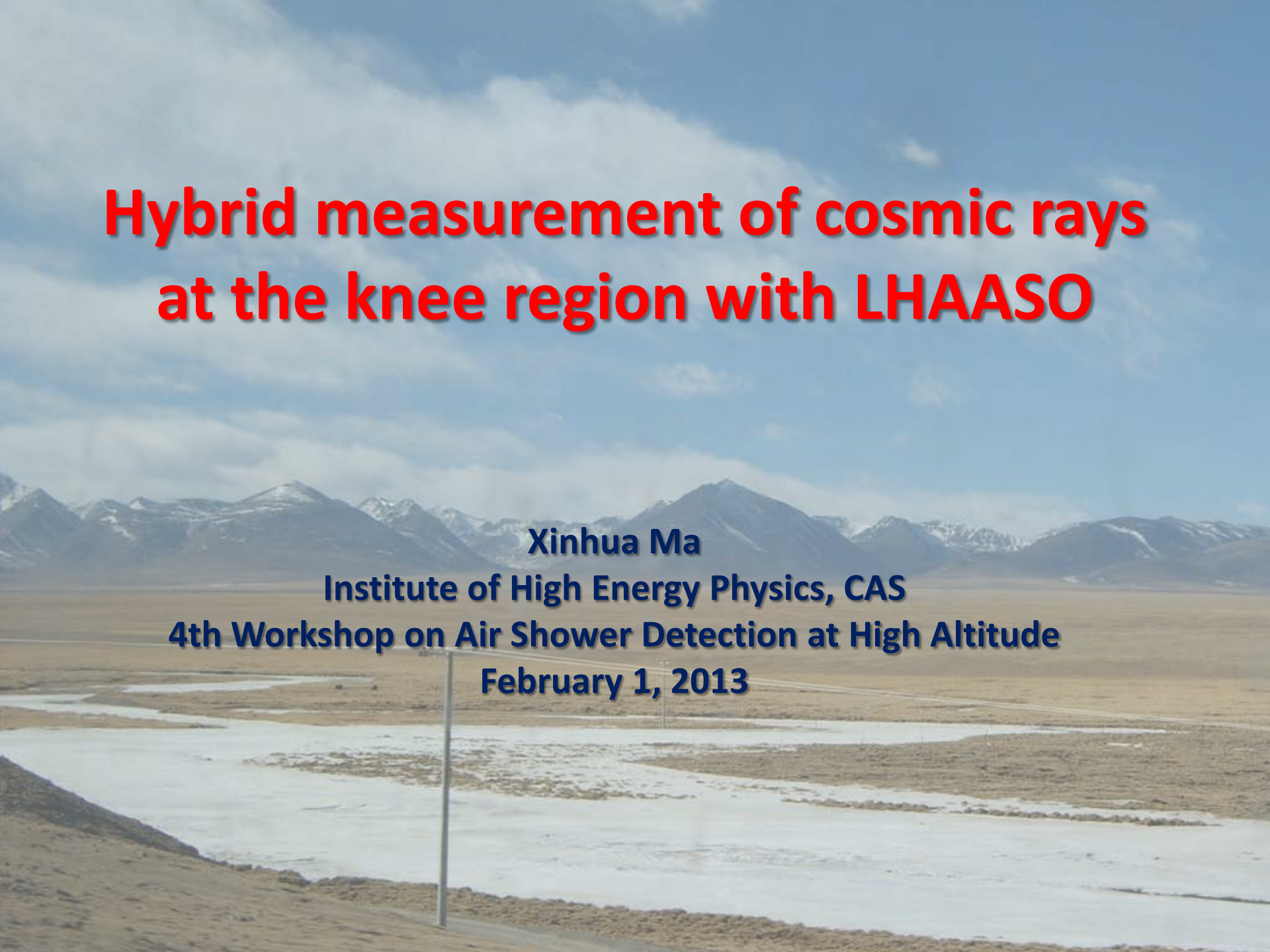
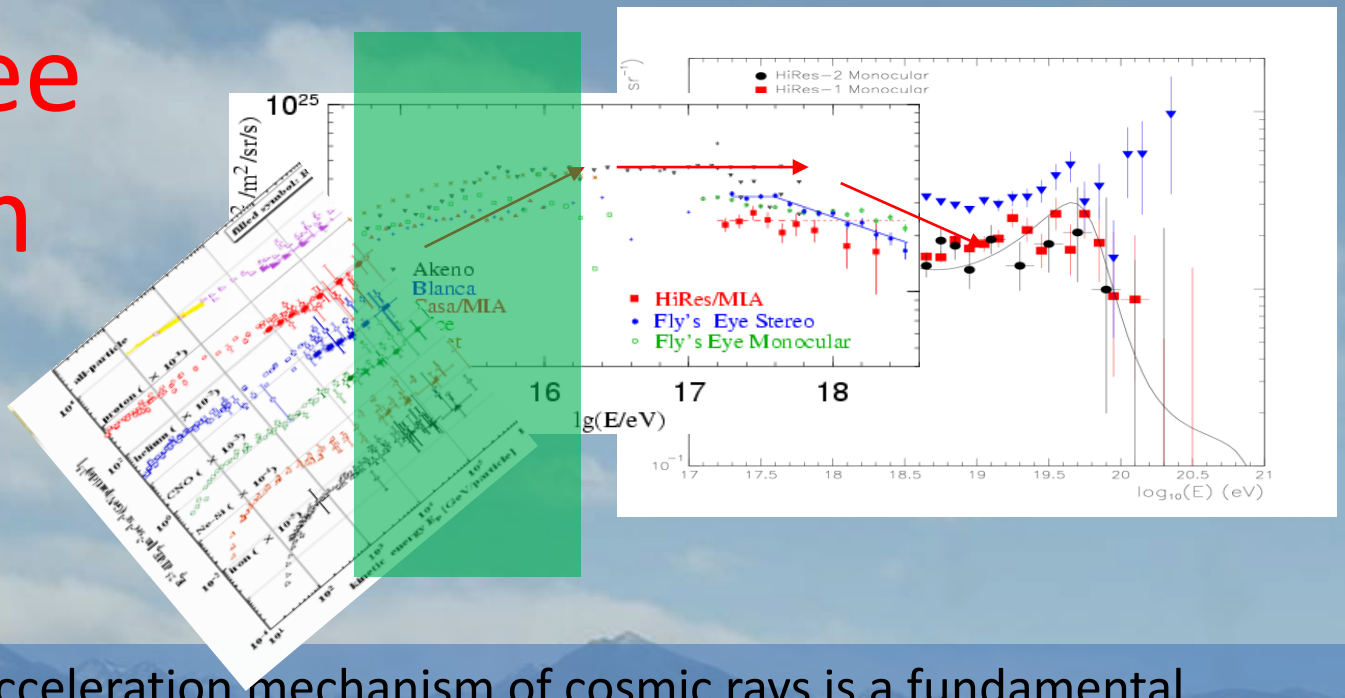


# Hybrid measurement of cosmic rays at the knee region with LHAASO

Xinhua Ma
Institute of High Energy Physics, CAS
4th Workshop on Air Shower Detection at High Altitude
February 1, 2013

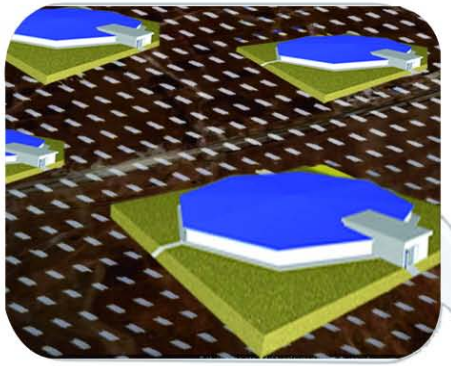
# the Knee Region



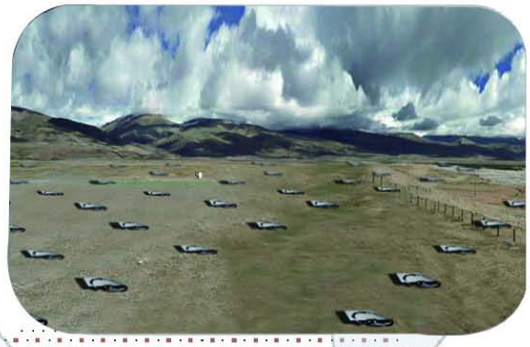

- Origin and acceleration mechanism of cosmic rays is a fundamental problem of particle astrophysics, and the “knee” region as the first “turning point” in the cosmic ray spectrum is very sensitive to the solution.
- Due to low cosmic ray flux in the knee region, measurements of primary energy and composition can be made with ground-based experiments to detect air showers.
- Results of several observations still differ with uncertainty of about 30%, and are hadronic interaction model-dependent.
- **LHAASO: high altitude + large area + hybrid detection**

