The AMS-02 RICH Imager Prototype In-Beam Tests with 20 GeV/c per Nucleon Ions

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Abstract

A prototype of the AMS Cherenkov imager (RICH) has been tested at CERN by means of a low intensity 20 GeV/c per nucleon ion beam obtained by fragmentation of a primary beam of Pb ions. Data have been collected with a single beam setting, over the range of nuclear charges $2 < Z < \sim 45$ in various beam conditions and using different radiators. The charge Z and velocity β resolution have been measured.

1. Introduction

The AMS spectrometer will be installed on the International Space Station in the year 2005, for a several years campaign of measurements during which a research program of fundamental interest will be covered: Search for antimatter of primordial origin and for dark matter, including also the study of the Cosmic Ray flux (CR) and gamma ray astronomy.

The Cherenkov imager of the experiment should make possible a thorough study of the nuclear Cosmic Ray flux by performing: a) Isotope identification (ID) for the light elements over a range of mass (A) and momentum of about ($A < \sim$15–20, 1 GeV/$c < \frac{P}{A} < \sim$12 GeV/c), and b) Charge measurements of the particles with charge resolution of the order of one unit around Fe ($Z < \sim 26$), the momentum range extending up to the upper limit of the spectrometer capability, in the TeV/c per nucleon range, $\frac{P}{A} < \sim$1 TeV/c, for the latter.

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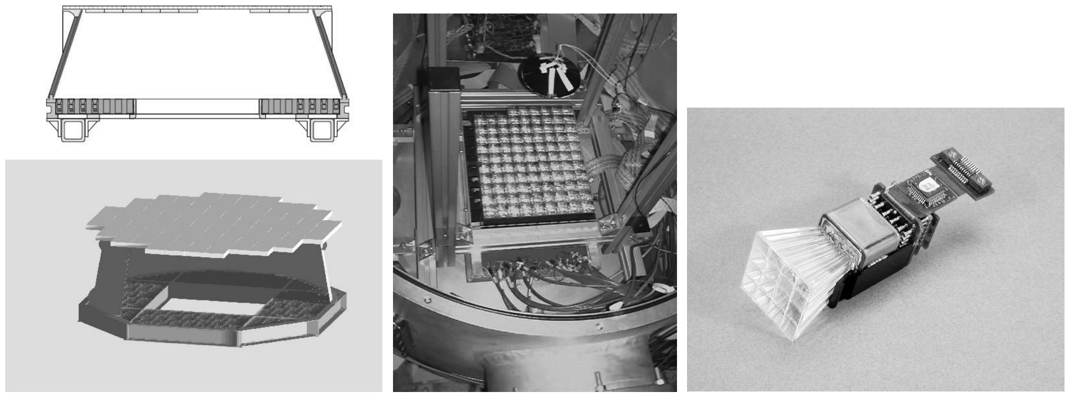

Fig. 1. RICH Counter structure (CAD view, left), matrix of detectors of the prototype in its testing environment (center), and detector cell used in the prototype including light guides, photomultiplier tube (PMT), read out electronics, and (half) plastic shell (right).

The technical requirements constraining the counter design (dimensions, weight, power consumption, long term reliability of photodetectors) have lead to the design of a proximity focusing type of imager, equipped with multianode photomultipliers for photon detection. The radiators were chosen in accordance with the physics requirements and ID capabilities of the counter: Sodium fluoride (NaF) and silica aerogel, to cover the low (1 GeV/$c < \frac{P}{A} < \sim$5 GeV/c) and high (4 GeV/$c < \frac{P}{A} < \sim$12 GeV/c) parts of the momentum range, respectively.

2. Counter architecture

The mechanical structure of the counter is shown on Fig. 1.. It consists of a radiator plane at the top, separated from the photodetector plane by a 45 cm drift space. The empty area in the detector plane corresponds to the location of the electromagnetic calorimeter. A conical mirror encloses the drift volume to increase the acceptance. The detector plane includes 680 PMTs, corresponding to 10880 readout channels. The radiator plane will be equipped with NaF (n=1.33) in the central region ($\sim 35\times35\times0.5$ cm^3) and aerogel (n=1.03–1.05, 3 cm thick) in the rest of the area.

3. Prototype

The prototype (Fig. 1.) consists of a fraction of the detector in a version close to the flight model design. This comprises 96 cells of photodetectors. Each cell includes a 16-anode PMT, 16-element light guide matrix, HV dividers and front end readout electronics [1], mounted altogether and enclosed in a plastic shell (Fig. 1.), inserted in a magnetic shielding grid. The DAQ systems reads out

1536 channels in total.

4. The CERN SPS test beam

The beam was obtained from the CERN SPS by fragmentation of primary Pb ions on a production target located at the entrance of the beam line. The beam line was operated as a magnetic spectrometer and used to select samples of ions with a given rigidity. The fragmentation products fly to a good approximation at the beam velocity γ_b, and only those particles entering the beam line with a ratio A/Z matching the rigidity settings for the beam line $B\rho = 3.1\gamma_b A/Z$, γ_b beam Lorentz factor, were transported to the detector. The most useful ratio A/Z=2 provided a secondary beam including the whole range of nuclear masses: ^{2}H,^{4}He,^{6}Li,^{10}B,^{12}C,^{14}N,^{16}O,..,^{28}Si,...,^{40}Ca,..., ^{52}Fe,..etc.., produced by projectile fragmentation. Other more selective field settings have been used to pick one $A/Z \neq 2$ isotope ratio, like 3/2 for ^{3}He and 7/4 for ^{7}Be. Details on the beam design and performances are given in Ref. [2].

