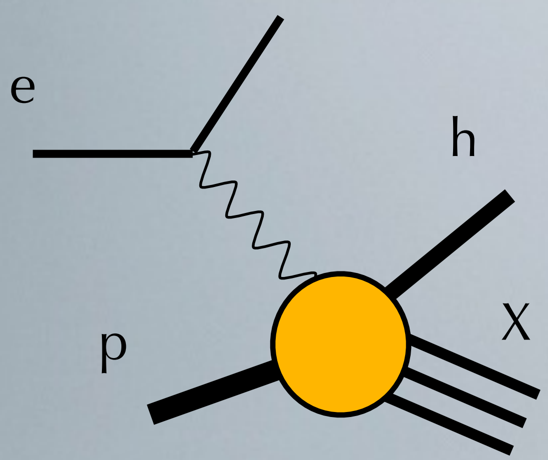
QCD Evolution Workshop

Exploring the Flavor dependence of partonic transverse momentum

Marco Radici
INFN - Pavia

INFN Istituto Nazionale di Fisica Nucleare

SIDIS @leading twist



8 TMD PDF

quark pol.

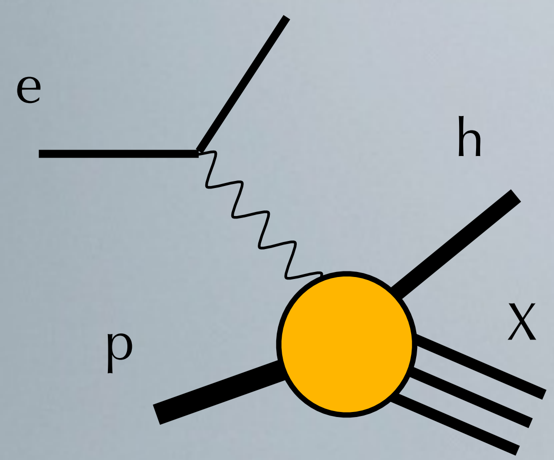
nucleon pol.	U	L	T
U	f_1		$h_1^{\perp}$
L		g_{1L}	$h_{1L}^{\perp}$
T	$f_{1T}^{\perp}$	g_{1T}	h_1, $h_{1T}^{\perp}$

2 TMD FF

quark pol.

U	L	T
D_1		$H_1^{\perp}$

SIDIS @leading twist



8 TMD PDF

quark pol. / nucleon pol.

	U	L	T
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T	$f_{1T}^\perp$	g_{1T}	h_1, $h_{1T}^\perp$

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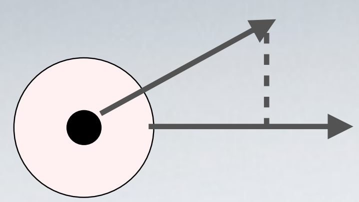
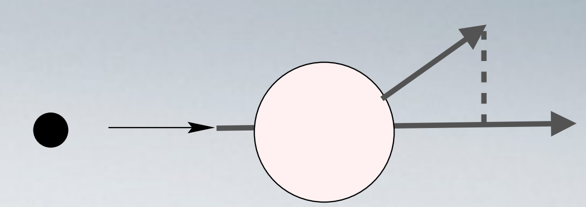
$f_1 =$ 

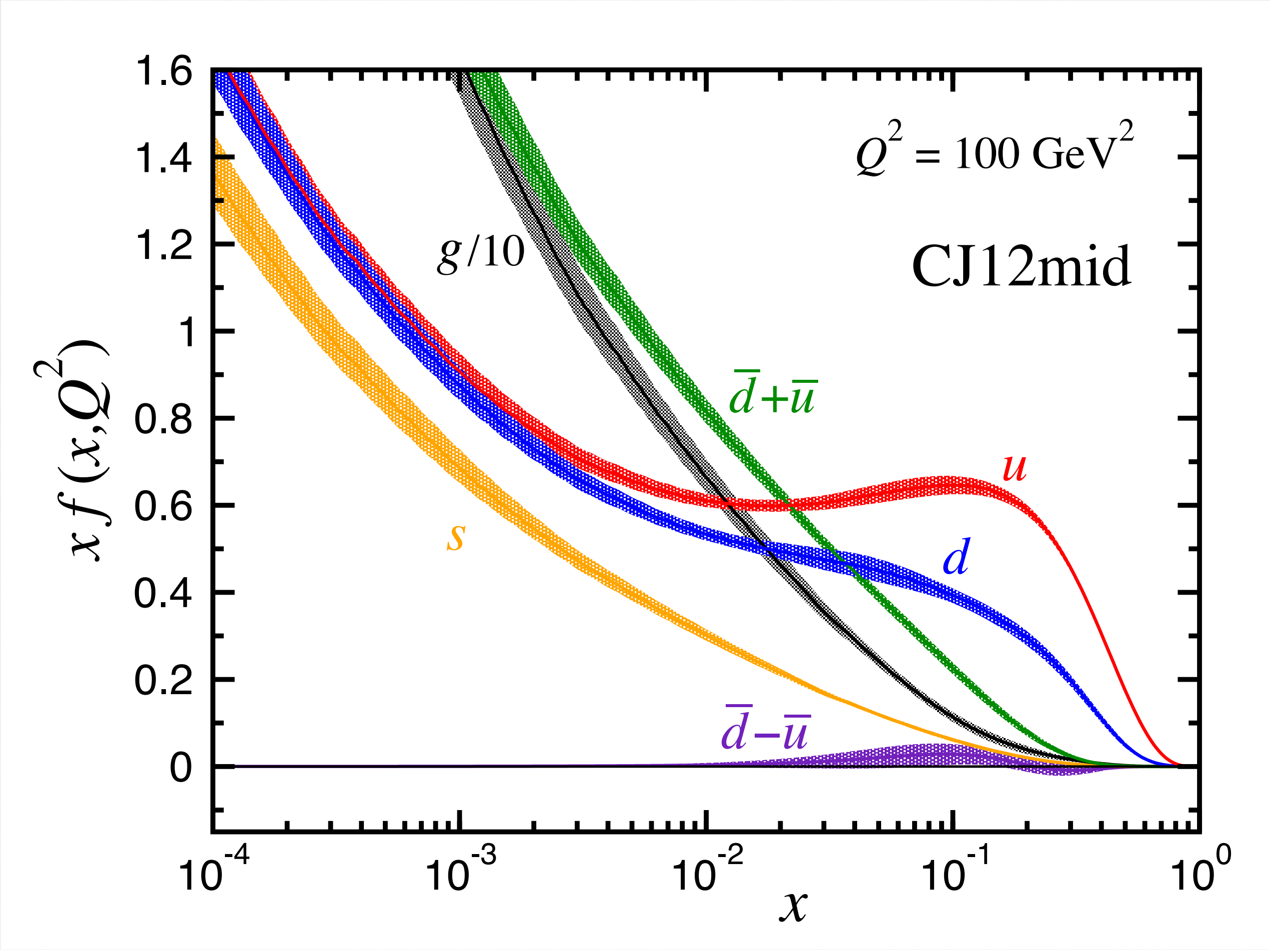
$D_1 =$ 

explore the flavor dependence of partonic transverse momentum in SIDIS

evidence from : collinear PDF fits

example :

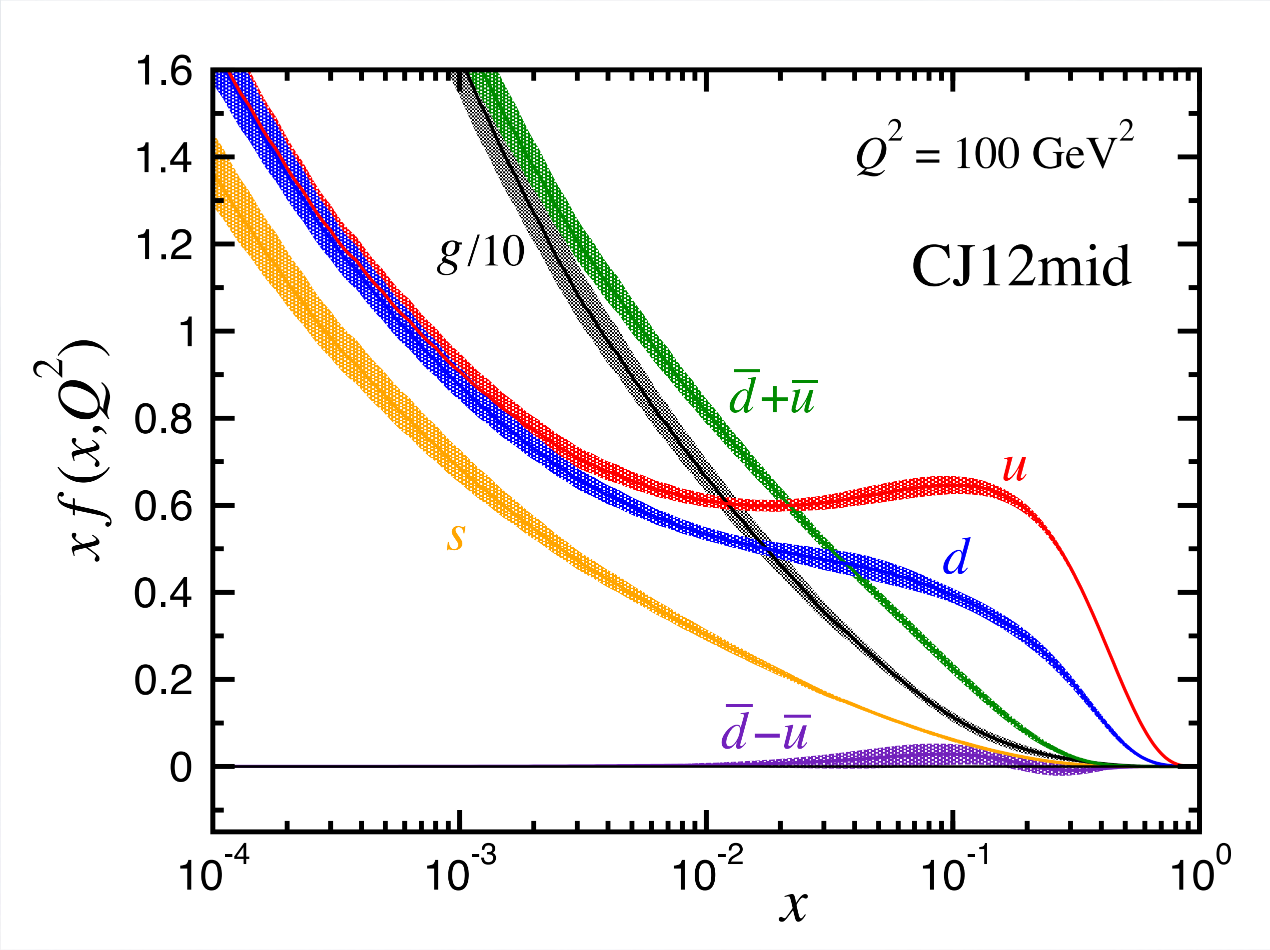
Owens, Accardi, Melnitchouk (CJ12)
P.R. D**87** (13) 094012



similar evidences in

Jimenez-Delgado, Reja (JR09), P. R. D**80** (09) 114011
Alekhin *et al*. (ABKM09), P. R. D**81** (10) 014032
Lai *et al*. (CT10), P. R. D**82** (10) 074024
Alekhin, Blümlein, Moch (ABM11), P. R. D**86** (12) 054009
Ball et al. (NNPDF13), N. P. **B867** (13) 244
....

evidence from : collinear PDF fits



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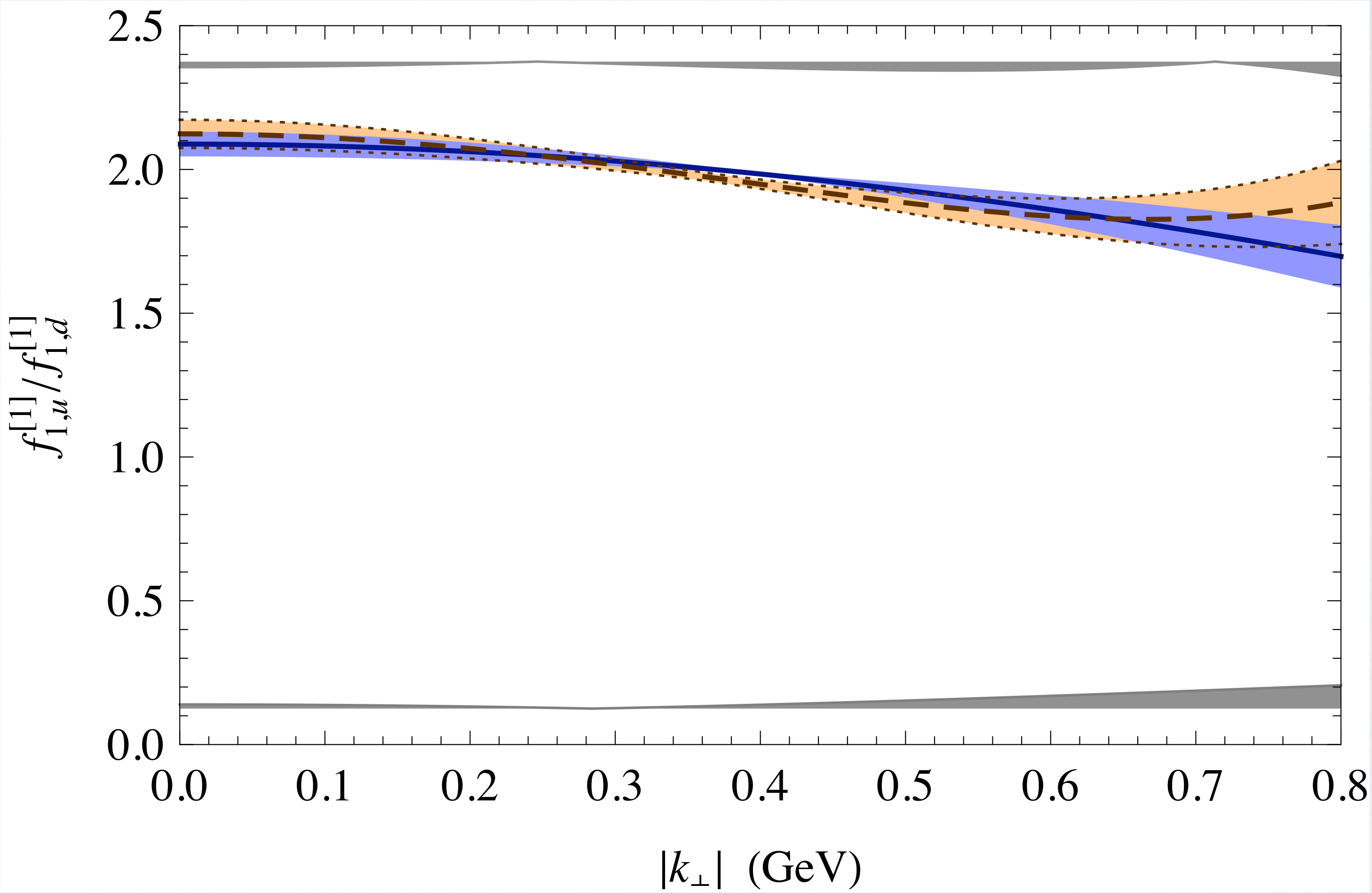
....

why not for
$\boldsymbol{k}_\perp$ dependence
of TMD ?

evidence from : lattice

valence picture of proton : #u / #d = 2

ratio of
number densities
(moments of f_1^q)
depends upon $|\boldsymbol{k}_\perp|$



Musch *et al.*, P.R. D**83** (11) 094507

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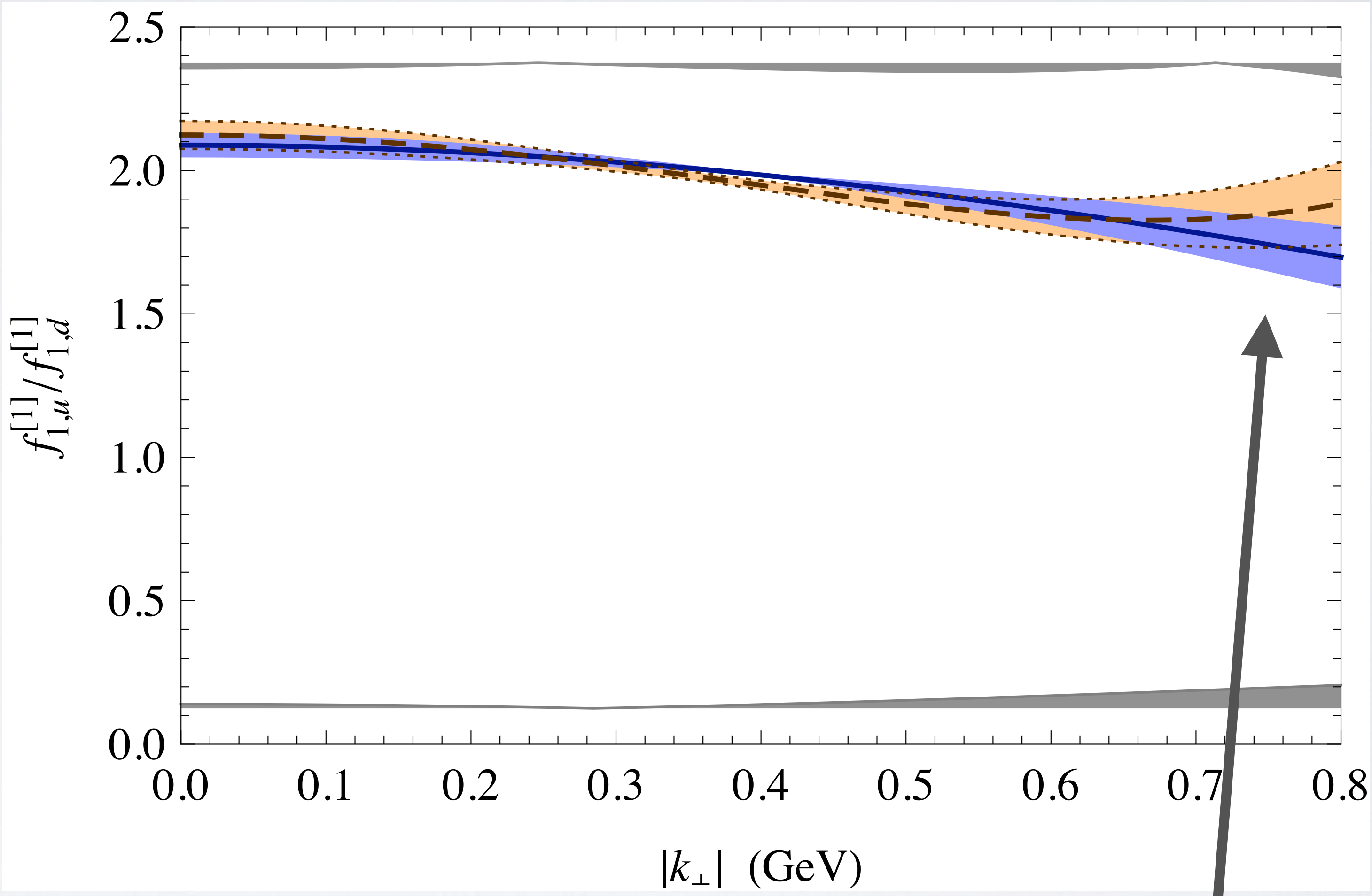


