How to Relate Particle Physics and Air Shower Development : the EPOS Model

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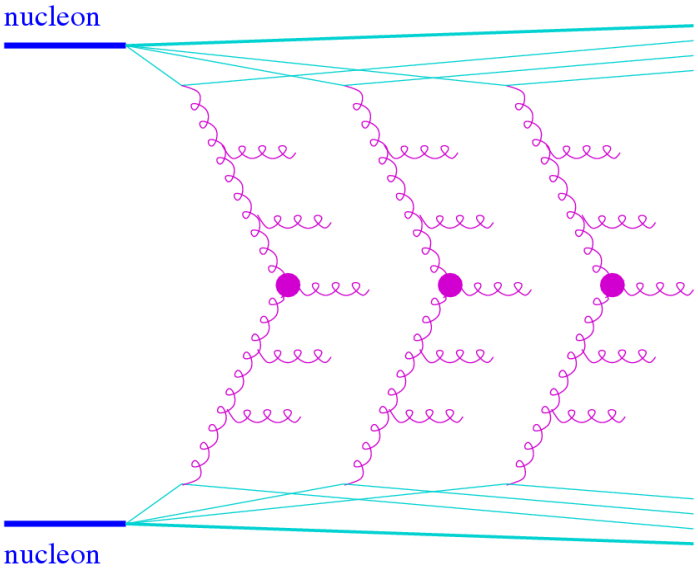
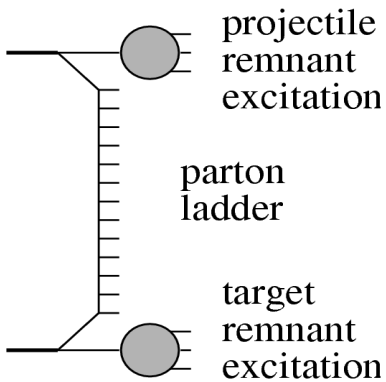
Outline

- **The EPOS model**
- **Constrains from air showers**
  - Cross section
  - Multiplicity
  - Forward spectra
  - Baryon production
- **New results**

The EPOS Model





EPOS* is a parton model, with many binary parton-parton interactions, each one creating a parton ladder.

- Energy-sharing : for cross section calculation AND particle production
- Parton Multiple scattering
- Outshell remnants
- Screening and shadowing via unitarization and splitting

EPOS designed to be used for particle physics experiment analysis (SPS, RHIC, LHC)

EPOS is a complex monte-carlo for minimum bias hadronic interaction generation (h-p to A-B) : suitable for air shower !

*T.Pierog, S. Porteboeuf and K. Werner

EPOS and Air Showers

Success :

- Large increase of # muons (MIA data, Auger S1000)
  - baryon-antibaryon contribution
  - remnant breakup

needed here !

Problems :

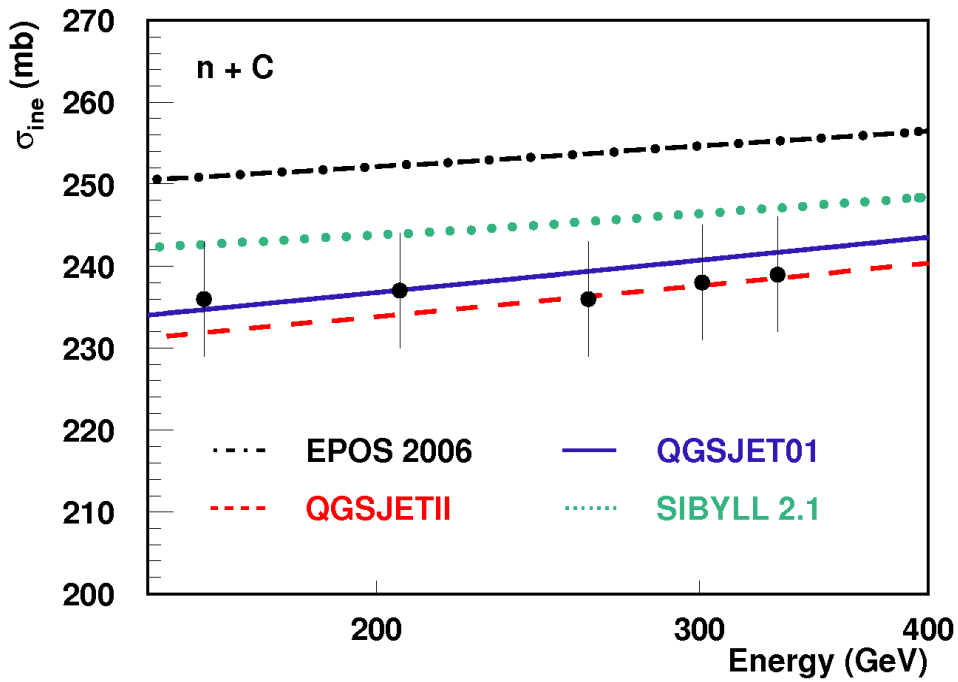
- KASCADE data (talks by Haungs and Hörandel) :
  - composition too light : too many muons or not enough elec. ?
  - Hadron energy too low : shower too old ?
- Auger : not enough muons in inclined showers :
  - Muon energy too low : shower too old ?

