Results from the Alpha Magnetic Spectrometer

Andrei Kounine / MIT
on behalf of the AMS Collaboration

DM Paradigm / PCTS 16 October 2013
AMS: a U.S. DOE sponsored international collaboration
16 Countries, 60 Institutes and 600 Physicists

Strong support from NASA and DOE
AMS: A TeV precision, multipurpose spectrometer in space.

Particules and nuclei are identified by their charge ($Z$) and energy ($E \sim P$).

Z, $P$ are measured independently from Tracker, RICH, TOF and ECAL.
Transition Radiation Detector: TRD

Identify $e^+$, reject $p$

Leak rate: $\text{CO}_2 \approx 5 \mu g/s$

Storage: 5 kg, >20 years lifetime
TRD performance on ISS

TRD estimator = \(-\ln\left(\frac{P_e}{P_e + P_p}\right)\)

Normalized probabilities $P_e$ and $P_p$
Proton rejection at 90% $e^+$ efficiency

TRD performance on ISS

- ISS data
Time of Flight (TOF)

Provides trigger for charged particles

Trigger time is synchronized to UTC time to 1µs

Measures the time of relativistic protons to 160 picoseconds

![Diagram of TOF system]

- **Z=2**
  - $\sigma_\beta=2\%$
  - $\sigma_{\text{Time}}=80\text{ps}$

- **Z=6**
  - $\sigma_\beta=1.2\%$
  - $\sigma_{\text{Time}}=48\text{ps}$
Silicon Tracker

$\text{MDR}_p = 2.0 \ \text{TV}$
$\text{MDR}_{\text{He}} = 3.7 \ \text{TV}$

Test Beam

$\sigma \sim 8.5 \ \mu\text{m}$
Stability of the alignment on Tracker plane 1 & 9

Align with cosmic rays

Layer 1

Layer 9

Entries

Constant
Mean
Sigma

Layer 1

4890
758.04 ± 13.89
0.04 ± 0.04
3.07 ± 0.04

Layer 9

4890
611.13 ± 10.75
-0.05 ± 0.05
3.82 ± 0.04
Ring Imaging Cherenkov Detector (RICH)

Intensity $\propto Z^2$

$\Theta \propto V$

10,880 photosensors

RICH test beam $E=158$ GeV/n

Single Event Displays

Number of events

Nuclear Charge $Z$

He Li Be B C N O F Ne Na Mg Al Si P S Cl Ar K Ca Sc Ti V Cr Mn Fe Co

10,000,000

1,000,000

100,000

10,000

100

10

Calorimeter (ECAL)

A precision, $17 X_0$, TeV, 3-dimensional measurement of the directions and energies of light rays and electrons

\[
\sigma(E) = \frac{10.4}{\sqrt{E}} + 1.4\% 
\]

Test Beam Results

50,000 fibers, $\phi = 1$ mm
distributed uniformly
Inside 1,200 lb of lead
Separation of protons and electrons with ECAL

ISS data: 83–100 GeV

Boosted Decision Tree, BDT:
19 variables describing 3D shower shape combined
(B.Roe et al., NIM A543 (2005) 577)

\[ \varepsilon_e = 90\% \]
Data from ISS: Proton rejection using the ECAL
Intensive Tests at CERN, August 2010
<table>
<thead>
<tr>
<th>Particle</th>
<th>Momentum (GeV/c)</th>
<th>Positions</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protons</td>
<td>400 + 180</td>
<td>1,650</td>
<td>Full Tracker alignment, TOF calibration, ECAL uniformity</td>
</tr>
<tr>
<td>Electrons</td>
<td>100, 120, 180, 290</td>
<td>7 each</td>
<td>TRD, ECAL performance study</td>
</tr>
<tr>
<td>Positrons</td>
<td>10, 20, 60, 80, 120, 180</td>
<td>7 each</td>
<td>TRD, ECAL performance study</td>
</tr>
<tr>
<td>Pions</td>
<td>20, 60, 80, 100, 120, 180</td>
<td>7 each</td>
<td>TRD performance to 1.2 TeV</td>
</tr>
</tbody>
</table>
AMS installed on the ISS at 5:15 CDT  May 19, 2011

AMS taking data since 9:35 CDT  May 19, 2011
To date AMS collected over 40 billion events

35.7 billion events have been analyzed

29 month of AMS operations
Cosmic ray electrons and positrons

1. Positron fraction
2. Positron and electron fluxes
3. Combined electron and positron flux
4. Positron anisotropy
Physics of Positron Fraction

E. Ponton and L. Randall, JHEP 0904 (2009) 080;

\[ \chi + \chi \rightarrow e^+ + \ldots. \]

\[ m_\chi = 800 \text{ GeV} \]

\[ m_\chi = 400 \text{ GeV} \]

Collision of Cosmic Rays

Dark Matter model based on I. Cholis et al., arXiv:0810.5344
Event selection.

