Semi-Inclusive Reactions at 12 GeV in Hall C

($\pi^{\pm}/K^{\pm}$ Electroproduction on H and D)

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Quark-Hadron Transition in Structure and Fragmentation Functions.
HU Workshop

Jefferson Lab. April 17-18, 2000

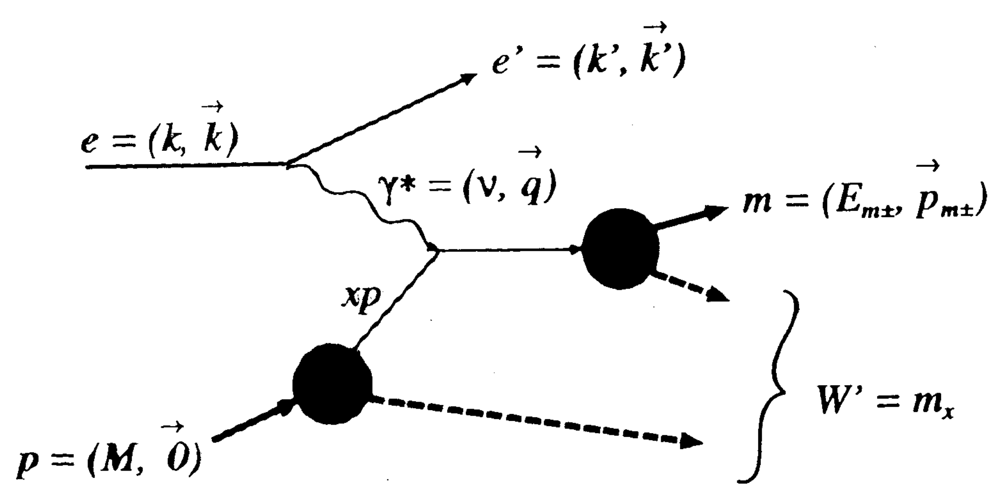
Factorization

At very high energy loss, the cross section factorizes:

$$\sigma \propto f(z, Q^2)\, g(x, Q^2)$$

- ➡ $g(x, Q^2)$ describes the photon-quark interaction
- ➡ $f(z, Q^2)$ describes the quark hadronization

Factorization holds at high energies; how low does it work?



Assume factorization (scaling) works for:

$$W'^2 = M^2 + Q^2(1/x - 1)(1-z) \gtrsim 4 \ GeV^2/c^2$$

$z > 0.3$

$(P_m > 2.5 \ GeV/c)$

Results for JLab test run:

$W'^2 \sim 3$

$z > 0.5$

$P_m \sim 3 \ GeV/c$

H(e,e'π+) D(e,e'π+)

H(e,e'π−) D(e,e'π−) = Al(e,e'π−) / Al(e,e'π+) × D(e,e'π+)

JLab Test Run Analysis

~ 8 hours !!

E GeV	$\theta_{e'}$ deg.	E' GeV	Q^2 (GeV/c)^2	x	θ_π deg.	p_π GeV/c	z	W'^2 GeV^2
5.51	30.0	1.6	2.36	0.32	13.0	2.0	0.51	3.3
						2.5	0.64	2.6
						3.0	0.77	2.0

ν ~ 4 GeV

W² ~ 5 GeV²/c²

$$q \leftrightarrow \overline{q} \quad \Rightarrow \quad D_q^{\pi^+} = D_{\overline{q}}^{\pi^-}$$ Charge Inv.

$$u \leftrightarrow d \quad \Rightarrow \quad D_u^{\pi^+} = D_d^{\pi^-}$$ Isospin Inv.

$$n \leftrightarrow p \quad \Rightarrow \quad u_p = d_n$$

Favored: $D^+ \equiv D_u^{\pi^+} = D_d^{\pi^-} = D_{\overline{u}}^{\pi^-} = D_{\overline{d}}^{\pi^+}$

Unfavored: $D^- \equiv D_u^{\pi^-} = D_d^{\pi^+} = D_{\overline{u}}^{\pi^+} = D_{\overline{d}}^{\pi^-}$

$$\frac{1}{N_e}\frac{dN^h}{dz} = \frac{\sum_f e_f^2\, q_f(x)\, D_f^h(z)}{\sum_f e_f^2\, q_f(x)}$$

