The ⟨lnA⟩ study with the Muon Tracking Detector in the KASCADE-Grande experiment – comparison of hadronic interaction models

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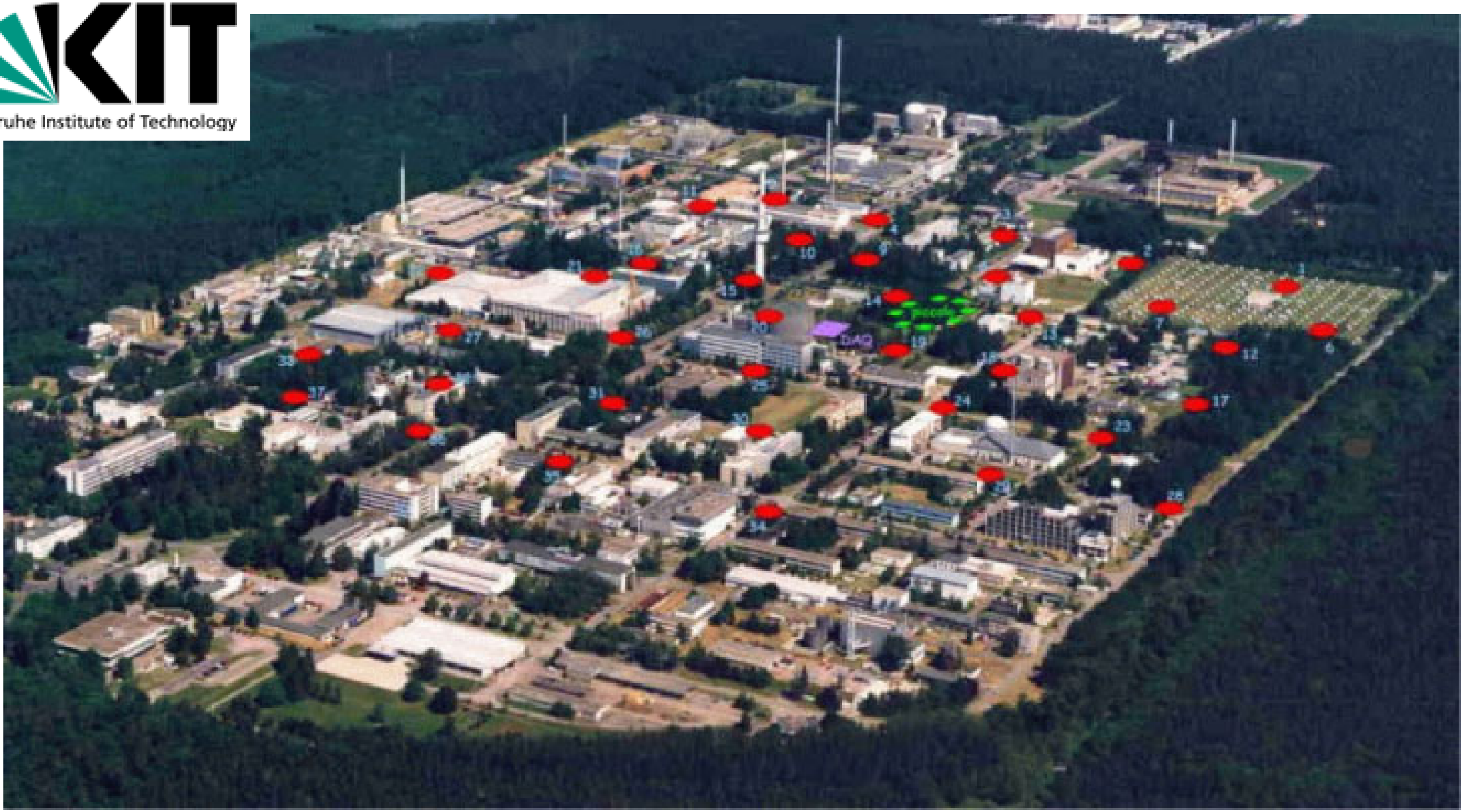
Outline

- Short introduction to the KASCADE-Grande experiment
- The Muon Tracking Detector
- Pseudorapidity of muons
- The mass sensitivity of the EAS muon pseudorapidity
- <lnA> analysis:<η> and the first quartile of the pseudorapidity distribution
- The results: <ln A> values for QGSJet-II-2, QGSJet-II-4, EPOS 1.99 and EPOS LHC
- Conclusions

