

Longitudinal Shower Development Studies Near 8 TeV

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Interpretation of KASCADE-Grande Data using MC

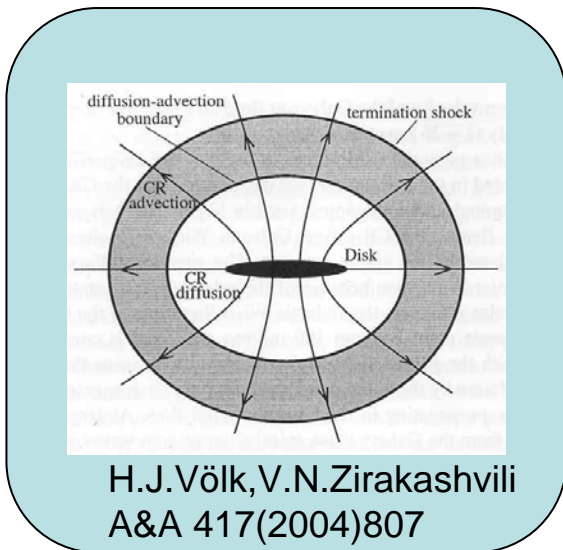


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CORSIKA, D.Heck et al. FZKA 6019, Forschungszentrum Karlsruhe

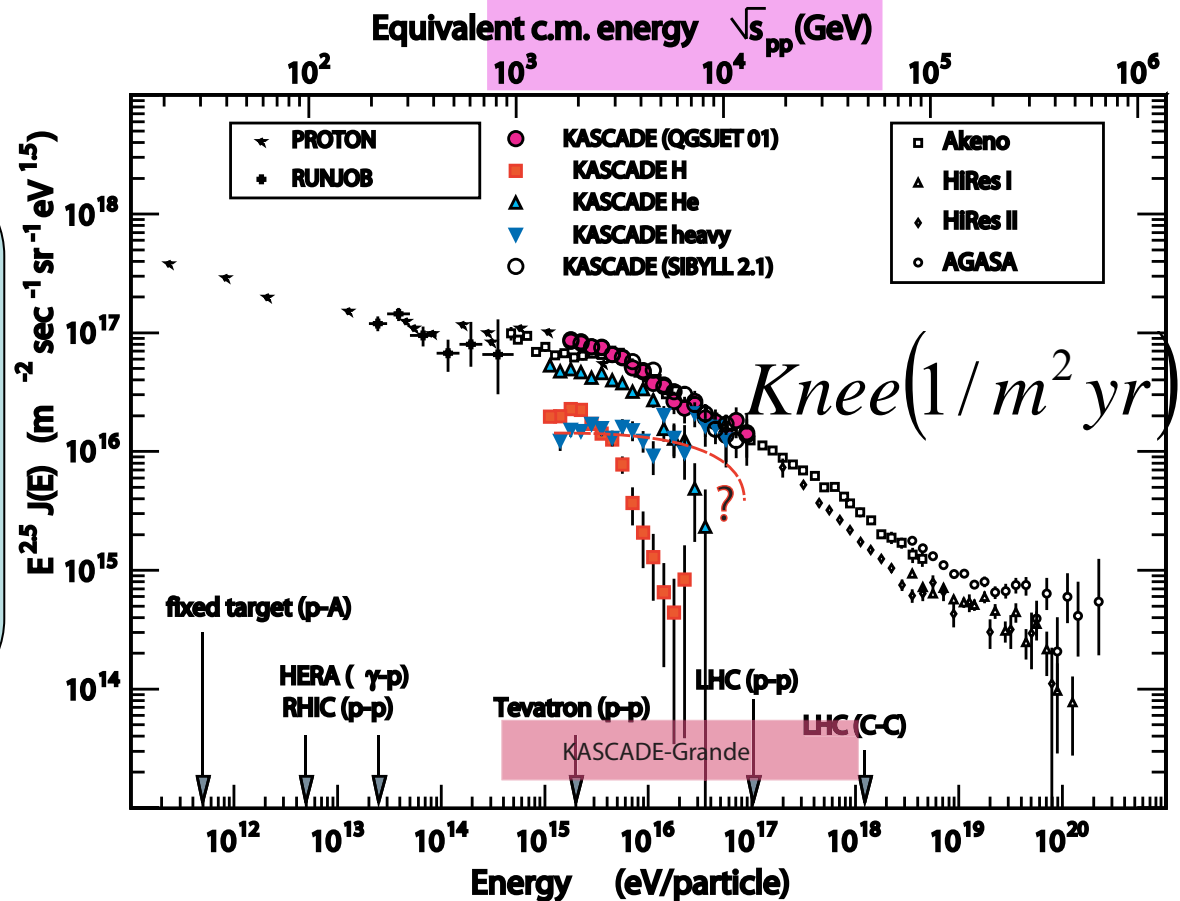
Study of Cosmic Rays (CR)

Cosmic Radiation opens a window to the high energy processes in the Cosmos. We obtain information from electromagnetic and particle radiation.



