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LETTER OF INTENT

Δ^{++} SPECTROSCOPY STUDIES IN THE SPLIT FIELD MAGNET

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INTRODUCTION AND BACKGPOUND

We wish to propose a Δ^{++} spectroscopy experiment to be performed with the split field magnet. The motivation for this experiment is to test whether or not the properties of

$$pp \rightarrow \Delta^{++} + \text{anything} \qquad (1)$$

observed between 7 and 28 GeV/c in conventional bubble chamber experiments survive at ISR energies.

A remarkable property of this class of reaction has been observed at 7 and 28 GeV/c in a series of papers by Colton et al. (1,2.3) and by Ellis et al. (4). It is observed that cross section ratios for different reactions (1) are simply related to cross section ratios for $\pi^- p$ interactions going to the same states "anything", when $t_{p\Delta} \lesssim 0.2$ GeV^2

$$\frac{\sigma(pp \rightarrow \Delta^{++} X_i)}{\sigma(pp \rightarrow \Delta^{++} X_j)} = \frac{\sigma(\pi^- p \rightarrow X_i)}{\sigma(\pi^- p \rightarrow X_j)} \qquad (2)$$

for any X_i and X_j but providing $M_{x_i} = M_{x_j}$.

The essential results of Colton et al. (1,2) and Ellis et al. (4) are shown in figures 1, which show measured values of ratio quantities as in the left side of eq. 2 compared with the known $\pi^- p$ cross section ratios as in the right hand side of eq. 2 from the 7 and 28.5 GeV/c experiments. These results are as expected for a factorization model description of reactions (1) with pion-exchange as the dominant ingredient as shown as the inset in Fig. 2a. An additional result of Colton et al (3) shows that both the 7 and 28 GeV/c data on

$$pp \rightarrow \Delta^{++} \pi^- p \qquad (3)$$

are in absolute magnitude agreement for $M_{\pi^- p} \gtrsim 1.5$ GeV with the zero-free-parameter pion exchange expectations shown as the curves in figures 2. Both the cross section ratios and the absolute cross section results argue rather convincingly that the process shown in Fig. 2a is dominantly responsible for reactions 1 ~~and 2~~ up to the highest energies studied thus far.

EXPERIMENT

It is important to determine whether or not this picture of Δ^{++} production is valid up to ISR energies. This is all the more important in view of the fact that reactions (1) comprise a rather large part of the total pp cross section. If one generalizes the Δ^{++} system to include masses up to ~2 GeV, includes inelastic as well as elastic channels, and takes into account the other Δ charge states which must arise from the same mechanism, the process shown in Fig. 2a accounts for the major part of the pp total cross section at energies thus far measured.[5] Detailed description of these estimates will be included in the forthcoming proposal which we shall submit shortly.

If this picture even approximately survives the increase to ISR energies, it will be possible to measure the $\pi^- p$ total cross section $\sigma^{TOTAL}_{\pi^- p}$ by measuring the inclusive Δ^{++} cross section

$$pp \rightarrow \Delta^{++} + \text{everything} \qquad (4)$$

and extrapolating the differential cross section in $t_{p,\Delta}$ to the pion exchange pole at fixed mass of "everything". With 25 GeV circulating protons in each ring of the ISR, The measurement of $\sigma^{TOTAL}_{\pi^- p}$ could be carried out well above the energies currently known from the Serpukhov experiments. Table I shows the π^- p_{lab} in a conventional PS accelerator, the corresponding $\pi^- p$ CM-energy (X) and the t_{min} that we can reach in $pp \to \Delta^{++}(1238) + X$ with 25 GeV/c circulating protons.

TABLE I

π^- P_{Lab}	$\pi^- p$ E^*_{CM}	$M_\Delta = 1236$ t^{ISR}_{min}	$M_\Delta = 1400$ t^{ISR}_{min}
70	11.5	0.04 GeV^2	0.06 GeV^2
100	13.7	0.06 GeV^2	0.09 GeV^2
200	19.4	0.14 GeV^2	0.21 GeV^2

In the M_X region where we already know $\sigma^{TOTAL}_{\pi^- p}$, these measurements actually form part of the tests that the pion exchange picture holds up at higher energies. In making these measurements, note that it is not necessary to see the entire solid angle in the $p\pi^+$ rest frame; if only a portion is seen, $d\sigma/d\Omega$ for $\pi^+ p$ scattering is used in the pole equation instead of $\sigma^{TOTAL}_{\pi^+ p}$.

