EicC CDR writeup on GPD related Exclusive Processes

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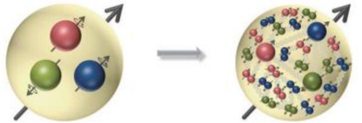

- **3D structure of nucleon and Meson (GPD&TDA) @ EicC**
- Topics: DVCS, DVMP at forward & backward domain
- Pages: 36pp + refs.

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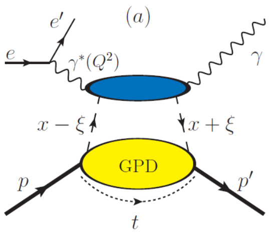
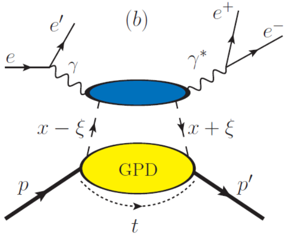
- Ting Lin, Weizhi Xiong (Shandong U.), Yutie Liang, Aiqiang Guo (IMPCAS)

Introduction

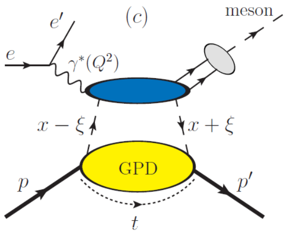
- **From 1D to 3D structure of proton:**
  - GPD: DVCS, TCS, DVMP, DDVCS



- Deeply Virtual Compton Scattering $\xi = x_B/(2 - x_B)$



- Timelike Compton Scattering
- **share the same final states with nucleon-to-photon TDA**
- **but with backward u-channel** $\xi = \tau/(2 - \tau)$



- Deeply Virtual Meson Production
- **share the same light meson with nucleon-to-meson TDA & hadron physics**
- **heavy quarkonium: gravitation form factors or proton mass?**
- **fully construction of all particles & kinematics**

Introduction

- **From CFFs to GPDs, for example, in the case of DVCS:**

$$\mathcal{H}(x_B, t, Q^2) = \sum_{a=u,d,\ldots,g} \int_{-1}^{1} \frac{dx}{2\xi}\, T^a_{\mathrm{DVCS}}(x, \xi, Q^2)\, H^a(x, \xi, t, Q^2)\,,$$

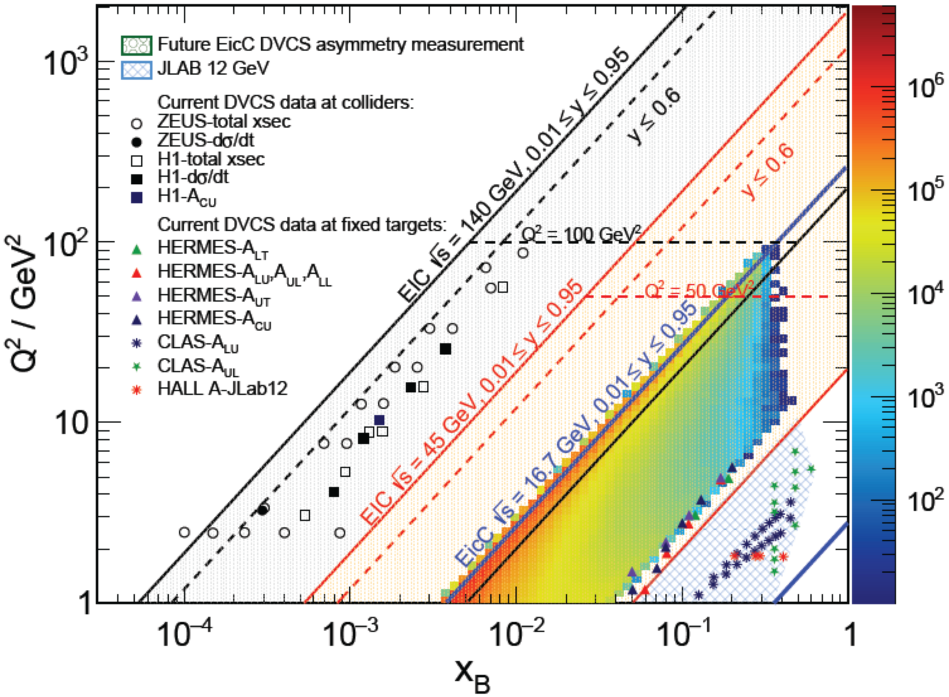
- Models inspired by the double distribution ansatz [44] — **GK, VGG model**
- Models that describe GPDs in the space of conformal moments [45] — **KM model**
- Models that represent Compton form factors as neural networks [49, 28] — **PARTONS, Gepard**

1. Determination of form factors, more or less directly, from experimental observables
2. Determination of GPDs from the corresponding form factors.

- **DVMP: Factorization?** CLAS12, 2307.07874, $Q^2 < 8$ GeV^2

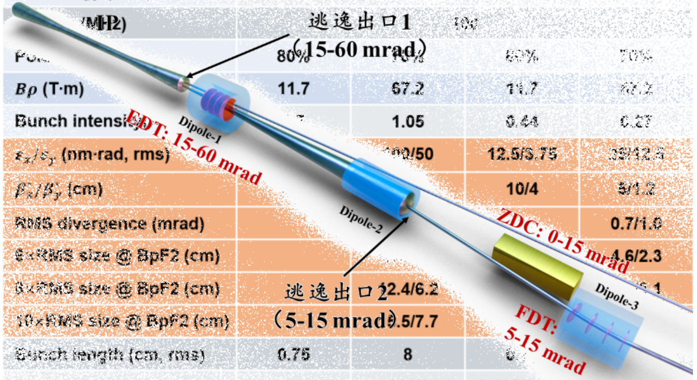
Exclusive Process I: DVCS

- **3D structure of nucleon (GPDs) @ EicC**
- Worldwide data *VS.* pseudodata (flitered by the state-of-the-art detetctor)



High Lumi. **Low Lumi.**

Designs	HIAF-U-New, V0		V1	
Particle	e	p	e	p
Circumference(m)	1151.20	1149.07	1151.20	1149.07
Kinetic energy (GeV)	3.5	19.08	3.5	19.08
Momentum (GeV)	3.5	20	3.5	20
Total energy (GeV)	3.5	20.02	3.5	20.02
CM energy (GeV)	16.76			
[illegible] (MHz)	[illegible]			
Po[illegible]	80%	[illegible]	[illegible]	[illegible]
$B\rho$ (T·m)	11.7	67.2	11.7	[illegible]
Bunch intensi[illegible]	[illegible]	1.05	0.44	0.27
$\varepsilon_x/\varepsilon_y$ (nm·rad, rms)	[illegible]	[illegible]/50	12.5/3.75	[illegible]
β_x^*/β_y^* (cm)	[illegible]	[illegible]	10/4	5/1.2
RMS divergence (mrad)	[illegible]	[illegible]	[illegible]	0.7/1.0
[illegible]×RMS size @ BpF2 (cm)	[illegible]	[illegible]	[illegible]	4.6/2.3
[illegible]×RMS size @ BpF2 (cm)	[illegible]	12.4/6.2	[illegible]	[illegible]
10×RMS size @ BpF2 (cm)	[illegible]	[illegible]/7.7	[illegible]	[illegible]
Bunch length (cm, rms)	0.75	8	[illegible]	[illegible]
BB parameter ξ_x/ξ_y	0.102/0.118	0.0144/0.01	0.105/0.121	0.015/0.010
Laslett tune shift	-	0.066/0.105		0.065/0.10
Energy loss (MeV/turn)	0.32	-		
Total SR power (MW)	0.86	-		
Average Current (A)	2.7	1.68		
Crossing angle (mrad)	50			
Luminosity ($cm^{-2}\cdot s^{-1}$)	4.25×10^{33} (H=0.52)		1.13×10^{33} (H=0.52)	

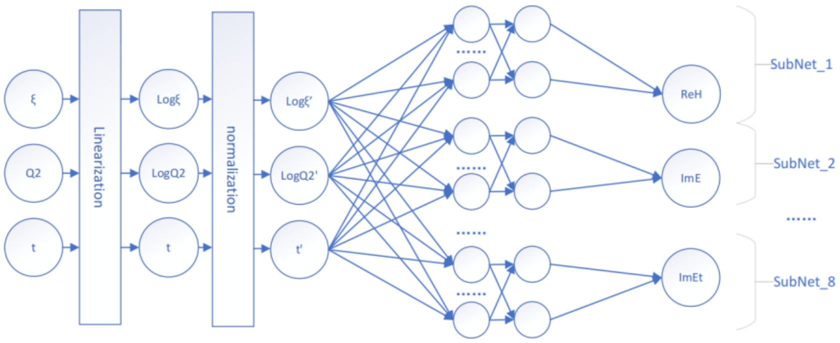


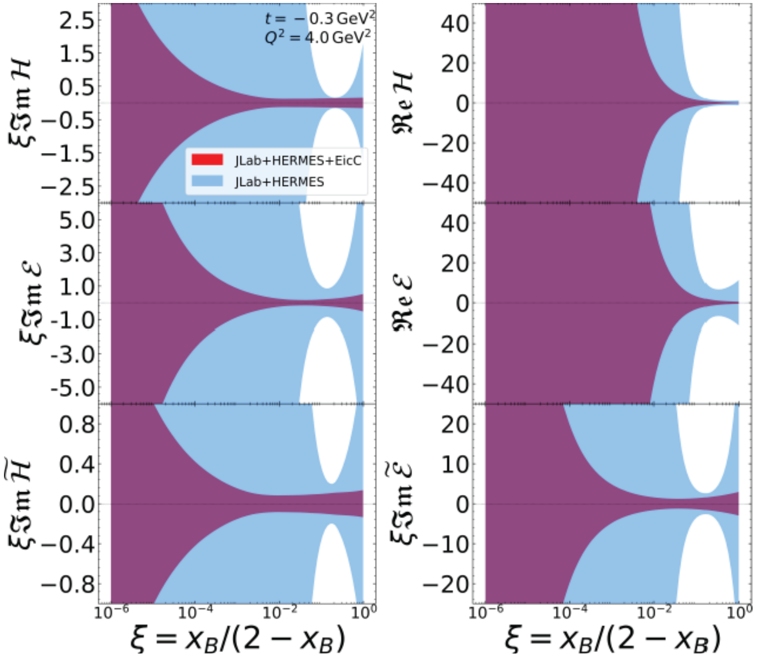
Exclusive Process I: DVCS

- **3D structure of nucleon (GPDs) @ EicC**
- Accessing Compton Form Factors by all pseudo-data of asymmetry at the EicC

