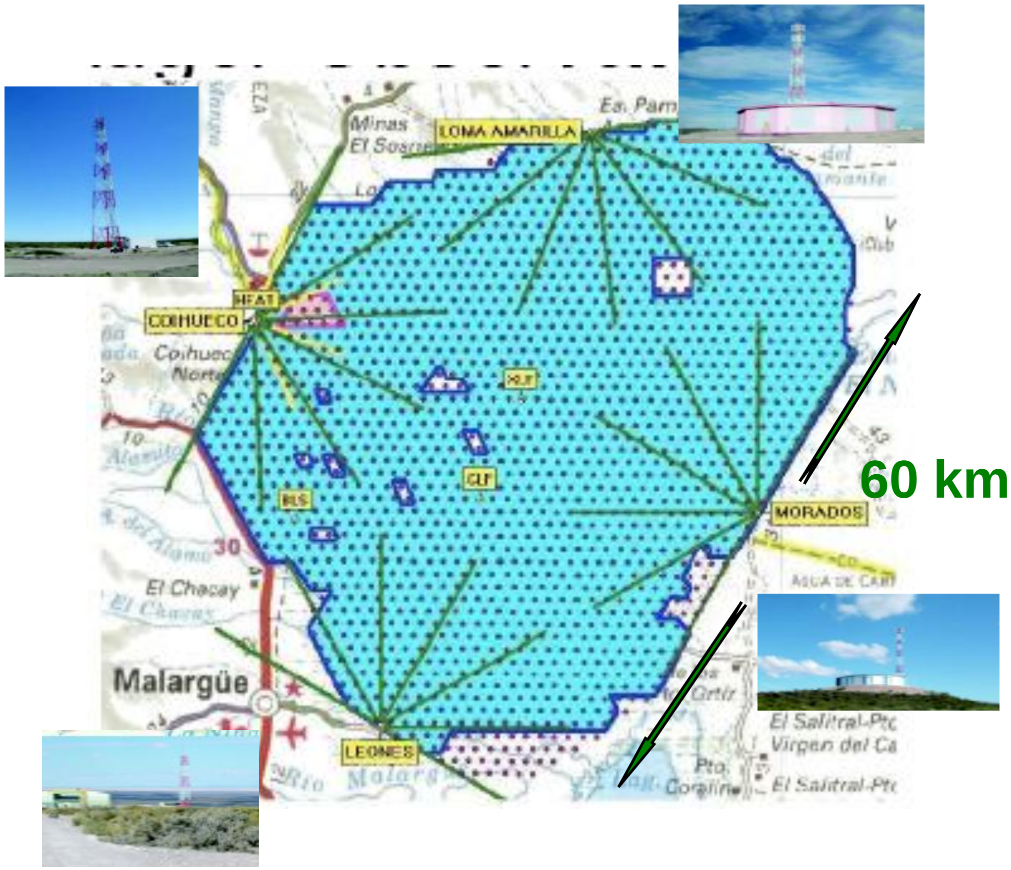
Pierre Auger Observatory

Present and future

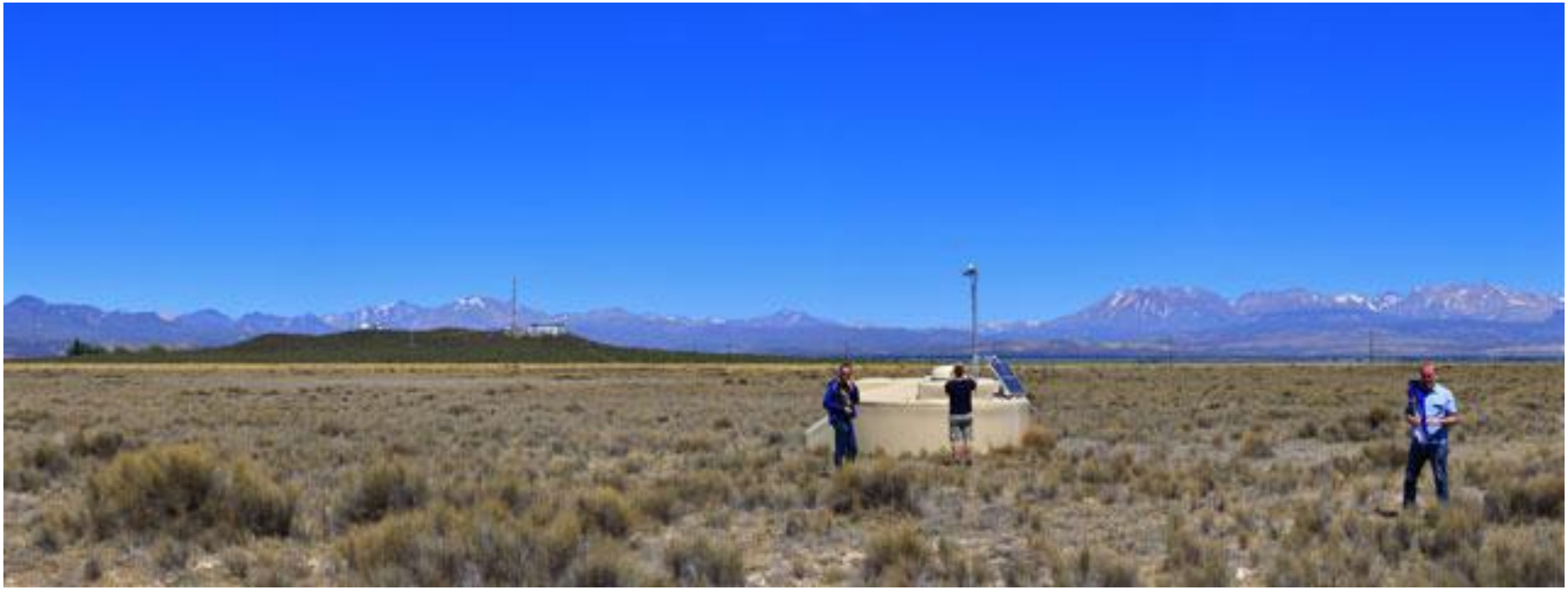


Area ~ 3000 km2

27 telescopes

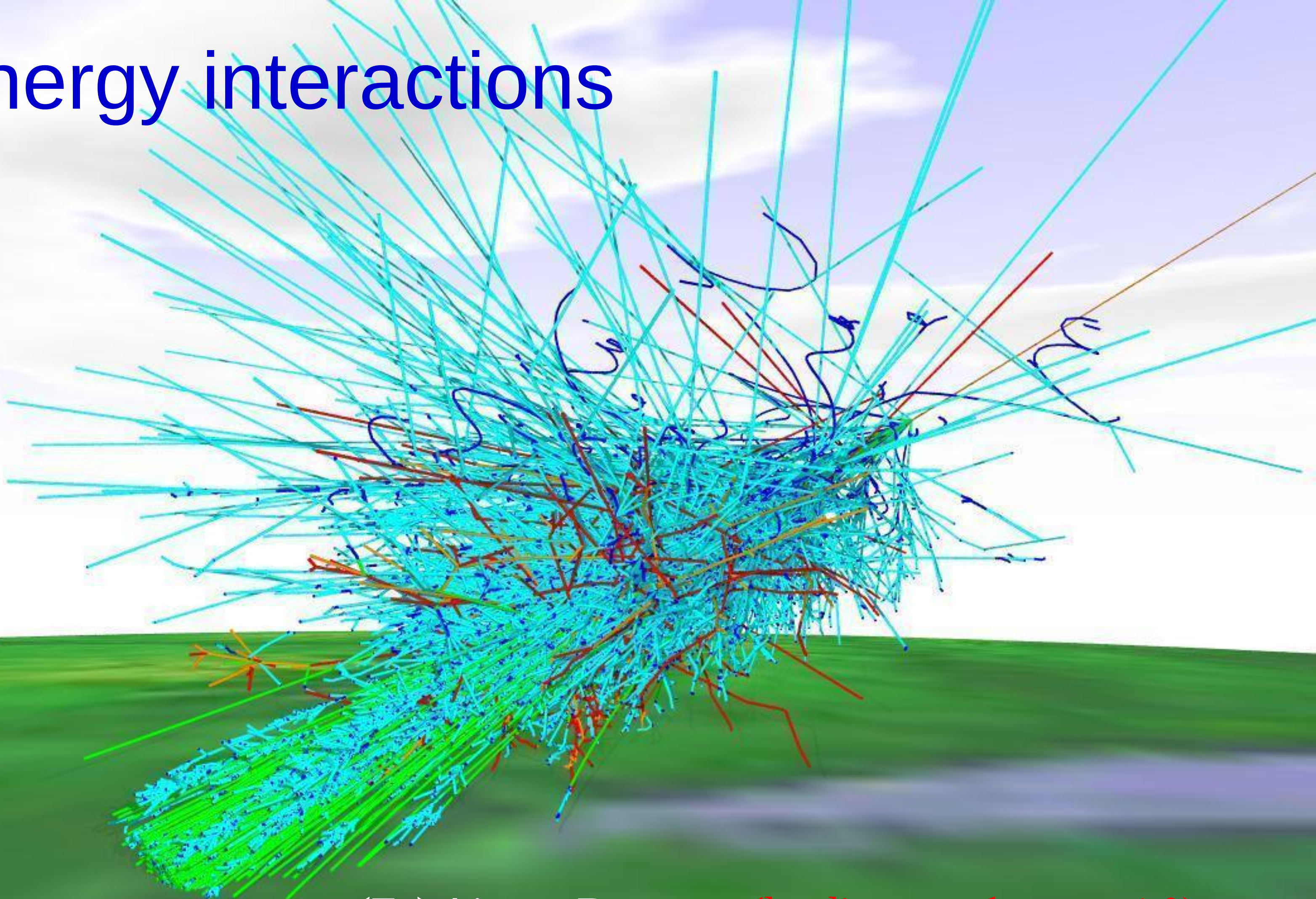
1600 tanks

Mário Pimenta
Lisboa, June 2014




Escuela Nº 4-190
Dr. James W. Cronin
MALARGÜE - MENDOZA

High Energy interactions



p(Fe) Air $\rightarrow$ Baryons (leading, net-baryon $\neq 0$)

$\rightarrow \pi^0$ $(\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^- e^+e^- \rightarrow \ldots)$

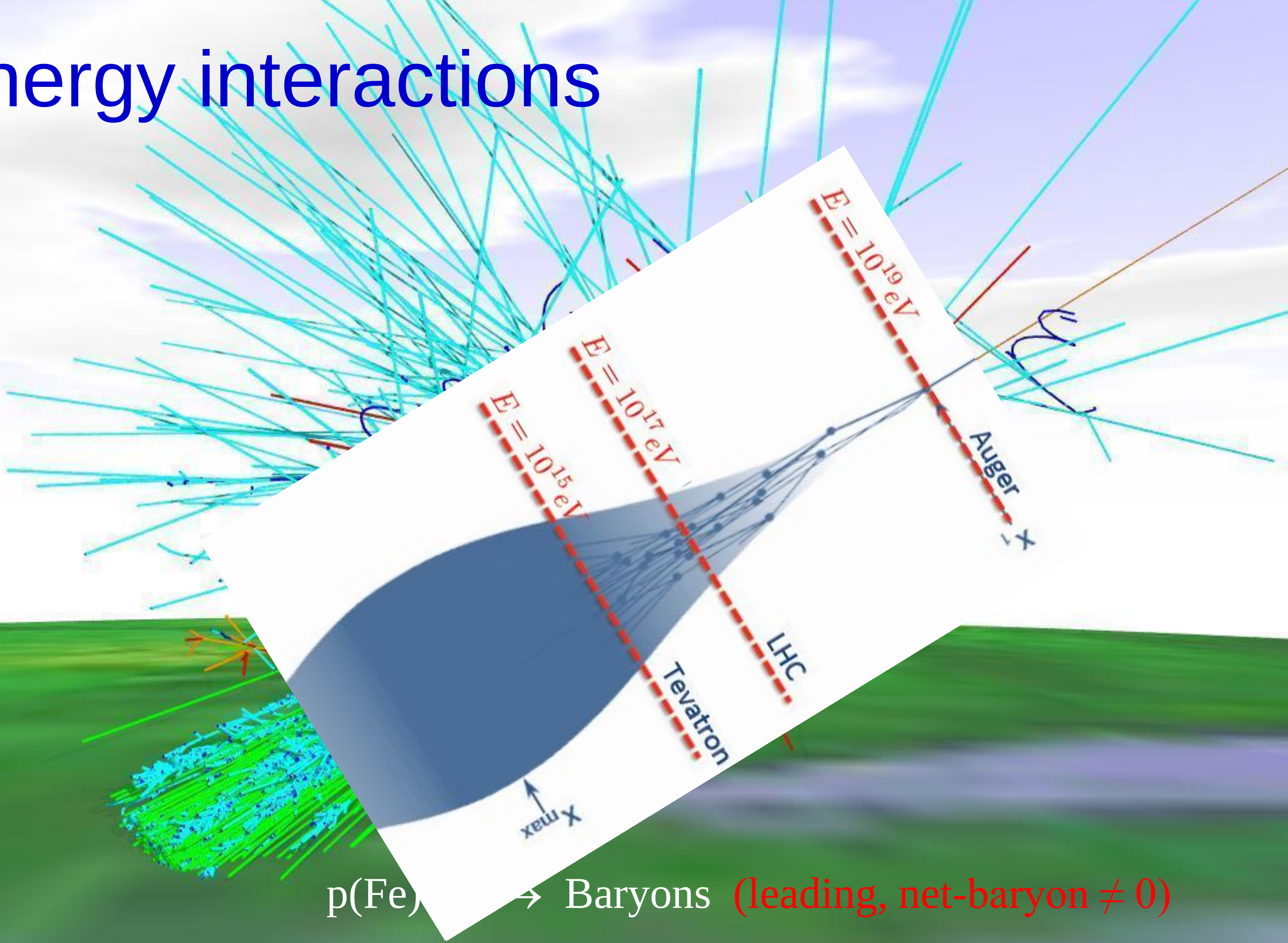
$\rightarrow \pi^\pm$ $(\pi^\pm \rightarrow \nu \mu^\pm$ if $L_{decay} < L_{int})$

$\rightarrow K^\pm$, D. …

Hajo Drescher, Frankfurt U.

time = 0 µs

High Energy interactions



p(Fe) … → Baryons (leading, net-baryon ≠ 0)

