Progress towards nCTEQ24 - A new global analysis of nuclear parton distribution functions

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Heavy Ion physics in the EIC Era, INT, Seattle

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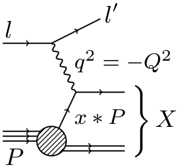
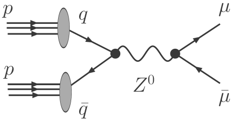
Introduction – Collinear factorization

- **Factorization** in case of **Deep Inelastic Scattering** (DIS)



$$\frac{d^2\sigma}{dxdQ^2} = \sum_{i=q,\bar{q},g} \int_x^1 \frac{dz}{z} f_i(z,\mu) d\hat{\sigma}_{il\to l'X}\left(\frac{x}{z}, \frac{Q}{\mu}\right) + \mathcal{O}\left(\frac{\Lambda^2_{\text{QCD}}}{Q^2}\right)$$

- **Factorization** in case of **Drell-Yan lepton pair production** (DY)



$$\sigma_{pp\to l\bar{l}X} = \sum_{i,j=q,\bar{q},g} \int_{x_1}^1 dz_1 \int_{x_2}^1 dz_2 f_i(z_1,\mu) f_j(z_2,\mu) \times \hat{\sigma}_{ij\to l\bar{l}X}\left(\frac{x_1}{z_1}, \frac{x_2}{z_2}, \frac{Q}{\mu}\right) + \mathcal{O}\left(\frac{\Lambda^2_{\text{QCD}}}{Q^2}\right)$$

- $f_i(z,\mu)$ – **UNIVERSAL** proton PDFs of parton i (**non-perturbative**).
- $\hat{\sigma}_{ij\to l\bar{l}X}$ – parton level matrix element (**calculable in pQCD**).
- $\mathcal{O}\left(\frac{\Lambda^2_{\text{QCD}}}{Q^2}\right)$ – non-leading terms defining accuracy of factorization formula.

Introduction – Properties of PDFs

- **Number sum rules** – connect partons to quarks from SU(3) flavour symmetry of hadrons; proton (uud), neutron (udd). For protons:

$$\int_0^1 dx[\underbrace{f_u(x) - f_{\bar{u}}(x)}_{u-\text{valence distr.}}] = 2 \qquad \int_0^1 dx[\underbrace{f_d(x) - f_{\bar{d}}(x)}_{d-\text{valence distr.}}] = 1$$

- **Momentum sum rule** – momentum conservation connecting all flavours

$$\sum_{i=q,\bar{q},g} \int_0^1 dx\, x f_i(x) = 1$$

- x-**dependence** of PDFs is NOT calculable in pQCD
- μ^2-**dependence** is calculable in pQCD – given by **DGLAP** equations

$$\mu^2 \frac{d}{d\mu^2} \begin{pmatrix} f_i(x,\mu^2) \\ f_g(x,\mu^2) \end{pmatrix} = \sum_j \frac{\alpha_s}{2\pi} \int_x^1 \frac{dz}{z} \begin{pmatrix} P_{q_i q_j}\left(\frac{x}{z}\right) & P_{q_i g}\left(\frac{x}{z}\right) \\ P_{g q_j}\left(\frac{x}{z}\right) & P_{gg}\left(\frac{x}{z}\right) \end{pmatrix} \begin{pmatrix} f_j(z,\mu^2) \\ f_g(z,\mu^2) \end{pmatrix}$$

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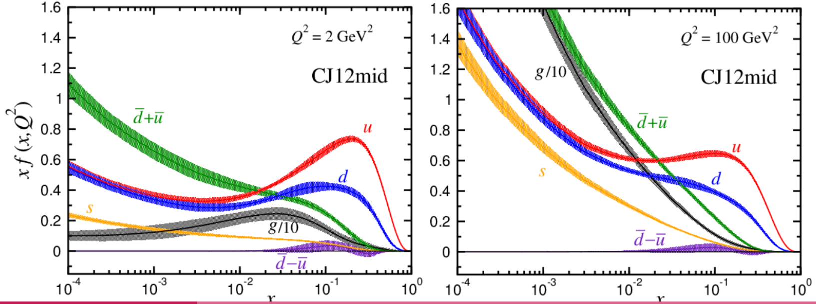
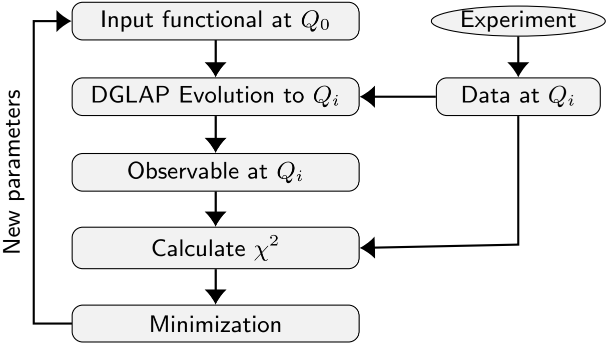


Introduction – PDF fitting procedure

- PDF x-dependence is extracted from data
- Assume a parameterization in x at some input scale Q_0

