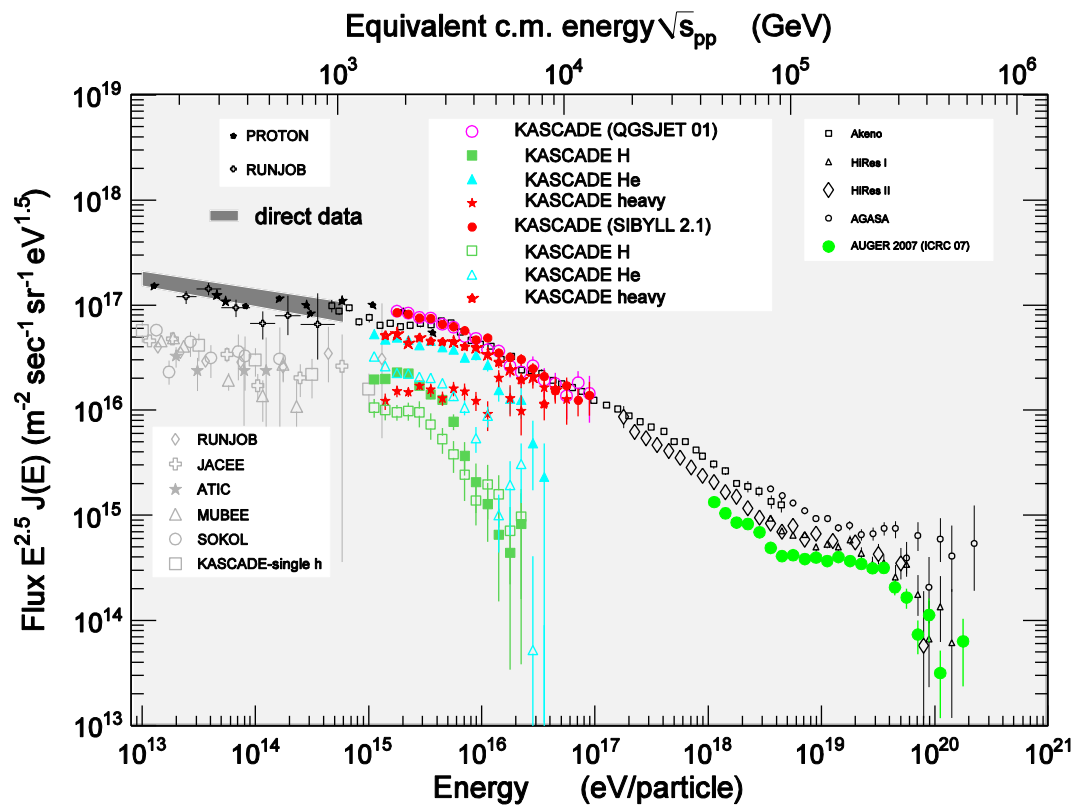


Air shower measurements above the knee of the CR Energy Spectrum

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Experimental results

- Proton spectrum agrees with direct measurements
- **Knee observed in the spectra of all EAS components**
- Primary chemical composition gets heavier crossing knee energies
- **Knee is attributed to light primaries**
- Radiation is highly isotropic.

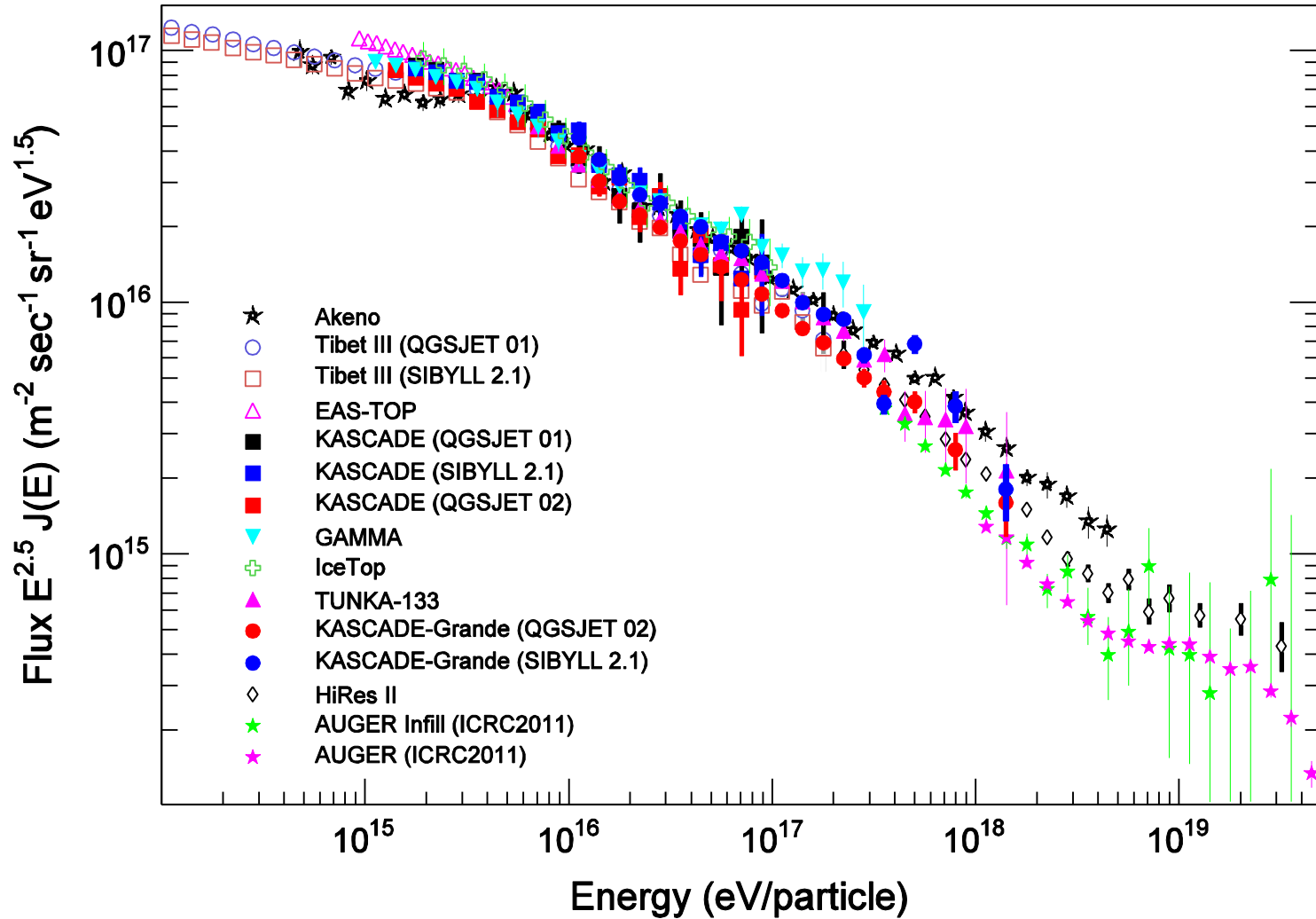
Open Issues in the knee Energy Range:

- ✓ Single Element Spectra?
 - ✓ Rigidity Dependent knee?
 - ✓ Composition at the knee?
 - ✓ Heavy primaries knee?
 - ✓ End of Galactic Spectrum?
 - ✓ Transition Galactic-Extragalactic radiation?
 - ✓ Anisotropy?
-
- Hadronic Interaction model
 - Overlap Direct-Indirect measurements

Experiments operating between 10^{16} - 10^{18} eV

- **KASCADE-Grande (110 a.s.l.)**
 - N_{ch}, N_{μ} (Scintillators)
 - Shower Size \rightarrow NKG like ldf
- **TUNKA-133 (675 m a.s.l.)**
 - Atmospheric Cherenkov light
 - Q125
- **GAMMA (3200 m a.s.l.)**
 - N_{ch}, N_{μ} (Scintillators)
 - Shower Size \rightarrow NKG like ldf
- **IceTop (2835 m a.s.l.)**
 - Cherenkov light emitted in ice
 - S125
- **Auger Infill (1400 m a.s.l.)**
 - Cherenkov light emitted in water tanks
 - S450
 - Hybrid detector

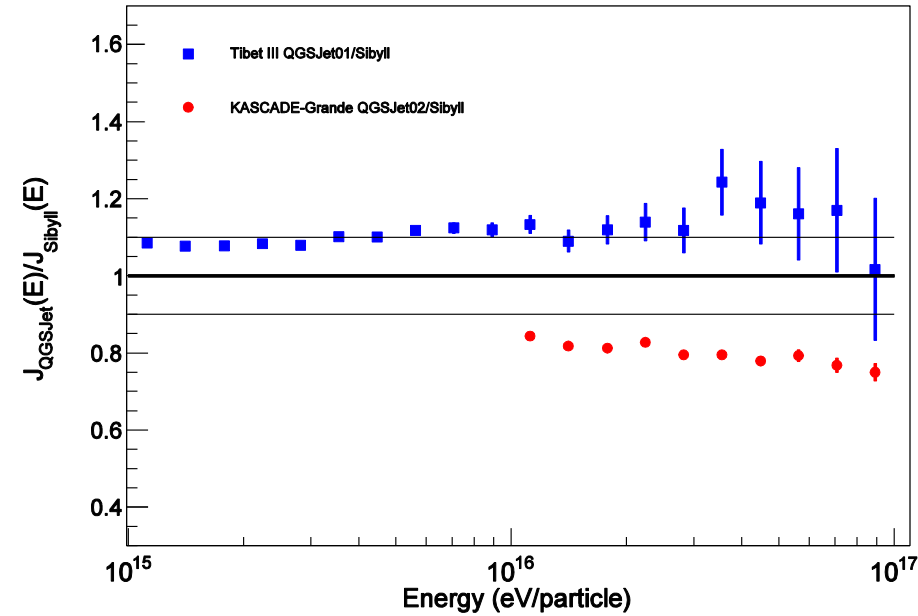
All particle Cosmic Rays Energy Spectrum



$J_{\text{QGS}}(E)/J_{\text{sibyll}}(E)$ (TibetIII and KASCADE-Grande data)

