双光子过程中的高扭度运动学效应

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高扭度核子结构研讨会

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References:
C. Lorce, B. Pire and Qin-Tao Song, Phys. Rev. D106 (2022), 094030.
B. Pire and Qin-Tao Song, Phys. Rev. D 107 (2023), 114014.
B. Pire and Qin-Tao Song, arXiv:2311.06005 [hep-ph].

Generalized Parton distributions (GPDs)

GPDs can be accessed in Deeply Virtual Compton Scattering (DVCS).

GPDs

- Proton spin puzzle
- Energy momentum tensor (EMT) form factors of hadrons
- mass radius, mass distribution, pressure distribution and shear force distribution

Interesting, little known

↓

Recent Reviews:

M. V. Polyakov and P. Schweitzer, Int. J. Mod. Phys. A 33 (2018) no.26, 1830025.

V. D. Burkert, L. Elouadrhiri, F. Girod, C. Lorce, P. Schweitzer and P. Shanahan, arXiv:2303.08347, accepted by Rev. Mod. Phys.

EMT form factors and mass radius of pions?

The GPDs of pions cannot be accessed by DVCS, since there is currently no such a facility. $\gamma^* + \pi \to \gamma + \pi$

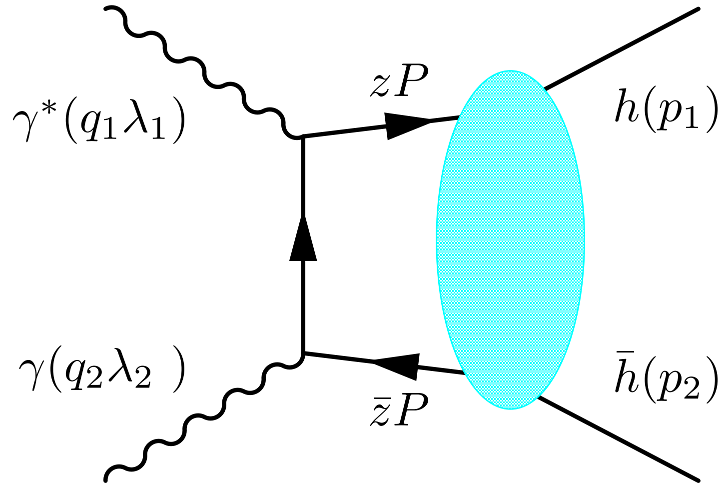
How to obtain EMT form factors of pions?

Option 1: Model calculations of EMT form factors.

Option 2: EMT form factors can be obtained from generalized distribution amplitudes (GDAs) of pions

M. Masuda et al. [Belle Collaboration], PRD 93 (2016), 032003.
S. Kumano, Qin-Tao Song and O. Teryaev, PRD **97** (2018) 014020.

GDAs in $\gamma^* + \gamma \to h + \bar{h}$:



Hard part: $\gamma^* + \gamma \to q + \bar{q}$
Soft part: $q + \bar{q} \to h + \bar{h}$, GDAs.

Quark GDA of a scalar meson is defined as:

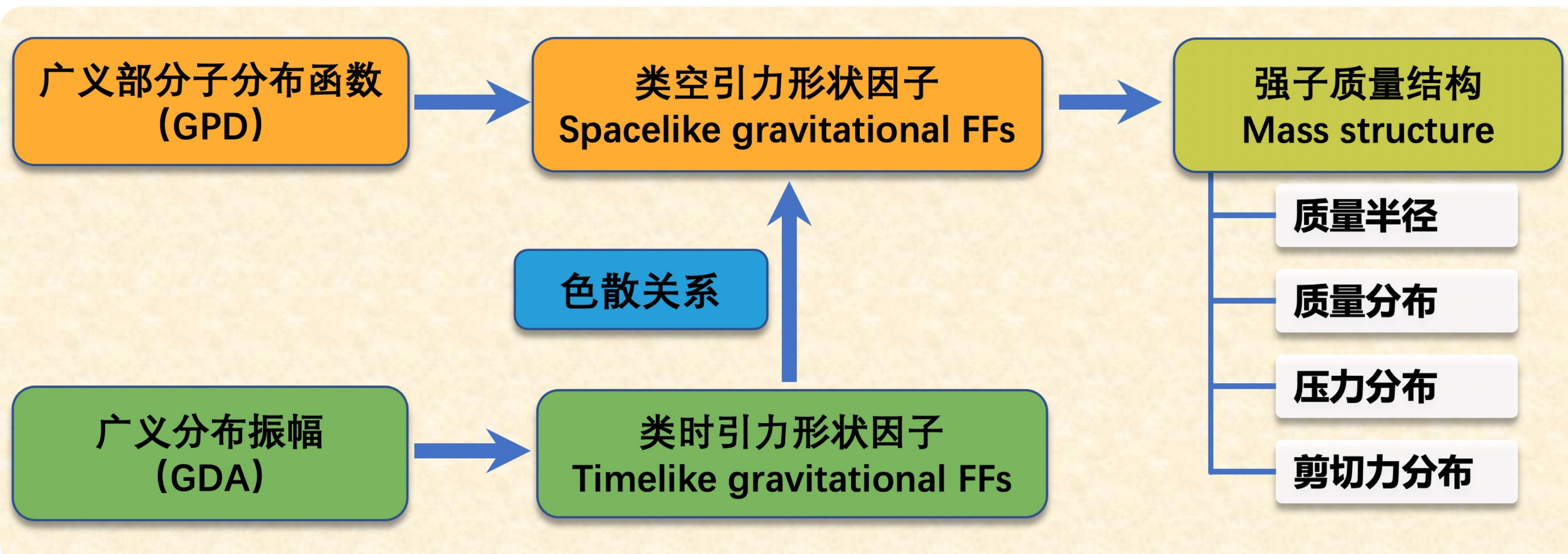
$$\Phi(z, \cos\theta, s) = \int \frac{dx^-}{2\pi} e^{-iP^+x^-} \langle h(p)\bar{h}(p')|\bar{q}(x^-)\gamma^- q(0)|0\rangle$$

M. Diehl, T. Gousset, B. Pire and O. Teryaev, PRL **81** (1998) 1782.
M. Diehl, T. Gousset and B. Pire, PRD **62** (2000) 07301.
M. V. Polyakov, NPB **555** (1999) 231.

Gluon GDA: J. P. Ma and J. S. Xu, PLB 510 (2001), 161-166

GDAs are also important inputs for decays of B mesons.

W. F. Wang, H. N. Li, W. Wang and C. D. Lu, PRD 91 (2015), 094024.
Y. Li, A. J. Ma, W. F. Wang and Z. J. Xiao, PRD 95 (2017), 056008.
M. K. Jia, C. Q. Zhang, J. M. Li and Z. Rui, PRD 104 (2021), 073001.



Recent progress on EMT form factors (incomplete)

Pressure distribution of proton:

V. D. Burkert, L. Elouadrhiri and F. X. Girod, Nature 557 (2018) 7705, 396.
Krešimir Kumerički, Nature 570 (2019) 7759, E1-E2.

