PacSPIN2015 Summary

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University of Illinois at Urbana-Champaign

The 10th Circum-Pan-Pacific Symposium on High Energy Spin Physics, October 5-8, 2015

Analects of Confucius

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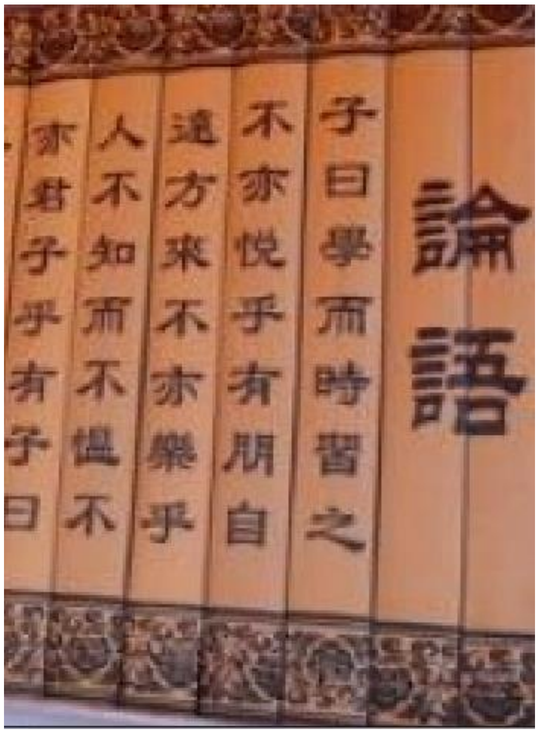
(first three sentences)



- Learning the new, and frequently reviewing the old, isn’t that fun?
- Having friends coming from afar, isn’t that delightful?
- Not being offended when other people do not recognize your work, isn’t that a true gentleman?

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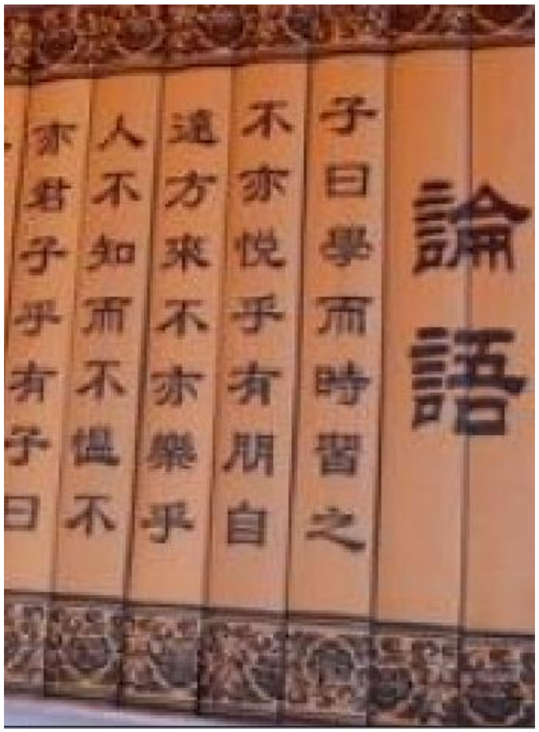
(first three sentences)



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Don’t be offended if your talk is not properly cited

T. Shibata

1st	1996	Kobe University (19 years ago),	Toshiyuki Morii
2nd	1999	RIKEN,	Koichi Yazaki
3rd	2001	Peking University,	Bo-Qiang Ma
4th	2003	University of Washington,	Xiang-Dong Ji
5th	2005	Tokyo Tech,	Toshi-Aki Shibata
6th	2007	Vancouver,	Andy Miller
7th	2009	Yamagata University,	Takahiro Iwata
8th	2011	Cairns,	Anthony W. Thomas
9th	2013	Shandong University,	Zuo-Tang Liang
10th	2015	Academia Sinica,	Hai-Yang Cheng, Wen-Chen Chang

2

Tremendous contributions to spin physics

Broad and in-depth talks in PacSPIN2015

- Theory (16 talks)
  - Ji, Ma, Hatta, Kumano, Lin, Doi, Xiong, X. Chen, Kao, Kroll, Tanaka, Qiu, Thomas, Yoshida, Brodsky, Liang
- Experiment (22 talks)
  - Mallot, Gao, Pisano, Schnell, Sawada, d'Hose, Fimushkin, Choi, Kunne, Kim, Sichtermann, Kawall, Mibe, J. Chen, Miyachi, Denisov, Xu, Goto, Nakano, Meziani, Lansberg
- Topics
  - Overview, Lattice, Spin decomposition, 3D tomography, Form-factor, Longitudinal spin, Transverse spin, GPD, Future facilities, Muon g-2 and EDM, etc.

Spin structures of the nucleons

Why is it interesting?

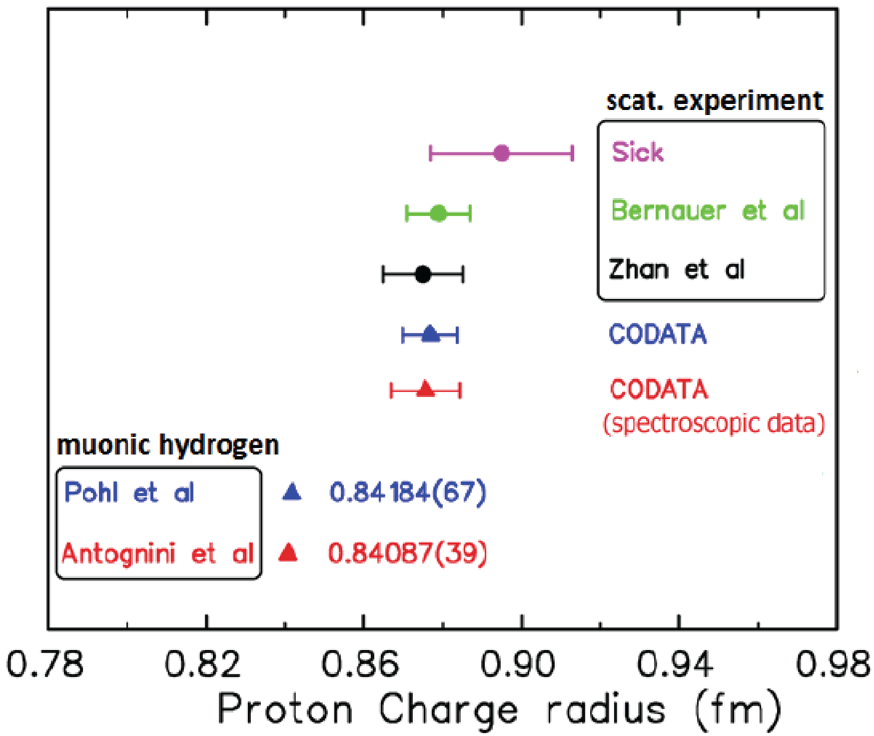
- Full of surprises and enigmas. Resolving them often led to important new insight on QCD.
- Close synergy between theory and experiment.
- The progress of lattice QCD calculations allow direct comparison with the experiments
- Novel parton distributions and their properties become accessible by experiments using lepton and hadron beams

Intricate internal structure of the nucleons

- Carved from a single piece of elephant ivory
- A total of 21 nested concentric layers
- Each layer rotates freely
- Various windows allow us to view deeper and deeper inside

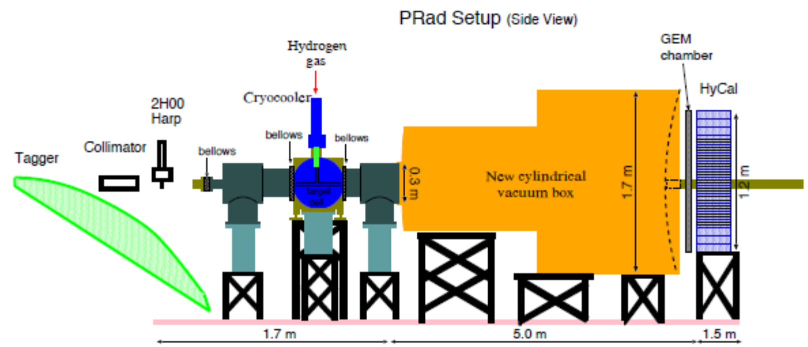
The Proton Radius Puzzle

The proton radius puzzle intensified



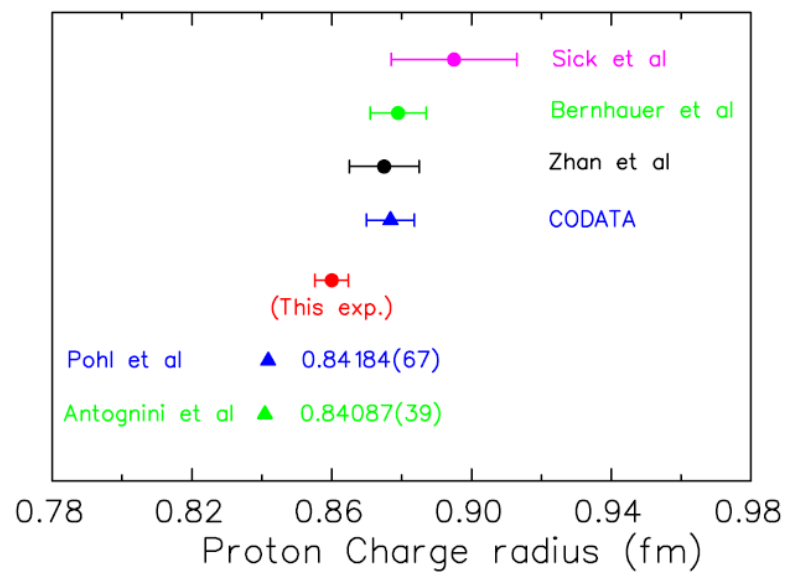
Haiyan Gao

PRad Experimental Setup in Hall B at JLab



- **Q^2 range of 2×10^{-4} – 0.14 GeV^2**

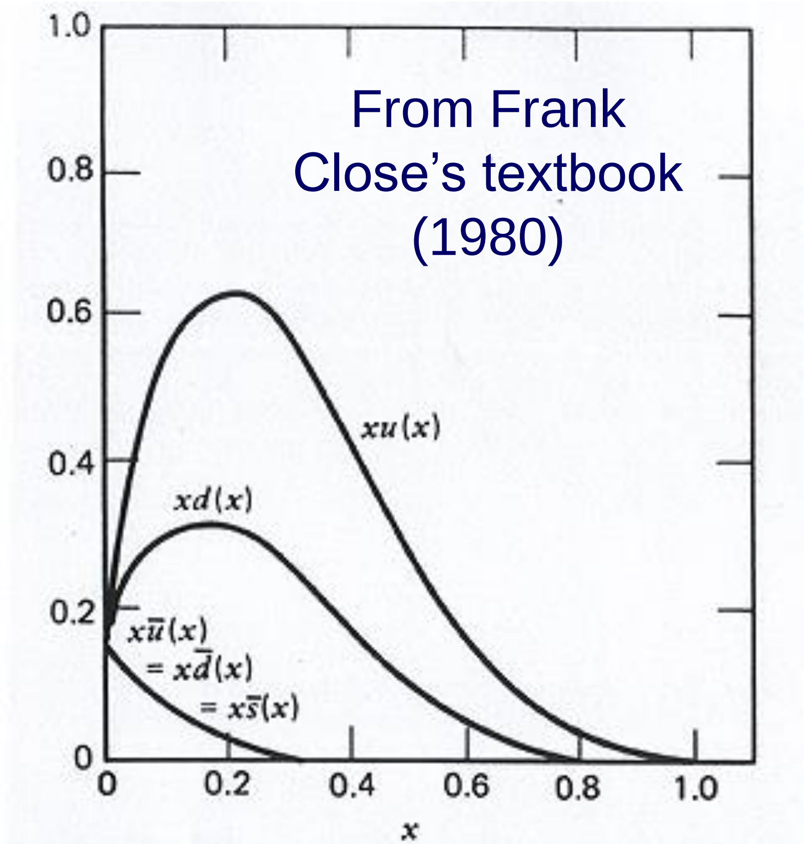
PRad Projected Result



There was a time when nucleon was nice and simple……

Flavor structure of the proton sea

$$\bar{u}(x) = \bar{d}(x) = \bar{s}(x) = s(x) \Rightarrow SU(3) \text{ symmetric sea}$$



Questions

- Is $u_V(x) = 2d_V(x)$?
- Is $\bar{u}(x) = \bar{d}(x)$?
- Is $\bar{s}(x) = \bar{u}(x)$?
- Is $\bar{s}(x) = s(x)$?
- Is $u_p(x) = d_n(x)$?
- Is $g_p(x) = g_n(x)$?

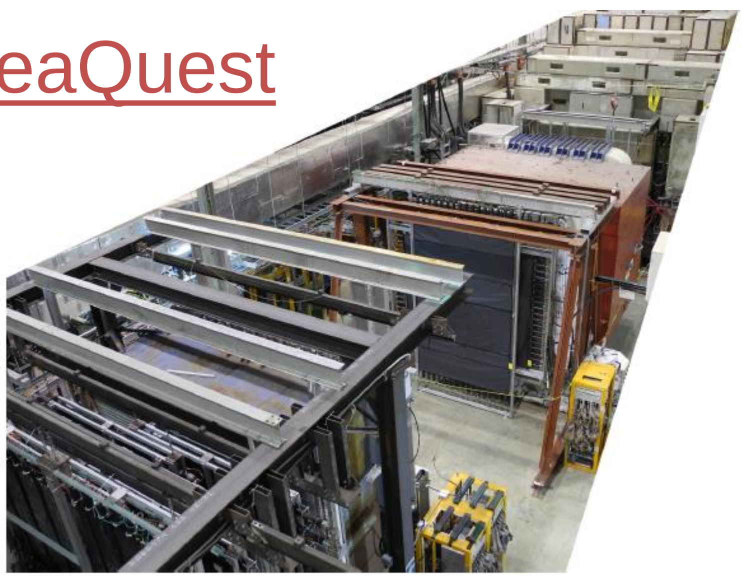
Actually, the nucleon is full of surprises !!

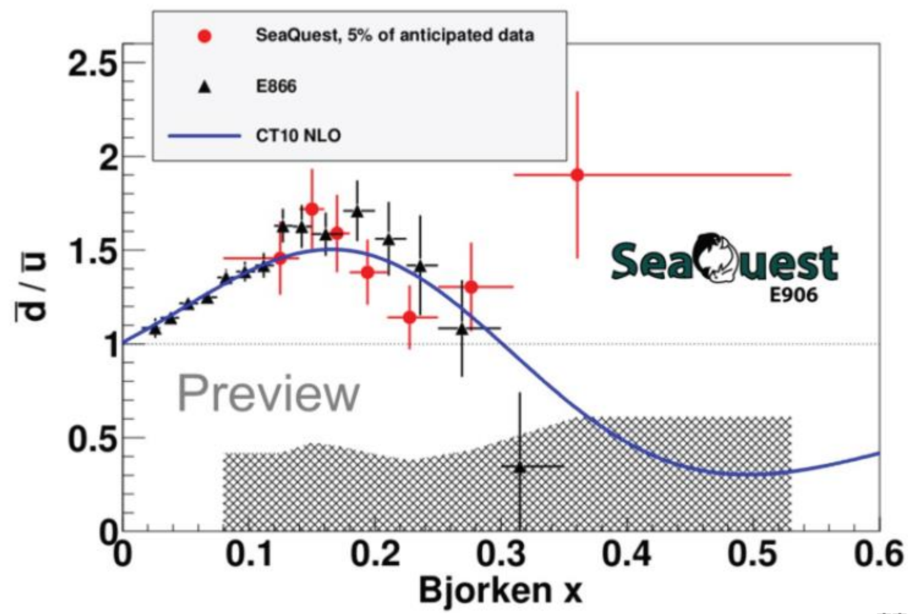
Anti-Quark Flavor Asymmetry — $\bar{u} \neq \bar{d}$

- (Almost) symmetric in gluon splitting ($g \to u\bar{u}$ or $d\bar{d}$)
- CERN NMC ('90)
  - Gottfried Sum: $S_G = 0.2281(65) \neq 1/3$
  - $\int \bar{d}(x)dx > \int \bar{u}(x)dx$
- Direct measurements of $\bar{u}(x)$ & $\bar{d}(x)$
  - CERN NA51 ('94): $\bar{d} > \bar{u}$ at $x \sim 0.18$
  - FNAL E866/NuSea ('98): $\bar{d}(x)/\bar{u}(x)$ for $x \in (0.015, 0.35)$

Kenichi Nakano

SeaQuest





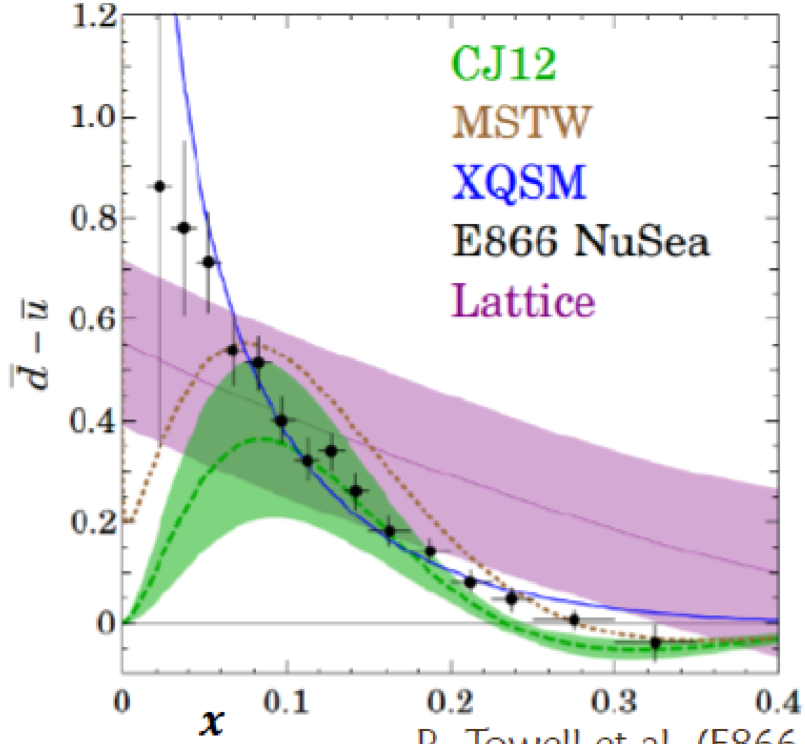
First Lattice calculation of $\bar{u}(x) - \bar{d}(x)$

Huey-Wen Lin

§ Lattice exploratory study

- $M_\pi \approx 310$ MeV

HWL et al 1402.1462; in preparation



Compared with E866

Too good to be true?

