Detector Construction and Array Performance Simulation for Alborz Observatory Array (Alborz-I)

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IPM

پژوهشگاه دانش‌های بنیادی

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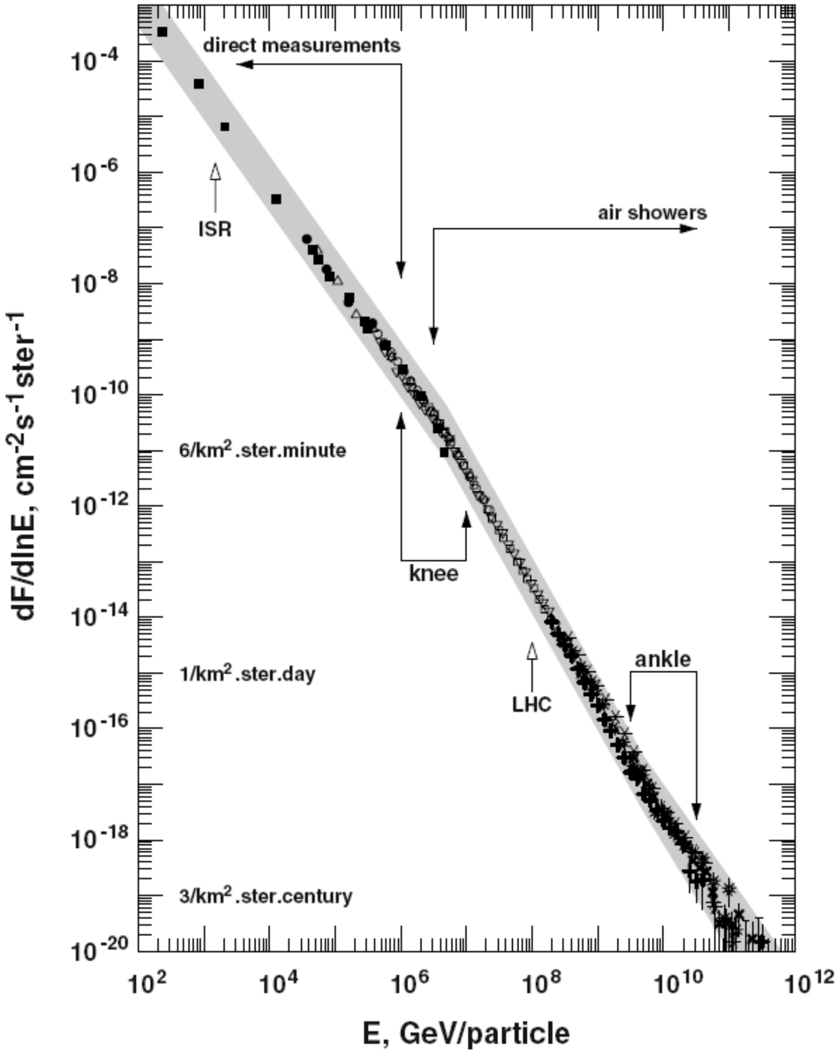
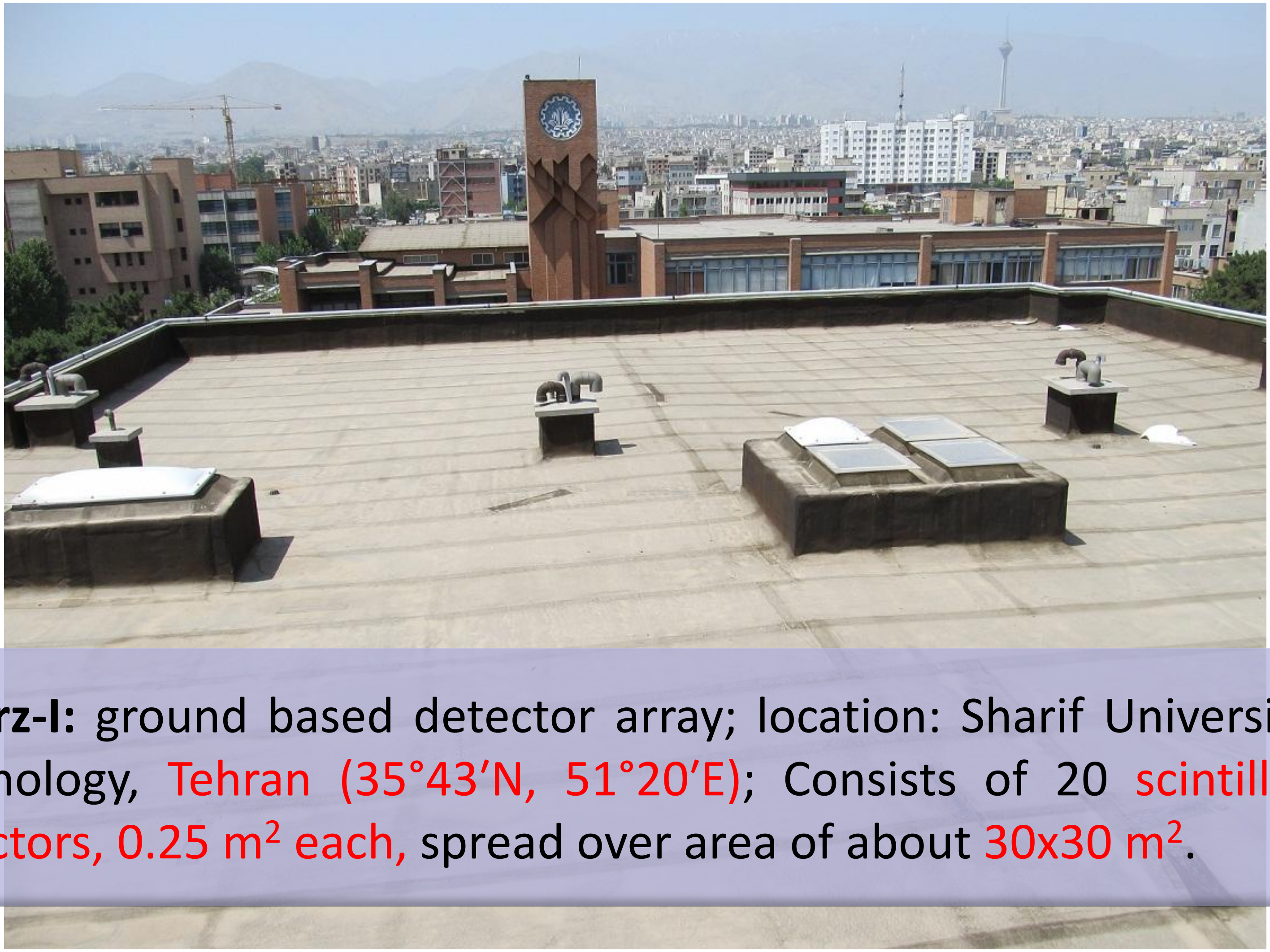
Cosmic Rays and Extensive Air Showers

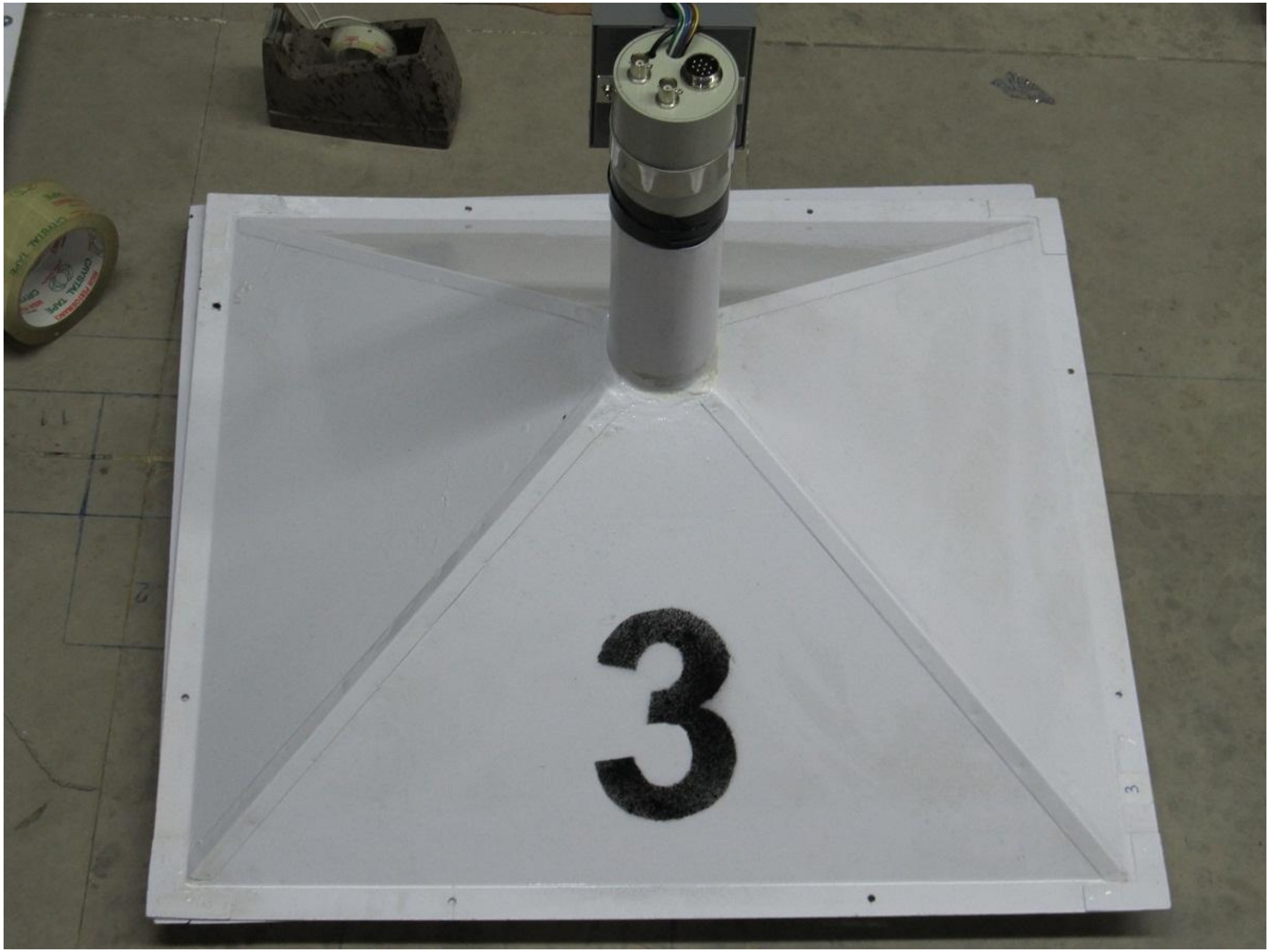


Alborz-I

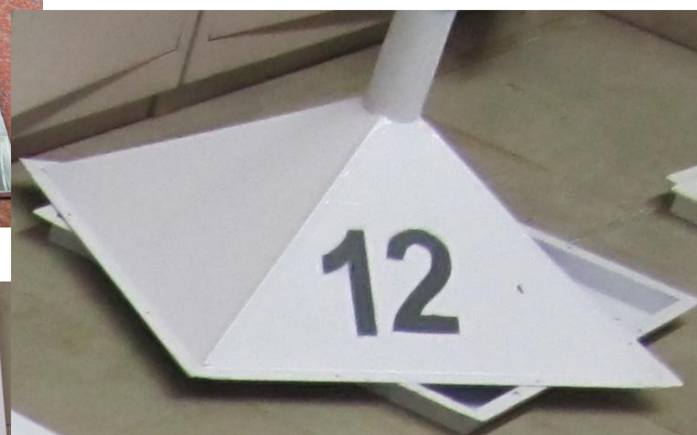


Alborz-I: ground based detector array; location: Sharif University of Technology, Tehran (35°43′N, 51°20′E); Consists of 20 scintillation detectors, 0.25 m^2 each, spread over area of about 30x30 m^2.

