Diffractive Production of Missing Mass in Air-Showers above 10**16 eV

(KASCADE-Grande Collaboration)

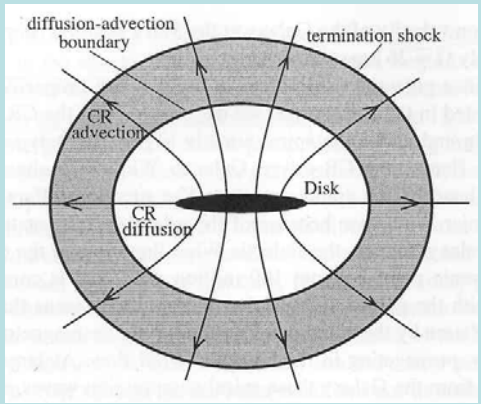
P.Doll for KASCADE-Grande

5-4-2018

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

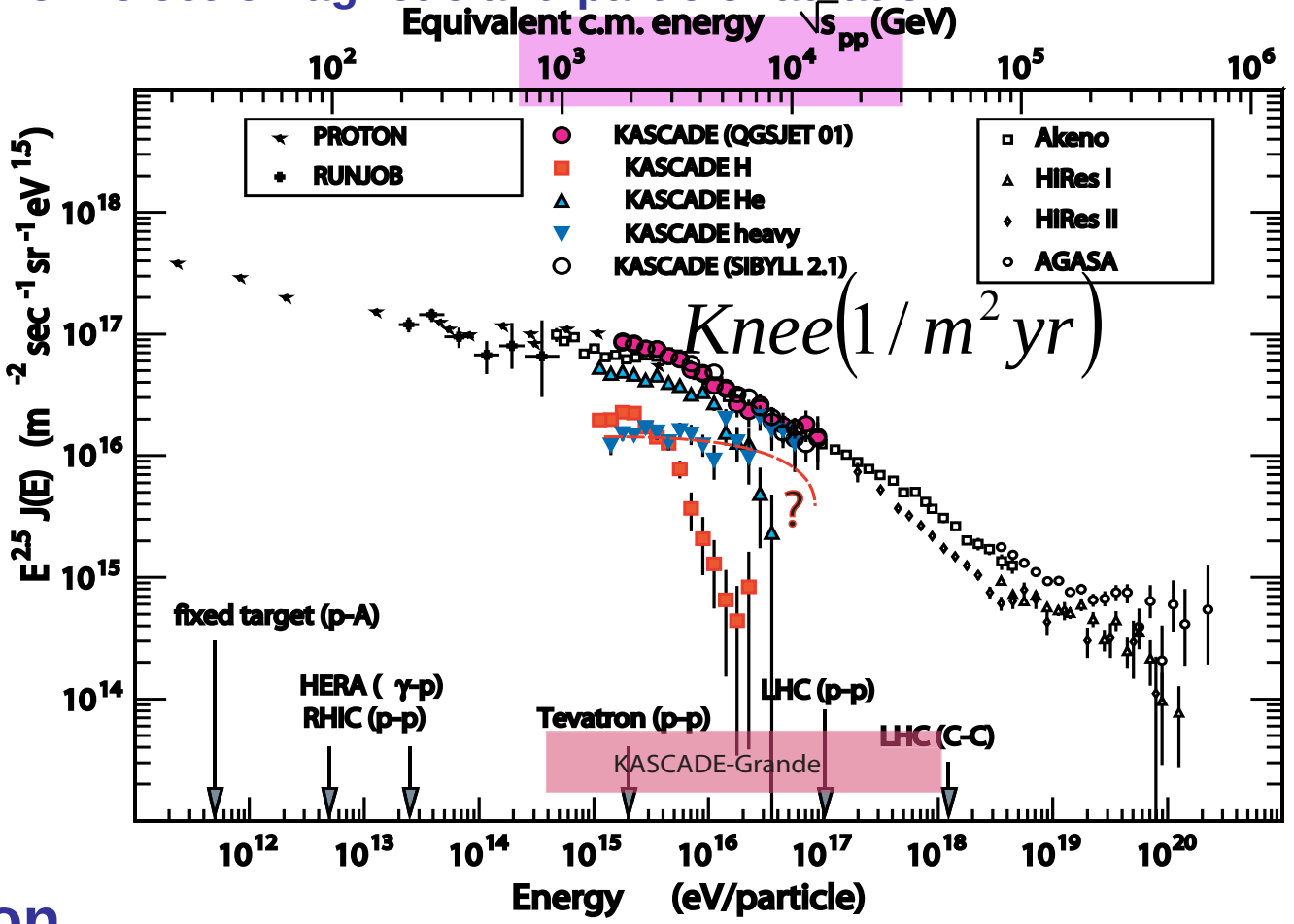
Study of Cosmic Rays

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



H.J.Völk,V.N.Zirakashvili