Lost resolution in small-*x* region

Future improvement to have larger lattice volume

$$\int dx\,(\bar{u}(x) - \bar{d}(x)) \approx -0.16(7)$$

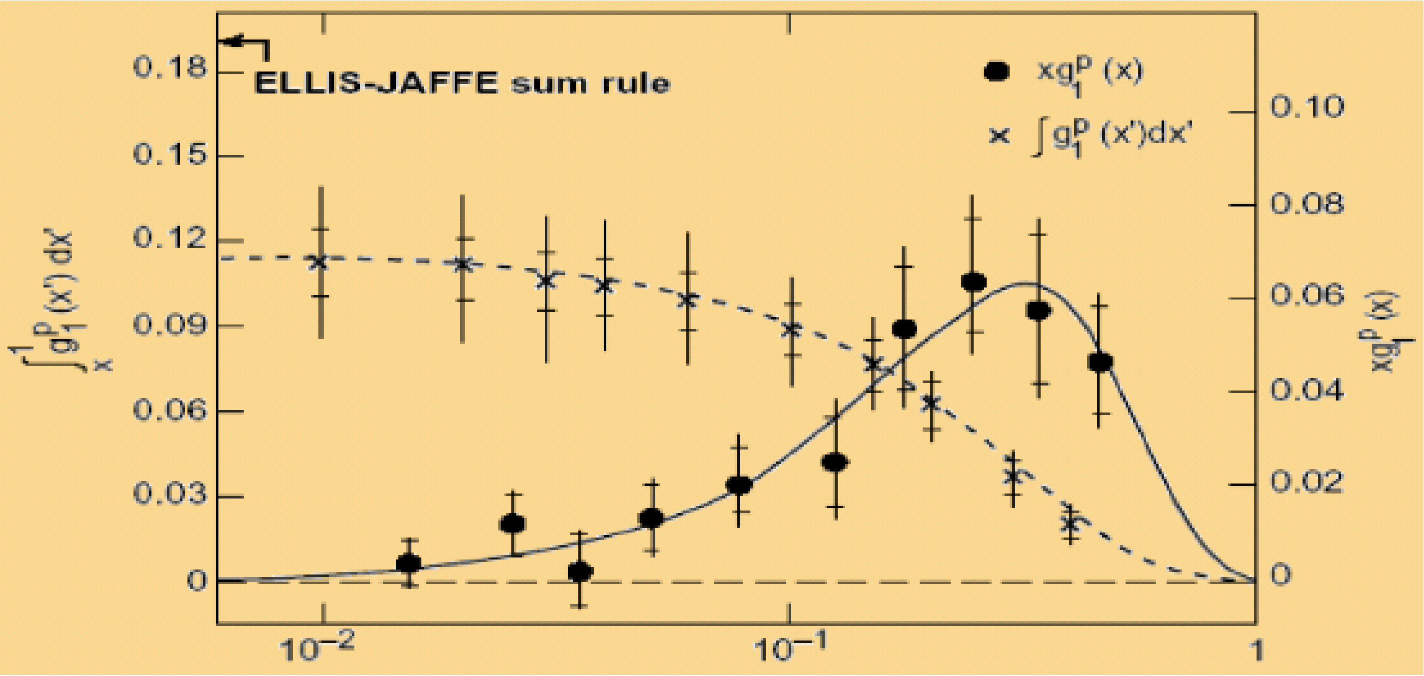
Experiment	x range	$\int_0^1[\bar{d}(x)-\bar{u}(x)]dx$
E866	$0.015<x<0.35$	0.118 ± 0.012
NMC	$0.004<x<0.80$	0.148 ± 0.039
HERMES	$0.020<x<0.30$	0.16 ± 0.03

R. Towell et al. (E866/NuSea), Phys.Rev. D64, 052002 (2001)

See related talk of Xiaonu Xiong

Where does the spin of the proton come from?

EMC experiment in 1988/1989



$$g_1(x) = \frac{1}{2}\sum_q e_q^2\left[\Delta q(x) + \Delta\bar{q}(x)\right] + \mathcal{O}(\alpha_s) + \mathcal{O}(1/Q)$$

$$\Delta\Sigma = \sum_q \Delta q + \Delta\bar{q} = 0.2 - 0.3 \;\rightarrow\; \text{"Spin Crisis"}$$

Impressive experimental progress in QCD spin physics in the last 30 years

Z. Meziani

- **Inclusive spin-dependent DIS**
  - CERN: EMC, SMC, COMPASS
  - SLAC: E80, E142, E143, E154, E155
  - DESY: HERMES
  - JLab: Hall A, B and C
- **Semi-inclusive DIS**
  - SMC, COMPASS
  - HERMES, JLab
- **Polarized pp collisions**
  - ANL: ZGS
  - FERMILAB: E704,….
  - BNL: AGS, PHENIX, STAR and BRAHMS
- **Polarized e+e- collisions**
  - KEK: Belle

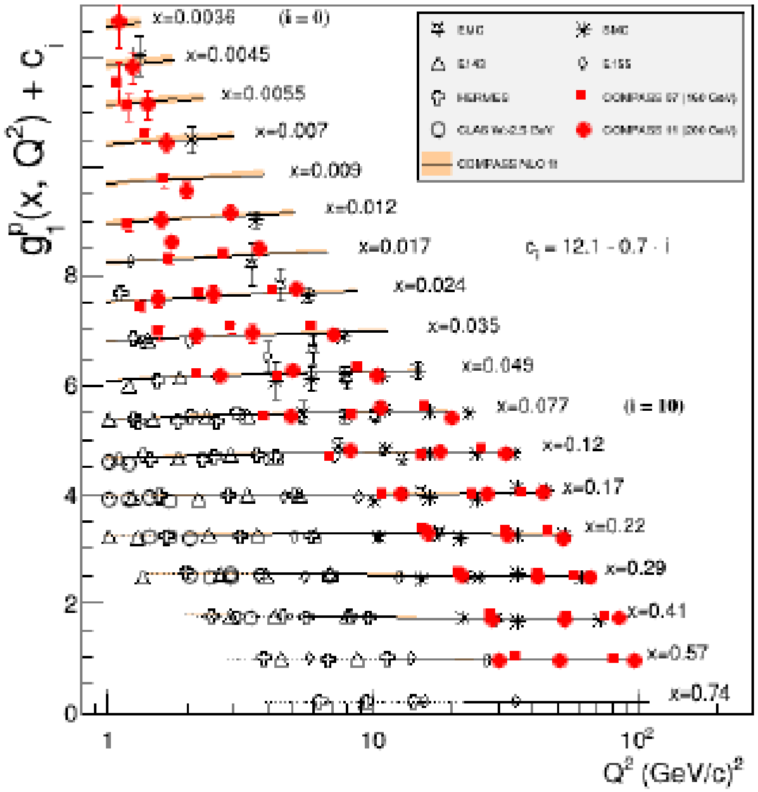




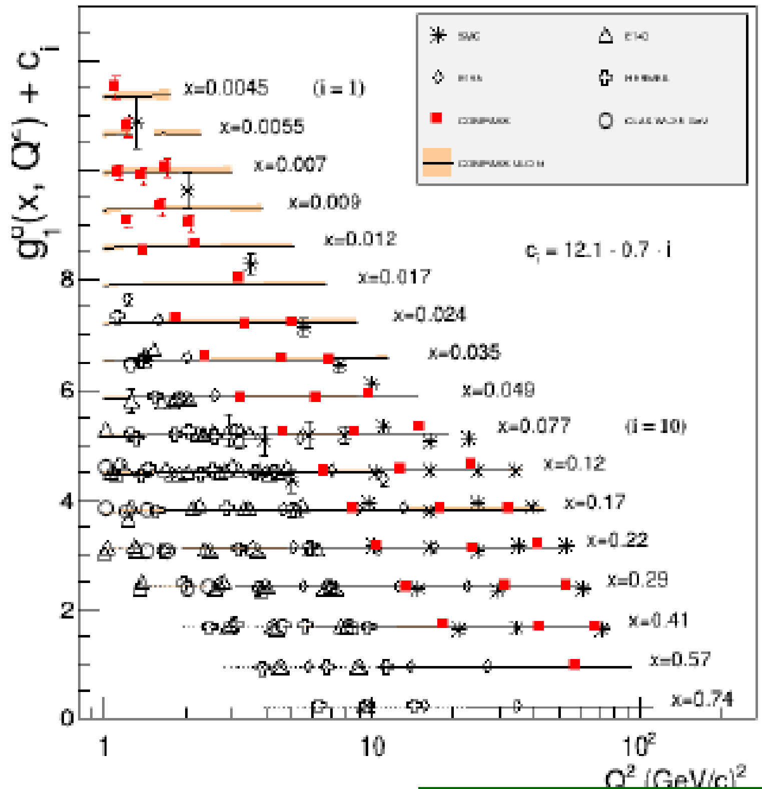

World data on $g_1{}^p$ and $g_1{}^d$

F. Kunne

proton



deuteron



hep-ex/1503.08935
to be published in PLB

- 200 GeV proton data:lower x and higher Q^2

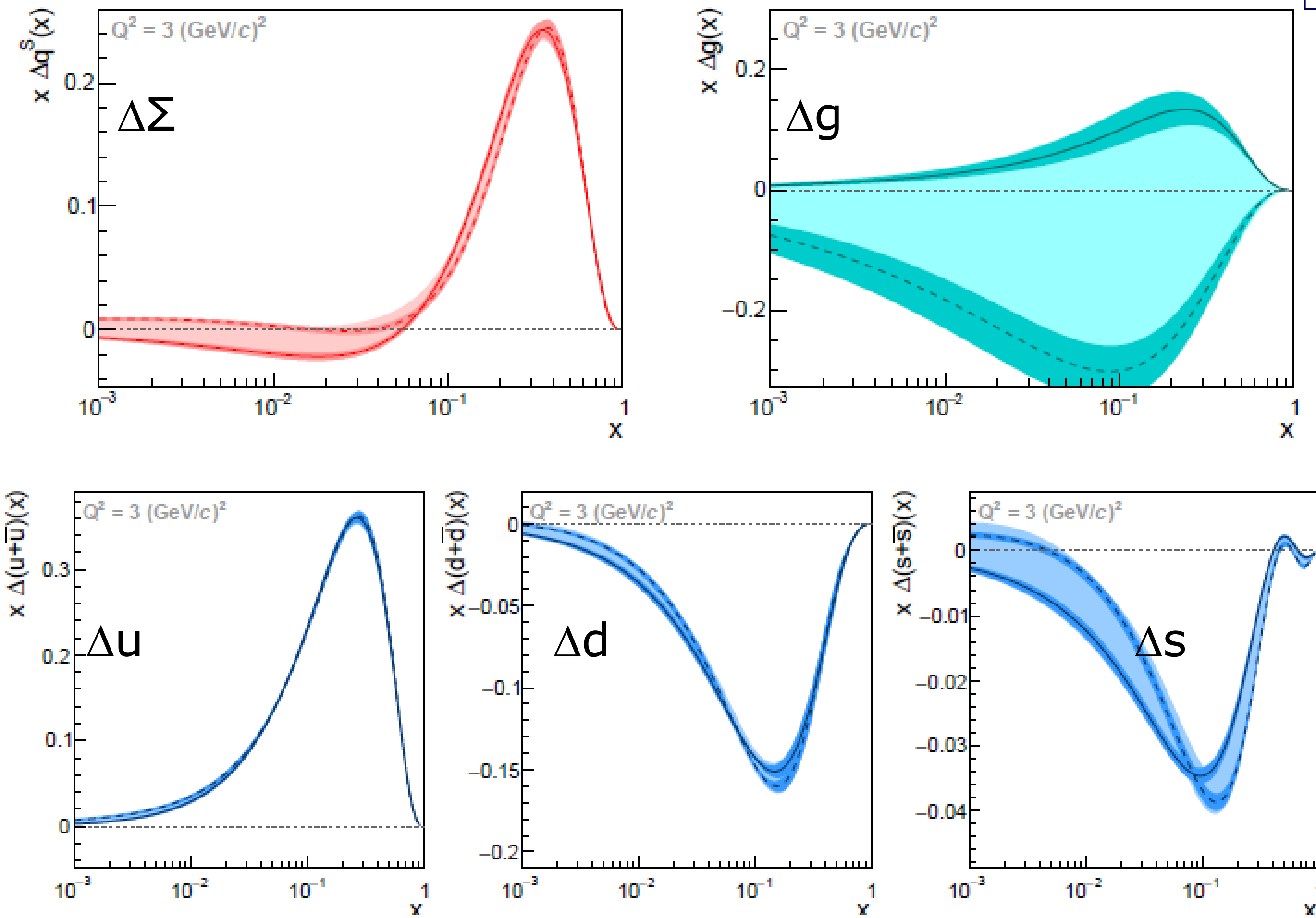
g_1 data as will be used in global QCD fits for extraction of $\Delta q_f(x)$ and $\Delta G(x)$

$$\boxed{\frac{d\, g_1}{d\, Log(Q^2)} \propto -\Delta g(x,Q^2)}$$

NLO QCD fit to world DIS data

COMPASS

G. Mallot



$Q^2 = 3\ \mathrm{GeV}^2$

integrals:

$0.27 \leq \Delta\Sigma \leq \quad 0.39$

$-1.6 \quad \leq \Delta G \leq \quad 0.5$

$0.82 \leq \Delta U \leq \quad 0.85$

$-0.45 \leq \Delta D \leq -0.42$

$-0.11 \leq \Delta S \leq -0.08$

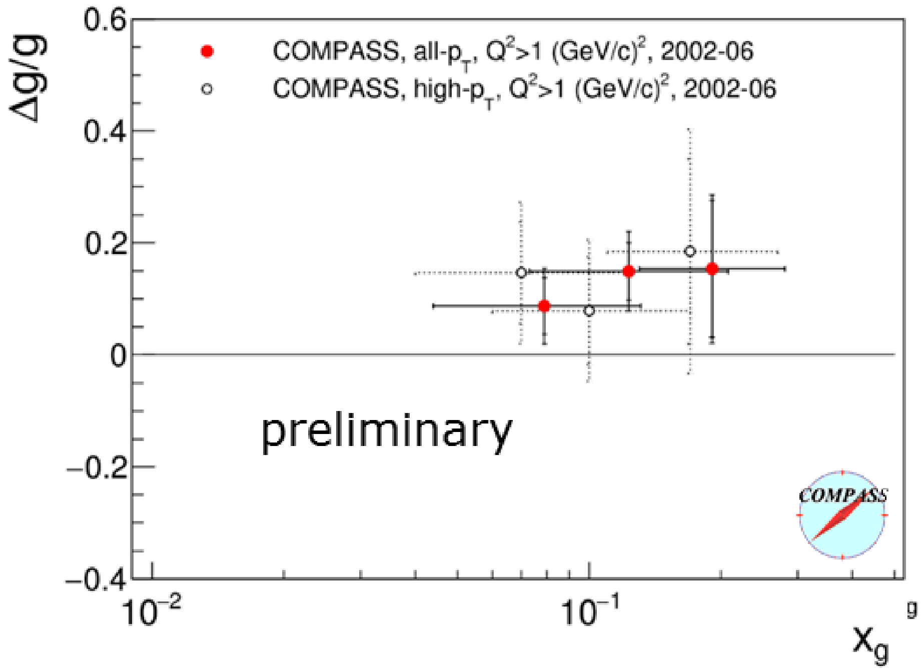
using different functional shapes and Q_0^2

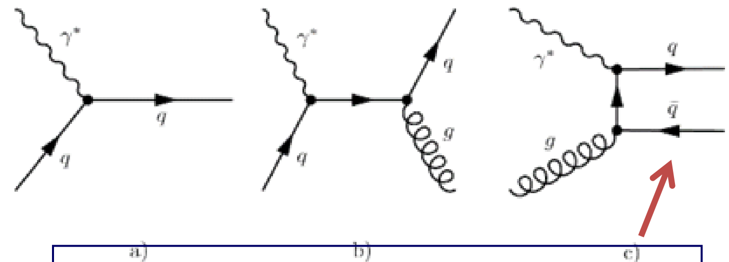
arXiv:1503.08935

- come back to World data fits incl. SIDIS and pp later

$\Delta g/g$ from PGF (DIS, LO)

G. Mallot





Photon-gluon fusion

- $Q^2 > 1$ GeV^2

- $\Delta g(x)$ small, maybe positive around $x \cong 0.1$, caveat: LO
- no clear x dependence

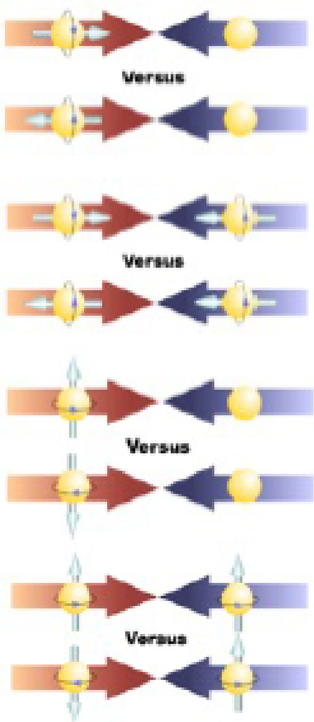
Di-hadron production suggests positive $\Delta g/g$

