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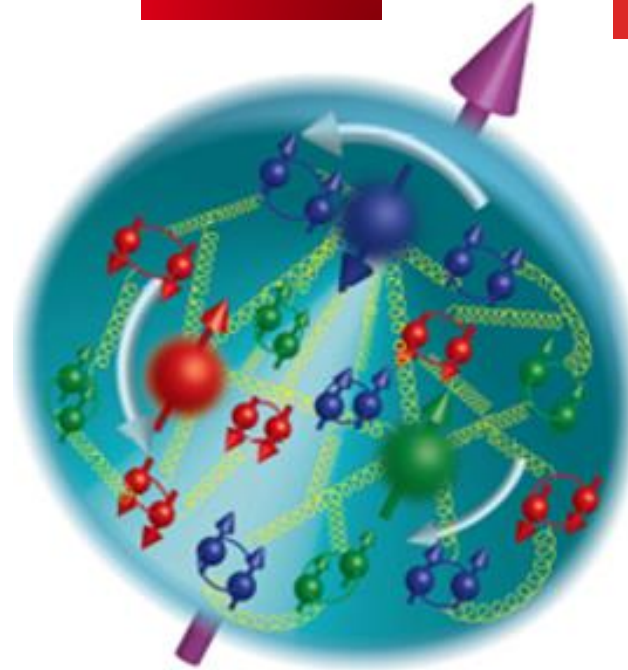
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WP23 - JRA5 GPD-ACT: Generalized Parton Distributions

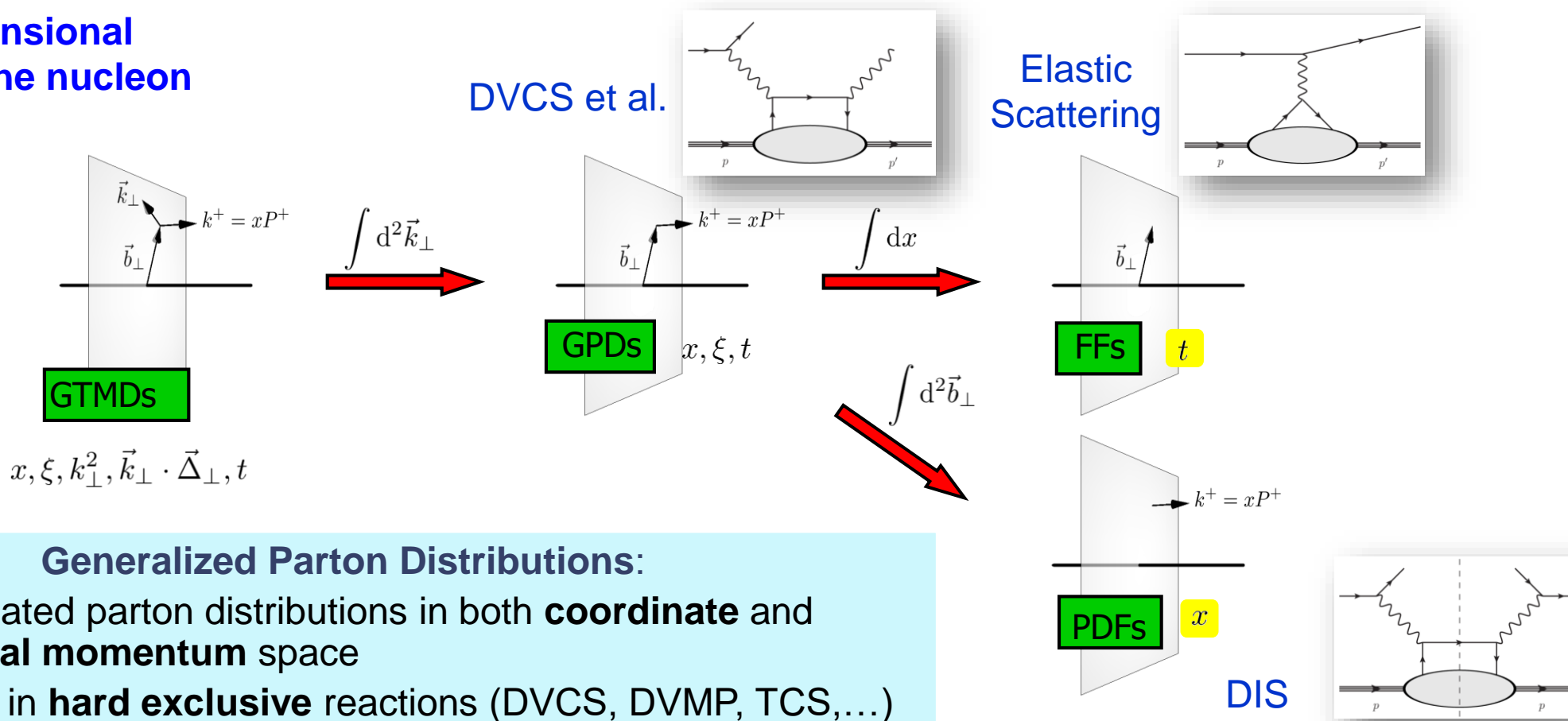
Silvia Niccolai (IJCLab, France) & Kresimir Kumericki (U. Zagreb, Croatia)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

Generalized Parton Distributions (GPDs)

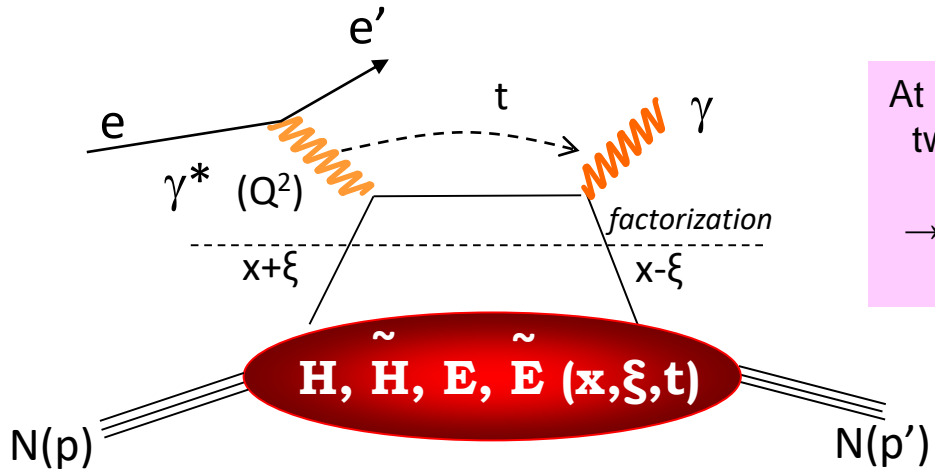
Multidimensional mapping of the nucleon



Generalized Parton Distributions:

- Fully correlated parton distributions in both **coordinate** and **longitudinal momentum** space
- Accessible in **hard exclusive** reactions (DVCS, DVMP, TCS,...)

