Bergische Universität Wuppertal

Calculation of atmospheric Neutrino- and Myonfluxes with respect to Cosmic Ray Composition

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Content

***Goal* /Motivation**: Determine atmospheric ν – and μ- fluxes.
-> Calibration / Background for μ- / ν- Telescopes using KASCADE-data

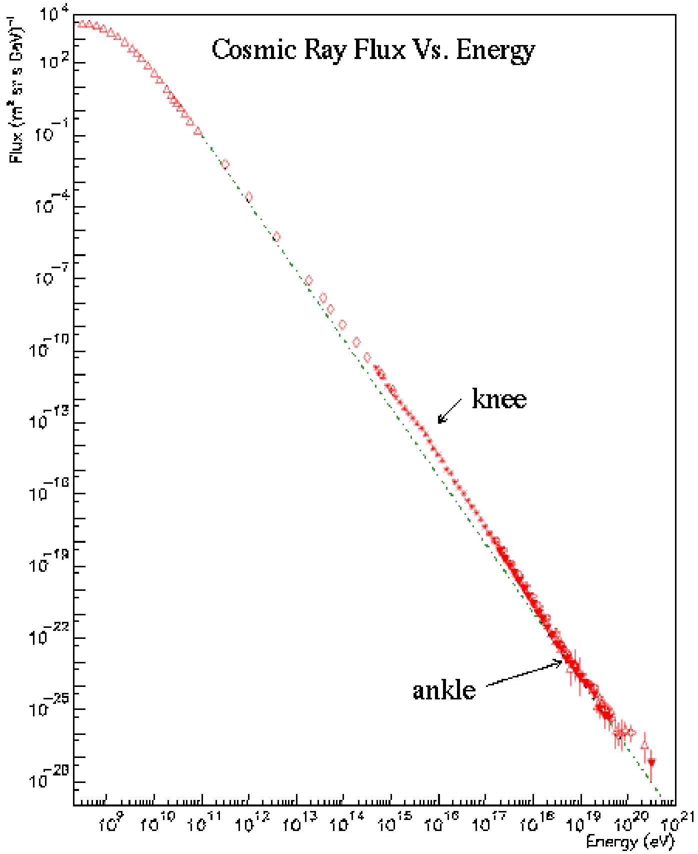
1. Basics
2. Input data / What I am doing
3. Unfolding based on QGSJet and SIBYLL
4. Fit strategy
5. Summary & Outlook

1. Basics

- Energy range of the knee ~ $4*10^{15}$eV
- γ_1 = 2,7 for E< $4*10^{15}$eV
- γ_2 = 3 for $4*10^{15}$ eV < E < $5*10^{18}$eV
- Further γ`s doesn`t play a role here

- $\frac{dJ}{dE} = c * E^{-\gamma}$, c = constant

(c is a „fluxparameter“)



- „Knee“ is a consequence of the „steepening“ of the spectra of light elements (evidence follows)

•Assumption : $E_{knee}(Z_X) = Z_X * E_{knee}(p)$

2. Input data

- KASCADE measures Electron- and Myonnumbers.
- $$X^{measured} = M * \frac{dJ^{true}}{dE}$$
- M includes propagation, properties of detectors…

- Data is unfolded by using two high energetic interaction models (QGSJet , SIBYLL)
-> see KASCADE paper in addition
- Models differ in their predictions about interactions.

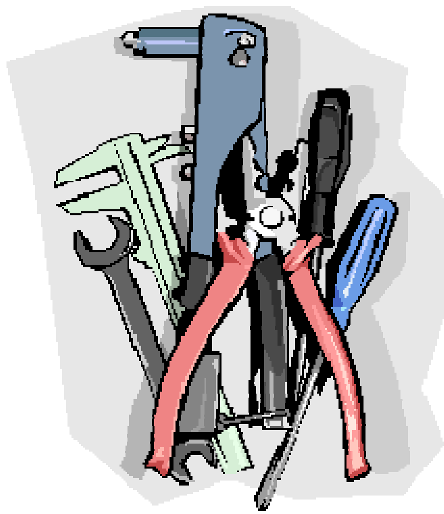
➡ Energy spectra for five representative mass groups (p, He , C, Si, Fe) are reconstructed.

- „Knee region“ is in energy window of KASCADE data.

2. What I am doing

• Spectra for each model have to be fitted „simultaneously" for all element groups.

