Vector Meson Production in QCD

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GPD representations

DVMP in the collinear factorization framework

Other frameworks

NLO corrections

DVCS+DVMP small x_B fits at LO

in collaboration with

M. Meškauskas, K. Passek-Kumerićki, T. Lautenschlager, A. Schäfer
K. Kumerićki

M. Meśkauskas and D.M., 1112.2597 [hep-ph]
flexible GPD model fits@LO for small *x* and fits to vector mesons/DVCS H1/ZEUS data
C. Bechler and D.M., 0906.2571 [hep-ph]
GPD description of π+ electroproduction from HERMES/JLAB
T. Lautenschlager, DM, K.Passek-Kumerićki, A. Schäfer, to be polished
NLO corrections to DVMP in conformal space

Overview: GPD representations

``light-ray spectral functions''

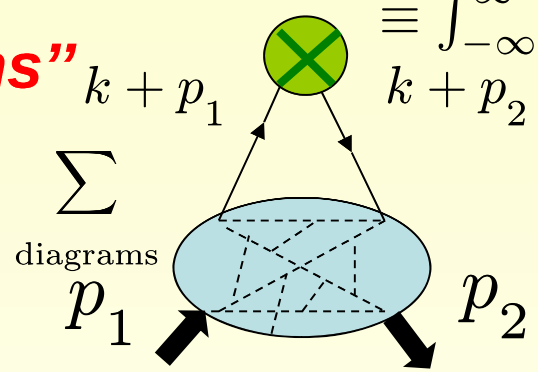
diagrammatic α-representation

DM, Robaschik, Geyer,
Dittes, Hořejši (88 (92) 94)

called ***double distributions***

A. Radyushkin (96)

$$\equiv \int_{-\infty}^{\infty} \frac{d\kappa}{2\pi}\, e^{i\kappa(xP^+ - P^+ - 2k^+)}$$



light cone wave function overlap

(Hamiltonian approach in light-cone quantization)

Diehl, Feldmann,
Jakob, Kroll (98,00)

Diehl, Brodsky,
Hwang (00)

SL(2,R) (conformal) expansion

(series of local operators)

Radyushkin (97);
Belitsky, Geyer, DM, Schäfer (97);
DM, Schäfer (05); ….

one version is called Shuvaev transformation,
used in `dual' (*t*-channel) GPD parameterization

Shuvaev (99,02); Noritzsch (00)
Polyakov (02,07)

each representation has its own ***advantages***,
however, they are ***equivalent*** **(clearly spelled out in [Hwang, DM 07])**

Summing up conformal PWs

- GPD support is a consequence of Poincaré invariance (polynomiality)

$$H_j(\eta, t, \mu^2) = \int_{-1}^{1} dx\, c_j(x,\eta) H(x,\eta,t,\mu^2)\,, \qquad c_j(x,\eta) = \eta^j C_j^{3/2}(x/\eta)$$

- conformal moments evolve autonomous (to LO and beyond in a special scheme)

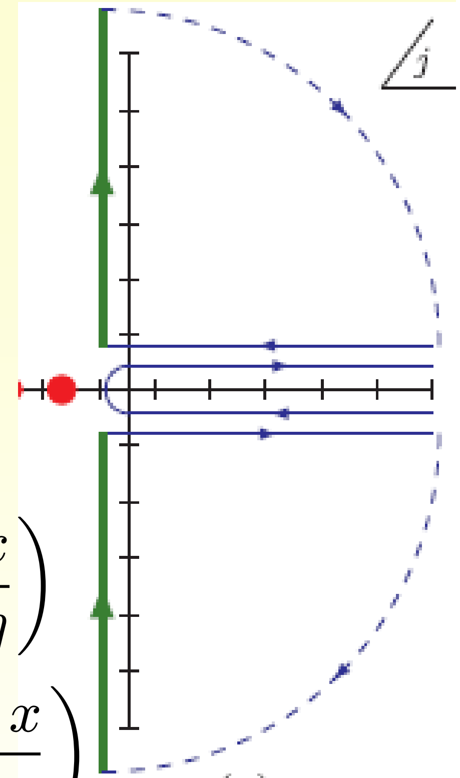
$$\mu \frac{d}{d\mu} H_j(\eta, t, \mu^2) = -\frac{\alpha_s(\mu)}{2\pi} \gamma_j^{(0)} H_j(\eta, t, \mu^2)$$

- inverse relation is given as series of mathematical distributions:

$$H(x,\eta,t) = \sum_{j=0}^{\infty} (-1)^j p_j(x,\eta) H_j(\eta,t)\,,\ p_j(x,\eta) \propto \theta(|x| \le \eta) \frac{\eta^2 - x^2}{\eta^{j+3}} C_j^{3/2}(-x/\eta)$$

- various ways of resummation were proposed:
  - smearing method [Radyushkin (97); Geyer, Belitsky, DM., Niedermeier, Schäfer (97/99)]
  - mapping to a kind of forward PDFs [A. Shuvaev (99), J. Noritzsch (00)]
  - dual parameterization [M. Polyakov, A. Shuvaev (02)]
  - based on conformal light-ray operators [Balitsky, Braun (89); Kivel, Mankewicz (99)]
  - ***Mellin-Barnes integral*** [DM, Schäfer (05); A. Manashov, M. Kirch, A. Schäfer (05)]

Sommerfeld-Watson transform



✓ rewrite sum as an integral around the real axis:

$$F(x,\eta,\Delta^2) = \frac{1}{2i}\oint_{(0)}^{(\infty)} dj\, \frac{1}{\sin(\pi j)} p_j(x,\eta)\; F_j(\eta,\Delta^2)$$

✓ find appropriate analytic continuation of p_j and F_j (Carlson's theorem)

$$p_j(x,\eta) = \theta(\eta - |x|)\eta^{-j-1}\mathcal{P}_j\left(\frac{x}{\eta}\right) + \theta(x-\eta)\eta^{-j-1}\mathcal{Q}_j\left(\frac{x}{\eta}\right)$$

$$\mathcal{P}_j(x) \;=\; \frac{2^{j+1}\Gamma(5/2+j)}{\Gamma(1/2)\Gamma(1+j)}(1+x)\,{}_2F_1\left(\begin{matrix}-j-1,\, j+2\\ 2\end{matrix}\,\middle|\,\frac{1+x}{2}\right)$$

$$\mathcal{Q}_j(x) \;=\; -\frac{\sin(\pi j)}{\pi}\; x^{-j-1}\;{}_2F_1\left(\begin{matrix}(j+1)/2,\, (j+2)/2\\ 5/2+j\end{matrix}\,\middle|\,\frac{1}{x^2}\right)$$

