Lateral density distributions of muons and electrons EAS from the KASCADE-Grande data for different zenith angle intervals.

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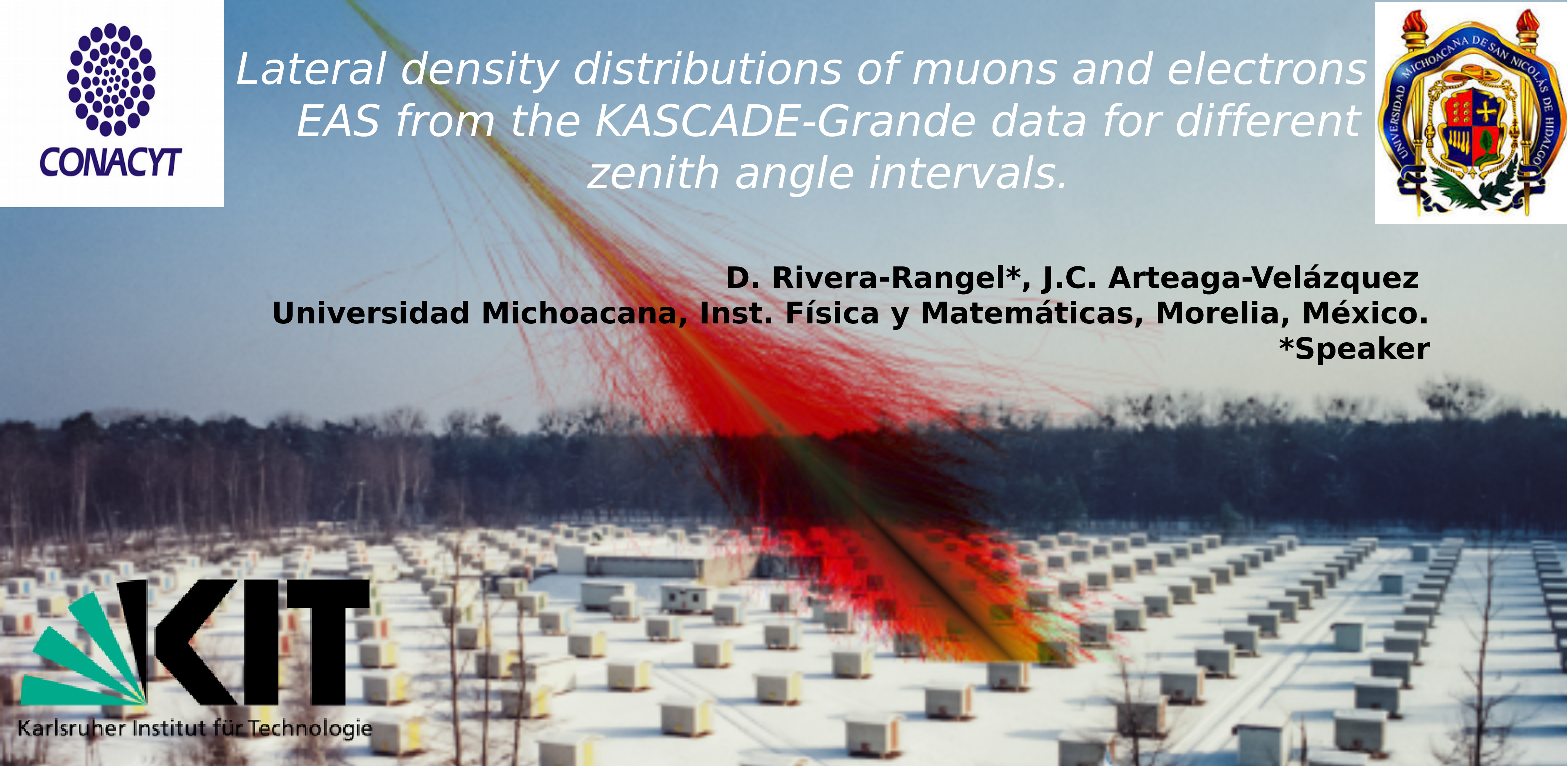
***Speaker**



ONLINE ICRC 2021
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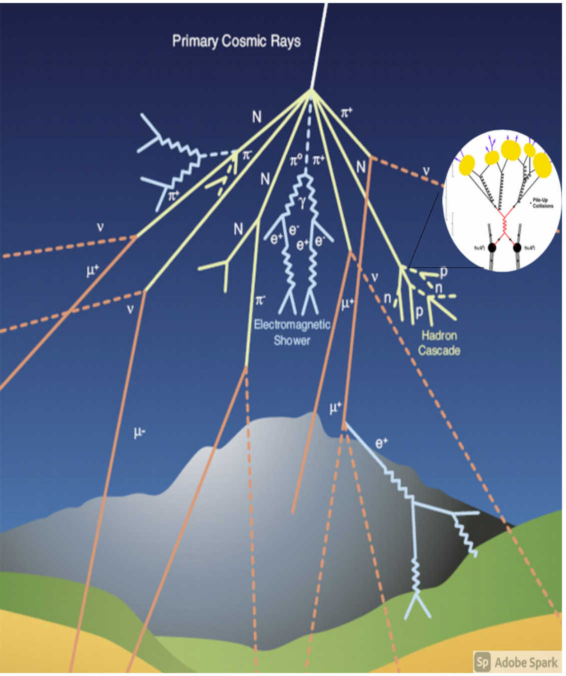
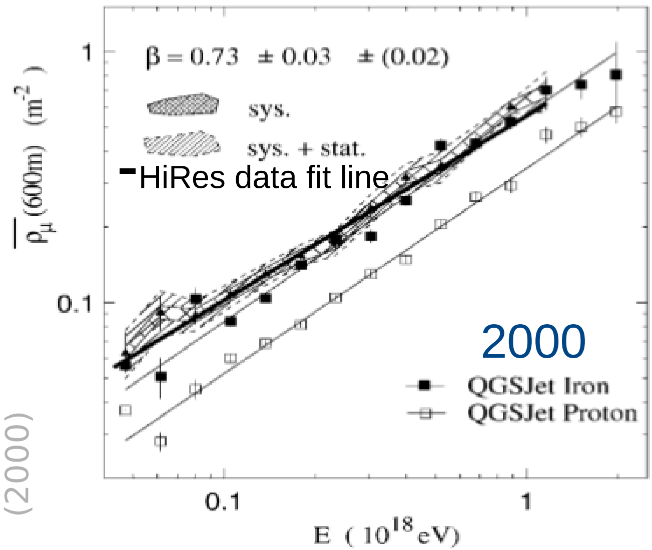
Motivation

