Update on phenomenological extraction of the proton tensor charge

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In collaboration with
A. Bacchetta Univ. Pavia

European Research Council
3DSPIN MAPPING THE PROTON IN 3D
HAS QCD HADRONIC STRUCTURE AND QUANTUM CHROMODYNAMICS

The tensor "charge" of the proton

tensor charge connected to tensor operator

but also to 1st Mellin moment of transversity PDF

$$\langle P, S_p | \, \bar{q} \sigma^{\mu\nu} q \, | P, S_p \rangle = (P^\mu S_p^\nu - P^\nu S_p^\mu) \, \delta q(Q^2)$$

$$= (P^\mu S_p^\nu - P^\nu S_p^\mu) \int_0^1 dx \, h_1^{q-\bar{q}}(x, Q^2)$$

tensor operator not accessible in tree-level Standard Model
low-energy footprint of new physics at higher scales ?

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$$= (P^\mu S_p^\nu - P^\nu S_p^\mu) \int_0^1 dx \, h_1^{q-\bar{q}}(x, Q^2)$$

compute on lattice

lattice **δ**q

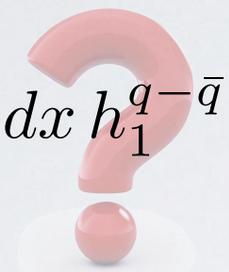
extract transversity from data with transversely polarized protons

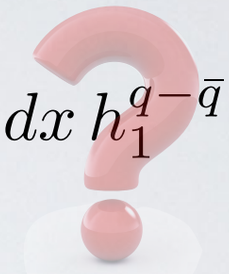
pheno **δ**q

pheno δq vs. lattice δq

main problem of "pheno δq" is extrapolating outside data..

$$\delta q = \int_0^{x_{\min}} dx\, h_1^{q-\bar{q}} + \int_{x_{\min}}^{x_{\max}} dx\, h_1^{q-\bar{q}} + \int_{x_{\max}}^{1} dx\, h_1^{q-\bar{q}}$$





First Monte Carlo global analysis of nucleon transversity with lattice QCD constraints

H.-W. Lin,[1] W. Melnitchouk,[2] A. Prokudin,[2,3] N. Sato,[4] and H. Shows III[5]

Jefferson Lab Angular Momentum (JAM) Collaboration

(Dated: October 30, 2017)

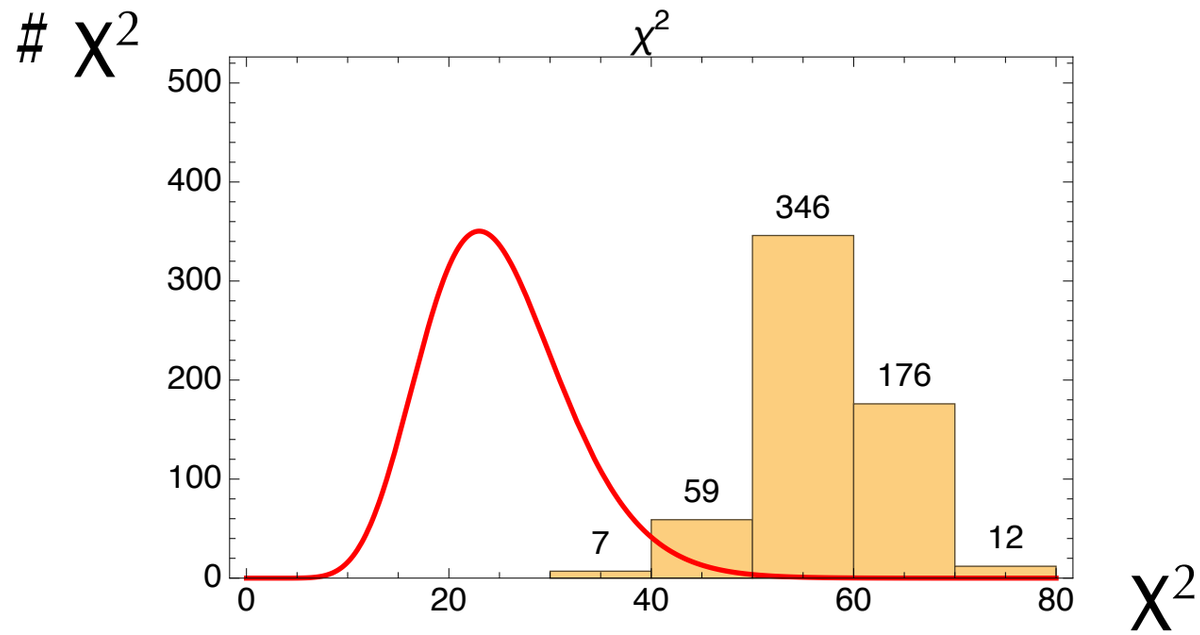
We report on the first global QCD analysis of the quark transversity distributions in the nucleon from semi-inclusive deep-inelastic scattering (SIDIS), using a new Monte Carlo method based on nested sampling and constraints on the isovector tensor charge g_T from lattice QCD. A simultaneous fit to the available SIDIS Collins asymmetry data is compatible with g_T values extracted from a comprehensive reanalysis of existing lattice simulations, in contrast to previous analyses which found significantly smaller g_T values. The contributions to the nucleon tensor charge from u and d quarks are found to be $\delta u = 0.3(2)$ and $\delta d = -0.7(2)$ at a scale $Q^2 = 2$ GeV^2.

P.R.L. **120** (18) 152502,
arXiv:1710.09858

constraining "pheno δq" from SIDIS data with lattice isovector tensor charge g_T = δu - δd

Our findings

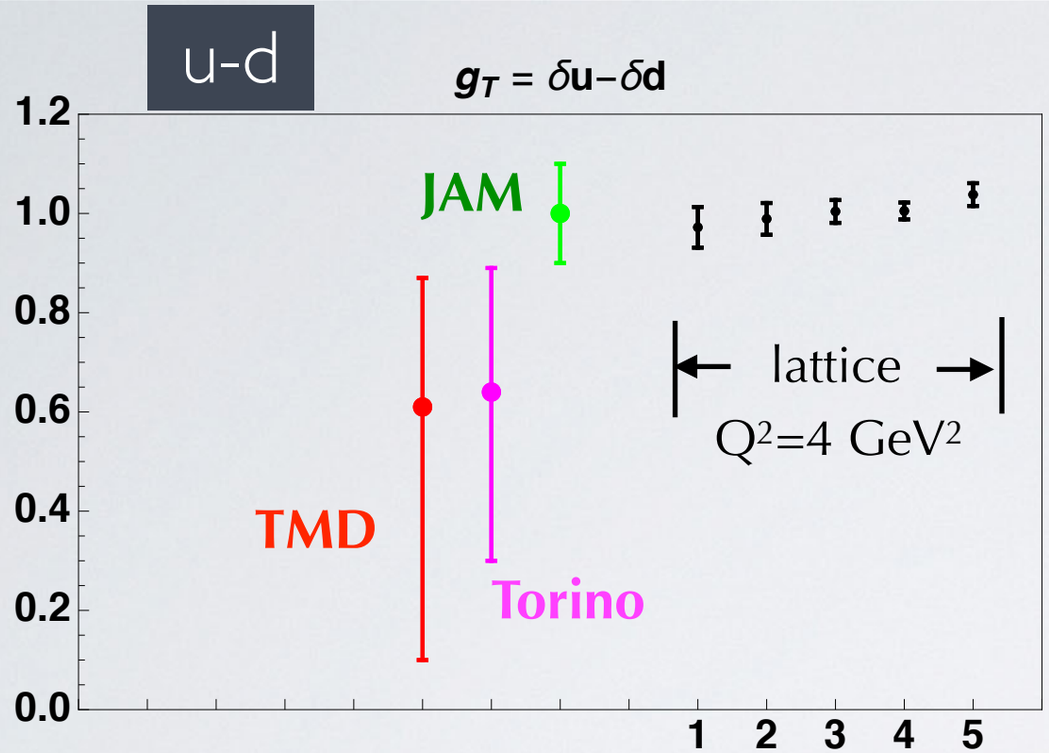
probability density function of
χ^2 distribution for 25 d.o.f.



$\chi^2/\text{dof} = 2.29 \pm 0.25$ for $\chi^2/\text{dof} = 1$ perfect overlap

forcing compatibility between "pheno **δ**q" and "lattice **δ**q"
for **δ**q = up, down, isovector, is statistically very unlikely

The state of the art



- isovector tensor charge $g_T = \delta u - \delta d$
- "pheno g_T" from only SIDIS data
- **JAM** includes constraint from "lattice g_T"

TMD fit Q^2=10 *Kang et al., P.R. D93 (16) 014009*

Torino fit Q^2=1 *Anselmino et al., P.R. D87 (13) 094019*

JAM fit Q^2=2 *Lin et al., P.R.L. 120 (18) 152502*

1) **"MILC" '19** *Hasan et al., arXiv:1903.06487*

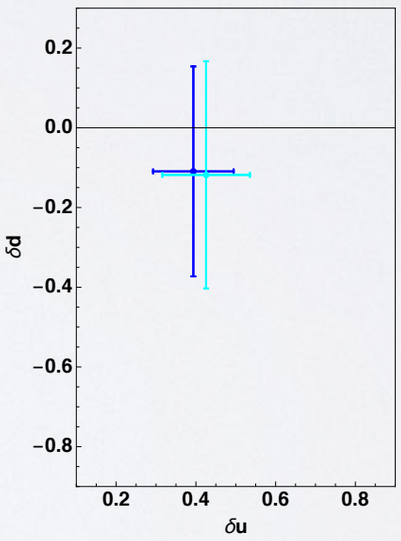
2) **PNDME '18** *Gupta et al., P.R. D98 (18) 034503*

3) **ETMC '17** *Alexandrou et al., P.R. D95 (17) 114514; E P.R. D96 (17) 099906*

