Precision Measurement of the Cosmic Boron-to-Carbon Ratio with AMS

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On behalf of the AMS Collaboration

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Multiple Measurements of Charge

Carbon (Z=6)

<table>
<thead>
<tr>
<th>Plane</th>
<th>ΔZ (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracker Plane 1 (L1)</td>
<td>0.30</td>
</tr>
<tr>
<td>TRD</td>
<td>0.33</td>
</tr>
<tr>
<td>Upper TOF (1 counter)</td>
<td>0.16</td>
</tr>
<tr>
<td>Inner Tracker (L2-L8)</td>
<td>0.12</td>
</tr>
<tr>
<td>Lower TOF (1 counter)</td>
<td>0.16</td>
</tr>
<tr>
<td>RICH</td>
<td>0.32</td>
</tr>
<tr>
<td>Tracker Plane 9 (L9)</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Multiple Measurements of Energy

Tracker, $R = p/Z$

$MDR (Z=6) \approx 3TV$

TOF, $\beta$

$\Delta \beta (\beta=1, Z=6) \approx 0.01$

RICH, $\beta$

$\Delta \beta (\beta=1, Z=6) \approx 5 \times 10^{-4}$
Flux and Ratio Determination

B/C is a flux ratio. Flux is given by:

\[ \Phi(\bar{K}_n) = \frac{N(K_n, K_n + \Delta K_n)}{A \in \Delta T \Delta K_n} \]

- Acceptance (m^2 sr)
- Efficiency
- Exposure Time
- Bin Width

\( K_n \) is the kinetic energy per nucleon, is measured from TOF and RICH (beta) or from Tracker (rigidity).
Nuclei Identification with Inner Tracker

Contamination from neighboring charges $< 10^{-4}$, identification efficiency is $> 98\%$.

![Diagram showing distribution of various nuclei charges and their identification with inner tracker.](image)
Identification of Fragmentation Events

Layer 1 = 6.1
TRD = 6.0
UTOF = 7.6
Inner = 4.8
LTOF = 5.2
RICH = 5.0

R = 10 GV
Purity Estimation

Selection efficiency is >70% for both Boron and Carbon, ratio is ≈ 1.
Boron selected with Inner Tracker and TOF.
Background estimated down to accuracy of 0.1%.

Boron Purity = 97%

Tracker L1 Charge
Estimation of Fragmentation

Acceptance is convolution of geometry and fragmentation effects. Carbon selected with L1 and UTOF. Fragmentation distribution evaluated with LTOF. Data and MC agreement evaluated being at 2% level.
The ratio of Boron and Carbon track efficiencies is calculated and cross-checked with MC up to 100 GV. Is about 2% correction.
Trigger efficiency is estimated with an unbiased trigger sample. Efficiency is $> 95\%$, no apparent difference between B and C.
Top-of-the-Instrument Correction

Carbon to Boron conversion on materials above L1.

$$\left( \frac{B}{C} \right)_{L1} = \frac{B + C \cdot \epsilon_{C \rightarrow B}}{C} = \left( \frac{B}{C} \right)_{TOI} + \epsilon_{C \rightarrow B}$$

Correction to the ratio has been estimated with MC: $\epsilon_{C \rightarrow B} = 0.005 \pm 0.002$. 
Isotopic Fraction Evaluation

RICH evaluates the isotopic composition of Boron. This fraction is used for the Tracker rigidity → kinetic energy conversion. 

\[ \frac{^{11}B}{^{11}B + ^{10}B} = 0.7 \pm 0.1 \rightarrow \sim 1\% \text{ systematic error on ratio} \]
Systematics

(a) 2% from MC and data comparison of interactions.

(b) 1% from isotopic composition evaluation.

(c) <2% from TOI correction.

(d) bin-to-bin migration error is <1% up to 200 GeV/n, and 2% above.

Systematic error will be reduced with more data.
B/C Ratio

10% of total expected data

Boron-to-Carbon Ratio vs. Kinetic Energy (GeV/n)

Orth et al. (1972)
Dwyer & Meyer (1973-1975)
Simon et al. (1974-1976)
HEAO3-C2 (1980)
Webber et al. (1981)
CRN-Spacelab2 (1985)
Buckley et al. (1991)
AMS-01 (1998)
ATIC-02 (2003)
CREAM-I (2004)
TRACER (2006)

AMS-02
AMS B/C Ratio

10% of total expected data

AMS-02

Boron-to-Carbon Ratio vs. Kinetic Energy (GeV/n)

Conclusions

Measurement of the B/C between 0.5 to 670 GeV/n with AMS has been presented.

Sources of differences between Boron and Carbon counting were investigated and corrections applied when needed.

Main limitation for the ratio measurement and systematics error evaluation at high energy is the statistics.

AMS has collected 10% of the expected statistics.

The B/C behavior at high energy will be become more clear with more data.