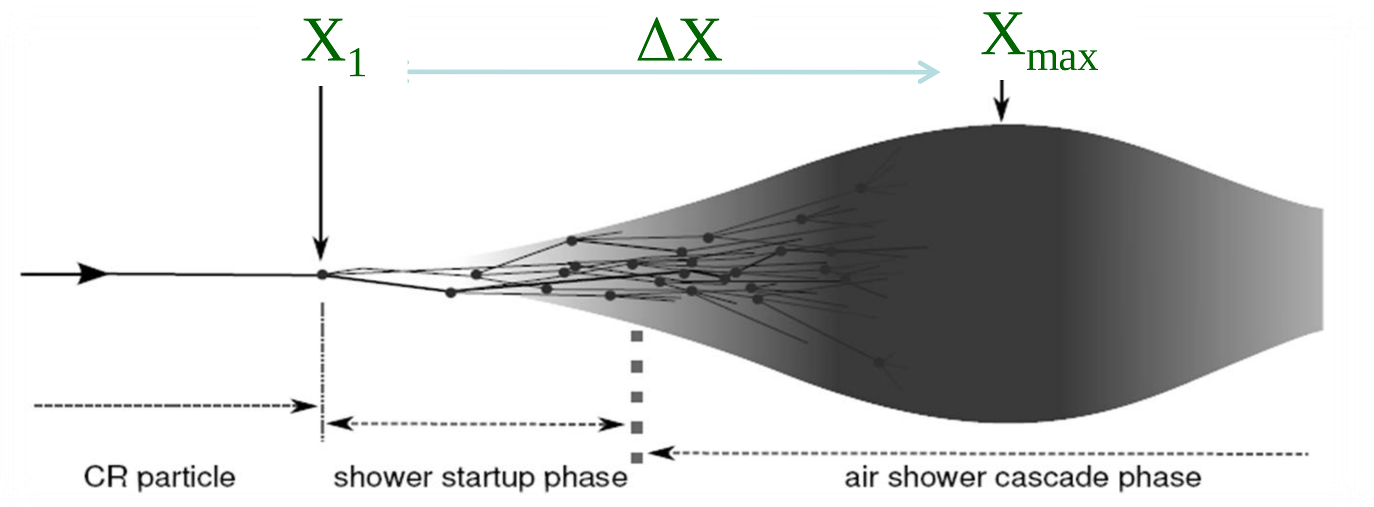
→ π^0 ($\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^- \, e^+e^- \rightarrow \ldots$)

→ $\pi^\pm$ ($\pi^\pm \rightarrow \nu\,\mu^\pm$ if $L_{decay} < L_{int}$)

→ $K^\pm$, D. …

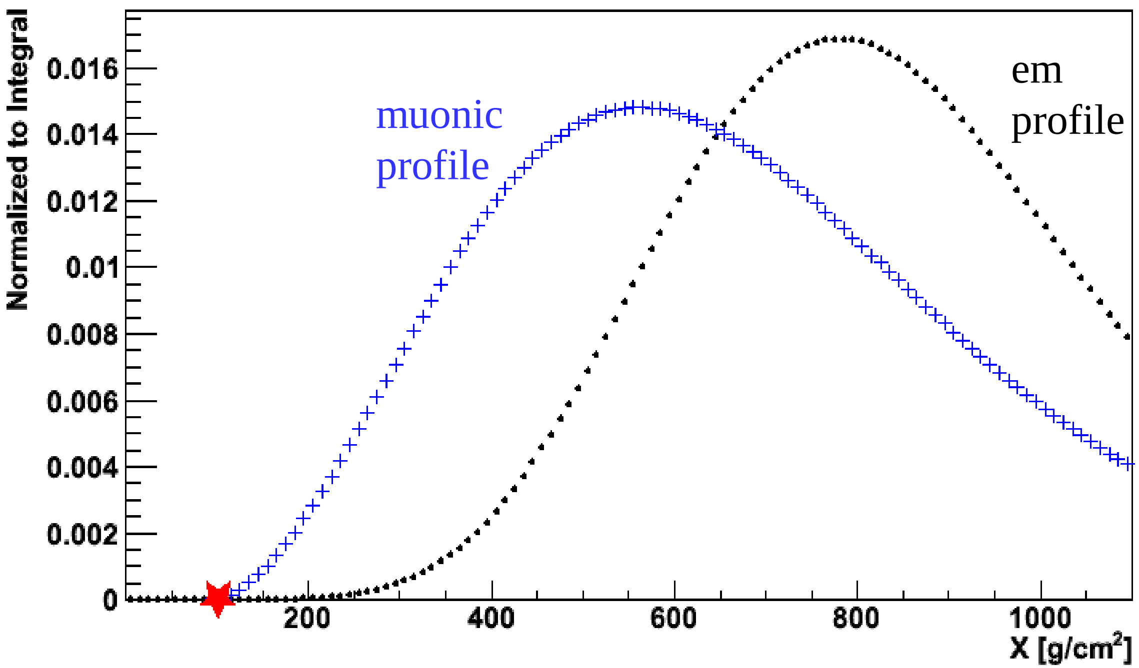
time = 0 μs

Shower development



$$X(l) = \int_0^l \rho(x)\,dx$$

$$X_{max} = X_1 + \Delta X$$

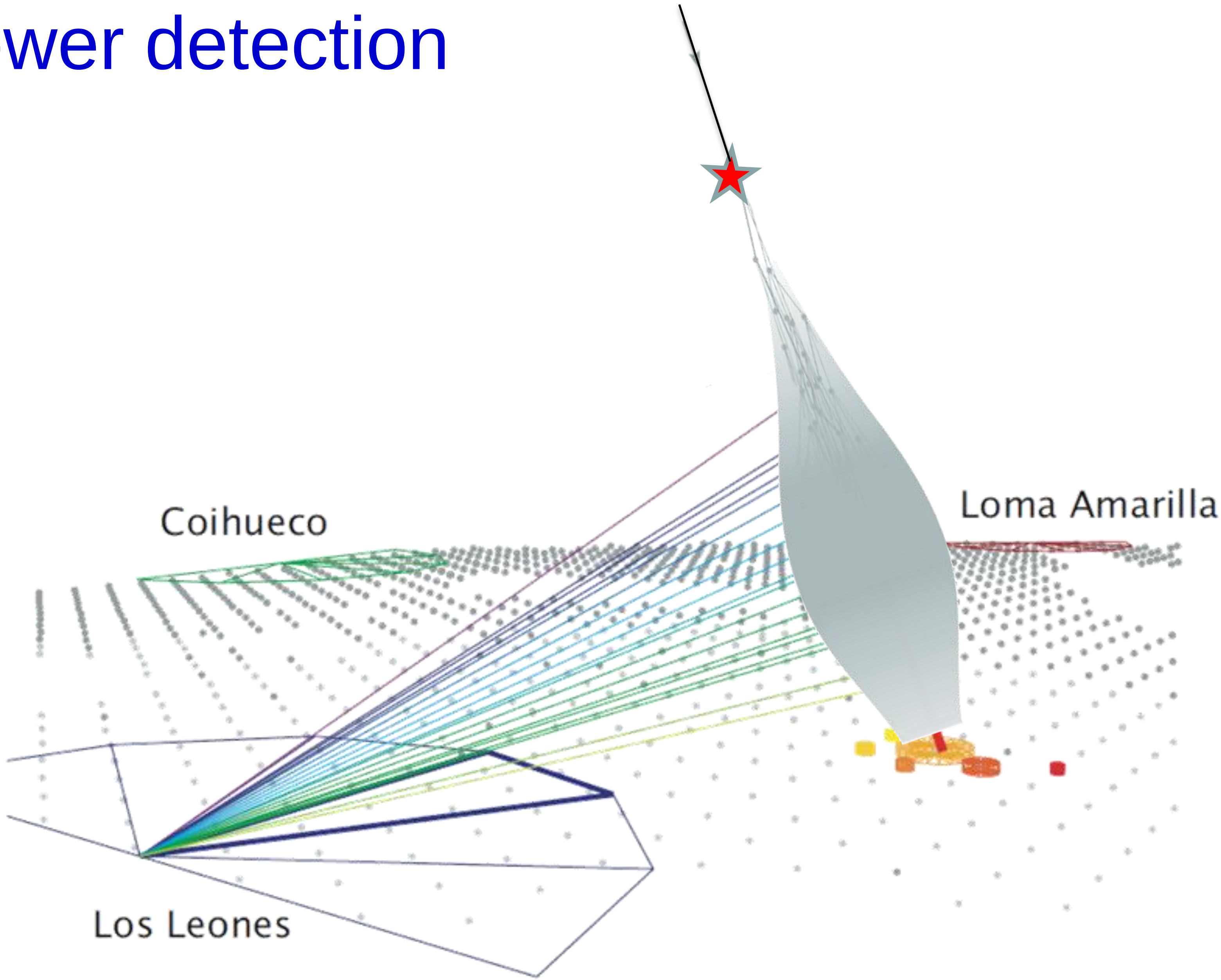


$$E \propto N_e$$

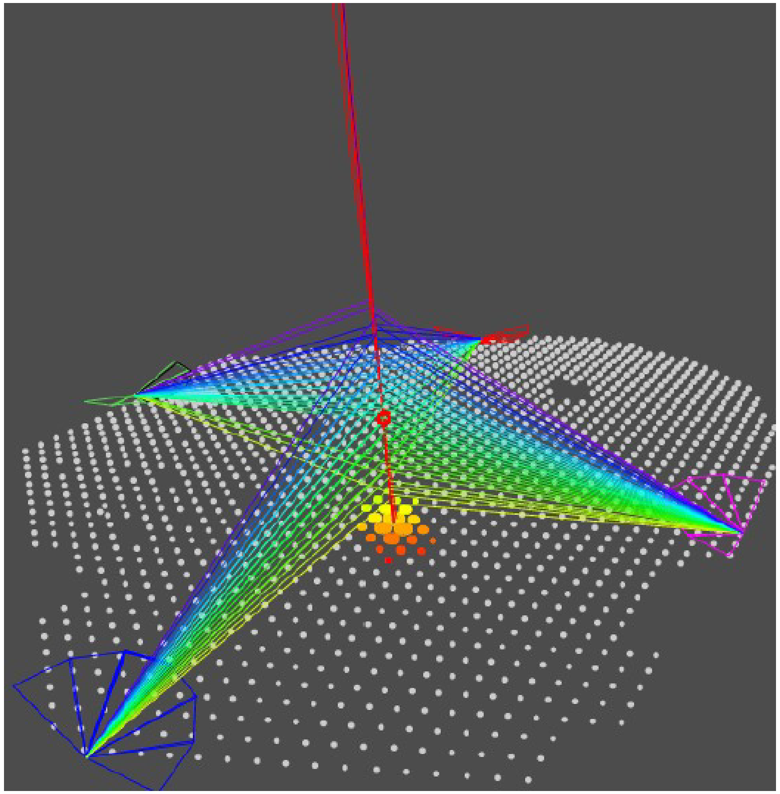
$$\propto \int \frac{dN_e}{dX}\,dX$$

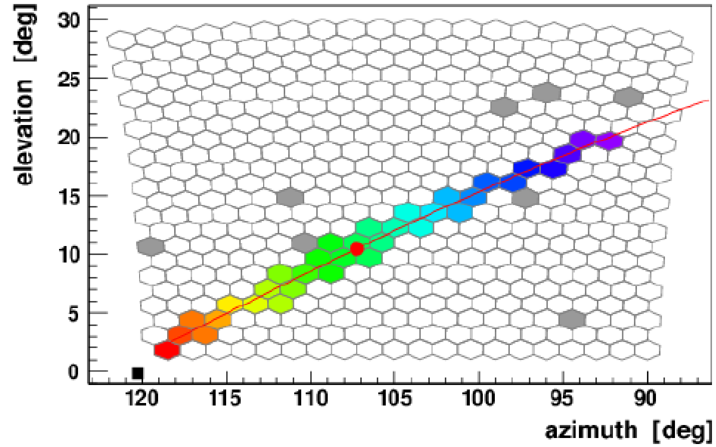
$$N_\mu \cong \int \frac{dN_\mu}{dX}\,dX$$

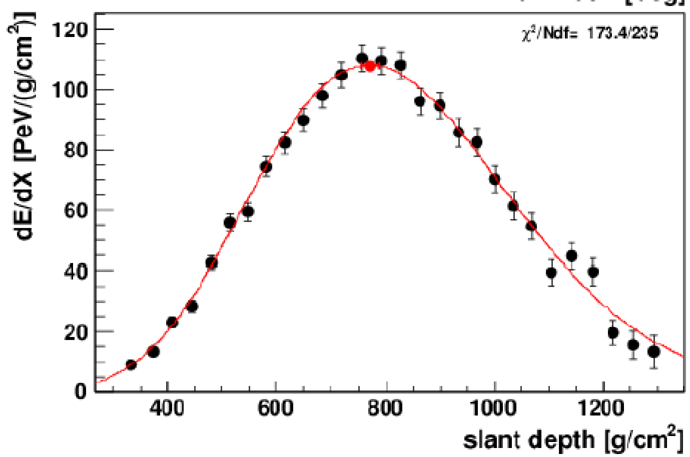
Shower detection

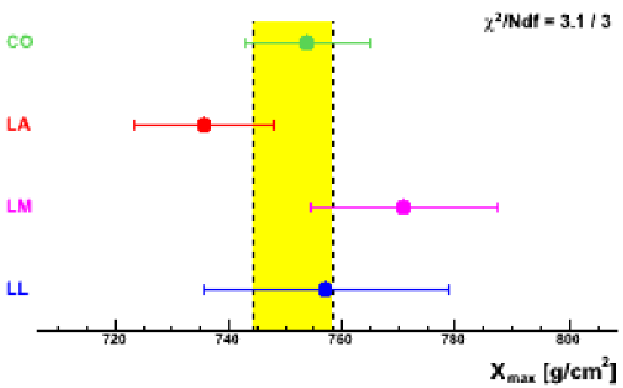


A 4 eyes hybrid event !









