HYPERON POLARIZATION NEWS

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NATURE HAS NO DIFFICULTY PRODUCING POLARIZED HYPERONS

BRIEF HISTORY

1.) $p \to \Lambda$ $\quad \vec{P}_\Lambda$ opposite to $\vec{k}_{IN} \times \vec{k}_{OUT}$

SU(6) baryon wave functions + s quarks with spin down first proposed in our group by Ken Heller

$\vec{P}_\Lambda = \vec{P}_s$ gives correct sign for $P_{\Sigma^+}, P_{\Xi^-}, P_{\Xi^0}, P_{\Xi^-}$

predicts $\vec{P}_{\Sigma^+} = -\frac{1}{3}\vec{P}_\Lambda$ too small

2.) $\vec{P}_{\Sigma^+} \sim -\vec{P}_\Lambda$ so need polarized diquarks too

$\left.\begin{array}{ll} \text{single quark pol} & \epsilon \\ \text{diquark pol} & \delta \end{array}\right\}$ DeGrand + Miettinen

DGM model cont'd

leading partons decelerate and acquire pos pol
trailing partons accelerate and acquire neg pol

Polarizations for various transitions predicted by the leading-partons–trailing-partons model.

$B \to B'$ transition	Polarization
$p \rightleftarrows n$, $\Sigma^+ \rightleftarrows \Xi^0$, $\Sigma^- \rightleftarrows \Xi^-$, $\Sigma^\pm \rightleftarrows \Sigma^0$, $\Xi^0 \rightleftarrows \Sigma^0$	$-\frac{20}{21}\epsilon + \frac{1}{42}\delta$
$p \rightleftarrows \Sigma^+$, $n \rightleftarrows \Sigma^-$, $p \rightleftarrows \Sigma^0$, $n \rightleftarrows \Sigma^0$, $\Xi^0 \rightleftarrows \Xi^-$	$\frac{1}{3}\epsilon + \frac{2}{3}\delta$
$p,n \rightleftarrows \Lambda$	$-\epsilon$
$\Sigma^\pm \rightleftarrows \Lambda$, $\Xi^0, \Xi^- \rightleftarrows \Lambda$	$-\frac{2}{3}\epsilon + \frac{1}{6}\delta$
$p \to \Sigma^-$, $n \to \Sigma^+$, $\Sigma^+ \to \Xi^-$, $\Sigma^- \to \Xi^0$, $\Xi^0 \to p$, $\Xi^- \to n$	$\frac{2}{3}\epsilon - \frac{1}{6}\delta$
$p \rightleftarrows \Xi^-$, $n \rightleftarrows \Xi^0$, $\Sigma^+ \rightleftarrows \Sigma^-$, $p \to \Xi^0$, $\Xi^0 \to \Sigma^-$, $\Sigma^- \to p$, $n \to \Xi^-$, $\Xi^- \to \Sigma^+$, $\Sigma^+ \to n$	$-\frac{1}{3}\epsilon - \frac{2}{3}\delta$
$\pi, K^+ \to \Lambda$	$-\delta/2$
$K^- \to \Lambda$	ϵ

Exptl evidence $\Rightarrow$ $\epsilon \sim 5$ to 20%

DG+M SCORE CARD

1985

TABLE I. Comparison of the model of Ref. 11, with $\epsilon = \delta$, with data from unpolarized beams.

Transition	Predicted asymmetry	Observed asymmetry	Energy (GeV)	Reference
$p \to \Lambda$	$-\epsilon$	-0.1 to -0.2	24–2000	1
$p \to \bar{\Lambda}$	0	0	24–2000	1
$p \to \Sigma^+$	ϵ	0.1 to 0.2	400	2
$p \to \Sigma^-$	$\epsilon/2$	0.15 , 0.3	400	3,4
$p \to \Sigma^0$	ϵ			
$p \to \Xi^0$	$-\epsilon$	-0.1 to -0.2	400	5
$p \to \Xi^-$	$-\epsilon$	-0.1 to -0.2	400	6
$K^+ \to \bar{\Lambda}$	ϵ	> 0.4, $x_F > 0.3$	32,70	7
$K^- \to \Lambda$	ϵ	0.4	14	8
$\pi^- \to \Lambda$	$-\epsilon/2$	-0.05	18	9
$\gamma \to \Lambda$	$-\epsilon/2$	-0.1	20	10

WA89 $\Sigma^- \to \Xi^-$ $-\epsilon$ OK WITHIN ERRORS 330 GeV

$x_F > 0$
$p_T > 1$
ACCMOR $\pi^- \to \Lambda$ $-\epsilon/2$ -0.28 ± 0.09 230 GeV
" $\pi^- \to \bar{\Lambda}$ -0.01 ± 0.12 "

ALMOST EQUAL NUMBERS OF Λ + $\bar{\Lambda}$

DG+M SCORE CARD CONT'D

POLARIZATION BY OTHER BARYONS

WA 89 $\Sigma^- \to \Sigma^+$ $-\epsilon$ -0.035 ± 0.012 $\langle P_T \rangle = 1.0$ $\langle x \rangle = 0.27$ 330 GeV

OK, BUT SMALL X

SELEX WA89 $\Sigma^- \to \Lambda$ $-\epsilon/2$ SEE PLOT - WRONG SIGN

WA89 DATA CONSISTENT WITH SELEX, BUT LED TO OPPOSITE CONCLUSION.

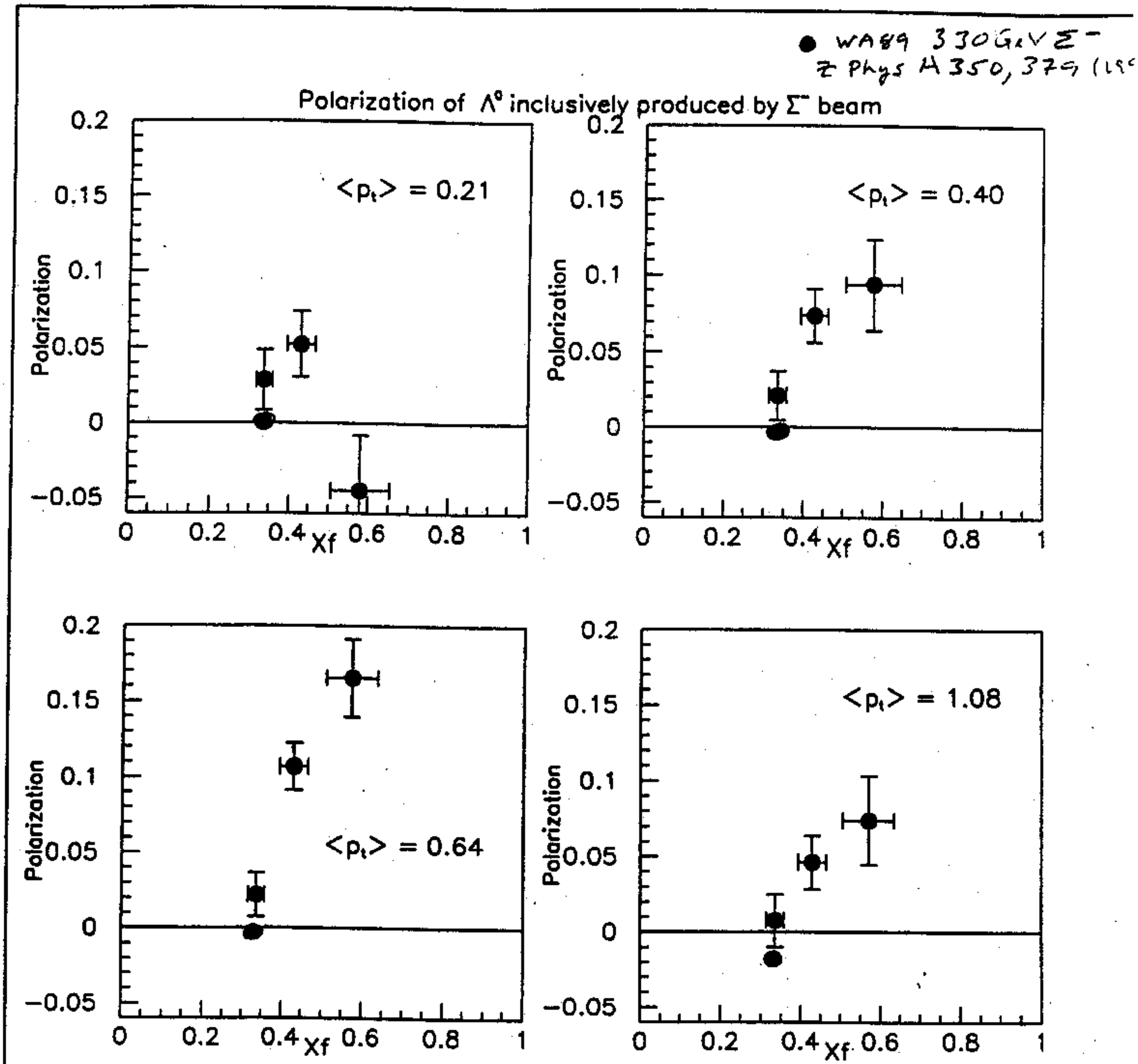
NEUTRAL BEAM PRODUCTION 1.8 MRAD 395 GeV NEG BEAM

