

Inclusive Λ , $\bar{\Lambda}$ and $\Sigma^{\pm}(1385)$ Production
in 405 GeV/c pp Interactions

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Abstract

We have investigated inclusive Λ , $\bar{\Lambda}$ and $\Sigma^{\pm}(1385)$ productions in 405 GeV/c pp interactions. The observed cross sections are $\sigma(\Lambda) = 4.05 \pm 0.39$ mb, $\sigma(\bar{\Lambda}) = 0.63 \pm 0.17$ mb, $\sigma(\Sigma^+(1385)) = 0.74 \pm 0.17$ mb and $\sigma(\Sigma^-(1385)) = 0.56 \pm 0.17$ mb. $\bar{\Lambda}$ production is dominated in a central region of $|x| \leq 0.4$. The $\Lambda/\bar{\Lambda}$ production ratio at $|x| \approx 0$ is found to be 1.2 ± 0.5 . The excess, about 0.2 mb, of $\sigma(\Sigma^+(1385))$ over $\sigma(\Sigma^-(1385))$ is most likely attributed to proton fragmentations ($|x| \geq 0.4$), and gives an evidence for scaling.

Recently there have been many interesting results reported on inclusive particle and resonance productions in hadron-hadron interactions at various energies, from intermediate energies to the ISR-energy [1-8]. However, there is only a little information about strange baryon resonance productions at hundred GeV region [4]. In this letter we would like to give a brief report on Λ , $\bar{\Lambda}$ and $\Sigma^+(1385)$ productions in 405 GeV/c pp interactions, using 20,600 pictures of 70 mm film taken at the Fermilab 30-inch liquid hydrogen bubble chamber. The results come from the analysis of 115 events with an associated Λ and 14 events with a $\bar{\Lambda}$.

In order to find events with an associated V^0 , two independent scans of the film were made. The V^0 events with a clear signature of electron or positron spiral were excluded. The third scan was made by physicists to resolve all conflicts between the two scans. A total of 1,132 events with an associated V^0 was found in a restricted fiducial volume. The overall scanning efficiency was 98%. After track-matching of secondary tracks by physicists in the course of scanning, measurements of V^0 tracks, beam tracks, and secondary tracks were carried out with conventional manual measuring projectors. Secondary tracks in a forward jet cone were measured as many as possible, even within an opening angle of one degree with respect to the incident beam direction. Measured events were geometrically reconstructed using the TVGP program. Well reconstructed tracks were selected according to its residuals. About 92% of the measured secondary tracks were found to be successfully reconstructed, which corresponded to 65% of all secondary tracks. The inclusive differential cross section for those well measured secondary tracks showed no bias at the backward hemisphere in the center-of-mass system. The identification of V^0 events as Λ or $\bar{\Lambda}$ was made from the mass distribution and the transverse momentum distribution analyses for each mass hypothesis (γ , K_S^0 , Λ or $\bar{\Lambda}$). The effective mass of V^0 for the mass hypothesis of Λ ($\bar{\Lambda}$) was required to be between 1102 and 1128 MeV, and the transverse momentum P_T^- of negative(positive) track with respect to the V^0 momentum direction was less than 105 MeV/c and greater than 15 MeV/c. The events with P_T^- less than 15 MeV/c were removed as γ events, and with P_T^- greater than 105 MeV/c as K_S^0 events, referring to the difference of Q values. Still $K_S^0 - \Lambda$ ($\bar{\Lambda}$) ambiguous events were resolved from the mass distribution analysis. A check on ionization loss was also

made to be consistent with the mass hypothesis of $\Lambda(\bar{\Lambda})$. The association of Λ or $\bar{\Lambda}$ with a primary interaction vertex was defined with an association angle less than 75 milli-radian. After these procedures we have obtained 115 and 14 events with associated Λ and $\bar{\Lambda}$ respectively in the backward hemisphere. The mean value of Λ mass was 1115.5 ± 0.6 MeV and the mass resolution was 4 MeV FWHM. Analysis of the normalized decay length distribution L/p of Λ was also made, where L and p were the decay length and the laboratory momentum of Λ respectively. The decay curve was consistent with the expectation due to the restricted fiducial volume. Further details on experimental procedures will be reported in a separate paper [9].

