Observation of γ-rays with the AMS-02 Electromagnetic Calorimeter

Luca Morescalchi

on the behalf of the AMS-02 ECAL collaboration

University of Siena, INFN Sezione di Pisa

1. The AMS-02 Experiment

The *Alpha Magnetic Spectrometer* (**AMS-02**) is a multipurpose astroparticle physics detector installed since May 2011 as an external module on *the International Space Station* (ISS). AMS-02 orbits at an altitude of about 430 Km for measuring with an unprecedented accuracy the **flux and composition of primary cosmic rays** (p, e^-, e^+, nuclei, γ-rays, etc..) in the GeV-TeV energy range, searching for primordial **Anti-Matter** and probing the nature of **Dark Matter**.

Transition Radiation Detector (TRD)

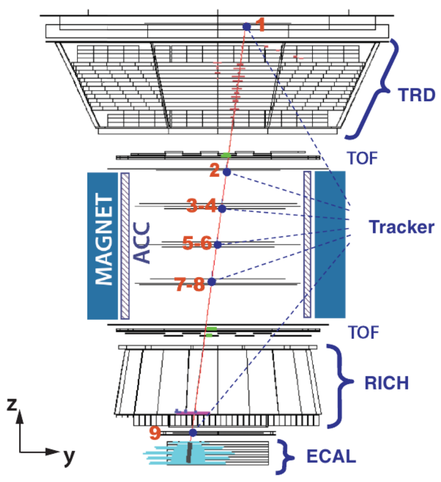
5248 straw tubes on 20 layers
Electrons/protons discrimination

Silicon Tracker (TRK)

2284 silicon strips on 9 layers
Trajectory of charged particles in the B-field, so to derive momentum and charge sign
Redoundant measurments of Z

Ring Imaging Cerenkov Counter (RICH)

Aereogel and NaF radiator, conical mirror and PMT plane
Velocity and Z



Schematic view of the AMS-02 detector

Permanent Magnet (PM)

6000 Ne-Fe-B blocks
B-field of 0.15 T

Time-of-Flight System (TOF)

4 layers of plastic scintillators
Timing informations, velocity and Z

Anti-Coincidence Counters (ACC)

16 scintillating paddles
Veto for particles traversing the magnet

Electromagnetic Calorimeter (ECAL)

18 lead-scintillating fibers layers
Energy and arrival direction of e.m. particles
Lepton/hadron discrimination

2. The Electromagnetic Calorimeter

The AMS-02 Electromagnetic Calorimeter (**ECAL**) is an high granularity **lead-scintillating fibers** sampling calorimeter consisting of a pancake of 9 *"superlayers"*, each made of 11 grooved 1 mm lead foils interleaved with 1 mm diameter scintillating fibers.

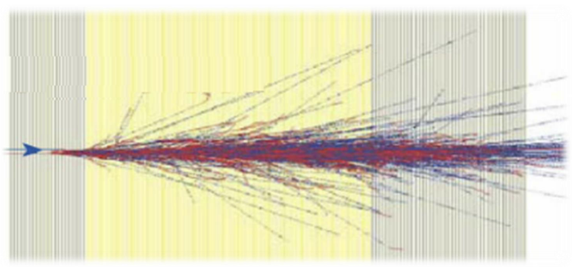
ECAL superlayers disposition: each 10 fiber layers, the fiber orientation is rotated by 90 degrees.

Each *superlayer* is read by 36 four anode PMTs, for a total of **1296 "*cells*"** [18 layers x 72 columns]. Thanks to its high granularity, 9x9 mm², the ECAL design provides an **excellent 3D imaging capability**!

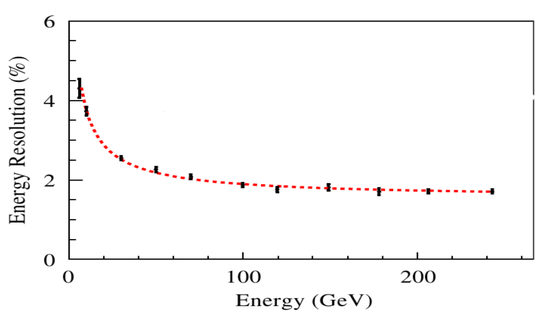
⇨ **Leptonic/hadronic shower discrimination.**

⇨ **Shower axis reconstruction.**

With its total thickness, corresponding to **~17 radiation length X_0** for perpendicular incident particles, ECAL **is the deeper calorimeter actually involved into a space-based experiment**.



Development of a 100 GeV photon shower in ECAL.



ECAL energy resolution measured at test beam.

The maximum of the longitudinal shower development is contained also for TeV particles, so limiting the size of the rear leakage corrections .

