Particles and Cosmology

16th Baksan School on Astroparticle Physics

New detector for a search of muon bundles in ultra-high energy cosmic rays

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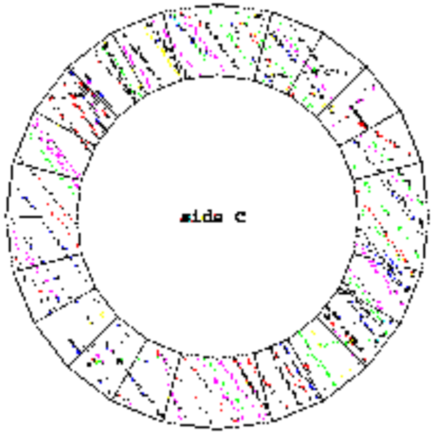
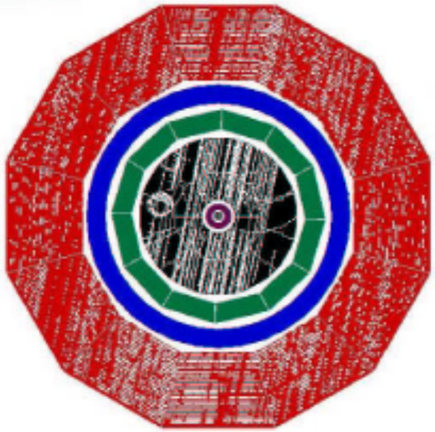
NRNU MEPhI (Moscow) 2019

Excess of muon bundles with high multiplicity according to DELPHI and ALEPH detectors (LEP, CERN)



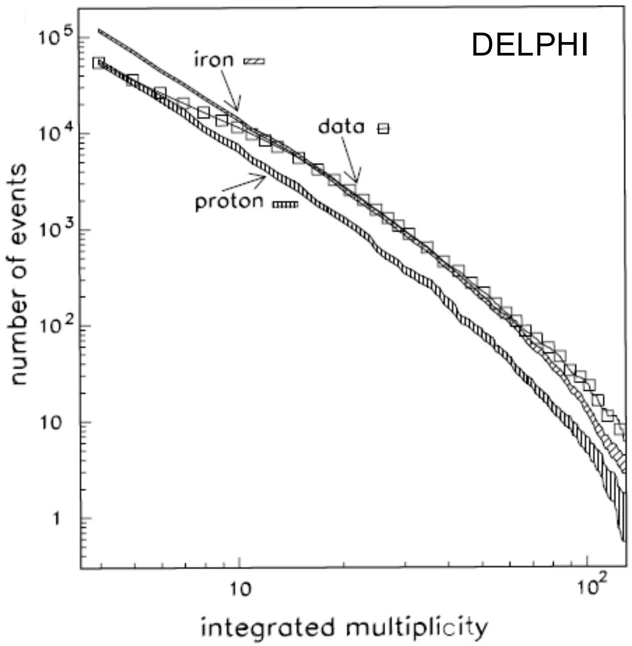
DELPHI

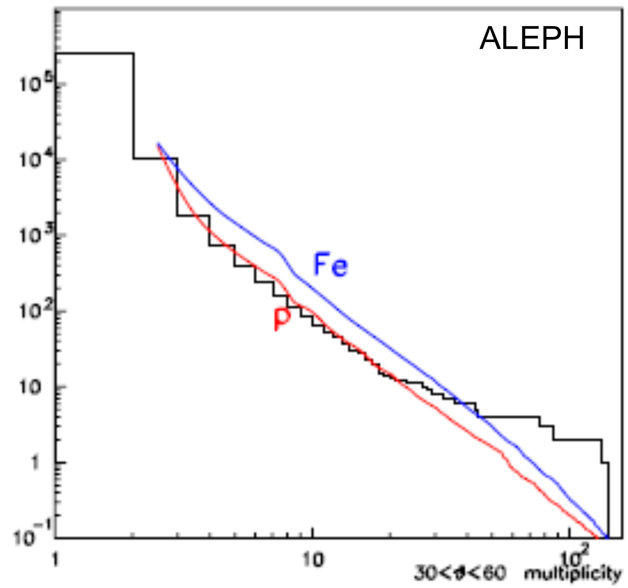
ALEPH



J. Abdallah et al., Astroparticle Physics 28 (2007) 273

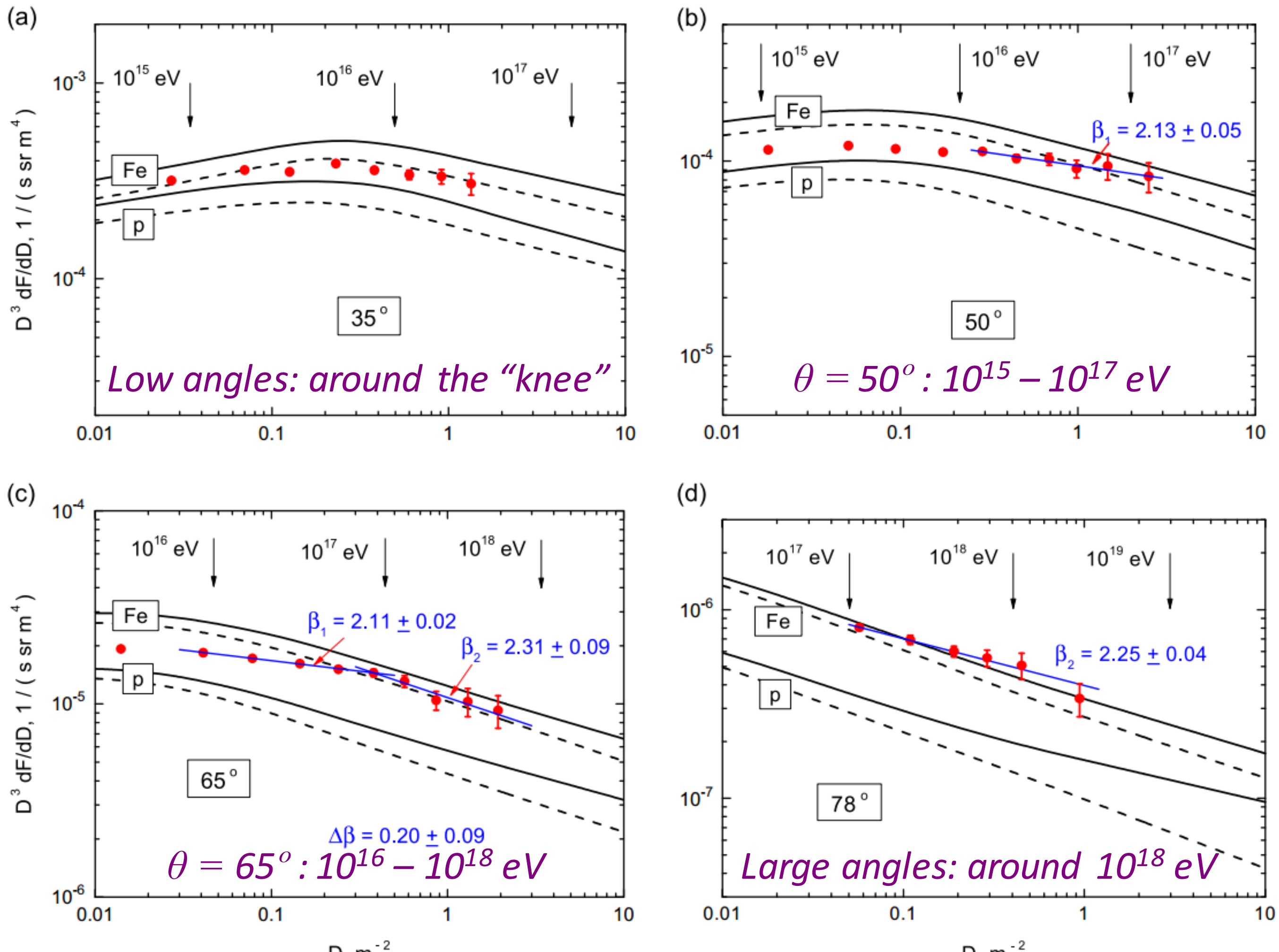
C. Grupen et al., Nucl. Phys. B (Proc. Suppl.) 175-176 (2008) 286





