Near-vertical local density spectra of the EAS charged particles in the energy range of 10^{14} – 10^{17} eV

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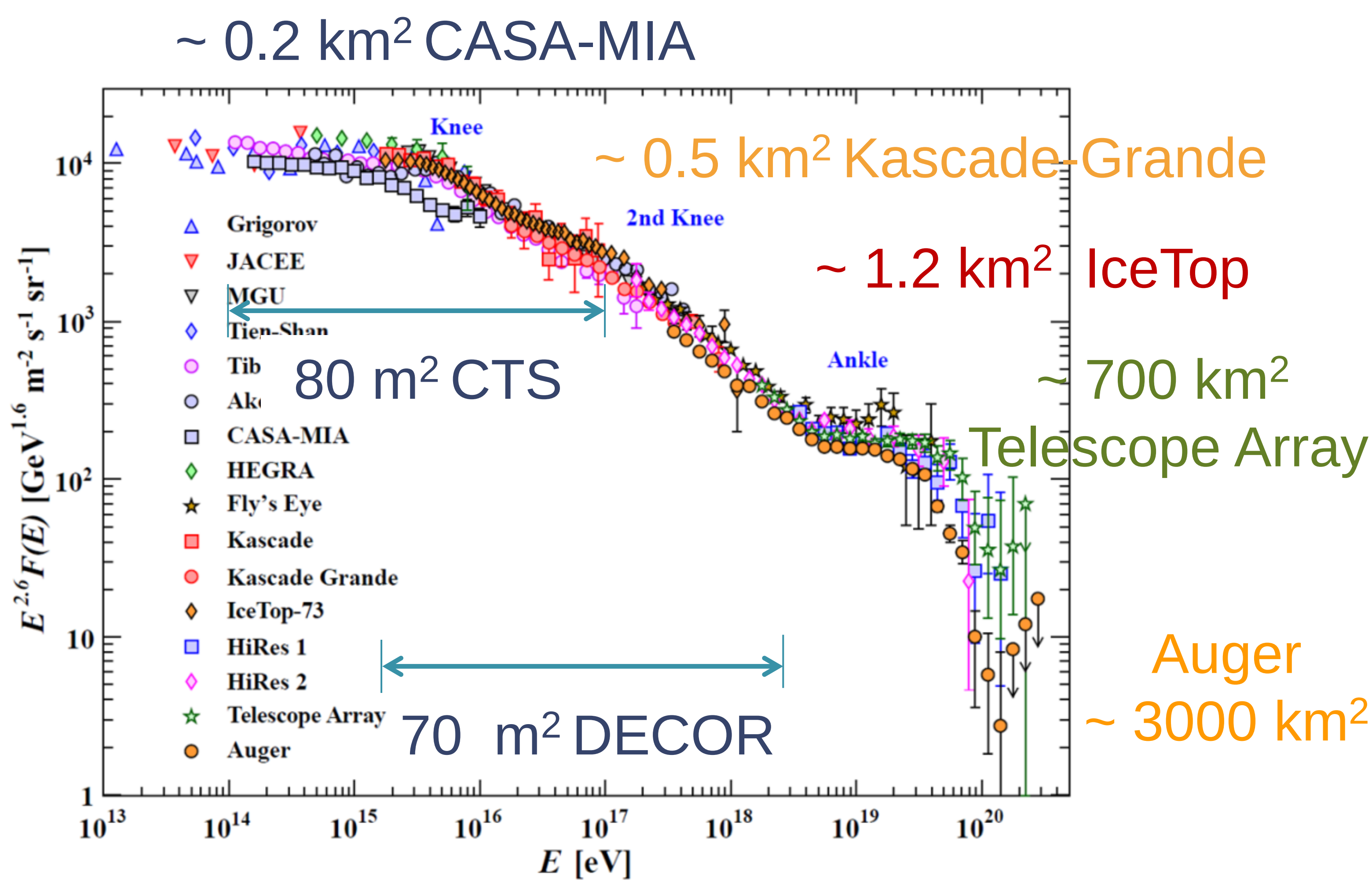
Introduction

There is a tendency to create large-scale installations for the study of ultra-high energy cosmic rays

