

MENU 2026

The 17th International Conference on Meson-Nucleon Physics and the Structure of the Nucleon

Recent advances in Theory

Marc Vanderhaeghen

19 - 23 October, 2026, Stony Brook University

JOHANNES GUTENBERG
UNIVERSITÄT MAINZ



Research Unit
FOR 5327

Photon-photon interactions in
the Standard Model and beyond

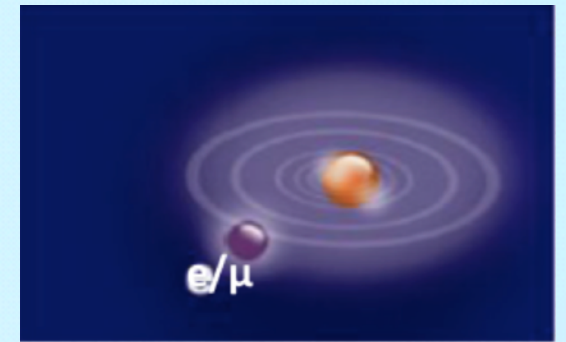
Exploiting the discovery potential from MESA to the LHC



Outline

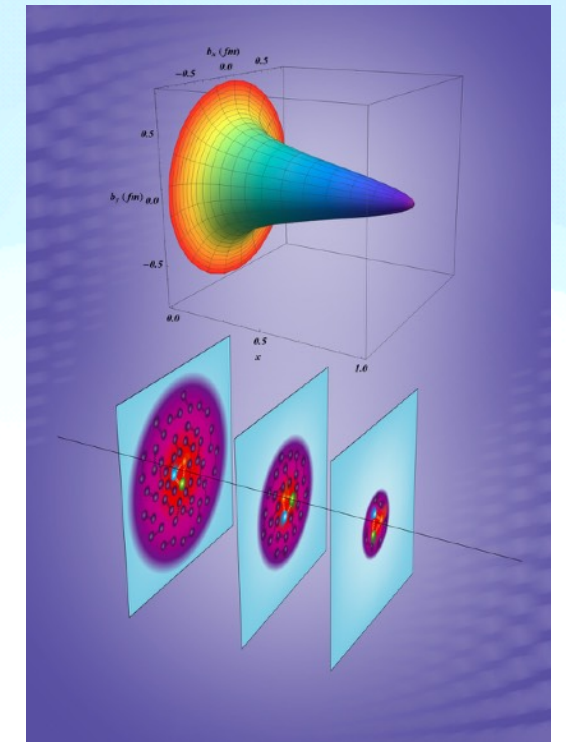
➔ Low Q: proton size and electromagnetic structure

- Radii from e^- scattering and atomic spectroscopy
- $N \rightarrow N^*, \Delta^*$ transitions and low Q^2 structure functions
- Proton generalised **polarizabilities**



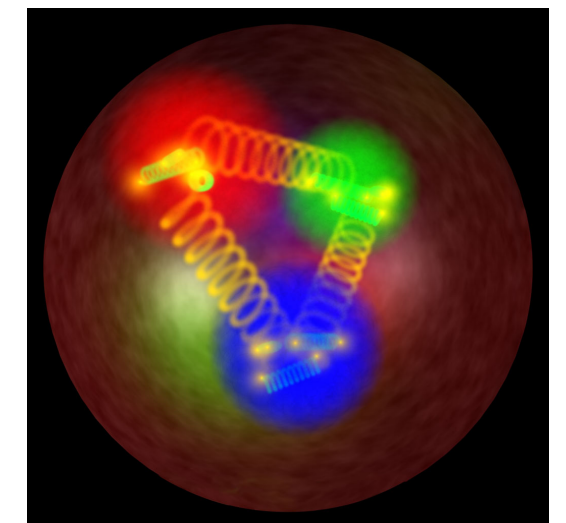
➔ High Q: unifying structure and dynamics

- Parton imaging through **GPDs**
- Proton gluonic structure and radii through J/ψ and Υ **production**
- **Deuteron tensor** structure: a new sum rule

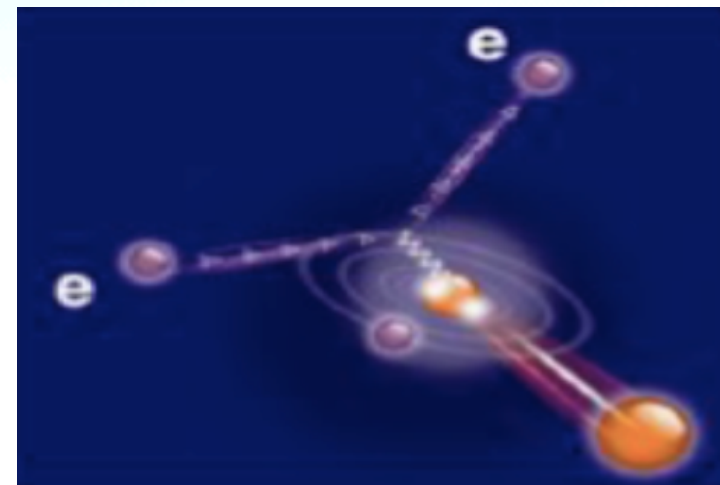
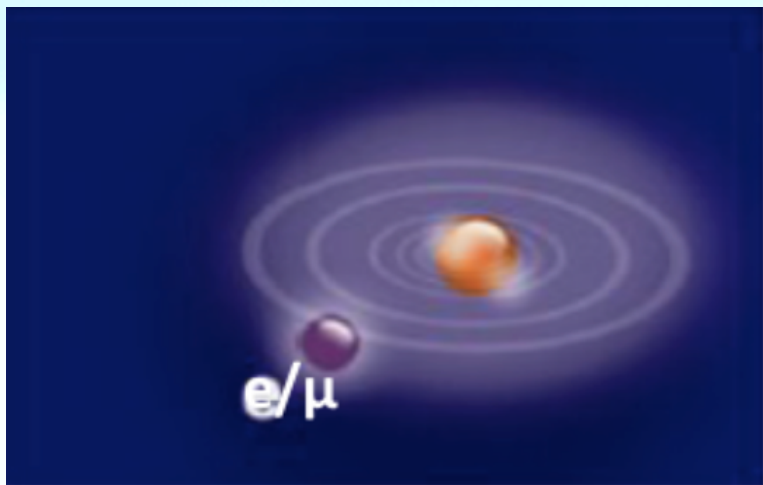


➔ High Q: unifying structure and spectroscopy

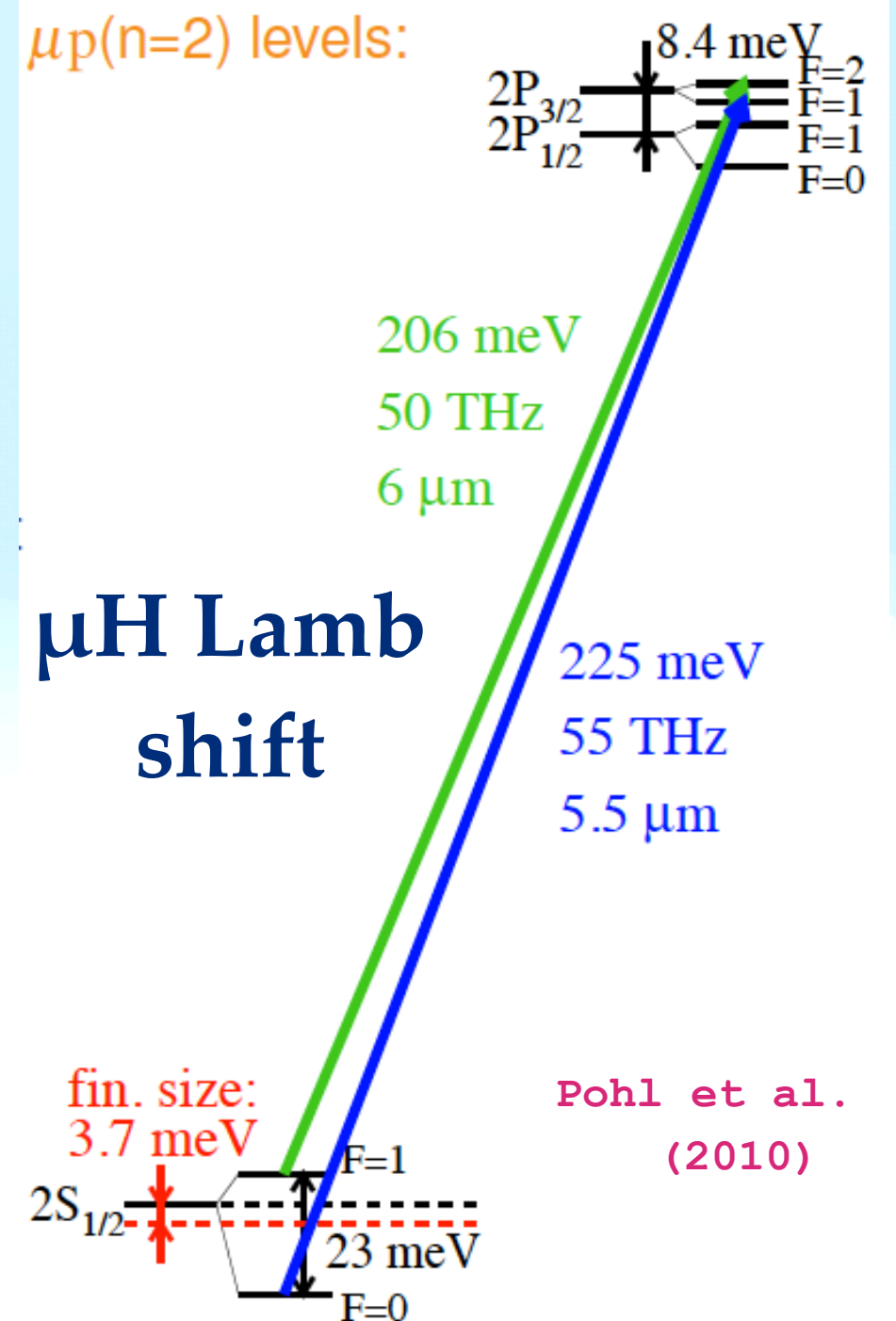
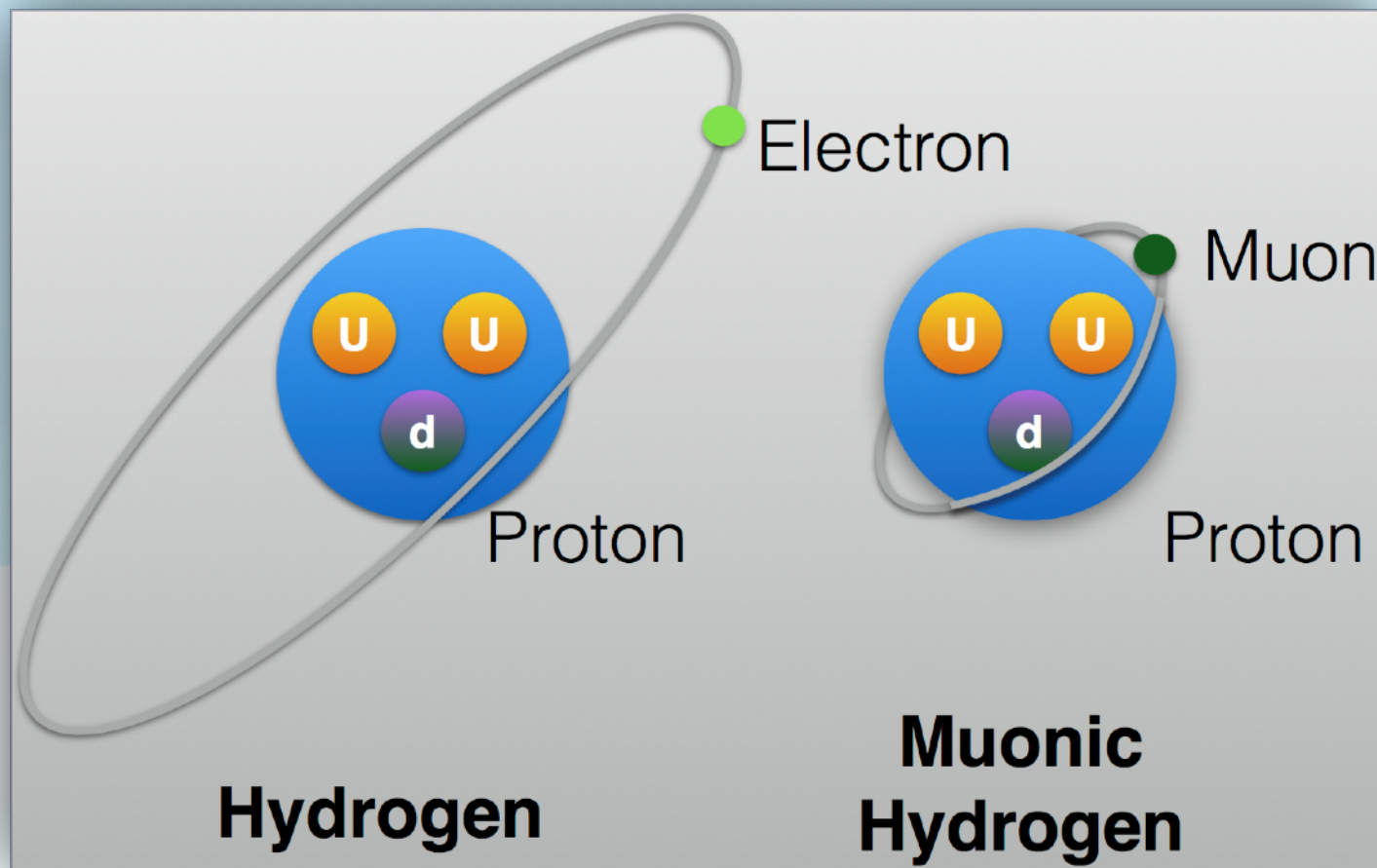
- Partonic structure in $N \rightarrow N^*, \Delta^*$ transitions through GPDs



Low Q : proton size and electromagnetic structure



Proton radius from Hydrogen spectroscopy



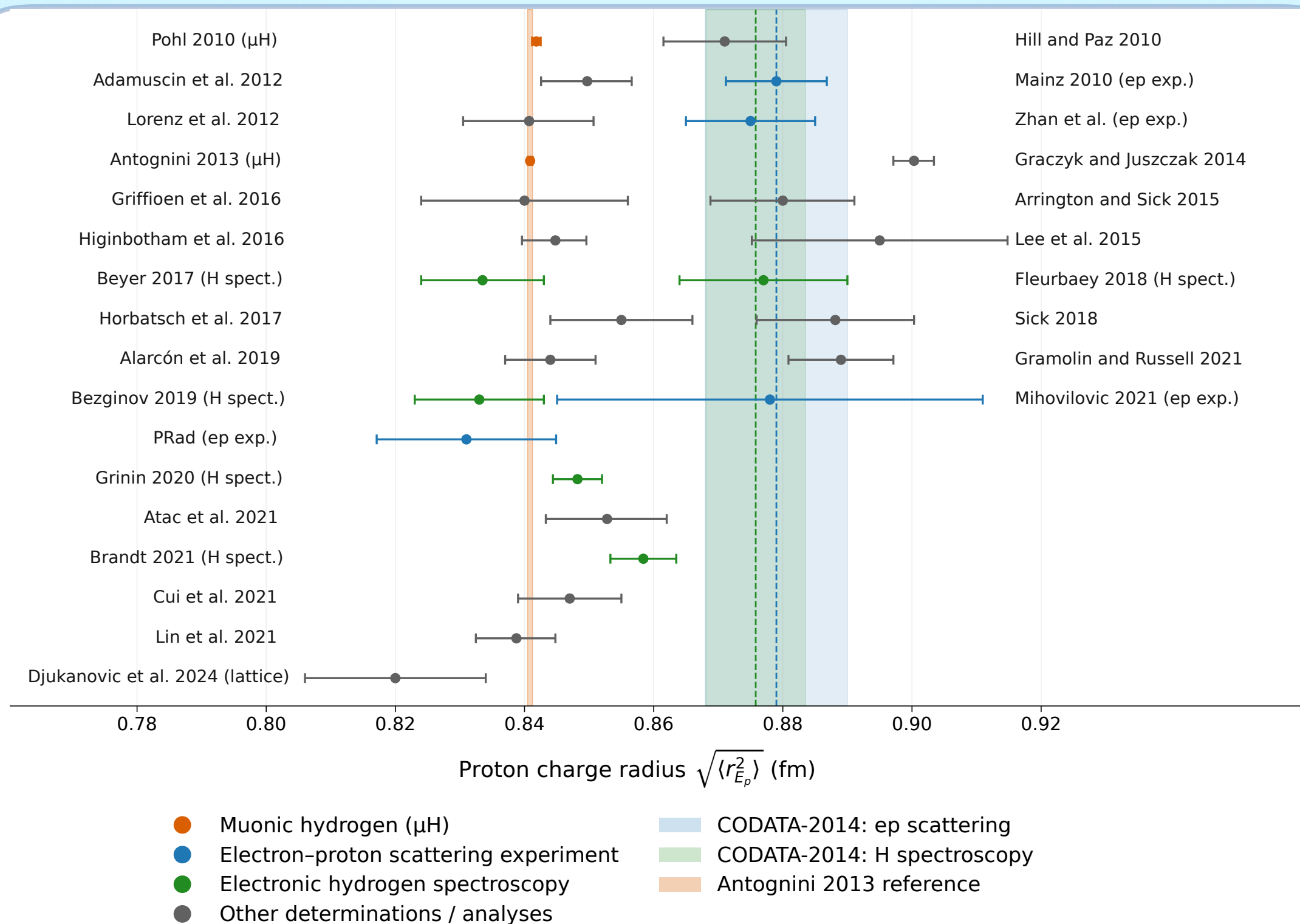
$$\Delta E_{LS} = 206.0336 (15) - 5.2275 (10) R_E^2 + \Delta E_{TPE} \quad \text{meV}$$

Antognini et al. (2013)

3.70 meV

0.0332 (20) meV
O(α^5) correction

Proton charge radius: present experimental status





Near future perspectives at low Q

- ➡ **muonic atom spectroscopy:** shift from puzzle to **precision** !
 - **μH LS:** CREMA coll.: factor 5 improvement planned
 - **μH 1S HFS:** next frontier 1ppm precision, **underway** !
- ➡ **muon scattering plans:**
 - MUSE@PSI : **Parallel II talk E. Cline (Tue)**
 - AMBER@CERN: pilot run 2024, physics data-taking 2025-2026
70 million elastic events in range $10^{-3} < Q^2 < 4 \times 10^{-2} \text{GeV}^2$
- ➡ **electron/positron scattering plans:**
 - ULQ2@Sendai: e⁻ scattering @ 10 - 60 MeV, Q^2 down to $3 \times 10^{-5} \text{GeV}^2$
data taking completed May 2024, under analysis
 - PRad-II@JLab: improvement of stat. uncertainty by factor 3 vs PRad
Parallel II talk H. Nguyen (Tue)
 - MAGIX@MESA: under construction, start in 2027 **Plenary talk A. Denig (Mon)**
 - Further plans: JLab, e⁺ @JLab, ARIEL e⁻ LINAC, ...