Excess muon bundles in the experiment NEVOD-DECOR

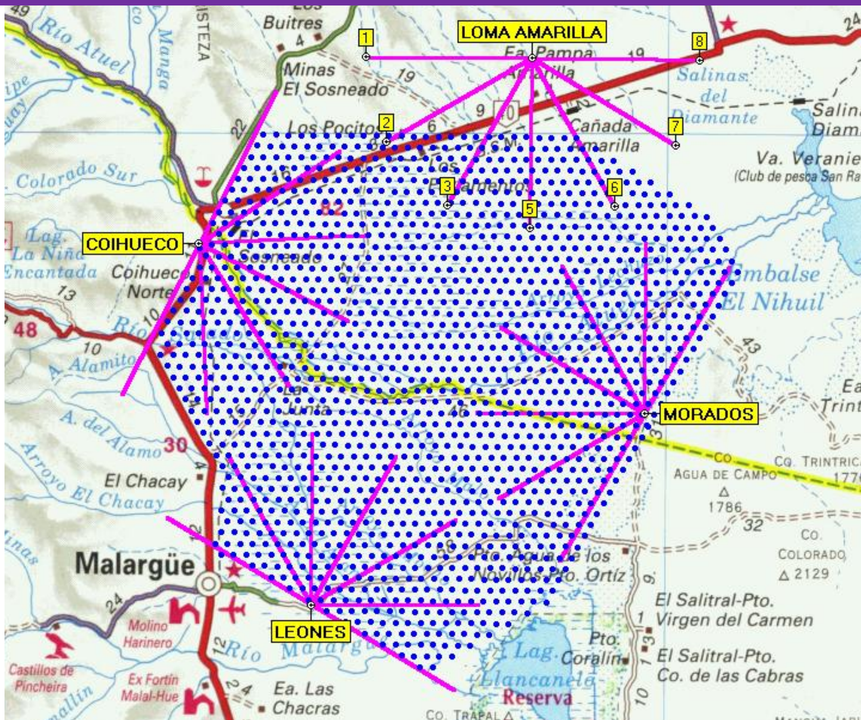
A.A. Petrukhin Nuclear Instruments and Methods in Physics Research A742 (2014) 228–231

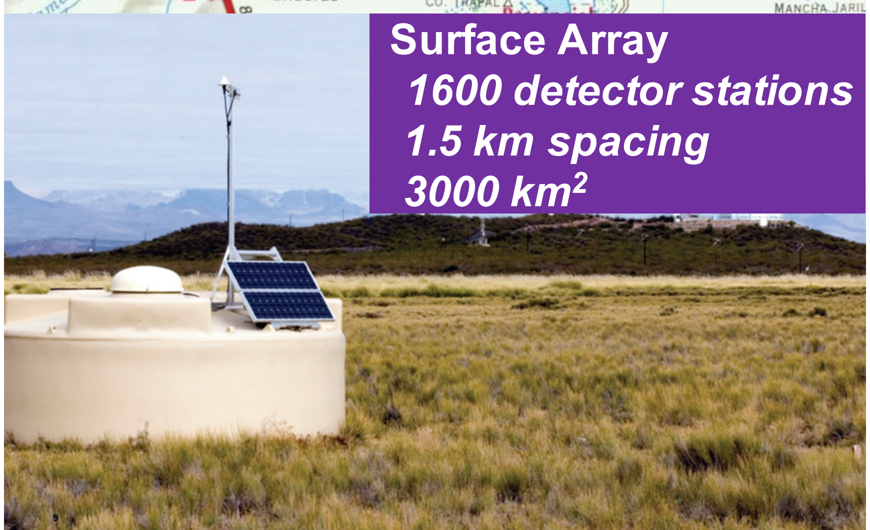


Solid: QGSJET01
Dashed: SIBYLL-2.1

Measured points and calculated dferential LMDS for 4 zenith angles. Partial power fits between 10^{16} and 10^{17} eV - integral spectrum slope β_1, and above 10^{17} - primary energy - β_2.

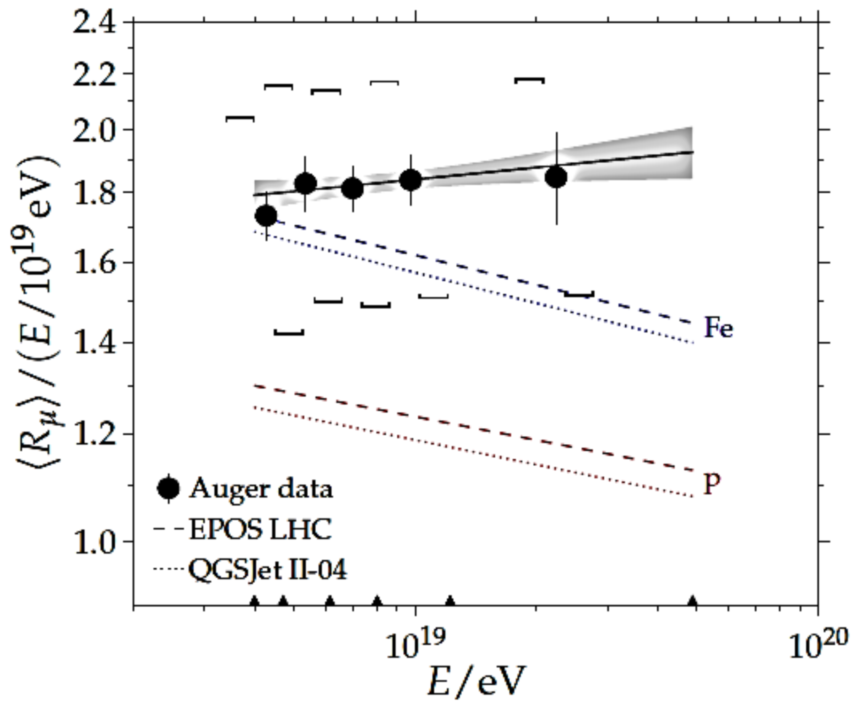
Excess number of muons in near-horizontal EASs registered at the Pierre Auger Observatory