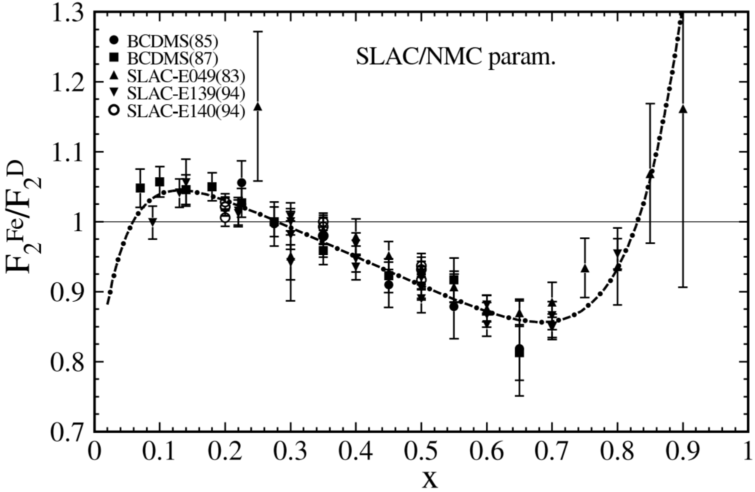
$$xf_i(x, Q_0) = N(1-x)^{p_{i,1}} x^{p_{i,2}} P(x, p_{i,3}, ...)$$

- Set parameters $p_{i,j}$ to some values, calculate theoretical predictions, compare to data, iterate:



Introduction – Nuclear PDFs

Nuclear PDFs are more than the sum of their parts, i.e. not just the sum of Z proton PDFs and $(A - Z)$ neutron PDFs.



Introduction – Parameterization

- The full nPDFs are parametrized in terms of the bound nucleon PDFs:

$$f_i^{A,Z}(x,Q) = \frac{Z}{A} f_i^{p/A}(x,Q) + \frac{A-Z}{A} f_i^{n/A}(x,Q)$$

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- Bound proton PDF parametrizations at $Q_0 = 1.3$ GeV :

$$x f_i^{p/A}(x,Q_0) = c_0 x^{c_1}(1-x)^{c_2} e^{c_3 x}(1+e^{c_4}x)^{c_5}, \quad i = u_v, d_v, g, \bar{u}+\bar{d}, s+\bar{s}$$

$$\frac{\bar{d}}{\bar{u}} = c_0 x^{c_1}(1-x)^{c_2} + (1+c_3 x)(1-x)^{c_4}$$

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$$c_k(A,Z) = p_k + a_k(1 - A^{-b_k})$$

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- The dependence of nPDFs on A, Z is parametrized as

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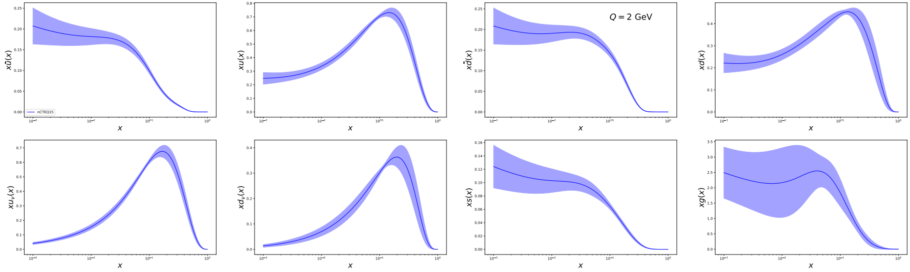
- Open parameters:

$$\{a_1^{u_v},\ a_2^{u_v},\ a_4^{u_v},\ a_5^{u_v},\ a_1^{d_v},\ a_2^{d_v},\ a_5^{d_v},\ a_1^{\bar{u}+\bar{d}},\ a_5^{\bar{u}+\bar{d}},\ a_1^{g},\ a_4^{g},\ a_5^{g},\ b_0^{g},\ b_1^{g},\ b_4^{g},\ b_5^{g},\ \boldsymbol{a_0^{s+\bar{s}}},\ \boldsymbol{a_1^{s+\bar{s}}},\ \boldsymbol{a_2^{s+\bar{s}}}\}$$

Old main release: **nCTEQ15** [Kovarik et al., PRD 93 (2016) 085037]



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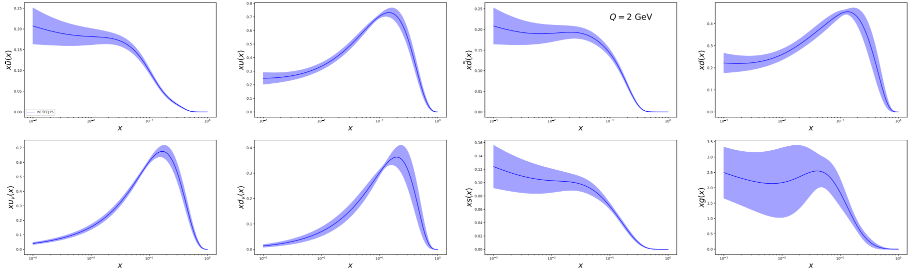
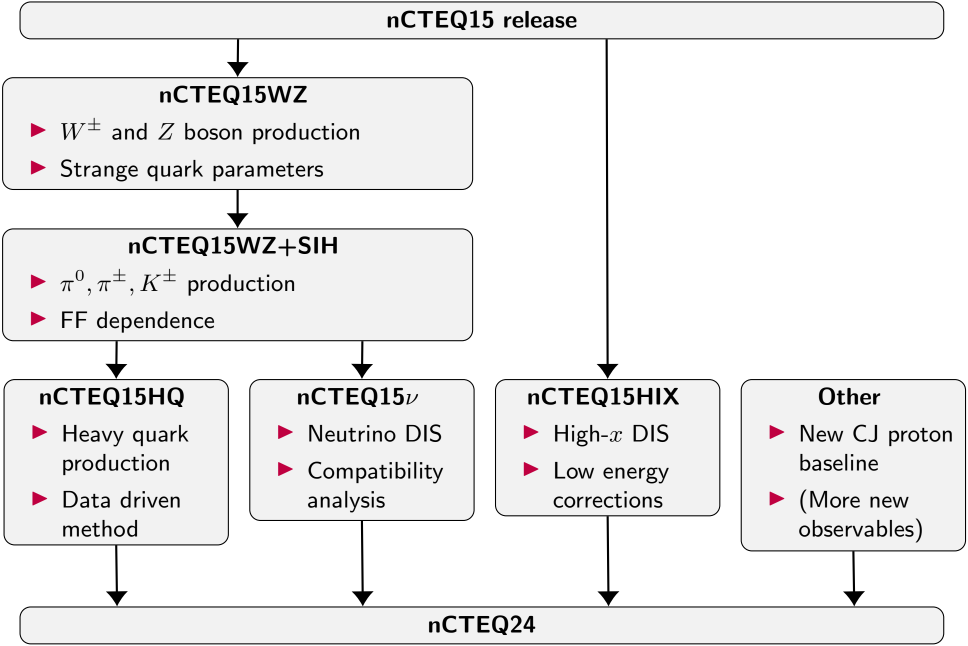