C. Lorce, H. Moutarde and A. P. Trawinski, EPJC 79 (2019), 89.

P. E. Shanahan and W. Detmold, PRL 122 (2019), 072003.

EMT FFs of proton:

D. Chakrabarti *et.al*, PRD 102 (2020), 113011.

X. B. Tong, J. P. Ma and F. Yuan, JHEP 10 (2022), 046.

O. V. Selyugin and O. V. Teryaev, PRD 79 (2009), 033003.

Mass radius of proton:

R. Wang, W. Kou, C. Han, J. Evslin and X. Chen, PRD 104 (2021), 074033.

X. Y. Wang, F. Zeng and Q. Wang, PRD 105 (2022), 096033.

EMT FFs of pion meson:

S. Kumano, Qin-Tao Song and O. Teryaev, PRD 97 (2018), 014020.

A. Freese and I. C. Cloet, PRC 100 (2019), 015201.

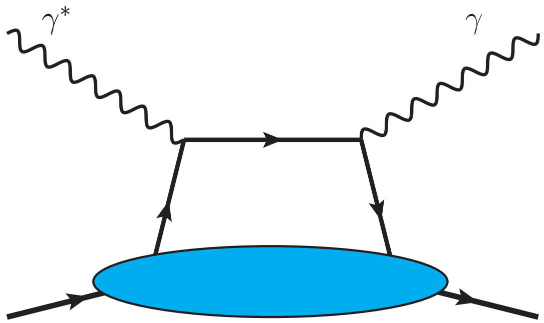
J. L. Zhang *et. al*., PLB 815 (2021), 136158.

EMT FFs of rho meson:

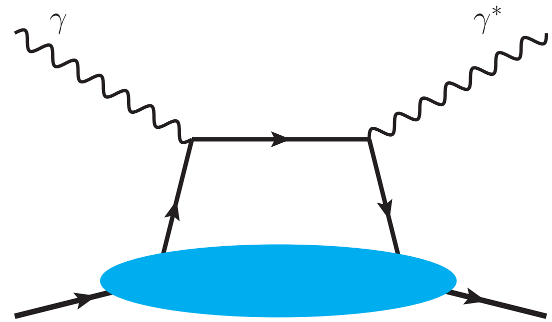
B. D. Sun and Y. B. Dong, PRD 101 (2020), 096008.

GPDs and GDAs are measured in two-photon reactions

GPDs:



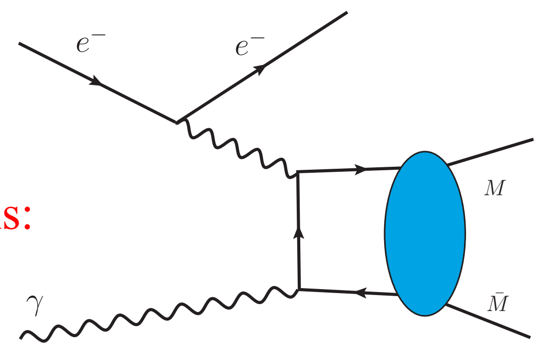
DVCS@JLAB, Compass,
EIC-US, EicC



Timelike Compton scattering(TCS)
@JLAB, EIC-US, EicC

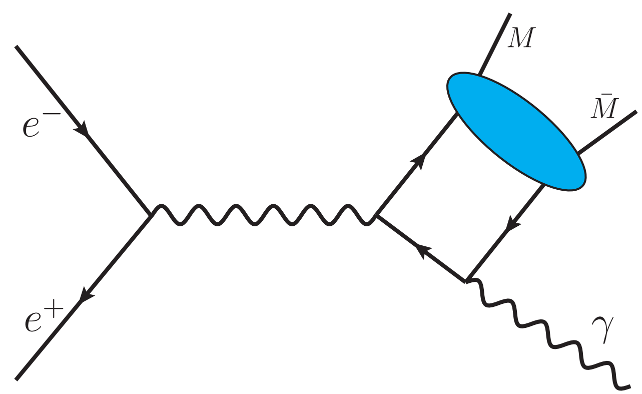
First measurement of TCS: PRL 127 (2021), 262501

GDAs:



$e^- + \gamma \to e^- + \mathrm{M} + \bar{\mathrm{M}}$
@Belle and Belle II

M. Masuda et al. [Belle], PRD 93 (2016), 032003.
M. Masuda et al. [Belle], PRD 97 (2018), 052003.

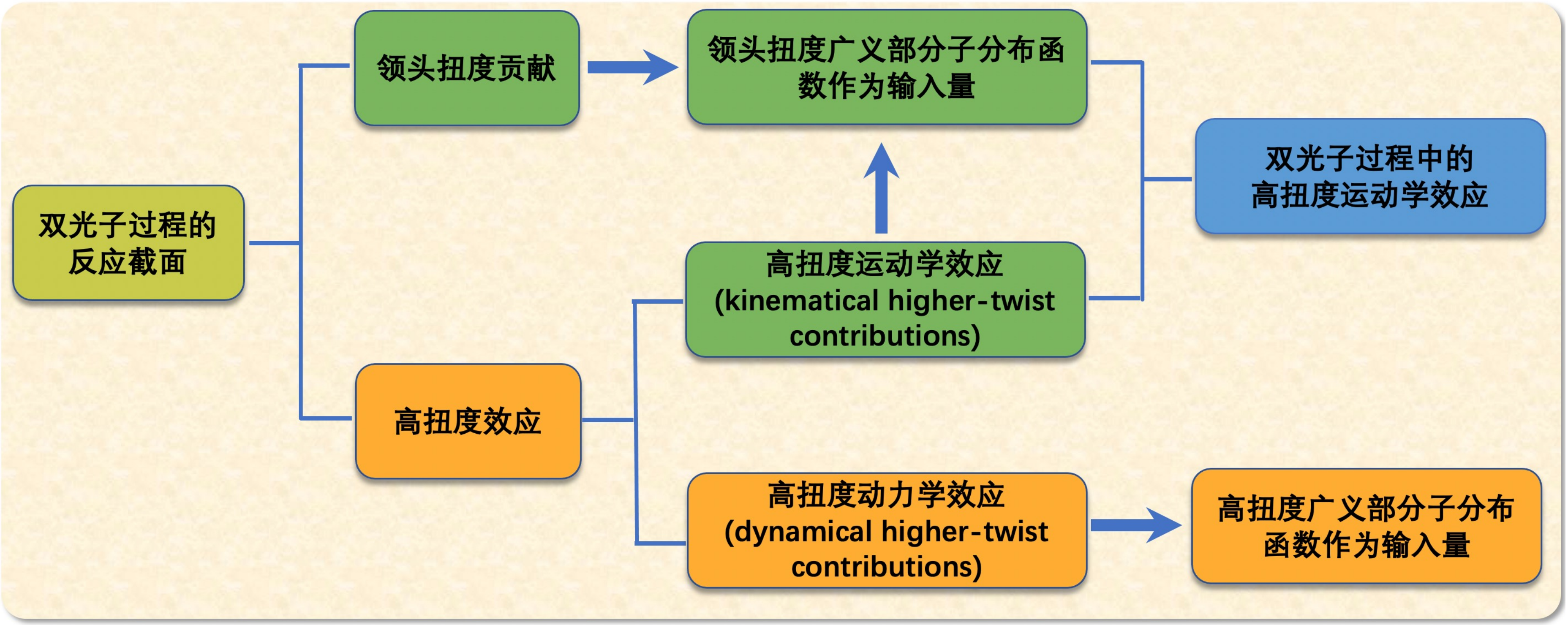


$\mathrm{e}^+\mathrm{e}^- \to \gamma^* \to \mathrm{M} + \bar{\mathrm{M}} + \gamma$@BESIII
@STCF

Higher-twist contributions of order s/Q^2 and m^2/Q^2 are important in the measurements.
Kinematical higher-twist corrections of the above reactions are discussed in this talk.

Kinematical higher-twist contributions

DVCS: $\gamma^* + h \to \gamma + h$



The kinematical higher-twist contributions can give a better description of experimental measurements without introducing genuine higher-twist GPDs.

Higher-order corrections of α_s also introduce new distributions (gluon GPDs).

Kinematical higher-twist contributions in DIS

Kinematical higher-twist contributions in DVCS can be considered as a general case of the target mass corrections in DIS, $\sim m^2/Q^2$.

