LHEP2010

Large High Altitude Air Shower Observatory (*LHAASO*) *Project*

Huihai He, IHEP, CAS
on behalf of the LHAASO collaboration

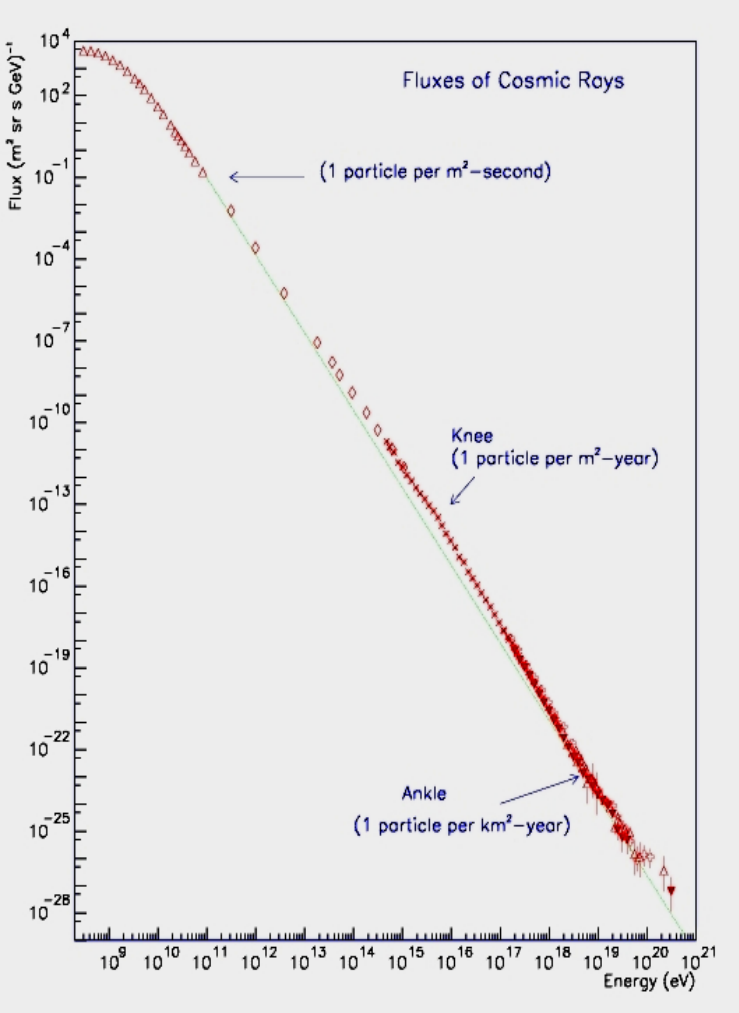
Contents

- Origin of cosmic rays and VHE γ ray astronomy
- LHAASO Project
- LHAASO prototype detectors and engineering array
- Conclusion

A centennial puzzle: Origin of high energy cosmic rays

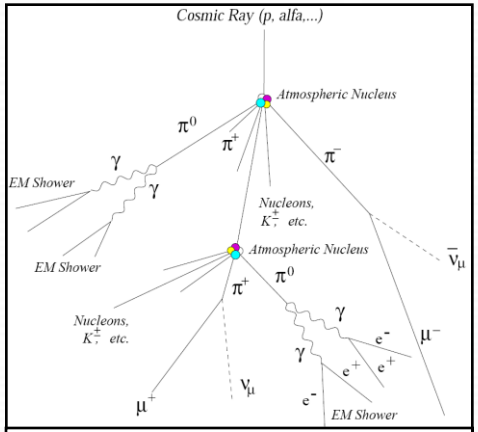
- The only matter from the universe
  - P、He…C、N、O…Mg、Al、Si…Fe…
  - neutrinos
  - few e, γ, …
- Energy range: >10 orders
- Flux: >30 orders

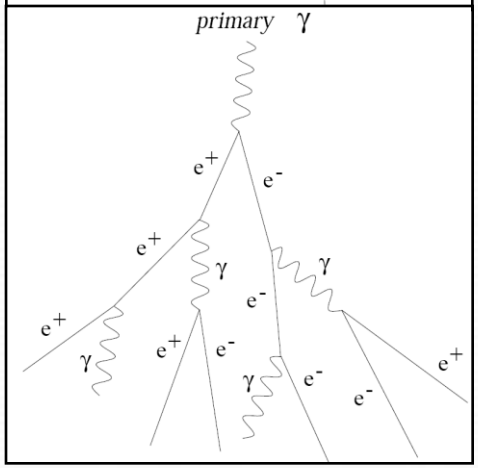
- Messenger of: particle acceleration and propagation, forming and evolution, inner structure and environment, medium and background…
- Origin is the key question, while the Sun is the only known source
- How? SED、composition、anisotropy

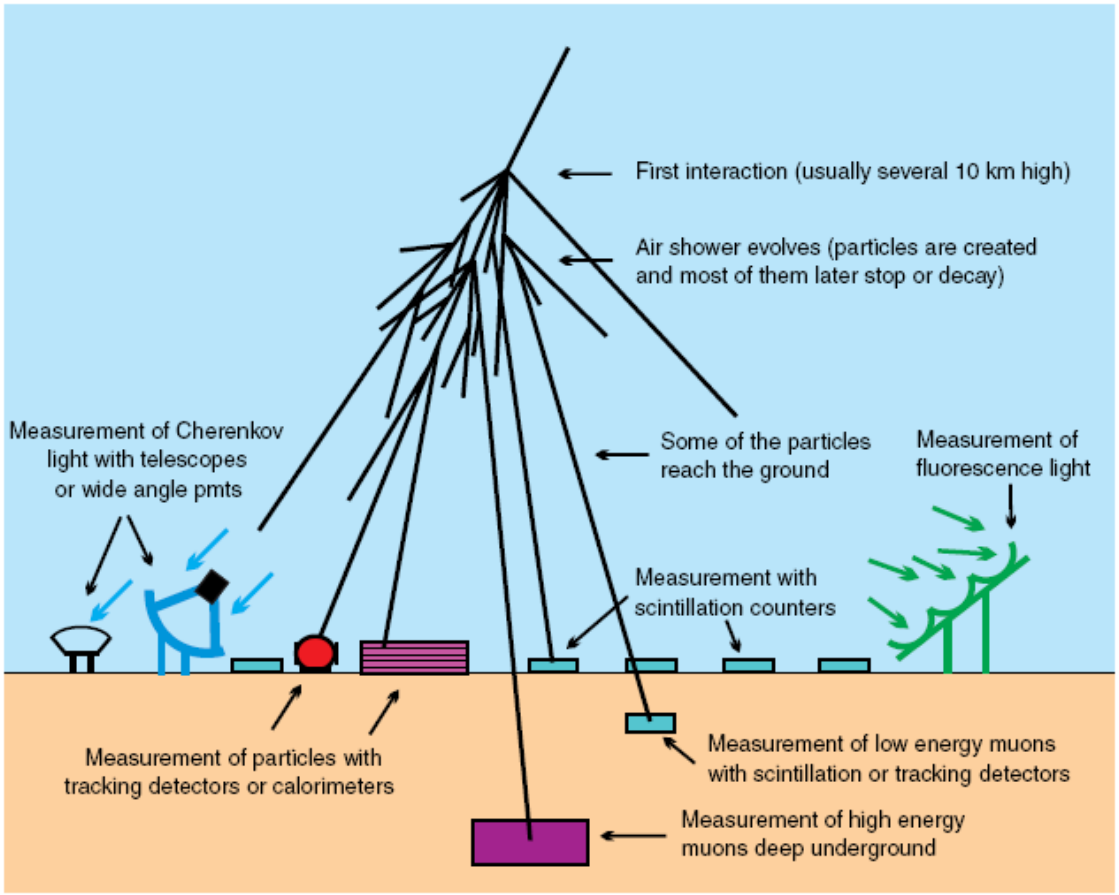


Detection of Extensive Air Showers

- **lateral：hadronic, EM, muon, etc.**
- **longitudinal：Cerenkov/Fluorescence light**





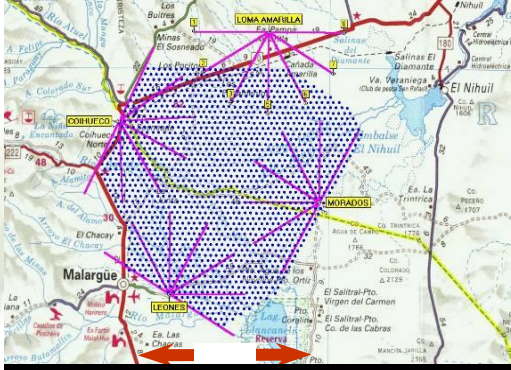


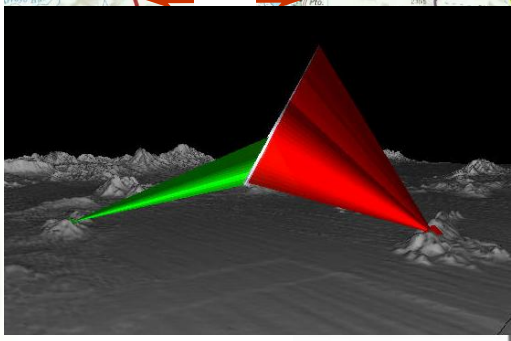
VHEγAstronomy

HESS，MAGIC

YBJ，MILAGRO

Origin of UHE cosmic rays

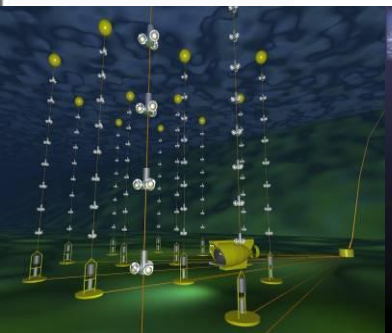


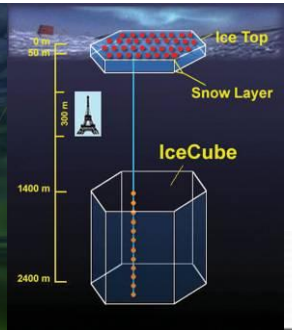


EHE cosmic ray

HIRES，AUGER

TA/TALE



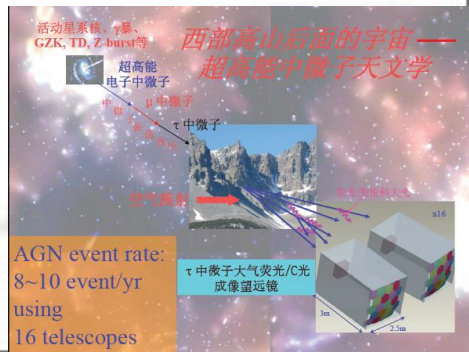


VHE/UHE astronomy

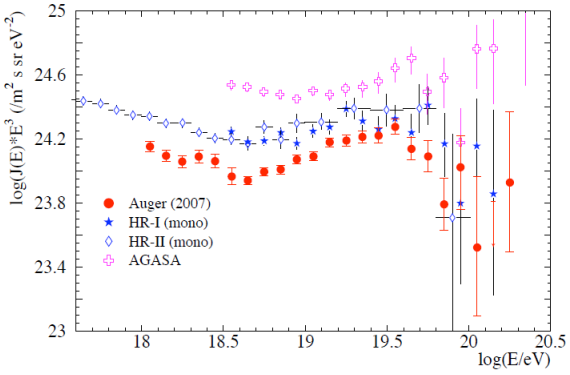
ICECUBE，KM3

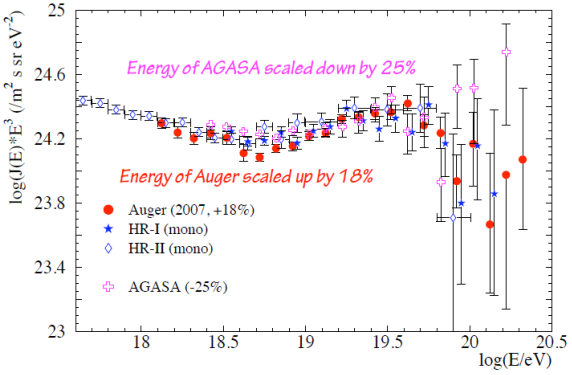
CRTNT，NUTEL，

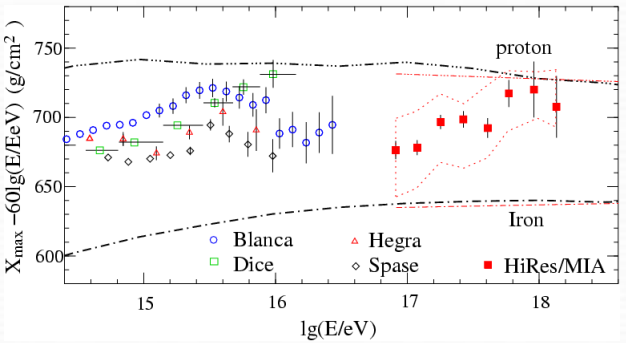
ANITA

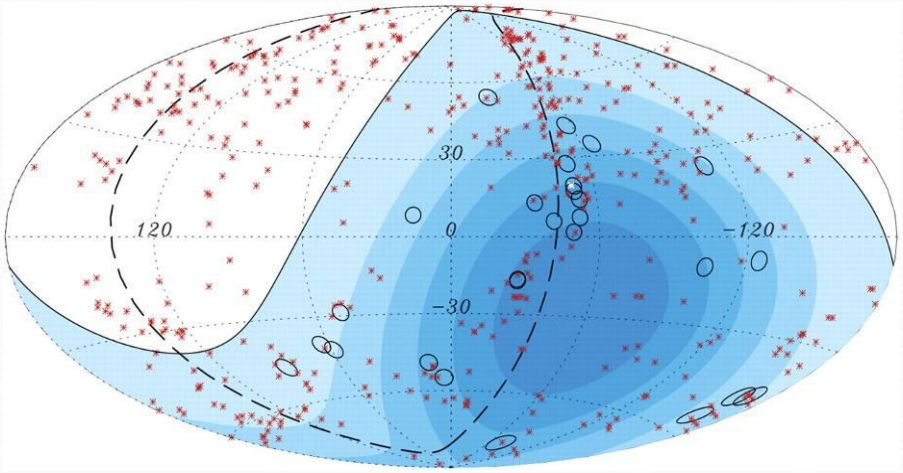


Cosmic ray study above the knee



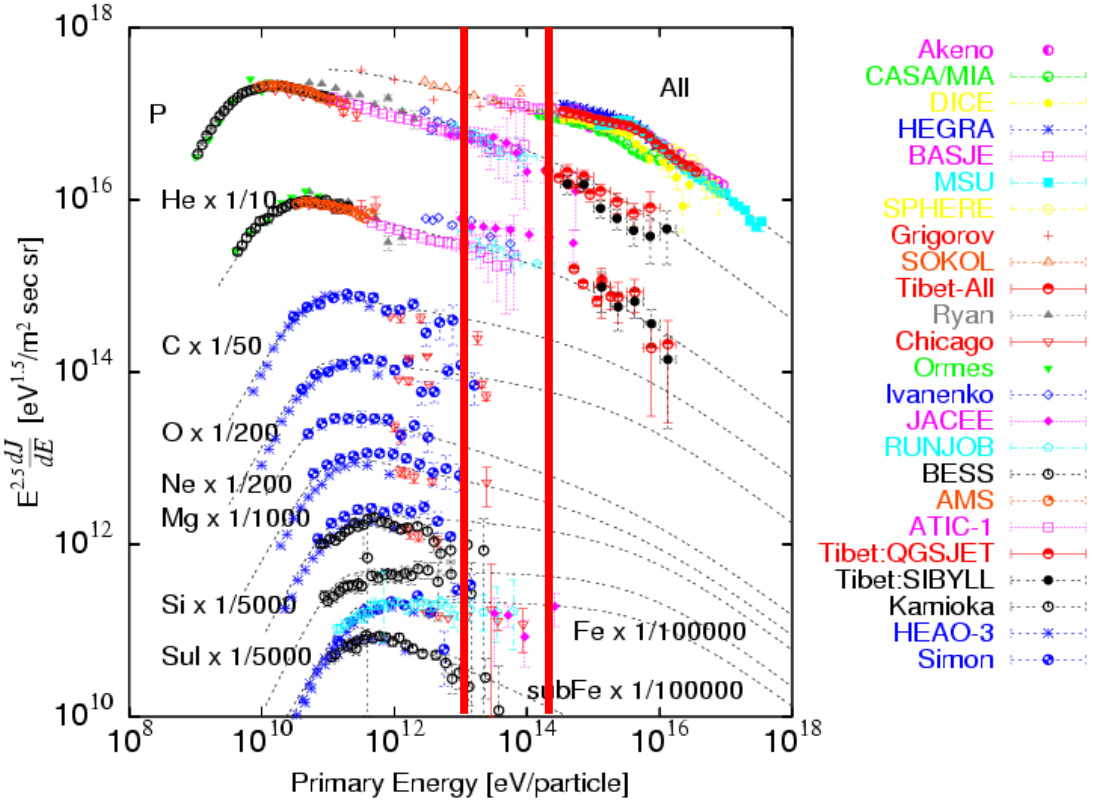






- SED: energy scale (calibration, interaction model), narrow
- Composition: inconsistency
- Anisotropy: poor statistics, confirmation