Many open problems:

- Gluon - huge uncertainties at low-x
- Strange quark - fixed to a constant fraction of $\bar{u} + \bar{d}$
- Considerable uncertainties even for valence quarks at high-x

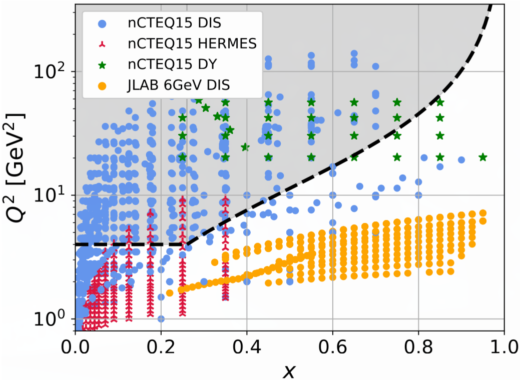

nCTEQ15 release
nCTEQ15WZ
$W^\pm$ and Z boson production
Strange quark parameters
nCTEQ15WZ+SIH
$\pi^0, \pi^\pm, K^\pm$ production
FF dependence
nCTEQ15HQ
Heavy quark production
Data driven method
nCTEQ15ν
Neutrino DIS
Compatibility analysis
nCTEQ15HIX
High-x DIS
Low energy corrections
Other
New CJ proton baseline
(More new observables)
nCTEQ24

nCTEQ15HIX – High-x JLab data

[Segarra et al., PRD 103 (2021) 114015]

Goal: Lower kinematic cuts to include more data and constrain high-x PDFs

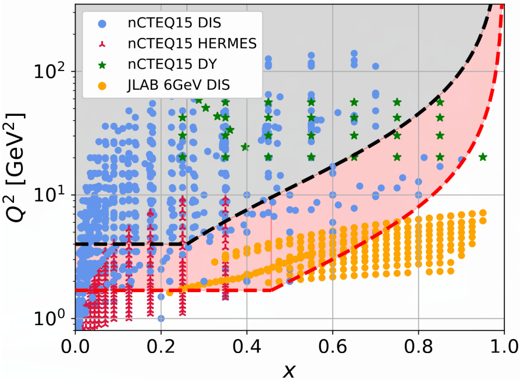
- **Old**: $Q_{\text{min}} = 2\,\text{GeV}$ and $W_{\text{min}} = 3.5\,\text{GeV}$
  - 708 DIS data points
  - JLab fully excluded



[Segarra et al., PRD 103 (2021) 114015]

Goal: Lower kinematic cuts to include more data and constrain high-x PDFs

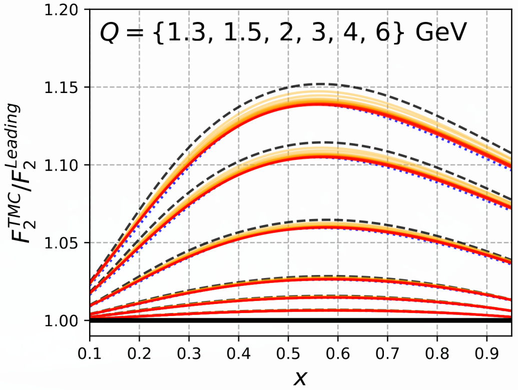
- **Old**: $Q_{\min} = 2$ GeV and $W_{\min} = 3.5$ GeV
  - 708 DIS data points
  - JLab fully excluded
- **New**: $Q_{\min} = 1.3$ GeV and $W_{\min} = 1.7$ GeV
  - 1564 DIS data points
  - JLab and HERMES contribute significant amounts
  - Requires low-energy corrections



nCTEQ15HIX – Theoretical challenges

Target mass corrections:
[Ruiz et al., arXiv:2301.07715]

- Revisited derivation for nuclear DIS



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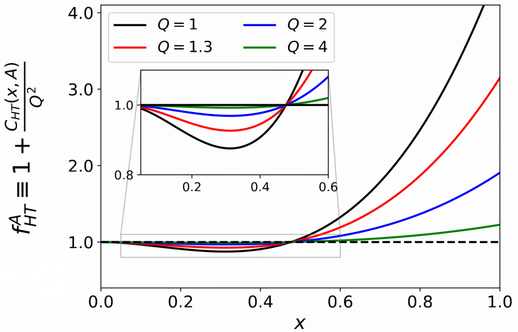
Higher twist effects:

- Independenct of the nucleus
- Using parameterization from the CJ15 analysis [Accardi et al, PRD 93 (2016) 114017]



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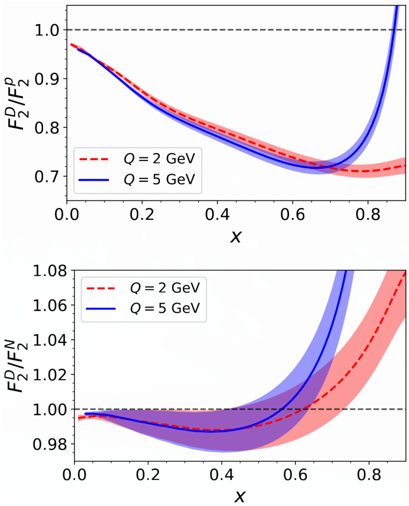
- Revisited derivation for nuclear DIS

Higher twist effects:

- Independent of the nucleus
- Using parameterization from the CJ15 analysis [Accardi et al, PRD 93 (2016) 114017]

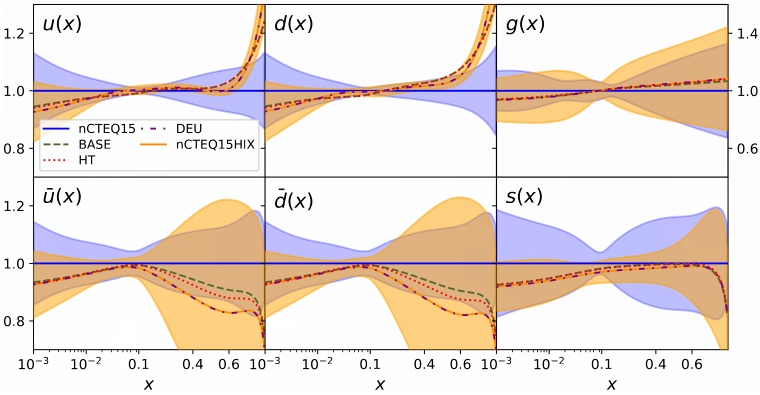
Deuteron corrections:

- Lightest bound nucleus
- Considerable differences to heavier targets
- Corrections have been extracted in the CJ15 analysis



nCTEQ15HIX – Resulting PDFs

Iron PDF ratios to nCTEQ15 ($Q = 2\,\text{GeV}$)

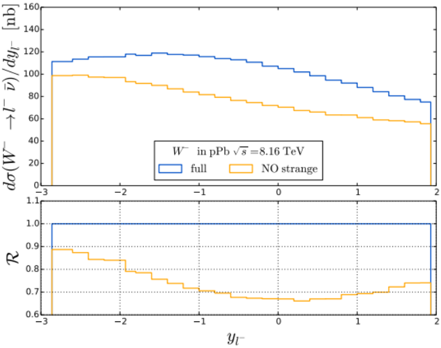


- BASE: nCTEQ15 with relaxed cuts + TMC
- HT: BASE + higher twist corrections
- DEU: BASE + deuteron corrections
- nCTEQ15HIX: BASE + higher twist and deuteron corrections

[Kusina et al., EPJC 80 (2020) 968]

Goal: Constrain the strange quark (and gluon) PDFs

- Open up strange quark parameters
- Strange quark channel contributes up to 30% of the total cross section
- 120 new data points



Data Overview						
			$\sqrt{s_{NN}}$ [TeV]	Norm σ	No Points	Ref.
ATLAS	Run I	$W^\pm$	5.02	2.7%	10+10	[49]
ATLAS	Run I	Z	5.02	2.7%	14	[50]
CMS	Run I	$W^\pm$	5.02	3.5%	10+10	[51]
CMS	Run I	Z	5.02	3.5%	12	[52]
CMS	Run II	$W^\pm$	8.16	3.5%	24+24	[53]
ALICE	Run I	$W^\pm$	5.02	2.0%	2+2	[54, 55]
LHCb	Run I	Z	5.02	2.0%	2	[56]

nCTEQ15WZ+SIH – Single inclusive hadron production

[Duwentäster et al., PRD 104 (2021) 094005]

Goal: Constrain the gluon PDFs

- Sensitivity to gluon PDFs not only from DGLAP evolution
- Precise new data from ALICE

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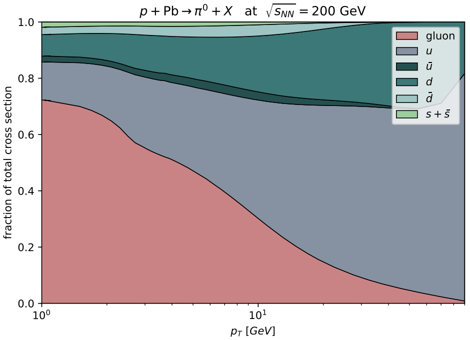