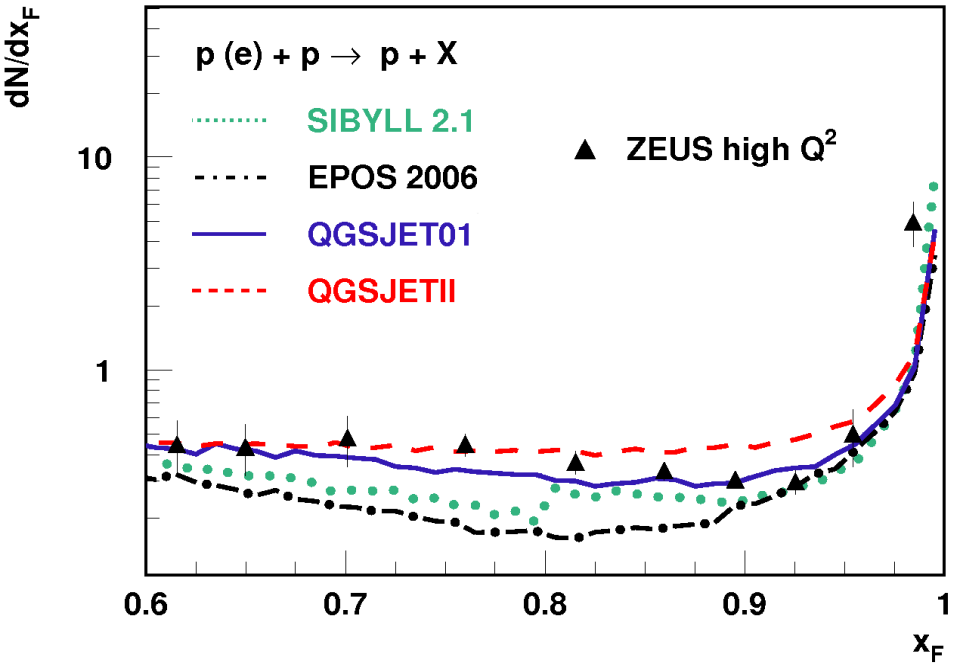
cross section or inelasticity too large ?

Cross Section and Inelasticity

Cross-section too large in pA :

- Problem with the calculation of pA cross- sections





Number of protons at large x_F too small :

- remnant break-up too large at high energy
- inelasticity too large

Problem seen in CR confirmed by accelerator data !

