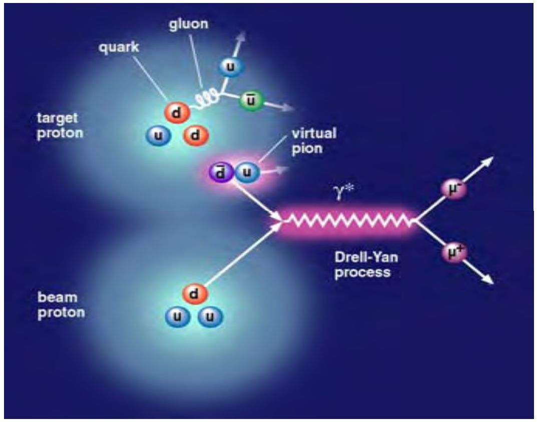
Exploring the nucleon structure with Drell-Yan

Lingyan Zhu

University of Illinois at Urbana-Champaign

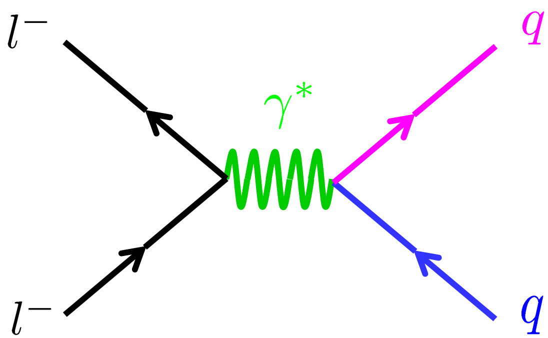
Fermilab E866/Nusea Collaboration



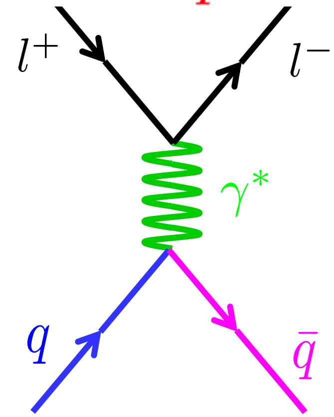
- dbar/ubar asymmetry
- nuclear dependence
- cos2phi asymmetry
- Projection with E906.

Drell-Yan & DIS

DIS $: ep \to e'X$

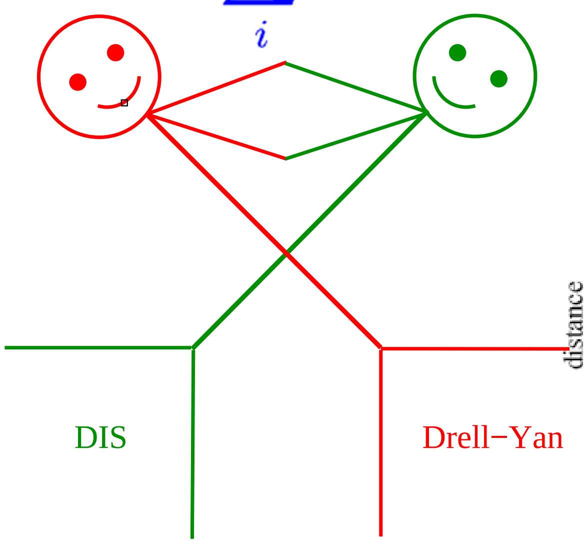


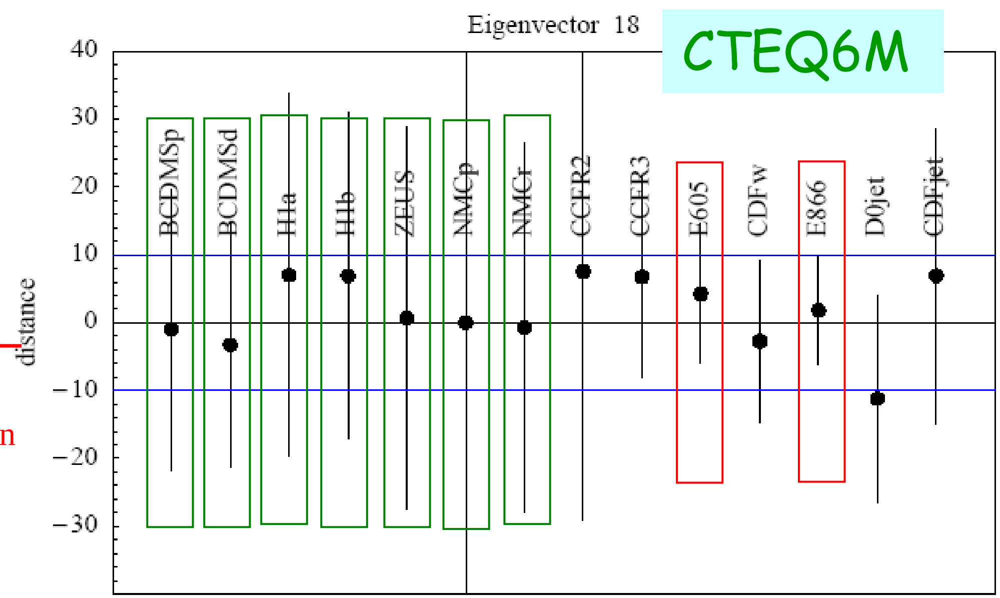
Drell – Yan $: pN \to \mu^+\mu^- X$



$$\sigma_{DIS} \propto \sum_i e_i^2 \left[q_i(x_t) + \bar{q}_i(x_t)\right]$$

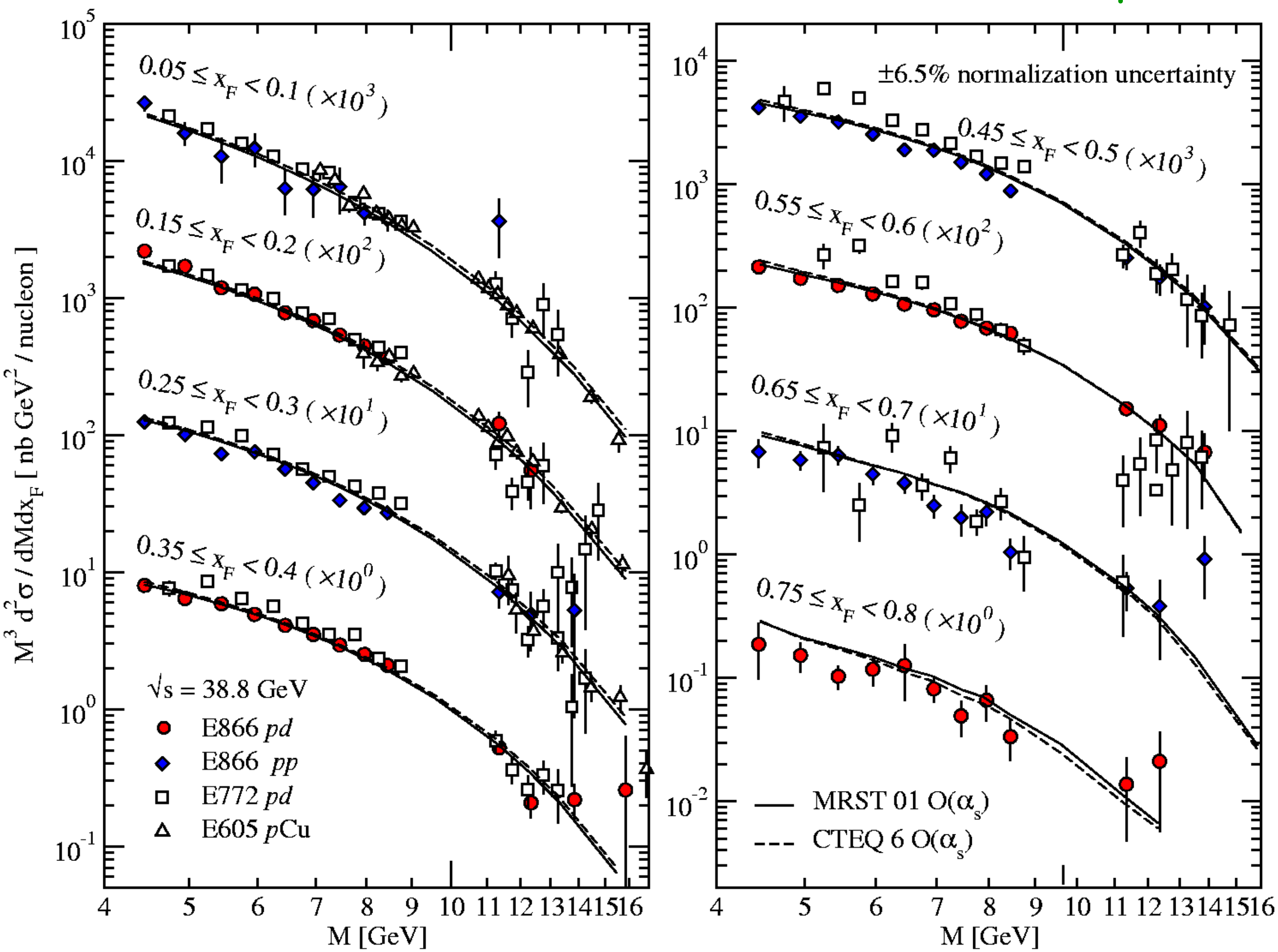
$$\sigma_{DY} \propto \sum e_i^2 \left[q_i(x_b)\bar{q}_i(x_t) + \bar{q}_i(x_b)q_i(x_t)\right]$$





Drell-Yan Cross Sections & Global PDF

E866(J.C.Webb et al.), hep-ex/0302019.



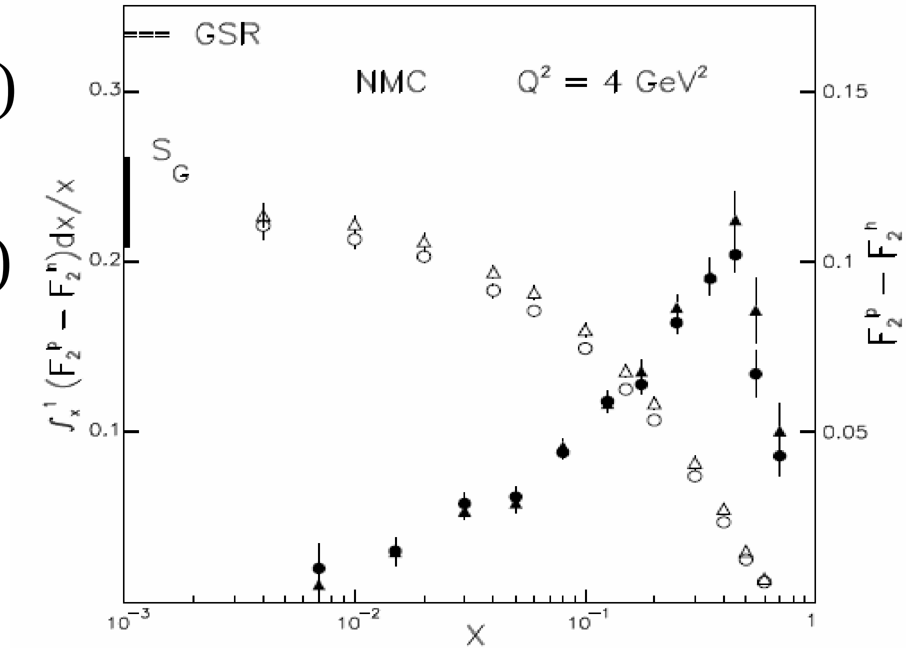
Sea Asymmetry from DIS

$$F_2^p / x = \frac{4}{9}(u+\bar{u}) + \frac{1}{9}(d+\bar{d}) + \frac{1}{9}(s+\bar{s})$$

$$F_2^n / x = \frac{4}{9}(d+\bar{d}) + \frac{1}{9}(u+\bar{u}) + \frac{1}{9}(s+\bar{s})$$

$$[F_2^p - F_2^n] / x = \frac{1}{3}(u+\bar{u}) - \frac{1}{3}(d+\bar{d})$$

$$\text{proton[uud]} ==> \int_0^1 [u_v - d_v] dx = 1$$



$$\int_0^1 [\bar{d} - \bar{u}] dx = \frac{1 - 3\boxed{\int_0^1 [F_2^p - F_2^n] / x dx}}{2} = \frac{1 - 3 * \boxed{0.235}}{2} = 0.148 \neq 0$$

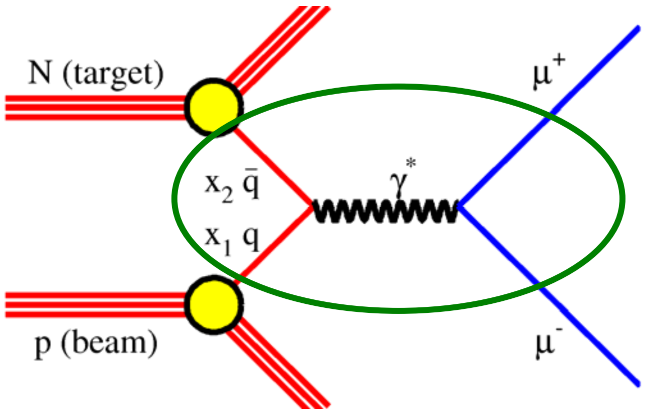
Gottfried Integral S_G=1/3?

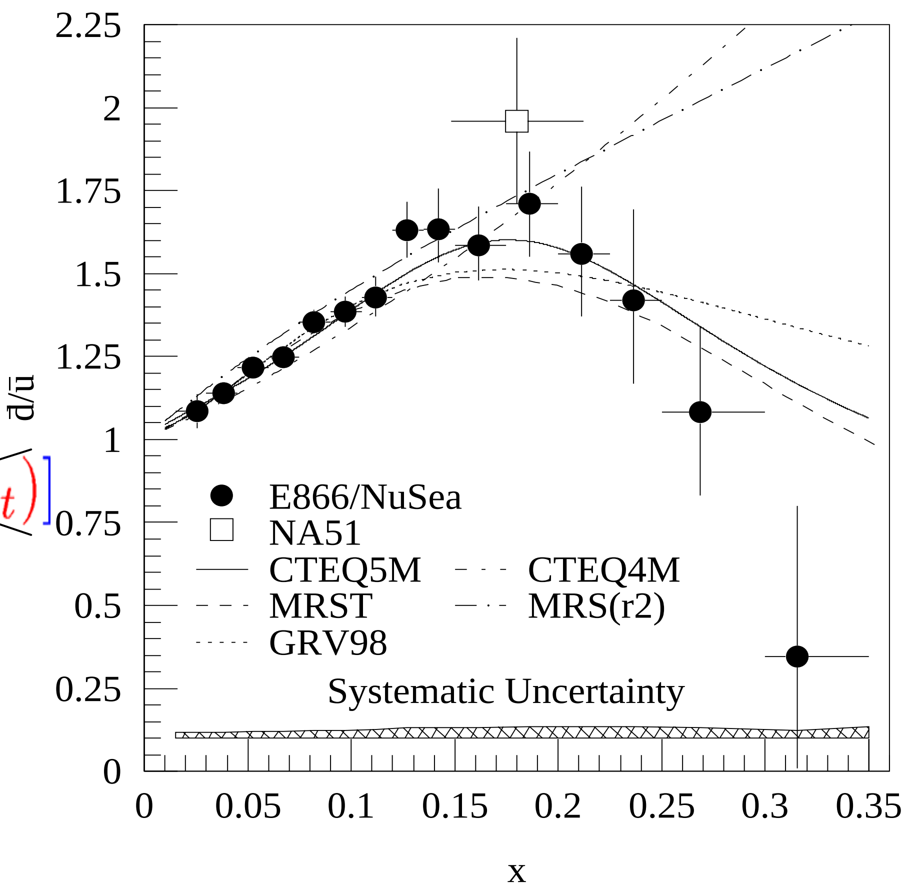
NMC at CERN: PRL66(1991)2712;PRD50(1994)R1

Sea Asymmetry from Drell-Yan

$pN \rightarrow \mu^+\mu^- X$

Towell et al., Phys.Rev. D64 (2001) 052002



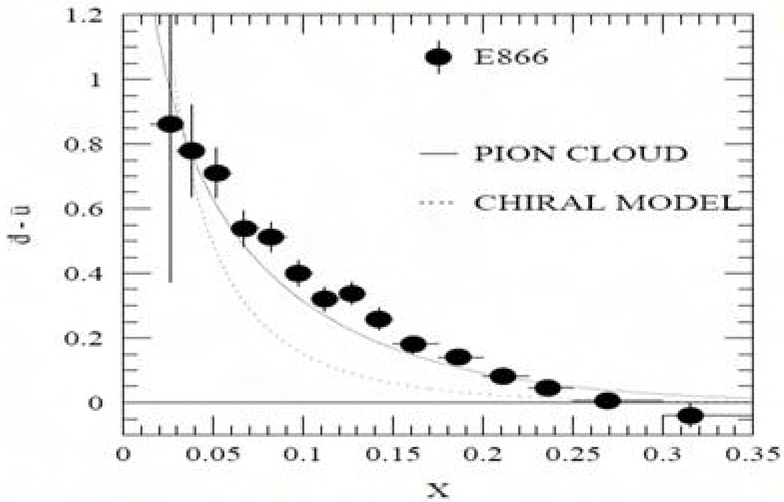


$$\sigma_{DY} \propto \sum_i e_i^2 \left[q_i(x_b)\bar{q}_i(x_t) + \cancel{\bar{q}_i(x_b)q_i(x_t)} \right]$$

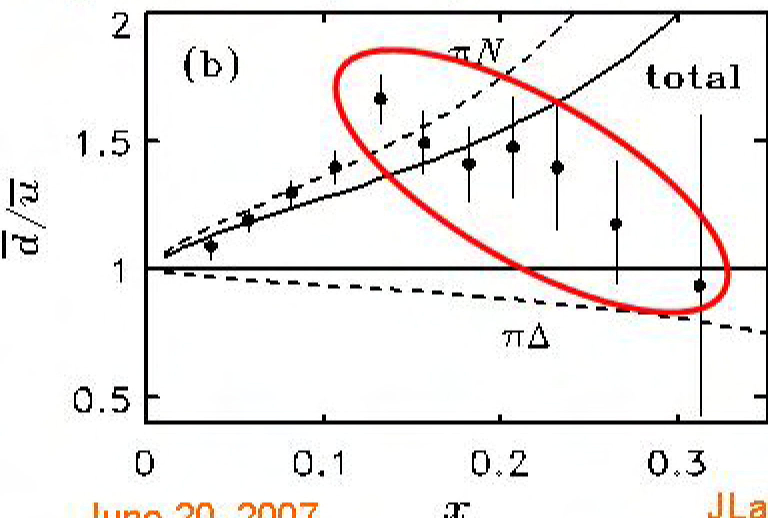
$$\left.\frac{\sigma^{pd}}{2\sigma^{pp}}\right|_{x_b \gg x_t} \approx \frac{1}{2}\left[1 + \frac{\bar{d}(x_t)}{\bar{u}(x_t)}\right]$$

Sea Asymmetry from Models

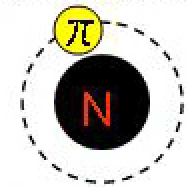
Prog.Part.Nucl.Phys.47(2001)203



Phys.Rev.D59(1999)014033

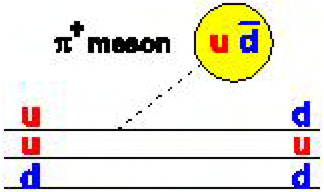


Pion cloud models: Bare nucleon +pion cloud



$$
\begin{aligned}
|p> \quad &\rightarrow \quad \sqrt{1-a-b}|p_0> \\
&+ \quad \sqrt{a}\left(-\sqrt{\frac{1}{3}}|p_0\pi^0> + \sqrt{\frac{2}{3}}|n_0\pi^+>\right) \\
&+ \quad \sqrt{b}\left(-\sqrt{\frac{1}{2}}|\Delta_0^{++}\pi^-> - \sqrt{\frac{1}{3}}|\Delta_0^{+}\pi^0> + \sqrt{\frac{1}{6}}|\Delta_0^{0}\pi^+>\right)
\end{aligned}
$$