Energy

$E = (7.1 \pm 0.2)\ 10^{19}$ eV

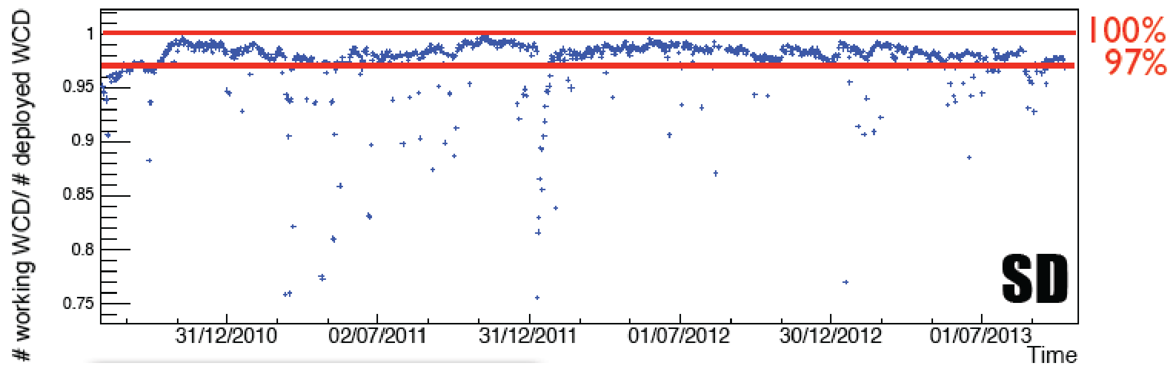
Depth of the maximum

$X_{max} = (752 \pm 7)$ g/cm^2

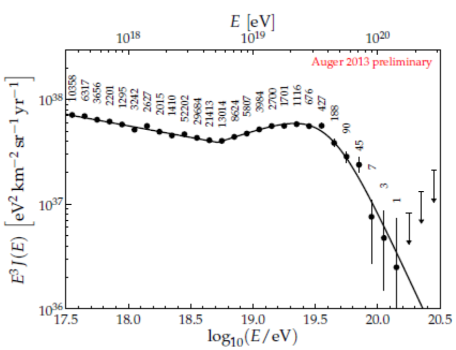
Where we stand

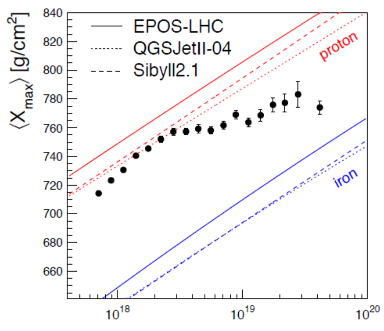
The Swiss clock!

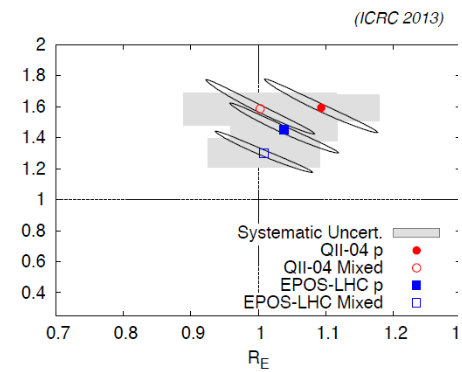
Fraction of Water Cherenkov Tanks in operation

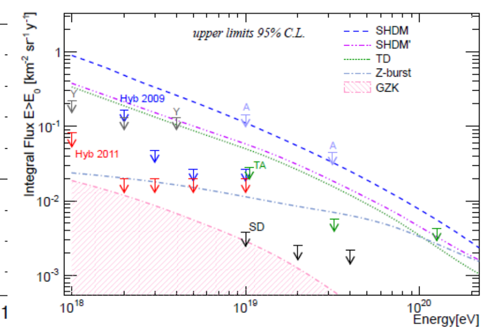


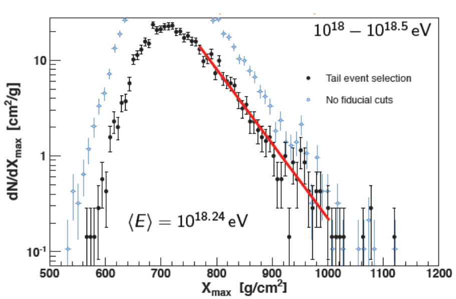
Many and important results !

