NNPDF studies using LHeC pseudodata

Alberto Guffanti
Albert-Ludwigs-Universität Freiburg

On behalf of the NNPDF Collaboration:

R. D. Ball, L. Del Debbio, M. Ubiali (Edinburgh), S. Forte, A. Piccione, J. Rojo (Milano),
J. I. Latorre (Barcelona)

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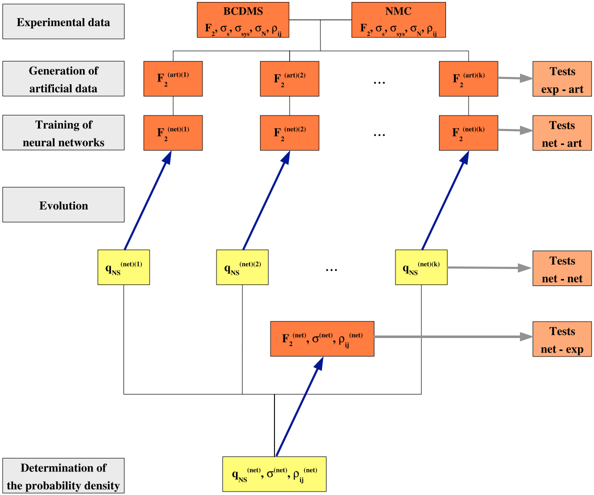
Motivation

Shortcomings of stanard PDF fits

- One of the main shortcomings of the standard PDF fitting strategy is that the PDFs parametrization and the statistical treatment ($\Delta\chi^2$) are tailored to the data included in the fits
- It is often the case that inclusion of new data leads to an increase of the errors on PDFs due to a change in the parametrization
- Might be a source of problems when trying to
  - assess the impact of adding new data
  - disentangle PDF errors in precision determination of physical parmeters

THE NNPDF METHODOLOGY

The NNPDF methodology



The Neural Network Approach in a Nutshell

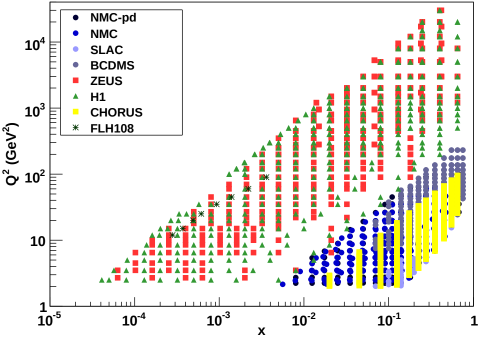
- Generate N_{rep} Monte-Carlo replicas of the experimental data.
- Fit a set of Parton Distribution Functions (each PDF is parametrized with a Neural Network) to each replica, thus defining a sampling of probability density on the space of the PDFs.
- Expectation values for observables are Monte Carlo integrals

$$\langle \mathcal{F}[f_i(x,Q^2)] \rangle = \frac{1}{N_{rep}} \sum_{k=1}^{N_{rep}} \mathcal{F}\left(f_i^{(net)(k)}(x,Q^2) \right)$$

... the same is true for errors, correlations, etc.

RESULTS

NNPDF1.0: Experimental data



OBS	Data set	OBS	Data set
F_2^p	NMC	σ^{-}_{NC}	ZEUS
	SLAC		H1
	BCDMS	σ^{+}_{CC}	ZEUS
F_2^d	SLAC		H1
	BCDMS	σ^{-}_{CC}	ZEUS
σ^{+}_{NC}	ZEUS		H1
	H1	σ_ν , $\sigma_{\bar{\nu}}$	CHORUS
F_2^d / F_2^p	NMC-pd	F_L	H1

- Kinematical cuts:
  $Q^2 > 2$ GeV^2
  $W^2 = Q^2(1-x)/x > 12.5$ GeV^2
- $\sim$ **3000** points.