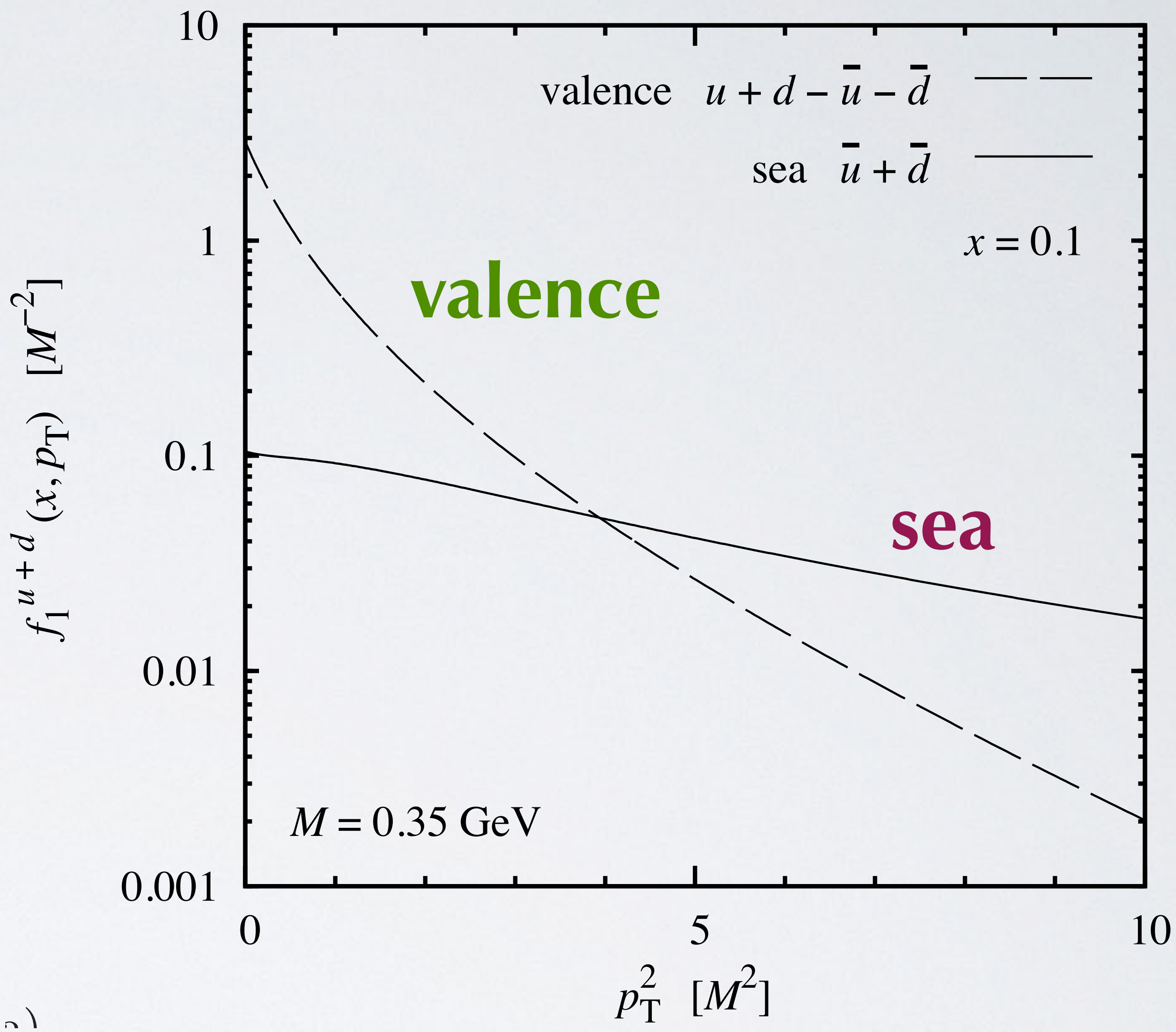
Musch *et al.*, P.R. D**83** (11) 094507

"less" up at large $|\boldsymbol{k}_\perp|$

evidence from : models of **TMD PDF**

example :
chiral quark soliton model

Schweitzer, Strikman, Weiss
JHEP **1301** (13) 163



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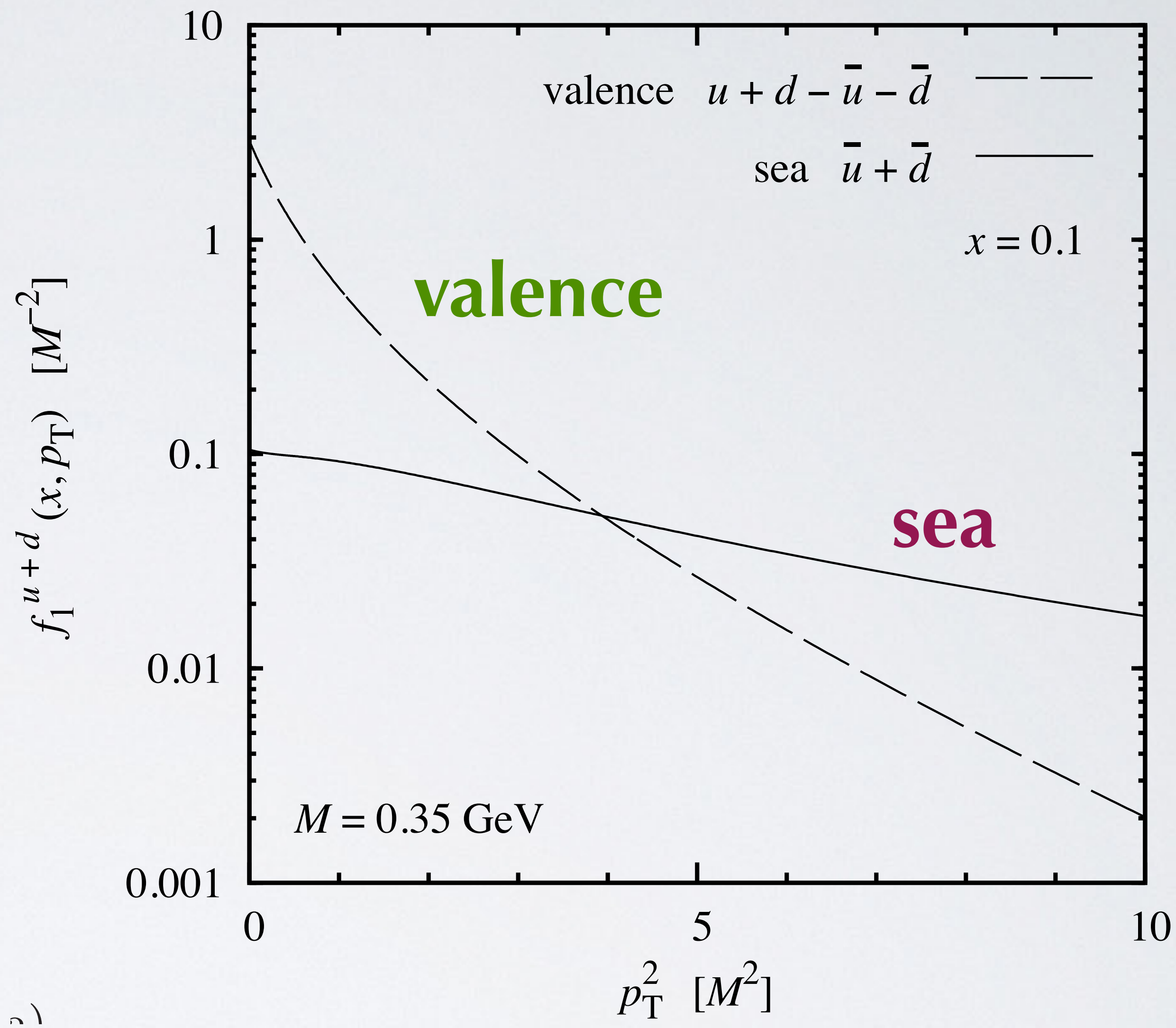
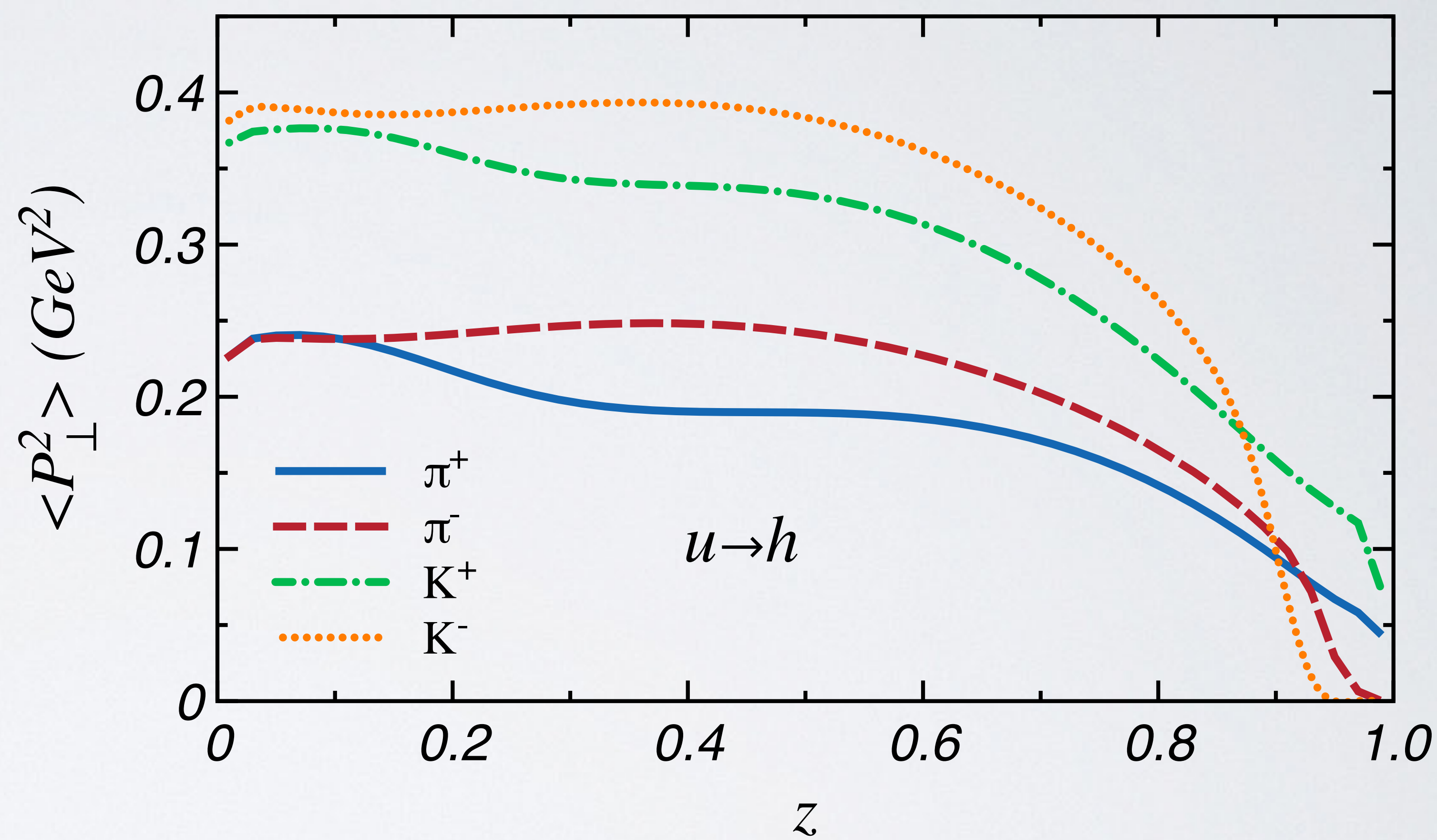
JHEP **1301** (13) 163



similarly in other models like
- diquark spectator (Bacchetta, Conti, Radici, P. R. D**78** (08) 074010)
- statistical approach (Bourrely, Buccella, Soffer, P. R. D**83** (11) 074008)
- ……

evidence from : "model MC" of **TMD FF**

example : NJL-jet model

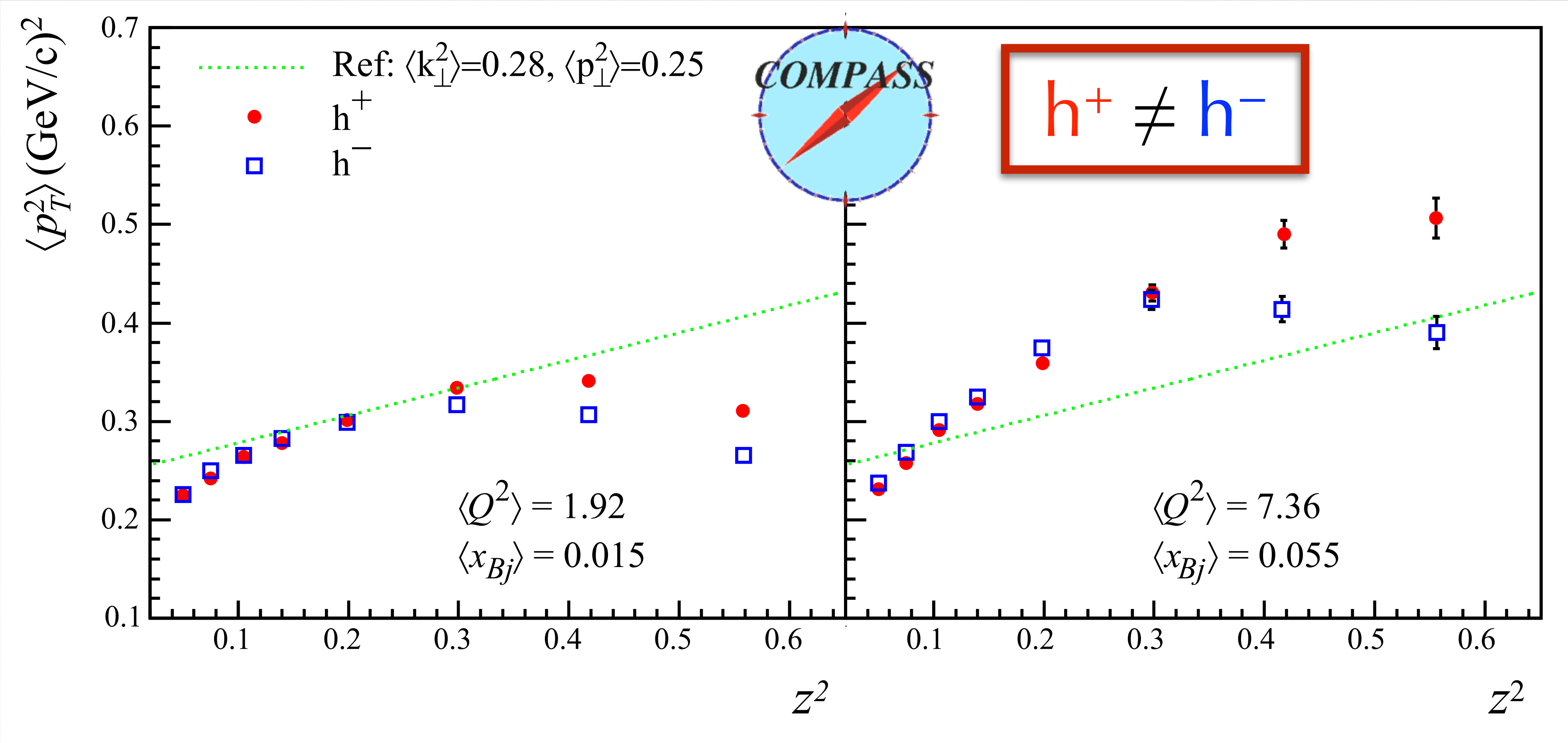


Matevosyan *et al.*,
P. R. D**85** (12) 014021

evidence from :   data

Adolph *et al.*, E.P.J. **C73** (13) 2531

$<P_{hT}^2>$



see also
Asaturyan *et al.* (E00-108),
P. R. C**85** (12) 015202

Jefferson Lab

and
Airapetian *et al.*,
P. R. D**87** (13) 074029

hermes

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Adolph *et al.*, E.P.J. **C73** (13) 2531

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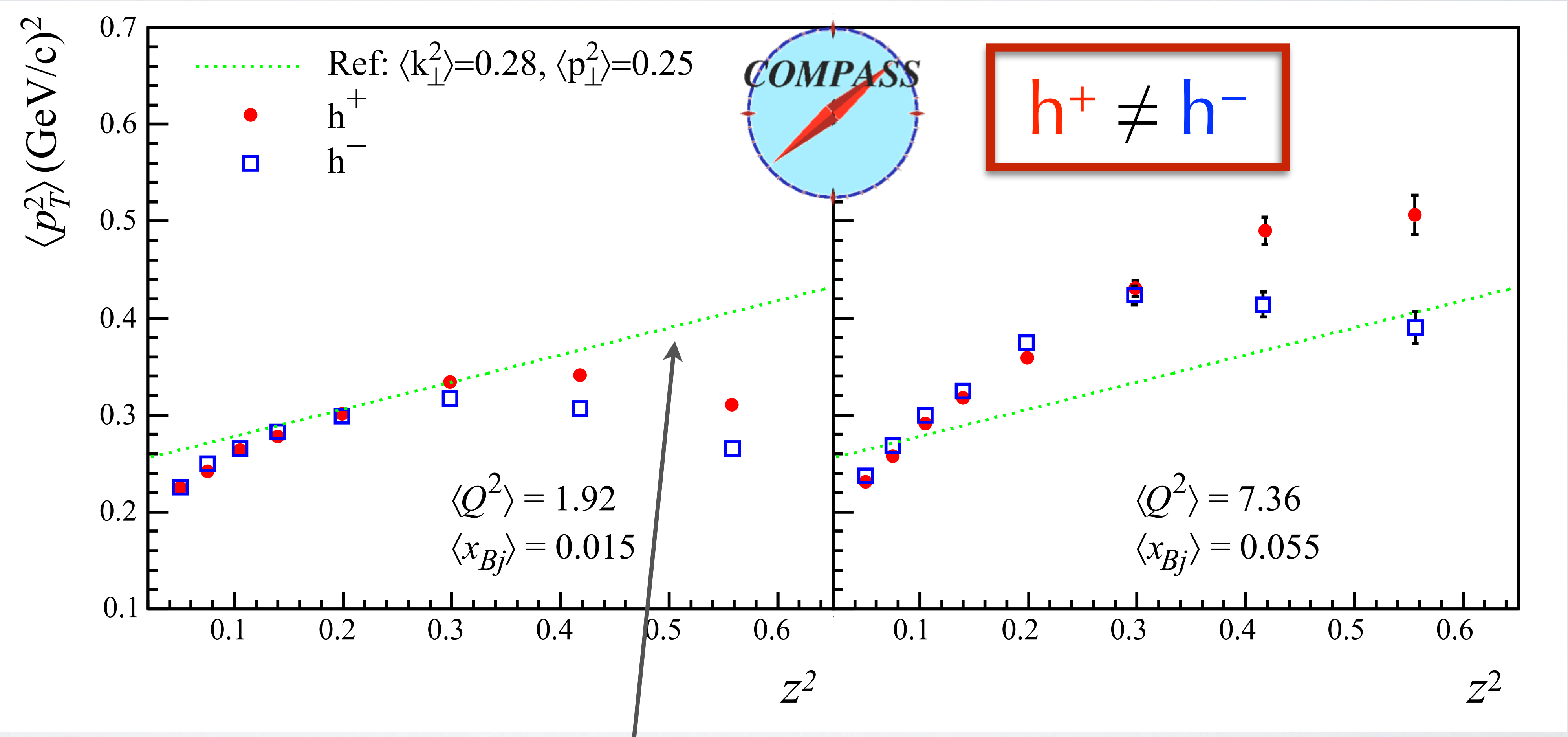

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Jefferson Lab

and
Airapetian *et al.*,
P. R. D**87** (13) 074029

hermes

Gaussian fit with **no flavor** $\Rightarrow$ $\langle \boldsymbol{P}_{hT}^2 \rangle = z^2 \langle \boldsymbol{k}_\perp^2 \rangle + \langle \boldsymbol{P}_\perp^2 \rangle$

Anselmino et al, E.P.J. **A31** (07)

TMD PDF   **TMD FF**

Gaussian widths

different trend $<P_{hT}^2>$ (z) from data

our work

explore the flavor dependence of
partonic transverse momentum

1st part: published
(this talk)

JHEP
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PUBLISHED: *November 27, 2013*

Investigations into the flavor dependence of partonic transverse momentum

Andrea Signori,[a,b] Alessandro Bacchetta,[c,d] Marco Radici[c] and Gunar Schnell[e,f]

JHEP**1311** (2013) 194

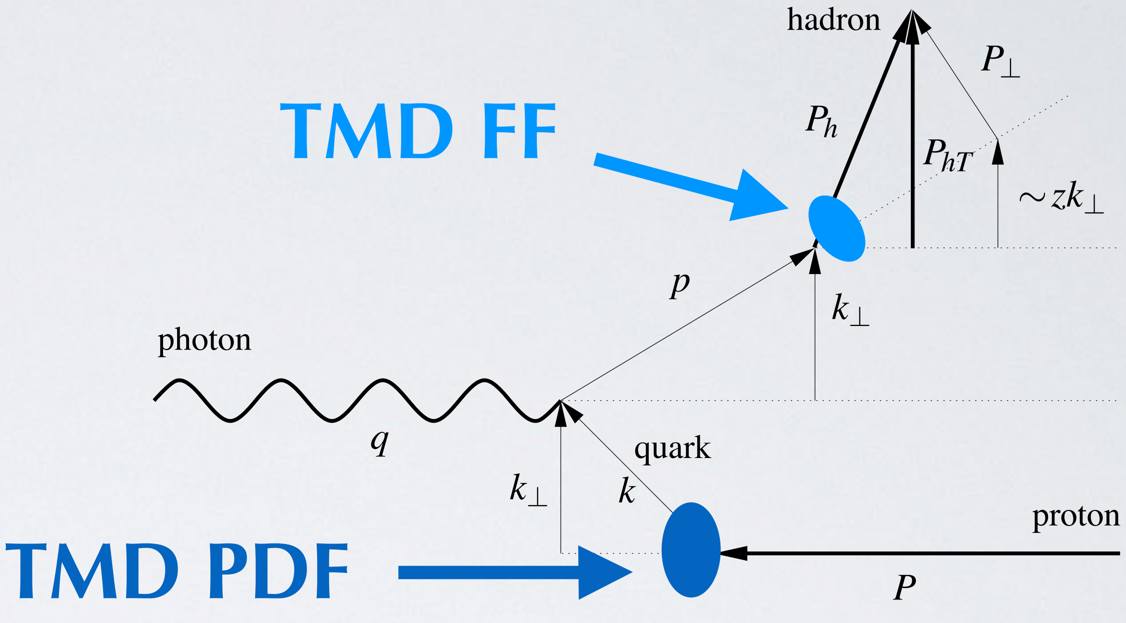
2nd part: ongoing work
(next talk by A. Bacchetta)

unpol. TMD and structure functions

notation as in
"Seattle convention"
arXiv:1108.1713

$\perp$ intrinsic

T lab (measurable)