1. Acceleration
2. Propagation
3. Fragmentation

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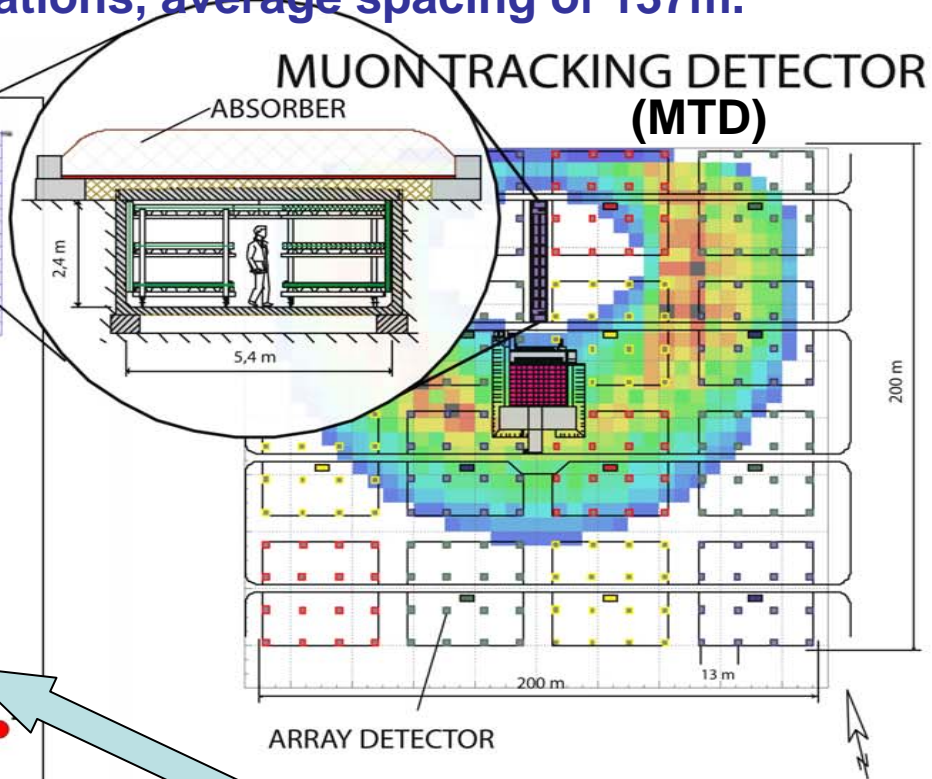
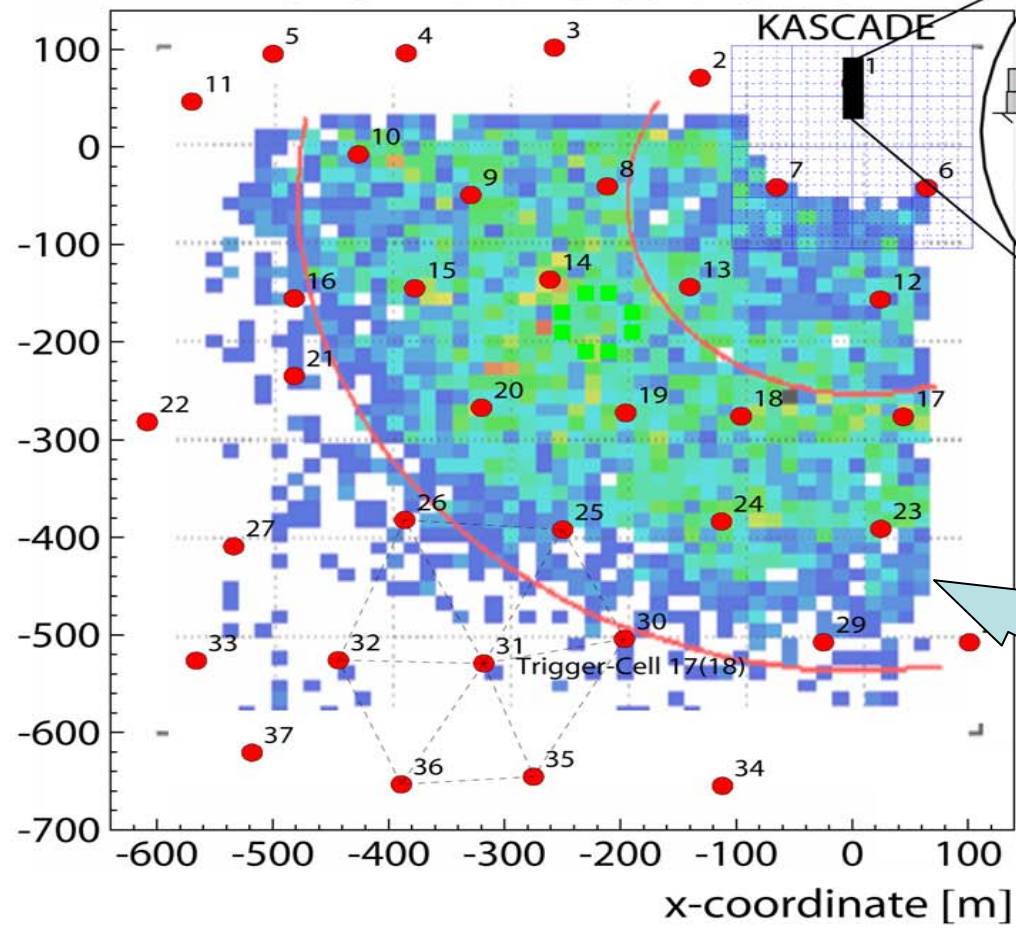