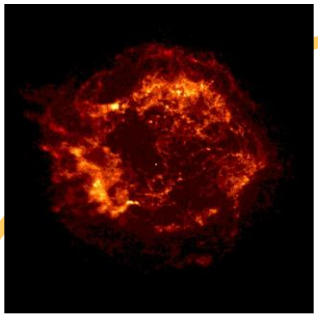
The Knee—a 50-year puzzle

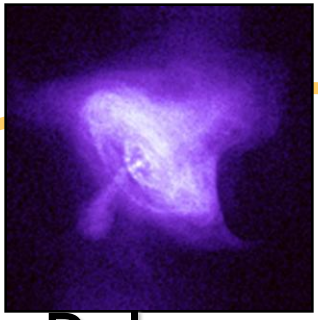


- Direct measurement (balloon & satellite) un-reachable
- Inconsistency in ground-based indirect measurements
  - Difficulty in composition identification (model dependent, poor measurement)
  - Energy scale

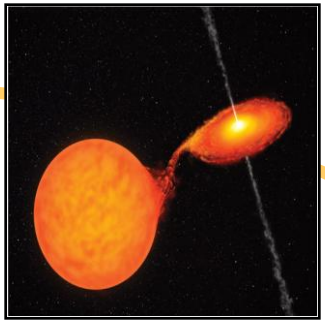
The VHE γ-ray Physics Program

SNRs
Origin of
Cosmic Rays

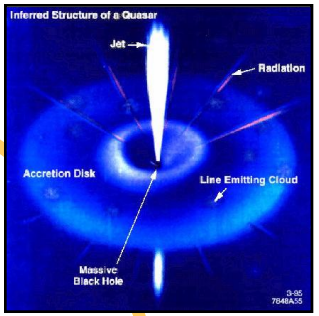




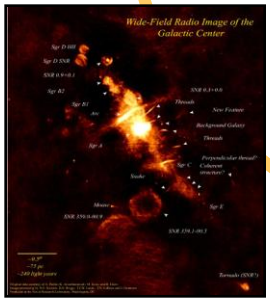
Pulsars



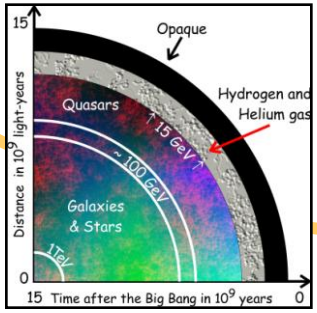
Microquasars



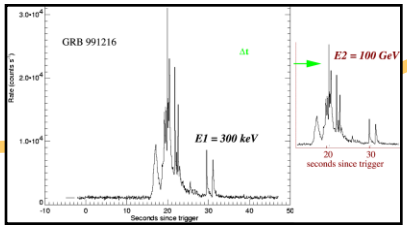
AGNs



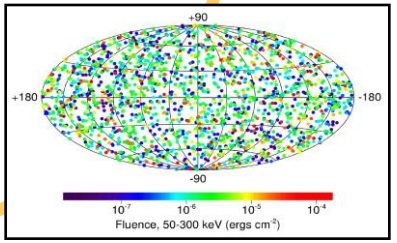
Cold Dark
Matter



cosmological
γ-Ray Horizon

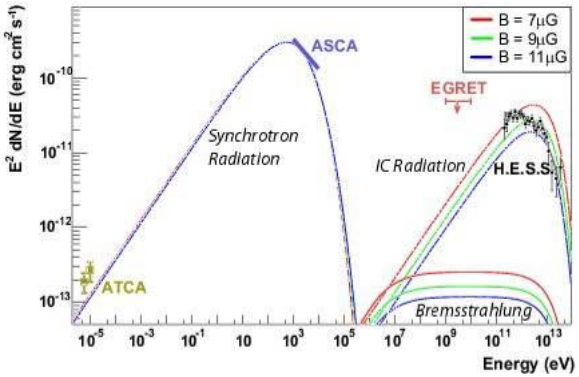


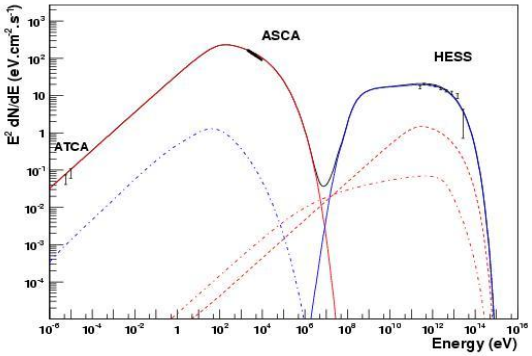
Test of the speed
of light invariance



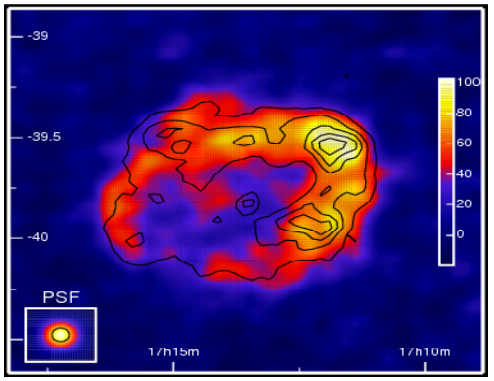
GRBs

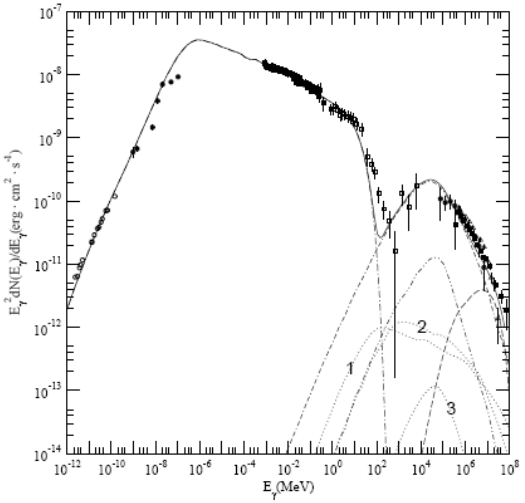
VHE γ astronomy—the first light

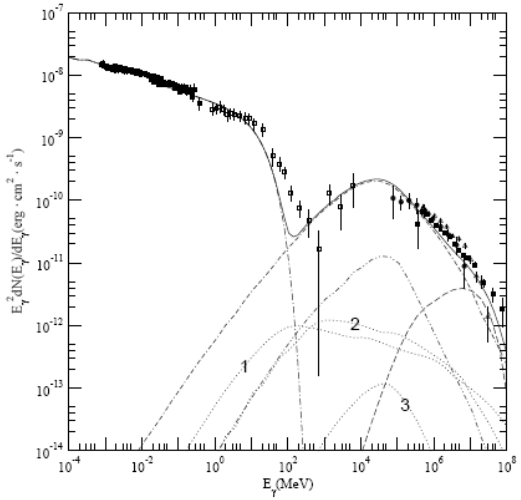




(Leptonic model) RXJ1713 (Hadronic model)



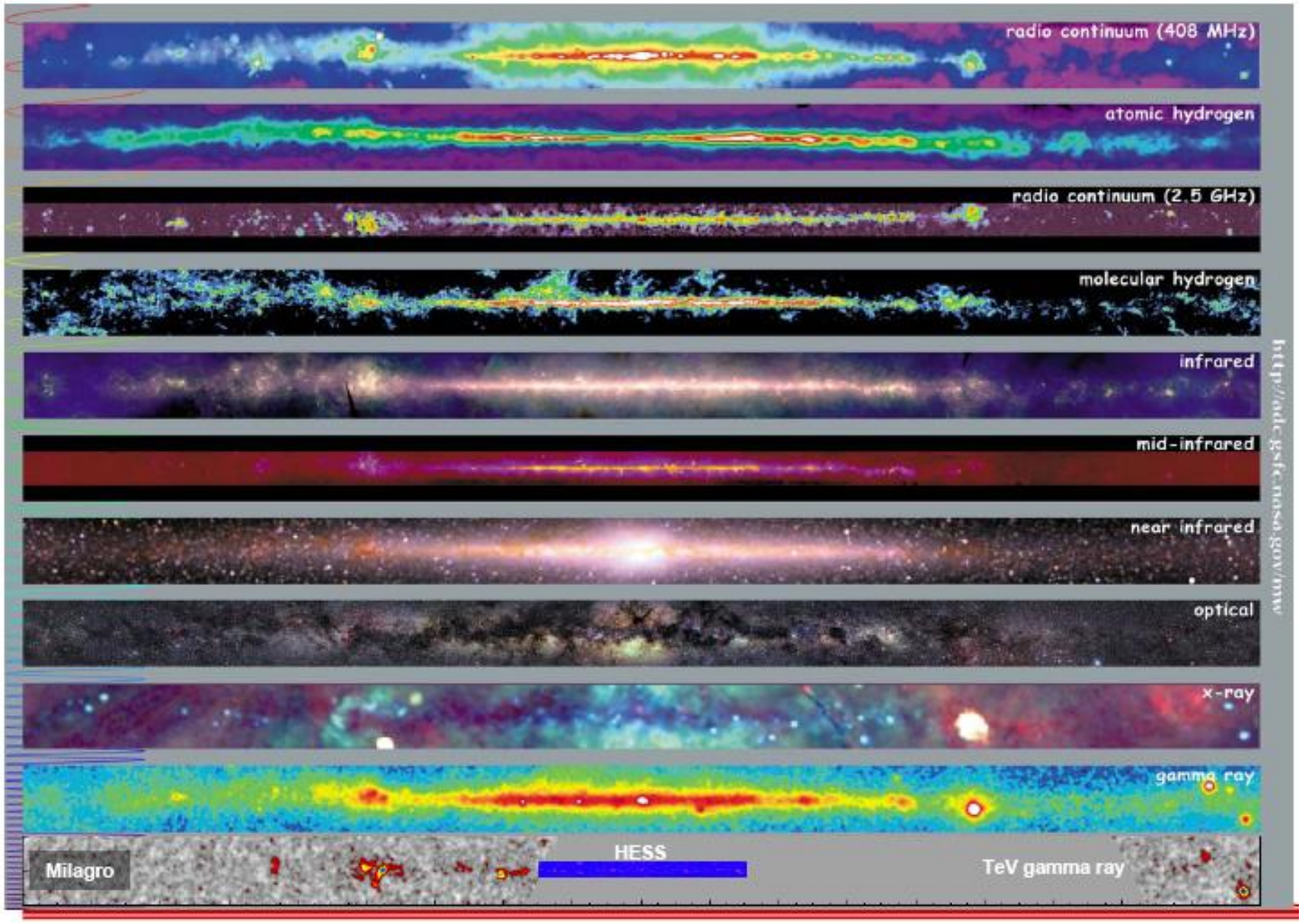




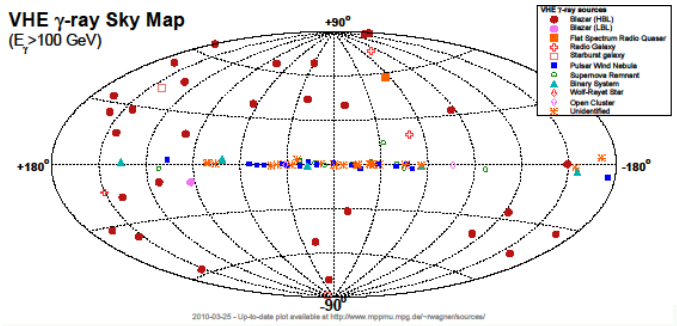
Standard candle Crab Nebula

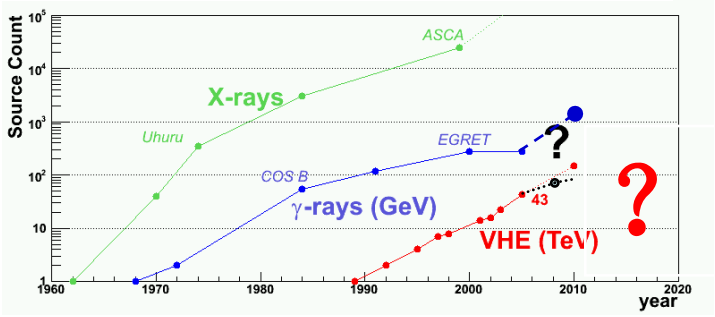
- **hadronic/electronic?**
  - **SED@100TeV**
  - **SED@10GeV**
  - **morphology**