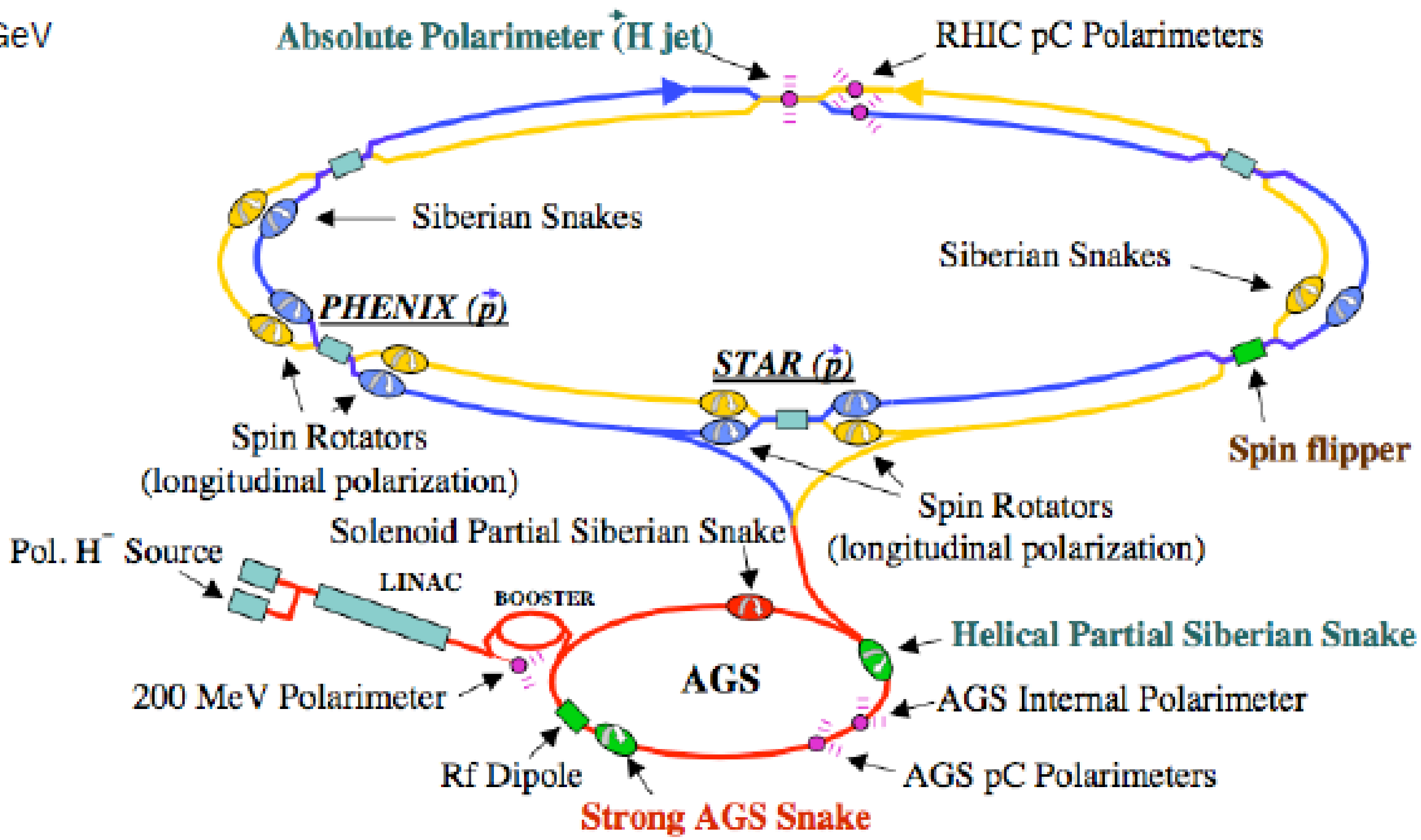
RHIC - Polarized Proton-Proton Collider

E. Sichtermann

Unique opportunities to study nucleon spin properties and spin in QCD,

√s = 62, 200, and 500 GeV

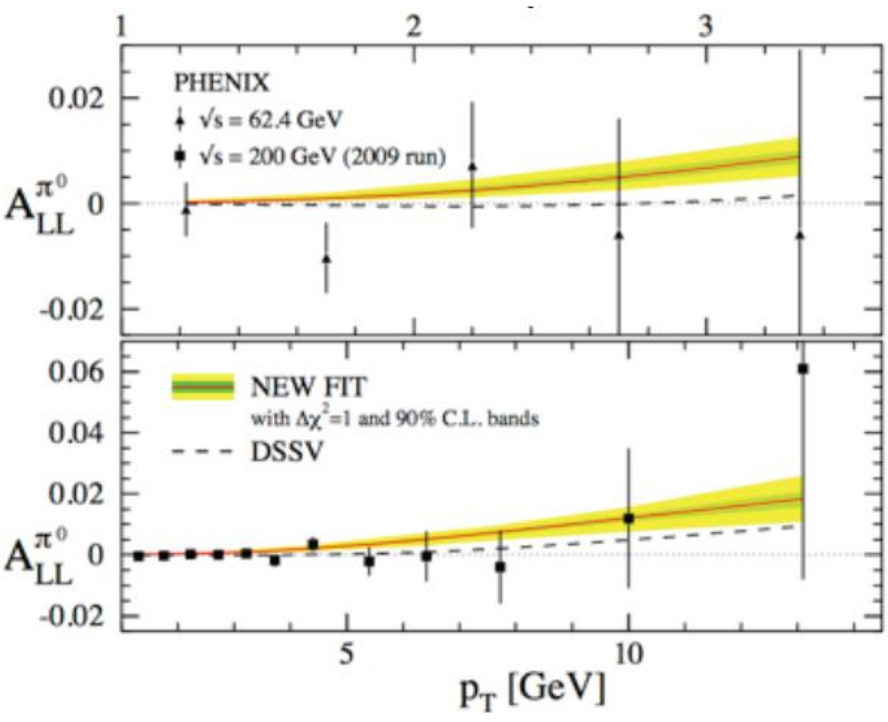


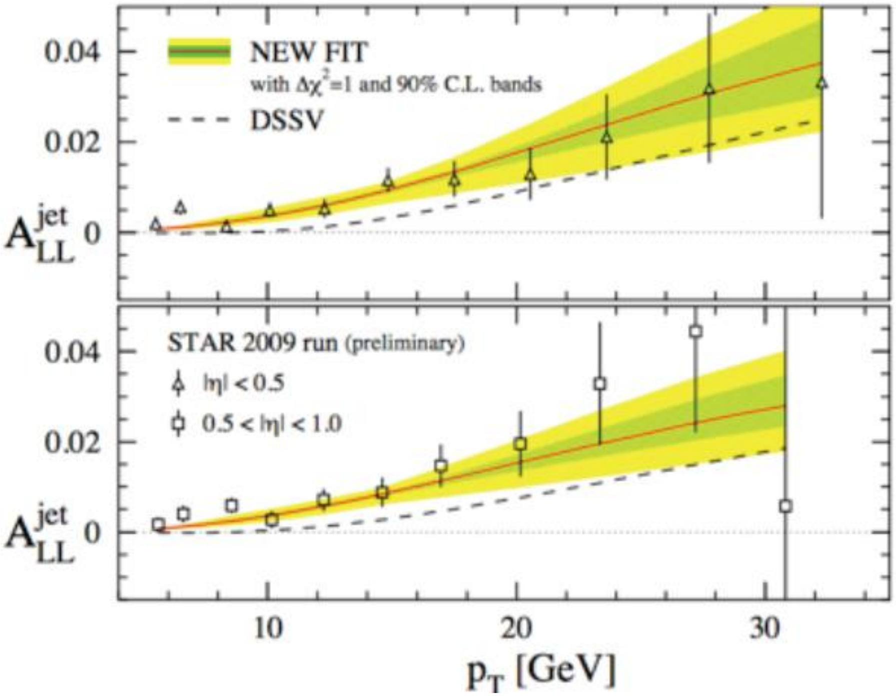


Δg from RHIC-spin

$A_{LL}^{\pi^0}$ from PHENIX

A_{LL}^{jet} from STAR



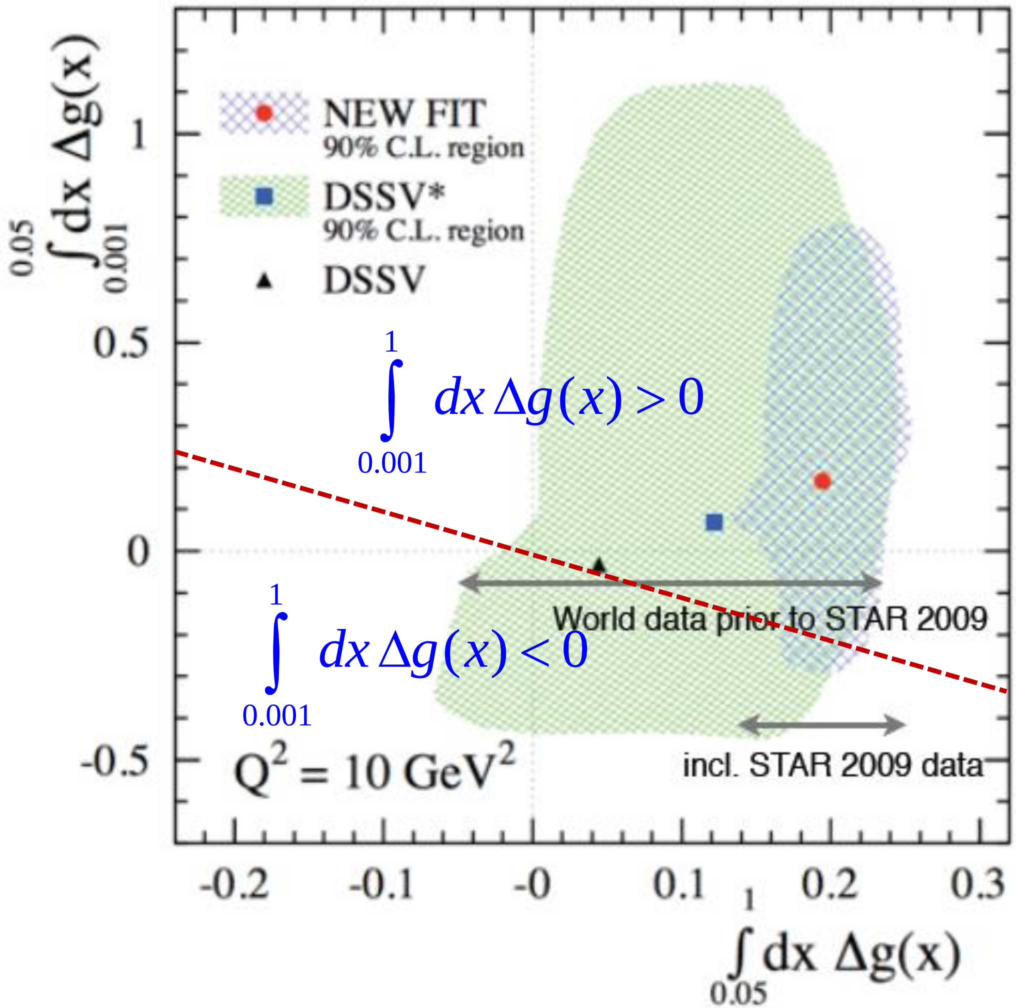


Chong Kim

E. Sichtermann

Δg from global fits

DSSV, Phys.Rev.Lett. 113, 012001



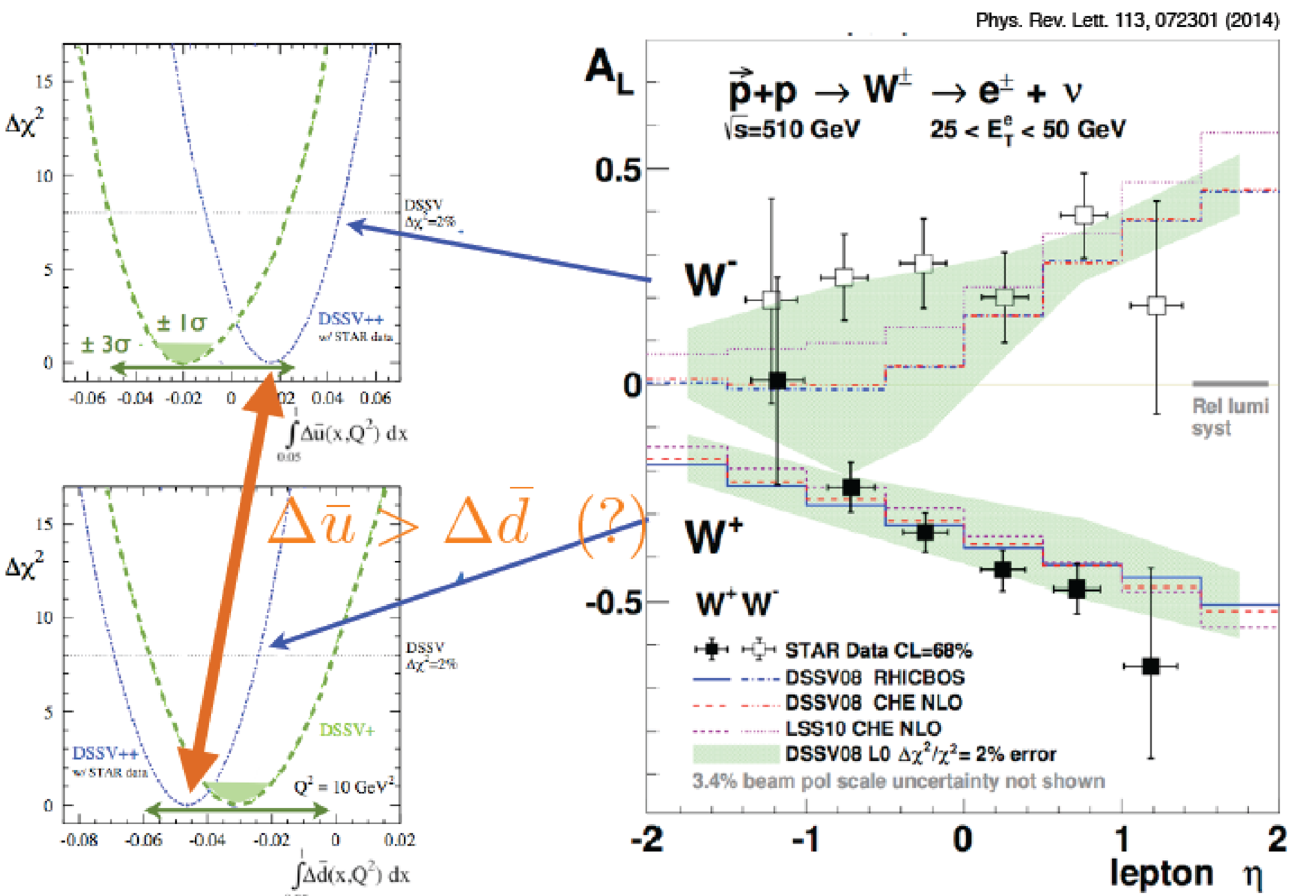
Global fits favor positive Δg

$\Delta\bar{u}(x)$ and $\Delta\bar{d}(x)$ from A_L of $W^{\pm}$ production

E. Sichtermann

STAR data

Phys. Rev. Lett. 113, 072301 (2014)



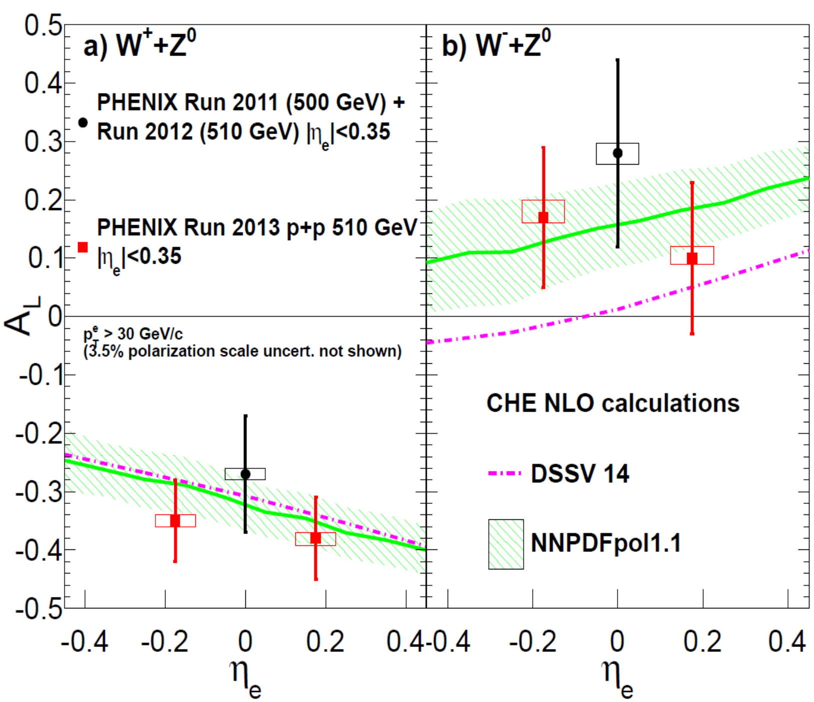
$\Delta\bar{u} > \Delta\bar{d}$ consistent with some models and Lattice

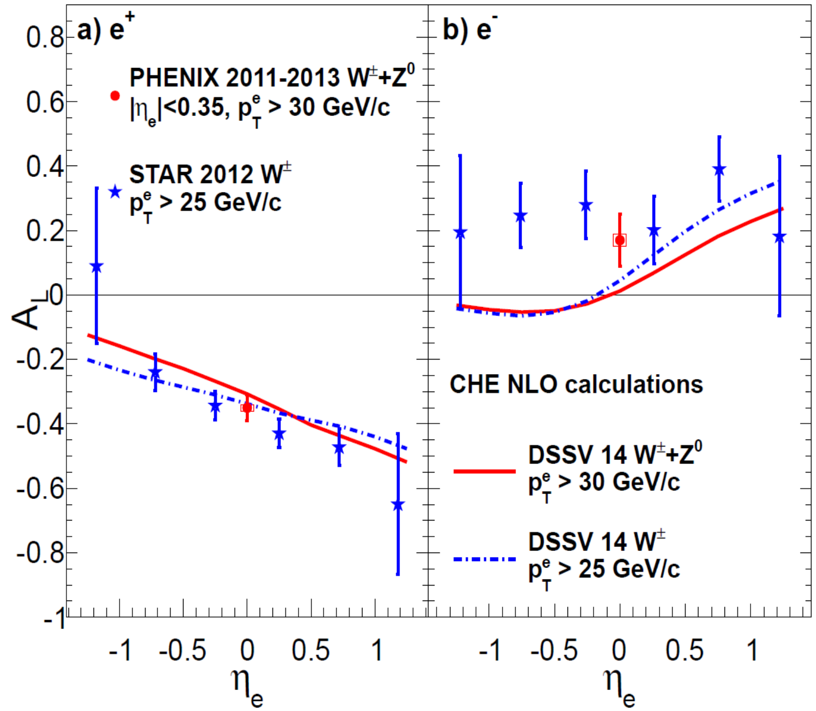
$\Delta\bar{u}(x)$ and $\Delta\bar{d}(x)$ from A_L of $W^{\pm}$ production

Chong Kim

PHENIX data

•arXiv:1504.07451





$\Delta\bar{u} > \Delta\bar{d}$ consistent with STAR result

Spin Decomposition

Xiang-Dong Ji

- There has been much theoretical confusion about spin sum rule for the nucleon, many dozens of theoretical papers have been written on the subject.
  - ➔ F. Wang, X. S. Chen, Wakamatsu, E. Leader, C. Lorce, Y. Hatta, X. Ji, F. Yuan, Y. Zhao, …
- But the confusion is over, move on!

See talks by Bo-Qiang Ma and Xiang-Song Chen

Partonic spin sum rule

- Partonic spin sum rule was proposed by Jaffe and Manohar (1991)

$$\tfrac{1}{2} = \tfrac{1}{2}\,\Delta\Sigma + \Delta G + \ell_q + \ell_g$$

- Locality and gauge-invariance yield the unique result (Ji, 1996)

$$\tfrac{1}{2} = \tfrac{1}{2}\,\Delta\Sigma + L_q + J_g$$

- No direction calculation of ΔG from lattice QCD, because it is a "light-cone" quantity
- Now we provide a first recipe
  - → Calculate E x A in an appropriate gauge with a finite momentum nucleon and boost!