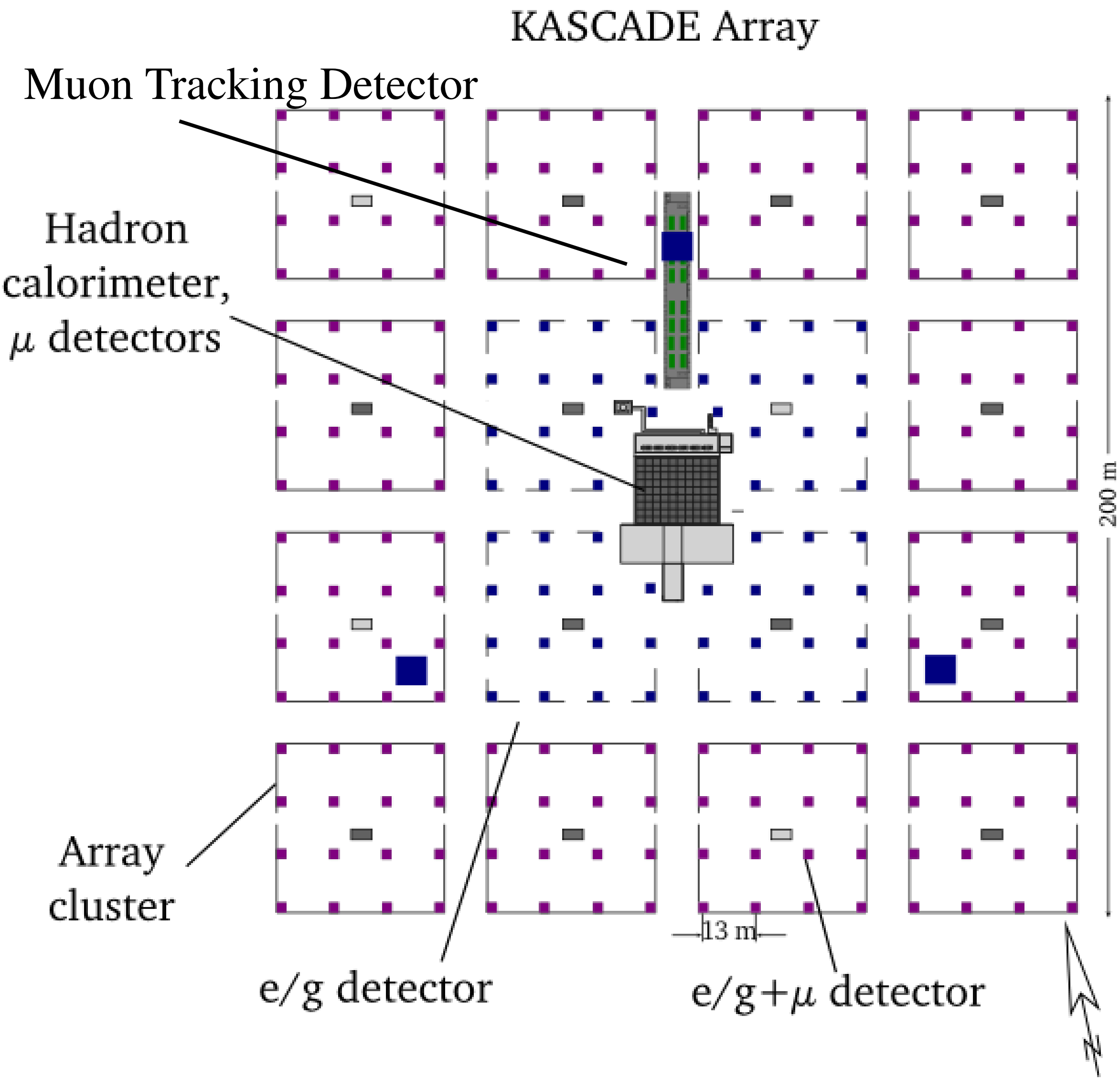
Introduction to the KASCADE-Grande experiment

Karlsruhe Institute of Technology



KASCADE-Grande was located at Karlsruhe Institute of Technology, Campus North, Germany at 110 m a.s.l., corresponding to an average atmospheric depth of 1022 g/cm^2. Energy range of detected EAS: 3×10^{14} eV to 10^{18} eV

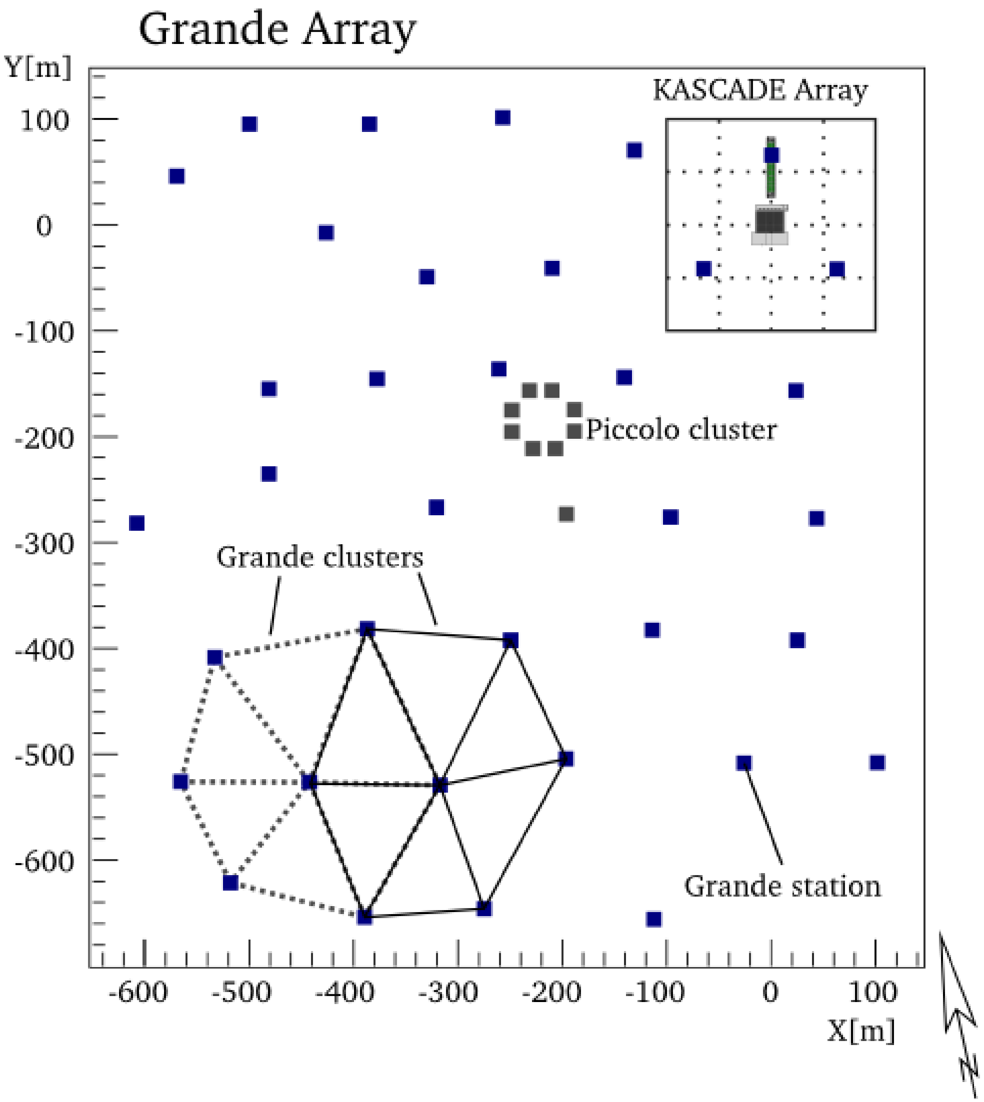
Introduction to the KASCADE-Grande experiment



KASCADE Array:
252 detector stations detecting charged particles (liquid scint., energy above 5MeV, 490 m^2 of total area,) and/or muons (plastic scint.,energy above 230 MeV, 622 m^2 of total area), hadron calorimeter and the large area Muon Tracking Detector

