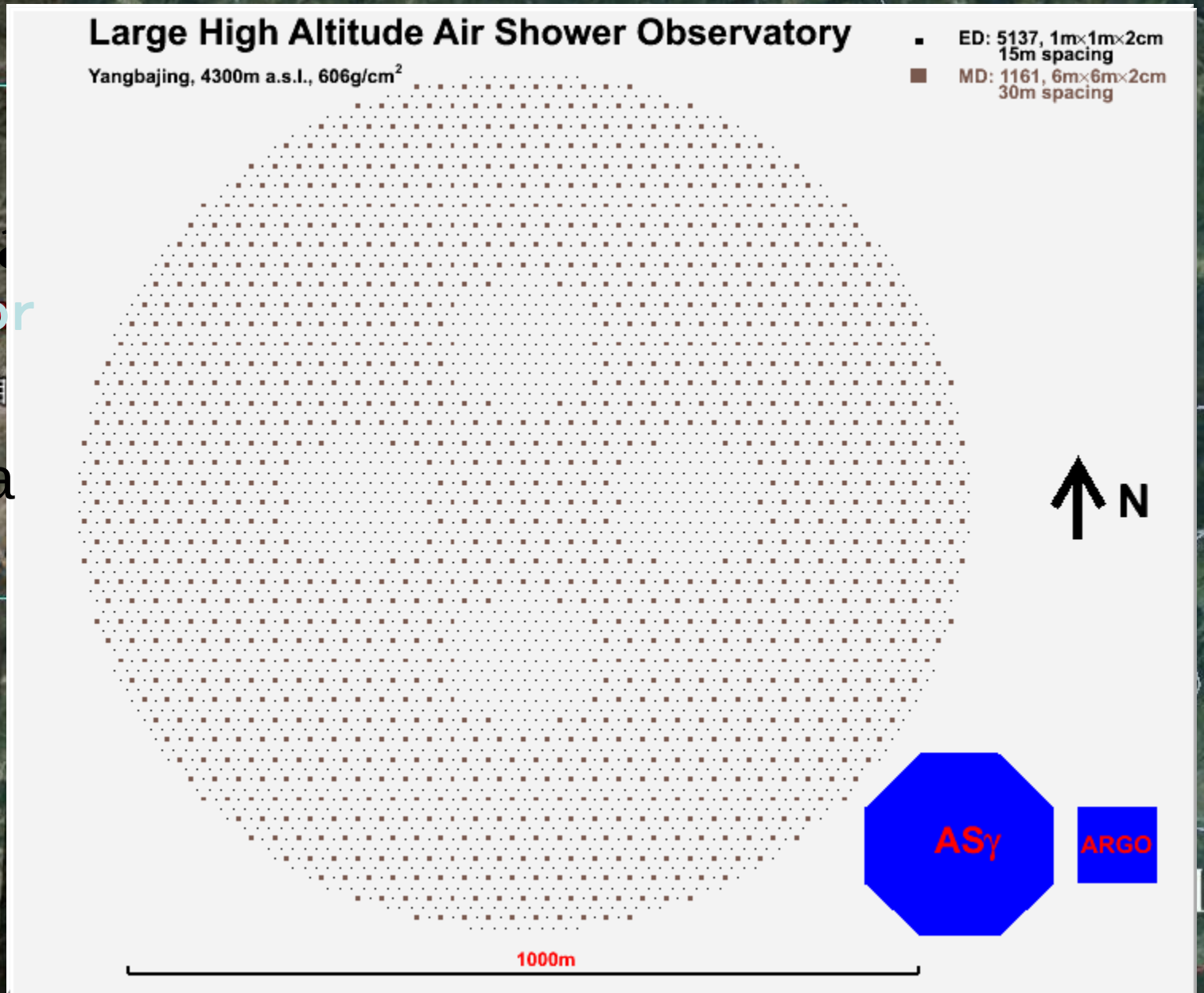


# LHAASO Project: γ astronomy and origin of CR

Charge Particle Array

μ detector Array

Shangrila



# LHAASO Project: γ astronomy and origin of CR

Charge Particle Array

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μ detecto

Array

Water C

Shangrila

Array

Wide FOV

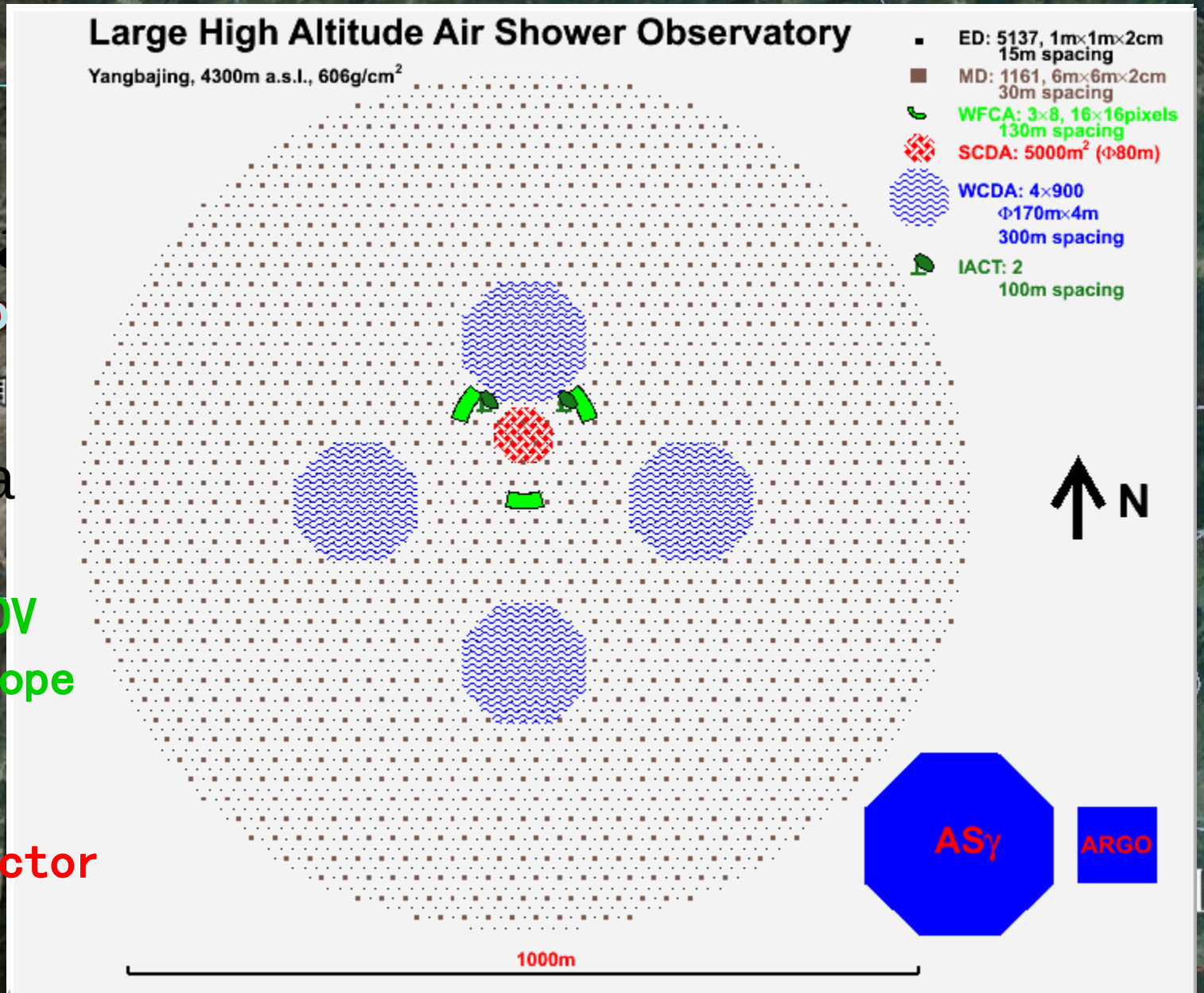
C-Telescope

Array

&

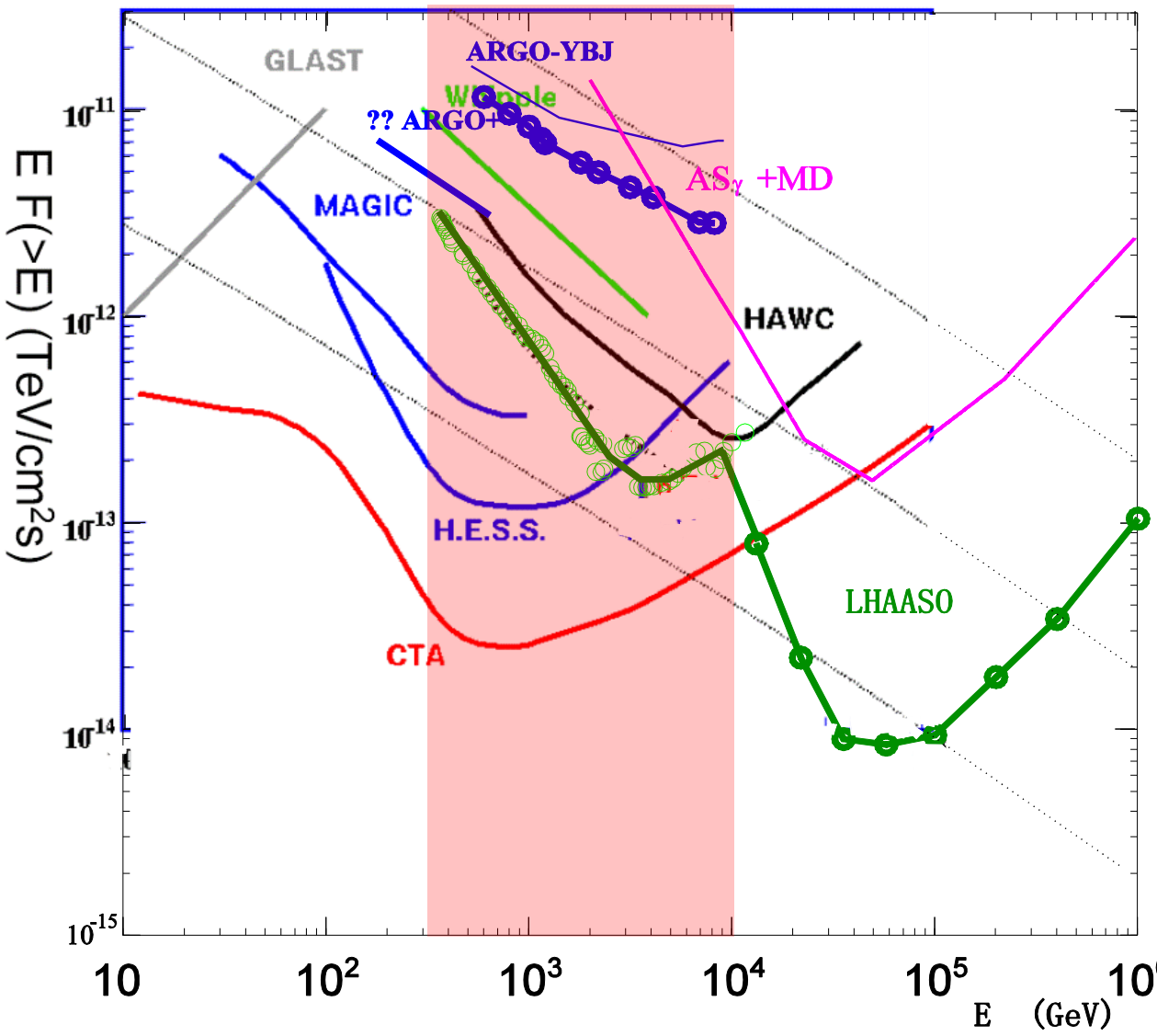