Deeply Virtual Compton Scattering and interest of GPDs



At leading order QCD, twist 2, chiral-even, quark sector
→ **4 GPDs for each quark flavor**

DVCS allows access to 4 complex GPDs-related quantities:
Compton Form Factors CFF(x,t)

$$T^{DVCS} \sim P \int_{-1}^{+1} \frac{GPDs(x, \xi, t)}{x \pm \xi} dx \pm i\pi GPDs(\pm \xi, \xi, t) + \dots$$

$$Re\mathcal{H}_q = e_q^2 P \int_0^{+1} (H^q(x, \xi, t) - H^q(-x, \xi, t)) \left[\frac{1}{\xi - x} + \frac{1}{\xi + x} \right] dx$$

$$Im\mathcal{H}_q = \pi e_q^2 [H^q(\xi, \xi, t) - H^q(-\xi, \xi, t)]$$

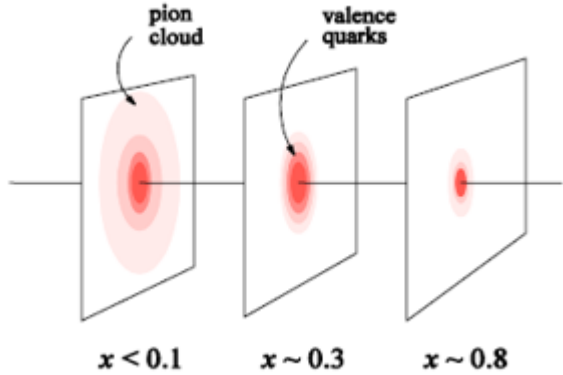
Quark angular momentum (Ji's sum rule)

$$\frac{1}{2} \int_{-1}^1 x dx (H(x, \xi, t=0) + E(x, \xi, t=0)) = J = \frac{1}{2} \Delta \Sigma + \Delta L$$

Nucleon tomography

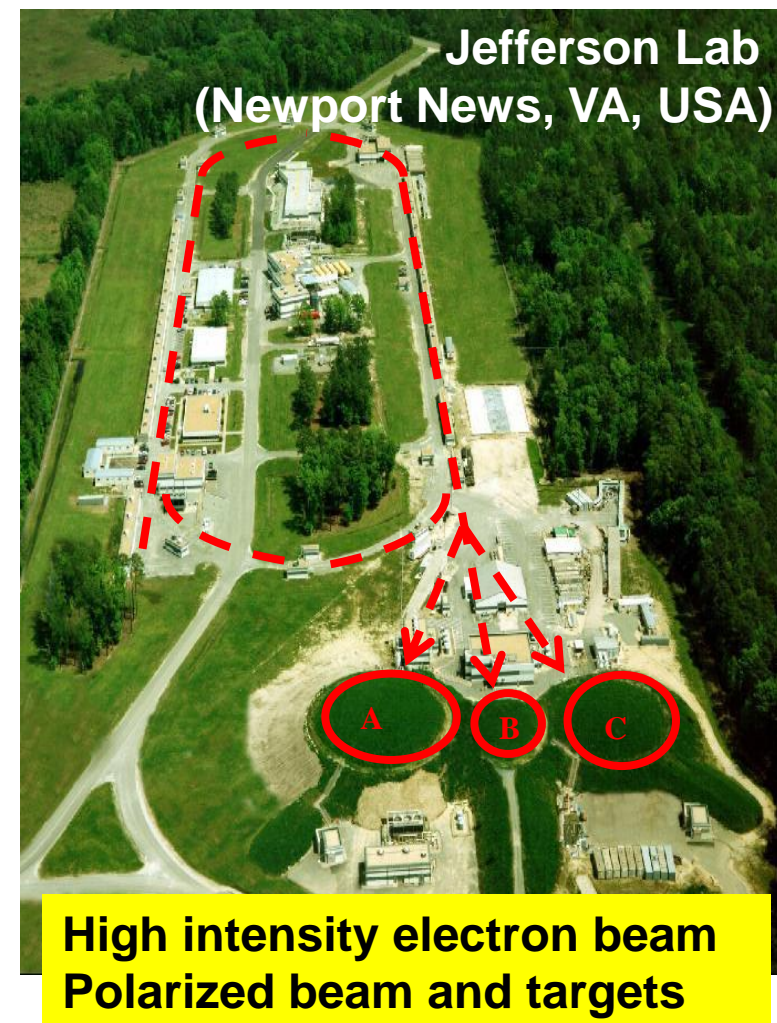
$$q(x, b_{\perp}) = \int_0^{\infty} \frac{d^2 \Delta_{\perp}}{(2\pi)^2} e^{i\Delta_{\perp} b_{\perp}} H(x, 0, -\Delta_{\perp}^2)$$

$$\Delta q(x, b_{\perp}) = \int_0^{\infty} \frac{d^2 \Delta_{\perp}}{(2\pi)^2} e^{i\Delta_{\perp} b_{\perp}} \tilde{H}(x, 0, -\Delta_{\perp}^2)$$



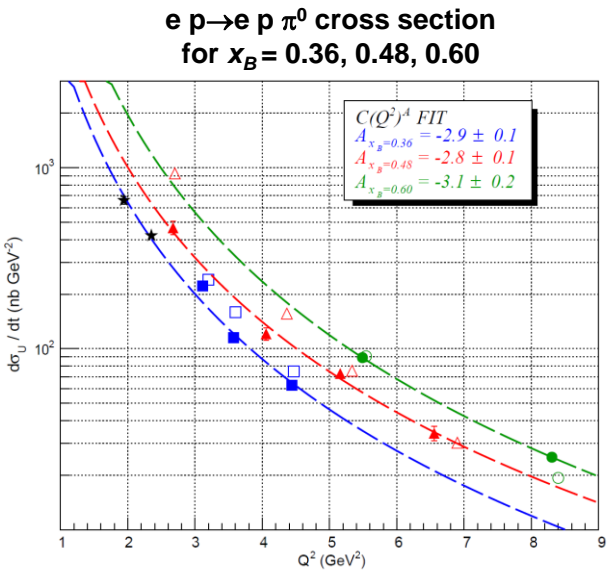
JRA5 GPD-ACT: Objectives

- Analysis of GPD experiments at **JLab@6 GeV** and of DVCS and DVMP with a recoil detector at **COMPASS**
- Preparation, data taking, and analysis of new experiments for **JLab@12GeV** (nDVCS, nuclear DVCS, TCS, DDVCS)
- Producing projections for GPD experiments to propose for the Electron Ion Collider (EIC)
- Building models of GPDs (standard twist-2, but also twist-3 and transversity GPDs), using also the constraints obtained by lattice QCD calculations
- Improved theoretical studies, including higher order and higher twist corrections
- Both experimental and theoretical efforts will be combined in **extraction of GPD information by fits to the data.**



