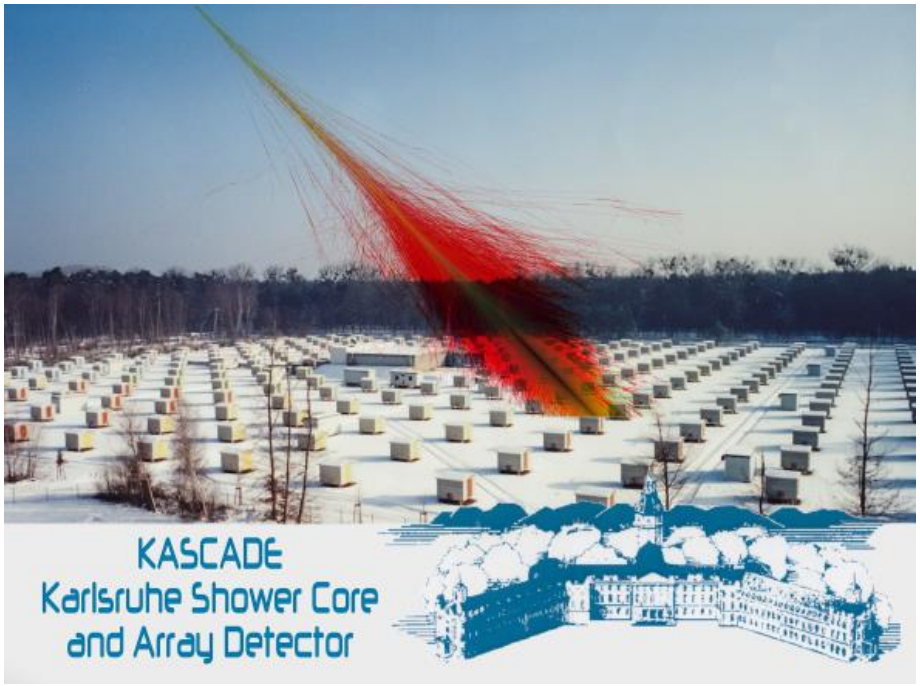
Latest Results from KASCADE-Grande

Donghwa Kang and Andreas Haungs*
for the KASCADE-Grande Collaboration

***speaker**
PoS (ICRC2019) 306

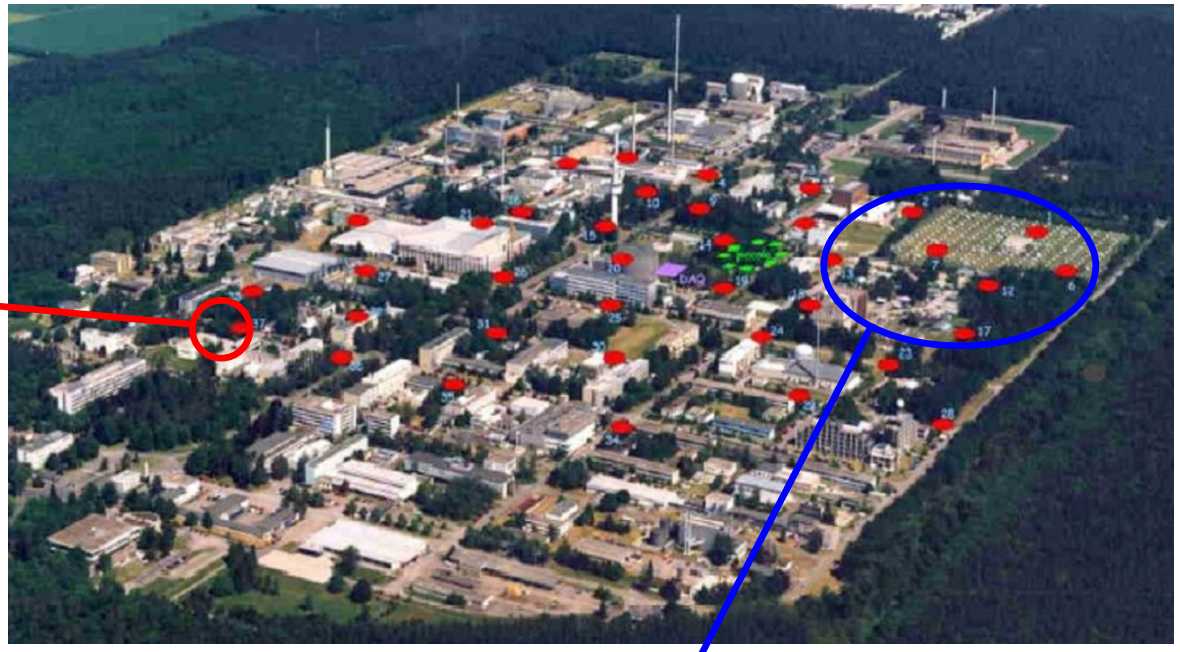


36th ICRC
July 24th – August 1st 2019
Madison, WI, U.S.A.

Karlsruhe Institute of Technology

KArlsruhe Shower Core and Array DEtector + Grande

- 10 PeV – 1 EeV
- 0.5 km^2
- 37 stations (each 10 m^2)

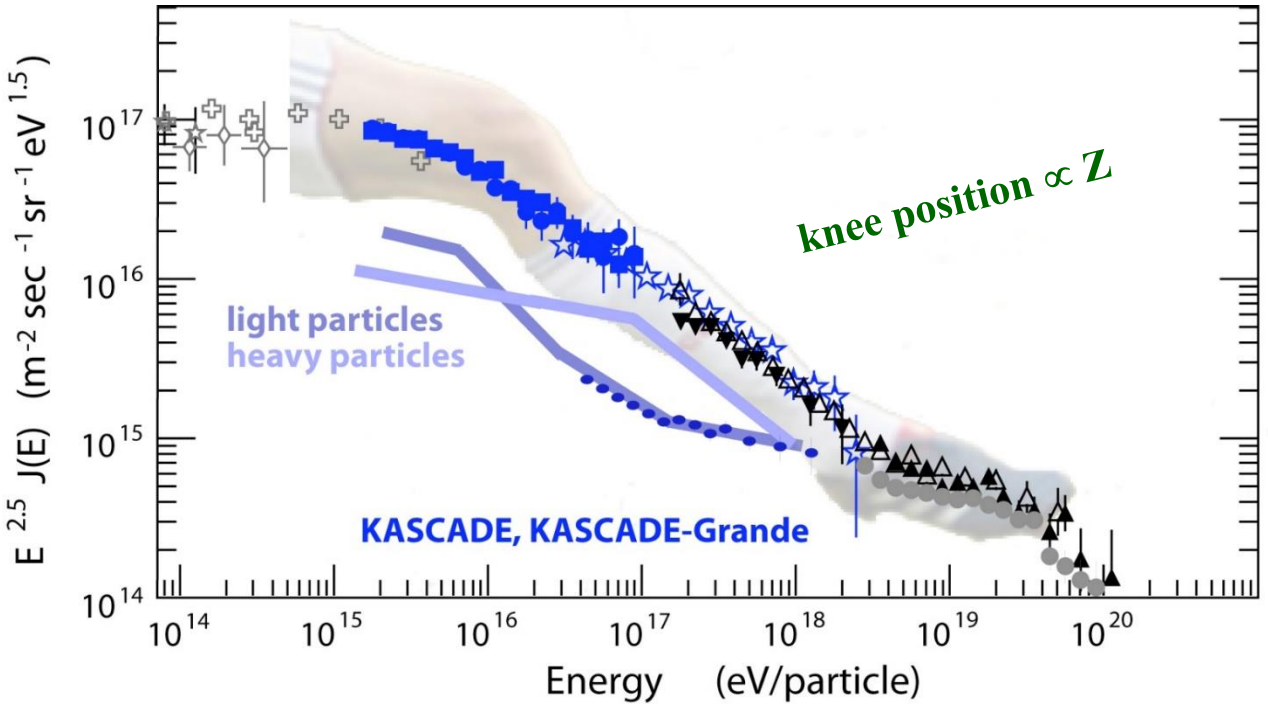


completed data acquisition at the end of 2013

The data from more than 20 years of measurements are now available for public use

- 100TeV – 80PeV
- 252 scintillation detector stations
- Large number of observables

KASCADE-Grande: energy spectra of single mass groups



- ➔ **KASCADE: knee of light primaries at ~3·10^{15}eV (He-dominant)**
- ➔ **Hardening at 10^{16}eV due to knee of medium primaries**
- ➔ **KASCADE-Grande: knee of heavy primaries at ~9·10^{16} eV**
- ➔ **heavy knee less distinct compared to light knee**
- ➔ **mixed composition for 10^{15} to ~ 8·10^{17} eV**
- ➔ **light ankle at 1-2·10^{17} eV**
- ➔ **composition (relative abundancies) hadronic model dependent**

Validity Tests of the Hadronic Interaction Model SIBYLL 2.3c Based on Shower Size

[D. Kang]