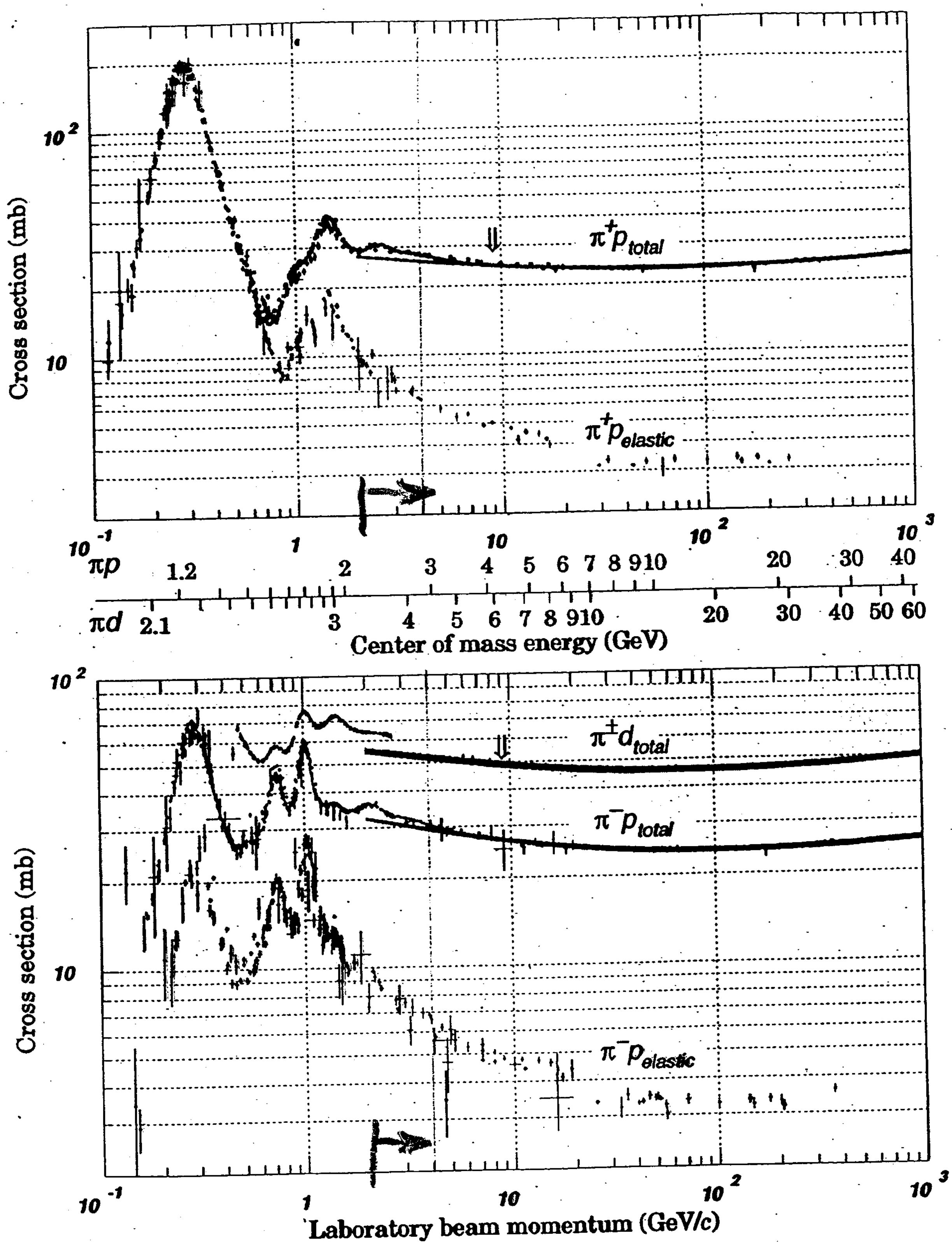
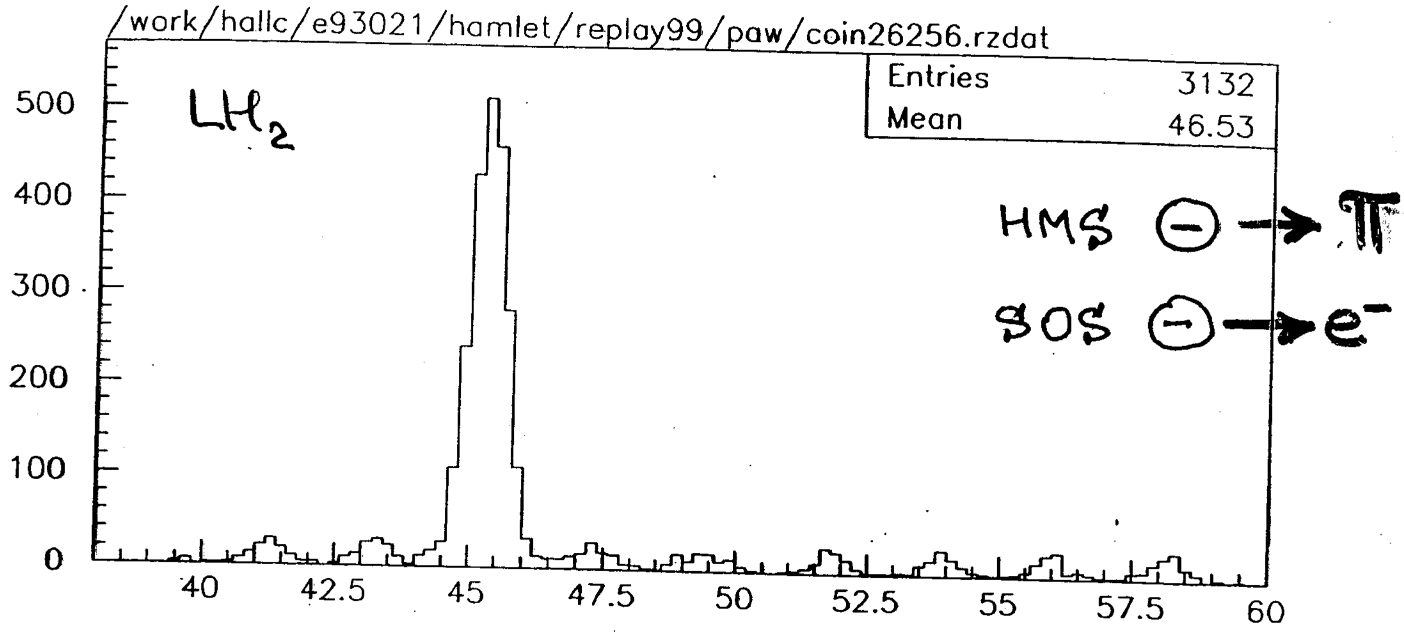