W.D. Apel et al. NIM A 620 (2010) 202–216

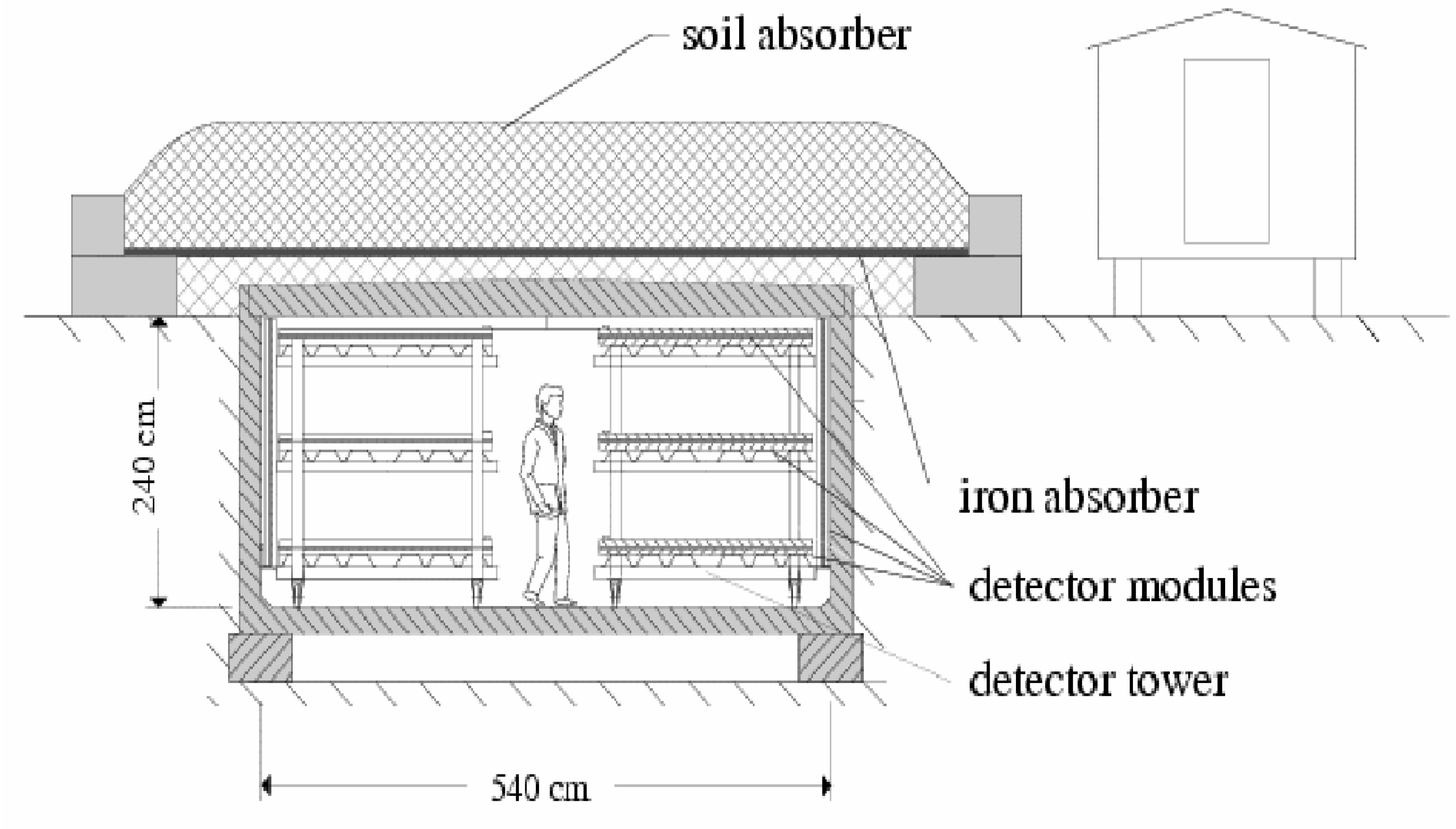
Introduction to the KASCADE-Grande experiment



Grande Array:
37 detector stations, each with 10 m^2 of plastic scintillators for detection of charged particles with energy above 3 MeV

W.D. Apel et al. NIM A 620 (2010) 202–216

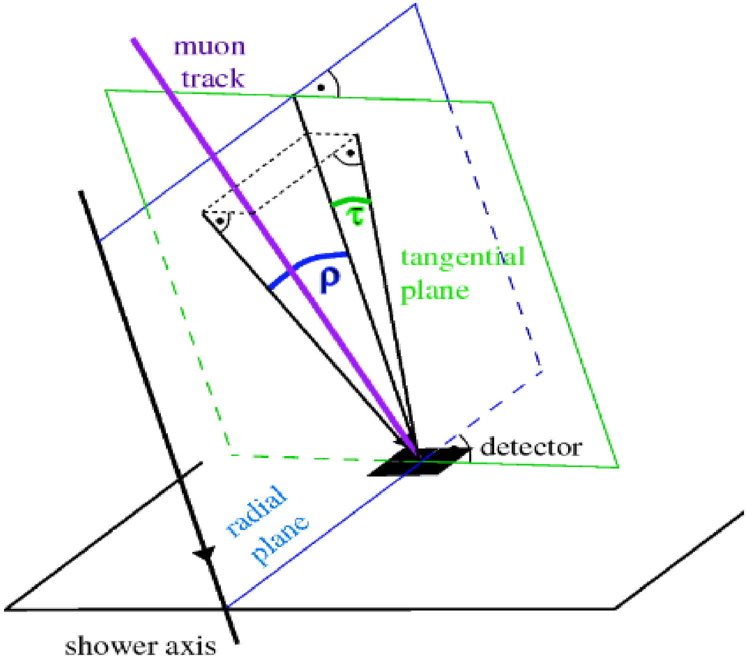
The Muon Tracking Detector



The Muon Tracking Detector:
16 streamer tube muon telescopes, 128 m^2 total area, located in concrete tunnel under concrete-soil-iron absorber, energy threshold for muons: 800 MeV
Directions of muon tracks are measured with angular resolution of ~0.35°

P. Doll et al. NIM A 488 (2002) 517–535

Pseudorapidity of muons



In terms of radial and tangential angle pseudorapidity is given by the formula[1]:

$$\eta = -\ln\left(\frac{\sqrt{\rho^2+\tau^2}}{2}\right)$$

valid when |ρ|<=0.4 rad and |τ|<=0.4 rad.

