Parity-violating Asymmetries in $W^{\pm}$ Production with STAR

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In addition to its crucial role in accurately determining the polarized gluon structure function for the proton via measurements of the longitudinal spin correlation coefficient (A_{LL}) in $pp \to \gamma$ + jet reactions at $\sqrt{s}$ = 200 GeV, the proposed end-cap electromagnetic calorimeter (EEMC) upgrade to STAR also allows important determinations of flavor-specific quark and antiquark polarizations through measurements of the $e^{\pm}(\nu)$ decay of $W^{\pm}$ bosons produced in collisions of longitudinally polarized protons at $\sqrt{s}$ = 500 GeV. The ability to relate the measured parity-violating single-spin asymmetry (A_L) directly to the quark or antiquark polarization is greatest when the $e^{\pm}$ from $W^{\pm}$ decays are detected at large pseudorapidity, $1 < \eta < 2$, corresponding to the acceptance of the proposed EEMC.

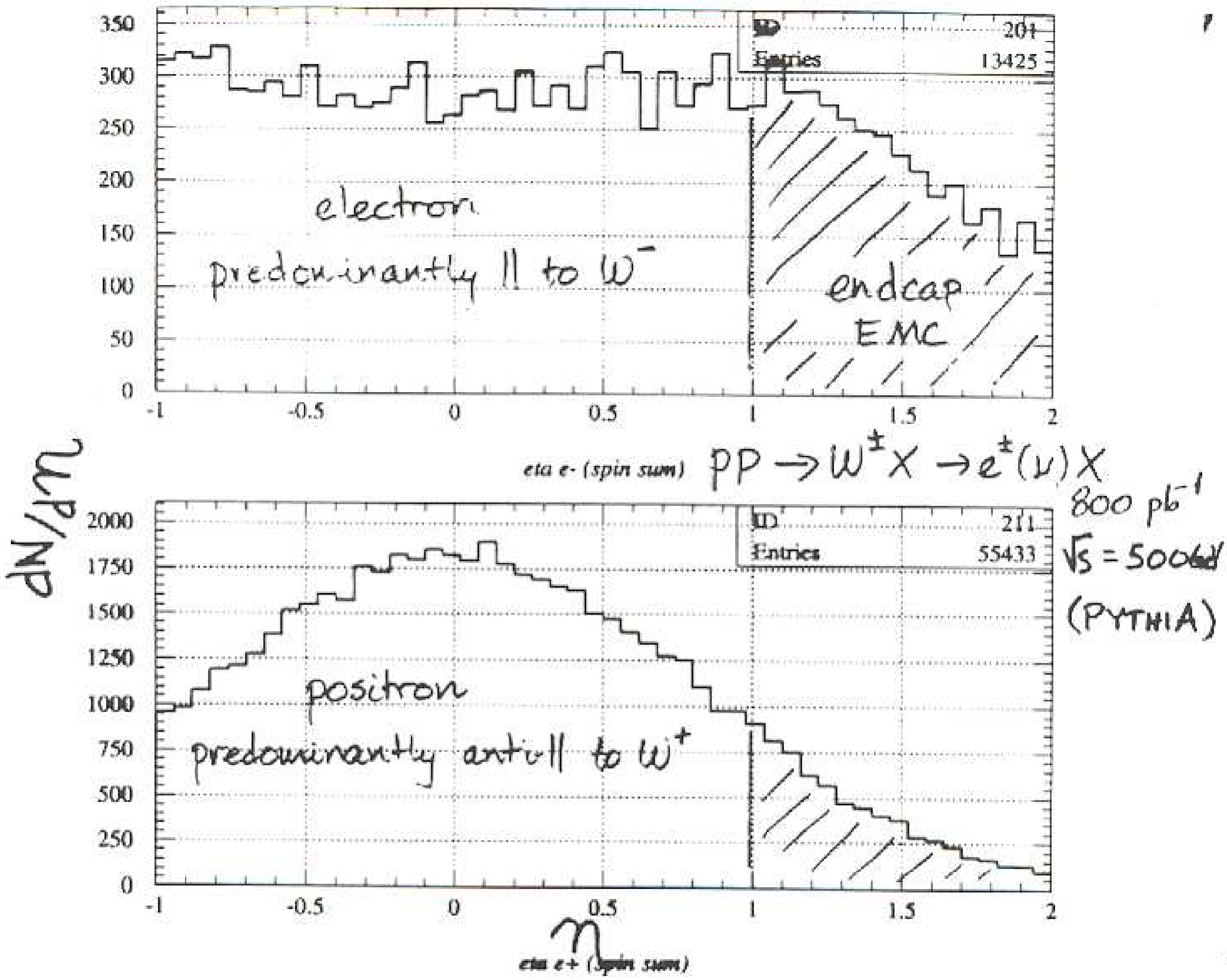
Fig. 1 shows the expected η distribution of $e^{\pm}$ from $W^{\pm}$ decays for pp collisions at $\sqrt{s}$ = 500 GeV as generated by PYTHIA [1]. Simple expressions for the $W^{\pm}$ production cross section from ref. [2] provide substantial insight. In particular, when the $W^{\pm}$ are produced at large rapidity, y_W, then in leading-order, we expect the most asymmetric collisions in the initial state corresponding to the partonic momentum fractions, $x_1 >> x_2$. For such asymmetric collisions, we expect (Fig. 2) a direct relationship between the measured A_L and the $u(d)$ and $\bar{d}(\bar{u})$ polarizations.

