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INCLUSIVE NEUTRAL PARTICLE PRODUCTION

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ABSTRACT

Results of recent inclusive neutral particle production experiments are compared to existing experimental results. These experiments range from 15 GeV/c to 2000 GeV/c in laboratory beam momentum and use π^- , π^+ , p and $\bar{p}$ beams.

In this report I shall give results of seven experiments on inclusive neutral particle production. These are the papers¹⁻⁷ submitted to the Seattle conference of the APS Division of Particles and Fields. In Table I provide general information about these experiments. Five of these experiments were performed in a bubble chamber with hydrogen as a target. Two of the experiments were counter experiments; one performed at Fermilab and one at the CERN ISR. I shall restrict my discussion to total inclusive cross section, dependence on charge multiplicity and P_T^2 inclusive distributions.

TABLE I
Experiments Submitting Papers

Institutions	Beam	Momentum (GeV/c)	Principle Device	Particles Produced
Michigan State U - Tufts - Fermilab	$\bar{p}$	14.75	BNL 80" BC	γ, K^0, Λ^0
Columbia - SUNY (Binghamton)	π^+	15	SLAC 82" BC	$\pi^0, K^0, \Lambda^0, \bar{\Lambda}^0$
Michigan State U - Cambridge - Fermilab	$\bar{p}$	100	Fermilab 30" BC	$\gamma, K^0, \Lambda^0, \bar{\Lambda}^0$
Fermilab - Florida State U	π^-	250	Fermilab 15' BC	$K^0, \Lambda^0, \bar{\Lambda}^0$
ANL - Kansas - SUNY (Stoneybrook) - Tufts	p	300	Fermilab 15' BC	γ
Wisconsin - Michigan - Rutgers	p	300	Fermilab Counter Exp.	$K^0, \Lambda^0, \bar{\Lambda}^0, \Xi^0$
UCLA - SACLAY	p	653	CERN ISR	Λ^0
AACHEN - UCLA - CERN	p	2050	CERN ISR	Λ^0

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The inclusive cross section for the production of a particle is the cross section for production of that particle plus anything else. Figure 1⁸ shows the inclusive cross section for the production of π^0 by pp and $\bar{p}p$ interactions as a function of beam momentum. For low energy experiments these cross sections are determined by seeing both photon conversions of the π^0 , but at high energies where only a single photon conversion is observed, $\sigma(\pi^0)$ is implied from the cross section for production of photons. The cross section for π^0 production by pp interactions increases rapidly and approximately linearly with increasing $\log p_{\text{beam}}$. It has been observed experimentally that $\sigma(\pi^0) \approx \frac{1}{2} [\sigma(\pi^-) + \sigma(\pi^+)]$. The production of π^0 for $\bar{p}$ induced interactions is larger than the π^0 production for the p induced interactions at the same energy, however the difference tends to get smaller at higher energy.

In Figure 2 the $K_S^0, \Lambda^0, \bar{\Lambda}^0$ inclusive cross production sections⁸ for pp interactions are shown. Defining low energy to be interactions with less than 50 GeV/c laboratory momentum, one sees that $\sigma(\Lambda^0 X)$ is greater than $\sigma(pp \rightarrow K_S^0 X)$ in the low energy region. In the intermediate energy region the K_S^0 production cross section overtakes the Λ^0 production cross section. In the high energy region the Λ^0 cross section is approximately constant independent of incident momentum. The K_S^0 production cross section increases linearly with $\log p_{\text{Lab}}$. Points in the ISR energy region have been included to show that these trends continue. An ISR experiment producing Λ^0 at equivalent lab momenta of 652 GeV/c and 2050 GeV/c is included in the data. As K_S^0 production from ISR experiments is not presently available, estimates from K^+ and K^- cross sections were made. The rising K_S^0 cross section and constant Λ^0 cross section may be explained by the domination of K_S^0 production by central region processes such as $K^0 \bar{K}^0$ production whereas the Λ^0 production is dominated by fragmentation processes like $K\Lambda^0$ production. The non-domination of the Λ^0 cross section by the $\Lambda^0 \bar{\Lambda}^0$ contribution to the Λ^0 cross section is confirmed by the size of the $\bar{\Lambda}^0$ production cross section. Comparing the K_S^0 production cross section to the π^0 cross section we see that the ratio is approximately 5% in the high energy region.