# LHAASO Large High Altitude Air Shower Observatory

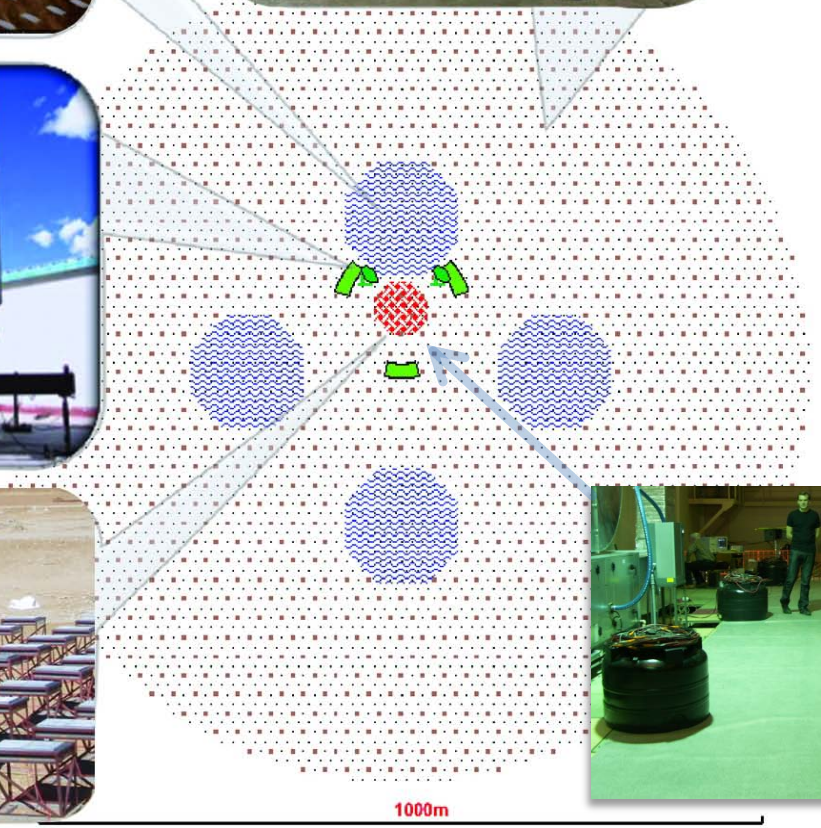
WCDA



KM2A



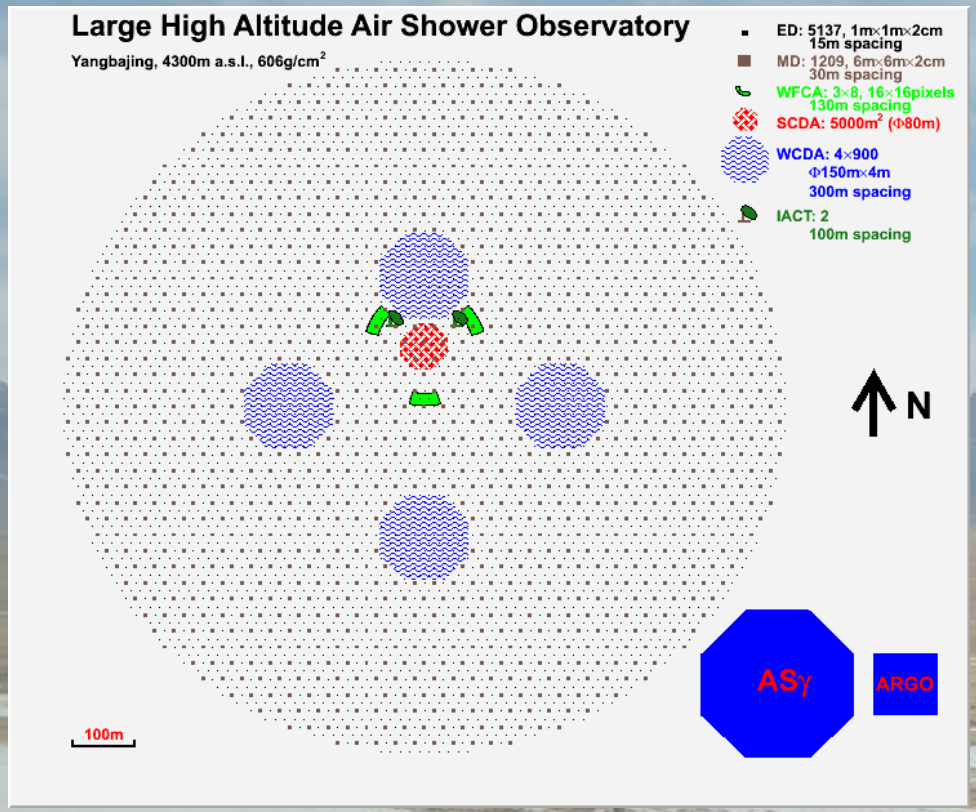
WFCTA




PRISMA

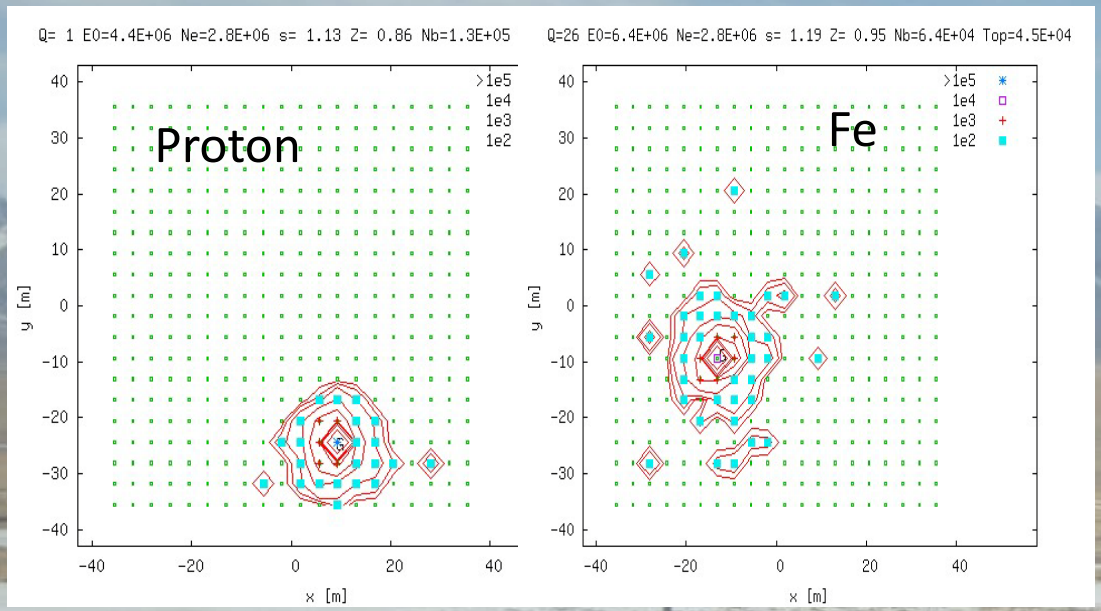
SCDA

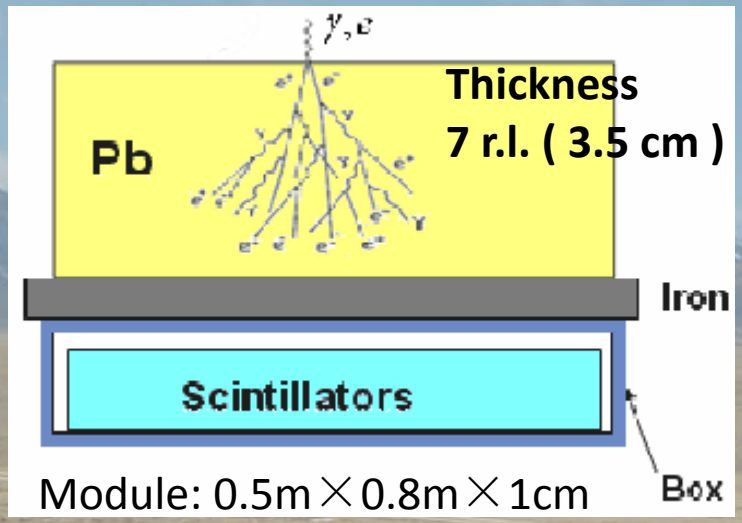
# LHAASO-knee hybrid detection



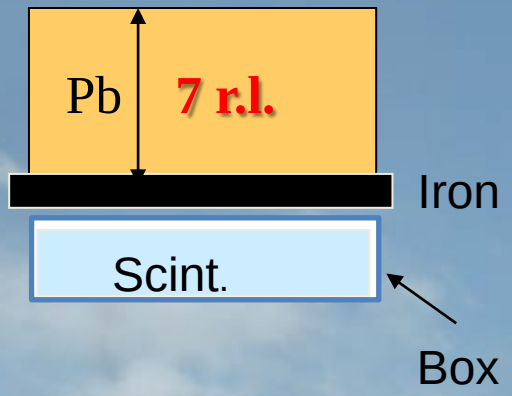

- KM2A : e,μ
- WFCTA: Č
- SCDA: γ family at core →π0
- WCDA: μ
- PRISMA: thermal neutrons →π+π-