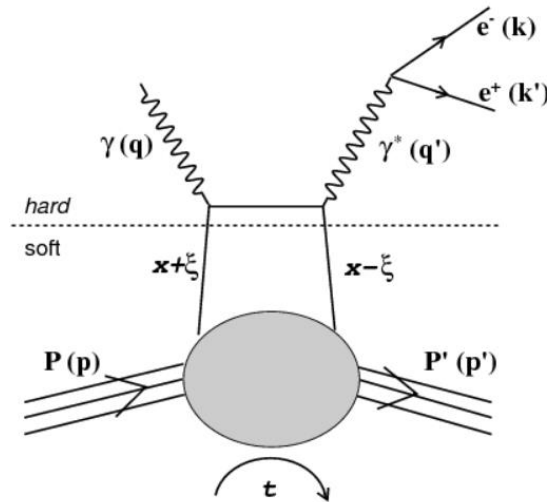
Newly published results from JLab@12 GeV (Task 1)

Hall A 11 GeV DVCS experiment:
Phys.Rev.Lett. 127 (2021) 15, 152301



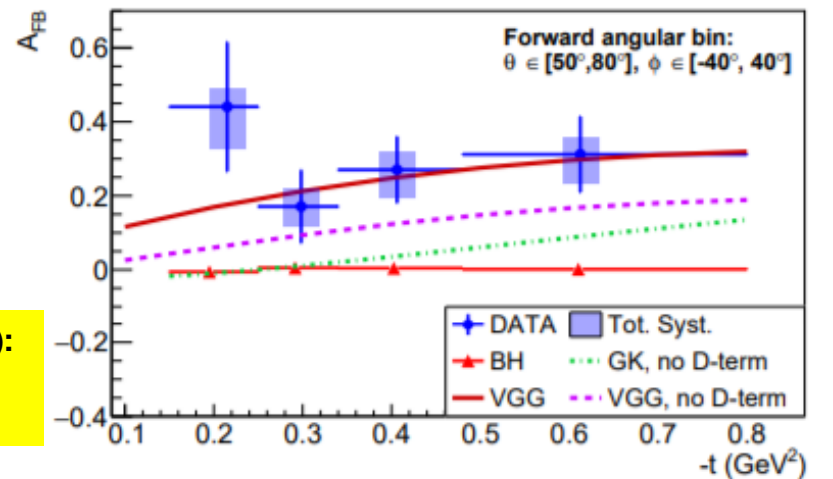
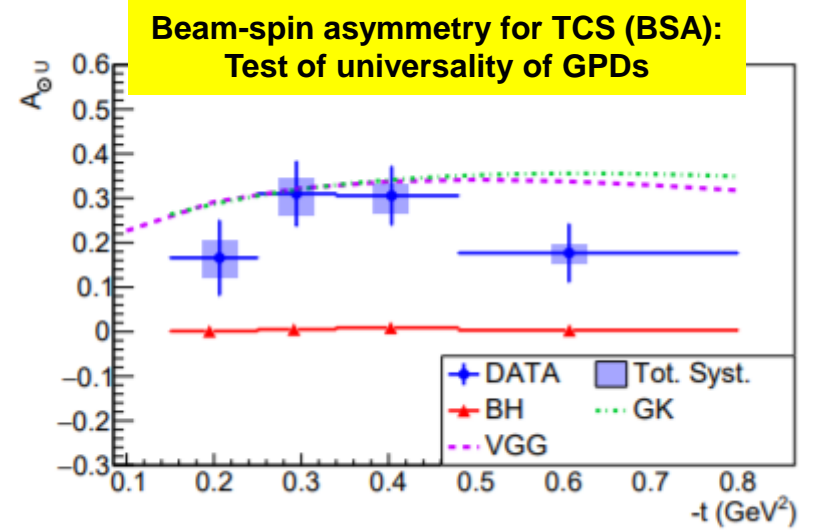
Dominance of the transverse amplitude: access to transversity GPDs of the proton

CLAS12@11 GeV: First-time observation of Timelike Compton Scattering
arXiv:2108.11746 - submitted to PRL



