Dipole model analysis of $F_2^{c\bar{c}}$ and PDFs from the new HERA data

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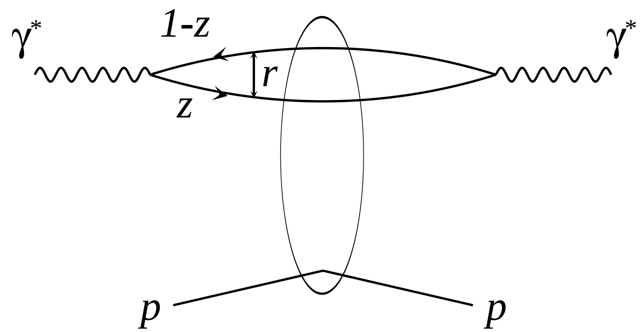
Outline

Motivation : Investigation of the gluon density with dipole model, as an alternative to the PDF approach. Prefered choice : BGK dipole model, which has very similar physics interpretation as PDFs, i.e. DGLAP evolution in the kt factorization scheme (in contrast to the collinear factorization for PDFs).

- Dipole model approach
- GBW and BGK parametrization of dipole cross section
- Results of the fits
  - Fits to $F_2^{c\bar{c}}$ function
  - Fits to σ_r with different valence quarks contributions
  - Fits to σ_r from HERAFitter package
- Conclusions

Dipole model of DIS

- Dipole picture of DIS at small x in the proton rest frame



r - dipole size

z - longitudinal momentum fraction of the quark/antiquark

- Factorization: dipole formation + dipole interaction

$$\sigma^{\gamma p} = \frac{4\pi^2 \alpha_{em}}{Q^2} F_2 = \sum_f \int d^2 r \int_0^1 dz \, |\Psi^\gamma(r, z, Q^2, m_f)|^2 \;\; \hat{\sigma}(r, x)$$

- Dipole-proton interaction

$$\hat{\sigma}(r, x) = \sigma_0 \left(1 - \exp\{-\hat{r}^2\}\right) \qquad \hat{r} = r/R_s(x)$$

Dipole cross section with GBW parametrization

- GBW (Golec-Biernat, Wüsthoff) parametrization

$$\hat{\sigma}(r,x) = \sigma_0 \left(1 - \exp(-r^2/R_s^2)\right), \qquad R_s^2 = 4 \cdot (x/x_0)^{\lambda} \text{ GeV}^2$$

- The dipole scattering amplitude in such a case reads

$$\hat{N}(\mathbf{r},\mathbf{b},x) = \theta(b_0 - b)\left(1 - \exp(-r^2/R_s^2)\right)$$

where

$$\hat{\sigma}(r,x) = 2\int d^2b\, \hat{N}(\mathbf{r},\mathbf{b},x)$$

- Parameters b_0, x_0 and λ from fits of $\hat{N}$ to F_2 data

$$\lambda = 0.288 \qquad x_0 = 4 \cdot 10^{-5} \qquad 2\pi b_0^2 = \sigma_0 = 29 \text{ mb}$$

Dipole cross section with BGK parametrization

- BGK (Bartels-Golec-Kowalski) parametrization

$$\hat{\sigma}(r,x) = \sigma_0 \left\{1 - \exp\left[-\pi^2 r^2 \alpha_s(\mu^2) xg(x,\mu^2)/(3\sigma_0)\right]\right\}$$

- R_s^2 is replacing by a gluon density with explicit DGLAP evolution
- $\mu^2 = C/r^2 + \mu_0^2$ is the scale of the gluon density
- gluon density is evolved according to the (LO) DGLAP equation

$$xg(x,\mu_0^2) = A_g\, x^{-\lambda_g}\, (1-x)^{C_g}$$

Structure functions in dipole models

- The $q\bar{q}$ components from T and L polarised photons are given by

$$F_T^{(q\bar{q})} = \frac{3Q^4}{64\pi^4} \sum_f e_f^2 \int_{z_f}^{1/2} dz\, z(1-z) \times \left\{ [z^2 + (1-z)^2]\, Q_f^2\, \phi_1^2 + m_f^2\, \phi_0^2 \right\}$$

$$F_L^{(q\bar{q})} = \frac{3Q^6}{16\pi^4} \sum_f e_f^2 \int_{z_f}^{1/2} dz\, z^3(1-z)^3\, \phi_0^2$$