Core Detector

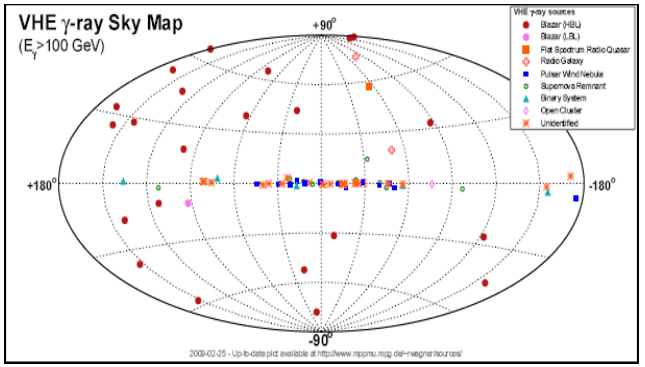
Array

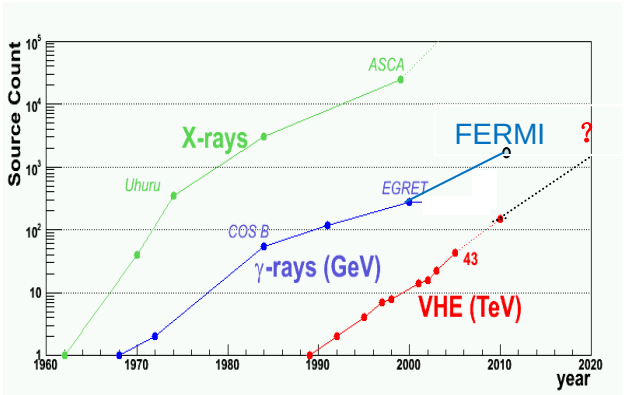


# Survey for γ sources

## ( a few hundreds extra-galactic sources are expected )

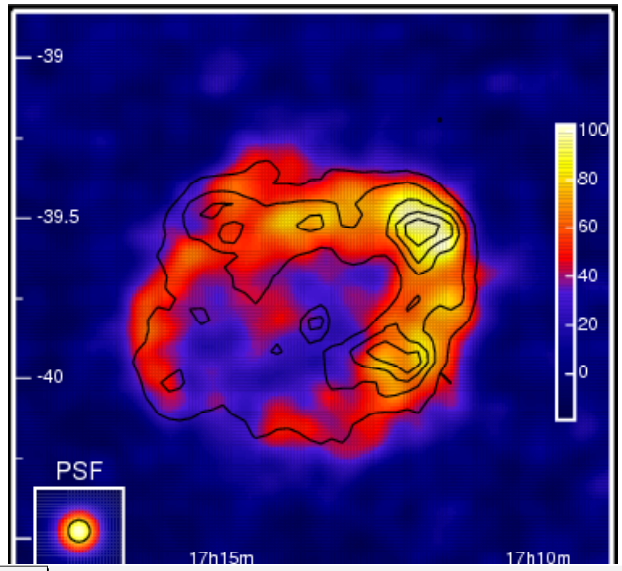


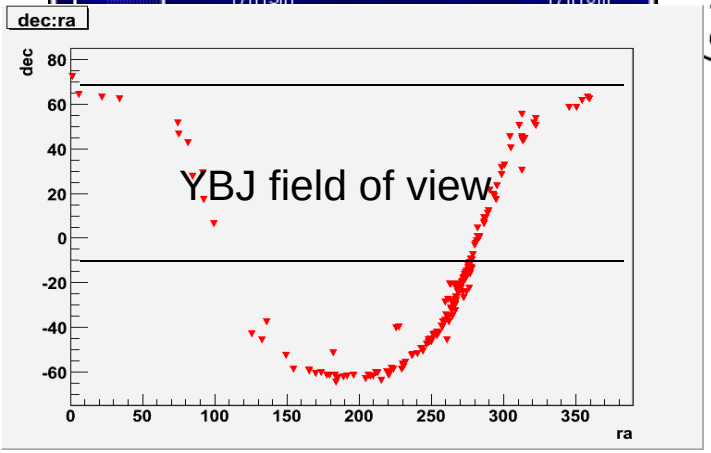



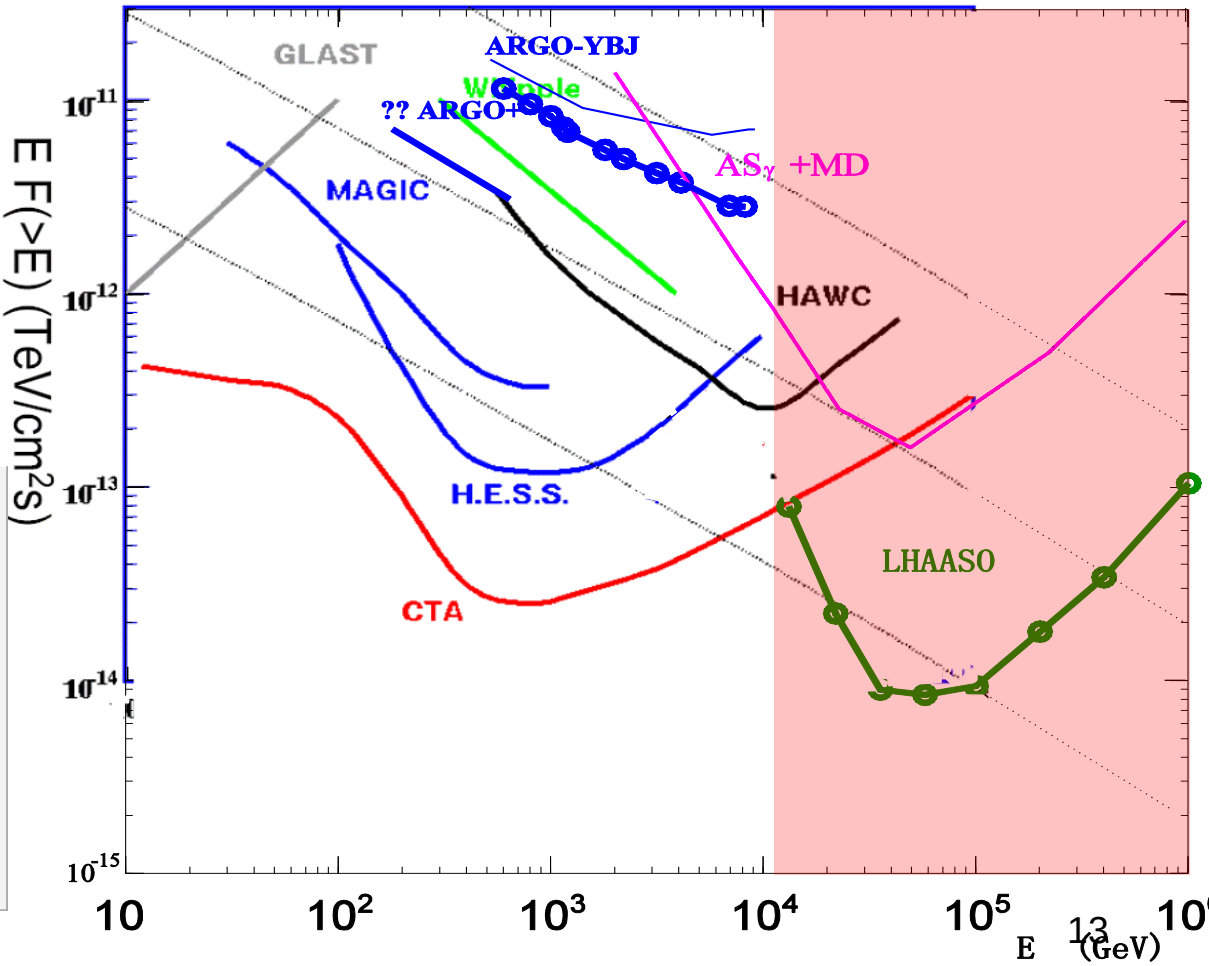
# Searching for CR origin

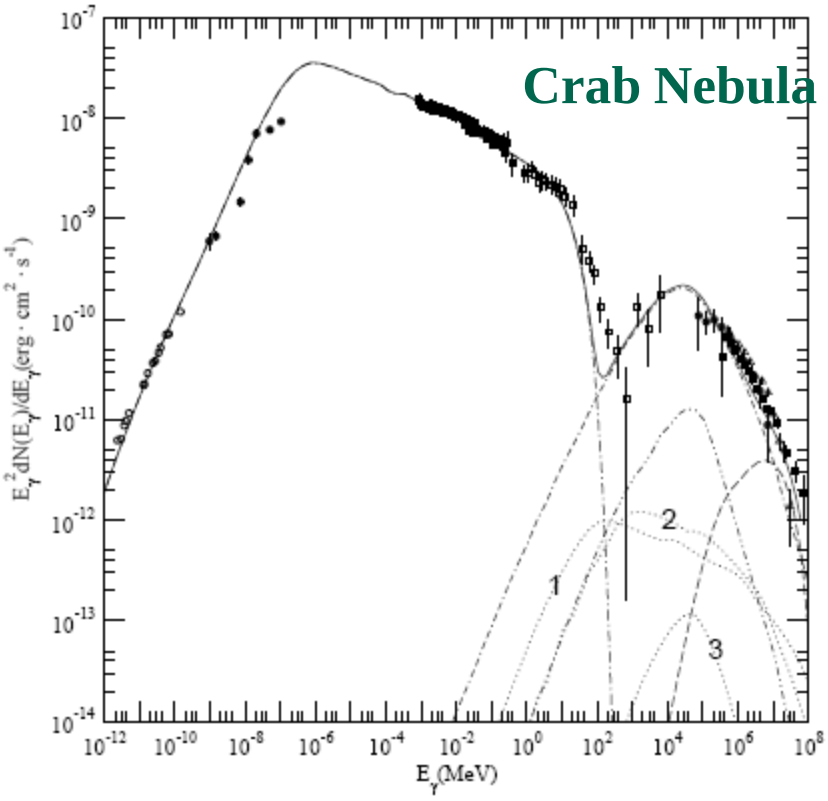
## the most Sensitive detector for 10TeV γ sky