TeV γ Rays: New Window on the Sky

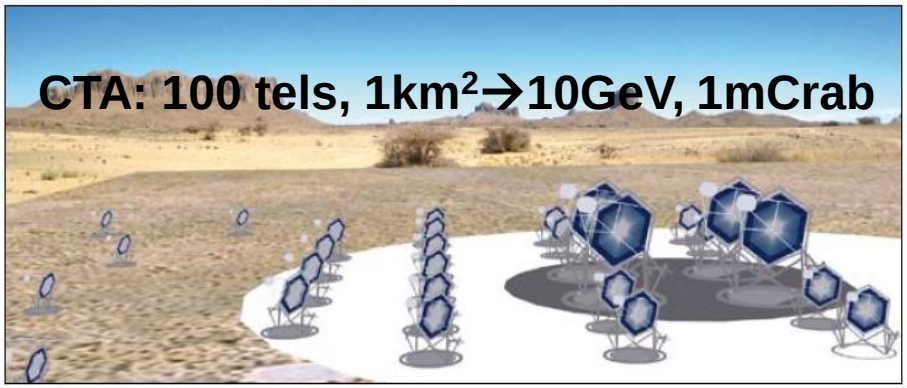


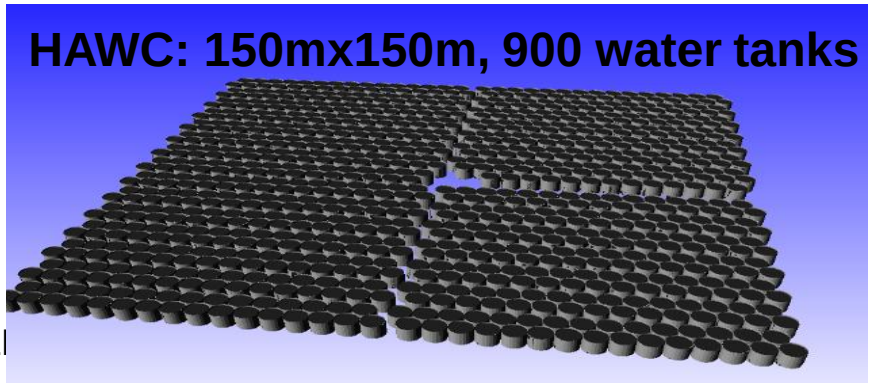
VHE γ ray astronomy
success of IACTs and the bottleneck





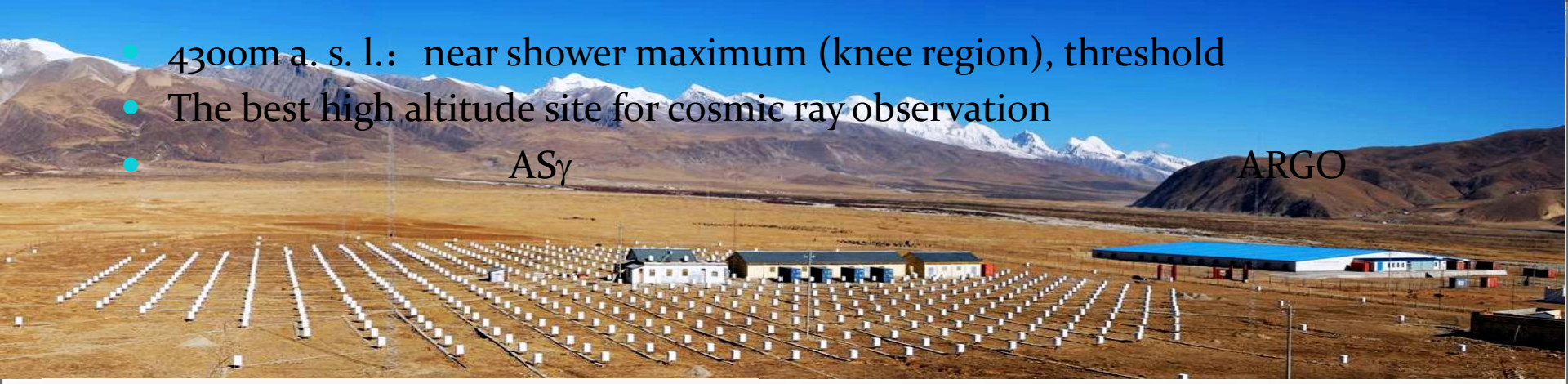
- ~100 VHE γ ray sources
  - Galactic: 60 (after 2009: 3)
  - extra-galactic: 38 (after 2009: 16)
- ➢ FOV, duty cycle (10%)
- ➢ Full duty cycle, full sky survey
- ➢ Lower threshold, higher sensitivity

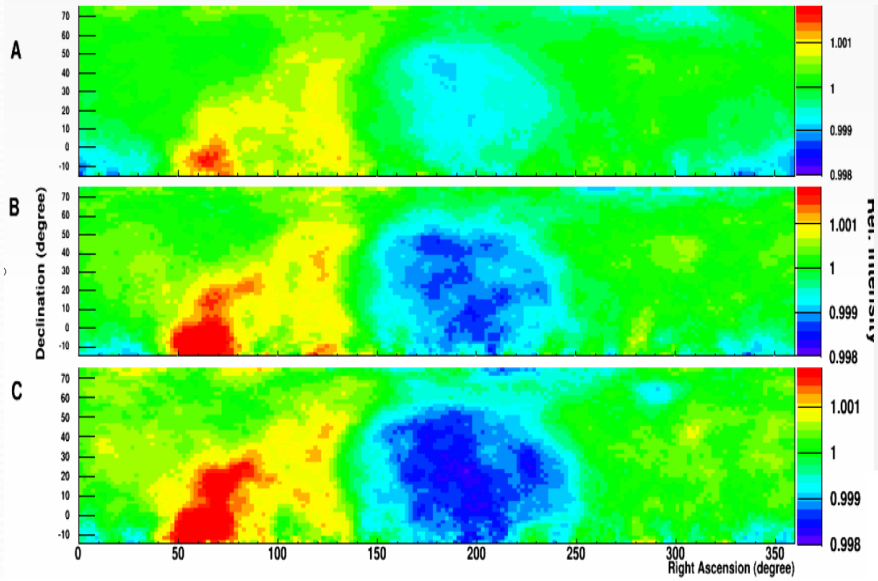


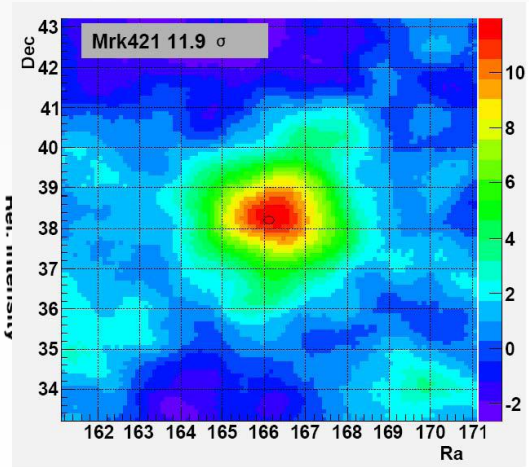


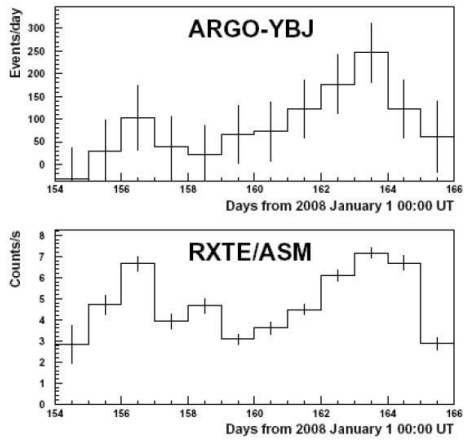
@LI

- 4300m a. s. l.: near shower maximum (knee region), threshold
- The best high altitude site for cosmic ray observation
- ASγ ARGO

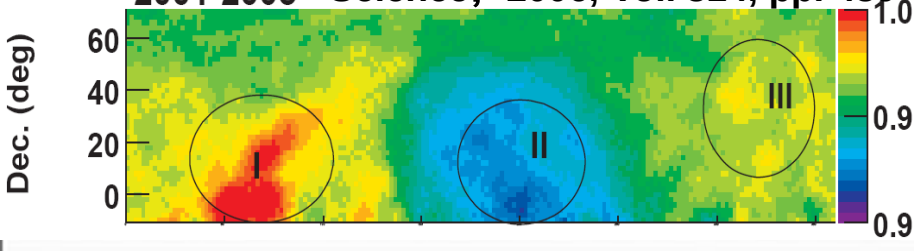


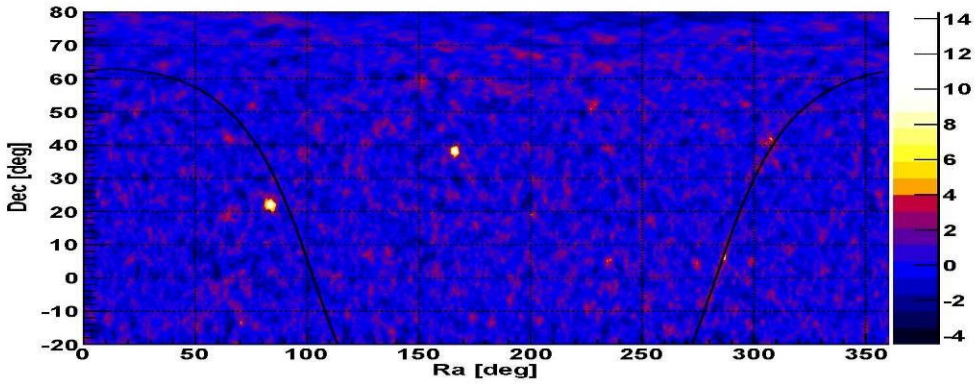




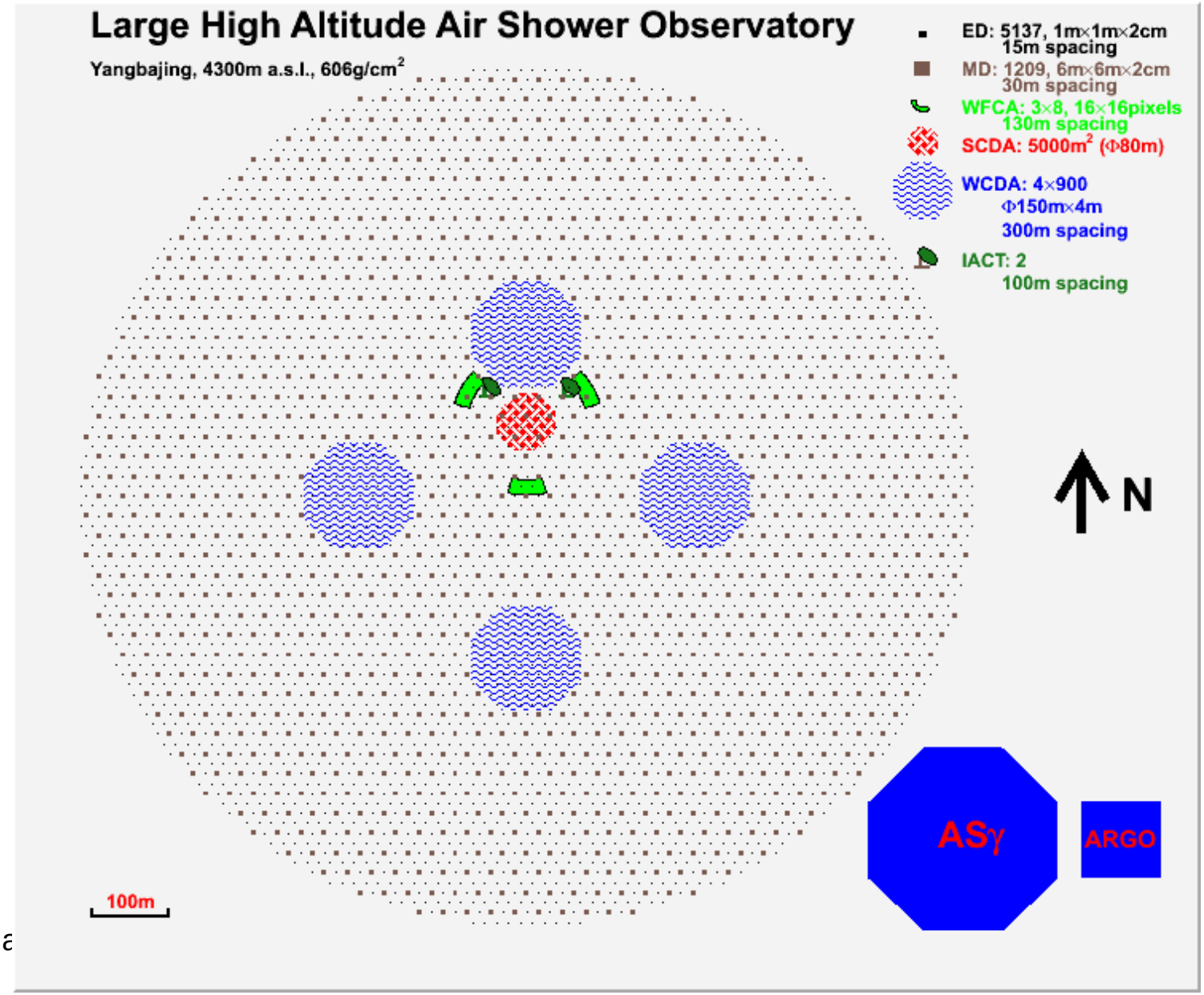


2001-2005 Science, 2006, Vol. 314, pp. 439





LHAASO project—12th “5-year plan”