Target masss corrections were already included when the parton distribution functions were extracted.

N. Sato et al. [Jefferson Lab Angular Momentum], PRD 93 (2016), 074005.

The total derivative of the leading twist operators contribute in DVCS.

$$\left[iP^{\mu}, \left[iP_{\mu}, \mathcal{O}^{t=2}\right]\right]$$

$$\left[iP^{\mu}, \frac{\partial}{\partial x^{\mu}}\mathcal{O}^{t=2}\right]$$

$$\xrightarrow{\text{DVCS}}$$

$\sim t/Q^2$, $\sim m^2/Q^2$ corrections

Twist-2 operator:

$$\mathcal{O}^{t=2}(z_1x, z_2x) = \frac{1}{2}[O_V(z_1x, z_2x) - O_V(z_2x, z_1x) - O_A(z_1x, z_2x) - O_A(z_2x, z_1x)]$$

In DIS, the matrix elements of total derivative operators vanish, only target mass corrections of m^2/Q^2 are available.

Kinematical higher-twist contributions in DVCS

Theory :

A separation of kinematical and dynamical contributions in the operator product of two electromagnetic currents was proven by Braun *et. al*.

V. M. Braun and A. N. Manashov, PRL 107(2011), 202001;JHEP 01 (2012), 085; PPNP 67 (2012), 162–167.

The kinematical corrections of order t/Q^2 and m^2/Q^2 were estimated for DVCS.

Scalar meson:

$\gamma^* + \pi \to \gamma + \pi$

V. M. Braun, A. N. Manashov, and B. Pirnay, PRD 86 (2012), 014003.

Proton case:

$\gamma^* + P \to \gamma + P$

V. M. Braun, A. N. Manashov, and B. Pirnay, PRL 109 (2012), 242001.
V. M. Braun, A. N. Manashov, D. Müller, and B. M. Pirnay, PRD 89 (2014), 074022.

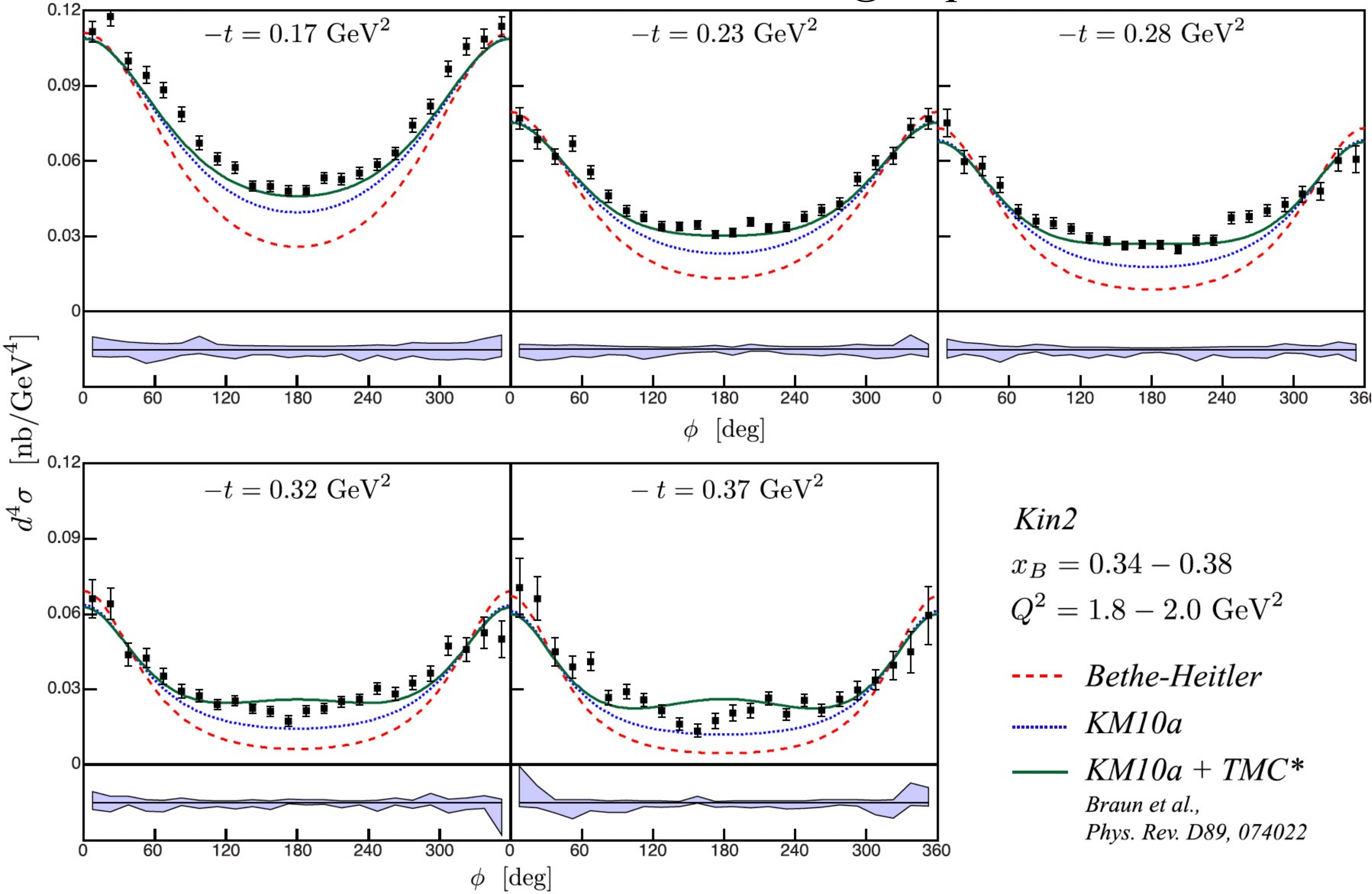
Experiment:

The kinematical corrections are included in recent experiment measurements.

DVCS measurements:

F. Georges et al. [Jefferson Lab Hall A], PRL. 128 (2022), 252002.
M. Defurne et al., Nature Communication 8(2017), 1408.
M. Defurne et al., Hall A collaboration, PRC92 (2015) no.5, 055202

Picture taken from slides of M. Defurne @3Dpartons 2022



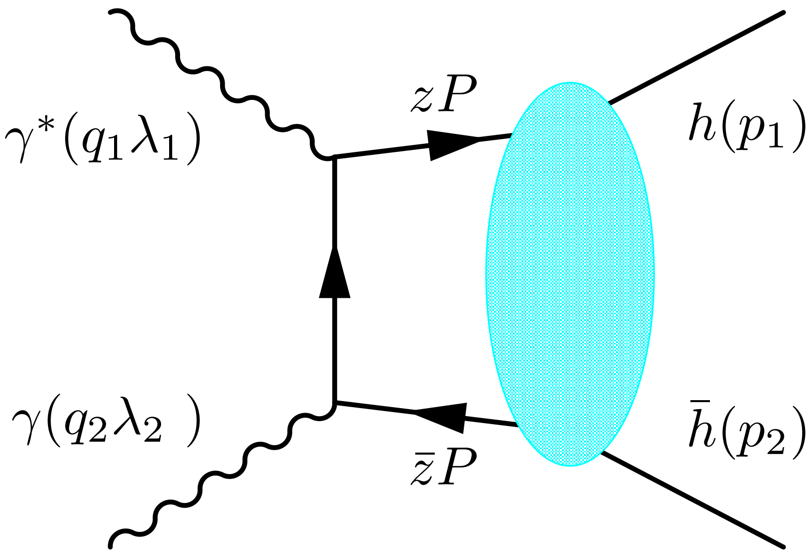
Kinematical power corrections seems to explain the gap.

