Dipole model BGK analysis of the new HERA I+II data

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Introduction

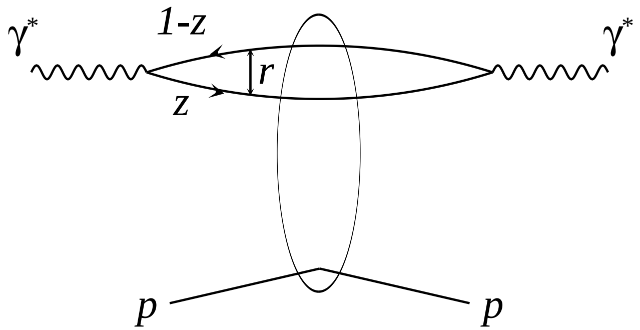
- Motivation: Investigation of the gluon density with BGK dipole model, as an alternative to the PDF approach. BGK dipole model, uses a very similar evolution scheme as PDFs, i.e. DGLAP evolution in the kt factorization scheme (in contrast to the collinear factorization for PDFs).
- The analysis was done in the xFitter framework.

Outline

- Dipole model approach.
- GBW and BGK parametrization of dipole cross section.
- Results of the fits from BGK dipole model
- Comparision with HERA data.
- Predictions for FL function.
- Summary.

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

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

- Dipole-proton interaction

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

Dipole cross section

- BGK (Bartels-Golec-Kowalski) parametrization

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

- $\mu^2 = C/r^2 + \mu_0^2$ is the scale of the gluon density
- μ_0^2 is a starting scale of the QCD evolution. $\mu_0^2 = Q_0^2$
- gluon density is evolved according to the LO or NLO DGLAP eq.
- soft gluon:

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

- soft + hard gluon:

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

- soft + negative gluon:

$$xg(x,\mu_0^2) = A_g\, x^{\lambda_g}\, (1-x)^{C_g} - A'_g\, x^{\lambda'_g}\, (1-x)^{C'_g}$$

Results of the Fits

- Dipole model BGK fit with and without valence quarks

1.1 BGK NLO fit with valence quarks for σ_r for HERA1+2-NCep-460, HERA1+2-NCep-575, HERA1+2-NCep-820, HERA1+2-NCep-920 and HERA1+2-NCem in the range $Q^2 \geq 3.5$ GeV^2 and $Q^2 \geq 8.5$ and $x \leq 0.01$. *Soft gluon.*

No	Q^2	HF Scheme	σ_0	A_g	λ_g	Cg	$cBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT OPT	85.111	1.857	-0.12596	11.339	4.0	568	605.29	1.07
2	$Q^2 \geq 8.5$	RT OPT	72.451	2.015	-0.1185	12.682	4.0	482	495.44	1.03

1.2 BGK NLO fit without valence quarks for σ_r for HERA1+2-NCep-460, HERA1+2-NCep-575, HERA1+2-NCep-820, HERA1+2-NCep-920 and HERA1+2-NCem in the range $Q^2 \geq 3.5$ GeV^2 and $Q^2 \geq 8.5$ and $x \leq 0.01$. *Soft gluon.*

No	Q^2	HF Scheme	σ_0	A_g	λ_g	Cg	$cBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT OPT	85.111	2.075	-0.093	4.989	4.0	568	592.46	1.04
2	$Q^2 \geq 8.5$	RT OPT	123.31	1.997	-0.0975	4.655	4.0	482	479.37	0.99

Results of the Fits

- Dipole model BGK fit with fitted valence quarks

1.3 BGK NLO fit with fitted valence quarks for σ_r for HERA1+2-NCep-460, HERA1+2-NCep-575, HERA1+2-NCep-820, HERA1+2-NCep-920 and HERA1+2-NCem in the range $Q^2 \geq 3.5$ GeV^2 and $Q^2 \geq 8.5$ and $x \leq 0.01$. *Soft gluon.*