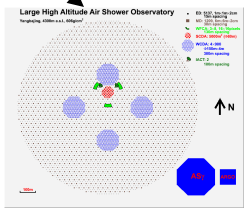
Cost Free high energy (1EeV) extension

Re-Configuration

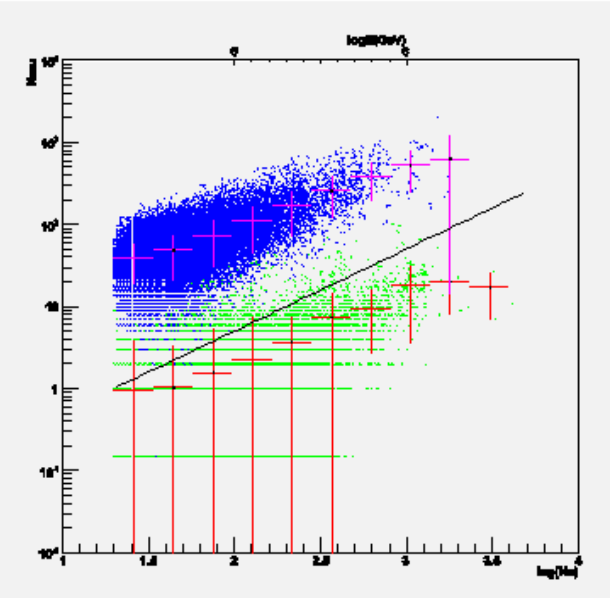
Tower CT: 16

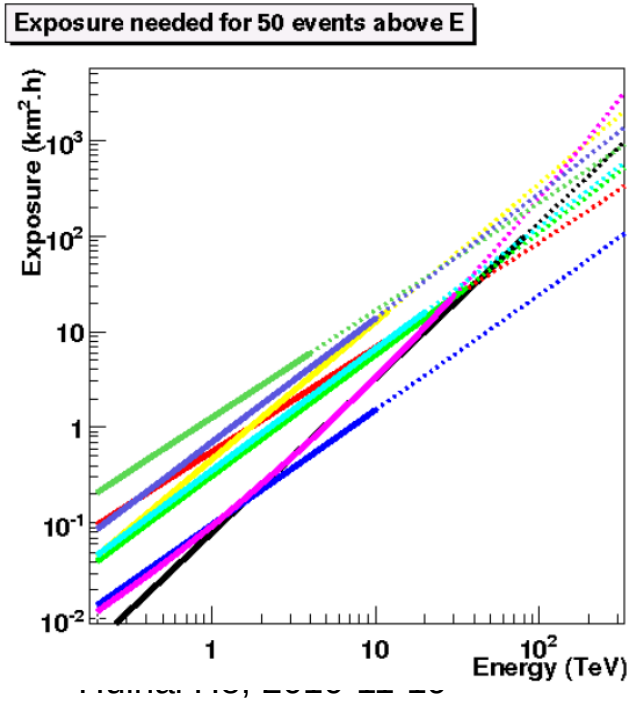
μ : 40000m^2

Side Trigger CT: 2x4



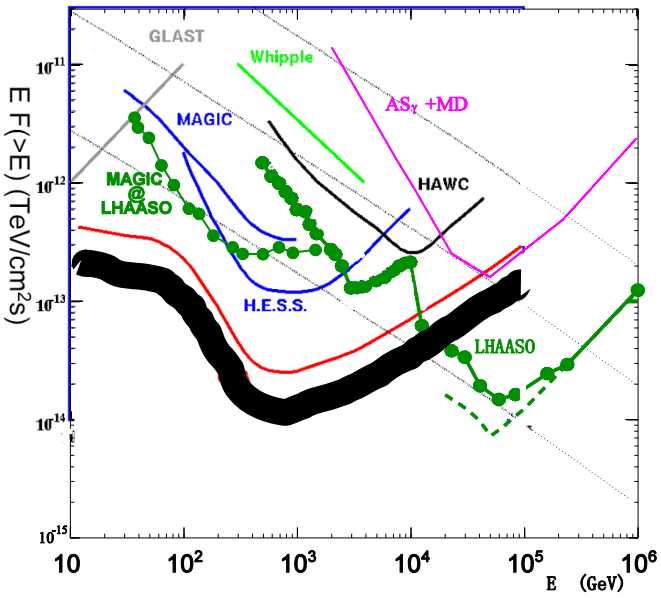
- **40,000m² μ detector: p/γ**
  - >50TeV CR BG-free(10^{-5})
  - γ survival ~99%



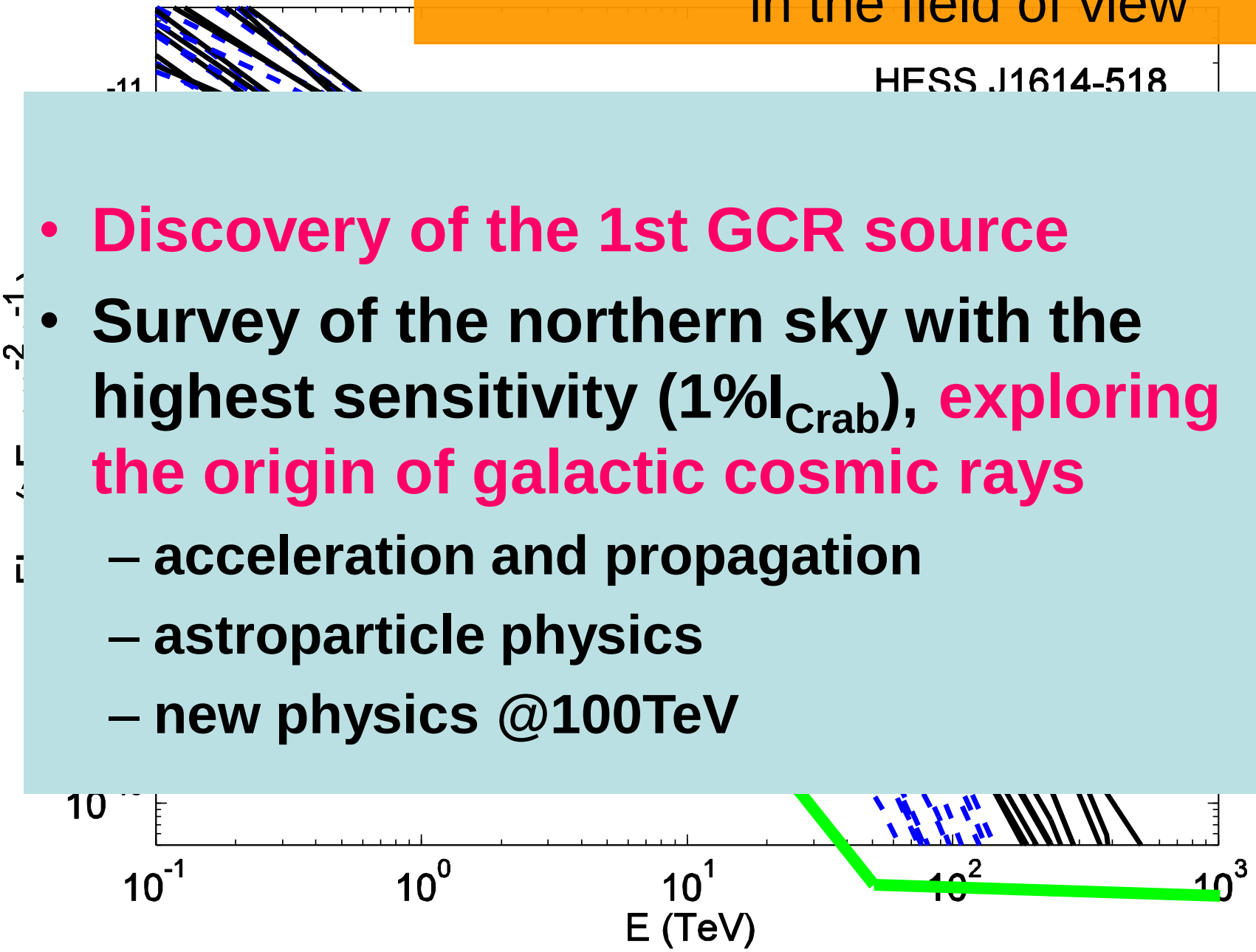


exposure/year

- **LHAASO ~1500km²h (survey)**
- **CTA ~100km²h (pointing)**

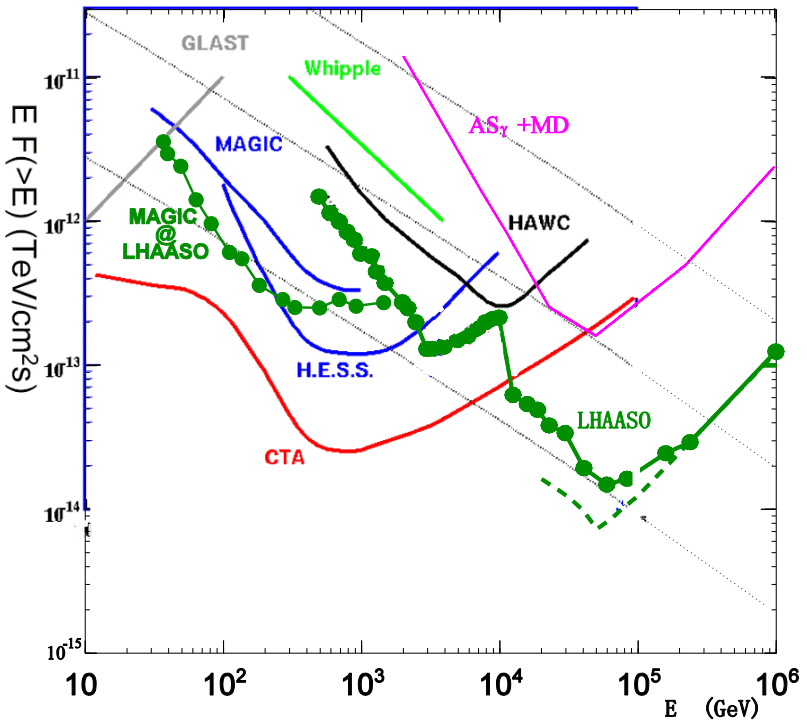


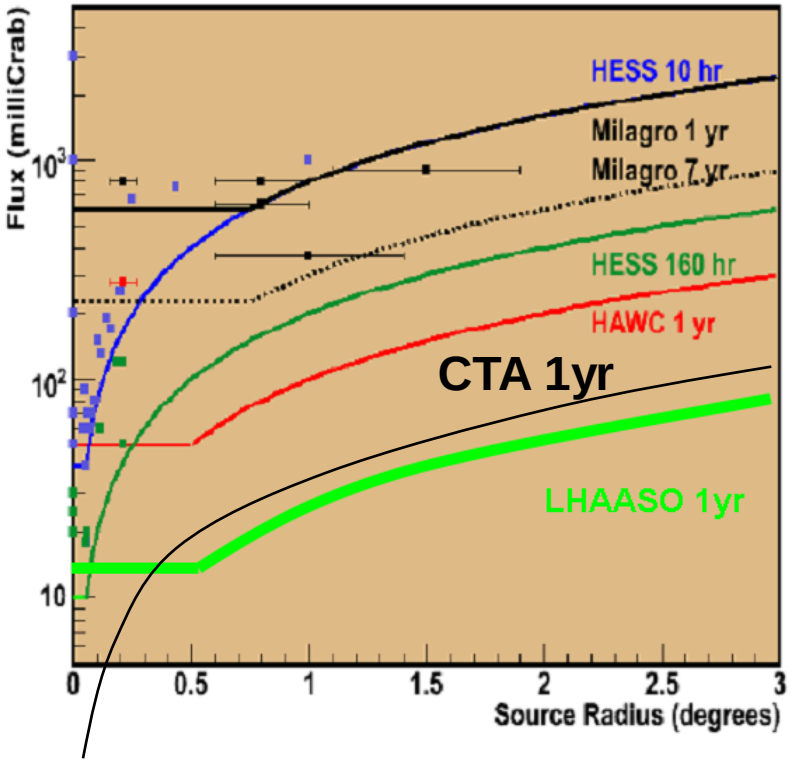
Expectation: if HESS sources are in the field of view



- **Discovery of the 1st GCR source**
- **Survey of the northern sky with the highest sensitivity (1%I_{Crab}), exploring the origin of galactic cosmic rays**
  - **acceleration and propagation**
  - **astroparticle physics**
  - **new physics @100TeV**

Survey of the VHEγ ray sky

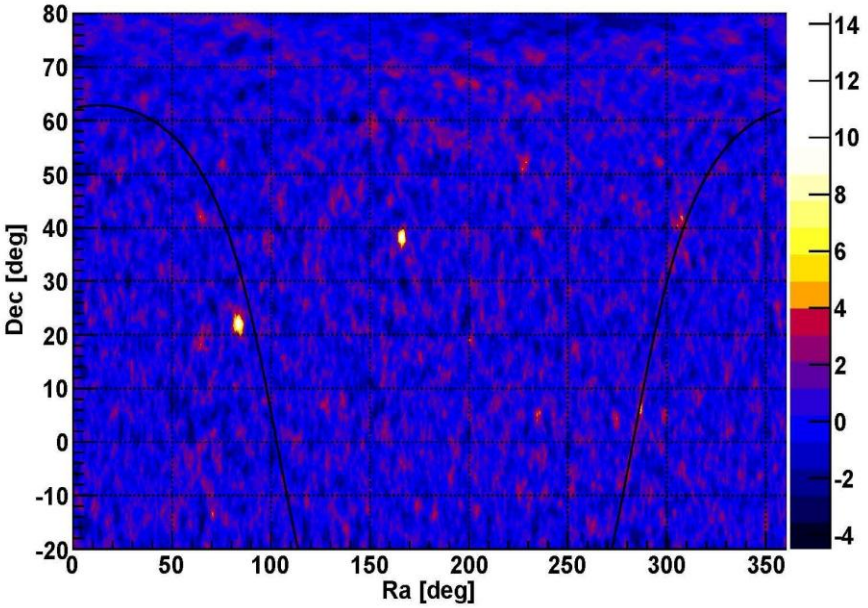


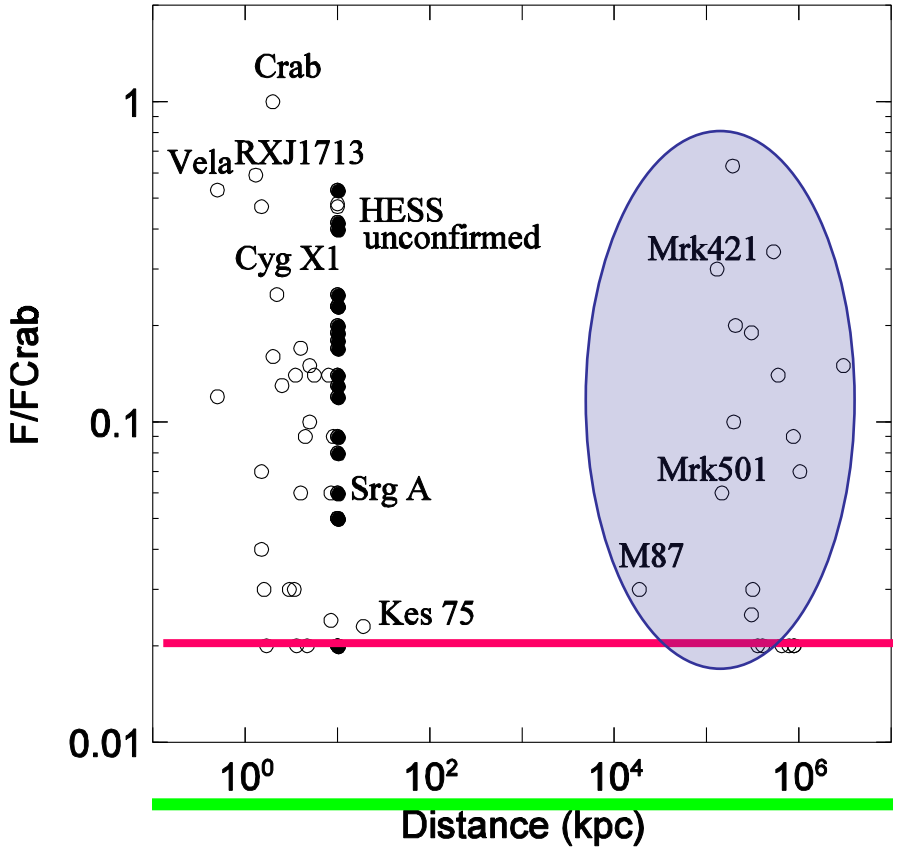


LHAASO@TeV Sky Survey

- **Discover >1000 VHEγ sources (transient, extended)**

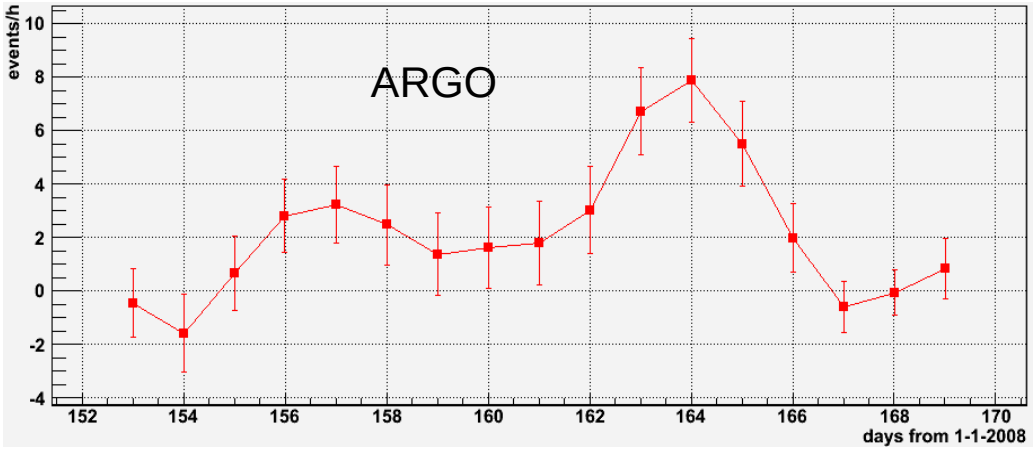
ARGO sky map in 3 years
LHAASO one day!