TCS: test of universality of GPDs
Two measured observables

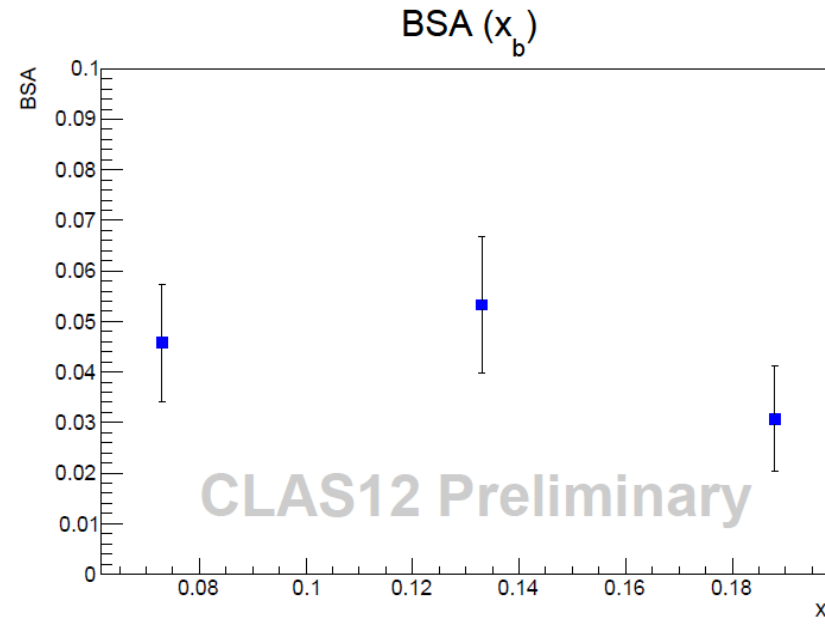
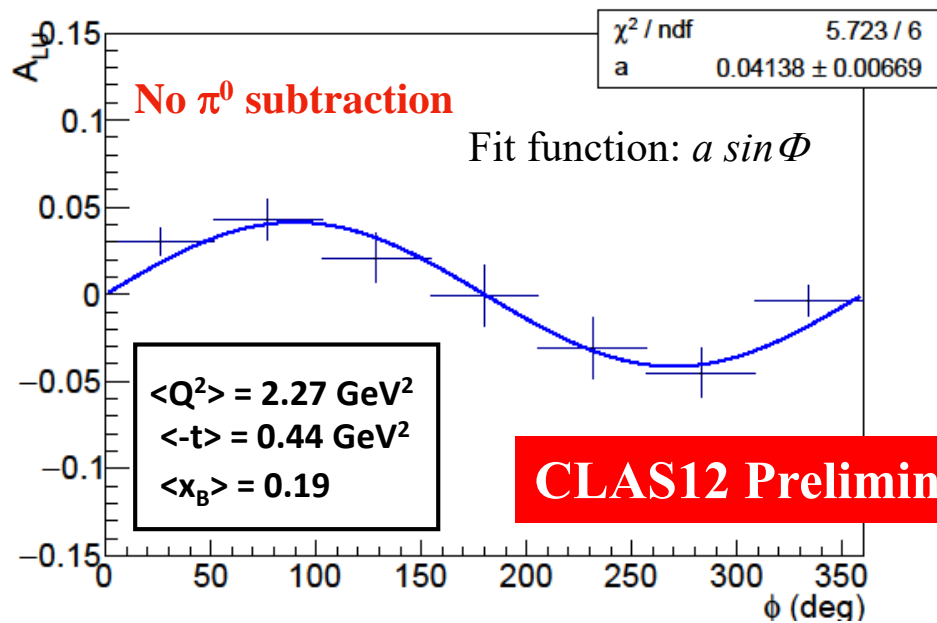
TCS Forward-backward asymmetry (A_{FB}):
Access to D-term → mechanical properties of the proton



Preliminary CLAS12 results on nDVCS (Task 1)

- A combined analysis of DVCS observables for **proton and neutron** targets is necessary for **flavor separation** of GPDs
- The **beam-spin asymmetry for nDVCS** is **the most sensitive observable to the GPD $E \rightarrow J_i$'s sum rule for QAM**

$\vec{e}d \rightarrow e n \gamma(p)$



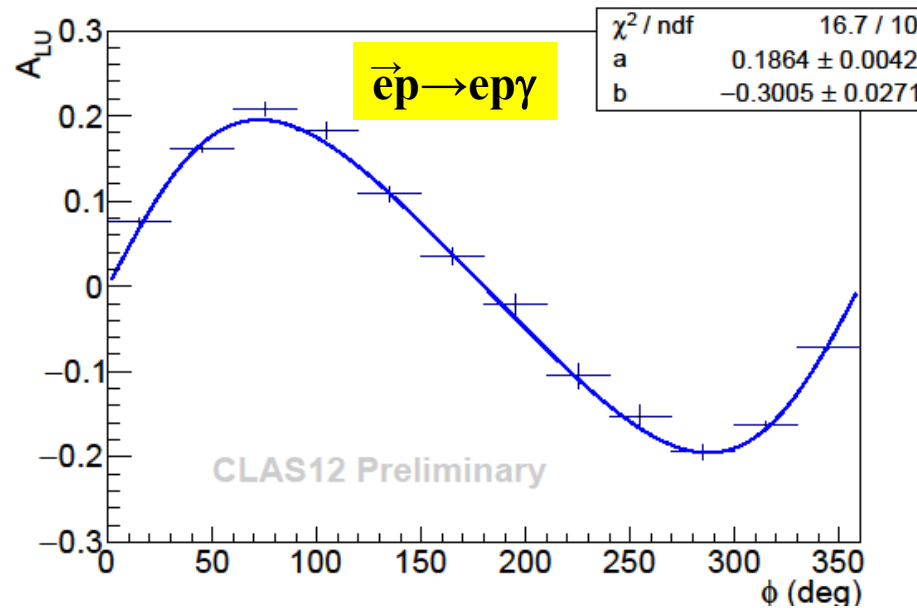
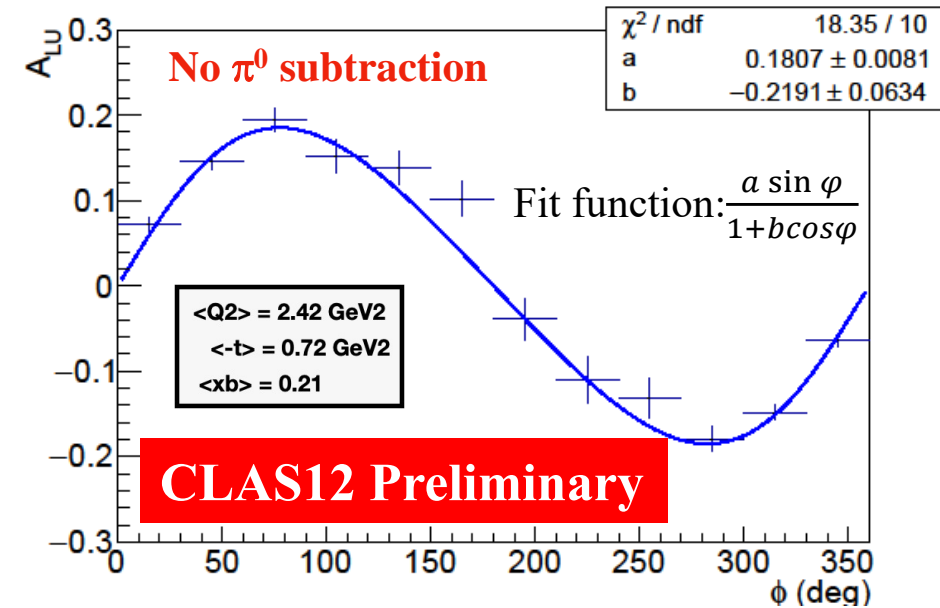
- CLAS12 data taken from March 2019 to the end of January 2020
- Preliminary results presented in several conferences
- Analysis note in preparation
- Publication expected in spring 2022

