PROCEEDINGS OF SCIENCE

Measurement of cosmic-ray positron fraction and lepton fluxes with AMS

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The AMS-02 detector is a particle detector mounted on the International Space Station (ISS) since May 2011. During the first three years of operation, more than 50 billion events have been collected, which allows a precise measurement of cosmic-ray particle fluxes. In this contribution, the latest measurements of the positron fraction up to 500 GeV, the electron flux up to 700 GeV, the positron flux up to 500 GeV and the $e^{+}+e^{-}$ flux up to 1 TeV are presented.

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1. Introduction

Cosmic rays detected near earth consist of 88% protons, 10% helium, 1% heavy nuclei (Z>2) and 1% electrons and positrons (Figure 1). Through unprecedented precision measurement of cosmic-ray particle fluxes, AMS searches for primordial anti-matter and for indirect evidence of dark matter; it may bring to light individual astrophysical sources and will refine propagation models.

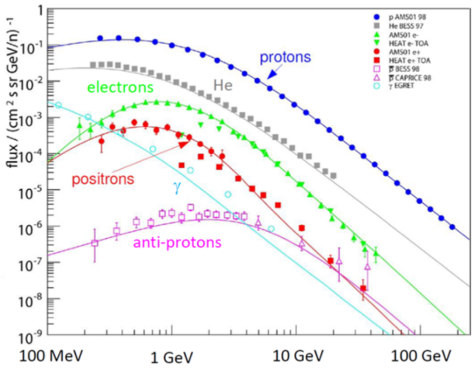

Figure 1: Fluxes of protons measured by AMS-01 (blue), helium by HESS 97 (grey), electrons by AMS-01 and HEAT (green), positrons by AMS-02 and HEAT (red), photons by EGRET (cyan) and anti-protons by BESS and CAPRICE (magenta) (Reference [1]).

In this contribution, first the AMS detector is shortly described. Then before presenting several results on cosmic ray positrons and electrons, proton rejection methods and charge confusion estimation in AMS are reviewed.

2. The AMS-02 detector

The AMS-02 is a 64 cubic meters and weighs 8.5 tons multi-purpose particle detector on the ISS. It consists of:

- A Transition Radiation Detector (**TRD**) for separation of electrons and protons
- A Time of Flight (**TOF**) system which triggers the data acquisition for charged particles and measures their velocity and charge detection
- **Silicon Tracker** surrounded by a permanent dipole magnet of 0.14 Tesla to measure the rigidity and the sign of charged particles, as well as charge by using dE/dx information in the 9 layers
- A Ring Imaging CHerenkov detector (**RICH**) that measures the particle velocity and charge with high accuracy
- An Electromagnetic CALorimeter (**ECAL**) located at the bottom of the detector for energy measurement for electromagnetic particles, electron/proton separation and electron/photon trigger

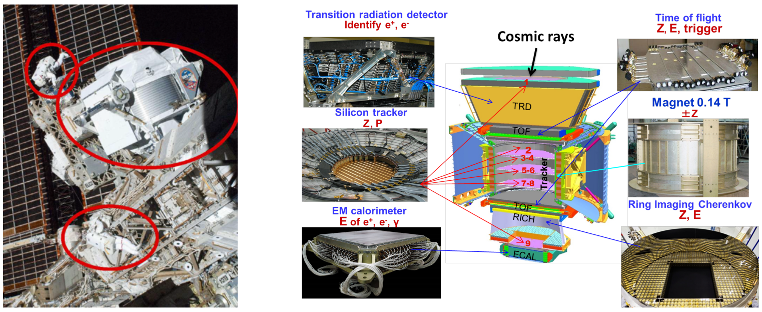

Figure 2: Left: AMS on the ISS with 2 astronauts. Right: the sub-detectors of AMS-02 and their functions.