Muonic atom spectroscopy needs nucleon/nuclear input

2S-2P Lamb Shift:

THEORY

EXPERIMENT

	$\Delta E_{TPE} \pm \delta_{theo} (\Delta E_{TPE})$	Ref.	$\delta_{exp}(\Delta_{LS})$	Ref.
μH	$33 \mu\text{eV} \pm 2 \mu\text{eV}$	Antognini et al. (2013)	$2.3 \mu\text{eV}$	Antognini et al. (2013)
μD	$1750 \mu\text{eV} \pm 20 \mu\text{eV}$	Pachucki et al. (RMP 2023)	$3.4 \mu\text{eV}$	Pohl et al. (2016)
$\mu^3\text{He}^+$	$15.50 \text{ meV} \pm 0.38 \text{ meV}$	Pachucki et al. (RMP 2023)	0.05 meV	Schuhmann et al. (2023)
$\mu^4\text{He}^+$	$9.28 \text{ meV} \pm 0.43 \text{ meV}$	Pachucki et al. (RMP 2023)	0.05 meV	Krauth et al. (2020)

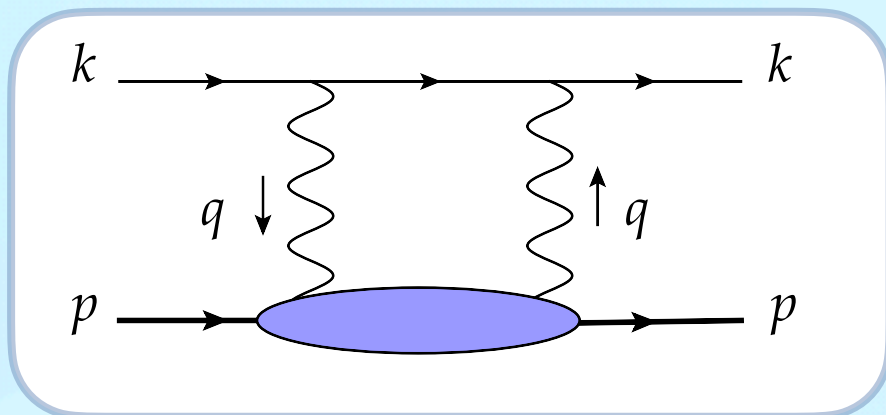
μH :

present accuracy comparable with experimental precision
 Future: factor 5 improvement on Lamb shift planned @PSI
 CREMA, FAMU, J-PARC: 1S hyperfine splitting in μH to 1ppm

$\mu\text{D}, \mu^3\text{He}^+, \mu^4\text{He}^+$:

present accuracy factor 6 - 9 worse than experimental precision

Two-photon exchange: hadronic corrections



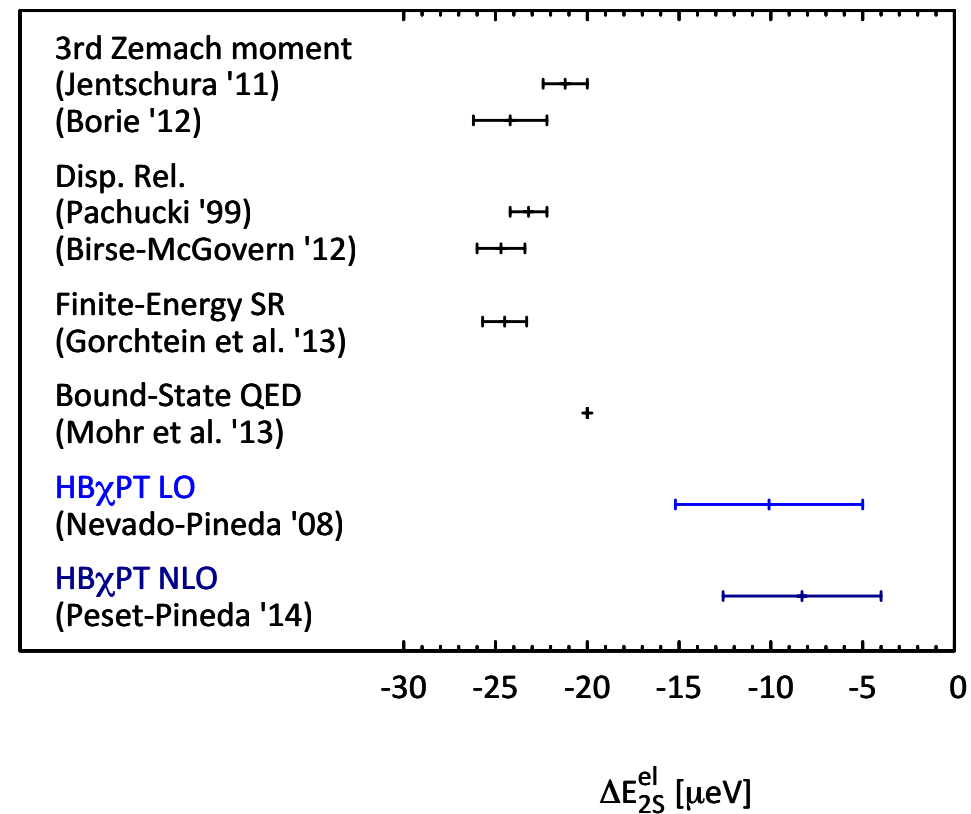
$$T^{\mu\nu}(p, q) = \left(-g^{\mu\nu} + \frac{q^\mu q^\nu}{q^2} \right) T_1(\nu, Q^2) + \frac{1}{M^2} \left(p^\mu - \frac{p \cdot q}{q^2} q^\mu \right) \left(p^\nu - \frac{p \cdot q}{q^2} q^\nu \right) T_2(\nu, Q^2)$$

- **Two-photon exchange (TPE)**: lower blob contains both elastic (nucleon) and inelastic states
- **Lamb shift**: described by unpolarized amplitudes T_1 , T_2 : functions of energy ν and Q^2
- **Hyperfine splitting**: described by polarized amplitudes S_1 , S_2
- **Imaginary parts**: directly proportional to nucleon structure functions F_1 , F_2 resp. g_1 , g_2
- **Real parts**: obtained as dispersion integral over the imaginary parts modulo a subtraction function in case of T_1

$\Delta E = \Delta E^{el} + \Delta E^{subtr} + \Delta E^{inel}$		Elastic state: involves nucleon form factors Subtraction: involves nucleon polarizabilities Inelastic state: involves nucleon structure functions
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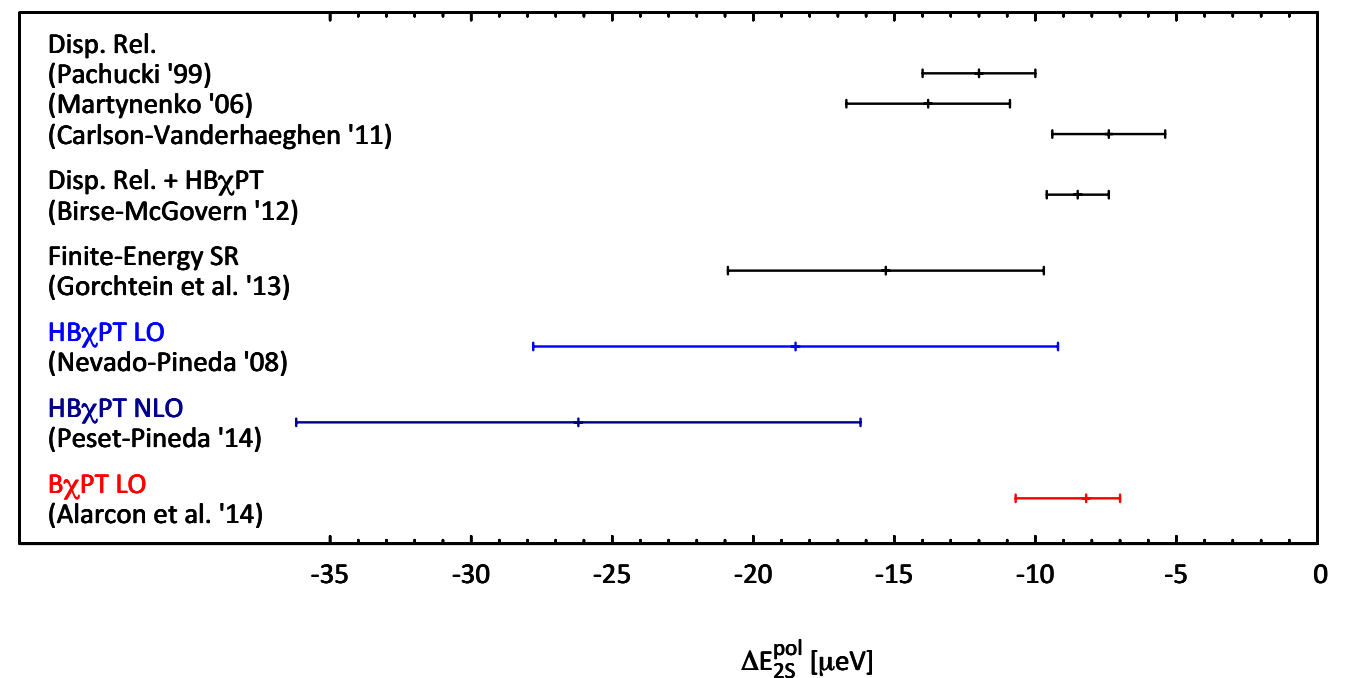
Hadron/Nuclear physics input needed !

TPE elastic correction:



TPE polarizability correction:

Hagelstein, Miskimen,
Pascalutsa (2016)



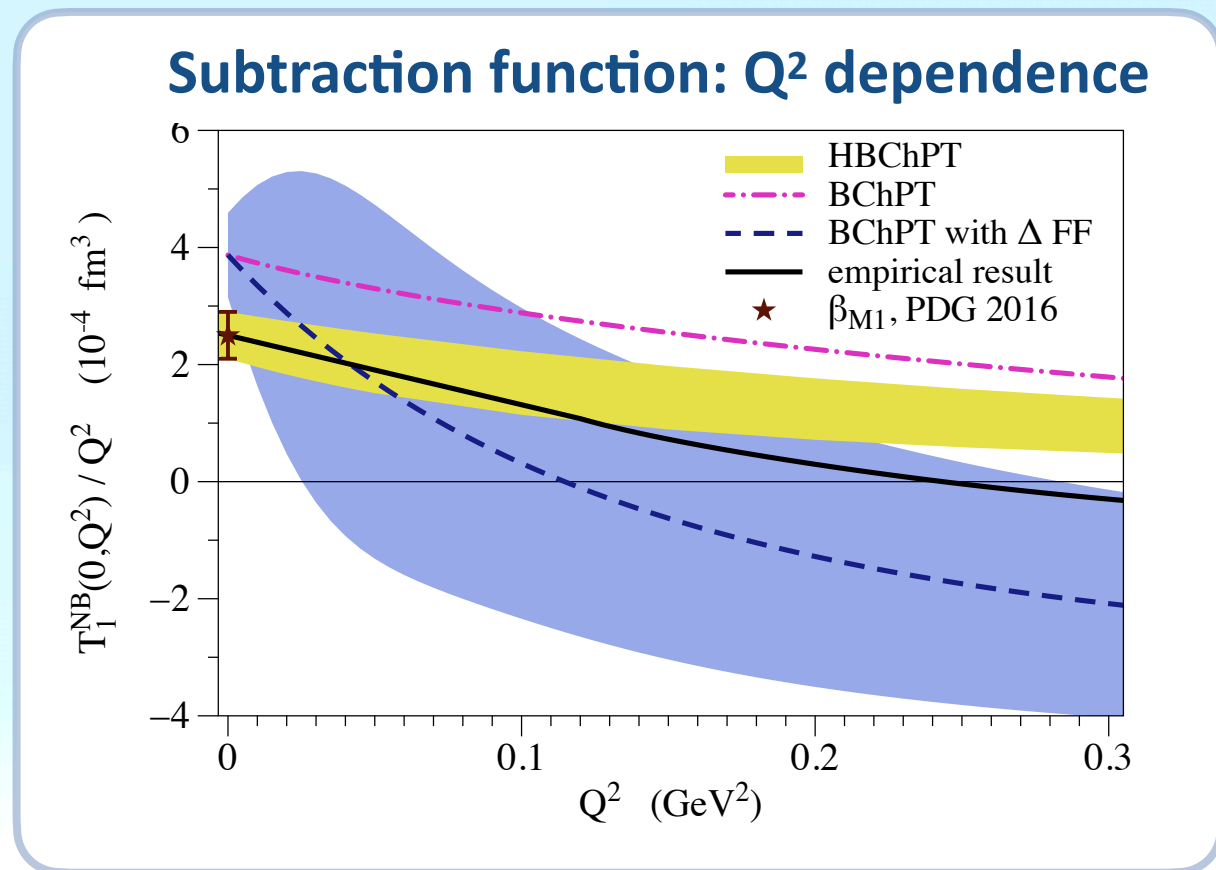
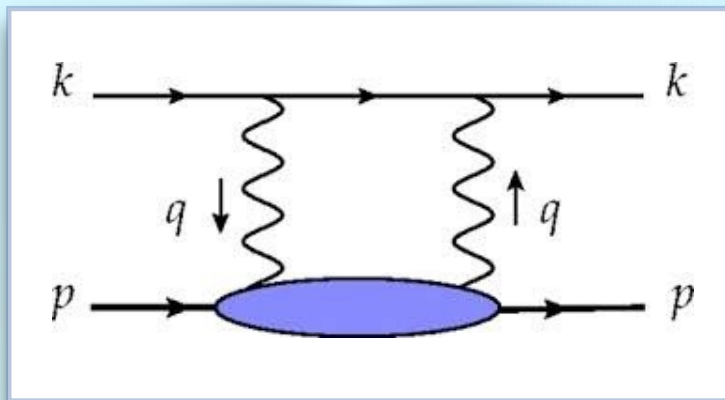
review: Antognini, Hagelstein, Pascalutsa

Ann.Rev.Nucl.Part.Sci. 72 (2022) 389

Improved determination of subtraction function (Lamb shift)

Future plan @PSI:
factor 5 improvement
on LS for muonic H !

Antognini, Pohl



Lensky, Hagelstein, Pascalutsa, Vdh (2018)

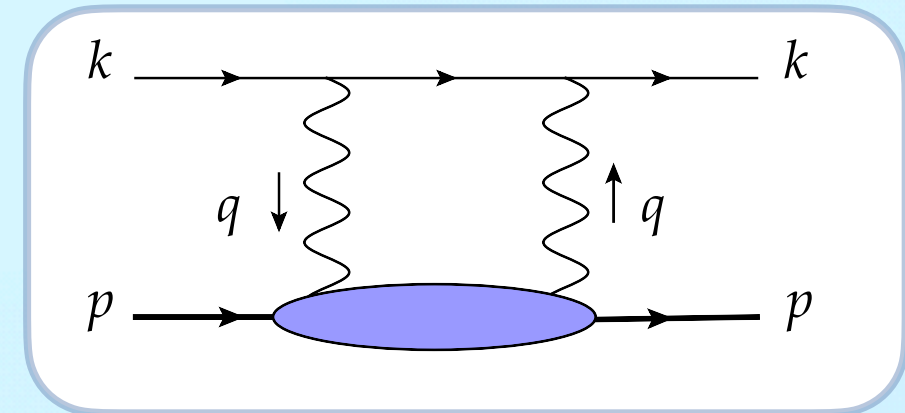
To improve on uncertainty due to subtraction function: **several avenues**

- Full **NLO** calculation in **Baryon ChPT** Hagelstein, Pascalutsa et al. (in preparation)
- New prospect for **lattice determination** of subtraction function Hagelstein, Pascalutsa (2020)
Fu, Feng, Jin, Liu, Wen (2025)
- **Analytic parameterisations** of the forward doubly-virtual Compton amplitudes

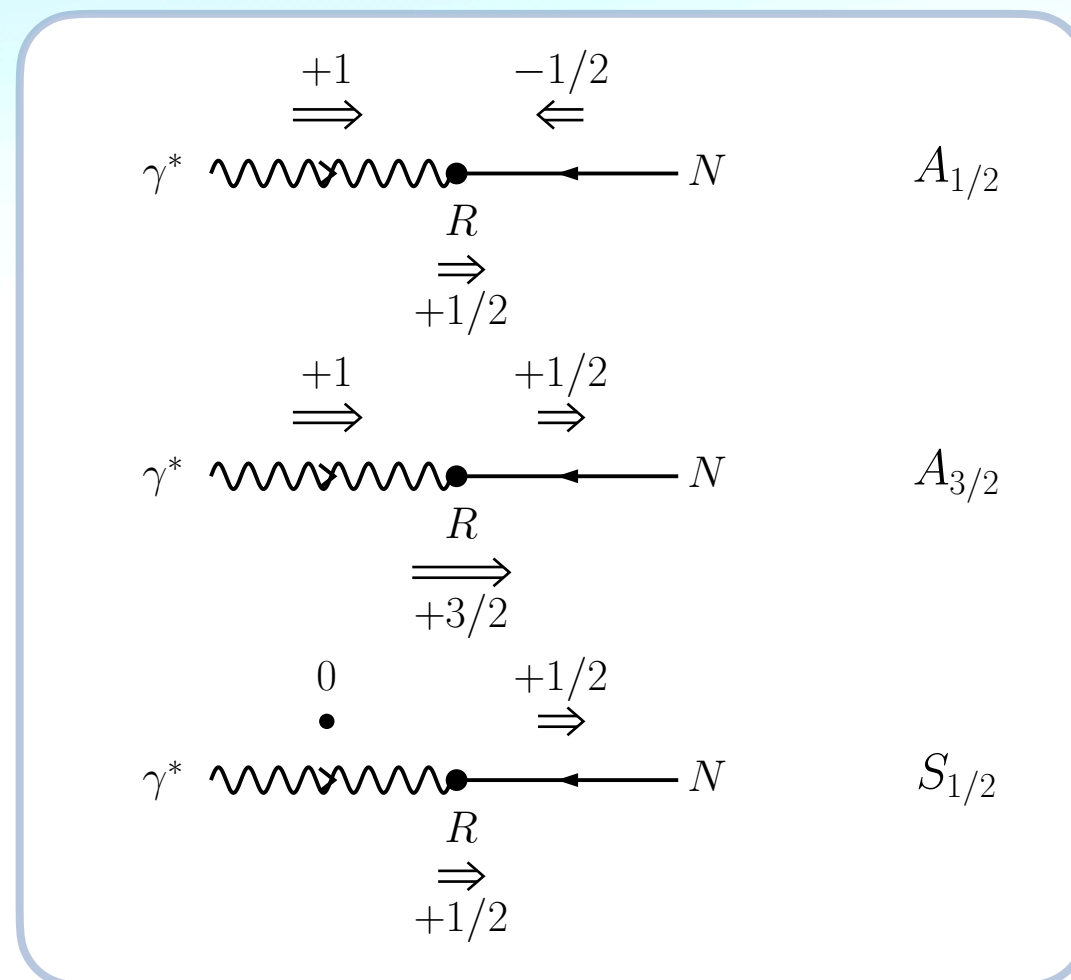
Kalamidas, Vdh (2026, in preparation)

Proton structure functions: analytic parameterisations

Analytic parameterisation of forward doubly-virtual Compton amplitude

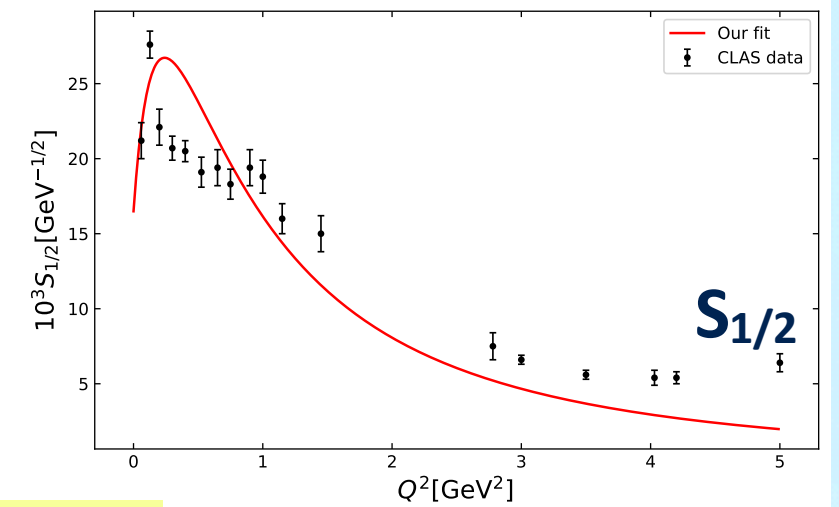
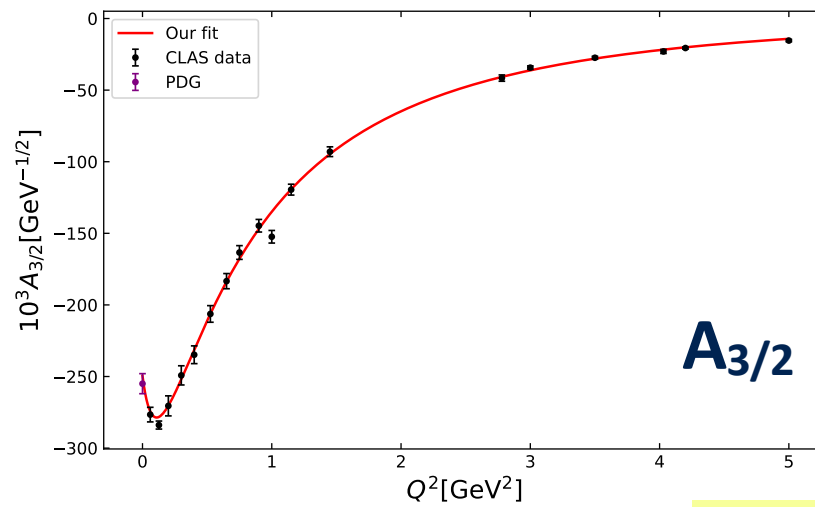
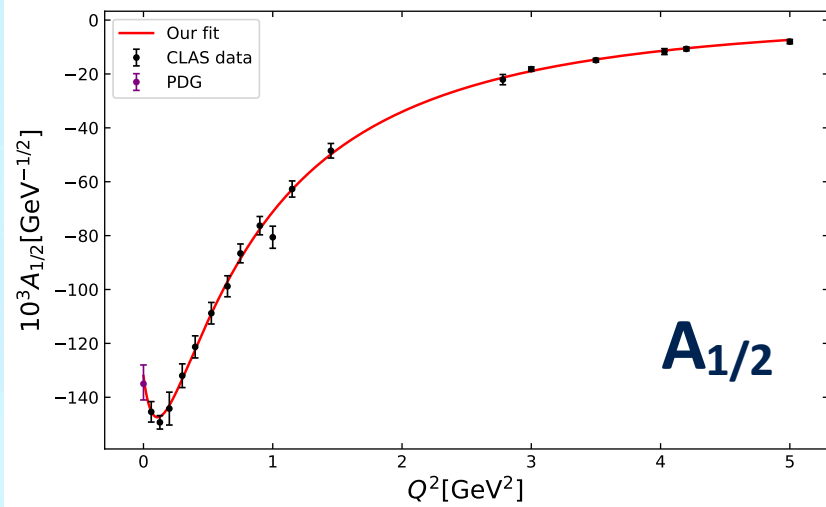


- **Resonance contributions (all 4^* N and Δ resonances below 1.7 GeV):**
completely fixed from exclusive data πN , ηN , $\pi\pi N$, ... channels



