Results from a while ago …

Lessons about muons from CASA-MIA

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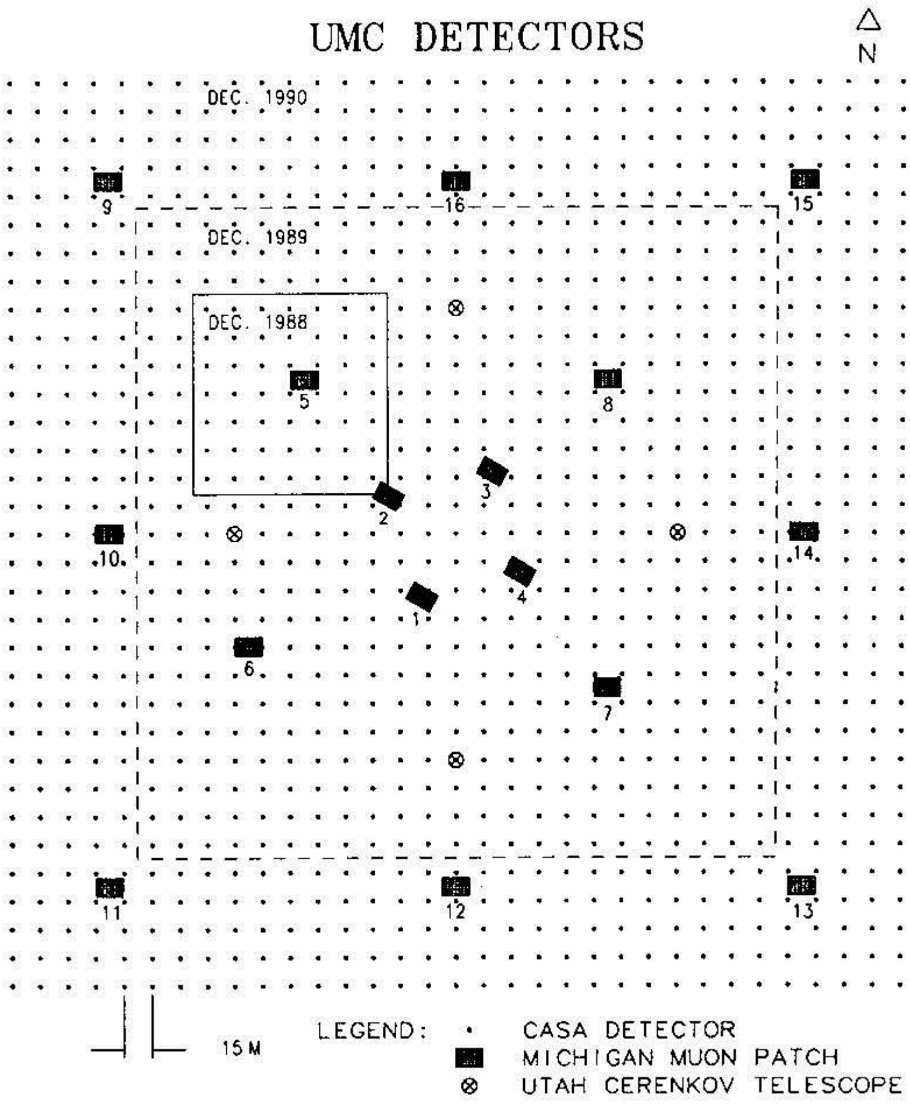
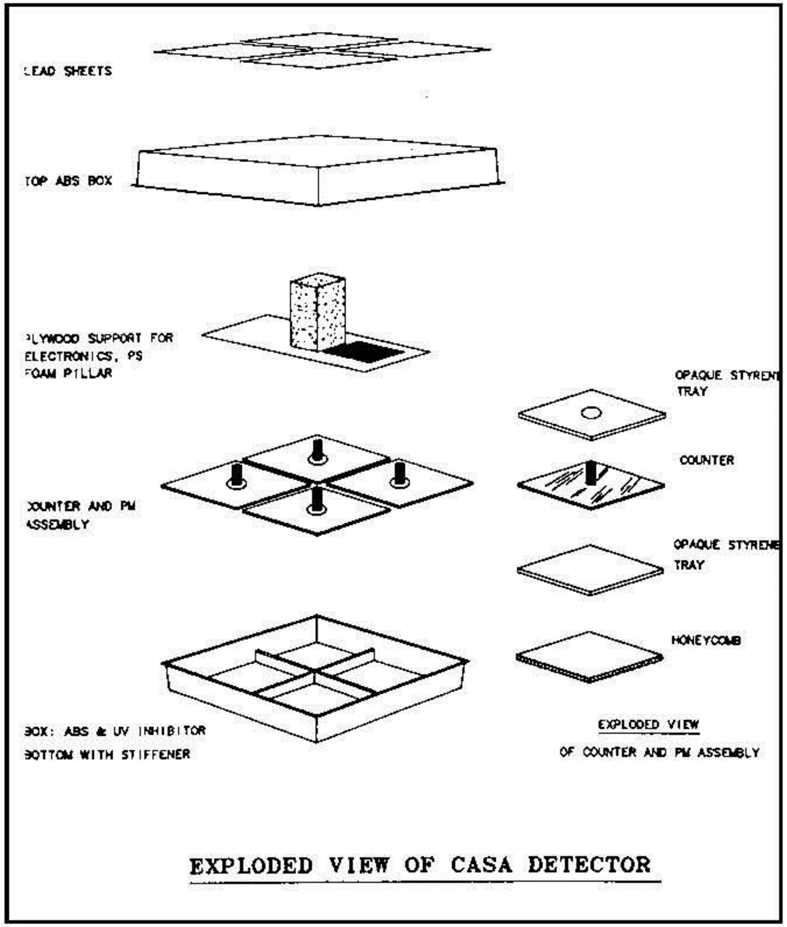
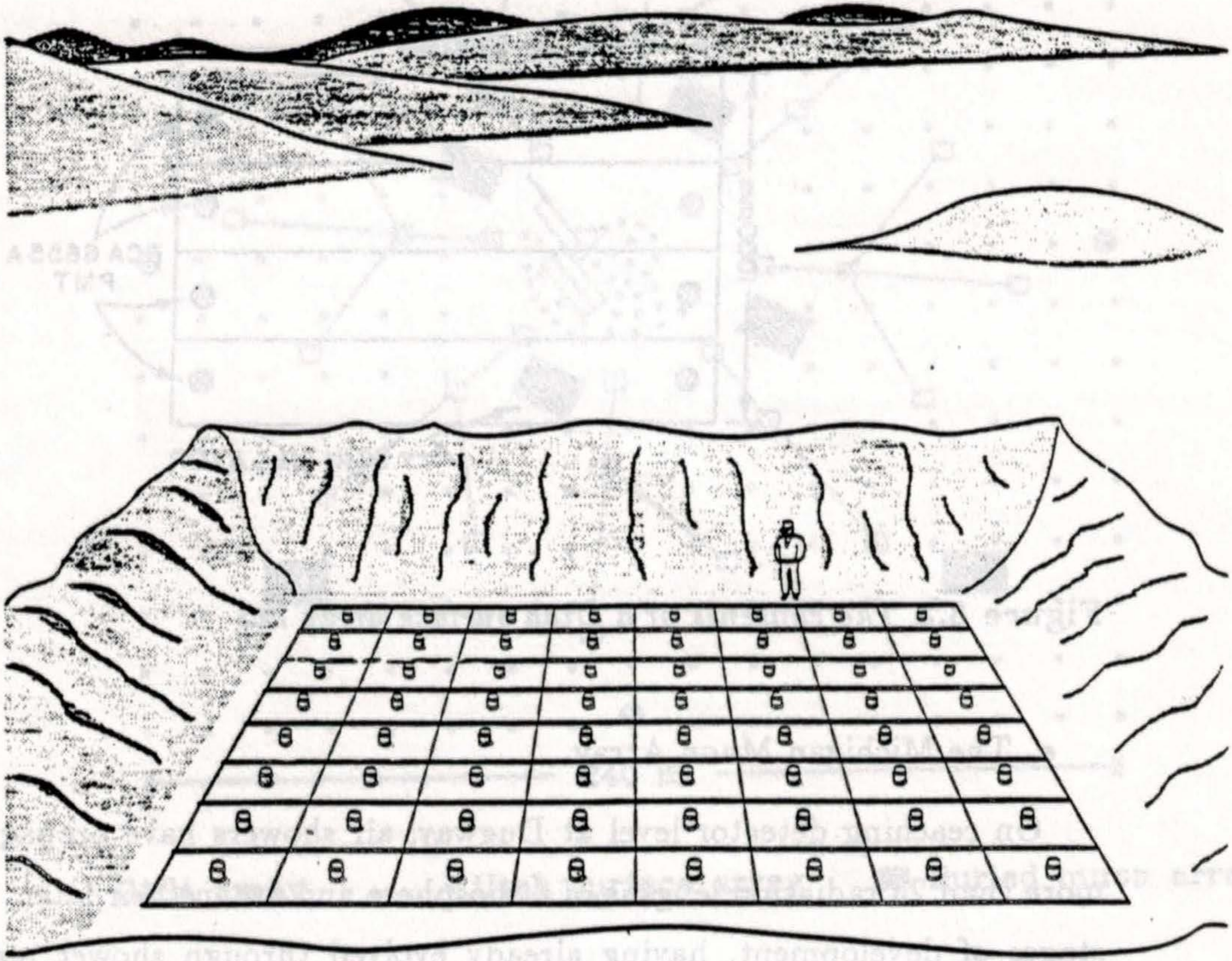
CASA-MIA   Dublin ICRC 1991

