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The AMS Tracker Performance

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Eight layers of double sided silicon microstrip sensors embedded in a 0.8 T magnetic field constitute the core of the AMS-02 apparatus. In each layer, simultaneous measurements of position and energy loss in silicon are performed along the particle trajectory. With its high spatial resolution, the silicon tracker will determine the rigidity and the charge sign of particles up to several TVs, with a relative resolution $\sim 2.5\%$ at $R < 100$ GV. The low noise and wide dynamic range of the silicon readout electronics allows to exploit the energy loss measurements to determine the particle absolute charge for nuclei up to Fe. The performance of the silicon detectors observed under beam tests are presented.

1. Introduction

A description of the Alpha Magnetic Spectrometer (AMS) and of the goals of its mission on the ISS can be found in [1].

The AMS tracker consists of 8 layers of silicon detectors accurately measuring the trajectory of charged particles along about one meter inside the bore of a 0.8 T superconducting magnet. The simultaneous measurement of the energy loss in the silicon wafers allows to determine the charge of the traversing particle.

The silicon detectors are built from high resistivity n wafers, with p and $n+$ strips implanted respectively on the upper and the lower face. The strips on the two sides run in orthogonal directions allowing the measurement of two coordinates. On the junction side (p-side), which measures the bending coordinate, there are 2560 strips with an implantation (readout) pitch of 27.5(110) μm . On the ohmic side (n-side) there are 1536 strips with an implantation(readout) pitch of 52(208) μm.

The 2264 sensors are electrically grouped together in ladders, made of 7 to 15 silicon sensors, for a total of 192 ladders and ~ 6.4 m^2 of instrumented area. Detailed information on the AMS silicon tracker and on its construction can be found elsewhere in these proceedings [2].

To evaluate the performance of the AMS tracker 6 flight ladders have been exposed to a test beam together with a prototype of the RICH detector and 4 TOF scintillator slabs. The setup of test beam is sketched in Fig.1.

The detectors were installed in the T9 PS experimental hall at CERN and they have been exposed to proton and ions beams. The ions, produced in the interaction between high energy In fully ionized with a Be target, have been magnetically selected to obtain A/Z=2 and A/Z=2.25 beams. The average momentum per nucleon was ~ 10 GeV/n for all the beams.

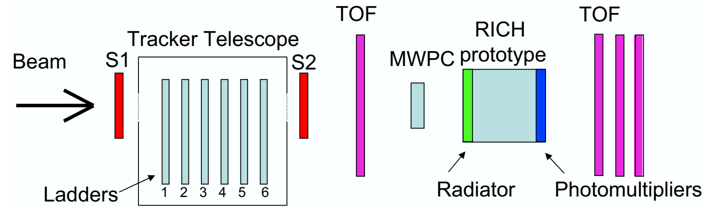

Figure 1. Setup of the CERN test beam.

2. Tracker performance

Cluster selection and charge determination The energy deposited in the silicon by a relativistic particle of charge Z is proportional to Z^2 and approximatively follows a Landau distribution. The readout system of the AMS tracker has been designed to cover a large dynamic range, to have the capability to separate heavy ions. The front end electronics is a custom designed hybrid board based on the VA-hdr9a readout chip, a high dynamic range chip based on the VA and on the Viking chips [3].

Non linear effects on the signal collection in the microstrips, and the details of the implementation of the read out chains can introduce deviations from the expected behaviour. In particular we have observed: a dependence of the mean collected signal on the particle impact position (**IP**) in the gap between two readout strips; a dependence of the signal amplitude on the absolute charge Z. Both the observed dependences appear with different features on p and n sides.