Results

Takumi Doi

Spin = 25(12)%

Glue = 28(08)%

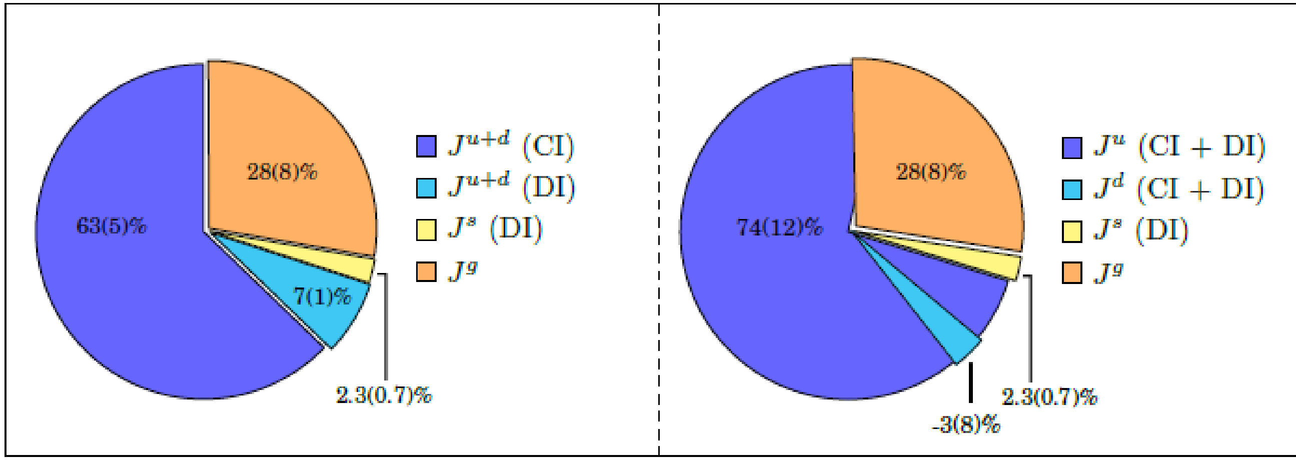
Orbital = 47(13)%

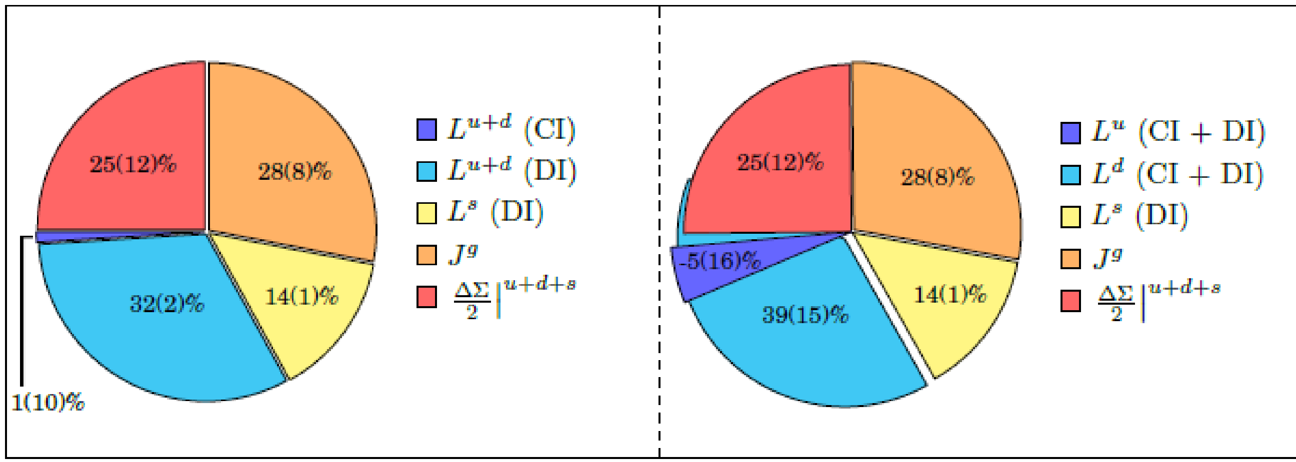
DI part is important

L(u) + L(d) [CI] ~= 0

J(u) >> J(d) [CI] ~= 0

(observed in other Lat)





	CI(u)	CI(d)	CI(u+d)	DI(u/d)	DI(s)	Glue
$\langle x \rangle$	0.413(38)	0.150(19)	0.565(43)	0.038(7)	0.024(6)	0.334(55)
$T_2(0)$	0.286(108)	-0.220(77)	0.062(21)	-0.002(2)	-0.001(3)	-0.056(51)
$2J$	0.700(123)	-0.069(79)	0.628(49)	0.036(7)	0.023(7)	0.278(75)
g_A	0.91(11)	-0.30(12)	0.62(9)	-0.12(1)	-0.12(1)	–
$2L$	-0.21(16)	0.23(15)	0.01(10)	0.16(1)	0.14(1)	–

From our old results:
Dong et al., PRL75(1995)2096

Effect of the Pion Cloud/ Chiral Symmetry

Tony Thomas

	$2\,L_{u+ubar}$	$2\,L_{d+dbar}$	Σ
Non-relativistic			1.0
Relativity (e.g. Bag)	0.46	-0.11	0.65
Plus OGE	0.52	-0.02	0.50
Plus pion	0.50	0.12	0.38

At model scale: $L_u + S_u = 0.25 + 0.42 = 0.67 = J_u$

: $L_d + S_d = 0.06 - 0.22 = -0.16 = J_d$

Features of Supersymmetric Equations

Stan Brodsky

- J =L+S baryon simultaneously satisfies both equations of G with L , L+1 for same mass eigenvalue
- $J^z = L^z + 1/2 = (L^z + 1) - 1/2$ $\quad S^z = \pm 1/2$
- Baryon spin carried by quark orbital angular momentum: $<J^z> = <L^z{}_q>$
- Mass-degenerate meson "superpartner" with $L_M = L_B + 1$. *"Shifted meson-baryon Duality"*

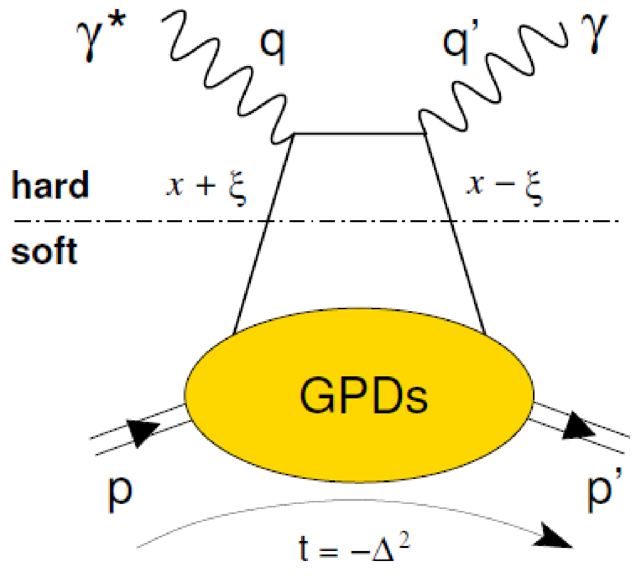
Meson and baryon have same κ !

Proton spin carried by quark orbital angular momentum

Generalized PDF's

- Correlating transverse spatial and longitudinal momentum degrees of freedom
- PDFs and elastic FF as limiting cases
- $H, \tilde{H} \to f_1, g_1$ for $\xi \to 0$;
- no such limiting cases for E, $\tilde{\mathrm{E}}$
- *H (E)* for nucleon helicity (non)conservation

DVCS



$$H(x, \xi, t, Q^2); \quad Q^2 \text{ large, } t \text{ small}$$

$$H^f, E^f, \tilde{H}^f, \tilde{E}^f \text{ with } f = q, g$$

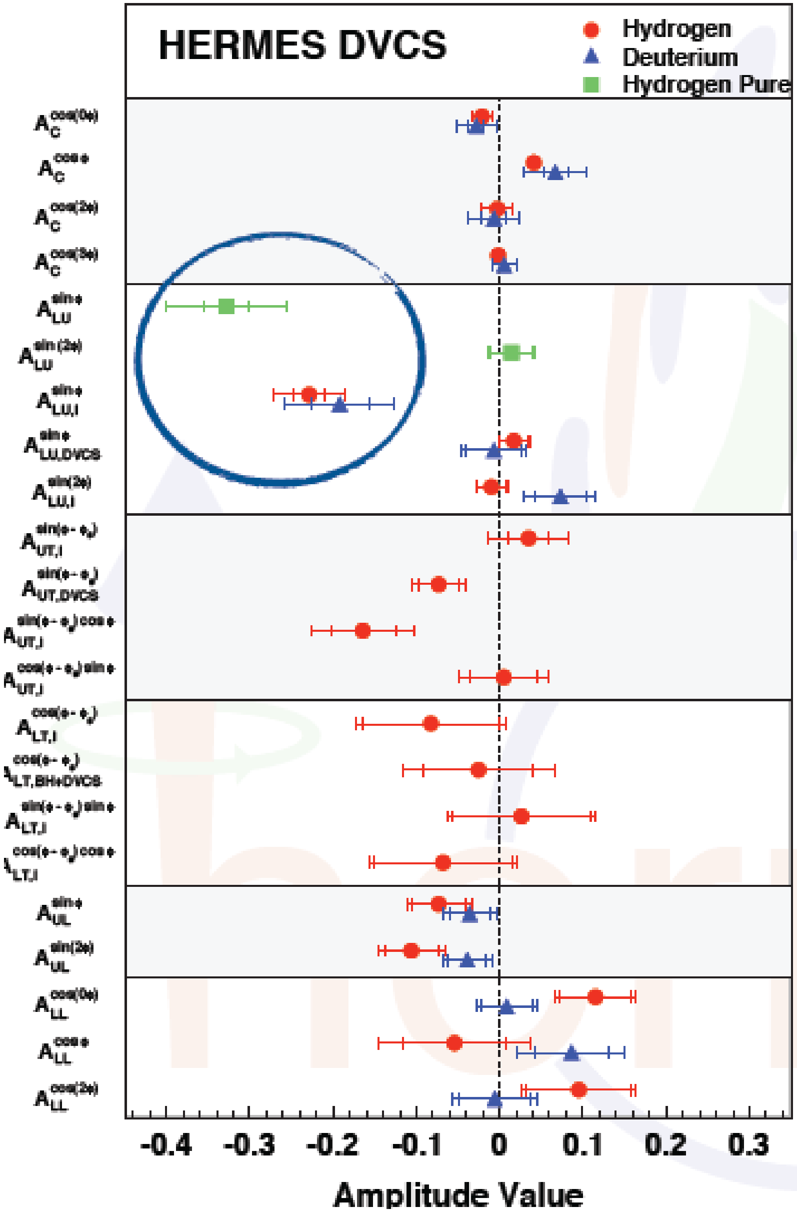
Gerhard Mallot

Ji's sum rule for total orbital momentum:

$$J^f(Q^2) = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} \mathrm{d}x\, x \left[H^f(x, \xi, t, Q^2) + E^f(x, \xi, t, Q^2) \right]$$

X.-D. Ji, PRL 78 (1997) 610

DVCS @ HERMES



HERMES analyzed a wealth of DVCS-related asymmetries on nucleon and nuclear targets

data with recoil-proton detection allows clean interpretation

indication of larger amplitudes for pure sample

-> assoc. DVCS in "traditional" analysis mainly dilution, supported by **recent results from HERMES [JHEP 01 (2014) 077]:**

assoc. DVCS results consistent with zero but also with model prediction

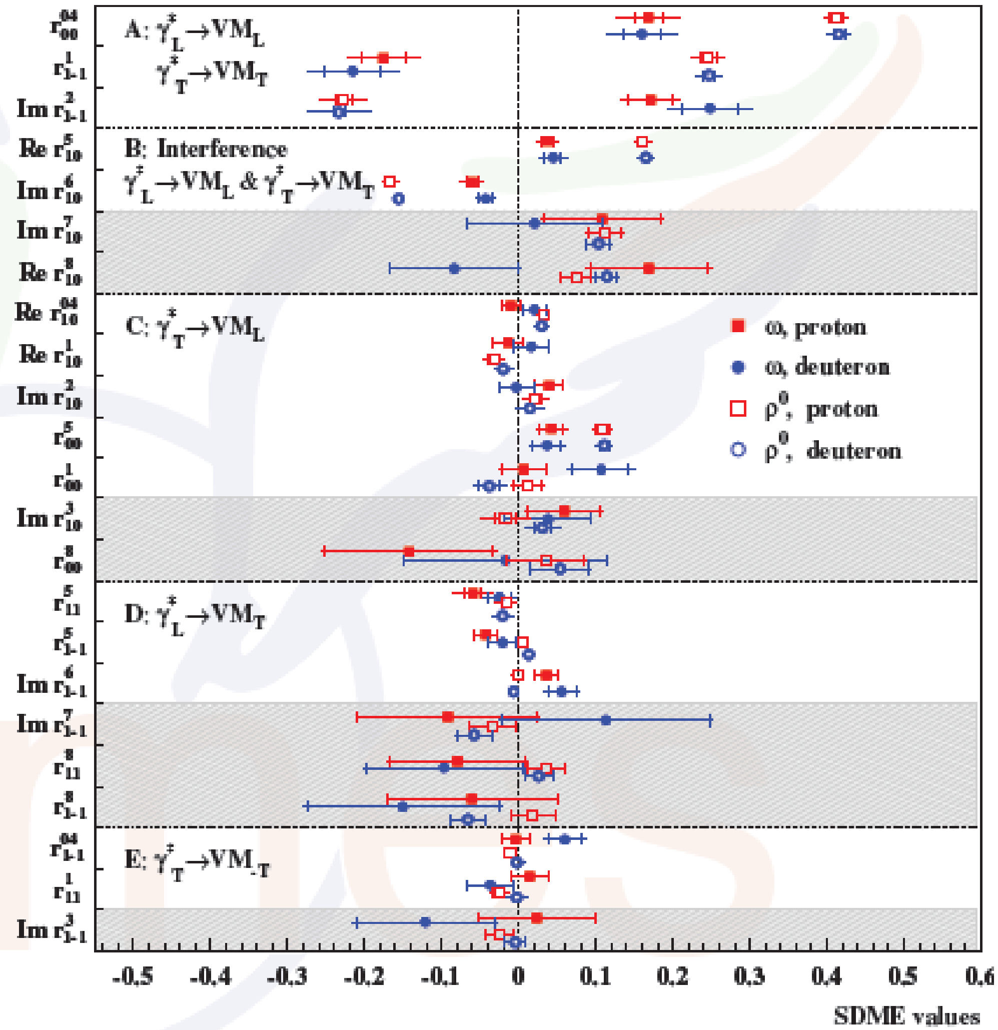
Gunar Schnell

Gunar Schnell

HEMP @ HERMES

- extensive data set on unpolarized and polarized SDMEs in vector-meson production
- (not shown:) cross section and A_{UT} for excl. π^+
- essential input in model building
- recent results on omega production require pion-pole contribution with a preference for positive $\pi\omega$ transition FF

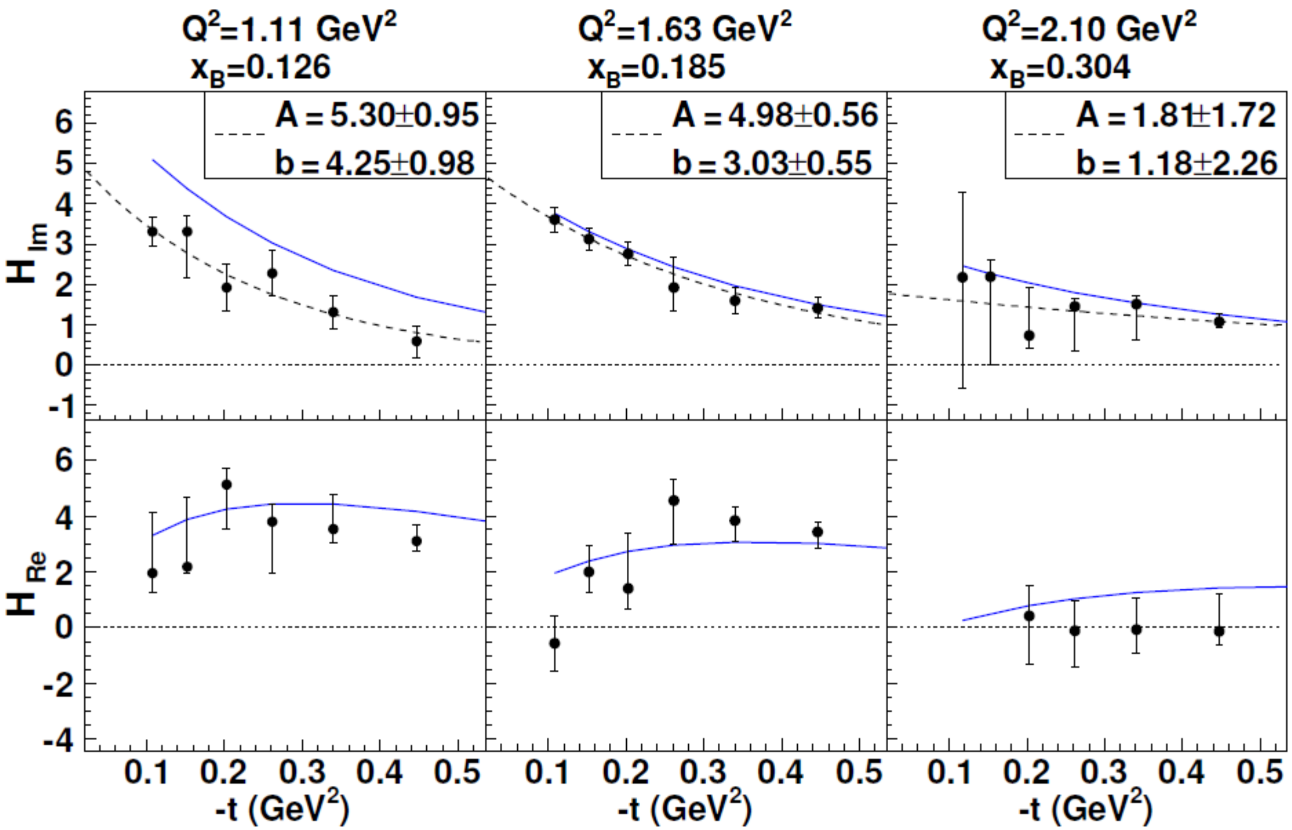
[A. Airapetian et al., EPJ C74 (2014) 3110, EPJ C62 (2009) 659]



DVCS at JLab

Silvia Pisano

Hall-B: DVCS cross-section on the proton in Hall-B (E01-113)



- ○ VGG model
- ○ Ae^{bt}

- A, b increases with x_B
- $\longrightarrow$ the partonic content of the nucleon increases when probing smaller x_B

- *H. S. Jo et. al., hep-ex*:1504.02009, accepted by PRL

Extraction and applications of generalized parton distributions

Peter Kroll

Ji's sum rule for 2nd moments of H and E

$$J^a = \frac{1}{2}\left[q_{20}^a + e_{20}^a\right] \qquad J^g = \frac{1}{2}\left[g_{20} + e_{20}^g\right] \qquad (\xi = t = 0)$$

q_{20}^a, g_{20} from ABM11 (NLO) PDFs $\qquad (a = u, d, s, \bar{u}, \bar{d}, \bar{s})$

