VELOCITY AND CHARGE RECONSTRUCTION WITH THE AMS/RICH DETECTOR

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The Alpha Magnetic Spectrometer (AMS), to be installed on the International Space Station (ISS) in 2008, will be equipped with a proximity focusing Ring Imaging Čerenkov detector (RICH). This detector will be equipped with a dual radiator (aerogel+NaF), a lateral conical mirror and a detection plane made of 680 photomultipliers and light-guides, enabling measurements of particle electric charge and velocity. A likelihood method for the Čerenkov angle reconstruction was applied leading to a velocity determination for protons with a resolution around 0.1%. The electric charge reconstruction is based on the counting of the number of photoelectrons and on an overall efficiency estimation on an event-by-event basis. Results from the application of both methods are presented.

1. The AMS02 detector

AMS [?] (Alpha Magnetic Spectrometer) is a precision spectrometer designed to search for cosmic antimatter, dark matter and to study the relative abundance of elements and isotopic composition of the primary cosmic rays. It will be installed in the International Space Station (ISS), in 2008, where it will operate, at least, for a period of three years.

The spectrometer will be capable of measuring the rigidity ($R \equiv pc/|Z|e$), the charge (Z), the velocity (β) and the energy (E) of cosmic rays within a geometrical acceptance of $\sim 0.5\,\mathrm{m}^2$.sr. Fig. **??** shows a schematic view of the AMS spectrometer. On top, a Transition Radiation Detector (TRD) will discriminate between leptons and hadrons. It will be followed by the first of the four Time-of-Flight (TOF) system scintillator planes. The TOF will provide a fast trigger, charge and velocity measurements for charged particles, as well as information on their direction of incidence. The tracking system will be surrounded by Veto Counters and embedded in a magnetic field of about 0.9 Tesla produced by a superconducting magnet.

It will consist on a Silicon Tracker, constituted of 8 double sided silicon planes, providing both charge and rigidity measurements with an accuracy better than 2% up to 20 GV. The maximum detectable rigidity is around 1 TV. The Ring Imaging Čerenkov Detector (RICH), described in the next section, will be located right after the last TOF plane and before the Electromagnetic Calorimeter (ECAL) which will enable e/p separation and will measure the energy of the detected photons.

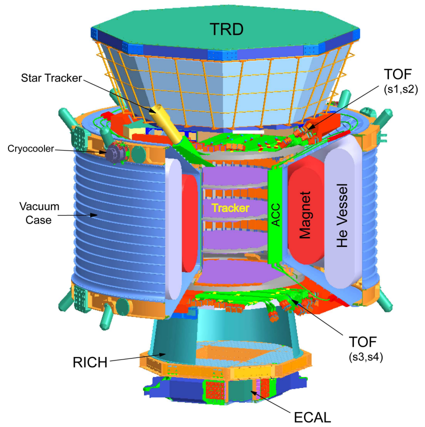

Figure 1. A whole view of the AMS Spectrometer.

1.1. *The RICH detector*

The RICH is a proximity focusing device with a dual radiator configuration on the top (low refractive index aerogel 1.050, 3 cm thick and a central square of sodium fluoride (NaF), 0.5 cm thick); a lateral conical mirror of high reflectivity increasing the reconstruction efficiency and a detection matrix with 680 photomultipliers and light guides. The active pixel size of the PMTs is planned to be of 8.5 mm with a spectral response ranging from 300 to 650 nm with a maximum at $\lambda \sim 420$ nm. There will be a large non-active area at the centre of the detection area due to the insertion of the ECAL. For a more detailed description of the RICH detector see Ref. **?**. The RICH detector of AMS was designed to measure the velocity of charged particles with a resolution $\Delta\beta/\beta$ of 0.1%, to extend the electric charge separation capability up to Z∼26, to provide more information on the albedo rejection and to contribute in e/p separation. Its acceptance is of $\sim$0.35 $m^2.sr$. Figure **??** shows a view of the RICH and a beryllium event display with a

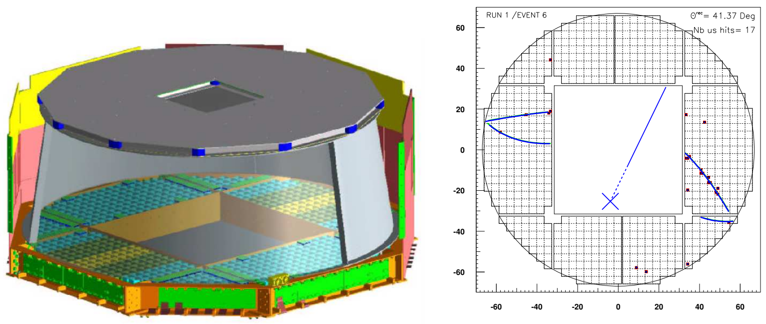

Figure 2. *On the left:* View of the RICH detector. *On the right:* Beryllium event display generated in a NaF radiator. The reconstructed photon pattern (full line) includes both reflected and non-reflected branches. The outer circular line corresponds to the lower boundary of the conical mirror. The square is the limit of the non-active region.

detailed view of the PMT matrix.

2. Velocity reconstruction

A charged particle crossing a dielectric material of refractive index n with a velocity β, greater than the speed of light in that medium, emits photons. The aperture angle of the emitted photons with respect to the radiating particle is known as the Čerenkov angle, θ_c, and it is given by (see Ref. **?**).

$$\cos\theta_c = \frac{1}{\beta\ n} \tag{1}$$

It follows that the velocity of the particle, β, is straightforward derived from the Čerenkov angle reconstruction, which is based on a fit to the pattern of the detected photons. Complex photon patterns can occur at the detector plane due to mirror reflected photons, as can be seen on right display of Fig. **??**. The event displayed is generated by a simulated beryllium nucleus in a NaF radiator.