✓ change integration path so that singularities remain on the l.h.s.

$$F(x,\eta,\Delta^2) = \frac{i}{2}\int_{c-i\infty}^{c+i\infty} dj\, \frac{1}{\sin(\pi j)} p_j(x,\eta)\, F_j(\eta,\Delta^2)$$

Model based on SL(2,R) and SO(3) PWE

- SL(2,R) GPD moments: $$F_j(\eta,t) = \sum_{J=J^{\min}}^{j+1} f_j^J(t)\,\eta^{j+1-J}\,\hat{d}_J(\eta)$$

partial wave amplitudes depending on j and J

reduced Wigner rotation matrices

- taking 2 better 3 SO(3) PWs: (two parameters s_2 and s_4)

$$f_j^{j-1}(t) = s_2 f_j^{j+1}(t)\,,$$
$$f_j^{j-3}(t) = s_4 f_j^{j+1}(t)\,,$$

- resulting CFF easy to handle:

$$\mathcal{F} = \frac{1}{2i}\sum_{\substack{k=0\\ \text{even}}}^{4}\int_{c-i\infty}^{c+i\infty} dj\,\xi^{-j-1}\frac{2^{j+1+k}\Gamma(5/2+j+k)}{\Gamma(3/2)\Gamma(3+j+k)}\left(i-\frac{\cos(\pi j)\mp 1}{\sin(\pi j)}\right)$$
$$\times s_k E_{j+k}(\mathcal{Q}^2) f_j^{j+1}(t)\hat{d}_j(\xi), \quad s_0 = 1$$

- zero-skewness GPD: $$h_j^{j+1} = q_j\frac{j+1-\alpha(0)}{j+1-\alpha(0)-\alpha' t}\left(1-\frac{t}{M_j^2}\right)^{-p}$$

PDF

\`pomeron intercept' (biuld in PDF) + Regge slope

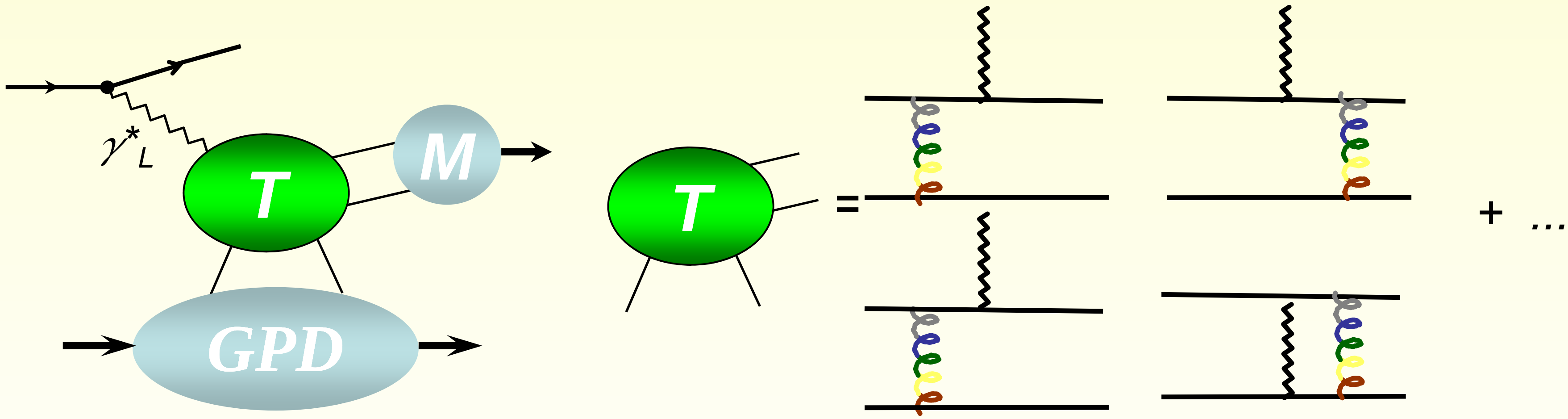
residual t dependence

2x(2, 3, or 4) parameters:

***s_2, s_4, M or b*, (perhaps α')**

Collinear factorization framework

at large Q^2 **longitudinal** DVMP amplitude factorizes at twist-two level into a hard scattering part, GPD, and a meson distribution amplitude (DA) **[Collins, Frankfurt, Strikman 98]**, e.g.,



collinear factorization = integrating out k_T

perturbative + non-perturbative corrections

$$\mathcal{F}(x_{\mathrm{B}}, t, \mathcal{Q}^2) = \frac{C_F f_{\mathrm{M}}}{N_c \mathcal{Q}} F(x, \xi, t, \mu_{\mathrm{F}}^2) \overset{x}{\otimes} T\left(\frac{\xi - x}{2\xi}, \bar{v} \middle| \cdots \right) \overset{v}{\otimes} \varphi(v, \mu_{\varphi}^2)\Big|_{\xi = \frac{x_{\mathrm{B}}}{2 - x_{\mathrm{B}}}}$$

$$\bar{u} = 1 - u, \quad \bar{v} = 1 - v$$

at LO in α_s twist-two amplitudes "factorize"

$$\mathcal{H}^{pV}\left(x_{\mathrm{B}}, t, \mathcal{Q}^2\right) \stackrel{\mathrm{LO}}{=} \frac{4\alpha_s(\mu_{\mathrm{R}})}{9}\frac{f_V}{\mathcal{Q}} 3\mathcal{I}^V\left(\mu^2\right)\mathcal{H}^{pV}\left(x_{\mathrm{B}}, t, \mu^2\right)$$

in inverse moment of meson distribution amplitude

$$\mathcal{I}^V(\mu^2) = \frac{1}{3}\int_0^1 du\, \frac{\varphi^V(u,\mu^2)}{u}\,, \qquad \int_0^1 du\, \varphi^V(u,\mu^2) = 1\,,$$