We also propose to measure the topological cross sections in reactions (1) using kinematic fits wherever possible to obtain additional ratio information. These ratios will then be compared with existing $\pi^- p$ cross section ratios up to 10 GeV CM energy from the Serpukhov-Mirabelle experiments and probably also up to ~ 14 GeV CM energy from the early NAL $\pi^- p$ bubble chamber experiments which should exist by the time SFM system is operational.

Absolute cross section comparisons can be made between reaction (3) and any other 4-constraint reaction such as $pp \to \Delta^{++} p \pi^- \pi^+ \pi^-$ whose corresponding $\pi^- p$ cross sections are available.

ČERENKOV COUNTERS

In order to distinguish protons from pions, hodoscopic Čerenkov counters will be utilized between the SFM and the compensator magnets.

JETS

It is interesting to note that in the picture of Figure 2a, "jets' are a "natural" occurance. A "jet" is said to occur whenever the two vertex clusters each travel in small cones about their direction of motion. This requirement places upper limits on the two vertex masses (at fixed ISR circulating beam energy). For example : with 25 GeV/c protons and taking

$$pp \to (p\pi^+)(p\pi^-)$$

as an example, the $p\pi^{\pm}$ systems produced at t_{min} each with $\sim$1.8 GeV invariant mass will have opening angles of $\sim$ 100 mrad in the ISR rest frame. At $\sim$ 1.8 GeV, $\pi^{\pm}p$ scattering is already quite inelastic and thus clusters of more than 2 particles are likely to be found. In any event, the pion exchange picture permits cross section predictions to be made just based on known $\pi^{\pm}p$ cross sections.

MASS RESOLUTIONS

This question has been looked into and the situation found to be satisfactory. The answer is somewhat complicated in the sense that when reaction (4) is being measured, the missing mass resolution (assuming a 4% uncertainty in measurement of the Δ^{++} momentum) is at its worse (typically 4-5 GeV). However, when information on the non-Δ^{++} prongs is included, the mass uncertainty in "everything" is improved considerably.

Let us just briefly remark here on the worst case, namely the pure missing mass configuration. The data is used in this form for the purpose of investigating $\sigma^{TOTAL}_{\pi^- p}$. We argue that since we are not searching for structure in this quantity, but rather just its absolute magnitude which is anticipated to continue its rather momentum independent behaviour, we would be quite content in a first generation experiment of this type to have $\sigma^{TOTAL}_{\pi^-}$ averaged over a 4-5 GeV energy range. A later generation higher resolution experiment might consist of two fairly large septum magnets positioned on either side of a vacuum pipe downstream of an intersection region to detect π^{+} and proton, respectively.

CROSS SECTIONS

Cross section predictions are presently being calculated and will be submitted to the ISRC as soon as they are available. Suffice it to say at this point that the total cross section for reactions (1) is large.

To see that this must be the case, even before looking at any detailed calculations, think of the following picture which is embodied in Fig. 2a. One proton finds itself in the very likely virtual state $p \to \Delta^{++}\pi^-$ while the second proton (P_2) is flying by. P_2 scatters dominantly on the π^- and we ask for its total cross section, not matter what $P_2\pi^-$ mass the system finds itself in or whether it undergoes elastic or inelastic scattering. As long as we integrate over the $P_2\pi^-$ mass, the cross section will not drop very much with increasing momentum. Such drop as occurs comes about because we restrict the mass at the $p\pi^+$ vertex. In any case, the cross section is always much larger than the expected few nbarn cross section for $pp \to \Delta^{++} n$ which requires that P_2 absorb the π^- in flight and become a neutron.

TRIGGER

The best trigger arrangement has not yet definitely been decided on. The only difficult part of the experiment concerns the inclusive Δ^{++} + everything part of the experiment. However since a 25 GeV/c $\Delta(1238)$ has an opening angle of $\sim$ 35 mrad, coincidence between the hodoscopic Cerenkov counter and an appropriately arranged scintillator hodoscope positioned before the Cerenkov counter should permit detection of the $p\pi^+$ system without seriously biasing the non-Δ^{++} system. Their is no significant bias at all for the low-mass jet-like events and not much for the high mass events. The trigger acceptance for the $p\pi^+$ system should be large enough to accept a mass range somewhat larger than the $\Delta(1238)$ width so that the cleanliness of the peak can be judged. As pointed out above, this need only be the case for some limited $p\pi^+$ decay angular configuration which simplifies considerably the situation.