Berezinsky et al., Nucl.Phys.B(Proc.Suppl.)151(2006)497
 Wibig et al., J.Phys.G 31(2005)255
 de Rujula et al., Nucl.Phys.B (Proc.Suppl.)151(2006)23
 R.Engel priv.communication

Air Shower Experiment KASCADE-Grande

Area: 0.5 km² , Grande array of 37 stations, average spacing of 137m.

Grande-Stations



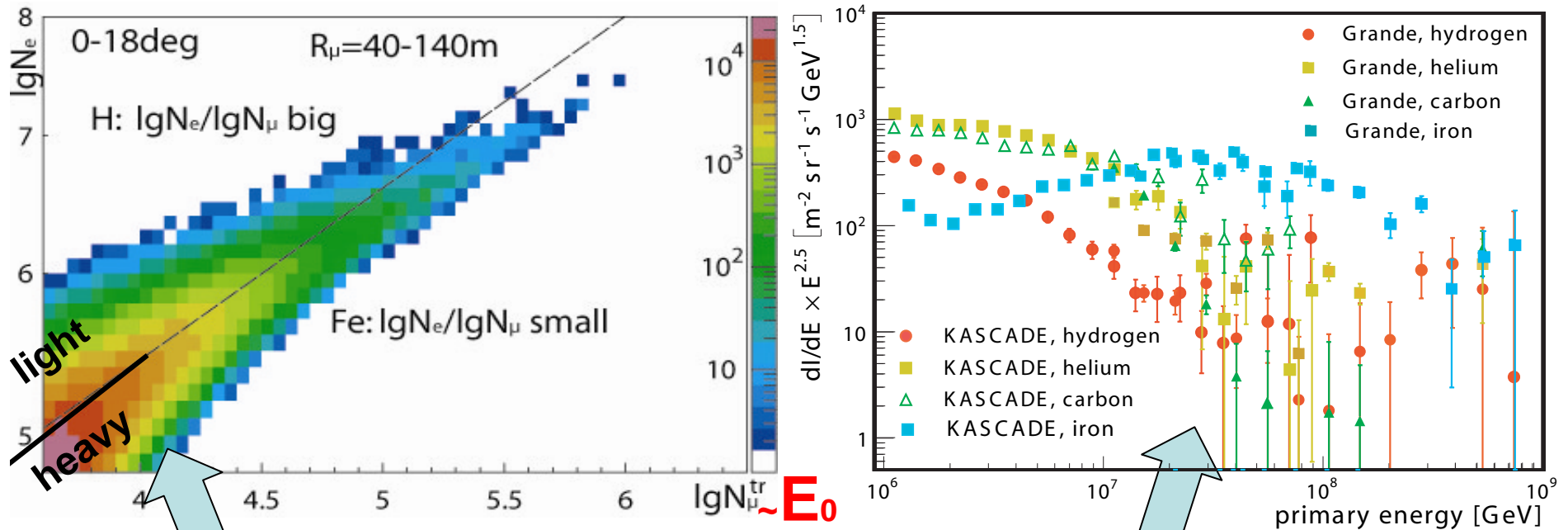
Shower-Core Distribution

parameters : $N_e, \theta_s, \varphi_s, N_\mu, \theta_\mu, \varphi_\mu, N_h, E_h$