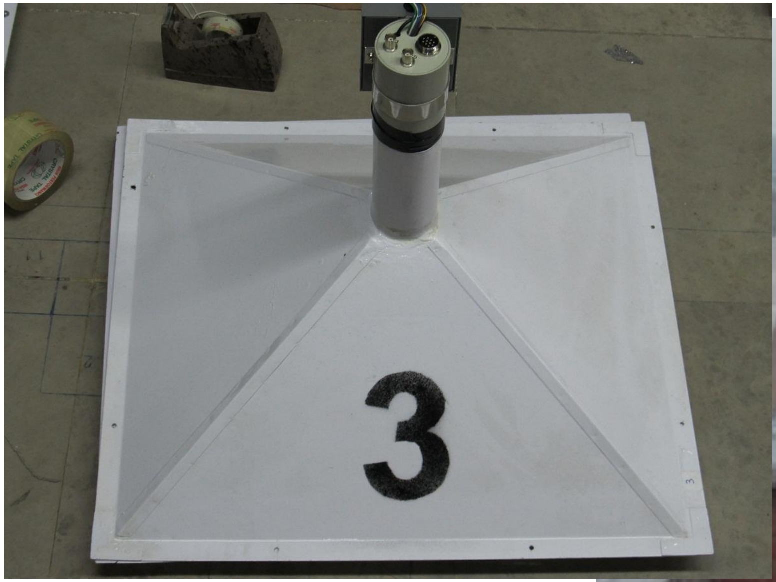
Detector Parts



Detector Parts



Detector Parts



Light Enclosures

What is the best choice for Light Enclosures?

- Extended experiments before 1998 to find best choice for finishing inside of Light Enclosure (with 1 m^2 scintillators):
  5 enclosure heights (5, 15, 30, 42 and 50) with 4 different finishing (white, black, steel, mirror)

- The comparison between Light Enclosures with different inside finish showed that: **White inside finish** for LE enhances the detection efficiency. Also the total counts for the pyramidal shape LE with white finish show a peak at PMT height of **15 cm**.

M.Bahmanabadi et. al., Experimental Astronomy, 1998, 8(3): page 211-229

Light Enclosures

Recent studies about Light Enclosures

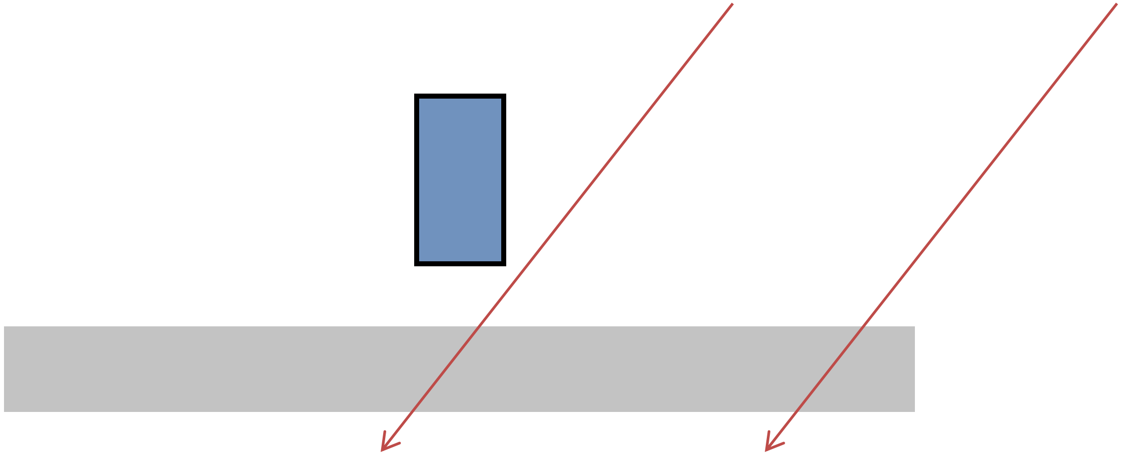
Changing the size of detector: 1×1 m^2 changed to 0.5×0.5 m^2

After resizing detector sizes for new array, we need to find best height again. Also we need to have better understanding of how does the detectors work?

- Experiments to choose best height
- 2 sets of simulations:
  - Extended Code
  - Geant4

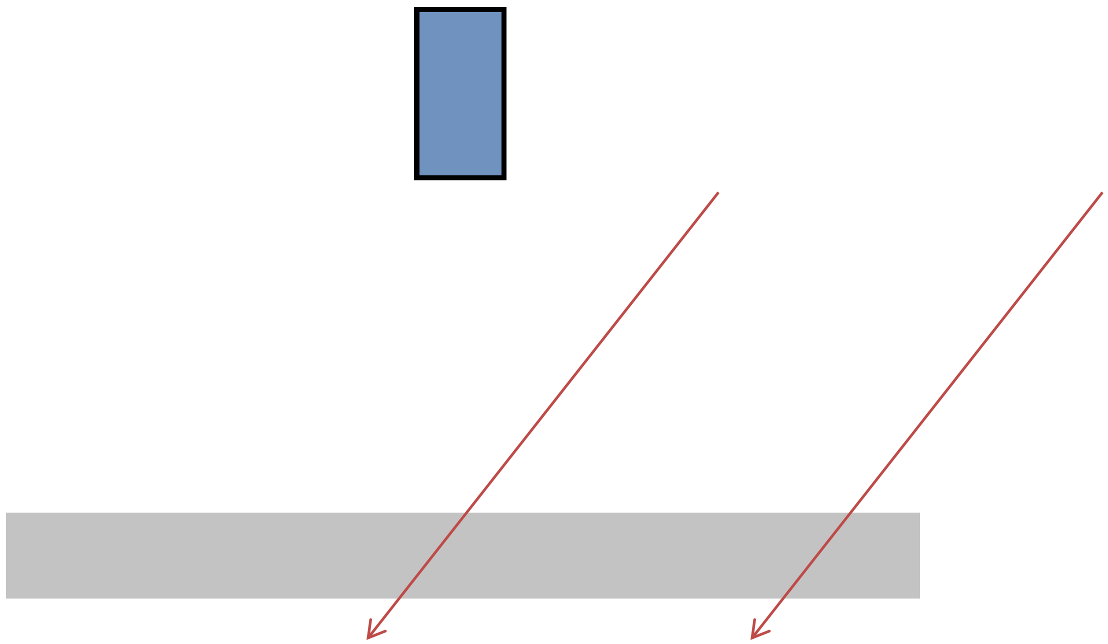
Light Enclosures

Uniformity and better **Efficiency**



Light Enclosures

Uniformity and better **Efficiency**



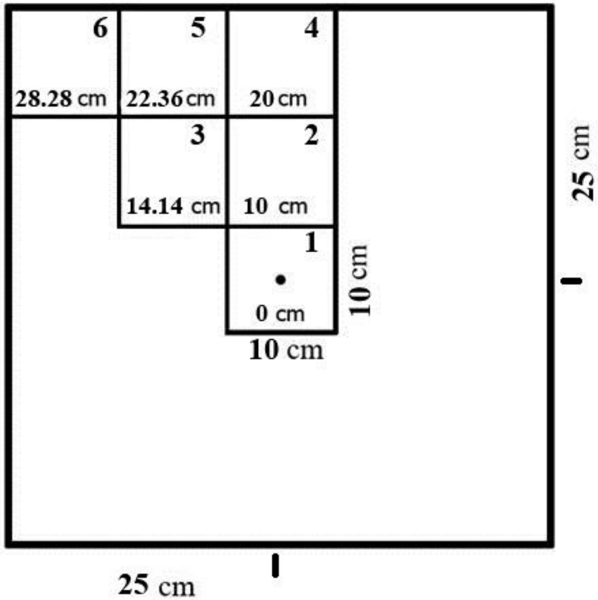
Experiment

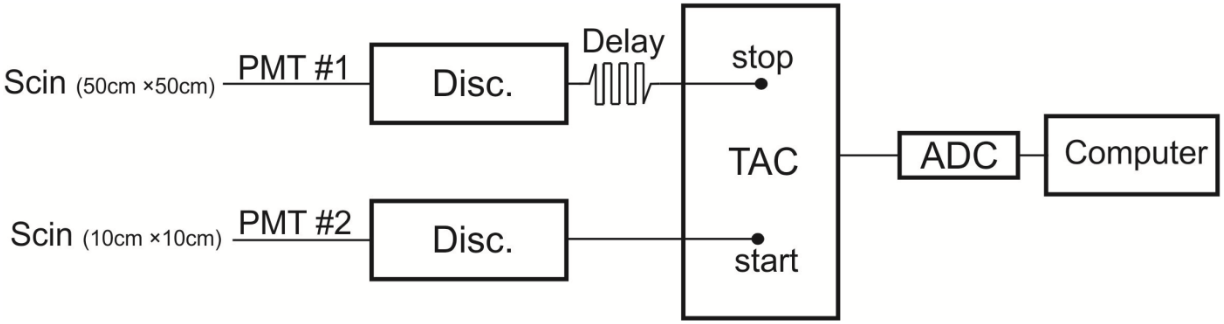
Comparison of 4 LE with different heights

