ABSORPTION CROSS-SECTIONS OF 25 GeV/c ANTIDEUTERONS IN Li, C, Al, Cu AND Pb

F. BINON *, S. P. DENISOV **, S. V. DONSKOV **, P. DUTEIL *, G. GIACOMELLI ***, Yu. P. GORIN **, V. A. KACHANOV **, V. M. KUTYIN **, J.-P. PEIGNEUX ‡, A. I. PETRUKHIN **, Yu. D. PROKOSHKIN **, E. A. RAZUVAEV **, R. S. SHUVALOV **, D. A. STOYANOVA ** and J.-P. STROOT ‡‡

IHEP-CERN Collaboration, Institute for High Energy Physics, Serpukhov, USSR

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In this letter the first measurements of the interaction of antideuterons in nuclei are presented. These were performed on lithium, carbon, aluminium, copper and lead targets with 25 GeV/c antideuterons at the 70 GeV proton synchroton of the Institute for High-Energy Physics.

The antideuterons were produced by proton interactions at small angles in an internal target of the synchroton. Beam description has been given elsewhere [1].

The total flux of negative particles in the beam in a momentum band of ±1% was about 5×10^5 particles per burst of 0.8 sec duration. About one antideuteron was obtained per minute, corresponding to a ratio $\bar{d}/\pi^- \approx 5 \times 10^{-7}$. Antideuterons were identified by the logical counter combination $\bar{B} \equiv M\,\bar{C}_1\bar{C}_4\bar{C}_5C_6^*$. M was the output signal from five scintillation counters in coincidence and two halo scintillation counters in anticoincidence. This counter combination defined the beam geometrically and gave the total incident flux. $\bar{C}_1\bar{C}_4\bar{C}_5$ indicates anticoincidence from three threshold gas Čerenkov counters, whose pressures were set to reject π^-, K^- and $\bar{p}$'s. In this way, the counting rate $M\,\bar{C}_1\bar{C}_4\bar{C}_5$ for particles lighter than antideuterons was already decreased by a factor of more than 10^{-7}. C_6^* was the output signal of a gas Čerenkov counter, working in the differential-threshold mode [2], tuned at the antideuteron mass. About 2000 antideuterons were recorded during the measurements.

* CERN, Geneva, Switzerland.
** IHEP, Serpukhov, USSR.
*** Visitor at CERN from the University of Bologna and INFN, Bologna, Italy.
‡ Visitor at CERN from the Faculté des Sciences, Clermont-Ferrand, France.
‡‡ Visitor at CERN from Institut Interuniversitaire des Sciences Nucléaires, Brussels, Belgium.

Cross-section measurements were made by using the standard transmission technique [3]. Absorption targets were mounted on a rotating wheel, positioned behind the last beam-defining scintillation counter.

Five transmission counters (T_1-T_5) and a small efficiency counter S_ϵ were placed about 9 m behind the targets. In this region the beam was parallel, with a diameter of 7 cm. The transmission counters had diameters of 20, 24, 28, 34 and 40 cm respectively, so that beam size effects do not need to be considered, at least at the present level of accuracy.

The beam signal B was strobed with each of the five transmission counters ($B\,T_i$), with the same counters delayed by 165 nsec ($B - T_i$), 165 nsec being the period of the accelerating radiofrequency and with one transmission counter together with the efficiency counter ($B\,T_i\,S_\epsilon$). These three types of coincidences provides, respectively, the beam flux through each transmission counter, an indication on the randoms in each channel and the efficiency of one channel. The efficiency of each transmission counter was regularly checked by triggering on antiprotons. Efficiencies were never lower than 99%. The number of accidental counts was less than 2.5% for each channel.

Measurements consisted of a series of antideuteron runs with the Li, C, Al, Cu and Pb targets, and also without any target. These yielded the partial cross-sections σ_i as seen by each transmission counter. Similar measurements were also made for pions and antiprotons.

The transmission counters covered the t-range 0.08-0.31 (GeV/c)^2, where t is the maximum four-momentum transfer squared accepted by each counter. The extrapolation of the partial antideuteron cross-sections σ_i to zero solid angle was performed assuming an exponential dependence in

$$\sigma_i = \sigma_a' \exp(bt) \tag{1}$$

for the extrapolating curve, as was proved to be satisfactory in the case of π^- and $\bar{p}$ with much larger statistics [3]. The computed χ^2 values were satisfactory in all cases.

The currently measured pion and antiproton absorption cross-sections agree well with the previous resulsts [3].

The contamination in the antideuteron beam was not larger than 3%. The results of the measurement were compared with other data obtained with more stringent antideuteron identification triggers, which included either one supplementary threshold Čerenkov counter in coincidence, tuned above antideuteron threshold, or a gas differential Čerenkov counter [1]. No measurable effect was observed on the cross-sections.

