Title

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DISCLAIMER

CHARGE ASYMMETRY IN INELASTIC $\pi^- p$ INTERACTIONS AT 205 GeV/c FOR PARTICLES WITH TRANSVERSE MOMENTUM > 1.0 GeV/c[*]

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ABSTRACT

In 205 GeV/c $\pi^- p$ inelastic interactions, negative particles with transverse momentum greater than 1.0 GeV/c moving forward in the center of mass outnumber similar positive particles by a factor of 3.7 to 1, greatly in excess of the corresponding ratio for small transverse momentum. The asymmetry is reversed in the backward direction. The forward asymmetry is most prominent in 2-, 4-, and 6-prong interactions, but both forward and backward asymmetries are also substantial for higher multiplicity interactions.

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Numerous results have been published on transverse momentum (p_T) distributions of particles emerging from high energy pp collisions at the CERN ISR [1-4] and at Fermilab [5]. Substantial production of particles with large p_T ($p_T > 1.0$ GeV/c) has been observed in the region of 90° in the center of mass, and small charge asymmetries have been reported [6], with positive exceeding negatives by 10-20%.

We describe in this paper an investigation of charge asymmetry in inelastic π^-p interactions at 205 GeV/c ($s = 385$ GeV^2). For particles with $p_T > 1.0$ GeV/c, we find substantial charge asymmetries in the forward and backward directions in the center of mass. The present experiment differs from previous experiments on large p_T phenomena in two important respects: the beam particles are negative pions rather than protons, and the particles emerging from the interactions are detected in all directions, rather than in a limited angular region in the center of mass.

Experimental Details. The data were obtained from a 48,000 picture exposure of the Fermi National Accelerator Laboratory 30" hydrogen bubble chamber. View-to-view track matching was done by hand using bubble patterns where necessary. Events were measured on film-plane digitizers and geometrically reconstructed with TVGP, yielding a total of 2040 inelastic interactions. No events with multiplicity greater than 16 are included in the present study. Additional details on the experimental arrangement, and on the scanning and measuring of events may be found in Refs. [7,8,9].

For purposes of kinematical calculations, particles were taken to be pions except those identified by ionization as protons. This separation is reliable for tracks of momentum < 0.6 GeV/c and is useful for some tracks up to 1.4 GeV/c. Thus some protons of momentum greater than 0.6 GeV/c may be included in the tracks taken as π^+. Assuming that one proton is produced per two non-beam-diffraction events, and subtracting the identified protons, we estimate that ∿8% of the positive tracks taken as pions are protons. From a study of K_s^o decays observed in the chamber, and assuming equal K^+, K^o, $\bar{K}^o$ and K^- cross sections, we estimate that ∿4% of the charged tracks taken as $\pi^\pm$ are really $K^\pm$. These are global estimates made without reference to transverse momentum, but calculated values of p_T are nearly independent of the mass assumed for the particle. Rapidities do change somewhat, however, according to the mass hypothesis. For values of p_T ∿0.3 GeV/c, the rapidity calculated for the π^+ hypothesis is about one unit greater than that for the proton hypothesis, but for p_T ∿1.0 GeV/c the rapidity difference is only about 0.3. Since only ∿8% of unidentified positives are protons we neglect this effect. In all subsequent analysis we group all positives together.

We have made an extensive analysis of the errors introduced into the value of p_T through the errors in measurement of momentum and angles, since it is crucial to verify that the observed asymmetries are not spurious, i.e., generated by the experimental measurement and analysis. We have thus compared the results obtained with no cuts to those obtained with cuts on the fiducial volume, on the fractional error in p_T, and on the FRMS* value of each track.

First we removed events with production vertex in the downstream half of the bubble chamber. All forward tracks then have $\ell > 30$ cm. We then studied the dependence of the fractional error $\Delta p_T/p_T$ on p_T to determine to what extent errors in p_T generate large measured values of p_T. No significant systematic increase with $\Delta p_T/p_T$ was found in the fraction of tracks with large p_T up to a fractional error of 0.8 in p_T.