Unfolding $\lg N_e/\lg N_\mu$ Size using CORSIKA-simulations:

$$p_A\left(\left(\lg N_e, \lg N_\mu\right)_i \mid \lg E_0\right)$$

Each cell in the $\lg N_e/\lg N_\mu$ presentation has contributions from different cosmic ray particles A and different particle energy E_0 .



$$\left(\frac{dJ}{d \lg N_e d \lg N_\mu}\right)_i = \sum_A \int_{-\infty}^{+\infty} p_A\left(\left(\lg N_e, \lg N_\mu\right)_i \mid \lg E_0\right) \frac{dJ_A}{d \lg E_0} d \lg E_0$$

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QGSJET II: S.Ostapchenko, Phys.Rev.D 74 (2006) 014026

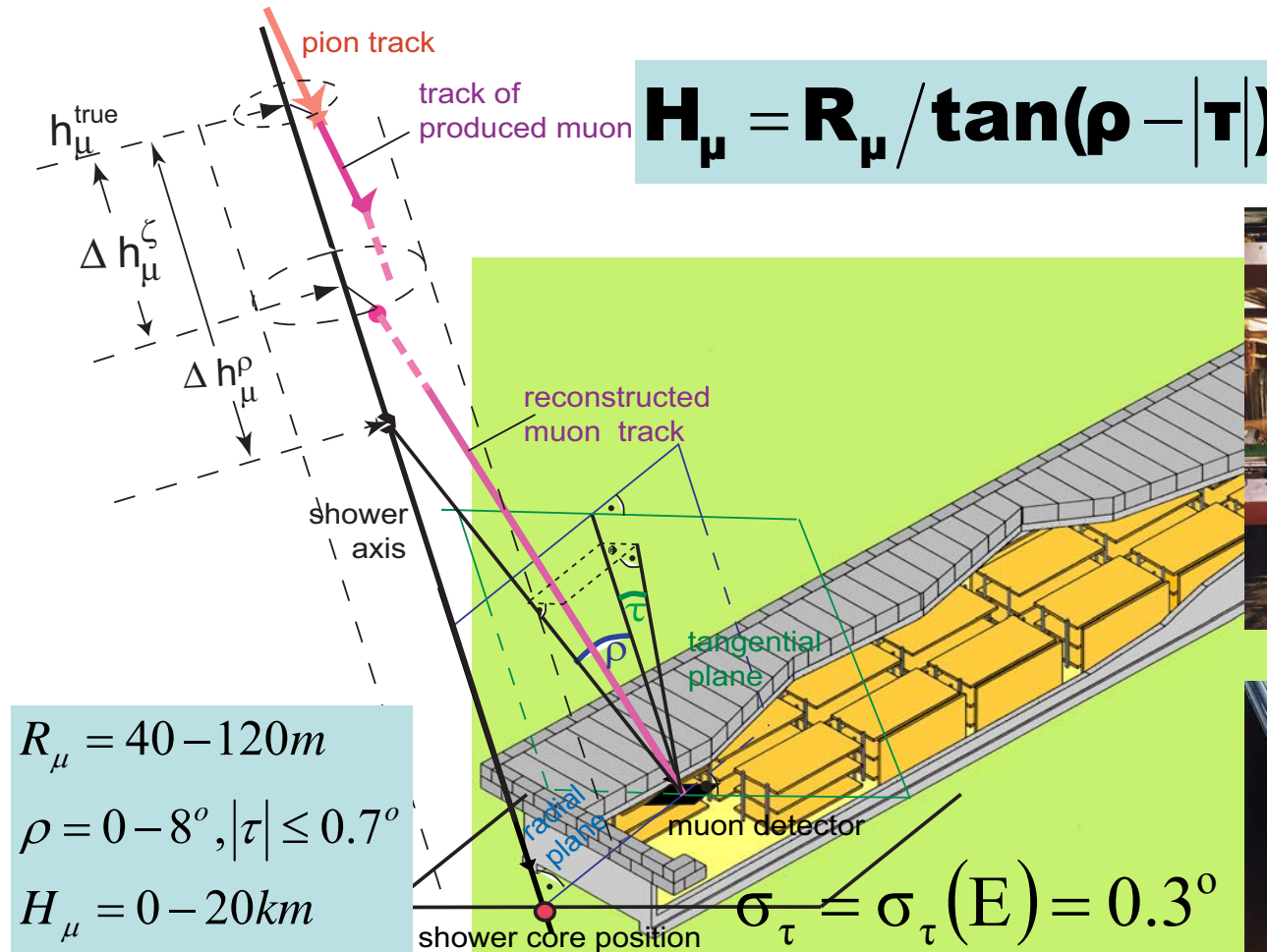
T.Antoni et al. KASCADE, Astropart.Phys. 24(2005)1

