Preliminary simulations for the LHAASO-WFCTA

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9th FCPPL workshop, 31 March – 01 April 2016
Strasbourg, France

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
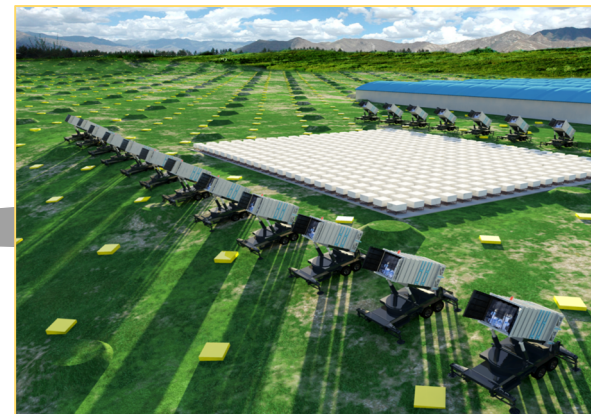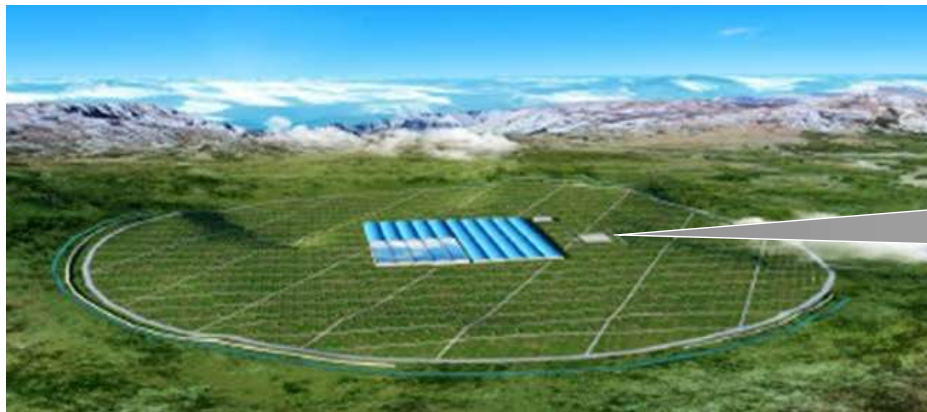$100PeV \sim 1EeV$ in Fluorescence mode

