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Analysis of the electron-photon and hadron components of EAS according to the data of the NEVOD-EAS and PRISMA-32 installations

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NEVOD-EAS array

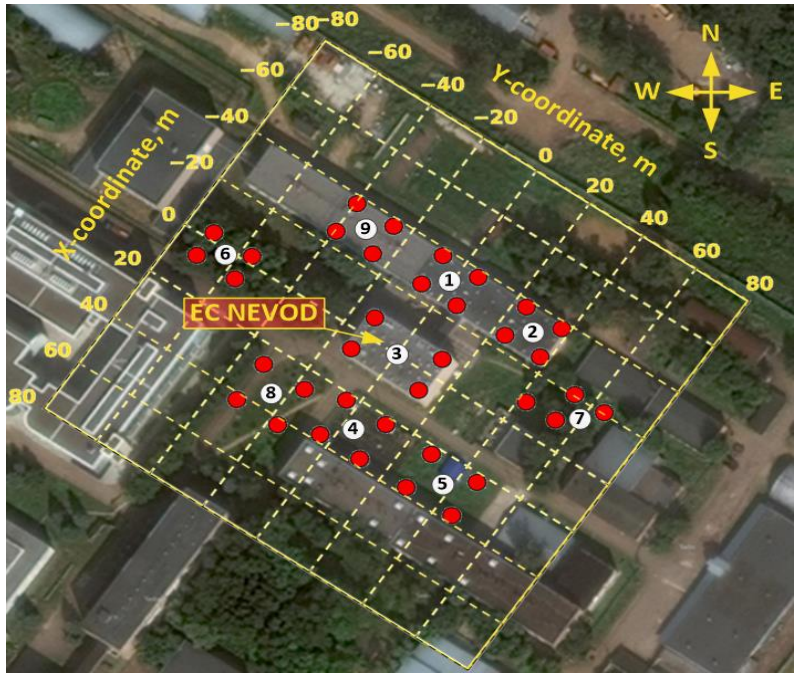
Electron-photon component of showers

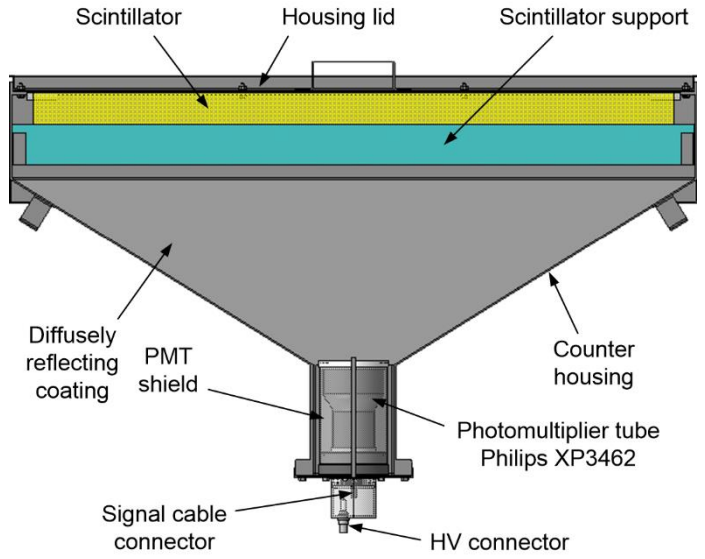
- **9** clusters, **36** detector stations;
- Array area: 10^4 m^2.

The array gives the main shower parameters:

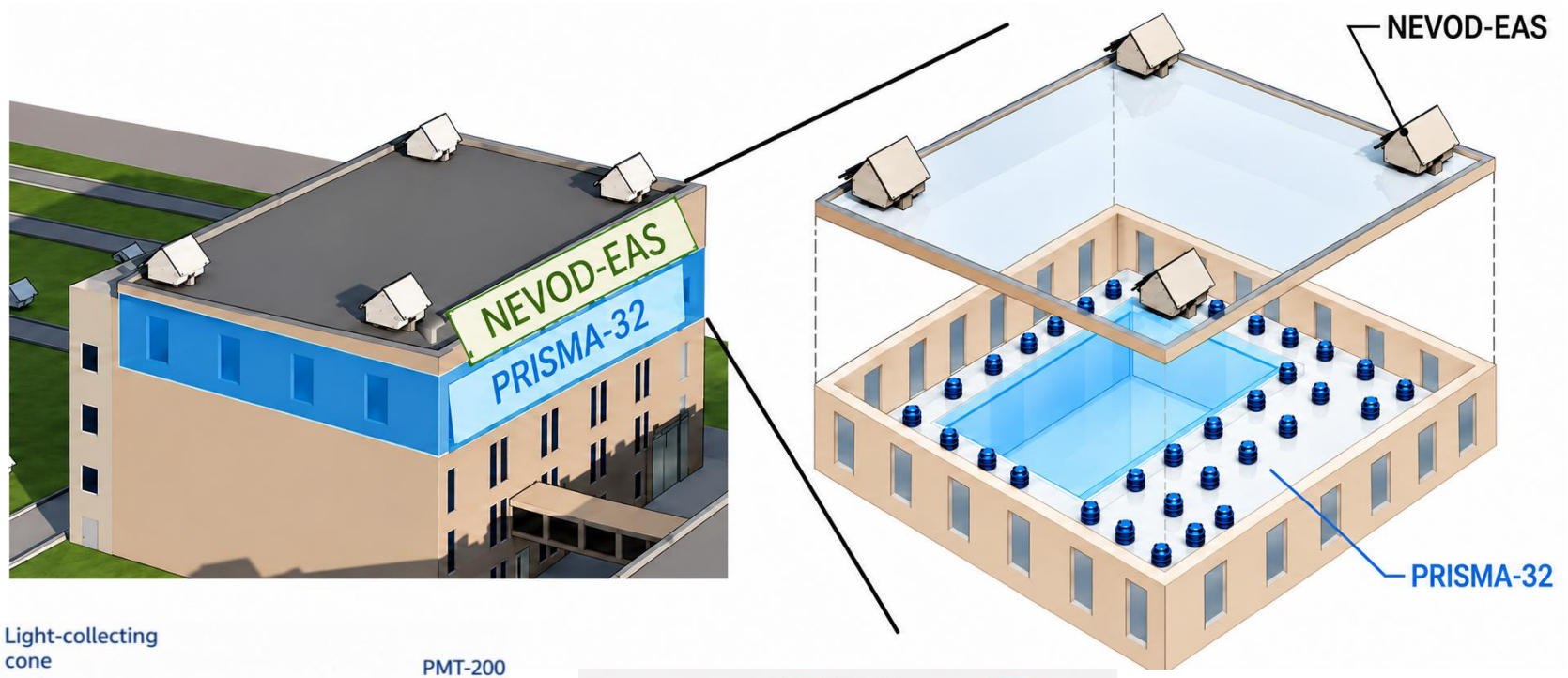
- arrival direction and axis position,
- shower size and shower age.