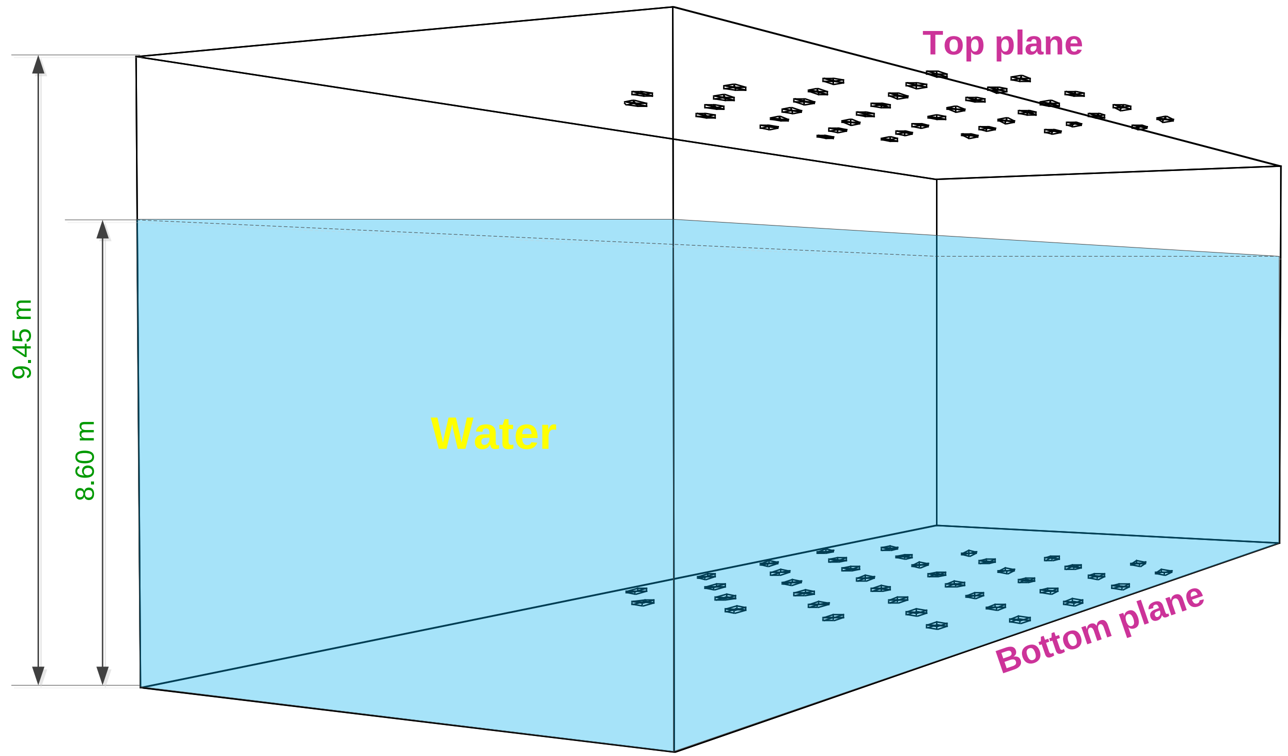
However, there is an experience of operation of relatively small installations to study EAS components in a wide range of primary energy.



Calibration telescope system (CTS)

One plane:

- 80 m^2 occupied space
- 40 scintillation counters
- ~ 1 – 800 particles/m^2 dynamic range



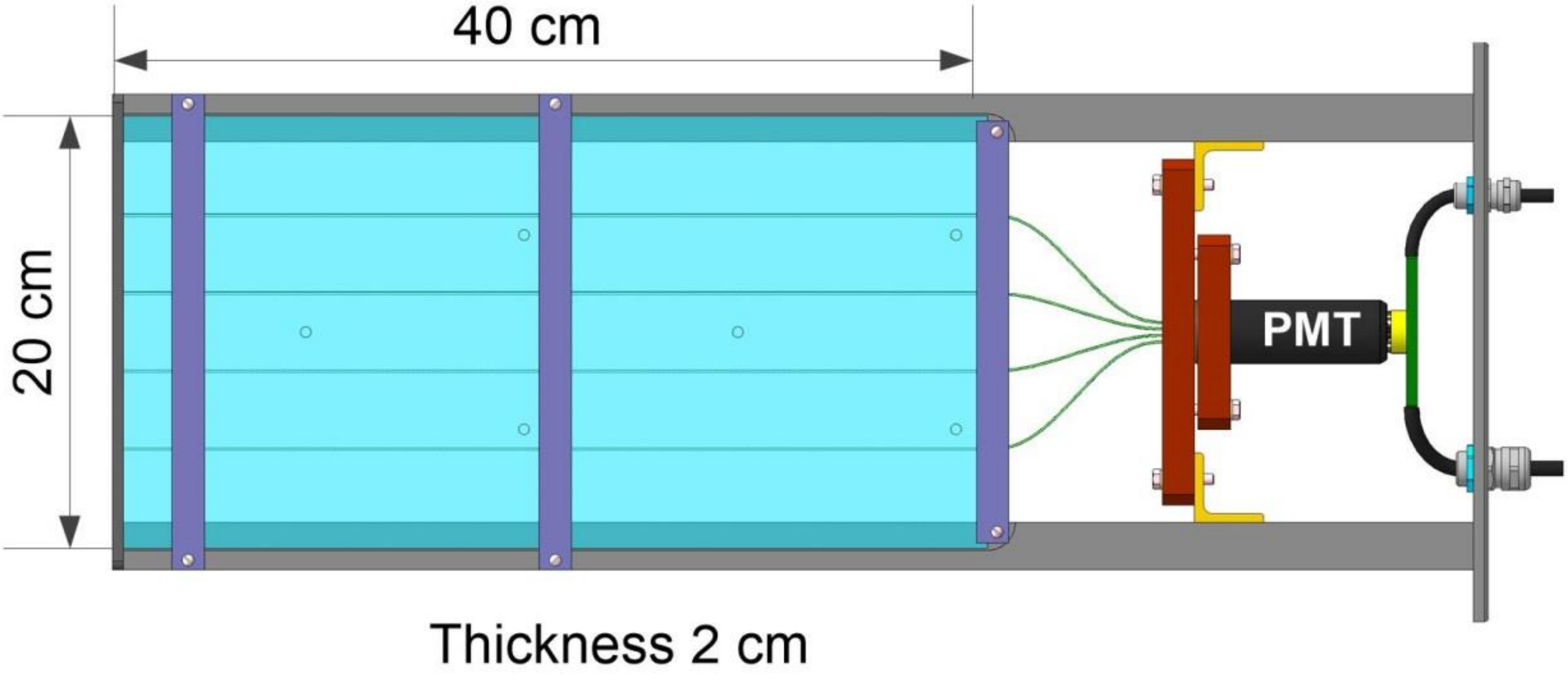
Calibration telescope system (CTS)