(n, Λ, Ξ^0) UNPOL $\to \Xi^-$ $P_{\Xi^-} = 0.0062 \pm 0.0042$

(n, Λ, Ξ^0) UNPOL $\to \Omega^-$ $P_{\Omega^-} = +0.053 \pm 0.012$

$\bar{p}$ (UNPOL) $\to \bar{\Omega}^-$ $P_{\bar{\Omega}^-} = -0.01 \pm 0.01$

SELEX Collab UNPUBLISHED DATA



WA89

$\langle p_T \rangle$	Λ Pol
1.32	-0.055 ± 0.015
1.80	-0.033 ± 0.020

$$\hat{n} = \vec{k}_{beam} \times \vec{k}_{part}$$

DG + M SCORE CARD CONT'D

SPIN EXCHANGE AND Λ ASYMMETRY

FOR $p\uparrow \rightarrow \Lambda$ 200 GeV p's E704

THE Λ SHOULD NOT KNOW ANYTHING ABOUT THE PROTON SPIN

BUT IT DOES.

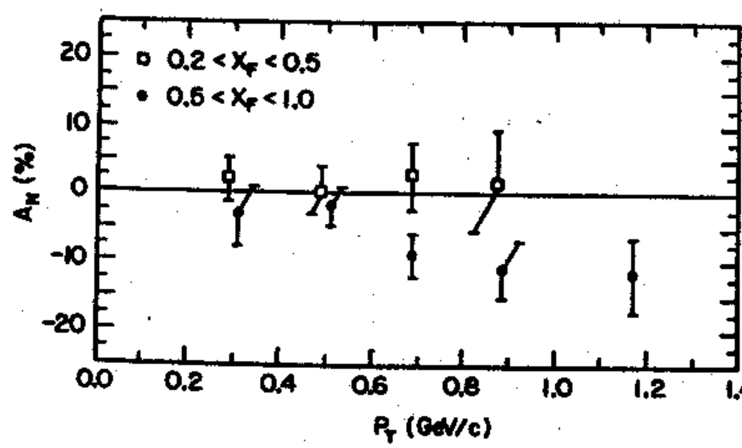


FIG. 4. A_N data for $p\uparrow + p \rightarrow \Lambda^0 + X$ as a function of p_T.

Λ ASYMMETRY RESEMBLES THE Λ POLARIZATION, JUST LIKE ELASTIC SCATTERING!

SPIN EXCHANGE

NEG POLARIZED NEUTRAL BEAM → 395 GeV
NEG BEAM

$(n, \Lambda, \Xi^{\circ}) \rightarrow \Xi^{-}$ $\quad P_{\Xi^{-}} = -0.1172 \pm 0.0062$

$(n, \Lambda, \Xi^{\circ}) \rightarrow \Omega^{-}$ $\quad P_{\Omega^{-}} = -0.076 \pm 0.021$

THOSE RESULTS MAKE SENSE.

ANTI HYPERON POLARIZATION

$p \to \bar{\Lambda}$ — NO POLARIZATION

$p \to \bar{\Xi}^{+}$ $\quad P \sim P_{\Xi^-} \neq 0$

$p \to \bar{\Sigma}^{-}$ $\quad P \sim P_{\Sigma^+} \neq 0$

$p \to \bar{\Xi}^{0}$ NO POLARIZATION ! KTeV

11

Ho, et Al

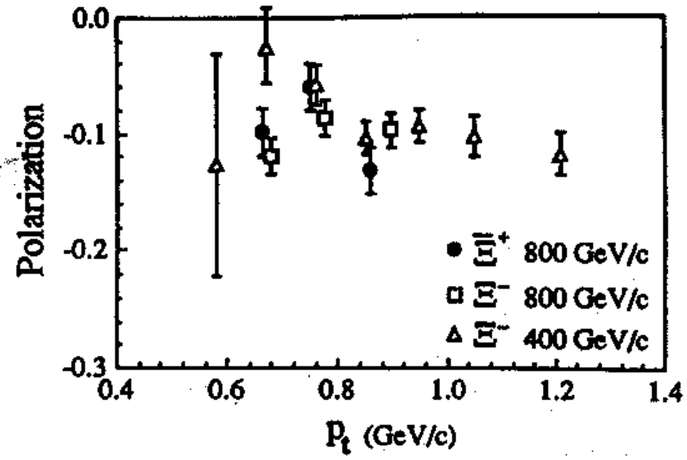


FIG. 4. Comparison of the $\bar{\Xi}^+$ and Ξ^- polarization from this experiment with that of the Ξ^- data taken at 400 GeV/*c* and a production angle of 5 mrad. (See Rameika *et al.*, Ref. 2.)

Morelos et Al

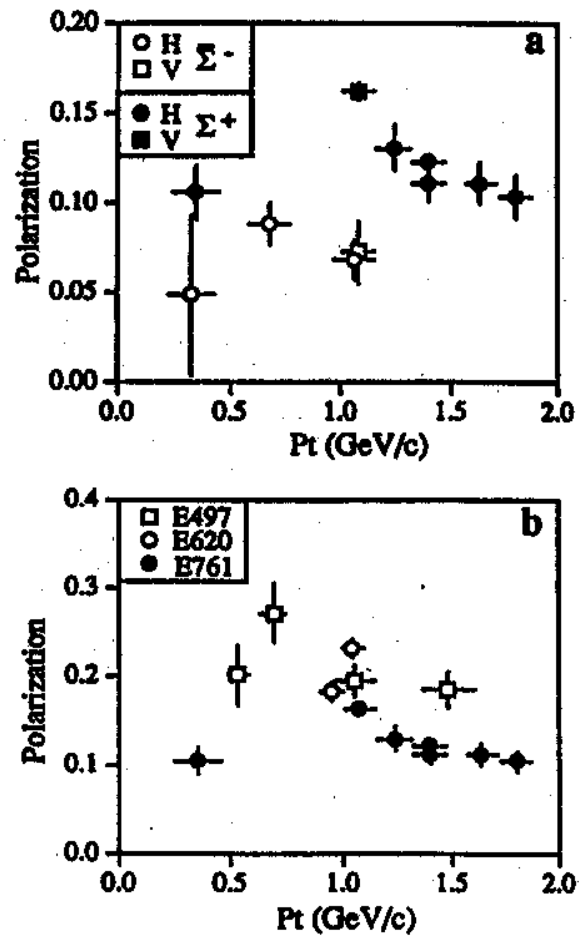


FIG. 3. (a) Comparison of polarizations for Σ^+ and $\bar{\Sigma}^-$ as a function of p_t from this experiment. (b) Polarization of Σ^+ as a function of p_t and comparison with previous measurements at 400-GeV incident proton energy. Note that the E620 data are from production on a Be target. The others use a Cu target. All of these data are in the range $0.47 < x_F < 0.53$.