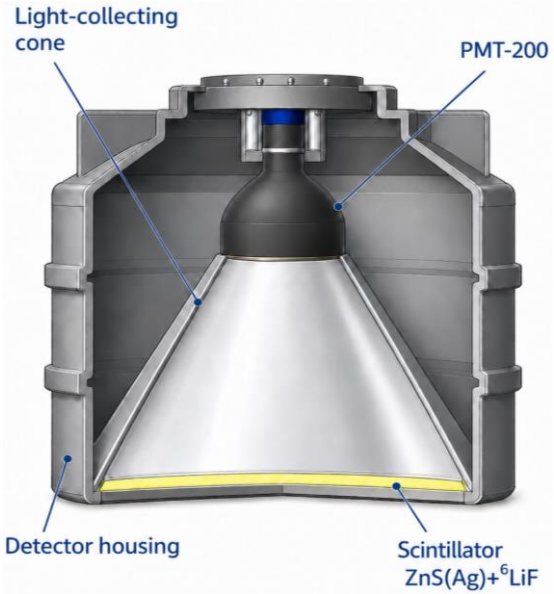


PRISMA-32 array



Hadron + charged component

- **32** en-detectors;
- Area: **500** m^2.





Scintillator: **ZnS(Ag) + ^{6}LiF**

$^6Li + \mathbf{n} \rightarrow {}^3H + \alpha + 4.8$ MeV

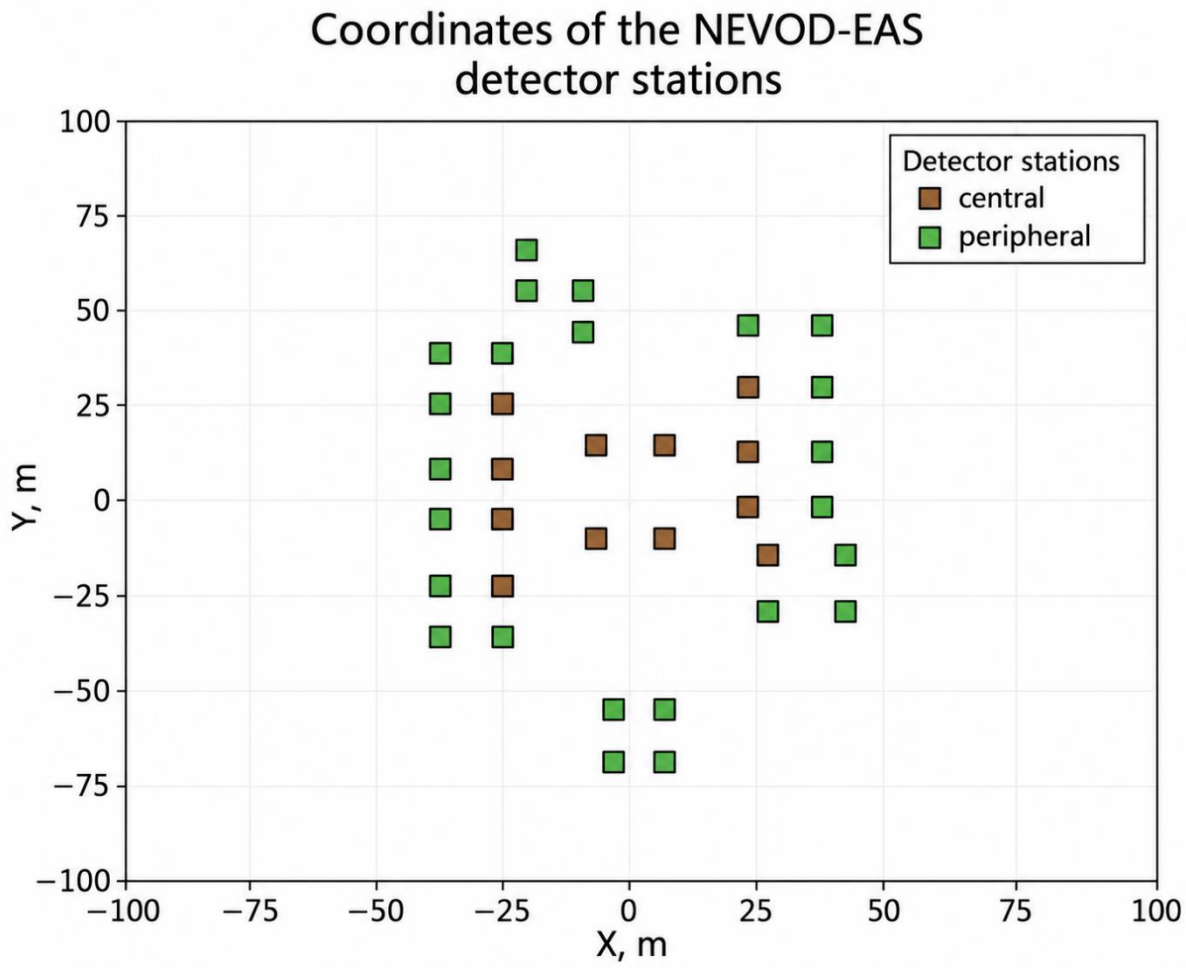
Data for analysis

NEVOD-EAS and PRISMA-32 data from 2018 to 2023

Joint events: 152 000

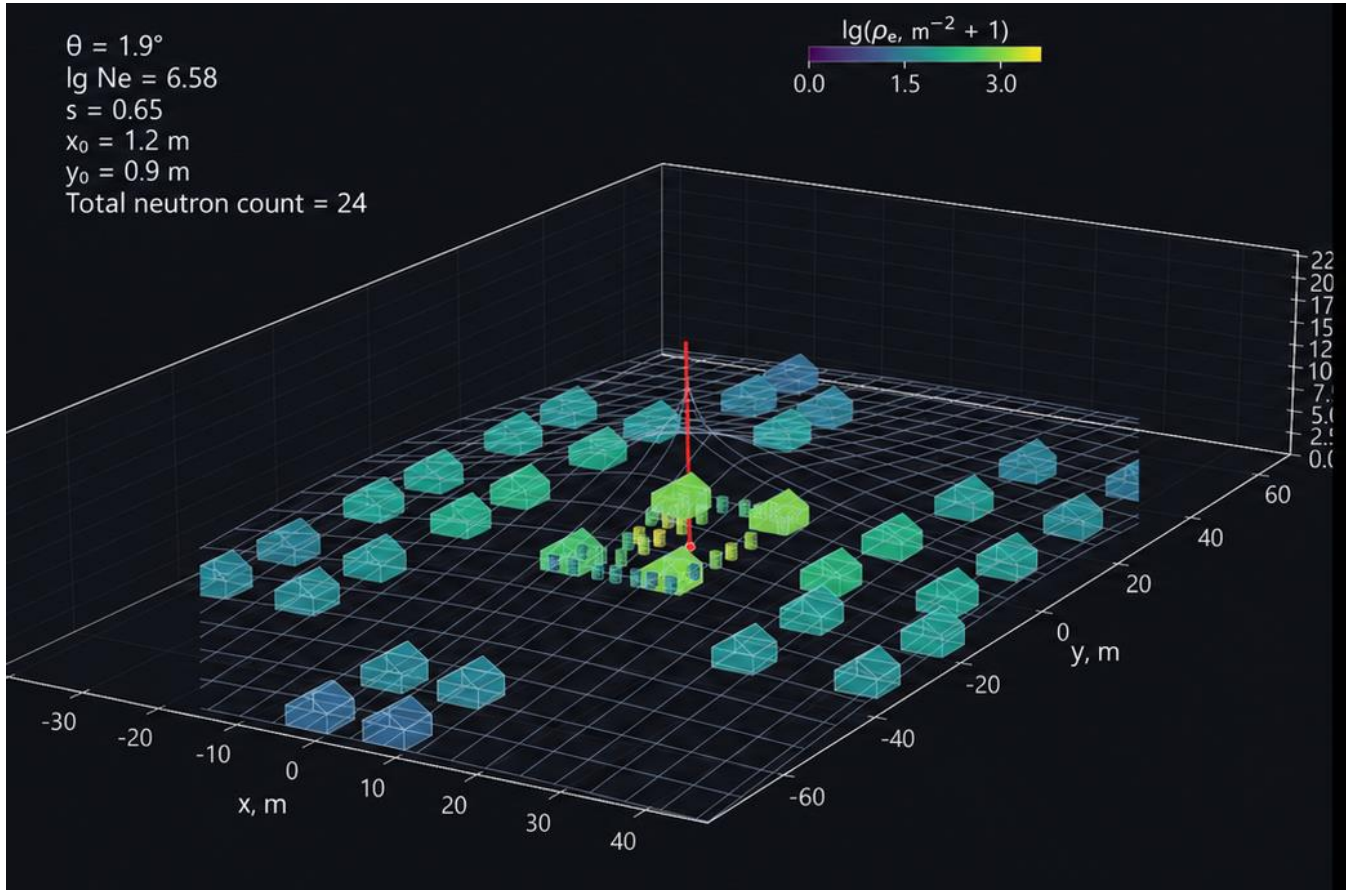
- ρ_{max} in central detectors
- Energy deposit ≥1 GeV
- Zenith angle < 30°