One plane:

- $80\ m^2$ occupied space
- 40 scintillation counters
- ~ 1 – 800 particles/m^2 dynamic range

One counter:

- $40 \times 20 \times 2\ cm^3$ scintillator
- 60 MIP dynamic range



Experimental data

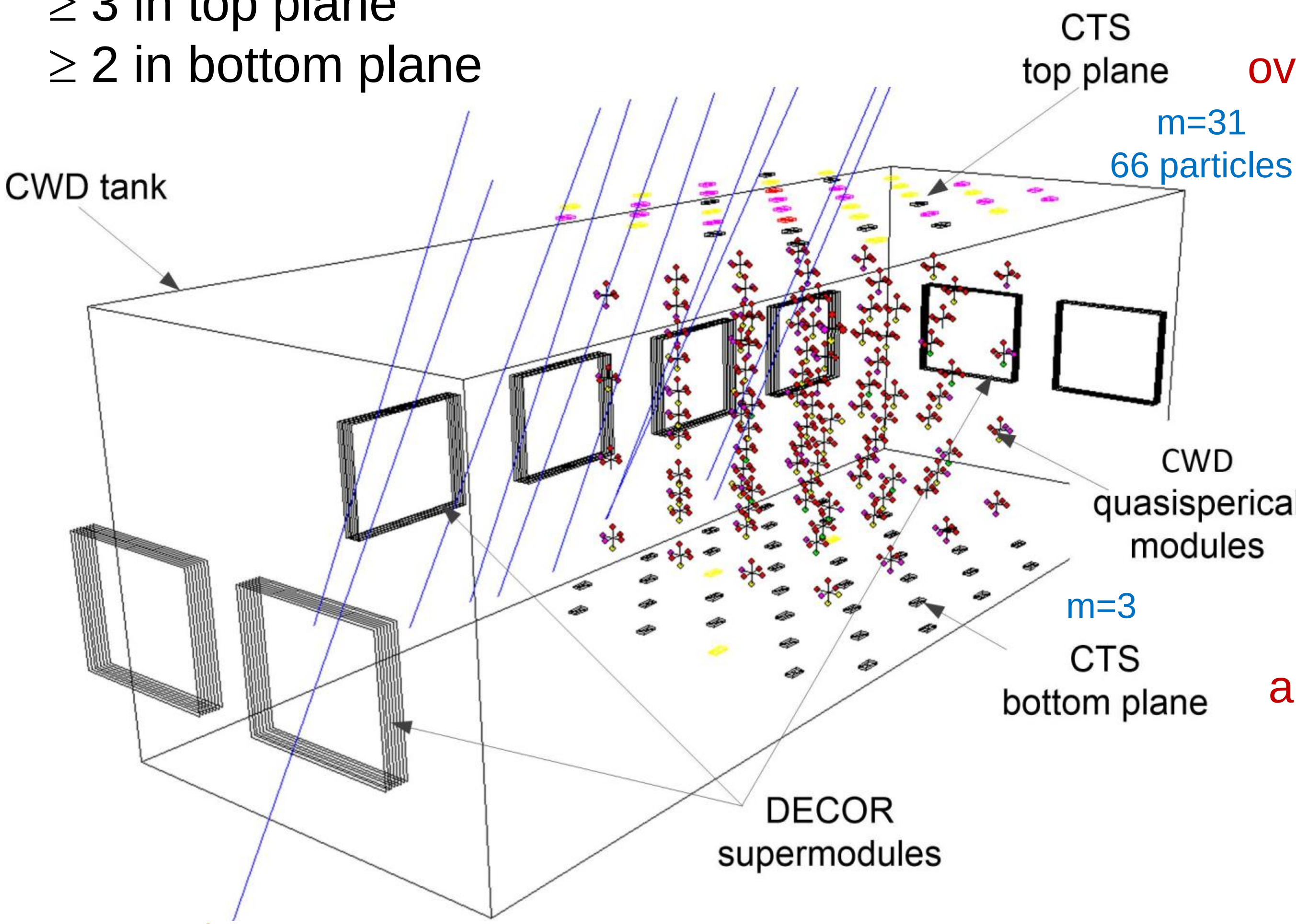
Exposition from June 2013 to April 2019

Trigger cases:
≥ 3 in top plane
≥ 2 in bottom plane

“Live” time = 39820 hours