To test this idea, a simulation model for the $\vec{p}p \to W^{\pm}X \to e^{\pm}(\nu)X$ reaction at $\sqrt{s}$ = 500 GeV was developed. Events were generated for $W^{\pm}$ production, excluding the proton polarization, using PYTHIA. The partonic kinematics for the event were then used to evaluate the expected A_L for each of the two beam longitudinally polarized beams (assuming P_{beam} = 0.7) using the expressions from ref. [2] and polarized structure functions from ref. [3]. The detection of $e^{\pm}$ from $W^{\pm}$ decays was modeled by including only the acceptance of the STAR TPC and barrel and end-cap EMC. The events were subjected to particle identification cuts to distinguish $e^{\pm}$ from the most important background arising from the prolific production of hadrons ($h^{\pm} \equiv$ protons(anti-protons), $K^{\pm}$ and $\pi^{\pm}$) with large transverse momentum, $p_T > 10$ GeV/c. Other backgrounds such as Z^0 decay, with only a single $e^{\pm}$ detected and single electrons from the Dalitz decay of high-p_T π^0 have been considered and found to be negligible. Clean distinction between $e^{\pm}$ and $h^{\pm}$ relies on (1) *isolation cuts* applied to the candidate $e^{\pm}$, (2) the much smaller response of the EMC to incident $h^{\pm}$ relative to $e^{\pm}$, and (3) rejecting events that have an accompanying jet with $p_T > 5$ GeV/c in the azimuthal angle range, $|\pi - (\phi_{jet} - \phi_h)| < 1$ radian. The first two of these cuts have been discussed before [4]; the third cut further reduces the hadronic background by an additional order of magnitude. The end result is that STAR can cleanly detect $e^{\pm}$ from $W^{\pm}$ decays.

Fig. 3 shows the expected A_L for the four independent quantities that can be measured (asymmetries from either beam longitudinally polarized, and detection of either e^+ or e^-). To examine if the measured asymmetries are directly related to quark and antiquark polarizations, the identities of the partons involved in the $W^{\pm}$ production were examined. Figs. 4 and 5 show the x distribution of the initial-state partons, available from PYTHIA for two different ranges of $e^{\pm}$ pseudorapidity. It's clear that only when the $e^{\pm}$ are detected at large η that A_L can be directly related to $u(d)$ and $\bar{d}(\bar{u})$ polarizations.

