Precision measurement of the $e^-$, $e^+$, $e^+e^-$ fluxes with AMS

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A precision, multipurpose, up to TeV spectrometer

Z, P are measured independently by the Tracker, RICH, TOF and ECAL

TRD
Identify e⁺, e⁻

Silicon Tracker
Z, P

TRD

TOF

RICH

ECAL

Magnet
±Z

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Matteo Duranti - The 34th International Cosmic Ray Conference (ICRC)
Detectors involved: TRD

TRD classifier = -log10\(P_e\)-2
Detectors involved: Tracker/ECAL

- Energy / | Rigidity |

- Protons
- Electrons

Normalized Entries
Detectors involved: ECAL

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

![Diagram of detectors: ECAL, TRD, TOF, Tracker, RICH](image)
Detectors involved: ECAL

Test Beam Electrons

ECAL Reconstructed Energy (GeV)

Normalized Entries
Detectors involved: ECAL

Boosted Decision Tree, BDT:
19 variables describing
3D shower shape combined
(*) details on how the charge-confusion is identified (TOF, Tracker, …) and determined from data in the next talk by Dr. A. Kounine
Data analysis
Reference spectra for the signal and the background are fitted to data as a function of the TRD classifier for different cuts on the ECAL BDT estimator.

Measurement is performed for the cut on the ECAL classifier that minimizes the overall statistical + systematic uncertainty ($\epsilon_{\text{BDT}}$).
Stability of the signal ($e^+e^-$)

Dominating systematic uncertainties on $N_{e^+e^-}$

- Knowledge of the TRD reference distributions
- Stability of the fit result for different background levels, e.g. ECAL classifier cuts

The analysis was repeated 2000 times in each energy bin varying the ECAL classifier cut and different values of selection cuts used to construct the templates. The stability of the results verified within a 5% window in ECAL classifier cut efficiency.
The RMS of the $N_{e^+e^-}$ has been used as systematics uncertainty. The effect of purely statistical contributions were taken into account and subtracted estimated from a dedicated simulation.

Negligible contribution to the measurement error below $\approx 200$ GeV
Dominant source of systematic error at higher energies ($> 500$ GeV)
The flux measurement:

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

\[ \Phi \quad = \text{Absolute differential flux (m}^{-2} \text{sr}^{-1} \text{GeV}^{-1}) \]
\[ N_{obs} \quad = \text{Number of observed events} \]
\[ \Delta T_{exp} \quad = \text{Exposure time (s)} \]
\[ A_{eff} \quad = \text{Effective acceptance (m}^{2} \text{sr}) \]
\[ E_{\text{trig}} \quad = \text{Trigger efficiency} \]
The detector acceptance has been obtained using a dedicated MC simulation.

Data driven correction evaluated from the comparison of each selection cut efficiency on ISS data and MC sample.

- Data/MC ratio on all cuts used to evaluate $\delta$
- The tiny deviation from unity contributes to the measurement systematic uncertainty

$A_{geom} \sim 550 \text{ cm}^2 \text{sr}$

$A_{eff} = A_{geom} \varepsilon_{sel}(1 + \delta)$
Results
Electron and positron fluxes (PRL 113, 121102 - 2014)

Electron and Positron Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station

Electrons

Positrons
1. Electron flux and the positron flux are significantly different in their magnitude and energy dependence.
2. Both spectra cannot be described by single power laws in the whole energy range.
3. The spectral indices of electrons and positrons are different.
4. Both change their behavior at ~30 GeV.
5. The rise in the positron fraction from 20 GeV is due to an excess of positrons, not the loss of electrons (the positron flux is harder).
Precision Measurement of the \((e^+ + e^-)\) Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the Alpha Magnetic Spectrometer on the International Space Station
The flux:

- is smooth and show no structures
- cannot be described by a single power law in the whole energy range
- is consistent with a single power law above ~30 GeV

\[ \gamma = -3.170 \pm 0.008 \text{ (stat + syst.)} \pm 0.008 \text{ (energy scale)} \]
…next step
Conclusions

- $e^+$ flux has been measured up to 500 GeV
- $e^-$ flux has been measured up to 700 GeV
- $e^+e^-$ flux has been measured up to 1 TeV

- The data show very interesting features and will surely allow very deep phenomenological and theoretical studies

- Next step is to extend the energy range and further reduce the systematics