Seminar

Northcarolina State University
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BSA of VMP
in (3+1) scalar field model

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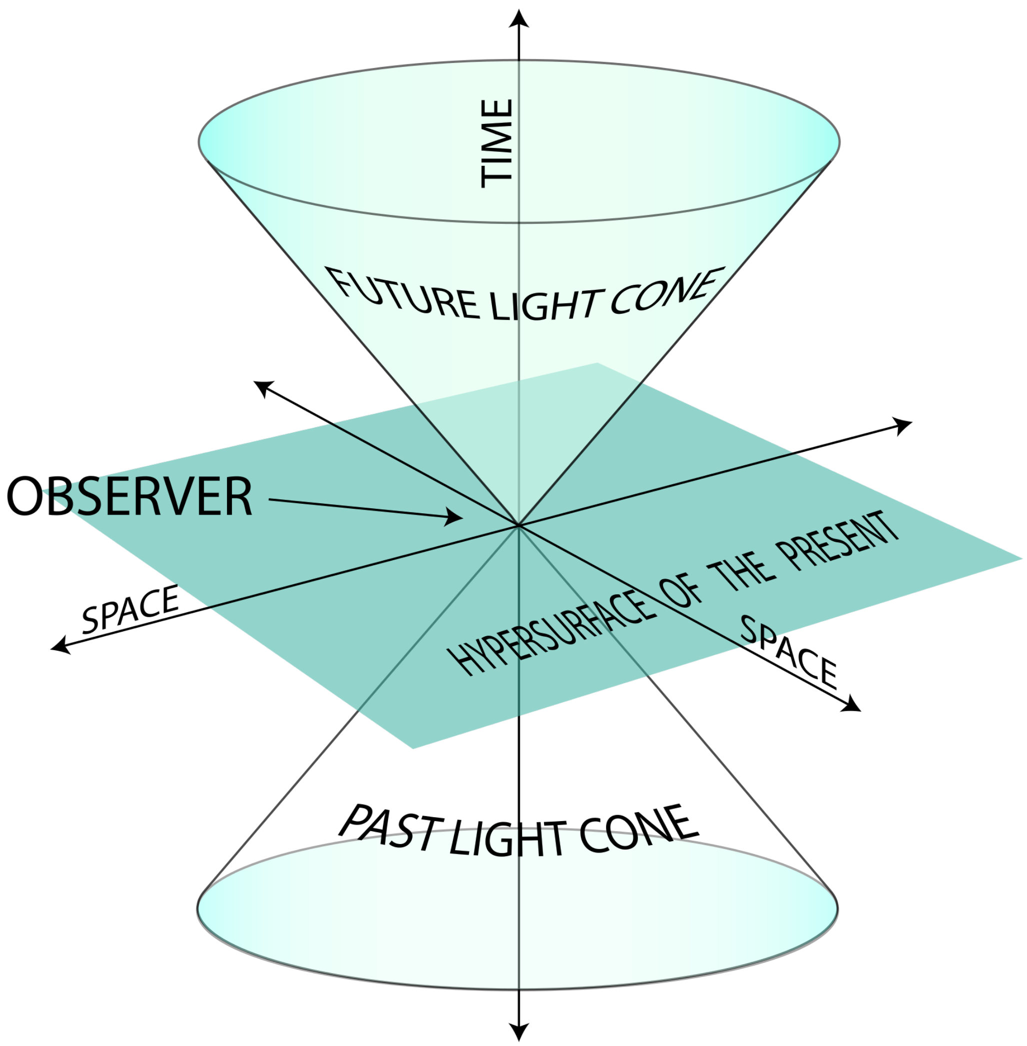


I. Aim of this work

II. One-Loop Scalar Model

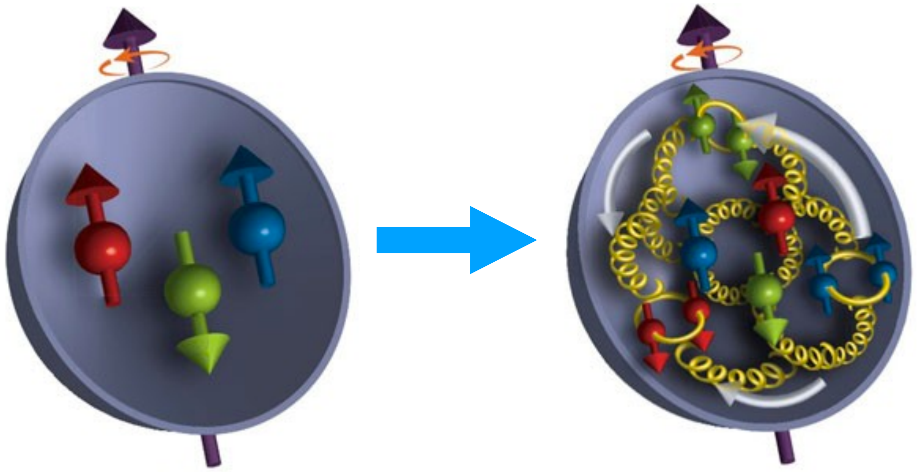
III. Deeply Virtual Limit

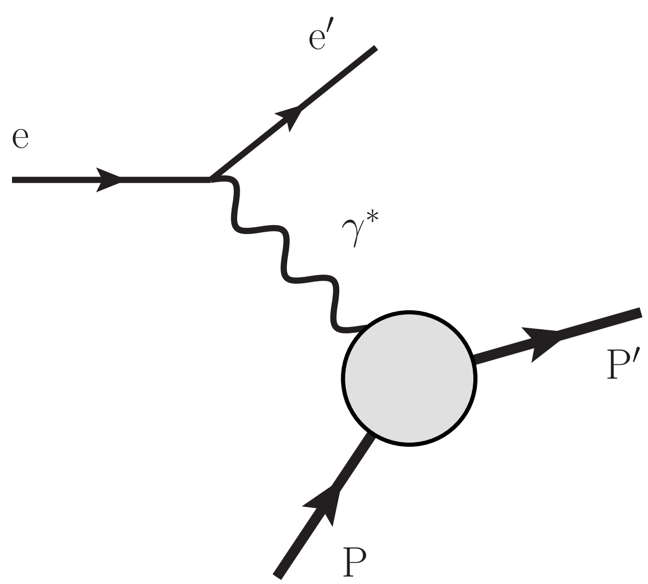
IV. Compare Two Model

I. Aim of this work

Hadron Structure

Hadron (meson and baryon) is a composite system made of **quarks**, **anti-quarks**, and **gluons**, held together by **non-perturbative QCD interaction**.

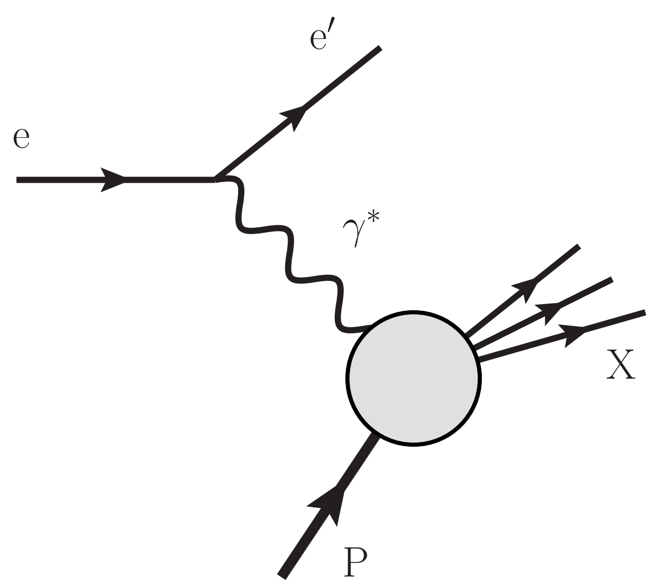




Elastic scattering

Density

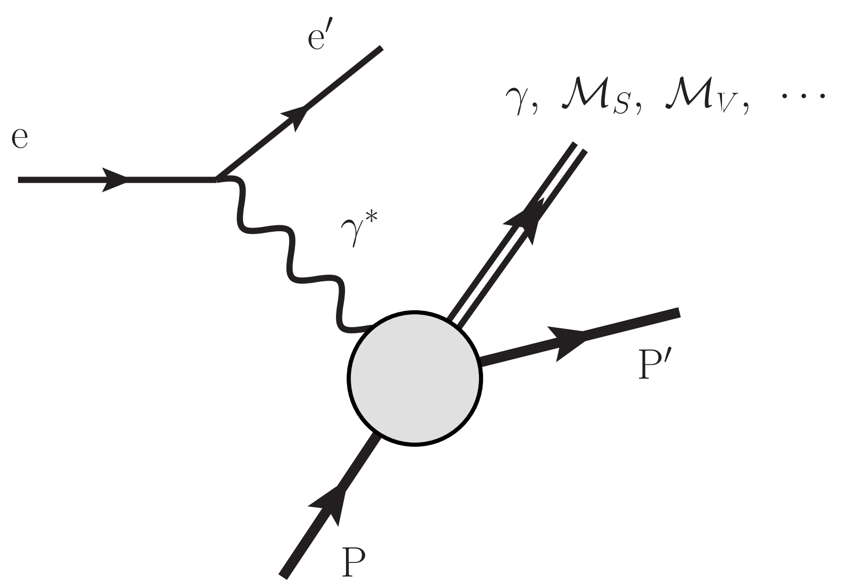
$$\langle P' | \bar{\psi}(0)\ \hat{\mathcal{O}}\ \psi(0) | P \rangle$$