Chiral Models:

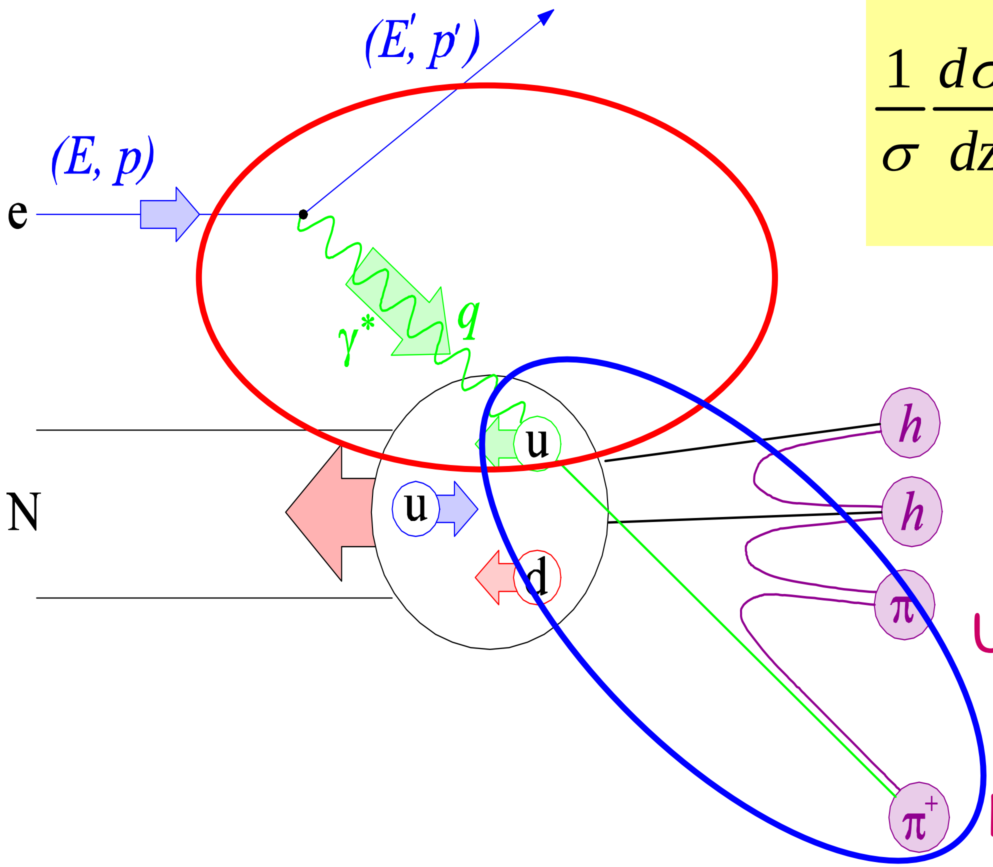


Constituent quarks + Goldstone Bosons

$$
\begin{aligned}
U \quad &\rightarrow \quad (1-\frac{3}{2}\alpha)U + \alpha\pi^+ D + \frac{1}{2}\alpha\pi^0 U \\
p \quad &\rightarrow \quad 2U + D + \frac{7\alpha}{4}(u+\bar{u}) + \frac{11\alpha}{4}(d+\bar{d})
\end{aligned}
$$

More: Instanton Models, Lattice Gauge Approach, Chiral-Quark Soliton Model

Flavor Decomposition in Semi-Inclusive DIS



$$\frac{1}{\sigma}\frac{d\sigma}{dz}(ep \to hX) = \frac{\sum_q e_q^2 f_q(x) D_q^h(z)}{\sum_q e_q^2 f_q(x)}$$

$f_q(x)$: parton distribution function

$D_q^h(z)$: fragmentation function

$z = E_\pi / \nu$

Unfavored fragmentaion D⁻

$$u \to \pi^-(d\bar{u}) \text{ or } d \to \pi^+(u\bar{d})$$

Favored fragmentation D⁺

$$u \to \pi^+(u\bar{d}) \text{ or } d \to \pi^-(d\bar{u})$$

Isospin Symmetry & Charge Conjugation Invariance:

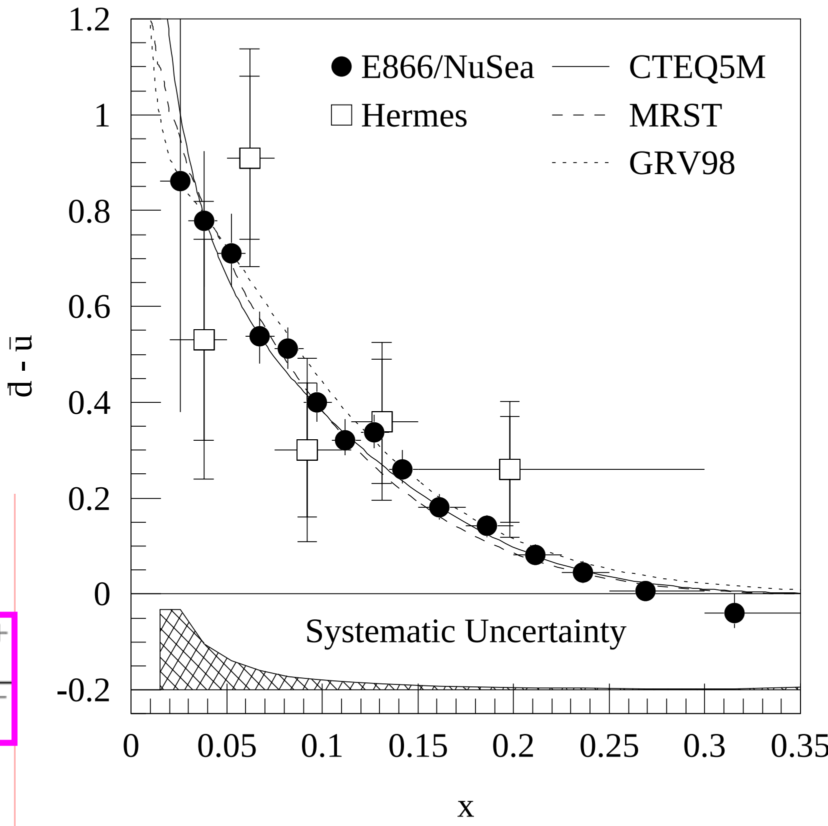
$$D_\pi^+ \equiv D_u^{\pi^+} = D_{\bar{u}}^{\pi^-} = D_{\bar{d}}^{\pi^+} = D_d^{\pi^-}$$
$$D_\pi^- \equiv D_{\bar{u}}^{\pi^+} = D_u^{\pi^-} = D_d^{\pi^+} = D_{\bar{d}}^{\pi^-}$$

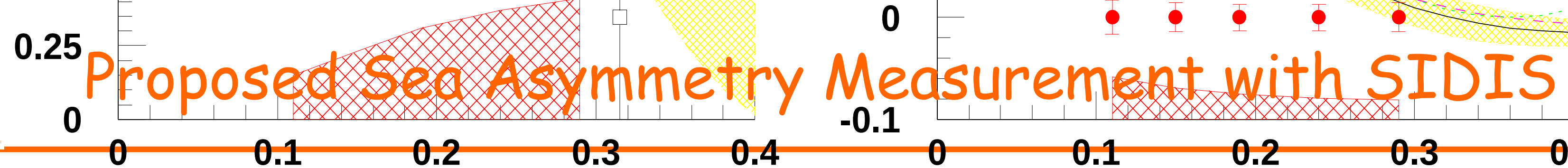
$$Y_p^{\pi^+} \propto \frac{1}{9}[4uD_\pi^+ + dD_\pi^- + 4\bar{u}D_\pi^- + \bar{d}D_\pi^+ + sD_\pi^s + \bar{s}D_\pi^s]$$
$$Y_p^{\pi^-} \propto \frac{1}{9}[4uD_\pi^- + dD_\pi^+ + 4\bar{u}D_\pi^+ + \bar{d}D_\pi^- + sD_\pi^s + \bar{s}D_\pi^s]$$
$$Y_n^{\pi^+} \propto \frac{1}{9}[4dD_\pi^+ + uD_\pi^- + 4\bar{d}D_\pi^- + \bar{u}D_\pi^+ + sD_\pi^s + \bar{s}D_\pi^s]$$
$$Y_n^{\pi^-} \propto \frac{1}{9}[4dD_\pi^- + uD_\pi^+ + 4\bar{d}D_\pi^+ + \bar{u}D_\pi^- + sD_\pi^s + \bar{s}D_\pi^s]$$

$$r(x,z) = \frac{Y_p^{\pi^-}(x,z) - Y_n^{\pi^-}(x,z)}{Y_p^{\pi^+}(x,z) - Y_n^{\pi^+}(x,z)}$$

$$J(z) = \frac{3}{5}\left(\frac{1+D'(z)}{1-D'(z)}\right), \quad D'(z) = \boxed{\frac{D_\pi^-}{D_\pi^+} \approx \frac{4Y_d^{\pi^-} - Y_d^{\pi^+}}{4Y_d^{\pi^+} - Y_d^{\pi^-}}}$$

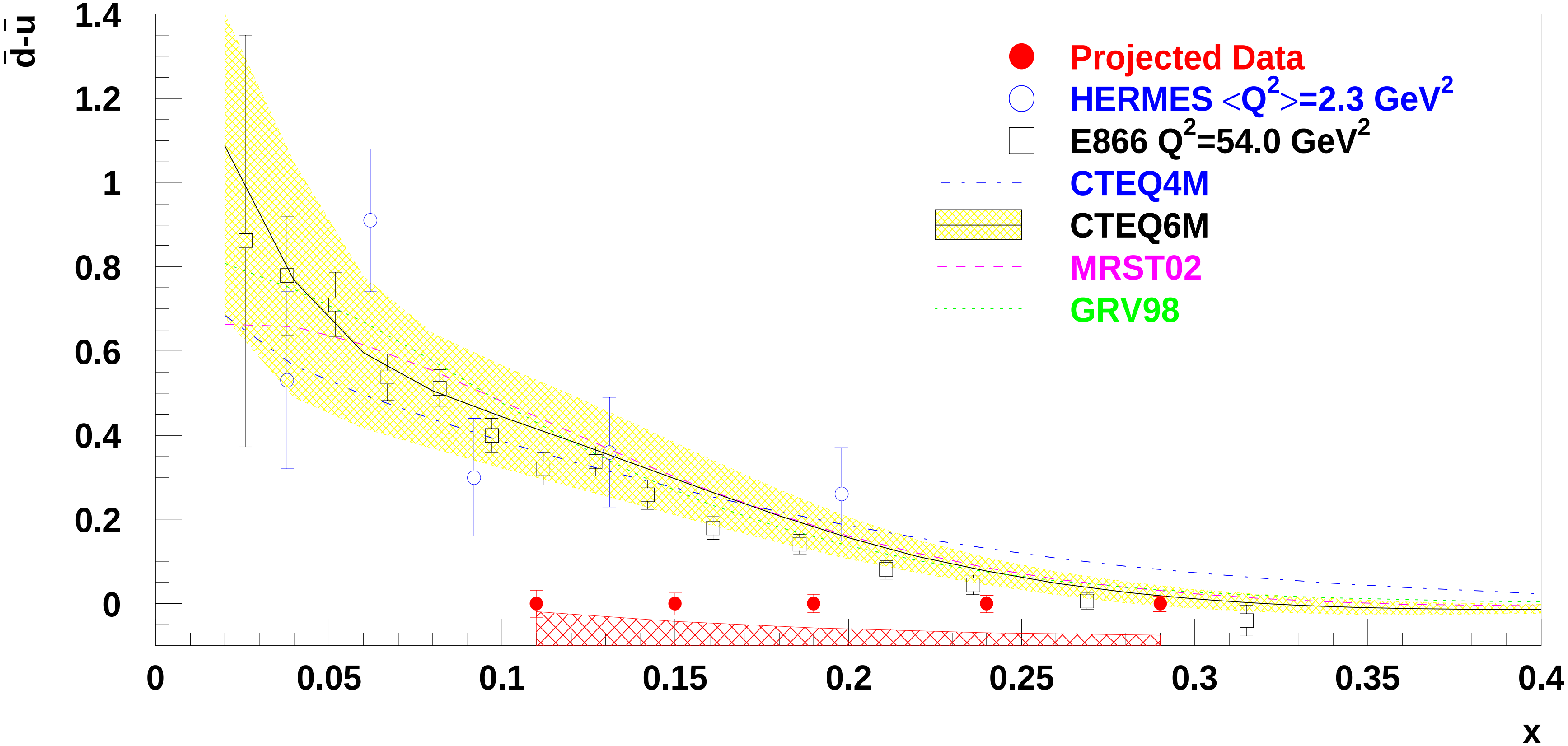
$$r_H \equiv \frac{J(z)[1-r(x,z)] - [1+r(x,z)]}{J(z)[1-r(x,z)] + [1+r(x,z)]} = \frac{\bar{d}(x) - \bar{u}(x)}{u(x) - d(x)}$$





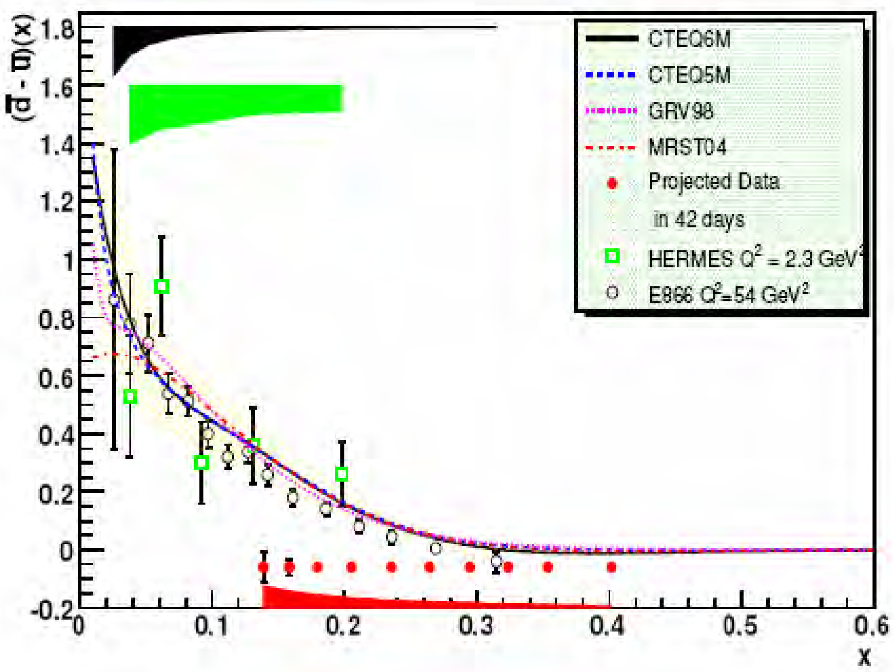
Proposed Sea Asymmetry Measurement with SIDIS

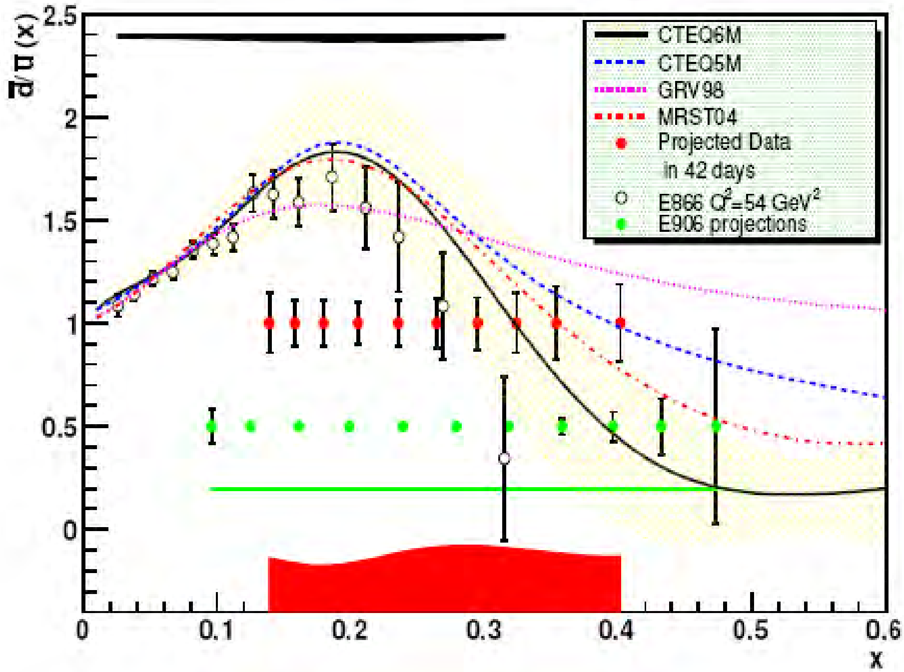
L.Y.Zhu, J.P.Chen, X. Jiang and J.C. Peng, JLab Hall A PR04-114



Sea Asymmetry Measurement with JLab Upgrade

H. Gao, A.Bruell, H.Mkrchyan, J.P.Chen&L.Y.Zhu, JLab Proposal PR12-06-111





The systematic uncertainty with SIDIS is large.