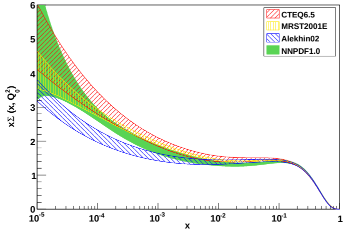
NNPDF1.0: Parametrization

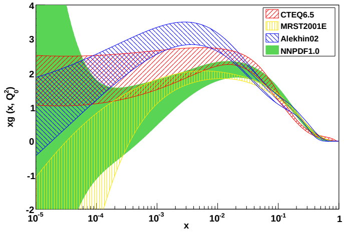
Parametrization of 5 combinations of PDFs at $Q_0^2 = 2\ \text{GeV}^2$

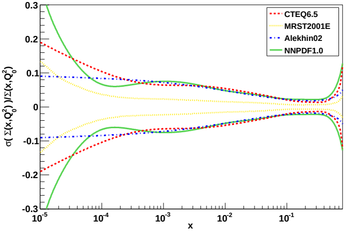
Singlet : $\Sigma(x)$	$\longmapsto \mathrm{NN}_{\Sigma}(x)$	2-5-3-1 37 pars
Gluon : $g(x)$	$\longmapsto \mathrm{NN}_{g}(x)$	2-5-3-1 37 pars
Total valence : $V(x) \equiv u_V(x) + d_V(x)$	$\longmapsto \mathrm{NN}_{V}(x)$	2-5-3-1 37 pars
Non-singlet triplet : $T_3(x)$	$\longmapsto \mathrm{NN}_{T3}(x)$	2-5-3-1 37 pars
Sea asymmetry : $\Delta_S(x) \equiv \bar{d}(x) - \bar{u}(x)$	$\longmapsto \mathrm{NN}_{\Delta}(x)$	2-5-3-1 37 pars

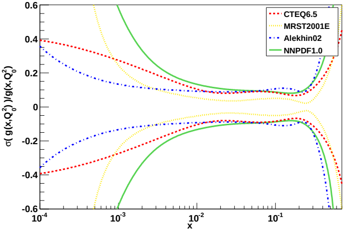
185 parameters

NNPDF1.0 Results





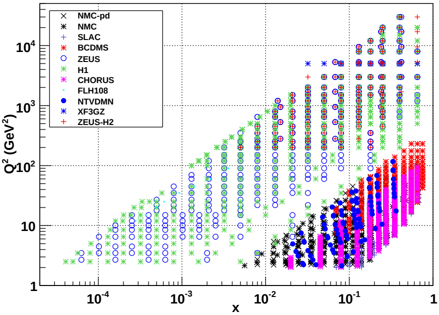




NNPDF1.2: Constraining the strange distribution

- Determination of both s and $\bar{s}$ allowed by inclusion of NuTeV dimuon data

$$\frac{1}{E_\nu}\frac{d^2\sigma^{\nu(\bar\nu),2\mu}}{dx\,dy}(x,y,Q^2) \equiv \frac{1}{E_\nu}\frac{d^2\sigma^{\nu(\bar\nu),c}}{dx\,dy}(x,y,Q^2)\cdot\langle \mathrm{Br}\,(D\to\mu)\rangle\cdot\mathcal{A}\,(x,y,E_\nu)$$

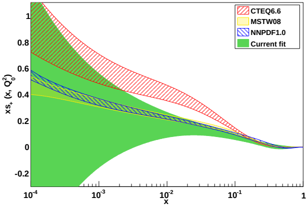


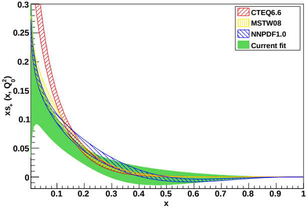
$$\begin{aligned}
\tilde\sigma^{\nu(\bar\nu),c} &\propto \left(F_2^{\nu(\bar\nu),c},\, F_3^{\nu(\bar\nu),c},\, F_L^{\nu(\bar\nu),c}\right)\\
F_2^{\nu,c} &= x\left[C_{2,q}\otimes 2|V_{cs}|^2 s + \frac{1}{n_f}C_{2,g}\otimes g\right]\\
F_2^{\bar\nu,c} &= x\left[C_{2,q}\otimes 2|V_{cs}|^2 \bar{s} + \frac{1}{n_f}C_{2,g}\otimes g\right]
\end{aligned}$$

* Neutrino and anti-neutrino dimuon production from NuTeV.
* HERA-II ZEUS data on NC and CC reduced xsec at large-Q^2.

