MEASUREMENT OF CHARGED PION YIELDS FROM NUCLEI IN THE (p,nπ⁺) REACTION FROM 2-13 MeV ABOVE THRESHOLD

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Proton induced positive pion production differential cross sections have been measured for various nuclei utilizing the DØ pion spectrometer. The DØ spectrometer has made possible the measurement of positive pion cross sections closer to threshold than previously reported by other groups. Pions with laboratory energies as low as 2 MeV and differential cross sections as low as 1 nb/sr have been observed.

The energy and A dependence of the positive pion production process is being studied using ¹⁰B, ¹³C, ¹⁶O, ⁴⁰Ca, and ⁹⁰Zr targets. Complete angular distributions have been obtained for pion production to the ground states of ¹¹B, ¹⁴C, and ¹⁷O at Tₚ = 155 MeV (Tₑc.m. = 10,10 and 8 MeV respectively), ¹¹B and ¹⁴C at Tₚ = 151 MeV (Tₑc.m. = 7 MeV ), ⁴¹Ca at Tₚ = 144 and 140 MeV (Tₑc.m. = 7.8 and 3.8 MeV) and ⁹¹Zr at Tₚ = 144 MeV (Tₑc.m. = 8 MeV). The energy dependence of the differential cross sections (θₑlab = 25 deg) for the production of ¹¹B ground state pions has been extended down to Tₑc.m. = 1.7 MeV (2.2 MeV above threshold).

The detector stack used consisted of 3 to 5 elements. The 5 element stack consists of a 100 µm Al absorber and a 10 mil NE 102 plastic scintillator followed by a silicon detector stack consisting of a 200 → 500 µm × 150 mm² ΔE, 5000 µm × 100 mm² stopping detector and a 500 µm × 450 mm² veto detector. This stack is suitable for detecting pions in the 4 to 14 MeV range. The three element stack does not include either the ΔE silicon or the Al absorber and the 10 mil scintillator is replaced by a 5 mil scintillator. The 3 element stack is suitable for detecting pions with energies greater than 1.5 MeV. In addition to the energy loss information obtained from the detectors, TOF between the cyclotron's RF and the plastic scintillator and pulse shape discrimination in the 5 mm stopping detector were used. In order to observe cross sections of the order of 1 nb/sr in the forward direction (high background region) a further requirement was made that the positron from the muon's decay be observed. This requirement reduces the detector stack's efficiency by a varying factor of 2 or 3 but reduces the background events by more than an order of magnitude and completely eliminates the high energy tail in the summed energy spectra due to the decay positrons.

Fig. 1 shows an example of the data obtained in the 144 MeV calcium run with all appropriate background cuts applied. The plots show summed energy (includes 4.1 MeV from the μ⁺ν decay) vs. ΔE and the relative RF TOF. The ground state and 2 MeV doublet of ⁴¹Ca are clearly observed as well as a few pions from higher excited states. The cross section for the production of the ground state pions shown in Fig. 1 is approximately 8 nb/sr.
Figures 2 and 3 display samples of the angular distributions (preliminary) obtained with the DD. Figure 3 also includes the angular distribution taken with the QDMM spectrograph at $T_p = 160$ MeV (Ref. 1). Figures 4 and 5 show the excitation function for calcium and boron and include points taken with the QDMM at IU as well as points derived from Uppsala data (Ref. 2 and 3). The Uppsala data points are multiplied by a factor of 1.8 to normalize their data to that of IUCF (Ref. 4).

These data combined with higher energy data from other groups should provide a severe test of competing pion production models.

Figure 2

$^{40}\text{Ca}(P,\pi^+)^{41}\text{Ca}_{g.s.} D D$

$T_{\pi\text{C.M.}} = 3.8$ MeV ($\bigcirc$)

$7.8$ MeV ($\bigtriangledown$)

Figure 3

$^{90}\text{Zr}(P,\pi^+)^{91}\text{Zr}_{g.s.}$

$\bigcirc =$ QDDM $T_{\pi\text{C.M.}} = 24$ MeV

$\square =$ DD $T_{\pi\text{C.M.}} = 8$ MeV

Figure 4

$^{40}\text{Ca}(P,\pi^+)^{41}\text{Ca}_{g.s.}$

$\bigcirc =$ Uppsala x 1.8

$\triangle =$ IUCF QDDM

$\square =$ DD IUCF

$\sigma_{\text{total}}$ (µb)

$\beta \gamma_{\text{C.M.}} = \frac{P_{\pi\text{C.M.}}}{M_{\pi}}$

Figure 5

$^{16}\text{O}(P,\pi^+)^{17}\text{O}_{g.s.}$

$\theta_{\pi\text{lab}} = 25$ deg

$\bigcirc =$ Uppsala x 1.8

$\triangle =$ QDDM

$\square =$ DD

$\beta \gamma_{\text{C.M.}} = \frac{P_{\pi\text{C.M.}}}{M_{\pi}}$

$0.1 \ldots 0.8$