No	Q^2	HF Scheme	σ_0	A_g	λ_g	Cg	$cBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	RT OPT	85.111	1.921	-0.103	4.674	4.0	557	575.30	1.03
2	$Q^2 \geq 8.5$	RT OPT	93.581	1.665	-0.124	6.066	4.0	473	476.71	1.01

- HERAPDF fit with fitted valence quarks

1.4 HERAPDF NLO fit with fitted valence quarks for σ_r for HERA1+2-NCep-460, HERA1+2-NCep-575 HERA1+2-NCep-820, HERA1+2-NCep-920, HERA1+2-NCem, HERA1+2-CCep and HERA1+2-CCem 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	1131	1356.70	1.20
2	$Q^2 \geq 8.5$	RT	456	470.88	1.15

Results of the Fits

- $m_{u,d,s} = 140\ MeV$, $m_c = 1.3\ GeV$
- $\hat{\sigma}(r,x) = \sigma_0 \left\{1 - \exp\left[-\pi^2 r^2 \alpha_s(\mu^2) x g(x,\mu^2)/(3\sigma_0)\right]\right\}$ with saturation

1.1 **BGK NLO fit without valence quarks for σ_r for HERA1+2-NCep-460, HERA1+2-NCep-575, HERA1+2-NCep-820, HERA1+2-NCep-920 and HERA1+2-NCem in the range $Q^2 \geq 3.5$ GeV^2 and $x \leq 0.01$.** *Soft gluon.*

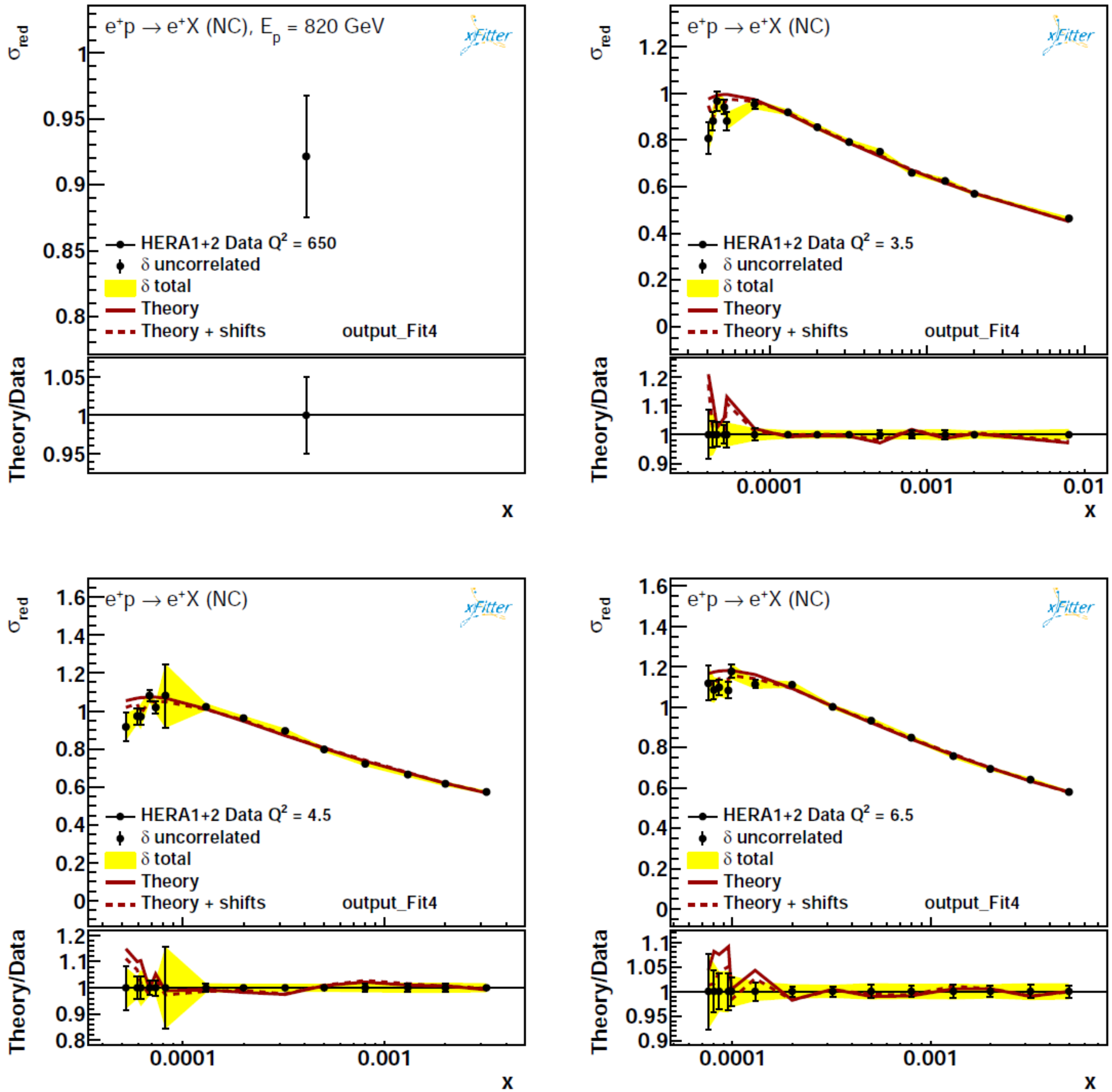
No	Q^2	$Q_0 = eBGK$	σ_0	A_g	λ_g	Cg	$cBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	$Q_0 = 1.1$	0.143E+07	2.3921	0.0137	4.3512	4.0	535	540.54	1.01
2	$Q^2 \geq 3.5$	$Q_0 = 1.5$	474.14	2.4536	-0.0354	5.7561	4.0	535	545.63	1.02
3	$Q^2 \geq 3.5$	$Q_0 = 1.9$	270.16	2.4788	-0.0663	6.9093	4.0	535	567.10	1.06