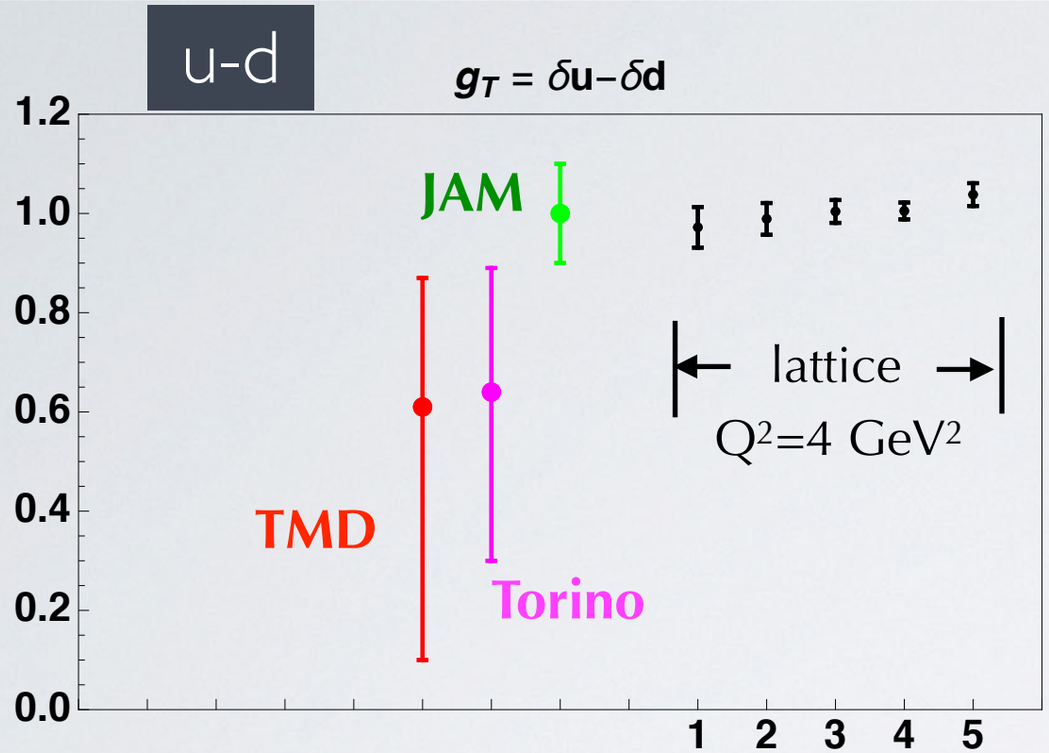
4) **RQCD '14** *Bali et al., P.R. D91 (15)*

5) **LHPC '12** *Green et al., P.R. D86 (12)*

but evolution
1 → 4 GeV^2
is small



The state of the art



- isovector tensor charge $g_T = \delta u - \delta d$
- "pheno g_T" from only SIDIS data
- **JAM** includes constraint from "lattice g_T"

But if we look also at **δ**u and **δ**d …

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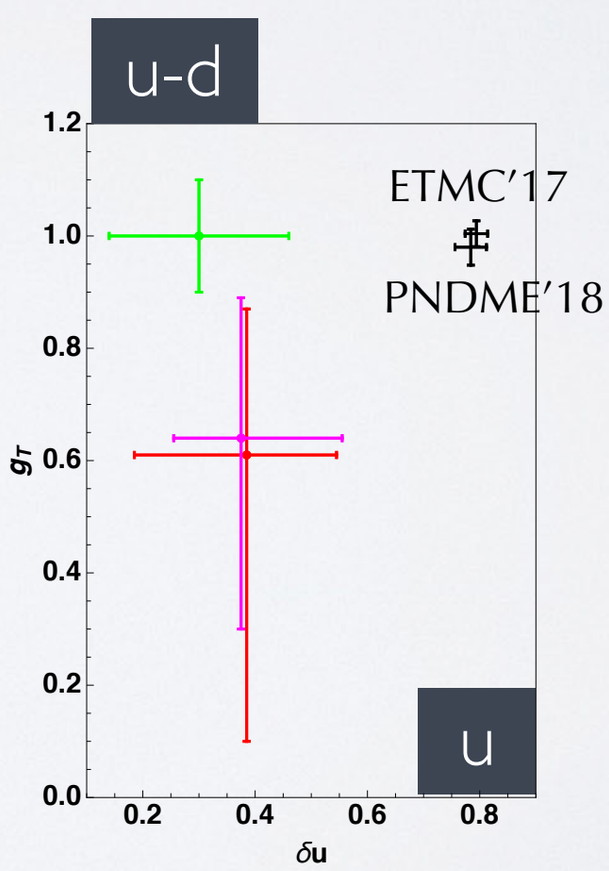
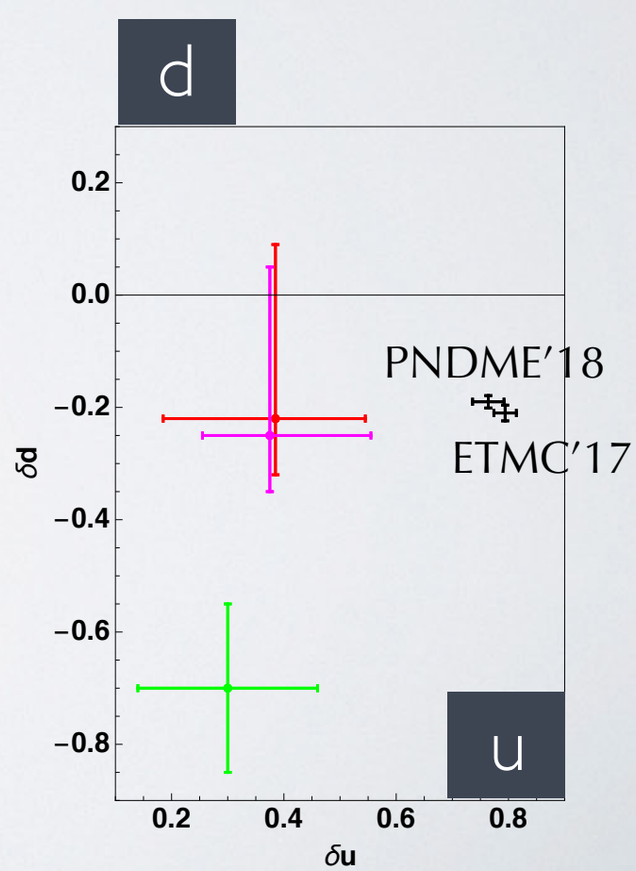




Our first global fit

first ever extraction of transversity from data of SIDIS and proton-proton collisions

Radici and Bacchetta, P.R.L. ***120*** *(18) 192001*

SIDIS

COMPASS — *Adolph et al., P.L.* ***B713*** *(12)*

hermes — *Airapetian et al., JHEP* ***0806*** *(08) 017*

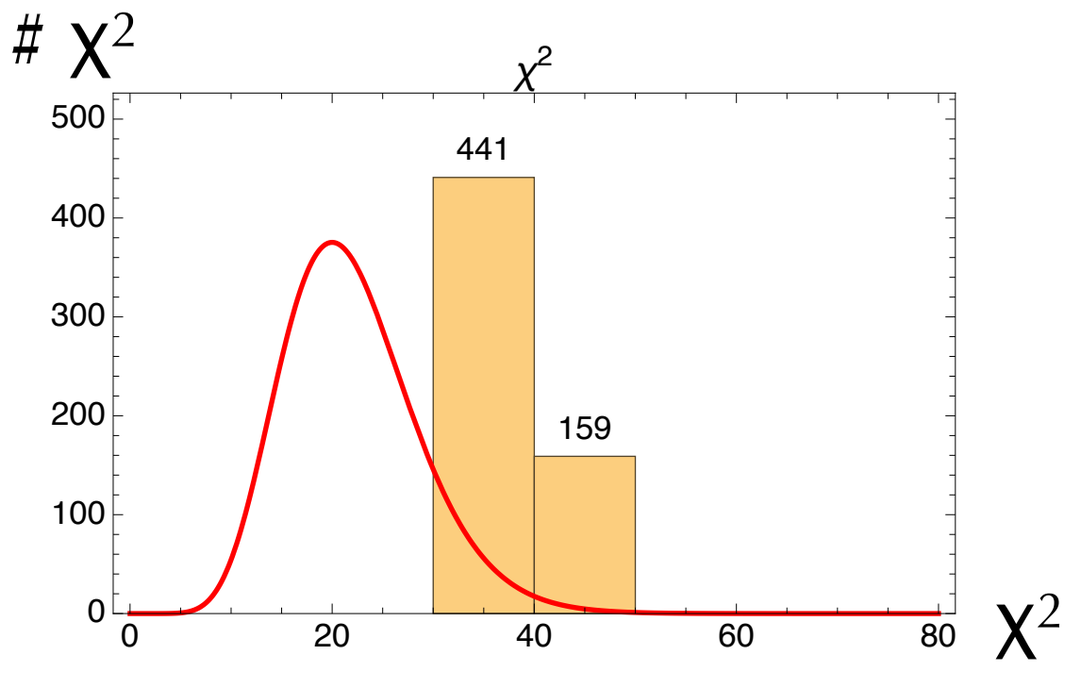
pp collisions

STAR — *Adamczyk et al., P.R.L.* ***115*** *(2015) 242501*

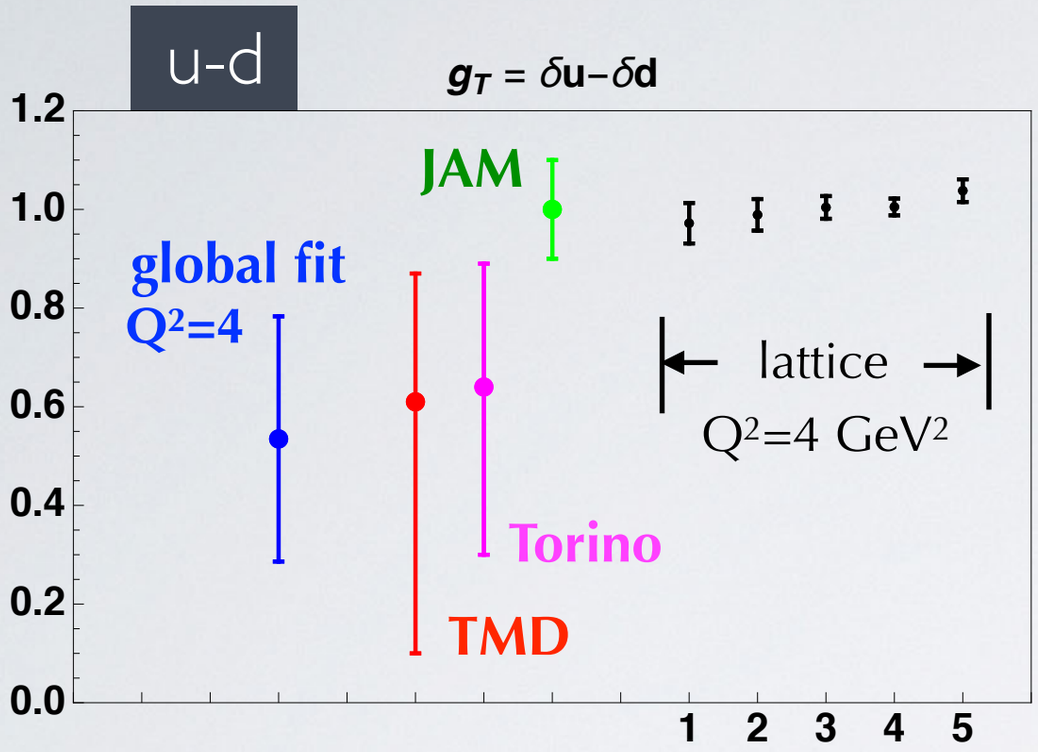
probability density function of χ^2 distribution for 22 d.o.f.