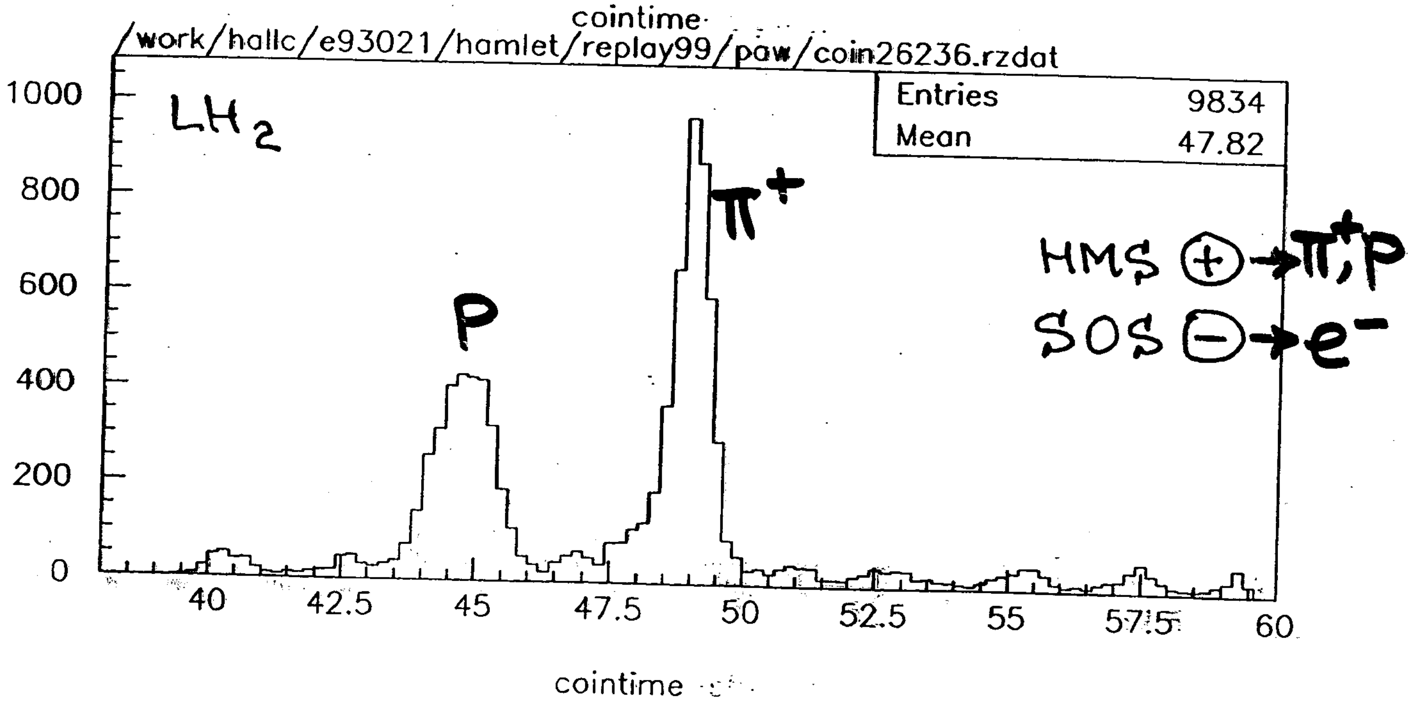