A&A 417(2004)807

1.Acceleration
2.Propagation
3.Fragmentation



Berezinsky et al., Nucl.Phys.B(Proc.Suppl.)151(2006)497
Wibig et al., J.Phys.G 31(2005)255
D.Kang and S.Schoo, 35.ICRC(2017), Buson, Korea
R.Engel priv.communication

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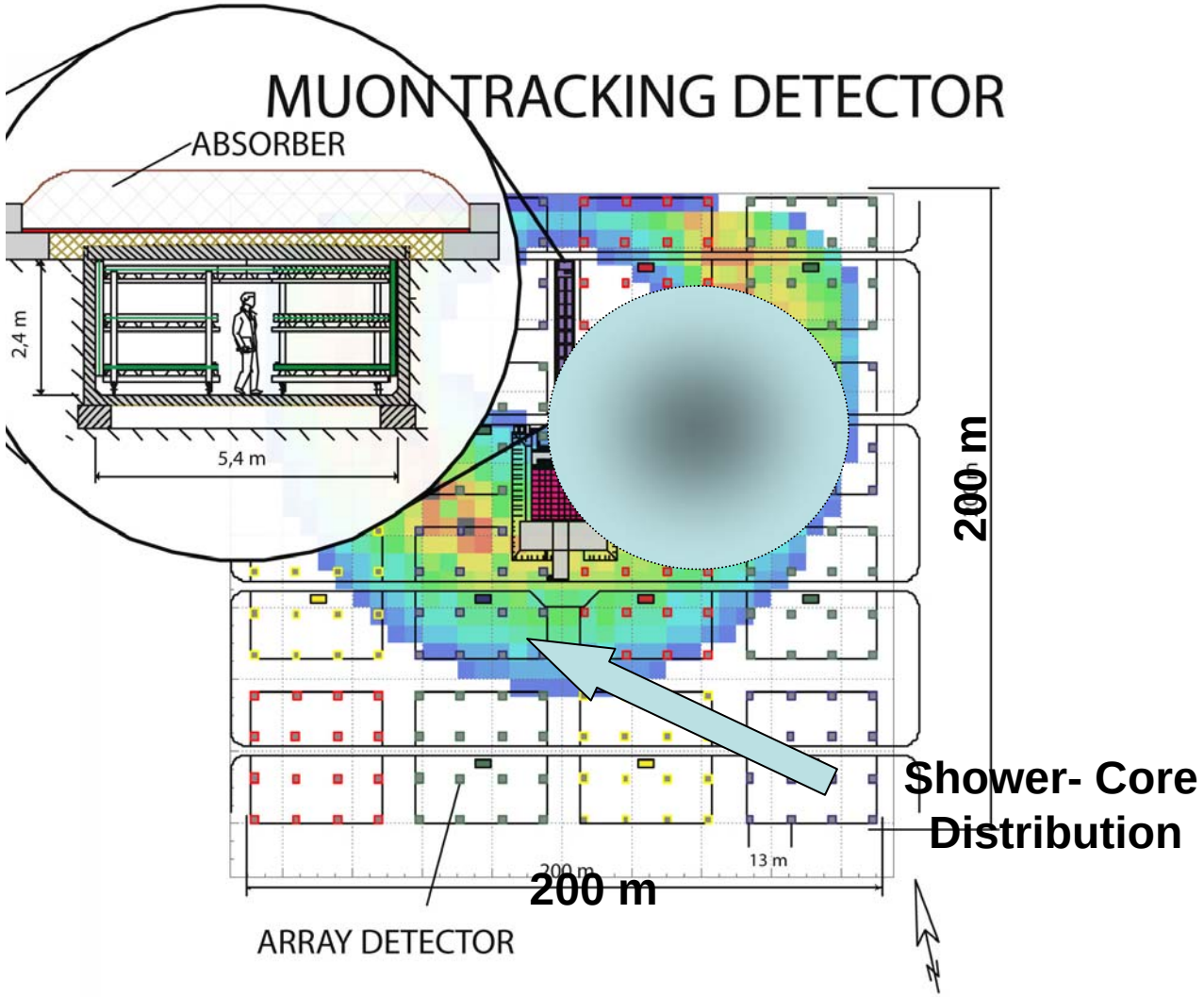
Air Shower Experiment KASCADE-Grande