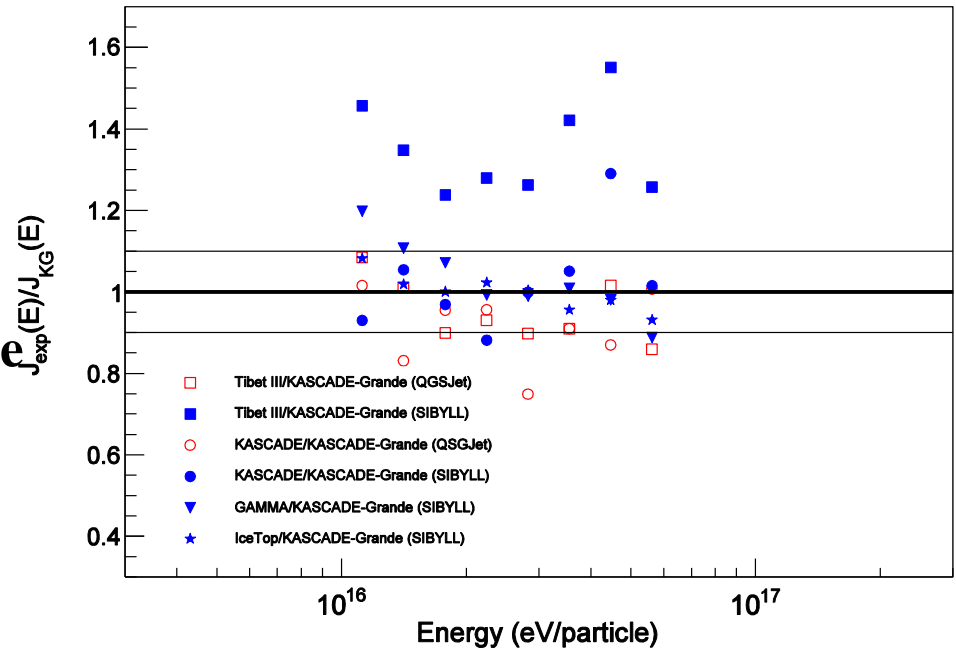
Different ratios at different heights

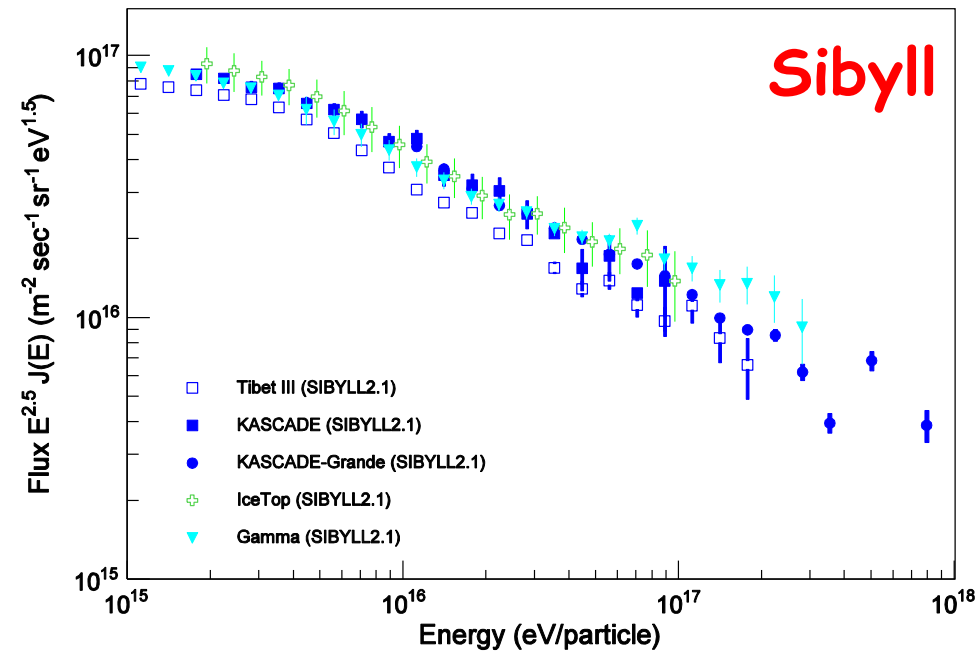
@ sea level ~20%



$$J_{\text{EXP}}(E)/J_{\text{KG}}(E)$$

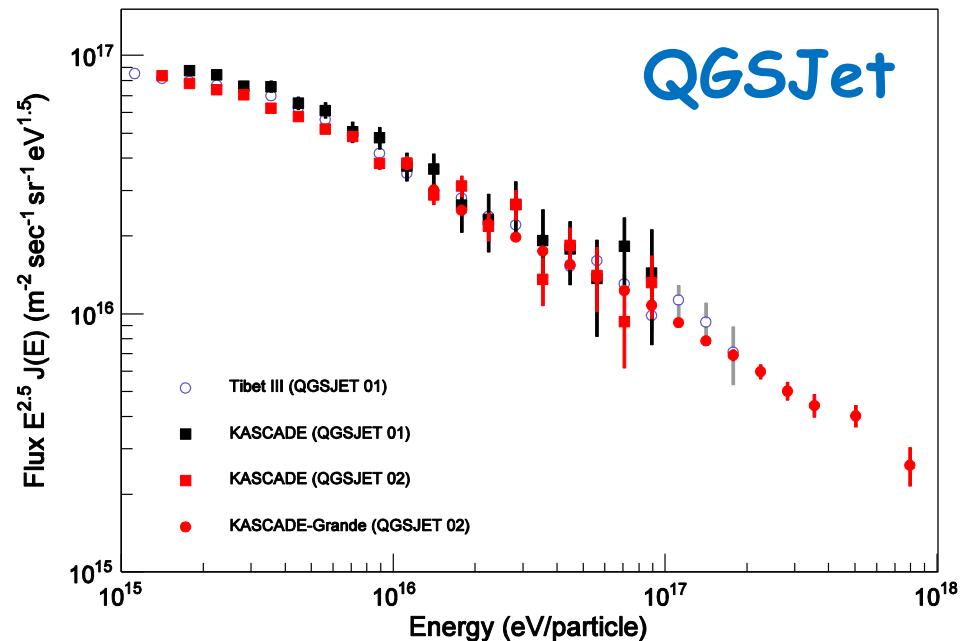
Excluding TibetIII differences between experiments when using the same interaction model are below ~10%





Same data as previous plot, results are grouped by the interaction model used to convert the experimental observable(s) to primary energy

