Transversity 2014

Fourth International Workshop on

Transverse Polarisation Phenomena in Hard Processes

9-13 June, 2014 - Chia, Cagliari, Italy

Di-hadron Fragmentation Functions and Transversity

Marco Radici

INFN - Pavia

INFN Istituto Nazionale di Fisica Nucleare

in collaboration with:

A. Bacchetta (Univ. Pavia)

A. Courtoy (Univ. Liege)

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NEW FIT !

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Outline

- why di-hadron semi-inclusive production?
  brief review of advantages w.r.t. Collins effect

- review of existing results about extraction of transversity

  including recent Compass analysis of their new proton data (see C. Braun's talk)

- new fit : what's new ?

- conclusions and outlooks

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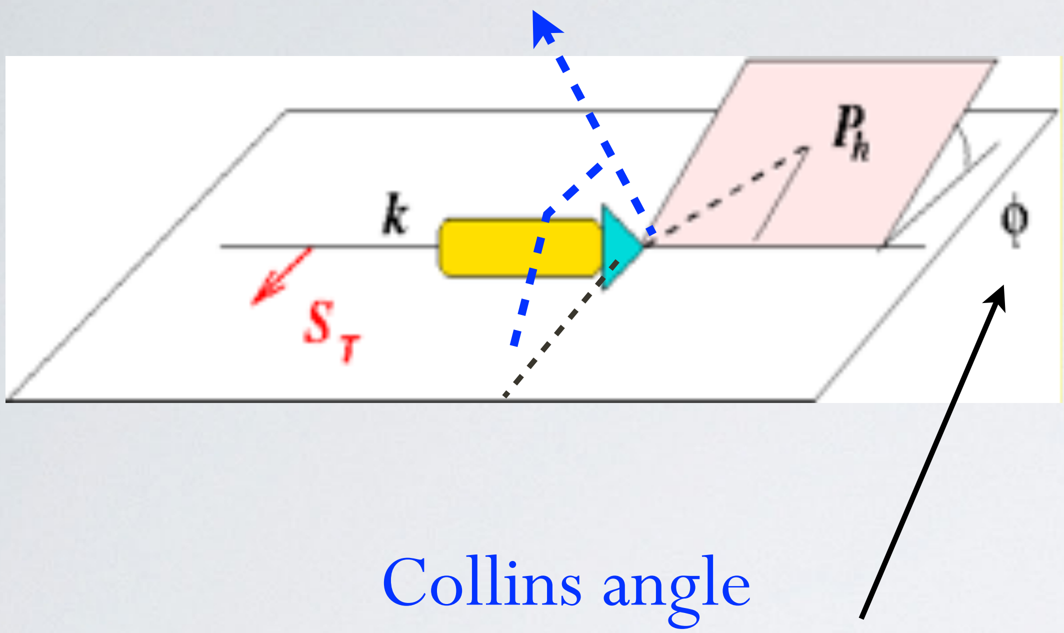
- new fit : what's new ?

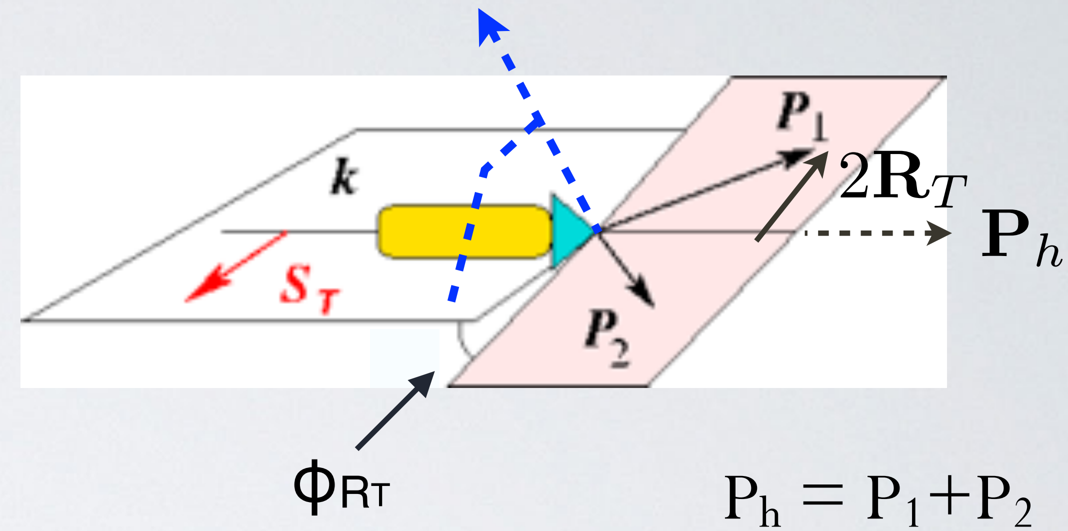
- conclusions and outlooks

Collins effect vs. DiFF

*J. Collins, NP**B396** (93)*

*Collins, Heppelman, Ladinsky, NP **B420** (94)*





$P_h = P_1 + P_2$

$2R = P_1 - P_2$

$$\mathbf{k} \times \mathbf{P}_h \cdot \mathbf{S}_T \propto \sin(\phi + \phi_S)$$

$$\mathbf{P}_h \times \mathbf{R}_T \cdot \mathbf{S}_T \propto \sin(\phi_{R_T} + \phi_S)$$

$\mathbf{P}_{hT} \neq 0$ transverse momentum of hadron required

effect relies on $\mathbf{R}_T \neq 0$

$\mathbf{P}_{hT} = 0$ the pair is collinear

Collins effect vs. DiFF

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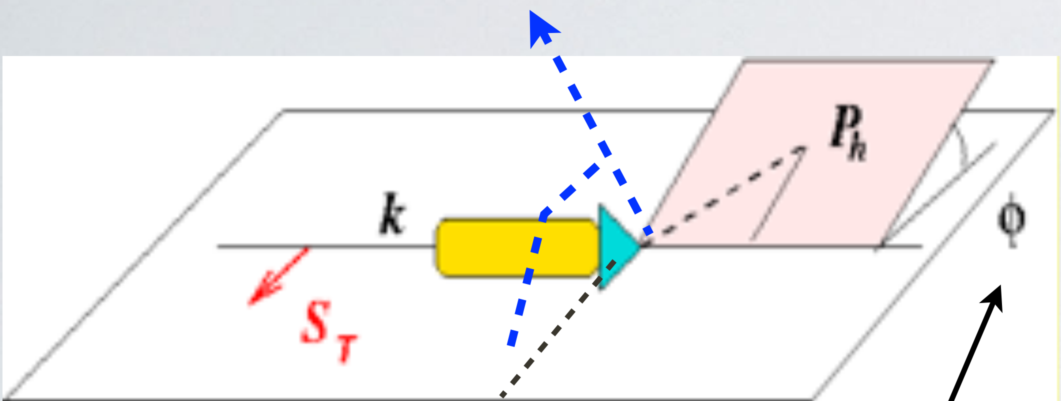

Collins angle

$$\mathbf{k} \times \mathbf{P}_h \cdot \mathbf{S}_T \propto \sin(\phi + \phi_S)$$

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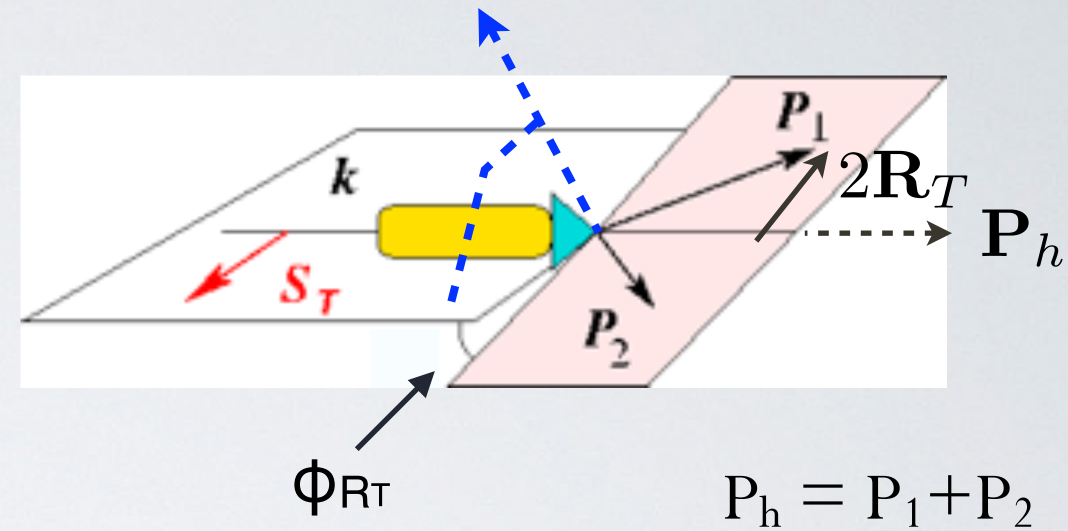
framework of TMD factorization

Collins, Heppelman, Ladinsky, NP ***B420*** *(94)*



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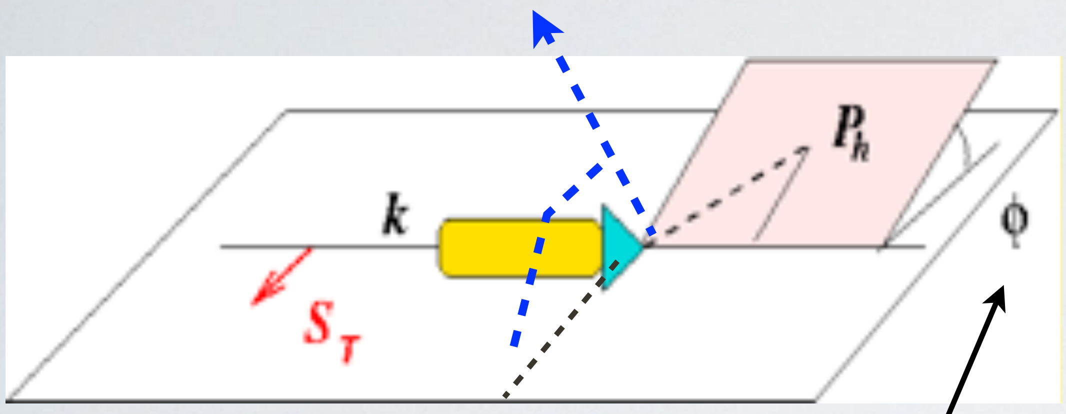

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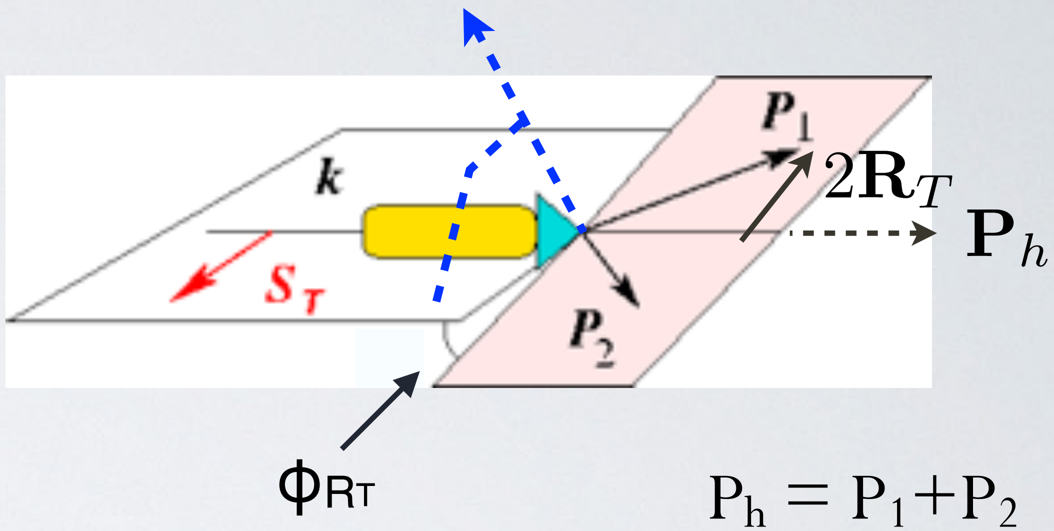

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framework of collinear factorization

Collins effect vs. DiFF

Collins effect
TMD factorization

1h - SIDIS single-spin asymmetry

$$A_{UT}^{\sin(\phi+\phi_S)} \propto \frac{\sum_q e_q^2\, h_1^q \otimes_w H_1^{\perp\, q}}{\sum_q e_q^2\, f_1^q \otimes D_1^q}$$

DiFF
collinear factorization

2h - SIDIS single-spin asymmetry

$$A_{UT}^{\sin(\phi_R+\phi_S)} \propto -\frac{|\boldsymbol{R}|}{M_h}\, \frac{\sum_q e_q^2\, h_1^q(x)\, H_1^{\sphericalangle\, q}(z, M_h^2)}{\sum_q e_q^2\, f_1^q(x)\, D_1^q(z, M_h^2)}$$

Radici, Jakob, Bianconi
*PR D**65** (02)*
Bacchetta, Radici,
*PR D**67** (03)*

Collins effect vs. DiFF

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TMD factorization

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convolution on
⊥-moment dependence
of h_1 and $H_1^{\perp}$

TMD evolution eq.
required

DiFF
collinear factorization

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Radici, Jakob, Bianconi
PR D65 (02)
Bacchetta, Radici,
PR D67 (03)

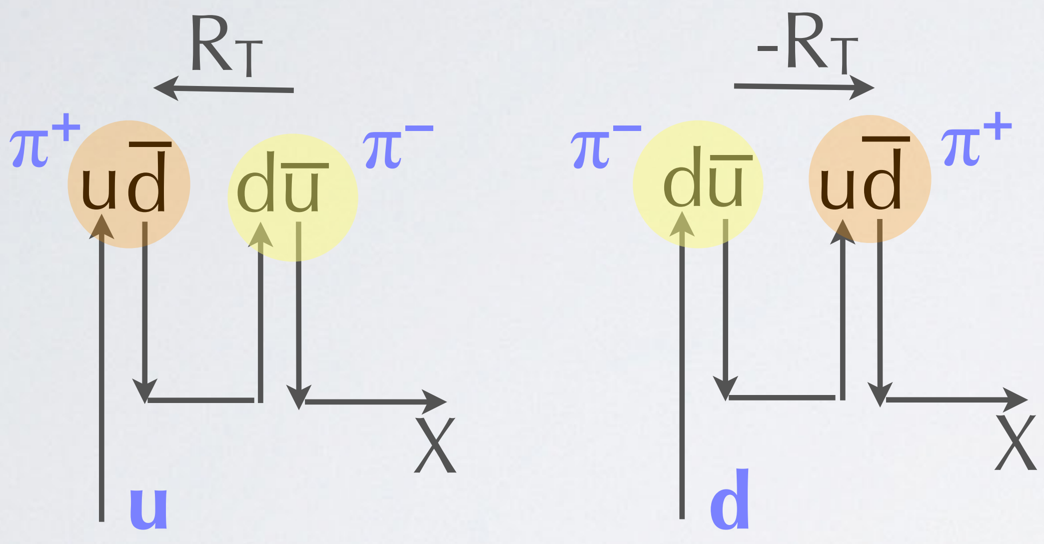
simple product
of h_1 and $H_1^{\sphericalangle}$

DGLAP evolution eq.
(well known)

Ceccopieri, Radici, Bacchetta,
P.L. B650 (07)

first extraction of $x\, h_1^{u_v} - x\, h_1^{d_v}/4$

$$A_{UT}^{\sin(\phi_R+\phi_S)} \propto -\frac{|\boldsymbol{R}|}{M_h} \frac{\sum_q e_q^2\; h_1^q(x)\; H_1^{\sphericalangle\, q}(z, M_h^2)}{\sum_q e_q^2\; f_1^q(x)\; D_1^q(z, M_h^2)}$$



isospin symmetry + charge conjugation

$$H_1^{\sphericalangle\, u} = -H_1^{\sphericalangle\, d}$$
$$H_1^{\sphericalangle\, q} = -H_1^{\sphericalangle\, \bar{q}}$$
$$D_1^q = D_1^{\bar{q}}$$

consistent with sign of exp. A_{UT}

proton target

$$x h_1^p(x) \equiv x h_1^{u_v}(x) - \frac{1}{4} x h_1^{d_v}(x)$$
$$\propto -\frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2\; H_1^{\sphericalangle\, u}} \left[\sum_{q=u,d,s} \frac{e_q^2}{e_u^2}\; x f_1^{q+\bar{q}}(x) \int dz dM_h^2\; D_1^q \right]$$

first extraction of $x\, h_1^{u_v} - x\, h_1^{d_v}/4$

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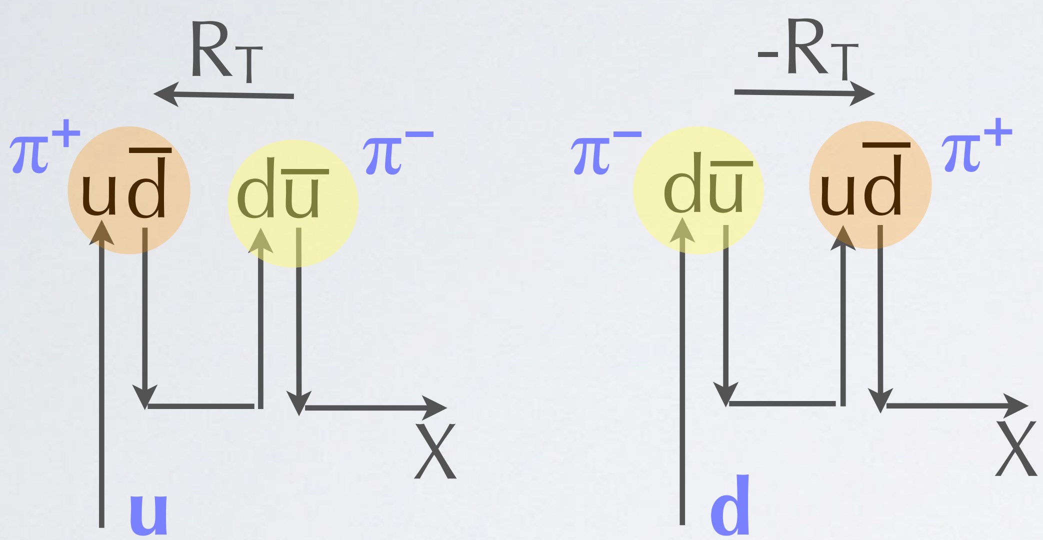

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hermes

MSTW08

first extraction of $x\, h_1^{u_v} - x\, h_1^{d_v}/4$

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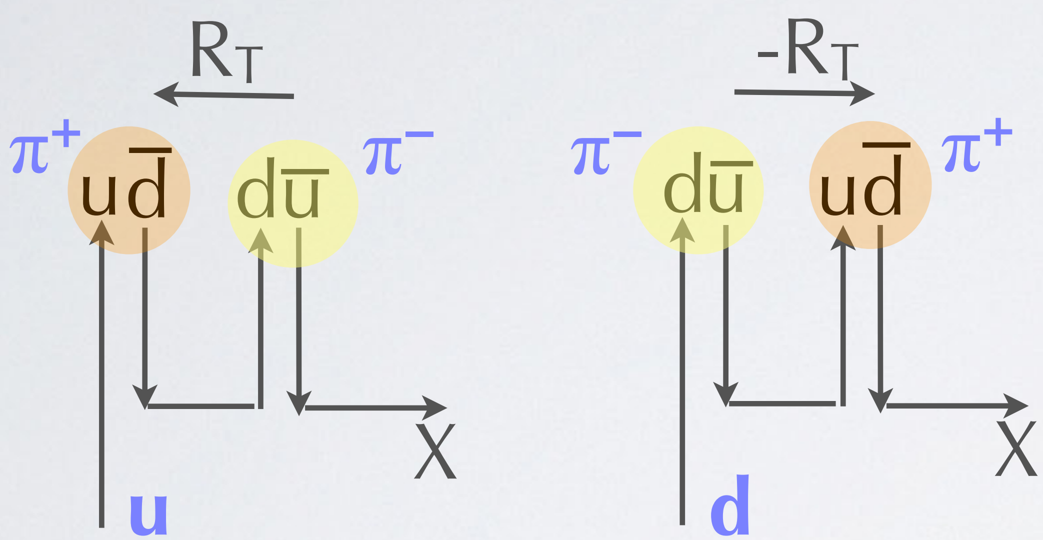

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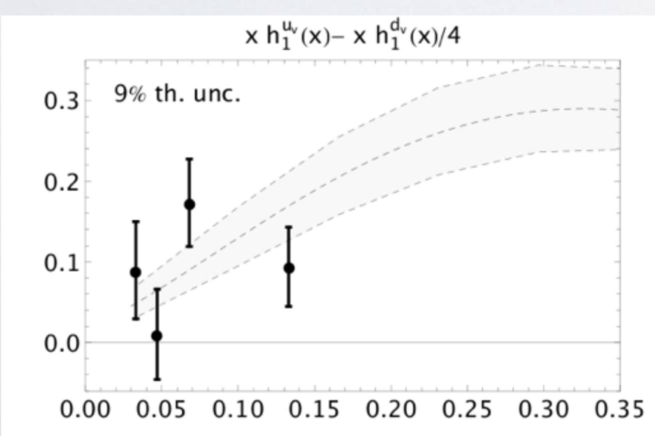
hermes

MSTW08

extracting from

$e^+e^- \to (\pi^+\pi^-)(\pi^+\pi^-)$

BELLE



Bacchetta, Courtoy, Radici,
P.R.L. ***107*** *(11) 012001*

first extraction of $x\, h_1^{u_v}$, $x\, h_1^{d_v}$

repeat for deuteron target

$$
\begin{aligned}
xh_1^D(x) &\equiv xh_1^{u_v}(x) + xh_1^{d_v}(x) \\
&\propto -\frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2\; H_1^{\sphericalangle\, u}}\, \frac{4}{3} \\
&\quad \times \left[\left(\sum_{q=u,d} x f_1^{q+\bar{q}}(x) \right) \left(\sum_{q=u,d} \frac{e_q^2}{e_u^2} \int dz dM_h^2\; D_1^q \right) + x f_1^{s+\bar{s}}(x)\, \frac{1}{2} \int dz dM_h^2\; D_1^s \right]
\end{aligned}
$$

proton data — access to $x\, h_1^{u-\bar{u}}(x) - \frac{1}{4} x\, h_1^{d-\bar{d}}(x)$

deuteron data — access to $x\, h_1^{u-\bar{u}}(x) + x\, h_1^{d-\bar{d}}(x)$

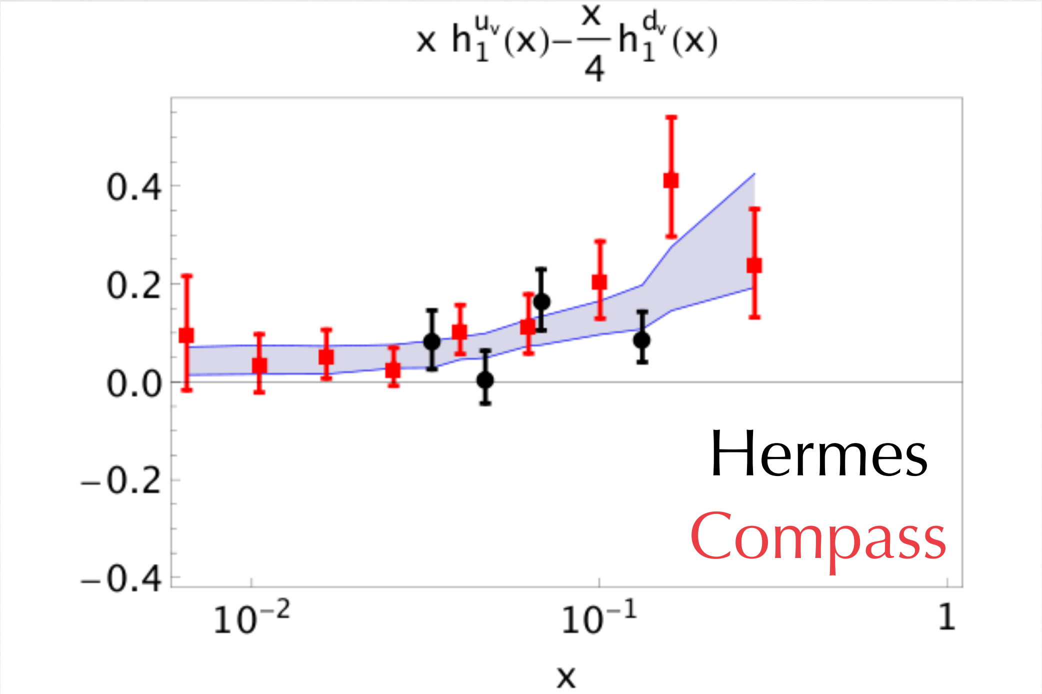
combination of both sets → access to valence transversities separately

*Bacchetta, Courtoy, Radici, JHEP **1303** (13) 119*

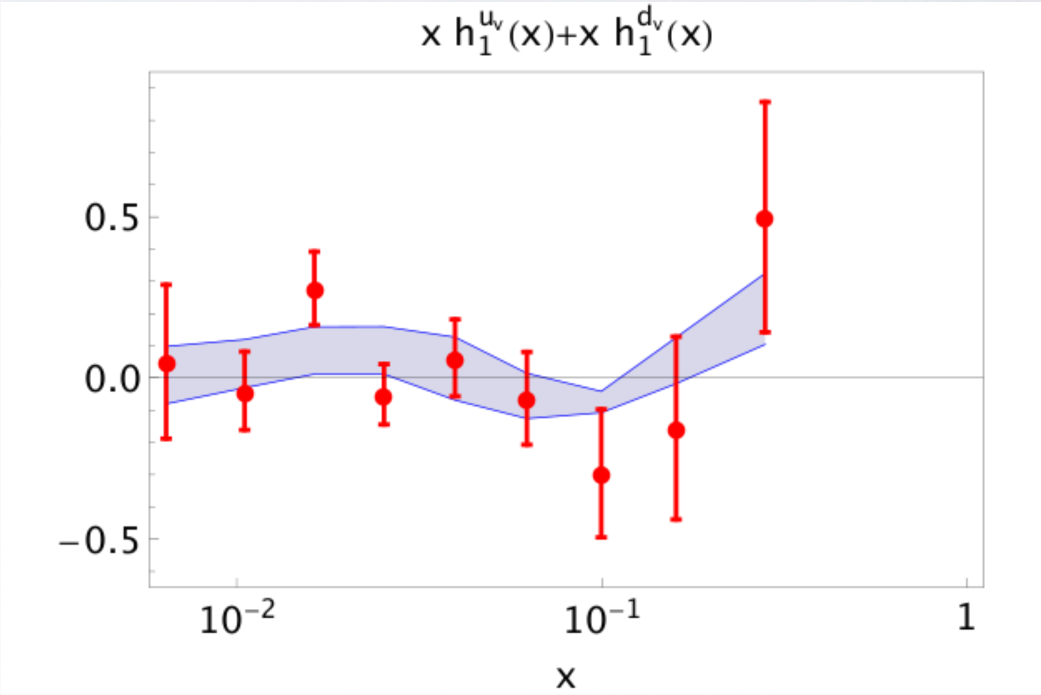
first extraction of $x\,h_1^{u_v}$, $x\,h_1^{d_v}$

