The AMS Brick: an HV Power Supply for the Space Experiment AMS-02

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I. AMS02 ON THE INTERNATIONAL SPACE STATION.

AMS[1] is a particle physics experiment in space. The purpose is to perform accurate, high statistics, long duration measurements of the spectra of energetic (up to multi-TeV) primary charged cosmic rays in space. It contains the following main components:

1) A twenty layers of Transition Radiation Detector (TRD) which identifies electrons and positrons with a measured rejection factor against hadrons of 10^3 to 10^2 from 1.5 Gev to 300 GeV.
2) Four layers of Time of Flight (TOF) hodoscopes that provide precision time of flight measurements (~ 120 pS) and dE/dX measurements.
3) The superconducting magnet, which provides a bending power of $BL^2 = 0.86\ Tm^2$.
4) Eight layers (6.45 m^2) of silicon tracker, which provide a proton rigidity (=momentum/charge) resolution of 20% at 0.5 TV and a heliun (He) resolution of 20% at 1 TV and charge resolution of nuclei up to iron (Z=26).
5) Veto, or anticoincidence, counters (ACC) which ensure that only particles passing through the magnet aperture will be accepted.
6) A Ring Imaging Cerenkov Counter (RICH), which measures the velocity (to 0.1%) and charge |Z| of particles or nuclei. This information, together with the measurement of momentum in the tracker, will enable AMS to unambiguously determine the mass of these particles and nuclei.
7) A 3-D sampling calorimeter (ECAL) made out of 16.7 X_0 (radiation lengths) of lead and scintillating fibers which measures the energy of gamma rays, electrons and positrons and distinguishes electrons and positrons from hadrons with a rejection of 10^4 in the range between 1.5 GeV to 1 TeV.

AMS is scheduled to be installed on the Space Station in Aril 2007 for a period of three to five years.

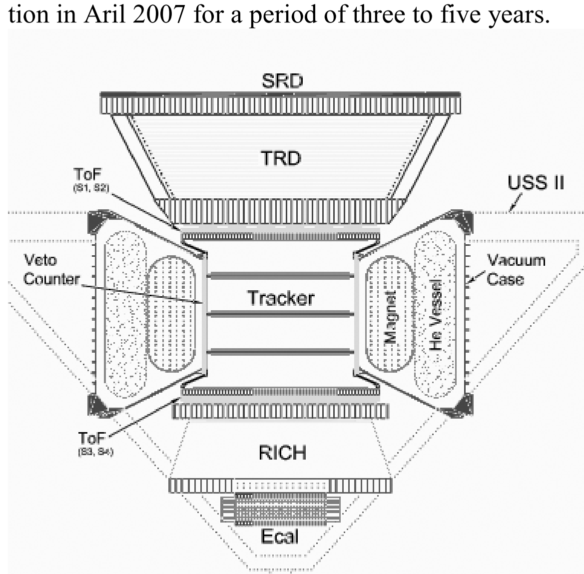

Fig. 1 AMS02

II. THE STRUCTURE OF THE BRICK

Tree components (TOF, RICH and ECAL) use photomultiplier and need a complex High Voltage system, controllable through serial links. In the following table are shown the number and the distribution of Photomultipliers for each subdetector.

Det. Name	N° PMT	V. Range	PMT current
ECAL	324	0V-900V	150 µA
RICH	160	0v-950V	100 µA
TOF	160	0V-2300V	50 µ A

We developed a modular structure to manage the large number of independent High Voltage channels, optimizing volumes, masses, number and length of cables, and taking in account the efficiency and the reliability.

ENGINEERING OPTIMIZATION RESULTS:

	ECAL	RICH	TOF
Brick number	6	4	4
BOX HV-DC/DC conv (Number for Brick)	2	1	1
HV-DC/DC conv. N° (for BOX HV-DC/DC)	1/1 hot/cold	1/1 hot/cold	1/1 hot/cold
BOX HV-Lin.Reg. N° (for BRICK)	5	5	3
Linear Regulator N° (for BOX-HV-Lin.Reg)	8/8 hot/cold	8/8 hot/cold	8/8 hot/cold
HV output Lines (for BOX-HV-Lin.Reg)	11 (3x2+5)	8	8
BRICK HV Lines	55	40	24
Total HV outputs (full redundant)	330 6 spares	160	96
Total HV Linear Reg. (redundant)	240	160	96
BRICK Mass	3.70 Kg	3.26 Kg	3.06 Kg
BRICK Volume	3700 cm^3	3400 cm^3	3400 cm^3

This system was the “Brick”, a set of interconnected modules (boxes) which contains DC/DC converters to generate HV from the 28 V. DC available from the space station(BOX HV-DC/DC), linear regulators to fine adjust the voltage of each Phtomultiplier (BOX HV-Lin.Reg.) and the logic board with the digital link that sets and monitors the various voltages (xPSC).