Surface Array
1600 detector stations
1.5 km spacing
3000 km²

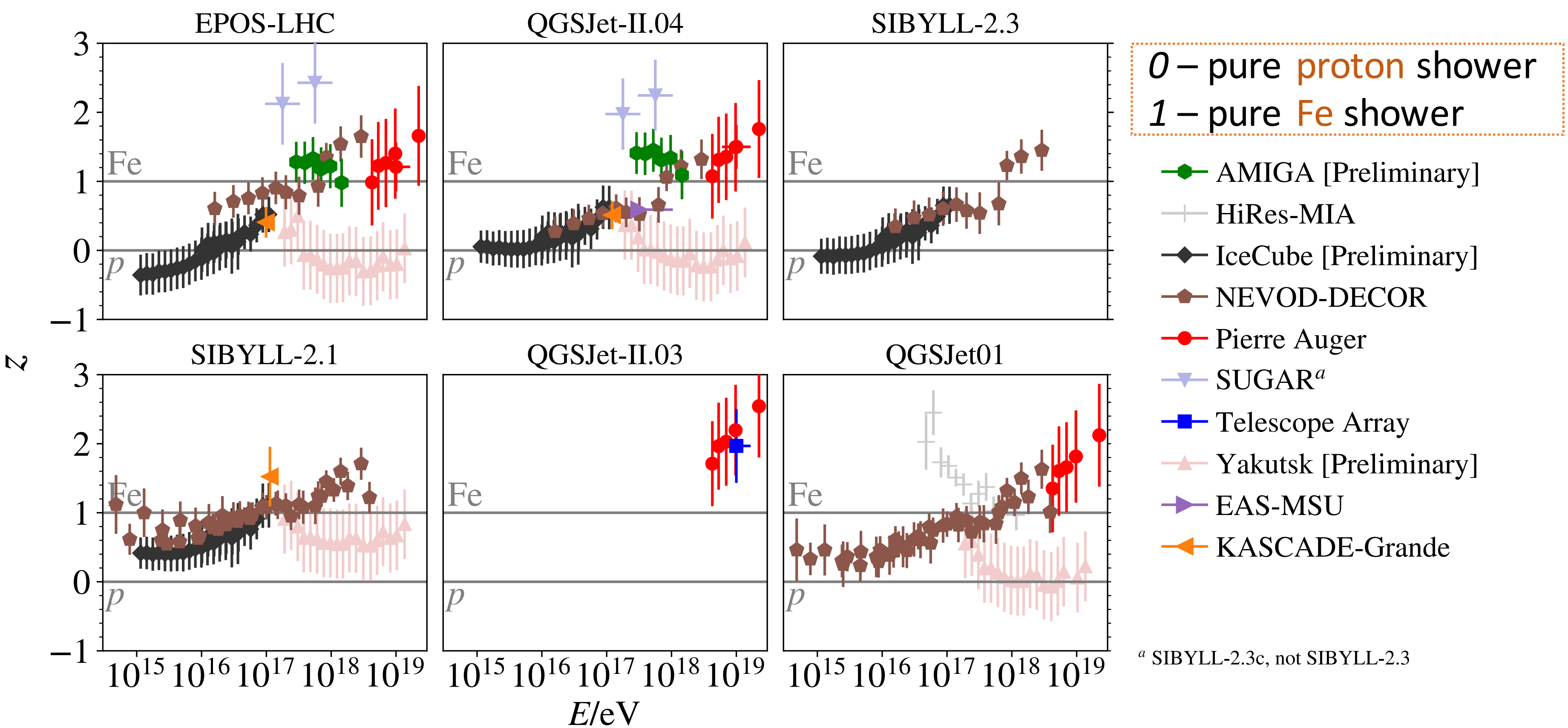
A. Aab et al. Phys. Rev. D 91, 032003 (2015)



Average muon content $\langle R_\mu \rangle$ per shower energy E as a function of the shower energy E in double logarithmic scale.

Combining muon measurements (*Report on Tests and Measurements of Hadronic Interaction Properties with Air Showers*)

