Origin of cosmic rays with LHAASO and Auger

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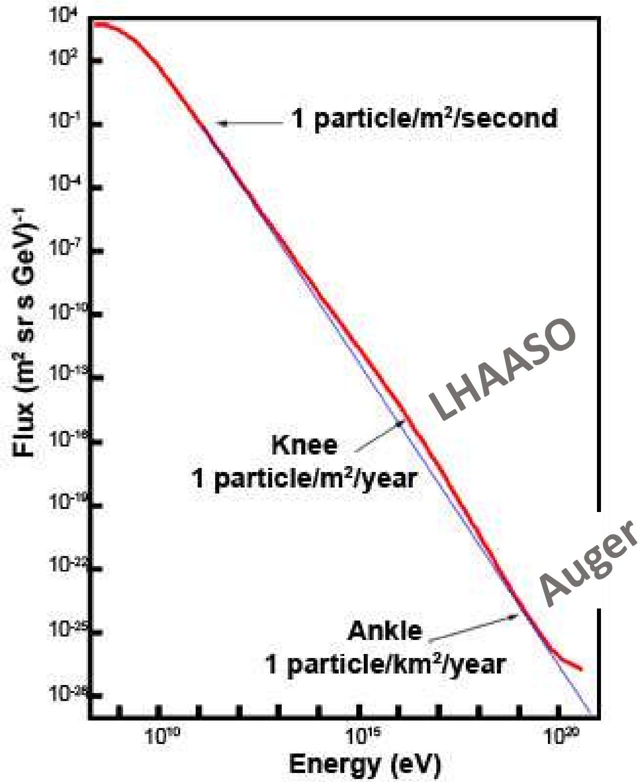
PHENIICS Doctoral School Days, 10 May 2016
Orsay, France

About the thesis

- 2^{nd} year PhD student in IPN-Orsay
- Working for LHAASO and the Pierre Auger Observatory



Cosmic Ray spectrum
(http://astronomy.swin.edu.au/)

LHAASO and **Auger** are both scientific projects aiming to search for the cosmic-ray origin

LHAASO
(Large High Altitude Air Shower Observatory)
Energy range of air shower detection:
10^{14}eV to 10^{18}eV (around "knee" region)

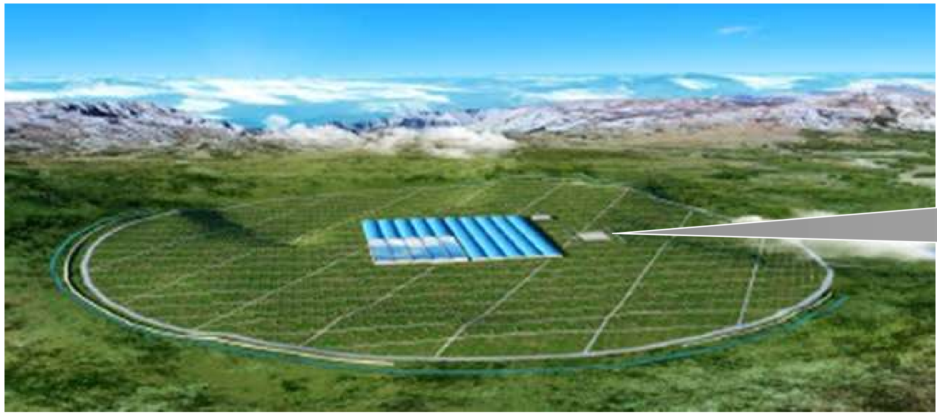
Auger
Energy range of air shower detection:
above 10^{18}eV

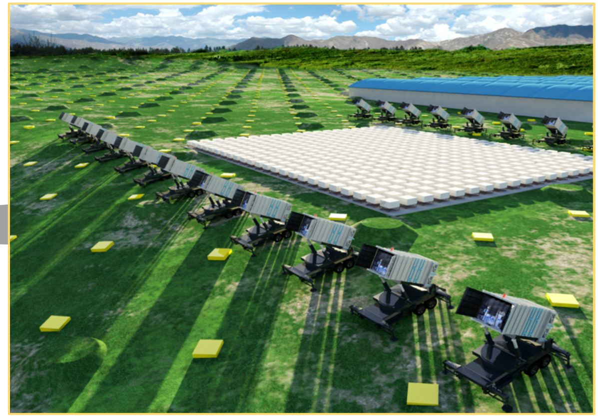
WFCTA in LHAASO

WFCTA : (Wide Field of View Cherenkov Telescope Array)