It was designed completely redundant: the generation, regulation and control of HV and the serial links. The high reliability was obtained with the redundancy and selection of components. The modularity allowed us to use the same hardware, in different configurations, for the various detectors. It is very easy to integrate it since it needs only the connection to the 28V of ISS and to the serial links. All the High Voltage connections are inside and the connections to the Photomultiplier are done via coaxial connectors for “space” use. The selected modularity of 16 Linear Regulators (8 redundant) per box enhances the Potting and reduces the possibility of failures. The use of few DC/DC converters for many exploiters allowed to minimize the number of components, the weight and the volume. The HV output of each linear regulator is protected against overloads so to avoid failure propagation. Each HV is settable with a resolution of 10 bits, allowing a precision of 1V in case of ECAL and RICH and of 2,5V in the case of TOF. They can also be remotely monitored through serial link.

III. THE MECHANICS

A great care has been put on the mechanics: we needed a light structure, compact and robust. The various “boxes” were designed to be obtained from a single peace of aluminium, very light and extremely tough.

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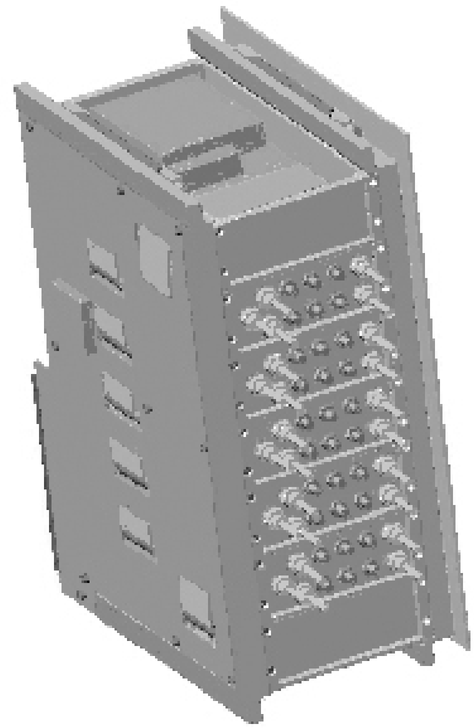

Fig. 2 Mechanical drawing of an ECAL Brick

In Fig. 2 it is shown the drawing of the ECAL version of brick, where are visible 7 boxes: the first and the last are BOX HV-DC/DC , the 5 central ones are BOX

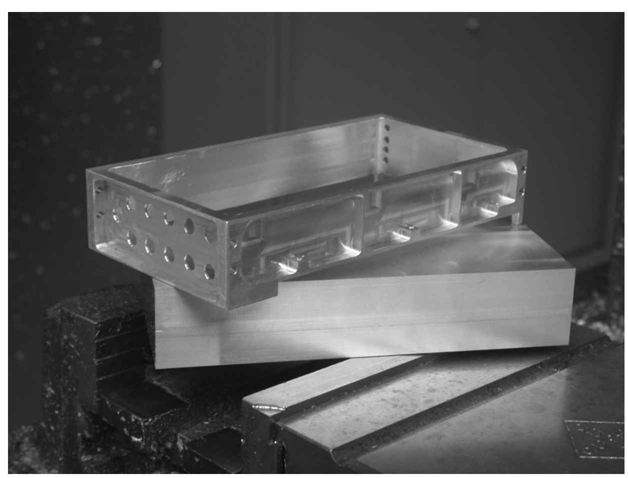

Fig. 3 The box of HV-Lin-Reg on the piece of aluminium from which it is derived

HV-Lin.Reg, with 11 front HV connectors, and, on the left side, it is visible also the xPSC. The interconnections inside are also optimised to reduce the total weight.

