From Muon Telescope to EAS Array at Sharif University of Technology

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IPP12

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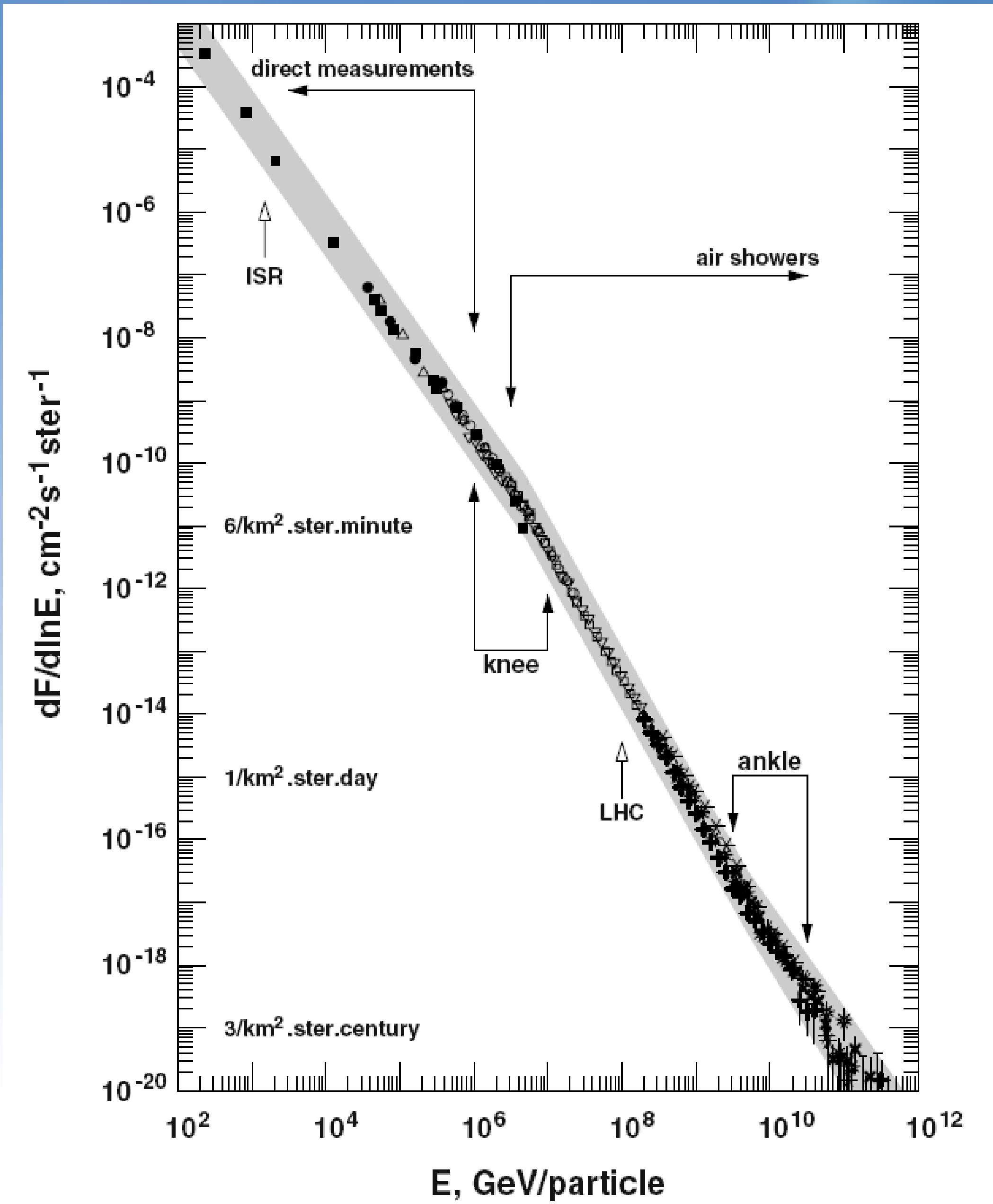
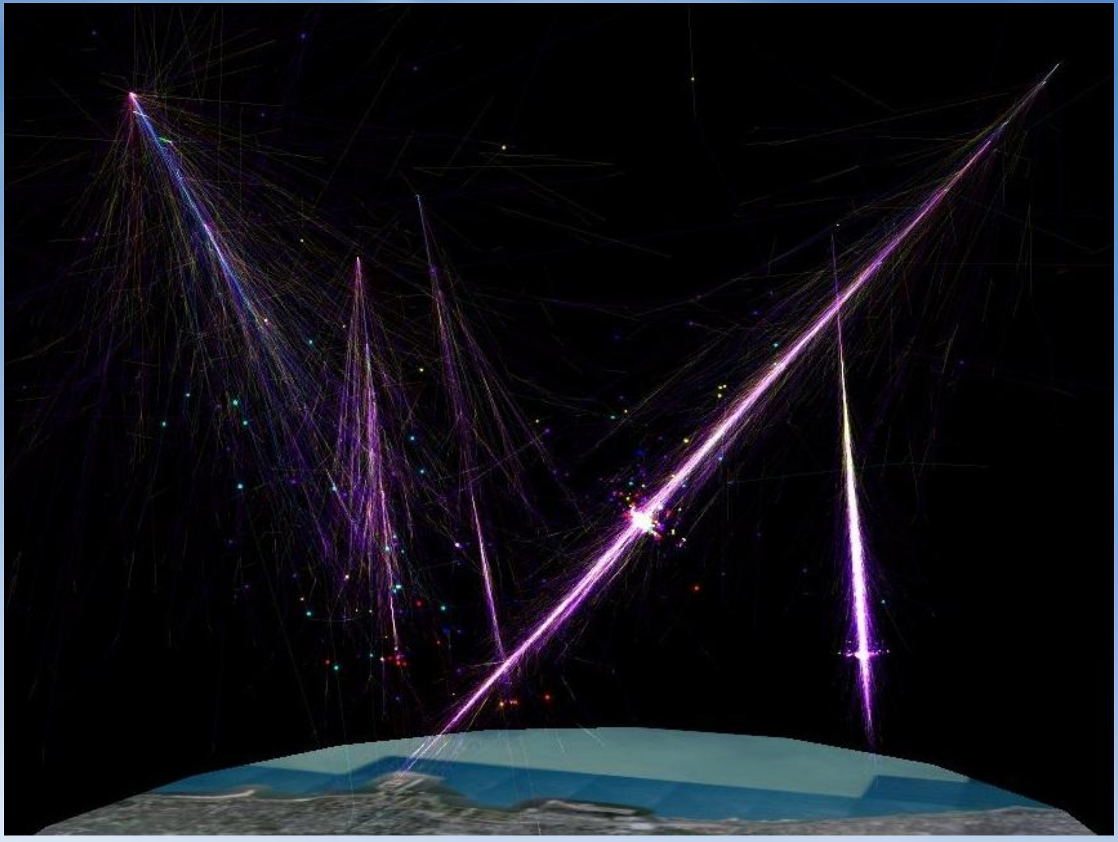
Outline

- Introduction
- CR Research at SUT
- Muon Telescope
- Muon Ratio Experiment
- EAS Arrays
- Current Project
- Simulation Results

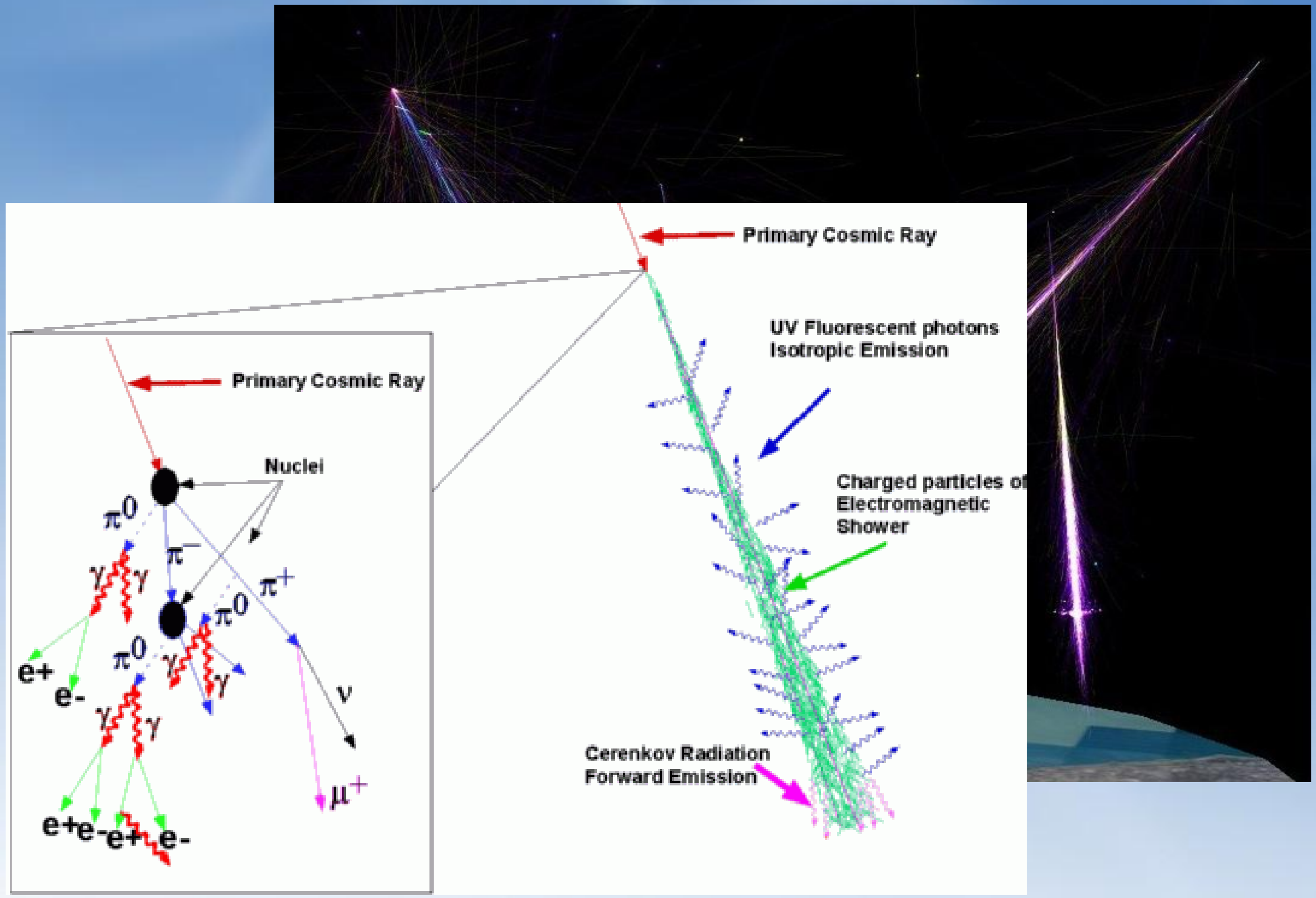
Introduction



Introduction



Introduction



CR Group Activity at SUT

Instrumentation
- Hodoscope
- Spark Chamber
- Cherenkov Detector
- Scintillation Detectors
- RPC

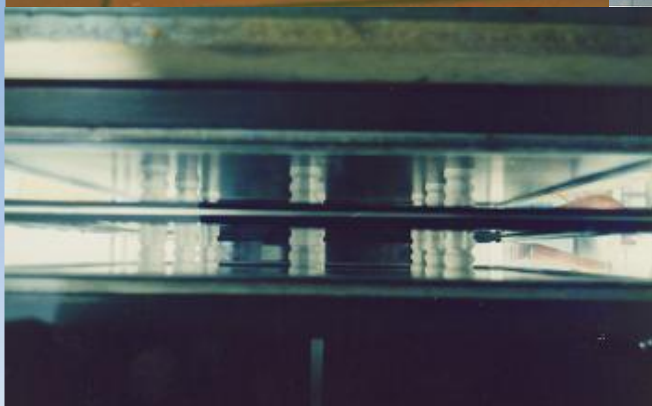
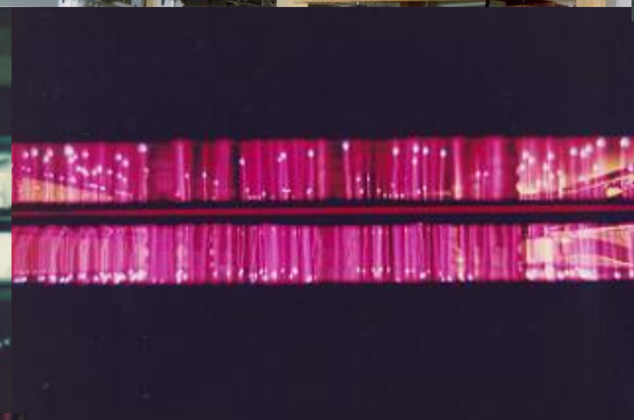
Muon Telescope
- To study muon charge ratio
- Effect of earth magnetic field on muons
- Zenith angle dependence of muon flux
- To study effect of sun on CR flux
- ….

