Cosmic-ray session summary

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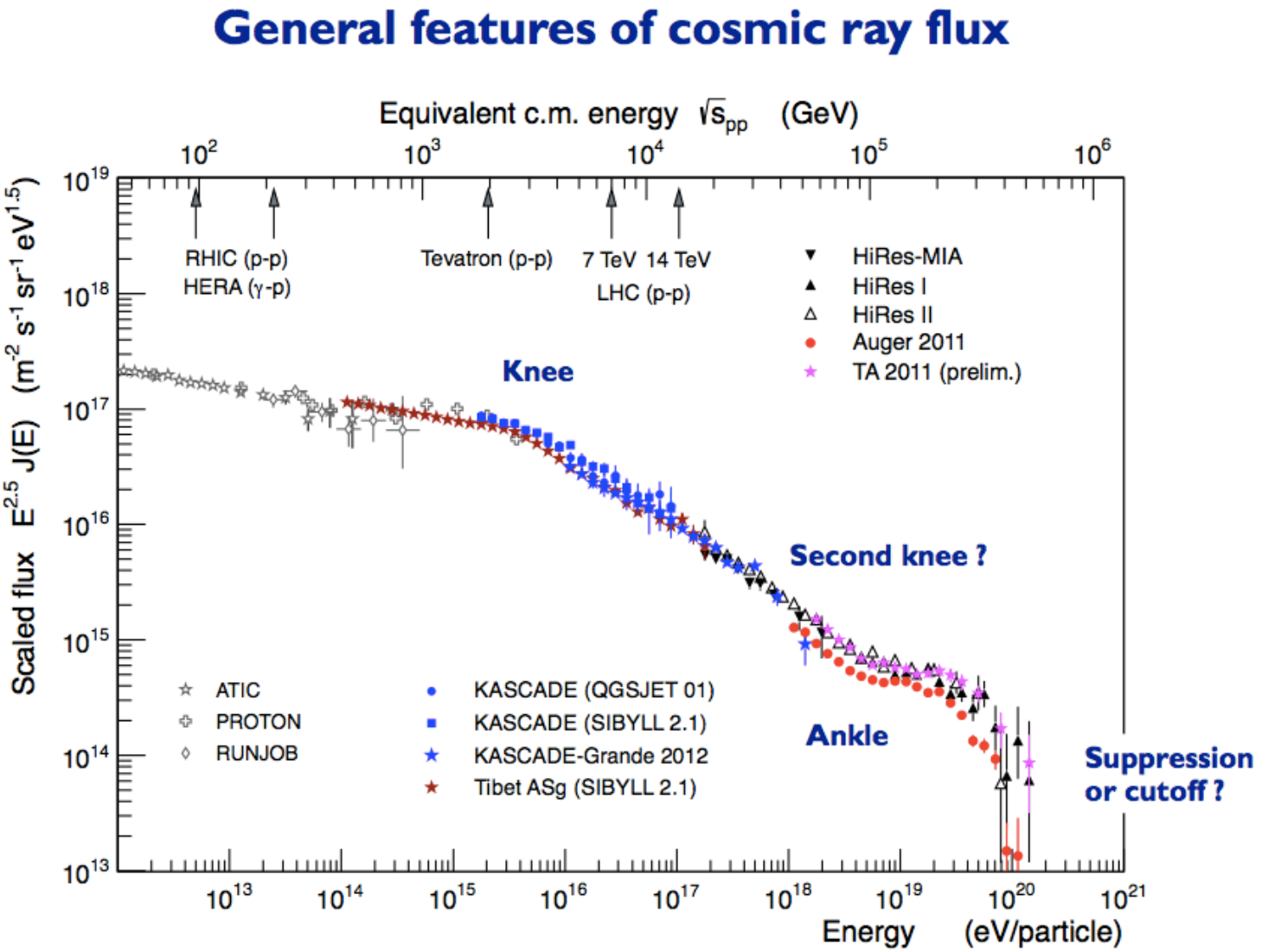
12. Feb 2013

