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Abstract

The absorption of 239 MeV positive pions on ^{3}He, ^{4}He, N, and Ar has been studied. A strong enhancement has been seen in the differential cross sections in the kinematic region associated with free π–p scattering. This enhancement is interpreted as a clear signature of initial state interactions in the absorption of pions on nuclei.

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The study of pion absorption in nuclei remains a subject of considerable interest in medium energy physics, primarily because the absorption process frequently appears to involve more than two nucleons. It had long been expected that absorption on two nucleons would be the dominant process of sharing the energy and momentum of the pion. Two-nucleon absorption has indeed been observed to be important, but absorption on more than two nucleons also appears to play a significant role [1,2]. The role of nucleon rescattering in raising the final state particle multiplicity has been largely understood [3,4], but that of an initial state interaction (ISI) of the incident pion, which based on the free π–N and N–N cross sections should be a significantly larger effect, has not been established.

In a simple picture of ISI, a pion scatters off a nucleon before being absorbed on a nucleon pair, and the originally-scattered nucleon has a correlation between its energy and angle given by two-body scattering kinematics. Compared to scattering from a free proton, this correlation is smeared out by the Fermi motion of the nucleon. Early searches for evidence of ISI were not conclusive [5–8], but such a correlation has recently been observed in absorption on ^{3}He and quantitatively identified as an ISI signature [9] by comparison with simulations. In this paper we extend the identification from ^{3}He to ^{4}He, N, and Ar for the absorption of positive pions of 239 MeV kinetic energy.

The experiment was performed at the Paul Scherrer Institute in Villigen, Switzerland using the Large Acceptance Detector System (LADS). The LADS detector is a cylindrical, non-magnetic detector which includes two layers of multi-wire proportional chambers (MWPCs) followed by three layers of plastic scintillator. These detector elements provide particle identification, energy resolution, and tracking capability for a wide dynamic range of medium-energy charged particles. The inclusion of endcaps allows the detector to cover over 98% of 4π solid angle. The energy threshold of the detector, determined mainly by energy losses in the carbon fiber walls of the high pressure gas target and in the MWPCs, is below 25 MeV for protons. A more complete description of the detector is available elsewhere [10].

For this paper we have focused on *ppp* final states. In order to enhance the strength of the ISI signal in the data sample it was required that three protons and no other energetic particles be detected, and that each of the protons have more than 30 MeV kinetic energy. This largely removed reactions in which one of the protons was a spectator or was emitted in an evaporation process. In addition, it was required that the unobserved energy be less than 50 MeV in order to exclude most reactions in which undetected nucleons participated. This last restriction was especially important to enhance the visibility of the ISI signal from N and Ar.

Once a sample of events was selected, the correlation between energy and angle was plotted for each of the three detected protons. The results are shown in Fig. 1 for ^{3}He, ^{4}He, N, and Ar. The salient feature on the plots is the prominent enhancement in the lower left hand sector, which for ^{3}He has been identified as being due to the recoil proton from ISI [9]. The line passing through this region indicates the relationship between energy and angle for free π^+–p scattering.

Because of the lack of complete models describing the pion absorption process (especially for the heavier nuclei), it is difficult to fully correct the data in these figures for the detector's acceptance. Apart from any effects from the imposed 30 MeV threshold, the largest missing correction is for the geometrical acceptance of the detector. The losses are thus small between 25° and 155°, but the acceptance falls to zero smoothly over about 15° outside of this range. Structures visible in the figures at energies greater than 180 MeV are largely artefacts of thresholds within the detector. For further discussion of the acceptance and data extraction, see [11].

Figure 2 shows distributions as a function of energy for the data appearing in Fig. 1 between 15° and 25°. For all nuclei, the enhancements identified as ISI in Fig. 1 appear in these spectra as broad peaks near the energy of the recoil proton from free π^+–p scattering, which is indicated by the dotted line. The dashed lines on these plots are spectra of protons resulting from simulations combining a uniform distribution over three-nucleon phase space with the detector's response, normalized to the data at the high energy end of the spectra. In these simulations, the residual nucleus momentum distribution was included by incorporating a weighting factor consistent with a spectator distribution. The dotted line shows the average energy of the proton from free π^+–p scattering in this angular region. The phase space spectra show that these peaks are not due to the detector acceptance.