Particle Arrays
- With 3 Sci. detectors
- With 4 Sci. detectors
- With 4 Cherenkov detectors
- **New Array**

Simulation
- Of detectors (scintillation and Cherenkov detector and RPC)
- Of EAS properties
- Other experiments like those related to muon telescope
- Array
- ….

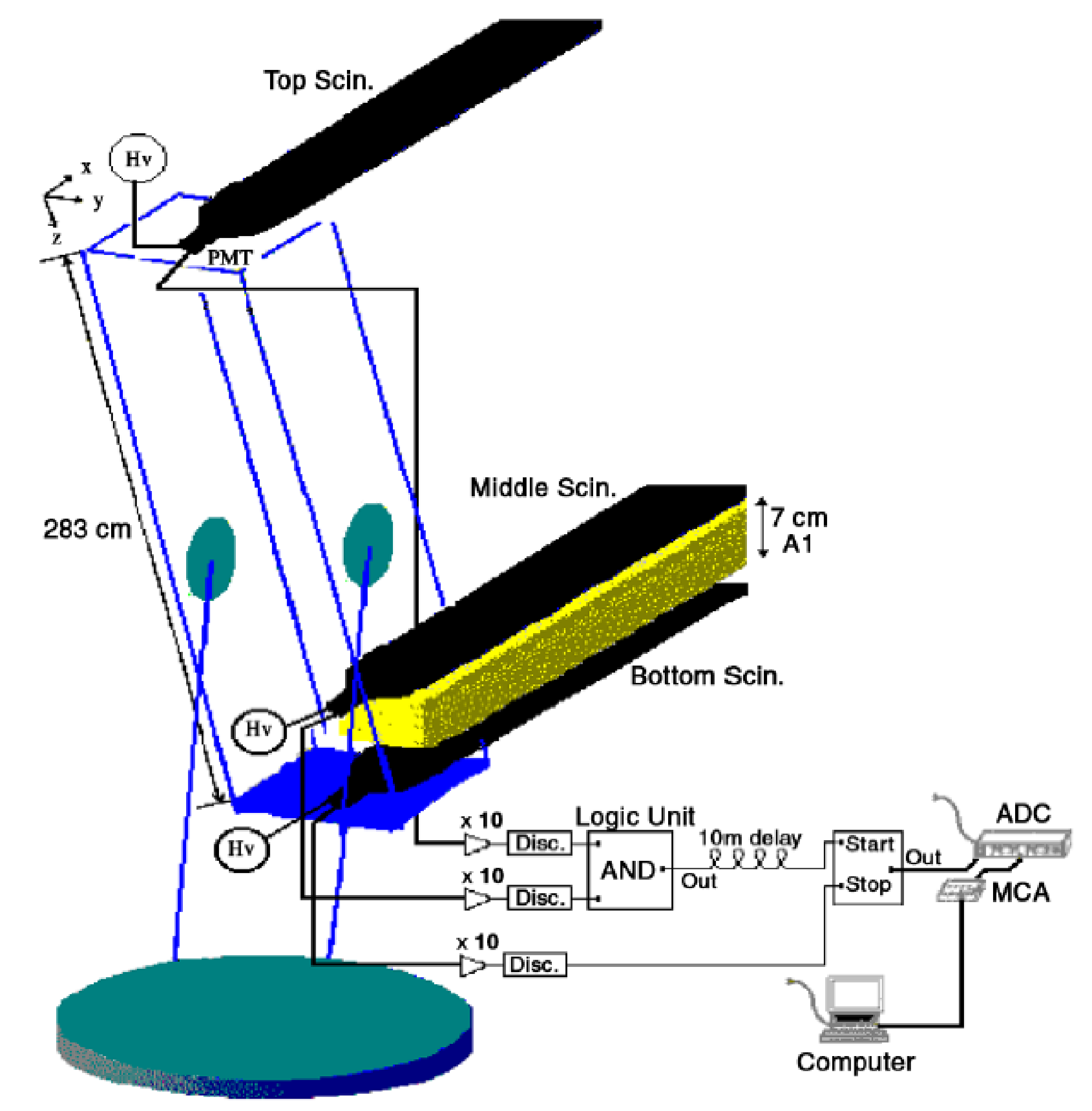
Instrumentation




Muon Telescope
& Muon Ratio Experiment

Muon Telescope



Muon Ratio Experiment

$$A_{\mathrm{CR}} + A_{\mathrm{Air}} \longrightarrow \pi^{\pm}, \pi^{0}, k^{\pm},$$

$$\pi^{\pm} \longrightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu}) \sim 100\%$$

$$k^{\pm} \longrightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu}) \sim 63.5\%$$

$$\mu^{\pm} \longrightarrow e^{\pm} + \nu_{e}(\bar{\nu}_{e}) + \bar{\nu}_{\mu}(\nu_{\mu}) \quad \tau_0 = 2.197\ \mu\mathrm{s}$$

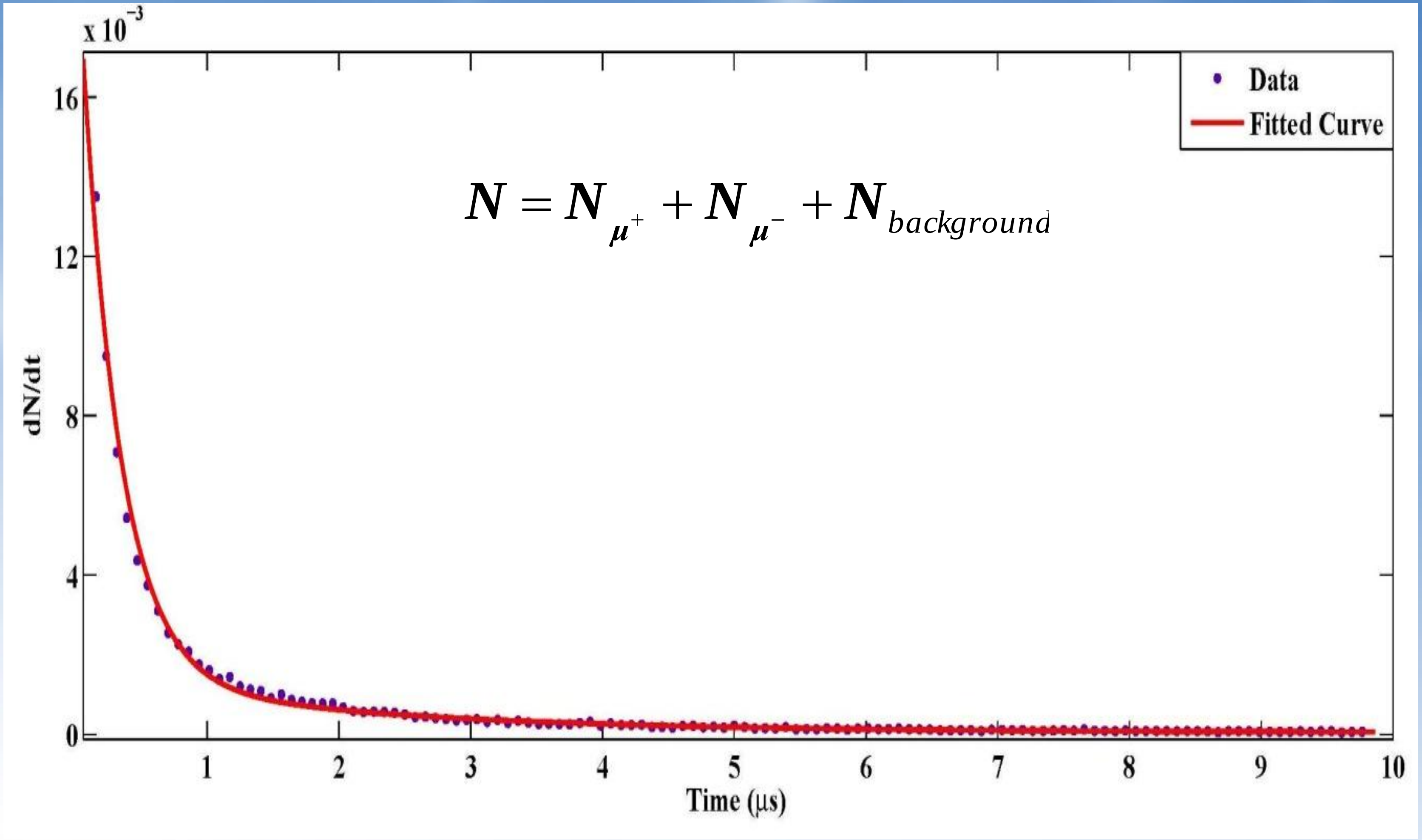
$$\mu^{+}/\mu^{-} = \nu_{e}/\bar{\nu}_{e}$$

$$R_{\nu} = \frac{\nu_{\mu} + \bar{\nu}_{\mu}}{\nu_{e} + \bar{\nu}_{e}} = 2$$

Muon Ratio Experiment

- 4th floor of Physics Department of SUT, under 80 cm concrete in Tehran (35º43´N, 51º20´E)
- 1200 m above sea level (890 gcm^{-2})

Muon Ratio Experiment



Muon Ratio Experiment

$$N_{\mu^+} = N^0_{\mu^+} e^{\frac{-t}{\tau_{\mu^+}}}$$

Medium	Mean Life Time (ns)	Decay Probability (%)
vacuum	2197.03±0.04	100.00
Carbon	2026.3±1.5	92.15
Oxygen	1795.4±2	81.57
Aluminum	864.0±1	39.05
Silicon	756.0±1	34.14
Lead	75.4±1	2.75