$N \rightarrow N^*, \Delta^*$ e.m. transition FFs

$\Delta(1232)3/2^+$

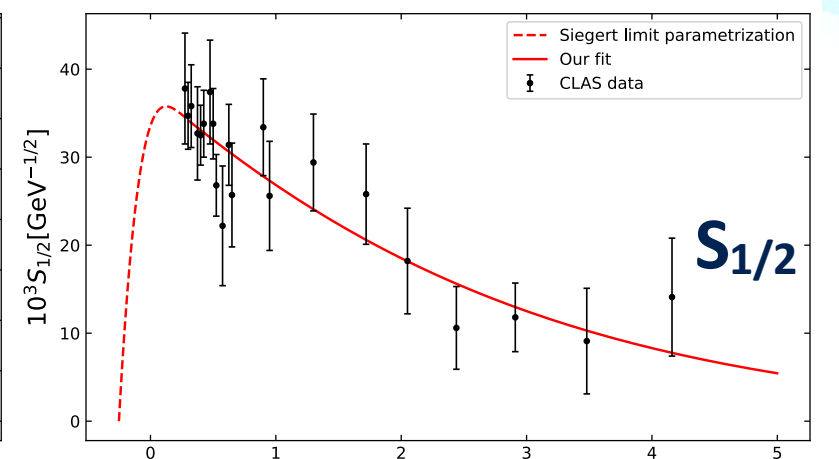
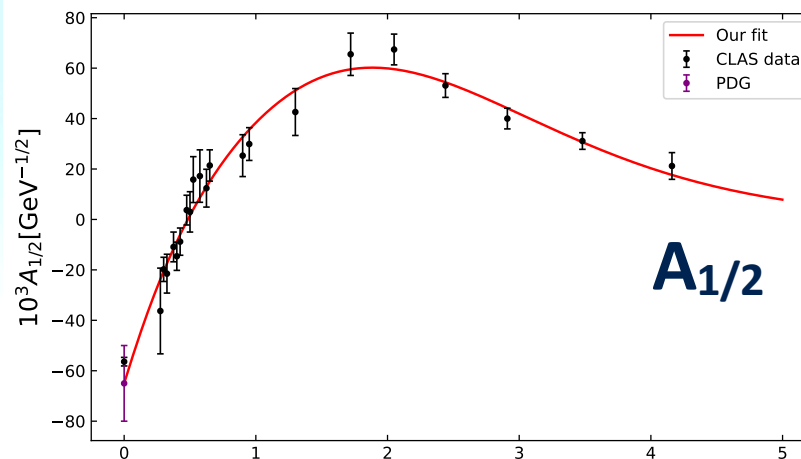


Fit to PDG photocouplings
and CLAS FF data

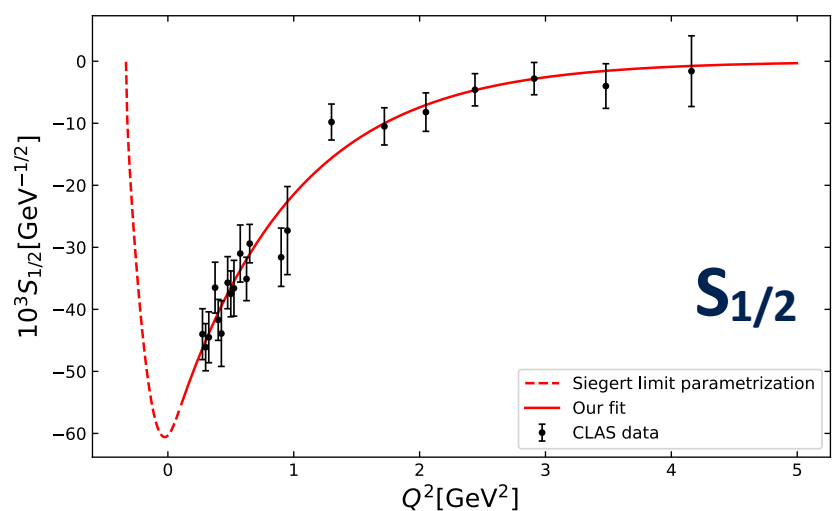
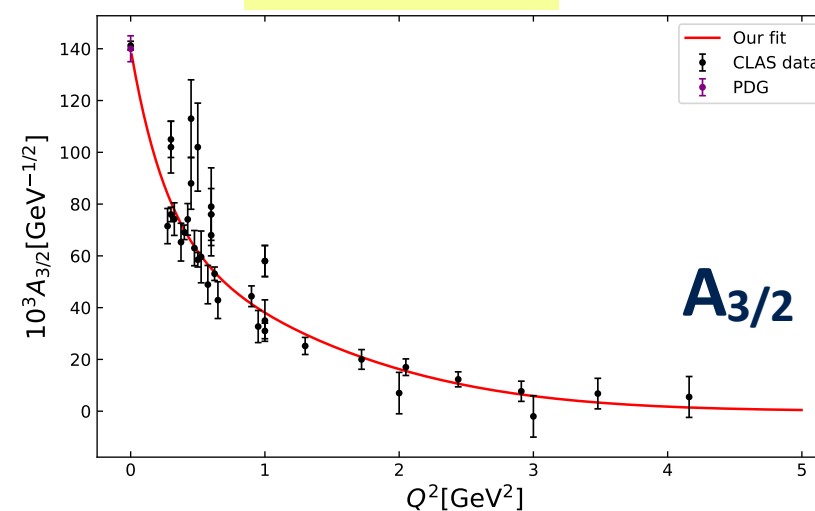
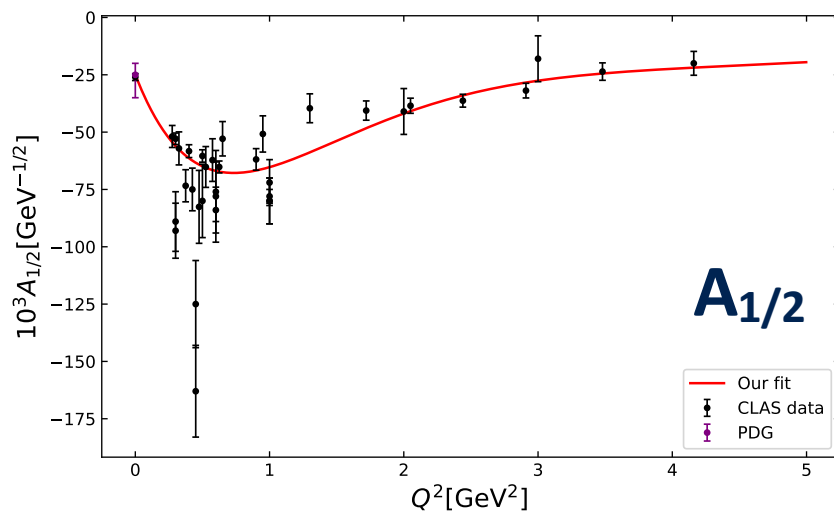
Hiller Blin et al. (2019)

Kalamidas, Vdh(2026)

$N(1440)1/2^+$



$N(1520)3/2^-$

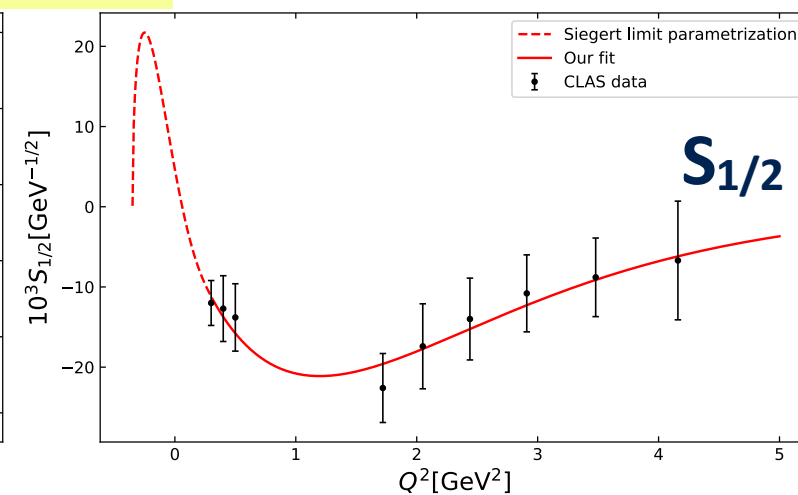
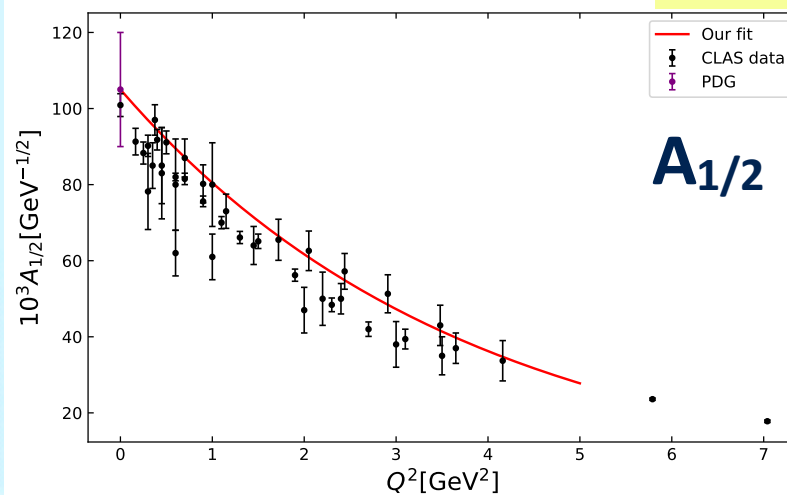


$N \rightarrow N^*, \Delta^*$ e.m. transition FFs (selection)

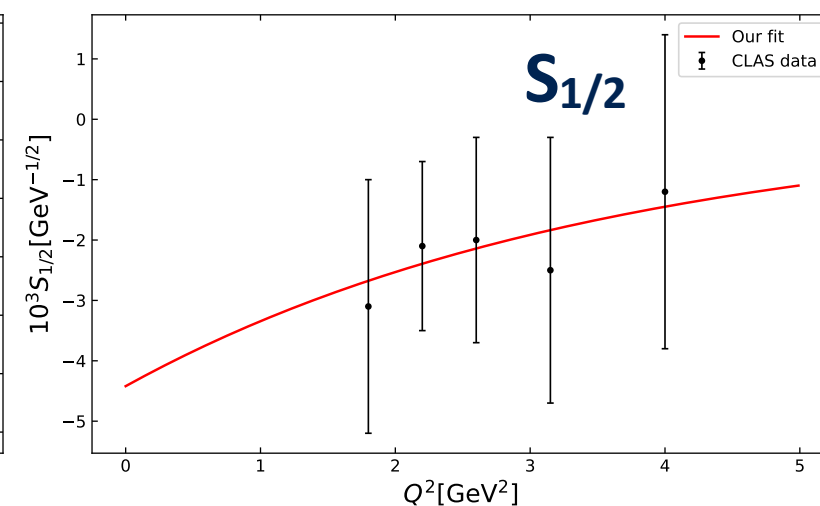
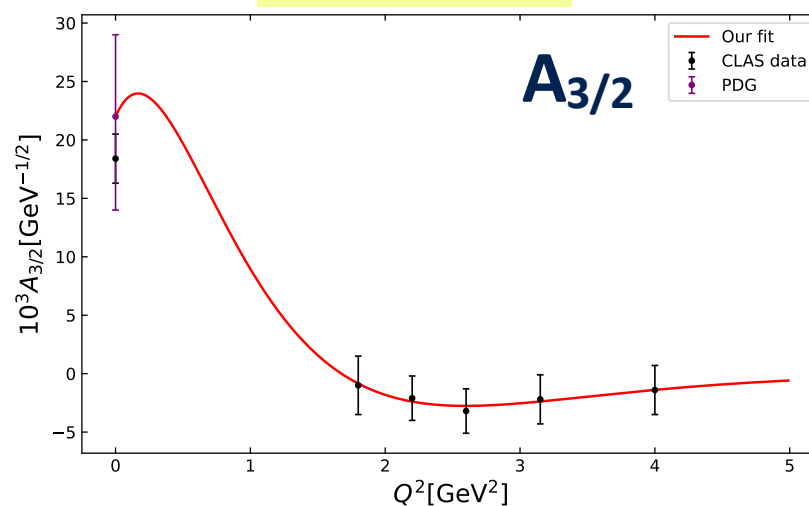
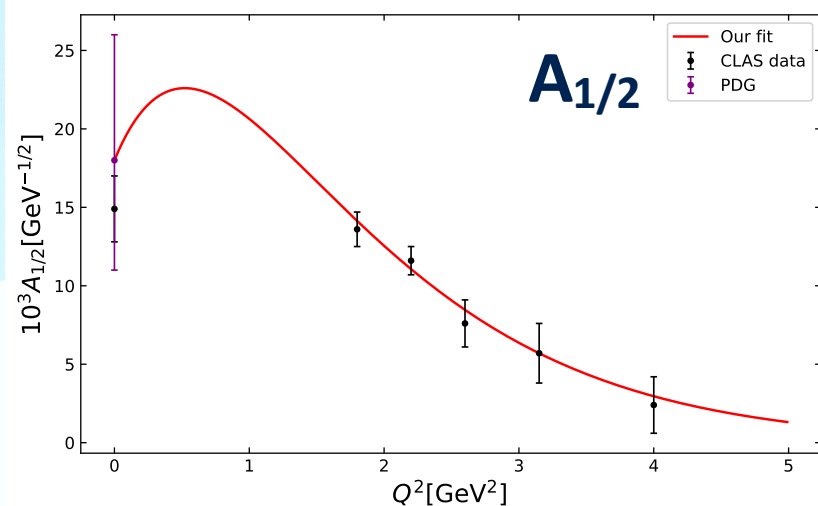
Fit to PDG photocouplings and CLAS FF data

Kalamidas, Vdh (2026)

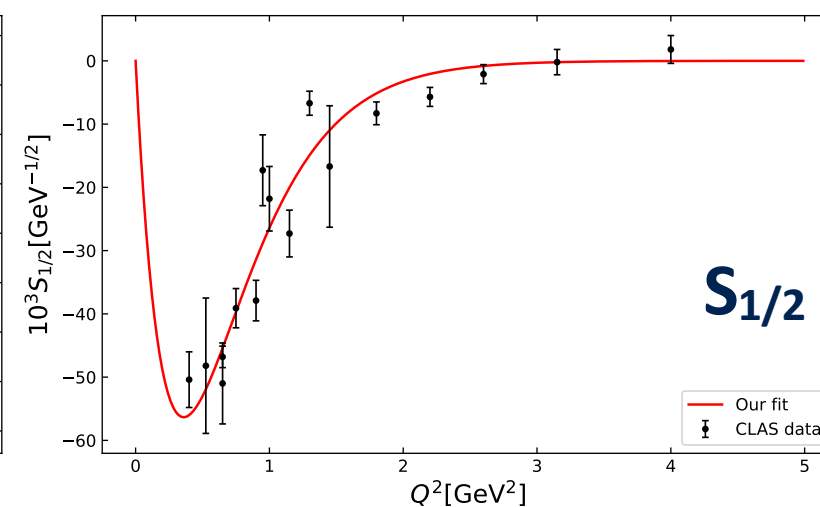
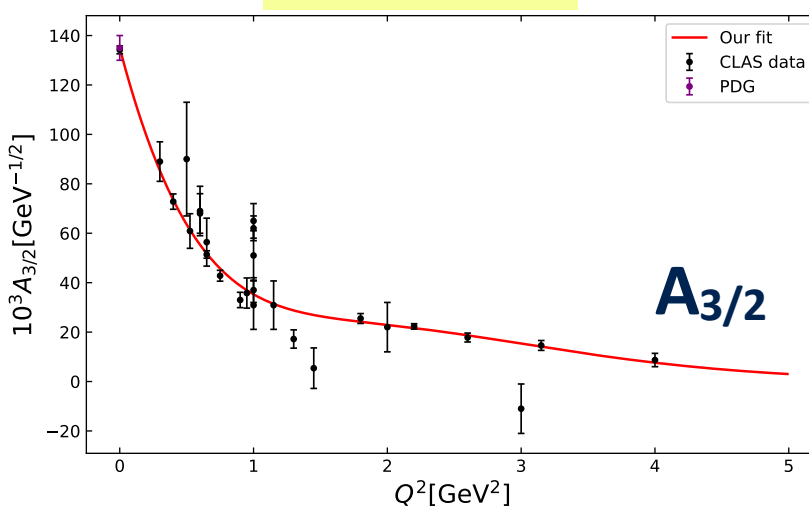
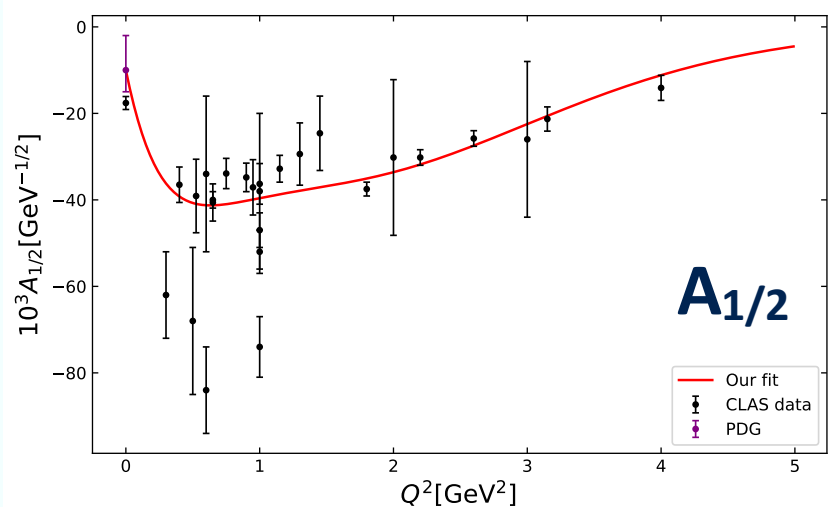
$N(1535)1/2^-$



$N(1675)5/2^-$

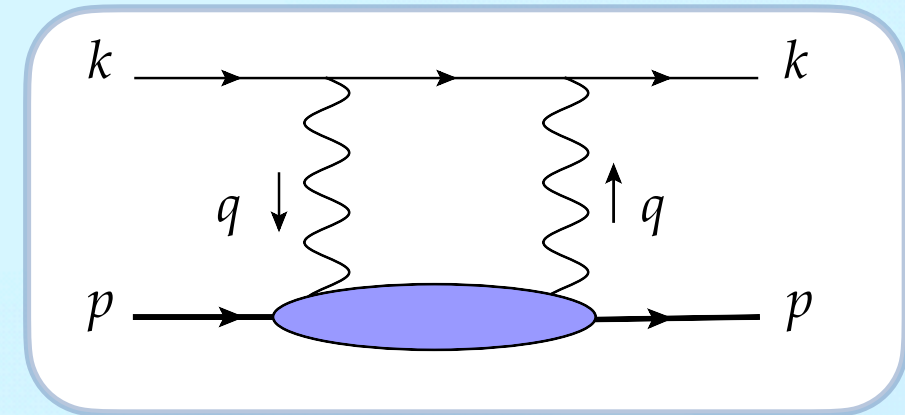


$N(1680)5/2^+$



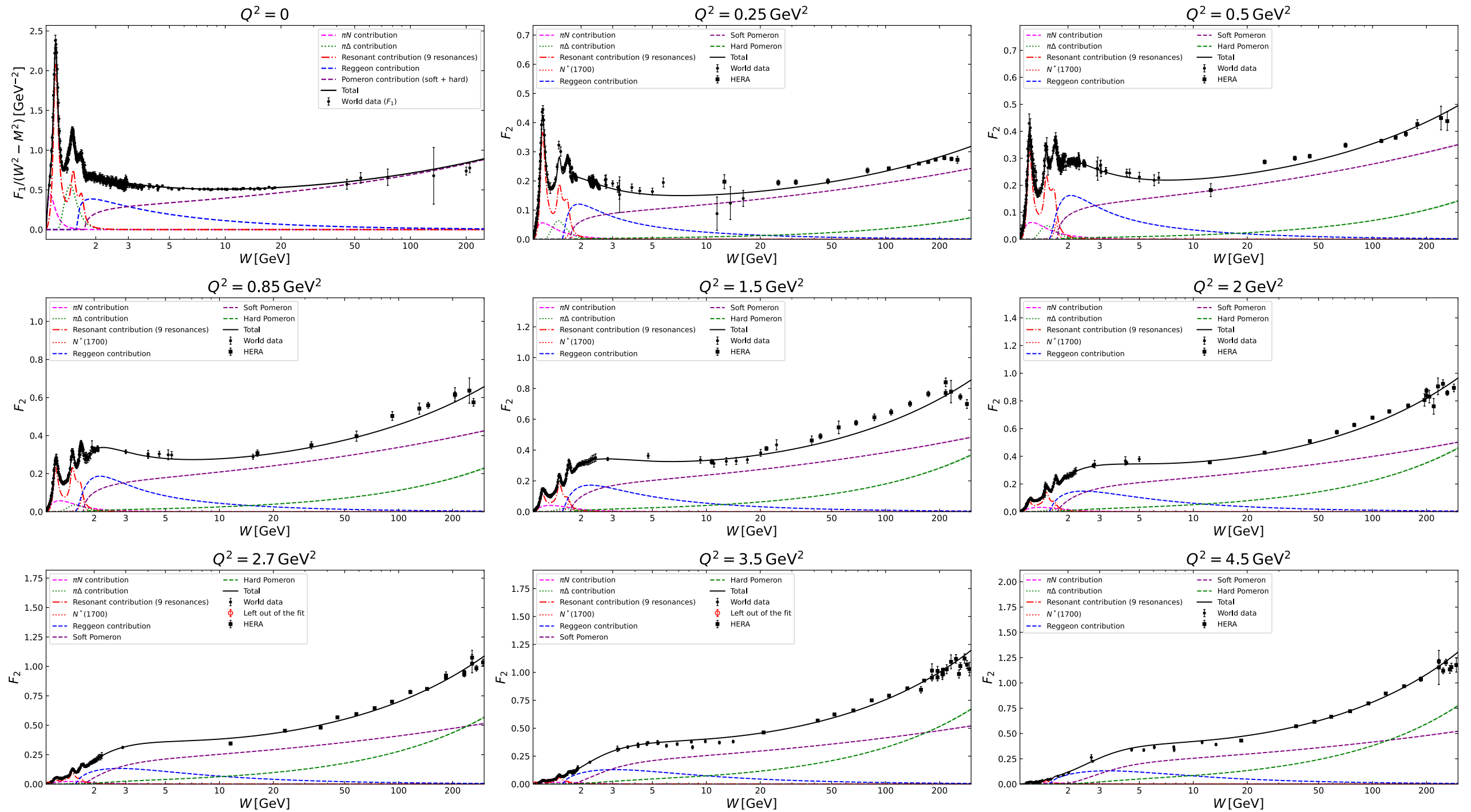
Proton structure functions: analytic parameterisations