• Results of the simultaneous fit provides eight parameters :
p_1 : Knee position
p_2 : Spectral index below the knee
p_3 : Spectral index above the knee
$p_4 - p_8$: Fluxparameter for each mass group



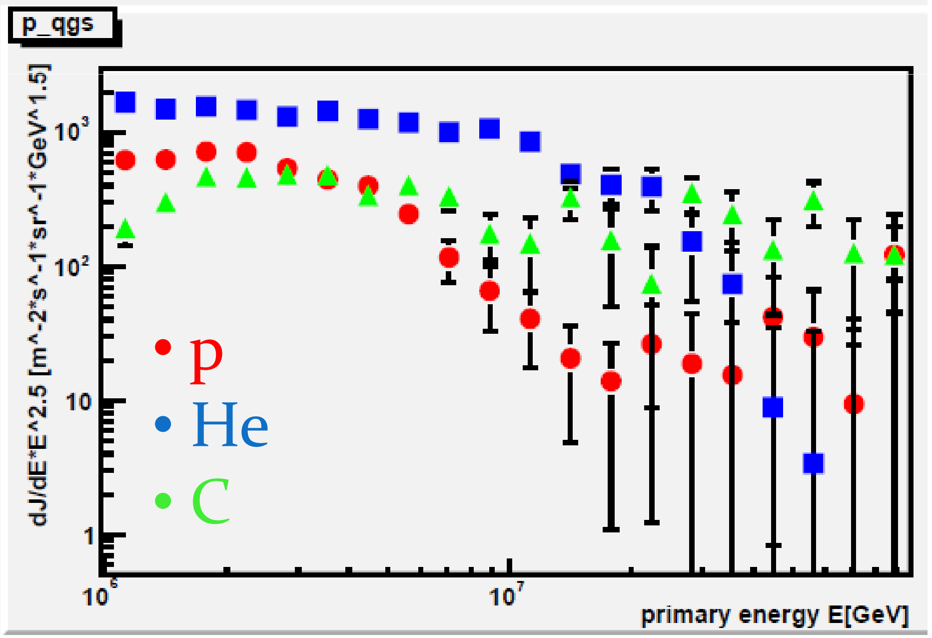
• Use $p_1 - p_8$

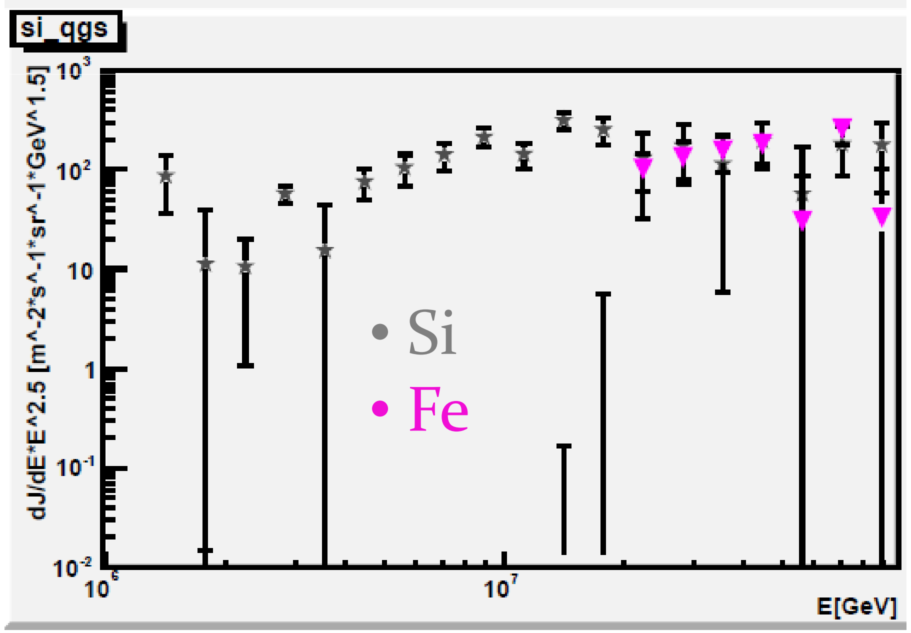
• Weight CORSIKA – shower according to fitparameters $p_1 - p_8$
➡ Predictions for μ- and ν- Fluxes.

• How dependent are the desired fluxes from details of the spectra of the mass groups for each model?

