Measurement of the electron and lepton fluxes with the AMS

Thesis by

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Acknowledgments

Abstract

In this thesis I describe my work in the Alpha Magnetic Spectrometer (AMS) experiment at the International Space Station (ISS).

In part I of this thesis, I perform a measurement of the electron flux with the electromagnetic calorimeter of AMS.

In part II of this thesis, I perform a energy control by using the geomagnetic cutoff.

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Part II

AMS Detector

AMS-02 is a particle detector mounted on the upper Payload Attach Point(S3) on the main truss of ISS, which orbits the Earth at an altitude of about 300 km. AMS-02 studies with an unprecedented accuracy of the cosmic ray particles, such as $e^{\pm}$, γ, $\bar{p}$, $\bar{D}$ and nuclei from H to Fe. The objectives of AMS-02 include search for primordial antimatter and evidence of dark matter by measuring $\bar{H}e$, anti-proton and positron. By measuring the ratio $\bar{p}/p$ and B/C, AMS can refine the propagation models. A particle is identified by its properties such as charge and energy. The design of AMS detector assures redundant and independent measurements of such properties.

Chapter 1

AMS sub-detectors

AMS-02 has five sub-detectors. They are

1.1 Transition Radiation Detector

1.2 Time of Flight

1.3 Silicon Tracker and Magnetic Field

1.4 Ring Imaging Cherenkov Detector

1.5 Electromagnetic Calorimeter

1.6 Particle identification

Chapter 2

Performance of ECAL

Chapter 3

AMS trigger system

Among the sub-detectors presented above, ToF and ECAL have independent trigger systems [1]. They can generate fast triggers for precise timing measurement.The time required for fast trigger decision is 40ns. The fast triggers FTC and FTZ, respectively designed for charged particle and big Z particle, are generated by ToF; the fast trigger FTE, specially designed for neutral particle detection, is generated by ECAL.

An event is registered if the particle satisfies one of the triggers. For ISS data, the trigger rate is about 500 events per second. And after 1 year's operation, 17 billion events are registered by AMS-02.

Part III

Calibration of ECAL

Chapter 1

Energy control

1.1 E/E_{beam} with test beam

1.2 E/P control Test Beam vs Data

Chapter 2

Energy control at low energy with geomagnetic cutoff

Part IV

Electron flux measurement with AMS

Chapter 1

Data analysis of flux measurement

The electron flux is by definition...

In this analysis, 29 months of data up to November 2013 are used. Monte Carlo electron is the current version B620dev. The electron sample is got by applying cuts on TRD, ToF and tracker; the electron number is counted with template-fit method on an ECAL estimator.

1.1 Electron identification and number counting

Electron identification is the process to reject protons and helium in the data sample. The most efficient identification method is using ECAL and TRD. Some additional cuts on the ToF and Tracker also help to clean the sample and guarantee the data quality.

In this analysis, the electron number is counted with template fit method on the EcalStandaloneEstimatorV3 (ESEV3) variable, which is an ECAL standalone estimator for electrons and protons. The sample on which the fit is performed is preselected with TRD estimator.

1.1.1 Preselection

With the preselection, the events badly reconstructed are rejected. The cuts for preselection is

- Live time greater than 0.5
- At least 1 shower in the ECAL
- At least 1 track in the tracker
- TRD estimator correctly calculated

- Reconstructed energy greater than the rigidity of geomagnetic cutoff:

1.1.2 Electron selection

The electron selection is divided into two categories: ECAL selection and tracker related selection.

1.1.2.1 ECAL selection

The ECAL selection includes two basic cuts on the ECAL shower: fiducial volume and number of showers.

Fiducial volume: The showers who fall at the border of the ECAL are often pooly reconstructed, which will lead to important energy migration and lepton misidentification. A fiducial volume cut is applied on ECAL to minimize such negative effects.

Number of showers: For an event who has more than one shower in the ECAL, the most energetic shower is selected for the analysis. However, when more than 2 showers are present, the reconstructed energy accuracy as well as lepton identification is great reduced. So in this analysis, it is required that the number of showers is smaller than 2.

