Extracting GPDs from DVCS data: Border and skewness functions at LO

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NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

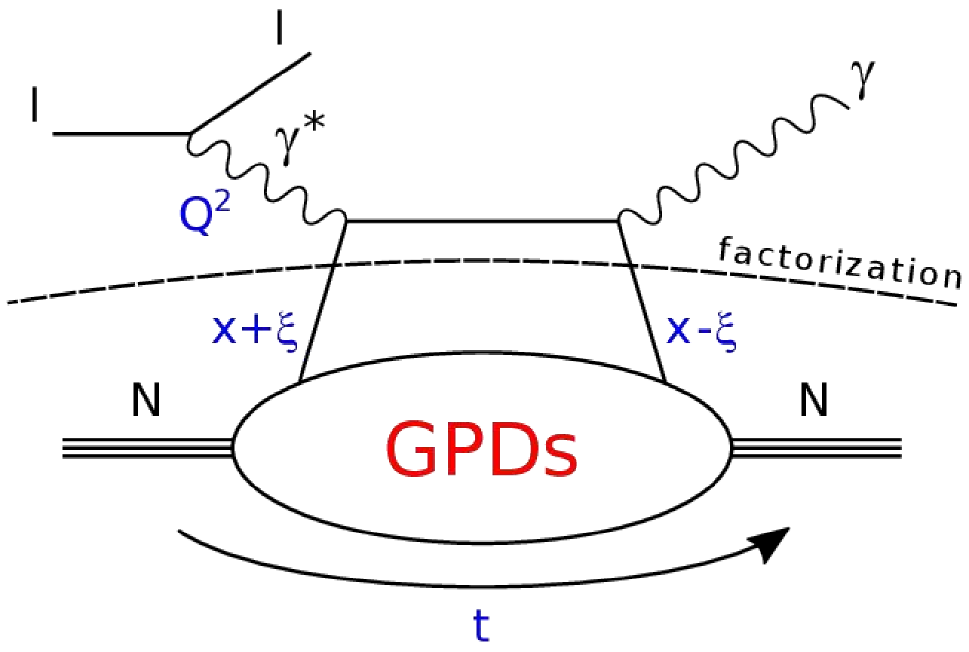
PARTONS

JLab Theory seminar
August 20, 2018

Outline

- Introduction
- PARTONS project
- Global analysis of DVCS
- Summary

Deeply Virtual Compton Scattering (DVCS)

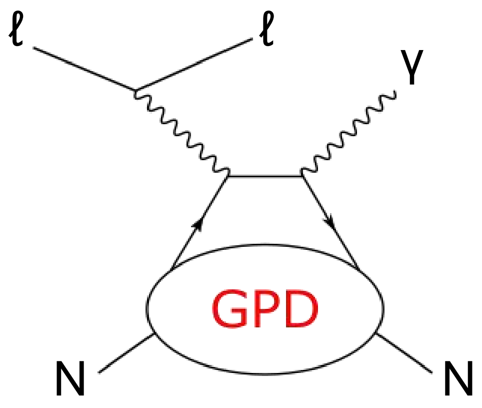


factorization for |t|/Q² ≪ 1

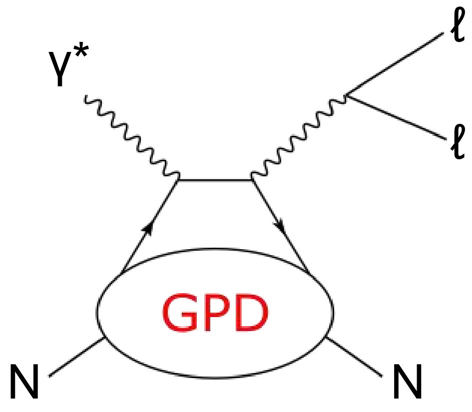
Chiral-even GPDs:
(helicity of parton conserved)

$H^{q,g}(x,\xi,t)$	$E^{q,g}(x,\xi,t)$	*for sum over parton helicities*
$\widetilde{H}^{q,g}(x,\xi,t)$	$\widetilde{E}^{q,g}(x,\xi,t)$	*for difference over parton helicities*
nucleon helicity conserved	*nucleon helicity changed*	

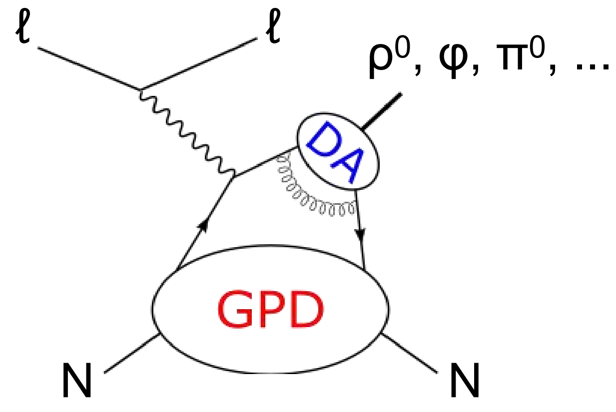
GPDs accessible in various production channels and observables
→ experimental filters



DVCS
Deeply Virtual Compton Scattering



TCS
Timelike Compton Scattering



HEMP
Hard Exclusive Meson Production

more production channels sensitive to GPDs exist!

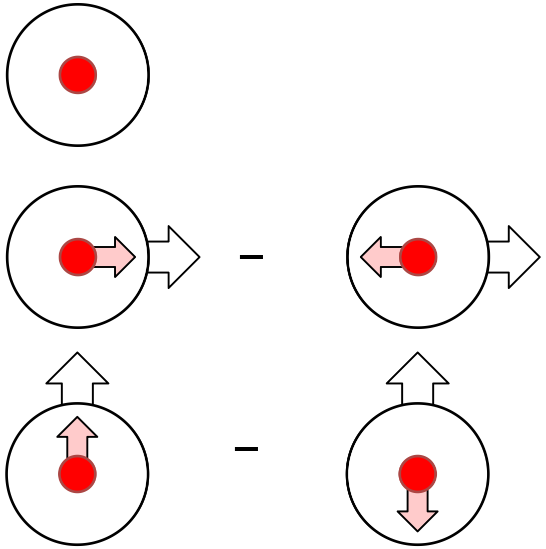
Introduction

- Reduction to PDFs:

$$H^q(x,0,0) \equiv q(x)$$

$$\widetilde{H}^q(x,0,0) \equiv \Delta q(x)$$

$$H_T^q(x,0,0) \equiv h_1(x)$$



no corresponding relations exist for other GPDs

- Reduction to Elastic Form Factors (EFFs):

$$\int_{-1}^{1} H^q(x,\xi,t) \equiv F_1^q(t) \qquad \int_{-1}^{1} E^q(x,\xi,t) \equiv F_2^q(t)$$

$$\int_{-1}^{1} \widetilde{H}^q(x,\xi,t) \equiv g_A^q(t) \qquad \int_{-1}^{1} \widetilde{E}^q(x,\xi,t) \equiv g_P^q(t)$$

Polynomiality - non-trivial consequence of Lorentz invariance:

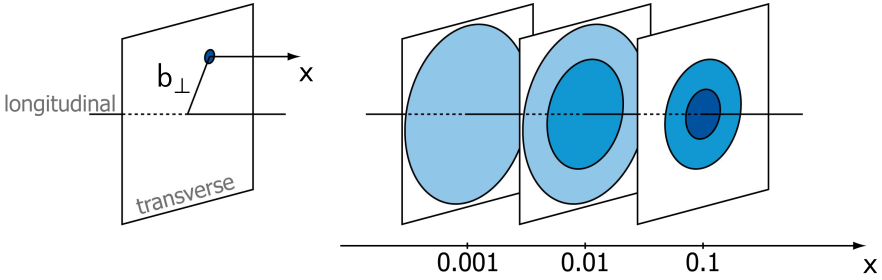
$$\int_{-1}^{1} \mathrm{d}x \; x^n H^q(x,\xi,t) = h_0^{q,n}(t) + \xi^2 h_2^{q,n}(t) + \ldots + \mathrm{mod}(n,2)\xi^{n+1} h_{n+1}^{q,n}(t)$$

$$\int_{-1}^{1} \mathrm{d}x \; x^n \widetilde{H}^q(x,\xi,t) = \tilde{h}_0^{q,n}(t) + \xi^2 \tilde{h}_2^{q,n}(t) + \ldots + \mathrm{mod}(n+1,2)\xi^{n} \tilde{h}_{n}^{q,n}(t)$$

strong constraint on GPD parameterizations

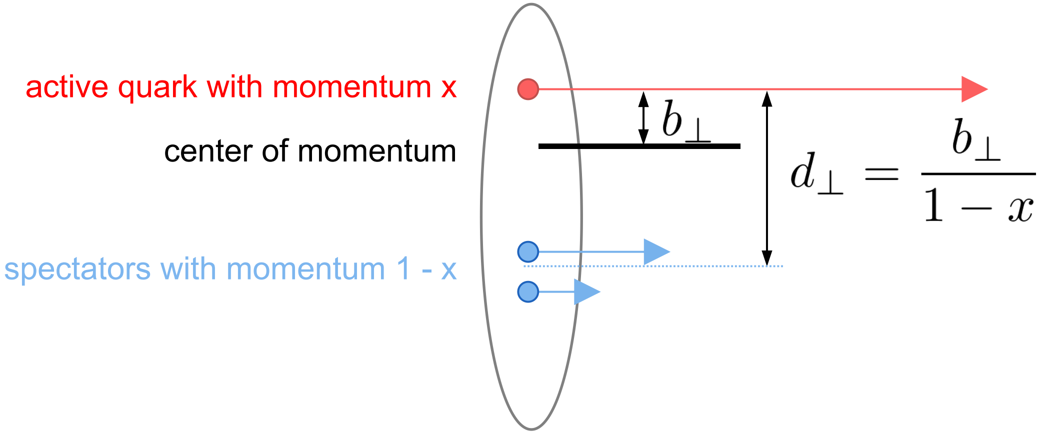
- Nucleon tomography

$$q(x, \mathbf{b}_\perp) = \int \frac{d^2\mathbf{\Delta}}{4\pi^2} e^{-i\mathbf{b}_\perp \cdot \mathbf{\Delta}} H^q(x, 0, t = -\mathbf{\Delta}^2)$$



- Study of long. polarization with GPD $\widetilde{H}$
- Study of distortion in transv. polarized nucleon with GPD E

- Impact parameter $\mathbf{b}_\perp$ defined w.r.t. center of momentum, such as $\sum x\, \mathbf{b}_\perp = 0$



Inequalities:

$$|\Delta q(x, \mathbf{b}_\perp)| \leq q(x, \mathbf{b}_\perp)$$

$$\frac{\mathbf{b}_\perp^2}{m^2} \left(\frac{\partial}{\partial \mathbf{b}_\perp^2} e(x, \mathbf{b}_\perp) \right)^2 \leq (q(x, \mathbf{b}_\perp) + \Delta q(x, \mathbf{b}_\perp)) \times (q(x, \mathbf{b}_\perp) - \Delta q(x, \mathbf{b}_\perp))$$

to avoid violation of the positivity in the impact parameter space

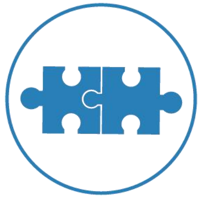
Energy momentum tensor in terms of form factors:

$$\langle p', s' | \widehat{T}^{\mu\nu} | p, s \rangle = \bar{u}(p', s') \left[\frac{P^\mu P^\nu}{M} A(t) + \frac{\Delta^\mu \Delta^\nu - \eta^{\mu\nu} \Delta^2}{M} C(t) + M \eta^{\mu\nu} \bar{C}(t) + \frac{P^\mu i \sigma^{\nu\lambda} \Delta_\lambda}{4M} [A(t) + B(t) + D(t)] + \frac{P^\nu i \sigma^{\mu\lambda} \Delta_\lambda}{4M} [A(t) + B(t) - D(t)] \right] u(p, s)$$

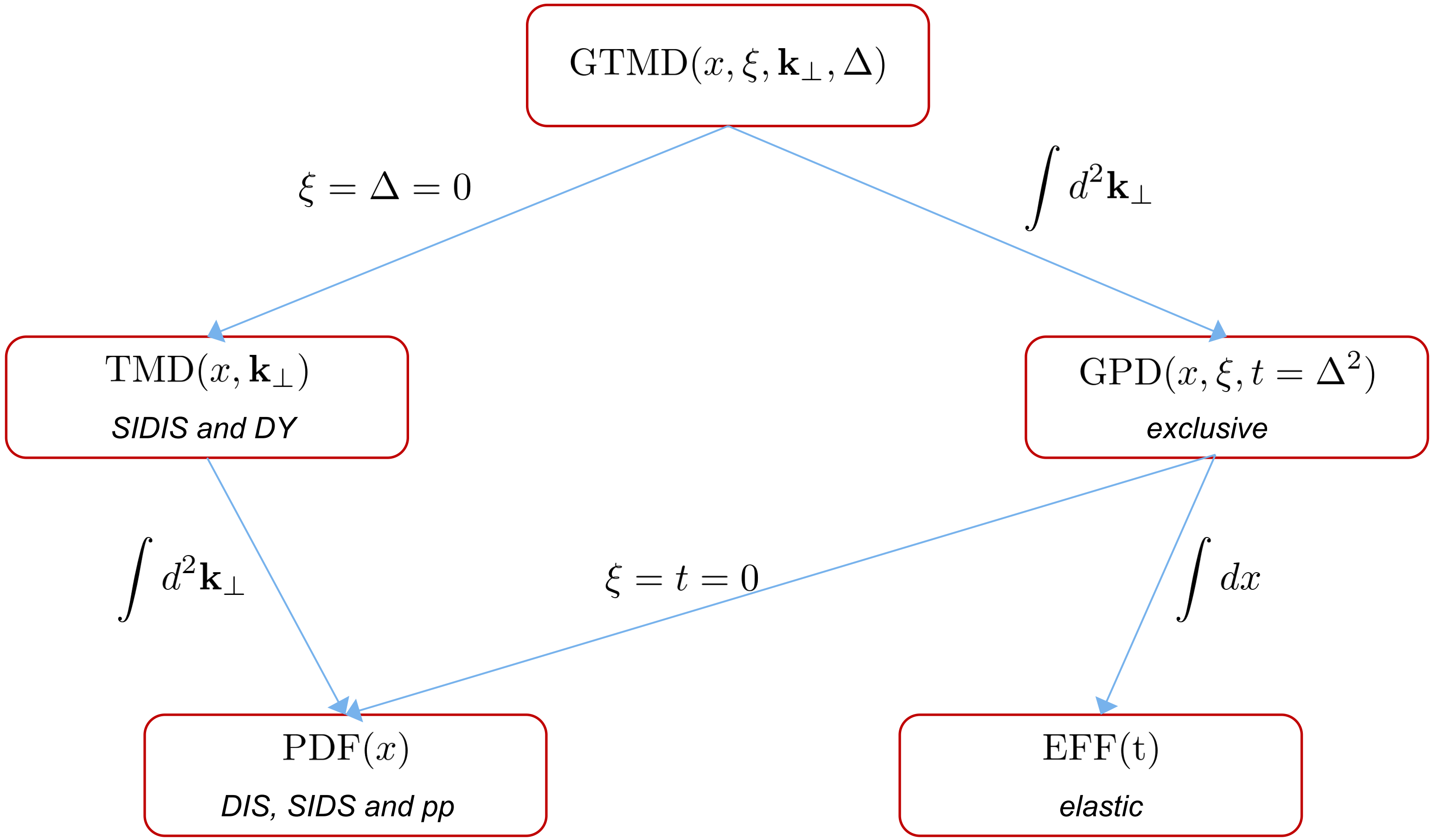
Access to total angular momentum and forces acting on quarks

$$A^q(0) + B^q(0) = \int_{-1}^{1} x \left[H^q(x, \xi, 0) + E^q(x, \xi, 0) \right] = 2J^q$$