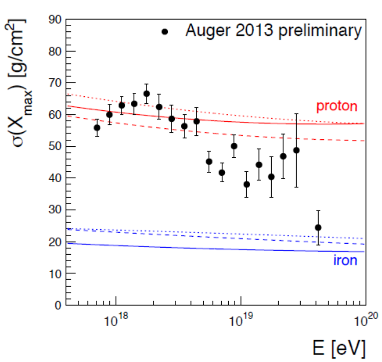


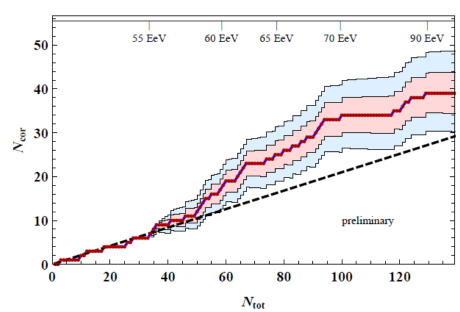


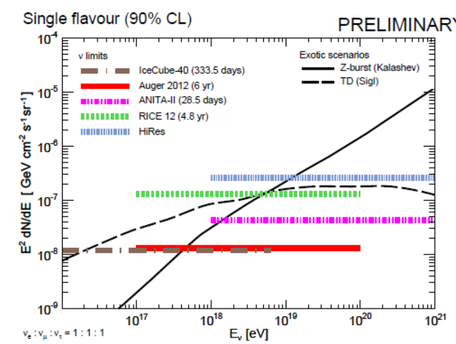




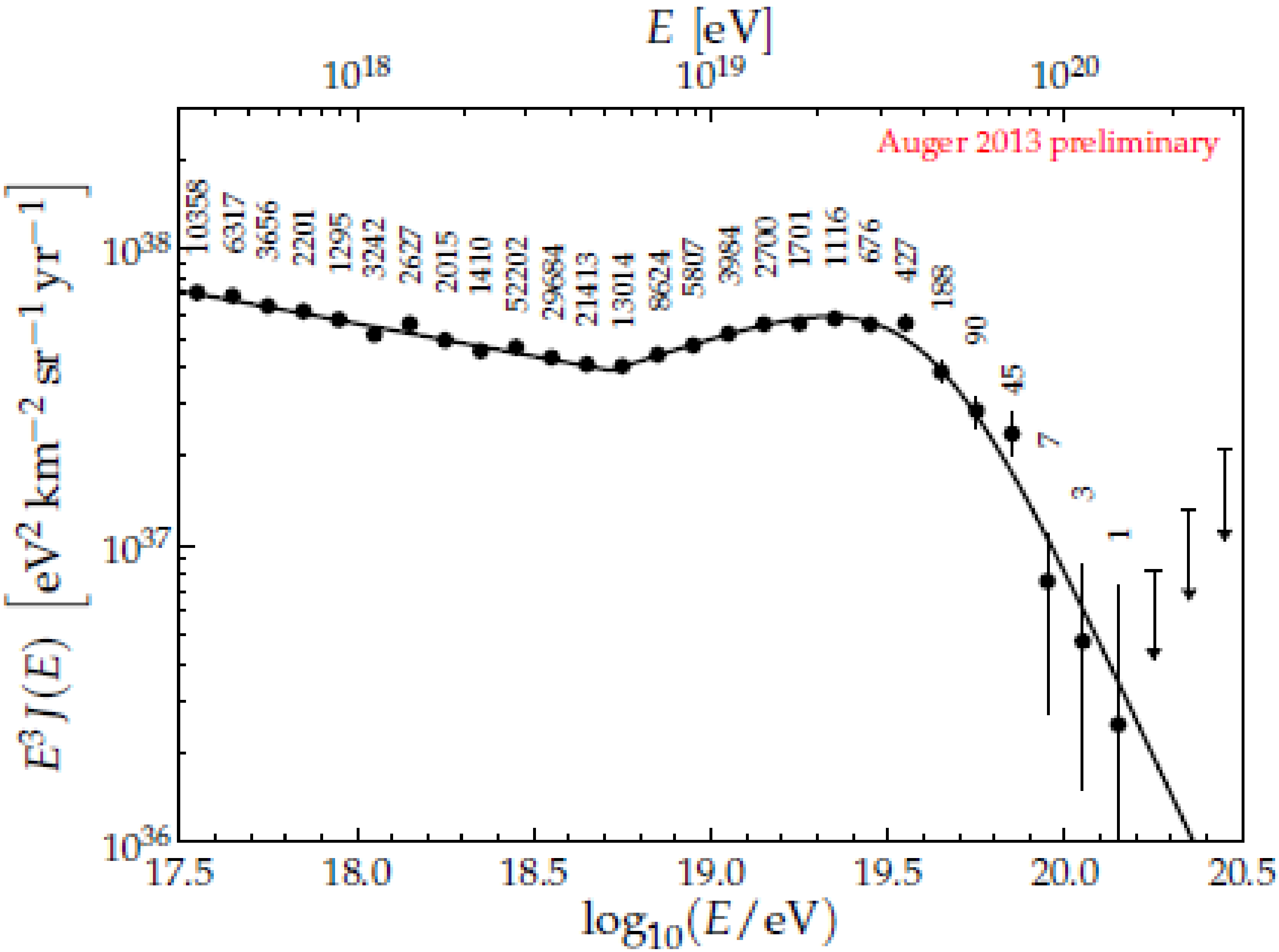


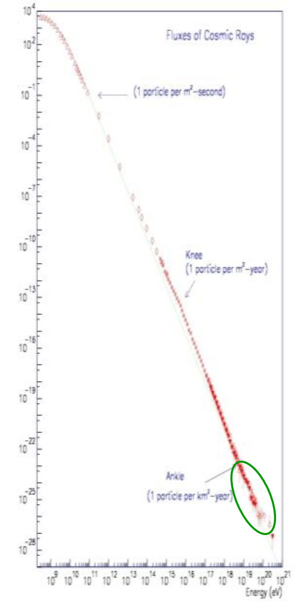




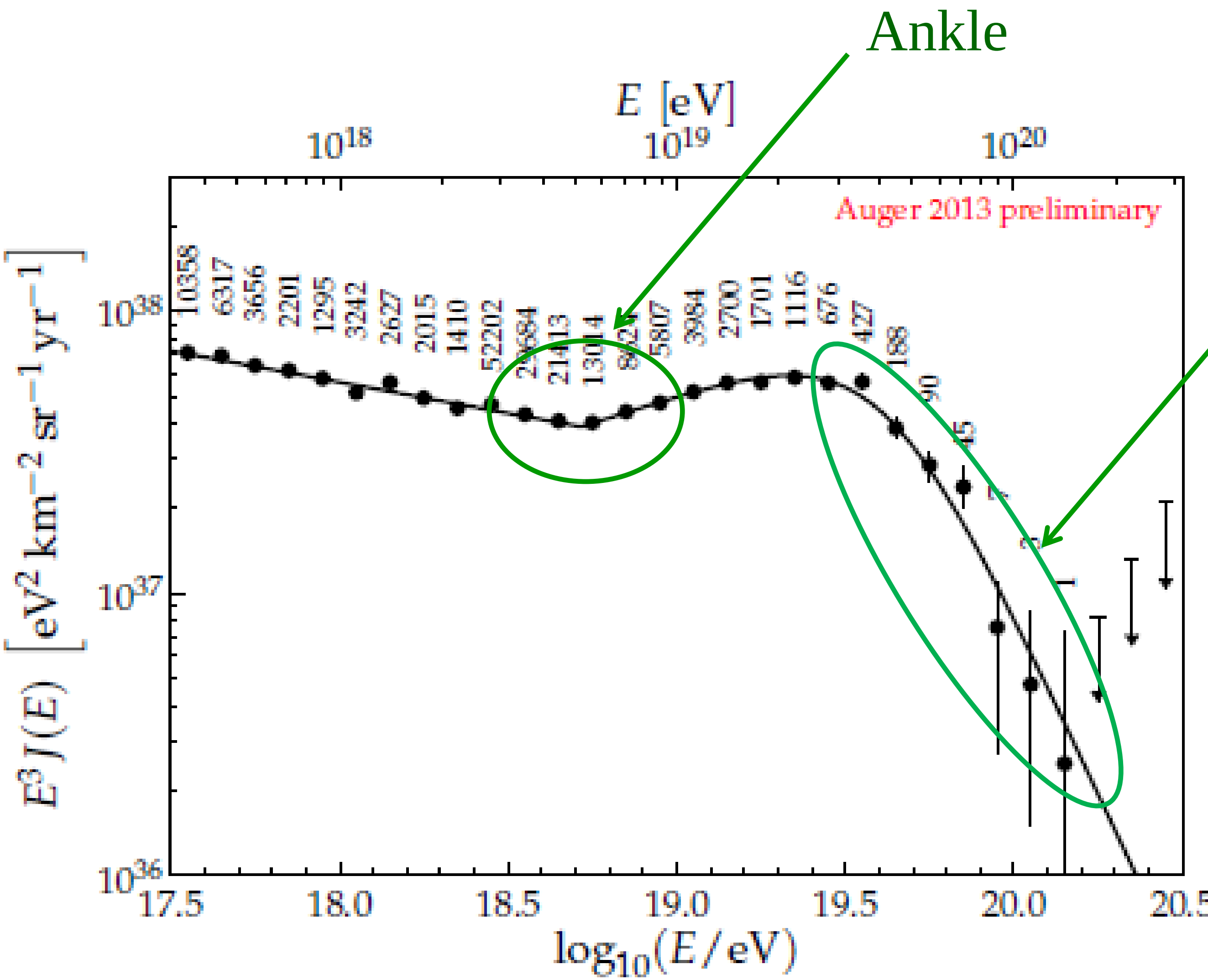


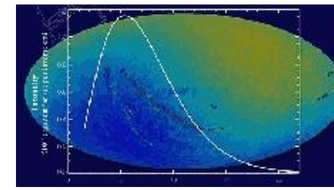
Energy spectrum

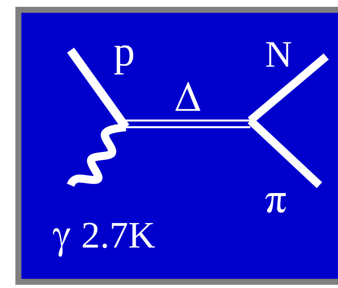




Energy spectrum



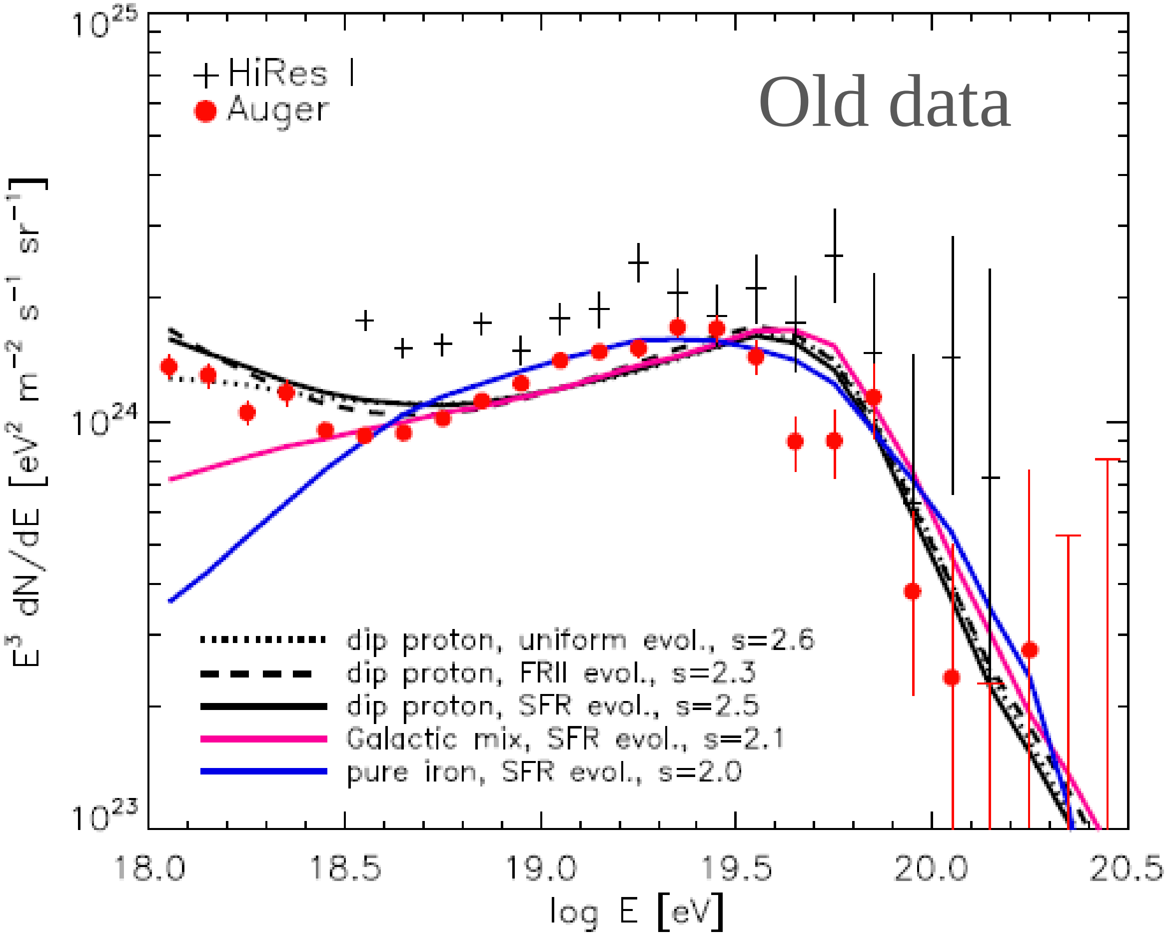




GZK like suppression !!!

Energy spectrum (interpretation)

Kotera &Olinto



GZK:
$p\ \gamma \rightarrow \Delta \rightarrow p\ N$

Dip (Berezinsky et al) :
$p\ \gamma \rightarrow p\ e^+ e^-$

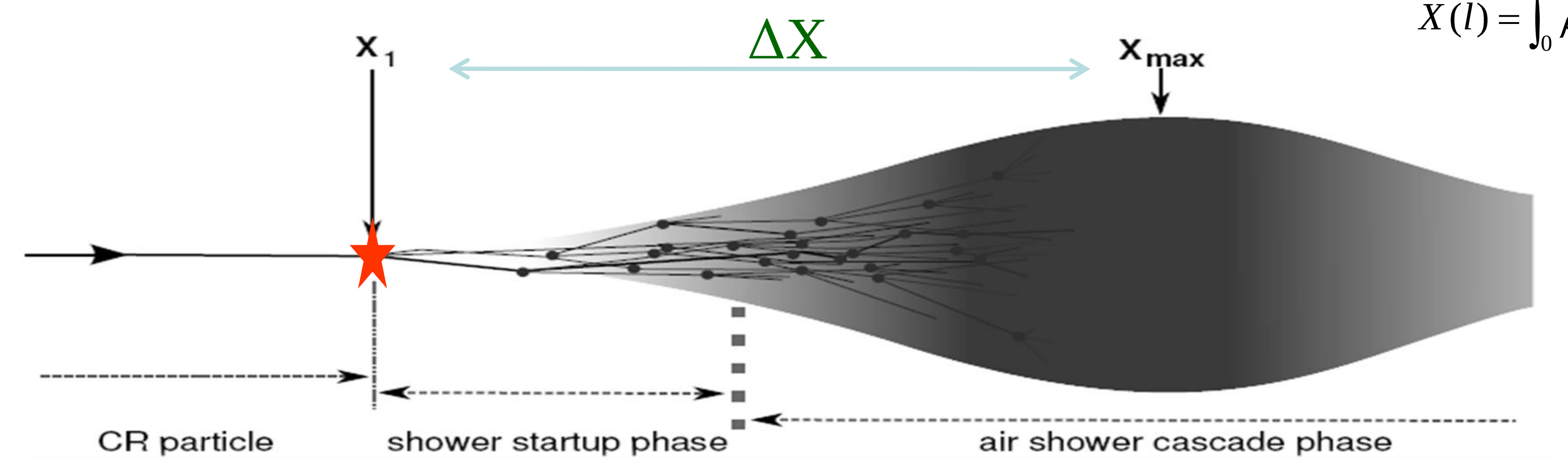
The "disappointing" model: heavy nuclei and no cosmogenic neutrinos

Mixed models:
fine tuning!

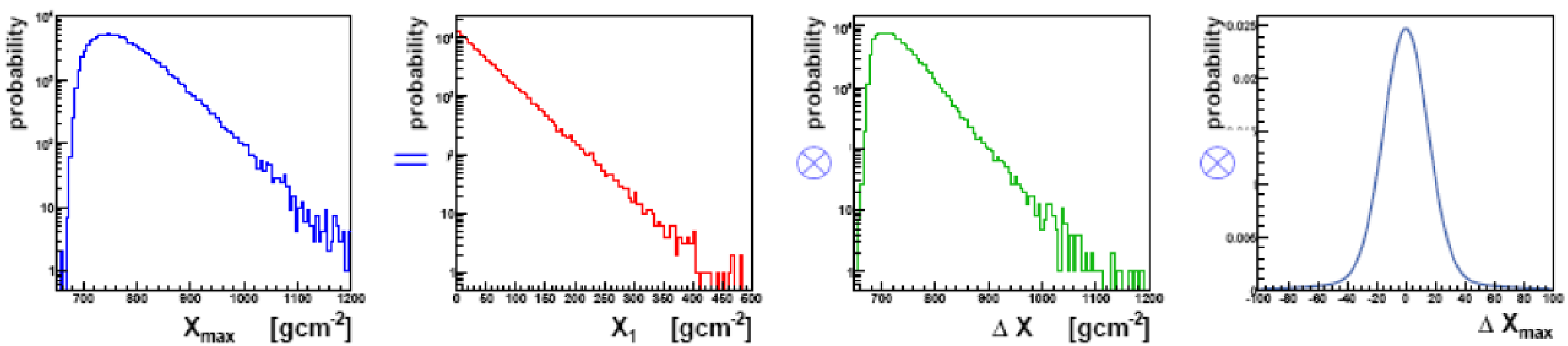
Do we see the GZK or the exhaustion of sources (or both …)???

The “X_{max} distributions”