Kinematical higher-twist corrections in $\gamma^* + \gamma \to \mathrm{M} + \bar{\mathrm{M}}$

Kinematical contributions in $\gamma^* + \gamma \to M + \bar{M}$

We can also calculte the amplitudes of $\gamma^* + \gamma \to M + \bar{M}$ by using the operator results of the kinematical contributions in two electromagnetic currents.

$$T_{\mu\nu} = \mathrm{T}\{j_\mu(z_1 x) j_\nu(z_2 x)\}$$



Helicity amplitudes of a scalar meson:

$$A_{\lambda_1\lambda_2} = T_{\mu\nu}\epsilon^{\mu}(\lambda_1)\epsilon^{\nu}(\lambda_2)$$

There are three independent helicity amplitudes: A_{++} ,A_{0+} and A_{+-}.

Leading twist amplitude: A_{++}
Higher twist amplitudes: A_{0+} and A_{+-}.

M. Diehl, T. Gousset, B. Pire and O. Teryaev, PRL **81** (1998) 1782.
M. Diehl, T. Gousset and B. Pire, PRD **62** (2000) 07301.
M. V. Polyakov, NPB **555** (1999) 231.

Helicity amplitudes (up to twist 4):

$$A^{(0)} = \chi\left\{\left(1-\frac{s}{2Q^2}\right)\int_0^1 dz\,\frac{\Phi(z,\eta,s)}{1-z} - \frac{s}{Q^2}\int_0^1 dz\,\frac{\Phi(z,\eta,s)}{z}\,\ln(1-z)\right.$$
$$\left. - \left(\frac{2s}{Q^2}\eta + \frac{\Delta_T^2}{\beta_0^2 Q^2}\frac{\partial}{\partial\eta}\right)\frac{\partial}{\partial\eta}\int_0^1 dz\,\frac{\Phi(z,\eta,s)}{z}\left[\frac{\ln(1-z)}{2} + \mathrm{Li}_2(1-z) - \mathrm{Li}_2(1)\right]\right\},$$

$$A^{(1)} = \frac{2\chi}{\beta_0 Q}\frac{\partial}{\partial\eta}\int_0^1 dz\,\Phi(z,\eta,s)\,\frac{\ln(1-z)}{z},$$

$$A^{(2)} = -\frac{2\chi}{\beta_0^2 Q^2}\frac{\partial^2}{\partial\eta^2}\int_0^1 dz\,\Phi(z,\eta,s)\,\frac{2z-1}{z}\,\ln(1-z),$$

$\eta = \cos\theta$

C. Lorce, B. Pire and Qin-Tao Song, PRD 106 (2022) , 094030

$A_{++} = A^{(0)}$

$A_{0+} = -A^{(1)}\Delta\cdot\epsilon^{\mu}(-) \longrightarrow \propto \Delta_T$

$A_{-+} = -A^{(2)}[\Delta\cdot\epsilon^{\mu}(-)]^2 \longrightarrow \propto (\Delta_T)^2$

Δ is the relative momentum of final meson pair.

Asymptotic form of pion GDAs:

$$\Phi(z,\cos\theta,s) = 18z(1-z)(2z-1)[\tilde{B}_{10}(s) + \tilde{B}_{12}(s)\,P_2(\cos\theta)]$$

The nonvanishing helicity-flip amplitudes A_{0+} and A_{+-} indicate the existence of the D-wave GDAs.

Numerical estimate of the cross section

$$\frac{d\sigma(e+\gamma \to e+M+\bar{M})}{dQ^2 ds d\cos\theta} = \frac{\alpha^3 \beta_0}{8 s_{e\gamma}^2} \frac{1}{Q^2(1-\varepsilon)} \left(|A_{++}|^2 + |A_{-+}|^2 + 2\varepsilon |A_{0+}|^2 \right)$$

M. Diehl, T. Gousset and B. Pire, PRD **62** (2000) 07301.

Three types of GDAs are employed to estimate the cross section

- π π GDA extracted from Belle measurements

S. Kumano, Qin-Tao Song and O. Teryaev, PRD **97** (2018) 014020.
M. Masuda et al. [Belle Collaboration], PRD 93 (2016), 032003.

- Asymptotic π π GDA

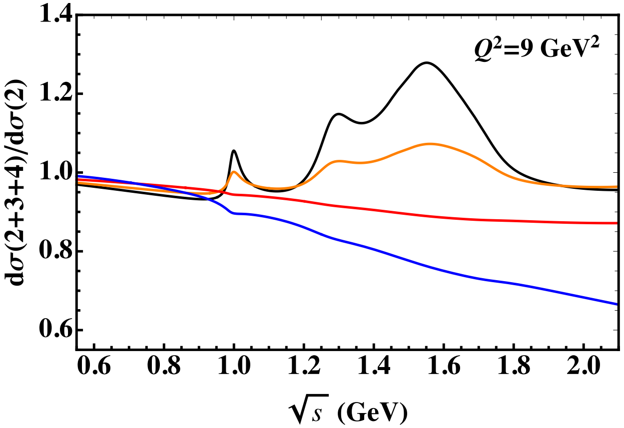
M. Diehl, T. Gousset and B. Pire, PRD **62** (2000) 07301.

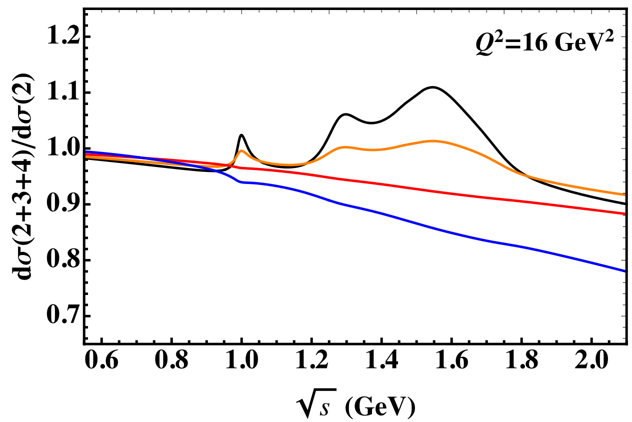
- Model for $\eta\ \eta$ GDA

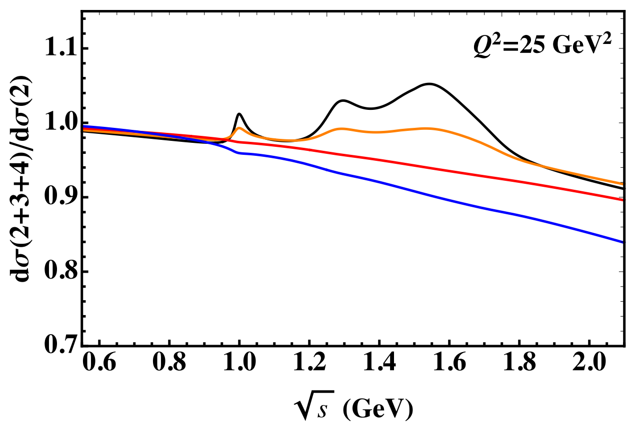
The range of kinematics in the following plots are same with that of Belle measurements.