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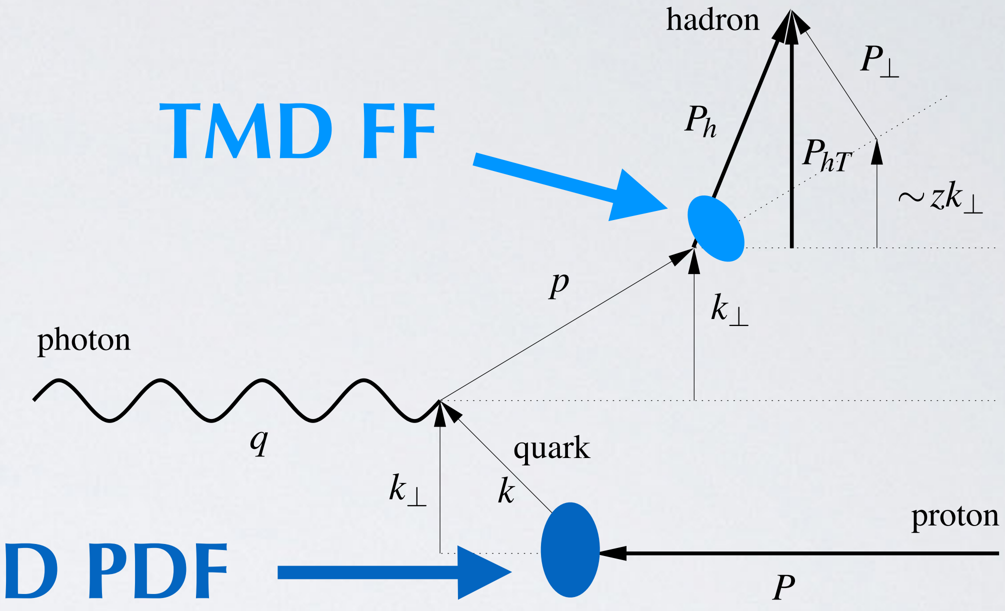

hard scattering

full formula

$$F_{UU,T}(x,z,\boldsymbol{P}_{hT}^2,Q^2) = x \sum_a \mathcal{H}^a_{UU,T}(Q^2;\mu^2) \int d\boldsymbol{k}_\perp \, d\boldsymbol{P}_\perp \, f_1^a(x,\boldsymbol{k}_\perp^2;\mu^2) \, D_1^{a\to h}(z,\boldsymbol{P}_\perp^2;\mu^2) \, \delta(z\boldsymbol{k}_\perp - \boldsymbol{P}_{hT} + \boldsymbol{P}_\perp)$$

$$+ Y_{UU,T}(Q^2,\boldsymbol{P}_{hT}^2) + \mathcal{O}(M^2/Q^2)$$

$\boldsymbol{P}_{hT}{}^2 \sim Q^2$
match pQCD

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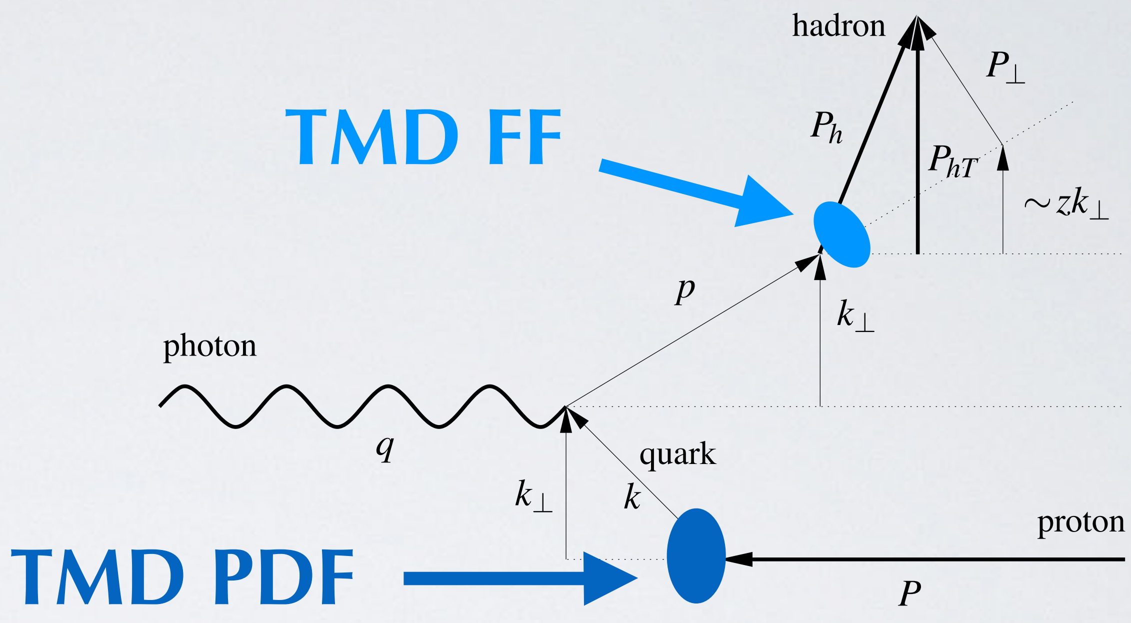

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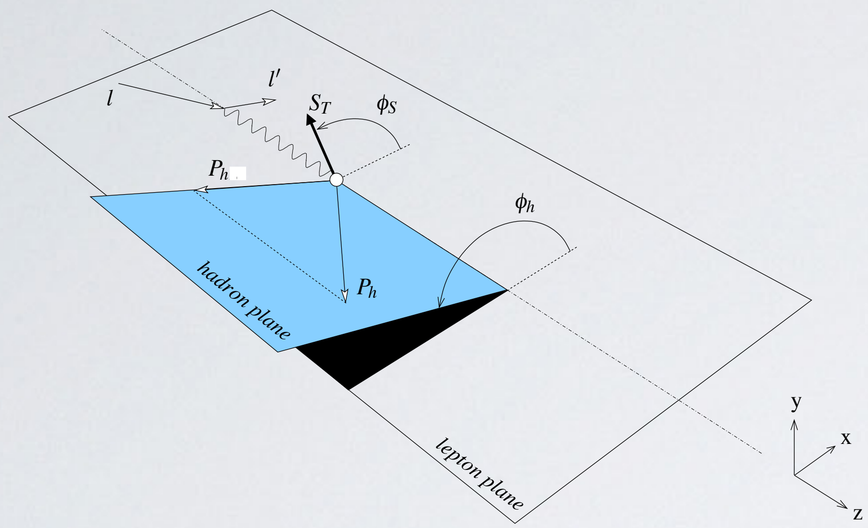
$$+\, Y_{UU,T}(Q^2,\boldsymbol{P}_{hT}^2) + \mathcal{O}(M^2/Q^2)$$

$\boldsymbol{P}_{hT}{}^2 \sim Q^2$
match pQCD

parton model (M^2, $\boldsymbol{P}_{hT}{}^2 \ll Q^2$)

$$F_{UU,T}(x,z,\boldsymbol{P}_{hT}^2;Q^2) = \sum_q e_q^2\, x\int d\boldsymbol{k}_\perp\, d\boldsymbol{P}_\perp\,\delta(z\boldsymbol{k}_\perp+\boldsymbol{P}_\perp-\boldsymbol{P}_{hT})\, f_1^q(x,\boldsymbol{k}_\perp^2,Q^2)\, D_1^{q\to h}(z,\boldsymbol{P}_\perp^2;Q^2)$$
$$= \sum_q e_q^2\,\left[f_1^q \otimes D_1^{q\to h}\right]$$

exp. observable : multiplicity



SIDIS process

$$\ell(l) + N(P) \to \ell(l') + h(P_h) + X,$$

hadron species

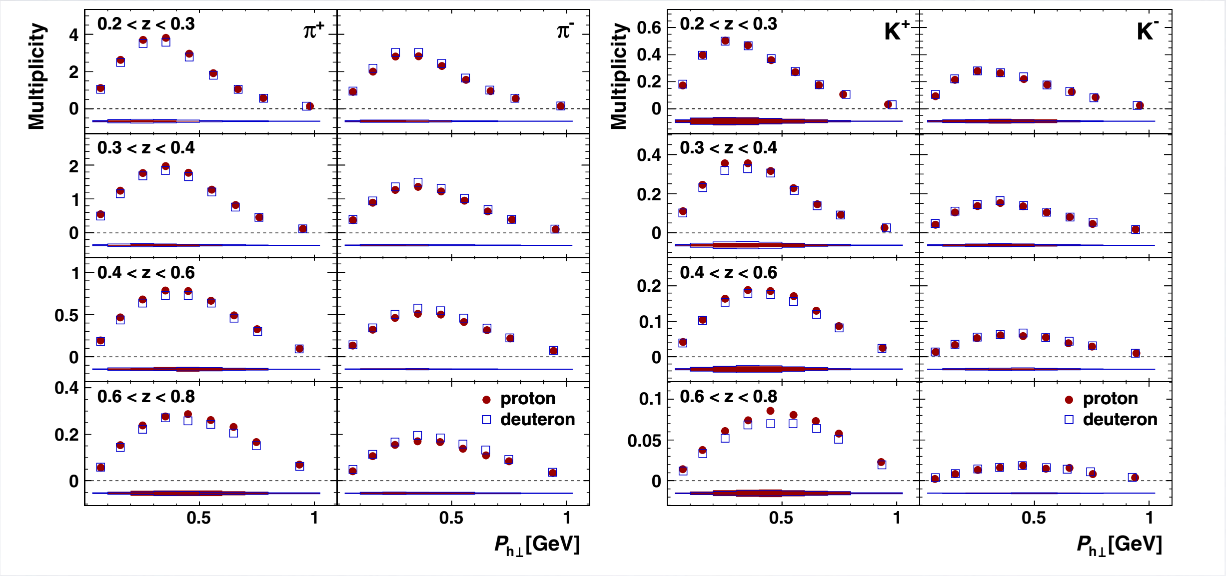
$$m_N^h(x, z, \boldsymbol{P}_{hT}^2, Q^2) = \frac{d\sigma_N^h/(dx\,dz\,d\boldsymbol{P}_{hT}^2\,dQ^2)}{d\sigma_{\mathrm{DIS}}/(dx\,dQ^2)} \approx \frac{\pi\, F_{UU,T}(x, z, \boldsymbol{P}_{hT}^2, Q^2)}{F_T(x, Q^2)}$$

target

1. M^2, $\boldsymbol{P}_{\mathrm{hT}}{}^2 \ll Q^2$: leading twist TMD
2. $O(\alpha_s{}^0)$: parton model
3. Φ_h integrated : acceptance in systematic error

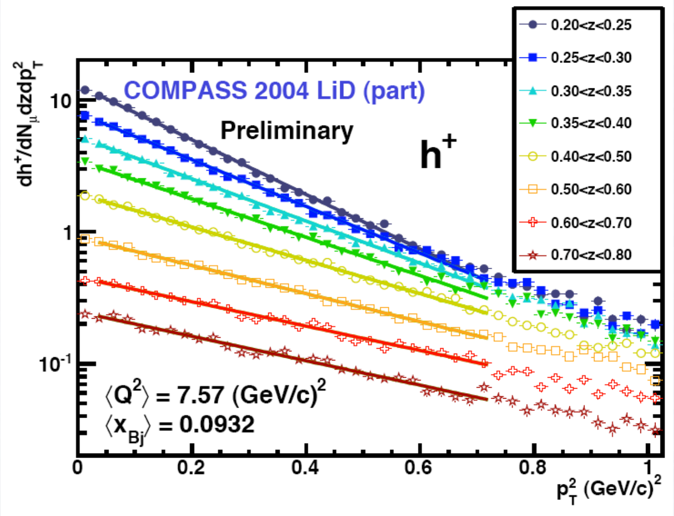
recent data on SIDIS multiplicities

Airapetian *et al.*, P.R. D**87** (13) 074029



- target: proton, deuteron
- final state: π^+, π^-, K^+, K^-

Adolph *et al.*, E.P.J. **C73** (13) 2531

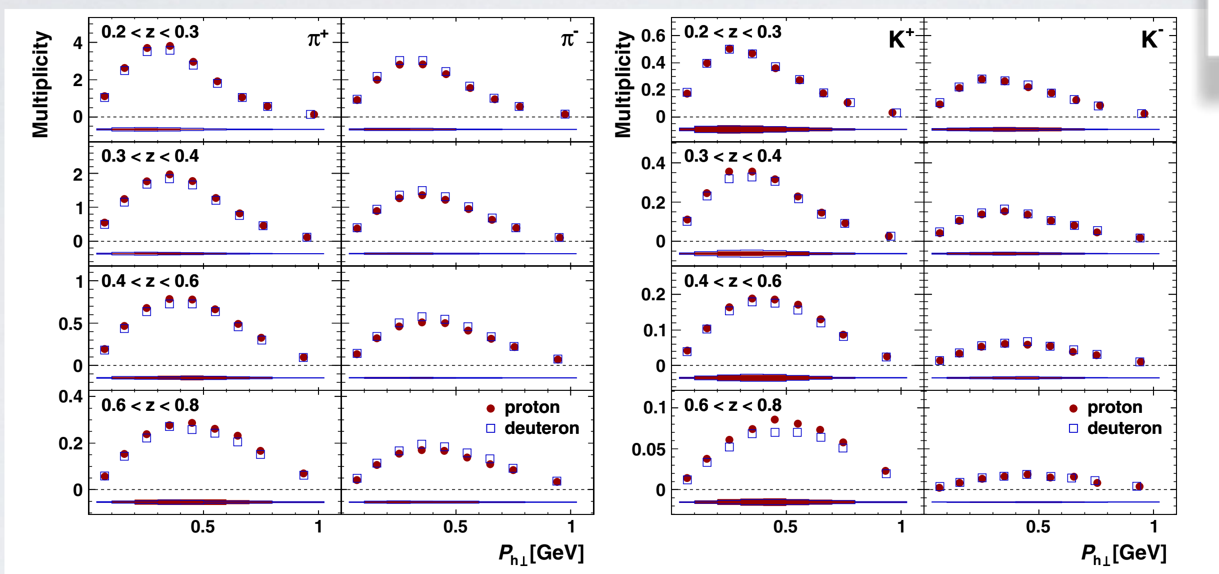


about 20000 data points (!), but
- target: deuteron
- final state: h^+, h^- unidentified (at the time of this work)

ongoing work on π^+,π^-,K^+,K^-

recent data on SIDIS multiplicities

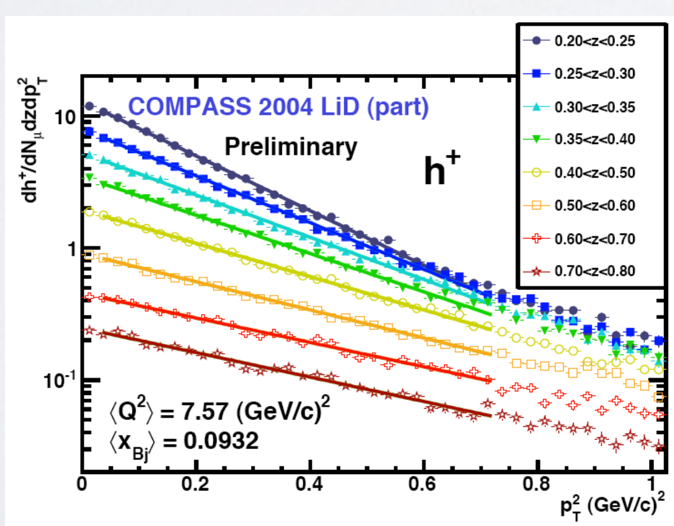
Airapetian *et al.*, P.R. D**87** (13) 074029



ideal for flavor analysis

- target: proton, deuteron
- final state: π^+, π^-, K^+, K^-

Adolph *et al.*, E.P.J. **C73** (13) 2531



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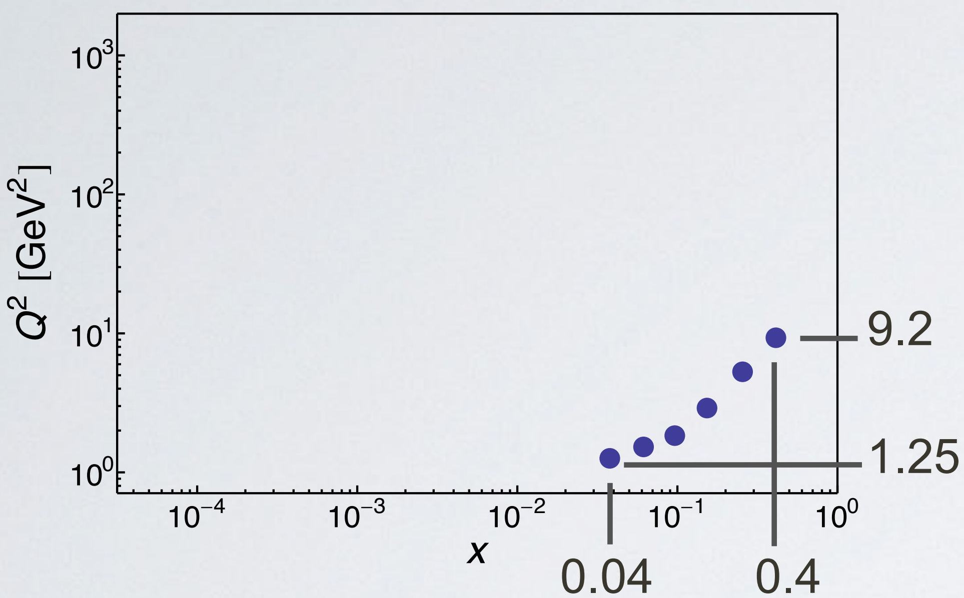
selection of data



limited (x, Q^2) range:	6 bins	x
$0.1 \leq z \leq 0.9$	8 bins	x
$0.1 \leq \lvert \boldsymbol{P}_{hT} \rvert \leq 1$ GeV	7 bins	x
p , D	2 targets	x
π^+, π^-, K^+, K^-	4 final h's	
total	2688 points	

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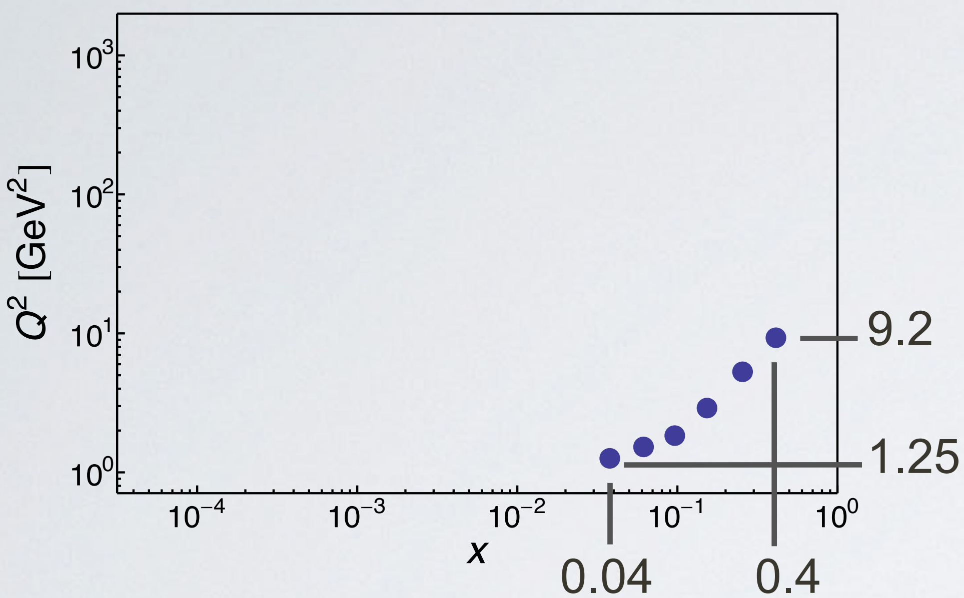

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- $\boldsymbol{P}_{hT}^2 \ll Q^2 \Rightarrow$ cut $Q^2 > 1.4$ GeV^2 ($\leftrightarrow$ lowest x)
- cut $z < 0.8$ as in DSS (and use VM subtracted set)
- cut 0.15 GeV$^2 < \boldsymbol{P}_{hT}^2 < Q^2/3$ 1538 points ≈ 60 %