Heights = 10, 20, 30 and 40 cm

Repeating Exp. for 6 sections of each height

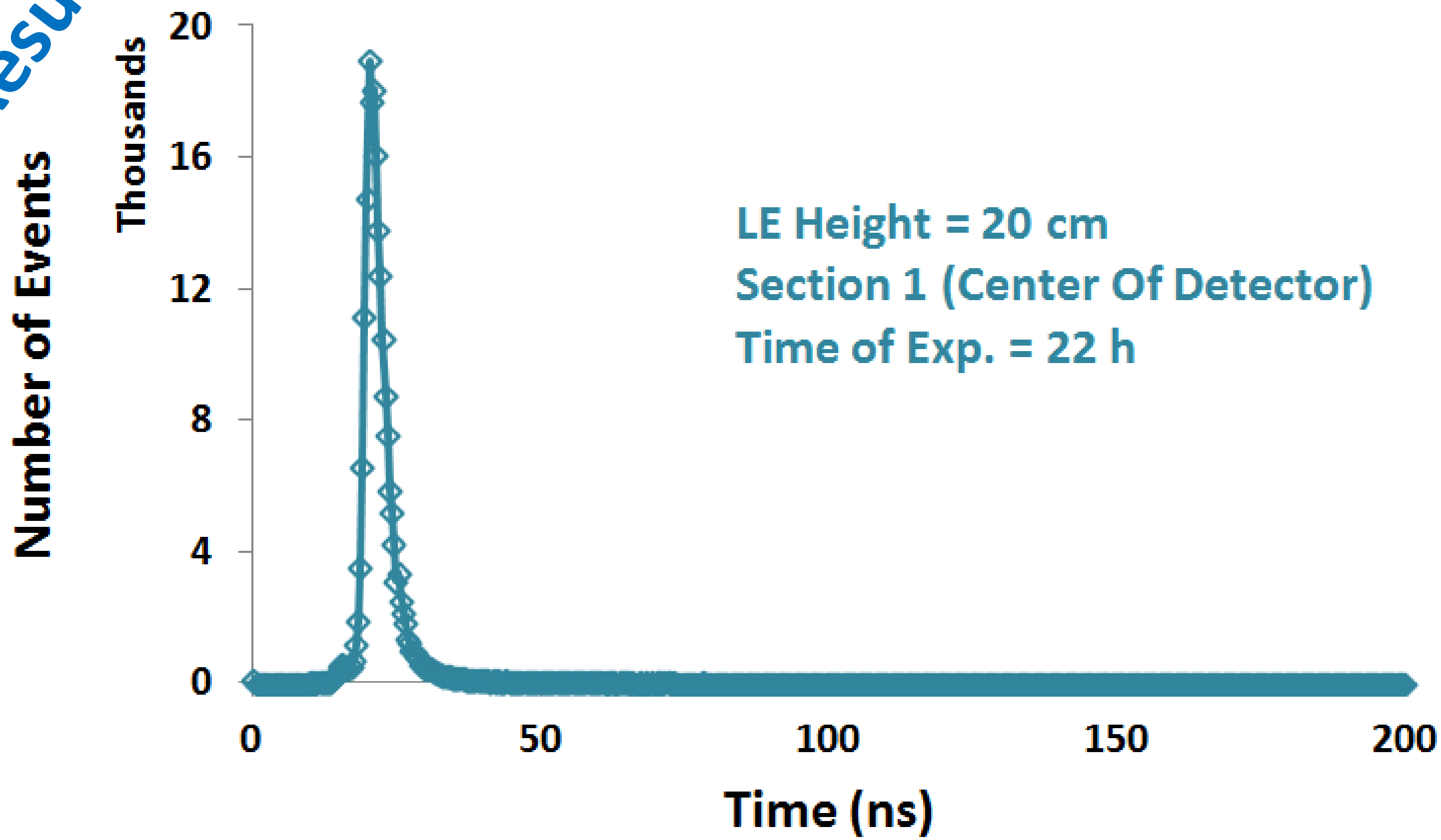
Time of each Exp. = 22 hours





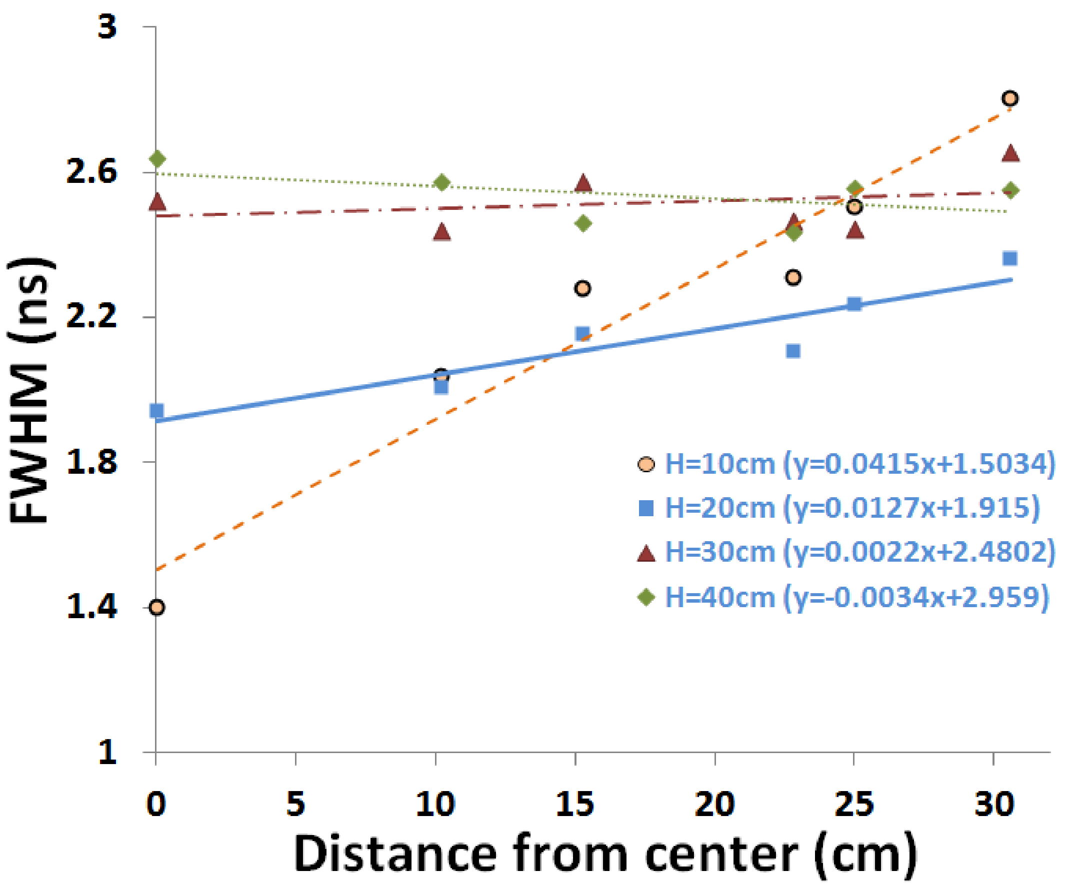
Experiment

Experiment Results



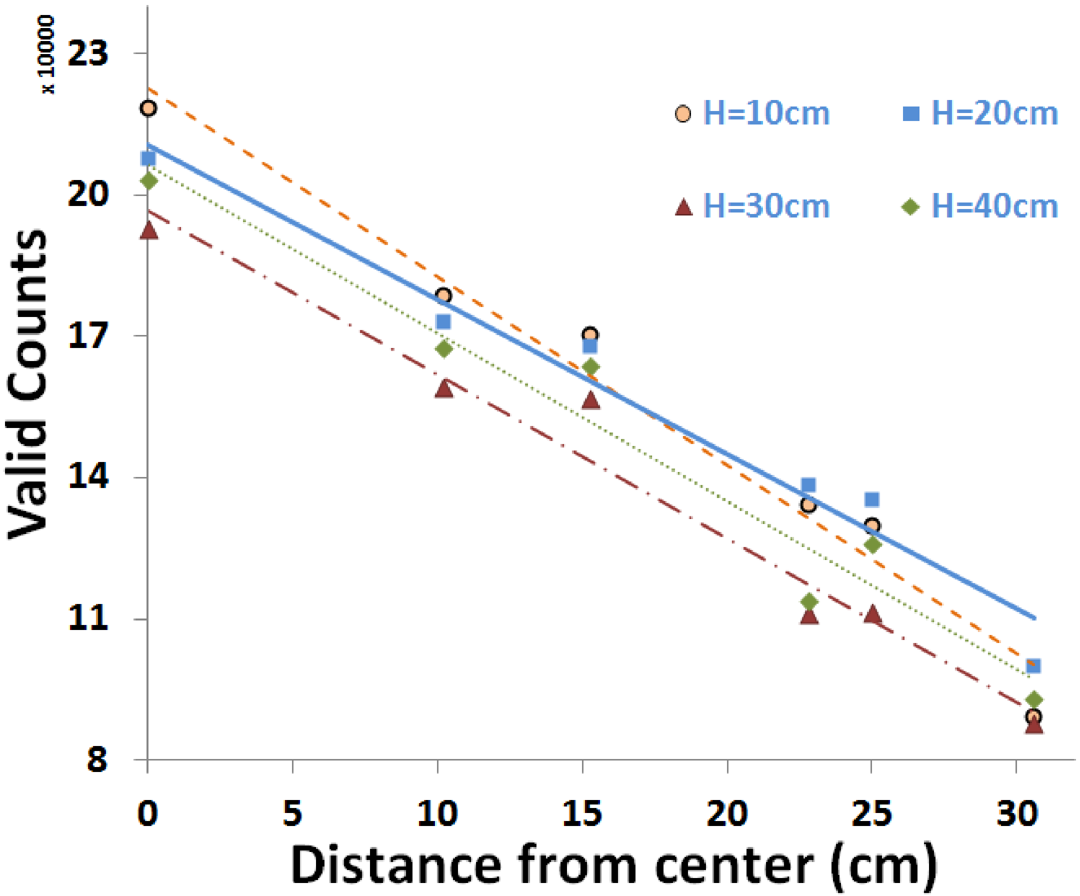
Experiment

Experiment Results



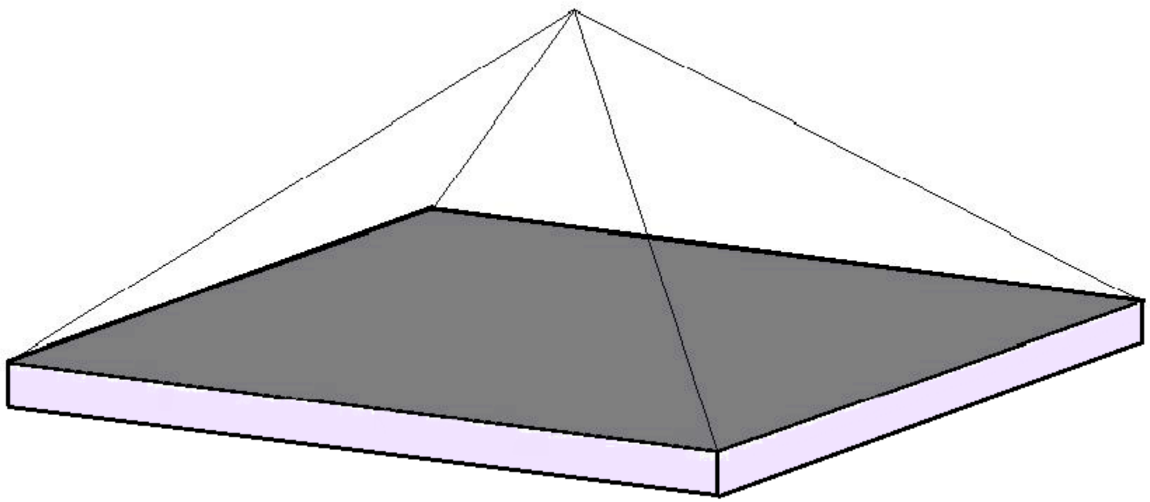
Experiment

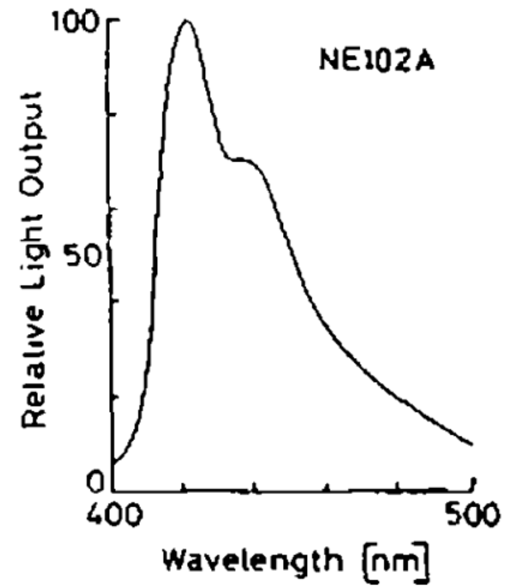
Experiment Results



Height (cm)	Efficiency (%)
10	$65\varepsilon_0$
20	$66\varepsilon_0$
30	$58\varepsilon_0$

Detection process





Maximum is at 423 nm

Created photons in Scintillator

Extended-code Results

Emmited (Created in Scintillator)	48588
Reached to PMT	196
Trapped (Internal Reflection)	37623
Trapped (Internal Reflection) 2	6874
Attenuation	319
Absorption in Ground	496
Absorption in Walls of LE	3302