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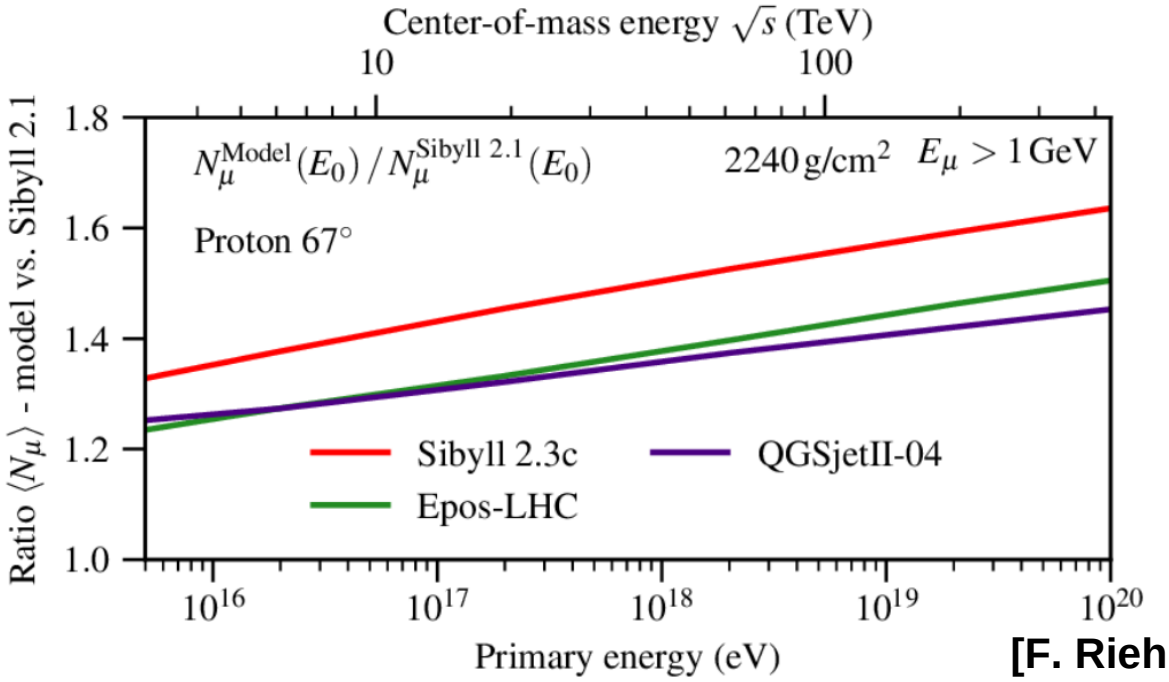
SIBYLL 2.3c

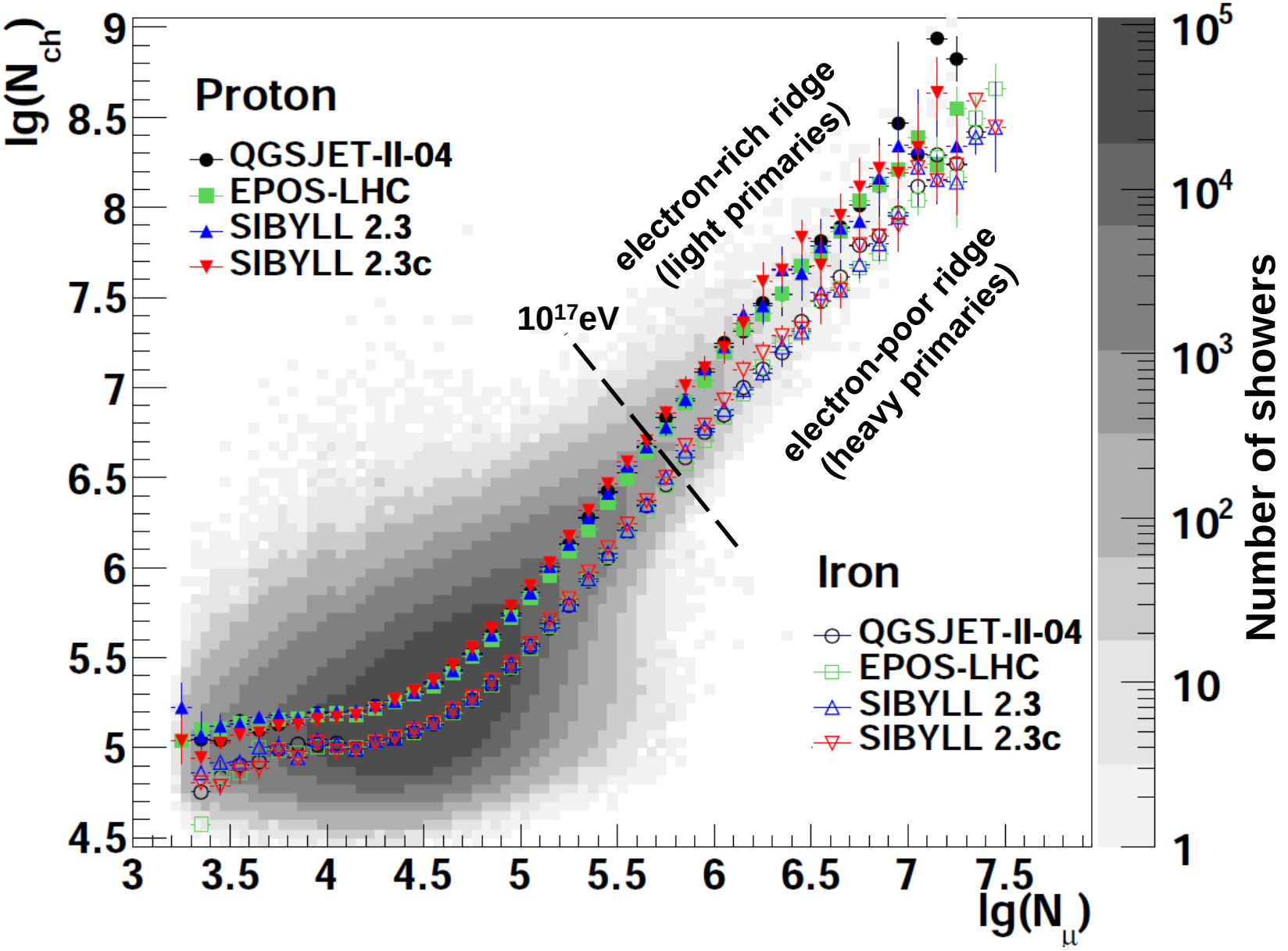
The latest version of SIBYLL, SIBYLL 2.3c, is developed by improving the model version 2.3 to obtain a better description of NA49 data



[F. Riehn et al., ICRC 2017]

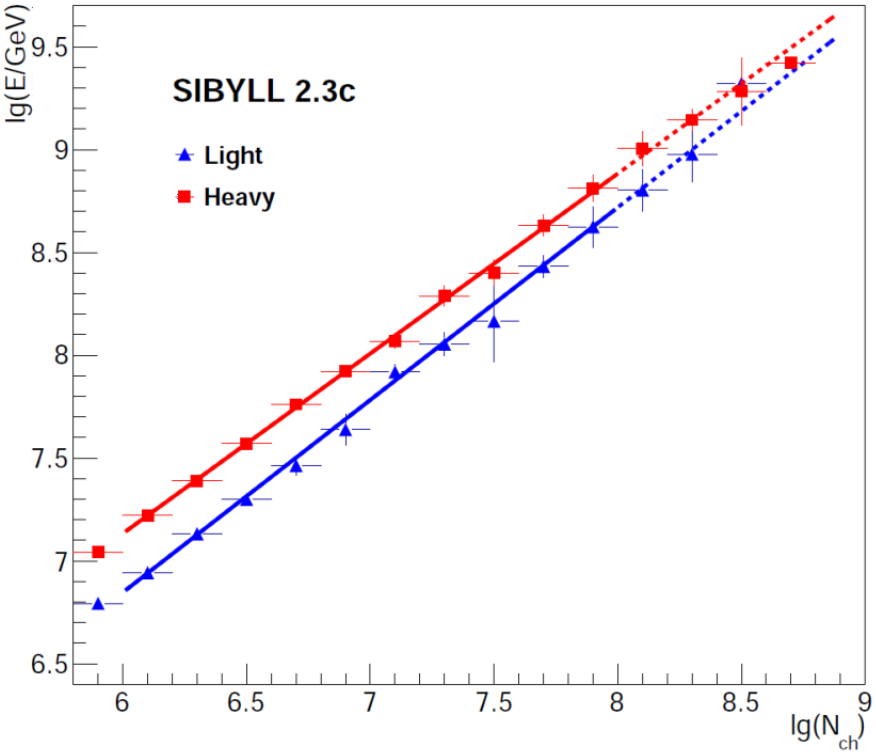
Prediction for extensive air showers:

- **Similar to SIBYLL 2.3**
- **~ 20 g/cm^2 deeper X_{max}**
- **~ 50% more muons (all ground, E > 1GeV)**