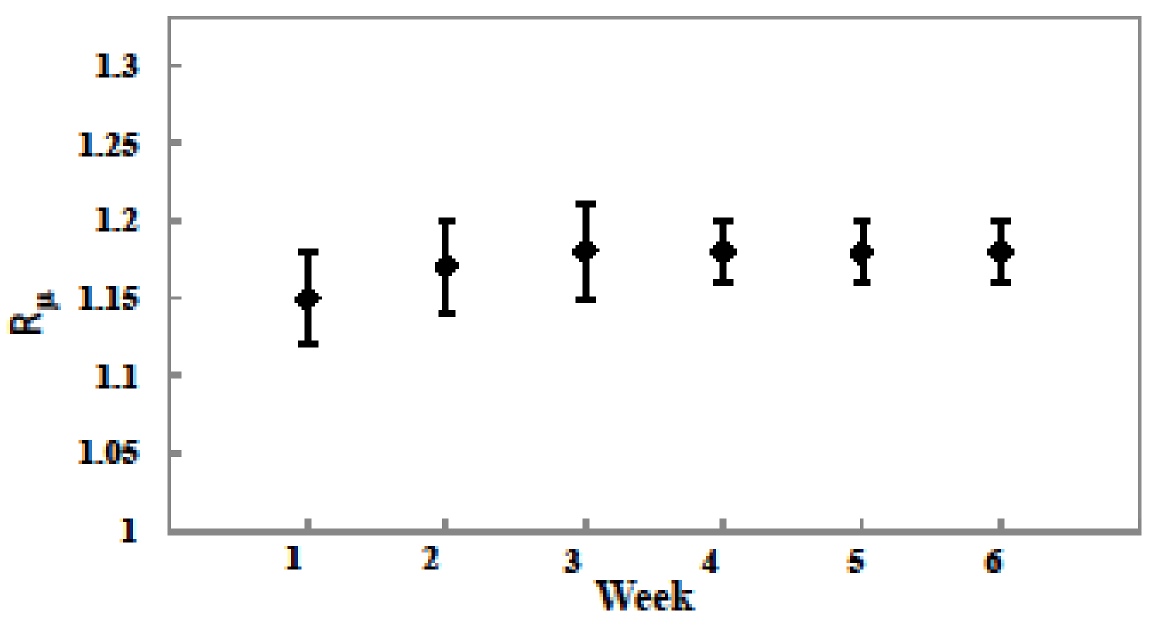
Suzuki T, Measday D F and Roalsvig J P 1987 Phys. Rev. C 35 2212

$$\frac{dN}{dt} = \frac{N_{\mu^+}}{\tau_{\mu^+}} e^{\left(\frac{-(t+\tau_{delay})}{\tau_{\mu^+}}\right)} + \frac{N_{\mu^-}}{\tau_{\mu^-}} P_{decay} e^{\left(\frac{-(t+\tau_{delay})}{\tau_{\mu^-}}\right)} + C_{bg} e^{\left(\frac{-(t+\tau_{delay})}{\tau_{bg}}\right)} + \varepsilon_{bg}$$

Muon Ratio Experiment

Average muon charge ratio was obtained: 1.15±0.03 in one week time intervals (168-h)

The values of muon charge ratio in different time intervals, show the fluctuations are very small and for three-week time interval and more, the values of R_μ tend to a fixed amount 1.18±0.02.



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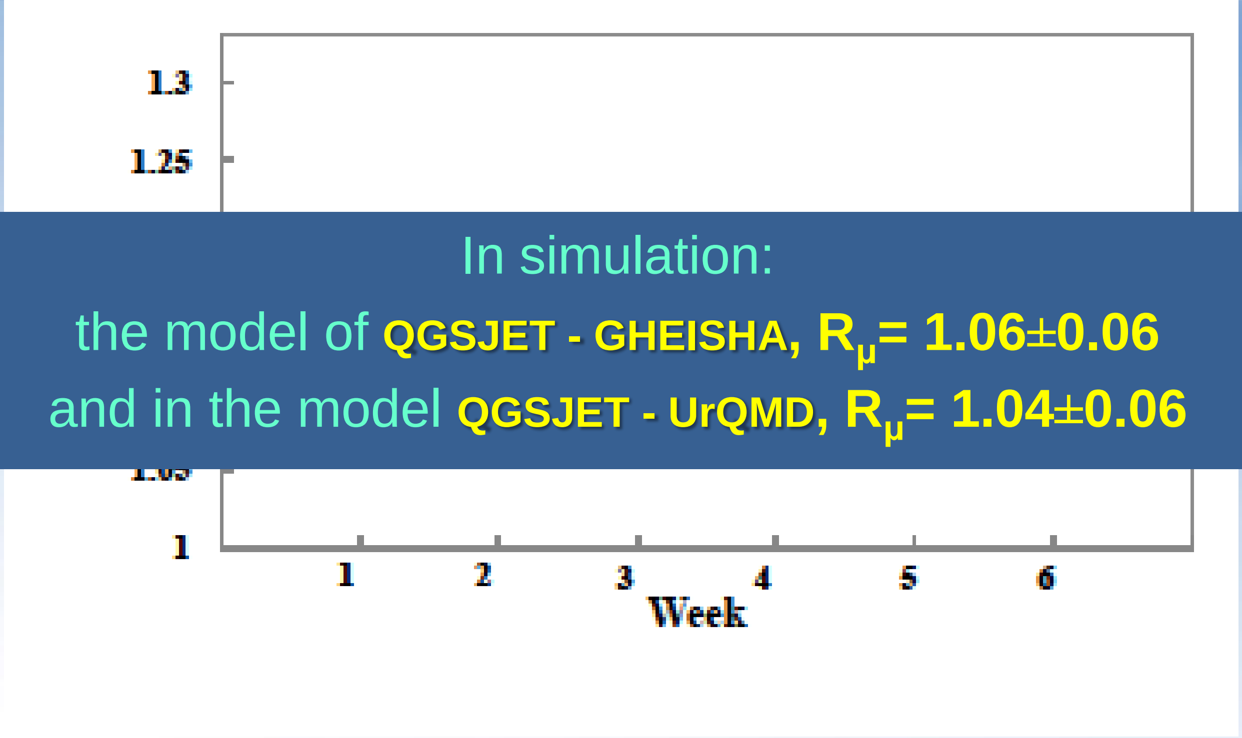
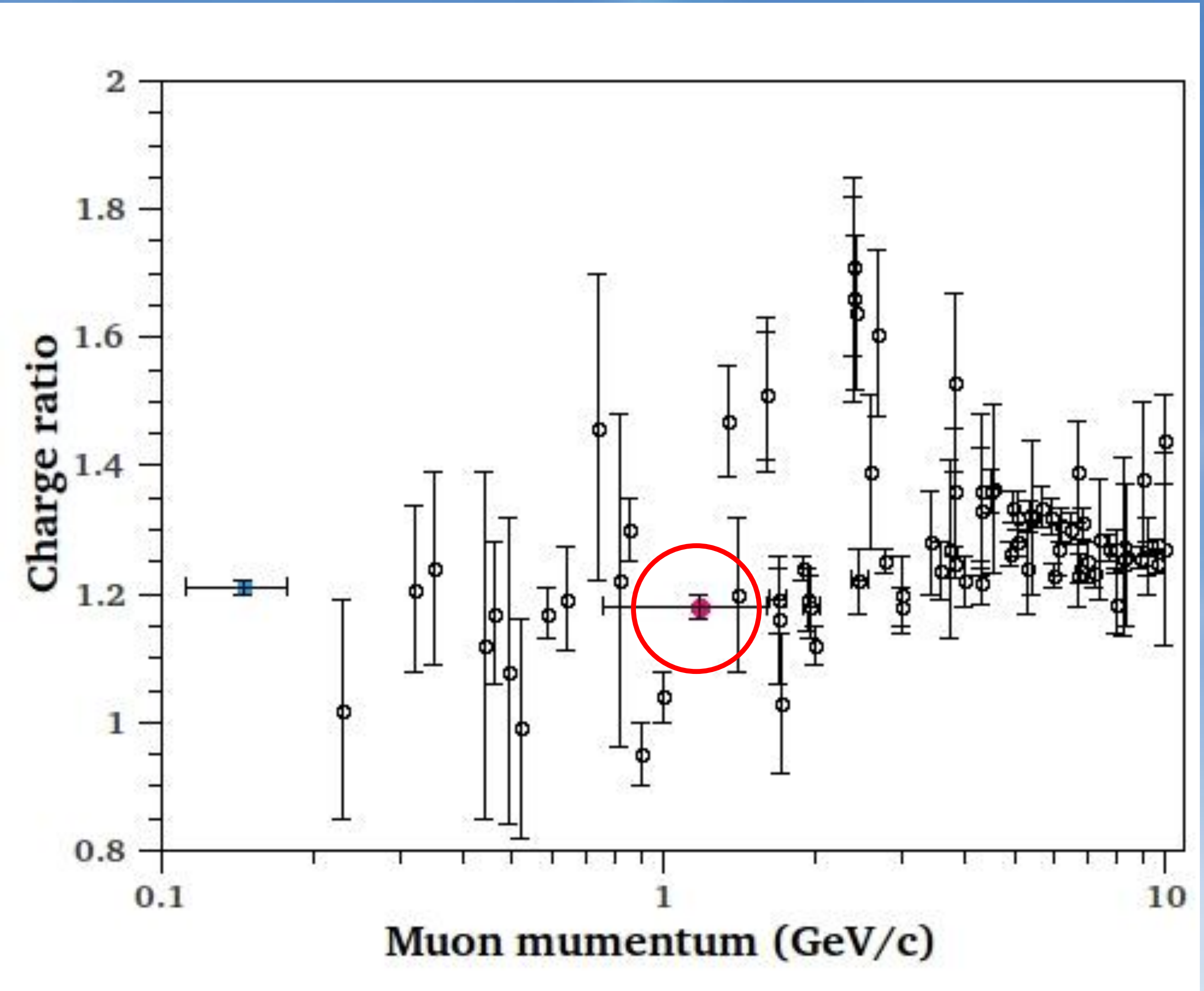


In simulation:

the model of **QGSJET - GHEISHA, R_μ= 1.06±0.06**

and in the model **QGSJET - UrQMD, R_μ= 1.04±0.06**

Muon Ratio Experiment



Vulpescu B et al 1998 NIM A 414 205
Haino S et al 2004 Phys. Lett. B 594 35-46
CMS Collaboration 2010 Phys. Lett. B 692 83-104

EAS Arrays

EAS Arrays

EAS Arrays

For θ=20º,   Δθ=13º

EAS Arrays

Conclusions for new project:

- Increase Number of Detectors (20)
- Reduce size of detectors (50x50 cm^2)
- Use new electronic system

