The sensitivity of KASCADE-Grande to the cosmic ray primary composition between $10^{16}$ and $10^{18}$ eV

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**Location:** Forschungszentrum Karlsruhe (D).

**Goal:** Study cosmic ray energy spectrum & primary composition in the range $10^7$ - $10^9$ eV through Extensive Air Showers detection.

- **Grande array:** KASCADE array work jointly.
  - KASCADE array: 252 scintillation detectors, 622 m^2 muon detection area.
  - Grande array: 37 scintillator modules 10 m^2 each, over 7000 m^2.

- Expansion of KASCADE acceptance increases $>10^9$ without significant loss in resolution.

- Charged particle size $N_p$ of each EAS measured with Grande, muon size $N_M$ measured with KASCADE.
- Electron size $N_e$ obtained from subtraction of muon from charged particle density.
- Accurate event reconstruction achieved [1][2].

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**Fit with a single primary:** bad one element cannot describe the data selection.
Each simulated primary overlapping the data selection gives:

<table>
<thead>
<tr>
<th>Primary</th>
<th>Proton</th>
<th>Helium</th>
<th>Carbon</th>
<th>Silicon</th>
<th>Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2$</td>
<td>$6.79/0.09$</td>
<td>$404.59$</td>
<td>$26.44$</td>
<td>$17.20$</td>
<td>$10.44$</td>
</tr>
</tbody>
</table>

**Fit with two primaries:** Fits step up but at least a third element is required.
Here and in next pictures: experimental plot normalized to 1; each primary normalized to relative abundance. Right side star: rate of events beyond 2RMS.

- Left side: rate of events below 2RMS.
- $E_{\gamma}$: $6.11 < \log(N_p) < 6.36$.

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**Checking consistency of the result:**
- At larger zenith angles (deeper atmospheric depths): some fits performed in larger bin of equal acceptance $29.86^\circ$ to $40^\circ$.
- The present analysis: next step for experimental results validation.
- It verifies:
  - KG sensitivity to different primaries.
  - KG data reproducibility with hadronic interaction model QGSJetII as a function of electron size and atmospheric depth.
  - Consistency of these observations with KASCADE in an overlapping energy region.

- In this analysis:
  - Electron size $N_e$ and muon size $N_M$ of each event are considered.

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**Features of the analysis:**
- Data selection: $6.49 < \log(N_p) < 6.74$, $0^\circ < \theta < 23.99^\circ$.
- Full reconstruction efficiency + high statistics.
- Same event selection on QGSJetII simulated primaries: p, He, C, Si, Fe.
- $N_p/N_e$ experimental distribution of selected events is studied.
- $N_p/N_e$ histogram is fitted with a linear combination of elemental contributions from simulations:
  
  $F_{\text{sim}}(i) = \sum_{i} a_i F_{\text{sim}}(i)$

- $F_{\text{sim}}(i)$ total theoretical fraction of events falling in channel $i$.

- $a_i$ total fraction for the single primary element $\alpha$.
- $\Sigma_{i}$ sum over the different primaries.

- Fit performed through minimization of following Chi Square:

  $\chi^2 = \sum_{i} (F_{\text{exp}}(i) - F_{\text{sim}}(i))^2 / \text{of}(i)$

- Conditions for fit parameters:
  - $a_i$ fixed for each $\alpha$.
  - $\Sigma a_i = 1$.

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**Comparison with KASCADE data:** in overlapping region $6.11 < \log(N_p) < 6.36$, $29.86^\circ$ to $40^\circ$.

- Generally QGSJetII is well reproducing the KASCADE data.

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