Recall our goals

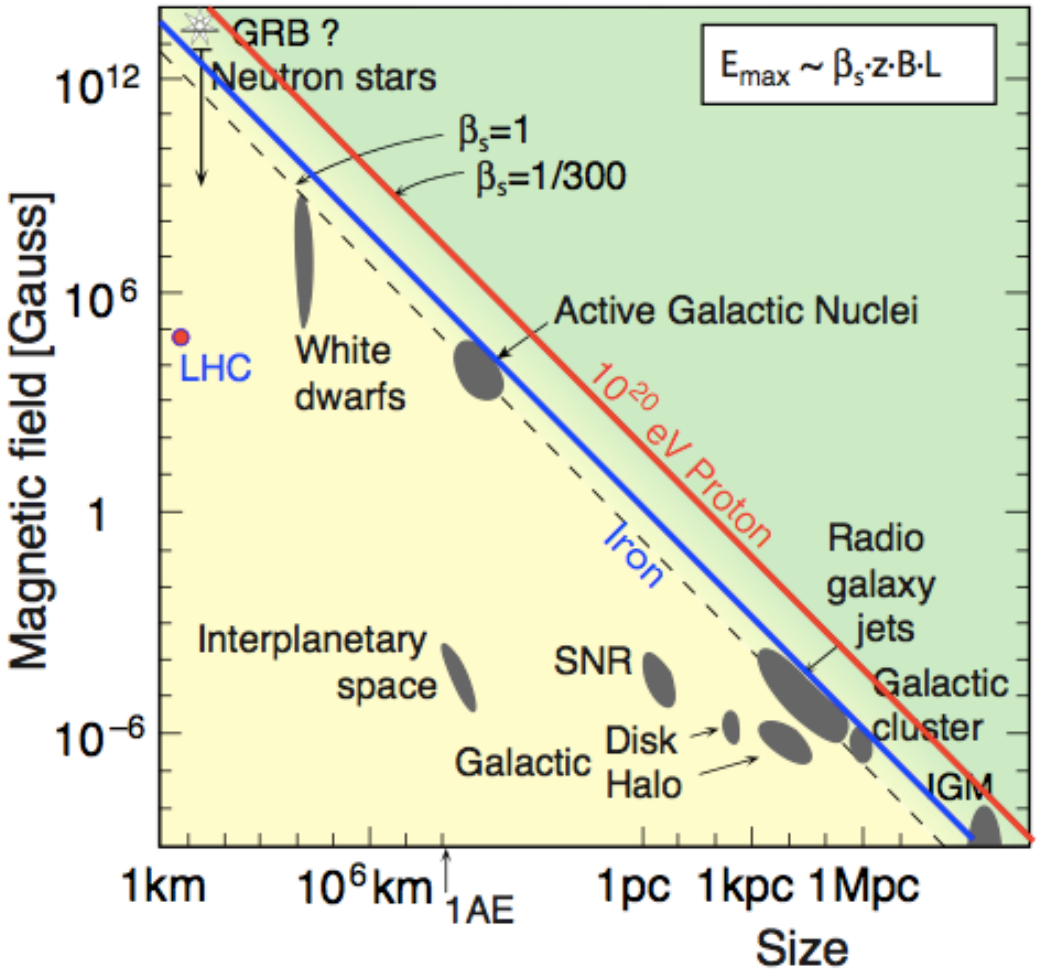
- Identify areas connecting cosmic-ray physics and physics done with collider detectors
- Compile a list of measurements that are most important for understanding air shower
- We need a common sense for what's needed, and should try to establish a way to achieve this (future activities!)

Science questions very brief



R.Engel

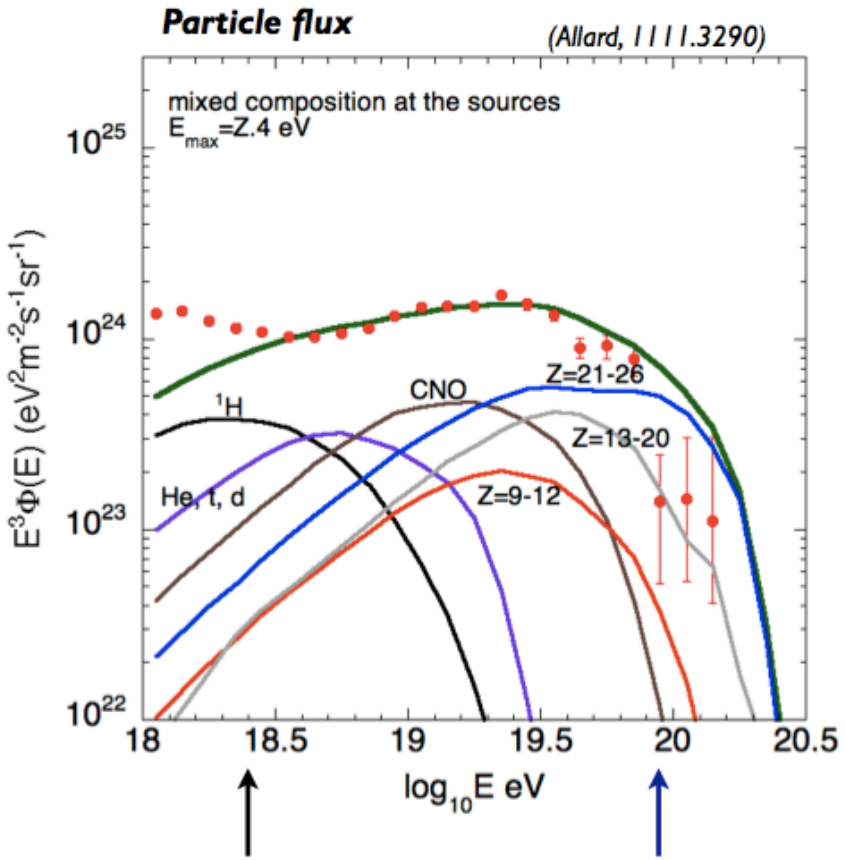
Science questions very brief



R.Engel

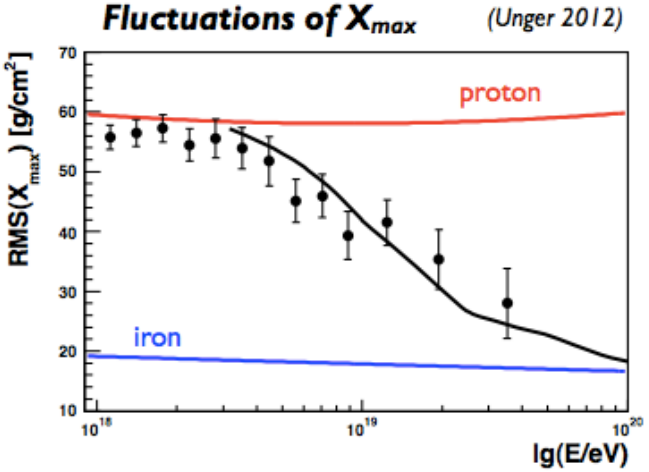
Science questions very brief

Upper end of source energy spectrum seen ?



(see also Calvez et al. 2010, Aloisio et al. 2011)

Natural transition to heavier composition at high energy !