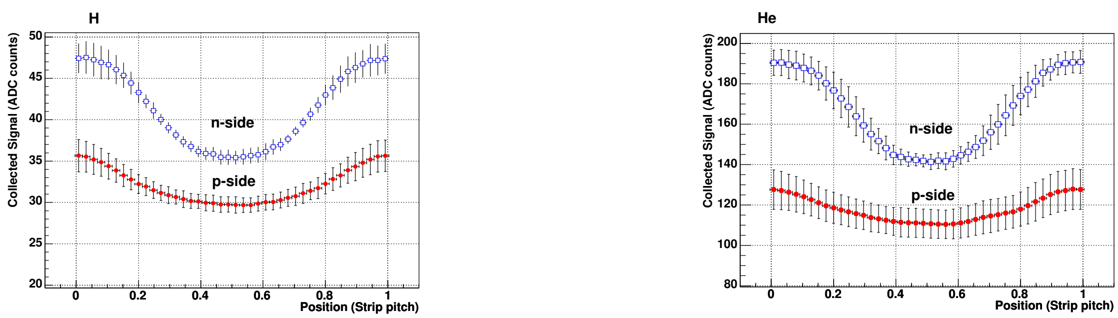

Figure 2. Total signal versus impact position in the strip gap for H(left) and He (right) nuclei.

To better determine the charge of a traversing particle a set of correction factors have been calculated using clean samples of the different ion species. These samples have been obtained imposing tight cuts on the signal of the first ladder and studying the behaviour of the signals in the remaining five.

In Fig.2 the mean signal collected for H and He nuclei is shown as a function of the particle **IP**. In these figures the **IP** estimation is based on the extrapolation of the track measured with all the ladders but the one under study. A different response as a function of **IP** in the gap that depends on the ions species has been observed. As an example, Fig.3 shows the average signal collected as a function of the **IP** for different Z and the two readout sides. In these figures the **IP** estimate is based on the η function defined as:

$$\eta = \frac{S_R}{S_L + S_R} \quad (1)$$

where S_R and S_L are the signals of the left and the right strips with respect the reconstructed impact point.

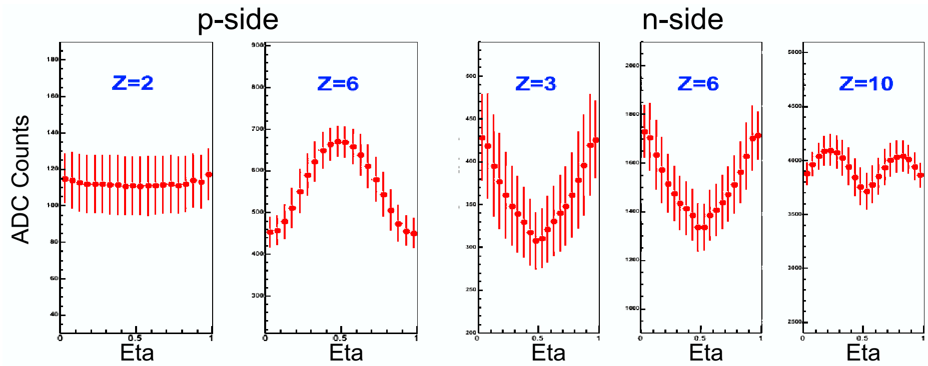

Figure 3. Average signal versus η for the two silicon sides and for different charges.

Fig.4 (left) shows the relation between the particle charge (Z) and the square root of the collected signal corrected for its **IP** dependence. A linear behaviour is observed on the n-side up to Z=13, above this threshold the slope becomes steeper and the resolution worsens. On the p-side (not shown) a linear behaviour is observed below Z=5 and above Z=10, while in between a non-linear transition zone is present. A detailed discussion of these effects can be found in [4]. The **IP** dependence of cluster signal varies smoothly with the deposited energy. A set of correction factors depending on η and on the cluster signal have been calculated in order to linearize the detector response.

Fig.4 (right) shows the truncated mean of the signals (n-side) on the 6 ladders with all corrections applied compared with the charge measurements from the RICH detector. A very good correlation between the two detectors is observed, the clusters corresponding to the different ions can be separated up to Iron.

Spatial resolution To study the spatial resolution of the AMS ladders for different ions we selected the events which have signals compatible with the desired charge both on p and n sides and on all six ladders. For each event a linear fit of the cluster positions on the ladders excluding the ladder under investigation has been made. The distribution of the distance δ between the cluster and the position predicted by the fit has been considered. A double gaussian distribution describes the distribution of δ, with the broader gaussian