CASA-MIA ~1987-1997

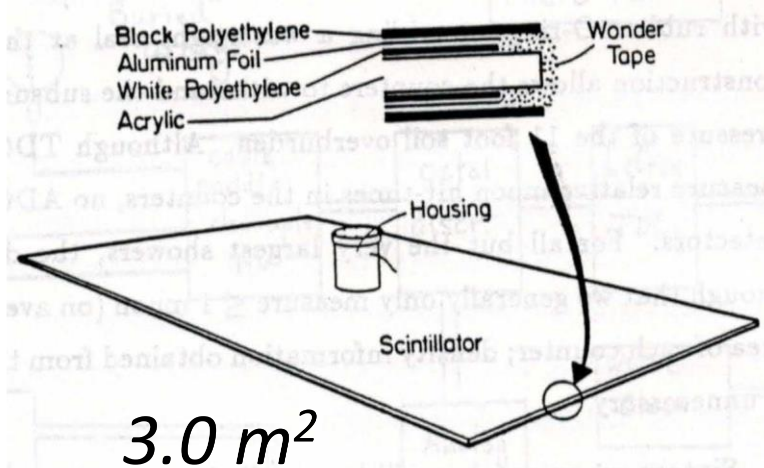


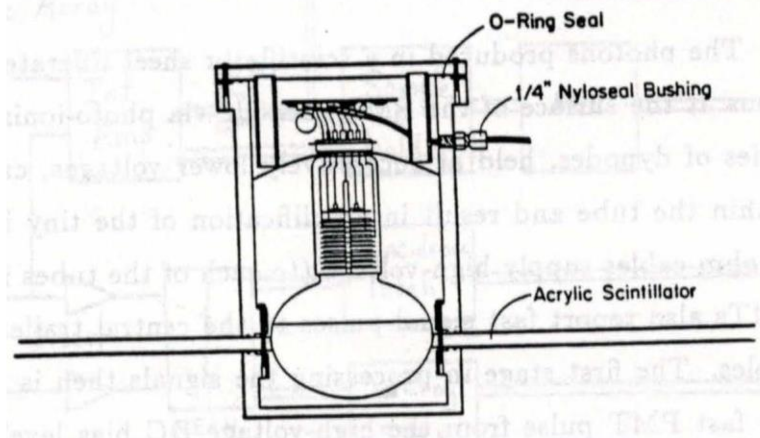




The muon counters were designed as a veto for gamma-ray showers

Only timing recorded, not pulse height





(old IMB tubes)