*Bacchetta, Courtoy, Radici, JHEP **1303** (13) 119*

proton data
$x\,h_1^{p}(x)$



deuteron data
$x\,h_1^{D}(x)$



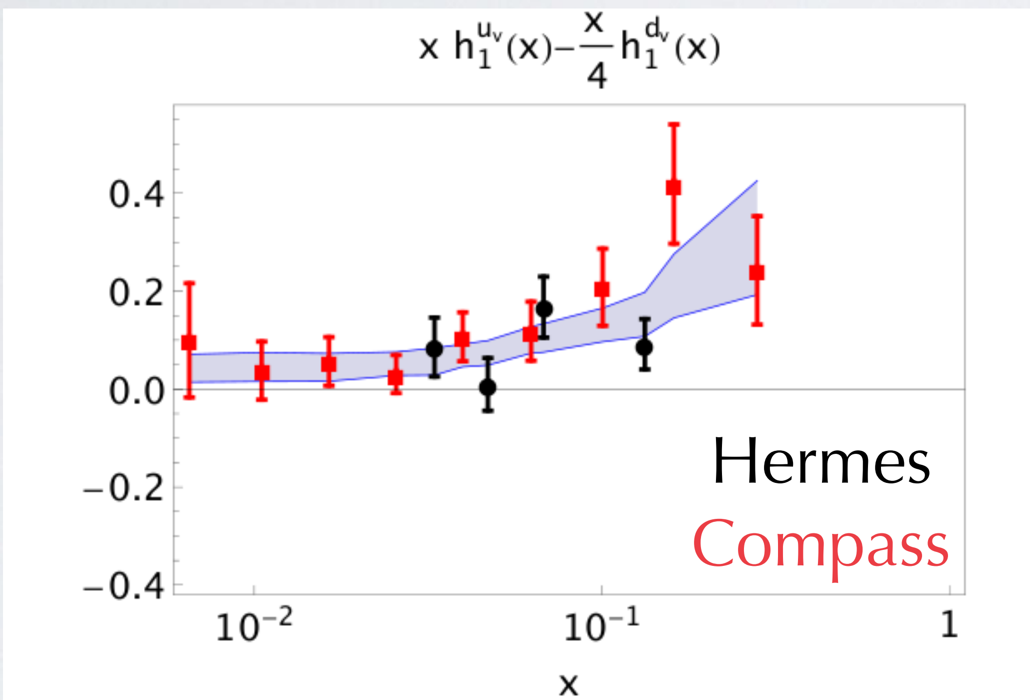
extraction point by point

first extraction of $x\, h_1^{u_v}$, $x\, h_1^{d_v}$

Bacchetta, Courtoy, Radici, JHEP ***1303*** *(13) 119*

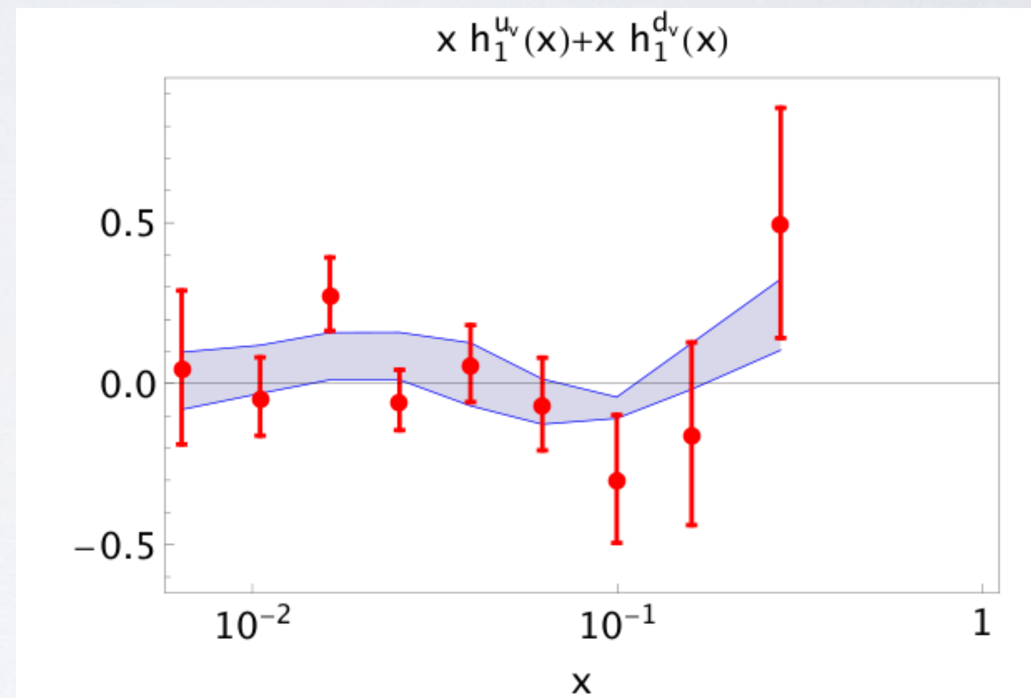
proton data

$x\, h_1^{p}(x)$



deuteron data

$x\, h_1^{D}(x)$



extraction point by point

next step: true fit of $x\, h_1^{p}(x)$ and $x\, h_1^{D}(x)$

two ways: standard Hessian method

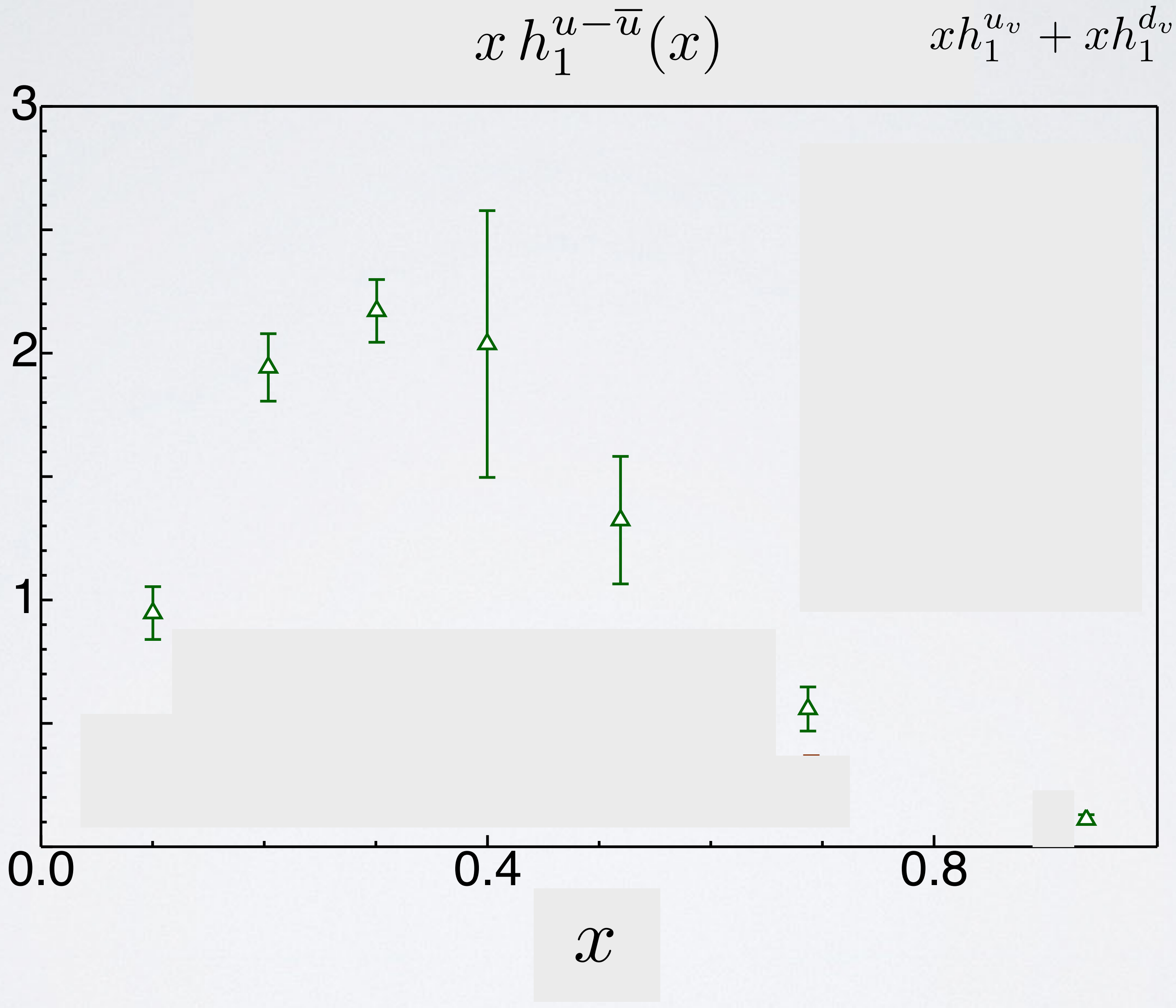
replica method

our fitting procedure

inspired by NNPDF

$$x h_1^{u_v} - \frac{1}{4} x h_1^{d_v} \propto - \frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2 \; H_1^{\sphericalangle\, u}} \cdots$$

$$x h_1^{u_v} + x h_1^{d_v} \propto - \frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2 \; H_1^{\sphericalangle\, u}} \, \frac{4}{3} \cdots$$



sample of original data

our fitting procedure

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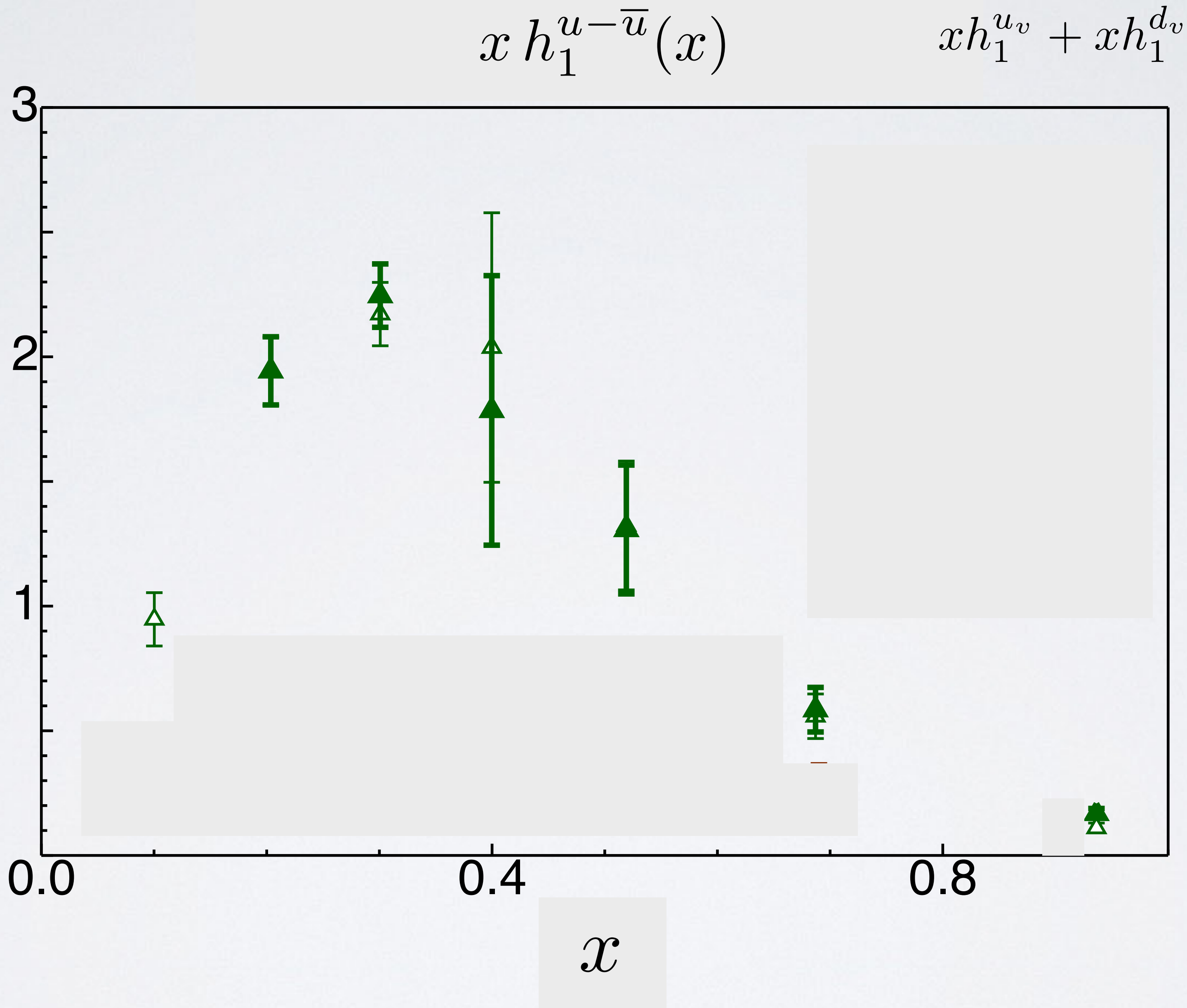
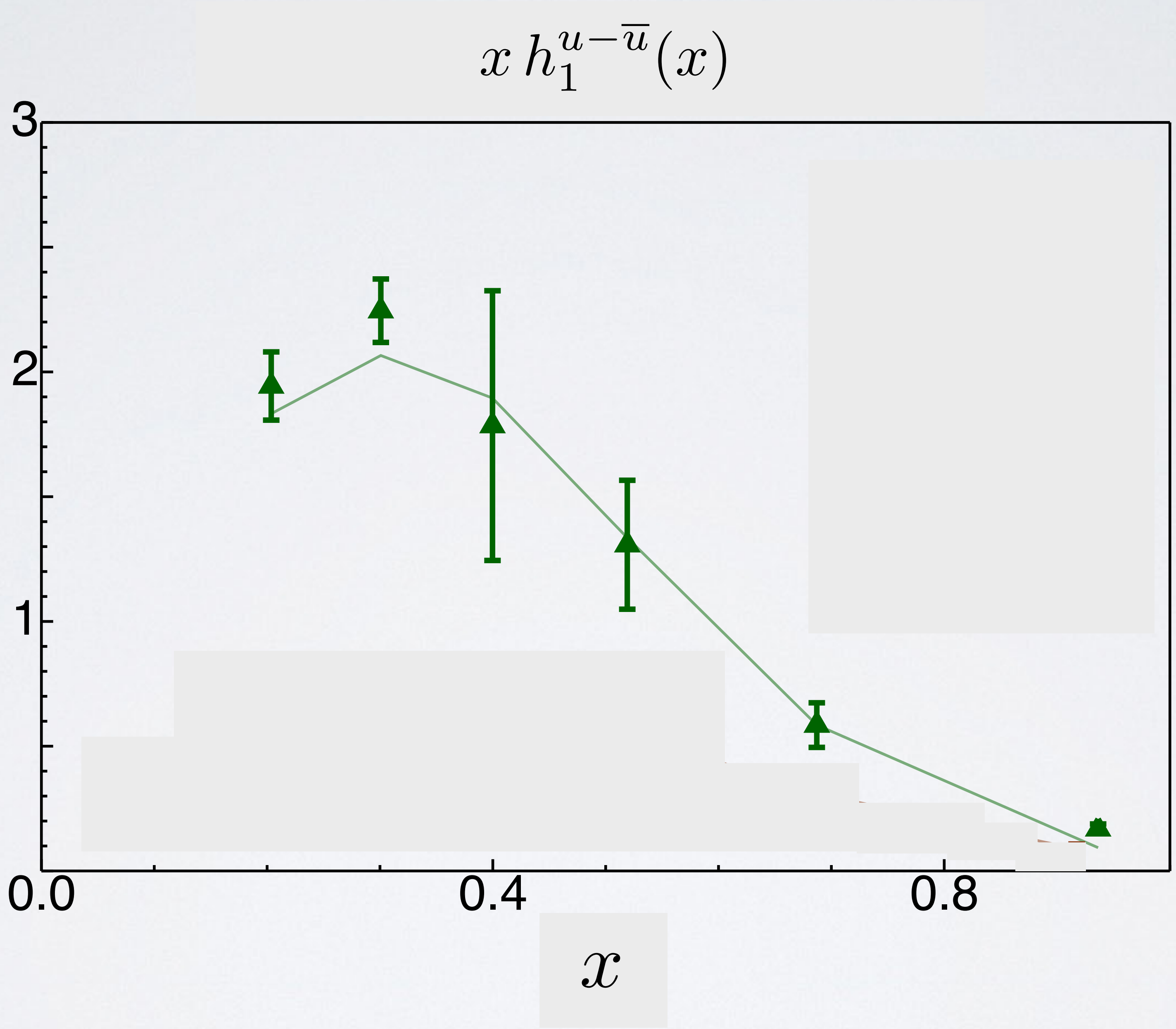


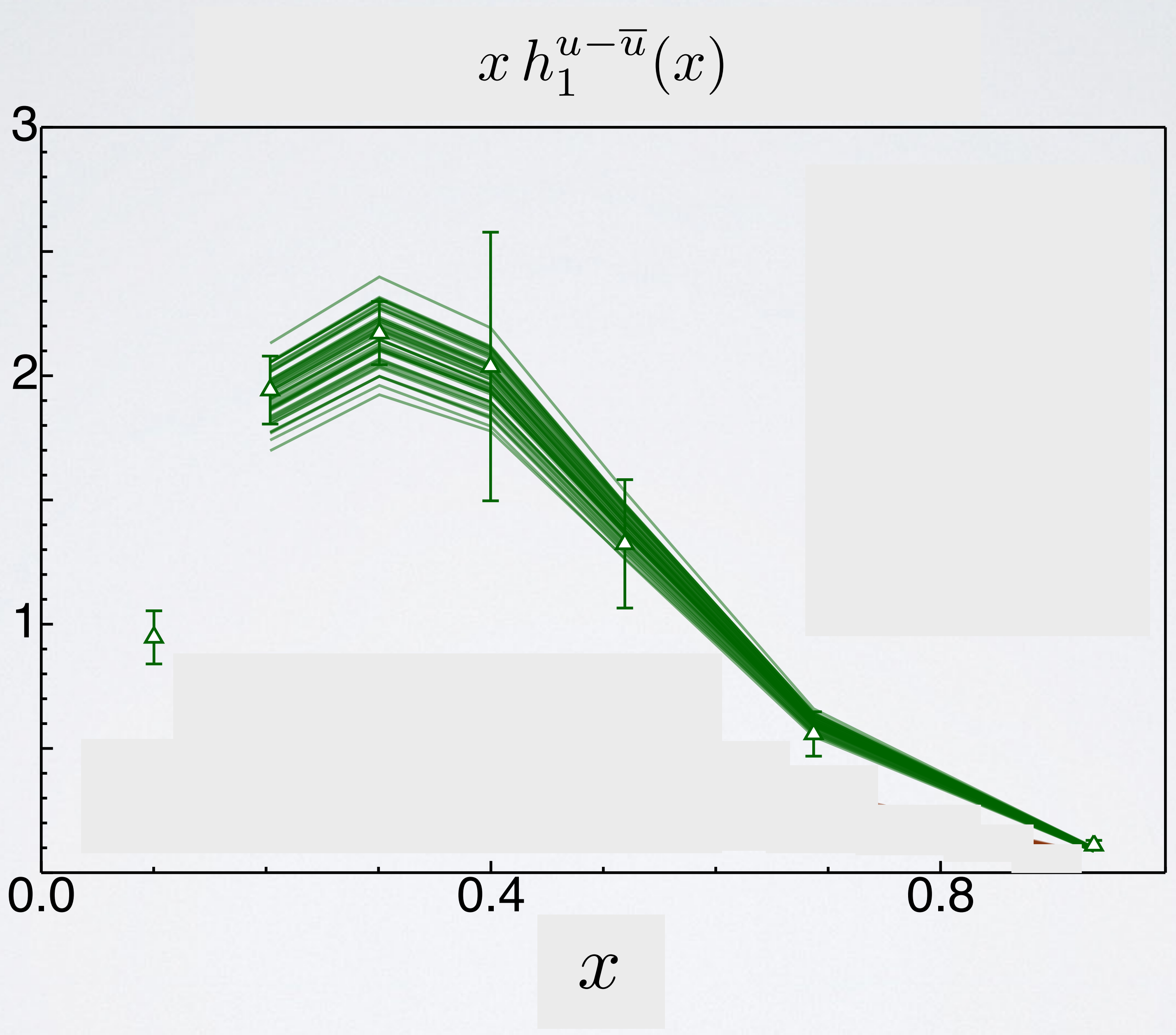
data are replicated with Gaussian noise
within exp. variance

our fitting procedure



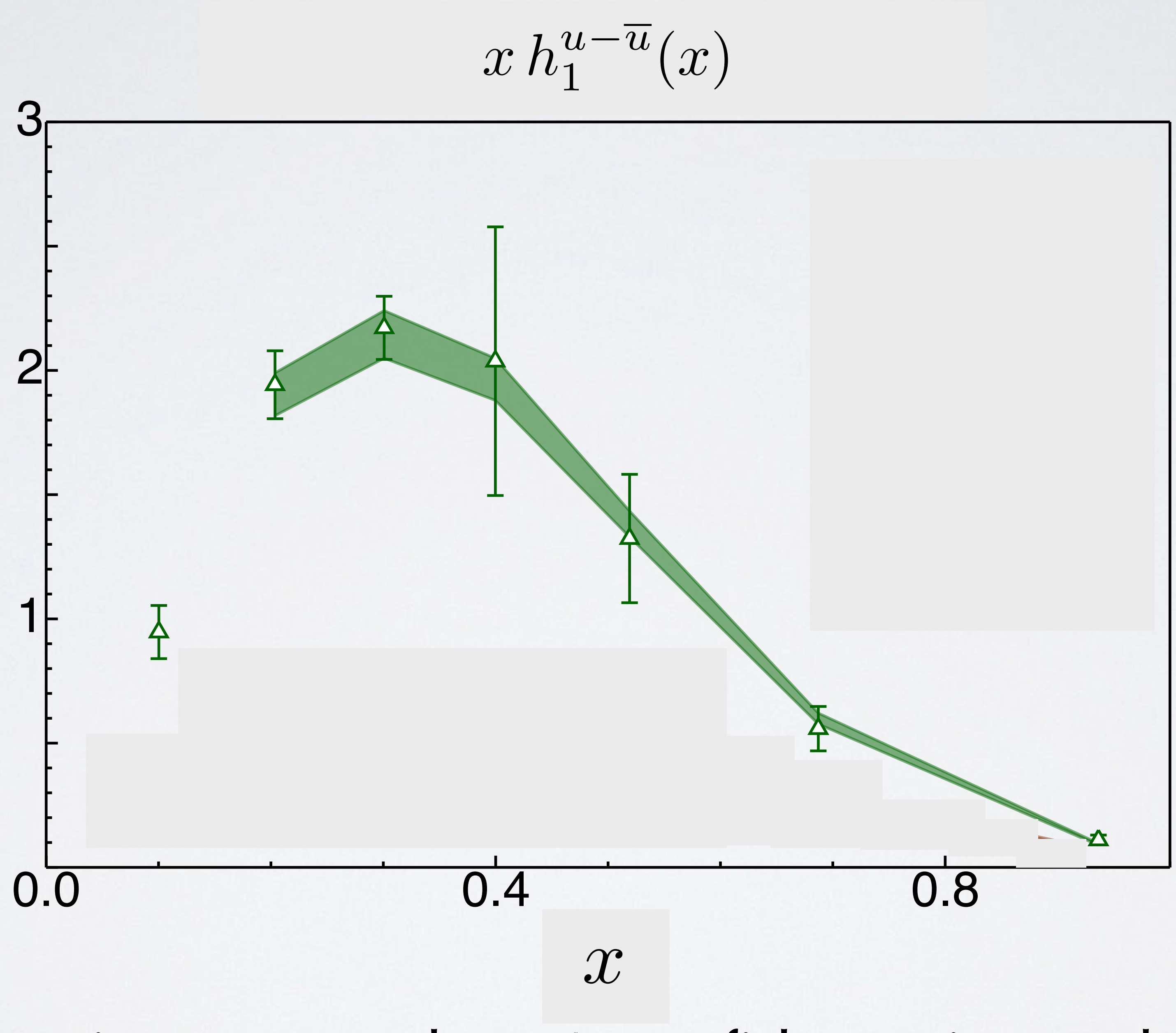
fit the replicated data

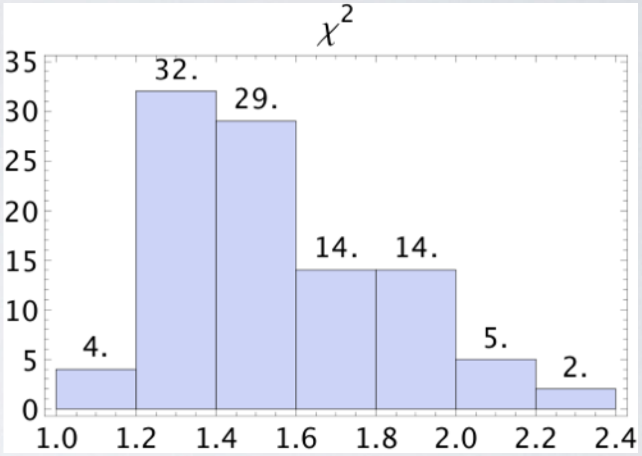
our fitting procedure



procedure repeated 100 times
(until reproduce mean and std. deviation of original data)

our fitting procedure





distribution of χ^2 should be peaked around χ^2 ~ 1

for each point, a central 68% confidence interval is identified (distribution is not necessarily Gaussian)

Fitting : the functional form

at starting scale $Q_0^2 = 1$ GeV^2

$$xh_1^{q_v}(x) = \tanh\left[\sqrt{x}\,\left(A_q + B_q x + C_q x^2 + D_q x^3\right)\right]\,\left[x\,\mathrm{SB}_q(x) + x\,\overline{\mathrm{SB}}_{\bar{q}}(x)\right]$$

$\mathrm{SB}_q + \overline{\mathrm{SB}}_{\bar{q}} \to \infty \quad x \to 0$
grants finite and stable
tensor charge

automatically satisfies
Soffer bound
at any Q^2

$$2|h_1^q(x, Q^2)| \leq 2\ \mathrm{SB}_q(x) = |f_1^q(x) + g_1^q(x)|$$

MSTW08LO (f_1^q) DSSV (g_1^q)

error on SB negligible
w.r.t. exp. error and
uncertainty on DiFF fit

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rigid

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MSTW08LO

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MSTW08LO DSSV

rigid

flexible

error on SB negligible
w.r.t. exp. error and
uncertainty on DiFF fit

Fitting : the functional form

at starting scale $Q_0^2 = 1\ \mathrm{GeV}^2$

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grants finite and stable
tensor charge

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Soffer bound
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$$2|h_1^q(x,Q^2)| \leq 2\ \mathrm{SB}_q(x) = |f_1^q(x) + g_1^q(x)|$$

