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Extraction of Average Multiplicities in K^+p and $K^+\pi^+$ Scattering from Inclusive Λ Production at 100 GeV/c.*

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Abstract

High recoiling masses and high average charged multiplicities, $\langle N_{ch}\rangle$, are associated with Λ's produced in 100 GeV/c pp and π^+p interactions. If one demands a gap of at least one unit in rapidity between the Λ and its recoiling mass, the associated $\langle N_{ch}\rangle$ in pp interactions agrees with that of on-mass-shell K^+p interactions. Application of this technique to π^+p interactions shows that the extracted $\langle N_{ch}\rangle$ is higher in $K^+\pi^+$ scattering than in K^+p.

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In a recent letter[1], it was shown that $\Delta^{++}(1236)$ production in π^+p and pp interactions is consistent with one-pion exchange and that the average multiplicity of the mass recoiling off the Δ^{++} in pp interactions is consistent with that of π^-p scattering. The average multiplicity of the $\pi^-\pi^+$ scattering is then extracted from the system recoiling off the Δ^{++} produced in π^+p interactions.

The quantum numbers for a Λ produced backward in the center of mass off a proton target are consistent with kaon exchange. Here we will extend the technique of Ref. 1 to extract the average charged multiplicity, $\langle N_{ch}\rangle$ for $K^+\pi^+$ scattering from the mass, M, recoiling off the Λ in π^+p interactions at 100 GeV/c. A consistency check is made by extracting $\langle N_{ch}\rangle$ for K^+p scattering from the process $pp \rightarrow \Lambda + X^{++}$ at 100 GeV/c and comparing with the on-mass-shell K^+p values. Unlike the study of Δ^{++} production, here we have acceptance for all values of momentum transfer and have a sample of events with high M^2. This allows us to investigate the range of validity in M^2 of the kaon exchange picture.

The details of analyzing neutral particle production in this experiment are discussed in another recent letter.[2] Only Λ's produced backward in the center of mass are used. It is interesting to note that in π^+p interactions there are no 2-prong events when a Λ is produced, and that in pp interactions only one event is of the type $pp \rightarrow \Lambda K^+p$. Fig. 1 shows the square of the mass recoiling from the Λ. The distribution is peaked toward higher M^2 values.

Our large binning in M^2 is not merely due to limited statistics. Even with good statistics, the M^2 distribution will be smeared by an unknown amount of Σ^0 production. It is reasonable to assume Λ and Σ^0 are produced in the same way, since they have the same quantum numbers. However, the square of the missing mass recoiling from the Λ, M_Λ^2 , for $\Sigma^0 \to \Lambda\ \gamma$, is not a good measure of the square of the missing mass from the parent Σ^0 , M_Σ^2 . In the extreme cases where the γ makes a large angle with the recoiling mass as viewed in the rest system of the Σ^0, M_Λ^2 is a large <u>over-estimate</u> of M_Σ^2. The bounds of M^2 are given in equation (1):

$$M_\Lambda^2 = \frac{1}{2m_\Sigma^2}\left[(m_\Sigma^2 + m_\Lambda^2)\, M_\Sigma^2 + (m_\Sigma^2 - m_\Lambda^2)(s - m_\Sigma^2 \pm \lambda^{\frac{1}{2}}(s, M_\Sigma^2, m_\Sigma^2)\right] , \qquad (1)$$

where $\lambda(s, M_\Sigma^2, m_\Sigma^2) = (s - (M_\Sigma + m_\Sigma)^2)(s - (M_\Sigma - m_\Sigma)^2)$, and $m_\Sigma(m_\Lambda)$ is the rest mass of the $\Sigma(\Lambda)$. For the energy of our experiment, Fig. 2 shows the bounds of the uncertainty, $M_\Lambda^2 - M_\Sigma^2$, as a function of M_Σ^2 when the Λ is actually the product of $\Sigma^0 \to \Lambda\ \gamma$. The uncertainty is large at small M^2 and small at large M^2. It is not meaningful to have a bin size smaller than the smear. Fortunately, the region with the best statistics (large M^2) is also the place where the smearing due to Σ^0-production is smallest.

The average multiplicity of the X^{++} system as a function of M^2 is shown in Fig. 3. For the reaction $pp \to \Lambda\ X^{++}$, $\langle N_{ch}(X^{++})\rangle$ is, in the kaon exchange picture, the average multiplicity of the off-mass-shell K^+p scattering. We compare these values to the average multiplicity of the on-mass-shell K^+p scattering at s equal to M^2. In Ref. 1 we used equation (2) to represent the data of the on-mass-shell π^-p inelastic scattering.

$$\langle N_{ch} \rangle = -4.5 + 10/\sqrt{s} + 2 \ln s \ . \qquad (2)$$

Not much data is available for on-mass-shell K^+p inelastic scattering.[3] We find equation (2) can represent those data with an uncertainty of $\pm$ 0.4 units.