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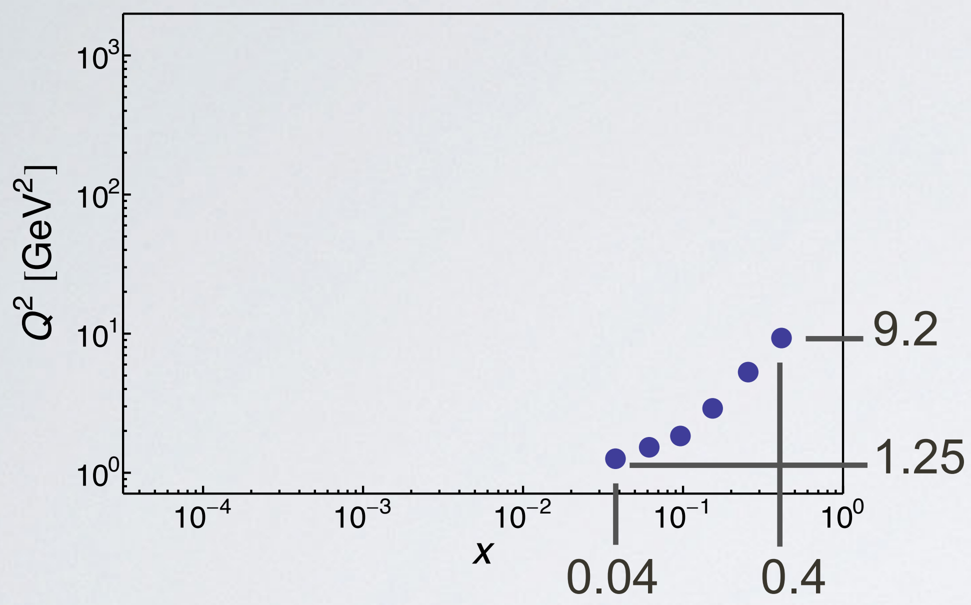

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limited Q^2 range $\Rightarrow$ safely neglect evolution <u>everywhere</u>

our analysis : flavor dependent Gaussian

TMD PDF

$$f_1^q(x, \boldsymbol{k}_\perp^2; Q^2) = f_1^q(x; Q^2)\, \frac{e^{-\boldsymbol{k}_\perp^2/\langle \boldsymbol{k}_{\perp,q}^2 \rangle}}{\pi \langle \boldsymbol{k}_{\perp,q}^2 \rangle}$$

TMD FF

$$D_1^{q\to h}(z, \boldsymbol{P}_\perp^2; Q^2) = D_1^{q\to h}(z; Q^2)\, \frac{e^{-\boldsymbol{P}_\perp^2/\langle \boldsymbol{P}_{\perp,q\to h}^2 \rangle}}{\pi \langle \boldsymbol{P}_{\perp,q\to h}^2 \rangle}$$

multiplicity

$$m_N^h(x, z, \boldsymbol{P}_{hT}^2; Q^2) \propto \sum_q e_q^2 \left[f_1^q \otimes D_1^{q\to h} \right]$$

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for each Gaussian in flavor q $\quad \langle \boldsymbol{P}_{hT,q}^2 \rangle = z^2 \langle \boldsymbol{k}_{\perp,q}^2 \rangle + \langle \boldsymbol{P}_{\perp,q\to h}^2 \rangle$

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sum of Gaussians $\neq$ Gaussian

for each Gaussian in flavor q $\quad \langle \boldsymbol{P}_{hT,q}^2 \rangle = z^2 \langle \boldsymbol{k}_{\perp,q}^2 \rangle + \langle \boldsymbol{P}_{\perp,q\to h}^2 \rangle$

our analysis : TMD PDF parameters

$$f_1^q(x, \boldsymbol{k}_\perp^2) = f_1^q(x)\Big|_{Q^2=2.4\,\mathrm{GeV}^2} \frac{e^{-\boldsymbol{k}_\perp^2/\langle \boldsymbol{k}_{\perp,q}^2 \rangle}}{\pi \langle \boldsymbol{k}_{\perp,q}^2 \rangle}$$

MSTW08 LO

Martin *et al*., E.P.J. **C63** (09) 189

x-dependent width

$$\langle \boldsymbol{k}_{\perp,q}^2 \rangle (x) = \langle \widehat{\boldsymbol{k}_{\perp,q}^2} \rangle \frac{(1-x)^\alpha \, x^\sigma}{(1-\hat{x})^\alpha \, \hat{x}^\sigma}$$

$\hat{x} = 0.1$

5 parameters

our analysis : **TMD PDF** parameters

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5 parameters

α σ

[0,2] [-0.3,0.1]

randomly chosen

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Martin *et al*., E.P.J. **C63** (09) 189

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$\hat{x} = 0.1$

5 parameters

$\widehat{\langle \boldsymbol{k}_{\perp,u_v}^2\rangle}$ up valence

$\widehat{\langle \boldsymbol{k}_{\perp,d_v}^2\rangle}$ down valence

$\widehat{\langle \boldsymbol{k}_{\perp,\mathrm{sea}}^2\rangle}$ sea

α → [0,2]

σ → [-0.3,0.1]

randomly chosen

our analysis : TMD FF parameters

$$D_1^{q\to h}(z,\boldsymbol{P}_\perp^2) = D_1^{q\to h}(z)\Big|_{Q^2=2.4\,\mathrm{GeV}^2} \frac{e^{-\boldsymbol{P}_\perp^2/\langle\boldsymbol{P}_{\perp,q\to h}^2\rangle}}{\pi\langle\boldsymbol{P}_{\perp,q\to h}^2\rangle}$$

DSS LO

De Florian *et al.*, P.R. D**75** (07) 114010

z-dependent width

$$\langle\boldsymbol{P}_{\perp,\,q\to h}^2\rangle(z) = \langle\widehat{\boldsymbol{P}_{\perp,\,q\to h}^2}\rangle \frac{(z^\beta+\delta)\,(1-z)^\gamma}{(\hat{z}^\beta+\delta)\,(1-\hat{z})^\gamma}$$

$\hat{z} = 0.5$

$\langle\widehat{\boldsymbol{P}_{\perp,\mathrm{fav}}^2}\rangle$ favored π

β γ δ

7 parameters

$\langle\widehat{\boldsymbol{P}_{\perp,uK}^2}\rangle$ favored $u \to K$

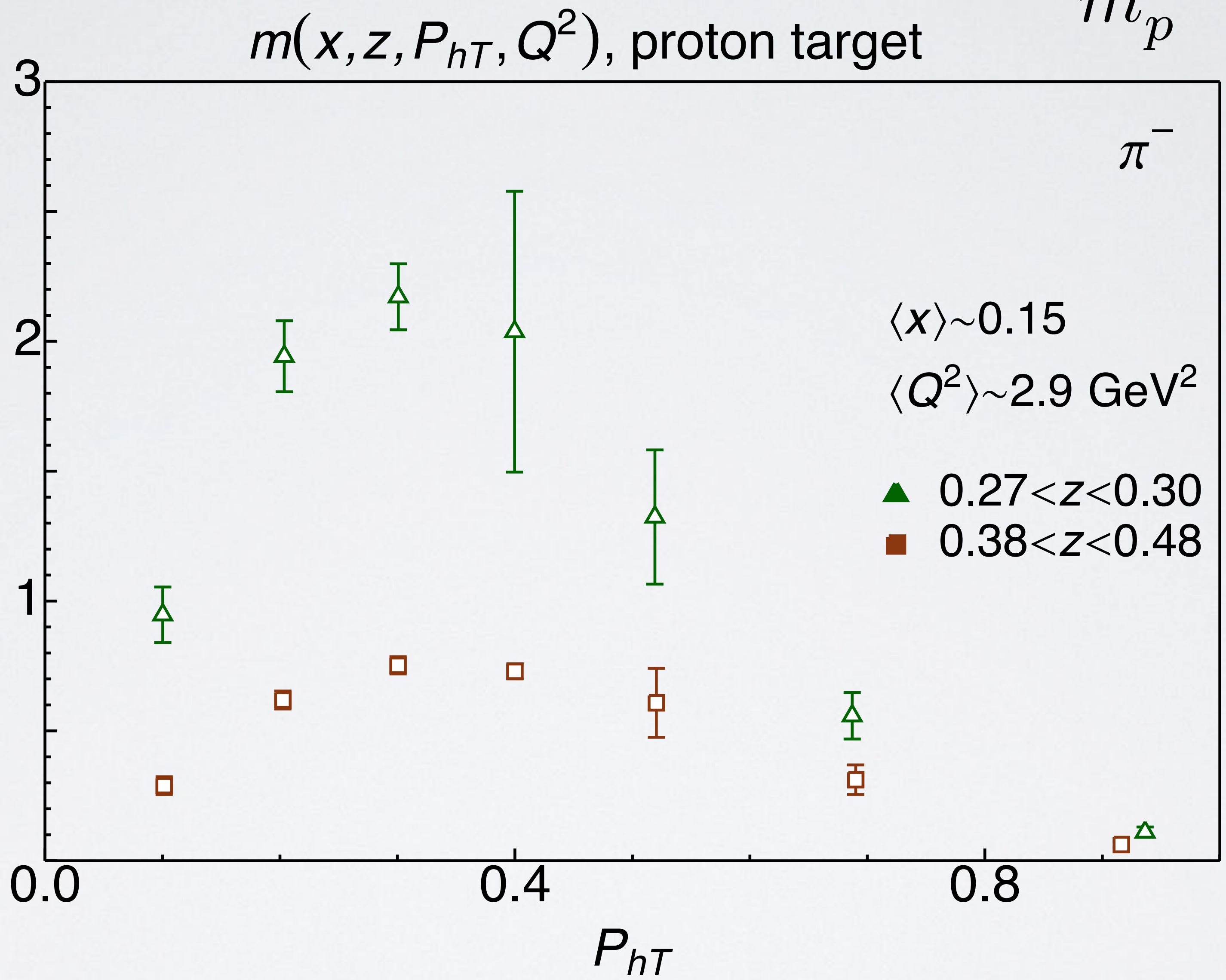
$\langle\widehat{\boldsymbol{P}_{\perp,sK}^2}\rangle$ favored $s \to K$

randomly chosen [0.125,0.25]

$\langle\widehat{\boldsymbol{P}_{\perp,\mathrm{unf}}^2}\rangle$ unfavored

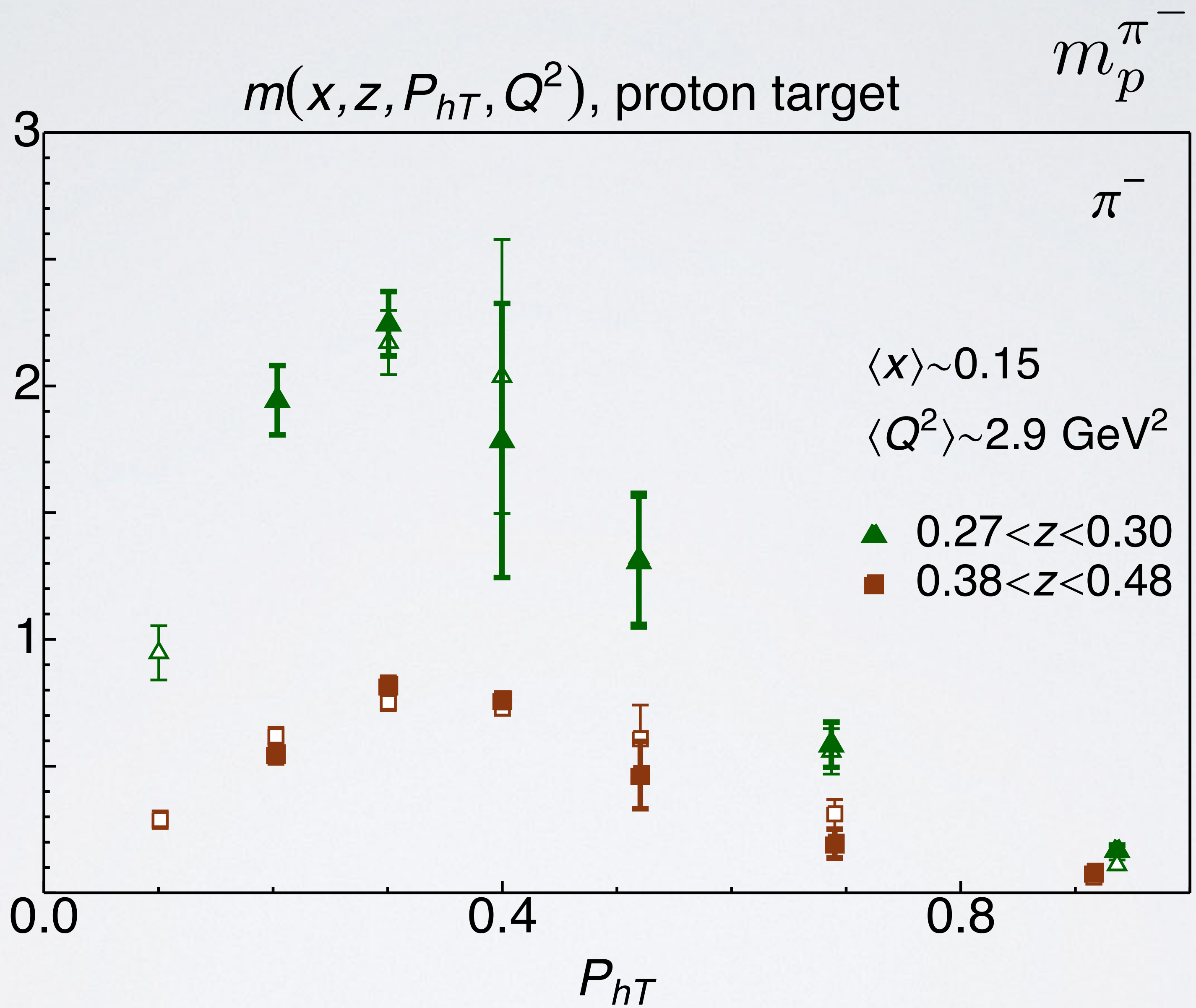
fitting : replica method

$m_p^{\pi^-}$



sample of original data

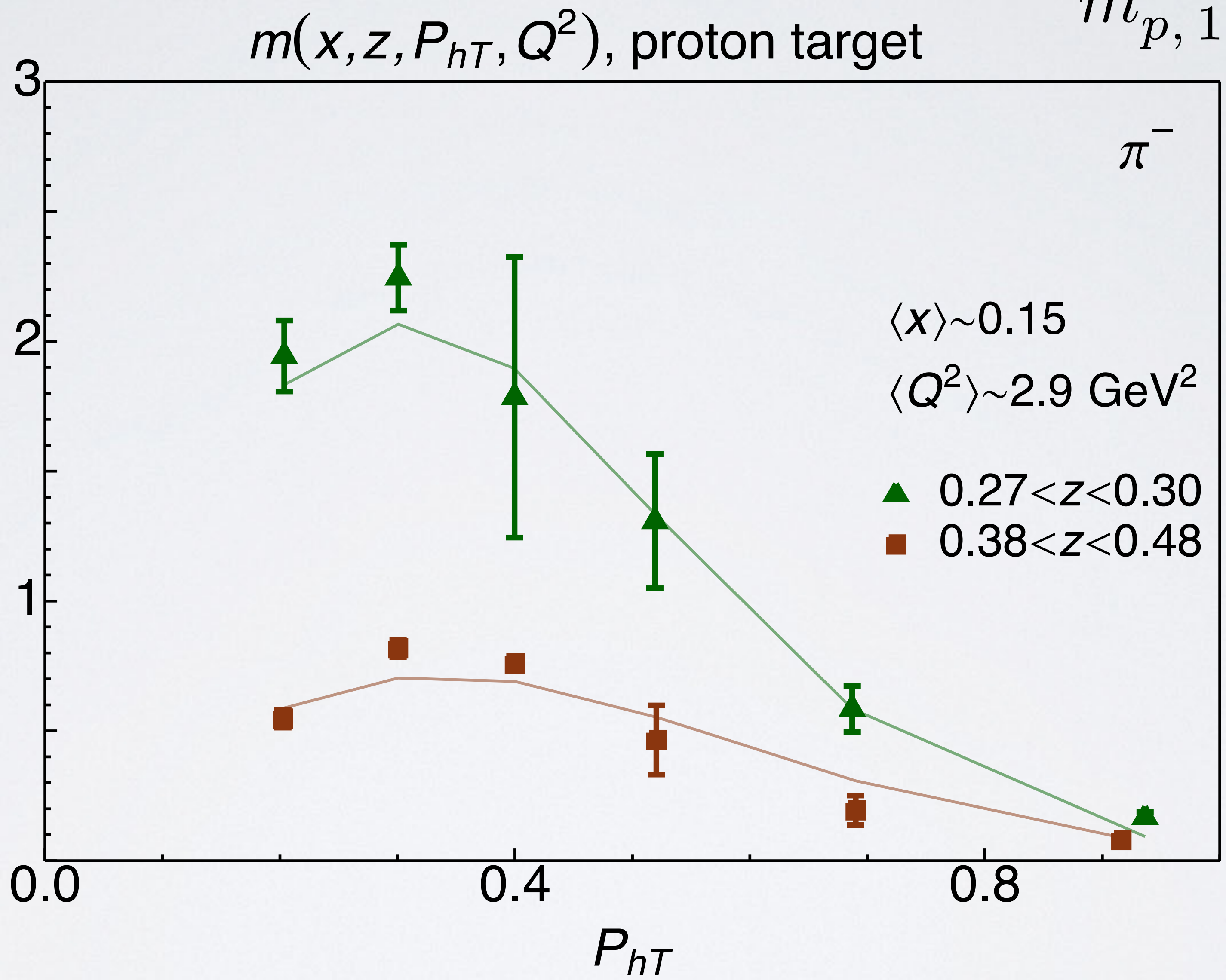
fitting : replica method



data are replicated with Gaussian noise
(within exp. variance)