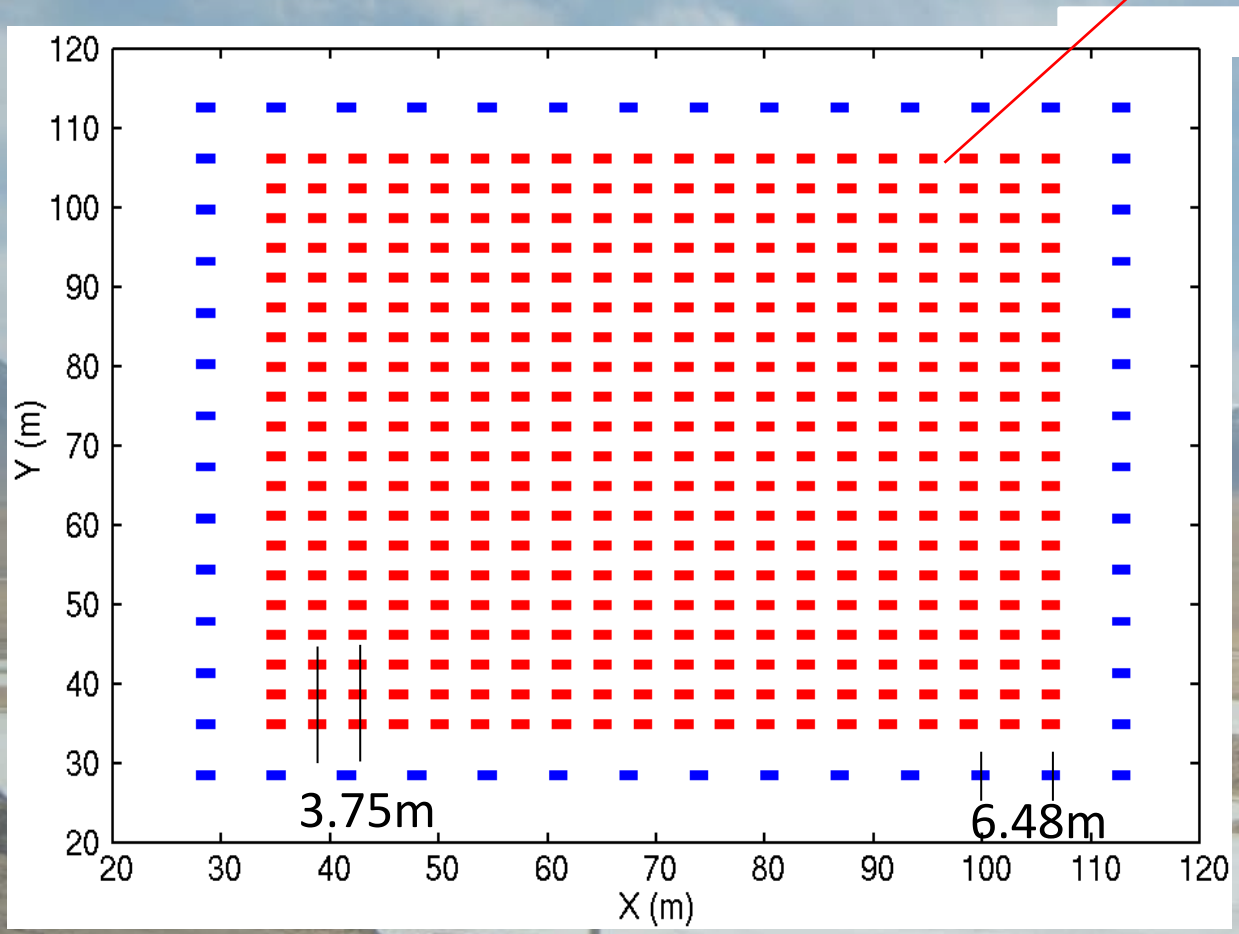
# SCDA: shower core detector array



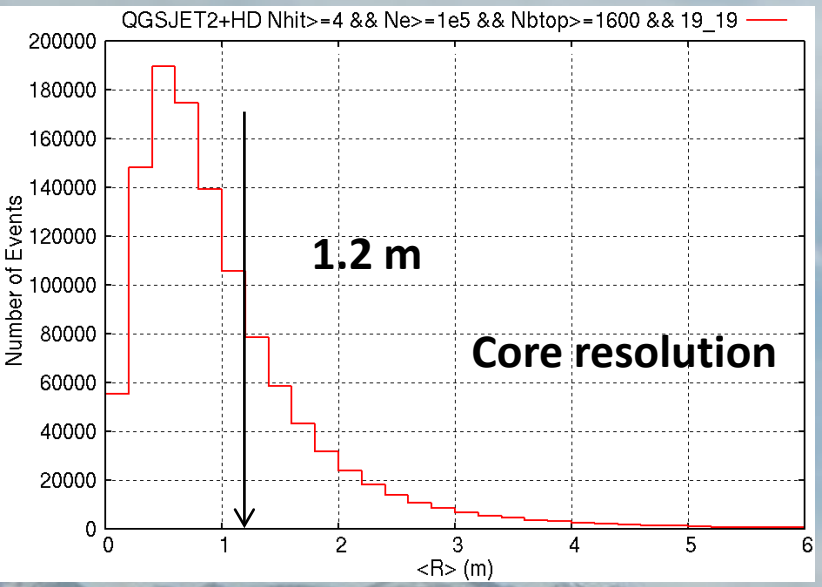
# SCDA （452 units）



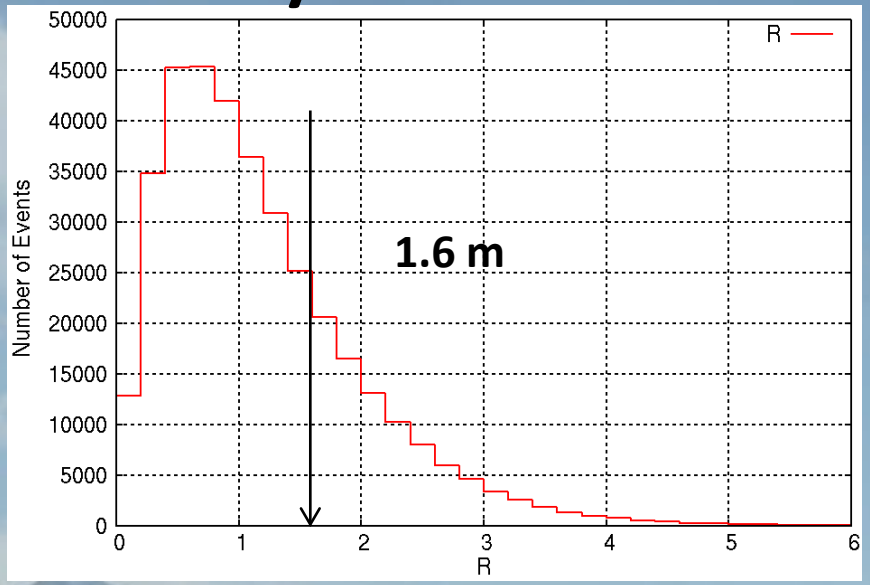



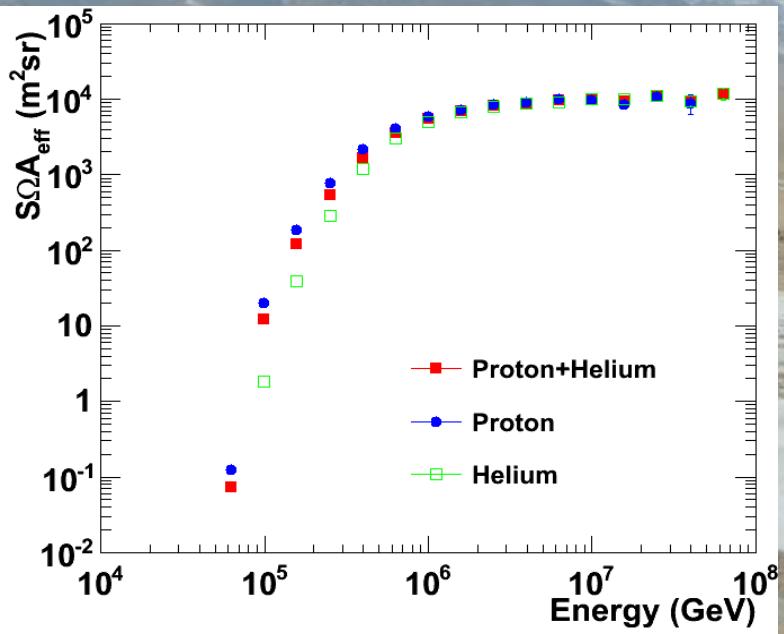

**SCDA : 5170 $m^2$**
**Space : 3.75 m**
**Pb : 7 r.l. ( 3.5 cm )**

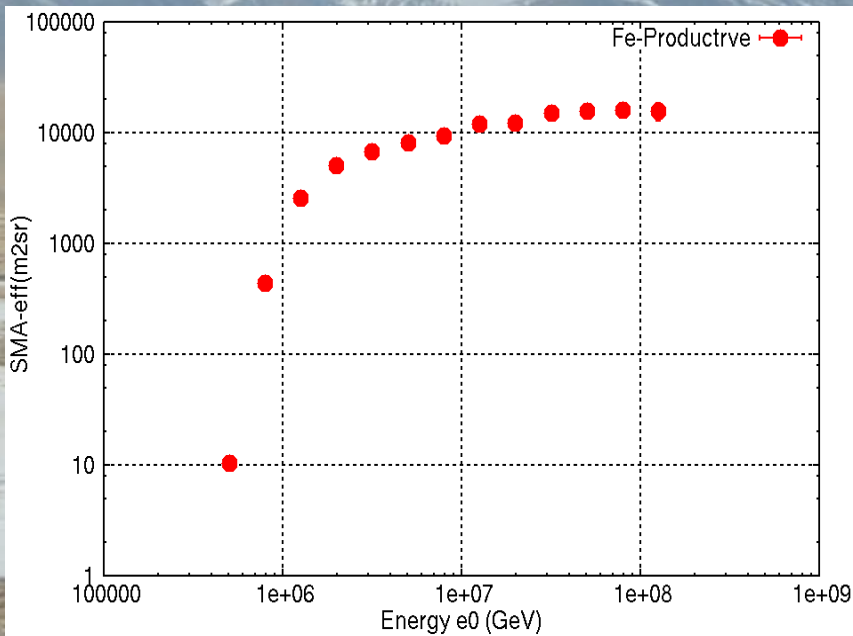
# Light nuclei




# Heavy nuclei

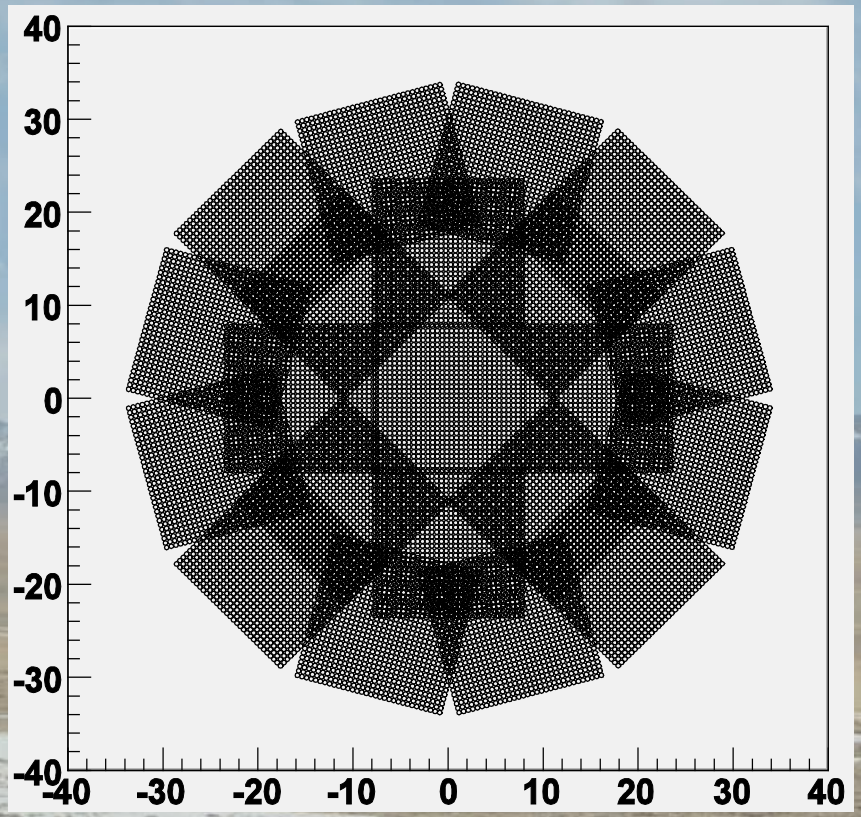


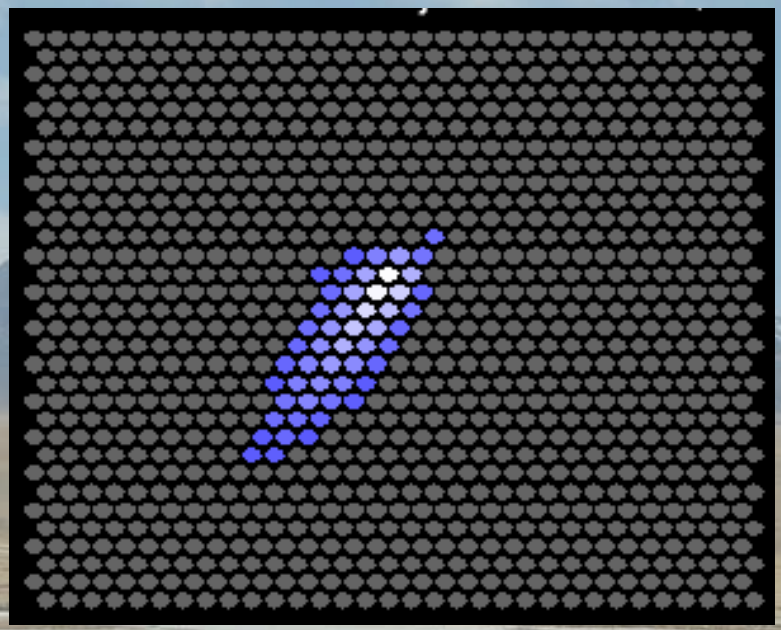
# WFCTA: wide field Cerenkov telescope array

- 21 telescopes, compact configuration
- Wide field: solid angle 35°
- Working mode: Cherenkov imaging
- parameters： Xmax， Hillas

