The LHAASO observatory

(Large High Altitude Air Shower Observatory)

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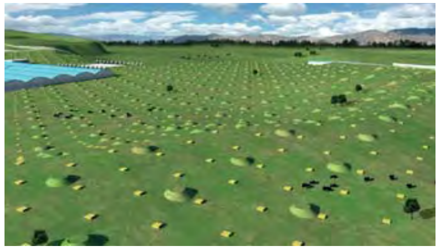
on behalf of the LHAASO Collaboration

Outline

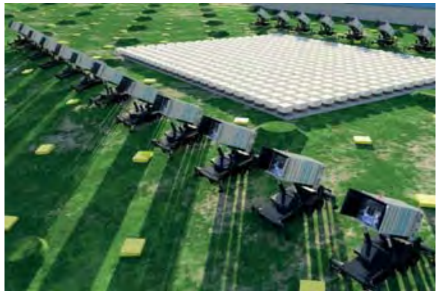
- Overview of the LHAASO project
- Scientific topics
- Status of the project
- Conclusions

The LHAASO project

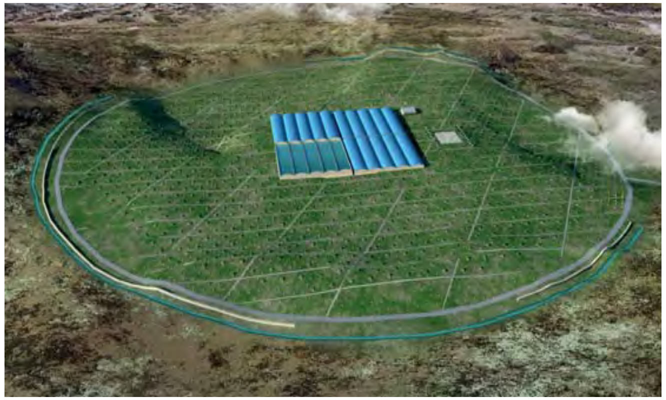
The Large High Altitude Air Shower Observatory (LHAASO) project is a new generation all-sky instrument to perform a combined study of cosmic rays and gamma-rays in the wide energy range 10^{11} -- 10^{17} eV.



The experiment will be located at 4300m asl (606 g/cm^2) in the Sichuan province



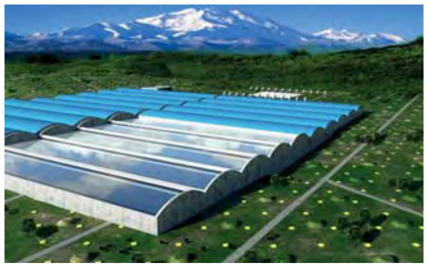
1 KM2A:
5635 EDs
1221 MDs



WFCTA:
24 telescopes
1024 pixels each

WCDA:
3600 cells
90,000 m^2

SCDA:
452 detectors

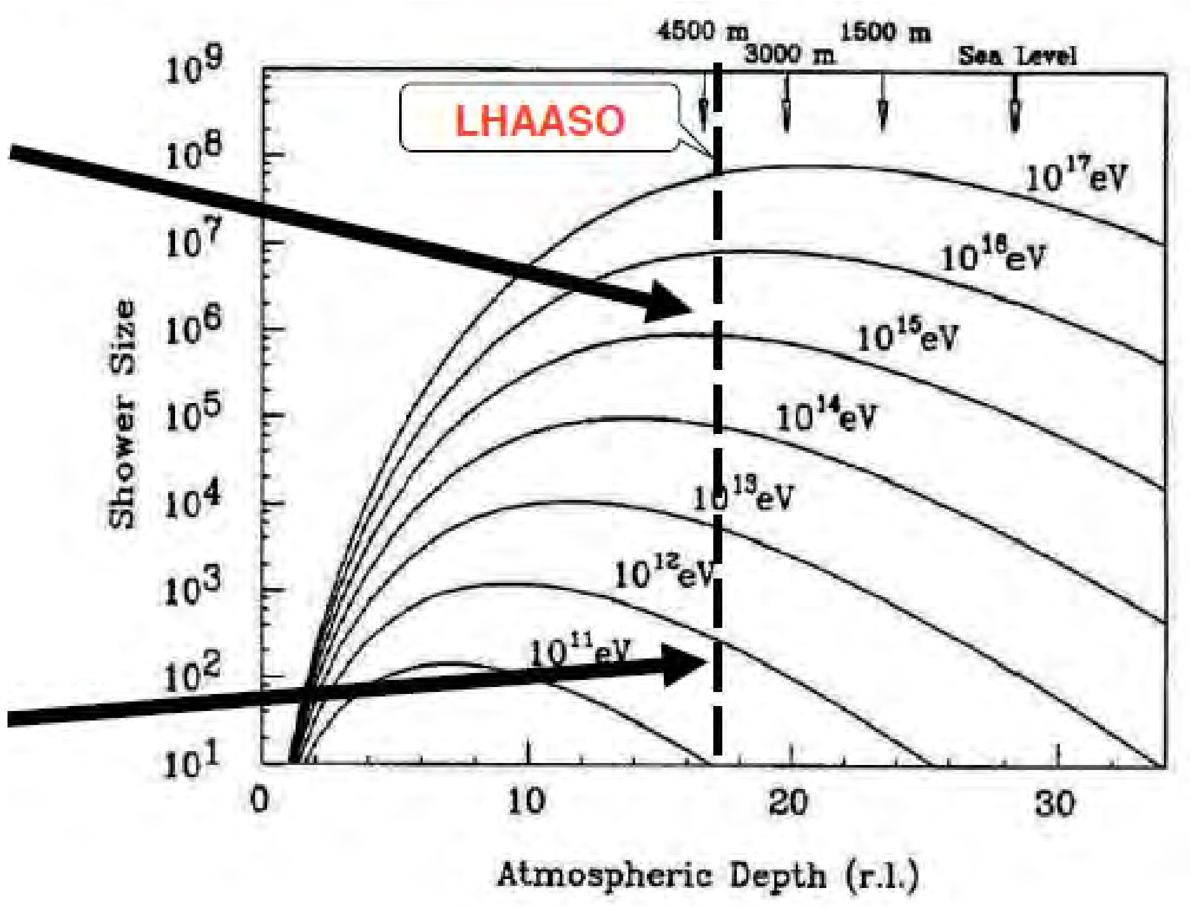


Coverage area: 1.3 km^2

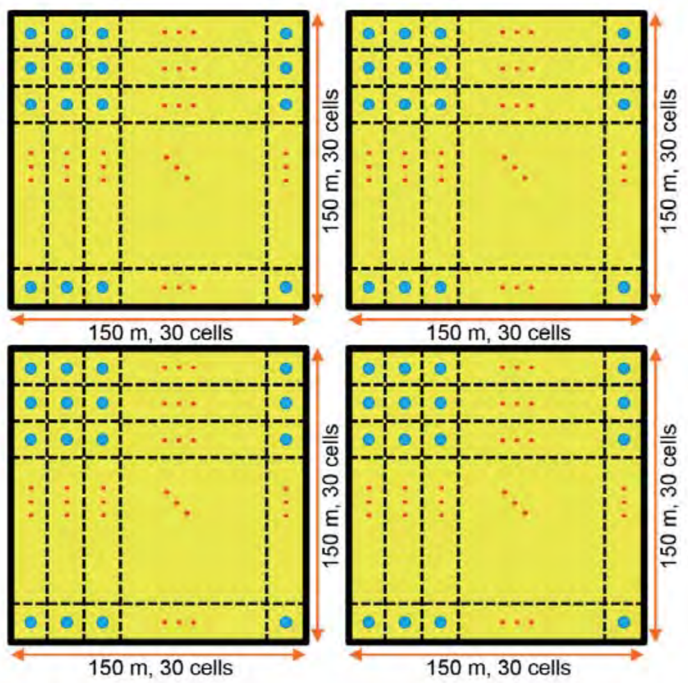
Shower at high altitude

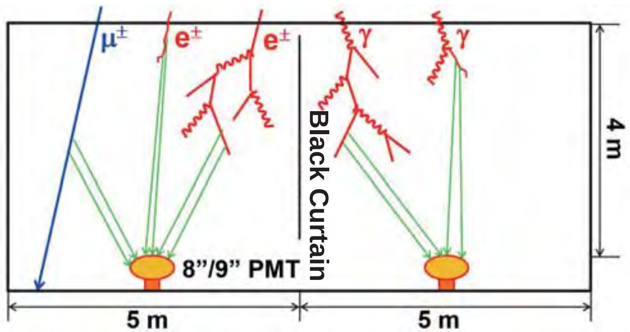
High energy: near Xmax => large number of particles, lower fluctuation, better σ_e

Low energy threshold



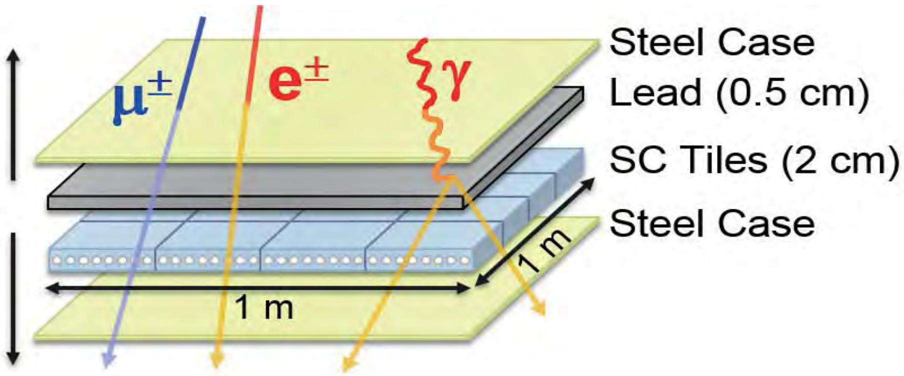
Water Cherenkov Detector Array

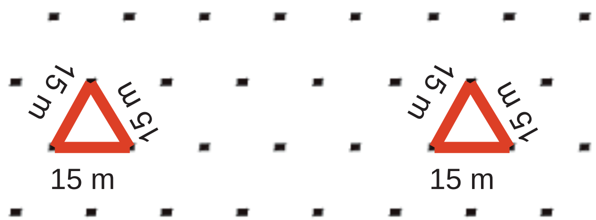




Item	Value
Cell area	25 m^2
Effective water depth	4 m
Water transparency	> 15 m (400 nm)
Precision of time measurement	0.5 ns
Dynamic range	1-4000 PEs
Time resolution	<2 ns
Charge resolution	40% @ 1 PE 5% @ 4000 PEs
Accuracy of charge calibration	<2%
Accuracy of time calibration	<0.2 ns
Total area	90,000 m^2
Total cells	3600

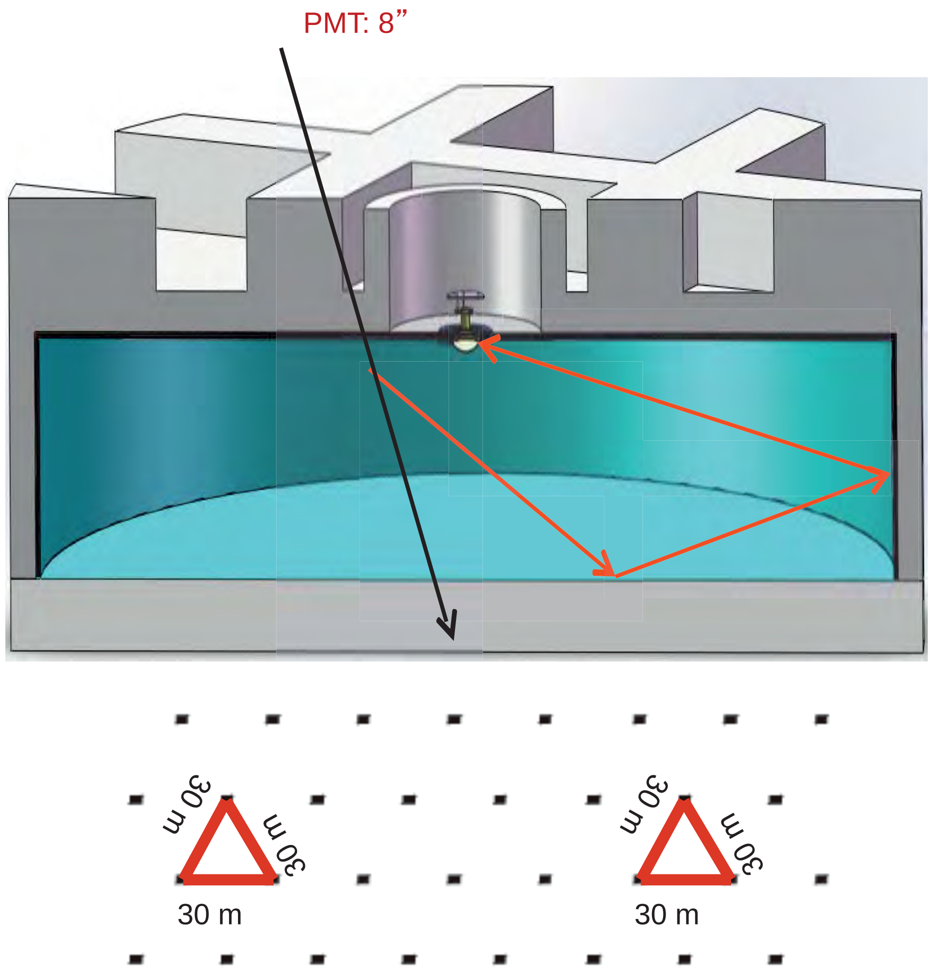
Electromagnetic particle Detector





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

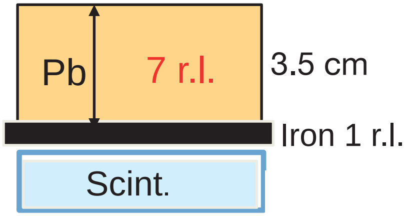


Item	Value
Area	$36\ m^2$
Depth	1.2 m
underneath soil	2.5 m
Water transparency (att. len.)	> 30 m (400 nm)
Reflection coefficient	>95%
Time resolution	<10 ns
Particle counting resolution	25% @ 1 particle 5% @ 10,000 particles
Aging	>10 years
Spacing	30 m
Total number of detectors	1221