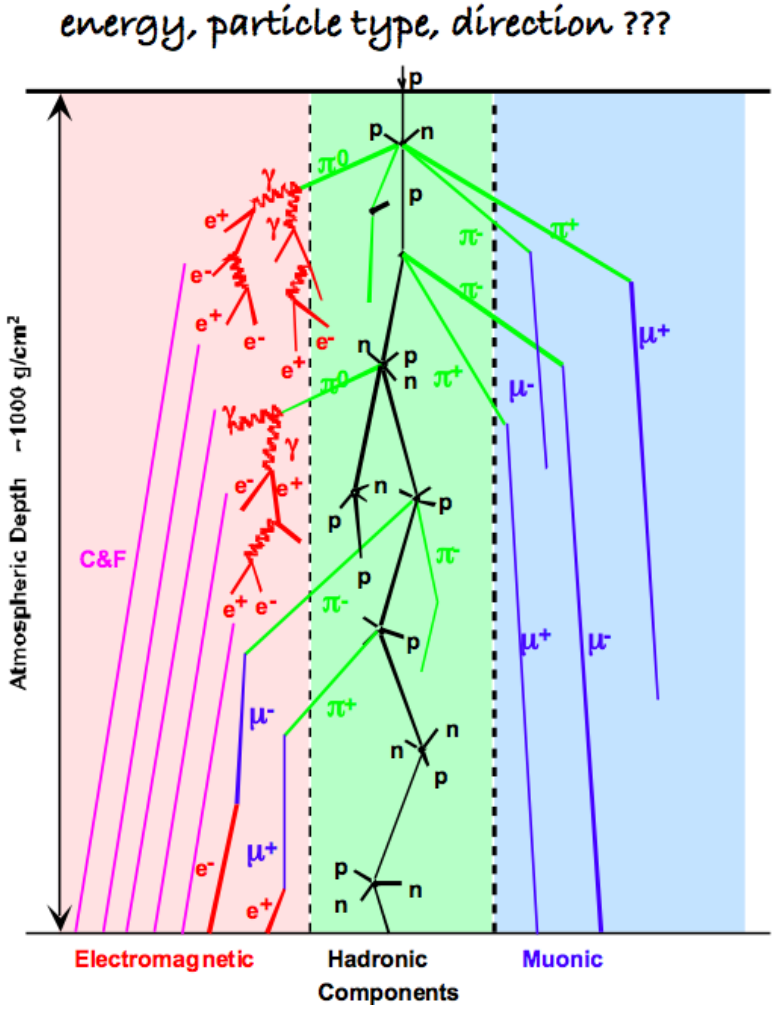


Different interpretation:
Suppression not due mainly to GZK energy-loss effect

R.Engel

Measuring type and energy of primary particles

Schematic Shower Development



p, n, π : near shower axis

μ, e, γ : more widely spread

e, γ : from π^0, μ decays ≈ 10 MeV

μ : from $\pi^{\pm}$, K, decays ≈ 1 GeV

Ne,γ : Nμ ≈ 10 - 100 varying with core distance, energy, mass, Θ, ...

Details depend on:

hadronic and el.mag. particle production, cross-sections, decays, transport, ...

at energies from ≈ 10^6 ... >10^{20} eV (far above man-made accelerators)

Earth magnetic field, ...

the ever-changing atmosphere ....

Complex interplay with many correlations

J.Knapp

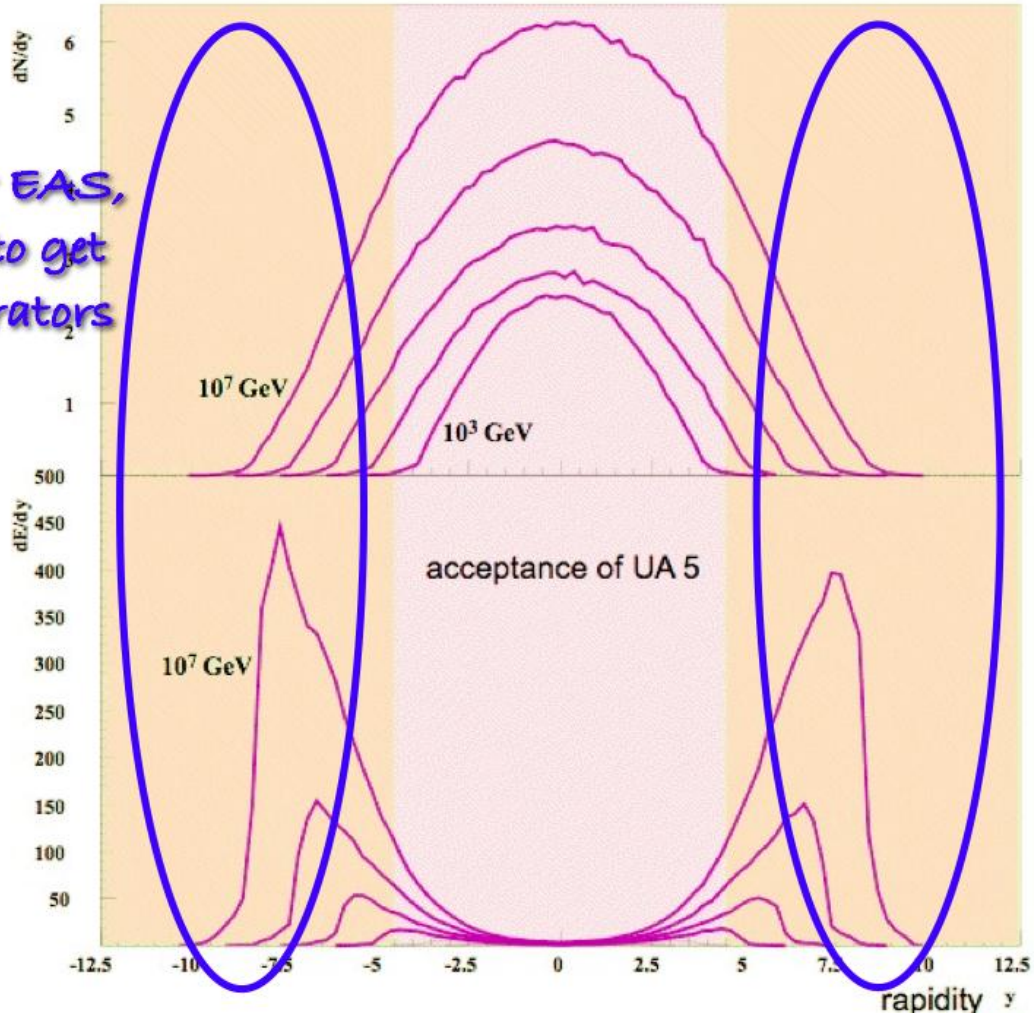
Measuring type and energy of primary particles