Fig. 3a shows the multiplicity associated with the Λ in pp interactions compared with equation (2). The off-mass-shell multiplicity, $\langle N_{ch} \rangle$, agrees with that for on-mass-shell K^+p scattering except for the largest M^2 bins (dashed data points). As s/M^2 becomes small, so does the rapidity gap Δy between the Λ and its missing mass. The kaon exchange picture is not expected to be valid when Δy falls below one unit. Demanding at least one unit of rapidity gap between the Λ and its missing mass (solid data points), one obtains good agreement with on-mass-shell K^+p scattering. With Δy less than 1, Λ's are presumably produced in some other process, the average multiplicity of which seems to be higher.

The average multiplicity associated with the Λ in π^+p interactions is shown in Fig. 3b. At large M^2, the solid and dashed points are those with and without at least one unit of rapidity gap between the Λ and its missing mass. The solid points are the extracted average multiplicities of $K^+ \pi^+$ scattering. The values of average multiplicity are close to one unit above that of K^+p scattering at all M^2.

We conclude that the effect which we observed in pion exchange reactions[1] is present also in kaon exchange. The average multiplicity in off-mass-shell meson-proton scattering agrees with the on-mass-shell values;

meson-meson scattering has a higher average multiplicity than baryon-meson scattering.

References

1. J. Erwin, R.D. Kass, J.H. Klems, Winston Ko, R.L. Lander, D.E. Pellett, P.M. Yager and M. Alston-Garnjost, Phys. Rev. Lett. 35, 980 (1975).

2. Margaret Alston-Garnjost, J. Erwin, J.H. Klems, W. Ko, R.L. Lander, D.E. Pellett and P.M. Yager, Phys. Rev. Lett. 35, 142 (1975).

3. See J. Whitmore, Phys. Rep. 10c, 273 (1974).

Figure Captions

Figure 1. Distribution of the square of the mass recoiling off the Λ.

Figure 2. For Λ's as product of $\Sigma^0 \to \Lambda\ \gamma$, the bounds of the over-estimate of M_Σ^2 when M_Λ^2 is used.

Figure 3. The average charged multiplicity of X^{++} versus M^2. At large M^2, the solid and dashed points are those with and without demanding at least one unit of rapidity gap between the Λ and its missing mass. The curve represents the average multiplicity in on-mass-shell K^+p scattering (same as π^-p scattering), with the substitution $M^2 = s$.