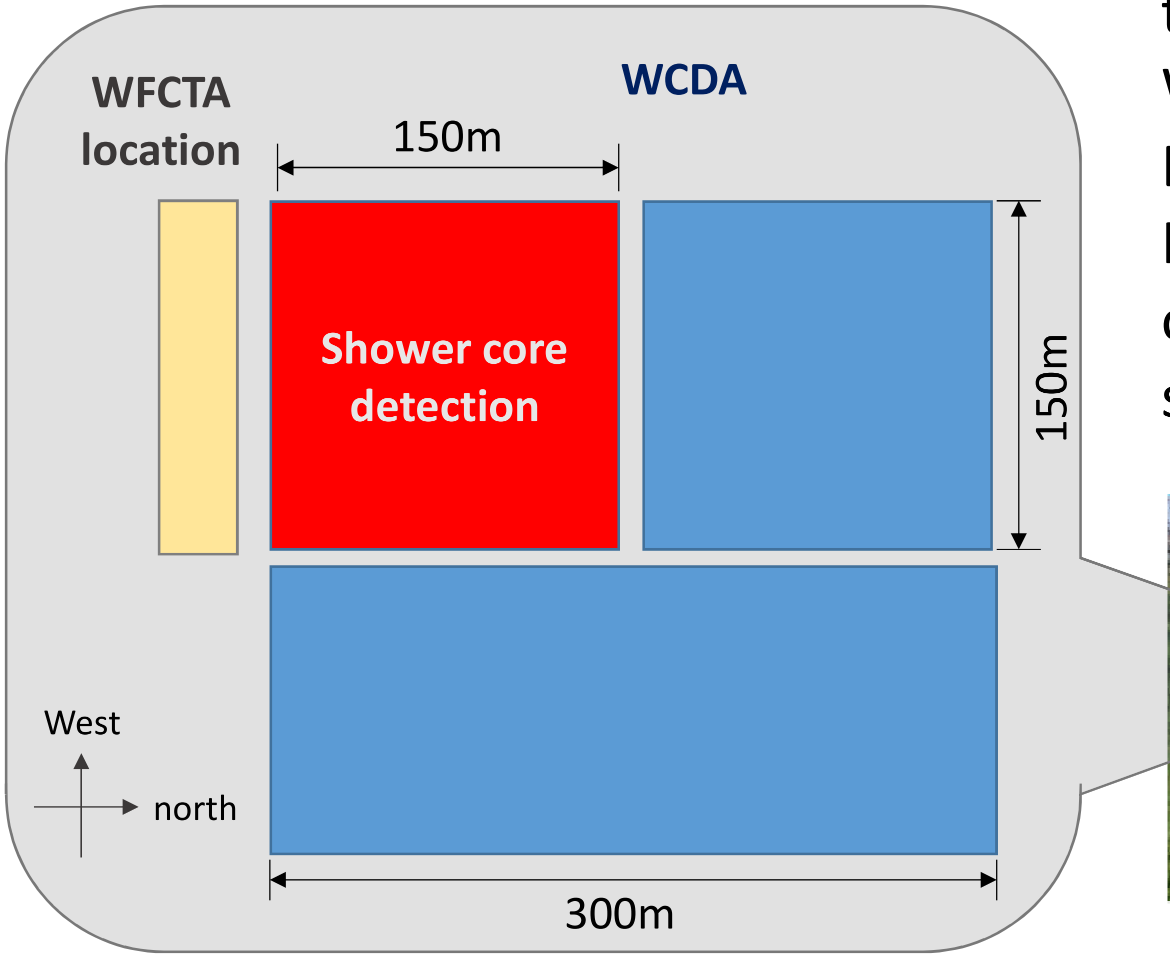
Three phases：
$30TeV \sim 10PeV$ in Cherenkov mode
$10PeV \sim 100PeV$ in Cherenkov mode
$100PeV \sim 1EeV$ in Fluorescence mode

WFCTA:
32×32 PMTs in each camera
$16° \times 14°$ field of view
$\sim 0.5°$ pixel size
$12\ (or\ 18)$ telescopes

