Sensitivity of KASCADE-Grande data to hadronic interaction models

KASCADE results:
- Tests of hadron interaction models
- Energy spectrum with QGSJET, SIBYLL, EPOS

KASCADE-Grande:
- Muon density investigations
- Comparison of QGSJET-II-2 and EPOS 1.99

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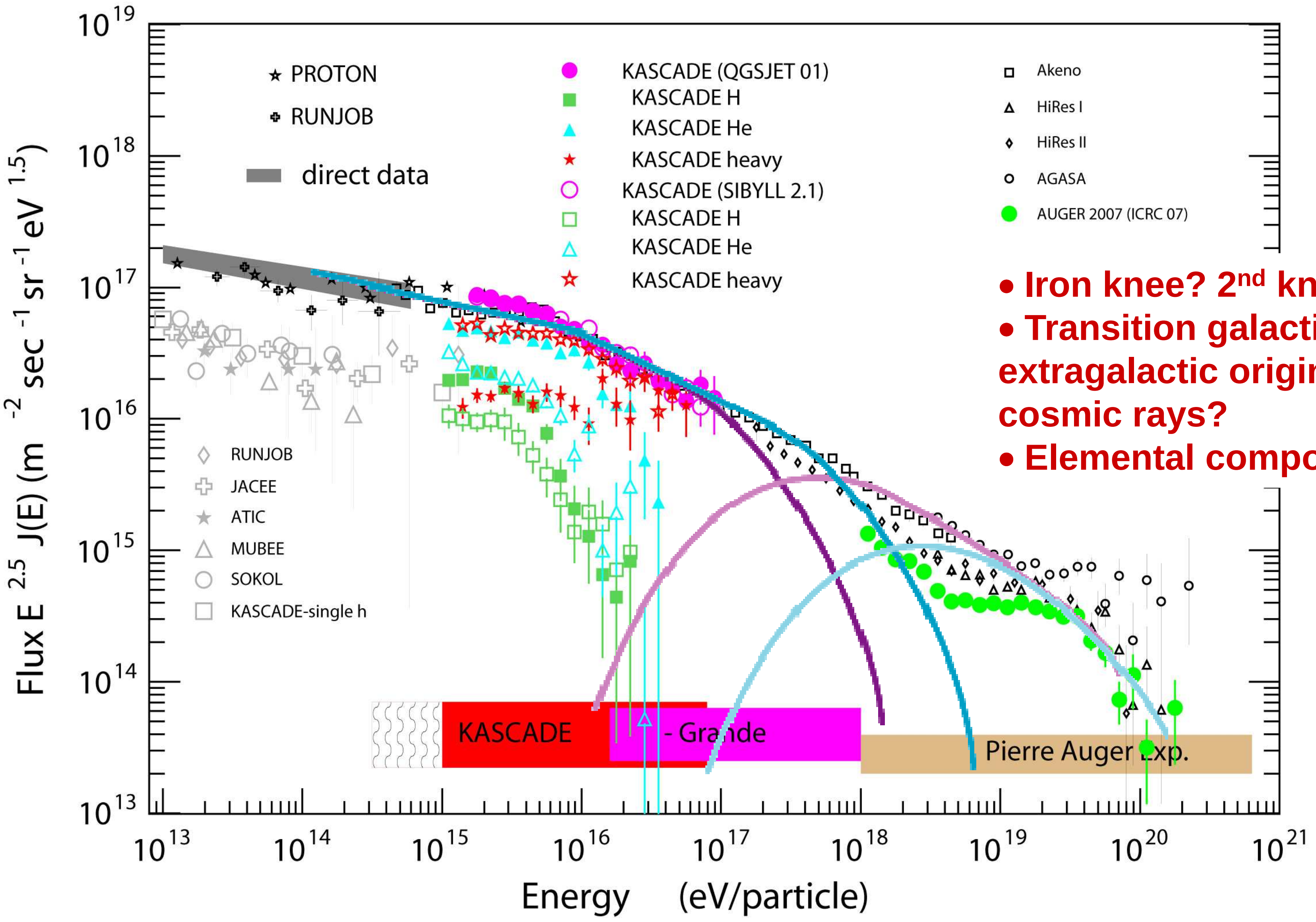
ISVHECRI, 28 June – 2 July 2010, Fermilab

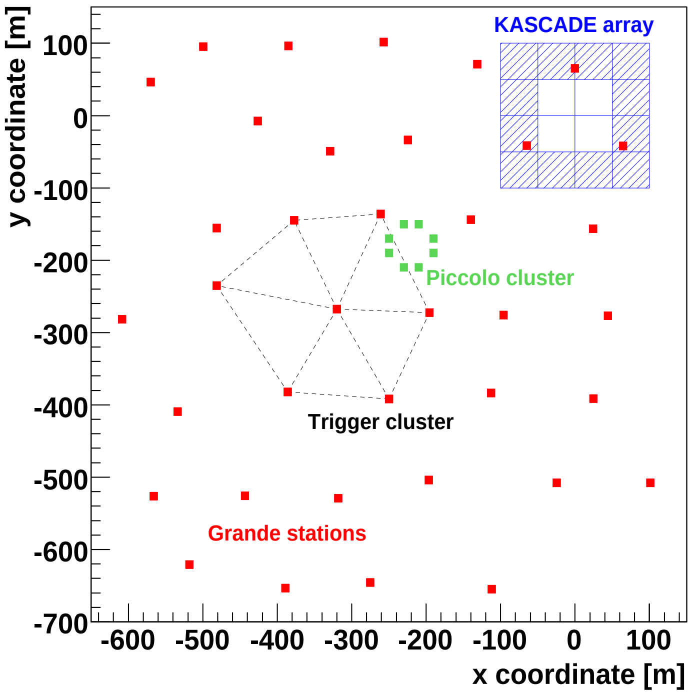
Motivation for measurement of 10^{16} to 10^{18}eV

