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THE SCINTILLATOR COUNTERS OF THE TOF OF THE AMS-02 EXPERIMENT

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Abstract

The Time Of Flight system of the AMS-02 detector is beeing built in the INFN laboratories of Bologna. The high magnetic field produced by the AMS-02 superconducting magnet imposes the utilization of special PMTs and light guides for the TOF counters. The TOF detector must give the fast trigger to the whole AMS experiment and must measure the absolute charge by particle energy loss, at least up to z=20. To control the TOF-02 performances, a series of thermal-vacuum tests together with a beam test have been made, and the results are quite encouraging.

1 Introduction

The TOF apparatus of the AMS-02 experiment [1] is being built at the INFN laboratories of Bologna. The operation in space imposes several requirements on the mechanical design and on the servicing electronics for the TOF system. The modules have to be housed in a light-tight and robust cover and the support structure of the modules has to conform the NASA specification, so vibrational and thermal-vacuum tests on the structure components have to be done.

2 The requirements for the TOF of the AMS-02 experiment

The Time Of Flight system of AMS-02 will provide:

1. the fast trigger to the experiment;
2. the measurement of the time of flight of the particles traversing the detector with a resolution sufficient to distinguish upward from downward going particles at a level of at least 10^{-9}, and electrons from anti-protons at $E < 1.5$ GeV;
3. the measurement of the absolute charge of the particle in addition to the measurements done by the silicon tracker and by the RICH.

Thus the TOF scintillators must give a very fast and reliable response to the energy lost by the particle traversing the detector. The system will also provide a measurement of the particles charge with a resolution to distinguish nuclei up to $Z \leq 20$: a dynamic range of more than 10000 in the measurement of the pulse height is thus required (taking into account the attenuation along the counter and the need to have a good measurement of singly charged particles).

3 The TOF-02 design and mechanics

The geometrical acceptance of the TOF has been fixed at $0.4\,\mathrm{m}^2\mathrm{sr}$ to maximize the sensitivity of the spectrometer for antimatter search. To match the acceptance of the magnet, each plane of the TOF system covers roughly a circular area of about $1.2\,\mathrm{m}^2$, with 12 cm wide scintillator pads of different length, overlapped by 0.5 cm to avoid geometrical inefficiencies.

The high absolute value of the field ($1.5 \div 2$kG) forced the adoption of a special kind of PMT (fine mesh Hamamatsu R5946). Even though the fine mesh can operate inside intense magnetic fields, their response depends strongly on the angle between the field and their longitudinal axis (see section 3.1). Thus, tilted light guides were designed in order to minimize this angle for each PMT.

3.1 The fine mesh PMTs

To study the behaviour of the fine mesh photomultiplier Hamamatsu R5946 in the magnetic field, they were performed significant tests in the Bologna laboratory: it was measured the PMT response to a red light emitting diode (LED) inside the poles of an electro-magnet (maximum field 4 kG) on a movable stand which could be be rotated at a maximum angle of 90°. The photomultiplier response was measured for different values of the magnetic field $\vec{B}$ and of the angle between the tube axis and the field direction [2].

A complete simulation of the fine mesh phototubes has also been developed [3] and the results of the simulation are in good agreement with the

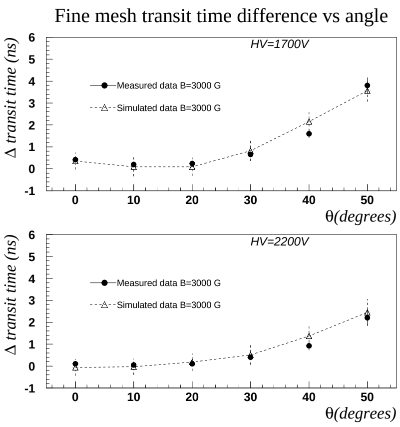

Figure 1: Measured and simulated transit time difference ($t_{B>0} - t_{B=0}$) for fine mesh photomultipliers in a magnetic field B=3000 G, as a function of the angle θ between $\vec{B}$ and the PM axis [3].

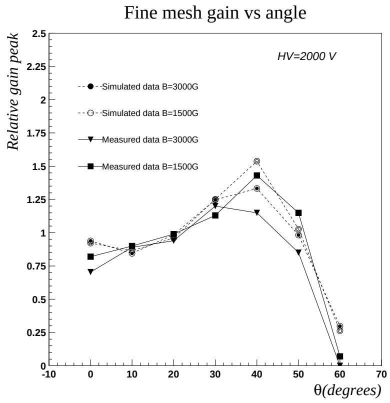

Figure 2: Measured and simulated PM gain versus the angle between the magnetic field and the PM axis [3]: the fine mesh response drops down above $\sim 30°$, both in the data and in the simulation.

data taken, both for the fine mesh response in time and for the gain response, for various inclination of the PM inside the magnetic field. Figures 1 and 2 show the data taken together with the simulation made. The results of both measured data and simulation show that the fine mesh cannot work for $\theta > 30°$, because of their time response degradation and since their gain has an abrubpth fall [2].

3.2 Counters

The plastic scintillator of the TOF counters is by Eljen-Technology (Texas-USA), 12 cm wide, 1 cm thick. They are of variable widht and variable lenght ($117 \div 134$ cm). Figure 3 shows a view of the TOF couple of upper planes with the scintillators and the light guides.