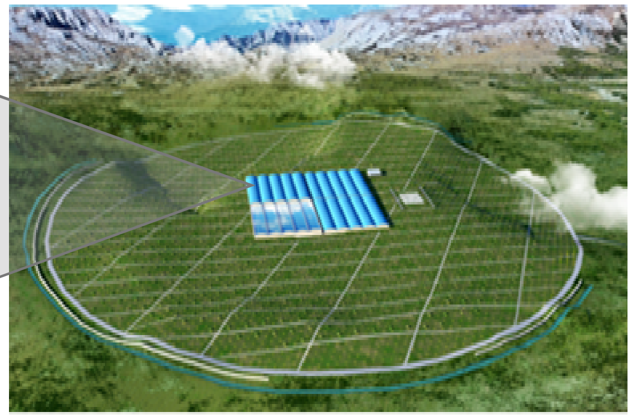




WFCTA Layout



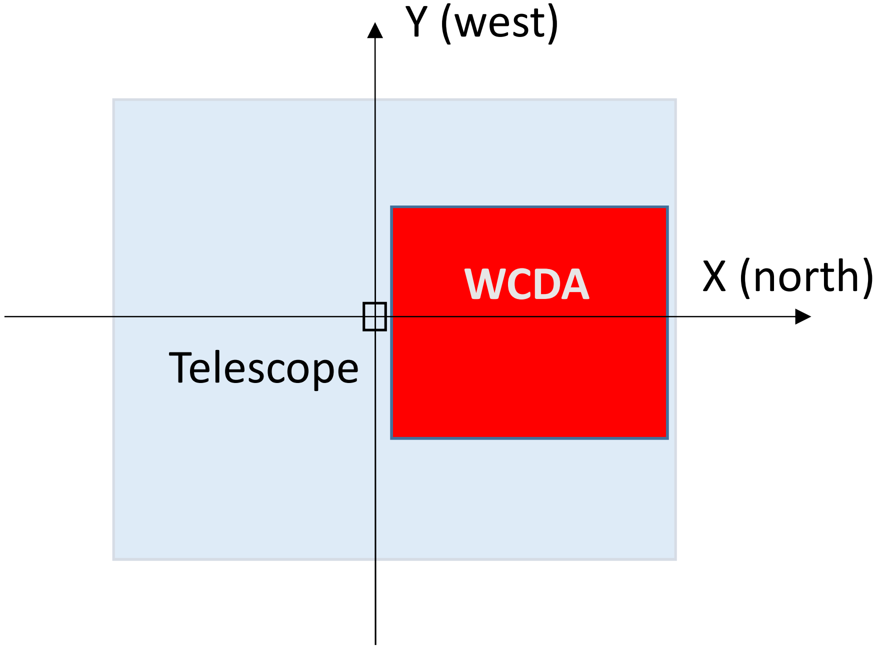
Hybrid observations together with WCDA(Water Cherenkov Detector Array) and KM2A($1km^2$ Array), 1/4 of the WCDA used as shower core detector.



Single Telescope Simulations

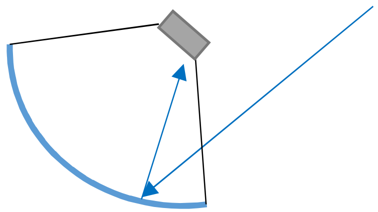
Shower simulation by CORSIKA:

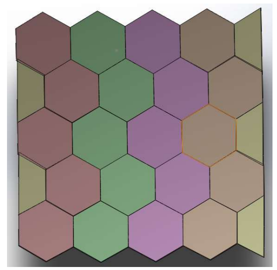
Primary Energy: $100TeV \sim 10PeV$
Slope of energy spectrum: -2.7
Zenith: $24° \sim 38°$
Azimuth: $77° \sim 103°$
Particle type: p, He, CNO, MgAlSi, iron



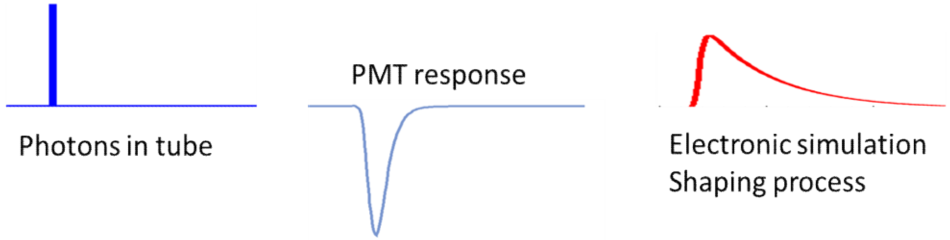
Telescope simulation:

- Pointing $(\theta_{zenith}, \varphi_{azimuth})$ = (30°, 90°)
- Optical ray-tracing to each PMT in the camera (by L.L.Ma)



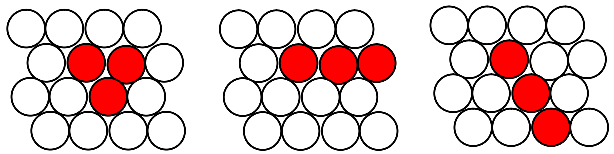


- Signal response & process in PMT & Electronics

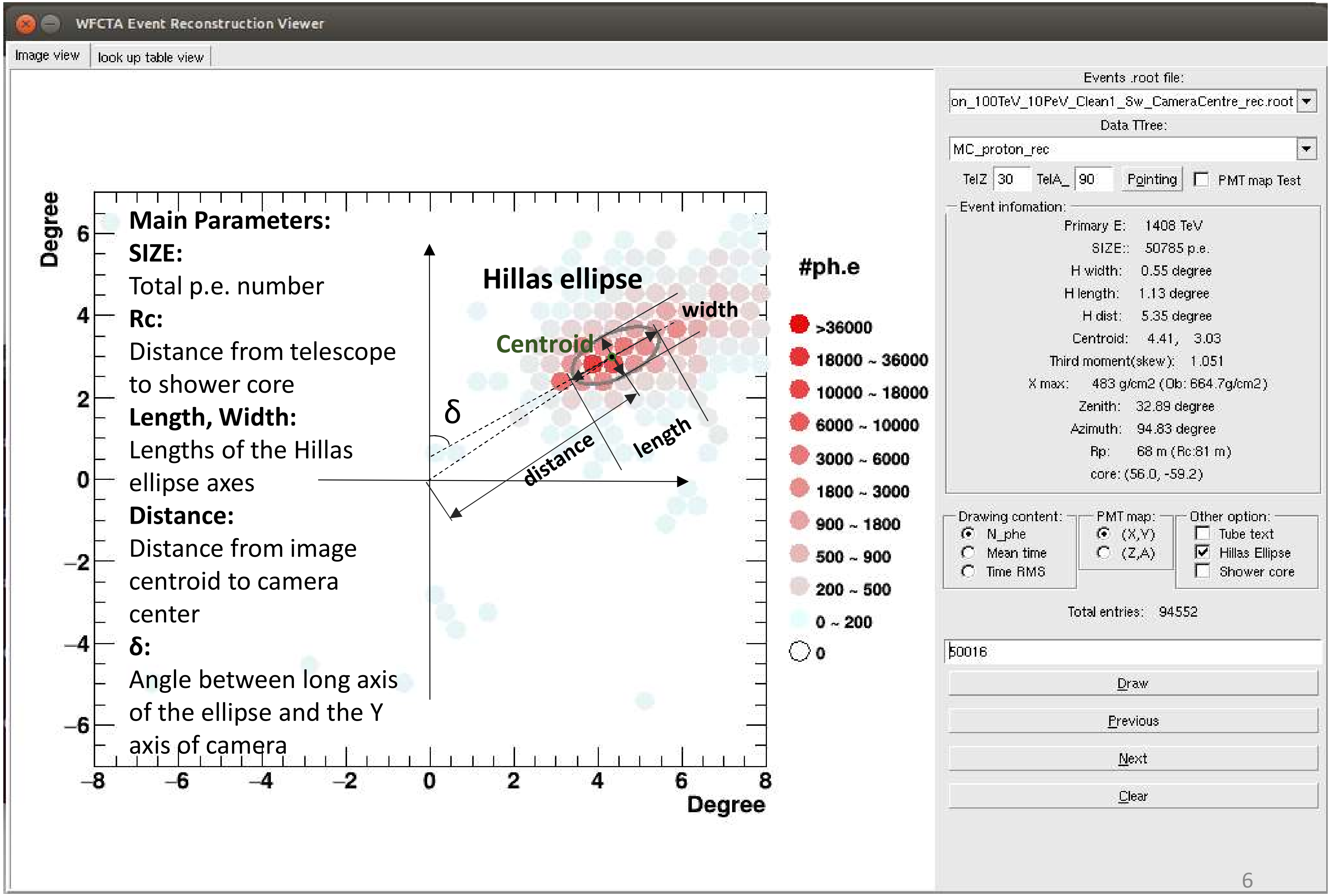


Different shaping and tube-trigger modes for both traditional and ASIC-based front-end electronics