The next step to take with the simulation model is to attempt the reconstruction of the initial-state $u(d)$ and $\bar{d}(\bar{u})$ momentum fractions (x) assuming collinear collisions. As well, a more accurate simulation of the response of the STAR detector is essential to quantitatively establish the accuracy of the determination of the $u(d)$ and $\bar{d}(\bar{u})$ polarizations.

[1] PYTHIA 5.7 / JETSET 7.4 T. Sjöstrand, Comp. Phys. Comm. **82** (1994) 74.
[2] C. Bourrely, J. Soffer, F.M. Renard and P. Taxil, Phys. Rept. **177** (1989) 319.
[3] T. Gehrmann and W.J. Stirling, Phys. Rev. **D53** (1996) 6100.
[4] A.A. Derevschikov, V.L. Rykov, K.E. Shestermanov and A. Yokosawa in *Proc. 11th Intl. Symp. on High Energy Spin Physics*, Bloomington, 1994, eds. Kenneth J. Heller and Sandra L. Smith, AIP Conf. Proc. No. 343 (1995) p. 472.



$$\frac{d\sigma}{dy}\underset{W^-}{(W^+)} = G_F\frac{\sqrt{2}}{3}\pi\tau\left[\underset{d}{u}(x_a, M_W^2)\,\underset{\bar{u}}{\bar{d}}(x_b, M_W^2) + (a \leftrightarrow b)\right]$$

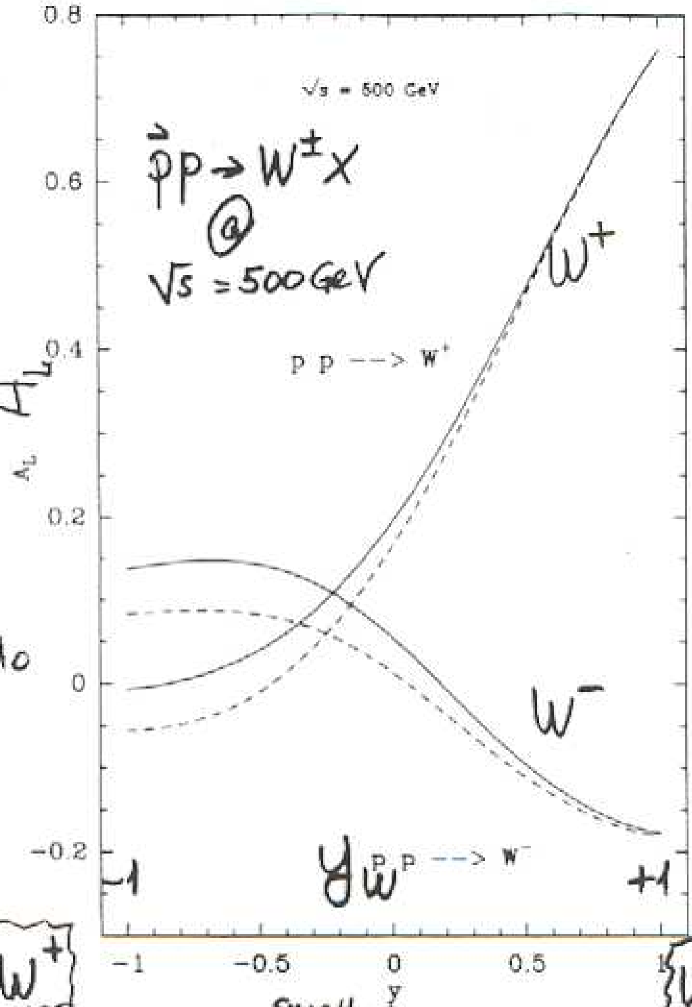
$$\tau = \frac{M_W^2}{s_{pp}} \qquad x_1 = \sqrt{\tau}\, e^{-y_W} \qquad x_2 = \sqrt{\tau}\, e^{+y_W}$$

If $y_W \sim y_e$ then endcap $\Rightarrow$ $x_2 \gg x_1$

$\Rightarrow$ Interpret A_L in terms of $\frac{\Delta q}{q}$ & $\frac{\Delta \bar{q}}{\bar{q}}$?