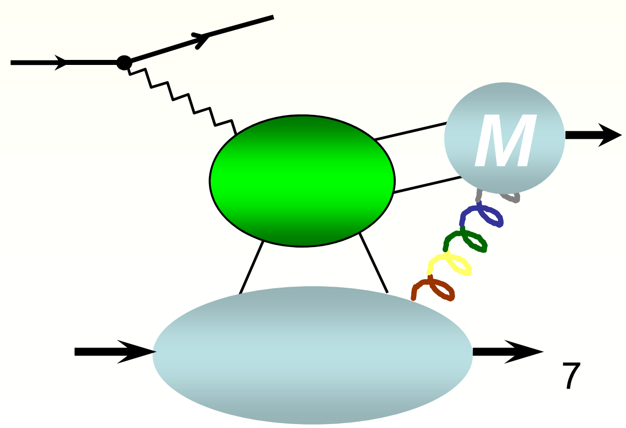
and GPD part "CFFs" , e.g.,

$$\mathcal{H}^{q(+)}(x_{\mathrm{B}}, t, \mu^2) \stackrel{\mathrm{LO}}{=} \int_{-1}^{1} dx\, \left[\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon}\right] H^q(x,\xi,t,\mu^2)\Big|_{\xi = x_{\mathrm{B}}/(2-x_{\mathrm{B}})}\,.$$

factorization might be broken at twist-3 level
due to the initial/final state interaction

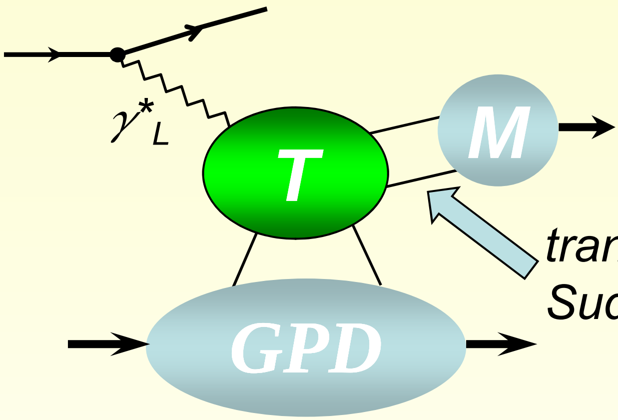
indicated by endpoint singularities at LO

"pragmatic point of view" (introduce a cut-off)
[Mankiewicz et. al (98)]



Other frameworks

GPD inspired model of Goloskokov/Kroll (contains quark + gluons)

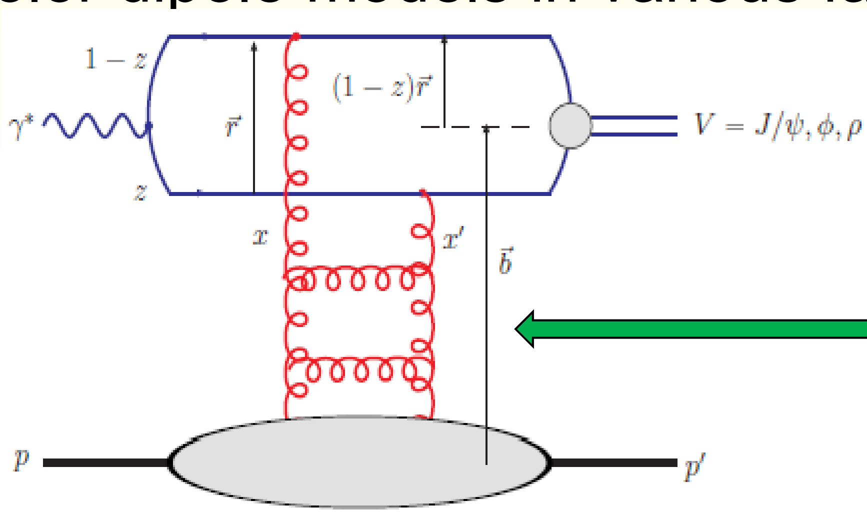


$$\frac{1}{\xi - x - i\epsilon} \Rightarrow \frac{1}{\xi - x + 2\xi\, u\, k_T^2/Q^2 - i\epsilon}$$

transverse degrees
Sudakov suppression

suppressed by energy² rather Q²

color dipole models in various fashions **[A. Mueller (90), ... ,Kowalski et. al, ...]**



applicable at small x, Regge inspired

non-perturbative vector-meson WF

only contains **other** gluons
(**universal color dipole amplitude**)

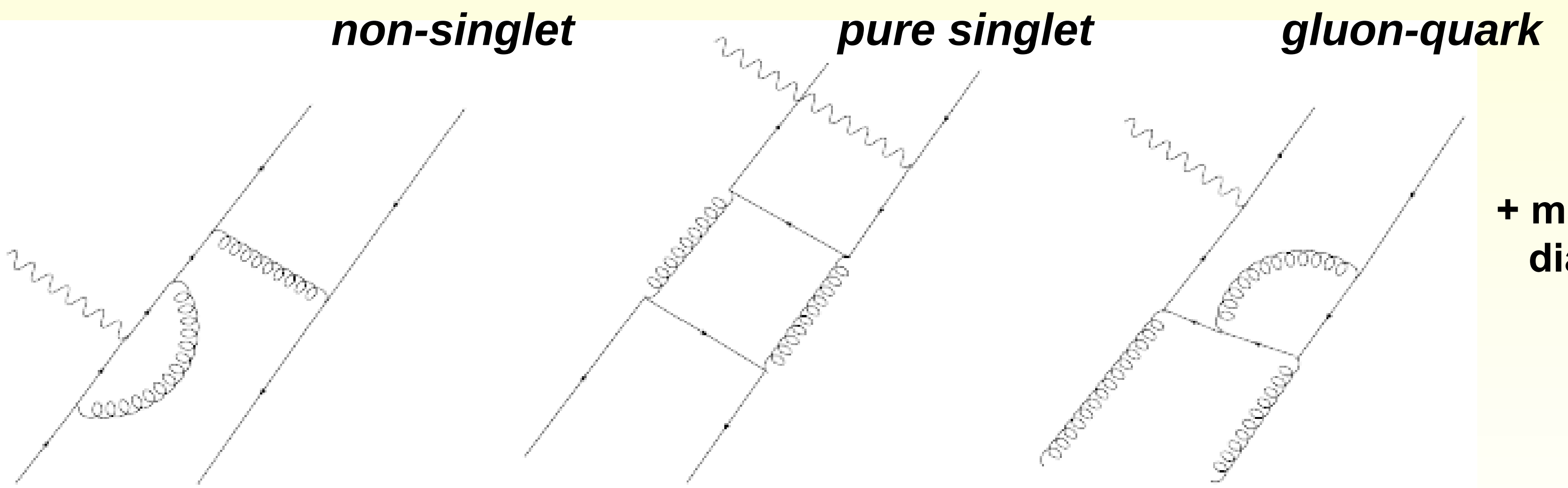
[picture from Kowalski, Motyka, Watt (06)]