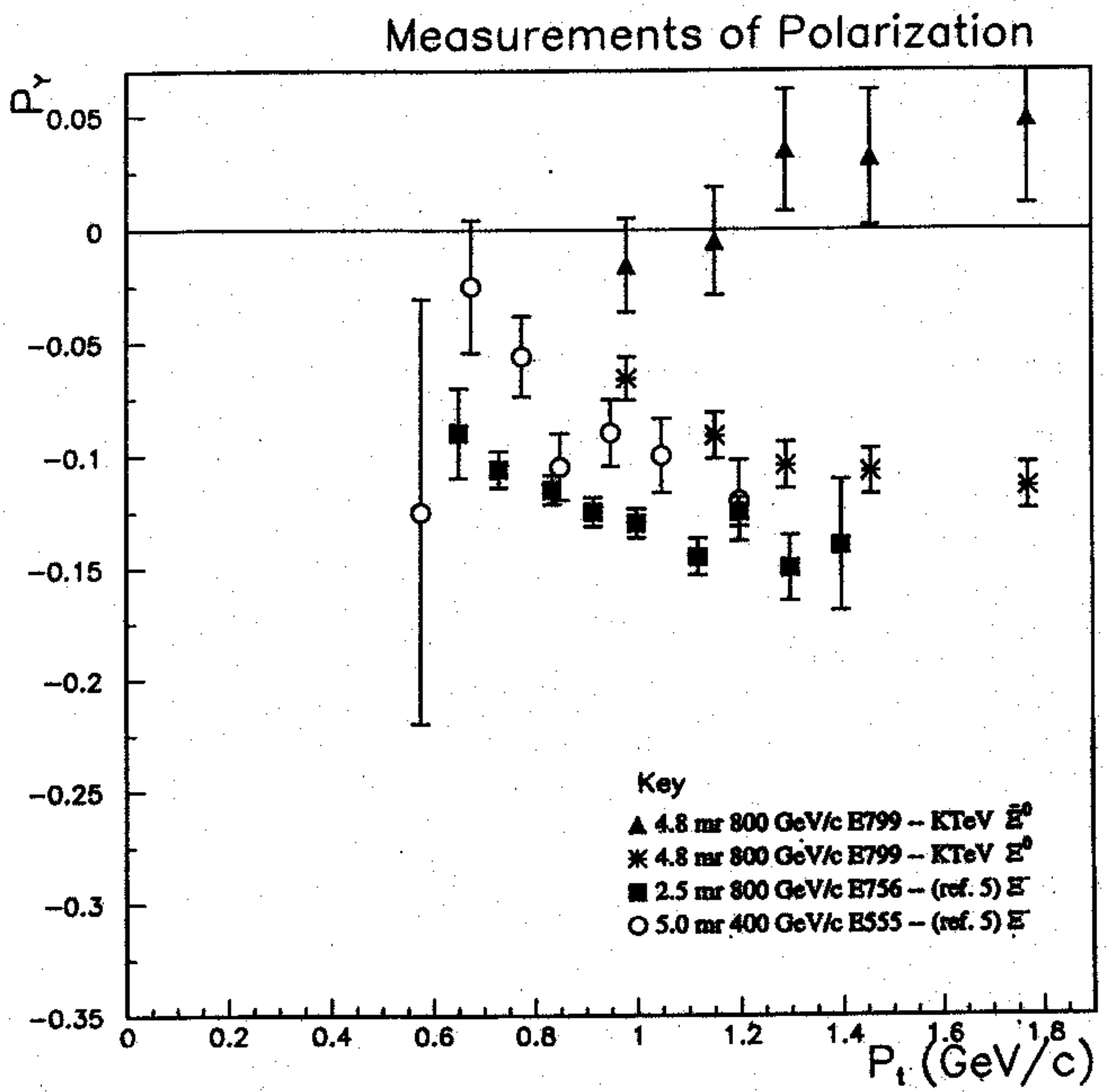
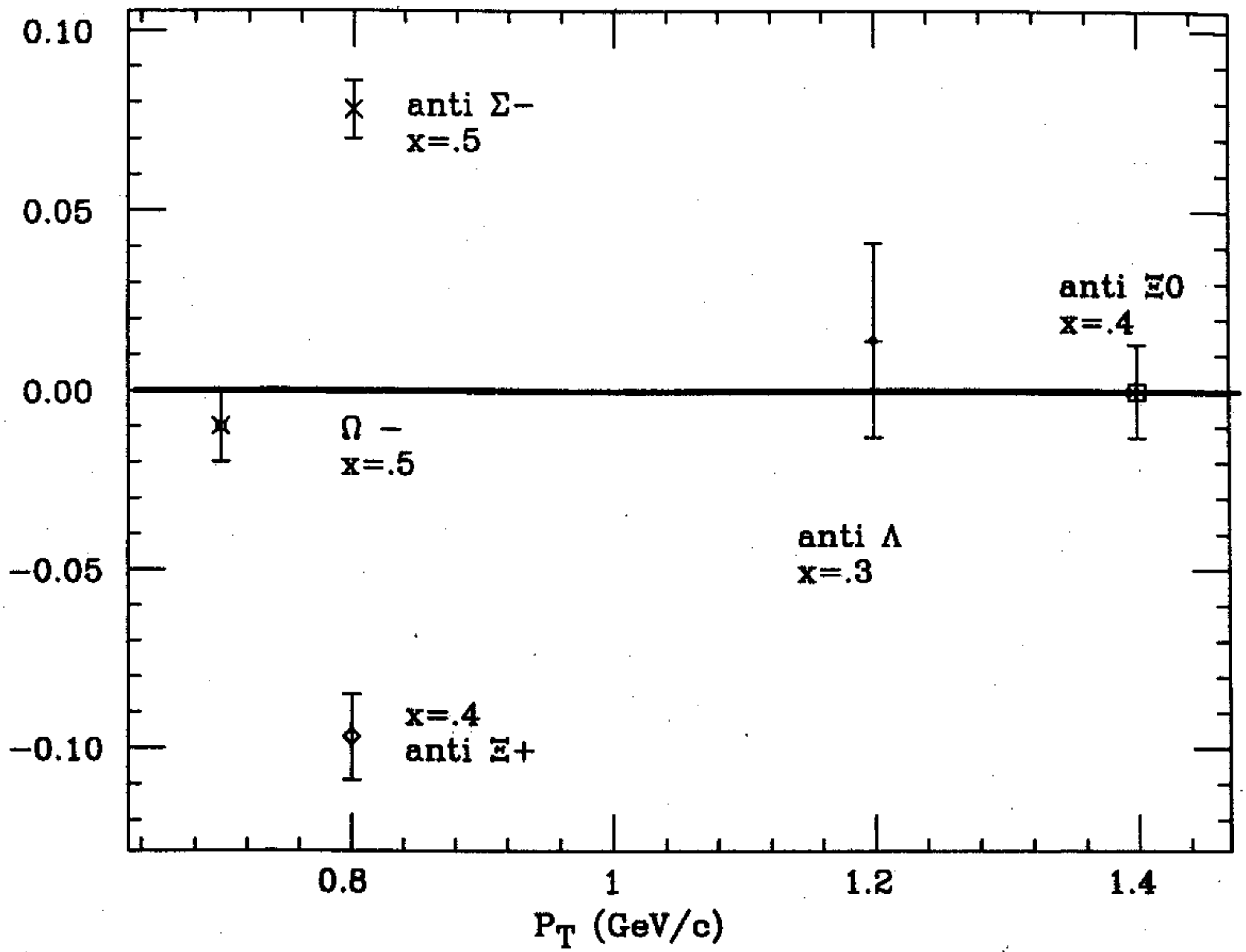


