ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Perugia

INFN/AE-96/36
17 Ottobre 1996

B. Alpat:

AMS (ALPHA MAGNETIC SPECTROMETER) EXPERIMENT FOR ANTIMATTER, DARK MATTER SEARCH ON INTERNATIONAL SPACE STATION ALPHA

SIS–Pubblicazioni
dei Laboratori Nazionali di Frascati

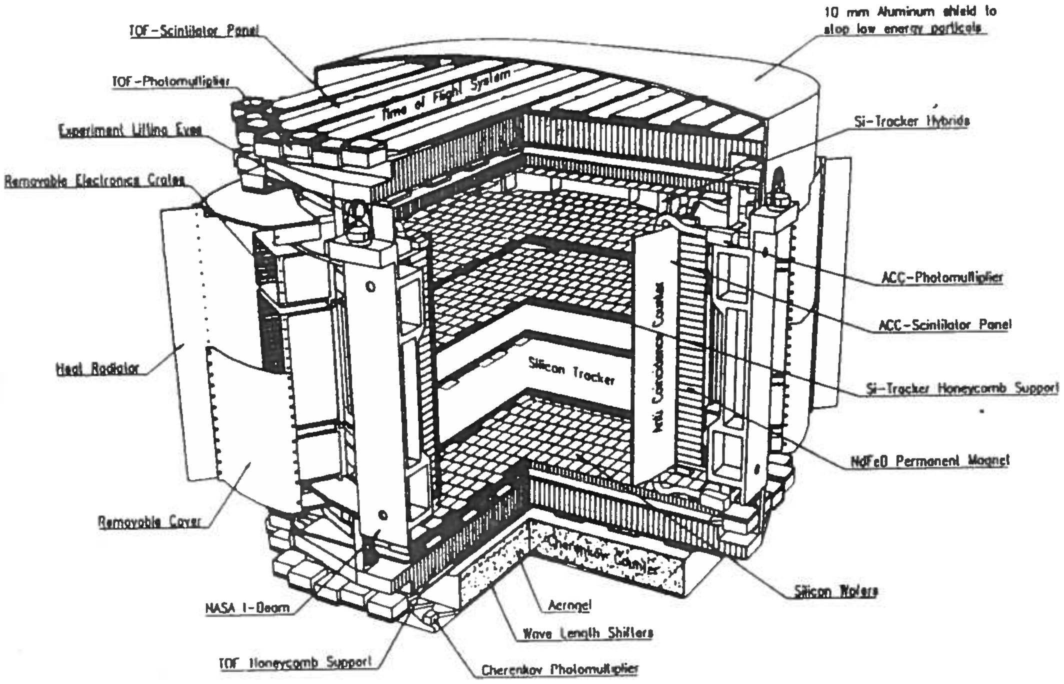

Figure 1. AMS general assembly.

Table 1 (tracker spatial resolutions are given both for bending (1) and non bending (2) planes).

IMPORTANT PARAMETERS OF AMS	
Weight	3 tons
Power	1 kW
GF	0.6 $m^2.sr$
BL^2	0.15 Tm^2
Field Strength	0.1 T
TK resolution (1)	10μm
TK resolution (2)	30μm
ToF resolution	100 ps

Table:1 The main parameters of AMS.

The AMS detector consists of the following components (see Fig. 2):

- A ring permanent magnet of 1.8 tons made out of 64 premagnetized highest grade rare earth Nd–Fe–B pieces (BxH > 50.10^6 GOe). This magnet with good homogeneity, low fringe field and vanishing dipole moment will have a field of about 1 kG.
- Anticoincidence counters surrounding the inner wall of the magnet to reject background induced by the passage of charged particles through the magnet.
- A tracker consisting of six layers of high precision, very transparent ($7x10^{-3}$ X_0/layer) double sided silicon detectors. Four layers will be inserted into the magnet while the first and the last layers will be located at top and at bottom of the magnet in order to have the largest geometrical factor (0.6 $m^2.sr$). Spatial resolutions of 10 μm and 30 μm in bending and non-bending planes, respectively, will give precise measurement of the rigidity (p/Z) up to a MDR=500 GV. The particle trajectory will give the sign of the particle charge. Each layer will give a separate measurement of dE/dX, which combined with that of time of flight system, will contribute to determine with precision the absolute particle charge.
- Four layers of scintillators (S1 to S4) will

of particles can be measured up to a maximum detectable rigidity of 500 GV.

The momentum resolution is limited to ≈ 6% due to multiple scattering.