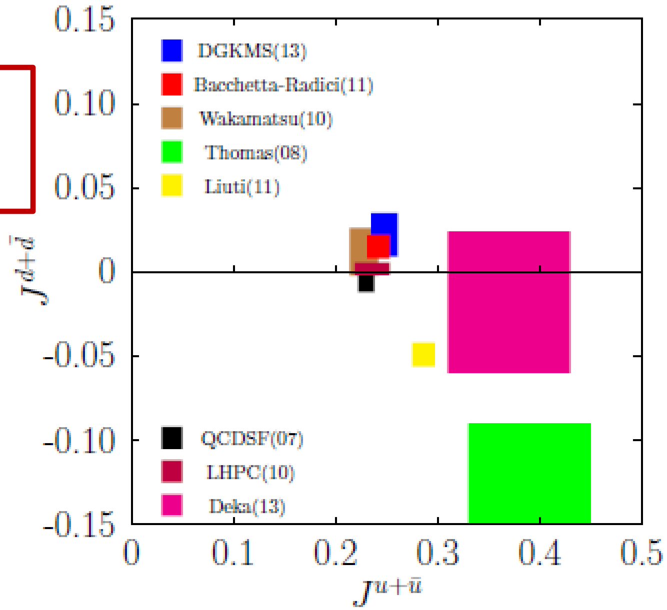
$e_{20}^{a_v}$ from form factor analysis Diehl-K. (13):

$e_{20}^s \simeq 0 \ldots -0.026$ from analysis of A_{UT} in DVCS and pos. bound

e_{20}^g from sum rule for e_{20}: $\int_0^1 dx x e_g(x) \equiv e_{20}^g = -\sum e_{20}^{a_v} - 2\sum e_{20}^{\bar{a}}$

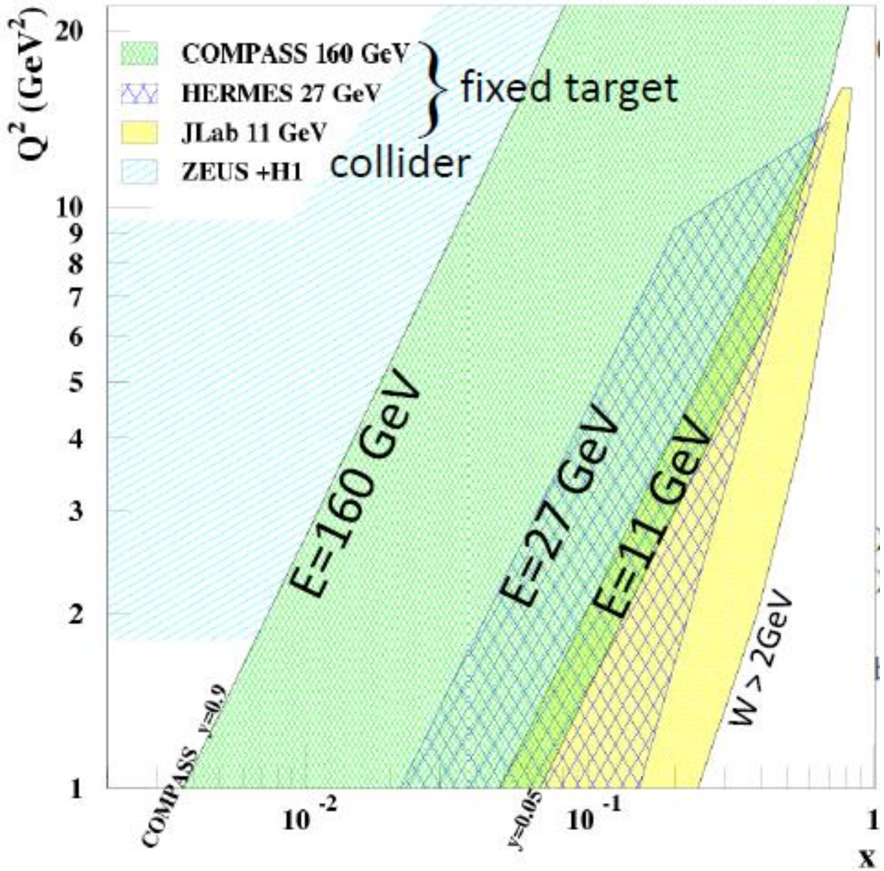
(Diehl-Kugler(07), Goloskokov-K (09), K. 1410.4450)

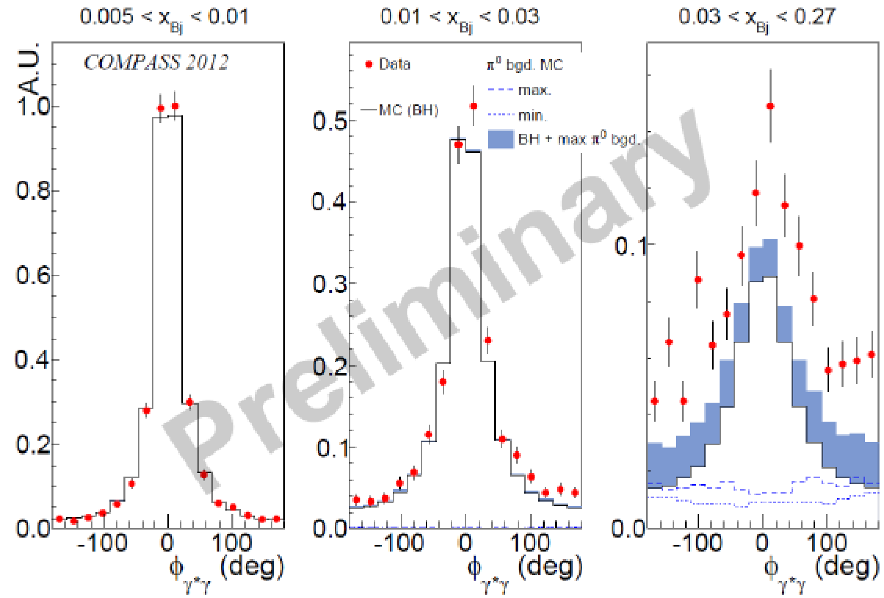
$$\boxed{\begin{aligned} J^{u+\bar{u}} &= 0.261\ldots 0.235\,; \qquad J^{d+\bar{d}} = 0.035\ldots 0.009\,; \\ J^g &= 0.187\ldots 0.265\,; \qquad J^{s+\bar{s}} = 0.017\ldots -0.009\,; \end{aligned}}$$



GPD studies at COMPASS
Exclusive measurements

Nicole d'Hose





K. Tanaka

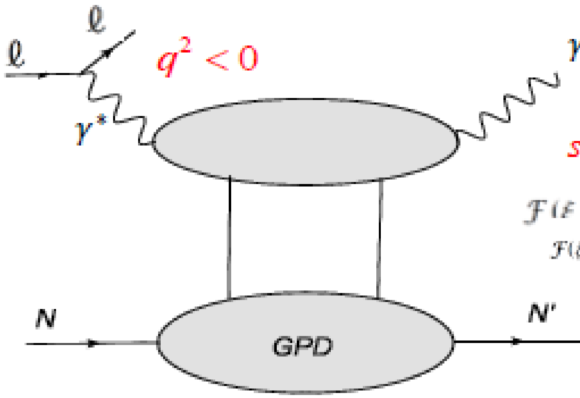
T. Sawada

Extraction of **GPD**

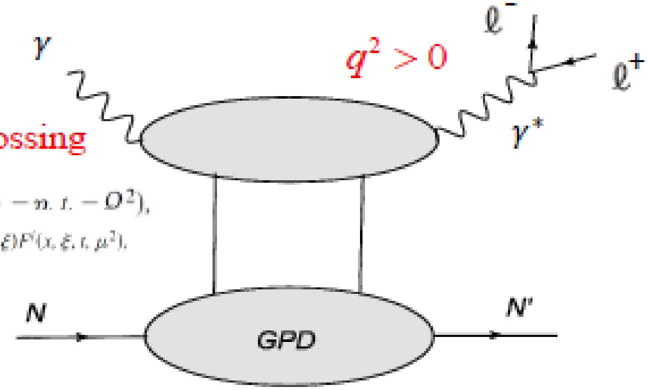
Space-like vs. **Time-like** Processes

Muller et al., PRD 86 031502(R) (2012)

Deeply Virtual Compton Scattering (DVCS)



Time-like Compton Scattering (TCS)

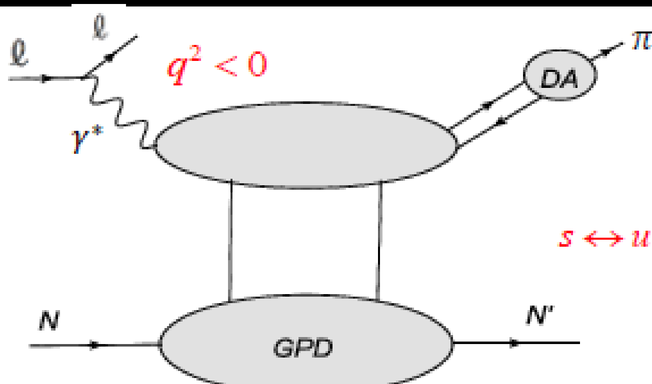


$s \leftrightarrow u$ channel crossing

$$\mathcal{F}(\xi = \eta, t, Q^2) \overset{\mathrm{SL}\to\mathrm{TL}}{\Rightarrow} \mathcal{F}(\xi = -\eta, t, -Q^2),$$

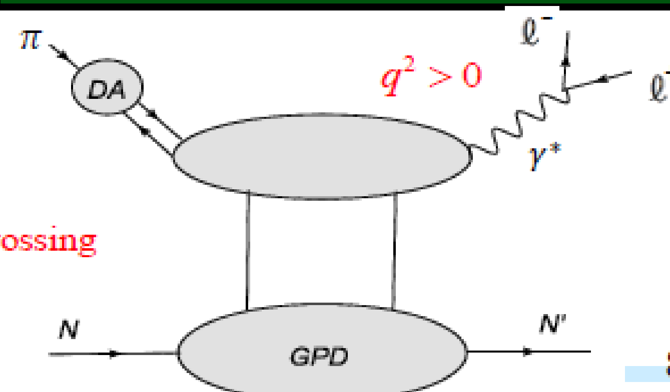
$$\mathcal{F}(\xi, t, Q^2) = \int_{-1}^{1} dx \sum_{i=u,d,\cdots,s} {}^{S}T^i(x,\xi) F^i(x,\xi,t,\mu^2).$$

Deeply Virtual Meson Production (DVMP)



$s \leftrightarrow u$ channel crossing

Exclusive meson-induced DY



8

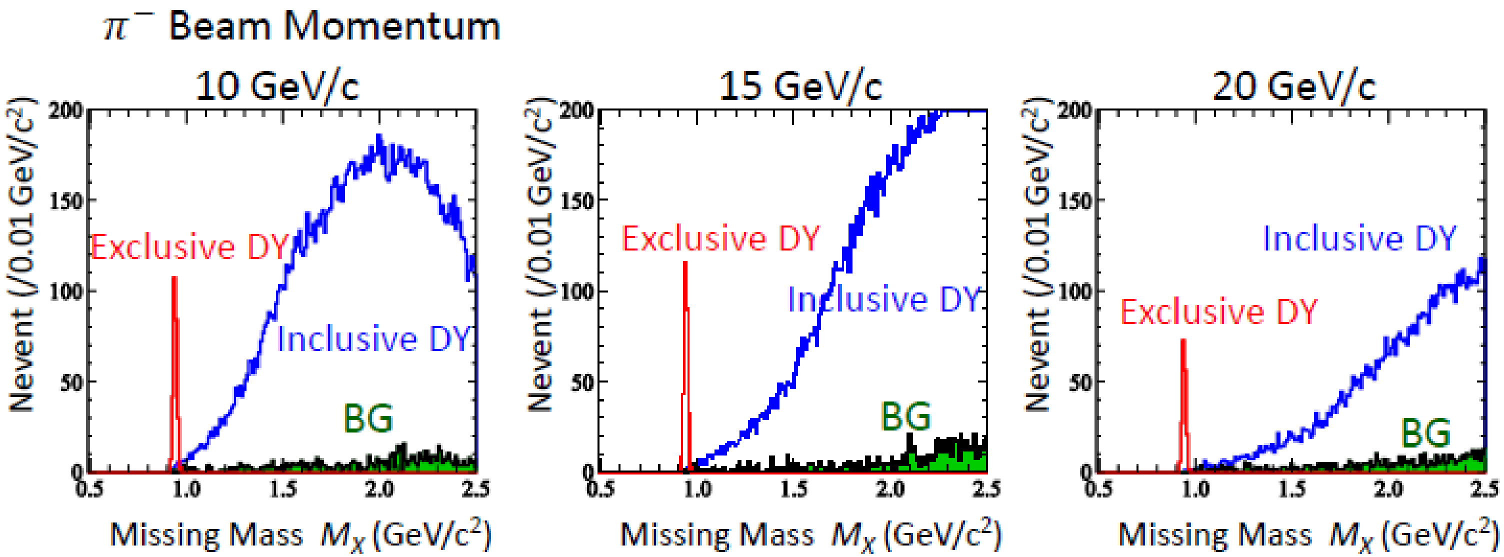
J-PARC High-Momentum beam and the P-50 spectrometer

T. Sawada

Data Taking Period: 50 days

$1.5 < M_{\mu^+\mu^-} < 2.9\ \mathrm{GeV}/c^2$

Preliminary



- The signal of exclusive Drell-Yan processes can be clearly identified in the missing mass spectrum of dimuon pairs.
- Because of the low event rate, this program could be accommodated into the E50 experiment.

23

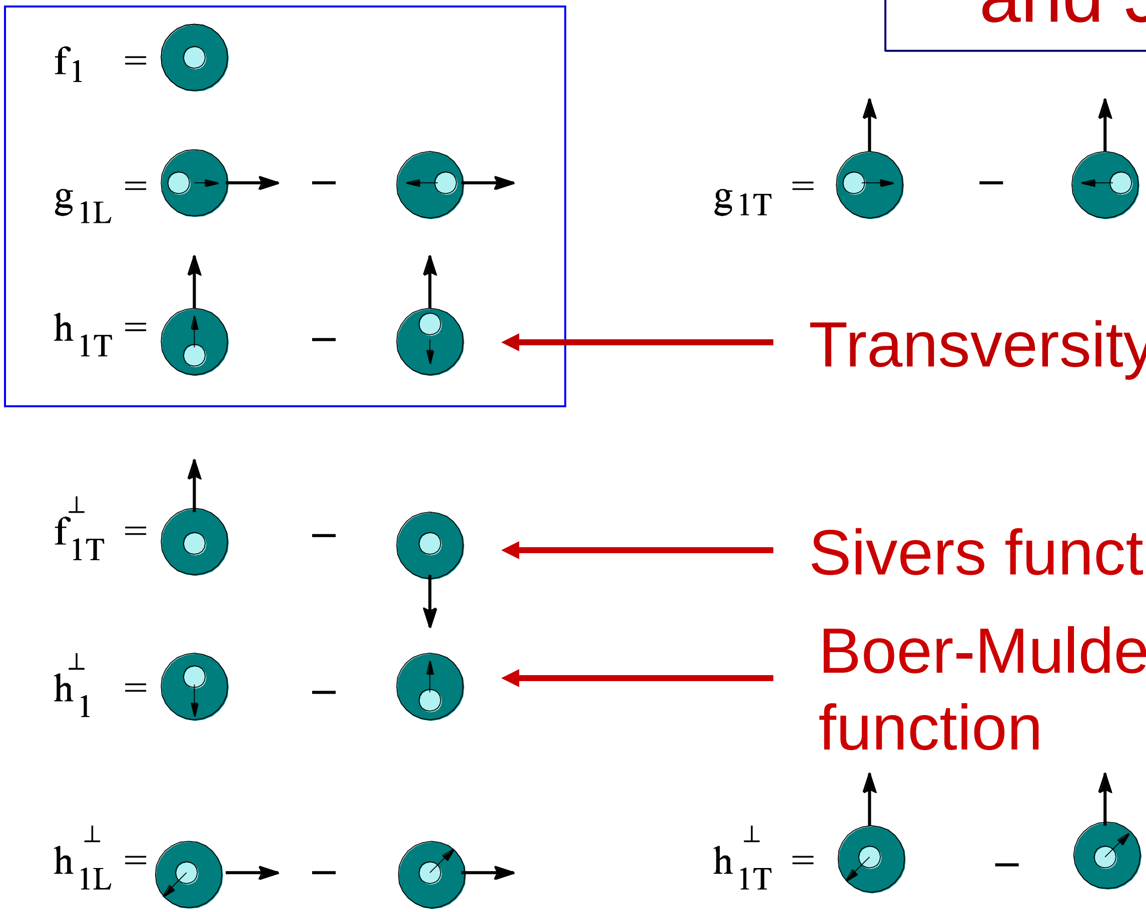
Transverse Momentum Dependent (TMD) Quark Distributions

See overviews by Z. Liang and J. Qiu

Leading-Twist Quark Distributions

(A total of eight distributions)

Three survive after $K_\perp$ integration



Transversity

Sivers function

Boer-Mulders function

The other five are transverse momentum ($K_\perp$) dependent (TMD)

Three parton distributions describing transverse momentum and/or transverse spin

Three transverse quantities:

1) Nucleon transverse spin

$\vec{S}_\perp^N$

2) Quark transverse spin

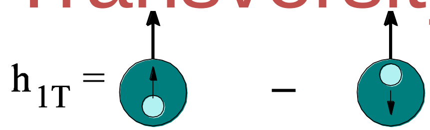
$\vec{s}_\perp^q$

3) Quark transverse momentum

$\vec{k}_\perp^q$

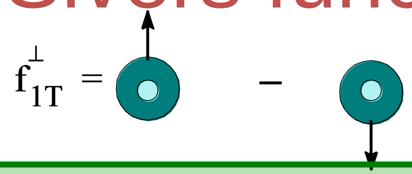
$\Rightarrow$ Three different correlations

1) Transversity



Correlation between $\vec{s}_\perp^q$ and $\vec{S}_\perp^N$

2) Sivers function



Correlation between $\vec{S}_\perp^N$ and $\vec{k}_\perp^q$

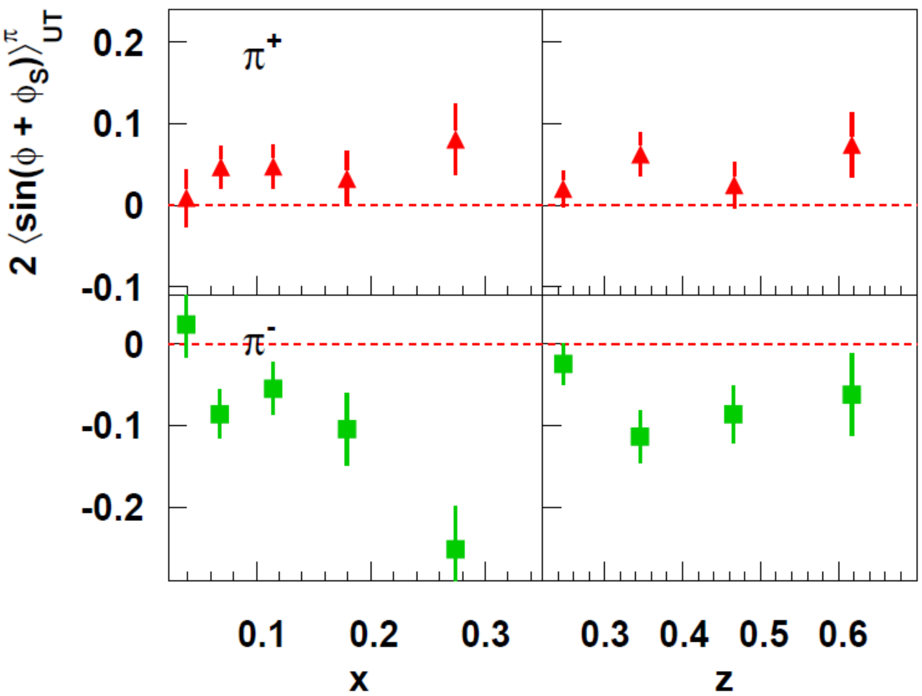
3) Boer-Mulders function

Correlation between $\vec{s}_\perp^q$ and $\vec{k}_\perp^q$

Observation of $\sin(\phi+\phi_S)$ dependence in SIDIS

Y. Miyachi

Hermes (2005)