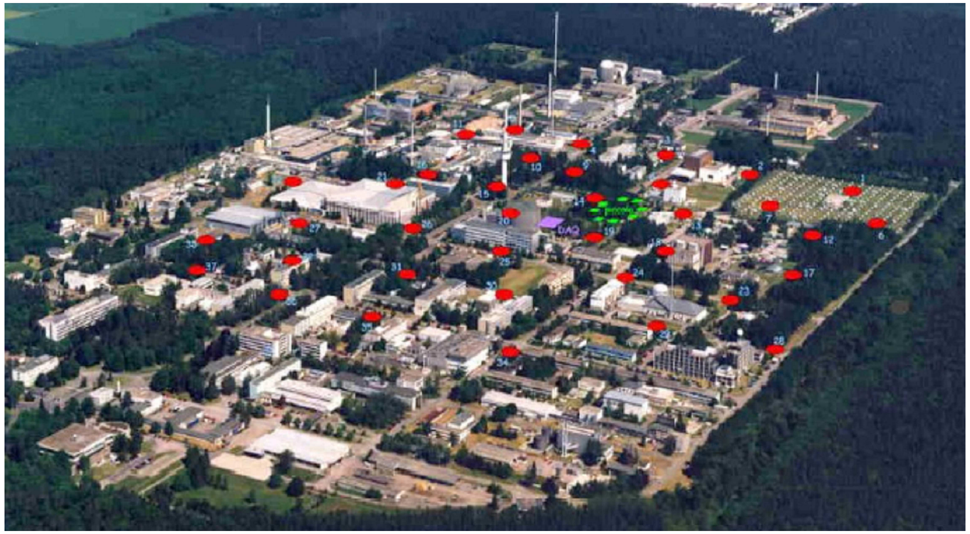


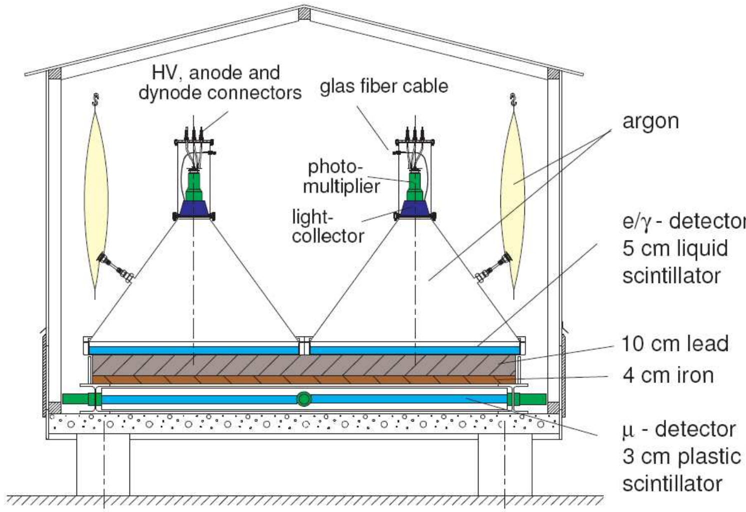
- Iron knee? 2nd knee?
- Transition galactic to extragalactic origin of cosmic rays?
- Elemental composition

Talk by J. C. Arteaga-Velázquez

KASCADE-Grande experiment







- Total effective area: 0.5 km^2
- Large array of 37 stations with an average spacing of 137m
- Each station has a plastic scintillation detector of 10 m^2
- 18 trigger clusters (0.5Hz)

Grande detectors are sensitive to all charged particles, while KASCADE detector measure e/γ and μ components separately.

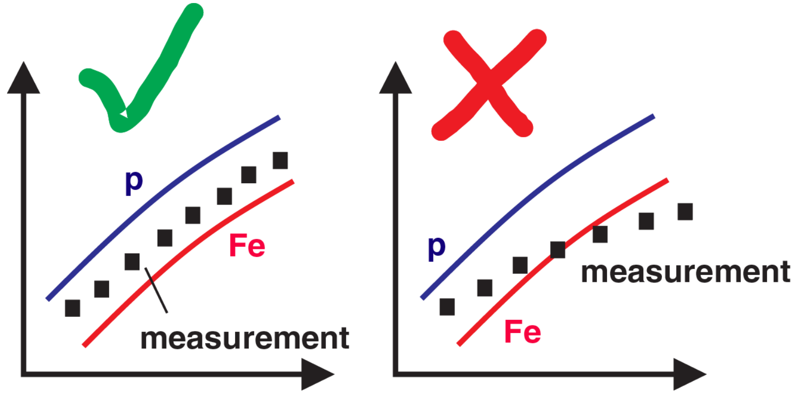
Hadrons in air shower cores: Test of hadronic interaction models

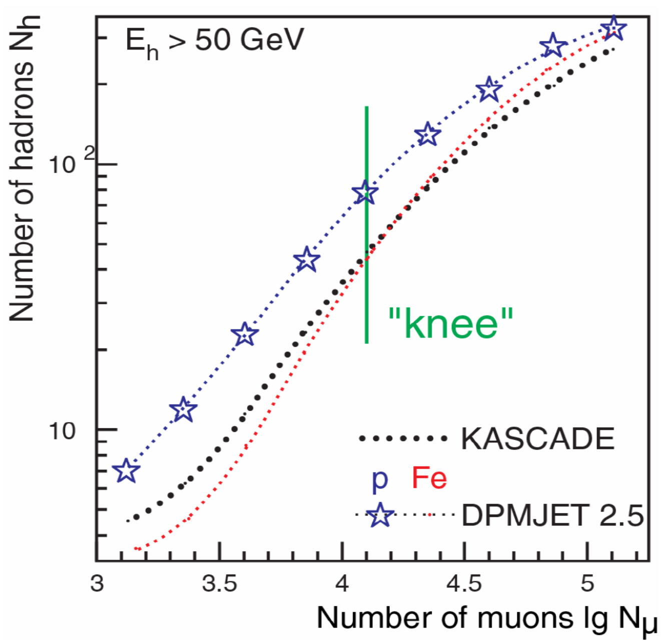
KASCADE observables per individual EAS:

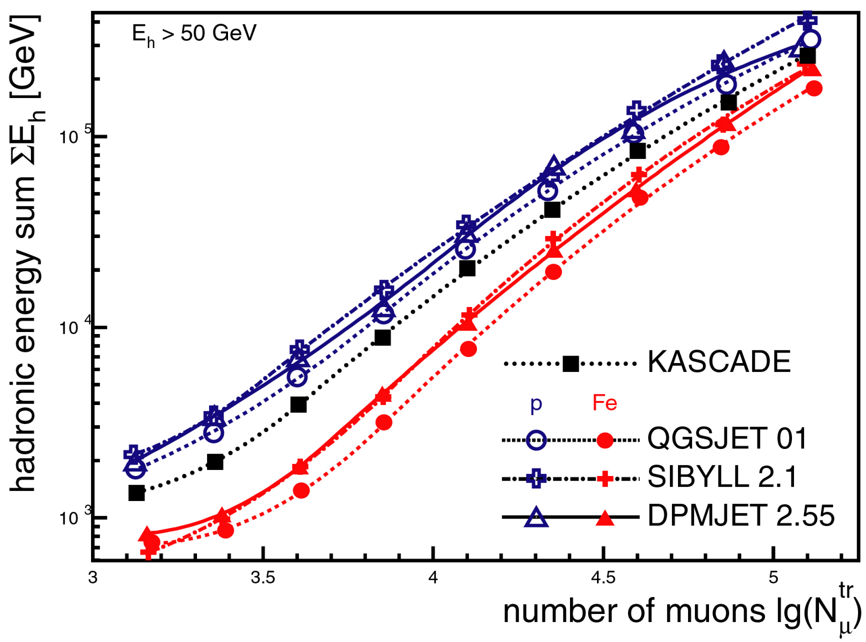
From detector array: general shower paramters

From hadron calorimeter:

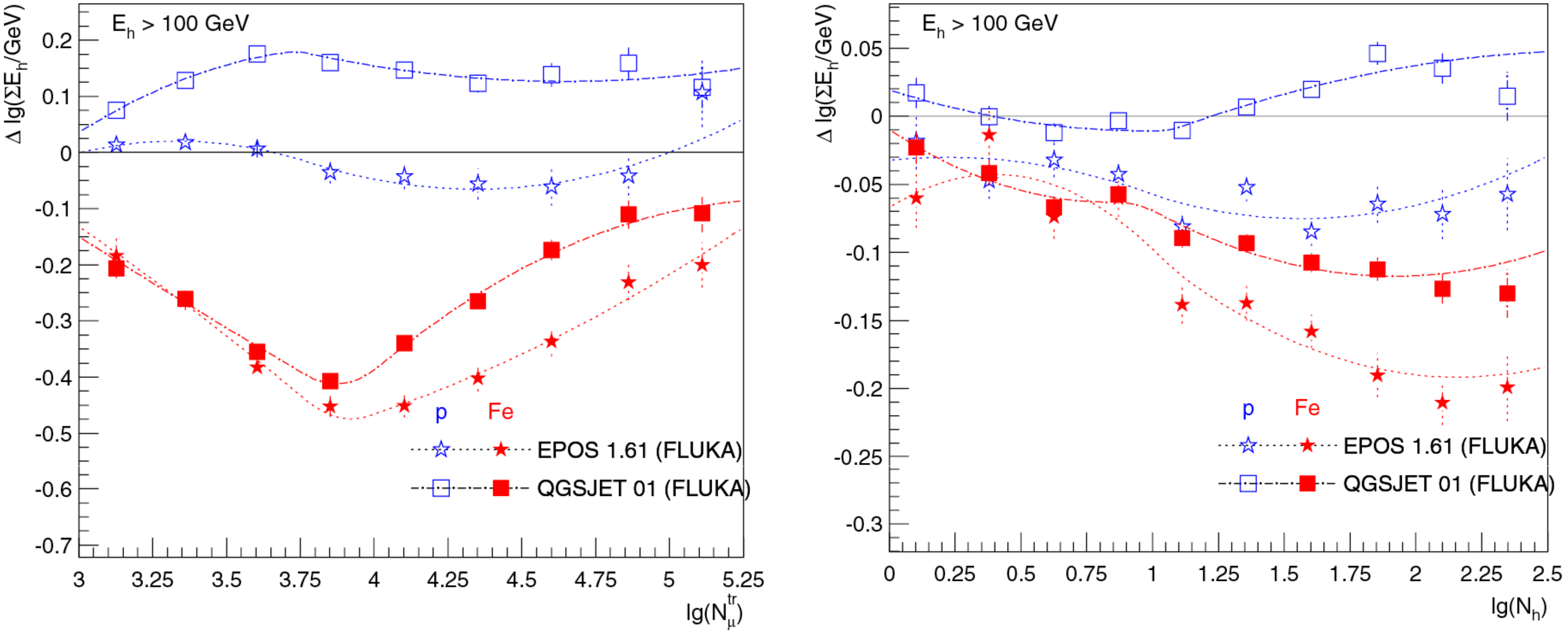
- Number of reconstructed hadrons (E_h > 100GeV): N_h
- Sum of reconstructed hadronic energy ΣE_h
- Energy of leading hadron E_h^{max}







KASCADE: Test of EPOS 1.61 with hadrons



• The predicted hadronic energy sum, relative to the measured values, is plotted as function of the number of reconstructed hadrons.

• EPOS 1.61 delivers not enough hadronic energy to the observation level and the energy per hadron seems to be too small.

J. Phys. G: Nucl. Part. Phys. (2009) 035201

KASCADE
Shower observable correlations: model tests

QGSJET 98
~~VENUS~~
~~SIBYLL 1.6~~

J. Phys. G: Nucl. Part. Phys. 25 (1999) 2161

DPMJET II.55
~~DPMJET II.5~~
QGSJET 01
SIBYLL 2.1
~~NEXUS 2~~

J. Phys. G: Nucl. Part. Phys. 34 (2007) 2581

~~EPOS 1.61~~
QGSJET II

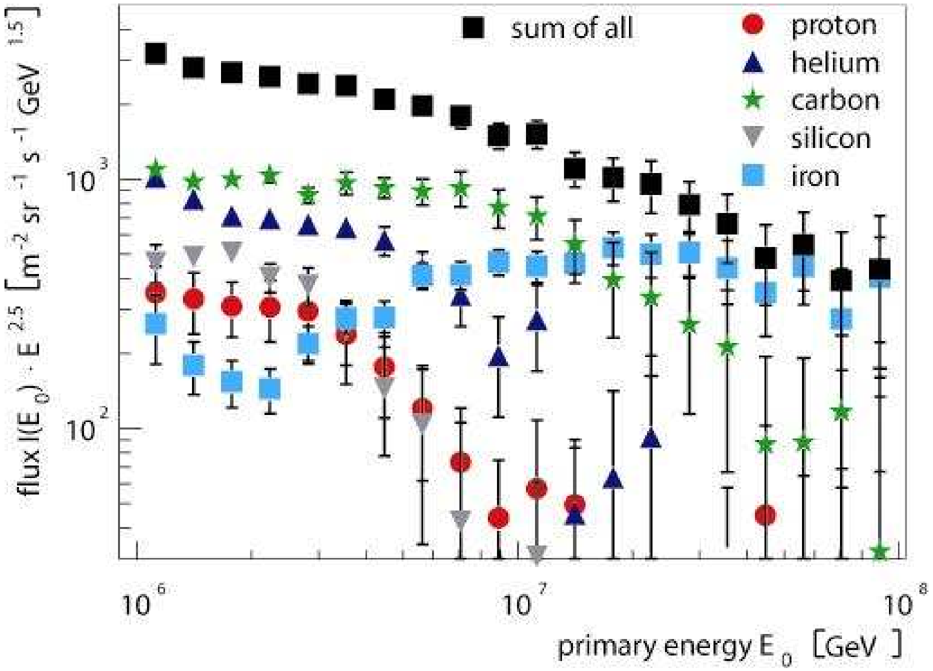
J. Phys. G: Nucl. Part. Phys. (2009) 035201