To determine whether measurement errors in dip and azimuth angles had any systematic effects, we studied the distribution of p_{Tx} vs. p_{Tz}, the two components of p_T along dip and azimuthal directions, for tracks with $p_T > 1.0$ GeV/c. For $\Delta p_T/p_T < 0.5$, no asymmetry was apparent in this distribution.

Another possible source of error is mismatching of tracks in different views producing a false track which could have large p_T. There was no noticeable difference between FRMS distributions for high p_T tracks and all tracks. Both distributions peaked at 1.5μ and only 2% of the tracks had FRMS > 4μ. From a study of events in which tracks were deliberately mismatched, we conclude that track mismatch effects are negligible, particularly if tracks with FRMS > 4.0μ are removed from the sample. In general, we know of no biases in track momentum that would affect π^- and not π^+ or vice versa. From the above considerations we

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*The FRMS value is given by the root mean square deviations of the measured points from the projection of the reconstructed track on film in the three views.

conclude that the observed charge asymmetries are real and not due to measurement errors. For a more detailed discussion of the errors, see Ref. [9].

Results. Fig. 1 shows $d\sigma/dy$ for positive and negative tracks as a function of rapidity y in three different p_T intervals: (a) $p_T < 0.5$ GeV/c, (b) $0.5 < p_T < 1.0$ GeV/c, and (c) $p_T > 1.0$ GeV/c. The charge asymmetry is apparent for all three intervals; there are more negatives than positives in the forward direction and vice versa in the backward direction. The effect increases with increasing p_T except near the target or beam rapidity.

Fig. 2a shows the ratio of the inclusive $d\sigma/dy$ for negative tracks to that for positive tracks as a function of y for two intervals of transverse momentum: small p_T ($p_T < 0.5$ GeV/c) and large p_T ($p_T > 1.0$ GeV/c). We have plotted the ratios for no cuts, and with cuts on fiducial volume and FRMS, using two different cuts on $\Delta p_T/p_T$ to illustrate that the observed effect is not due to measurement error. In Fig. 2b, finer bins in y are used, and the −/total ratios are plotted for various cuts described in the figure caption. (Use of the −/total ratio rather than the −/+ ratio avoids infinity in the −/+ ratio in some bins.) Table 1 shows −/+ ratios for small, intermediate and large p_T integrated over the forward, central and backward regions.

The −/+ ratio is strikingly greater for large p_T than for small p_T in the forward direction and the effect is reversed in the backward direction. In the central rapidity interval, $-0.5 < y < 0.5$, the −/+ ratio is unity within statistics independent of p_T and of the type of cut chosen. For small p_T the asymmetry remains small except near the target rapidity ($y = -3$) and the beam rapidity ($y = +5$). For large p_T large charge asymmetries begin to appear on either side of the central interval.

For small p_T the (-/total) ratio (Fig. 2b) is nearly 0.5 except for regions near the beam (or target) rapidity. Thus it is tempting to associate the observed charge asymmetries in these regions with leading particle effects and in particular with diffractive dissociation of the target (or beam) particle [8,10]. Indeed, the excess low p_T backward positive and forward negative tracks are consistent with being associated almost entirely with low multiplicity ($\leqslant$ 8 prong) beam and target diffraction dissociation* events, respectively.

For the high p_T tracks, however, the large asymmetries are not limited to regions near the beam or target rapidity but are apparent in all but the central rapidity interval, and are often found to be associated with non-diffractive processes.

In Figs. 3a(b) we plot the cross sections to produce a forward (backward) large p_T negative or positive track as a function of the event

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*A beam diffraction dissociation event is here defined as one having an identified proton with missing mass squared recoiling against the proton less than 30 GeV^2. For target dissociation we require that the angle between the fastest π^- track and the beam direction be less than 0.5° and that the event not be beam diffraction dissociation; see Refs. [8, 10].

multiplicity, n_{ch}. Fig. 3a shows that the forward asymmetry is greatest for low multiplicity events when high p_T tracks are selected. The asymmetry for tracks with large p_T is also substantial, however, in both forward and backward directions for events with $n_{ch} \geqslant 8$, i.e., for high multiplicity events not associated with diffractive processes.