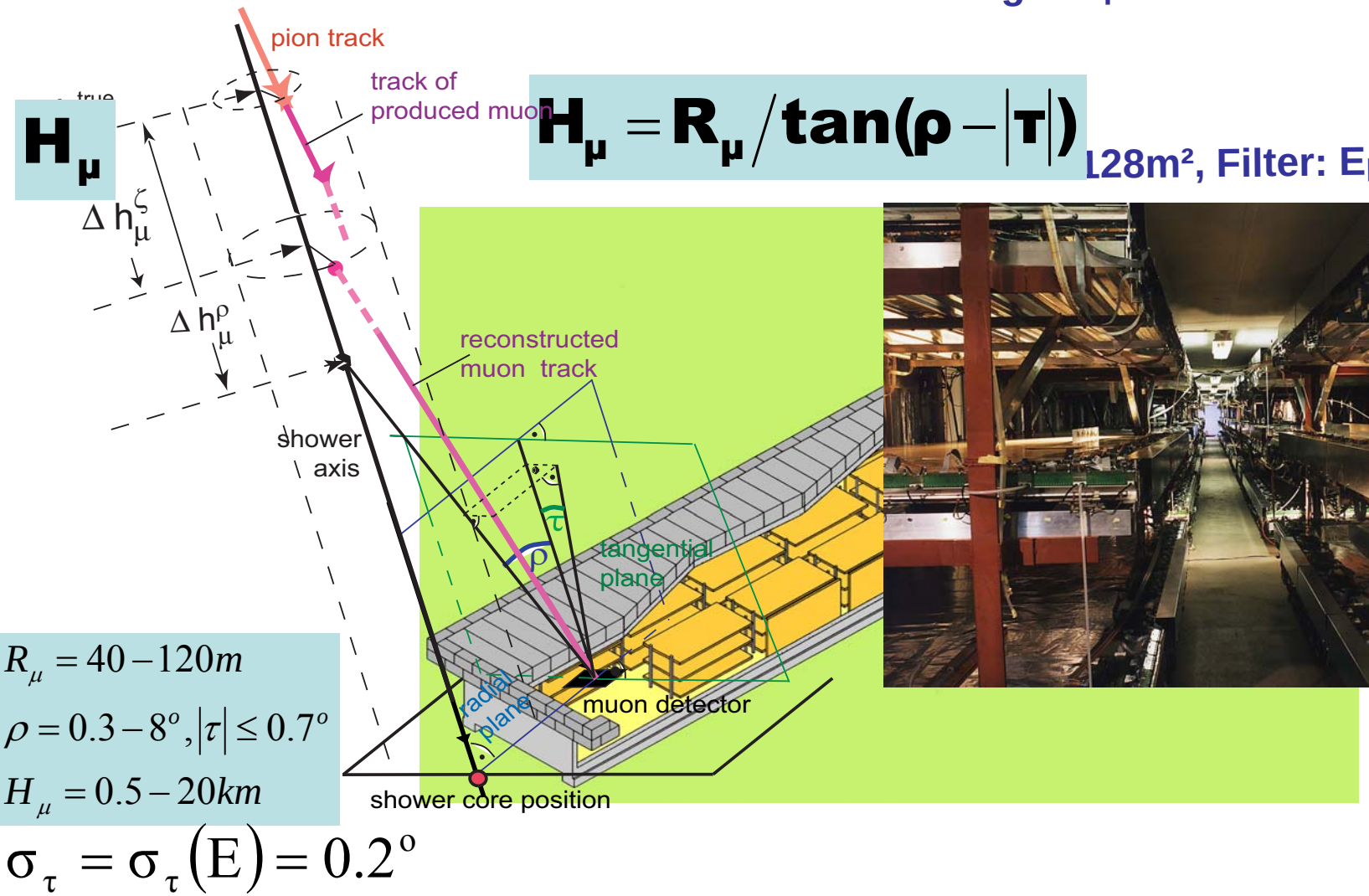


parameters : $N_e, \theta_s, \varphi_s, N_\mu, \theta_\mu, \varphi_\mu, N_h, E_h$

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

Muon Production Height (Shower Cascade)

