Towards a global NNPDF analysis

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DIS 2009 Workshop
Madrid, 28 April 2009

Work in collaboration

NNPDF collaboration

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NNPDF collaboration, Nucl. Phys. B 809, 1 (2009) [arXiv:0808.1231] NNPDF1.0
NNPDF collaboration, [arXiv:0811.2288] NNPDF1.1
NNPDF collaboration, in preparation NNPDF1.2
NNPDF collaboration, in preparation NNPDF2.0

Outline

1. Introduction
   - Parton fits
   - NNPDF approach: the main ingredients
2. Results
   - NNPDF1.0
   - NNPDF1.1
   - NNPDF1.2
   - NNPDF2.0
3. Conclusions

Outline

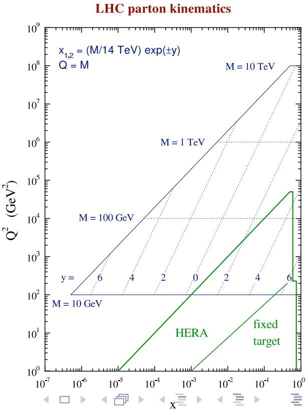
Parton Distribution Functions

- Factorization Theorem ($Q^2 \gg \Lambda^2_{\mathrm{QCD}}$):

$$\frac{d\sigma_H}{dX} = \sum_{a,b} \int dx_1 dx_2 f_a(x_1, \mu_f) f_b(x_2, \mu_f) \otimes \frac{d\hat{\sigma}}{dX}(\alpha_s(\mu_r), \mu_r, \mu_f, x_1, x_2, Q^2)$$

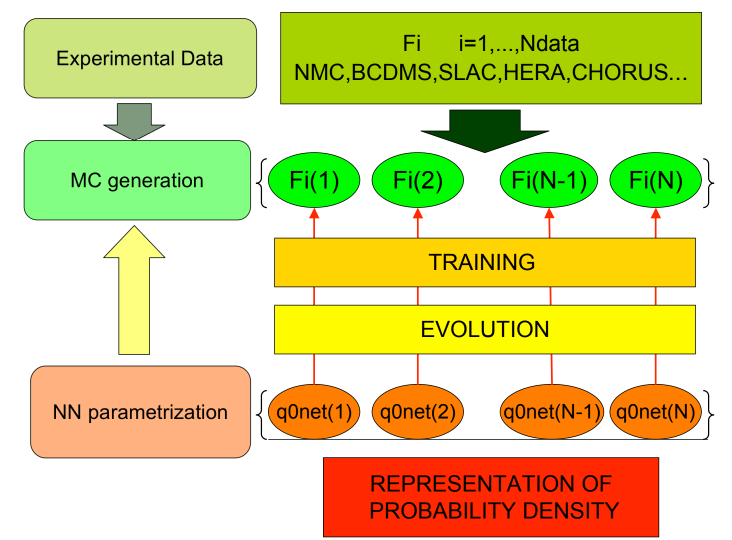
- DGLAP equations:

$$\frac{d}{dt}\begin{pmatrix} q \\ g \end{pmatrix} = \frac{\alpha_s}{2\pi}\begin{pmatrix} P_{qq} & P_{qg} \\ P_{gq} & P_{gg} \end{pmatrix} \otimes \begin{pmatrix} q \\ g \end{pmatrix} + O(\alpha_s^2)$$



* Need robust input for analyses at LHC.
* Need statistically reliable interpretation for PDFs error bars: will provide dominant contribution to systematic uncertainties for some processe

NNPDF approach



NNPDF approach

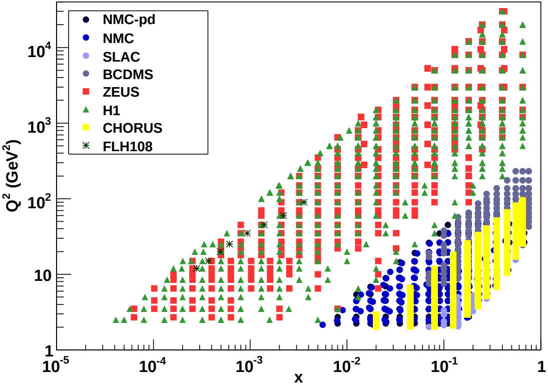
Determination of unbiased PDFs with faithful estimation of their uncertainties.

$$\langle \mathcal{F}[f_i(x)] \rangle = \int [\mathcal{D} f_i]\, \mathcal{F}[f_i(x)] \mathcal{P}[f_i(x)] \rightarrow \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} \mathcal{F}[f_i^{(k)(\rm net)}(x)]$$

* The measure $\mathcal{P}[f_i(x)]$ in space of PDFs is determined with MC method.
* Use all information contained in experiments.
* Redundant parametrization of PDFs: reduce bias.
* Statistic estimators to assess errors, correlations, stability and size of systematics.
* All details explained in arXiv:0809.3716.

