Influence of the hadronic interaction models on the size of the missing energy of cosmic ray showers

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Outline

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Missing energy

- The shower can be detected by a fluorescence detectors.
- $N_2$ molecules are excited – during deexcitation the fluorescence photons are emitted proportional to the energy losses of electrons.
- Fraction of energy is carried out by neutrinos and muons → cannot be detected → missing energy.
- Missing energy is an important parameter for energy reconstruction of the shower.
Determination of missing energy

- simulation of the longitudinal profile in CONEX

\[
f_{GH}(X) = \frac{dE}{dX_{\text{max}}} \left( \frac{X-X_0}{X_{\text{max}}-X_0} \right)^{\frac{X_{\text{max}}-X_0}{\lambda}} \frac{X_{\text{max}}-X}{\lambda} e^{-\frac{X_{\text{max}}-X}{\lambda}}
\]

\[
E_{\text{cal}} = \int_0^{\infty} f_{GH}(X) \, dX,
\]

- missing energy:

\[
E_{\text{miss}} = E_{\text{prim}} - E_{\text{cal}},
\]

**Figure 9.1:** One of the typical fits. This fit was done for QGSJETII interaction model, the primary energy was $10^{18.5}$ eV and primary particle was iron nucleus. The fit of the equation (9.2) was made.
Distribution of Emiss

(a) neXus, iron nuclei, $E = 10^{17.5}$ eV.

(b) neXus, protons, $E = 10^{17.5}$ eV.

Figure 9.2: The distribution of missing energy in %, neXus high energy interaction model.
Figure 9.6: The mean missing energy as a fraction of primary energy (computed as an average from 500 simulated showers for each interaction model) for protons and iron nuclei as a function of energy. The QGSJET01, QGSJET02, SYBILL and neXus interaction model are used.
Figure 9.7: The average mean missing energy for protons and iron nuclei and the total average mean missing energy as a function of energy and the influence of the interaction models (error bars).
Previous method

- previous method – Barbosa work
- detailed simulation with CORSIKA
- each particle was tracked to some threshold then the contribution of muons and neutrinos was summarized
Comparison of methods

QGSJET 01, zenith angle 0°
Remarks on results

- this method is very fast and easy to use
- good agreement with Barbosa's method

- Influence of the choice of high energy interaction models to determination of the size of the missing energy is not so high – about 1%~2%

- Most important contribution to the uncertainty of the missing energy correction applied in shower energy reconstruction is our absence of knowledge of the chemical composition of CR
New approach?

- the muons carry away a big fraction of energy, which is undetectable
- some experiments measure the muon component – number of the muons on the ground
- there is a natural correlation between the number of muons on the ground and the size of the missing energy
- How does this correlation look like for different high energy interaction models and for different primary particles?
New approach?
New approach?
Conclusions

• first method:
  • fast and easy to use
  • missing energy: dependence on the choice of the high energy interaction models and strong dependence on the type of the primary particle

• new approach:
  • It seems, that dependences on the high energy interaction models and on the type of primary particle can be much reduced using the measurement of muon component....
  • ... but there is still a lot of work!!!