H.Ulrich et al. KASCADE-Grande, ISVHECRI, Weihei China (2006)

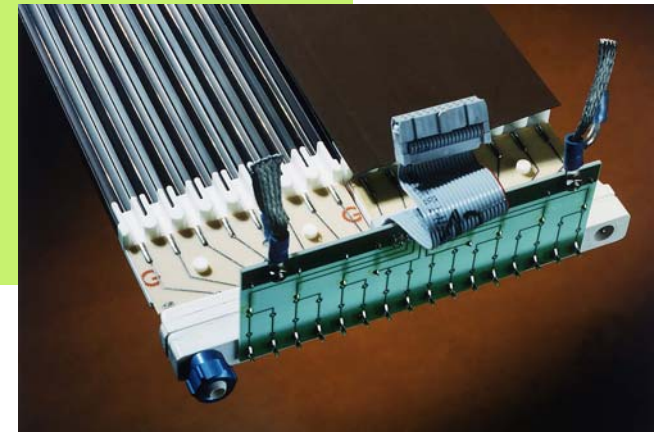
M.Finger PhD 2011 University Karlsruhe

Muon Production Height

The Muon Tracking Detector (MTD) measures direction of muons with respect to the shower axis. One can determine the Muon Production Height H_μ .

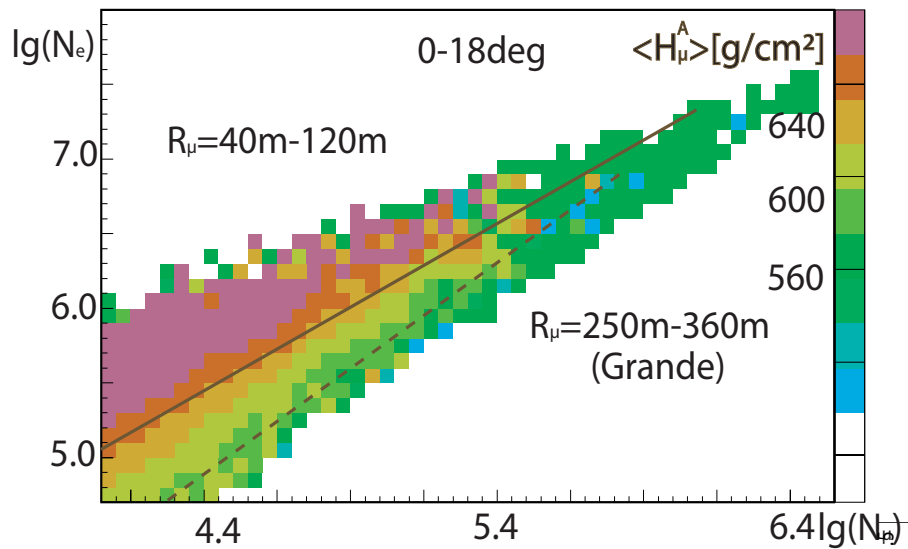


128m², Filter: $E_\mu > 0.8\text{GeV}$



Mass Dependent Energy Spectra

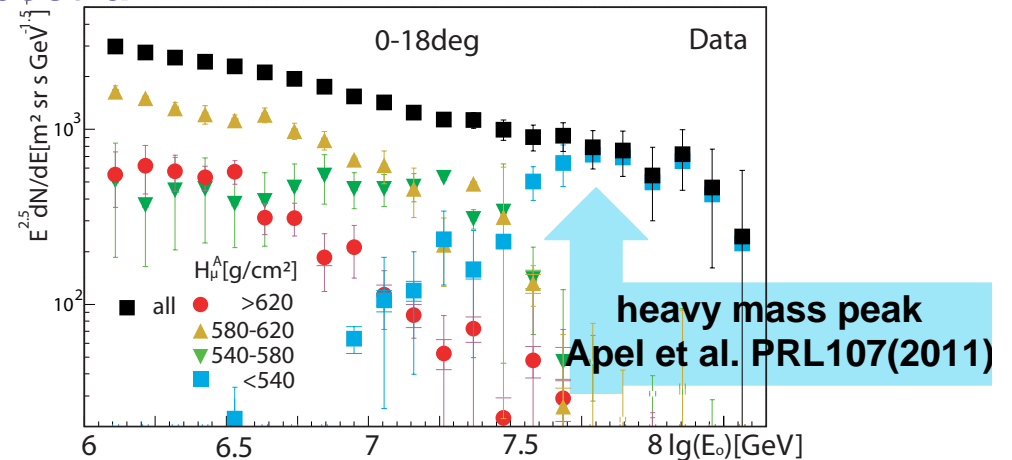