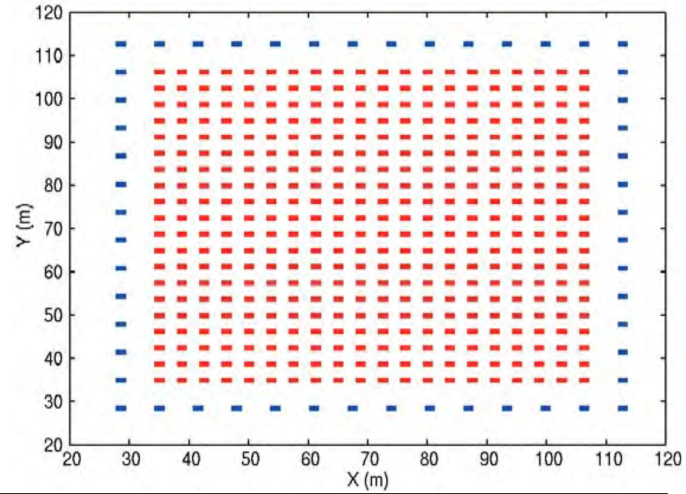
Shower Core Detector Array

425 close-packed burst detectors, located near the centre of the array, for the detection of high energy secondary particles in the shower core region.

Burst detector

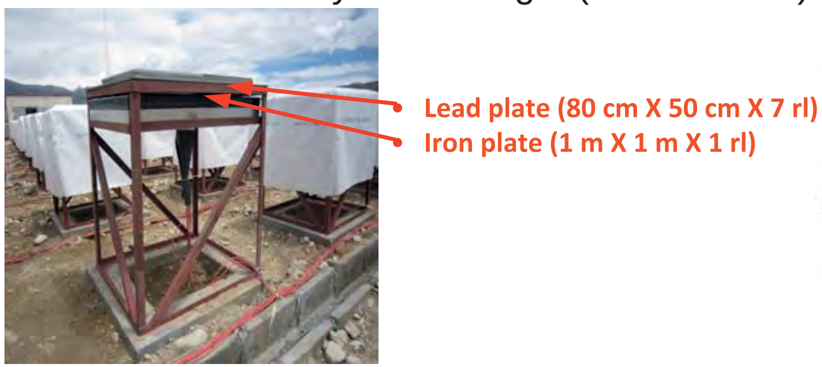


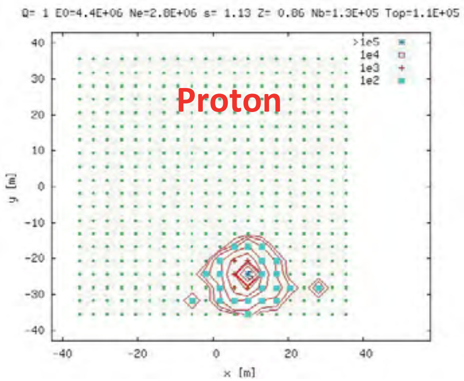
The burst detectors observe the electron size (burst size) under the lead plate induced by high energy e.m. particle in the shower core region

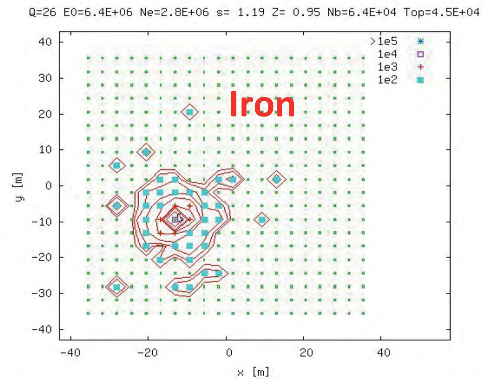


Each burst detector is constituted by 20 optically separated scintillator strips of 1.5 cm x 4 cm x 50 cm read out by two PMTs operated with different gains to achieve a wide dynamic range (1- 10 ^{6} MIPs).

Number of SCD:	**$0.5m^2$ x 452**
Cover Area:	**$5170m^2$**
Energy region:	**30 TeV - 10 PeV**
Core position resolution:	**1.5 m @50 TeV**



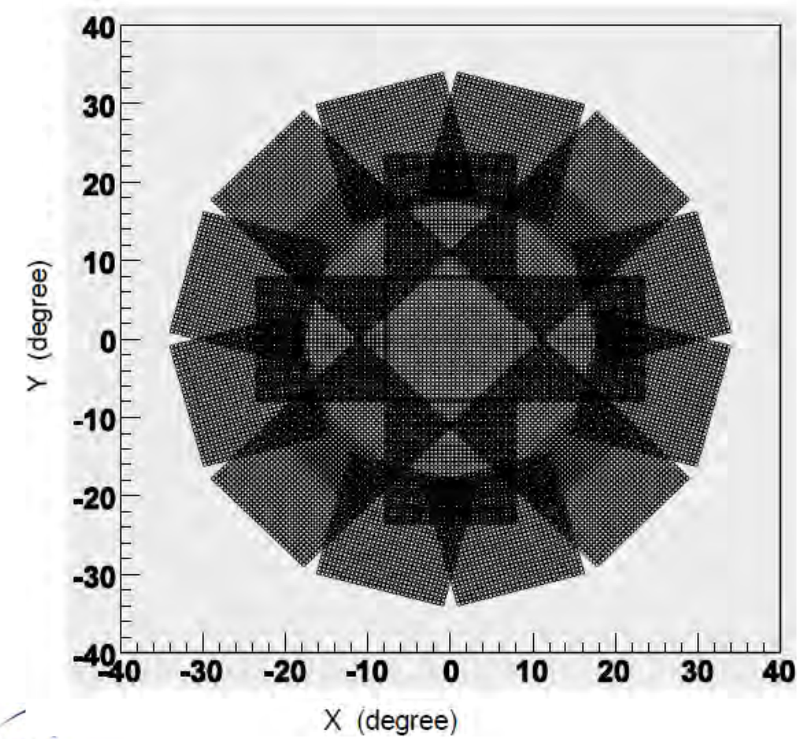


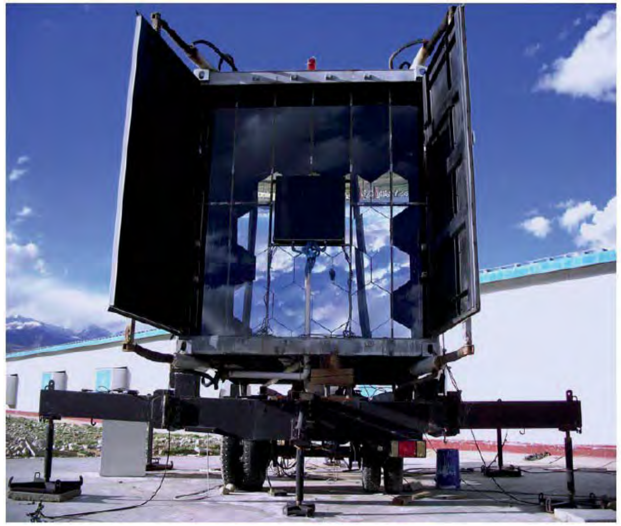


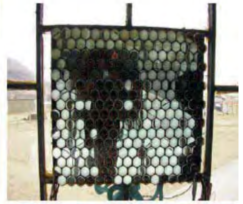
Wide field of view Cherenkov Telescope Array

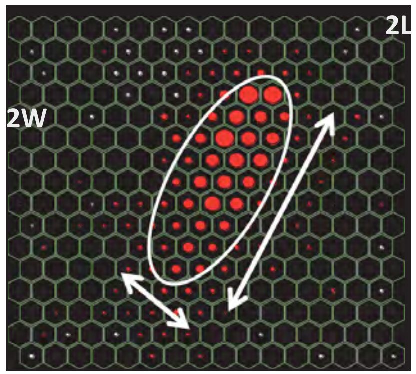
24 telescopes (Cherenkov/Fluorescence)

- 4.7 m^2 spherical mirror
- 32x32 PMT array
- FOV: 16ºx 16º

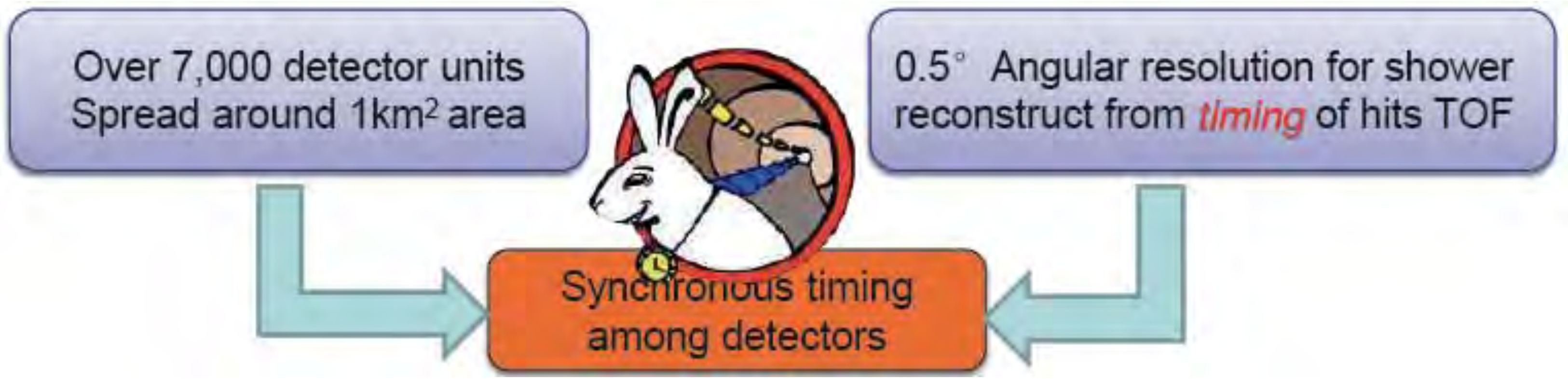








LHAASO timing distribution

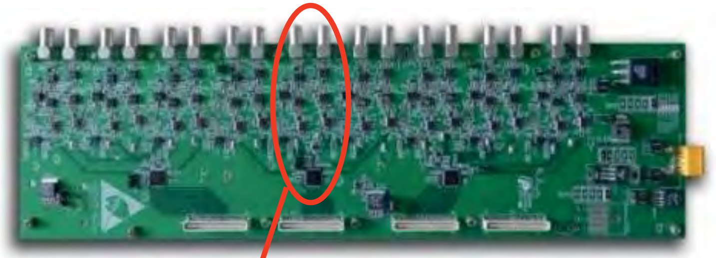


- Distribution of synchronous ADC clock with <100ps skew
- Time stamp of more than 7000 nodes aligned better than 500ps (rms)
- Compesation of time delay, due to environmental condition, in real time