Ratios are estimated with the asymptotic π π GDA

Ratio=(twist 2+twist 3+twist 4)/ twist 2







Both types of π π GDAs indicate that the higher-twist kinematical contributions cannot be neglected if s > 1 GeV^2

GDAs $\longrightarrow$ Timelike EMT form factors

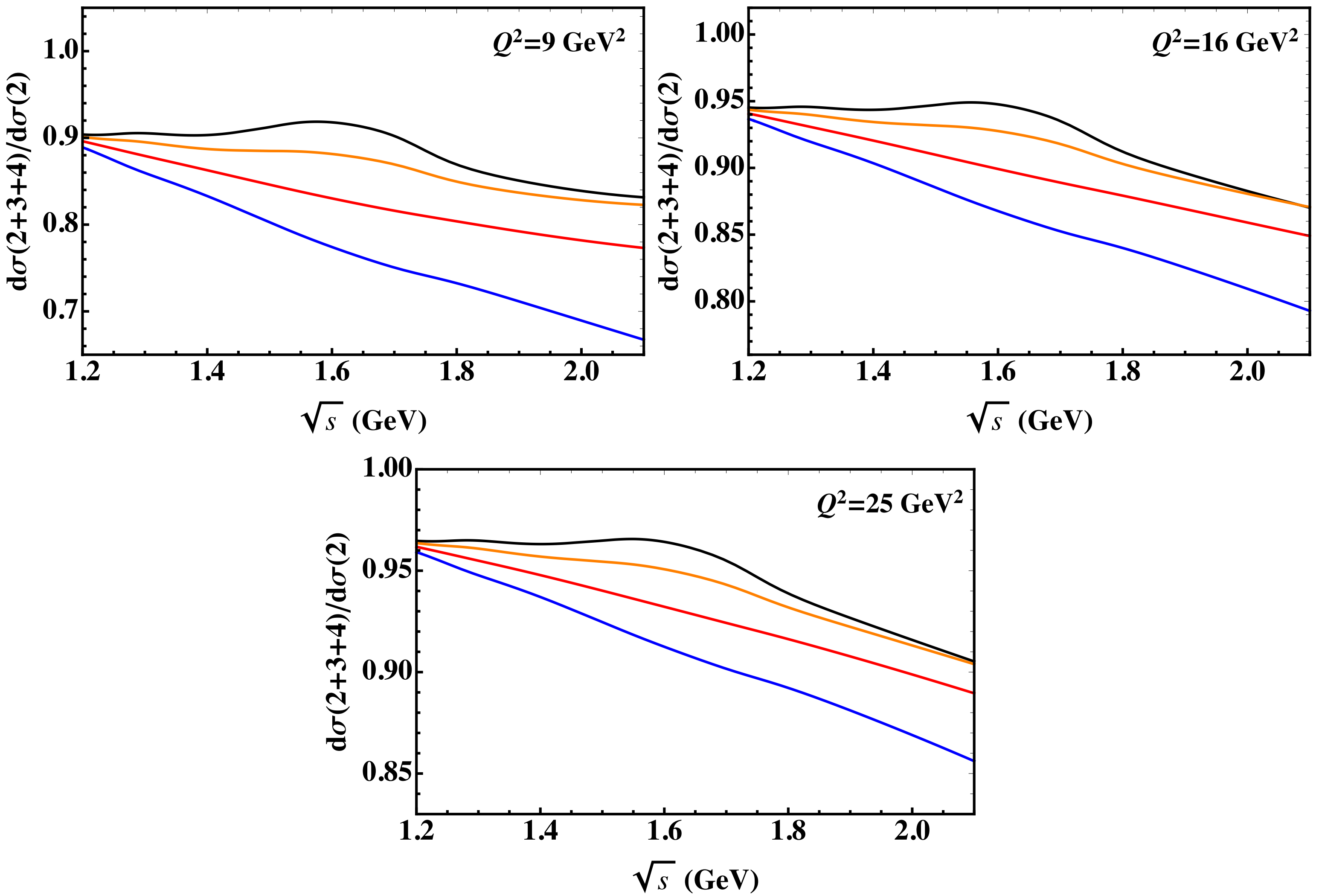
$\Lambda\ \geq 3\ \text{GeV}^2$ is necessary for pion EMT form factor, PRD 97 (2018) 014020.

Dispersion relation: Spacelike form factor t<0

$$F(t) = \int_{4m^2}^{\Lambda} \frac{ds}{\pi} \frac{\mathrm{Im}[F(s)]}{s - t - i\varepsilon}$$

Timelike form factor s>0

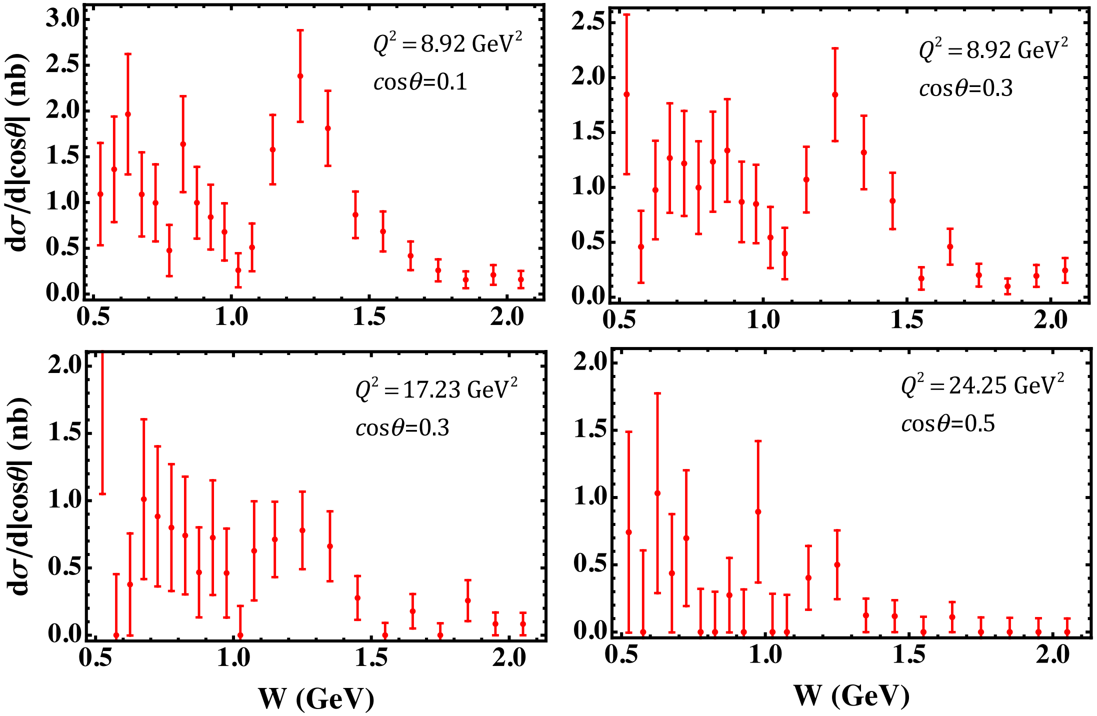
Ratios are estimated with the model for $\eta\,\eta$ GDA



The kinematical higher-twist contributions have a significant impact on the cross section even in the region which is close to the ηη threshold.

C. Lorce, B. Pire and Qin-Tao Song, PRD 106 (2022) , 094030

Experimental measurements of $\gamma^* + \gamma \to \mathrm{M} + \bar{\mathrm{M}}$ in future



Belle measurements on $\boldsymbol{\gamma}^*\boldsymbol{\gamma} \to \pi^0\pi^0$ in 2016

$$8\ \mathrm{GeV}^2 < Q^2 < 24\ \mathrm{GeV}^2$$
$$0.2\ \mathrm{GeV}^2 < s < 4\ \mathrm{GeV}^2$$

$\sim s/Q^2$, $\sim m^2/Q^2$
kinematical corrections

The errors are large, and statistical errors are dominant, however, this situation can be improved by Belle II.

Luminosity: $2\times 10^{34}\ \mathrm{cm}^{-2}s^{-1} \to 8\times 10^{35}\ \mathrm{cm}^{-2}s^{-1}$

A precise description of the cross section requires the inclusion of kinematical higher-twist contributions!