Number of events

over 100 millions

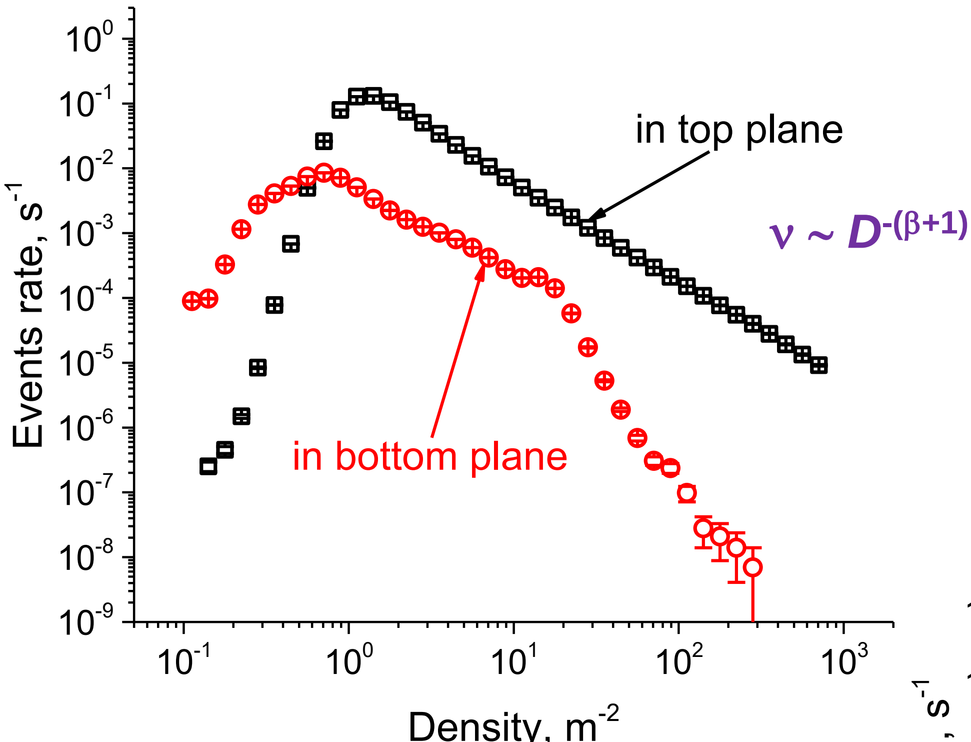


about 8 millions

The event RUN_782 #529702 on 27.10.2018

Measurement results

Particle density distribution

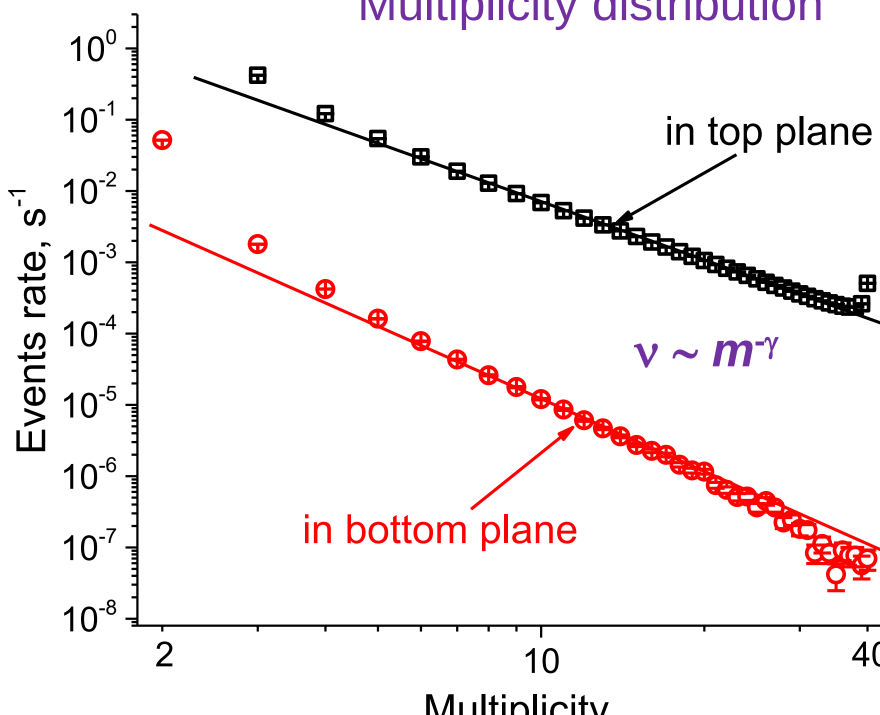


top: $\beta = 1.56 \pm 0.01$

Density $\in$ [9 m^{-2}, 90 m^{-2}]

bottom: We cannot say about local muon density by amplitude data for the bottom plane.