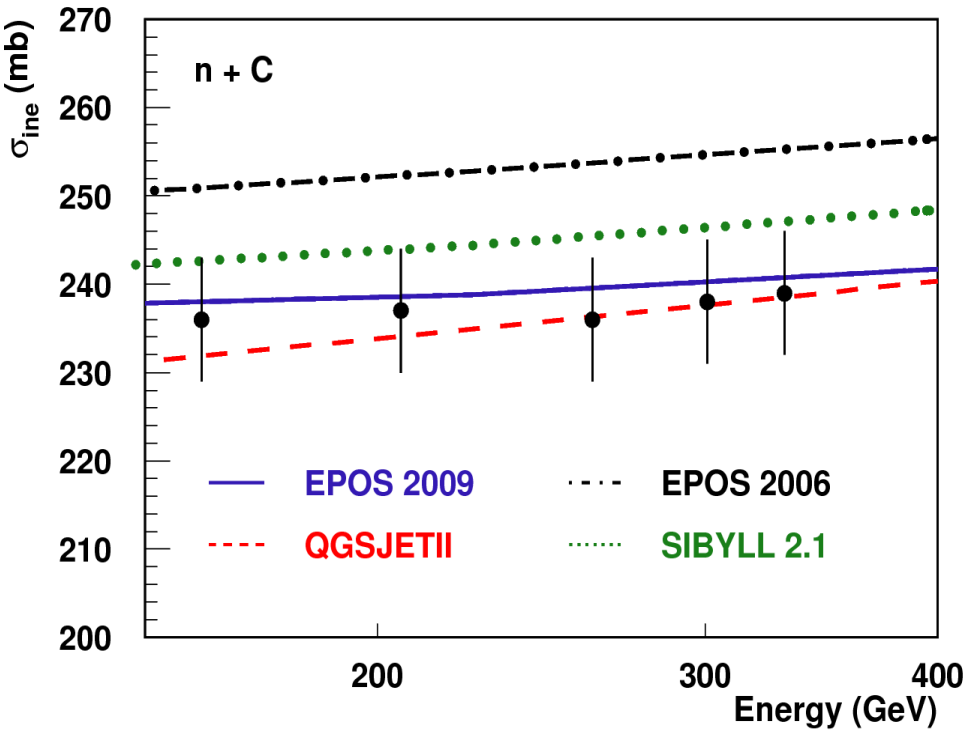
Constrains by Air Showers

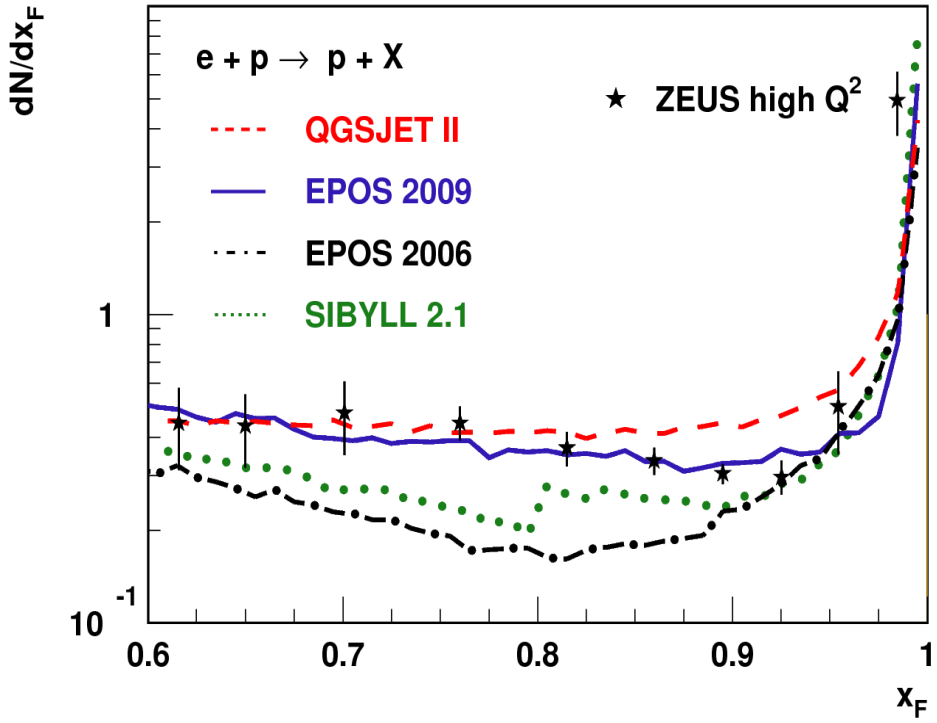
Air shower data give global constrains on the hadronic interactions

- **Low cross section / inelasticity**
  - Equilibrium remnant/central particle production
  - Strong sreening effect but with saturation
    - Reduction of multiple interaction
    - Limited growth of multiplicity
    - Limited growth of hard scattering ???
- **High muon number**
  - Modified fragmentation : evolution with energy
    - Increase of diquark production
    - Cronin effect (pt kink)
    - π^0 spectra