Fig. 1

Bourrely & Soffer



$u\bar{d} \to W^+$

$d\bar{u} \to W^-$

A_L measurements give sensitivity to

$$\Delta q = q_{\uparrow} - q_{\downarrow}$$

$$\Delta \bar{q} = \bar{q}_{\uparrow} - \bar{q}_{\downarrow}$$

$\boxed{W^+}$ $\boxed{W^-}$

"a" polarized

$$\frac{\Delta u(x_a)\,\bar{d}(x_b) - \Delta\bar{d}(x_a)\,\cancel{u(x_b)}^{\text{small}}}{u(x_a)\,\bar{d}(x_b) + \bar{d}(x_a)\,\cancel{u(x_b)}} \qquad \frac{\Delta d(x_a)\,\bar{u}(x_b) - \Delta\bar{u}(x_a)\,\cancel{d(x_b)}^{\text{small}}}{d(x_a)\,\bar{u}(x_b) + \bar{u}(x_a)\,\cancel{d(x_b)}}$$

$$\xrightarrow[x_a \gg x_b]{} \frac{\Delta u(x_a)}{u(x_a)} \qquad \xrightarrow[x_a \gg x_b]{} \frac{\Delta d(x_a)}{d(x_a)}$$

"b" polarized

$$\frac{u(x_a)\,\Delta\bar{d}(x_b) - \bar{d}(x_a)\,\Delta u(x_b)}{u(x_a)\,\bar{d}(x_b) + \bar{d}(x_a)\,\cancel{u(x_b)}_{\text{small}}} \qquad \frac{d(x_a)\,\Delta\bar{u}(x_b) - \bar{u}(x_a)\,\Delta d(x_b)}{d(x_a)\,\bar{u}(x_b) + \bar{u}(x_a)\,\cancel{d(x_b)}_{\text{small}}}$$