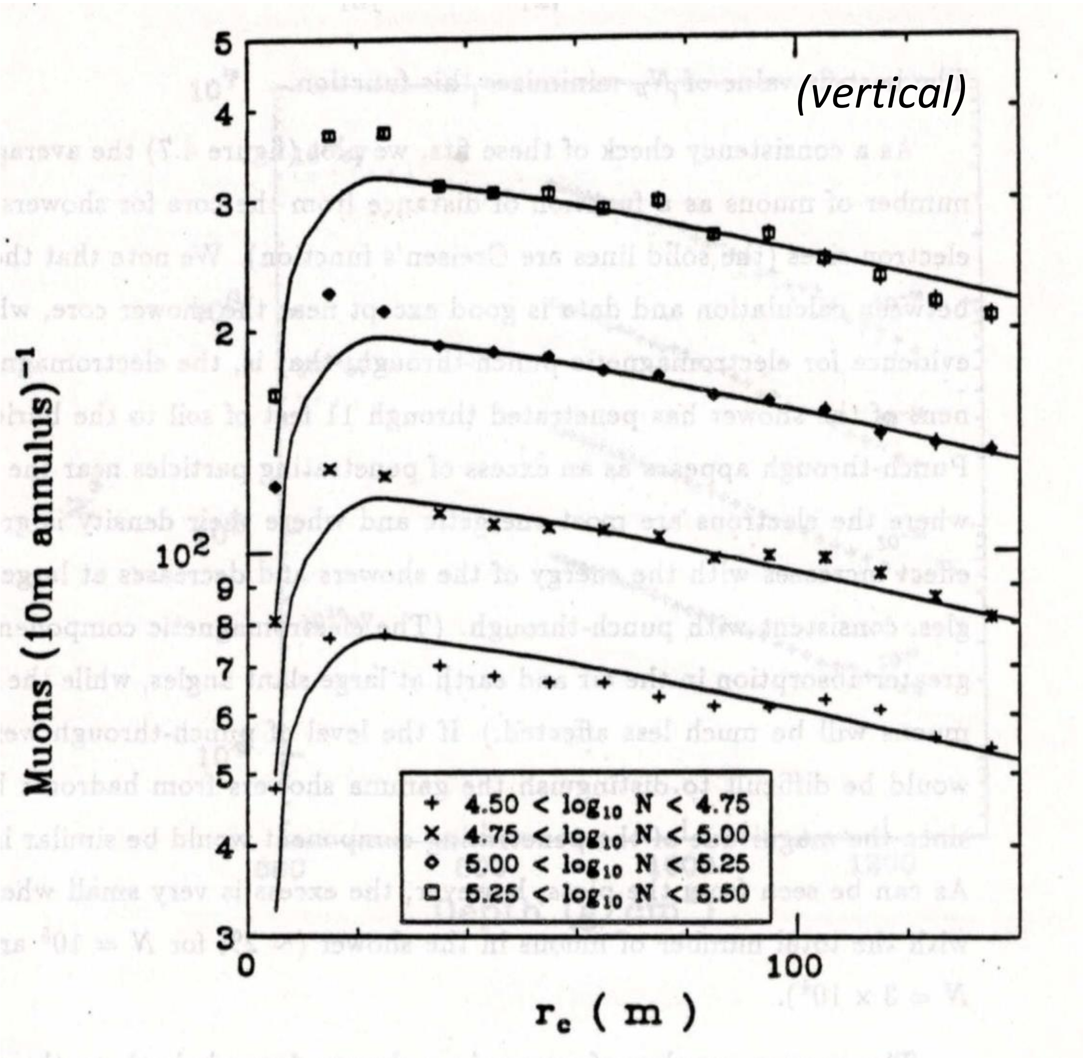
Maximum-likelihood fit of the lateral distribution for the purpose of finding total muon size N_μ

Greisen Function*:

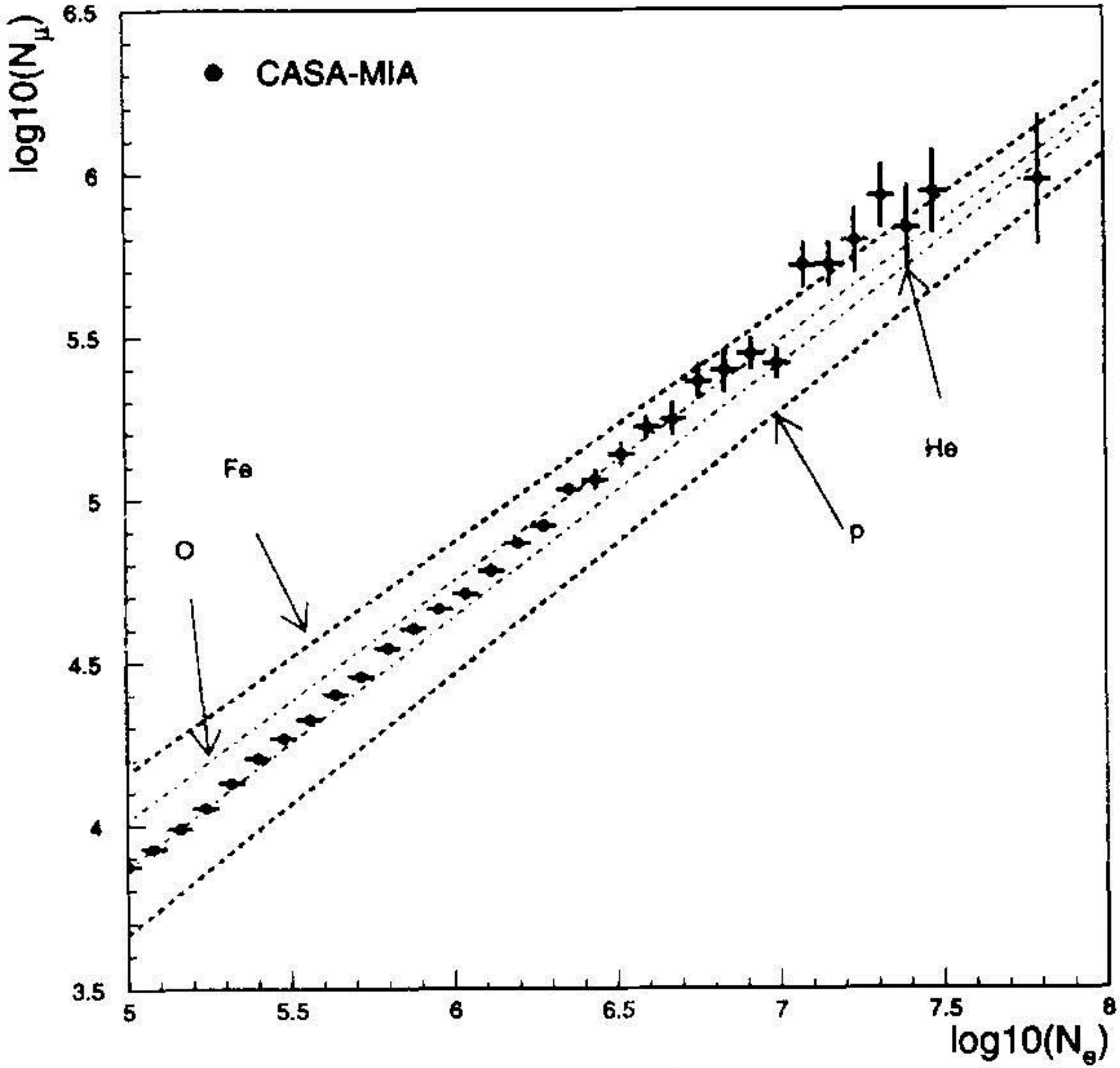
$$\rho_\mu \sim N_\mu \; r^{-0.75} (1+r/r_o)^{-2.5}$$

$r_o = 300\ m$

(Also used things like ρ_μ (600))

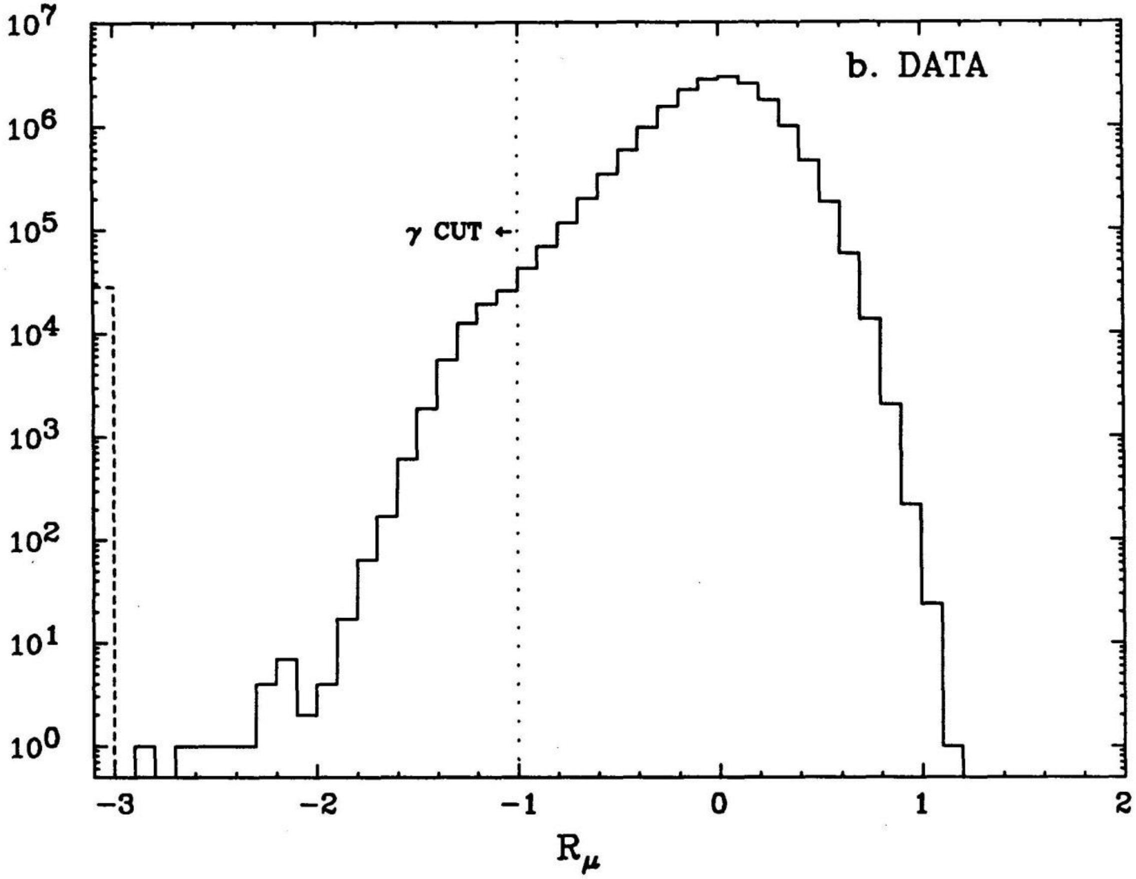


*K. Greisen, Prog. Elem. Part. C.R. Phys. III (1956)