New Developments

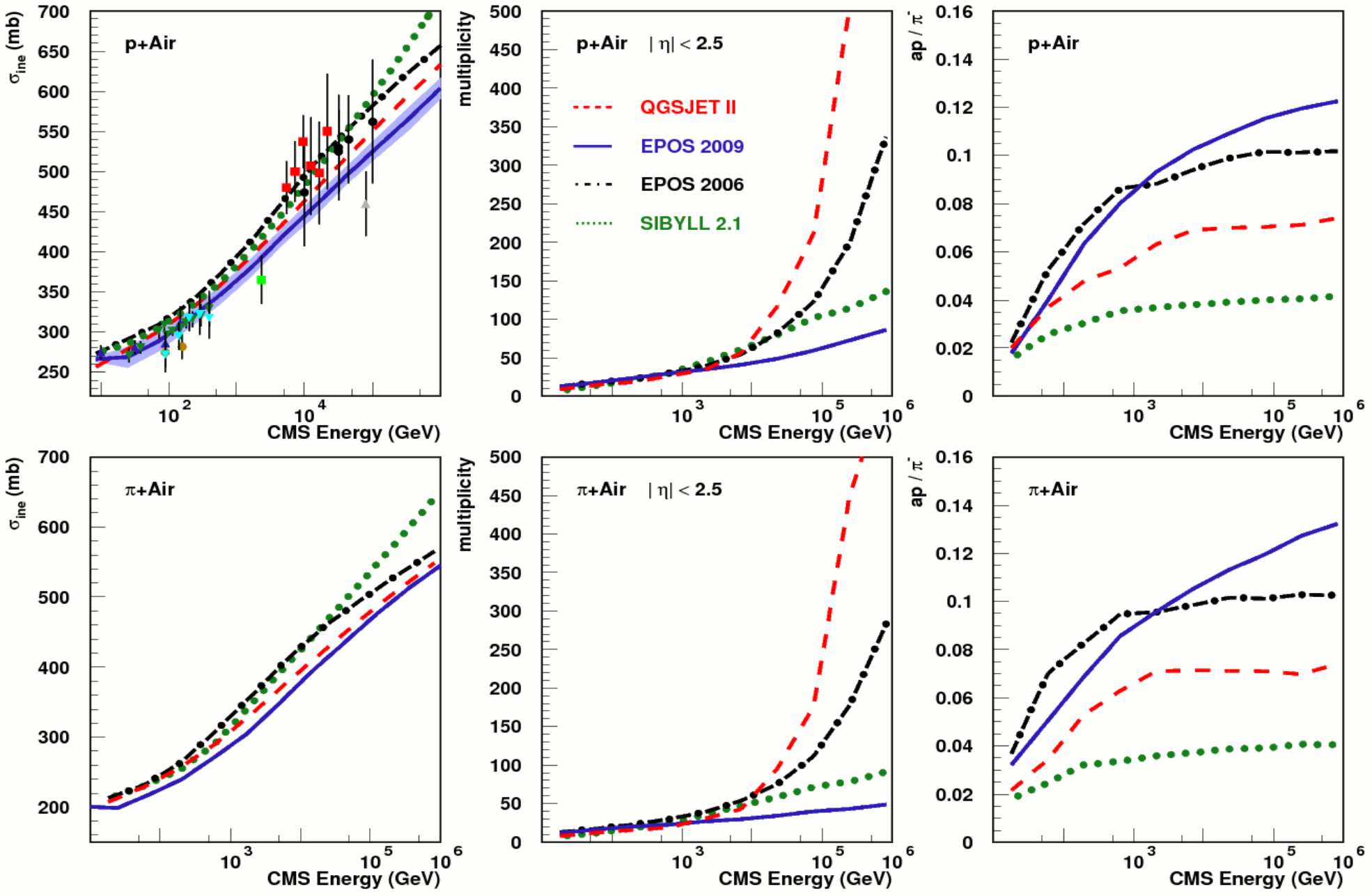
- **To increase predictive power : less parameters**
  - improvement of screening effect
  - unique saturation scale (pA cross section and RHIC p_t)
- **More contrains on other parameters** (break-up, baryons, ...)