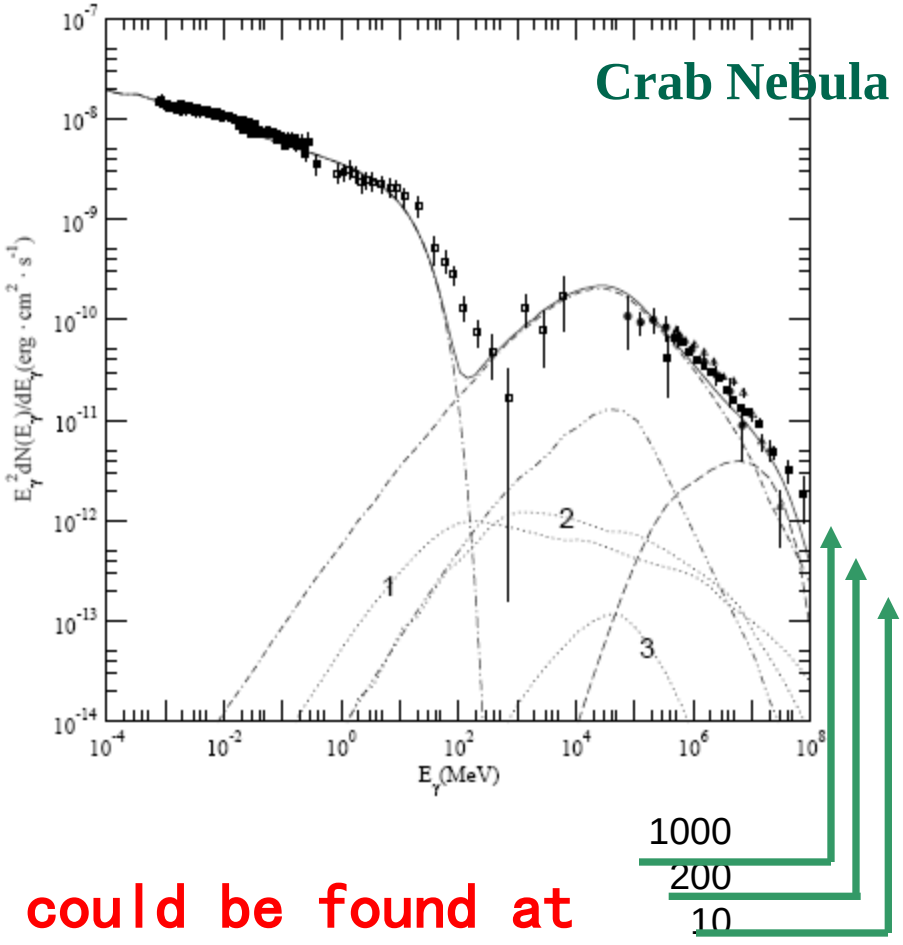


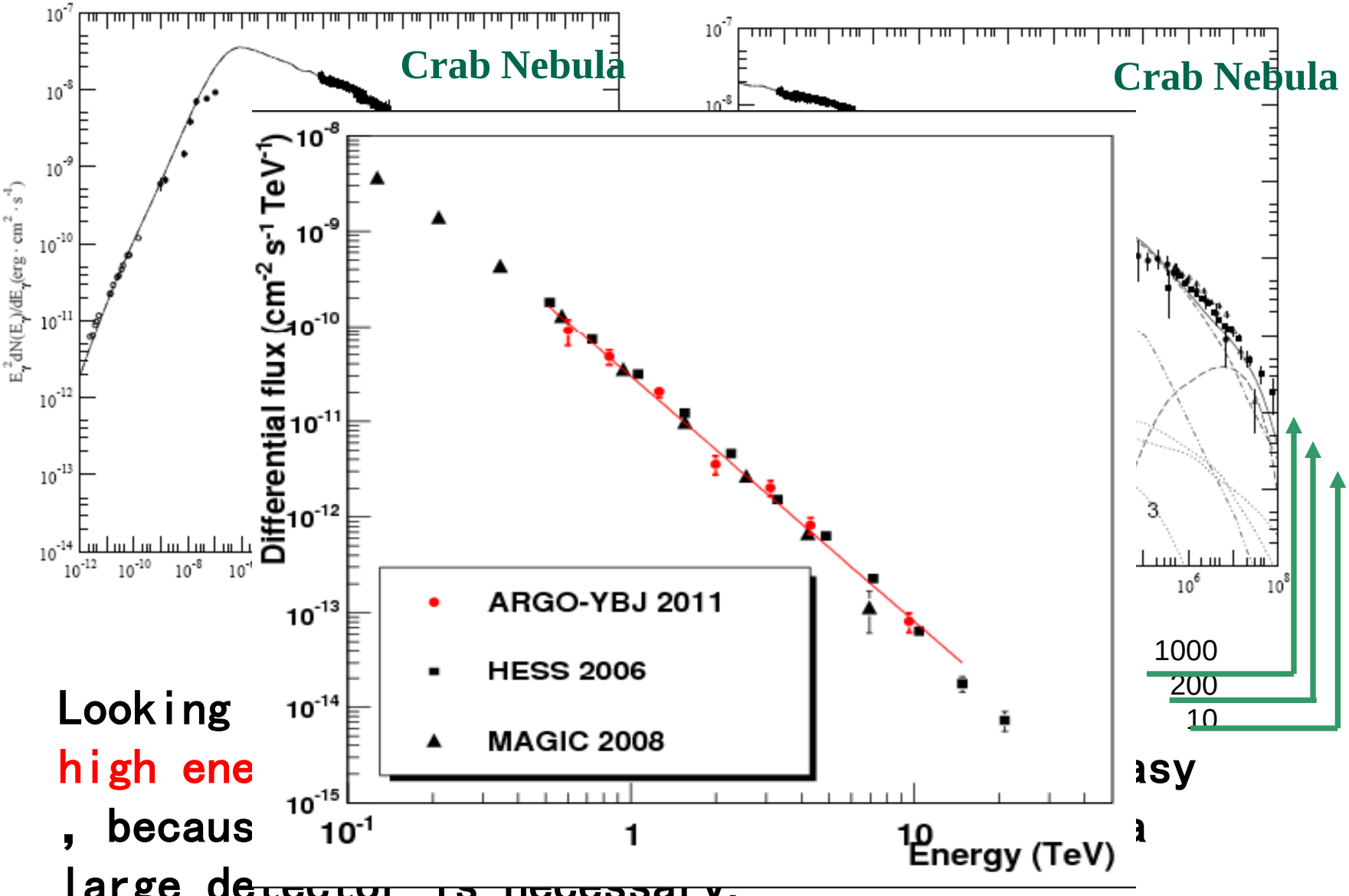

E-resolution 20%






Looking for Smoking guns could be found at high energies. Observationally, it is not easy , because the flux is too small, therefore a large detector is necessary.




Looking

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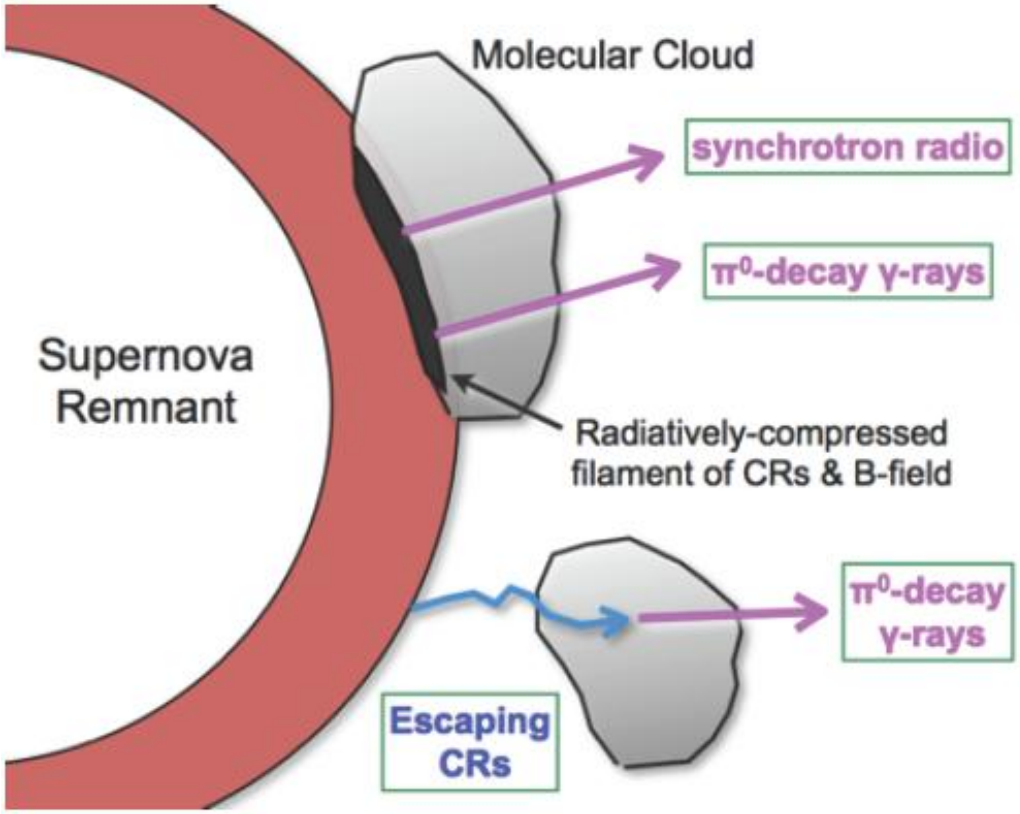
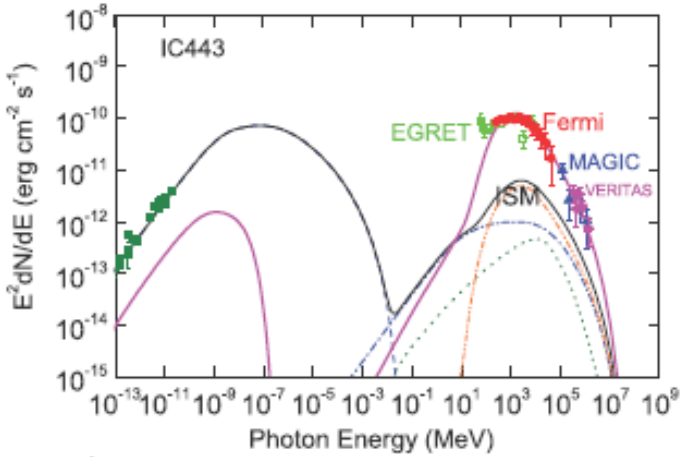
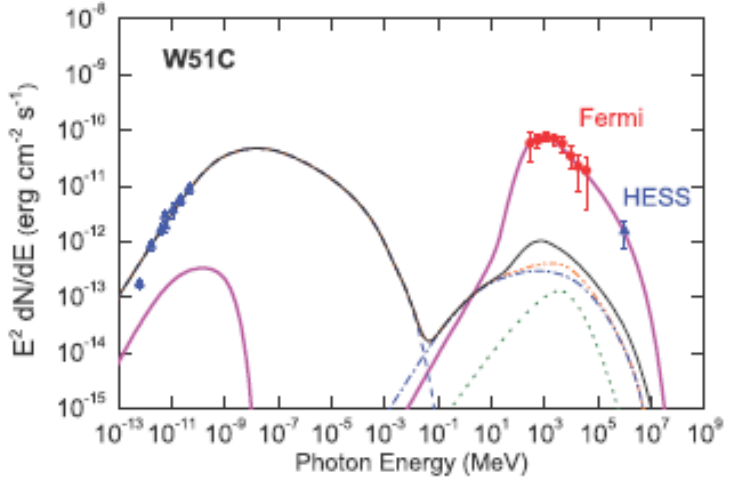
# SNRs with Molecular Clouds

– Fermi has observed W51C, W44, IC443, W28, W49B, W30, CTB37A, ..
– They could be hadron sources