Figure 7.8: More past results plotted against transverse momentum.

nti hyperon polarization, 800 GeV protons



THE PION IDEA

SOME AUTHORS, LIKE K. KUBO ET AL HAVE SUGGESTED THAT $\bar{\Upsilon}$ POLARIZATION COULD BE EXPLAINED BY FAST PIONS

$$\left.\begin{aligned} p &\to n\pi^+ \\ p &\to \Delta^{++}\pi^- \end{aligned}\right\} \text{pion} \to Y\bar{Y}$$

Remember $\pi^- \to \Lambda, \bar{\Lambda}$ IN APPX EQUAL NUMBERS

AND $P_{\bar{\Lambda}} = 0$, CONSISTENT WITH $p \to \bar{\Lambda}$

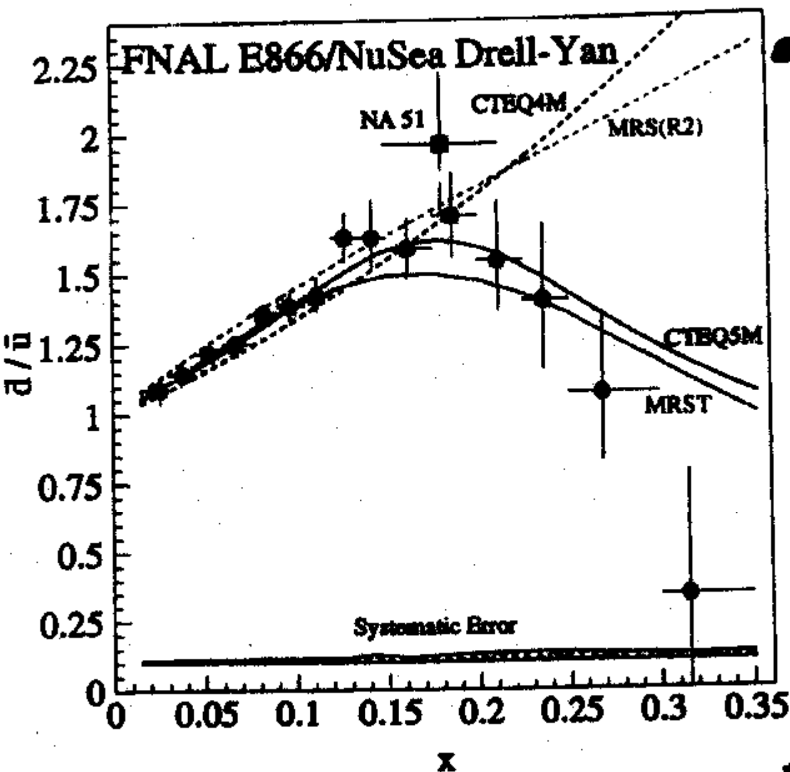
HAS $\pi \to \Sigma, \bar{\Sigma}$ been MEASURED?

THESE IDEAS, LIKE OPE, ARE ENJOYING A RENAISSANCE

FOR INSTANCE $\frac{\bar{d}}{\bar{u}} > 1$

MAX KLEIN LP'99

flavour asymmetry in the nucleon sea $\bar{u} \neq \bar{d}$



● E866/NuSea

pp, pd DY.

$3.7 \cdot 10^5$ μ pairs

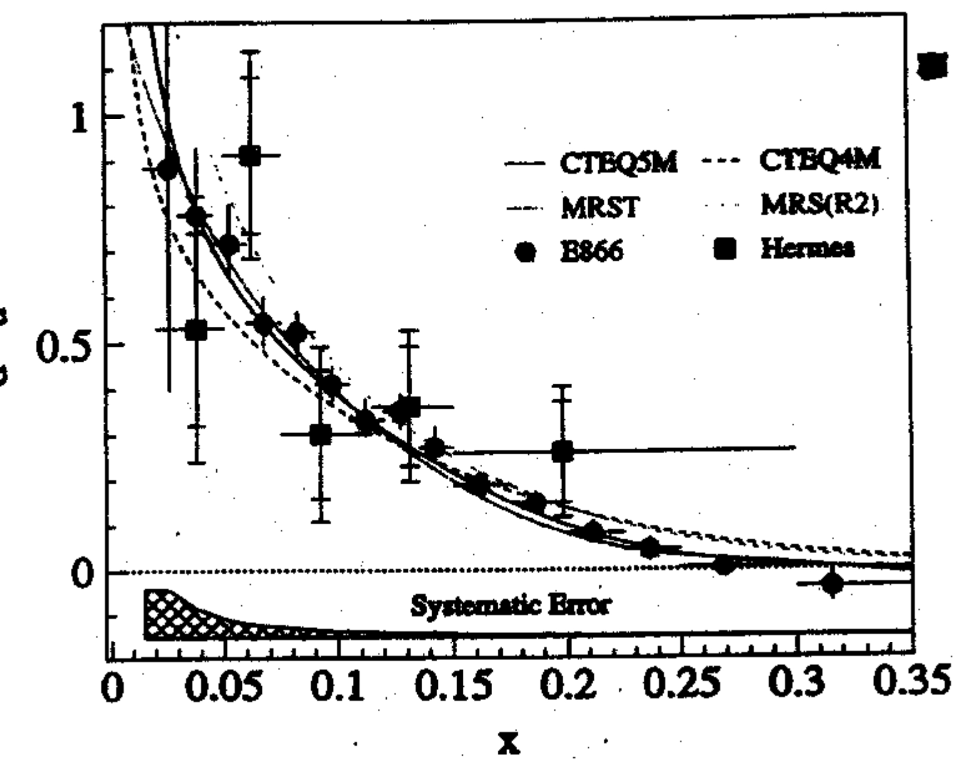
$\langle Q^2 \rangle \approx 54\ \mathrm{GeV}^2$

$\int_0^1 (\bar{u}-\bar{d})\,dx$

Gottfried SR: $\int \frac{1}{x}(F_2^p - F_2^n)\,dx = \frac{1}{3} + \frac{2}{3}\int(\bar{u}-\bar{d})\,dx$

