$\bar{\text{p}}$d TOPOLOGICAL CROSS SECTIONS IN THE MOMENTUM RANGE 50–920 MeV/c

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Abstract

The total and topological cross sections are presented for events seen in the interaction of 50–920 MeV/c antiprotons with deuterium in the BNL 30 in. bubble chamber.

Experimental Details

In this paper we report on $\bar{\text{p}}$d topological cross sections in the momentum range 50–920 MeV/c. The data were obtained from 10 runs at different beam momenta using the BNL 30 in. bubble chamber. The beam details are given by Caro and Klein (1969).

In the frames scanned in this study a total of 11 000 interactions were observed. Events were sorted into momentum bins approximately 50 MeV/c wide by using a template consisting of beam streamlines crossed by isomomentum lines that were separated by equal track length intervals. The central momentum uncertainty in each bin is estimated to be ± 15 MeV/c. Two independent scans were made and discrepancies were resolved by a third physicist scan. The overall scan efficiency is estimated to be better than 99%.

Results

Total $\bar{\text{p}}$d cross sections σ have been calculated using the expression

$$\sigma = (m/\rho x)\ln(I_0/I)\,,$$

where ρ is the deuterium density, m the mass of the deuteron, x the distance between the isomomentum lines defining a bin, I_0 the number of $\bar{p}$ tracks entering a bin, and I the number of beam tracks leaving the bin without interacting. Table 1 displays the resulting topological cross sections and the calculated total $\bar{\text{p}}$d cross section. In calculating the latter an allowance must be made for a 4° scan cutoff in the projected angle for scattering events. The correction for scattered tracks with large

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dip angles is estimated to be of order 25 mb from angular distributions obtained by measuring elastic scattering events. A further correction for lost forward scattering events is estimated by using the optical theorem to be of order 2 mb.

The total p̄d cross section data reported here together with the trend of previous data at higher momenta (Galbraith *et al.* 1965; Abrams *et al.* 1967; Allaby *et al.* 1969) are plotted in Figure 1 against the reciprocal of the antiproton momentum in the p̄N c.m.s. system. The plot indicates that the total cross section is almost linear in this quantity in the range 0·35–50 GeV/*c*. For comparison we have plotted the $\sigma_{\text{tot}}(\bar{p}p)$ data (Galbraith *et al.* 1965; Amaldi *et al.* 1966; Abrams *et al.* 1967; Allaby *et al.* 1969) on the same figure.

TABLE 1

OBSERVED TOPOLOGICAL AND TOTAL CROSS SECTIONS

σ_n, σ_{ns} denote cross sections for topologies with n fast charged outgoing tracks and s denotes the presence of a positive "stub" of length $\leqslant$ 5 cm. σ_1 and σ_{1s} contain 5–15% of one fast prong annihilation whilst σ_2 contains $\sim$ 20% of two fast prong annihilation; the remainder of these are made up of p̄d, p̄p, and p̄n elastic scattering (in the spirit of the impulse approximation)

Momentum (MeV/*c*)	Cross Sections (mb) $\sigma_1+\sigma_{1s}$	σ_2	$\sigma_3+\sigma_{3s}$	σ_4	$\sigma_5+\sigma_{5s}$	σ_6	σ_0	Other	Total	Scattering Correction	Corrected σ_{tot} (mb)
~50*	180	478	429	600	180	74	57	37	2040	27	2067±90
335*	109	64	48	82	18	14	13	13	365	25	390±15
404	108	50	43	63	14	8	14	5	306	28	334±12
450	100	47	43	52	13	8	19	4	289	27	316±7
504	88	44	37	57	14	8	15	4	269	26	295±7
560	78	44	31	51	11	8	15	5	246	25	271±6
605	79	42	33	49	14	7	10	5	241	28	269±7
650	78	38	29	52	12	5	10	3	228	30	258±8
705	65	37	29	39	12	6	10	2	203	27	230±10
762	71	35	27	48	12	7	10	9	222	31	253±10
813	62	32	29	37	9	4	8	8	190	28	218±11
866	54	33	28	35	7	5	8	6	181	27	208±10
920	49	35	28	40	12	5	7	2	184	26	210±9

* The momenta associated with the two lowest momentum bins are extremely uncertain because of the rapid variation of cross section and range for very low momenta. The errors represent counting statistics only.