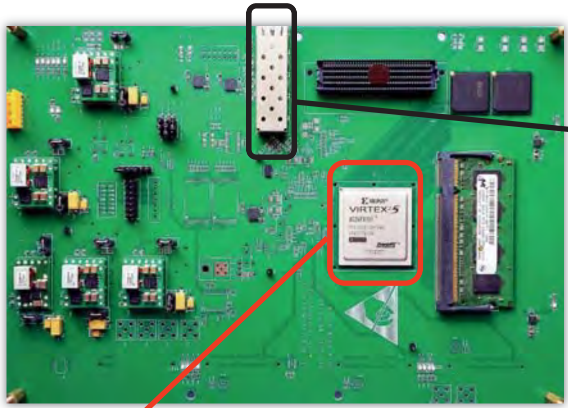
The LHAASO timing distribution is based on a network of White Rabbit switches to distribute the clock to the front end electronic modules

LHAASO Front end

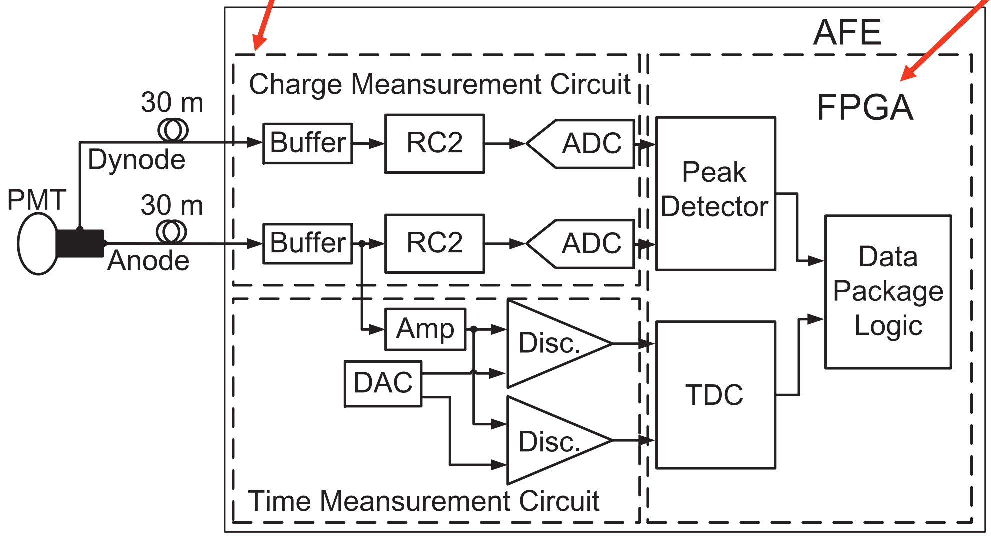
Each LHAASO acquisition node implement a TCP/IP White Rabbit core, to perform time synchronization and data transmission



WCDA front end



SFP Laser; physical layer of the White Rabbit protocol

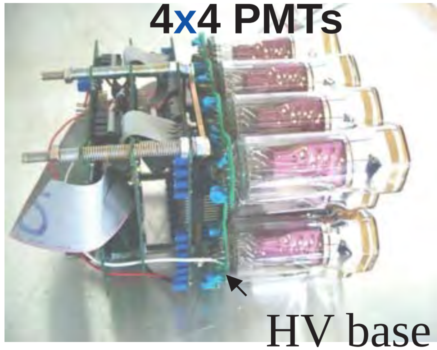


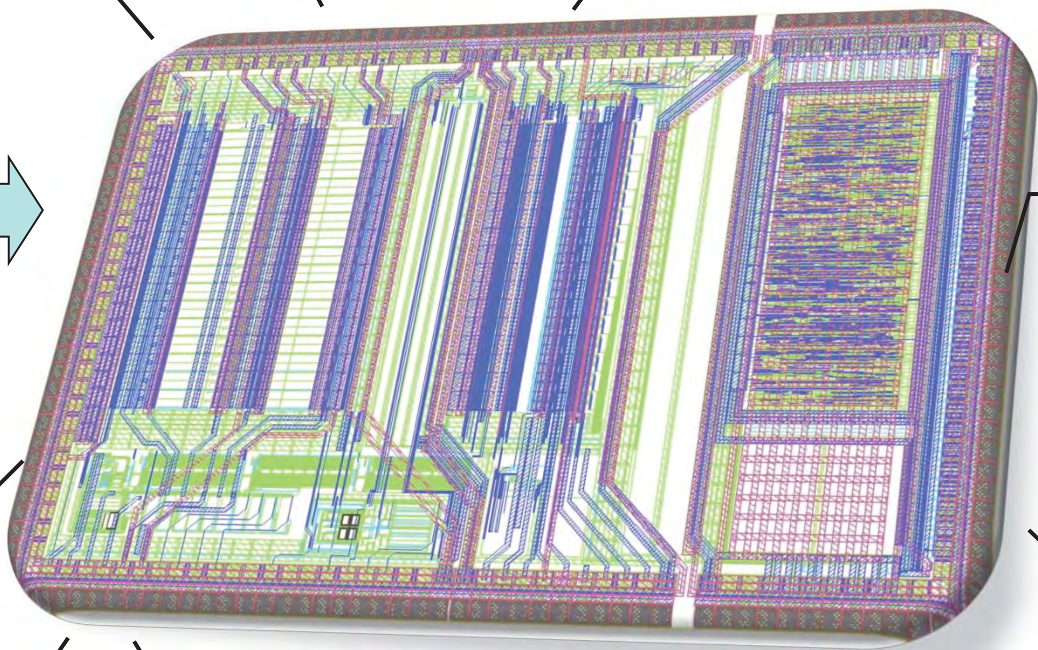
Charge/ADC:
•shaping with (RC)2
•peak seeking with FPGA

Time/TDC:
•leading edge of anode signal
•time being measured with FPGA-TDC (binsize 0.333 ns).

WFCTA ASIC

PARISROC 2 is designed by OMEGA Group





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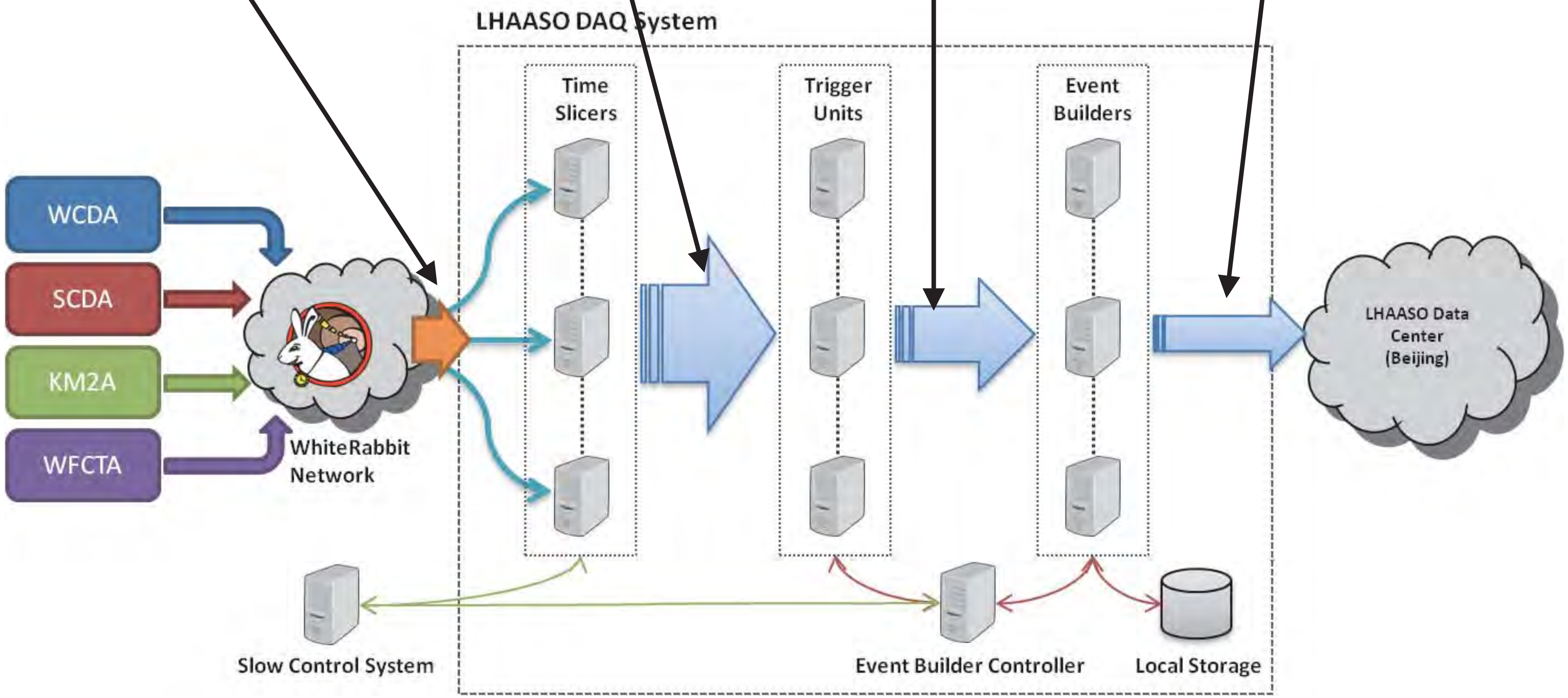
LHAASO online DAQ architecture