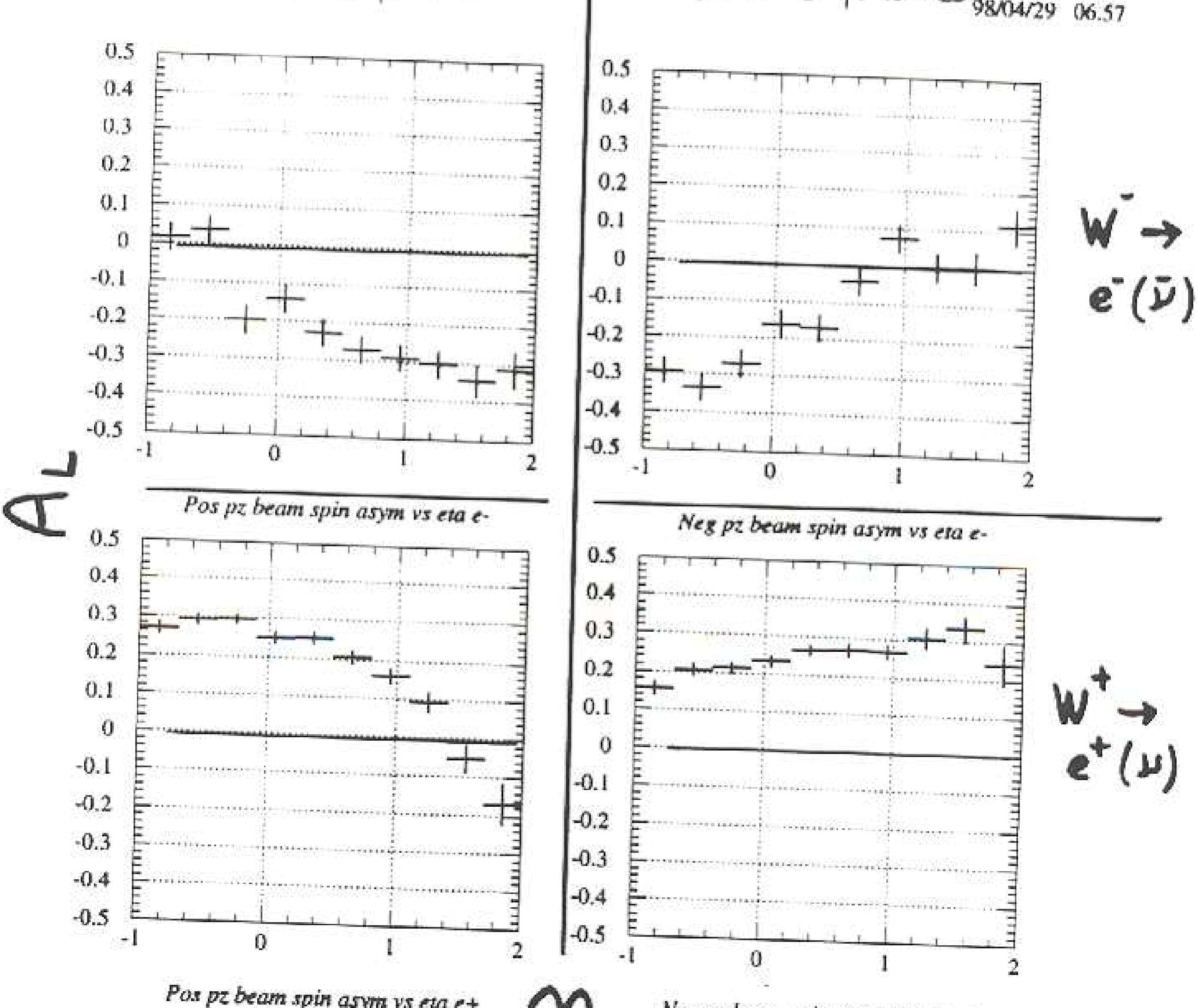
$$\xrightarrow[x_a \gg x_b]{} \frac{\Delta\bar{d}(x_b)}{\bar{d}(x_b)} - \frac{\bar{d}(x_a)\,\Delta u(x_b)}{u(x_a)\,\bar{d}(x_b)} \qquad \xrightarrow[x_a \gg x_b]{} \frac{\Delta\bar{u}(x_b)}{\bar{u}(x_b)} - \frac{\bar{u}(x_a)\,\Delta d(x_b)}{d(x_a)\,\bar{u}(x_b)}$$