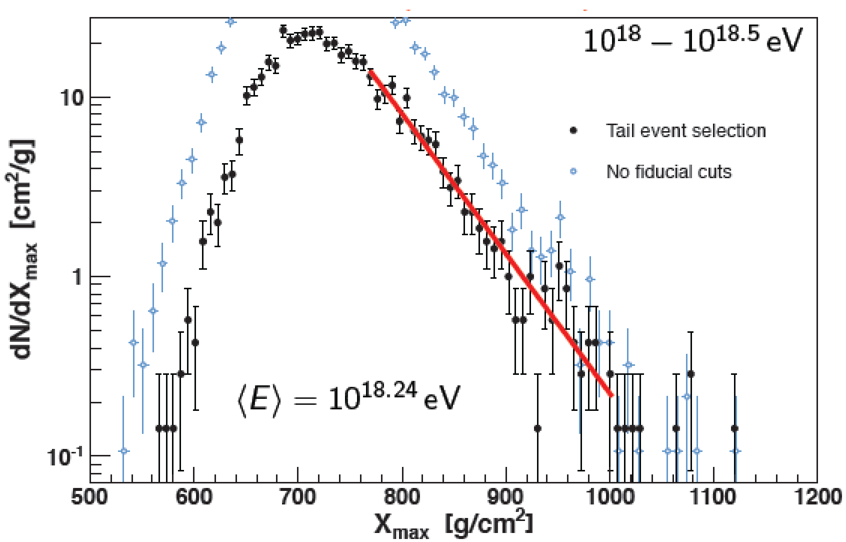
$$X(l) = \int_0^l \rho(x)\,dx$$



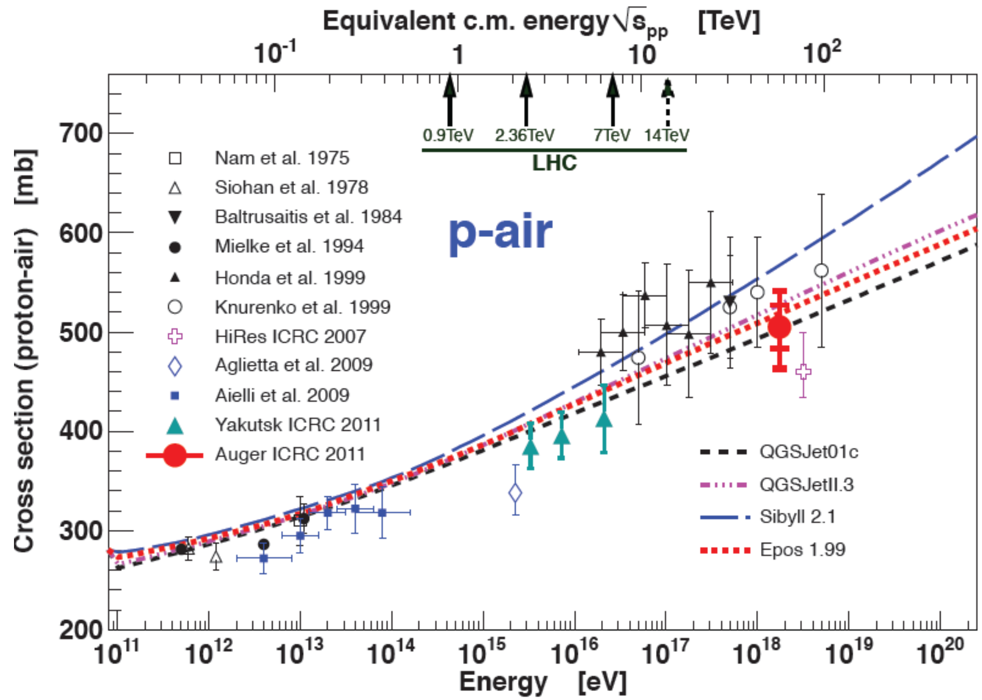
X1 ΔX Experimental resolution

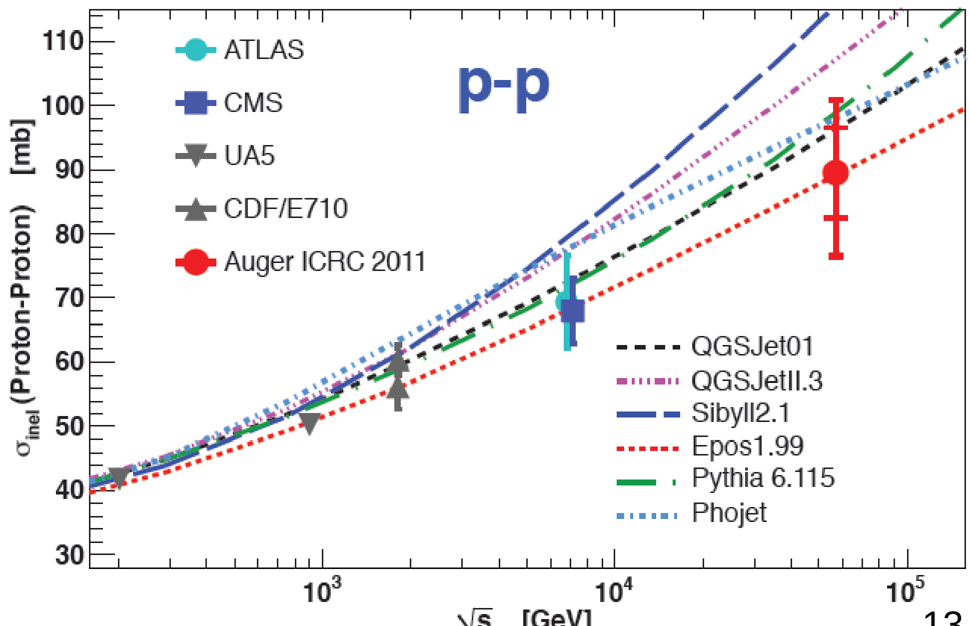


Proton cross-section



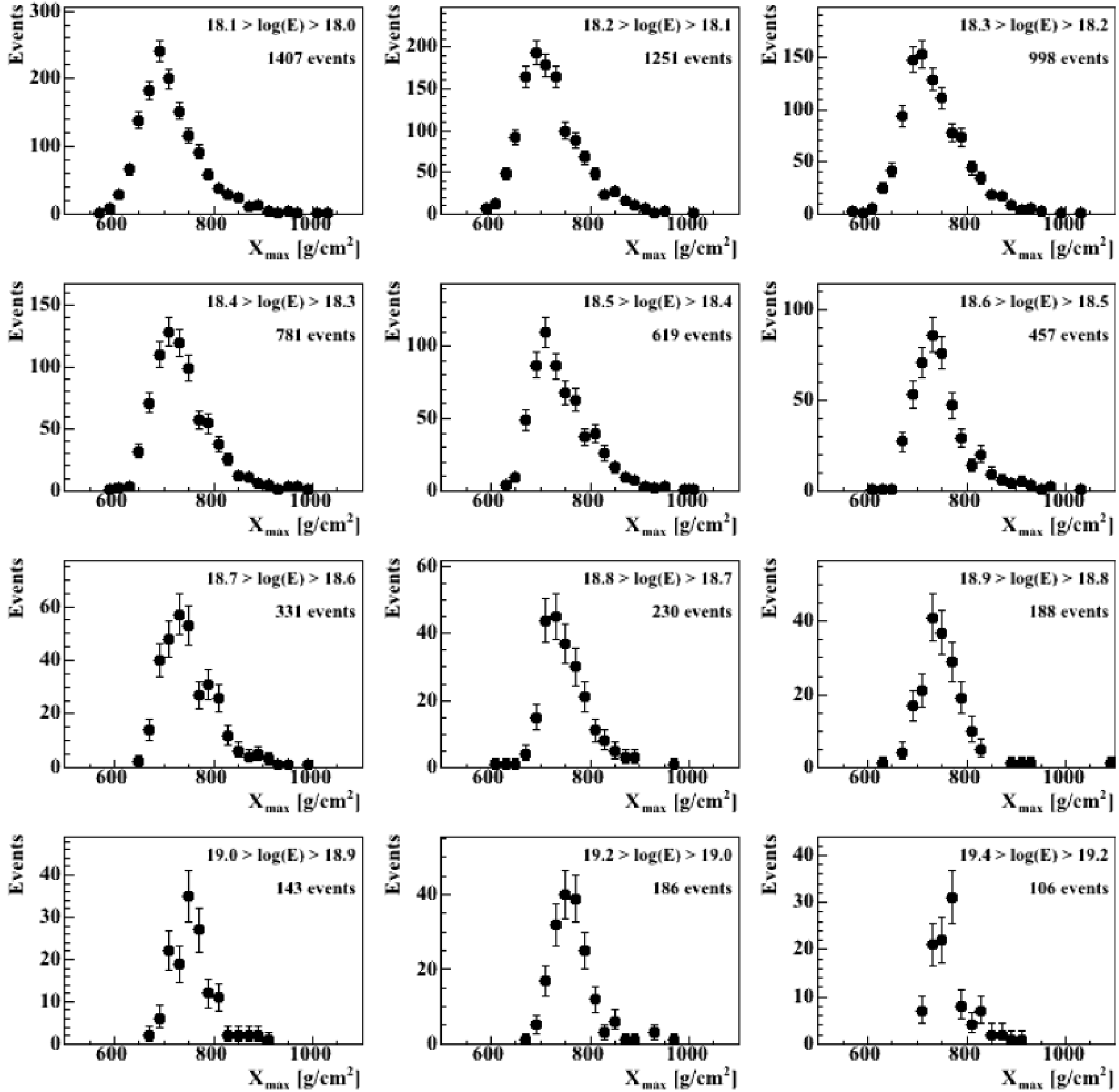
If % p > 20%, % He < 25%



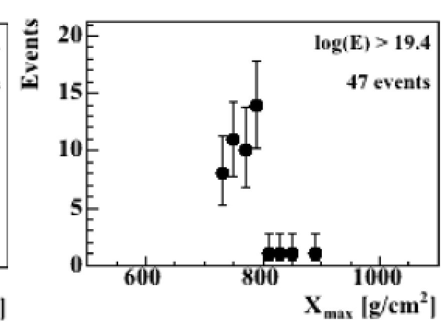


Slightly lower than it was expected at the time by most of the models, but in good agreement with recent LHC data.

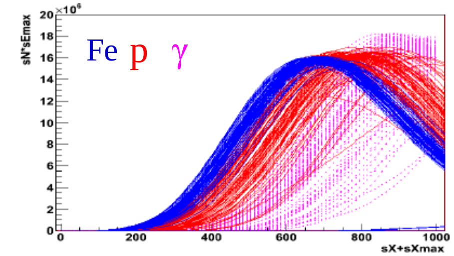
X_{max} distributions



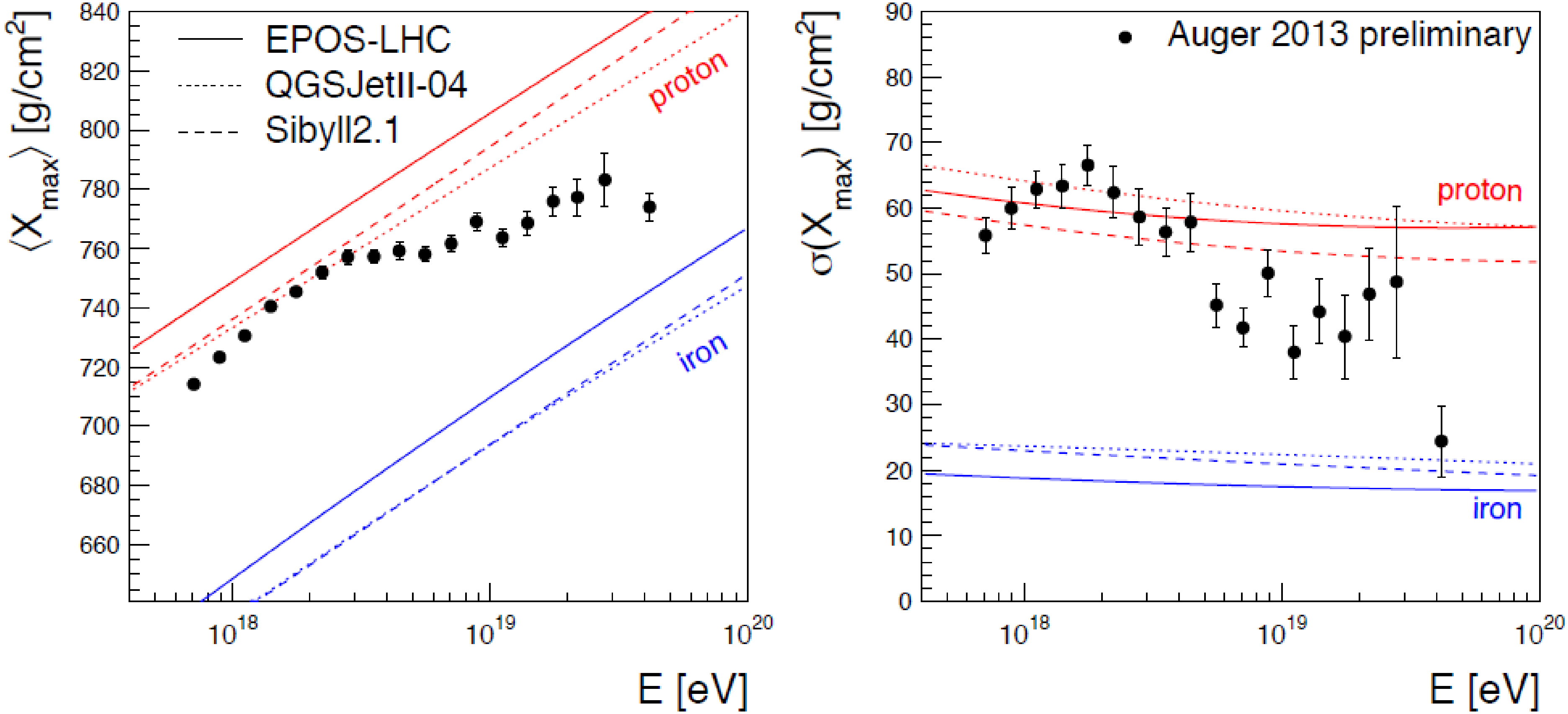
As the energy increases the distributions become narrower !!!



$<X_{max}>$ and RMS(X_{max})



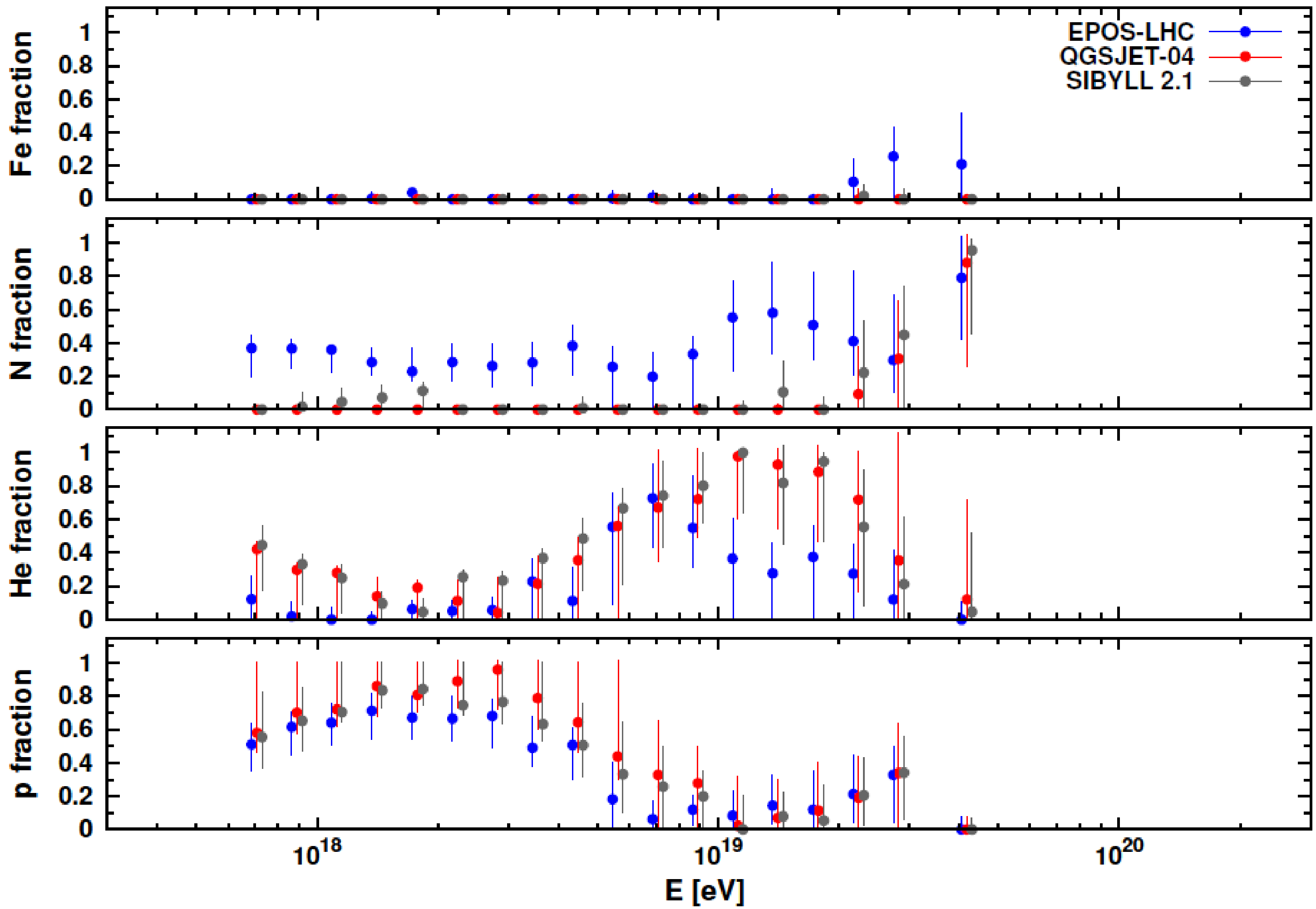
(ICRC 2013)



A clear change above 3 10^{18} eV

Beam composition ??? Hadronic interactions???

Nuclei fraction from X_{max} distributions

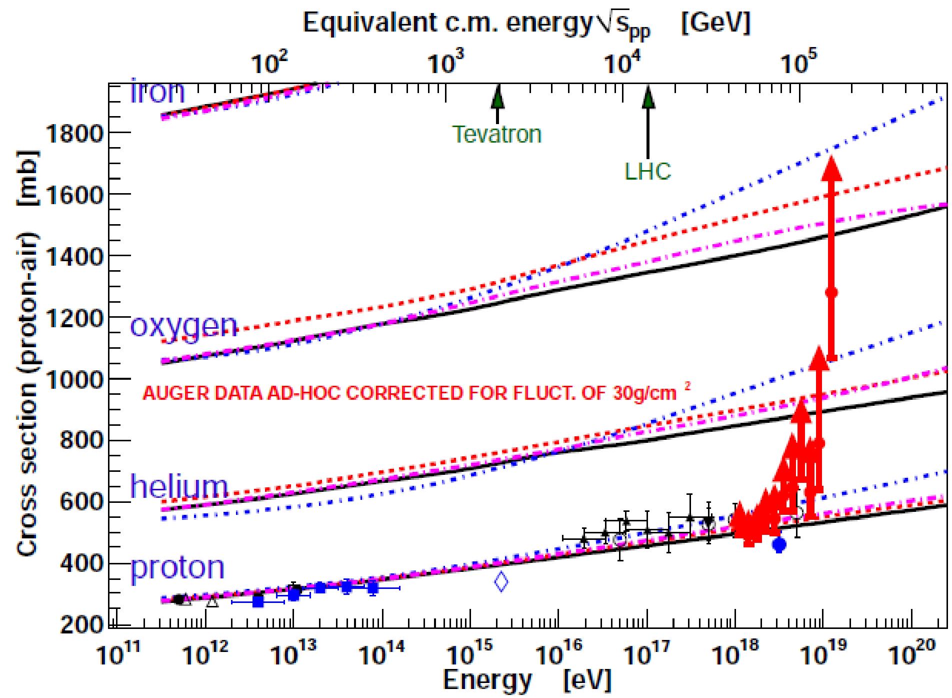


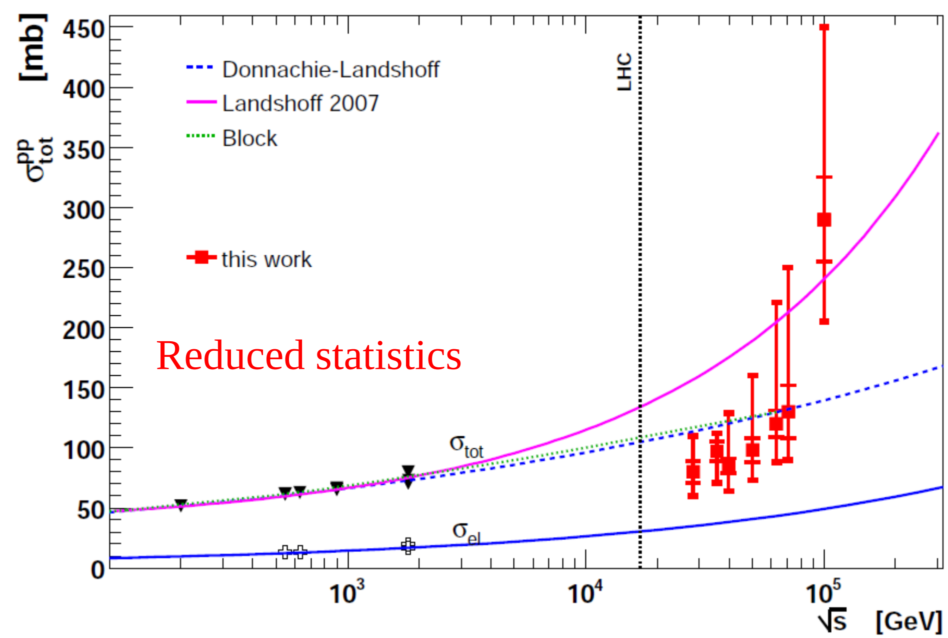
almost no Fe and <10% of p at the highest energies

a no “standard” astrophysics scenario !