The very forward region

particle density

energy density

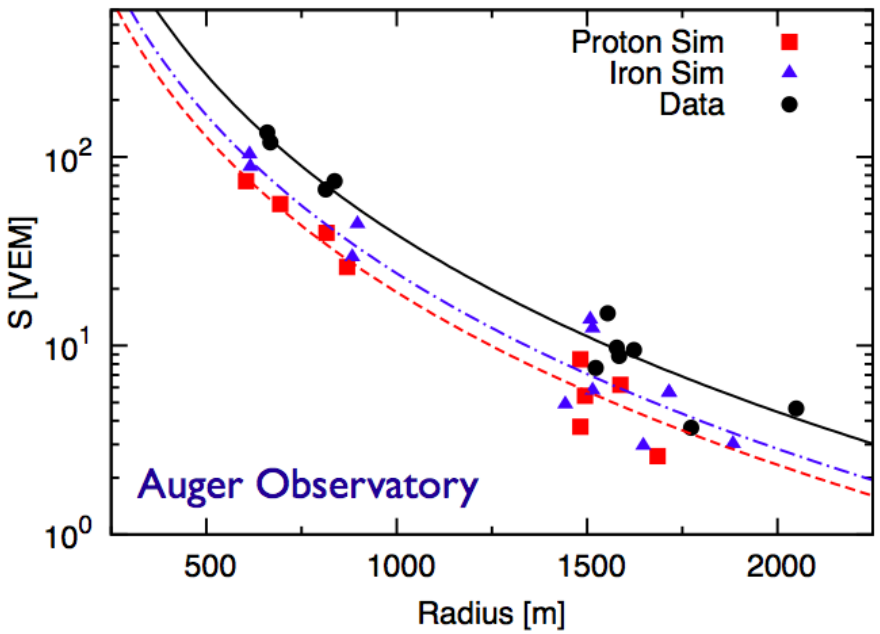
important for EAS, but difficult to get at with accelerators

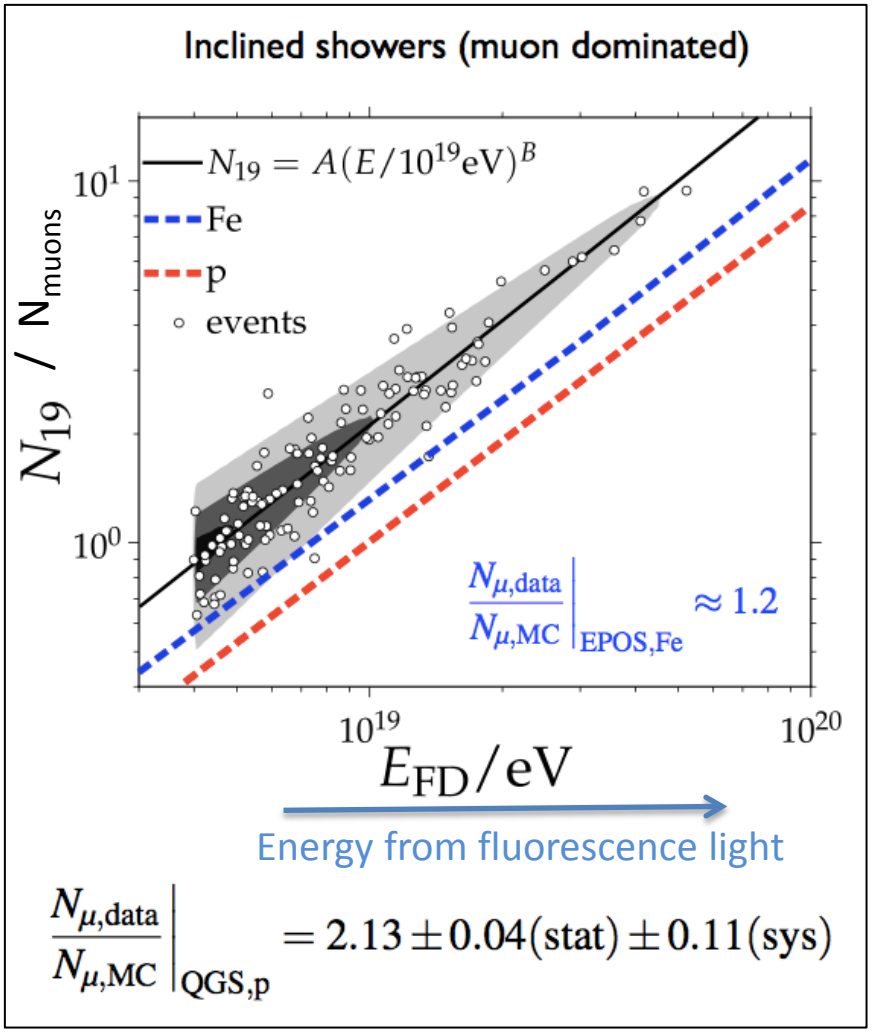


p-p non-diffractive interactions

J.Knapp

Muon excess measured by Auger





Cosmic-ray experiments measure primary particle energies via muon numbers on ground and fluorescence light (electrons/positrons excite nitrogen molecules, these de-excite by emitting photons).