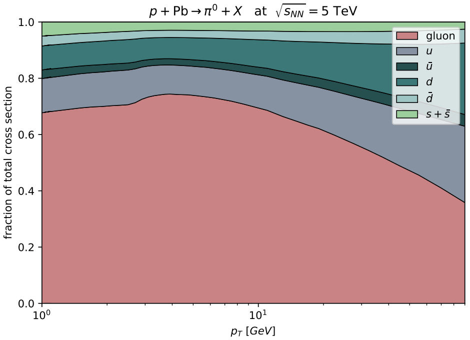

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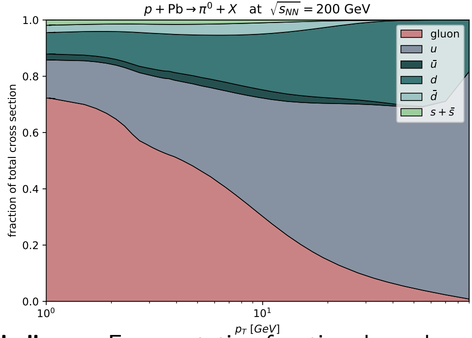
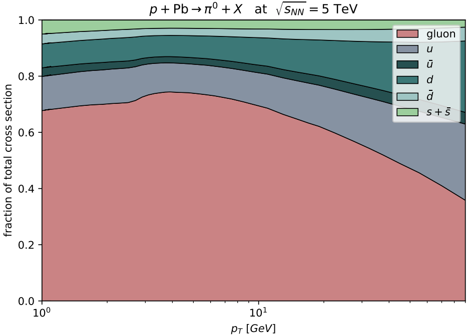


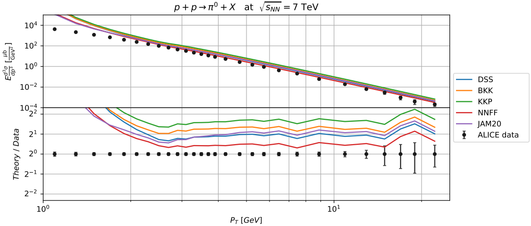


Challenge: Fragmentation function dependence

- The most precise data lies in non-perturbative low p_T region
- Fragmentation Function dependence

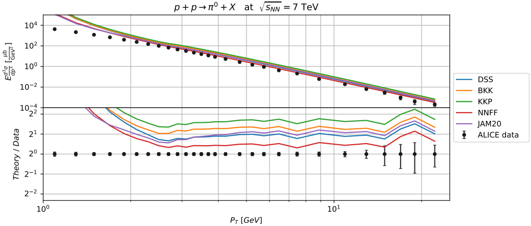
nCTEQ15WZ+SIH – FF dependence

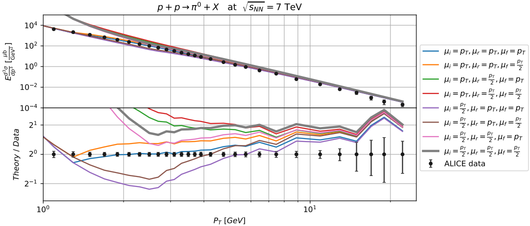
- **FF dependence**: Boils down to normalization shift → cancels in ratio



nCTEQ15WZ+SIH – FF dependence

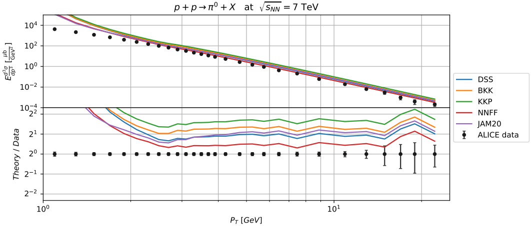
- **FF dependence**: Boils down to normalization shift $\rightarrow$ cancels in ratio
- **Scale dependence**: $\mu = \mu = \mu = \frac{1}{2} p_T$ gives optimal description

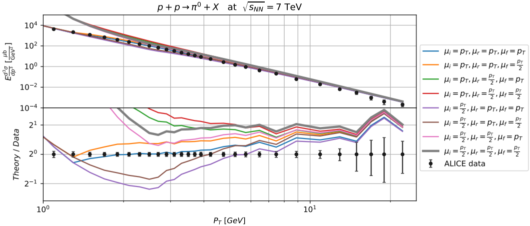




nCTEQ15WZ+SIH – FF dependence

- **FF dependence**: Boils down to normalization shift $\rightarrow$ cancels in ratio
- **Scale dependence**: $\mu = \mu = \mu = \frac{1}{2} p_T$ gives optimal description
- **Caveat**: No combination of FF and scale choice can describe data with $p_T < 3\,\text{GeV}$

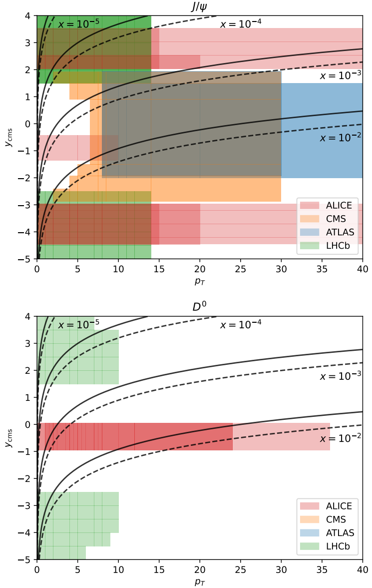




nCTEQ15HQ – Motivation

[Duwentäster et al., PRD 105 (2022) 114043]

Why is heavy-flavour production data interesting for nuclear PDFs?