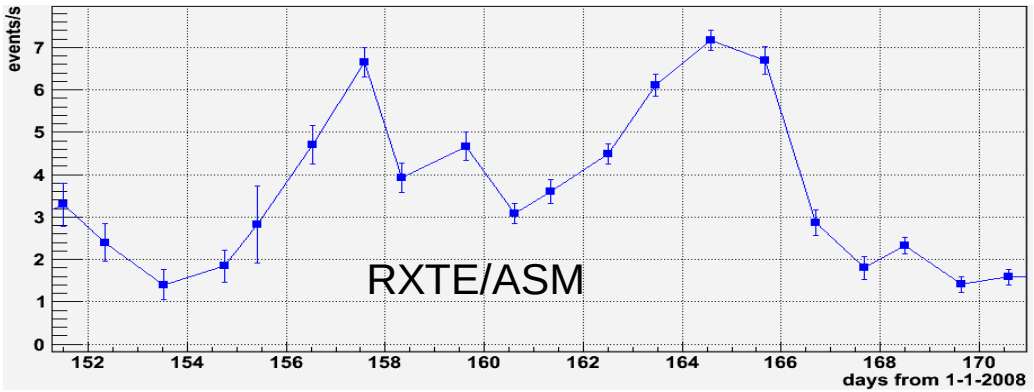




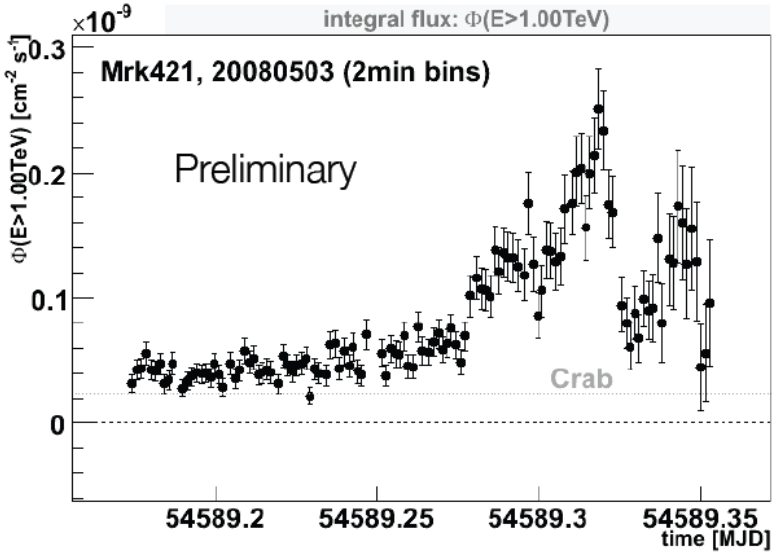
LHAASO@Transient sources

- Real time alarm
- Light curve: day→minute



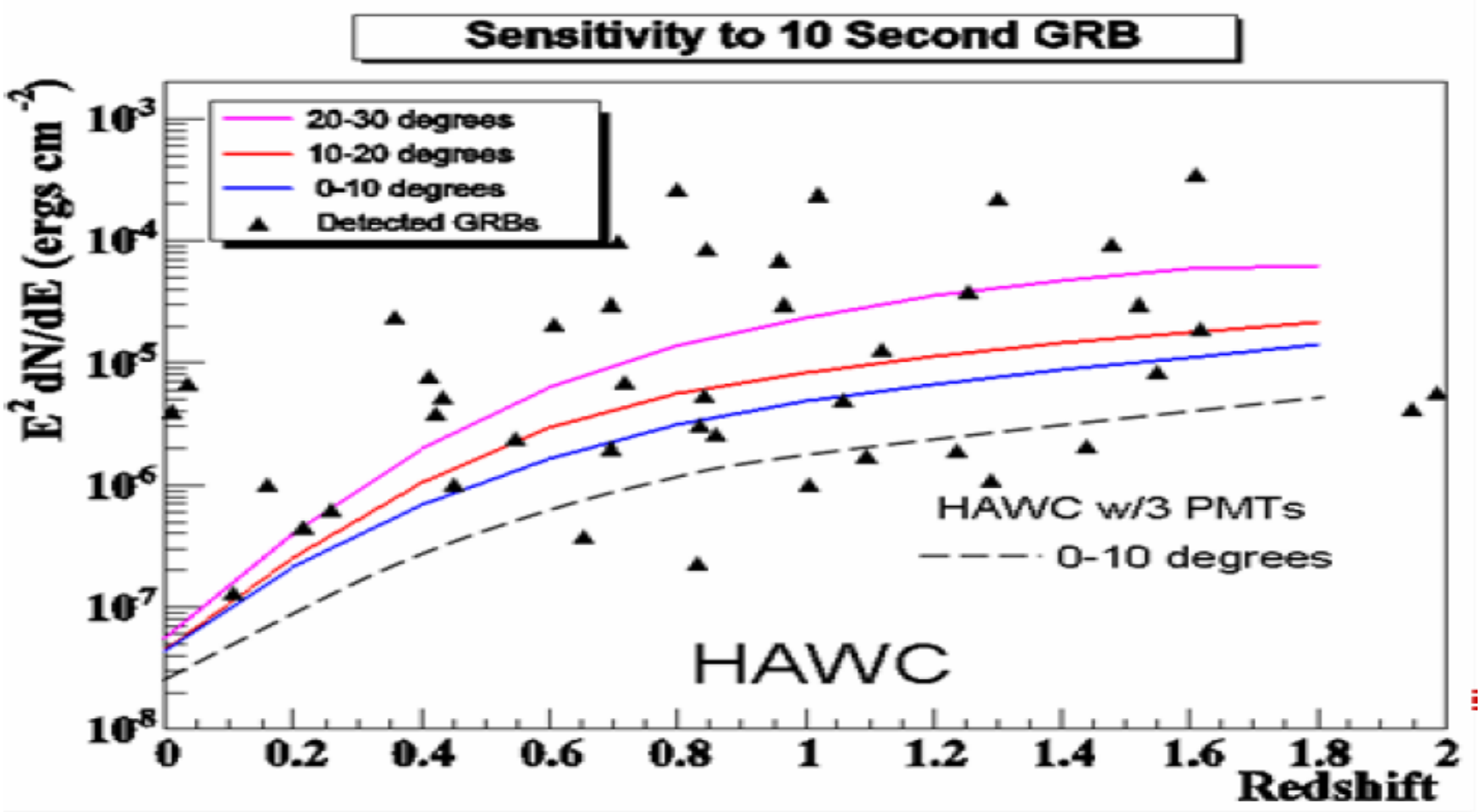


Whipple+VERYTAS



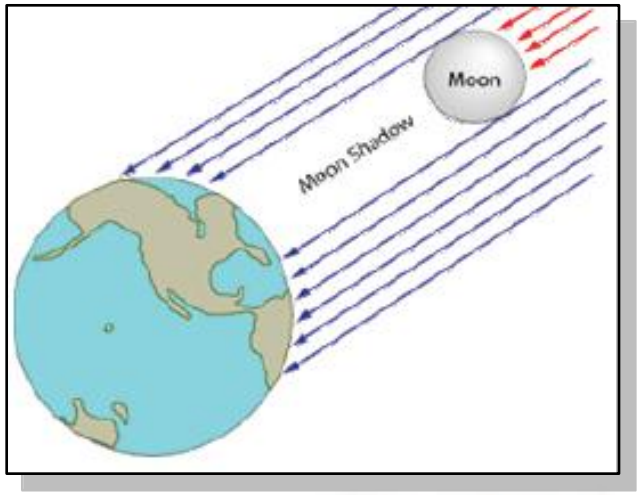
Mrk421

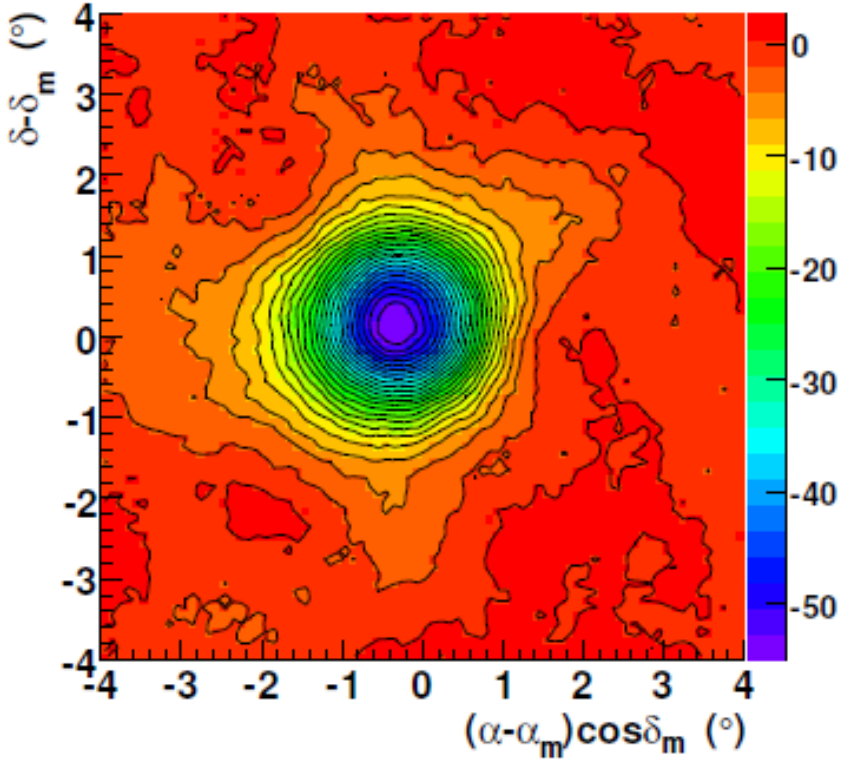
LHAASO@GRB

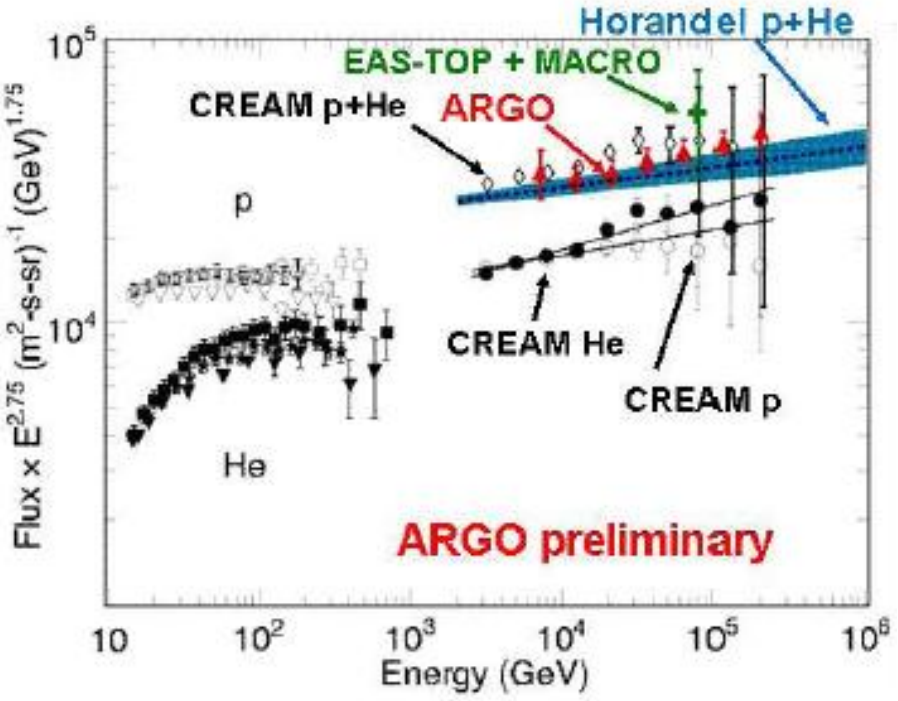

Sensitivity to 10 Second GRB
20-30 degrees
10-20 degrees
0-10 degrees
Detected GRBs
HAWC w/3 PMTs
0-10 degrees
HAWC
E² dN/dE (ergs cm⁻²)
Redshift
10³
10⁴
10⁵
10⁶
10⁷
10⁸
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Anchoring the energy scale @5TeV

- Moon shadow



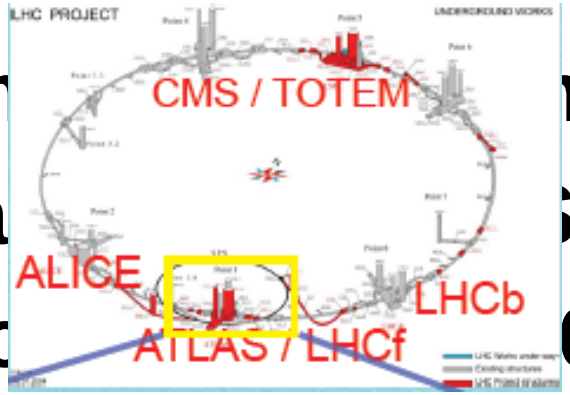


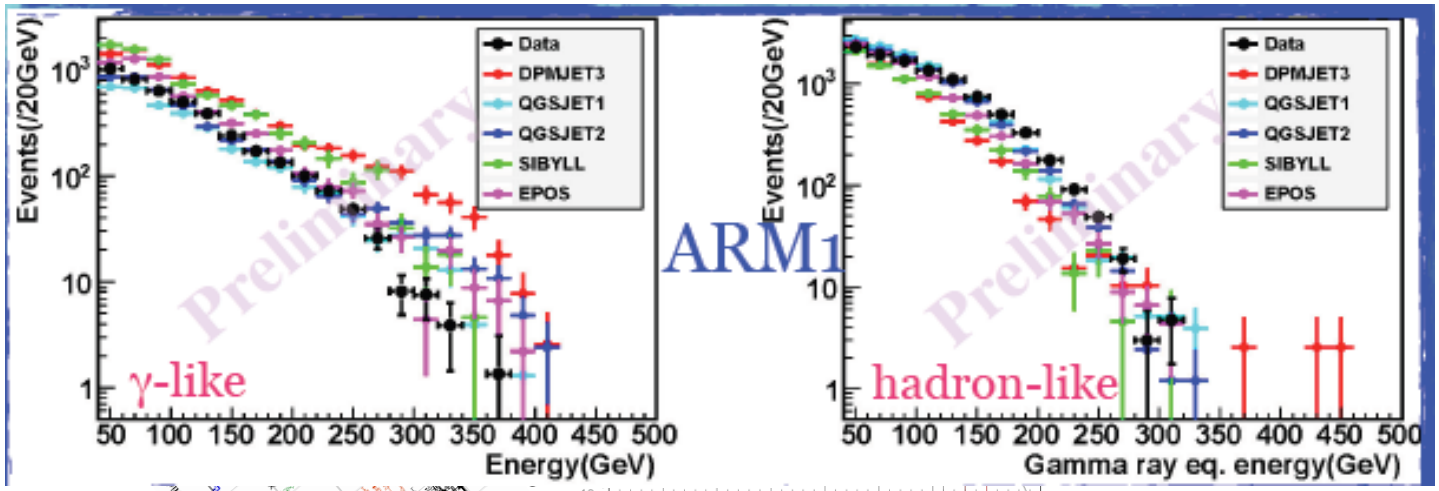


LHAASO@Cosmic ray: >=Knee

---the widest energy coverage

- Multiple paran muon, Xmax)
- Accurate mea ED
- Wide energy c 0^{12}-10^{18}eV)