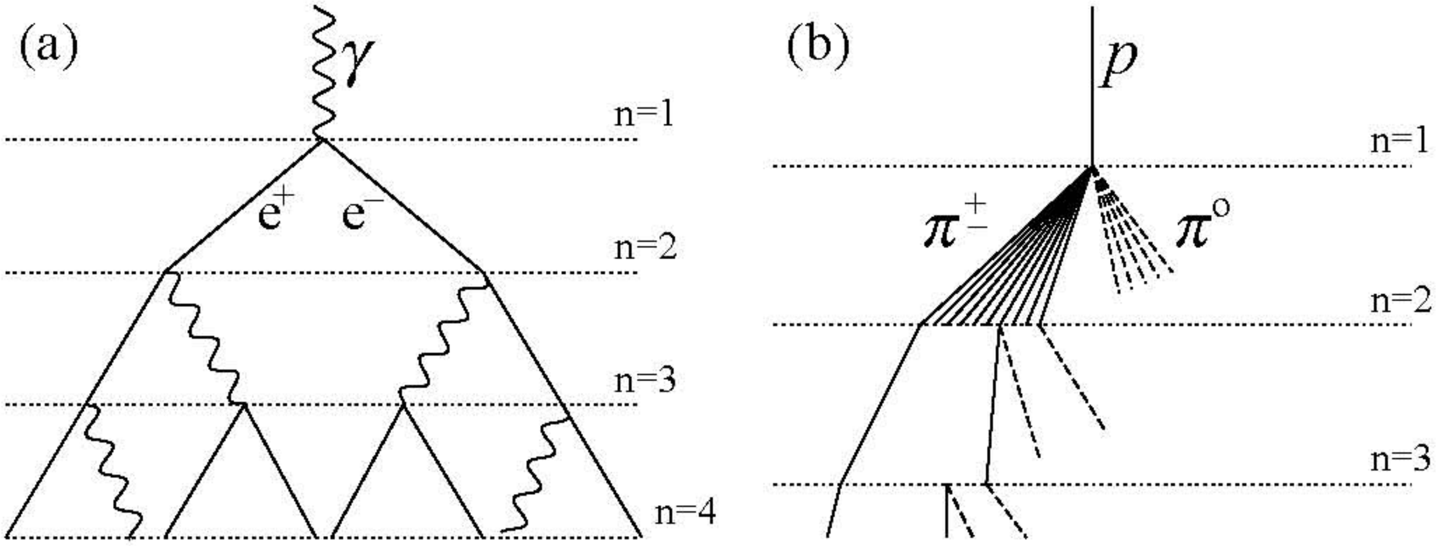
CASA-MIA
log10(N_μ)
log10(N_e)
Fe
O
p
He
6.5
6
5.5
5
4.5
4
3.5
5
5.5
6
6.5
7
7.5
8

$R_\mu = \log N_\mu - < \log N_\mu >$



Diffuse gamma rays in the knee region: flux limit ~10^{-5} of CR

J. Matthews et al., Ap. J. ***375*** *(1991) 202; M. Chantell et al., PRL* ***79*** *(1997) 1805;*
A. Borione et al., Ap. J. ***493*** *(1998) 175*