~ 1 day running surpasses old data of A_{UT}

X. C, Jinlong Zhang, EPJC 83 (2023) 505

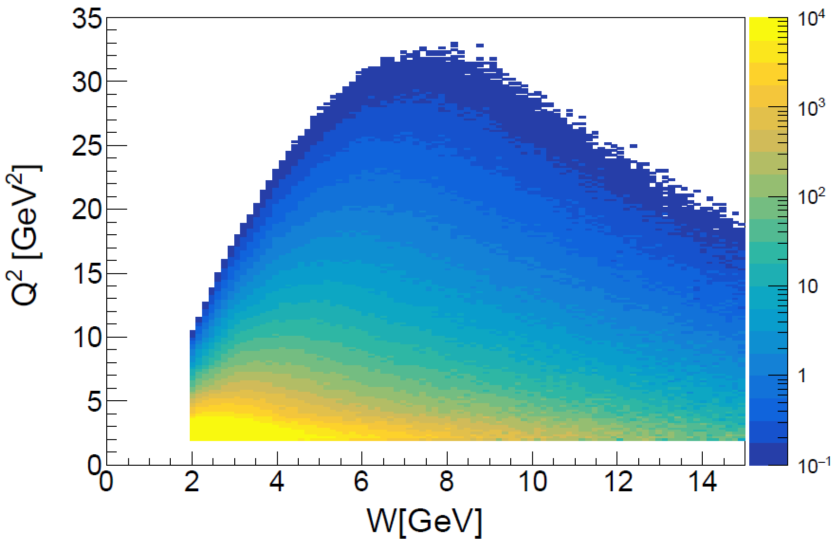


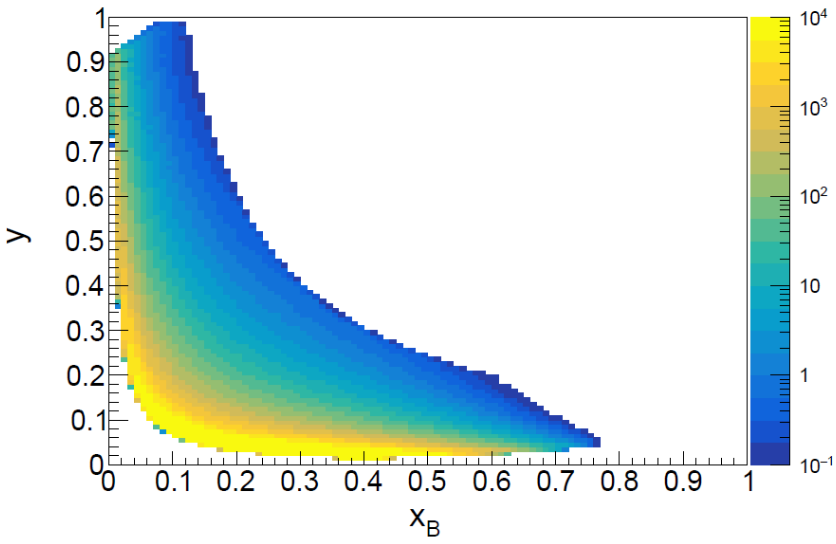


- Re-training (less-biased) within Gepard neural network (Kresimir, Yuanyuan Huang)
- Have rewriten and polished most of the text: quark OAM is addressed

Exclusive Process II: DVMP

- **3D structure of nucleon (GPDs) @ EicC**
- DVMP events generated by updating Sartre (Yaping Xie)

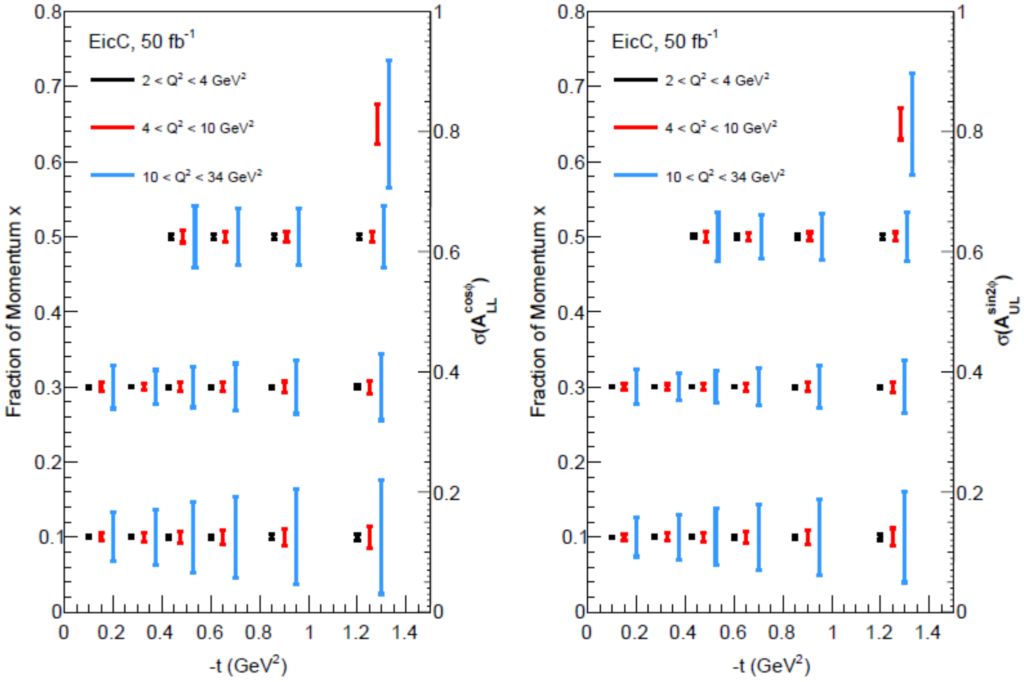




- Input: state-of-the-art GK model (arxiv: 2206.06547,2209.14493)

Exclusive Process II: DVMP

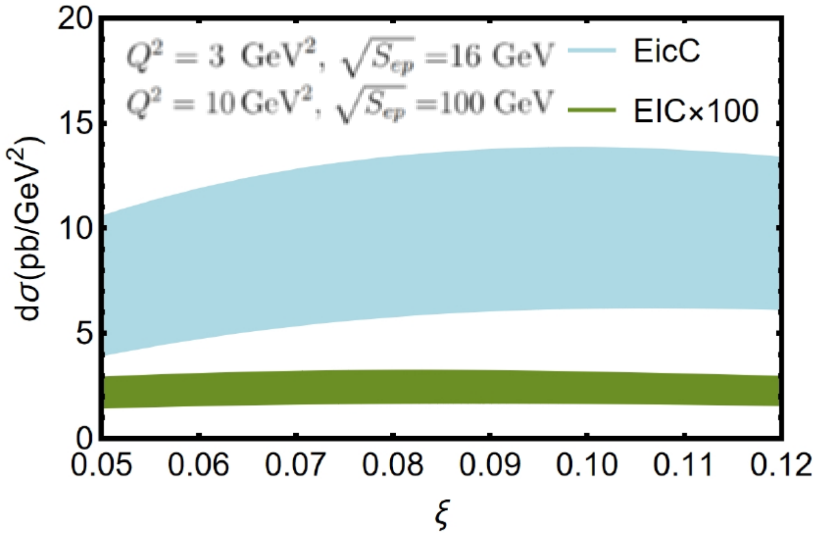
- **3D structure of nucleon (GPDs) @ EicC**
- DVMP pseudo-data of asymmetry (Ting Lin)

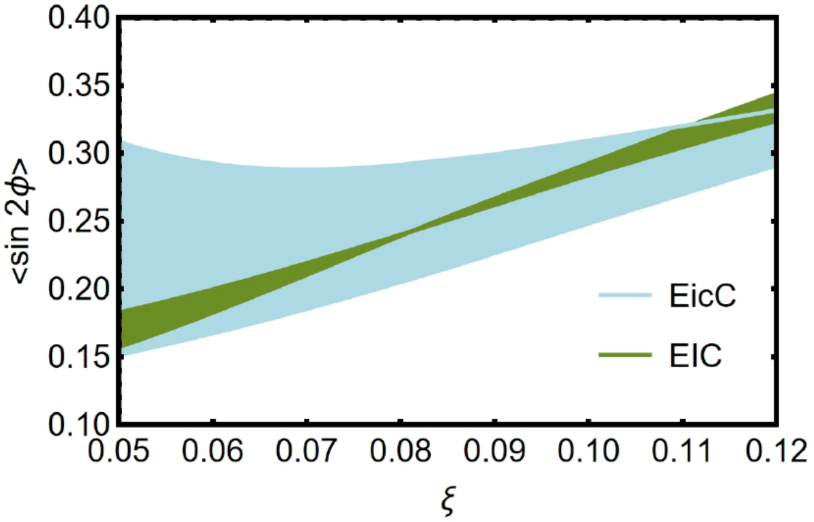


- Test Factorization up to $Q^2 \sim 20.0\ GeV^2$

Exclusive Process II: DVMP

- **3D structure of nucleon (GPDs) @ EicC**
- Proton longitudinal spin asymmetry (Jian Zhou)
- Free of the contamination from final state soft gluon radiation effect
- A twist-three contribution, such that the asymmetry can be maximally enhanced

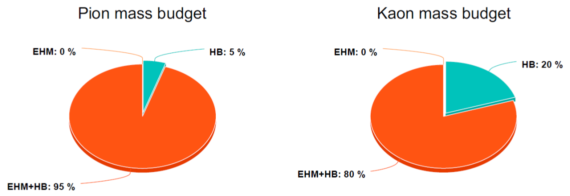


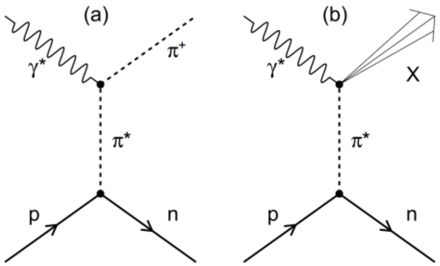


- Probe quark OAM in relation to the Jaffe-Manohr sum rule

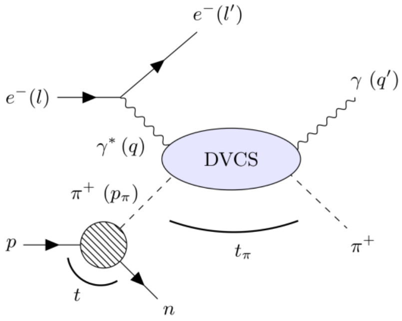
Exclusive Process III: Sullivan processes

- **From 1D to 3D structure of pions & kaons:**
- Pions/Kaons as the approximate Nambu–Goldstone bosons of spontaneously broken chiral symmetries associated with the (near) masslessness of quarks
- Probed by Drell-Yan process and Sullivan process
- Detection of leading neutron/Lambda