The production cross sections of Λ and $\bar{\Lambda}$ were obtained with the corrected number of Λ and $\bar{\Lambda}$ events and the total beam path length [10]. The values obtained are 4.05 ± 0.39 mb for Λ and 0.63 ± 0.17 mb for $\bar{\Lambda}$ respectively. These results are plotted together with other data [1,2] as a function of s , the total center-of-mass energy squared [fig.1]. The cross sections look well fitted to a tendency observed at lower energies. The cross section of $\bar{\Lambda}$ is rapidly increasing in this energy range. The increase of the production cross section is found to be about 0.5 mb between 69 and 405 GeV/c.

In figs. 2(a) and (b), are shown the inclusive differential cross sections $d\sigma/d|x|$ and $d\sigma/dp_T^2$ respectively, for both Λ and $\bar{\Lambda}$ productions. p_L , p_T and p_{\max} are the longitudinal, the transverse and the maximum momentum of out-going particles in the center-of-mass system respectively. Here the Feynman variable x is defined as $x = p_L/p_{\max}$. As shown in fig. 2(a), Λ 's are produced in a broad x range between fragmentation and central regions, while $\bar{\Lambda}$ production is dominated in a central region of $|x| \leq 0.4$. The production ratio $\Lambda/\bar{\Lambda}$ is found to be 1.2 ± 0.5 at $|x| \leq 0.1$, compatible with the value of 1.6 ± 0.4 of the CERN ISR data [3]. In spite of the significant difference in x distributions, the p_T distributions for Λ and $\bar{\Lambda}$ are very similar and their slopes are nearly equal within errors as shown in fig. 2(b). The fitted values are 3.32 ± 0.37 (GeV/c) $^{-2}$ at $p_T^2 \leq 1.3$ (GeV/c) 2 for Λ and 3.7 ± 1.3 (GeV/c) $^{-2}$ at $p_T^2 \leq 1.0$ (GeV/c) 2 for $\bar{\Lambda}$. The results are compatible with the universal p_T^2 distributions of directly produced particles with a slope of about 3.2 (GeV/c) $^{-2}$ [7,8]. The momentum transfer distribution $t' = |t - t_{\min}|$ between the Λ and initial proton is plotted in fig. 2(c). A very sharp

break is evident at $t' \approx 1.6(\text{GeV}/c)^2$. The differential distribution was fitted with an exponential form of $A \cdot e^{-B \cdot t'}$. The fit yields $A = 4.61 \pm 0.92 \text{ mb}/(\text{GeV}/c)^2$ and $B = 1.45 \pm 0.27(\text{GeV}/c)^{-2}$ for $t' \leq 1.6$, and $A = 0.62 \pm 0.42 \text{ mb}/(\text{GeV}/c)^2$, $B = 0.24 \pm 0.14(\text{GeV}/c)^{-2}$ for $1.6 \leq t' \leq 6.0(\text{GeV}/c)^2$. The break at $t' \approx 1.6$ have been reported in 12.4 and 200 GeV/c pp interactions [2]. The structure of t' distribution may indicate two contributions for Λ production, the one from a fragmentation ($|x| \geq 0.4$) and the other from a central region production, as shown in fig. 2(d). The t' distribution of $\bar{\Lambda}$ shows a less steeper slope due most likely to a central production, which would be compatible with that for Λ in the region of $|x| \leq 0.4$.

Figs. 3(a) and (b) show the effective mass distributions of $(\Lambda\pi^\pm)$, where all the positive and negative tracks were assumed to be positive and negative pions, respectively. A sharp peak of $\Sigma^+(\Lambda\pi^+, 1385 \text{ MeV})$ and a little broader bump of $\Sigma^-(\Lambda\pi^-, 1385 \text{ MeV})$ are observed. The background has been evaluated by associating Λ with the charged tracks from the other irrelevant events with a Λ . After subtraction of smoothed background (solid curves), the corresponding cross sections were estimated at each peak. The cross sections are found to be $0.74 \pm 0.17 \text{ mb}$ for $\Sigma^+(1385)$ and $0.56 \pm 0.17 \text{ mb}$ for $\Sigma^-(1385)$, after further correction for decay branching ratios. The shaded histogram in each case is for the events with $|x| \leq 0.4$. The differential distribution $d\sigma/d|x|$ for $\Sigma^+(1385)$ is also shown in fig. 3(c). About 65% ($\sim 0.5 \text{ mb}$) of all $\Sigma^+(1385)$ seem to be produced in the central region of $|x| \leq 0.4$, and leaving other about 35% ($\sim 0.2 \text{ mb}$) of $\Sigma^+(1385)$ produced in the proton fragmentation region. The cross section value for $\Sigma^+(1385)$ production in the central region is nearly equal to the 0.56 mb cross section for $\Sigma^-(1385)$ production. The latter is expected to occur only in the central region, and not in the proton fragmentation region as it requires double charge exchange.