Figure 38.20: Total and elastic cross sections for $\pi^{\pm}p$ and $\pi^{\pm}d$ (total only) collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at `http://pdg.lbl.gov/xsect/contents.html` (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, April 1998.)

$P_{HMS} = 3.0$ GeV/c

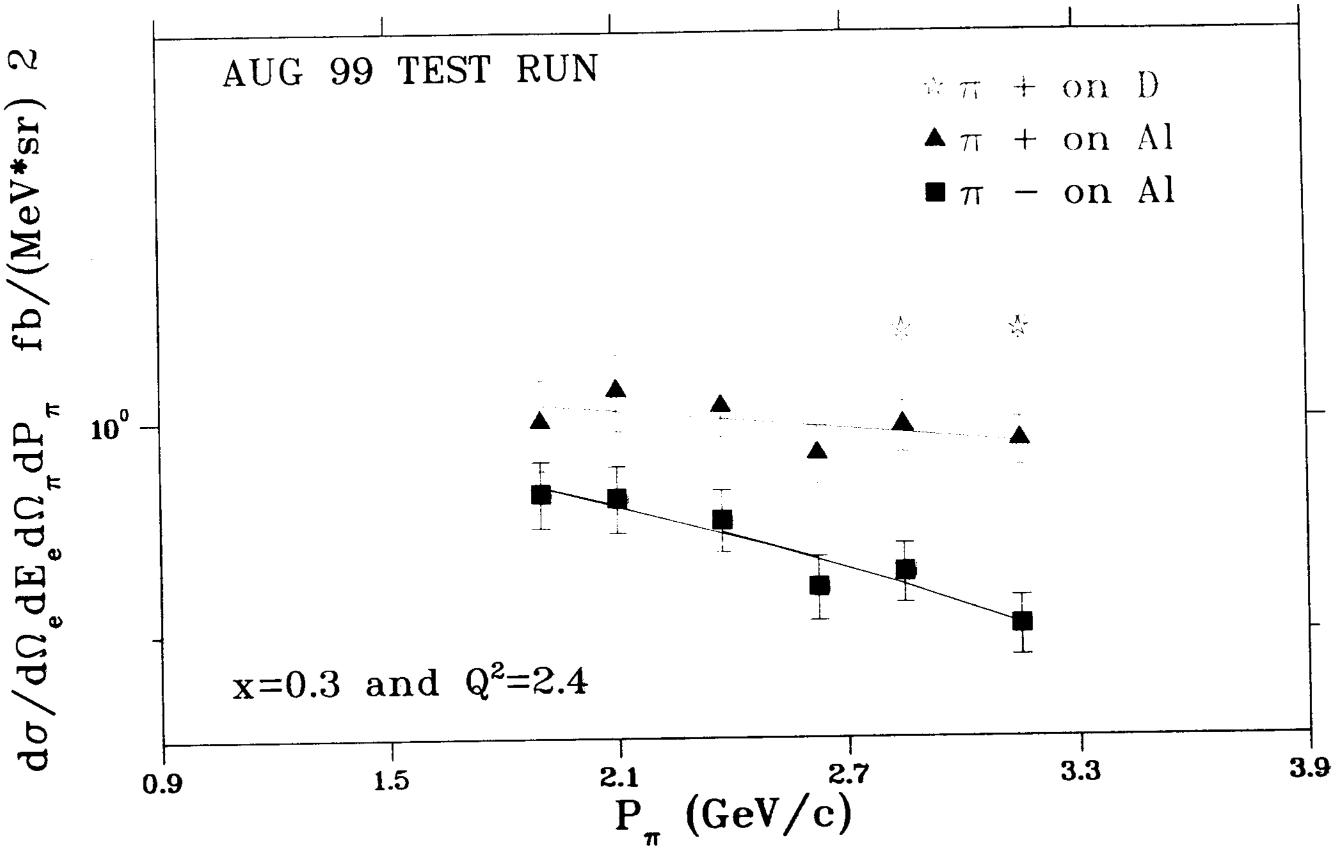
$P_{SOS} = 1.6$ GeV/c

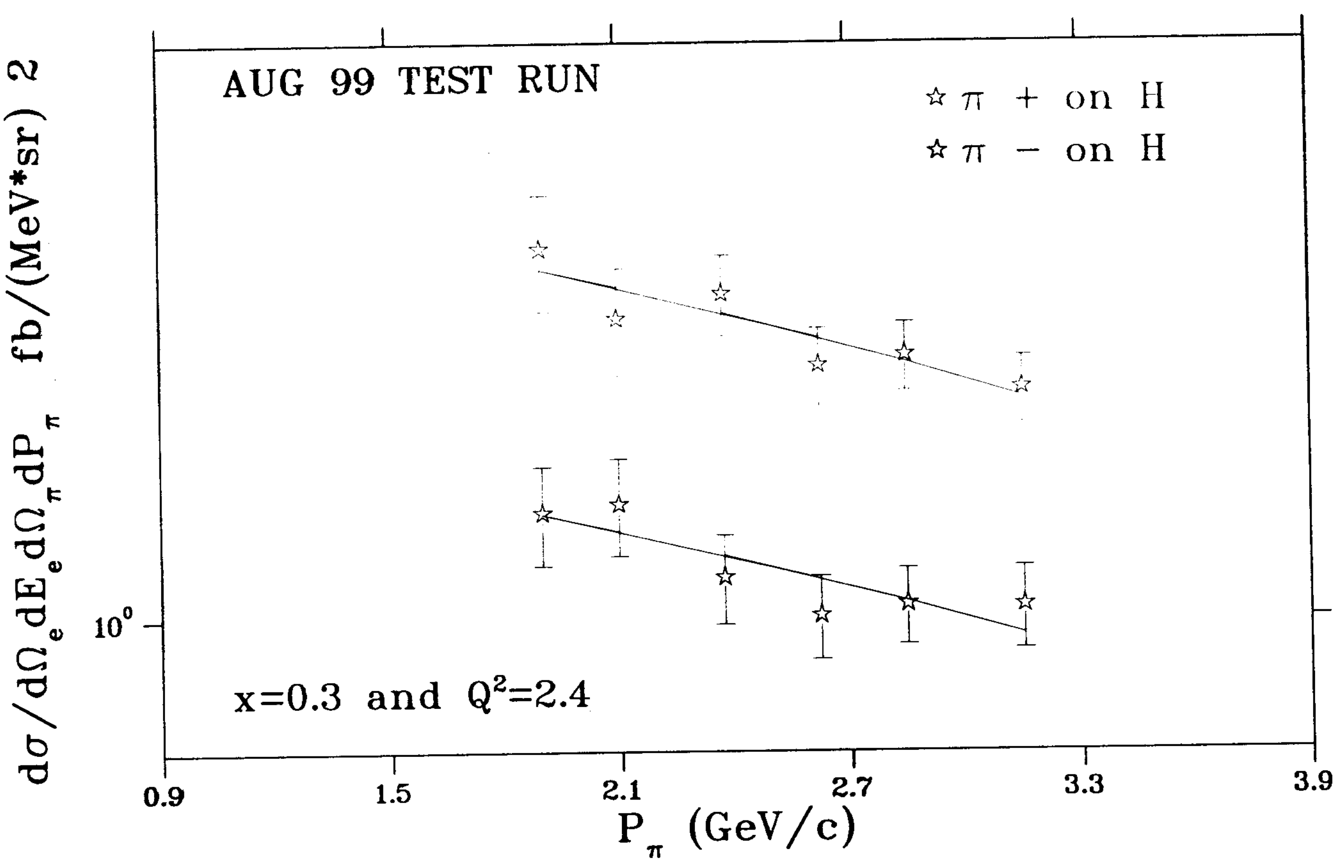




16 Aug '99

π^- and π^+ Differential Cross Section





Cross Section Reduction

$$\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m} \Rightarrow \frac{dN}{dz}$$

By convention,

$$\frac{\frac{d\sigma}{d\Omega_e dE_e dx dp_\perp^2 d\phi}}{\frac{d\sigma}{d\Omega_e dE_e}} = \frac{dN}{dz} b \exp(-bp_\perp^2) \frac{1 + A\cos(\phi) + B\cos(2\phi)}{2\pi}.$$

Use $d\Omega_m dp_m = \frac{1}{2p_m^2} dp_\perp^2 \, dp_{||} \, d\phi$ and $dp_{||} = \nu dx$:

$$\frac{\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m}}{\frac{d\sigma}{d\Omega_e dE_e}} = \frac{2p_m^2}{\nu} \frac{dN}{dz} b \exp(-bp_\perp^2) \frac{1 + A\cos(\phi) + B\cos(2\phi)}{2\pi}.$$