E866: -0.118 ± 0.011

NMC: -0.15 ± 0.04



■ HERMES

$eN \to e\pi^{\pm}X$

p, d

$\langle Q^2 \rangle = 2.3\ \mathrm{GeV}^2$

this is not $x(\bar{d}-\bar{u})$

OTHER NEW RESULTS

1.) KTeV $p \to \Xi^0$ 800 GeV p's

2.) E781 $p \to \Sigma^+$ 800 GeV p's

3.) Exclusive CHANNES AT BNL

27.5 GeV PROTONS

		events
$pp \to p \Lambda K^+$	$\pi^+\pi^-$	5421
	$\pi^+\pi^-\pi^+\pi^-$	51195
	$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$	48195
	8 CHARGED π's	14582

QUOTE AVGE FIT ADEQUATE χ^2

$P_\Lambda = (-0.443 \pm 0.037)\, x_p\, p_T$ $\quad -1 \leq x_F \leq +1$

$0.5 \leq p_T \leq 1.8$ GeV

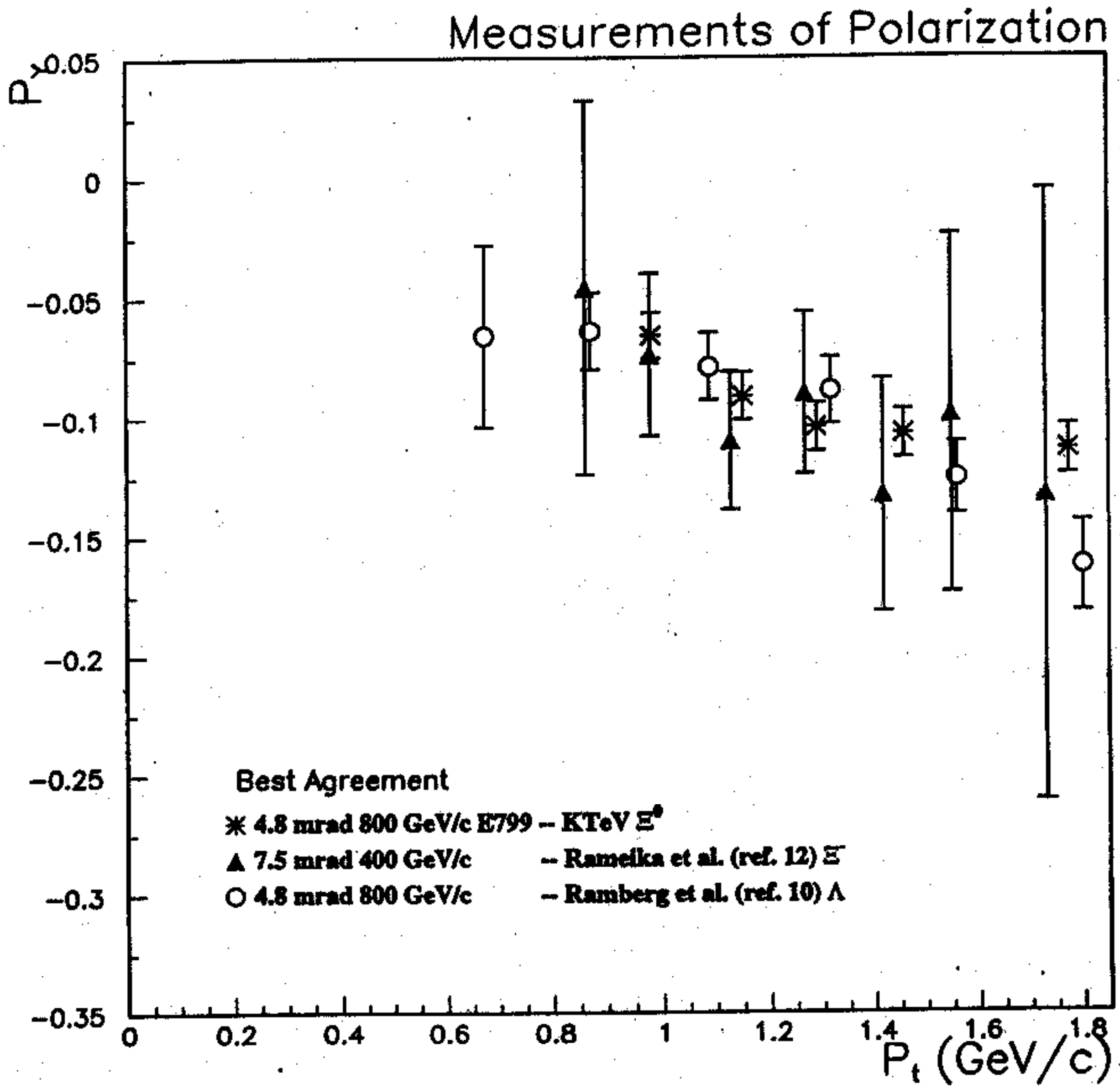


Figure 7.9: Past results plotted with ours versus transverse momentum.

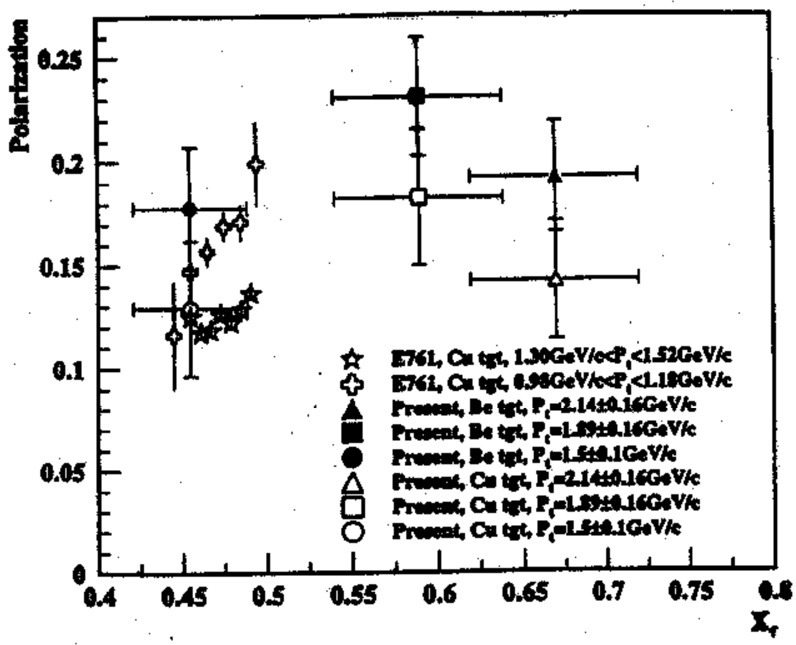


Figure 4: X_f dependence of the Σ^+ polarization (only statistical errors are shown). Open symbols correspond to the Cu production target, filled symbols – to the Be target. Open crosses and stars represent the E761 data [2] at $p_t \approx 1$ GeV/c and $p_t \approx 1.5$ GeV/c, respectively. Circles correspond to the present measurement at $p_t \approx 1.50$ GeV/c. Boxes correspond to the present measurement at $p_t \approx 1.89$ GeV/c. And, finally, triangles correspond to the present measurement at $p_t \approx 2.14$ GeV/c.