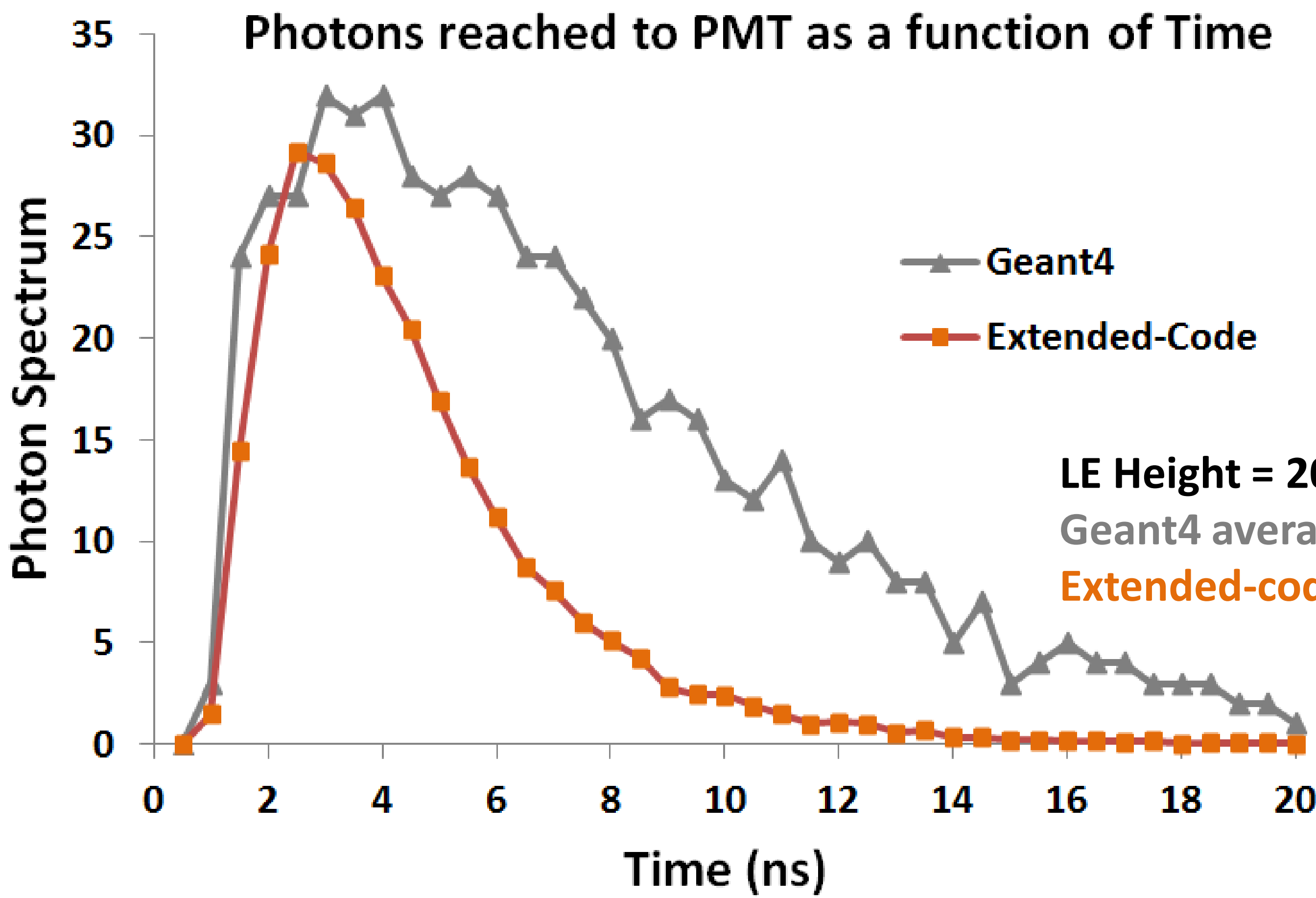
Photons reached to PMT

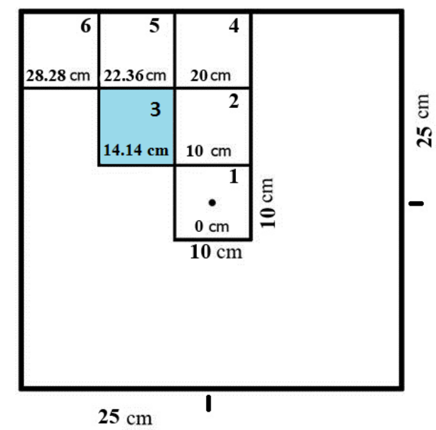
Extended-code Results

About 196 photos reached to PMT in average, what is the number of collisions with the walls of light enclosure?

Number of Collisions with walls	Average Number of Reached Photons	Percentage of Reached Photons
0	65.4	33.4
1	59.3	30.3
2	34.5	17.6
3	18.5	9.5
4	9.4	4.8
5	4.5	2.3
6	2.2	1.1
7	1.0	0.5
8	0.5	0.2
9	0.2	0.1
10	0.1	0.1

Comparison between Extended-code and Geant4 results





LE Height = 20 cm

Geant4 averaged over 10 runs

Extended-code averaged over 100 runs

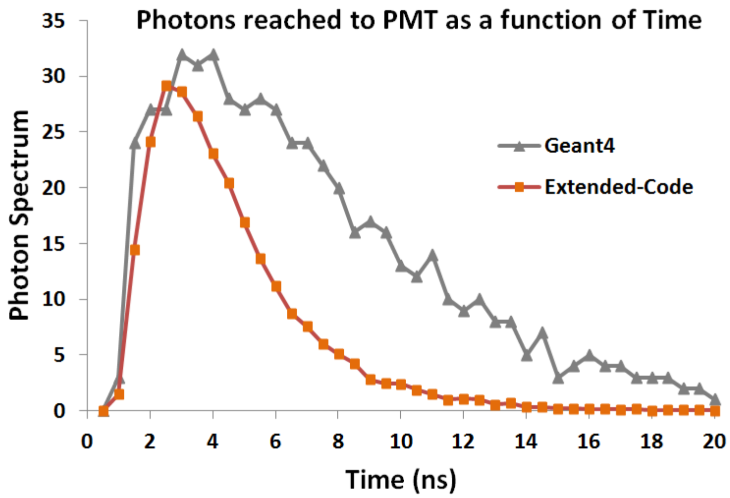
Comparison between Extended-code and Geant4 results

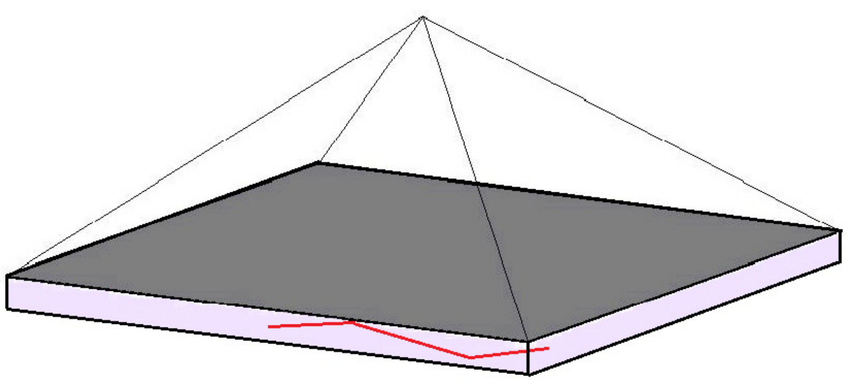
There are 3 points which could explain the difference

1- Ionizing particle in Geant4 is 1 GeV electron while in extended-code it is MIP

2- Emitted photons from scintillator in Geant4 have different wavelengths while those of extended code are monochromatic

3- Photons encounter total internal reflection in extended-code are supposed to be trapped while some of them may come back to PMT after reaching end of plastic