- Event pattern trigger in camera (by B.Y.Bai)



WFCTA image and parameterization



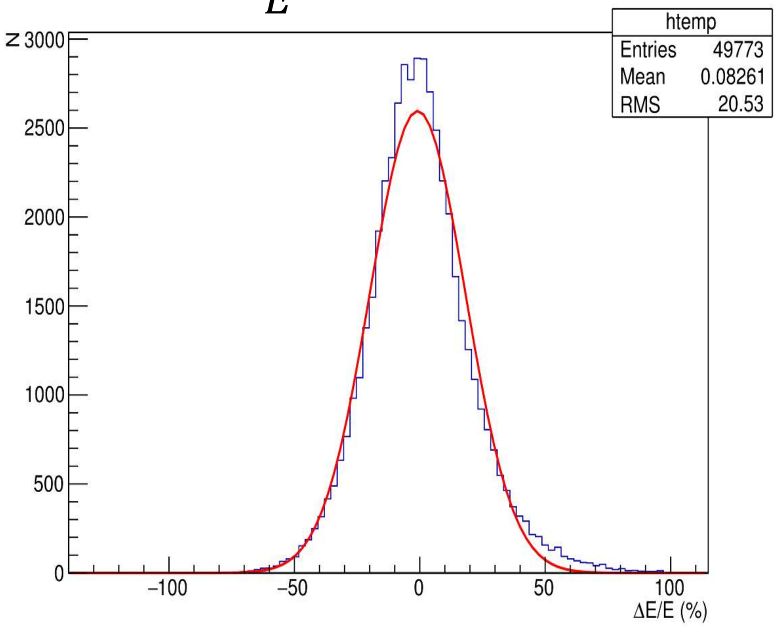
Reconstruction: Primary Energy

$$log_{10}recEnergy = \boldsymbol{f(log_{10}SIZE, R_c}, \delta, dist, core)$$
$$= \boldsymbol{f_1(log_{10}SIZE, R_c)} + f_2(\delta, dist, core)$$

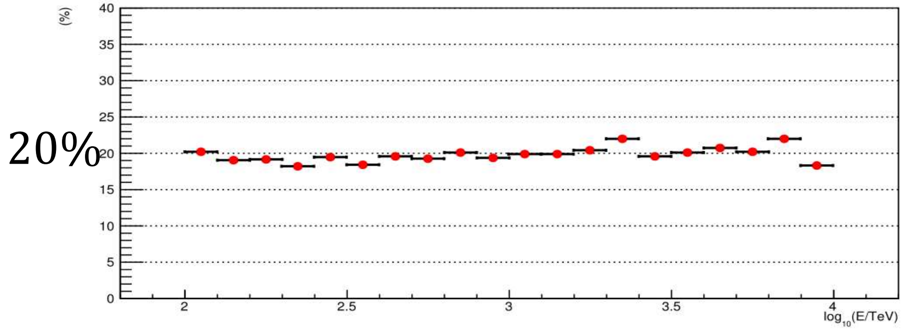
Primary Energy related *Direction related*