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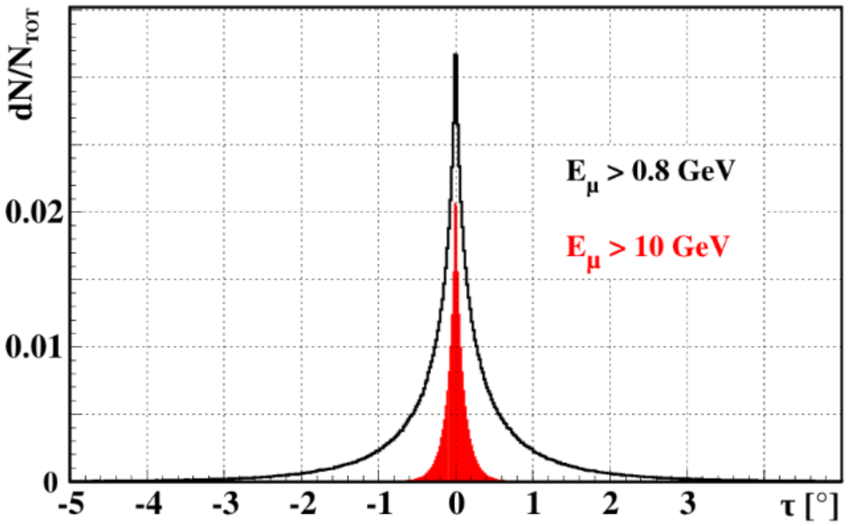
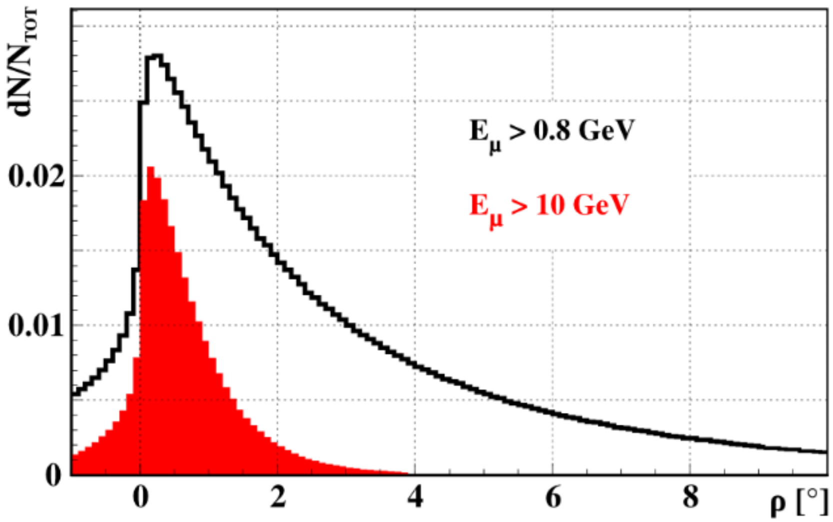
1) J. Zabierowski, K. Daumiller, P. Doll,Nucl. Phys B (Proc. Suppl.)122 (2003) 275

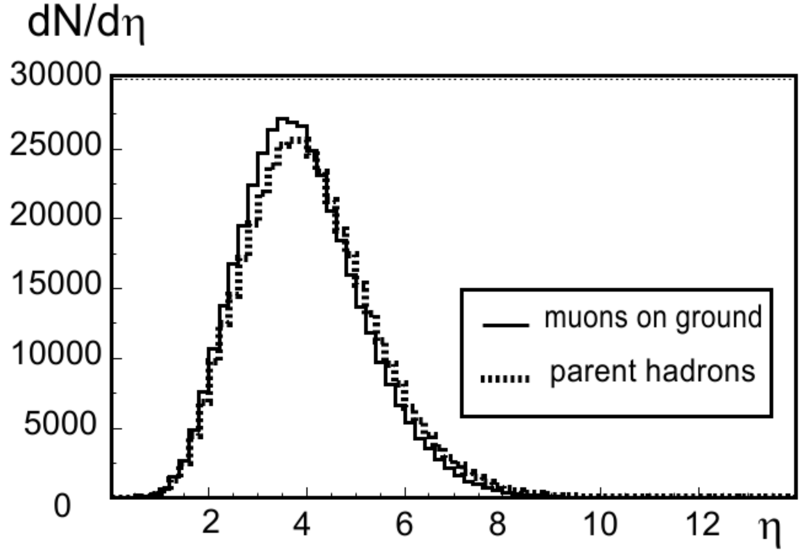




Pseudorapidity of muons as a tool for testing hadronic interaction models

Pseudorapidity of EAS muons is sensitive to the longitudinal development of the EAS.
It reflects the development of the air shower in similar way as the muon production height¹⁾.
Pseudorapidity of EAS muons reflects also the pseudorapidity of their parent hadrons²⁾, giving us insight into hadronic interactions within the air shower. This makes it an excellent tool for testing hadronic interaction models used to describe the EAS.

Pseudorapidity of EAS muons on ground compared with rapidity of their parent hadrons.