3. Unfolding (QGSJet)

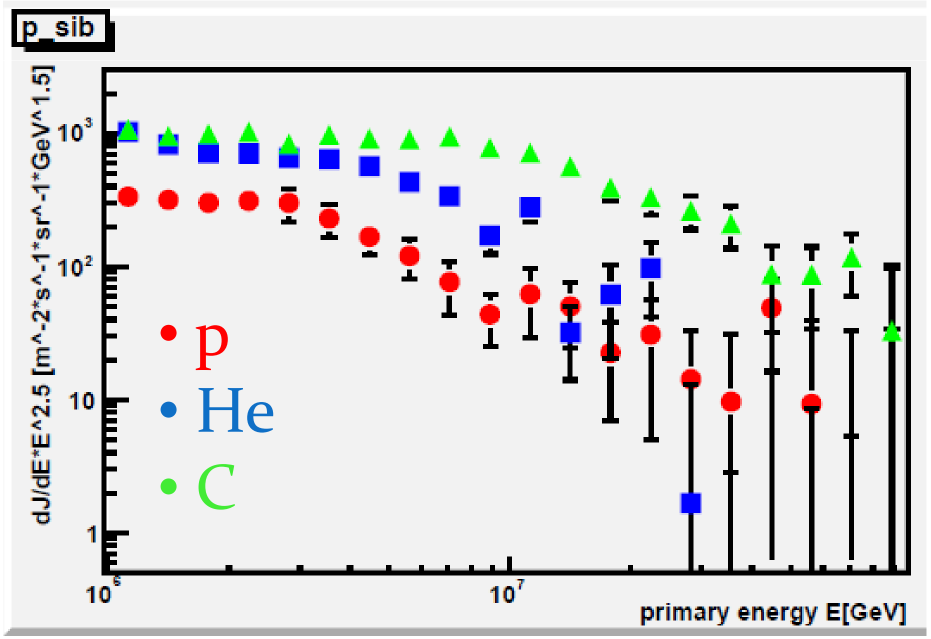
- Unfolded KASCADE data using QGSJet

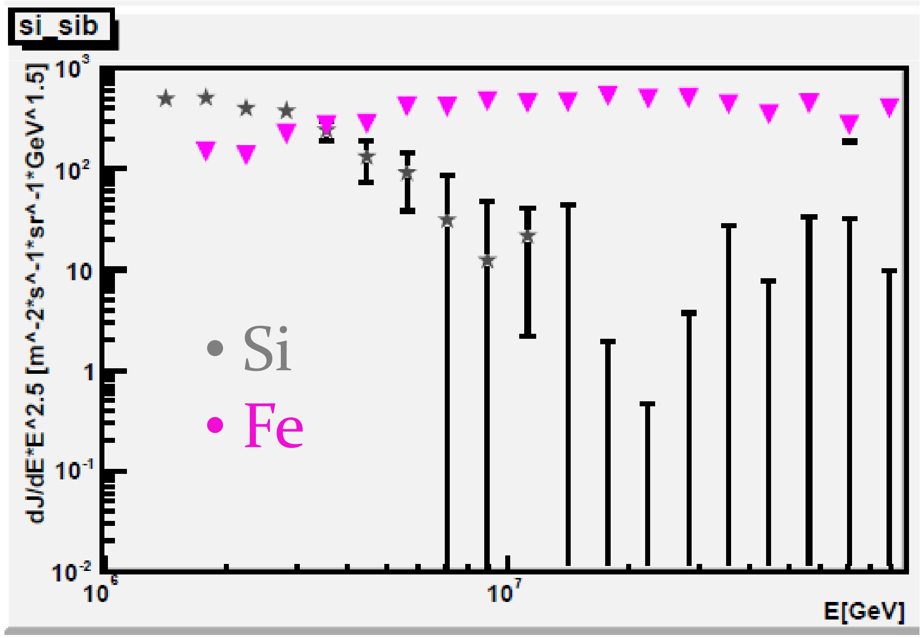




3. Unfolding (SIBYLL)

• Unfolded KASCADE data using SIBYLL





4. Fit strategies

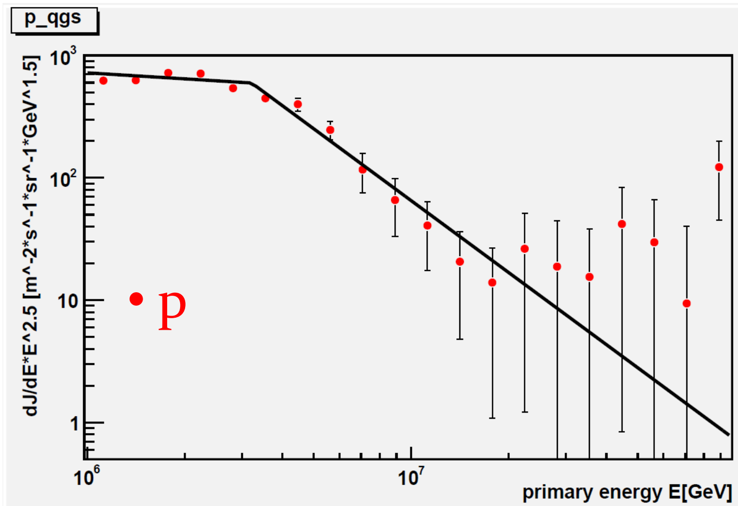
- **Parametrisation** of the fit(Example for Protons: non-simultaneous fit):