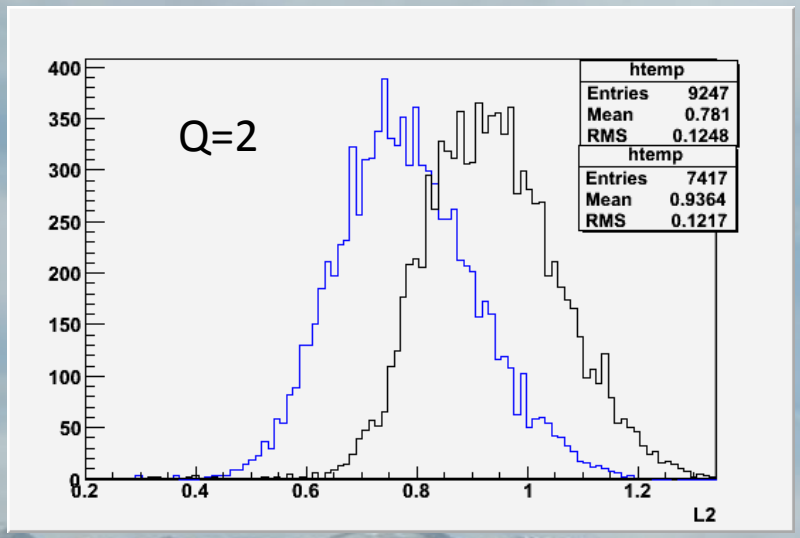


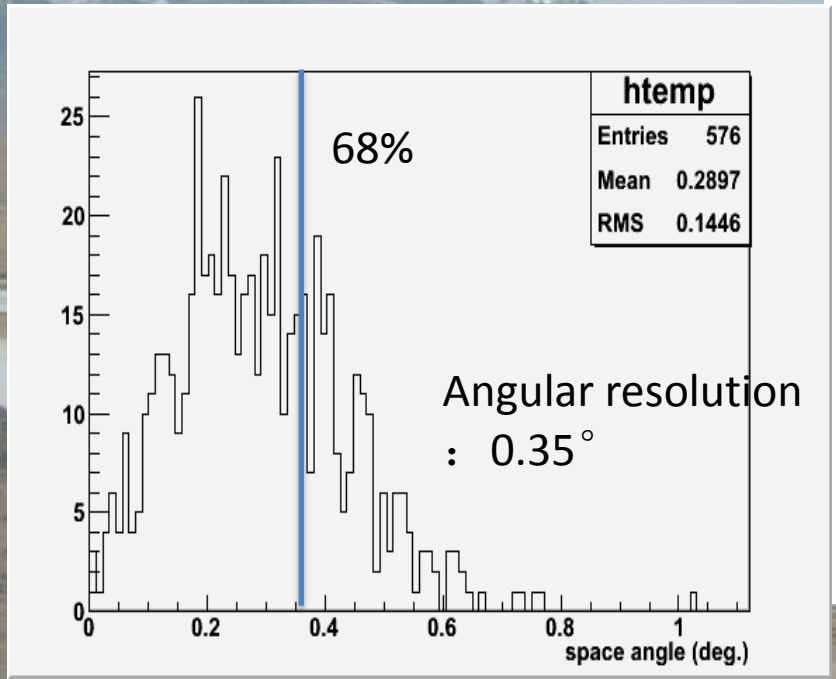
# WFCTA : one telescope

- Cherenkov telescope:
  - 5 $m^2$ spherical mirror;
  - Camera: 32×32 PMT array
  - Pixel size 0.5°;
  - FOV: 14° × 16°;

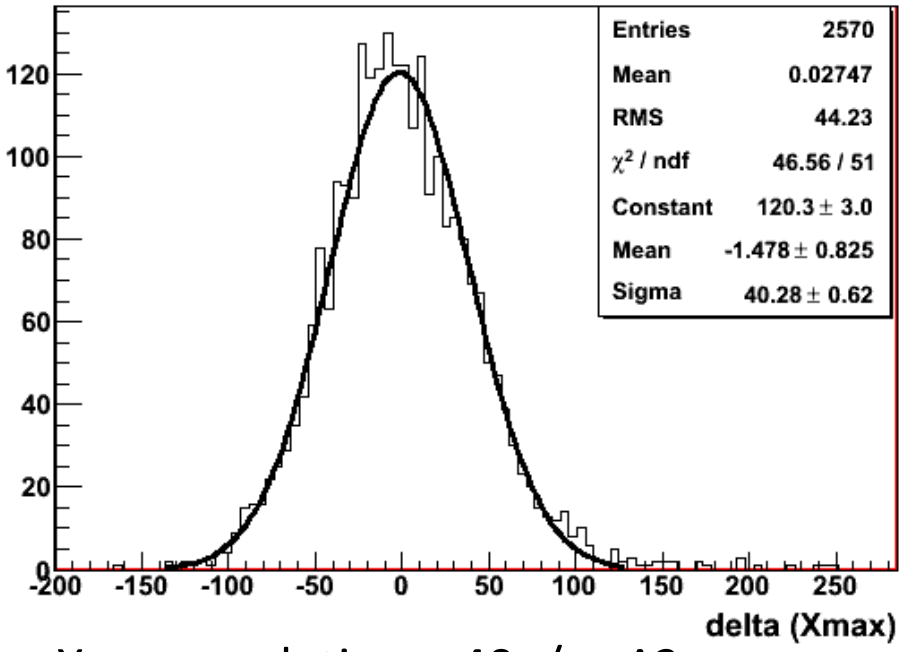


# WFCTA



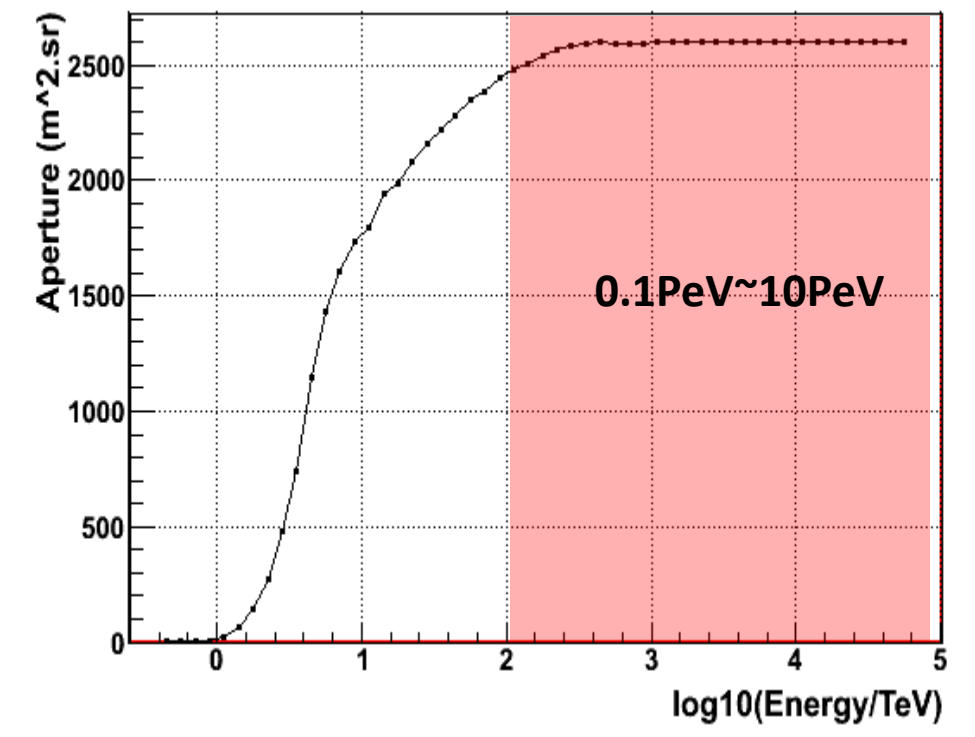



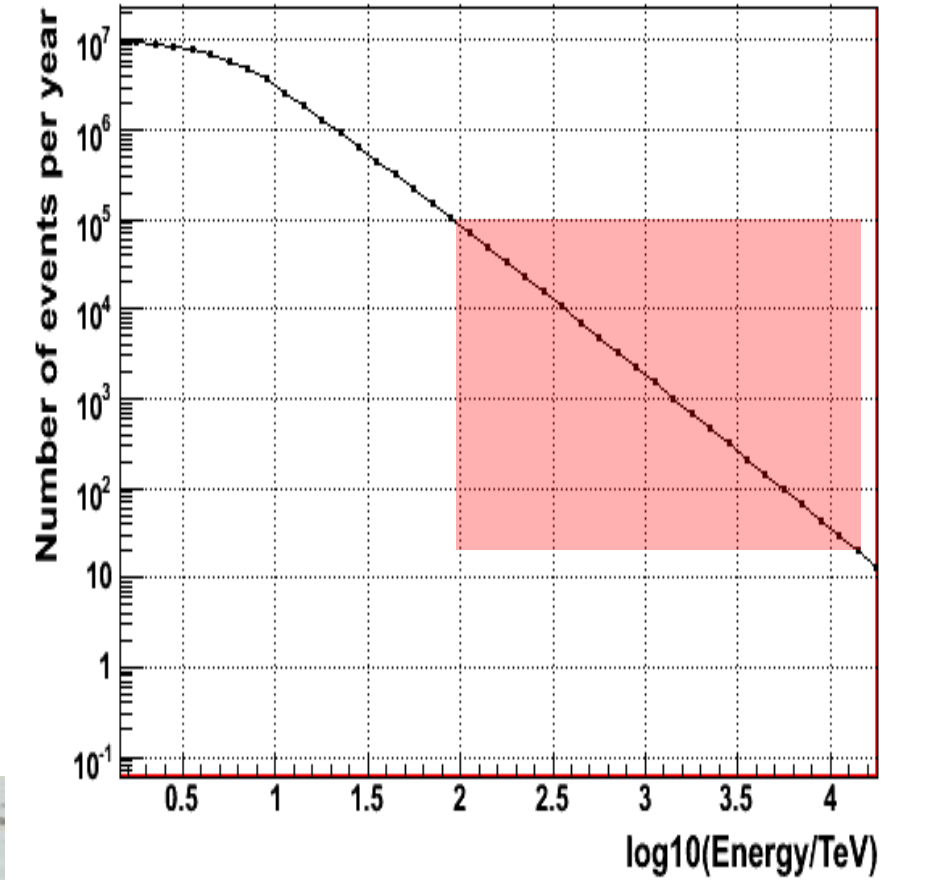

Angular resolution ：0.35°




Xmax resolution：40g/cm^2

# WFCTA


Aperture (m^2.sr)
2500
2000
1500
1000
500
0
0
1
2
3
4
5
log10(Energy/TeV)
0.1PeV~10PeV


Number of events per year
$10^7$
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
10
1
$10^{-1}$
0.5
1
1.5
2
2.5
3
3.5
4
log10(Energy/TeV)