Results for proton:,

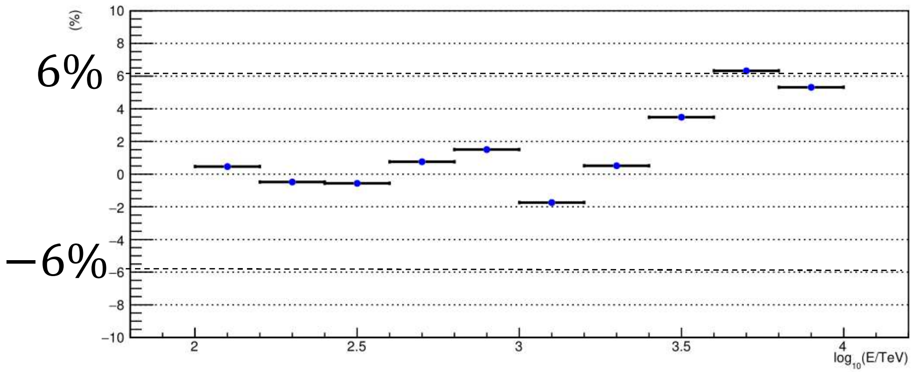
$$\frac{recE\ - E}{E} \times 100\%$$



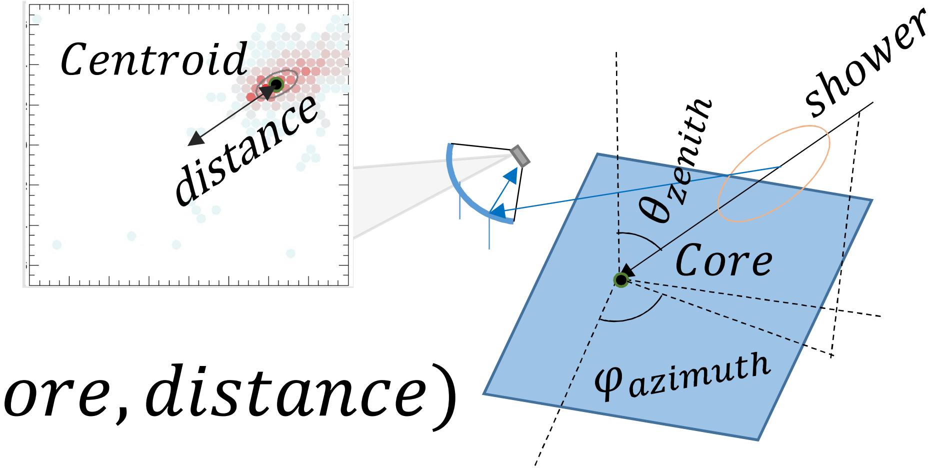
$E\ resolution \sim 20\%$



$Bias < 6\%$

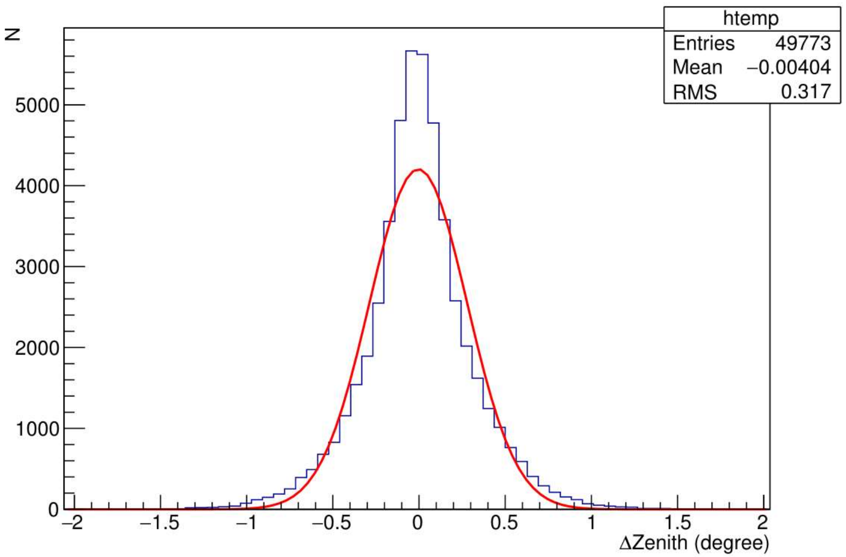


Reconstruction: Incident Angle

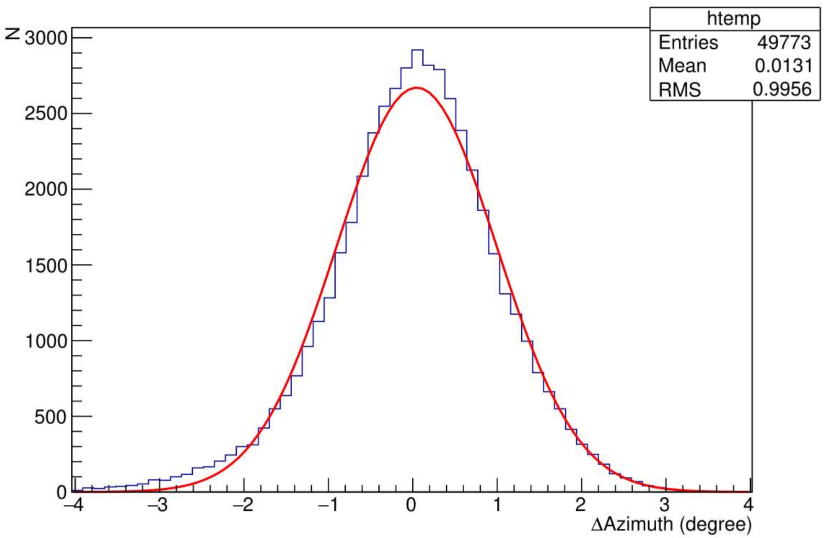


$$(\theta^{rec}_{zenith}, \varphi^{rec}_{azimuth}) = f(TelPointing, Centroid, Core, distance)$$