- $$\frac{dJ}{dE}_{left} = a * E^{\gamma_1} \qquad \frac{dJ}{dE}_{right} = b * E^{\gamma_2}$$ (broken power law)

- Continuity : $E = E_{knee} \rightarrow \frac{dJ}{dE}_{left} = \frac{dJ}{dE}_{right} \rightarrow b = a * E_{knee}^{\gamma_1 - \gamma_2}$

$$\frac{dJ}{dE}_{left} = a * E^{\gamma_1}$$

$$\frac{dJ}{dE}_{right} = a * E_{knee}^{\gamma_1 - \gamma_2} * E^{\gamma_2}$$



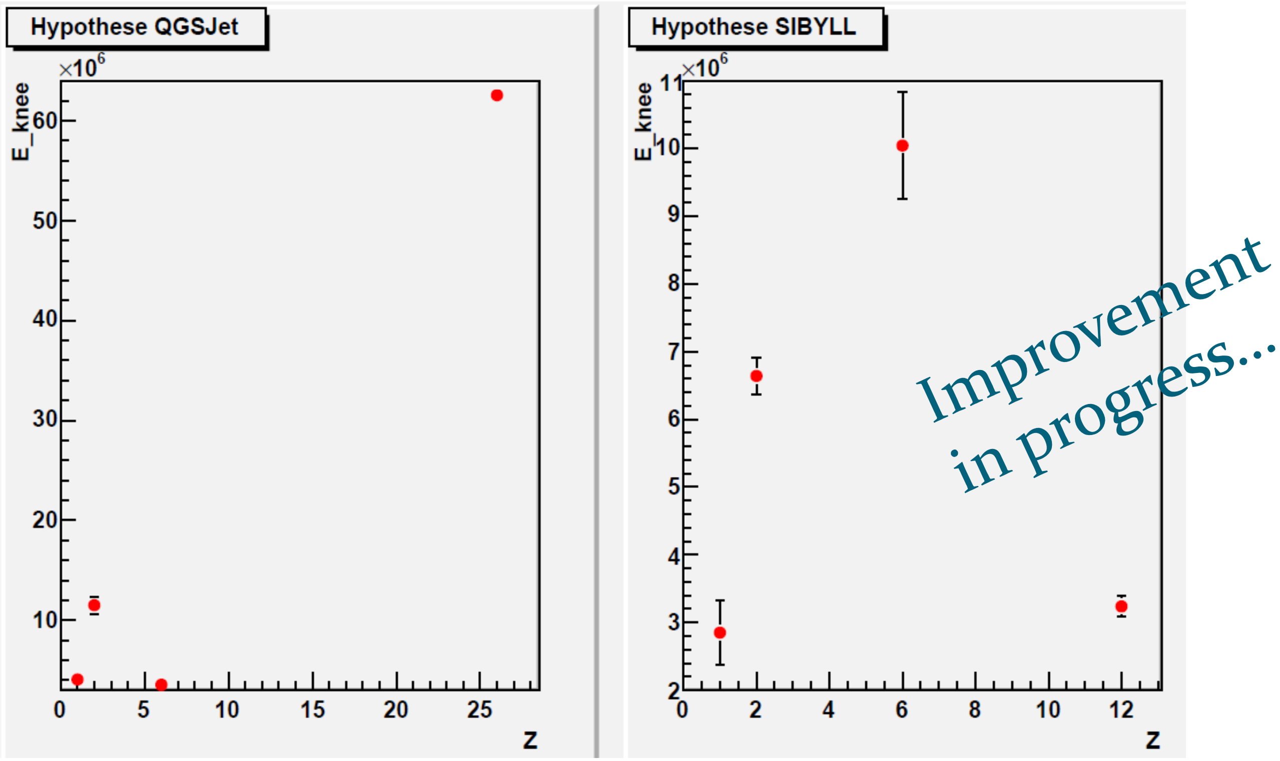
4. Fit strategies

Test of hypothesis:

$$E_{knee}(X) = Z * E_{knee}(p)$$

➡ Plot E_{knee} against Z to test hypothesis.