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



$$H_\mu = R_\mu / \tan(\rho - |\tau|)$$

L28m², Filter: Eμ>0.8GeV

$$R_\mu = 40 - 120m$$

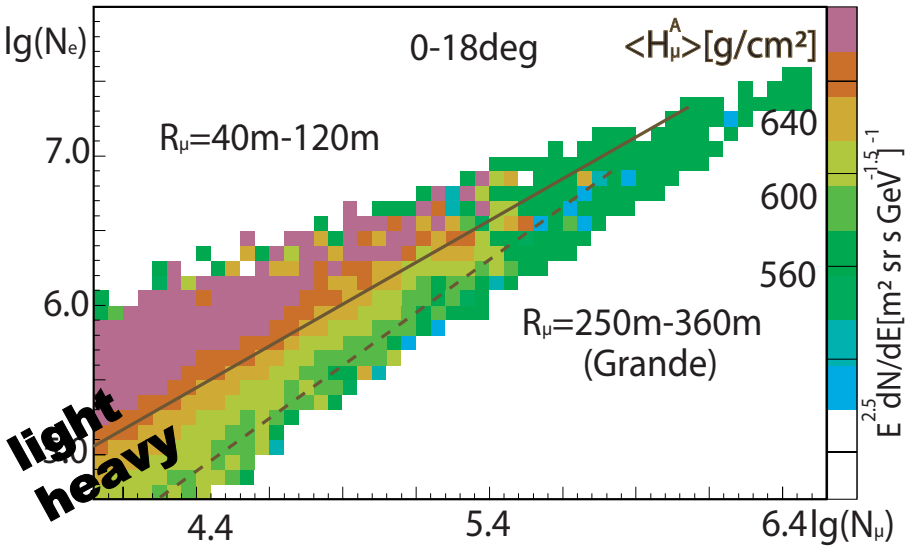
$$\rho = 0.3 - 8^o, |\tau| \le 0.7^o$$

$$H_\mu = 0.5 - 20km$$

$$\sigma_\tau = \sigma_\tau(E) = 0.2^o$$

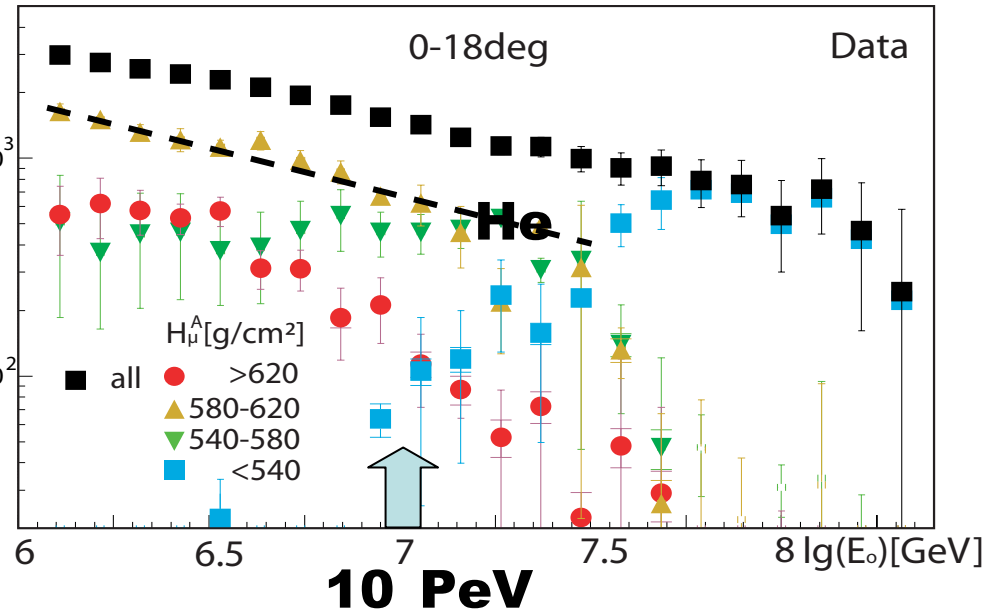
Production Height Dependent Energy Spectra