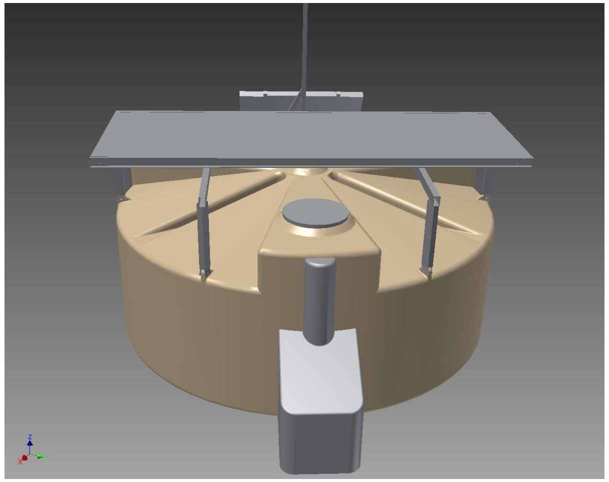
$\theta_{zenith} - \theta^{rec}_{zenith}$: *Resolution*: $\sim\mathbf{0.3}°$

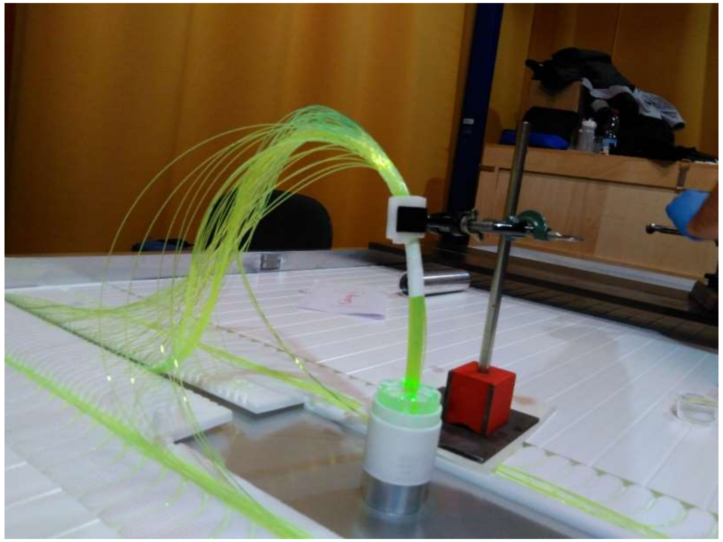


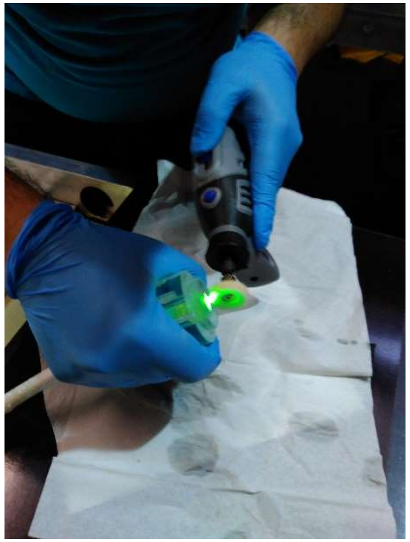
$\varphi_{azimuth} - \varphi^{rec}_{azimuth}$: *Resolution*: $\sim\mathbf{1}°$