Analytic parameterisation of forward doubly-virtual Compton amplitude



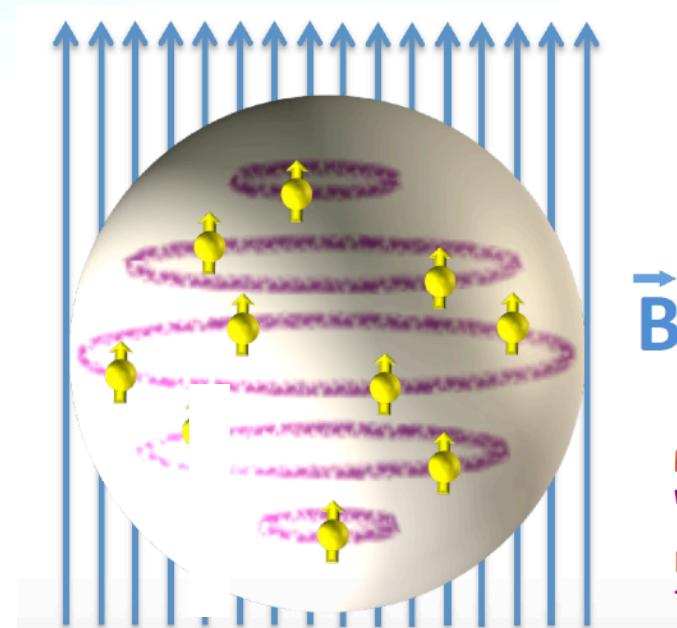
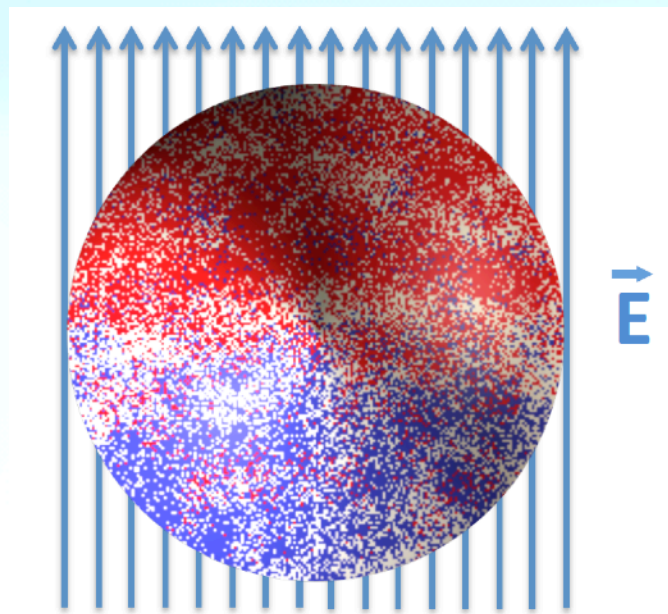
- **Resonance contributions (all 4* N and Δ resonances below 1.7 GeV):**
completely fixed from exclusive data πN , ηN , $\pi\pi N$, ... channels
- **Non-resonant contributions:**
 πN and $\pi\Delta$ channels
- **High-energy behavior ($W > 1.75$ GeV):**
connects to Regge fit of high-energy (HERA) data
- Fit to **F_2 and F_L data for $Q^2 \lesssim 4 \text{ GeV}^2$** ($> 10^4$ data points)
- Can be matched to PDF fits for $Q^2 > 4 \text{ GeV}^2$
- **superconvergence sum rules** allows to extract improved hadronic TPE correction to muonic H

Proton structure functions: analytic parameterisations

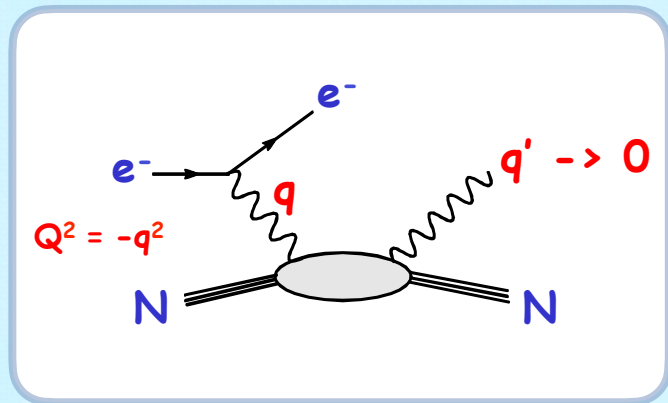


Parallel II talk P. Kalamidas (Tue)

Nucleon structure from Virtual Compton Scattering

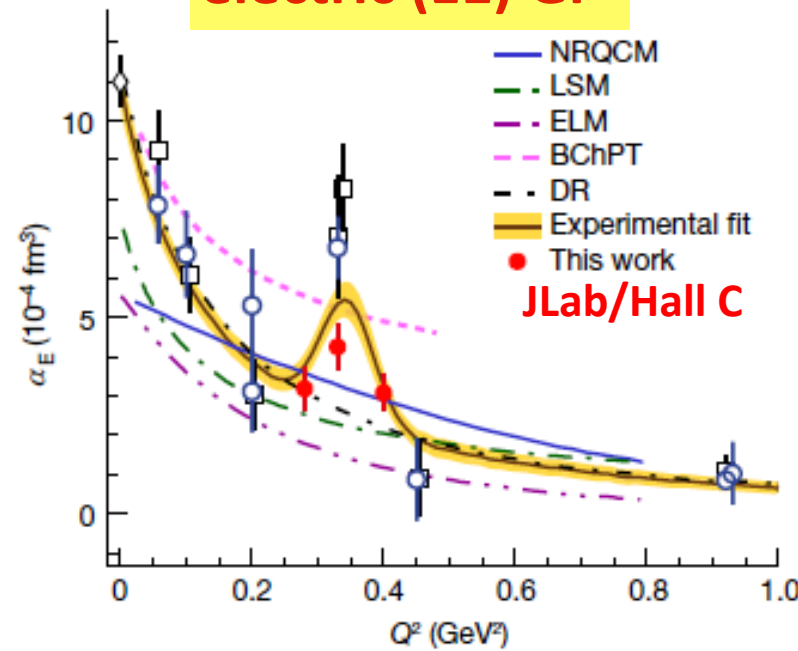


Nucleon structure at low Q with virtual photons: Generalized Polarizabilities in VCS

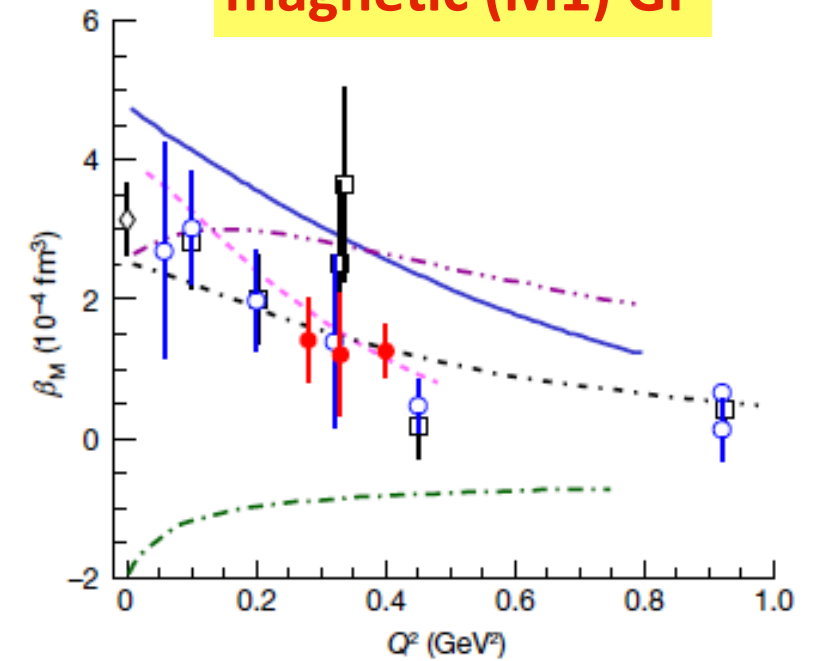


BATES, MAMI,
JLab data

electric (E1) GP



magnetic (M1) GP



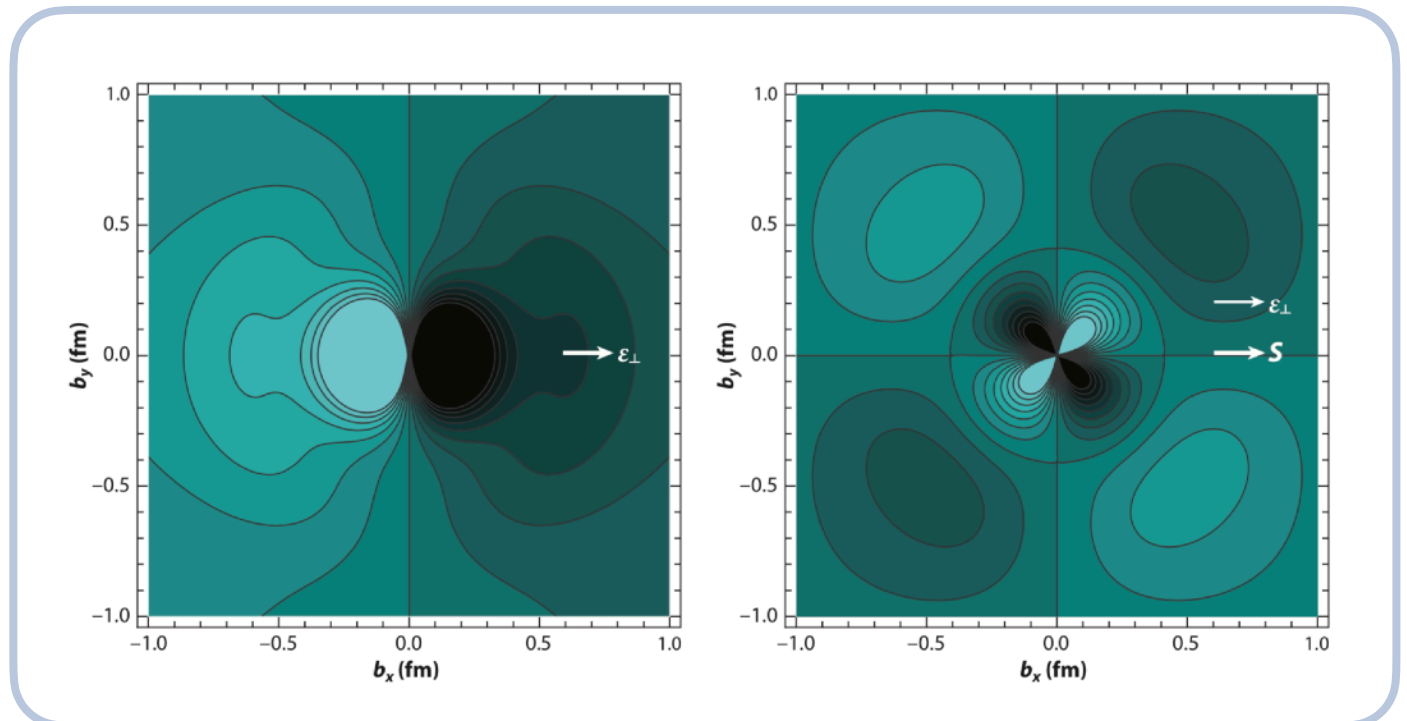
Li, Sparveris et al. Nature 611,265 (2022)

energy shift: $\delta E = -\vec{E} \cdot \vec{P}_0$

induced polarization

$$\begin{aligned}\vec{P}_0(\vec{b}) &= \int \frac{d^2 \vec{q}_\perp}{(2\pi)^2} e^{-i\vec{q}_\perp \cdot \vec{b}} \vec{P}_0(\vec{q}_\perp) \\ &= \hat{b} \int_0^\infty \frac{dQ}{(2\pi)} Q J_1(bQ) A(Q^2)\end{aligned}$$

combination of nucleon
generalized polarizabilities



Gorchtein, Lorcé, Pasquini, Vdh (2009) ; Pasquini, Vdh (2018)

VCS in $\Delta(1232)$ resonance region: update in theory

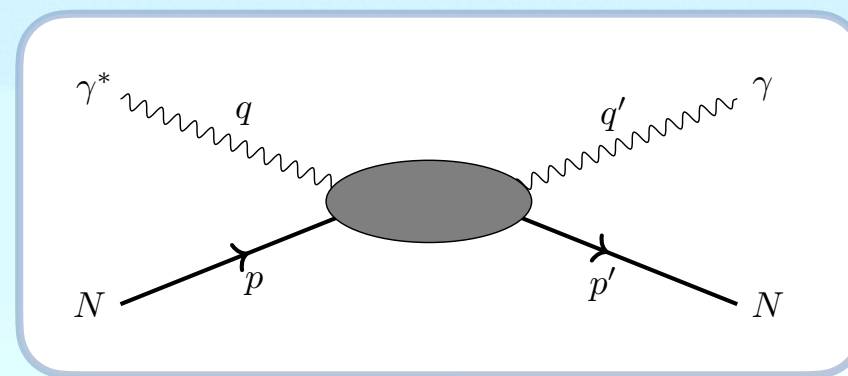
➡ Extraction of polarizabilities using dispersion relations

- unsubtracted framework:

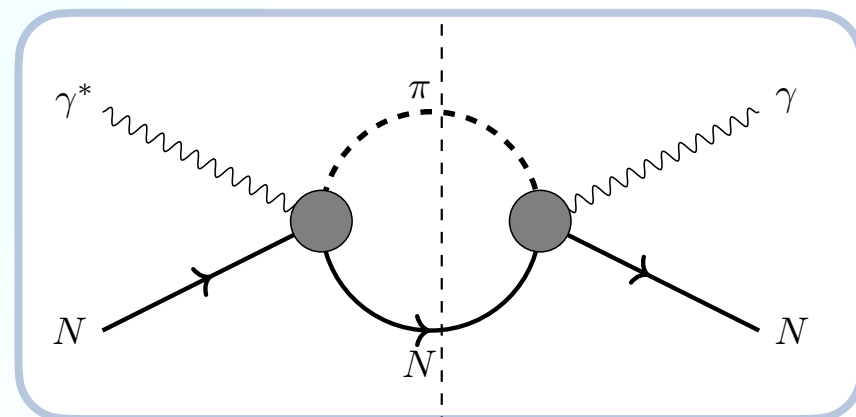
Pasquini, Drechsel, Gorchtein, Metz, Vdh (2000)

- subtracted framework:

Danilkin, Pasquini, Ronchi, Vdh (2026)



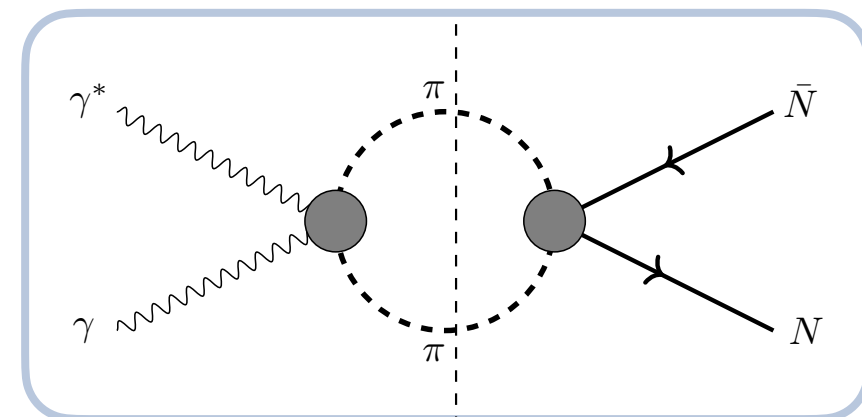
πN s-channel cut
(MAID2008)



$\pi\pi$ t-channel cut

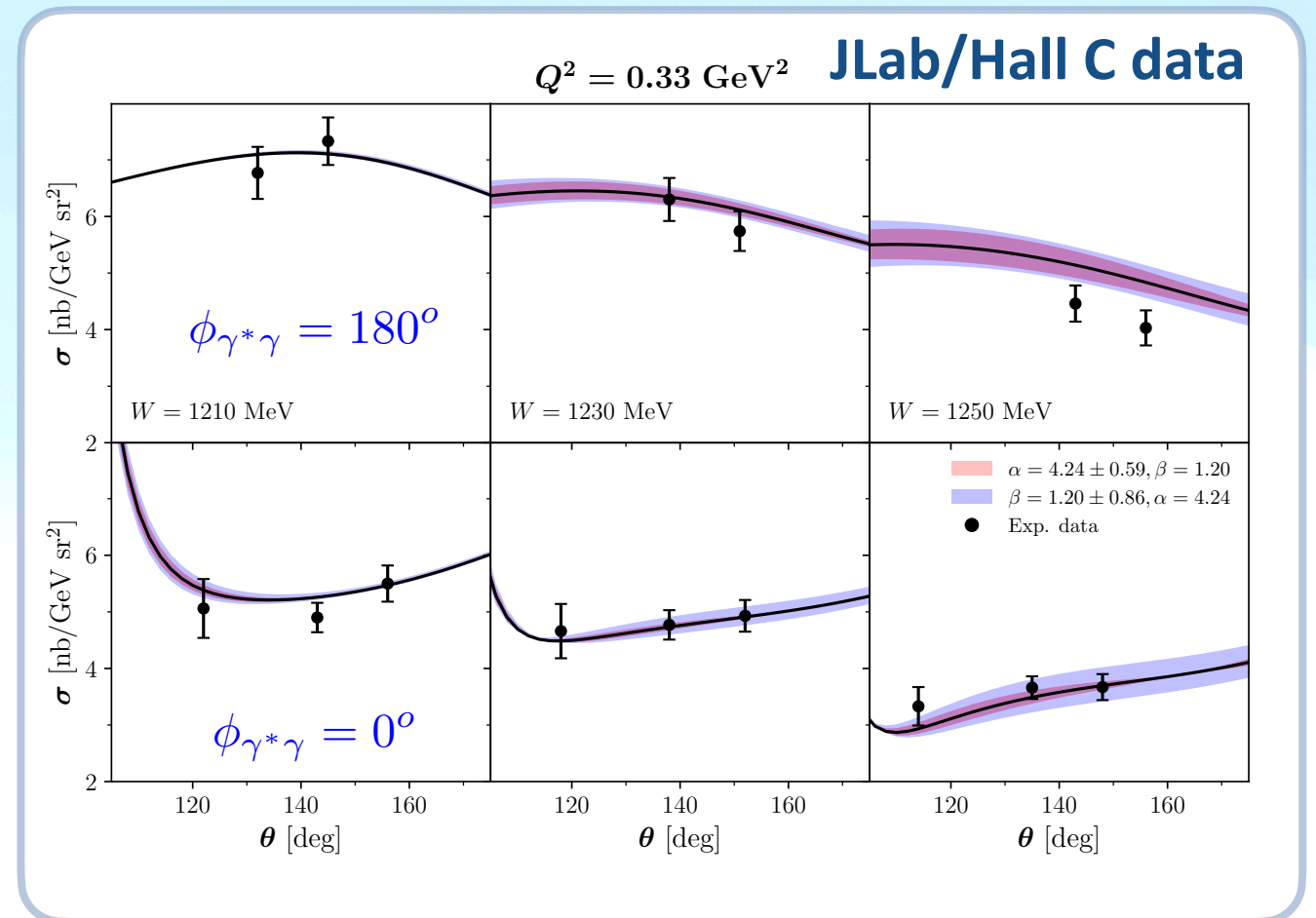
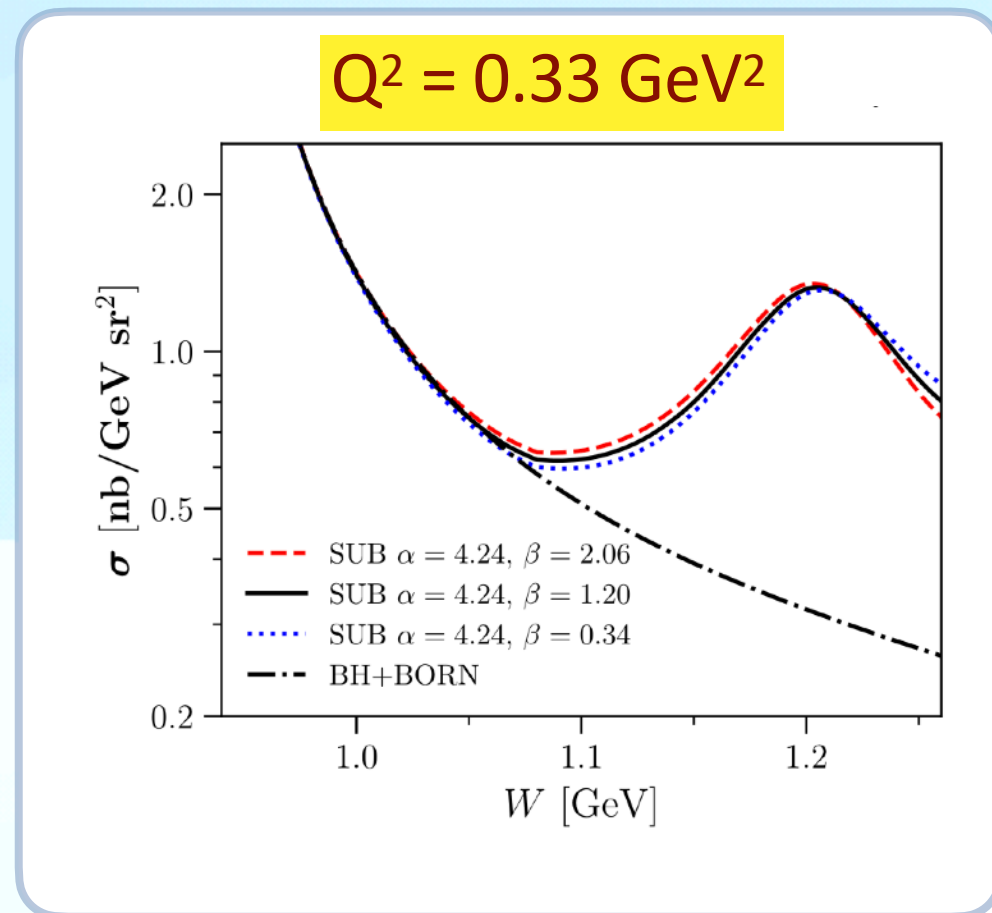
$\gamma^* \gamma \rightarrow \pi\pi$ Danilkin, Vdh (2019)

$\pi\pi \rightarrow N\bar{N}$ Hoferichter, Ruiz de Elvira, Kubis, Meissner (2016)



VCS in $\Delta(1232)$ resonance region: update in theory

➡ **Consistency check** on formalism: GP contribution changes sign on resonance due to interference with real part of $\Delta(1232)$ production amplitude



Danilkin, Pasquini, Ronchi, Vdh (2026)

➡ **VCS-II experiment:** measurement across the $\Delta(1232)$ region underway

Parallel IV talk
S. Lee (Thu)

High Q: unifying nucleon structure and dynamics

MRI studies brain anatomy.