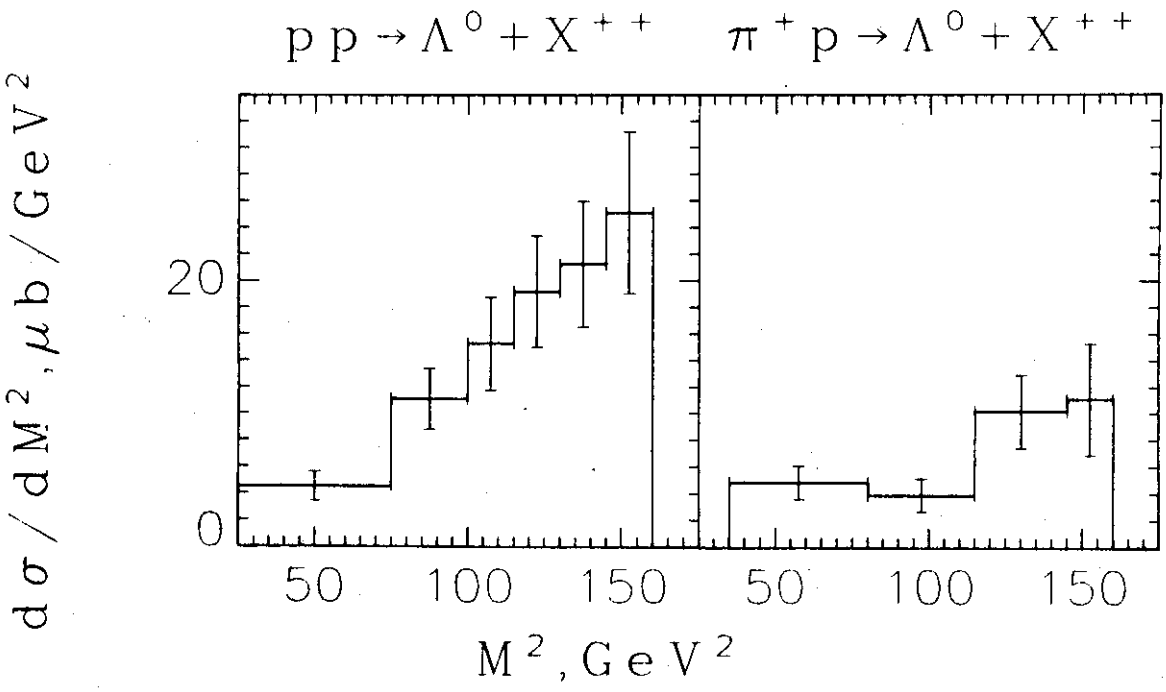

Figure 1

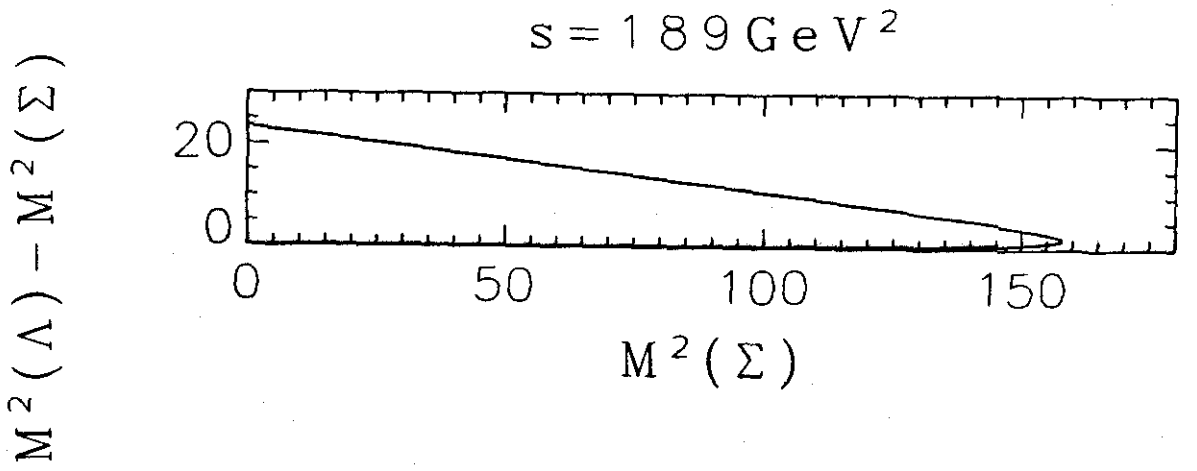

Figure 2

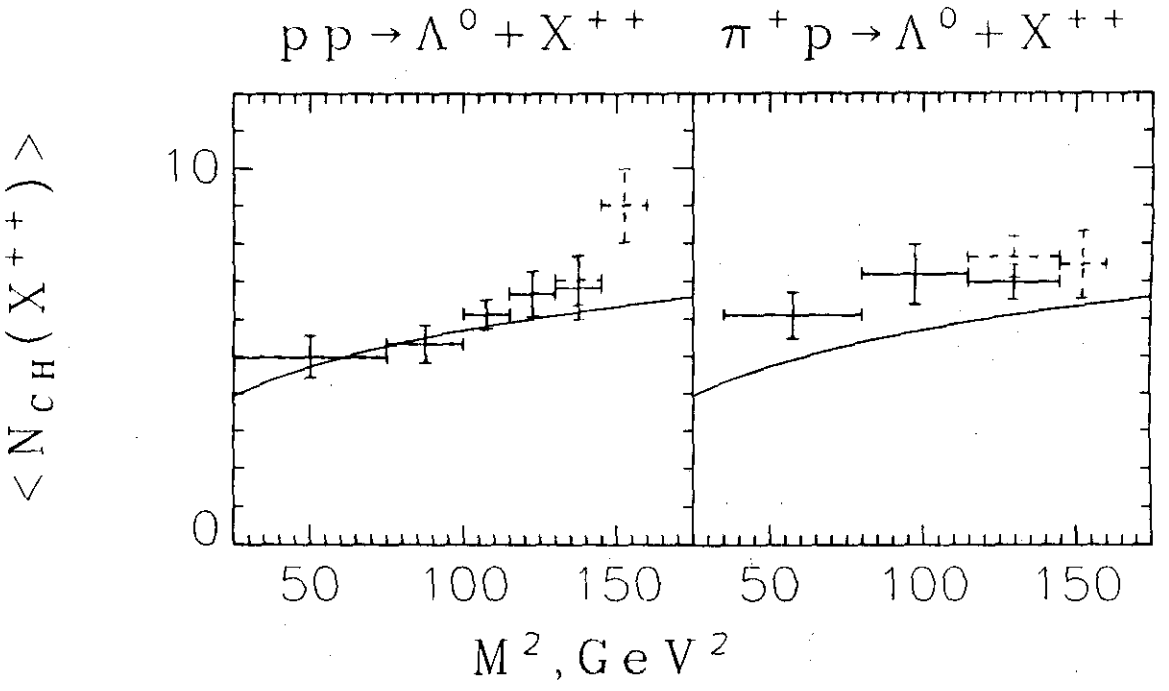

Figure 3