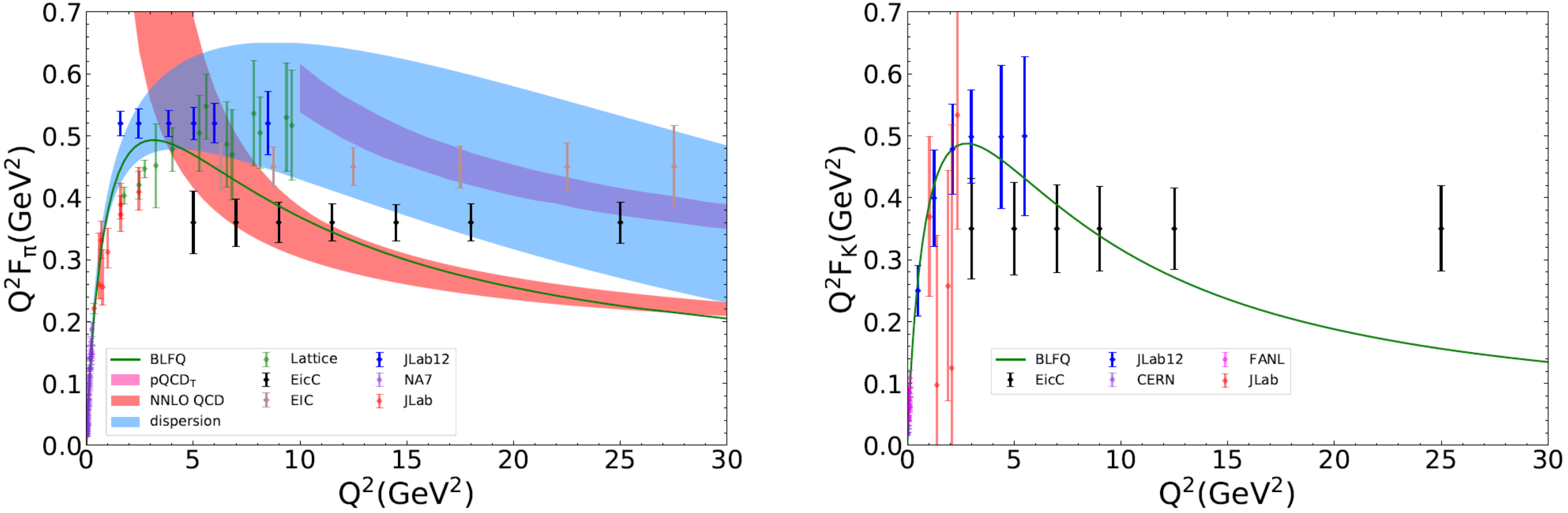
- Structure function: see Weizhi Xiong's talk
- **Sensitivity to elastic form factor and Parton Distribution Functions**



- π^+-DVCS
- **quarks and gluons interfere destructively**
- see J. M. Morgado Chávez *et al.*, Phys.Rev.Lett. 128 (2022) 202501

Exclusive Process III: Sullivan processes

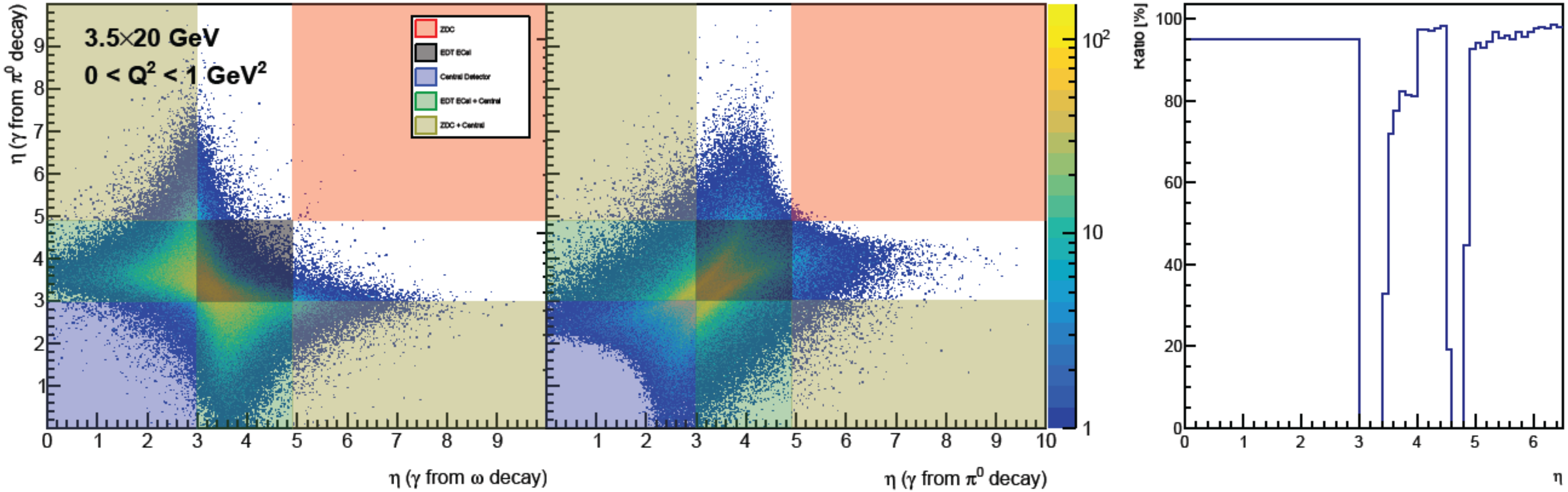
- **1D & 3D structure of meson @ EicC**



- Kaon is hightlighted at EicC

Exclusive Process III: backward DVMP

- **Nucleon-to-meson TDA @ EicC**
- Forward Photon Detection (Ting Lin)



- Pseudorapidity distributions of photons from u-channel ω production

Exclusive Process III: new ideas

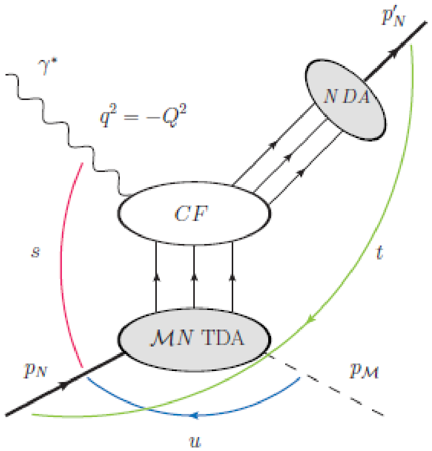
- **Many new processes proposed @ EicC& EIC**
- Mostly Stay at the theoretical level

- backward DVCS

- Timelike Compton scattering

- Double deeply virtual Compton scattering

- ……many others



- The small cross sections of those processes emphasize the urgent need of careful feasibility studies.

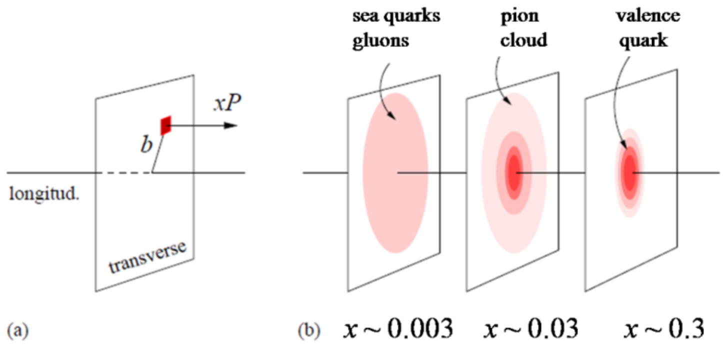
Bernard Pire, Paweł Sznajder, Víctor Martínez-Fernández, Jakub Wagner (NCBJ, Warsaw)

Summary

- **Fruitful exclusive processes have been written in the EicC CDR**
- Selected observables are highlighted in different processes

- **A lot of efforts from detector group**
- Coverage, reconstruction efficiency and resolution of detector
- small Q2 & large-*t*
- Detect all particles! efficiency^n

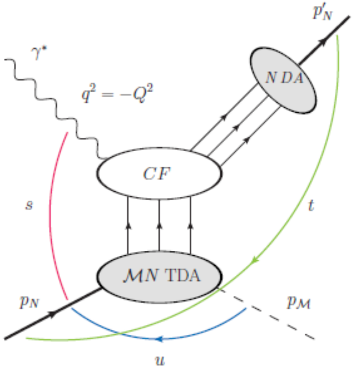
Efforts and comments are welcome

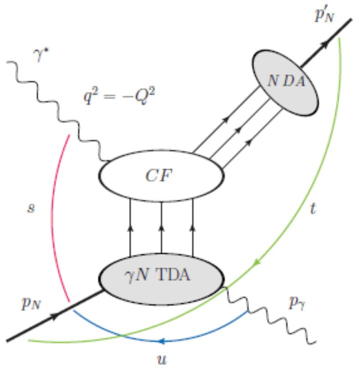


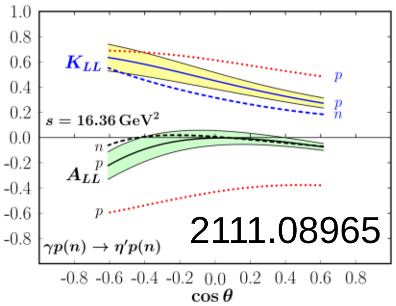
Special Thanks to Many Contributors in Exclusive Working Group ……

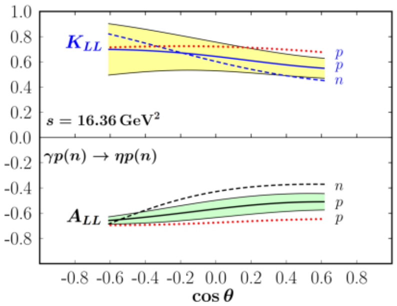
- **From 1D to 3D structure of proton:**

  - TDA: backward (u-channel) processes
  - Backward meson production
  - Backward DVCS







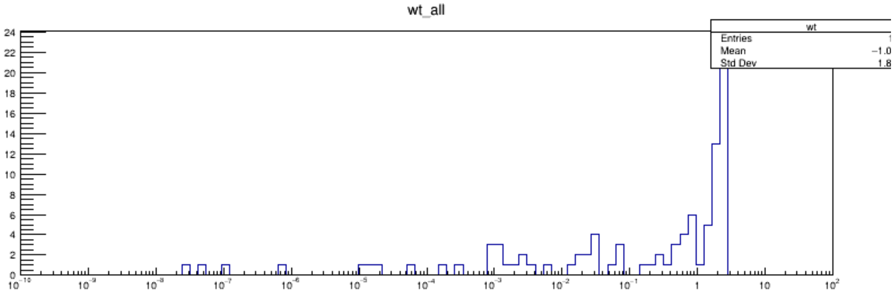


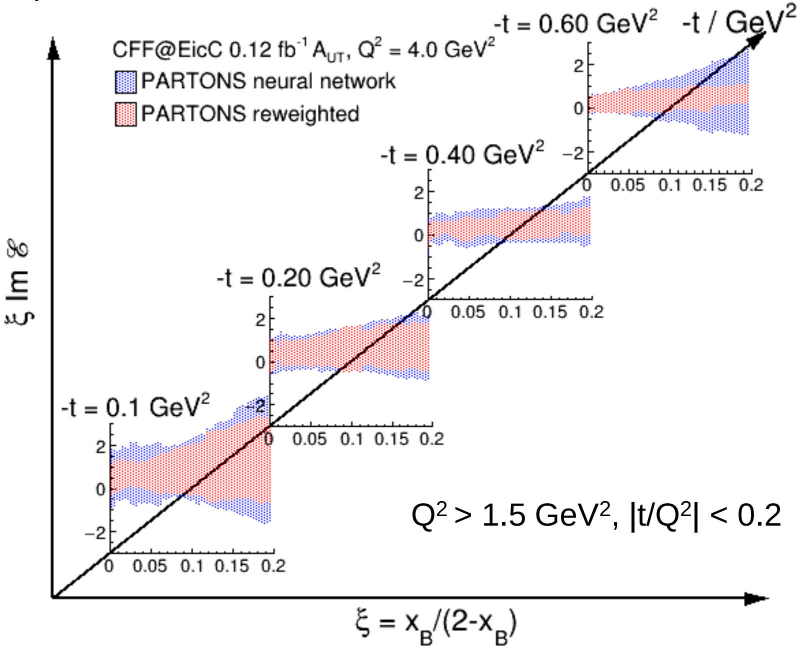
- … and more new theotical ideas:
  η, η´or meson+photon