H.P. Dembinski et al. arXiv:1902.08124v1 [astro-ph.HE] 21 Feb 2019

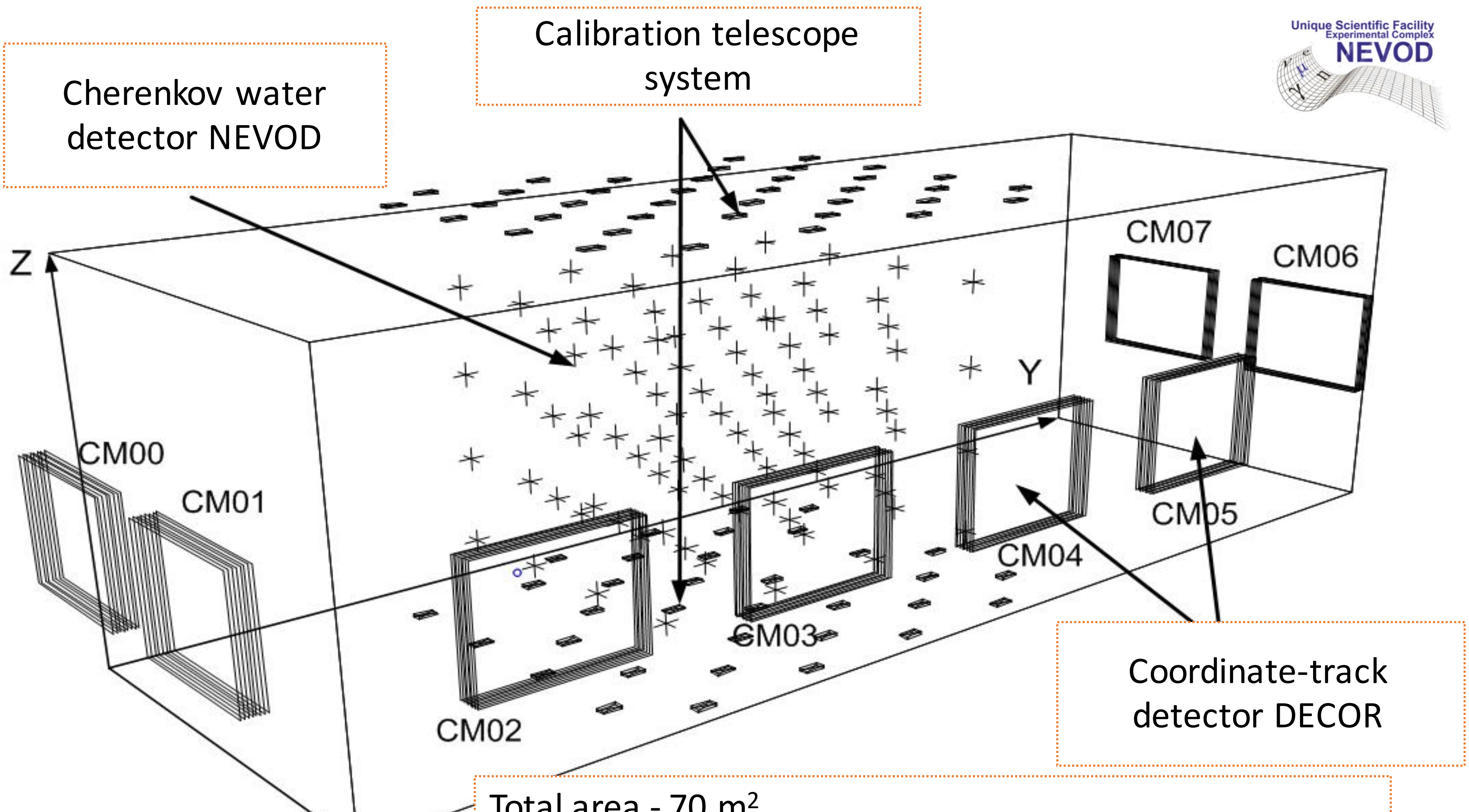


0 – pure proton shower
1 – pure Fe shower

$$z = \frac{\ln N_{\mu}^{\mathrm{det}} - \ln N_{\mu,p}^{\mathrm{det}}}{\ln N_{\mu,\mathrm{Fe}}^{\mathrm{det}} - \ln N_{\mu,p}^{\mathrm{det}}}$$

N_{μ}^{det} – the muon density estimate as seen in the detector, $N_{\mu,p}^{det}$ and $N_{\mu,Fe}^{det}$ the simulated muon density estimates for proton and iron showers after full detector simulation.

Experimental complex NEVOD-DECOR

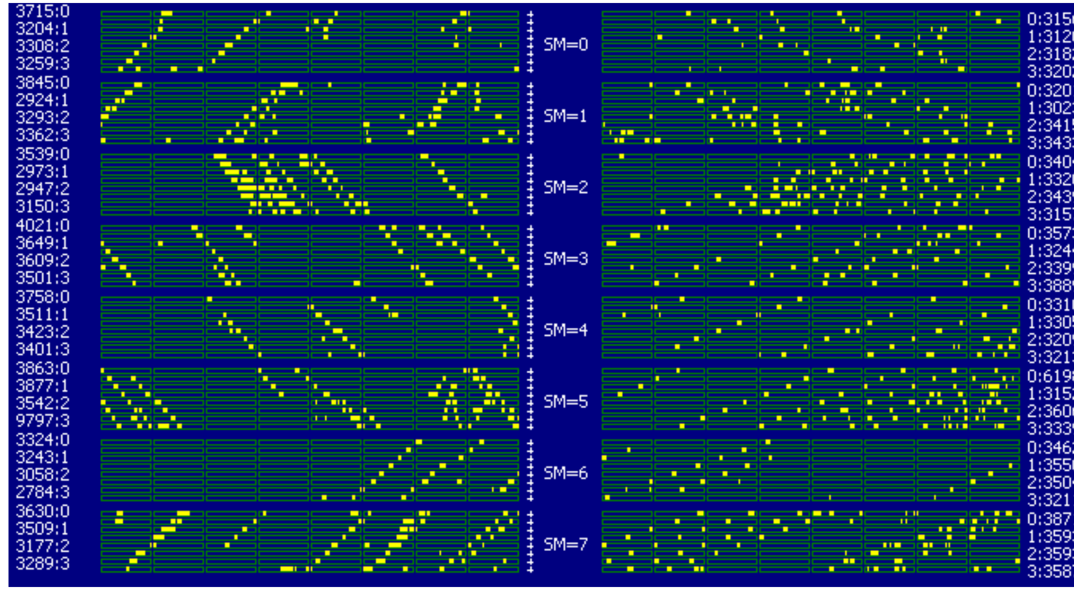


Water tank size – 9x9x26 m^3 -> mean threshold energy of muons $\simeq$2GeV

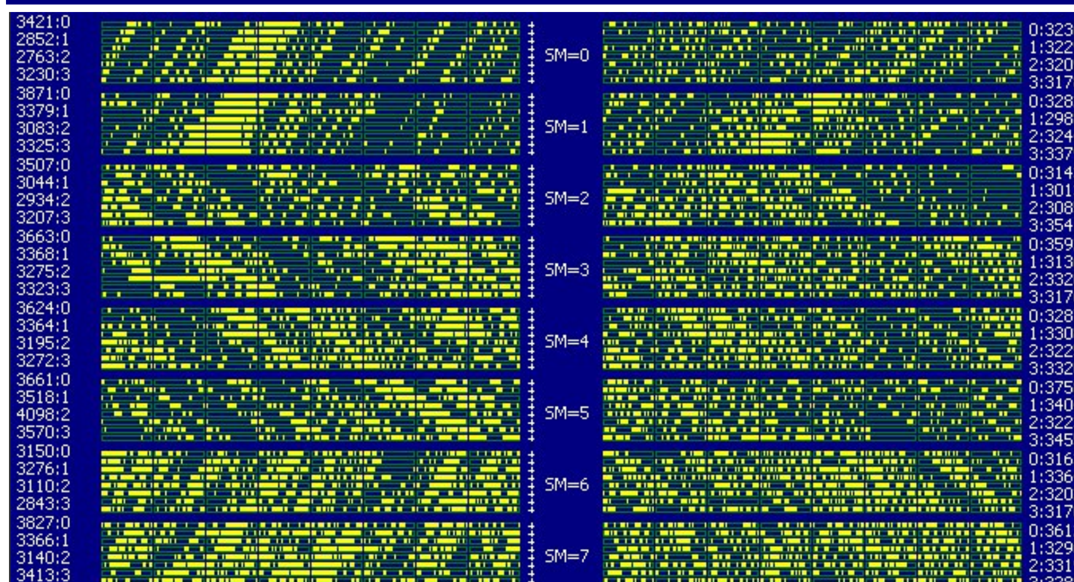
Total area - 70 m^2
Not complete overlap of the aperture of the CWD
Track resolution $\simeq$ 3 cm
Number of channels - 32786