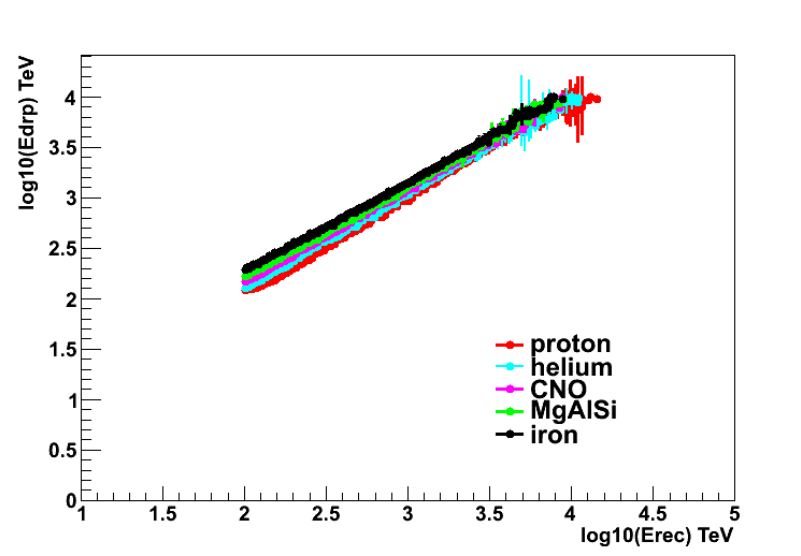
# WFCTA

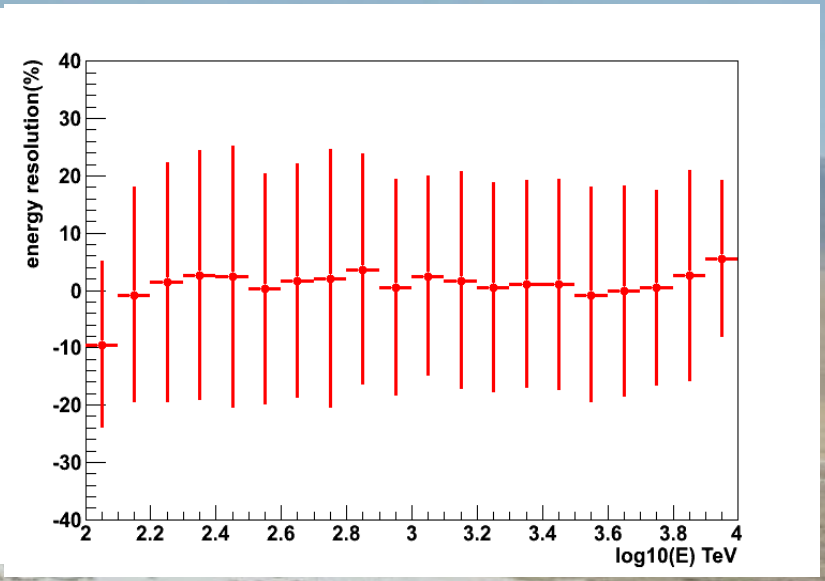
energy reconstruction

E’=log10(Npe)+0.0074834*rp

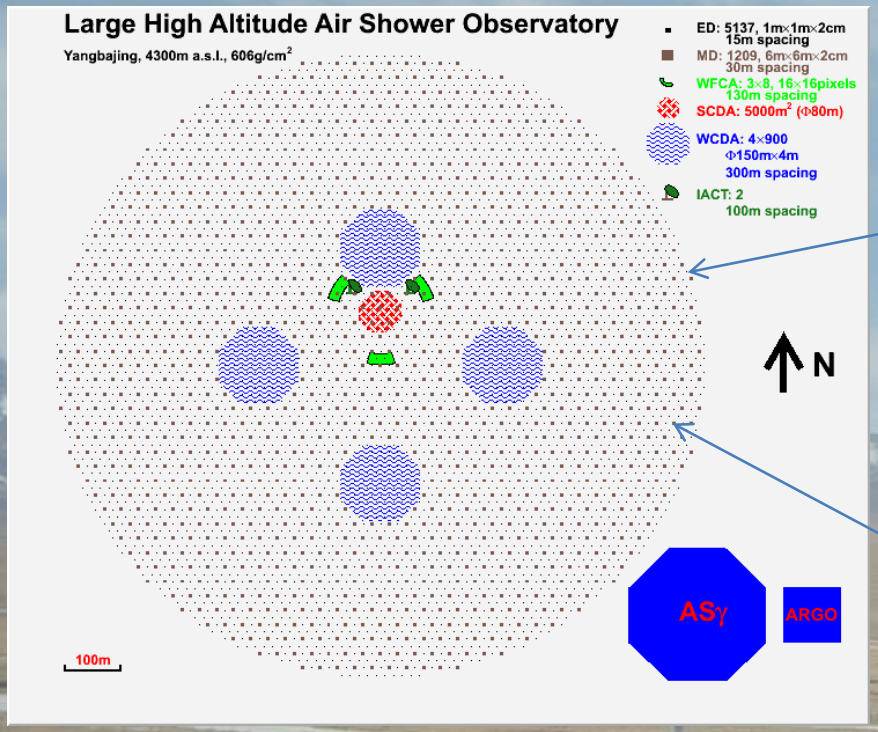
Erec=pow(10,(0.0320582*E’ +0.58409)*E’ -1.22705)

Rp: impact parameter decided by KM2A



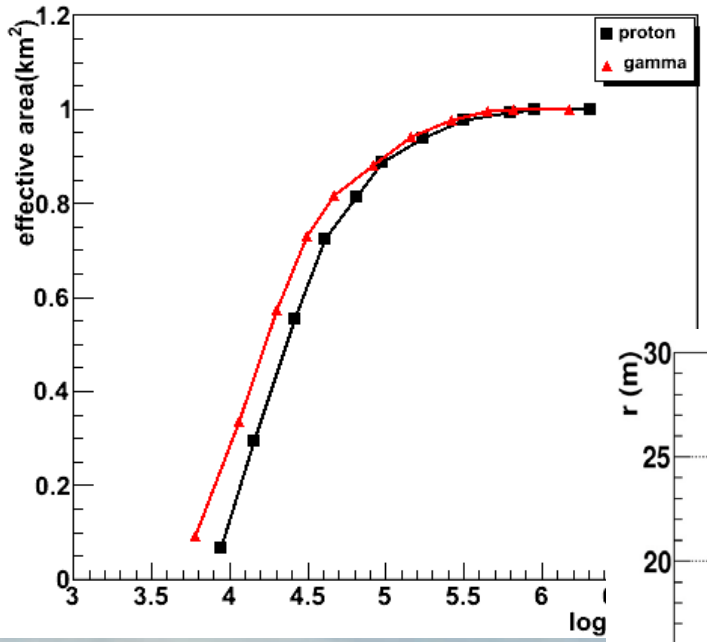
# KM2A: one km$^2$ air shower array

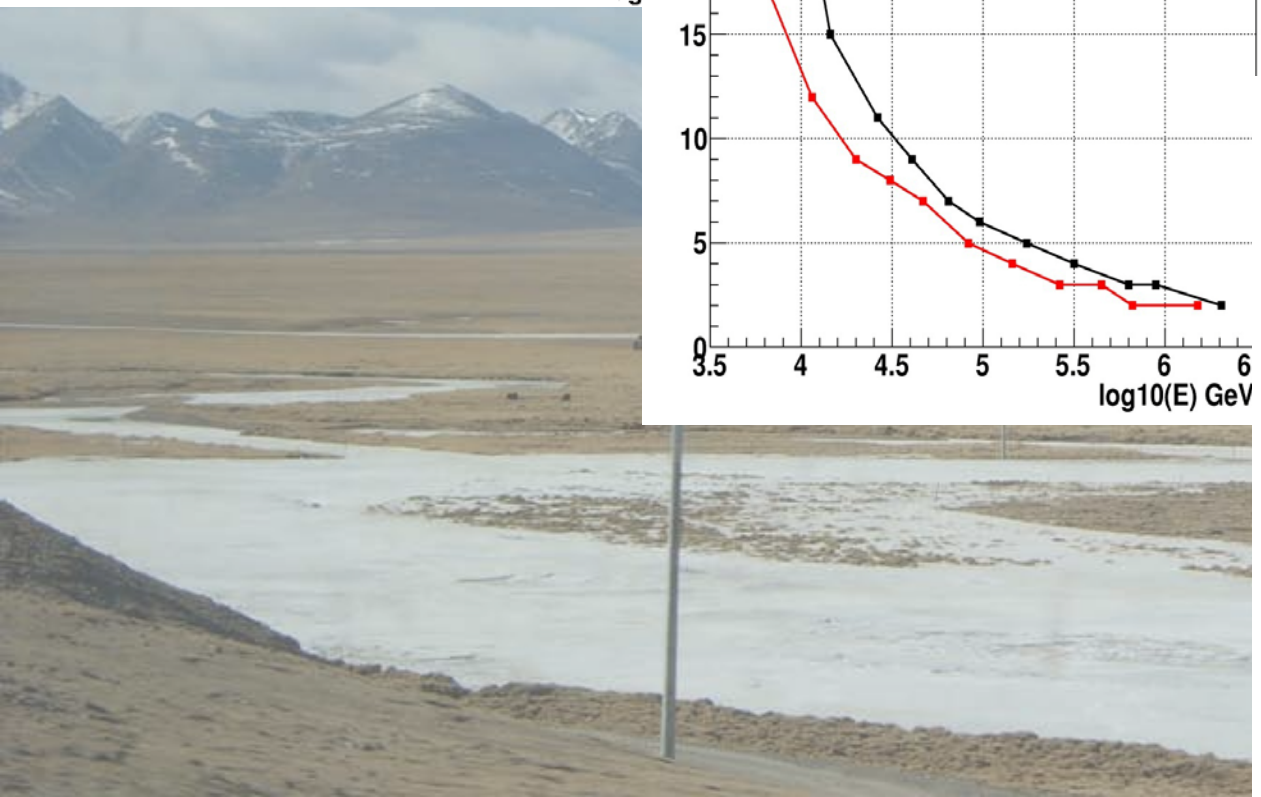



ED： ~5000 plastic scintillators+fibers, distance :15m， size: 1m×1m×2cm，0.5cm lead plate as γ converter,

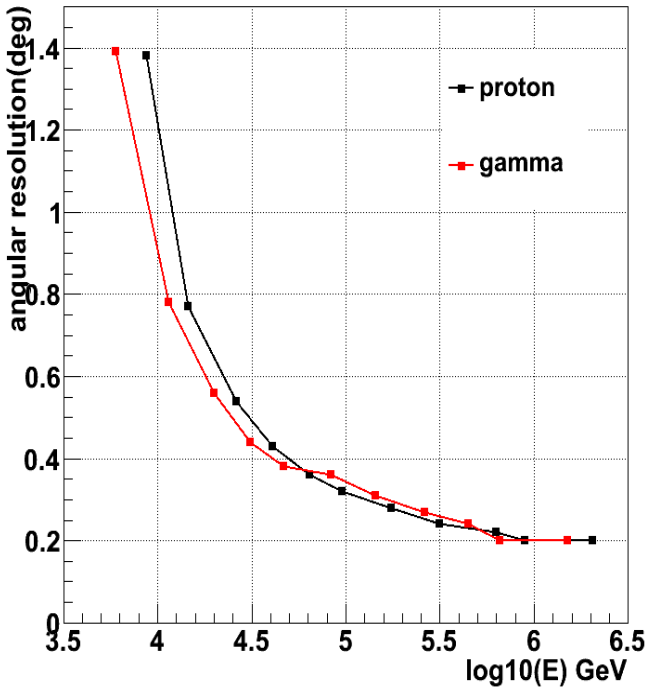
MD： ~1200 water Č detectors, distance:30m， size:6m×6m，2.8m dirt overburden

# KM2A


proton
gamma
effective area(km$^2$)
1.2
1
0.8
0.6
0.4
0.2
0
3
3.5
4
4.5
5
5.5
6
log




r (m)
30
25
20
15
10
5
0
3.5
4
4.5
5
5.5
6
log10(E) GeV
proton
gamma

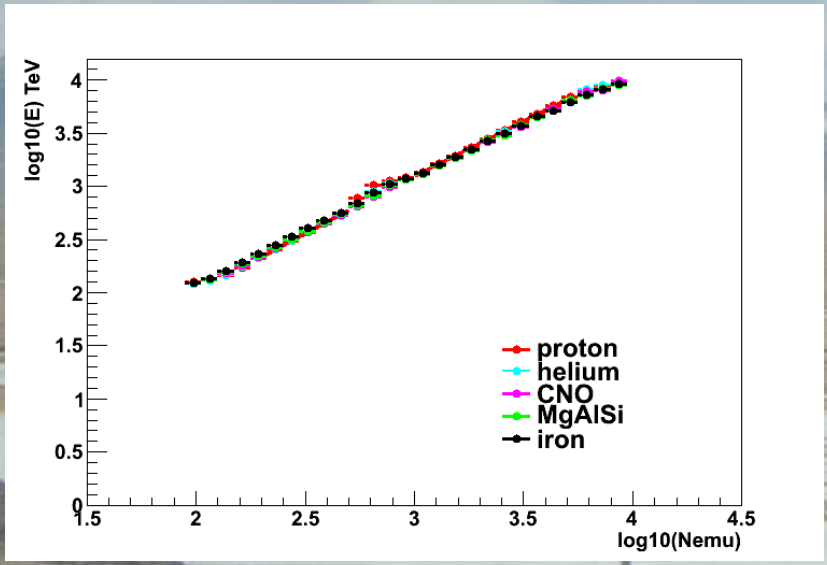

angular resolution(deg)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
3.5
4
4.5
5
5.5
6
6.5
log10(E) GeV
proton
gamma