Regions of constant H_μ^A . Sorting the $\lg N_e, \lg N_\mu$ events after the range in H_μ^A one can obtain mass dependent energy spectra.



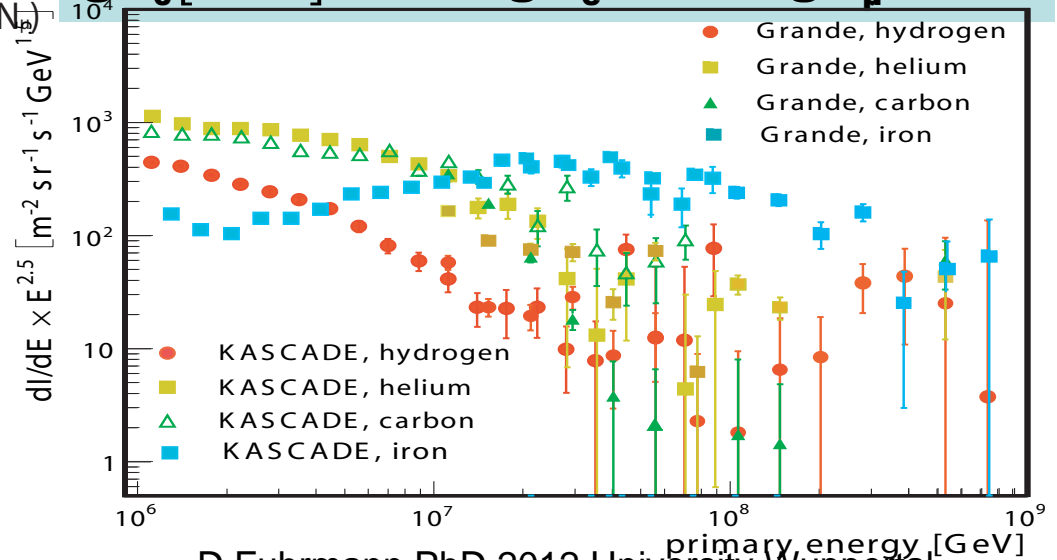
$$\langle H_\mu^A \rangle = \langle H_\mu^P \rangle - X_0 \ln A$$

Unfolding $\lg N_e / \lg N_\mu$ size using CORSIKA-simulations can be improved including H_μ parameter.

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$$\lg E_0 [\text{GeV}] = 0.19 \lg N_e + 0.79 \lg N_\mu + 1.93$$