- **DAQ:** efficiency > 50% (no SAA)

- **Geomagnetic cutoff:**
  \( E > 1.2 \cdot \text{max cutoff} \)

- **TRACKER:**
  - Track quality
  - Geometrical match with ECAL shower

- **TRD:** at least 15 hits

- **TOF:** downgoing particle, \( \beta > 0.8, \quad 0.8 < Z < 1.4 \)

- **ECAL:**
  - Shower axis within the fiducial ECAL volume
  - Electromagnetic shape of the shower
Event selection: charge

Resolution: $\Delta Z \approx 0.05$ for $Z = 1$
Separation of protons and electrons with ECAL

ISS data: 83–100 GeV

Selection: BDT > -0.8

\[ \varepsilon_e = 90\% \]

ECAL estimator

Fraction of events
Selection efficiency is high, ~90%, and uniform in a wide energy range, 2–400 GeV

Ne± ≈ 6,800,000  Np ≈ 700,000

• MC simulation
Analysis: 2D fit to measure $N_{e^\pm}$ and $N_p$

2D reference spectra for the signal and the background are fitted to data in the $[\text{TRD estimator} - \log(E/|P|)]$ plane.

The method combines information from TRD, ECAL, and Tracker; and provides much better statistical accuracy compared to cut-based analysis.

![Protons and Positrons](https://via.placeholder.com/150)

83.2-100 GeV

$\log_{10}(E/|P|)$

TRD estimator

Probability Density

$10^{-3}$
Results of the fit:

The TRD Estimator shows clear separation between protons and positrons with a small charge confusion background.

\[ \chi^2/\text{ndof} = 0.83 \]
### AMS Result: Measurement of the positron fraction