CONCLUSIONS

We have discussed the properties of pp multiplarticle data which form a consistent picture from 7 to 28.5 GeV/c and suggested that one of the most interesting modes of operation of the initial SFM system would be to verify or disprove the validity of this at ISR energies.

We would welcome the collaboration of other interested parties on this experiment.

REFERENCES

1) E. Colton, P. Schlein, E. Gellert and G. Smith, Phys. Rev. Letters 21, 1548 (1968)

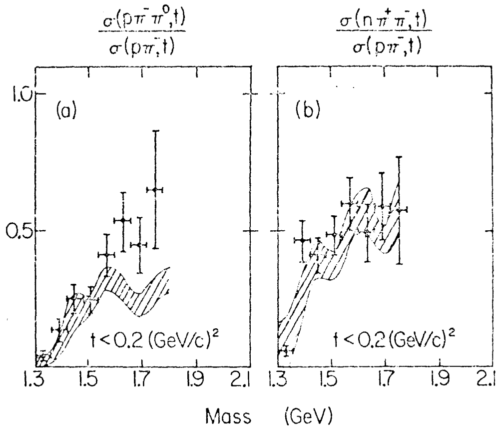
2) E. Colton et al., Phys. Rev. D2, 2108 (1970)

3) E. Colton et al., Phys. Rev. D3, 1063 (1971)

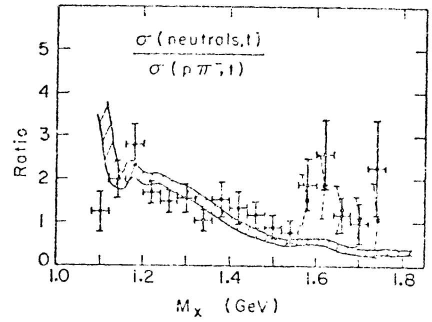
4) W.E. Ellis et al., Phys. Letters 32B, 140 (1970)

5) The apparent contradiction between this statement and the statement that pomeron exchange dominates high energy process does not in fact exist, the pomeron exchange also exists concurrently but at the upper π-p interaction vertex.