$\chi^2/\text{dof} = 1.76 \pm 0.11$

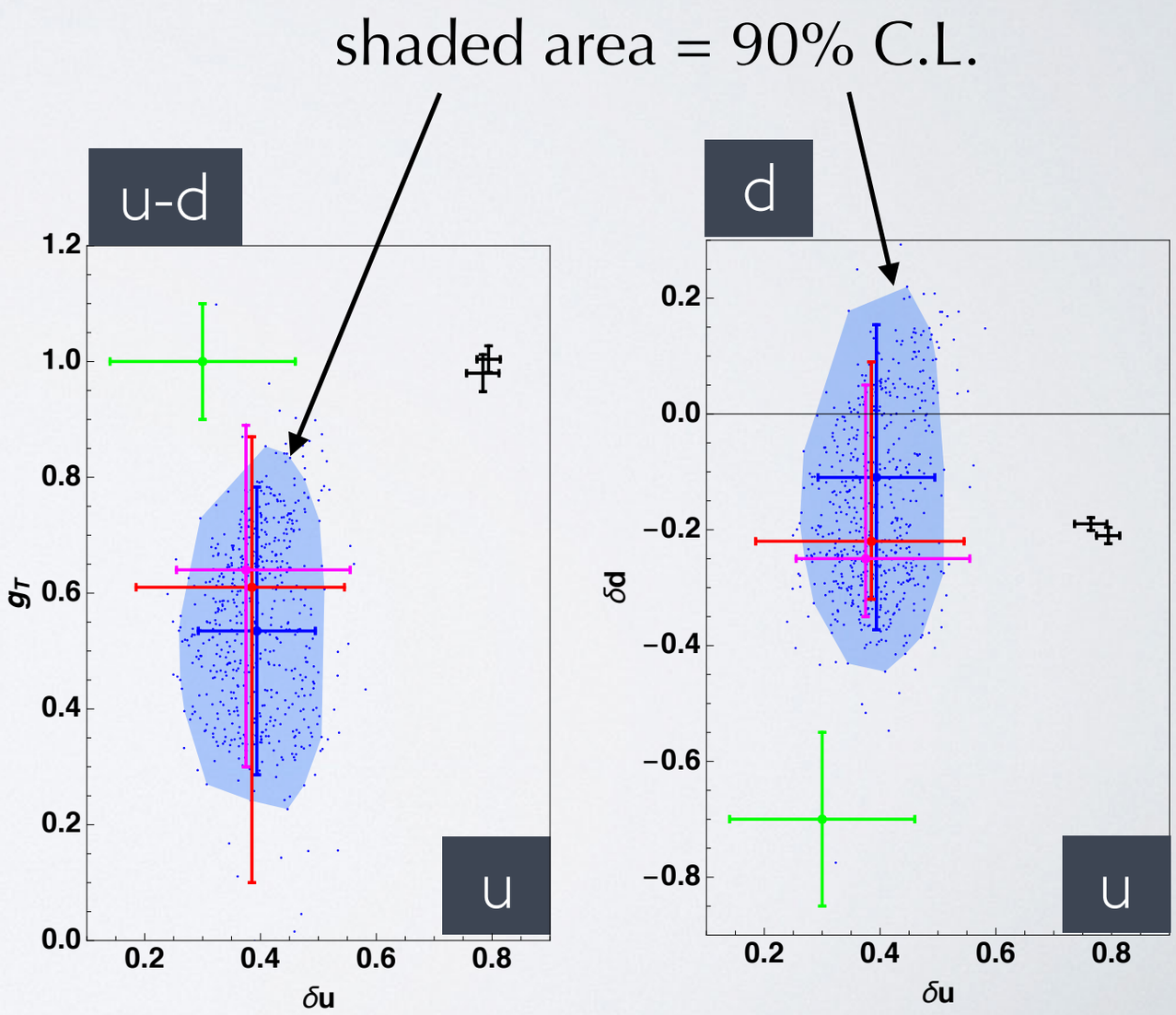
for $\chi^2/\text{dof} = 1$ perfect overlap



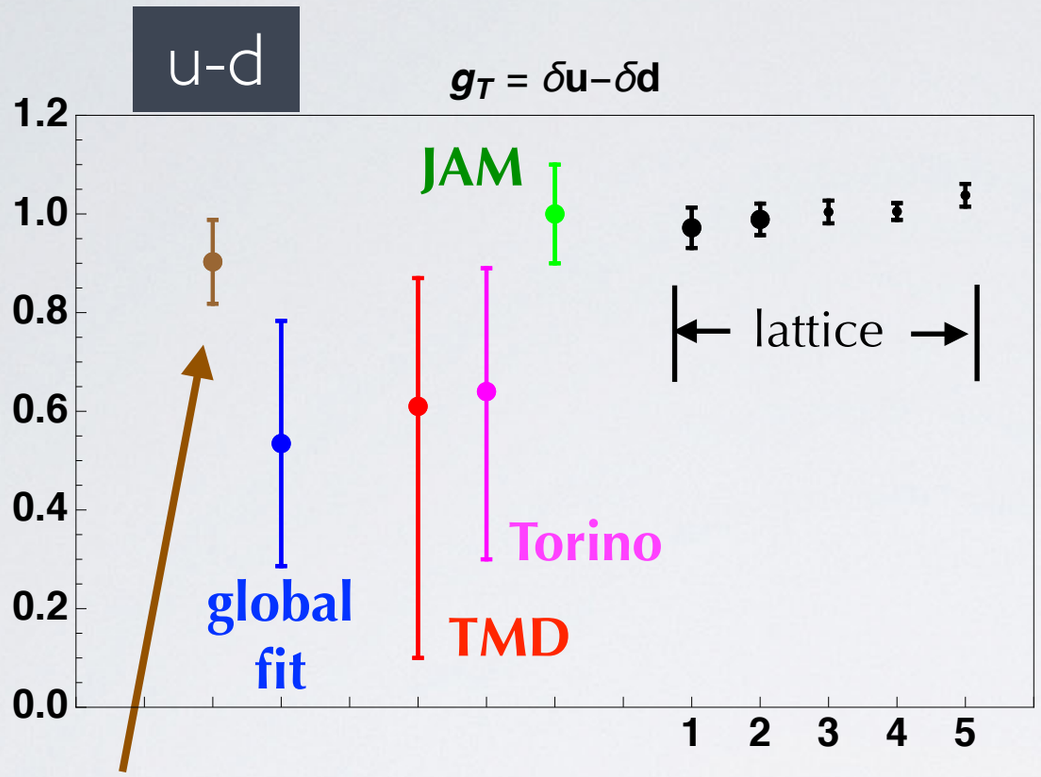
Results for our global fit



no simultaneous compatibility between "pheno **δ**q" and "lattice **δ**q"

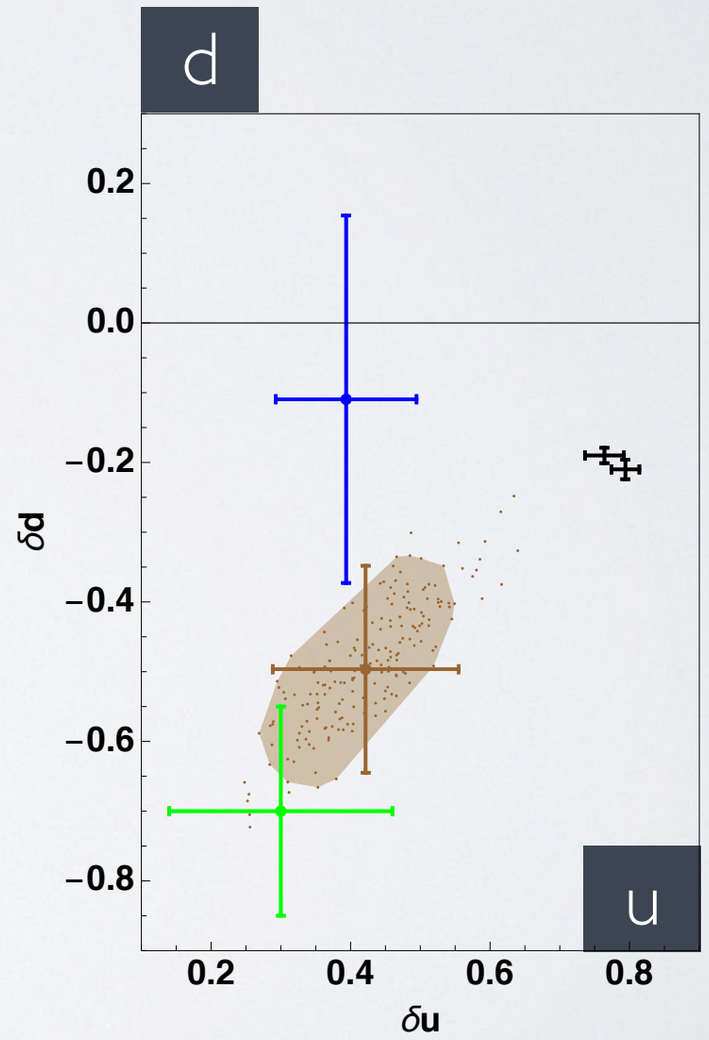


Constraining our global fit with "lattice g_T"