"Collins" asymmetry :

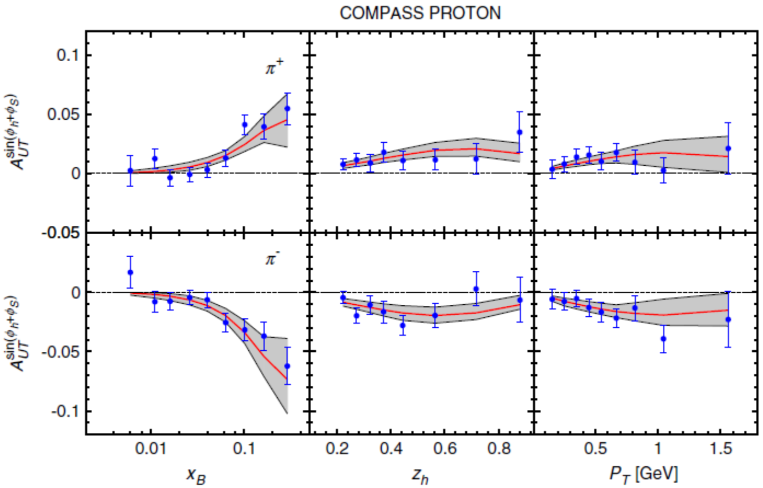
$$\langle\sin(\phi+\phi_S)\rangle_{UT} \propto h_1 \otimes H_1^{\perp}$$

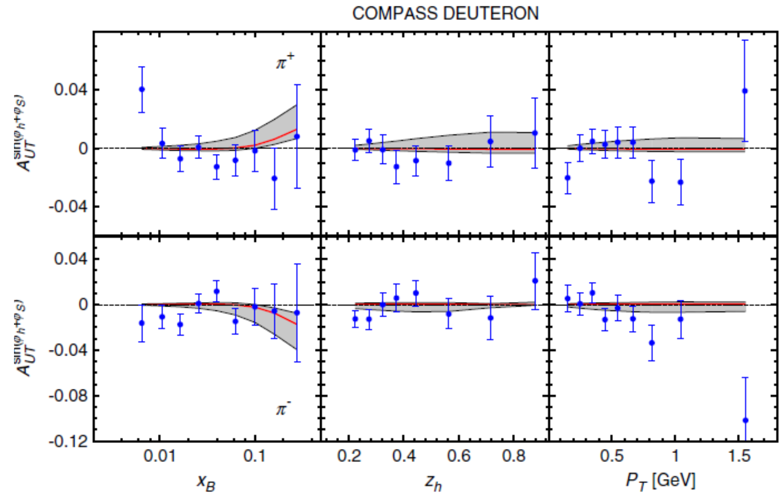
- Product of $h_1(x)H_1^{\perp}(z)$ is non-zero
- A surprising flavor dependence : $H_1^{\perp,\,unfavored} / H_1^{\perp,\,favored} \approx -1$
- Extraction of $h_1(x)$ requires an independent measurement of Collins function $H_1^{\perp}(z)$

Extraction of Transversity and Collins fragmentation function from SIDIS and Belle data

Torino group, Anselmino et al., PRD 87, 094019 (2013)

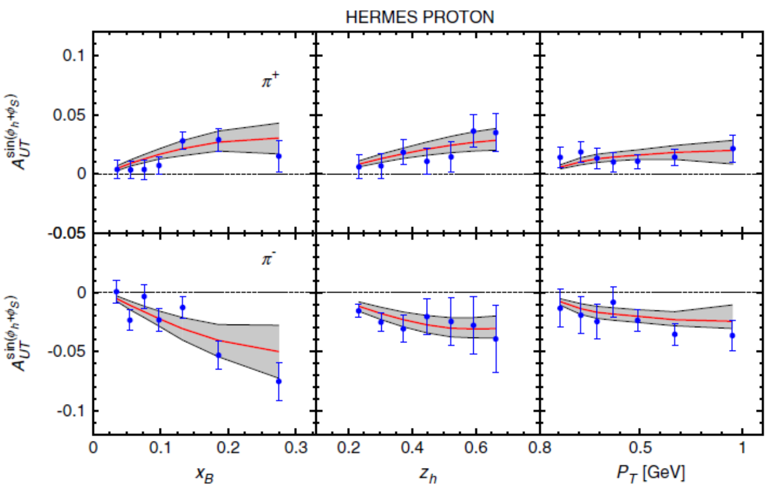
SIDIS on *p*

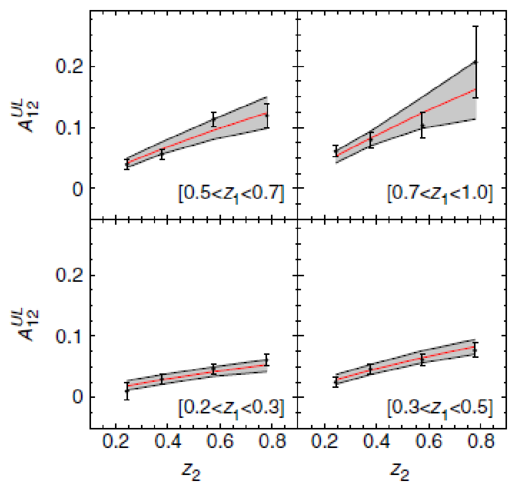




SIDIS on *d*

SIDIS on *p*





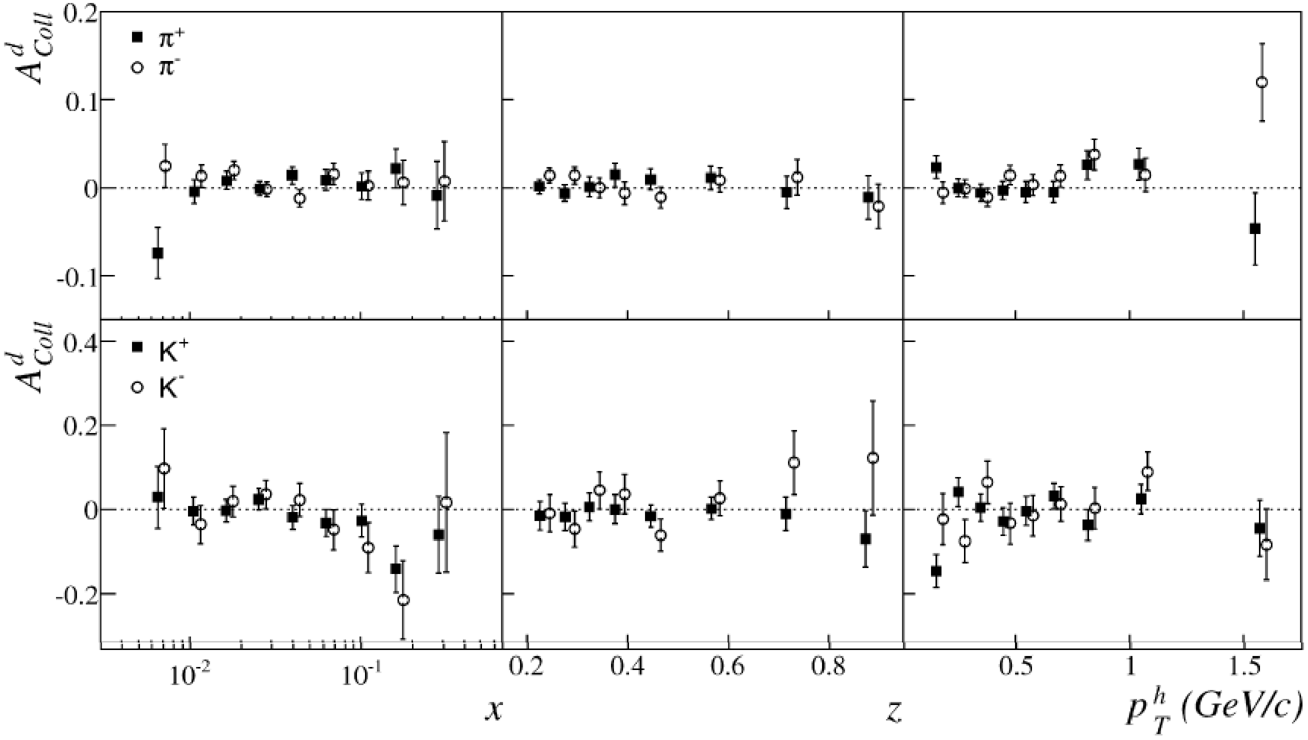
Belle

e^+e^-

$\sin(\phi+\phi_S)$ dependence from COMPASS

160 GeV/c muon on polarized ^{6}Li D target

Oleg Denisov



Consistent with zero!

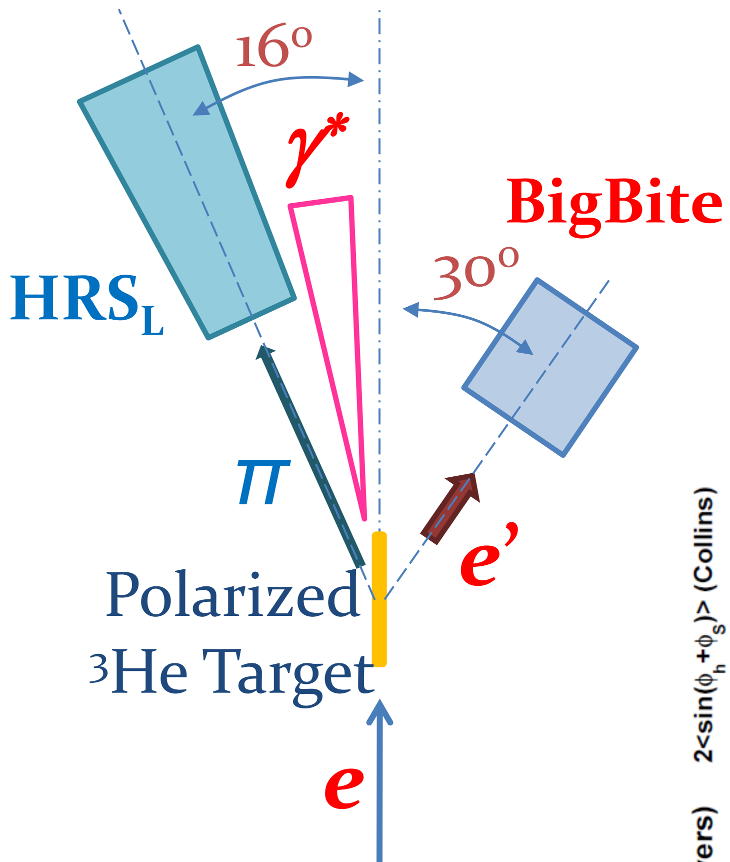
Compass (2005)

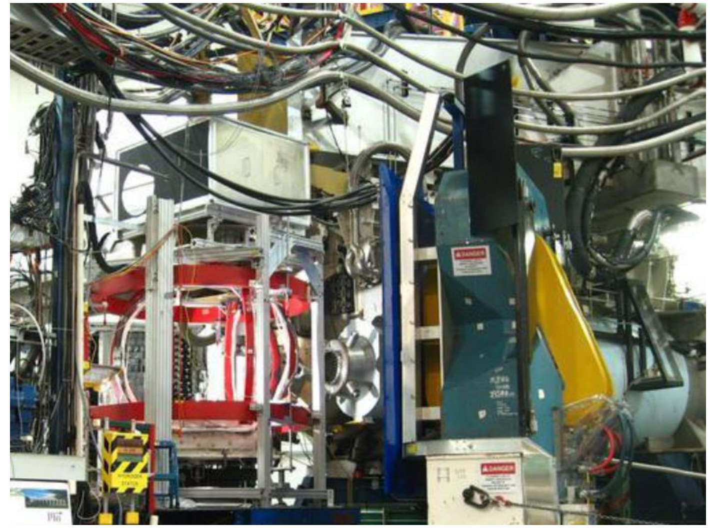
Cancellation between proton and neutron in deuteron ?

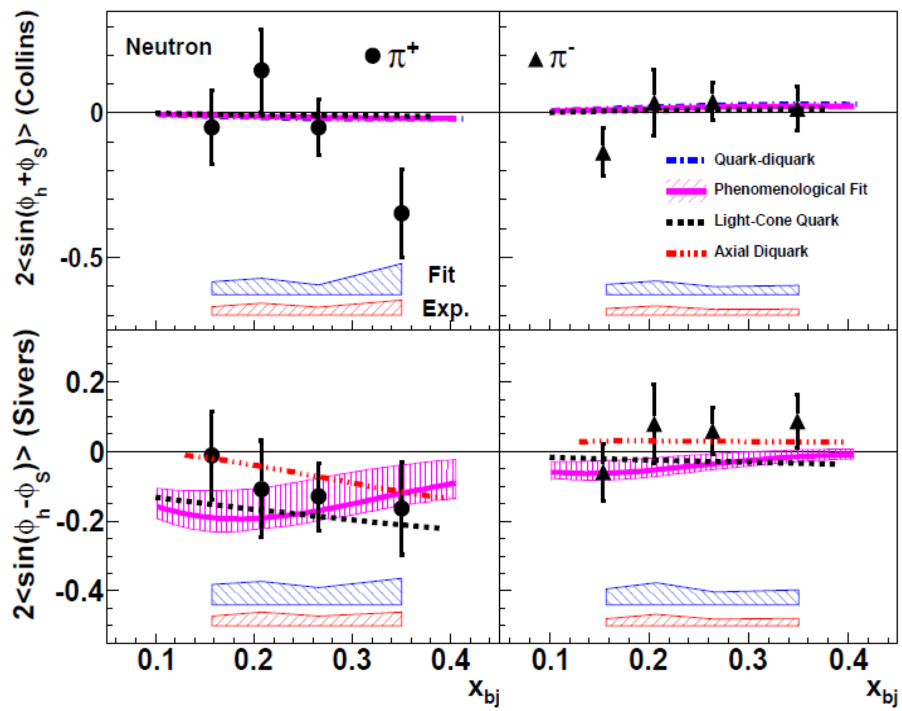
Need an independent measurement on neutron

$^3He^{\uparrow}(e,e'\pi^{+/-})x$ at JLab Hall A

J. Chen



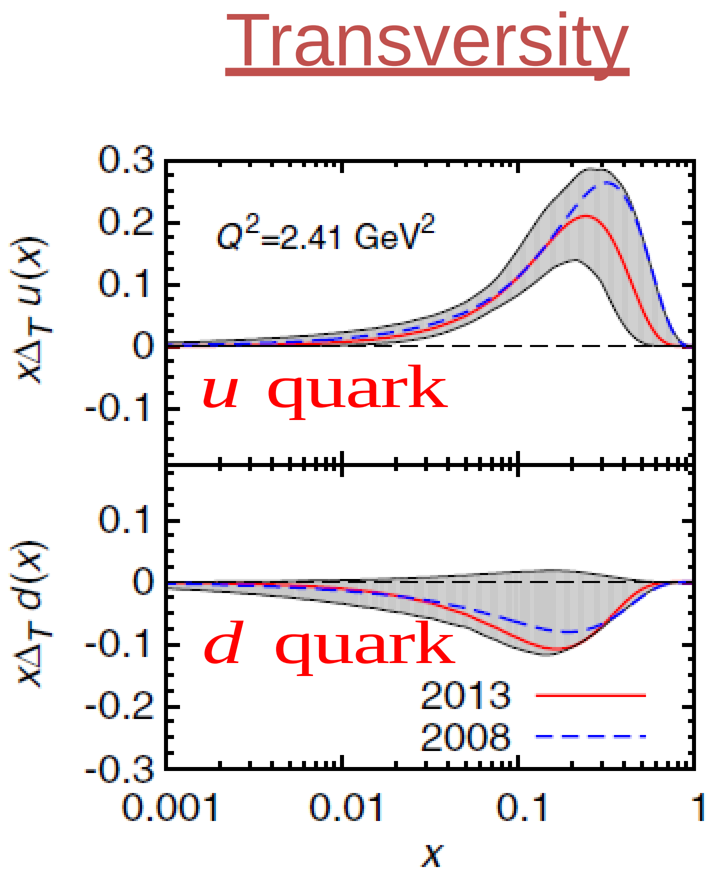


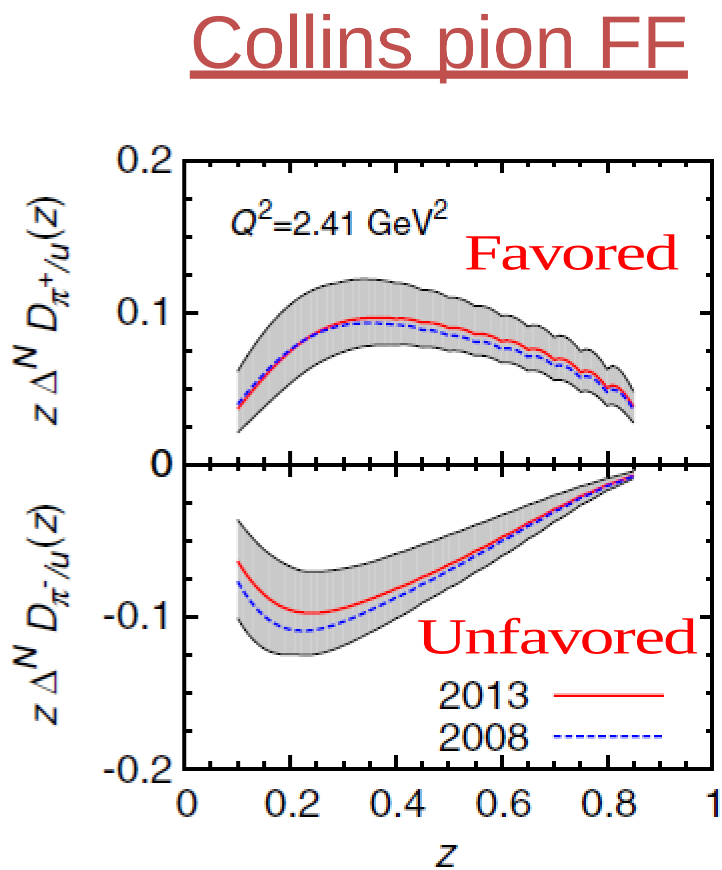


Obtain full coverage in Φ angle by rotating the target spin direction

Extraction of Transversity and Collins fragmentation function from SIDIS and Belle data