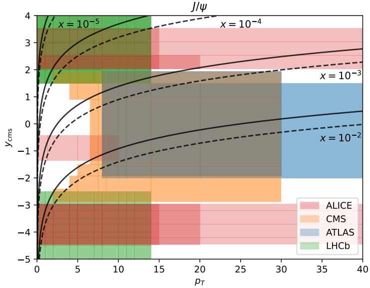


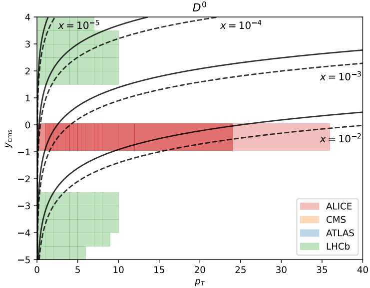
nCTEQ15HQ – Motivation

[Duwentäster et al., PRD 105 (2022) 114043]

Why is heavy-flavour production data interesting for nuclear PDFs?

- Sensitivity to gluon PDFs down to very low x values ($x \approx 10^{-5}$)
- Large available proton-lead data sets from multiple LHC experiments for $D^0, J/\psi, \psi(2S)$ and $\Upsilon(1S)$
- Interesting data-driven approach [A. Kusina et al., PRL 121 (2018) 052004; PRD 104 (2021) 014010]





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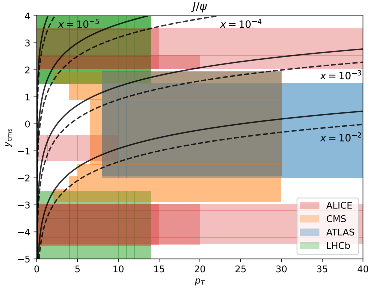
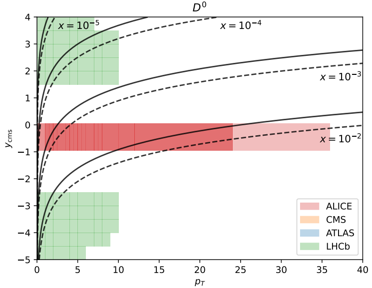
- Interesting data-driven approach [A. Kusina et al., PRL 121 (2018) 052004; PRD 104 (2021) 014010]
    - Understanding of quarkonium production in pQCD is limited
    - Can quantify theory uncertainties
    - Potentially applicable for many single-inclusive particle production processes
    - Fast calculation





nCTEQ15HQ – Data-driven Approach

Derive effective theory from p-p collision data to use with p-Pb data in the nPDF fit

$$\sigma(AB \to \mathcal{Q} + X) = \int \mathrm{d}x_1 \; \mathrm{d}x_2 f_{1,g}\left(x_1\right) f_{2,g}\left(x_2\right) \frac{1}{2\hat{s}} \overline{\left|\mathcal{A}_{gg \to \mathcal{Q}} + X\right|^2} \mathrm{dPS}$$

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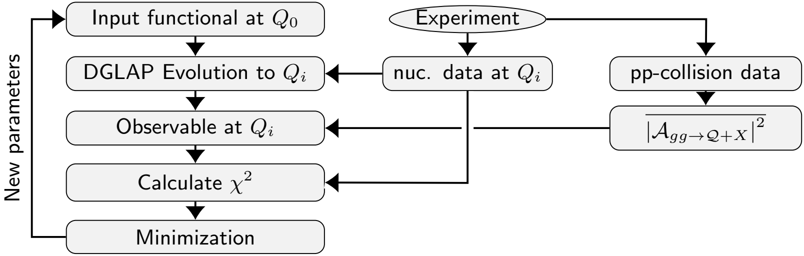

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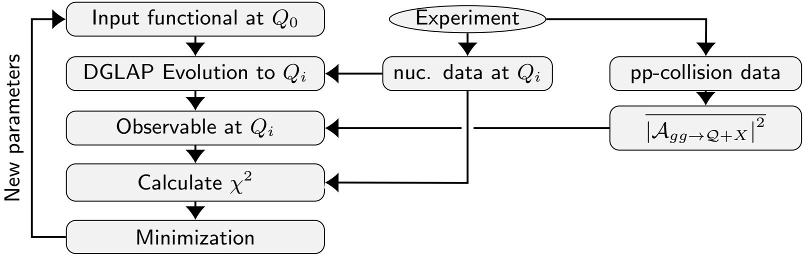
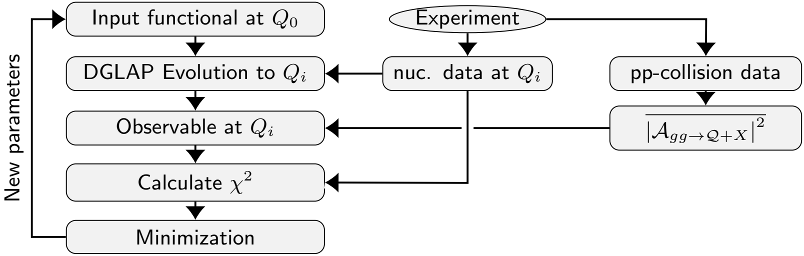


$$\overline{|\mathcal{A}_{gg\to\mathcal{Q}+X}|^2} = \frac{\lambda^2 \kappa \hat{s}}{M_{\mathcal{Q}}^2} \begin{cases} e^{-\kappa \frac{p_T^2}{M_{\mathcal{Q}}^2} + a|y|} & \text{if } p_T \leq \langle p_T \rangle \\ e^{-\kappa \frac{\langle p_T \rangle^2}{M_{\mathcal{Q}}^2} + a|y|} \left(1 + \frac{\kappa}{n} \frac{p_T^2 - \langle p_T \rangle^2}{M_{\mathcal{Q}}^2}\right)^{-n} & \text{if } p_T > \langle p_T \rangle \end{cases}$$