In Fig. 3c we plot the percentages of events of charged multiplicity n_{ch} which produce a forward high p_T track of negative or positive charge. For negative tracks the data are consistent (χ^2 probability of 70%) with being independent of n_{ch}, i.e. there is a constant probability of 8.1 ± 0.9% (weighted average) for an event of any n_{ch} to produce a forward high p_T negative track. For $n_{ch} \geqslant 6$, the positives are likewise consistent (χ^2 probability of 75%) with a constant probability of 2.9 ± 0.6% for an event to produce a large p_T positive track in the forward direction.

Similarly, Fig. 3d shows the percentages of events yielding backward high p_T positives or negatives. Although the errors are large, the data indicate that the probability per event for production of large p_T positives in the backward direction increases with multiplicity, but for negatives does not vary appreciably with multiplicity for $n_{ch} \geqslant 6$. The mean n_{ch} of the events producing backward positive large p_T tracks is 10.3 ± 0.7 compared with the overall $\langle n_{ch} \rangle$ of 8.0 ± 0.1 [7]. A similar effect was found by E. W. Anderson et al. [11] in pp interactions at 28.5 GeV/c.

We conclude that large charge asymmetries occur for tracks with $p_T >$ 1.0 GeV/c in 205 GeV $\pi^- p$ interactions. The charge asymmetry at large p_T is often associated with non-diffractive processes and with rapidities not close to the beam or target rapidity. These results are suggestive of hard collisions between structural entities like partons in the pion and proton and are qualitatively consistent with various parton models of large p_T phenomena*.

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*See, for example, Ref. [12] and other references therein.

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TABLE 1

	$y<-0.5$	$-0.5<y<0.5$	$y>0.5$
$p_T<0.5$ GeV/c	0.67±0.03	1.00±0.06	1.31±0.06
$0.5<p_T<1.0$ GeV/c	0.54±0.05	1.31±0.16	1.88±0.15
$p_T>1.0$ GeV/c	0.29±0.10	1.25±0.37	3.68±0.91

Ratio of the invariant cross section for negative tracks to that for positive tracks for small p_T (p_T < 0.5 GeV/c), intermediate p_T (0.5 < p_T < 1.0 GeV/c) and large p_T (p_T > 1.0 GeV/c) for backward, central, and forward regions of rapidity in the center of mass. Data are for $\Delta p_T/p_T < 0.5$.

FIGURE CAPTIONS

Figure 1. Inclusive center-of-mass rapidity distributions for positive and negative tracks for (a) $p_T < 0.5$ GeV/c, (b) $0.5 < p_T < 1.0$ GeV/c, and (c) $p_T > 1.0$ GeV/c. The target rapidity ≈ -3.0 and the beam rapidity $\approx +5.0$. Tracks with $\Delta p_T/p_T > 0.5$ have been removed. This cut biases the y distributions significantly for $y \gtrsim 2$ but does not bias the -/+ ratio. Curves are to guide the eye.

Figure 2(a). Ratios of negative to positive tracks versus the center-of-mass rapidity y. Ratios are shown for $p_T < 0.5$ GeV/c (solid points and dashed lines indicating the rapidity interval) and for $p_T > 1.0$ GeV/c (open points and solid lines). In each case points are plotted for the following cuts on the tracks: i) no cuts (circles), ii) fiducial volume and FRMS cuts, and tracks with $\Delta p_T/p_T > 0.5$ removed (triangles), iii) the same fiducial volume and FRMS cuts, and tracks with $\Delta p_T/p_T > 0.2$ removed (squares).