Exclusive Process I: DVCS

- **3D structure of nucleon (GPDs) @ EicC:** ~ 1day running surpasses old data of A_{UT}
- Accessing Compton Form Factors: An Impact study on Im$\mathcal{E}$

see X. C, Jinlong Zhang, arXiv:2301.06940, EPJC 83 (2023) 505





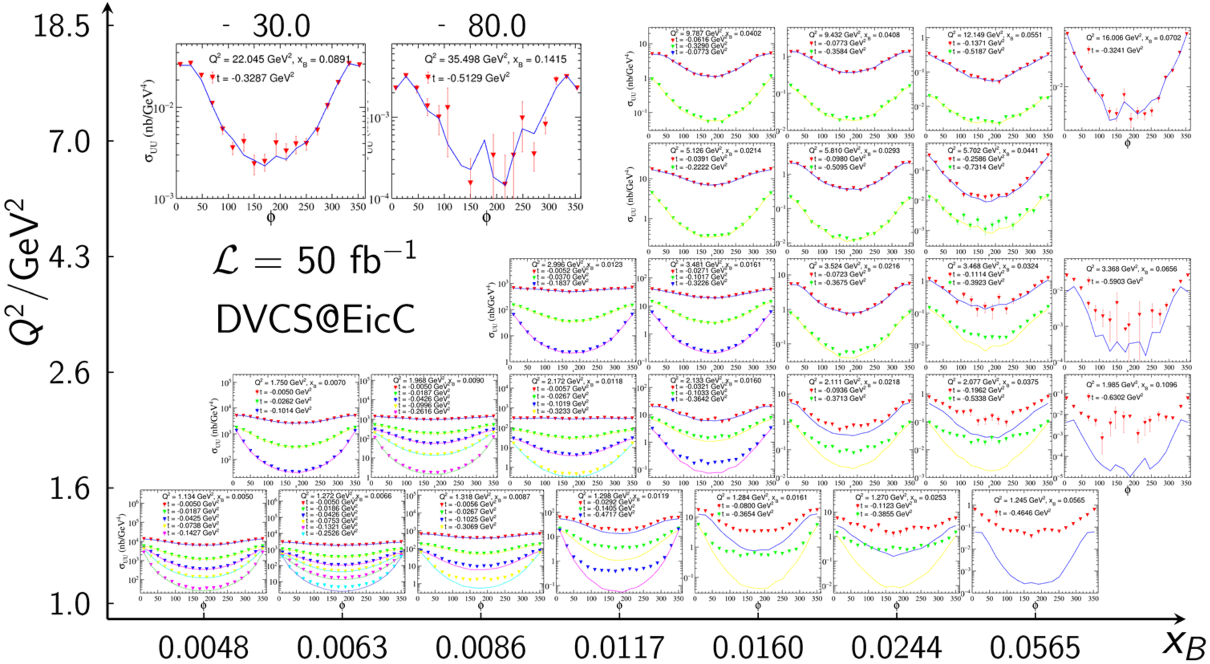
- NNPDF: $$w_k = \frac{(\chi_k^2)^{\frac{1}{2}(n-1)} e^{-\frac{1}{2}\chi_k^2}}{\frac{1}{N}\sum_{k=1}^{N}(\chi_k^2)^{\frac{1}{2}(n-1)} e^{-\frac{1}{2}\chi_k^2}}.$$

$$\langle \mathcal{O} \rangle_{\text{new}} = \int \mathcal{O}[f]\,\mathcal{P}_{\text{new}}(f)\,Df = \frac{1}{N}\sum_{k=1}^{N} w_k \mathcal{O}[f_k]\,.$$

- quark OAM: neutron target or a transversely polarized proton beam
- reweighting the replicas from PARTONS(EPJC79:614) by $\sin(\phi-\phi_s)\cos(\phi)$ module of A_{UT}

Exclusive Process I: DVCS

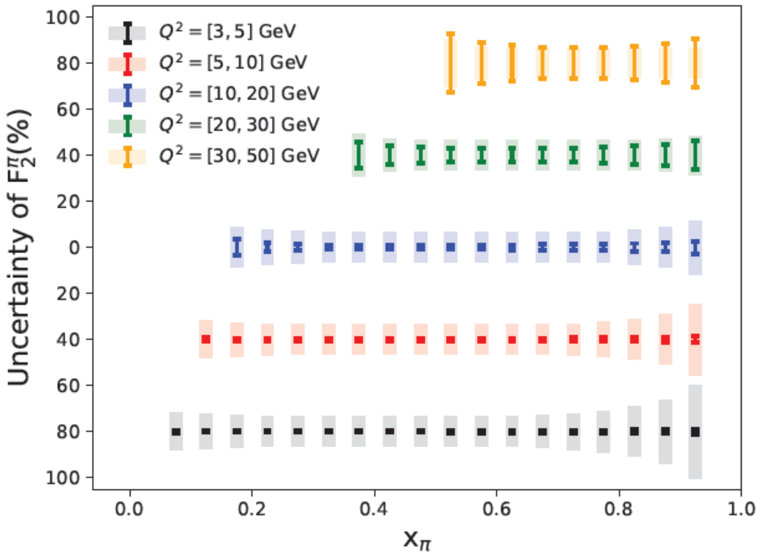
- **3D structure of nucleon (GPDs) @ EicC**
- Accessing Compton Form Factors by all pseudo-data at the EicC

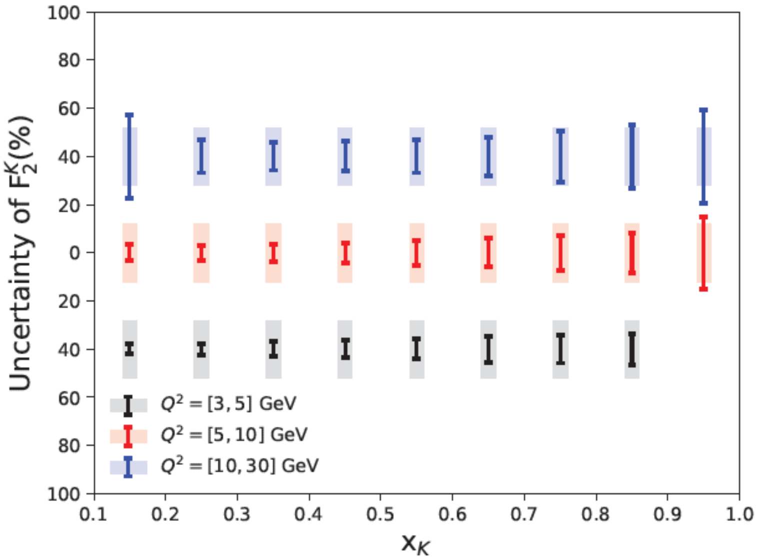


- Re-training (less-biased) within Gepard neural network
- Have rewriten and polished most of the text

Exclusive Process III: Sullivan processes

- **structure function of meson through inclusive processes @ EicC**

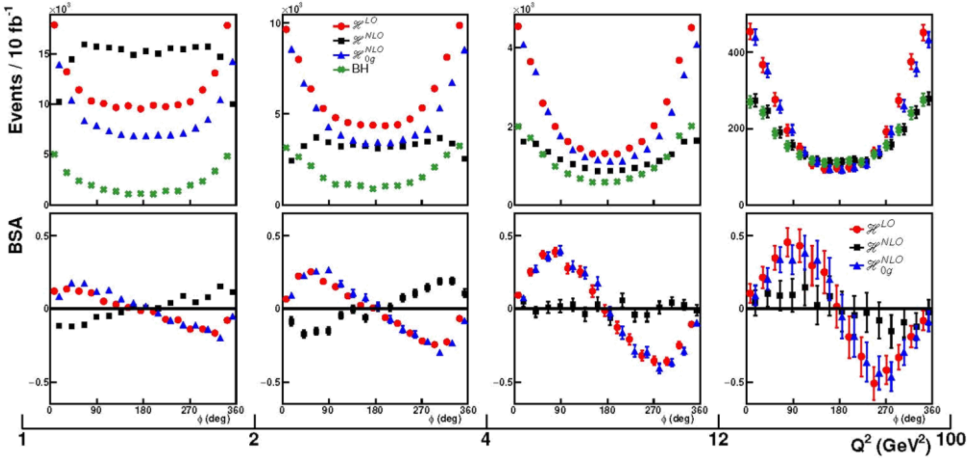


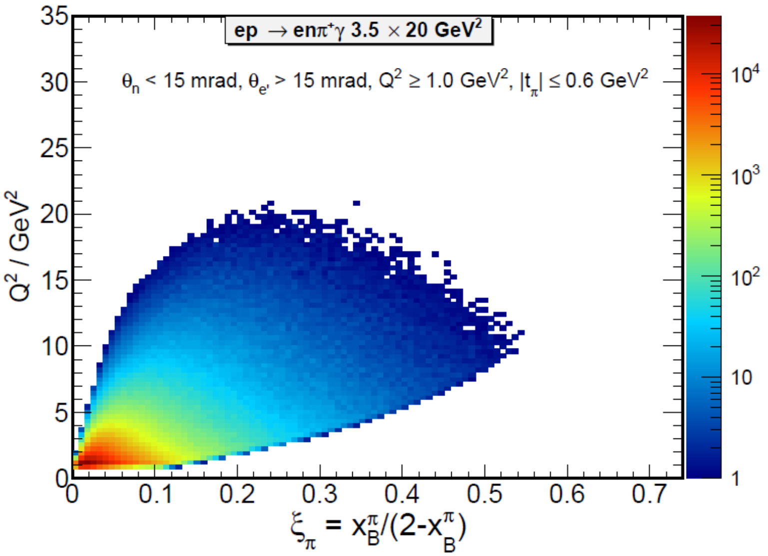


- Kaon is hightlighted at EicC

Exclusive Process III: Sullivan processes

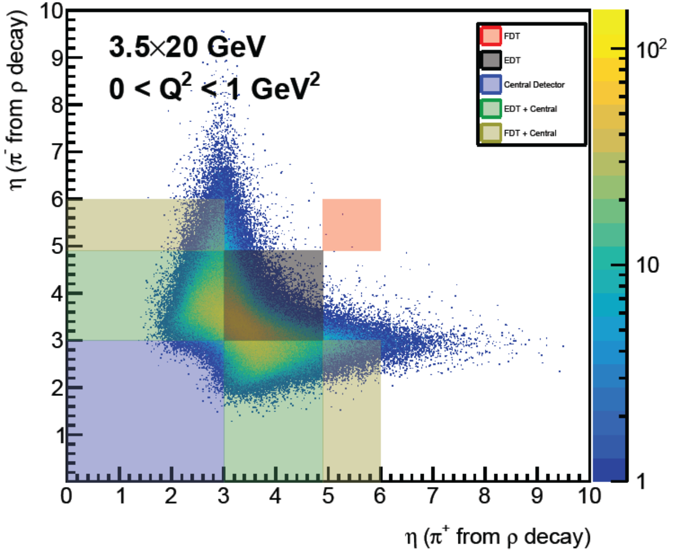
- **1D & 3D structure of meson @ EicC**
- π^+-DVCS through Sullivan process (filtered by detector at EicC)
- Over eff. ~ 20.0%