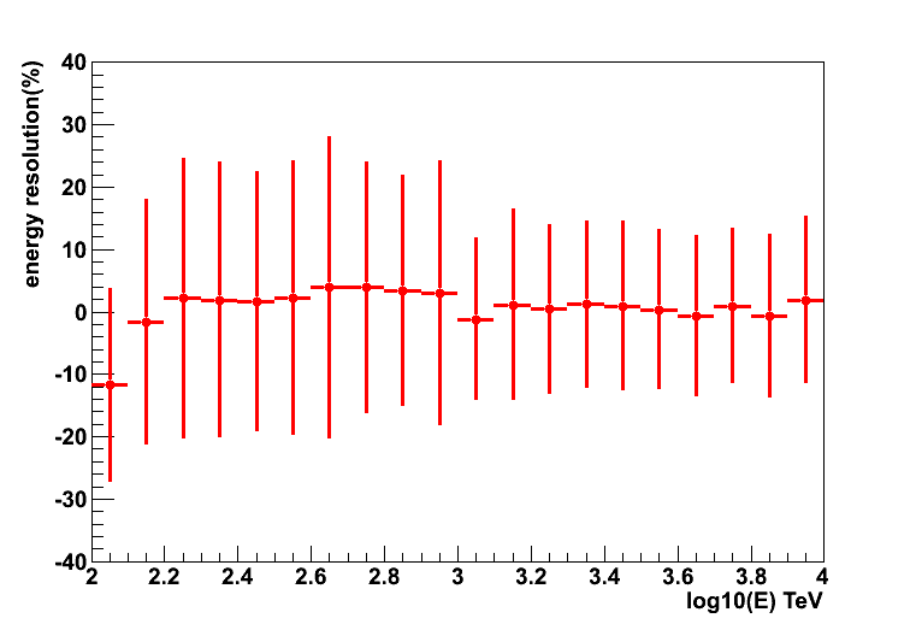
# KM2A

Energy reconstruction: component independent

Neμ =sqrt(Ne*Nμ*pow(cosθ,2))

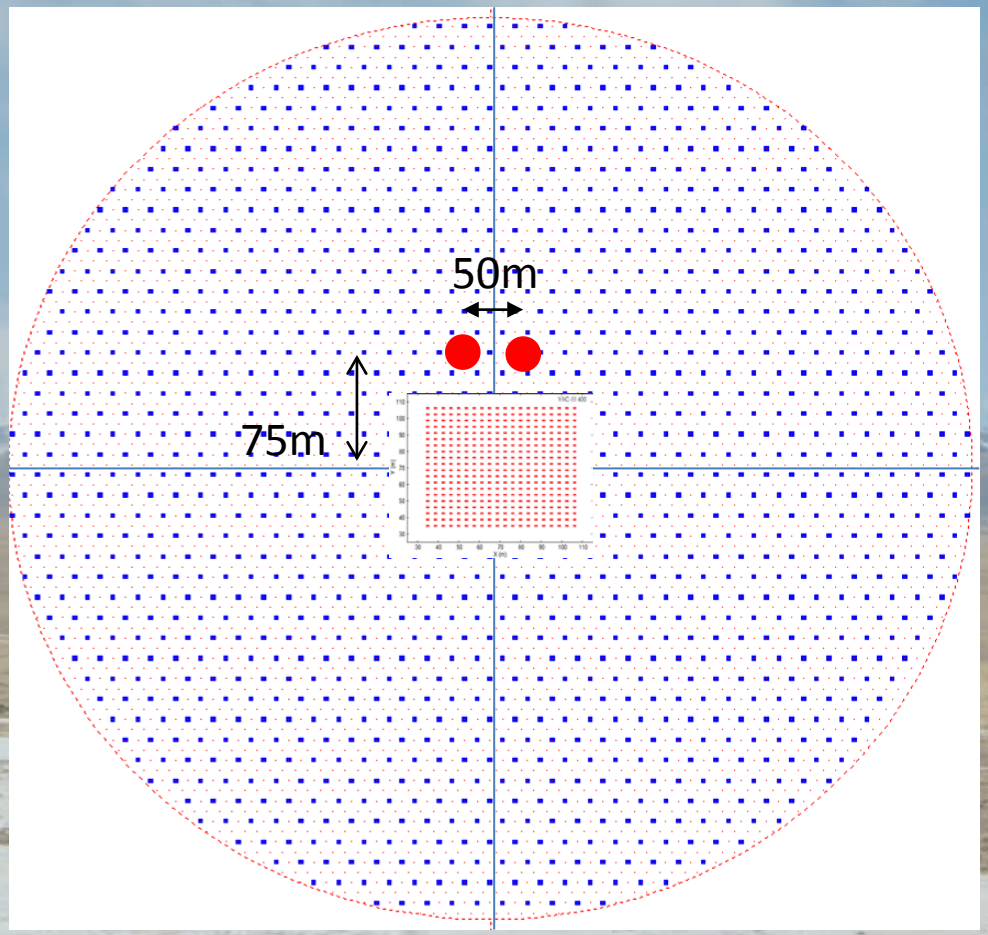
Energy resolution: RMS/mean



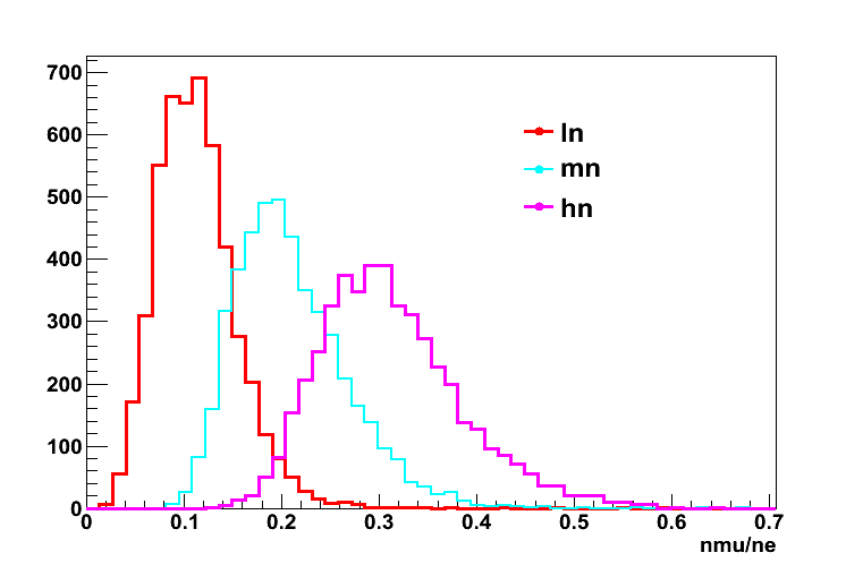



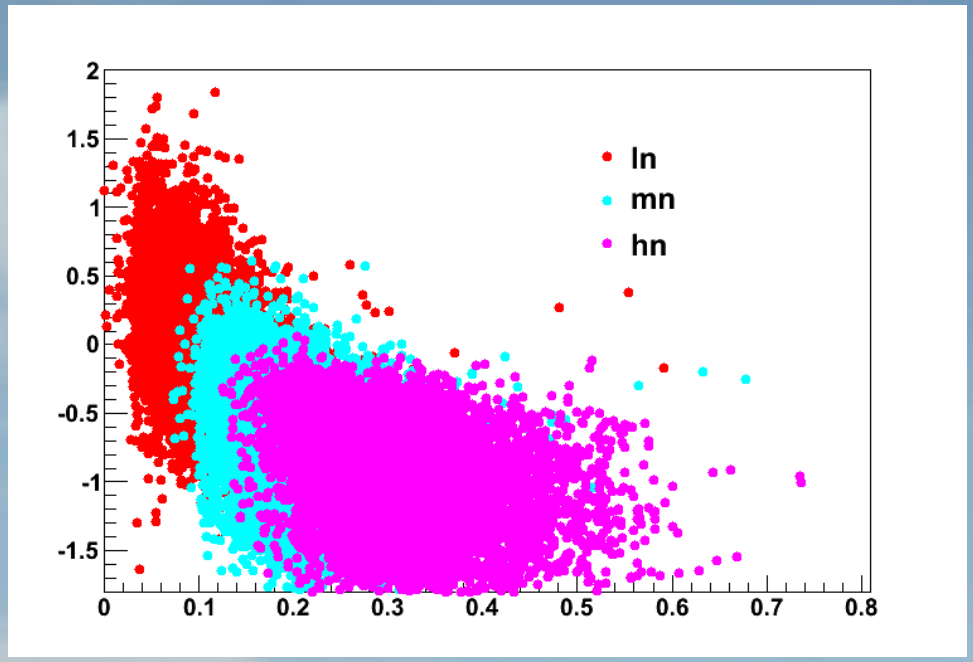
# Hybrid simulation

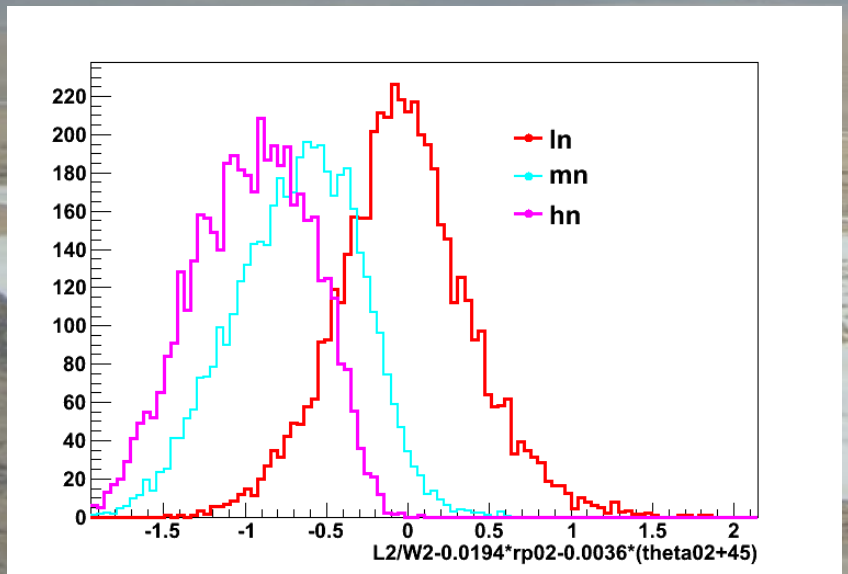
- CORSIKA, QGSJETII+GHEISHA
- proton, helium, CNO, MgAlSi, iron
- Energy range : 100TeV - 10PeV
- Energy index: -2.7
- Zenith: 24. - 38.
- Azimuth: 77. - 103.
- drop:160m*160m
- Only events with core inside SCDA are selected.