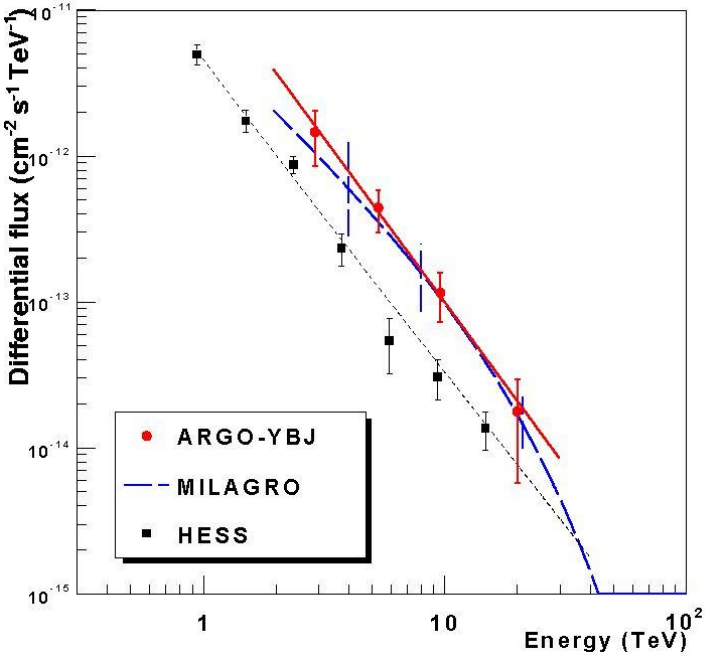


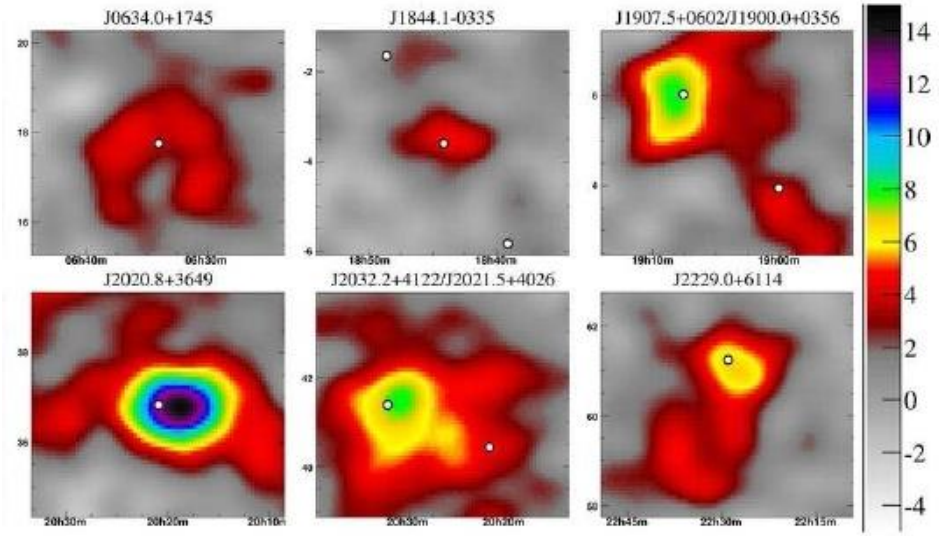



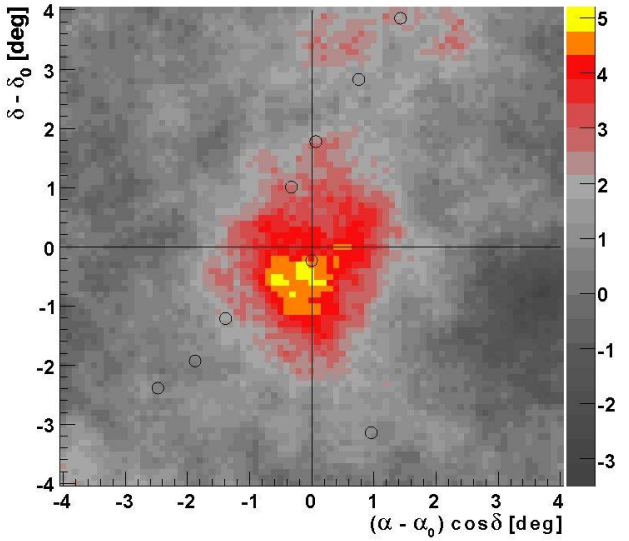



# Spectroscopy: CR Sources?

- Bright existing Sources
  - J1908+06,
  - Geminga
  - ……
  - All possible proton acceleration sites



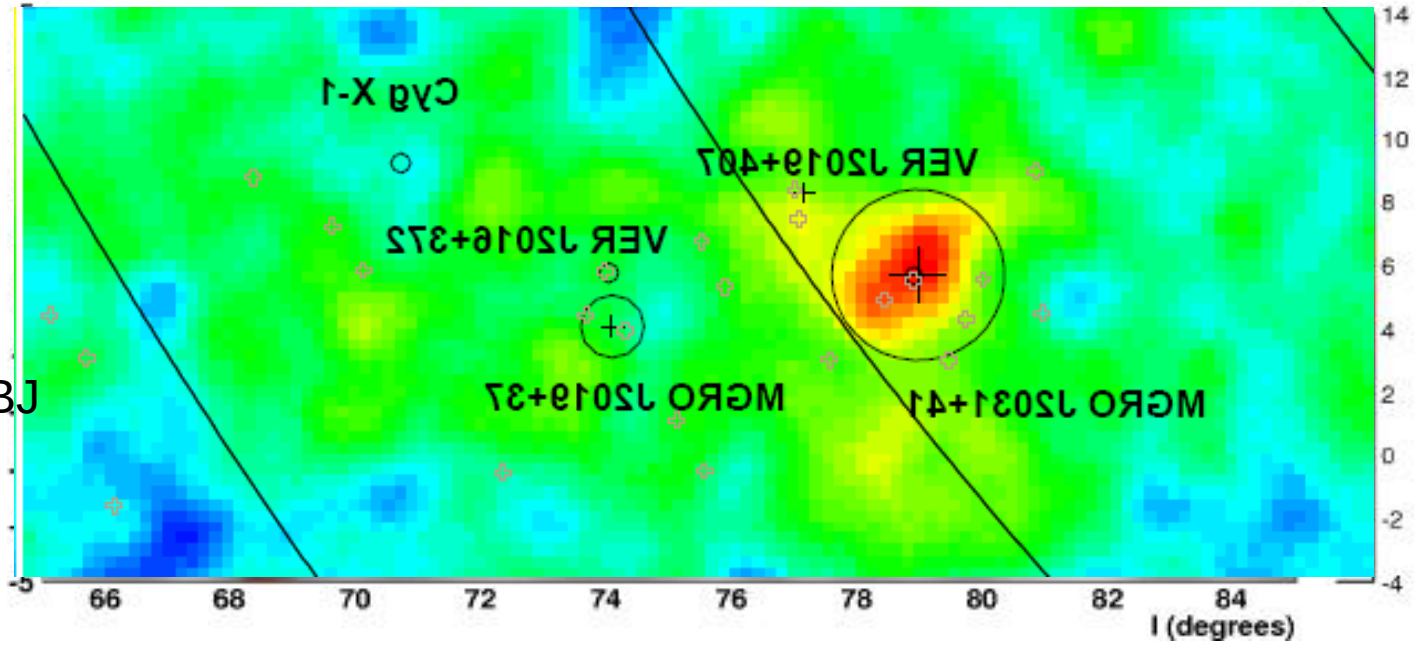



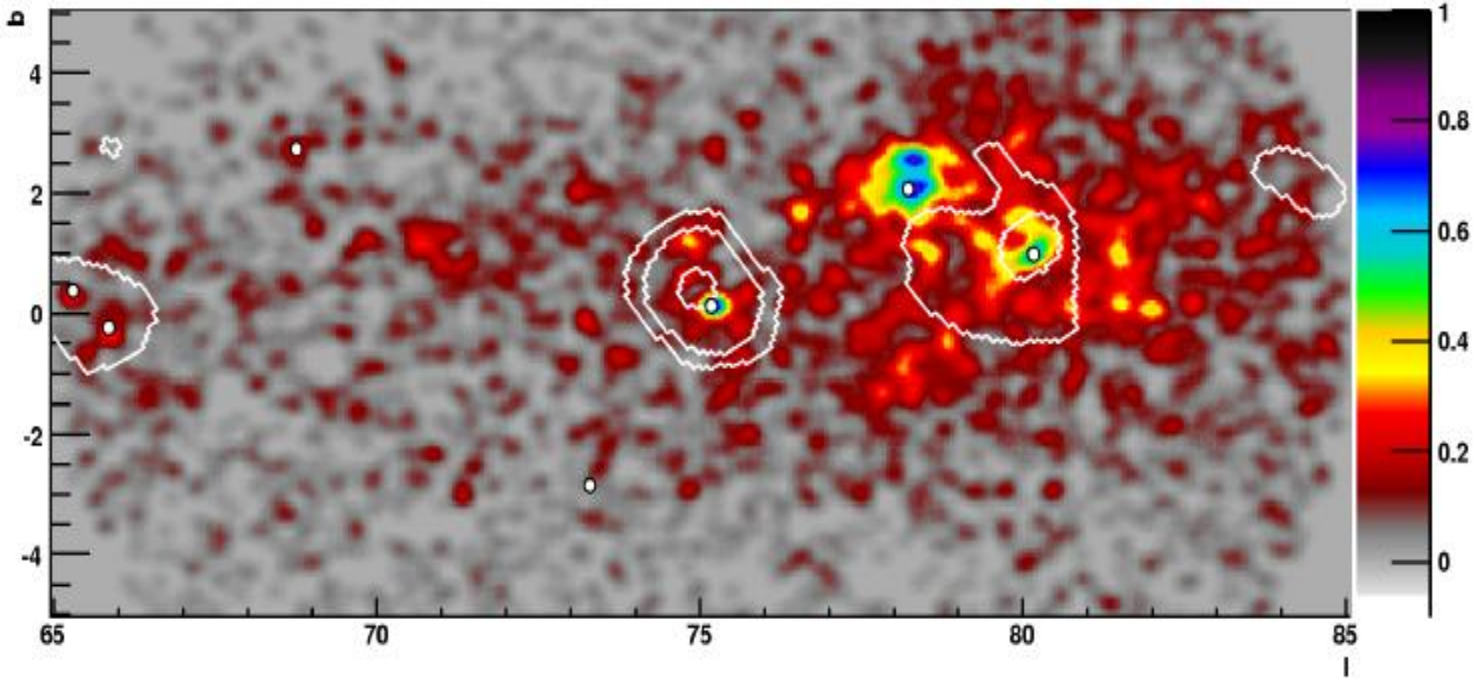
# Many unidentified strong sources in the Cygnus region