- EPOS 1.6 is not compatible with KASCADE measurements
- QGSJET-II has some deficiencies
- QGSJET 01 and SIBYLL 2.1 still most compatible models

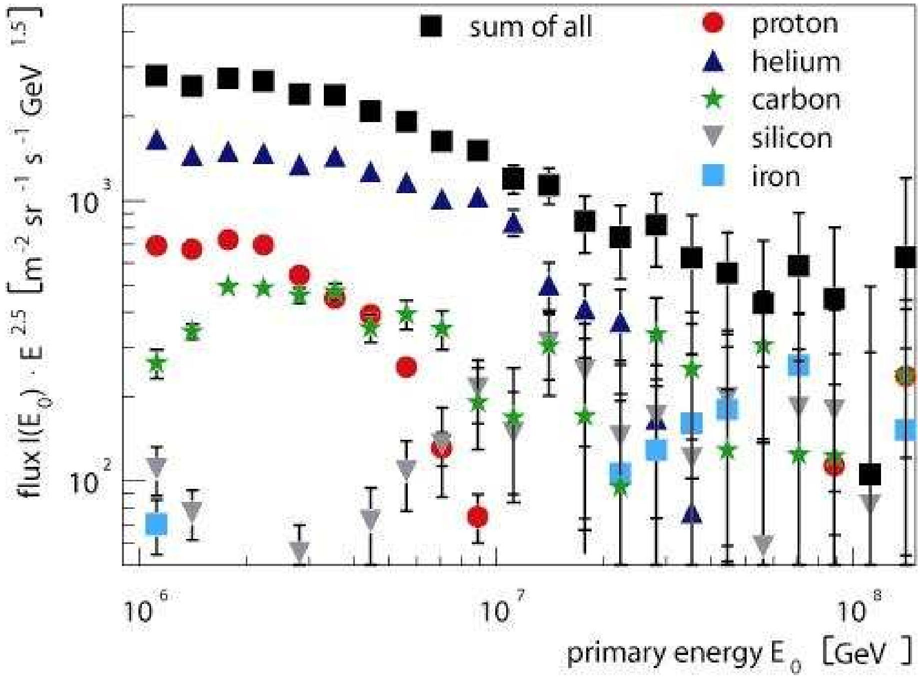
New models are welcome for cross - tests with KASCADE data

KASCADE results

SIBYLL 2.1



QGSJET-01



<u>Searched:</u> energy and mass of the cosmic ray particles

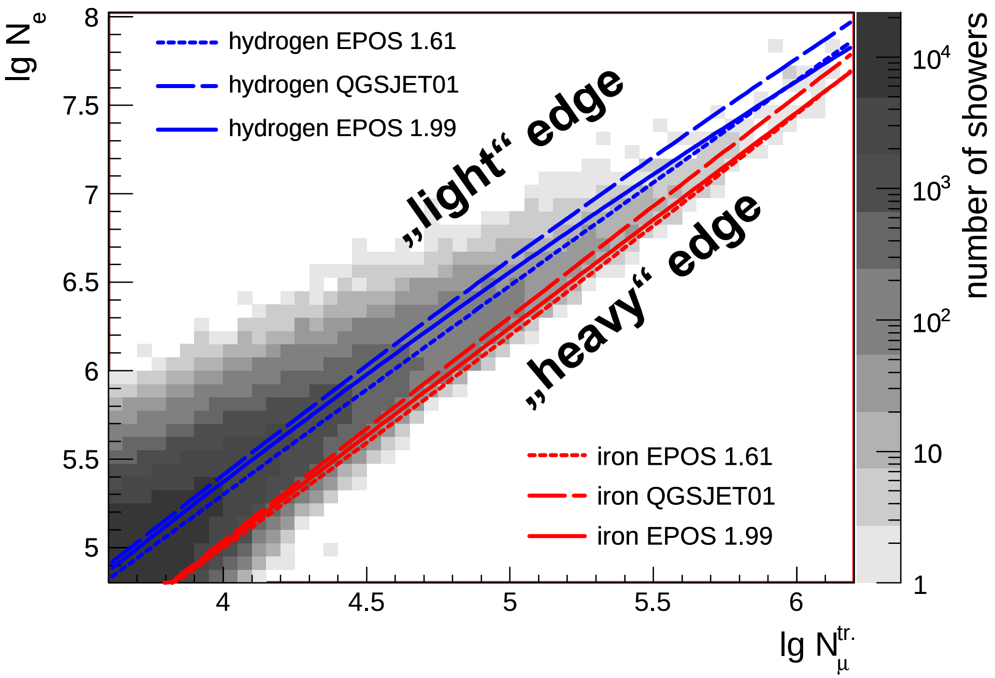
<u>Given:</u> N_e and N_μ for each single event→solve the inverse problem