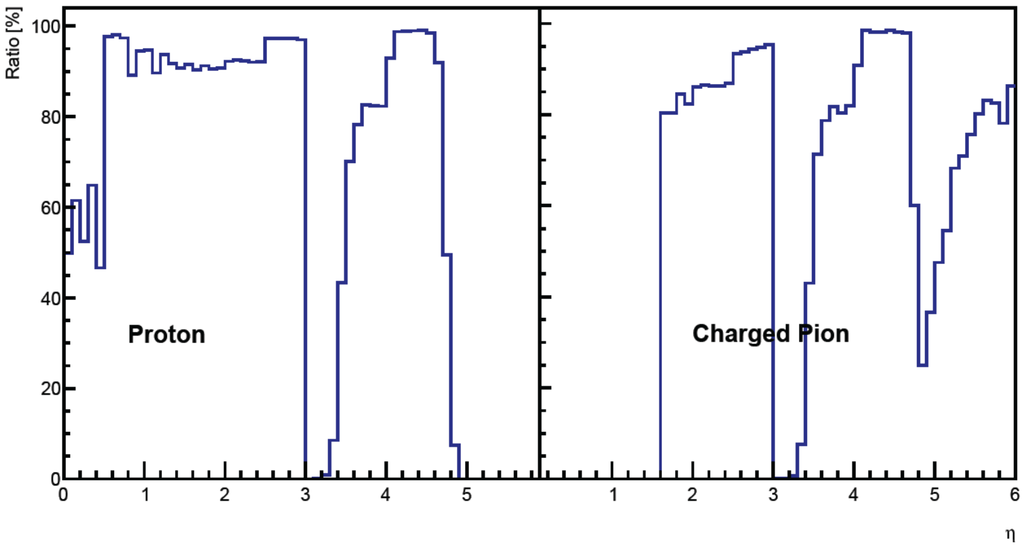




Exclusive Process III: backward DVMP

- **Nucleon-to-meson TDA @ EicC**
- Forward Charge Pion Detection (Ting Lin)





- pseudorapidity distribution of π± from u-channel ρ0 production

Introduction

One of the central scientifical goal of EicC is to map parton transverse spatial distribution which is encoded in Generalized Parton Distributions(GPDs) [1, 2, 3, 4, 5]. GPDs depend on three kinematics variables: x, that is the average longitudinal momentum fraction carried by the active quark; ξ and t, which are the half longitudinal momentum faction transferred to the target and the squared four-momentum transferred to the target, respectively. The study of GPDs allows us to address a variety of aspects of hadron structure. First of all, they reduce to the corresponding ordinary PDFs in the forward limit $\xi = 0$ and $t = 0$. The electromagnetic form factors of

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Another important motivation for studying GPDs in physics is to understand the spin structure of nucleons. According the Ji's sum rule [3], the total angular momentum of partons is related to the first x moment of the sum of GPDs H and E which can be measured in exclusive processes. For example, the GPD H can be measured in Deeply Virtual Compton Scattering (DVCS) process, while the most promising observable for accessing the GPD E is the target transverse single spin asymmetry in exclusive J/ψ production in ep collisions [10]. The quark

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ploring the internal nucleon structure from many aspects, the experimental studies of GPDs at EicC have been identified as the one of the central scientific goals.

Introduction

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with corresponding partonic hard-scattering amplitudes T^a. For example, in the case of DVCS,

$$\mathcal{H}(x_B, t, Q^2) = \sum_{a=u,d,\ldots,g} \int_{-1}^{1} \frac{dx}{2\xi} T^a_{\mathrm{DVCS}}(x, \xi, Q^2)\, H^a(x, \xi, t, Q^2)\,, \tag{1}$$

where $\xi \approx x_B/(2 - x_B)$. The above form factors are complex functions, each corresponding to a GPD (e.g., $\mathcal{H}$, $\mathcal{E}$, etc.), making the extraction of GPDs a two-step process:

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The situation is analogous to deep inelastic scattering (DIS), where structural functions $F_i(x, Q^2)$ were first determined, followed by the extraction of parton distribution functions (PDFs). However, the GPD extraction problem is more involved due to a greater number of unknown functions and of independent kinematic variables on which they depend.

The second step is further complicated by the inherent impossibility of deconvoluting the expression (1), a challenge highlighted by the issue of "shadow GPDs" [30, 31]. Generally,

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Introduction

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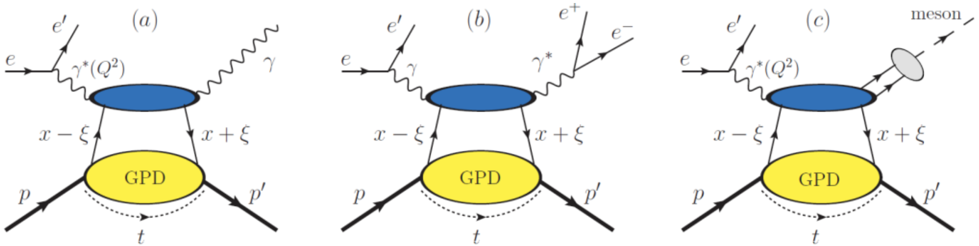
the separation and extraction of these functions are greatly facilitated when the experimental facility can work with polarized particles and covers a wide range of kinematic variables — characteristics that EicC should possess. The extended range of available values for the scale Q^2 is particularly interesting, as the evolution of GPDs with Q^2, a well-known phenomenon, may provide an additional means of extracting these functions.

GPDs play a role in a series of exclusive processes, with deeply virtual Compton scattering (DVCS), time-like Compton scattering, and deeply virtual meson production (DVMP) [2, 3] being among the most studied, see Figure 1. The amplitudes for all these processes are known up to next-to-the-leading order (NLO) ref. Recently, some other processes involving GPDs, such as double DVCS [32, 33, 34, 35] or boson pair production [36, 37, 38, 39, 40], have gained prominence, with their first experimental measurements yet to come. Brief mention of other new ideas: backward TCS ....



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Introduction

Currently, GPD extractions are primarily based on DVCS data and, to a somewhat lesser extent, on DVMP data. Some earlier extractions [41, 42, 43] were conducted locally, only for kinematic points corresponding to experimental measurements, thus minimizing model dependencies and uncertainties due to extrapolation and interpolation in the multidimensional kinematic space. The obtained results generally show the dominance of the GPD H for most observables and demonstrate general consistency of the entire approach. However, for a genuine understanding of the three-dimensional quark-gluon structure of nucleons, global extractions are necessary, requiring the selection of a GPD model and fitting it to the data.

Several categories of models have been proposed in the literature:

- Models inspired by the double distribution ansatz [44]
- Models that describe GPDs in the space of conformal moments [45]
- Models that represent Compton form factors as neural networks [49, 28]

Introduction

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Most published fits and extractions are currently at the leading-order (LO) level of perturbative QCD, which lags behind the standards for extracting ordinary PDFs and GPD-related Transverse Momentum Dependent PDFs (TMDs), routinely performed at the next-to-next-to-the-leading order (NNLO). The reason for this is, on one hand, the lack of computer implementations of known relevant NLO and NNLO hard-scattering amplitudes and evolution operators, and on the other hand, the insufficient precision and kinematic range of currently operational experimental facilities (JLab). This situation will undoubtedly change with the advent of EicC. An exception is the historically first fit to DVCS data in [46] performed at the NLO level in the $\overline{\text{MS}}$ scheme (and even at NNLO in a special $\overline{\text{CS}}$ scheme), as well as recent NLO fits simultaneously to DVCS and DVMP data [53]. Although these fits are limited to small values of x_B and are not genuinely global, they clearly show that at high energies (and thus likely in EicC kinematics), the NLO approach is necessary, especially in multi-channel fits due to the different roles of gluons in DVCS and DVMP processes.

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Introduction

True global fits [27, 47, 48] are currently still at the LO level. Thanks to the dominance of the imaginary part of high-energy amplitudes and the fact that at LO, the imaginary part of the hard-scattering amplitude in (1) is proportional to $\delta(x-\xi)$, experimental observables are most sensitive to the so-called cross-over trajectory $x=\xi$. Extraction is cleanest on this trajectory. One way to reliably extract GPDs for $x \neq \xi$ is to use lattice QCD results [54, 55], and the other is to use measurements with a wide range of Q^2, which will again be possible with the EicC facility. Until then, considering the current state of fits and extractions, it can be said that most work has been done using DVCS, and some CFF form factors are reasonably well-extracted in the middle range of x_B from CLAS, COMPASS, Hall A, and HERMES collaboration data. Various groups agree well on the values of $\mathcal{H}$ and $\widetilde{\mathcal{H}}$, while the knowledge of $\mathcal{E}$, whose corresponding GPD E is crucial for the Ji sum rule [3], still has a relatively large uncertainty.

Regarding fits to DVMP data, the popular GK model [56, 57] has been developed using them, showing reasonably good agreement for describing DVCS data as well [58], thus demonstrating the universality of GPD functions, further confirmed in [53].

.... what is particular for EicC?

Breif summary on GPD physics requirement for detector (Weizhi, Yutie).

Exclusive Process II: DVMP

GPDs were proposed to study the exclusive processes at large Q^2 such as the deeply virtual compton scattering, deeply virtual meson production (DVMP) (see e.g.[126, 127]). what is particular for EicC? It is interesting to study GPDs, especially transversity one, which are no well known, in future experiments on exclusive DVMP at EicC.

Within the handbag model that is used in GK model [?] the meson production amplitude at sufficiently high photon virtuality Q^2 is factorized [?, ?, ?] into a hard subprocess amplitude $\mathcal{H}$ and GPDs, which contain information on the hadron structure. The GPDs are estimated using the double distribution (DD) representation [?] that connect GPDs with PDFs with the help of DD integration that generates the skewness ξ dependence of GPDs.