<table>
<thead>
<tr>
<th>Energy [GeV]</th>
<th>(N_{e^+})</th>
<th>Fraction</th>
<th>(\sigma_{\text{stat.}})</th>
<th>(\sigma_{\text{acc.}})</th>
<th>(\sigma_{\text{sel.}})</th>
<th>(\sigma_{\text{mig.}})</th>
<th>(\sigma_{\text{ref.}})</th>
<th>(\sigma_{\text{c.c.}})</th>
<th>(\sigma_{\text{sys.}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00-1.21</td>
<td>9335</td>
<td>0.0842</td>
<td>0.0008</td>
<td>0.0005</td>
<td>0.0009</td>
<td>0.0008</td>
<td>0.0001</td>
<td>0.0005</td>
<td>0.0014</td>
</tr>
<tr>
<td>1.97-2.28</td>
<td>23893</td>
<td>0.0642</td>
<td>0.0004</td>
<td>0.0002</td>
<td>0.0005</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0006</td>
</tr>
<tr>
<td>3.30-3.70</td>
<td>20707</td>
<td>0.0550</td>
<td>0.0004</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0004</td>
</tr>
<tr>
<td>6.56-7.16</td>
<td>13153</td>
<td>0.0510</td>
<td>0.0004</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0002</td>
</tr>
<tr>
<td>09.95-10.73</td>
<td>7161</td>
<td>0.0519</td>
<td>0.0006</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0002</td>
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<tr>
<td>19.37-20.54</td>
<td>2322</td>
<td>0.0634</td>
<td>0.0013</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0003</td>
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<tr>
<td>30.45-32.10</td>
<td>1094</td>
<td>0.0701</td>
<td>0.0022</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0004</td>
</tr>
<tr>
<td>40.00-43.39</td>
<td>976</td>
<td>0.0802</td>
<td>0.0026</td>
<td>0.0002</td>
<td>0.0005</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0004</td>
<td>0.0007</td>
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<tr>
<td>50.87-54.98</td>
<td>605</td>
<td>0.0891</td>
<td>0.0038</td>
<td>0.0002</td>
<td>0.0006</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0004</td>
<td>0.0008</td>
</tr>
<tr>
<td>64.03-69.00</td>
<td>392</td>
<td>0.0978</td>
<td>0.0050</td>
<td>0.0002</td>
<td>0.0010</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0007</td>
<td>0.0013</td>
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<td>74.30-80.00</td>
<td>276</td>
<td>0.0985</td>
<td>0.0062</td>
<td>0.0002</td>
<td>0.0010</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0010</td>
<td>0.0014</td>
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<tr>
<td>86.00-92.50</td>
<td>240</td>
<td>0.1120</td>
<td>0.0075</td>
<td>0.0002</td>
<td>0.0010</td>
<td>0.0000</td>
<td>0.0003</td>
<td>0.0011</td>
<td>0.0015</td>
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<tr>
<td>100.0-115.1</td>
<td>304</td>
<td>0.1118</td>
<td>0.0066</td>
<td>0.0002</td>
<td>0.0015</td>
<td>0.0000</td>
<td>0.0003</td>
<td>0.0015</td>
<td>0.0022</td>
</tr>
<tr>
<td>115.1-132.1</td>
<td>223</td>
<td>0.1142</td>
<td>0.0080</td>
<td>0.0002</td>
<td>0.0019</td>
<td>0.0000</td>
<td>0.0004</td>
<td>0.0019</td>
<td>0.0027</td>
</tr>
<tr>
<td>132.1-151.5</td>
<td>156</td>
<td>0.1215</td>
<td>0.0100</td>
<td>0.0002</td>
<td>0.0021</td>
<td>0.0000</td>
<td>0.0005</td>
<td>0.0024</td>
<td>0.0032</td>
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<tr>
<td>151.5-173.5</td>
<td>144</td>
<td>0.1364</td>
<td>0.0121</td>
<td>0.0002</td>
<td>0.0026</td>
<td>0.0000</td>
<td>0.0006</td>
<td>0.0045</td>
<td>0.0052</td>
</tr>
<tr>
<td>173.5-206.0</td>
<td>134</td>
<td>0.1485</td>
<td>0.0133</td>
<td>0.0002</td>
<td>0.0031</td>
<td>0.0000</td>
<td>0.0009</td>
<td>0.0050</td>
<td>0.0060</td>
</tr>
<tr>
<td>206.0-260.0</td>
<td>101</td>
<td>0.1530</td>
<td>0.0160</td>
<td>0.0003</td>
<td>0.0031</td>
<td>0.0000</td>
<td>0.0013</td>
<td>0.0095</td>
<td>0.0101</td>
</tr>
<tr>
<td>260.0-350.0</td>
<td>72</td>
<td>0.1550</td>
<td>0.0200</td>
<td>0.0003</td>
<td>0.0056</td>
<td>0.0000</td>
<td>0.0018</td>
<td>0.0140</td>
<td>0.0152</td>
</tr>
</tbody>
</table>
Two sources: large angle scattering and production of secondary tracks along the path of the primary track. Both are well reproduced by MC. Systematic errors correspond to variations of these effects within their statistical limits.
Positron fraction – $\text{Ne}^+/(\text{Ne}^+ + \text{Ne}^-)$

M. Aguillar et al., PRL 110, 141102 (2013)
From 20 to 350 GeV the slope decreases by order of magnitude.
Comparing data with a minimal model.

\[ \Phi_{e^+} = C_{e^+} E^{-\gamma e^+} + C_s E^{-\gamma s} e^{-E/E_s} \]

\[ \Phi_{e^-} = C_{e^-} E^{-\gamma e^-} + C_s E^{-\gamma s} e^{-E/E_s} \]

Data

\[ \chi^2/d.f. = 28.5/57 \]

\[ 1/E_s = 0.0013 \pm 0.0007 \text{GeV}^{-1} \]

\[ E_s = 760^{+1000}_{-280} \text{GeV}. \]
AMS data and numerous phenomenological models

**Astrophysical objects**

**Dark Matter**
Kopp hep-ph/1304.1184

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Cutoff energy / DM mass $\geq 500$ GeV, however different energy behavior of the positron fraction:
- DM prediction: steeper fall at high energies
- Pulsars predictions: slow fall at high energies
AMS data and phenomenological models: can we ascertain the origin of the excess?

