Signal Efficiency and Background Rejection Analysis of Photon Reconstruction In Calorimetric Mode Using AMS-02

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Abstract - Photon reconstruction efficiency and background rejection of Alpha Magnetic Spectrometer - 02 (AMS-02) are studied using Monte Carlo generated events. An event selection algorithm using the Time of Flight (TOF) signals is applied. A cut-based signal efficiency of 88% is achieved, while the proton background rejection is $8.4 * 10^4$.

AMS-02 is an astro-particle physics experiment that was installed on the International Space Station on 19^{th} of May, 2011. It is a large acceptance magnetic spectrometer designed to measure the cosmic ray spectrum. Recent studies of AMS-02 data[1] shows an excess of the cosmic positron electron fraction, which may be due to dark matter self annihilation. The study of cosmic high energy photons has the potential of independently probing the dark sector by revealing possible line structures in the cosmic high energy photon spectrum.

AMS-02 consists of several subdetectors that independently measure the particle properties[1]. Particle momentum and sign of charge are determined by fitting the tracker hits. The magnitude of the particle charge is reconstructed from the energy deposition of the clusters. The Transition Radiation Detector (TRD) measures the transition radiation as well as energy deposition from the primary particle. Therefore it can distinguish highly relativistic particles, i. e., positrons, from relatively less relativistic particles such as protons. The electromagnetic calorimeter (ECAL) measures the shower energy and participates in the positron-proton separation. The time of flight (TOF) is a pair of scintillator planes producing the fast trigger for the detector. Ring Imaging Cherenkov detector measures the velocity and the magnitude of the charge of the particle. Lastly the Anti Coincidence Counter (ACC) vetos particles that pass through the lateral sides of the detector. A schematic of the detector showing a photon shower in the calorimeter is given in Figure 1.

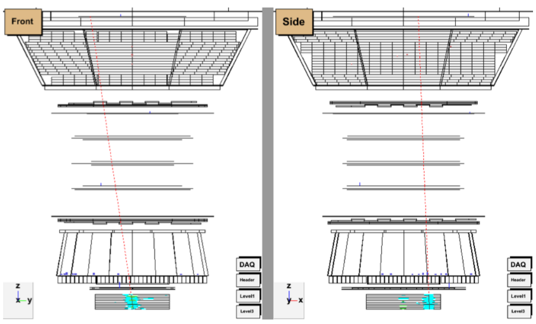

FIG. 1: Side and front views of an event display of AMS-02. A down-going photon is shown leaving a shower in the ECAL.

There are two orthogonal methodologies for reconstructing photons using AMS-02. In pair conversion mode the photon produces an e^-/e^+ pair whose tracks can be reconstructed in the tracker. Unlike the former, in calorimetric mode, the photon leaves an electromagnetic shower in the calorimeter. However some up-going backscattered particles are also produced, which may saturate the RICH PMTs, leave signals on tracker layers, TOF or the ACC paddles. Therefore simply requiring an absence of hits in these detectors reduces the selection efficiency.

Events in which there are backscattered particles can be recovered by using the relative timing of signals on the TOF layers. In the case of a backscatter the TOF clusters in the lower TOF layers are *earlier* in time than the TOF clusters in the upper TOF layers. Therefore the maximum time interval among the pairs in the upper and lower TOF

$$\Delta t = max(t^i_{lower} - t^i_{upper}) \tag{1}$$

indicates whether a down-going charged particle crosses the TOF system. In a photon shower Δt peaks approximately at -4 ns since there are only up-going charged particles. This is in contrast to events with a down-going charged particle, where the distribution peaks at +4 ns. The distribution of Δt values is shown in Figure 2. The behavior of photon (red), proton (green) and electron (blue) Monte Carlo events is compared to that of data shown with black dots.

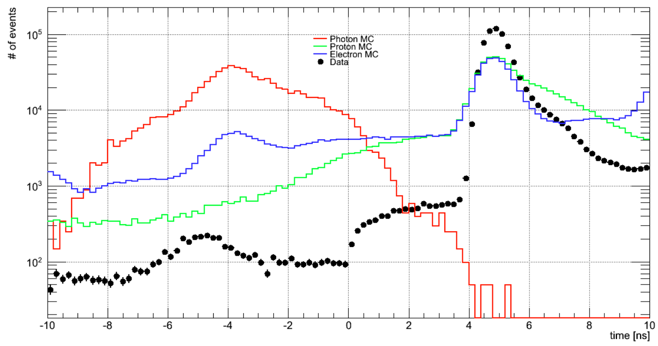

FIG. 2: Distribution of the maximum time differences among TOF cluster pairs in upper and lower TOF layers

Efficiency and background rejection of the algorithm are studied using Monte Carlo generated events. Selecting photon Monte Carlo events by requiring

$$-6.5ns < \Delta t < -1.5ns \tag{2}$$

results in a selection efficiency of $\eta_\gamma = 88\%$ for generation energies between 10 GeV and 100 GeV. When the same criterion is applied on the proton Monte Carlo events on average one background event out of $8.4 * 10^4$ is accepted.

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[1] M. Aguilar et al. (AMS Collaboration). First results from Alpha Magnetic Spectrometer on the International Space Station: Precision measurement of the positron fraction in primary cosmic rays of 0.5 350 GeV. (2013). Physical Review Letters, 110(14)