Preliminary results for pDVCS in a deuterium target with CLAS12 (Task 1)

Interest of pDVCS on deuterium:

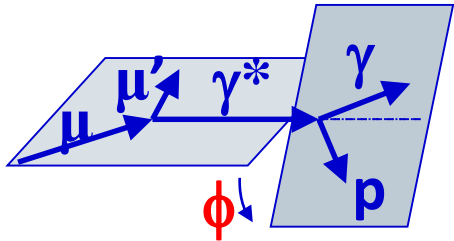
- In itself: nuclear medium effects on proton structure
- To evaluate FSI for nDVCS, comparing to free pDVCS
- To validate the BSA analysis on nDVCS

$\vec{e}d \rightarrow e\gamma(n)$

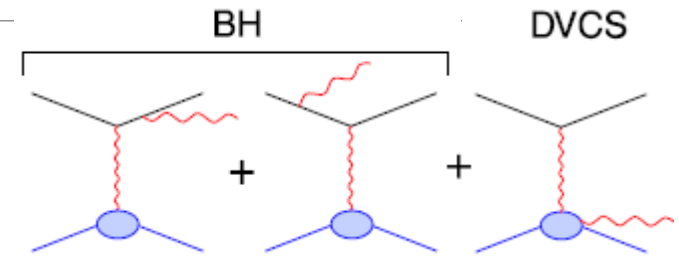


- Raw BSA integrated over all kinematics and detection topologies
- **Compatible with raw BSA from pDVCS in free proton data from CLAS12, no evidence of medium effects at this stage**
- Analysis note in progress
- Publication foreseen for spring 2022

COMPASS 2016: DVCS cross section at $E_\mu = 160$ GeV (Task 2)



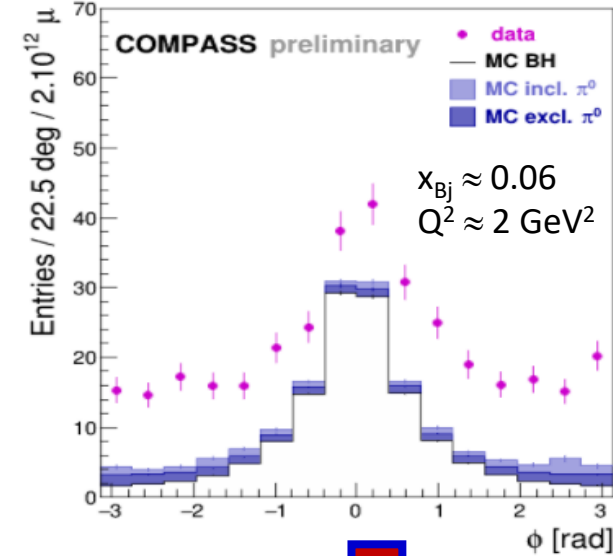
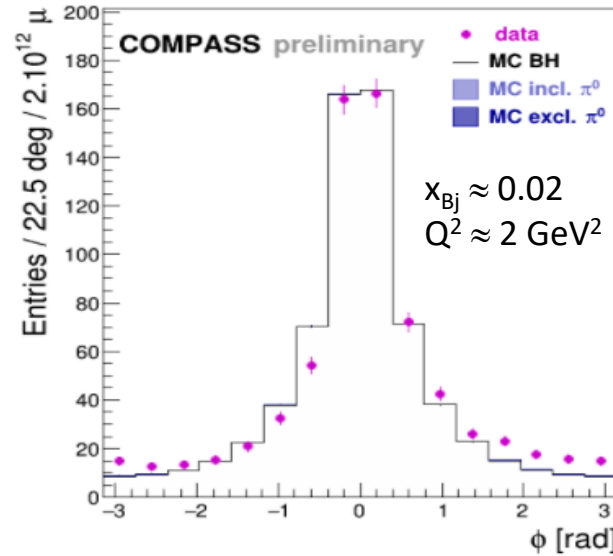
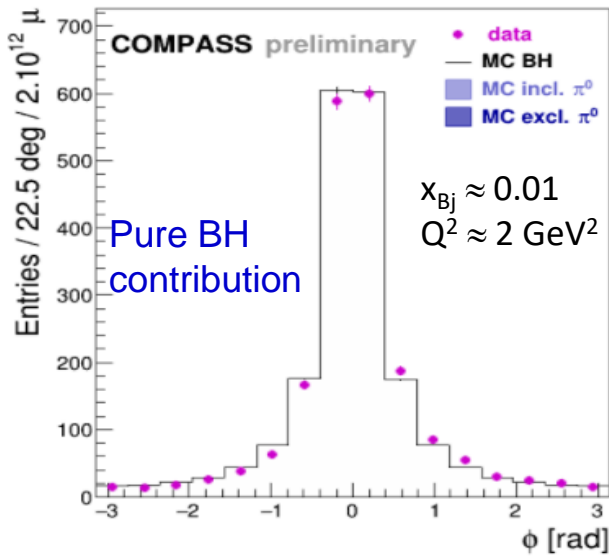
$$d\sigma \propto |T^{BH}|^2 + \text{Interference Term} + |T^{DVCS}|^2$$