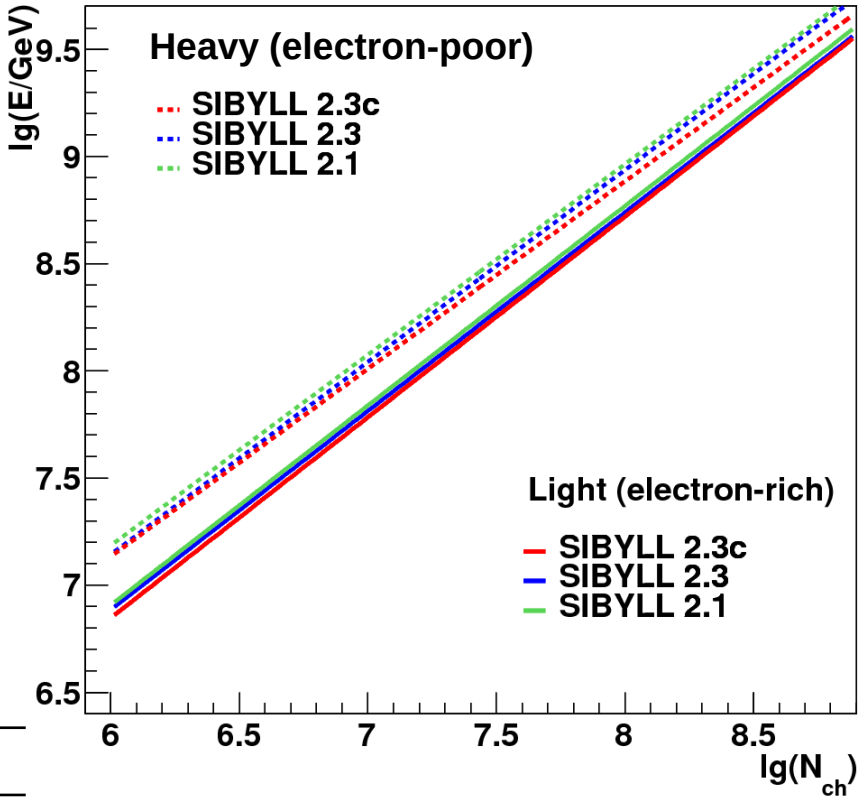


2-dim. shower size spectrum, along with proton and iron induced showers for QGSJET-II-04, EPOS-LHC, SIBYLL 2.3 and SIBYLL 2.3c simulations

Energy Calibration



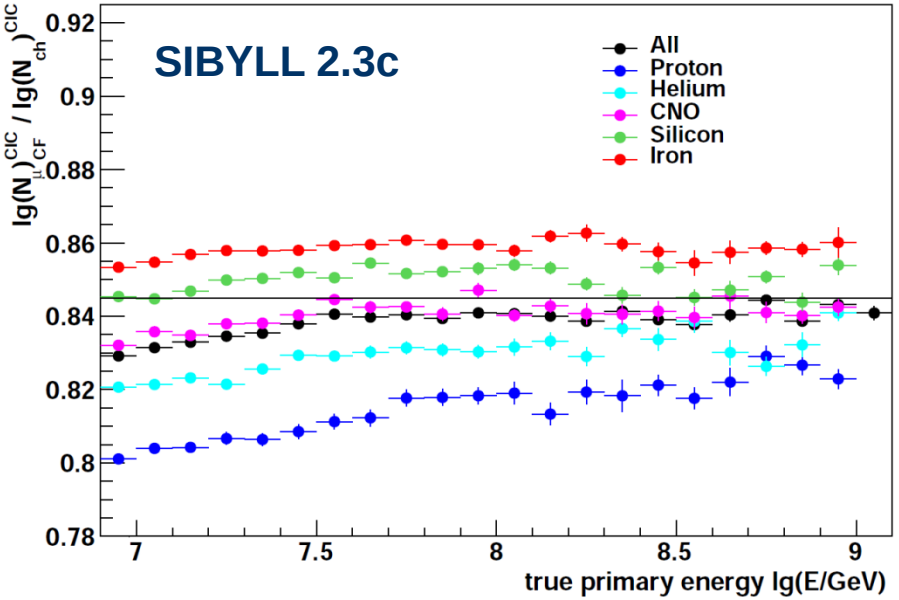
For same shower size SIBYLL 2.3c predicts slightly lower energy



Fit: $\log_{10}E_{true} = p0 \cdot \log_{10}N_{ch} + p1$

	HEAVY		LIGHT	
	p0	p1	p0	p1
SIBYLL 2.3c	0.875	1.883	0.936	1.229
SIBYLL 2.3	0.897	1.764	0.927	1.321
SIBYLL 2.1	0.890	1.847	0.931	1.321