We do not attempt to display separate p̄p and p̄n elastic and inelastic cross sections since the extraction of these from p̄d data is unreliable at low momentum.

Figure 2 displays the cross section difference $\sigma_{\text{odd}}-\sigma_{\text{even}}$, where

$$\sigma_{\text{odd}} = \sigma_1+\sigma_{1s}+\sigma_3+\sigma_{3s}+\sigma_5+\sigma_{5s} \tag{1a}$$

and

$$\sigma_{\text{even}} = \sigma_0+\sigma_2+\sigma_4+\sigma_6\,. \tag{1b}$$

If we assume that (1) σ_{odd} contains most of the p̄n interactions and σ_{even} the p̄p interactions and (2) the mesonic resonances reported by Cline *et al.* (1968; personal communication) at 1925 and 1945 MeV exist, then the deviations of our points in Figure 2 at 450 and 560 MeV/*c* from a smooth curve tend to indicate that the 1925 MeV resonance is $I = 1$, and the 1945 MeV resonance is $I = 0$.

Detailed measurements of the elastic scattering processes in deuterium and of the annihilation channels leading to three seen pions are in progress. A study is also being made of the interaction $\bar{p}d \to \Lambda K(n\pi)$ for which some 50 examples have so far been obtained.

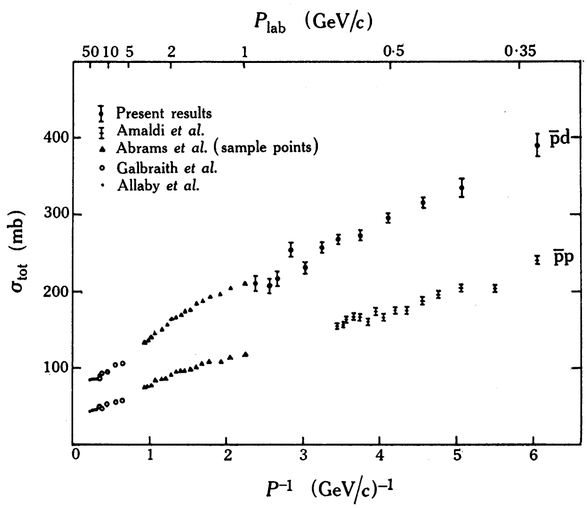

Fig. 1.—Total $\bar{p}$d cross section versus reciprocal $\bar{p}$N c.m.s. momentum P. Also shown is the total $\bar{p}$p cross section. To facilitate comparison of the graphs the antiproton–nucleon centre of mass momentum has been employed. The $\bar{p}$ laboratory momentum is shown on the top abscissa.

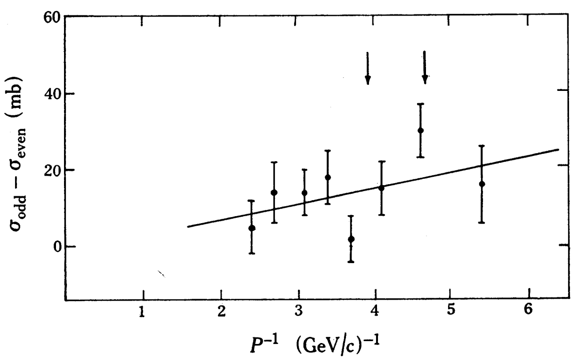

Fig. 2.—Cross section difference $\sigma_{odd} - \sigma_{even}$ versus reciprocal $\bar{p}$N c.m.s. momentum P, where σ_{odd} and σ_{even} are defined by equations (1). Several momentum bins have been lumped to improve statistics. The arrows indicate the positions of the resonances reported by Cline *et al.* (1968).

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References

Abrams, R. J., *et al.* (1967).—*Phys. Rev. Lett.* **18**, 1209.

Allaby, J. V., *et al.* (1969).—*Phys. Lett.* B **30**, 500.

Amaldi, U., Jr., *et al.* (1966).—*Nuovo Cim.* **46**, 171.

Caro, D. E., and Klein, A. G. (1969).—School of Physics, University of Melbourne, Internal Rep. No. UM-P-69/3.

Cline, D., English, J., Reeder, D. D., Terrell, R., and Twitty, J. (1968).—*Phys. Rev. Lett.* **21**, 1268.

Galbraith, W., *et al.* (1965).—*Phys. Rev.* B **138**, 913.