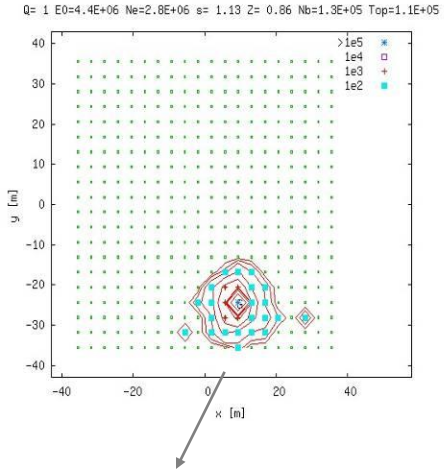




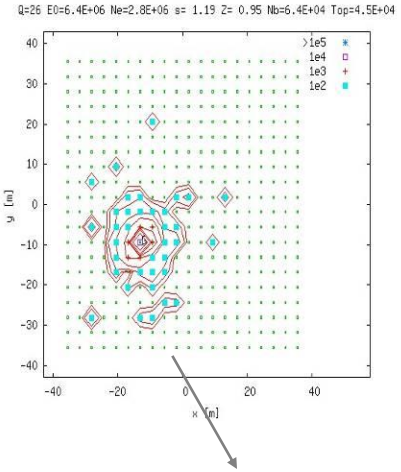
Resolution for light and heavy compositions

μ -content, Xmax and HE (>30TeV) shower particles

Proton



Iron

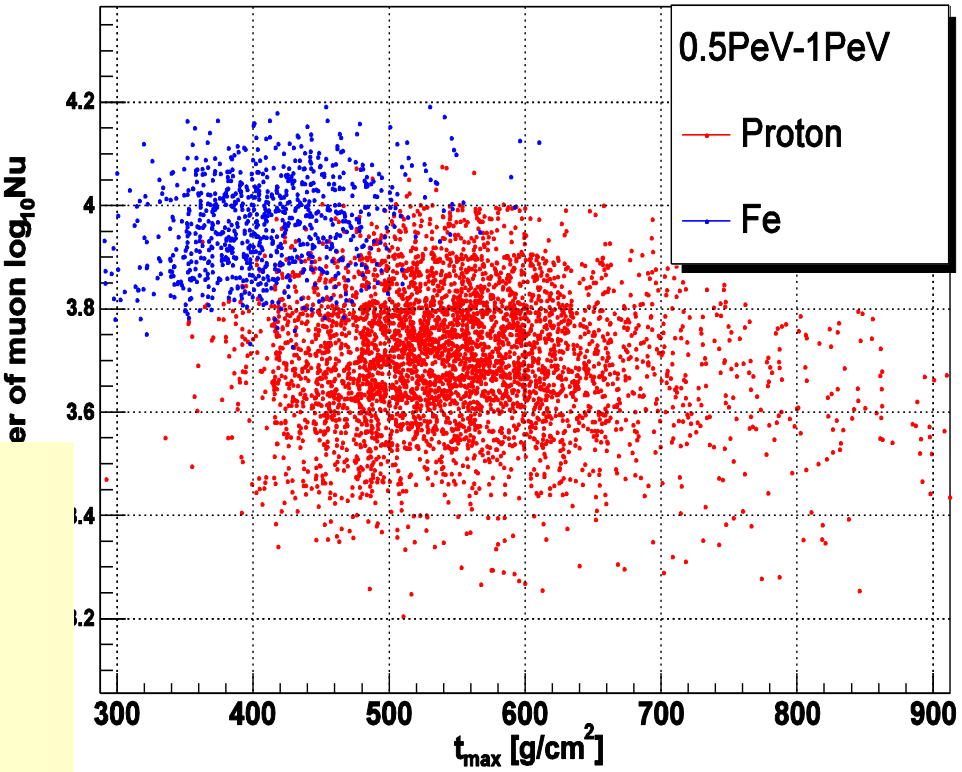


For Proton and Helium:

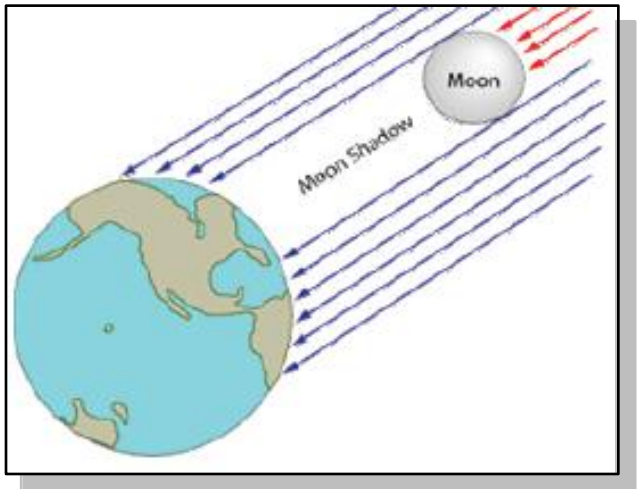
- 1.5 m spacing
- Nb>100 , any 5 (> 30 GeV)

For Iron:

- 3.75m spacing
- Nb>100 , any 21 (> 30 GeV)



LHASSO@anti-matter: CRs blocked by the Moon



Calibration of the ARGO-YBJ detector

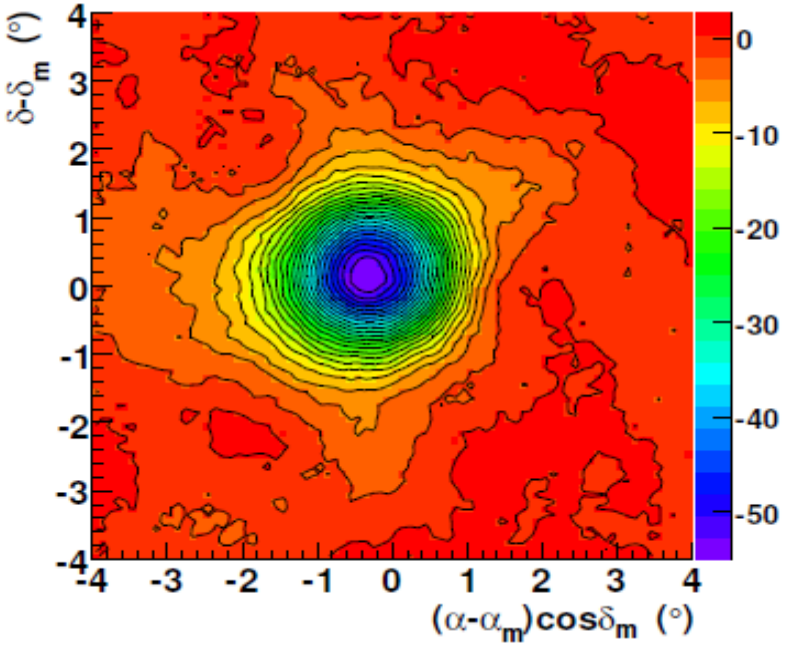
Energy scale, angular resolution and pointing direction

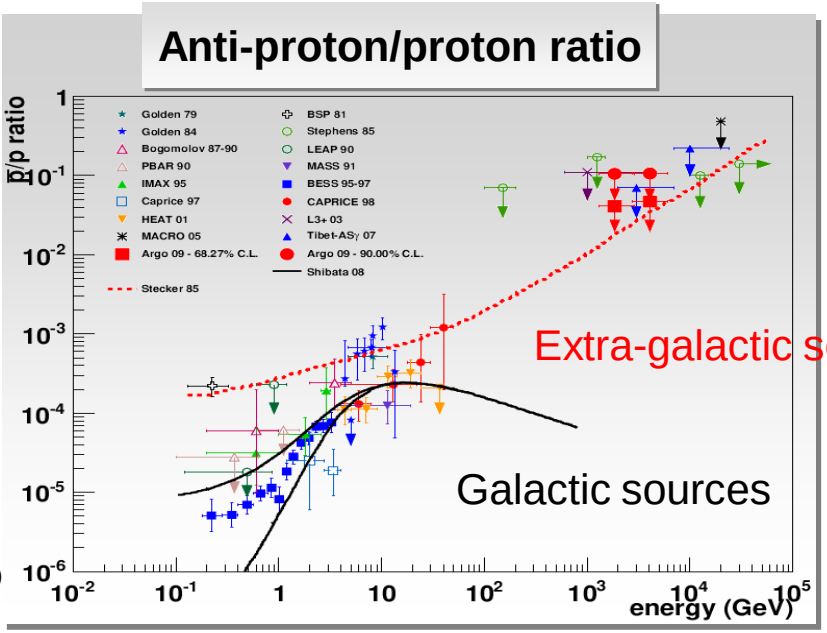
July 2006 to Dec 2008: 2063 hrs

significance：43σ

Pointing error: ~0.2°

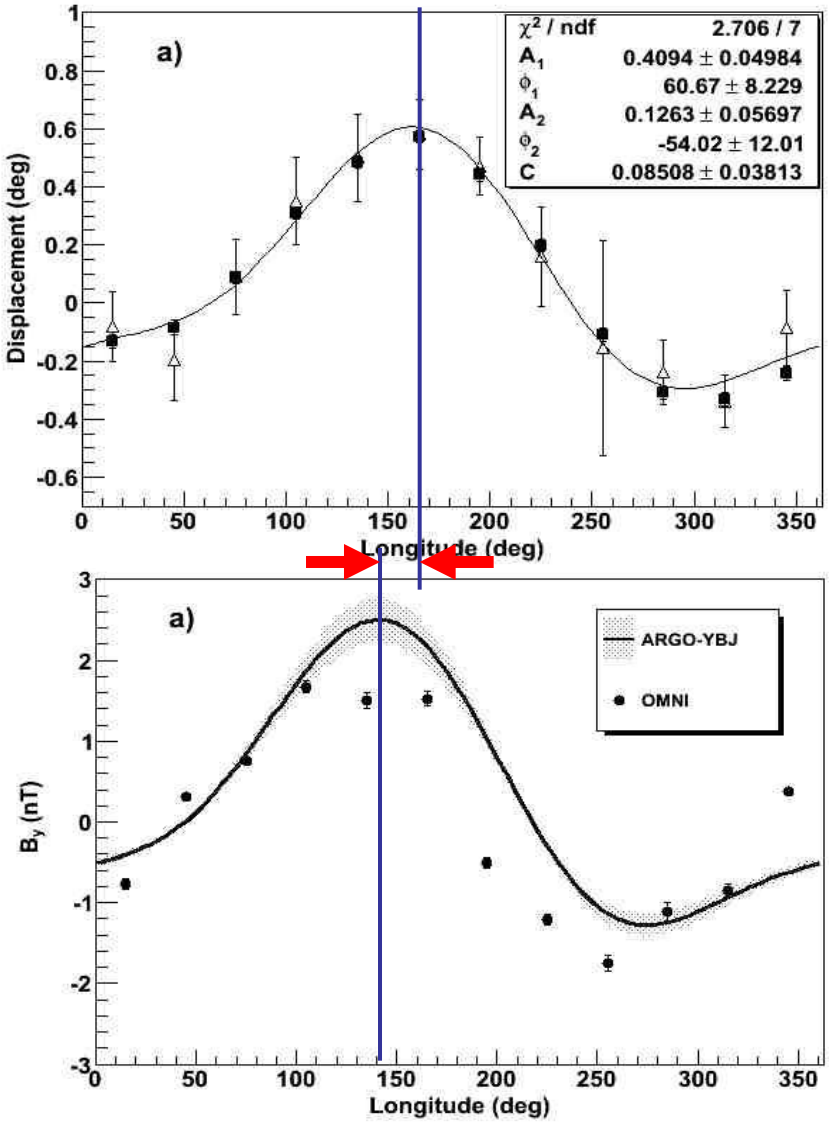
Resolution: 0.5° (E>1TeV)