Functional MRI
(fMRI) studies brain
function.



Unifying structure and dynamics: quark spatial vs momentum distributions

**elastic
scattering**



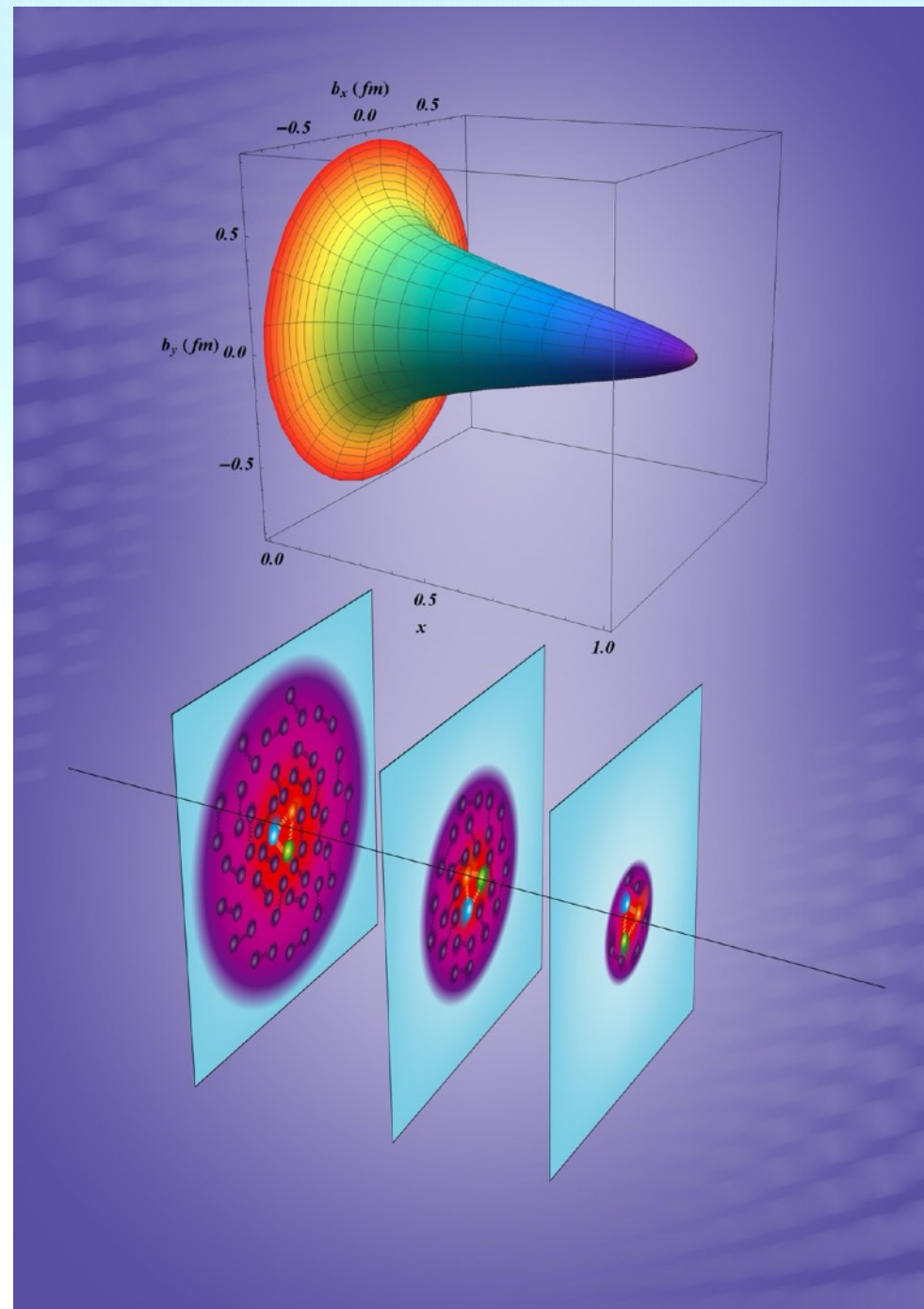
DIS

quark
distributions in
**transverse
position space**

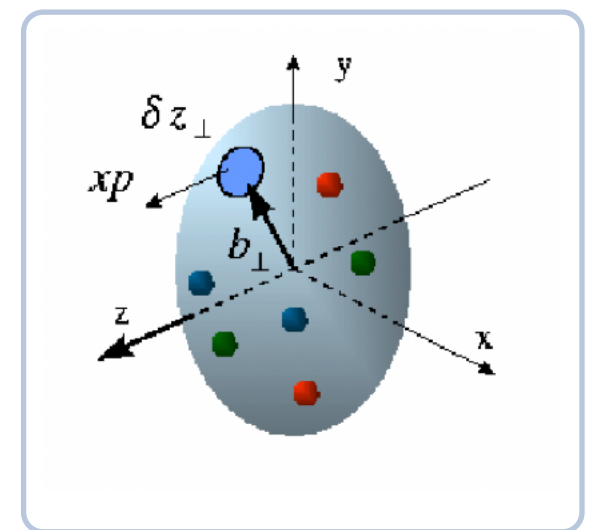
proton
3D imaging

Burkardt (2000, 2003)

Belitsky, Ji, Yuan
(2004)

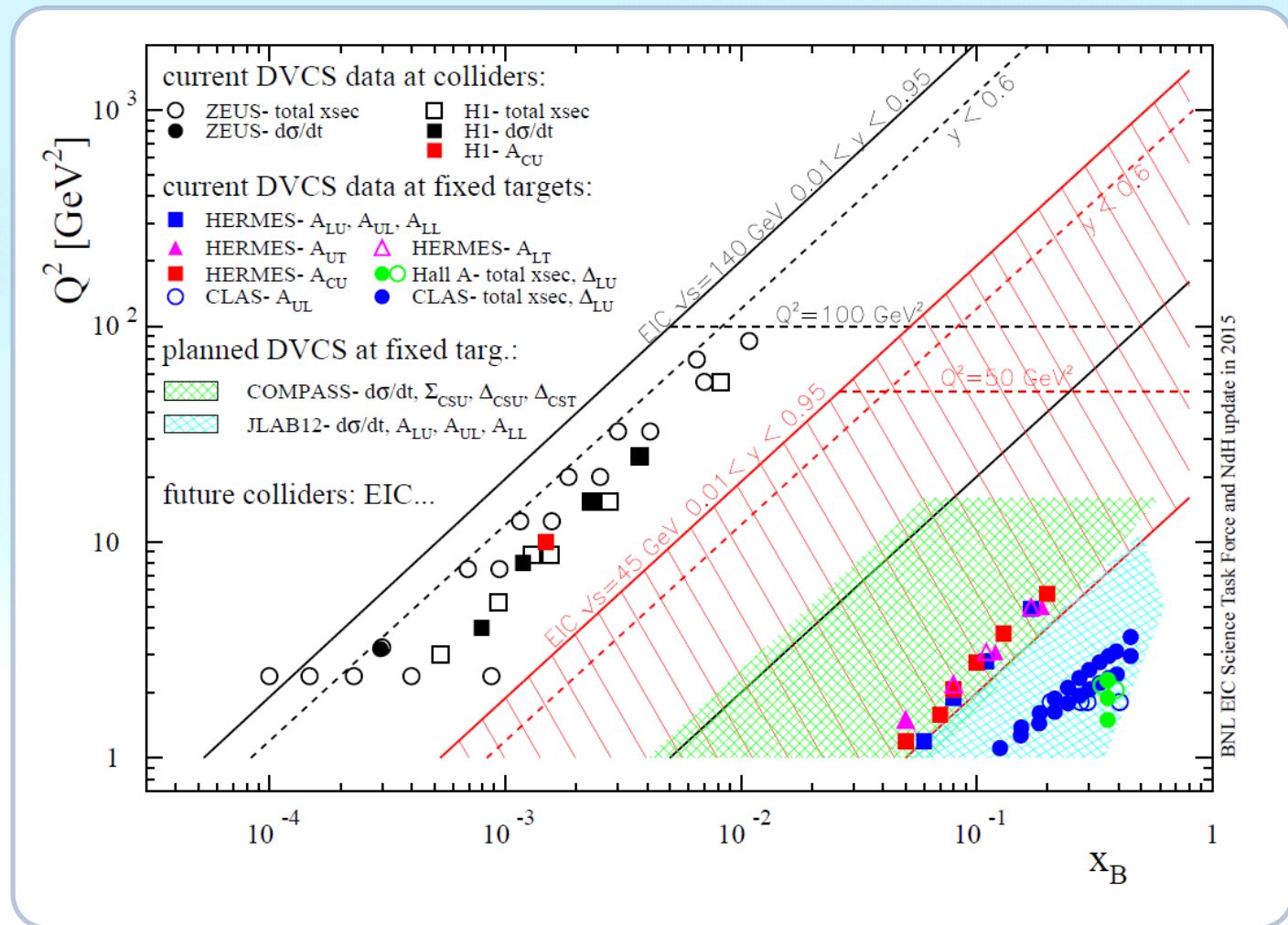
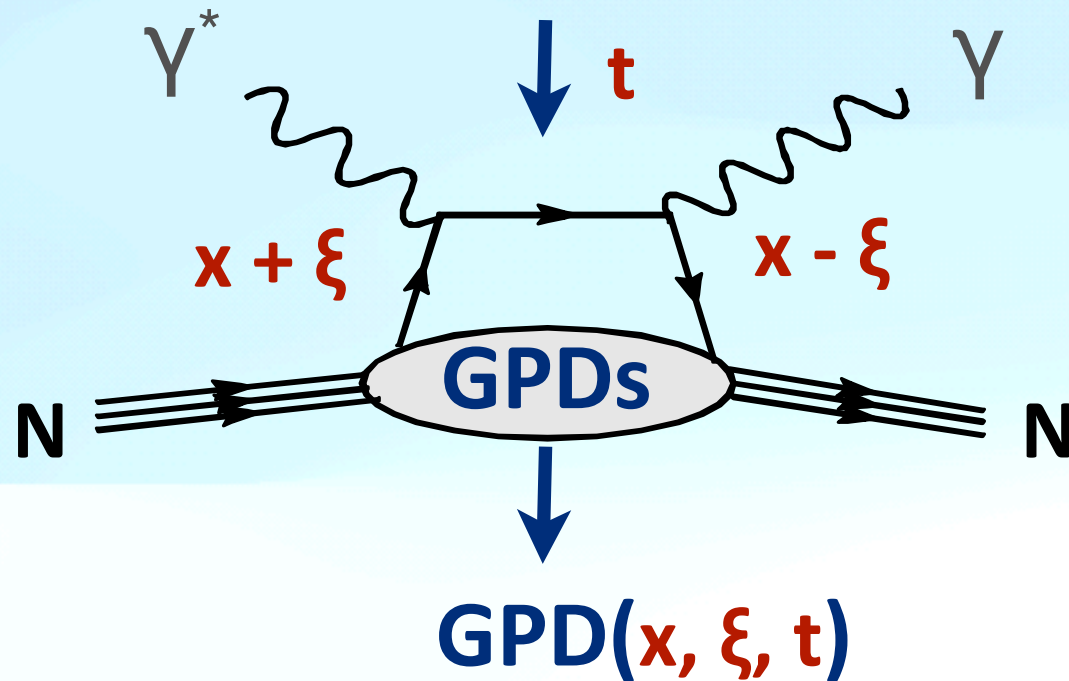


quark
distributions in
**longitudinal
momentum**



DVCS: tool to access GPDs

$$Q^2 \gg 1 \text{ GeV}^2$$



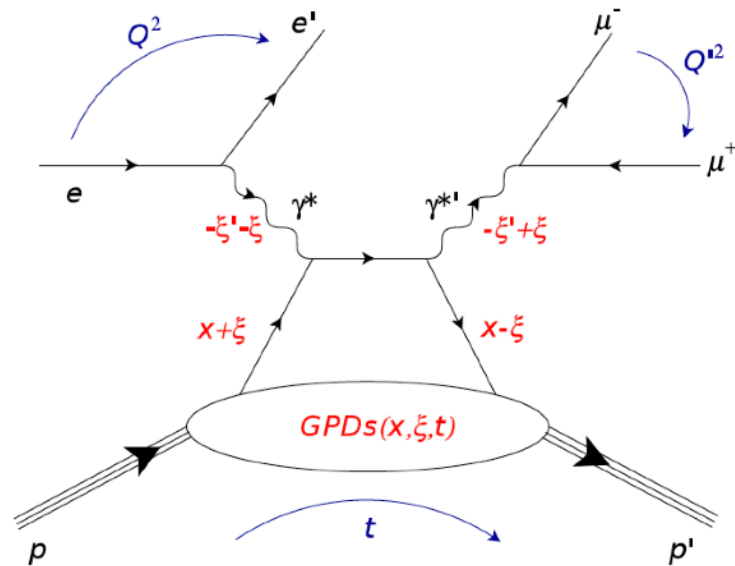
➡ at large Q^2 : **QCD factorization theorem**

Müller et al (1994) Ji (1995) Radyushkin (1996) Collins, Frankfurt, Strikman (1996)

at twist-2: **4 quark helicity conserving GPDs**

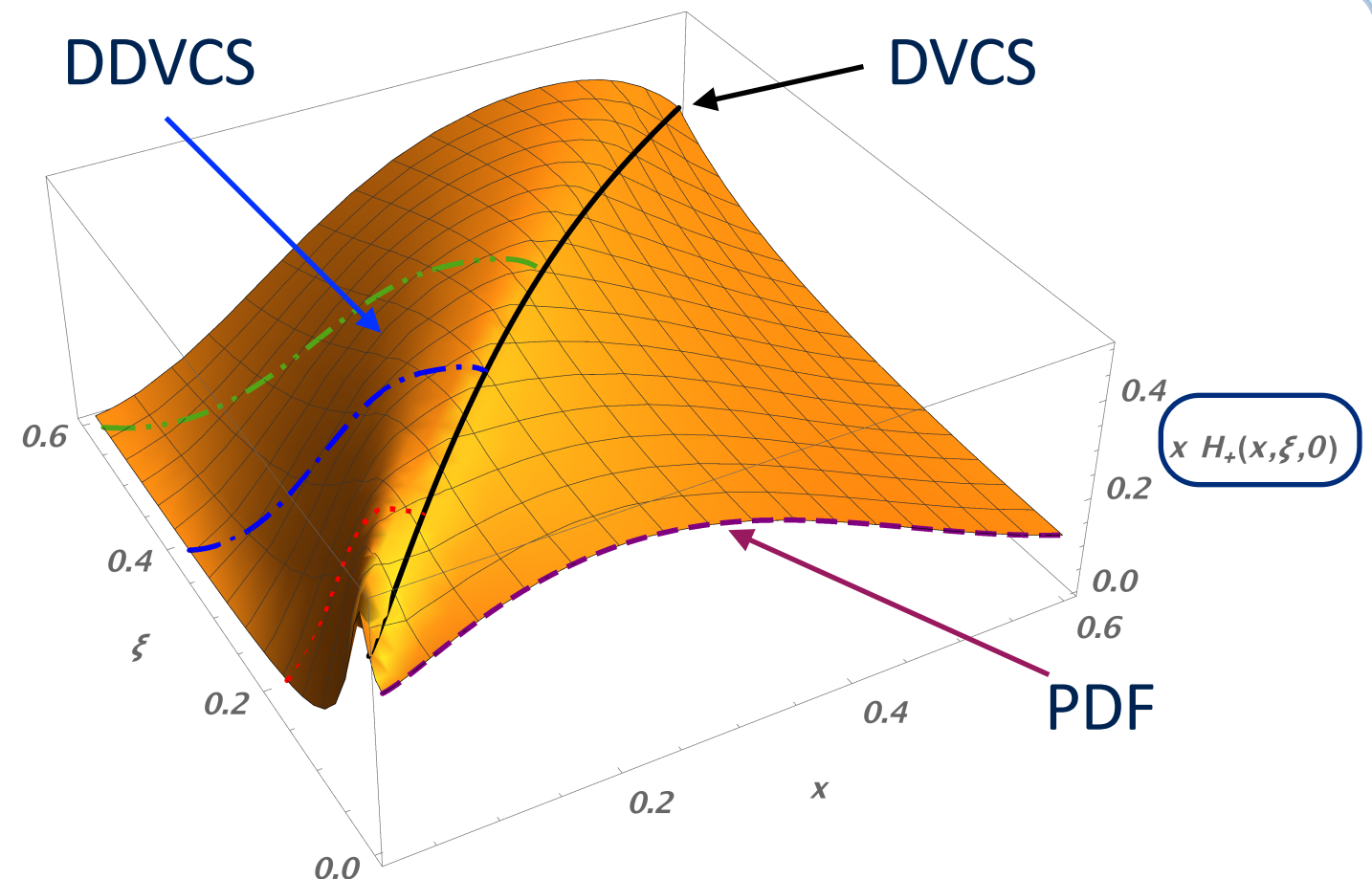
➡ key: Q^2 leverage needed to test **QCD scaling** -> **EIC**

Double DVCS allows direct access to GPDs



$$\xi' = \frac{Q^2 - Q'^2 + t/2}{2Q^2/x_B - Q^2 - Q'^2 + t}$$

$$\xi = \frac{Q^2 + Q'^2}{2Q^2/x_B - Q^2 - Q'^2 + t}$$



$$\mathcal{F}(\xi', \xi, t) = \mathcal{P} \int_{-1}^1 dx F_+(x, \xi, t) \left[\frac{1}{x - \xi'} \pm \frac{1}{x + \xi'} \right] - i\pi F_+(\xi', \xi, t)$$

Guidal, Vdh(2003); Belitsky, Mueller (2003)

Deja et al.(2023)

DVCS process accesses Compton Form Factors,
double DVCS needed to directly access GPDs

Parallel I talks: M. Mathison, A. Singh,
L. Xu, Y. Zeng (Tue),

Parallel IV talk O. Jevons (Thu)

Nucleon Energy-Momentum Tensor (EMT)

→ $\langle P | T^{\mu\nu} | P \rangle = 2P^\mu P^\nu$

$$2M^2 = \langle P | \frac{\tilde{\beta}(g)}{2g} G_{\alpha\beta}^a G^{a\alpha\beta} | P \rangle + \langle P | \sum_{l=u,d,s} m_l (1 + \gamma_{m_l}) \bar{q}_l q_l | P \rangle$$

In chiral limit all of hadron mass is due to the trace anomaly

Gluonic contribution

Quark contributions to hadron mass: sigma-terms

~ 10% (u, d, s) Lattice QCD

→ Matrix element of full nucleon EMT: parametrised by **3 form factors (FFs)**

$$\langle P + \frac{q}{2} | T^{\mu\nu}(0) | P - \frac{q}{2} \rangle = \bar{u}(P + \frac{q}{2}) \left\{ A(Q^2) \gamma^{(\mu} P^{\nu)} + B(Q^2) P^{(\mu} i\sigma^{\nu)\alpha} \frac{q_\alpha}{2M} + C(Q^2) (q^\mu q^\nu - q^2 g^{\mu\nu}) \frac{1}{M} \right\} u(P - \frac{q}{2})$$

Page1s
(1966)

A → momentum distribution

A + B → angular momentum distribution

C → pressure distribution

Parallel II talks: K. Tanaka, X. Gao, A. Freese, I. Zahed (Tue)

GPDs: moments, total angular momentum



$$\int_{-1}^{+1} dx x H^q(x, \xi, t) = A(t) + \xi^2 C(t)$$

$$\int_{-1}^{+1} dx x E^q(x, \xi, t) = B(t) - \xi^2 C(t)$$



form factors of energy-momentum tensor

Polyakov, Weiss (1999)

Polyakov (2003)