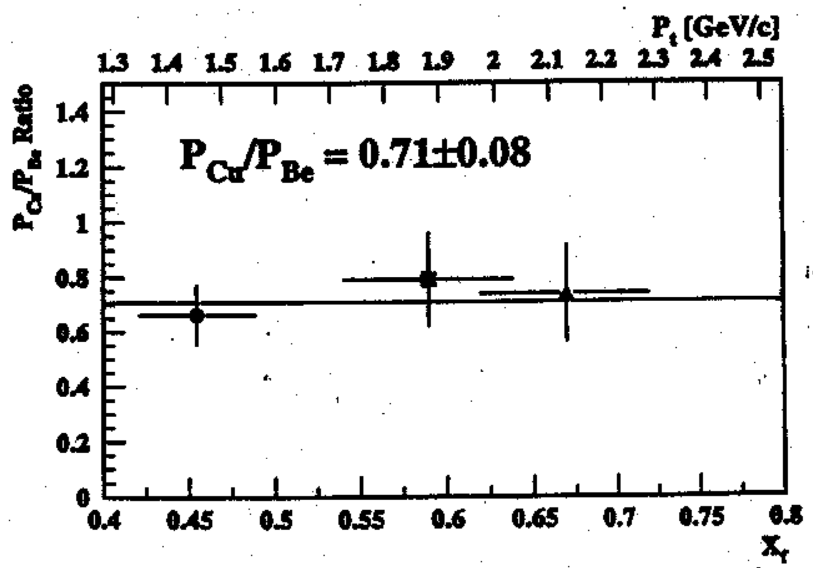
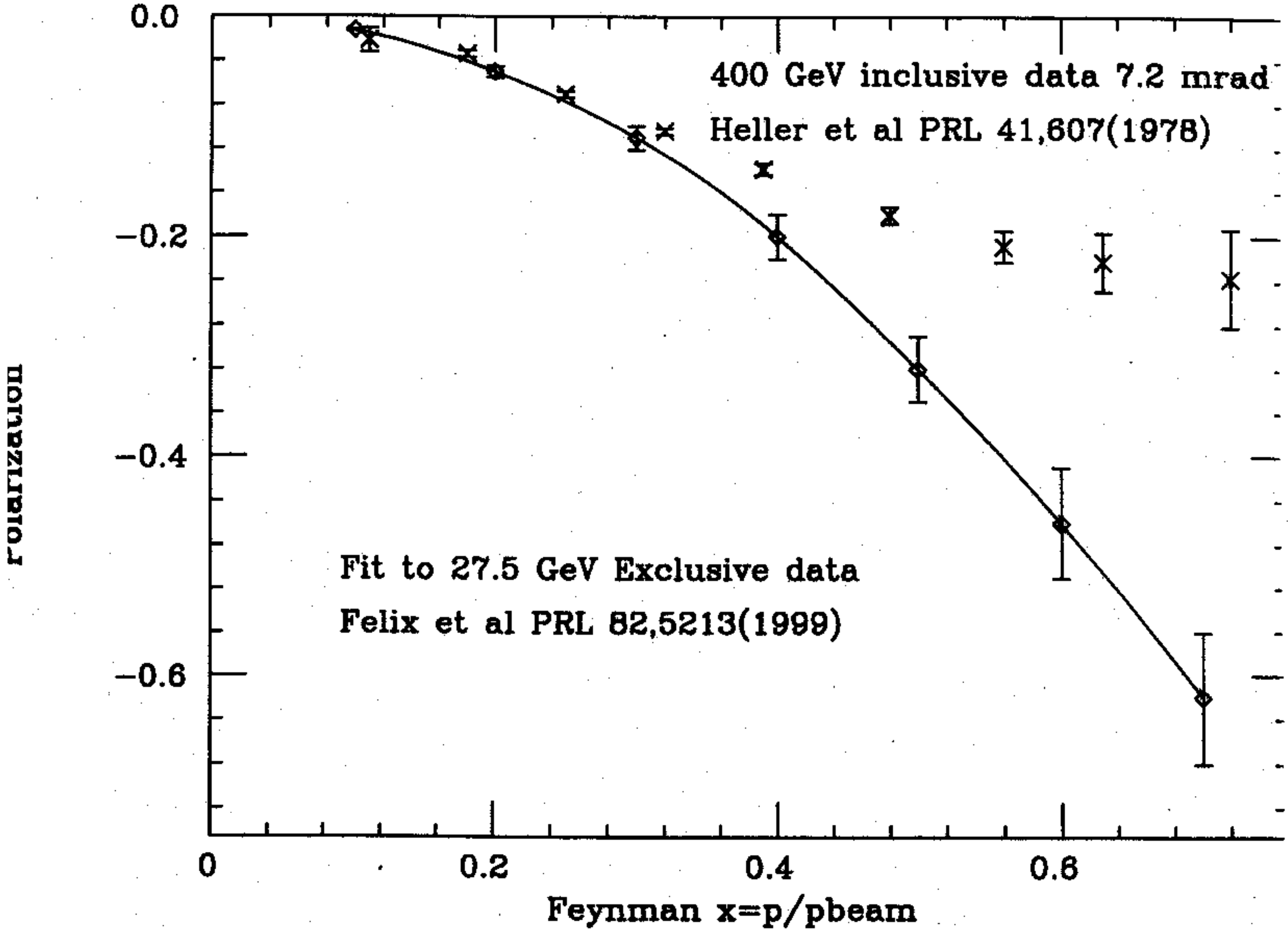


Figure 5: Ratio of the Σ^+ polarization values for Cu and Be targets (only statistical errors are taken into account). The horizontal line corresponds to the average ratio of 0.71 ± 0.08.