Milagro

ARGO-YBJ



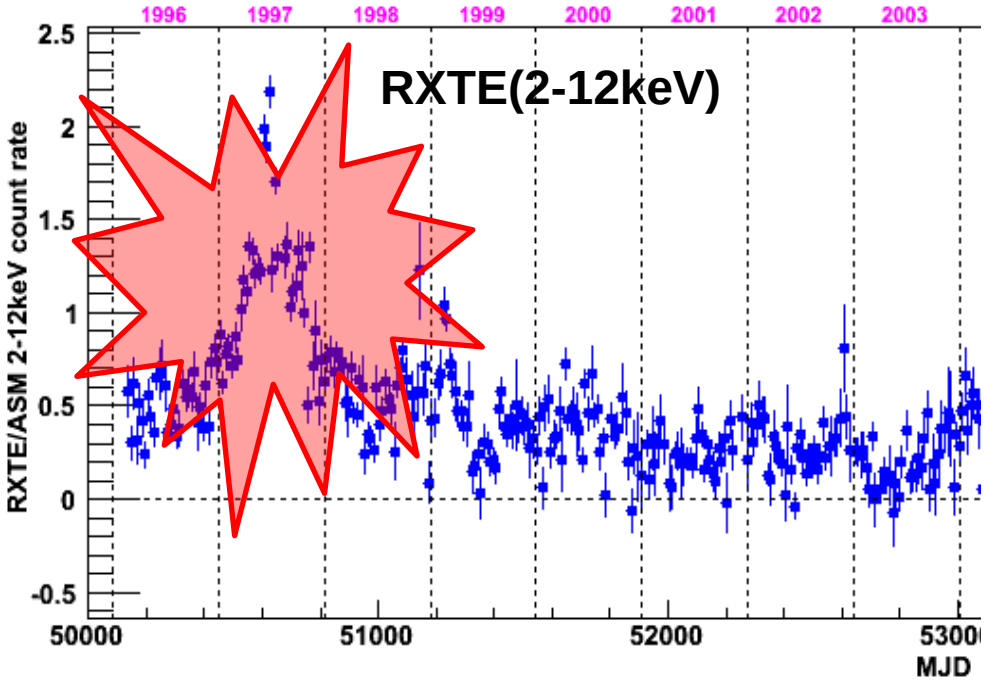

FERMI Cocoon

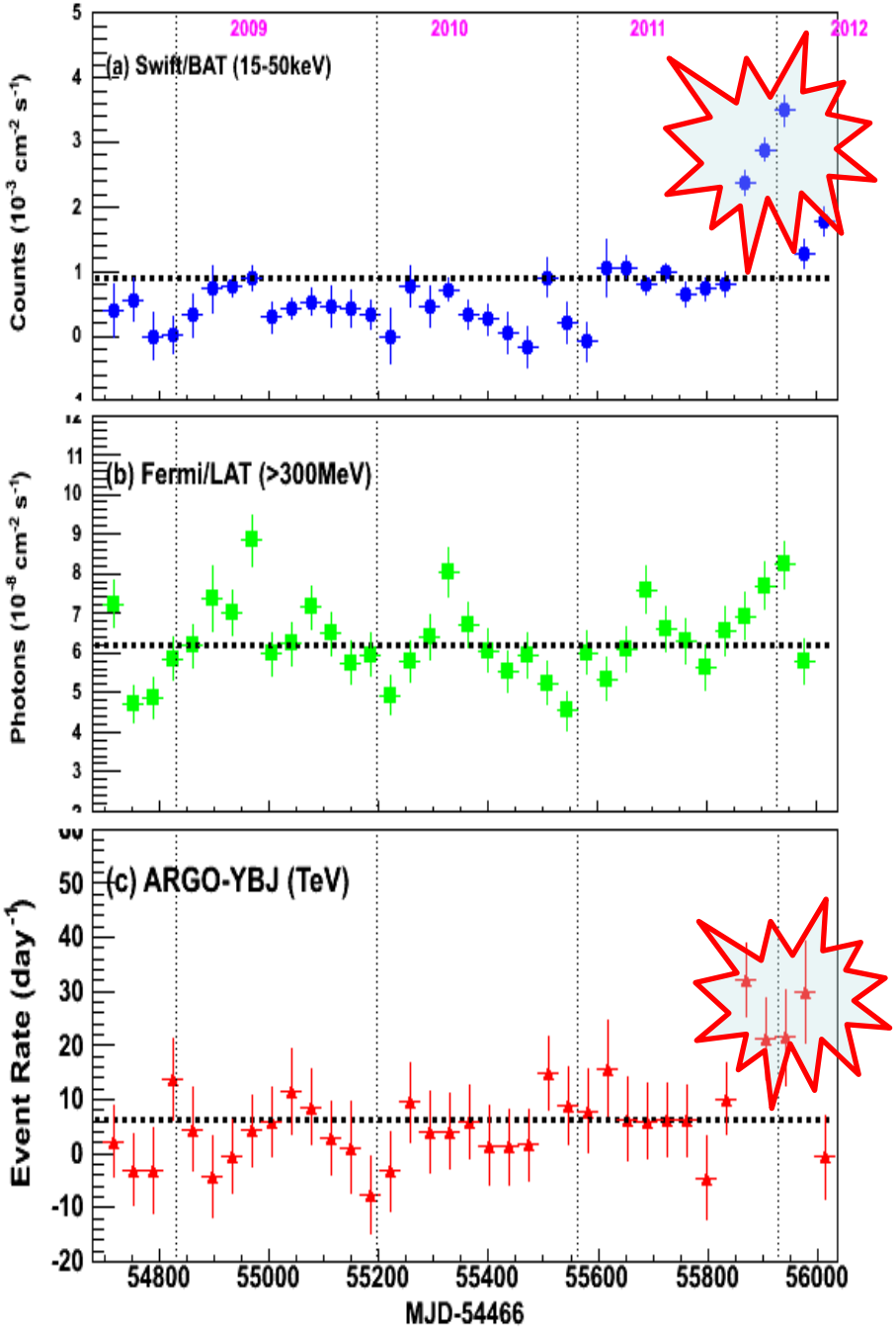


# AGN： transients

Mrk501

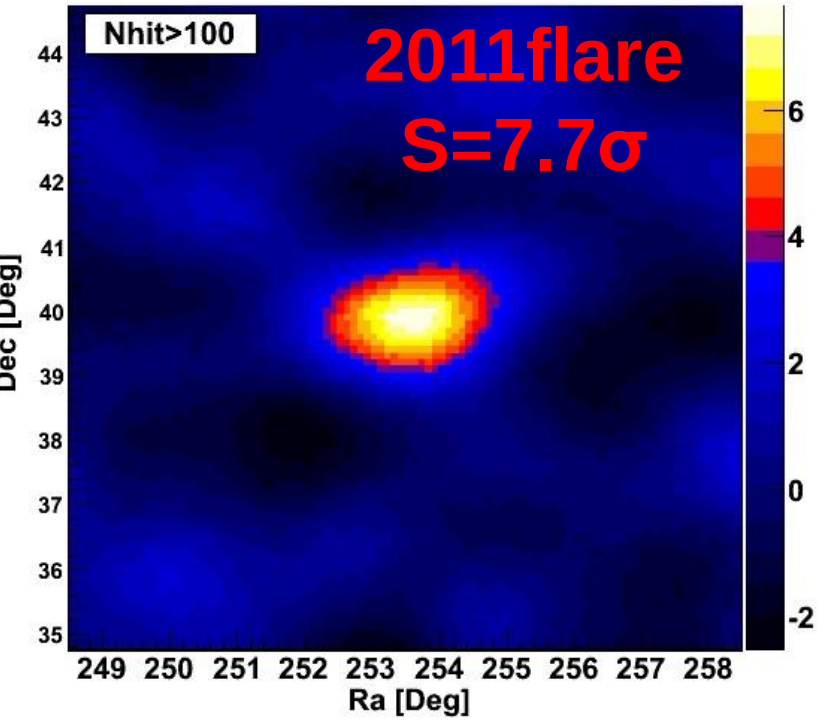
Mrk421

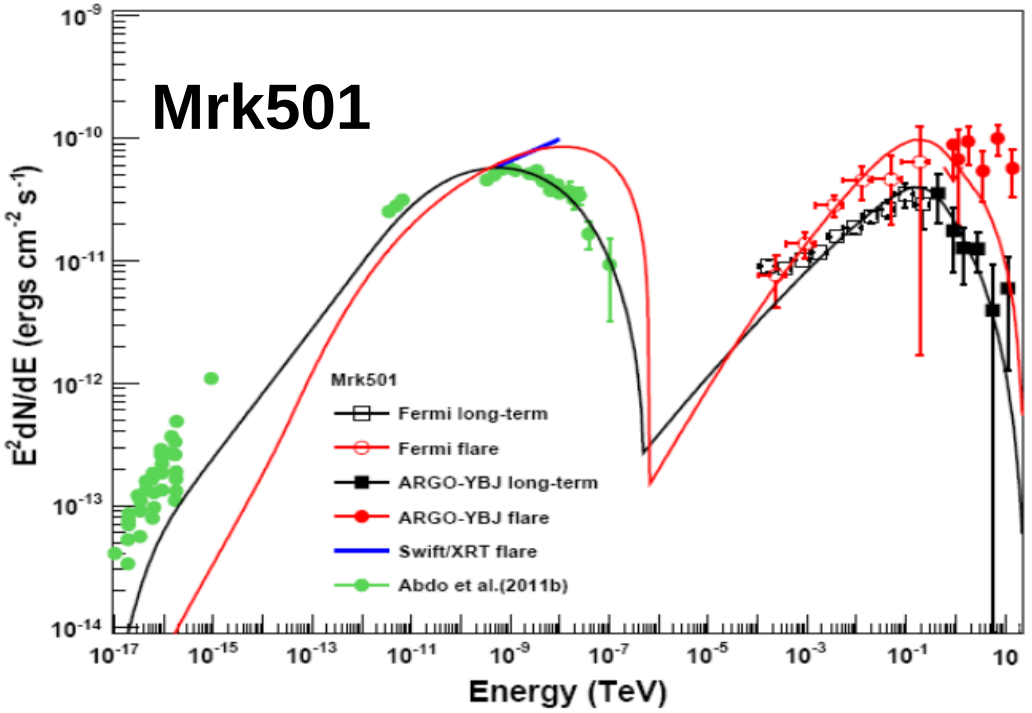


# SED Analysis for Radiation Mechanism

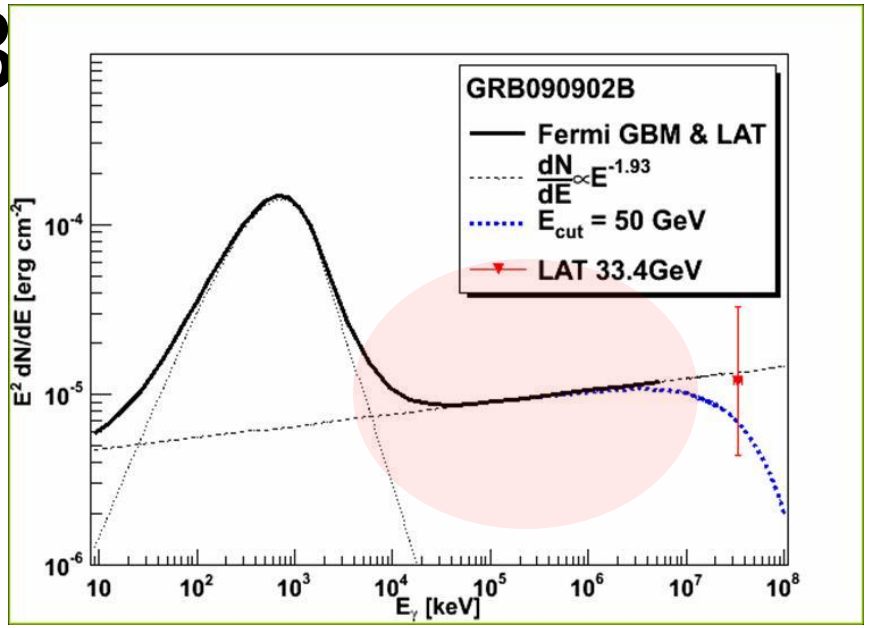
- For steady states, the SSC model is favored.
- **During flares, the spectrum is hardened. Simple SSC model is not favored**
- **Evolution is well observed**

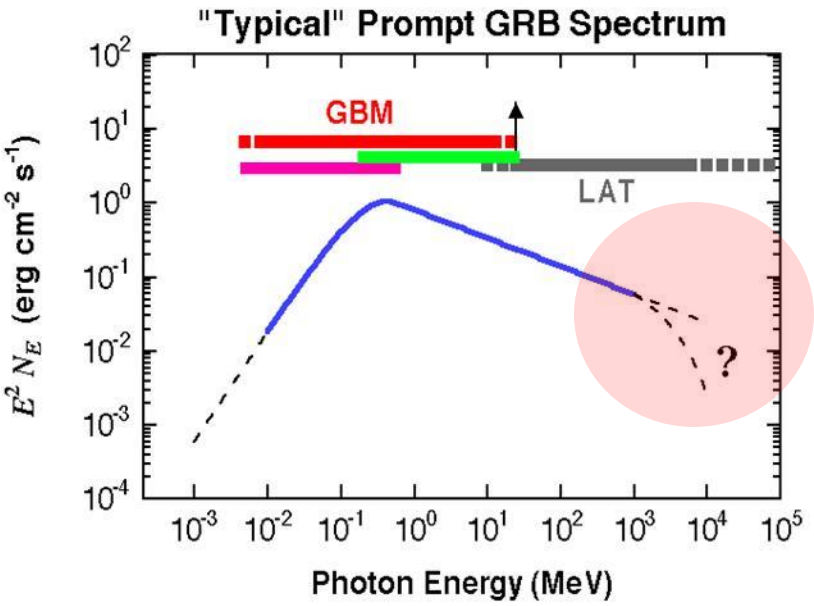


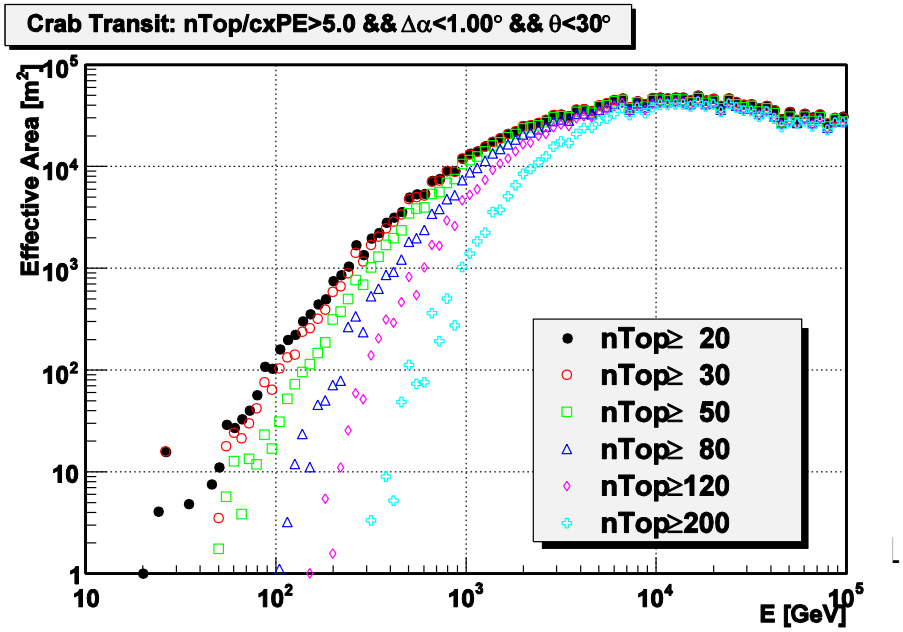



# Transient(2): GRB

- Estimate number of bursts with effective detecting area
- Light curves and number of expected photons at different energies
- Multi-wavelength spectroscopic analysis