Muon bundles in the data of the coordinate-tracking detector DECOR

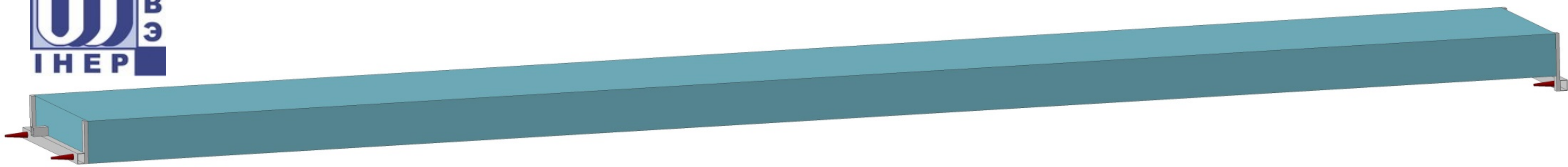
Bundles density ≈1 particles per square meter

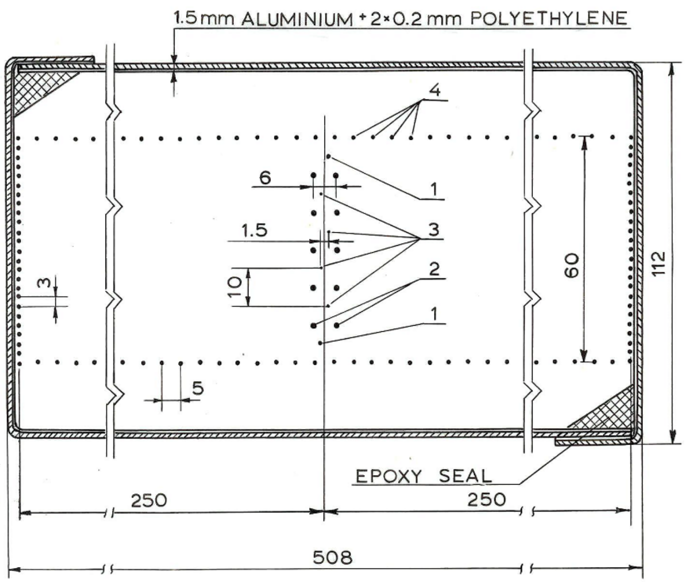


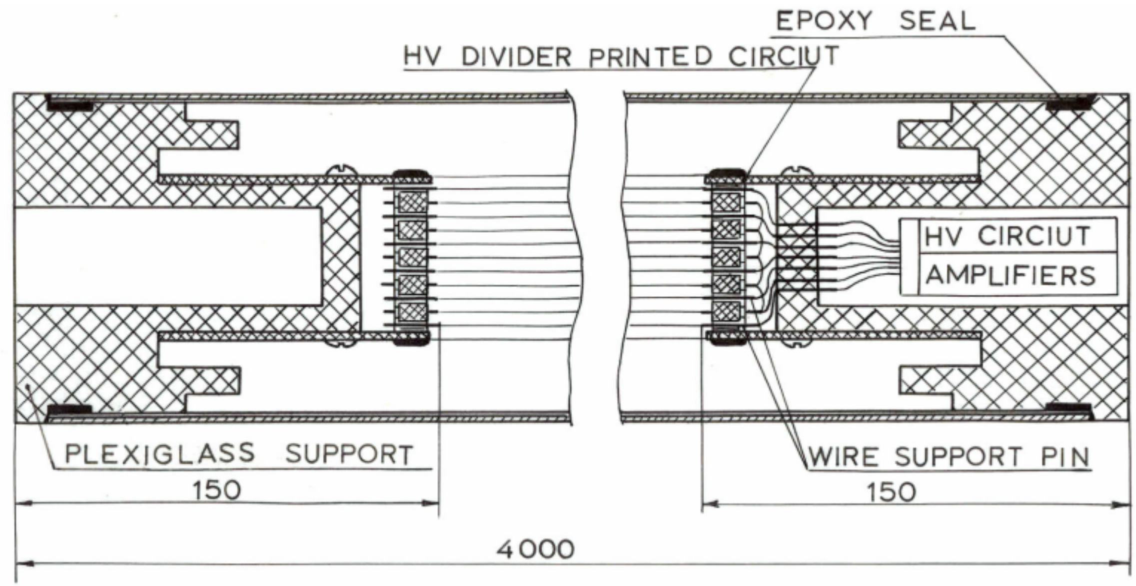
Bundles density ≈5 particles per square meter