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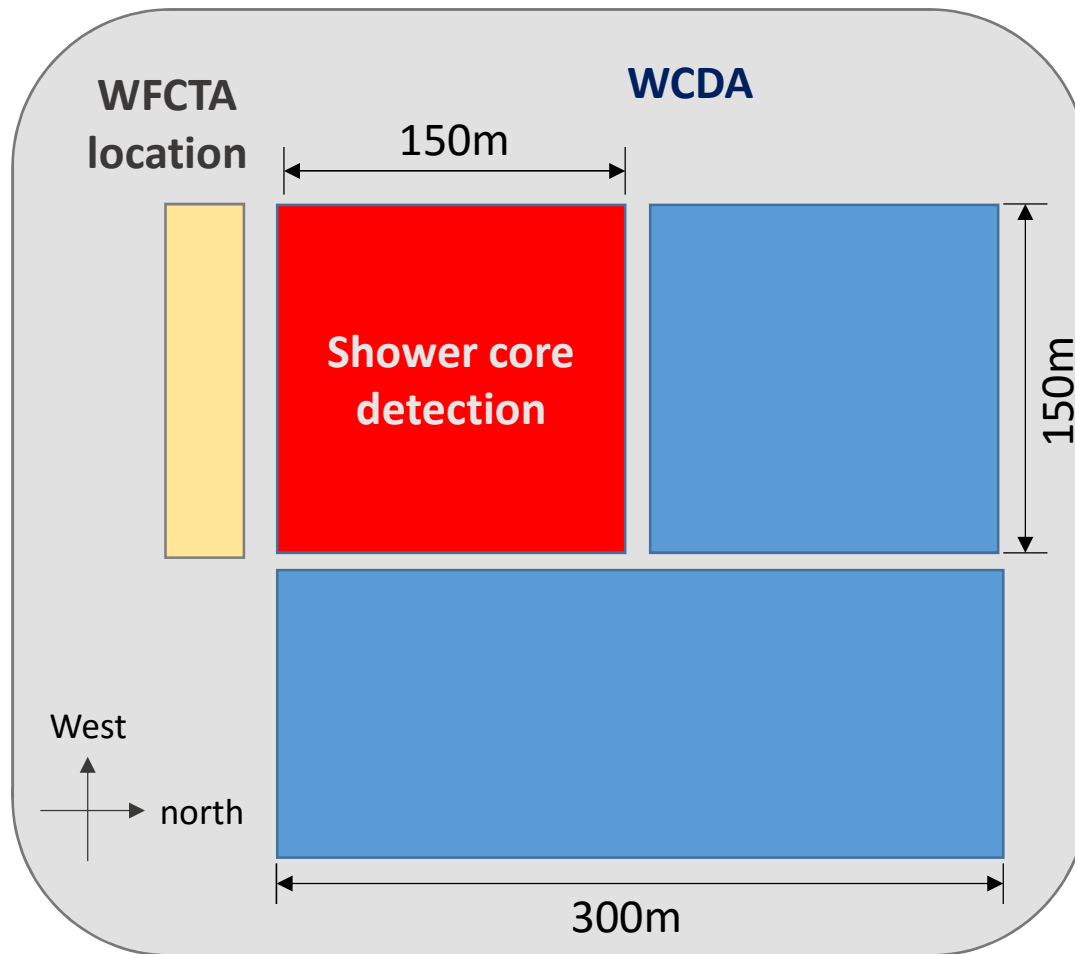$32×32$　　PMTs in each camera
$16° × 14°$ field of view
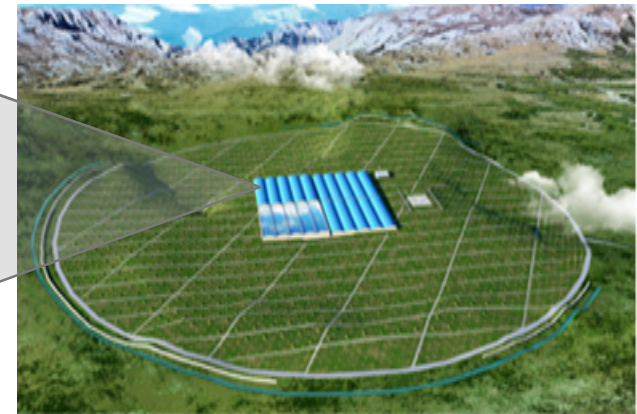$\sim 0.5°$　　pixel size
$12 \ (or \ 18)$ telescopes

ASIC-based front-end electronics designed by previous FCPPL PhD student Dr. Y.T. CHEN in IPN-Orsay