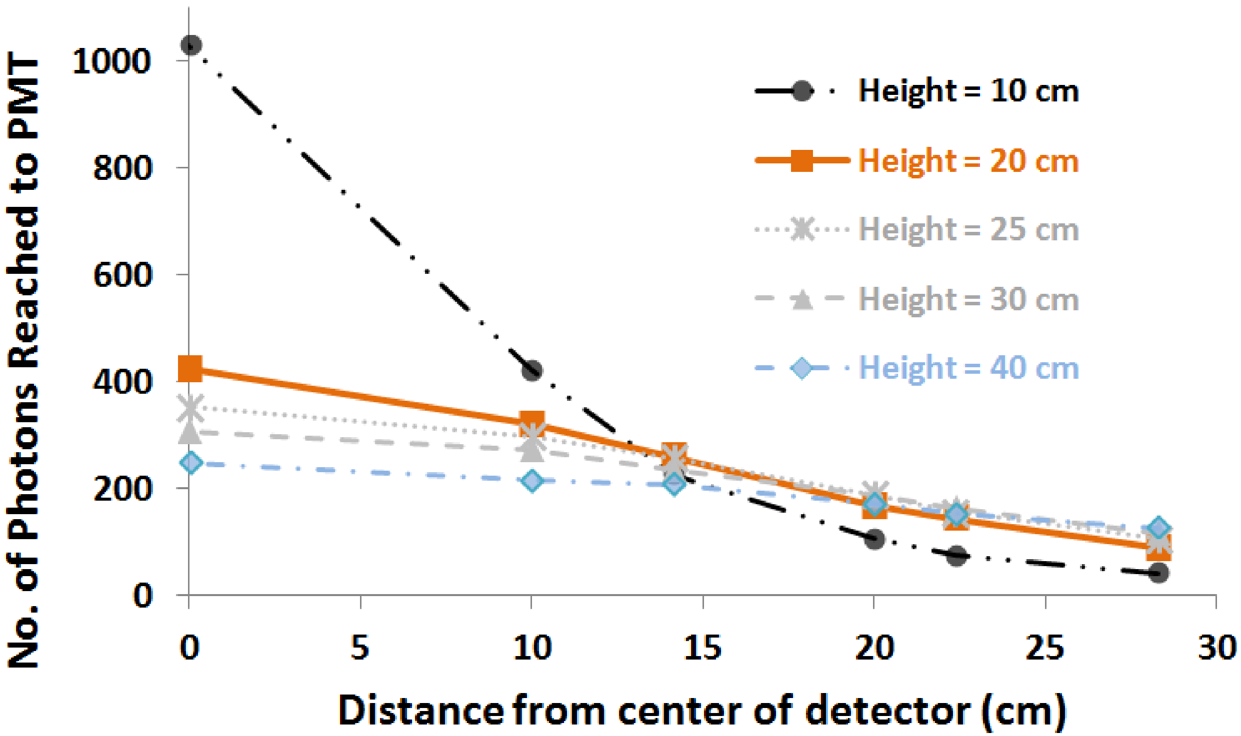


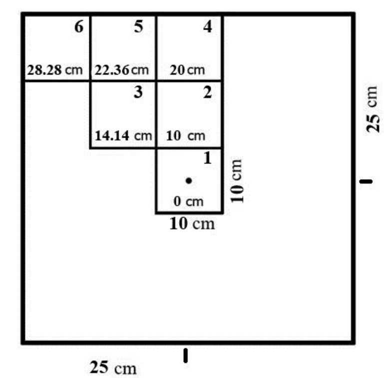


Extended-code Simulation

Extended-code Results

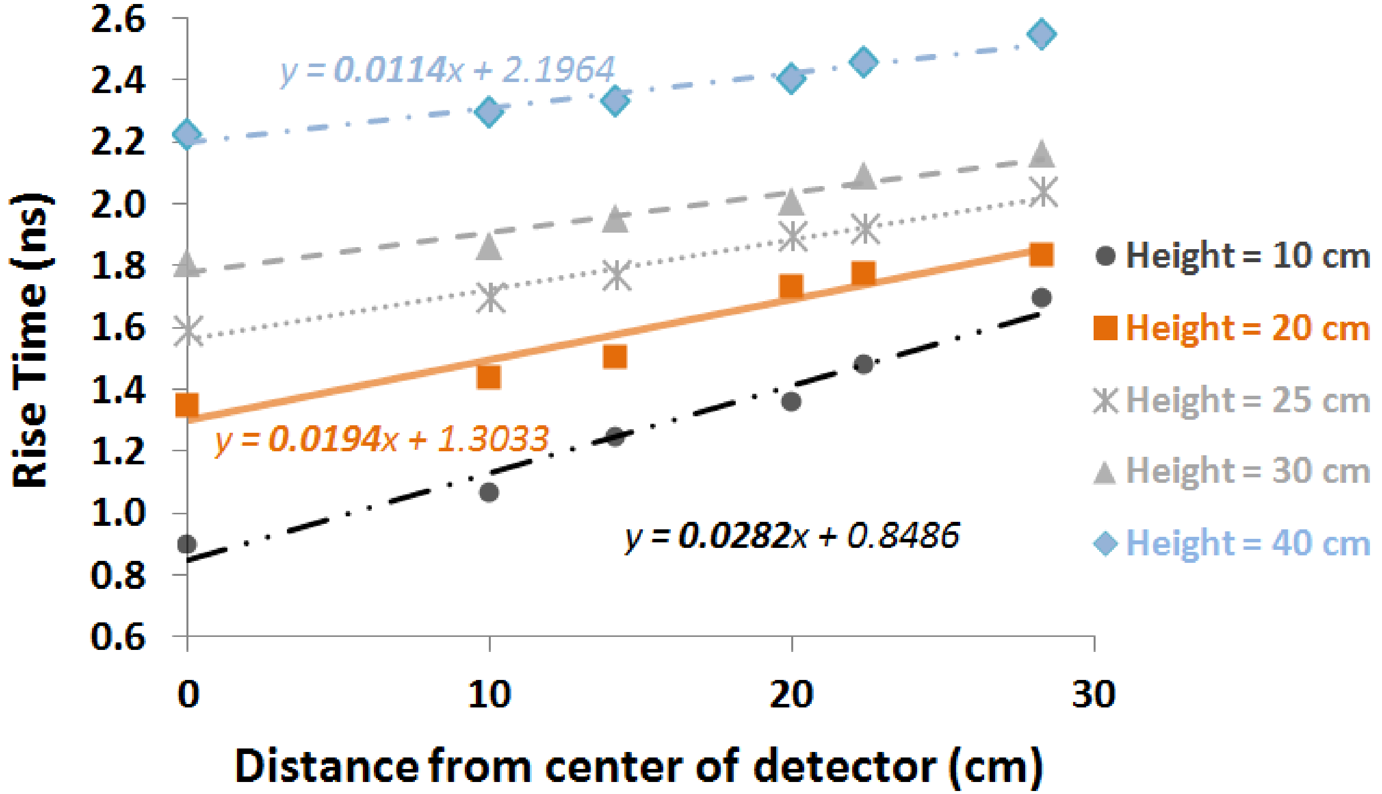
We repeat the simulation 100 times for 5 heights (10, 20, 25, 30 and 40 cm) and for 6 sections in each height.



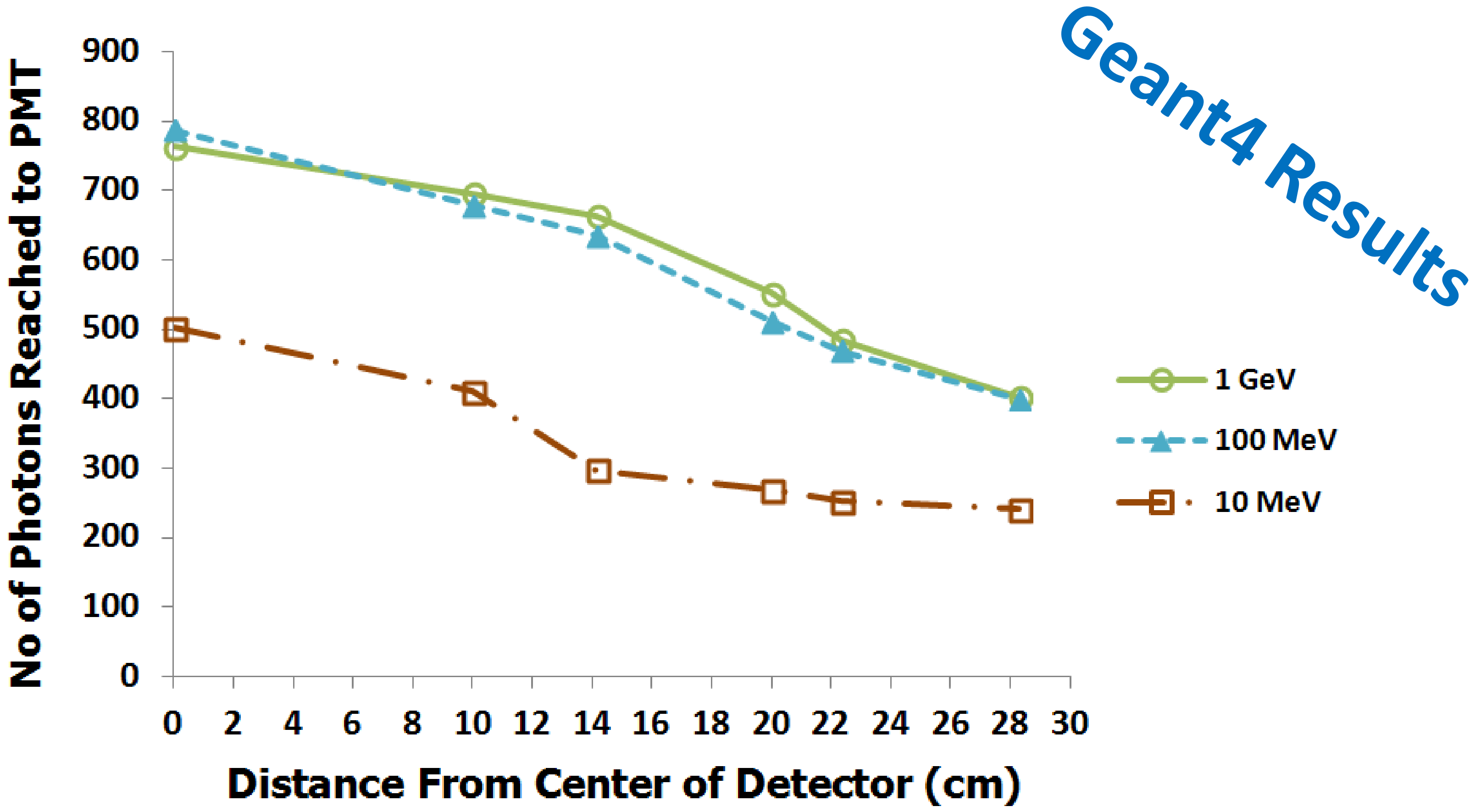


Extended-code Simulation

Extended-code Results



Geant4

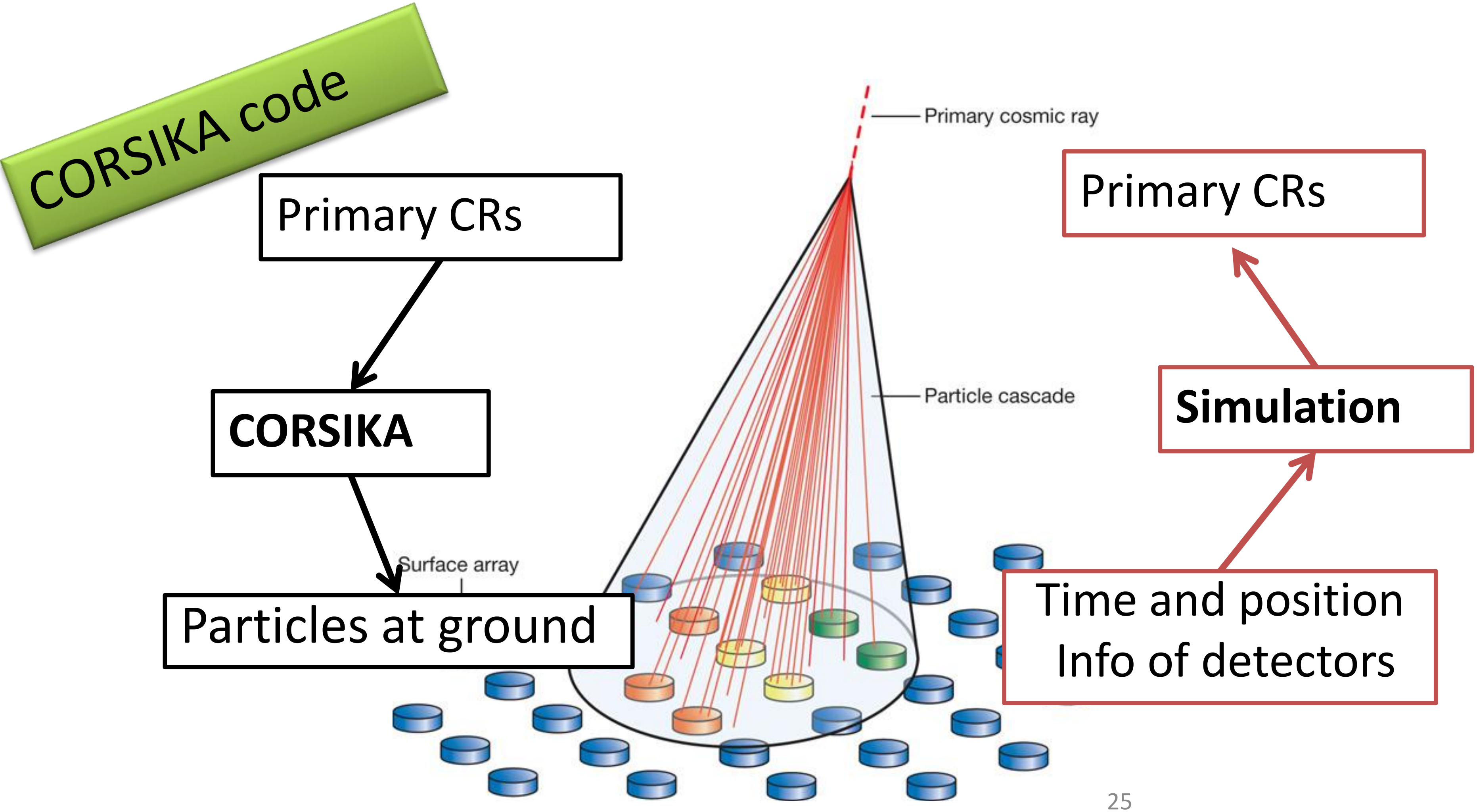

Geant4 Results
No of Photons Reached to PMT
900
800
700
600
500
400
300
200
100
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Distance From Center of Detector (cm)
1 GeV
100 MeV
10 MeV