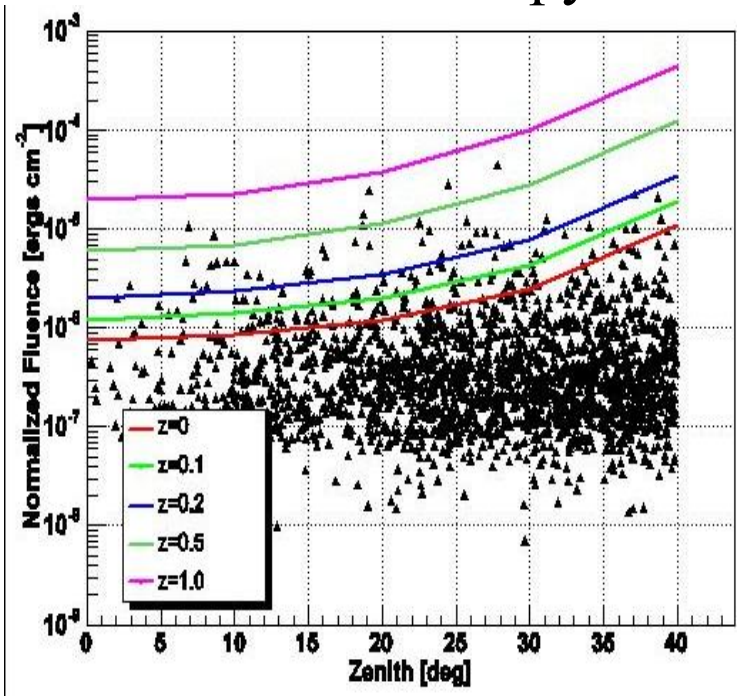



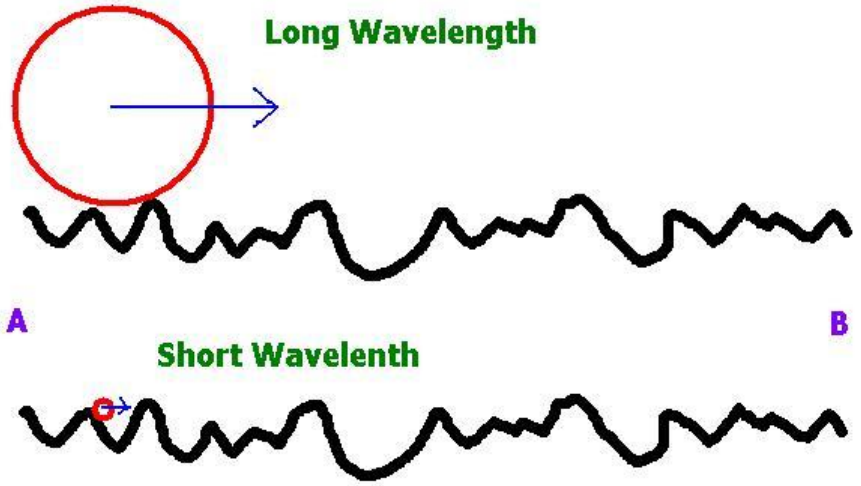



# Energy dependence of the Speed of light

By Martinez

- Space-time becomes "foamy" due to Quantum fluctuations
- For shorter wavelength photons, the path is longer because the road is "bumpy"




- The energy scale at the Planck Mass

$M_{QG} = O(M_P) = O(10^{19})$ GeV

$v(E)/c \sim 1-(E/M_{QGn})^n$ , here n=1,2

$\Delta t \sim 0.1$ sec for 100GeV gamma from 1Gpc and n=1

# QG-Related Limits from GRB 090510

**Abdo et al, Nature 462, 331 (2010)**

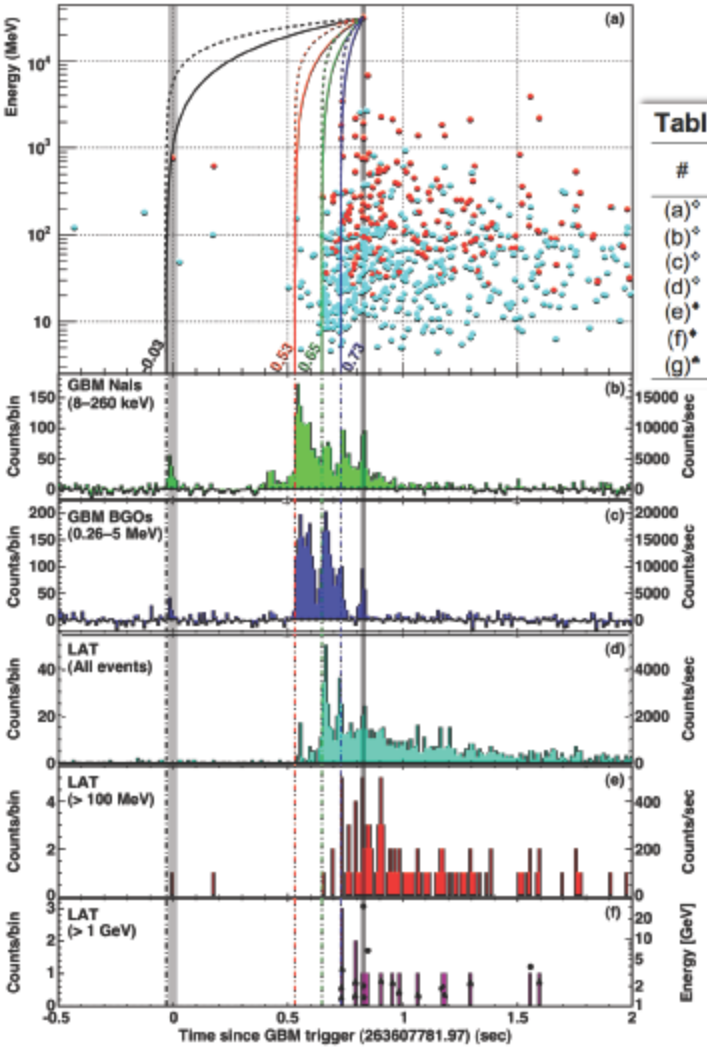


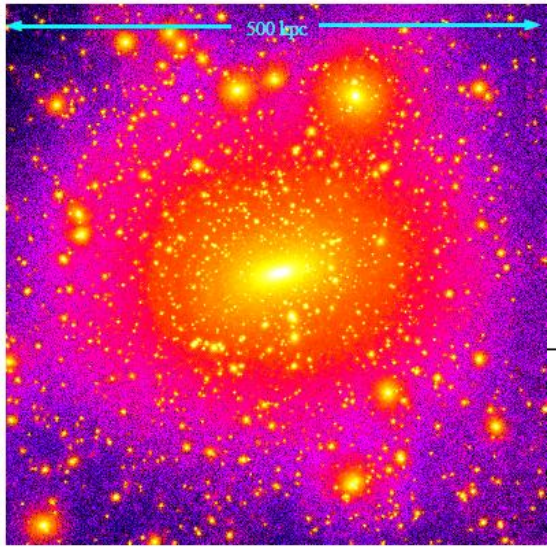

**Table 2 | Limits on Lorentz Invariance Violation**

| # | $t_{start} - T_0$ (ms) | Limit on $\|\Delta t\|$ (ms) | Reasoning for choice of $t_{start}$ or limit on $\Delta t$ or $\|\Delta t/\Delta E\|$ | $E_l$† (MeV) | Valid for $s_n$* | Lower limit on $M_{QG,1}/M_{Planck}$ |
|---|---|---|---|---|---|---|
| (a)◇ | −30 | < 859 | start of any < 1 MeV emission | 0.1 | 1 | > 1.19 |
| (b)◇ | 530 | < 299 | start of main < 1 MeV emission | 0.1 | 1 | > 3.42 |
| (c)◇ | *648* | < 181 | start of main > 0.1 GeV emission | 100 | 1 | > 5.63 |
| (d)◇ | 730 | < 99 | start of > 1 GeV emission | 1000 | 1 | > 10.0 |
| (e)♦ | — | < 10 | association with < 1 MeV spike | 0.1 | ±1 | > 102 |
| (f)♦ | — | < 19 | If 0.75 GeV‡ γ-ray from 1st spike | 0.1 | −1 | > 1.33 |
| (g)♣ | $\|\Delta t/\Delta E\|$ < 30 ms/GeV | | lag analysis of > 1 GeV spikes | — | ±1 | > 1.22 |

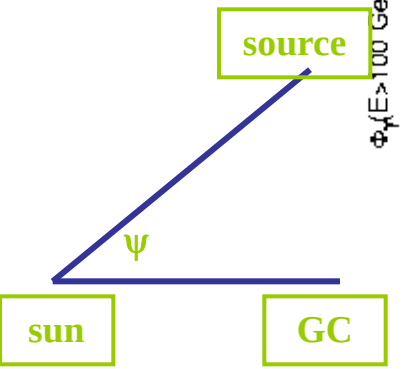
**With the assumption that the HE photons are not emitted *before* the LE photons**