MSTW08LO DSSV

rigid

flexible

extra-flexible

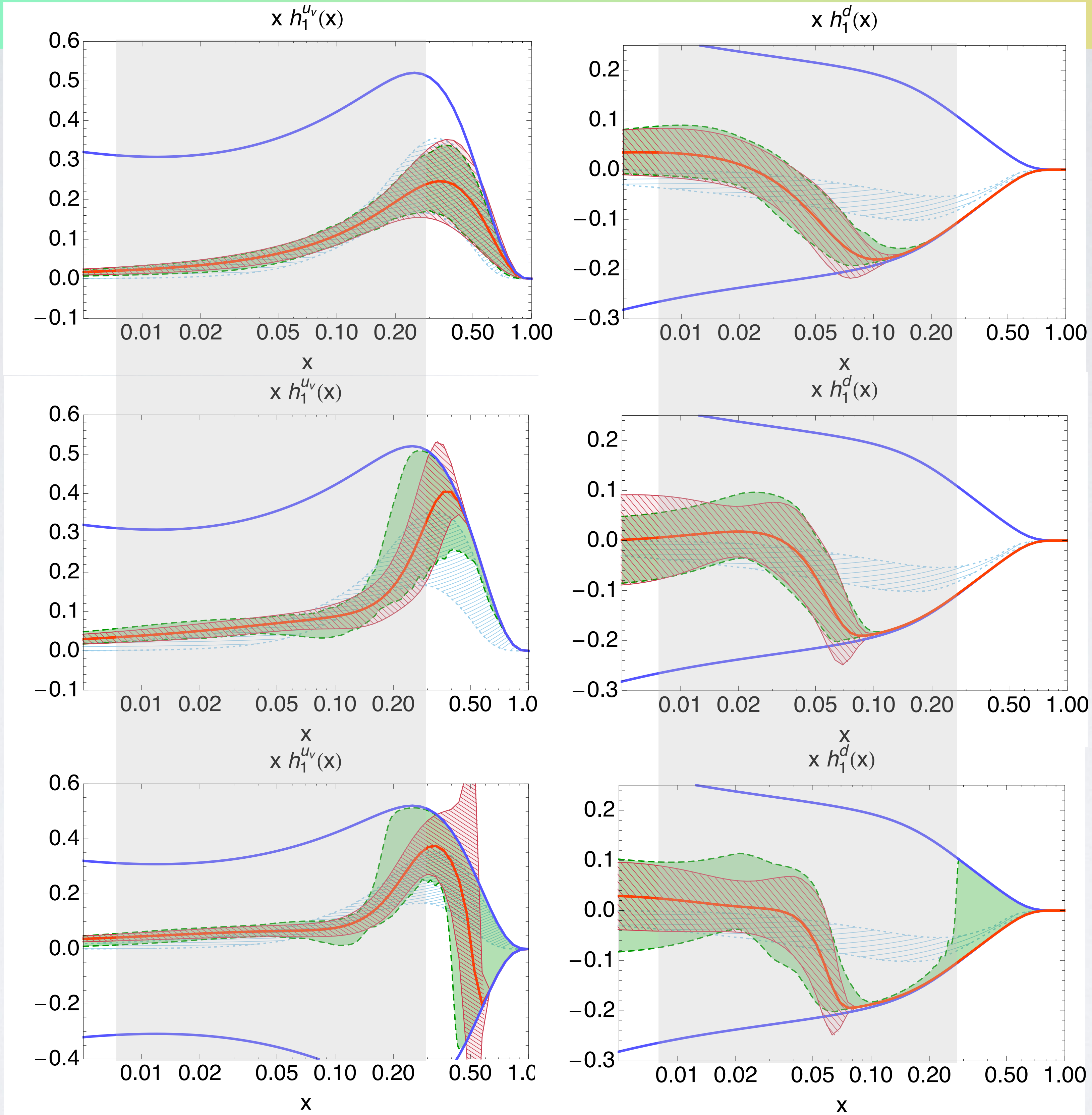
$\chi^2/\mathrm{dof} \sim 1.2$

error on SB negligible
w.r.t. exp. error and
uncertainty on DiFF fit

$Q^2 = 2.4$ GeV^2

$x\, h_1^{q-\bar{q}}(x)$

$u - \overline{u}$ $\qquad$ $d - \overline{d}$



rigid

flexible

extra flexible

Bacchetta, Courtoy, Radici,
JHEP ***1303*** *(13) 119*

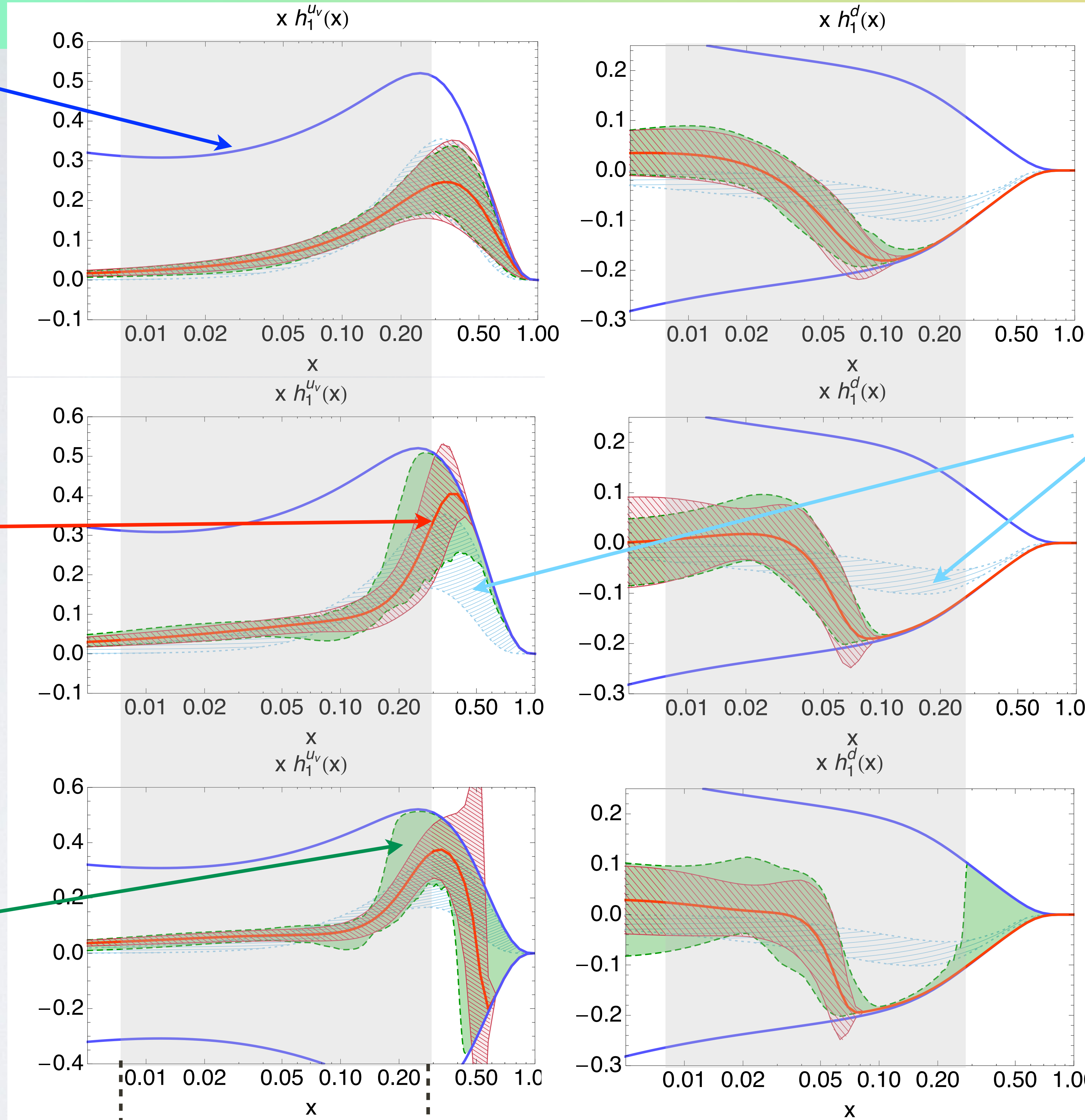
$Q^2 = 2.4\ \mathrm{GeV}^2$

$u - \bar{u}$ $\quad x\, h_1^{q-\bar{q}}(x)$ $\quad d - \bar{d}$

Soffer bound

central value
for standard fit
with 1σ band

68% band of
replicas



Torino param.
2009

rigid

flexible

extra
flexible

← data →

Bacchetta, Courtoy, Radici,
JHEP ***1303*** *(13) 119*

$Q^2 = 2.4\ GeV^2$

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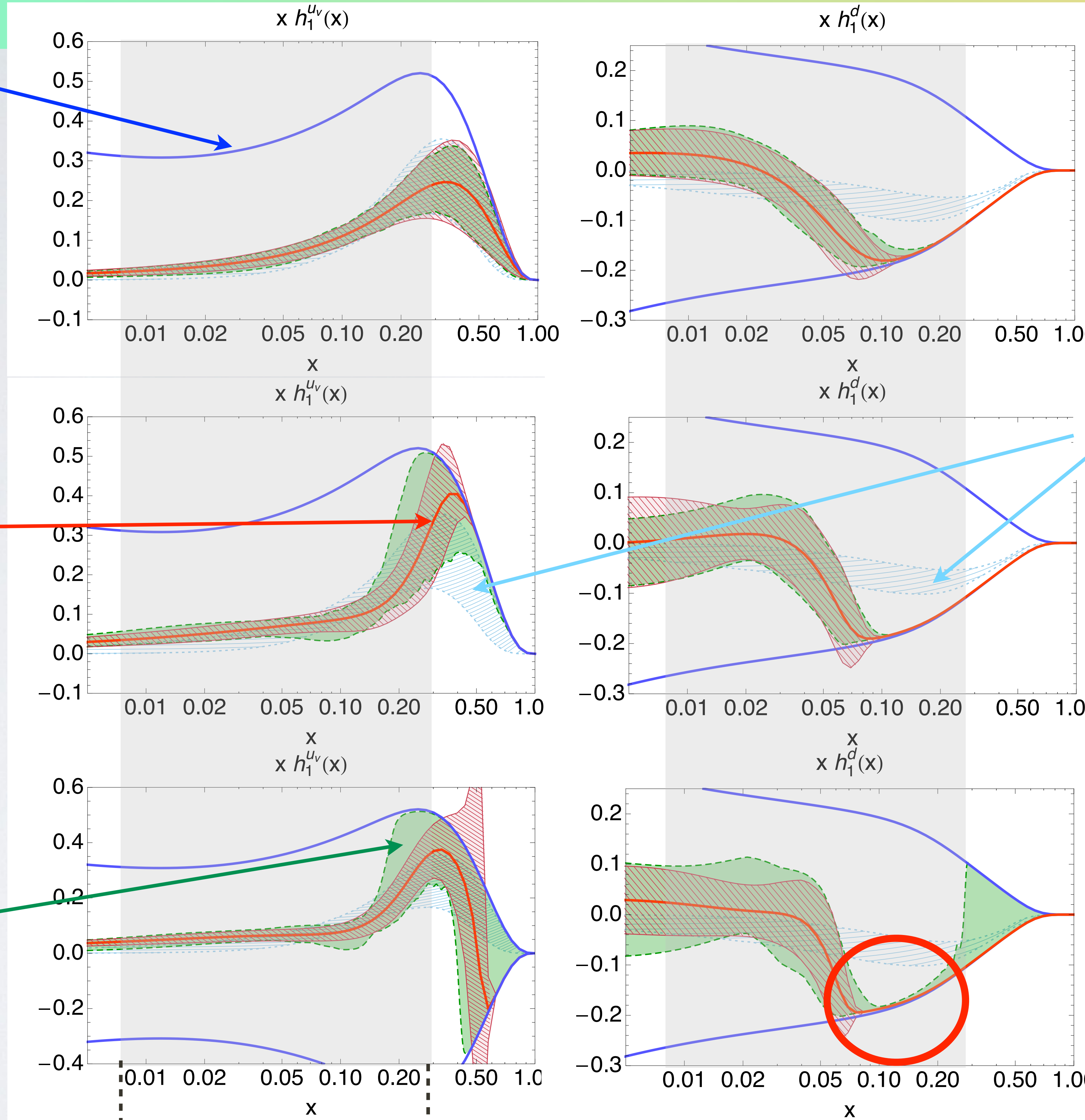


Soffer bound

central value for standard fit with 1σ band

68% band of replicas

Torino param. 2009

rigid

flexible

extra flexible

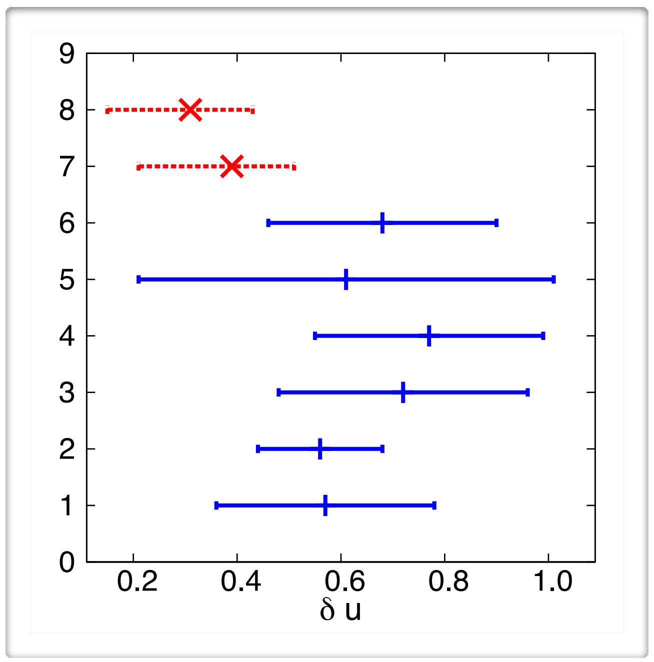
data

driven by COMPASS deuteron data

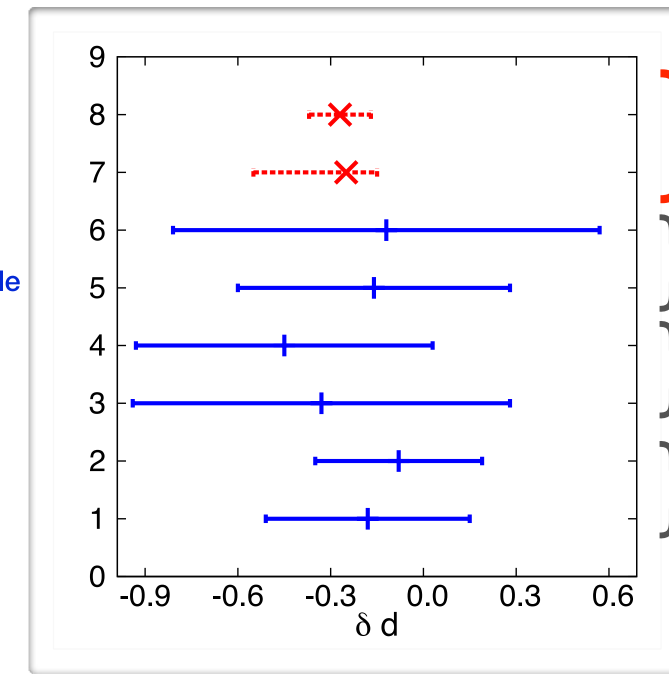
Bacchetta, Courtoy, Radici, JHEP ***1303*** *(13) 119*

tensor charges

up



down



8. fit of A_0

7. fit of A_{12}

6. MC extra flexible

5. standard extra flexible

4. MC flexible

3. standard flexible

2. MC rigid

1. standard rigid

Collins effect

$Q_0^2 = 1$ GeV^2 $\quad$ $\delta q = \int_{\sim 0}^{1} dx\, h_1^{q_v}(x)$ $\quad$ full range

Bacchetta, Courtoy, Radici,
JHEP ***1303*** *(13) 119*

tensor charges

$g_T = \delta u - \delta d$

LHPC

g_T=1.038(20)

*Green et al., P.R. D**86** (12)*

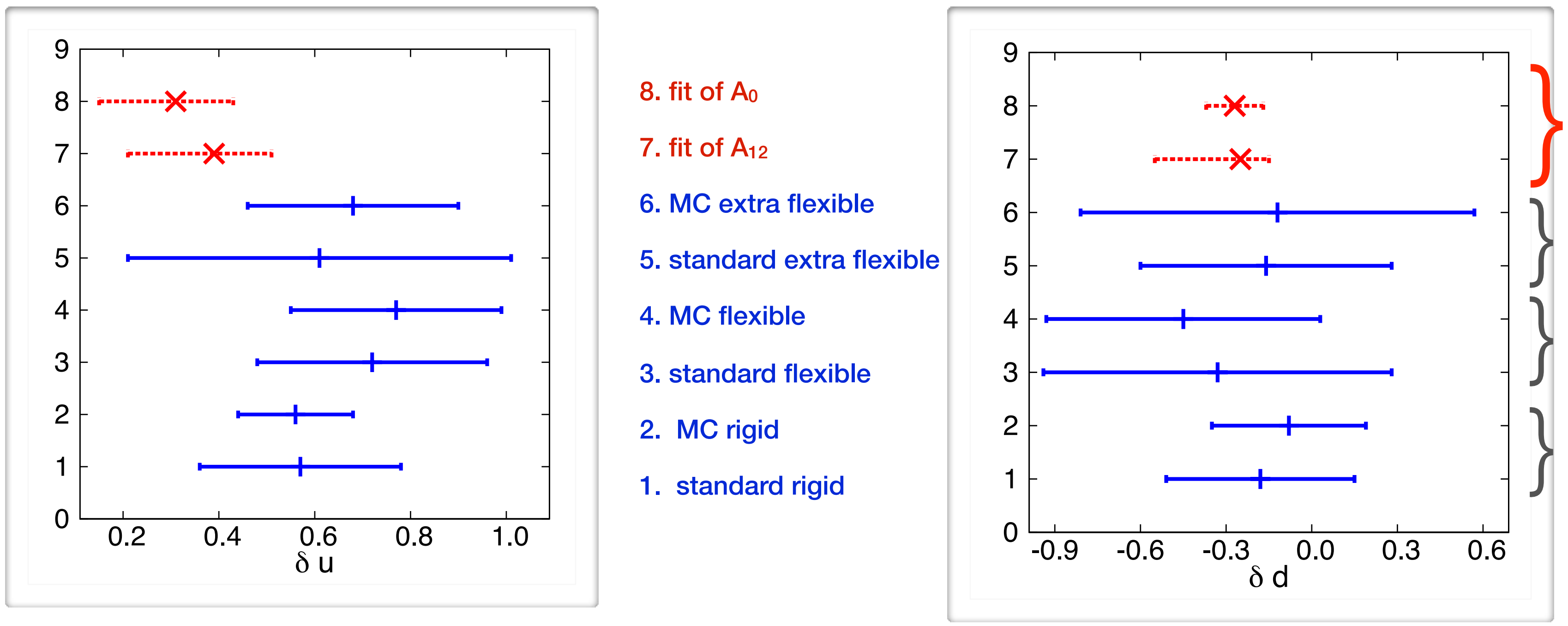
MILC

g_T=1.083(48)

Bhattacharya et al., arXiv: 1306.5435

up

down



Collins effect

Q_0^2 = 1 GeV^2

$$\delta q = \int_{\sim 0}^{1} dx\, h_1^{q_v}(x)$$

full range

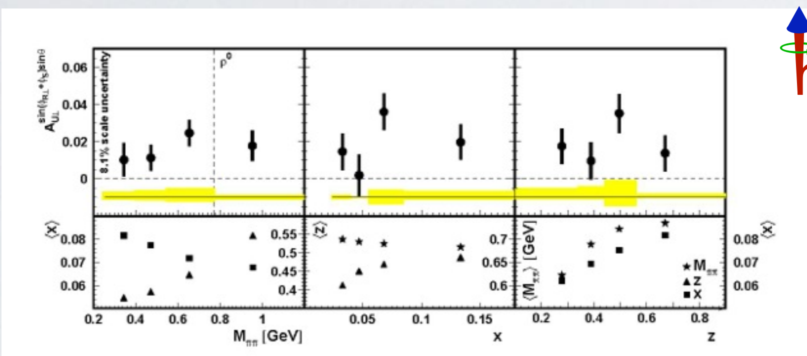
extrapolation of data
large uncertainty!

*Bacchetta, Courtoy, Radici, JHEP **1303** (13) 119*

interlude with partial summary

our analysis *Bacchetta, Courtoy, Radici, JHEP **1303** (13) 119*

has used data from

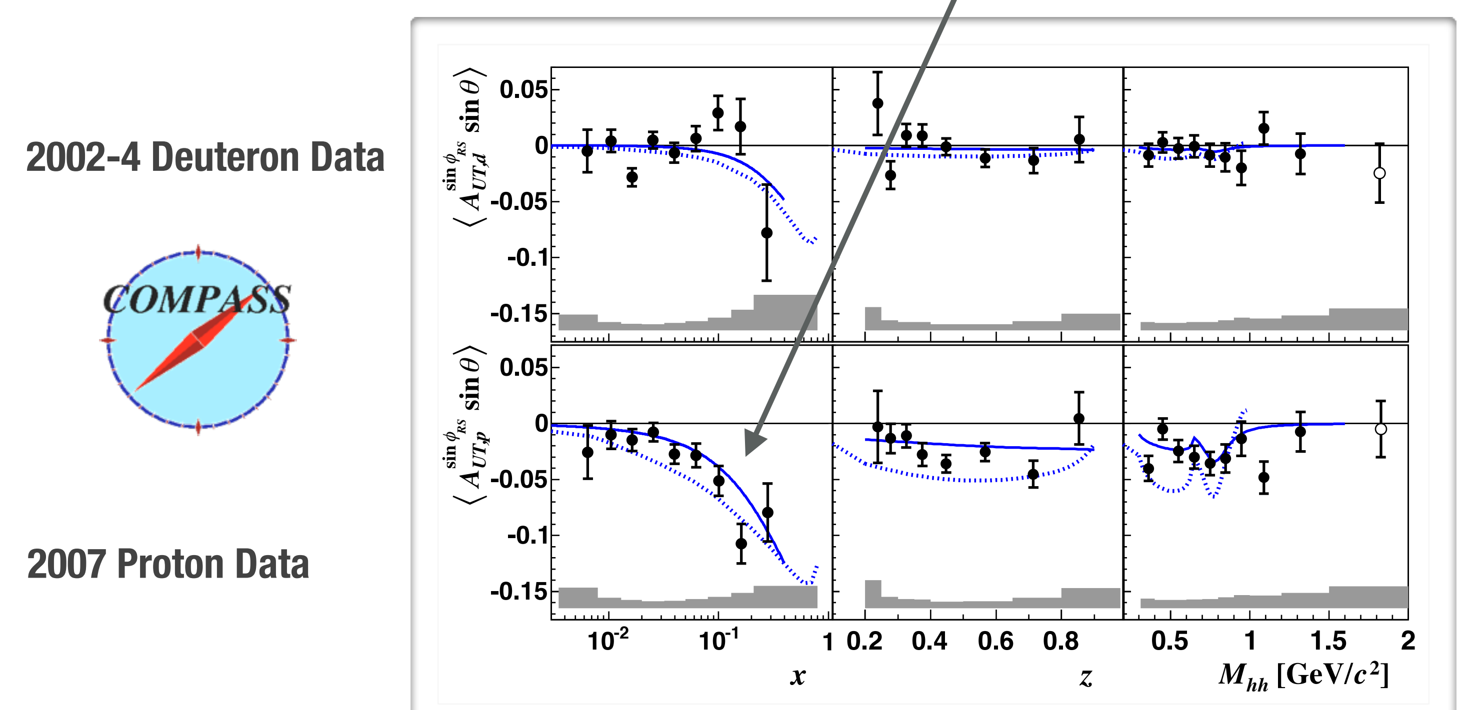


proton

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

*Bacchetta & Radici, P.R. D**74** (06) 114007*

prediction

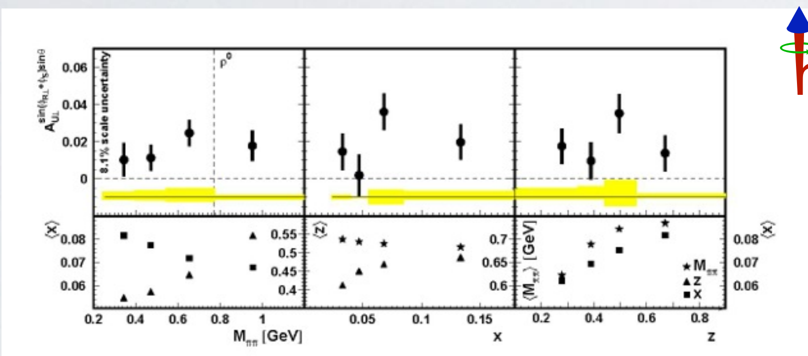


*C.Adolph et al. (Compass), PL **B713** (12)*

interlude with partial summary

our analysis *Bacchetta, Courtoy, Radici, JHEP **1303** (13) 119*

has used data from

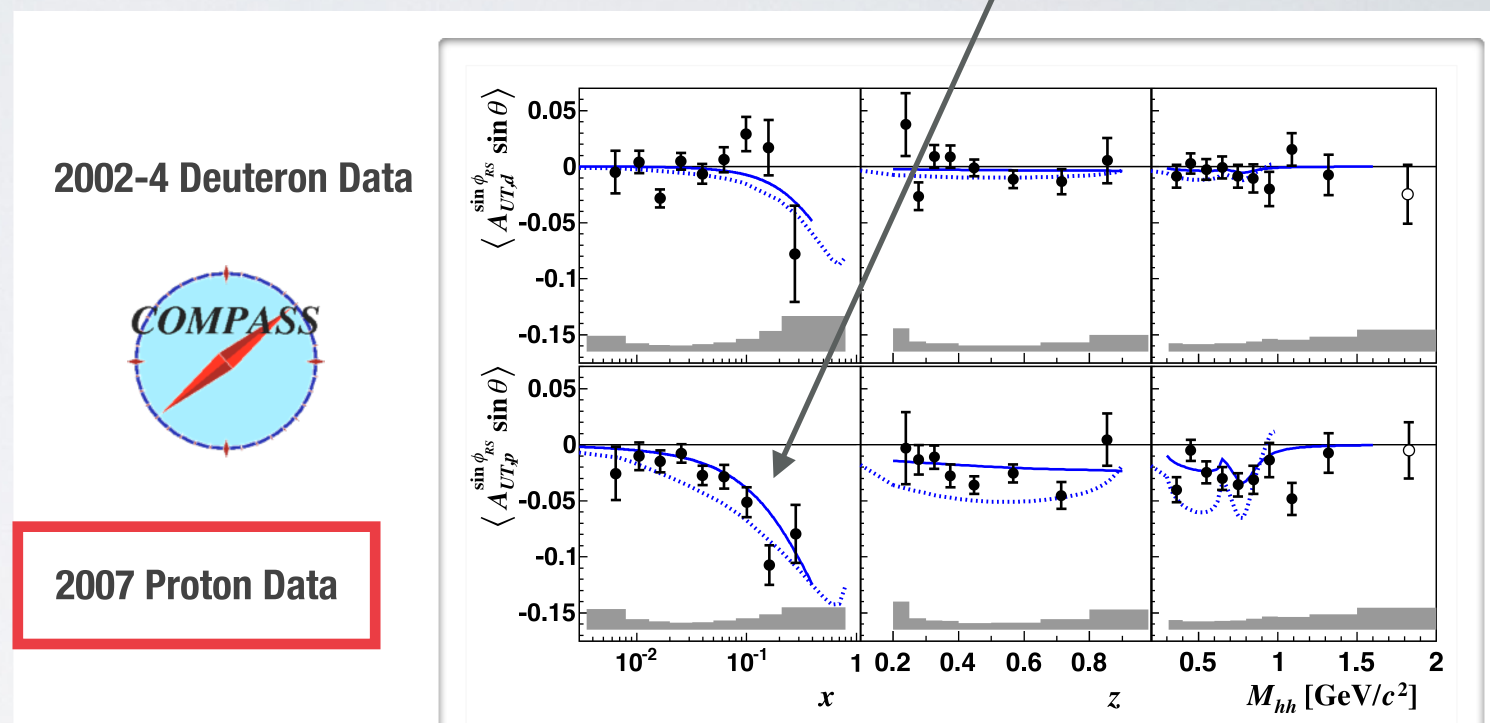


hermes proton

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

*Bacchetta & Radici, P.R. D**74** (06) 114007*

prediction



*C.Adolph et al. (Compass), PL **B713** (12)*

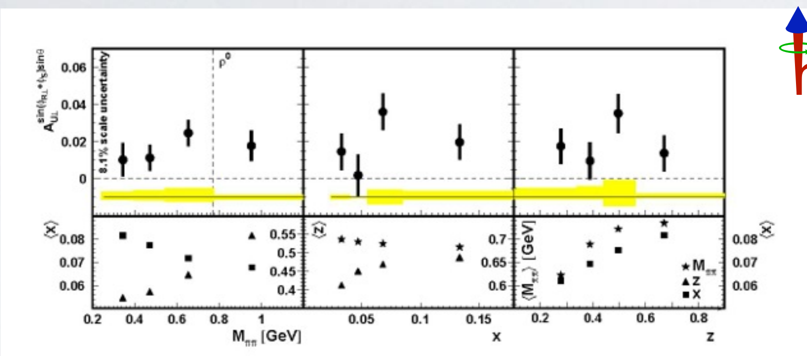
interlude with partial summary

our analysis *Bacchetta, Courtoy, Radici, JHEP **1303** (13) 119*

has used data from

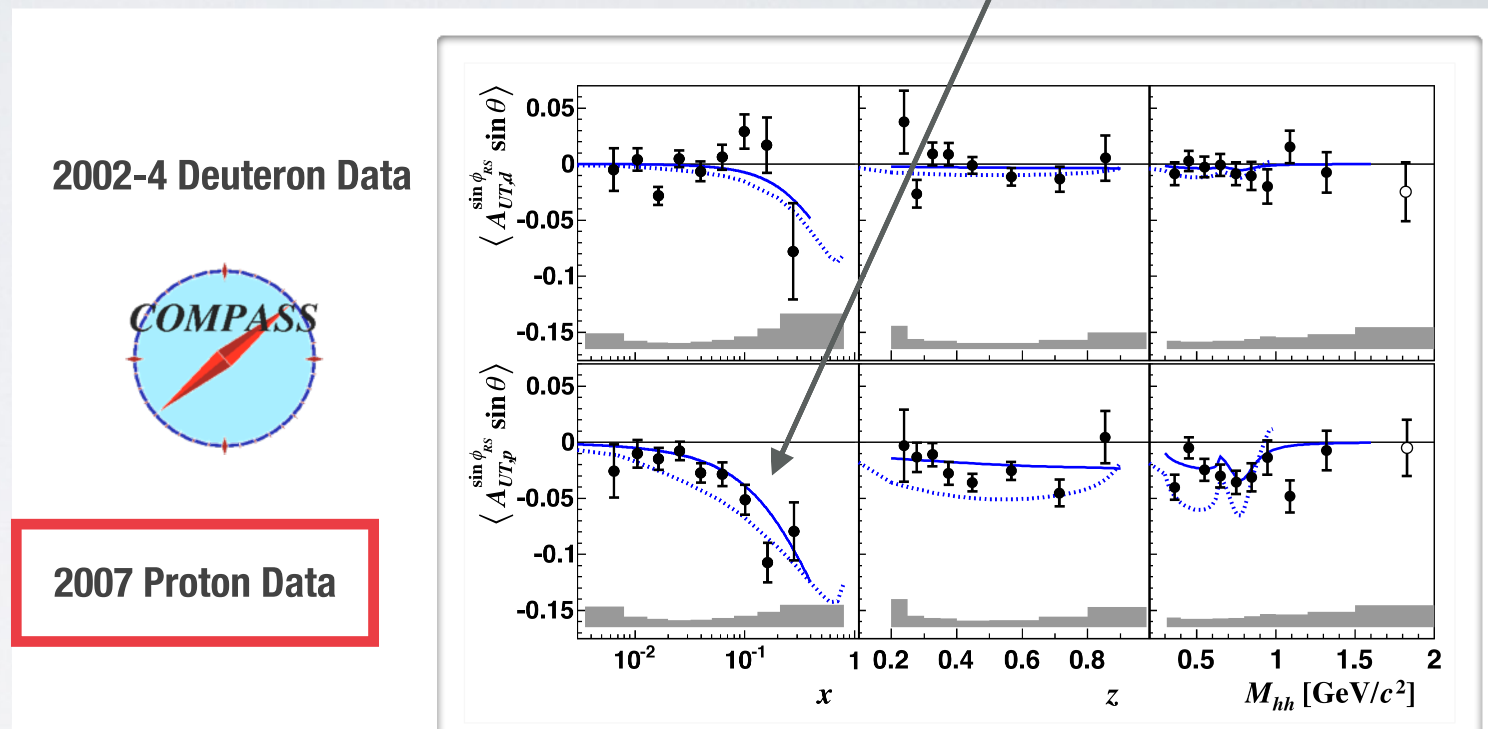
*Bacchetta & Radici, P.R. D**74** (06) 114007*