1/2



Ji's sum rule



$\mathrm{GTMD}(x, \xi, \mathbf{k}_\perp, \Delta)$
$\xi = \Delta = 0$
$\int d^2\mathbf{k}_\perp$
$\mathrm{TMD}(x, \mathbf{k}_\perp)$
SIDIS and DY
$\mathrm{GPD}(x, \xi, t = \Delta^2)$
exclusive
$\int d^2\mathbf{k}_\perp$
$\xi = t = 0$
$\int dx$
$\mathrm{PDF}(x)$
DIS, SIDS and pp
$\mathrm{EFF}(\mathrm{t})$
elastic

Analysis

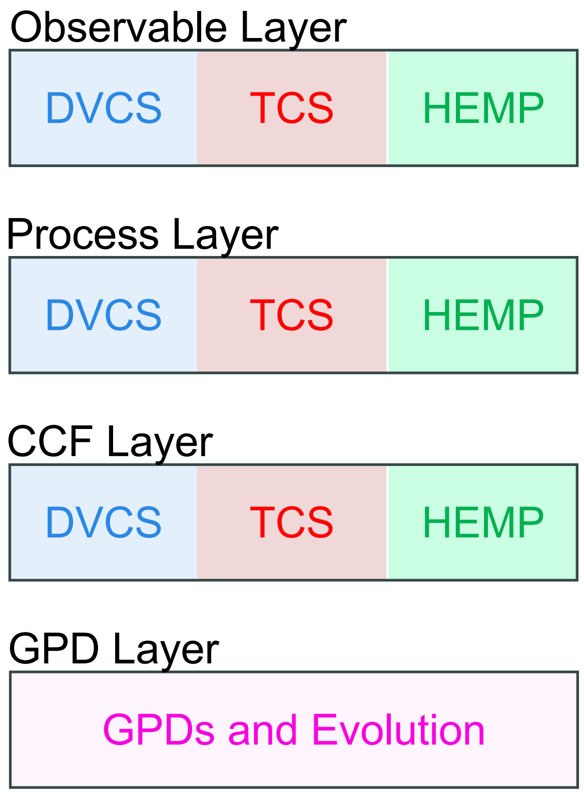
H. Moutarde, P. S., J. Wagner "*Border and skewness functions from a leading order fit to DVCS data*"
arXiv:1807.07620 [hep-ph]

Goal: global extraction of Compton Form Factors (CFFs) from DVCS data using LO/LT formalism

Analysis done within PARTONS project

PARTONS project

- PARTONS - platform to study GPDs
- Come with number of available physics developments implemented
- Addition of new developments as easy as possible
- To support effort of GPD community
- Can be used by both theorists and experimentalists



- More info in: Eur. Phys. J. C78 (2018) 6, 478

  http://partons.cea.fr

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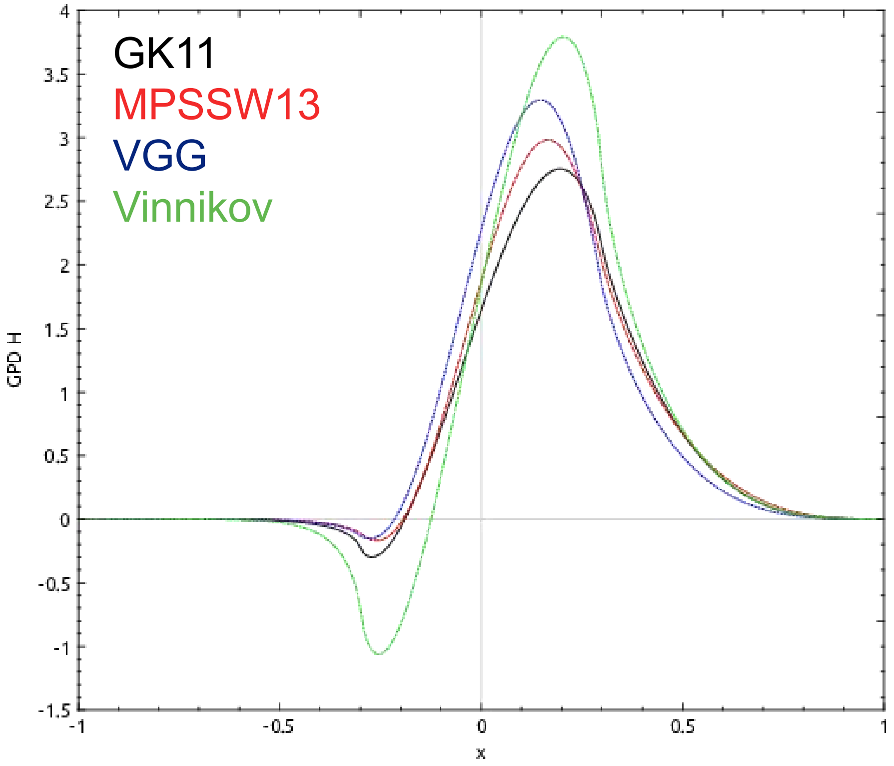
H^u @ $x = 0.2$, $t = -0.1$ GeV^2, $\mu_F^2 = \mu_R^2 = 2$ GeV^2



Compton Form Factors

- imaginary part $Im\mathcal{G}(\xi,t) \quad = \pi G^{(+)}(\xi,\xi,t) = \pi \sum_q e_q^2 G^{q(+)}(\xi,\xi,t)$

$$G^{q(+)}(x,\xi,t) = G^q(x,\xi,t) \mp G^q(-x,\xi,t)$$
$$G^{q(+)}(\xi,\xi,t) = G^{q_{\mathrm{val}}}(\xi,\xi,t) + 2G^{q_{\mathrm{sea}}}(\xi,\xi,t)$$

"−" for $G \in \{H, E\}$
"+" for $G \in \{\widetilde{H}, \widetilde{E}\}$

- real part $$Re\mathcal{G}(\xi,t) = \mathrm{P.V.} \int_0^1 G^{(+)}(x,\xi,t) \left(\frac{1}{\xi - x} \mp \frac{1}{\xi + x}\right) \mathrm{d}x$$

$$Re\mathcal{G}(\xi,t) = \mathrm{P.V.} \int_0^1 G^{(+)}(x,x,t) \left(\frac{1}{\xi - x} \mp \frac{1}{\xi + x}\right) \mathrm{d}x + C_G(t)$$

$$C_H(t) = -C_E(t) \qquad C_{\widetilde{H}}(t) = C_{\widetilde{E}}(t) = 0$$

Subtraction Constant

Relation between subtraction constant and D-term:

$$C_G^q(t) = 2\int_{-1}^{1} \frac{D^q(z,t)}{1-z}\mathrm{d}z \equiv 4D^q(t)$$

where

$$z = \frac{x}{\xi}$$

Decomposition into Gegenbauer polynomials:

$$D^q(z,t) = (1-z^2)\sum_{i=0}^{\infty} d_i^q(t) C_{2i+1}^{3/2}(z)$$

Connection to EMT FF:

$$D^q(t) = \sum_{\substack{i=1 \\ \mathrm{odd}}}^{\infty} d_i^q(t)$$

$$d_1^q(t) = 5C^q(t)$$

Subtraction Constant

Comparing CFFs evaluated with two methods

$$C_G^q(t) = \int_0^1 \left(G^{q(+)}(x,\xi,t) - G^{q(+)}(x,x,t)\right)\left(\frac{1}{\xi - x} - \frac{1}{\xi + x}\right) dx$$

for ξ = 0

$$C_G^q(t) = 2\int_0^1 \left(G^{q(+)}(x,x,t) - G^{q(+)}(x,0,t)\right)\frac{1}{x}dx$$

divergent integral!

but

$$C_{G,j}^q(t) = 2\int_0^1 \left(G^{q(+)}(x,x,t) - G^{q(+)}(x,0,t)\right)x^j\,dx$$

well defined for odd positive j

Subtraction Constant

Subtraction constant as analytic continuation of Mellin moments to *j* = -1

$$C^q_G(t) = C^q_{G,-1}(t) = 2\int_{(0)}^{1}\left(G^{q(+)}(x,x,t) - G^{q(+)}(x,0,t)\right)\frac{1}{x}dx$$

Analytic regularization prescription

$$\int_{(0)}^{1}\frac{f(x)}{x^{a+1}} = \int_{0}^{1}\frac{f(x)-f(0)-xf'(0)-\dots}{x^{a+1}} + f(0)\int_{(0)}^{1}\frac{dx}{x^{a+1}} + f'(0)\int_{(0)}^{1}\frac{dx}{x^{a}} + \dots =$$

$$\int_{0}^{1}\frac{f(x)-f(0)-xf'(0)-\dots}{x^{a+1}} - \frac{f(0)}{a} - \frac{f'(0)}{a-1} + \dots$$

applicable if f(x) analytic and not-vanishing at x = 0

Ansatz for H and $\widetilde{H}$

$$G^q(x,0,t) = \mathrm{pdf}_G^q(x)\ \exp(f_G^q(x)t)$$

$$f_G^q(x) = A_G^q \log(1/x) + B_G^q(1-x)^2 + C_G^q(1-x)x$$

- modify "classical" log(1/x) term by $B_G^q(1-x)^2$ in low-x and by $C_G^q(1-x)x$ in high-x regions
- polynomials found in analysis of EFF data → good description of data
- allows to use the analytic regularization prescription
- finite proton size at x → 1

Ansatz for H and $\widetilde{H}$

$$G^q(x, x, t) = G^q(x, 0, t)\; g^q_G(x, x, t)$$

$$g^q_G(x, x, t) = \frac{a^q_G}{(1 - x^2)^2} \left(1 + t(1 - x)(b^q_G + c^q_G \log(1 + x))\right)$$

- at x → 0 constant skewness effect
- at x → 1 reproduce power behavior predicted for GPDs in Phys. Rev. D69, 051501 (2004)
- t-dependence similar to DD-models with (1-x) to avoid any t-dep. at x = 1

Ansatz for H and $\widetilde{H}$

"trouble" with analytic regularization

$$\int_{(0)}^{1} \frac{f(x)}{x^{a+1}} = \int_{0}^{1} \frac{f(x) - f(0) - xf'(0) - \ldots}{x^{a+1}} - \frac{f(0)}{a} - \frac{f'(0)}{a-1} + \ldots$$

where in our case

$$a = \delta + A_G^q t \qquad\qquad q(x) \sim x^{-\delta}$$

$$f(x) = \frac{G^q(x,x,t) - G^q(x,0,t)}{x^{-a}} = \frac{G^q(x,0,t)\left(g_G^q(x,t) - 1\right)}{x^{-a}}$$

compensating terms infinite for $t \equiv t_0^{\infty} = -\delta/A_G^q$ and $t \equiv t_1^{\infty} = (1-\delta)/A_G^q$
unless $f(0) = 0$ at t_0^{∞} and $f'(0) = 0$ at t_1^{∞}, condition provided by:

$$b_G^q = \frac{A_G^q(a_G^q - 1)}{a_G^q \delta} \qquad c_G^q = \frac{(a_G^q - 1)}{p_0\,(\delta - 1)\,a_G^q \delta}\left(p_0\,(2B_G^q - C_G^q)\,(\delta - 1) + A_G^q p_0\,(\delta - 1 - \alpha) + A_G^q p_1\right)$$

where δ, α, p_0, p_1 are PDF parameterization parameters

Ansatz for E and Ẽ

- for GPD E

$$E^{q_{\mathrm{val}}}(x,0,t) = e^{q_{\mathrm{val}}}(x)\exp(f_E^{q_{\mathrm{val}}}(x)t)$$

$$e^{q_{\mathrm{val}}}(x) = \kappa_q N_{q_{\mathrm{val}}} x^{-\alpha_{q_{\mathrm{val}}}}(1-x)^{\beta_{q_{\mathrm{val}}}}(1+\gamma_{q_{\mathrm{val}}}\sqrt{x})$$

from Eur. Phys.J. C73 (2013) 4, 2397

$$E^{q_{\mathrm{val}}}(x,x,t) = E^{q_{\mathrm{val}}}(x,0,t)g_E^{q_{\mathrm{val}}}(x,t)$$

$$g_E^{q_{\mathrm{val}}}(x,t) = \frac{a_E^{q_{\mathrm{val}}}}{(1-x^2)^3}$$

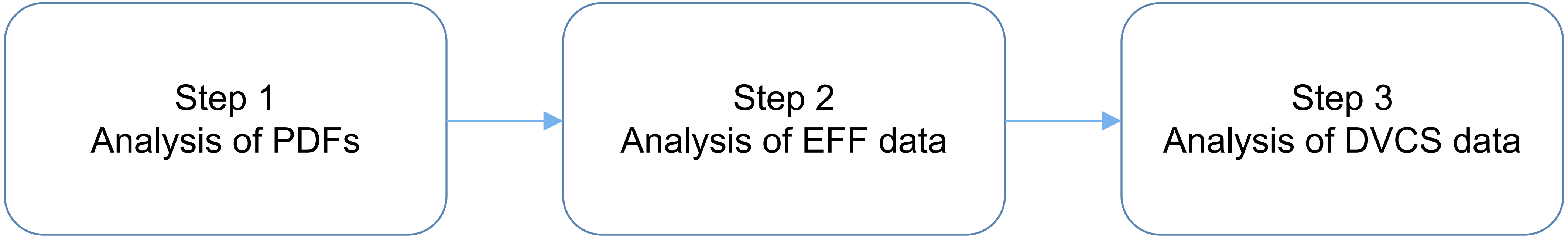
from Phys. Rev. D69, 051501 (2004)