Fig. 2

$\vec{p}p \to W^{\pm}X \to e^{\pm}(\nu)X$ $\sqrt{s} = 500$ GeV

800 pb^{-1} $P_{beam} = 0.7$

beam a polarized | beam b polarized



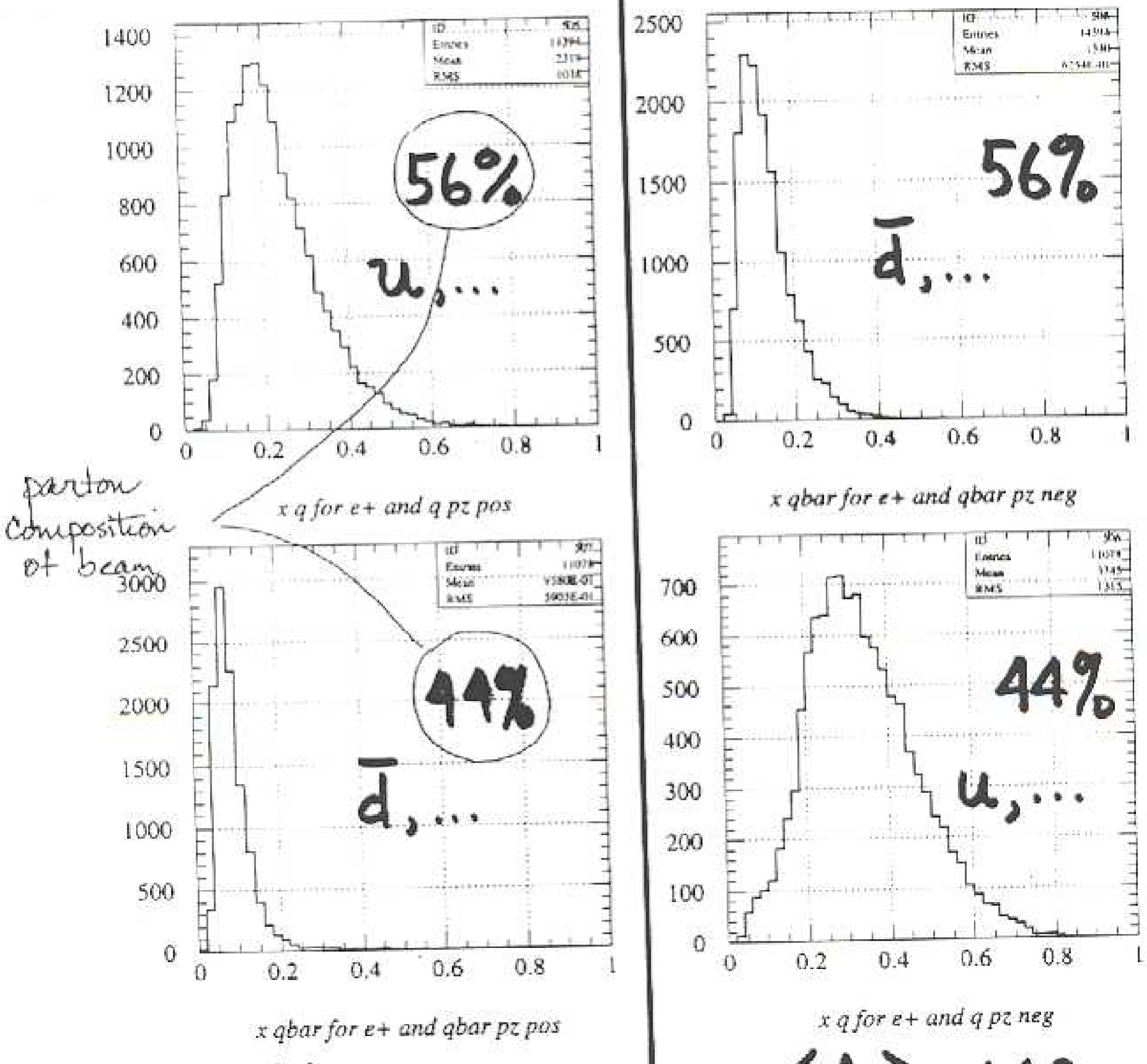
Do A_L values determine $\frac{\Delta q}{q}$, $\frac{\Delta \bar{q}}{\bar{q}}$?

$\to$ Look in different η ranges

Fig. 3

$W^+ \to e^+ \nu$

beam a | **beam b** 98/04/25 21.58



$\langle A_L \rangle \sim +0.3$ $\quad x \quad$ $\langle A_L \rangle \sim +0.2$

$$-1 < \eta_{e^+} < 0$$

$\Rightarrow$ A_L not directly related to $\frac{\Delta u}{u}$ or $\frac{\Delta \bar{d}}{\bar{d}}$

