PION PRODUCTION BY 24 GeV/c PROTONS IN HYDROGEN
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We present here some preliminary results of measurements on photographs taken at CERN by the bubble chamber group during an exposure of their 30 cm hydrogen chamber to a beam of 24 GeV/c protons from the proton synchrotron.

350 interactions have been measured. They were selected so that their apices fell in a fiducial region such that at least 3 cm of primary track was visible and secondary particles close to the beam direction were at least 15 cm long. Beam track measurements indicated that the maximum detectable momentum of the chamber was 80 GeV/c.

\[ \bar{n}_{\omega} = 4.2 \pm 0.1 \]

Figure 1

\[ 433 \]
Figure 2
Figure 3

2 Prongs

Identified Protons

\( \bar{p}_T = 0.36 \pm 0.03 \)

\( \bar{p}_T^+ = 0.27 \pm 0.04 \)

\( \bar{p}_T^- = 0.36 \pm 0.02 \)

\( \bar{p}_T^+ = 0.36 \pm 0.03 \)

4 Prongs

\( \bar{p}_T = 0.36 \pm 0.02 \)

\( \bar{p}_T^- = 0.32 \pm 0.03 \)

6 Prongs

\( \bar{p}_T^+ = 0.35 \pm 0.02 \)

\( \bar{p}_T^- = 0.36 \pm 0.03 \)

\( \bar{p}_T^- = 0.32 \pm 0.02 \)

\( \bar{p}_T^- = 0.36 \pm 0.03 \)

\( \bar{p}_T^- = 0.32 \pm 0.03 \)

10 Prongs

\( \bar{p}_T^- = 0.32 \pm 0.08 \)

\( \bar{p}_T^- = 0.36 \pm 0.04 \)

\( \bar{p}_T^- = 0.32 \pm 0.04 \)

\( \bar{p}_T^- = 0.17 \pm 0.06 \)
RESULTS

1 - MULTIPLICITY DISTRIBUTION -

The charged multiplicity distribution is shown in figure 1. The mean charged multiplicity was $4.2 \pm 0.1$. This may be compared with the figure of $4.8 \pm 0.2$ predicted by the statistical theory of meson production [1] and the value of $4.1 \pm 0.1$ observed in $16 \text{ GeV/c } \pi^-\text{-p interactions}$ for which the available energy in the centre-of-mass system (C.M.S.) is essentially the same as in this experiment.

2 - CROSS-SECTIONS -

Elastic events, separated from the rest by applying kinematic criteria, are plotted as a histogram against $\cos \theta^*$ in figure 2. An analysis making use of the optical theorem indicated that 16 elastic events with proton recoil ranges of less than 1 cm had probably been missed during scanning. Applying this correction we find an elastic cross-section $\sigma_{el} = 9.8 \pm 1.0 \text{ mb}$.

For the inelastic interactions the cross-section was $31.9 \pm 1.7 \text{ mb}$ so that the total cross-section $\sigma_{el}$ will be $41.7 \pm 2.0 \text{ mb}$.

3 - INELASTIC EVENTS -

The distributions of various quantities as a function of the multiplicity of the interaction are shown, for positive and negative particles, in figures 3-7. Protons of momenta less than $750 \text{ MeV/c}$ were identified visually from their bubble density.

The transverse momentum $P_T$, (figure 3) appears independent of the multiplicity and of the sign of the particles and is the same as that observed in pion interactions, $(0.37 \pm 0.01 \text{ GeV/c})$.

The C.M.S. angular distributions (figures 4 & 5) exhibit a marked anisotropy in the lower multiplicity interactions especially for positive particles. We may compare the negative particle distribution, presumable consisting mainly of pions, with the distribution of positive particles by arbitrarily normalising the curves so that the number of negative particles equals the number of positive particles between $\cos \theta^* = \pm 0.7$. This has been done for the case of the 4-prong events.

![Figure 4](image-url)

Figure 4

436
No.

C.M.S. ANGULAR DISTRIBUTION
OF POSITIVES.

\[
\begin{align*}
Z &= \frac{\cos \theta}{1 - \cos \theta} \\
|\cos \theta^*| &= 0.79
\end{align*}
\]

Figure 4 (suite)

437
$| \cos \theta^* | = 0.75$
6 PRONG +VE

$|\cos \theta^*| = 0.69$

10 PRONG +VE

$|\cos \theta^*| = 0.47$

Figure 4 (fin)
4 PRONG - VE.