Ji's angular momentum sum rule

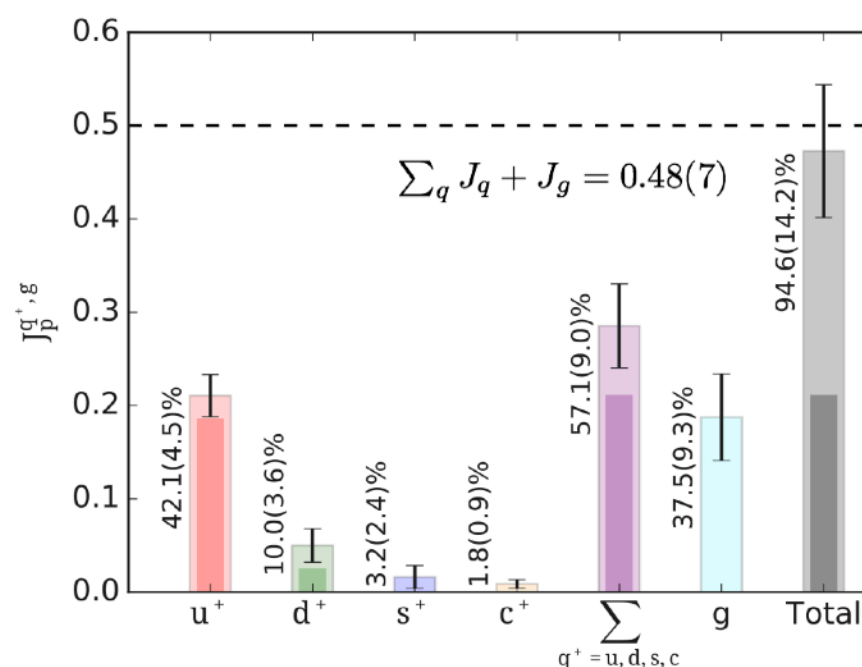
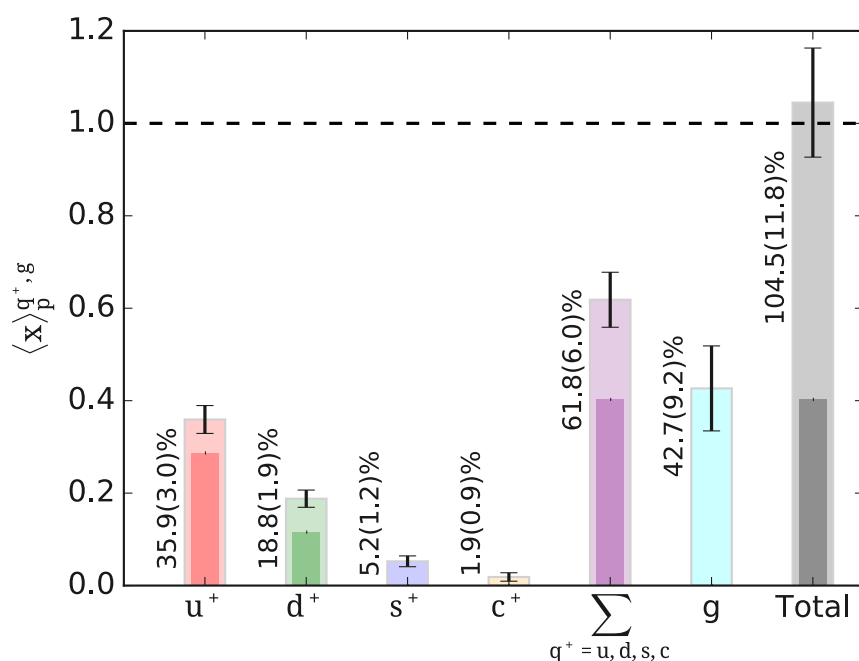
Goeke, Schweitzer et al. (2007)

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



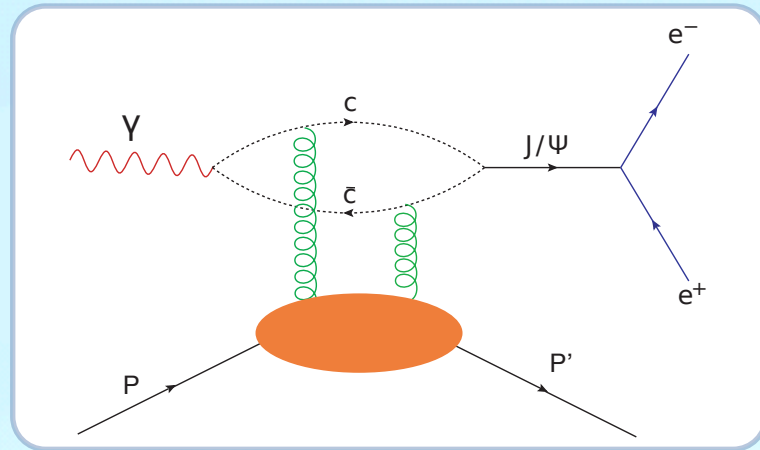
lattice QCD calculations at the physical point ($\overline{\text{MS}}$ at 2 GeV)

Alexandrou et al. (ETMC) (2020)



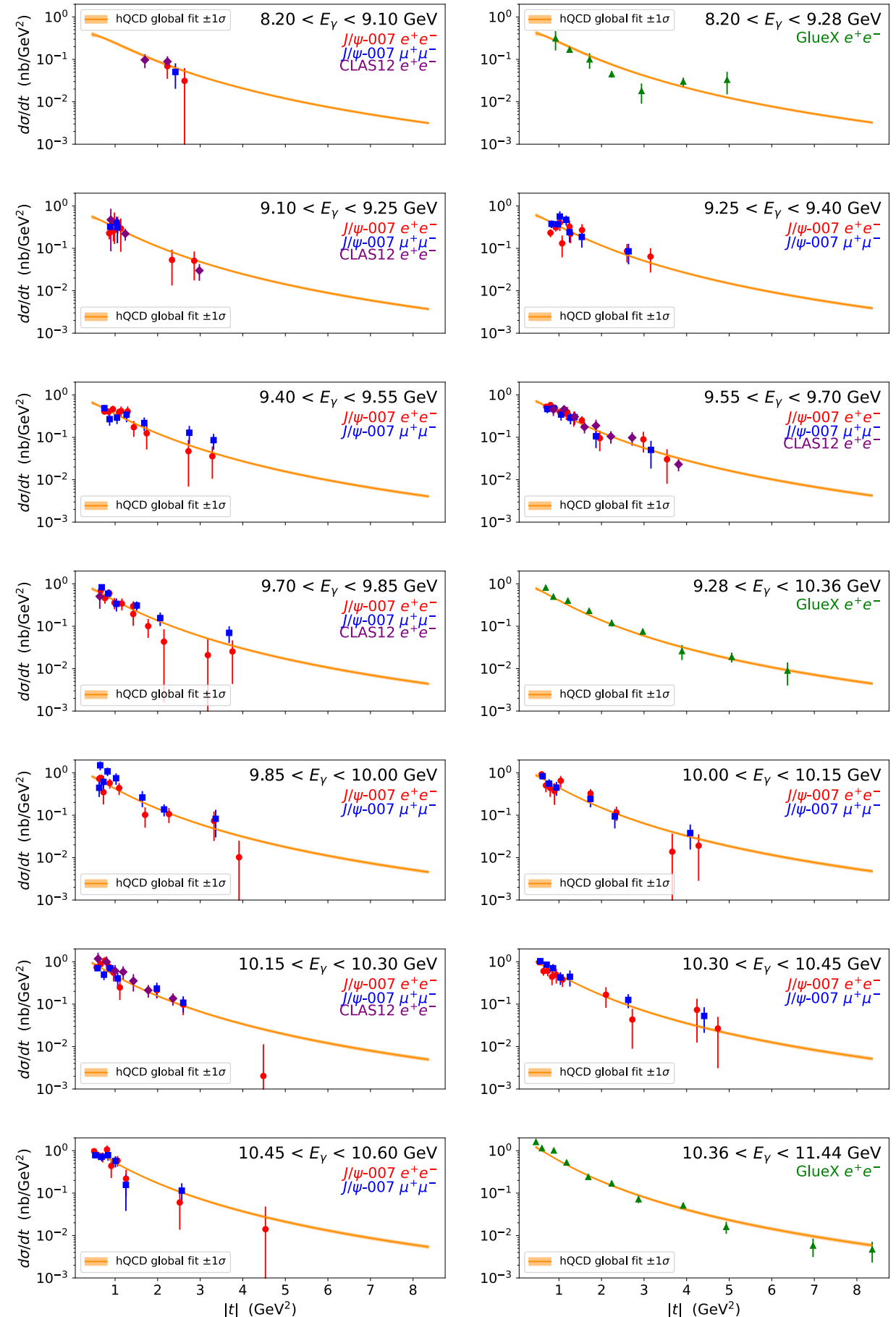
Sharing of momentum and total angular momentum between quarks and gluons identical in proton !
Approximately for each parton species separately

Threshold J/ψ photo-production



Access to **gluonic part** of
nucleon EMT FFs

**JLab data for threshold
 J/ψ photoproduction:
GlueX, HallC, CLAS12**

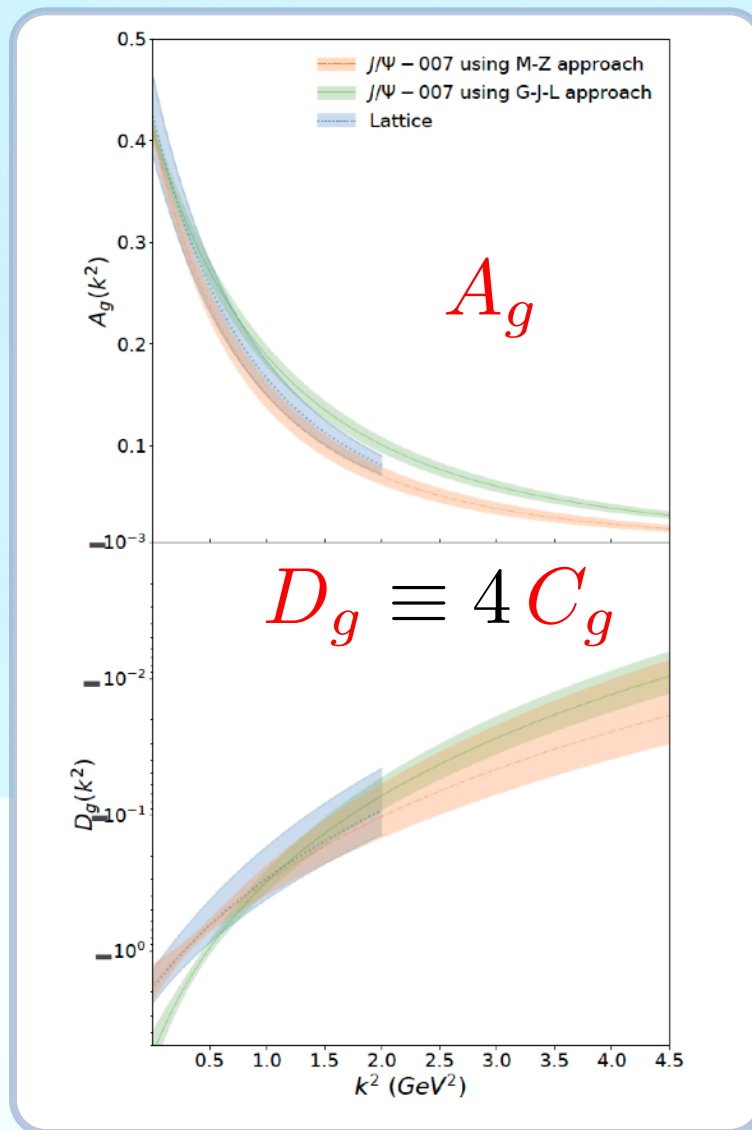


First extraction of gluonic scalar/mass radius of nucleon

Analyzed in different approaches

- ➡ Holographic QCD model Mamo, Zahed (2021)
- ➡ GPD model Guo, Ji, Liu (2021)
- ➡ Lattice QCD Pefkou, Hackett, Shanahan (2022)

Duran, Meziani, Joosten, et al. (2022)



matter radius scalar radius

	$\sqrt{\langle r_m^2 \rangle}$ (fm)	$\sqrt{\langle r_s^2 \rangle}$ (fm)
Holographic QCD	0.755 ± 0.035	1.069 ± 0.056
GPD	0.472 ± 0.042	0.695 ± 0.071
lattice QCD	0.7464 ± 0.025	1.073 ± 0.066

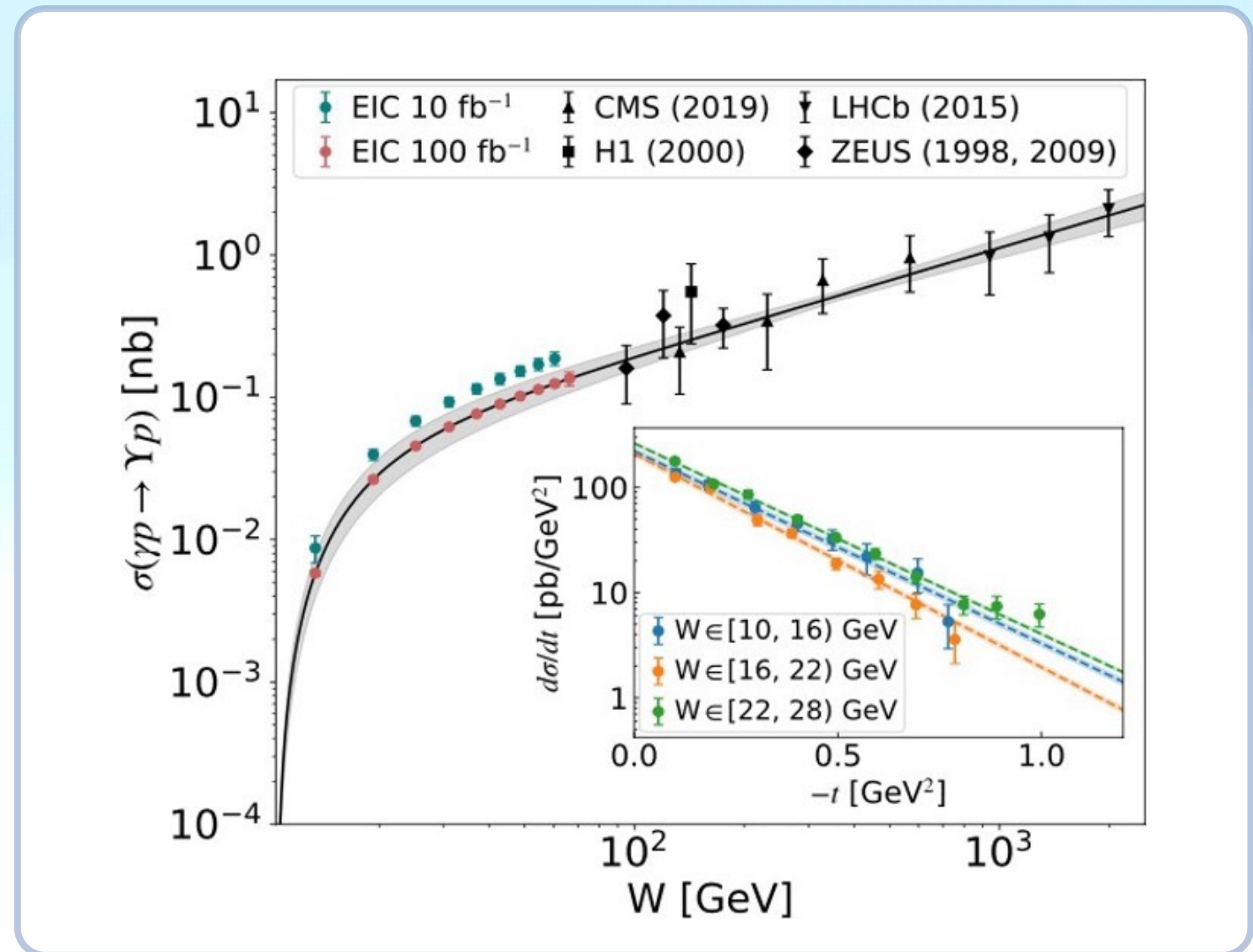
Gluonic radii of nucleon different from charge radius (0.841 fm) ?

suggests a proton structure with 3 regions:

- inner core with tensor gluonic field structure
- charge radius due to quarks
- outer region due to scalar confining gluon density

Υ photo-/electroproduction @ EIC

- ➡ Υ @EIC complements J/ψ studies @ JLab (GlueX, Hall-C, Hall-B)
- ➡ Larger mass of Υ vs J/ψ : reduces theoretical uncertainties
- ➡ Extra channel : study of universality in the extraction of EMT form factors
- ➡ Initial feasibility study for EIC performed



Gryniuk, Joosten, Mezzani, Vdh (2020)

Deuteron tensor structure: a new sum rule

➡ Structure functions for **spin-1** target: 4 extra tensor polarised structures

$$W_{\mu\nu} = -F_1 \tilde{g}_{\mu\nu} + \frac{F_2}{M\nu} \tilde{p}_\mu \tilde{p}_\nu + \frac{ig_1}{\nu} \epsilon_{\mu\nu\alpha\beta} q^\alpha s^\beta + \frac{ig_2}{\nu^2} \epsilon_{\mu\nu\alpha\beta} q^\alpha \left(\nu s^\beta - \frac{s \cdot q}{M} p^\beta \right) \\ - b_1 r_{\mu\nu} + \frac{1}{6} b_2 (s_{\mu\nu} + t_{\mu\nu} + u_{\mu\nu}) + \frac{1}{2} b_3 (s_{\mu\nu} - u_{\mu\nu}) + \frac{1}{2} b_4 (s_{\mu\nu} - t_{\mu\nu})$$

$$r_{\mu\nu} = \frac{A_\chi}{\nu^2} \tilde{g}_{\mu\nu}$$

tensor operator $A_\chi \equiv (q \cdot \chi^*)(q \cdot \chi) - \frac{q^2}{3}$

$$s_{\mu\nu} = \frac{2A_\chi}{M\nu^3} \tilde{p}_\mu \tilde{p}_\nu$$

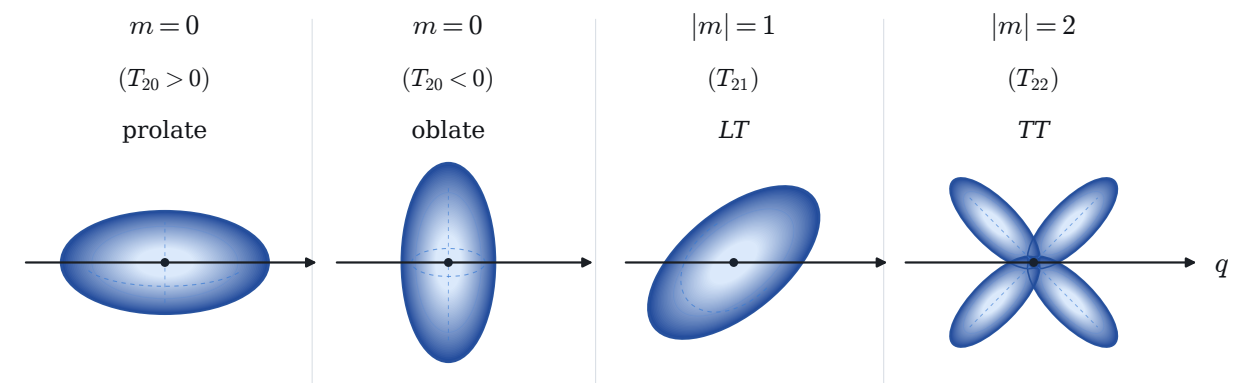
χ : spin polarisation vector

$$t_{\mu\nu} = \frac{1}{2\nu^2} \left\{ (q \cdot \chi^*) [\tilde{p}_\mu \tilde{\chi}_\nu + \tilde{p}_\nu \tilde{\chi}_\mu] + (q \cdot \chi) [\tilde{p}_\mu \tilde{\chi}_\nu^* + \tilde{p}_\nu \tilde{\chi}_\mu^*] - \frac{4\nu}{3M} \tilde{p}_\mu \tilde{p}_\nu \right\}$$

$$u_{\mu\nu} = \frac{M}{\nu} \left[\tilde{\chi}_\mu^* \tilde{\chi}_\nu + \tilde{\chi}_\nu^* \tilde{\chi}_\mu + \frac{2}{3} \tilde{g}_{\mu\nu} - \frac{2}{3M^2} \tilde{p}_\mu \tilde{p}_\nu \right]$$

➡ **b₁** describes how parton distributions differ in $m = 0$ and $m = 1$ target states

➡ Spin tensor alignment patterns ➡



Deuteron tensor structure: a new sum rule

➡ Application of photon-photon sum rules to massive **spin-1** target:

Pascalutsa, Vdh (2010, 2012)

generalising GDH sum rule

Pascalutsa (2025)

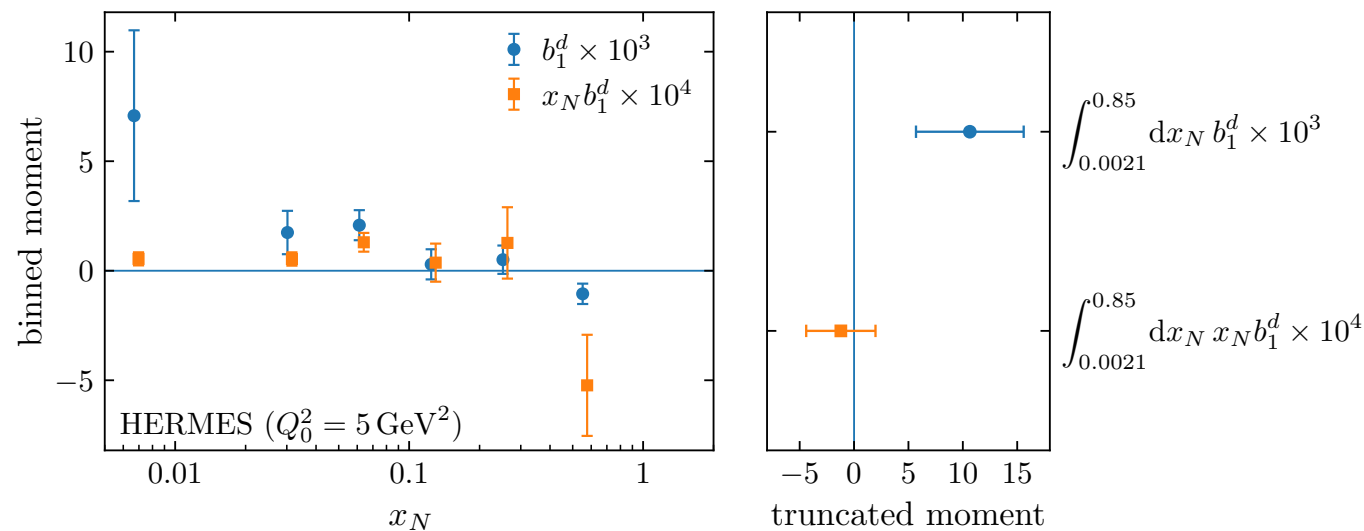
Pascalutsa, Vdh arXiv:2610.09862 [hep-ph]

$$\int_0^1 dx [b_2(x, Q^2) - 3b_4(x, Q^2)] = 0$$

super-convergence hypothesis
BC type sum rule

➡ Partonic verification (twist-2): $b_2 \rightarrow 2xb_1$, $b_4 \rightarrow 0$

$$\int_0^1 dx x b_1 = 0$$



Close, Kumano (1990)

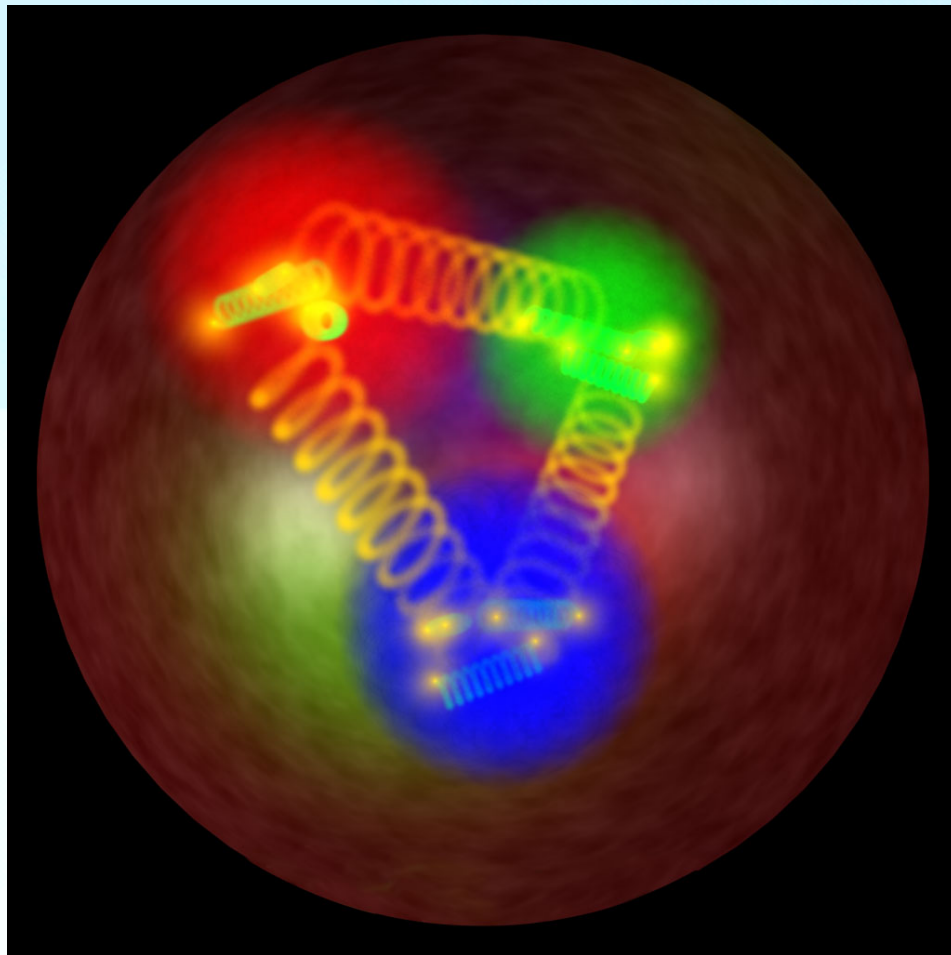
Efremov, Teryaev (1982)

➡ Higher-twist: target mass corrections to b_1 , b_2 , b_3 , b_4 worked out Detmold (2006)

Target mass corrected structure functions verify sum rule !