Derive effective theory from p-p collision data to use with p-Pb data in the nPDF fit

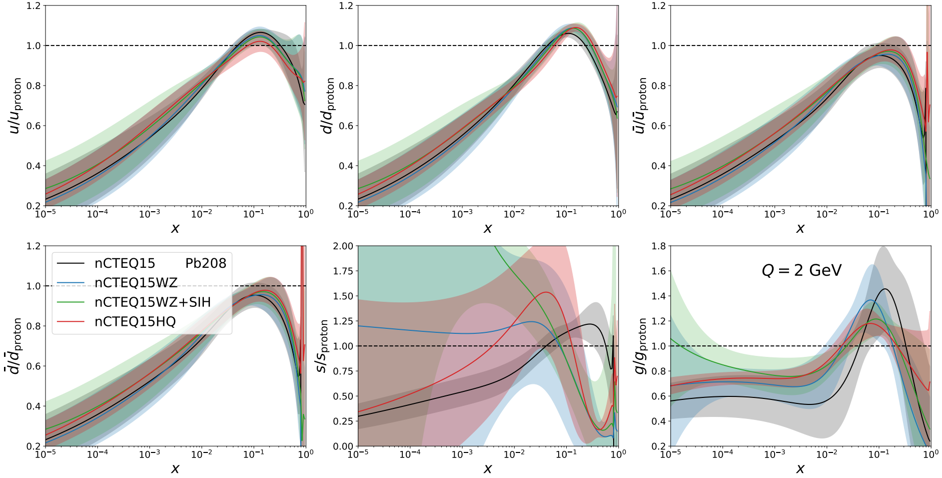
$$\sigma(AB \to \mathcal{Q} + X) = \int \mathrm{d}x_1 \, \mathrm{d}x_2 f_{1,g}(x_1) \, f_{2,g}(x_2) \, \frac{1}{2\hat{s}} \overline{|\mathcal{A}_{gg \to \mathcal{Q}} + X|^2} \mathrm{dPS}$$



$$\overline{|\mathcal{A}_{gg\to\mathcal{Q}+X}|^2} = \frac{\lambda^2 \kappa \hat{s}}{M_{\mathcal{Q}}^2} \begin{cases} e^{-\kappa \frac{p_T^2}{M_{\mathcal{Q}}^2} + a|y|} & \text{if } p_T \leq \langle p_T \rangle \\ e^{-\kappa \frac{\langle p_T \rangle^2}{M_{\mathcal{Q}}^2} + a|y|} \left(1 + \frac{\kappa}{n} \frac{p_T^2 - \langle p_T \rangle^2}{M_{\mathcal{Q}}^2}\right)^{-n} & \text{if } p_T > \langle p_T \rangle \end{cases}$$

- Fit parameters $\to$ uncertainties can be determined just like those of PDFs
- 5 parameters per process $\to$ 6×5 parameters describe ≈ 1000 data points very well
- Agrees well with NRQCD predictions for J/ψ and GMVFNS predictions for D^0

nCTEQ15(WZ, WZ+SIH, HQ) – Resulting PDFs



- Significant reduction in gluon and low-x uncertainties
- Strange quark still poorly constrained

nCTEQ15ν – Neutrino DIS revisited

[Muzakka et al., PRD 106 (2022) 074004]

Motivation:

- Reduce the uncertainty of the strange PDF
- Improve flavour separation
- **HUGE** data sets

Neutrino Data used in this analysis:

Data set	Nucleus	#pts	Corr.sys.
CDHSW ν CDHSW $\bar{\nu}$	Fe	465 464	No
CCFR ν CCFR $\bar{\nu}$	Fe	1109 1098	No
NuTeV ν NuTeV $\bar{\nu}$	Fe	1170 966	Yes
Chorus ν Chorus $\bar{\nu}$	Pb	412 412	Yes
CCFR dimuon ν CCFR dimuon $\bar{\nu}$	Fe	40 38	No
NuTeV dimuon ν NuTeV dimuon $\bar{\nu}$	Fe	38 34	No

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- Tensions within ν-DIS data sets
- Tensions between ν-DIS and other data

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- Tensions between ν-DIS and other data

Improved methodology:

- Treatment of normalization uncertainties.
- Deuteron correction from CJ15 analysis.
- More PDF parameters to fit.
- New tools for compatibility analysis

Neutrino Data used in this analysis:

Data set	Nucleus	#pts	Corr.sys.
CDHSW ν CDHSW $\bar{\nu}$	Fe	465 464	No
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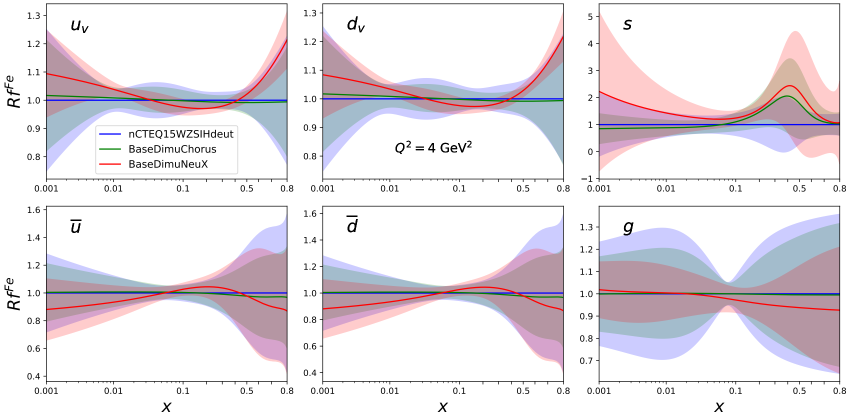
nCTEQ15ν – New fits