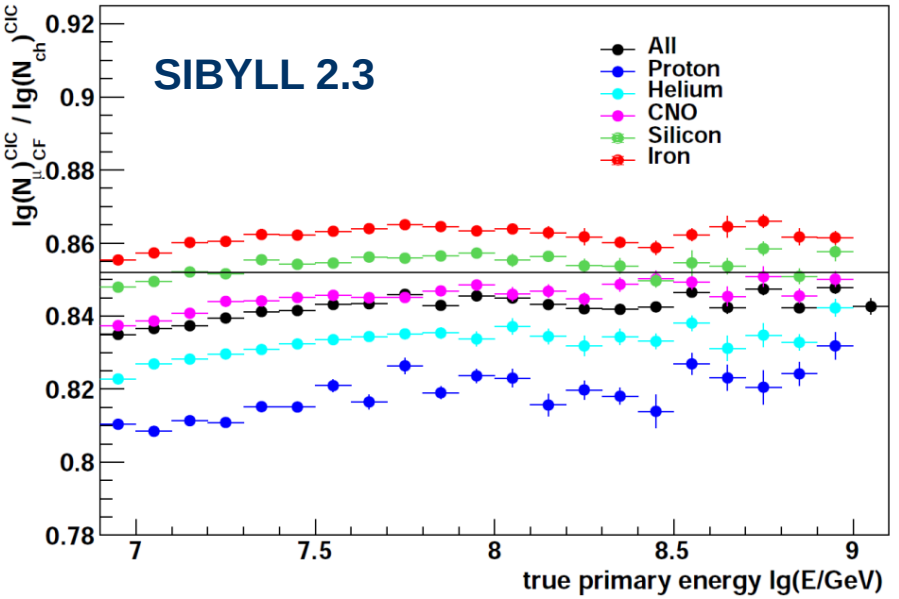
Selecting Primary Mass Group

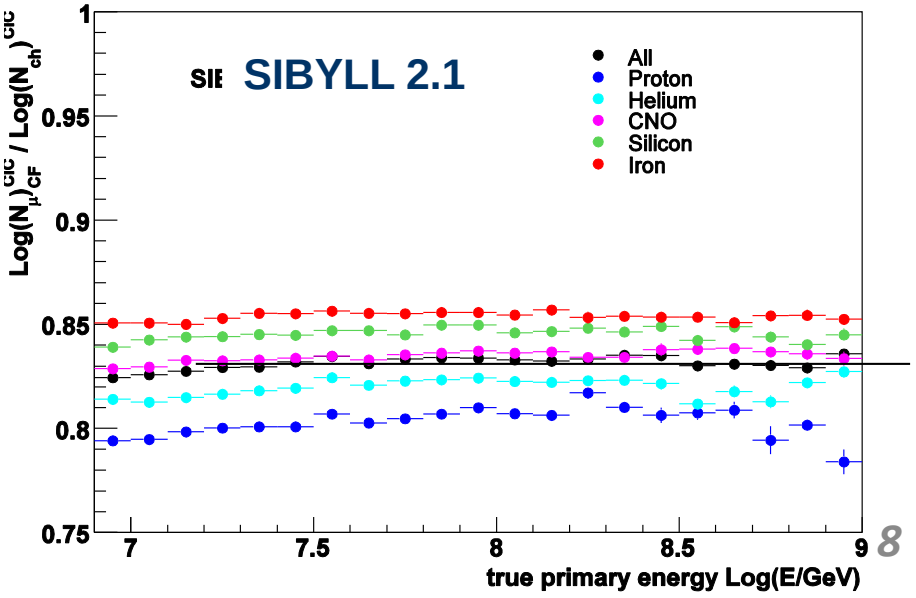


For same true energy SIBYLL 2.3c reconstructs a lighter mass

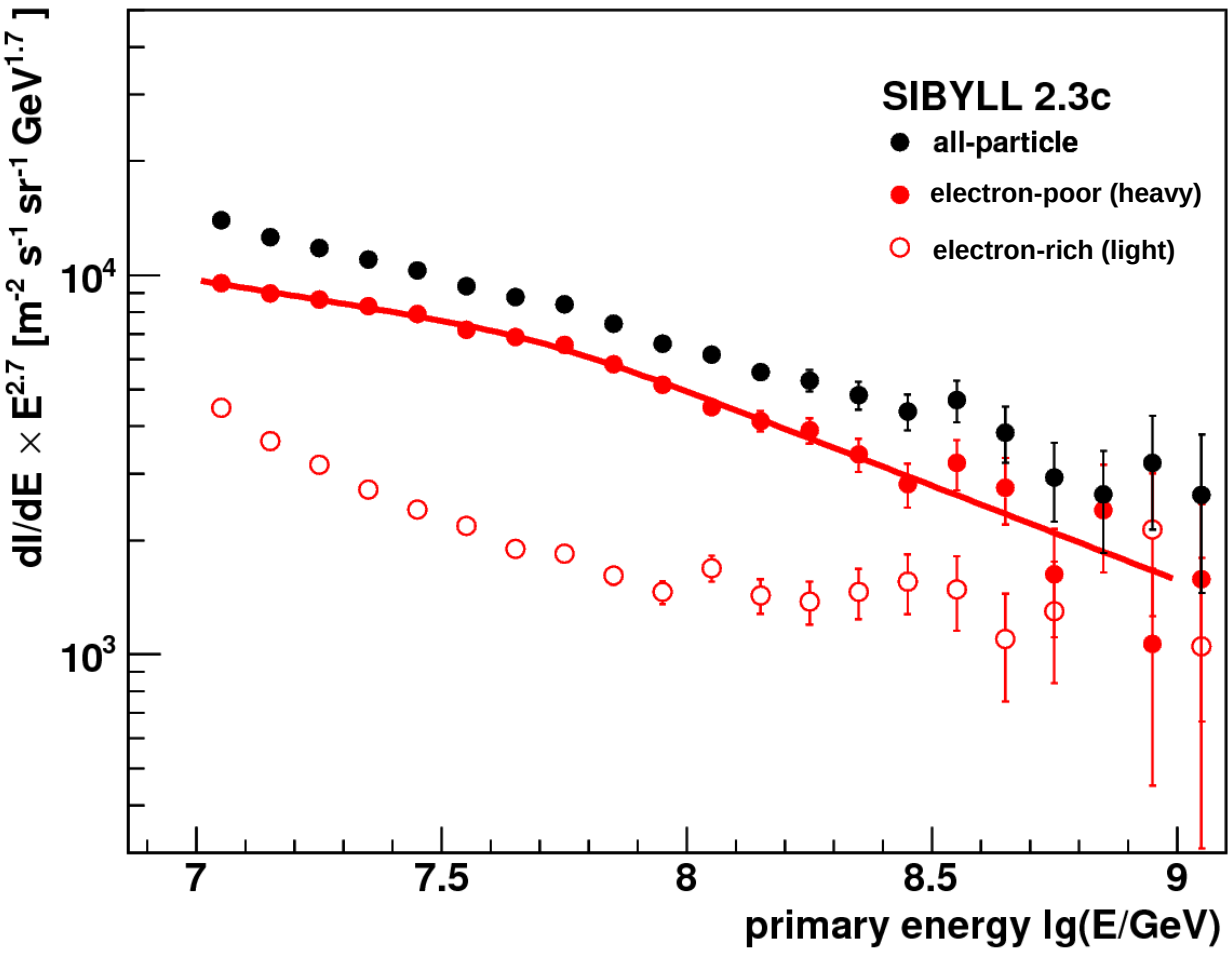
$$Y_{CIC} = lg(N_{\mu,CF})^{CIC} / lg(N_{ch})^{CIC}$$

	Y_{CIC}
SIBYLL 2.3c	0.845
SIBYLL 2.3	0.852
SIBYLL 2.1	0.840



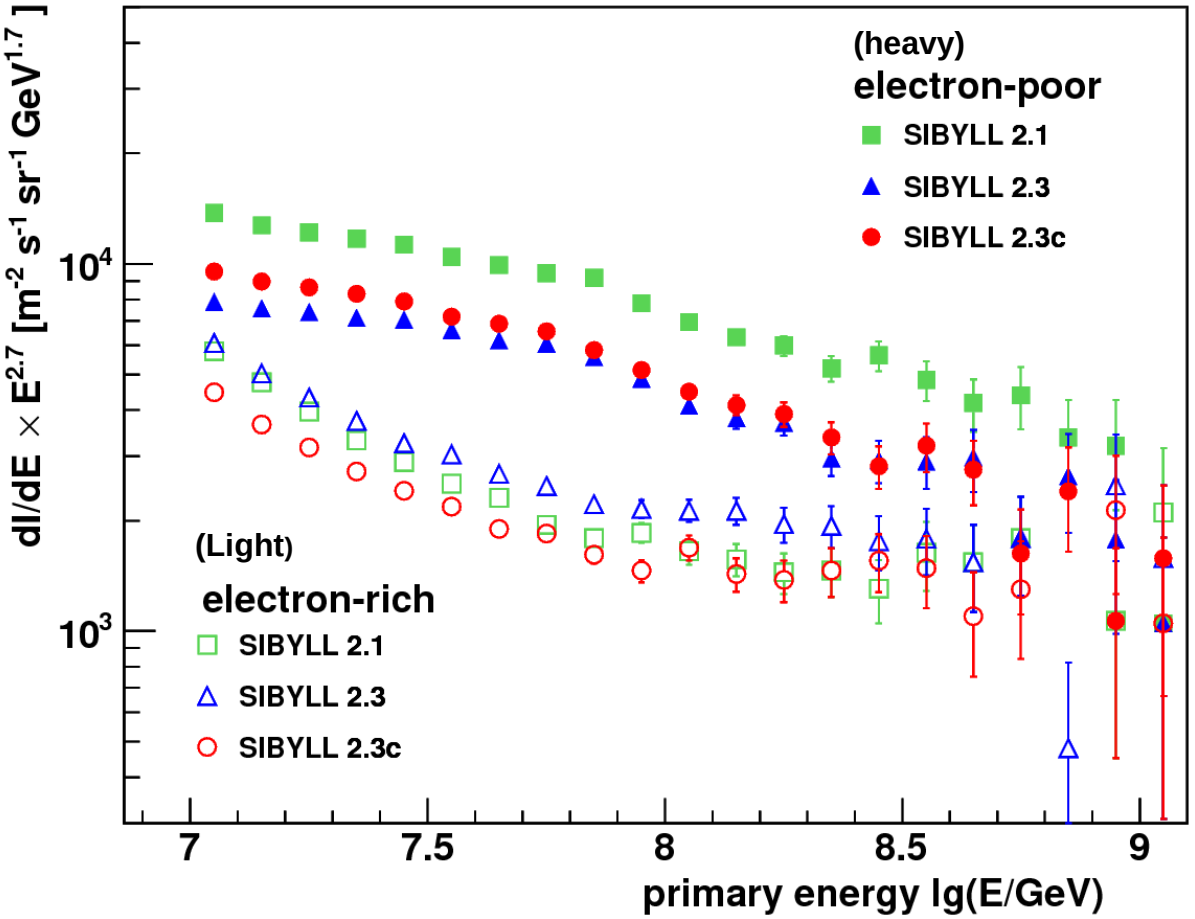


Spectra of Individual Mass Groups



- Knee-like structure of heavy primaries below 10^{17} eV
- Hardening of light primaries is significant
- Estimation of systematic uncertainties is ongoing (expected to be about the order of 20%)