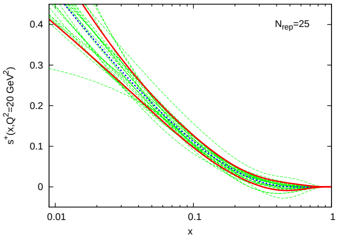
NNPDF 1.2 Results

Total strangeness determination



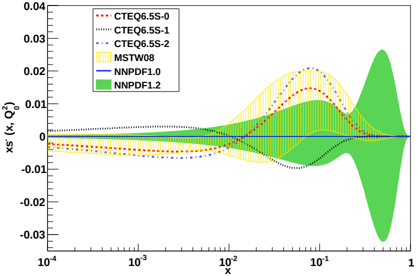


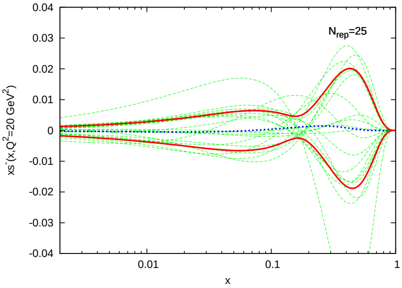
- Data region
  → Moderate uncertainties, larger than CTEQ6.6/MSTW08
- Extrapolation region
  → Blow-up of uncertainties due to lack of experimental constraints
- Difference with NNPDF1.0 is a signal of bias due to theoretical assumptions



NNPDF 1.2 Results

Strange Asymmetry determination: $s^-(x, Q^2)$





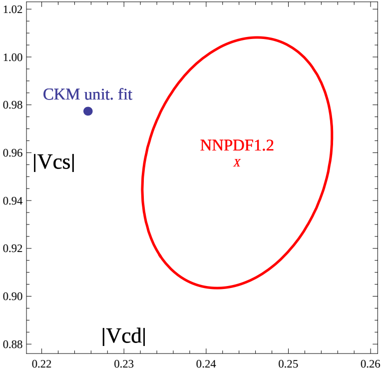
Analysis	$[S^-](Q^2 = 20\,\mathrm{GeV}^2) \cdot 10^3$
NNPDF1.2	0 ± 10
MSTW08	1.4 ± 1.2
CTEQ6.5s	1.2 ± 1.1
AKP08	1.0 ± 1.3
NuTeV07	1.3 ± 0.8

NNPDF uncertainty on $[S^-]$ is large enough to explain the NuTeV (non-)Anomaly.

NNPDF 1.2 Results

CKM matrix elements determination

- Joint determination of $|V_{cd}|$ and $|V_{cs}|$ CKM matrix elements



- Result for the combined fit

$$|V_{cs}| = 0.96 \pm 0.07$$
$$|V_{cs}| = 0.244 \pm 0.019$$
$$\rho[V_{cs}, V_{cd}] = 0.21$$

- $|V_{cs}|$ most accurate direct determination
- $|V_{cd}|$ accuracy comparable to other determinations from dimuons

- Ability to disentangle (large) uncertainties on PDFs from (small) uncertainties on physical parameters

Towards NNPDF 2.0

The first NNPDF Global Fit

- Inclusion of hadronic data (Drell-Yan EW gauge boson production and Jets) crucial to constrain certain PDFs.
- NLO computation for hadronic observables too slow to be used in a parton fit $\Rightarrow$ many parton fits use $K-$factors (impact on the accuracy difficult to assess).
- We use *fastNLO* to include jet observables and develop our own *fastDY* for DY-like observables.
- First preliminary fits look promising expect the set to be public in Winter.

LHeC STUDIES

LHeC Scenarios

Several scenarios for LHeC under investigation:

config.	E(e)	E(N)	N	$\int L(e^+)$	$\int L(e^-)$	|Pol|	$L/10^{32}$	P/MW	years	type
A	20	7	p	1	1	-	1	10	1	SPL
B	50	7	p	50	50	0.4	25	30	2	RR hiQ^2
C	50	7	p	1	1	0.4	1	30	1	RR lo x
D	100	7	p	5	10	0.9	2.5	40	2	LR
E	150	7	p	3	6	0.9	1.8	40	2	LR
F	50	3.5	D	1	1	--	0.5	30	1	eD
G	50	2.7	Pb	0.1	0.1	0.4	0.1	30	1	ePb
H	50	1	p	--	1	--	25	30	1	lowEp

Studies with LHeC pseudodata

Methodology

- Generate pseudodata for $F_2(x, Q^2)$ and $F_L(x, Q^2)$ at small$-x$ using NNPDF 1.0 as input PDF set, accounting fot statistical fluctuations:

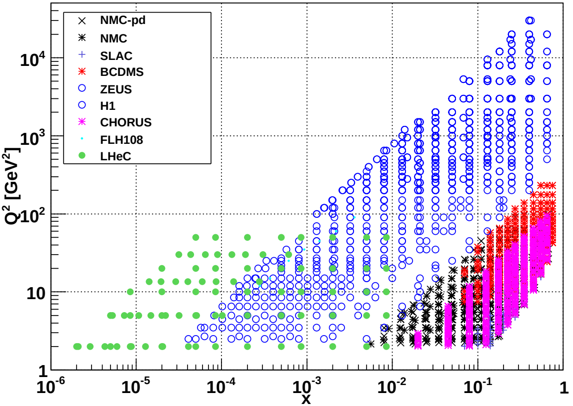
$$F_k(x, Q^2)|_{\mathrm{LHeC}} = F_k(x, Q^2)|_{\mathrm{NNPDF1.0}} + r^{(l)}\sigma^{\mathrm{tot}}_{k,\mathrm{LHeC}}$$

- Include pseudodata in the latest NNPDF fit (NNPDF 1.2) and study the variation of PDF uncertainties in the pseudodata region.
- Consider extreme scenarios, i.e. generate pseudodata using replicas which lie at the boundary of the one sigma error band for a given PDF.
- Assess the ability of LHeC to discriminate among extreme scenarios.

Studies with LHeC pseudodata

NNPDF 1.2 + LHeC Kinematical coverage

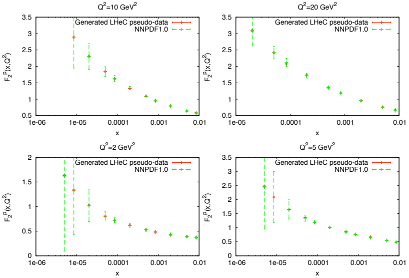
- Scenario: $E_e = 70$ GeV, $\int \mathcal{L} = 1$ fb^{-1}, $\theta_e \leq 179°$
- LHeC pseudodata for F_2 and F_L for $x \leq 0.01$, $Q^2 \leq 50$ GeV^2

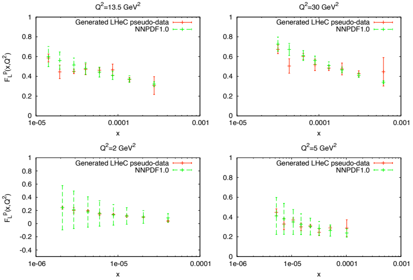


Studies with LHeC pseudodata

F_2, F_L pseudodata

- Very small statistical errors on the $F_2(\mathcal{O}(2\%))$ and $F_L(\mathcal{O}(8\%))$

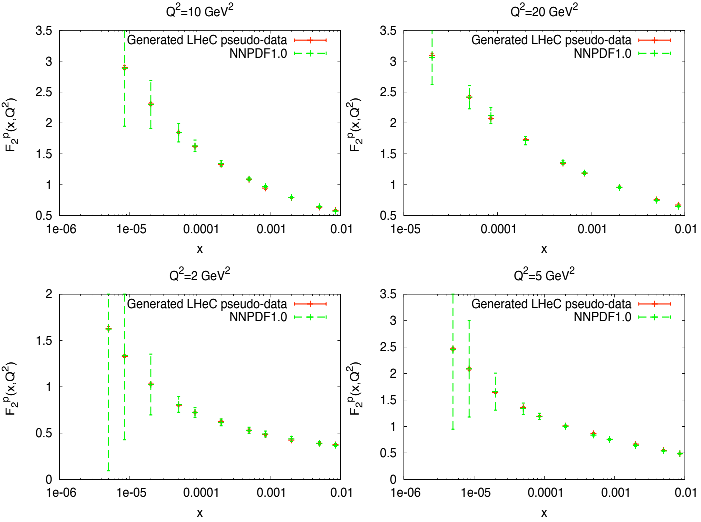




Studies with LHeC pseudodata

Including pseudodata in the fit - Observables

- Before the fit ...