It is interesting to compare these results with the data observed in the K^-p interactions at intermediate energies. It is reported in K^-p interactions [6], the cross sections for $\Sigma^\pm(1385)$ production are approximately constant in the energy range from 10 to 16 GeV/c, being $\sim 0.35 \text{ mb}$ for $\Sigma^+(1385)$ and $\sim 0.25 \text{ mb}$ for $\Sigma^-(1385)$, and the excess ($\sim 0.1 \text{ mb}$) of the $\Sigma^+(1385)$ cross section over that for $\Sigma^-(1385)$ is almost due to the fragmentation of the target proton. In our data, on the other hand, the excess of the $\Sigma^+(1385)$ cross section over that of $\Sigma^-(1385)$

is about 0.2 mb, which corresponds to ~ 0.1 mb for a target proton fragmentation. This result may indicate an early scaling behavior of the target proton fragmentation for $\Sigma^+(1385)$ production in K^-p interactions at the intermediate energies.

Finally, the overall production ratio of $\Sigma^+(1385)/\Lambda$ is found to be about 0.17 in our data at 405 GeV/c interactions. The same ratio is also reported in the K^-p experiment giving the value of about 0.15[6].

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10. To each event in the fiducial volume the following weight was

corrected:

$$\text{weight} = \frac{1}{e^{-L_{\min}/L_0} - e^{-L_{\text{pot}}/L_0}}$$

where L_{pot} is the potential length of the vee (i.e., the path length from the primary vertex to the edge of the fiducial volume), L_{\min} is the minimum length permitted between the primary and the V^0 -vertices, defined as 2 cm, and L_0 is the decay length of the vee particle, given as $L_0 = c\tau_{\Lambda}/m_{\Lambda}$. The average weights were 1.71 for Λ and 2.21 for $\bar{\Lambda}$ respectively.

Figure Captions

Fig. 1. Inclusive Λ and $\bar{\Lambda}$ cross sections in pp interactions as a function of s , the total center-of-mass energy squared. Data are from this experiment and refs. 1 and 2.

Fig. 2. The differential cross sections of Λ and $\bar{\Lambda}$. (a) $d\sigma/d|x|$, (b) $d\sigma/dp_T^2$, (c) $d\sigma/dt'$ for Λ only, and (d) $d\sigma/dt'$ for Λ and $\bar{\Lambda}$ as a function of $|x|$.

Fig. 3. (a) $\Lambda\pi^+$ effective-mass distribution. (b) $\Lambda\pi^-$ effective-mass distribution. The background has been calculated by associating Λ with the charged particles from all of the other irrelevant events with a Λ . The shaded histogram in each case is for the events with $|x| \leq 0.4$. (c) $d\sigma/d|x|$ distributions for $\Sigma^+(1385)$.

