Efficiency determination for the ATRAP detector system

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The ATRAP experiment at the CERN Antiproton decelerator (AD) aiming for a precise CPT test by studying the antihydrogen atom includes a detection system for the antiproton annihilation products. Antihydrogen production studies require the knowledge of the produced antihydrogen atoms as well as absolute antiproton losses during the development.

In 2008 the ATRAP experiment has been modified by adding an additional solenoid to improve the $\bar{p}$ trapping and has been operated at a lower main field 1 T. Furthermore some photomultipliers have been exchanged and the PM voltages have been adjusted. Therefore the efficiency for the detection of an antiproton annihilation has been determined by using cosmic rays and Monte Carlo studies.

In order to get accurate values for the detection efficiency of a $\bar{p}$ annihilation one should trap a single antiproton, release it at a well defined time, observe the registered detector signals and do this procedure a sufficient number of times to reach a low statistical uncertainty. The trapping of single antiprotons within the ATRAP setup has been achieved in 2008 but it has to be further developed before this experimental efficiency determination is available.

Another possibility is the use of Monte Carlo studies which have been done by using the GEANT4 software package. As input for the simulation studies one needs a realistic geometry and the energy thresholds for the registration of a signal in the individual detector components.

As a first step the efficiency of the different detector components for the detection of a minimum ionized particle is determined by measuring cosmic particles. The detector system is sketched in fig. 1. It consists of four fiber rings surrounding the trap, two staggered straight fiber rings that a particle passing the double fiber ring must hit a scintillating fiber and two helical fiber rings where each fiber covers an angular range of about 155 °. At the outside of the magnet an arrangement of scintillator plates is installed, 8 large plates (outer) and 16 smaller plates (inner) where every two inner are covering one outer. The lines in fig. 1 indicate straight tracks of cosmic particles.

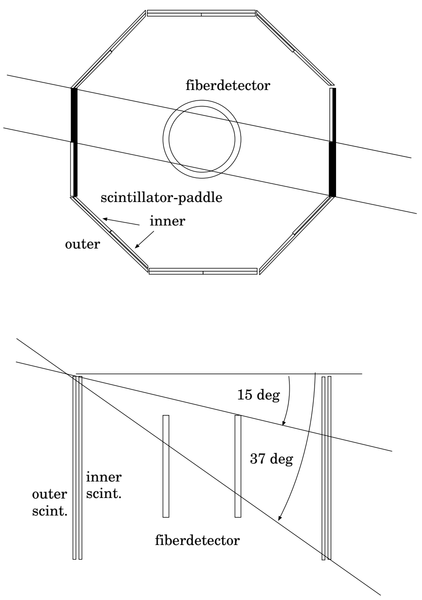

Fig. 1: Sketch of the detection system at ATRAP-II with the fiber detector and the outer scintillator paddles.

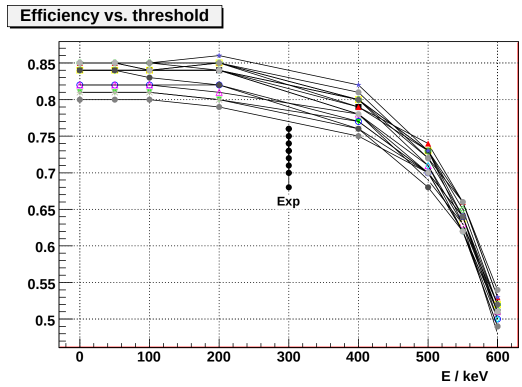

Fig. 2: Detection efficiency for the straight fiber layer from Monte Carlo data as a function of the energy threshold in keV compared to the experimental points.

The efficiency for the scintillator plates is determined by selecting cosmic events with a signal in two opposite large (small) scintillator plates and a signal in one corresponding small (large) scintillator plate. The detection efficiency is close to 100% which is consistent with the ADC distributions of these elements. For the detection efficiency of the straight fibers cosmic events are selected with signals in two opposite large and small scintillator plates. These cosmic particles have to pass also the fiber detector if the inclination angle is not too small. The distribution of hit straight fibers shows two bumps for the two regions of possible hit fibers which can be reproduced by Monte Carlo data. In fig. 2 the mean efficiency from Monte Carlo data as a function of the energy threshold E_{th} is shown. The comparison to the experimental points suggest a threshold of 470 keV which is compatible with the observed threshold in the ADC spectra. The mean efficiency determined by this method is 0.88 (the value has to be normalized to the value at zero threshold). Alternatively the fiber detection efficiency was determined by selecting cosmic events with the four outer scintillators and a straight (helical) fiber for the helical (straight) fiber efficiency from which values of 0.84 for the helical and 0.87 for the straight result.

The efficiency for the detection of a $\bar{p}$ annihilation is determined from Monte Carlo by including the extracted energy thresholds for the detetctor elements. It depends on the signals which are requested for the identification of a $\bar{p}$ annihilation. Depending on the fiber multiplicity (M_{fiber}) and the paddle multiplicity (M_{paddle}), whereby a paddle signal means here coincident signals in one large and one of the associated small scintillator plates, the signal to noise ratio can be improved but the optimal condition depends also on the total event number. For $M_{fiber} > 0$ and $M_{paddle} > 0$ the mean efficiency is 0.78, for $M_{fiber} > 1$ and $M_{paddle} > 0$ its 0.7, and for $M_{fiber} > 1$ and $M_{paddle} > 1$ it reduces to 0.4. For each condition used in the analysis the particular efficiency is determined and is used for the calculation of absolute numbers.