20-100% more muons measured than predicted!

R.Engel

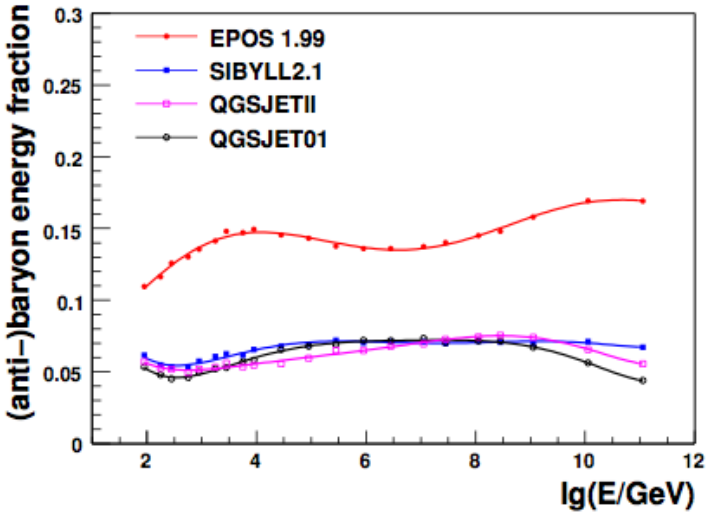
Muon excess measured by Auger

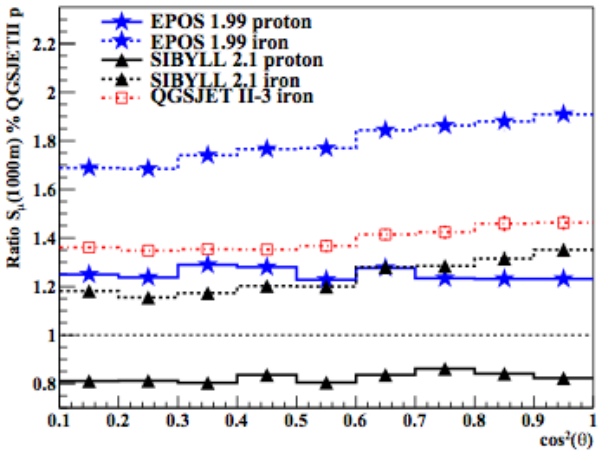
Muons in UHE Air Showers

Number of muons depends on energy fraction of produced hadrons

- $\pi^0 \rightarrow$ electromagnetic shower
- $\pi^{\pm}$
- $\rho^0 \rightarrow \pi^+\pi^-$
- (anti-) baryons