log10(Neμ)>2&& log10(Neμ)<=3

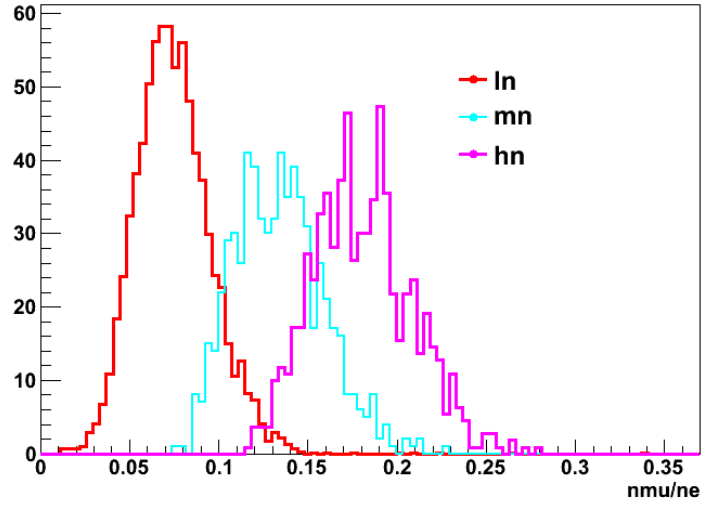


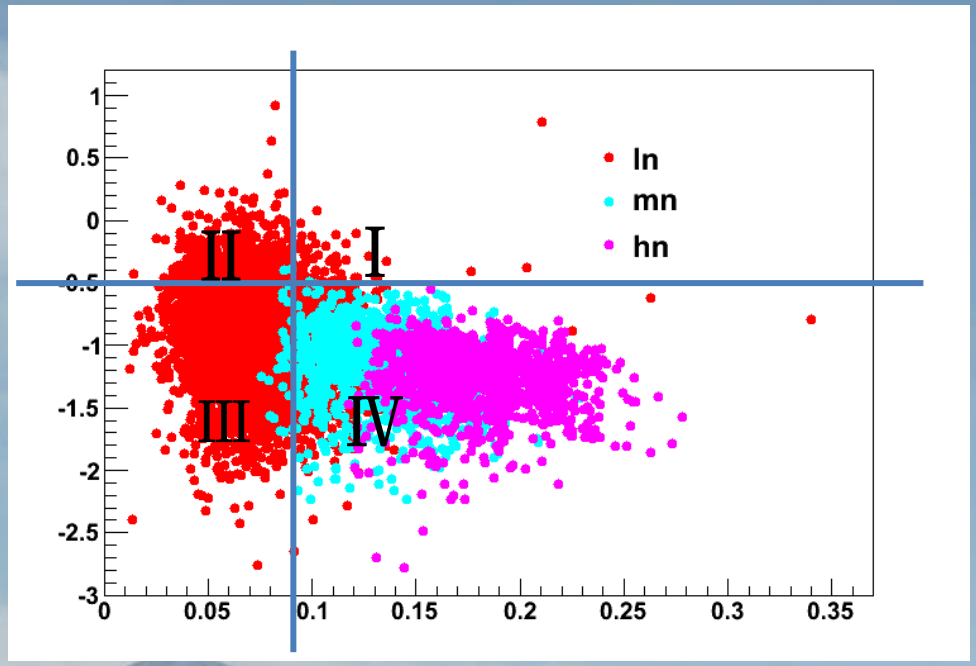



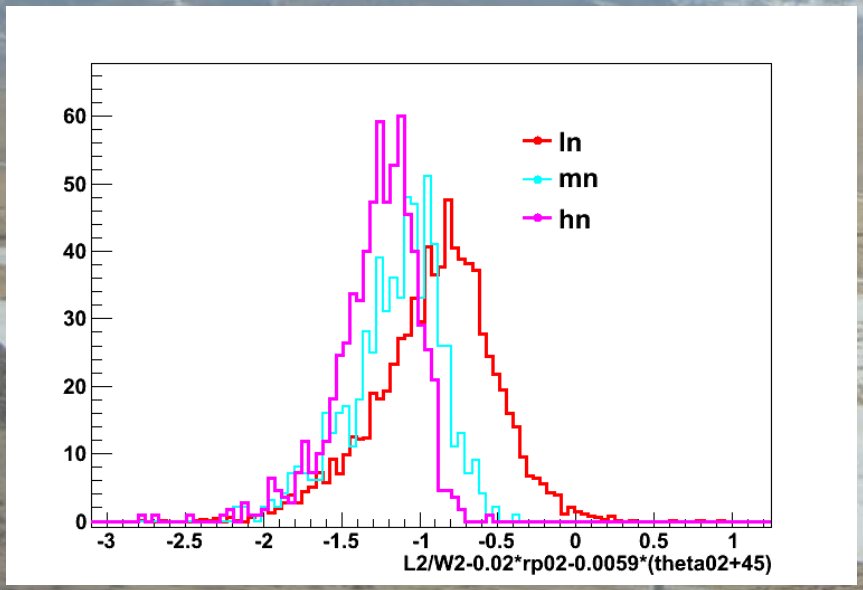



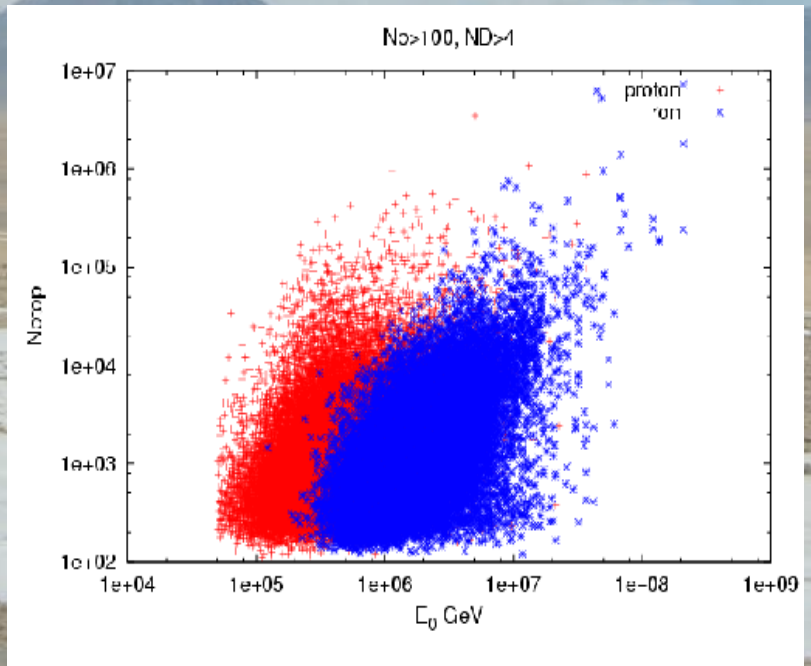

L2: length
W2: width
Rp02: impact parameter

log10(Neμ)>3&& log10(Neμ)<=4



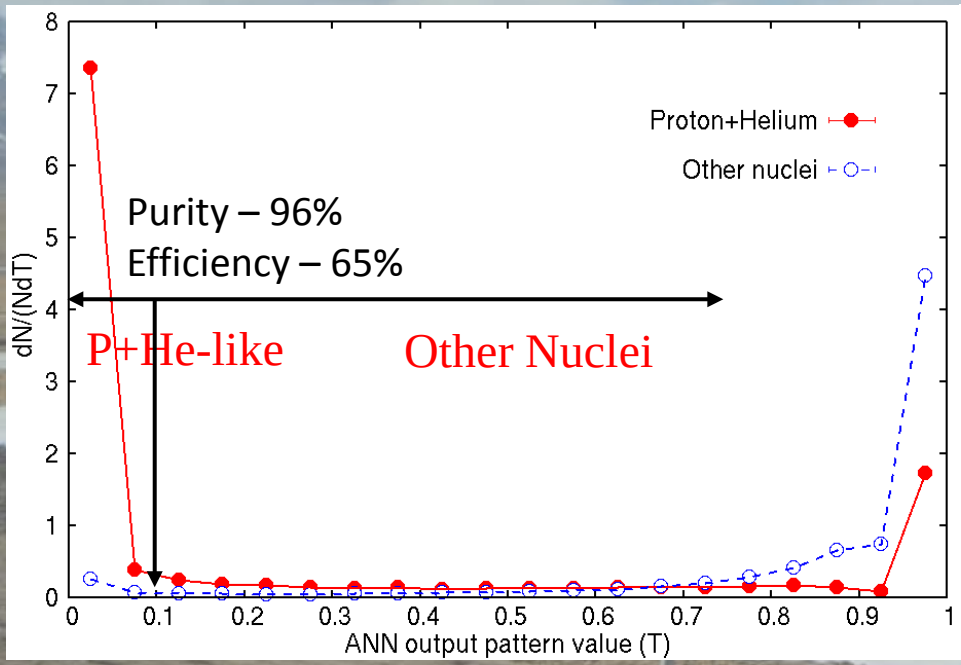



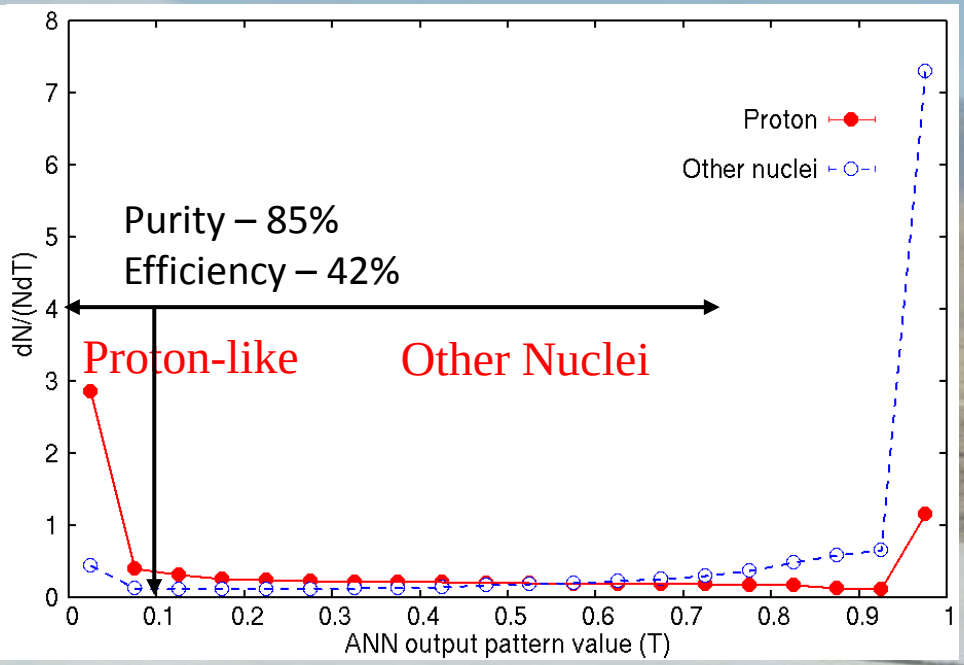
# Light nuclei

- **SCDA+KM2A: ANN（artificial neural network）**

The following 8 parameters are input to the ANN:

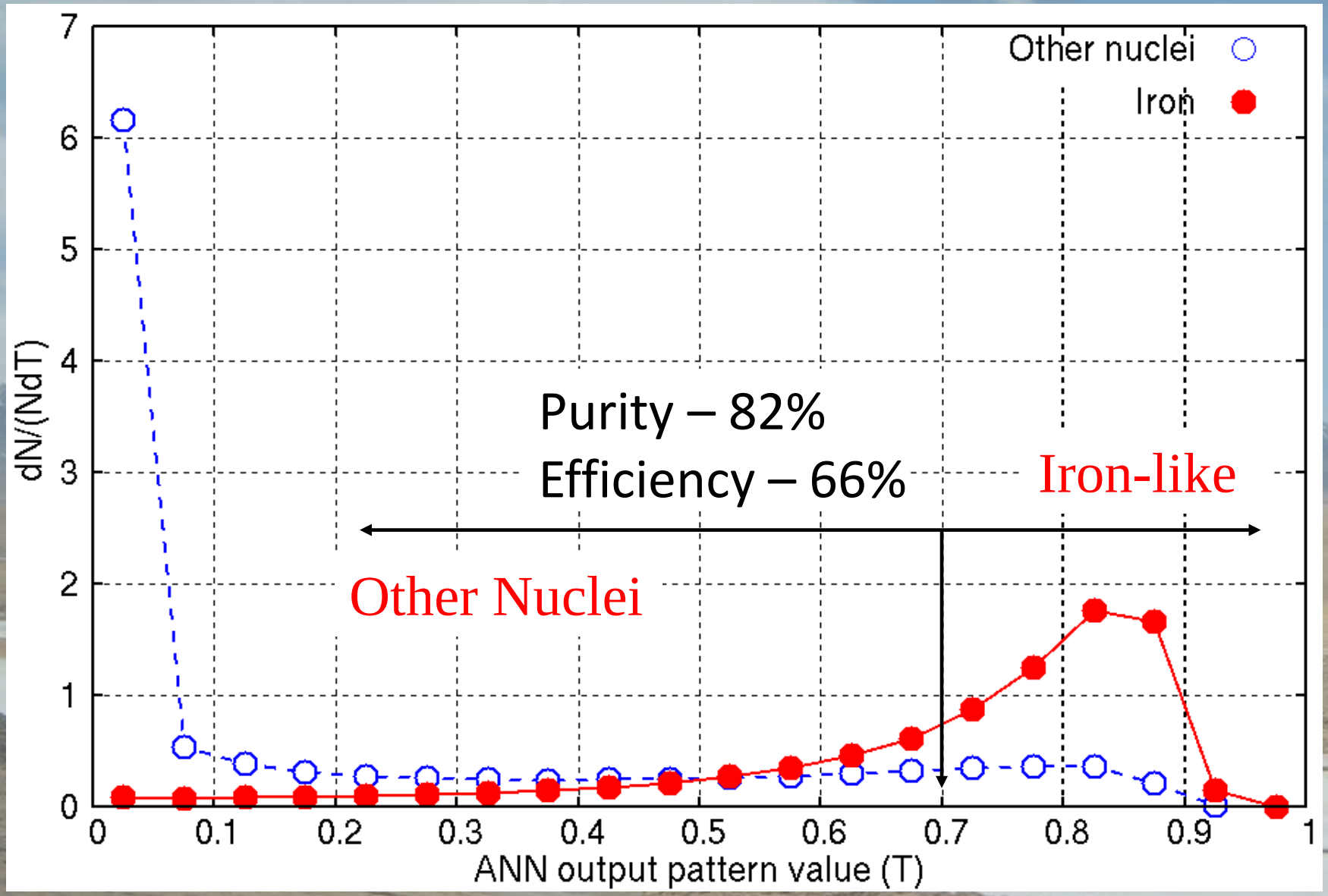
$$N_{\text{hit}},\ \sum N_b,\ N_b^{\text{top}},\ < R0 >,\ < N_b \cdot R0 >,\ N_e,\ \theta,\ Age$$



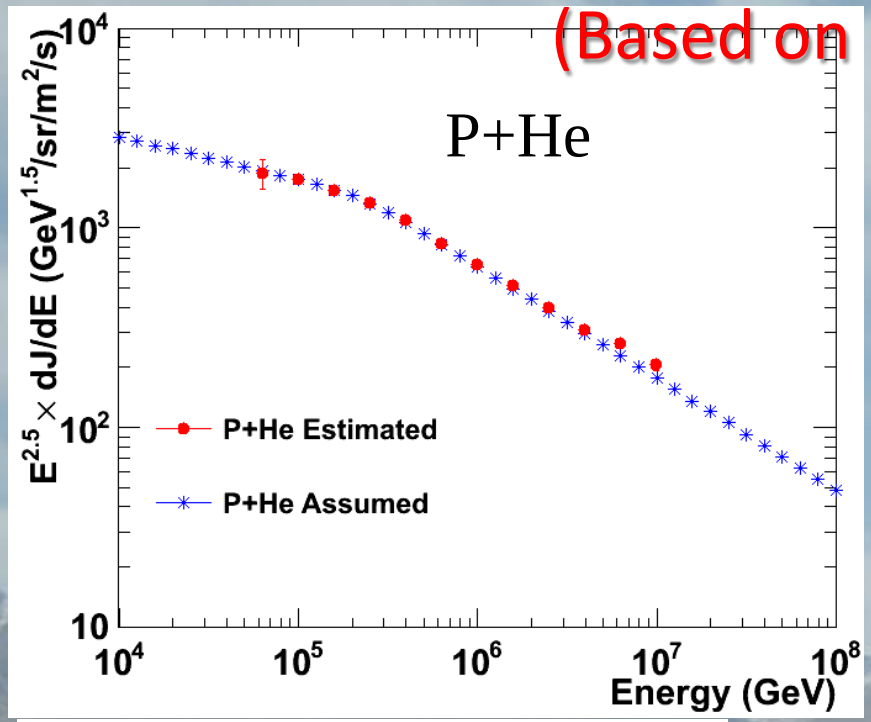
# Heavy nuclei

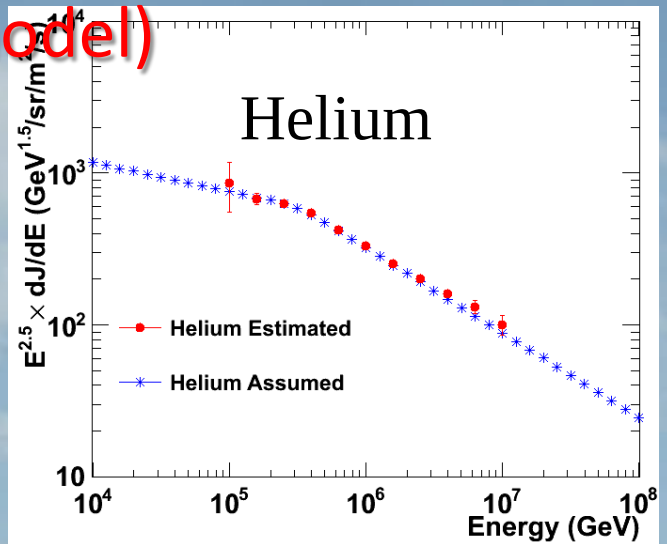
◆ **SCDA+KM2A: ANN**

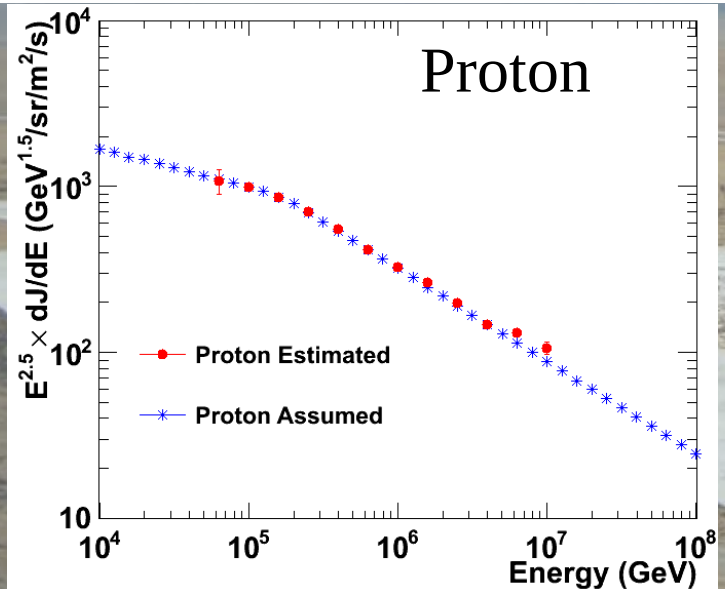


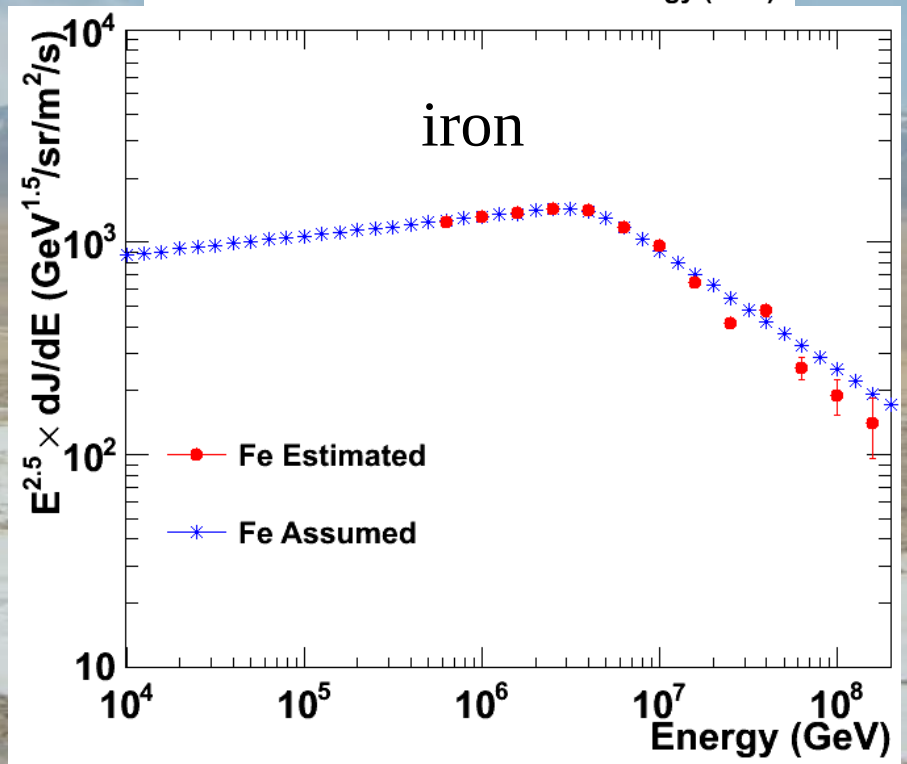
# Expected results by (SCDA+KM2A)

## (Based on HD model)



# summary

- LHAASO has powerful capability of Hybrid measurement of cosmic rays at the knee region
- It needs further work to effectively combine all the detectors in LHAASO to study cosmic ray spectrum and composition.