- Data ISS (as of today)
- DM model
- Pulsar model
- Background

Cutoff energy = DM Mass ≈ 700 GeV
AMS future data and phenomenological models: can we ascertain the origin of the excess?

Cutoff energy = DM Mass ≈ 700 GeV

in 10 years from now
AMS positron data

Positron $E=870$ GeV

Positron $E=717$ GeV

AMS will measure positrons up to $\sim 1$ TeV
Flux measurement

\[ \Phi(E) = \frac{N(E, E + \Delta E)}{\Delta E \Delta T_{\text{exp}} A_{\text{eff}} \varepsilon_{\text{trig}}} \]

- \( \Phi \) = Absolute differential flux \( (m^{-2} \text{sr}^{-1} \text{GeV}^{-1}) \)
- \( N \) = Number of observed events
- \( \Delta T_{\text{exp}} \) = Exposure time \( (s) \)
- \( A_{\text{eff}} \) = Effective acceptance \( (m^2 \text{sr}) \)
- \( \varepsilon_{\text{trig}} \) = Trigger efficiency
100% efficiency at E>3 GeV

\[
\text{Trigger} = \frac{N_{\text{physics}}}{N_{\text{physics}} + f_p \times N_{\text{unbiased}}}
\]
Acceptance – estimated from MC

\[ A_{\text{eff.}}(E) = A_{\text{generated}} \times \frac{N_{\text{selected}}(E)}{N_{\text{generated}}(E)} \]
Acceptance – estimated from MC

Preselection

Selection

Acceptance (m$^2$ sr)

Energy (GeV)
Data taking period

Data taken from: 19 May 2011 to: 19 May 2013

- Total exposure time:
  \[ T_{\text{exp.}} (R > 25 \text{ GV}) = 51.2 \times 10^6 \text{ sec} \]

- Average live time fraction:
  \[ T_{\text{exp.}} / 2 \text{ years} = 81.6 \% \]
Electron flux

\[ E^3 \text{ Flux (GeV}^3/(s \text{ sr m}^2 \text{ GeV})) \]

4% scaling error not included
Positron flux

4% scaling error not included

Fermi data above 100 GeV are off scale.
Measurement of the combined $e^\pm$ flux

![Graph showing the combined electron and positron flux versus energy. The graph includes data from various experiments: AMS-02, ATIC01&02 (2001 & 2003), BETS04 (2004), Fermi-LAT (2009), H.E.S.S. (2004-2007), and H.E.S.S. (LE) (2004 & 2005).]
Combined $e^\pm$ flux and models

Background evaluated from a simple power law for $e^+$ and $e^-$, with differences in the spectral index and normalization fixed by the AMS-02 positron fraction measurement. DM and Pulsar signal shapes adapted from Cholis et al, arxiv hep-ph1304.1840.
Combined $e^\pm$ flux and models in 10 years from now

- DM model
- Pulsar model
- Background

$e^+e^-$ flux (GeV m$^2$ sr s$^{-1}$) $\times E^3$ vs. Energy (GeV)
- Behaviour of the positron fraction at high energies indicates primary sources of high energy $e^\pm$ whether from a particle physics or an astrophysical origin.

- Primary sources of cosmic ray positrons and electrons may induce some degree of anisotropy on the measured $e^+/e^-$ ratio.
Build the sky map of the positrons and electrons arrival directions in galactic coordinates \((b,l)\)

Positrons \((E > 16 \text{ GeV})\)

Electrons \((E > 16 \text{ GeV})\)
Positron to electron ratio anisotropy

The observed sky map shows no evident pattern

The sky map of the relative fluctuation of the positron to electron ratio, \( r_e = \frac{e^+/e^-} \), in galactic coordinates (b,l)

\[ 16 < E < 350 \text{ GeV} \]

The observed sky map shows no evident pattern
The fluctuations of the observed positron ratio are described by using a spherical harmonic expansion

\[
\frac{r_e(b, l)}{\langle r_e \rangle} - 1 = \sum_{\ell=0}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m} Y_{\ell m}(\pi/2 - b, l)
\]

The amplitudes of spherical harmonic expansion are fitted to data for a given angular scale (\( \ell \))
The amplitudes are consistent with the hypothesis of isotropy at any angular scale ($\ell = 1, 2, 3$) and energy range.