Outline

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.

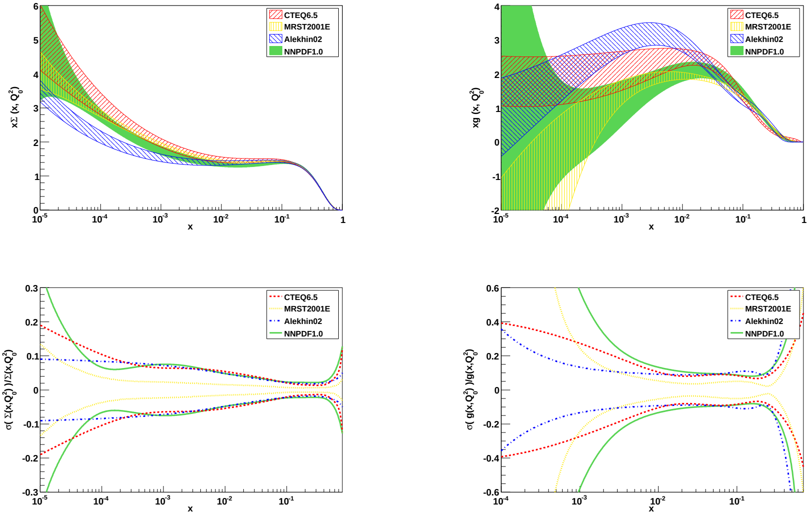
NNPDF1.0: Parametrization

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: Partons



NNPDF1.1: A consistency check

- NNPDF1.0: flavor assumptions, symmetric strange sea proportional to non strange sea according to $C_s \sim 0.5$ suggested by neutrino DIS data.

$$s(x) = \bar{s}(x) \qquad \bar{s}(x) = \frac{C_s}{2}(\bar{u}(x) + \bar{d}(x))$$

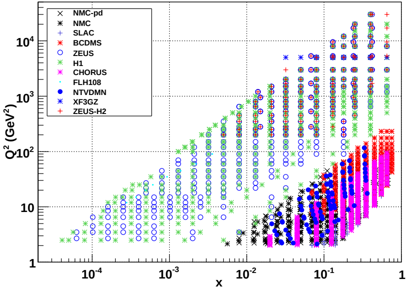
- NNPDF1.1: independent parametrization of the strange content of the nucleon.

Total strangeness : $s^+(x) \equiv (s(x) + \bar{s}(x))/2 \longmapsto \mathrm{NN}_{(s+)}(x)$ 2-5-3-1 37 pars

Strangeness valence : $s^-(x) \equiv (s(x) - \bar{s}(x))/2 \longmapsto \mathrm{NN}_{(s-)}(x)$ 2-5-3-1 37 pars

- Randomized preprocessing.
- Large uncertainty for strange PDFs.
- Same χ^2 and statistical features of the fit.
- Check of stability and consistency of our statistically-sound approach.

NNPDF1.2: Constrain the strange distribution



- Neutrino and anti-neutrino dimuon production from NuTeV.
- HERA-II ZEUS data on NC and CC reduced xsec at large-Q^2.
- HERA-II ZEUS data on $xF_3^{\gamma Z}$.

$$\tilde{\sigma}^{\nu(\bar{\nu}),c} \propto (F_2^{\nu(\bar{\nu}),c}, F_3^{\nu(\bar{\nu}),c}, F_L^{\nu(\bar{\nu}),c})$$

$$F_2^{\nu,c} = x\left[C_{2,q} \otimes 2|V_{cs}|^2 s + \frac{1}{n_f} C_{2,g} \otimes g\right]$$

$$F_2^{\bar{\nu},c} = x\left[C_{2,q} \otimes 2|V_{cs}|^2 \bar{s} + \frac{1}{n_f} C_{2,g} \otimes g\right]$$