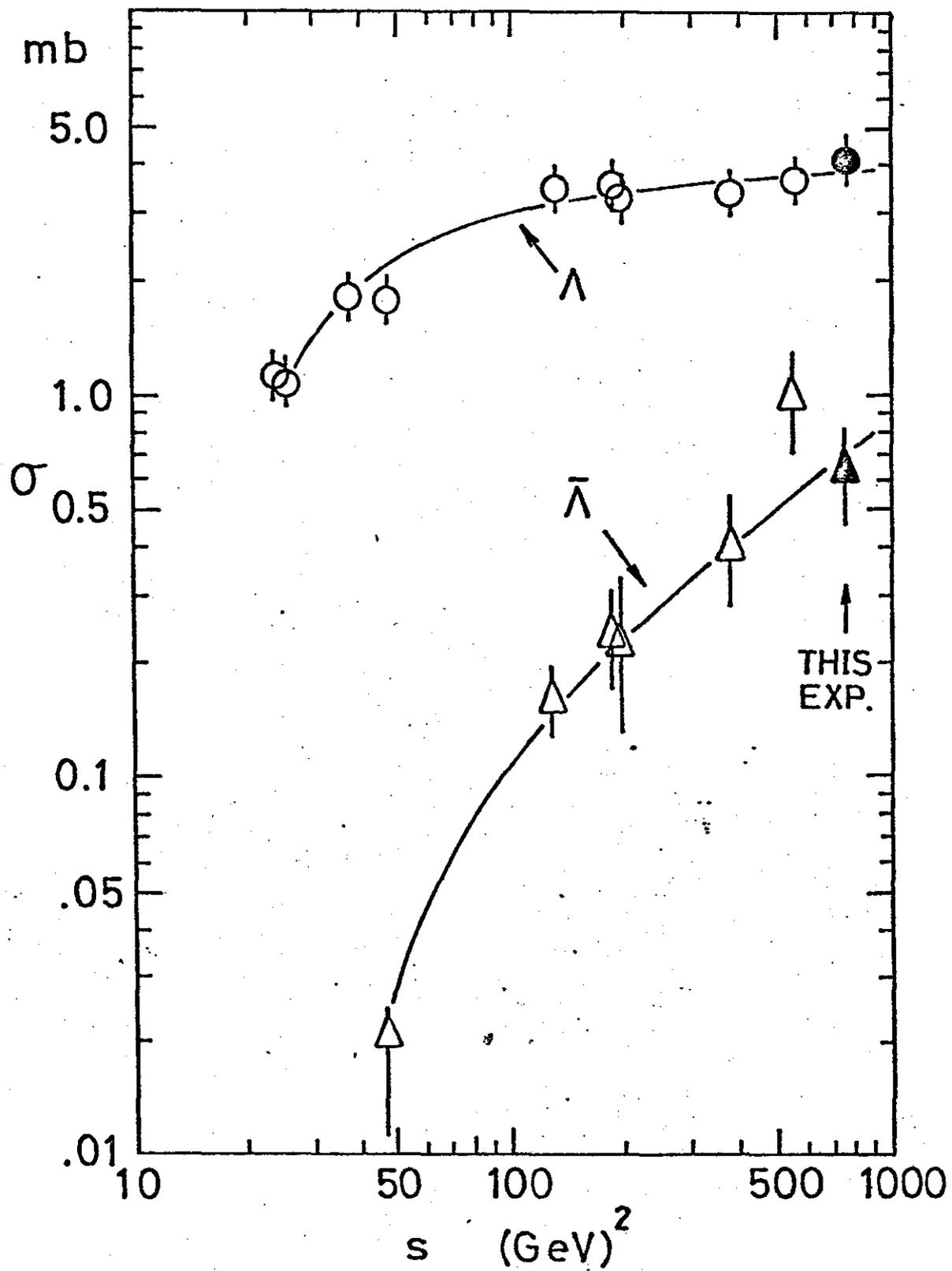


Fig. 1