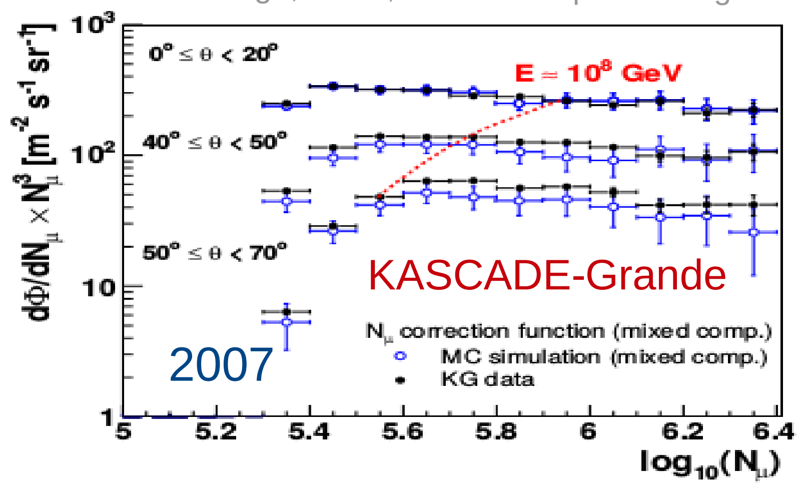


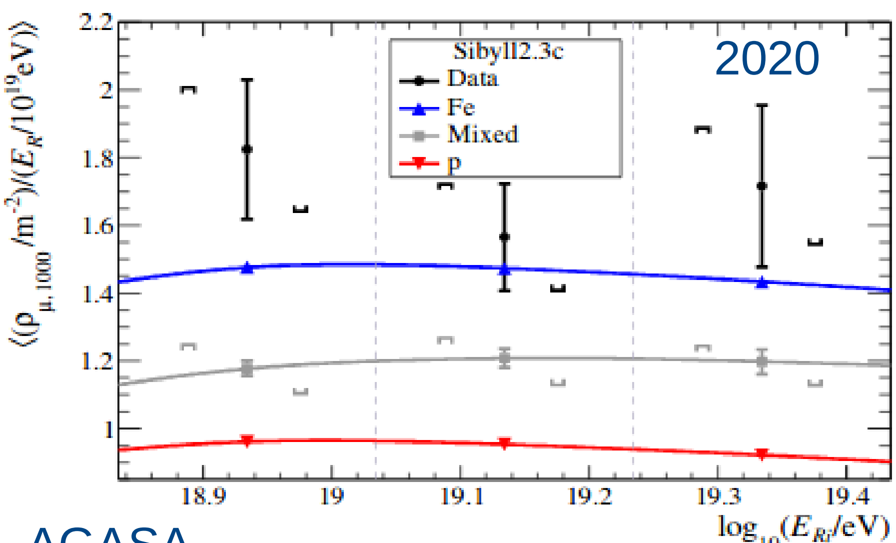
Development of the Extended Air Showers are described by fenomenological models which are based on colliders data.

T. Abu-Zayyad et al. (MIA, HiRes), 4276 (2000)



J.C. Arteaga, et. al., ICRC 2007 proceedings.

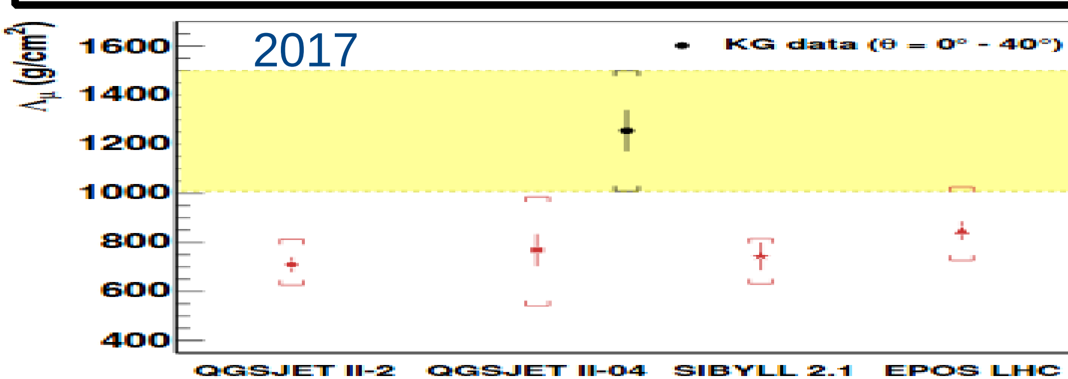




AGASA

A.D. Supanitsky, et al, Physical Review 101 (2020)

- Experiments show a bigger abundance of muons than models predictions
- Discrepancies between hadronic models and experimental data on the muon espectrum, muon densities and muon attenuation length.



J.C. Arteaga-Velazquez, et al., Astropart. Phys. 95 (2017) 25.

KASCADE-Grande experiment

www.iap.kit.edu/kascade

Karlsruher Institut für Technologie

Karlsruhe, Germany.

- 110 m a.s.l., 49°N, 8°E

KASCADE

- Area: 200x200 m²
- 252 e/γ detectors (scintillator)
- 192 μ detectors.
- Central Detector.
- Calorimeter.
- Muon Tracking detector.

Observables:

- N_e, N_μ, $N_{hadrons}$
- $E=10^{14}$-10^{17} eV

GRANDE detector:

- Area: 0.5 km²
- $A_{detector}$: 10 m²
- 37 detector stations
- Plastic Scintillators.
- Separation: 137 m
- Extend detection energy to 1 EeV.
- Hexagonal clusters of 7 detectors.

μ

N_{ch}

DAQ

piccolo

W.D. Apel, et al., Nuclear instruments in physics Research. 2010.