fitting : replica method

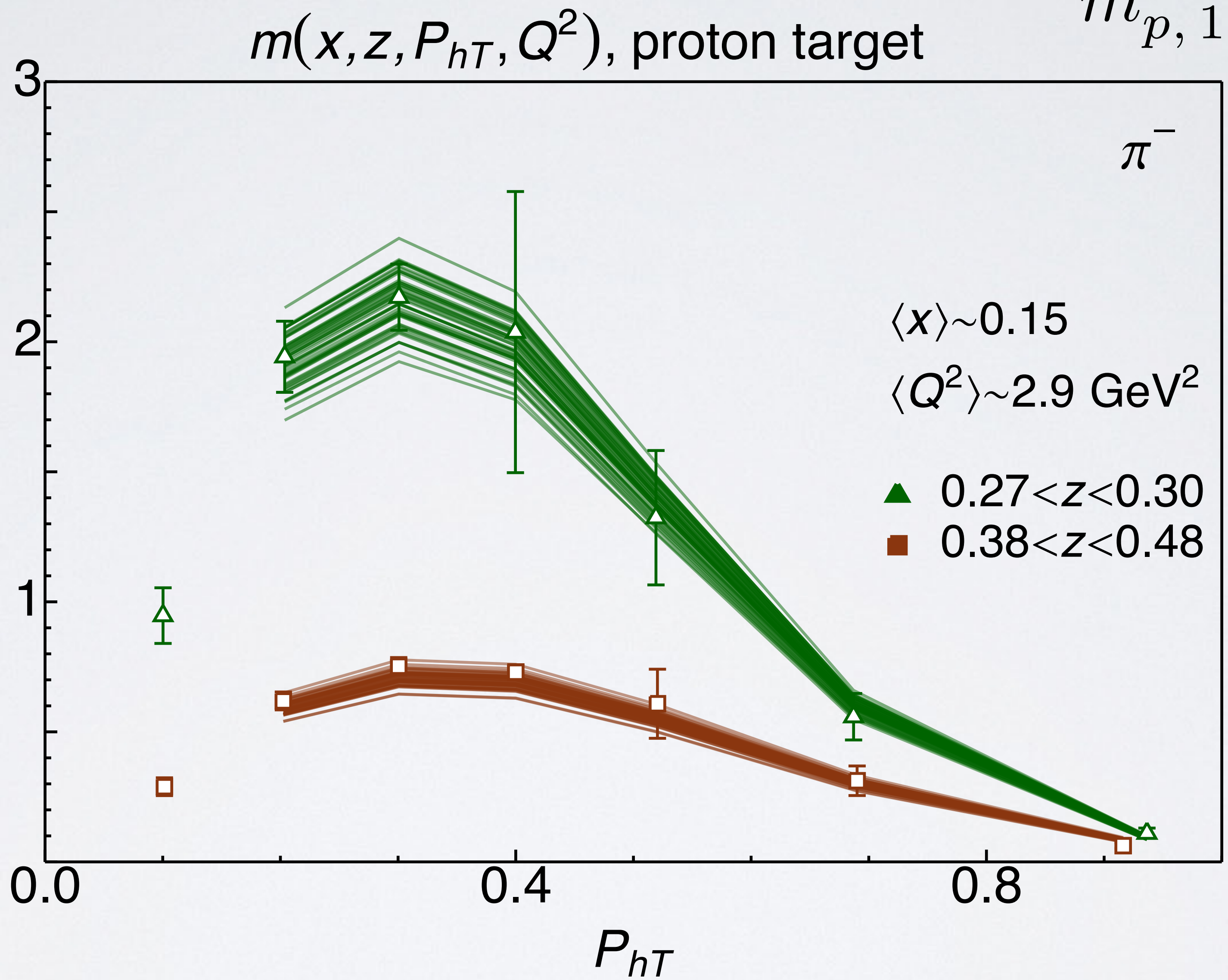
$m_{p,\,1}^{\pi^-}$



fit the replicated data

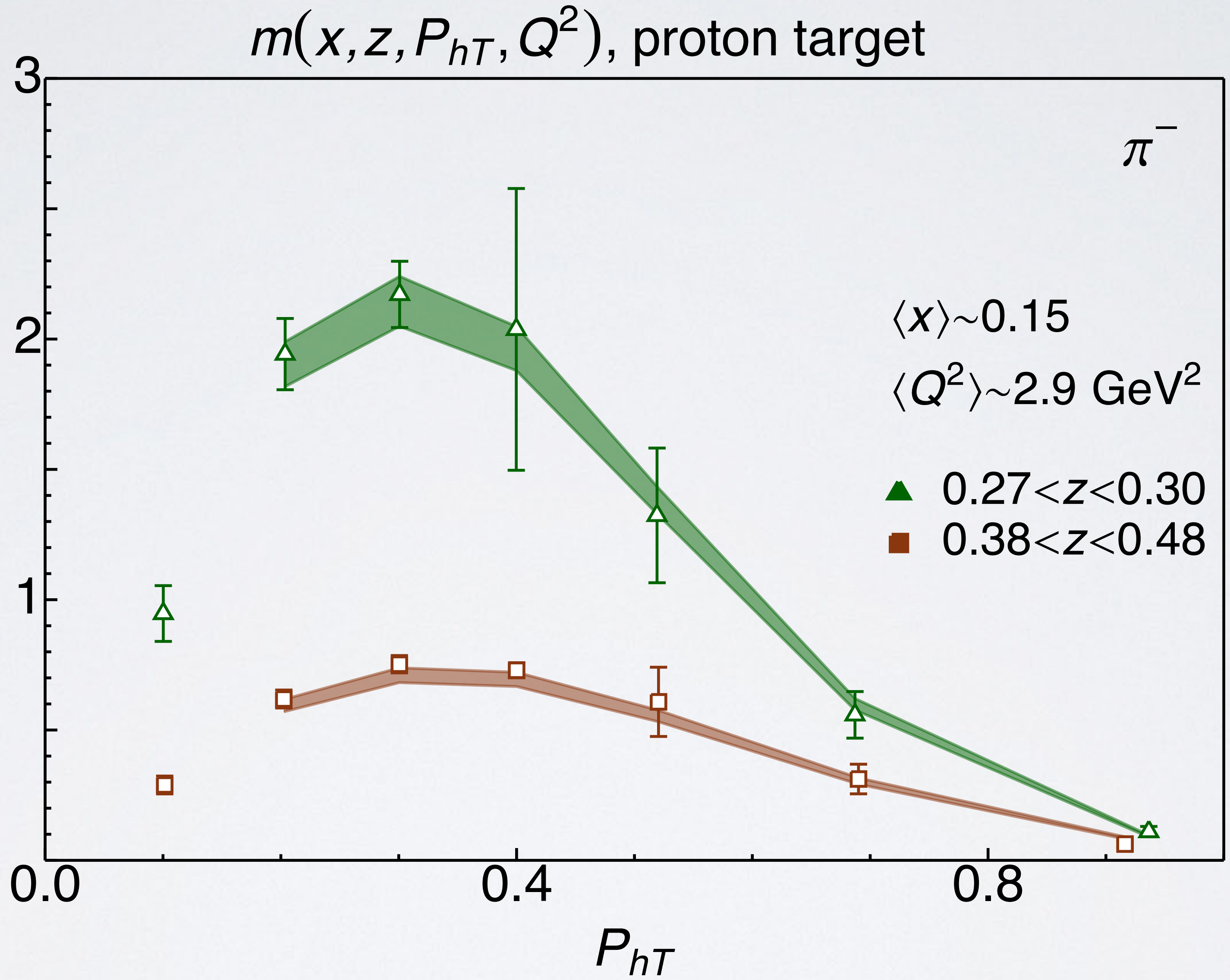
fitting : replica method

$m_{p,\,1-200}^{\pi^-}$



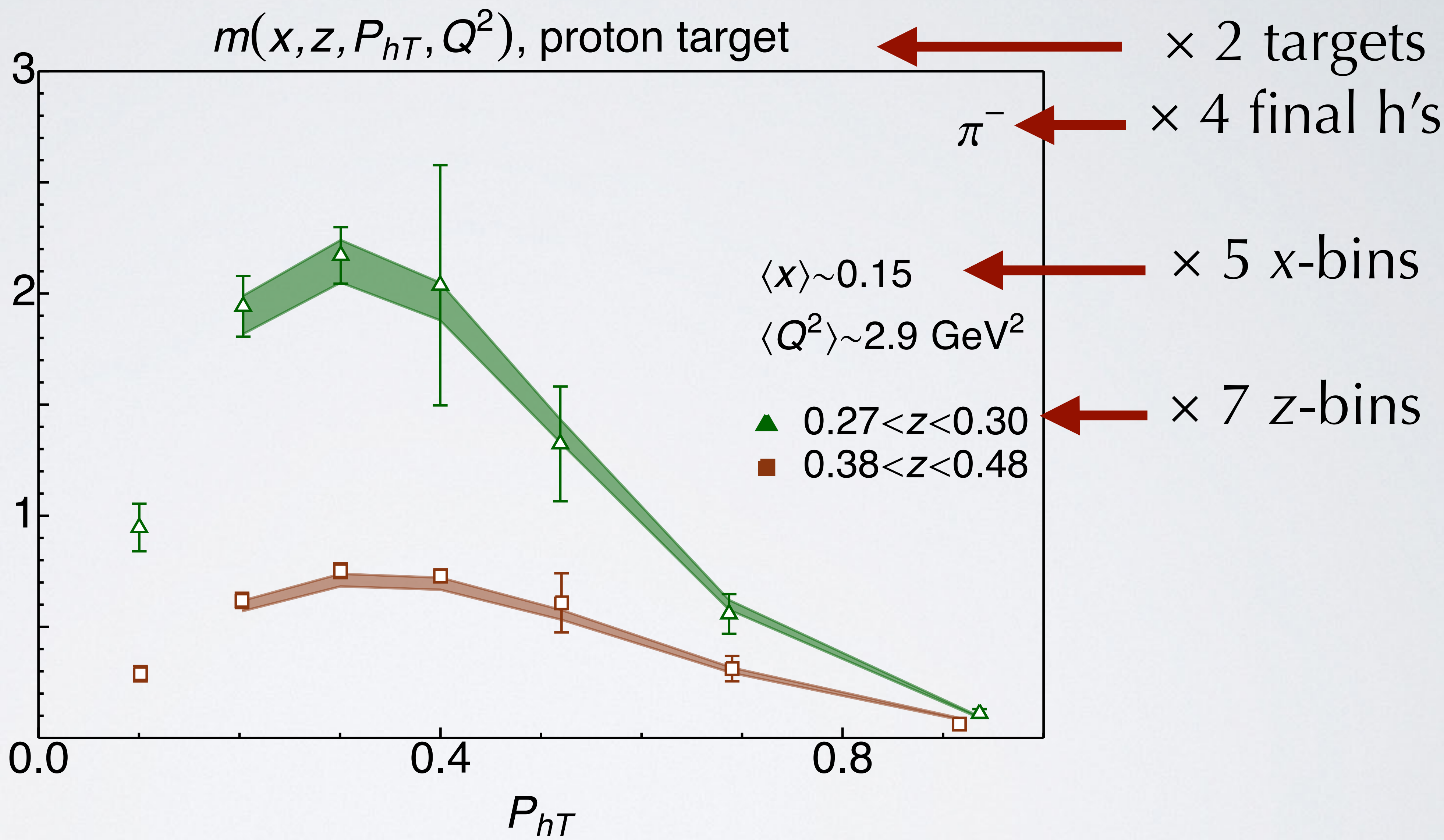
procedure repeated 200 times
(until reproduce mean and std. deviation of original data)

fitting : replica method



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

fitting : replica method



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

quality of the fit

global χ^2 / d.o.f. = 1.63 ± 0.12

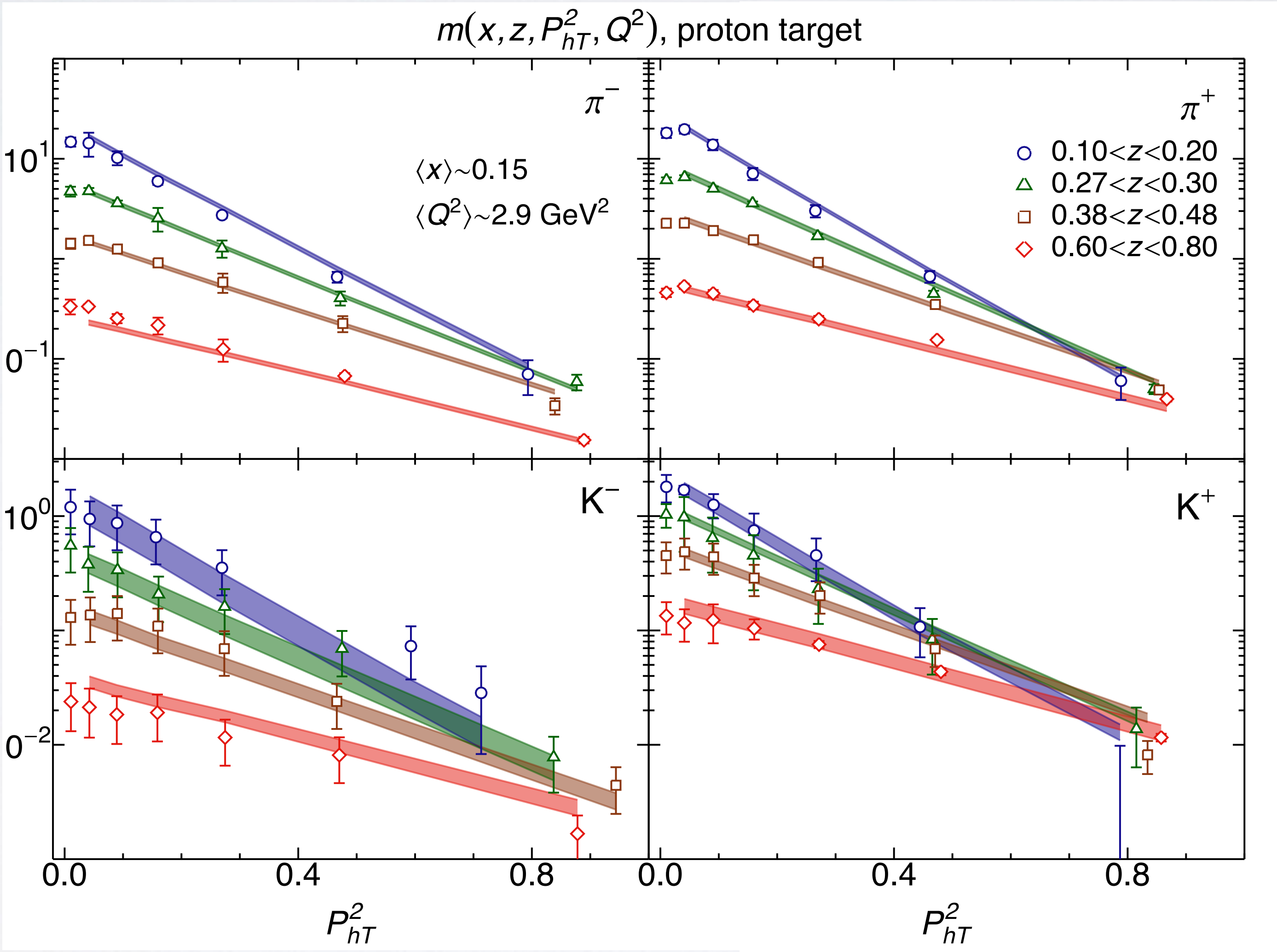
no flavor dep. 1.72 ± 0.11

quality of the fit

global χ^2 / d.o.f. = 1.63 ± 0.12
no flavor dep. 1.72 ± 0.11

proton target

π^-	π^+
1.80 ± 0.27	2.64 ± 0.21
1.83 ± 0.25	2.89 ± 0.23
K^-	K^+
0.78 ± 0.15	0.46 ± 0.07
0.87 ± 0.16	0.43 ± 0.07

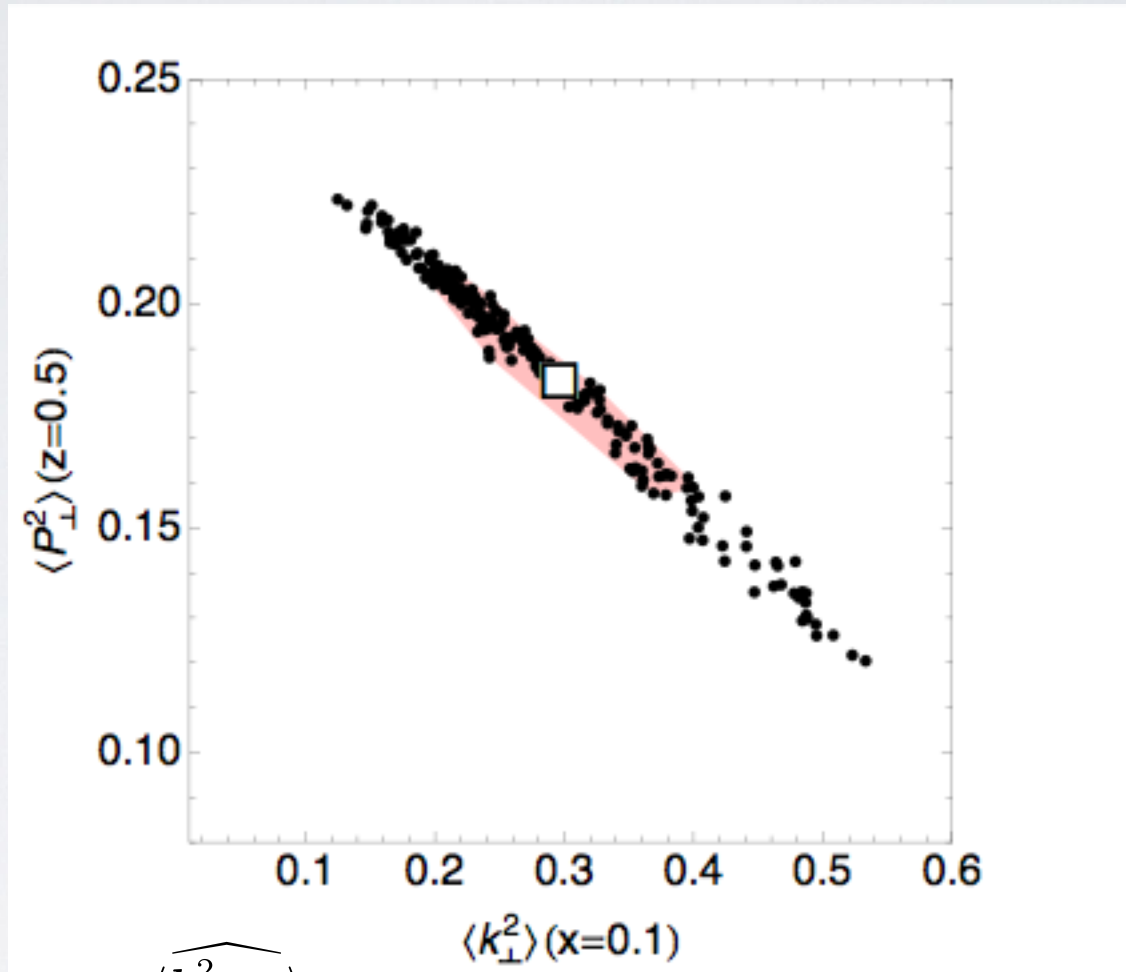


for more details, see JHEP **1311** (2013) 194

Results : **no** flavor dep.

TMD FF

$$\langle \widehat{\boldsymbol{P}^2_{\perp,\,\mathrm{fav}}} \rangle,\ \langle \widehat{\boldsymbol{P}^2_{\perp,\,uK}} \rangle,\ \langle \widehat{\boldsymbol{P}^2_{\perp,\,sK}} \rangle,\ \langle \widehat{\boldsymbol{P}^2_{\perp,\,\mathrm{unfav}}} \rangle \rightarrow \langle \widehat{\boldsymbol{P}^2_{\perp}} \rangle$$



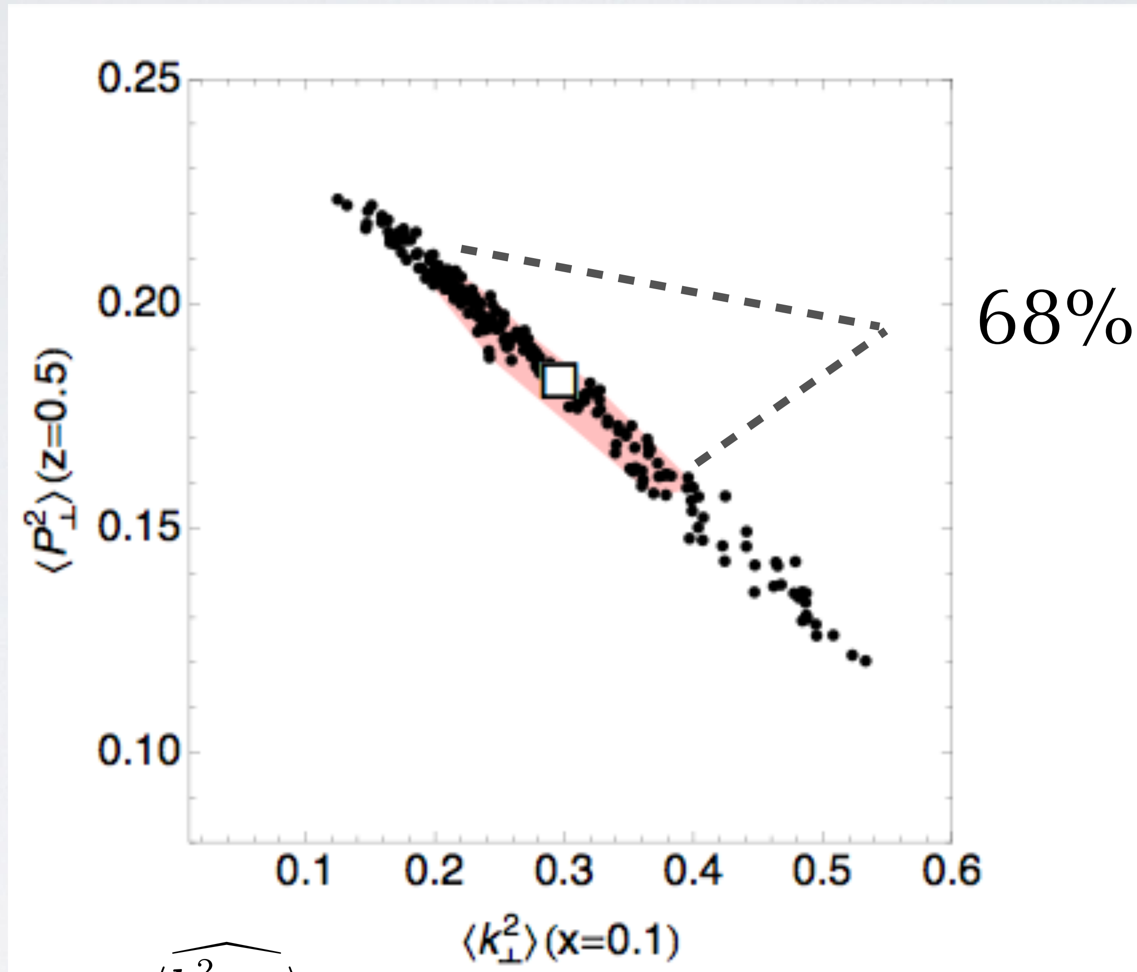
$$\langle \widehat{\boldsymbol{k}^2_{\perp,\,u_v}} \rangle,\ \langle \widehat{\boldsymbol{k}^2_{\perp,\,d_v}} \rangle,\ \langle \widehat{\boldsymbol{k}^2_{\perp,\,\mathrm{sea}}} \rangle \rightarrow \langle \widehat{\boldsymbol{k}^2_{\perp}} \rangle$$

TMD PDF

Results : **no** flavor dep.