- for GPD Ẽ

$$\widetilde{\mathcal{E}}(\xi,t) = N_{\widetilde{E}}\widetilde{\mathcal{E}}_{\mathrm{GK}}(\xi,t)$$

CFF from GK GPD model

Steps of analysis:



Effectively we combine (semi-)inclusive, pp, elastic and exclusive data in a single analysis

PDFs

Ansatz:

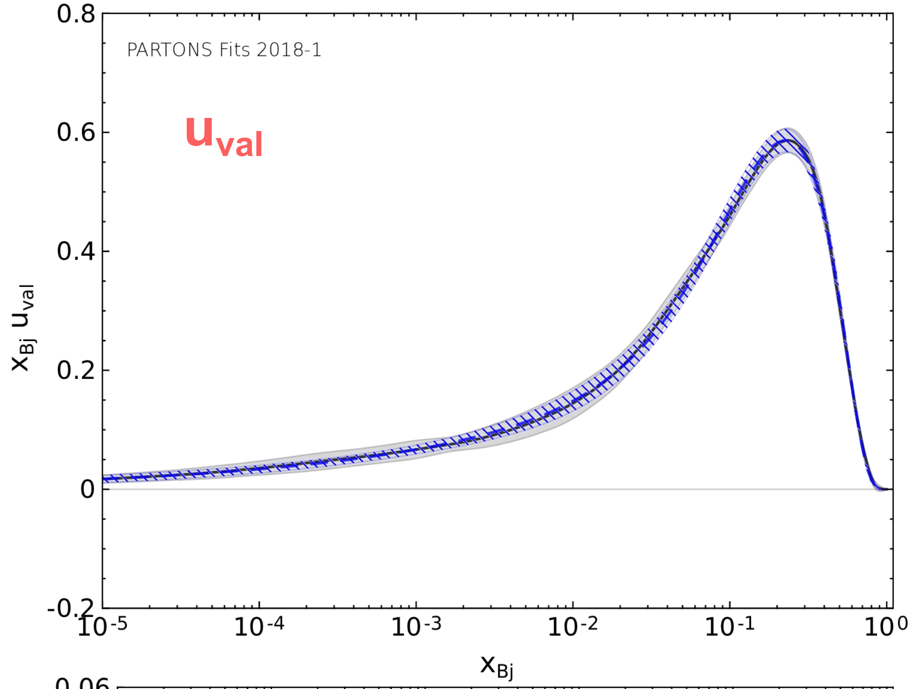
$$\mathrm{pdf}_G(x, Q^2) = x^{-g(\delta_p, \delta_q, Q^2)}(1-x)^{\alpha} \sum_{i=0}^{4} g(p_i, q_i, Q^2) x^i$$

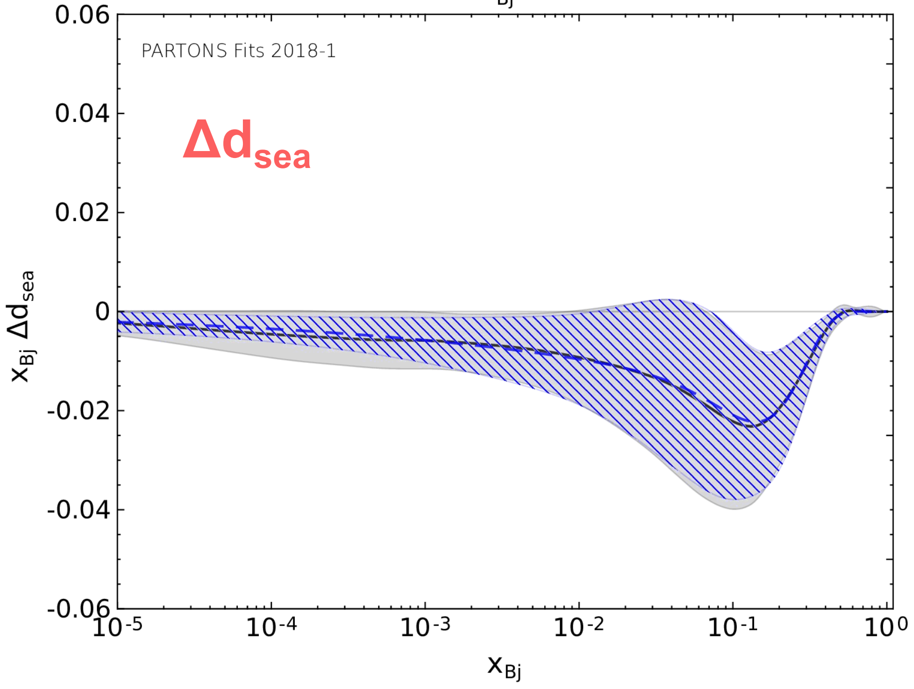
$$g(p, q, Q^2) = p + q \log \frac{Q^2}{Q_0^2}$$

13 parameters:

$\delta_p, \delta_q, \alpha, p_i, q_i$ where $i = 0, 1, \ldots, 4$

constrained by NNPDF3.0 and NNPDFpol11 sets (per each flavor and each PDF replica)





Elastic FF data

Free parameters for valance quarks and GPDs H and E constrained by EFF data

$$\int_{-1}^{1} H^q(x,\xi,t) \equiv F_1^q(t)$$

$$\int_{-1}^{1} E^q(x,\xi,t) \equiv F_2^q(t)$$

From Dirac and Pauli partonic FFs to Sachs nucleon FFs

$$F_i^p = e_u F_i^u + e_d F_i^d \qquad i = 1,2$$

$$F_i^n = e_u F_i^d + e_d F_i^u$$

$$G_M^i = F_1^i + F_2^i \qquad i = p,n$$

$$G_E^i = F_1^i + \frac{t}{4m^2} F_2^i$$

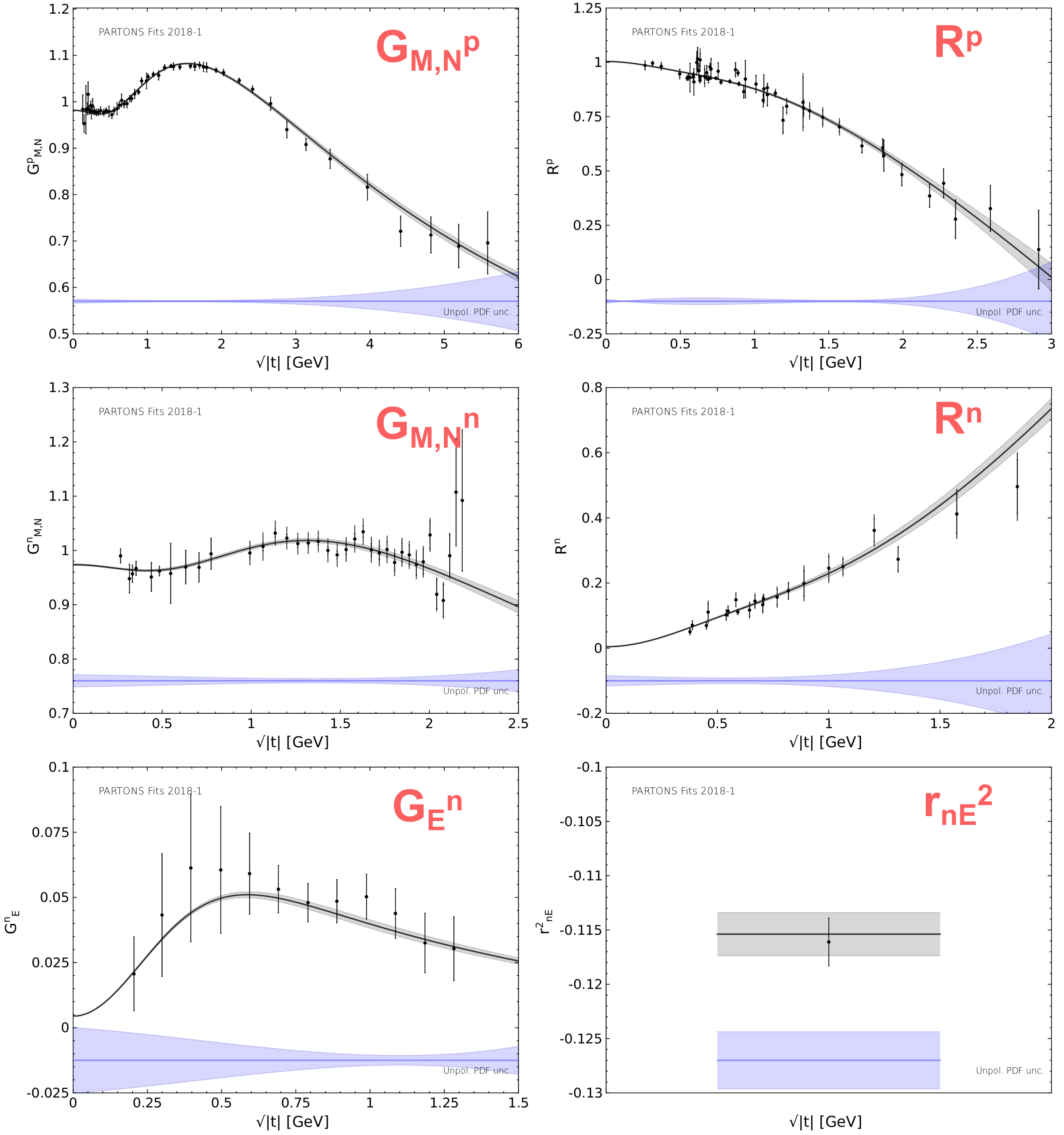
Observables

$$G_{M,N}^i(t) = \frac{G_M^i(t)}{\mu_i G_D(t)} \qquad i = p,n$$

$$R^i(t) = \frac{\mu_i G_E^i(t)}{G_M^i(t)}$$

$$r_{nE}^2 = 6 \left. \frac{dG_E^n(t)}{dt} \right|_{t=0}$$

for the selection of observables and experimental data we follow *Eur. Phys.J. C73 (2013) 4, 2397*



Performance:

$$\chi^2/\text{ndf} = 129.6/(178-9) \approx 0.77$$

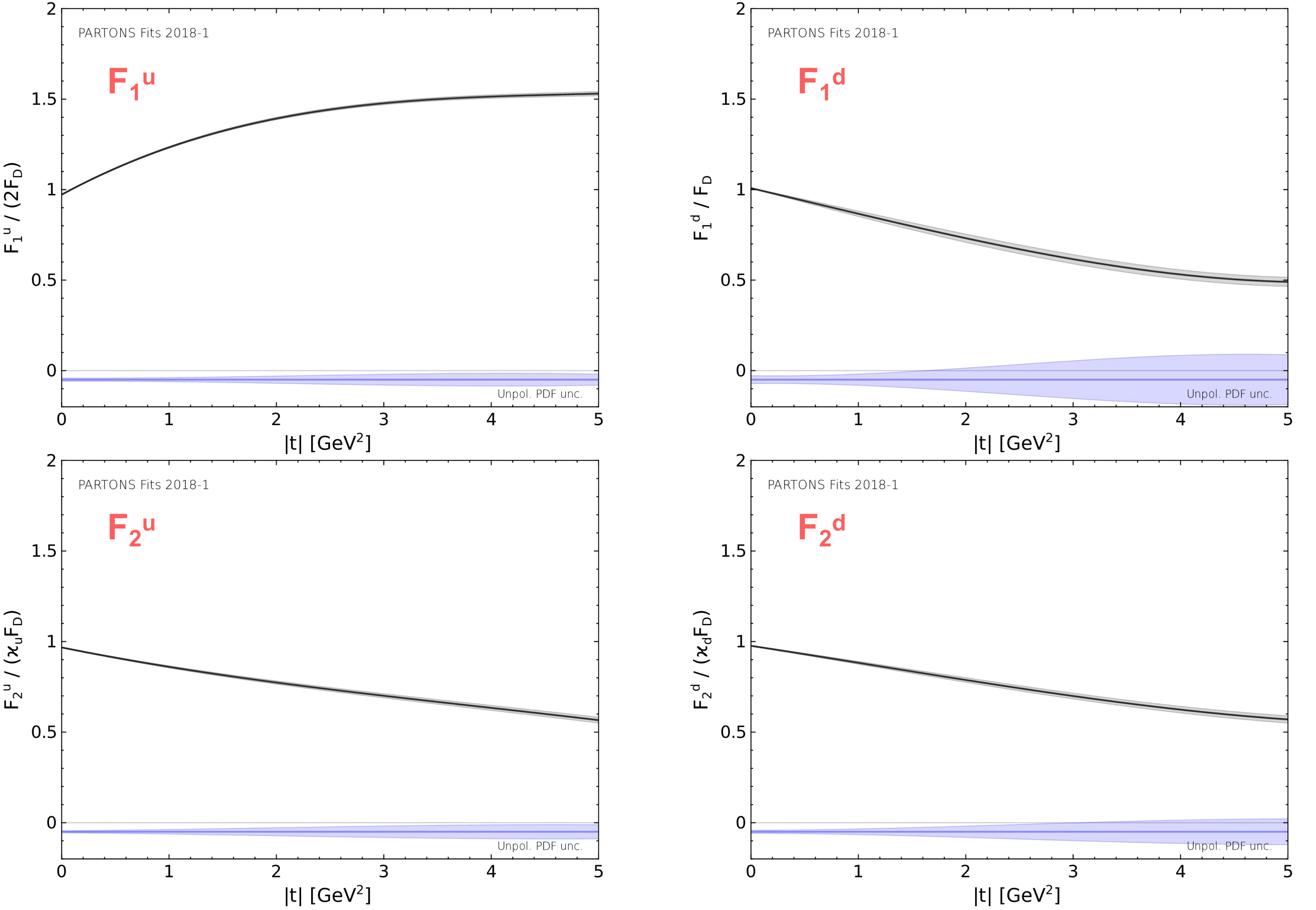
Replication of experimental data to estimate corresponding uncertainties:

$$v_i \pm \Delta_i^{\text{tot}} \xrightarrow{\text{replica } j} \text{rnd}_j(v_i, \Delta_i^{\text{tot}}) \pm \Delta_i^{\text{tot}}$$

$$\Delta_i^{\text{tot}} = \sqrt{(\Delta_i^{\text{stat}})^2 + (\Delta_i^{\text{sys}})^2}$$