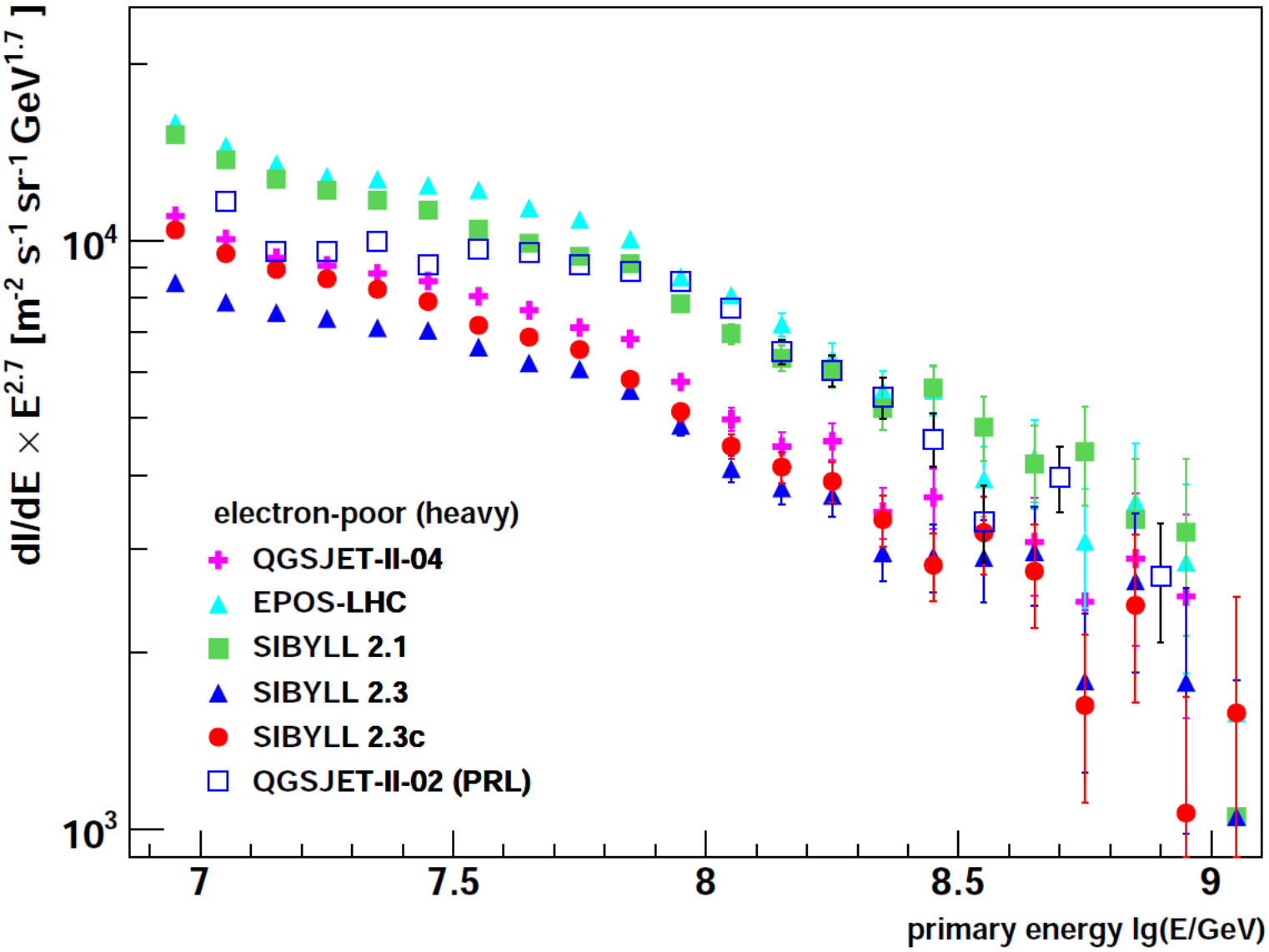
Spectra of Individual Mass Groups



- **Difference between light and heavy primaries is large for SIBYLL 2.3c**
- **Knee-like structure of heavy primaries and hardening of light primaries are similar**
- **Fit:**

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

electron-poor	lg(E_k/GeV)	γ_1	γ_2	$\Delta\gamma$	χ^2/ndf
SIBYLL 2.1	7.75 ± 0.09	2.87 ± 0.03	3.15 ± 0.05	0.28	1.28
SIBYLL 2.3	7.71 ± 0.05	2.83 ± 0.01	3.18 ± 0.05	0.35	0.96
SIBYLL 2.3c	7.71 ± 0.05	2.89 ± 0.01	3.18 ± 0.04	0.29	1.05


dI/dE × E^2.7 [m^-2 s^-1 sr^-1 GeV^1.7]
10^4
10^3
7
7.5
8
8.5
9
primary energy lg(E/GeV)
electron-poor (heavy)
QGSJET-II-04
EPOS-LHC
SIBYLL 2.1
SIBYLL 2.3
SIBYLL 2.3c
QGSJET-II-02 (PRL)

Muon Contents in Air Showers between 10 PeV and 1 EeV Determined from Measurements with KASCADE-Grande

[J.C. Arteaga-Velazquez]

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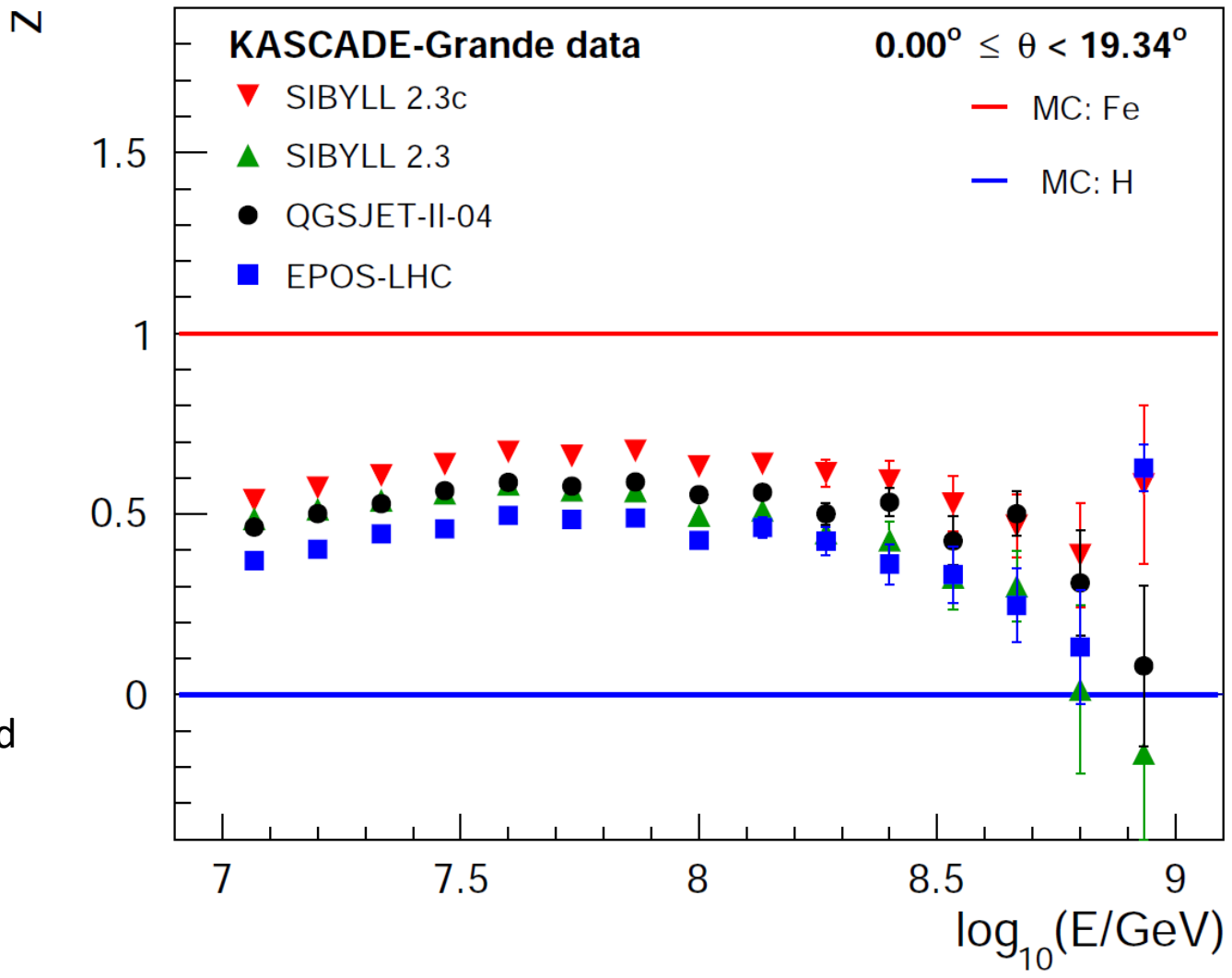
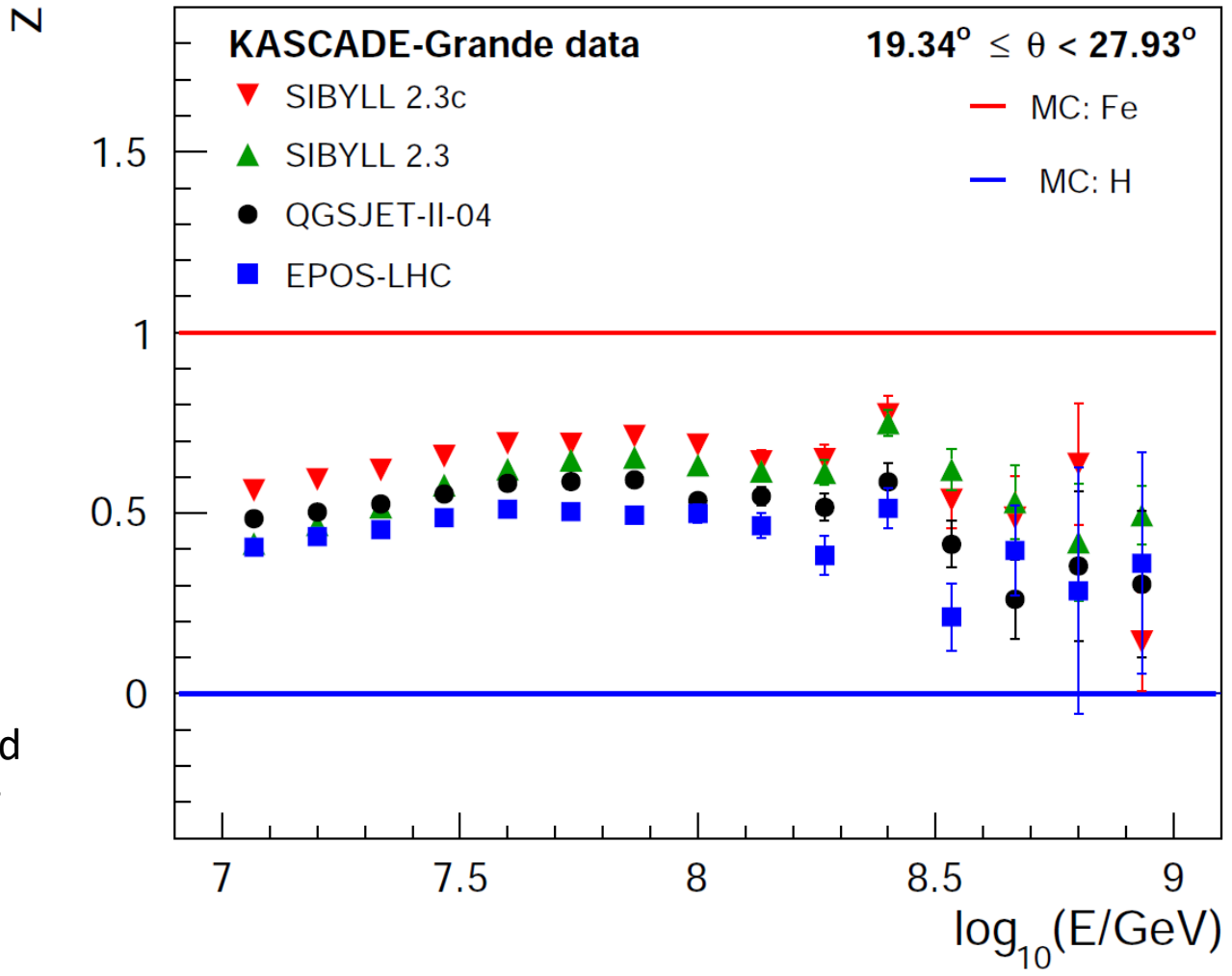
PS3-138