Inclusive / Inelastic

Momentum

$$\langle P | \bar{\psi}(0)\ \hat{\mathcal{O}}\ \psi(y) | P \rangle$$



Exclusive / Inelastic

Angular momentum

$$\langle P' | \bar{\psi}(0)\ \hat{\mathcal{O}}\ \psi(y) | P \rangle$$

One-loop scalar model and deeply virtual limit

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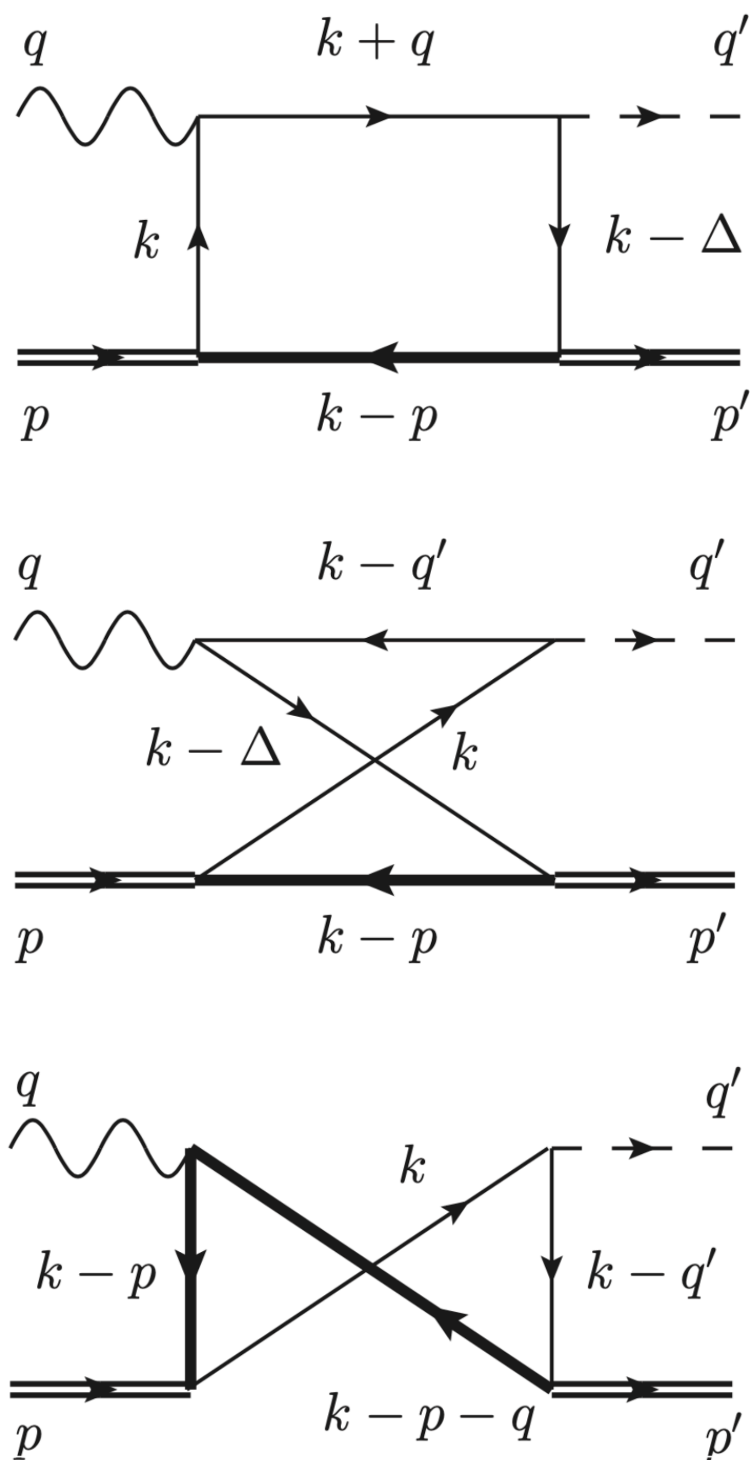
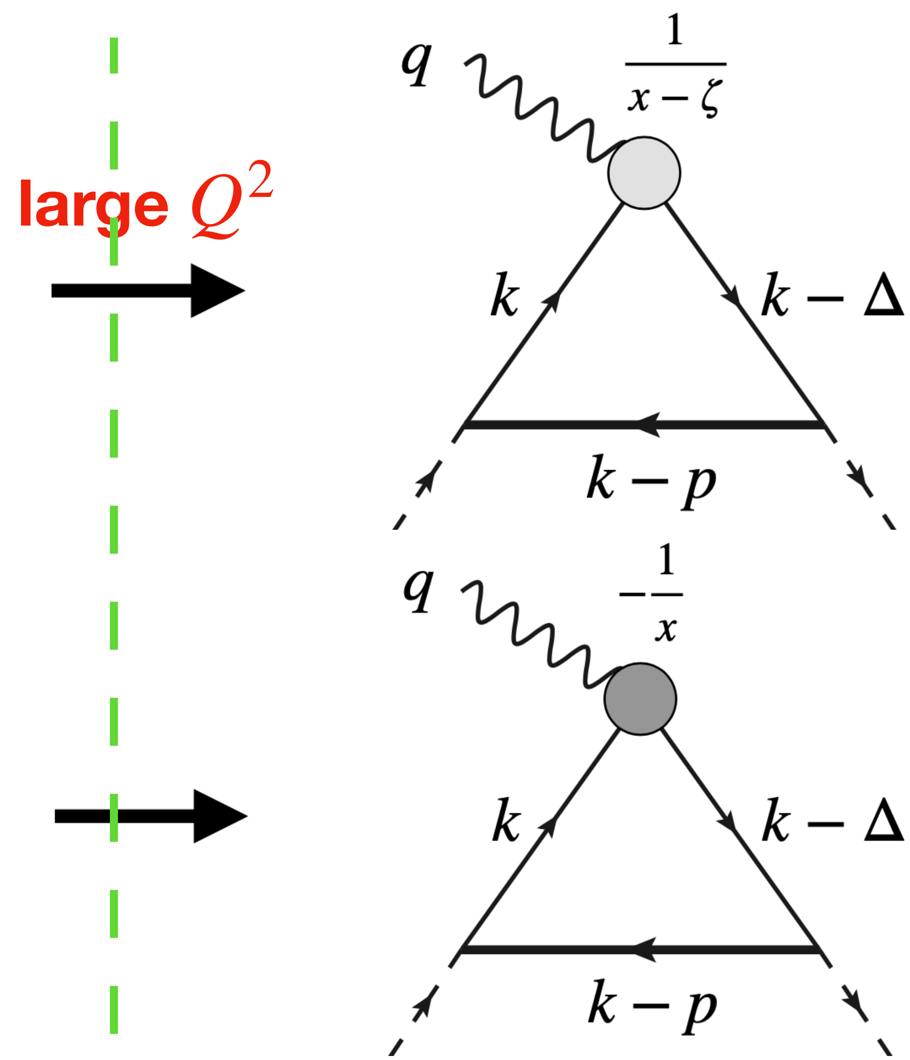
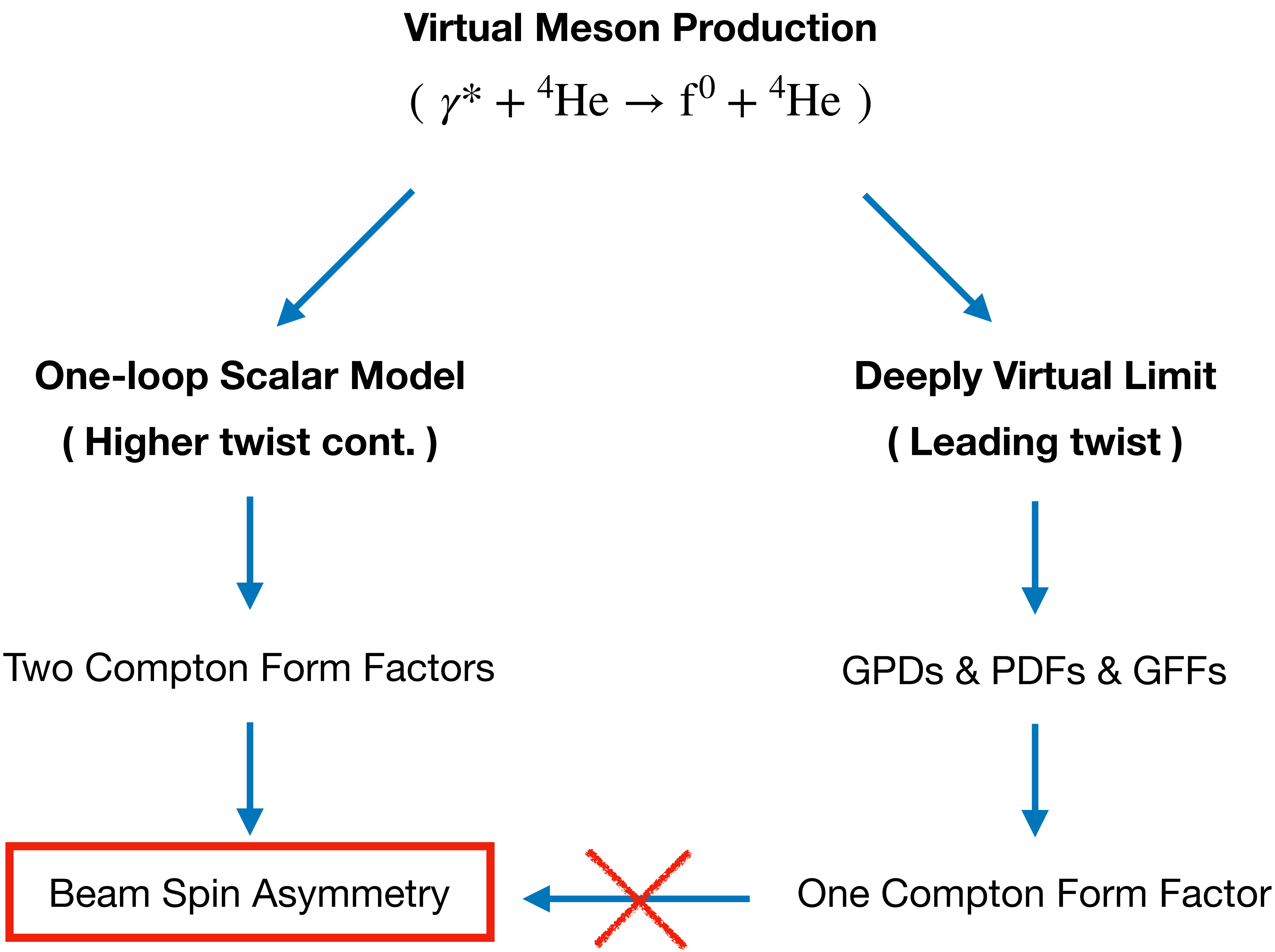