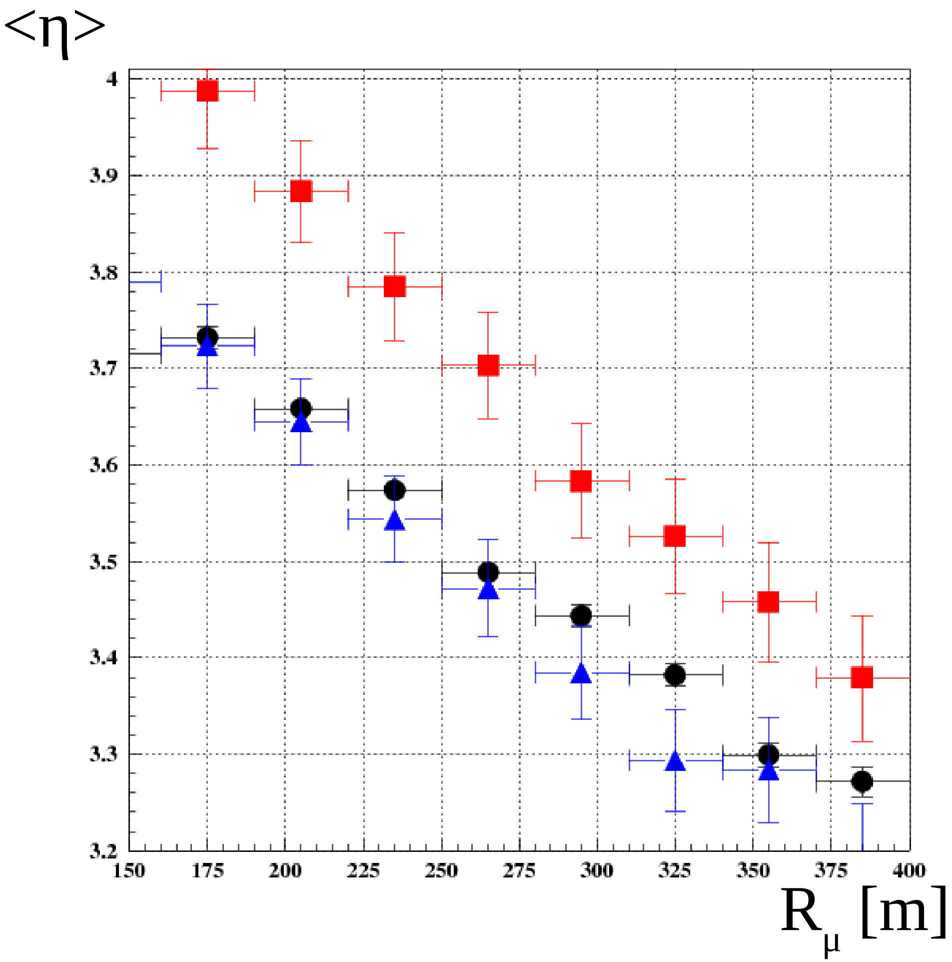


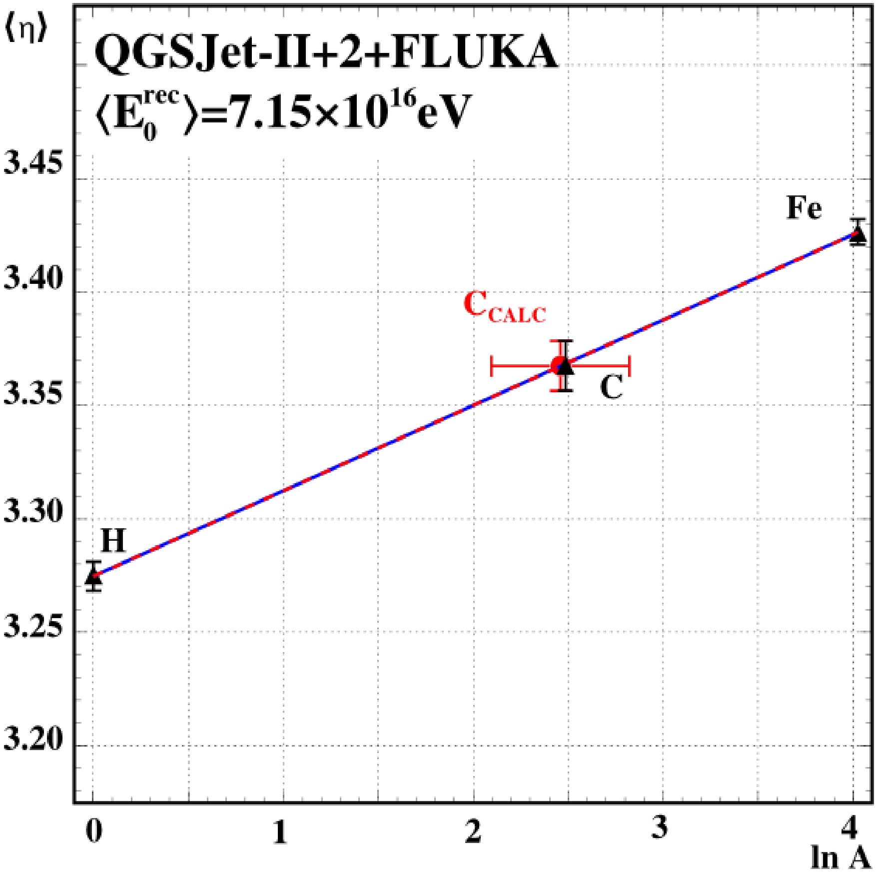
1) W.D. Apel et al., Astropart. Phys. 34 (2011) 476–485

2) J. Zabierowski et al. 29th ICRC vol. 6, p 357–360, Pune, India, 2005. FZKA 7187

The mass sensitivity of the EAS muon pseudorapidity: the mean of the pseudorapidity distribution