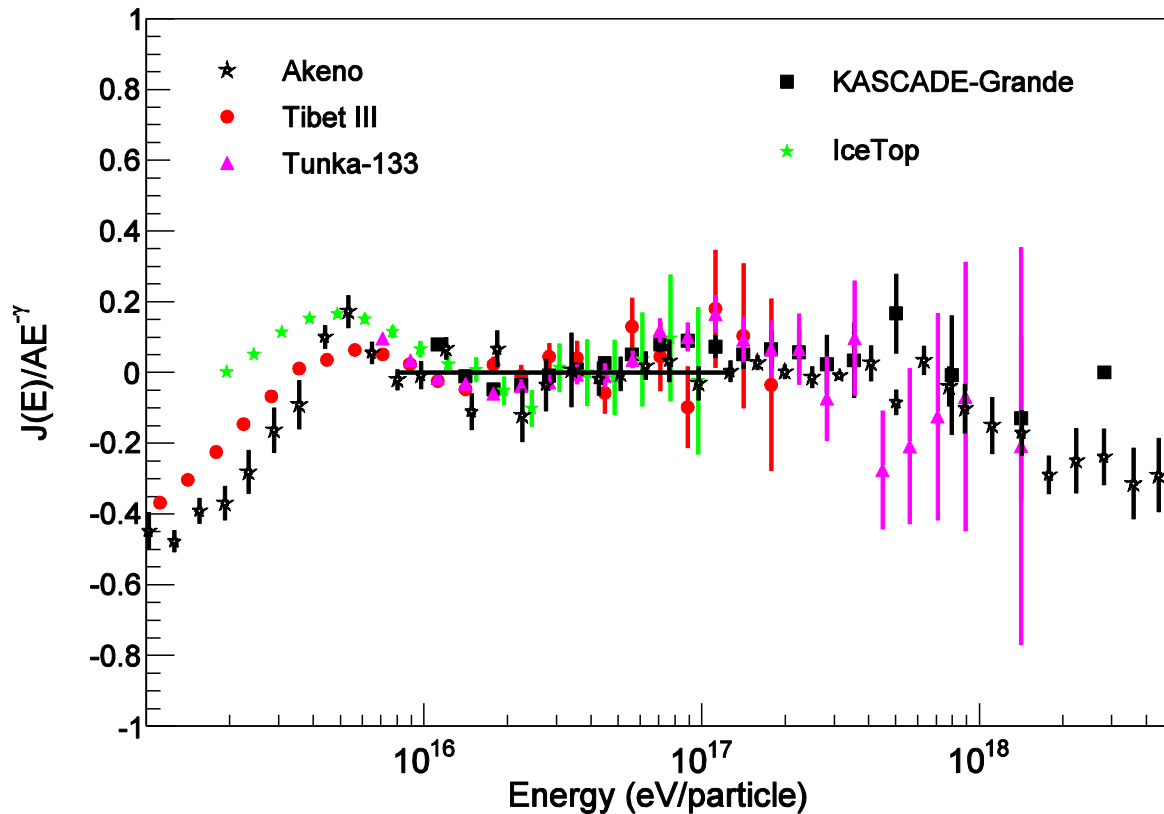
Flux differences can mainly be attributed to hadronic interaction used to convert to primary energy



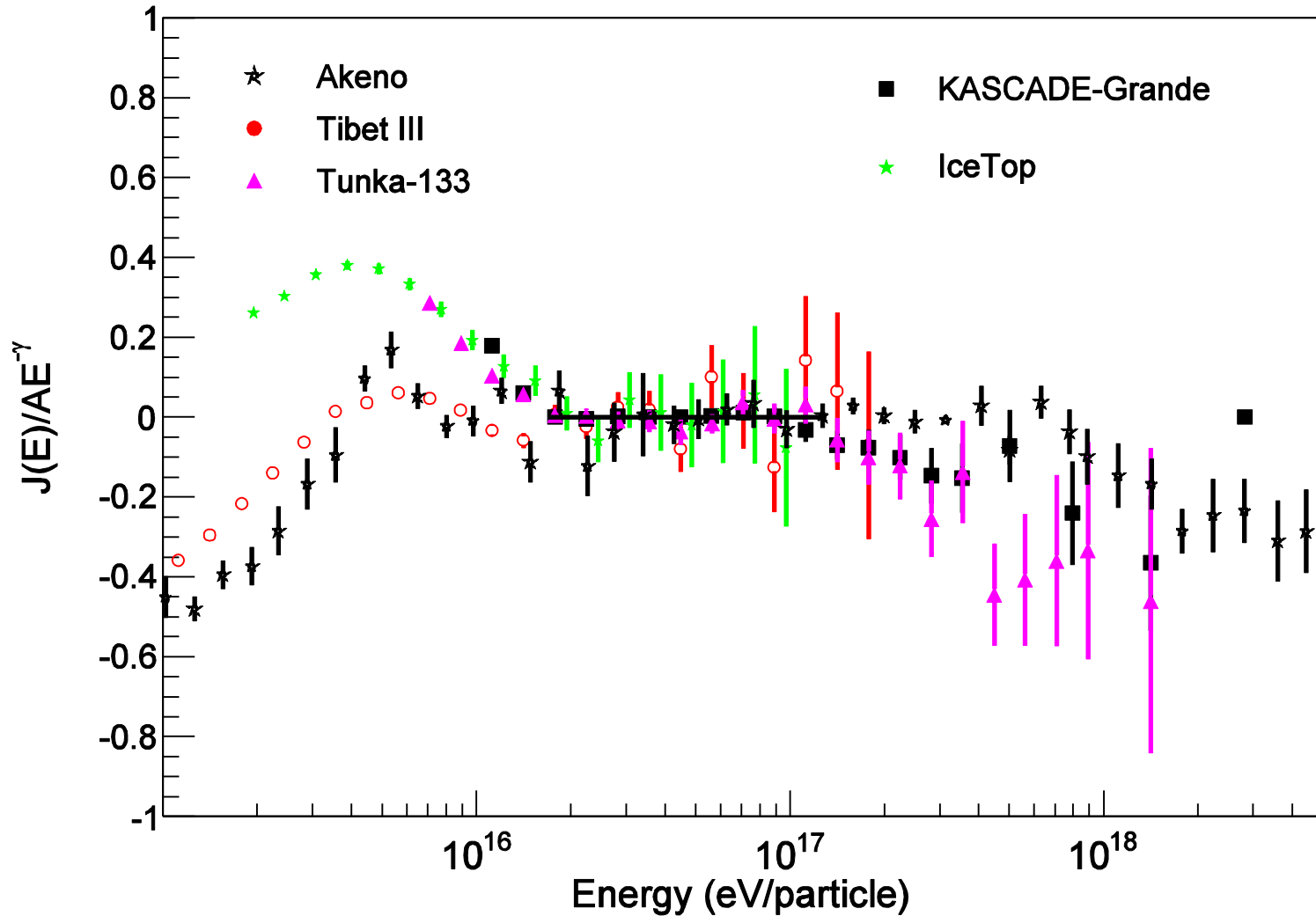
1. This difference mainly concerns the absolute energy scale

2. Structures are visible in most of the spectra

Residual plot obtained fitting each spectrum with a single slope power law in a fixed energy range (8×10^{15} - $1,3 \times 10^{17}$ eV)



- **Structure enhanced using the range above the concavity claimed by the KG experiment (1.7×10^{16} - 1.3×10^{17} eV)**