Shower size reconstruction

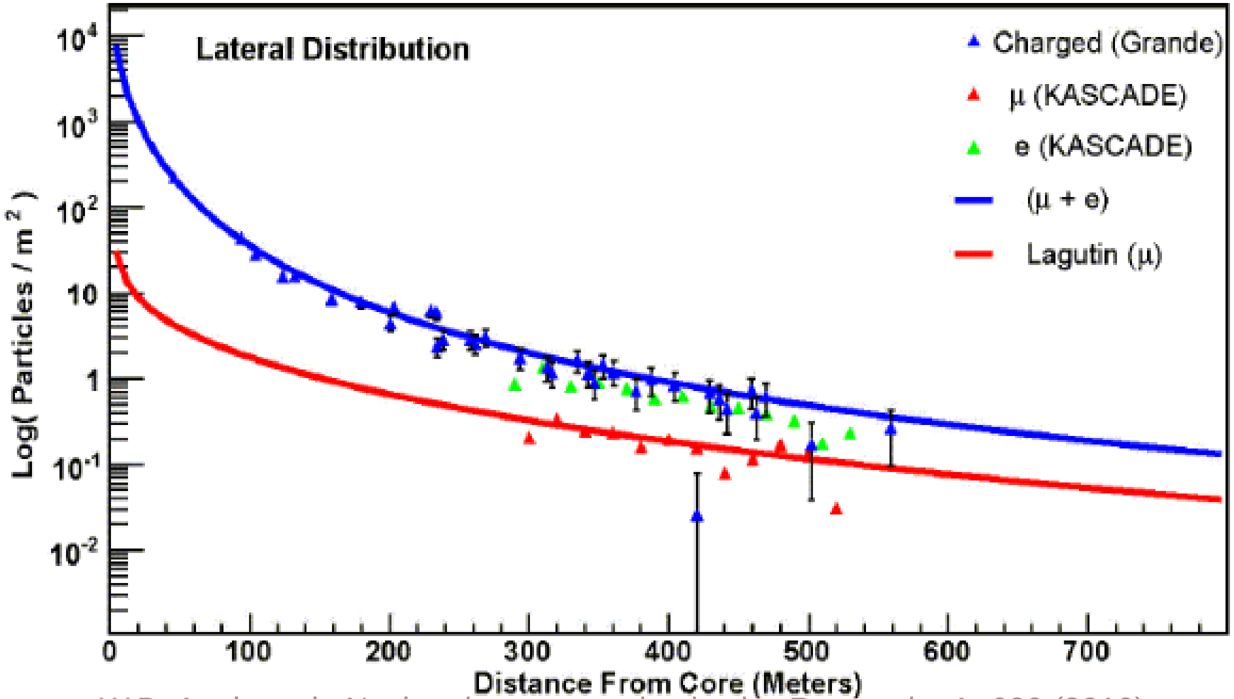
The number of muons has to be estimated

The total number of muons N_μ in the shower disk is derived from a maximum likelihood estimation to to the local muon data measured with KASCADE.

Lateral distribution

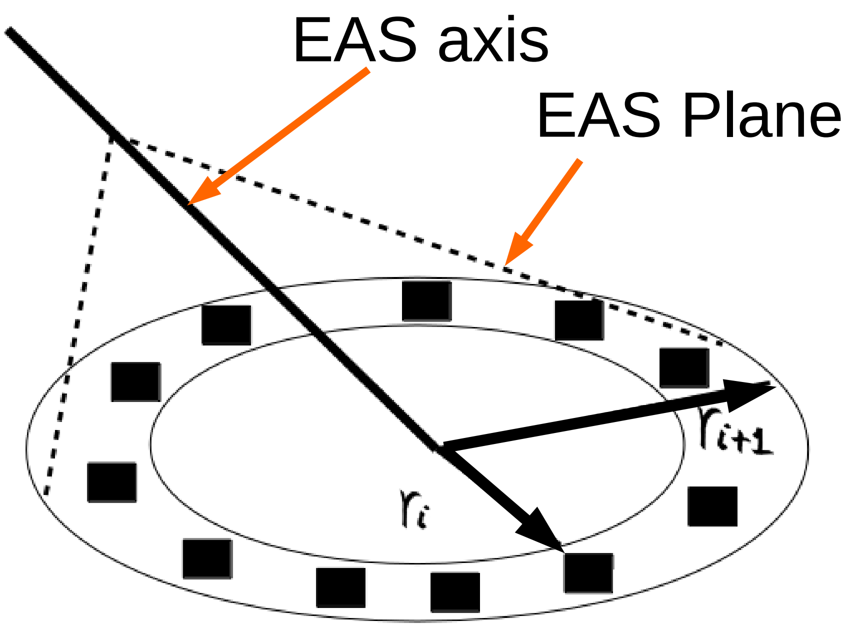
$$\rho_\mu(r) = N_\mu f(r)$$

The lateral distribution function for the fit is a Lagutin-Raikin function with a fix shape. It is derived from MC simulations using CORSIKA.



W.D. Apel, et al., Nuclear instruments in physics Research. A. 620 (2010).