Drift chamber



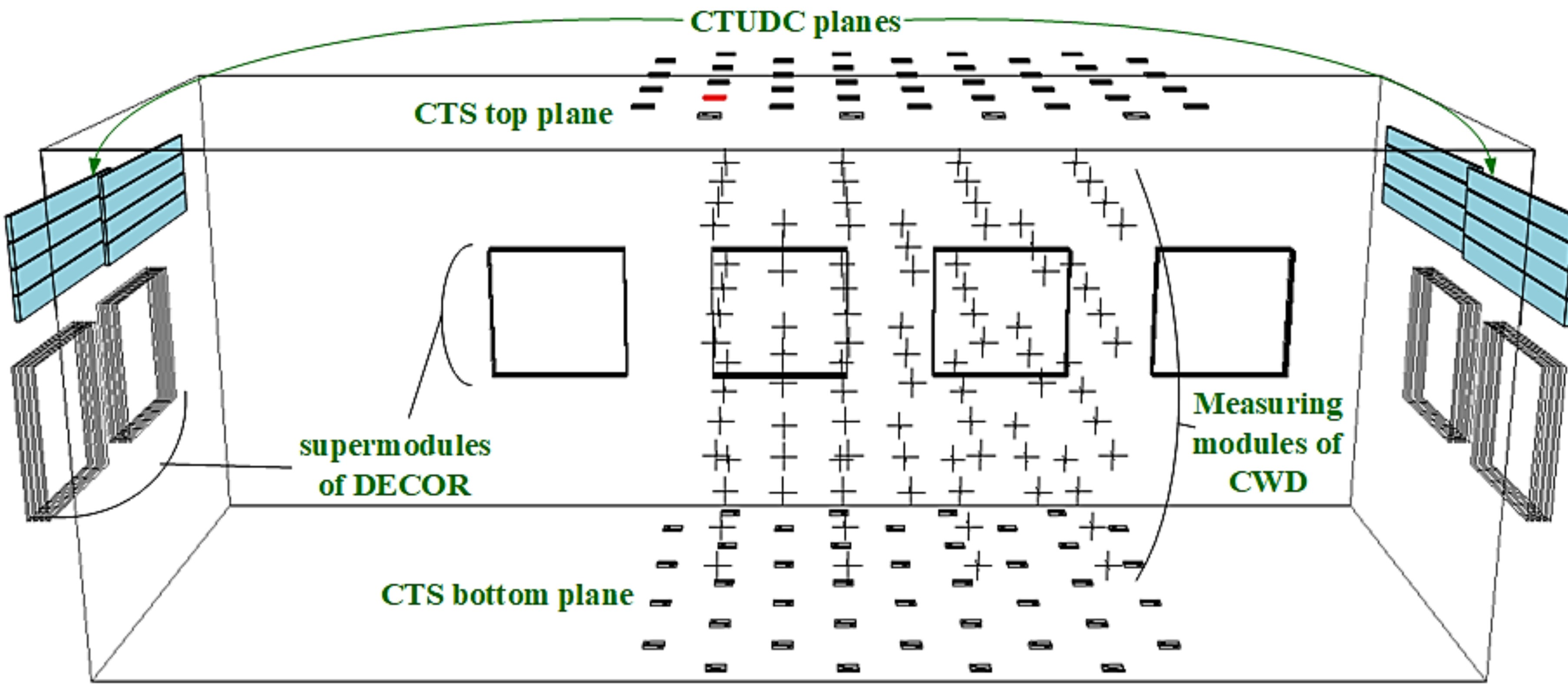




Spatial accuracy ≃ 1 mm
Angular accuracy ≃ 1.7°
Area of a single DC 2 m^2
Two track resolution ≃ 3 mm

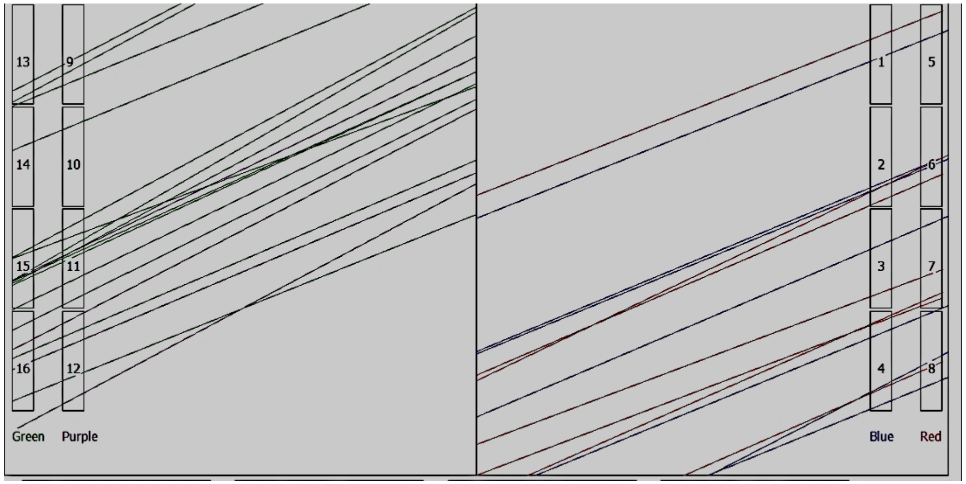
Max drift time < 6 μs
Drift velocity – 0,04 mm/ns
Gas mixture: 94% Ar + 6% CO_2

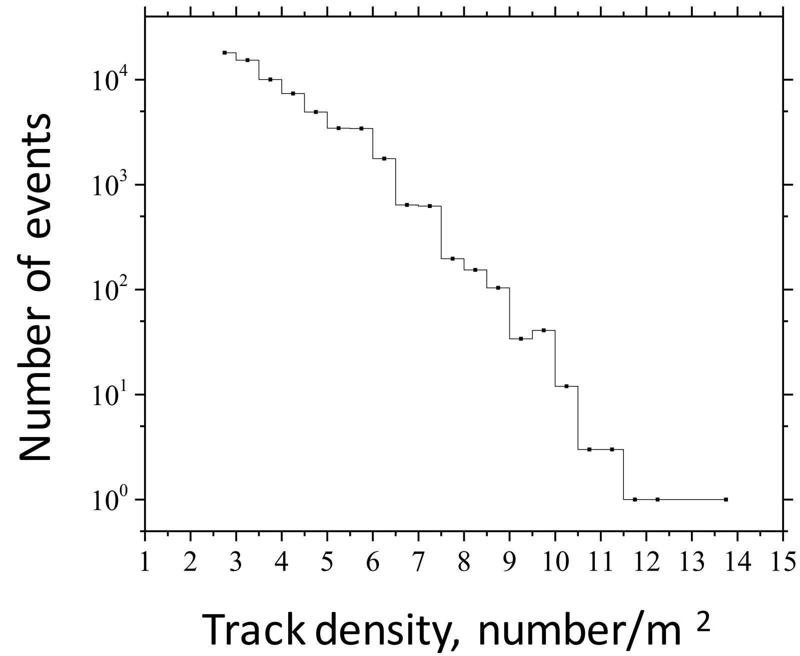
Coordinate-Tracking Unit on Drift Chambers (CTUDC)

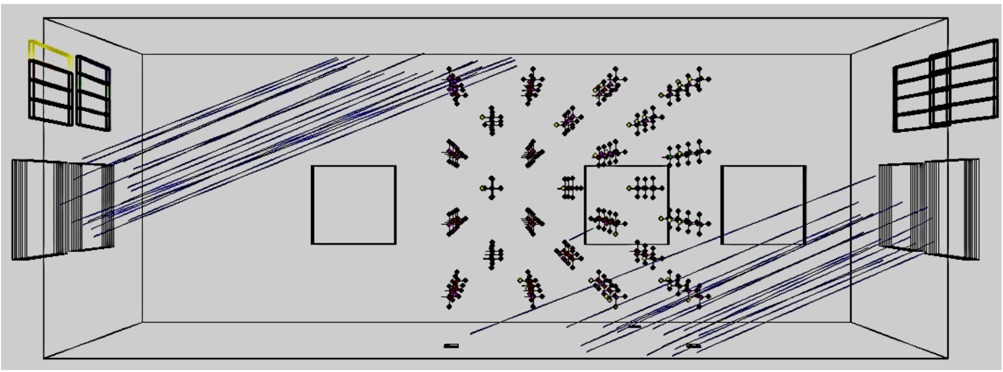


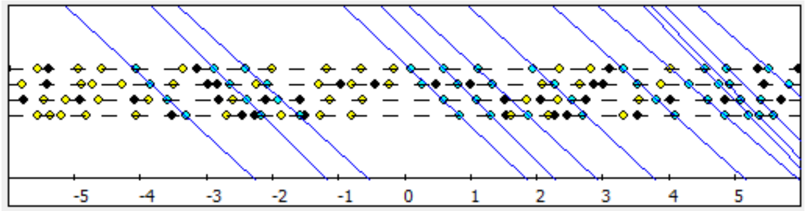
- Number of drift chambers - 16
- Effective area – 29,6 m^2
- Number of channels – 64