In conclusion, evidence of the existence of ISI in pion absorption has been shown, extending its direct observation from ^{3}He to much heavier nuclei. In reference [9], it was estimated that ISI directly accounts for about 30% of the yield from ^{3}He when three protons share the energy of a 239 MeV incident π^+. Quantitative estimates for the heavier nuclei require a more detailed analysis than presented here. However, the data shown in Fig. 2 indicate that the fraction of ISI in the *ppp* final state does not greatly change between ^{3}He and Ar.

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REFERENCES

[1] H.J. Weyer, Phys. Rep. **195**, 295 (1990).

[2] C.H.Q. Ingram, Nucl. Phys. **A533**, 573c (1993).

[3] D.F. Geesaman *et al.*, Phys. Rev. Lett. **63**, 734 (1989); G. Garino *et al.*, Phys. Rev. **C45**, 780 (1992).

[4] S. Hyman *et al.*, Phys. Rev. **C47**, 1184 (1993).

[5] W. Brückner *et al.*, Nucl. Phys. **A469**, 617 (1987).

[6] G. Backenstoss *et al.*, Phys. Lett. **B222**, 7 (1989).

[7] R. Tacik *et al.*, Phys. Rev. **C40**, 256 (1989).

[8] W. Burger *et al.*, Phys. Rev. **C41**, 2215 (1990).

[9] G. Backenstoss *et al.*, submitted for publication.

[10] T. Alteholz *et al.*, accepted for publication in Nucl. Inst. and Meth. **A**.

[11] D. Rowntree, Ph.D. thesis, Massachusetts Institute of Technology, 1995.