$|\cos \theta^*| = 0.67$

8 PRONG. - VE

$|\cos \theta^*| = 0.58$
**DISTRIBUTION**

**GATIVE PARTICLES**

6 PRONG - ve.

\[ |\cos \theta| = 0.60 \]

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10 PRONG - ve

\[ |\cos \theta| = 0.57 \]
C.M.S. MOMENTUM DISTRIBUTION OF POSITIVE PARTICLES

No. of Protons (< 750 MeV/c)

No. of particles yielding \( p^\ast > 3.4 \text{ GeV/c} \)

2 PRONG

\( \bar{p} \) = 1.35 ± 0.1

No. of particles other than protons (< 750 MeV/c)

No. of particles yielding \( p^\ast > 3.4 \text{ GeV/c} \)

Protons

Figure 6
Figure 6 (suite)
C.M.S. MOMENTUM DISTRIBUTION
OF NEGATIVE PARTICLES

4 PRONG -VE
\[ \bar{p}^* = -0.52 \pm 0.06 \]

6 PRONG -VE
\[ \bar{p}^* = -0.52 \pm 0.04 \]

8 PRONG -VE
\[ \bar{p}^* = -0.45 \pm 0.1 \]

10 PRONG -VE
\[ \bar{p}^* = -0.2 \pm 0.1 \]

Figure 7
Total \( \pi^- \) Momentum

Distribution in C.M.S.

\[ \langle p^\pi \rangle = 0.52 \pm 0.01 \text{ GeV/c} \]

Hagedorn \( \pi \) Spectrum

- With \( T_{3/2} \) isobar.
- Without isobar.

Figure 8

C.M.S. Momentum

Distribution of protons (c. 750 MeV/c in lab. system)

Statistical theory prediction.

Figure 9

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and an excess of positive particles, presumably nearly all protons, is observed in the region of $\cos \theta^* = \pm 1$. The presence of unidentified protons ($\sim 60$), even if they are isotropically distributed, in the region $\cos \theta^* = \pm 0.7$ does not seriously affect the conclusion that the proton distribution is more markedly anisotropic than that of the pions.

Figures 6 & 7 show the C.M.S. momentum distributions. Again, comparison of negative with positive distributions indicates that the protons have considerably larger momenta than the pions, a characteristic feature of peripheral interactions. On the other hand our identified protons are all of momentum in the lab. system of $< 750 \text{ MeV}/c$ which necessarily discriminates against slow protons in the CMS.

In figure 8 the CMS momentum spectrum of all the negative particles is compared with the \ensuremath{\pi} meson spectrum calculated by Hagedorn [1] using the statistical theory of meson production. The agreement is seen to be good when the \ensuremath{T_{3/2}} isobar is taken into account. However it should be noted that we seem to have a higher percentage of energetic protons than is predicted by the statistical model (figure 9).

In figure 10 are plotted the M-value distributions for pairs of like and unlike charged particles from the 4-prong events when both particles are emitted into the backward hemisphere in the p-p. CMS, and one of them is an identified proton the other being treated as a pion (M is the total energy of a pair in its rest system). Clustering of the M values in the region of the \ensuremath{T_{3/2}} isobar mass can be seen.

Our results are summarised in Table I.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{figure10.png}
\caption{M($p\pi^\pm$) for 4-prong events in which a proton is identified and \ensuremath{\pi^\pm} go backward in C.M.S.}
\end{figure}
### Table I

Mean(*) values - pp interactions at 24.5 GeV/c
(Values in brackets are corresponding values of 16 GeV/c π-p interactions)

| Multiplicity | \( p^{+} \) | \( p^{-} \) | \( p^{*} \) | \( p^{-} \) | \( |\cos \theta^{+}| \) | \( |\cos \theta^{-}| \) |
|--------------|---------|---------|---------|---------|---------------|---------------|
| 2 (inelastic) | .36 (.42) | - (.41) | 1.35 (.86) | - (.20) | .79 (.73) | - (.80) |
| 4            | .36 (.36) | .32 (.36) | .88 (.64) | .58 (.63) | .75 (.62) | .67 (.67) |
| 6            | .35 (.35) | .36 (.38) | .77 (.52) | .52 (.51) | .69 (.55) | .60 (.55) |
| 8            | .36 (.42) | .35 (.32) | .61 (.57) | .45 (.40) | .69 (.54) | .58 (.43) |
| 10           | .32 - | .17 - | .38 - | .2 - | .47 - | .57 - |

Typical error in mean: .03 .03 .04 .04

Mean of Total: .36 ± .01 .33 ± .02

\( c_{\text{sys}} = 31.9 \text{ mbs} \); \( c_{t} = 9.7 ± 1.0 \text{ mbs} \); \( c_{t} = 41.7 ± 2.0 \text{ mbs} \);

(21.9) (3.5) (25.4)

(*) In the case of \( p^{+} \) and \( p^{*} \), identified protons are excluded and all other particles treated as pions.

#### Reference