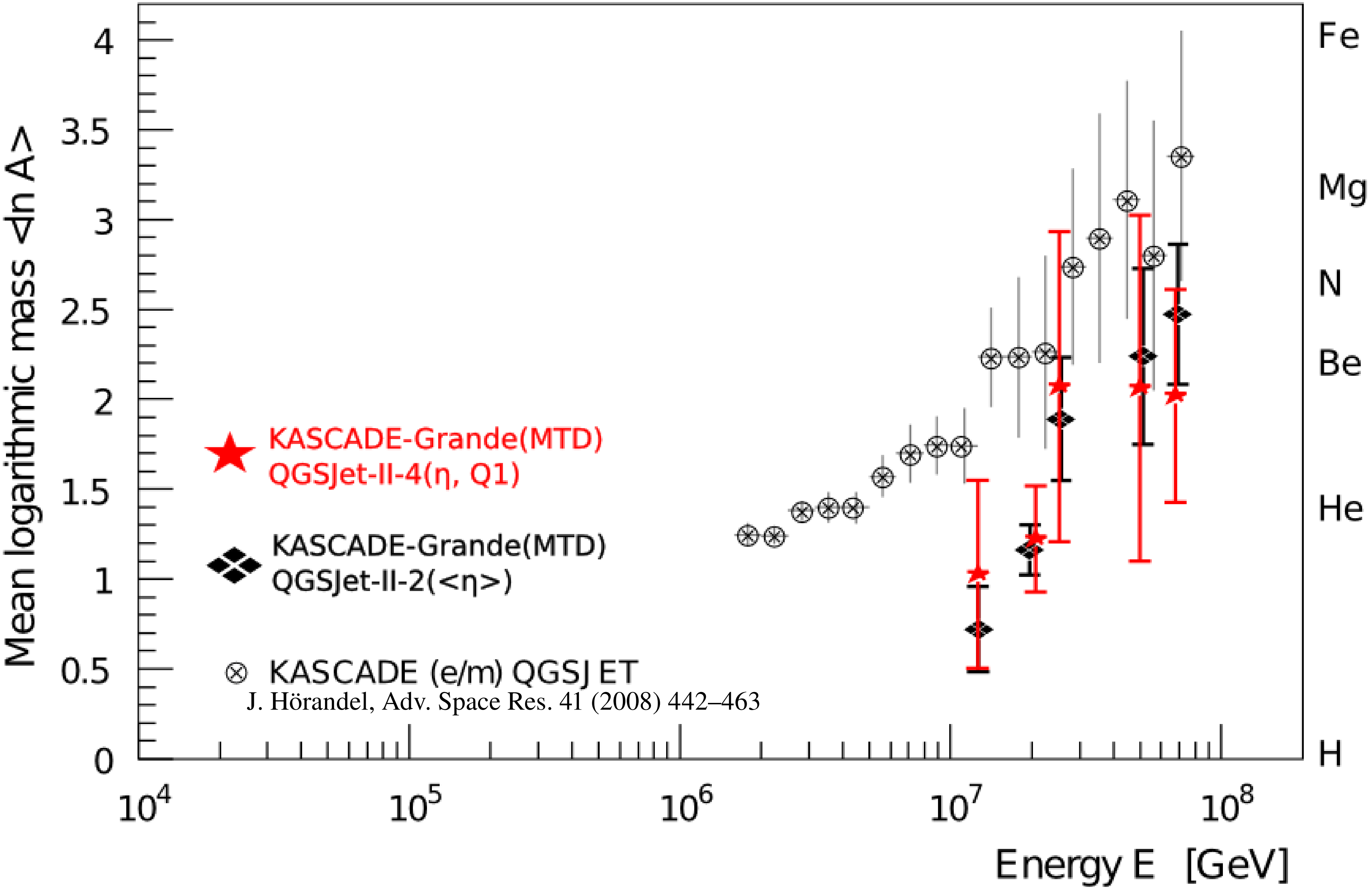
$$\langle \ln A \rangle \equiv \sum_i r_i \ln A_i, \xrightarrow{\text{superposition mode}} \langle \ln A \rangle = \frac{\langle \eta \rangle - \langle \eta_H \rangle}{\langle \eta_{Fe} \rangle - \langle \eta_H \rangle} \ln(A_{Fe})$$





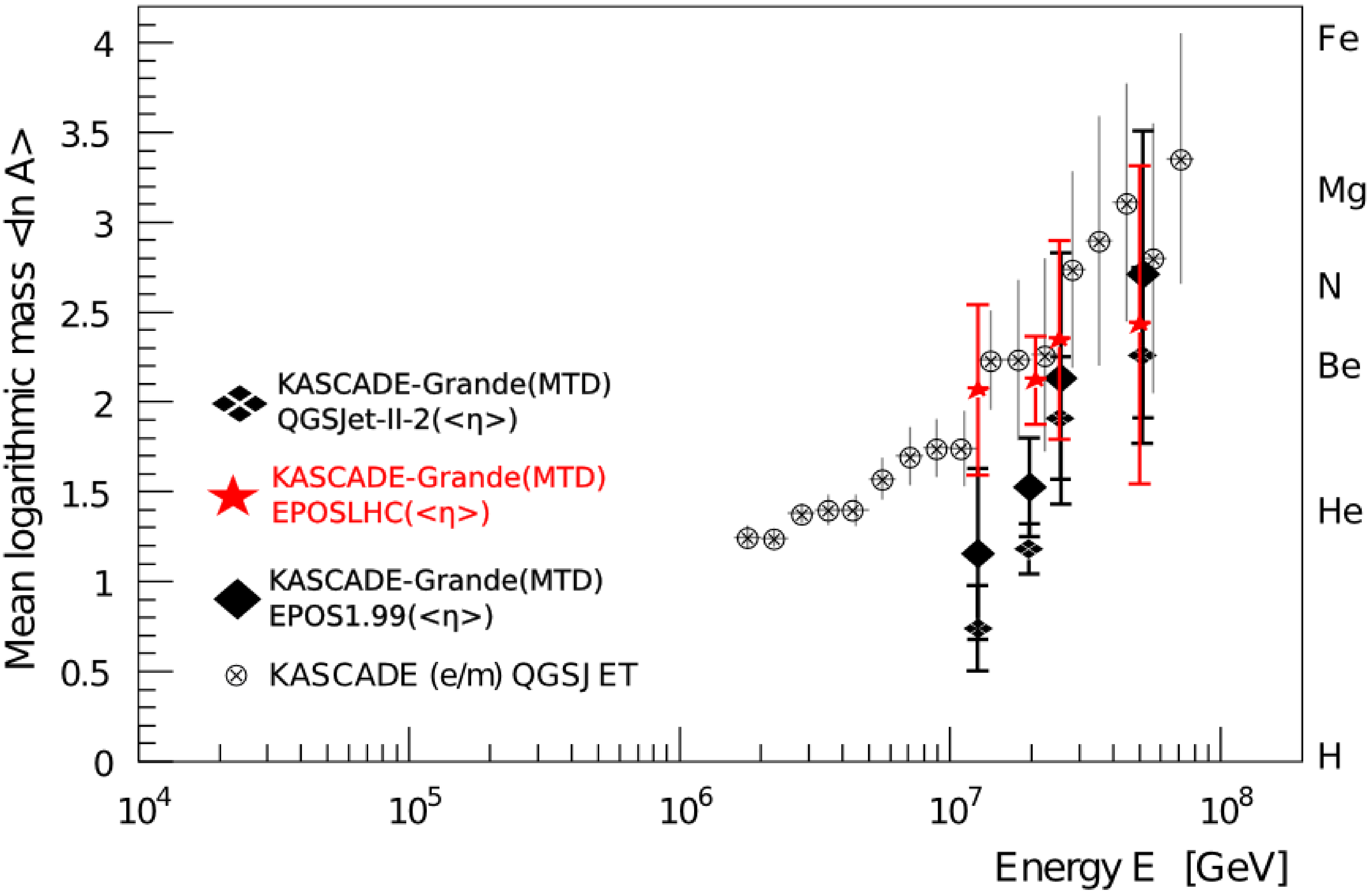
P. Łuczak, Ph.D. Thesis, NCNR, Poland, 2012, http://www.ncbj.gov.pl/node/1951