After selection criteria: 9 900 events

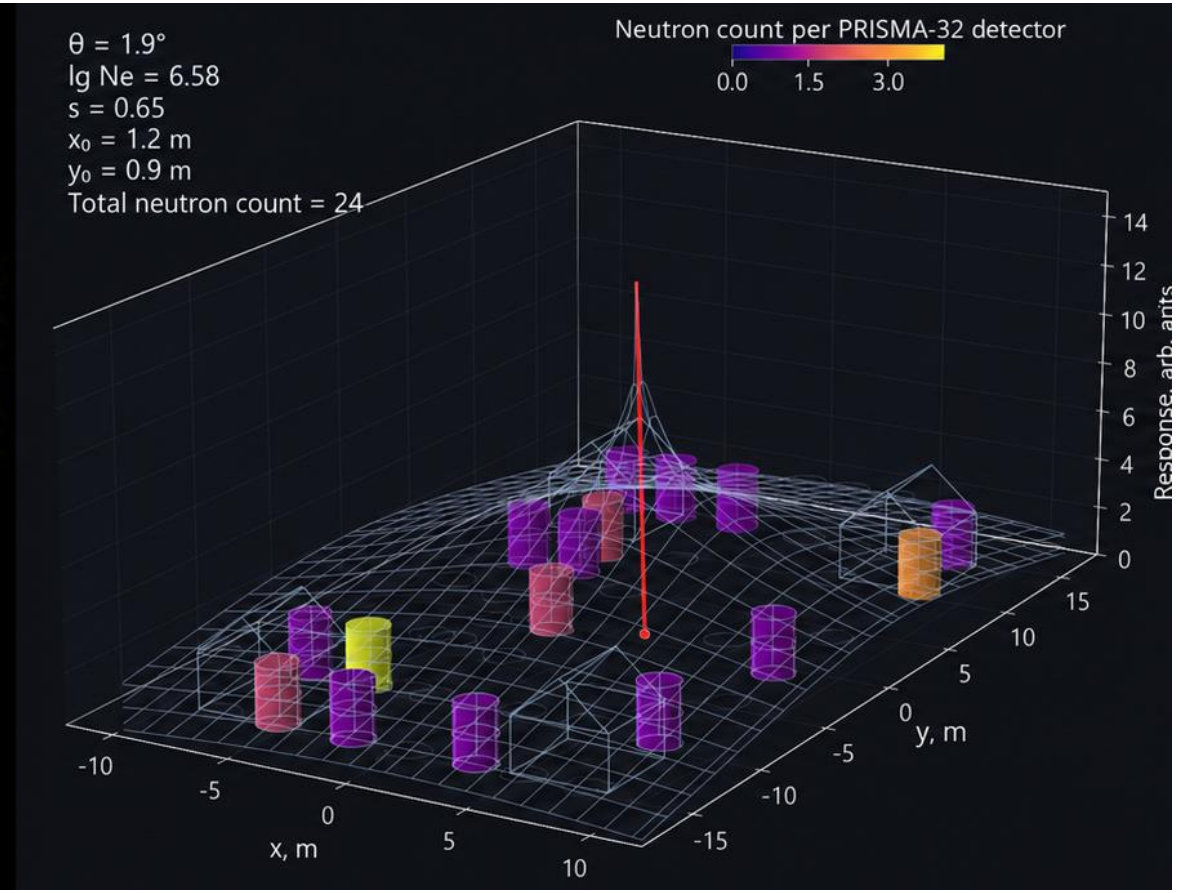


Example of a coincident event

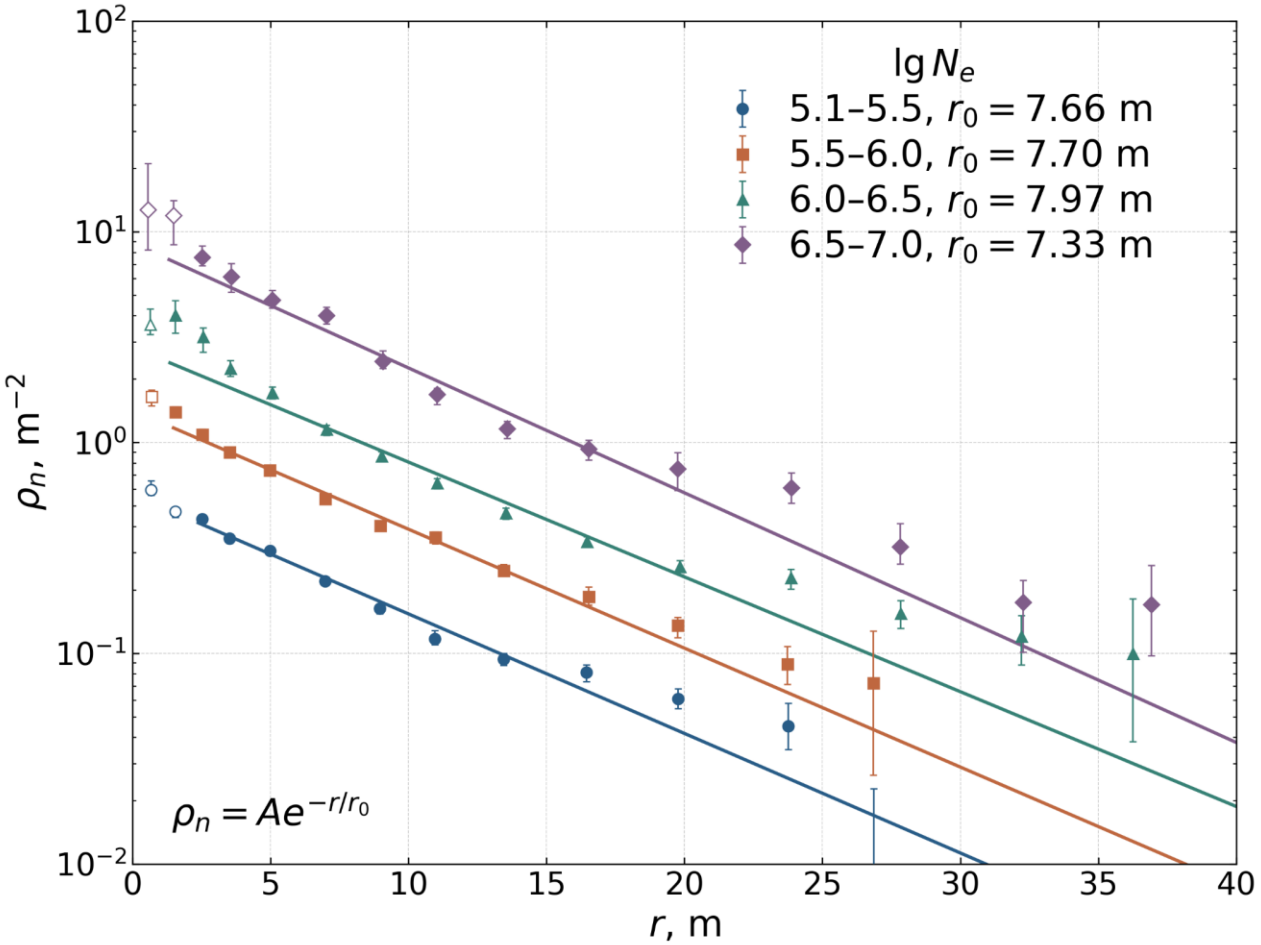
Charged-particle: NEVOD-EAS

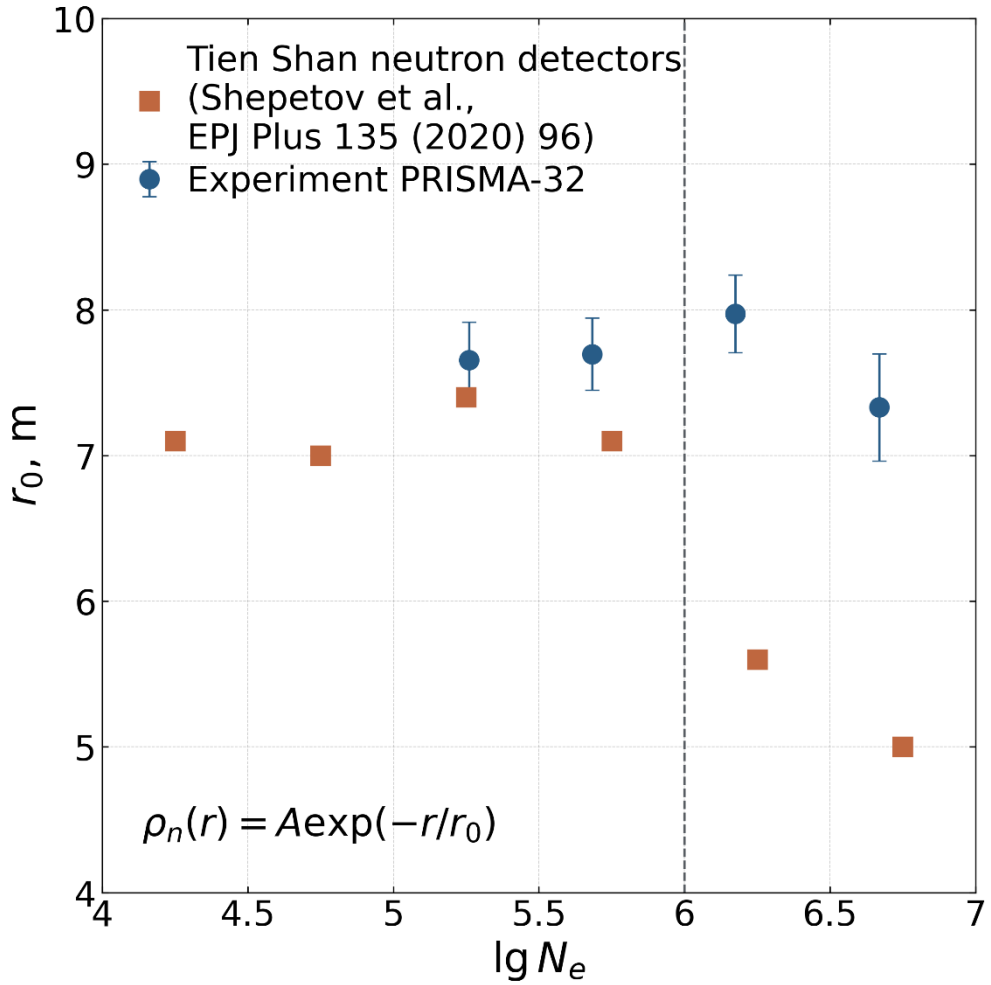


Thermal neutrons: PRISMA-32



Lateral distribution of thermal neutrons

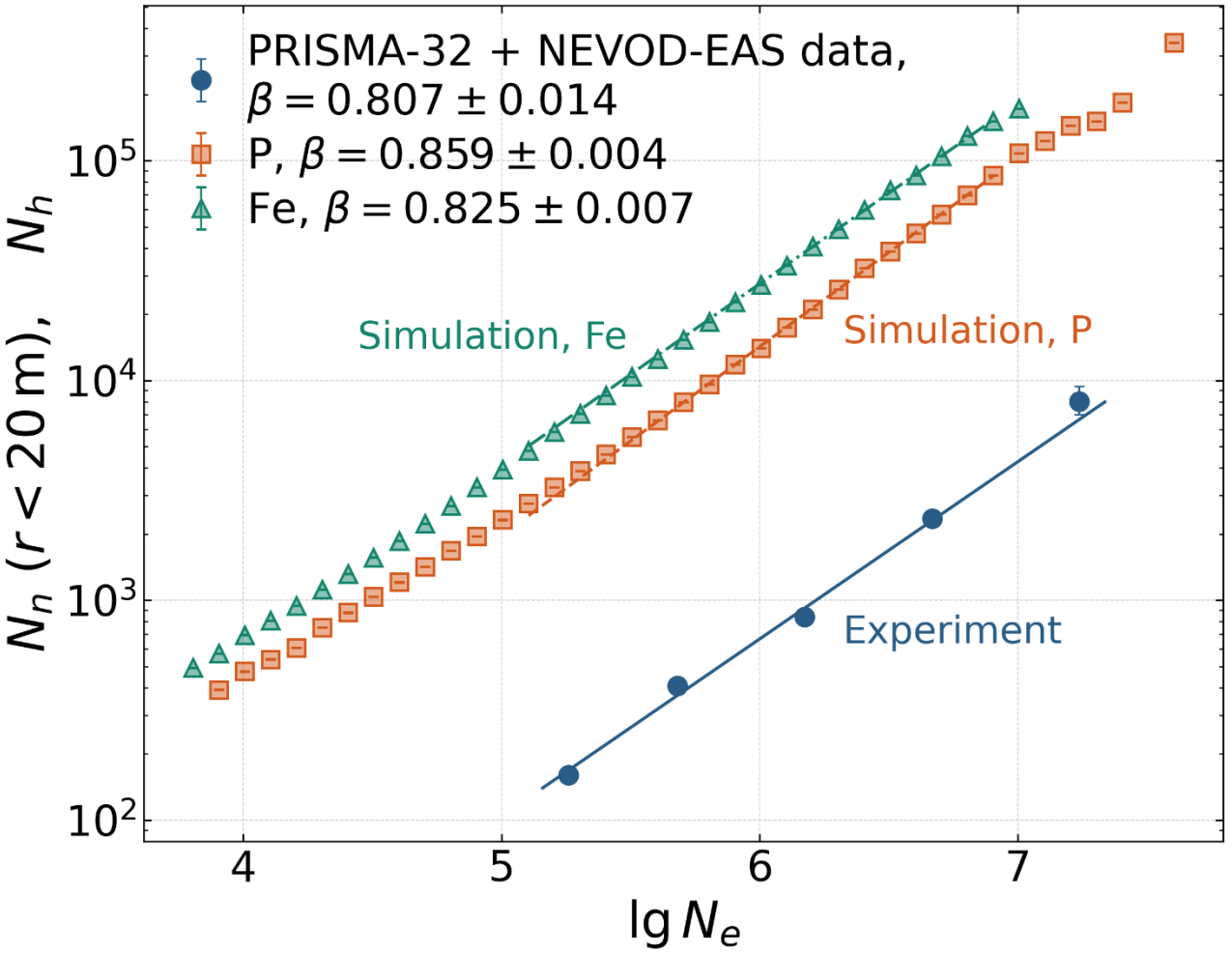




The r_0 parameter is independent of shower size within uncertainties.
The mean radius is 7.56 ± 0.21 m.

Mean radius from Tien Shan data: below the knee 7.15 m and 5.30 m above the knee at lgN_e = 6.00.