Array Performance Simulation

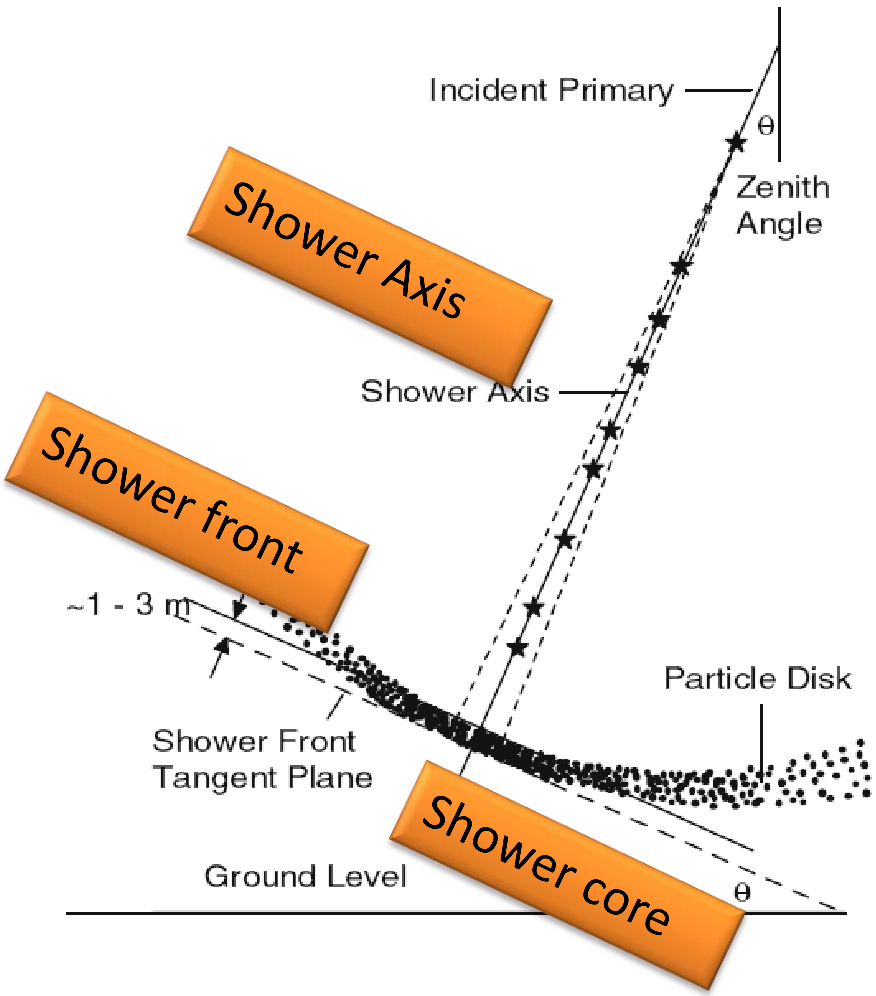
What are the questions?

- Which part of CR Spectrum will be relevant for this array?
- What is our estimation for number of detectable showers in each day?
- In what accuracy the direction of CRs could be extracted?
- In order to find shower parameters, which configuration for detectors and trigger conditions is better?
- What would be the error of determining core location?
- ….

Technical terms



Technical terms



Triggered Showers or Efficiency (ε) is a function of

1- Trigger condition,

2- core location (x,y) and

3- energy of CR (E)

Array Performance Simulation

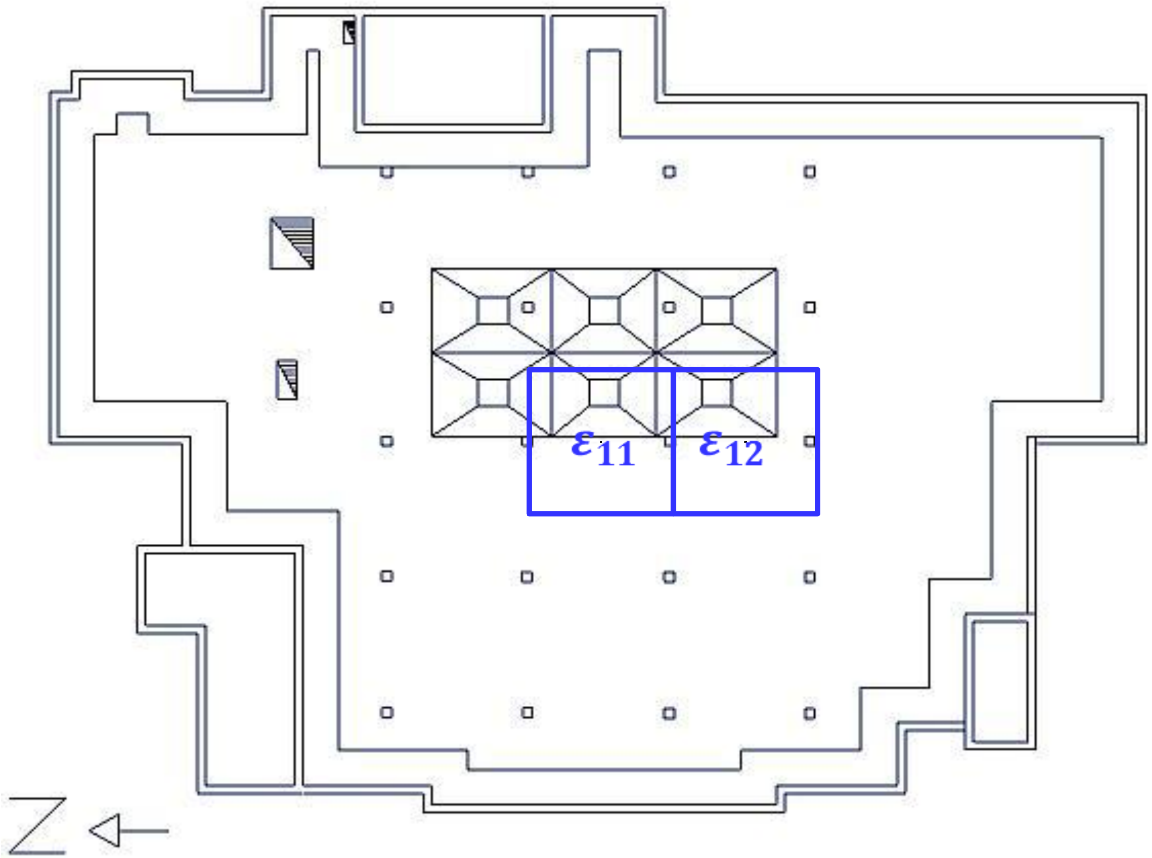
First two questions:

- **Which part of CR Spectrum will be relevant for this array?**
- **What is our estimation for number of detectable showers in each day?**

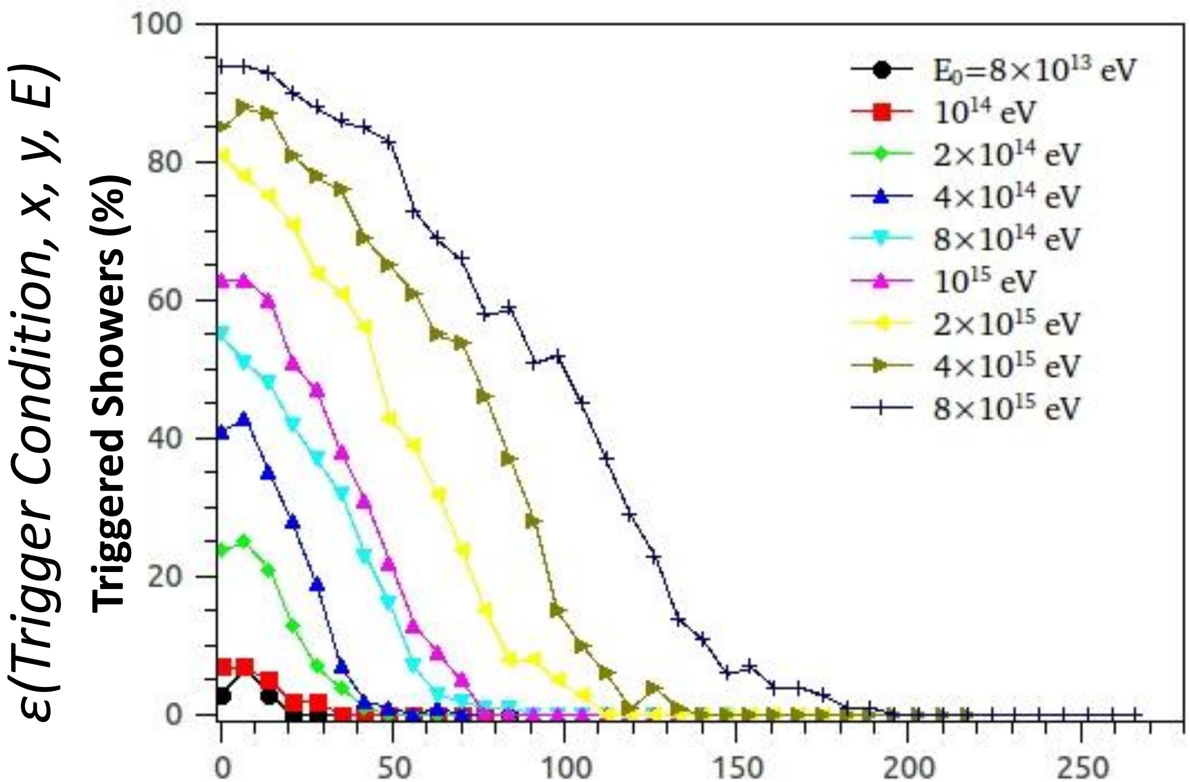
Configuration: Rectangular grid (4×5), 4 different spacing between detectors: **150, 350, 700 and 1400 cm**;
Trigger condition: ≥10;
Energy Range: 16 bins from **10^{12} eV to 10^{16} eV**;
100 showers in each bin;
Primary particles: Proton & Heilum;
QGSJET & GHEISHA low energy hadronic models;
Secondary particles: electrons & muons;