The Čerenkov angle reconstruction procedure relies on the information of the particle direction provided by the Tracker. The tagging of the hits signaling the passage of the particle through the solid light guides in the detection plane provides an additional track element, however, those hits are excluded from the reconstruction. The best value of θ_c will result from the maximization of a Likelihood function, built as the product of the probabilities, p_i, that the detected hits belong to a given (hypothetical) Čerenkov photon pattern ring,

$$L(\theta_c) = \prod_{i=1}^{nhits} p_i^{n_i}\left[r_i(\theta_c)\right]. \tag{2}$$

Here r_i is the closest distance of the hit to the Čerenkov pattern and n_i the signal strength. For a more complete description of the method see Ref. **?**. The resolution achieved for singly charged particles crossing the aerogel radiator with $\beta \sim 1$ is ~ 4 mrad and for those crossing the NaF radiator the resolution is ∼8 mrad. The evolution of the relative resolution of β with the charge can be observed on the left plot of Fig. **??**. It was extracted from reconstructed events generated in a test beam at CERN in October 2003 with fragments of an Indium beam of 158 GeV/nuc, in a prototype of the RICH detector.

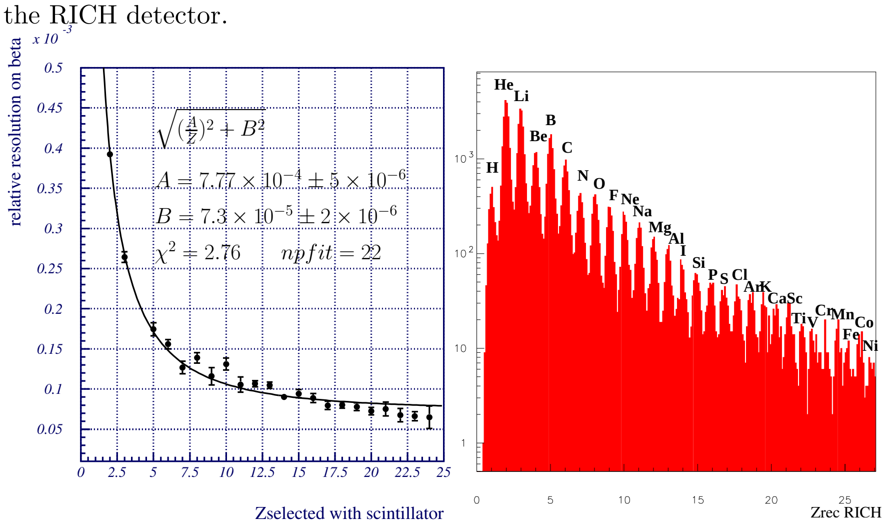

Figure 3. At left evolution of the relative resolution on β with the charge and at right the reconstructed charge peaks. Both are reconstructions with data from a test beam at CERN in October 2003, using an Indium beam of 158 GeV/nuc.

3. Charge reconstruction

The Čerenkov photons produced in the radiator are uniformly emitted along the particle path inside the dielectric medium, L, and their number per unit of energy depends on the particle's charge, Z, and velocity, β, and on the refractive index, n, according to the expression:

$$\frac{dN_\gamma}{dE} \propto Z^2 L \left(1 - \frac{1}{\beta^2 n^2}\right) = Z^2 L \sin^2 \theta_c \tag{3}$$

So to reconstruct the charge the following procedure is required:

- Čerenkov angle reconstruction.
- Estimation of the particle path, L, which relies on the information of the particle direction provided by the Tracker.
- Counting the number of photoelectrons. The number of photoelectrons related to the Čerenkov ring has to be counted within a fiducial area, in order to exclude the uncorrelated background. Therefore, photons which are scattered in the radiator are excluded.

A distance of 13 mm to the ring was defined as the limit for photoelectron counting, corresponding to a ring width of ∼5 pixels.

- Evaluation of the photon detection efficiency. The number of radiated photons (N_γ) which will be detected ($n_{p.e}$) is reduced due to the interactions with the radiator (ε_{rad}), the photon ring acceptance (ε_{geo}), light guide efficiency (ε_{lg}) and photomultiplier efficiency (ε_{pmt}).

$$n_{p.e.} \sim N_\gamma \; \varepsilon_{rad} \; \varepsilon_{geo} \; \varepsilon_{lg} \; \varepsilon_{pmt} \tag{4}$$

The charge is then calculated according to expression **??**, where the normalization constant can be evaluated from a calibrated beam of charged particles. Reconstructed charge peaks are visible in the right plot of Fig. **??**. Data were obtained with an aerogel radiator 1.05, 2.5 cm thick from the mentioned test beam at CERN in October 2003. The charge resolution obtained for helium is ∼0.2 and it is possible to separate charges up to Z=27. For a more complete description of the charge reconstruction method see Ref. **?**.

4. Conclusions

AMS is a spectrometer designed for antimatter and dark matter searches and for measuring relative abundances of nuclei and isotopes. The instrument will be equipped with a proximity focusing RICH detector based on a mixed radiator of aerogel and sodium fluoride, enabling velocity measurements with a resolution of about 0.1% and extending the charge measurements up to the Iron element. Velocity reconstruction is made with a Likelihood method. Charge reconstruction is made in an event-by-event basis. Both algorithms were successfully applied to simulated data samples with flight configuration. Evaluation of the algorithms on real data taken with the RICH prototype was performed at the LPSC, Grenoble in 2001 and in the test beam at CERN, in October 2002 and 2003.

References

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