- Knee energies received by fitting spectra independent from each other. Improvement is in progress!

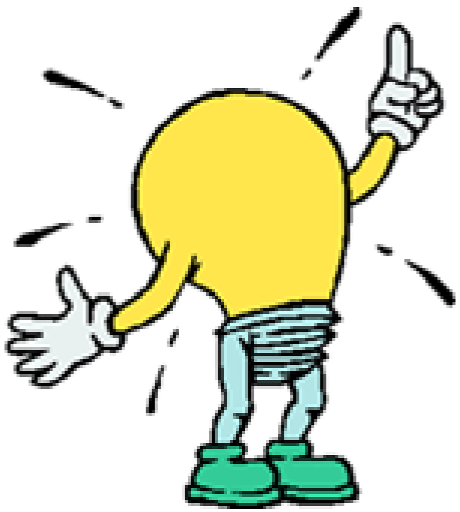


4. Fit strategies

• Simultaneous fit has the following structure :

[1] = Knee position
[2],[3] = spectral indices below and above the knee
[0],[4],[5],[6],[7] = fluxparameters of the different mass groups

$$[0][Z_P * 1][2][3]$$
$$[4][Z_{He} * 1][2][3]$$
$$[5][Z_C * 1][2][3]$$
$$[6][Z_{Si} * 1][2][3]$$
$$[7][Z_{Fe} * 1][2][3]$$



• Assumption = Spectral indices are the same constants for all mass groups.

4. Fit strategies

Fit Method : Minuit

- Concept of Minuit is to write χ^2 by yourself.
- χ^2 depends on data points , errors and free parameters.
- χ^2 can be minimized by several algorithms („MIGRAD“ is used here).

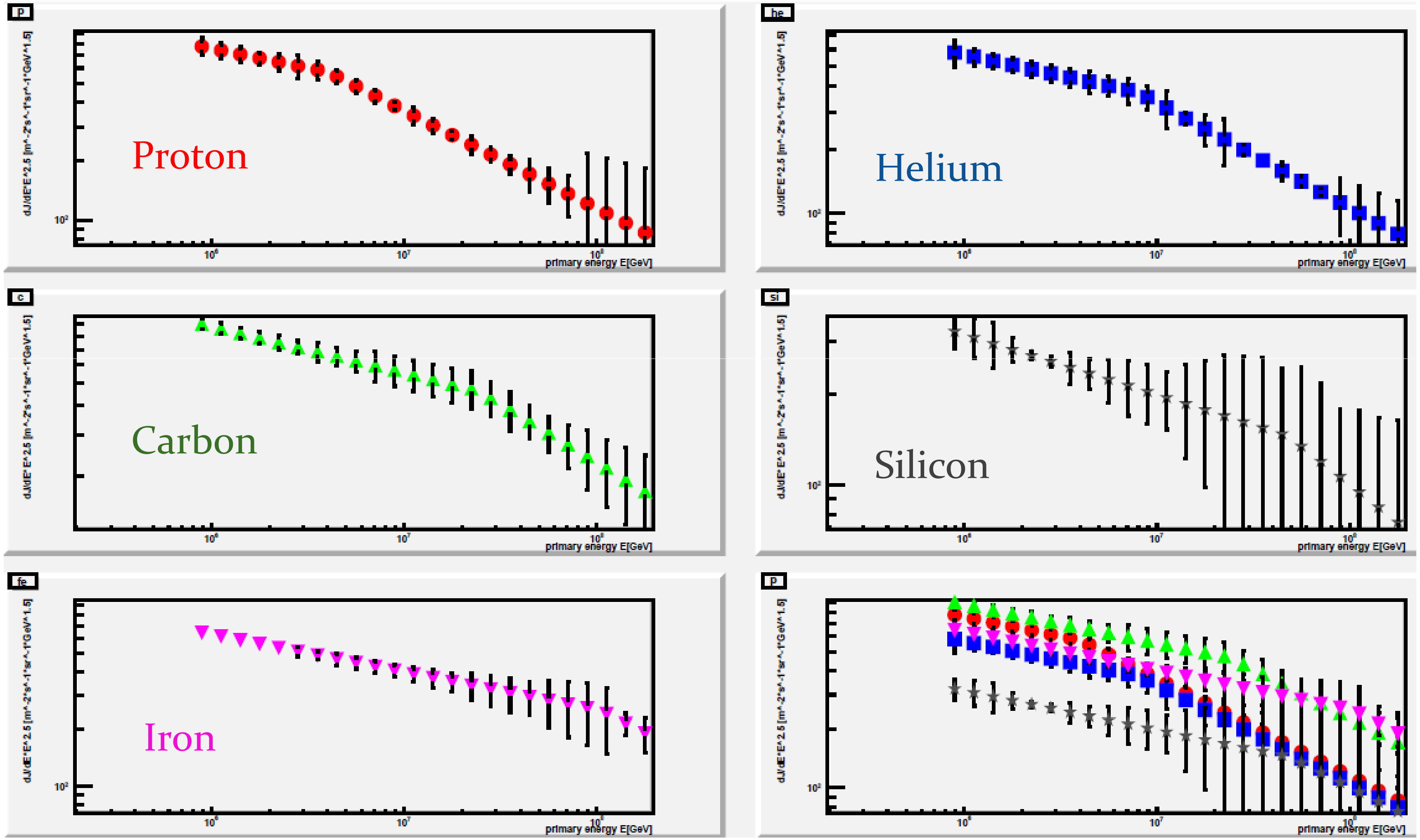
- Final Parameters (QGSJet):
  [1] = 1,69017*10^6 GeV ± 8,16605*10^7 GeV
  [2] = -4,97137 ± 4,81064
  [3] = -2,03364 ± 3,30407