Multiplicity distribution



top: $\gamma = 2.71 \pm 0.01$

$m \in [8, 30]$

bottom: $\gamma = 3.52 \pm 0.01$

$m \in [8, 20]$

Method of local density spectrum reconstruction

Our investigation method is based on phenomenology of the local density of charged particles.

This method was presented yesterday in the report of Rostislav Kokoulin at session 1A.

Differential local charged particle density spectra can be reconstructed from

- hit counter multiplicity distribution
- particle density distribution

$$\frac{dF_0}{dD d\Omega} = A_0 \left(D_{\mathrm{m}} / D_0 \right)^{-(\beta+1)} f\left(\theta\right) [\mathrm{m}^2 \mathrm{s}^{-1} \mathrm{sr}^{-1}]$$

is a trial spectrum

$$\frac{dF}{dD d\Omega} = \frac{\nu_{\mathrm{m}}^{\mathrm{ex}}}{\nu_{\mathrm{m}}} \frac{dF_0}{dD d\Omega}\left(D^*, \theta^* \right)$$

is reconstructed spectrum

Characteristic zenith angle

$$<\ln\left(\cos\theta^*\right)>=\frac{\int\limits_0^\infty\left(\int\limits_0^1 \ln\left(\cos\theta\right)\frac{dF_0}{dDd\Omega}d\cos\theta\right)dD}{\int\limits_0^\infty\left(\int\limits_0^1 \frac{dF_0}{dDd\Omega}d\cos\theta\right)dD}$$

For EAS electron component (top plane):

P. K. F. Grieder, Extensive air showers, high energy phenomena and astrophysical aspects, (Heidelberg, Springer 2010) Vol. ***2****.*

$$f\left(\theta\right)=\exp\left(-\beta X_0\left(\sec\theta-1\right)/\Lambda\right)\simeq\cos^{8.5}\theta$$

where X_0 is an atmospheric depth (~1020 g/cm^2), *L* is a nucleon attenuation length in the atmosphere (~120 g/cm^2).

$$\theta^* \sim 20°$$

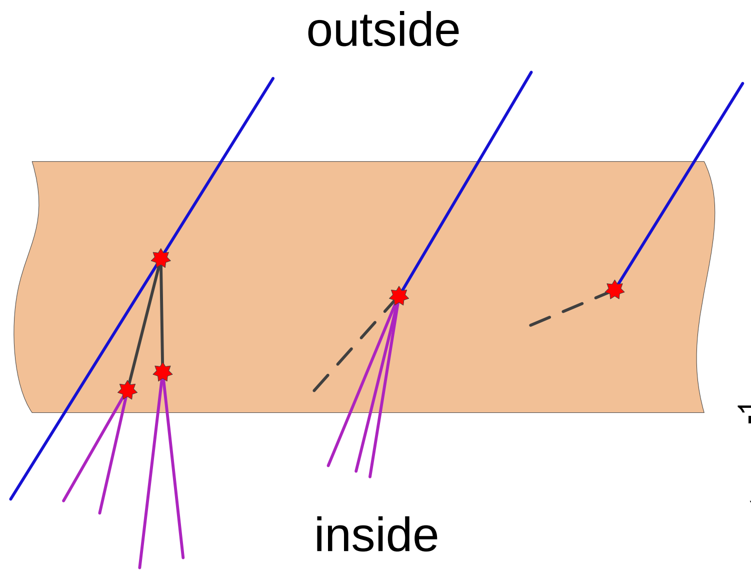
For EAS muon component (bottom plane):