constraining **global fit** with lattice g_T

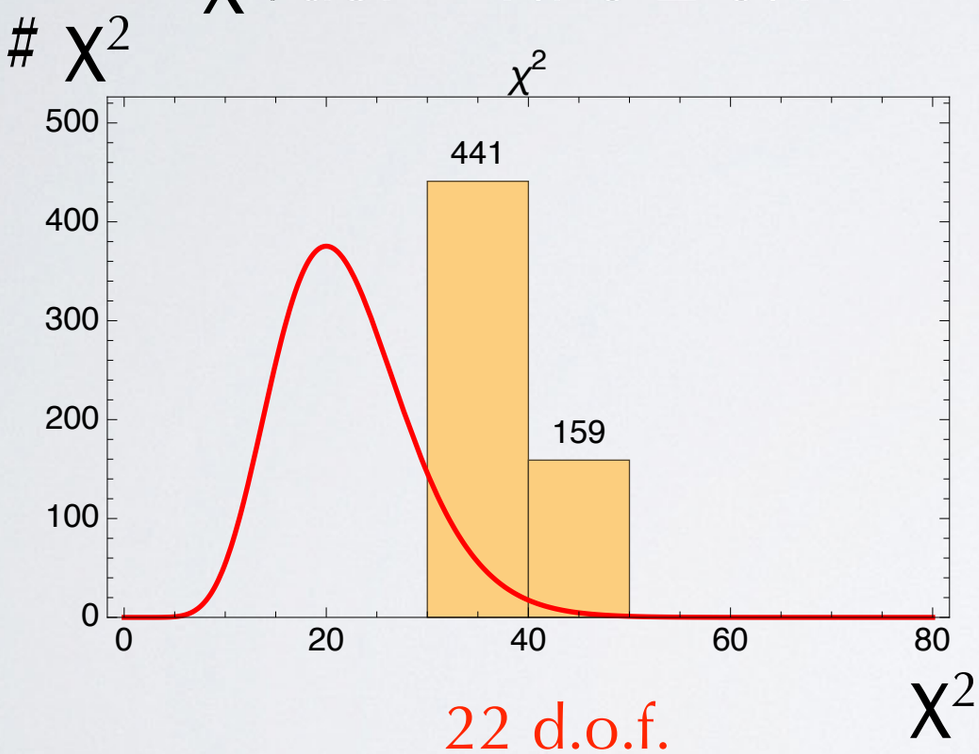
confirm JAM results:
constraining "pheno g_T" with "lattice gT"
at the price of
incompatibility for **δ**u and **δ**d



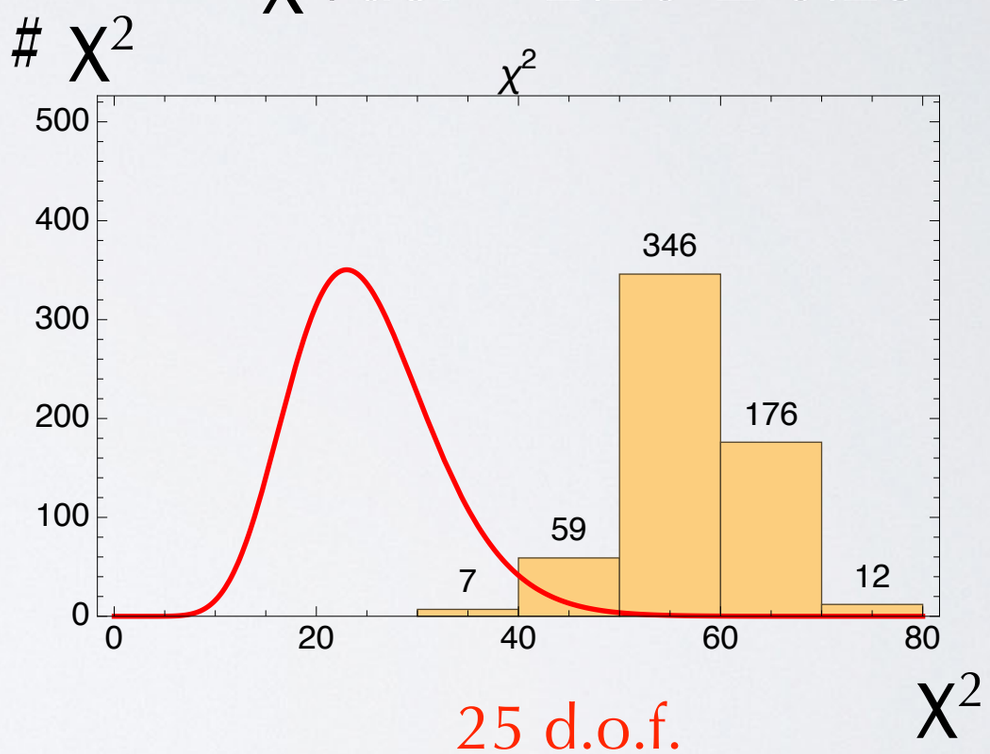
Tension "pheno" - "lattice"

if we constrain our **global fit** with lattice results
for all components of tensor charge (up, down, isovector)
the χ^2 clearly deteriorate

χ^2/dof = 1.76 ± 0.11



χ^2/dof = 2.29 ± 0.25



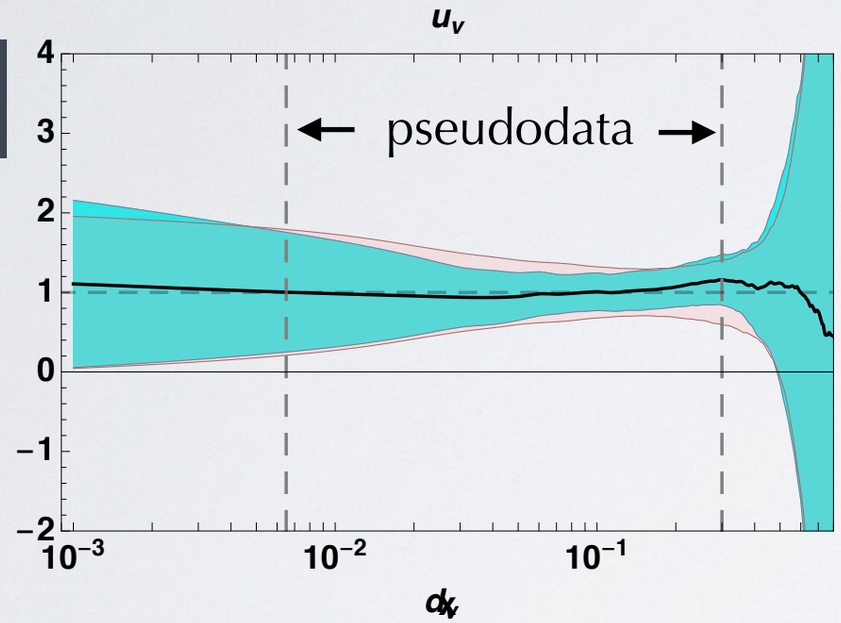
statistically very unlikely ….

Adding Compass pseudodata

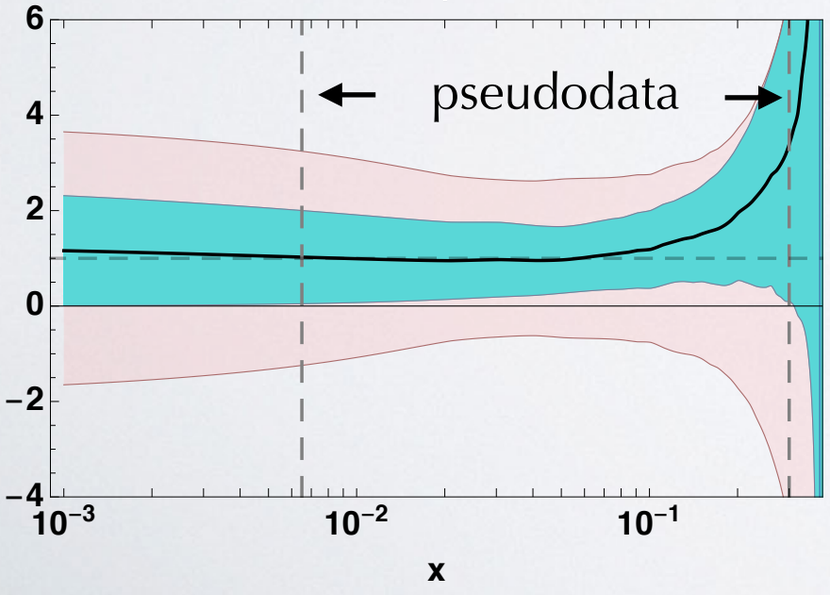
add to our **global fit**
a set of Compass SIDIS pseudodata for **deuteron** target
in the same range [0.0065, x , 0.28]