The leading twist contributions to the Vector Meson Production (VMP) amplitude off spin non-flip and spin flip proton can be described in terms of various parton contributions

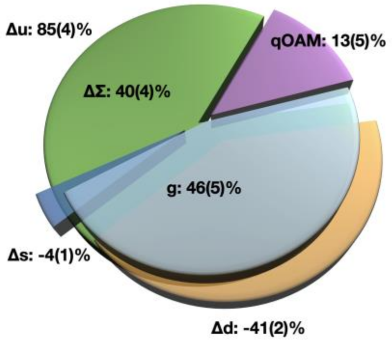
$$
\begin{aligned}
M_{\mu'+,\mu+} &= \langle H \rangle \propto \quad \int_{-1}^{1} dx \mathcal{H}^{a}_{\mu'+,\mu+} H^{a}(x,\xi,t) \\
M_{\mu'-,\mu+} &= \langle E \rangle \propto \frac{\sqrt{-t}}{2m} \int_{-1}^{1} dx \mathcal{H}'^{a}_{\mu'+,\mu+} E^{a}(x,\xi,t).
\end{aligned}
\tag{4}
$$

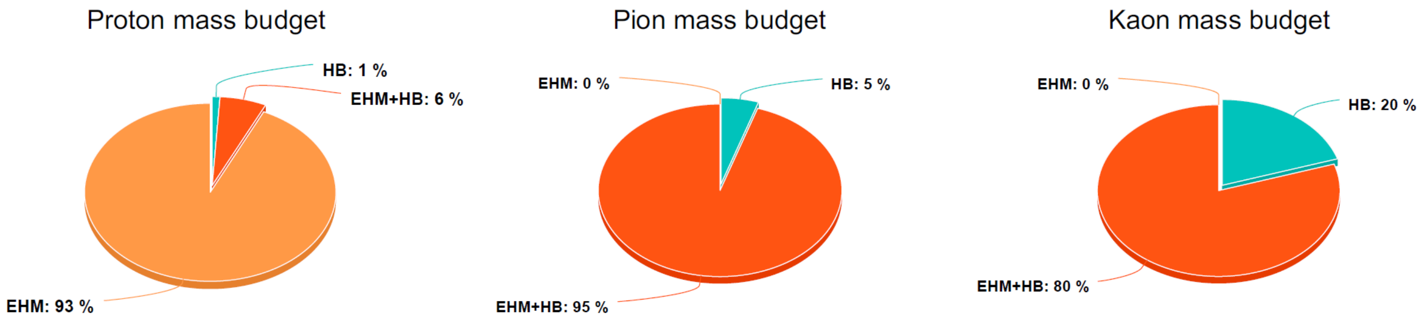
$$
\frac{d^2\sigma}{dt d\phi} = \frac{1}{2\pi}\left(\frac{d\sigma_T}{dt} + \epsilon\frac{d\sigma_L}{dt} + \epsilon\cos 2\phi\frac{d\sigma_{TT}}{dt} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi\frac{d\sigma_{LT}}{dt}\right)
$$

Introduction

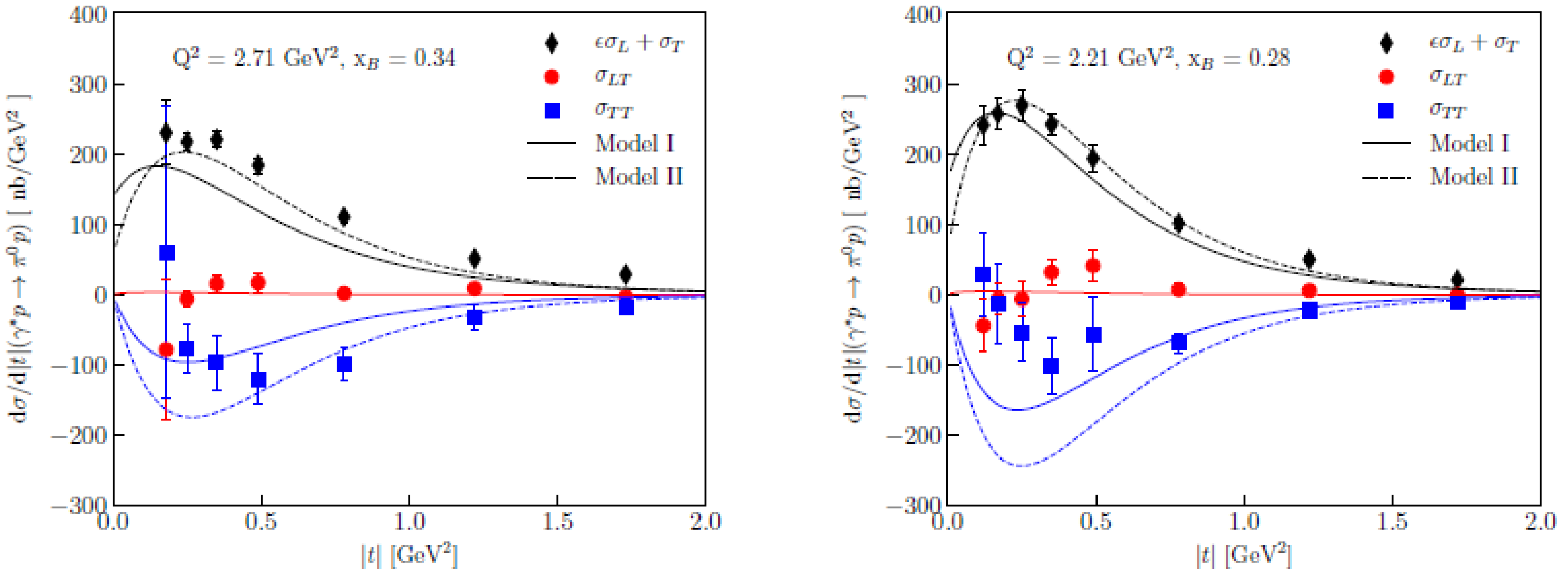
- **GPD: General Parton Distributions (trans. spatial position b$^{\perp}$ & longi. Momentum):**
- **TDA: Transition Distribution Amplitudes (nucleon-to-photon & nucleon-to-meson):**
- How does proton's spin influence the spatial distribution of partons?
- …… probed by the exclusive process

- **From 1D to 3D picture of hadron & meson**
- **Origin of the Proton/Meson mass & spin**



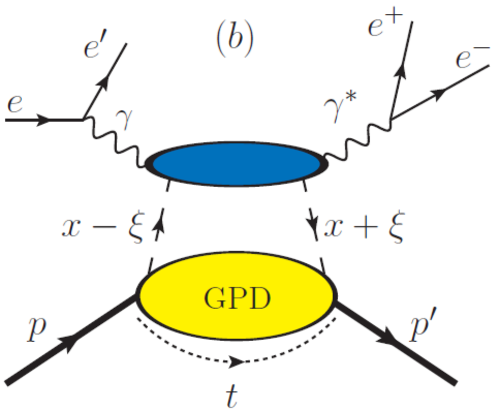


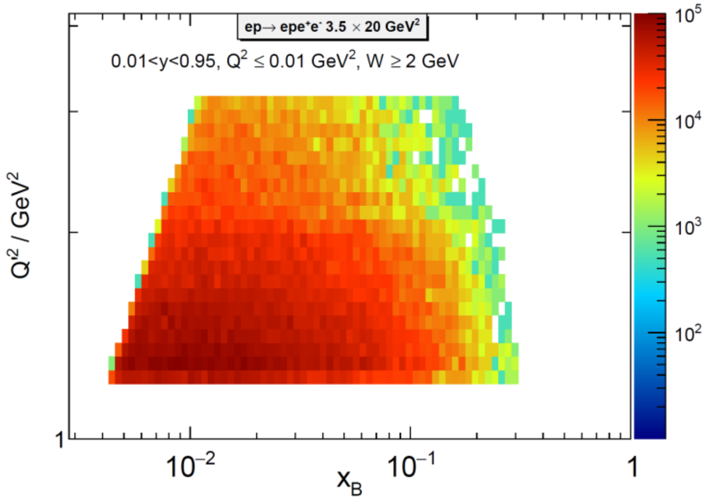
Exclusive Process II: DVMP



Exclusive Process II: TCS

- **3D structure of nucleon (GPDs) @ EicC**
- Preliminary simulation of timelike Compton Scattering, Detector efficiency is not implemented
- cross section 0.05nb (3 – 8% of DVCS)





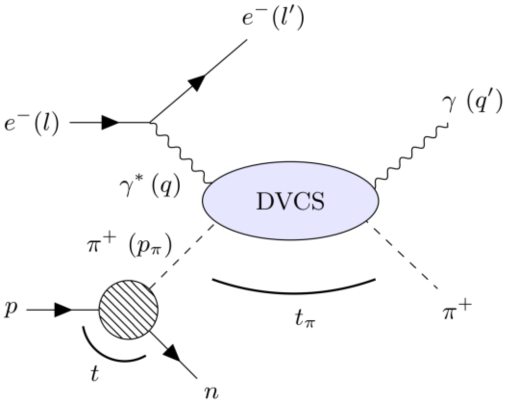
Included: BH + GPD

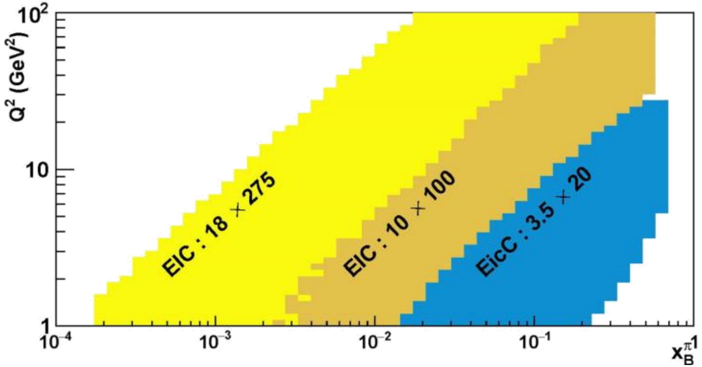
Not-included: vector meson electroproduction

- Quasi-Real photon!
- generated by EpIC, Eur. Phys. J. C (2022) 82:819

Exclusive Process VII

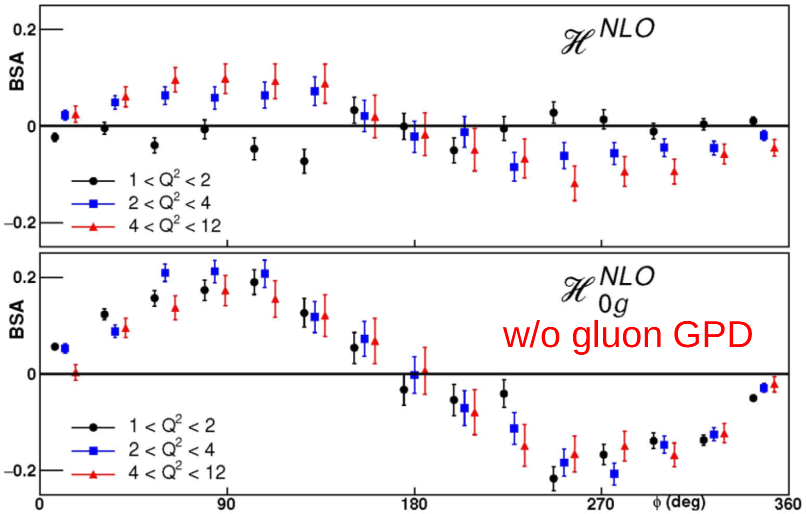
- **3D structure of pion (GPDs) @ EicC** (Phys.Rev.Lett. 128 (2022) 202501)
- π^+-DVCS through Sullivan process





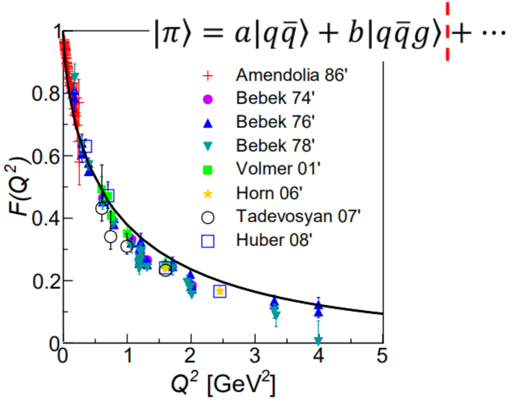
Relies on a state-of-the-art model of π^+-GPD