prediction



proton

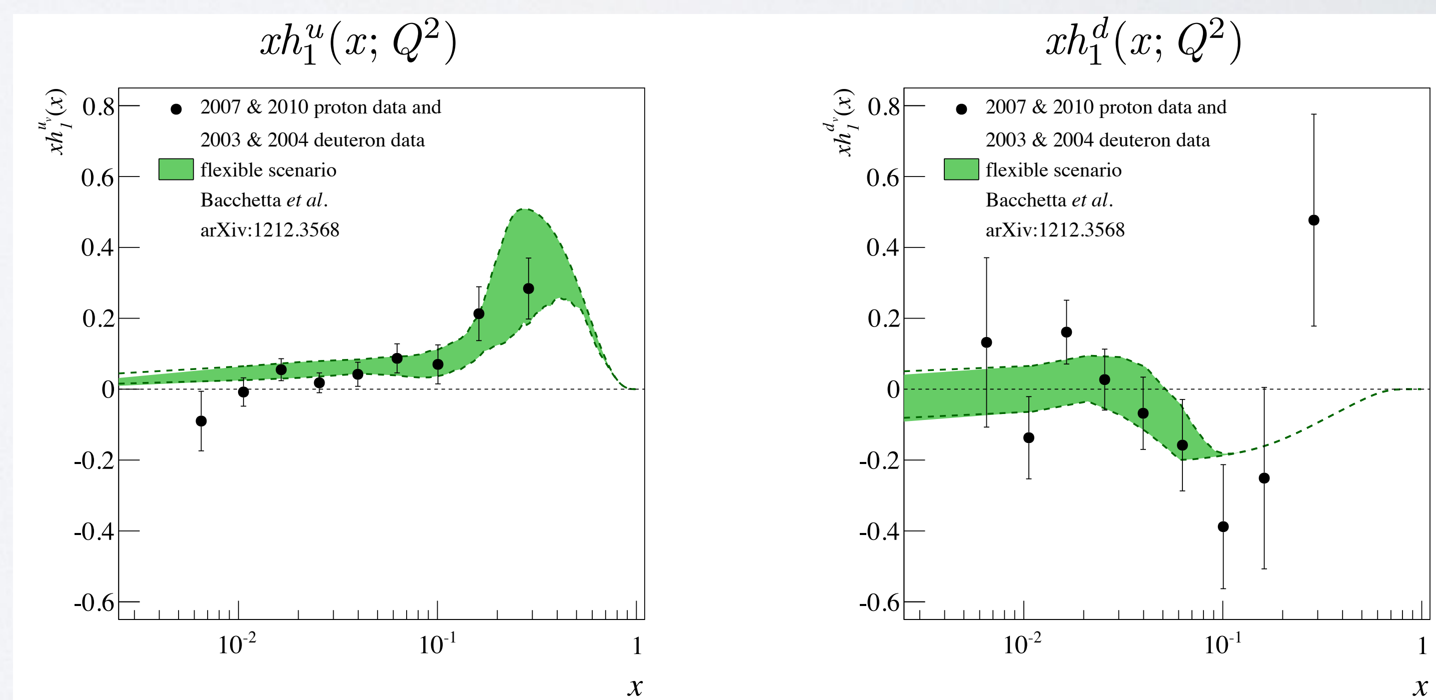
*Airapetian et al., JHEP **0806** (08) 017*



*C.Adolph et al. (Compass), PL **B713** (12)*

C. Braun's talk
point-by-point extraction
but uses new 2010 proton
data for π+π-

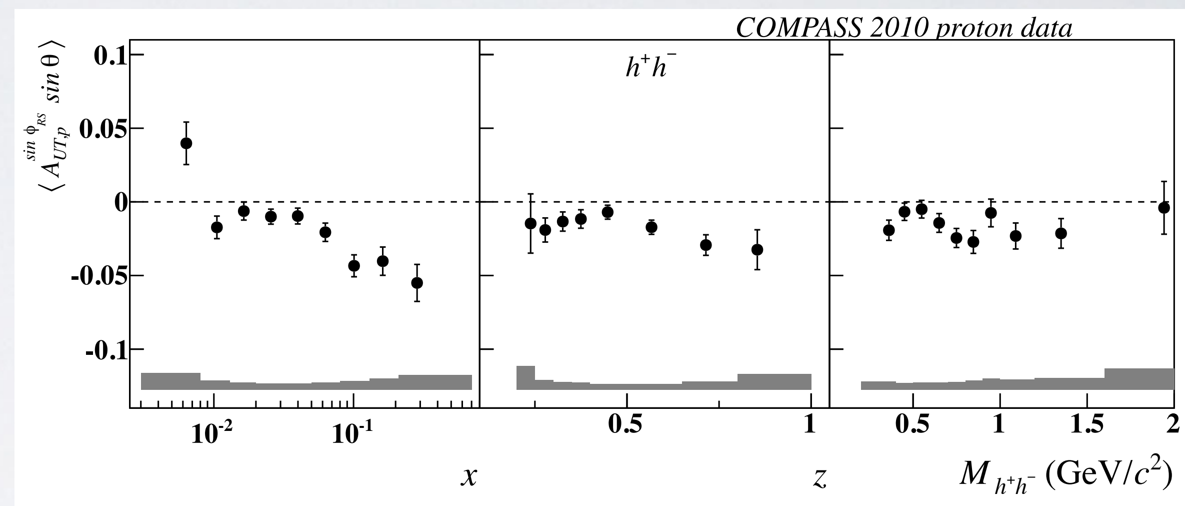
⇒ agreement



new fit

1. use new COMPASS 2010 proton data for h+h-

A_{UT} (x, z, M_h)



C.Adolph et al. (Compass), arXiv:1401.7873

new fit

1. use new COMPASS 2010 proton data for h+h-

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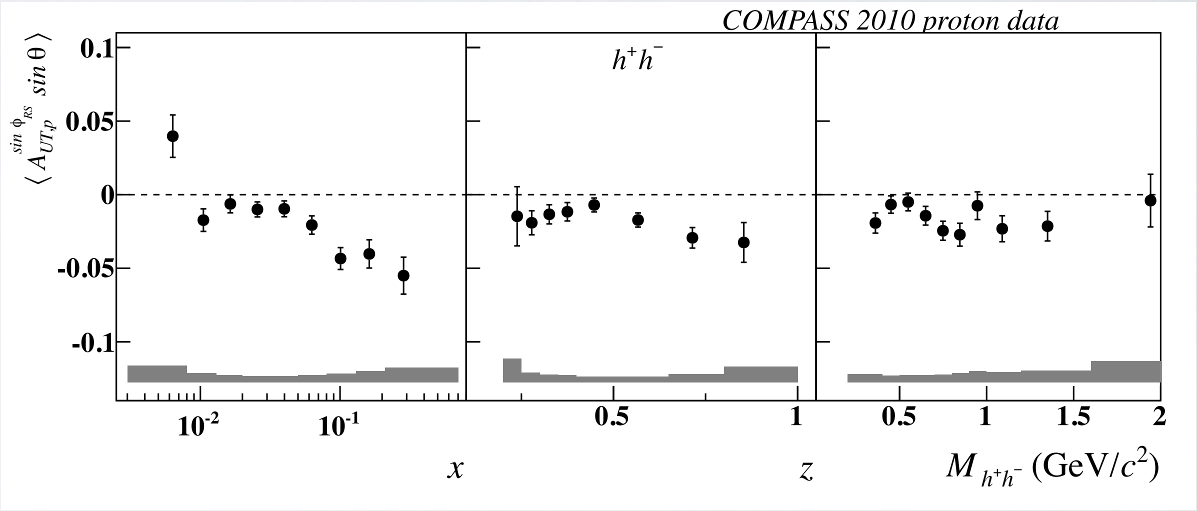


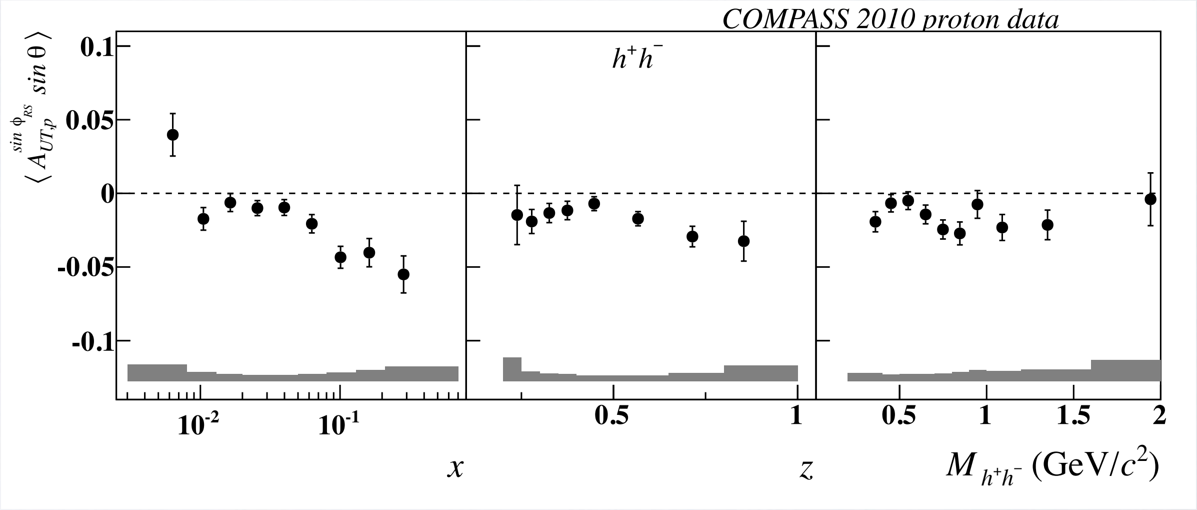
C.Adolph et al. (Compass), arXiv:1401.7873

2. use replica method to extract DiFF from BELLE data

new fit

1. use new COMPASS 2010 proton data for h+h-

A_{UT} (x, z, M_h)



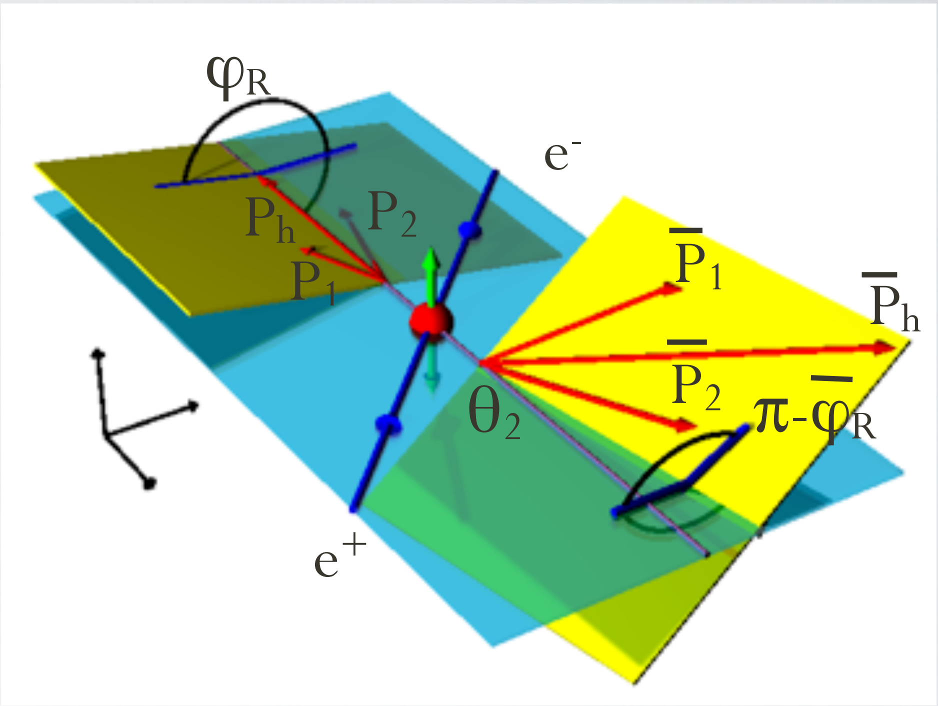
C.Adolph et al. (Compass), arXiv:1401.7873

2. use replica method to extract DiFF from BELLE data

current most realistic estimate of uncertainty on transversity

fit Belle data ➡ extract DiFF

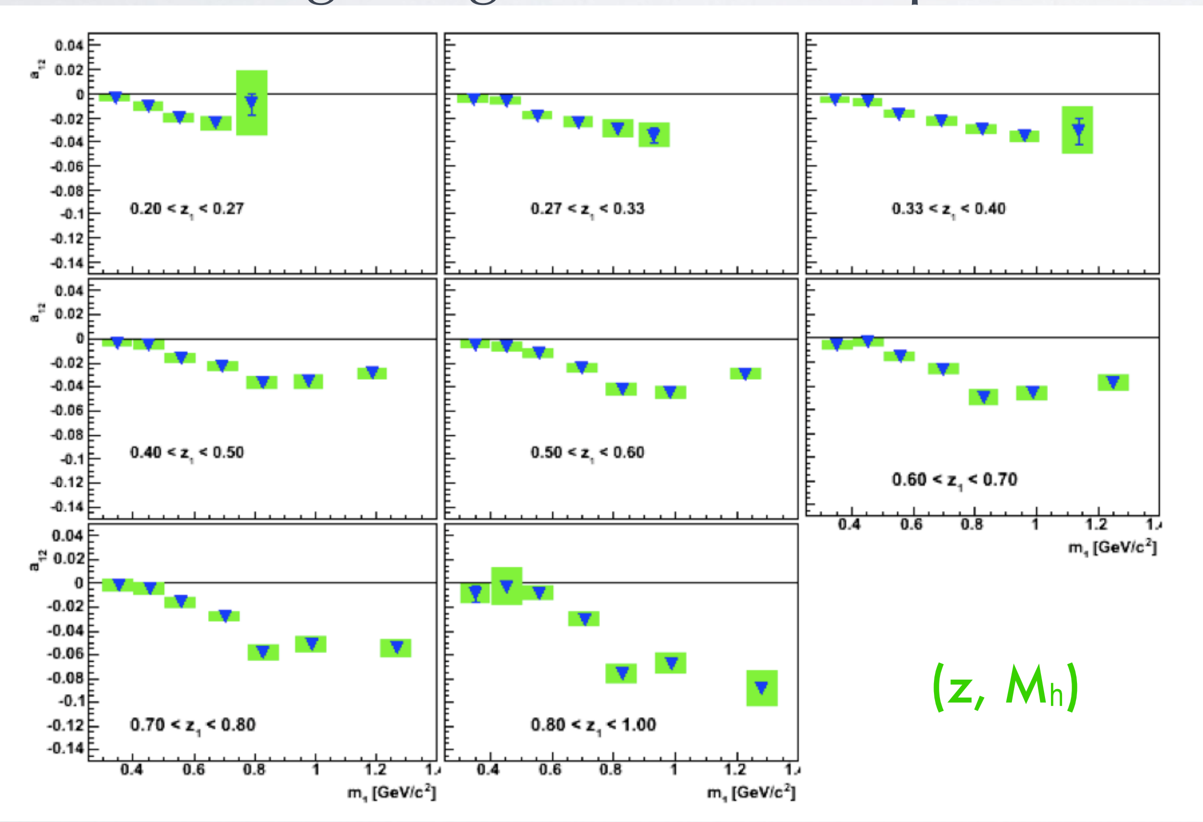
$e^+e^- \rightarrow (\pi^+\pi^-)(\pi^+\pi^-) + X$



$$A^{\cos(\phi_R+\overline{\phi}_R)} = \frac{\sin^2\theta_2}{1+\cos^2\theta_2}\frac{|\mathbf{R}_T|}{M_h}\frac{|\overline{\mathbf{R}}_T|}{\overline{M}_h} \times \frac{\sum_q e_q^2\, H_{1,sp}^{\sphericalangle q}(z,M_h^2)\,\overline{H}_{1,sp}^{\sphericalangle \overline{q}}(\overline{z},\overline{M}_h^2)}{\sum_q e_q^2\, D_1^q(z,M_h^2)\,\overline{D}_1^{\overline{q}}(\overline{z},\overline{M}_h^2)}$$

*Boer, Jakob, Radici, P.R. D**67** (03) 094003*
*Artru & Collins, Z.Ph. C**69** (96) 277*

(integrating on one hemisphere)



unpol. D_1 extracted from PYTHIA adapted to Belle (very large statistics)

pol. $H_1^{\sphericalangle}$ extracted from fitting $A^{\cos}$

*Vossen et al., P.R.L. **107** (11) 072004*

first ever extraction of DiFF

*Courtoy, Bacchetta, Radici, Bianconi, P.R. D**85** (12) 114023*

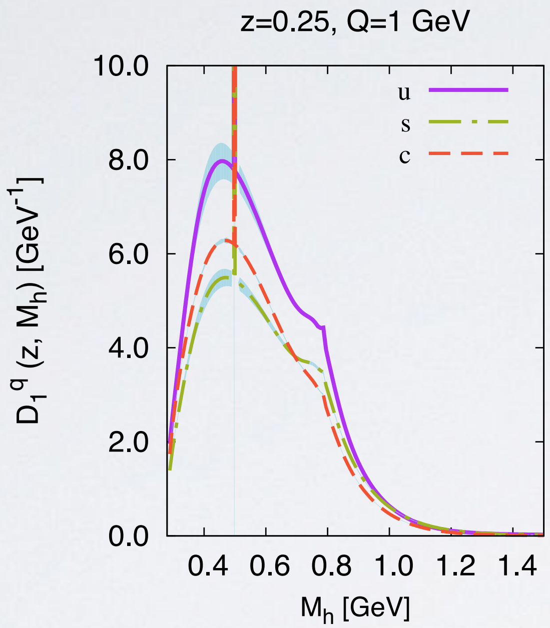
D_1^q

M_h behaviour

z behaviour

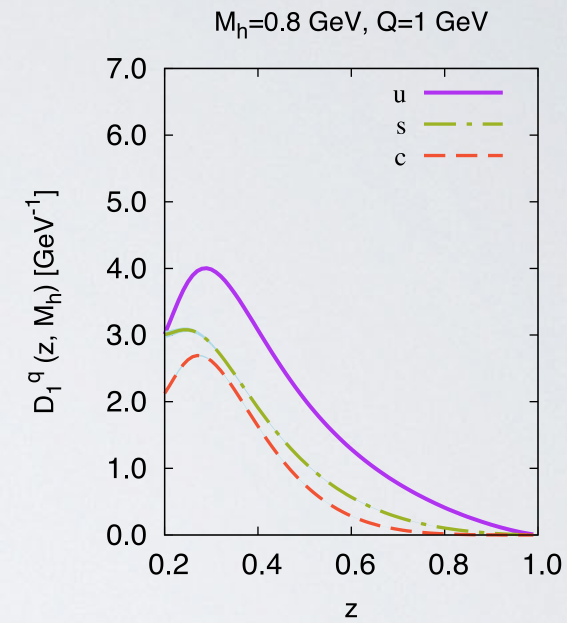
D_1^q (z=0.25, M_h)

Q_0^2 = 1 GeV^2



D_1^q (z, M_h=0.8)

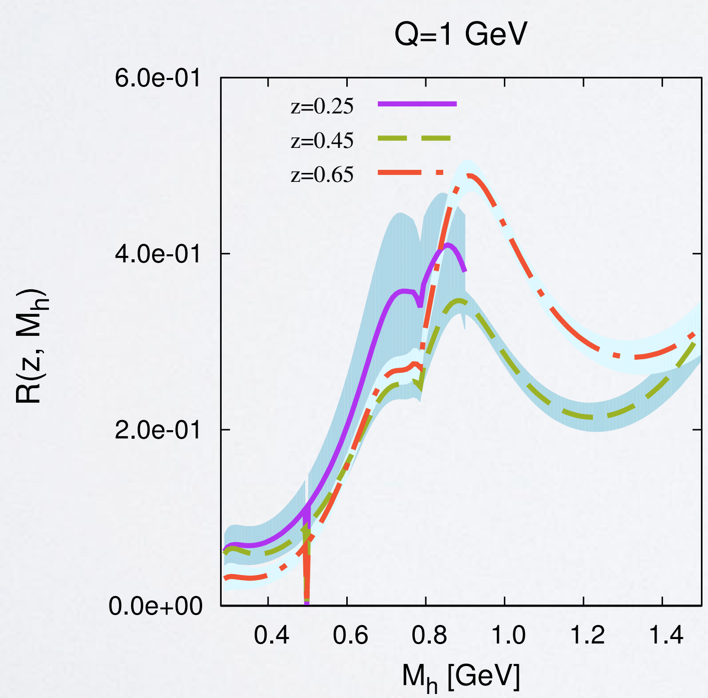
Q_0^2 = 1 GeV^2



$$\frac{|\mathbf{R}|}{M_h} \frac{H_1^{\sphericalangle\, u}}{D_1^u}$$

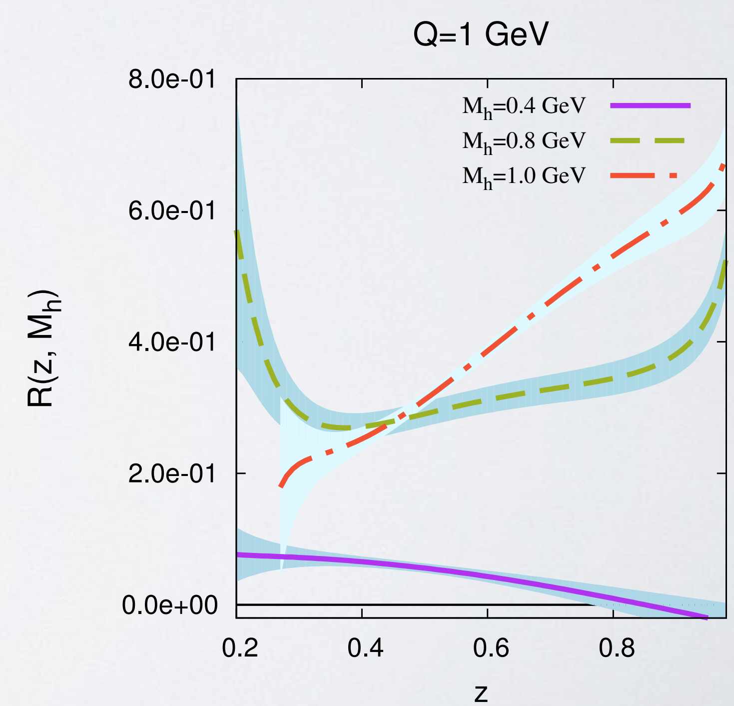
z=0.25
z=0.45, M_h
z=0.65

Q_0^2 = 1 GeV^2



M_h=0.4
M_h=0.8, z
M_h=1.