If just proton …

R.Ulrich



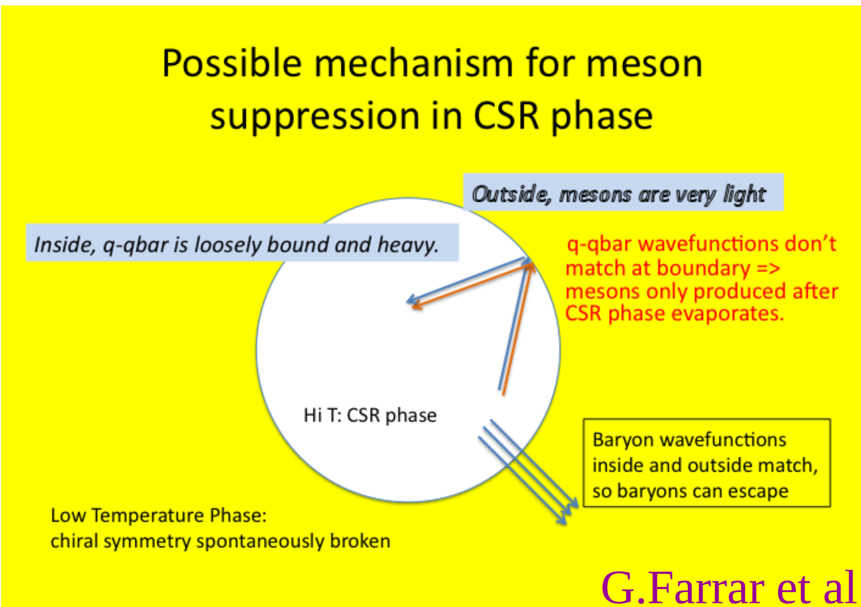


A dramatic increase in the proton-proton cross section around :

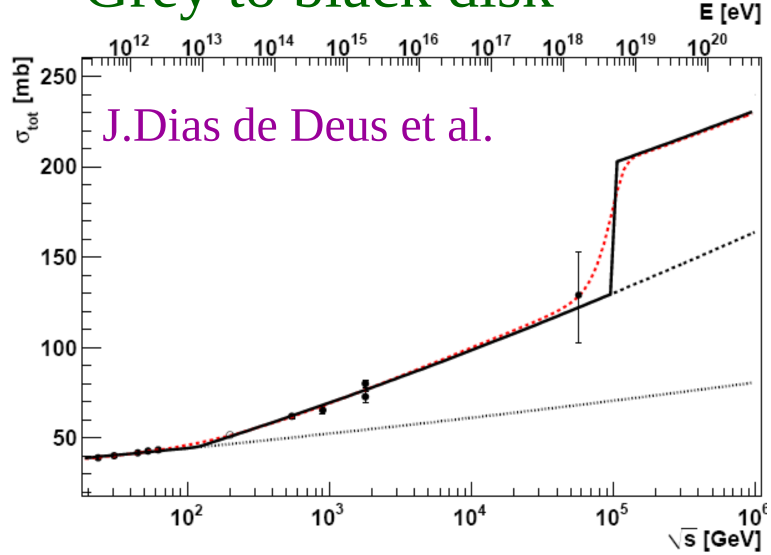
$$\sqrt{s} = 100 \text{ TeV !!!}$$

Several models …

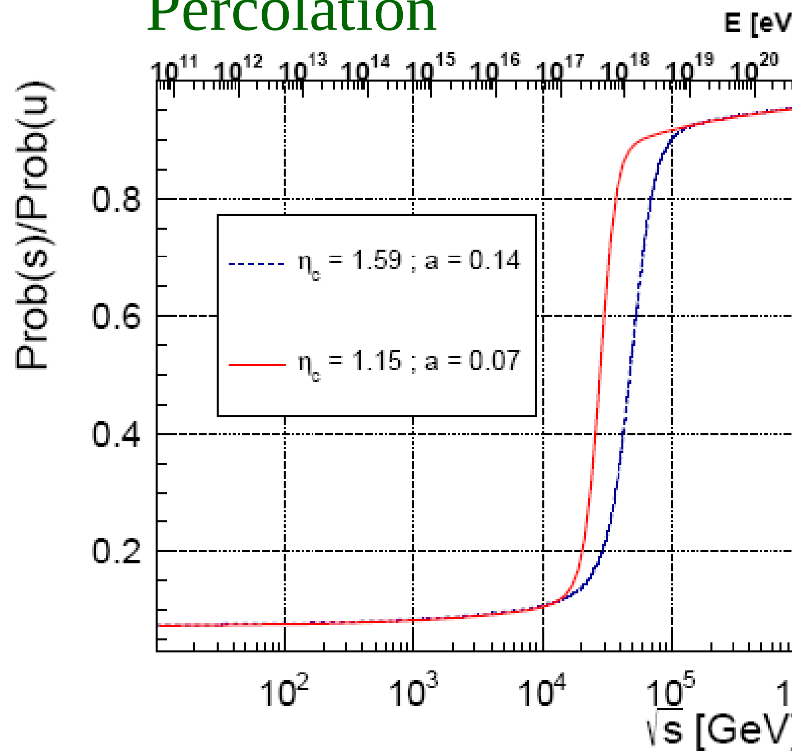
Chiral Symmetry Restoration



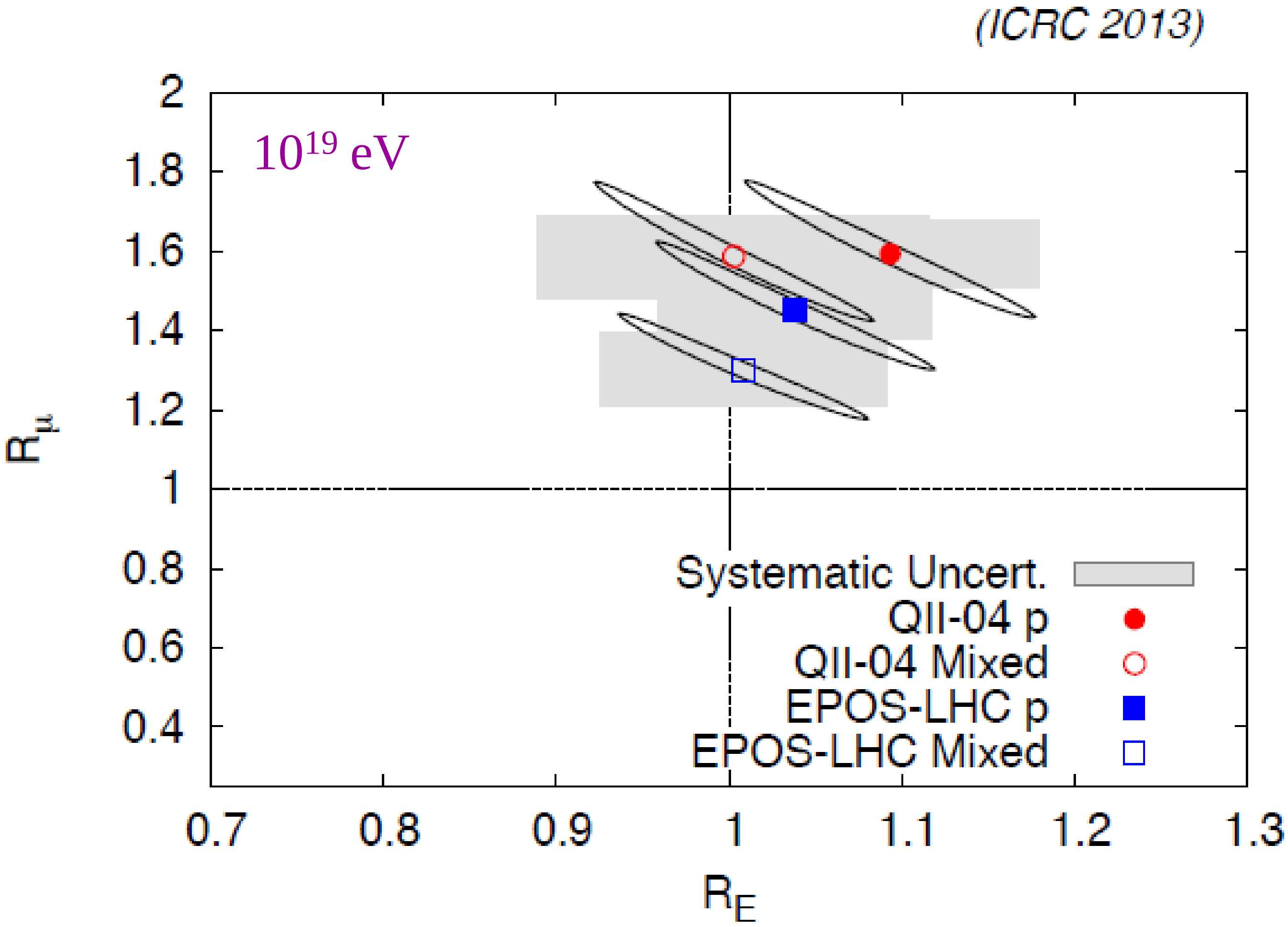
Grey to black disk

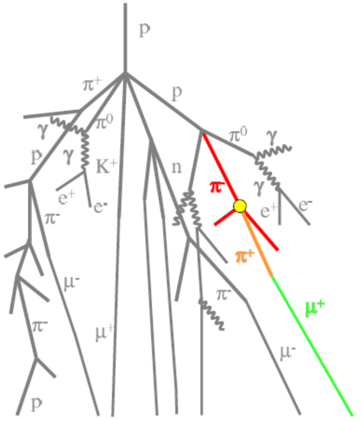


Percolation



The “number of μ”



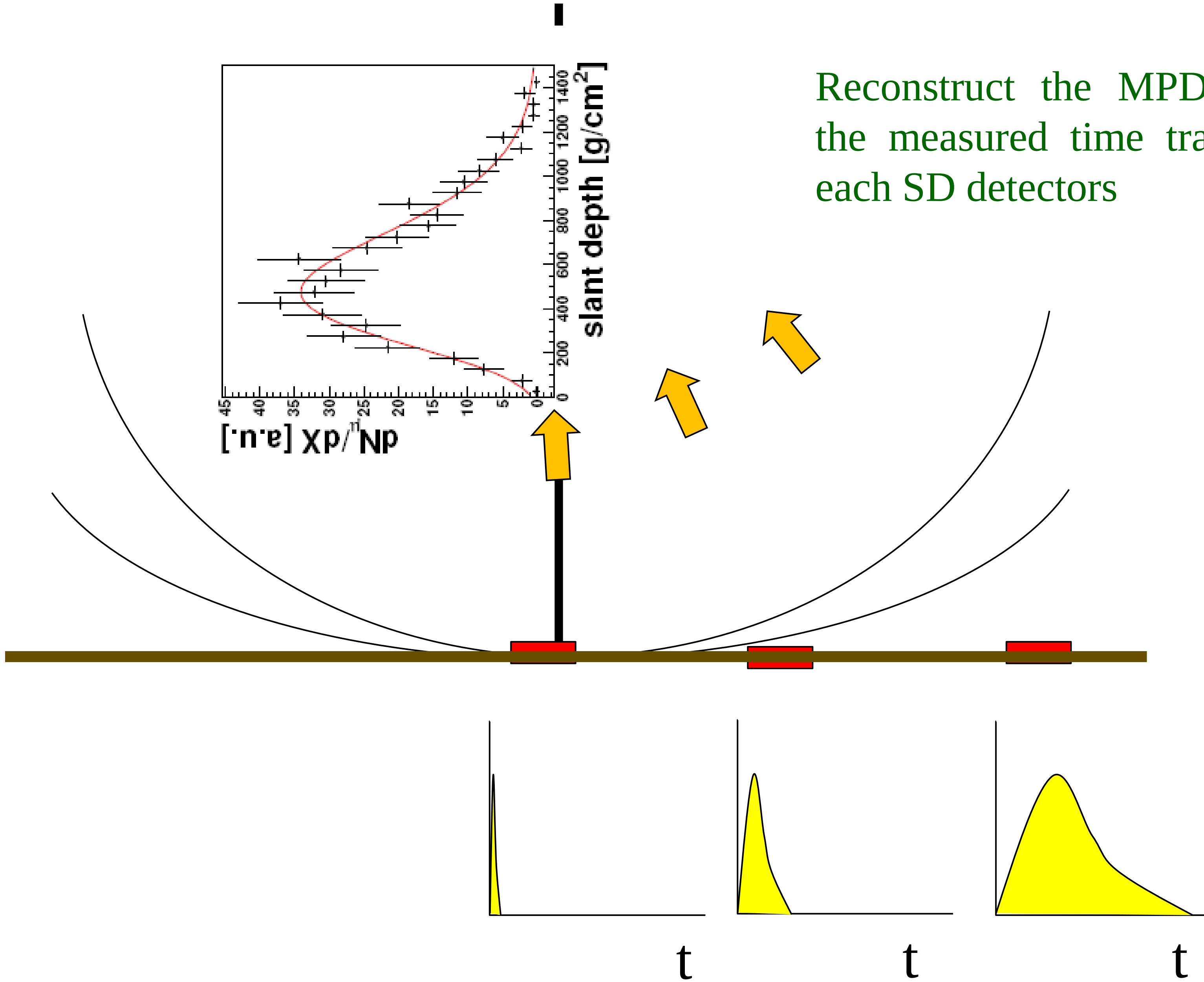


Current simulations do not provide a good description of the number of muons produced in air-showers!