The first prototypes were characterized in the laboratory and tested in a heavy ions beam in 2002 and 2003. On each side, up to 15 cm long clear plastic guides collect the scintillator light on the photocathodes of two (or three) R5946 Hamamatsu photomultipliers. The bialkali photocathode sensitivity matches the scintillator light spectrum. In 2004 the TOF counters have been characterized in the Bologna laboratory with a proper cosmic ray telescope. The results of the TOF counters caracterization can be consulted on line [5].

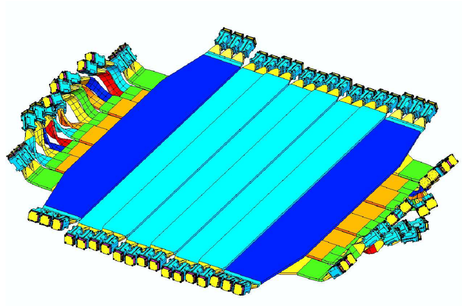

Figure 3: Upper TOF couple of planes (the edge counters are of trapezoidal shape).

4 Space qualification tests

The TOF detector will undergo variations of temperatures from $-20°$C to $+50°$C and it will survive the strong acceleration produced by the shuttle launch, and its measurements should not be affected by this vibration. Hence, thermal-vacuum and mechanical tests must be carried on with the TOF structure, before the flight.

A group of 10 photomultipliers was tested in the Bologna thermal-vacuum simulator at a pressure of $10^{-7} \div 10^{-6}$ mbar with temperature varying between $-30°$C and $+55°$C. They were re-calibrated after each cycle of temperature and their characteristics remained the same [4]. Other six PMTs were also monitored for the dark current.

Figure 4 shows the variation of the dark current versus temperature for a couple of phototubes. Even if an increase is clearly measured at high temperature, the dark current is always negligible [6].

5 Beam test results

In 2003, four scintillators (named C1,C2,C3 and C4) were used with a 158 GeV/c/A ion beam obtained from the primary In SPS beam and tuned with the H8 selection line. Data analysis is still in progress for this beam test run.

Two of the scintillators used (C2,C3) represented the worst situations, with twisted and bended light guides. The charge peaks of the most problematic counter (C2) are clearly seen in figure 6. The charge resolution was also computed, both for the anode signal and for the dynode signal (passive sums of the two PMTs), as it can be noticed in fig. 5.

From the time of flight measurements between the different counters (for example C2-C3 is shown in figure 7) it is possible to infer the TOF resolution,

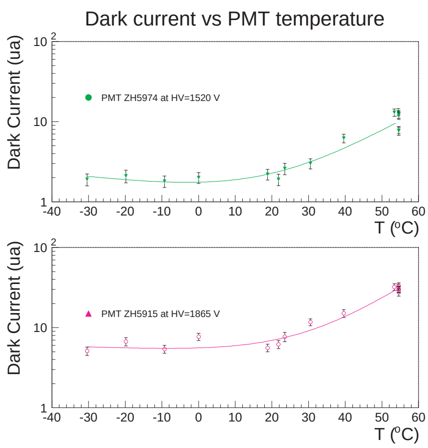

Figure 4: Fine mesh dark current as a function of the temperature [6] for a couple of phototubes. High gain PM on top, low gain PM on bottom.

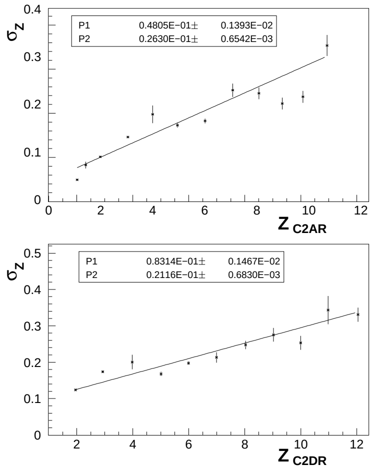

Figure 5: C2 charge resolution as a function of the particle charge for anode (above) and dynode (below) signals.

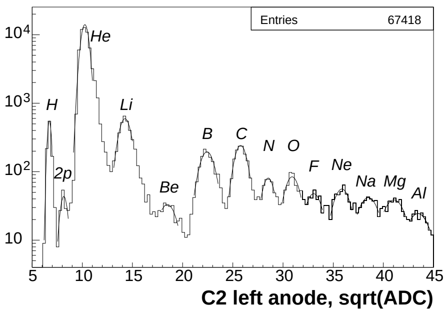

Figure 6: Square root of the integrated charge measured with left anode of a TOF counter (peak "2p" is due to singly charged particles crossing in time).

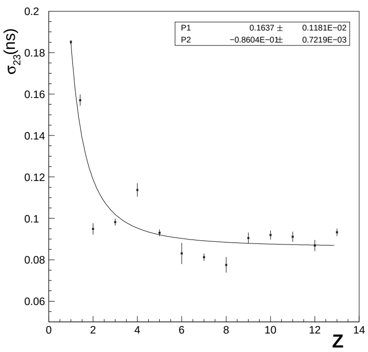

Figure 7: Resolution on the time of flight between two TOF counters (named C2 and C3 respectevely) as a function of the particle charge.

that turns out to be of the order of 130 ps for singly charged particles [1].

[1]for the four planes $\sigma_{tof} \simeq \frac{\sigma_{23}}{\sqrt{2}}$

References

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