Q_0^2 = 1 GeV^2

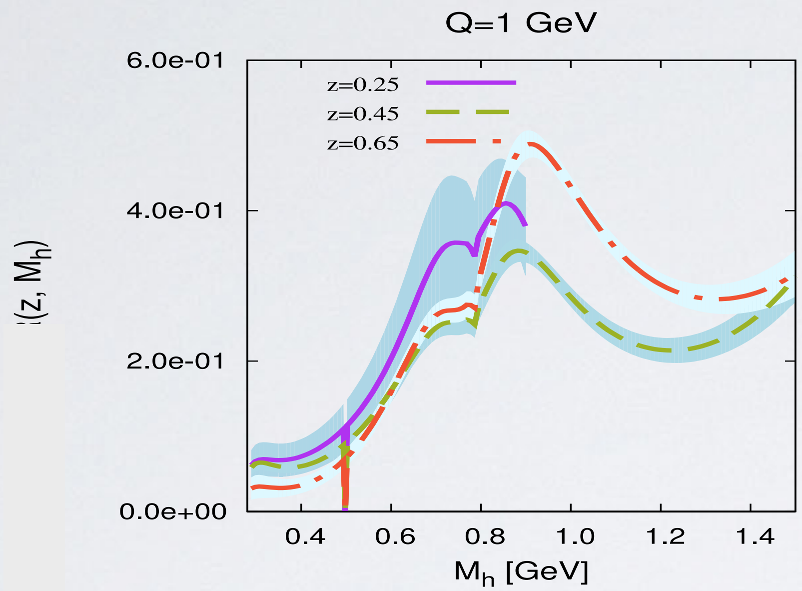


re-fit $H_1^{\sphericalangle q \to \pi^+\pi^-}$ using replica method

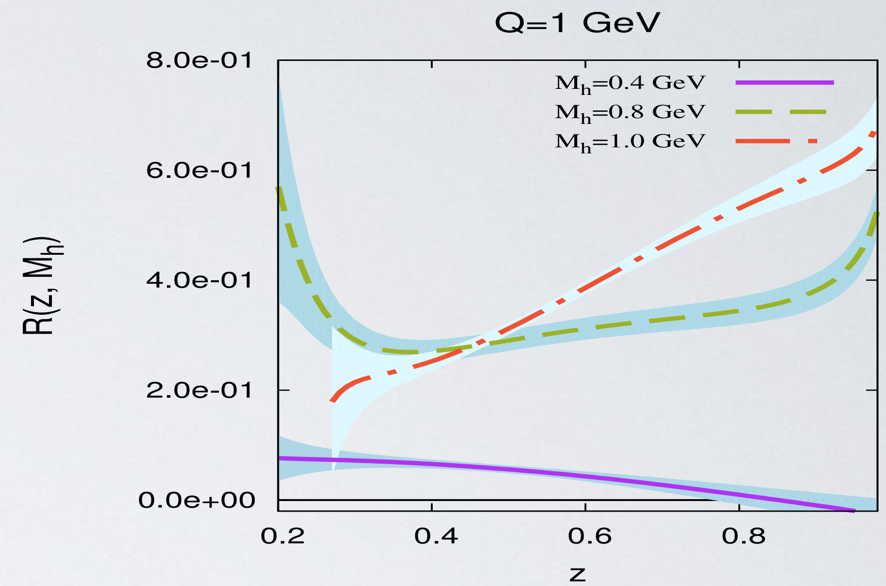
$u \to \pi^+\pi^-$

$$\frac{|\mathbf{R}|}{M_h} \frac{H_1^{\sphericalangle u}}{D_1^u}$$

M_h behaviour

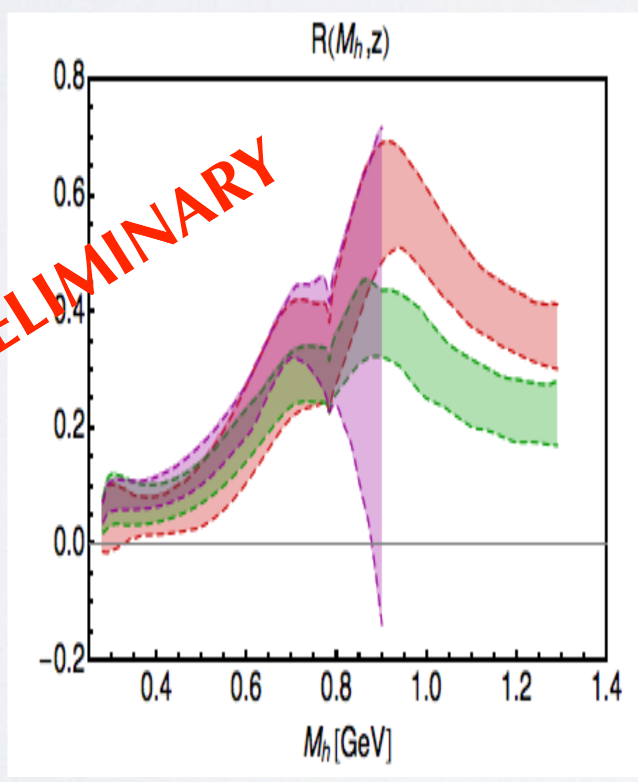


z behaviour



z=0.25
z=0.45, M_h
z=0.65

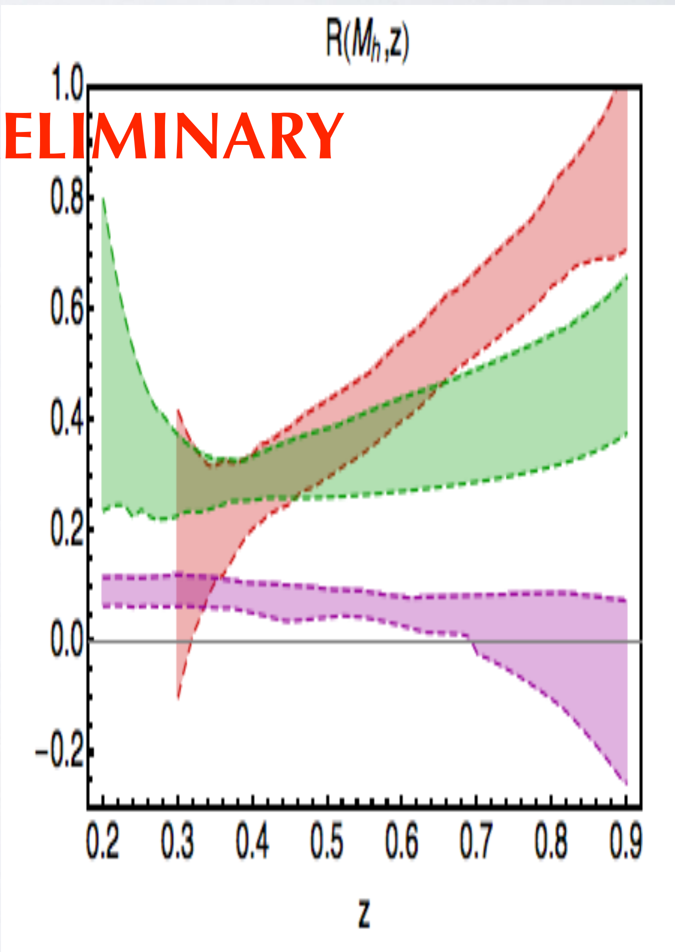
$Q_0^2 = 1$ GeV^2



M_h=0.4
M_h=0.8, z
M_h=1.

$Q_0^2 = 1$ GeV^2

PRELIMINARY



impact on transversity extraction

Ex: proton data

$$
\begin{aligned}
x h_1^p(x) &\equiv x h_1^{u_v}(x) - \frac{1}{4} x h_1^{d_v}(x) \\
&\propto -\frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2 \; H_1^{\sphericalangle\, u}} \left[\sum_{q=u,d,s} \frac{e_q^2}{e_u^2} \, x f_1^{q+\bar{q}}(x) \int dz dM_h^2 \; D_1^q \right]
\end{aligned}
$$

impact on transversity extraction

Ex: proton data $$xh_1^p(x) \equiv xh_1^{u_v}(x) - \frac{1}{4} xh_1^{d_v}(x)$$

$$\propto -\frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2\ H_1^{\sphericalangle\, u}} \left[\sum_{q=u,d,s} \frac{e_q^2}{e_u^2}\ xf_1^{q+\bar{q}}(x) \int dz dM_h^2\ D_1^q \right]$$

more precise data points

more realistic error on $H_1^{\sphericalangle}$

impact on transversity extraction

Ex: proton data

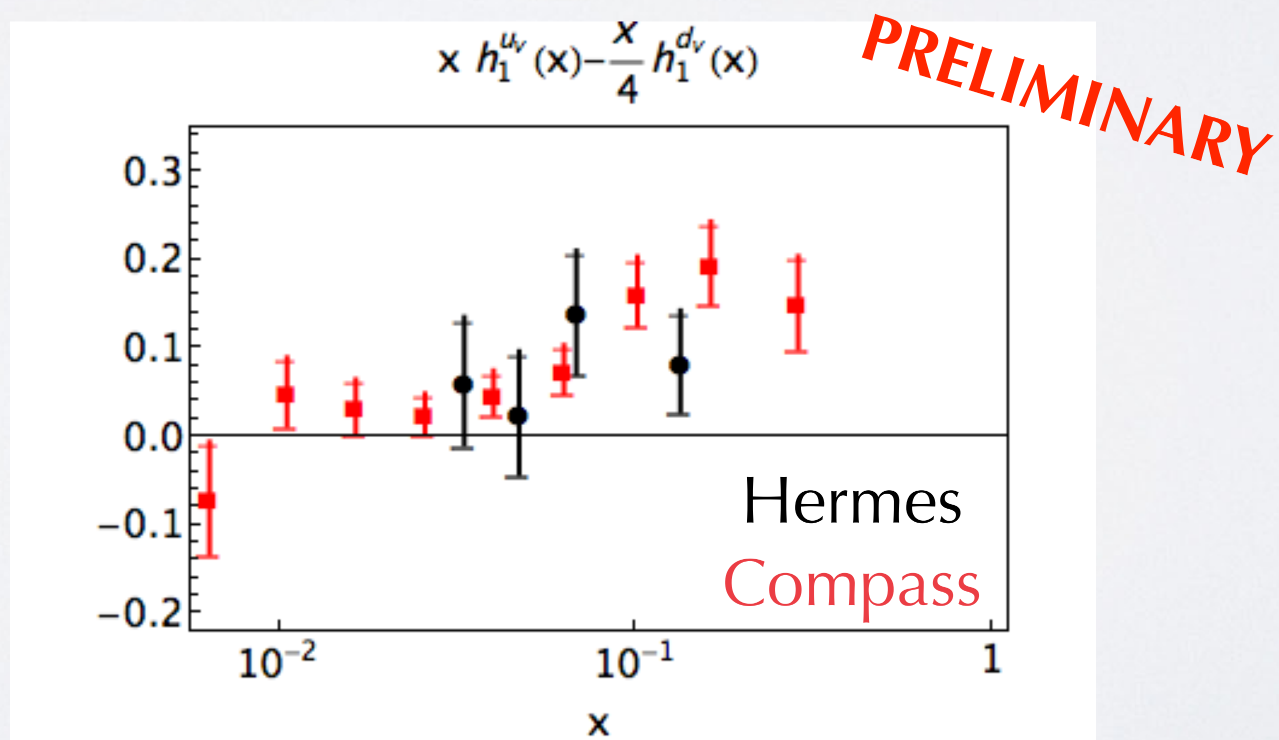
$$xh_1^p(x) \equiv xh_1^{u_v}(x) - \frac{1}{4} xh_1^{d_v}(x)$$

$$\propto -\frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2 \; H_1^{\sphericalangle\, u}} \left[\sum_{q=u,d,s} \frac{e_q^2}{e_u^2} \, x f_1^{q+\bar{q}}(x) \int dz dM_h^2 \; D_1^q \right]$$

more precise data points

more realistic error on $H_1^{\sphericalangle}$

extraction
point by point



impact on transversity extraction

Ex: proton data

$$xh_1^p(x) \equiv xh_1^{u_v}(x) - \frac{1}{4} xh_1^{d_v}(x)$$

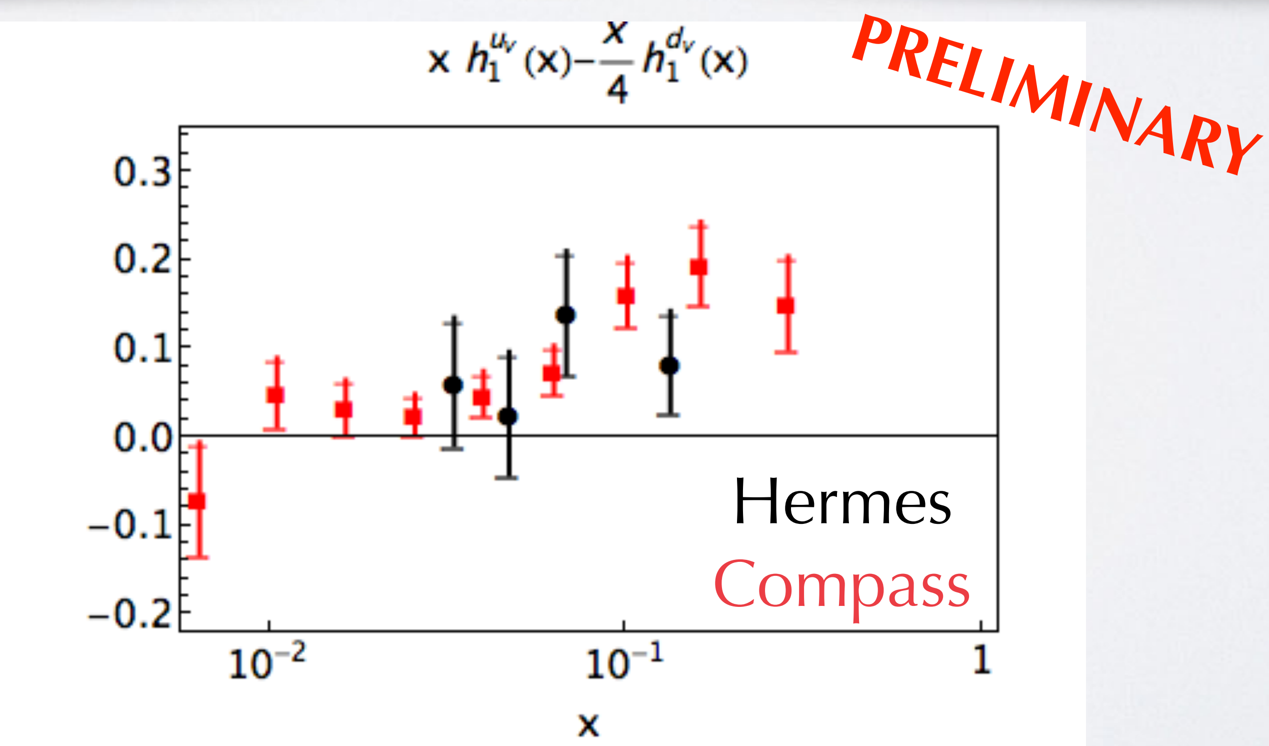
more precise data points

$$\propto -\frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2 \; H_1^{\sphericalangle\, u}} \left[\sum_{q=u,d,s} \frac{e_q^2}{e_u^2} \, x f_1^{q+\bar{q}}(x) \int dz dM_h^2 \; D_1^q \right]$$

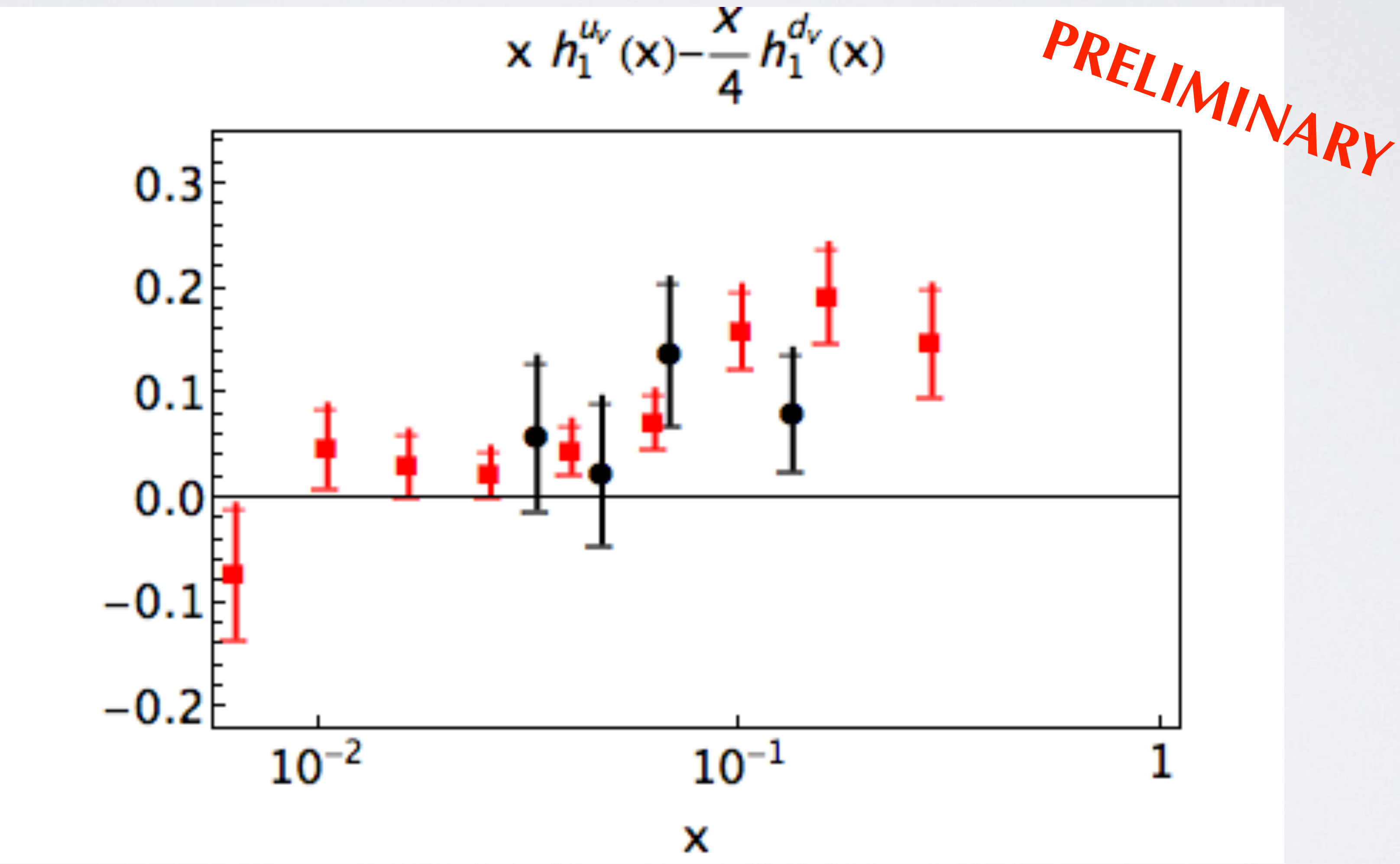
more realistic error on $H_1^{\sphericalangle}$

replica method: alter data with Gaussian noise and randomly pick up corresponding $H_1^{\sphericalangle}$