Fermilab E866/NuSea

(M. Leitch)

- Data in 1996-1997
- 800 GeV proton beam

$$\sqrt{s} = 38.8\mathrm{GeV}$$

Fermilab E906

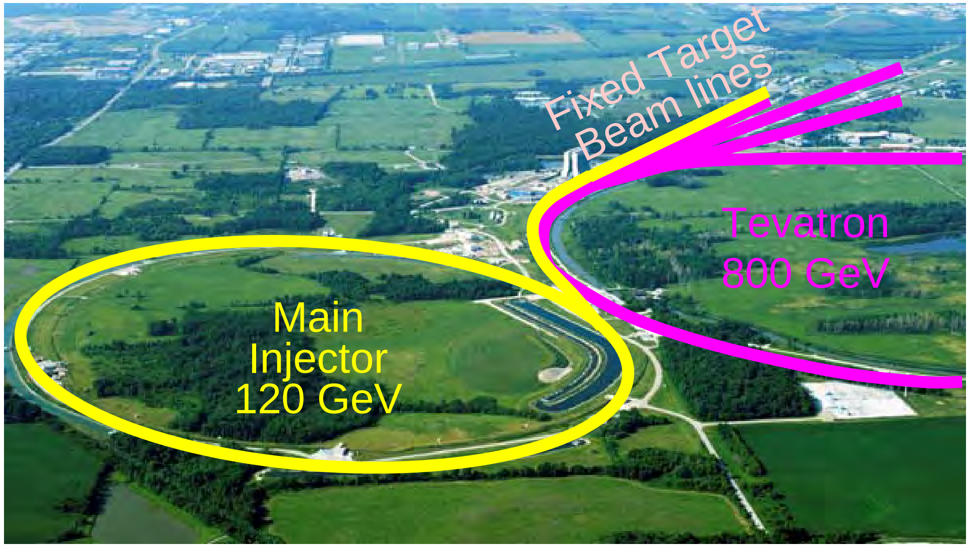
(D. Geesaman, P. E. Reimer)

- Data in 2009
- 120 GeV proton Beam

$$\sqrt{s} = 15.1\mathrm{GeV}$$

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9x_1 x_2 s} \sum_i e_i^2 \left[q_{ti}(x_t)\bar{q}_{bi}(x_b) + \bar{q}_{ti}(x_t)q_{bi}(x_b)\right]$$

$$\sigma_{J/\Psi} = A\exp(-B\sqrt{M_{J/\Psi}^2/s})$$



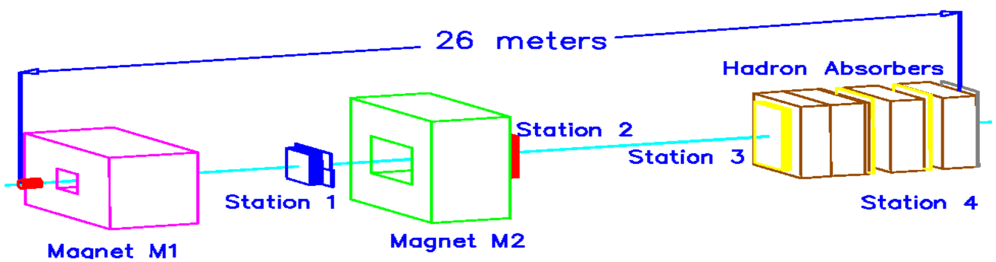
- Cross section scales as 1/s
- Backgrounds, primarily J/ψ decays drop with s

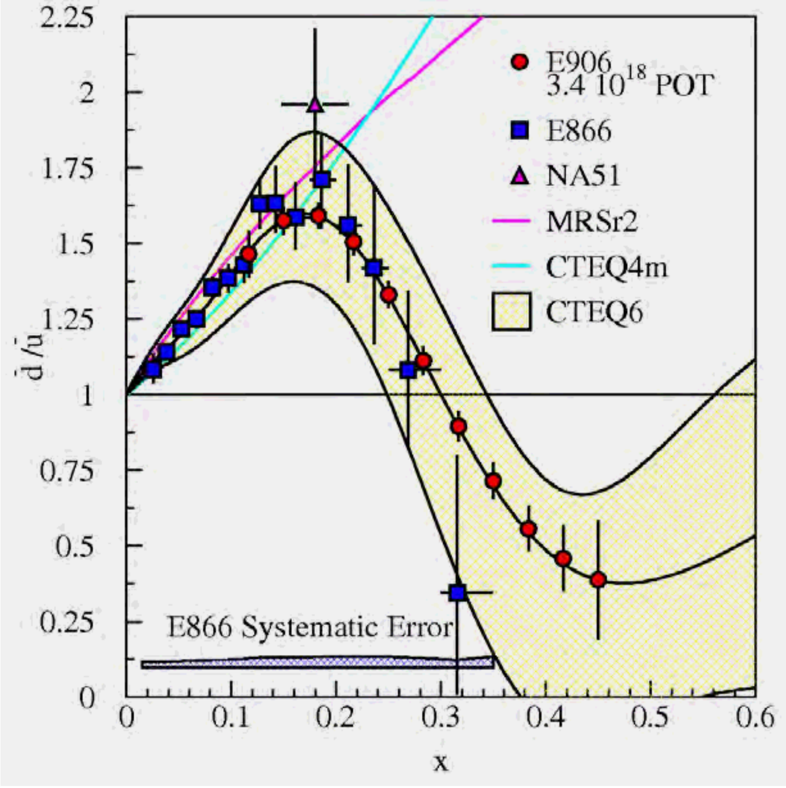
E789,PRD52(1995)1507

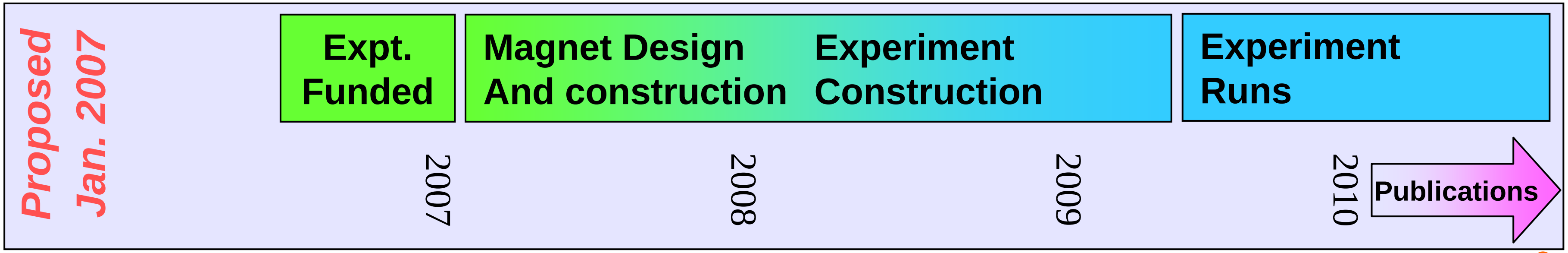
50× statistics!!

Fermilab E906 Drell-Yan timeline

- 2001: approved by Fermilab PAC
- 2006: reaffirmed by Fermilab PAC
- Funding request to DOE:
  ~$2M primarily for the magnets.

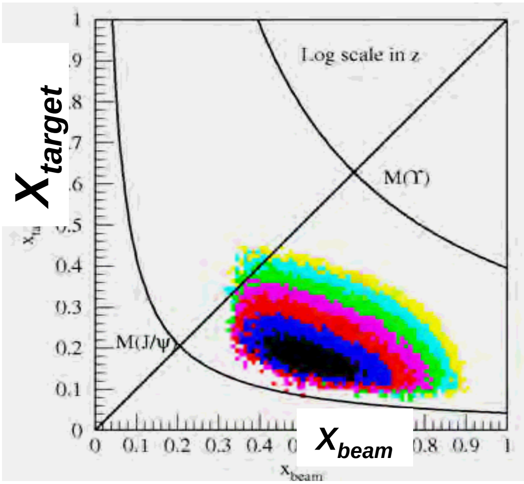




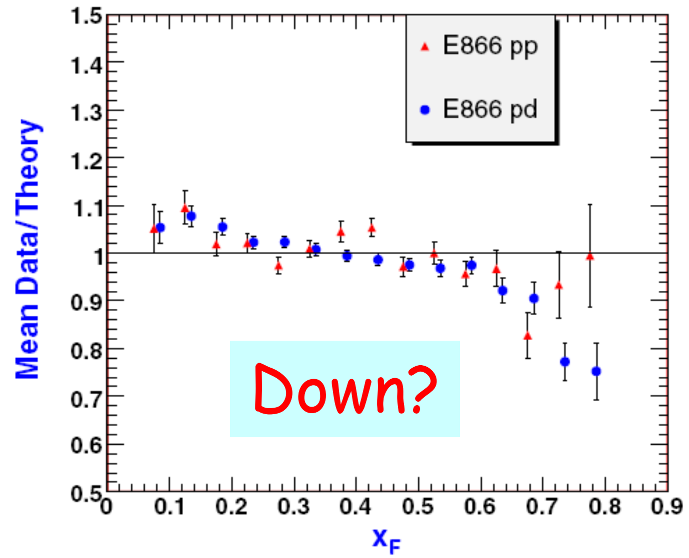


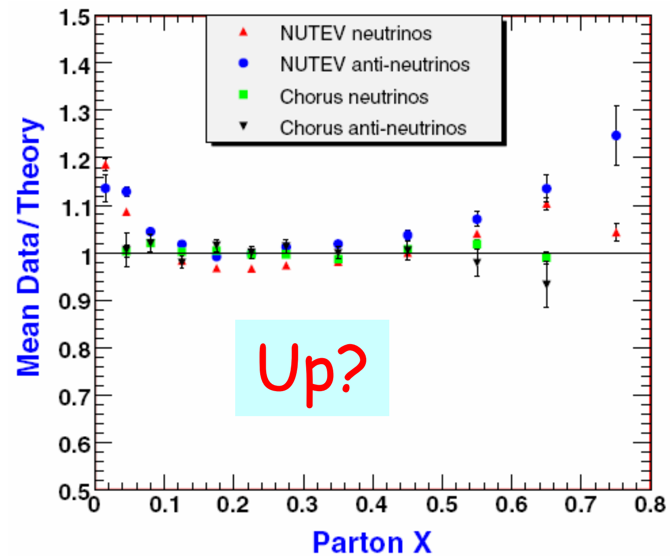
Impact of Drell-Yan on large-x PDFs

- E906 Drell-Yan will also probe the large-x region, like E866.



$$x_F = x_b - x_t$$

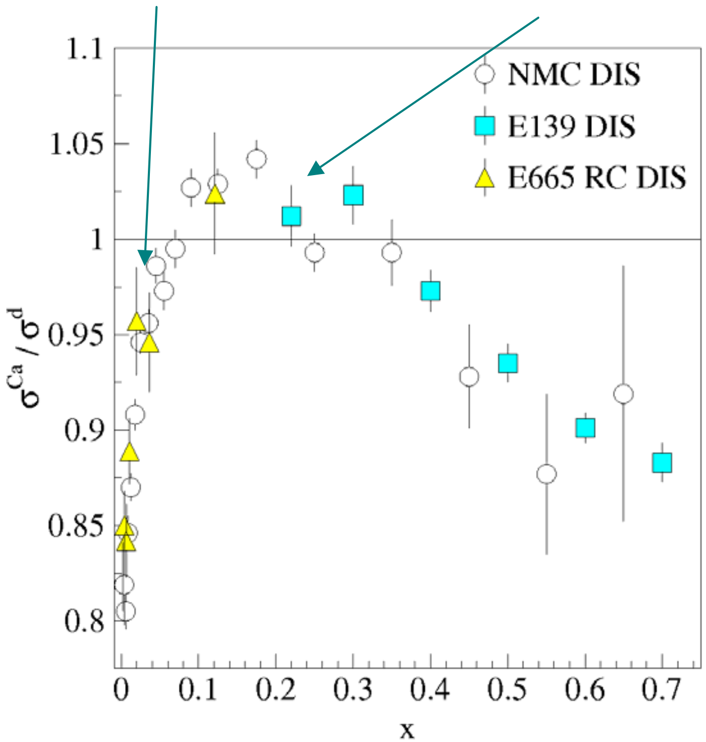




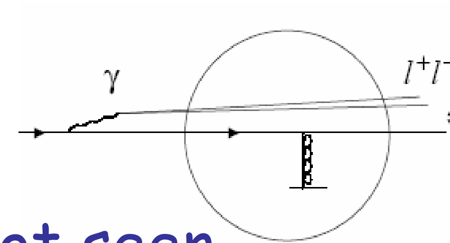
- There is some discrepancy between the E866 and NUTEV. Due to he nuclear corrections for NUTEV ?

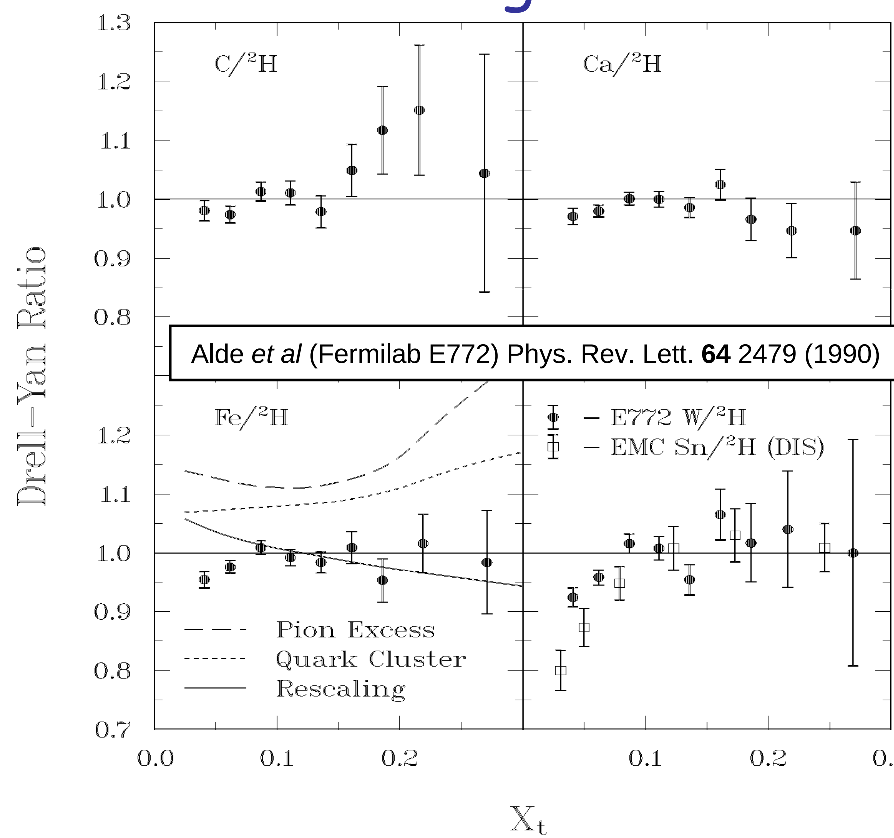
Owens *et al.*, PRD75(2007) 054030

- DIS: shadowing, antishadowing,…



- E772 Drell-Yan: shadowing seen; antishadowing not seen .

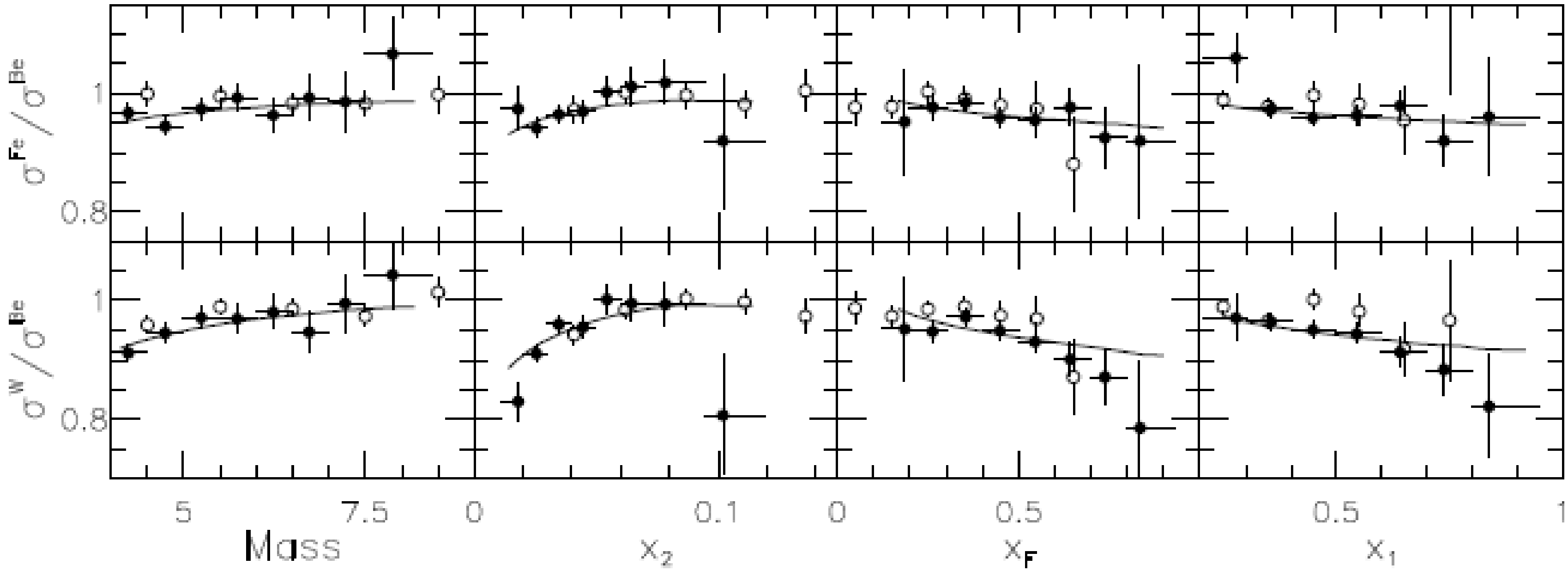


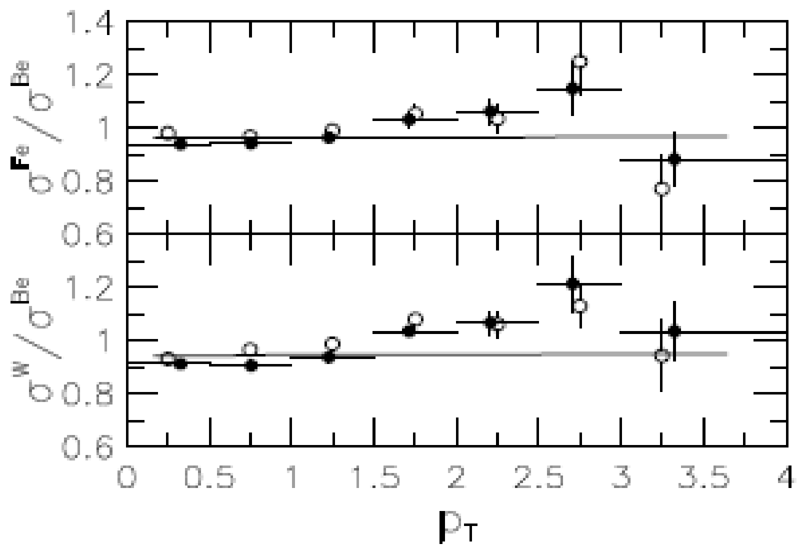


Alde *et al* (Fermilab E772) Phys. Rev. Lett. **64** 2479 (1990)

E866 Drell-Yan with Nuclear Targets

E866(Vasiliev *et al.*),PRL83(1999)2304



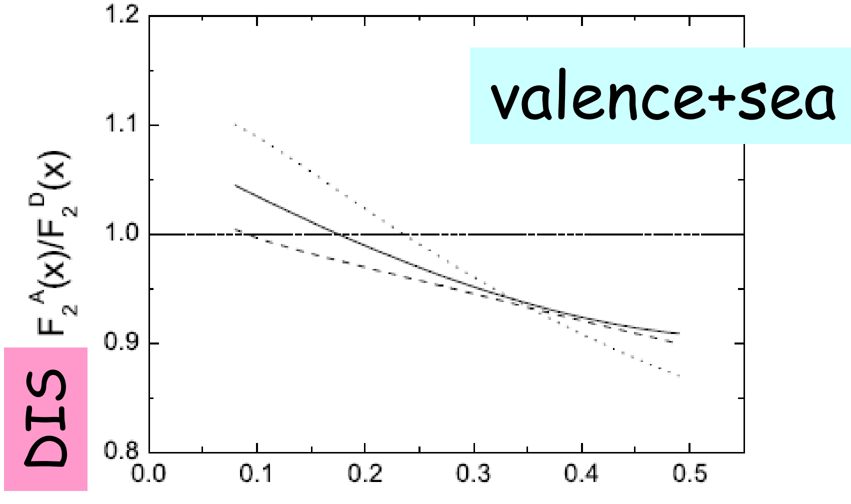


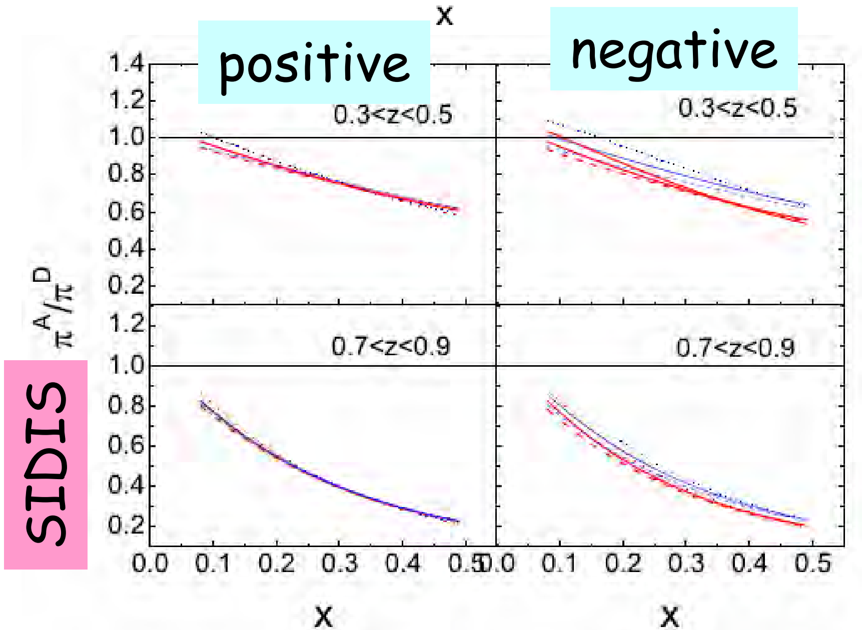
Compared with E772:

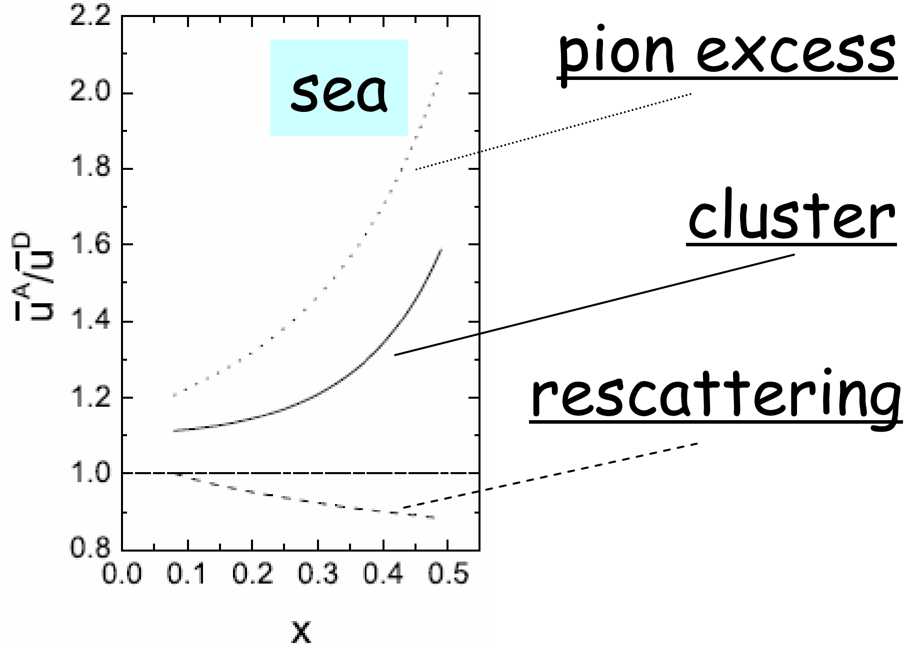
smaller x_2

bigger x_1,x_F

Models for EMC effect



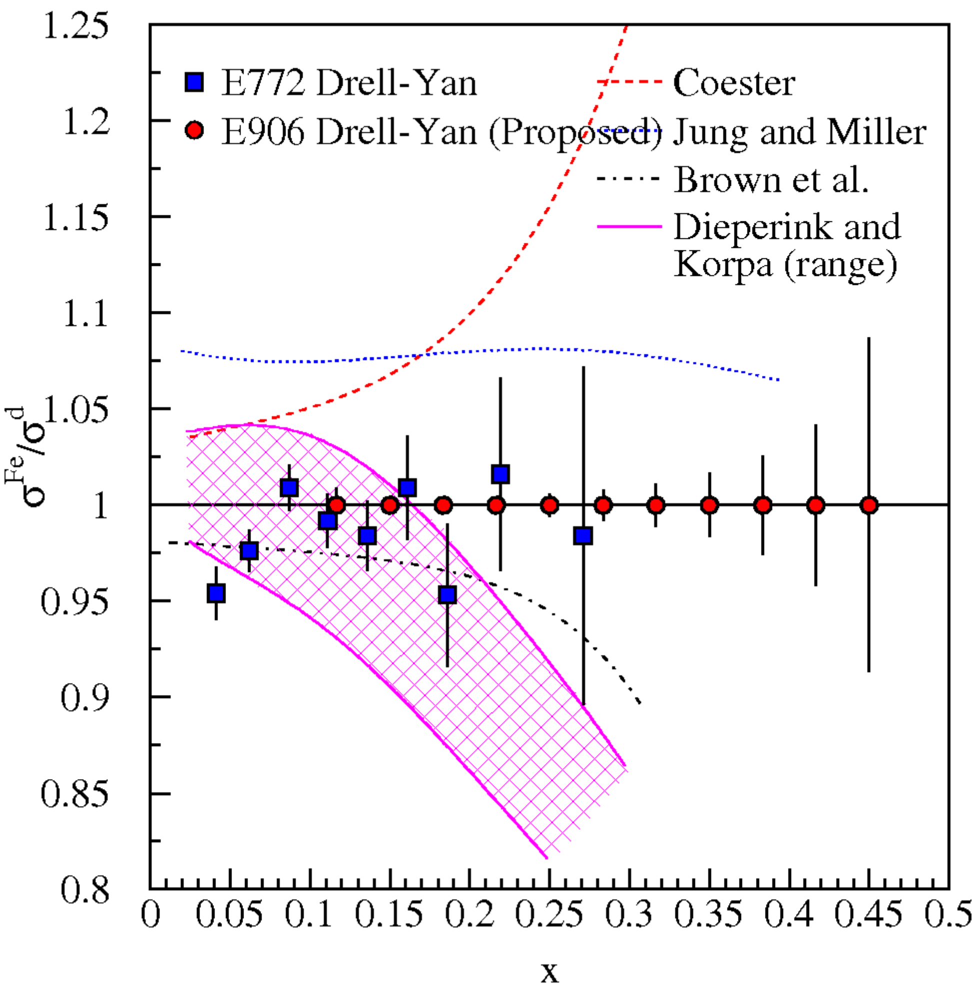




Lu & Ma, PRC74(2007)055202

E906 Drell-Yan with Nuclear Targets

- E906 will use three nuclear targets in addition to proton and deuterium.
- E906 will significantly reduce the statistical uncertainties while extend to higher x.
- The improvement will be essential to check different models.



Partonic Energy Loss

- The nuclear dependence is more sensitive to the partonic energy loss at low beam energy.

$$x_1^A = x_1^p + \alpha \frac{<L>_A}{E_p}; \alpha = \frac{dE}{dx}$$

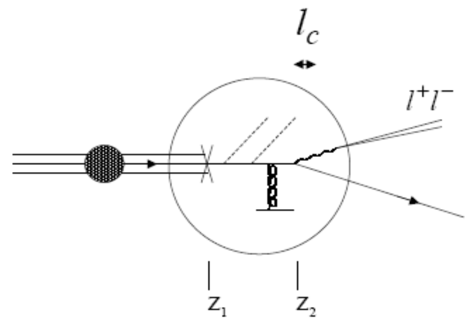
$$\frac{d\sigma^{DY}_{p+A}}{d\sigma^{DY}_{p+D}}\Big|_{x_1 \to 1, x_2} \sim 1 - \frac{2\alpha <L>_A}{E_p(1-x_1^p)}$$

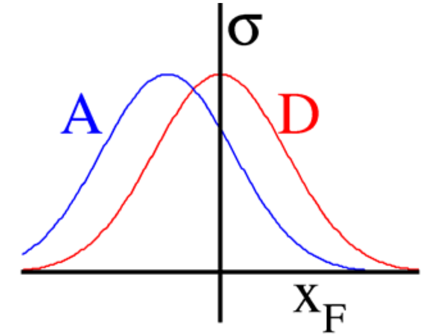
Garvey & Peng, PRL90(2003)092302

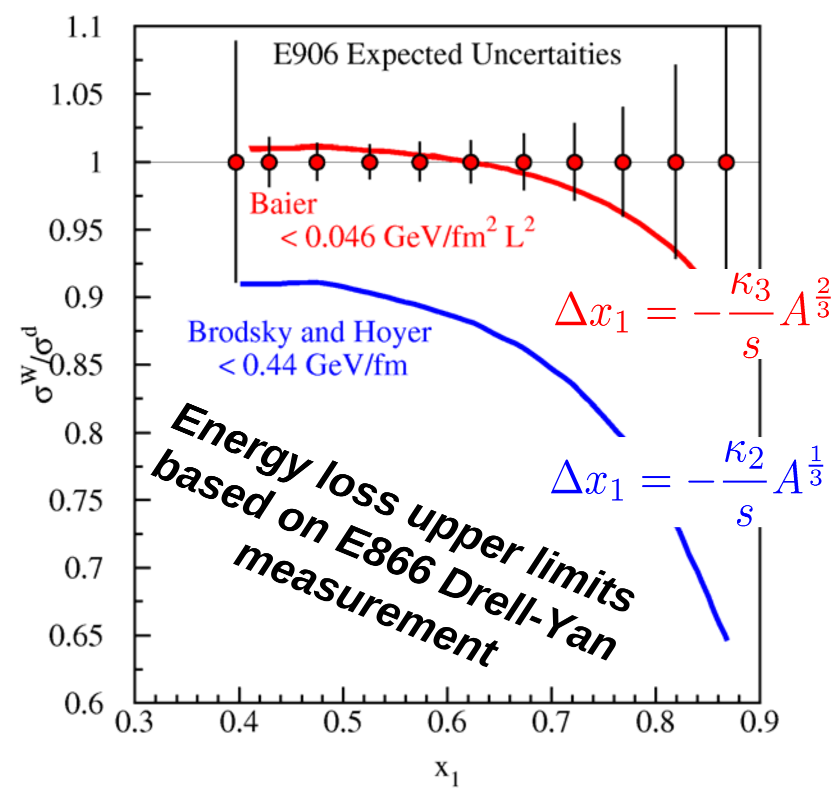
- Difficulty with Drell-Yan: At fixed $x_F = x_1 - x_2$, the partonic energy loss at large x_1 is coupled with shadowing effect at very small x_2. E866 only set the limit on energy loss.

E866(Vasiliev *et al.*),PRL83(1999)2304

- With good statistics, E906 allows us to select a region with small shadowing at x_2>0.1.

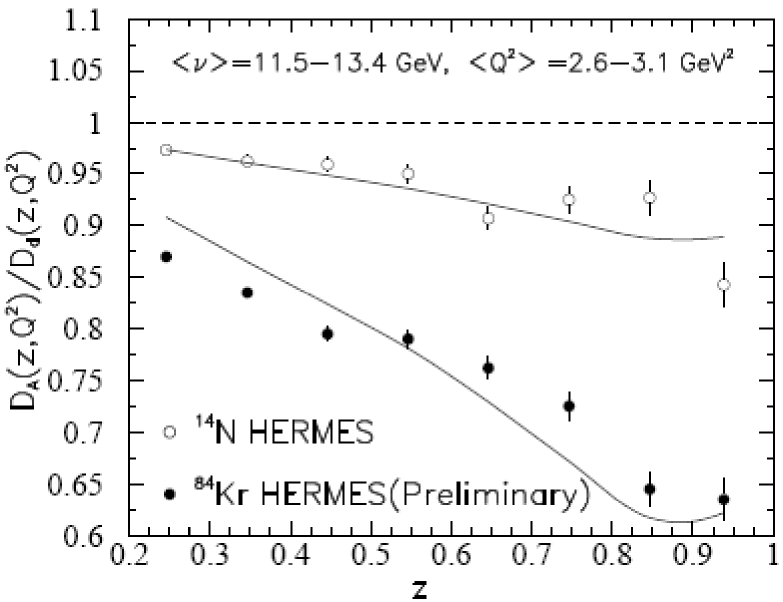


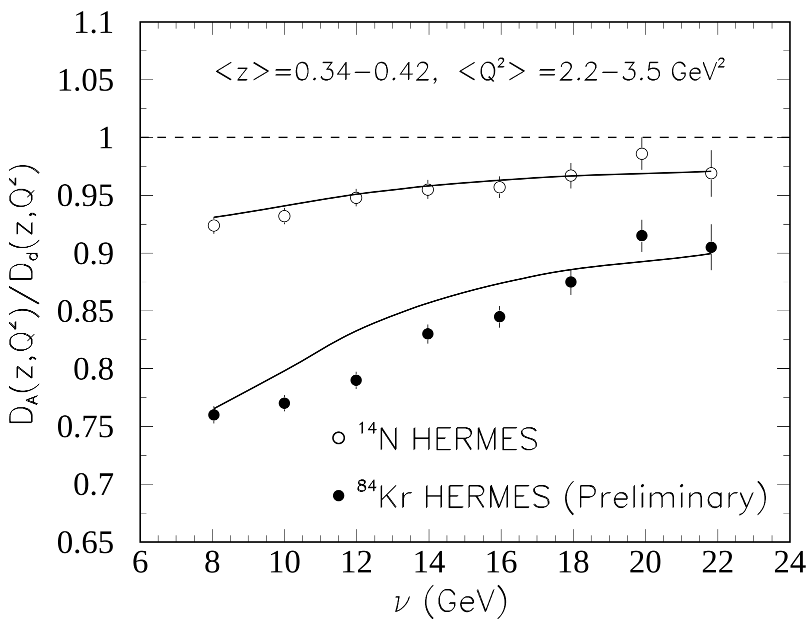




Energy Loss from SIDIS

❖ HERMES results: Wang & Wang, PRL89(2002) 162301





dE/dx=0.5 GeV/fm

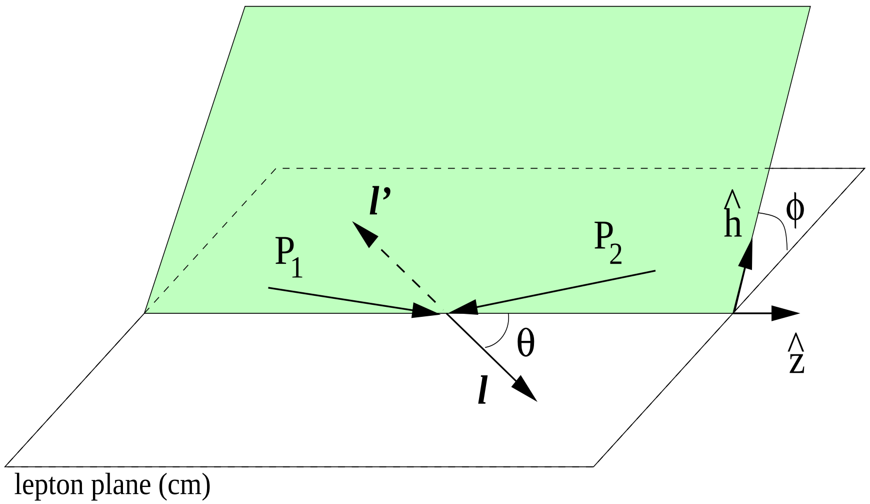
❖ The production time (related to the energy loss/p_T broadening) as well as the hadron formation length will be measured with CLAS12.

W. Brooks *et al.*, JLab proposal PR12-06-117.

Angular Distribution in the Drell-Yan

$$pN \rightarrow \mu^+\mu^- X$$

$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega} = \frac{3}{4\pi}\frac{1}{\lambda+3}[1+\lambda\cos^2\theta+\mu\sin 2\theta\cos\phi+\frac{\nu}{2}\sin^2\theta\cos 2\phi]$$



In the simple parton model:

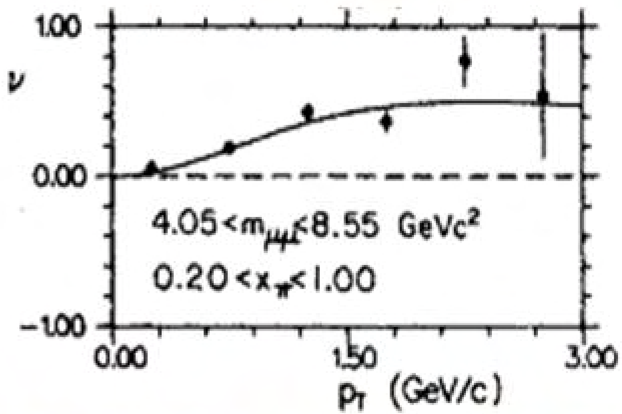
(for massless quarks and θ measured relative to the annihilation axis)

λ=1 and μ=ν=0

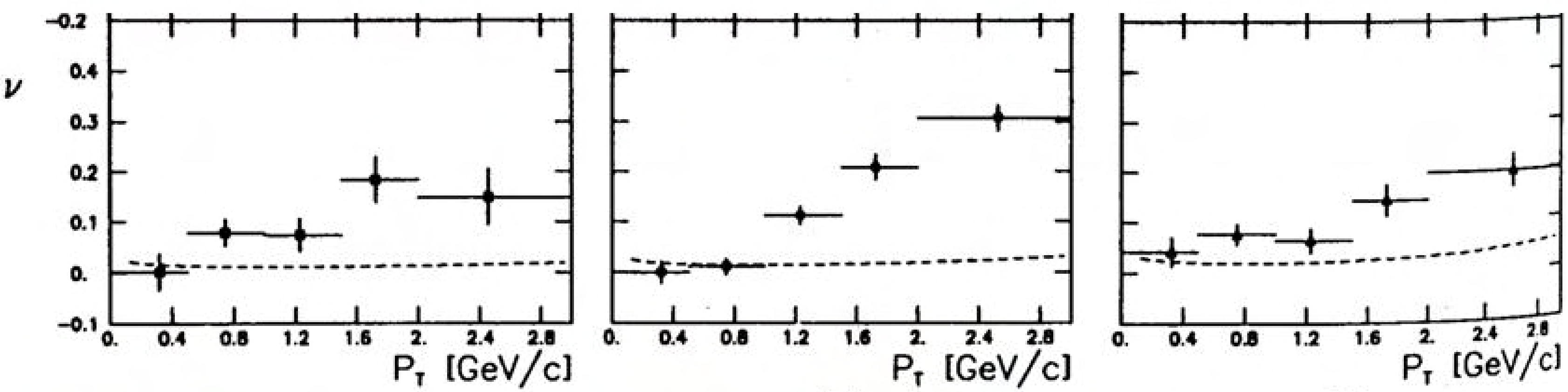
$$\frac{d\sigma}{d\Omega} \propto 1+\cos^2\theta$$

cos2φ Distribution in the πW Drell-Yan

E615 at Fermilab: 252 *GeV* π^- + W   Conway et al., PRD39,92(1989)



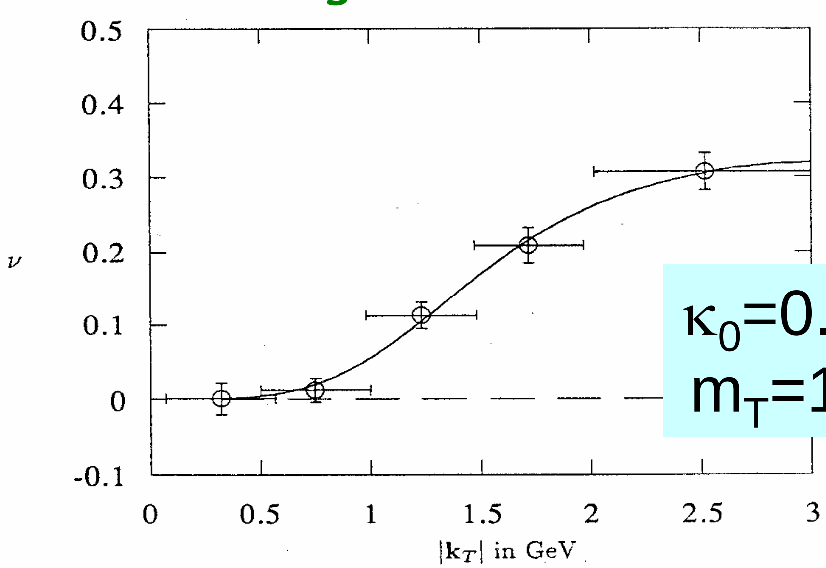
NA10 at CERN: 140/194/286 *GeV* π^- + W Z. Phys. *C37*, 545 (1988)



QCD Vacuum Effect

- The factorization-breaking spin correlation due to nontrivial QCD vacuum may fit the NA10 data at 194 GeV

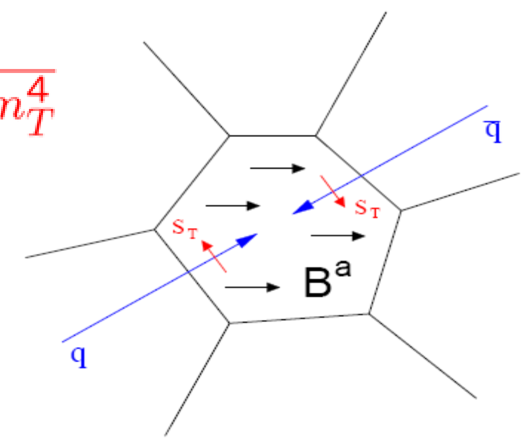
Brandenburg, Nachtmann & Mirkes, Z. Phy. C60,697(1993)



κ_0=0.17
m_T=1.5

$$\nu \approx 2\kappa = 2\kappa_0 \frac{p_T^4}{p_T^4 + m_T^4}$$

$$\lambda \approx 1; \mu \approx 0$$



- The helicity flip in the instanton-induced contribution may lead to nontrivial vacuum.