Torino group, Anselmino et al., PRD 87, 094019 (2013)





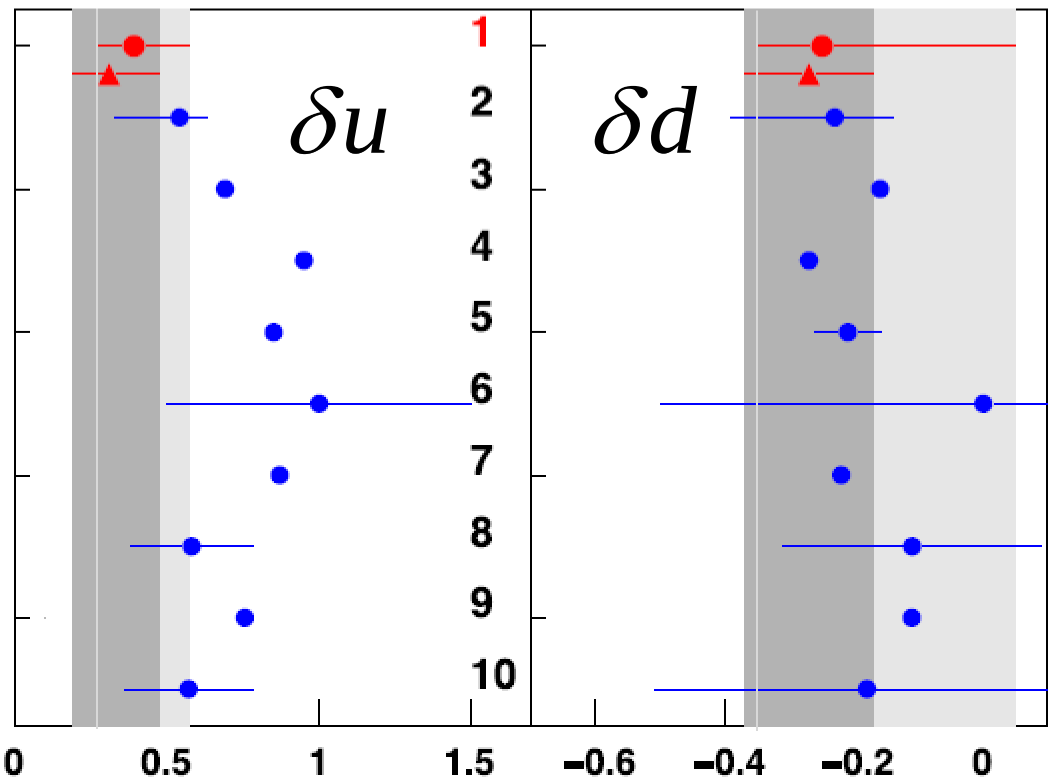
Extraction of nucleon tensor charge

Torino group, Anselmino et al., PRD 87, 094019 (2013)

● $\delta u = 0.39^{+0.18}_{-0.12}$ ● $\delta d = -0.25^{+0.30}_{-0.10}$

▲ $\delta u = 0.31^{+0.16}_{-0.12}$ ▲ $\delta d = -0.27^{+0.10}_{-0.10}$

$$\delta q = \int_0^1 [h_1^q(x) - h_1^{\bar{q}}(x)]dx$$



$\Delta u = 0.787$ $\Delta d = -0.319$

1 : Extractions from global fits (using two different Collins FF parameterizations)

2-10: Predictions from various models (including LQCD)

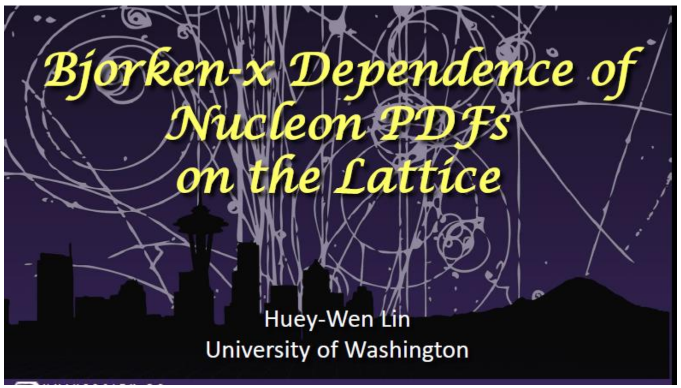
- Tensor charges are smaller than axial charge
- Discrepancy could be caused by neglecting sea transversity in the fit

Recent progress in LQCD suggests the possibility to calculate the *x*-dependence of parton distributions

PRL **110,** 262002 (2013) PHYSICAL REVIEW LETTERS week ending 28 JUNE 2013

Parton Physics on a Euclidean Lattice

Xiangdong Ji[1,2]



Transversity Distribution

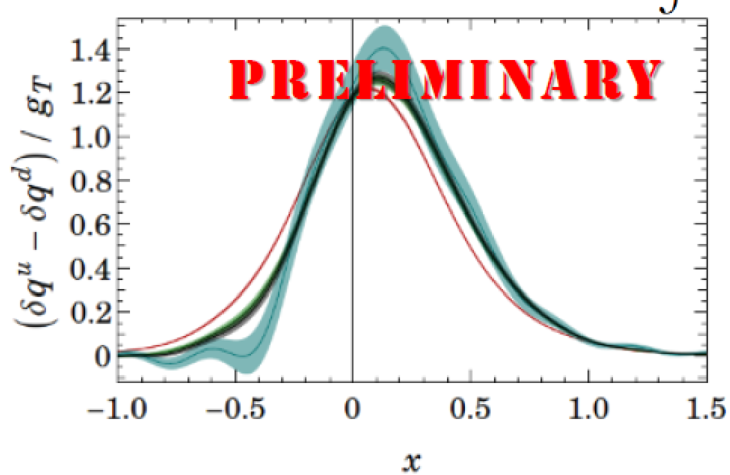
§ Exploratory study

- We found $\delta\bar{u} < \delta\bar{d}$ with large sea asymmetry
- Chiral quark-soliton model

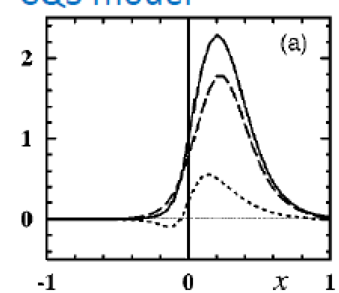
$$\int dx \, \frac{\delta\bar{u}(x) - \delta\bar{d}(x)}{g_T} \approx -0.320\,(18)$$

$$\int dx \left(\delta\bar{u}(x) - \delta\bar{d}(x)\right) \approx -0.082$$

B. Dressler et al., hep-ph/9809487



CQS model

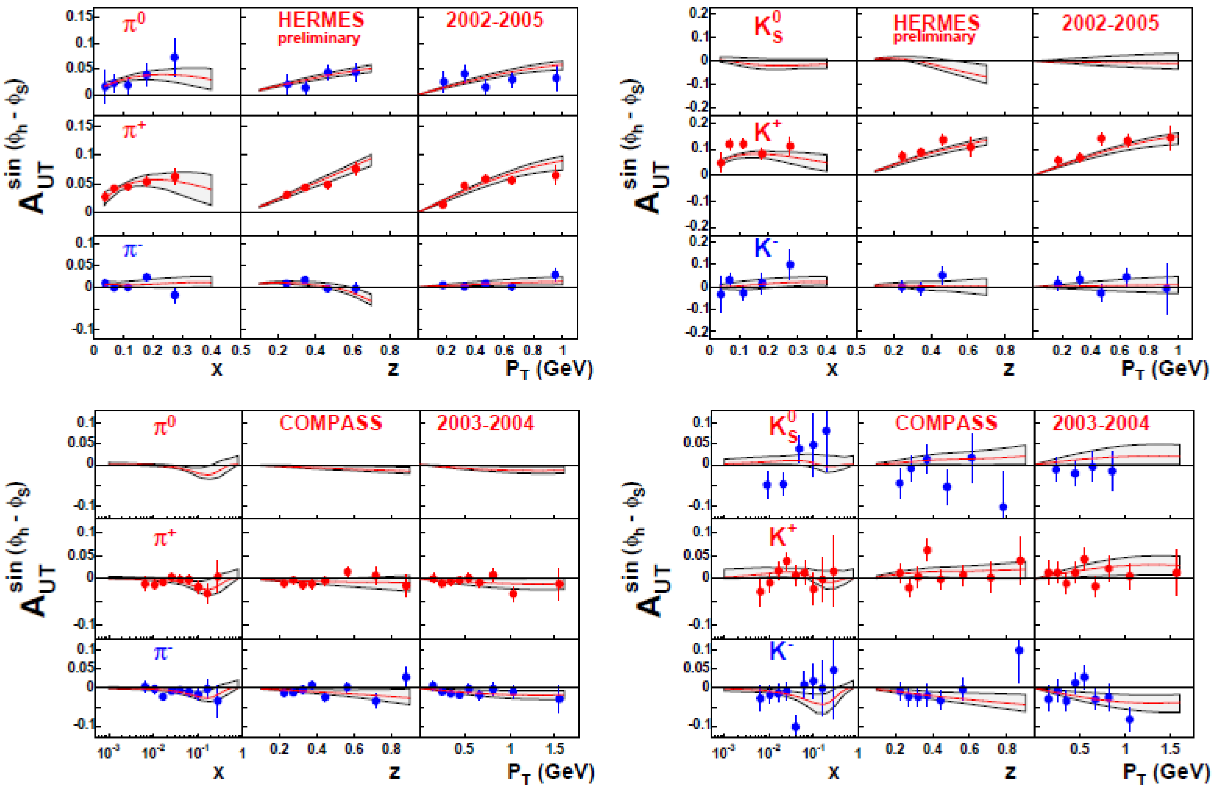


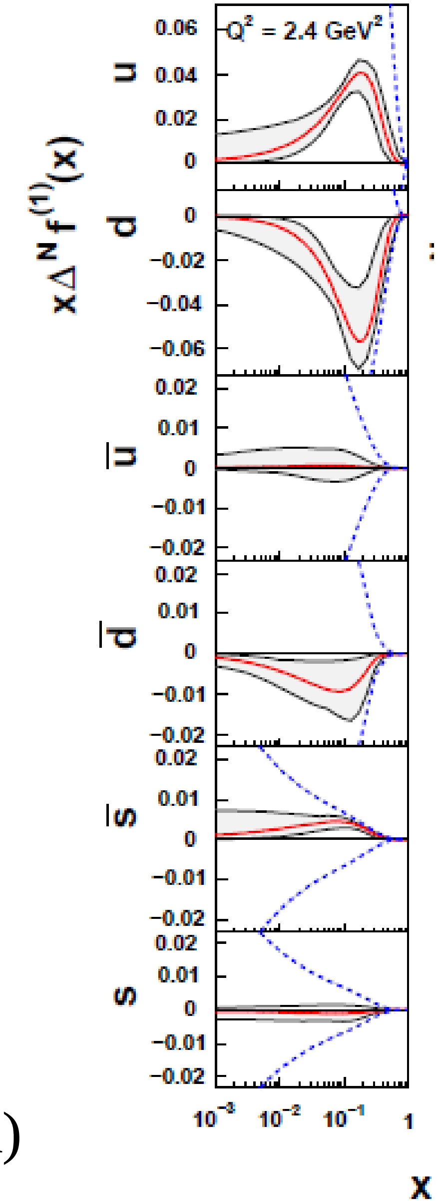
P. Schweitzer et al. PRD 64, 034013 (2001)

The *x*-dependence of the quark and antiquark transversity distributions can be calculated (not just their moments)

Extraction of Sivers function from SIDIS data

Torino group, Anselmino et al.,
Eur. Phys. J. A39 (2009) 89





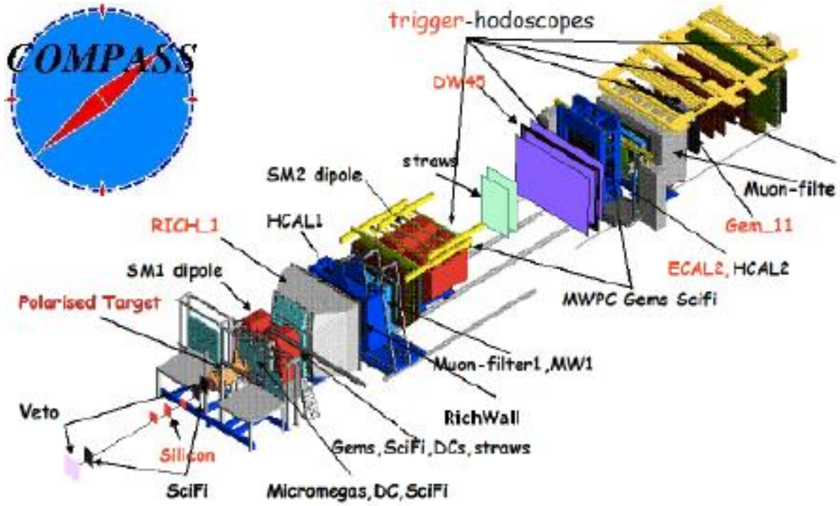
- $u-$and d - quark Sivers functions have opposite signs
- Sea-quark Sivers functions are non-zero (from K^+ data)

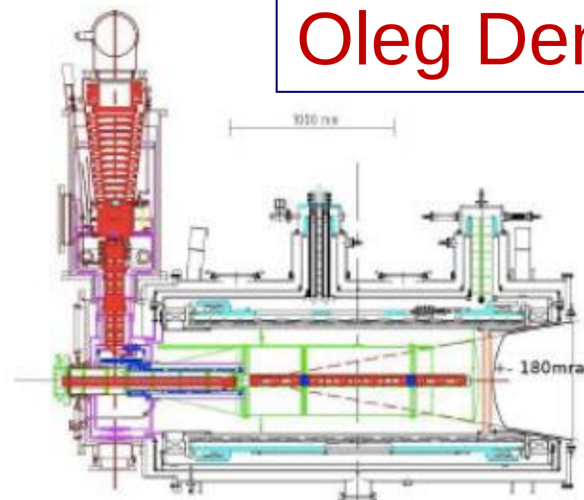
Outstanding questions on Sivers function

- Does Sivers function change sign between DIS and Drell-Yan?
- Sign and magnitude of the sea-quark Sivers functions?
- Q^2-evolution of the Sivers function?

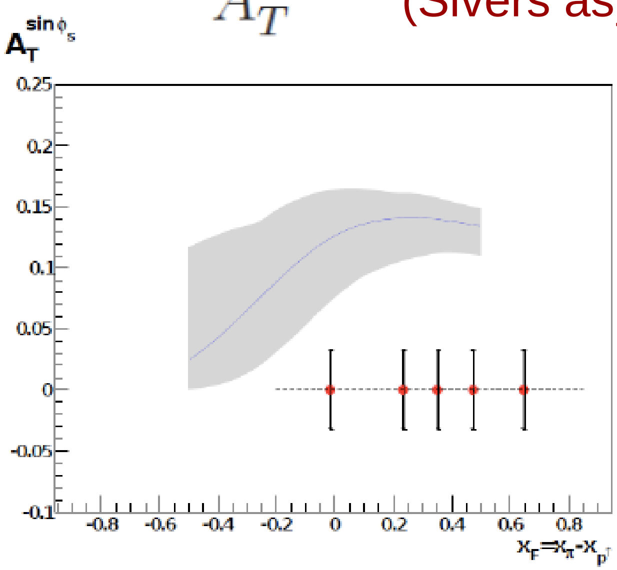
Polarized Drell-Yan with 190 GeV/c pion beam

Oleg Deniosov

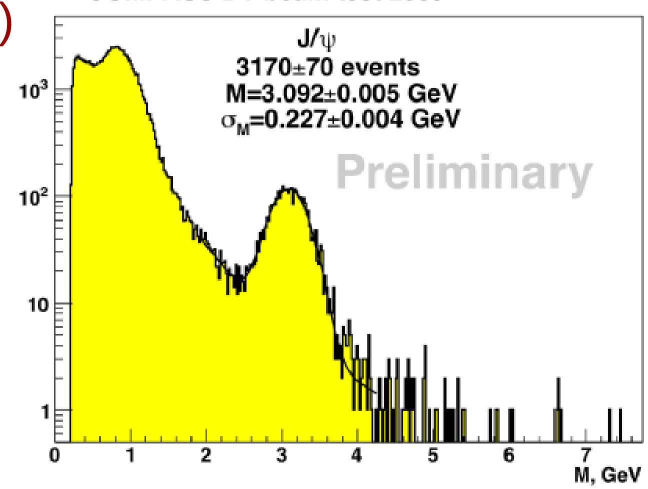




$A_T^{\sin\phi_S}$ (Sivers asymmetry)



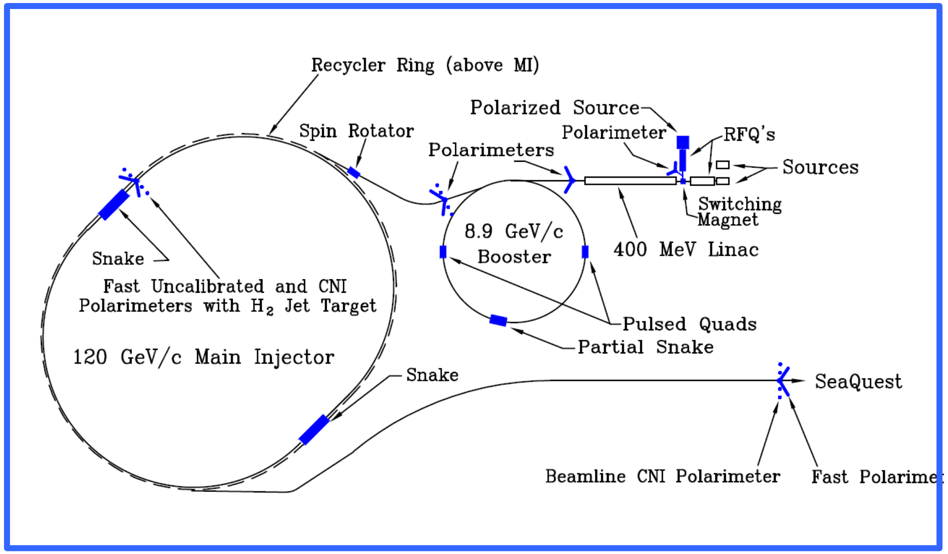
COMPASS DY beam test 2009

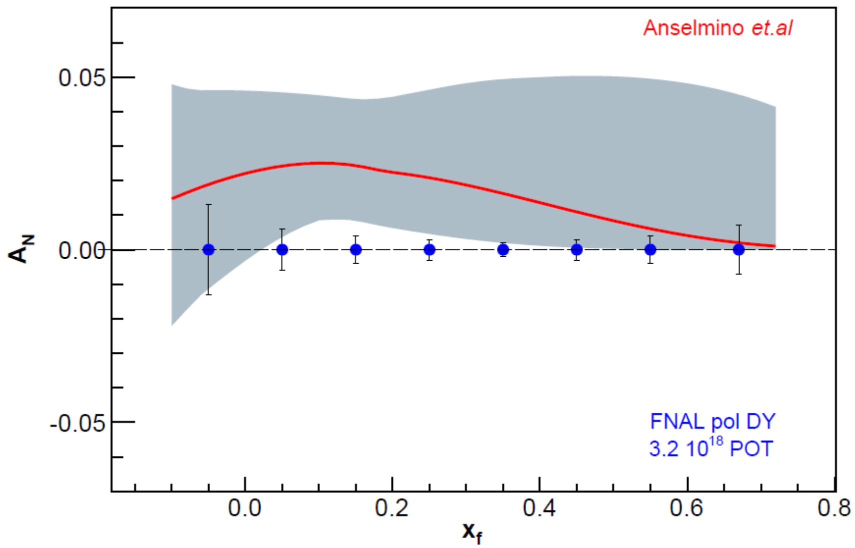


Proposal to measure Sivers in polarized Drell-Yan at Fermilab

W. Lorenzon

Proposal (P-1027) (Polarized Drell-Yan with polarized proton beam)