Joint registration of high multiplicity event



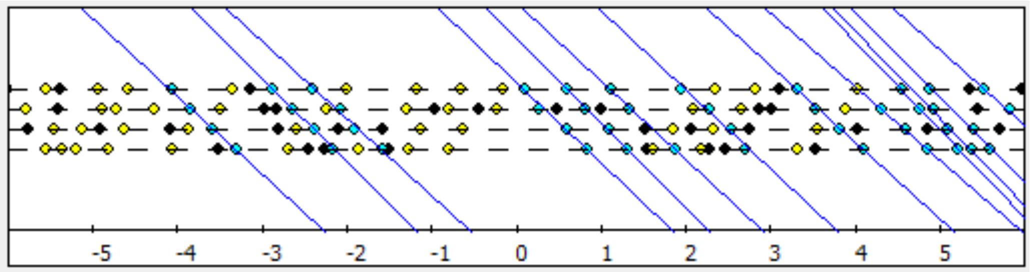




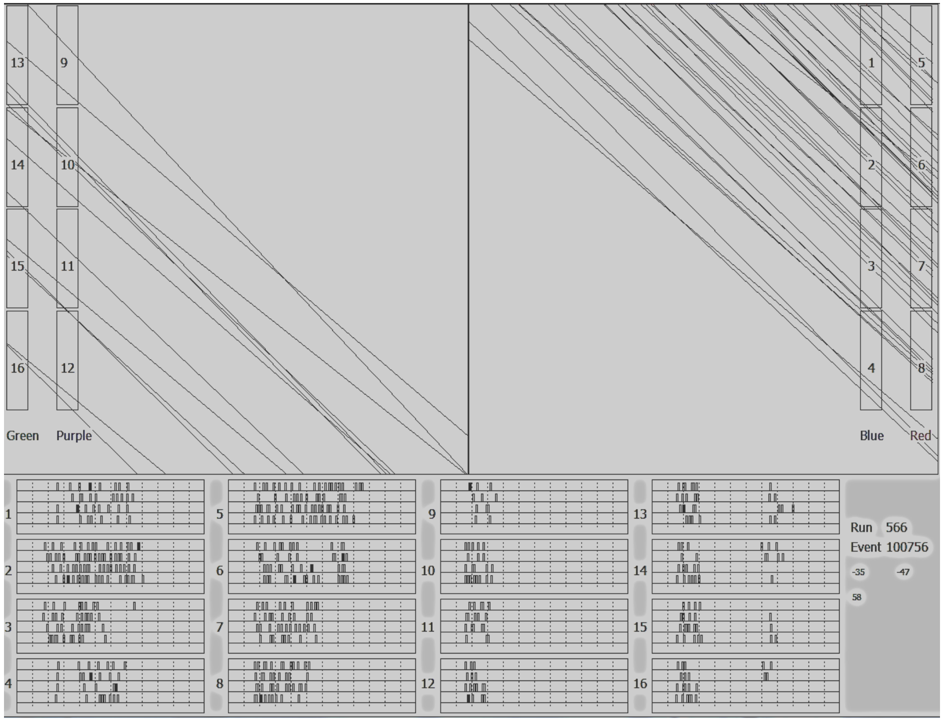


	CTUDC	DECOR
Projection zenith angle	65°	63.5°
Muon density per m^2	1.3±0.2	1.4±0.2

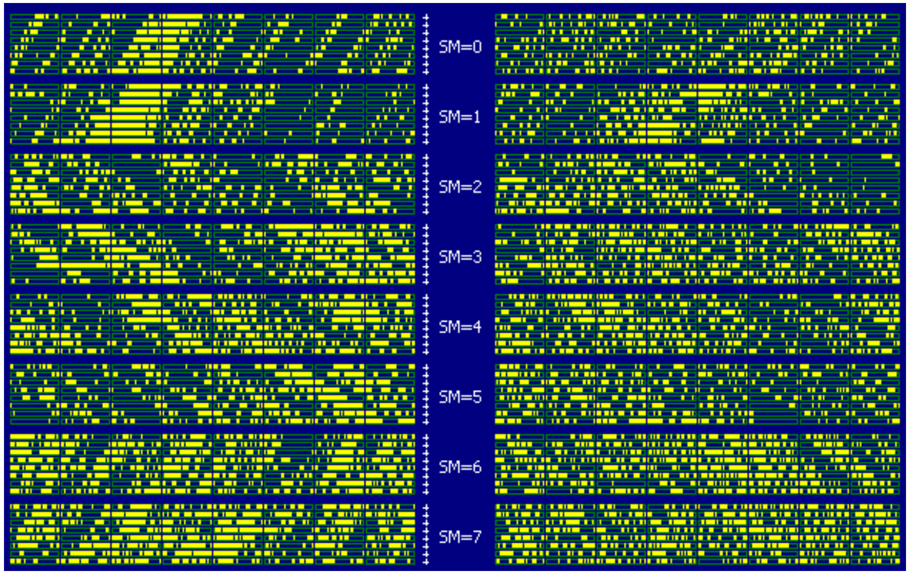
Event with high multiplicity - comparison