The $K_S^0, \Lambda^0, \bar{\Lambda}^0$ production cross sections for π^-p interactions are shown in Figure 3. In the high energy region we find that the ratio of Λ^0 production by π^-p to pp is ~ 0.5 where the corresponding ratios for K_S^0 is 0.57. If we assume factorization of the vertices and that Λ^0 production is predominantly associated to the proton vertices, then we might expect $\sigma(\pi^-p \rightarrow \Lambda^0 X)$ to be $1/3$ of $\sigma(pp \rightarrow \Lambda^0 X)$. There is of course some Λ cross section associated with $\Lambda^0 \bar{\Lambda}^0$ production which is not in the fragmentation region. To explain this with $\Lambda^0 \bar{\Lambda}^0$ production we would want a larger $\bar{\Lambda}^0$ cross section than is observed. The K_S^0 production cross section ratios can be explained. If the K_S^0 cross section was associated only with central region processes one would expect the ratio of K_S^0 production cross sections to be equal to the ratio of inelastic cross sections (~ 0.63), however if there are proton fragmentation processes such as $K_S^0 \Lambda^0$ production, one would expect a lower ratio since there are two proton vertices in pp interactions. Figure 4a and 4b show the cross sections for K_S^0 and Λ^0 production when compared to pp interactions. The lower Λ^0 cross section may be associated to the presence of a single proton for the

$\bar{p}p$ interactions.

Reactions that produce neutral particles also produce charged particles. The correlation of the number of charged particles with the various kinds of neutral particles are of interest. Figures 5 and 6 show $\langle n_{K_S^0} \rangle$ and $\langle n_{\Lambda^0} \rangle$, the average number of K_S^0 and Λ^0 per inelastic collision, as a function of n_- , the number of negative charged prongs. Looking at the pp data we see that $\langle n_{K_S^0} \rangle$ is low for low multiplicity events, rising and possibly tapering off at higher multiplicities. One might expect K_S^0 to increase with n_- in a manner similar to π^0 , however with a lower slope because of the larger K_S^0 mass. The tapering off at higher multiplicity would be due to diminishing availability of energy. We find that $\langle n_{\Lambda^0} \rangle$ is consistent with being independent of multiplicity, as would be expected if the Λ^0 production were dependent on the fragmentation proton.

The inclusive differential cross section with respect to $x \equiv P_L^{cm}/P_{Lmax}^{cm}$ and P_T^2 reveal features about the interactions. Figure 7a and 7b show the invariant cross section $F_1(x)$ for K_S^0 and Λ^0 production by π^-p interactions at 18.5 GeV/c¹⁰ and 250 GeV/c⁴. The $F_1(x)$ distribution for K_S^0 production is slightly asymmetric in π^-p interactions since there is no $K_S^0 \bar{\Lambda}^0$ produced at the beam fragmentation vertex as with pp interactions. In the central region, $|x| < 0.3$, the 250 GeV/c data is higher than the 18.5 GeV/c data indicating that scaling in this region has not been achieved at 18.5 GeV/c. The fragmentation region is consistent with scaling. The invariant differential cross section with respect to P_T^2 seems roughly exponential for $K_S^0, \Lambda^0, \bar{\Lambda}^0$ production. Figure 8 shows $\langle P_T \rangle$ for various beam energies, beam particles and produced particles. As different experiments display their results in different manners it was necessary to estimate $\langle P_T \rangle$ from $\langle P_T^2 \rangle$, $\langle 1/P_T^2 \rangle$, etc. Thus, data points in this graph should be considered approximate, however certain trends are evident, $\langle P_T \rangle$ is not very dependent on beam energy or beam particle, but heavier mass produced particles seem to have larger values of $\langle P_T \rangle$.

In Figure 9 data is shown from the Wisconsin-Michigan-Rutgers experiment.⁶ The ratio of the $\bar{\Lambda}$ to Λ is plotted against P_{Lab} . $X = 0$ corresponds to about $P_{Lab} = 12$ GeV/c where one sees that $\bar{\Lambda}/\Lambda \approx 1$, verifying that Λ produced in that region are associated to $\bar{\Lambda}\bar{\Lambda}$ production. This same experiment sees Ξ^0 and $\bar{\Xi}^0$ but their yields are preliminary at this point. The Ξ^0 yield is probably less than 1% of Λ^0 yield.

To conclude I would like to say that a large amount of data exists for single strange particle measurements. An interesting direction for new experiments to move is to study multiple production of strange particles (in the 15-foot Bubble Chamber, for example) and to study correlations and rapidity distributions of neutrals along with charged mesons.

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Fig. 1 - $\sigma(\pi^0)$ in mb as a function of laboratory momentum of the beam.

Fig. 2 - pp cross sections for neutral production.

Fig. 3 - πp cross sections for neutral production.

Fig. 4 - $\bar{p}p$ cross sections for neutral production.

Fig. 5 and 6 - Average number of K_S^0 and Λ^0 vs. number of negative prongs.

Fig. 7 - $F_1(x)$ for $\pi^- p \rightarrow X_S^0 X$ and $\pi^- p \rightarrow \Lambda^0 X$

Fig. 8 - $\langle P_T \rangle$ for $K_S^0, \Lambda^0, \bar{\Lambda}^0$

Fig. 9 - $\bar{\Lambda}^0/\Lambda^0$ vs. lab momentum.

(Wisconsin-Rutgers-Michigan Data)