One-loop scalar model

Deeply virtual limit

Aim of this work



II. One-Loop Scalar Model

Kinematics

Q^2 : virtuality of virtual photon,

x_B : Bjorken x

X : longitudinal momentum fraction,

ζ : longitudinal momentum change of target,

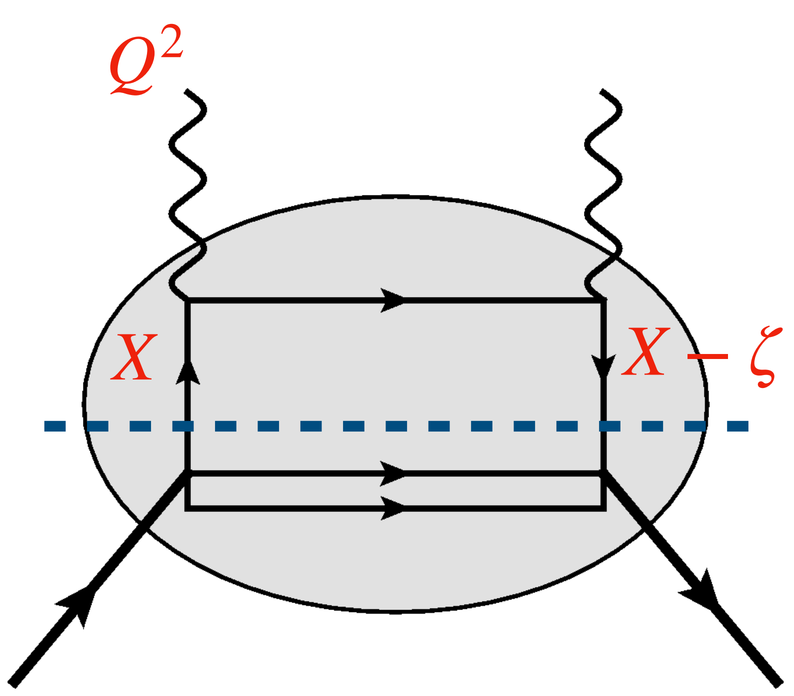
t : momentum transfer,

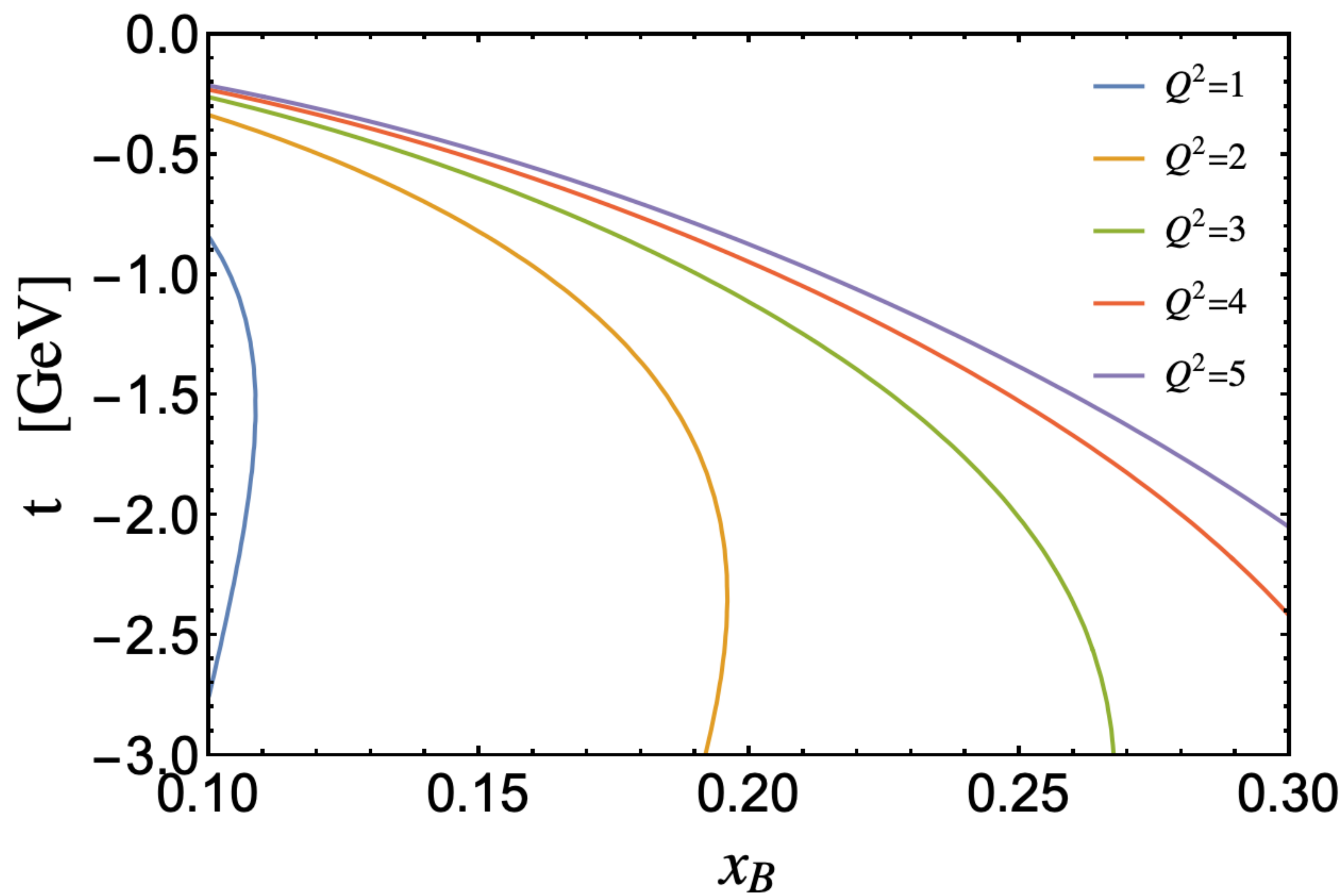
CFF → $\mathscr{F}(Q^2, x_B, t)$

GPD → $\mathscr{H}(X, \zeta, t)$

$\lim_{Q^2 \to \infty} \zeta = x_B$

deeply virtual limit

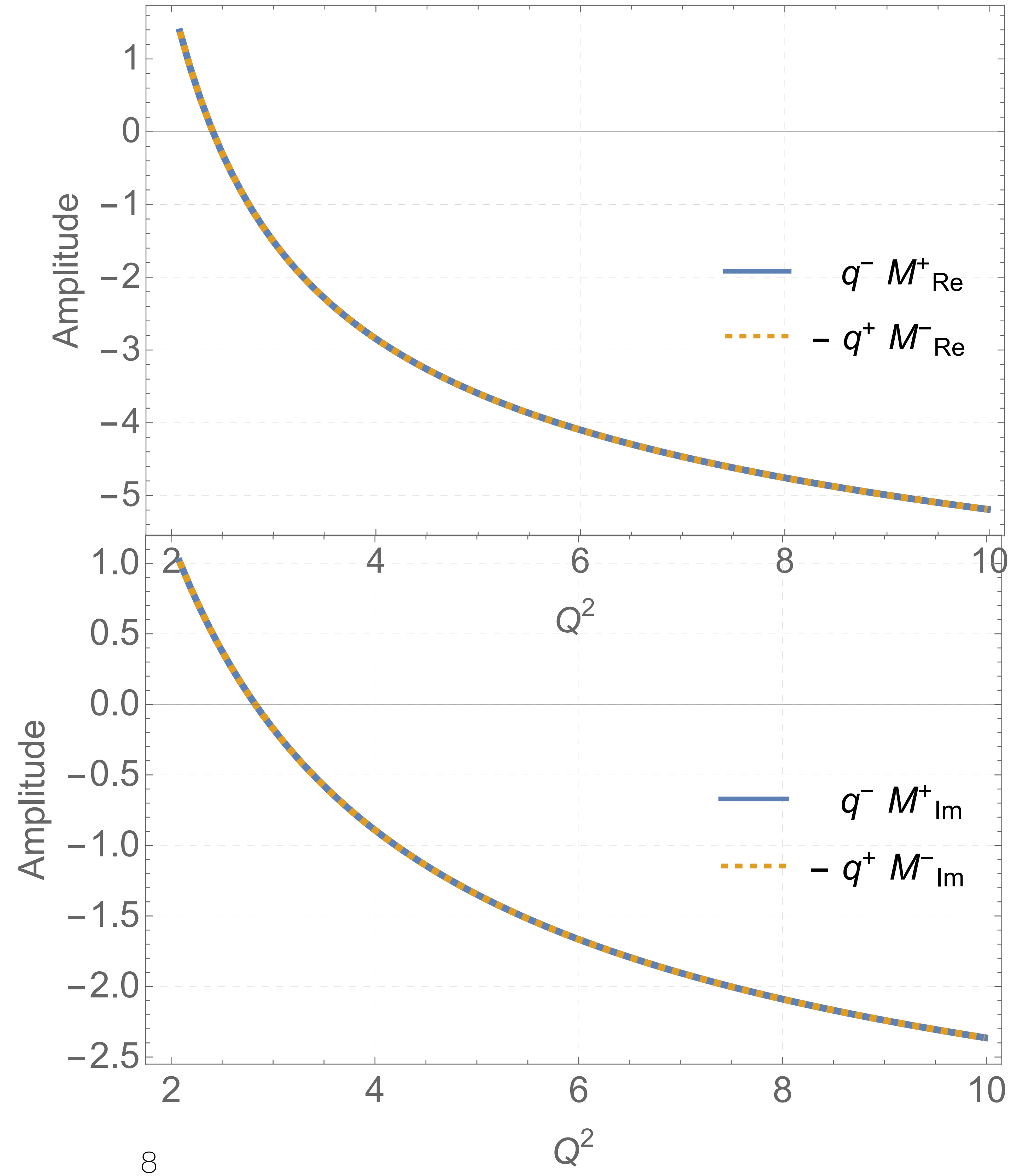




Ward Identity