Dependence of the number of hadrons and the shower size

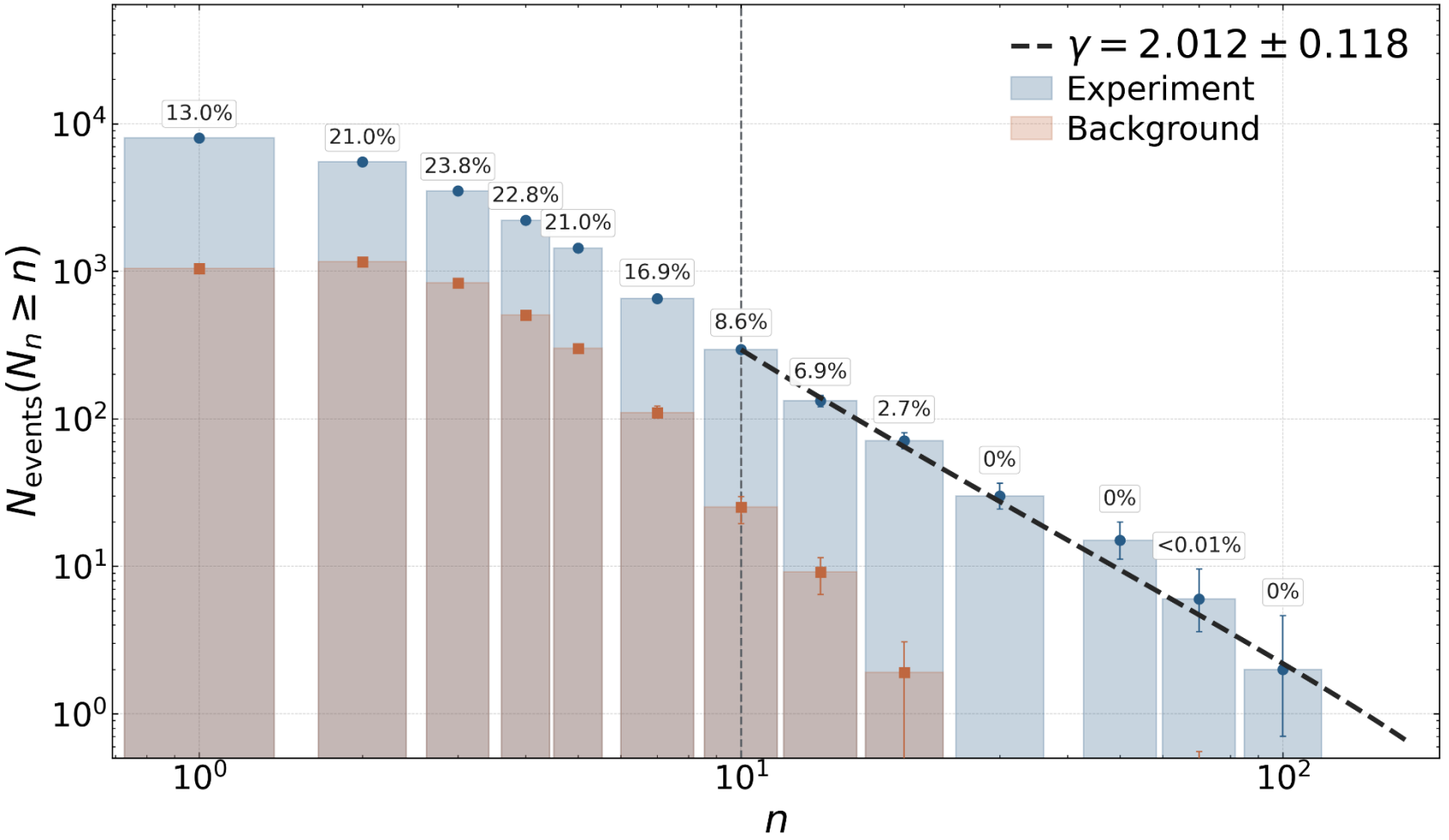


$N_h \sim N_e^{\beta}$

β = 0.92	Kiel + Yakutsk[1] (sea level, neutron monitors)
$\beta_1 = 0.58$ Knee lg$N_e \approx 6$ $\beta_2 = 1.04$	Tien Shan[2] (3340 m, ^{3}He counters)
β = 0.807	This work PRISMA-32 + NEVOD-EAS

CORSIKA (QGSJET-II-04 + FLUKA 2020.0.3); *p,* Fe
$E = 10^{14} - 10^{17}$ eV, (γ + 1) = 2.7 (3 million events).

The integral spectrum of thermal neutrons



PRISMA-YBJ[3] (4300 m)

γ = 1.95 ± 0.05

ENDA-64 LHAASO [4] (4410 m)
Simulation

γ ≈ 2.1

This work

PRISMA-32

γ = 2.012 ± 0.118

The spectral indices agree within uncertainties

Conclusion

1. We combined data on the electron-photon and neutron components of EAS.
2. The r_0 parameter is independent of shower size within uncertainties.
3. The integral neutron spectrum index is $\gamma = 2.012 \pm 0.118$.
4. Within uncertainties, the number of neutrons in a shower follows the number of hadrons at observation level.