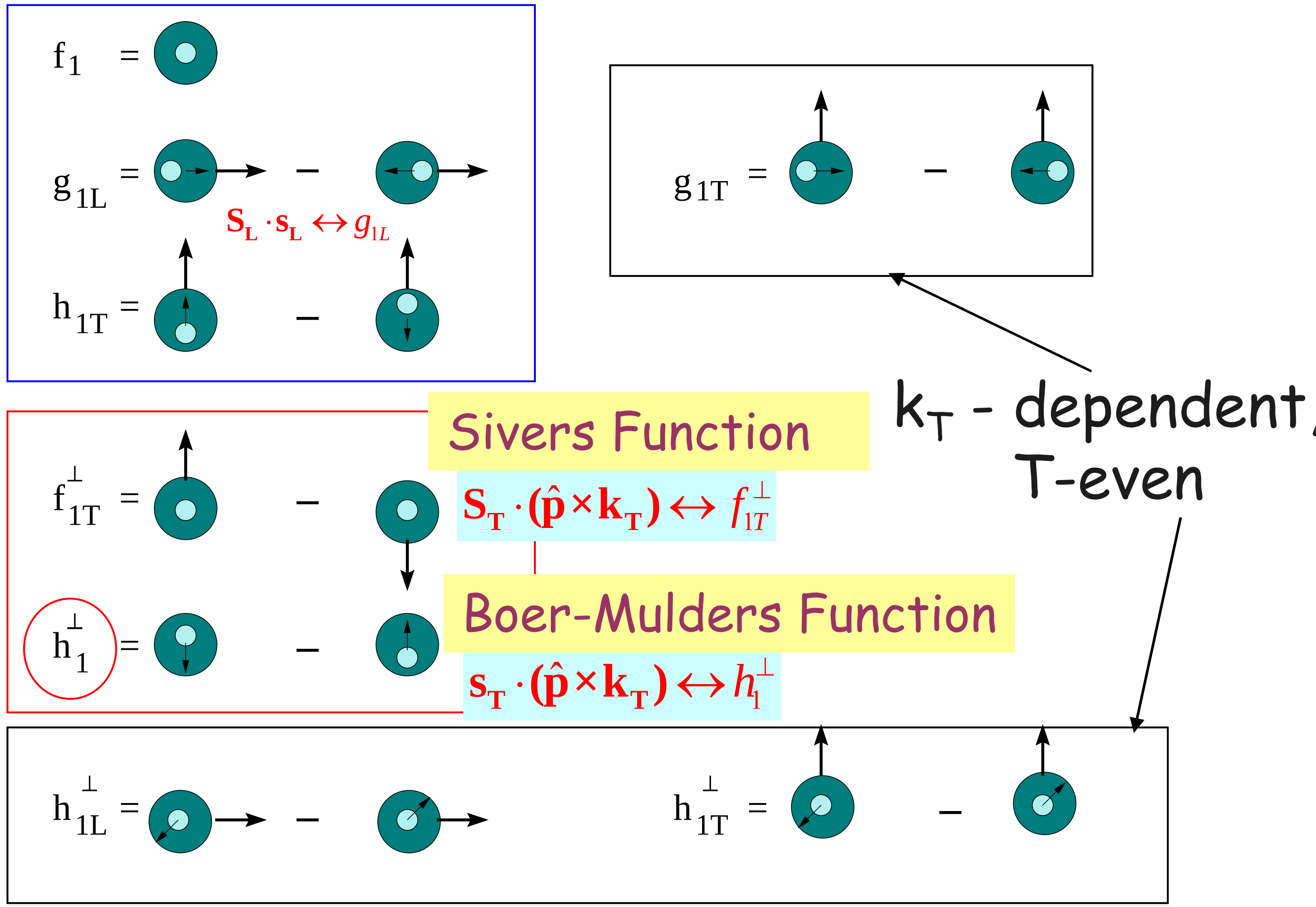
Boer,Brandenburg,Nachtmann&Utermann, EPC40,55(2005).

Brandenburg,Ringwald&Uermann, hep-ph/0605234

- This vacuum effect should be flavor blind.

Leading-Twist Parton Distribution Functions

Survive k_T integration



k_T - dependent,
T-odd

$$\left.\frac{h_1^{\perp}}{f_1}\right|_{x\to 1} \sim (1-x)$$

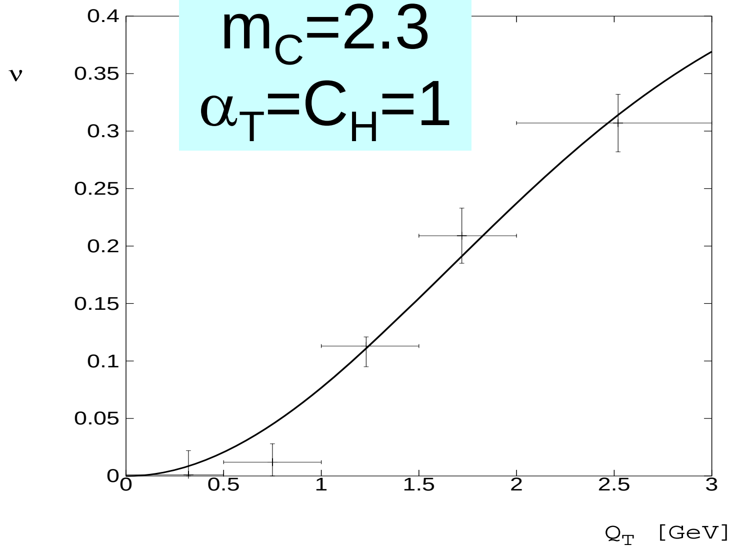
Brodsky & Yuan, hep-ph/0610236.

Boer-Mulders Function $h_1^\perp$

❖ An spin-correlation approach in terms of $h_1^\perp$ can fit the NA10 data at 194 GeV. Boer, PRD60,014012(1999)

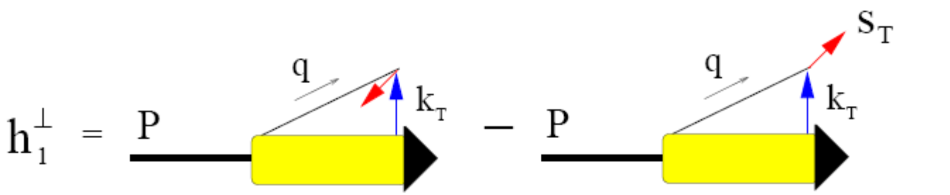
$$\nu = 2\kappa = 4\kappa_1 \frac{Q_T^2 M_C^2}{(Q_T^2 + 4M_C^2)^2}; \quad \lambda = 1; \mu = 0$$

$\kappa_1=0.5$
$m_C=2.3$
$\alpha_T=C_H=1$



$$\boxed{\nu \propto h_1^\perp(x_1)\bar{h}_1^\perp(x_2)}$$

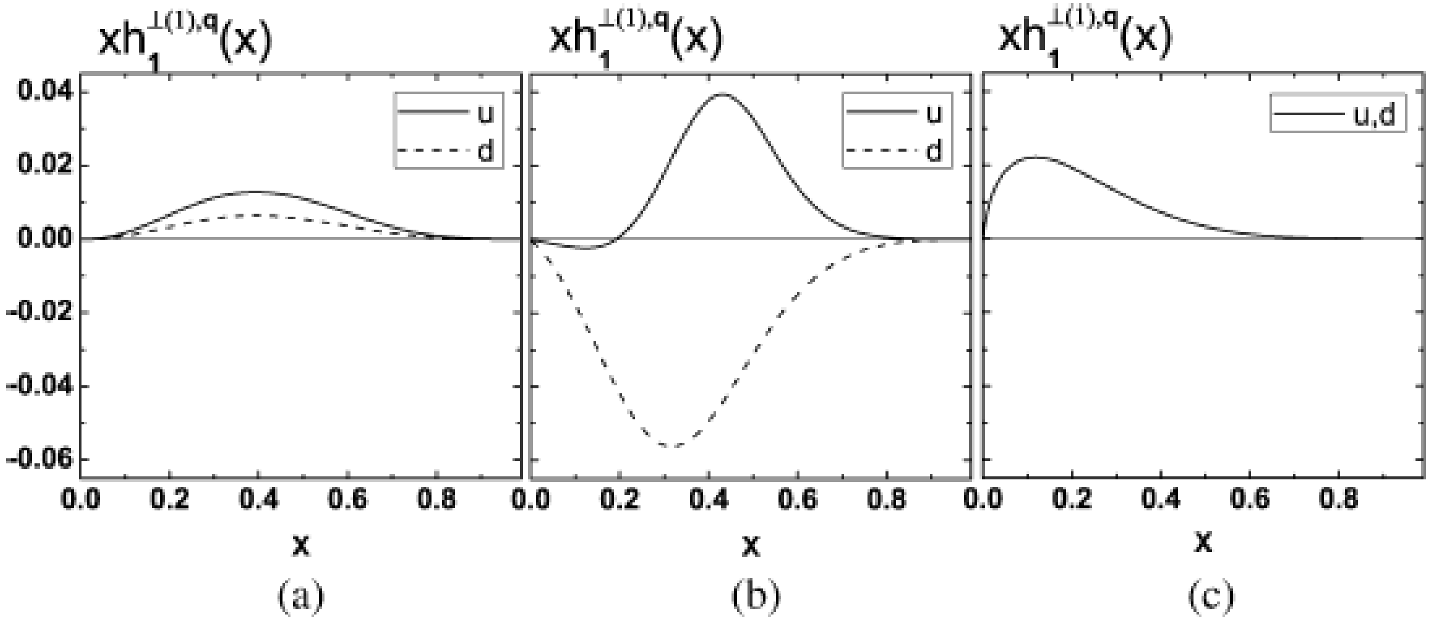
$$h_1^\perp(x, k_T^2) = \frac{\alpha_T}{\pi} c_H \frac{M_C M_H}{k_T^2 + M_C^2} e^{-\alpha_T k_T^2} f_1(x)$$



❖ On the base of quite general arguments, for $|q_T| \ll Q(=m_{\mu\mu})$, Salvo,hep-ph/0407208. $\nu \propto |q_T|^2/Q^2$

Boer-Mulders Functions from Models

Z. Lu, B.Q. Ma and I. schmidt, Phys. Lett. B639(2006)494.

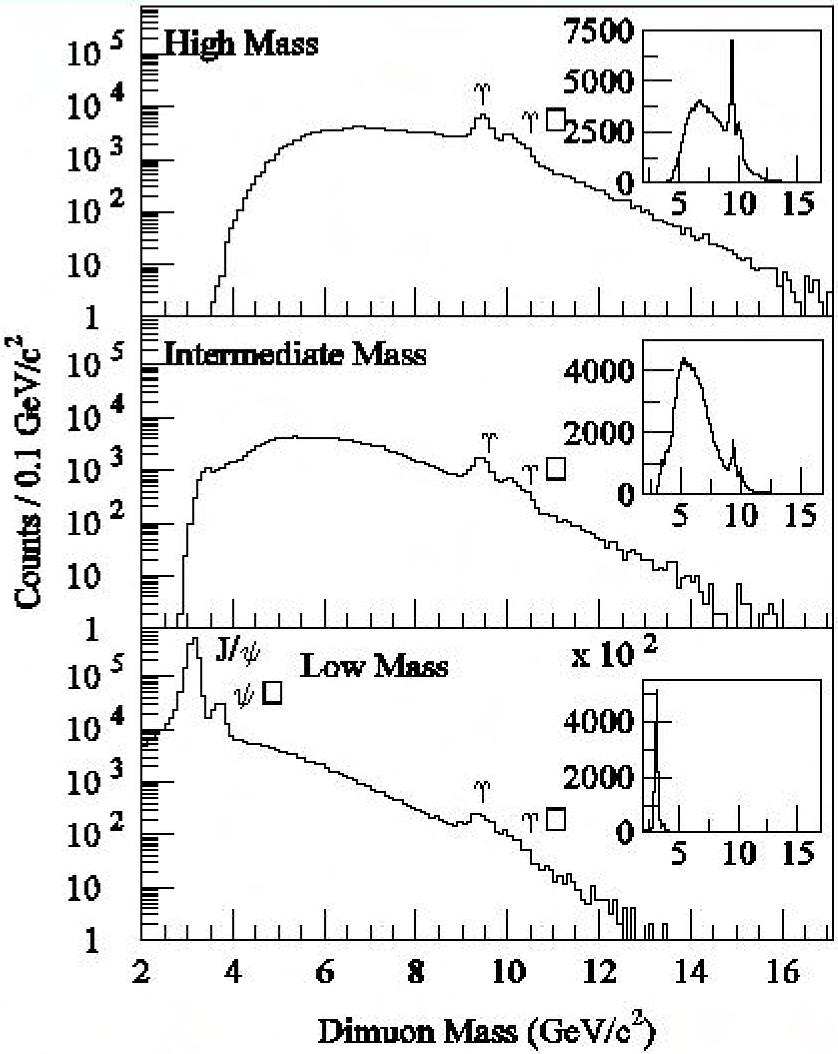


(a)MIT bag model: F. Yuan, Phys. Lett. B575,45(2003).

(b)Spectator model with axial-vector diquark: Bacchetta, Schaefer & Yang, Phys. Lett. B578,109(2004).

(c)Large-N_c limit, P.V. Pobylitsa, hep-ph/0301236

E866 Dimuon Mass Distribution



$\sqrt{s} = 38.8\text{GeV}$

Target: Proton, Deuterium

Data used for cos2 ϕ analysis:

High Mass: dset7-39k (+ polarity)

dset8-85k (+ polarity)

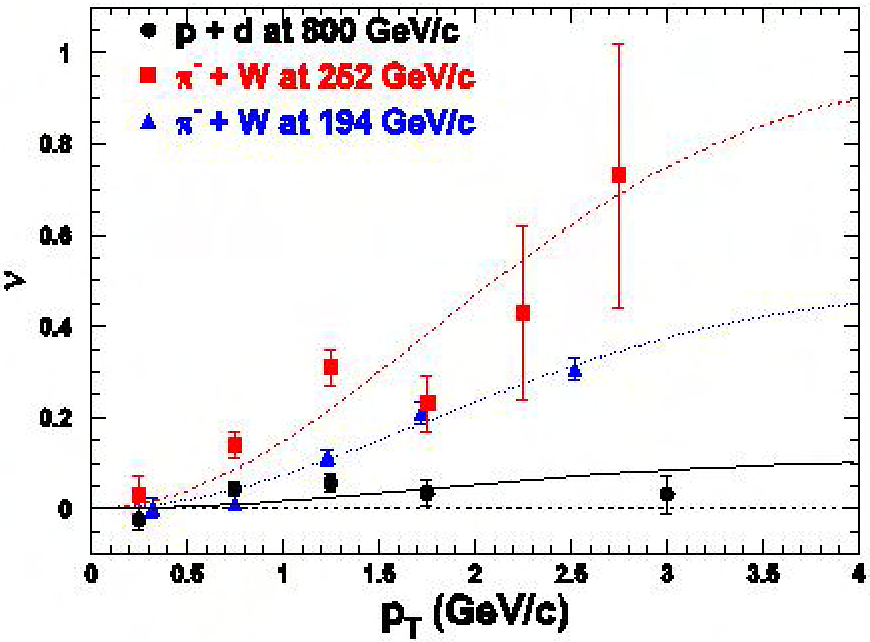
dset11-25k (- polarity)

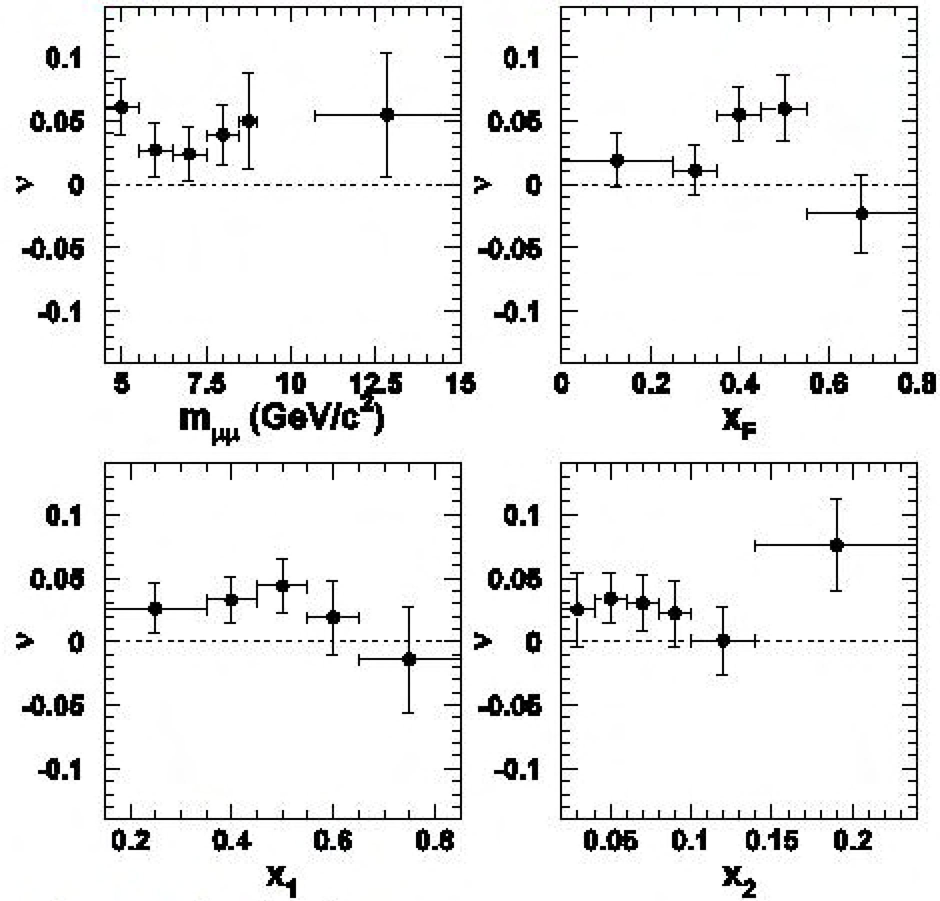
Low Mass: dset5-68k (+ polarity)

Towell et al., Phys.Rev. D64 (2001) 052002

Azimuthal Distribution from E866 pd Drell-Yan

L.Y. Zhu, J.C. Peng, P. Reimer et al., hep-ex/0609005.