3. Lepton identification

Leptons are efficiently identified by the TRD estimator, a likelihood based on the signal amplitude in each layer of TRD, the ECAL estimator, a boosted decision tree (BDT) relying on the 3D shower shape (Reference [2]) and the variable E/P, energy measured by ECAL over momentum measured by Tracker. The separation power of the first two estimators are illustrated in Figure 3 as well as a clean event display of electron detected at 1.03 TeV. Combining the information from TRD, Tracker and ECAL, the proton rejection of AMS reaches more than 10^5 up to 500 GeV.

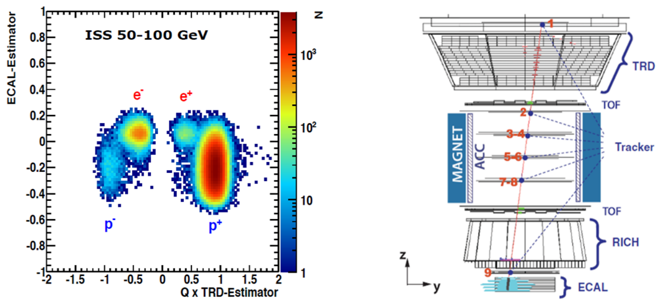

Figure 3: Left: 2D distribution of $Q\times$TRD (X) and ECAL (Y) estimators where positrons, electrons, antiprotons and protons are well separated. Righht: electron event display at 1.03 TeV (right).

Counting the number of leptons can be performed on either TRD or ECAL estimator. Lepton numbers are extracted from fitting the data with electron and proton templates obtained from data. Fit examples are given in Figure 4. The electron and positron numbers are obtained by respectively fitting on the negative and positive samples and then corrected for the charge confusion.

4. Charge confusion estimation

Two approaches exist for the charge confusion estimation: get the charge confusion from Monte Carlo data and then correct the fitted electron or positron number, or simultaneously fit the charge confused and non-confused numbers with a dedicated estimator. For the latter method, a BDT using Tracker information was developed (Reference [3]). Good agreement between the two methods, data estimation and Monte Carlo prediction, is observed as shown in Figure 5.

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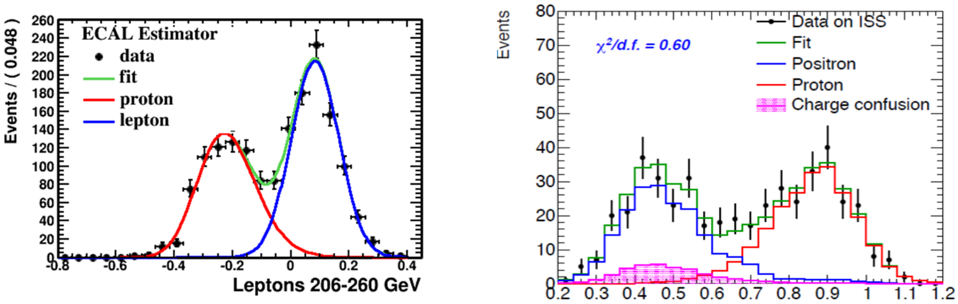

Figure 4: Examples of template fits on the lepton sample with the ECAL estimator (left) and on the positron sample with the TRD estimator (right), electrons in green and protons in red. Pink shade in the positron sample represents the charge confused electrons.

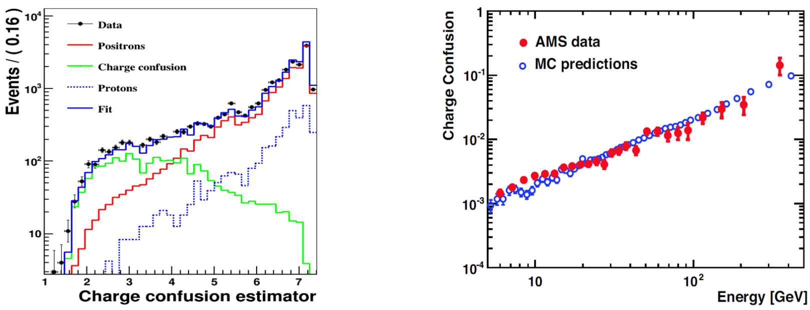

Figure 5: Left: example of positron fit on the charge confusion BDT: together with a lepton/proton estimator, the numbers of positrons (red), charge confused electrons (green) and background protons (dashed blue) are simultaneously obtained. Right: comparison of charge confusion estimated by the ISS data (red) and Monte Carlo (blue).