Integration over ϕ and $p_\perp$ yields (assume no ϕ dependen[ce])

$$\frac{dN}{dz} = \frac{1}{2\pi b p_{\perp max}^2} \frac{\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m}}{\frac{d\sigma}{d\Omega_e dE_e}}.$$

parameter $b \simeq 4.0 \text{ GeV}^{-2}$

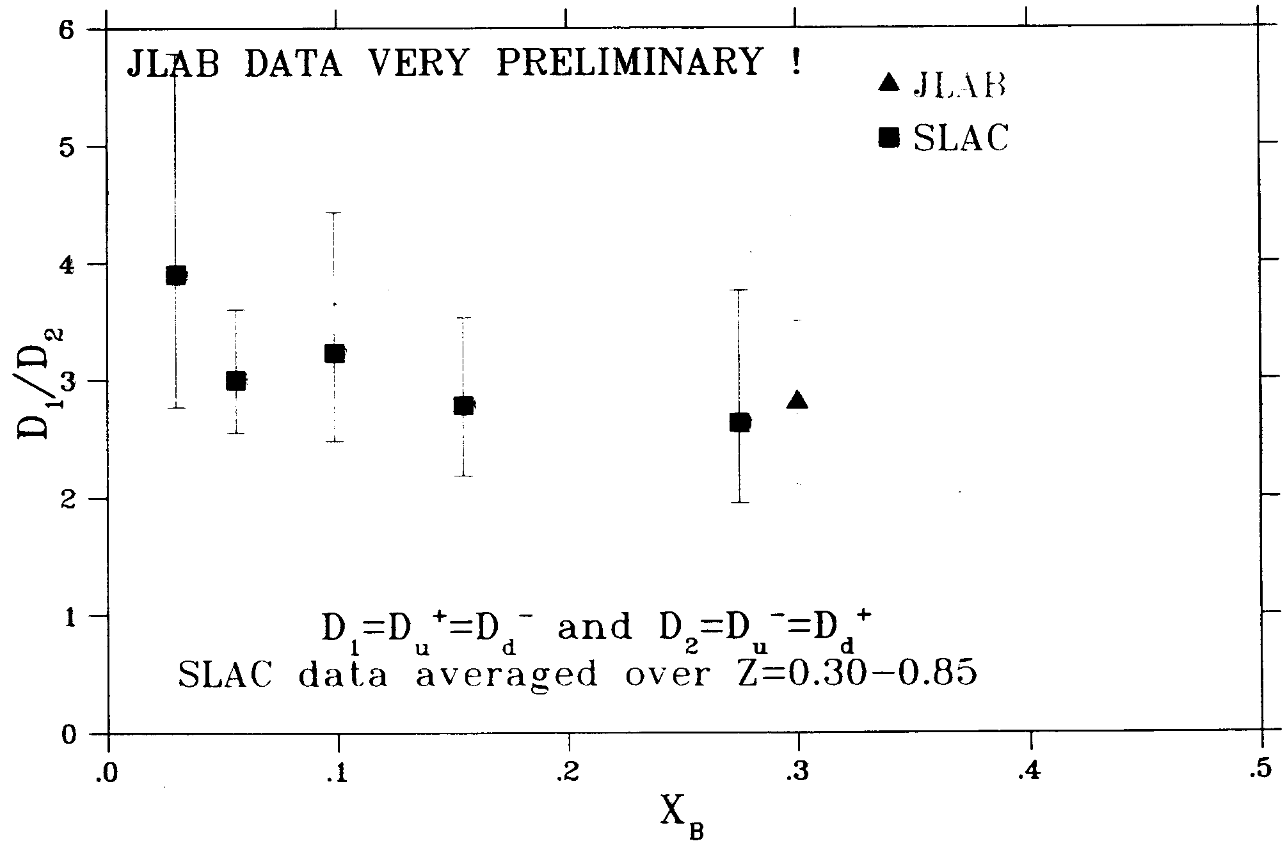
(from SLAC experimen[t])

The ratio of average fragmentation functions

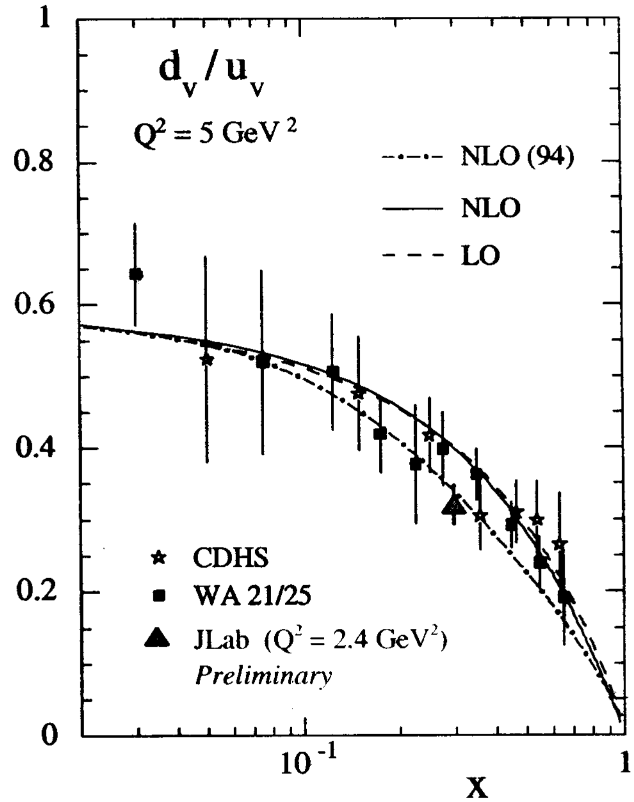
QPM - prediction:

$$\frac{(\sigma_p^+ - \sigma_n^-) - (\sigma_n^+ - \sigma_n^-)}{(\sigma_p^+ + \sigma_p^-) - (\sigma_n^+ + \sigma_n^-)} = \frac{5}{3} \times \frac{D_1/D_2 - 1}{D_1/D_2 + 1}$$

The ratio of average fragmentation functions



JLab Test Runs: Factorization at Low Energies?