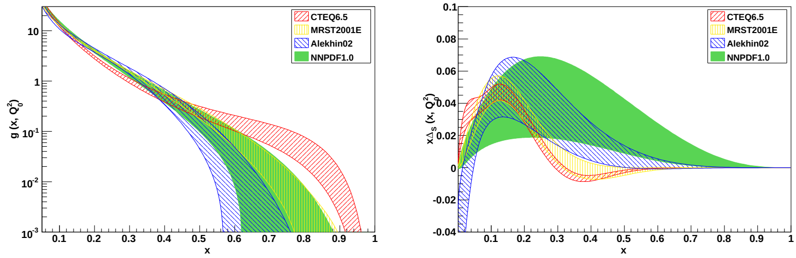
Results

- No bias on the shape or normalization of strange valence and total strange.
- The only constraint comes from strange valence sum rule.
- Faithful determination of uncertainties of strange content of the nucleon.
- Interesting applications: NuTeV anomaly, V_{cs} determination...

See Joan Rojo talk.

Towards a global neural fit: NNPDF2.0

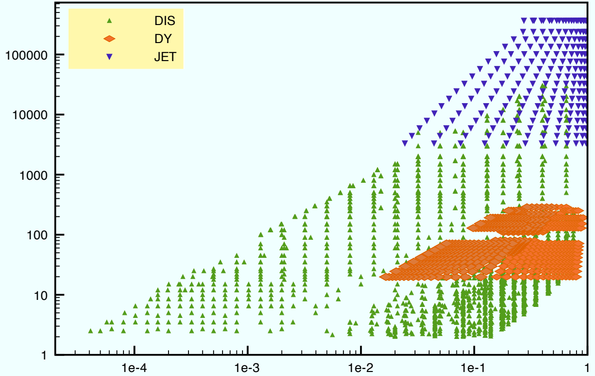
- The inclusion of hadronic data is necessary to constrain large-x gluon behavior, sea quarks, u/d ratio at large x.



- Upcoming NNPDF2.0 is the first neural global fit including most available hadronic data.
- Fit soon competitive with MSTW and CTEQ parton fits.

NNPDF2.0: Experimental data

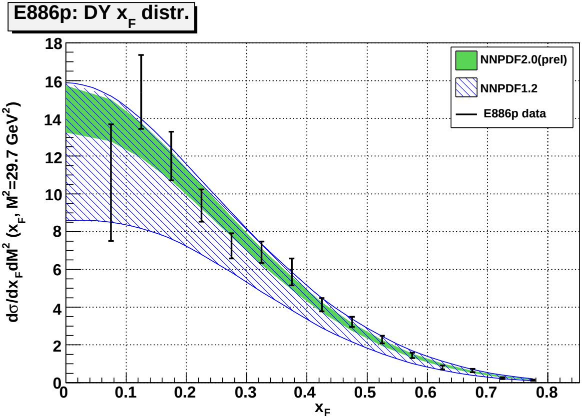
Inclusion of fixet-target Drell-Yan data, Tevatron electroweak gauge boson production, Run II inclusive jet data from Tevatron.



OBS	Data set
$d\sigma^{\mathrm{DY}}/dM^2dy$	E605
$d\sigma^{\mathrm{DY}}/dM^2dx_F$	E772
$d\sigma^{\mathrm{DY}}/dM^2dx_F$	E886
W asym.	D0/CDF
Z rap. distr.	D0/CDF
incl. σ^{jet}	CDF(k_T)
incl. σ^{jet}	D0(cone)

$800_{\mathrm{DY}} + 200_{\mathrm{JET}} = \mathcal{O}(1000)$ new data.

NNPDF2.0: Predictions on Observables (preliminary)



- Predictions evaluated with NNPDF1.2 and NNPDF2.0 (prel) error sets.
- NNPDF1.2: Large error bands on predictions, compatible with data.
- NNPDF2.0: Smaller error bands, data are well described.

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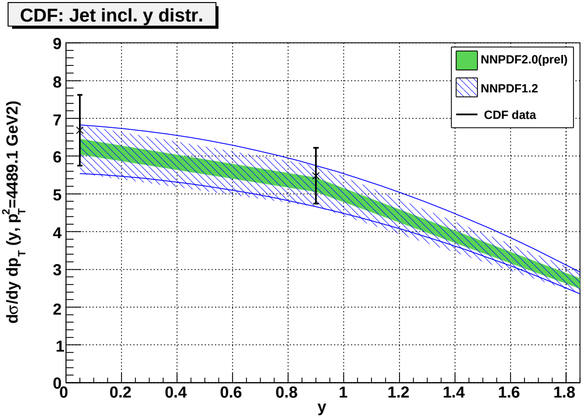