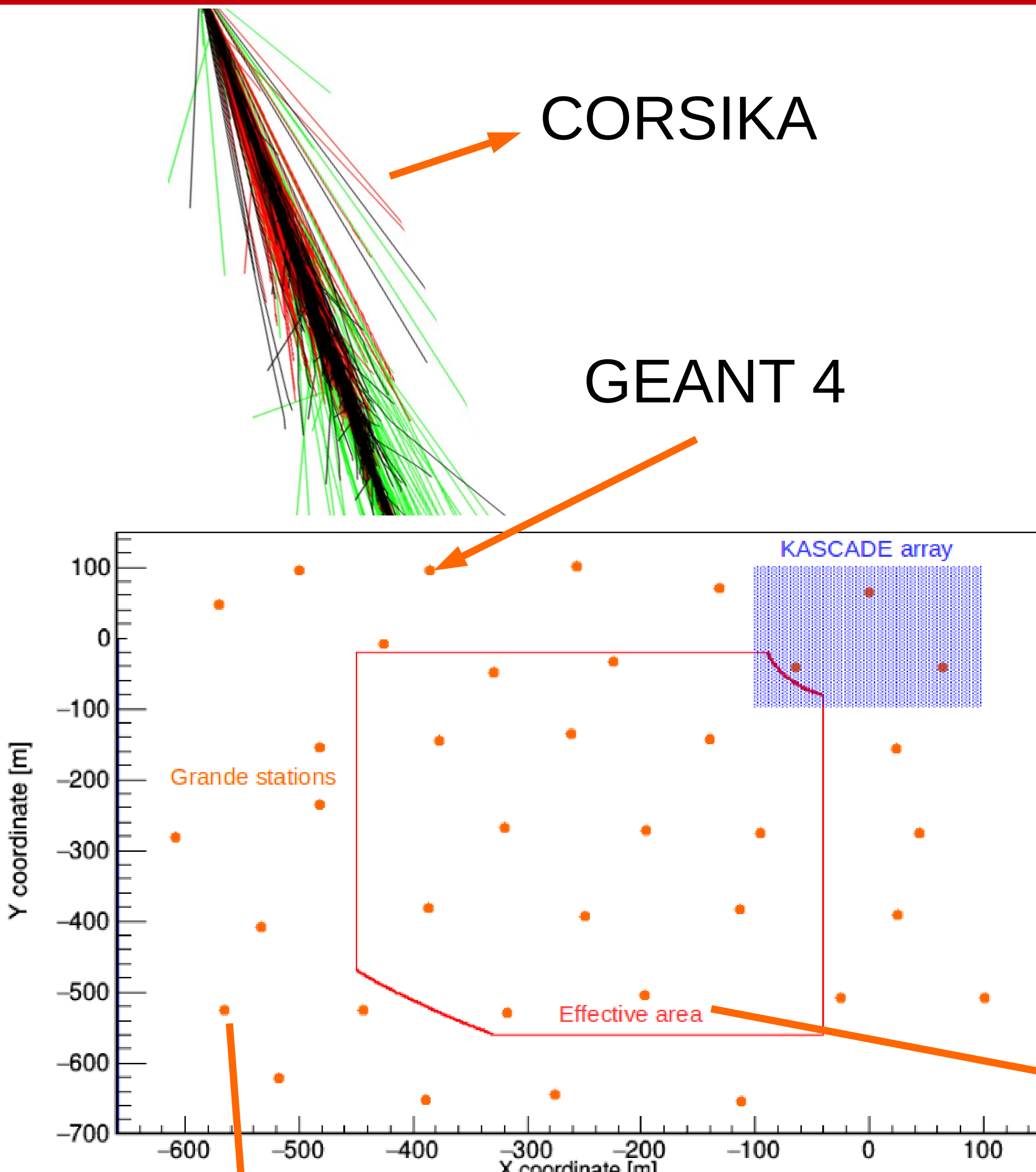
Particle density estimation



$$\rho_i = \frac{\sum_j^k n_j}{\sum_j^k A_j}$$

- n_j is the number of particles measured in one detector inside a ring of radius r_i.
- A_j is the sensitive area of the detector inside a ring of radius r_i.
- r_i is the radius of the i^{th} ring.

Selection Cuts



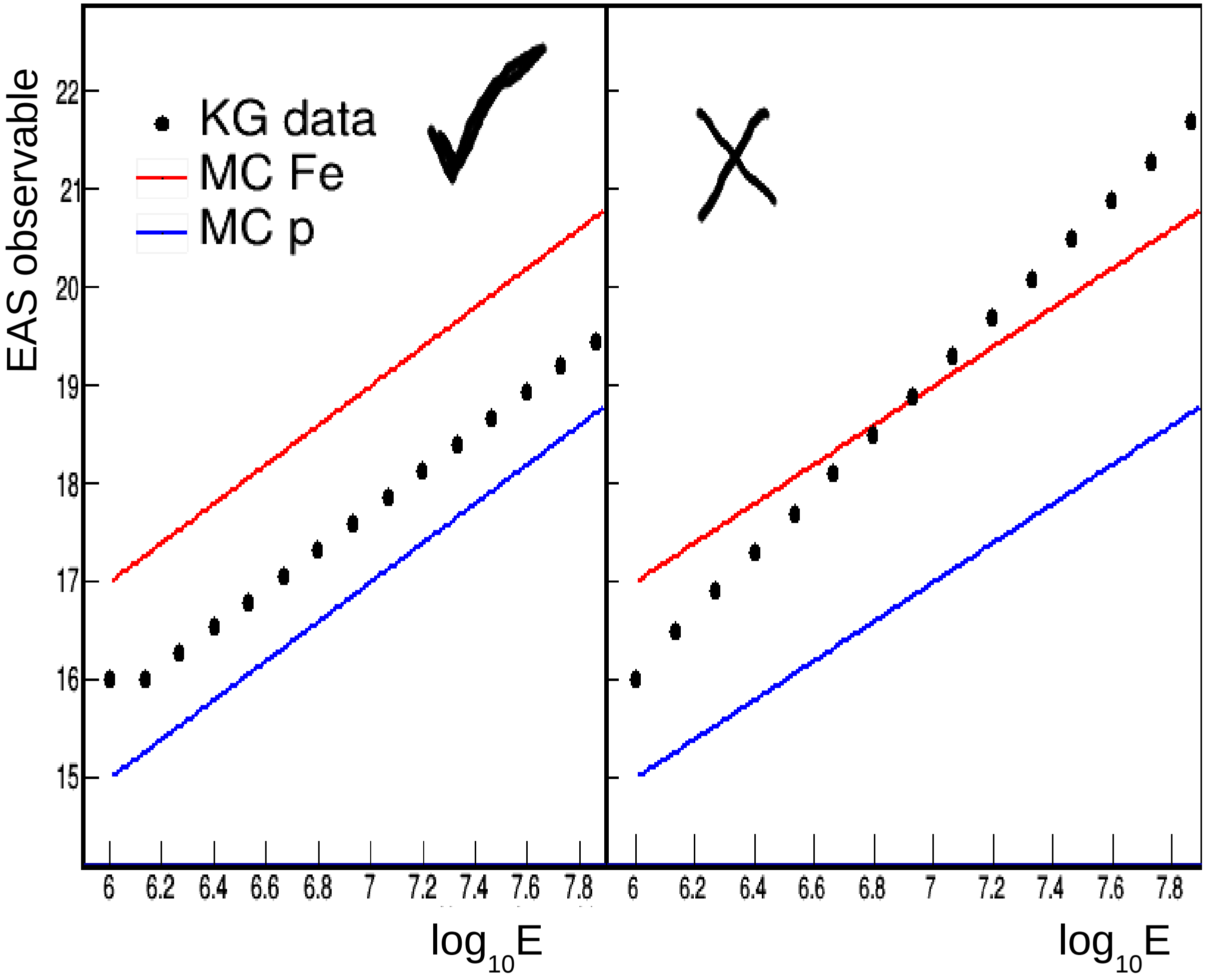
Grande scintillator detectors

- Fiducial Area
  $x \in [-430\,m, -40\,m] \quad y \in [-560\,m, 25\,m]$
  $r \in [150\,m, 650\,m]$
- Cuts on the direction of arrival angle (Use only the data that passed the selection)
  - **Acceptance** 656.902 m^2*sr
    - Three intervals of equal acceptance.
    - [0°,21.78°]
    - [21.78°, 31.66°]
    - [31.66°, 40°]
- Cuts over the number of charged particles:
  - N_{ch} divided in intervals that reproduce the energy of 10 PeV, 100 PeV and 1 EeV using a lineal relation.
  - The charged particle range is subdivided depending on the zenith angle
- Cuts over the trigger.
  - All the stations in the cluster detects particles.
- Maximum detector efficiency.

$$2.252 \times 10^5\, m^2$$

¡Reducing the systematic error!