arXiv:1812.07281

u



d



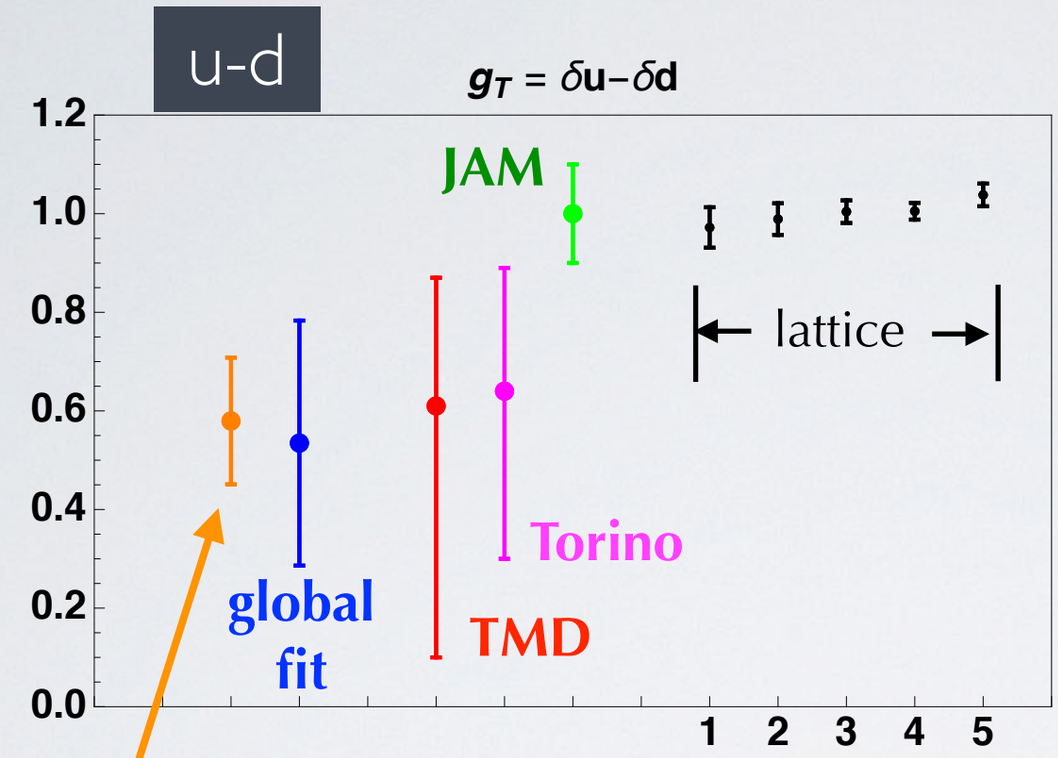
$$\frac{h_1}{\langle h_1 \rangle}$$

deuteron target
→ better precision on down

global fit

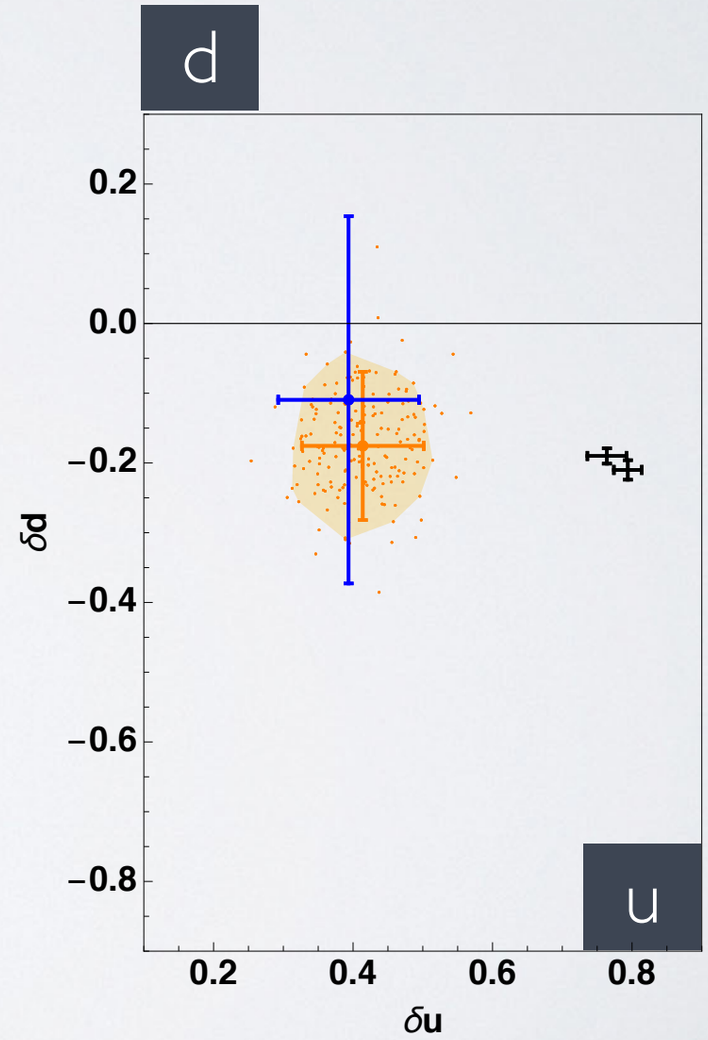
global fit + pseudodata

results with Compass pseudodata



including Compass pseudodata

improving precision, but confirming tension with lattice

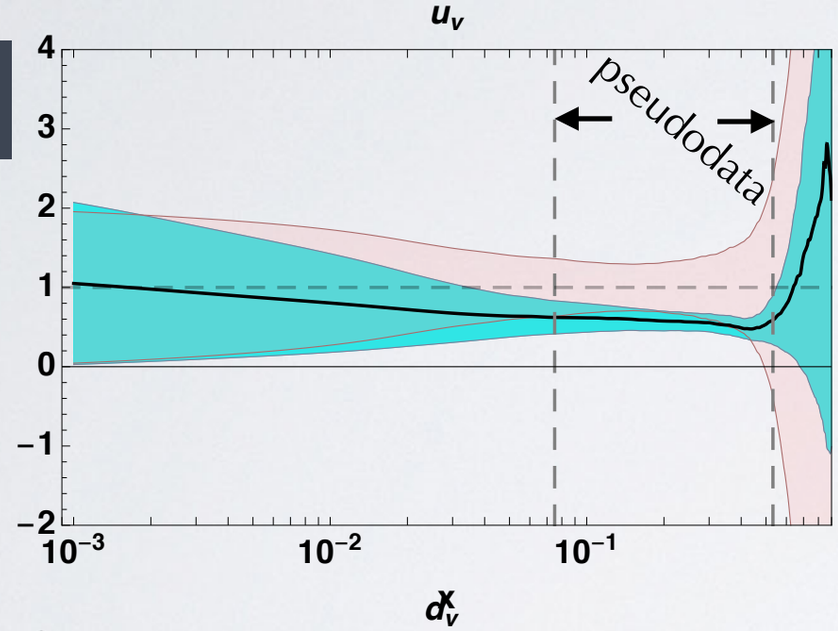


Adding CLAS12 pseudodata

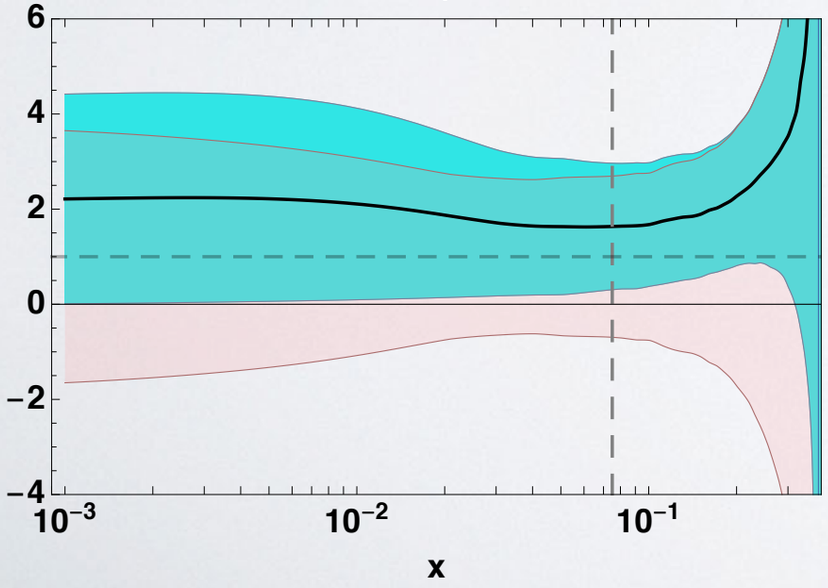
add to our **global fit**
a set of CLAS12 SIDIS pseudodata for **proton** target
in the range [0.075, x , 0.53]

