AMS as a photon detector - Emre Ergecen

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Alpha Magnetic Spectrometer 02 (AMS-02) is an astro-particle physics experiment that was installed on the International Space Station (ISS) on 19th of May, 2011. It is a large acceptance magnetic spectrometer designed to measure the cosmic ray spectrum.

Cosmic rays are stable particles that impinge on the earth's atmosphere from outer space. Most of the particles are protons and alpha particles, while the rest consists mainly of heavy nuclei, electrons, positrons, anti-protons and photons. The main purpose of AMS experiment is to probe into high energy astrophysics phenomena which we are not aware of, such as dark matter.

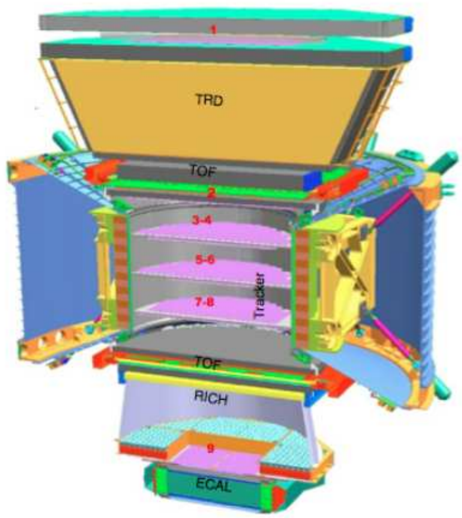

Figure 1 - AMS Detector and its Subdetectors

ECAL (Electromagnetic Calorimeter) can be used to measure the photon flux and the photon spectrum up to 1 TeV, since it has a length of 17 radiation length. ECAL has 18 layers. Therefore, AMS is a perfect detector to detect any high energy gamma rays which can be coming from a distant astrophysical source or from dark matter annihilation into two photons.

AMS is a versatile detector and can be triggered by any kind of particle, such as protons, photons, electrons and positrons. To use AMS as a photon detector, background should be totally eliminated before getting the spectrum, because other charged particles can leave traces in ECAL. My main job during this summer period is to develop efficient algorithms to eliminate background efficiently.

Since photon is not a charged particle, it cannot leave any track on the tracker, any hits on the TRD. By eliminating those events, we can get rid of background comprised of charged particles. However, there can be charged particles which can reach to ECAL without making any track on the tracker and any hits on TRD. That is why we need to employ new methods to get rid of charged particle background mostly comprised of protons which are abundant in the universe.

Both protons and photons interact with the calorimeter, but the way they interact is quite different from each other.

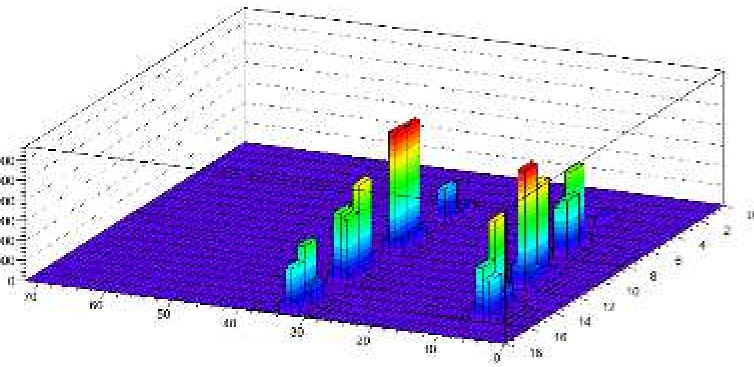

Figure 2 - Photon Shower (Courtesy of Tansu Daylan)

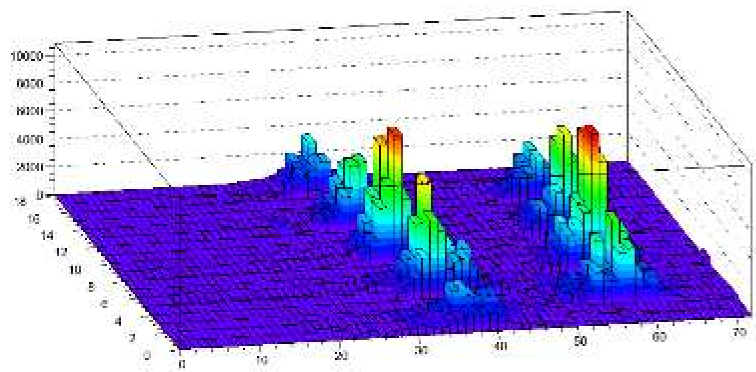

Figure 3 - Proton Shower (Courtesy of Tansu Daylan)

The main differences between the hadronic and electromagnetic showers are the lateral and longitudunal evolution of a shower. Photons start to interact with the detector after traversing the detector, whereas protons interact immediately with the material due to the cross section of nuclear interactions. On the other hand, since protons make hard interaction with ECAL, proton showers have more lateral dispersion. These parameters can be used to distinguish photons from protons.