Regge inspired models **[Laget et al]** (also applied at low W)

NLO corrections

• NLO hard scattering coefficients are calculated in momentum fraction space

i. non-singlet quark-quark channel **[Belitsky, DM, 01]** (extend form factor hard scattering part)
ii. pure singlet quark-quark channel **[Ivanov, Szymanowski, Krasnikov 04, PK et al.]**
iii. gluon-quark channel **[Ivanov, Szymanowski, Krasnikov 04]**



+ many more diagrams

iv. NLO quark-gluon channel is still missing (needed for η/η')

NLO hard scattering part are to be transformed in conformal Mellin-space
(to implement in our flexible GPD model framework)

• NLO evolution kernels in conformal moment space and momentum fraction
[Belitsky, DM, 98] and **[Belitsky, DM, Freund 00]**

NLO example: pure singlet quark-quark channel

momentum fraction representation

$$ {}^{\Sigma}T^{(1)}\left(\overline{u}\,,\overline{v}\,\middle|\,\frac{\mathcal{Q}^2}{\mu_{\mathrm{F}}^2}\right) = C_{\mathrm{F}}\,{}^{\Sigma}T^{(1,F)}\left(\overline{u}\,,\overline{v}\,\middle|\,\frac{\mathcal{Q}^2}{\mu_{\mathrm{F}}^2}\right)\,, \quad \overline{u}\, = 1-u, \overline{v}\, = 1-v $$

mathematically trivial terms (factorization in *u* and *v* terms except for $\Delta T^{(1,G)}$)

$$ {}^{\Sigma}T^{(1,\mathrm{F})}(u,v) = \left[\ln\frac{\mathcal{Q}^2}{\mu_{\mathrm{F}}^2} + \frac{\ln u + \ln(v\overline{v}\,)}{2} - 2\right]\frac{\overline{u}\, - u}{\overline{u}\,v\overline{v}}\ln u + \frac{2\ln u}{v\overline{v}} + \frac{1}{2}\Delta\,{}^{\Sigma}T^{(1,\mathrm{F})}(u,v) $$

factorization log matches evolution

logarithmical enhancement at endpoints

new pole at u=1

nontrivial term (free of 1/*(u-v)* singularities) can be nicely written as

$$ \Delta\,{}^{\Sigma}T^{(1,\mathrm{F})}(u,v) \;=\; \frac{d}{dv}\,\frac{L(u,v)}{u-v} + \frac{\overline{u}\; - u}{v\,\overline{v}}\,\frac{L(u,v)}{u-v} $$

$$ L(u,v) \;=\; \mathrm{Li}_2(v) - \mathrm{Li}_2(u) + \ln\overline{v}\,\ln u - \ln\overline{u}\,\ln u $$

dispersion relation representation – imaginary part

dispersion relation allows to evaluate the real part from the imaginary one

$$\Re\mathrm{e}\mathcal{H}^{pV}\left(x_{\mathrm{B}}, t, \mathcal{Q}^2\right) = \frac{1}{\pi}\mathrm{PV}\int_0^1 dx\, \frac{2x}{x^2-\xi^2}\Im\mathrm{m}\mathcal{H}^{pV}\left(\frac{2x}{1+x}, t, \mathcal{Q}^2\right) + \mathcal{C}\left(t, \mathcal{Q}^2\right)|_{\xi=\frac{x_{\mathrm{B}}}{2-x_{\mathrm{B}}}}$$

GPD in the outer region is needed

“D-term” projection is needed to calculate the subtraction constant

imaginary part can be straightforwardly evaluated *(x > ξ)*

$$\Im\mathrm{m}\mathcal{F}(x_{\mathrm{B}}, t, \mathcal{Q}^2) = \frac{C_F f_{\mathrm{M}}}{N_c \mathcal{Q}} F(x, \xi, t, \mu_{\mathrm{F}}^2) \overset{x}{\otimes} T^{\Im\mathrm{m}}\left(\frac{x}{\xi}, \bar{v}\middle|\cdots\right) \overset{v}{\otimes} \varphi(v, \mu_\varphi^2)\Big|_{\xi=\frac{x_{\mathrm{B}}}{2-x_{\mathrm{B}}}}$$

u=1 pole turns into x=0 pole

$$\begin{aligned} {}^{\Sigma}t^{(1,F)} &= \left[\ln\frac{\mathcal{Q}^2}{\mu_{\mathrm{F}}^2} + \ln\frac{1-x}{1+x} + \ln(v\overline{v}\,) - 1\right]\frac{1}{x(1+x)v\overline{v}} \\ &+ \frac{1-x}{1+x}\left[1 - 2\ln\frac{1+x}{2xv} - \frac{2vx}{1+x-2xv}\ln\frac{1+x}{2xv}\right]\frac{1}{(1+x-2vx)\overline{v}} \end{aligned}$$

reminder conformal representation of distribution amplitudes

conformal partial wave expansion of meson distribution amplitude

$$\varphi(u,\mu^2) = \sum_{\substack{k=0\\ \text{even}}}^{\infty} 6u\bar{u}\, C_k^{3/2}(u-\bar{u})\, \varphi_k(\mu^2)\,, \quad \varphi_0 = 1\,, \quad \bar{u} = 1-u$$

conformal partial wave amplitudes evolve autonomously at LO

$$\int_0^1 du\, T(u)\varphi(u) \quad \Rightarrow \quad \sum_{\substack{k=0\\ \text{even}}} T_k \varphi_k \qquad T_k = \int_0^1 du\, T(u)\, 6u\bar{u}\, C_k^{3/2}(u-\bar{u})$$

to calculate T_k one might use Rodrigues formula + partial integration

$$T_k = \frac{3(2+k)}{k!} \int_0^1 du\, (u\bar{u})^{k+1} \frac{d^k}{du^k} T(u)$$

simple LO example: $T(u) = \frac{1}{u}$ $\qquad T_k = 3(2+k)(-1)^k \int_0^1 du\, u^{k+1} = 3(-1)^k$

all NLO expressions (LO decorated by *ln* and Li_2 functions) are analytically known

fixing $(-1)^k = \sigma = \mp 1$ allows to employ Carlson theorem to find expressions for complex k
(analytic continuation of a function with integer argument)

conformal representation of transition form factors

$$ {}^{\Sigma}T^{(1,\mathrm{F})}(u,v) \quad \Rightarrow \quad {}^{\Sigma}T^{(1,\mathrm{F})}_{jk} \propto \int_0^1 du \int_0^1 dv\, u\bar{u}\, C_j^{3/2}(u-\bar{u})\, {}^{\Sigma}T^{(1,\mathrm{F})}(u,v) v\bar{v}\, C_k^{3/2}(v-\bar{v}) $$