To check the numerical calculation,

$$q_\mu \, \mathscr{M}^\mu = q^+ \mathscr{M}^- + q^- \mathscr{M}^+ = 0$$

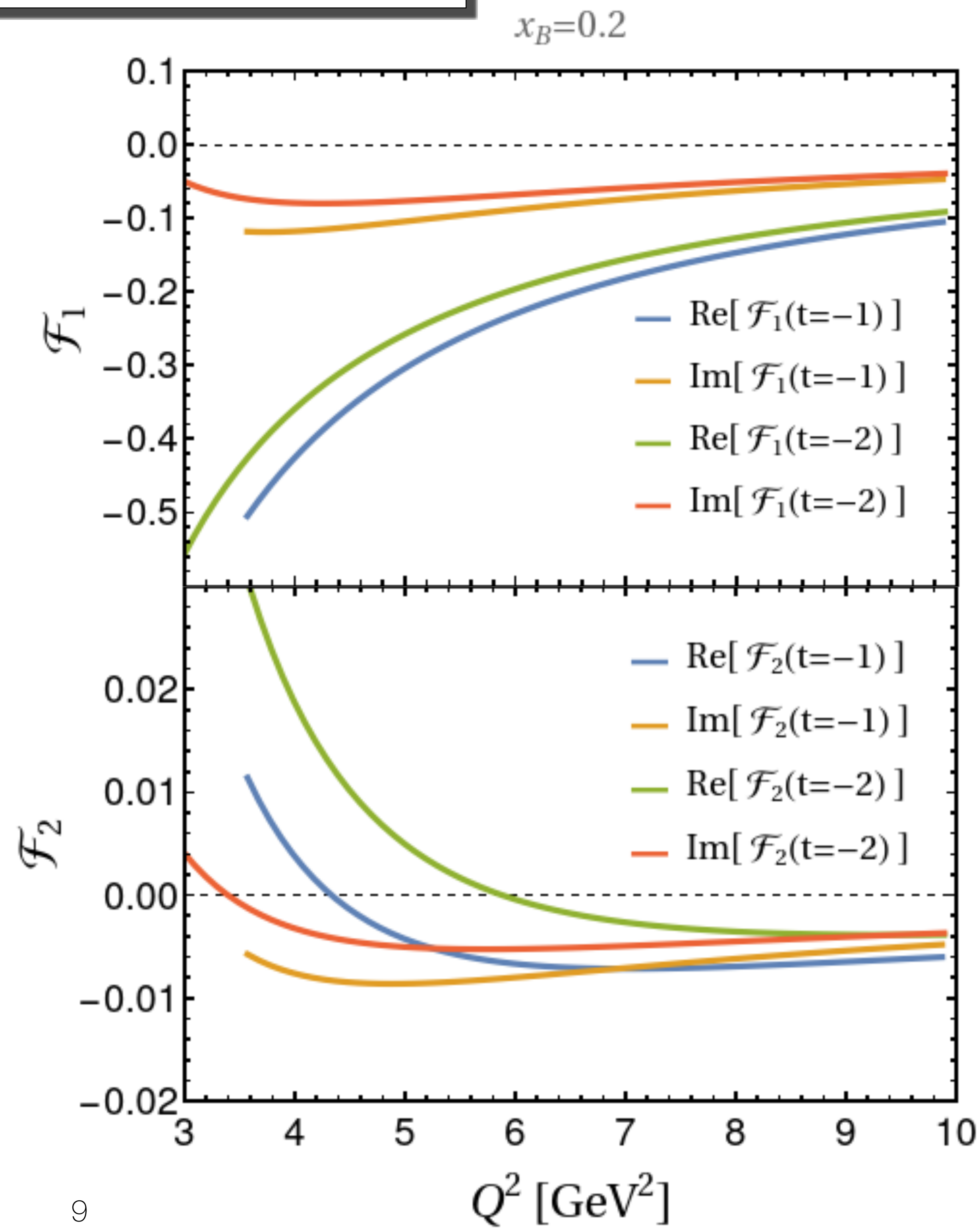


Compton Form Factors

Spin-0 Helium Target

$$\mathscr{M}^\mu = \left[\ (\Delta \cdot q)\ q^\mu - q^2\ \Delta^\mu\ \right] \mathscr{F}_1$$

$$+ \left[\ (\Delta \cdot q)\ \mathscr{P}^\mu - (\mathscr{P} \cdot q)\ \Delta^\mu\ \right] \mathscr{F}_2$$



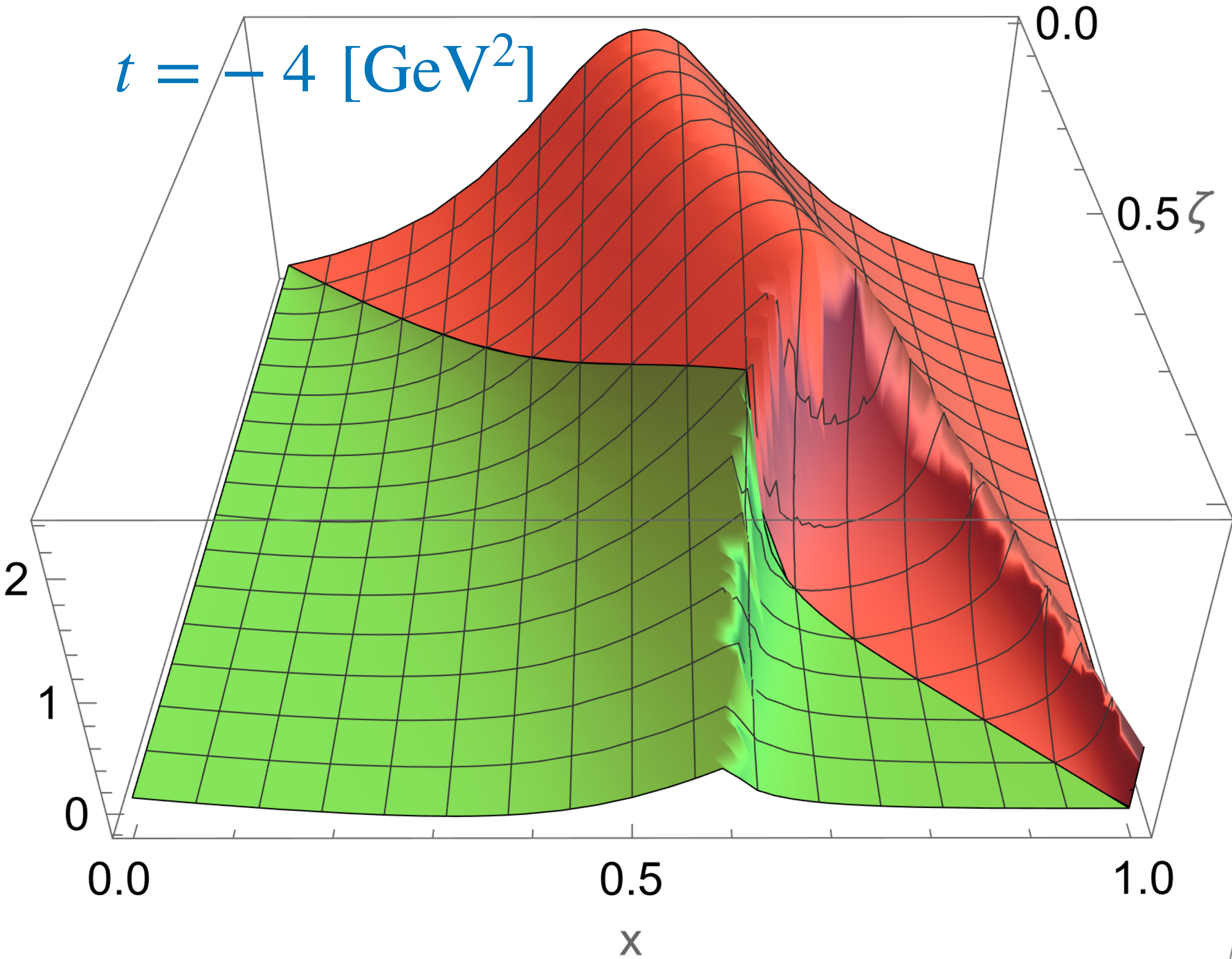
Remarks

1. $\mathscr{F}_1$ is approximately 10 orders of magnitude larger than $\mathscr{F}_2$.