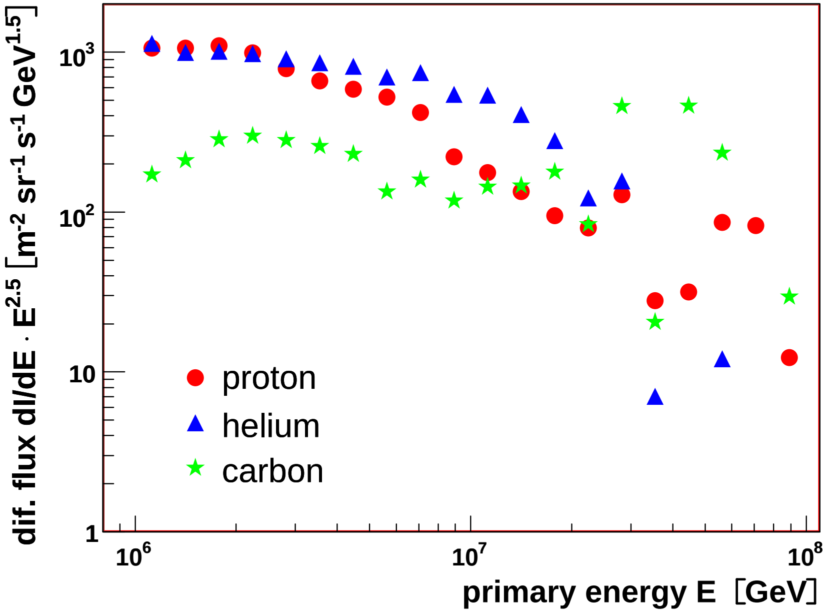
$$\frac{dJ}{d\lg N_e d\lg N_\mu^{tr}} = \sum_A \int_{-\infty}^{+\infty} \frac{dJ_A}{d\lg E} p_A(\lg N_e, \lg N_\mu^{tr} \mid \lg E)\, d\lg E$$

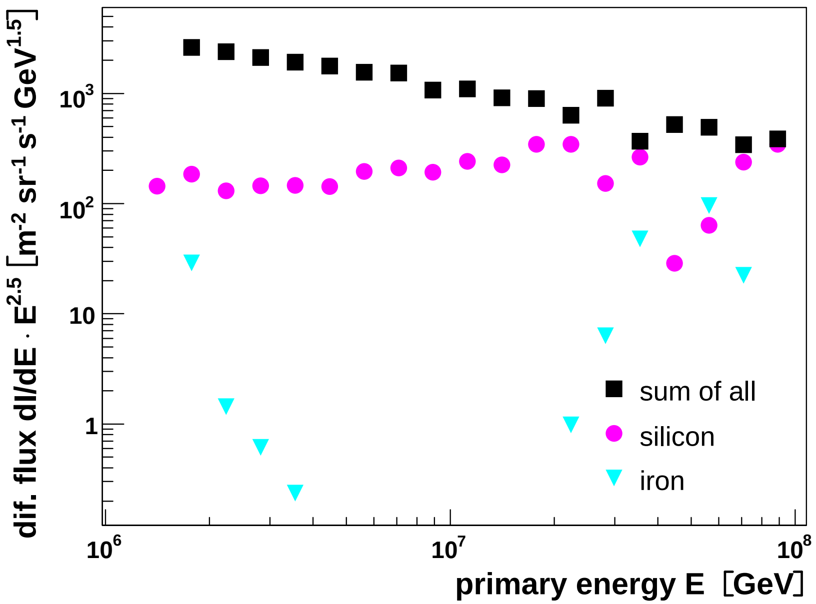
- Kernel function obtained by Monte Carlo simulations (CORSIKA)
- Contains: shower fluctuations, efficiencies, reconstruction resolution

Same unfolding but based on two different interaction models: SIBYLL 2.1 and QGSJET-01 (both with GHEISHA 2002) all embedded in CORSIKA

KASCADE: sensitivity to EPOS 1.99



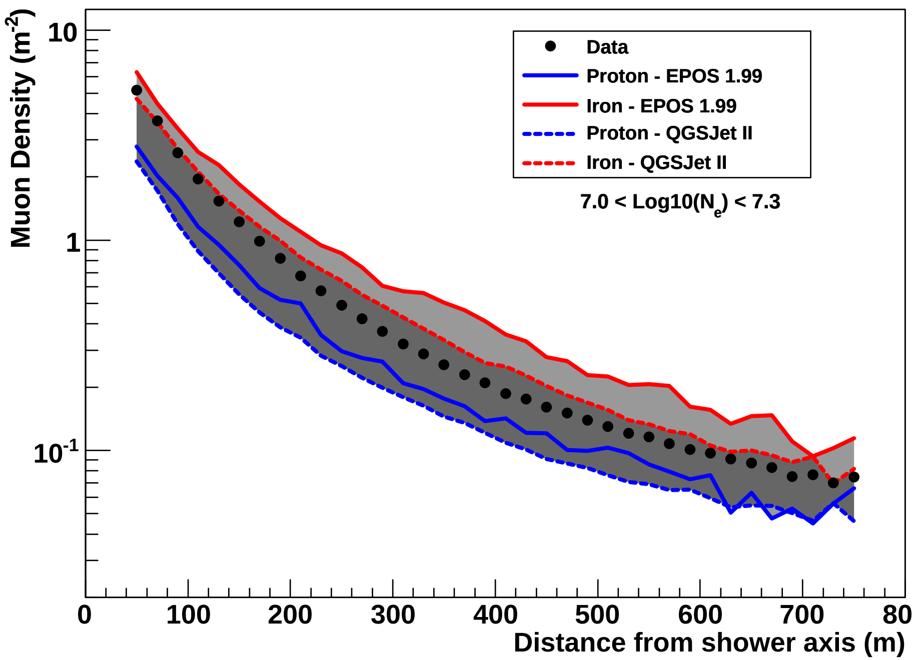


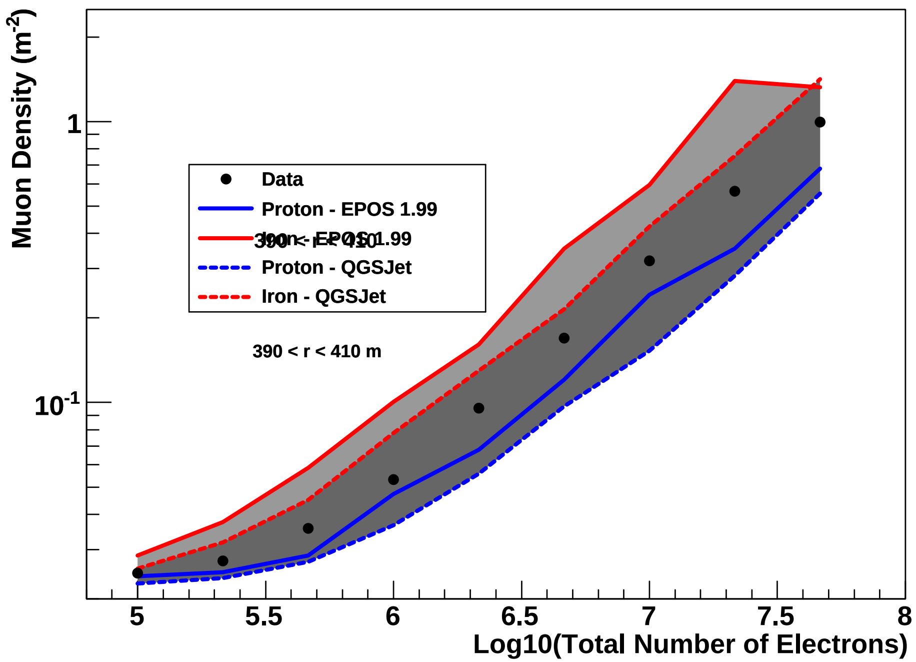


- Unfolding based on EPOS and FLUKA
- light (helium + proton) dominant
  (Proton dominant for EPOS 1.61)
- Knee caused by light elements