- $\hat{\sigma}(r,x) = \sigma_0 \left[\pi^2 r^2 \alpha_s(\mu^2) x g(x,\mu^2)/(3\sigma_0)\right]$ without saturation

2.1 **BGK NLO fit without valence quarks for σ_r for HERA1+2-NCep-460, HERA1+2-NCep-575, HERA1+2-NCep-820, HERA1+2-NCep-920 and HERA1+2-NCem in the range $Q^2 \geq 3.5$ GeV^2 and $x \leq 0.01$.** *Soft gluon.*

No	Q^2	$Q_0 = eBGK$	σ_0	A_g	λ_g	Cg	$cBGK$	Np	χ^2	χ^2/Np
1	$Q^2 \geq 3.5$	$Q_0 = 1.1$	118.34	2.3918	0.0137	4.3505	4.0	535	540.53	1.01
2	$Q^2 \geq 3.5$	$Q_0 = 1.5$	118.34	2.1287	-0.0441	4.3064	4.0	535	568.78	1.06
3	$Q^2 \geq 3.5$	$Q_0 = 1.9$	118.34	2.0861	-0.0721	4.6379	4.0	535	632.78	1.18

Comparision with HERAI+II data



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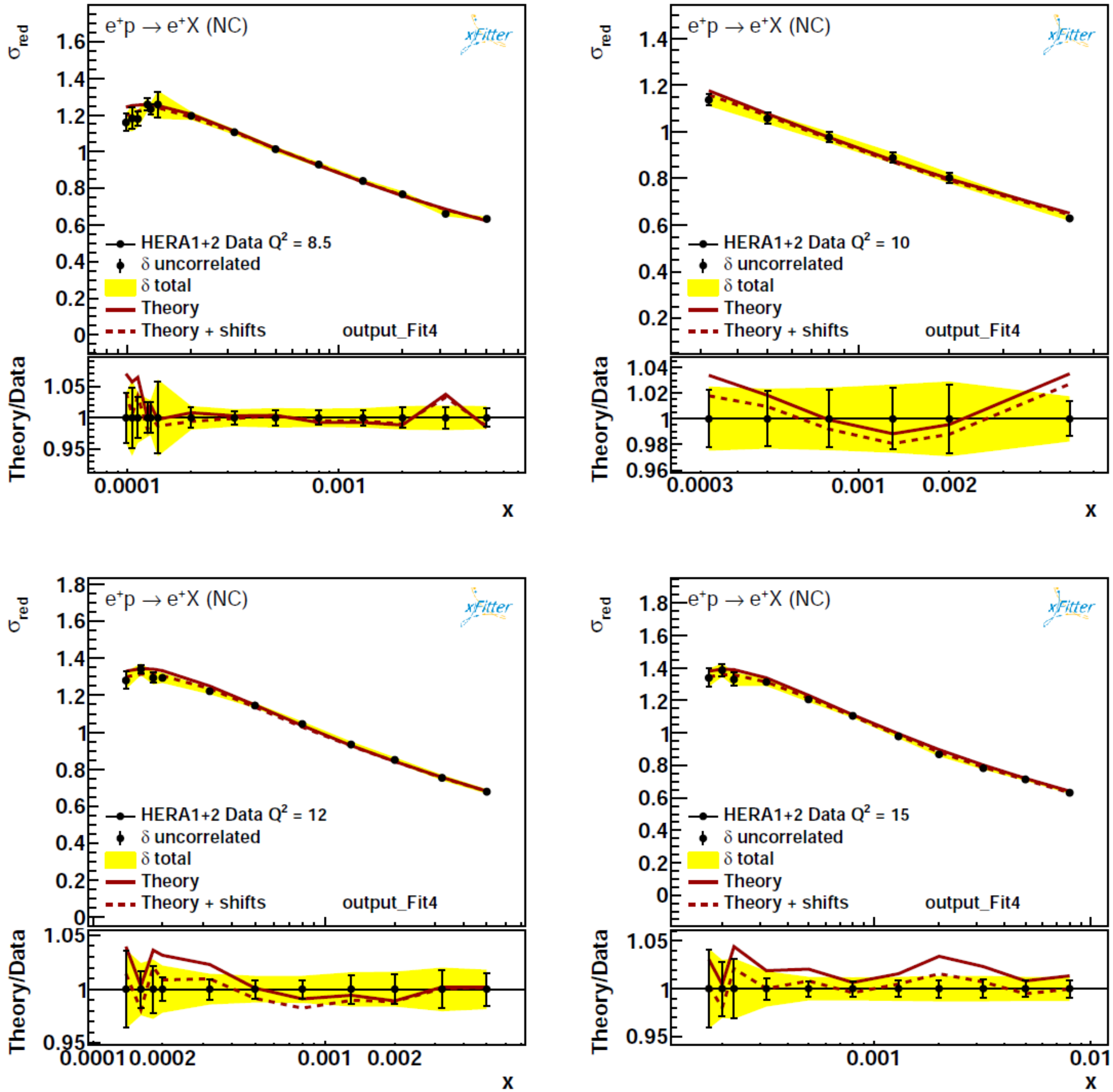