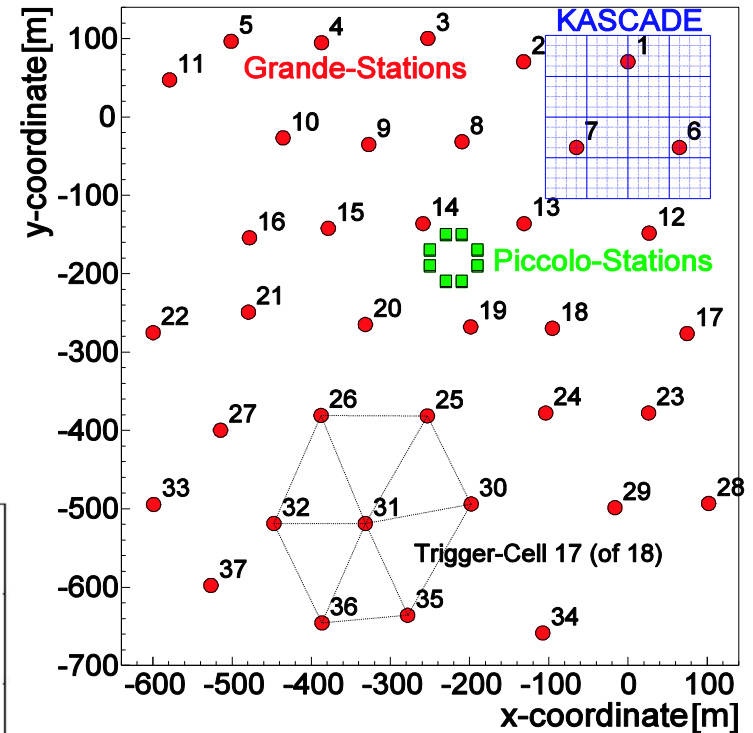
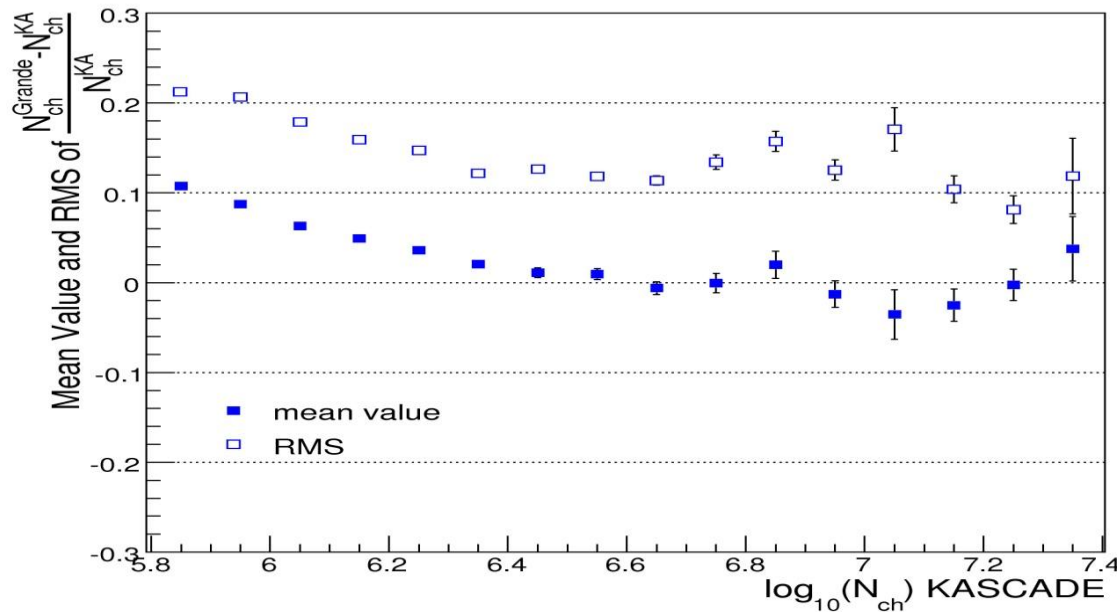
Study of the Structure at $\sim 10^{17}$ eV