Fig. 4

$W^- \to e^- \bar{\nu}$

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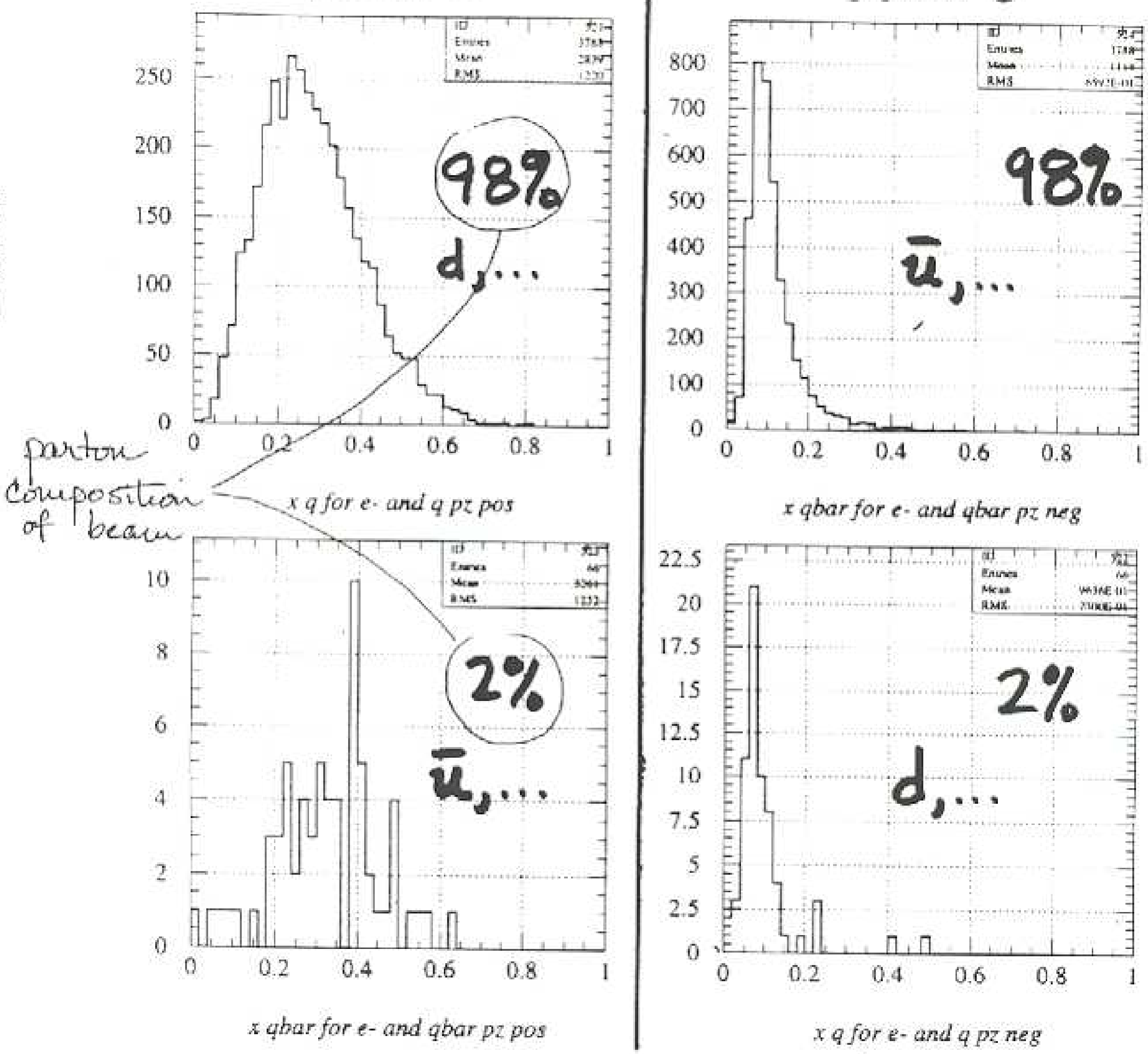
beam a | beam b



$\langle A_L \rangle \sim -0.3$ x $\langle A_L \rangle \sim 0$

(endcap EMC)

$1 < \eta_{e^-} < 2$

Fig. 5 $\Longrightarrow$ A_L is directly related to $\frac{\Delta d}{d}$ (beam a) & $\frac{\Delta \bar{u}}{\bar{u}}$ (beam b)