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New results of the antiproton-carbon annihilation cross section measurement at low energies

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Abstract. The antinucleon-nuclei annihilation cross section at very low energy has been measured at the LEAR facility (CERN) during the 80's and 90's and recently at the Antiproton Decelerator. The results have raised some interesting questions that still need answers. The ASACUSA collaboration performed an experiment to measure the σ_{ann} of 100 MeV/c antiprotons on carbon target and the preliminary results are presented here.

1 Introduction

The interest for the very low energy $\bar{p}$- and $\bar{n}$-nuclei interaction is due to their influence on both fundamental cosmology and nuclear physics. The study of the annihilation cross section on matter can give some contribution to the universe matter-antimatter asymmetry puzzle, as well as helping in the definition of strong interaction model parameters.

So far, the collected data for the antiproton and antineutron cross section show some discrepancies: at momenta of 300-400 MeV/c they both result [1] larger than predicted by the optical potential model which well reproduces the existing data at higher energies [2]. Moreover, the $\bar{n}$ annihilation cross section on several nuclei measured in the 70-400 MeV/c momentum range [1] seems to follow a $1/p^2$ trend rather than a 1/p that is the expected one for a neutral projectile.

A comparison between the $\bar{p}$ and $\bar{n}$ data can represent a step forward in the clarification of the unsolved issues. Antiproton annihilation cross section data on proton are available for momenta below 80 MeV/c and on Sn for 100 MeV/c [3]. The ASACUSA Collaboration recently performed the measurement of the antiproton annihilation cross section in the ~100 MeV/c momentum region and the first preliminary results will be shown here.

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2 Experimental apparatus and technique

The experimental setup is presented in Fig. 1. A vacuum chamber composed by two cylindrical sections (total length 300 cm, diameters 120 cm and 60 cm) is put into the existing ASACUSA beam line which is equipped with two GEM profile beam monitors for the beam alignment and focusing. A system of 4 movable holders allows the positioning of 13 mm diameter circular frames (with or without targets) on the beam axis in different positions [4]. The targets consist in very thin self-supporting diamond-like carbon layers by Micromatter[1] with a thickness of 700 nm and 1000 nm.

Outside the chamber, in a position corresponding to the target, an arrangement of planar detectors is installed to detect the passage of the charged particles from $\bar{p}$ annihilations. They are made of plastic scintillator bars readout by multi-anode PMTs and a custom designed electronics system [6]. A Cherenkov counter is placed at the end of the beam line where all the $\bar{p}$s annihilate.

Bunches of $\sim 5\times10^6$ antiprotons, 50 ns long (rise time ~15 ns) are provided by the AD at a kinetic energy of 5.3 MeV. The $\bar{p}$s travel in the vacuum chamber at a speed of 3 cm/ns and almost all of them arrive at the end of the beam line after ~120 ns, while a small fraction, of the order of 1-10 every 10^6 incoming, can undergo in-flight annihilation in the target (the physics process under study). The $\bar{p}$s scattered on the lateral walls can represent a background for the measurement. Actually their annihilation is delayed of more than 20 ns with respect to the early annihilations in the target since the chamber radius is 60 cm. Therefore, a fiducial time interval to count the annihilation events is selected: it corresponds to the first 20 ns region of the annihilations.

The data acquisition system performs a sampling at 300 MHz of the scintillator channel signal providing a hit time profile for every crossing bunch (see Fig. 2a). The time resolution at the ns level of the acquisition chain is enough to distinguish the hits coming from the target region and the ones from the chamber walls (time separation of ≥20 ns).

The calibration of the Cherenkov detector which monitors the beam intensity is performed with dedicated runs: a second circular empty frame is put 15 cm downstream of the target in order to intercept a known angular fraction of the scattered $\bar{p}$s that can be calculated using the Rutherford cross section and compared to the acquired data in this configuration.

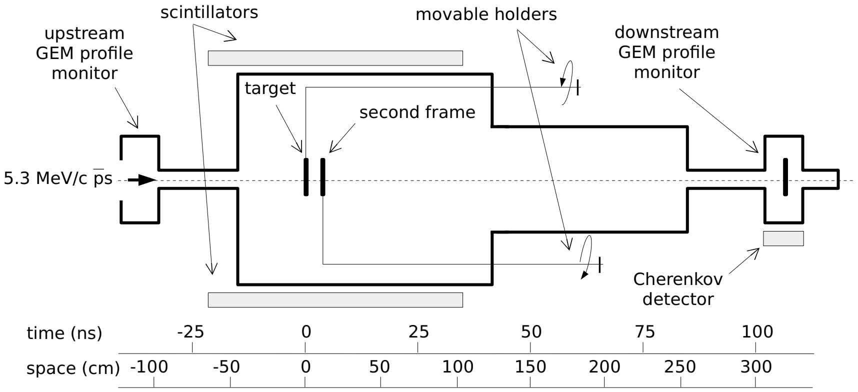

Figure 1: Scheme of the experimental setup. The time scale is based on $\bar{p}$ speed of 3 cm/ns.

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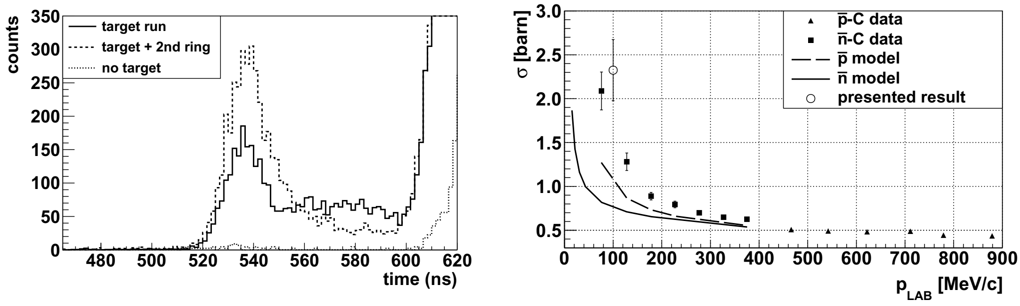
[1] http://www.micromatter.com/dlc.php

3 Results

The plots in Fig. 2a show the time profiles, for different types of runs, detected while the $\bar{p}$ bunch crosses the target. The time separation between the annihilation in the target region (defined as the 520–540 ns window), from the lateral walls (after 20 ns or more) and from the end wall (after 100 ns) is possible. Our measurements lead to a preliminary evaluation of: $\sigma_{ann} = 2.32 \pm 0.35$ barn (statistical contribution to the error is 6%). Fig. 2b presents the obtained result superimposed to the existing $\bar{p}$ and $\bar{n}$ annihilation data on carbon [1, 7] and calculation from [2]. The total error can be reduced from ~15% to ~10% by implementing a better synchronization in the detector data.



(a) (b)

Figure 2: (a) Normalized hit profiles of one of the scintillator plane for different runs. (b) Result of the $\bar{p}$ annihilation cross section on carbon measurement superimposed to the existing data for p̄, n̄ and the corresponding theoretical predictions [2].

4 Conclusions

We reported the preliminary result for the $\bar{p}$-C annihilation cross section measurements at 5.3 MeV. The number is larger (1.5 times) than the $\bar{n}$-C one as expected by a Coulomb focusing mechanism; nevertheless it is twice the optical model prediction [2], a still unexplained issue (the same occurs in the $\bar{n}$ case). In the near future, when the ELENA facility will be operative at the AD, the same measurements will be possible at 100 keV as already demonstrated in [8].

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