There are two main parameters describing the lateral and the longitudinal shower evolution. In each layer we can measure the maximum energy deposition and divide it to the total layer energy (MaxEdepRatio). This parameter will give us the lateral evolution of the shower, whereas the z coordinate of Center of Gravity (CoG) gives us the information about longitudinal evolution. Center of gravity is similar to the center of mass, but here instead of mass we are weighting every hit location with its energy and get the weighted mean. In protonic showers, center of gravity is much close to the entry point of the shower to ECAL. Also, the MaxEdepRatio in protonic showers are much less when compared to that of electromagnetic showers.

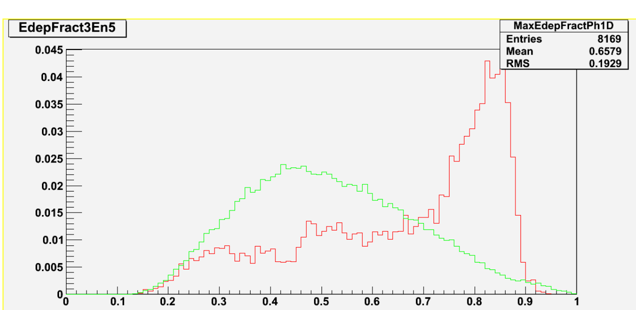

Figure 4 - MaxEdepRatio for layer 5 (red for photons, green for protons - X axis: MaxEdepRatio, Y axis: Normal-

ized event number)

By using these two methods, we can eliminate background protons which reach to the ECAL. This background elimination process can be extended further by adding other discriminating variables. These discriminating variables will improve the background rejection. These discriminating variables can be lateral shower dispersion, kurtosis and dispersion of z coordinate of Center of Gravity.

Lateral shower dispersion is the second moment of the hit distribution weighted by the energy of each hit. This value is calculated for each layer and yields the dispersion of the hit distribution from the CoG in each layer. For hadronic showers, one expects to get higher dispersion value than that of electromagnetic showers.

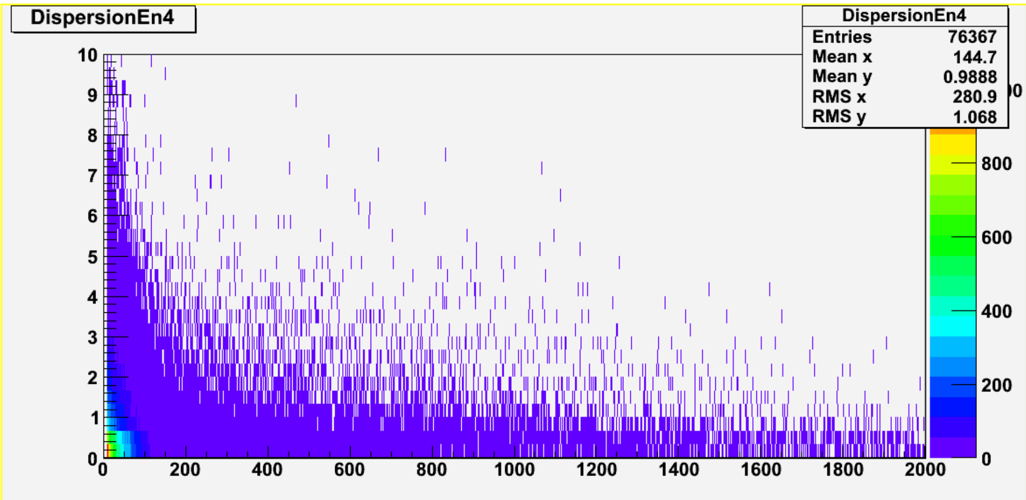

Figure 5 - Reconstructed shower energy (GeV) vs dispersion plot for protons for the hit distribution in layer 4

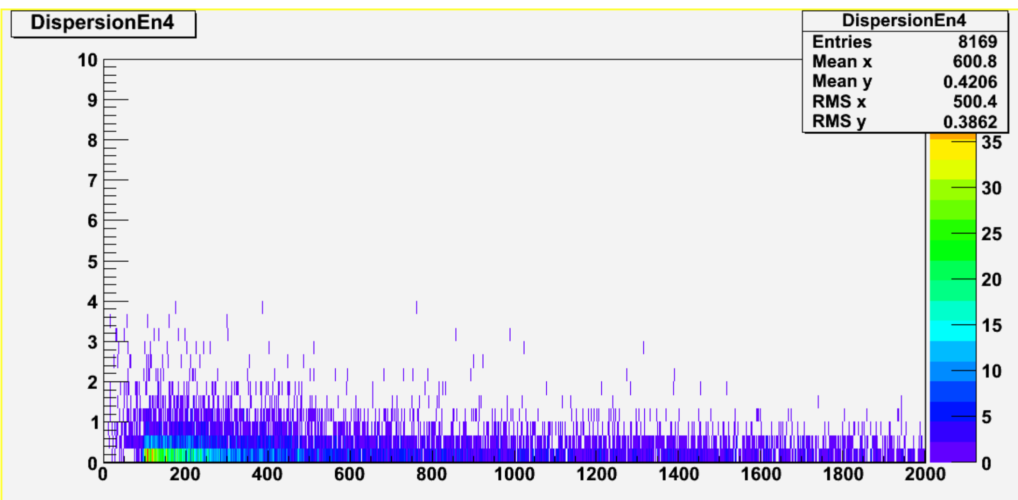

Figure 6- Reconstructed shower energy (GeV) vs dispersion plot for photons for the hit distribution in layer 4