A. G. Bogdanov, D. M. Gromushkin, R. P. Kokoulin, et al. Phys. Atom. Nucl. ***73****, 1852 (2010)*

$$f\left(\theta\right)=\cos^{4.5}\theta$$

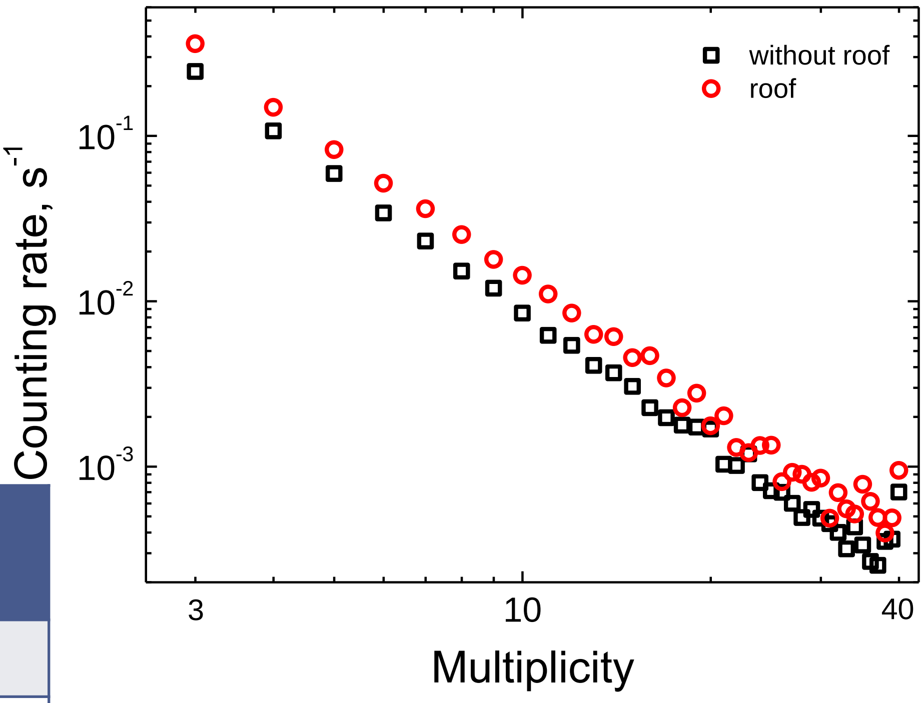
$$\theta^* \sim 29°$$

The effects of building construction and water pool



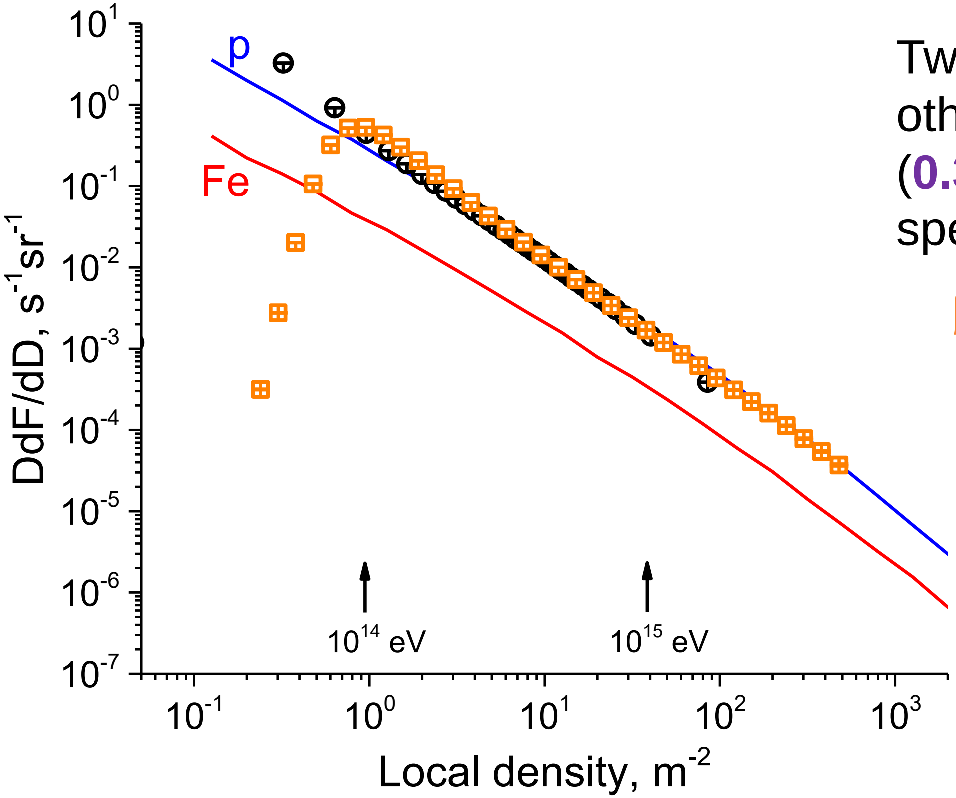
CORSIKA v.7.40 and Geant4 v.10.0

Multiplicity of hit counter distributions



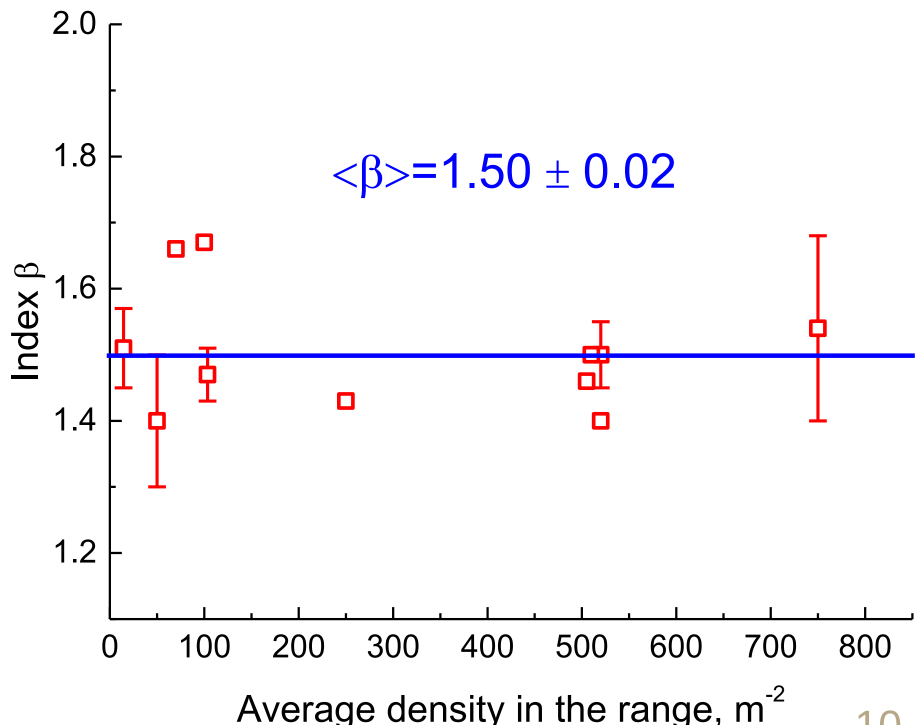
Plane	Method	Shift factor
Top	M	1.2
	A	1.5