No data reduction, just organization

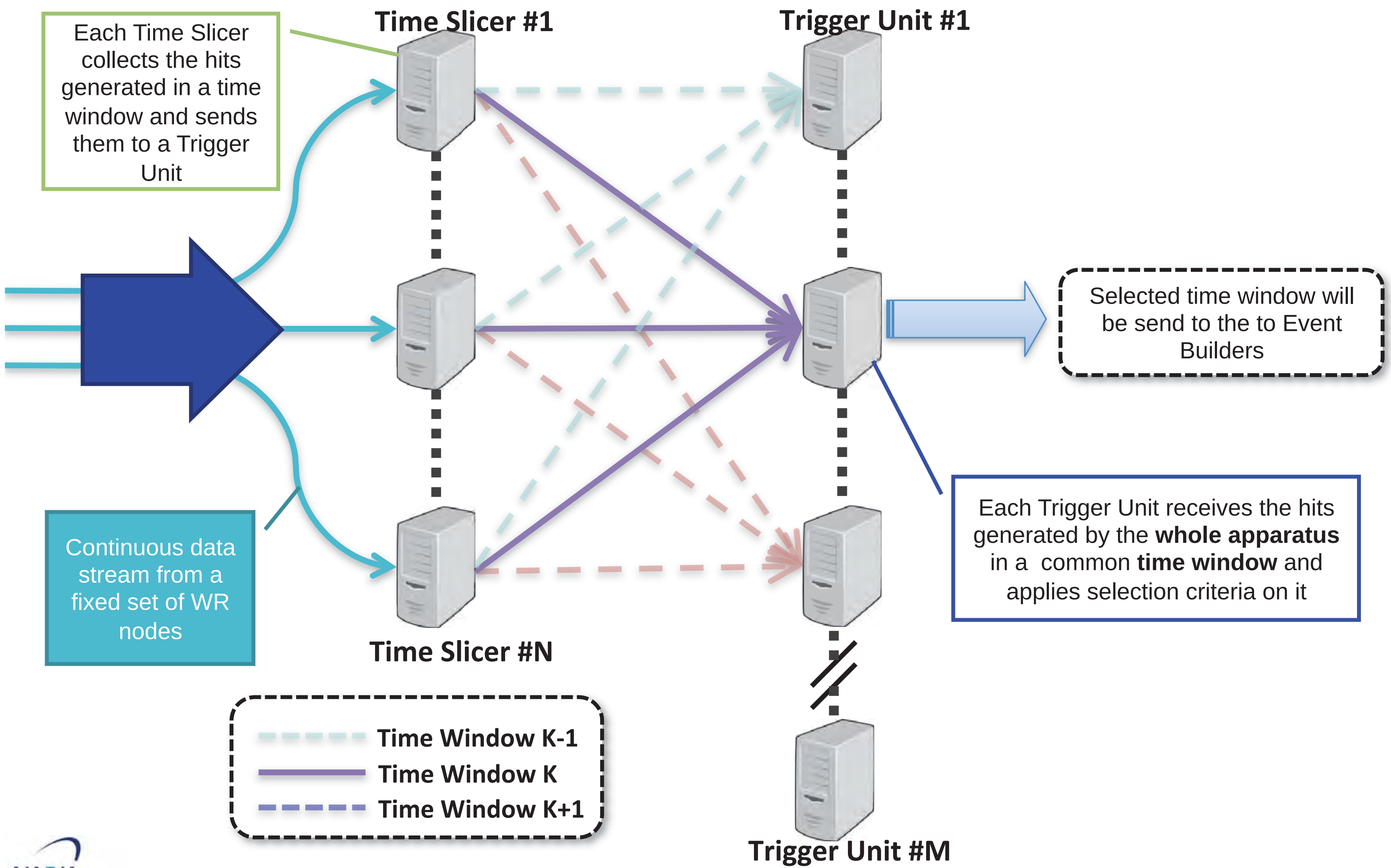
Triggered data rate ~5Gbps

Total data rate <50Gbps

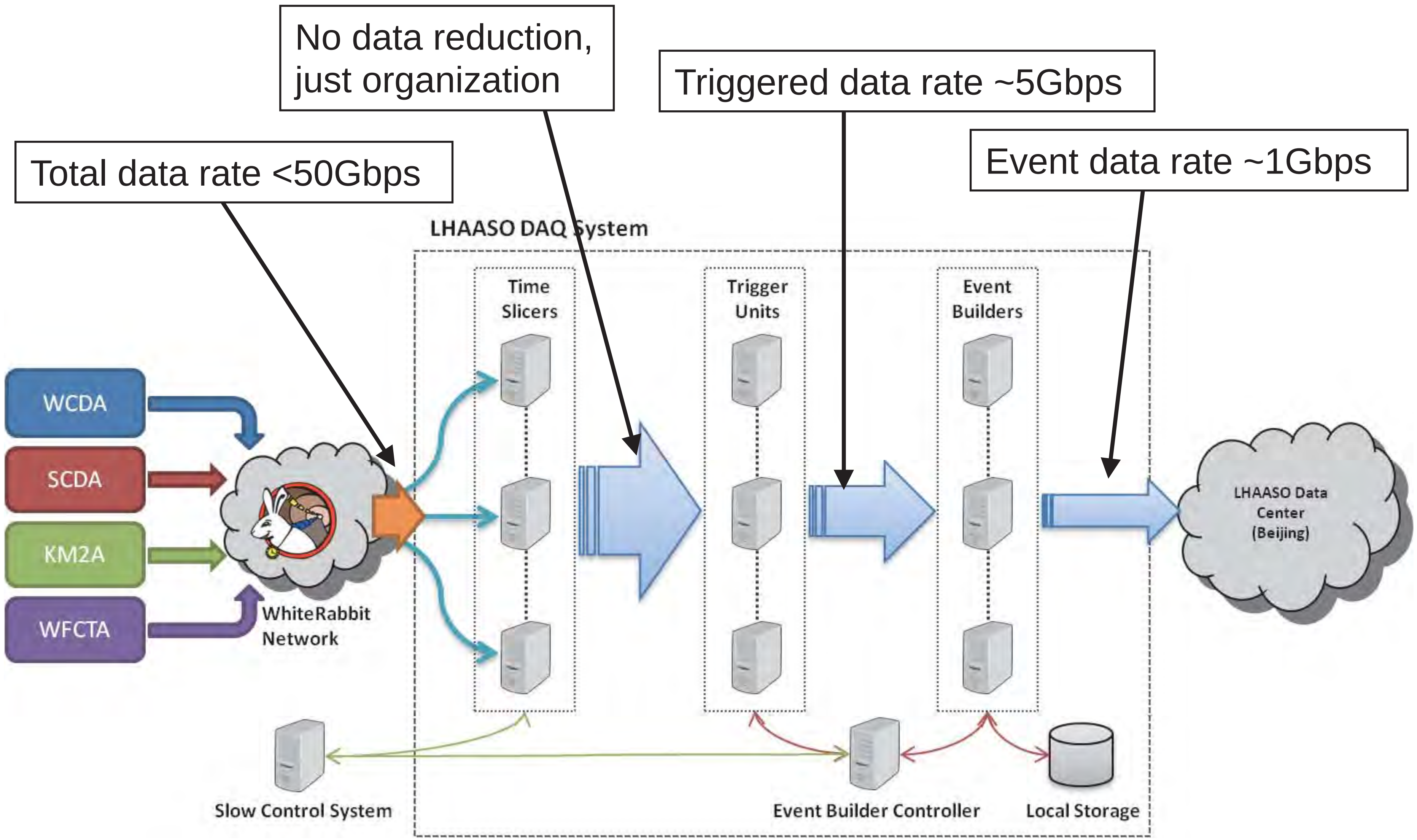
Event data rate ~1Gbps



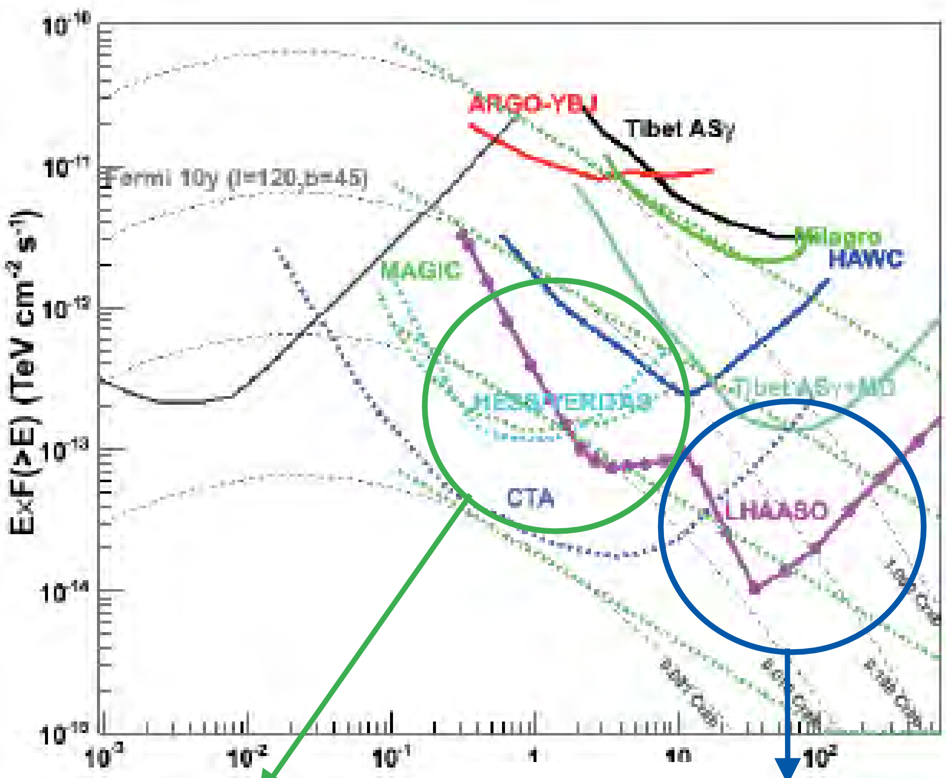
Time slicing mechanism



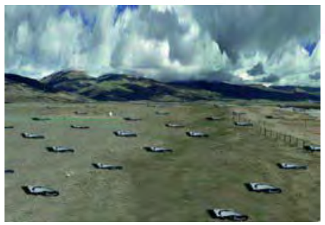
LHAASO online DAQ architecture



LHAASO integral sensitivity



WCDA



KM2A (EDs + MDs)

Angular resolution:

30 TeV ~0.4°

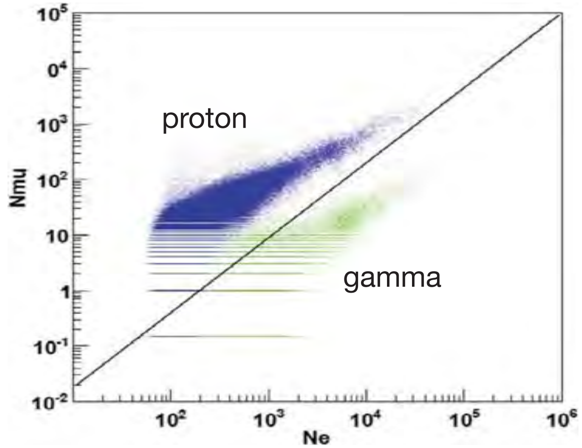
100TeV ~0.3 °

Energy relsolution:

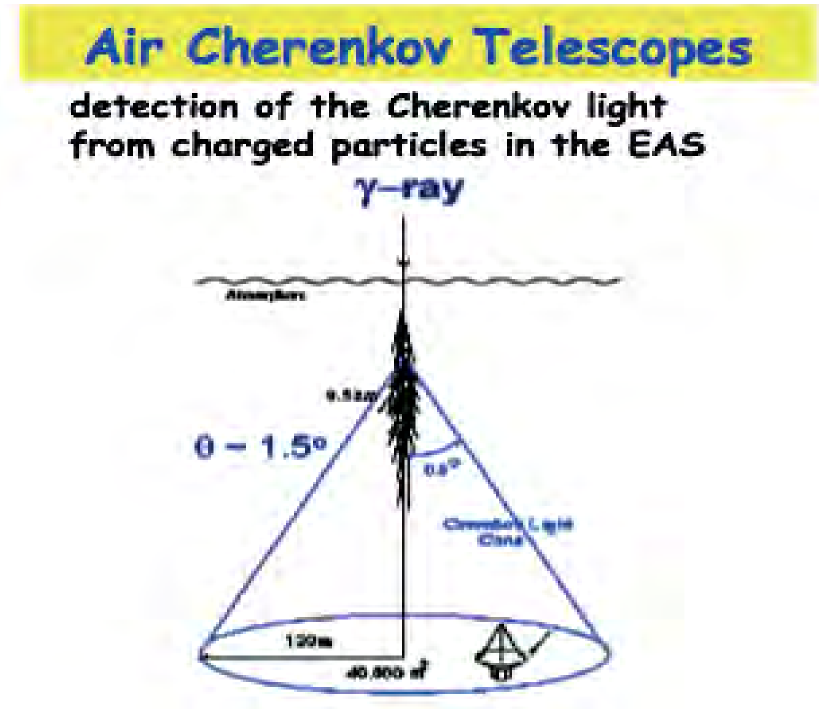
30 TeV ~30%

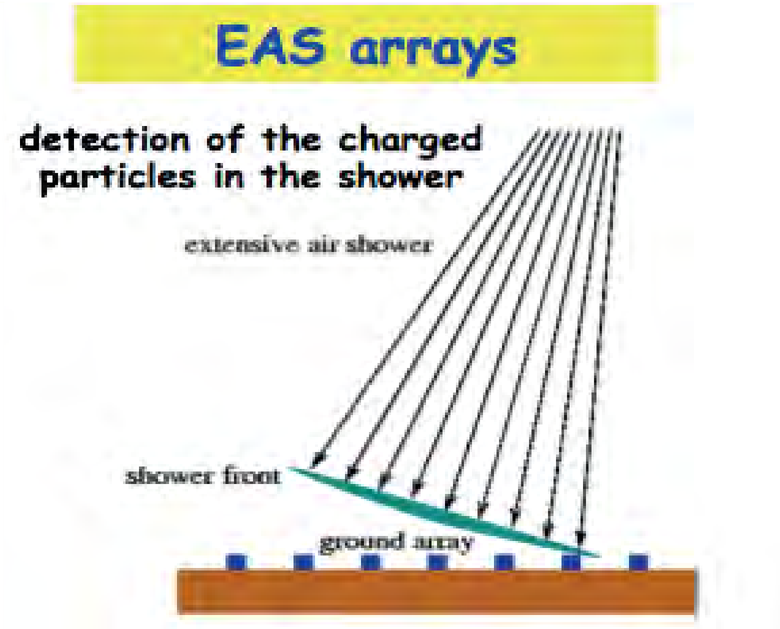
100 TeV ~20%

KM2A discrimination



Ground-based Gamma-Ray Astronomy

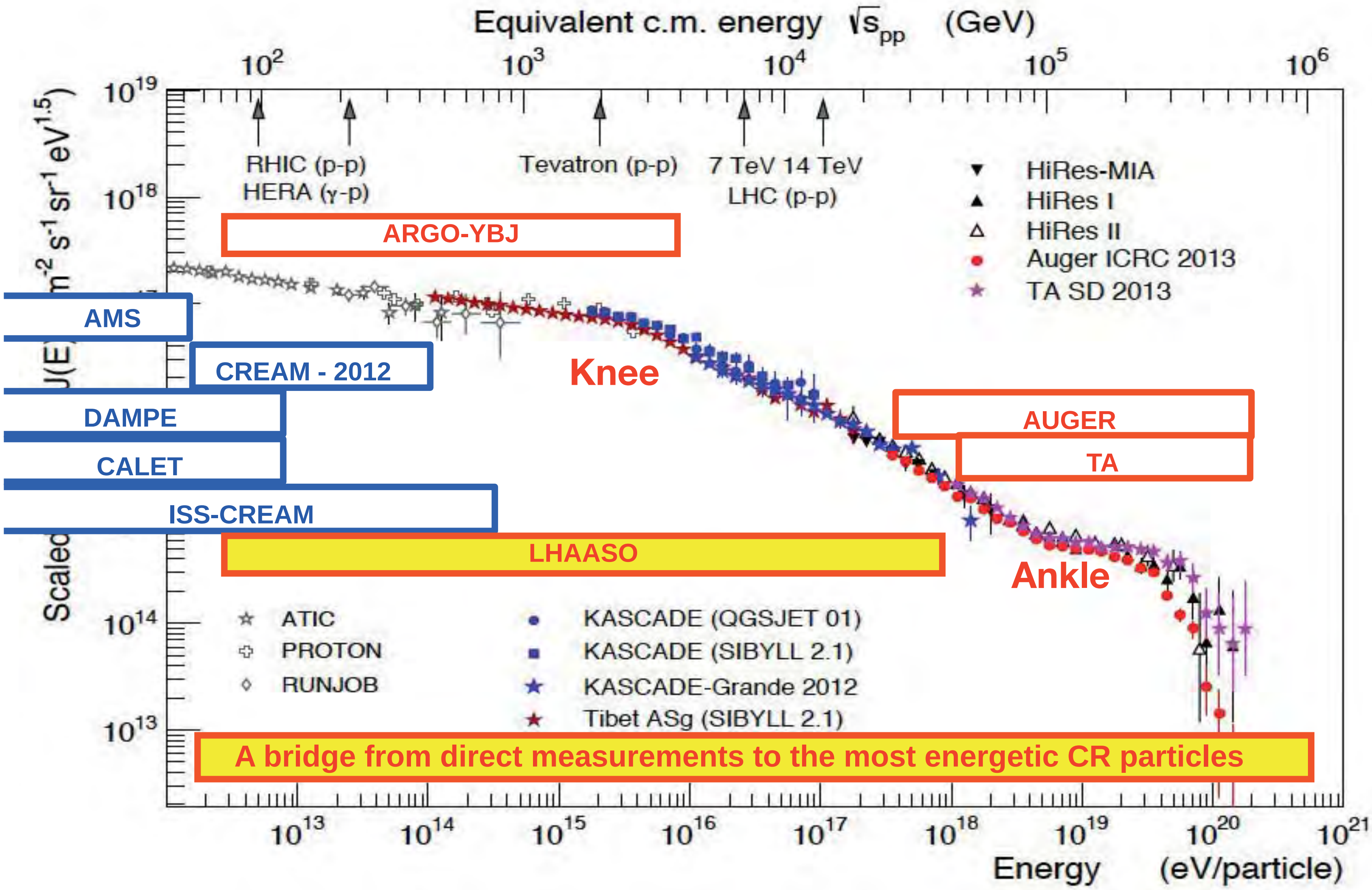




Very low energy threshold (≈50 GeV)
Excellent bkg rejection (>99%)
Excellent angular resolution (≈0.05 deg)
Good energy resolution (≈15%)
High Sensitivity (< % Crab flux)
Low duty-cycle (≈10%)
Small field of view (4-5 deg)

Higher energy threshold (≈300 GeV)
Good bkg rejection (>80%)
Good angular resolution (0.2-0.8 deg)
Modest energy resolution (≈50%)
Good Sensitivity (5-10% Crab flux)
High duty-cycle (≈100%)
Large field of view (≈2 sr)

LHAASO energy range

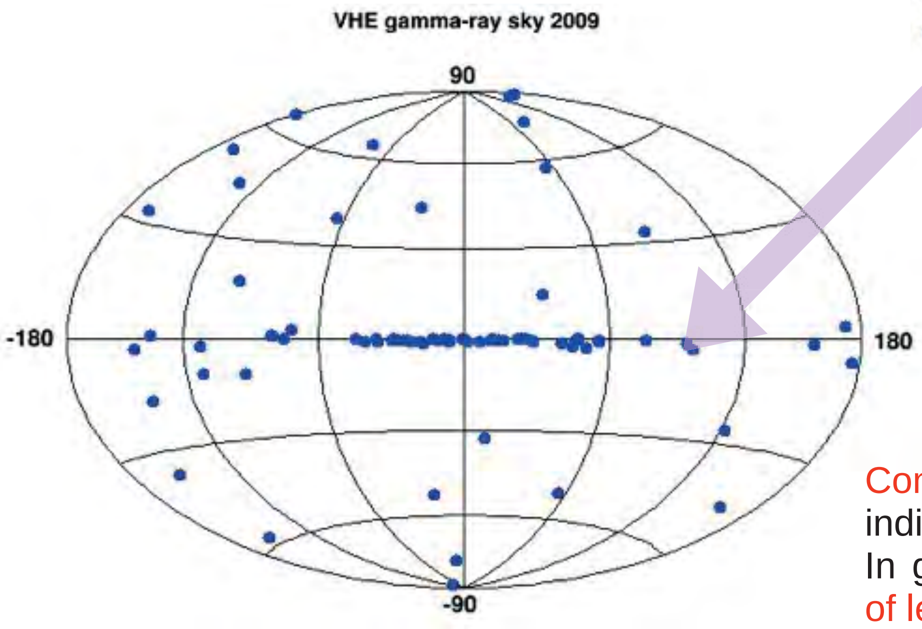


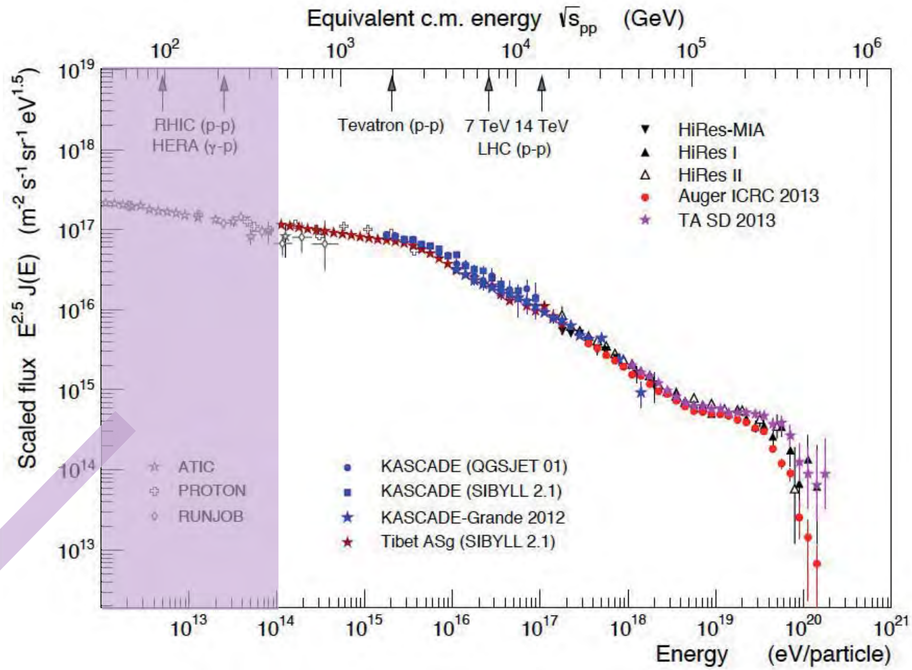
Scientific topics

$$p\ (p,\ \gamma) \longrightarrow \pi^0 + rest$$
$$\hookrightarrow \gamma\gamma$$

Gammas from Galactic Cosmic Rays: $E_\gamma \sim E_{CR}/10$

TeV Cosmic Rays
Photons > 100 GeV !



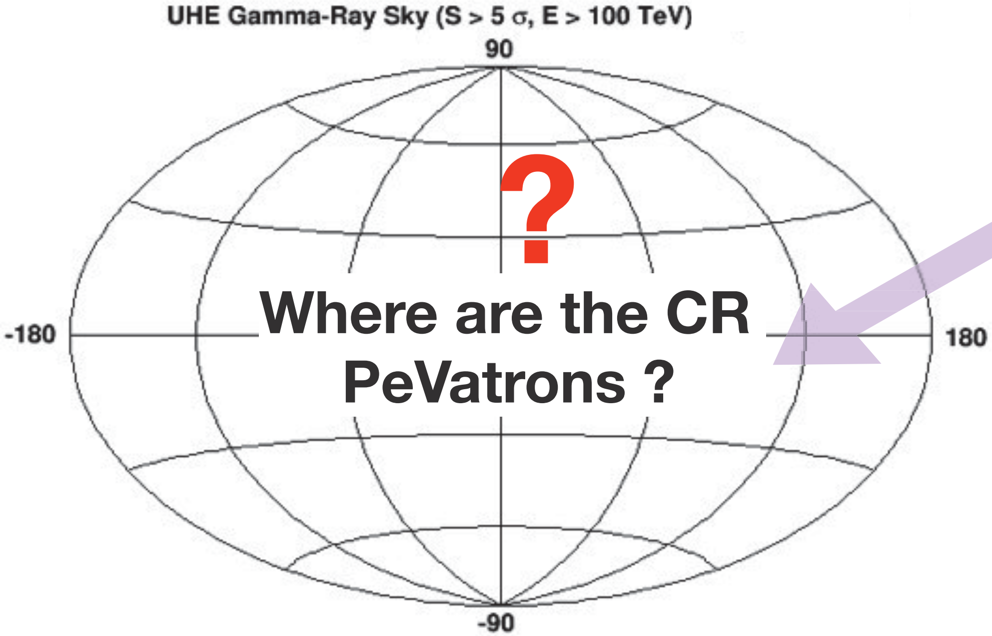


But smoking gun still missing…
leptonic ?
hadronic ?

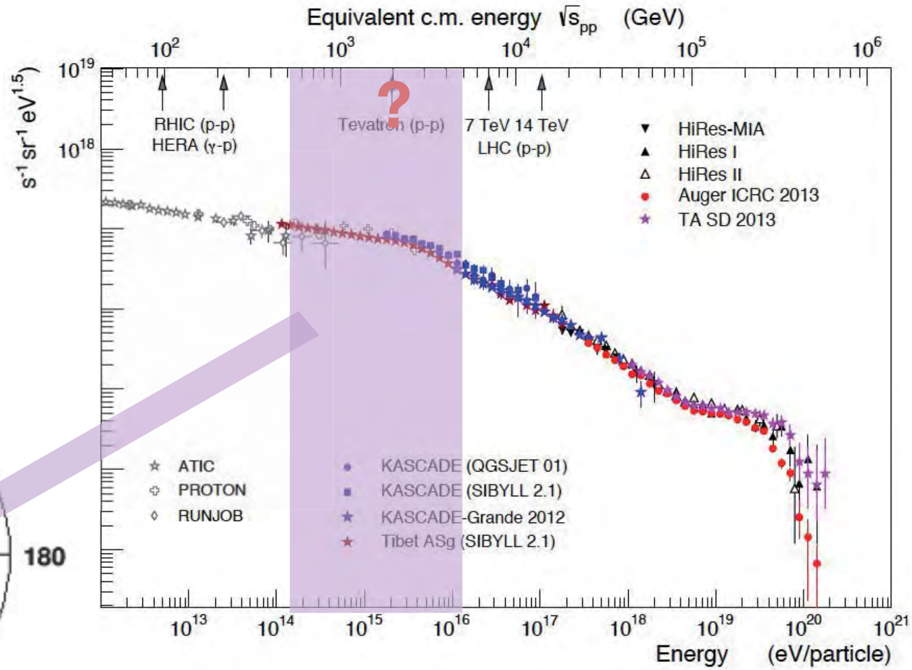
Complex scenario: each source is individual and has a unique behaviour. In general one expects a combination of leptonic and hadronic emission !

Scientific topics

PeV Cosmic Rays
Photons > 100 TeV !



Where are the CR PeVatrons ?



Bonus @ 100 TeV:
Hadronic spectra: *hard*
Leptonic spectra: *soft*
No hard IC gamma rays
>100 TeV IC in deep Klein-Nishina

★ A power law spectrum reaching 100 TeV without a cutoff is a very strong indication of the hadronic origin of the emission

Scientific topics

LHAASO

Cosmic Ray sources (*'PeVatrons'*) → Still open — Gamma/Neutrino Astronomy

NO smoking guns from TeV gamma-ray astronomy !

Composition at the knee ?
Rigidity – dependent knee ? → Still open

Results still conflicting in the knee energy region !

Anisotropy ? → Totally open

No theory of CRs exists yet to explain observed anisotropy !