- The functions ϕ_i take the following form for $i = 0, 1$

$$\phi_i = \int_0^\infty dr\, r\, K_i(Q_f r)\, J_i(k_f r)\, \hat{\sigma}(r, x)$$

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$$x = \frac{Q^2}{Q^2 + W^2}$$

Charm structure functions in dipole models

- Standard dipole model formula with $m_c = 1.4\ \mathrm{GeV}$ and $e_c = 2/3$

$$F_T^{(c\bar{c})} = \frac{3Q^4 e_c^2}{64\pi^4} \int_{z_c}^{1/2} dz\, z(1-z)$$
$$\times \quad \{[z^2 + (1-z)^2]\, Q_c^2\, \phi_1^2 + m_c^2\, \phi_0^2\}$$

with $z_c = (1 - \sqrt{1 - 4m_c^2/M^2})/2$

- For the heavy quark contributions we modyfied x in $\hat{\sigma}(r, x)$

$$x \rightarrow x(1 + \frac{4m_f^2}{Q^2}) = \frac{Q^2 + 4m_f^2}{Q^2 + W^2}$$

Results of the Fits

- Dipole model BGK fit with charm quark contribution

1.1 Pure dipole fit for σ_r with m_{ch} =1.3 GeV, m_{ud}= 0.03 GeV, E = 460, 575 and 920 GeV .

No	Data	Q^2	Npoints	χ^2	A_g	λ_g	μ_0	$\chi^2/Npoints$
1	H1 and ZEUS	$Q^2 \geq 0.25$	483	754.81	3.089	-0.059	0.959	1.56
2	H1 and ZEUS	$Q^2 \geq 1.5$	402	402.27	2.276	0.062	1.719	1.0
3	H1 and ZEUS	$Q^2 \geq 3.5$	356	343.02	2.159	0.085	2.016	0.96
4	H1 and ZEUS	$Q^2 \geq 8.5$	287	229.79	2.147	0.085	1.99	0.80

1.2 Pure dipole fit for σ_r with m_{ch} =1.4 GeV, m_{ud}= 0.03 GeV, E = 460, 575 and 920 GeV .

No	Data	Q^2	Npoints	χ^2	A_g	λ_g	μ_0	$\chi^2/Npoints$
1	H1 and ZEUS	$Q^2 \geq 0.25$	483	769.43	3.130	-0.059	0.954	1.59
2	H1 and ZEUS	$Q^2 \geq 1.5$	402	401.36	2.281	0.065	1.723	0.99
3	H1 and ZEUS	$Q^2 \geq 3.5$	356	344.27	2.175	0.086	1.994	0.97
4	H1 and ZEUS	$Q^2 \geq 8.5$	287	229.76	2.167	0.084	1.944	0.80