Previous measurements at Belle focused on EM FFs, however, the extraction of EMT FFs will be the main physical target for measurements of two-photon reactions at Belle II.

See talk of Dr. Masuda at Joint Meeting the APS and JPS 2023

Kinematical higher-twist corrections in $e^+e^- \to \gamma^* \to M + \bar{M} + \gamma$: neutral meson pair

Helicity amplitudes (up to twist 4):

The leading-twist amplitude: Z. Lu and I. Schmidt, PRD 73 (2006), 094021

Kinematical higher-twist helicity amplitudes: B. Pire and Q. T. Song, arXiv:2304.06389.

$$A^{(0)} = \chi \left\{ \left(1 + \frac{\hat{s}}{2s}\right) \int_0^1 dz \, \frac{\Phi(z,\eta,\hat{s})}{1-z} + \frac{\hat{s}}{s} \int_0^1 dz \, \frac{\Phi(z,\eta,\hat{s})}{z} \ln(1-z) \right.$$
$$\left. + \left(\frac{2\hat{s}}{s}\eta + \frac{\Delta_T^2}{\beta_0^2 s} \frac{\partial}{\partial \eta} \right) \frac{\partial}{\partial \eta} \int_0^1 dz \, \frac{\Phi(z,\eta,\hat{s})}{z} \left[\frac{\ln(1-z)}{2} + \mathrm{Li}_2(1-z) - \mathrm{Li}_2(1) \right] \right\},$$

$$A^{(1)} = -\frac{2\chi}{\beta_0 \sqrt{s}} \frac{\partial}{\partial \eta} \int_0^1 dz \, \Phi(z,\eta,\hat{s}) \, \frac{\ln(1-z)}{z},$$

$\eta = \cos\theta$

$$A^{(2)} = \frac{2\chi}{\beta_0^2 s} \frac{\partial^2}{\partial \eta^2} \int_0^1 dz \, \Phi(z,\eta,\hat{s}) \, \frac{2z-1}{z} \ln(1-z),$$

$$A_{++} = A^{(0)}$$
$$A_{0+} = -A^{(1)} \Delta \cdot \epsilon^{\mu}(-) \longrightarrow \propto \Delta_T$$
$$A_{-+} = -A^{(2)} [\Delta \cdot \epsilon^{\mu}(-)]^2 \longrightarrow \propto (\Delta_T)^2$$

Δ is the relative momentum of final meson pair.

Asymptotic form of pion GDAs:

$$\Phi(z, \cos\theta, s) = 18z(1-z)(2z-1)[\tilde{B}_{10}(s) + \tilde{B}_{12}(s) \, P_2(\cos\theta)]$$

Numerical estimate of the cross section

$$\frac{d\sigma(e^+ + e^- \to \mathrm{M} + \overline{\mathrm{M}} + \gamma)}{dW^2 du d\cos\theta} = \frac{\alpha^3 \beta_0}{8s^3} \frac{1}{(1+\varepsilon)} \left(|A_{++}|^2 + |A_{-+}|^2 + 2\varepsilon |A_{0+}|^2 \right)$$

M. Diehl, T. Gousset and B. Pire, PRD **62** (2000) 07301.

W is center-of-mass energy of meson pair

Three types of GDAs are employed to estimate the cross section

- π π GDA extracted from Belle measurements

S. Kumano, Qin-Tao Song and O. Teryaev, PRD **97** (2018) 014020.
M. Masuda et al. [Belle Collaboration], PRD 93 (2016), 032003.

- Asymptotic π π GDA

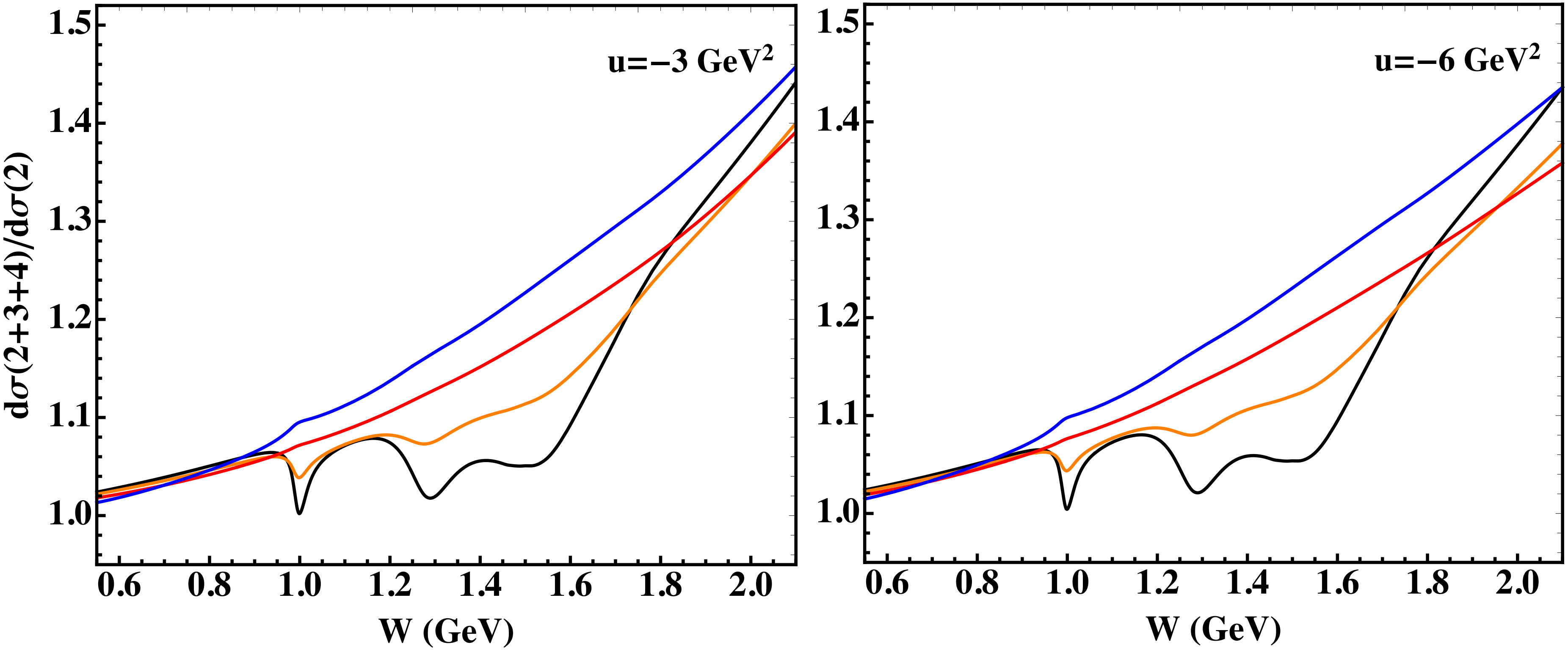
M. Diehl, T. Gousset and B. Pire, PRD **62** (2000) 07301.