extraction point by point

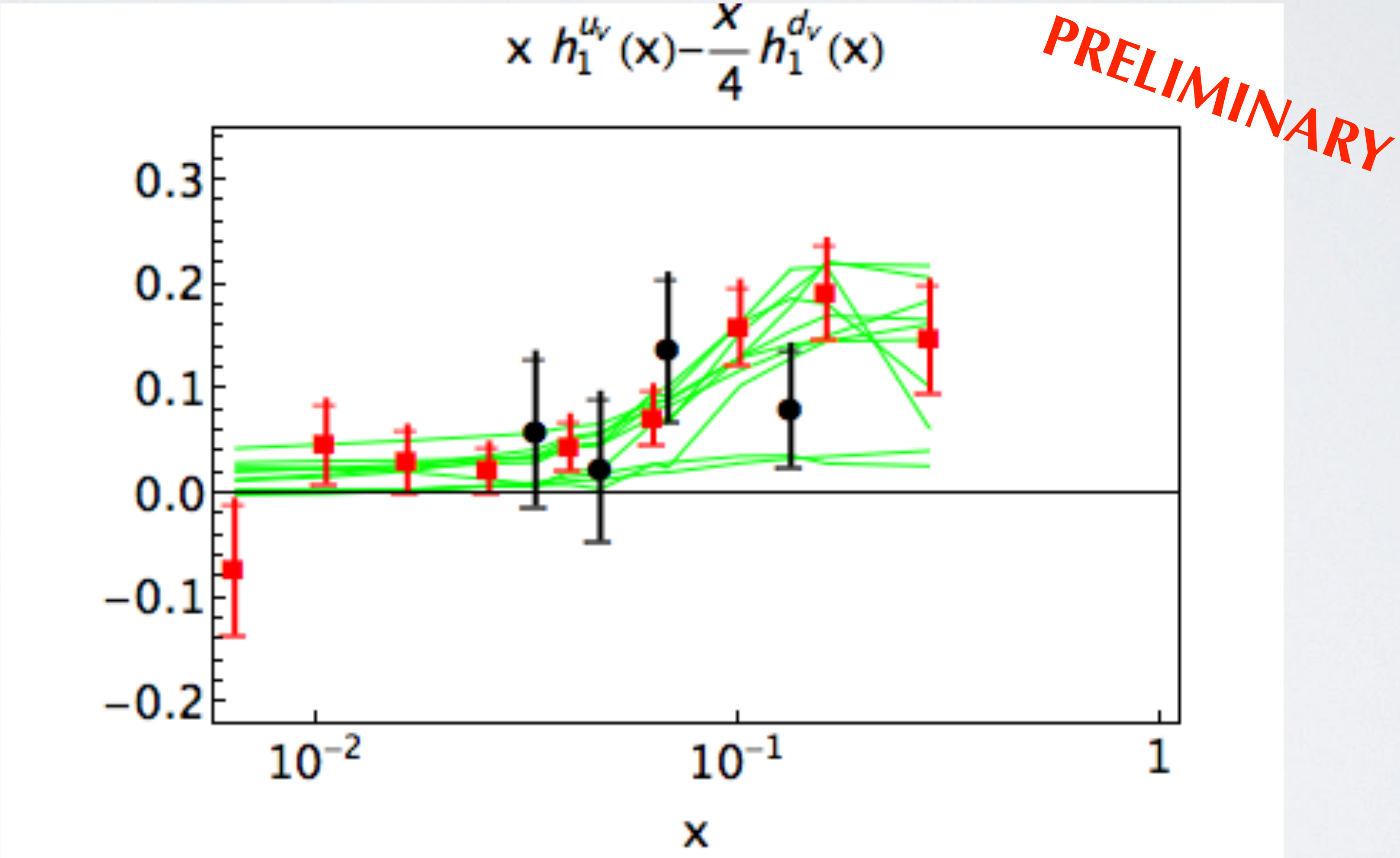


results of new fit



results of new fit

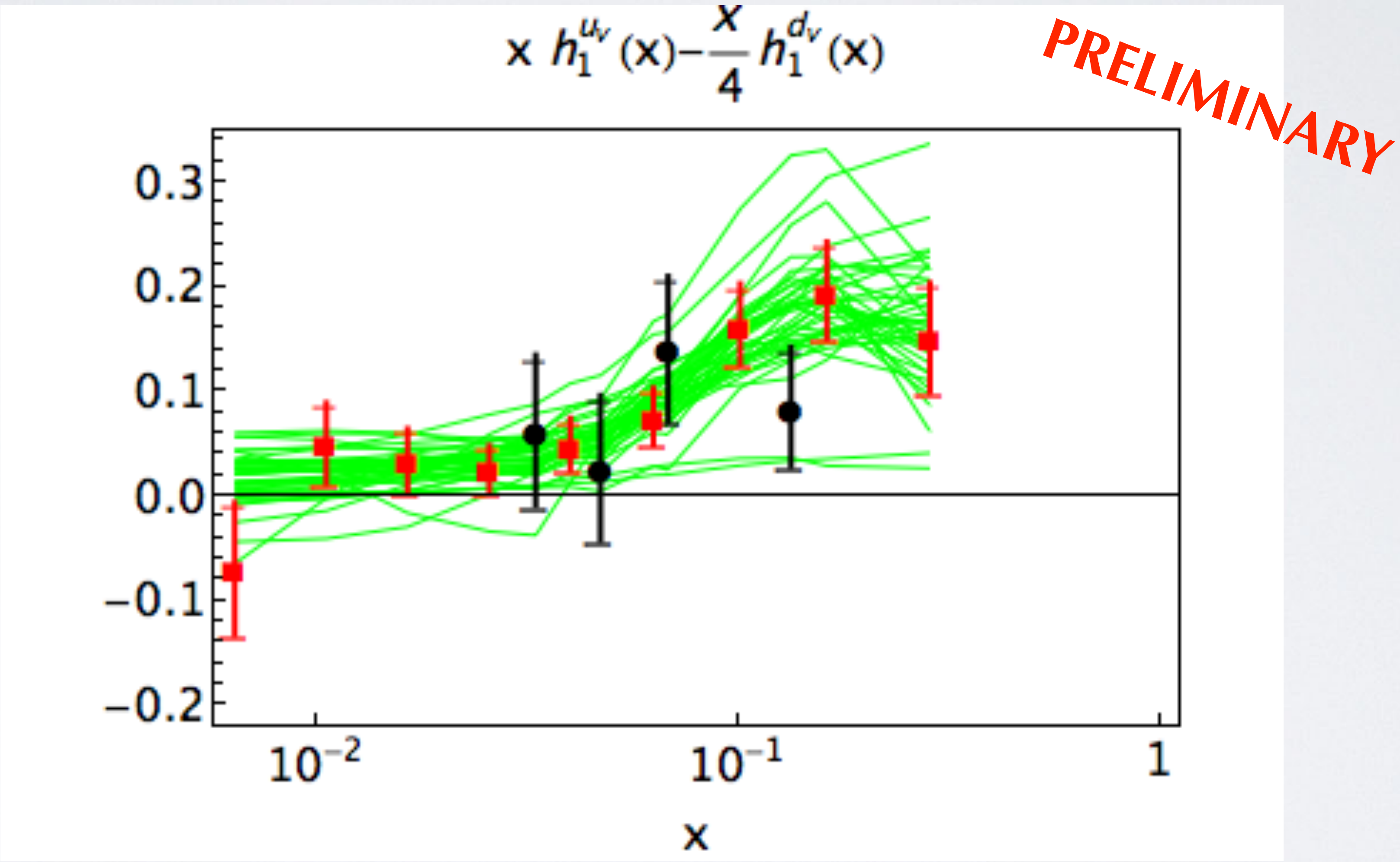
with **10** replica



flexible

results of new fit

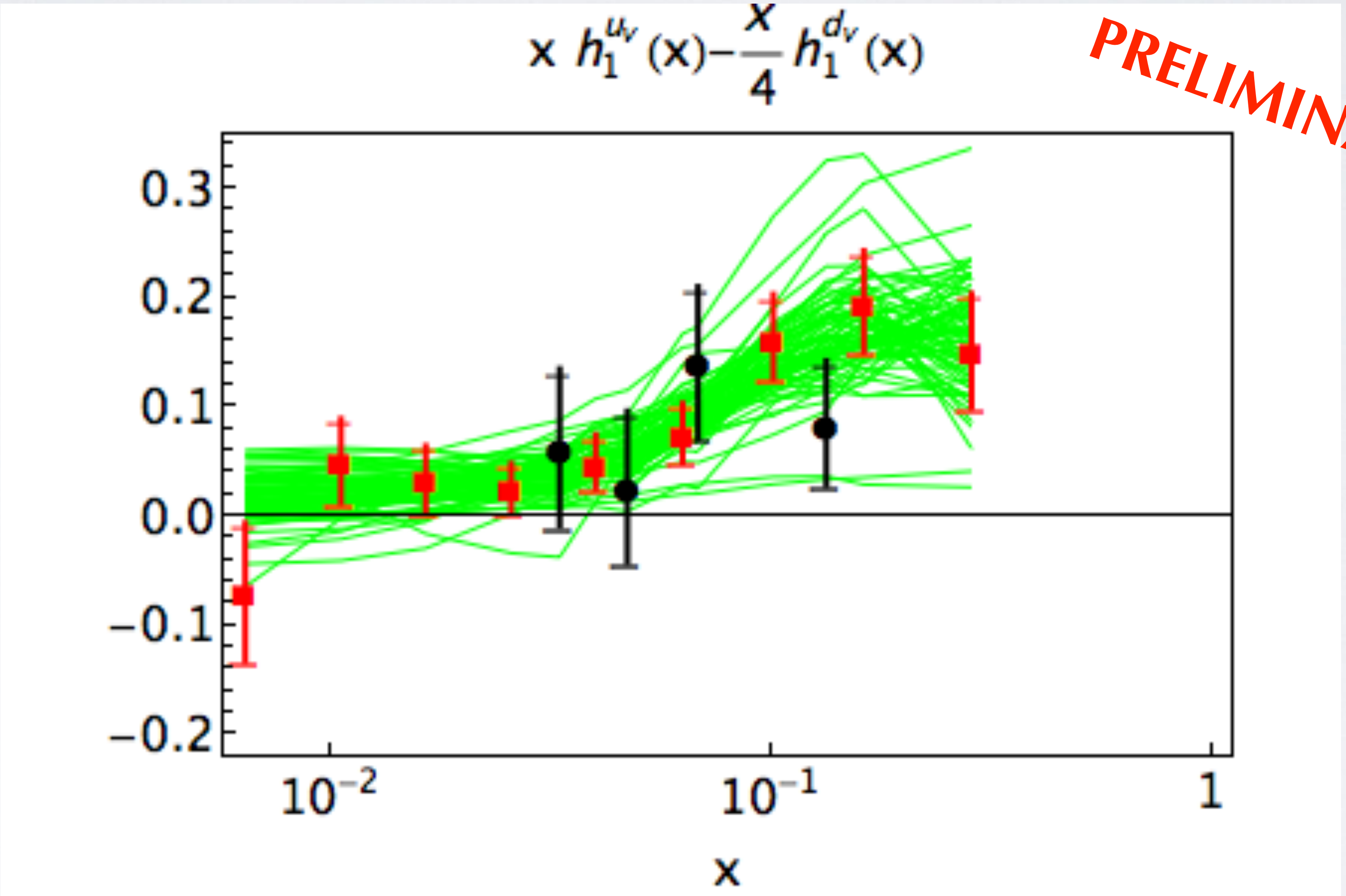
with **40** replica



flexible

results of new fit

with **70** replica

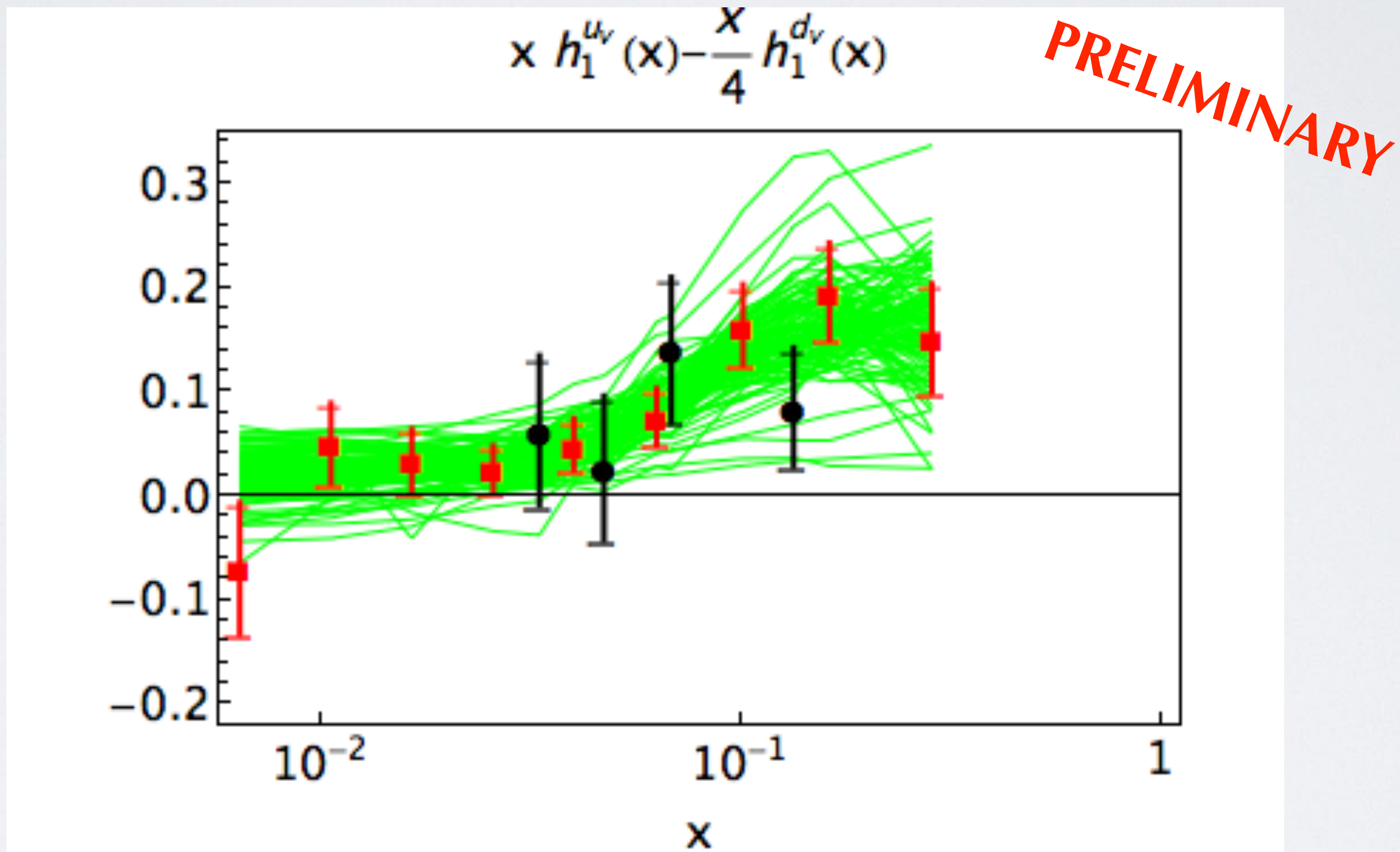


PRELIMINARY

flexible

results of new fit

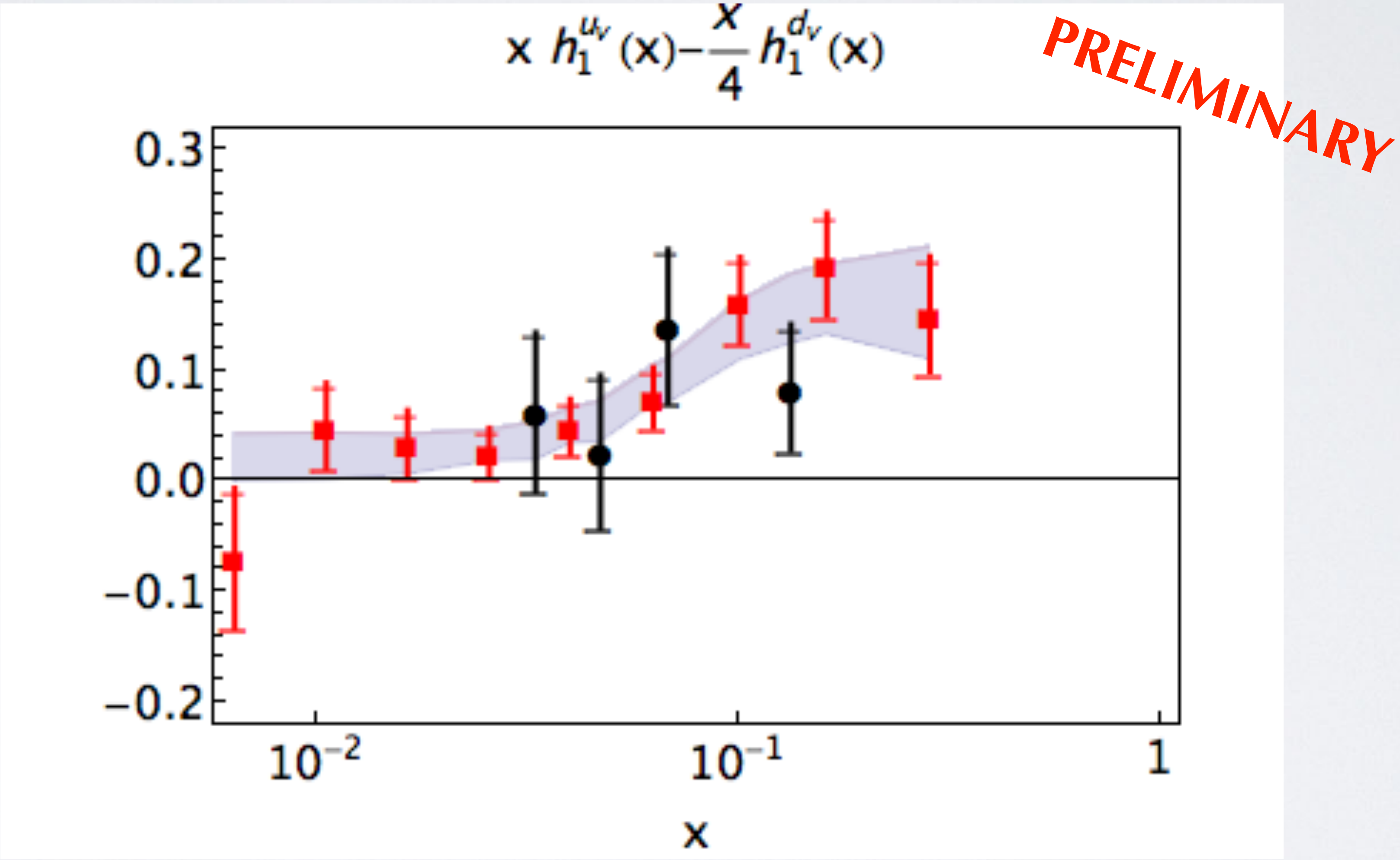
with **100** replica



flexible

results of new fit

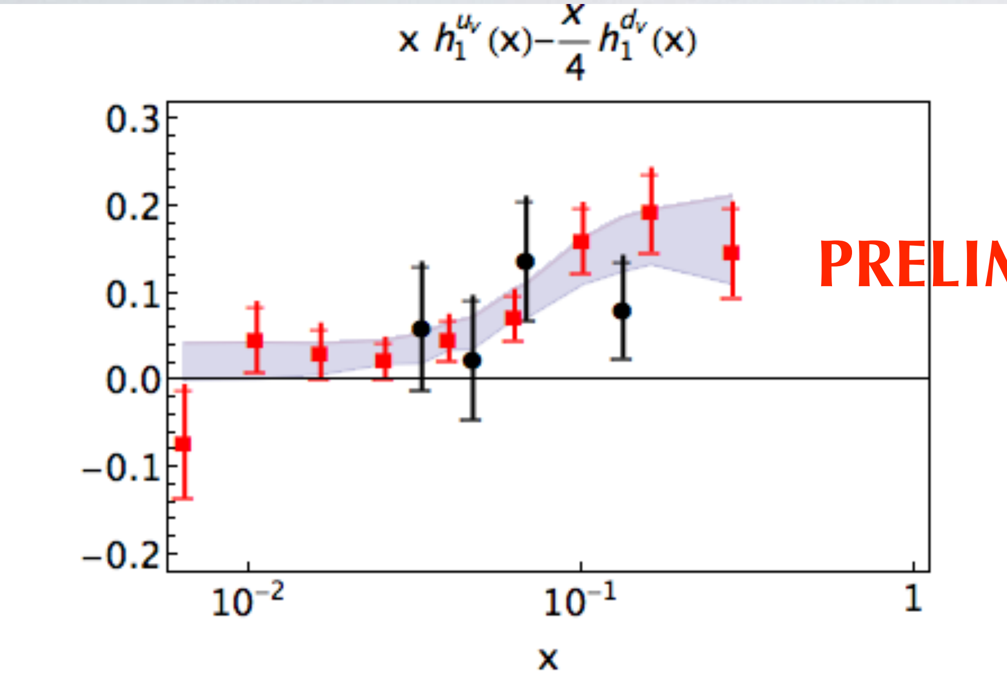
taking the **68%** band



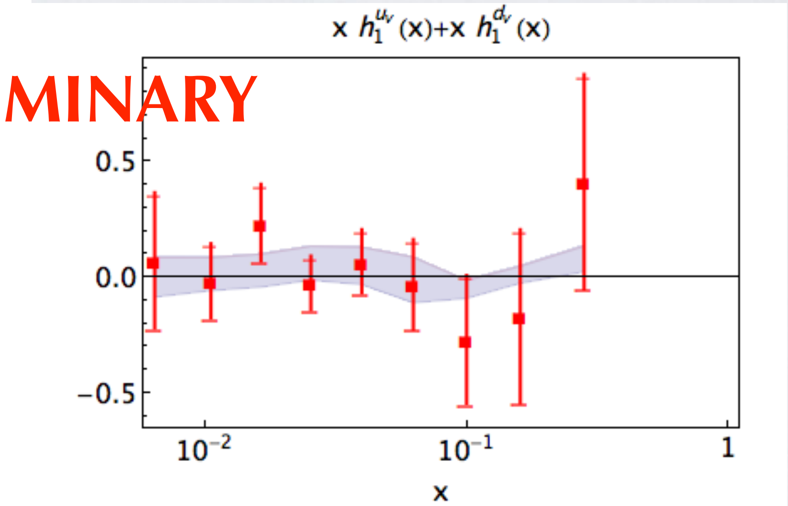
flexible

comparison new with previous fit

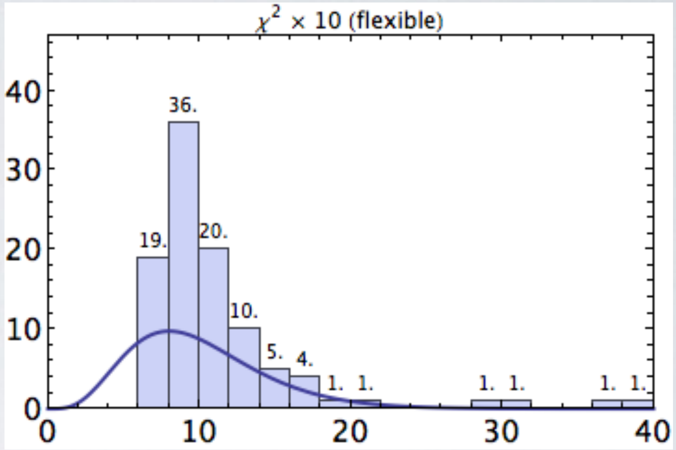
new



PRELIMINARY



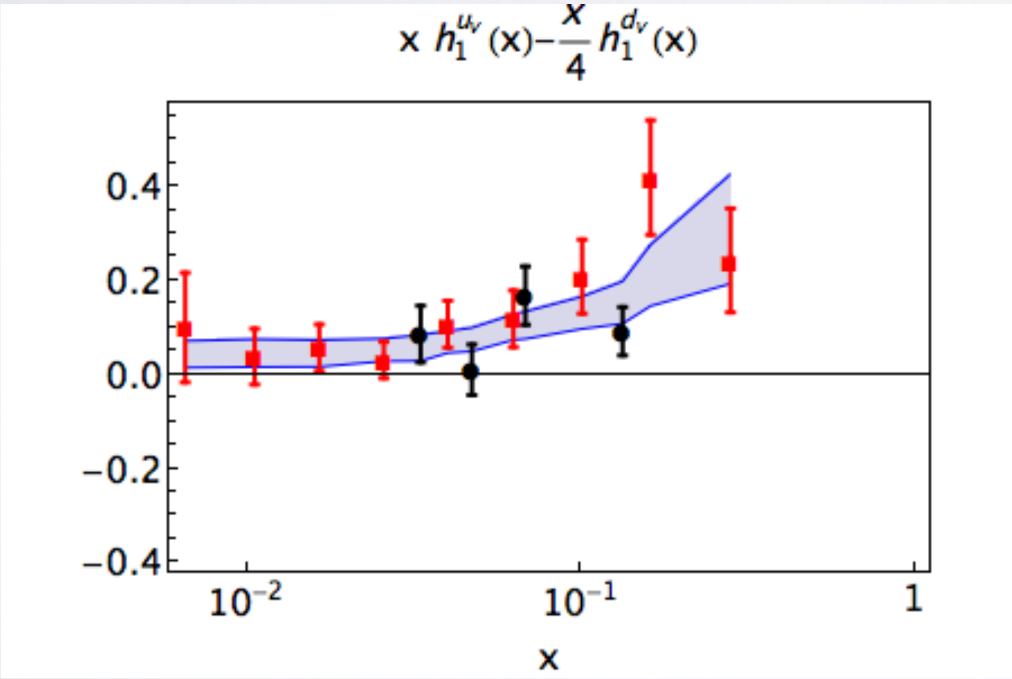
χ^2/dof × 10

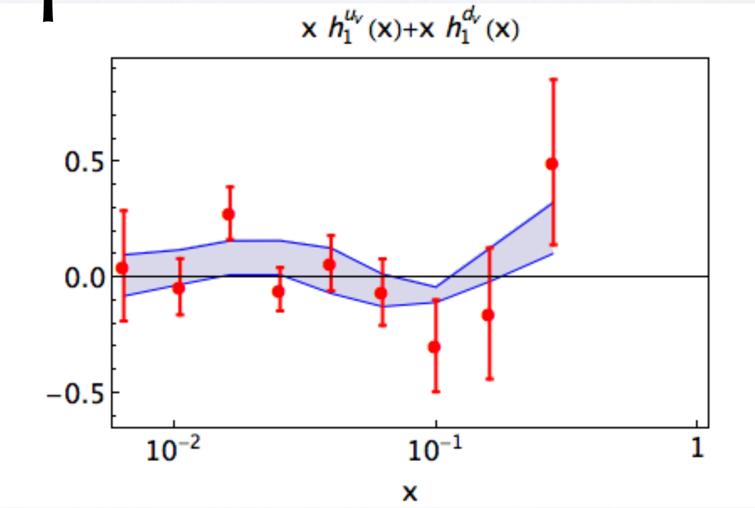


$$x h_1^{u_v} - \frac{1}{4} x h_1^{d_v} \propto -\frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz dM_h^2 \; H_1^{\sphericalangle\, u}} \cdots$$

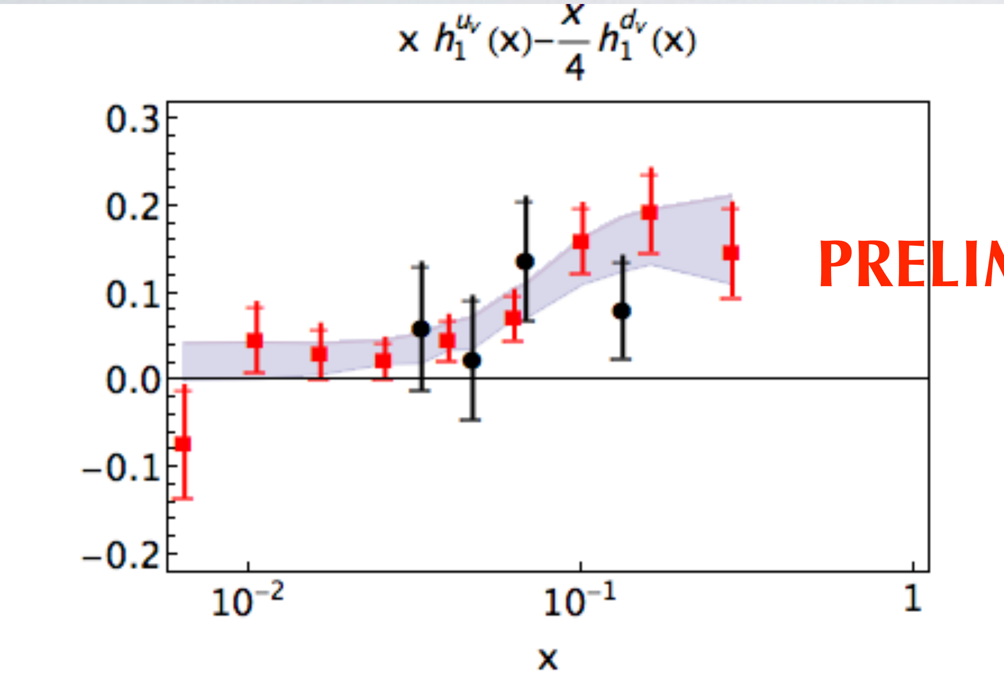
flexible

previous



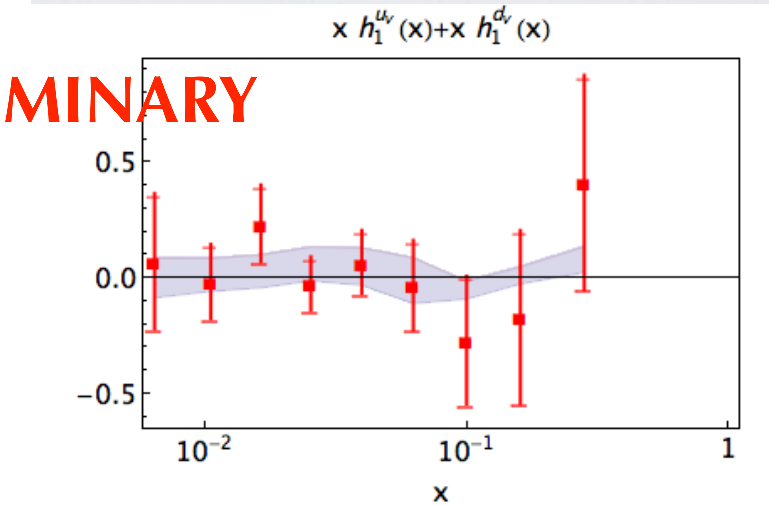


comparison new with previous fit

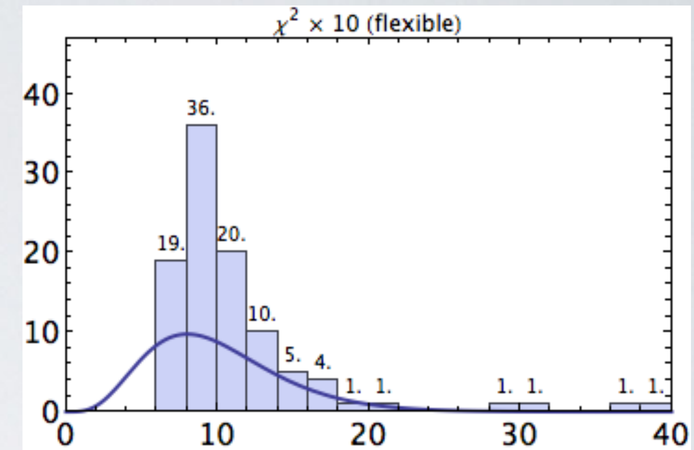


new

PRELIMINARY



χ^2/dof $\times$ 10



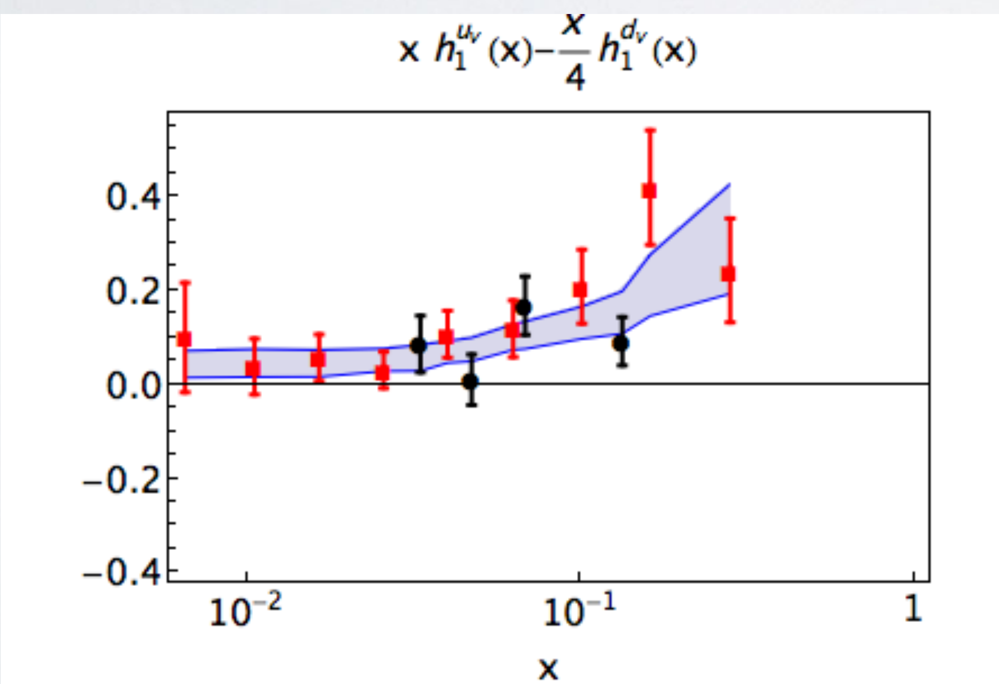
$$x h_1^{u_v} - \frac{1}{4} x h_1^{d_v} \propto - \frac{A_{UT}^{\sin(\phi_R+\phi_S)}}{\int dz\, dM_h^2\; H_1^{\sphericalangle u}} \cdots$$

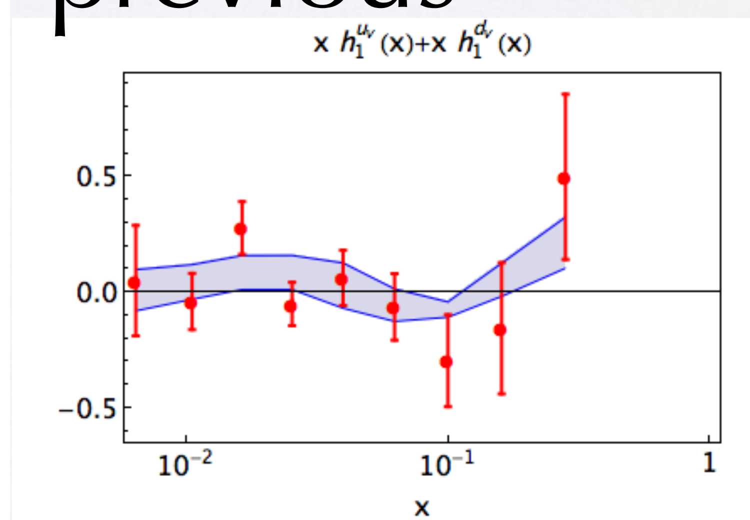
more precise data points

more realistic error on $H_1^{\sphericalangle}$

flexible

previous





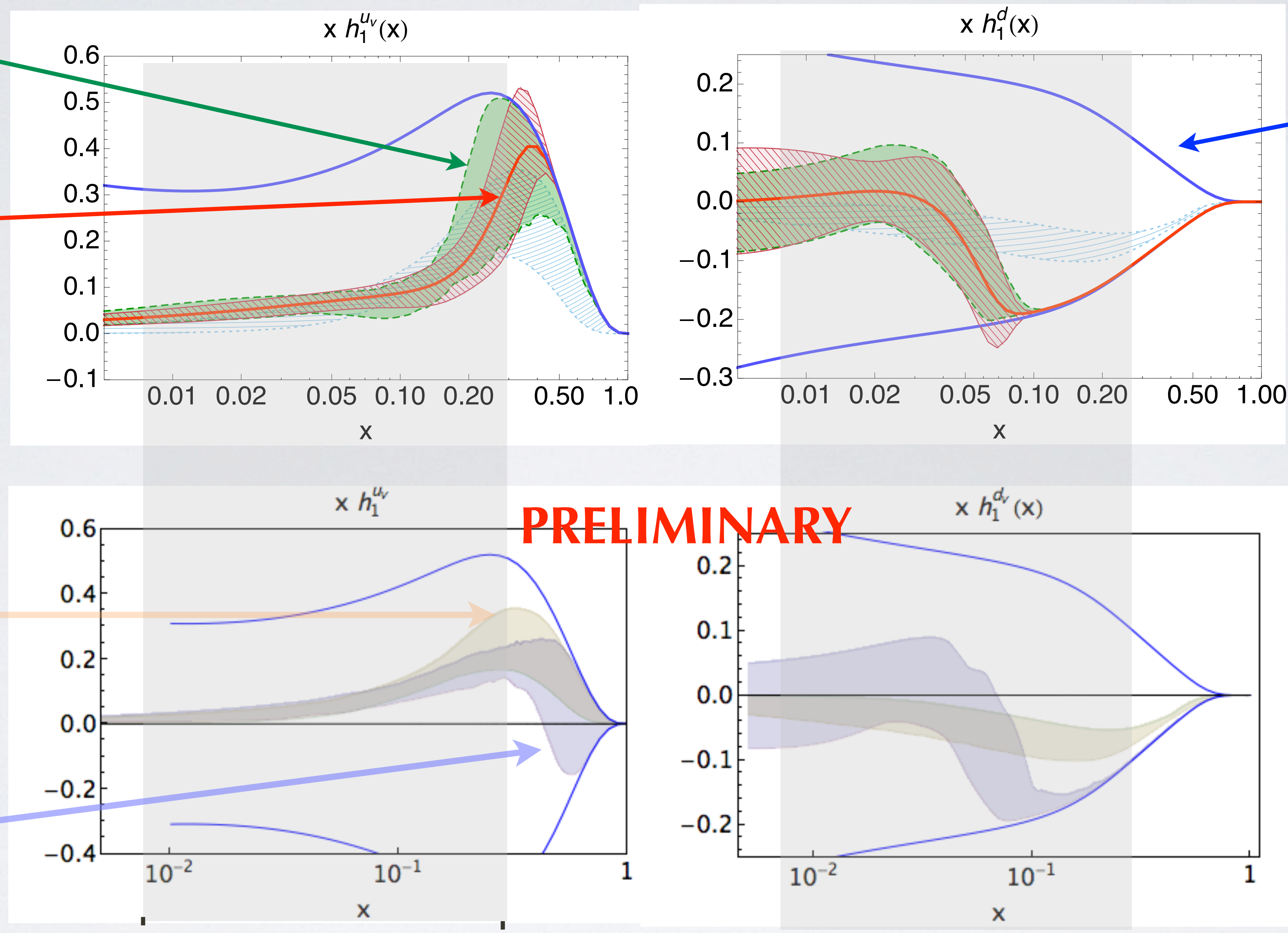
$Q^2 = 2.4$ GeV^2 $\quad u - \bar{u} \quad x\, h_1^{q-\bar{q}}(x) \quad d - \bar{d}$