NLO hard scattering part posses the form

T = $\Sigma_{f,g}$ *f(u) g(v)* + *δT(u,v)* ⇨ $T_{jk} = \Sigma_{f,g}\, f_j\, g_k + \delta T_{jk}$

known find appropriate representation

use “double dispersion relation” to get moments of δT_{jk} *for complex j (k)*

$$ \delta^{\Sigma}T^{(1,F)}(u,v) = \int_0^1 dy \int_0^1 dz\, \frac{1}{1-uy}\, \frac{1}{y+z-yz} \left[\frac{y}{z} - 1 - z\,\frac{\vec{d}}{dz}\right] \frac{z}{1-\bar{v}z} $$

conformal moments of *1/(1-uy)* are easily calculable and have the needed analytic properties ($v \in \{3/2, 5/2\}$)

$$ \widetilde{p}_k^{(\nu)}(y) \propto \int_0^1 du\, \frac{1}{1-uy}\, (u\bar{u})^{\nu-1/2}\, C_k^{\nu}(u-\bar{u}) \Rightarrow \widetilde{p}_k^{(3/2)}(y) \propto y^k \int_0^1 du\, \frac{(u\bar{u})^{k+1}}{(1-uy)^{k+1}} $$

analytical continuation of δT_{jk} can be numerical performed

$$ \delta^{\Sigma}T^{(1,F)}_{jk} = \int_0^1 dy \int_0^1 dz\, \widetilde{p}_j^{(3/2)}(y) \left[\frac{y}{z} - 1 - z\,\frac{\vec{d}}{dz}\right] z\widetilde{p}_k^{(3/2)}(z) $$

conformal moment representation (pure singlet)

$$T^{\Sigma(1)}_{j,k}(Q^2/\mu_F^2) \quad = \quad T^{(0)}_{j,k}\, C_{\rm F}\, {}^{\Sigma}c^{(1,{\rm F})}_{j,k}\left(\frac{\mathcal{Q}^2}{\mu_{\rm F}^2}\right)$$

$$\begin{aligned}{}^{\Sigma}c^{(1,{\rm F})}_{j,k} \;&=\; \left[-\ln\frac{\mathcal{Q}^2}{\mu_{\rm F}^2}+2S_1(j+1)+2S_1(k+1)-1\right]\frac{{}^{\rm G\Sigma}\gamma_j^{(0,{\rm F})}}{j+3}-2S_{-2}(j+1)-\zeta(2)\\ &\quad +\delta^{\Sigma}c^{(1,{\rm F})}_{j,k}-\frac{1}{(j+1)(j+2)}\left[\frac{2}{(j+1)(j+2)}+\frac{1}{(k+1)(k+2)}\right],\end{aligned}$$

j=0 pole is contained in anomalous dimension

$${}^{\rm G\Sigma}\gamma_j^{(0,{\rm F})} = -2\,\frac{(j+1)(j+2)+2}{j(j+1)(j+2)}$$

non-factorizable δc_{jk} terms in *j,k* can be numerically calculated for complex *j (k)*

- analog structure in NS and gluon channels
- δc_{jk} might be also analytically evaluated
  (they are harmless at j=0, large j or large k)

Size of NLO corrections

[Belitsky, DM 01] large NLO corrections in the NS sector (proportional to C_F, β_0)

known from pion form factor:
- removing β_0 term will push $\alpha_s(\mu_R)$ into non-perturbative region
- C_F proportional corrections indicate Sudakov suppression (different sign)

discussion how to set Brodsky, Lepage, Mackenzie scale to eliminate β_0 proportional hard scattering coefficient (dispersion relation) **[Pire et al., Brodsky et al.]**

[Ivanov, Szymanowski, Krasnikov 04] big NLO corrections at small *x*

[Diehl, Kugler 07] model studies without NLO evolution

analytic expressions allows easily to understand nature of NLO corrections
- big at small *x* (*j=0* pole) and large at large *x* (large *j*)
- increase with growing *k*
- still a large scale dependence at NLO

NLO corrections are model dependent

pragmatic point of view:

- not much hope to understand power suppressed corrections
- work hard to evaluate radiative corrections (? resummation)
- explore how the collinear factorization approach works to describe data

First step: H1/ZEUS fits at LO

DVCS cross section
$$\frac{d\sigma^{\gamma^* p\to\gamma p}}{dt} \stackrel{\mathrm{Tw-2}}{\approx} \pi\alpha^2 \frac{x_{\mathrm{B}}^2}{\mathcal{Q}^4} \left|\mathcal{H}\left(x_{\mathrm{B}}, t, \mathcal{Q}^2\right)\right|^2 + \cdots$$

$$\mathcal{H} \stackrel{\mathrm{LO}}{=} \frac{4}{9}\mathcal{H}^{(u)+} + \frac{1}{9}\mathcal{H}^{(d)+} + \frac{1}{9}\mathcal{H}^{(s)+} + \frac{4}{9}\mathcal{H}^{(c)+}$$

DVMP cross sections
$$\frac{d\sigma^{\gamma_{\mathrm{L}}^* p\to V p}}{dt} \stackrel{\mathrm{Tw-2}}{\approx} 4\pi^2\alpha\, \frac{x_{\mathrm{B}}^2}{\mathcal{Q}^4} \left|\mathfrak{H}^{pV}\left(x_{\mathrm{B}}, t, \mathcal{Q}^2\right)\right|^2 + \cdots$$

$$\mathfrak{H}^{pV}\left(x_{\mathrm{B}}, t, \mathcal{Q}^2\right) \stackrel{\mathrm{LO}}{=} \frac{4\alpha_s(\mu_{\mathrm{R}})}{9} \frac{f_V}{\mathcal{Q}} 3\mathcal{I}^V\left(\mu^2\right) \mathcal{H}^{pV}\left(x_{\mathrm{B}}, t, \mu^2\right)$$

$$\mathcal{I}^V(\mu^2) = \frac{1}{3}\int_0^1 du\, \frac{\varphi^V(u,\mu^2)}{u}\,, \qquad \int_0^1 du\, \varphi^V(u,\mu^2) = 1\,,$$

$$\mathcal{H}^{p\rho^0} \stackrel{\mathrm{LO}}{=} \frac{1}{\sqrt{2}}\left(\frac{2}{3}\mathcal{H}^{u(+)} + \frac{1}{3}\mathcal{H}^{d(+)} + \frac{3}{4}\mathcal{H}^{G}\right)$$