Configuration

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



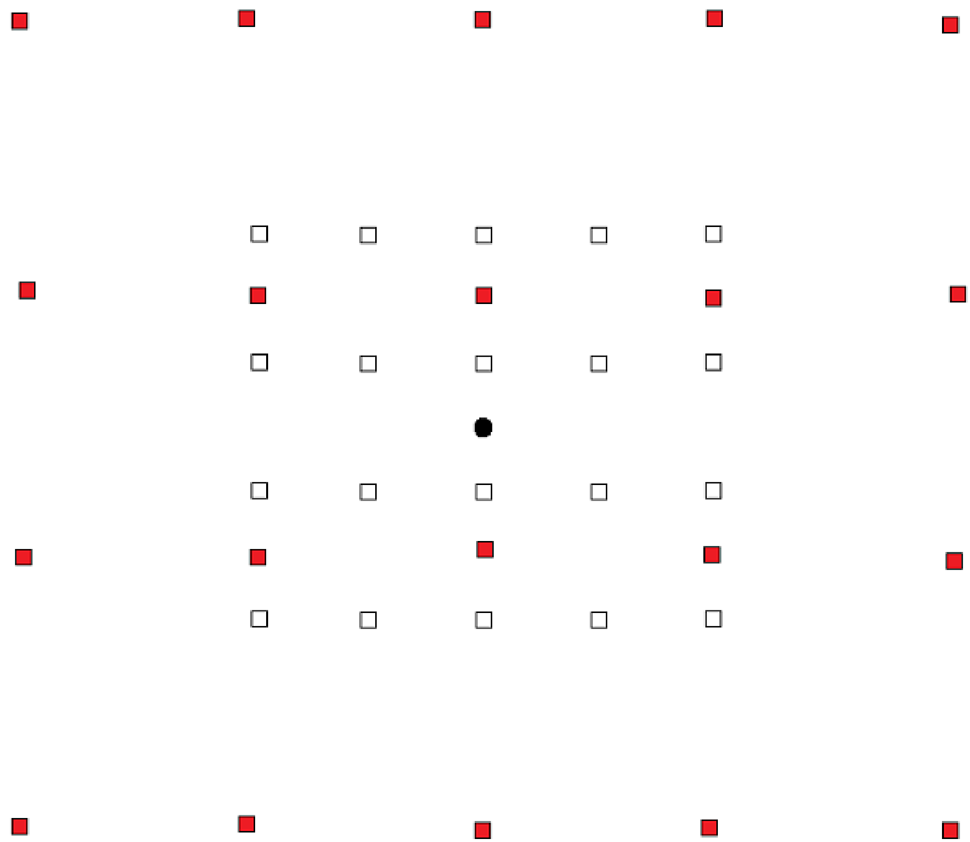
Efficiency



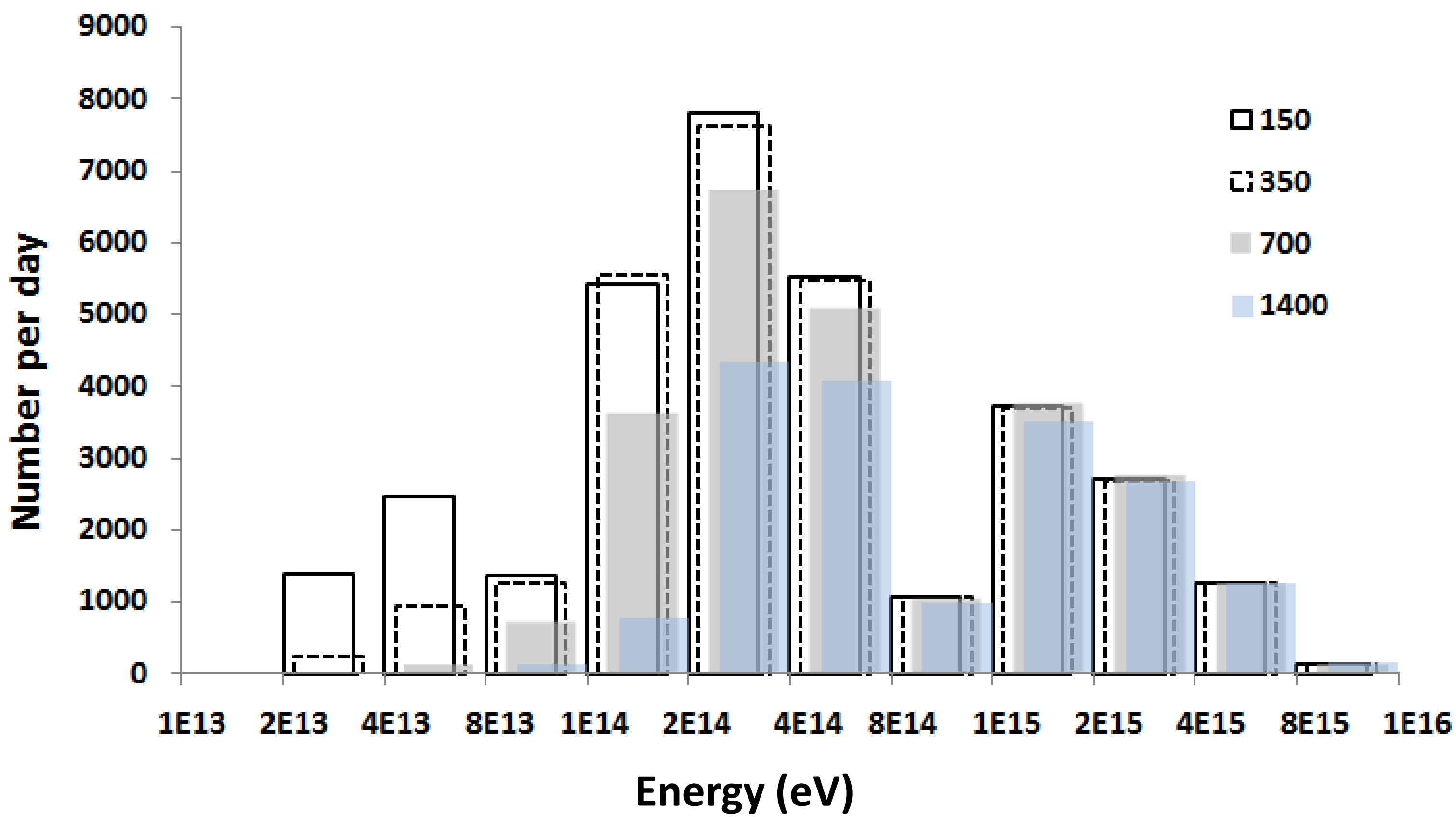
Distance between array center and core location (m)

Horizontal axis is toward **east**

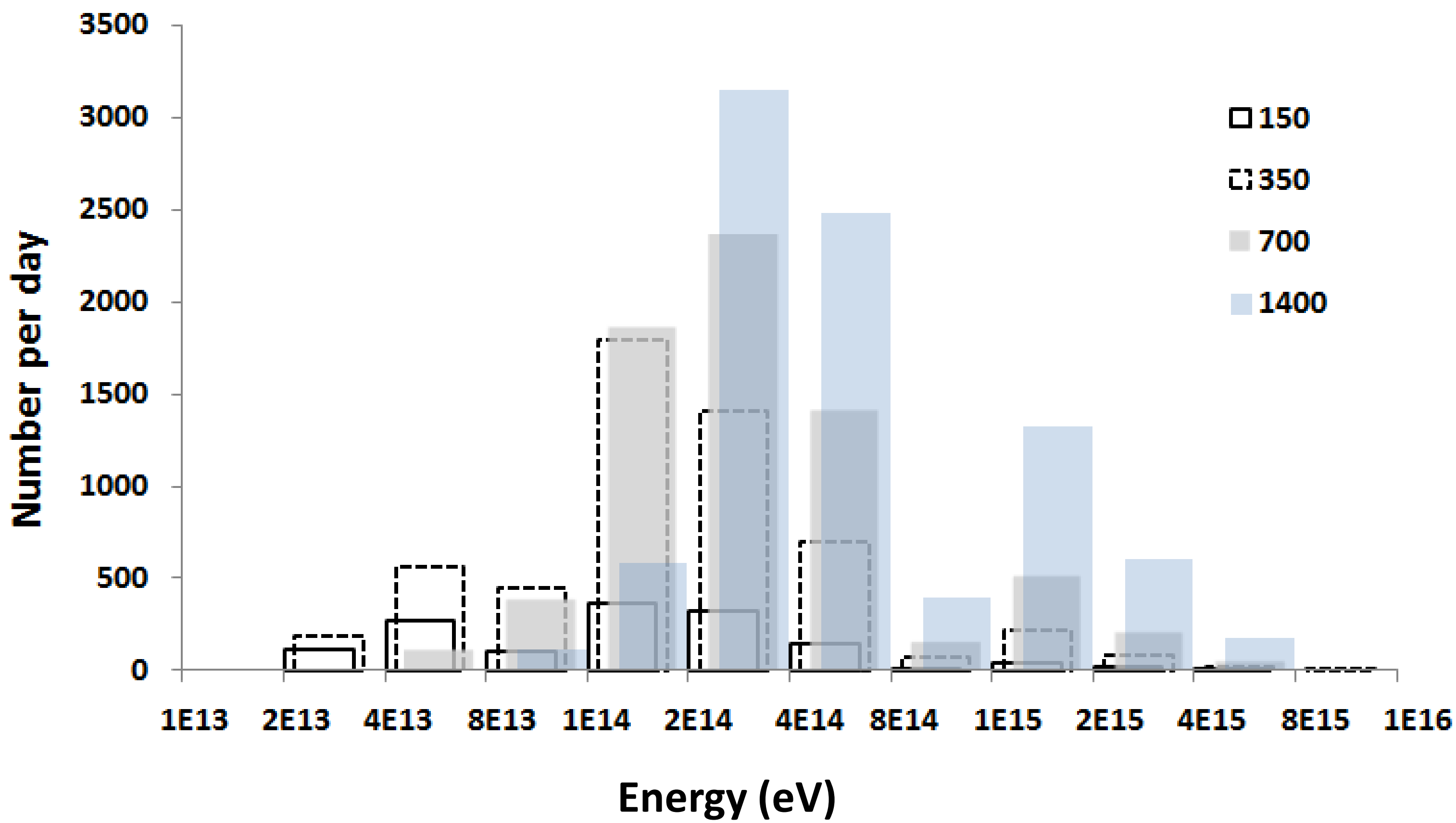
Increase distance between detectors!



Number of detected events per day



Number of detected events per day



Angular resolution

Third question:

- **In what accuracy the direction of CRs could be extracted?**

In the **energy** of **200 TeV**

Azimuthal angles in the range of 0˚-60˚

1000 shower in each 5˚ interval

Trigger condition: at least 10 detector is on

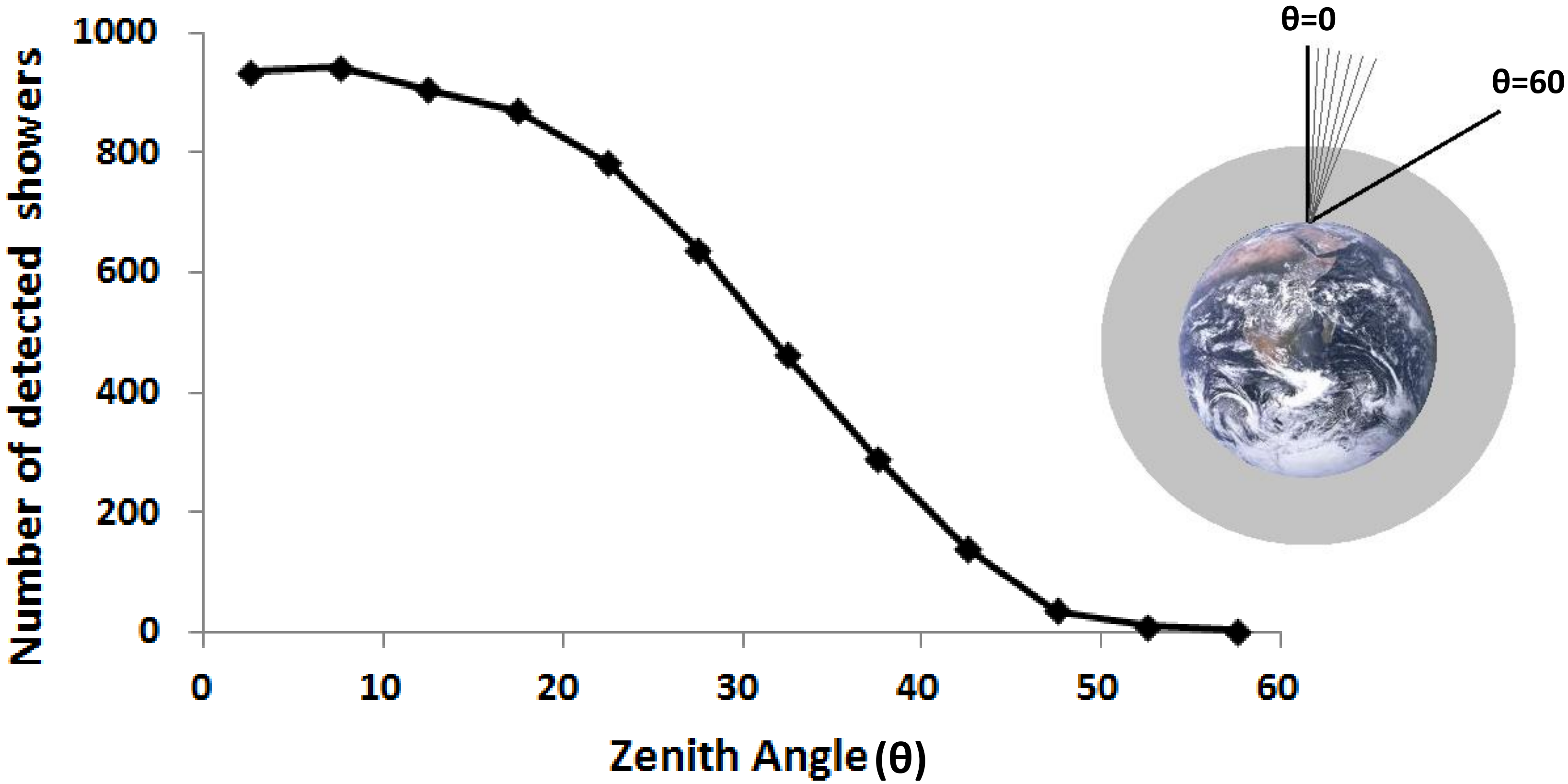
Primary particles: Proton & Heilum;