- Final Parameters(SIBYLL):
  [1] = 1,12248*10^6 GeV ± 1,66706 GeV
  [2] = -0,652245 ± 0,00393992
  [3] = -0,958628 ± 0,0117727

- Are the parameters meaningful? Is the used Method meaningful?

4. Fit strategies

Test of procedure : Roll the dice!

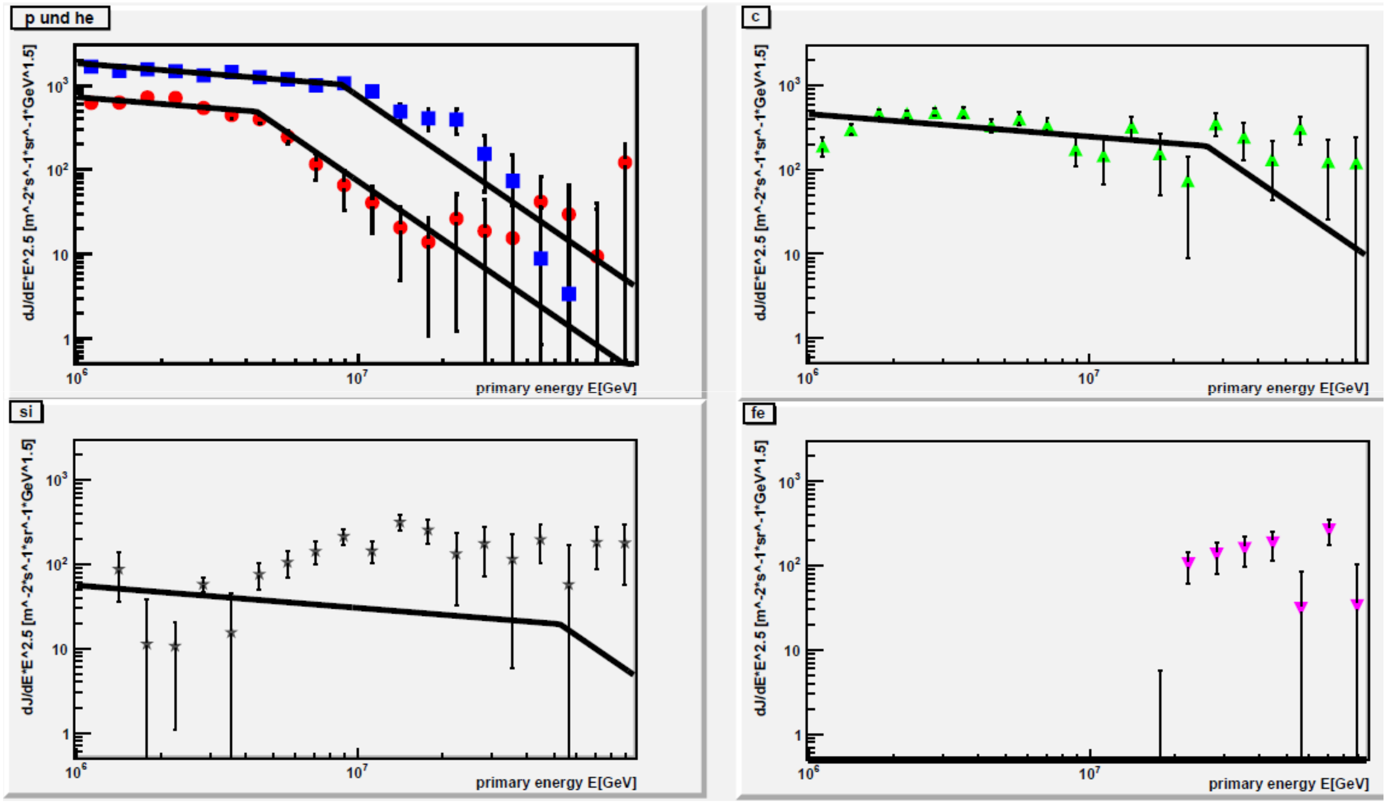


- First test successful , but must be improved!