$$\mathcal{H}^{p\omega} \stackrel{\mathrm{LO}}{=} \frac{1}{\sqrt{2}}\left(\frac{2}{3}\mathcal{H}^{u(+)} - \frac{1}{3}\mathcal{H}^{d(+)} + \frac{1}{4}\mathcal{H}^{G}\right)$$

$$\mathcal{H}^{p\phi} \stackrel{\mathrm{LO}}{=} (-1)\left(\frac{1}{3}\mathcal{H}^{s(+)} + \frac{1}{4}\mathcal{H}^{G}\right)$$

$$\mathcal{H}^{q(+)}(x_{\mathrm{B}}, t, \mu^2) \stackrel{\mathrm{LO}}{=} \int_{-1}^{1} dx \left[\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon}\right] H^q(x,\xi,t,\mu^2)\Big|_{\xi = x_{\mathrm{B}}/(2-x_{\mathrm{B}})}.$$

$$\mathcal{H}^{G}(x_{\mathrm{B}}, t, \mu^2) \stackrel{\mathrm{LO}}{=} \int_{-1}^{1} dx\, \frac{1}{2x} \left[\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon}\right] H^G(x,\xi,t,\mu^2)\Big|_{\xi = x_{\mathrm{B}}/(2-x_{\mathrm{B}})}$$

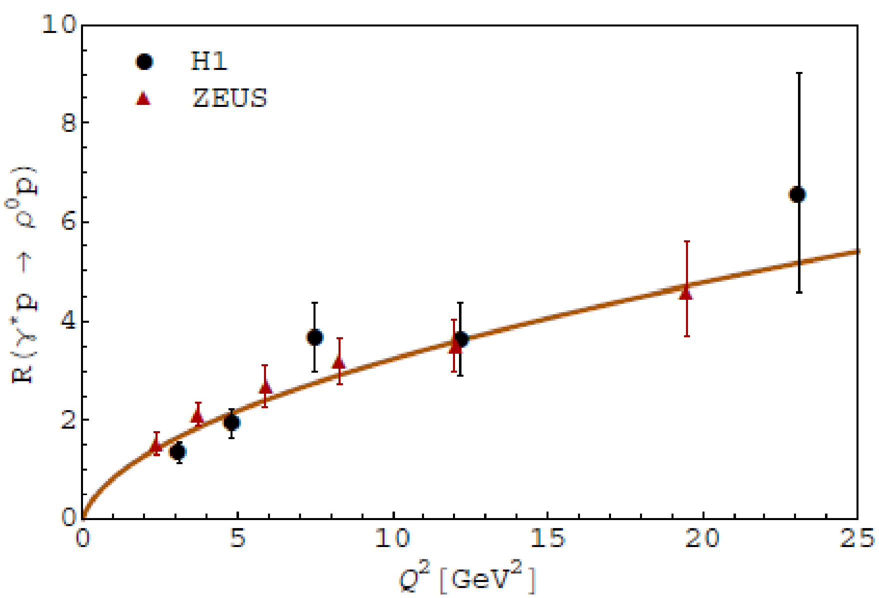
Cross sections and R-ratio

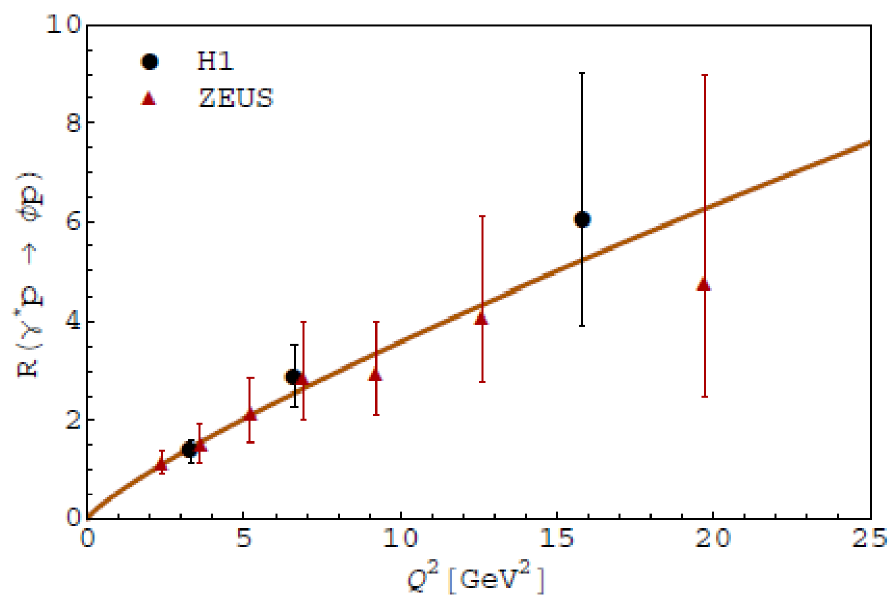
most of H1/ZEUS measurements are given for integrated cross section

$$\sigma(W,Q^2) = \left[\varepsilon(W,Q^2) + \frac{1}{R^{\rm exp}(Q^2)}\right]\int_{|t_{\rm min}|}^{|t_{\rm cut}|} dt\, \frac{d\sigma_{\rm L}(x_{\rm B},t,Q^2)}{dt} \qquad |t_{\rm cut}| < Q^2$$

R-ratio is extracted via s-channel helicity conservation hypothesis
it is assumed to be independent on *W* and *t* *(is not be entirely true)*

$$R^{\rm exp}(Q^2) = \frac{Q^2/m_V^2}{(1+aQ^2/m_V^2)^p} \quad \text{with} \quad \left\{\begin{array}{ll} a=2.2\,, & p=0.451 \\ a=25.4\,, & p=0.180 \end{array}\right\} \quad \text{for} \quad \left\{\begin{array}{c}\rho^0 \\ \phi\end{array}\right\}$$