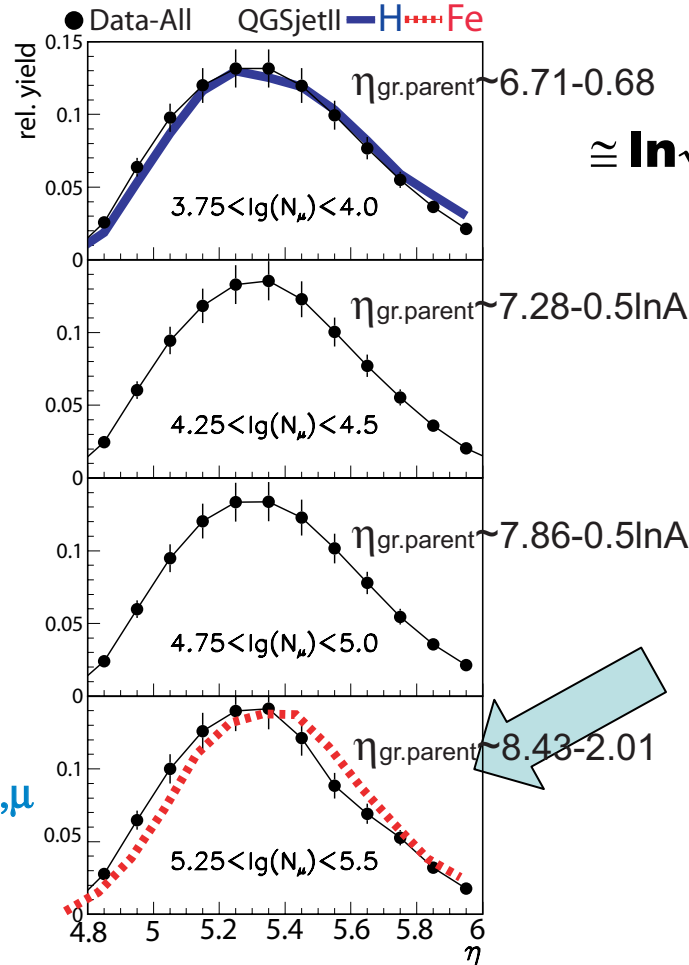
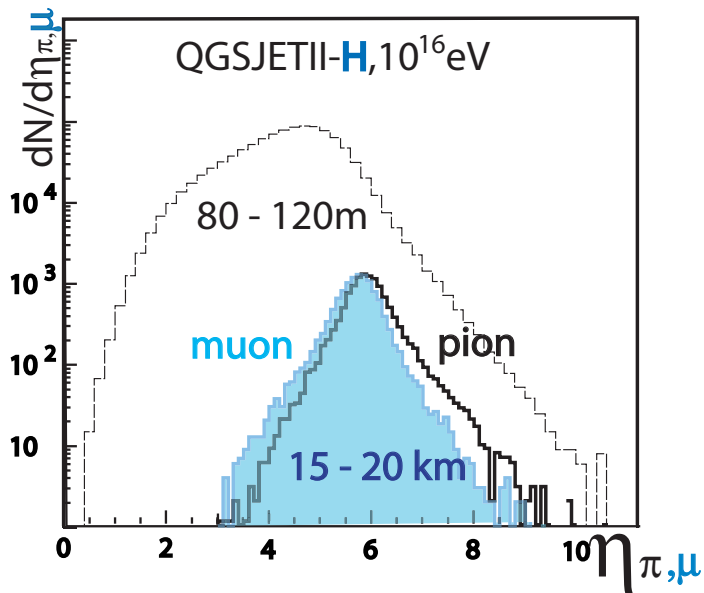
D.Fuhrmann PhD 2012 University Wuppertal
M.Finger PhD 2011 University Karlsruhe
J.Matthews Astro.Part.Phvs.22(2005)387

μ-Pseudorapidity Range in Diffraction

$$\eta \cong \ln(p_{||}/p_{\perp}) \cong -\ln(\sqrt{\rho^2 + \tau^2}/2)$$

$$(R_{\mu} = 80 - 120\text{m}, h_{\mu} > 15\text{km})$$

Which step in the shower-development do we see?