2. Size of CFFs seems to decrease As t gets larger.

III. Deeply Virtual Limit

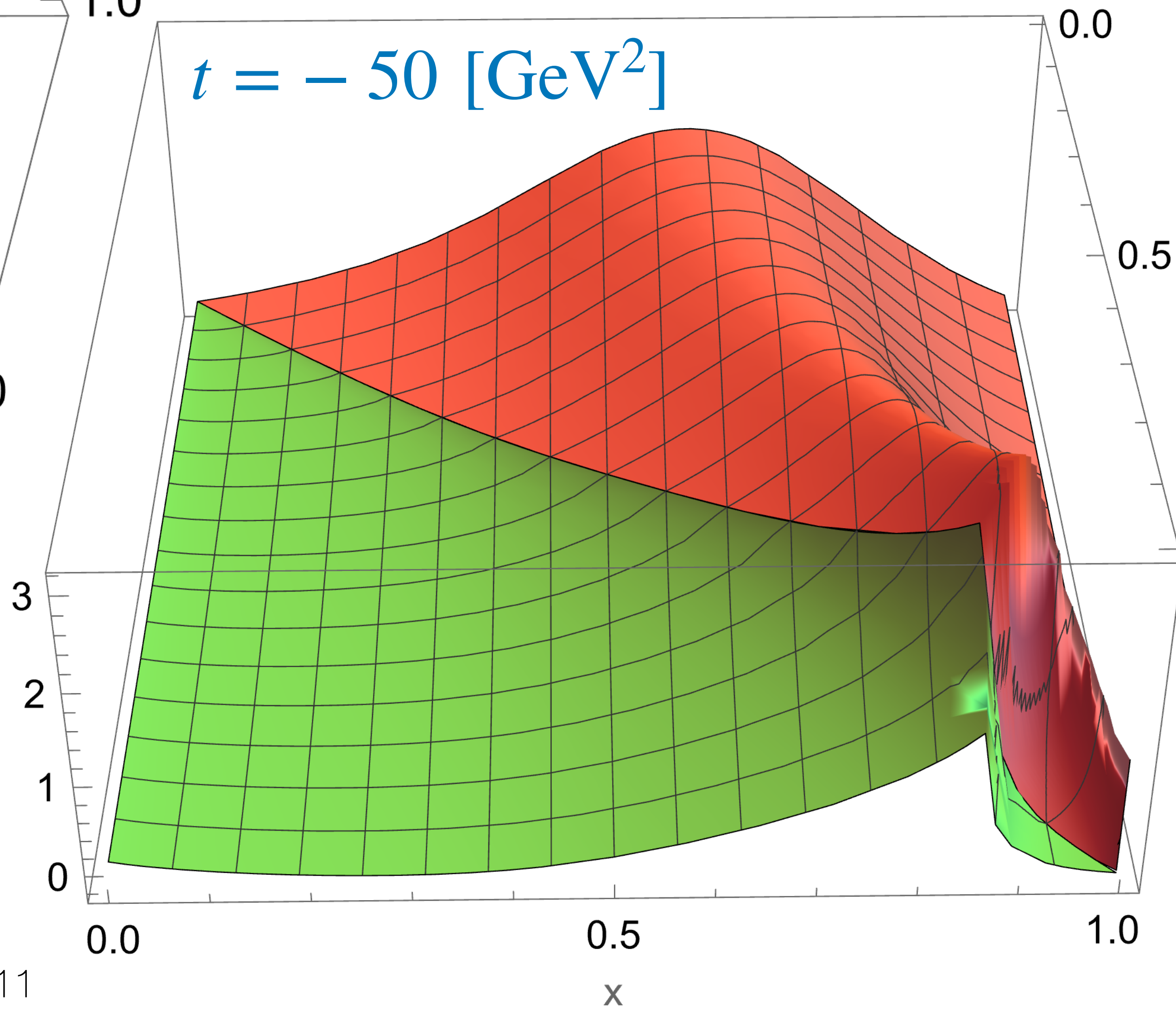
Generalized Parton Distribution



$$\mathscr{M}^{+}_{DVMP\ s+u} \sim \int_0^1 \left(\frac{1}{x-\zeta} - \frac{1}{x}\right) \mathrm{H}(x,\zeta,t)$$

$\mathrm{H}_{\mathrm{ERBL}}\ (0 \leq x \leq \zeta)$

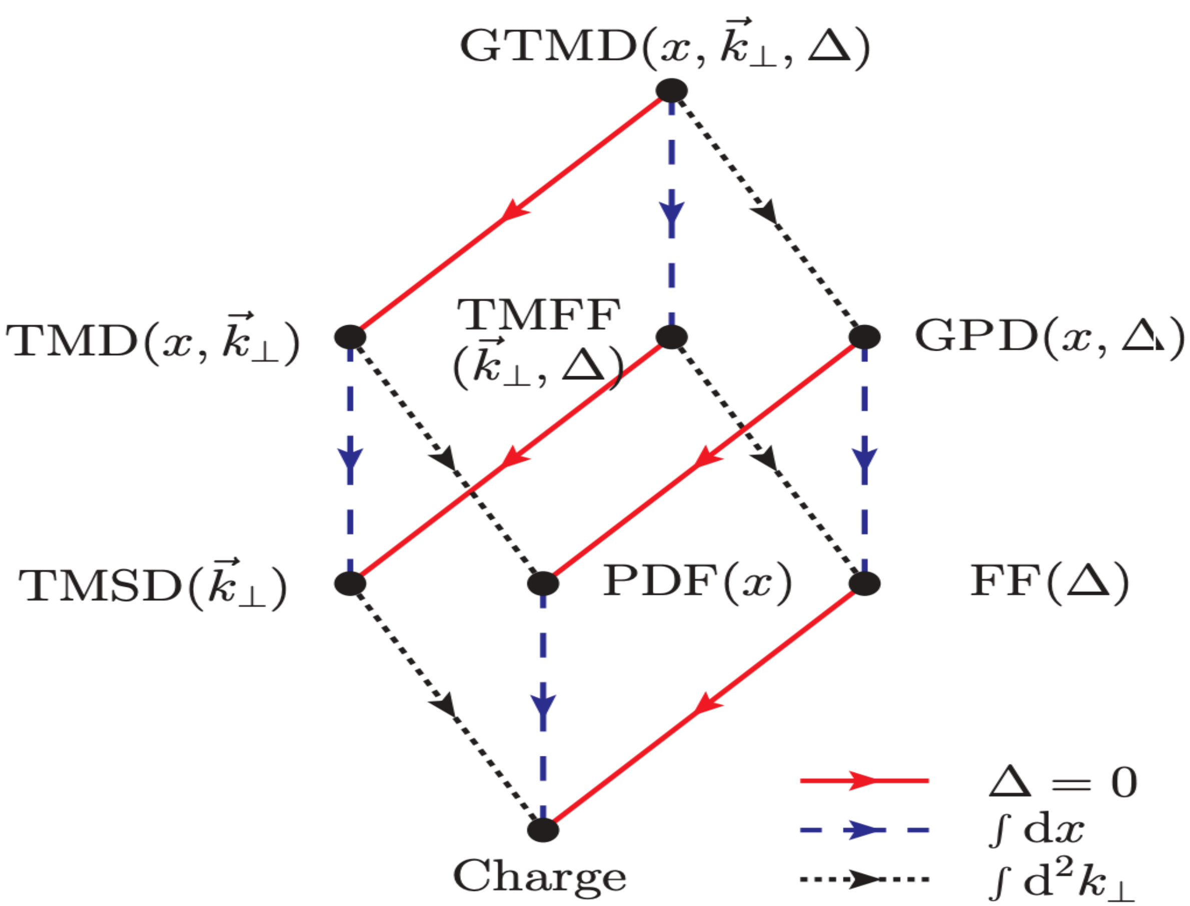
$\mathrm{H}_{\mathrm{DGLAP}}\ (\zeta \leq x \leq 1)$



Strange bump is probably due to $(\zeta - 1)t - \zeta^2 M^2 < 0$.