5. Positron fraction measurement

The positron fraction is the ratio of the positron flux over the positron plus electron flux, which is simplified into the number counting of positrons and leptons, $\frac{N_{e+}}{N_{e+}+N_{e-}}$. The latest measurement with 30 months of data is extended to 500 GeV with an improved accuracy compared to AMS first result published in 2013 (Reference [4]). A steady rise from 10 GeV is confirmed. From 275 ± 32 GeV, the positron fraction no longer exhibits an increase with energy. The uncertainty of the last point, 350 - 500 GeV, is still dominated by statistics with 72 positrons observed. With more data collecting, the uncertainty is expected to be reduced.

6. Flux measurements

The lepton flux at the energy E, Φ_e(E) is defined by

$$\Phi_e(E) = \frac{N_e(E)}{A_{eff}(E) \times corr_{data/MC}(E) \times \varepsilon_{trig.}(E) \times T_{expo}(E) \times \Delta E} \tag{6.1}$$

where N_e is the number of leptons or positrons or electrons, A_{eff} the effective acceptance, $corr_{data/MC}$ the efficiency correction Data/MC, $\varepsilon_{trig.}$ the trigger efficiency, T_{expo} the exposure time and ΔE the

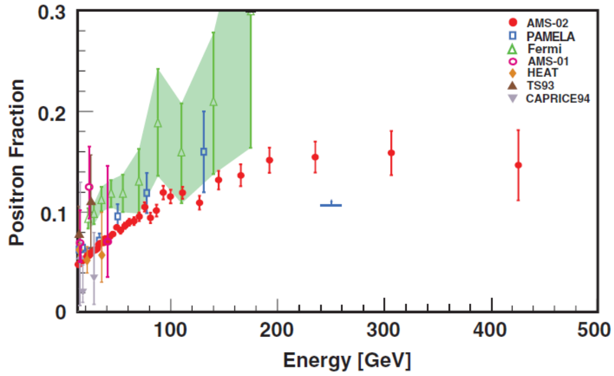

Figure 6: Positron fraction result from AMS-02 (red) compared with PAMELA (blue), Fermi-LAT (green band) and other experiments. (Reference [5])

energy bin width. The acceptance is estimated with Monte Carlo and corrected for the discrepancy between simulation and data. The trigger efficiency and the exposure time are measured with the ISS data (Figure 7).

The results of AMS electron and positron fluxes are presented in Figure 8. Though different in

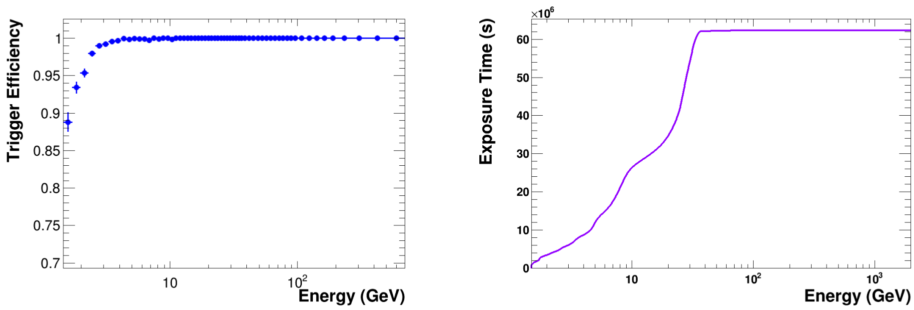

Figure 7: Trigger efficiency (left) and exposure time (right).

magnitude and energy dependence, none of them can be described by a single power law.