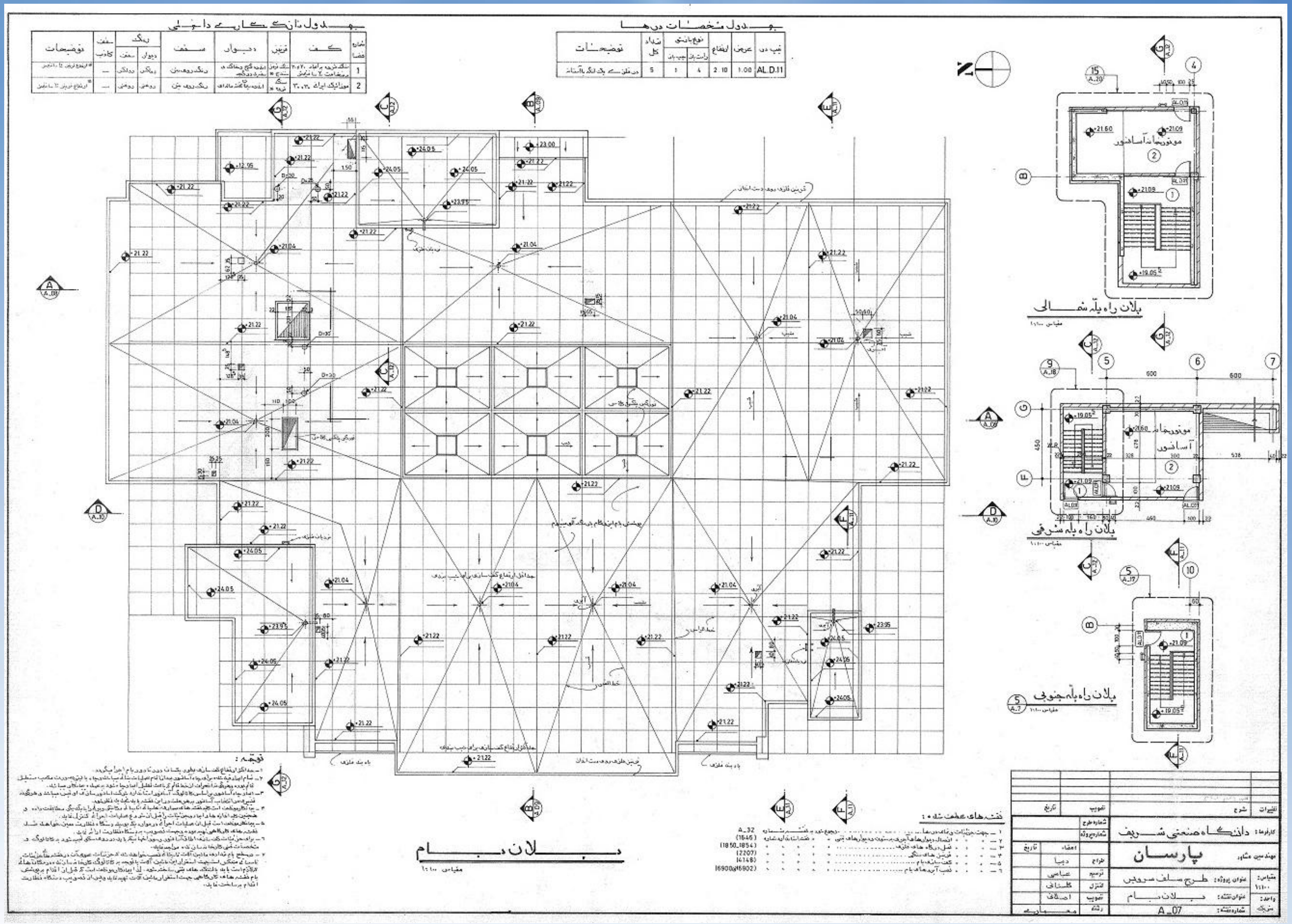
What should be done?

- Find a new place (bigger location)
- Optimize properties of detectors
- Primary simulations to know that:

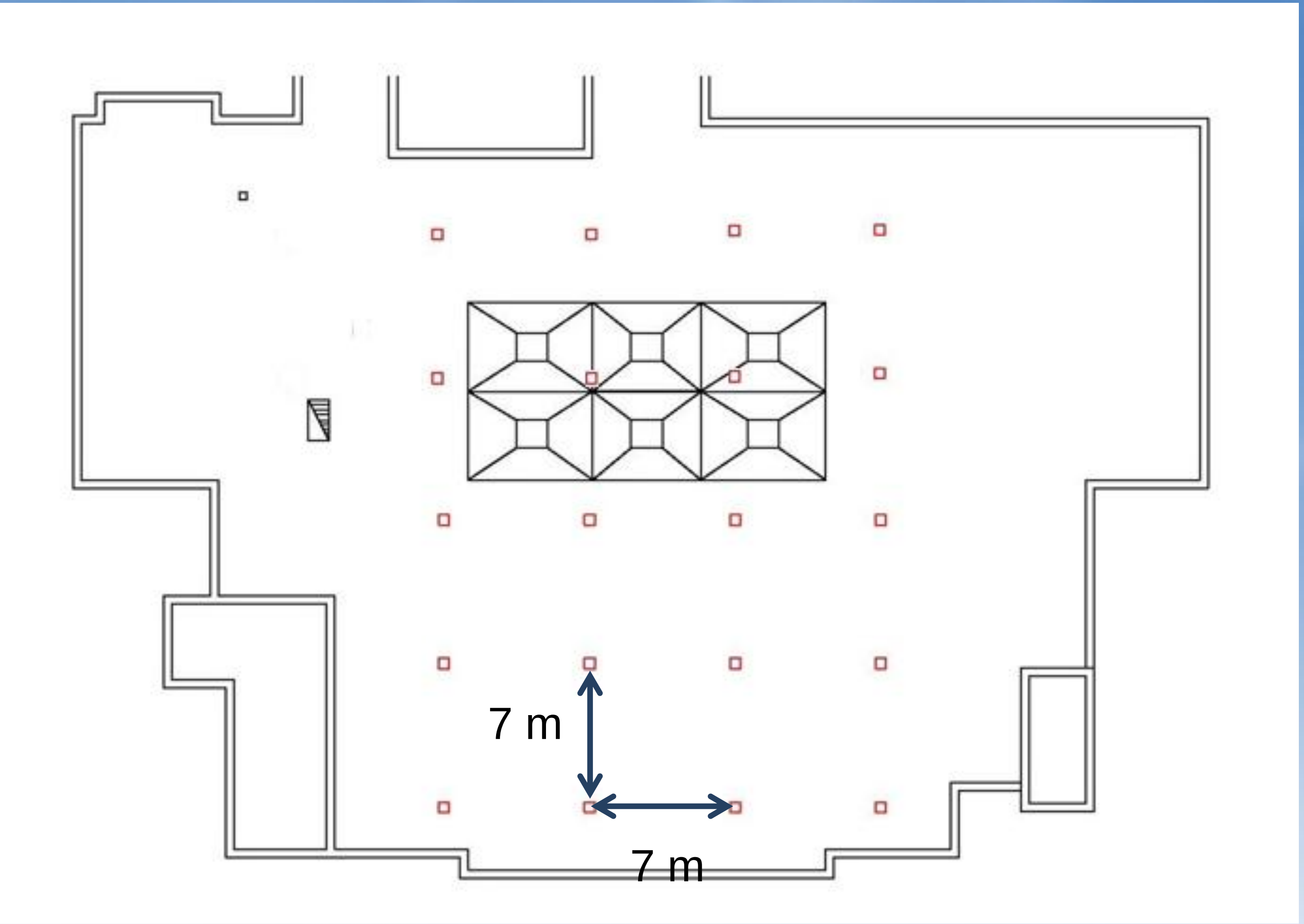
what can we get with this array?

Location

Location



Location

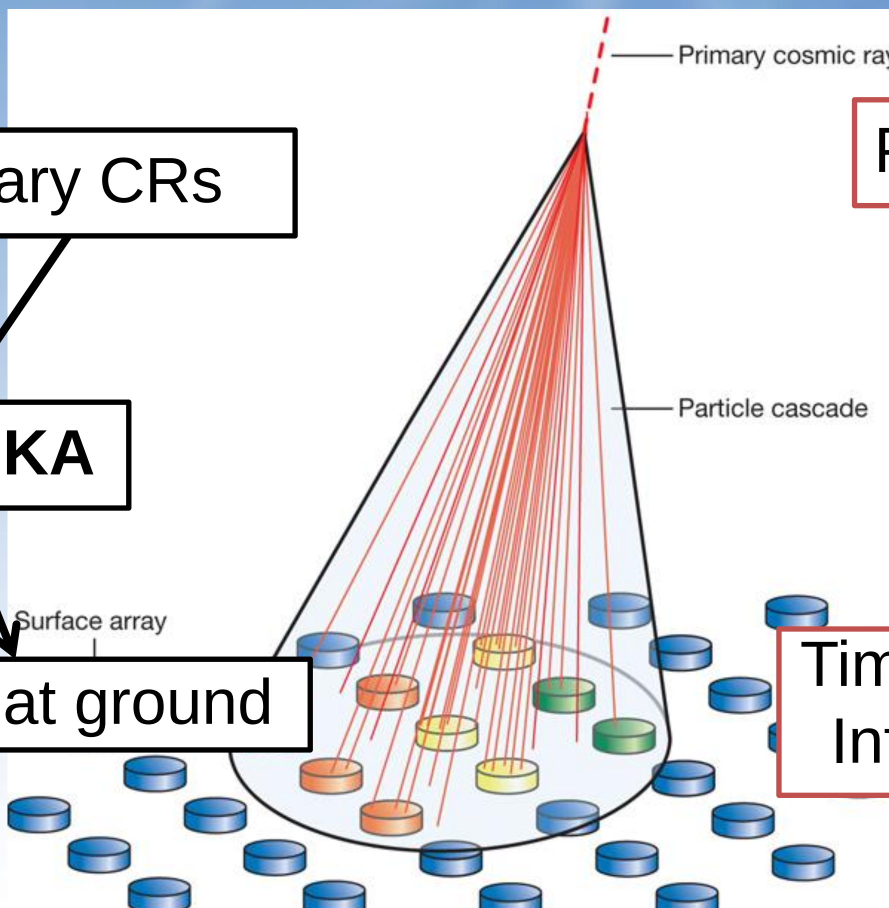


Detectors & Electronics

Simulation

Simulation

CORSIKA code



Primary CRs → **CORSIKA** → Particles at ground

Time and position Info of detectors → **Simulation** → Primary CRs

Simulation

Questions:

1- This array is **sensitive** to which part of CR **Spectrum**?

2- How many showers can be detected each day by this array?

3- How much **precise** we can calculate **direction of CRs** by this array?

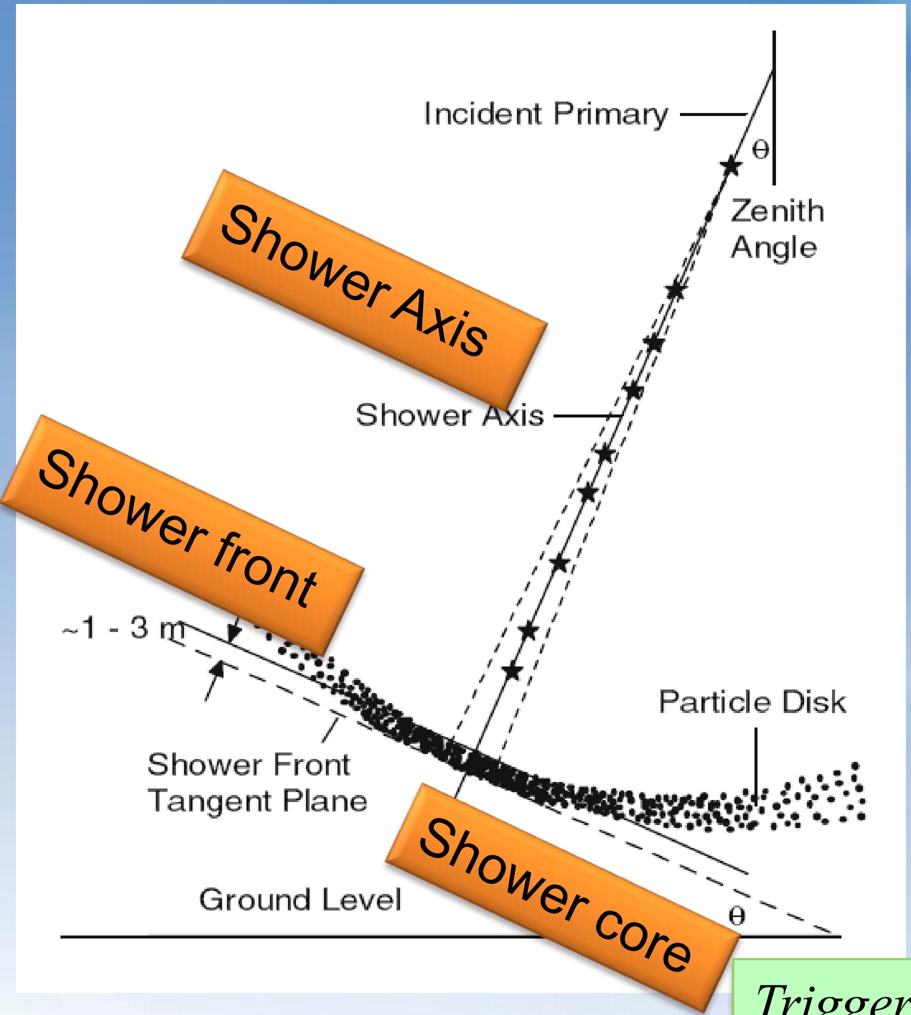
4- Which configuration is better?