EPOS 2009 = EPOS 1.99 last release, EPOS 2006 = EPOS 1.61 prev. release

h-Air Results



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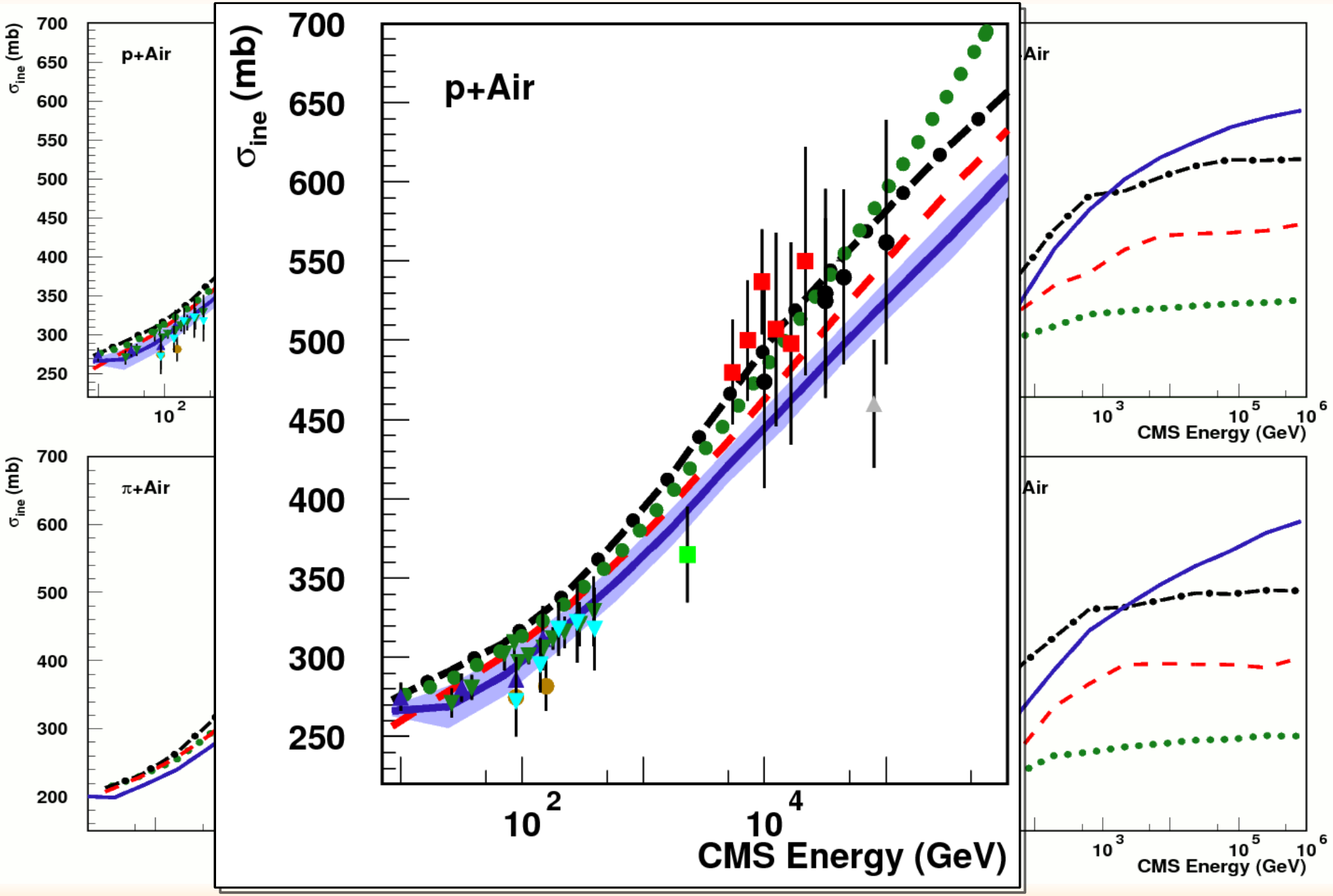
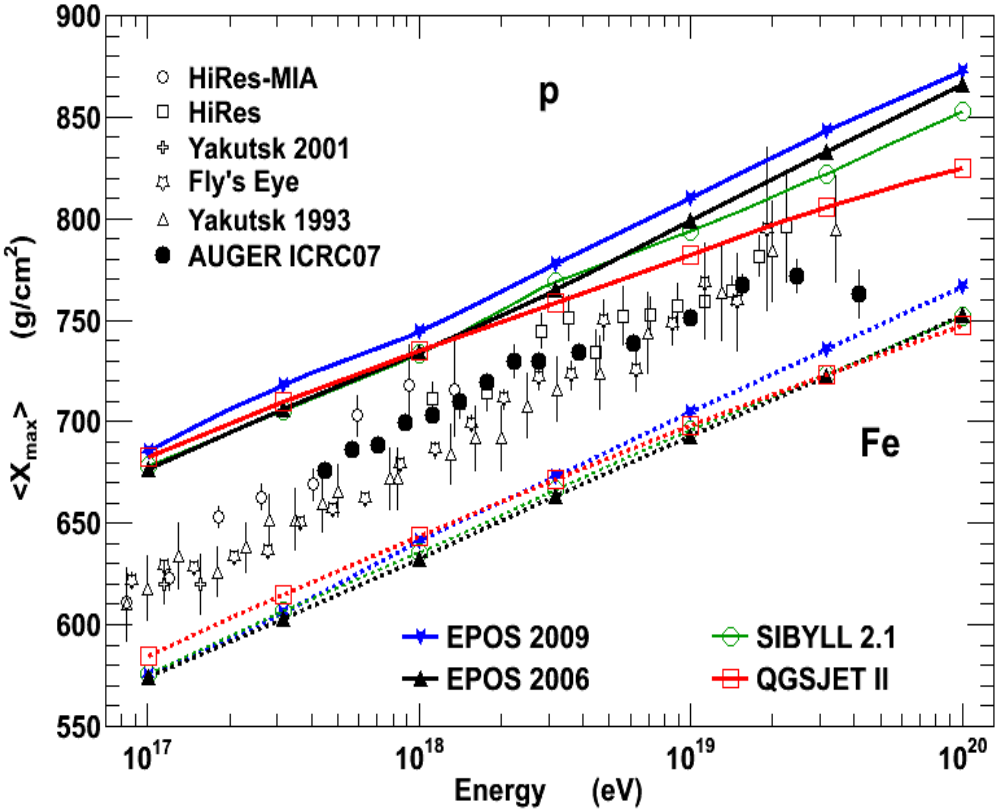
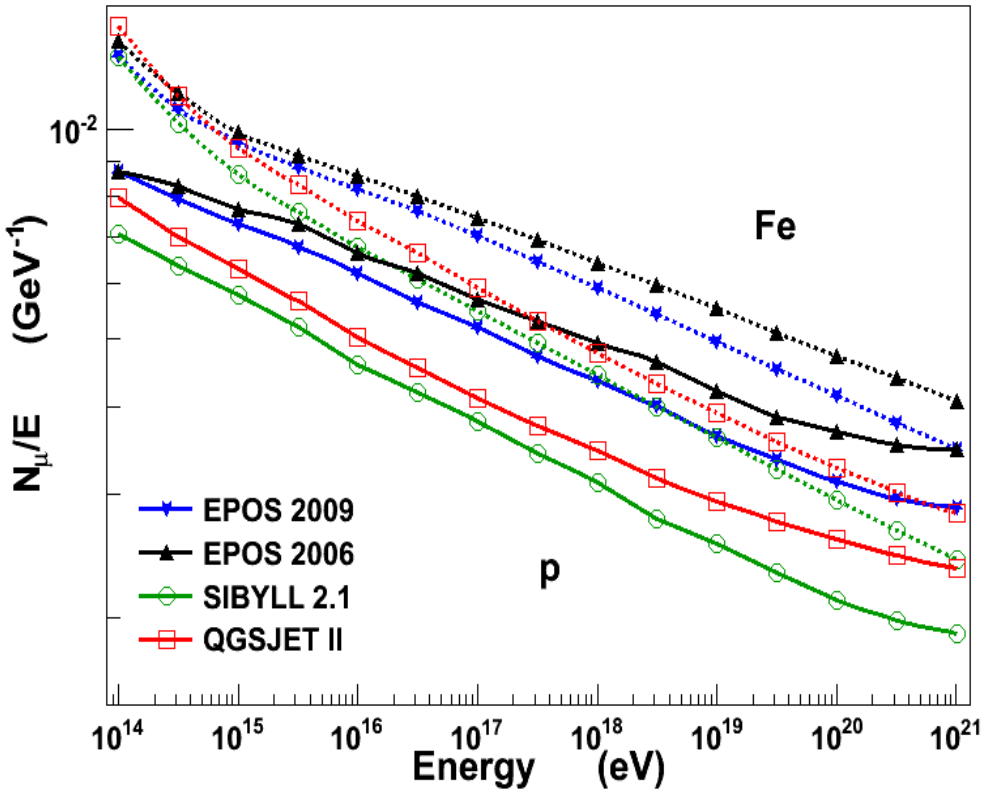