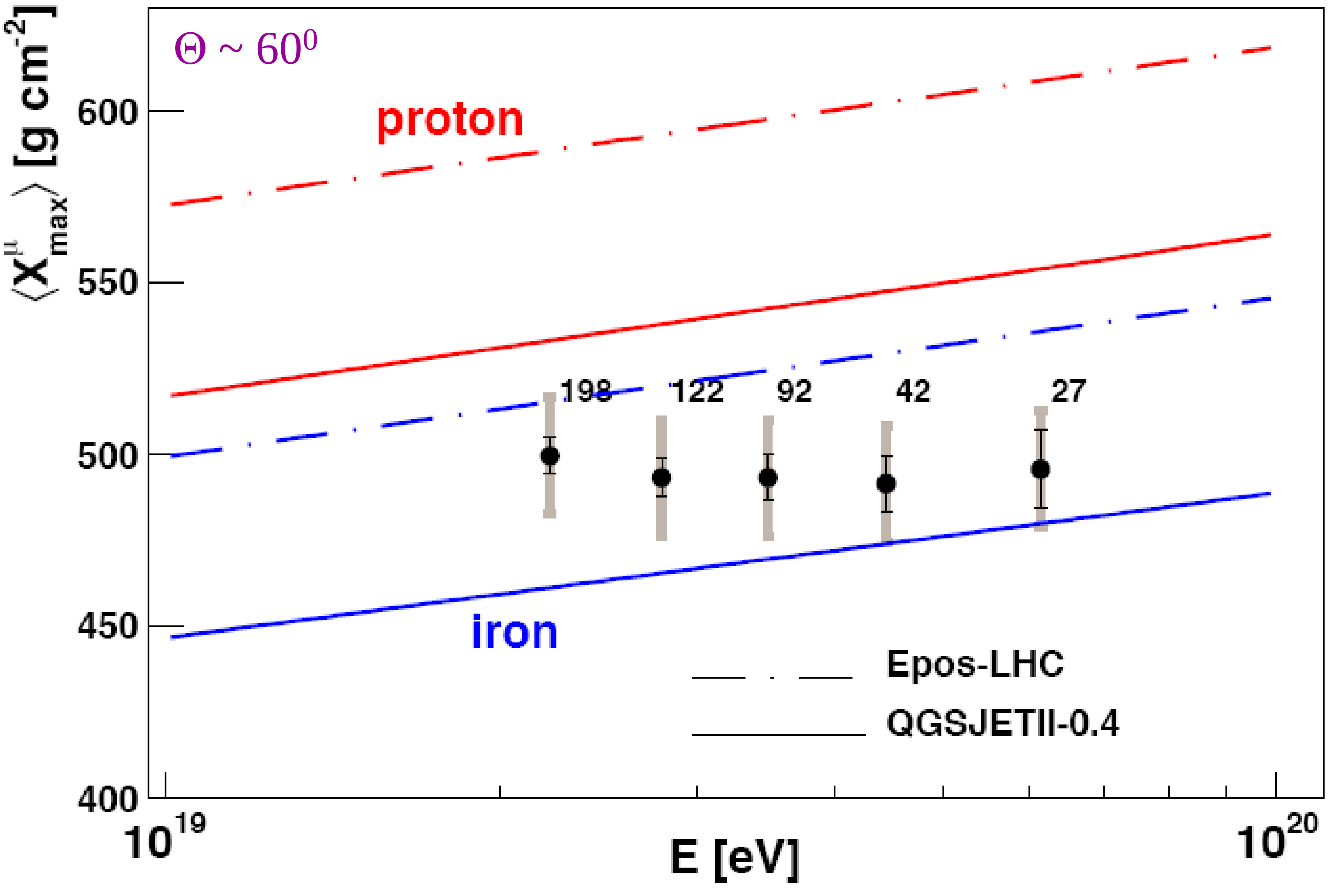
Muon Production Depth (MPD)

L. Cazon, R.A. Vazquez, A.A. Watson, E. Zas, Astropart.Phys.**21**:71-86 (2004)
L.Cazon, PhD Thesis (USC 2005)

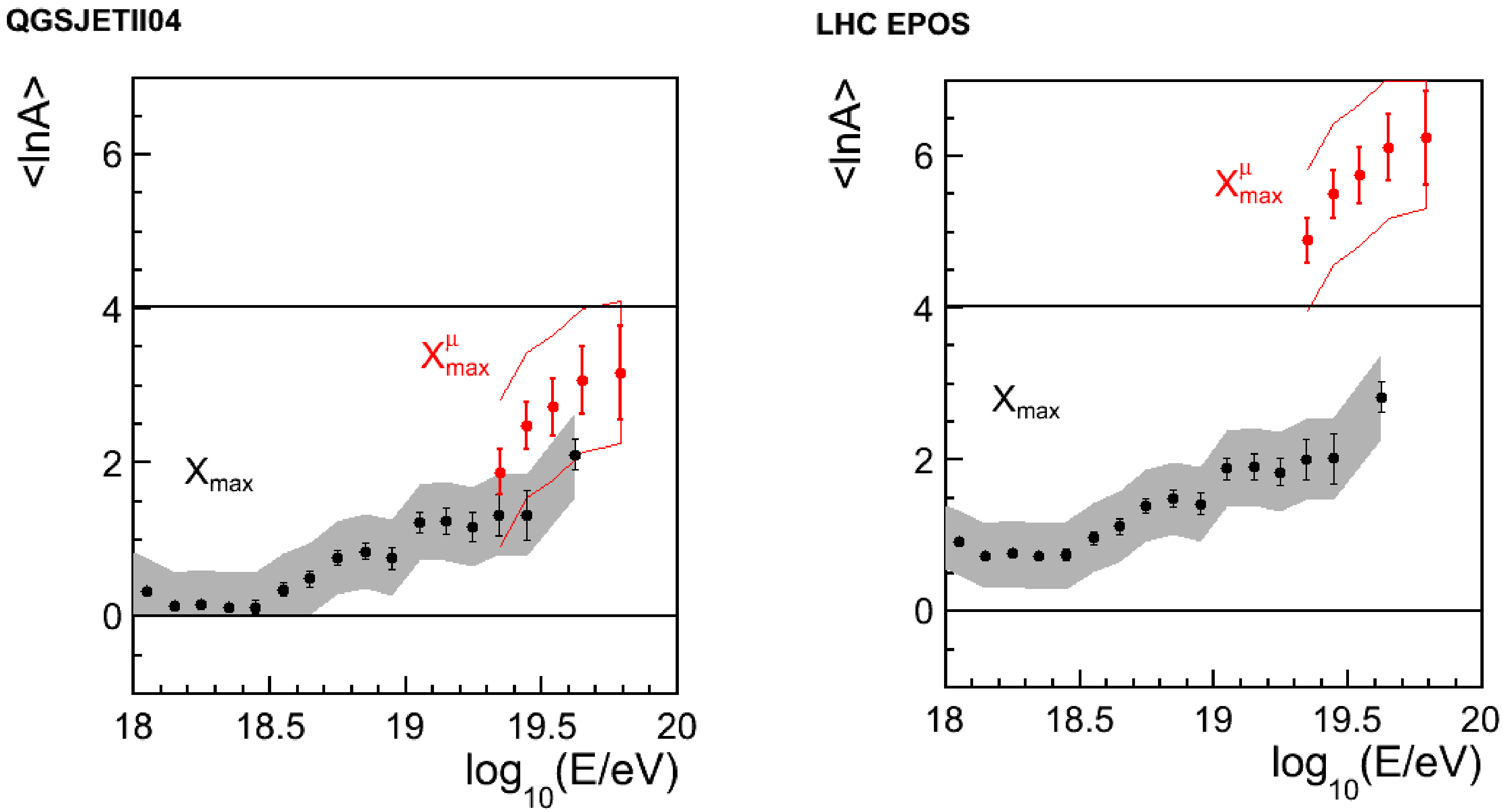
Reconstruct the MPD from the measured time traces at each SD detectors



$\langle X^{\mu}_{max} \rangle$



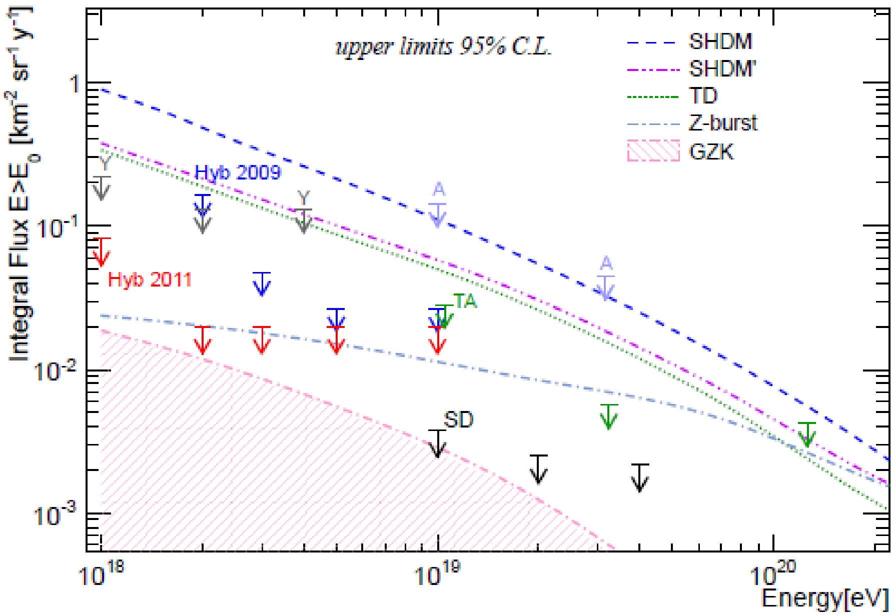
<ln A> from X_{max} and X^{μ}_{max}

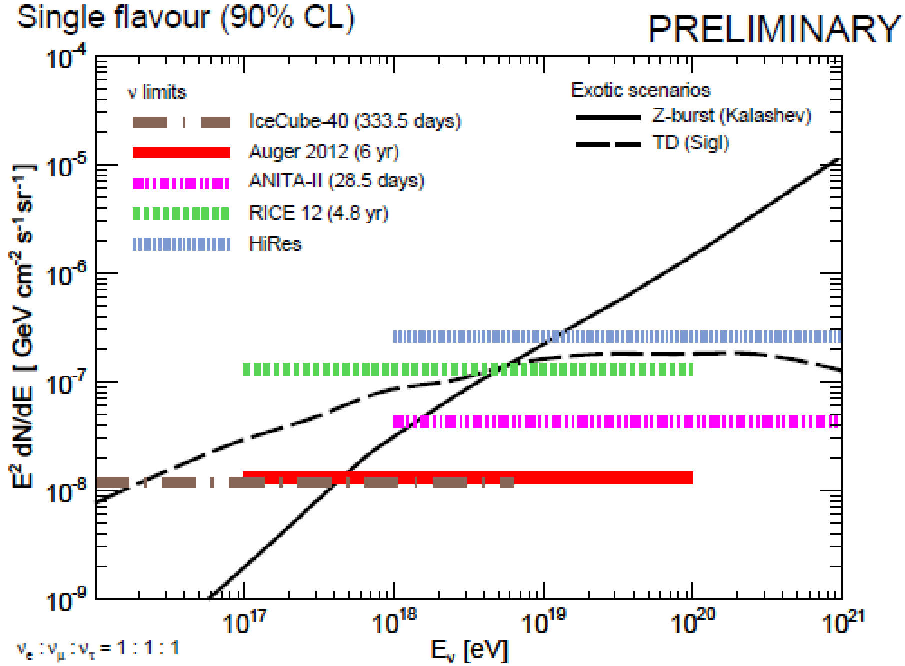


(X_{max} , X^{μ}_{max}) is sensitive to hadronic development of the shower (rapidity distributions, …)

Photon and neutrino limits

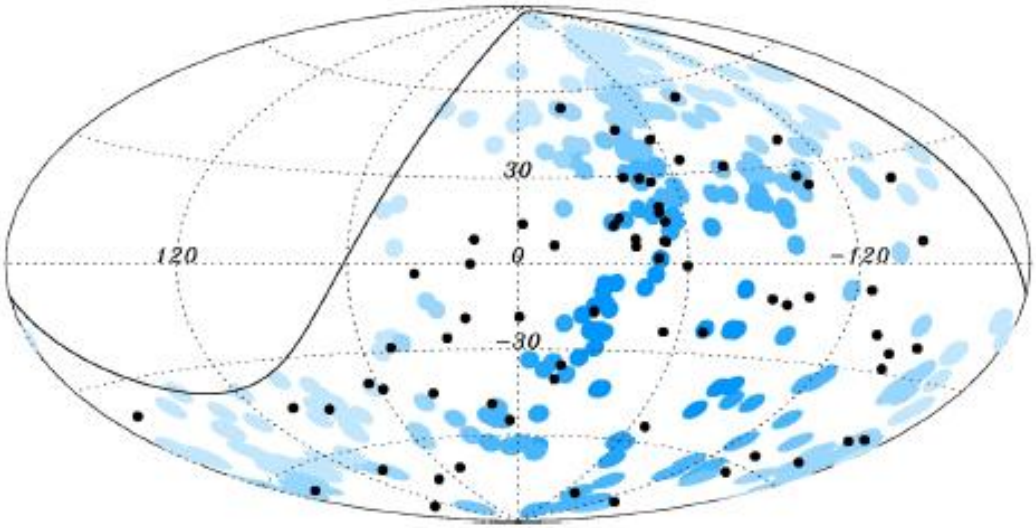
See Lu Lu talk





Current flux limits rule out or strongly disfavor top-down models

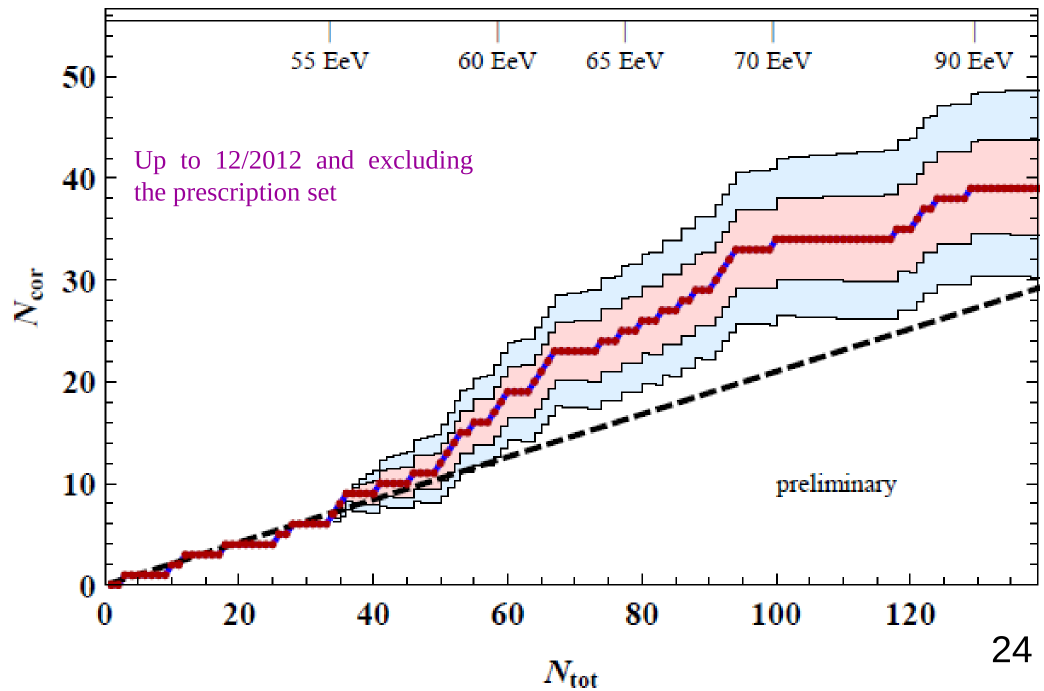
Correlation with AGNs



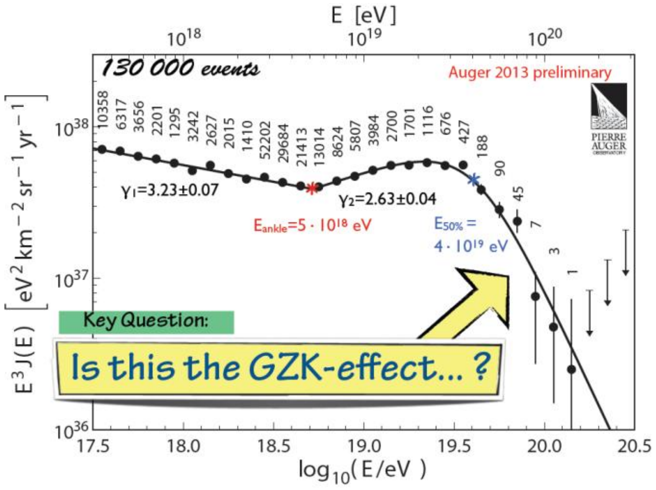
Vernon-Cetty-Vernon AGN catalog

E> 57 EeV, z<0.018, distance < 3.1 deg.