End of Galactic spectrum ?
Transition galactic - xgalactic ? → Open

Only hyphotheses

Hadronic interaction models ? → Still uncertain

cross sections,
diffractive, inelasticity

Cosmic Ray Physics / Neutrino Astronomy

LHAASO potential

Gamma-ray astronomy (10^2 – 10^6 GeV)

- Full sky continuous monitoring at ≈0.01 of the Crab flux
    - Transient sources
    - Complementary with CTA
    - Complementary with HAWC
- Unprecedented sensitivity above 30 TeV -> search for PeV cosmic ray sources

Cosmic ray (10^3 – 10^8 GeV)

- CR energy spectrum
- Elemental composition
- Anisotropy

Prototype of LHAASO at ARGO site

About 1% of LHAASO

•42 EDs

•2 MDs

•9-unit WCDA

•2 telescope

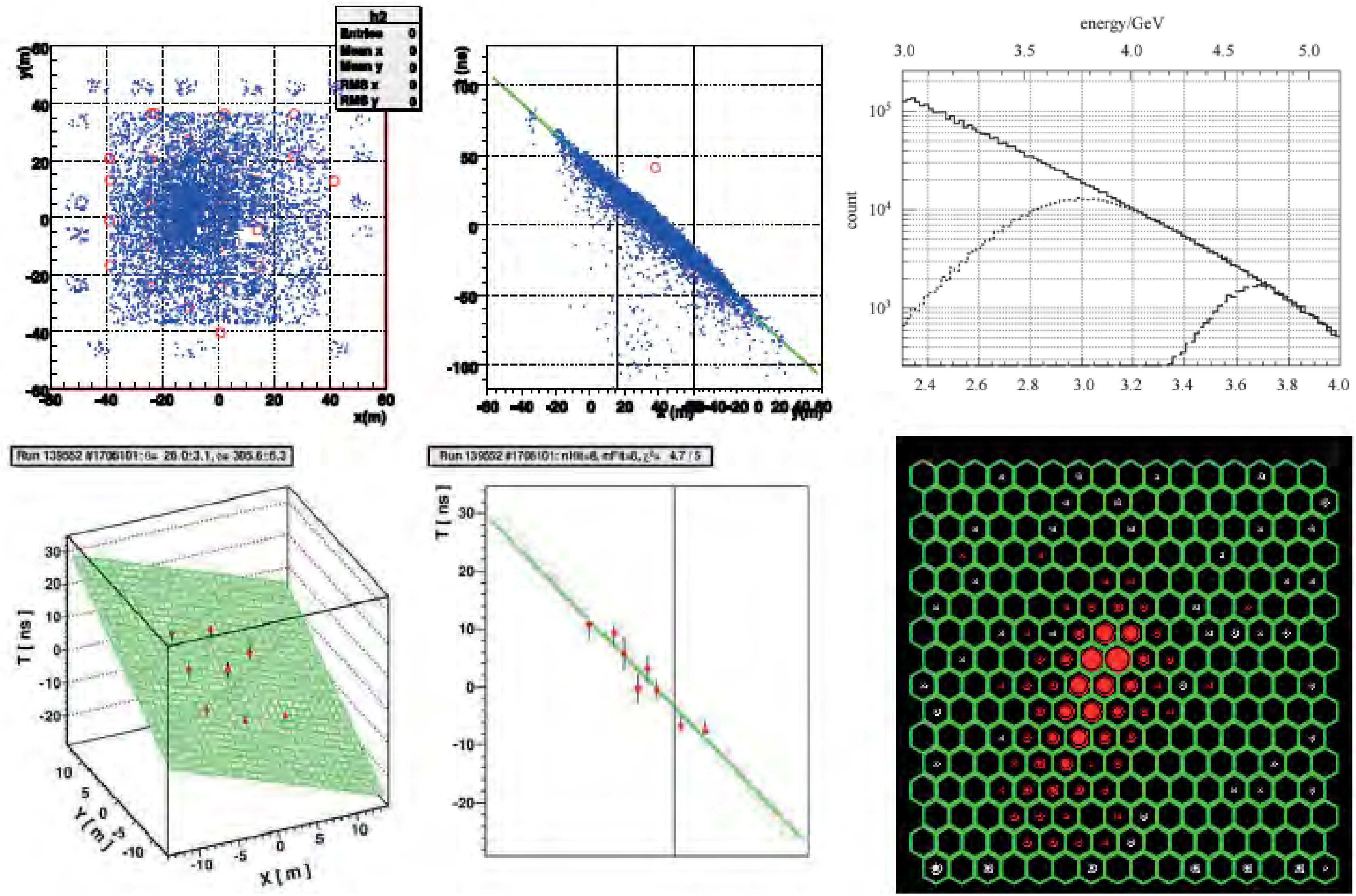
•100 shower core detectors

Fully implement the LHAASO design, including White Rabbit based clock distribution

Has been operating since two year



Shower example



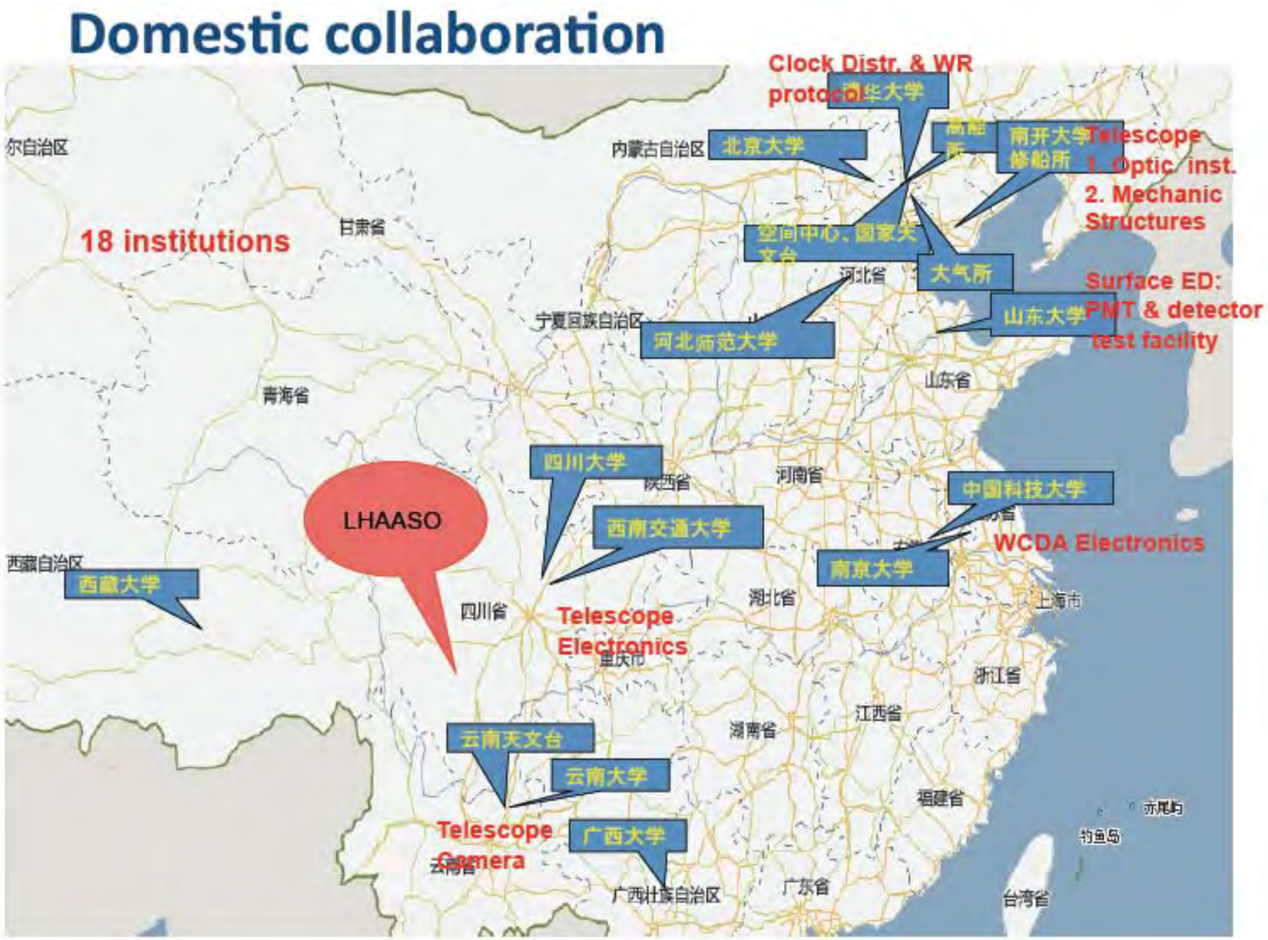
Status of LHAASO

LHAASO is one of the *'Five top priorities'* projects of the Strategic Plan of IHEP approved by the Chinese Academy of Sciences (CAS).
The National Reform and Development Commission (NRDC) and the Finance Ministry (FM) allocated for LHAASO 1 Billion CNY (about 160 M US$) *"Flagship Project"*.
The government of Sichuan province will cover the total cost of the infrastructure construction: 300 M CNY.

Foreseen time schedule

- ★ Sept. 2015: start of construction of infrastructures.
- ★ Spring 2016: start of construction of first quarter of WCDA, KM2A.
- ★ Spring 2017: installation of PMTs in the first pond.
- ★ Spring 2018: start scientific operation of the first quarter of LHAASO.
- ★ 2021: conclusion of installation of main components.

LHAASO collaboration



LHAASO international collaboration

- Collaboration with INFN (Online DAQ system)
- Collaboration with IPN-Orsay and OMEGA (PARISROC)
- Collaboration with Russian colleagues (neutron detector)
- Collaboration with Thailand solar CR group

Conclusions

•LHAASO is able to deal with all the main open problems of cosmic ray physics at the same time.

•LHAASO is a tool of great sensitivity - unprecedented above 30 TeV - to monitor '*all the gamma sky all the time*'

•Complementary to CTA in gamma astronomy

•Complementary to HAWK in time coverage of the north sky

•Prototype array ~1% LHAASO have been in operation at YBJ for more that 2 years

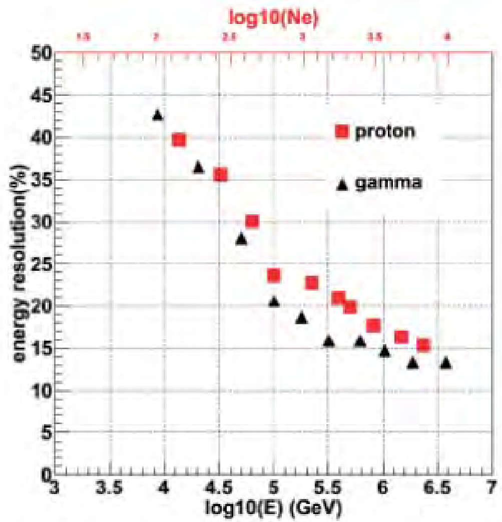
•The infrastructures construction is starting

