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RECENT RESULTS AT INTERMEDIATE ENERGIES

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Résumé - Les présentations de Session F sont discutées.

Abstract - The papers presented orally in Session F are discussed.

Before commenting on the interesting results presented during Session F, let me say first that four of the seven talks were presented, and presented very well, by graduate students. This is another good reason for continuing next time the policy introduced here of providing at least partial support for student travel and registration.

We began our session with pions, two of the few experiments with pions that we have heard about at this meeting. Now that polarized nuclear targets are becoming more available, it is likely that we will see a lot more pion-nucleus analyzing power data in the next few years. J. Görgen (one of our students) told us about the first data on asymmetries in the pion single-charge exchange reaction on a nucleus, here polarized $^{13}$C. The ultimate aim, as in studies of pion scattering on polarized targets, is to learn more about the little-known pion-nucleus spin-flip amplitude $g(\theta)$ in nuclei. Along the way, some interesting structure and reaction questions will have to be addressed, as the first theoretical calculations suggest. The data, with pions of 163 MeV from LAMPF, for two resolved states are shown in Fig. 1 along with very recent predictions by Siegel and by Chakravarti; the two calculations, as I understand them, are basically impulse approximation calculations with the same nuclear wave functions, but different ingredients to describe the reaction. Neither does very well overall, but the curve of Siegel does describe at least the low $q$ data for the ground state. The values of $A_{yy}$ are large, a virtue I think, and very different for the two states. In contrast, the analyzing powers for elastic pion scattering on $^{13}$C, shown by Y. Yen, are generally quite small; an example is illustrated in Fig. 2. Her results at 231 MeV are even smaller. Such small values of $A_{yy}$ have also been seen in the only previous data available (see Contribution 7F). Here the nuclear structure dependence can be seen in the comparison of the two calculations by Mach; the wave functions are those of Cohen and Kurath or Tiator. The results for $\pi^+$ scattering with the Tiator wave functions are quite good, though the same wave functions fail to yield a good description for $\pi^-$ scattering where the extra neutron in $^{13}$C is much more important. While it is too early to make a reliable forecast - the data thus far are few, and the calculations quite preliminary - to me it appears that it will be some time before clear information about $g(\theta)$ can be extracted from such results.

Professor Arai brought quarks explicitly into our session, with results from KEK on the polarization of lambdas produced in the $\pi^+ + ^{12}$C reaction at 4 GeV/c. Here the idea was to investigate effects of the nuclear many-body system on quark production by looking at backward angles where quasielastic production of lambdas on a single nucleon is strongly reduced. The polarization results are shown by the dark circles in Fig. 3. We learned from Heller yesterday that $P_A$ is generally negative at high energies and forward angles; here it is positive. An attempt to describe these data with a model based on incoherent production on nucleons in a Fermi gas, i.e., a model without many-body effects, fails completely as seen by the curves in the lower half of the figure. The solid curve is based on the so-called coherent tube model and on precession in the color field described by Heller. This curve is reasonably close to the data. The authors take this as evidence for a nuclear many body effect at the quark level - just what they were looking for. This, of course, will be very interesting if it can be confirmed. Clear

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Fig. 1 - Analyzing powers measured in the $^{13}\bar{C}(\pi^+,\pi^o)^{13}\bar{N}$ ground state reaction at 163 MeV. The theoretical calculations are by Siegel (solid) and Chakravarti (dashed).

Fig. 2 - Analyzing powers measured for inelastic pion scattering from $^{13}C$ at 132 MeV. The theoretical calculations by Mach used Cohen-Kurath (solid) or Tiator (dashed) wave functions.

evidence of a dependence on the target mass $A$ - a dependence not seen in Hellers data - would be a first step. Such a program is beginning at KEK.

On Tuesday, Otto Häsller mentioned that a reduction in the values of $A_y$ measured at the quasielastic peak for inclusive proton inelastic scattering can be explained by Dirac-based models and not, not yet at least, by non-relativistic calculations. The effect is attributed to the change in the effective mass of the nucleon inside the nucleus due to the large scalar and vector potentials. Andy Miller described to us exclusive $(p,2p)$ experiments at 500 MeV at TRIUMF, where he looked for explicit evidence of the density-dependence inherent in such an explanation by comparing $A_y$ for $s$ state and $p$ state knockout from $^{16}O$. The $s$ state results, in Fig. 4, reveal very large reductions in $A_y$ from the free values shown by the dashed curves. The reductions seen for $p$-state knockout
Fig. 3 - Polarization of lambda's measured in inclusive production with 4 GeV/c pions on
$^{12}\text{C}$ (solid circles). Previous data are shown by the x's. The theoretical curves are
described in the text.