proposal C12-12-009

u



d



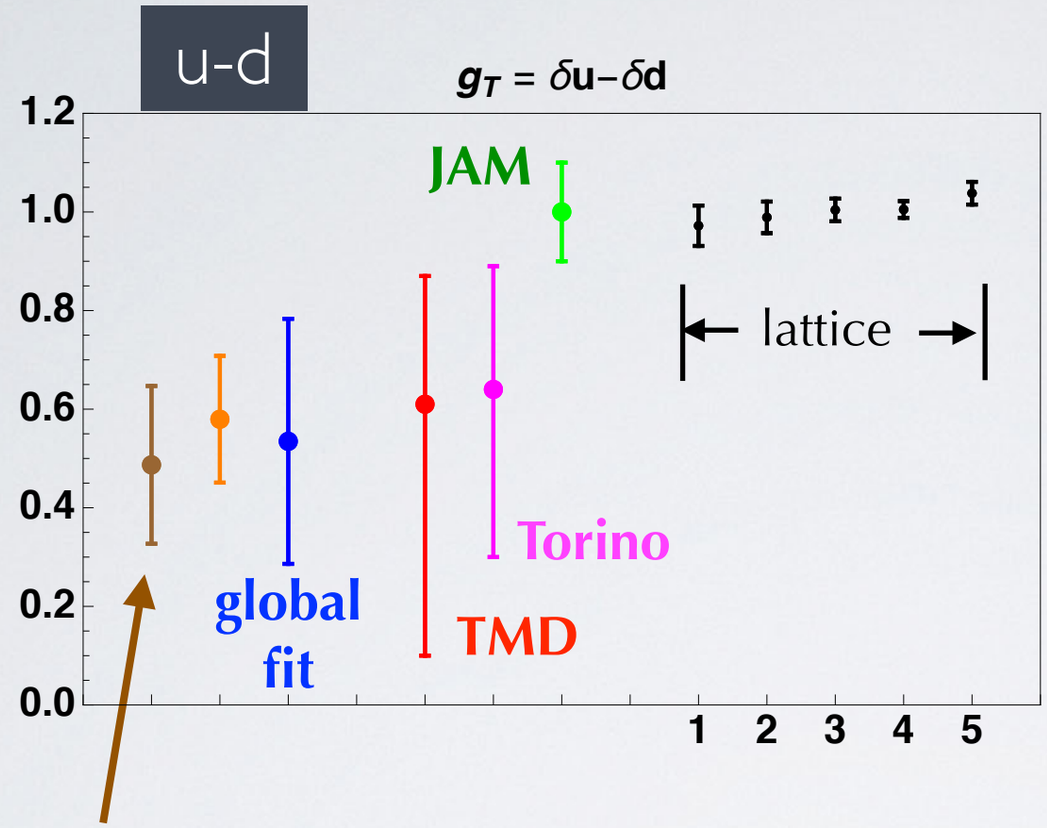
$$\frac{h_1}{\langle h_1 \rangle}$$

proton target
→ better precision on up

global fit

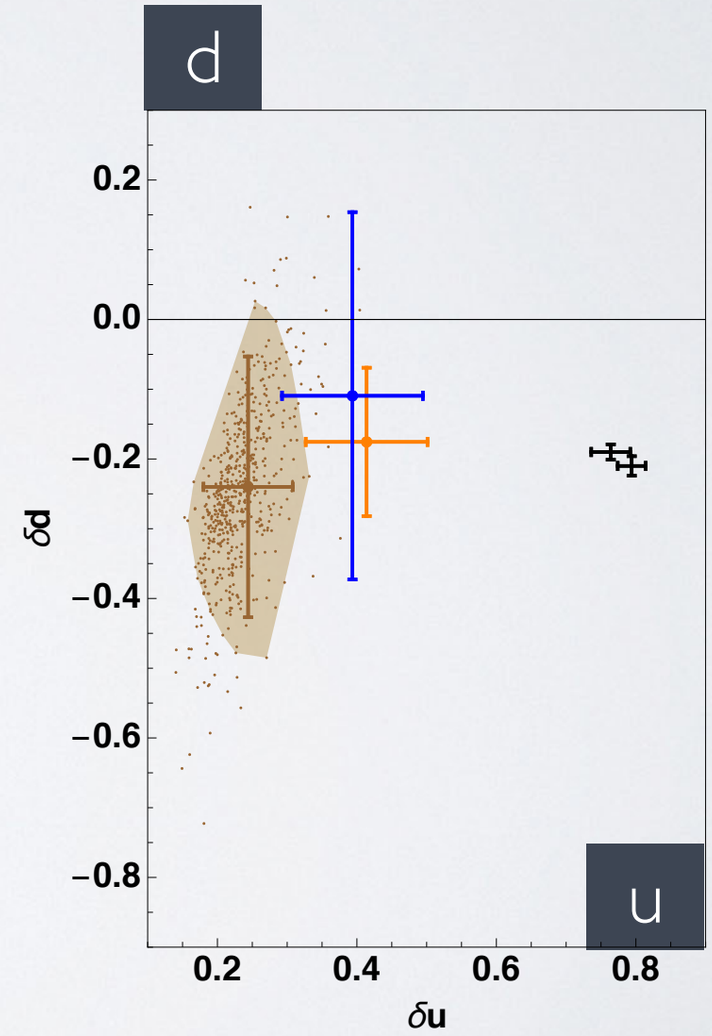
global fit + pseudodata

results with CLAS12 pseudodata



including CLAS12 pseudodata

again, improving precision but confirming tension with lattice



Conclusions

- **NO** simultaneous **compatibility between phenomenology and lattice** for up, down, and isovector tensor charges

- it is possible to **force compatibility** but it is **statistically very unlikely**

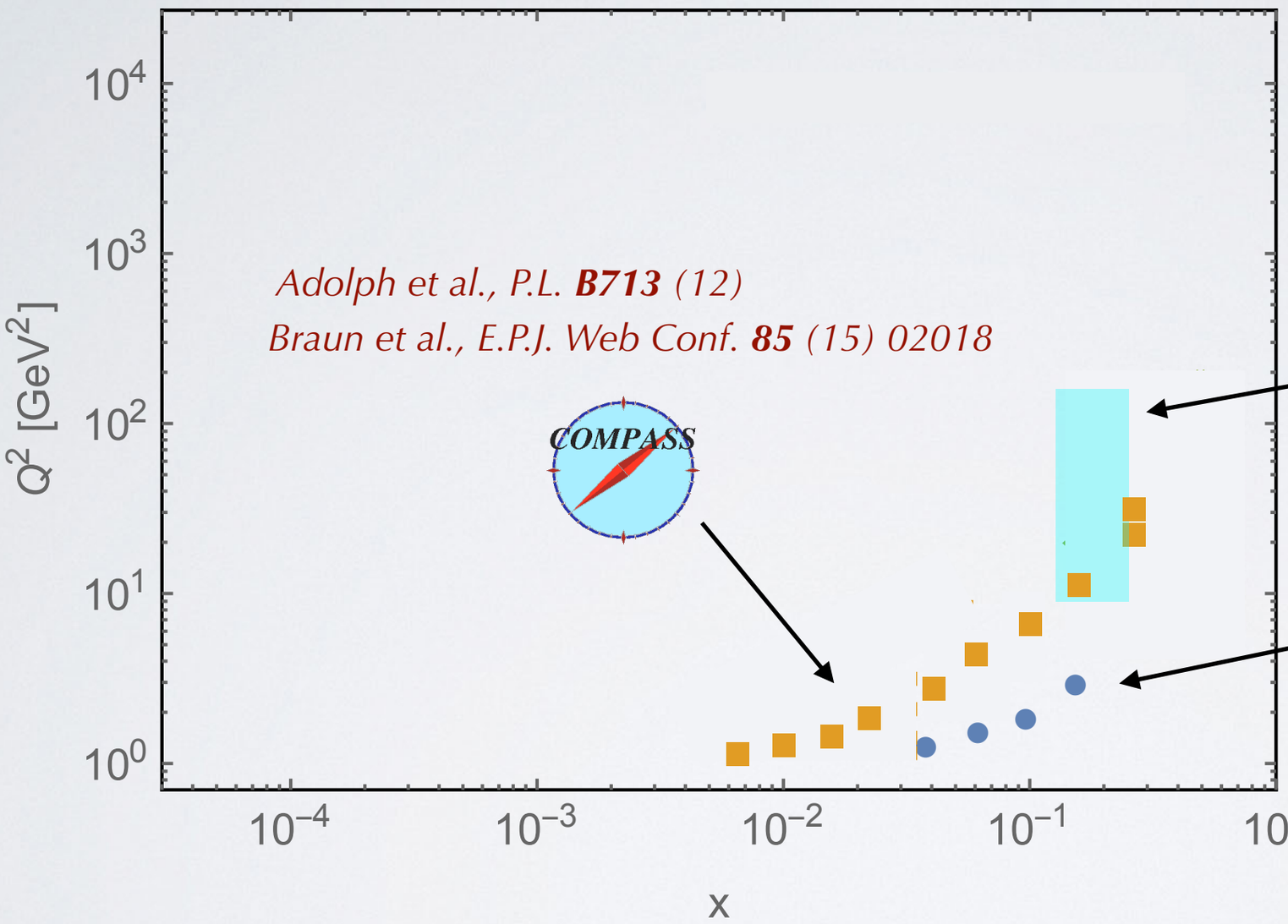
- adding **Compass** SIDIS **pseudodata for deuteron** increases precision of down, but **confirms tension**

- adding **CLAS12** SIDIS **pseudodata for proton** increases precision for up, but **confirms tension**

is there a "transverse spin puzzle" ??

Back-up

the phase space



STAR

run 2006
s=200 GeV^2

*Adamczyk et al. (STAR), P.R.L. **115** (2015) 242501*

hermes

*Airapetian et al., JHEP **0806** (08) 017*

χ^2 of the fit

proton SIDIS **13** data points = **4** + **9**

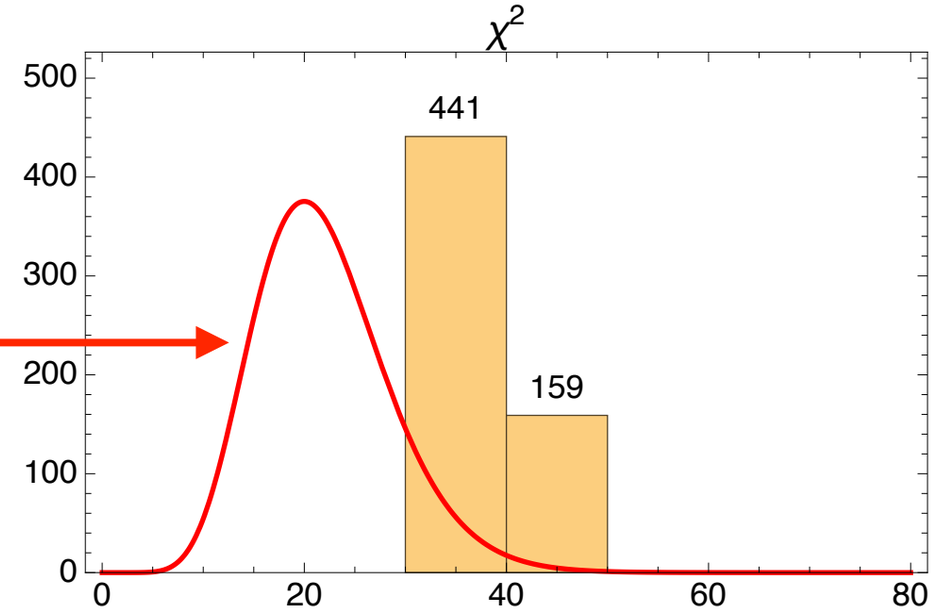
deuteron SIDIS **9** data points = + **9**

24 data points $(\mathbf{4}\ \eta)\times\frac{\mathbf{4}}{\mathbf{24}} + (\mathbf{10}\ M_h)\times\frac{\mathbf{10}}{\mathbf{24}} + (\mathbf{10}\ p_T)\times\frac{\mathbf{10}}{\mathbf{24}}$

global fit **10** parameters

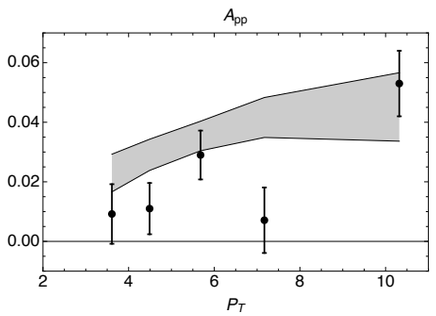
d.o.f. **22**

probability density function of χ^2 distribution for 22 d.o.f.