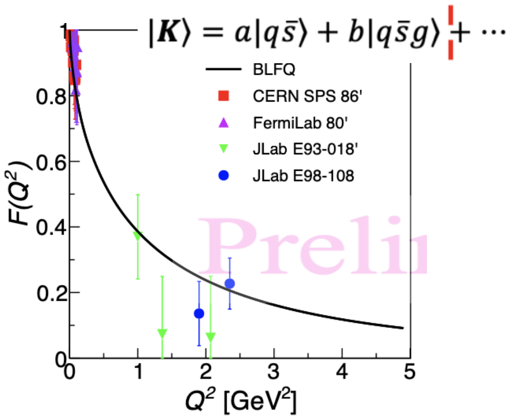
$$x_B^\pi \in [0.1; 0.5].$$



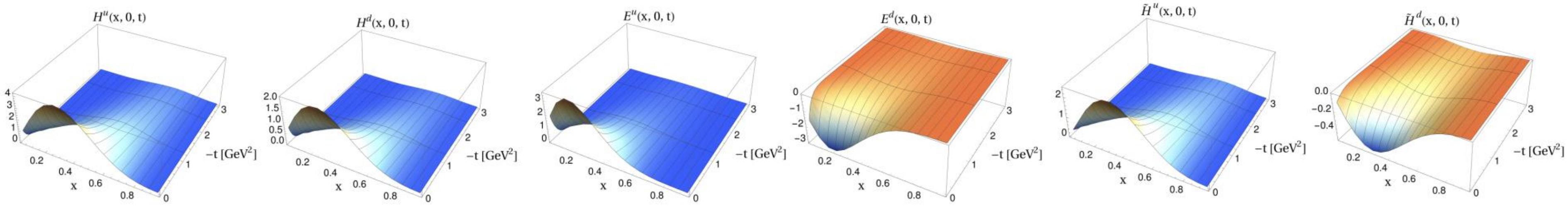
Theoretical tools II: BLFQ

- **Structure of pion/kaon (Elastic Form factors)** (from Jiangshan Lan, Xingbo zhao et al.)

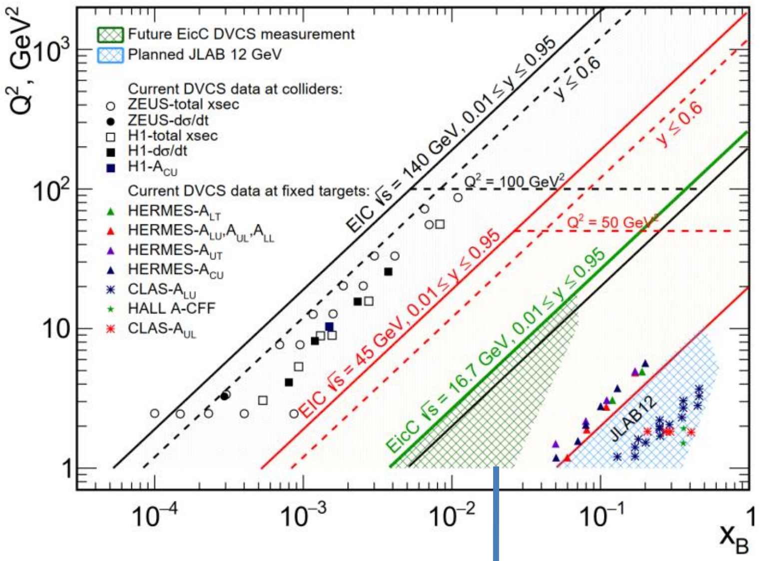


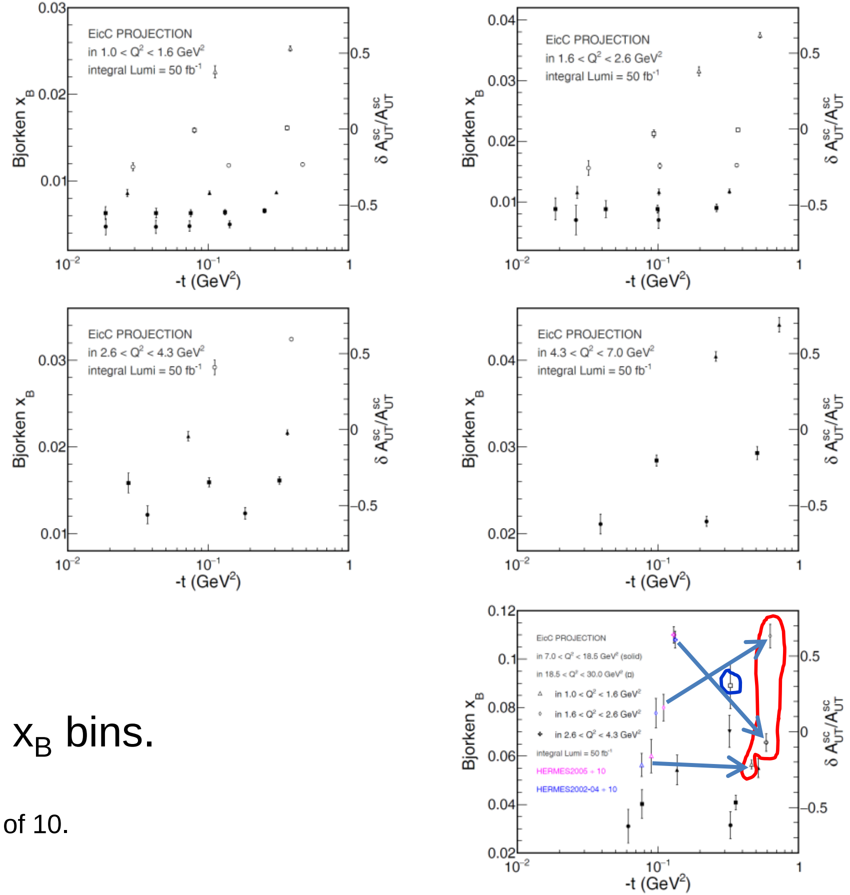


- **Nucleon GPDs** (from 2307.09869)



Projection Bins of DVCS@EicC



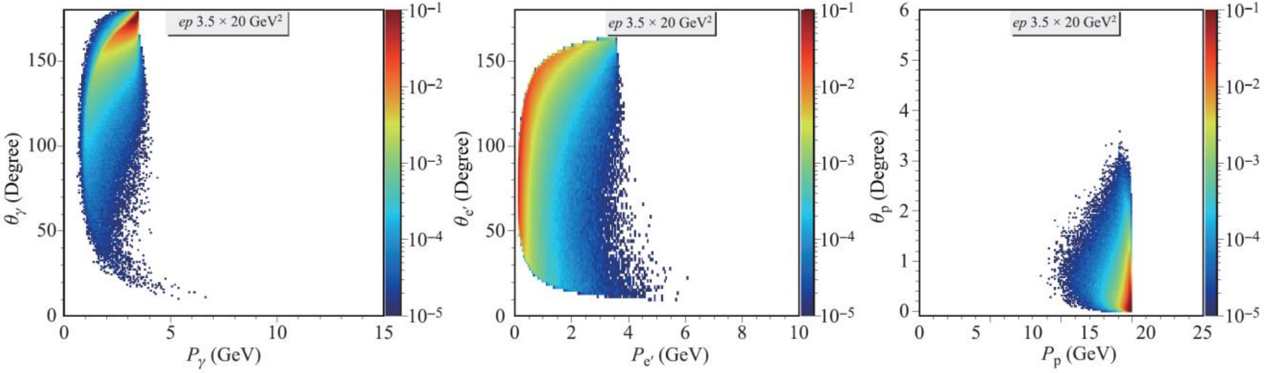


- A_{UT} with -t in all $1.0 < Q^2 < 30.0$ GeV^2 and x_B bins.
- HERMES data with the relative statistical errors divided by a factor of 10.

Exclusive Process

- 3D structure of nucleon (GPDs) @ EicC
- Pseudo-rapidity, azimuthal angle coverage and pt coverage?
- Any requirement on far-forward detector?

- large rapidity coverage, good high momentum resolution
- DVCS&DVMP Electron (Q^2 > 1.0 GeV^2, η > 2.0); TCS & hadron (Q^2 <1.0 GeV^2) need e-far-forward
- Proton: good far-forward detector; Photon: several to 15 GeV, 4π coverage

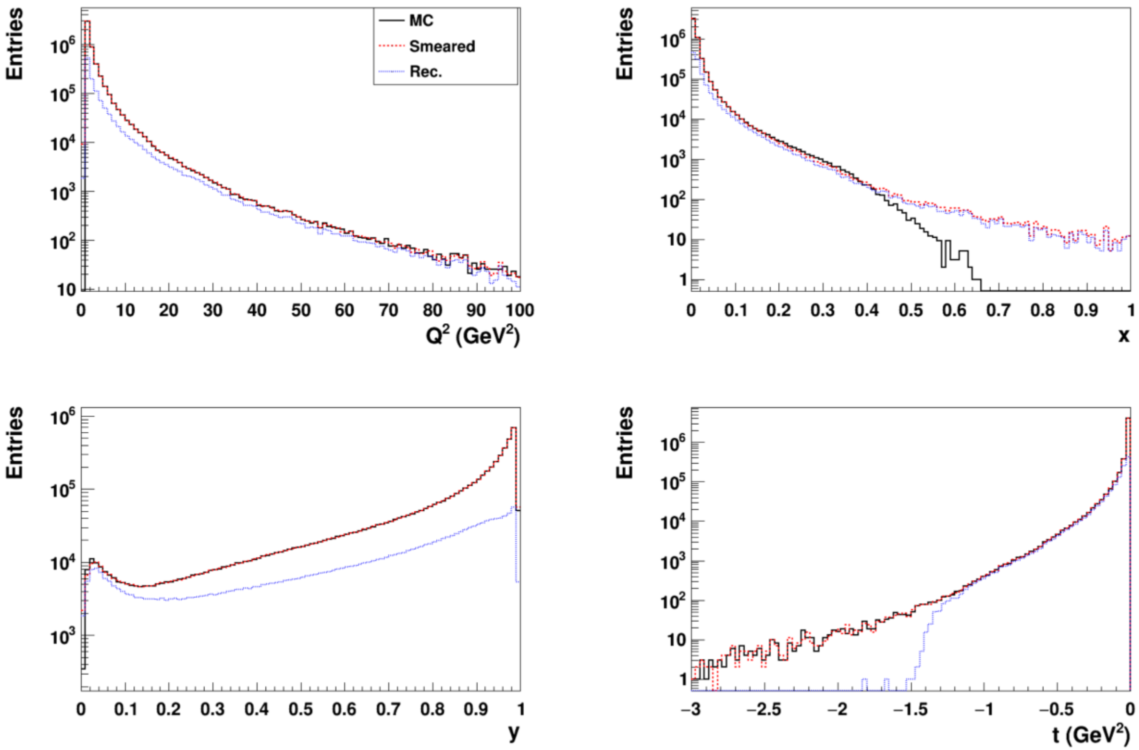


- >5mrad (previously 2mrad)