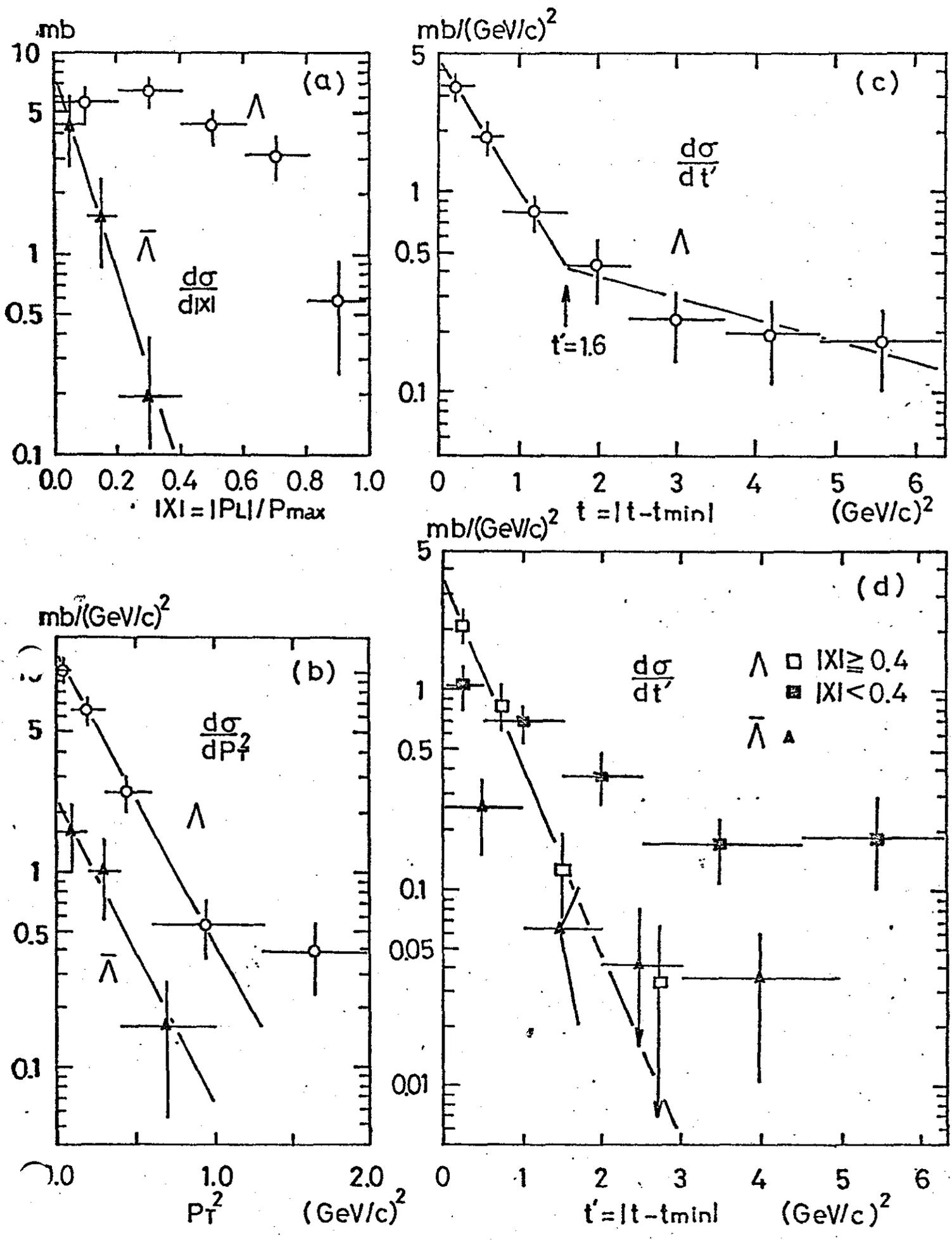


Fig. 2

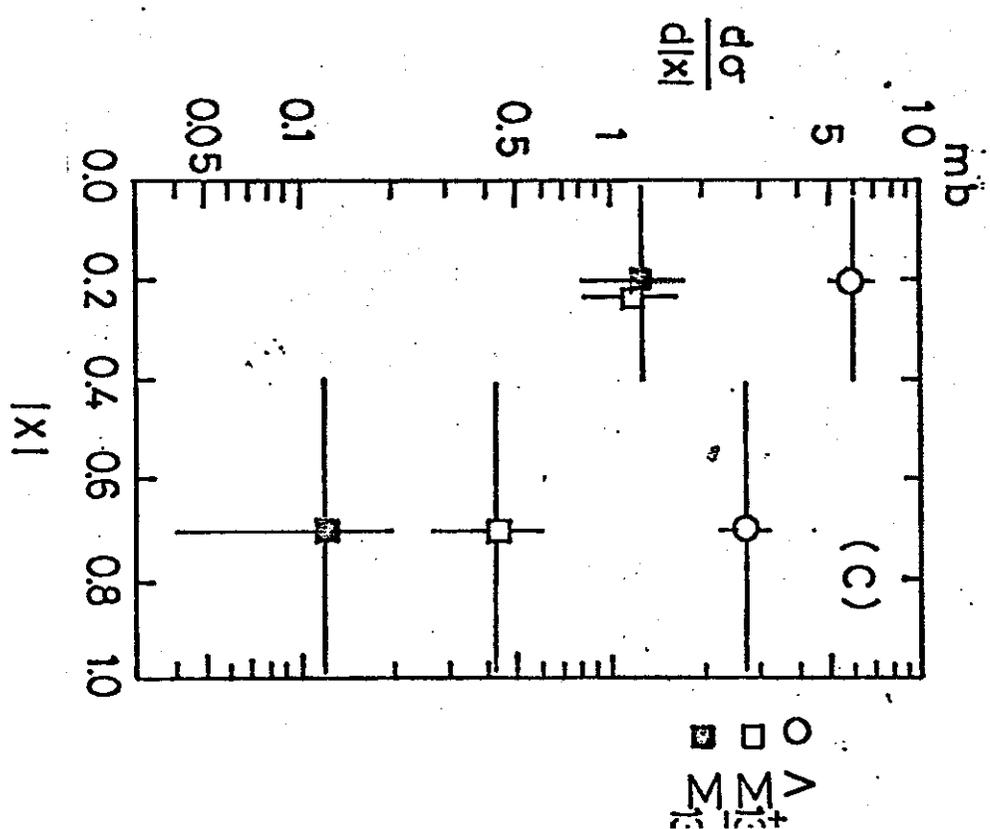