Assumption of factorization allows extraction of d_v/u_v from the test runs. Result is in agreement with high energy data.[5]

[5] M. Gluck *et al.*, e-print hep-ph/9806404 (1998)

Let assume we have:

- → 12 GeV ; 50 μA CW beam ;
- → HMS and SHMS in Hall C ($\Delta p \sim 20\%$; $\Delta\Omega \sim 7\,(\sim 2)$ msr)
- → 4 cm LH_2 and LD_2 targets

To estimate rates for

$$eN \rightarrow e'\pi^{\pm}X$$

we must know $\dfrac{d\sigma}{d\Omega_e\, dE_e\, d\Omega_\pi\, dp_\pi}$

To estimate

Cross Section Reduction

$$\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m} \Rightarrow \frac{dN}{dz}$$

By convention,

$$\frac{\frac{d\sigma}{d\Omega_e dE_e dx dp_\perp^2 d\phi}}{\frac{d\sigma}{d\Omega_e dE_e}} = \frac{dN}{dz} b \exp(-bp_\perp^2) \frac{1 + A\cos(\phi) + B\cos(2\phi)}{2\pi}.$$

Use $d\Omega_m dp_m = \frac{1}{2p_m^2} dp_\perp^2 \, dp_{||} \, d\phi$ and $dp_{||} = \nu dx$:

$$\frac{\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m}}{\frac{d\sigma}{d\Omega_e dE_e}} = \frac{2p_m^2}{\nu} \frac{dN}{dz} b \exp(-bp_\perp^2) \frac{1 + A\cos(\phi) + B\cos(2\phi)}{2\pi}.$$

Integration over ϕ and $p_\perp$ yields

$$\frac{dN}{dz} = \frac{1}{2\pi b p_{\perp max}^2} \frac{\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m}}{\frac{d\sigma}{d\Omega_e dE_e}}.$$

$$\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dP_m} = \frac{dN}{dZ} \times \frac{d\sigma}{d\Omega_e dE_e} \times 2\pi B P_{\perp max}^2$$

↑ D_{ff} ↑ e,e'x ↑ kin factor

KINEMATIC PARAMETERS AND EXPECTED RATES

X	Q2	E'	Thet_e	Pm	Z	dsig(e,e'x)	Dff	dsig(e,e'\pix)	1/sec
0.4	5.0	5.34	16.1	2.66	0.4	3.56	1.086	0.800	0.50
0.50	6.5	5.07	18.8	2.77	0.4	1.75	1.080	0.380	0.23
0.50	6.5	5.07	18.8	4.16	0.6	1.75	0.506	0.080	0.07
0.60	7.5	5.34	19.7	2.66	0.4	0.48	1.075	0.110	0.06
0.60	11.0	2.23	37.4	5.86	0.6	0.13	0.530	0.005	0.003
0.65	8.0	5.44	20.2	2.62	0.4	0.64	1.073	0.140	0.09
0.65	10.0	3.80	27.1	4.92	0.6	0.13	0.530	0.005	0.003
0.70	9.0	5.15	22.0	2.74	0.4	0.32	1.068	0.070	0.040

* for 4cm LH2 target at I=50uA beam
** The value of fragmentation function "D" calculated using parameterization from QPM model.

$W'^2 > 4\ GeV^2/c^2$

$Z > 0.3$

$P_m > 2.5\ GeV/c$

Beam time Request (hours

(proposed ~3% statistic err.)

z = 0.4

x	π^+_H	π^-_H	π^+_D	π^-_D	tot	+30%
0.4	1.5	2.5	1.5	1.5	~7	~10
0.5	2.5	3.5	2.5	2.5	~11	~15
0.6	8.5	13.5	8.5	8.5	~40	~55
0.7	15.0	15.0	15.0	15.0	~70	~90
Total Beam time ~170 hours						