$\}$ $\rightarrow$ hadronic shower



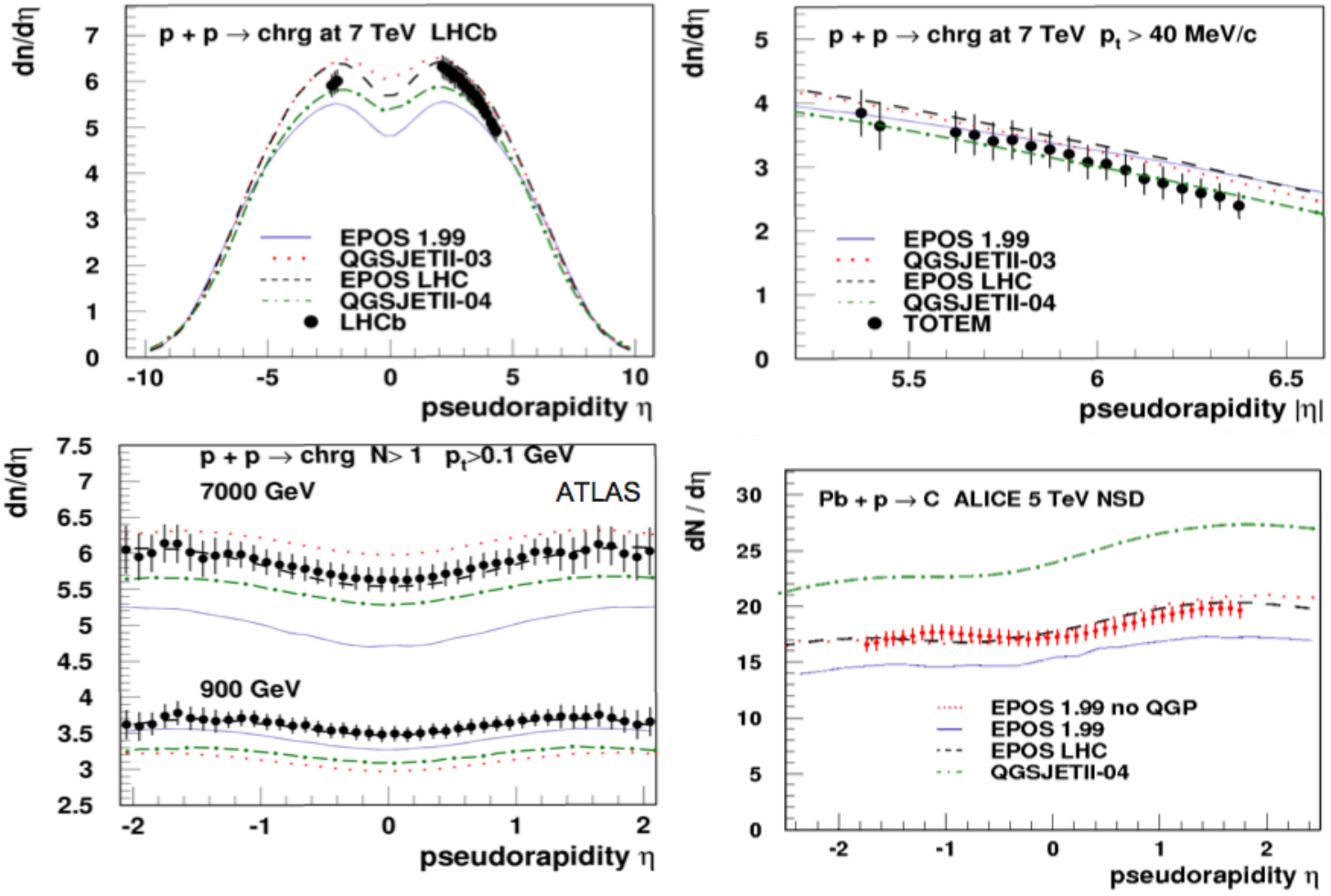


T. Pierog, Proc. ICRC09

M.Unger

Cosmic-ray MC generators 'challenging' collider MC

Pseudorapidity Distributions



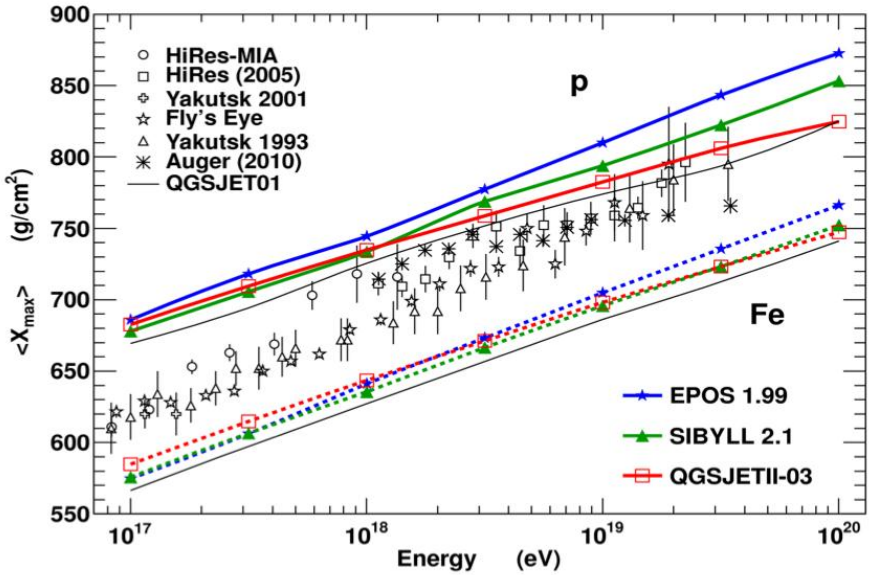
Particularly important in view of 13 TeV running after shutdown…

T.Pierog

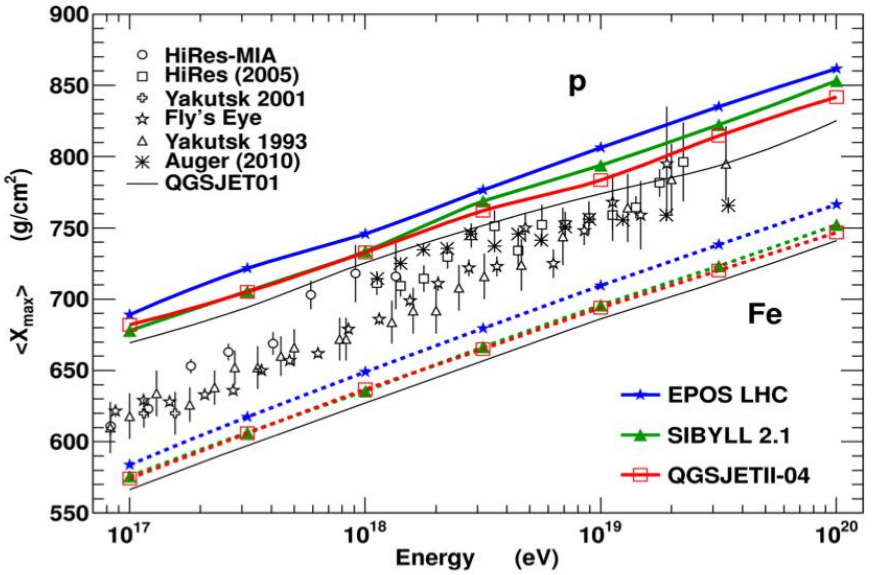
LHC impact on shower MC

T.Pierog

Pre-LHC



Post-LHC



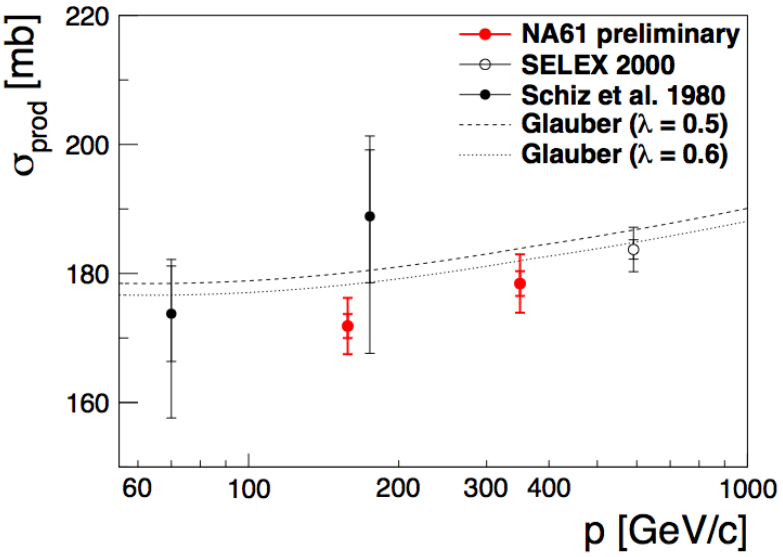
Lots of helpful measurements exist, many more can be done with existing data, one example of measurements that could, but cannot yet, be done: light ions