Density 5 particles/m^2
The distance between close tracks > 4mm

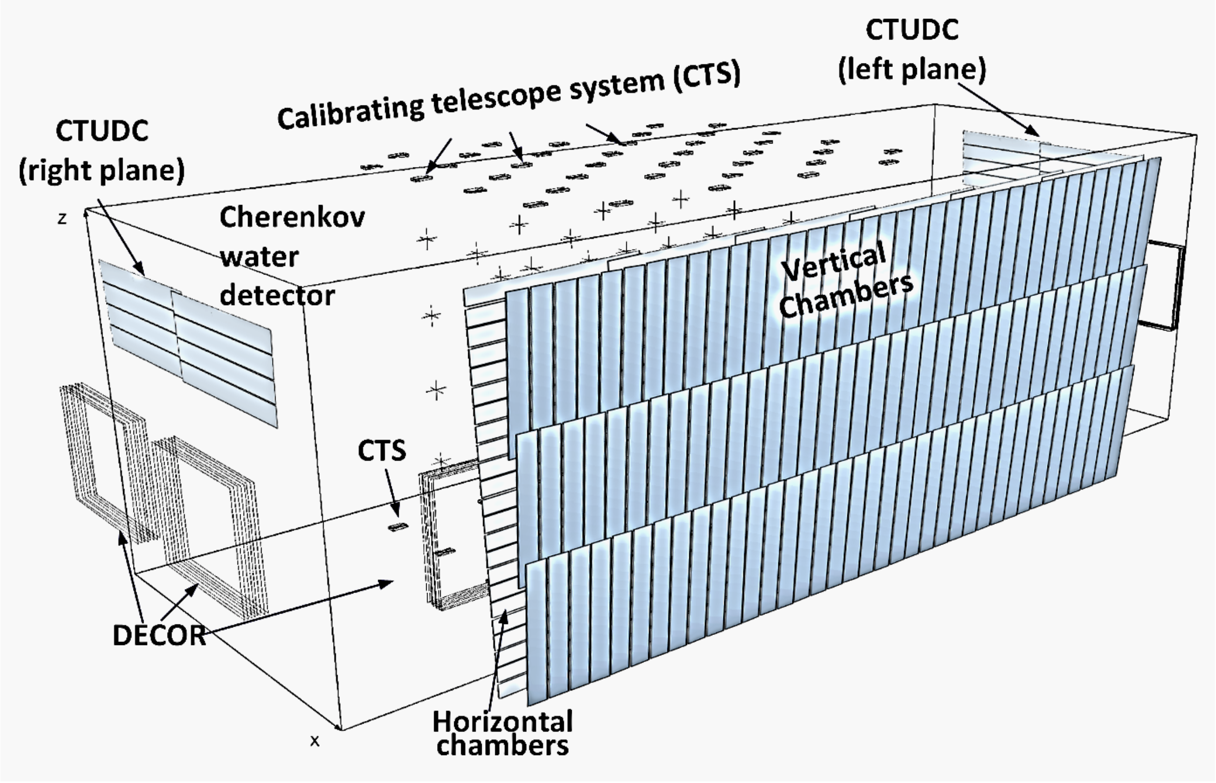


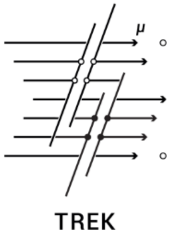
θ_{pr} = 47°

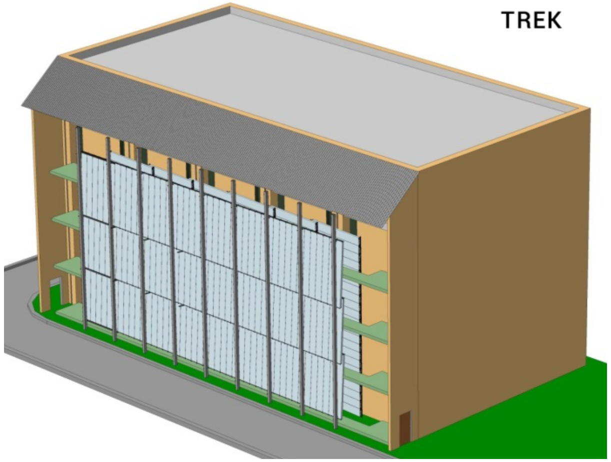


Response of DÉCOR
θ_{pr} = 45°

The detector on the drift chambers as part of the experimental complex







264 drift chambers
Full overlap of the aperture of the CWD
Area of TREK –254 m^2 (8 times more)
Two-track resolution ~ 3 mm (10 times less)

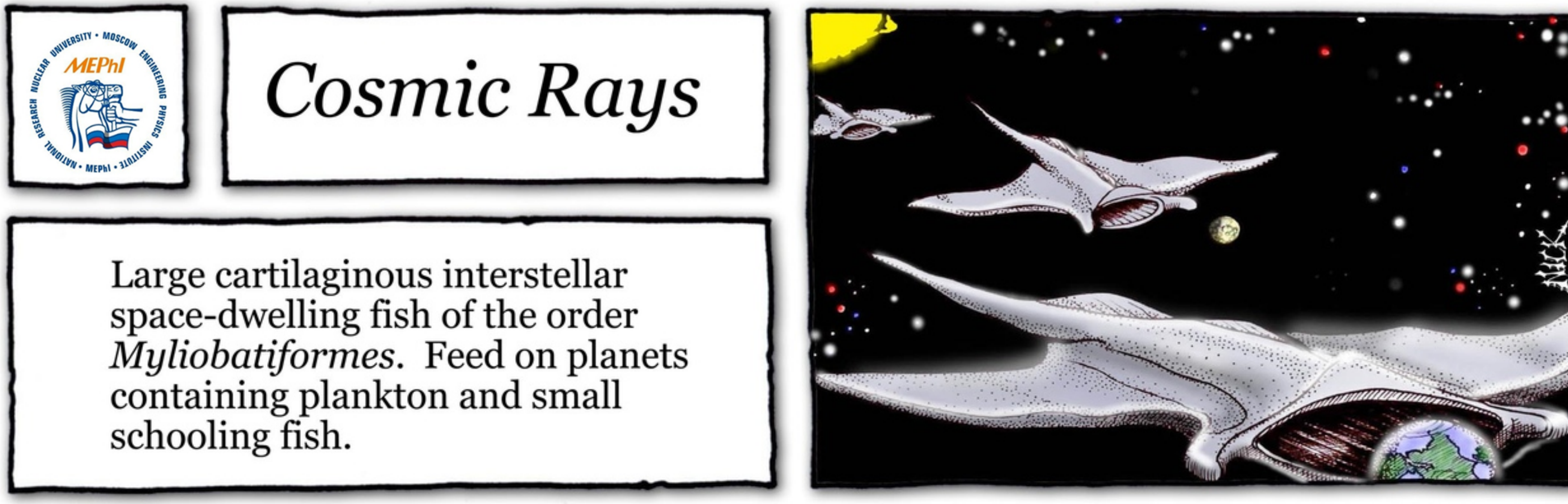
Conclusion

This new coordinate-track detector TREK:

- Significantly improve the quality of experimental data on the multiplicity of muons:

 - will increase the accuracy of muon number measurements, with more than 10 particles per square meter

 - will reduce the two-particle resolution threshold
- Will allow the extending of the total energy reach of the complex with an order (including 10^{19} eV), thus overlap the energy regions of Pierre Auger installation.



Thank you for your attention!