5- Precision in determining core location?

6- Possibility in determining Cosmic ray energy or type?

….

Technical Terms



Trigger condition

Efficiency of array

Triggered Showers or Efficiency (ε) is a function of

1- Trigger condition,

2- core location (x,y) and

3- energy of CR (E)

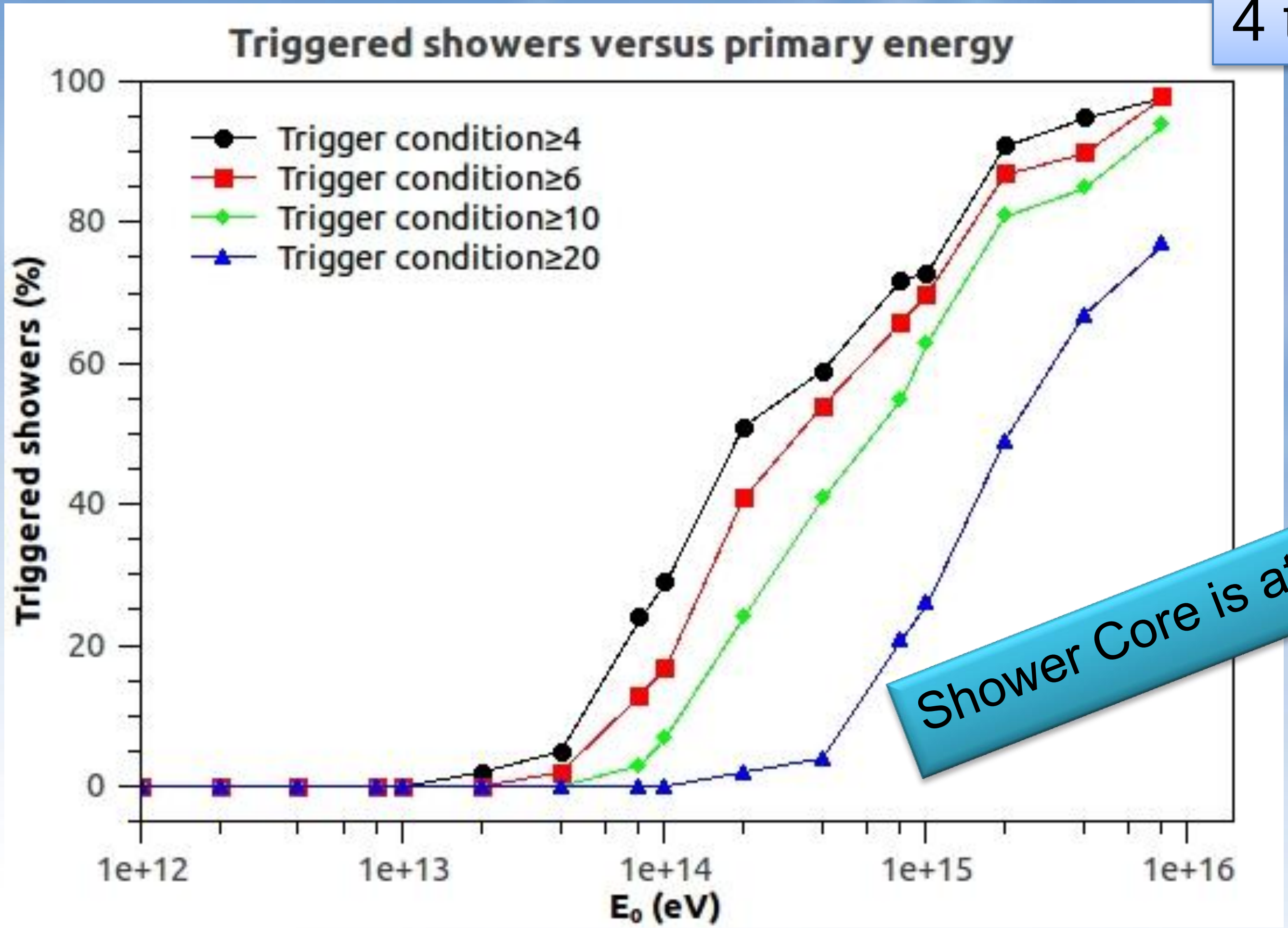
Energy Spectrum Sensitivity

Energy Sensitivity

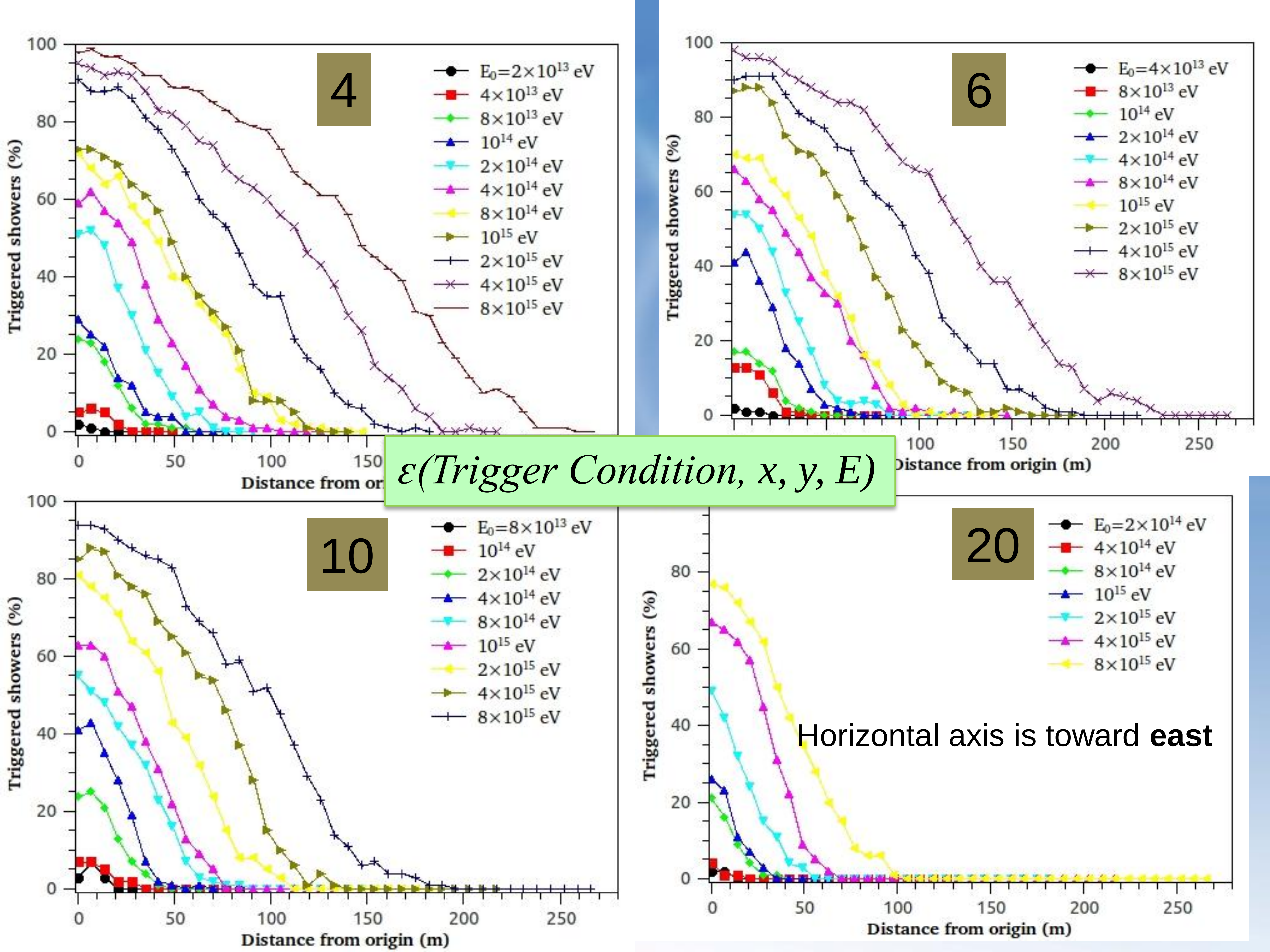
16 energy beam from 10^{12} to 10^{16} eV