Tests and R&D for Auger Upgrade



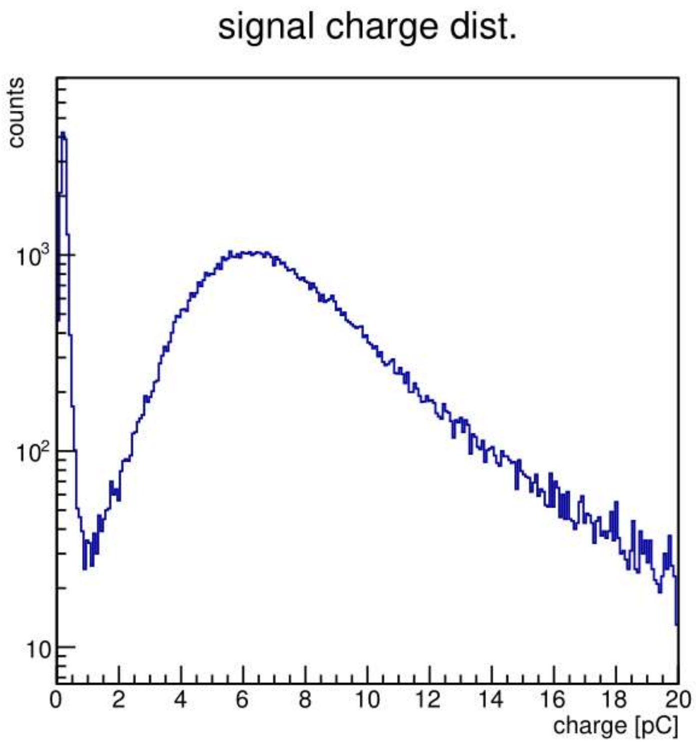




The key element of Auger upgrade will be the installation of a **Scintillator Surface Detector (SSD)** on top of each existing **Water Cherenkov Detector**. It will provide a measurement of primary composition by deducing **electromagnetic and muonic components of the shower.**

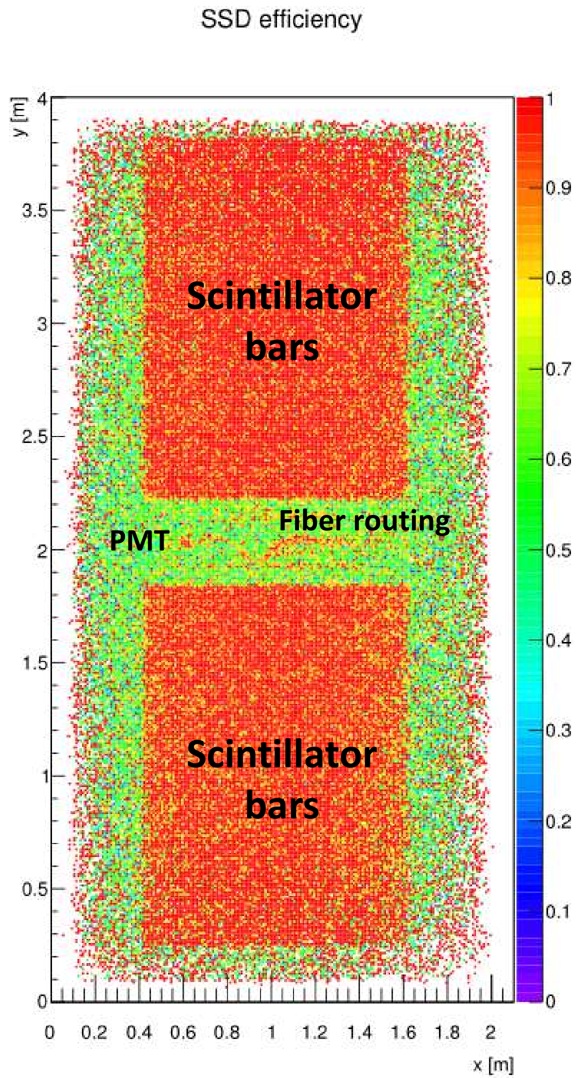
We tested different scintillator/fiber configurations and developed a fiber/PMT coupling method for SSD. April 2016, the detector with IPNO coupling was assembled and tested in KIT and will be installed in the Engineering Array on the observatory side

Preliminary results



Signal of charge = 6.52 pC
32.6 p.e./MIP

Peak to Valley ratio > 40



Conclusions:

- **LHAASO-WFCTA**

  Single WFCTA telescope simulation finished

  Reconstruction results:

  Primary Energy: $\sim 20\%$, bias $< 6\%$

  θ_{zenith}: $\sim 0.3°$

  $\varphi_{azimuth}$: $\sim 1°$

- **Auger Upgrade SSD**

  Tests to optimize SSD scintillator/fiber/optical coupling configuration are finished

  One SSD detector in the Engineering Array (EA) is equipped with IPNO coupling. The preliminary test results show that it has a good performance.

Next steps:

- **LHAASO-WFCTA:**

  Multi-telescope simulations & Hybrid analysis with WCDA and KM2A

- **Auger Upgrade SSD:**

  EA data analysis & Long term performance of the SSD detectors in the EA