33 out of 106 events correlate



Where we want to go

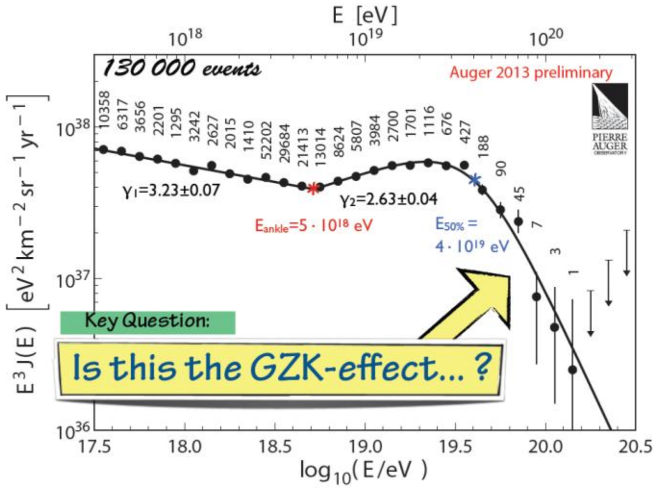


Energy cutoff

Resolve the question of the origin of the flux suppression (GZK or the exhaustion of sources?)

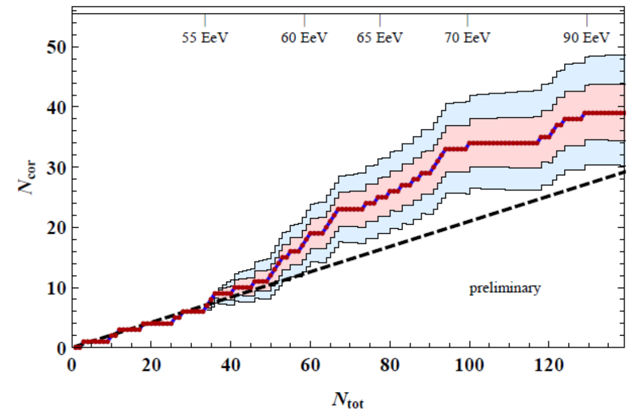
Where we want to go

Resolve the question of the origin of the flux suppression (GZK or the exhaustion of sources?)



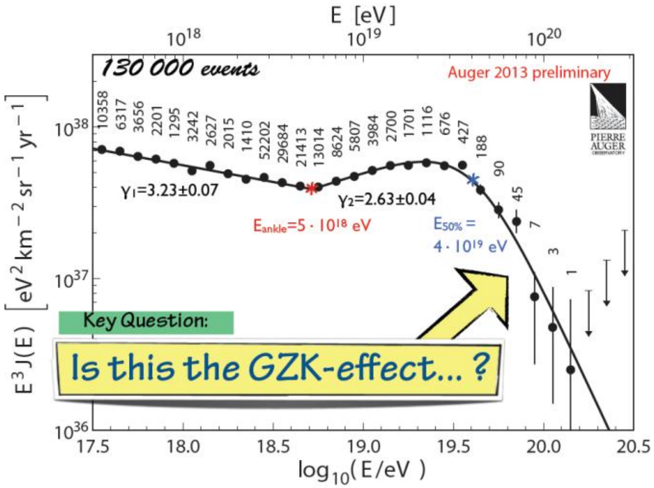
Energy cutoff

Search for a flux of protons at the highest energies opening a particle astronomy window



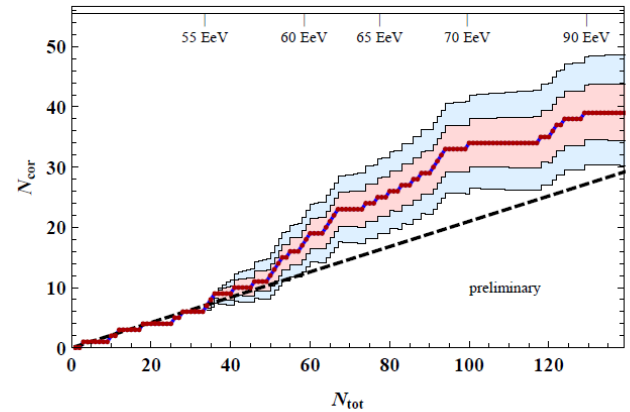
AGN correlation

Where we want to go



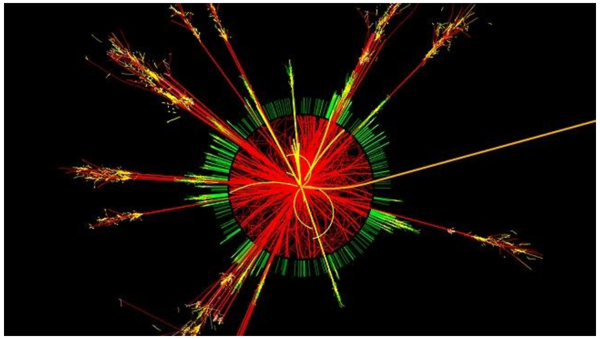
Energy cutoff

Resolve the question of the origin of the flux suppression (GZK or the exhaustion of sources?)



AGN correlation

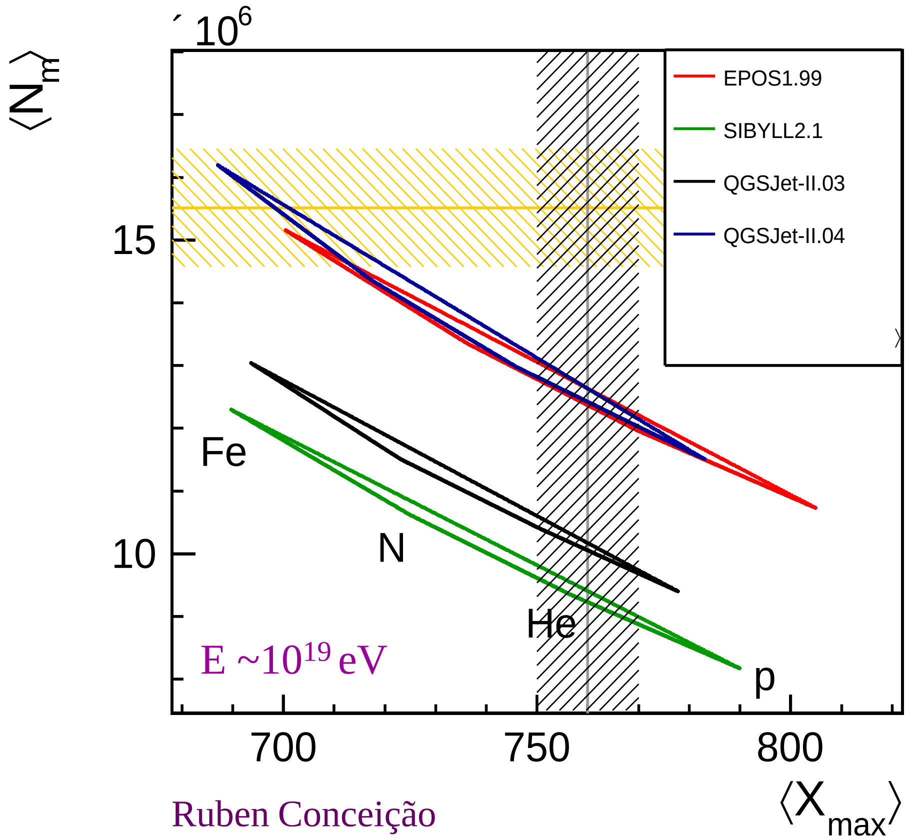
Search for a flux of protons at the highest energies opening a particle astronomy window

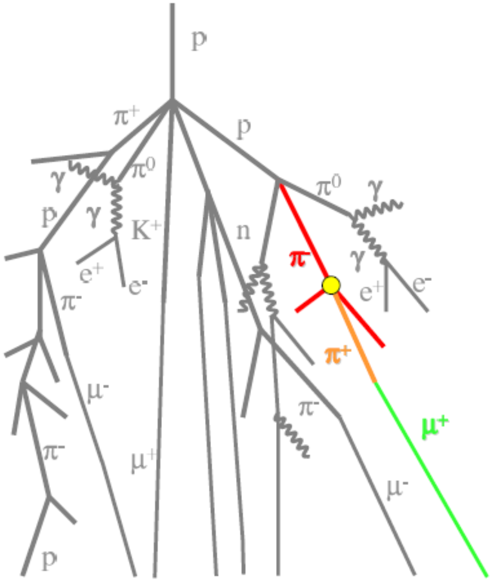


Study Hadronic Physics at the 100 TeV scale

Increase the sensitivity to muons

Disantangle hadronic models from composition scenarios





and

RMS (N_μ)

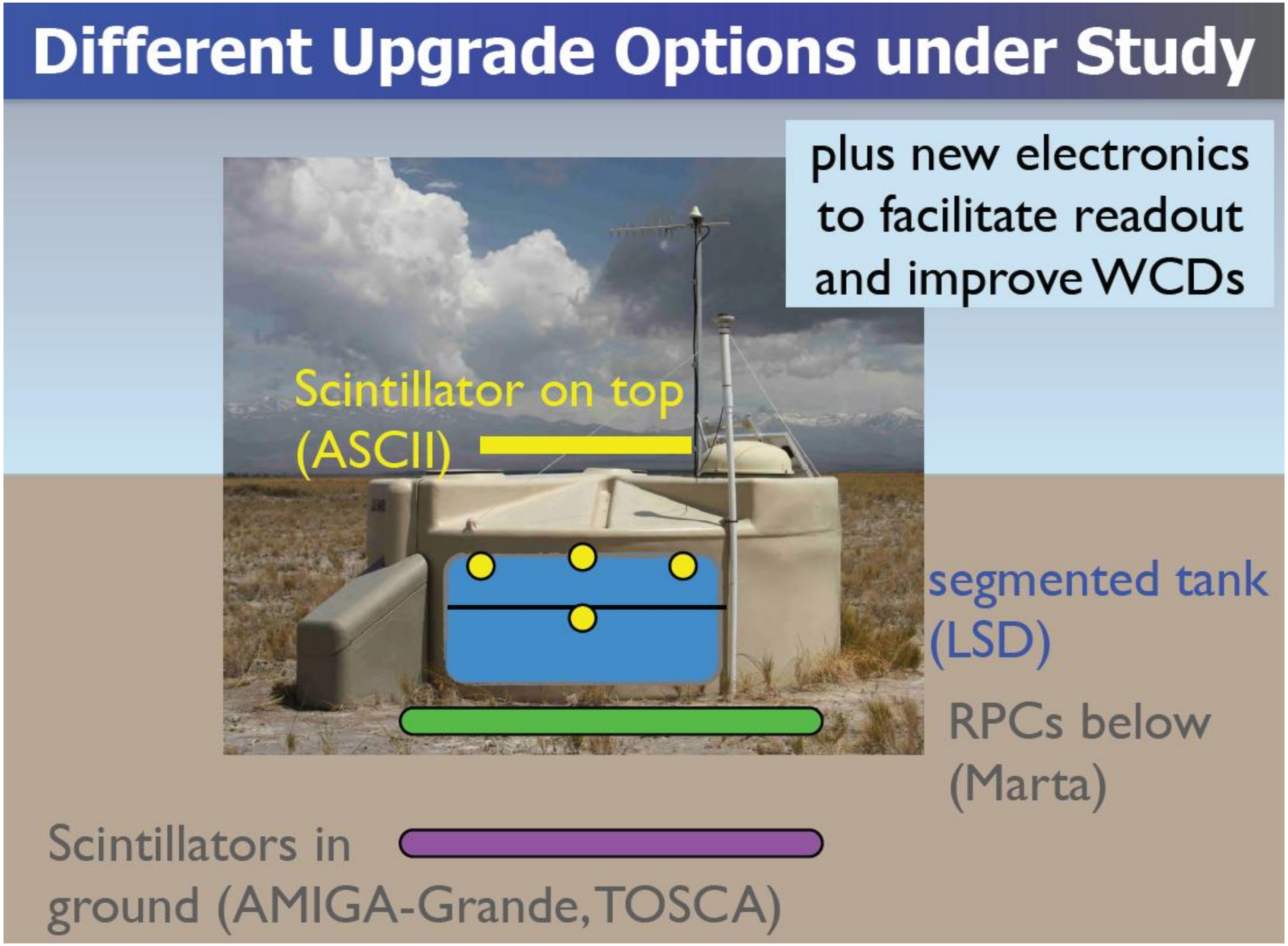
X^{μ}_{max}

LDF shape

....

Ruben Conceição

Auger 2015-2023



We are exploring the 100 TeV energy scale, well beyond LHC, and may be we are touching something fundamental!