Systematic error band for all models similar (see PS3-138)

Comparison of model predictions and measured data, via the z-scale:

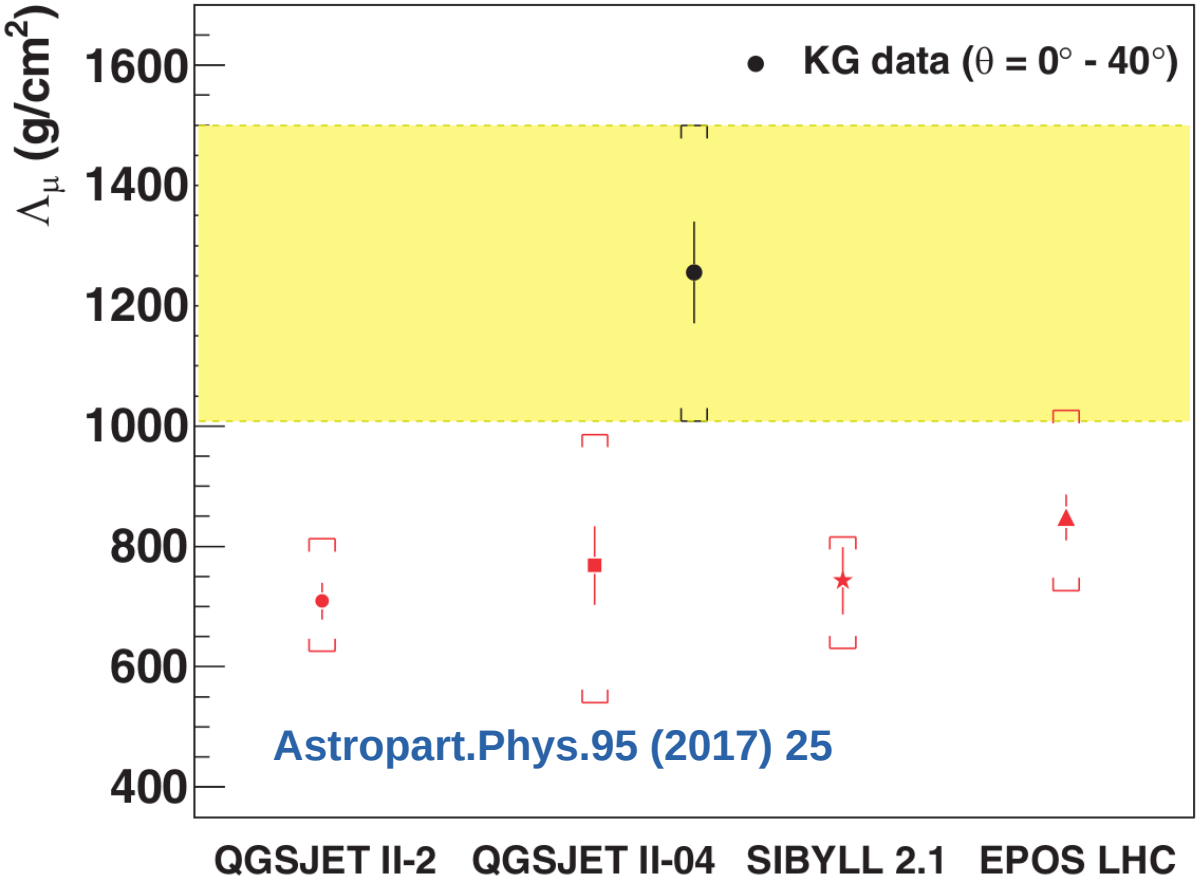
$$Z = \frac{\ln(N_{\mu,det}) - \ln(N_{\mu,p})}{\ln(N_{\mu,Fe}) - \ln(N_{\mu,p})}$$



Systematic error band for all models similar (see PS3-138)

- **The evolution of the mass composition shows a similar behaviour in all cases: a heavier mean mass at 100 PeV to lighter at 1 EeV**
- **An inconsistency with zenith angle is visible and increases with higher energy**
- **These muon studies are foreseen to be addressed in the working group report on the combined analysis of muon density measurements**

Muon Attenuation Length



Attenuation length measured is different from the predictions of Monte Carlo

→ Observed evolution of the muon content of EAS in the atmosphere is not described by the hadronic interaction models

→ Effects absolute energy and mass scale, but not spectral features

Search for Large-scale Anisotropy in the Arrival Direction of Cosmic Rays with KASCADE-Grande

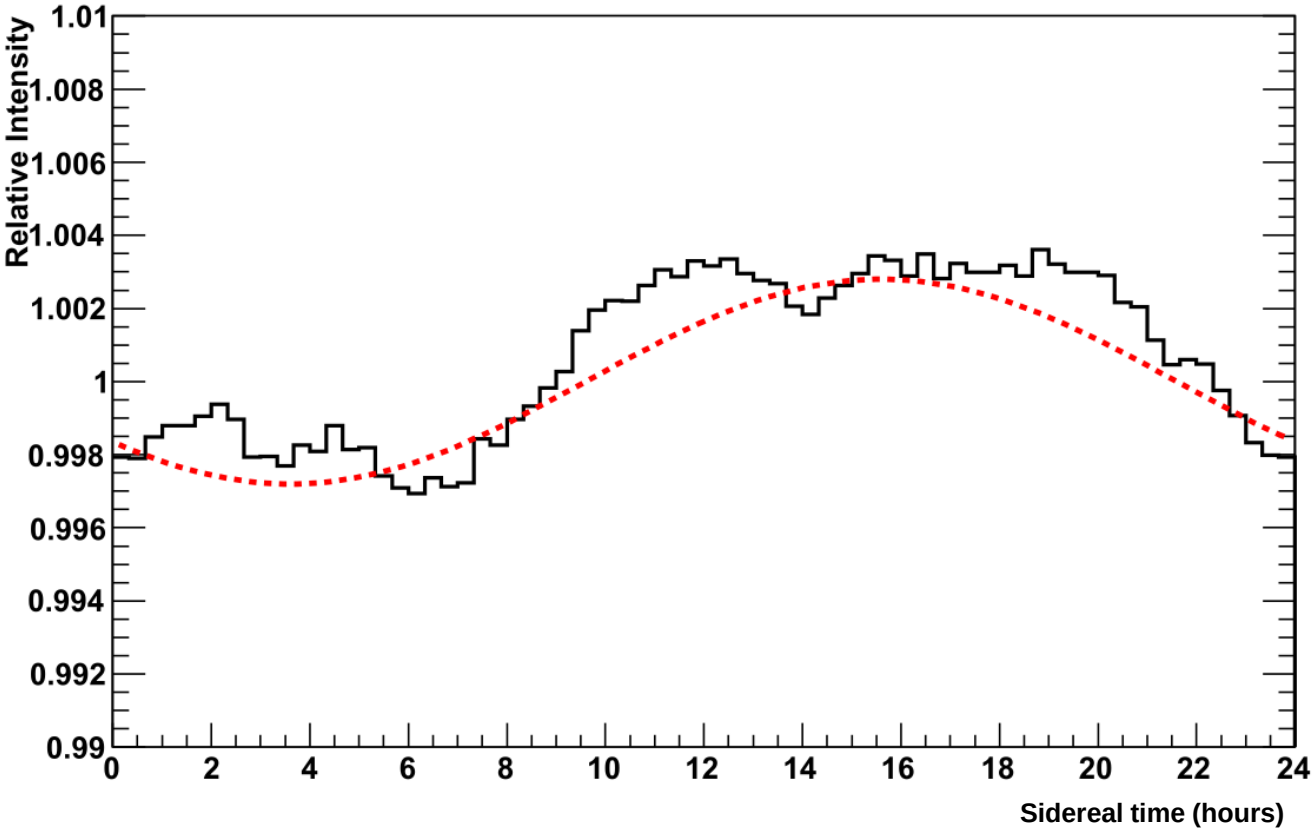
[A. Chiavassa]

