Precision Measurement of the Carbon and Oxygen Fluxes with AMS

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Carbon and oxygen are the most abundant nuclei after proton and helium in cosmic rays.

I will present the precise measurements of the carbon and oxygen fluxes with AMS in the rigidity range from 2.2 GV to 2.6 TV based on 16 million events.
AMS Carbon and Oxygen Measurement

Carbon (Z = 6) △Z (cu)
Tracker L1 0.3

Upper TOF 0.16

Inner Tracker 2-8 0.12

Lower TOF 0.16

RICH 0.32

Tracker L9 0.3

Rigidity (Momentum/Charge)
Tracker
Bending Coordinate Resolution 5-6µm
MDR ≈ 3.5TV

TOF (4 Layers)
△β/β² 1-2%

AMS
Carbon and Oxygen Measurement

Tracker

Velocity and Direction

Tracker

RICH

Velocity and Direction

RICH

△β/β ≈ 0.05%
Flux Measurement

Isotropic flux above geomagnetic cutoff in rigidity is defined as

\[ \Phi_i(R) = \frac{N_i}{T_i A_i \epsilon_i \Delta R_i} \]

- **Events Corrected for Background and for Bin to Bin Migration due to Tracker Rigidity Resolution**
- **Bin width**
- **Trigger Efficiency from Data**

**Rigidity 2.2-2600 GV**

**Time ~123,000,000 sec (R>30 GV, 5Years)**

**Effective Acceptance from MC, Corrected for Nuclei Interactions Verified with Data**
(i) Trigger efficiency

Trigger efficiency was measured by using unbiased event sample [3/4 TOF]. The efficiency is >95% with its error <1%.
(ii) Acceptance due to interactions

The inelastic cross sections of $C (O)+C$, $C + Al$ are only measured below few GV.

We develop a method to measure the nuclei Survival Probabilities $L2$ to $L1$ and $L8$ to $L9$ during “Horizontal” runs [$\sim 10^5$ sec exposure] in which nuclei can enter AMS both right to the left and left to the right. Moreover, $L8 \rightarrow L9$ Survival Probabilities can also be measured in ECAL acceptance during normal conditions.
(ii) Carbon Survival Probability L8 to L9 Data to MC Comparison

![Diagram showing normal condition with labels L1 and L9]

- Survival Probability Ratio L8 to L9
- Carbon Data/MC Ratio
- Systematic Error

![Graph showing Survival Probability Ratio L8 to L9 vs Rigidity [GV]]

- Axes: Rigidity [GV] on the x-axis and Survival Probability Ratio L8 to L9 on the y-axis
- Data points with error bars indicating Carbon Data/MC Ratio
- Dashed red line representing Systematic Error
(ii) Carbon Survival Probability
L1 to L9 Data to MC Comparison

“Horizontal” AMS

![Graph showing the survival probability ratio L1 to L9 for Carbon Data/MC comparison with systematic error.](image-url)
(iii) AMS Nuclei + C Inelastic Cross Section Measurements, 5-100 GV Rigidity

With the AMS measurement, C (O) acceptance error due to interactions is evaluated to be: <2.4 (3) % below 100 GV and 3.5 (5) % @ 2.6 TV
(iv) Background to Flux Measurement

background from elements of higher charges (F, Ne..), which interact within AMS detector to become Carbon is <1% and to become Oxygen is negligible
Rigidity Resolution

The spatial resolution of AMS silicon tracker is 5.1 µm (6.3 µm) for Carbon (Oxygen). This corresponds to the maximal detectable rigidity (MDR) about 3.5 TV. The unfolding (resolution) error [due to the uncertainty of N-N scattering and L1,9 alignment] is estimated to be 1% below 200 GV and 3-4% @2.6 TV.

Difference between measured coordinates in L3-L6 and whose interpolated from fitted track.
(vi) 5 Years Rigidity Scale

The Rigidity Scale \(\frac{1}{\Delta}\) was measured by comparing the Energy \([E, \text{Measured by ECAL}]/\text{Rigidity}[R, \text{Measured by Tracker}]\) ratio for electron and positron events and was determined with the accuracy of \(1/30 \text{ TV-1}\), limited mostly by the high energy positron statistics. The corresponding flux error is 6% @2.6 TV.

\[
\frac{1}{\Delta} = \frac{(E/R)_{e^+} - (E/R)_{e^-}}{E_{e^+} + E_{e^-}}
\]
Verification of the Systematic Error of Unfolding, Acceptance and Rigidity Resolution

Flux obtained using the rigidity measured by only the L1+inner tracker in a larger acceptance is in very good agreement with the flux measured using the full lever arm, specifically at high rigidities (200 to 1300 GV) where the unfolding effects and resolution functions of the L1+inner tracker (1.3 TV MDR) and the full lever arm one (3.5 TV MDR) are very different.
Carbon Flux Errors Breakdown

![Graph showing carbon flux errors breakdown with labels for Total, Statistical, Rigidity Scale, Unfolding, and Acceptance.](image)
FIG. 3. The AMS carbon flux (a) and oxygen flux (b) as a function of kinetic energy per nucleon $E_K$ multiplied by $E_K^{2.7}$.

Carbon Flux

8.3 Million Events
Oxygen Flux

Fig. 3. The AMS carbon flux (a) and oxygen flux (b) as a function of kinetic energy per nucleon $E_K$ multiplied by $E^{2.7}_K$. Compared with measurements since the year 1980 [4–12]. For the AMS measurement kinetic energy per nucleon is derived from the rigidity $\tilde{R}$ using:

$$ E_{C}^{K} = \frac{1}{1^{\frac{1}{2}}} \left( \sqrt{\left(6\tilde{R}ight)^2 + M_{C}^2} - M_{C} \right)^{\frac{1}{2}} $$

Where $M_{C}$ is the $^{12}$C mass and

$$ E_{O}^{K} = \frac{1}{1^{\frac{1}{2}}} \left( \sqrt{\left(8\tilde{R}ight)^2 + M_{O}^2} - M_{O} \right)^{\frac{1}{2}} $$

Where $M_{O}$ is the $^{16}$O mass. Data points from [4–12] are extracted using [29].

Preliminary Data. Please refer to the forthcoming publication in PRL.
Summary

• Precise measurements of carbon and oxygen fluxes based on 5 Years AMS Data were presented:
  – Based on 16 Million C and O nuclei
  – Systematic errors were studied in detail
  – Total flux errors is 3% @ 100GV.

• The measurements above 1 TV are still limited by statistics:
  – Rigidity measurement range will be extended to 3.5 TV.
  – Statistics will be significantly improved during the lifetime of ISS.