- π / K / η / η' / ω / φ separation: $\eta/\pi^0 \to \gamma\ \gamma$ required by DVMP and TDA physics

Exclusive Process

- **Detector efficiency**
- coutercy of detector group



Exclusive Process

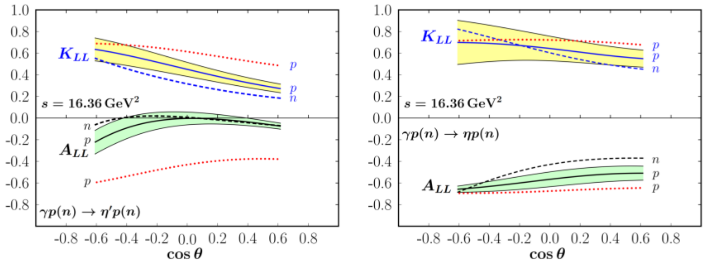
- **3D structure of nucleon (TDA)**
- *u*-channel meson production (Bill Wenliang@WM&JLab)

- Pseudo-rapidity, azimuthal angle coverage and pt coverage?
- outgoing scattered e': $0 < \eta < 3$; recoiled proton: $1.5 < \eta < 4$; π^0: $0 < \eta < 3.69$;
- Note: $\eta = 3.69$ is the far-forward region

- Momentum/Energy resolution?
- Energy resolution ($\sigma(\Delta E / E)$) in the far forward region and forward endcap: $0.02 + 0.077\sqrt{E}$ for photon. minimum requirement $0.35*\sqrt{0.35}$

- PID requirements?
- Any requirement on far-forward detector?
- Excellent forward γ/neutron separation
- Reconstruct photon energy.
- The forward acceptance: ±7mrad, >±5 mrad

Note (η' for glue, see 2111.08965):



Introduction

- e+p, e+d, e+^{3}He ……
- Effective tool for flavor separation

Particle	e	d	^{3}He^{++}	^{7}Li^{3+}	^{12}C^{6+}	^{40}Ca^{20+}	^{197}Au^{79+}	^{208}Pb^{82+}	^{238}U^{92+}
Kinetic energy (GeV/u)	3.5	12.00	16.30	10.16	12.00	12.00	9.46	9.28	9.09
Momentum (GeV/c/u)	3.5	12.90	17.21	11.05	12.90	12.90	10.35	10.17	9.98
Total energy (GeV/u)	3.5	12.93	17.23	11.09	12.93	12.93	10.39	10.21	10.02
CM energy (GeV/u)	–	13.48	15.55	12.48	13.48	13.48	12.09	11.98	11.87
$f_{\text{collision}}$ (MHz)	–	499.25	499.82	498.79	499.25	499.25	498.54	498.47	498.39
Polarization	80%	Yes	Yes	No	No	No	No	No	No
$B\rho$ (T·m)	11.67	86.00	86.00	86.00	86.00	86.00	86.00	86.00	86.00
Particles per bunch ($\times 10^9$)	40	6.1	3.0	2.04	1.00	0.30	0.07	0.065	0.055
$\varepsilon_x/\varepsilon_y$ (nm·rad, rms)	20	100/60	100/60	100/60	100/60	100/60	100/60	100/60	100/60
β_x^*/β_y^* (m)	0.2/0.06	0.04/0.02	0.04/0.02	0.04/0.02	0.04/0.02	0.04/0.02	0.04/0.02	0.04/0.02	0.04/0.02
Bunch length (m, rms)	0.01	0.015	0.015	0.02	0.015	0.015	0.02	0.02	0.02
Beam–beam parameter ξ_x/ξ_y	0.007	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Laslett tune shift	–	0.07	0.06	0.04	0.06	0.06	0.06	0.06	0.06
Current (A)	3.3	0.49	0.48	0.49	0.48	0.48	0.44	0.43	0.40
Crossing angle (mrad)					50				
Hourglass	–	0.94	0.94	0.92	0.94	0.94	0.92	0.92	0.92
Luminosity at nucleon level (cm^{-2}·s^{-1})	–	8.48×10^{32}	6.29×10^{32}	9.75×10^{32}	8.35×10^{32}	8.35×10^{32}	9.37×10^{32}	9.22×10^{32}	8.92×10^{32}

- The Luminosity is under optimization
- lever arm Q^2 > 30 GeV^2

Exclusive Process

- 3D structure of nucleon (GPDs)
- What is the flagship physics at EicC and the golden observables?
- Beam polarization requirement?

DVCS observables for Compton form factors (Leading Twist GPDs)

Lepton Beam Polarization	Nucleon Polarization: Un-Polarized (U)	Nucleon Polarization: Longitudinal Polarized (L)	Nucleon Polarization: Transversely Polarized (T)
U	Separates h.t. contributions to DVCS $\mathfrak{Re}\mathcal{T}^{DVCS}$	$\Delta\sigma_{UL} \sim \sin\phi$ $\mathrm{Im}\{F_1\tilde{\mathcal{H}}+\xi(F_1+F_2)(\mathcal{H}+x_B/2\,\mathcal{E})+...\}$ p $\mathfrak{Im}\tilde{\mathcal{H}}(x=\xi,\xi)$ n $\mathfrak{Im}\mathcal{H}(x=\xi,\xi)$	$\Delta\sigma_{UTy} \sim \cos\phi\ \sin(\phi_s-\phi)\{k[(2-x_B)F_1\mathcal{E} -4(1-x_B)/(2-x_B)F_2\mathcal{H})]+...\}$ p $\mathfrak{Im}\mathcal{E}(x=\xi,\xi)$ n $\mathfrak{Im}\mathcal{H}(x=\xi,\xi)$
L	$\Delta\sigma_{LU} \sim \sin\phi\ \mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}}+kF_2\mathcal{E}+...\}$ p $\mathfrak{Im}\mathcal{H}(x=\xi,\xi)$ n $\mathfrak{Im}\mathcal{E}(x=\xi,\xi)$	$\Delta\sigma_{LL} \sim (A+B\cos\phi)\ \mathrm{Re}\{F_1\tilde{\mathcal{H}} + \xi(F_1+F_2)(\mathcal{H}+x_B/2\ \mathcal{E})-\xi(x_B/2\ F_1+kF_2)\tilde{\mathcal{E}}\}$ p $\mathfrak{Re}\tilde{\mathcal{H}}(x,\xi)$ n $\mathfrak{Re}\mathcal{H}(x,\xi)$	$\Delta\sigma_{LTx} \sim (A+B\cos\phi)\ \mathrm{Re}\{k(F_2\mathcal{H} + F_1\mathcal{E})\}$ p $\mathfrak{Re}\mathcal{E}(x,\xi)$ n $\mathfrak{Re}\mathcal{H}(x,\xi)$

Ultimate Goal: impact of EicC on GPD of proton

- Flavor seperation? CFF , , , & , , ,

$$A_{LU,I}^{\sin\phi} \propto \mathrm{Im}\left[F_1\mathcal{H} + \xi(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4m^2}F_2\mathcal{E}\right],$$

$$A_{UL,I}^{\sin\phi} \propto \mathrm{Im}\left[\xi(F_1+F_2)(\mathcal{H} + \frac{\xi}{1+\xi}\mathcal{E}) + F_1\widetilde{\mathcal{H}} - \xi(\frac{\xi}{1+\xi}F_1 + \frac{t}{4M^2}F_2)\widetilde{\mathcal{E}}\right]$$

$$A_{LL,I}^{\cos\phi} \propto \mathrm{Re}\left[\xi(F_1+F_2)(\mathcal{H} + \frac{\xi}{1+\xi}\mathcal{E}) + F_1\widetilde{\mathcal{H}} - \xi(\frac{\xi}{1+\xi}F_1 + \frac{t}{4M^2}F_2)\widetilde{\mathcal{E}}\right]$$

$$A_{UT,I}^{\sin(\phi-\phi_s)\cos\phi} \propto \mathrm{Im}\Big[-\frac{t}{4M^2}(F_2\mathcal{H} - F_1\mathcal{E}) + \xi^2(F_1 + \frac{t}{4M^2}F_2)(\mathcal{H}+\mathcal{E}) - \xi^2(F_1+F_2)(\widetilde{\mathcal{H}} + \frac{t}{4M^2}\widetilde{\mathcal{E}})\Big],$$

$$A_{UT,I}^{\cos(\phi-\phi_s)\sin\phi} \propto \mathrm{Im}\,(F_2\widetilde{\mathcal{H}} - F_1\xi\widetilde{\mathcal{E}}),$$

$$A_{LT,I}^{\sin(\phi-\phi_s)\sin\phi} \propto \mathrm{Re}\,(F_2\mathcal{H} - F_1\mathcal{E}),$$

$$A_{LT,I}^{\cos(\phi-\phi_s)\cos\phi} \propto \mathrm{Re}\,(F_2\widetilde{\mathcal{H}} - F_1\xi\widetilde{\mathcal{E}}).$$

Ultimate Goal: impact of EicC on GPD of neutron

- Error propagation? CFF , , ˜, ˜ → GPD H, $\tilde{E}$, $\tilde{H}$, E

$$A_{LU,I}^{\sin\phi} \propto \mathrm{Im}\left[F_1\mathcal{H} + \xi(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4m^2}F_2\mathcal{E}\right],$$

$$A_{UL,I}^{\sin\phi} \propto \mathrm{Im}\left[\xi(F_1+F_2)(\mathcal{H}+\frac{\xi}{1+\xi}\mathcal{E}) + F_1\widetilde{\mathcal{H}} - \xi(\frac{\xi}{1+\xi}F_1+\frac{t}{4M^2}F_2)\widetilde{\mathcal{E}}\right]$$

$$A_{LL,I}^{\cos\phi} \propto \mathrm{Re}\left[\xi(F_1+F_2)(\mathcal{H}+\frac{\xi}{1+\xi}\mathcal{E}) + F_1\widetilde{\mathcal{H}} - \xi(\frac{\xi}{1+\xi}F_1+\frac{t}{4M^2}F_2)\widetilde{\mathcal{E}}\right]$$

$$A_{UT,I}^{\sin(\phi-\phi_s)\cos\phi} \propto \mathrm{Im}\Big[-\frac{t}{4M^2}(F_2\mathcal{H}-F_1\mathcal{E}) + \xi^2(F_1+\frac{t}{4M^2}F_2)(\mathcal{H}+\mathcal{E}) \\ -\xi^2(F_1+F_2)(\widetilde{\mathcal{H}}+\frac{t}{4M^2}\widetilde{\mathcal{E}})\Big],$$

$$A_{UT,I}^{\cos(\phi-\phi_s)\sin\phi} \propto \mathrm{Im}\left(F_2\widetilde{\mathcal{H}} - F_1\xi\widetilde{\mathcal{E}}\right),$$

$$A_{LT,I}^{\sin(\phi-\phi_s)\sin\phi} \propto \mathrm{Re}\left(F_2\mathcal{H} - F_1\mathcal{E}\right),$$

$$A_{LT,I}^{\cos(\phi-\phi_s)\cos\phi} \propto \mathrm{Re}\left(F_2\widetilde{\mathcal{H}} - F_1\xi\widetilde{\mathcal{E}}\right).$$