Light ions LHC running (Django Manglunki)

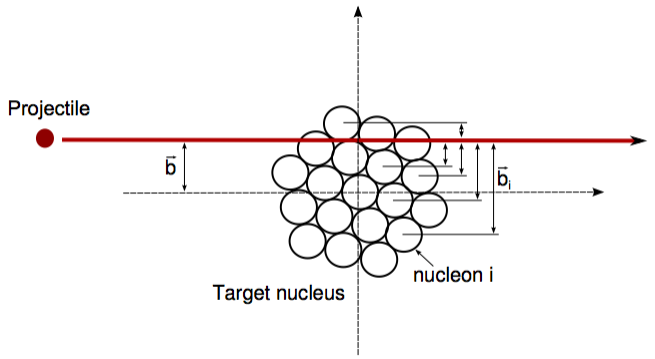
- In many ways light ions like Oxygen and Nitrogen should be collided with protons to connect to air-shower physics
- Rough informal feasibility study suggests that this is technically possible
  - Oxygen for example easier as it's already used for preparation of Pb beam
  - A few weeks of commissioning, parasitically
  - A case for forming a science case within a mixed community of LHC and CR physicists (LHC forward detectors in particular)
- Clear and strong interest formulated a couple of times, to be followed up

NA61: low-energy πC, pC, etc

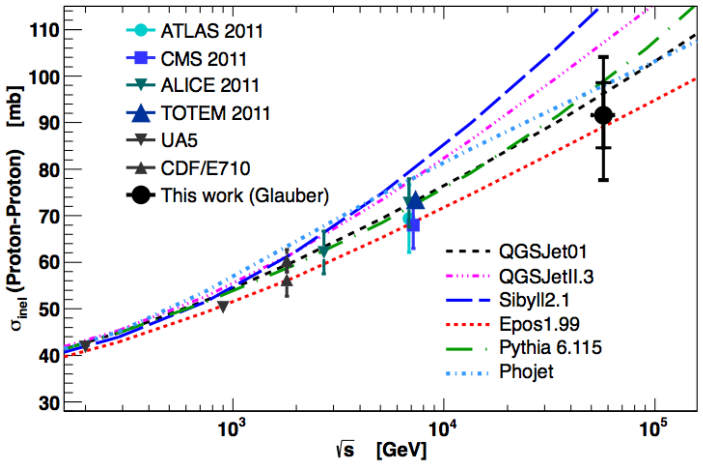
M.Unger, p-



Glauber model: geometric model

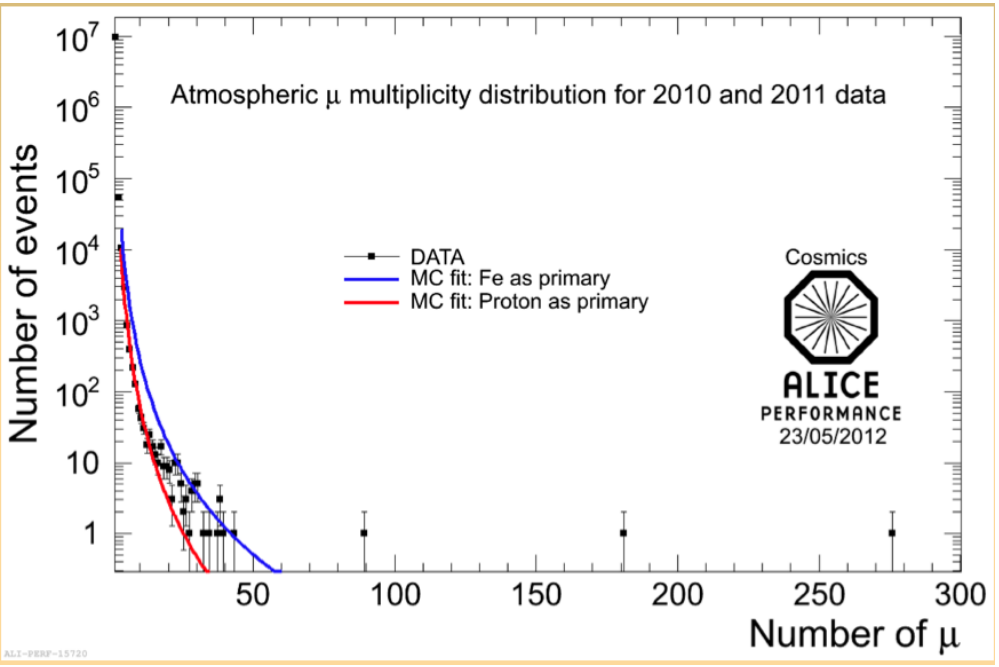


R.Ulrich

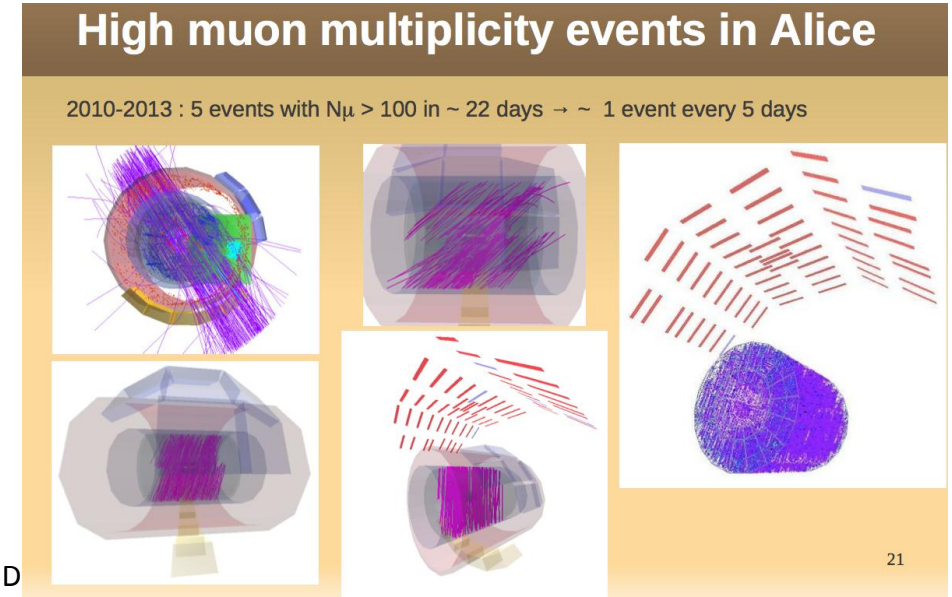


Auger, arXiv:1208.1520

Muon bundles