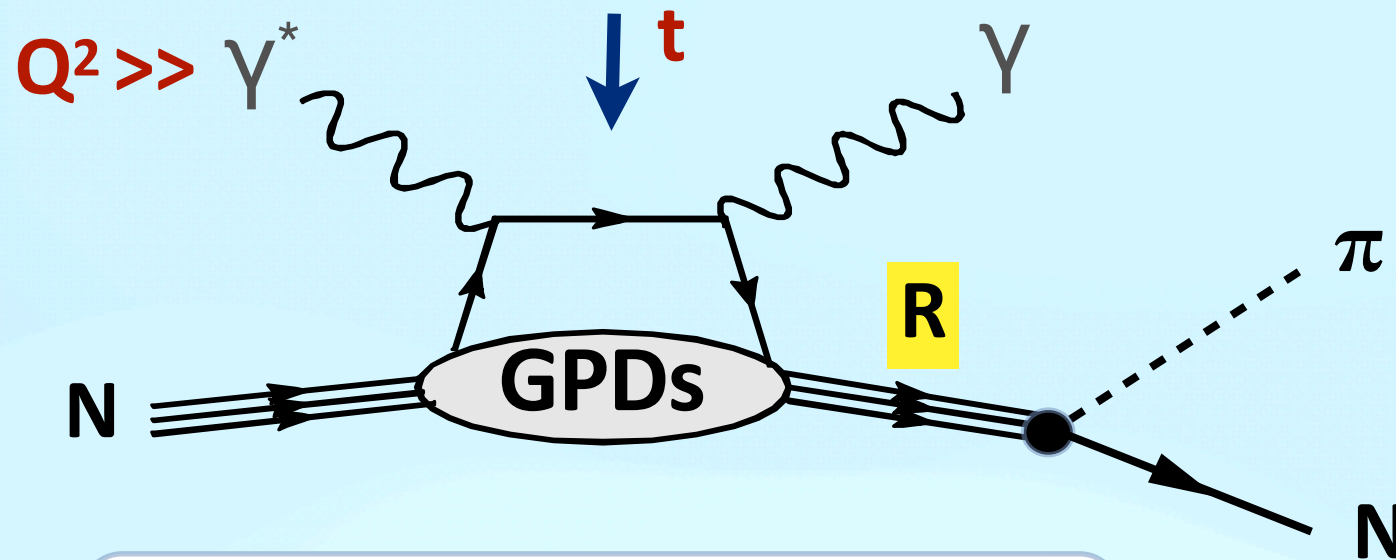
➡ Experimental opportunities for JLab and EIC !

High Q : unifying structure and spectroscopy

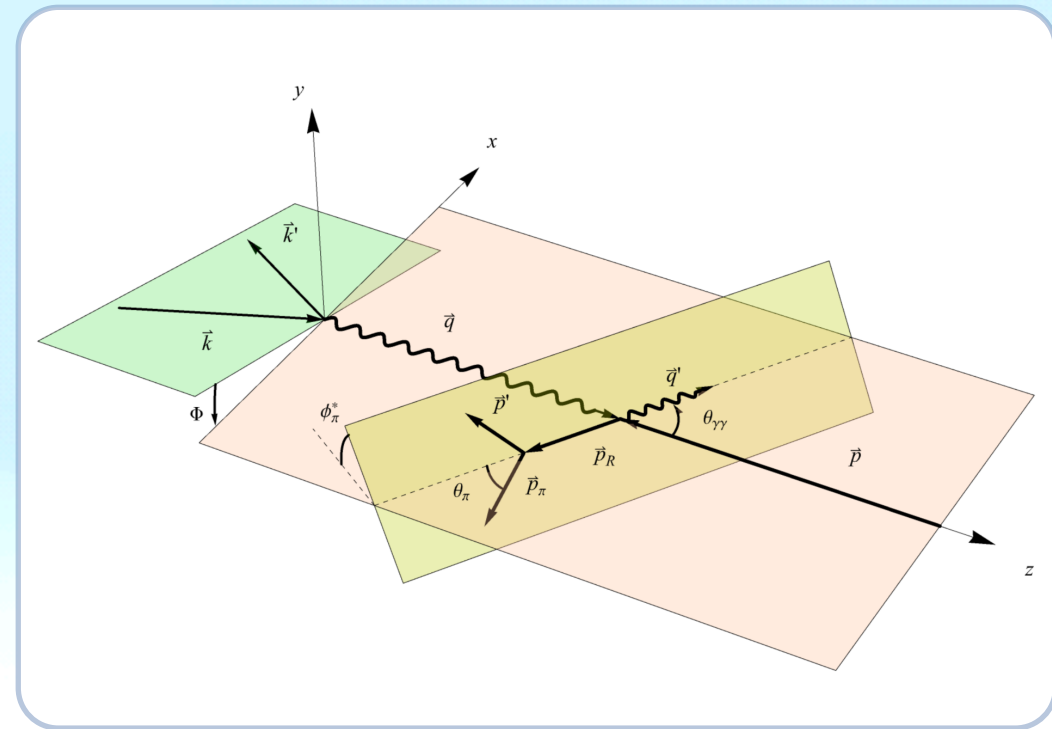


**Parton imaging in
nucleon-to-
resonance
transitions**

$e^- p \rightarrow e^- \gamma \pi N$ cross section and decay angular distribution



$$\frac{d\sigma}{dQ^2 dx_B dt d\Phi dM_{\pi N} d\Omega_{\pi}^*}$$



$e^- p \rightarrow e^- \gamma R$ process

characterized by

Q^2, x_B, t, Φ (out-of-plane angle)

$R \rightarrow \pi N$ decay process

characterized by

$M_{\pi N}$: πN invariant mass

$\theta_{\pi}^*, \phi_{\pi}^*$: decay angles in πN rest frame

- Bethe-Heitler process (γ emitted from electrons) added coherently to DVCS process
- Cut $M_{\pi\gamma} > 1$ GeV: to minimize contamination from $e^- p \rightarrow e^- \rho^+ n \rightarrow e^- (\gamma \pi^+) n$

N $\rightarrow$ $\Delta(1232)$ magnetic dipole GPD

large N_c :

$$H_M(x, \xi, t) = 2 \frac{G_M^*(0)}{\kappa_V} \{E^u(x, \xi, t) - E^d(x, \xi, t)\}$$

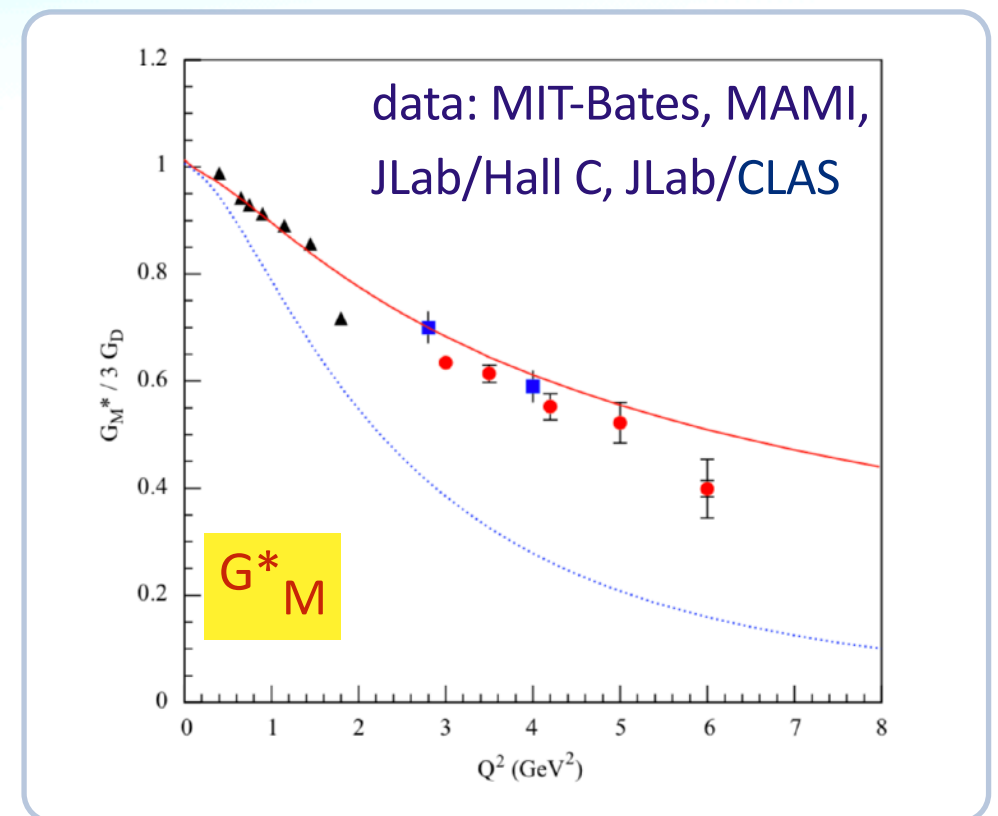
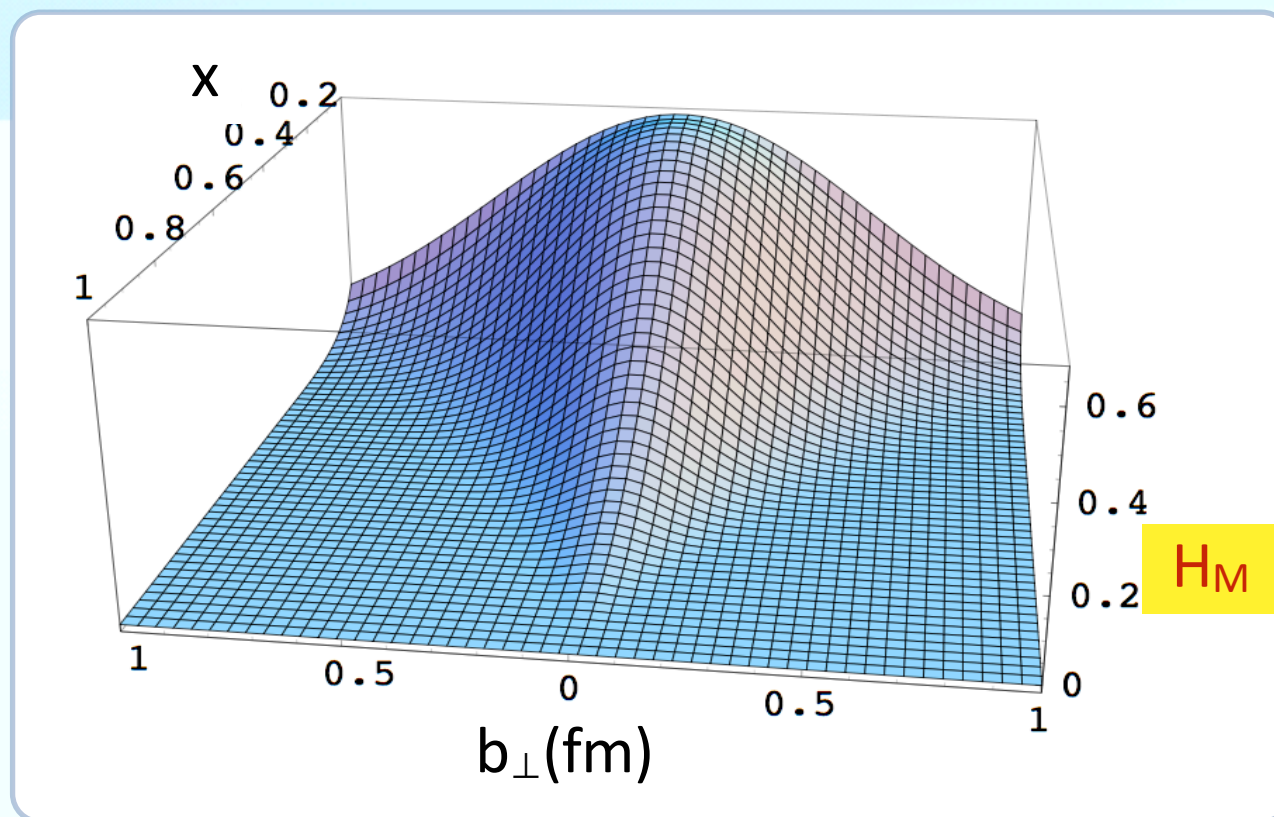
Frankfurt, Polyakov,
Strikman, Vdh (2000)

$$G_M^*(t) = \frac{G_M^*(0)}{\kappa_V} \int_{-1}^{+1} dx \{E^u(x, \xi, t) - E^d(x, \xi, t)\} = \frac{G_M^*(0)}{\kappa_V} \{F_2^p(t) - F_2^n(t)\}$$

large N_c : $G_M^*(0) = \kappa_V / \sqrt{2} \simeq 2.62$

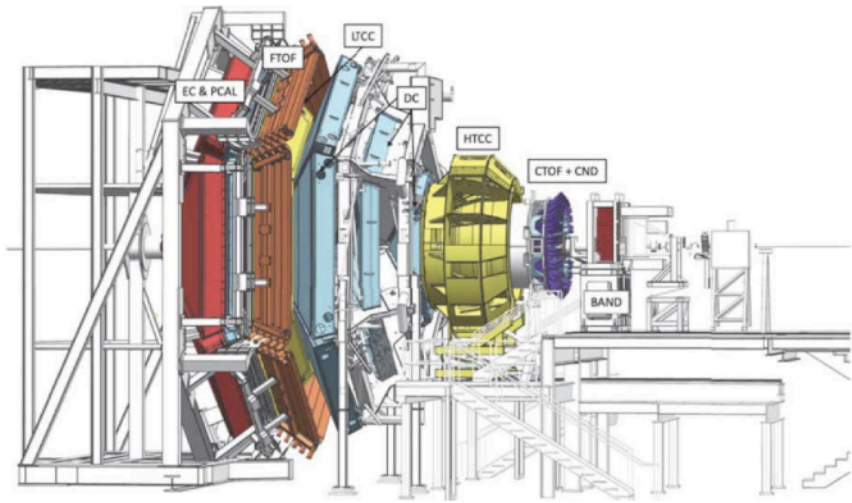
exp : $G_M^*(0) \simeq 3.02$

large N_c + nucleon Regge GPD model



Guidal, Polyakov, Radyushkin, Vdh (2005)

$e^- p \rightarrow e^- \gamma \pi^+ n$ DVCS events seen in CLAS12@JLab



V. Burkert et al., Nucl. Instrum. Meth.A 959 (2020) 163419

$W > 2 \text{ GeV}$
 $Q^2 \approx 2.3 \text{ GeV}^2$
 $x_B \approx 0.25$

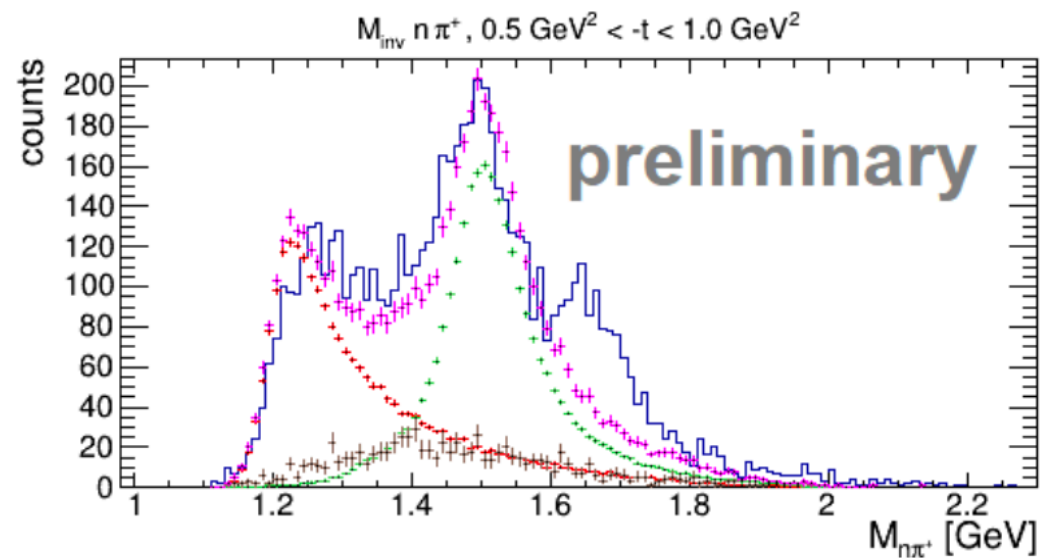
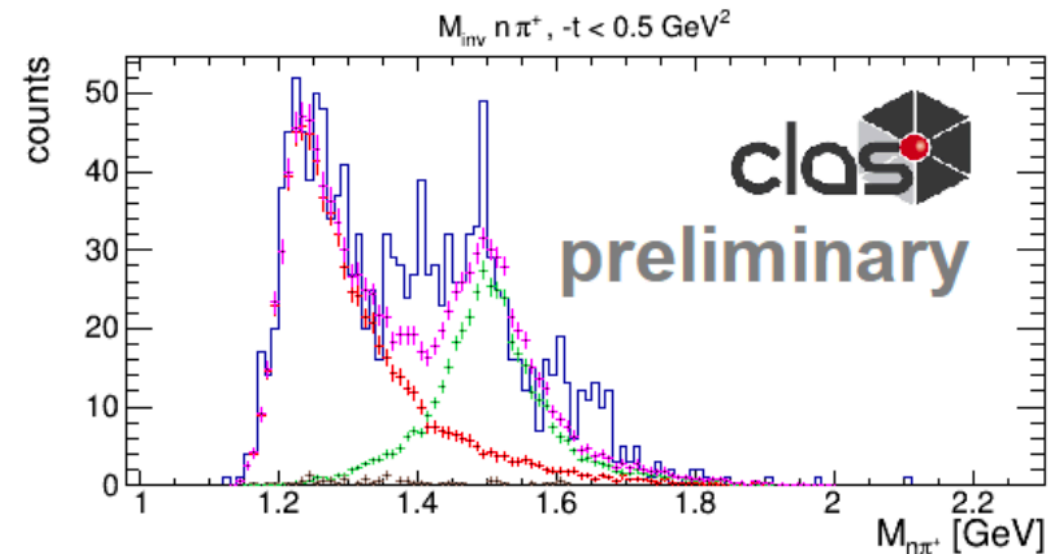
Preliminary CLAS12 data

-> white paper

S. Diehl et al. Eur.Phys.J.A (2025) 61:131

arXiv:2405.15386 [hep-ph]