for χ^2/dof = 1 perfect overlap

p_T, $\eta<0$

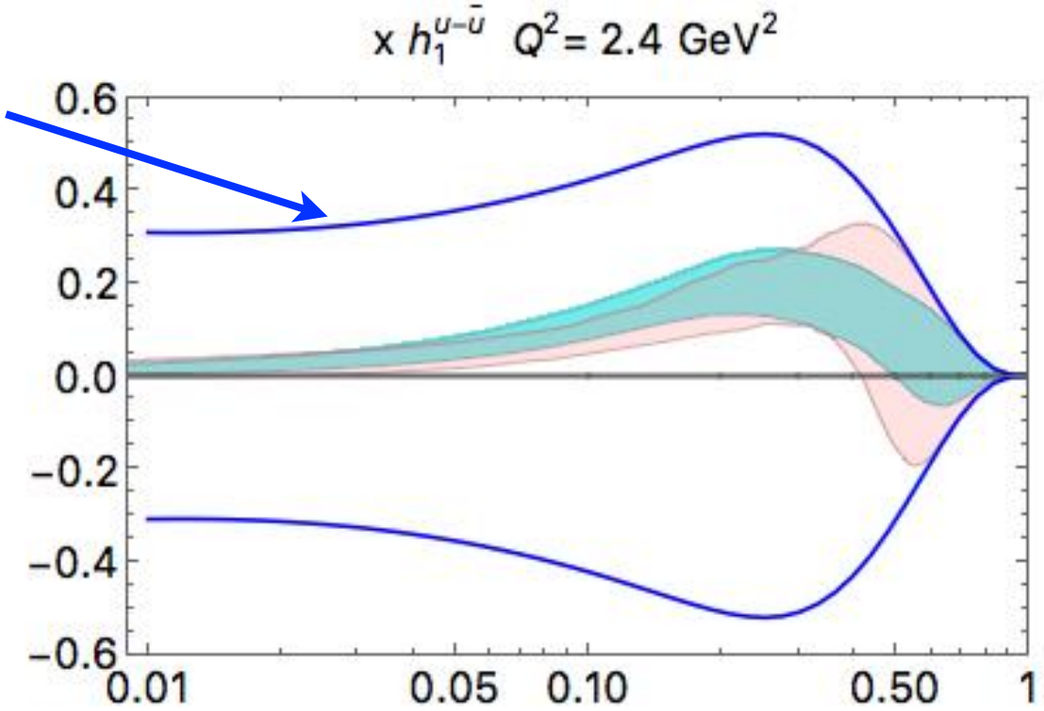


χ^2/dof = 1.76 ± 0.11

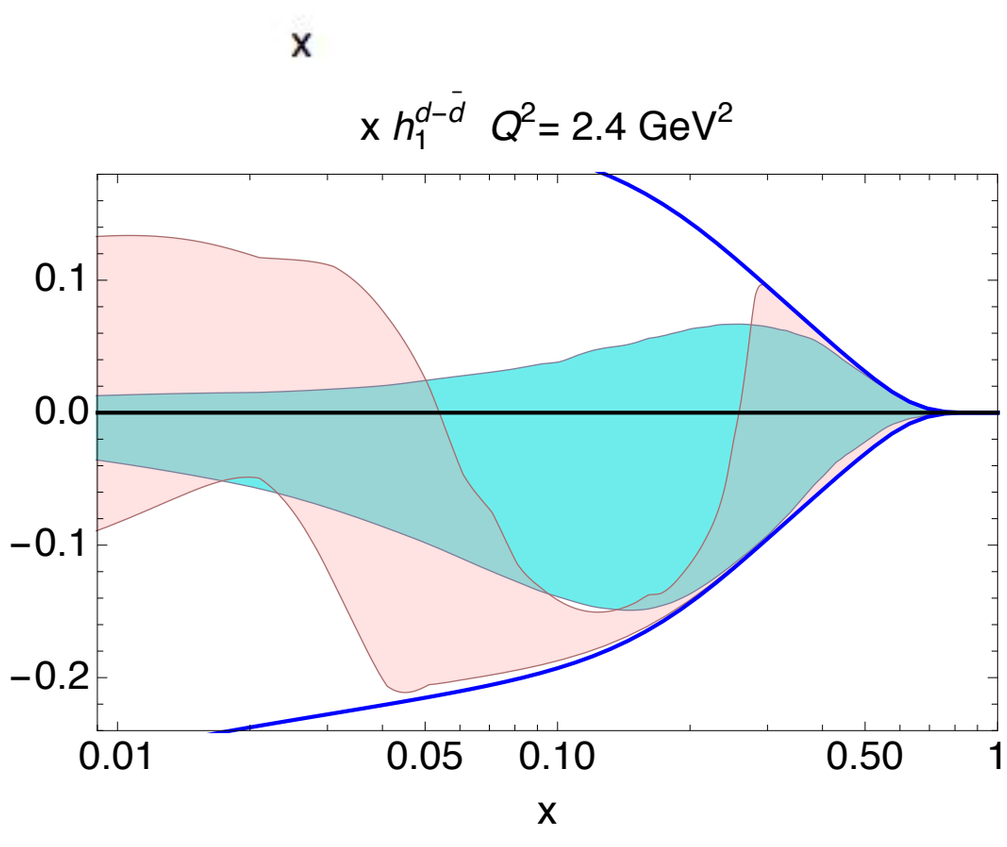
comparison with previous fit

Soffer bound

up



down



Radici & Bacchetta,
P.R.L. ***120*** *(18) 192001*

global fit

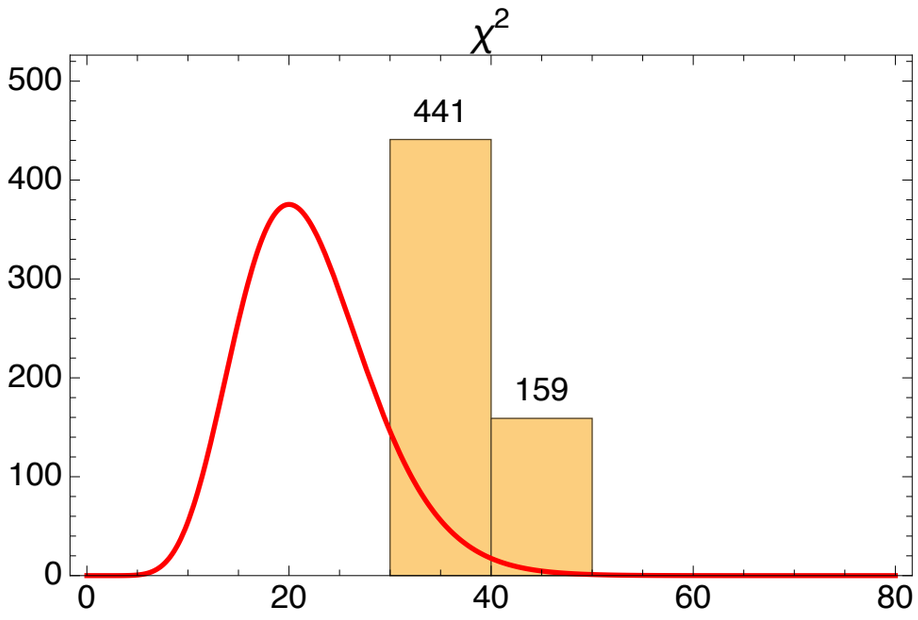
old fit (only SIDIS data)

Radici et al.,
JHEP ***1505*** *(15) 123*

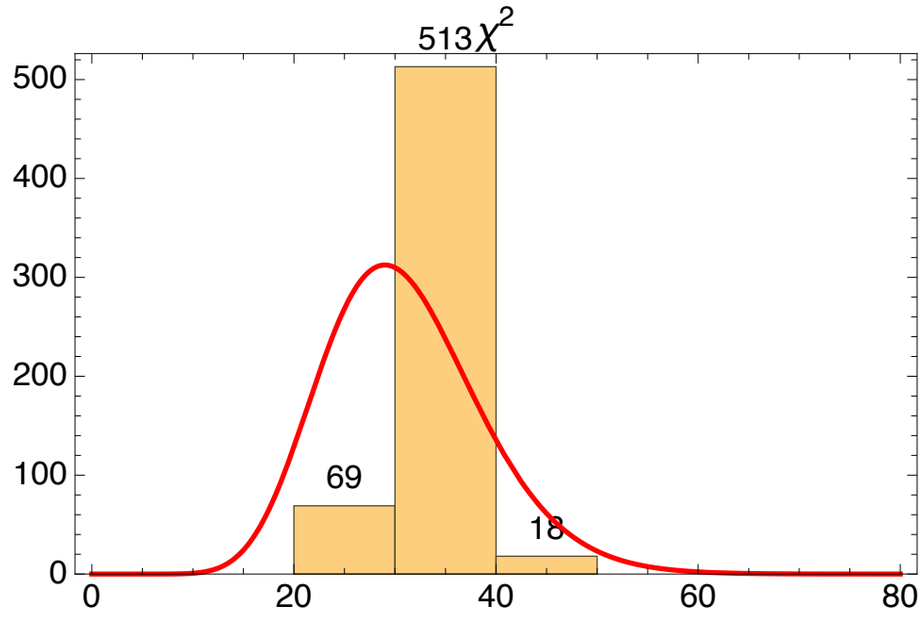
equivalent to Collins extraction

Compass pseudodata: better χ^2

χ^2/dof = 1.76 ± 0.11



χ^2/dof = 1.12 ± 0.09

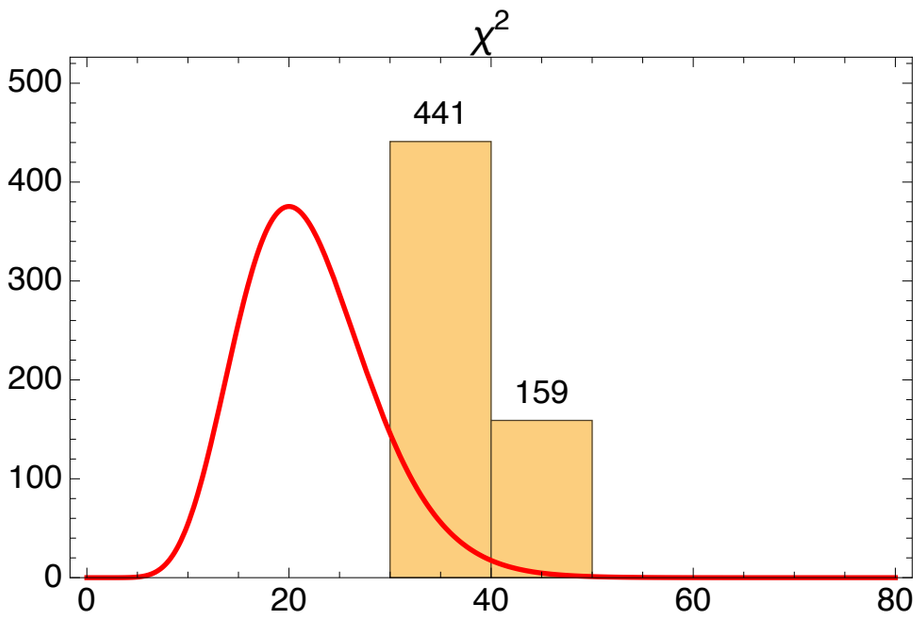


probability density function of
χ^2 distribution for
22 d.o.f. 31 d.o.f.