$W'^2 > 4\ GeV^2$

$P_m > 2.5\ GeV/c$

For $Z = 0.6$ we will need

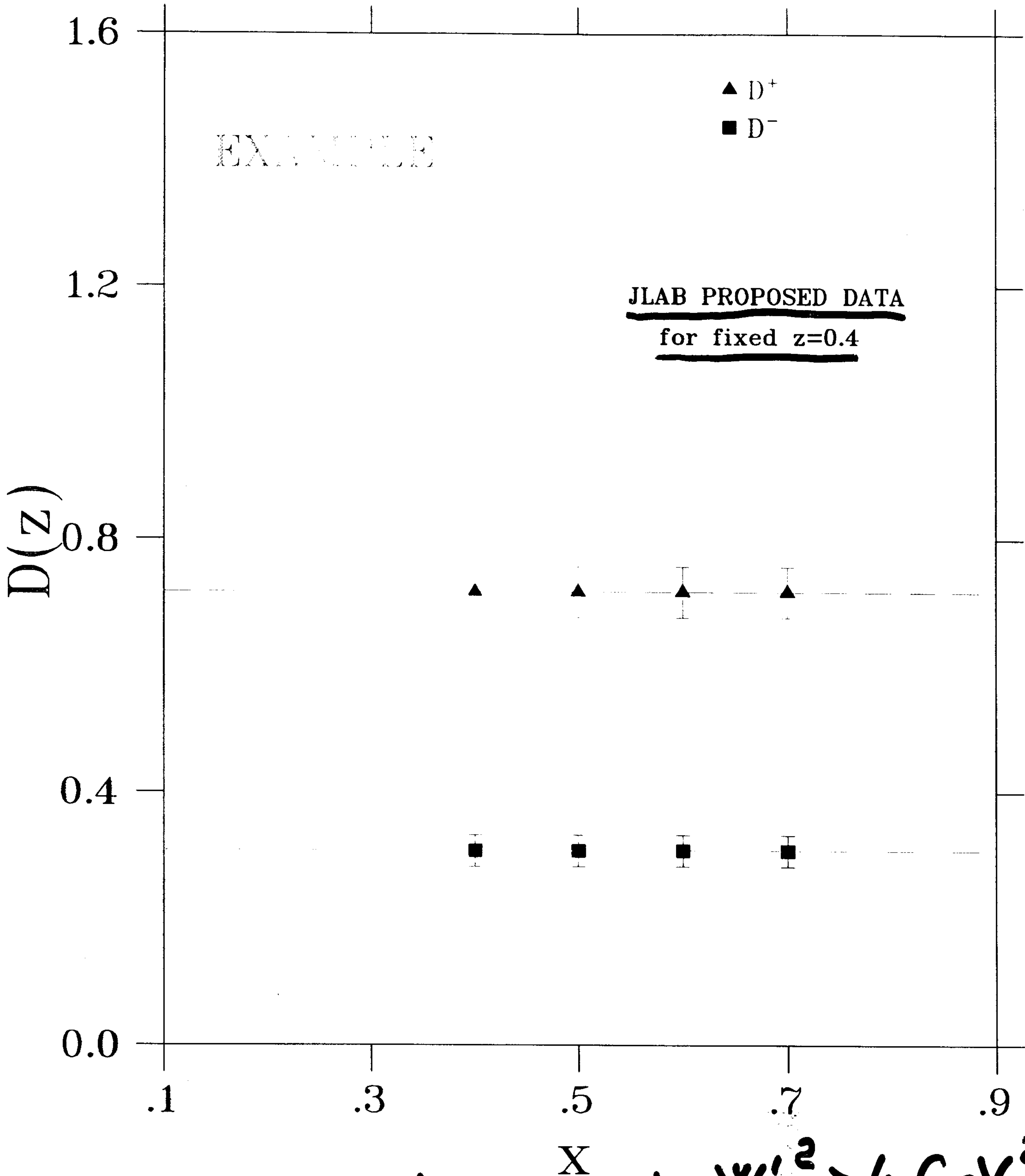
Beam time ~ 280 hours

→ ~450 hours ←

π^+, π^- on LH_2 and LD_2

at $z = 0.4$ and 0.6; and $x = 0.4 - 0.7$

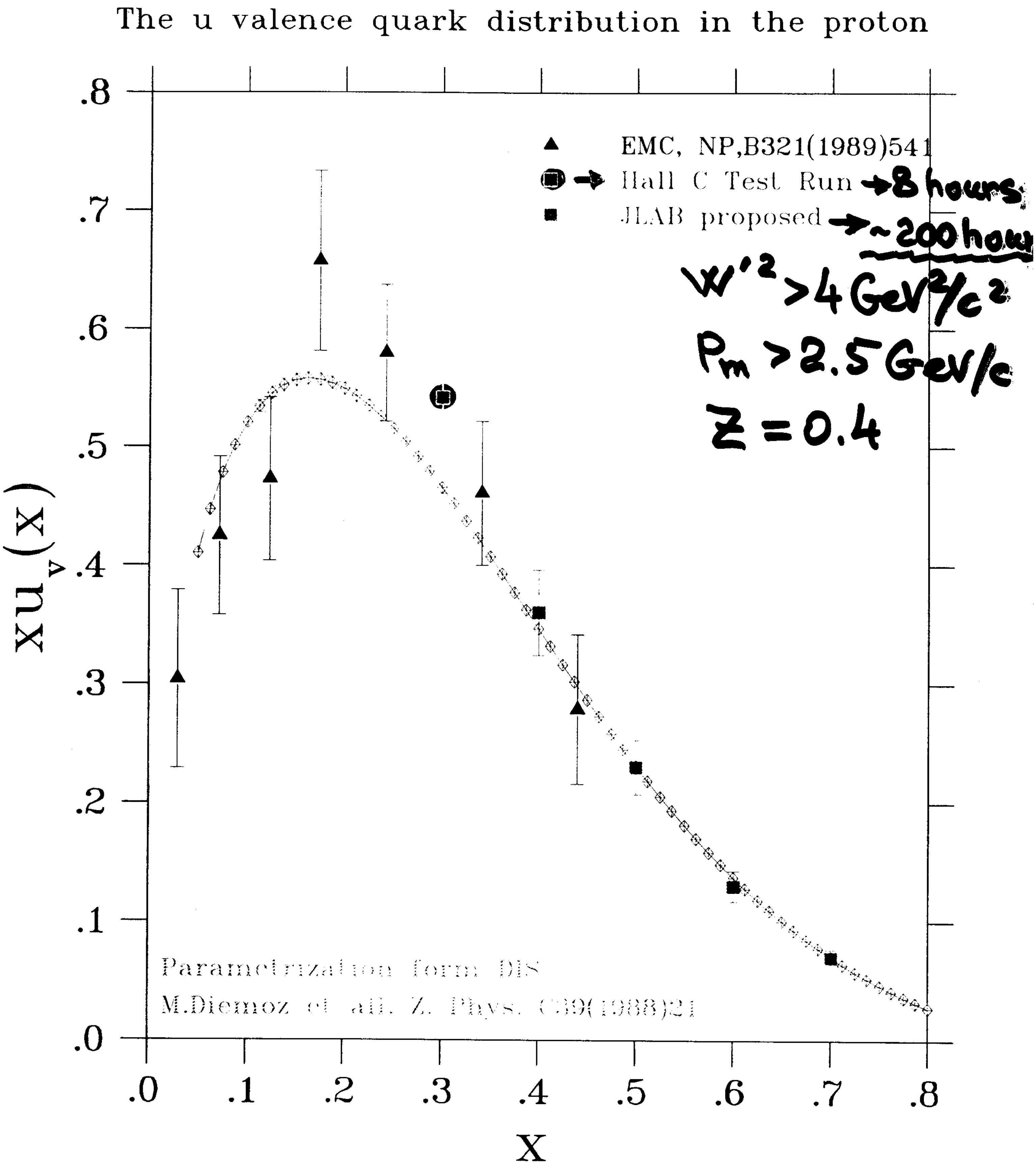
Does Factorization hold ? ⟹ Experimental Issue !