Hadronic interaction model tests



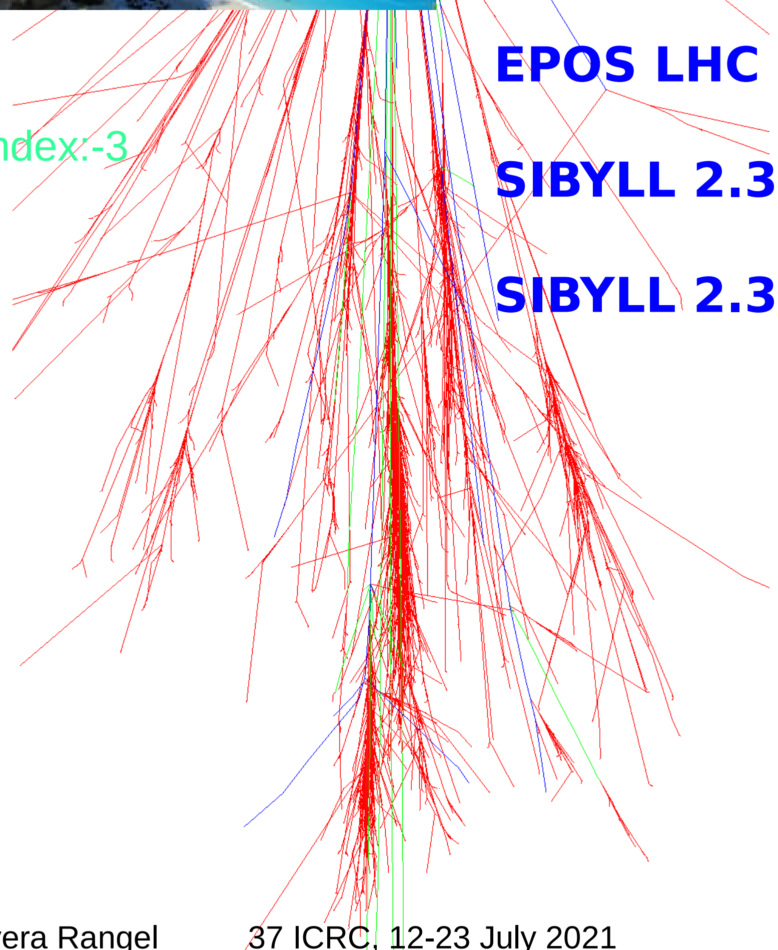
- The experimental results are compared with the predictions of the models for H and Fe primaries.