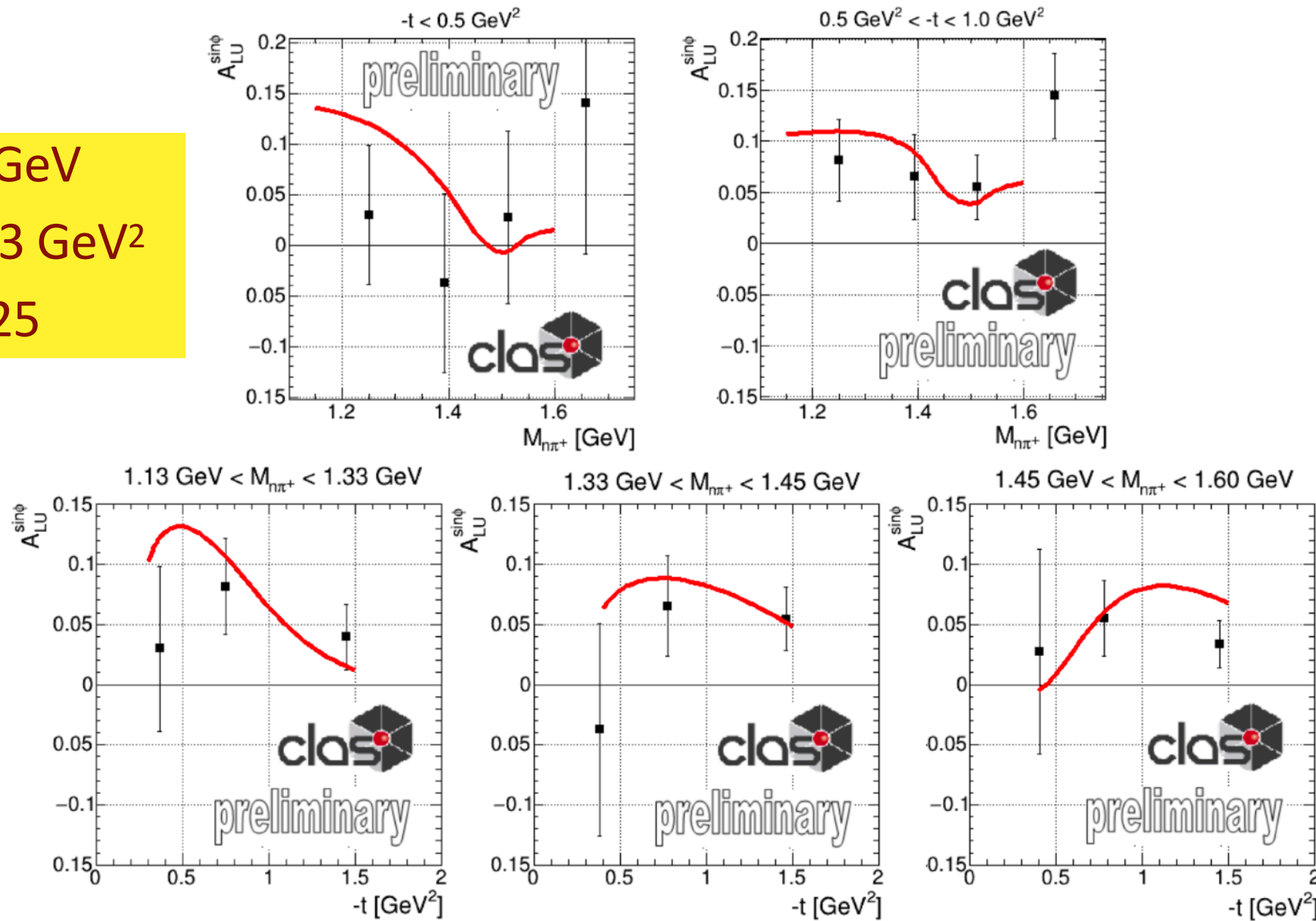
Theory predictions: K.Semenov-Tian-Shansky and M.Vdh Phys.Rev.D 108 (2023)



Preliminary data confirm that with **increasing -t**:
2nd resonance region becomes **more pronounced**

$e^- p \rightarrow e^- \gamma \pi^+ n$ DVCS events seen in CLAS12

$W > 2 \text{ GeV}$
 $Q^2 \approx 2.3 \text{ GeV}^2$
 $x_B \approx 0.25$

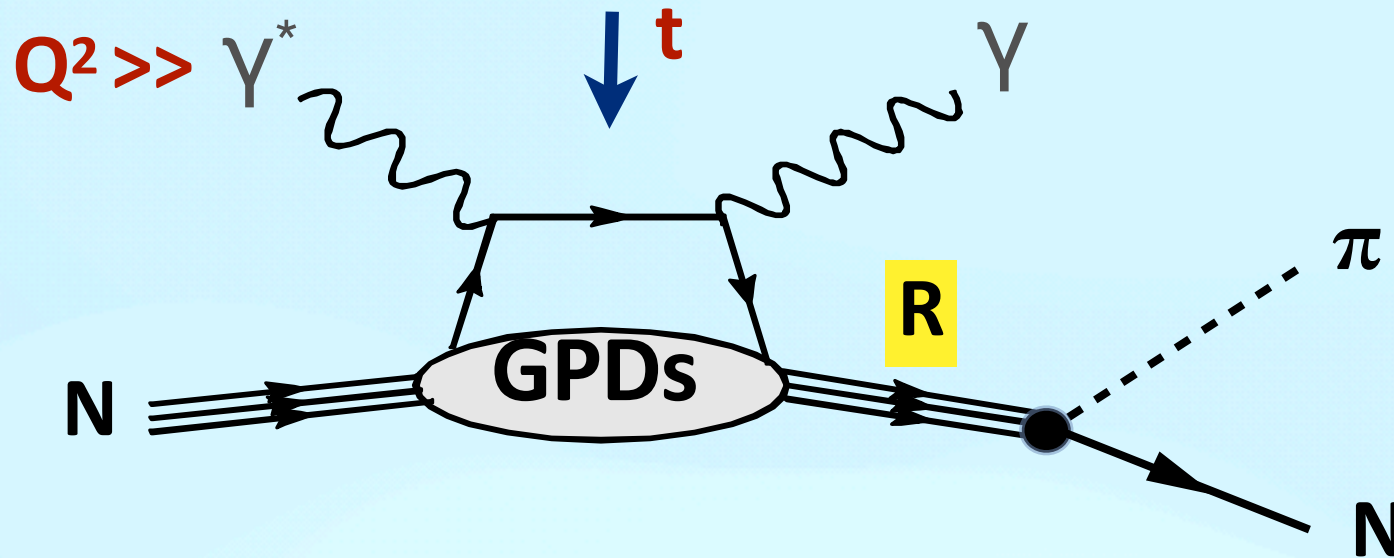


Theory predictions: [K.Semenov-Tian-Shansky and M.Vdh Phys.Rev.D 108 \(2023\)](#)

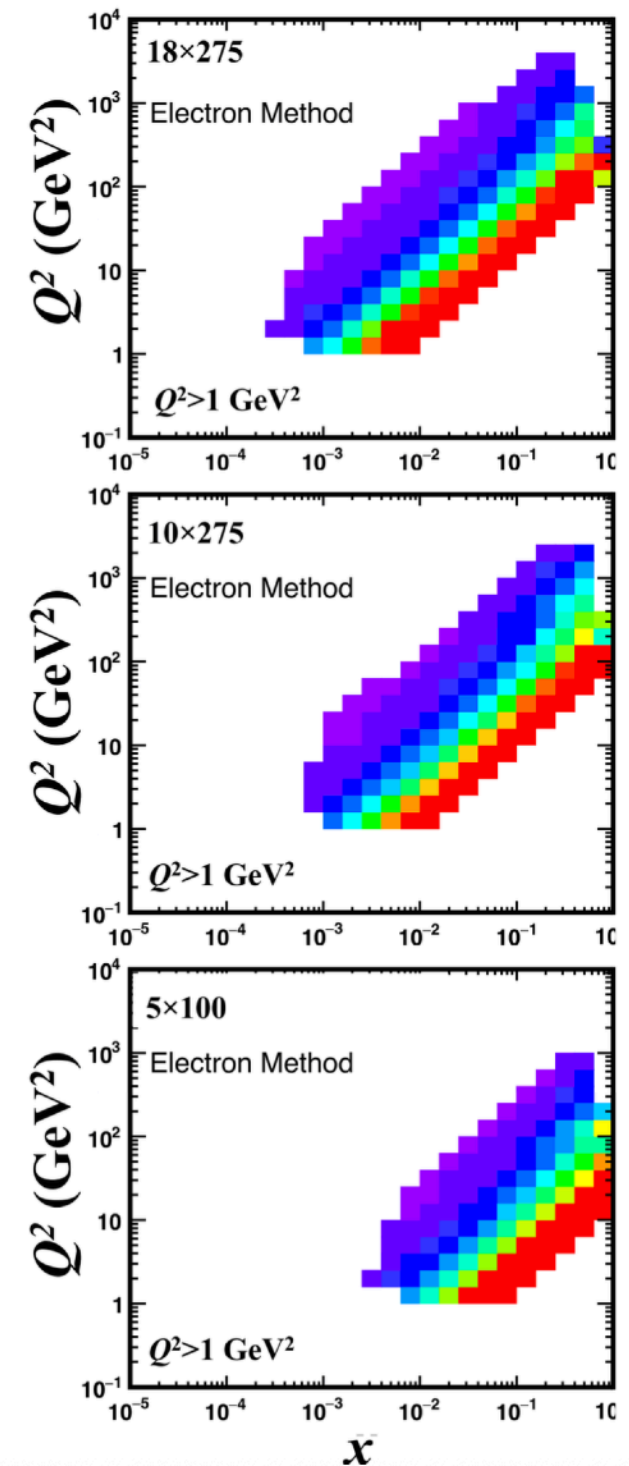
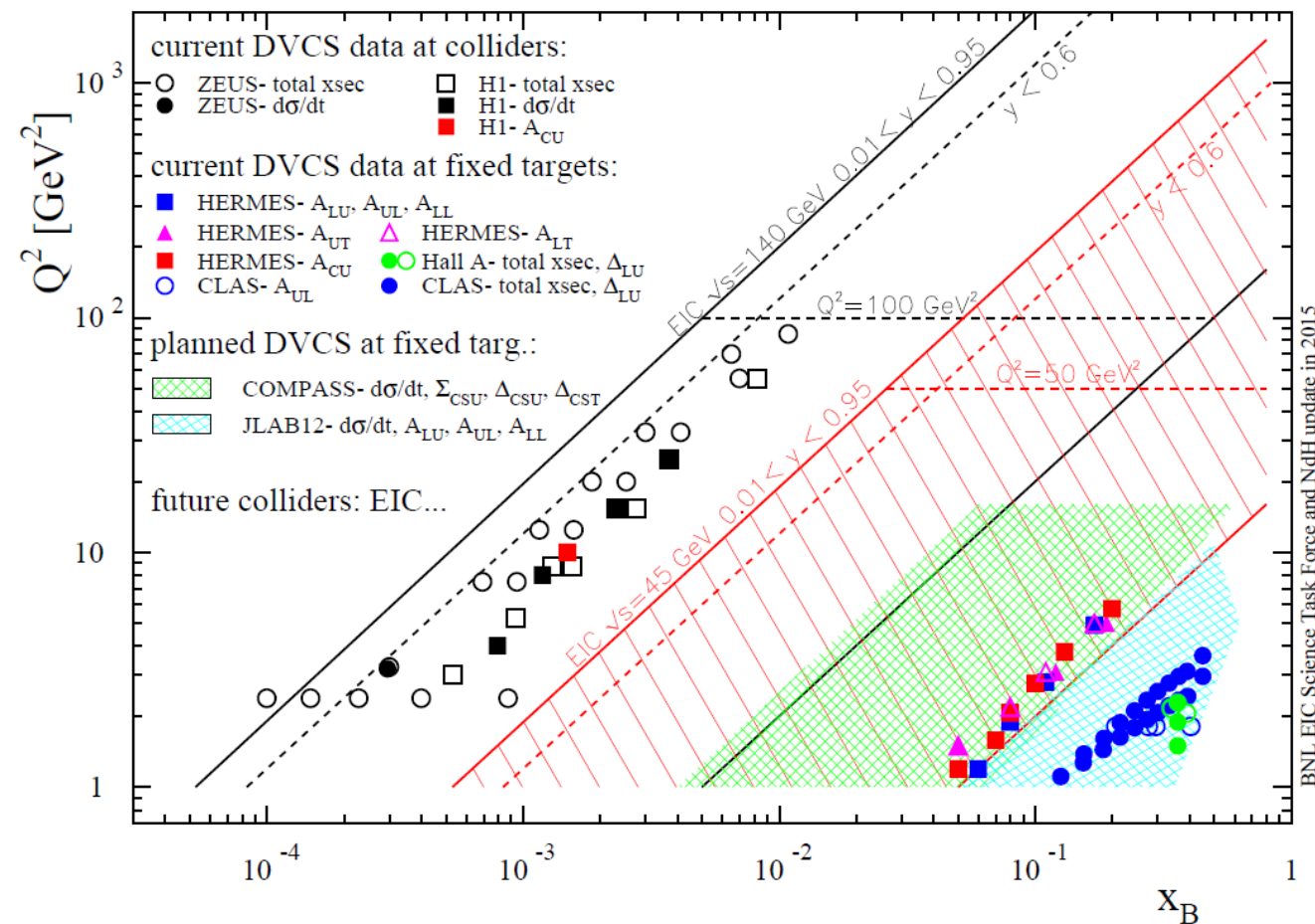
Preliminary CLAS12 data -> white paper: [S. Diehl et al. Eur.Phys.J.A \(2025\) 61:131](#)

CLAS12 preliminary BSA in 5 - 10% range

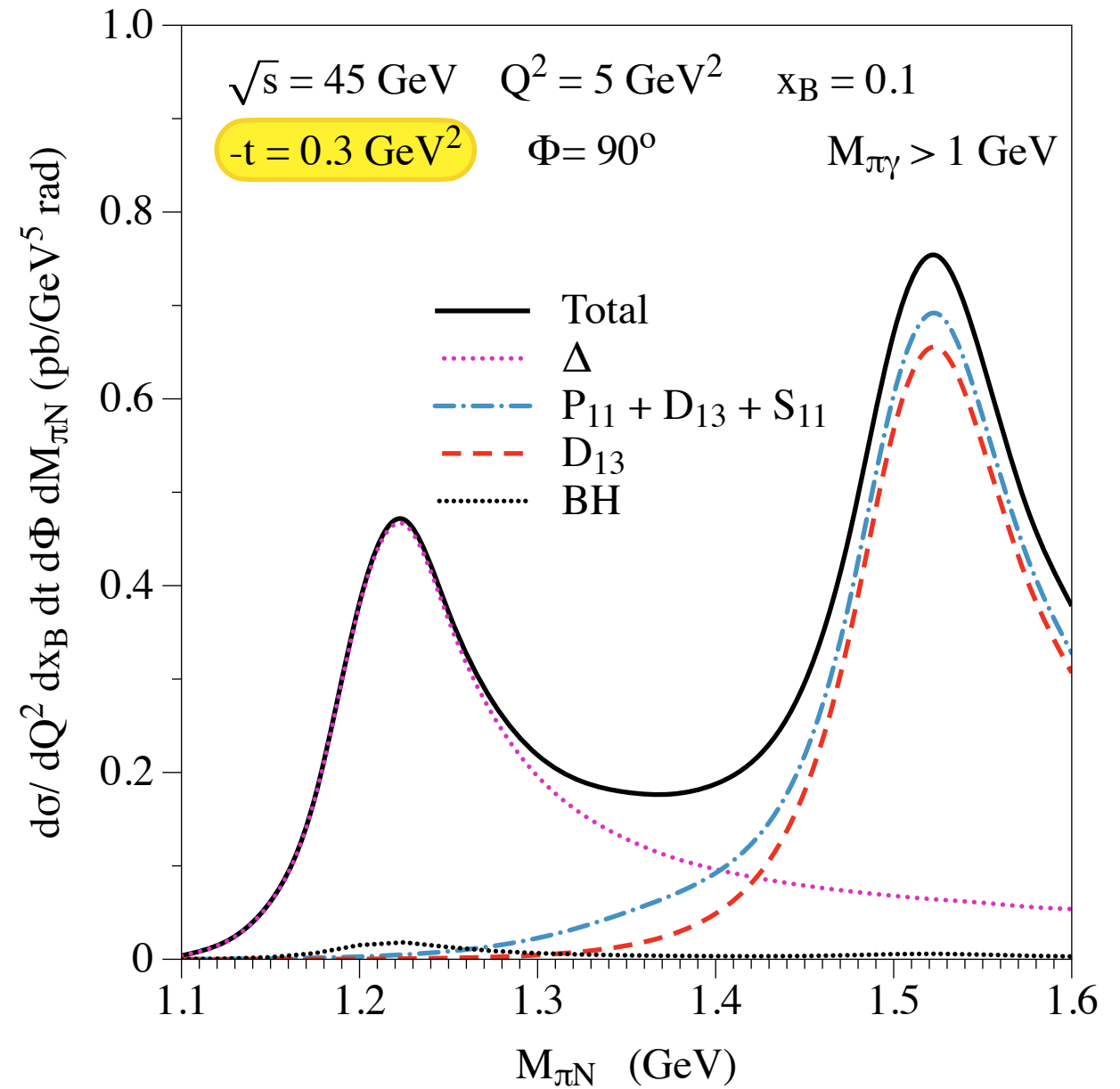
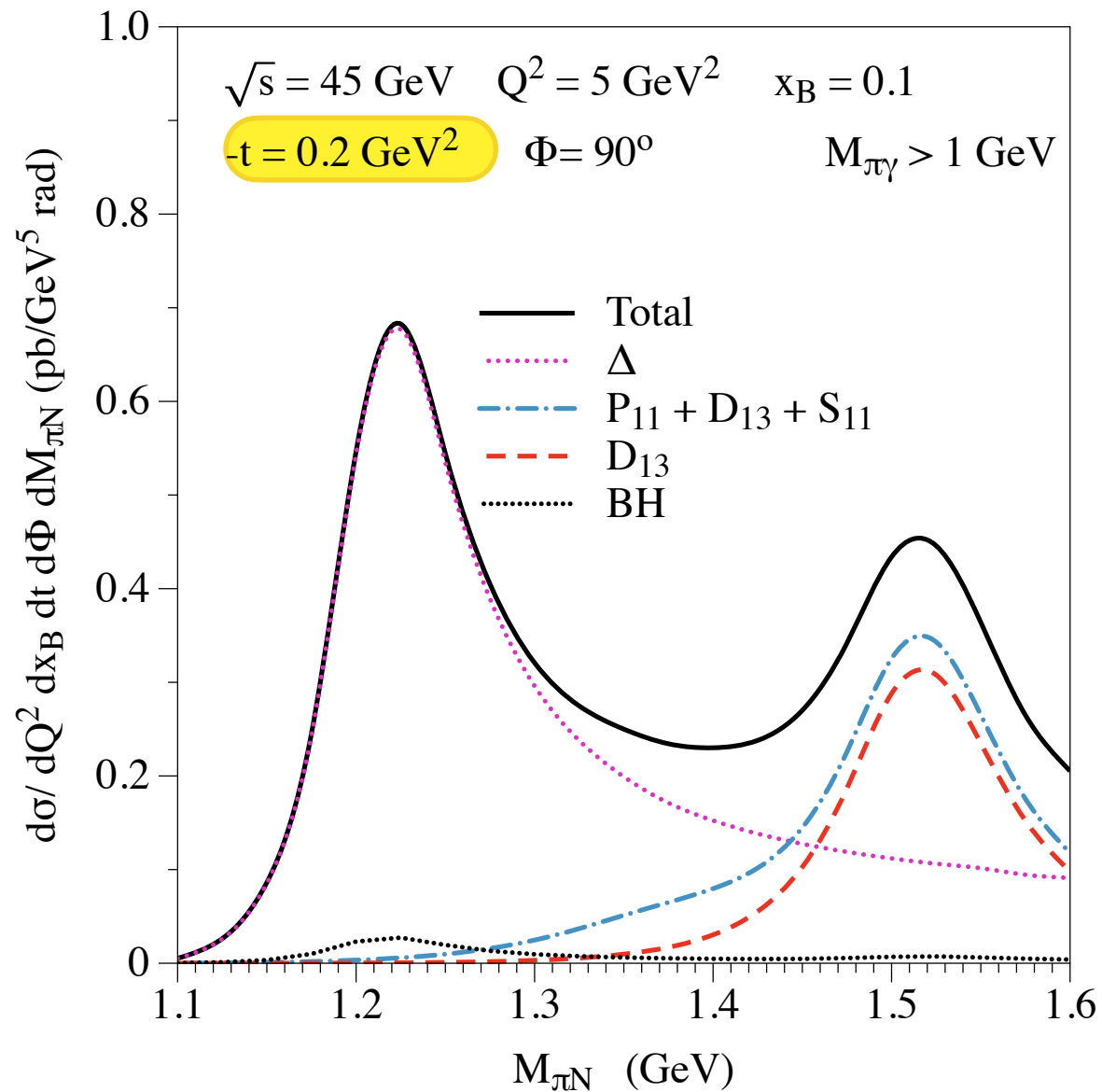
$e^- p \rightarrow e^- \gamma \pi N$ @ EIC



Accessible kinematics for different EIC settings



$e^- p \rightarrow e^- \gamma N^* \rightarrow e^- \gamma \pi^+ n$ @EIC



**@EIC: DVCS dominates over Bethe-Heitler,
 cross sections of similar size as DVCS process on nucleon**

with increasing $-t$: 2nd resonance region becomes more pronounced

Summary and Outlook



- ➡ **Low Q electromagnetic structure of nucleon**
 - Proton radii: new scattering and atomic spectroscopy expts. underway
theory improvements ongoing to meet demands required by spectroscopy
 - Proton polarizabilities: new dispersion theory for upcoming VCS expt.
- ➡ **High Q: unifying structure and dynamics**
 - Parton imaging through **GPDs**
@EIC: DDVCS allows direct access to GPDs
 - Proton gluonic structure and radii
@EIC: Υ **photo-/electroproduction** complements J/ψ studies at JLab
 - **Deuteron tensor** structure: a **new sum rule**
@EIC: new experimental opportunity
- ➡ **High Q: unifying structure and spectroscopy**
 - New opportunities on quark structure in $N \rightarrow N^*$, Δ^* DVCS transitions
@ EIC: regime where DVCS dominates over BH, gluonic transition structure