⇨ **2% energy resolution up to the TeV scale.**

3. ECAL Shower Axis Reconstruction

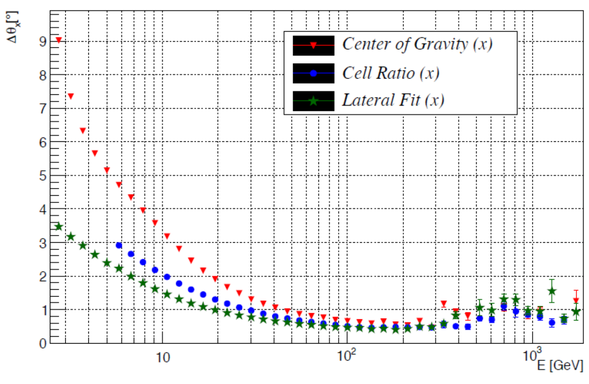
For each event the shower direction is determined separately in the (x,z) and (y,z) view and then is combined by fitting the axis position in each layer. Three methods have been developed for the reconstruction of the electromagnetic showers axis positions in each layer, namely:

1. **Center of Gravity (CoG)** – The shower axis position is evaluated in each layer as the energy weighted average of the centers of the cells which are part of the shower.

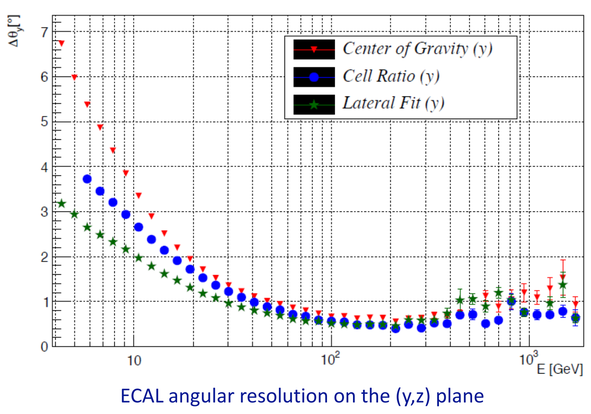
2. **Neighbouring Cells (NC)** – The ratio of the energy deposited in the neighboring cells to the most energetic one decreases as a function of the impact point on the cell. Parametrizing this relation it is possible to obtain a position measurment.

3. **Lateral Fit (LF)** – A detailed **GEANT-4** based simulation of the shower development is performed to parametrize, layer by layer, the lateral shower shape as a function of deposited energy. For each event, a comparison of data with the parametrized shape is performed and the shower axis position in the layer is obtained minimizing a χ^2 function.

A ***golden electron* sample** is used to evaluate the performances of these methods **directly from flight data:** the **angular resolution** is defined by the three-dimensional angle **with respect to the AMS-02 Tracker track direction** (whose error is negligible compared with the ECAL one) that contains 68% of the reconstructed events.



ECAL angular resolution on the (x,z) plane



ECAL angular resolution on the (y,z) plane

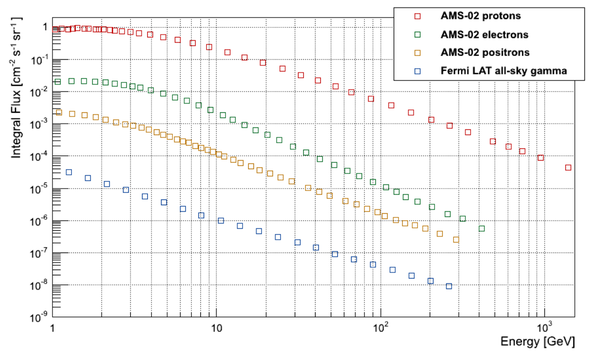
Angular resolution above 50 GeV is about 0.5 degrees!

4. Charged Background Rejection

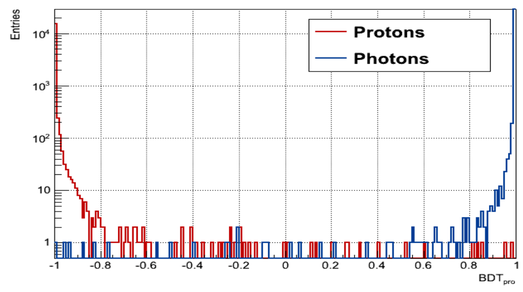
The particles reaching the top of the Earth's atmosphere are **mainly protons and fully ionized light atomic nuclei**, while γ-rays are only a **very small fraction** of the total cosmic rays composition.

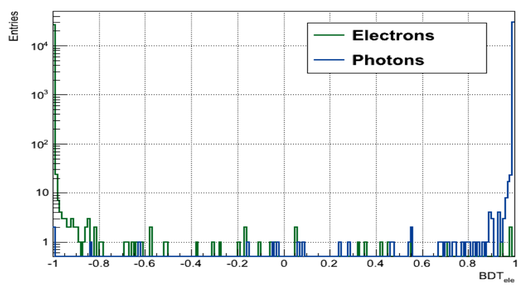
A large set of **experimental variables** related to the **longitudinal and lateral development of the shower in ECAL**, the matching of the axis shower with the **hits in the other sub-detectors** and **timing informations** were so used to identify photons and to reject background.