•The detector deployment will start by the end of next year

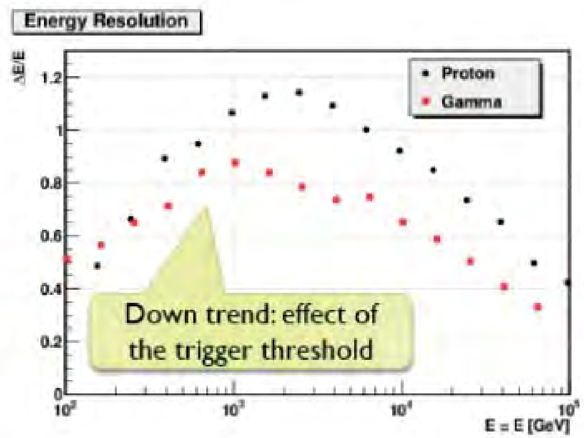
BACKUP

Angular and energy resolution

Energy resolution



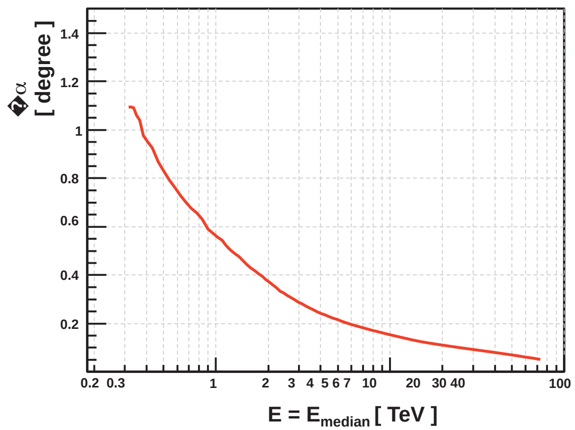
KM2A

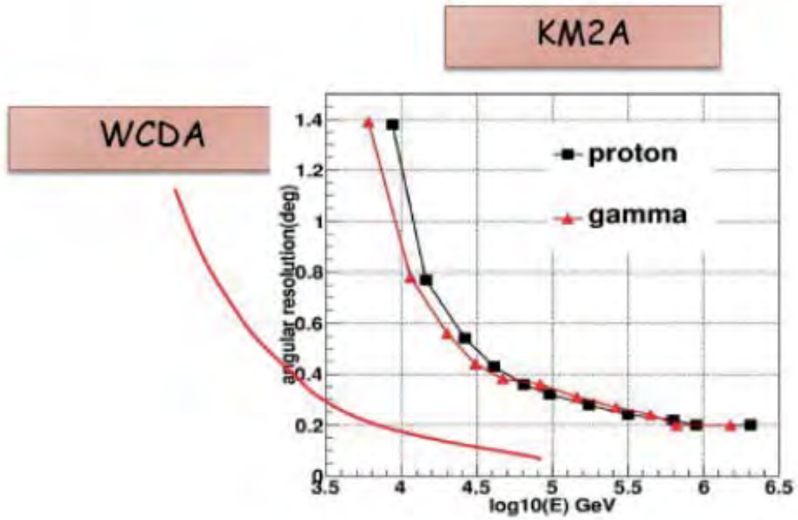


WCDA

Angular resolution

WCDA angular resolution





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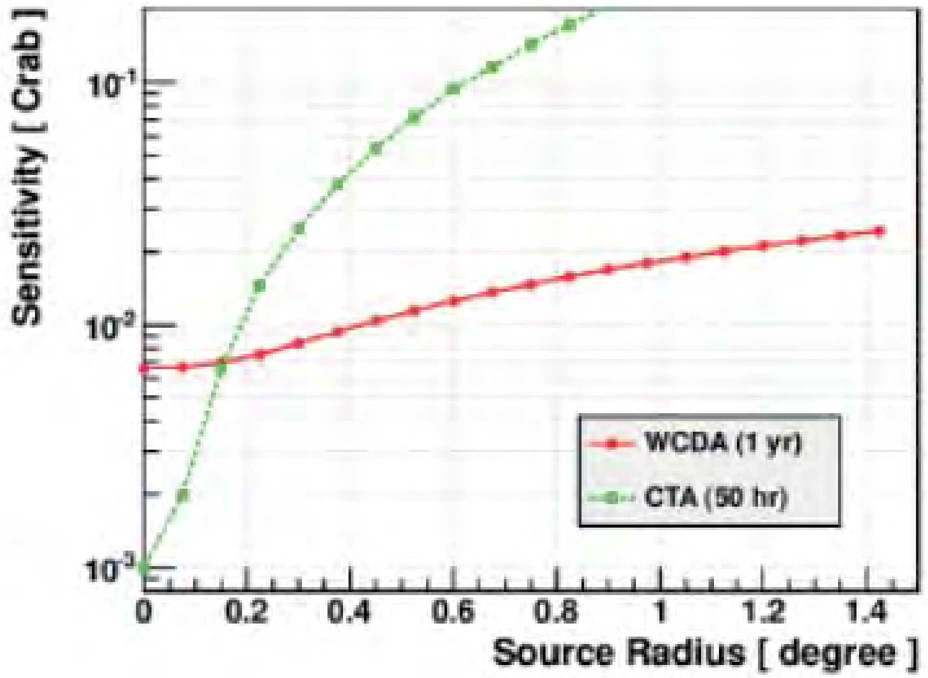
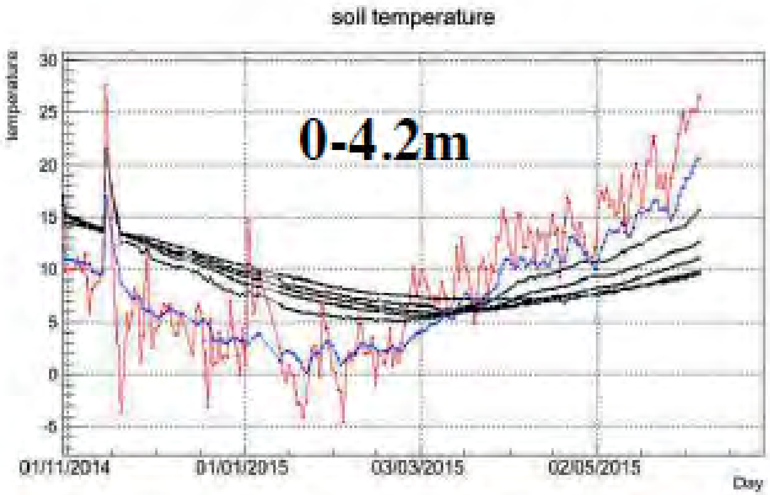
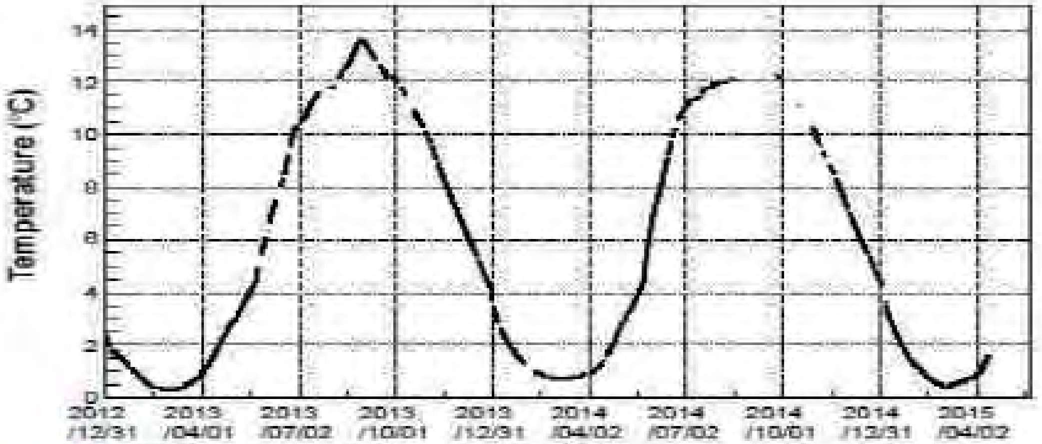
LHAASO sensitivity to extended sources

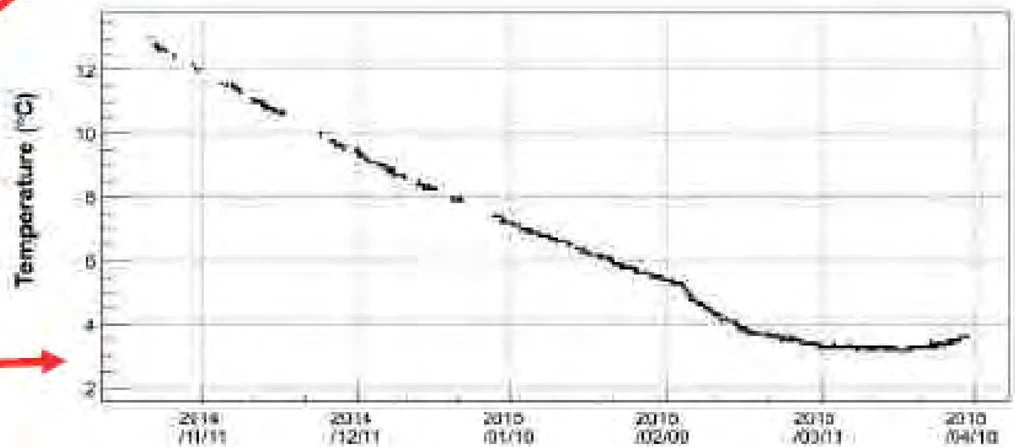


Sensitivity of LHAASO WCDA to extended sources as a function of size.
(The angular bin is optimized for the WCDA only.)

MD Water Temperature







The LHAASO site

The experiment will be located at 4300 m asl (606 g/cm^2) in the Daocheng site, Sichuan province

Coordinates: 29° 21' 31'', 100° 08' 15''

700 km to Chengdu
50 km to Daocheng City (3700 m asl, guest house !)
10 km to airport

Complementary to HAWK.

With LHAASO cover the north sky continuosly

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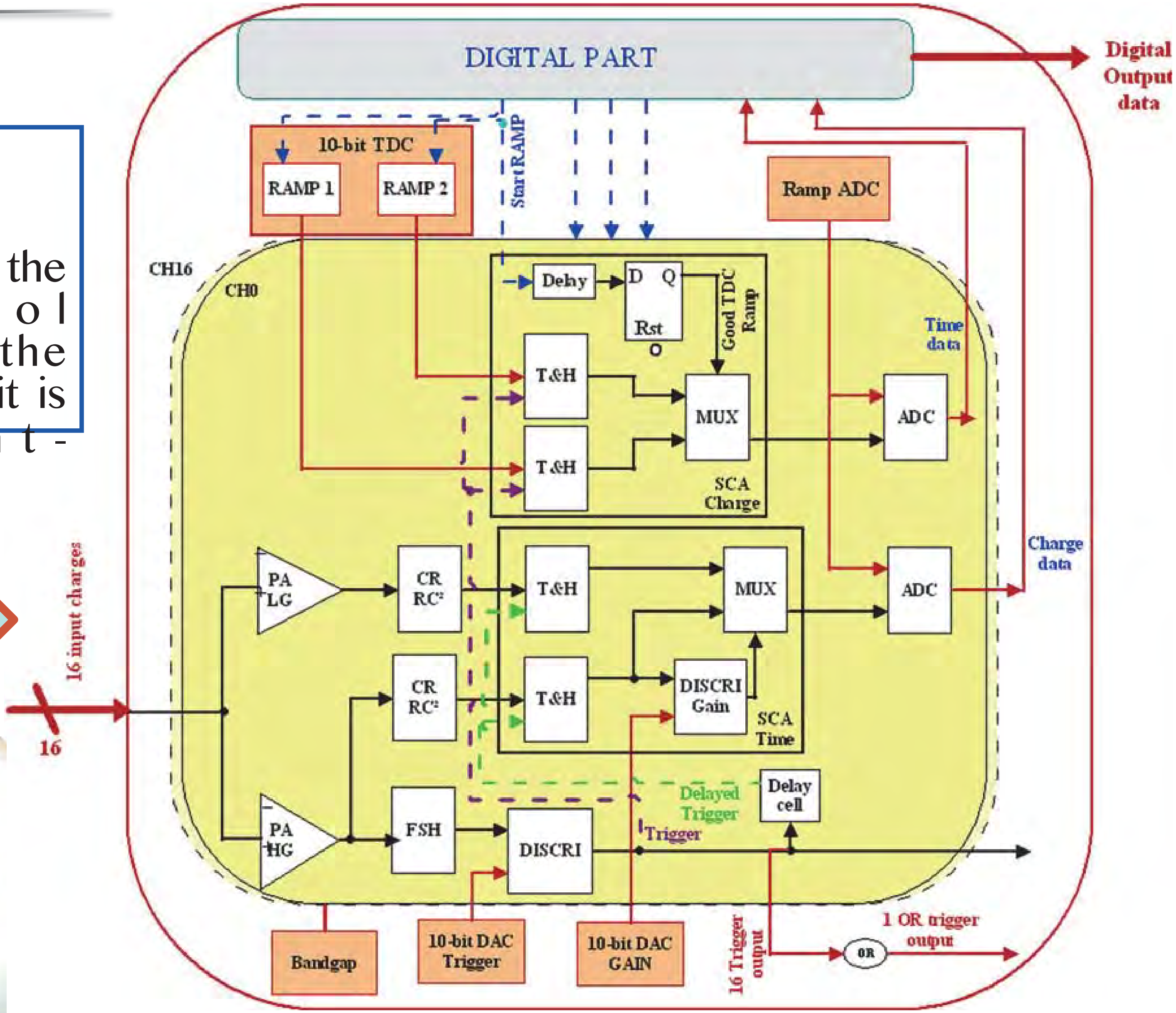
Simplified block schematic