WFCTA Layout
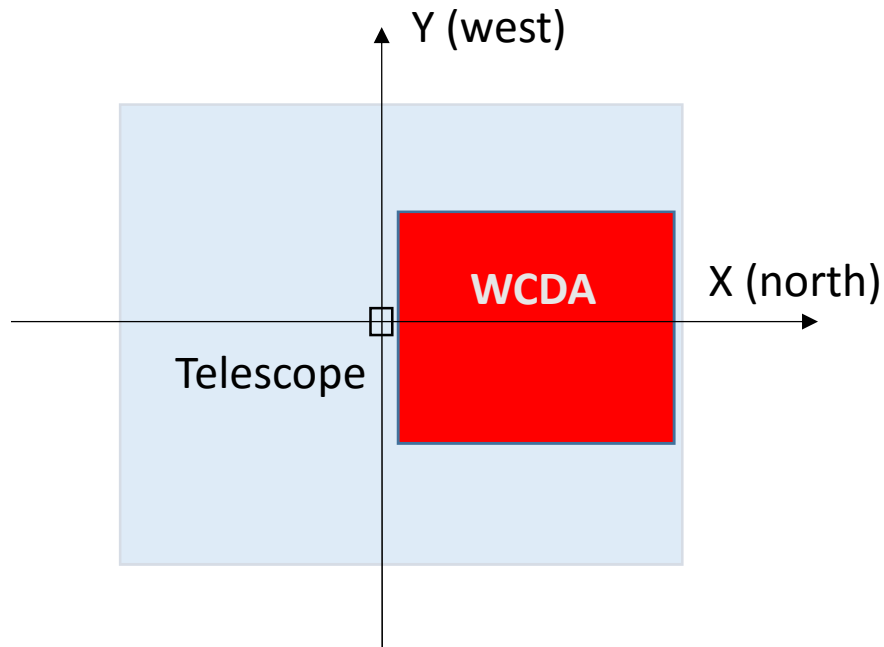

Hybrid observations together with WCDA and KM2A, 1/4 of the WCDA used as shower core detector.
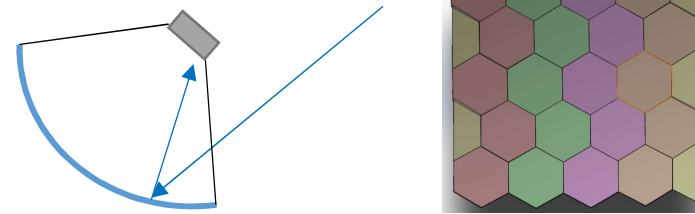
Single Telescope Simulations

Shower simulation by CORSIKA:

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

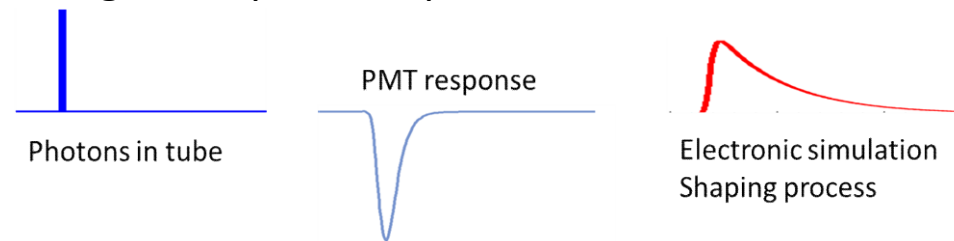**Telescope simulation:**

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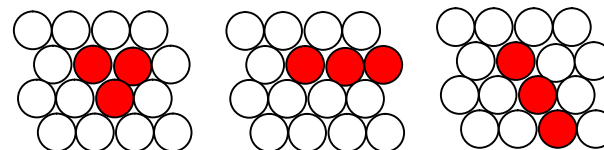- Optical ray-tracing to each PMT in the camera (by L.L.Ma)