Thanks for your attention!



Bibliography

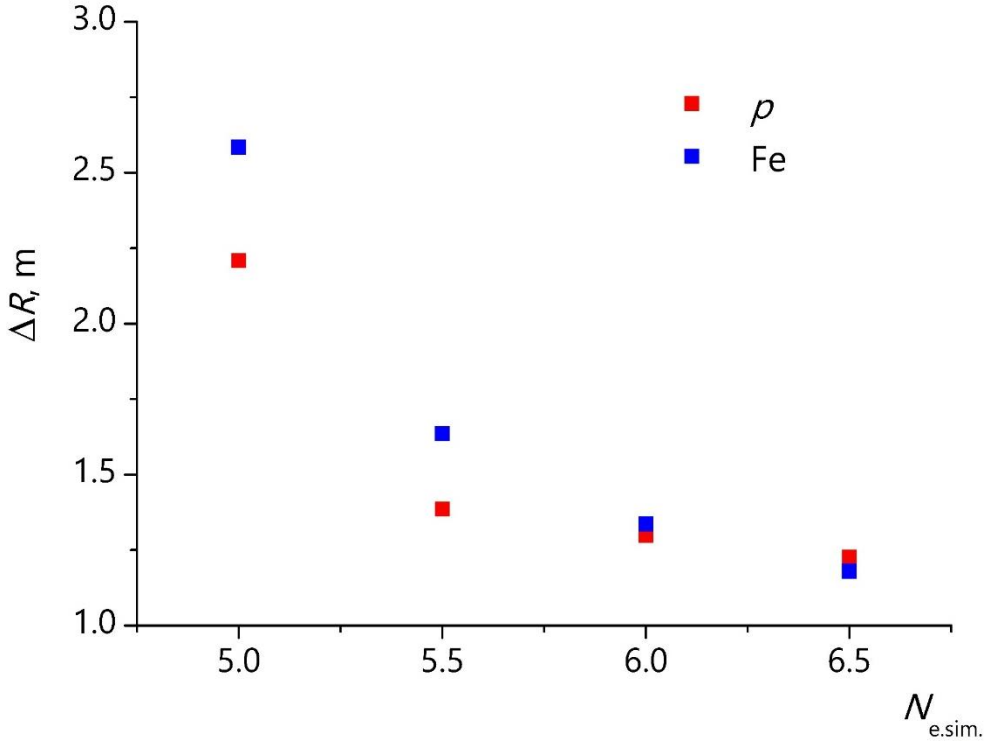
1. P.K.F. Grieder, Extensive Air Showers, Vol. 2, Springer, 2010, Sect. 13.6.1, Fig. 13.28a, p. 718.
2. A. Shepetov et al., Low-energy neutron and gamma-ray accompaniment of EAS in the knee region, arXiv:1912.13173.
3. B. Bartoli et al., Detection of thermal neutrons with the PRISMA-YBJ array in EAS, Astropart. Phys. 81 (2016) 49.
4. Li et al., Study of the lateral distribution of EAS thermal neutrons based on ENDA, PoS(ICRC2025)265.

Simulation

CORSIKA (QGSJET-II-04 + FLUKA 2020.0.3); *p*, Fe : $E = 10^{14} - 10^{17}$ eV, (γ + 1) = 2.7 (3 million events).

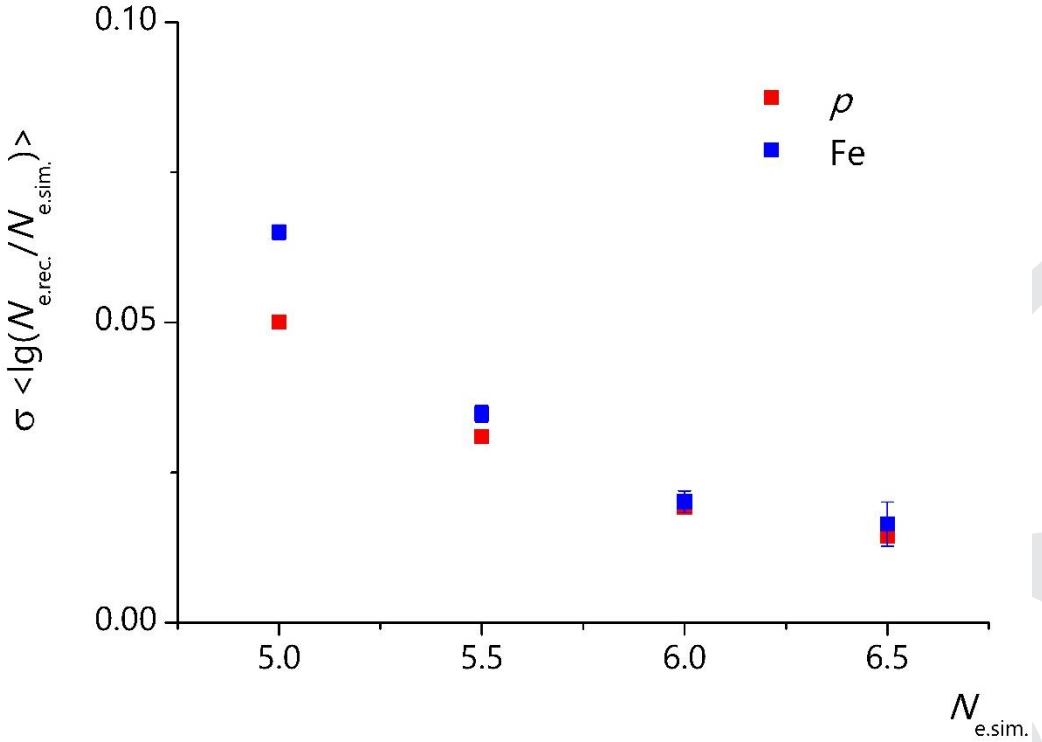
Direction reconstruction accuracy: *p* ~ **2.6°**, Fe ~ **2.2°**