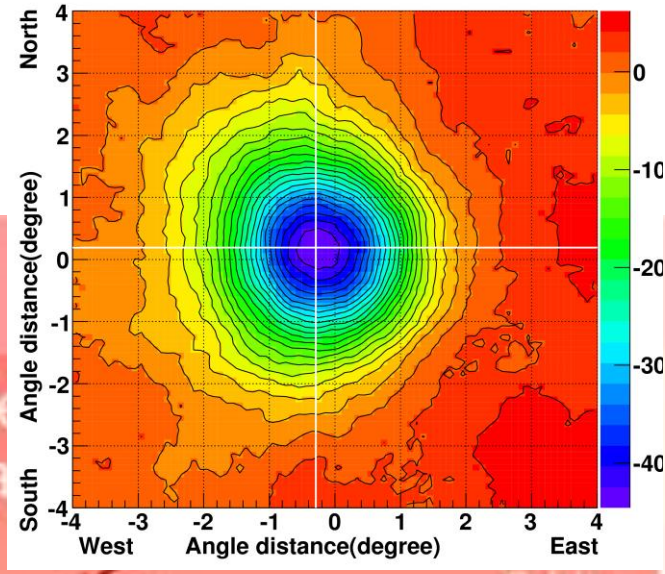




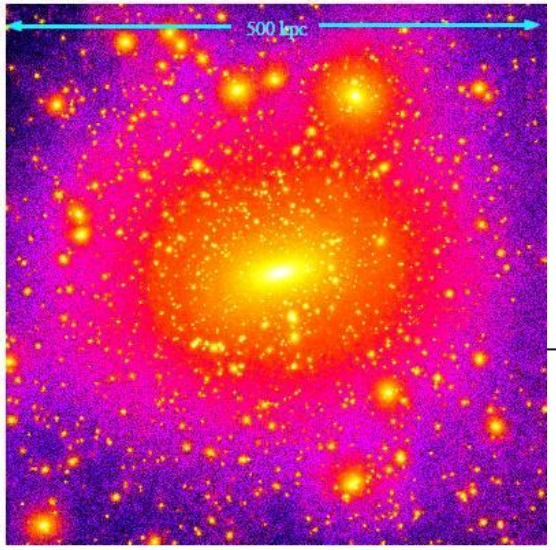
Solar activity

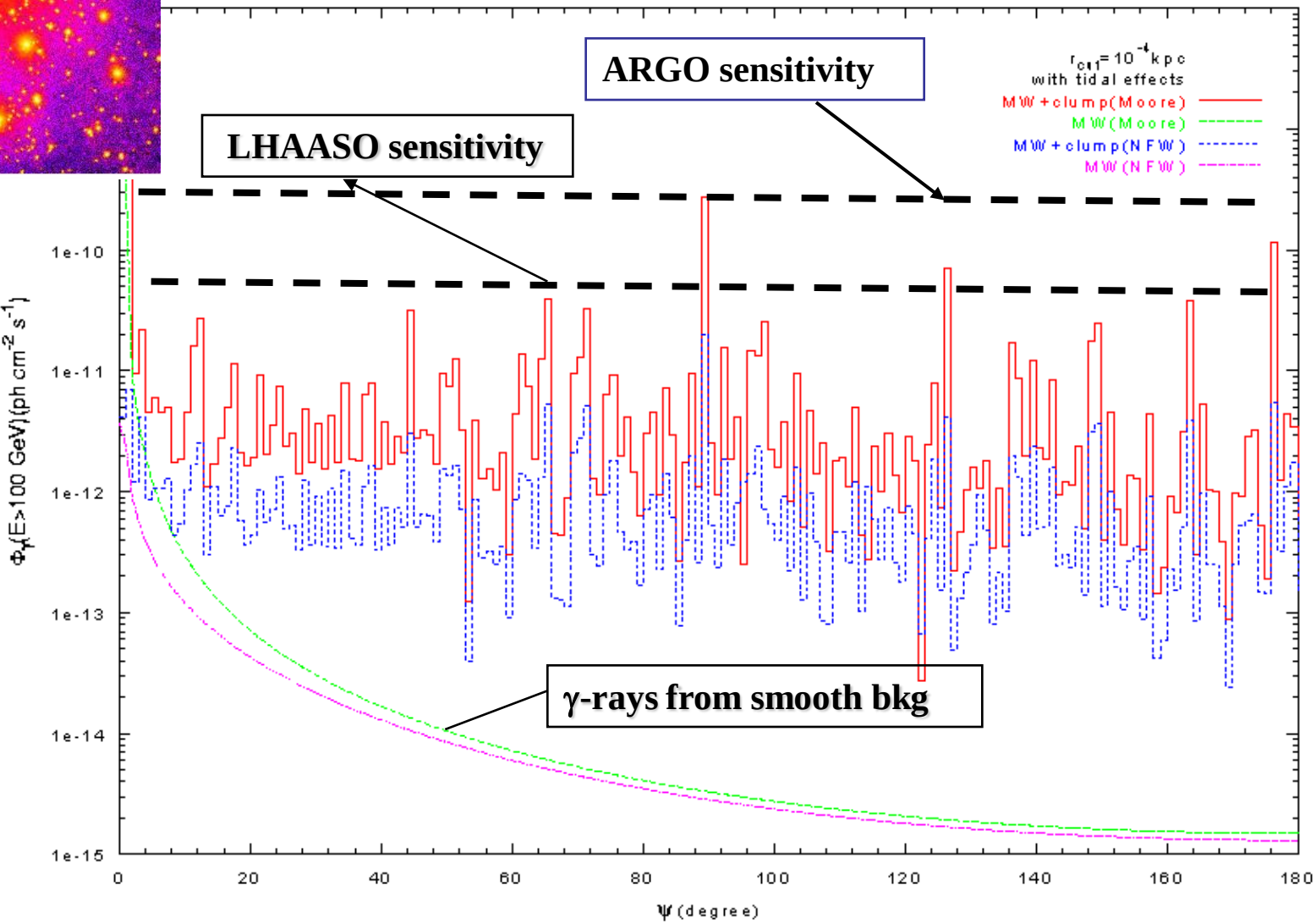
---forecast magnetic storms





Dark Matter γ-rays from the sub-halos



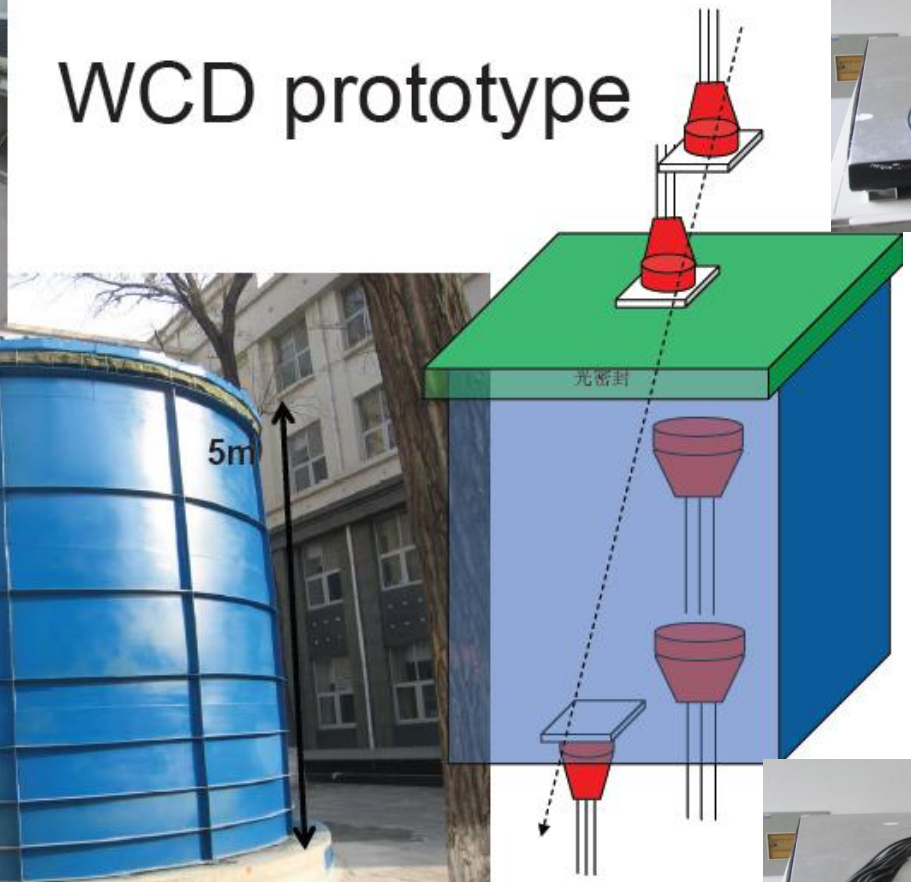


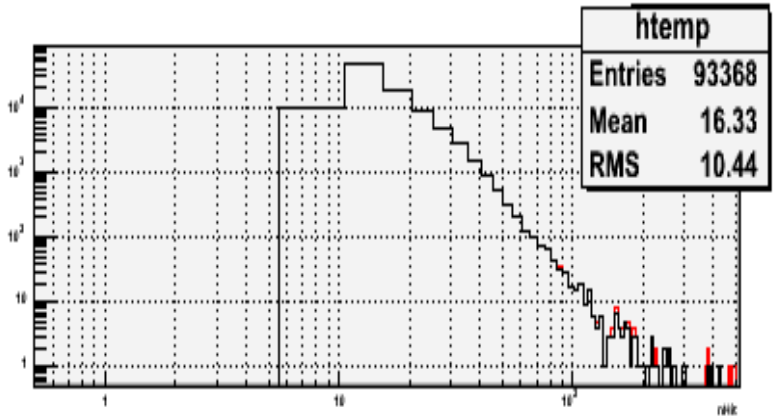
Huihai He, 201

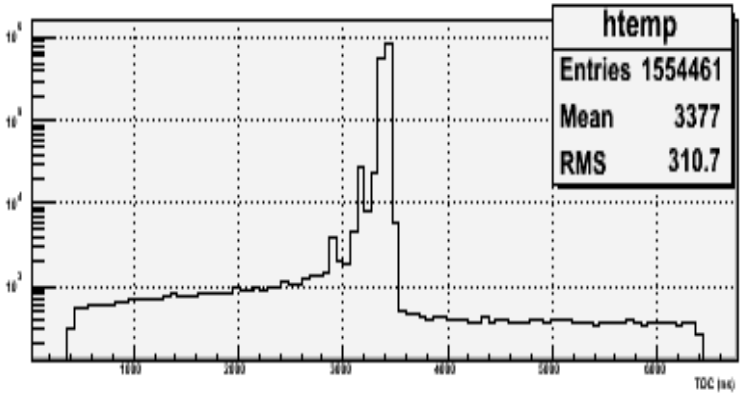
LHAASO

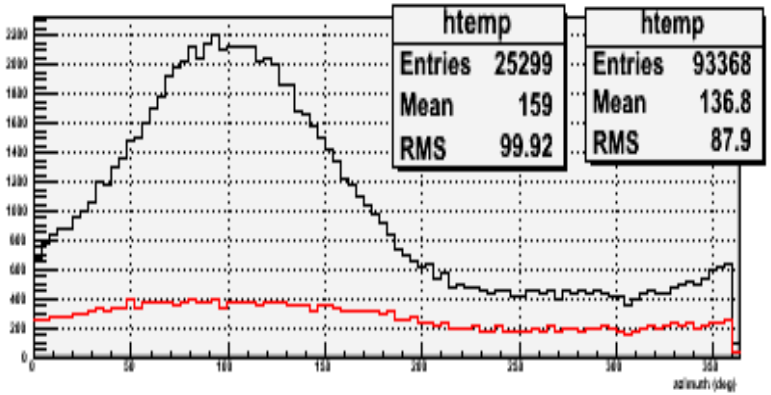
Detector prototypes

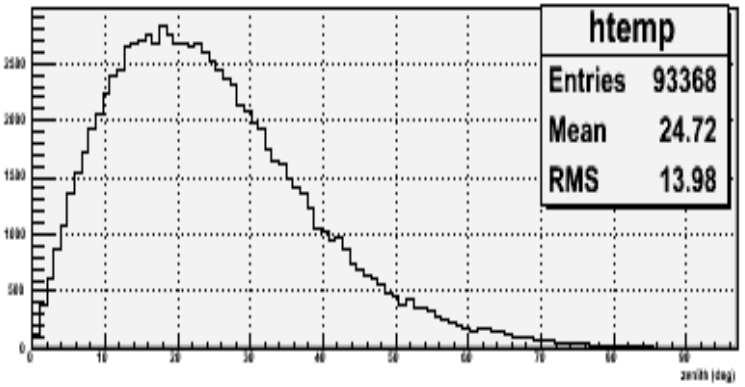
KM2A prototype




htemp
Entries 93368
Mean 16.33
RMS 10.44


htemp
Entries 1554461
Mean 3377
RMS 310.7


htemp
Entries 25299
Mean 159
RMS 99.92
htemp
Entries 93368
Mean 136.8
RMS 87.9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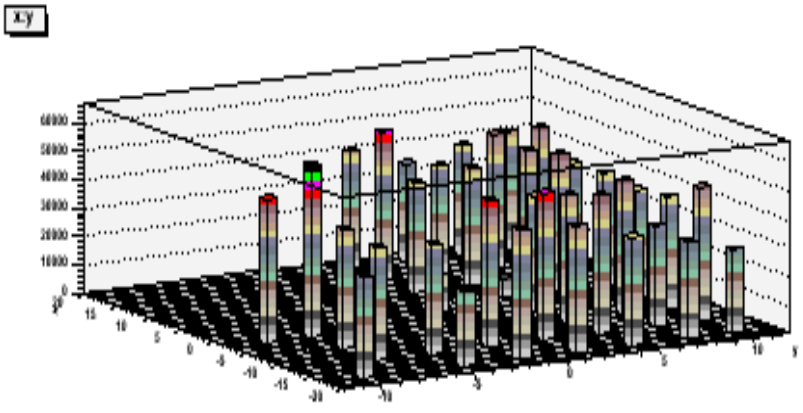
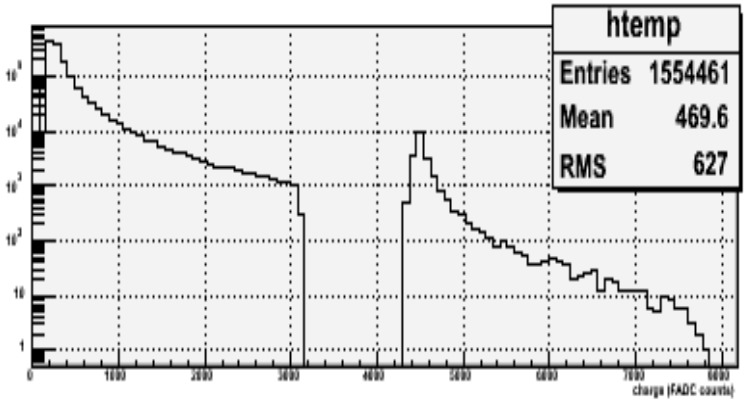
Entries 93368
Mean 24.72
RMS 13.98