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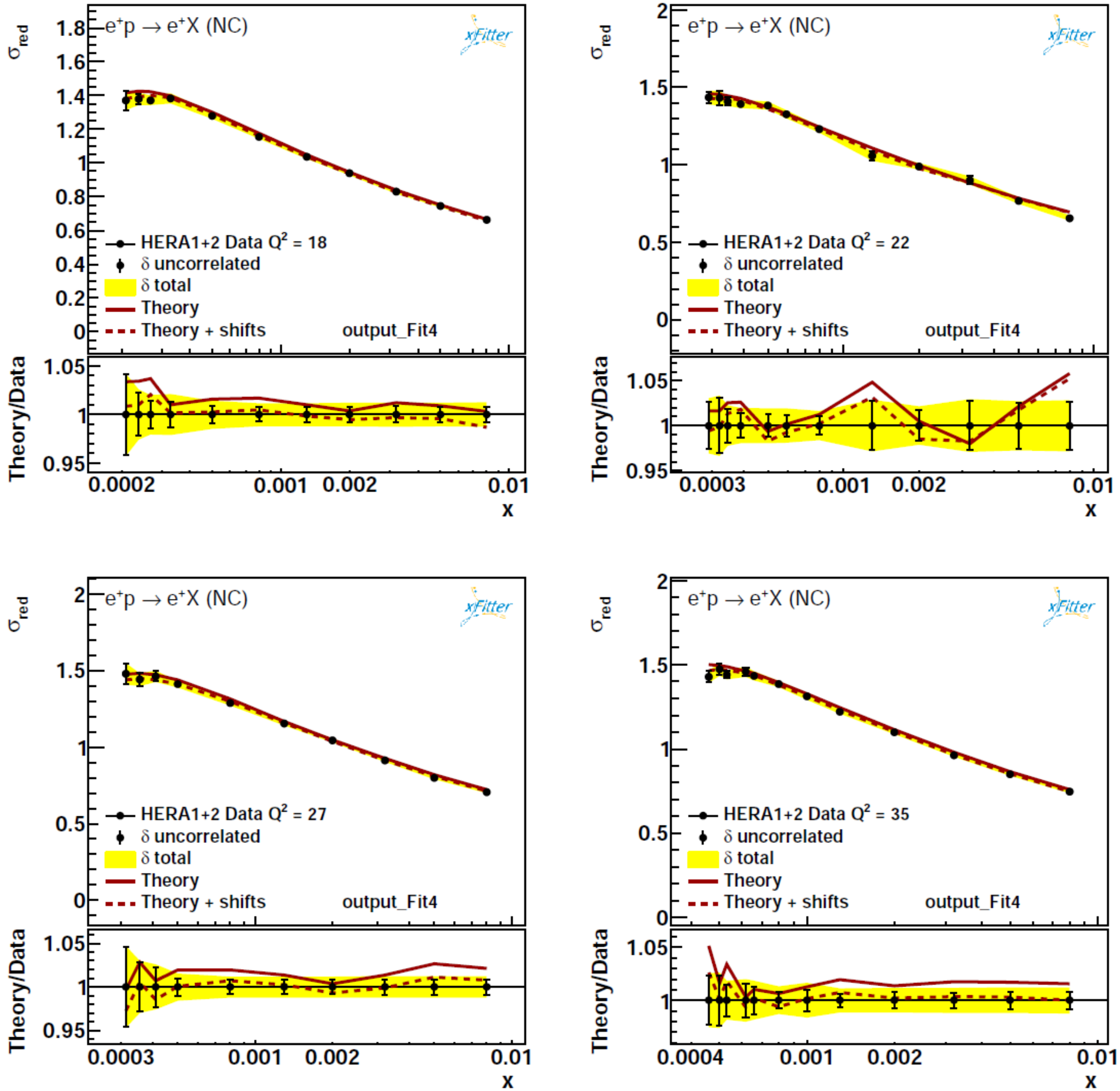
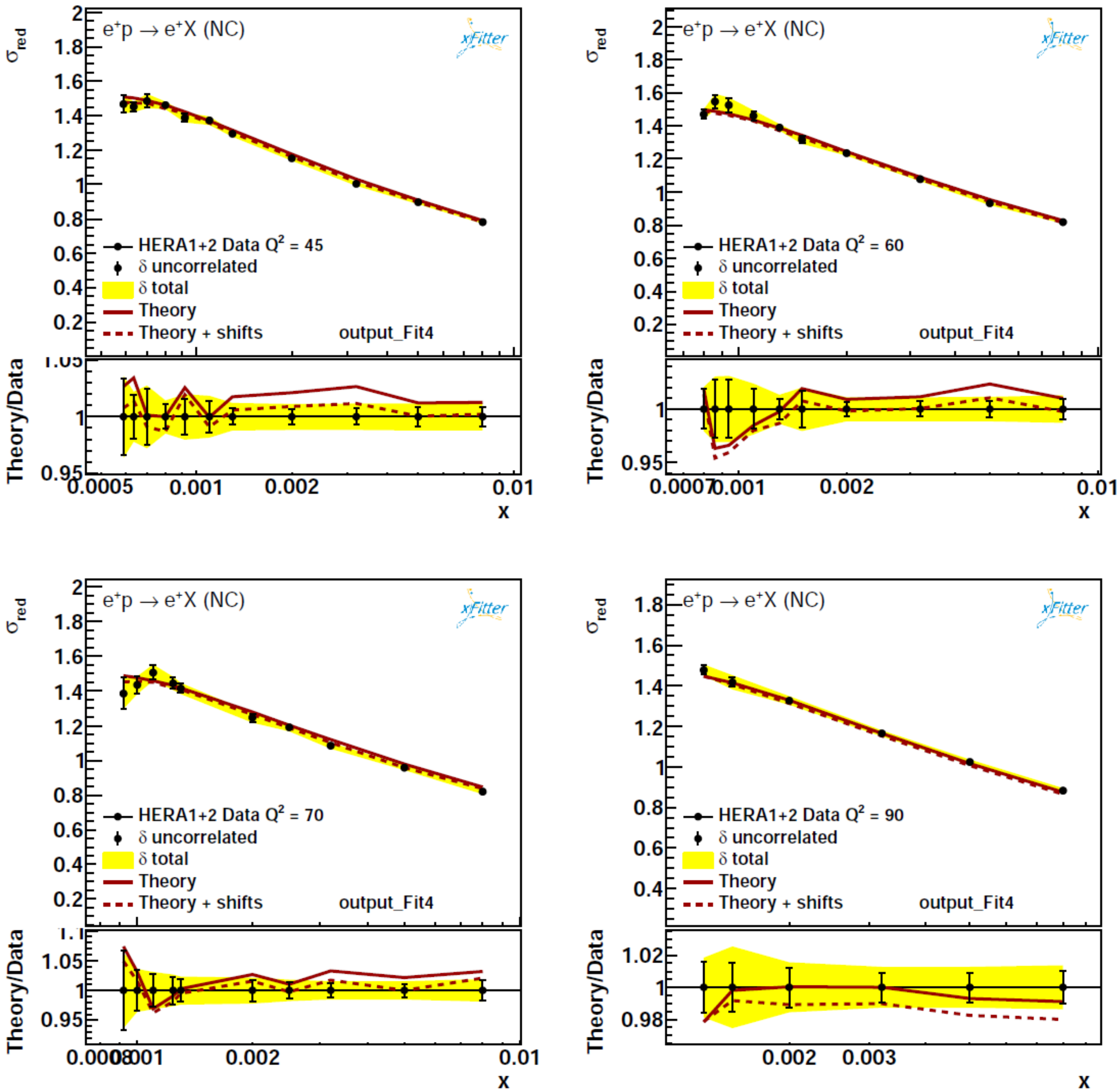