ApJ 870 (2019) 91

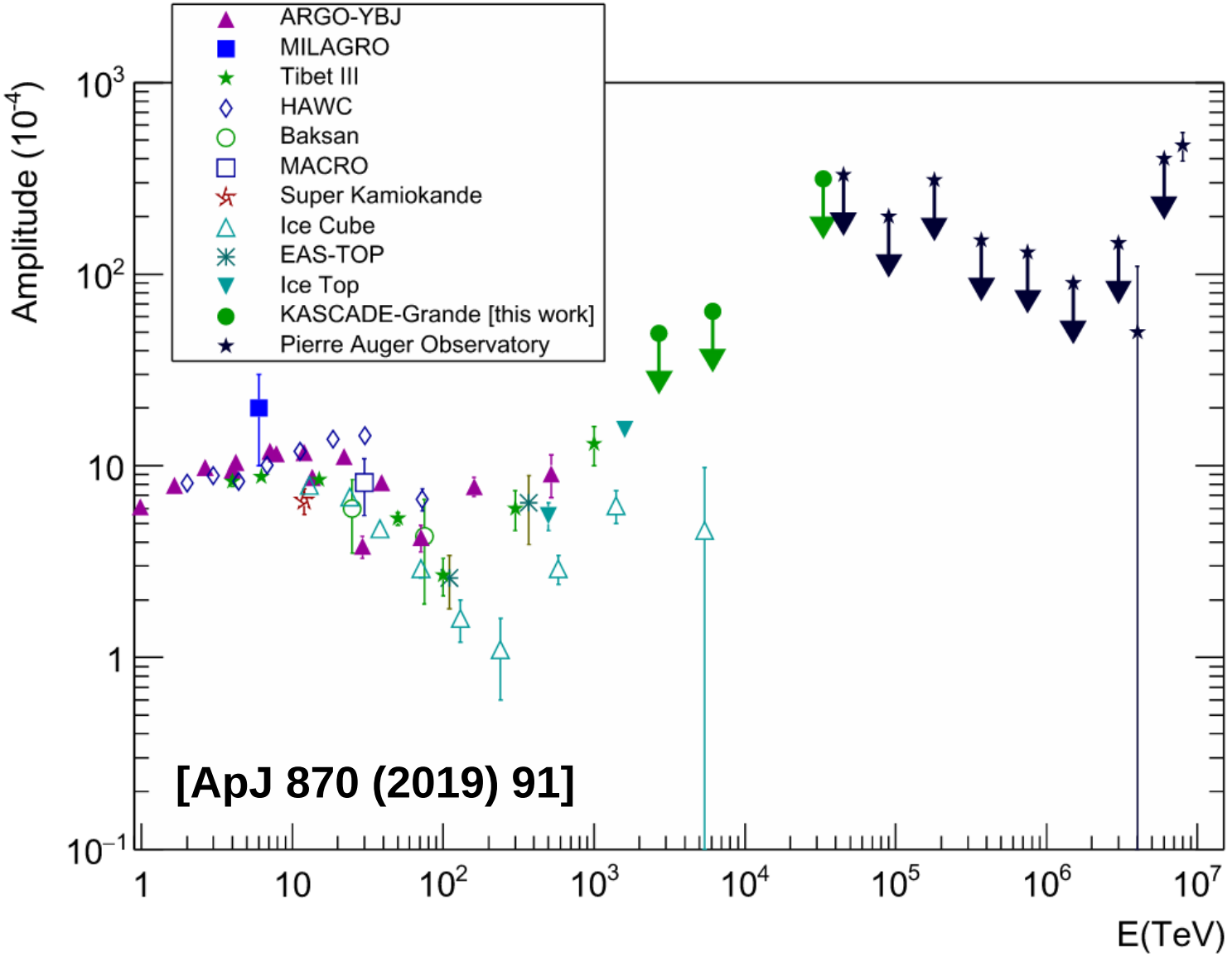
East-West method: allows to remove counting rate variations due to atmospheric and instrumental effects

Data from December 2003 to October 2011 (10^7 events)

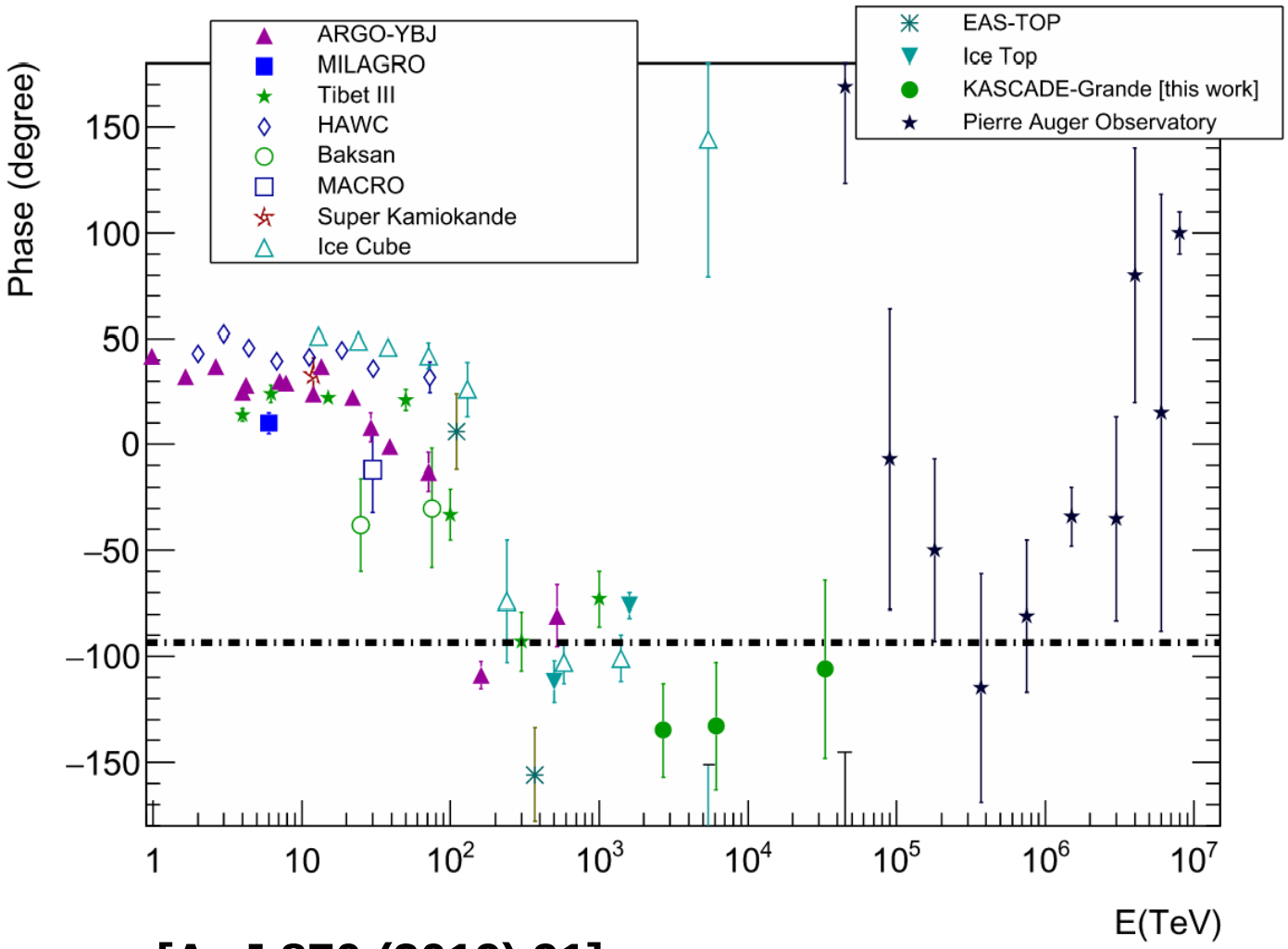
- **$\theta < 40°$**
- **$\log_{10}(Nch) > 5.2$**



- **Sidereal time variation of the number of counts obtained, in 20 minutes intervals, by applying the East-West method**
- **First harmonic fit → amplitude and phase values**



- **Significance of the amplitude of the first harmonic is 3.5 sigma**
- **Upper limits to the amplitude of the first harmonic obtained by KASCADE-Grande: $A \leq 0.49 \times 10^{-2}$, $A \leq 0.64 \times 10^{-2}$, $A \leq 3.15 \times 10^{-2}$**



[ApJ 870 (2019) 91]

Comparison of the first harmonic phase measured by KASCADE-Grande with other experimental results

This supports the hypothesis of a change of the phase of the first harmonic at energies greater than ~2×10^{14} eV

KASCADE Cosmic ray Data Centre

https://kcdc.ikp.kit.edu/

[A. Haungs et al.]