Fitted values:

Parameter	Mean	Data unc.	Unpol. PDF unc.
$A_{H/E}^{u_{\text{val}}}$	0.99	0.01	0.08
$B_H^{u_{\text{val}}}$	−0.50	0.02	0.14
$A_{H/E}^{d_{\text{val}}}$	0.70	0.02	0.08
$B_H^{d_{\text{val}}}$	0.47	0.07	0.24
α	0.69	0.01	0.03
$B_E^{u_{\text{val}}}$	−0.69	0.04	0.18
$C_E^{u_{\text{val}}}$	−0.92	0.04	0.09
$B_E^{d_{\text{val}}}$	−0.54	0.06	0.20
$C_E^{d_{\text{val}}}$	−0.73	0.06	0.22



PARTONS Fits 2018-1
F1u
F1u / (2FD)
Unpol. PDF unc.
|t| [GeV2]
PARTONS Fits 2018-1
F1d
F1d / FD
Unpol. PDF unc.
|t| [GeV2]
PARTONS Fits 2018-1
F2u
F2u / (ϰuFD)
Unpol. PDF unc.
|t| [GeV2]
PARTONS Fits 2018-1
F2d
F2d / (ϰdFD)
Unpol. PDF unc.
|t| [GeV2]

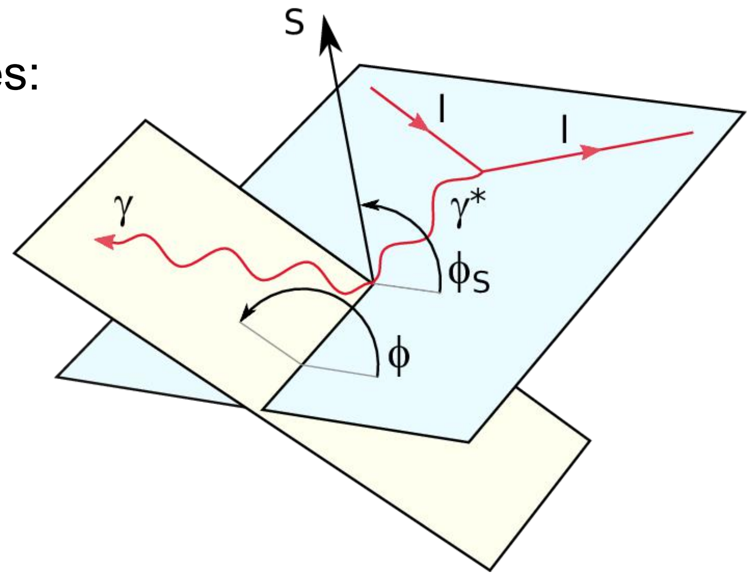
DVCS data

All DVCS proton data used in the fit, except:
- HERA data
- Hall A cross sections

Kinematic cuts:

$$Q^2 > 1.5\ \mathrm{GeV}^2$$
$$-t/Q^2 < 0.25$$

Angles:



No.	Collab.	Year	Observable		Kinematic dependence	No. of points used / all
1	HERMES	2001	A_{LU}^{+}		ϕ	10 / 10
2		2006	$A_{C}^{\cos i\phi}$	$i=1$	t	4 / 4
3		2008	$A_{C}^{\cos i\phi}$	$i=0,1$	x_{Bj}	18 / 24
			$A_{UT,\mathrm{DVCS}}^{\sin(\phi-\phi_S)\cos i\phi}$	$i=0$		
			$A_{UT,\mathrm{I}}^{\sin(\phi-\phi_S)\cos i\phi}$	$i=0,1$		
			$A_{UT,\mathrm{I}}^{\cos(\phi-\phi_S)\sin i\phi}$	$i=1$		
4		2009	$A_{LU,\mathrm{I}}^{\sin i\phi}$	$i=1,2$	x_{Bj}	35 / 42
			$A_{LU,\mathrm{DVCS}}^{\sin i\phi}$	$i=1$		
			$A_{C}^{\cos i\phi}$	$i=0,1,2,3$		
5		2010	$A_{UL}^{+,\sin i\phi}$	$i=1,2,3$	x_{Bj}	18 / 24
			$A_{LL}^{+,\cos i\phi}$	$i=0,1,2$		
6		2011	$A_{LT,\mathrm{DVCS}}^{\cos(\phi-\phi_S)\cos i\phi}$	$i=0,1$	x_{Bj}	24 / 32
			$A_{LT,\mathrm{DVCS}}^{\sin(\phi-\phi_S)\sin i\phi}$	$i=1$		
			$A_{LT,\mathrm{I}}^{\cos(\phi-\phi_S)\cos i\phi}$	$i=0,1,2$		
			$A_{LT,\mathrm{I}}^{\sin(\phi-\phi_S)\sin i\phi}$	$i=1,2$		
7		2012	$A_{LU,\mathrm{I}}^{\sin i\phi}$	$i=1,2$	x_{Bj}	35 / 42
			$A_{LU,\mathrm{DVCS}}^{\sin i\phi}$	$i=1$		
			$A_{C}^{\cos i\phi}$	$i=0,1,2,3$		
8	CLAS	2001	$A_{LU}^{-,\sin i\phi}$	$i=1,2$	—	0 / 2
9		2006	$A_{UL}^{-,\sin i\phi}$	$i=1,2$	—	2 / 2
10		2008	A_{LU}^{-}		ϕ	283 / 737
11		2009	A_{LU}^{-}		ϕ	22 / 33
12		2015	A_{LU}^{-}, A_{UL}^{-}, A_{LL}^{-}		ϕ	311 / 497
13		2015	$d^4\sigma_{UU}^{-}$		ϕ	1333 / 1933
14	Hall A	2015	$\Delta d^4\sigma_{LU}^{-}$		ϕ	228 / 228
15		2017	$\Delta d^4\sigma_{LU}^{-}$		ϕ	276 / 358
16	COMPASS	2018	b		—	1 / 1
					SUM:	2600 / 3970

DVCS data

Performance:

$$\chi^2/\text{ndf} = 2346.3/(2600-13) \approx 0.91$$

No.	Collab.	Year	χ^2	n	χ^2/n
1	HERMES	2001	9.8	10	0.98
2		2006	2.9	4	0.72
3		2008	24.2	18	1.35
4		2009	40.1	35	1.15
5		2010	40.3	18	2.24
6		2011	14.5	24	0.60
7		2012	25.4	35	0.73
8	CLAS	2001	—	0	—
9		2006	0.9	2	0.47
10		2008	371.1	283	1.31
11		2009	36.4	22	1.66
12		2015	351.4	311	1.13
13		2015	937.9	1333	0.70
14	Hall A	2015	220.2	228	0.97
15		2017	258.8	276	0.94
16	COMPASS	2018	10.7	1	10.67

Fitted values:

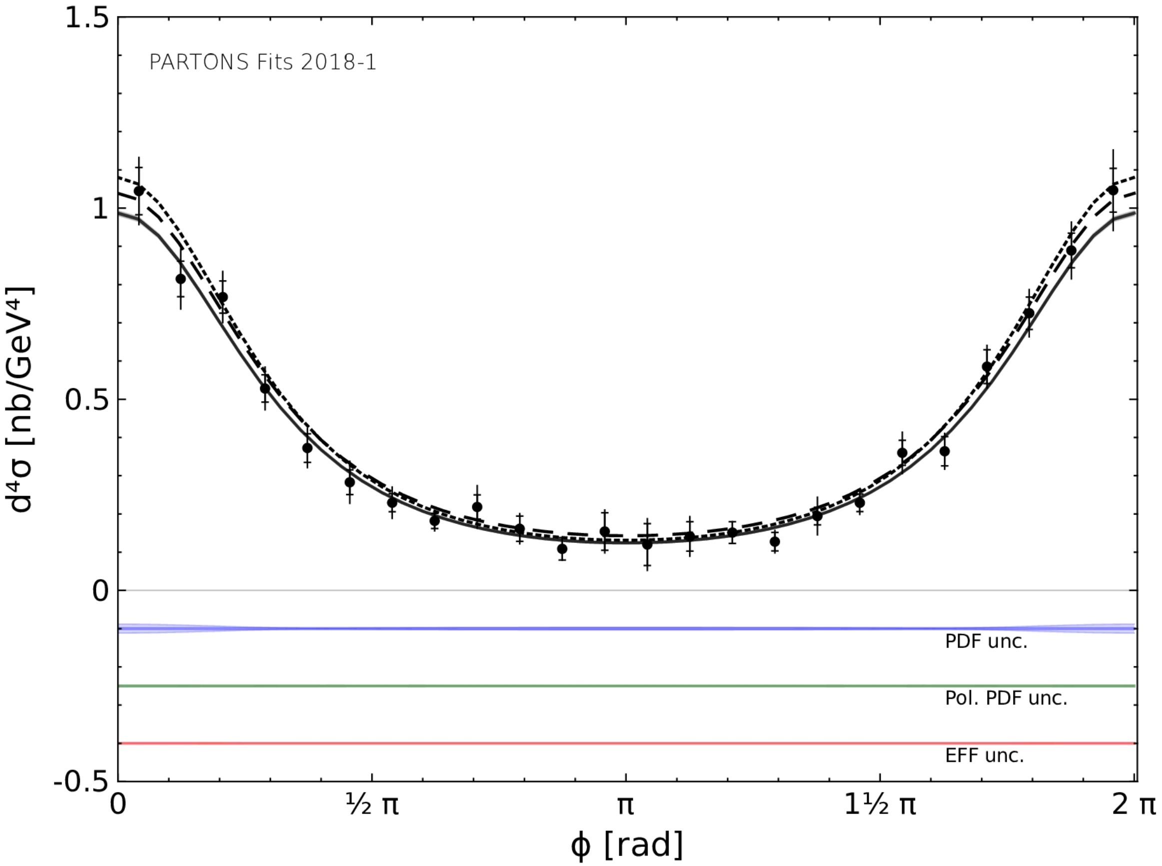
Parameter	Mean	Data unc.	Unpol. PDF unc.	Pol. PDF unc.	EFF unc.
$a_H^{q_{\text{val}}}$	0.81	0.04	0.17	0.02	<0.01
$a_H^{q_{\text{sea}}}$	0.99	0.01	0.02	<0.01	<0.01
$a_{\widetilde{H}}^{q}$	1.03	0.04	0.30	0.24	0.01
$N_{\widetilde{E}}$	-0.46	0.10	0.09	0.06	0.01
$A_H^{q_{\text{sea}}}$	2.56	0.23	0.30	0.09	0.03
$B_H^{q_{\text{sea}}}$	-5		at the limit		
$C_H^{q_{\text{sea}}}$	34	27	49	14	3
$A_{\widetilde{H}}^{u_{\text{val}}}$	0.77	0.12	0.30	0.23	0.07
$B_{\widetilde{H}}^{u_{\text{val}}}$	-0.02	0.26	0.75	0.24	0.15
$C_{\widetilde{H}}^{u_{\text{val}}}$	-0.92	0.07	0.44	0.24	0.04
$A_{\widetilde{H}}^{d_{\text{val}}}$	0.64	0.24	0.30	0.28	0.05
$B_{\widetilde{H}}^{d_{\text{val}}}$	-1.19	0.45	0.91	0.98	0.22
$C_{\widetilde{H}}^{d_{\text{val}}}$	-0.55	0.24	0.26	0.27	0.10

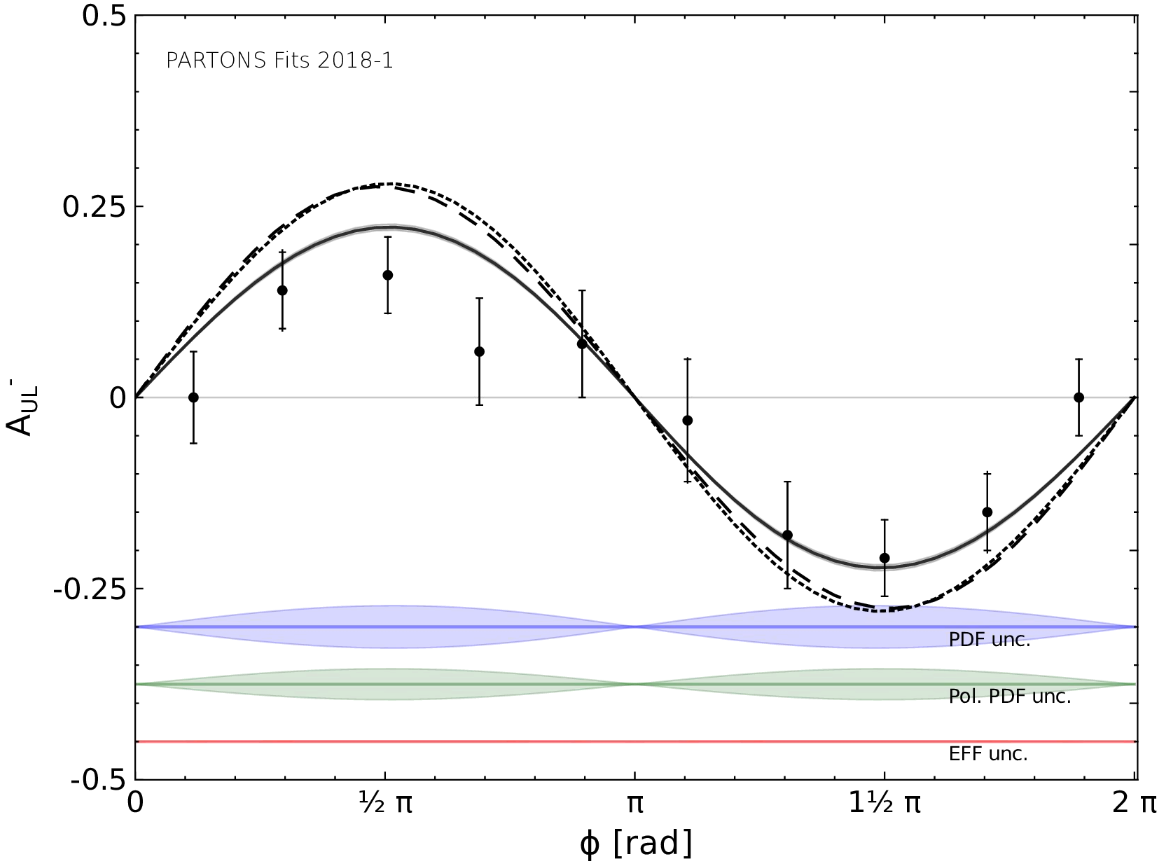
Replication of experimental data to estimate corresponding uncertainties:

$$v_i \pm \Delta_i^{\text{tot}} \xrightarrow{\text{replica } j} \left(\text{rnd}_j(v_i, \Delta_i^{\text{tot}}) \pm \Delta_i^{\text{tot}}\right) \times \text{rnd}_j(1, \Delta_i^{\text{norm}}) \qquad \Delta_i^{\text{tot}} = \sqrt{(\Delta_i^{\text{stat}})^2 + (\Delta_i^{\text{sys}})^2}$$

this analysis
GK model
VGG model

CLAS data:



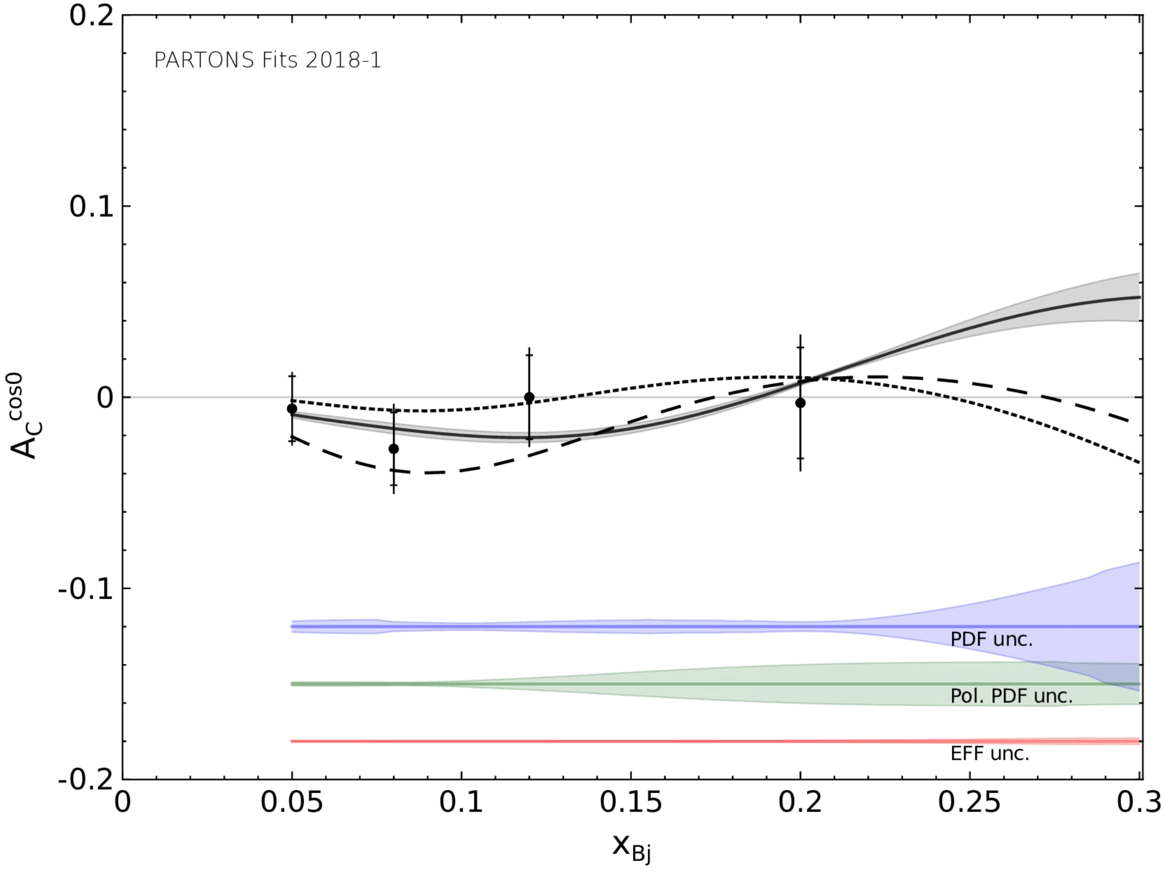


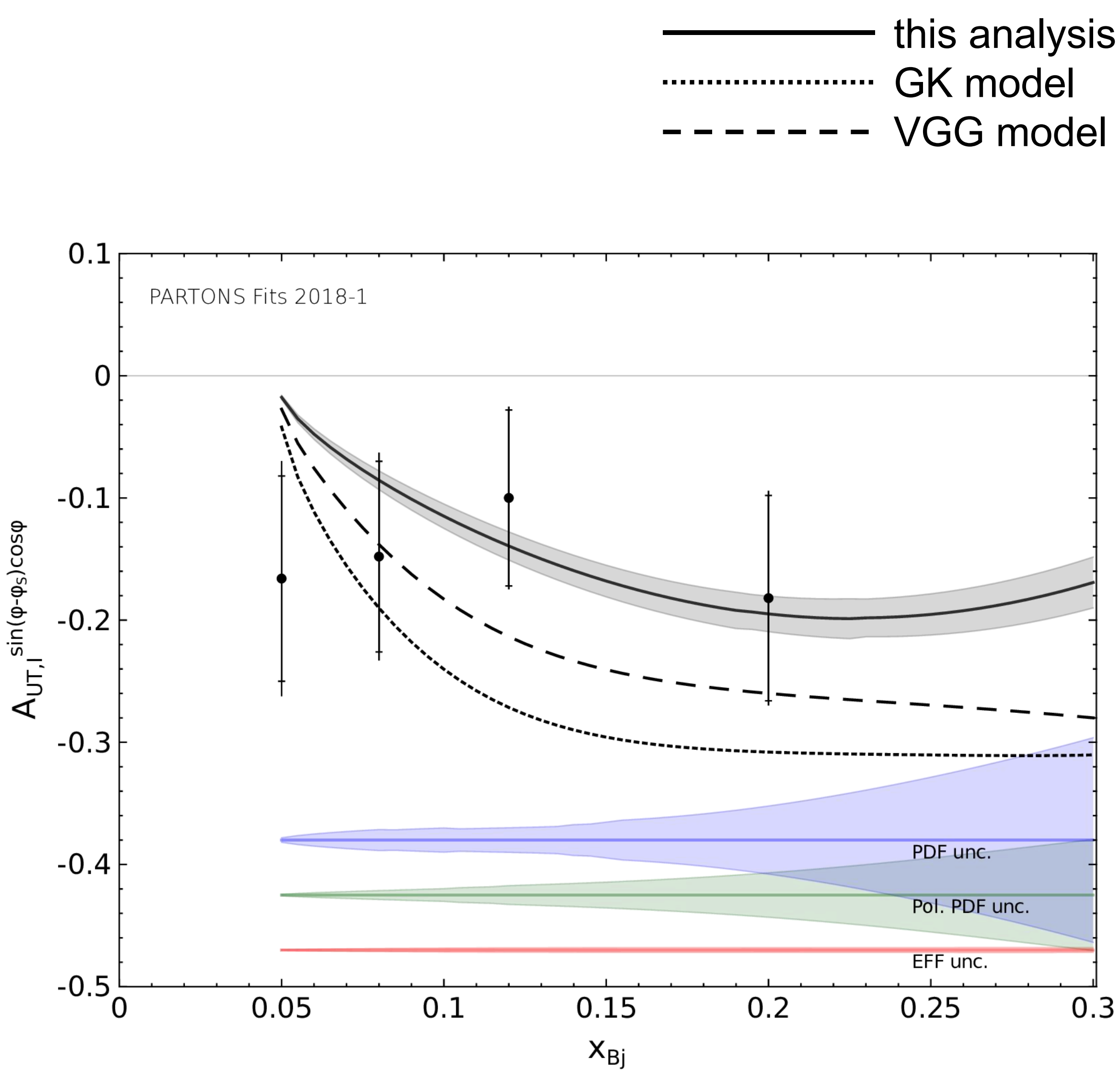
Phys. Rev. Lett. 115(21), 212003 (2015)
$\mathrm{x_{Bj}} = 0.244,\ t = -0.15\ \mathrm{GeV}^2,\ Q^2 = 1.79\ \mathrm{GeV}^2$

Phys. Rev. D91(5), 052014 (2015)
$\mathrm{x_{Bj}} = 0.257,\ t = -0.23\ \mathrm{GeV}^2,\ Q^2 = 2.02\ \mathrm{GeV}^2$

Results

HERMES data:



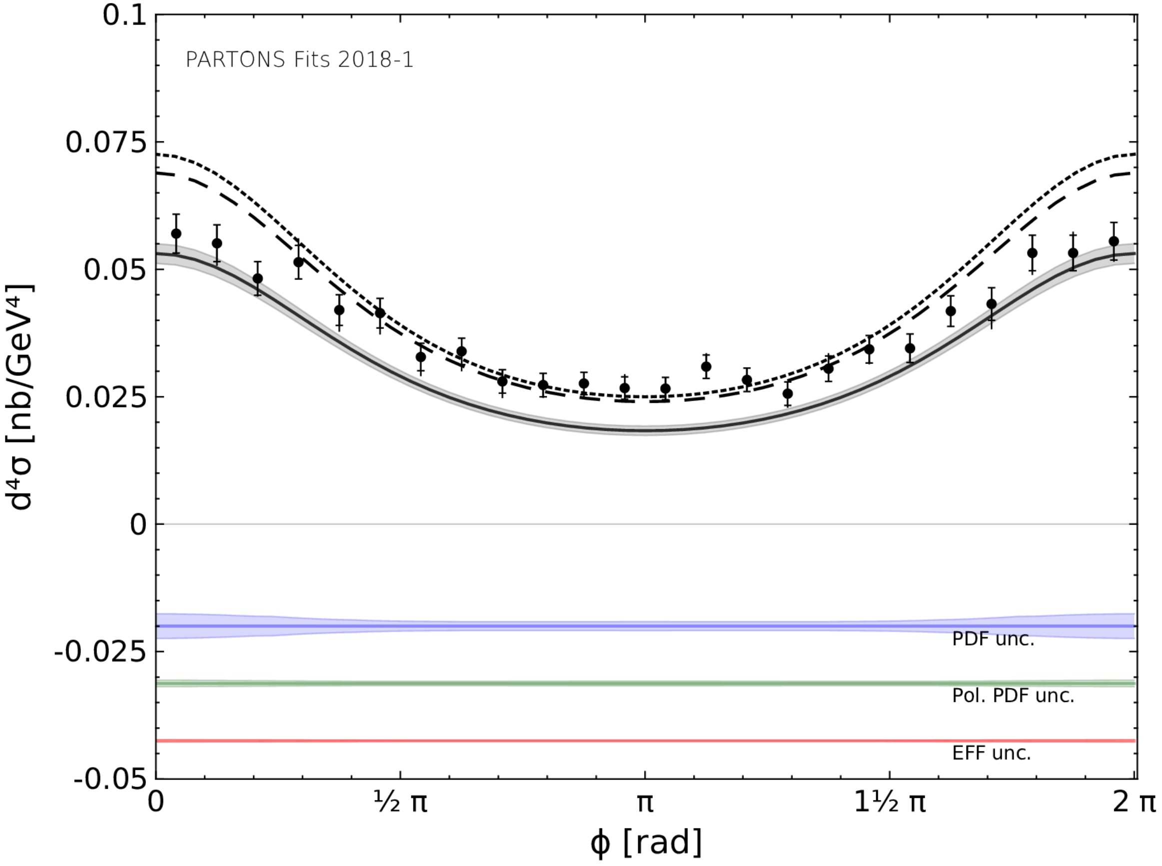


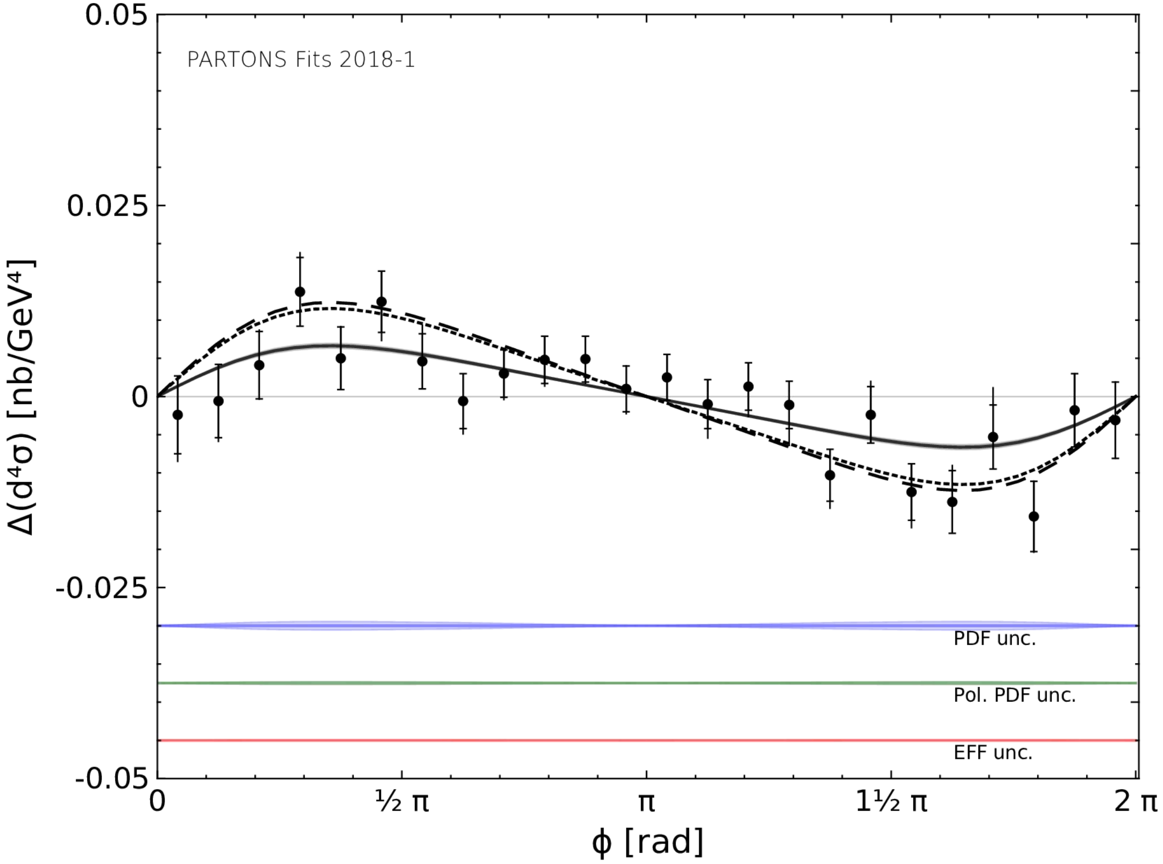
JHEP 06, 066 (2008)