Monte Carlo simulation

CORSIKA v 7.5
EAS simulation

GEANT 4
Detector simulation

Spectrum index: -2
Reweight to simulate spectral index:-3

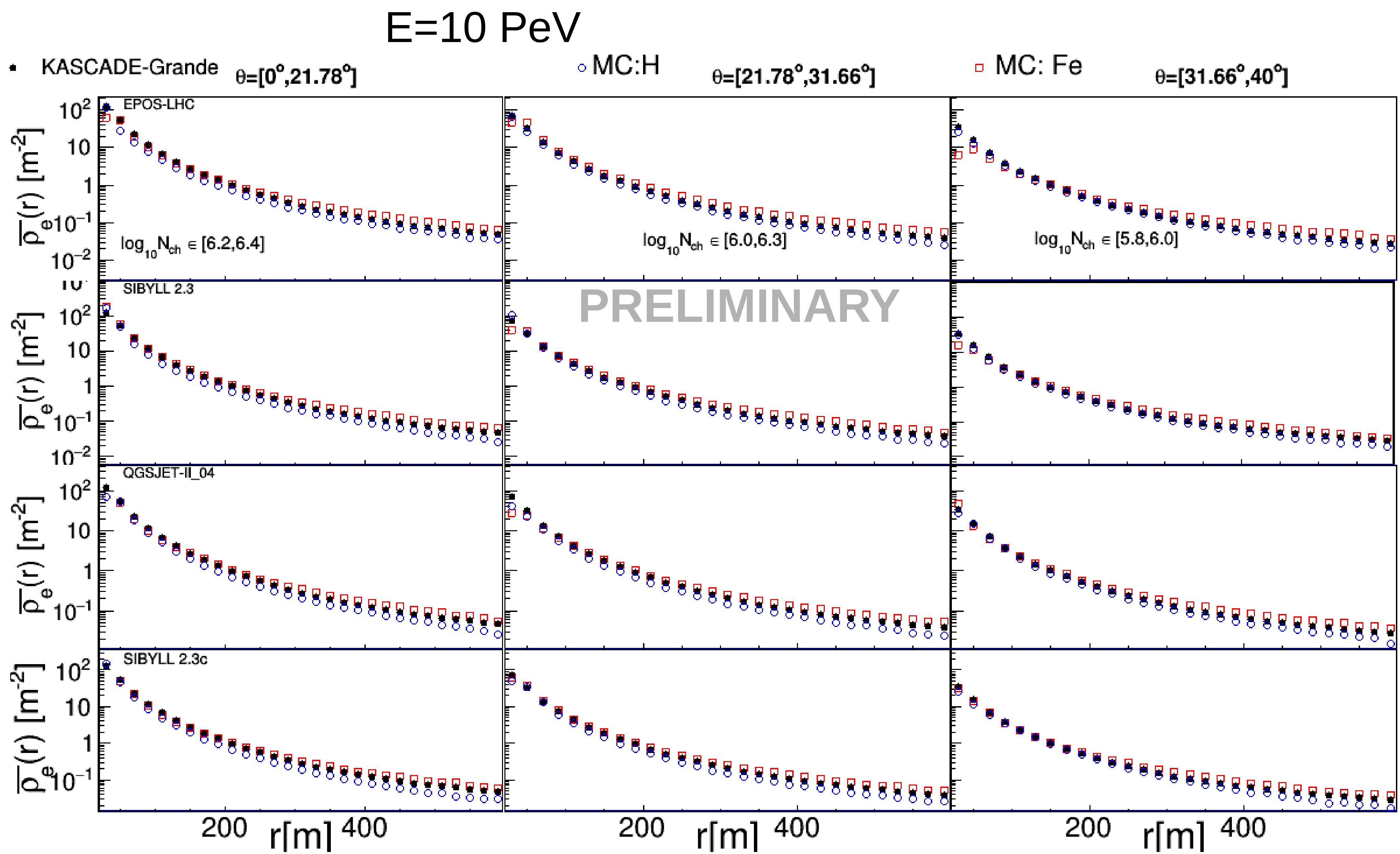


Low Energies $E_h < 200\,GeV$
FLUKA

High Energies
POST-LHC
QGSJET-II-04
EPOS LHC
SIBYLL 2.3
SIBYLL 2.3c

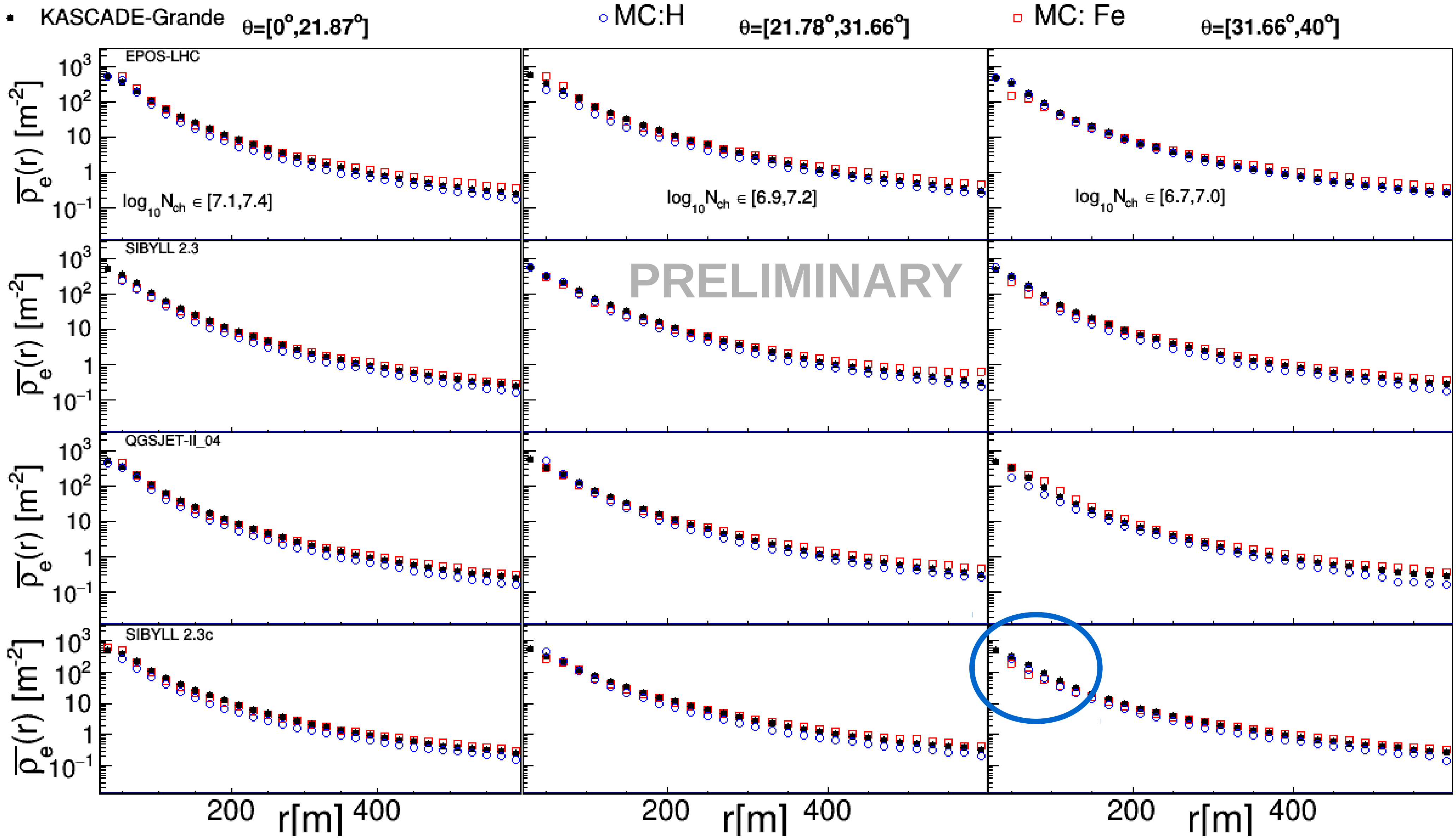
- Calibrated with LHC data.
- A bigger number of muons than the prediction of QGSJET-II-02 is generated.
- No-lineal and nuclear effects are considered.