- Model for $\eta\ \eta$ GDA

The range of kinematics in the following plots is chosen according to BESIII

Ratios are estimated with the asymptotic π π GDA

Ratio=(twist 2+twist 3+twist 4)/ twist 2



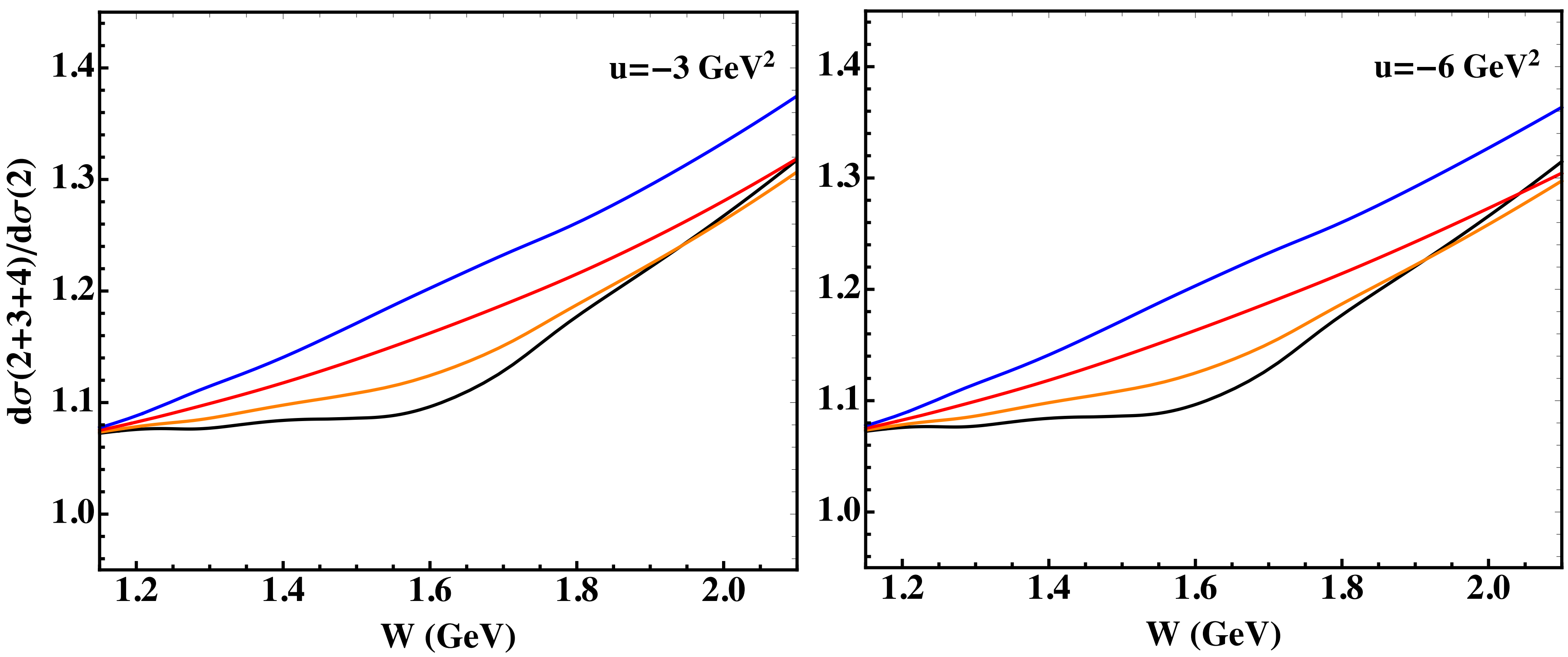
Both types of π π GDAs indicate that the higher-twist kinematical contributions cannot be neglected if W > 1 GeV.

GDAs ⟶ Timelike EMT form factors

Spacelike EMT form factors

Dispersion relation: the region of W > 1 GeV is necessary.

Ratios are estimated with the model for $\eta\,\eta$ GDA



The kinematical higher-twist contributions increase as W goes up.

B. Pire and Q. T. Song, PRD 107 (2023), 114014.

Kinematical higher-twist corrections in $e^+e^- \to \gamma^* \to M_1 + M_2 + \gamma$ and $e + \gamma \to e + M_1 + M_2$

Exotic hybrid mesons and shear viscosity

M_1M_2: $\pi\eta, \pi\eta'$

Search for the candidates of the isovector hybrid mesons in the P-wave of M_1M_2.
$I^G(J^{PC}) = 1^-(1^{-+})$
for example $\pi_1(1400), \pi_2(1600)$ and $\pi_1(2015)$

M_1M_2: $\eta\eta'$

Isocalar hybrid mesons
$I^G(J^{PC}) = 0^+(1^{-+})$
$\eta_1(1855)$

$\eta_1(1855)$ was observed by BESIII in $J/\psi \to \eta + \eta' + \gamma$ recently.

M. Ablikim et al. [BESIII], PRL 129 (2022), 192002.
M. Ablikim et al. [BESIII], PRD 106 (2022), 072012.

$J/\psi \to \gamma^*$: $\gamma^* \to \eta + \eta' + \gamma$ can be also measured by BESIII.

If the hybrid mesons are observed in $\gamma^* \to M_1 + M_2 + \gamma$ and $\gamma^* + \gamma \to M_1 + M_2$, it will indicate the existence of a new EMT FF.

$$\langle M_2(p_2)M_1(p_1)|T_q^{\mu\nu}|0\rangle \sim E_q(s)P^\mu\Delta^\nu$$

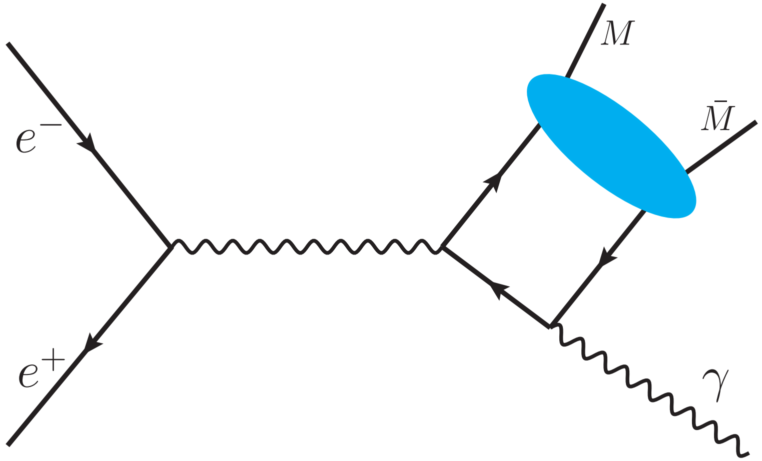
shear viscosity

O. Teryaev, JPS Conf. Proc. 37(2022), 020406.

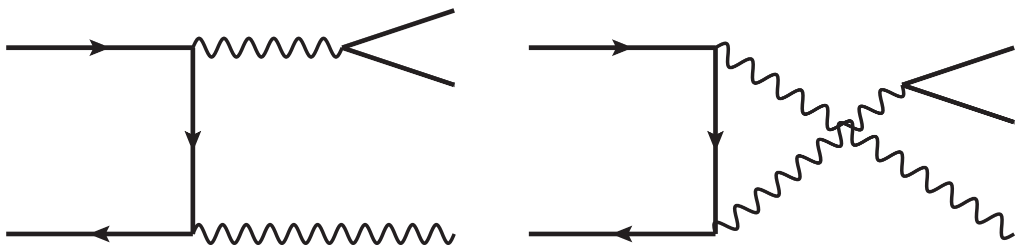
Its sum over quarks and gluons should be zero which is a consequence of the conserved EMT, however, it will exist for a single flavor q on condition that there is P-wave GDA

Kinematical higher-twist corrections in $e^+e^- \to M + \overline{M} + \gamma$: charged meson pair

Charged meson pair: $\pi^+\pi^-$ and K^+K^-



GDA process
C even meson pair



ISR process
C odd pair

Three types of contribution in the cross section

Interference term

$$d\sigma_{\mathrm{G}} : d\sigma_{\mathrm{I}} : d\sigma_{\mathrm{ISR}} \sim \hat{s} : \sqrt{\hat{s}s} : s$$

GDA process, same as neutral meson pair

ISR process, largest, no GDA

Advantages of interference term in charged meson production

- Larger cross section

- Extraction of the complete information of GDAs

$$d\sigma_{\mathrm{I}} \propto \mathrm{Re}(A_{ij} F_M^*(\hat{s}))$$

$$d\sigma_{\mathrm{G}} \propto \mathrm{Re}(A_{ij} A_{kl}^*) \quad \longrightarrow$$