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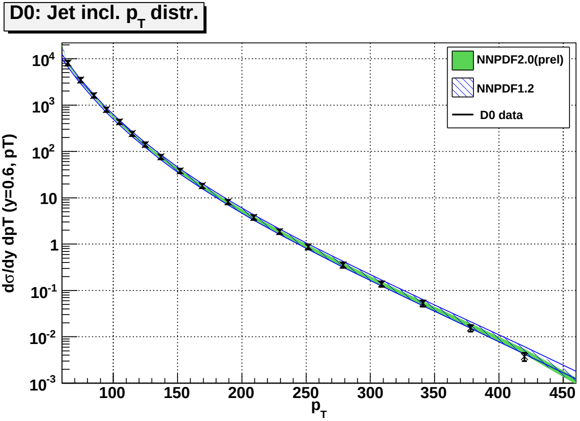

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Benchmark Partons

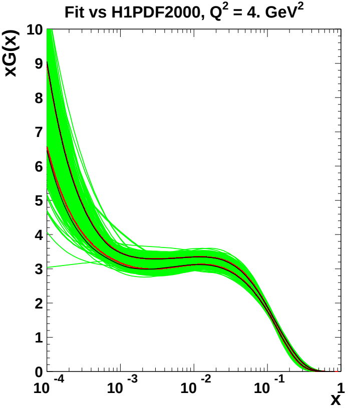
To understand differences between available approaches for determining parton uncertainties and to deal with incompatible data:

- Fix experimental data, QCD parameters, input parametrizations, error treatment.
- Assess the effect of the remaining assumptions.

HERA-LHC 09 workshop

1. H1 benchmark $\longrightarrow$ Hessian vs Monte Carlo error propagation.
2. H1-NNPDF benchmark $\longrightarrow$ Monte Carlo error propagation: polynomial vs NN parametrization.
3. H1-NNPDF benchmark $\longrightarrow$ Treatment of incompatible data.
4. NNPDF-MRST/MSTW benchmark $\longrightarrow$ Stability vs inclusion of new data. Confirmed by NNPDF2.0 plots.

I) H1 Benchmark: compare error propagation



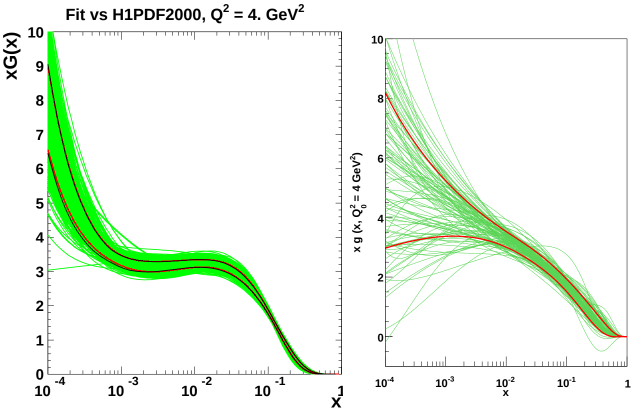
Spread of MC ensemble
RMS of MC ensemble, 1σ error band
Standard error calculation, 1σ error band

- Settings: same theoretical and flavour assumptions, same parametrization, same data and kinematical cuts.

Data Set	Data points	Observable
H197mb	35	$\tilde{\sigma}^{NC,+}$
H197lowQ2	80	$\tilde{\sigma}^{NC,+}$
H197NC	130	$\tilde{\sigma}^{NC,+}$
H197CC	25	$\tilde{\sigma}^{CC,+}$
H199NC	126	$\tilde{\sigma}^{NC,-}$
H199CC	28	$\tilde{\sigma}^{CC,-}$
H199NChy	13	$\tilde{\sigma}^{NC,-}$
H100NC	147	$\tilde{\sigma}^{NC,+}$
H100CC	28	$\tilde{\sigma}^{CC,+}$

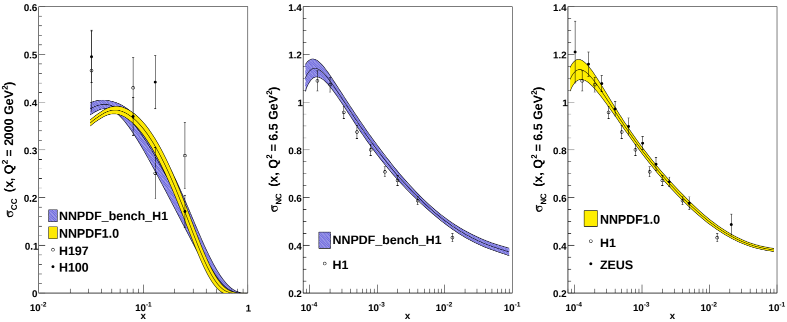
- Compare error propagation: standard Hessian vs MC method (sampling of the DATA).
- Results: MC (gaussian and lognorm distrib) and standard error propagation give the same error!!! ArXiv:0901.2504