100 showers in each energy

4 trigger conditions



Shower Core is at the center of Array

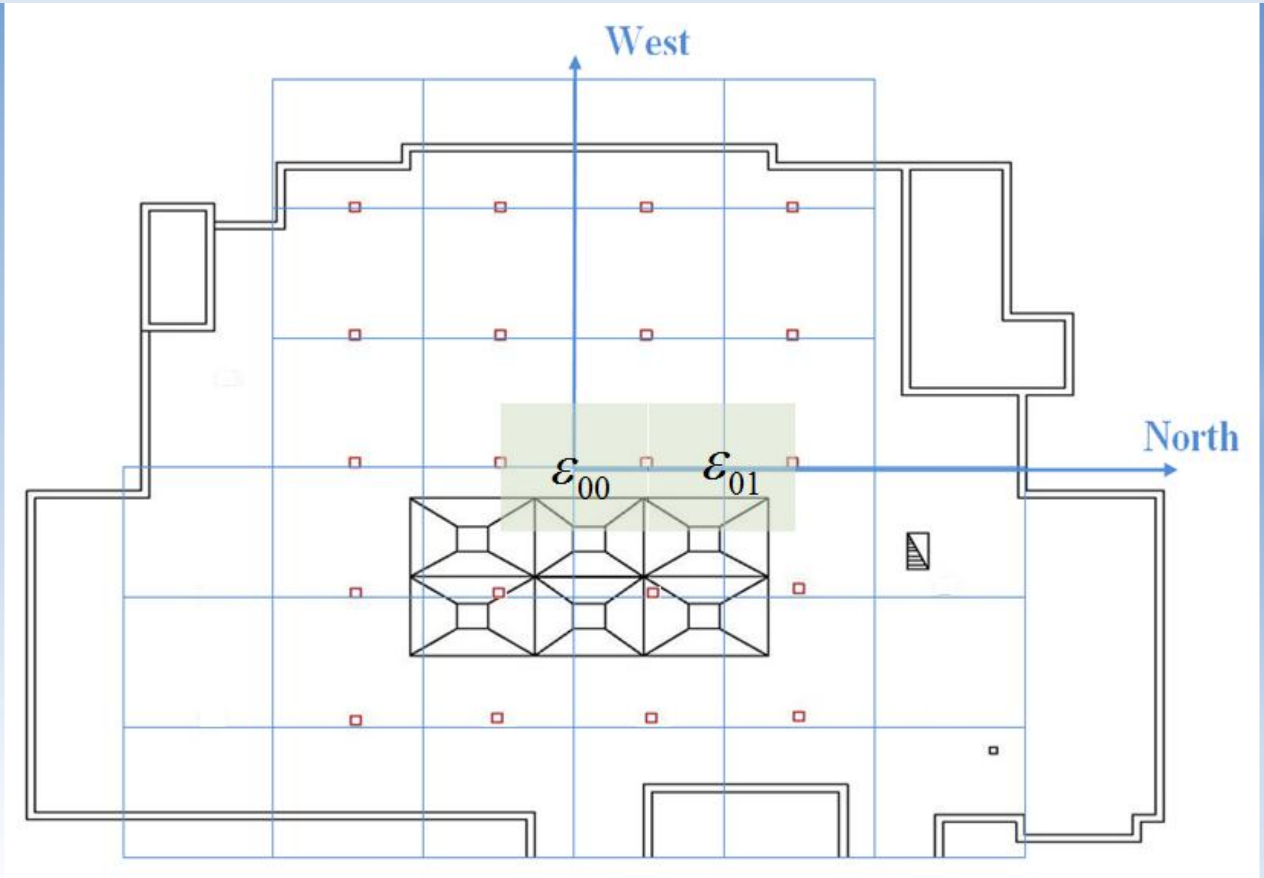

4
$E_0=2\times10^{13}$ eV
4×10^{13} eV
8×10^{13} eV
10^{14} eV
2×10^{14} eV
4×10^{14} eV
8×10^{14} eV
10^{15} eV
2×10^{15} eV
4×10^{15} eV
8×10^{15} eV
6
$E_0=4\times10^{13}$ eV
8×10^{13} eV
10^{14} eV
2×10^{14} eV
4×10^{14} eV
8×10^{14} eV
10^{15} eV
2×10^{15} eV
4×10^{15} eV
8×10^{15} eV
10
$E_0=8\times10^{13}$ eV
10^{14} eV
2×10^{14} eV
4×10^{14} eV
8×10^{14} eV
10^{15} eV
2×10^{15} eV
4×10^{15} eV
8×10^{15} eV
20
$E_0=2\times10^{14}$ eV
4×10^{14} eV
8×10^{14} eV
10^{15} eV
2×10^{15} eV
4×10^{15} eV
8×10^{15} eV
Triggered showers (%)
Distance from origin (m)
ε(Trigger Condition, x, y, E)
Horizontal axis is toward **east**

Daily Detectable Showers

Daily Detectable Showers

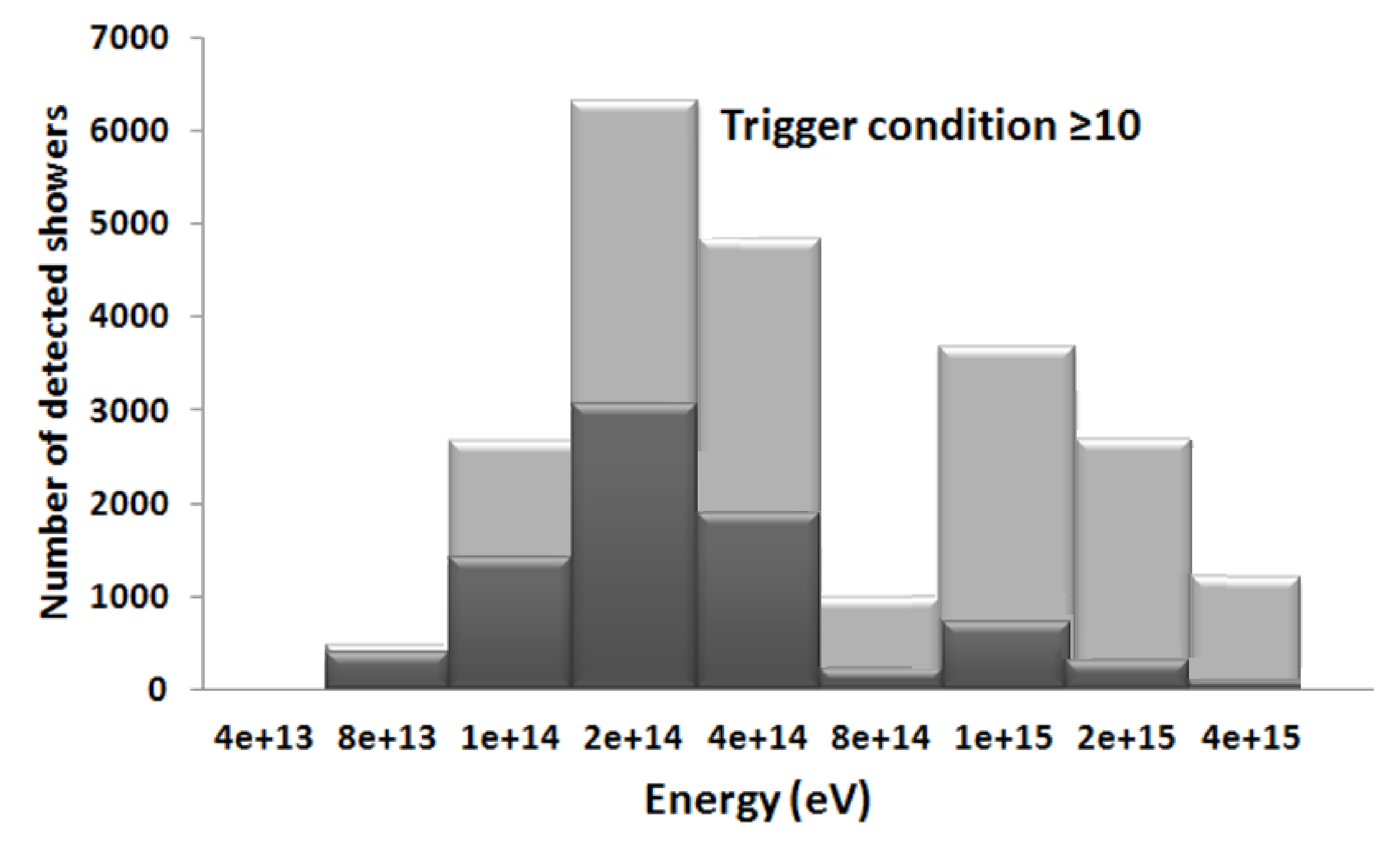
F(E): *Flux of CRs; from literature*

$\boldsymbol{\varepsilon_{ij}}$: *efficiency at position* $(i\times7, j\times7)$



$$\mathrm{N(E, E+\Delta E)} = \sum_{i,j} F(E) \times a\,(49m^2) \times T\,(24h) \times \Omega \times \Delta E \times \varepsilon_{ij}$$

Daily Detectable Showers



Core is inside Array area

8,132

No limitation for core location

23,485

Finding Direction

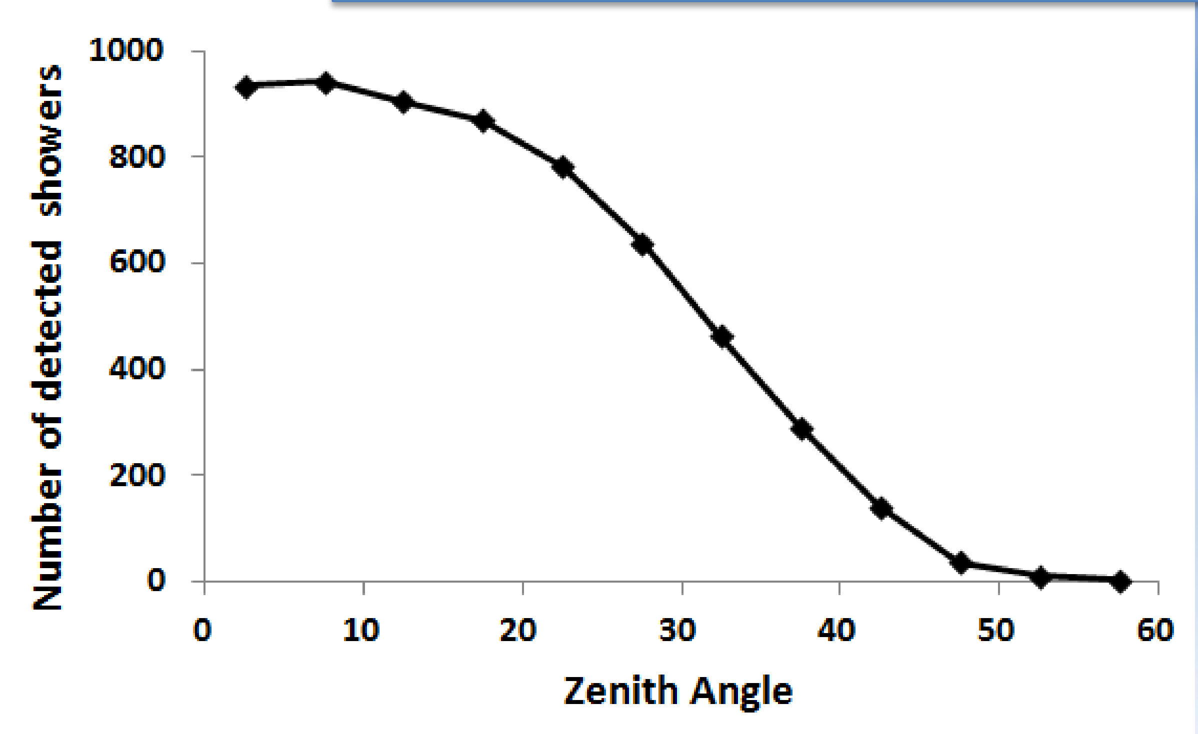
Finding Direction

In the energy of 200 TeV

Azimuth angles in the range of 0°-60°

1000 shower in each 5° interval

Trigger condition: at least 10 detector is on



Finding Direction

We seek θ and φ of a shower

We have 10 points
(from trigger condition)

Using X^2 method
Put points in function

Find θ and φ

$\theta_{10}, \varphi_{10}$

This is what people do usually

We have 10 points
(from trigger condition)