Antiprotons produced by the stripping of antideuterons in the counters defining the beam after the momentum analysing magnet have the same velocity as their parent antideuterons and thus they can be recorded as such in the Čerenkov counters. Owing to angle acceptance, such antiprotons need only to be considered when emitted in about the last five metres of beam. This contamination is then only a few per cent. It clearly has no measurable effect on the cross-sections at the present level of accuracy.

The absorption cross-section for antideuterons (i.e. the cross-sections for all inelastic processes) is the sum of the measured cross-section σ_a' and of the cross-section $\sigma_{str,\bar{p}}$ for the part of the stripping in which the antiproton does not interact. It has been shown at smaller momentum that these antiprotons are all emitted in a narrow angular range [4]. In our experiment they were all recorded in the transmission counters and were not distinguishable from antideuterons which did not interact or which were elastically scattered.

The experimental results σ_a' are listed in column 3 of table 1 and are presented in fig. 1 (black dots). The errors quoted are the sum of statistical and estimated systematic effects from randoms and beam contaminations.

Two different evaluations of deuteron-nucleus interactions have recently been published, based either on multiple scattering Glauber-type calculations [5] or on Monte Carlo methods in a cascade evaporation model [6]. Both obtain similar values for the ratio $\xi = \sigma_{str,p}/\sigma_a$ (table 1, column 4). These have been used directly with the present antideuteron data in order to evaluate the absorption cross-sections, inclusive of stripping and a small correction to take into account the finite thickness of the targets (table 1, column 5, white dots on fig. 1).

Table 1
Target materials, target thicknesses and measured cross-sections

Target	Thickness (g/cm^2)	σ_a' Measured cross-sections (mb)	$\xi = \frac{\sigma_{str,\bar{p}}}{\sigma_a}$	σ_a (including evaluated $\sigma_{str,\bar{p}}$) (mb)
Li	31.3	290 ± 30	0.40	465 ± 65
C	40.5	420 ± 70	0.36	640 ± 115
Al	47.3	720 ± 120	0.31	1030 ± 190
Cu	36.1	1310 ± 180	0.27	1770 ± 260
Pb	43.5	3370 ± 600	0.20	4260 ± 770

*) Refs. 5 and 6. A value of 55 mb for the total antinucleon-nucleon cross-section has been used to evaluate ξ from ref. 5. The uncertainty in the ratios ξ has been evaluated to be about 10%. It has been taken into account in the errors given for σ_a.

The fitting of the antideuteron absorption cross-sections to an equation of the type $\sigma_a = c\,A^{\alpha}$, where A is the atomic number of the target, yields

$$\sigma_a = (105 \pm 10)\,A^{(0.67 \pm 0.05)}, \tag{2}$$

whereas α is of the order of 0.75 when measured cross-sections without stripping corrections are fitted in the same way.

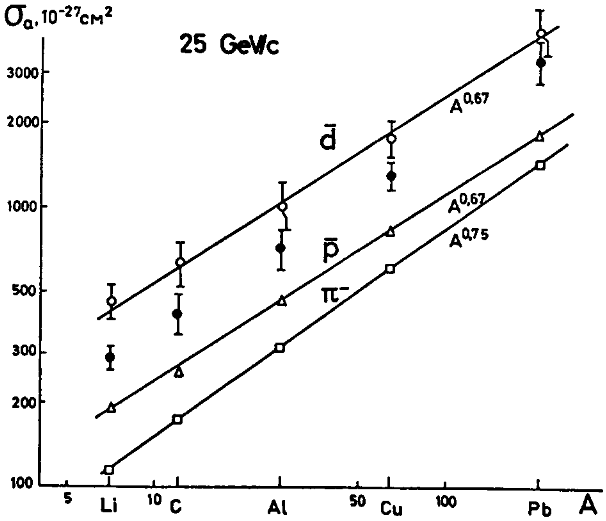

Fig. 1. Absorption cross-sections for 25 GeV/c antideuterons, antiprotons and negative pions.
The full circles represent σ_a', the measured antideuteron absorption cross-sections (without antiproton stripping). The open circles represent σ_a, the absorption cross-sections including evaluated antiproton stripping.

In fig. 1 are also shown the measured pion and antiproton absorption cross-sections.

The comparison of the various absorption cross-sections shows that nuclei are black for both $\bar{p}$ and $\bar{d}$ (that is $\alpha \approx \frac{2}{3}$ as expected by a diffraction model) but that the values of the cross-sections are much larger for $\bar{d}$ than for $\bar{p}$.

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