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PS1-170

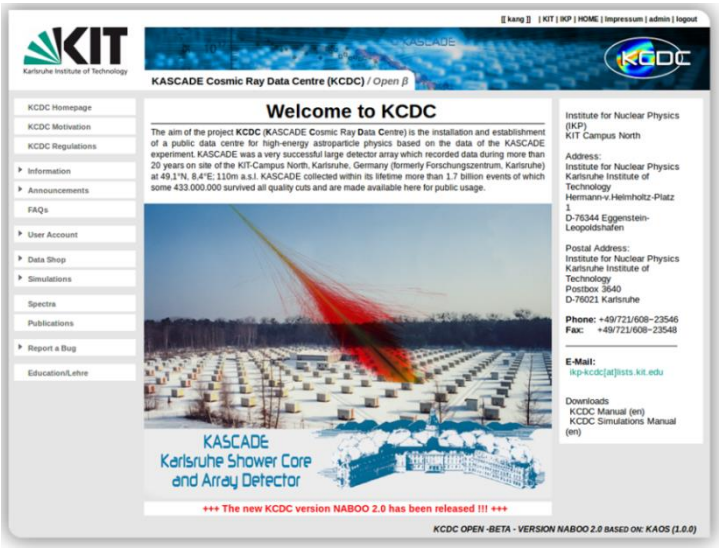
KCDC

- **KCDC (KASCADE Cosmic ray Data Centre)**
  = publishing research data
  from the KASCADE experiment

- **Motivation and Idea of Open Data:**
  - general public has to be able to access and use the data
  - the data has to be preserved for future generations

- **Web portal:**
  - provide a modern software solution
  - release the software as Open Source
  - educational examples

- **Data access:**
  - $4.3 \cdot 10^8$ EAS events
  - simulation data
  - energy spectra of other experiments



- **Pioneering work in publishing research data**

[Eur. Phys. J. C 78 (2018) 741]

[[kang]] | KIT | IKP | HOME | Impressum | admin | logout

Karlsruhe Institute of Technology

KASCADE

KASCADE Cosmic Ray Data Centre (KCDC) / *Open β*

- KCDC Homepage
- KCDC Motivation
- KCDC Regulations
- Information
- Announcements
- FAQs
- User Account
- Data Shop
- Simulations
- Spectra
- Publications
- Report a Bug
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Spectra Selection page

Select-Option 1: choose spectra by Digital Object Identifier (DOI)

DOI: Please, choose a DOI... Load

Select-Option 2: choose by detector (KASCADE, ...)

Detector: KASCADE-Grande Load

Choose format settings

In GeV: In Log10: Scale: 0

Changes will take effect only after clicking `Load`.

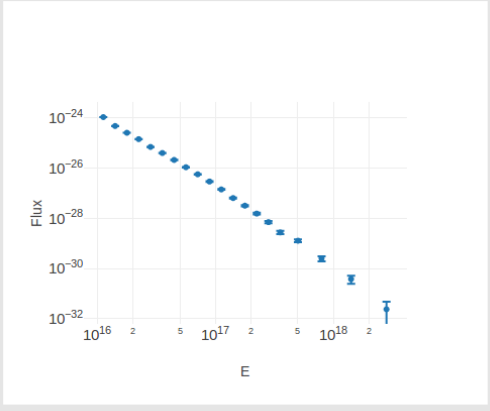
Spectra

To get spectra published with various cosmic ray detectors choose one of the 'Select-Options', choose the format and press the **'Load'** button.
A click inside the box where the papers are displayed will allow you to select the plots and download the data sets.
Besides the data sets from KASCADE and KASCADE-Grande you are offered a wide range of data collected with other detectors measuring the cosmic radiation in the energy range above 10^{14} eV.
A short table of spectra availabe can be found **here**

For details check the **KCDC Manual**

Detector	Journal	Issue	Year	Title
KASCADE-Grande	Proceedings of the 31st ICRC 2009	2009	2009	Cosmic ray energy spectrum based on shower size measurements of KASCADE-Grande
KASCADE-Grande	Thesis M.Finger	1	2011	Reconstruction of energy spectra for different mass groups of high-energy cosmic rays
KASCADE-Grande	Physical Review Letters	107	2011	Kneelike Structure in the Spectrum of the Heavy Component of Cosmic Rays Observed with KASCADE-Grande
KASCADE-Grande	Phsical Review D	87	2013	Ankle-like feature in the energy spectrum of light elements of cosmic rays observed with KASCADE-Grande
KASCADE-Grande	Proceedings of the 34th ICRC	2015	2015	KASCADE-Grande energy spectrum of cosmic rays interpreted with post-LHC hadronic interaction models
KASCADE-Grande	Proceedings of the 35th ICRC	2017	2017	Measurements of the muon content of EAS in KASCADE-Grande compared with SIBYLL 2.3 predictions

Spectrum	Show	Save
KG_QGSjet-II-03_heavy	Show Data	Download Data
KG_QGSjet-II-03_light	Show Data	Download Data
KG_QGSjet-II-03_all	Show Data	Download Data



KCDC OPEN -BETA - VERSION NABOO 2.1 BASED ON: KAOS (1.0.0)

98 published energy spectra of other experiments!

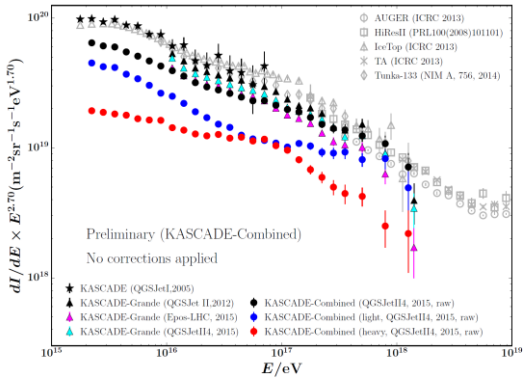
Summary

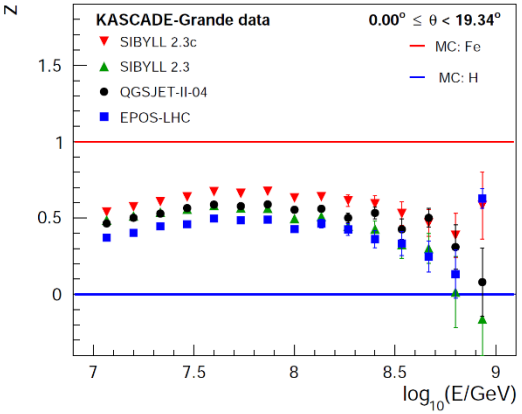
- **Validity test of the hadronic interaction model SIBYLL 2.3c: Total energy flux is slightly shifted**
  ➔ spectral features are stable

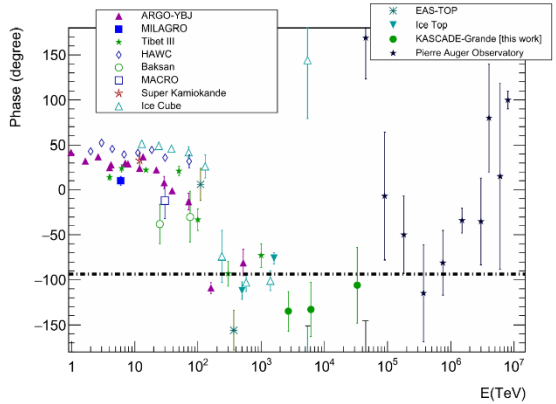
- **Test of the prediction on the shower muon content of the post-LHC hadronic interaction models**
  ➔ model variations, problem already at 10^{16} eV

- **Search for large-scale anisotropies in the arrival directions at energies higher than 10^{15} eV**
  ➔ confirm phase transition 10^{16} - 10^{17} eV

- **Pioneering work for open data of astroparticle physics (KCDC)**
  ➔ Towards a Global Data and Analysis Centre for Astroparticle Physics







➔ KASCADE-Grande is still contributing to cosmic-ray science

KASCADE KCDC Cosmic ray Data Centre