M. Finger

KASCADE-Grande:
Muon density investigations EPOS 1.99



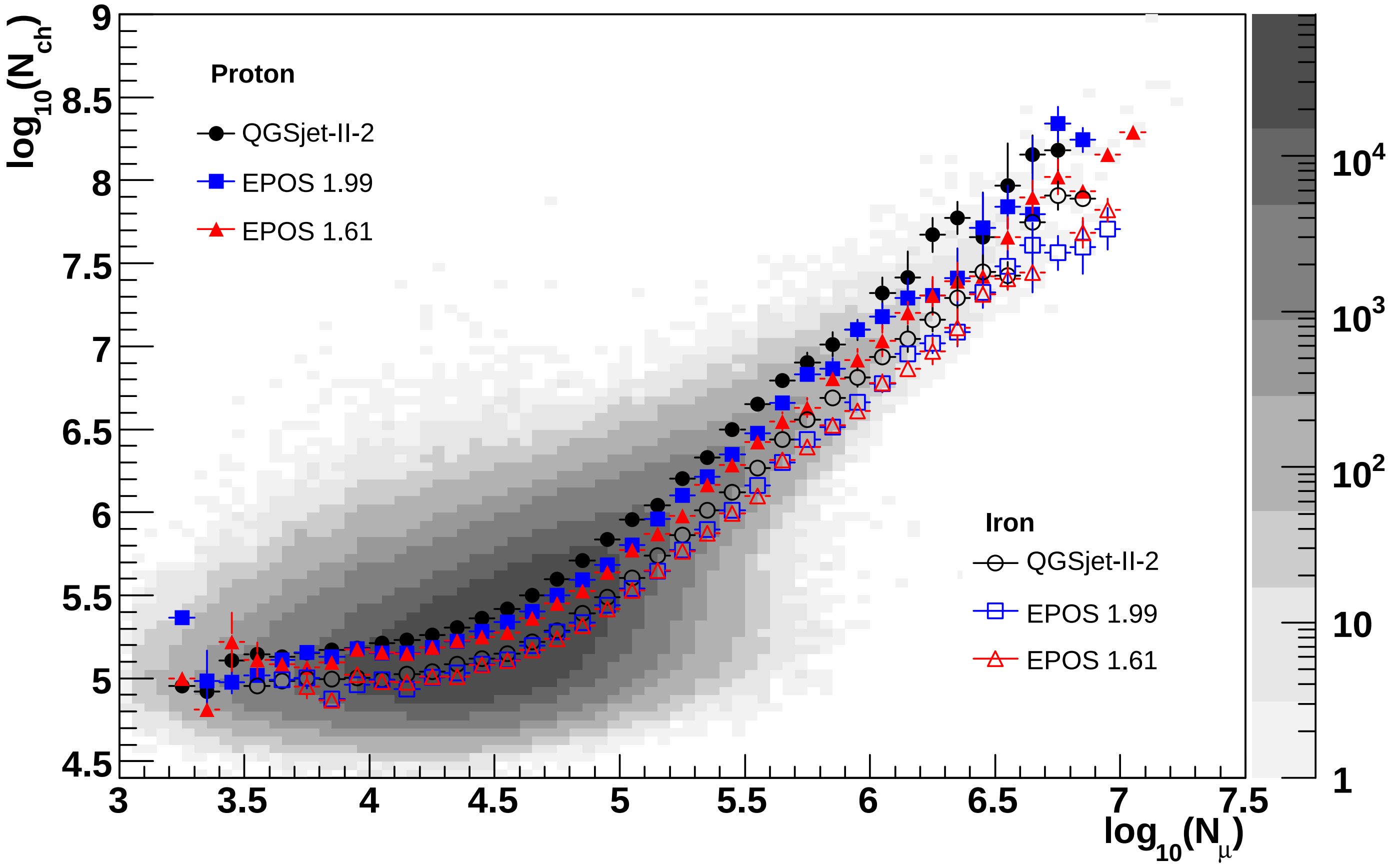


Muon density reconstruction possible for different distances:

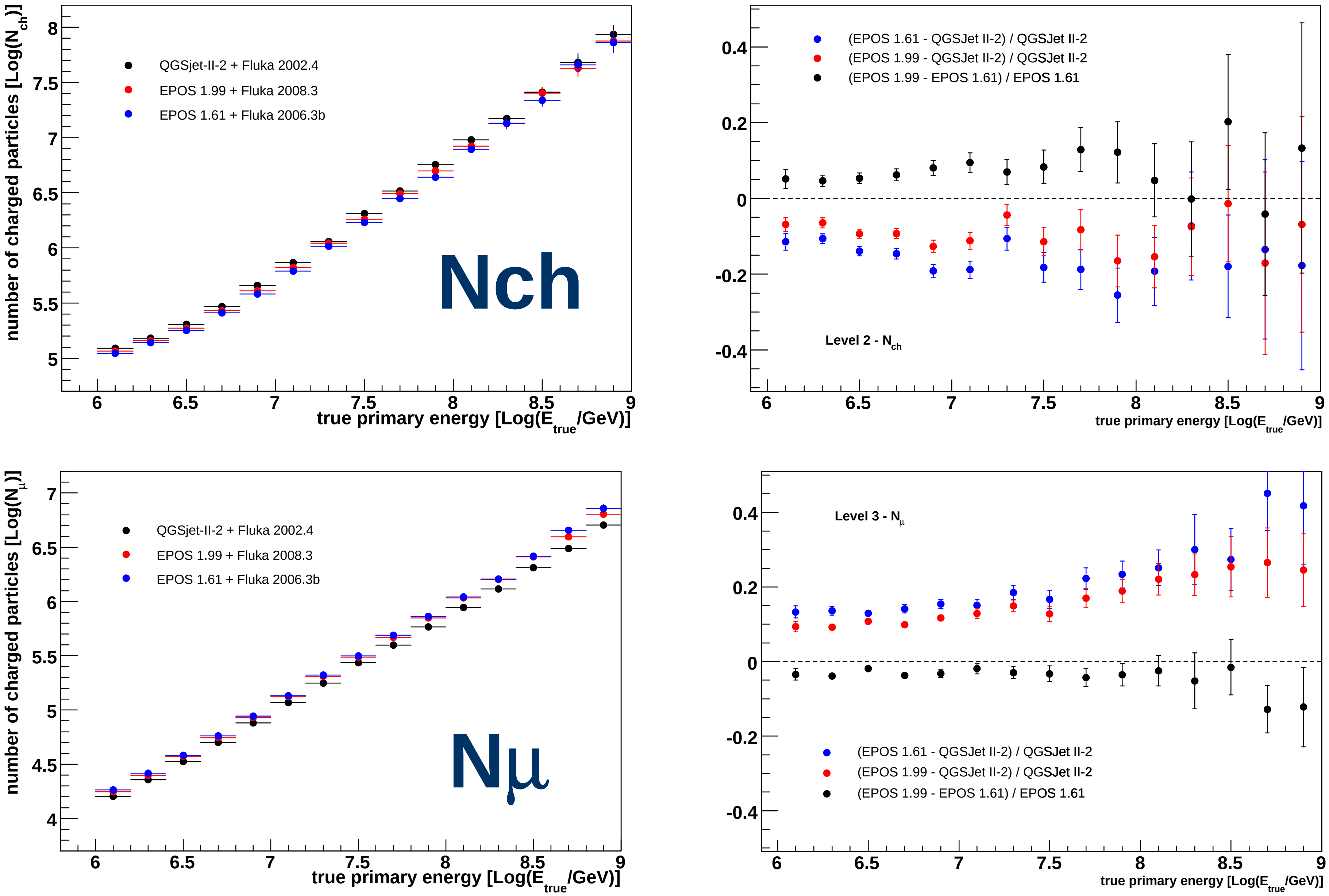
- Composition sensitivity
- Model tests: heavy for QGSJETII & light for EPOS

V. de Souza

KASCADE-Grande:
Comparison of QGSJET-II-2 & EPOS 1.99

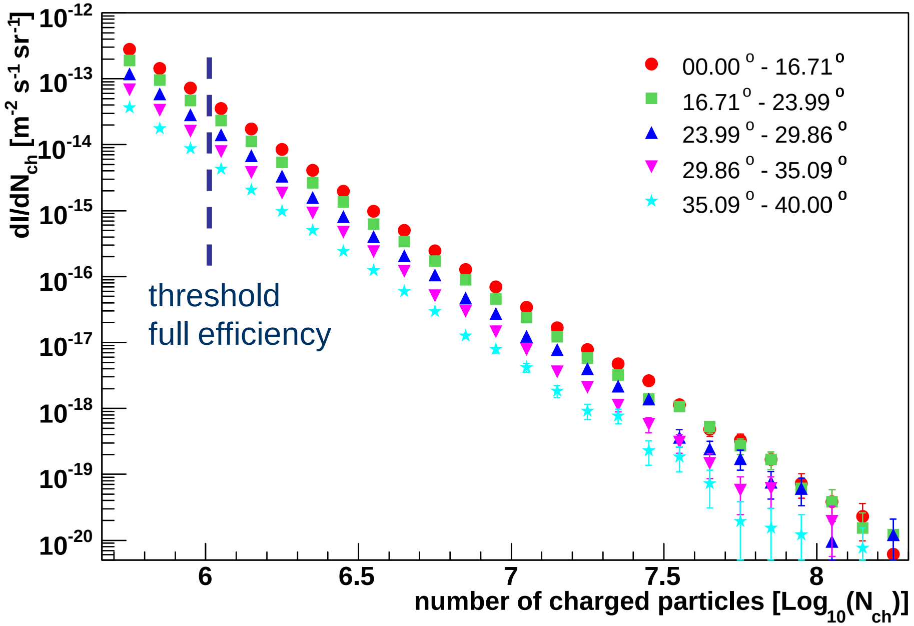


- KASCADE-Grande 2 dim. Nch/Nm plot + proton and iron for QGSJET and EPOS
- Difference between the two EPOS models in proton