$80 < \nu$ [GeV] < 144

$32 < \nu$ [GeV] < 80

$10 < \nu$ [GeV] < 32



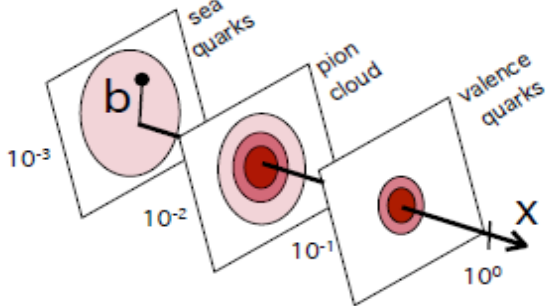
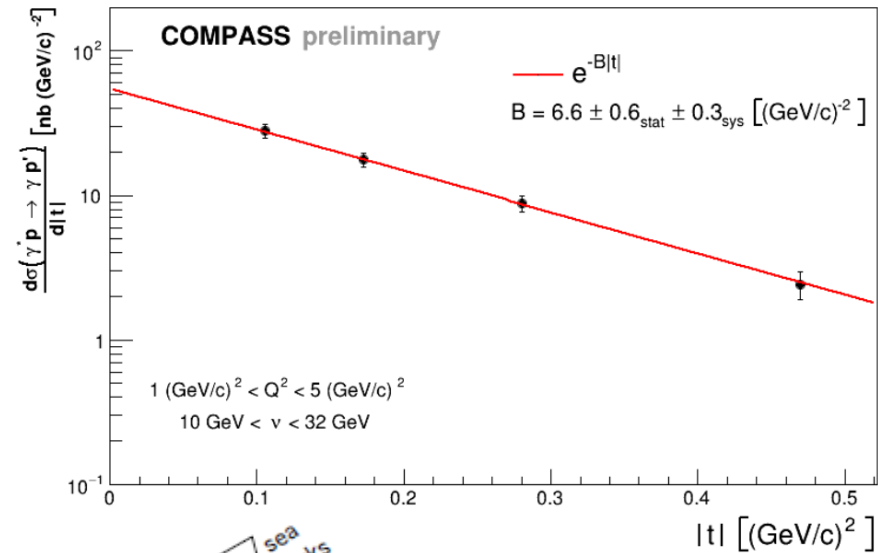
MC: BH normalisation based on integrated luminosity
 π^0 background contribution from SIDIS (LEPTO) + exclusive production (HEPGEN)



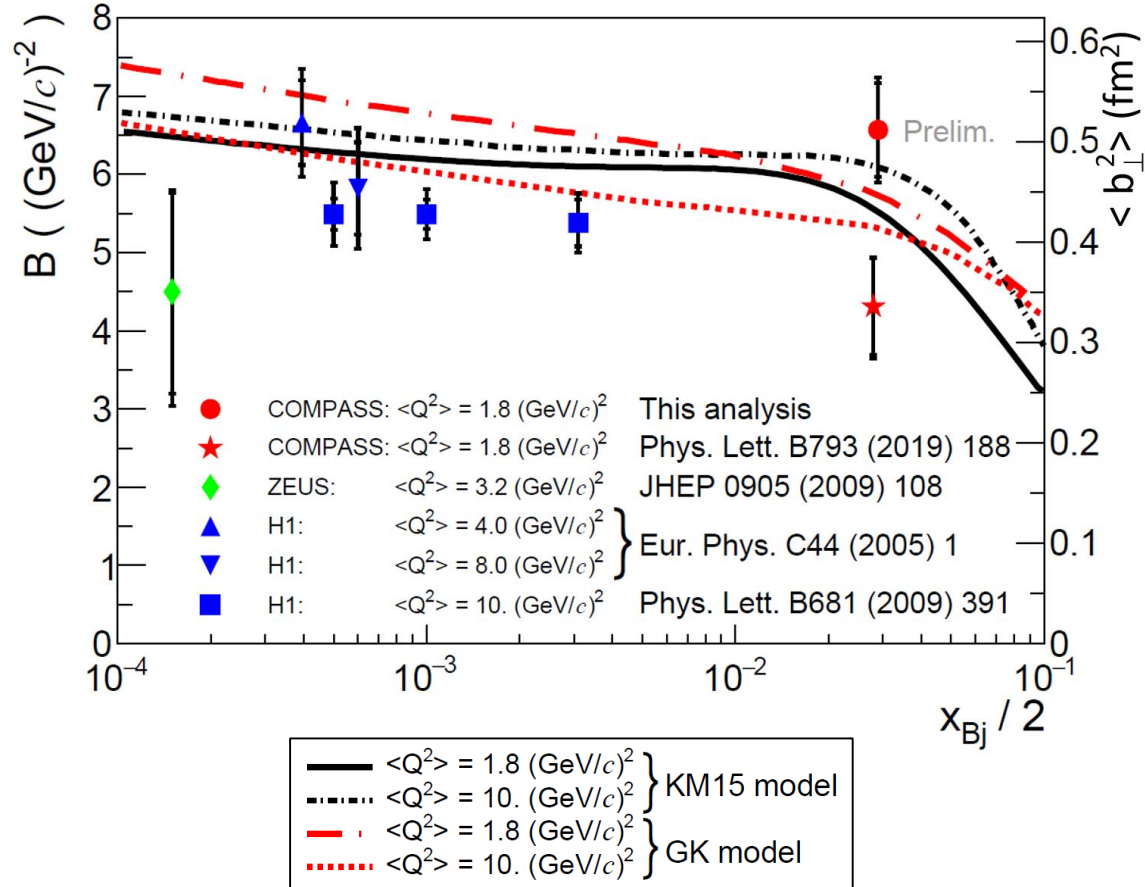
DVCS > BHcontribution

COMPASS 2016: Transverse extension of partons in the sea-quark range (Task 2)