$$|\boldsymbol{\Delta}| = \sqrt{(\zeta - 1)t - \zeta^2 M^2}$$

GPD sum rule



B. Pasquini, C. Lorcé

Parton Distribution Functions :

$$H^q(x, 0, 0) = f_1(x), \quad \tilde{H}^q(x, 0, 0) = g_1(x),$$

Form Factors (first Mellin moment) :

$$\int dx\ H^q(x, \xi, t) = F_1^q(t), \quad \int dx\ E^q(x, \xi, t) = F_2^q(t)$$

$$\int dx\ \tilde{H}^q(x, \xi, t) = G_A^q(t), \quad \int dx\ \tilde{E}^q(x, \xi, t) = G_P^q(t)$$

$$\lim_{\xi,t\to 0} \int \frac{dy^-}{2\pi}\ e^{ixP^+y^-} \boxed{\langle P' | \bar{\psi}(0)\ \hat{\mathcal{O}}\ \psi(y) | P \rangle} \Big|_{y^+=\mathbf{y}_\perp=0} = \int \frac{dy^-}{2\pi}\ e^{ixP^+y^-} \langle P | \bar{\psi}(0)\ \hat{\mathcal{O}}\ \psi(y) | P \rangle \Big|_{y^+=\mathbf{y}_\perp=0}$$

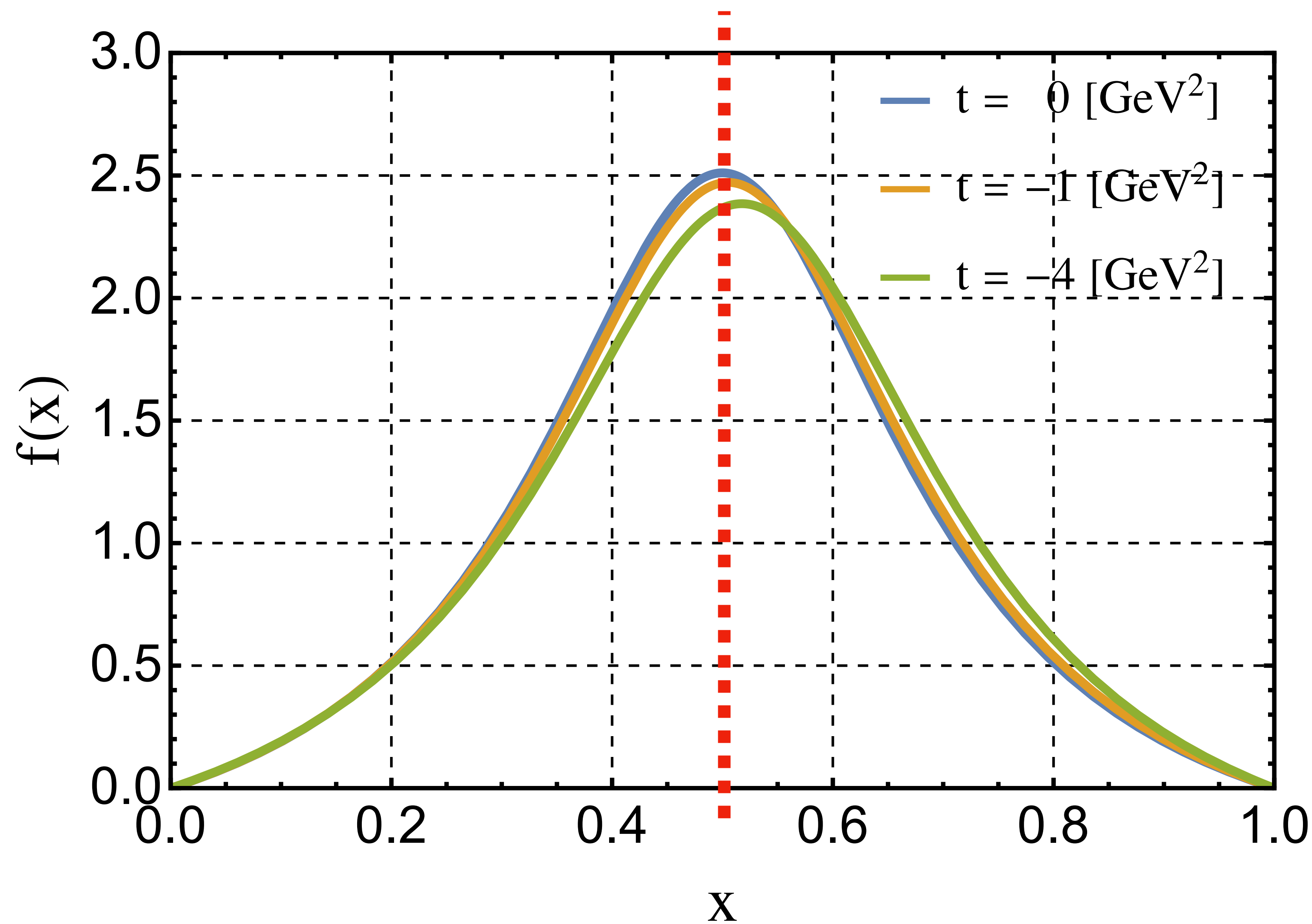
$$\int dx \int \frac{dy^-}{2\pi}\ e^{ixP^+y^-} \boxed{\langle P' | \bar{\psi}(0)\ \hat{\mathcal{O}}\ \psi(y) | P \rangle} \Big|_{y^+=\mathbf{y}_\perp=0} = \langle P' | \bar{\psi}(0)\ \hat{\mathcal{O}}\ \psi(0) | P \rangle \Big|_{y^+=\mathbf{y}_\perp=0}$$

Parton Distribution Function

$$\lim_{\xi,t\to 0} H(x,\xi,t) = \lim_{\zeta,t\to 0} H(X,\zeta,t) = H(X,0,0) = f(X)$$

1. $\zeta \to 0$ corresponds to $t \to 0$ in (1+1). In (3+1), PDF can be obtained with $\zeta,\ t \to 0$ simultaneously.

2. Helium is consist of **two effective quarks** with equal masses in our model. Momentum fraction of a single quark has highest probability at 0.5.



Electromagnetic Form Factor

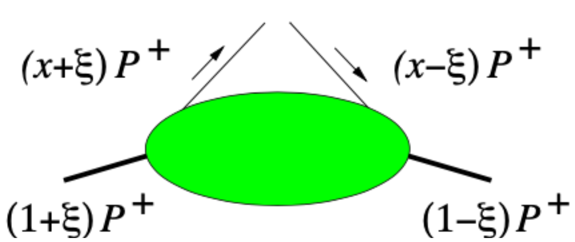
1st Melin moment

$$\int dx\ H(x,\ \xi,\ t)$$

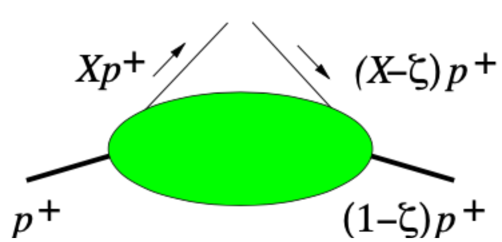
$$= \int dX\ \frac{2}{2-\zeta} H(X,\ \zeta,\ t) = F(t),$$

with different conventions,

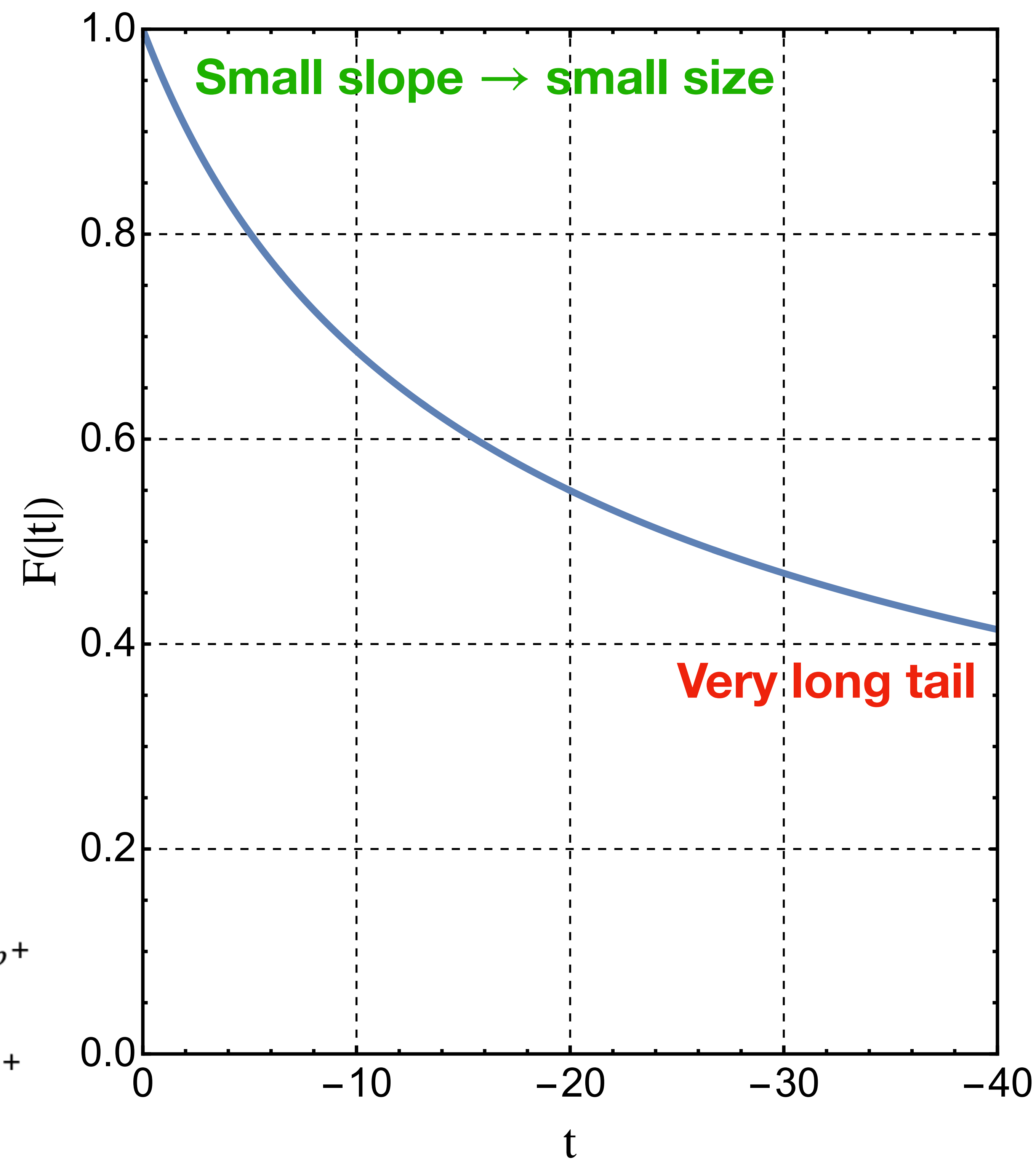
$$X = \frac{x+\xi}{1+\xi}, \quad \zeta = \frac{2\xi}{1+\xi}$$