4. Fit strategies

Improved fit with Minuit : Use iterations

QGSJet



[1] = 4.35895e+06 GeV +- 126266 GeV

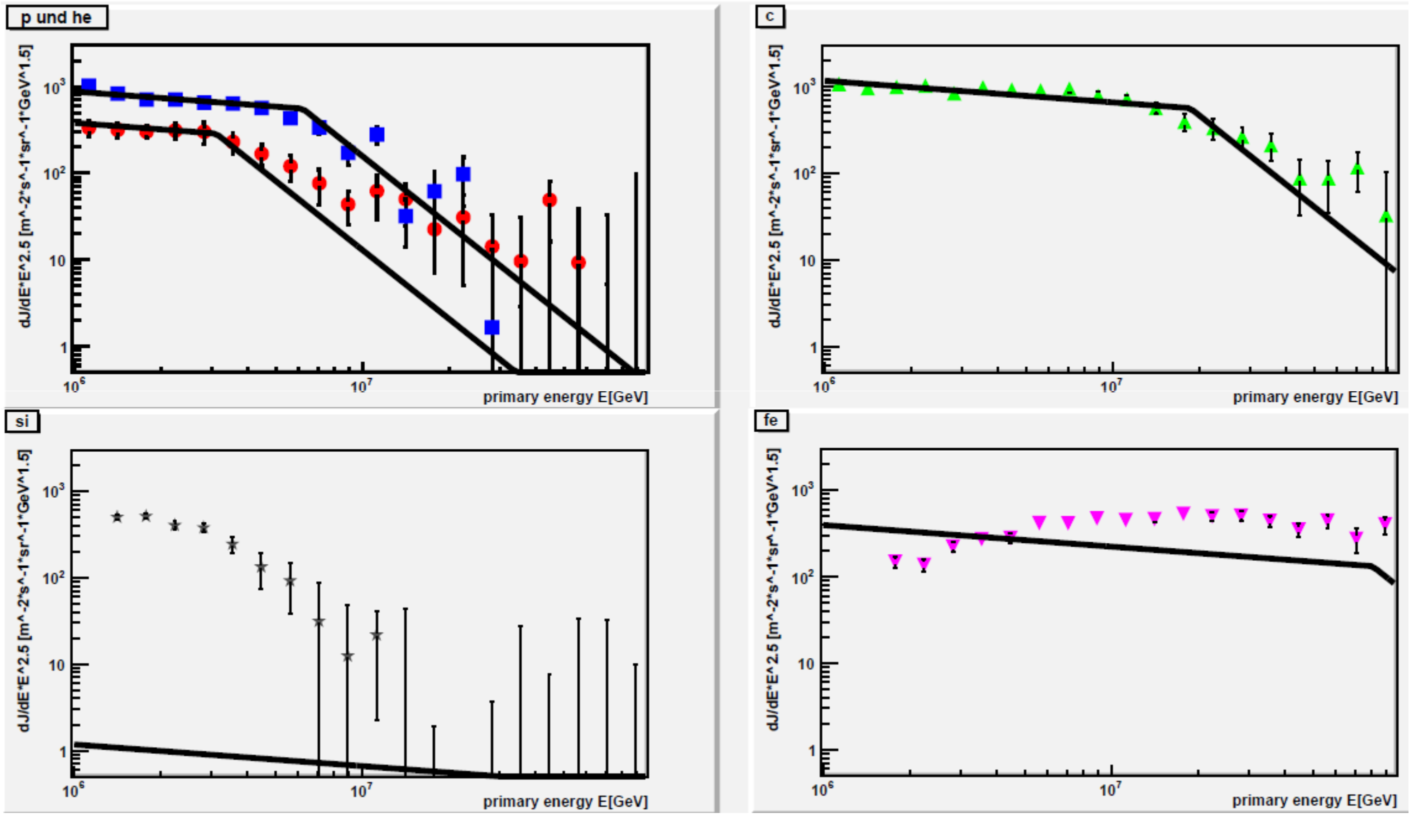
[2] = -0.267562 +- 0.021781

[3] = -2.28873 +- 0.134892

4. Fit strategies

Improved fit with Minuit : Use iterations

SYBILL

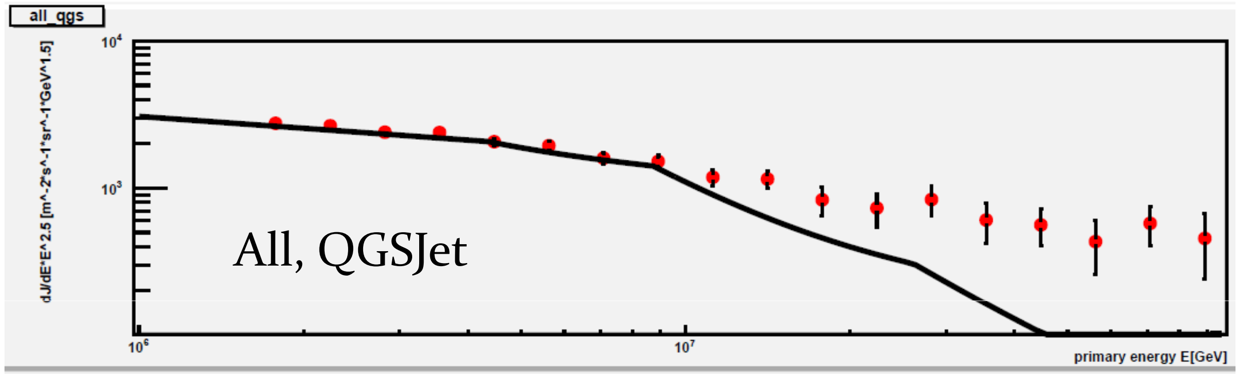


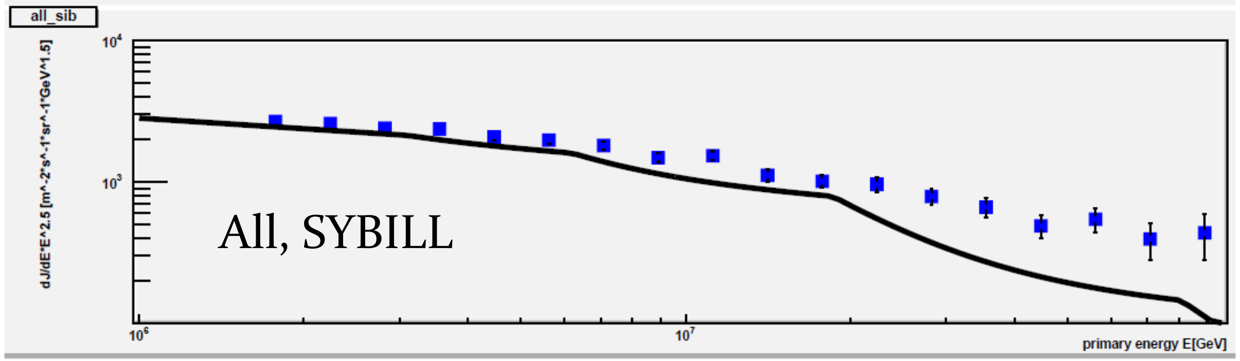
[1] = 3.10114e+06 GeV ± 109758 GeV
[2] = -0.249798 ± 0.018478
[3] = -2.64861 +- 0.150964

4. Fit strategies

Improved fit with Minuit : Use iterations

Plot sum of fit functions into all-particle spectra:





- Silicon iron is missing! -> Improvement by „eliminating“ data
- Is there an technical error?

5. Summary & Outlook

• Atmospheric μ- and ν-Fluxes are background for extragalactic ν ,μ and therefore must be known
• They can be calculated with CORSIKA by using parameters which describe spectra of mass groups

• Used fit method has to be improved furthermore, but in principle fluxes can be calculated now

• In near future further questions can be analysed , e.g.:

„Are Neutrino telescopes able to make a statement about the composition of CR with measured fluxes of atmospheric Neutrinos?

Thank you!!!

Literature

• Several KASCADE people :
„KASCADE measurements of energy spectra for elemental groups of cosmic rays : Results and open problems“ (2004)