Dispersion of z coordinate of Center of Gravity carries more information than z coordinate of CoG, because Center of Gravity is the mean z coordinate weighted by energy in each layer. We can also calculate the second moment, namely the standart deviation, of CoG and check if it can be a discriminating variable. Plots of the CoG dispersion for photons and protons are as follows.

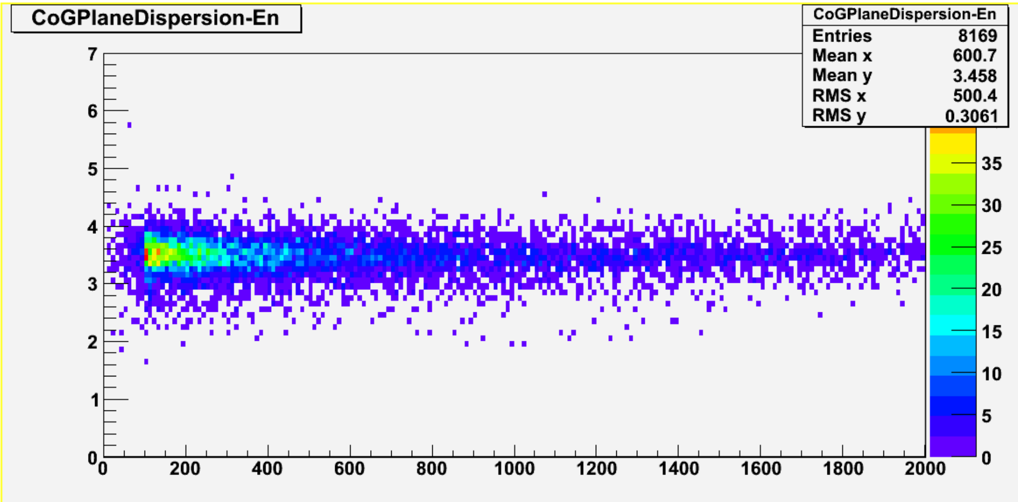

Figure 7 - CoG dispersion vs. Reconstructed photon energy (GeV) for photons

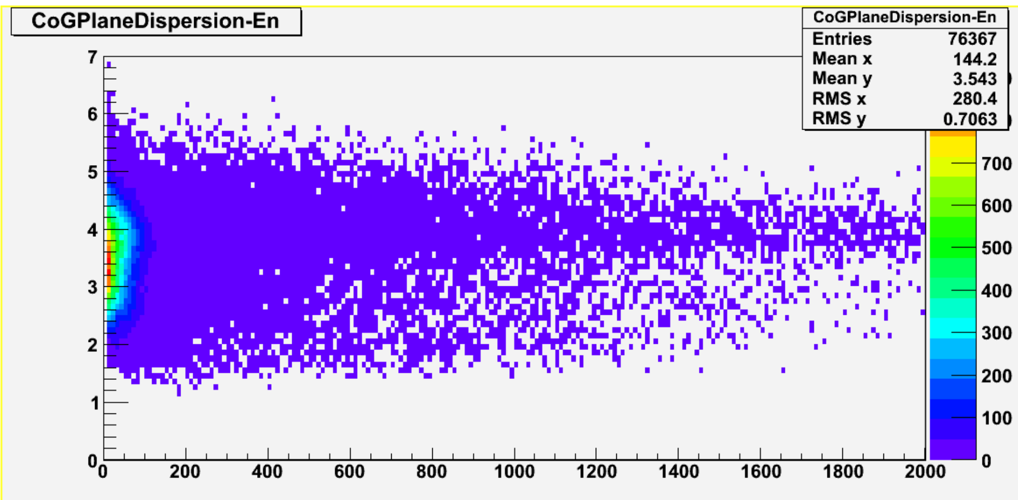

Figure 8 - CoG dispersion vs. Reconstructed photon energy (GeV) for protons

During the summer student period, I also tried other approaches such as kurtosis and template matching (an image processing based method). They turned out to be, however, inefficient discriminating variables between protons and photons. Therefore, the plots are not given.

Cosmic high energy photons might carry spectral signatures of dark matter annihilations, and to be able to measure these signatures, we need to obtain high signal to noise ratio. Increasing the signal efficiency and background rejection rate is the only way to detect dark matter signals which are expected to be very weak but very important for our understanding of the universe.