$$d\sigma^{DVCS}/dt = e^{-B|t|} = c_0^{DVCS} \propto (Im\mathcal{H})^2$$

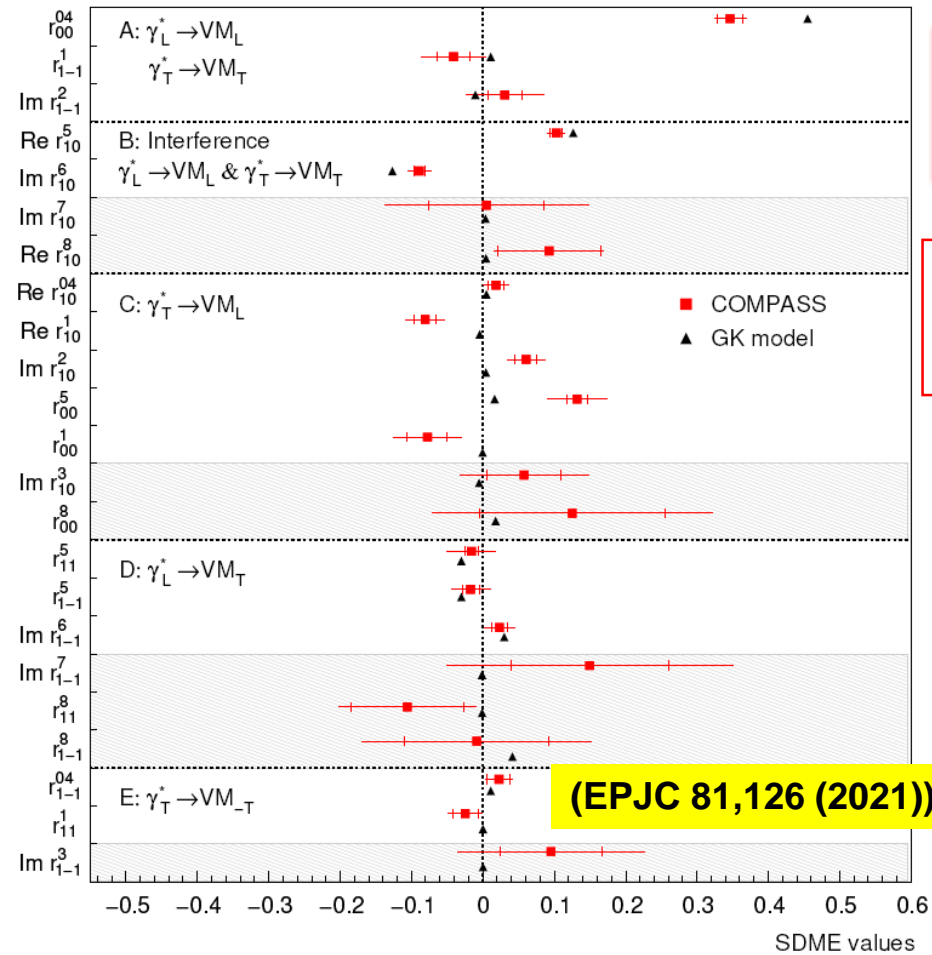


3 times more statistics are expected using the complete data set

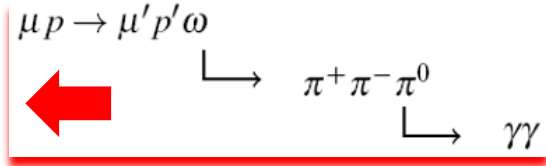


- the results of the 2016 DVCS analysis will be published in the next 6 months
- the π^0 analysis is done in parallel and is in very good progress

Spin Density Matrix Elements in Exclusive Vector Meson Muoproduction at COMPASS (Task 2)

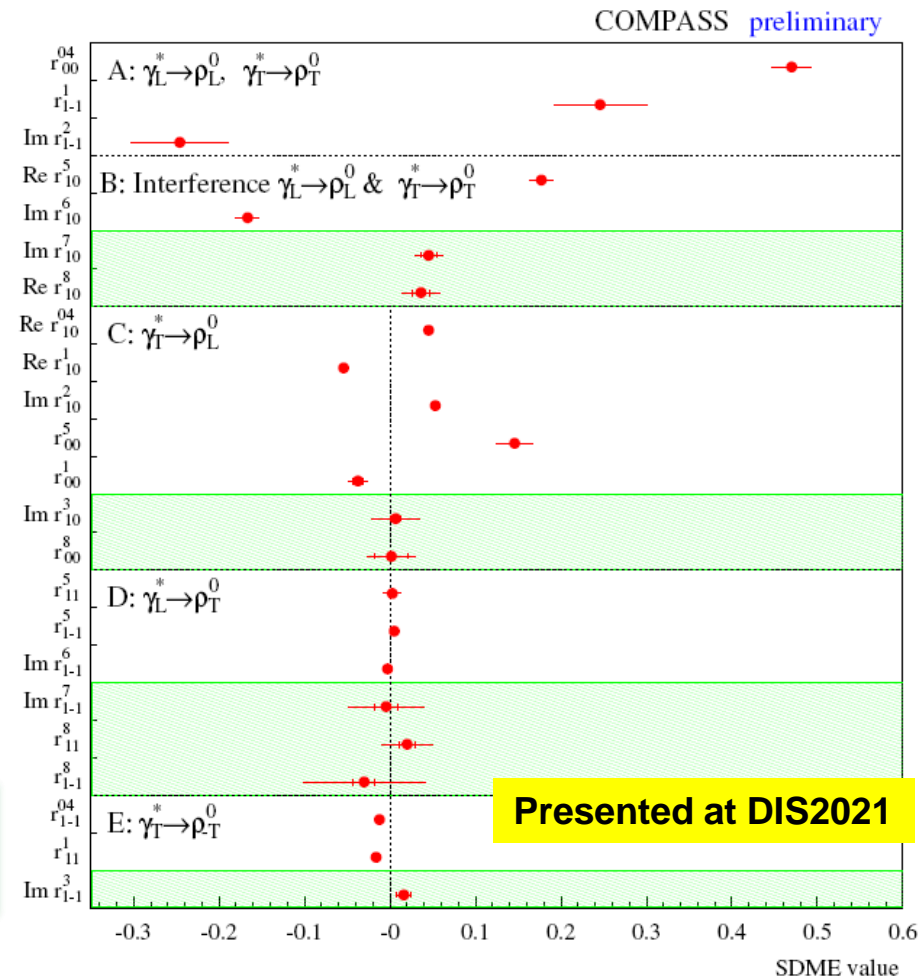
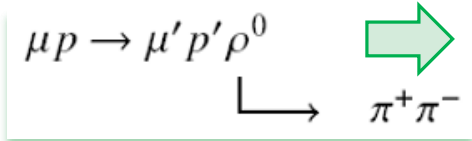


(EPJC 81,126 (2021))



COMPASS provides new constraints for the parameterisation of the GK model

SCHC not obeyed for transitions $\gamma_{T^*}^* \rightarrow \rho_L$
 \rightarrow sensitivity to transversity GPDs