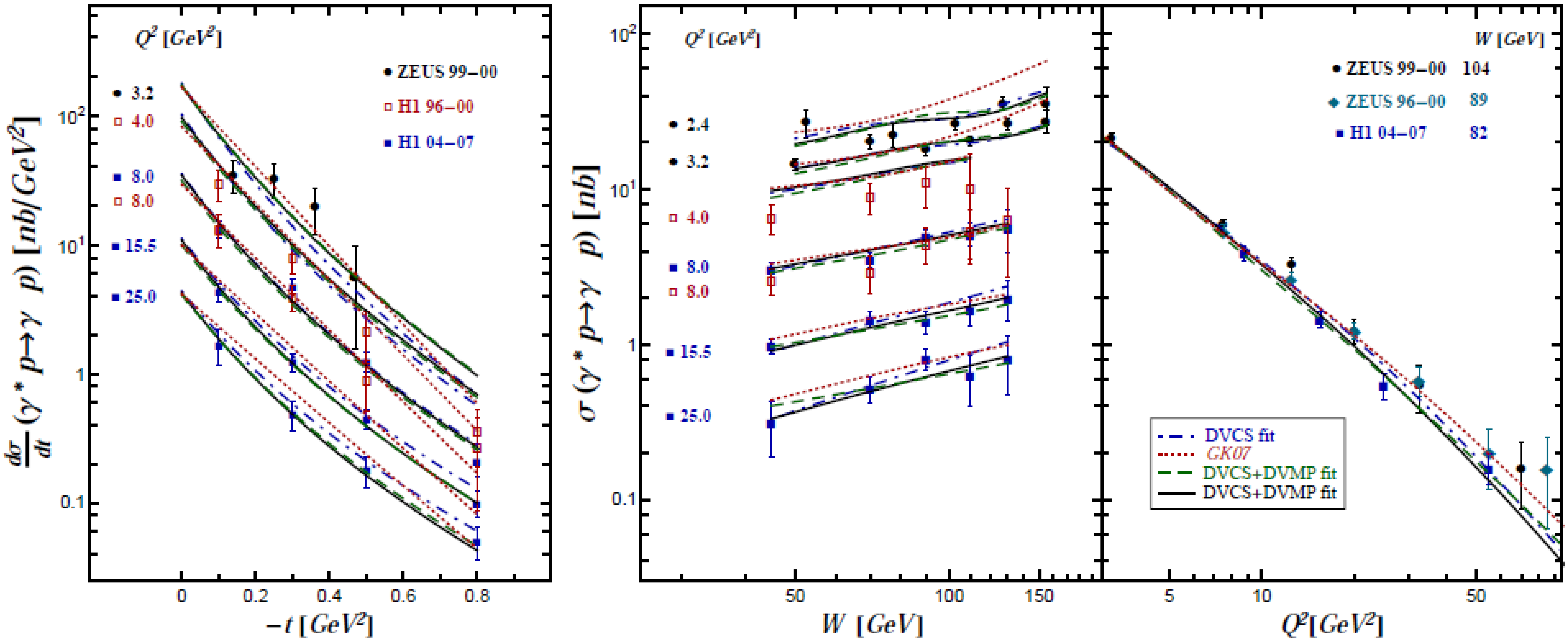


DVCS+DVMP fit to H1/ZEUS data

strategies: pure DVCS fit χ^2/d.o.f. = 130/(126-3)
DVCS + H1 DVMP fit χ^2/d.o.f. = 342/(230-6)
DVCS + H1/ZEUS DVMP fit -very soft gluon χ^2/d.o.f. = 618/(304-7)
confronting GK07 model with DVCS (χ^2/n.o.p. = 226/126)

R and normalization errors are not taken into account, cut Q^2 > 4 GeV^2 for DVMP data