Axis reconstruction accuracy



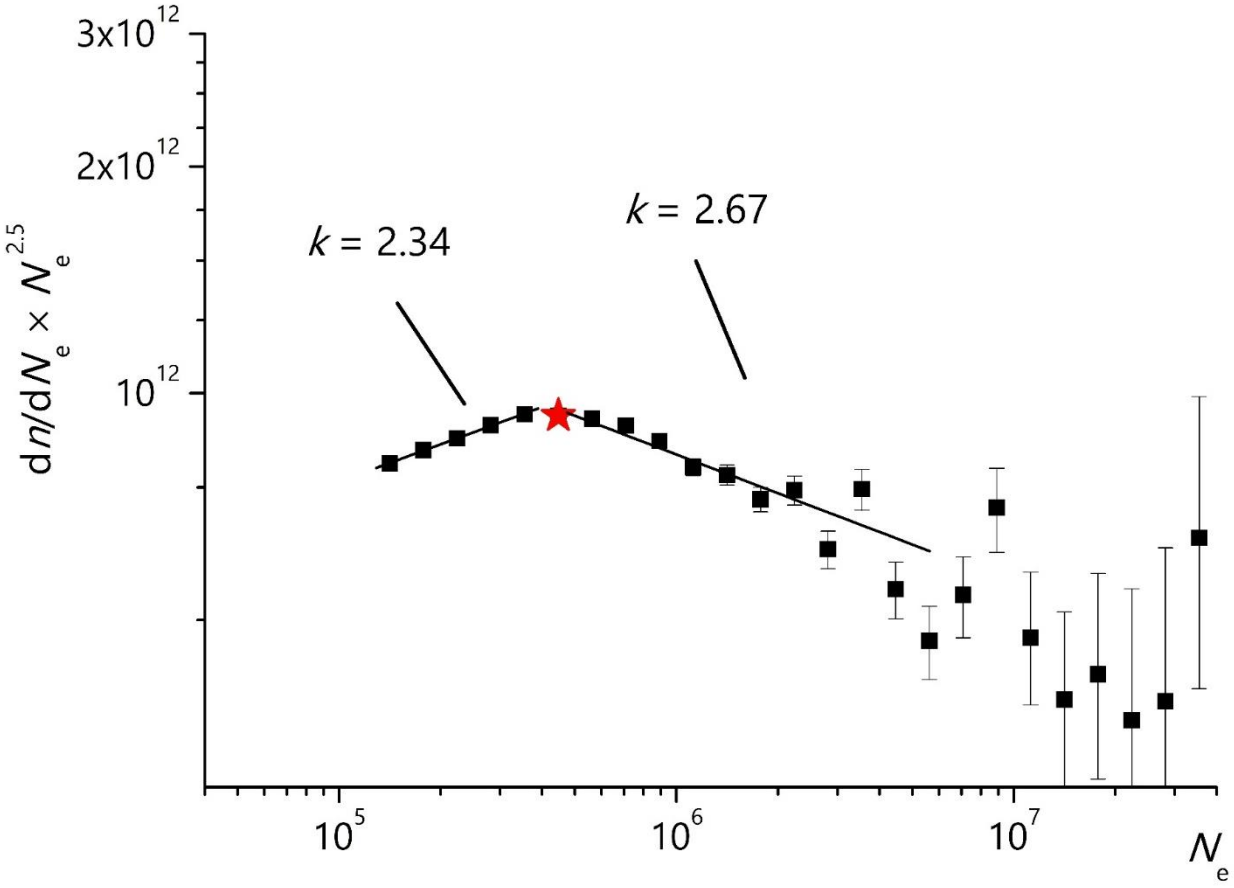
For $\lg N_{e(sim.)} = 5 \pm 0.1$: ΔR (*p*) ~ **2.2 m**, ΔR (Fe) ~ **2.6 m**