**Dipole case ($\ell = 1$)**

Fitted results are used to derive an upper limit on the amplitude of a dipole anisotropy.

\[ \delta = 3 \sqrt{\frac{C_1}{4\pi}} \quad , \quad \text{with} \quad C_\ell = \frac{1}{2\ell + 1} \sum_{m=-\ell}^{\ell} a_{\ell m}^2 \]
Limit on the amplitude of a dipole anisotropy in galactic coordinates on the positron to electron ratio

\[ \delta \leq 0.030 \text{ at the 95\% confidence level for } 16 < E < 350 \text{ GeV} \]
Anisotropy on $e^+/e^-$: Projected sensitivity

In 10 years, AMS will reach a sensitivity of

$$\delta = 0.010 \text{ at } 95\% \text{ CL}$$

for a dipole anisotropy in the positron to electron ratio
Cosmic ray protons and light nuclei

1. Helium flux
2. Proton flux
3. B/C ratio
Helium Measurement with AMS

Rigidity, Direction and Charge Sign

Tracker

Bending Coordinate Resolution 6 to 7 μm

MDR (Z=2) ≈ 3.3 TV

Velocity and Direction

TOF

$\Delta \beta / \beta^2 (Z=2) \approx 2\%$

Charge Magnitude Along He Trajectory

TRD, Tracker, RICH, TOF, ECAL

$\Delta Z (Z=2) \approx 0.07-0.35$
Helium Selection

(I) Downgoing Particle $\beta > 0.3$

(II) Rigidity ($R$) Above Geomagnetic Cutoff ($R_C$)

$$R > 1.2R_C + 2\sigma(R_C)$$

(III) Charge Compatible with that of He along Particle Trajectory

For instance, for Inner Tracker $1.6 < Z < 2.6$

(IV) $\chi^2$ of the Particle Trajectory Fit < 10

Rejects 1-2 % Events over Rigidity Range, while Bulk of Events with mismeasured Rigidity
Helium Selection

200,000,000 He Events Selected By TRD and TOF

- Proton background: $< 10^{-5}$
- Main Remaining Background: Ions Interacting on Top of AMS $< 10^{-3}$
He flux measurement

\[ F(R) = \frac{N_{\text{obs.}}(R)}{T_{\text{exp.}}(R) A_{\text{eff.}}(R) \varepsilon_{\text{trig.}}(R) \, dR} \]

(For isotropic flux with \( \theta_{\text{zen}} < 20^\circ \))

- **F** : Absolute differential flux \( (m^{-2} \text{sr}^{-1} \text{s}^{-1} \text{GV}^{-1}) \)
- **R** : Measured rigidity \( (\text{GV}) \)
- **N_{\text{obs.}}** : Number of events after proton selection
- **T_{\text{exp.}}** : Exposure life time \( (\text{s}) \)
- **A_{\text{eff.}}** : Effective acceptance \( (m^2 \text{ sr}) \)
- **\varepsilon_{\text{trig.}}** : Trigger efficiency
- **dR** : Rigidity bin \( (\text{GV}) \)
### Systematic Errors

<table>
<thead>
<tr>
<th>Source</th>
<th>Efficiency(%)</th>
<th>Error(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Trigger</td>
<td>95-99</td>
<td>0.5</td>
</tr>
<tr>
<td>• Track and Velocity Fit</td>
<td>94-96</td>
<td>0.7</td>
</tr>
<tr>
<td>• Event Selection</td>
<td>~80</td>
<td>0.7</td>
</tr>
<tr>
<td>• Monte Carlo Statistics</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>• Total of The Above</td>
<td></td>
<td>1.3</td>
</tr>
</tbody>
</table>

#### Unfolding Errors

<table>
<thead>
<tr>
<th>Rigidity Range (GV)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;250</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>250-500</td>
<td>0.5-1.5</td>
</tr>
<tr>
<td>500-900</td>
<td>1.5-2.5</td>
</tr>
<tr>
<td>900-1400</td>
<td>2.5-4.5</td>
</tr>
<tr>
<td>1400-2000</td>
<td>6</td>
</tr>
<tr>
<td>2000-3000</td>
<td>10</td>
</tr>
</tbody>
</table>
Monte Carlo Helium Interactions Validation by Measuring He Charge Along Trajectory