Results of the Fits

- Dipole model BGK fit for $F_2^{c\bar{c}}$

1.7 Charm fit for $F_2^{c\bar{c}}$ function,
m_{ch} =1.4 GeV, m_{ud}= 0.03 GeV.

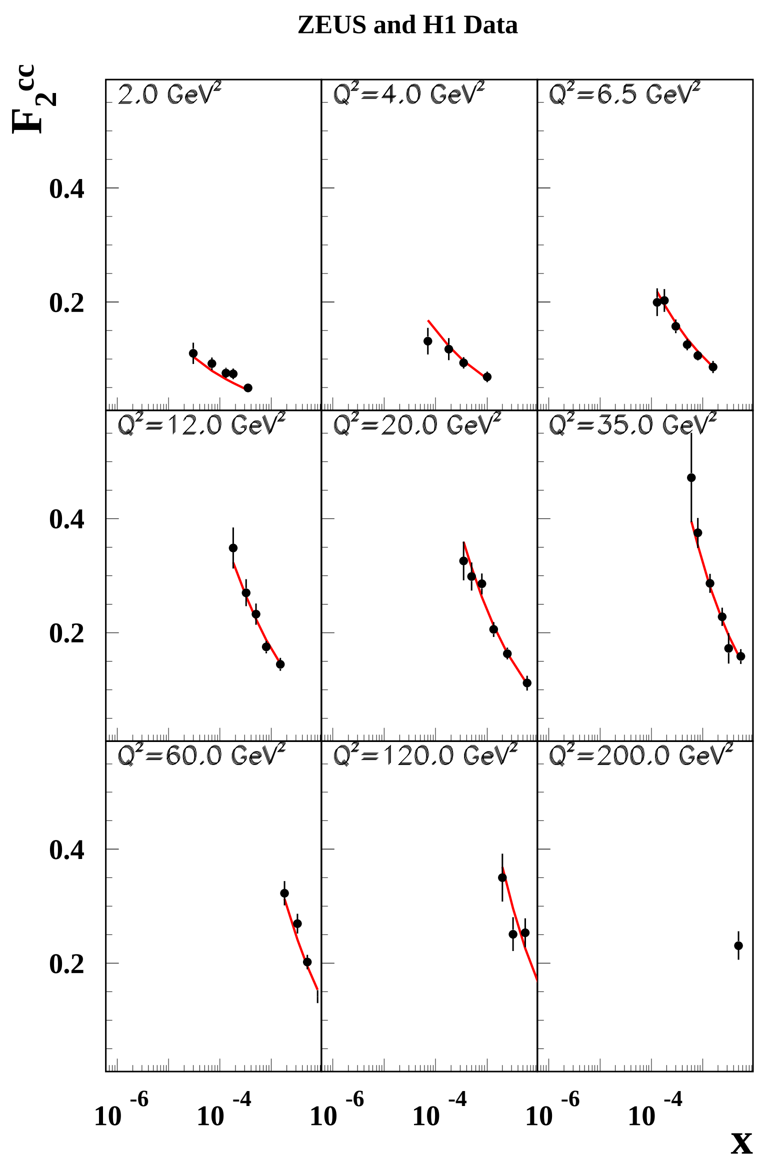
No	Data	Q^2	Npoints	χ^2	A_g	λ_g	μ_0	$\chi^2/Npoints$
1	H1 and ZEUS	$Q^2 \geq 2.5$	41	32.36	4.917	-0.349	0.415	0.89

1.8 Charm fit for $F_2^{c\bar{c}}$ function,
m_{ch} =1.3 GeV, m_{ud}= 0.03 GeV.

No	Data	Q^2	Npoints	χ^2	A_g	λ_g	μ_0	$\chi^2/Npoints$
1	H1 and ZEUS	$Q^2 \geq 2.5$	41	31.17	5.117	-0.231	0.221	0.93

Results of the Fits

- Predictions for $F_2^{c\bar{c}}$ from fits



Results of the Fits

- Dipole model BGK fit with different valence quarks contributions

1.4 Dipole fit with HERAPDF valence - quark contribution added to σ_r, m_{ch} =1.4 GeV, m_{ud}= 0.03 GeV, E = 820, 920 GeV.

No	Data	Q^2	Npoints	χ^2	A_g	λ_g	μ_0	$\chi^2/Npoints$
1	H1 and ZEUS	$Q^2 \geq 3.5$	177	229.93	1.446	0.109	1.341	1.29
2	H1 and ZEUS	$Q^2 \geq 8.5$	138	155.54	1.469	0.101	1.264	1.12

1.6 Dipole fit with MSTW valence - quark contribution added to σ_r, m_{ch} =1.4 GeV, m_{ud}= 0.03 GeV, E = 820, 920 GeV.

No	Data	Q^2	Npoints	χ^2	A_g	λ_g	μ_0	$\chi^2/Npoints$
1	H1 and ZEUS	$Q^2 \geq 3.5$	177	281.06	2.602	-0.050	0.785	1.58
2	H1 and ZEUS	$Q^2 \geq 8.5$	138	208.48	2.599	-0.050	0.785	1.51

Results of the Fits from HERAFitter package

- Dipole model BGK fit without valence quarks

1.1 Dipole model BGK fit without valence quarks for σ_r for H1ZEUS-NC-(e+p) and H1ZEUS-NC-(e-p) data in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 0.01$.