II) H1-NNPDF Benchmark: compare parametrization



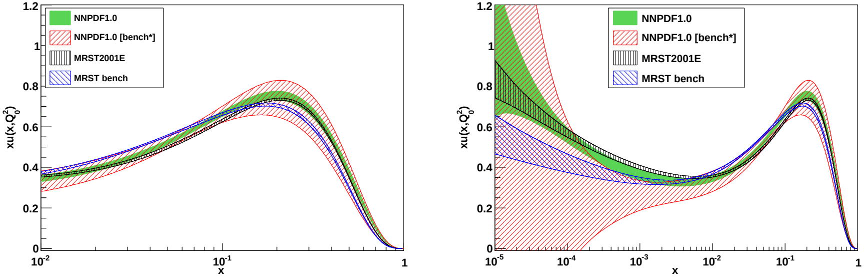
- Settings: same theoretical and flavour assumptions, same data and kinematical cuts.
- Same error propagation via Monte Carlo technique.
- Compare polynomial vs Neural Network redundant parametrization.
- Results: Larger spread for gluon due to flexibility of parametrization.
  ArXiv:0901.2504

III) H1-NNPDF Benchmark: treatment of inconsistent data



- CC cross-section: uncertainty shrinks because of the inclusion of CHORUS data (consistent to H1 data) in NNPDF1.0 analysis.
- NC cross-section: inclusion of ZEUS data (slightly inconsistent to H1 data) in NNPDF1.0 analysis does not shrink uncertainty.
- Systematic disagreement ZEUS vs H1 NC data is of the size of the uncertainty band.
- Inconsistency in data does not allow to reduce uncertainty beyond size of inconsistency!!

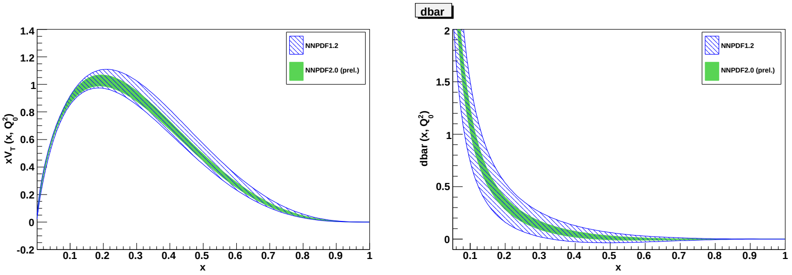
IV) NNPDF-MRST/MSTW Benchmark: stability versus data



- NNPDF1.0 is consistent with MRST01 global fit.
- NNPDFbench is consistent with NNPDF1.0 and MRST01.
- Same parametrization, flavour assumption and statistical treatment. ArXiv:0901.2504

NNPDF2.0: Parton Distributions (preliminary)

- Same stability in preliminary NNPDF2.0 parton distributions!!



- Error on $V_{\rm TOT}$ and $\bar{d}$ reduced due to inclusion of hadronic data.
- Partons compatible with previous determination.

NNPDF2.0: FastNLO-like evolution

- The NLO computation of hadronic observables might be too slow for parton global fits.
- Many parton fits rely on K-factor approximation, relatively fast.
- K-factor depends on PDFs and it is not always a good approximation.

* NNPDF2.0 includes full NLO calculation of hadronic observables.
* Use available fastNLO interface for jet inclusive cross-sections.[hep-ph/0609285]
* Built up our own **fastNLO-like evolution for Drell-Yan** observables, not available in literature.
* Fast code easy to benchmark versus other slow codes.

Outline

Conclusions

- The first NNPDF1.0 parton set [arXiv:0808.1231] from a comprehensive DIS anaysis is available on the common LHAPDF interface (http://projects.hepforge.org/lhapdf), the NNPDF1.1 is available on the NNPDF website (http://sophia.ecm.ub.es/nnpdf/)
- Inclusion of NuTev data constrains the strange distribution in the upcoming NNPDF1.2 fit.
- Inclusion of hadronic data (DY, jets, W asymmetry): first global NNPDF2.0 fit.
- Encouraging preliminary results!
- Implementation of a full fastNLO-like evolution strategy for hadronic observable, including Drell-Yan.