The results: the mean logarithm of mass calculated with the mean pseudorapidity



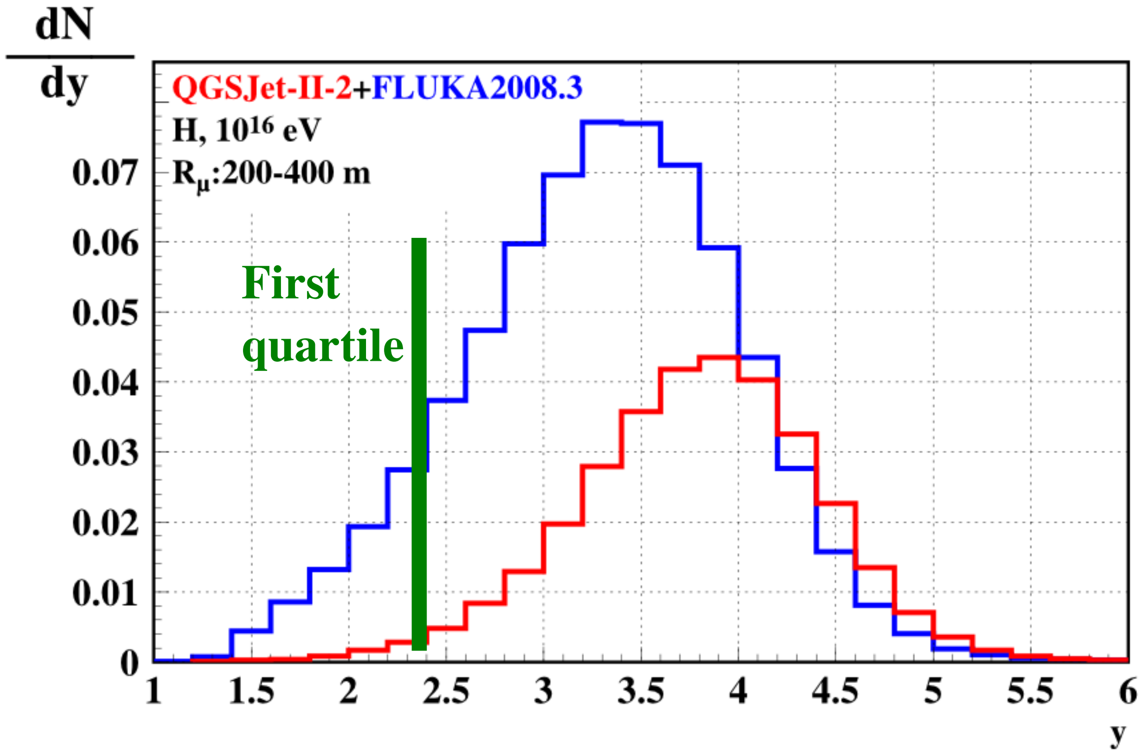
J. Hörandel, Adv. Space Res. 41 (2008) 442–463