No	Q^2	HF Scheme	σ_0	A_g	λ_g	$cBGK$	$eBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	40.43	1.596	-0.249	1.529	0.401	197	214.46	1.10
2	$Q^2 \geq 3.5$	ACOT Full	40.43	1.596	-0.249	1.529	0.401	197	214.46	1.10
3	$Q^2 \geq 8.5$	RT	32.48	1.691	-0.256	1.463	0.155	156	125.10	0.80
4	$Q^2 \geq 8.5$	ACOT Full	32.48	1.691	-0.256	1.463	0.155	156	125.10	0.80

1.2 Dipole model BGK fit without valence quarks for σ_r for H1ZEUS-NC-(e+p) and H1ZEUS-NC-(e-p) and H1-LowEp-460-575 data in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 0.01$.

No	Q^2	HF Scheme	σ_0	A_g	λ_g	$cBGK$	$eBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	38.67	1.593	-0.254	1.336	0.349	318	365.19	1.15
2	$Q^2 \geq 3.5$	ACOT Full	38.67	1.593	-0.254	1.336	0.349	318	365.19	1.15
3	$Q^2 \geq 8.5$	RT	31.47	1.74	-0.255	1.556	-0.542	249	224.48	0.90
4	$Q^2 \geq 8.5$	ACOT Full	31.47	1.74	-0.255	1.556	-0.542	249	224.48	0.90

Results of the Fits from HERAFitter

- HERAPDF fit with valence quarks

1.3 HERAPDF fit with valence quarks for σ_r for H1ZEUS-NC-(e+p), H1ZEUS-NC-(e-p) data in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 1.0$.

No	Q^2	HF Scheme	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	511	518.06	1.01
2	$Q^2 \geq 3.5$	ACOT Full	511	501.67	0.98
3	$Q^2 \geq 8.5$	RT	469	414.70	0.88
4	$Q^2 \geq 8.5$	ACOT Full	469	416.66	0.88

1.4 HERAPDF fit with valence quarks for σ_r for H1ZEUS-NC-(e+p), H1ZEUS-NC-(e-p) data in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 0.01$.

No	Q^2	HF Scheme	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	197	220.64	1.12
2	$Q^2 \geq 3.5$	ACOT Full	197	206.85	1.05
3	$Q^2 \geq 8.5$	RT	156	131.04	0.84
4	$Q^2 \geq 8.5$	ACOT Full	156	131.04	0.84

Results of the Fits from HERAFitter

- HERAPDF fit with valence quarks

1.5 HERAPDF fit with valence quarks for σ_r for H1ZEUS-NC-(e+p), H1ZEUS-NC-(e-p) H1ZEUS-CC-(e-p), H1ZEUS-CC-(e+p)data in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 1.0$.

No	Q^2	HF Scheme	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	579	575.08	0.99
2	$Q^2 \geq 3.5$	ACOT Full	579	560.01	0.97
3	$Q^2 \geq 8.5$	RT	537	468.34	0.87
4	$Q^2 \geq 8.5$	ACOT Full	537	474.78	0.88

1.6 Parameters are taken from fit nb.(1.5) in all region of x. Results with valence quarks for σ_r for H1ZEUS-NC-(e+p), H1ZEUS-NC-(e-p), H1ZEUS-CC-(e-p), H1ZEUS-CC-(e+p) data in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 0.01$.

No	Q^2	HF Scheme	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	256	270.75	1.06
2	$Q^2 \geq 3.5$	ACOT Full	256	327.58	1.28
3	$Q^2 \geq 8.5$	RT	217	193.31	0.89
4	$Q^2 \geq 8.5$	ACOT Full	217	200.08	0.92

Results of the Fits from HERAFitter

- HERAPDF fit with valence quarks

1.7 HERAPDF fit with valence quarks for σ_r for H1ZEUS-NC-(e+p), H1ZEUS-NC-(e-p), H1ZEUS-CC-(e-p), H1ZEUS-CC-(e+p) data and H1-LowEp-460-575 data in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 1.0$.