2(b). Ratios of negative to the sum of positive and negative tracks vs. y in finer bins of y. The solid points with error bars are for cuts (ii) as in (a). The open points are for cuts on fiducial volume and FRMS only. (Their errors bars, not shown, are smaller.) The square points (and solid curves to guide the eye) are for $p_T > 1.0$ GeV/c and the triangles and dashed curves are for $p_T < 0.5$ GeV/c.

Figure 3(a). Cross section to produce positive or negative tracks with $p_T > 1.0$ GeV/c and $y > 0.5$ vs. the charged multiplicity n_{ch} of the parent event.

3(b). As in (a), except $y < -0.5$.

3(c). Ratio of the cross sections in (a) to the cross section $\sigma(n_{ch})$ to produce an event with n_{ch}.

3(d). Ratio of the cross sections in (b) to $\sigma(n_{ch})$.

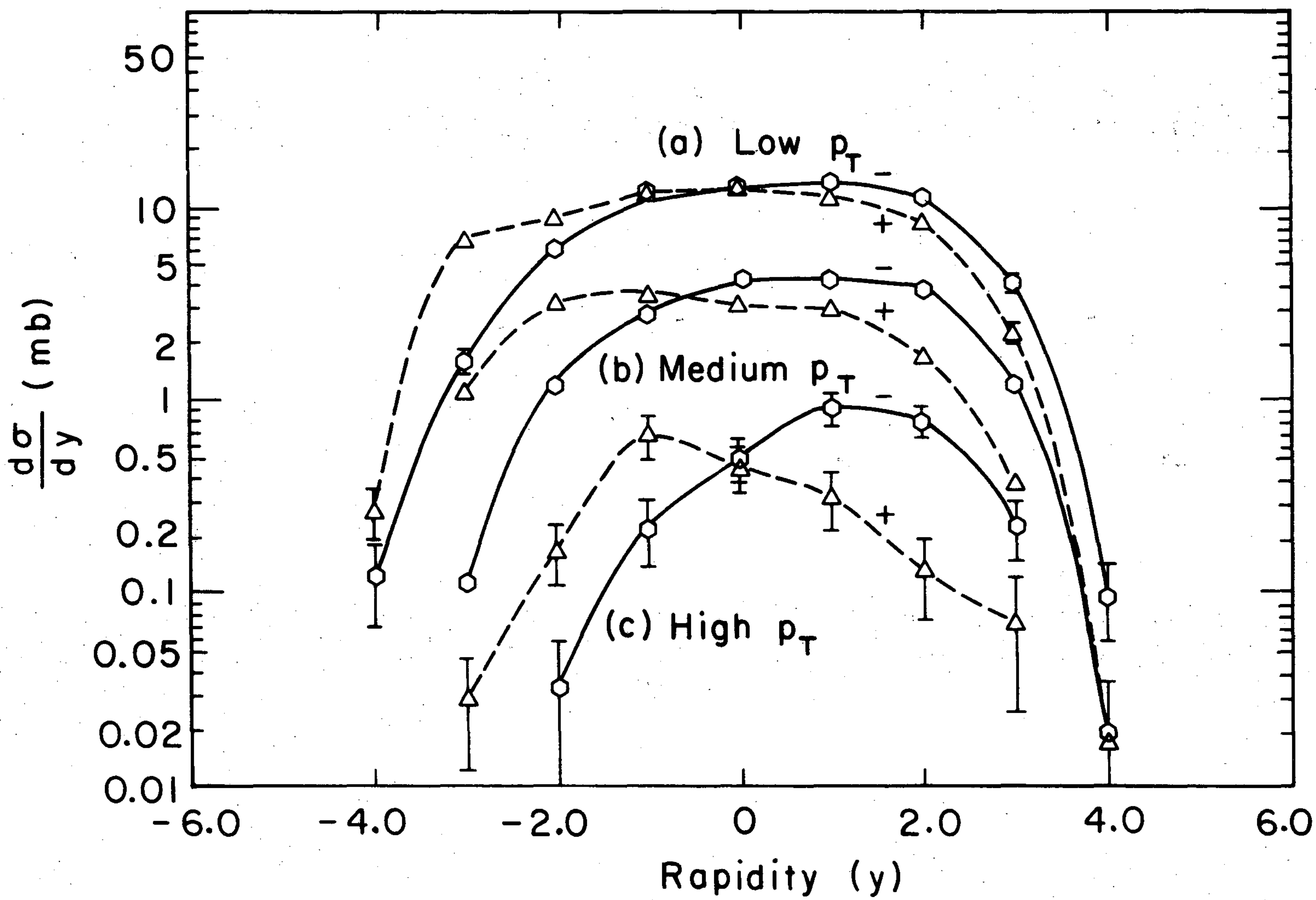