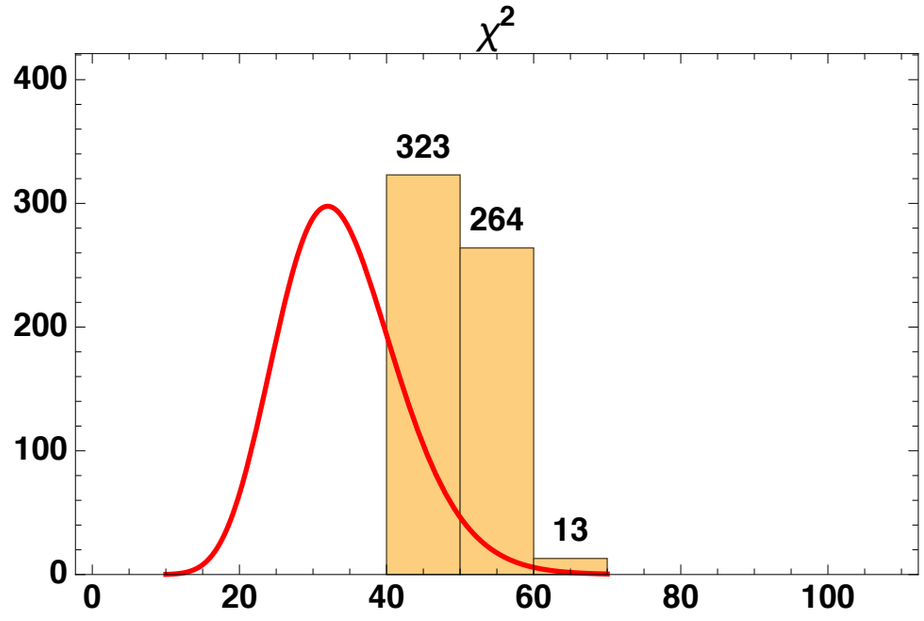
but central value of pseudodata not known
→ only spreading is meaningful

CLAS12 pseudodata: better χ^2

χ^2/dof = 1.76 ± 0.11



χ^2/dof = 1.48 ± 0.10



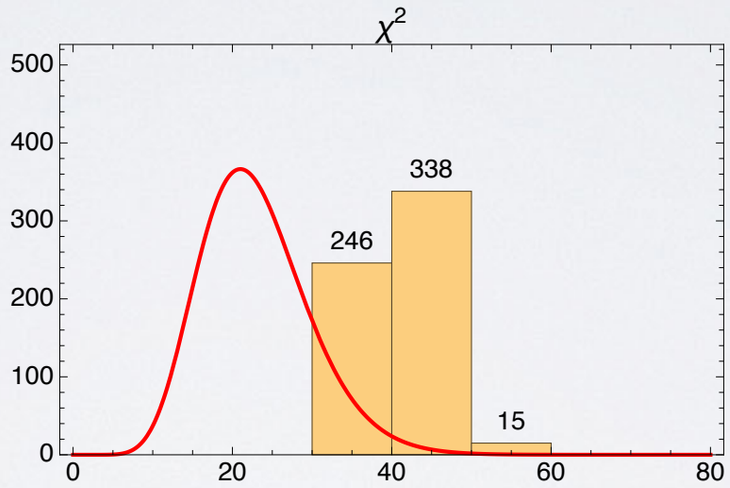
probability density function of
χ^2 distribution for
22 d.o.f. 34 d.o.f.

but central value of pseudodata not known
→ only spreading is meaningful

compatibility with lattice

add to SIDIS+pp data
constraint to reproduce from lattice
g_T , δu , δd

$\overline{g_T}^{latt} = 1.004 \pm 0.057$

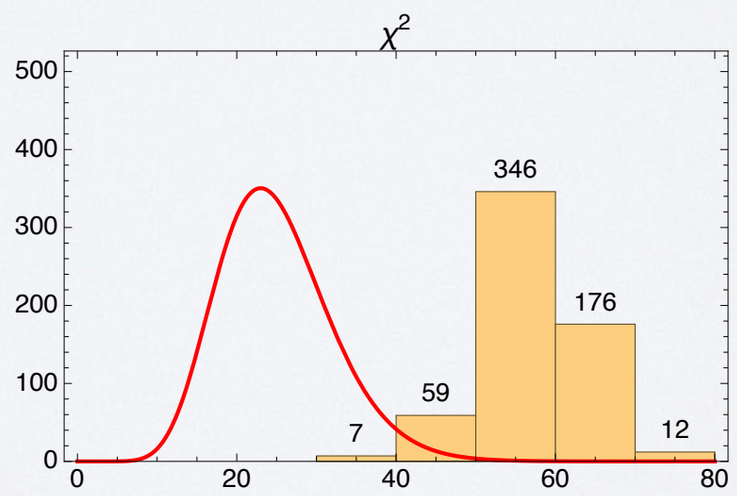


$\chi^2/dof = 1.82 \pm 0.25$

probability density function of χ^2 distribution for 23 d.o.f.

$\overline{\delta u}^{latt} = 0.782 \pm 0.031$

$\overline{\delta d}^{latt} = -0.218 \pm 0.026$



$\chi^2/dof = 2.29 \pm 0.25$

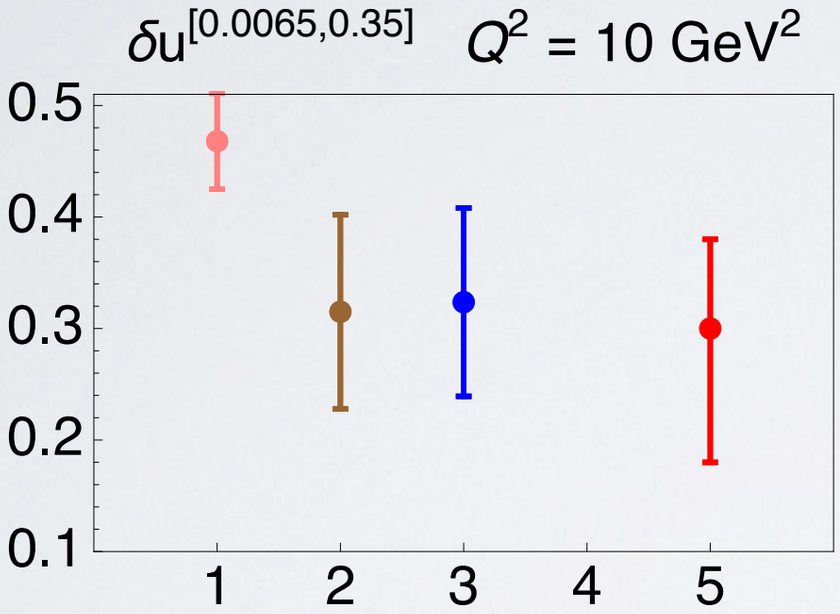
probability density function of χ^2 distribution for 25 d.o.f.

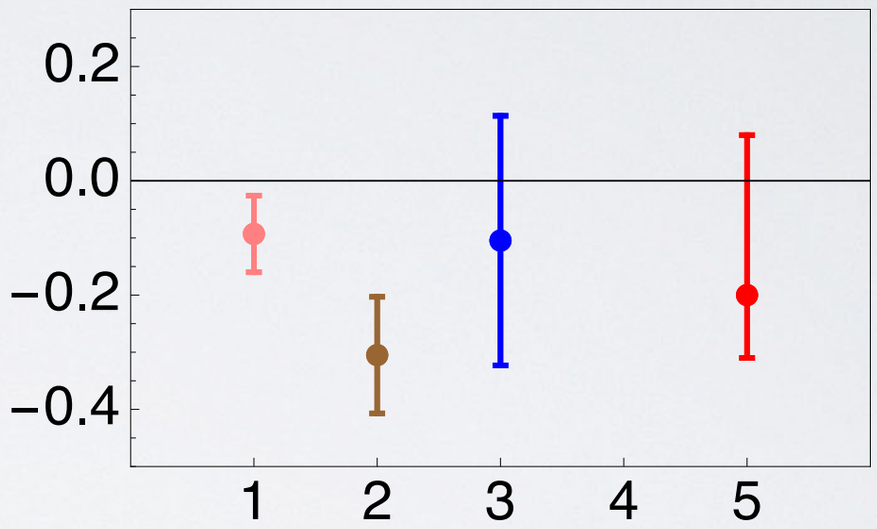
truncated tensor charge

truncated

$\delta q^{[0.0065,0.35]}$ $Q^2 = 10$

up





down

1) global fit + constrain g_T , δu , δd

2) global fit + constrain g_T

3) global fit '17 *Radici & Bacchetta, P.R.L. **120** (18) 192001*

5) "TMD fit" *Kang et al., P.R. D**93** (16) 014009*