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Title: **Quasi-Elastic and Continuum Scattering of 500-MeV Pions**

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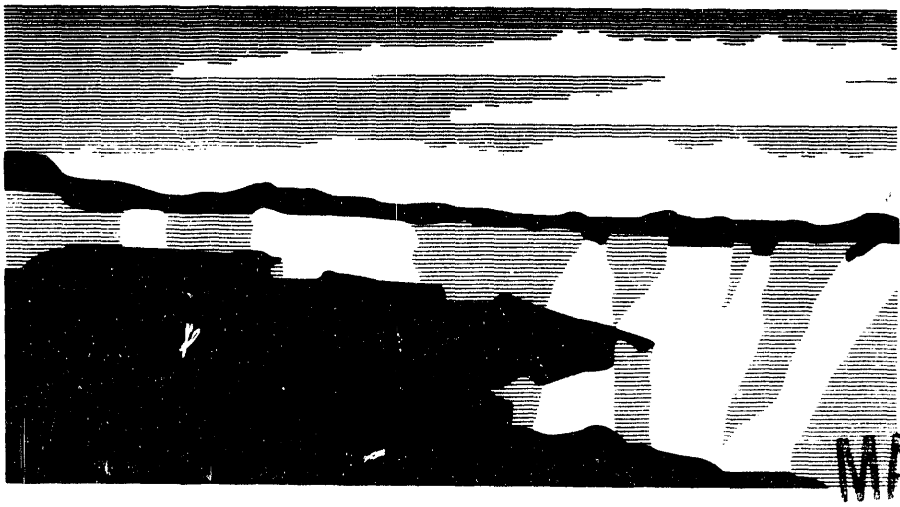

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Quasi-Elastic and Continuum Scattering of 500-MeV Pions

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Abstract

Results for the scattering of 500-MeV pions are compared to the (e,e′) data and to Intra-Nuclear cascade calculations. The (π,π') spectra, which are remarkably similar in shape to the (e,e′) spectrum, show a large enhancement in the region corresponding to resonant-energy pions. Possible mechanisms for this "pion transparency" are suggested.

Introduction

High energy (500-MeV) pions provide several unique features as a probe of the nuclear medium. These include a relatively long mean-free path; and the fact that pion production produces pions with energies near the $\Delta_{3/2,3/2}$ resonance. Together these two features allow the study of pions produced in the nuclear interior. Our initial expectation is that pions produced at energies above and below the Δ resonance will escape the nucleus and be observed, while pions with energy near 180-MeV will be absorbed or scattered to lower energies. The fact that this expectation is not realized is the subject of this talk.

In Fig. 1 pion spectra (T_π=500 MeV, θ_π=50°) on targets spanning the periodic table are compared to (e,e′) spectra from Ref. [1] (T_e=500 MeV, θ_e=60°). These spectra have, within 10%, the same momentum transfer versus energy loss. Except for the relative scale factor (see Fig. 2 for scale factors) there is a marked similarity being the data sets. A comparison of $^{12}C(\pi,\pi')$ data at 50° and 70° to a different set of (e,e′) data (higher T_e) can be found in Ref. [2].

We have also compared the pion data to Intra-Nuclear cascade (INC) calculations performed using a modified version of the code described in Ref. [3]. In these INC calculations pions are scattered from a realistic nucleus with correlations using the free πN cross sections. Pion production is taken into account using known $(\pi,2\pi)$ cross sections. The pion absorption in the INC calculation is adjusted to give the measured[4] 500-MeV absorption cross section of ~40 mb. Fig. 3 show a comparison of the INC inclusive spectra (solid histogram) to the measured $^{12}C(\pi,\pi')$ spectra (note that the INC calculations have an absolute normalization). While the quasi-elastic (QE) peak and the large energy loss portion of the spectra is reproduced, the region centered about outgoing pion energies between 150- and 200-MeV (energy losses of 350- to 300-Mev, respectively) is underpredicted by a factor of 2 to 5. The dip in the INC spectra shown in Fig. 3 is due to the absorption or scattering of resonant energy pions. This comparison points to the need for a mechanism that makes the nucleus transparent to pions at central nuclear densities with energies near central nuclear densities.

To test this suggestion we have implemented a hadronization time in the INC calculation. The agreement between the data and predictions in much better when pions involved in pion production are assumed to not interact for a time equal to 2 fm/c after the (π,2π) reaction takes place. This modified INC calculation is shown as the dashed histograms in Fig. 3.