Imaginary phases of GDAs cannot be extracted.

$$\frac{d\sigma_{\mathrm{I}}}{d\hat{s}\, du\, d(\cos\theta)\, d\varphi} = \frac{\alpha_{\mathrm{em}}^3 \beta_0}{8\pi s^2} \frac{\sqrt{2}\beta_0}{\sqrt{\hat{s} s \epsilon (1+\epsilon)}} \left[C_0 + C_1 \cos\varphi + C_2 \cos(2\varphi) + C_3 \cos(3\varphi)\right]$$

$$C_0 = -\,\mathrm{sgn}(\rho)\, \sqrt{\epsilon(1-\epsilon)}\sqrt{2x(x-1)}\mathrm{Re}(A_{++}F_M^*)\cos\theta + \mathrm{sgn}(\rho)\,(x-1)\sqrt{\epsilon(1-\epsilon)}\mathrm{Re}(A_{0+}F_M^*)\sin\theta,$$

$$C_1 = -\,[1-(1-x)(1-\epsilon)]\,\mathrm{Re}(A_{++}F_M^*)\sin\theta + 2\epsilon\sqrt{2x(x-1)}\mathrm{Re}(A_{0+}F_M^*)\cos\theta + (x-1)\mathrm{Re}(A_{-+}F_M^*)\sin\theta,$$

$$C_2 = \mathrm{sgn}(\rho)\, \sqrt{\epsilon(1-\epsilon)}x\mathrm{Re}(A_{0+}F_M^*)\sin\theta + \mathrm{sgn}(\rho)\, \sqrt{\epsilon(1-\epsilon)}\sqrt{2x(x-1)}\mathrm{Re}(A_{-+}F_M^*)\cos\theta,$$

$$C_3 = -\,\epsilon x \mathrm{Re}(A_{-+}F_M^*)\sin\theta.$$

B. Pire and Qin-Tao Song, arXiv:2311.06005 [hep-ph].

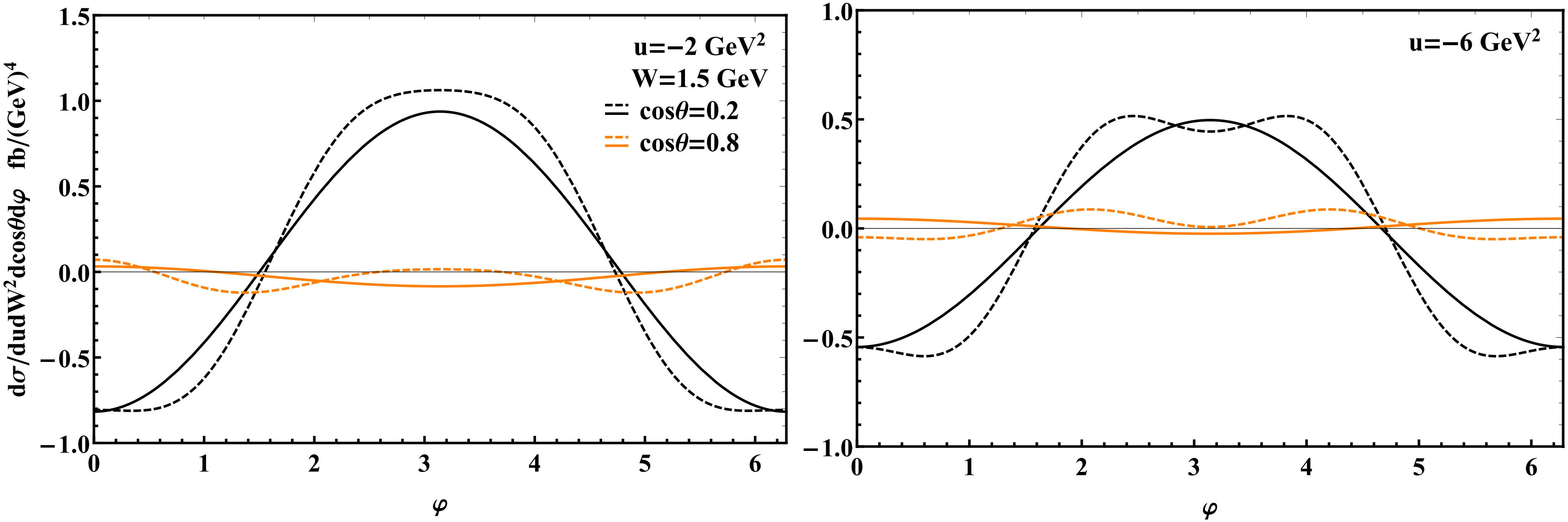
Only the interference term remains the same if one interchanges meson pair

$$d\sigma(M\bar{M}) - d\sigma(\bar{M}M) = 2d\sigma_{\mathrm{I}}$$

BaBar measurement of pion meson pair : PRD 92 (2015), 072015.

Numerical estimate of interference term

The dashed curves denote the twist-2 cross sections, and the solid ones include the kinematical higher-twist contributions, s=12 GeV^2 for BESIII.

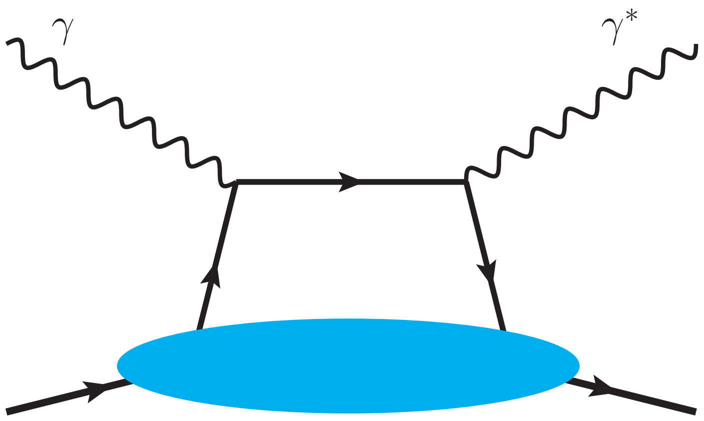


The higher-twist kinematical contributions cannot be neglected.

B. Pire and Qin-Tao Song, arXiv:2311.06005 [hep-ph].

Future plan on kinematical higher-twist corrections

(1) Timelike Compton scattering(TCS) for proton
@JLAB, EIC-US, EicC



TCS is one of three golden channels to access GPDs by experiment.

First measurement of TCS in 2021:

PRL 127 (2021), 262501

(2) DVCS for deuteron
@JLAB, EIC-US, EicC

There are eight leading-twist GPDs for spin-1 hadrons, hard work!

Summary

- GDAs can be considered as an alternative way to investigate the EMT form factors of pions.

- Kinematical higher-twist contributions are calculated for $\gamma^* + \gamma \to \mathrm{M} + \bar{\mathrm{M}}$ and $\gamma^* \to \mathrm{M} + \bar{\mathrm{M}} + \gamma$ from which the GDAs can be extracted. The numerical calculation indicates that kinematical contributions are significant for Belle (II) and BESIII (STCF).

- The measurements of $\gamma^* \to \mathrm{M} + \bar{\mathrm{M}} + \gamma$ at BESIII (STCF) can be a new research direction.

- In future, one can search for exotic hybrid mesons and study the new EMT FF (shear viscosity) in $\gamma^* \to M_1 + M_2 + \gamma$ and $\gamma^* + \gamma \to M_1 + M_2$.

- Kinematical higher-twist contributions for deuteron DVCS and proton TCS are in progress, which can be measured at EIC-US and EicC.

Thank you very much