Ji's



Radyushkin's



Energy Momentum Tensor FF

2nd Melin moment

$$\int dx\ xH(x,\xi,t) = A(t) + 4\xi^2\ C(t)$$

$$= \int dX\ \frac{2(2X-\zeta)}{(2-\zeta)^2}\ H(X,\zeta,t)$$

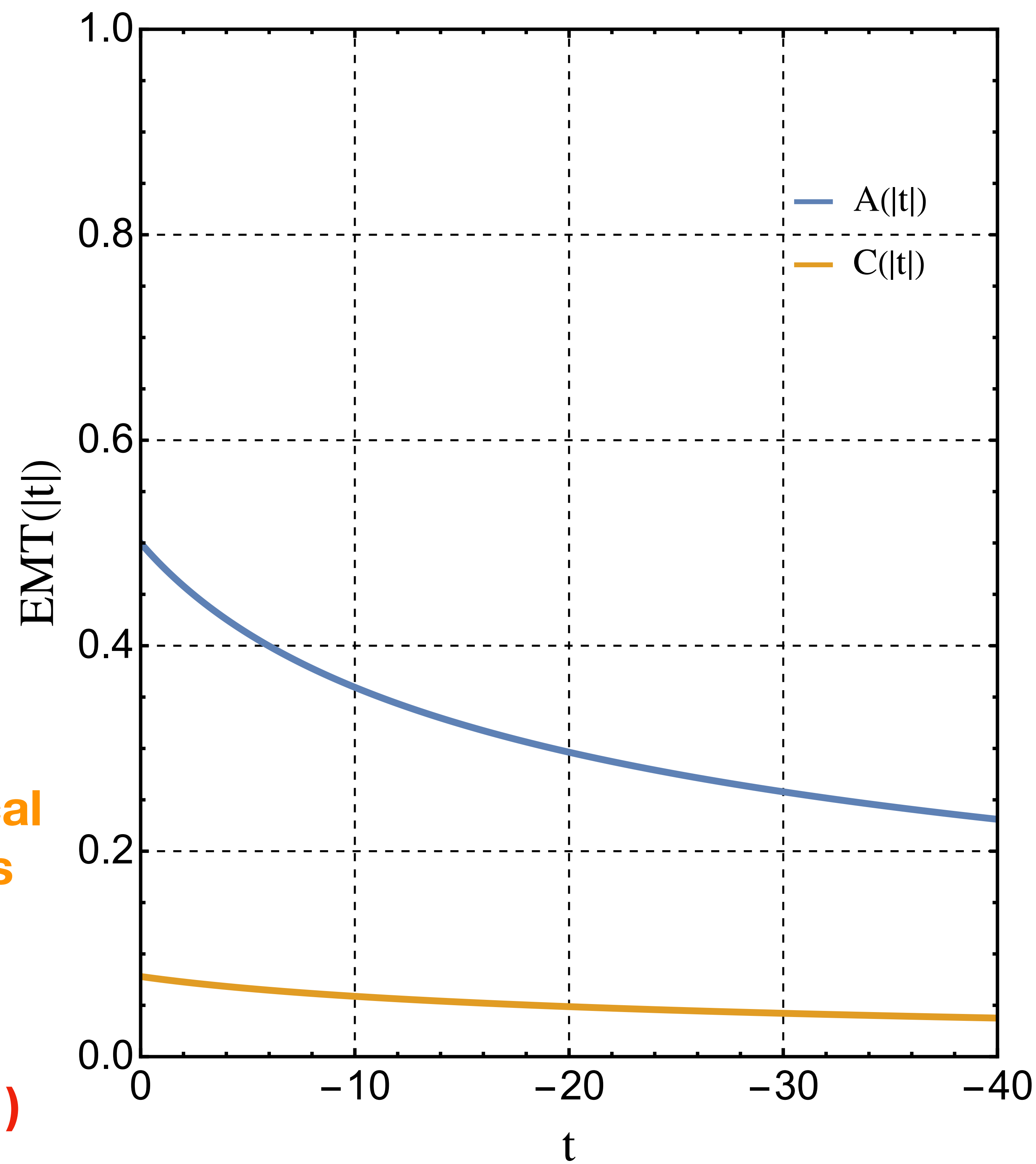
$$= A(t) + 4\left(\frac{\zeta}{2-\zeta}\right)^2\ C(t)$$

Mass

(half mass of quark)

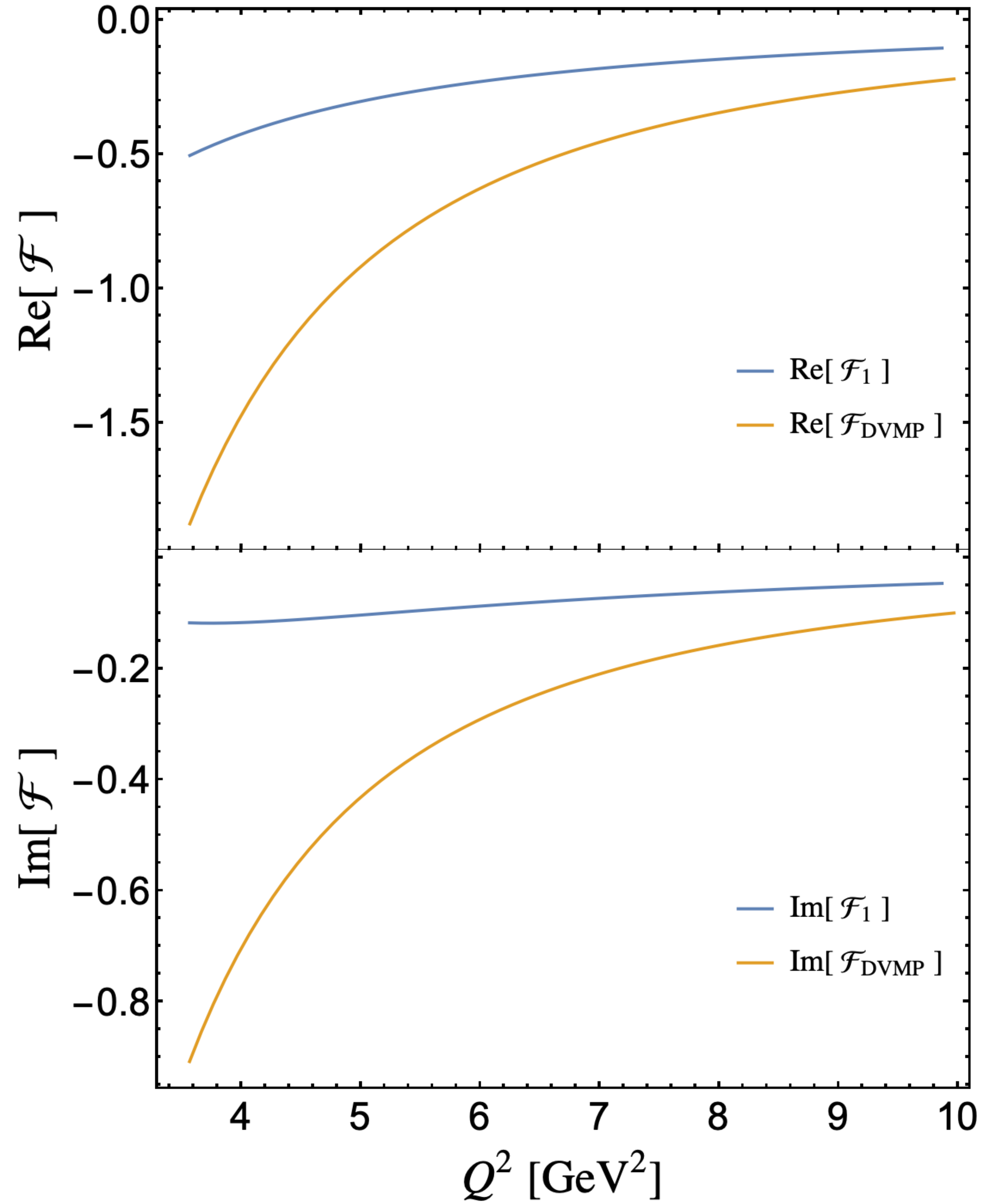
Mechanical properties

(pressure & shear forces)