- KASCADE-Grande

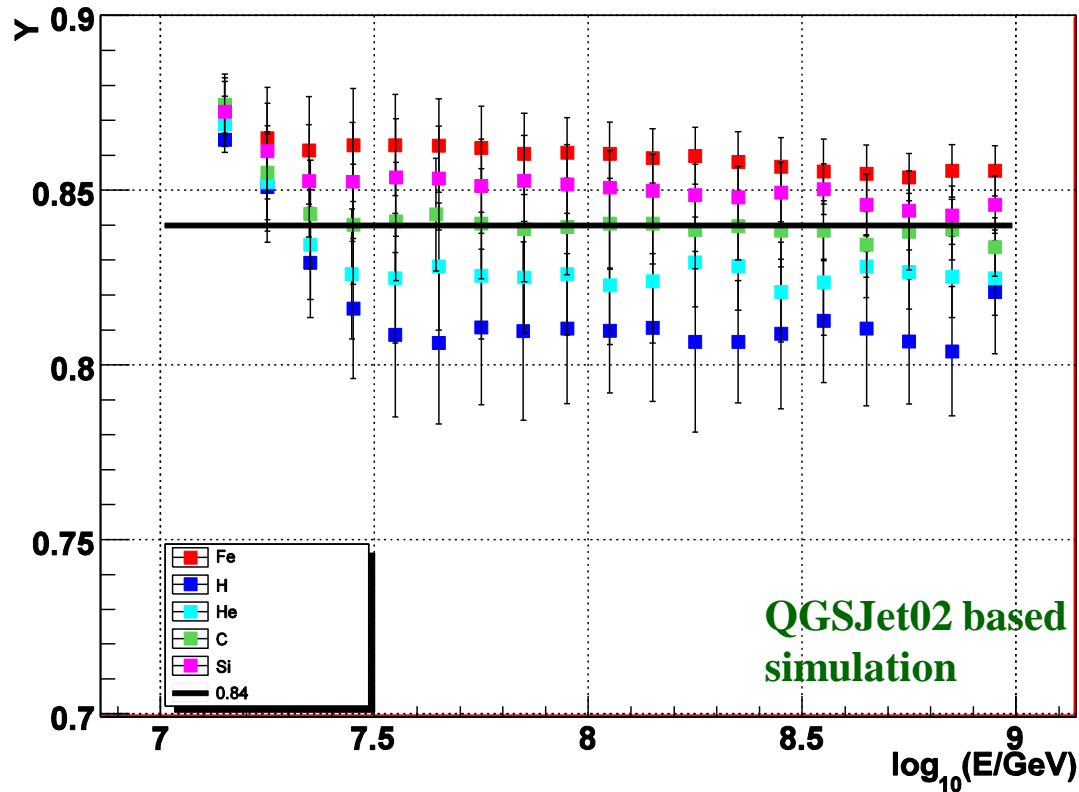
N_{ch} accuracy < 15%

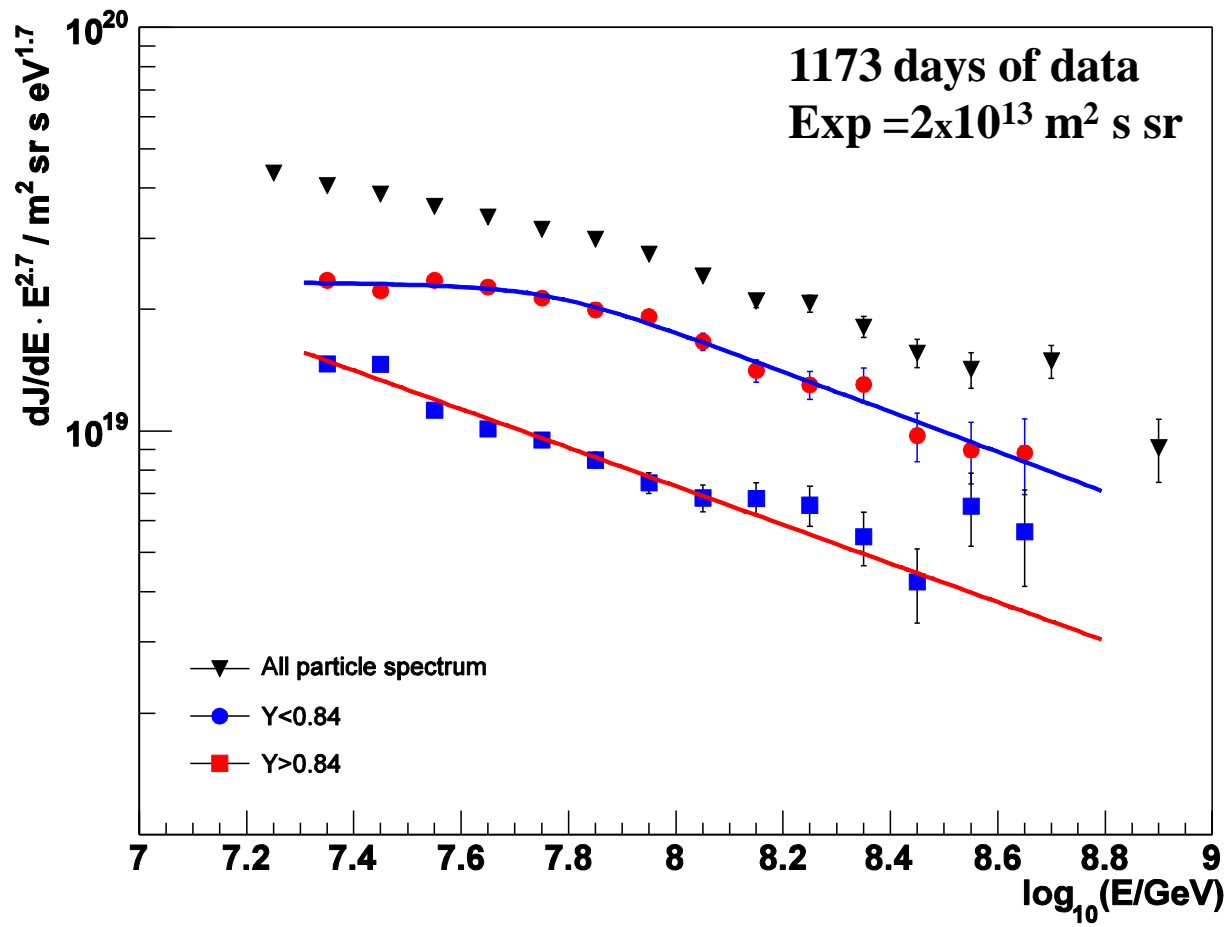
Systematic difference < 5%

N_{μ} accuracy < 20%



- Events divided in two samples according to the ratio:
 - $Y = \ln N_{\mu} / \ln N_{ch}$
- Spectra measured separately for the two samples





$$\Phi(E) = K \left(\frac{E(\text{eV})}{10^{17}} \right)^\gamma$$

$$\Phi(E) = KE^{\gamma_1} \left[1 + \left(\frac{E}{E_k} \right)^\varepsilon \right]^{\frac{\gamma_2 - \gamma_1}{\varepsilon}}$$