$N_{max} = E / \xi_c^e$

$X_{max} = \lambda \ln (E / \xi_c^e)$

$$E_\circ = \xi_c^e N_{max} + \xi_c^\pi N_\mu$$

ξ_c^e = 85 MeV

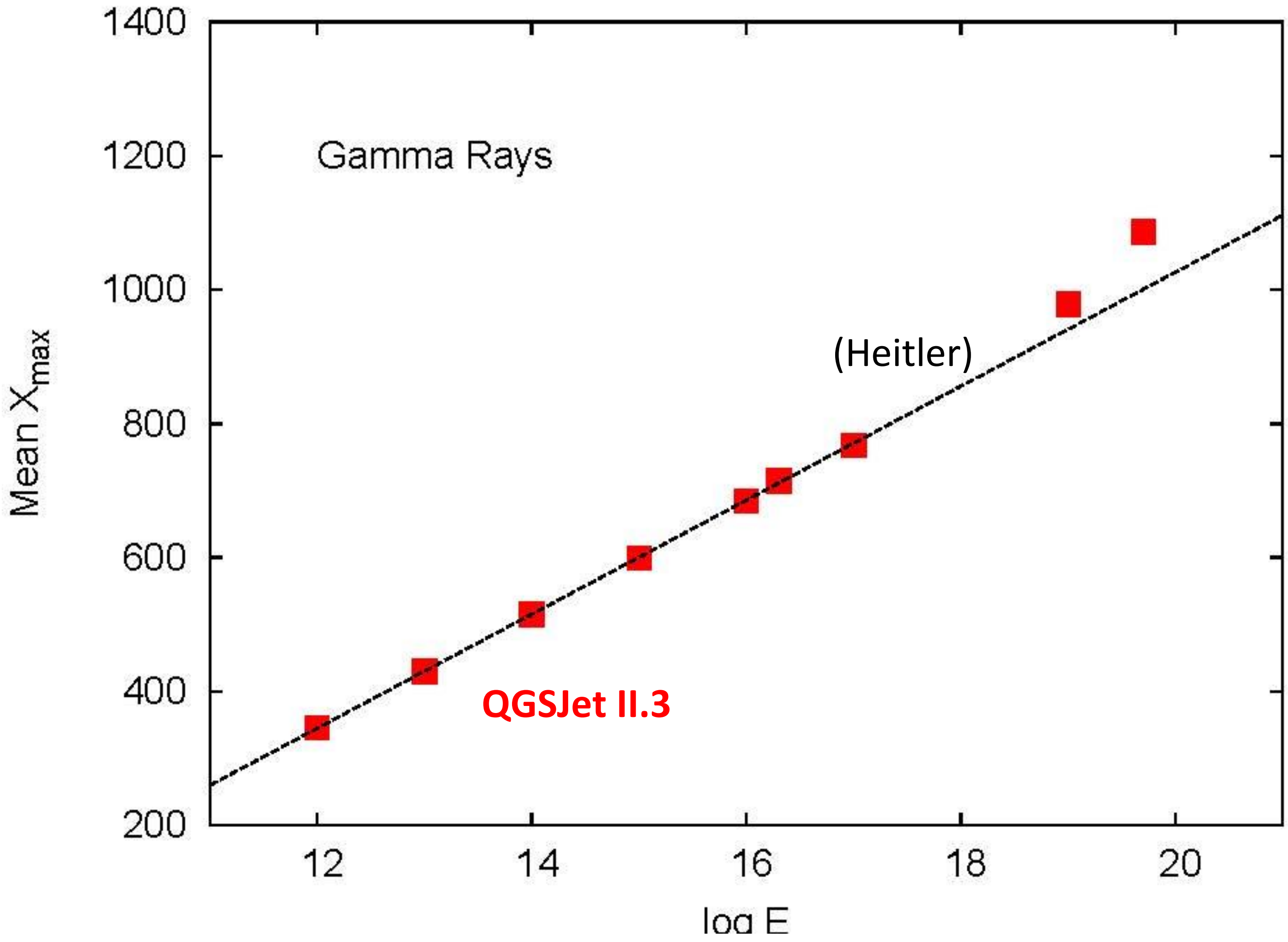
collision losses > radiative losses

ξ_c^π = 20 GeV

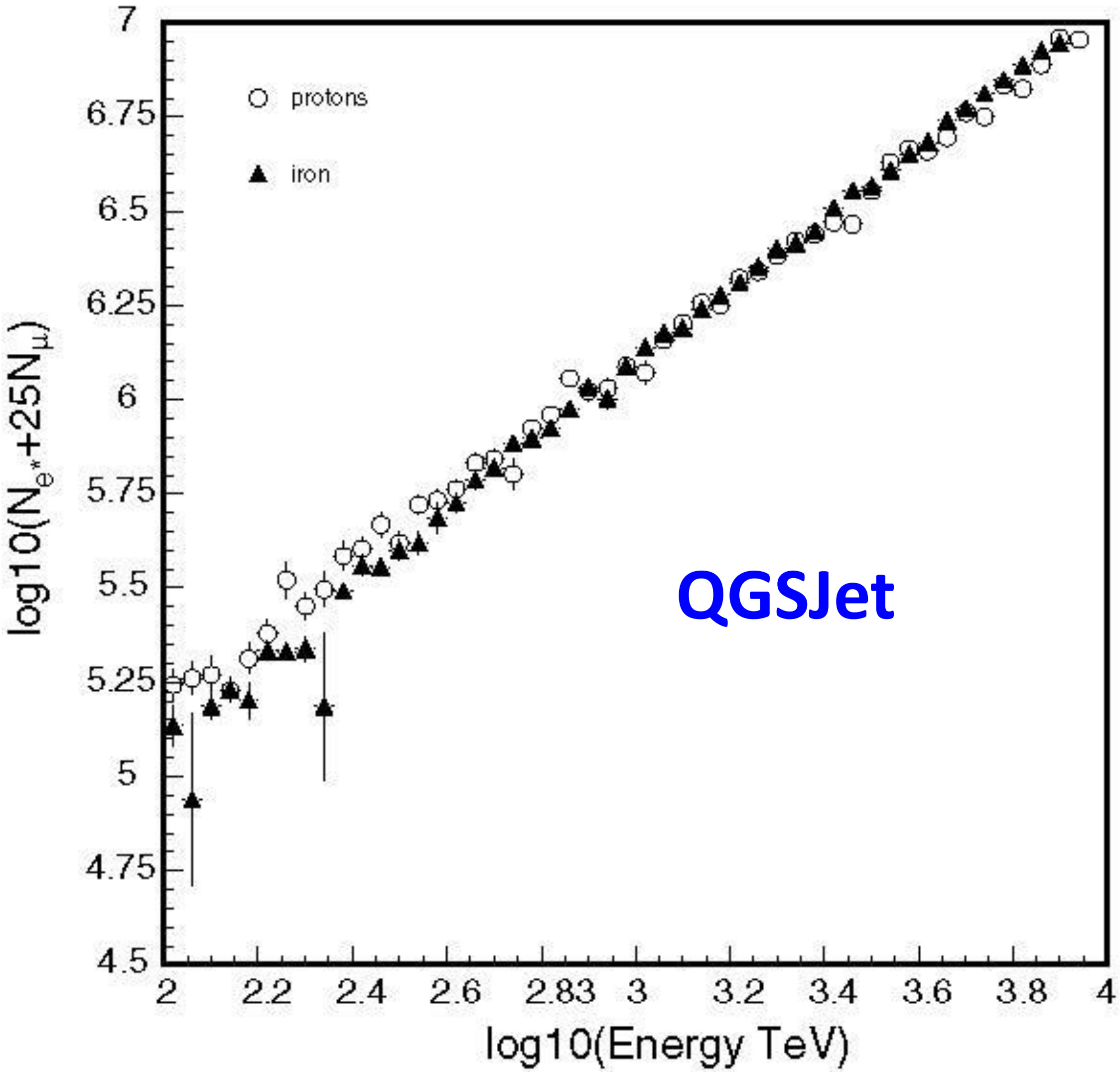
Prob decay > interaction

(Heitler, 1930's)

