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PS184: A STUDY OF ANTIPROTON-NUCLEUS INTERACTIONS AT LEAR

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(Presented by D.M. Drake)

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The PS184, a collaboration among experimental groups from Saclay, Strasbourg, Grenoble and Tel Aviv, is one of the experiments that has been approved for the study of nuclear physics with the antiproton beam provided by the Low-Energy Antiproton Ring (LEAR) at CERN. We use standard nuclear physics techniques centred around a magnetic spectrometer, SPES II¹, which has a momentum acceptance of $\pm 18\%$, a subtended solid angle of 30 msr, and a maximum momentum of 800 MeV/c.

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We have proposed and partially completed four types of experiments which should provide data for building and testing models of $\bar{p}$ -nucleus interactions. These are: 1) $A(\bar{p}, \bar{p})A$ elastic scattering; 2) $A(\bar{p}\bar{p}')A^*$ inelastic scattering; 3) $A(\bar{p}p)A_{Z-1, \bar{p}}$ knockout; and 4) $A(\bar{p}, x)X$ annihilation; of these, (3) and (4) have no exact analogy in normal nuclear physics.

Very little $\bar{p}$ -nucleus data existed before the summer of 1983, and most of these were concerned with total reaction cross-sections². Theoretical models³ were based on the elementary amplitudes of $\bar{N}N$ interactions folded over the nuclear volume. More pragmatic⁴ optical models were built on data which came from $\bar{p}$ -atomic X-rays and $\bar{p}$ absorption. The energy shift and width of the innermost X-rays can be interpreted in terms of V and W of the nuclear potential constrained by an assumed nucleon distribution. Potentials deduced from these data differ by factors as large as 3, have large errors, and are not unambiguous.

Our primary effort has been directed toward measuring elastically scattered $\bar{p}$ angular distributions at 300 and 600 MeV/c and extracting optical model parameters therefrom⁵. Figures 1 and 2 illustrate two examples: Fig. 1 shows $^{12}\text{C}(\bar{p}\bar{p})$ experimental cross-sections at 300 MeV/c, several theoretical predictions, and our coupled channel optical model fit; Fig. 2 is for $^{208}\text{Pb}(\bar{p}\bar{p})$ elastic scattering at 600 MeV/c. Table 1 goes with Fig. 1, giving several sets of optical model parameters which fit the data reasonably well. This table is typical of the fits for all the data in that χ^2/N is a slowly varying function of potentials. A common feature of these fits is that specific values of V and W are always found at a particular radius, $R_{1/2}$, almost independent of the fixed values of V_0 and W_0 .

One can search for the existence of $\bar{p}$ nuclear states by detecting protons emitted in the forward hemisphere from nuclei bombarded by $\bar{p}$'s. Since the elementary amplitude for $\bar{p}p$ scattering at 180°

Fig. 1. Angular distribution for $\bar{p}+^{12}\text{C}$ elastic scattering at 46.8 MeV.

Fig. 2. Angular distribution for $\bar{p}-^{208}\text{Pb}$ elastic scattering. The two curves represent: an optical model calculation (dashed line) with parameters $V_0 = 30$ MeV, $W_0 = 176.4$ MeV, $r_V = 1.2$ fm, $a_V = 0.52$ fm, $r_W = 0.95$ fm and $a_W = 0.55$ fm, and a KMT-type analysis (full line).

is known⁶, one can construct simple models⁷ in which a $(\bar{p}p)$ knock-out reaction in a nucleus would take place. Because the incident particle is a $\bar{p}$, for which neither the binding energy nor the annihilation probability is known, positive results, i.e. the appearance of a knockout peak above a smooth proton spectrum produced by annihilation, would allow us to extract information about $\bar{p}$ -nucleus

Table 1. Sets of optical model parameters which fit the $\bar{p}$ - ^{12}C scattering reasonably well. For different fixed values of V_0 and W_0 , V and W tend to be about 4 and 8 MeV at a radius $R_{1/2} = 3.3$ fm.

V_0 (MeV)	W_0 (MeV)	r_0 (fm)	a_0 (fm)	χ^2/N	$V(R_{1/2})$ (MeV)	$W(R_{1/2})$ (MeV)
10.9	20.3	1.55	0.4	0.95	4.3	8.0
12.4	25.6	1.48	0.45	0.88	3.9	8.0
15.3	34.5	1.37	0.50	0.87	3.6	8.0
23.2	52.8	1.22	0.55	0.90	3.5	8.0
43.3	89.9	1.00	0.60	1.00	3.7	8.7

states. Figure 3 shows the proton spectrum from three targets at 0° for incident $\bar{p}$'s of 600 MeV/c. No obvious peak appears in any of these spectra. Although the statistical quality of the data does not allow strict limits on the possible cross-section or width such a peak might have, our cross-sections are about a factor of 2 lower than those predicted by the models. These spectra can also be analysed in terms of the fourth area of our study, $\bar{p}$ annihilation in the nucleus and its subsequent decay. The spectra can be parametrized in a cascade model by a temperature representing the slope of the spectra and by a proton multiplicity related to the annihilation cross-section. The temperatures T_0 for our spectra are about 100 MeV, somewhat higher than the experimental results of Shibata⁸ who measured the proton evaporation spectra from nuclei bombarded by 4 GeV/c protons and pions and than the results of cascade model calculations⁹.

If we assume that the absorption cross-section goes as $\sigma_a = \sigma_0 A^{0.67}$, and that the cascade spectra of the targets have the same shape, we can extract relative proton multiplicities of 1.15 and

Fig. 3. Cross-sections for ($\bar{p}p$) reactions on carbon, copper, and bismuth as a function of emitted proton momentum; p_0 is 600 MeV/c.

0.93. These numbers represent the ratios of the number of protons emitted per absorption for copper and bismuth to that for carbon.

In future experiments we hope to study the A dependence of the $\bar{p}A$ potential; the effect of targets with spin; scattering from different isotopes of the same element, e.g. ^{16}O , ^{18}O . We plan to study the knockout reaction with much better statistics and a lighter target such as lithium for which the cascade background should be smaller and the nuclear protons more accessible.

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