Bacchetta, Courtoy, Radici, JHEP ***1303*** *(13) 119*

68% band of replicas

central value for standard fit with 1σ band

Soffer bound



Torino param.

new 68% band of replicas

data

flexible

$Q^2 = 2.4\ GeV^2$ $u - \bar{u}$ $x\ h_1^{q-\bar{q}}(x)$ $d - \bar{d}$

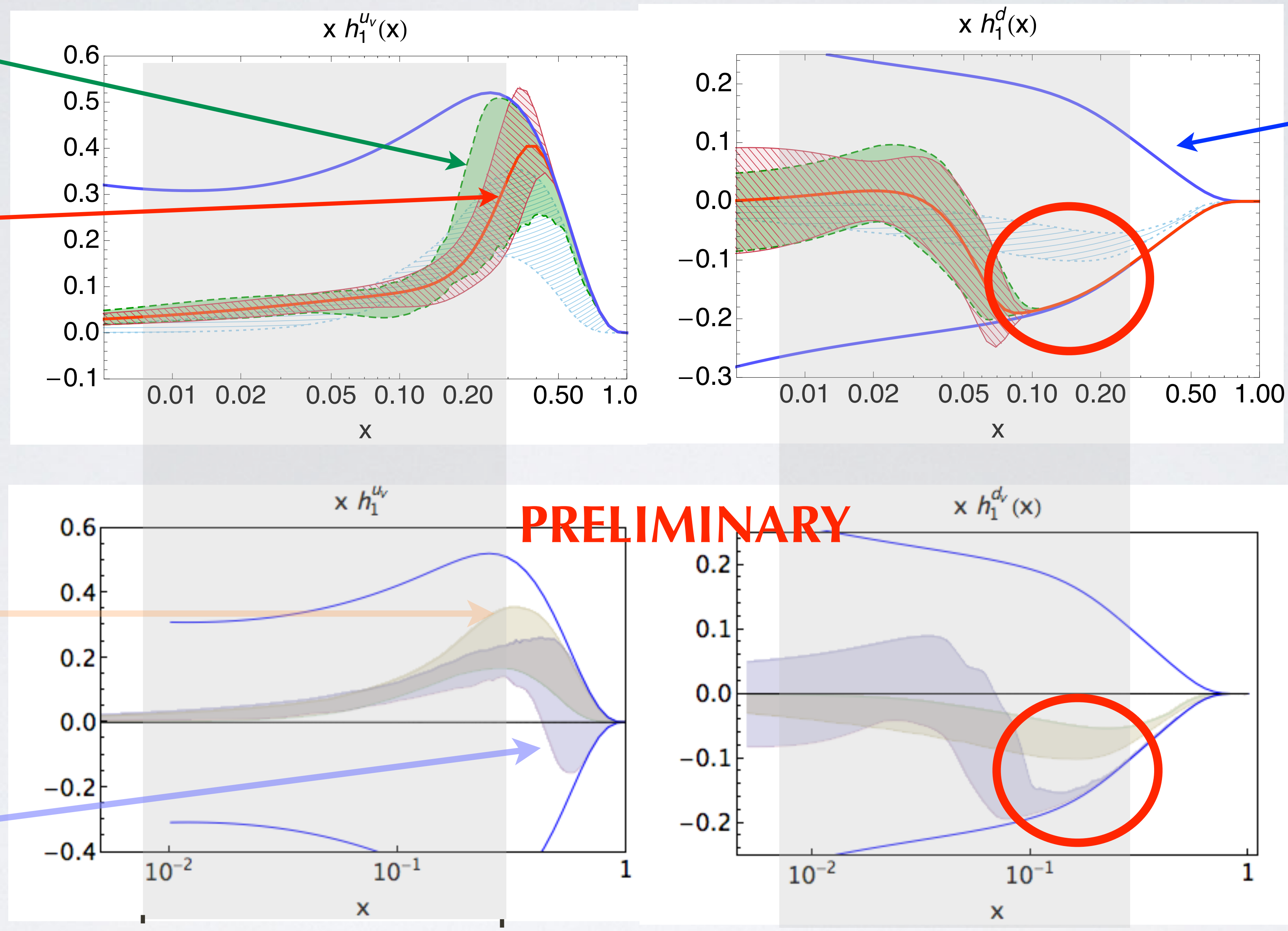
Bacchetta, Courtoy, Radici, JHEP ***1303*** *(13) 119*

68% band of replicas

central value for standard fit with 1σ band

Torino param.

new 68% band of replicas



Soffer bound

data

flexible

tension driven by COMPASS deuteron data

$Q^2 = 2.4\ \mathrm{GeV}^2$

$u-\bar{u}$ x $h_1^{q-\bar{q}}(x)$ $d-\bar{d}$

*Bacchetta, Courtoy, Radici, JHEP **1303** (13) 119*

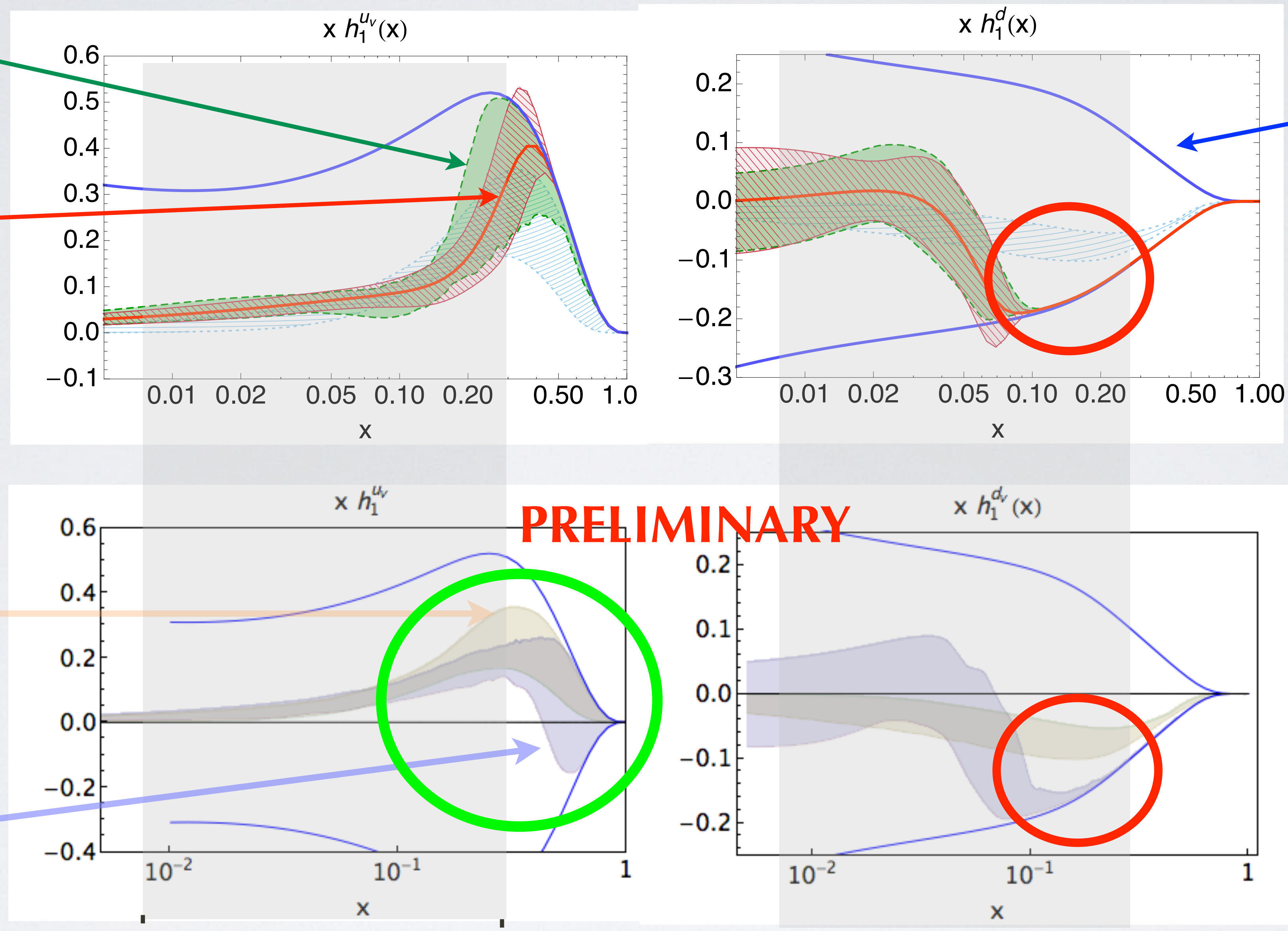
68% band of replicas

central value for standard fit with 1σ band

Torino param.

new 68% band of replicas

Soffer bound



data

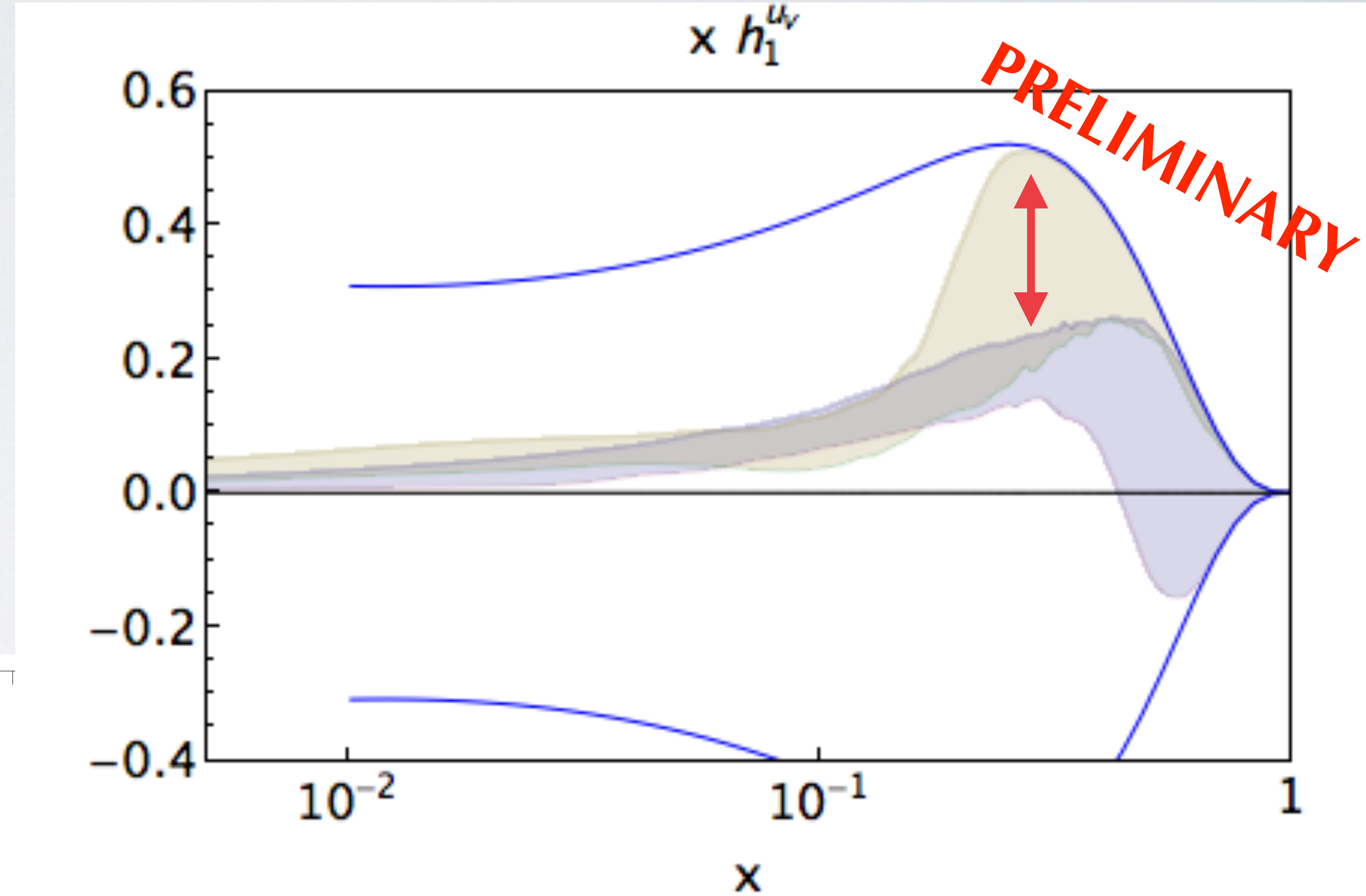
flexible

tension driven by COMPASS deuteron data

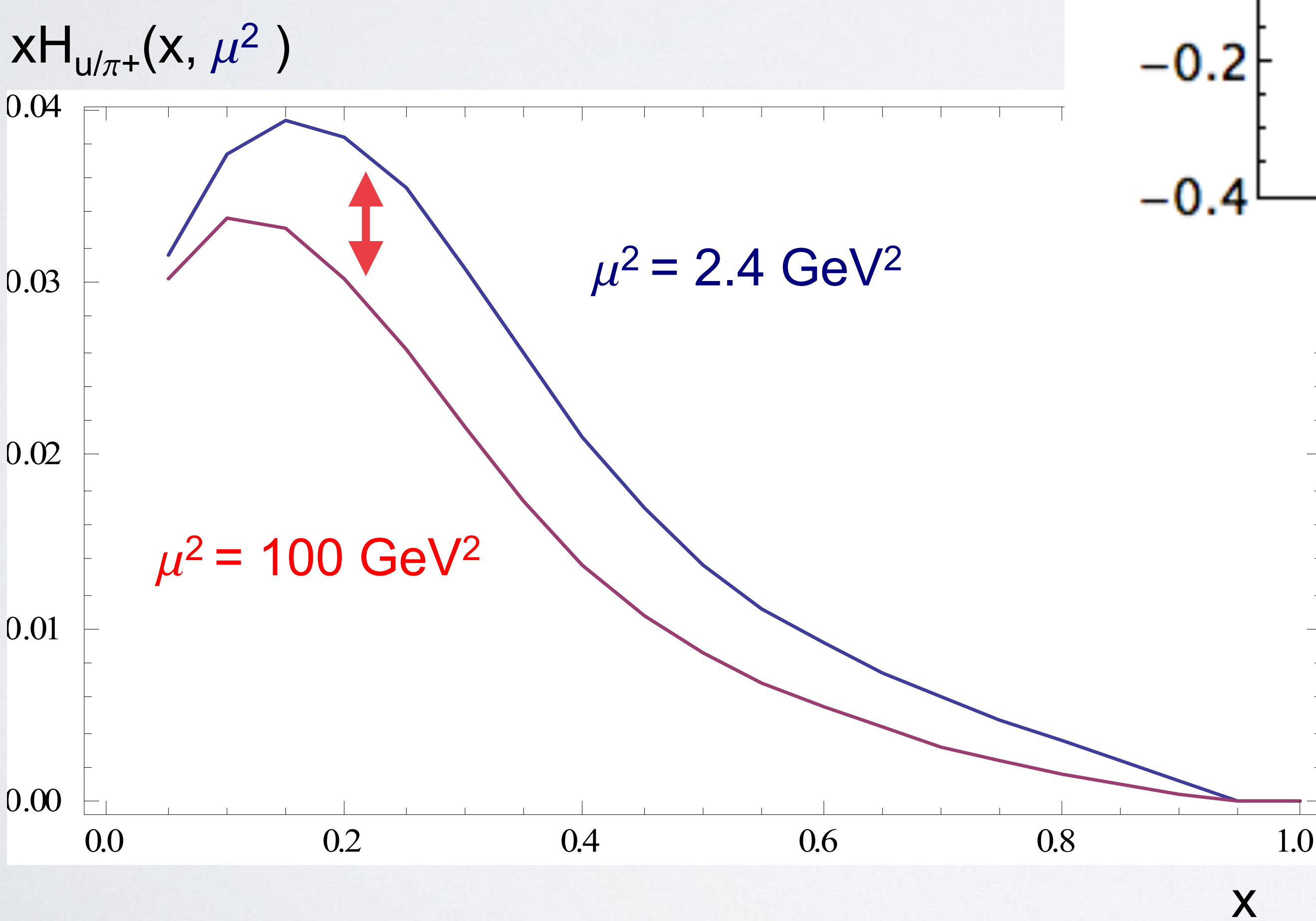
new 68% band for h_1 up is narrower (where there are data) and "smaller"

smaller transversity ??

smaller transversity



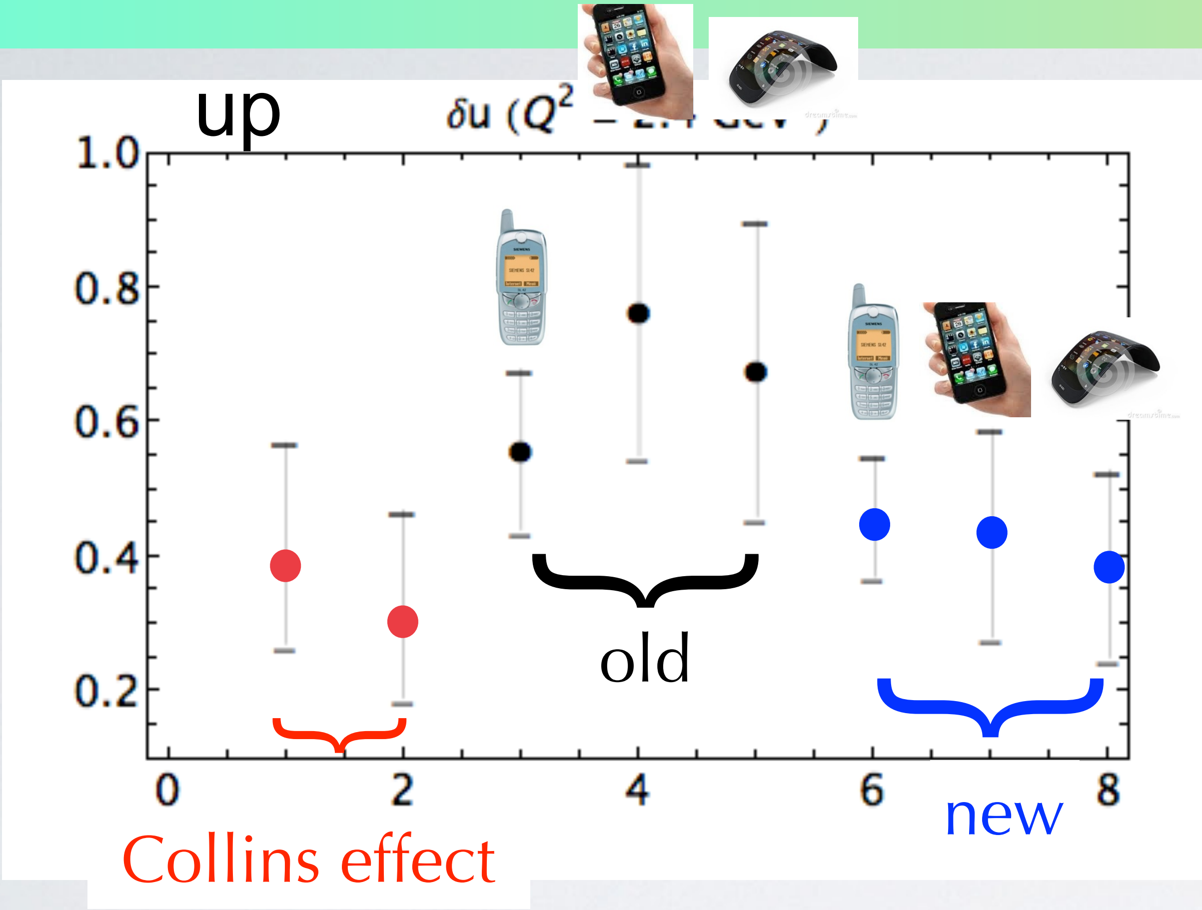
larger Collins



is it a consistent picture ??