$K, E_k, \gamma_1, \gamma_2, \varepsilon \rightarrow$ free parameters

$\gamma > 0.84$ Spectrum Fit Parameters

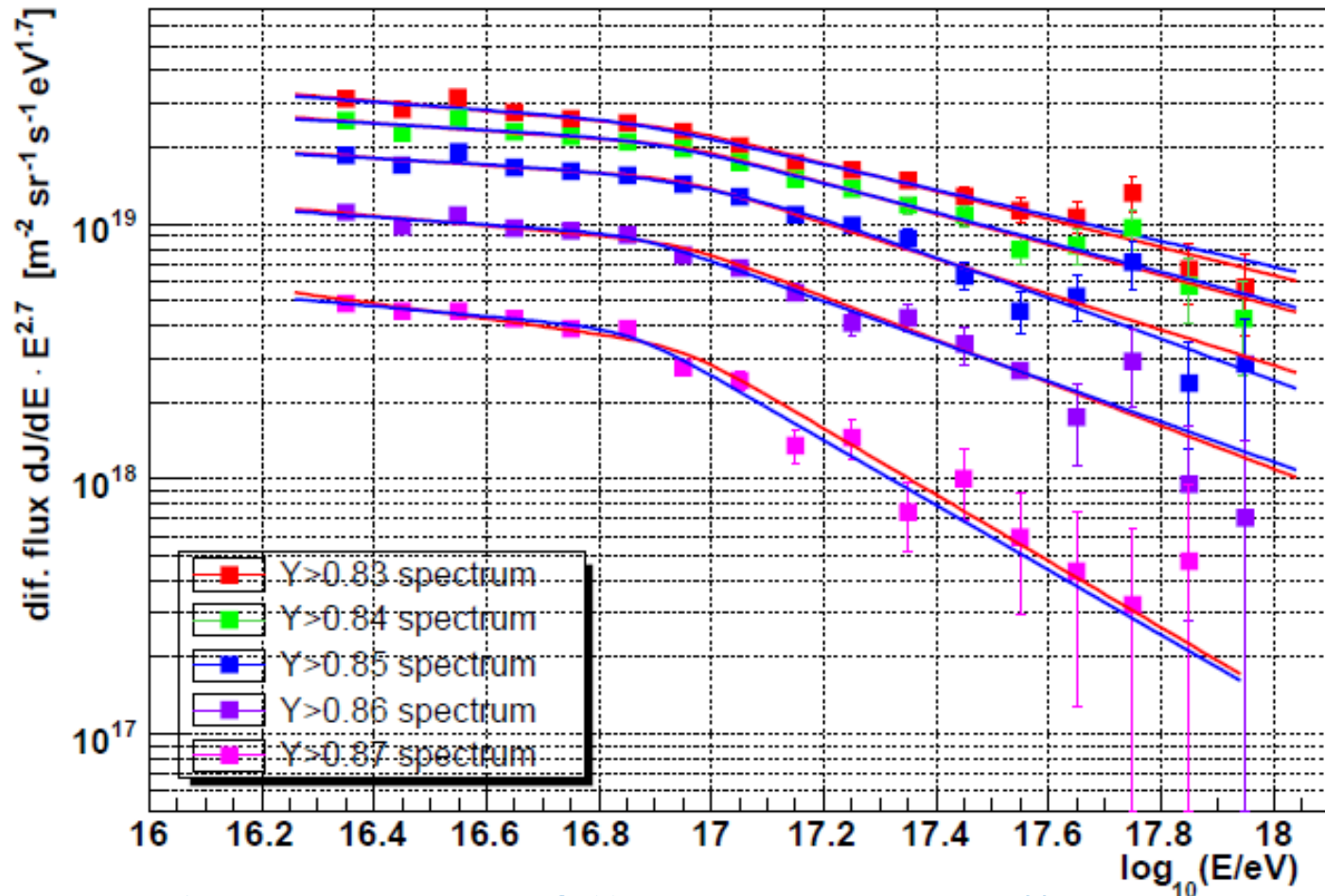
$\text{Log}(E_k/\text{eV})$	γ_1	γ_2	χ^2/dof	significance
16.92 0.04	2.76 0.02	3.24 0.05	1.98	3.5 σ