IV. THE ELECTRONICS REDUNDANCY

In these 3 subdetectors the redundancy is obtained doubling the electronics and the active part can be selected by giving power. As shown in figure 4, each box HV (in the Figure the Ecal brick) has two sections, HOT and COLD, that are directly connected to the relative HOT and COLD box Lin-REG. The control board, also divided in HOT and COLD parts, sets and monitors the voltages. The outputs of the two (HOT and COLD) linear regulators are "ored" together via HV diodes and connected to the HV Reynolds connectors.

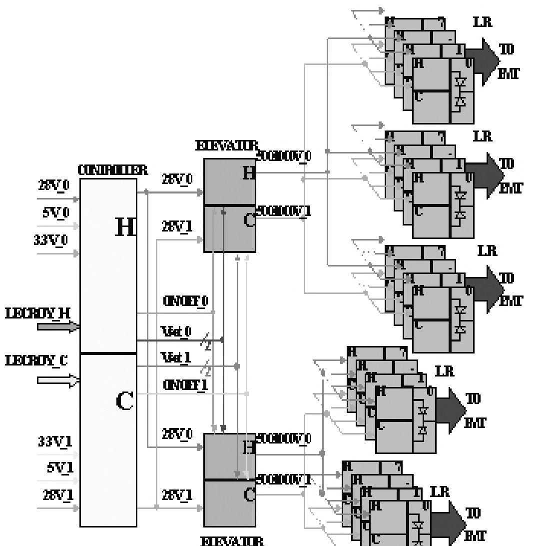

Fig 4 ECAL HV System: block diagram of one HV brick

V. THE PROTOTYPES AND CONCLUSIONS

A first prototype has been built and tested at the test beam at CERN in July 2003 for the ECAL.

Since the results obtained were satisfying, one year later, an engineering model has been made.

The design accomplishes the goal to have: temperature working range from -20° to +70°, capability to operate with magnetic fields as high as 500 Gauss, and capability to survive to radiations up to 10 Krad. The reliability is given by the respect of the dictate ESA PSS-01-301, soldering and mounting following dictate ESA PSS-01-738. Stacking and conformal coating following note NASA NHB 5300.4 (3J) ensure that it can operate at any pressure, also from 0,1 to 10 mBar, where, following the Paschen curve, the rigidity of air is lower. Tests done in the factory were Burn-in, thermal cycles, vacuum tests, electrical test and optical inspections after every assembling phase.

It is now under test with good results.

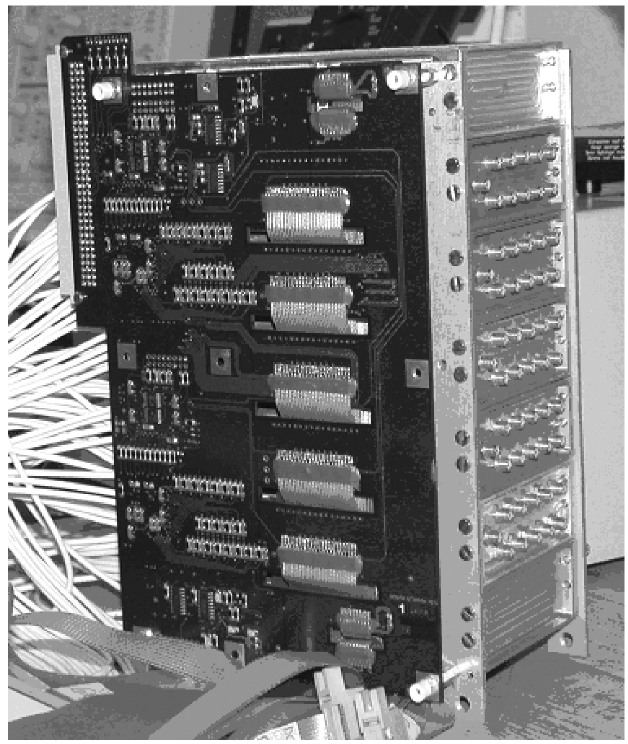

Fig. 5 Engineering model of ECAL Brick

VI. REFERENCES

[1] The AMS Collaboration: AMS on ISS, Construction of a particle physics detector on the International Space Station, Submitted to Nuclear Instruments and Methods A