1.1.2.2 ToF-Tracker selection

The ToF-Tracker selection consists of 6 cuts on the ToF and Tracker related variables.

BetaH: BetaH is the velocity measured by ToF. With a cut BetaH¿0.8, particles coming from the bottom as well as slow particles which are not lepton-like can be efficiently removed.

Single track: The number of tracker track is required to be one and only. This helps to improve the data quality and remove the interacting protons.

Tracker-ECAL matching: The match between tracker extrapolation and ECAL shower entry is asked to be within 3cm in X direction and 5cm in Y.

Energy-rigidity matching(EoP): In this analysis, two cuts related to EoP are applied: $E_{dep}/Rig >$ 0.6 and $E_{rec}/Rig < 10$, where E_{dep} is the deposited energy in the ECAL, Rig the rigidity measured by the Tracker and E_{rec} the reconstructed energy in the ECAL. The first cut gets rid of the protons and the second one removes the bad tracks.
For a lepton who has an electromagnetic shower, the ECAL energy is very close to the particle's true energy. So the ratio $Energy/Rigidity$ is close to 1.

Inner Tracker charge: Inner tracker charge is the electronic charge measured by the inner layers of the tracker. A cut at $Q_{tracker}$ <1.5 is used to get rid of helium in the data sample. Inner instead of max span is to avoid the interactions on the external layers and back splash from the ECAL.

1.1.3 Template fit and lepton numbers

After the above electron selection, the survived events are of good quality and electron-like. However, there still remains some protons. To remove the protons in the sample, the template fit method on ESEV3 is used.

1.1.3.1 Templates from data

The electron and proton templates are selected from data by the TRD likelihoodRatio.

1.1.3.2 Fit procedure for different energies

1.1.3.3 Fit on TRD likelihoodratio

1.2 Charge confusion estimation

1.2.1 Charge confusion from MC

1.2.2 Electron number corrected from charge confusion

1.2.3 Charge confusion estimator (Tracker BDT)

1.3 Trigger efficiency study

1.4 Exposure time measurement

1.5 Acceptance and selection efficiency estimation

1.5.1 Acceptance of the detector

1.5.2 Selection efficiency

1.5.2.1 Electron selection efficiency from MC

1.5.2.2 TRD likelihoodRatio cut efficiency

1.5.3 Data-MC efficiency correction

1.6 Unfolding of the electron rate

1.7 Systematic uncertainties in flux measurement

The systematic uncertainties in the flux measurement include the uncertainties in the cut efficiency Data-MC correction as mentioned in 1.5.3, the cutoff rigidity in 1.1.1 and the unfolding procedure in 1.6. The total systematic uncertainties σ_{syst} are calculated by

$$\sigma_{syst} = \sqrt{\sigma_{sel}^2 + \sigma_{cf}^2 + \sigma_{unf}^2} \tag{1.1}$$

1.7.1 Data-MC correction systematics

The systematics in electron selection are combined in two levels: preselection level and selection level. Similar to the procedures described in 1.5.3, different control samples are studied.

1.7.1.1 Systematics in preselection efficiency correction

1.7.1.2 Systematics in electron selection efficiency correction

1.7.2 Trigger efficiency systematics

1.7.3 Rigidity of cutoff systematics

The systematics in the $R_c f$ cut are studied by changing threshold of the safety factor.

1.7.4 Unfolding systematics

Chapter 2

Results

2.1 Lepton flux

2.2 Electron flux

2.3 Consistency checks

The consistency of the flux measurement is checked with three methods by varying the selection, flux binning and fit techniques.

2.3.1 Different selection

2.3.2 Different binning

2.3.3 Fit techniques

Chapter 3

Interpretation

Bibliography

[1] C. LIN, "Trigger logic design specification," Tech. Rep. AMS-JT-JLV1-LOGIC-R02c, NCU, 2005.