5. Results

The prototype has been tested with both CRs (mainly muons) and beam ions. The instrumental environment was the same as used previously for the study prototype [3]. Only the in-beam test results are reported here (see [4] for the formers). The tests were performed over 4 days on october 2002, at CERN. Incident 20 GeV/c per nucleon Pb ions were used to bombard a production target (10 cm Be or 40 cm Pb). The secondary beam intensity was set to about 1 to $3{\cdot}10^3$ particles per spill. The imaging performances of the prototype have been studied for various radiators: Silica aerogels with refraction index 1.03 to 1.05 from various manufacturers, and Sodium Fluoride (NaF). Cherenkov rings associated to ions over the covered range of charge have been observed, with the number of photons ranging from 4–7 (mean) for Z=1 elements, up to several thousands for high Z values. The charge and velocity resolutions are being evaluated from the analysis of the 5 million events recorded. A realistic evaluation of the isotope separation capability of the final counter will be produced from this analysis.

Fig. 2. shows a sample of results: Selection of single rings with different Z values obtained with a 3 cm thick n=1.03 aerogel radiator (top); Preliminary results of analysis showing the prototype performance for Z measurement with 3.1 cm thick n =1.04 aerogel (bottom left); And correlation with TOF hodoscopes dE/dX measurements (bottom right, see [5]), illustrating the ID capability of the spectrometer for isotopes. The measured resolution in Z is of the order of $\sigma(Z)$= 0.3 in the region of Fe (Z=26), in fair agreement with the estimates. Although the dynamic range goes beyond, and although higher Z data have been recorded in the run, up to around Z=45, the study of this range suffers from the

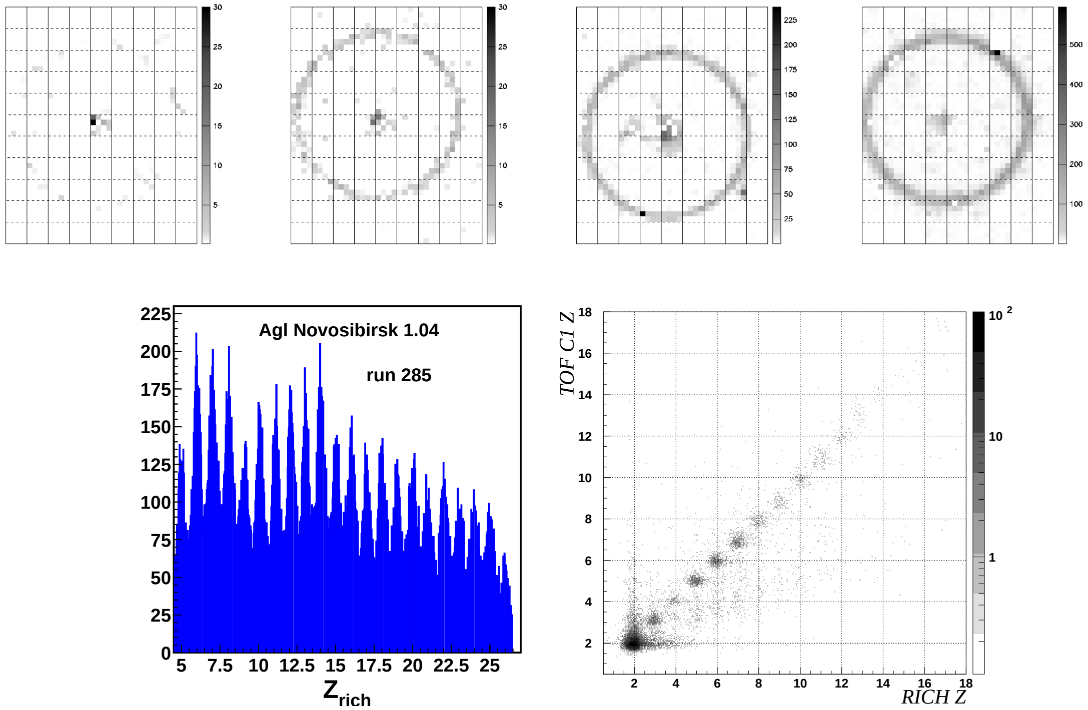

Fig. 2. Cherenkov patterns obtained with various ions with $Z = 2$, 6, 16, and >25, from left to right respectively (top); Z spectrum obtained from the RICH (bottom left), and correlation with the TOF measurement (bottom right) [5], measured with the ion beam at CERN.

lack of good external Z measurements. The work is in progress.

The velocity (β) resolution was found in agreement with the CR estimates, i.e., around $\frac{\Delta\beta}{\beta} \sim 10^{-3}$ for Z=1 particles. For larger Z values, the resolution first decreases (improves) as Z^{-1} for $Z < 7$ as observed previously [3], then starts decreasing progressively slower than Z^{-1} up to $Z \sim 25$, flattening above this value to a Z independent, constant value, according to the relation $\sigma(\beta) = 10^{-4}\sqrt{(8.2)^2/Z^2 + (1.2)^2}$. This latter limitation is set by the pixel size of the detector plane (evaluation on 1.03 aerogel data points).

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5. The AMS TOF collaboration (Casadei D. et al.), these proceedings.