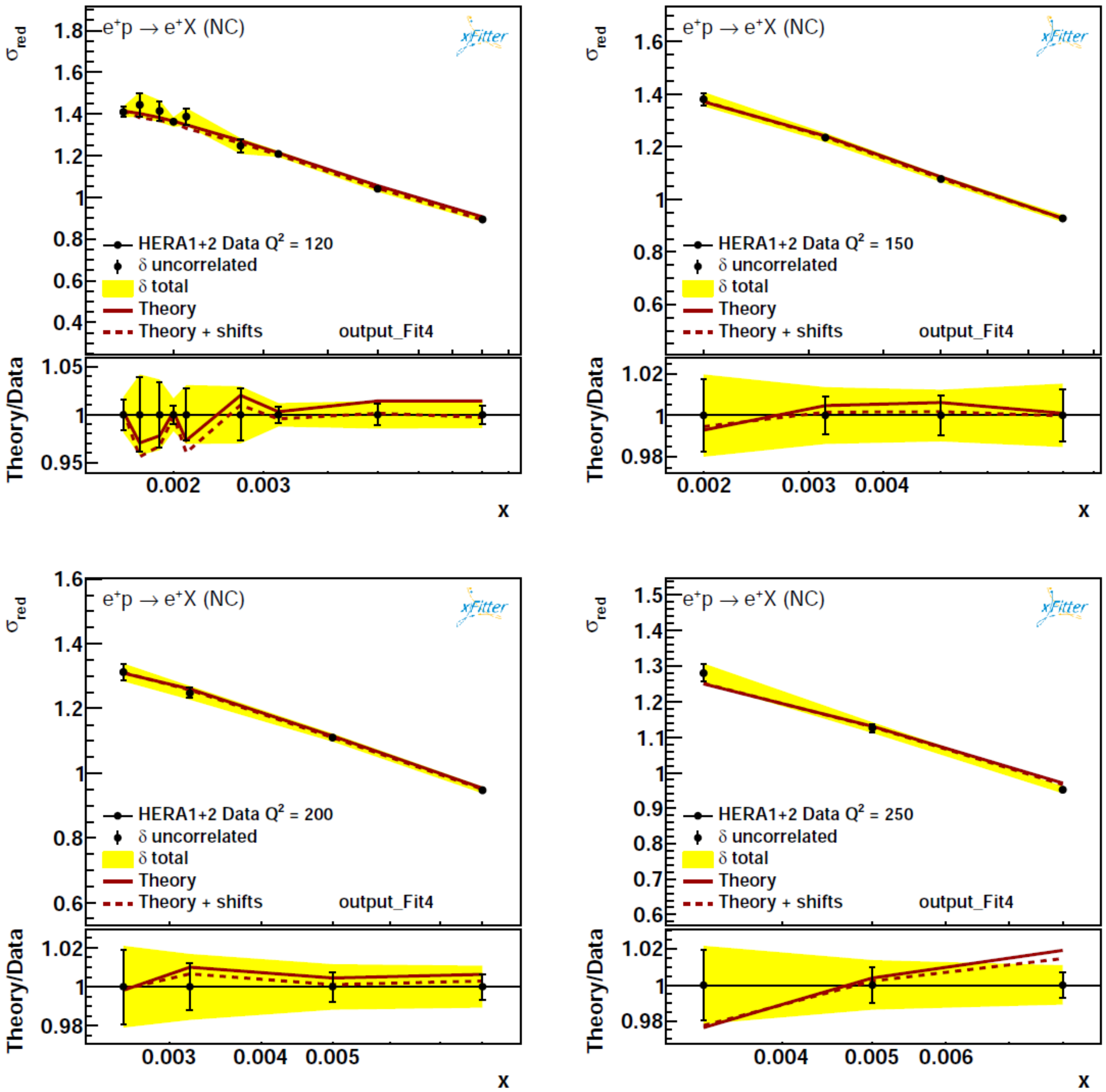