There are several possibilities for this apparent transparency. In the spirit of color transparency there may be a need for a hadronization time for the wave function of pions involved in pion production to settle into an eigenstate of mass. Another possible mechanism is for the pions to be transported through the nucleus by a weakly interacting intermediate particle. One possibility for this intermediate particle is the σ meson, which because it is isospin zero would not interact through the Δ and therefore should have a longer mean-free path than the pion. If the σ width was between 50- and 100-MeV, it would then have a lifetime between $\sim$4- and $\sim$2-fm/c, respectively; therefore a σ meson could be produced in the nucleus and would be likely to leave the nucleus without interaction before decaying into two pions. Other possibilities such as renormalized masses at central nuclear densities also exist.

Fig. 4 shows spectra at four different beam energies with about the same momentum transfer for elastic scattering from a nucleon in each case. The ^{16}O data in Fig. 4 is from Ref. [5]. Also shown in Fig. 4 are "standard" INC calculations for each case. One sees that the 300-MeV data set is underpredicted by the INC calculation in the region of resonance energy pions. While the assumption of *transparency* for pions from π-production improves the agreement between the 500-MeV data and the INC calculation, this assumption offers no improvement for data taken with a 300-MeV pion beam. This is because at 300-MeV there is little π-production, and what π-production there is does not produce resonance energy pions.

Conclusions (and/or questions)

The (π,π') spectra and (e,e$'$) spectra have very similar shapes for light targets. Is this to be expected or is this surprising? i.e. is it the same mechanism filling the "dip" for both probes or the similarities in the spectra coincidental?

There are large discrepancies between the data and the INC calculations in the portion of the spectra that corresponds to resonance energy pions coming from the reaction. Pion in the calculation are absorbed and/or rescattered so that they don't appear at resonance energies. This discrepancy is reduced if it is assumed that pion from (π,2π) reactions do not interact or are transparent for a time equal to 2 fm/c. This time is consistent with π-production taking place through an intermediate particle which does not interact strongly with the nucleus, but decays into two pions. This assumption does not remove the discrepancy between the INC calculation and the 300-MeV data.

The phenomenon giving rise to the enhanced yield of resonance energy pion is probably not the same as the "color transparency" that is discussed in the other talks in this session, it nevertheless important to understand. This mechanism has implication to future programs at both CEBAF and RHIC. At CEBAF the interpretation of electroproduction of baryonic resonances in nuclei will require a thorough understanding of pions in this energy range. Since Δ formation and decay provides the major route for energy transport through hot dense hadronic matter, understanding the transport mechanisms in this energy range will be crucial to the interpretation of current and planned experiments which rely on the measurement of pions as a hadronic signature of a quark-qluon plasma.

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Figure Captions

Fig. 1 - Comparison of pion spectra (T_π=500 MeV, θ_π=50°) and (e,e′) spectra (T_e=500 MeV, θ_e=60°) from Ref. [1] . The energy loss is the incident beam energy minus the outgoing particle energy. The targets are indicated in each panel. The relative normalization of the (e,e′) spectra is different for each panel and these factor are shown in Fig. 2.

Fig. 2 - The relative normalization of the (π,π') spectra to (e,e′) spectra shown in Fig. 1 are plotted as a function of target mass number.

Fig. 3 - The (π,π') data (open symbols) is compared with two different Intra-Nuclear cascade calculations. The solid histograms are from the standard calculation. The dash histograms are from a calculation where pions from (π,2π) reactions are assumed to not interact for a time equal to 2 fm/c after the reaction takes place. Arrows indicate the location of elastic scattering from the ^{1}H.

Fig. 4 - The (π,π') data obtained with different beam energies but the same momentum transfer is shown for comparison. The histograms are from "standard" Intra-Nuclear cascade calculations. The oxygen data is from Ref. [5] was obtained with an H_2O target, hence the strong peak from ^{1}H(π,π) elastic scattering. Arrows indicate the location of elastic scattering from the ^{1}H.