Regions of constant $H\mu^A$. Sorting the lgNe/lgNμ events after the range in $H\mu^A$ one can obtain mass-specific energy spectra.



$$H_\mu^A = H_\mu - \alpha E_o$$

$$< H_\mu^A > = < H_\mu^p > - X_o \ln A$$



Unfolding lgNe/lgNμ size using CORSIKA-simulations can be improved including Hμ parameter.

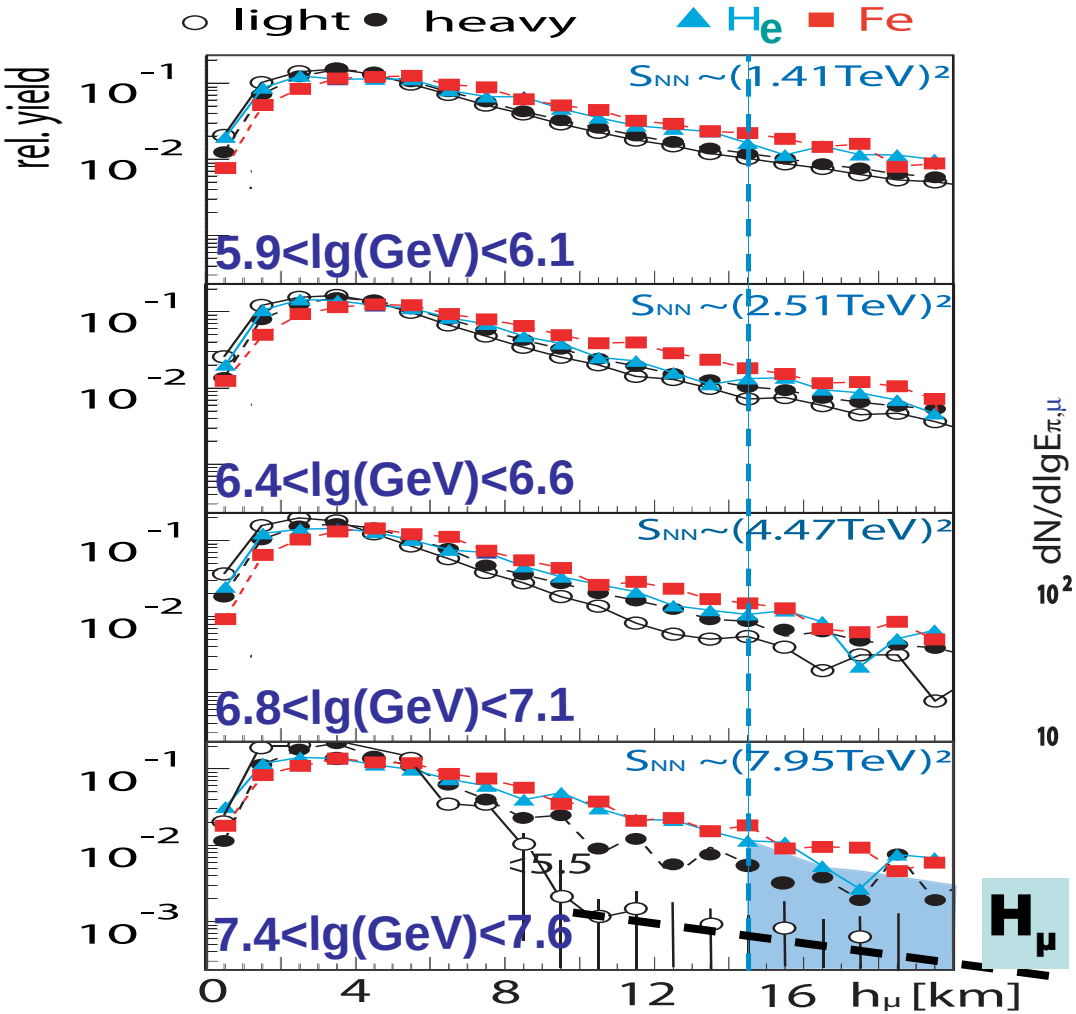
$$\lg E_0[\mathrm{GeV}] = 0.19 \lg N_e + 0.79 \lg N_\mu + 1.93$$