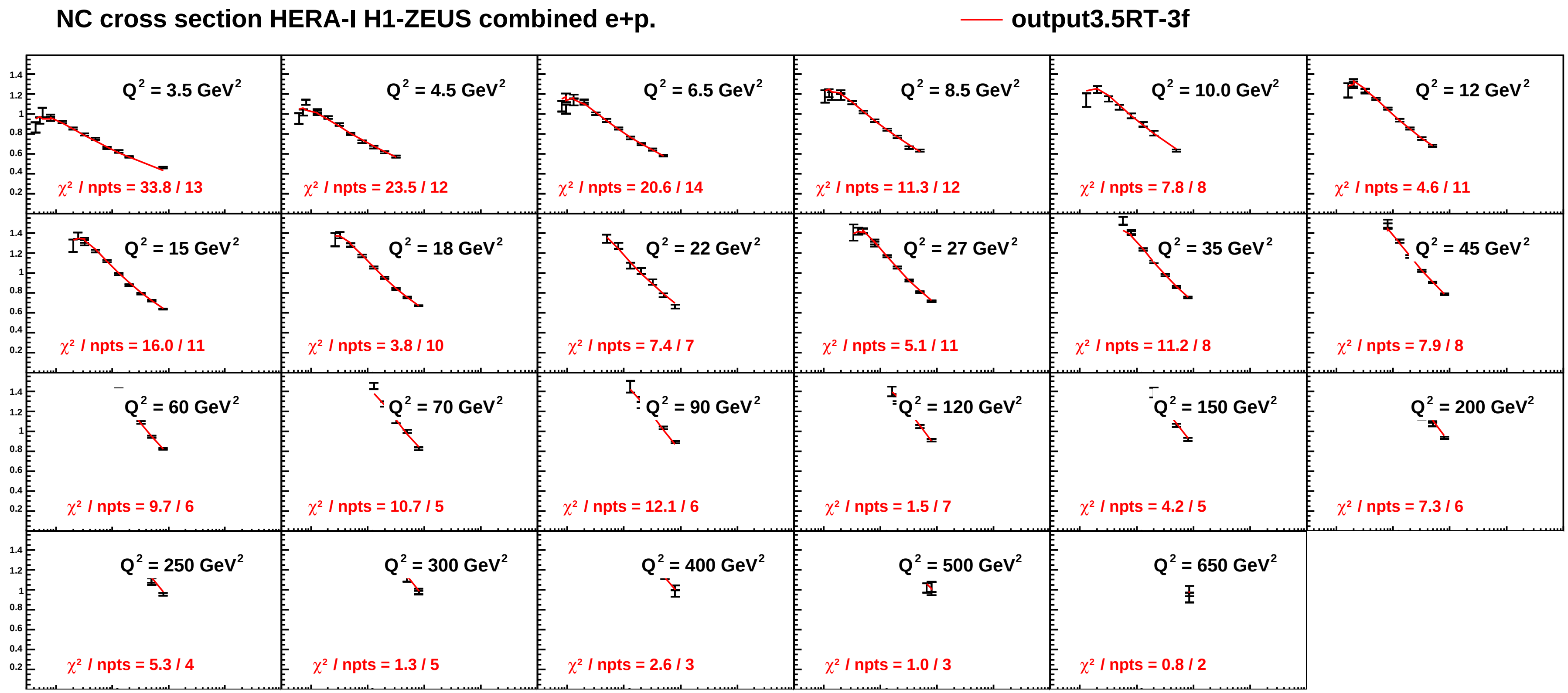
No	Q^2	HF Scheme	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	703	749.92	1.07
2	$Q^2 \geq 3.5$	ACOT Full	703	704.44	1.00
3	$Q^2 \geq 8.5$	RT	631	574.62	0.91
4	$Q^2 \geq 8.5$	ACOT Full	631	567.90	0.90

- Dipole model BGK fit with valence quarks

1.8 Dipole model BGK fit with valence quarks for σ_r for H1ZEUS-NC-(e+p) in the range $Q^2 \geq 3.5$ and $Q^2 \geq 8.5$ and $x \leq 0.01$.

No	Q^2	HF Scheme	σ_0	A_g	λ_g	$cBGK$	$eBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT	37.401	3.345	0.030	28.60	31.68	171	232.53	1.36
2	$Q^2 \geq 3.5$	ACOT Full	37.49	3.393	0.042	32.65	36.46	171	233.82	1.37

Comparison with HERA data



Summary

- BGK dipole model describe reasonable well the recent data from HERA for σ_r and $F_2^{c\bar{c}}$ function derived from D^* mesons.
- The treatment of the effects related to the charm quark contribution, is an important issue in the determination of parton distribution functions (PDFs).
- The valence quarks contributions in the region of small $x < 0.01$ needs refinement.
- Work in progress on BGK dipole model with valence quarks.