- Signal response & process in PMT & Electronics

Photons in tube   PMT response   Electronic simulation Shaping process
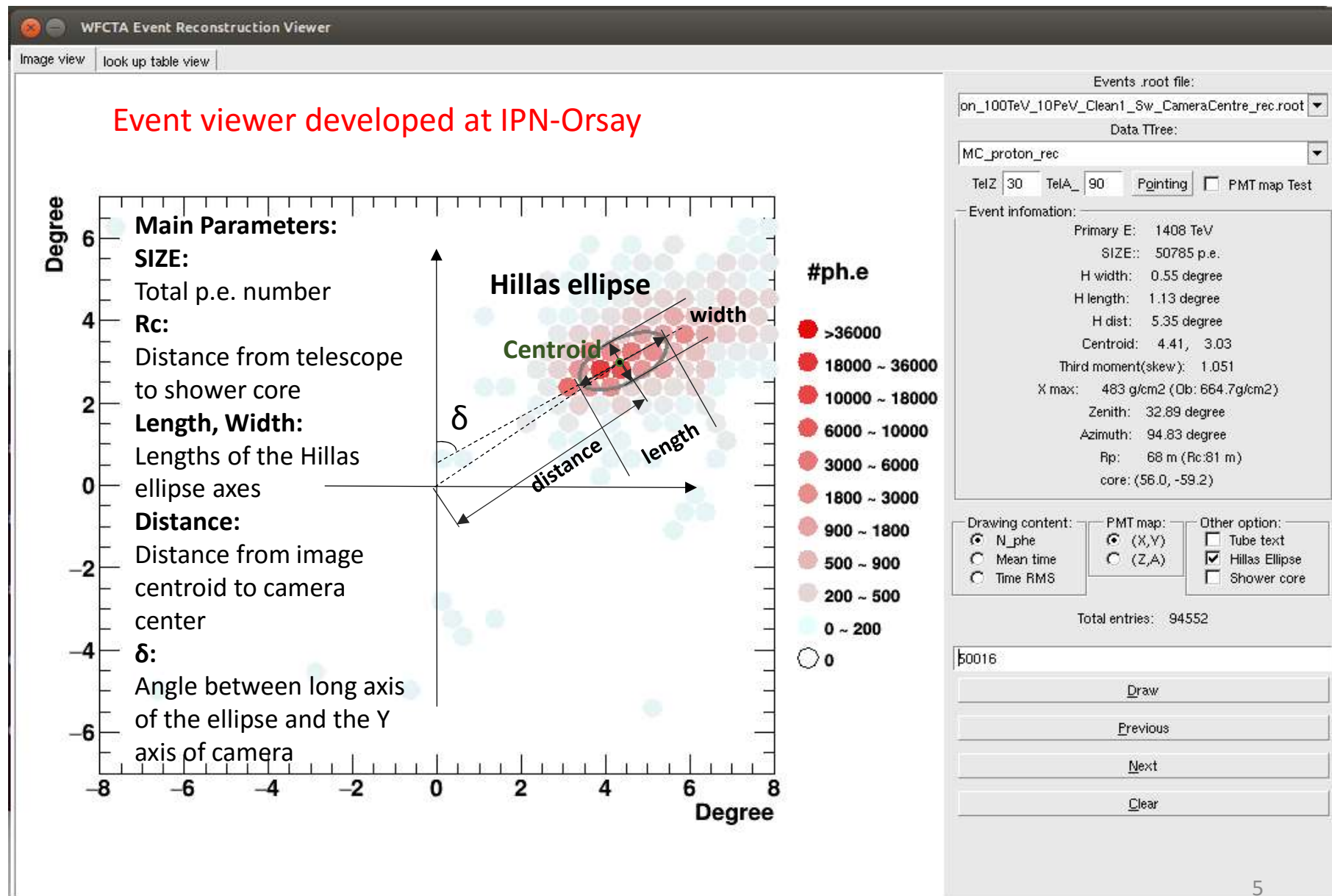
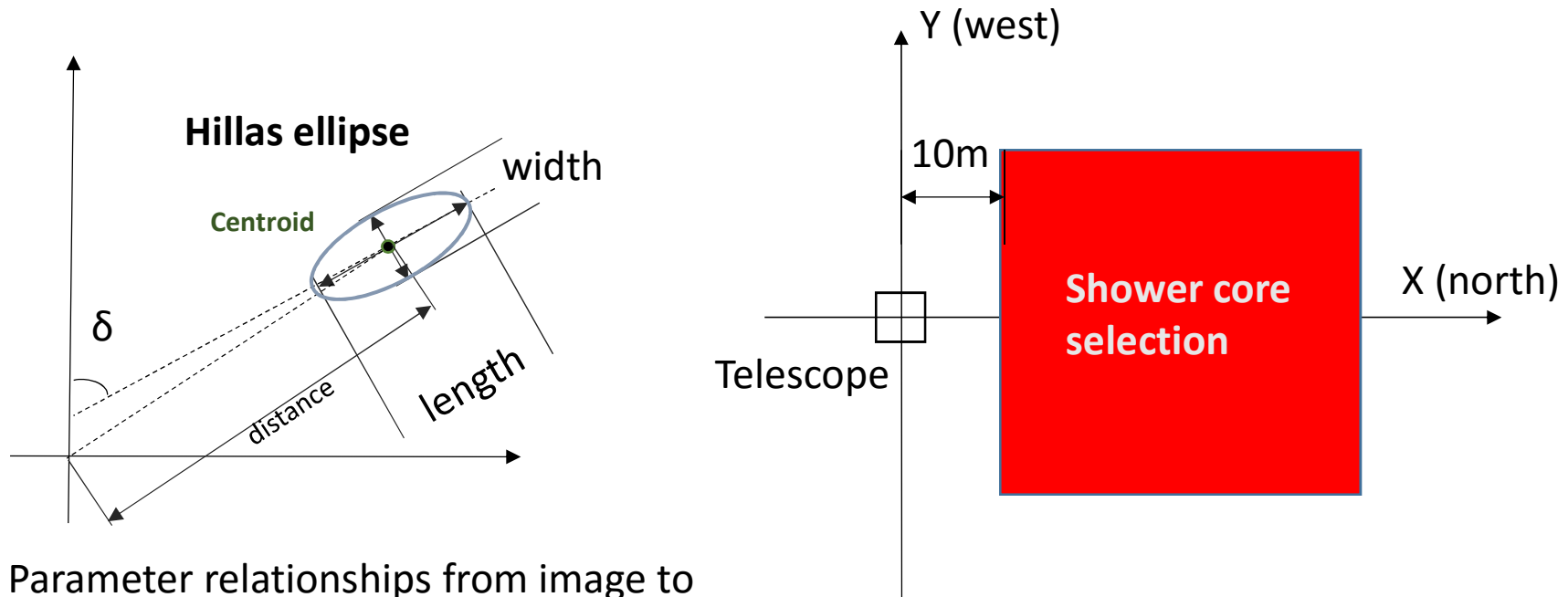Different shaping and tube-trigger modes for both traditional and ASIC-based front-end electronics