TMD FF

$$\langle \widehat{\boldsymbol{P}^2_{\perp,\,\text{fav}}} \rangle,\ \langle \widehat{\boldsymbol{P}^2_{\perp,\,uK}} \rangle,\ \langle \widehat{\boldsymbol{P}^2_{\perp,\,sK}} \rangle,\ \langle \widehat{\boldsymbol{P}^2_{\perp,\,\text{unfav}}} \rangle \rightarrow \langle \widehat{\boldsymbol{P}^2_{\perp}} \rangle$$



68% confidence band

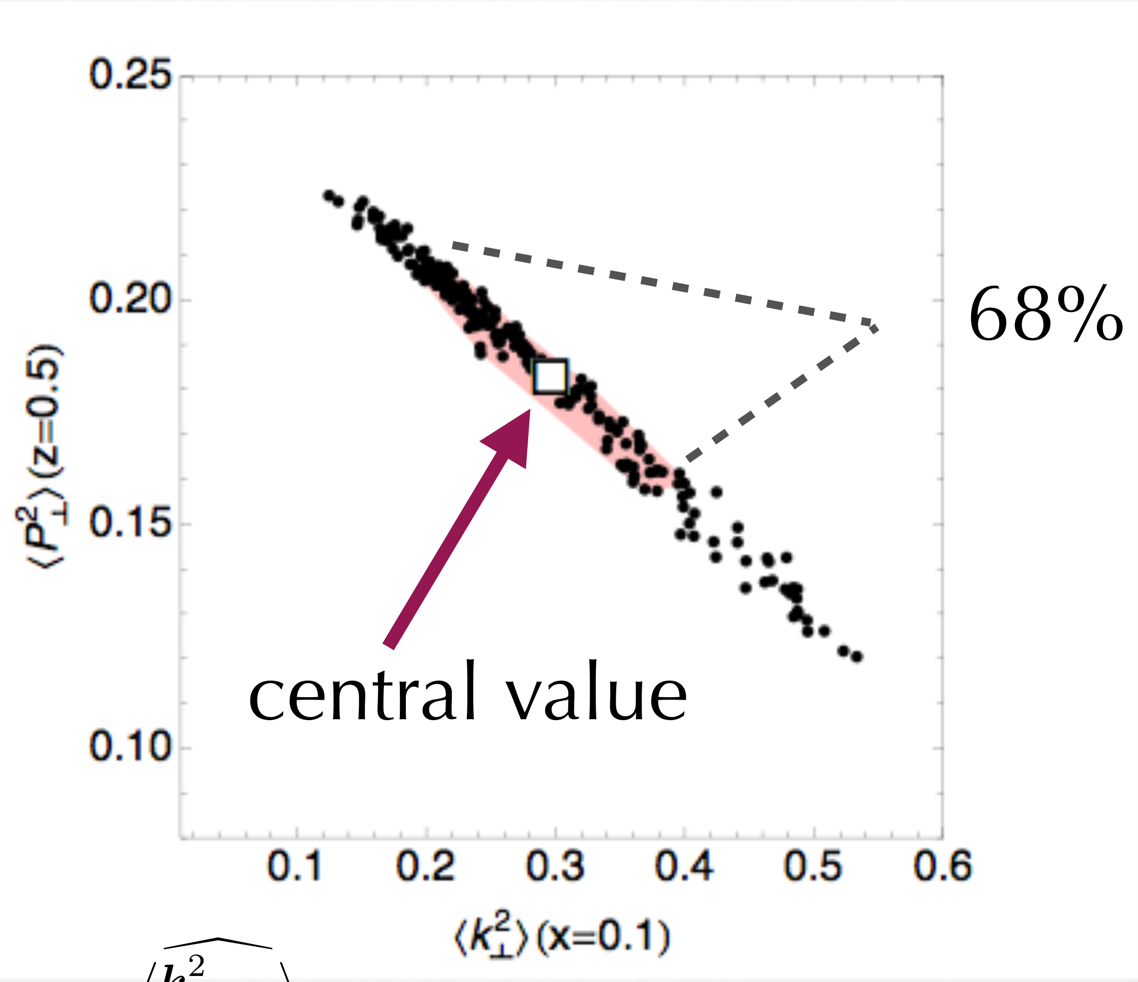
$$\langle \widehat{\boldsymbol{k}^2_{\perp,\,u_v}} \rangle,\ \langle \widehat{\boldsymbol{k}^2_{\perp,\,d_v}} \rangle,\ \langle \widehat{\boldsymbol{k}^2_{\perp,\,\text{sea}}} \rangle \rightarrow \langle \widehat{\boldsymbol{k}^2_{\perp}} \rangle$$

TMD PDF

Results :   **no** flavor dep.

TMD FF

$$\left.\begin{array}{l}\widehat{\langle \boldsymbol{P}^2_{\perp,\,\mathrm{fav}}\rangle}\\ \widehat{\langle \boldsymbol{P}^2_{\perp,\,uK}\rangle}\\ \widehat{\langle \boldsymbol{P}^2_{\perp,\,sK}\rangle}\\ \widehat{\langle \boldsymbol{P}^2_{\perp,\,\mathrm{unfav}}\rangle}\end{array}\right\} \rightarrow \widehat{\langle \boldsymbol{P}^2_{\perp}\rangle}$$



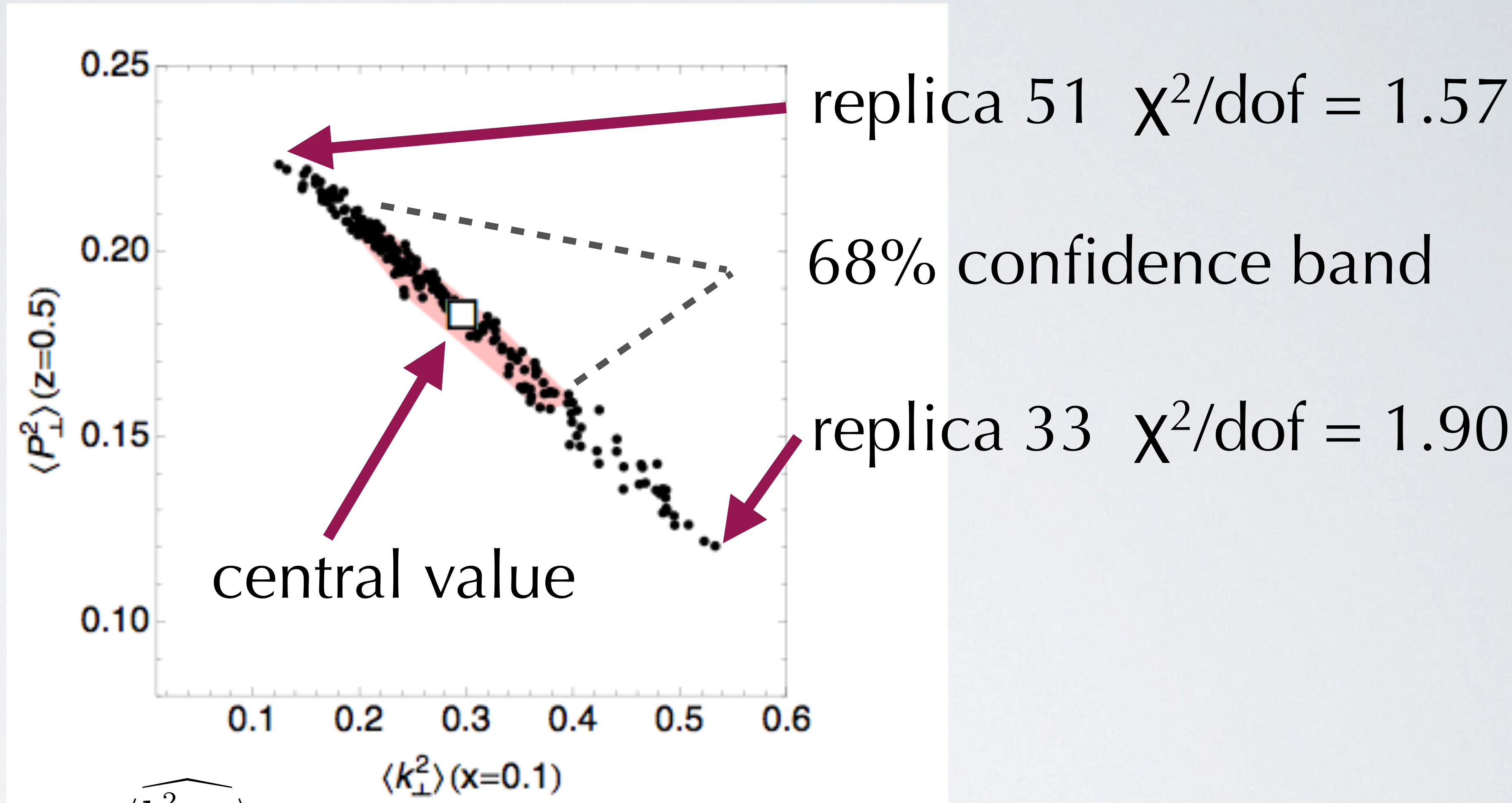
$$\left.\begin{array}{l}\widehat{\langle \boldsymbol{k}^2_{\perp,\,u_v}\rangle}\\ \widehat{\langle \boldsymbol{k}^2_{\perp,\,d_v}\rangle}\\ \widehat{\langle \boldsymbol{k}^2_{\perp,\,\mathrm{sea}}\rangle}\end{array}\right\} \rightarrow \widehat{\langle \boldsymbol{k}^2_{\perp}\rangle}$$

TMD PDF

Results :   **no** flavor dep.

TMD FF

$$\left.\begin{array}{l}\widehat{\langle \boldsymbol{P}^2_{\perp,\,\mathrm{fav}}\rangle} \\ \widehat{\langle \boldsymbol{P}^2_{\perp,\,uK}\rangle} \\ \widehat{\langle \boldsymbol{P}^2_{\perp,\,sK}\rangle} \\ \widehat{\langle \boldsymbol{P}^2_{\perp,\,\mathrm{unfav}}\rangle}\end{array}\right\} \rightarrow \widehat{\langle \boldsymbol{P}^2_{\perp}\rangle}$$



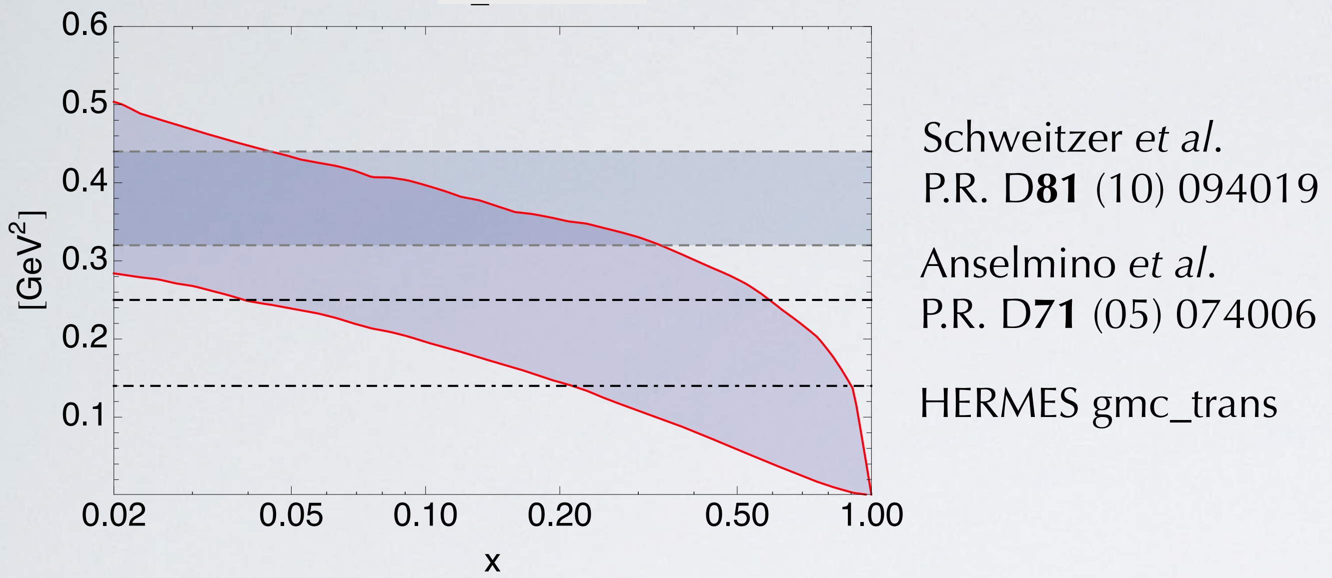
$$\left.\begin{array}{l}\widehat{\langle \boldsymbol{k}^2_{\perp,\,u_v}\rangle} \\ \widehat{\langle \boldsymbol{k}^2_{\perp,\,d_v}\rangle} \\ \widehat{\langle \boldsymbol{k}^2_{\perp,\,\mathrm{sea}}\rangle}\end{array}\right\} \rightarrow \widehat{\langle \boldsymbol{k}^2_{\perp}\rangle}$$

TMD PDF

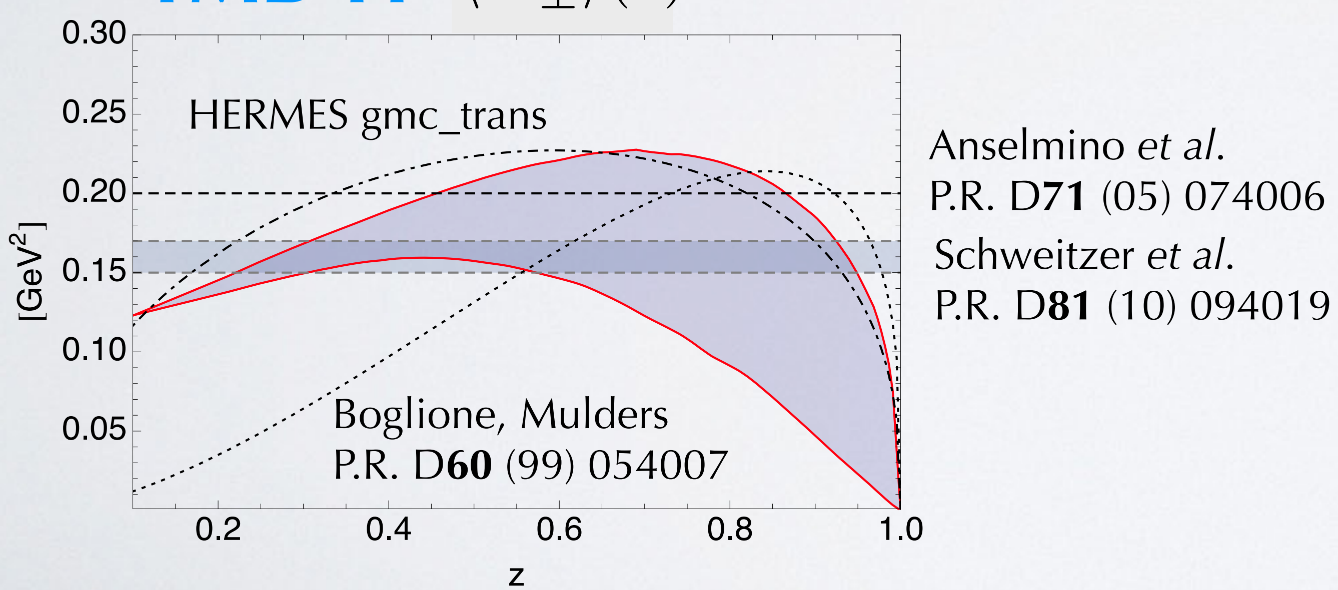
strong anticorrelation between **distribution** and **fragmentation**

anticorrelation and 68% band

TMD PDF $\langle \boldsymbol{k}_\perp^2 \rangle(x)$

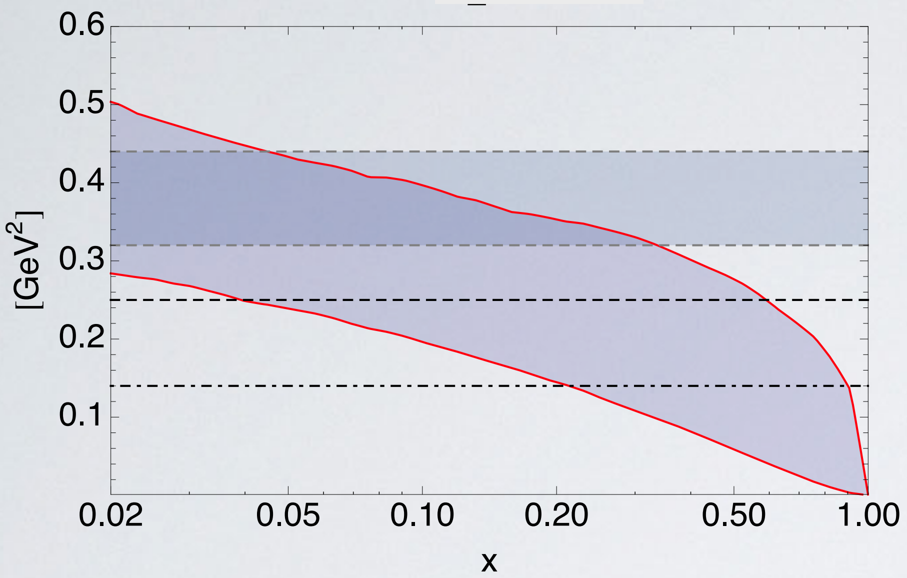


TMD FF $\langle \boldsymbol{P}_\perp^2 \rangle(z)$



anticorrelation and 68% band

TMD PDF $\langle \boldsymbol{k}_\perp^2 \rangle(x)$



Schweitzer *et al.*
P.R. D**81** (10) 094019

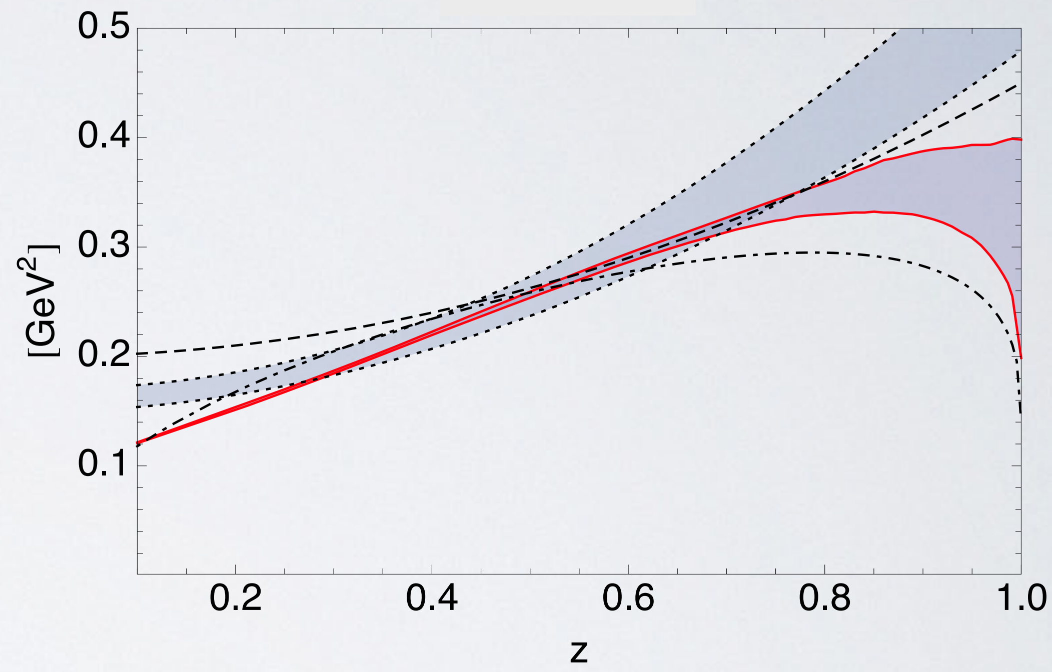
Anselmino *et al.*
P.R. D**71** (05) 074006

