Latest results from AMS: Positron fraction and antiproton ratio

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On behalf of the AMS Collaboration

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~85% of matter in the Universe is not visible and is called dark matter. Collision of “ordinary” Cosmic Rays produce e⁺, \(\bar{p}\)… Annihilation of Dark Matter (neutralinos, \(\chi\)) will produce additional e⁺, \(\bar{p}\).

To identify the signal of dark matter, we need to measure positrons and antiprotons with high precision to high energy.
AMS: A TeV precision, multipurpose spectrometer

Transition Radiation Detector
Identify $e^+$, $e^-$

Silicon Tracker
$Z$, $P$

Electromagnetic Calorimeter
$E$ of $e^+$, $e^-$

Particles and nuclei are defined by their charge ($Z$) and energy ($E$)

Time of Flight
$Z$, $E$

Magnet
$\pm Z$

Ring Imaging Cherenkov
$Z$, $E$

The Charge and Energy are measured independently by many detectors
TRD performance on the ISS

Typically, 1 in 1,000 protons may be misidentified as a positron

Proton rejection at 90% efficiency

TRD estimator = -ln(P_e/(P_e+P_p))

Electron
Proton

ε_e = 90%
ECAL Performance on the ISS

Typically, 1 in 10,000 protons may be misidentified as a positron
Event selection for the positron fraction analysis

- **Primary cosmic ray particle:**
  - $E > 1.2 \cdot \text{max cutoff}$

- **TRACKER:**
  - Track quality
  - Geometrical match with ECAL shower
  - $0.8 < |Z| < 1.4$

- **TRD:**
  - At least 15 hits

- **TOF:**
  - Down-going particle,
  - $\beta > 0.8$

- **ECAL:**
  - Shower axis within the ECAL fiducial volume
  - Electromagnetic shower shape

**Data sample:**
10.9 million of $e^\pm$ events are selected in the energy range 0.5–500 GeV
TRD Estimator shows clear separation between protons and positrons with a small charge confusion background.

\[ \chi^2/d.f. = 0.60 \]
# Systematic errors on the positron fraction $\text{Ne}^+ / (\text{Ne}^+ + \text{Ne}^-)$

1. Acceptance asymmetry
2. Selection dependence
3. Absolute energy scale and bin-to-bin migration
4. Reference spectra uncertainties
5. Charge confusion

<table>
<thead>
<tr>
<th>Energy [GeV]</th>
<th>$N_{e^b}$</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>$\sigma_{\text{syst.}}$</th>
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</thead>
<tbody>
<tr>
<td>74.30–80.00</td>
<td>450</td>
<td>0.0963</td>
<td>0.0047</td>
<td>0.0002</td>
<td>0.0010</td>
<td>0.0007</td>
<td>0.0002</td>
<td>0.0006</td>
<td>0.0014</td>
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<td>80.00–86.00</td>
<td>381</td>
<td>0.1034</td>
<td>0.0056</td>
<td>0.0002</td>
<td>0.0011</td>
<td>0.0007</td>
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<td>0.0015</td>
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<td>86.00–92.50</td>
<td>398</td>
<td>0.1207</td>
<td>0.0063</td>
<td>0.0002</td>
<td>0.0011</td>
<td>0.0007</td>
<td>0.0003</td>
<td>0.0009</td>
<td>0.0016</td>
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<td>92.50–100.0</td>
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<td>0.1169</td>
<td>0.0063</td>
<td>0.0002</td>
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<td>0.0003</td>
<td>0.0010</td>
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<td>100.0–115.1</td>
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<td>0.0002</td>
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<td>0.0004</td>
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<td>115.1–132.1</td>
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<td>0.0007</td>
<td>0.0005</td>
<td>0.0018</td>
<td>0.0026</td>
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<td>132.1–151.5</td>
<td>271</td>
<td>0.1327</td>
<td>0.0083</td>
<td>0.0002</td>
<td>0.0020</td>
<td>0.0007</td>
<td>0.0006</td>
<td>0.0024</td>
<td>0.0032</td>
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<td>151.5–173.5</td>
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<td>0.0023</td>
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<td>173.5–206.0</td>
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<td>0.0002</td>
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<tr>
<td>206.0–260.0</td>
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<td>0.0124</td>
<td>0.0003</td>
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<tr>
<td>260.0–350.0</td>
<td>135</td>
<td>0.1590</td>
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<td>0.0003</td>
<td>0.0045</td>
<td>0.0007</td>
<td>0.0015</td>
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<td>350.0–500.0</td>
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<td>0.0007</td>
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<td>0.0182</td>
<td>0.0194</td>
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</tbody>
</table>
Positron fraction based on 10.9 million events

![Graph showing positron fraction versus energy in GeV. The x-axis represents energy in GeV, ranging from 1 to 10^3, and the y-axis represents positron fraction, ranging from 0 to 0.2. The graph shows a trend where the positron fraction increases with energy.]
The energy at which positron fraction begins to increase

Positron fraction reaches minimum
The rate of increase with energy.
The non-existence of sharp structures.
The energy beyond which it ceases to increase.

Zero crossing $275 \pm 32$ GeV

Data

Fit $c \cdot \log(E/E_0)$
The expected rate at which it falls beyond the turning point.

In 10 years from now

MC simulation

275±32 GeV

m_χ = ~1 TeV

Collision of cosmic rays

Event selection for the $\bar{p}/p$ analysis

- **Primary cosmic ray particle:**
  - $|R| > 1.2 \cdot \text{max cutoff}$

- **TOF:**
  - Down-going particle
  - $\beta > 0.3$

- **TRD:**
  - at least 12 hits

- **TRACKER:**
  - Track quality
  - $0.8 < |Q| < 1.2$

- **ECAL:**
  - Hadron shower shape

**Data sample**

290,000 antiprotons are selected in the rigidity range 1–450 GV
Charge confusion estimator

BDT estimator:
10 variables based on
Track fit quality
Rigidity measurements
Charge measurements

$|R| > 100 \text{ GV}$
Antiproton identification

\[ \chi^2/\text{d.f.} = 44.6/38 \]

\(175 < |R| < 259 \) GV

Events vs. Charge confusion estimator

Data
- \( p \rightarrow \bar{p} \)
- \( \bar{p} \)
- Fit

\( p \rightarrow \bar{p} \)
AMS $\bar{p}/p$ results with 290,000 antiprotons
AMS $\bar{p}/p$ results

![Graph showing AMS $\bar{p}/p$ results with data points for AMS-02, PAMELA, and BESS. The x-axis represents rigidity (GV), and the y-axis represents $\bar{p}/p$ ratio on a logarithmic scale. The inset graph shows kinetic energy in GeV versus rigidity.](image-url)
AMS p/p results and the theoretic models

G. Giesen et. al., arXiv:1504.04276
Conclusions

1. Positron fraction is measured from 0.5 to 500 GeV:
   - Steadily increases from 10 to ~250 GeV;
   - At 275±32 GeV the fraction reaches its maximum;
   - Exact behavior of the positron fraction at high energies requires more statistics;

2. Antiproton analysis status is presented:
   - Rigidity range explored: 1–450 GV

New precision AMS measurements and model predictions with matching accuracy will uncover the underlying physics