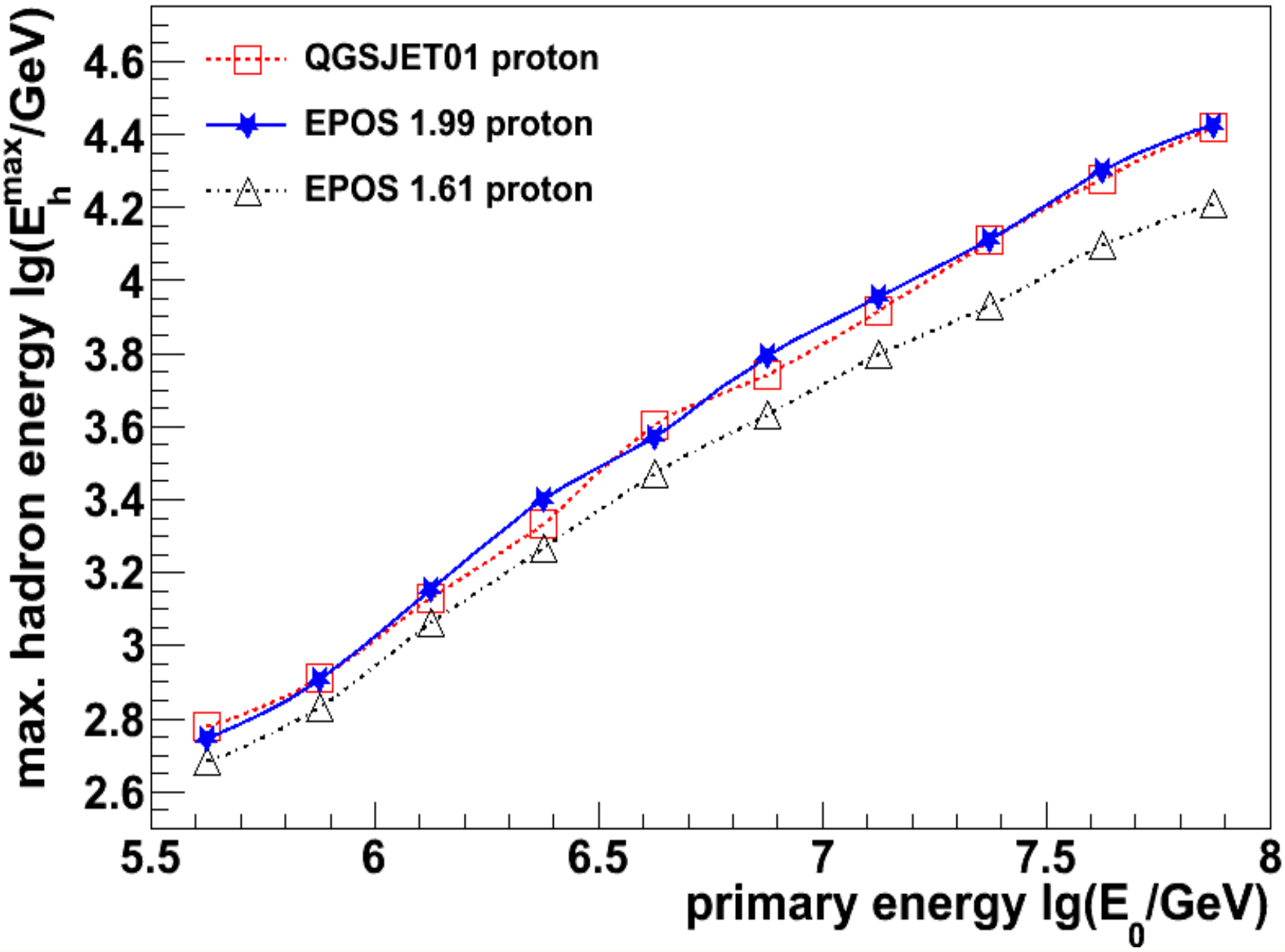
Consequences on Air Showers

- Smaller cross section = deeper shower (larger X_{max})
  - More electron @ ground
  - More energetic hadrons @ ground
- Slightly less muons (less break-up) but with more energy