$\gamma < 0.84$ Spectrum Fit Parameters

Two slopes fit	χ^2/dof	significance
	5.75	1.0 σ

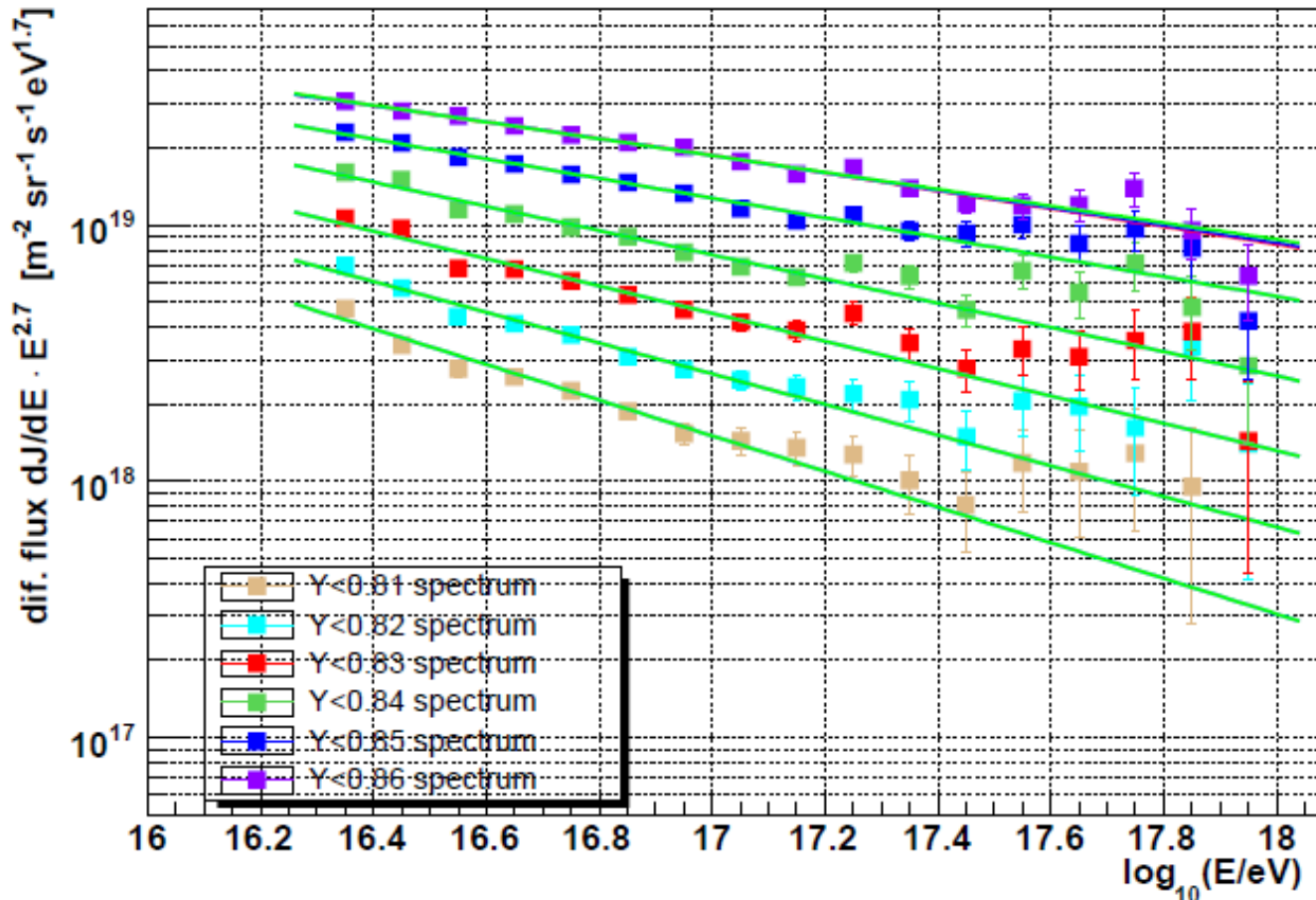
Single slope	γ	χ^2/dof
	3.18 0.01	4.60

Spectra obtained cutting at different Y values
→ i.e. different hadronic interaction models



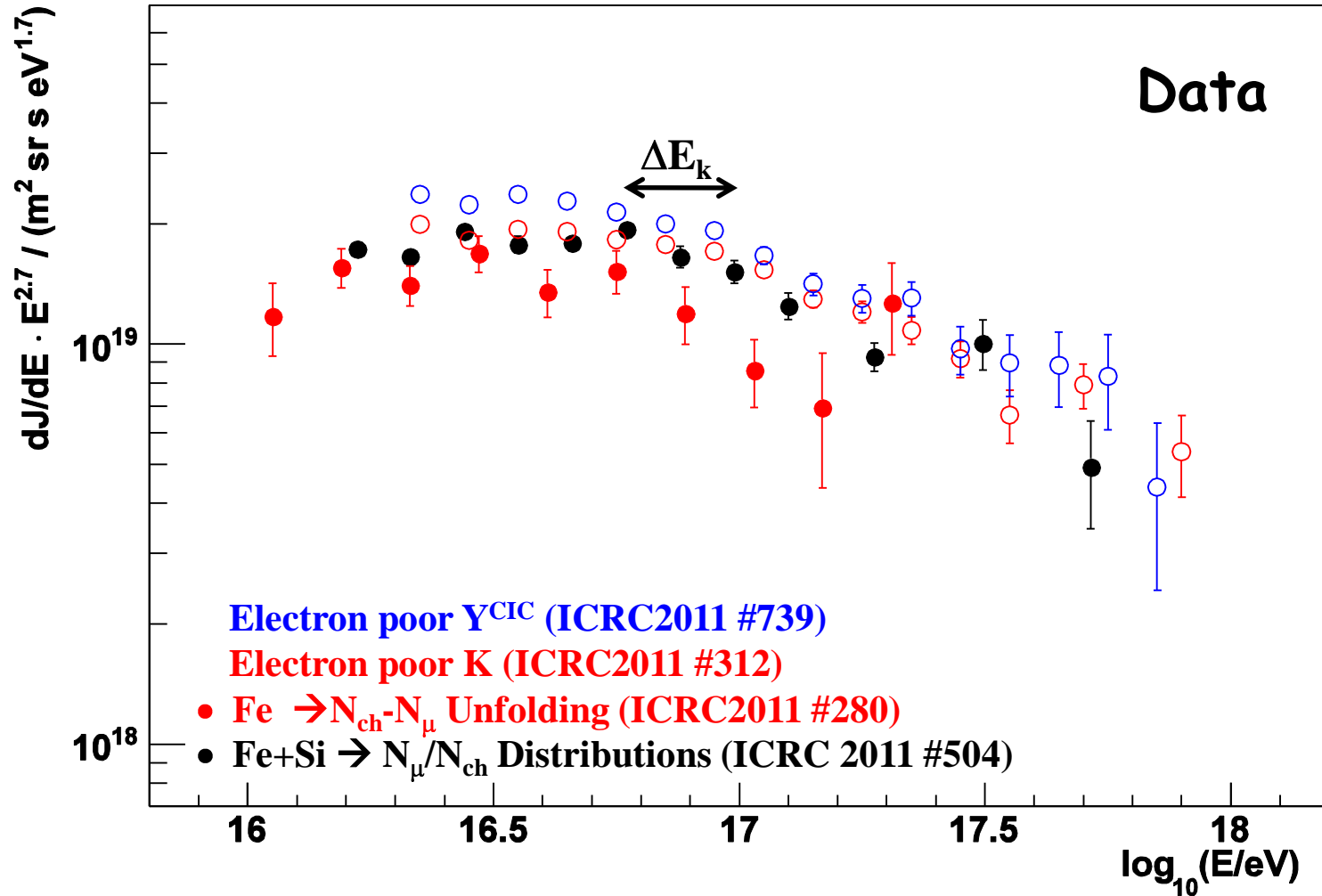
All spectra of “electron poor” events
show a change of slope

Spectra obtained cutting at different Y values
→ i.e. different hadronic interaction models



No spectra of “electron rich” events
show a change of slope

- The change of slope of the heavy mass group spectra is observed also with other approaches



Conclusions

- ✓ All particle spectra measured above the knee show:
 - Discrepancies in the absolute fluxes (<20%)
 - Agreement in the spectral structures
- ✓ A change of slope in the spectrum of heavy primaries has been detected by the KASCADE-Grande experiment
- ✓ Light element spectrum should be further investigated to evidence the transition from galactic to extragalactic cosmic rays