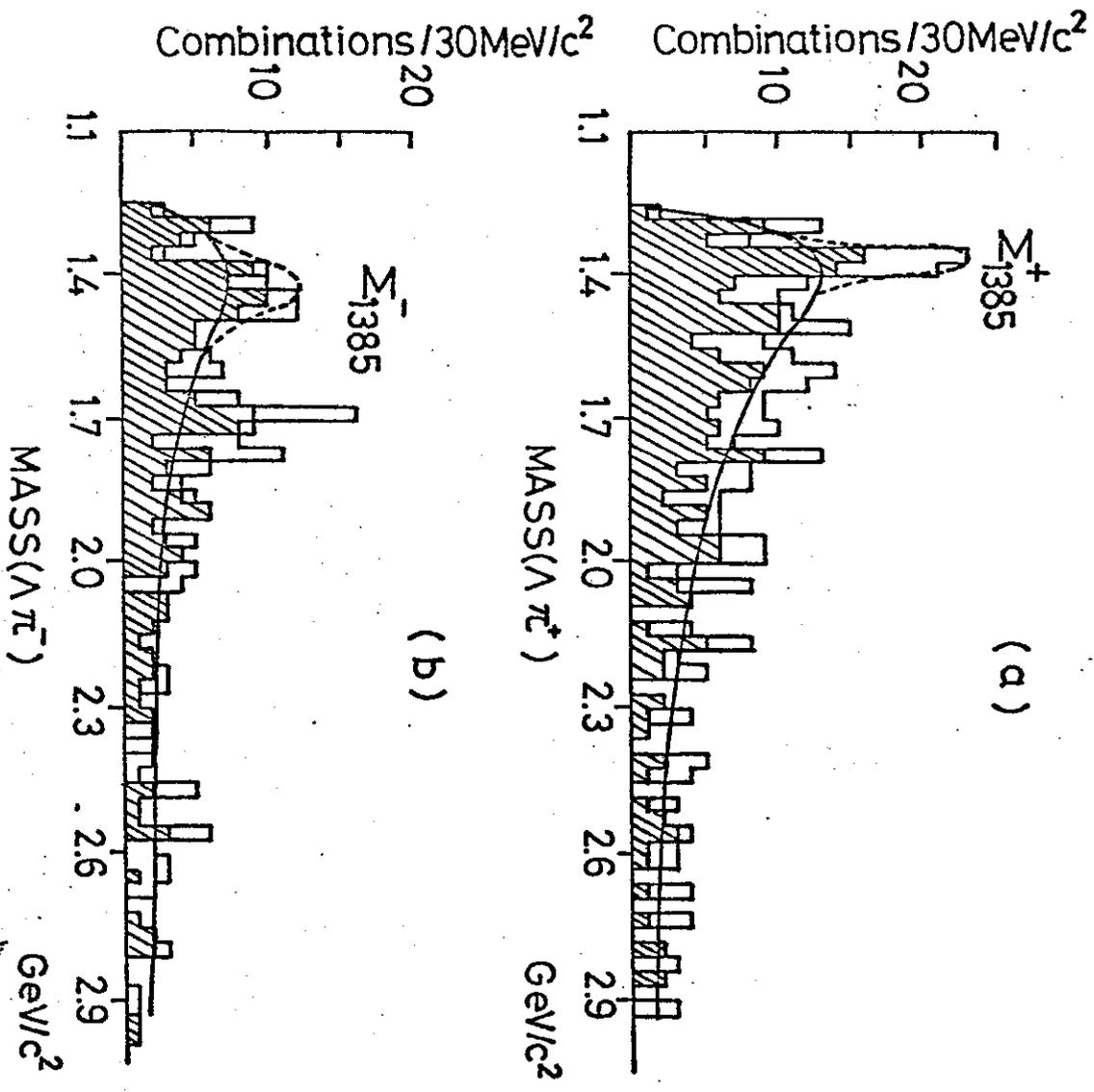


Fig. 3