Recent beam test results with ToF prototypes have shown 105 ps second time resolution can be achieved. More details about the tracker performance and AMS detector can be found in references [12,14,15].

4. PHYSICS OF AMS

4.1. Antimatter

The present state of the universe is characterized by four large-scale phenomena: the expansion of the universe (Hubble's law), the 2.76 K highly isotropic cosmic microwave background radiation, the ratio of 10^{-9} for the number of nucleons (baryons) per photon and the light element abundances. All these phenomena find explanation in the Big Bang theory which also predicts equally abundant matter and antimatter at the very hot beginning. In particular, there is a remarkable agreement between the light element observations and the theoretical predictions. But, at present, experimental results lead us to exclude the existence of significant amount of antimatter within about 10 Mpc from the earth.

The baryogenesis, which is the evolution of the a symmetric universe into an asymmetric one, requires baryon number and CP to be violated [16] These violations are fundamental properties of elementary particles theories which also allow for the baryon number violation. CP non conservation has been observed in K and B systems but the amount of the measured non conservation is not enough to explain the observed baryon, antibaryon asymmetry. Since, experimental evidence for baryon number violation in accelerators or in proton decay experiments has not yet been provided, the observed lack of antimatter in our part of the universe is the strongest evidence for baryon number violation.

Theories predicting total absence of antimatter, such as Grand Unified Theories (GUT's [17,18]) or electroweak theories [19,20], can explain the absence of antimatter if there is a very strong breakdown of T symmetry. GUT's require the existence of monopoles and massive neutrinos which both have not been observed yet. Electroweak theories require the mass of Higgs to be about 40 GeV while the present measurements gives $M_H > 60$ GeV. Theories predicting the existence of antimatter [21] postulate that the breakdown of the time–reversal symmetry in the early universe might have set different signs of CP in different regions of space. Since there are 10^8 clusters of galaxies and the observational constraints are limited to the scale of the clusters, the universe can be symmetric on a larger scale. Then, the observed matter–anti matter asymmetry would be a local phenomenon.

Since antiprotons and positrons are not direct indicators for the existence of primordial antimatter, the antimatter in AMS will be searched by measuring helium or heavier nuclei (CNO group). Particle rigidity and charge sign will be measured with the tracker, velocity with the ToF and absolute charge with the combined measurements of dE/dX in the tracker and ToF systems. After three years of data taking AMS will reach a sensitivity of antihelium/helium ratio of about 10^{-10}, 3–4 orders of magnitude better than the predictions based on matter-anti matter symmetric universe (see Fig. 4).

If no antinuclei is observed with AMS then the presence of anti matter up to the edge of the universe (≈ 1000 Mpc) could be excluded.

4.2. Dark Matter

Rotational velocities in spiral galaxies and dynamical effects in galactic clusters provide us convincing evidence that almost 90% of our universe is constituted by dark matter [22,23]. The "kind" of dark matter is strongly related to the large scale structure and galaxy formation in the early universe. There is a commonly used distinction between "hot" and "cold" dark matter. Hot dark matter consists of particles which are still relativistic when they separate (freeze out) from matter in an early phase of the universe. Hot relics such as light neutrinos have densities comparable to photons. On the other hand, cold dark matter is made out of heavy particles which are already nonrelativistic at freeze out. Cold relics candidates are axions,neutralinos, higgsinos or Weakly

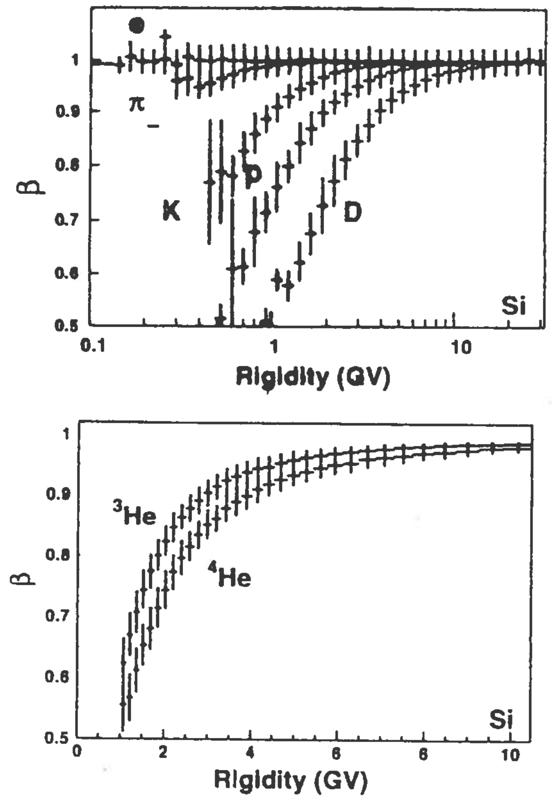

Figure 7. Particle identification with ToF vs rigidity (upper) and helium mass separation vs rigidity (lower) measured by silicon tracker