HERMES gmc_trans

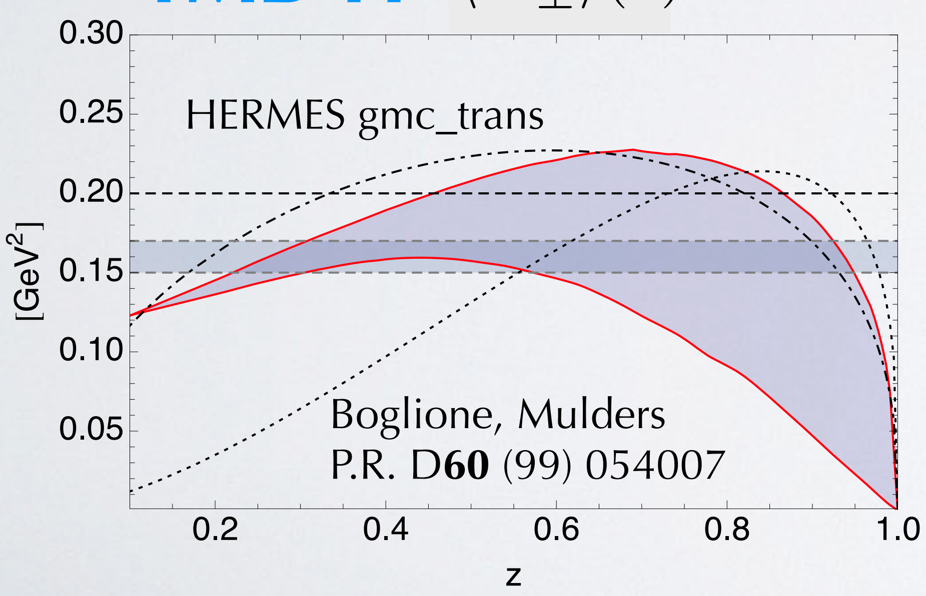
$$\langle \boldsymbol{P}_{hT}^2 \rangle = z^2 \langle \boldsymbol{k}_\perp^2 \rangle + \langle \boldsymbol{P}_\perp^2 \rangle$$

observed

$\langle \boldsymbol{P}_{hT}^2 \rangle(x = 0.1, z)$



TMD FF $\langle \boldsymbol{P}_\perp^2 \rangle(z)$

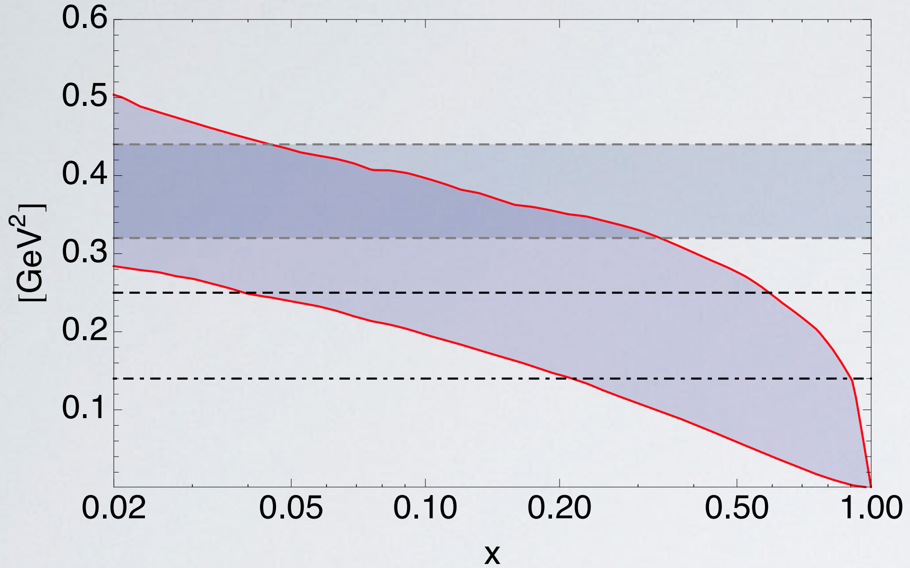


Anselmino *et al.*
P.R. D**71** (05) 074006

Schweitzer *et al.*
P.R. D**81** (10) 094019

anticorrelation and 68% band

TMD PDF $\langle \boldsymbol{k}_\perp^2 \rangle(x)$



Schweitzer *et al.*
P.R. D**81** (10) 094019

Anselmino *et al.*
P.R. D**71** (05) 074006

HERMES gmc_trans

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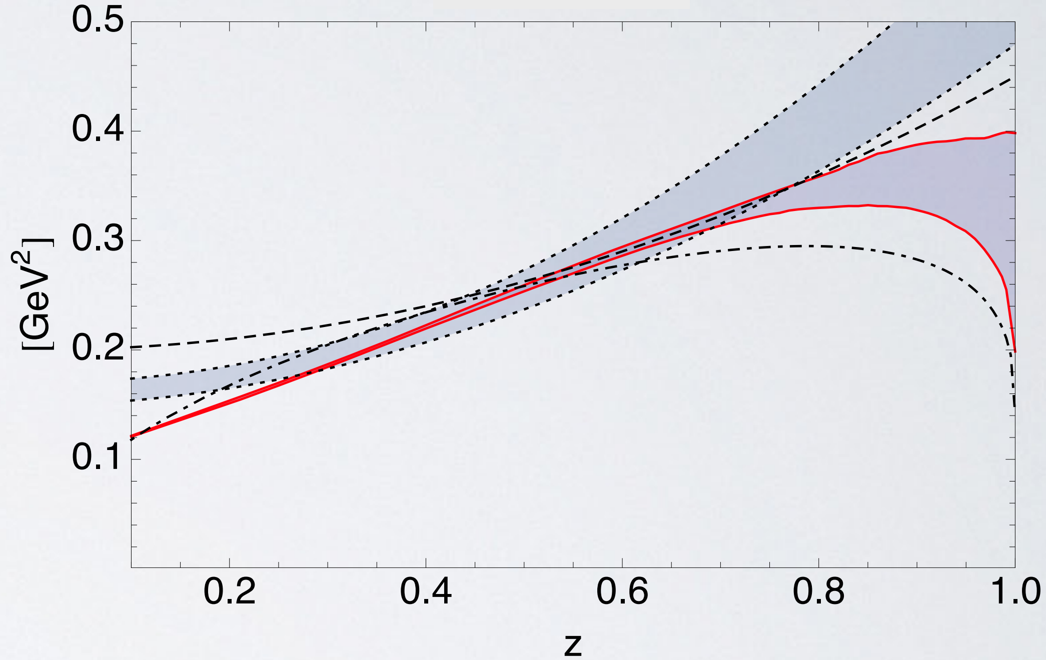
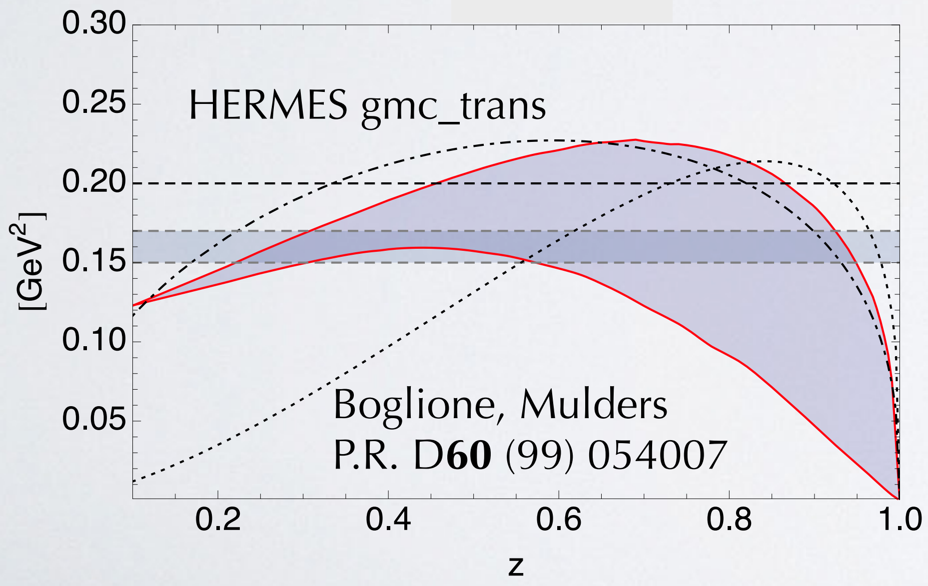
$\langle \boldsymbol{P}_{hT}^2 \rangle(x = 0.1, z)$



$$\langle \boldsymbol{P}_{hT}^2 \rangle = z^2 \langle \boldsymbol{k}_\perp^2 \rangle + \langle \boldsymbol{P}_\perp^2 \rangle$$

TMD FF $\langle \boldsymbol{P}_\perp^2 \rangle(z)$



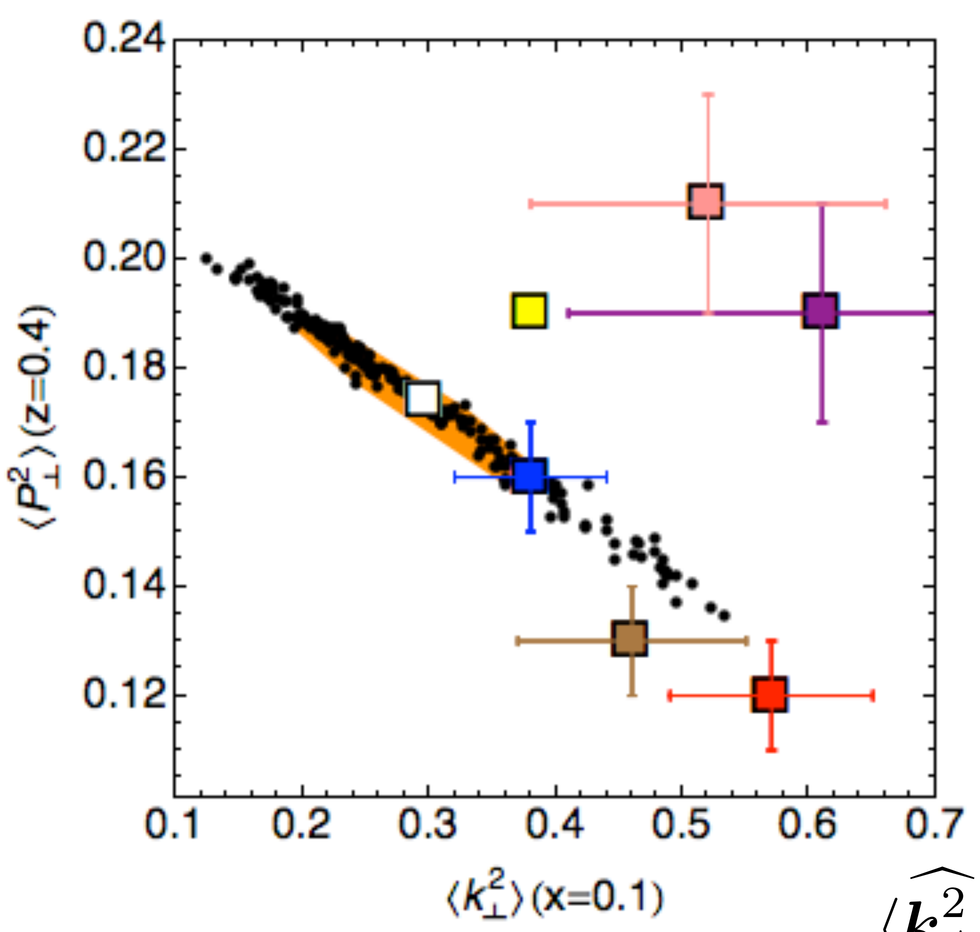
Anselmino *et al.*
P.R. D**71** (05) 074006

Schweitzer *et al.*
P.R. D**81** (10) 094019

several $\{\boldsymbol{k}_\perp, \boldsymbol{P}_\perp\}$
give same $\boldsymbol{P}_{hT}$

Comparison with other results

TMD FF $\langle \widehat{\boldsymbol{P}_\perp^2} \rangle$



$\langle \widehat{\boldsymbol{k}_\perp^2} \rangle$ TMD PDF

JHEP**1311** (2013) 194

this work

Schweitzer, Teckentrup, Metz

P.R.D**81** (2010) 094019

Anselmino et al., HERMES

" " " , high *z*

Anselmino et al., COMPASS

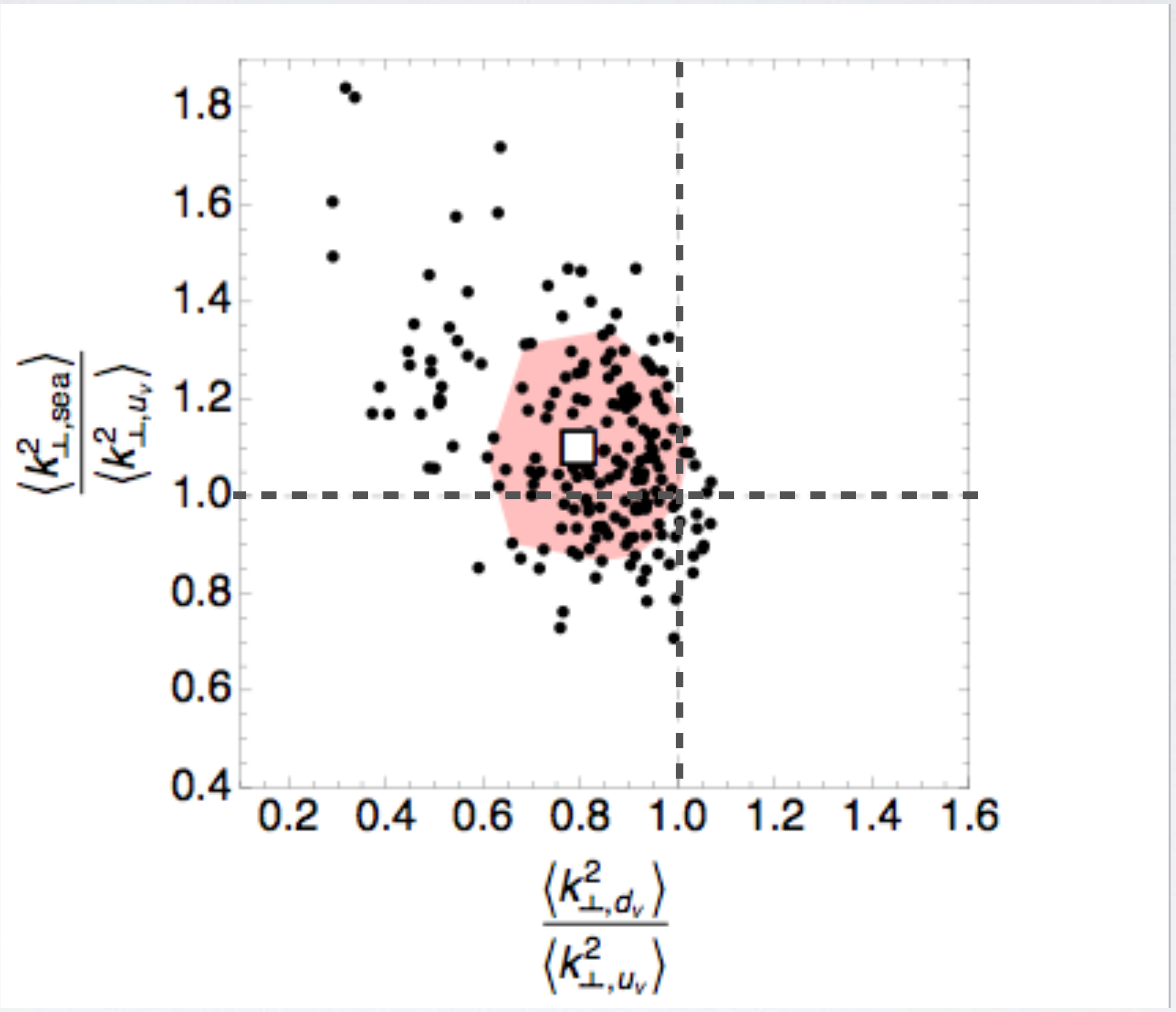
" " , high *z*, *y*-norm

JHEP**1404** (2014) 005

Echevarria, Idilbi, Kang, Vitev

P.R.D**89** (2014) 074013

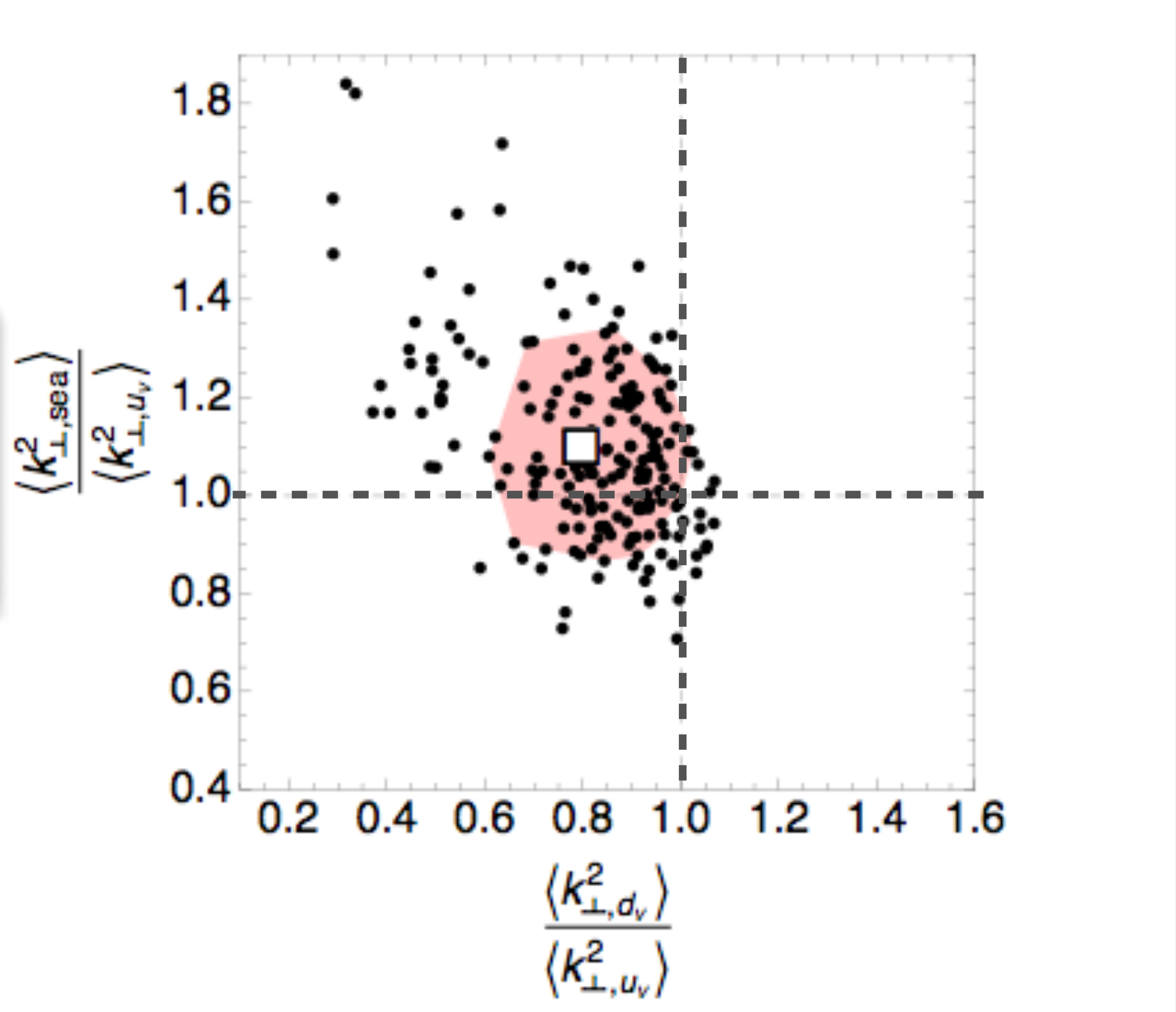
TMD PDF **with** flavor dep.



point of
no flavor dep.