Polarization of Λ hyperons by protons



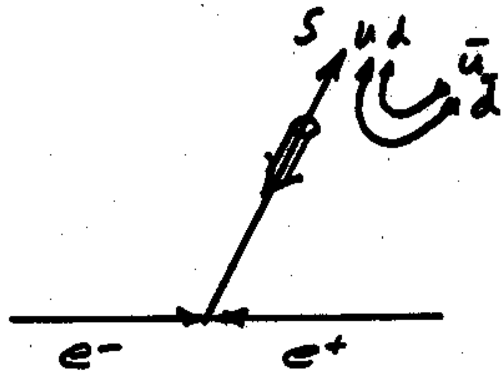
DecelERATING STRANGE QUARKS

AND

$$Z \rightarrow s\bar{s}$$

LARGE LONGITUDINAL POLARIZATION FOR STRANGE QUARKS

$s \to \Lambda$ VIA DIQUARK HADRONIZATION



ud SINGLET SPIN STATE

SOURCES OF Λ IN $Z \to q\bar{q}$

① LEADING S QUARK $\to \Lambda$ $\quad P_\Lambda = P_s$

② LEADING S QUARK $\to \Sigma, \Sigma^*, \Xi, \Xi^*$ $\quad P_\Lambda \neq 0$

③ LEADING u/d QUARK $\to \Lambda$

④ Λ CONTAINS NO LEADING QUARKS

$\Big\}$ $P_\Lambda = 0$ LONGITUDINAL

22

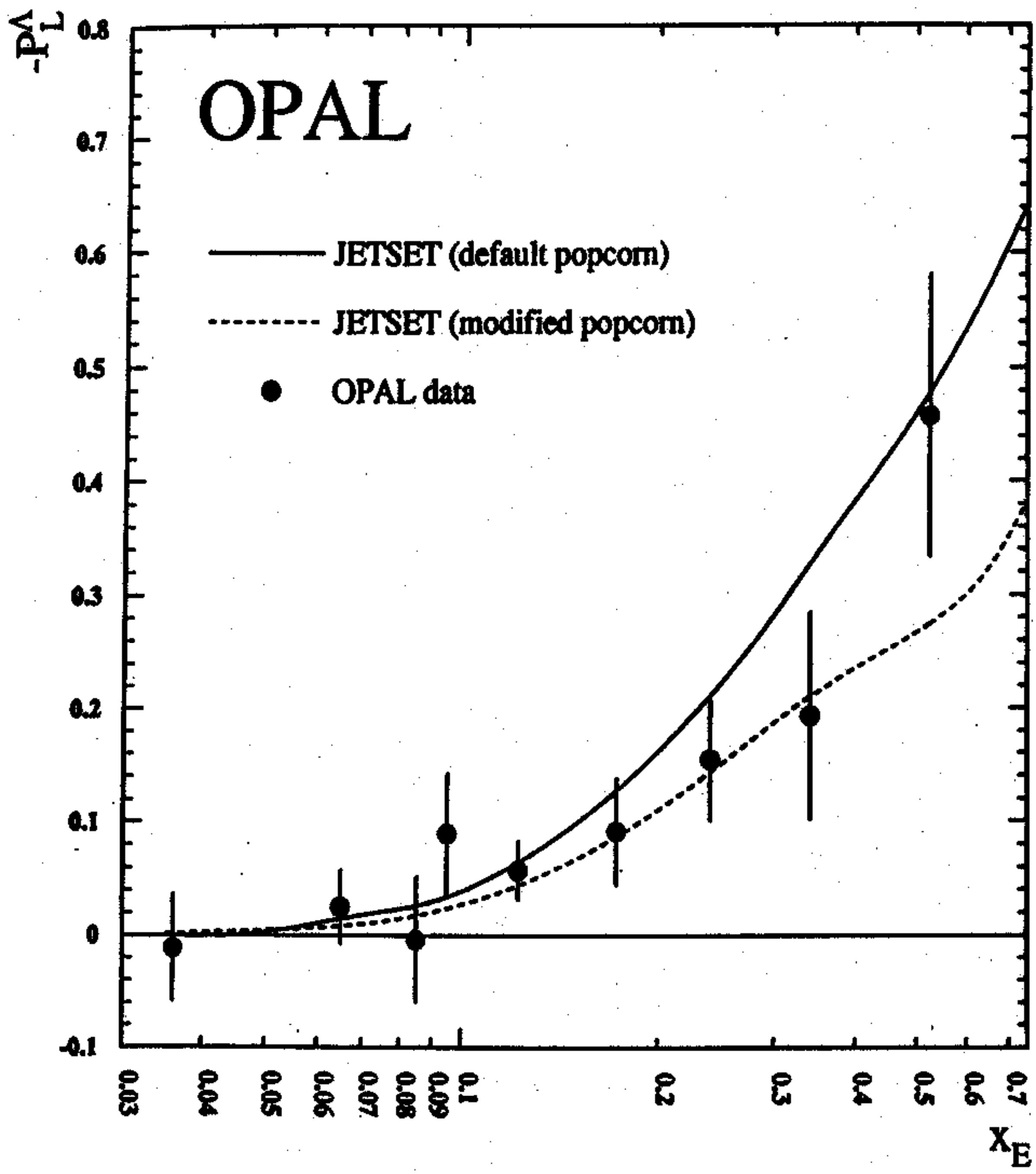
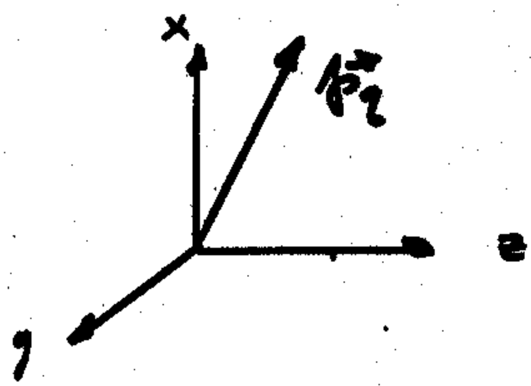


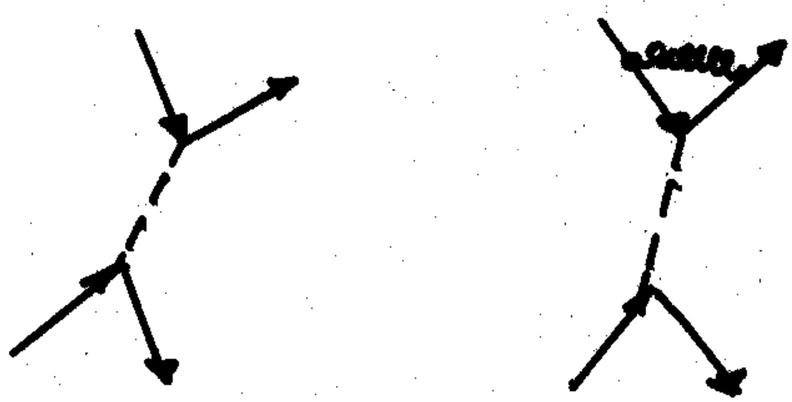
Figure 3: The longitudinal polarization predicted using tuned versions of JETSET with different versions of the popcorn model of baryon production. The measurements are shown as solid points and the error bars are the statistical plus systematic errors, added in quadrature.

TRANSVERSE POLARIZATION IN $Z \to q\bar{q}$

NORMAL TO $e^+e^- \to q\bar{q}$ PLANE $\hat{n} = \hat{y}$



VANISHES IN LOWEST ORDER (A)

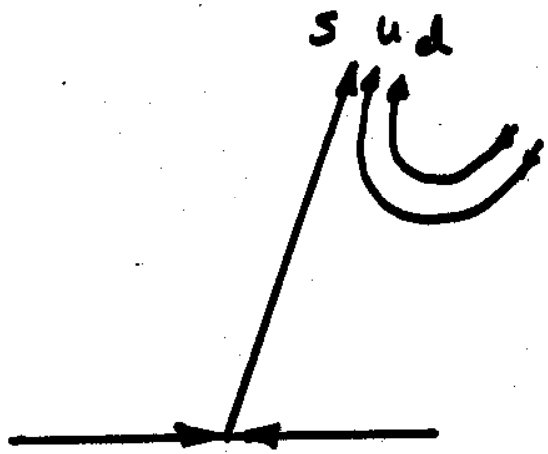


A B

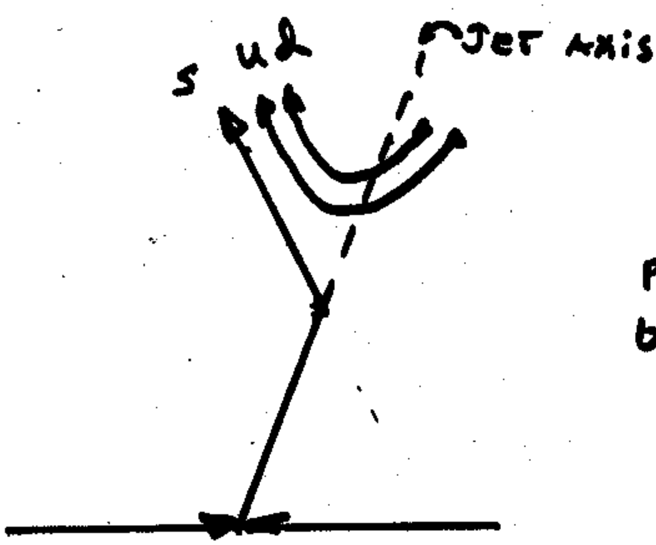
A + B interference $\rightarrow \vec{P} \cdot \hat{n} = \frac{4}{3} \alpha_s \frac{m_q}{Q} \frac{\sin\theta \cos\theta}{1 + \cos^2\theta}$

Kane, Pumplin, + Repko

Polarization in fragmentation



Transverse to what? Well, how about



Picture similar to beam fragmentation meson $\to \Lambda$?