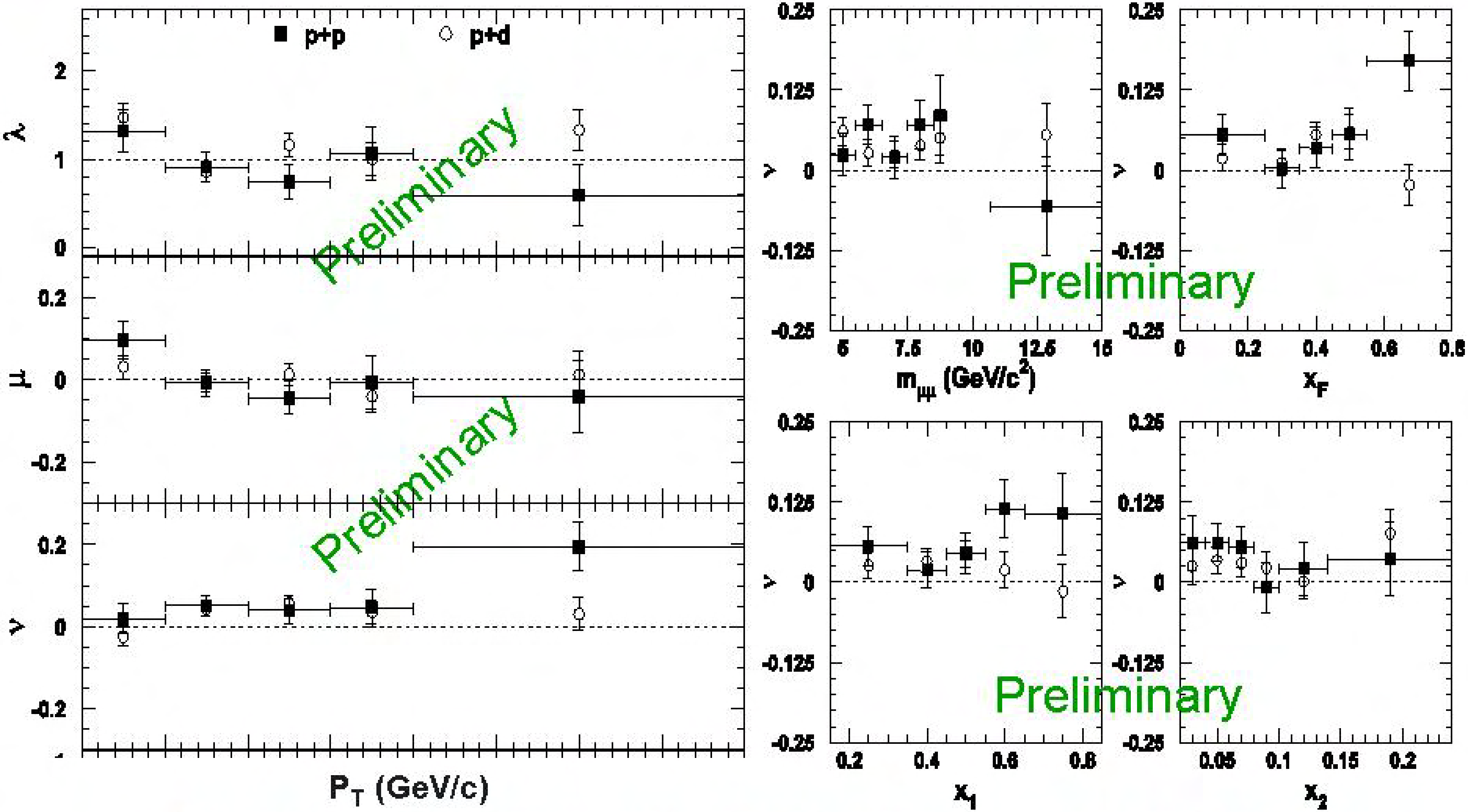


With Boer-Mulders function $h_1^{\perp}$:

$\nu\,(\pi^- W \rightarrow \mu^+\mu^- X) \sim$ valence $h_1^{\perp}(\pi)$ * valence $h_1^{\perp}(p)$

$\nu\,(pd \rightarrow \mu^+\mu^- X) \sim$ valence $h_1^{\perp}(p)$ * *sea* $h_1^{\perp}(p)$

Angular Distribution in E866 pp/pd Drell-Yan



The statistical uncertainties can be greatly improved in E906.

Boer-Mulders Function from SIDIS

- The cos2phi distribution in SIDIS is related to the coupling of Boer-Mulders function and Collins fragmentation function. It is sensitive to valence Boer-Mulders function at large x.

$$\sigma_{UU}^{ep\to eh} \sim \sum_q C_{Cahn} f_1 \otimes D_1 + h_1^\perp \otimes H_1^\perp$$

H. Avakian, Z.-E.Meziani,K.Joo and B.Seitz,

JLab proposal PR12-06-112

- It will be very interesting to check

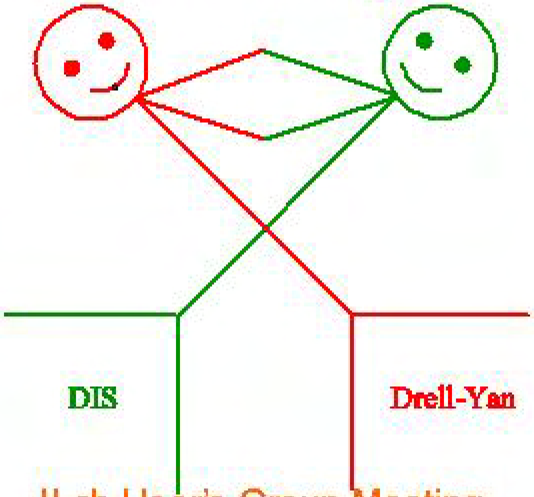
$h_1^\perp(x,p_T^2)_{SIDIS} = -h_1^\perp(x,p_T^2)_{DY}$

similar to that for Sivers function

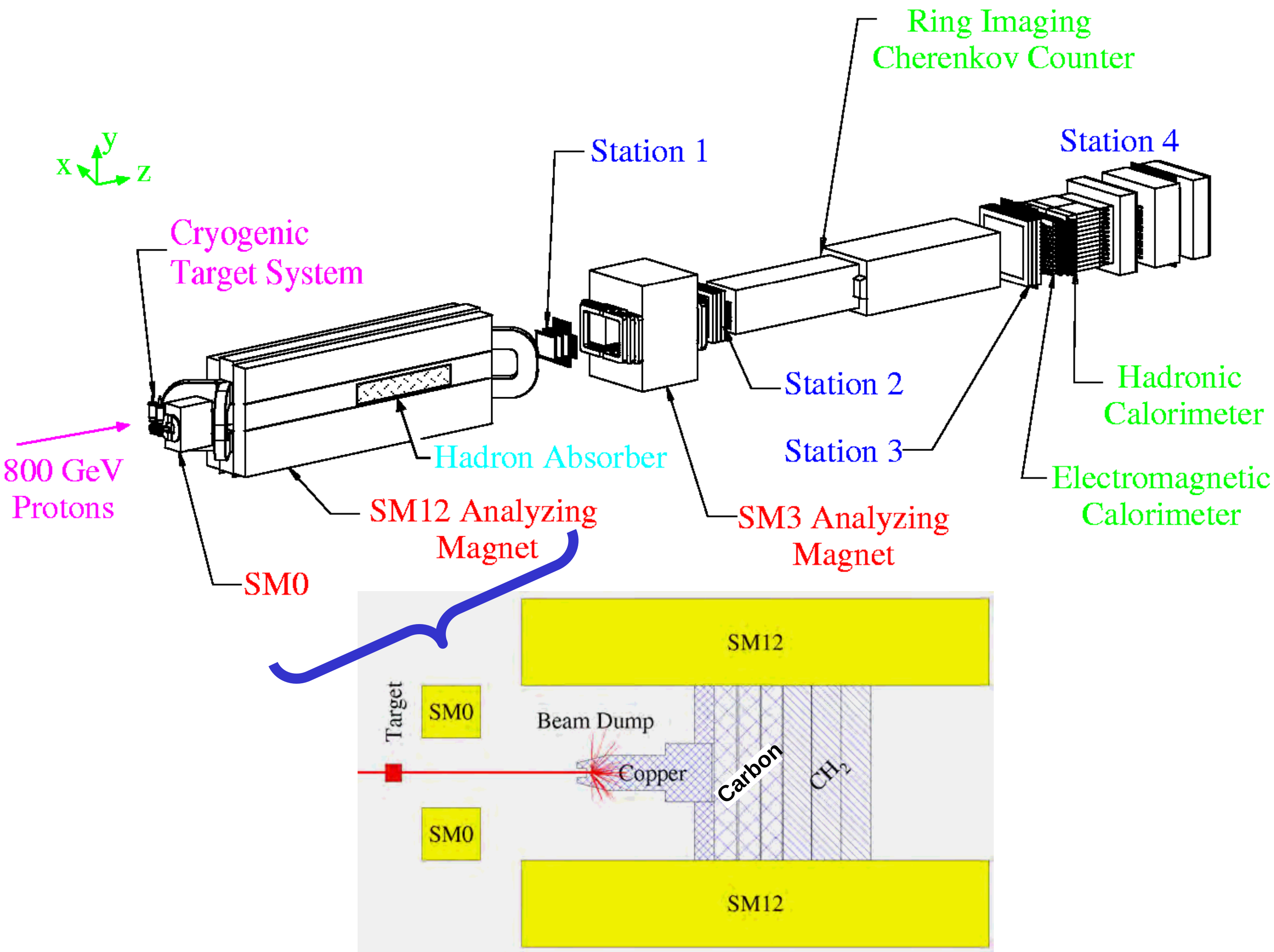
Collins, PLB536, 43(2002)

Summary

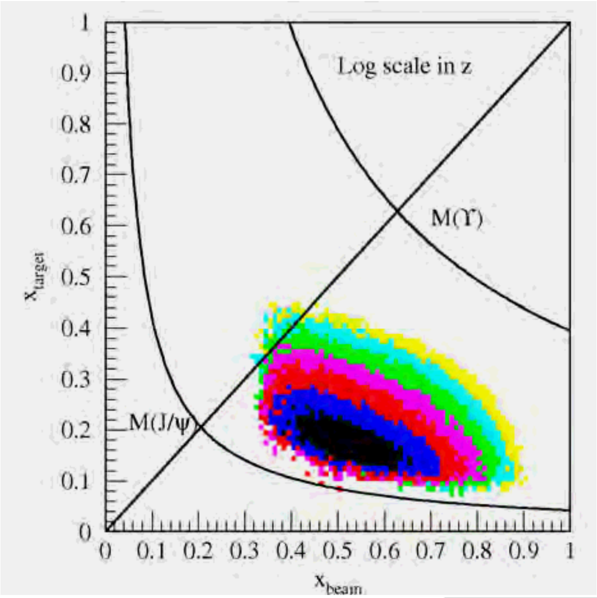
- The knowledge on sea quark distribution, nuclear effects and TMD PDFs are basically data driven. The Drell-Yan, complementary to DIS/SIDIS, is also a powerful tool to explore the proton structure.
- Drell-Yan including Fermilab E866 has produced a lot of interesting results. Fermilab E906 will extend the measurements to the large x region and further improve the statistics of the world unpolarized Drell-Yan data.

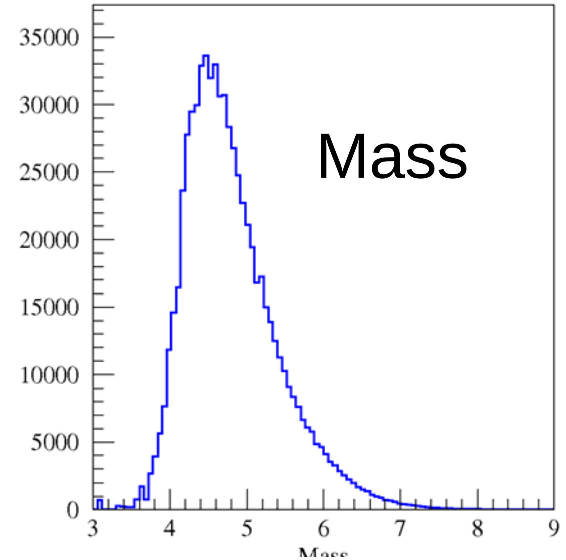


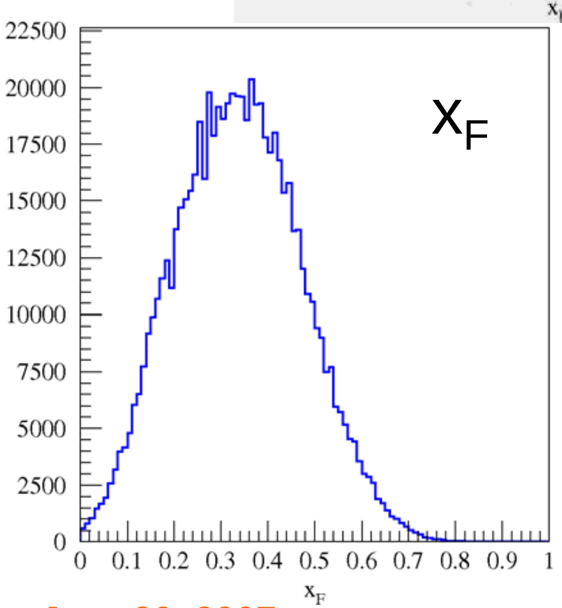
FNAL E866/NuSea Detector

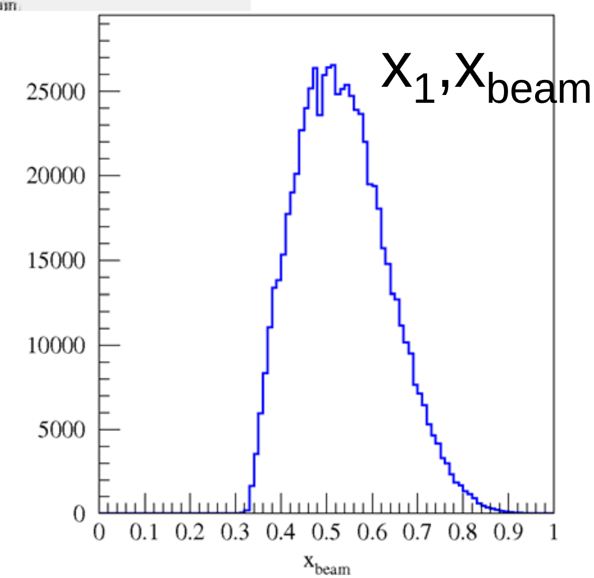


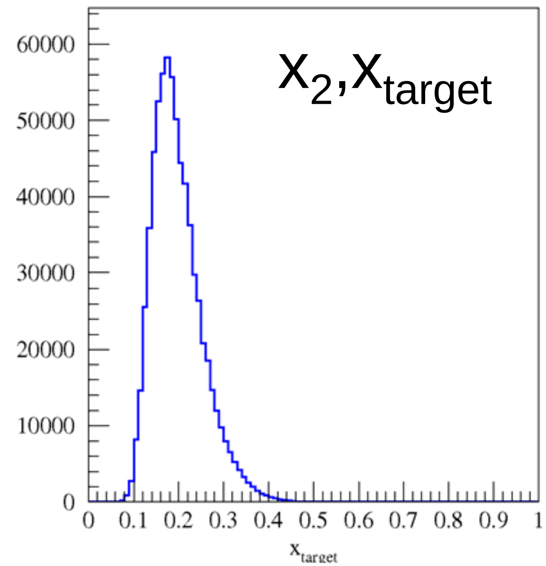
E906 Drell-Yan Acceptance





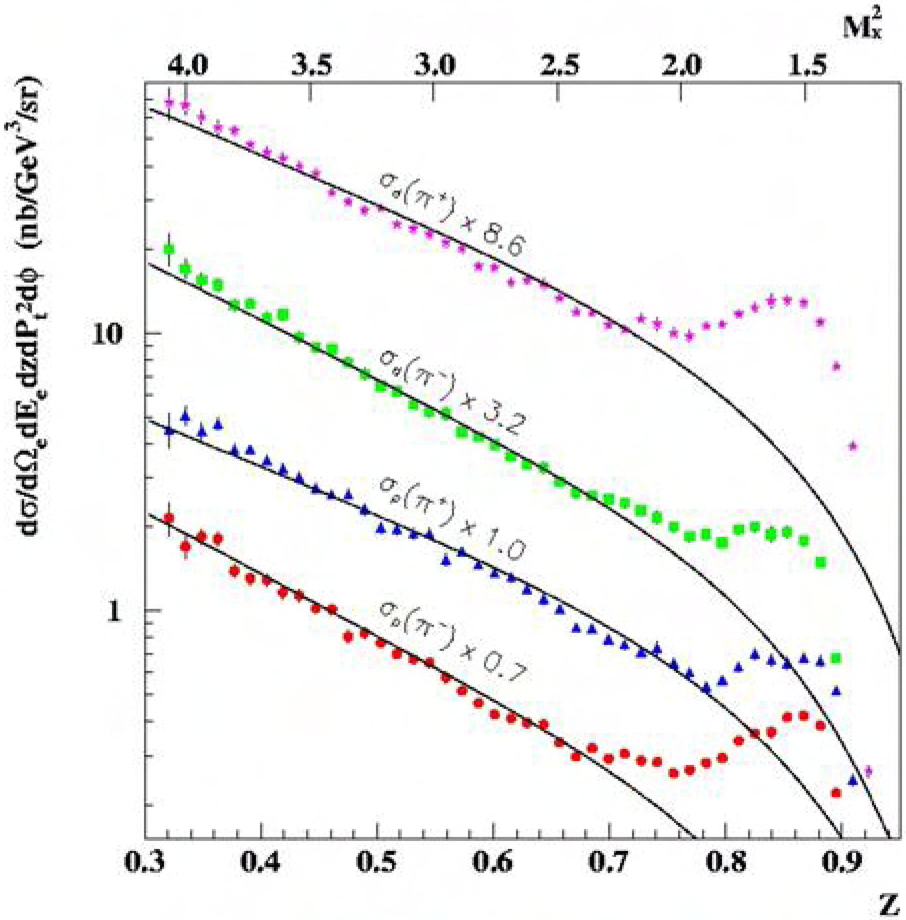


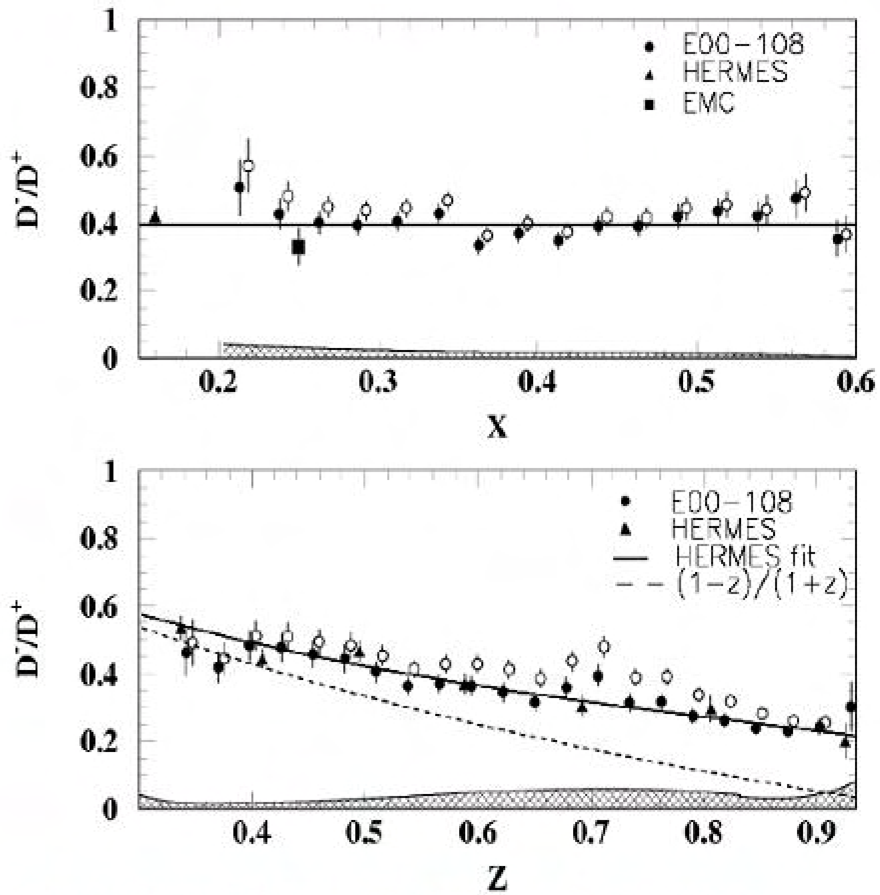




Factorization Check at JLab

$^{1,2}H(e,e'\pi^{+/-})$ from JLab Hall C E00-108: PRL98(2007) 022001 [hep-ph/0608214]





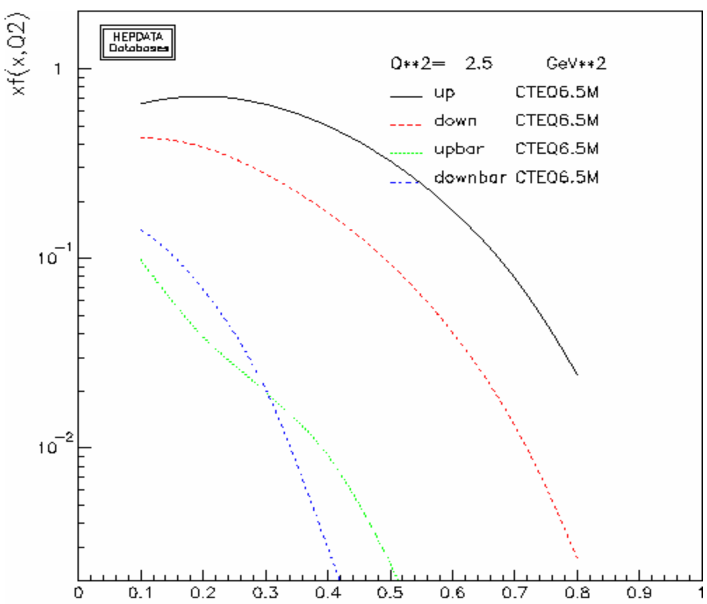
Data beyond Δ region are well described by LO SIDIS ansatz.