Main goals: 1) Accelerate polarized proton beam at the Main Injector

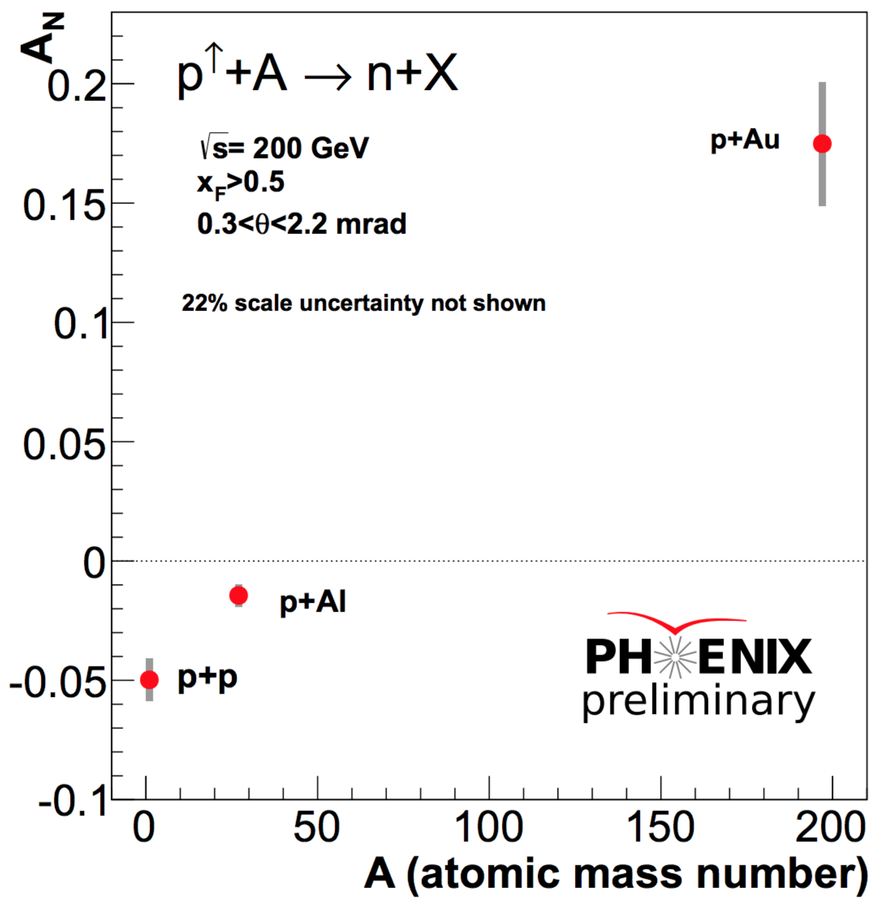
2) Test "sign-change" of T-odd Sivers function in Drell-Yan

- Propose using the existing dimuon spectrometer
- Possibility of polarized target is also being considered

A-dependence of neutron AN

Yuji Goto

- Isospin effect?
- Nuclear effect?
  - Nucleus size
  - Neutron skin
  - Coherent effect
- Other trigger or offline event selection results to be obtained



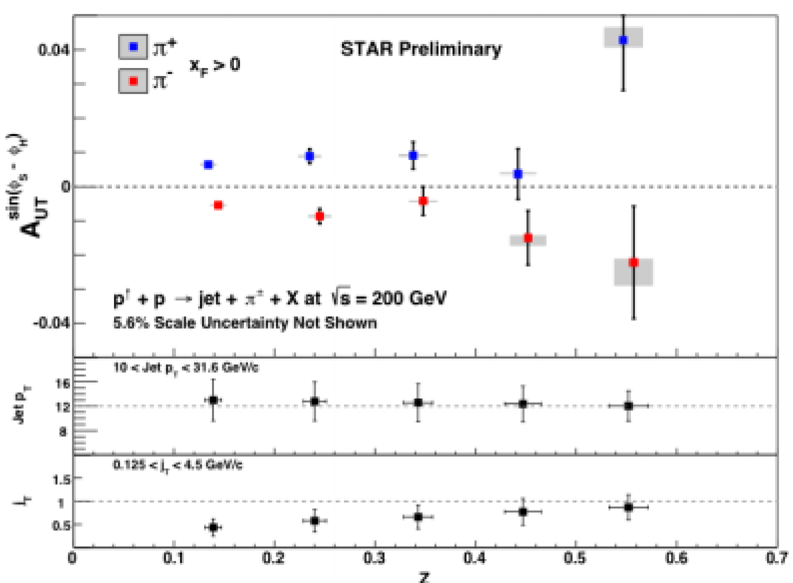
Collins Asymmetry from STAR

Qinghua Xu

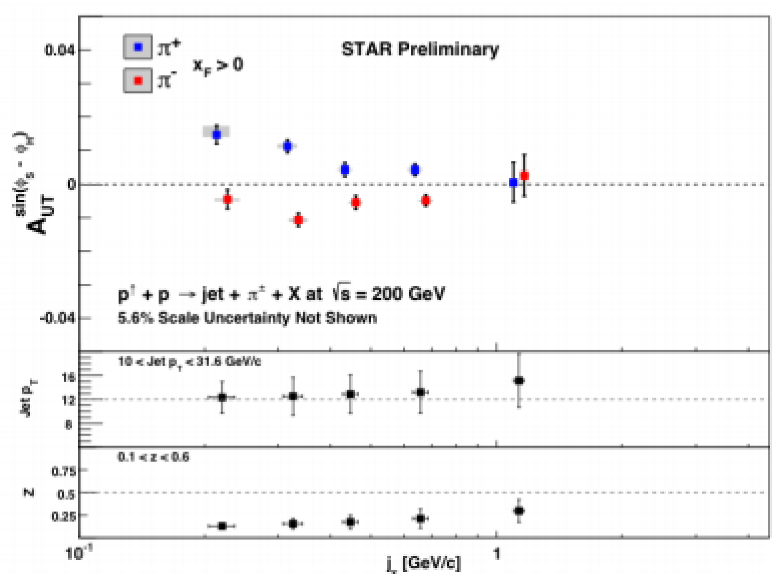
Mid-rapidity hadron-jet correlations (Collins)

- Non-zero Collins asymmetries observed from run2012 200 GeV

A_{UT} vs. z for $x_F > 0$



A_{UT} vs. j_T for $x_F > 0$



J.K. Adkins, SPIN 2014

2012 data, 20 pb^{-1} at 200 GeV, Pb=61%, anti-k_T jet algorithm, R = 0.7

Bo-Qiang Ma

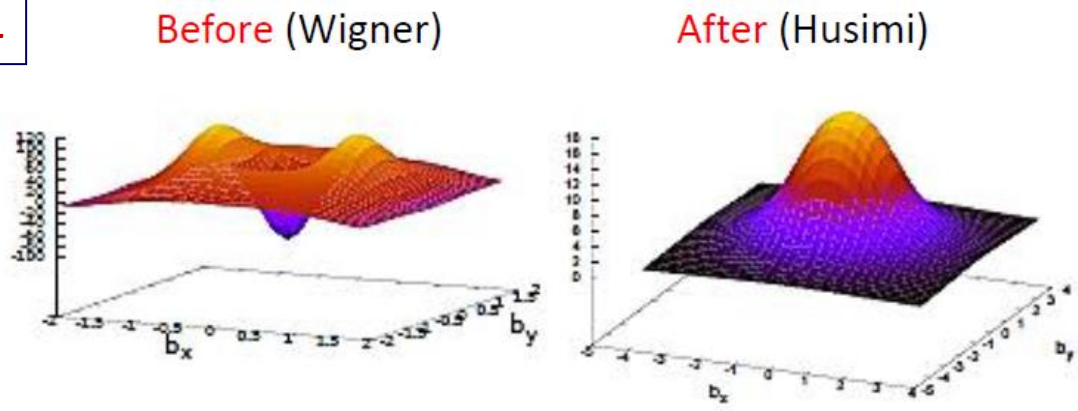
Melosh Rotation for Spin-1/2 Particle

The connection between spin states in the rest frame and infinite momentum frame

Or between spin states in the conventional equal time dynamics and the light-front dynamics

Husimi Distribution for Nucleon Tomography

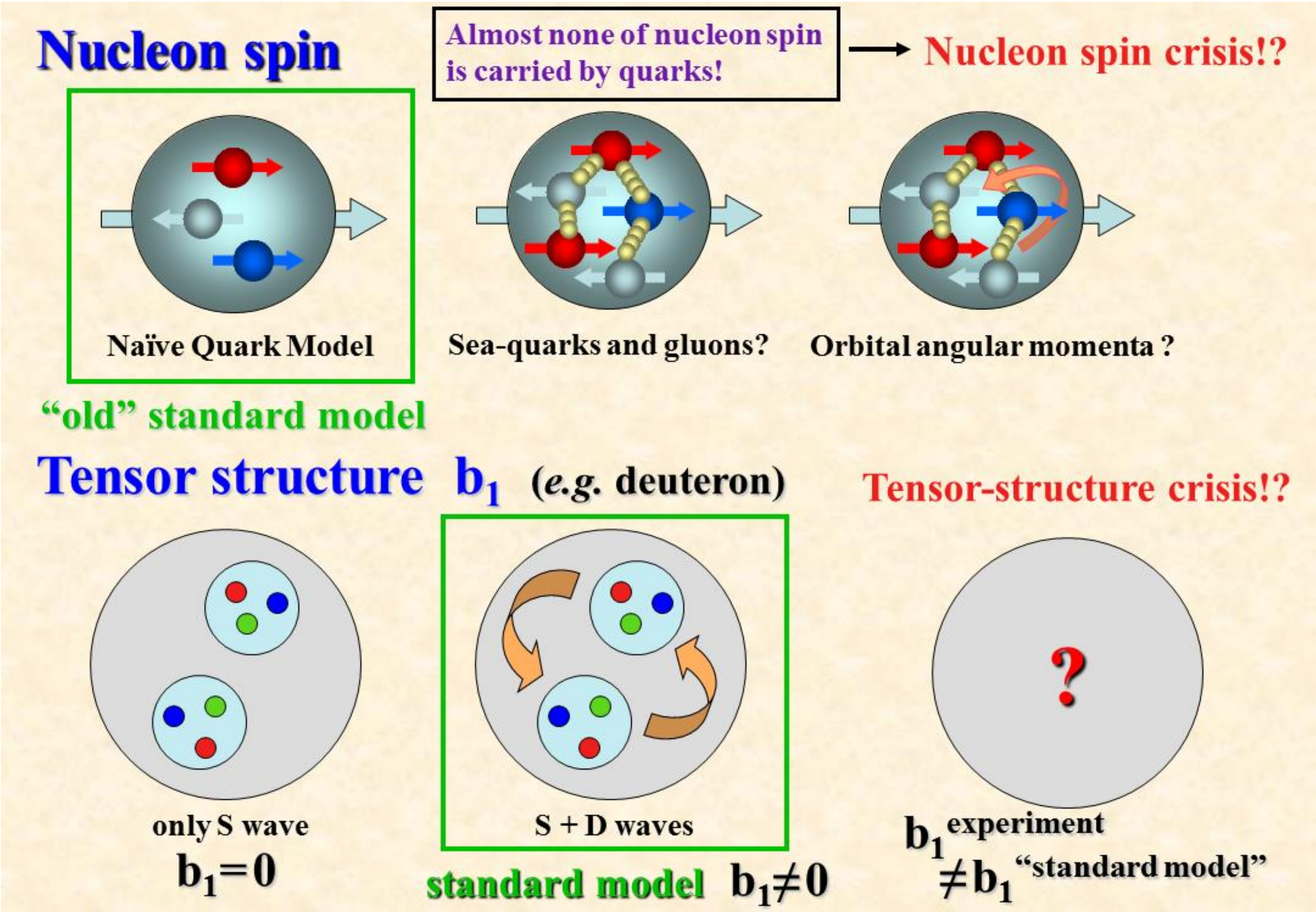
Yoshitake Hatta



$$x = 0.5,\ m^2 = 0.1\,\mathrm{GeV}^2,\ \ell = 1\,\mathrm{GeV}^{-1}$$

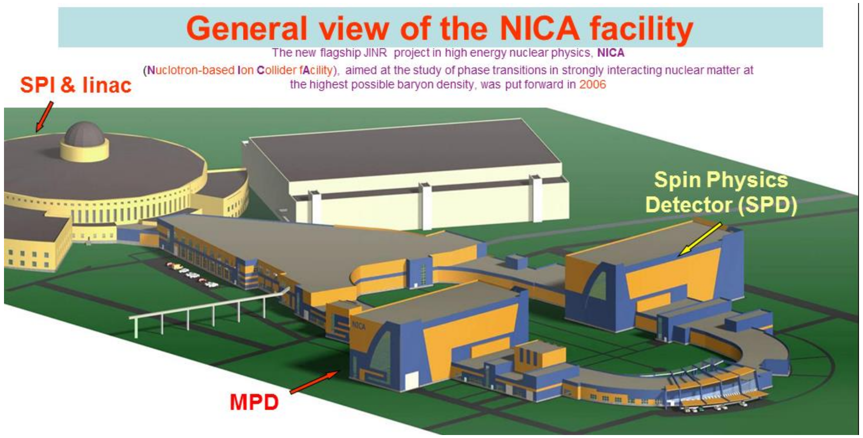
Structure Functions of Deuteron

S. Kumano

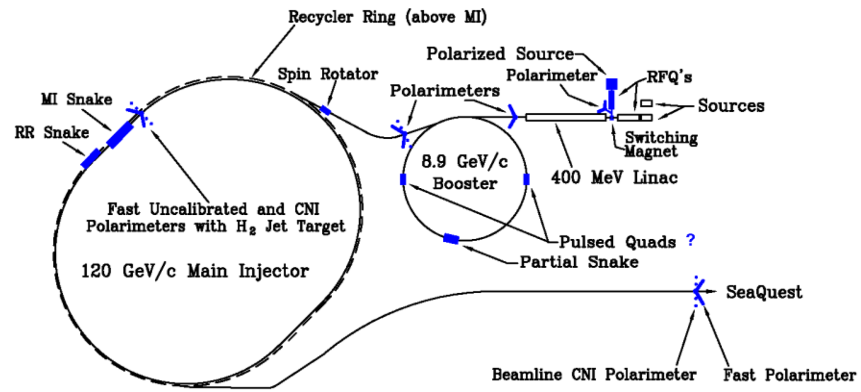


Future Facilities

V. Fimushkin



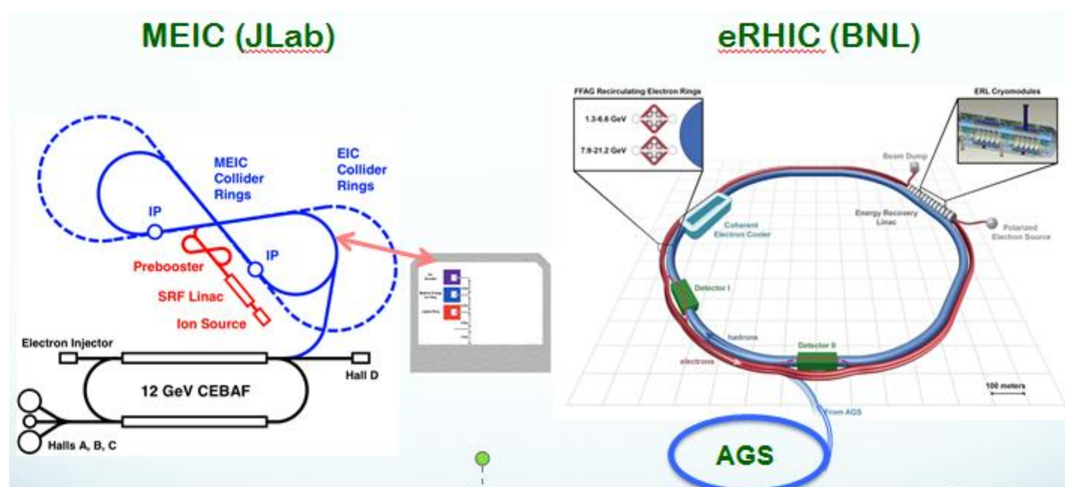
W. Lorenzon



J.-P. Lansberg

AFTER

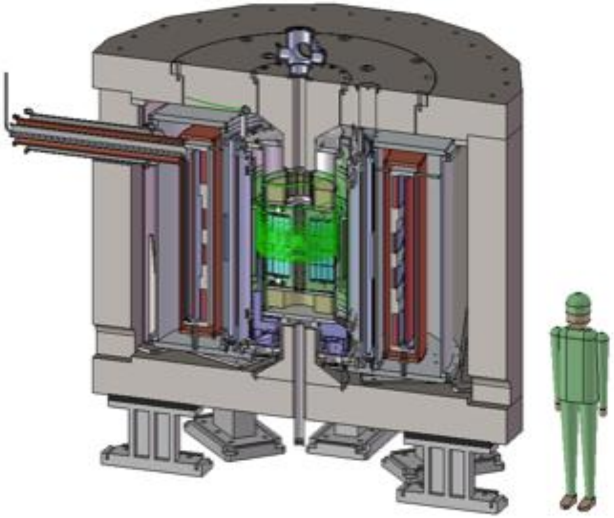
Z. Meziani



Muon g-2 and EDM experiments

David Kawall

Tutomu Mibe



Fermilab E989

J-PARC E34

Muon’s magnetic moment and EDM can be non-zero because it has non-zero spin

Tao-Te-Ching of Laozi
(first two sentences)

道可道，非常道。
名可名，非常名。

- The “Dao” which can be articulated is not the eternal “Dao”.
- The object which can be named is not the enduring object.

Tao-Te-Ching of Laozi
(first two sentences)

道可道，非常道。
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- The “Dao” which can be articulated is not the eternal “Dao”.
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A truly successful Symposium can not be summarized

A big "Thank you" to Wen-Chen Chang, Hai-Yang Cheng, and Ms. Jing-Xuan Su