(J.M., Astropart. Phys. ***22*** *(2005) 387)*



Heitler: $X_{max} = 37 \ln(E/\xi_c^e)$



E ~ N_e + 25 N_μ

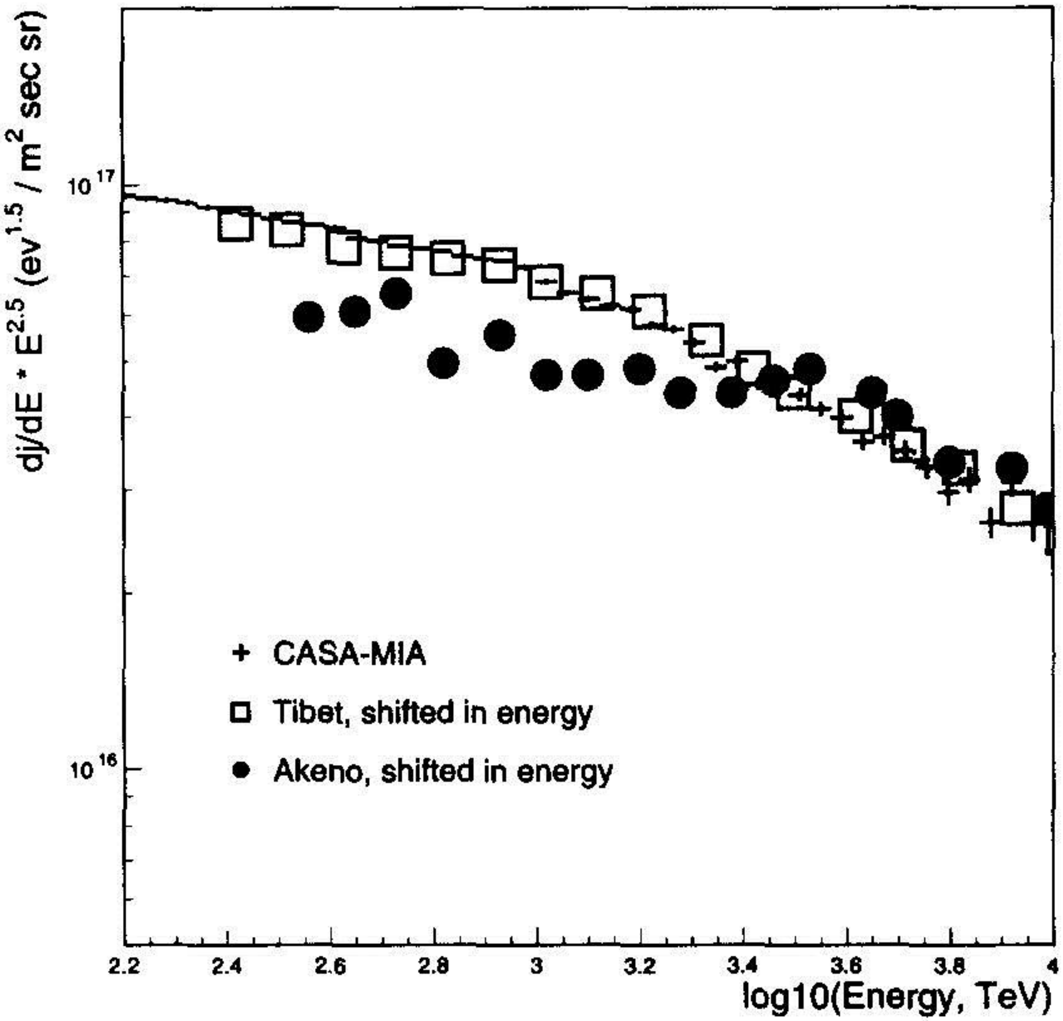
Independent of primary …

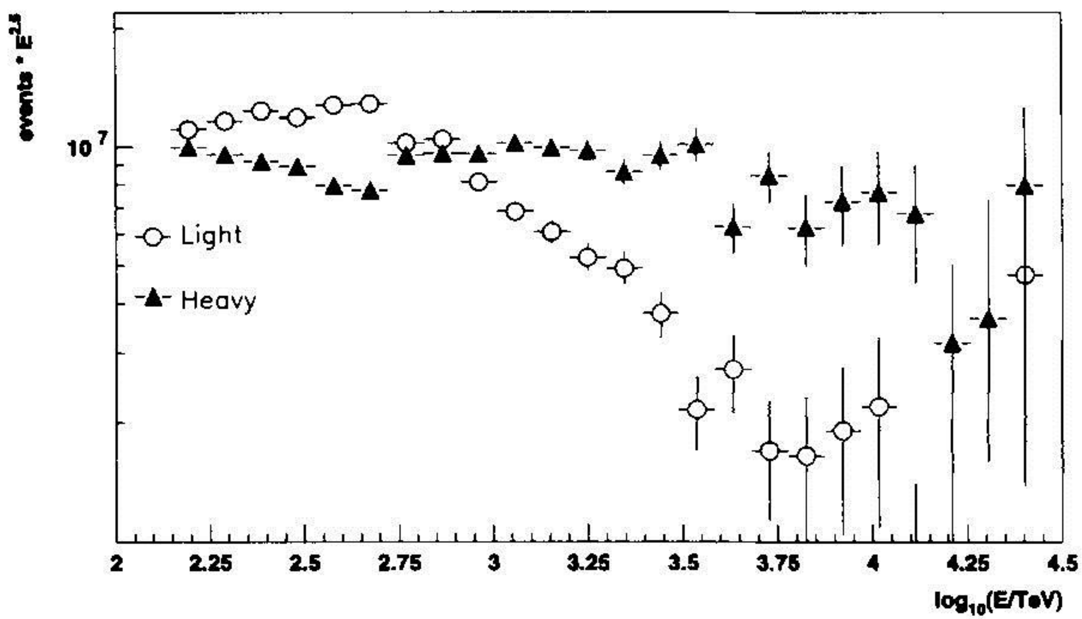
("25" is detector-dependent)