Results: Electron density data

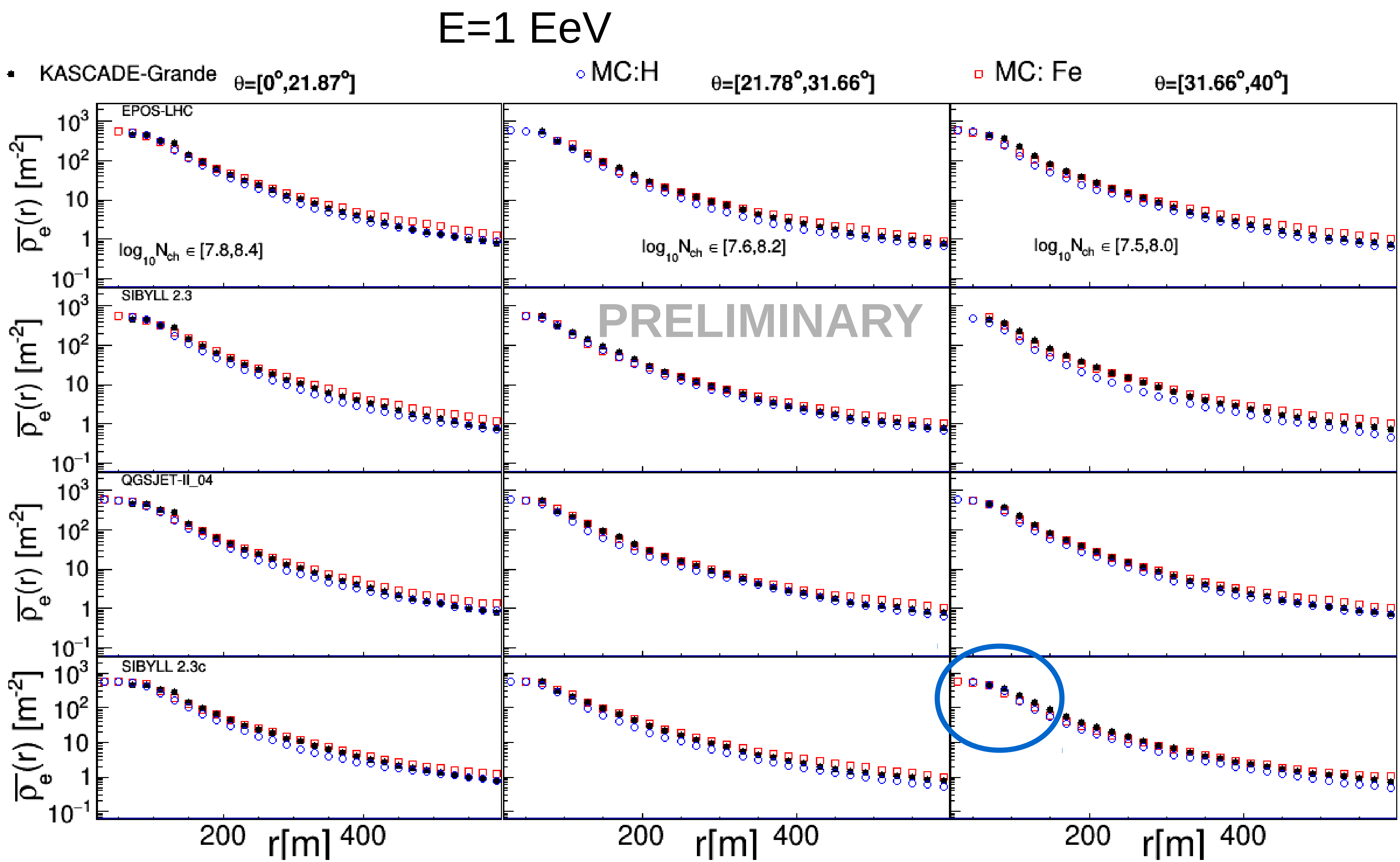


Results: Electron density data

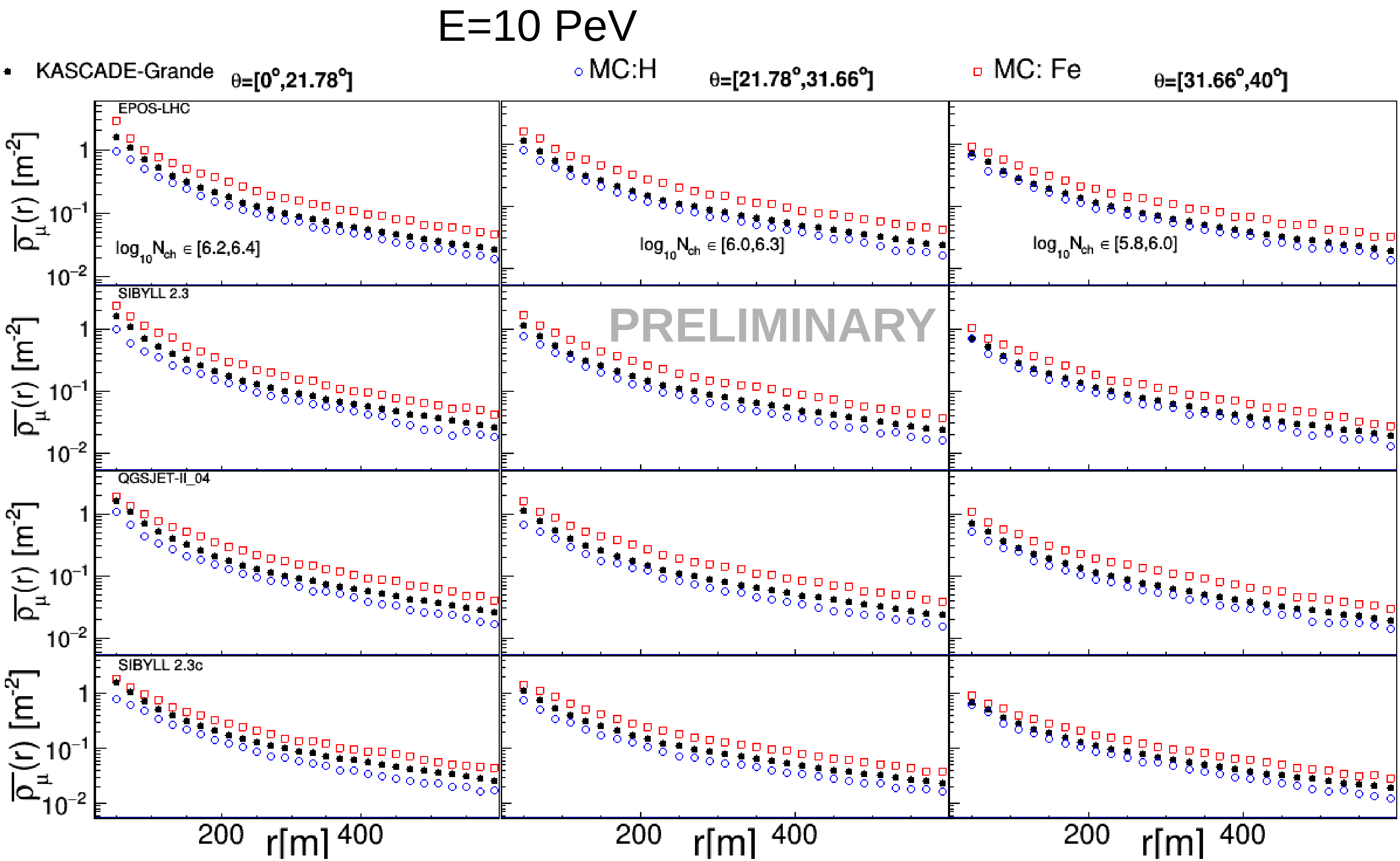
E=100 PeV



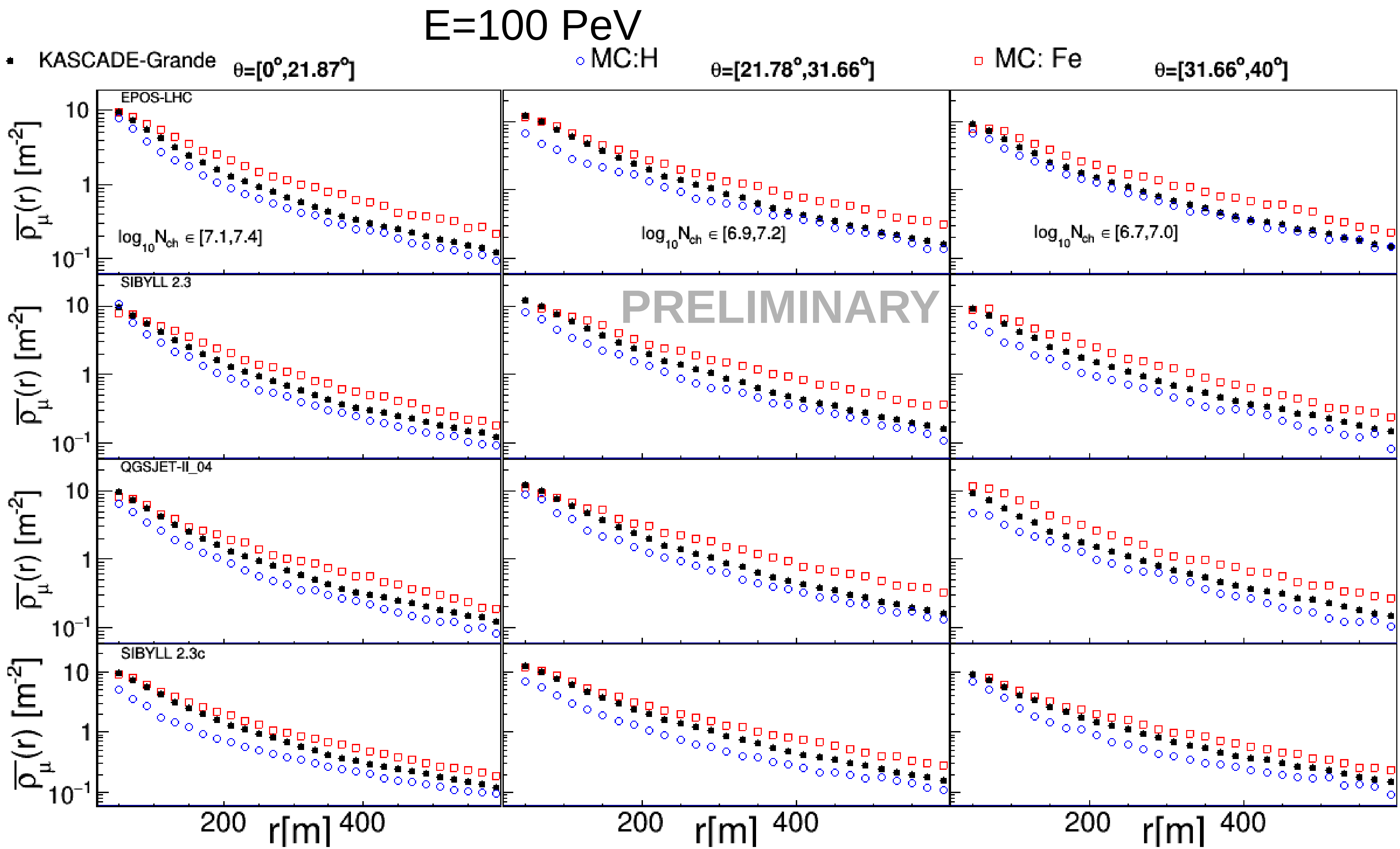
Results: Electron density data



Results: Muon density data

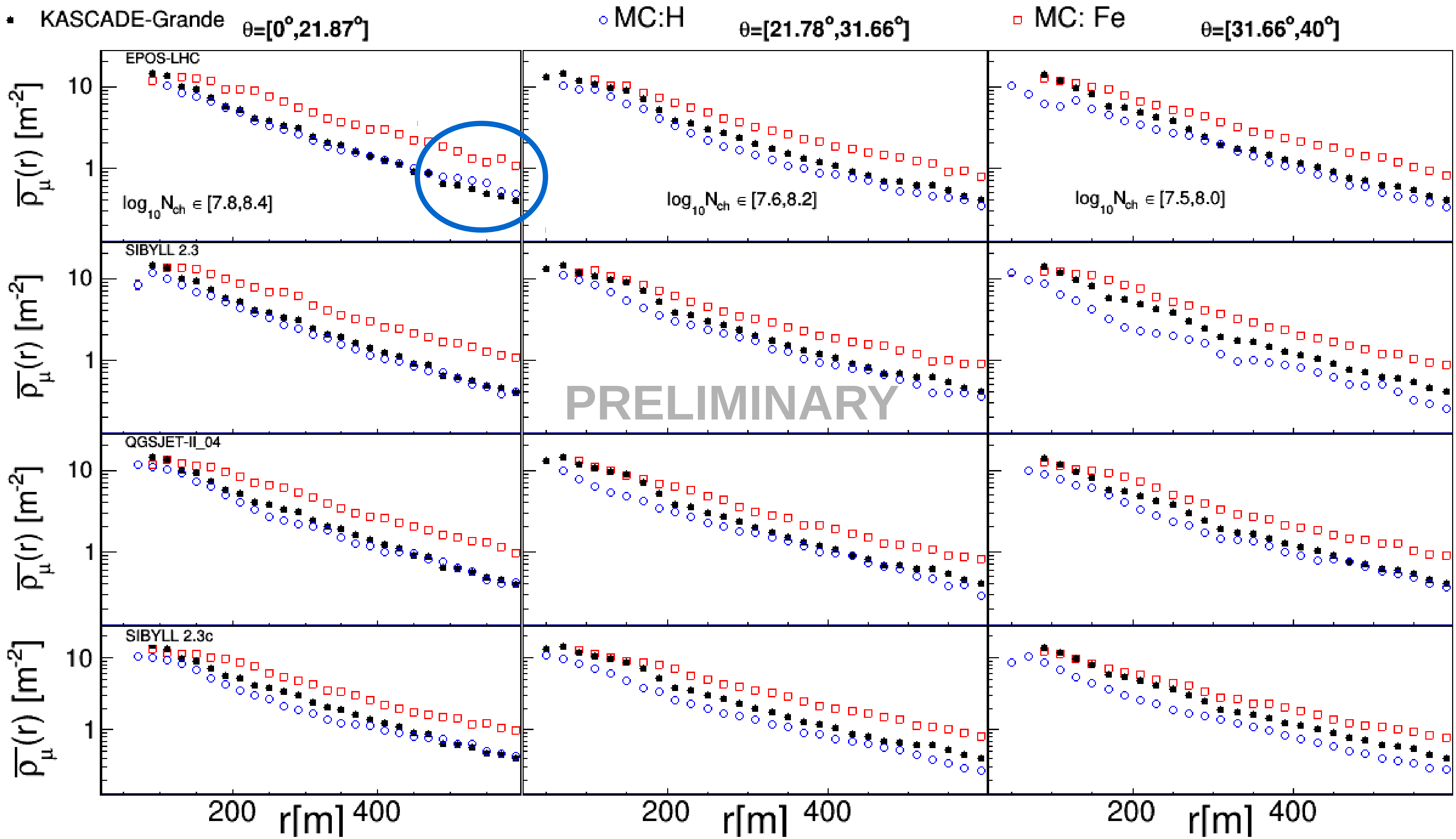


Results: Muon density data



Results: Muon density data

E= 1 EeV



Conclusions and final remarks

- ρ_e seems to be well described by the hadronic interaction models for E=10 PeV-1 EeV. However, SIBYLL 2.3 c shows a slight difference with the data in the region of $E \geqslant 100$ PeV and r < 200 m for the most inclined showers.
- On the other hand ρ_μ shows discrepancies between data and the predictions.
- Muon densities are steeper than the predictions from the hadronic interaction models above 100 PeV.
- For vertical EAS, EPOS-LHC seems to produce more muons than observed in data for r > 500 m.
- In addition, EPOS-LHC, QGSJET-II-04, SIBYLL 2.3 and SIBYLL 2.3 c do not describe the zenith angle evolution of the muon measurements: the cosmic ray composition seems to be heavier at large zenith angles.