IV. One-loop Scalar Model vs Deeply Virtual Limit

Comparison two models for CFFs



One-loop scalar model :

$$\mathcal{F}_1 >> \mathcal{F}_2$$

Deeply virtual limit :

only $\mathcal{F}_{DVMP}$

Beam Spin Asymmetry

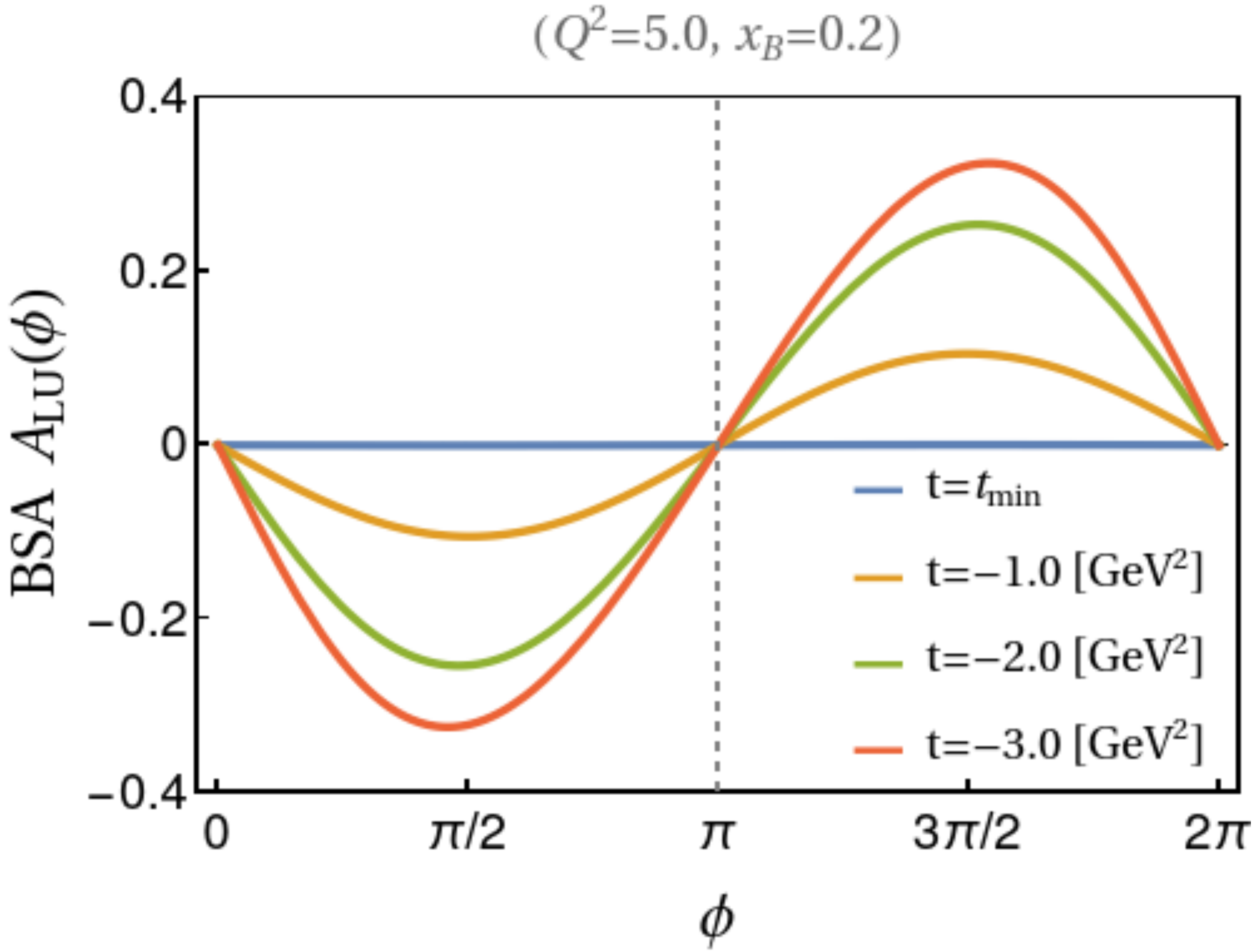
$$A_{LU}^{S}(\phi) \;=\; \frac{d\sigma_{BSA}^{S}}{d\sigma_{T}^{S}\,(1+\epsilon\,\cos(2\phi)) + d\sigma_{L}^{S}\,\epsilon_{L} + d\sigma_{LT}^{S}\,\cos(\phi)\sqrt{\epsilon_{L}(1+\epsilon)/2}}$$

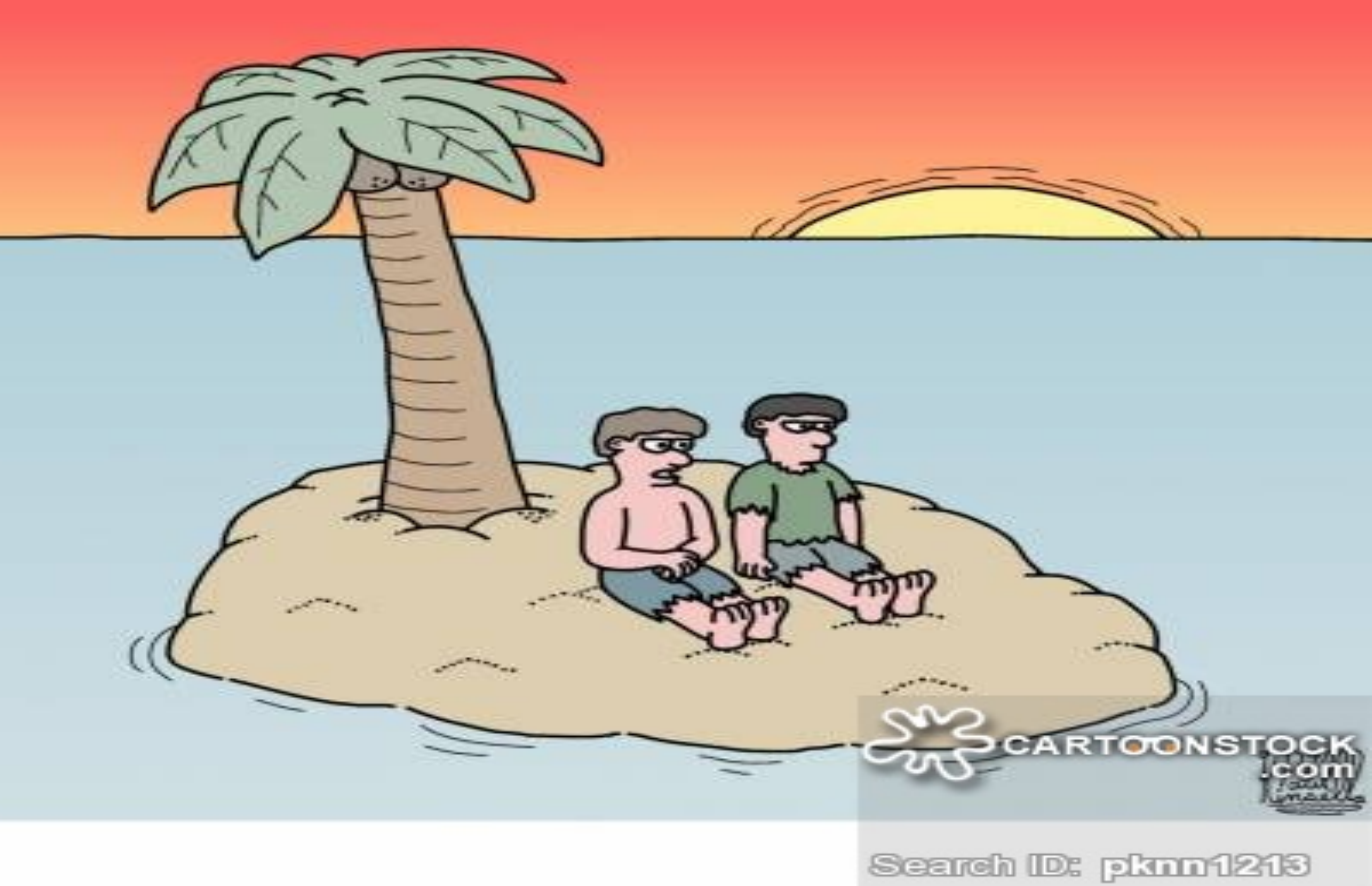
$$d\sigma_{BSA}^{S} = S_{A}\,(\mathscr{F}_1\mathscr{F}_2^{*} - \mathscr{F}_1^{*}\mathscr{F}_2)$$

Remarks

1. As t increases, magnitude of BSA increases.

2. For a given Q^2 and x_B, if $t = t_{min}$, BSA vanishes.





"Thank you for listening."