QGSJET & GHEISHA low energy hadronic models;

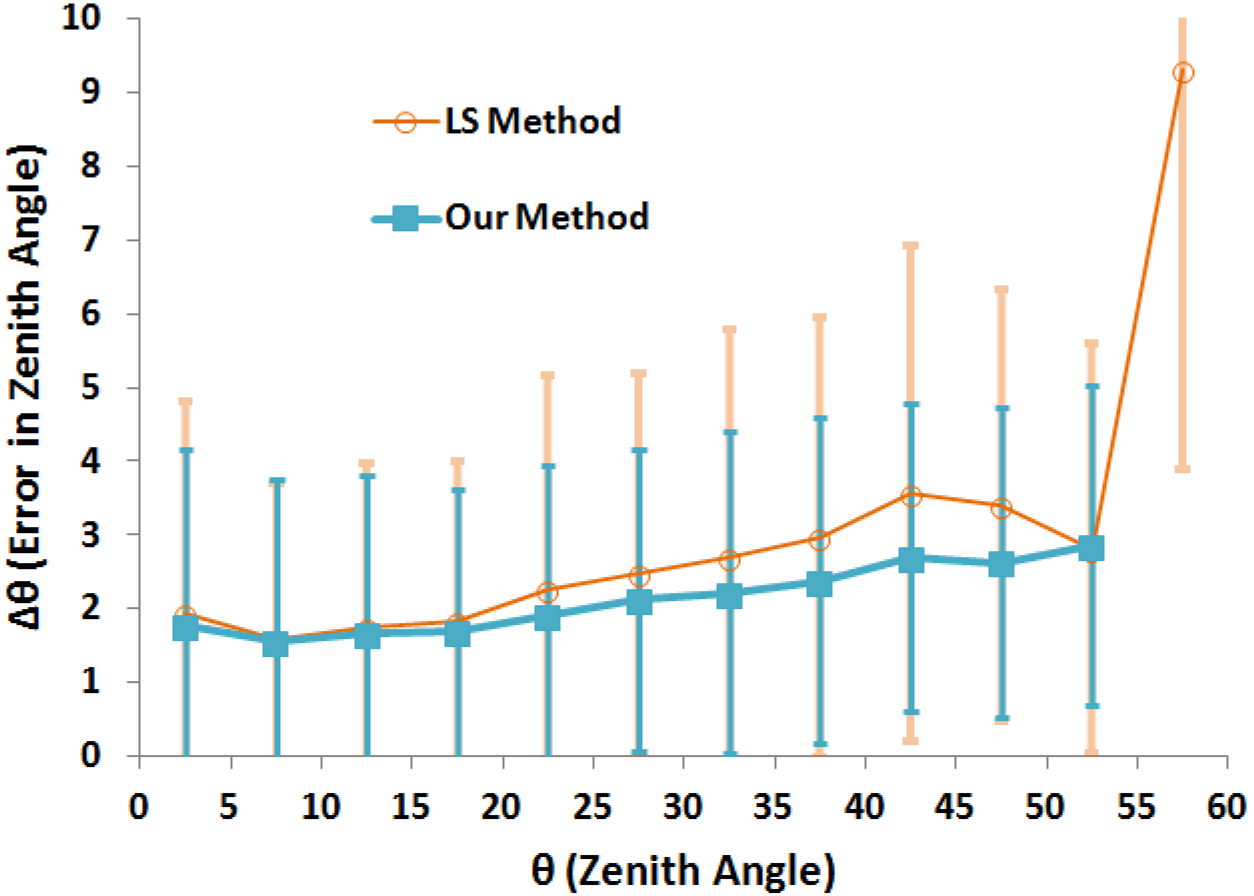
Secondary particles: electrons, muons & **photons**;

Angular resolution

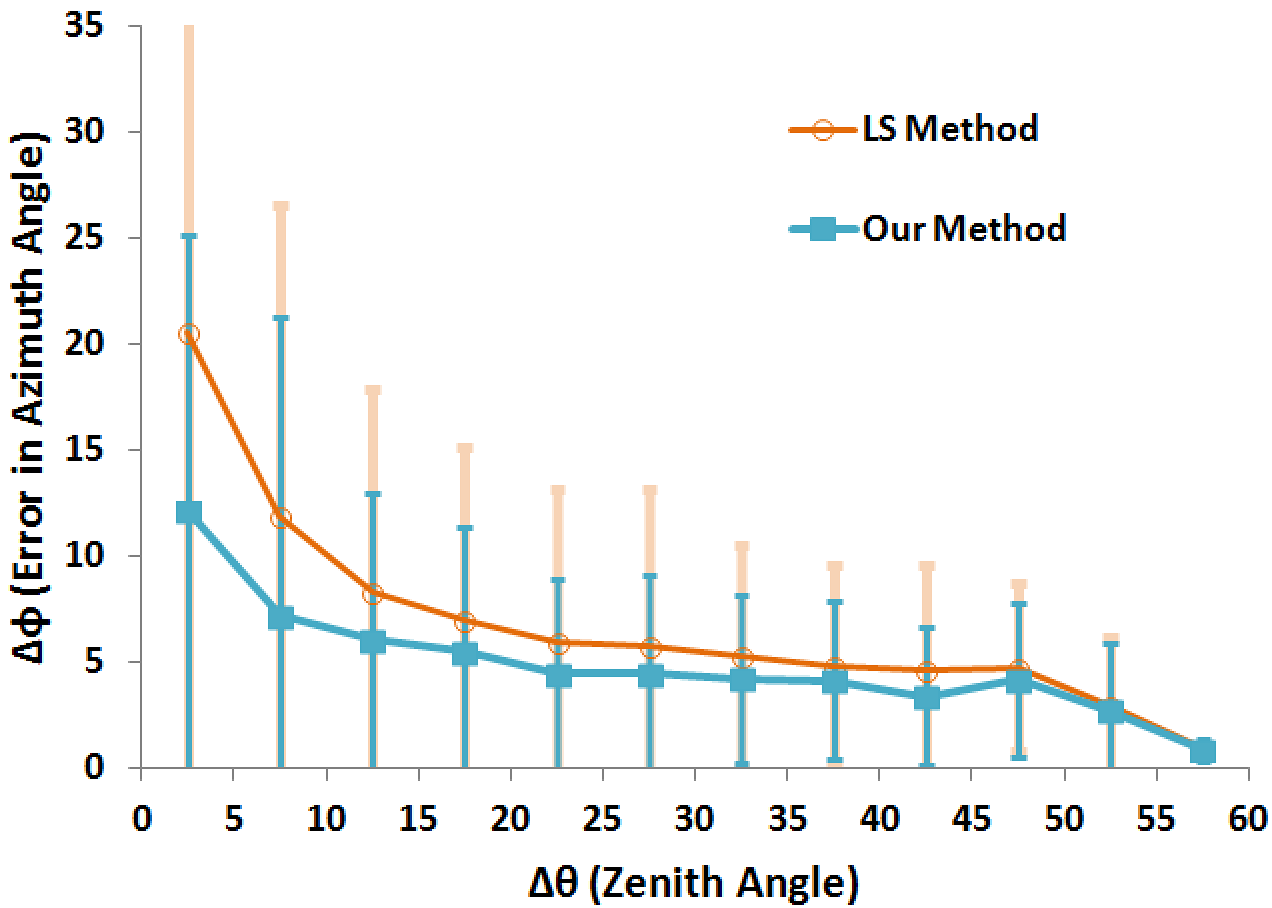
Number of Showers which fulfill trigger condition



Zenith angle error



Azimuth angle error



Conclusion

Forth and Fifth questions:

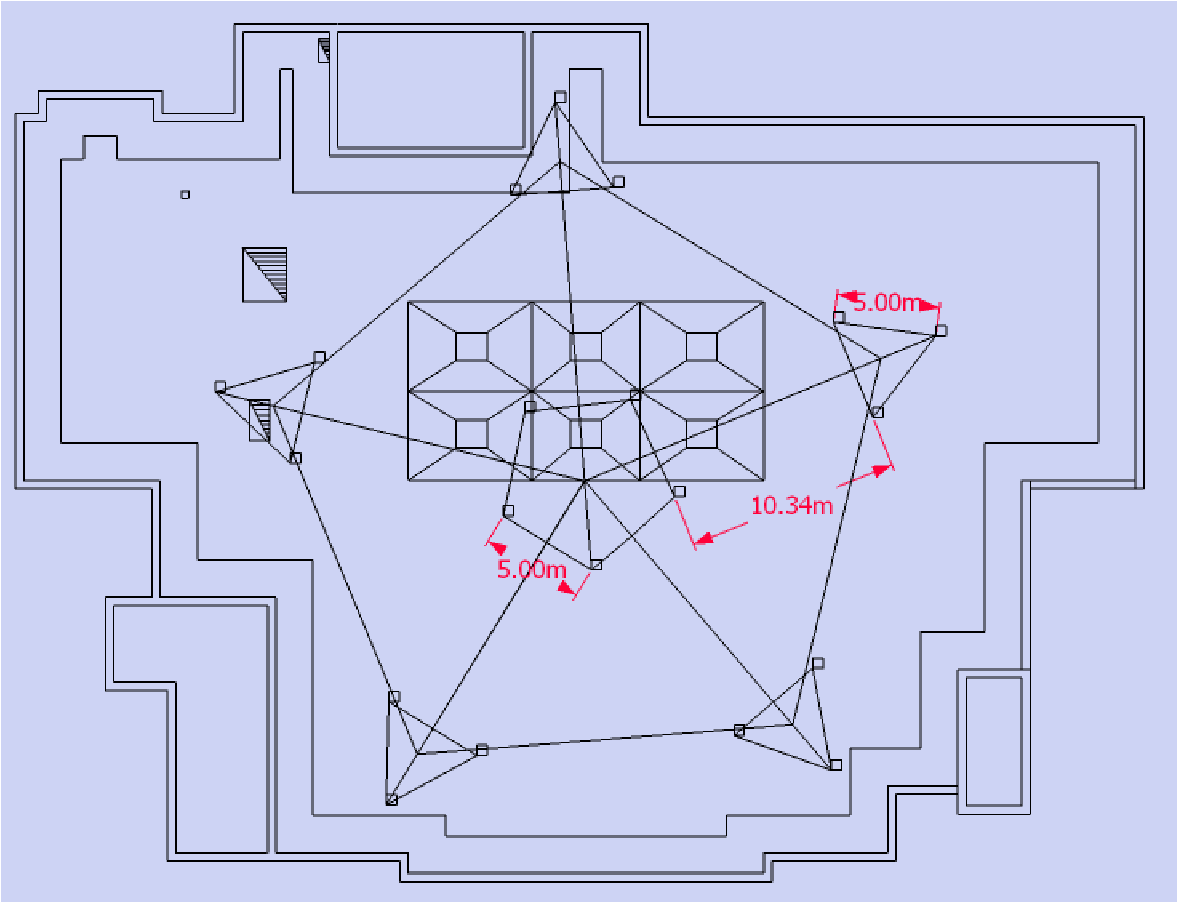
- **In order to find shower parameters, which configuration for detectors and trigger conditions is better?**
- **What would be the error of determining core location?**

Are subject of current studies

Next Step

Considerations for finding core location:

1- Clustering 2- Having more layers of detectors



Next Step

Thank you for your attention