Space based cosmic ray experiments:
highlights of recent results

Javier Berdugo. CIEMAT (Madrid)
Cosmic rays are a sample of solar, galactic and extragalactic matter which includes all known nuclei and their isotopes, as well as electrons, positrons and antiprotons.
Cosmic rays are a sample of solar, galactic and extragalactic matter which includes all known nuclei and their isotopes, as well as electrons, positrons and antiprotons.
Cosmic rays are a sample of solar, galactic and extragalactic matter which includes all known nuclei and their isotopes, as well as electrons, positrons and antiprotons. Understanding the origin, acceleration and propagation of CR require the knowledge of the chemical composition over a wide energy range.
Understanding the origin, acceleration and propagation of CR require the knowledge of the chemical composition over a wide energy range.
Electrons, Positrons constitute <1% of CR Particles

“Known source” of e+: collision of CR particles with ISM

Annihilation of Dark Matter, Pulsars, ... may produce additional e+, ...

Precision measurements of antiparticles can be obtained by experiments operating outside the atmosphere and capable to measure simultaneously the spectra of the different cosmic ray components.

- **PAMELA (Satellite):** Launched in June 2006
- **FERMI (Satellite):** Launched in June 2008
- **AMS-02 (ISS):** Launched in May 2011
Space based cosmic ray experiments: PAMELA

Launched on June 15th 2006

Acceptance: 21.5 cm$^2$ sr
Size: 1.3m x 0.7m x 0.7 m

Space based cosmic ray experiments: PAMELA


Electron flux


Electron flux

Space based cosmic ray experiments: Fermi

Launched on June 11, 2008

Image credit: NASA/Jerry Cannon, Robert Murray
Space based cosmic ray experiments: Fermi

Fermi Gamma-ray Space Telescope: Gamma-ray astronomy

The First Fermi-LAT Catalog of Sources Above 10 GeV
Space based cosmic ray experiments: FERMI

![Graphs showing data on energy and positron fraction](image_url)

Space based cosmic ray experiments: AMS-02
Selection of $Z > 1$ particles

Redundant measurements of the charge $Z$ of the particle
TRD, Tracker, RICH, TOF, ECAL

ISS Data

08/07/2014
AMS capability to measure electrons and positrons

**e/p Identification**

**TRD**
(radiation shape)

**ECAL/Tracker**
(E/p matching)

**ECAL**
(shower shape)
AMS capability to measure electrons and positrons

**e/p Identification**

**TRD**
(radiation shape)

**ECAL/Tracker**
(E/p matching)

**ECAL**
(shower shape)
Ground Tests and Calibrations

Space Qualification (EMI and TV at ESTEC)

TVT Chamber: $P < 10^{-9}$ bar
Ambient temperature: -90°C to 40°C

Test Beam at CERN (Calibration)

1,762 positions and angles with $p$, $e^+$, $e^-$, pion beams from 10 to 400 GeV/c
Lepton’s Energy measurement: ECAL

3-dimensional measurement of the directions and energies of electrons and photons

50,000 fibers, $\phi = 1$ mm distributed uniformly inside 600 kg of lead

Lead foil
(1 mm)

Fibers
($\phi$ 1 mm)

Test beams at CERN

Energy Resolution

\[ \sqrt{\left(\frac{10.4}{E}\right)^2 + (1.4)^2} \]

Test beams at CERN

\[ \sqrt{\left(\frac{5.8}{E}\right)^2 + (0.23)^2} \]
Since May 19, 2011 AMS has collected 50 billion events
All subsystems are operational
Recent results from AMS: electrons and positrons

ICHEP 2014. Valencia (Spain)
Ms. Maura Grazziani, Dr. Valerio Vigelli, Dr. Zhili Weng

Results based on the analysis of 30 months of data
Lepton Event Count

ISS Data, 20-100 GeV

Electromagnetic-like

Hadronic-like

08/07/2014
Lepton Charge identification

ISS Data, 20-100 GeV

ECAL BDT vs. Q(±1) TRD Estimator

Number of Events

08/07/2014
AMS 2013 positron fraction

Latest AMS Results: Positron Fraction

- AMS 2014
- PAMELA
- Fermi

0.5 GeV – 500 GeV
10.9 million positron-electron events

0.5 GeV – 350 GeV
6.8 million positron-electron events
Positron Fraction compared with Minimal Model

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

\[ E_S = 0.54^{+0.25}_{-0.13} \text{TeV} \]
AMS Results: Positron Flux

Event Sample: ~ 0.58 million $e^+$ events

Energy Range: 0.5 GeV to 500 GeV
AMS Results: Electron Flux

Event Sample: ~ 9.23 million $e^-$ events

Energy Range: 0.5 GeV to 700 GeV
Positron and Electron fluxes compared with Minimal Model

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

AMS-02 Positron Flux

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

AMS-02 Electron Flux
On the origin of excess positrons

Arrival direction of every electron and positron event is compared with Exposure map.

Data on ISS, Electron, $E > 25$ GeV

Exposure map, $E > 25$ GeV

Arrival directions of electrons and positrons are found to be consistent with isotropy.

$\delta \leq 0.030$ at the 95% CL for positrons above 16 GeV.
AMS Results: \((e^+ + e^-)\) flux

Event Sample: \(~ 10.5\) million \(e^\pm\) events

Energy Range: \(0.5\) GeV to \(1\) TeV
During the life time of ISS, AMS experiment expects to obtain 300 billion events.
The Space Station has become a unique platform for precision physics research.