6.6 GeV/c Colton et al.[1,2]

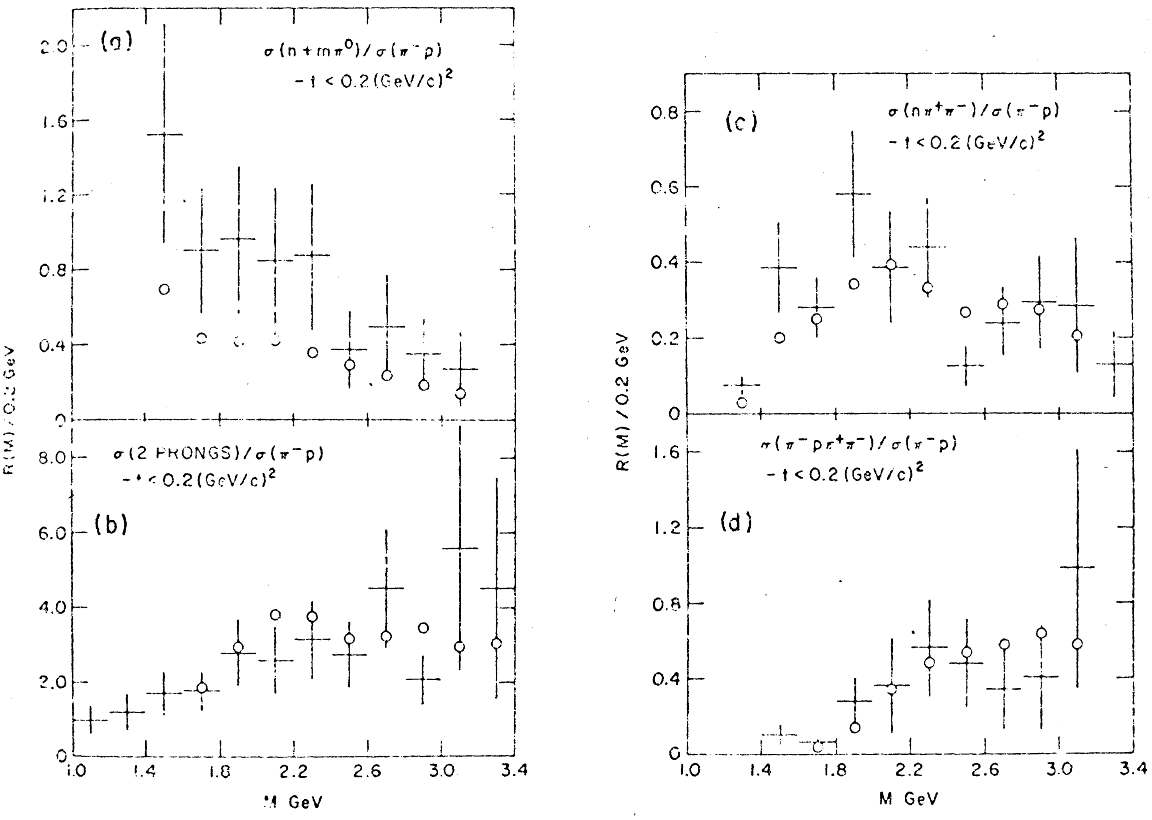


(a) Ratio of the cross section for $(pp \to \Delta^{++}p\pi^-\pi^0)/(pp \to \Delta^{++}p\pi^-)$ as a function of the mass of the non-Δ^{++} final-state system, where the momentum transfer to the Δ^{++} is $t<0.2$ GeV^2. (b) The same for $(pp \to \Delta^{++}n\pi^+\pi^-)/(pp \to \Delta^{++}p\pi^-)$. The shaded bands represent a summary of the known experimental ratios $(\pi^-p \to \pi^-\pi^0p)/(\pi^-p \to \pi^-p)$ and $(\pi^-p \to n\pi^+\pi^-)/(\pi^-p \to \pi^-p)$, respectively.



Cross-section ratio $\sigma(pp \to \Delta^{++}(neutrals))/\sigma(pp \to \Delta^{++}(p\pi^-))$ plotted as a function of the mass of the non-Δ^{++} final-state system, for momentum transfer to the Δ^{++} $|t| < 0.2$ GeV^2. The dashed points in the uppermost five mass bins represent the ratios calculated using $1.18 < M_{p\pi^+} < 1.26$ GeV for the Δ^{++} selection. The cross-hatched band is the known on-shell ratio $\sigma(\pi^-p \to neutrals)/\sigma(\pi^-p \to \pi^-p)$.

28.5 GeV/c Ellis et al.[4]



Ratios between cross sections for various final states, $R(M)$, for both off-shell (crosses, with statistical er[illegible]hatched) and on-shell data (circles indicate central value in 0.2 GeV mass bins).

Reactions

$p + p \to \Delta^{++} + (\pi^- + p)$

$\to \Delta^{++}$ + (all neutral particles)

$\to \Delta^{++}$ + (all events with one positive and one negative particle)

$\to \Delta^{++} + (n + \pi^+ + \pi^-)$

$\to \Delta^{++} + (\pi^- + p + \pi^+ + \pi^-)$

Compared with

$\sigma(\pi^-p \to$ all neutral$)/\sigma(\pi^-p \to \pi^-p)$

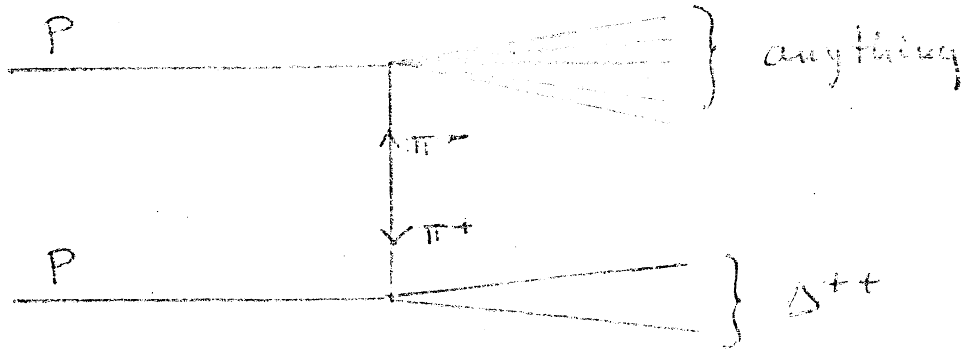
$\sigma(\pi^-p \to$ all "2 prong" events$)/\sigma(\pi^-p \to \pi^-p)$