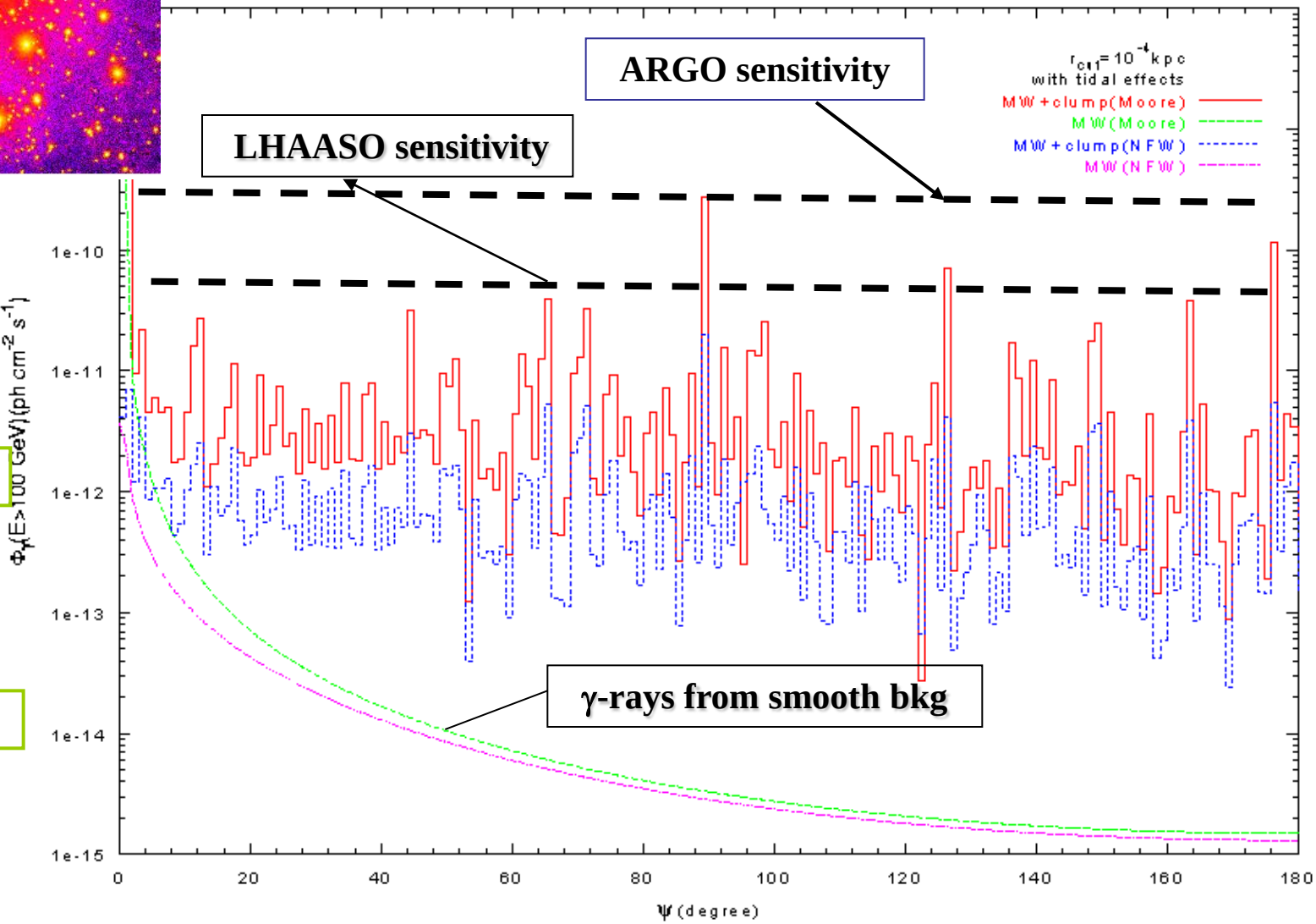
$$M_{QG} > 1.2\ M_{Planck}$$

# Dark Matter γ-rays from the sub-halos



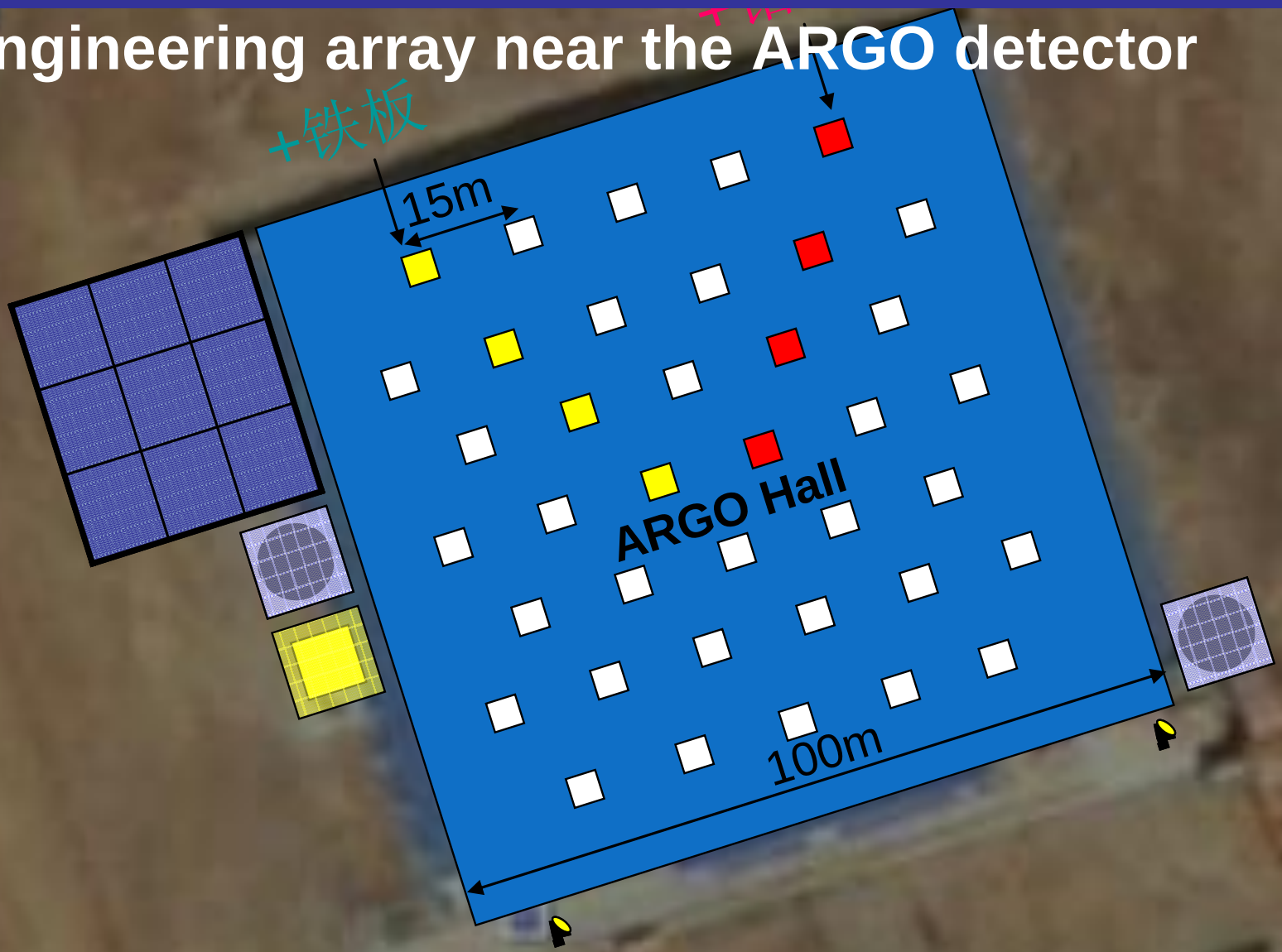

Reed et al, MNRAS35 7,82(2004)



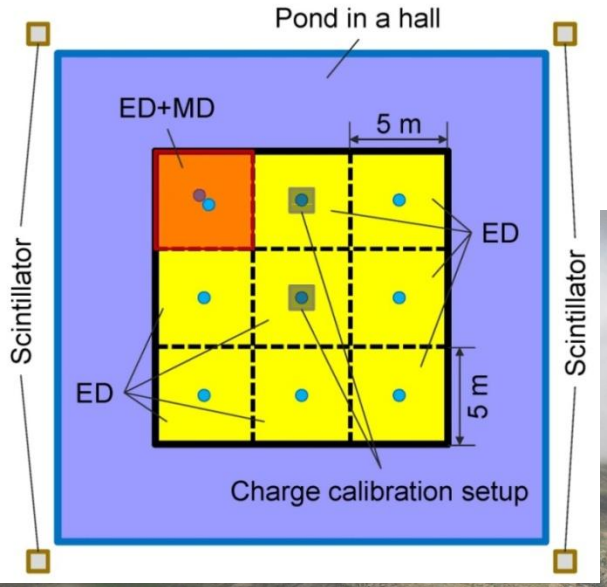



# Prototype of LHAASO at YBJ site

engineering array near the ARGO detector

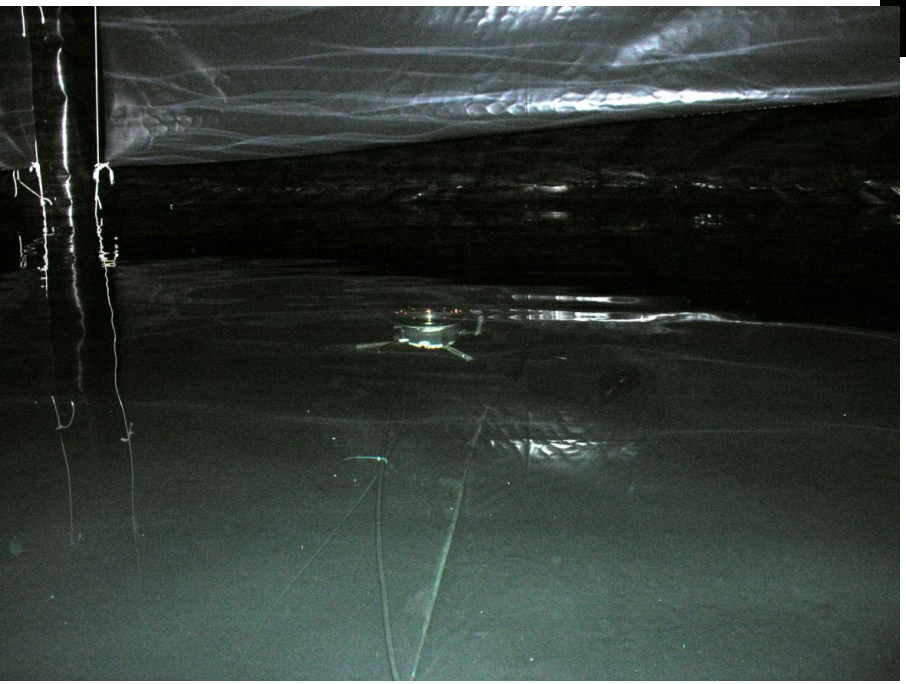


# WCDA

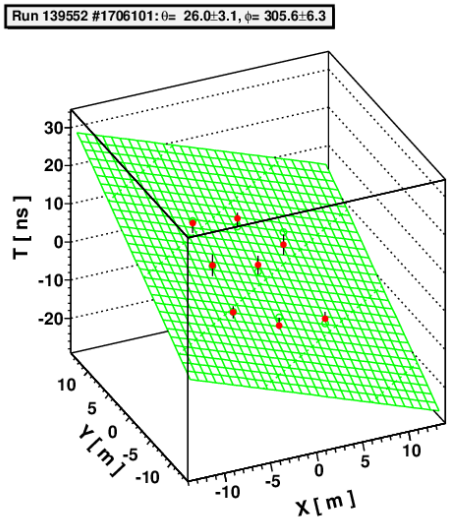

Pond in a hall
ED+MD
5 m
ED
ED
5 m
Scintillator
Scintillator
Charge calibration setup