Figure 1

XBL754-2667

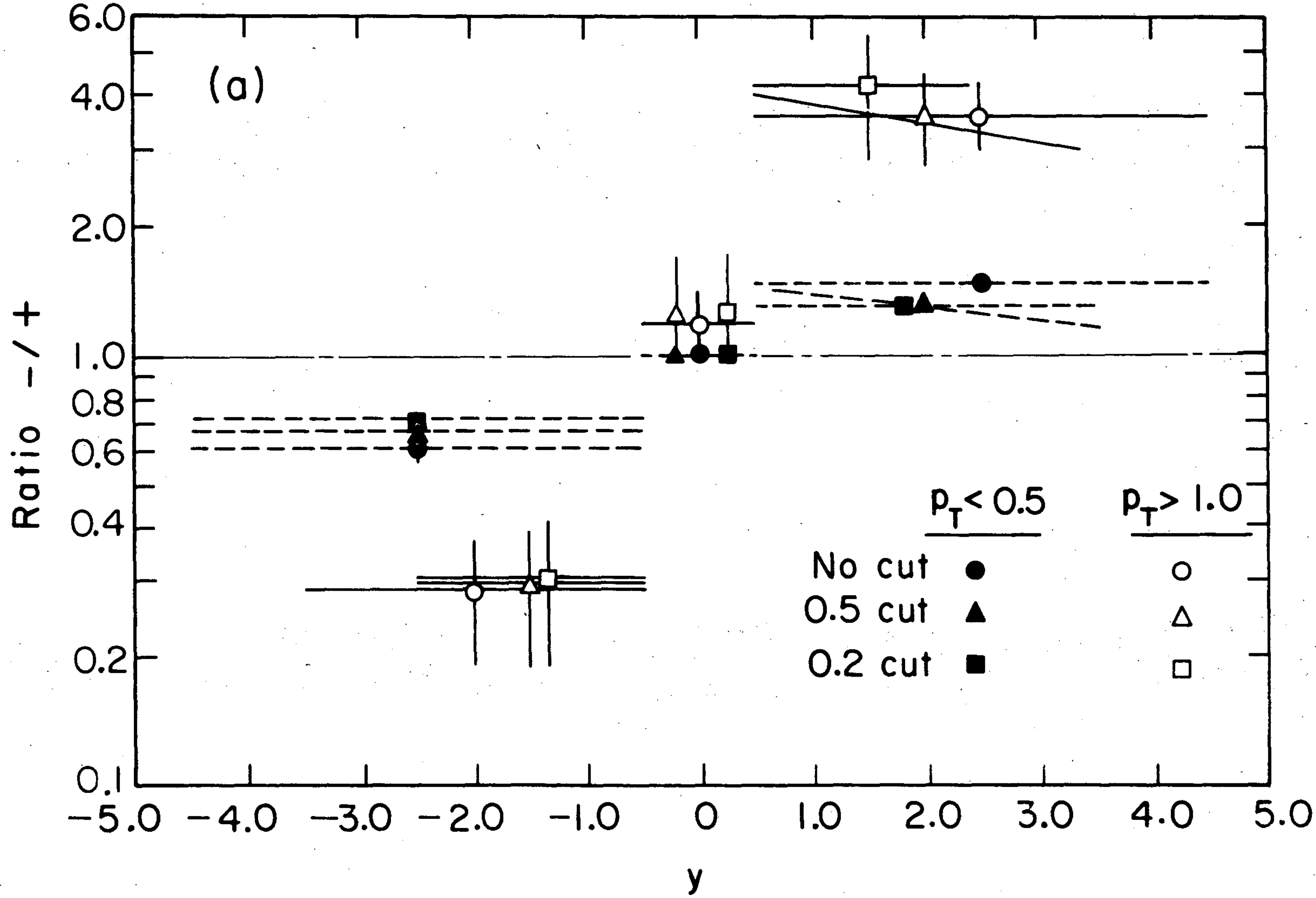

Figure 2a

XBL752-2406

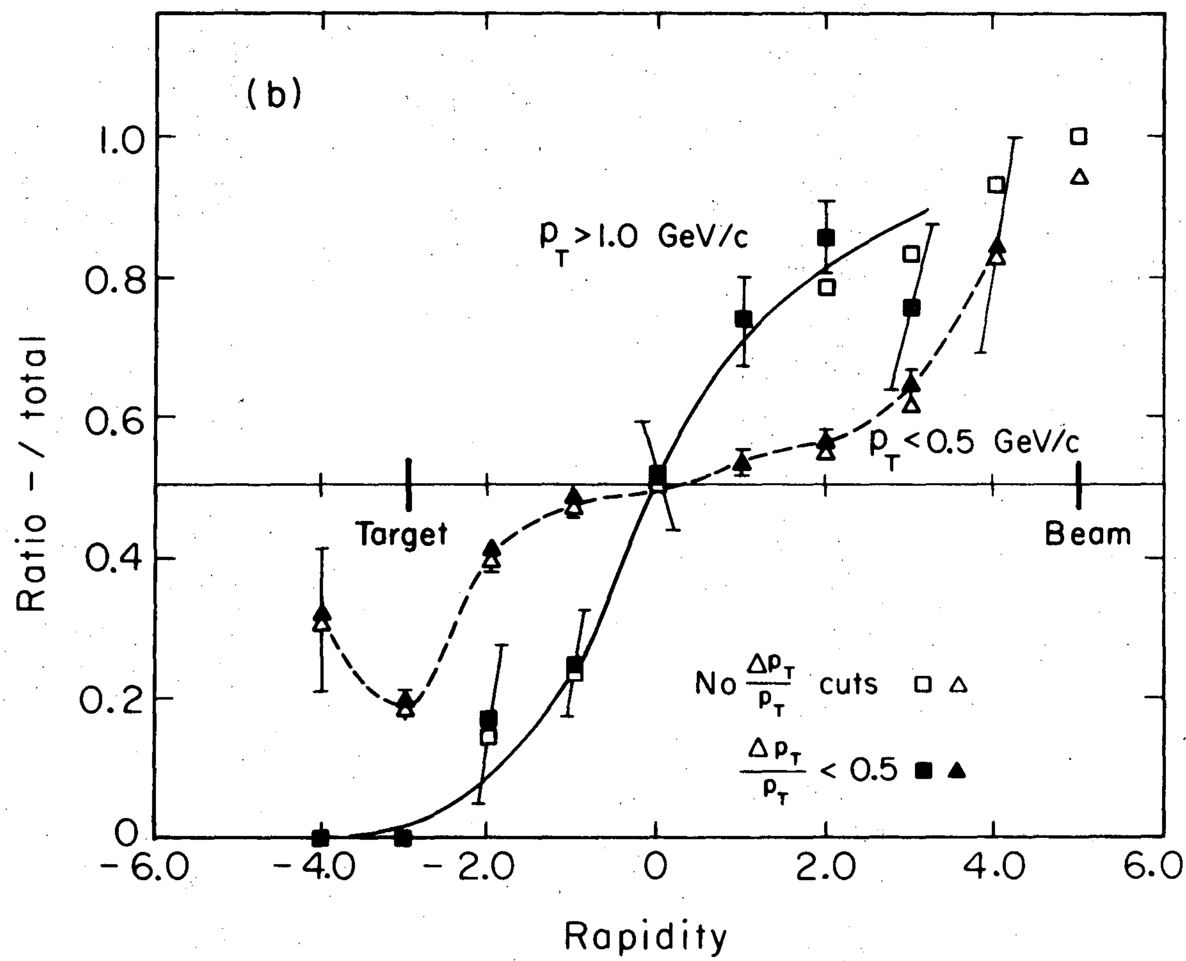

Figure 2b

XBL754-2665

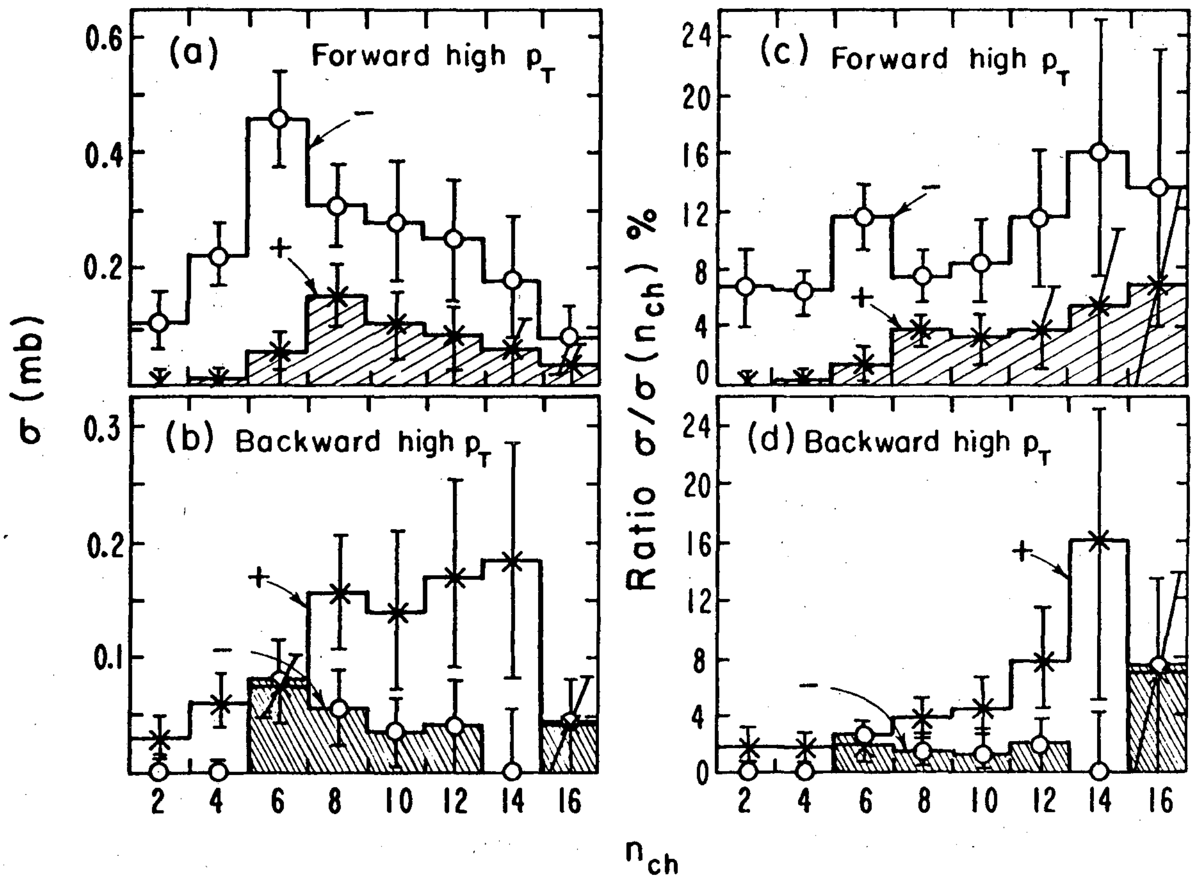

Figure 3

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