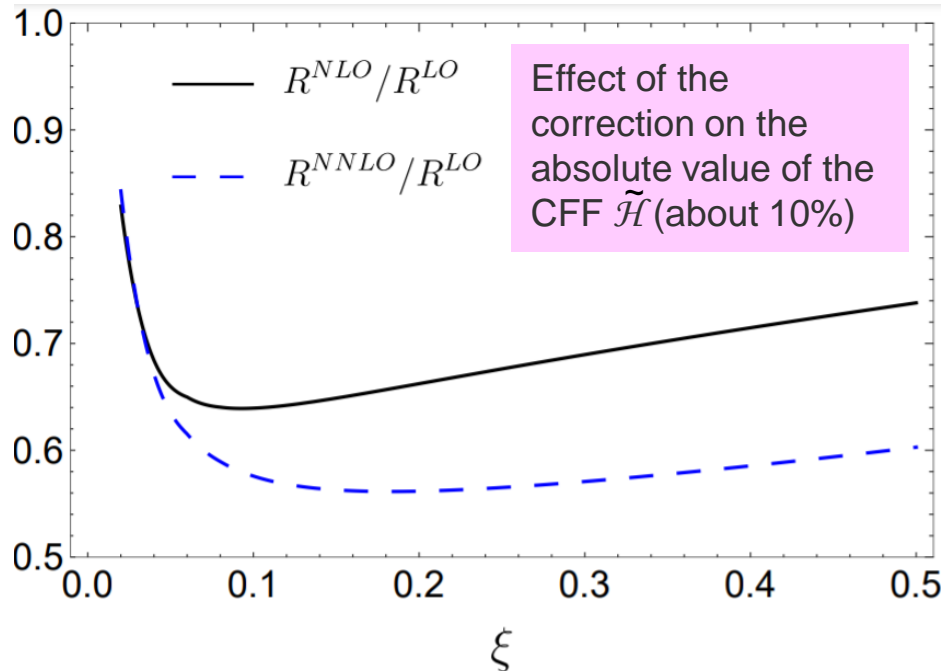


Presented at DIS2021

Highlights of recent theory/phenomenology results on GPDs (Task 3)

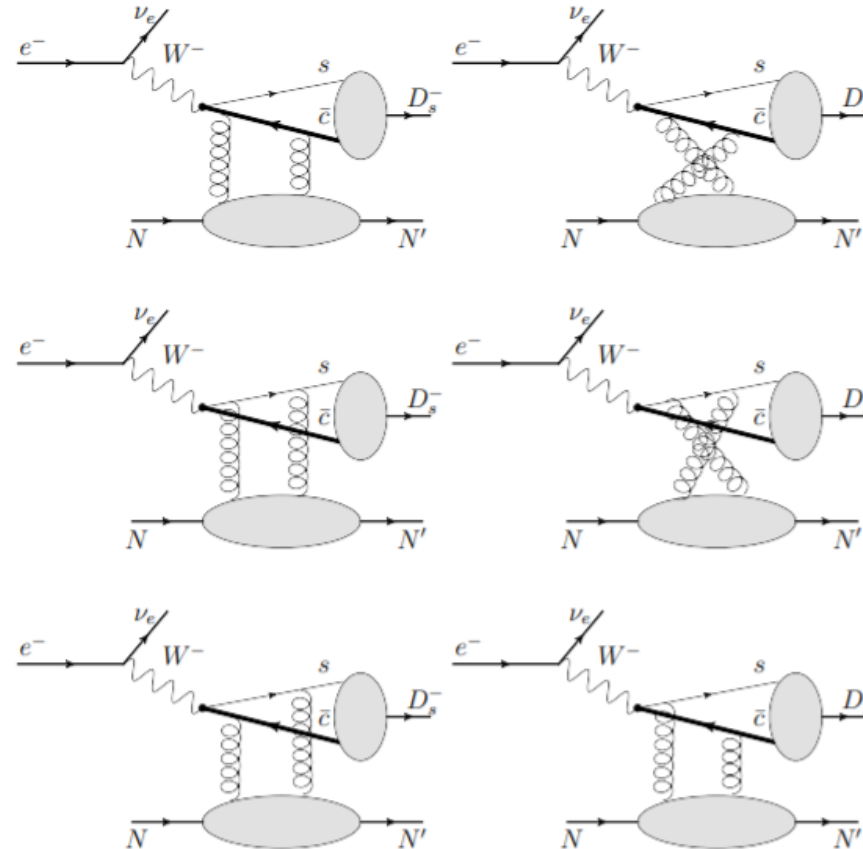
Axial-vector flavor-nonsinglet two-loop coefficient functions for DVCS

PRD104 (2021) 9, 094007



Charged current electroproduction of a charmed meson at an electron-ion collider

Phys.Rev.D 104 (2021) 9, 094002



The production cross sections for exclusive D_s charmed strange mesons, although small, are in the reach of future high luminosity electron-ion colliders making them another potential source of information for future programs aiming at the extraction of GPDs

Highlights of recent theory/phenomenology results on GPDs (Task 3)

- Feasibility study for DVCS on the pion at EIC at NLO and predictions for BSA, **arxiv:2110.06052v1**
- Study on the impact of a positron beam at JLab to determine CFFs **Eur. Phys.J.A 57 (2021) 8, 250**
- The problem of deconvolution in DVCS : given a CFF, can we obtain a GPD? **Phys. Rev. D 103 (2021) 11, 114019**
- Contributions to the EIC Yellow Report, **arxiv:2103.05419v3**
- Phenomenological assessment of proton mechanical properties from deeply virtual Compton scattering **Eur. Phys. J. C 81 (2021) 4, 300**
- Investigation on the possibility to detect Double Parton Scattering at the EIC close to the real photon limit, accessing information on the transverse proton structure, **arXiv:2103.13480**
- Comparison of lattice data with model results for two current correlations in the pion, **Eur. Phys. J. C 80 (2020) 10, 909**
- **And more...**

Deliverables

LIST OF DELIVERABLES (TABLE 3.1c)

Deliverable number	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (in months)
WPno.1	Publication of JLab@12GeV results	23	IPN Orsay	R	PU	36
WPno.2	Publication of COMPASS results	23	CEA-Saclay	R	PU	48
WPno.3	Public software serving GPD fit results	23	Uni Zagreb	OTHE R	PU	46

Milestones

LIST OF MILESTONES (TABLE 3.2a)

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
WPGPD.1	Completion of JLab Hall-A DVCS, and Hall-B TCS and <u>nDVCS</u> analyses		12/24/36	<u>Arxiv</u> publication/Conference presentation and/or analysis note
WPGPD.2	Publication of COMPASS t dependence for DVCS and π^0 cross sections		24	Published paper
WPGPD.3	Construction of the ALERT, NPS, and <u>FT-hodoscope</u> electronics		24/48	TDR/prototype (DEM)
WPGPD.4	Lattice moments of GPDs and global GPD fits		28	Presented at conference or published paper
WPGPD.5	Models for several classes of GPDs and published study of GPD-related observables	<u>QCDSOft</u>	36	Published papers

Status of JRA5 – GPD-ACT

- Most of the funding (66%) went for hiring **postdocs** (we hired 3 - CNRS, CEA, INFN - and they did or are doing excellent work)
- Rest of the funding (33%) is for **travel** – severely restricted due to the COVID-19 pandemic
- Deliverables are not in danger:
 - ✓ JLab results are being published for both 6 and 12 GeV
 - ✓ COMPASS results published for DVMP, soon to be published for DVCS
 - ✓ A wealth of publications for theory/phenomenology