The “knee” looked very much like that seen by the Tibet experiment

The energy systematically was less than Tibet, Akeno by about 20%

Glasmacher et al., Astropart. Phys. 10 (1999) 291





Distinguish “heavy” versus “light” by comparing (N_μ , N_e , LDF slope) to simulation population.

See a different knee.

Glasmacher et al., Astropart. Phys. 12 (1999) 1

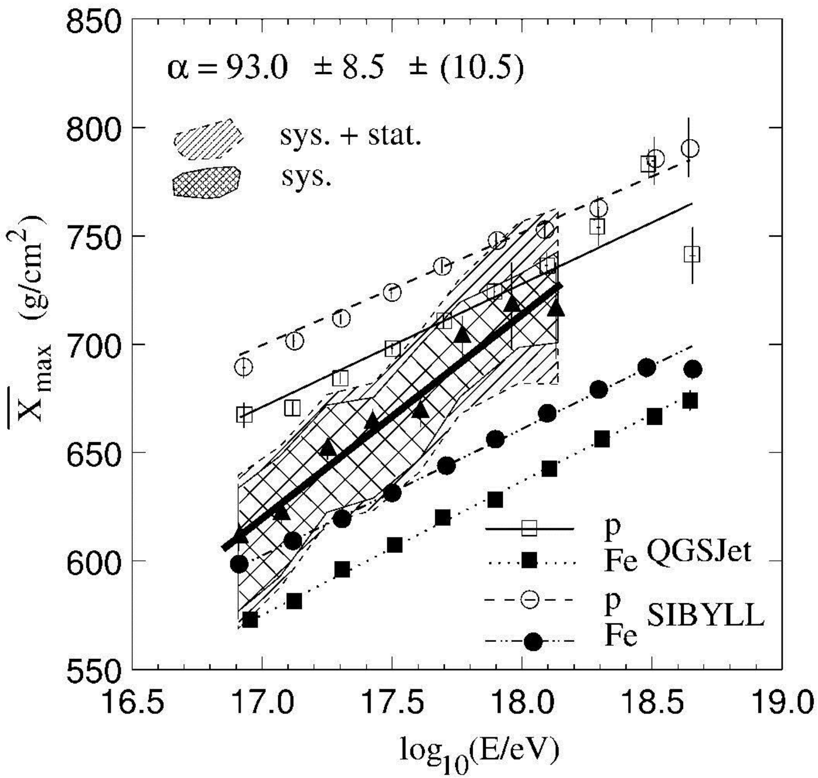
$R = N_{ch} / N_{tot}$

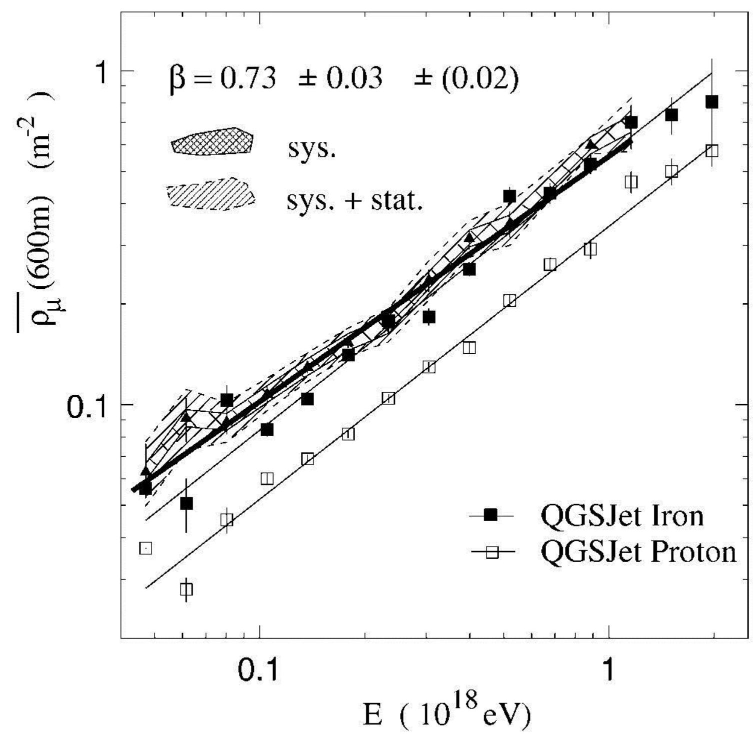
where "N_{ch}" meant $\pi^{\pm}$, but really is the number of particles which could decay into muons

$$\frac{dN_\mu}{N_\mu} = \frac{\ln[E_\circ/\xi_c^\pi]}{\ln[N_{tot}]}\frac{dR}{R} \approx (5-10)\frac{dR}{R}$$

Small changes in particle production (EPOS) or ***ρ^0*** *can have much larger changes in muon production*

Hi-Res (prototype) – MIA elongation rate





Fits use both HiRes and MIA (geometry)

Models: not enough muons?

T. Abu-Zayyad et al., PRL **84** (2000) 4276

Conclusions (or history lesson):

Muons are a vital and important measurement of air showers, and always have been.

(This is called "Preaching to the Choir")