$$\cong \ln\sqrt{s} = \ln\sqrt{2E_0/3} - 0.5\ln A$$

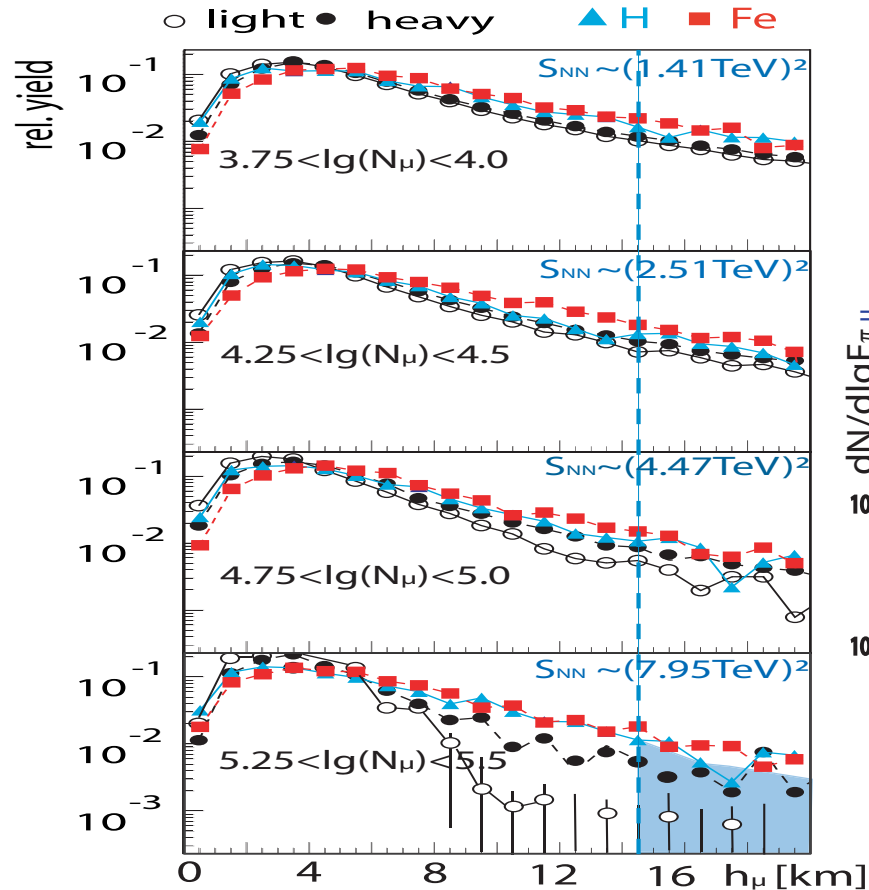
$$N_{\mu} = A(E_0/A)^{\beta}$$

$E_0/3A$ available in lab.system for π production.

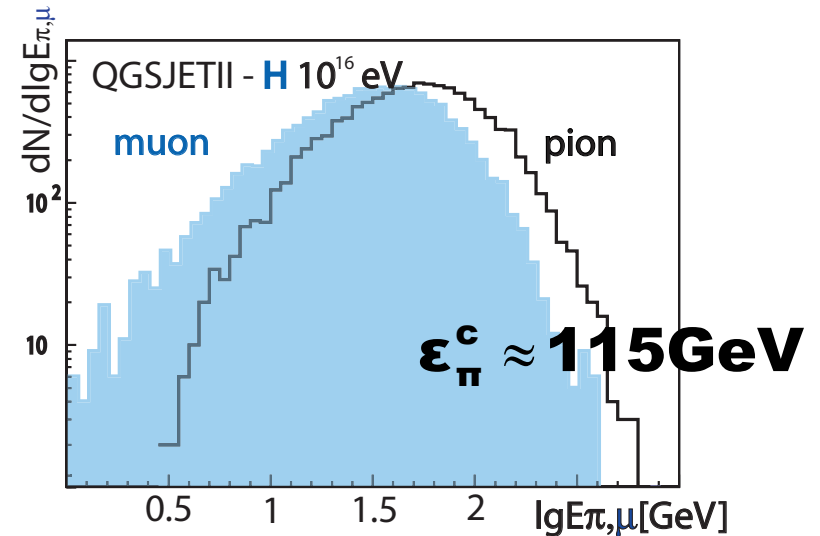
Rapidity Gap:
 $\eta_{gr.parent} - \eta_{\mu} \sim 3.$

Good description with QGSjetII.

Muon Production Height h_μ for light-heavy ($\lg N_e/\lg N_\mu$) CR-Mass



Parameter h_μ exhibits information from
1. Interaction (pt increase?).



missing secondary hadron production in the diffraction process at ~ 8 TeV,
regular shower development further down.

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S.I.Nikolsky, Nucl.Phys. B (Proc.Suppl.) 39A(1995) 228
P.Doll et al., <http://arxiv.org/abs/1010.2702>
QGSJET II: S.Ostapchenko, Phys.Rev.D 74 (2006) 014026

Longitudinal Shower Development Studies

1. Improved understanding of CR shower development from 1.4 - 8 TeV using Muon Tracking.
2. Muon Production Height shows near ~8 TeV above 15 km for light CR mass (proton) reduction of muons ($M_x \sim 1-2$ TeV).
3. Nikolsky (1995) also observed for light CR particles a change in the multiple pion production near ~8 TeV.
4. Comparison with future LChf and CASTOR studies.