Because the signal to noise ratio is very unfavorable (**10^{-5} with respect to protons** and **10^{-3} with respect to electrons**), the needed **rejection factor** is **greater than 10^6**.



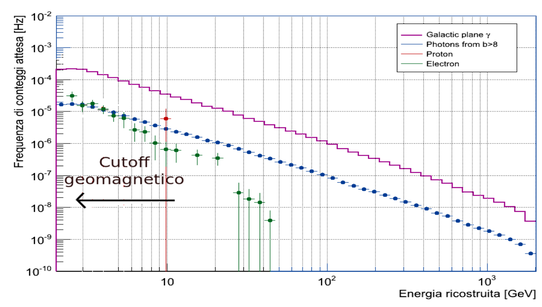
In order to fulfill this request maintaining an high efficiency, a photon classifier based on a **Boosted Decision Tree (BDT)** technique has been developed using **73** of these variables.

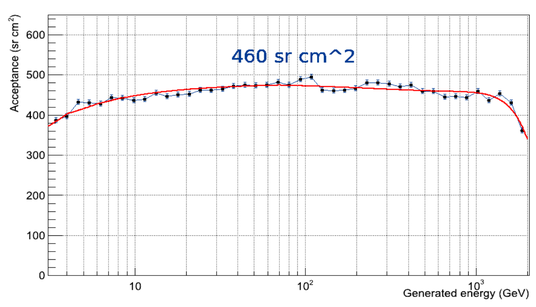




Resulting distributions for the BDT classifier applied to the electrons and protons MC test sample

The final acceptances and the expected rates for signal and background as a function of the reconstructed energy, after the BDT classifier selection, were evaluated according to a dedicated Monte Carlo simulation.

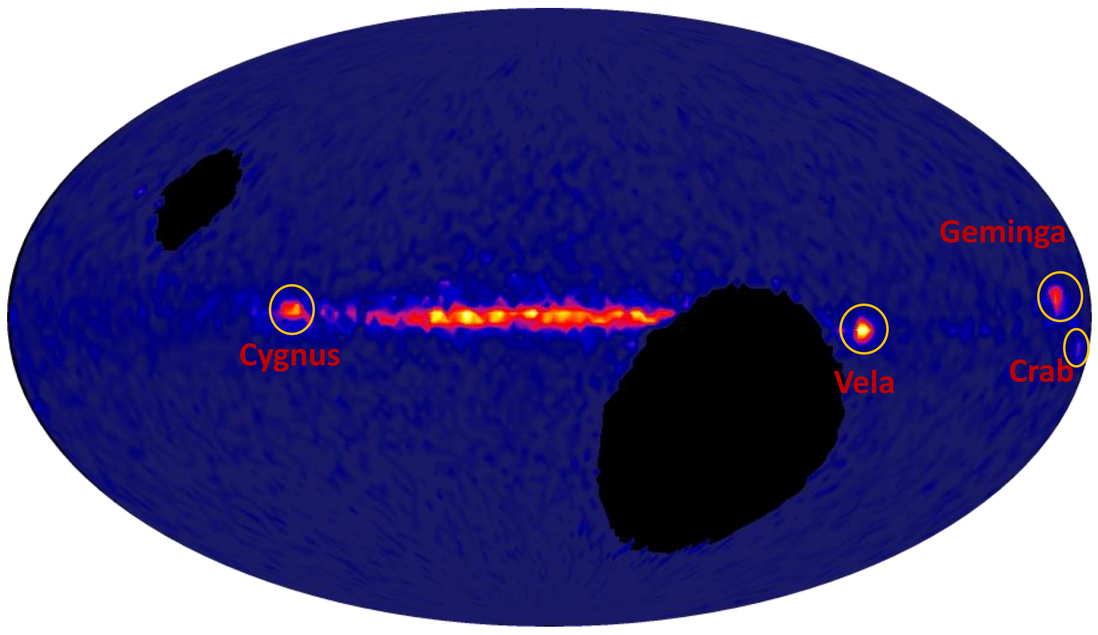




Above 10 GeV the selected photon sample is expected to have an high purity!

5. The ECAL sky-map

The sky map obtained with photon candidates confirms the **low residual background level** and the **good angular resolution** also for flight data. As expected the events in the map are **concentrated around the galactic plane** and the brightest spots reveal the emissions from **Vela**, **Geminga**, **Crab** and **Cygnus.**



ECAL is able to identify high energy photons from galactic or extragalactic sources!

More results are expected in the near future as soon as **more statistics will be available**, concerning in particular **the investigation of structures in the photon spectrum**…