D.Fuhrmann PhD (2012) University Wuppertal

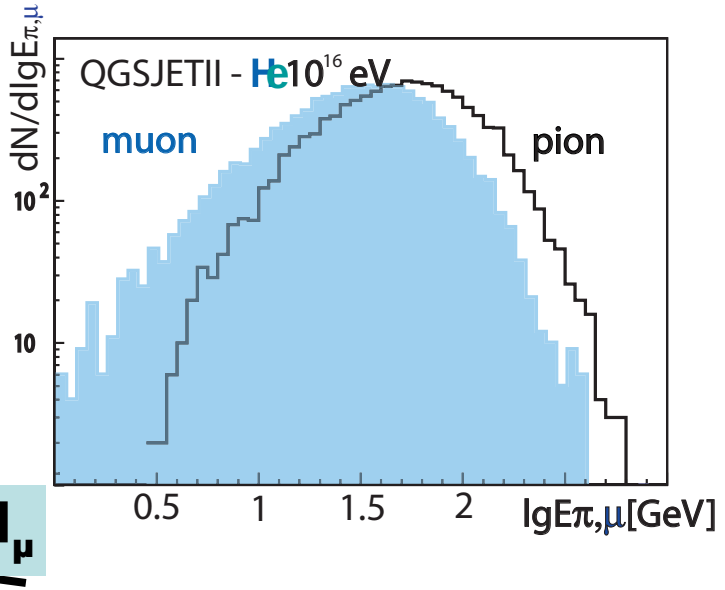
J.Matthews Astro.Part.Phys.22(2005)387

Muon Production Height Hμ

for light-heavy (lgNe/lgNμ) Cosmic Ray Particles



Parameter Hμ exhibits information from
1. Interaction (p_t increase?).



missing secondary hadron production in the diffraction process at ~8 TeV, regular shower development further down. **Mx ~ 60 x 40 GeV**

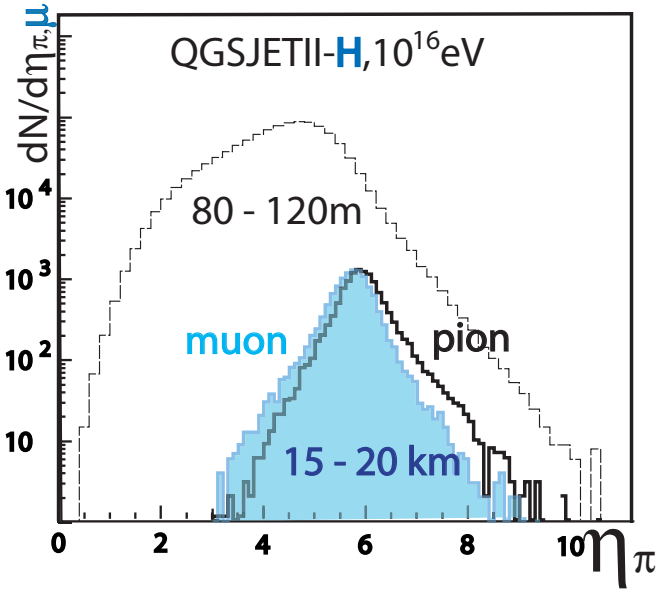
S.I.Nikolsky, Nucl.Phys. B (Proc.Suppl.) 39A(1995) 228
J.Kempa et al., Eur. J. Phys.10(2012) 723
QGSJET II: S.Ostapchenko, Phys.Rev.D 74 (2006) 014026