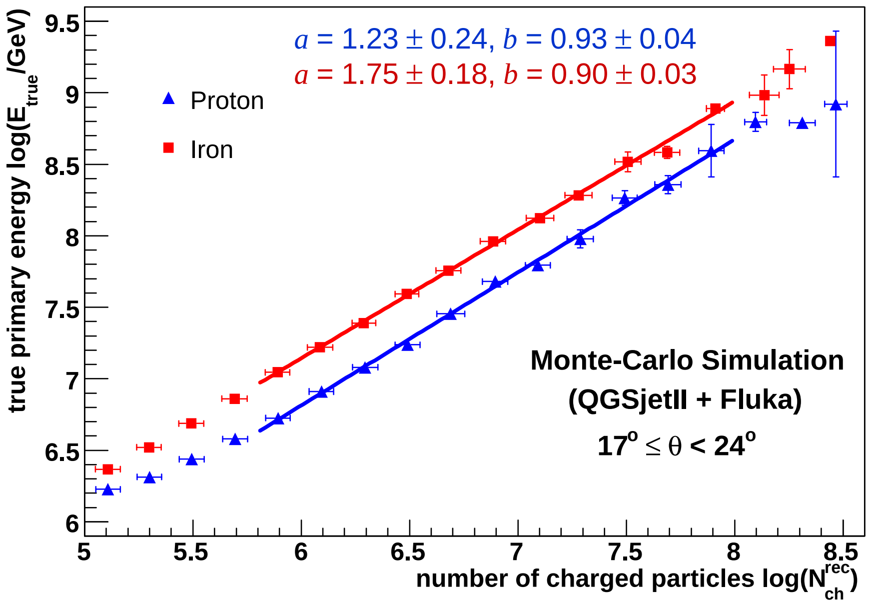


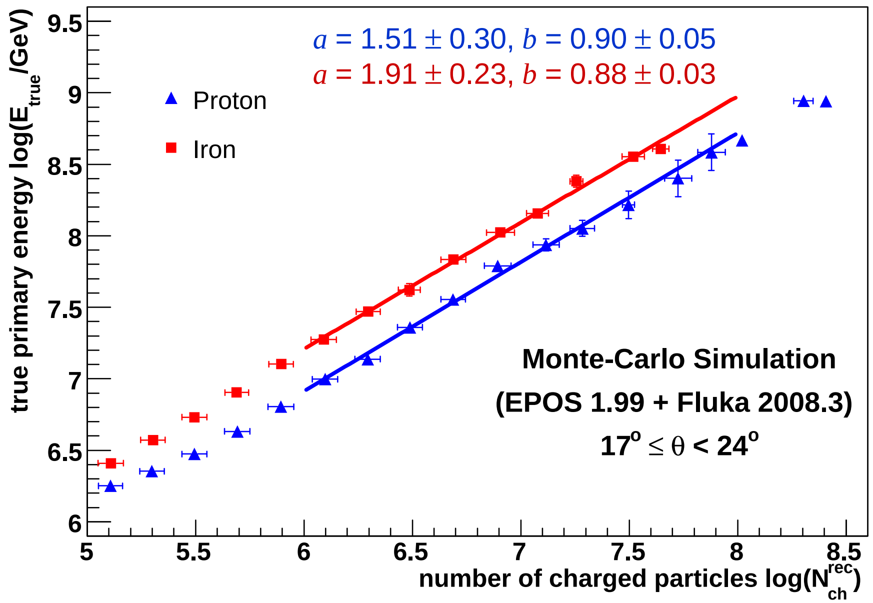
- Deviation of EPOS relative to QGSJet
- EPOS has less Nch and more muons with respect to QGSJET (roughly 10%)

KASCADE-Grande: Energy calibration

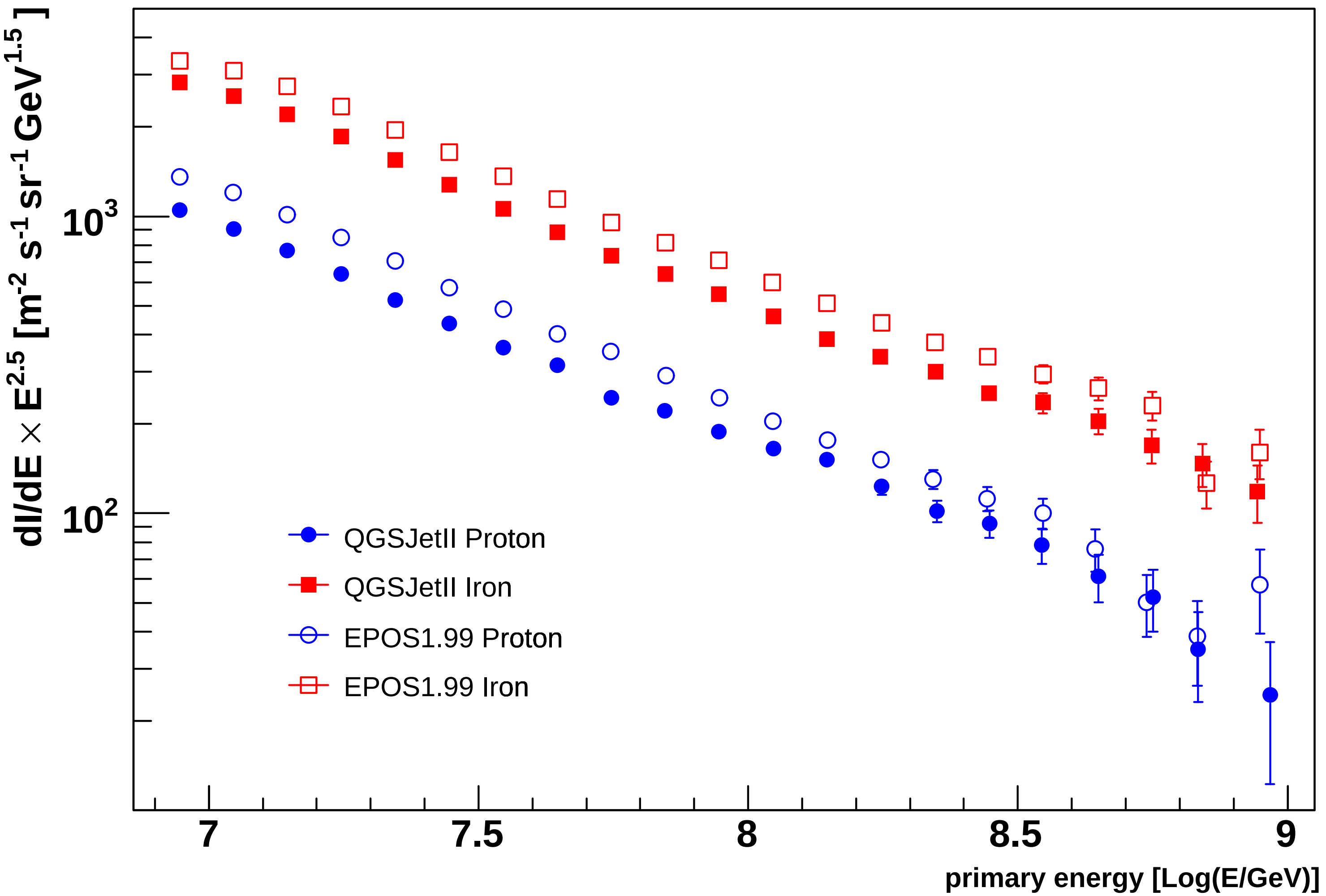


- Shower size spectra for different zenith angle bins
- Energy calibration for QGSJET-II-2 & EPOS 1.99
- Fit with $\log E = a + b \log N_{ch}$





KASCADE-Grande:
Energy spectrum based on QGSJET-II-2 & EPOS1.99



- Based on Constant Intensity Cut method (Talk by J. C. Arteaga-Velázquez)
- EPOS result leads to a significantly higher flux compared to the QGSJET-II result

Summary

KASCADE results:

- QGSJET 01 and SIBYLL 2.1 still most compatible models
- EPOS 1.61 is not compatible with KASCADE measurements

Results of KASCADE-Grande:

- Muon density investigations: QGSJET-II-2 could fit the data with an intermediate abundance. EPOS would require abundance of light primary particles in order to fit the data.
- The interpretation of the KASCADE-Grande data with EPOS leads to significantly higher flux compared to the QGSJET-II-2 result.
- More detailed investigations of EPOS 1.99 is still in work.

KASCADE-Grande Collaboration

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