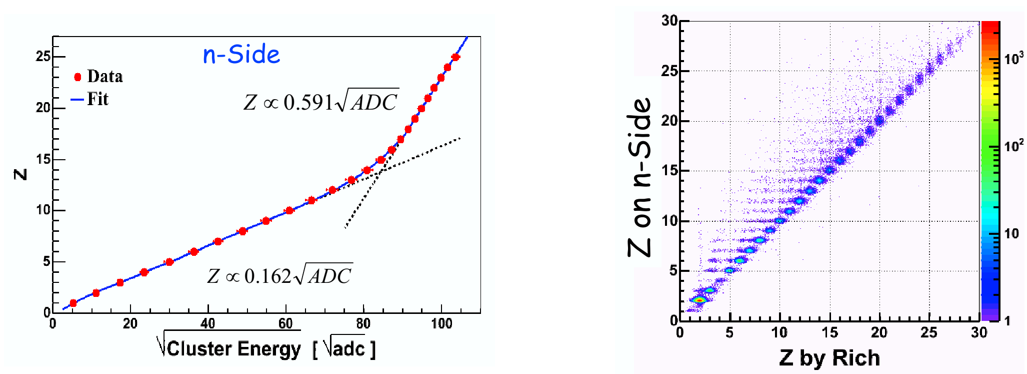

Figure 4. Left: charge of the sample versus the square root of the average η corrected signal (n-side). Right: n-side tracker charge measurement versus the RICH charge measurement.

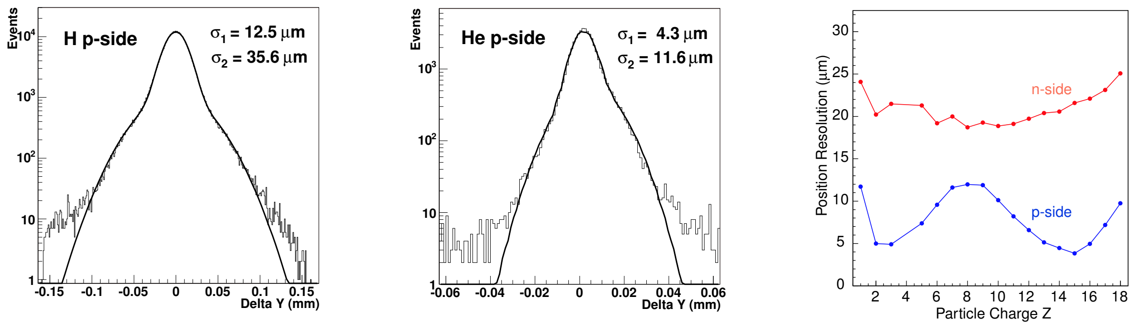

Figure 5. Left: p-side tracker resolution for H. Center: p-side tracker resolution for He Right: AMS tracker spatial resolution versus measured charge.

accounting for less than 20% of the events. The rms of the narrower gaussian (σ_δ) represents the spatial resolution of the single hit measurement (σ_{det}) convoluted with the error of the prediction from the linear fit (σ_{Fit}). The resolution is then defined as: $\sigma_{det} = \sqrt{\sigma_\delta^2 - \sigma_{Fit}^2}$.

A preliminary estimation of the tracker resolution for H and He nuclei is shown in Fig.5 (left and center). Fig.5 (right) shows the preliminary resolution for the different ions. On the p-side in the Z range from ~ 5 to ~ 10 where the response of the detector is not linear (see previous section) a coarse resolution is observed.

The influence on the resolution of the number of strips used in the definition of the cluster position (center of gravity) has been also studied. For the p-side the best resolution is obtained using a center of gravity calculated with only two strips, for the n-side a wider definition of the cluster improves the resolution for $Z > 11$.

3. Conclusions

Preliminary results on the AMS-02 silicon ladders performances have been presented in terms of spatial resolution and absolute charge measurement. The analysis of beam test data has shown that a single point resolution better than 5(20) μm can be obtained in the measurement of the bending (non bending) coordinate for He ions, while keeping this figure better than 12(24) μm for a wide range of the particle charge. The low noise level of the detector results in a good efficiency for low Z ion detection and the wide dynamic range of the readout system allows the charge determination for an extent range of ion species. The combined charge measurement of the six ladders under beam test has shown a charge discrimination capability up to Z=24, confirmed by the independent measurement of the RICH module. In the full AMS-02 tracker, where a combined measurement from eight ladders will be available, ion identification up to Fe will be reached.

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