DVCS data dominated by quark GPD
gluon GPD is to some extend not pinned down

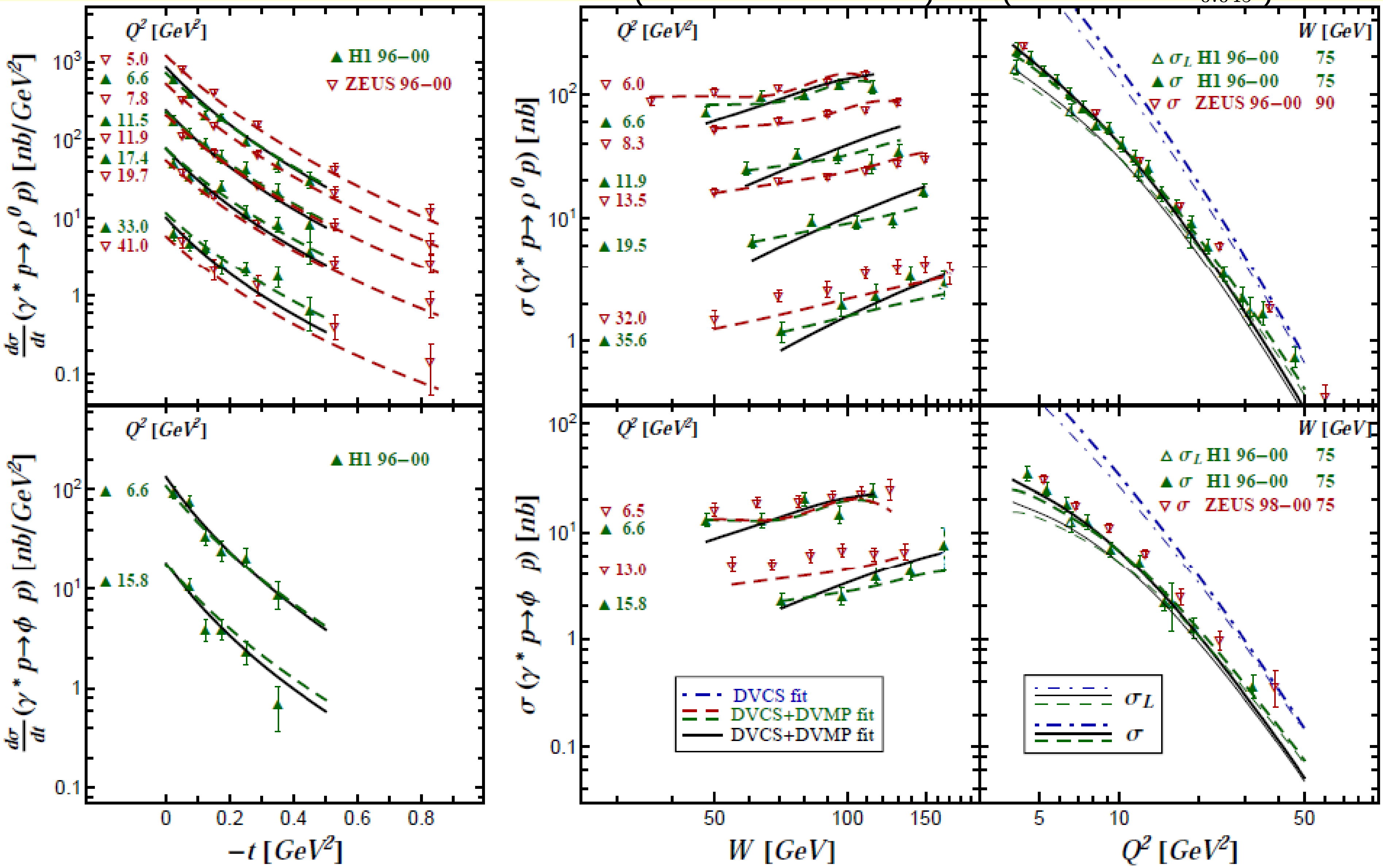


H1 and ZEUS DVMP data

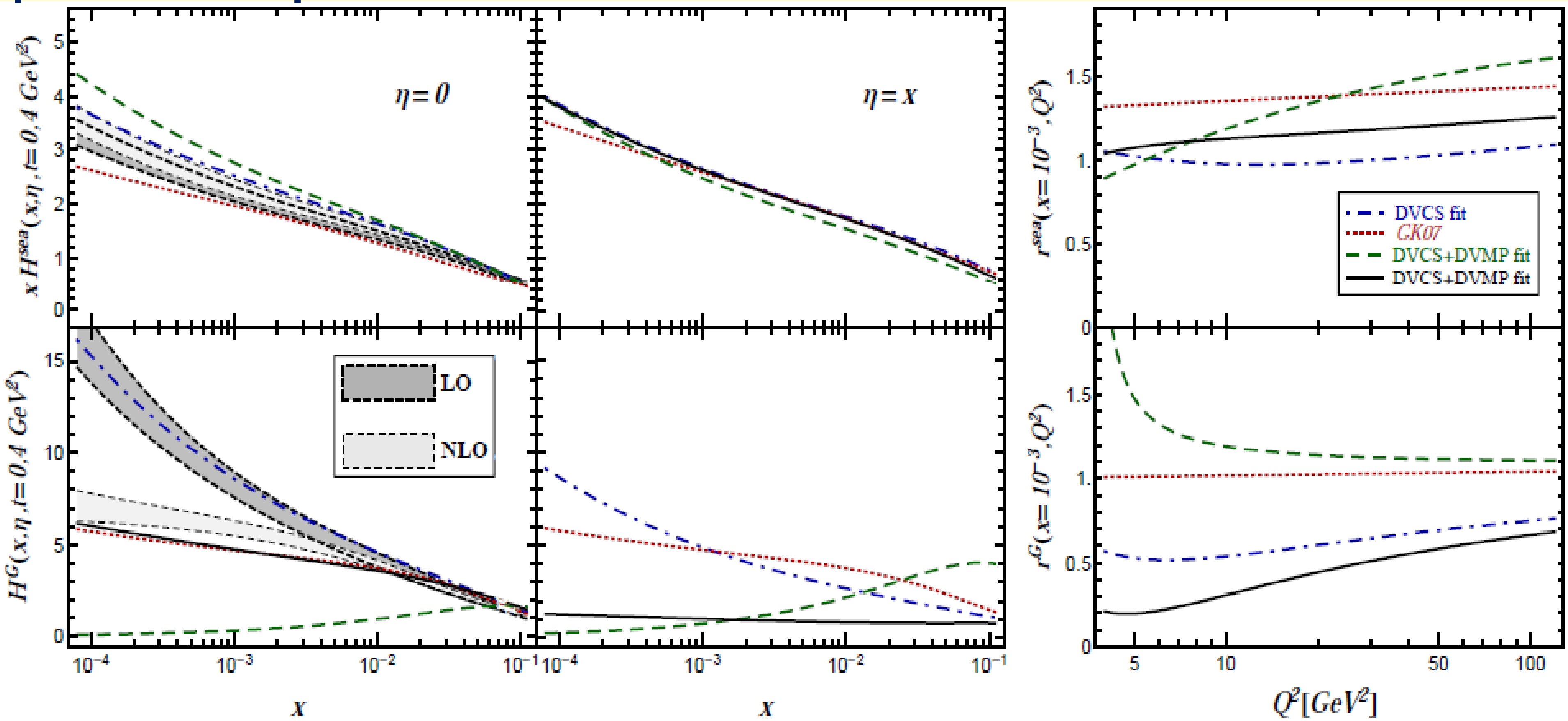
are compatible
however, there are differences

$$\left\{\begin{matrix} b^{\rm H1}(\mathcal{Q}^2 = 11.5\,{\rm GeV}^2) \\ b^{\rm ZEUS}(\mathcal{Q}^2 = 11\,{\rm GeV}^2) \end{matrix}\right\} = \left\{\begin{matrix} 6.72 \pm 0.53\ {}^{+0.23}_{-0.25} \\ 5.7\ \ \pm 0.5\ \ {}^{+0.2}_{-0.2} \end{matrix}\right\} /{\rm GeV}^2,$$

$$\left\{\begin{matrix} \delta^{\rm H1}(\mathcal{Q}^2 = 6.6\,{\rm GeV}^2) \\ \delta^{\rm ZEUS}(\mathcal{Q}^2 = 6\,{\rm GeV}^2) \end{matrix}\right\} = \left\{\begin{matrix} 0.57 \pm 0.10\ \ {}^{+0.05}_{-0.07} \\ 0.4\ \ \pm 0.052\ {}^{+0.048}_{-0.045} \end{matrix}\right\},$$



partonic interpretation



r^{sea}~1 (small skewness effect at LO) of sea quarks are driven by DVCS data

$r^G < 1$ gluon GPD is suppressed at LO

very soft gluon GPD is disfavored by DIS fit

GK07 model is based on NLO PDFs [(very) good DVCS description at LO]
interchange of skewing and evolution provides a very desired GPD behavior
remember Freund/McDermott could not reach DVCS description @LO with similar model

Conclusions

❖ LO fit to DVCS and DVMP works reasonably at small x_B

❖ contradicts common wisdoms

- exclusive physics in H1/ZEUS kinematics is dominated by gluons
- onset of perturbation regime is at $\sim 15\ GeV^2$ or so

❖ GPD interpretation for $Q^2 > 4\ GeV^2$ states that

- quark exchanges at small x_B are more important as thought
- gluons in off-forward kinematics are suppressed

❖ NLO corrections are available in conformal moment space

- to be implemented in NLO fitting routines to DVCS and DVMP
- lets see what comes out

❖ another partonic GPD interpretation arises in GK framework