TMD PDF **with** flavor dep.

most of the time
sea **wider than** up



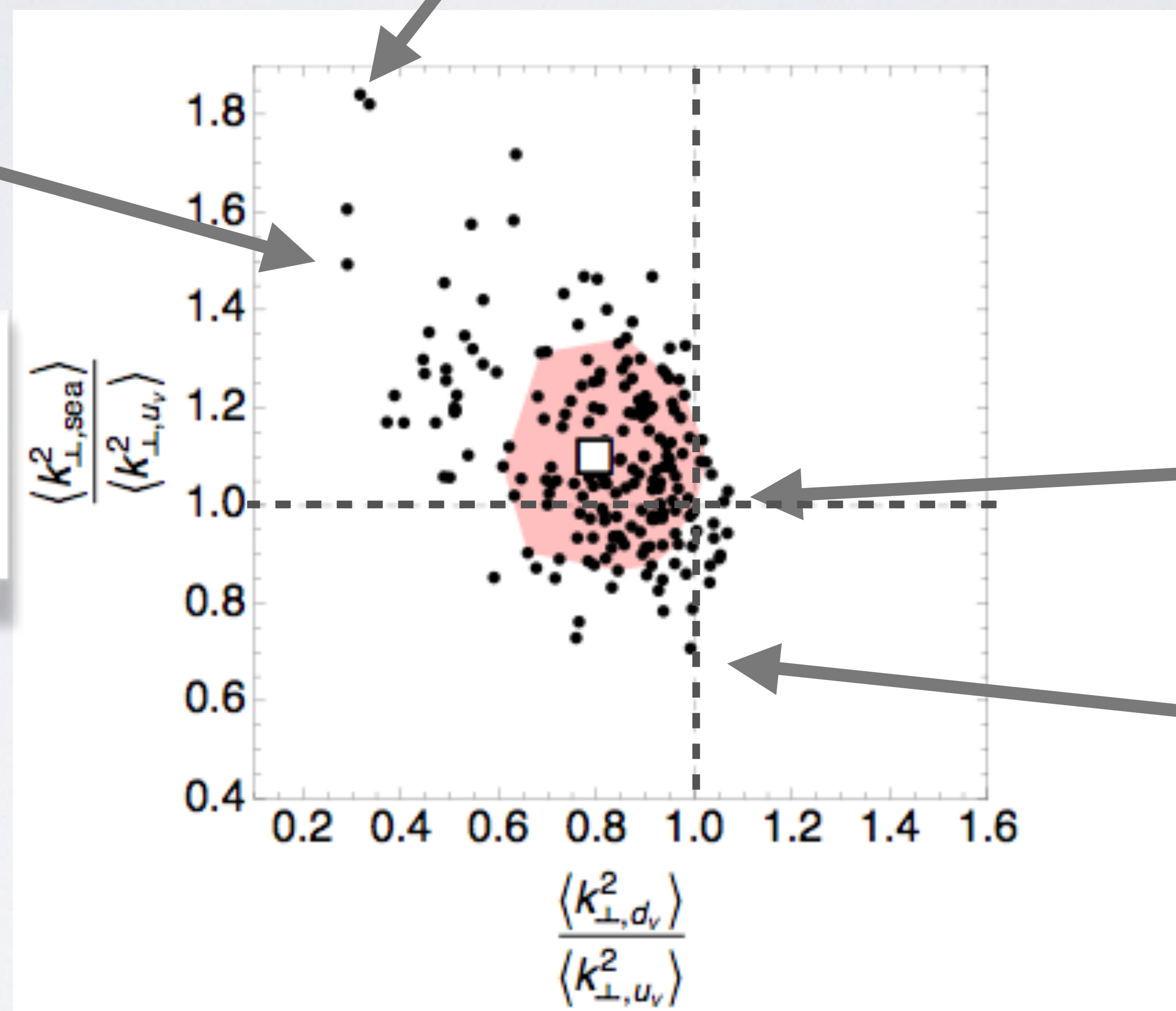
point of
no flavor dep.

most of the time
down **narrower than** up

TMD PDF **with** flavor dep.

replica 149
χ^2/dof = 1.87

replica 73
χ^2/dof = 1.70



most of the time
sea **wider than** up

replica 130
χ^2/dof = 1.77

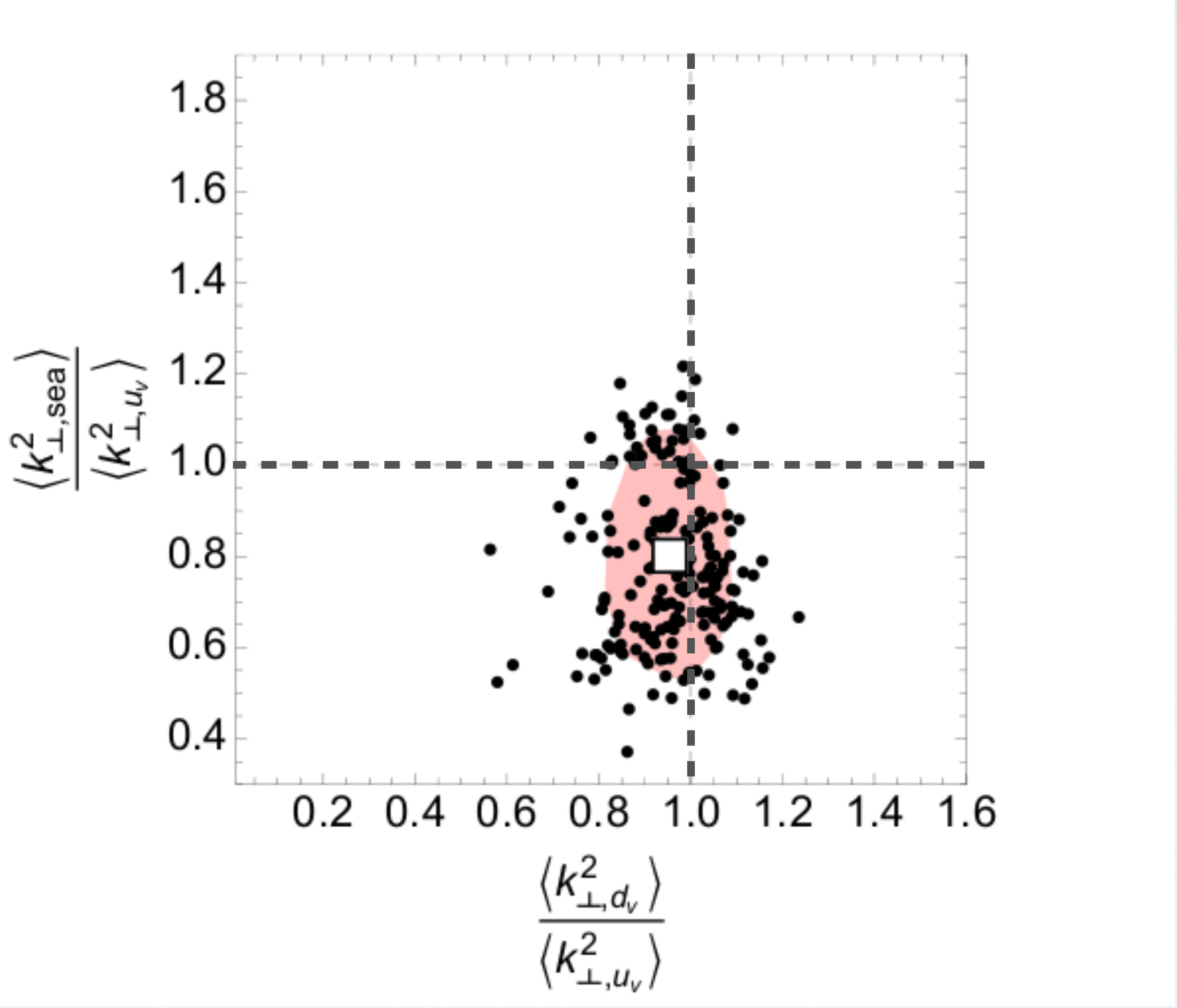
replica 186
χ^2/dof = 1.38

point of
no flavor dep.

most of the time
down **narrower than** up

TMD PDF **with** flavor dep.

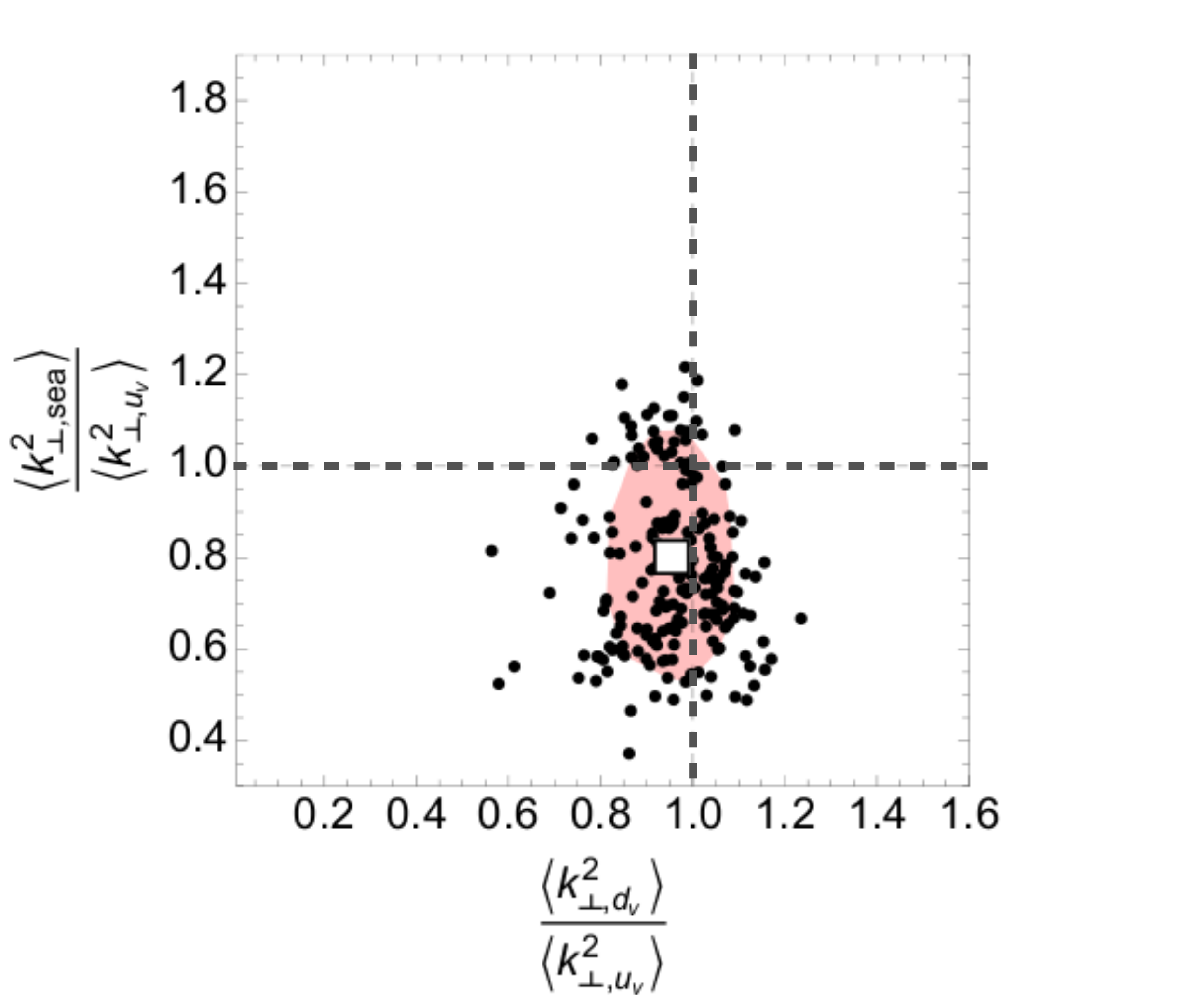
no Kaon data



point of
no flavor dep.

TMD PDF **with** flavor dep.

no Kaon data

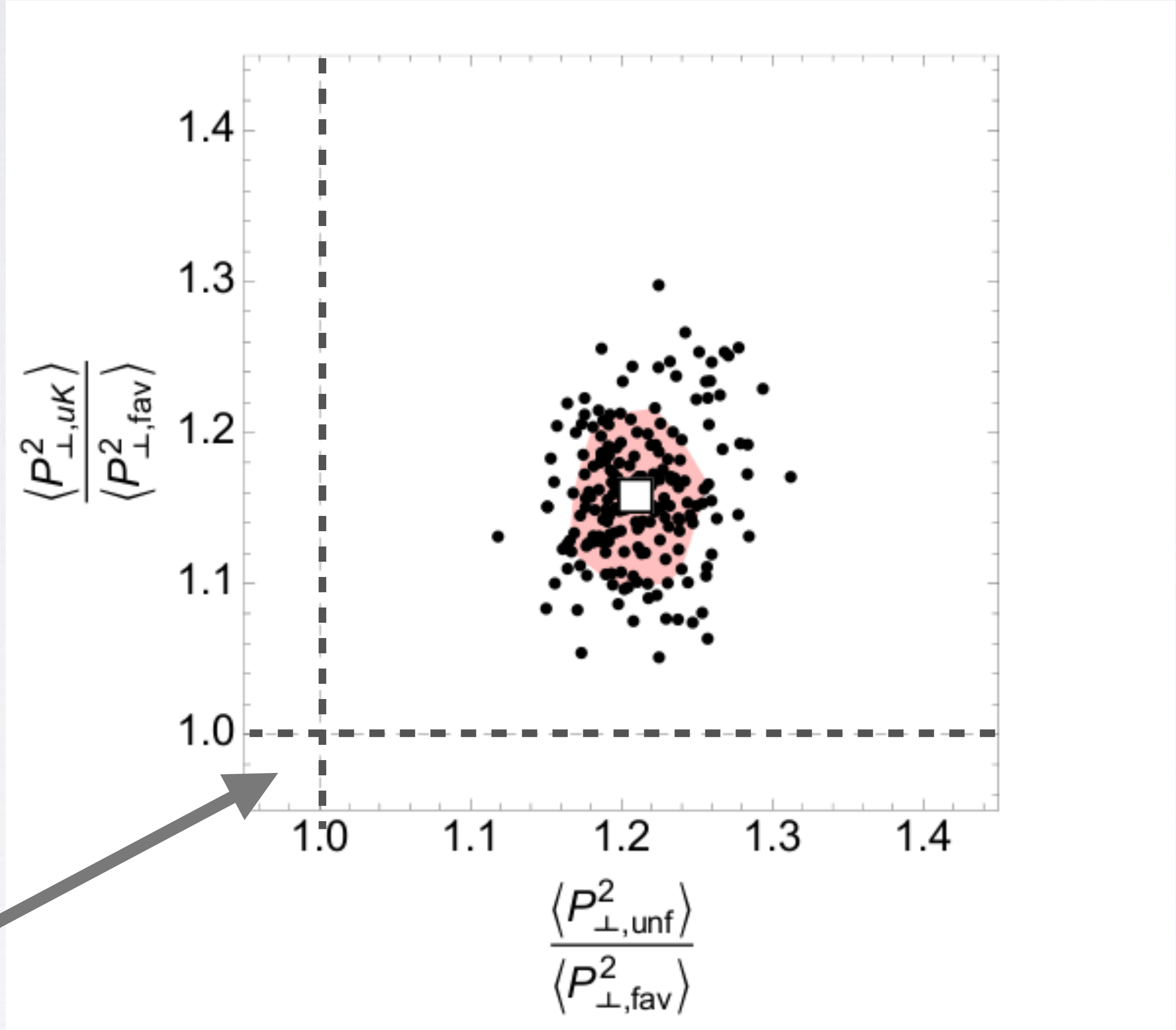


point of
no flavor dep.

$s, \bar{s}$ are important

TMD FF **with** flavor dep.

$q \rightarrow K$ favored
wider than
$q \rightarrow \pi$ favored



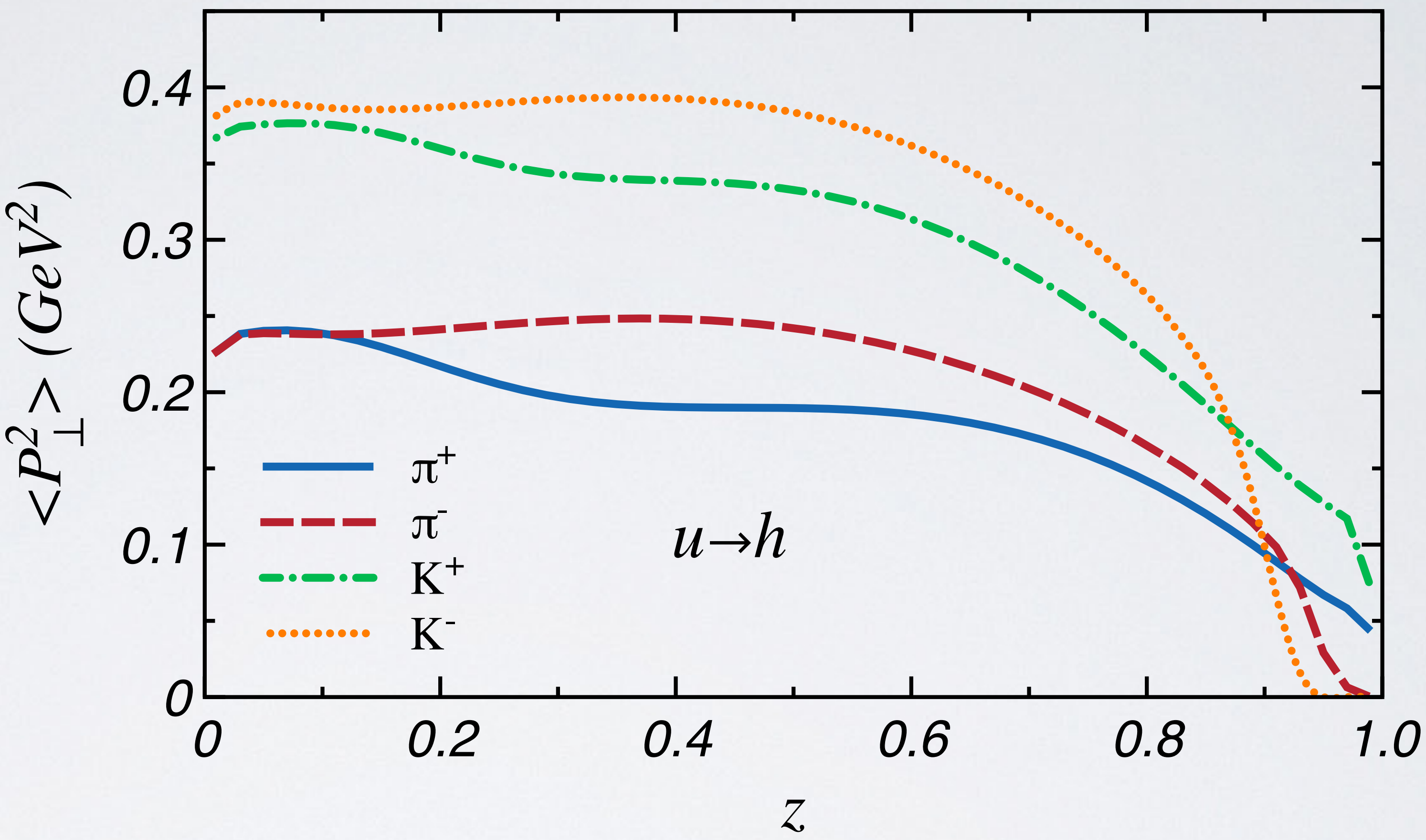
point of
no flavor dep.

unfavored
wider than
$q \rightarrow \pi$ favored

confirmed in "model MC" of **TMD FF**

NJL-jet model

Matevosyan *et al.*,
P. R. D**85** (12) 014021



$<\boldsymbol{P}_{hT}{}^2>$ unfavored / K fragmentation
wider than favored π fragmentation

unpol. TMD and Spin Asymmetries

example: the Sivers effect in SIDIS

$$A_{UT}^{\sin(\phi_h - \phi_S)} \propto \frac{\sum_q e_q^2 \left[\left(-\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_\perp}{M}\right) f_{1T}^{\perp,q}\right] \otimes D_1^q}{\sum_q e_q^2 \, f_1^q \otimes D_1^q}$$

unpol. TMD and Spin Asymmetries

example: the Sivers effect in SIDIS

$$A_{UT}^{\sin(\phi_h-\phi_S)} \propto \frac{\sum_q e_q^2 \left[\left(-\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_\perp}{M}\right) f_{1T}^{\perp,q}\right] \otimes D_1^q}{\boxed{\sum_q e_q^2\, f_1^q \otimes D_1^q}}$$

unpol. TMD can affect the extraction of $f_{1T}{}^{\perp}$
and, in general, of polarized TMD

Summary

fit hermes SIDIS multiplicities with TMD described by

1. flavor-dependent Gaussians

2. **TMD PDF** width $\langle \boldsymbol{k}_{\perp}^{2} \rangle (x)$ with **5** parameters

3. **TMD FF** width $\langle \boldsymbol{P}_{\perp}^{2} \rangle (z)$ with **7** parameters

4. error treatment using replica method

5. no evolution with hard scale

Results

1. **TMD FF** clear indication of $q \to K$ fav. wider $q \to \pi$ fav.
unfav. wider " "
$\langle \boldsymbol{P}_\perp^2 \rangle\,(z)$

2. **TMD PDF** most of time sea wider u_v wider d_v
hints of $\langle \boldsymbol{k}_\perp^2 \rangle\,(x)$
(large uncertainties but lot of room for flavor dep.)
importance of K data and s

3. flavor-indep. fit not ruled out, but limited by anticorrelation

4. Hermes is not sensitive to evolution
Compass is, but not enough to fix nonpert. evol. kernel (Torino analysis)

Results

1. **TMD FF** clear indication of $q \to K$ fav. wider $q \to \pi$ fav.
   unfav. wider " "
   $\langle P_\perp^2 \rangle$ (z)

2. **TMD PDF** most of time sea wider u_v wider d_v
   hints of $\langle \boldsymbol{k}_\perp^2 \rangle$ (x)
   (large uncertainties but lot of room for flavor dep.)
   importance of K data and s

3. flavor-indep. fit not ruled out, but limited by anticorrelation

4. Hermes is not sensitive to evolution
   Compass is, but not enough to fix nonpert. evol. kernel (Torino analysis)

SIDIS not enough to fix TMD $\Rightarrow$ consider e^+e^-
(next talk)