Drell-Yan & DIS Error Propagation

Drell – Yan : $pN \rightarrow \mu^+\mu^- X$

$$\left.\frac{\sigma^{pd}}{2\sigma^{pp}}\right|_{x_b \gg x_t} \approx \frac{1}{2}\left[1 + \frac{\bar{d}(x_t)}{\bar{u}(x_t)}\right]$$

$$\bar{d} - \bar{u} = \left[\frac{\frac{\bar{d}}{\bar{u}} - 1}{\frac{\bar{d}}{\bar{u}} + 1}\right](\bar{d} + \bar{u})$$



DIS : $ep \rightarrow e'X$

$$r(x,z) = \frac{Y_p^{\pi^-}(x,z) - Y_n^{\pi^-}(x,z)}{Y_p^{\pi^+}(x,z) - Y_n^{\pi^+}(x,z)}$$

$$J(z) = \frac{3}{5}\frac{1 + D'(z)}{1 - D'(z)}$$

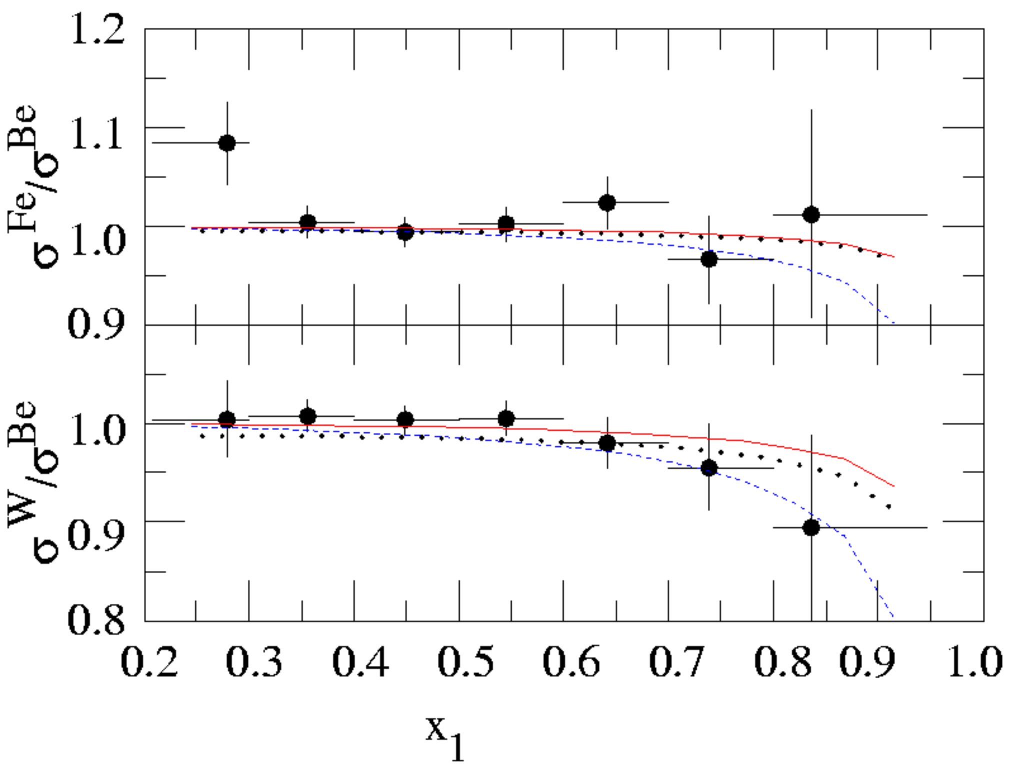
$$\frac{J(z)[1 - r(x,z)] - [1 + r(x,z)]}{J(z)[1 - r(x,z)] + [1 + r(x,z)]} = \frac{\bar{d}(x) - \bar{u}(x)}{u(x) - d(x)}$$

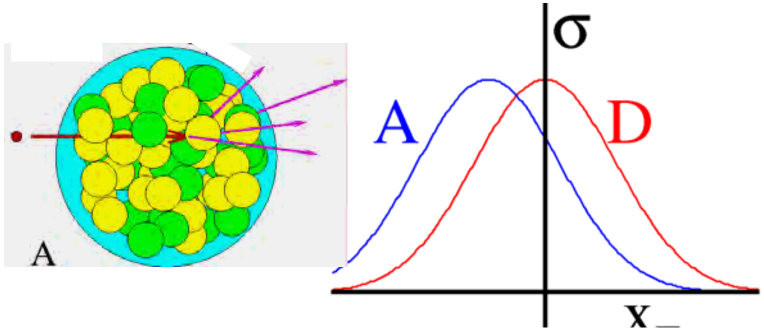
$$\bar{d} - \bar{u} = \left[\frac{\bar{d} - \bar{u}}{u - d}\right](u - d)$$

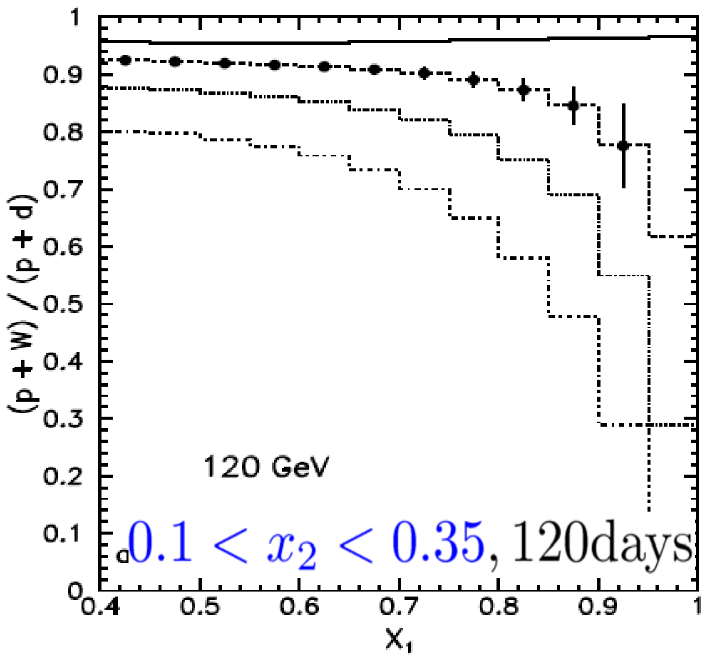
$Q^2 = 2.5$, CTEQ6.5M

	$\bar{d} + \bar{u}$	u-d
x=0.2	0.54	1.65
x=0.3	0.13	1.23

Partonic Energy Loss from Drell-Yan







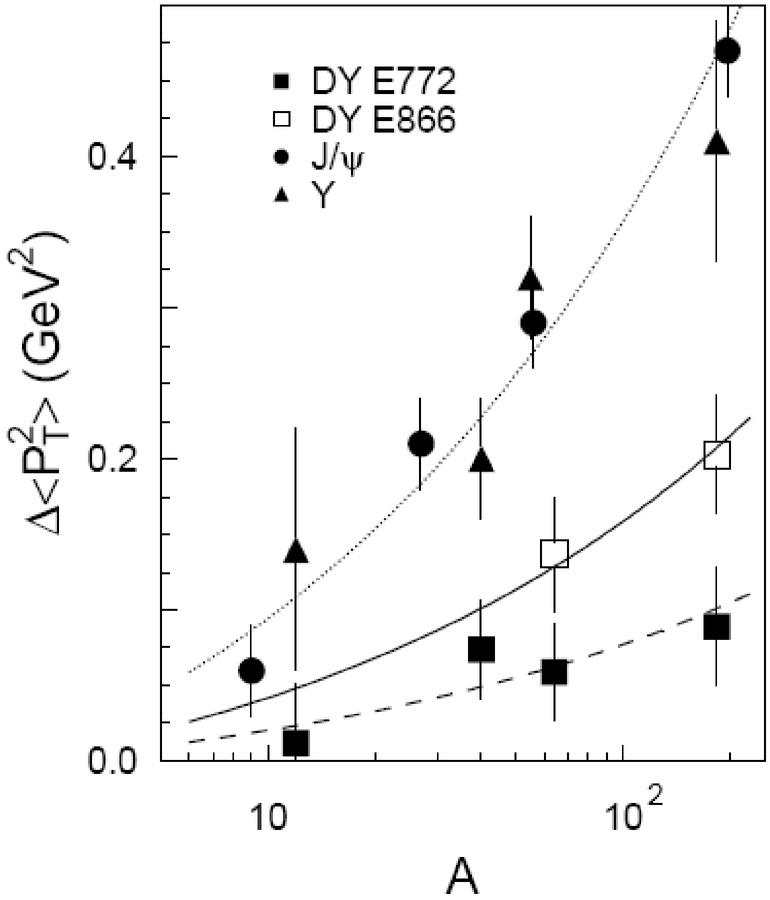
dE/dx=0.1,0.1,0.25,0.5 GeV/fm

Garvey & Peng, PRL90(2003)092302

Nuclear Broadening of Transverse Momentum

- There is a factor of two difference between the new and old results on nuclear broadening of transverse momentum. The broadening effect is much bigger for resonances than that for Drell-Yan.

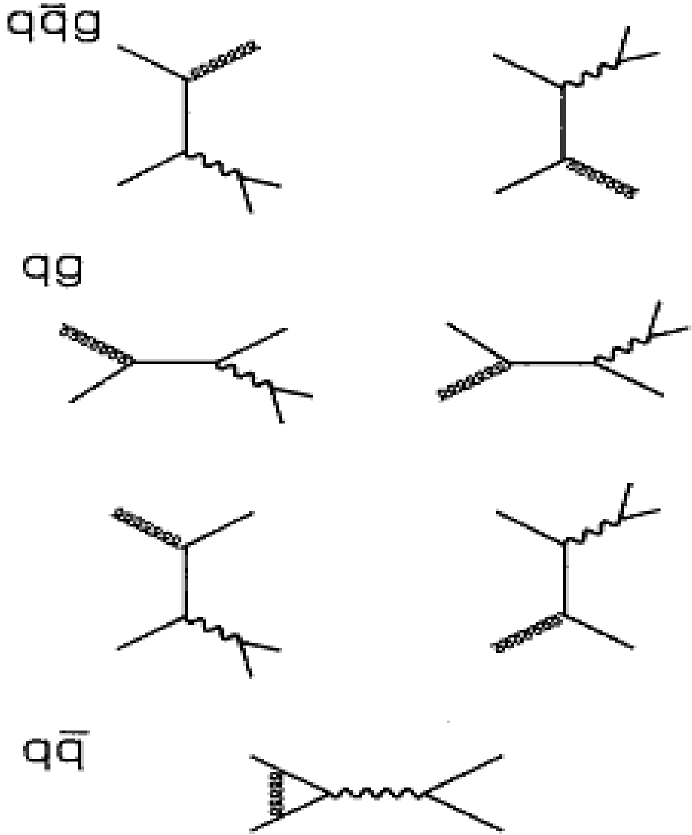
$$\Delta < p_T^2 > \equiv < P_T^2 >_A - < P_T^2 >_N$$
$$\Delta < p_T^2 > = D[(A/2)^{1/3} - 1]$$
$$D(E772) = 0.029 \pm 0.008$$
$$D(E886) = 0.059 \pm 0.009$$



Johnson et al, PRC75(2007)035206

- Nuclear P_T broadening leads to medium-induced gluon radiation or energy loss.

First-order QCD Corrections to Drell-Yan



- Increase the overall cross section by a K-factor~2.

- The Lam-Tung relation still hold (in any reference frame for massless quarks), reflecting the spin-1/2 nature of the quarks. Lam & Tung, PRD21,2712(1980)

$$1 - \lambda - 2\nu = 0$$

(Analog to Callan-Gross relation in DIS)

- The NLO correction at $\mathcal{O}(\alpha_s^2)$ to the angular distribution is small. Mirkes & Ohnemus, PRD51,,4891(1995)

Conway et al., PRD39,92(1989)

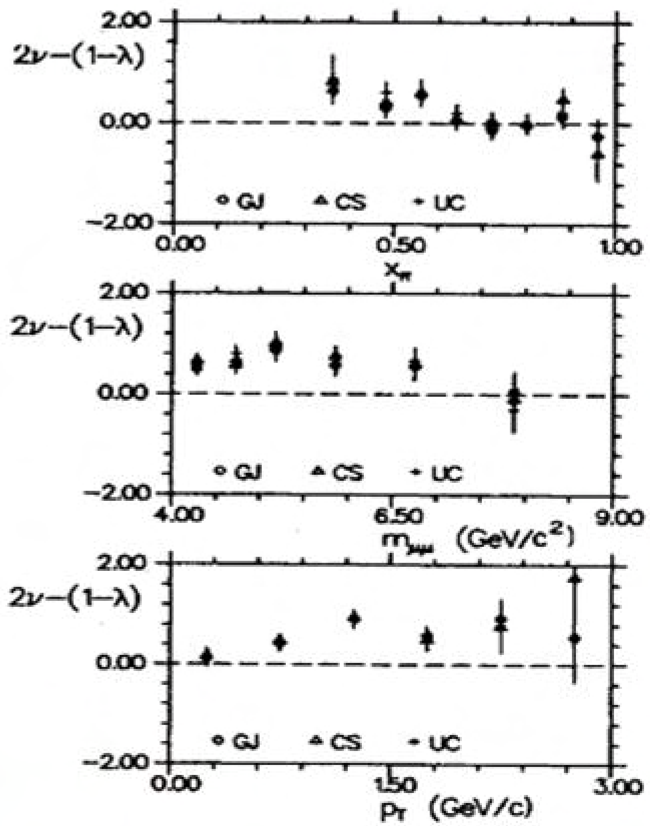
The QCD correction to the angular distribution is small.

Violation of the Lam-Tung Relation

E615 at Fermilab: 252 GeV $\pi^- + W$

Conway et al., PRD39,92(1989)

NA10 at CERN:
140/194 GeV $\pi^- + W$, 286 GeV $\pi^- + W/d$
Z. Phys. C37, 545 (1988)



- The deviations from $1+\cos^2\theta$ due to the soft-gluon resummation are less than 5%.

Chiappatta & Bellac,ZPC32,521 (1986)

- The correction due to the intrinsic transverse momenta is estimated to be less than 0.05

Cleymans & Kuroda, PLB105,68(1981)

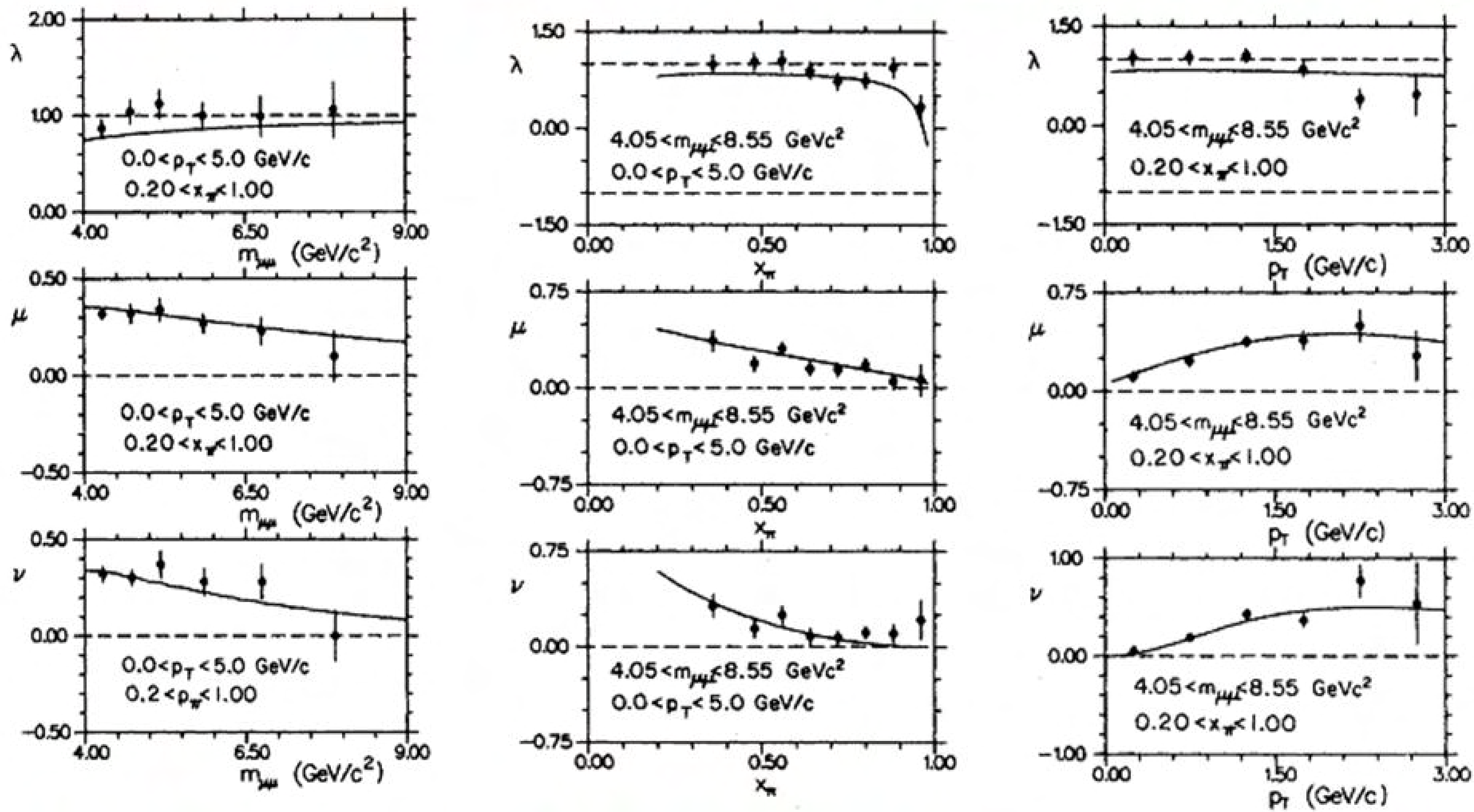
- Lam-Tung relation not affected by lowest order QCD correction even at small Q_T.