Studies with LHeC pseudodata

Including pseudodata in the fit - Observables

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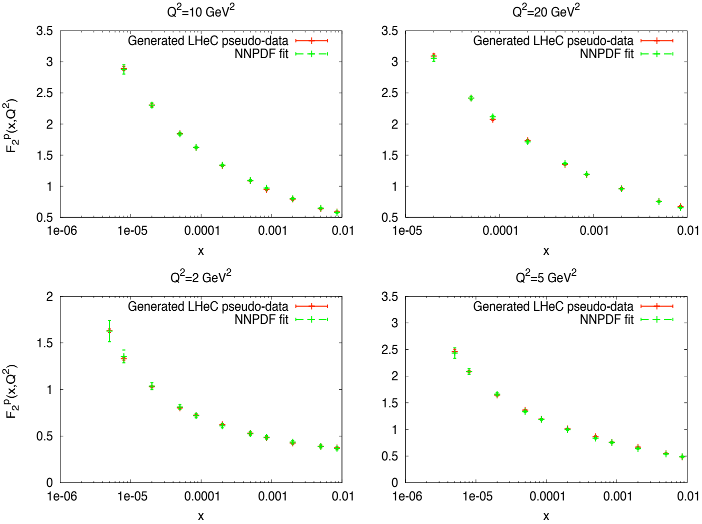
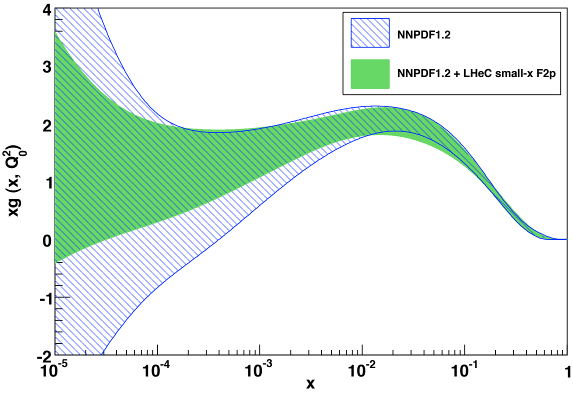


Studies with LHeC pseudodata

Including pseudodata in the fit - PDFs

- Including F_2 data

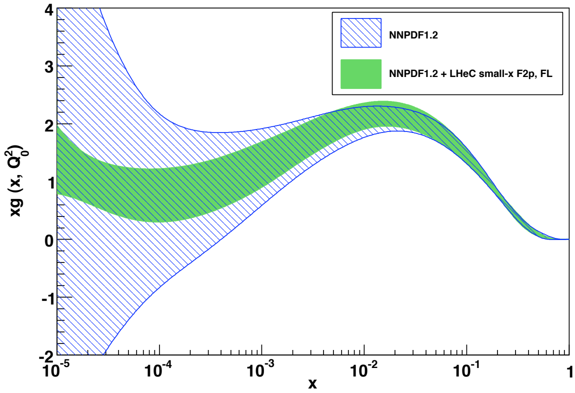


- Modest reduction of the error on the gluon at small$-x$.

Studies with LHeC pseudodata

Including pseudodata in the fit - PDFs

- Including F_2 and F_L data

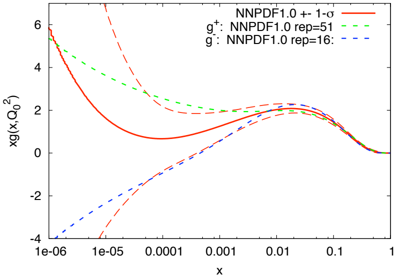


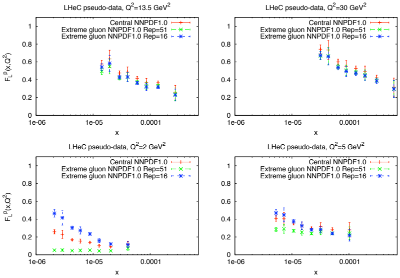
- Substantial reduction of the error on the gluon at small$-x$.

Studies with LHeC pseudodata

Disentangling extreme scenarios - Setup

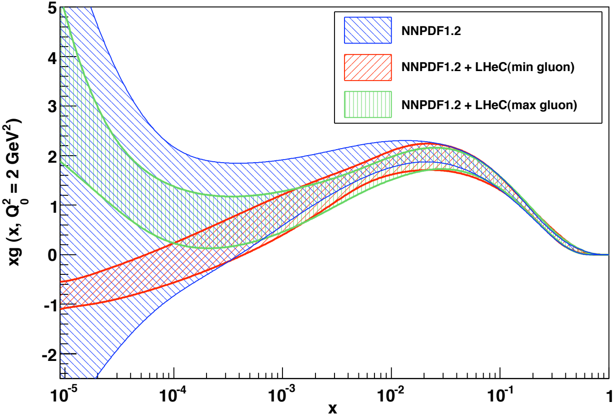
- Generate LHeC pseudodata using two extreme replicas from the NNPDF 1.0 set for the gluon
- F_L at small$-x$ is especially sensitive to the gluon distribution