So correlate the Λ spin with the normal to the jet-Λ plane.

S. Gourlay et al PRL 56 2244 (1986)
opposite sign convention

VOLUME 56, NUMBER 21 PHYSICAL REVIEW LETTERS 26 MAY 1986

$\hat{n} = \vec{p}_\Lambda \times \vec{p}_{beam} / |\vec{p}_\Lambda \times \vec{p}_b|$

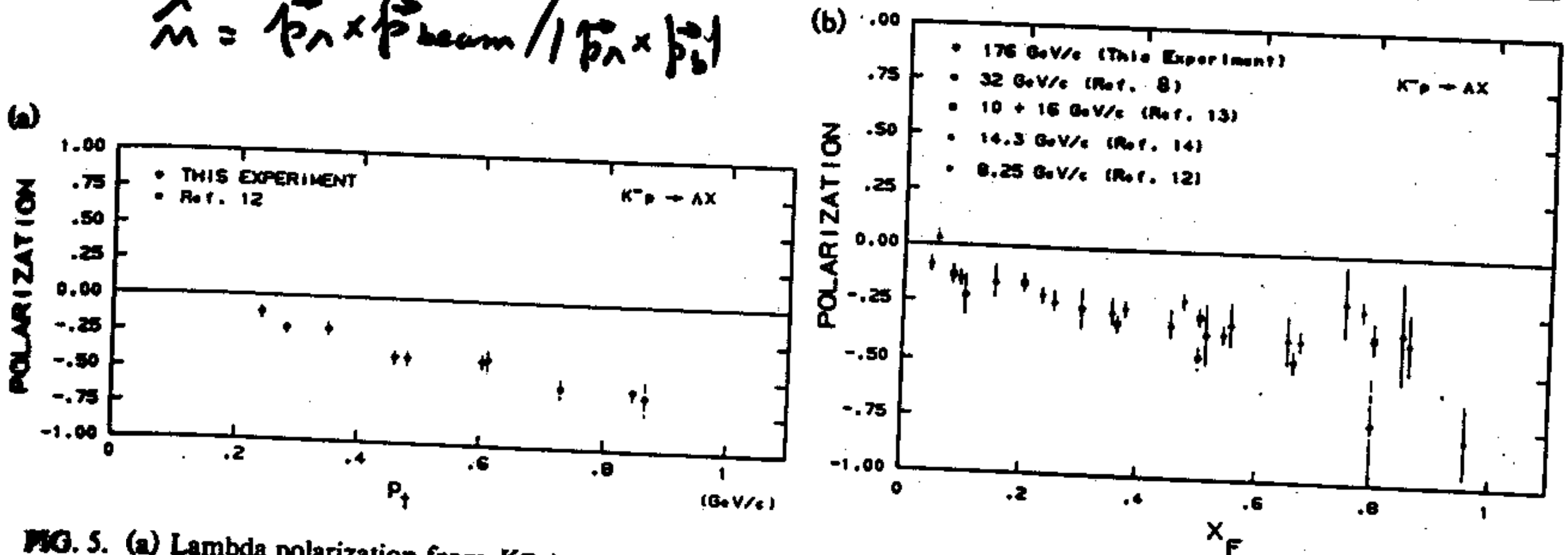


FIG. 5. (a) Lambda polarization from $K^- + p \to \Lambda + x$ and the 8.25-GeV/c data of Ref. 12 plotted vs p_t. (b) Lambda polarization from $K^- + P \to \Lambda + x$ and the data from Refs. 13 and 14 plotted vs x_F.

$K^+ \to \bar{\Lambda}$ similar - same sign
Ajinenko et al PL 121B, 183 (1983).

USING THE CONVENTION $\hat{n} = \dfrac{\vec{p}_{in} \times \vec{p}_{out}}{|\vec{p}_{in} \times \vec{p}_{out}|}$

$K^- p \rightarrow \Lambda X$ $\quad \vec{P}_\Lambda \cdot \hat{n}$ POSITIVE

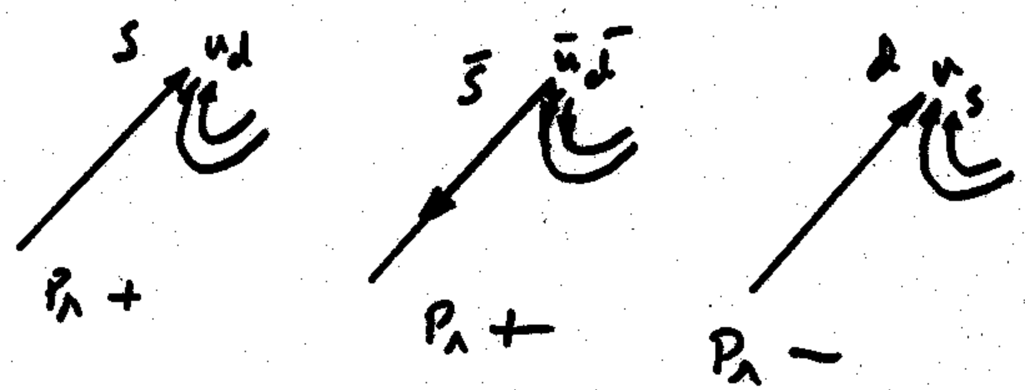
$K^+ p \rightarrow \bar{\Lambda} X$ $\quad \vec{P}_{\bar{\Lambda}} \cdot \hat{n}$ POSITIVE

EACH $P_\Lambda \sim 20\%$ IN BEAM FRAGMENTATION REGION

$\pi^- Cu \rightarrow \Lambda$ $\quad x_F > 0 \quad p_T > 1\,GeV$

$P_\Lambda = -0.28 \pm 0.09$ OPPOSITE SIGN

ACCMOR collab PL 325B, 531 (1994)



EXPERIMENTAL DATA

$$Z \to \Lambda, \bar{\Lambda}\ X$$

$$\vec{P}_\Lambda \cdot \hat{n} \qquad \hat{n} = \vec{p}_\Lambda \times \vec{p}_{THRUST} / |\vec{p}_\Lambda \times \vec{p}_{TH}|$$

OPAL

p_T (GeV/c)	P_T^Λ (%)
< 0.3	−1.8 ± 3.1 ± 1.0
0.3 − 0.6	0.4 ± 1.8 ± 0.7
0.6 − 0.9	1.0 ± 1.9 ± 0.7
0.9 − 1.2	0.8 ± 2.2 ± 0.6
1.2 − 1.5	0.0 ± 2.7 ± 0.6
> 1.5	1.8 ± 1.6 ± 0.5
> 0.3	0.9 ± 0.9 ± 0.3
> 0.6	1.1 ± 1.0 ± 0.4

le 6: Measured transverse polarization of Λ baryons as a function of p_T (the transverse nentum of the Λ measured relative to the event thrust axis). The first error is statistical, second systematic.

AUTHORS ALSO FOUND NO EFFECT WITH respect TO scattering plane.

If $K^- \to \Lambda$ + $K^+ \to \bar{\Lambda}$ produce polarization

Why do we not see $\Lambda \bar{\Lambda}$ transverse polarization in Z decay?

1.) All hadronic process is unrelated

2.) $\pi^- \to \Lambda$ has opposite sign, and data include Λ's from both sources (d + s quarks).

3.) Most of the data (~90%) have $x_E < .3$, and may not be sensitive

4.) Λ polarization in $K^- \to \Lambda$ + $K^+ \to \bar{\Lambda}$ could occur when the $\bar{u}$ or u quark is stripped off, rather than when the $s, \bar{s}$ is dressed.