Consequences on Air Showers



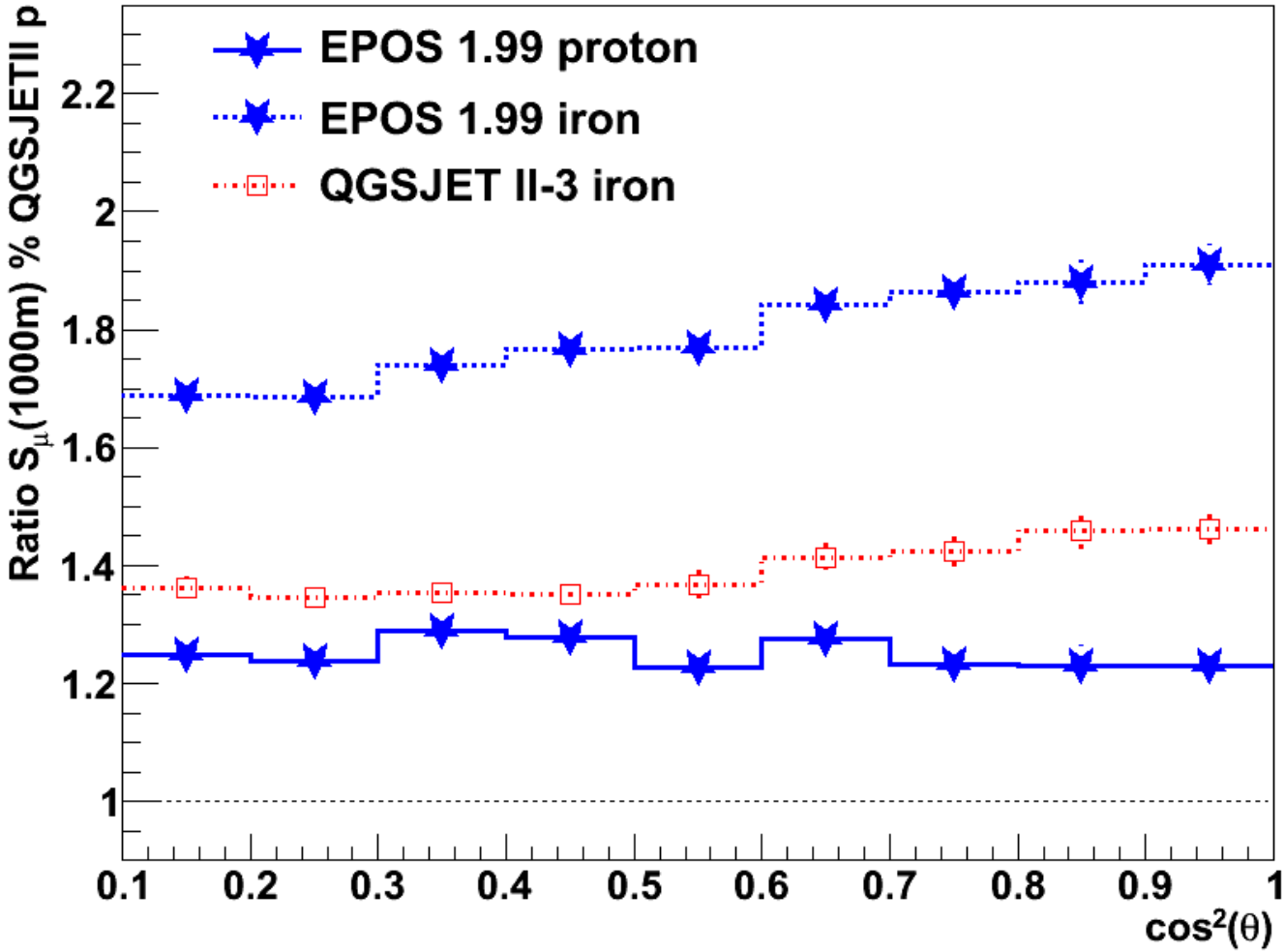
Summary

EPOS ... or how to relate cosmic ray physics and particle physics :

- Particle physics : baryons should be treated correctly
  - effects on muon number
- Cosmic ray : if a lot of muons, then pA cross section small
  - large nuclear screening effects
  - effect on multiplicity and p_t in pA
    - limitation by RHIC data on p_t
    - cross section limited by nuclear saturation
- Low multiplicity and low cross section = large X_{max} for Auger

Consequences on cosmic ray mass composition

Muons @ 1000 m – 10^{19} eV



PAO observable