Bottom	M	1.2
	A	–

Local density spectrum of EAS electron component



Two spectra are almost identical to each other in the density range from 6 to 40 m $^{-2}$ (**0.3 – 1 PeV**) and agree with simulated spectrum for primary protons.

$\beta_A = 1.55 \pm 0.01$ $\beta_M = 1.52 \pm 0.01$

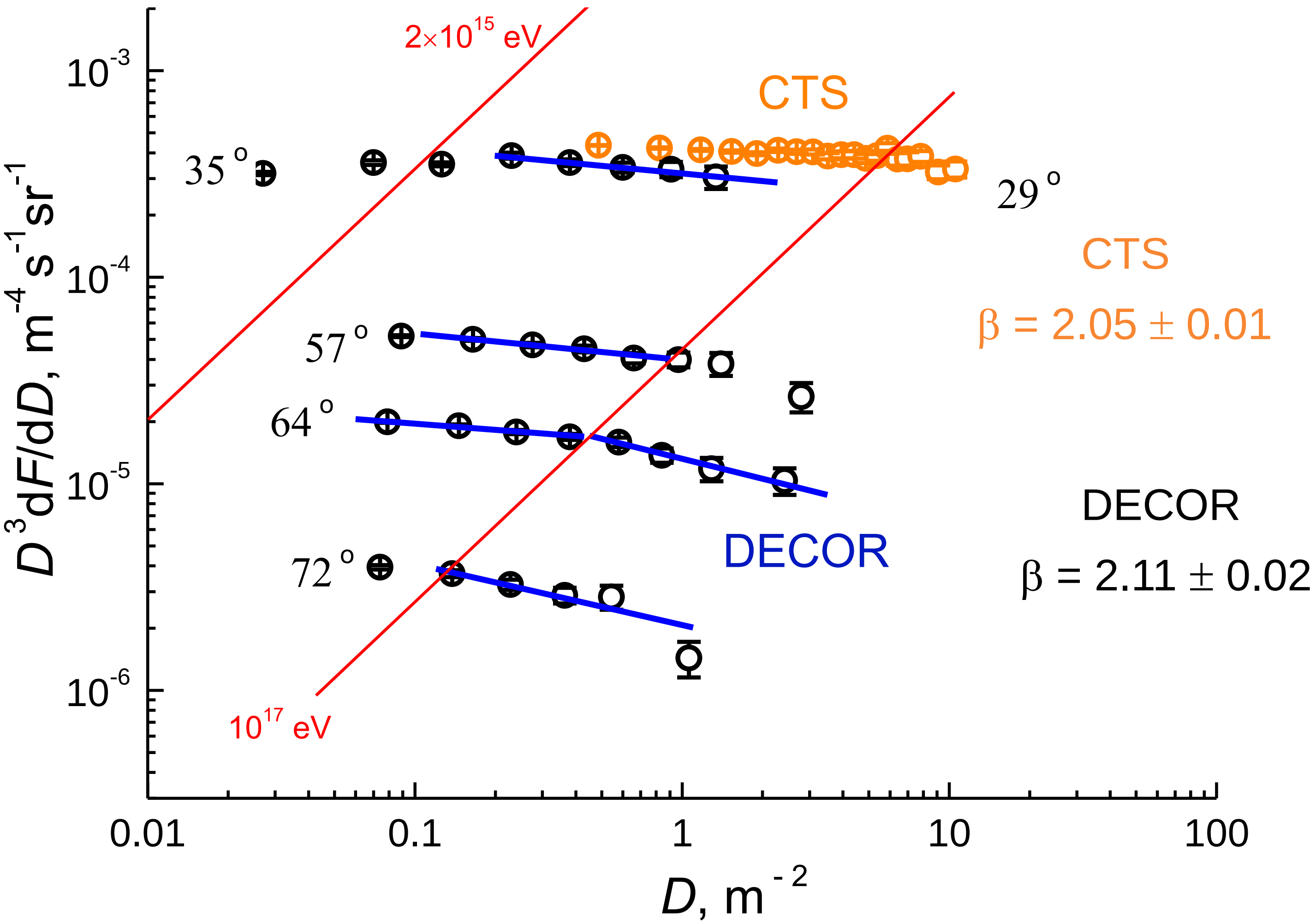


Also, our results agree with the previously obtained data with other installations on the density spectra of the EAS electron component.