Boer & Wogelsang, hep-ph/0604177

Angular Distribution in the πW Drell-Yan

E615 at Fermilab: 252 *GeV* π^- + W

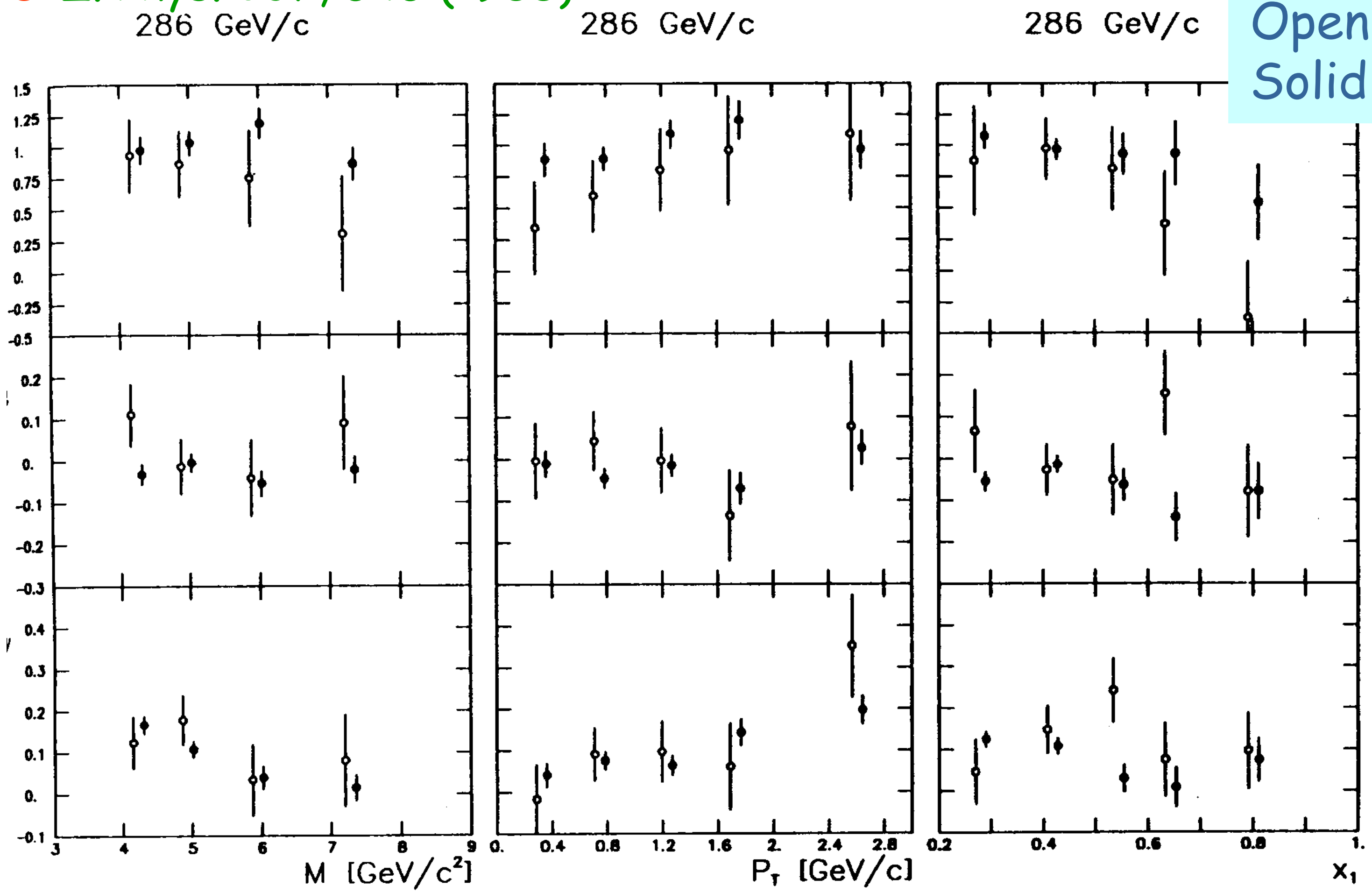
Conway et al., PRD39,92(1989)



Nuclear Effect?

NA10 Z. Phys. C37, 545 (1988)

Open: Deuterium
Solid: Tungsten



Nuclear effect not likely to be the dominant contribution.

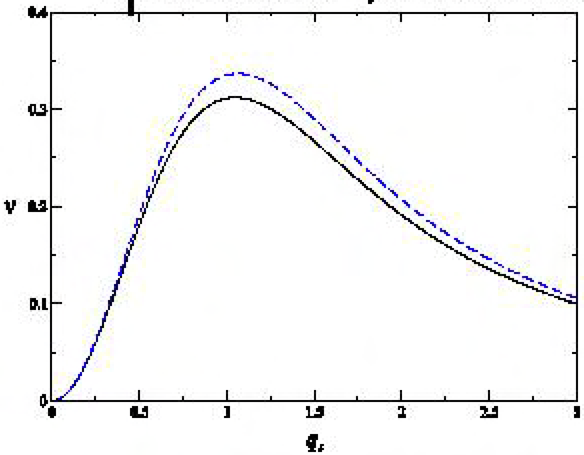
Boer-Mulders Function $h_1^\perp$ in Spectator Model

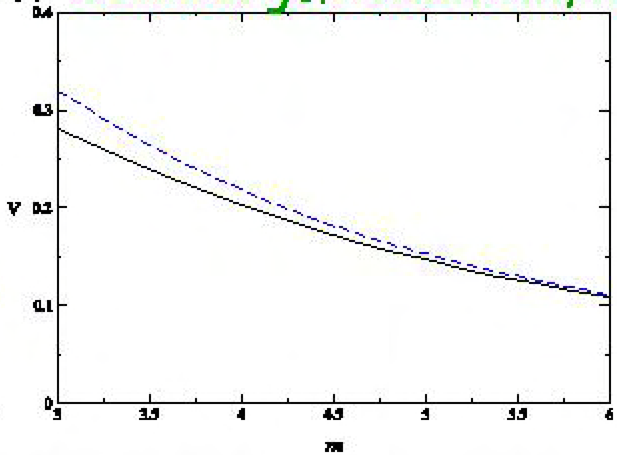
- Initial-state gluon interaction can produce nonzero $h1^\perp$ for the proton in the quark-scalar diquark model. In this model, $h_1^\perp = f_{1T}^\perp$.

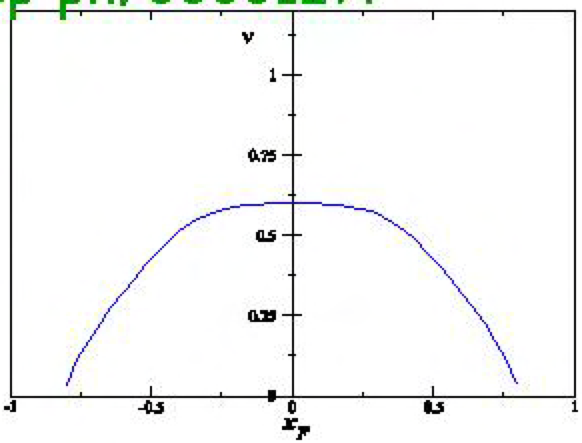
$$h_{1p}^{\perp}(x,\mathbf{k}_\perp^2) = \frac{A_p(x)}{\mathbf{k}_\perp^2[\mathbf{k}_\perp^2 + B_p(x)]} \ln[\frac{\mathbf{k}_\perp^2 + B_p(x)}{B_p(x)}]$$

Boer,Brodsky&Hwang, PRD67,054003(2003).

- Twist 2 (as well as the kinematic twist 4) contribution in a parton-spectator framework Gamberg&Goldstein, hep-ph/0506127.







$$\nu_2 = \frac{\sum_a e_a^2 \mathcal{F}\left[(2\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_\perp \cdot \hat{\boldsymbol{h}}\cdot\boldsymbol{p}_\perp - \boldsymbol{p}_\perp\cdot\boldsymbol{k}_\perp) h_1^\perp(x,\boldsymbol{k}_\perp)\bar{h}_1^\perp(\bar{x},\boldsymbol{p}_\perp)/(M_1 M_2)\right]}{\sum_a e_a^2 \mathcal{F}\left[f_1(x,\boldsymbol{k}_\perp)\bar{f}_1(\bar{x},\boldsymbol{p}_\perp)\right]}$$

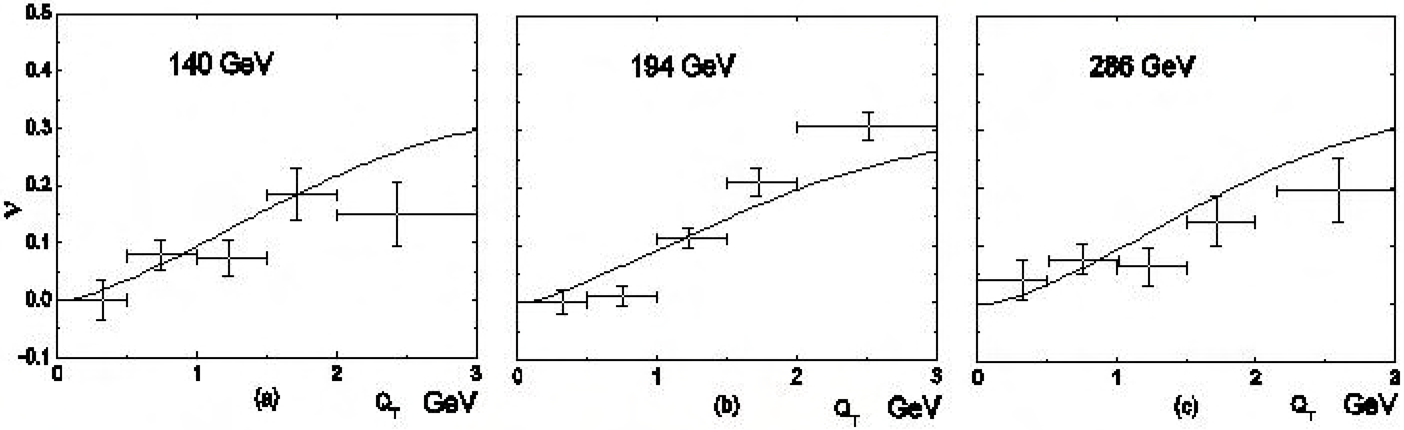
Pion Boer-Mulders Function

- Final-state interaction with one gluon exchange can produce nonzero $h_1^\perp$ for the pion in the quark-spectator-antiquark model with constant coupling g_π.

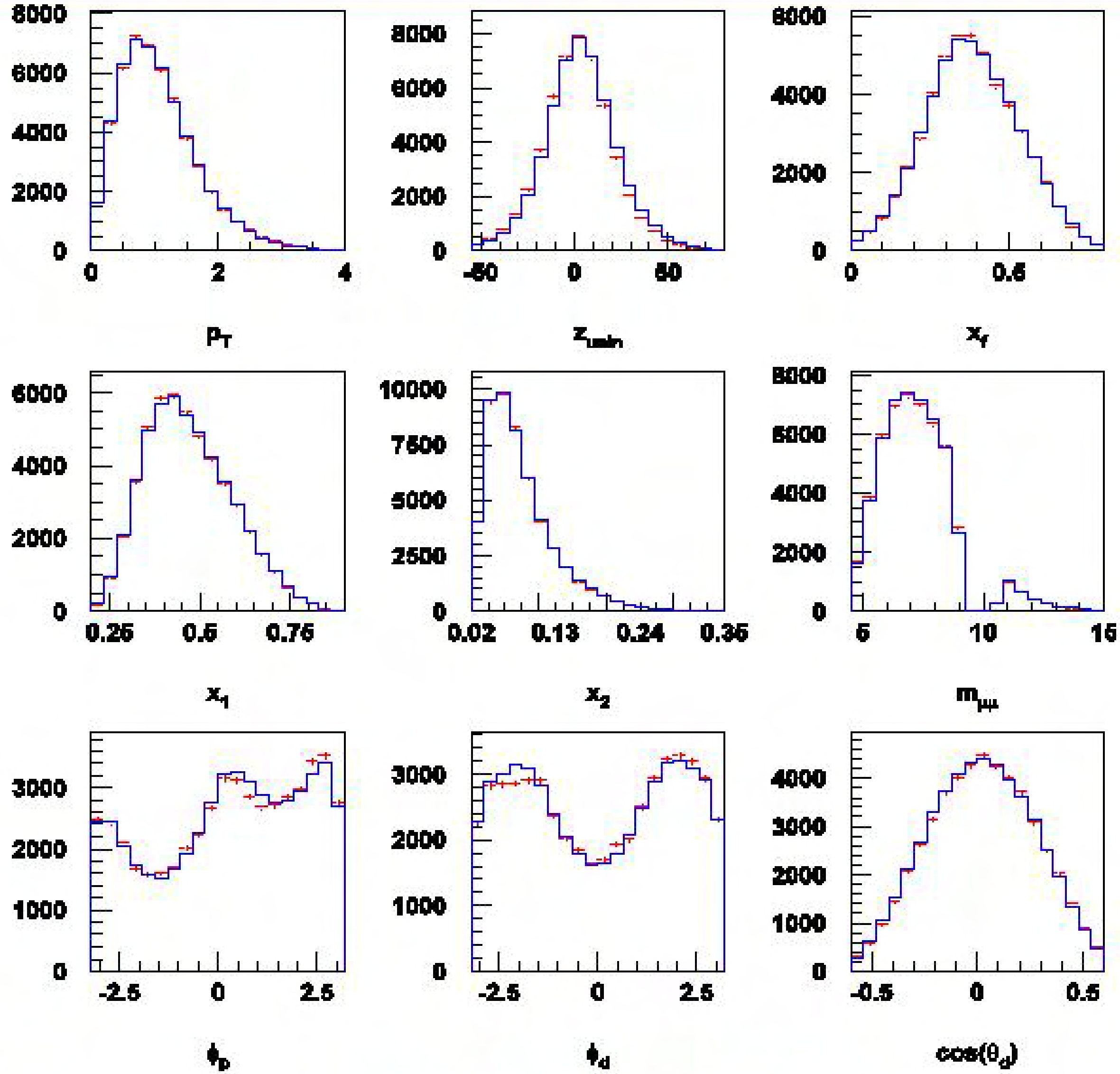
$$h_{1\pi}^{\perp}(x,\mathbf{k}_\perp^2) = \frac{A_\pi(x)}{\mathbf{k}_\perp^2[\mathbf{k}_\perp^2 + B_\pi(x)]}\ln[\frac{\mathbf{k}_\perp^2 + B_\pi(x)}{B_\pi(x)}]$$

Lu&Ma, PRD70,094044(2004).

- The quark-spectator-antiquark model with effective pion-quark-antiquark coupling as a dipole form factor Lu & Ma, hep-ph/0504184



Comparison of data and simulation



Blue: simulation

Red: data

(dset8)

Modeling Sea Boer-Mulders Functions

- Z. Lu, B.-Q. Ma and I. Schmidt, PRD75 (2007) 014026

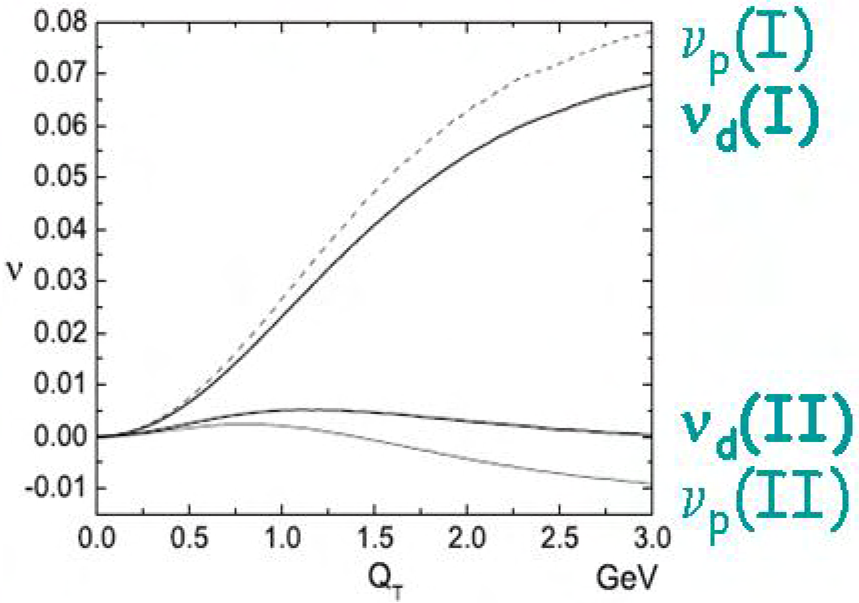
Meson-baryon fluctuation model:

$$p \rightarrow n + \pi^{+} \; ; p \rightarrow \Delta^{++} + \pi^{-}$$

Predictions depend on the choice of valence Boer-Mulders functions:

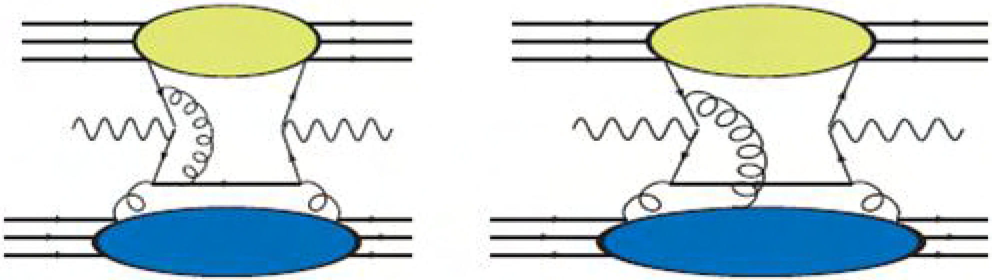
I--scalar diquark;

II—scalar & vector diquark



- Group led by L. Gamburg and G. Goldstein

Two possible contributions to sea from the gauge link.



Probing the sea Boer-Mulders functions may constrain the valence ones.

Polarized Drell-Yan

$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega d\phi_S} \propto 1+\lambda\cos^2\theta+\sin^2\theta[\frac{\nu}{2}\cos 2\phi+\rho|S_T|\sin(\phi+\phi_S)]+\ldots$$

Assuming u-quark dominance

$$\rho = \frac{1}{2}\sqrt{\frac{\nu}{\nu_{max}}}\frac{h_1^{\perp}}{f_{1T}^{\perp}}$$

Burkardt Relation

$$\frac{f_{1T}^{\perp q}}{E} \approx \frac{h_1^{\perp q}}{2\tilde{H}_T + E_T}$$