Select 8 points
& put in X^2 function

θ_8^1, φ_8^1

Select other 8 points
& put in X^2 function

θ_8^2, φ_8^2

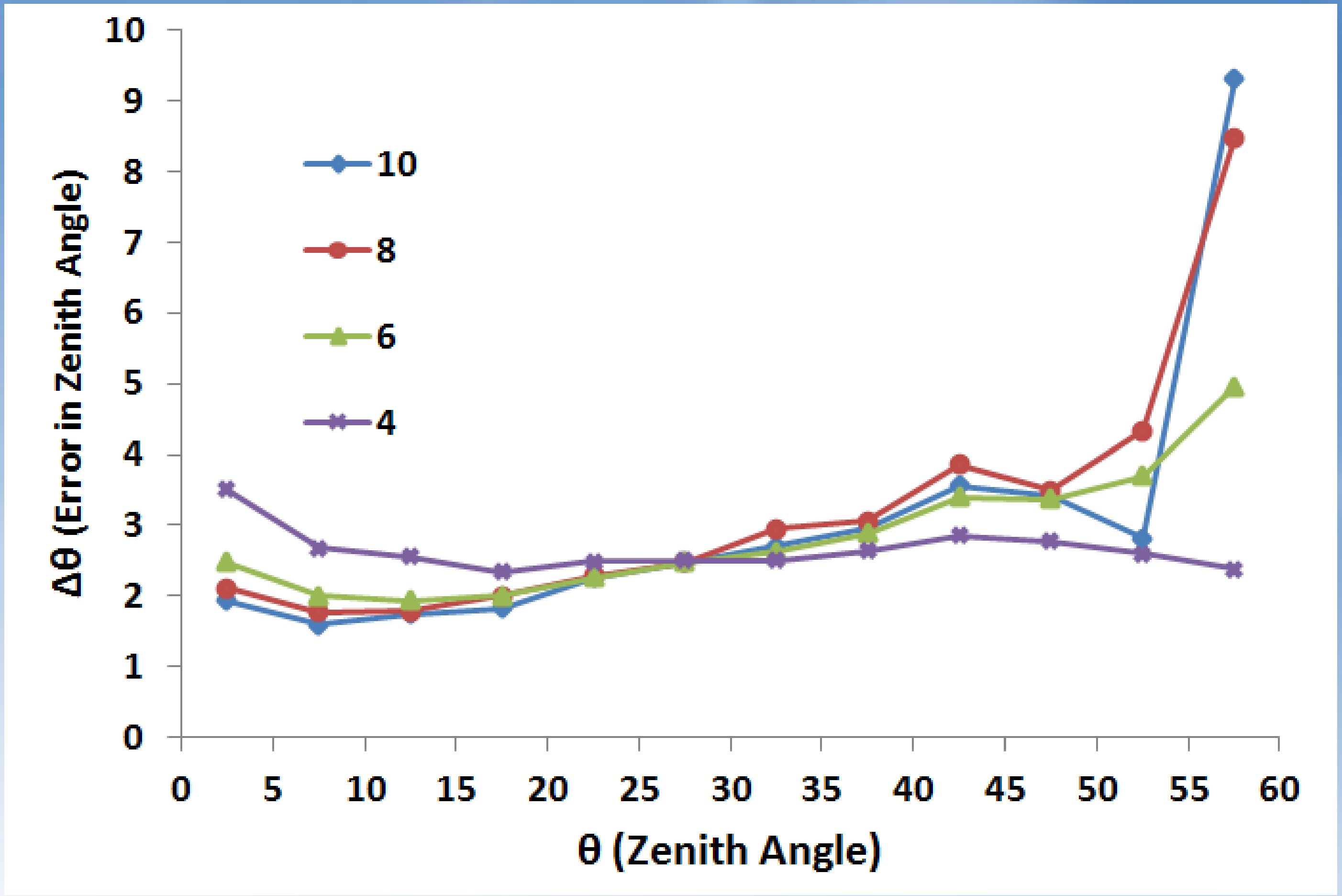
Averaging over all

θ_8^i, φ_8^i

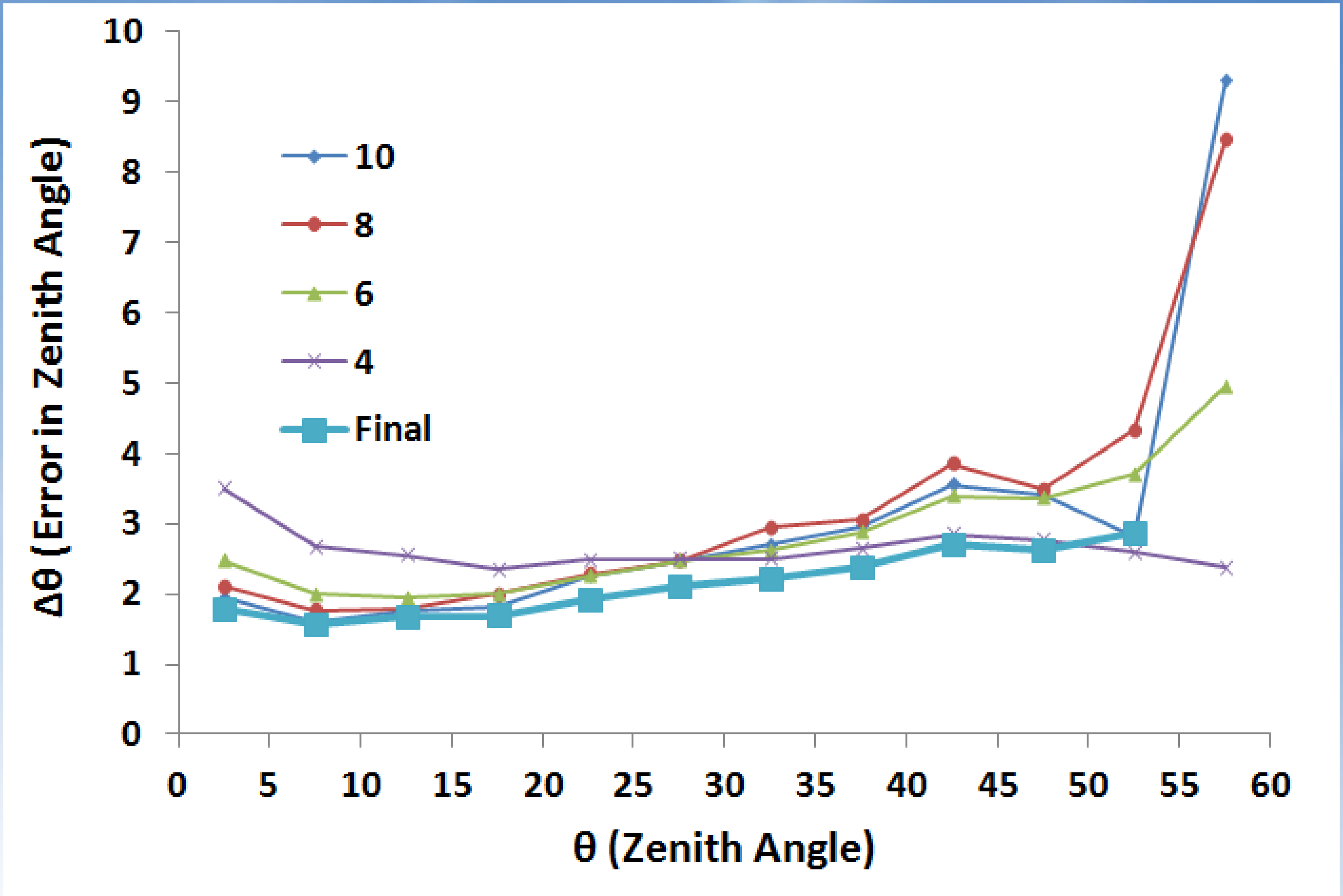
θ_8, φ_8

Continue for all possible selections of 8 out of 10

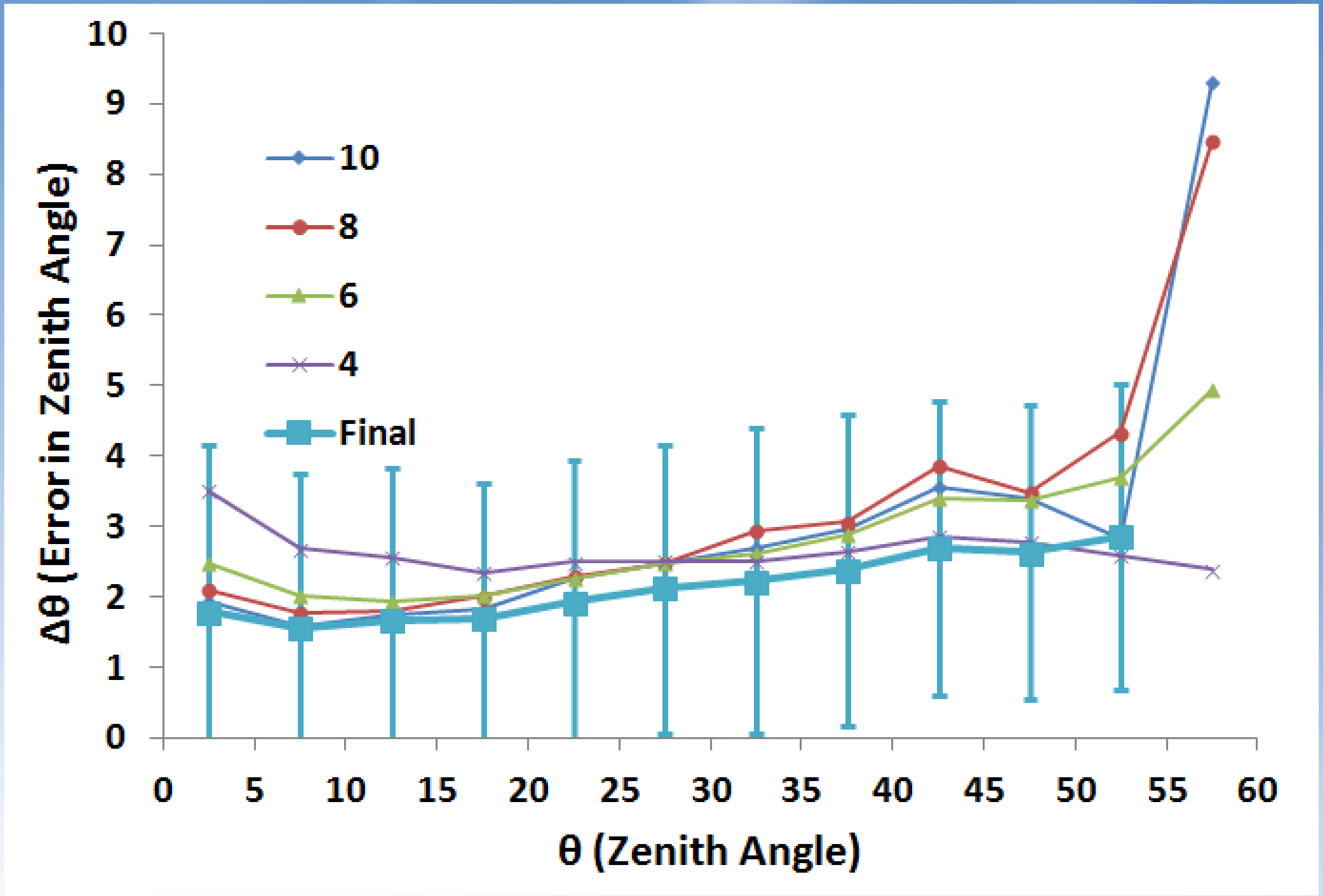
Zenith Angle



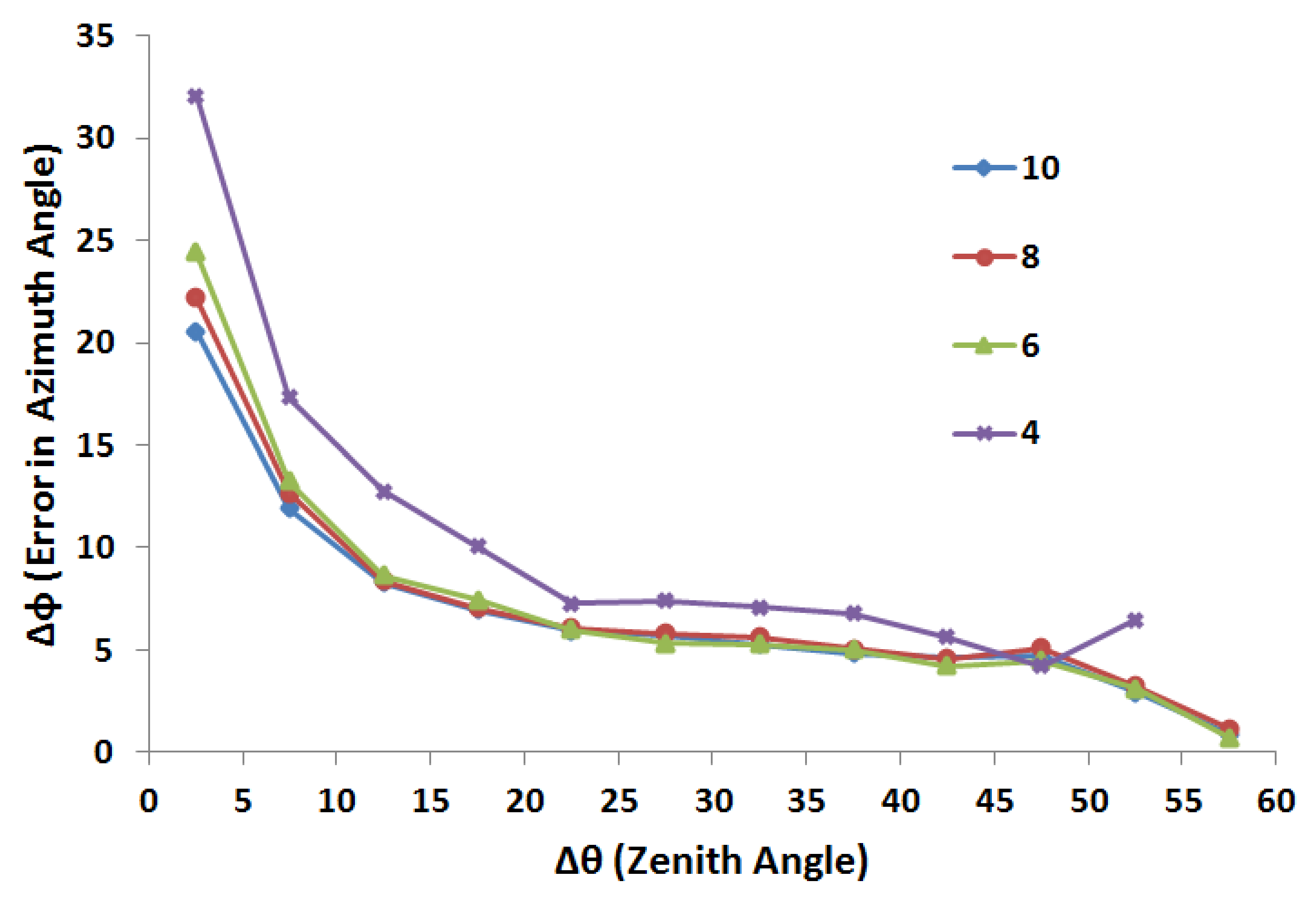
Zenith Angle



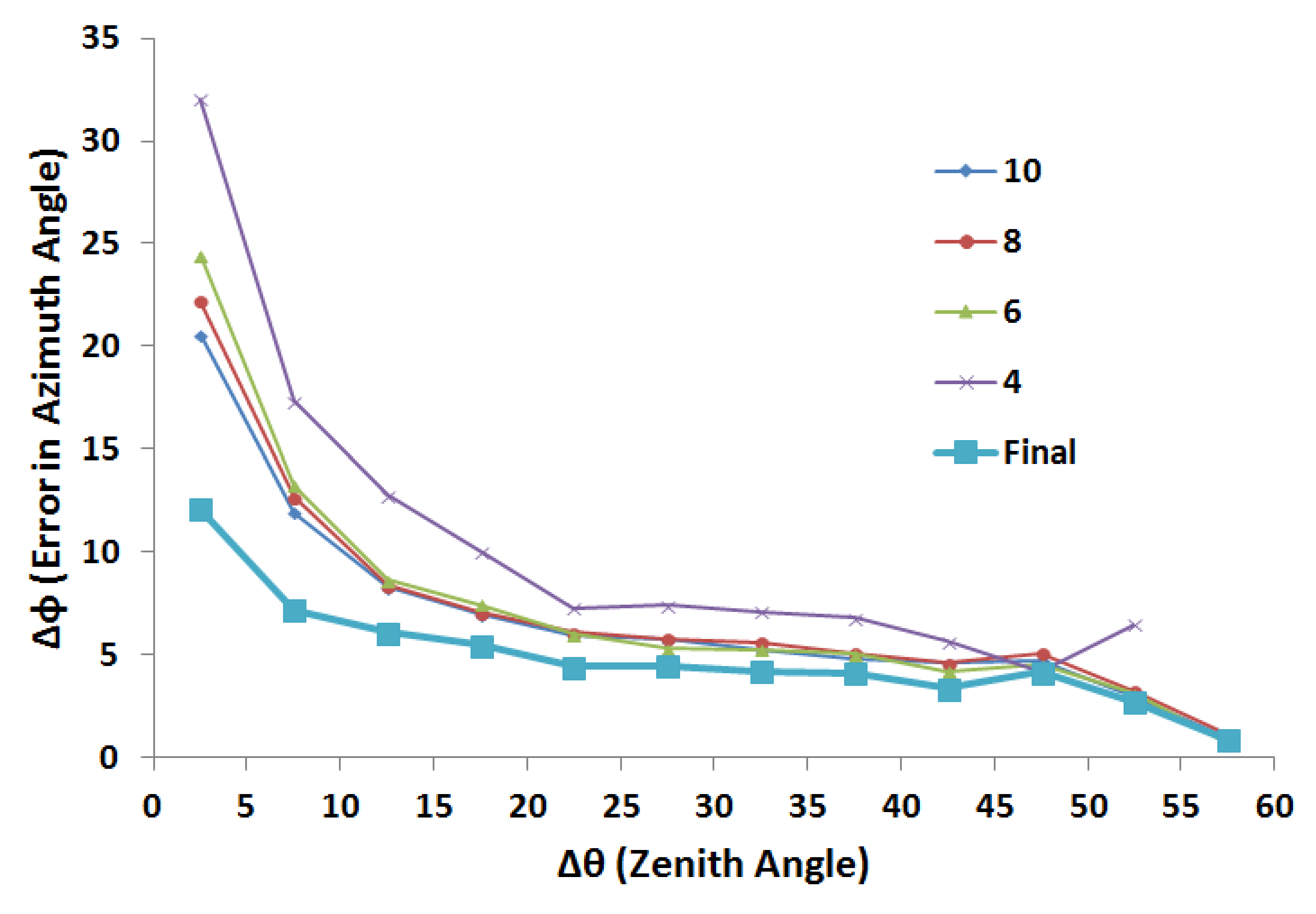
Zenith Angle



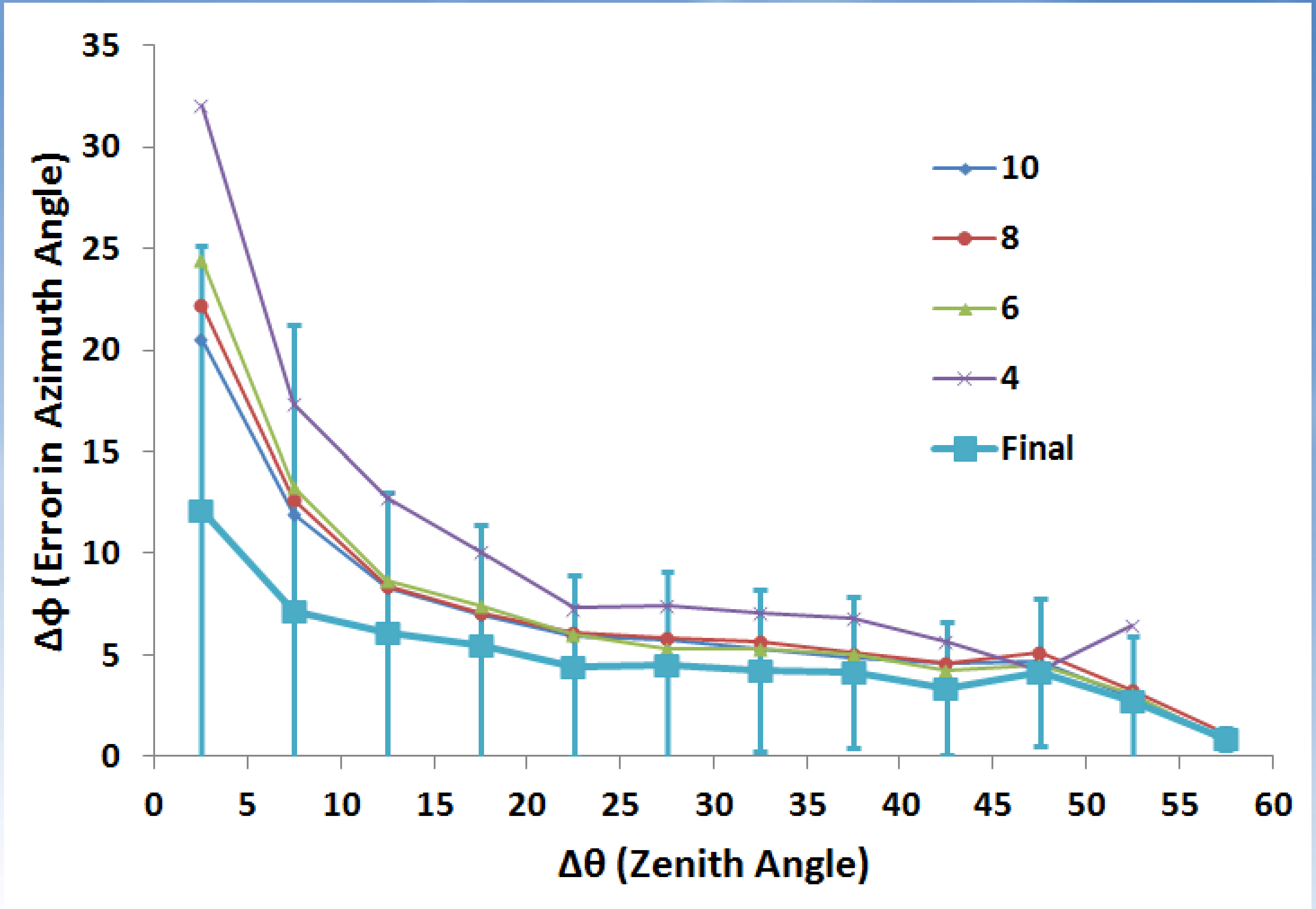
Azimuth Angle



Azimuth Angle



Azimuth Angle



Conclusion

- Muon Charge Ratio is found to be **1.18±0.02**
- Simulation give lower values **1.06±0.06**
- This array is sensitive to Showers with energy higher that **80 TeV**
- Maximum number of detected showers have energy about **200 TeV**
- Total number of showers which array may detect each day is about **23,500**
- We introduce a method to find Zenith and Azimuth angle of shower.
- Mean Error of zenith angle is between 1°-3°
- Mean Error of Azimuth angle depends on zenith angle of shower and varies from 13° to less than 1°

Thank you