$t = -0.12\ \mathrm{GeV}^2,\ Q^2 = 2.5\ \mathrm{GeV}^2$

this analysis
GK model
VGG model

Hall A data:



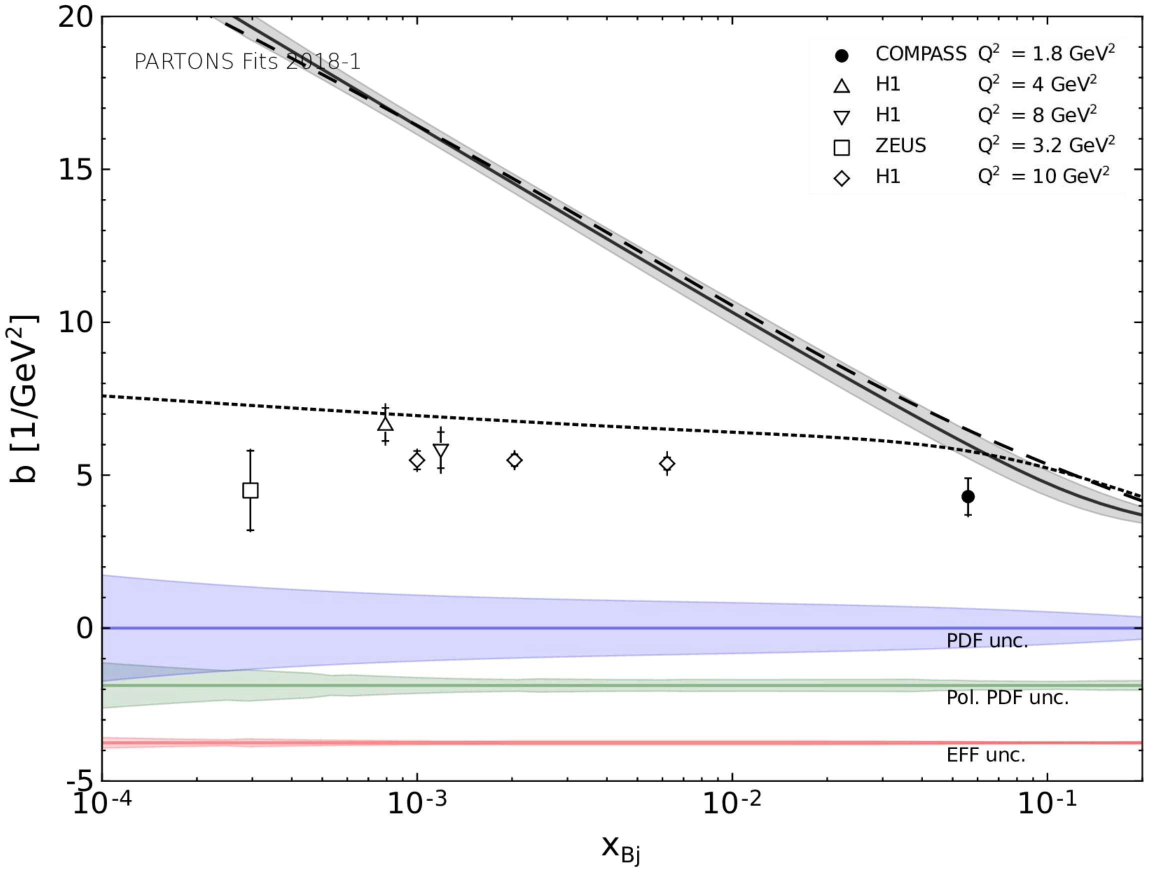


Phys. Rev. C92(5), 055202 (2015)

$\mathrm{x_{Bj}} = 0.392,\ t = -0.233\ \mathrm{GeV}^2,\ Q^2 = 2.054\ \mathrm{GeV}^2$

this analysis
GK model
VGG model

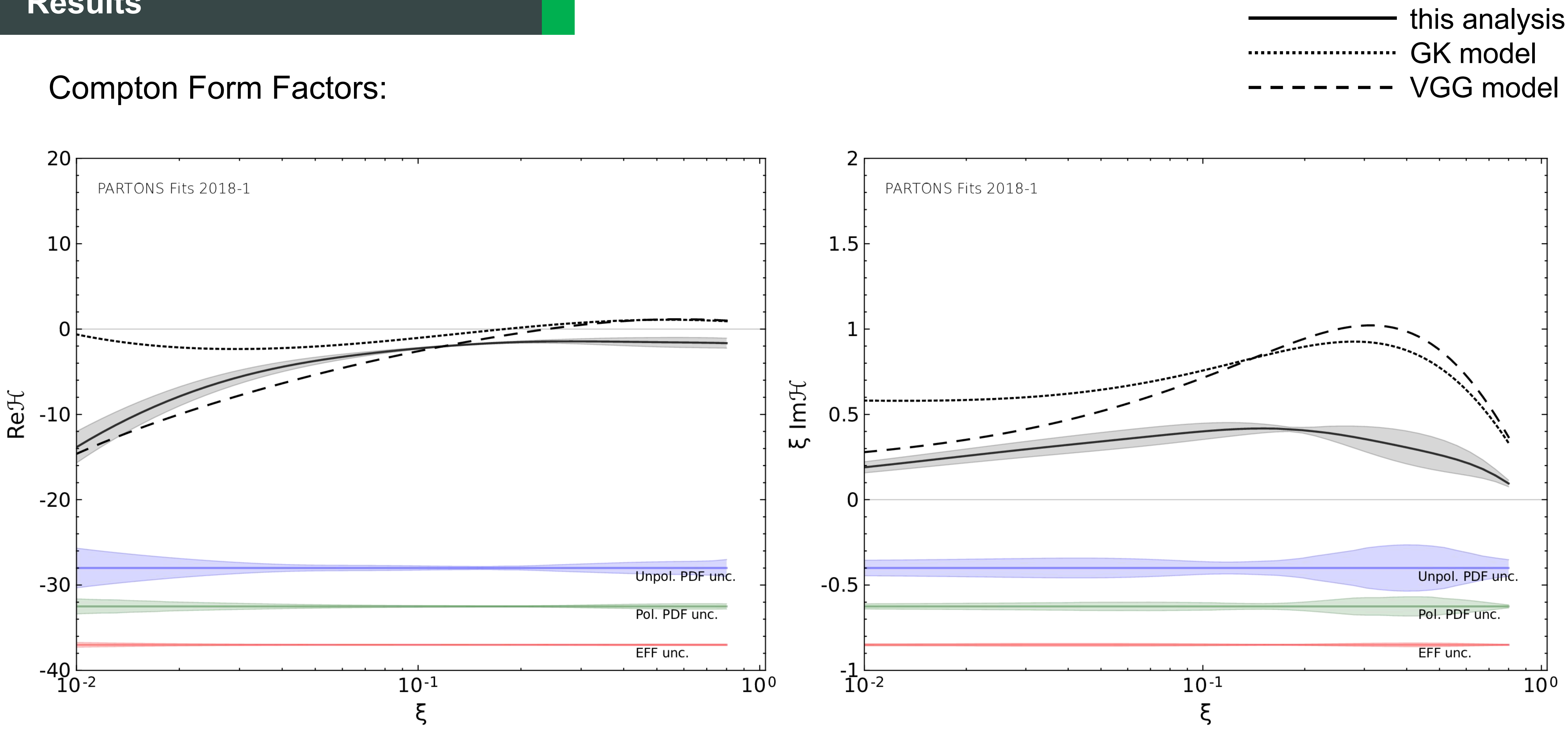
COMPASS and HERA:



arXiv: hep-ex/1802.02739

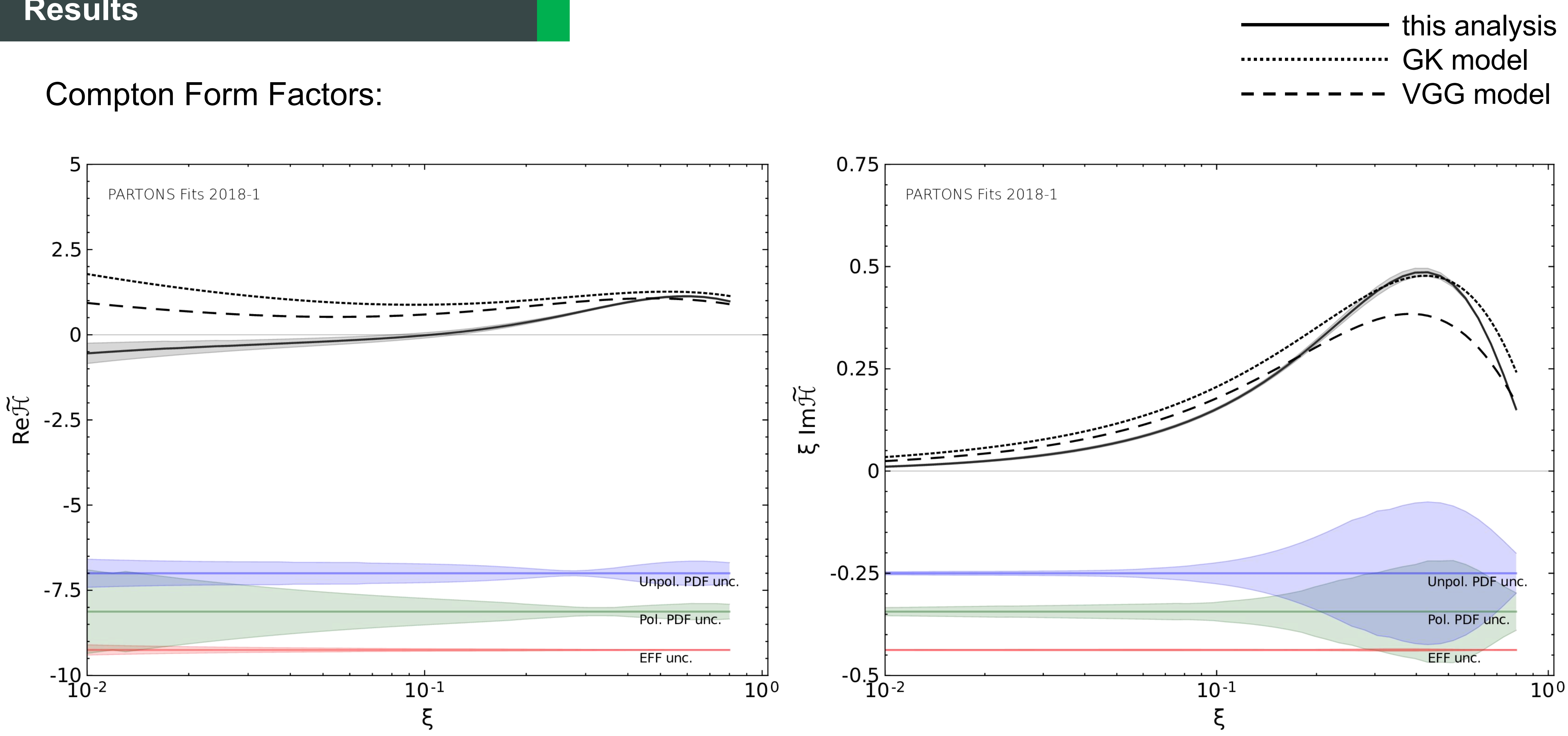
$Q^2 = 1.8\ \mathrm{GeV}^2$

Compton Form Factors:

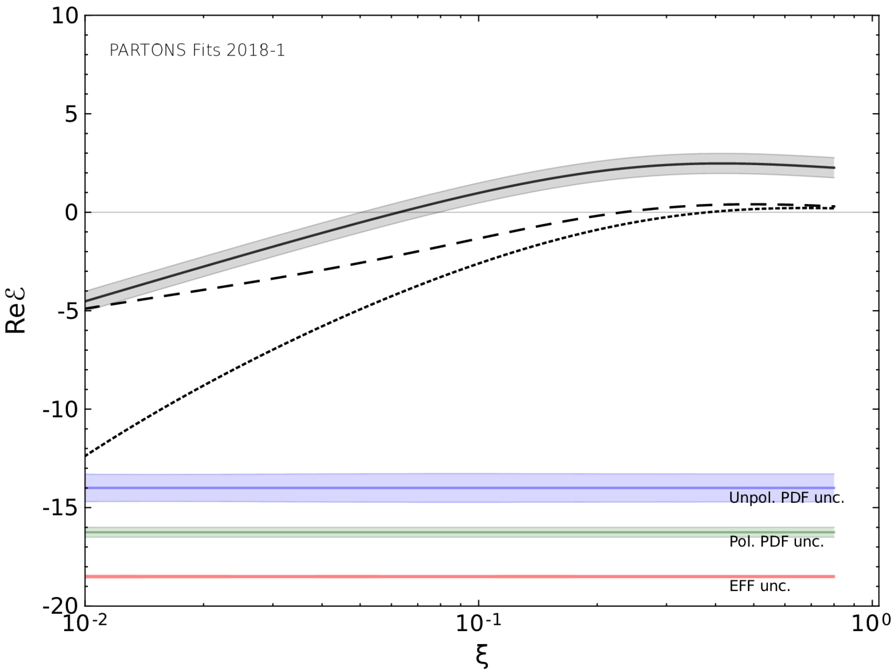


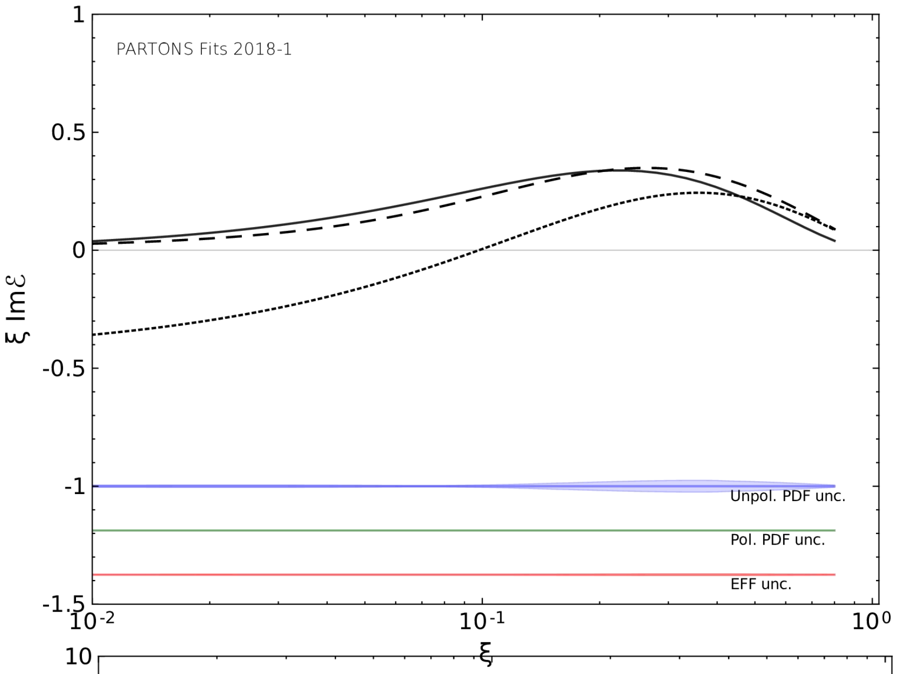
$t = \text{-0.3 GeV}^2$, $Q^2 = 2\ \text{GeV}^2$