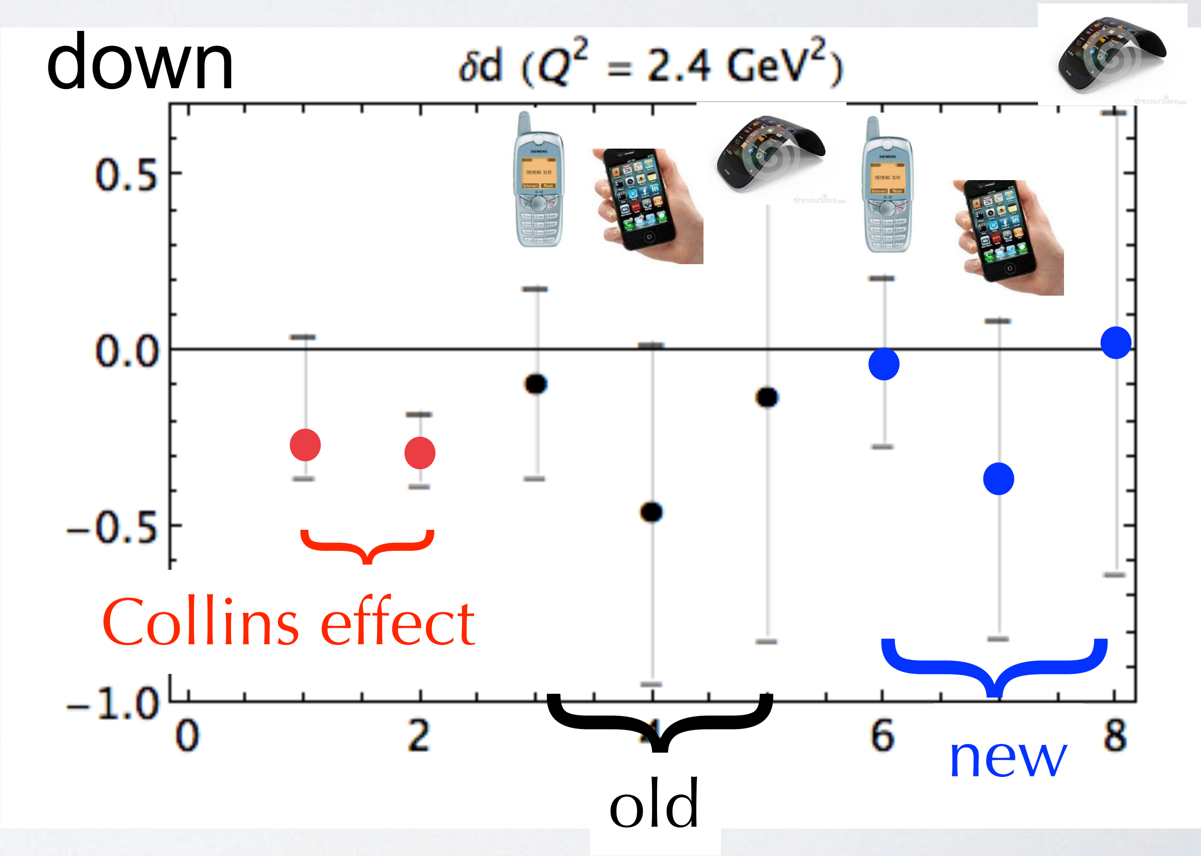
Peng Sun, QCD Evolution 2014

tensor charges

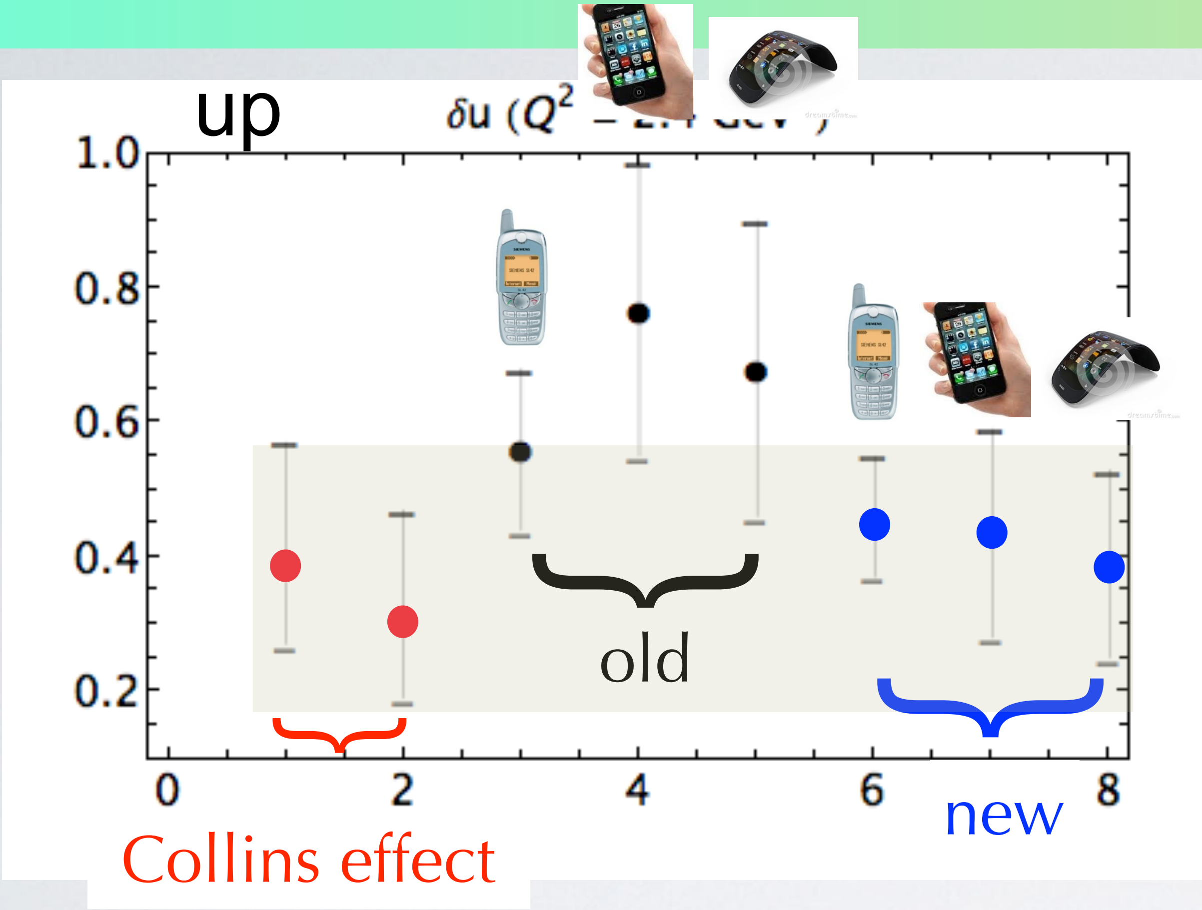


$$\delta q = \int_{\sim 0}^{1} dx\ h_1^{q_v}(x)$$

$Q_0^2 = 1\ \text{GeV}^2$

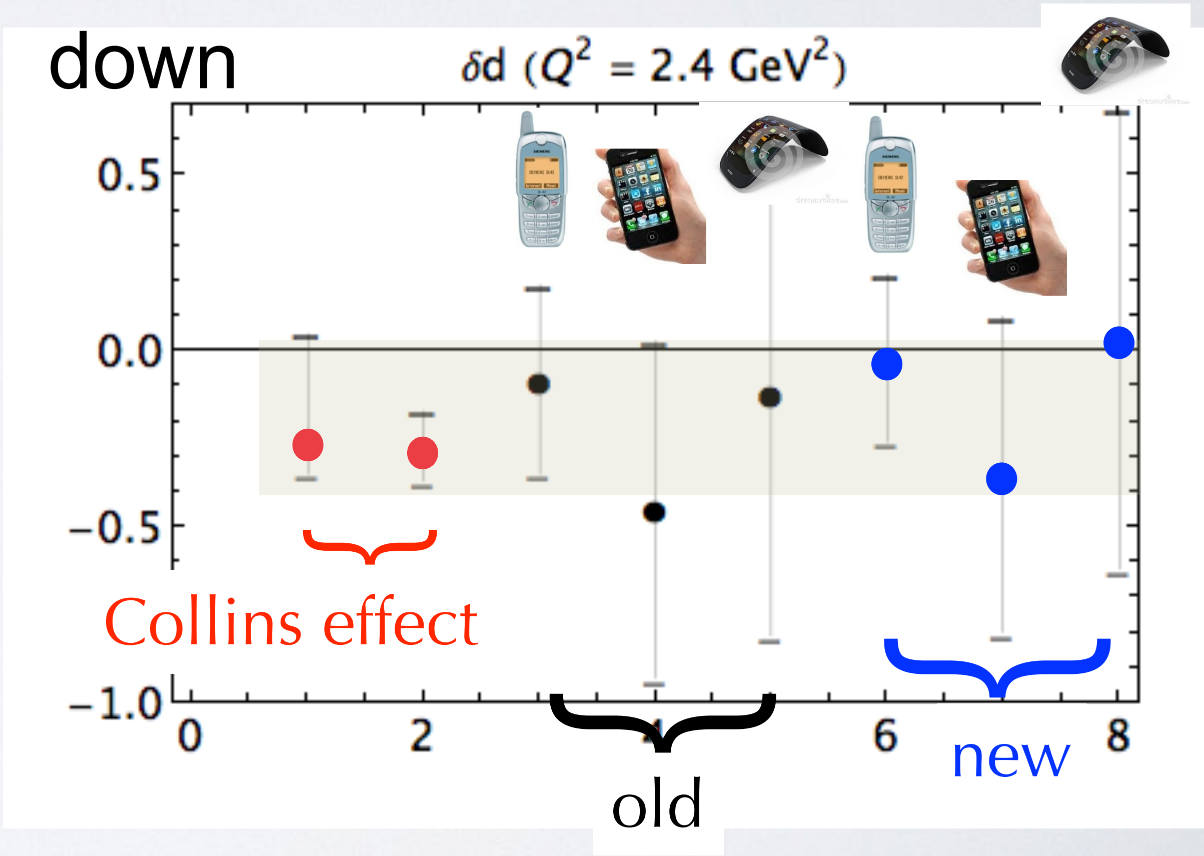


tensor charges

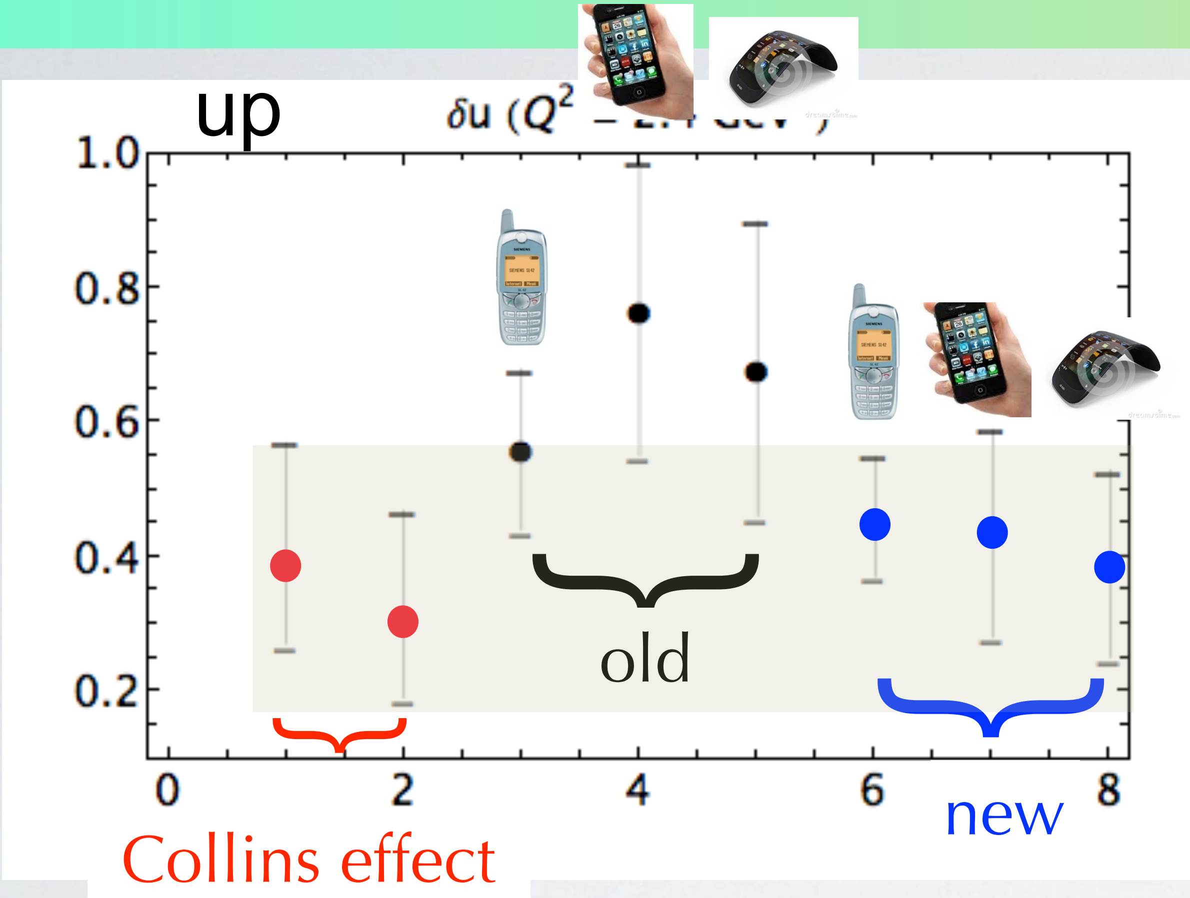


$$\delta q = \int_{\sim 0}^{1} dx \; h_1^{q_v}(x)$$

$Q_0^2 = 1 \text{ GeV}^2$



tensor charges



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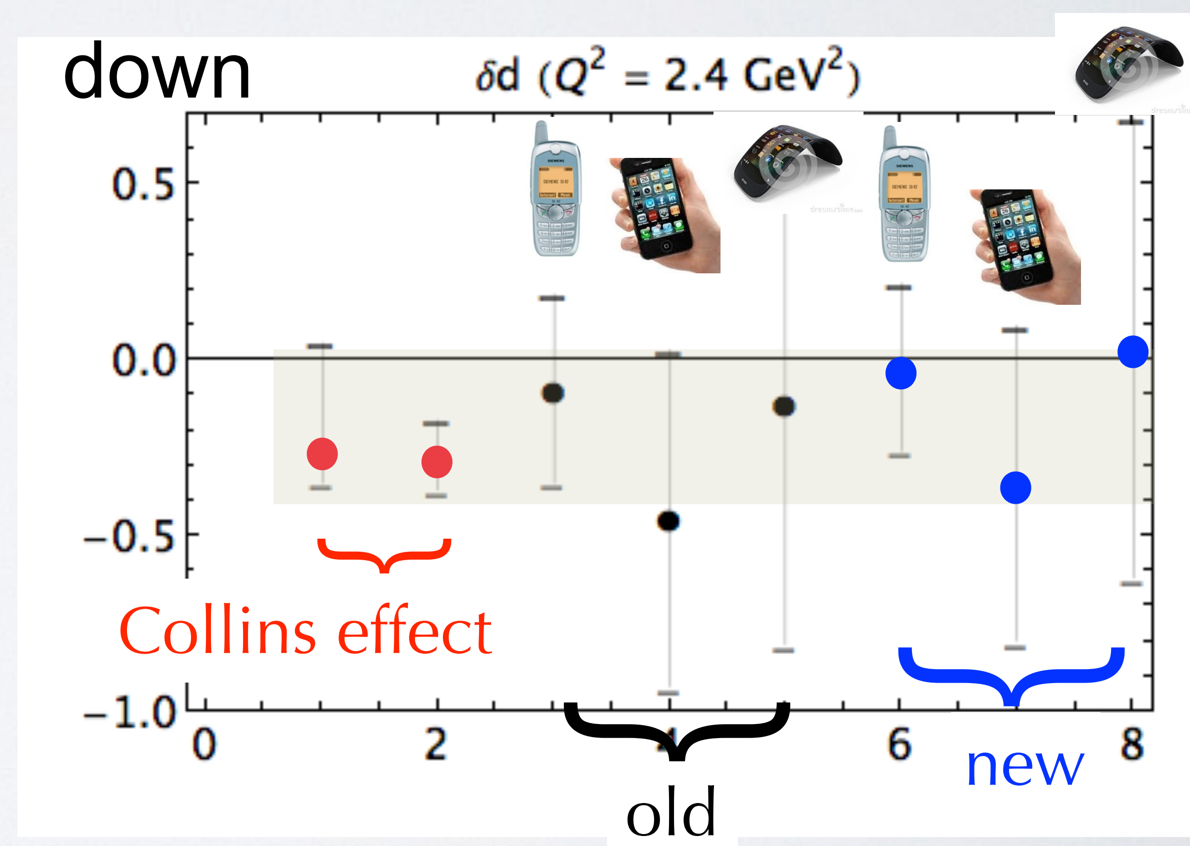
extrapolation → large uncertainty!
better ∫ where we have data



Conclusions and outlook

- di-hadron semi-inclusive production allows to consider single-spin asymmetries in collinear factorization framework
  ⇒ easier manipulation / known DGLAP evolution

- better quality of data → improving fit
  at present, new COMPASS proton data induce narrower uncertainty band for h_1^u

- new fit based also on more realistic errors on extraction of DiFF
  ⇒ **current most realistic estimate of errors on h_1**

- h_1^d unchanged, **h_1^u seems smaller**
  compatible with larger $H_1^\perp$ from TMD evolution ?

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- need D_1 from data, not from PYTHIA..

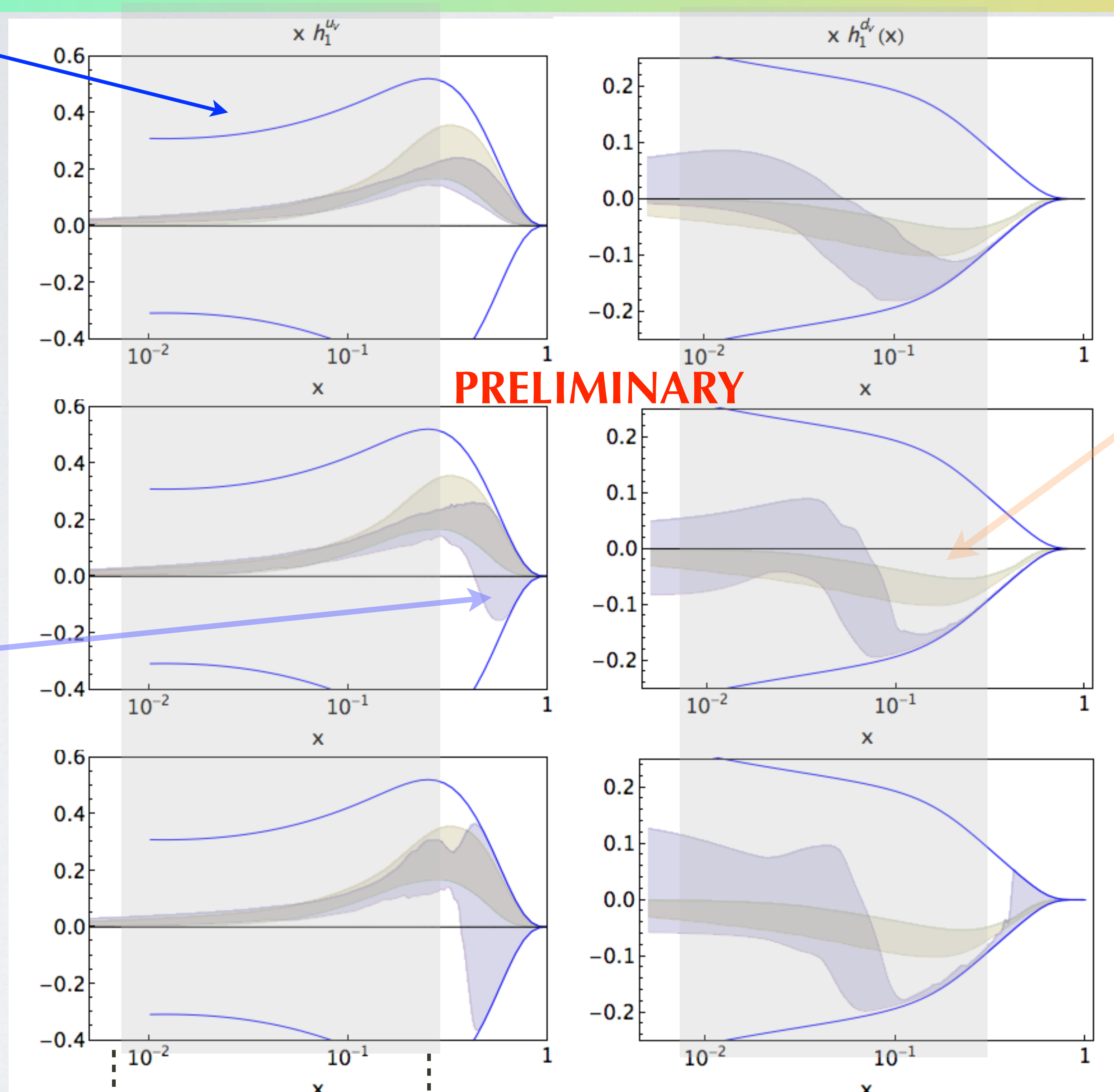
- beyond fitting functional form: Neural Network analysis ?


Bye!
thank you
© A. Prokudin

Backup

$Q^2 = 2.4$ GeV^2 $u - \overline{u}$ $x\, h_1(x)$ $d - \overline{d}$

Soffer bound



68% band of replicas

Torino param. 2009

data

rigid

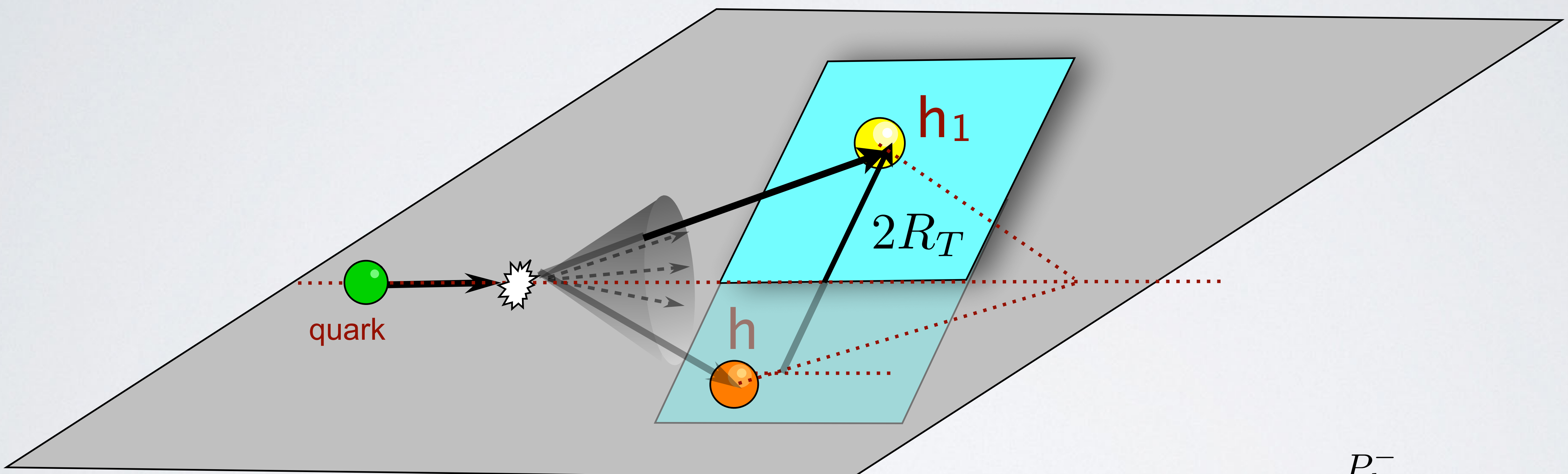
flexible

extra flexible

collinear pairs

$\int d\mathbf{P}_{hT}$

the total momentum of the pair
is collinear with
the fragmenting quark momentum

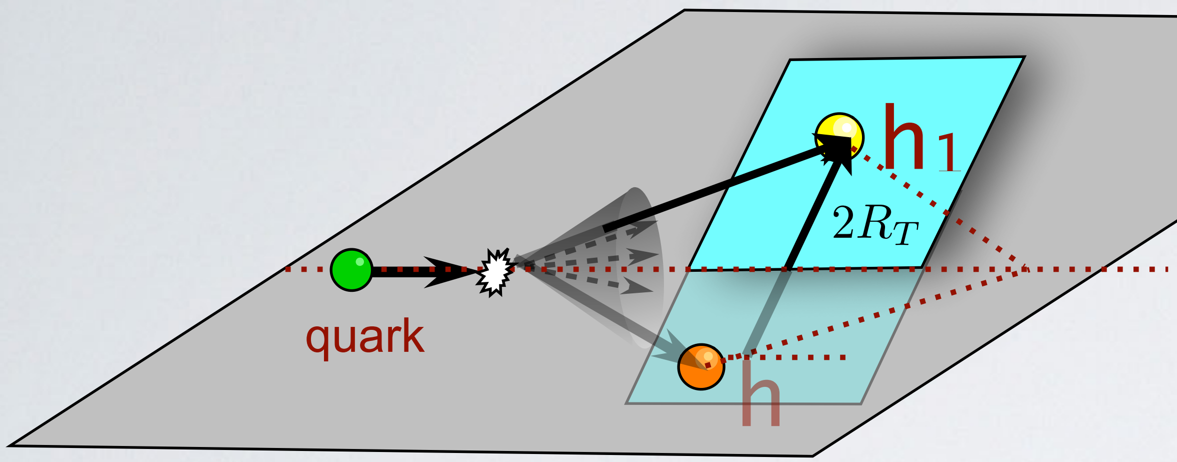


$$
\begin{aligned}
z &= \frac{P_h^-}{k^-} = z_1 + z_2 \\
\zeta &= \frac{2R^-}{P_h^-} = \frac{z_1 - z_2}{z} \\
\mathbf{R}_T^2 &\to M_h^2 = P_h^2 \\
\phi_R &\to \mathbf{P}_{hT} \cdot \mathbf{R}_T
\end{aligned}
$$

Δ depends on 4 variables :

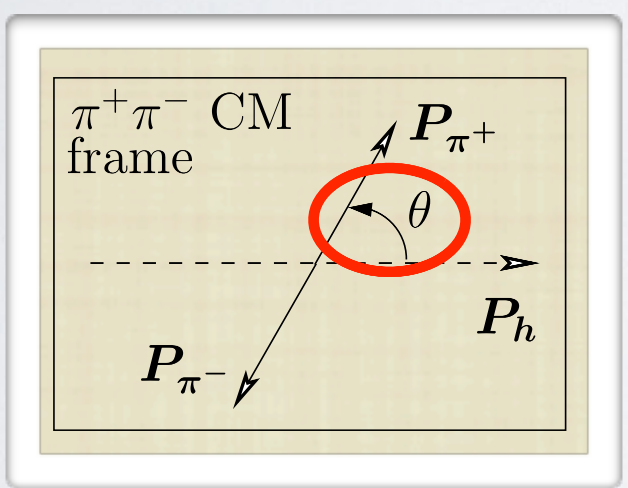
expansion in partial waves

*Bacchetta & Radici, P.R. D**67** (03) 094002*



for $M_h \lesssim 1$ GeV,
the system $(h_1,h_2)_L$
can be in L = 0 (*s*) or 1 (*p*)
relative partial wave

for (h_1,h_2) system in its c.m. frame



change of variable

$$\zeta = \frac{z_1 - z_2}{z} \quad \longleftrightarrow \quad \cos\theta$$

expansion in Legendre polinomials of cosθ

$$D_1^q(z,\zeta,M_h^2) \approx D_1^q(z,M_h^2) + D_{1\,sp}^q(z,M_h^2)\cos\theta + \ldots$$

$$H_1^{\sphericalangle\,q}(z,\zeta,M_h^2) \approx H_{1,sp}^{\sphericalangle\,q}(z,M_h^2) + H_{1,pp}^{\sphericalangle\,q}(z,M_h^2)\cos\theta + \ldots$$

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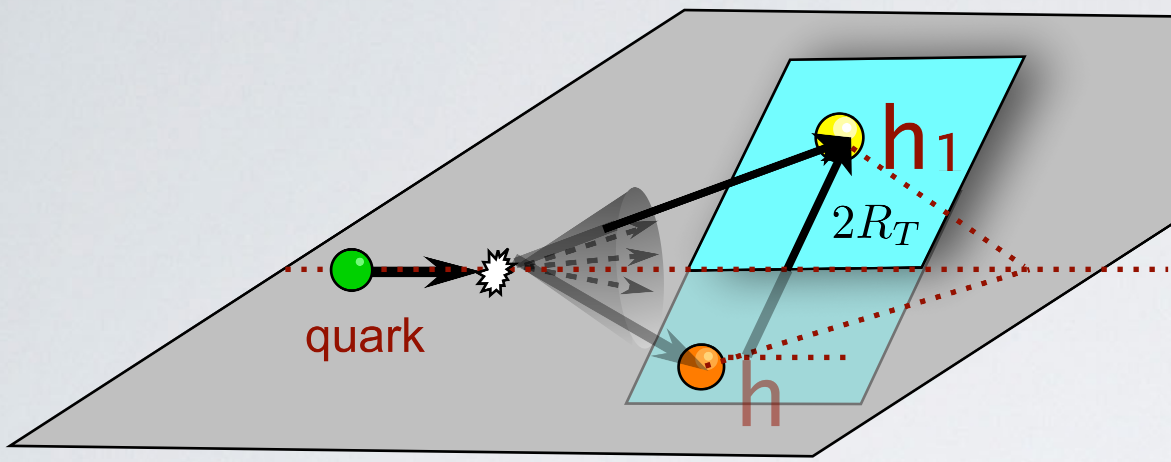

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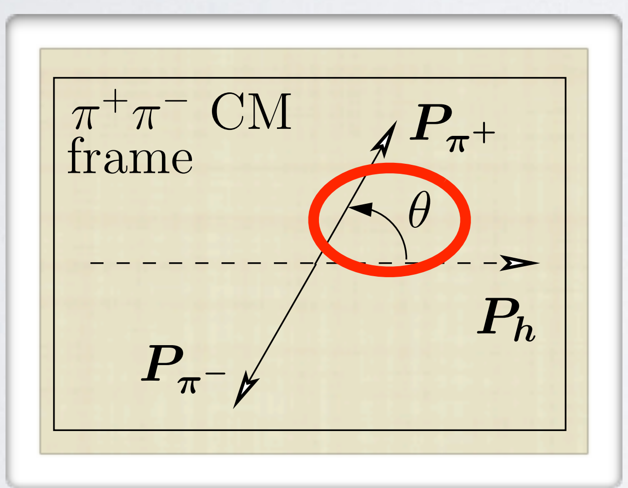

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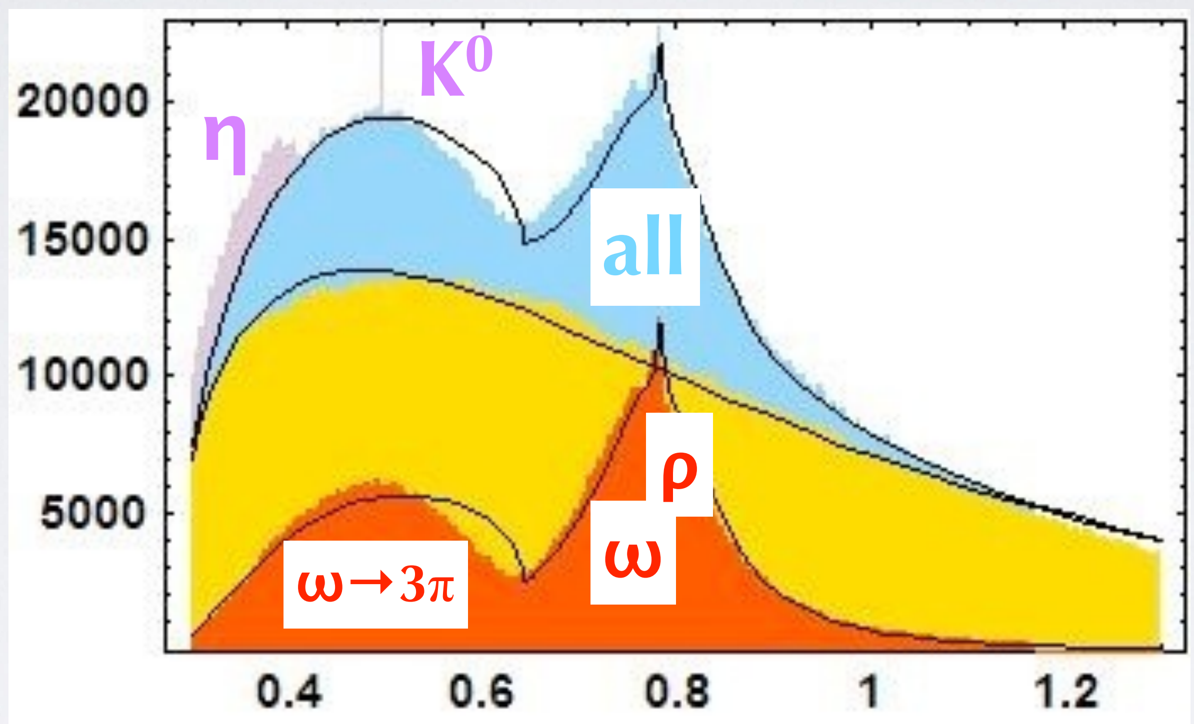
involved in recent measured asymmetries

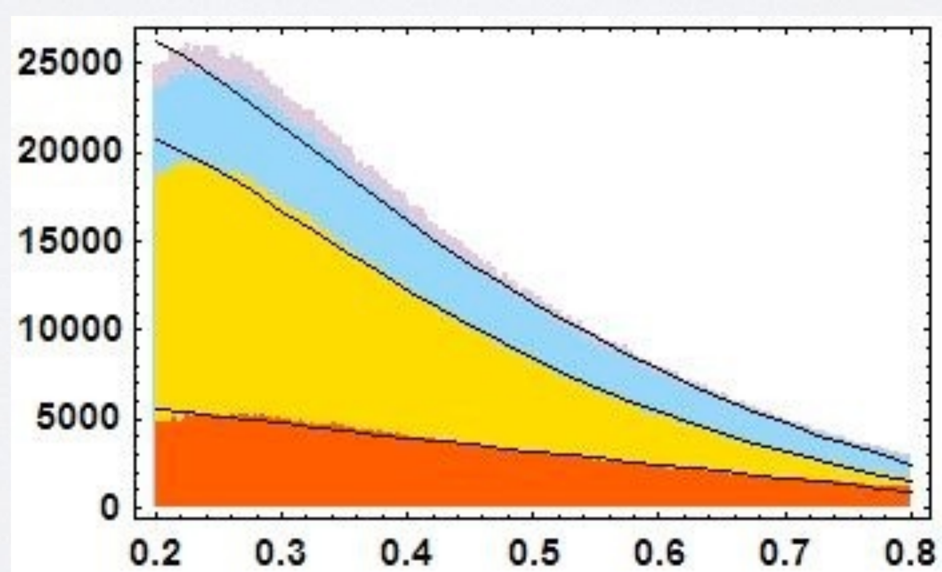
extract DiFFs : warning #2

invariant mass M_h dependence very complicated
model-inspired fitting functional form

counts



M_h



z

Bacchetta & Radici,
*P.R. D**74** (06) 114007*

background
=
all - (resonances)

assumed
$(\pi^+\pi^-)_{L=0}$