~200 hours at $I_e \simeq 50\,\mu A$

! $W'^2 > 4\ GeV^2/c^2$

$P_m > 2.5\ GeV/c$

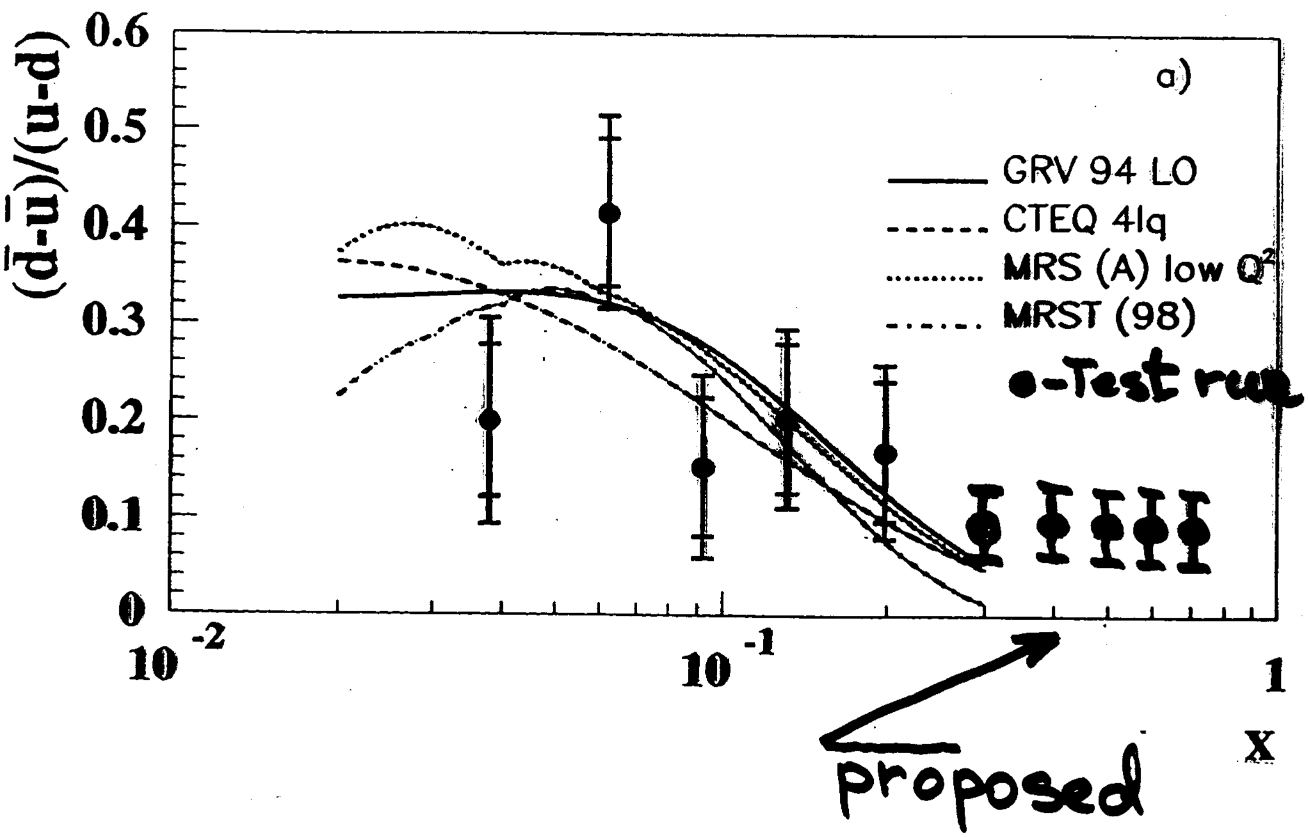

The u valence quark distribution in the proton
EMC, NP,B321(1989)541
Hall C Test Run → 8 hours
JLAB proposed → ~200 hours
W'² > 4 GeV²/c²
Pm > 2.5 GeV/c
Z = 0.4
Parametrization form DIS
M.Diemoz et all. Z. Phys. C39(1988)21
xu_v(x)
x
.0
.1
.2
.3
.4
.5
.6
.7
.8

H(e,e'π⁺)   D(e,e'π⁺)

H(e,e'π⁻)   D(e,e'π⁻)

<u>If factorization hold !</u>

Assume: $z \simeq 0.4$ $D^-/D^+ \simeq 0.5$



Semi-Inclusive-Electroproduction of $K^\pm$ on LH_2 and LD_2

$$N_H^{K^+} - N_H^{K^-} = \frac{(1/9)4xu(x)}{F_2^H(x)} \cdot [D_u^{K^+}(z) - D_u^{K^-}(z)]$$

$$N_D^{K^+} - N_D^{K^-} = \frac{(2/9)[xu(x) + xd(x)]}{F_2^V(x)} \cdot [D_u^{K^+} - D_u^{K^-}]$$

→ Expected rates for $K^\pm$ ~5-7 times low than for $\pi^\pm$

→ During $\pi^\pm$ runs we will collec ~150-200 kaons for each kinem setting

→ We will needed additional ~100 hours at $z=0.4$ and $x=0.$ 0.5 to get stat. errors ~5%

All program for $\pi^\pm$ and $K^\pm$ ⇒ ~55

SUMMARY

If factorization hold !

(seems to work for JLAB test run)

(At 12 GeV sould be much better!)

(than for test run 5.5 GeV)

1 month run:
- HMS + SHMS
- LH_2 and LD_2 targets
- $(e,e'\pi^{\pm})$ and $(e,e'K^{\pm})$

→ Precise data sets with strict cuts ($W'^2 \geq 4\ GeV^2/c^2$; $z \geq 0.3$) up $x \simeq 0.7$ for $u(x)$; $d(x)$; $s(x)$ and maybe $\bar{u}-\bar{d}$? would be.

→ Also $\Delta u, \Delta d, \Delta s$ possible with less precision. (or less strict cuts on z)

($\mathcal{L} \simeq 10^{37} \rightarrow 10^{35}$; CLAS ?)