Local density spectrum of EAS muon component

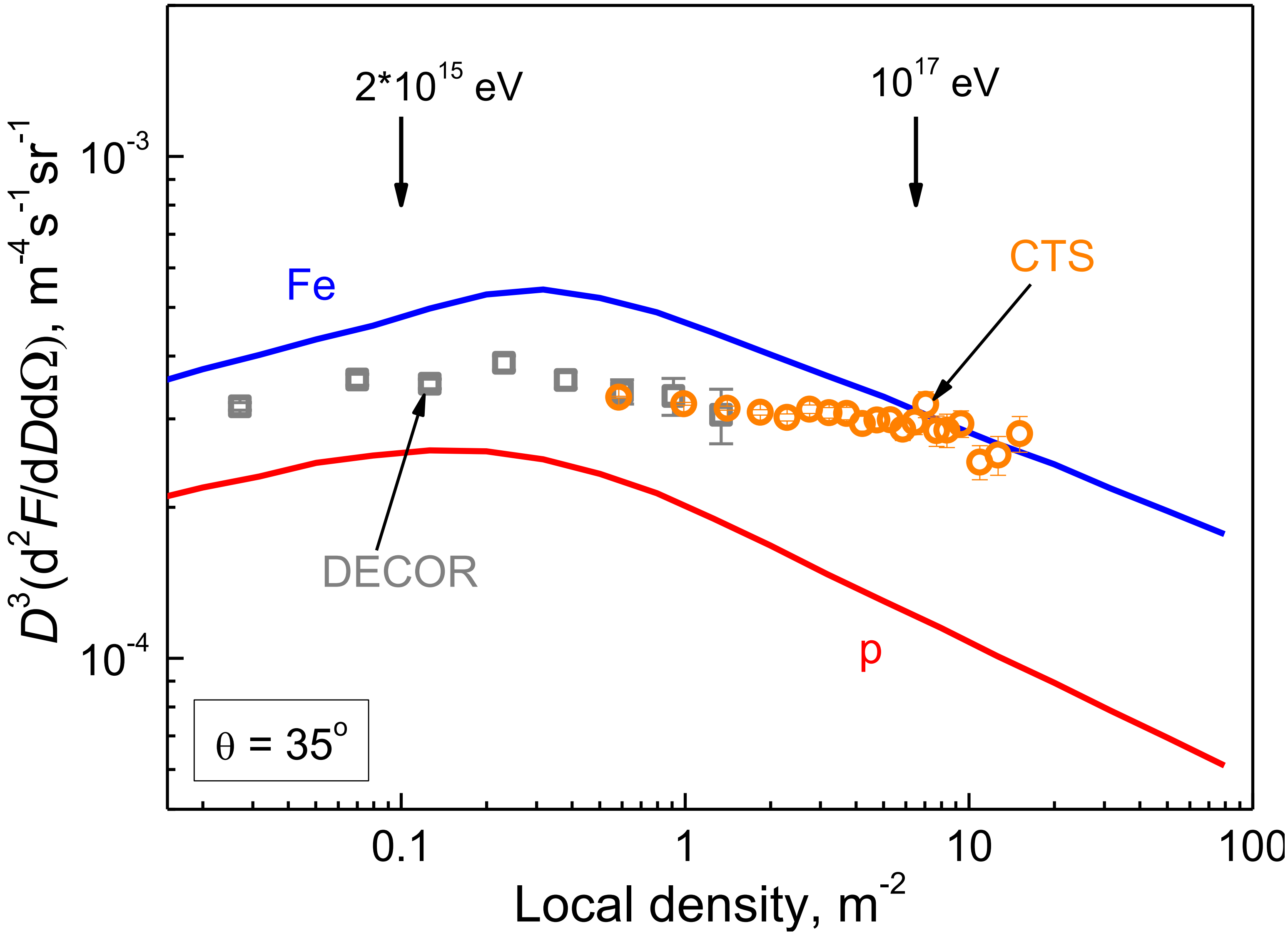
CTS data are re-calculated to zenith angle 35°

CTS vs DECOR data



Local density spectrum of EAS muon component

CTS data are re-calculated to zenith angle 35°



Conclusion

- We have obtained the spectra of local electron and muon density in non-overlapping energy ranges of primary particles from 0.3 to 1 PeV and from 10 to 100 PeV, respectively.
- Our results are in a good agreement with the data of other installations and simulations.
- We have shown that the studying of high-energy cosmic rays with a small size installation (less than 100 m^2) is possible.

Thank you

for attention!!!