FIGURES

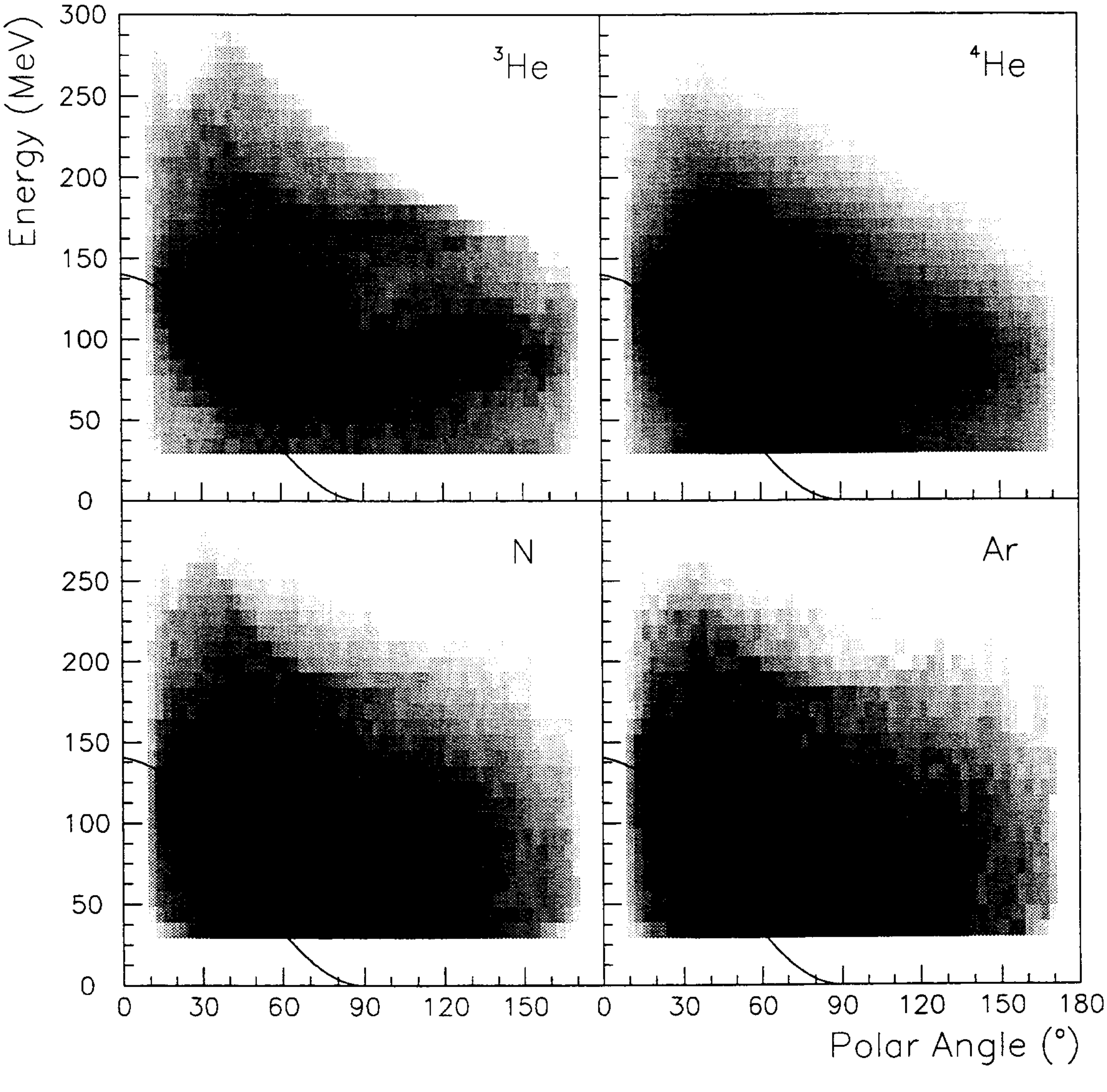

FIG. 1. Scatter plots of laboratory kinetic energy vs. angle from the pion beam axis for *ppp* final states following the absorption of 239 MeV π^+ on ^{3}He, ^{4}He, N, and Ar. The solid line shows the kinematics for free π^+–p scattering.

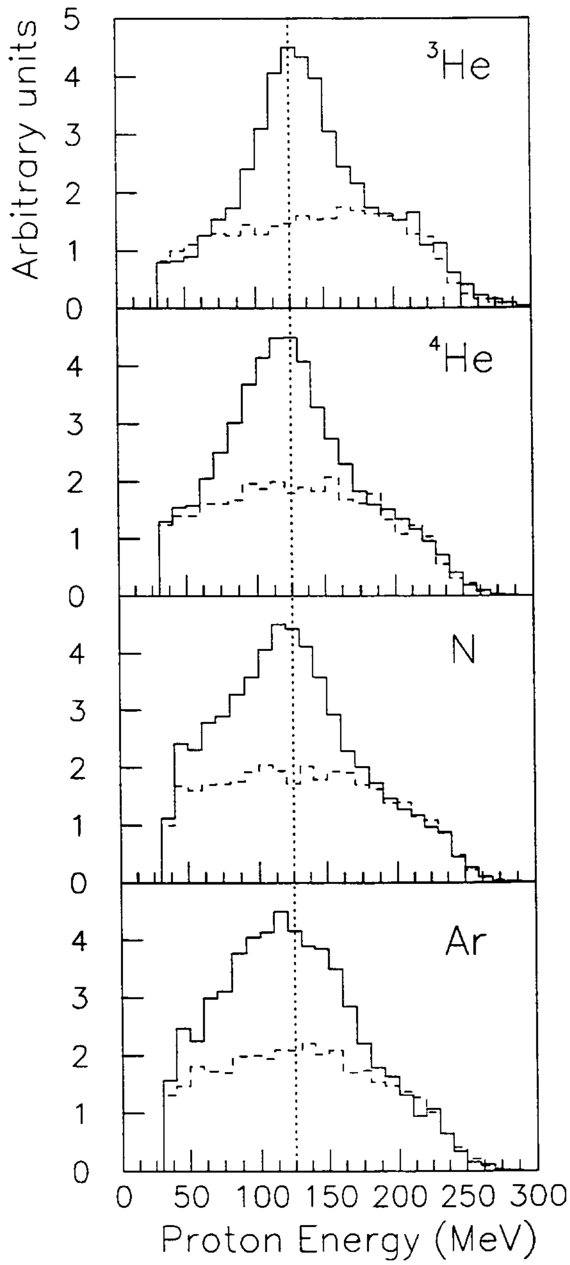

FIG. 2. The laboratory kinetic energy of protons with polar angles between 15° and 25° for *ppp* final states following the absorption of 239 MeV π^+ on ^{3}He, ^{4}He, N, and Ar. The dashed curves are the results of phase-space simulations, and the dotted line shows the average proton energy for free π^+–p scattering.