RING Imaging Cherenkov Detector (RICH) For the AMS Experiment

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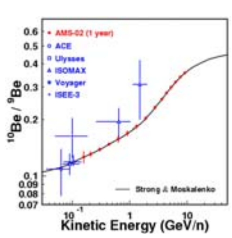
Abstract: The Alpha Magnetic Spectrometer (AMS) experiment to be installed on the International Space Station (ISS) will be equipped with a proximity focusing Ring Imaging Cherenkov (RICH) detector for measuring the charge and velocity of incoming cosmic-ray nuclei. From top to bottom, the detector consists of a radiator plane made of 1.05 aerogel and sodium fluoride (NaF) materials, an expansion volume enveloped by a high reflectivity conical shaped mirror, and a matrix of 680 16-anode photomultipliers coupled to light guides. A RICH prototype consisting of 96 photomultiplier units was tested in a secondary beam of ion fragments from a 158 GeV/c per nucleon primary beam of Indium ions (CERN SPS). The results of this prototype beam test, which confirmed the RICH design goals, are presented. Charge separation of elements from protons to iron nuclei was observed. Velocity resolution on the order of 0.1% was obtained for singly charged particles. Recent results from the RICH physics performance analysis, integration status, and preflight tests are reported.

Introduction

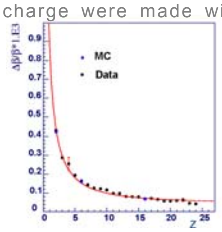
The Alpha Magnetic Spectrometer [1] (AMS) is a high energy physics experiment that will be installed on the International Space Station (ISS) by the year 2009. It will operate for a period of at least three years and will become the first large acceptance (~0.5 m^{2}sr) superconducting magnetic spectrometer in space able to detect cosmic-ray particles in a wide rigidity range (from a few hundred MV to ~1 TV). The long time exposure will allow AMS to extend by orders of magnitude the sensitivity reached by previous experiments on antimatter and dark matter searches. In addition, the measurements of the cosmic-ray fluxes up to the TV region and in a wide charge range (up to Z~26) will contribute to a better description of cosmic ray production, acceleration and propagation mechanisms, essential for a full understanding of the background spectra in dark matter searches. AMS–02 will allow to test propagation models through the precise measurements of secondary-to-primary ratios as D/p, ^{3}He/^{4}He in the energy range from few hundreds MeV to tens of GeV, and B/C, sub-Fe/Fe up to ~1 TV. In particular, the accurate measurement of ^{10}Be/^{9}Be in a wide energy range will allow to understand the age of the cosmic-ray confinement in the galaxy and will constraint the size of the galactic halo [2]. Current ^{10}Be/^{9}Be ratio measurements are performed at relatively low energies (T ≤1 GeV/n) and based on small statistics. Particle identification in AMS relies on a very precise determination of the magnetic rigidity, energy, velocity and electric charge. In the AMS spectrometer, the momentum is obtained from the information provided by the sili-con tracker with a relative accuracy of ~1% up to 10 GeV/c/n. Isotopic mass separation over a wide range of energies requires, in addition to an accurate momentum measurement, a velocity determination with low relative uncertainty. For this purpose, the AMS spectrometer includes a Ring Imaging Cherenkov detector (RICH) placed between the time-of-flight and electromagnetic calorimeter (ECAL) detectors. The RICH data for mass separation will help to eliminate a fake anti-He background in antimatter searches. Moreover, it will also AMS with a redundant electron/proton separation to further reduce the background in dark matter searches. For the isotopic separation, the RICH detector will cover a kinetic energy region ranging from 0.5 GeV/n up to around 10 GeV/n for A≤10. Figure shows the expected 10Be/9Be ratio to be measured by AMS, after 1 year exposition. An improvement over the previous measurements both in accuracy and the kinetic energy range is apparent.

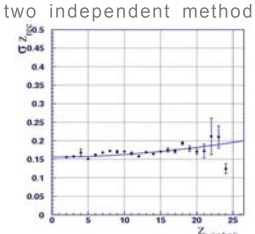


Expected performance of the AMS on the ^{10}Be/^{9}Be ratio after 1 year data taking com-pared to recent measurements. The ratio has been simulated according to the propagation models described in [2].