Studies with LHeC pseudodata

Disentangling extreme scenarios - Results



Studies with LHeC pseudodata

Further Studies

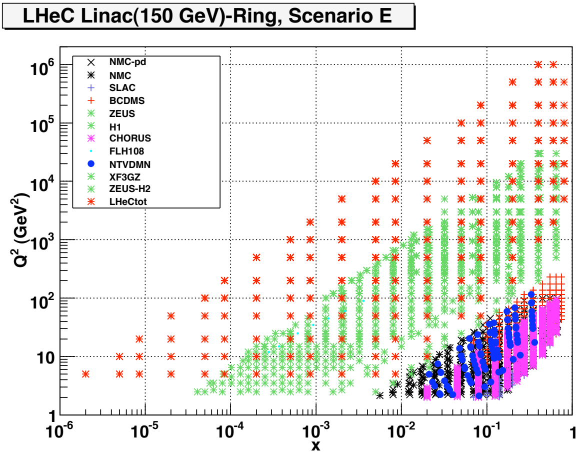
Assume **scenario E:** Linac-Ring option $E_e = 150 GeV$

config.	E(e)	E(N)	N	$\int L(e^+)$	$\int L(e^-)$	|Pol|	$L/10^{32}$	P/MW	years	type
A	20	7	p	1	1	-	1	10	1	SPL
B	50	7	p	50	50	0.4	25	30	2	RR hiQ^2
C	50	7	p	1	1	0.4	1	30	1	RR lo x
D	100	7	p	5	10	0.9	2.5	40	2	LR
E	150	7	p	3	6	0.9	1.8	40	2	LR
F	50	3.5	D	1	1	--	0.5	30	1	eD
G	50	2.7	Pb	0.1	0.1	0.4	0.1	30	1	ePb
H	50	1	p	--	1	--	25	30	1	lowEp

Studies with LHeC pseudodata

Further Studies - Kinematics

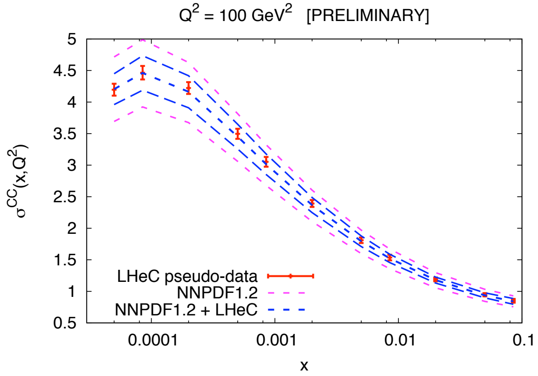
- Same methodology used for the small-*x* data, but now full NC and CC datasets included



Studies with LHeC pseudodata

Further Studies - Preliminary results

- LHeC will provide accurate CC in the whole *x* range
- Full flavour separation possible within a single experiment



- Work in progress with pseudo-data in other scenarios

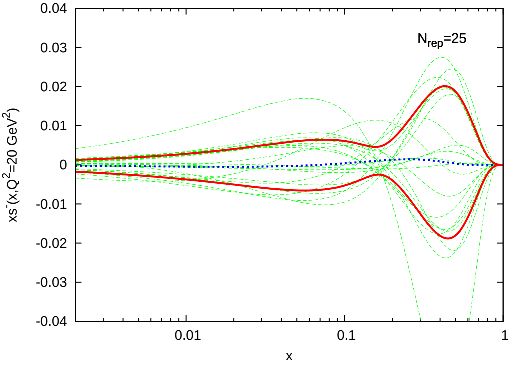
Conclusions

- We think the NNPDF methodology is effective in tackling problems which affect standard PDF fits
- Inclusion of LHeC pseudodata in NNPDF fits and studies of their impact on extracted parton densities is in progress
- Studies of deviation from DGLAP evolution (small-x resummation, saturation), see F. Caola's talk
- For precision studies (determination of EW parameters, $|V_{tb}|$) it is crucial to assess the LHeC impact on determination of PDFs in the medium-/high-x region (flavour separation)

NNPDF 1.2 Results

Strange Asymmetry determination: $s^{-}(x, Q^2)$

- Only theoretical constraints on $s^{-}(x, Q_0^2)$ is the valence sum rule.
- At least one crossing required by sum rule, but some replicas have two crossings.



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