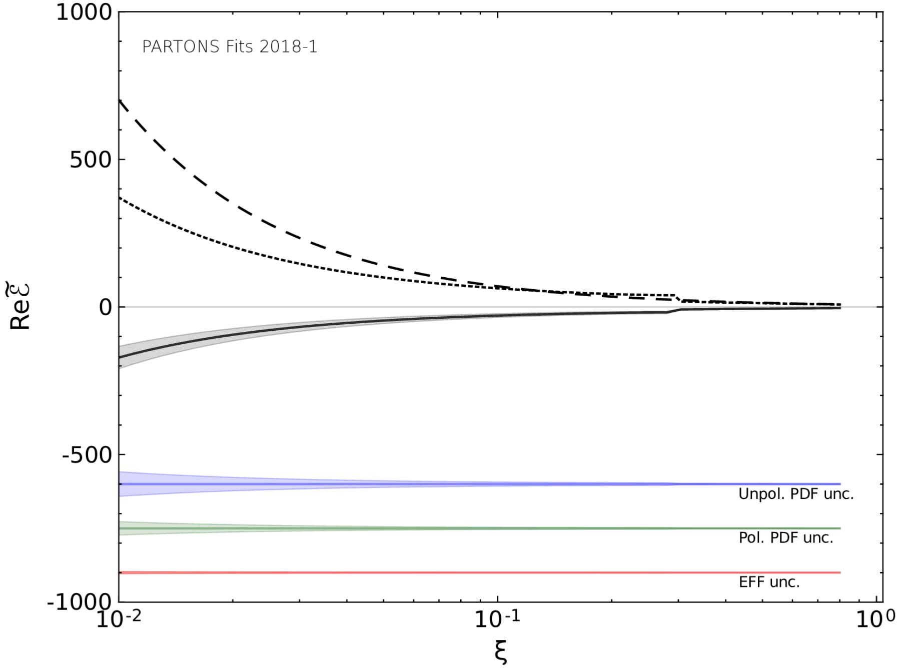
Compton Form Factors:

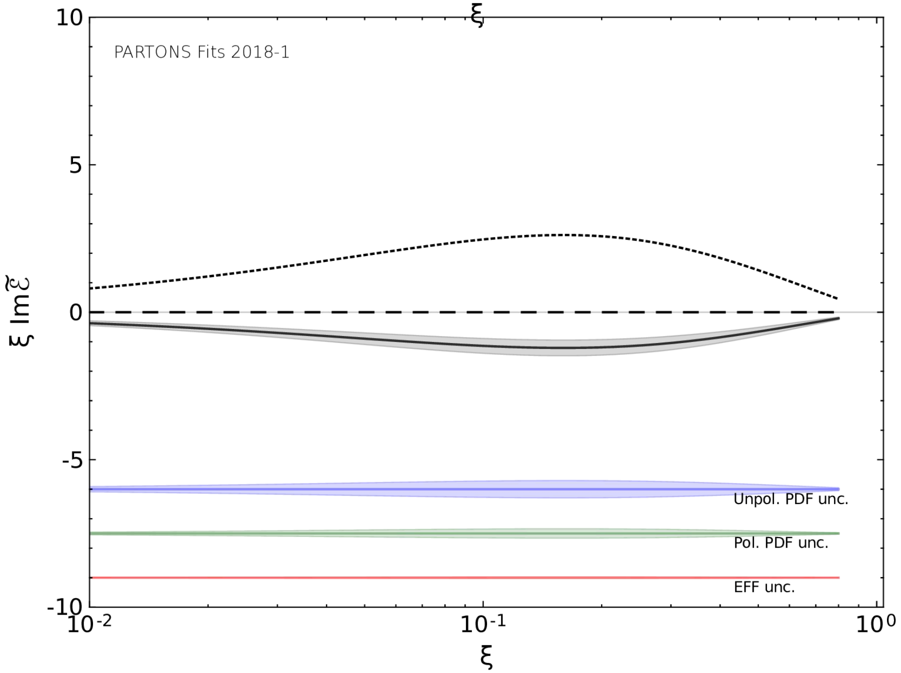


$t = \text{-}0.3\ \mathrm{GeV}^2,\ Q^2 = 2\ \mathrm{GeV}^2$


PARTONS Fits 2018-1
Unpol. PDF unc.
Pol. PDF unc.
EFF unc.
ξ

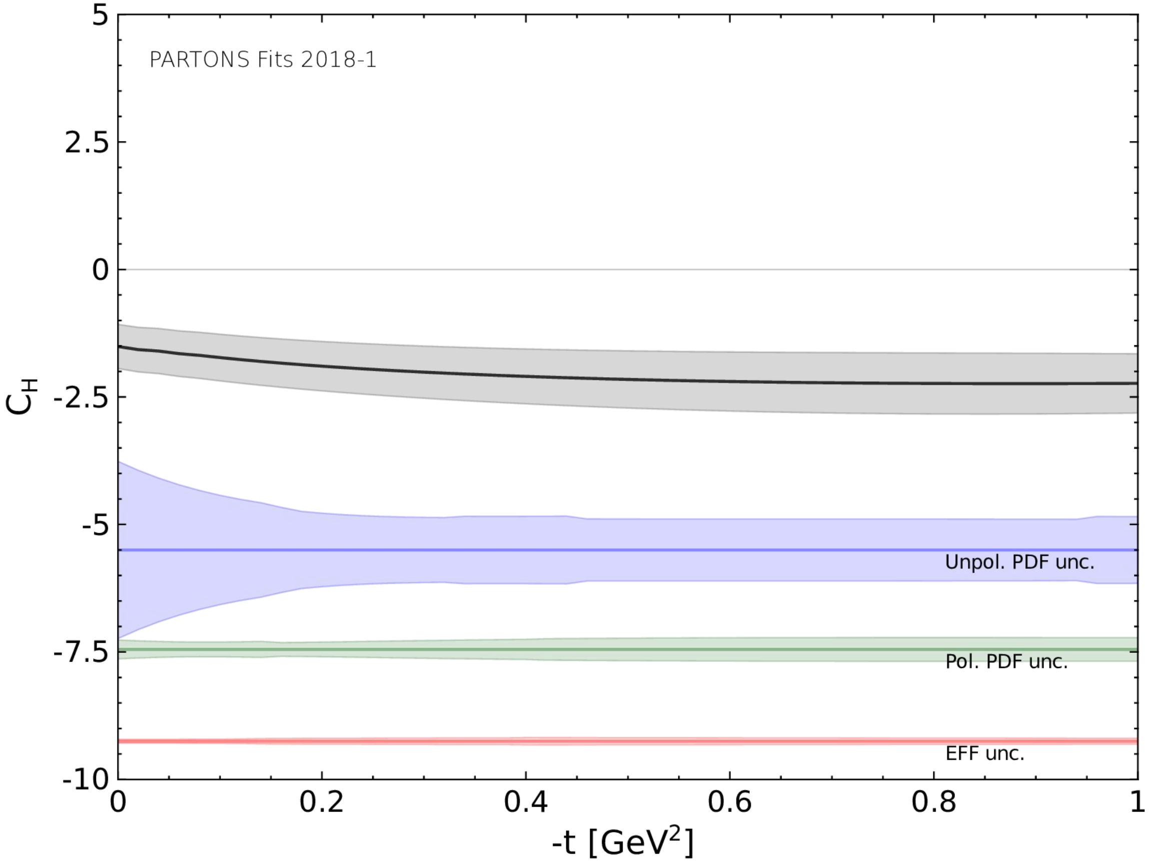

PARTONS Fits 2018-1
Unpol. PDF unc.
Pol. PDF unc.
EFF unc.
ξ


PARTONS Fits 2018-1
Unpol. PDF unc.
Pol. PDF unc.
EFF unc.
ξ

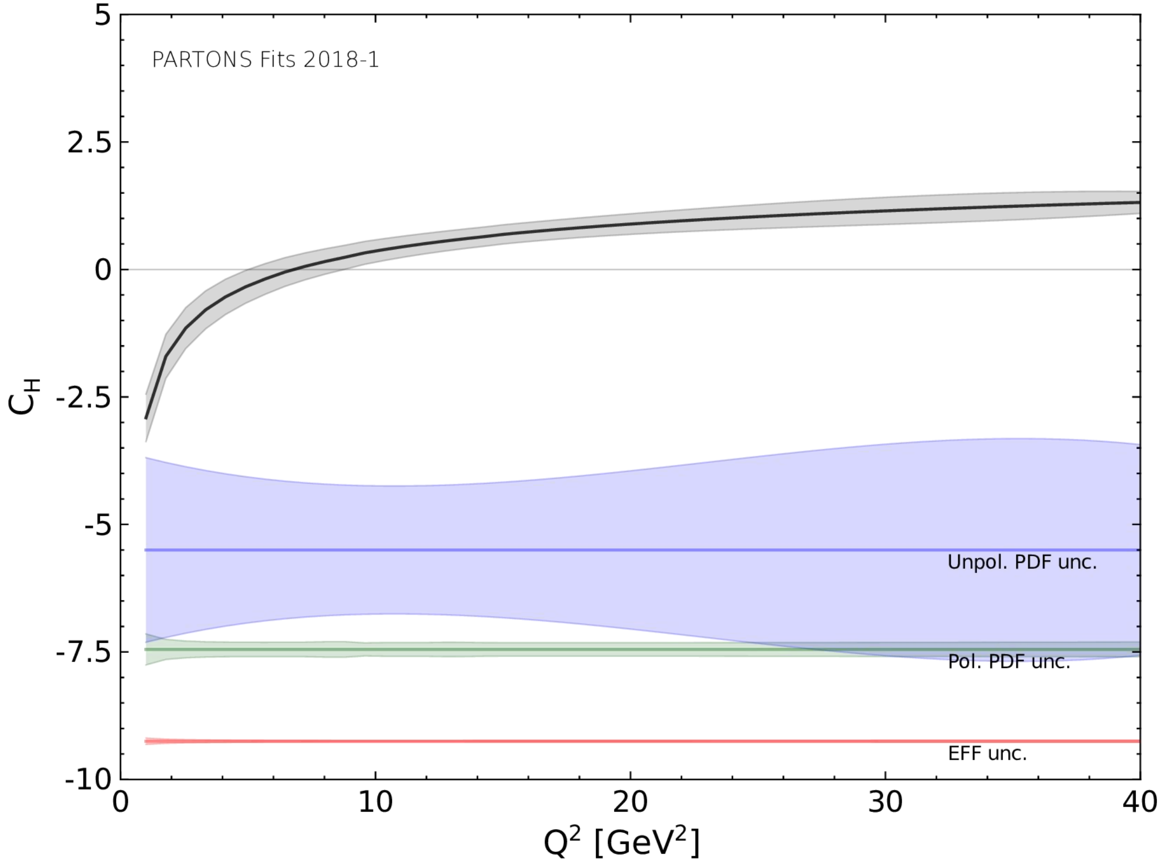

PARTONS Fits 2018-1
Unpol. PDF unc.
Pol. PDF unc.
EFF unc.
ξ

Results

Subtraction constant:

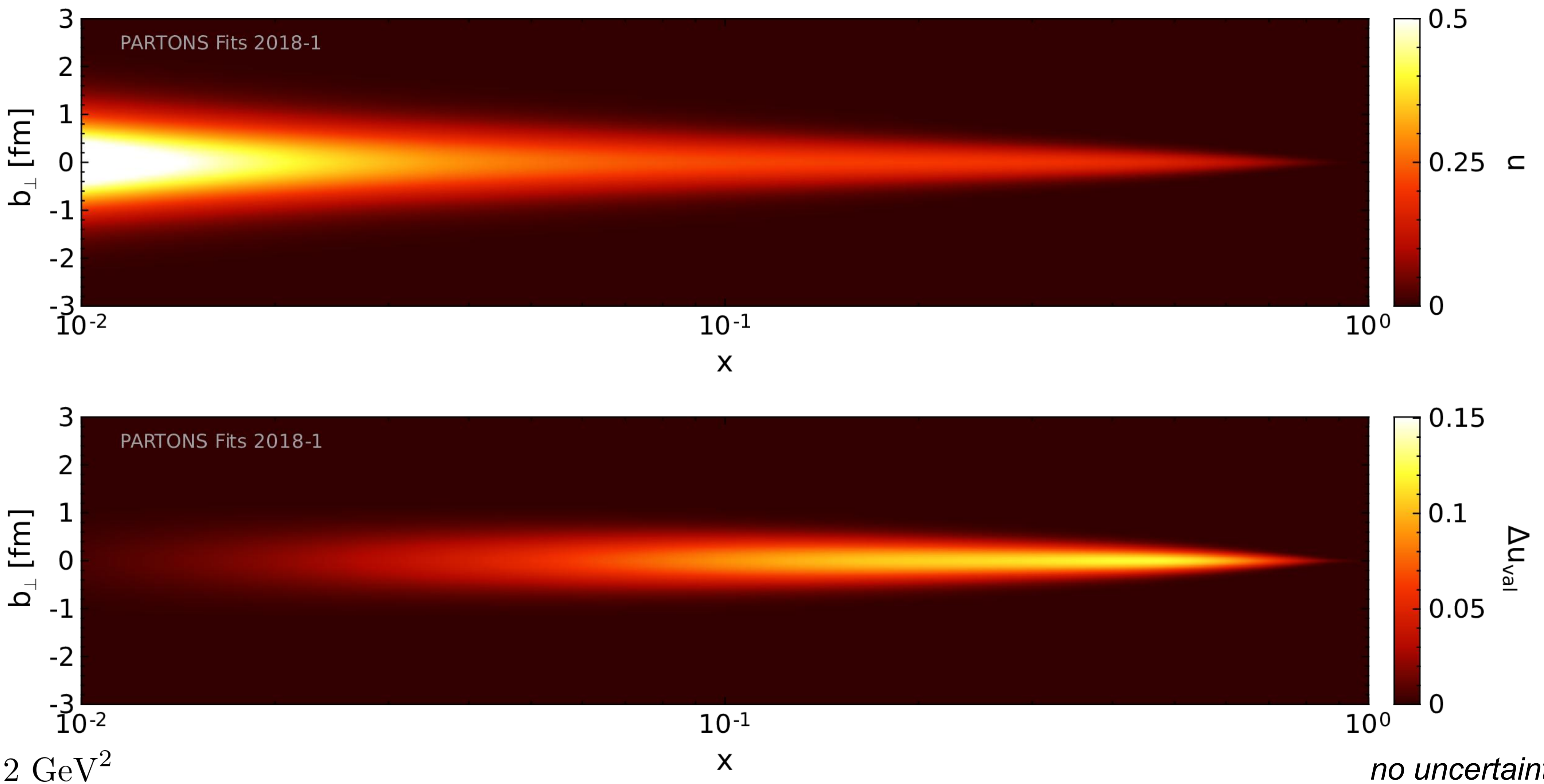


$$Q^2 = 2\ \mathrm{GeV}^2$$



$$t = 0$$

Nucleon tomography:

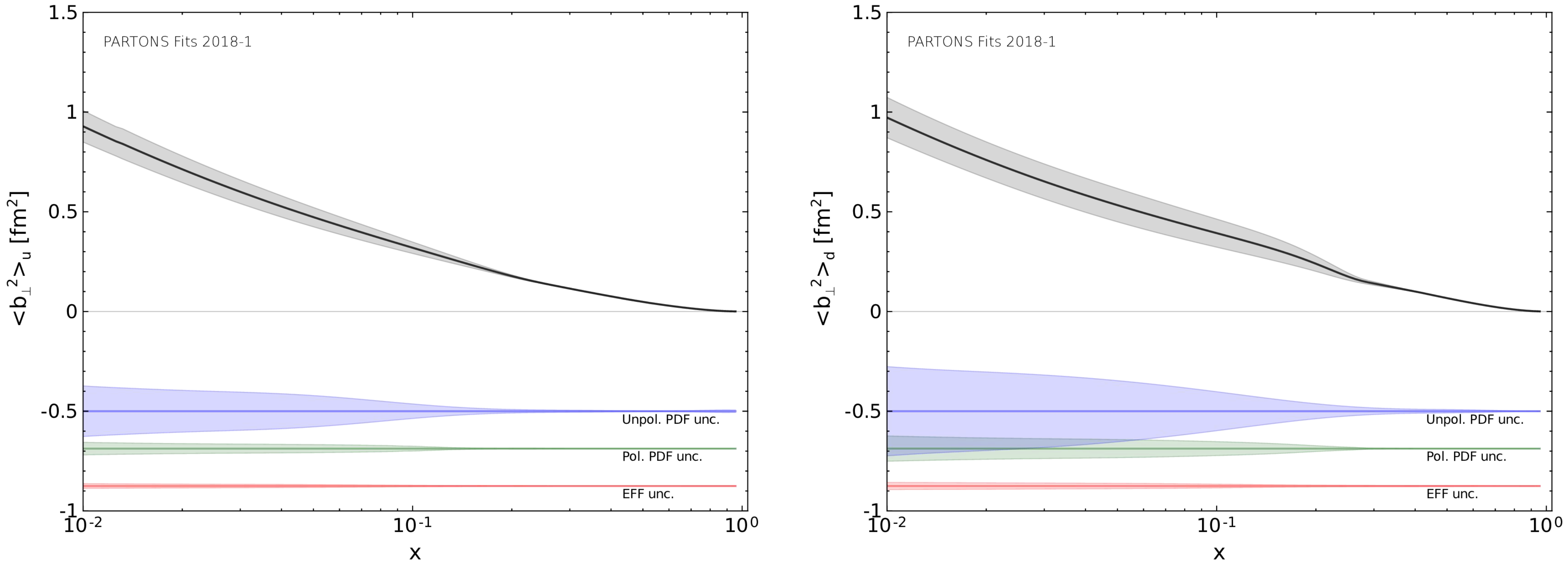


$Q^2 = 2\ \mathrm{GeV}^2$

no uncertainties!

Compton Form Factors: $$\langle b_\perp^2 \rangle_q(x) = \frac{\int d^2\mathbf{b}_\perp \; \mathbf{b}_\perp^2 q(x, \mathbf{b}_\perp)}{\int d^2\mathbf{b}_\perp \; q(x, \mathbf{b}_\perp)}$$

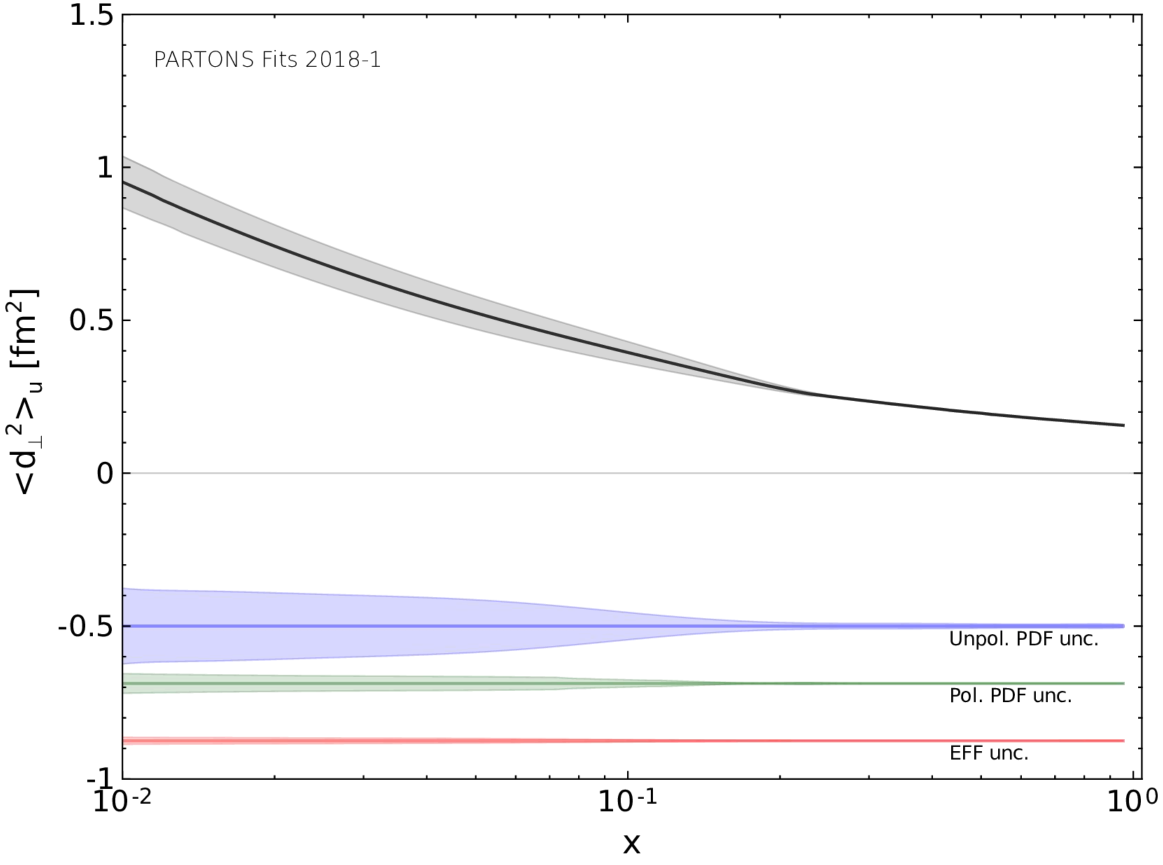
this analysis
GK model
VGG model

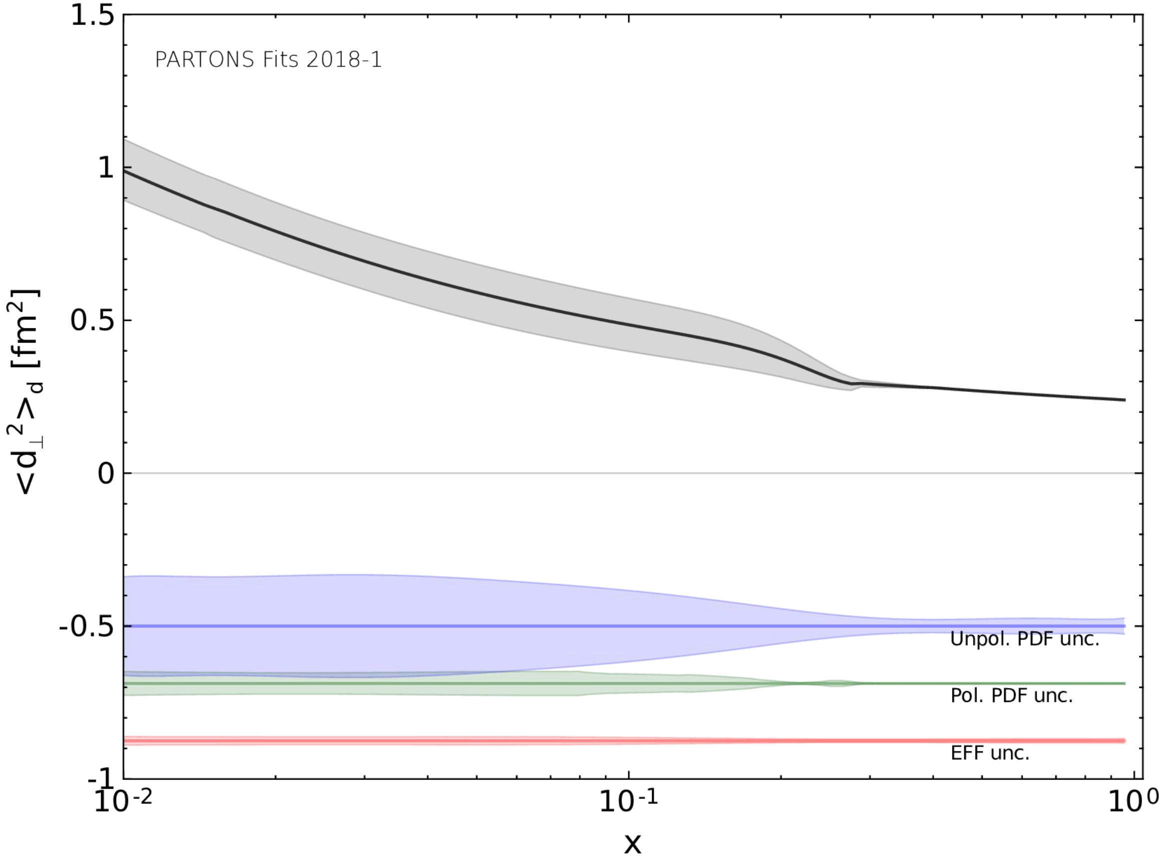


$Q^2 = 2\ \mathrm{GeV}^2$

Compton Form Factors:

$$\langle d_\perp^2 \rangle_q(x) = \frac{\langle b_\perp^2 \rangle_q(x)}{(1-x)^2}$$





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

SUMMARY

Fits to DVCS data

- New parameterizations of border and skewness function proposed
  - → basic properties of GPD as building blocks
  - → small number of parameters
  - → encoded access to nucleon tomography and subtraction constant
- Successful to fit EFF and DVCS data
  - → replica method for a careful propagation of uncertainties

What next?

- Neural network parameterization of CFFs
- Include other channels and more observables
- Include new and already existing theory developments
- Make consistent analysis of all those ingredients → PARTONS

BACKUP | PARTONS PROJECT

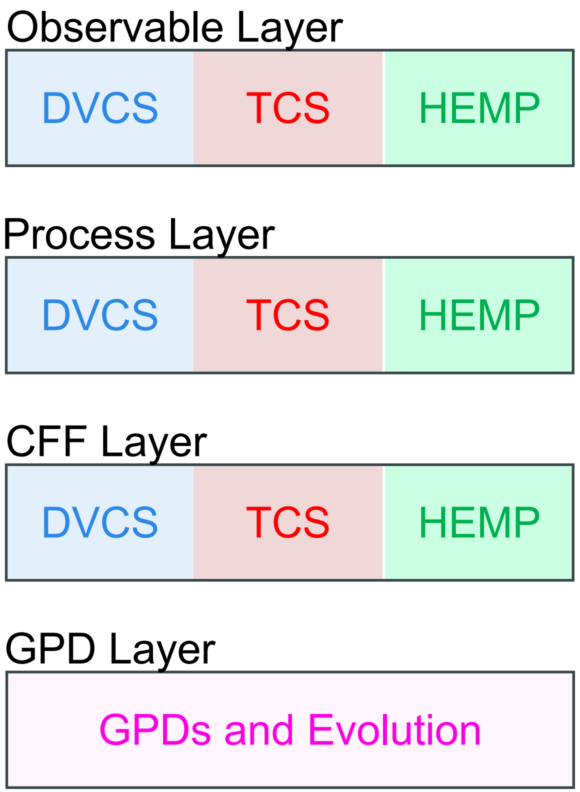
Layered structure:

- one layer = collection of objects designed for common purpose
- one module = one physical development
- operations on modules provided by Services, e.g. for GPD Layer

```
GPDResult computeGPDModel
        (const GPDKinematic& gpdKinematic, GPDModule* pGPDModule) const;
GPDResult computeGPDModelRestrictedByGPDType
        (const GPDKinematic& gpdKinematic, GPDModule* pGPDModule,
        GPDType::Type gpdType) const;
GPDResult computeGPDModelWithEvolution
        (const GPDKinematic& gpdKinematic, GPDModule* pGPDModule,
        GPDEvolutionModule* pEvolQCDModule) const;
...
```

- what can be automated is automated
- features improving calculation speed

  e.g. CFF Layer Service stores the last calculated values



Existing modules:

- GPD: GK11, VGG, Vinnikov, MPSSW13, MMS13
- Evolution: Vinnikov code
- CFF (DVCS only): LO, NLO (gluons and light or light + heavy quarks)
- Cross Section (DVCS only): VGG, BMJ, GV
- Running coupling: 4-loop PDG expression, constant value

H^u @ $x = 0.2$, $t = -0.1\ \mathrm{GeV}^2$, $\mu_F^2 = \mu_R^2 = 2\ \mathrm{GeV}^2$