mic rays have the same origin [25,26]. AMS will identify the deuterons up to about 4 GV and by collecting 6.10^8 events in 3 years, it will reduce the uncertainty on D/p by a factor 100. Furthermore, AMS will be able to separate ^{3}He from ^{4}He up 5 GV improving the ^{3}He/^{4}He ratio by a factor of $\approx$ 200.

Fig.7 shows the velocity versus rigidity of deuterium (upper) and helium (lower) as determined with AMS detectors.

Accurate determination if B/C ratio over wide energies will provide crucial information relative to the cosmic ray propagation in the galaxy [27]. In particular will help to determine the parameters of galactic wind which reduce the accessibility of extragalactic cosmic rays to our galaxy. AMS in one they will have better statistics on B/C ratio than the present data up to rigidities of about 100 GV.

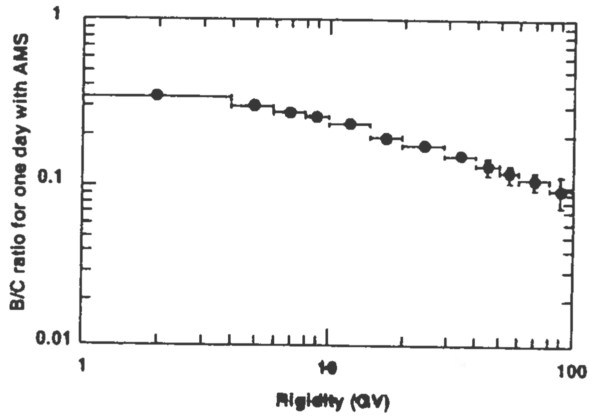

Figure 8. Accuracy of the measurement of B/C ratio by AMS with one day of data. The ratios are computed assuming the halo thickness of 2 kpc and zero convection velocity.

In Fig. 8 is shown the precision of the B/C measurement by AMS with one day of data.

The study of the radioactive isotope ^{10}Be to stable isotope ^{9}Be ratio will give the possibility to determine the mean interstellar matter traversed by cosmic rays hence the accurate determination of their galaxy confinement time [28]. At present there are 15 ^{10}Be events reported leading to an error on confinement time of 25 ± 10 Myr [29,30]. Aerogel Čerenkov detectors of AMS will perform accurate measurements up to rigidities about 2 GV by collecting 100's of ^{10}Be/day (see Fig.9).

4.3.2. Gamma Rays

Inserting a 0.3 X$_0$, high Z (tungsten) converter plate between TRD's above S1–S2 counters (see Fig. 2) AMS becomes a γ–ray detector. The γ–ray energy and direction will be determined from the measurements of electrons momentum

17. S. Dimopoulos, L. Susskind, Phys. Rev.D18, 4500(1978).
18. V.A. Kuzmin, et al., Phys. Lett.76B, 436(1978).
19. A.G. Cohen et al.,Ann. Rev. Nucl. Part. Phys. 43, 27(1993).
20. V.A. Kuzmin, et al., Phys. Lett.155B, 36(1985).
21. A.H. Guth, Phys. Rev. D23, 347(1981).
22. I. Novikov, Proc. Vulcano Workshop, S.I.F., V.47, 79(1994).
23. K. Pretzl, Proc. Vulcano Workshop, S.I.F., V.47, 89(1994).
24. P. Ferrando, Proc. 23rd Inter. Cosmic Ray Conf.3, 279(1993).
25. W.R. Webber, et al., Ap.J.380, 230(1991).
26. J.J. Beatty, et al., Ap.J.413, 268(1993).
27. W.R. Webber, et al., Ap.J.390, 96(1992).
28. A. Lukasiak, et al., Ap.J.423, 426(1994).
29. M.E. Wiedenbeck, D.R. Greiner, Ap.J.239, L139(1980).
30. J.A. Simpson, M. Garcia–Munoz, Space Sci. Rev.46, 205(1988).
31. E. Fiandrini, these proceedings.