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

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WFCTA image and parameterization

Telescope image parameters

Hillas ellipse

width

Centroid

δ

distance

length

Y (west)

10m

Shower core selection

X (north)

Telescope

Parameter relationships from image to shower:

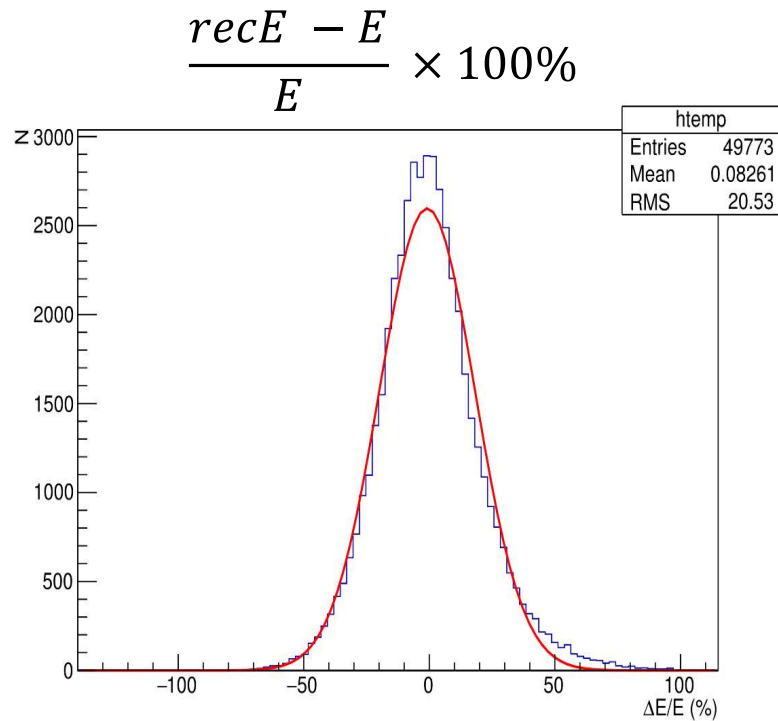|		
SIZE	→	Primary Energy
R_c	→	Primary Energy
Width, Length	→	X_{max} $\theta_{zenith}, \varphi_{azimuth}$
Centroid	→	$\theta_{zenith}, \varphi_{azimuth}$
δ, distance	→	$\theta_{zenith}, \varphi_{azimuth}$
...		

Event selection for reconstruction:

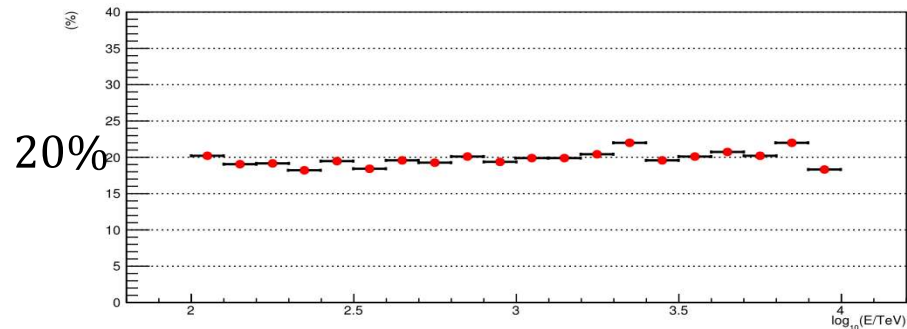- distance < 5°
- Shower core in WCDA

Reconstruction: Primary Energy

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

Primary Energy related   Direction related

Results for proton:,

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

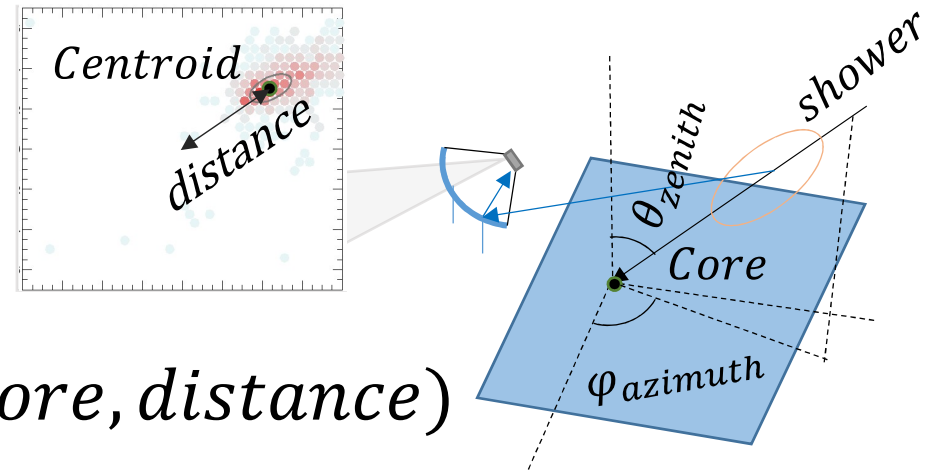| htemp	
Entries	49773
Mean	0.08261
RMS	20.53