$\sigma(\pi^-p \to n\pi^+\pi^-)/\sigma(\pi^-p \to \pi^-p)$

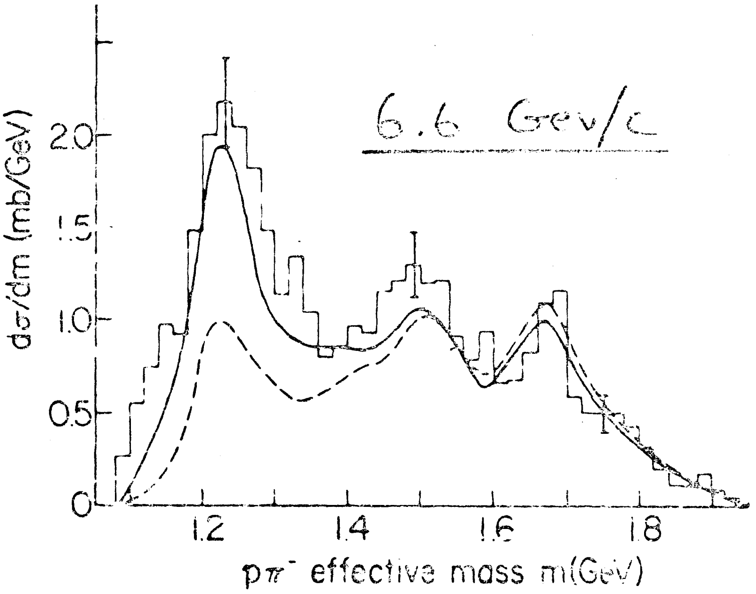
$\sigma(\pi^-p \to \pi^-p\pi^+\pi^-)/\sigma(\pi^-p \to \pi^-p)$

FIGURE 1

(a)

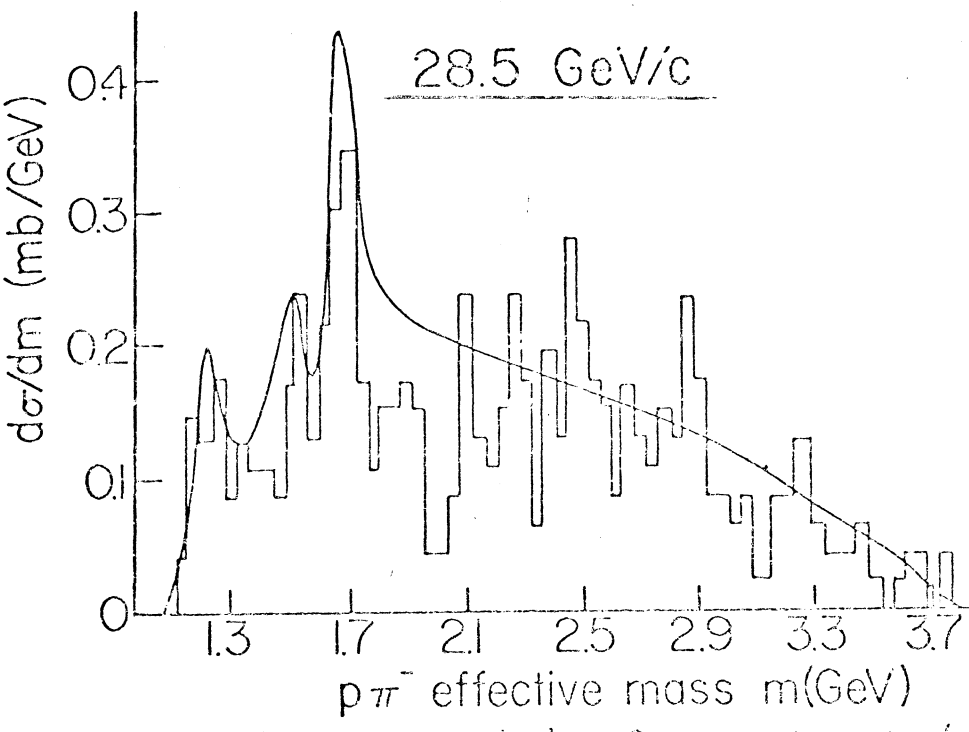


(b)



$pp \rightarrow p\pi^-\Delta^{++}$ at 6.6 Gev/c. $d\sigma/dm(\pi^- p)$ for momentum transfer to Δ^{++}, $t<0.3$ Gev^2 from Colton et al.[3] Absolute cross section units are shown.

(c)



same as (b) above but from 28.5 GeV/c Ellis et al.[4] experiment. Calculation by Colton et al[3]

FIGURE 2