The lepton flux is measured up to 1 TeV energy range in Figure 9, smooth and no sharp structure observed. The systematic uncertainty is lower compared to separate fluxes partly owing to the fact that the charge confusion is not involved in the lepton measurement.

7. Conclusions

AMS has been performing smoothly on the ISS over the last three years. 30 months data have been analyzed yielding 11 million positrons and electrons. The combination of the TRD and ECAL estimators achieves a proton rejection of 10^5 which allows reliable measurement of the cosmic ray positrons and electrons. The positron fraction and positron flux are measured up to 500 GeV, the electron flux up to 700 GeV and the lepton flux to 1 TeV.

References

[1] F. Barao, IST/LIP, IDPASC(Annecy, 2013), talk: *Cosmic Rays observations near earth.*

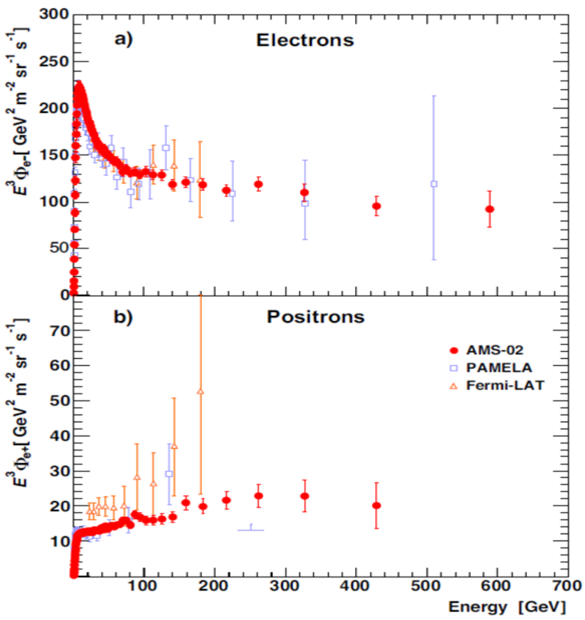

Figure 8: AMS electron (upper) and positron (lower) fluxes multiplied by E^3 in red, compared with results from PAMELA and Fermi-LAT (Reference [6]).

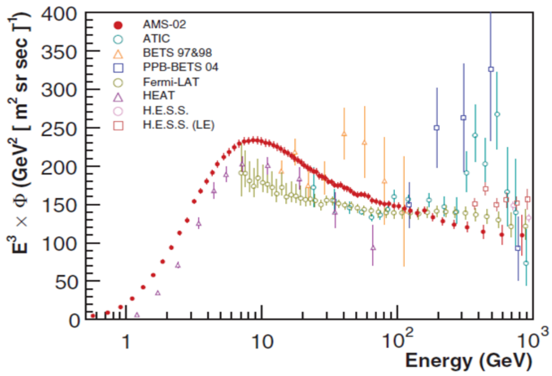

Figure 9: $e^+ + e^-$ flux multiplied by E^3, AMS in red compared with the results from other experiments. (Reference [7])

[2] L. Basara, LAPP, PhD thesis (2014) *Performance of the electromagnetic calorimeter of the AMS-02 experiment on the International Space Station and measurement of the positron fraction in the 1.5-350 GeV energy range*

[3] C. Goy et al., LAPP, AMS note 2014-11-01, *Lepton/proton separation, positron fraction and lepton fluxes with the ECAL based estimator ESE. A description of the analysis tools.*

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[5] AMS collaboration, Phys. Rev. Lett. 113, 121101 (2014).

[6] AMS collaboration, Phys. Rev. Lett. 113, 121102 (2014)

[7] AMS collaboration, Phys. Rev. Lett. 113, 221102 (2014)