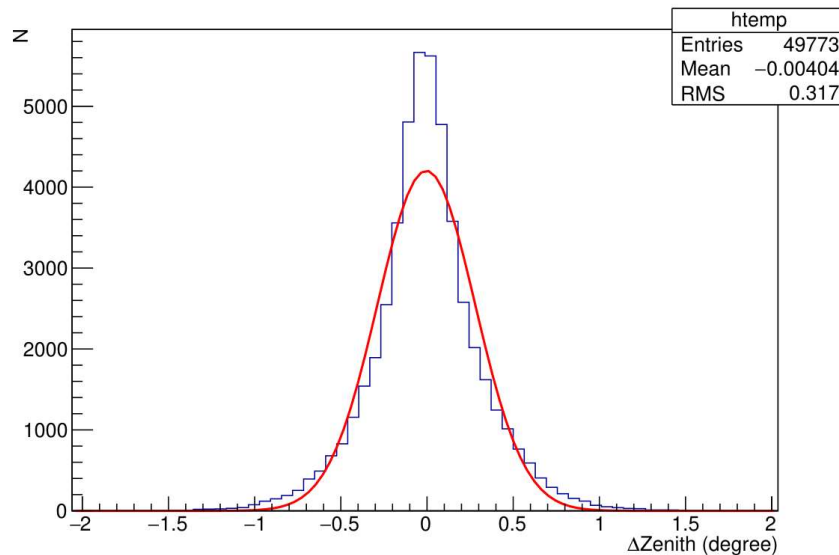$E\ resolution \sim 20\%$

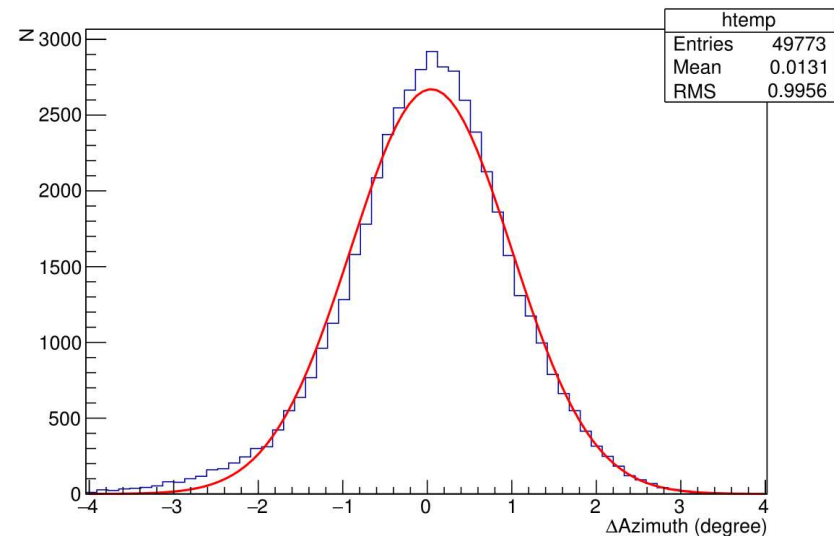$Bias < 6\%$
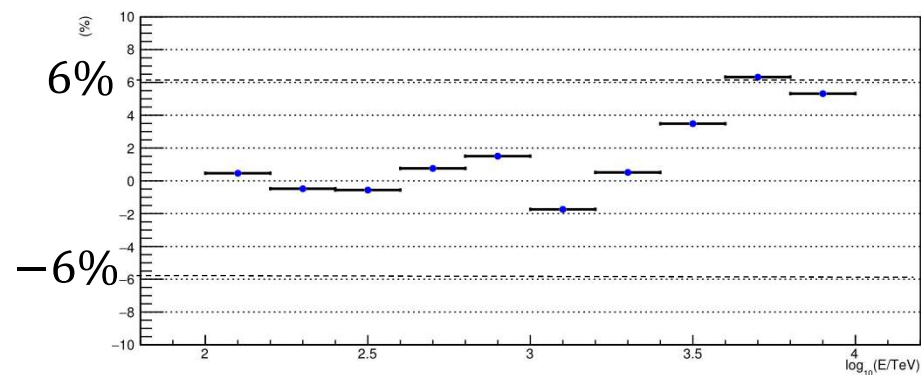
Reconstruction: Incident Angle

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

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

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

htemp

Entries	49773
Mean	−0.00404
RMS	0.317

ΔZenith (degree)

htemp

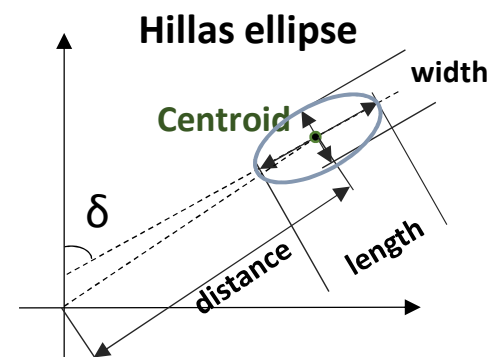|	
Entries	49773
Mean	0.0131
RMS	0.9956

ΔAzimuth (degree)
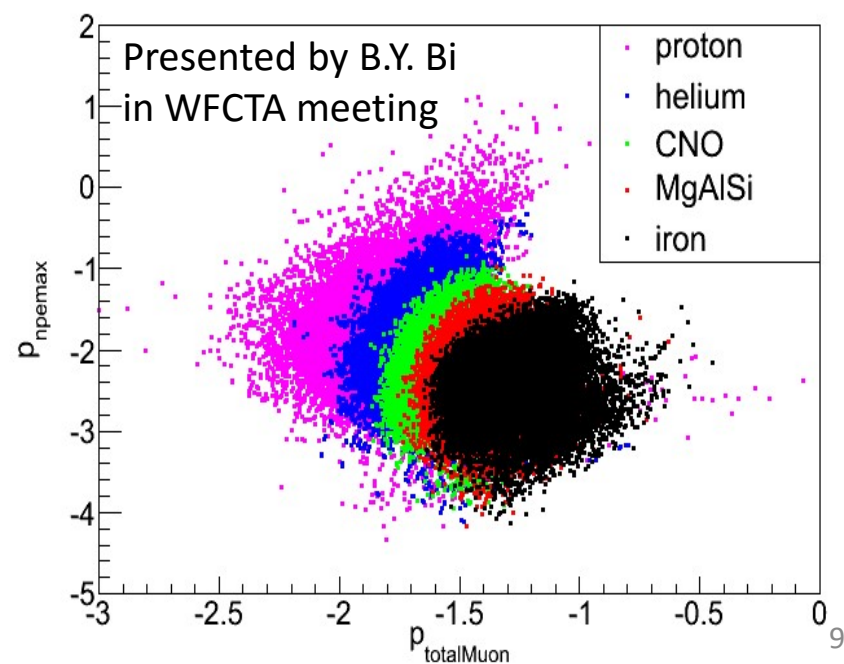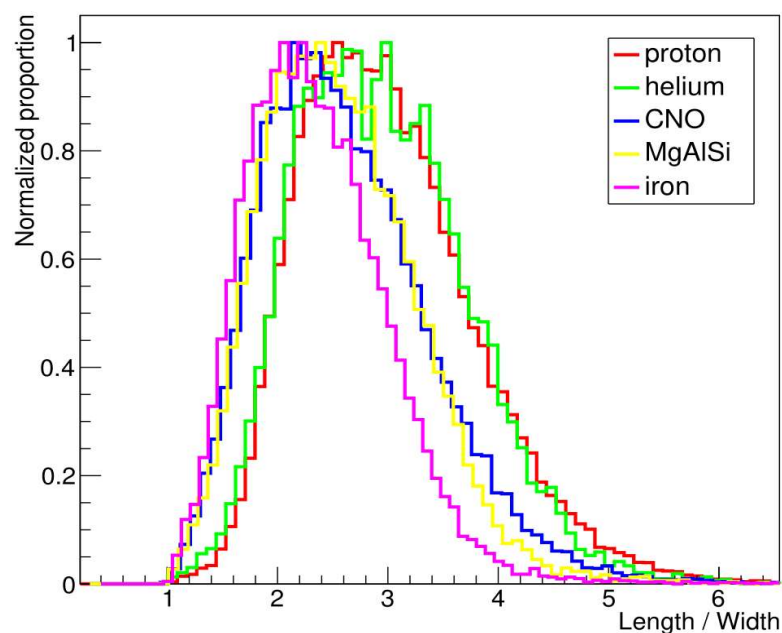
Reconstruction: Identification