Seen in LEP, seen now by LHC experiments, cosmic muon bundles at surprisingly large multiplicities.
Different type of interface between collider and cosmic-ray experiments…
Surface air-shower counters being discussed for ATLAS.

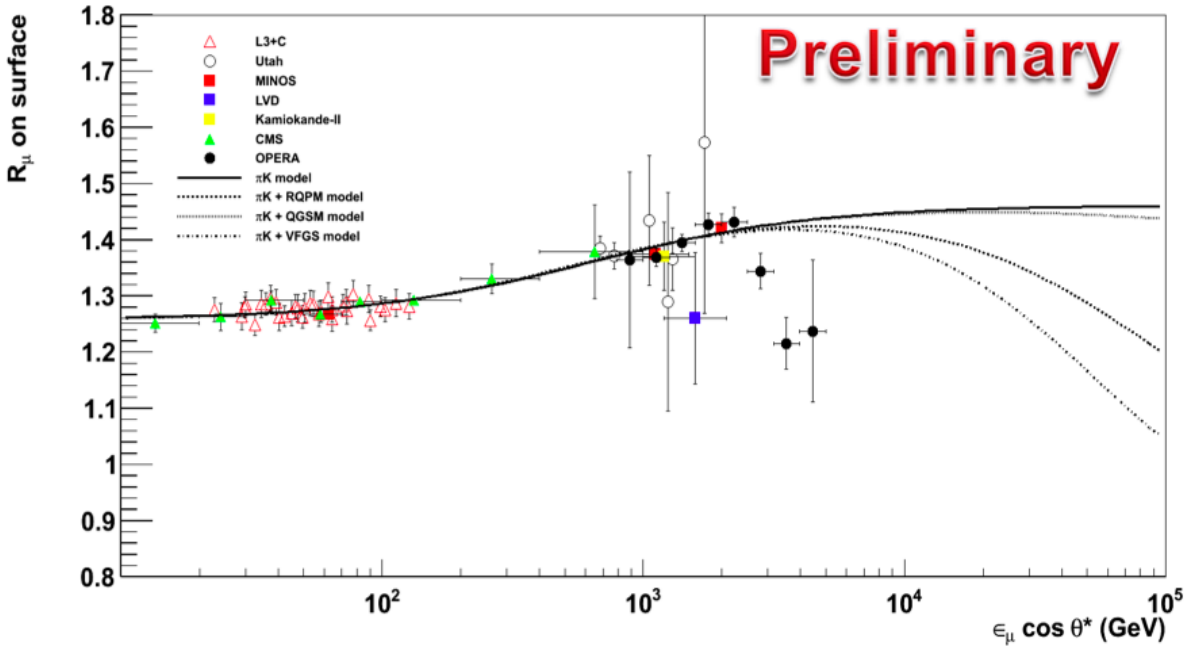


B.Alessandro

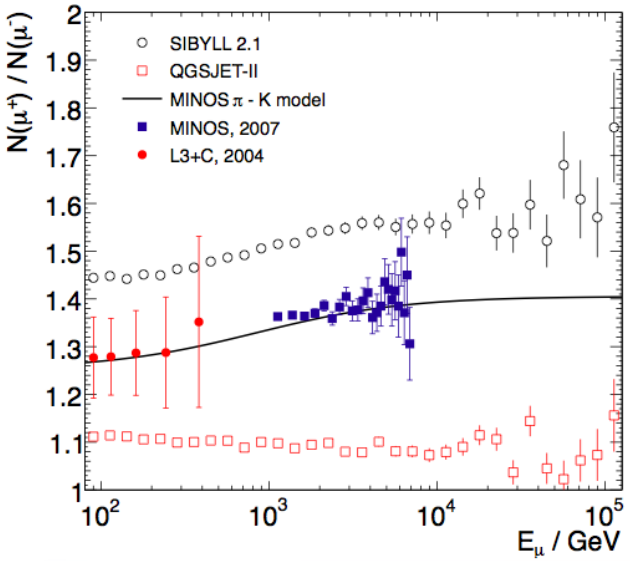
D

OPERA muon charge ratio

N.Mauri, OPERA



Models do not produce sharp drop (even when including charm), A. Fedynitch



Future activities – discussion

- Interactions are important but not sufficient, need common approach
  - List of actions helps, but is usually not enough
- Most (all?) of our resources focused on LHC mainstream physics
  - Example: ATLAS trigger detectors for soft charged particles will disappear
- LHC In-house versus Invasion

- Extend to generic astroparticle physics discussions?
  - Dark matter of course
  - Much more sensitive
  - Combination of LHC measurements, and LHC with others