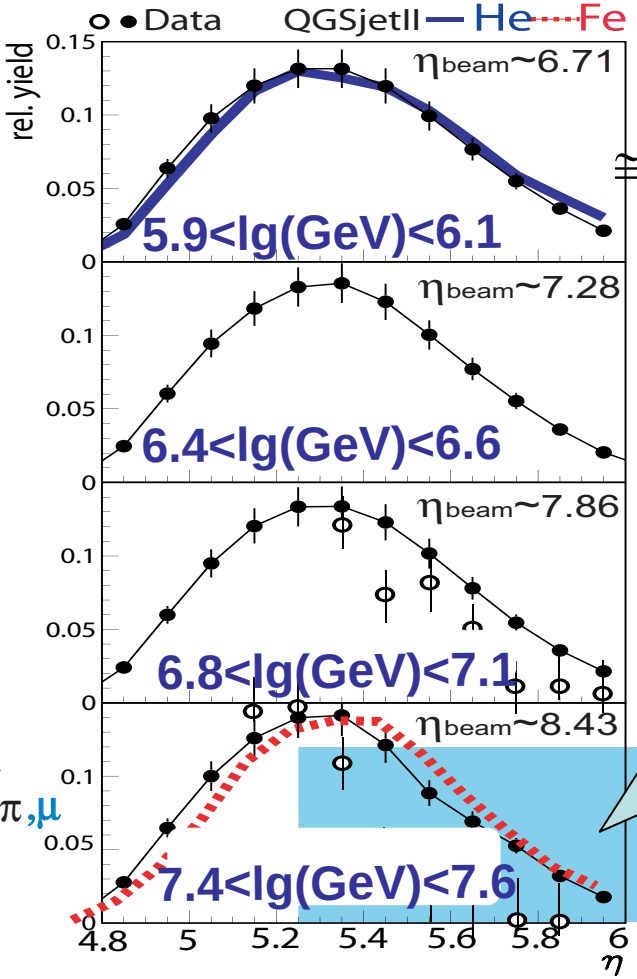
Muon Pseudorapidity Range in Diffraction

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

(R_μ =80 - 120m, H_μ >15km)

Which step in the shower-development do we see?.





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

E_o/3A available in lab.system for π production.

Rapidity Gap:

$\eta_{parent} - \eta_\mu \sim 3$

$$M_X^2 = S_{NN} \exp(-\Delta\eta)$$

P.Doll et al., http://arxiv.org/abs/1010.2702
V.A.Khoze,A.D.Martin,M.G.Ryskin, Eur.Phys.J.C.(2014)74:2756
QGSJET II: S.Ostapchenko, Phys.Rev.D 74 (2006) 014026

Longitudinal Shower Development Studies by Air Shower Experiment KASCADE-Grande

1. **Muon Production Height shows near ~8 TeV above 15 000 m for light cosmic ray mass (helium) a reduction of muons (M_x~1.8-2.2 TeV).**

2. **Nikolsky (1995) and Kempa (2012) also observed for light cosmic ray particles a reduction in the multiple pion production near ~8 TeV.**

3. **Comparison with ongoing TOTEM and CASTOR studies.**

P.Doll for KASCADE-Grande

S.I.Nikolsky, Nucl.Phys. B (Proc.Suppl.) 39A(1995) 228
J.Kempa et al.,Eur.J.Phys.,10(2012) 723
F.Oljemark,K.Oesterberg, TOTEM Coll.(2013)
CMS Coll. JHEP 08(2017) 046