The RICH prototype beam testing

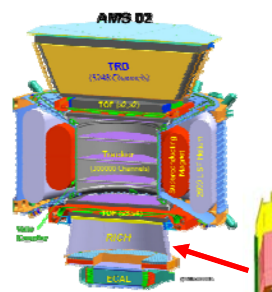
A prototype of the RICH detector consisting of an array of 9 x 11 cells filled with 96 photomultiplier readout units was constructed. Its performance was evaluated on cosmic muons and fragmented ions from CERN SPS beams in 2002 and 2003 [3]. Reconstruction of velocity and charge were made with two independent methods [4]

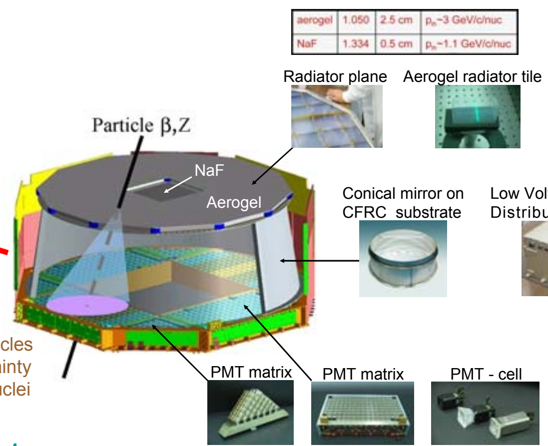




RICH prototype velocity (left) and charge (right) resolution. Test beam results obtained for the CIN aerogel with 1.05 refractive index.

AMS Ring Imaging Cherenkov (RICH) detector

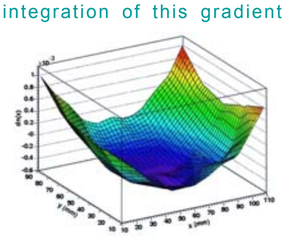




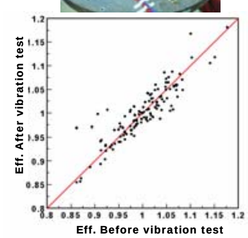
RICH measures charged particles velocity with a relative uncertainty of 0.1% (for *Z*=1)and of the nuclei electric charge up to Fe.

Integration and tests

RICH assembling activities started in September 2003. The final detector is scheduled to be operational in summer of 2007 for functionality tests and further integration into AMS. First, each readout cell and radiator tile passed a series of characterization tests to extract the information on gain, efficiency and refractive index variations. The data was used to obtain a maximum uniformity of the radiator and detector plains and to create the database of mapped elements performance. The precise determination of the refractive index for each tile required the elaboration of a dedicated measurement method, by laser beam deviation, done at LPSC, Grenoble. The vertical and horizontal deviation of the laser beam entering normally to the tile surface, allows a measurement of the refractive index gradient at a given position on the tile. The refractive index variation is obtained by integration of this gradient. The detector plane elements and the radiator tiles then were assembled together using the manufactured mechanical structures. The alignment was carefully controlled and the radiator plane as well as one of the detection matrix rectangular "boxes" passed a successful vibration test. The matrix functionality was checked before and after the vibration No significant performance change was observed. The RICH electronics functionality and thermal stress tests were successfully accomplished at Madrid and CSIST, Taiwan. The integration of the RICH is nearing its completion at CIEMAT, Madrid.



Aerogel tile refractive index



The detection matrix efficiency comparison before and after the vibration test.

Conclusion

A RICH detector is being assembled, and its integration in the AMS spectrometer is scheduled to start in summer of 2007. Cosmic muons and accelerator beam tests with fragmented ions validated the detector design goals. A detailed characterization of the detector plane parameters as well as the radiator tails small refractive index variations mapping was performed before the final assembly. The vibration and thermo-vacuum tests confirmed the RICH detector performance stability after the Shuttle launch and transportation to the International Space Station.

References

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