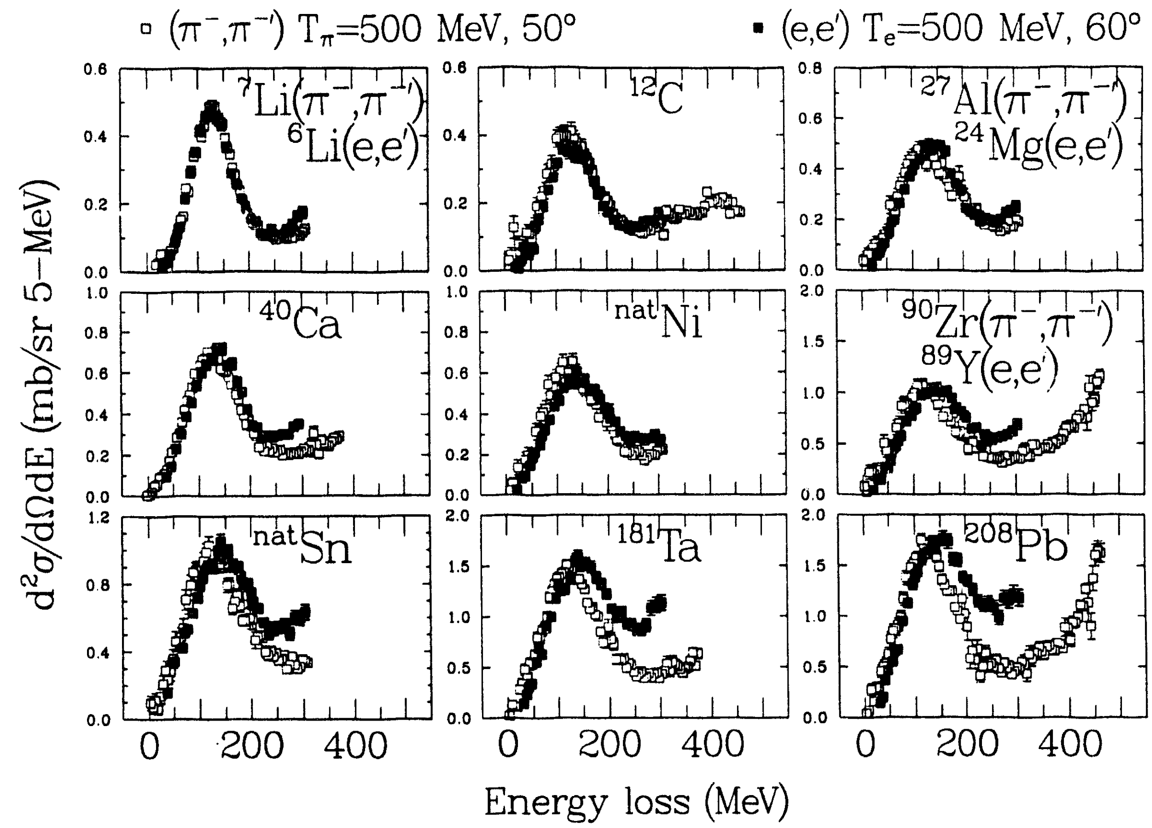


Figure 1

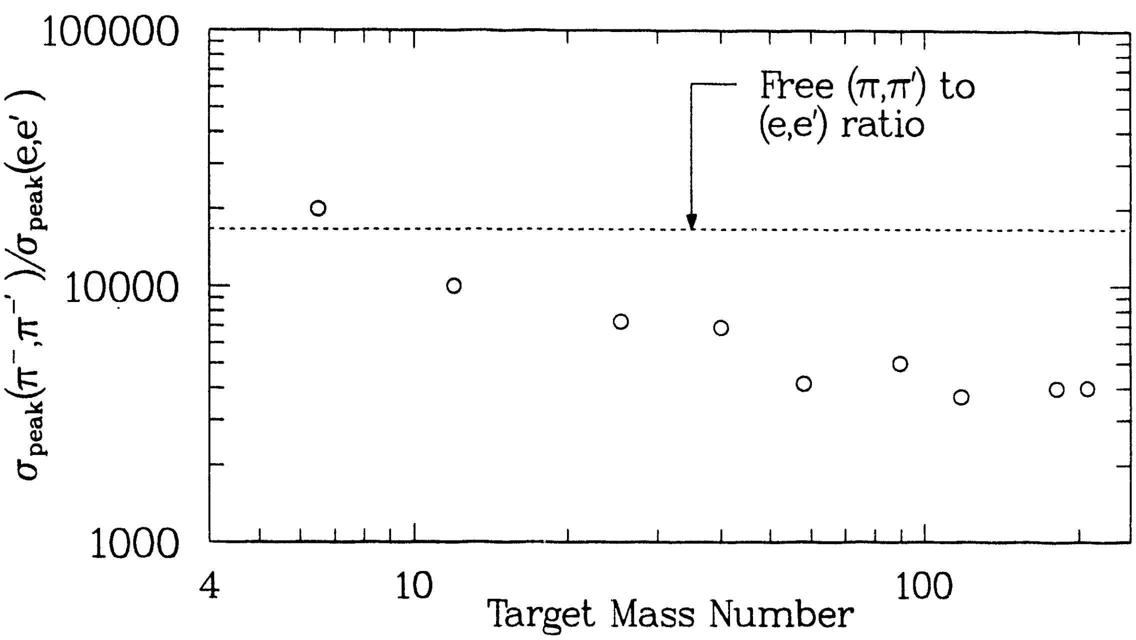


Figure 2

Figure 3
$^{12}C(\pi,\pi')$ T_π=500 MeV

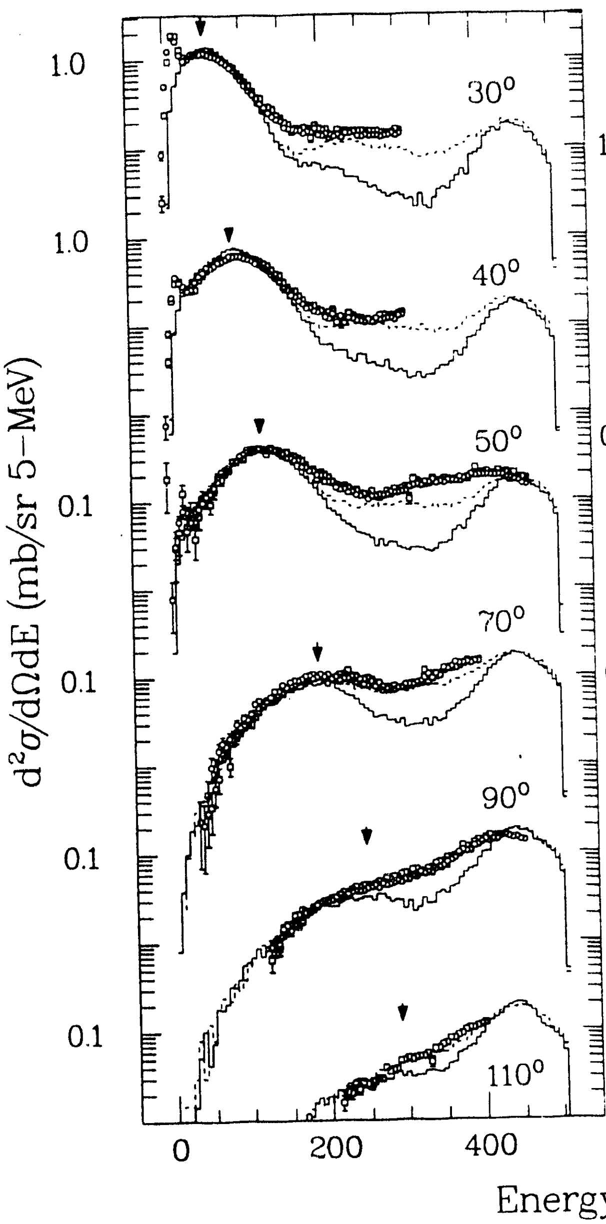