x_y

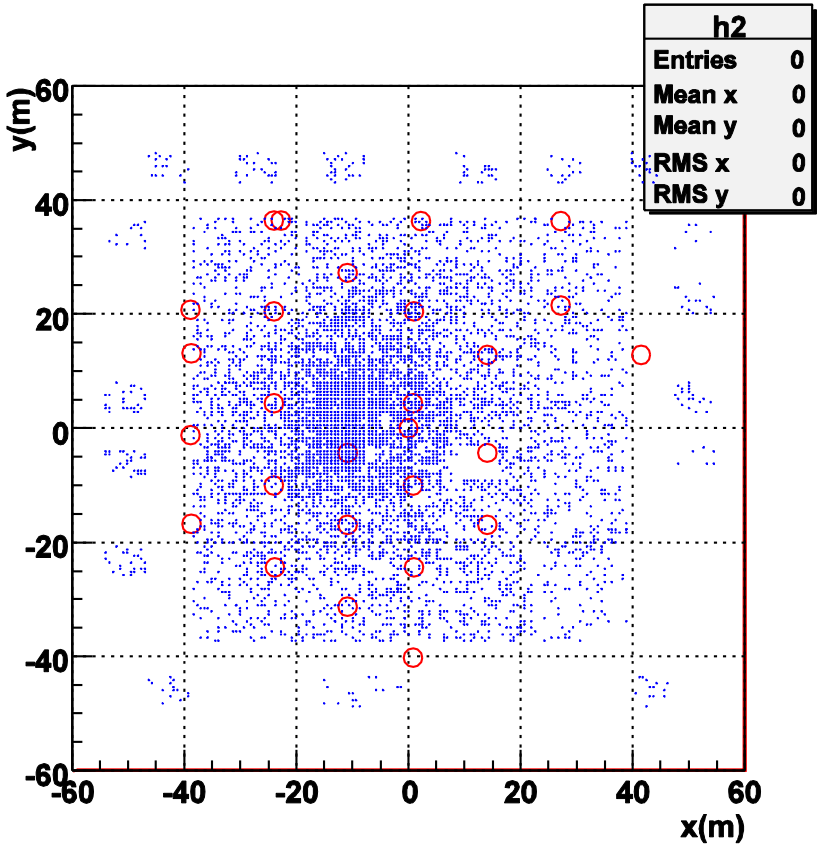

htemp
Entries 1554461
Mean 469.6
RMS 627

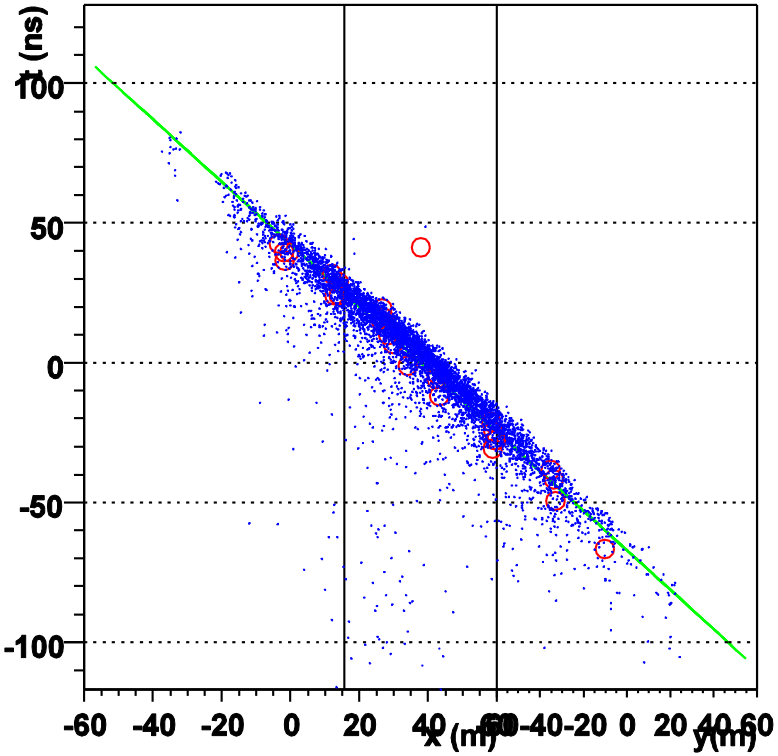
Prototype of WCD at YBJ site

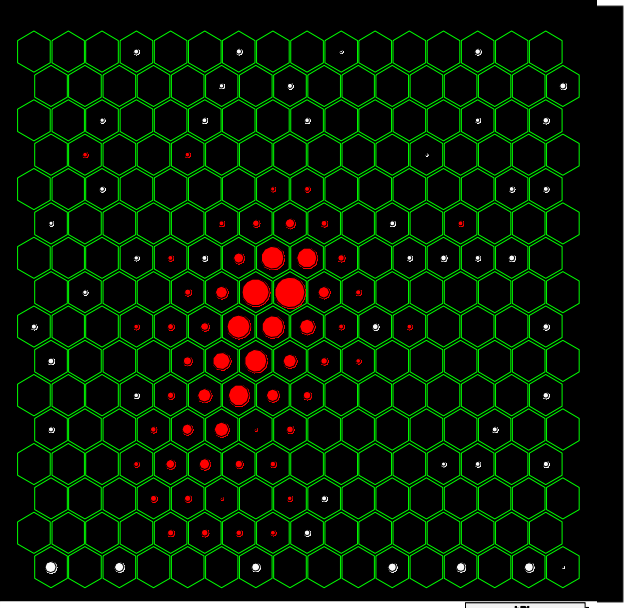
GO

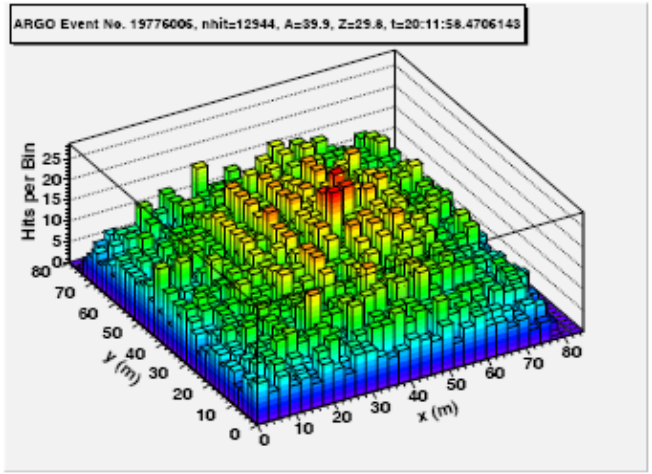
μ

Engineering array on site





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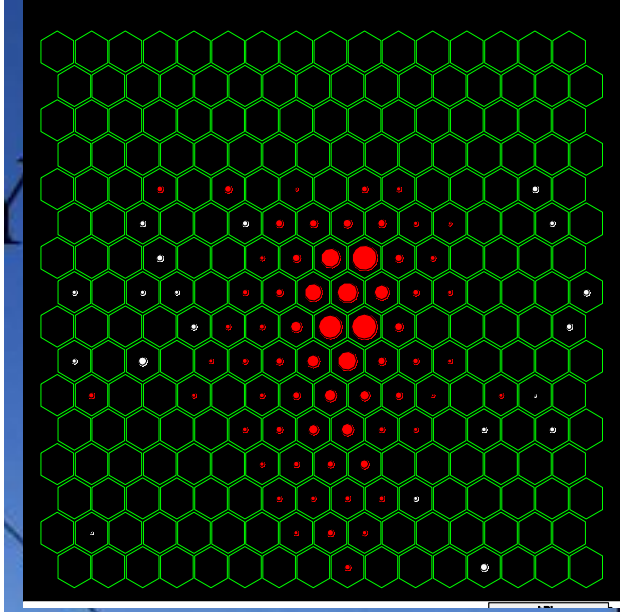
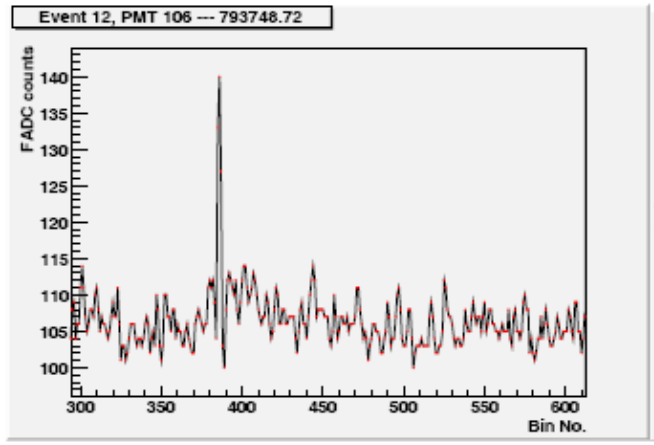
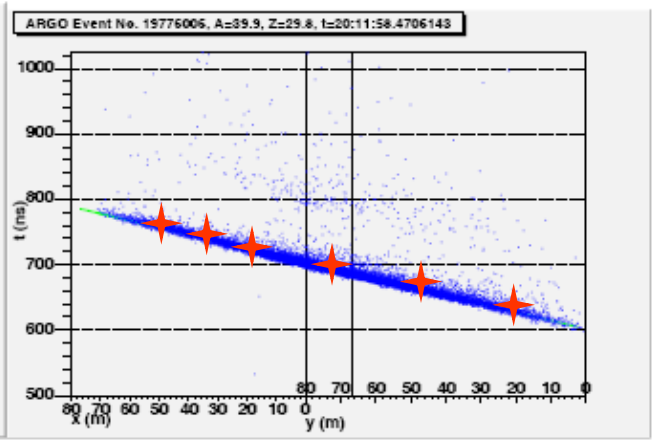
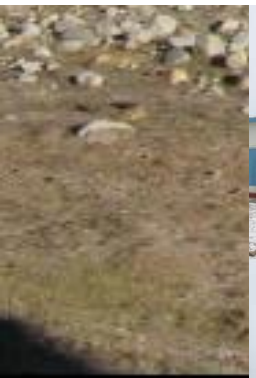
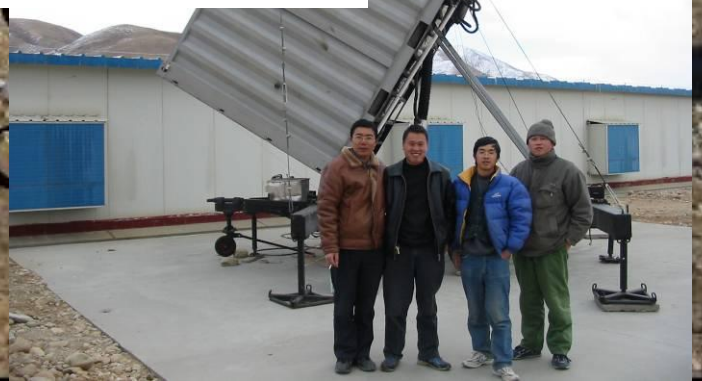
Hits per Bin
x (m)
y (m)



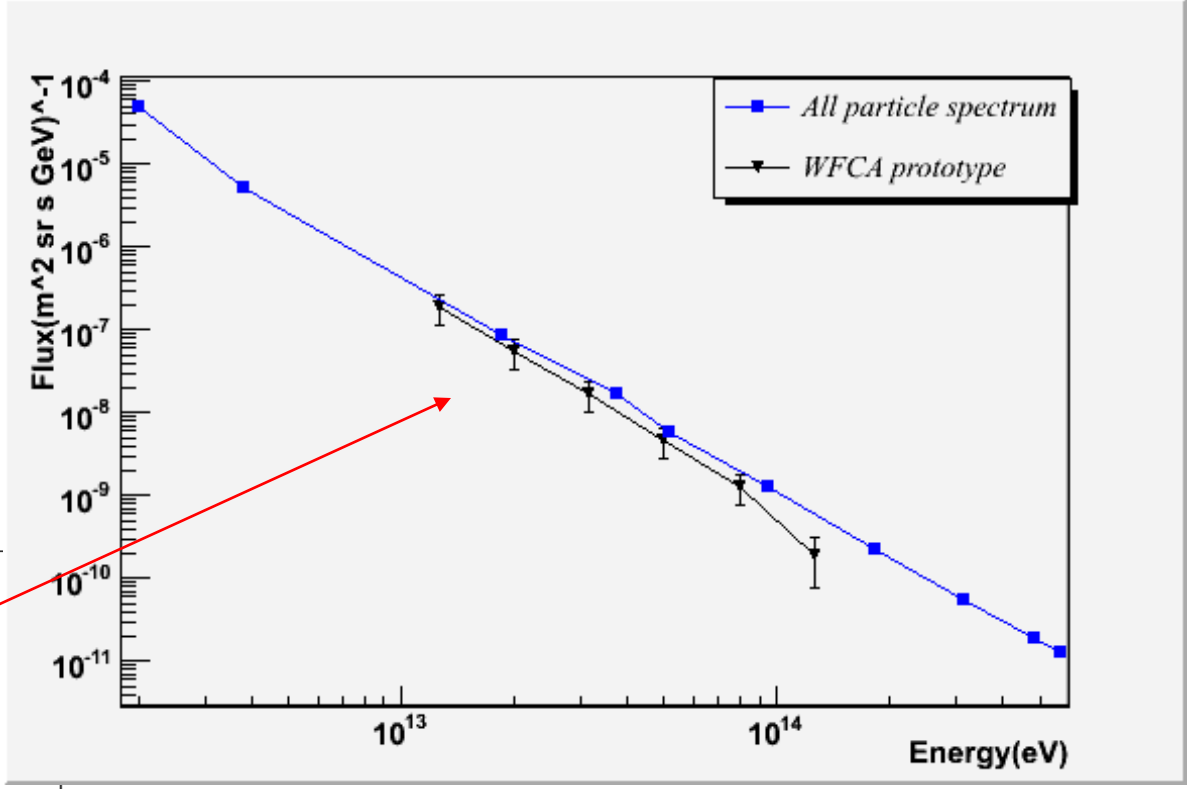

Event 12, PMT 106 --- 793748.72
FADC counts
Bin No.


ARGO Event No. 19776006, A=39.9, Z=29.8, t=20:11:58.4706143
t (ns)
x (m)
y (m)





CR Energy Spectrum (160k events)



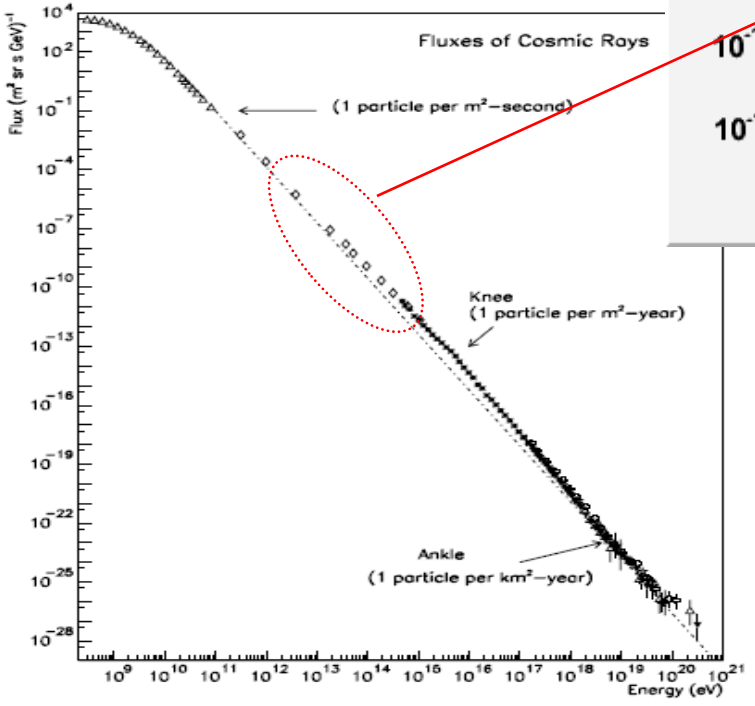


Figure 1. The all particle spectrum of cosmic rays – prepared by the author for Cronin *et al.*

resolution < 15%
With bias<3%
Core resolution <1m

Conclusion

- **LHAASO is proposed to explore the centennial puzzle: origin of high energy cosmic rays**
- **~1000 TeV γ ray sources are expected, while transient phenomenon @TeV will be monitored continuously**
- **LHAASO will measure accurately the cosmic ray spectrum from 5TeV up to 1EeV, anchoring and transferring the energy scale of ground-based experiments**
- **An engineering array is being constructed at YBJ for coincident observation with the ARGO-YBJ experiment**

大型高海拔空气簇射观测站(LHAASO)计划

- 承担单位：高能所
  - 粒子天体中心：总体负责，探测器和电子学研发
  - 实验物理中心：数据获取、电子学研发
  - 计算中心：数据管理、计算环境建设与维护
- 合作单位：
  - 西藏大学：土地、场地、基建等
  - 中国科技大学：探测器和电子学研发
  - 山东大学：探测单元（采购、测试与安装）
  - 云南大学：探测单元（采购、测试与安装）、 探测器设计优化
  - 大气所： 交叉科学研究任务（中高层大气物理）
  - 空间中心、国家气象局：交叉科学研究任务（空间天气预报）
  - 河北师大：供电及稳压电源
  - 北京大学、西南交大、南开大学、大连海事大学、兰州近代所、天津修船研究所、遗传所等单位负责数据分析、软硬件开发、交叉学科等

You're welcome to join LHAASO!