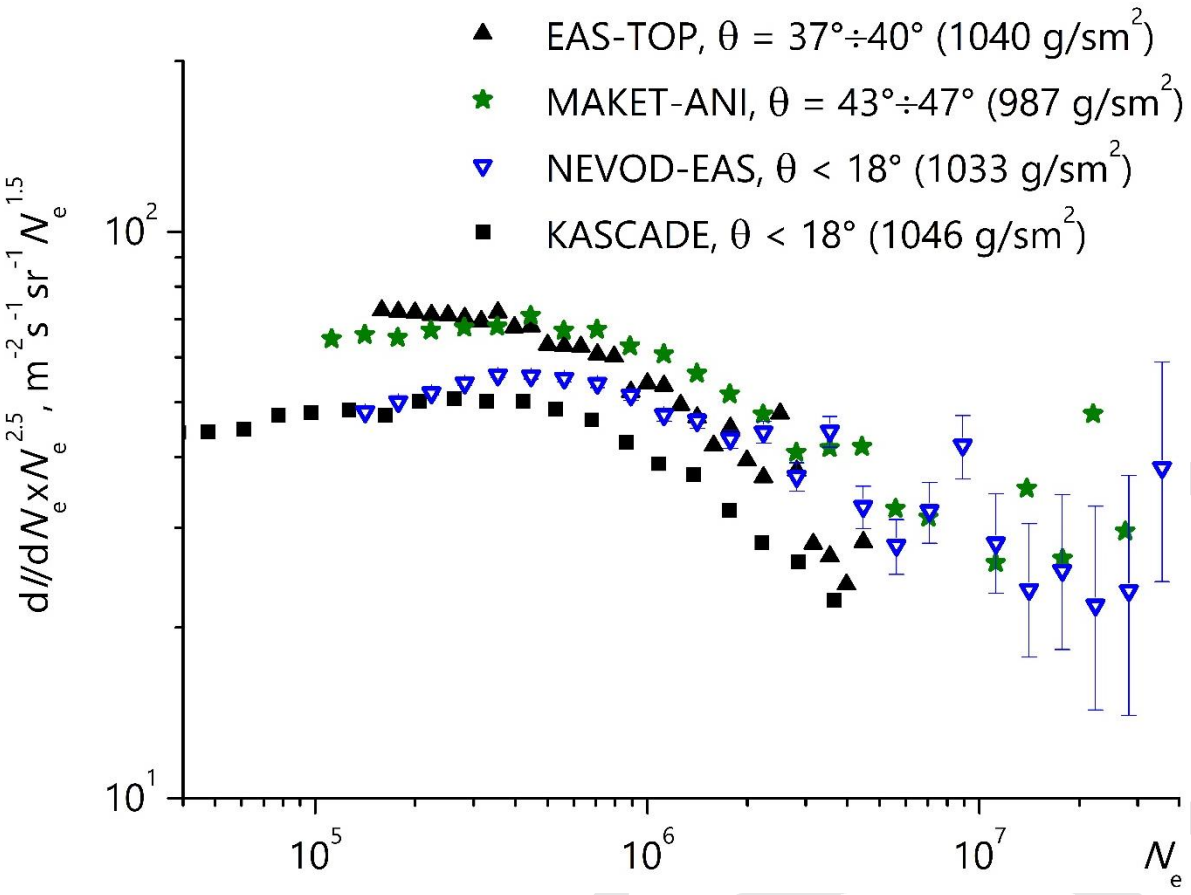
Size reconstruction accuracy



For $\lg N_{e(sim.)} = 5 \pm 0.1$: ΔN_e (*p*) ~ **0.05**, ΔN_e (Fe) ~ **0.06**

Shower size spectrum





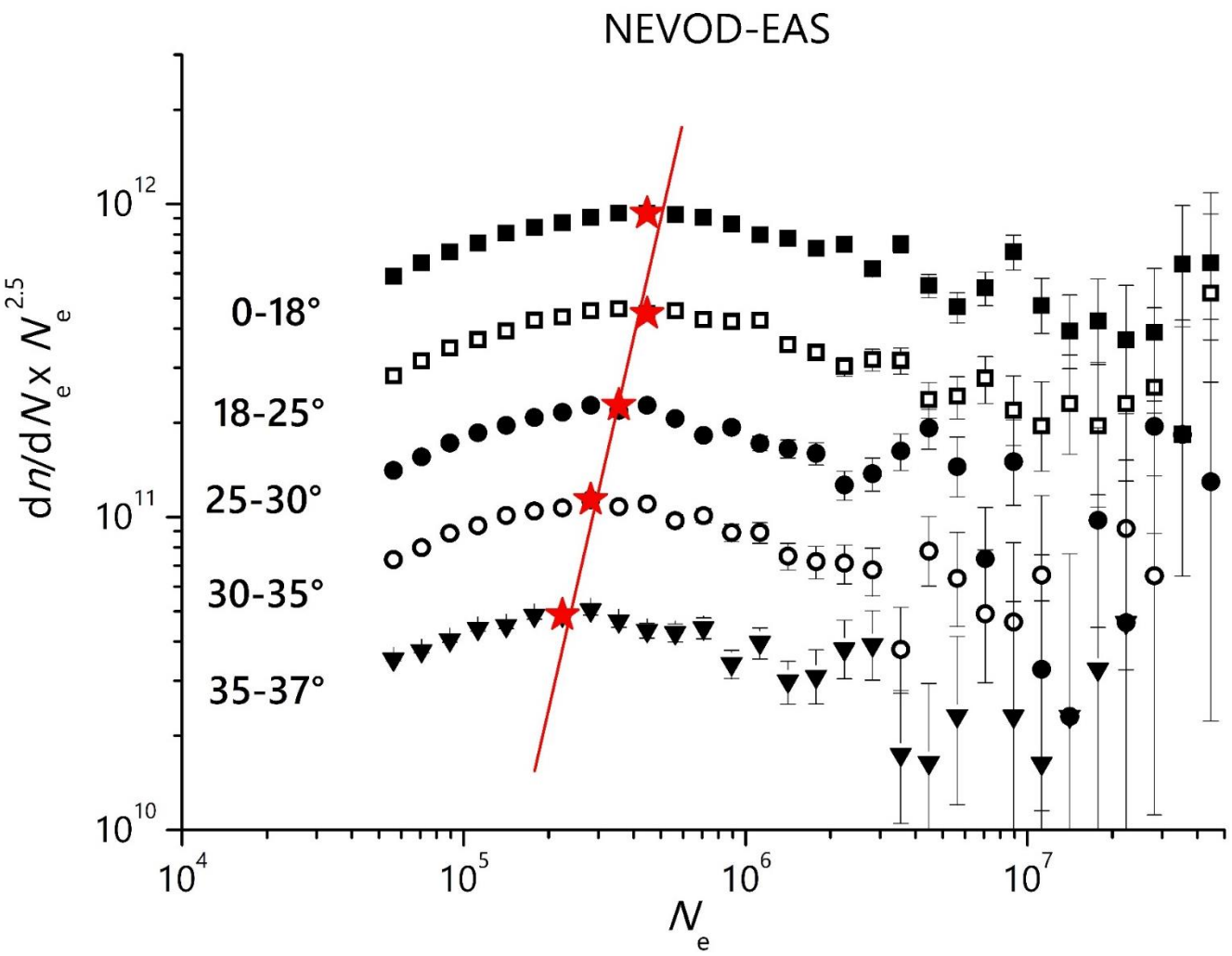
NEVOD-EAS
$\lg N_{ek} = 5.65$
$\Delta k = 0.33$

EAS-TOP
(M. Aglietta, 1999):
$\lg N_{ek} = 5.63 \pm 0.07$
$\Delta k = 0.25 \pm 0.07$

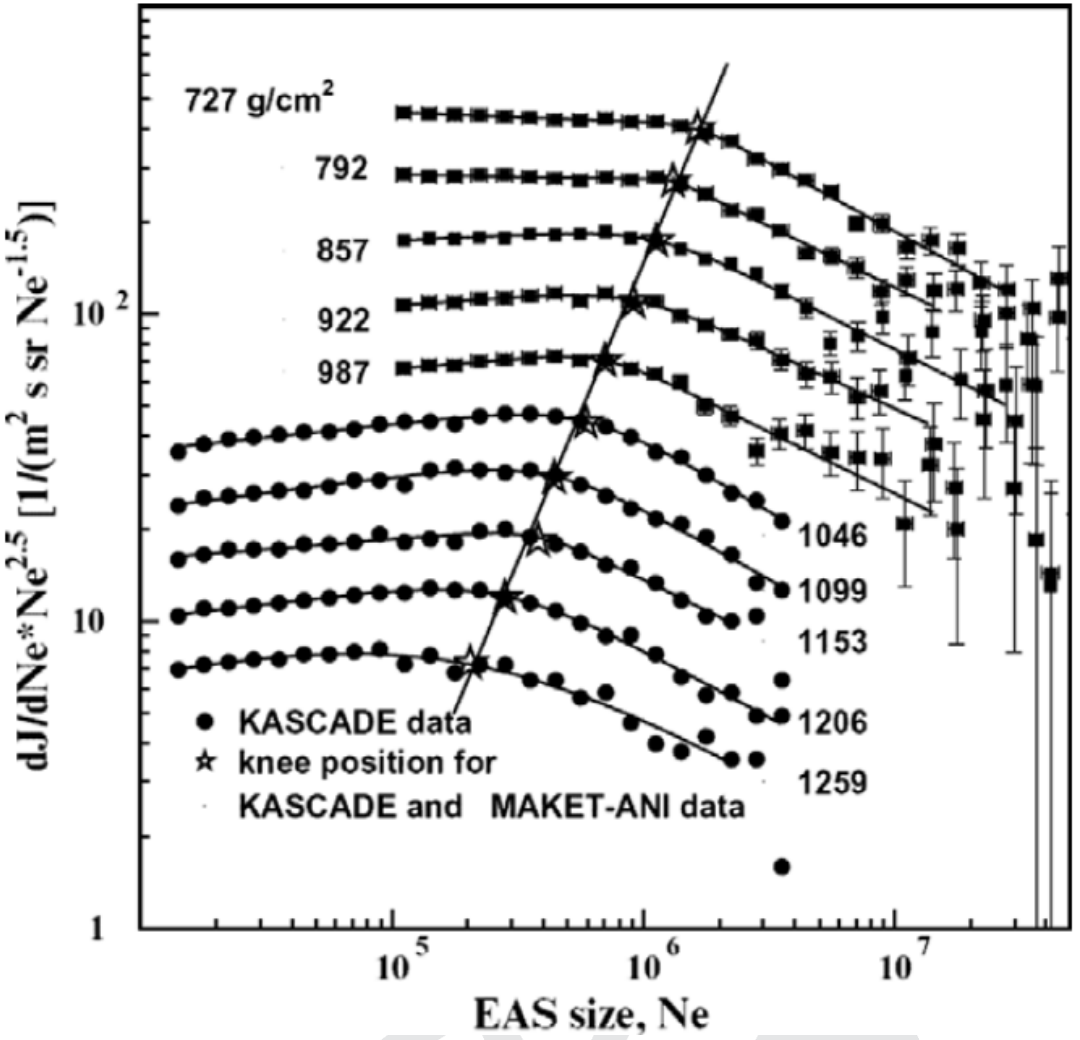
MAKET-ANI
(A.Chilingarian, 2007):
$\lg N_{ek} = 5.84 \pm 0.07$
$\Delta k = 0.48 \pm 0.04$

KASCADE
(K.-H. Kampert, 1998):
$\lg N_{ek} = 5.70 \pm 0.07$

Shower size spectrum



The position of the knee is changing :
from N_e (35°÷37°) = **2.2×10^5** to N_e (0°÷18°) = **4.5×10^5**.



A. Chilingarian et al. Astroparticle Physics 28 (2007) 58–71.