The results: the mean logarithm of mass calculated with the mean pseudorapidity

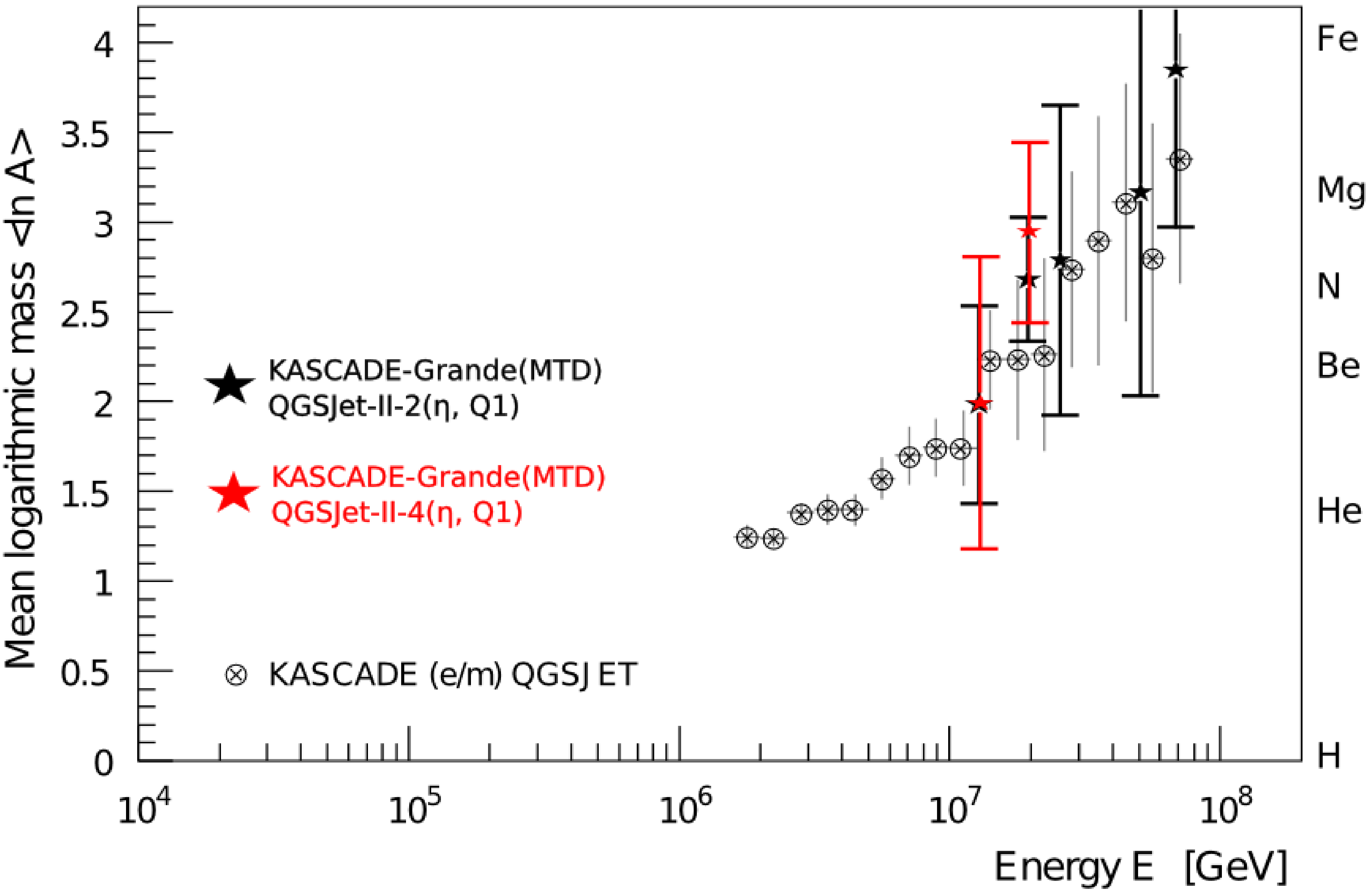


The mass sensitivity of the EAS muon pseudorapidity: the first quartile of the η distribution

With simulations we can investigate separately the pseudorapidity distributions of muons originating from hadrons which interactions are simulated with high energy and low energy interaction models. Applying angular cuts it is possible to reduce the influence of each population of muons.



The results: the mean logarithm of mass calculated with the first quartile of the pseudorapidity



Conclusions:

1) QGSJet-II-4+FLUKA model combination indicates the trend of the <lnA> towards higher values in comparison with the QGSJet-II-2+FLUKA. However the analysis requires larger statistics of simulated showers (work in progress).
2) The results from the first quartile analysis are compatible with the KASCADE and Grande results which means that this method can be used to investigate the mass composition using pseudorapidity of muons.

Conclusions: cd.

3) Comparison between EPOS1.99+FLUKA and EPOSLHC+FLUKA model combinations shows that the <lnA> from the later model combination has higher values.

4) The increase in <lnA> values is especially visible in the first three presented energy points. In the other energy ranges the <lnA> values are similar within statistical errors.

5) The results of the <lnA> analysis for the EPOSLHC model are compatible with KASCADE and Grande results, they have similar values which rise with the primary energy at similar rate.

6) This is a significant improvement with respect to the previous version of EPOS model, where the <lnA> values were lower than those from KASCADE analysis.

Thank You

Backup:

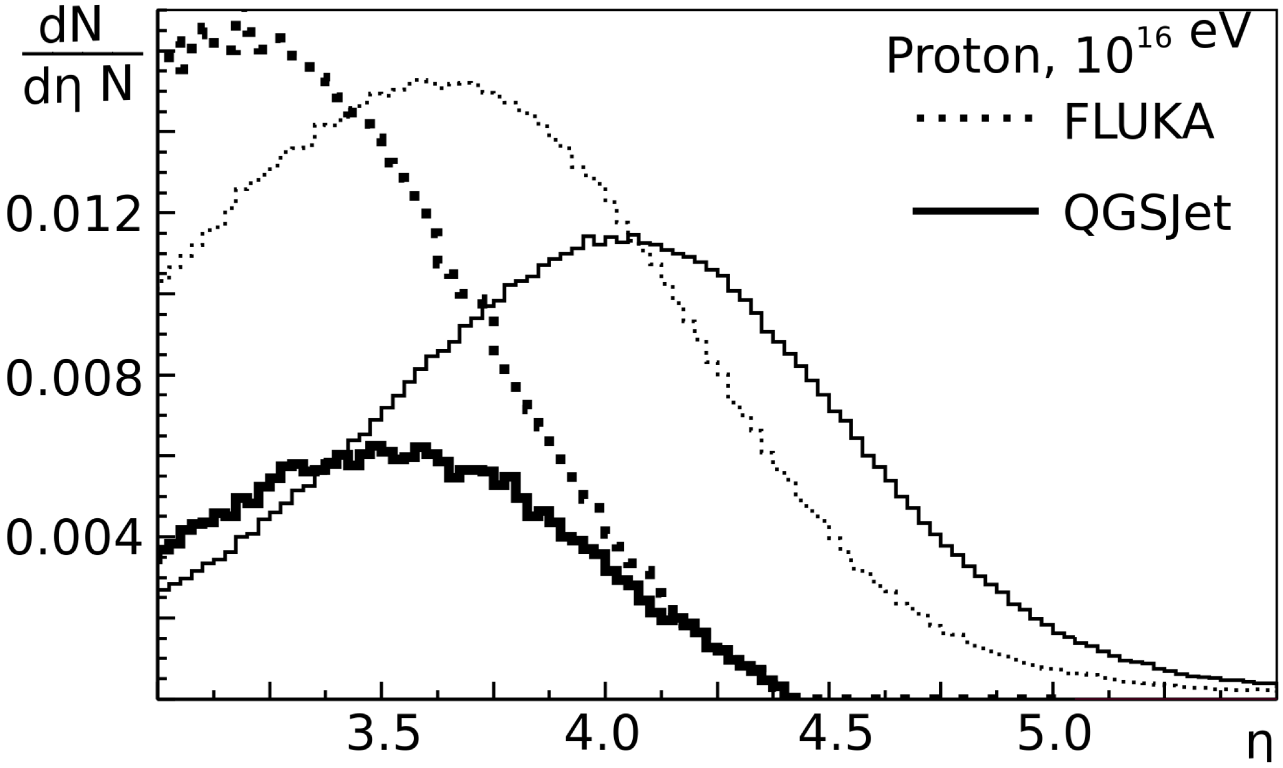


Figure shows the influence of angular cuts. Thin lines – eta distributions before the angular cuts, bold lines – eta distributions after the angular cuts.

However, in the data we can not cut angles too strong. For the purpose of this analysis the angle cuts are $0.75^\circ < \rho < 17^\circ$ and $0.2^\circ < |\tau| < 17^\circ$.