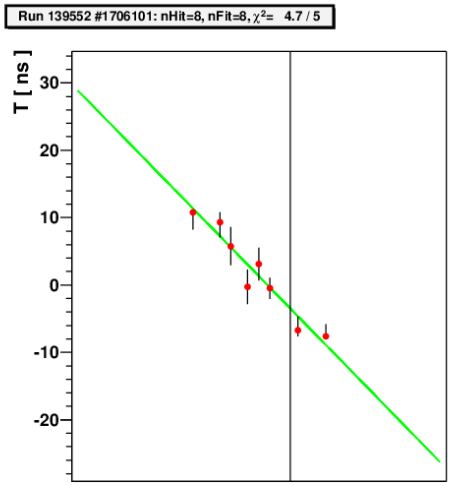
The WCDA before filling water

Water submarine the PMT in the pool



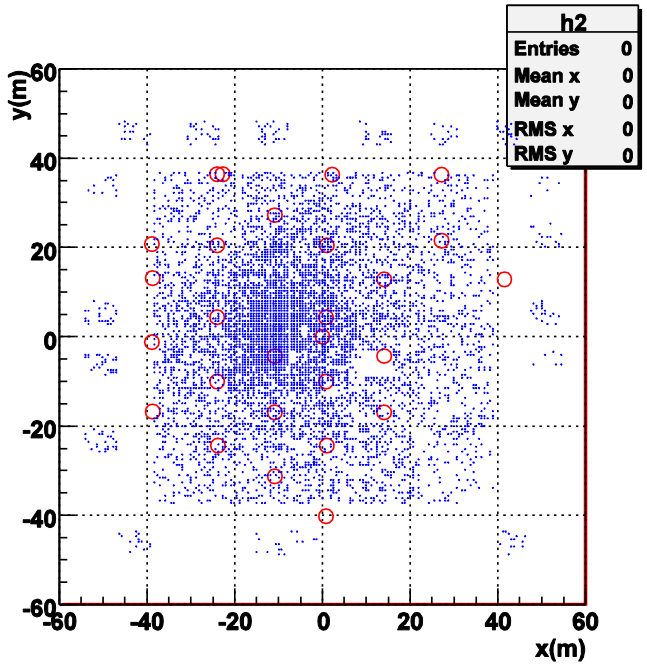
One event shower

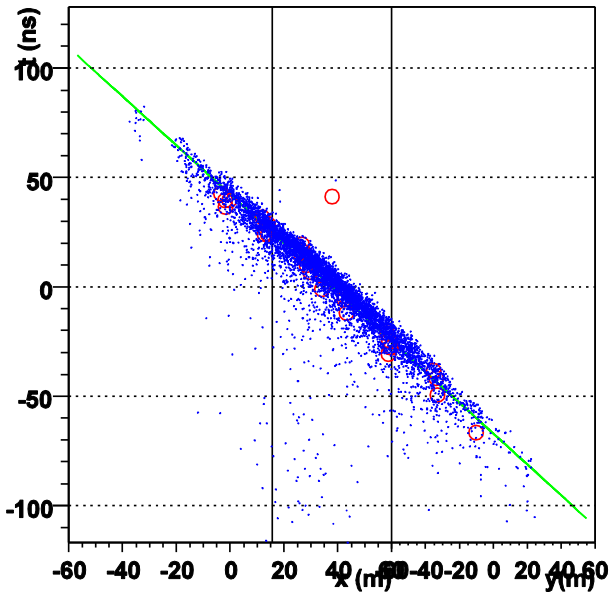


# Electromagnetic Detector

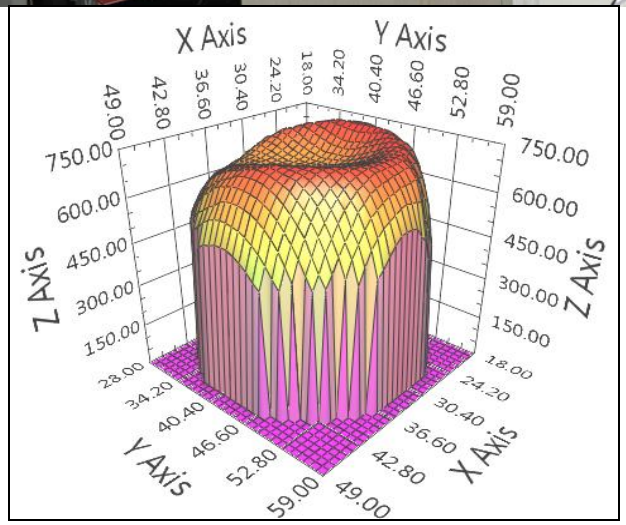
ED in ARGO hall



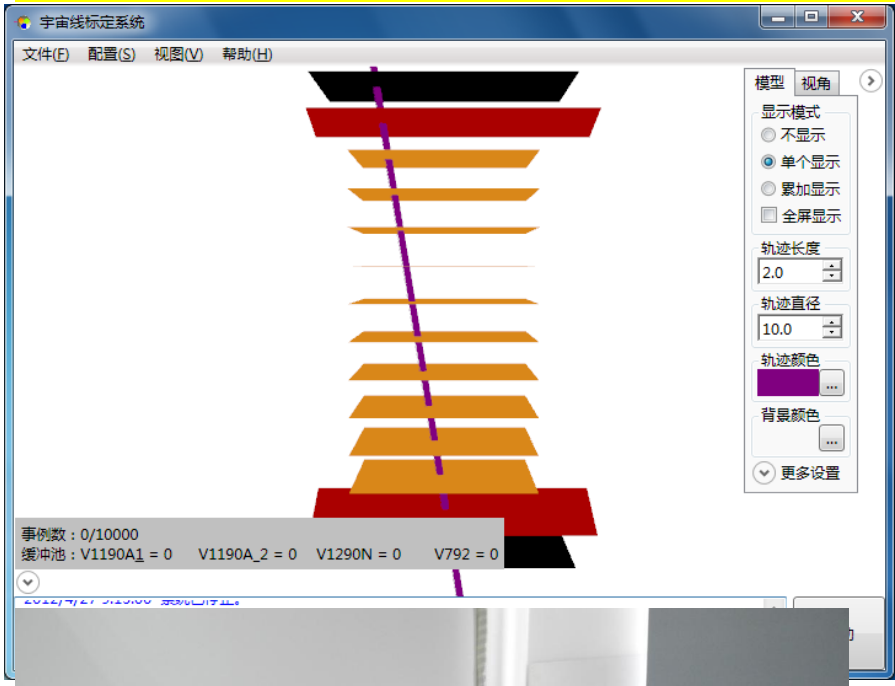




An event matched between ARGO and ED

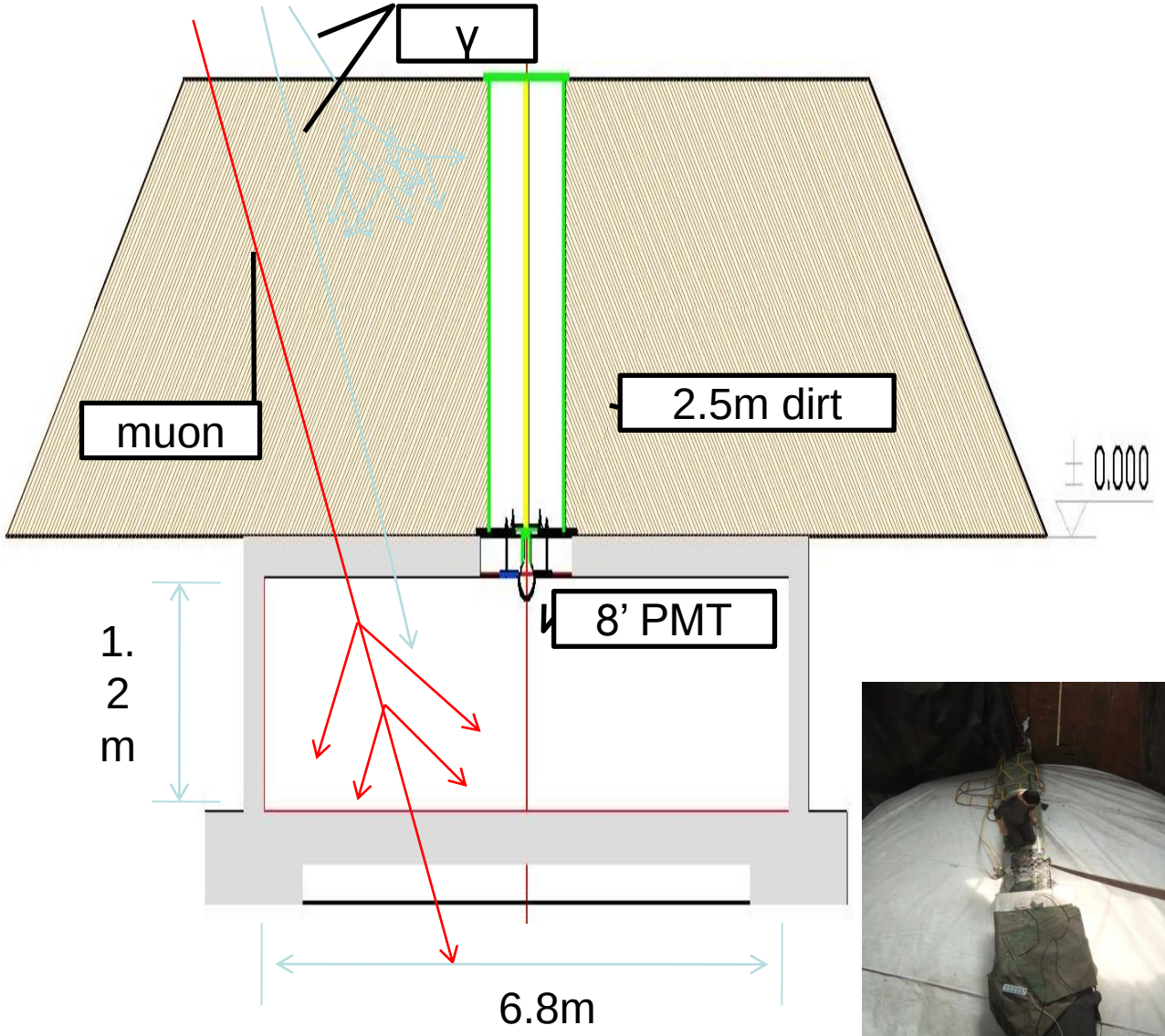
# PMT batch scan, test system


# ED detectors test system




# LHAASO—KM2A MD prototype

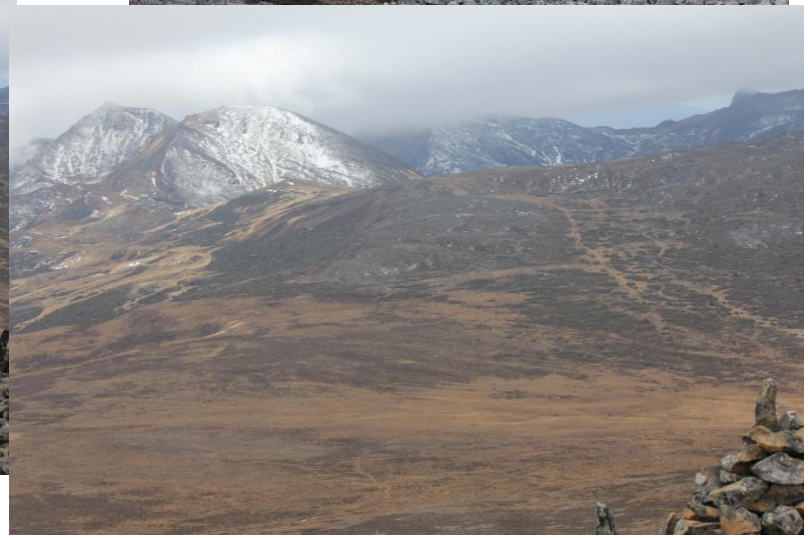


# The Best Candidate Sites

# 4300m to 4400m a.s.l.

East

South



West

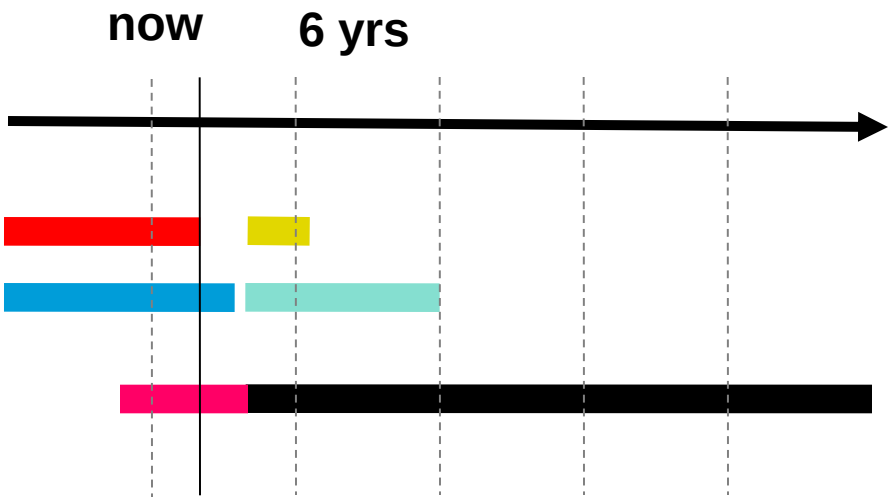
I am standing at the tip of little two hills on the north side of the site, the height is about 4450m a.s.l.

# Observatory Construction

It is planned for a construction of 5-6 years

- **yrs**

- **Detector R/D：** **1.5**
- **FEE R/D:** **2**
- **FEE Production:** **1.5**
- **DAQ & installation:** **0.5**
- **Detector deployment:** **4**
- **1% array test run:** **1**



# Conclusion

- **A ground based large and complex$\gamma$/CR observatory at high altitude (4300m a.s.l.) within 5~6 years**
  - **Great advantage for extend sources**
  - **High sensitive for variables**
  - **Useful for exploring new physics**
- **Engineering prototype at Tibet site is running**
- **The construction is expected to start in next year**