Comparision with HERAI+II data

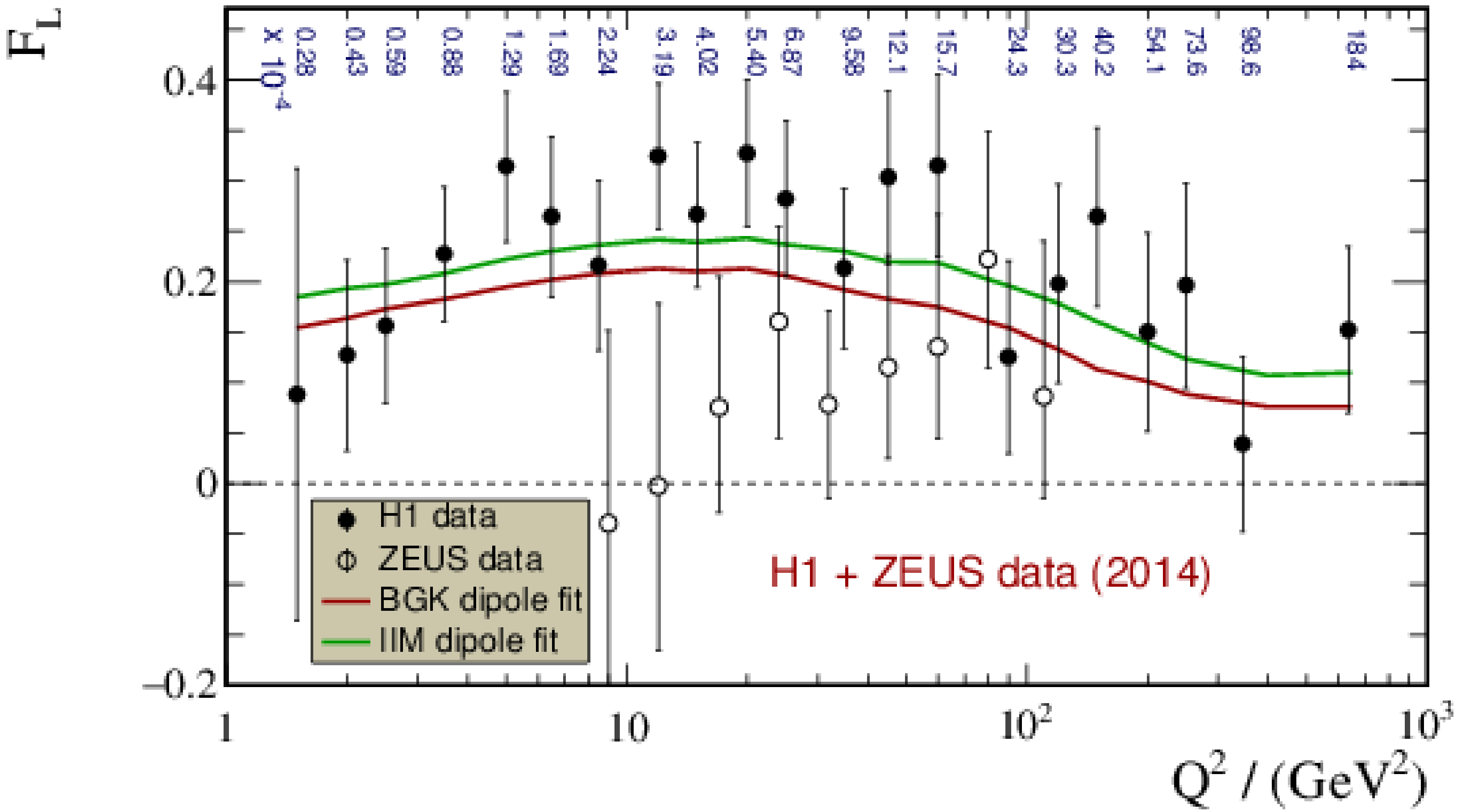


Comparision with HERAI+II data



Predictions for FL

- Predictions from BGK and IIM dipole models fits to FL function



Summary

- BGK dipole fits (with saturation) describe the final, high precision HERA data with $x < 0.01$, very well:
  - $\chi^2/Np \to 1$
- Little sensitivity to valence quarks contribution observed
- BGK fits seems not indicate sizable saturation effects:
  - $\chi^2/Np \to 1.18$ for $Q_0 = 1.9\ GeV^2$ and $Q^2 > 3.5\ GeV^2$

Dipole scattering amplitude with GBW parametrization

- GBW parametrization with heavy quarks $f = u, d, s, c$

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

- 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

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