- With telescope image and reconstructed shower core:
  Xmax-based Identification $(L, W, R_c, SIZE)$

Hillas ellipse

- LHAASO **hybrid** simulation: (Preliminary result presented by WFCTA group)
  Multi-parameter analysis $(N_{pe\,max}, N_{pe}^{WCD}$ by WCDA, $totalMuon\ by\ KM2A\ ...)$

Conclusions:

- Single WFCTA telescope simulation finished
- Reconstruction results:

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

    θ_{zenith}: $\sim 0.3°$

    $\varphi_{azimuth}$: $\sim 1°$
- WFCTA image parameters can help to identify the particles together with other detector arrays

Next steps:

- Multi-telescope simulations
- Hybrid analysis with WCDA and KM2A
- WFCTA module update for LHAASO simulation & analysis framework
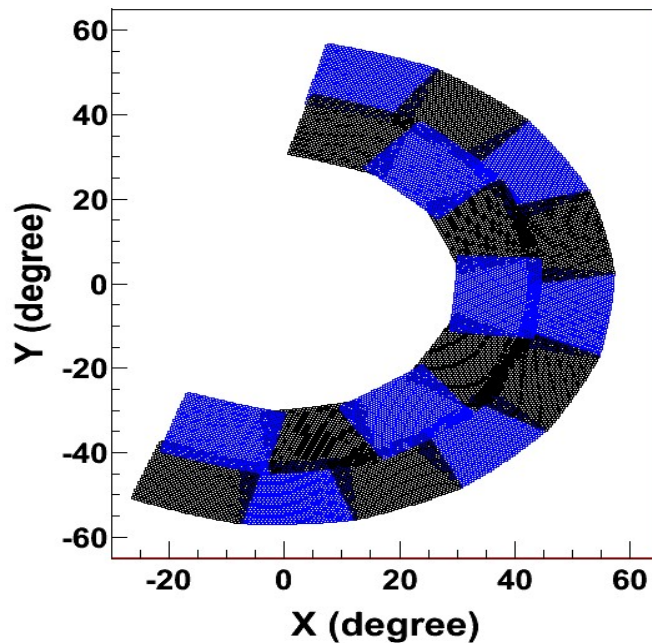
Back-up:
Equations for reconstruction

$$log_{10} recEnergy = a_s \cdot log_{10} SIZE + a_r \cdot R_c$$
$$+ a_\delta \cdot |\sin \delta| + a_{dist} \cdot \tan(dist)$$
$$+ pol2(core) + a_0$$

$$\theta_{zenith}^{rec} = \theta_{Tel} + Z(CentroidY, CentroidX, Corex)$$

$$\varphi_{azimuth}^{rec} = \varphi_{Tel} + A(CentroidY, CentroidX, Corey, Corex, dist)$$

Back-up:
WFCTA pointing for Phase 1,2

- Phase 1: $30TeV \sim 10PeV$

- Phase 2: $10PeV \sim 100PeV$