Tracker layer 1 (ΔZ=0.15)
TRD (ΔZ=0.16)
Upper TOF (ΔZ=0.07)
Inner Tracker (layers 2-8) (ΔZ=0.08)
Low TOF (ΔZ=0.07)
RICH (ΔZ=0.30)
Tracker layer L9 (ΔZ=0.15)
ECAL (ΔZ=0.35)
Rigidity>20 GV, Events identified as He by Tight Cut Charge on Tracker layer 1

He multiple interactions: ~3% Uncertainty
Helium flux

Comparison with other measurements

He Flux (m² sr sec GV⁻¹ xR².7)

Rigidity (GV)

Comparison with other measurements

AMS-02 (2011-2013)
PAMELA (2006-2008)
CREAM-I (2004-2005)
ATIC-02 (2003)
BESS-Tev (2002)
BESS-98 (1998)
AMS-01 (1998)
CAPRICE (1998)
IMAX (1992)
Baloon (1991)
MASS-91 (1991)
Helium flux
Comparison with the latest measurements

Flux × Rigidity$^{2.7}$ (m$^2$ s sr GV$^{-1}$ GV$^{2.7}$)

AMS data (presented at ICRC-2013)
Proton flux – systematic errors

- Acceptance $\varepsilon_{\text{acc}} = 2.8\%$
- Trigger efficiency $\varepsilon_{\text{trg.}} = 1.0\%$
- Track reconstruction efficiency $\varepsilon_{\text{trk.}} = 1.0\%$
- Total systematic errors of normalization:
  \[ \varepsilon_{\text{norm.}} = \left( \varepsilon_{\text{acc}}^2 + \varepsilon_{\text{trg}}^2 + \varepsilon_{\text{trk}}^2 \right)^{1/2} = 3.1\% \]
- Systematic error of unfolding
  \[ \varepsilon_{\text{unfold}} < 1\% \text{ at } R < 200 \text{ GV} \]
  \[ \varepsilon_{\text{unfold}} = 5.4\% \text{ at } R = 1 \text{ TV} \]

Systematic errors will be reduced with more data.
Proton flux
Comparison with the other measurements
Daily proton flux

Stat. Error $< \sim 1\%$

$(1 < R < \sim 20 \text{ GV})$
Proton flux
Comparison with the most recent measurements

AMS data (presented at ICRC-2013)
Cosmic Ray spectra with $Z > 1$

**Boron**
- Rigidity = 24 GV

**Carbon**
- Rigidity = 24 GV

*AMS Event Display Run/Event 1326201809 / 798775 GMT Time 2012-010.13:44:11*

**AMS Event Display Run/Event 1329490720 / 473181 GMT Time 2012-048.15:17:38**
Selection of $Z > 1$ particles

- Efficiency is $> 98\%$.
- Contamination between neighboring charges $< 10^{-4}$
- The charge misidentification is negligible.
- Very small energy dependence
Event Sample Analysis

Charge measurements on the Tracker Layer 1 and on the TRD is used to study the composition of the selected sample.

Rigidity = 10.6 GV

- $Z_{TRK\_L1} = 6.1$ (Front)
- $Z_{TRD} = 6.0$ (Side)
- $Z_0 = 9.9$
- $Z_1 = 5.3$
- $Z_{TRK\_IN} = 4.8$
- $Z_{TOF\_LOW} = 5.2$
- $Z_{RICH} = 5.1$
Boron and Carbon: Sample composition

Background estimated to an accuracy of 0.1%.
Selection efficiency is >70% for both Boron and Carbon.

\[ \frac{\text{Eff}_B}{\text{Eff}_C} \approx 1. \]
Acceptance Determination

Monte Carlo simulation is used to determine the acceptance of Carbon selected with Tracker L1 and UTOF. Fragmentation distribution evaluated with LTOF (4th TOF Layer).

Agreement is at 2% level.
B/C Ratio

Summary of systematic errors

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

(b) < 2% from Top of the Instrument correction.

(c) 1% from isotopic composition evaluation.

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

B/C Ratio

Boron-to-Carbon Ratio

Kinetic Energy (GeV/n)

AMS-02
B/C Ratio: 10 years projection

Extended up to the TeV/nucleon region with a statistical error of less than 20% in additional bins between 670 and 1630 GeV/nucleon
AMS is a precision particle physics detector in space: we understand the systematic errors to $\sim 1\%$.

To reach $\sim 1\%$ statistical error will take some time to collect data.