Fig. 4 - Analyzing powers measured in the $^{16}\text{O} (p, 2p) ^{15}\text{N}$ reaction with $s_{1/2}$ knockout. The
dotted curves are impulse approximation calculations; the solid curves have a relativistic change in the effective mass of the nucleon included.
were indeed significantly smaller, as expected since p-state wavefunctions sample less of the interior of the nucleus. An attempt to describe these data by inserting a relativistic density-dependence (DD) into a DWIA code was reasonably successful. A complete relativistic calculation of the (p,2p) reaction is expected soon. In order to test whether this reduction in $A_\gamma$ is really a signature of relativistic effects in nuclei, it is important to carry out equally complete non-relativistic calculations of (p,2p).

A strong effort in this direction was described by H. Arellano, the only theorist on our program. The nucleons in the nucleus obviously move, but most scattering calculations don't take this motion into account properly. We have heard about the importance of Fermi motion in the plenary session talks of Hauser and Baker. The calculation of Arellano et al. is a full-folding calculation for elastic scattering, a full-integration over the momentum-space wave function of the contributing orbitals with an off-shell t matrix dependent on momentum and energy embedded in-between. The results at 200 MeV for proton elastic scattering from $^{40}$Ca are plotted in Fig. 5. The full-folding (FF) calculation is shown on the left, the standard t$p$ approximation calculation on the right. The dashed and solid lines compare results based on the Paris and Bonn potentials, respectively. With both potentials, the effects of full-folding on $A_\gamma$ are very large, and reminiscent of results observed if a standard t$p$ calculation is based on the Dirac equation instead of the Schrödinger equation. A real comparison with data should await the inclusion of the density-dependence arising from the Pauli Principle in these non-relativistic calculations. The next step - the one I would particularly like to see happen soon - is to extend these calculations to inelastic scattering and the (p,2p) reaction.

Fig. 5 - Full-folding (FF) and standard (t$p$) calculations for 200 MeV proton elastic scattering from $^{40}$Ca. The solid curves are based on the Bonn potential, the dashed curves on the Paris potential.
Saturne II is the only facility where intermediate energy polarized deuterons are available, and polarized deuterons provide the only direct means of seeing the $T=0, S=1$ response of nuclei. Polarization-transfer measurements are the way to separate the $S=0$ and $S=1$ responses in $(p,p')$, as we have seen on Tuesday. Measurements with deuterons generally require both vector and tensor polarization measurements, but no tensor polarimeter has yet been built to cover a wide range of energies in the focal plane at energies of 400 MeV or more. M. Morlet presented results from vector polarization transfer measurements for separated $S=0$ and $S=1$ states in $^{12}\text{C}$ at 400 MeV which indicate that tensor polarization measurements may not be necessary, at least for an initial survey of $T=0, S=1$ strength. Fig. 6 shows a quantity labelled $\Sigma^Y_d$, the proposed signature of $S=1$ strength, for known $S=0$ and $S=1$ states at several angles. This $\Sigma^Y_d$ is a combination of observables which is like the spin-flip probability for deuterons. The results in Fig. 6 show a clear distinction between $S=0$ and $S=1$ states, and thus a nice signature of $S=1$ excitation. In order to use this signature for a quantitative extraction of $S=1$ strength in the continuum, good microscopic calculations of the $(d,d')$ reaction are necessary. This conference has provided a convenient avenue for encouraging theorists to move in this direction.

We closed our session with a review by Alena Opper of several new measurements of spin-transfer observables for isolated states in $(p,p')$ carried out at Indiana around 200 MeV. Here the goal is the determination of the effective NN interaction inside nuclei (and understanding it in terms of Pauli corrections, changes in the effective masses of mesons in nuclei, etc.). Ed Stephenson told us on Tuesday about evidence of such medium effects for $S=1, T=1$ excitations at high momentum transfer. Fig. 7 shows the present state of affairs for a $T=0$ state, the 19.80 MeV $4^-$ state in $^{16}\text{O}$. The $D_K$ shown here correspond to the four different spin-dependent components of the NN interaction; each is a combination of spin-transfer observables which, in the PWIA, is proportional to a single component. The curves illustrated correspond to non-relativistic DWIA calculations with the Bonn interaction, including Pauli corrections. These give a reasonable but not perfect account of these and several other $T=0$ data, and thus indicate only small, if any, exotic medium corrections in this channel. In order to determine whether the NN interaction in nuclei really is different from the free space interaction in interesting ways, it is important to carry out precise measurements of this sort for several well known states, e.g., stretched states, over a range of energies. This is only now beginning.

Fig. 6 - The signature $\Sigma^Y_d$ of $S=1$ transitions determined from the $^{12}\text{C}(d,d')$ reaction. The data for the $S=1 1^+ 12.71 \text{MeV}$ state are shown by the solid circles. Data for three $S=0$ states are combined into the vertical lines with negative values.
Fig. 7 - Measured values of the $D_k$ parameters for the 19.80 MeV $4^{-}\ T=0$ state in $^{16}O$ with 200 MeV protons. The solid curves are non-relativistic DWIA calculations based on the Bonn potential.