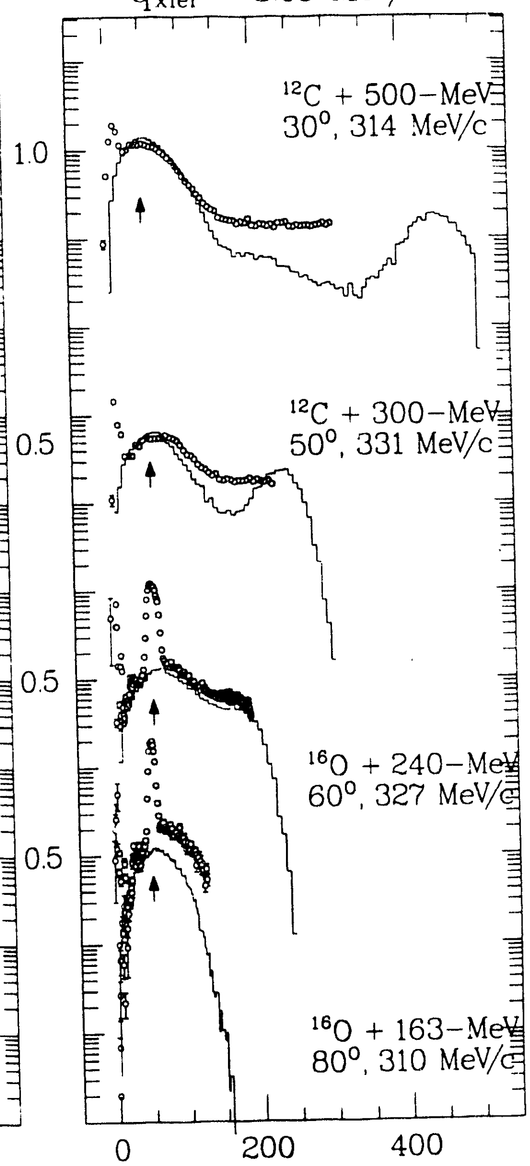


Figure 4
(π,π') spectra with
q_{xfer}=~320 MeV/c



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