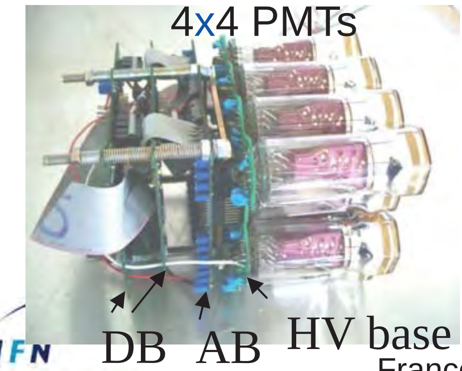
PARISROC 2

Each block is a complex structure

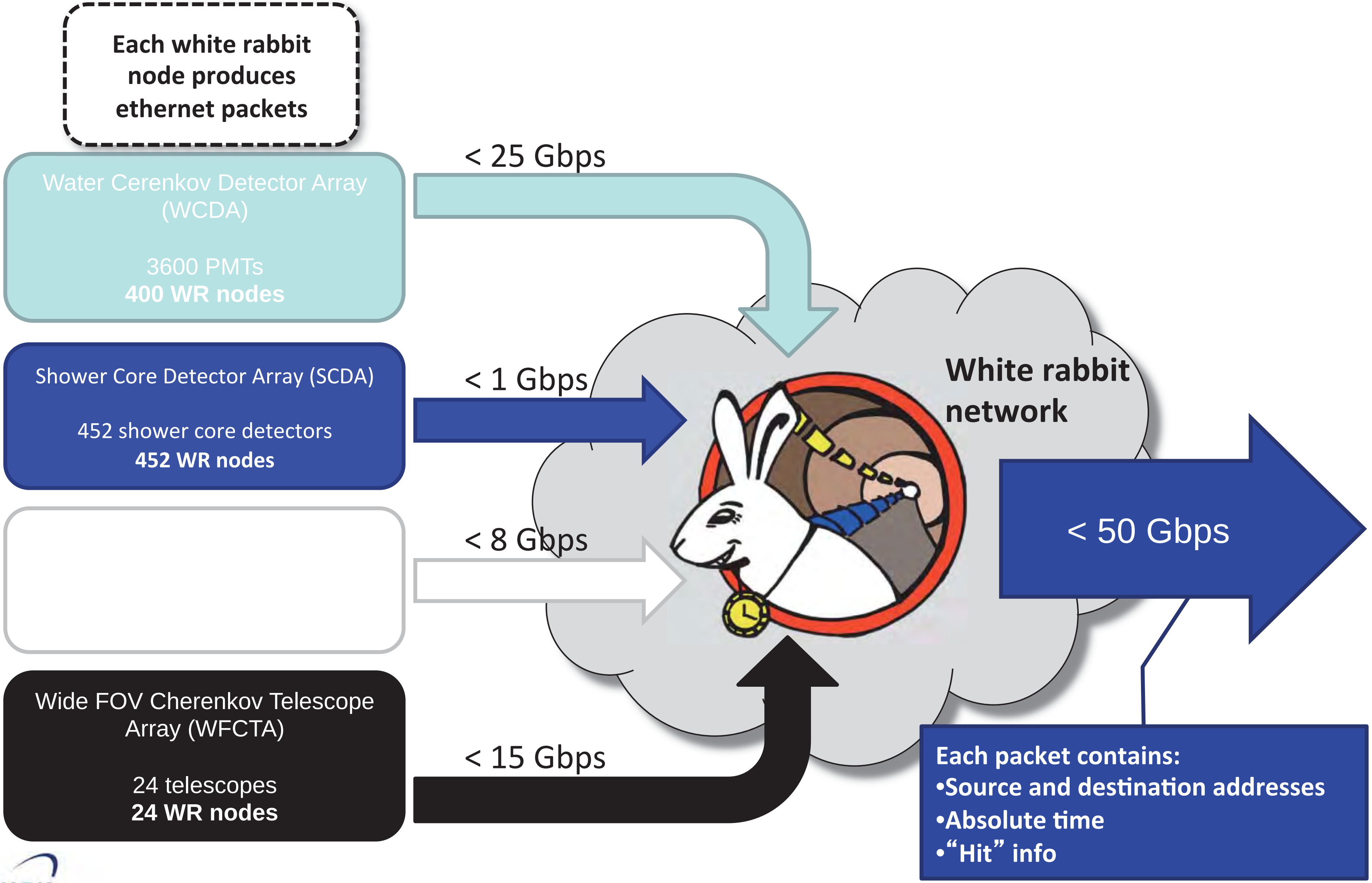
The decision of the slow control parameters is the crucial point and it is experiment-dependent.

5 mm X 3.4 mm

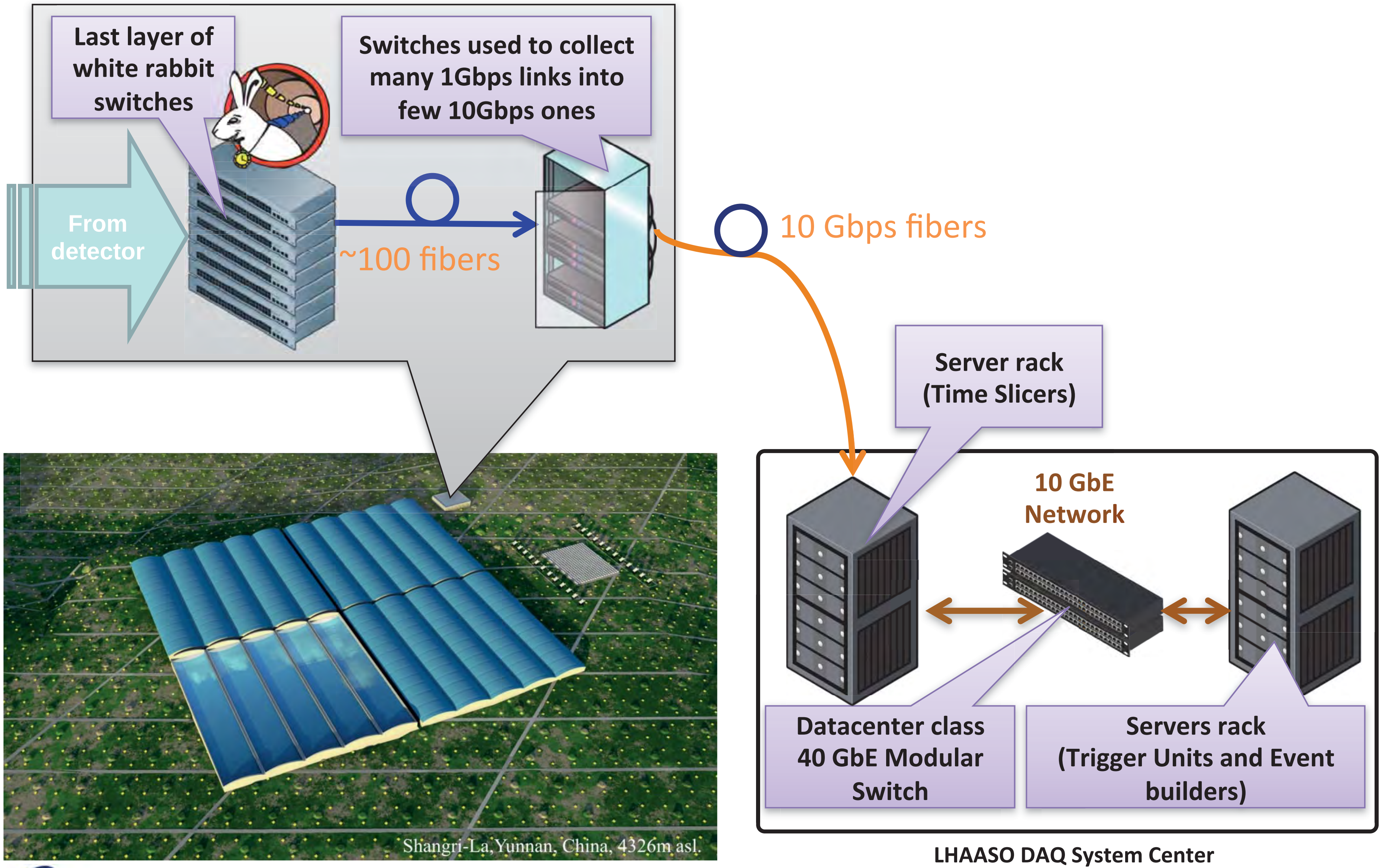




LHAASO raw data-rate



LHAASO online DAQ layout



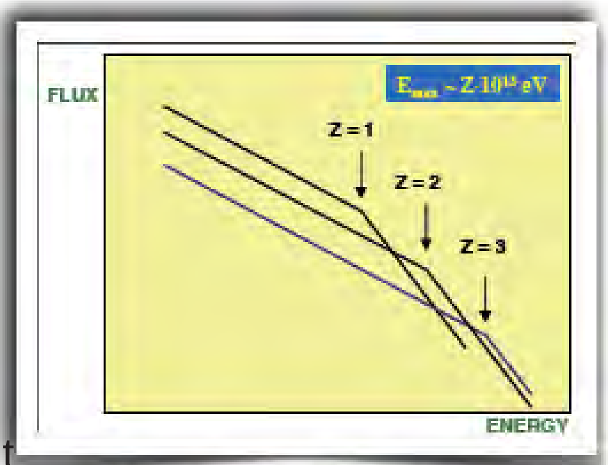
The standard model:

•Knee attributed yo light component

•Rigidity-dependent structure (Peters cycle): cut-offs at energies proportional tonuclear charge

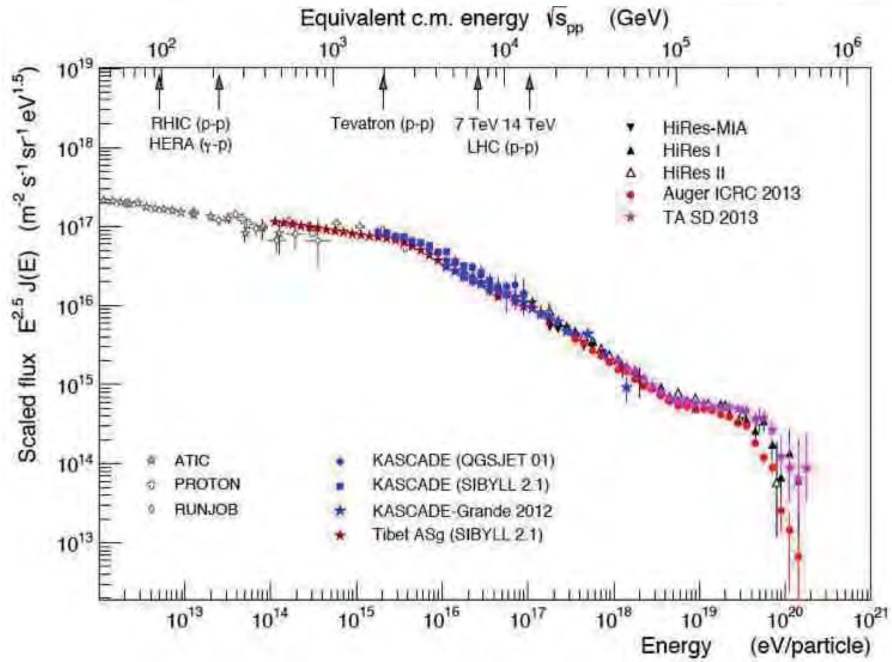
•The sum of the flux of all elemnts with individual cut-off makes up the all-particle spectrum

•Not only the spectrum becomes steeper due to such cut-off but alsoheavier



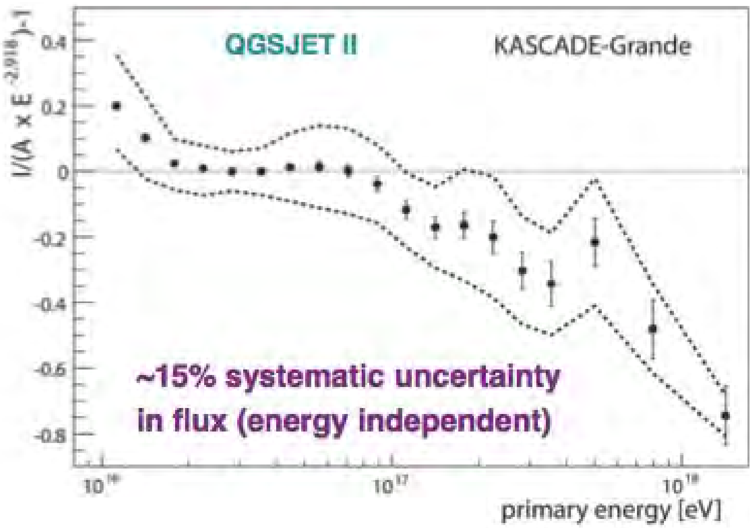
$E_{max}(iron) = 26 \cdot E_{max}(proton)$

Energy spectrum, elemental composition and anisotropy are crucial to understand origin, acceleration and propagation of the CR.



Experimental results still conflicting

KASCADE-Grande



- spectrum all-particle not a single power law
- hardening of the spectrum above 10^{16}eV
- steepening close to 10^{17}eV (2.1 σ)

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- steepening due to heavy primaries (3.5 σ)
- hardening at $10^{17.08}$ eV (5.8 σ) in light spectrum
- slope change from γ = -3.25 to γ = -2.79 !

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