- nCTEQ15WZSIHdeut = Base: $l^{\pm}$ DIS+DY+SIH+WZ (940 pts)
- BaseDimuNeuX: Base + Dimuon + Neutrino, with $x \leq 0.1$ data are removed from the dimuon and neutrino data (5584 pts)
- BaseDimuChorus: Base + Dimuon + Chorus (1914 pts)

Towards a new nCTEQ global nPDF analysis

Combine nCTEQ15HIX, nCTEQ15HQ and nCTEQ15ν

- relaxed kinematic cuts
- Improved theory: TMCs, deuteron corrections, ...
- Check consistency between all data sets

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Update data

- New W/Z data from ALICE and LHCb
- New π^0 data from LHCb
- New Heavy quark data from all ALICE, CMS and LHCb

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Possibly new observables (under investigation)

- Dijet production
- Direct photon production

Updated parameterization

Based on the new CTEQ-JLAB proton PDF analysis

$$xf_i(x, Q_0^2) = c_0 x^{c_1} (1-x)^{c_2} \left(1 + c_3\sqrt{x} + c_5\sqrt{x^3}\right) \qquad i = u_v, g, \bar{u} + \bar{d}, \bar{s} + \bar{s}$$

$$xd_v(x, Q_0^2) = c_0 x^{c_1} (1-x)^{c_2} \left(1 + c_3\sqrt{x} + c_5\sqrt{x^3}\right) + c_6 x^{c_7} u_v(x, Q_0^2)$$

$$x(\bar{d} - \bar{u}) = c_0 x^{c_1} (1-x)^{c_2} (1 + c_3 x)$$

Towards a new nCTEQ global nPDF analysis

Updated parameterization

Based on the new CTEQ-JLAB proton PDF analysis

$$
\begin{aligned}
xf_i(x,Q_0^2) &= c_0 x^{c_1}(1-x)^{c_2}\left(1+c_3\sqrt{x}+c_5\sqrt{x^3}\right) \qquad i=u_v,g,\bar{u}+\bar{d},\bar{s}+\bar{s} \\
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x(\bar{d}-\bar{u}) &= c_0 x^{c_1}(1-x)^{c_2}(1+c_3 x)
\end{aligned}
$$

Changing the nuclear A dependence

OLD: $c_k \to c_k(A) \equiv p_k + a_k(1-A^{-b_k})$

$$\Downarrow$$

NEW: $c_k \to c_k(A) \equiv p_k + a_k \ln(A) + b_k \ln(A)^2$

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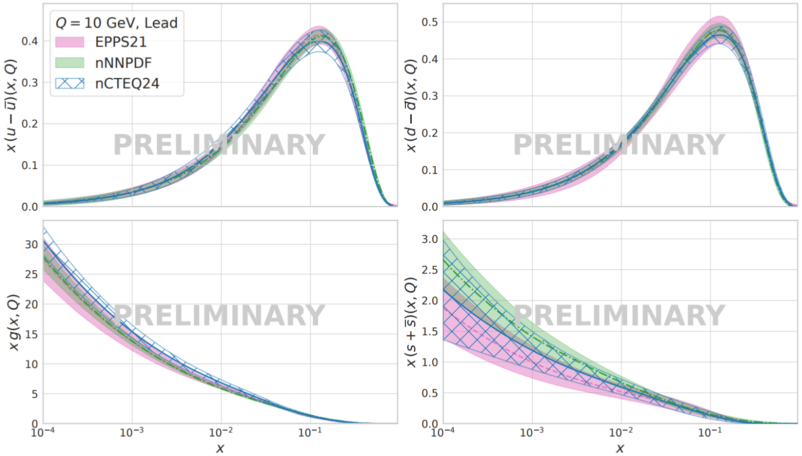
nCTEQ15 used 16 open parameters; nCTEQ15WZ and following used 19
nCTEQ24 will use more than 30

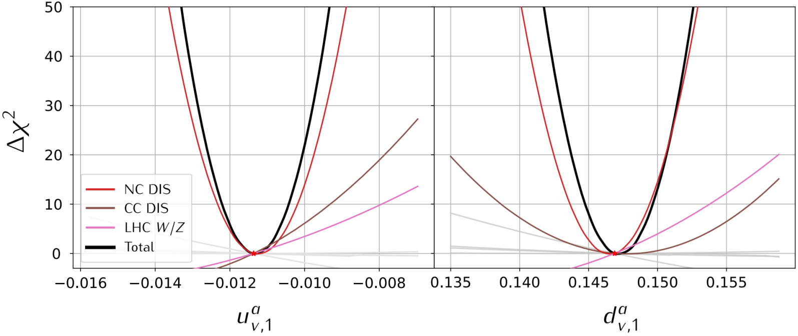
Preliminary results - PDFs

- Good agreement with other recent analyses by EPPS [Eskola et al., EPJC 82 (2022) 5,413] and nNNPDF [Khalek et al., EPJC 82 (2022) 6,507]
- Uncertainty bands are subject to significant change as we reevaluate the tolerance criterion



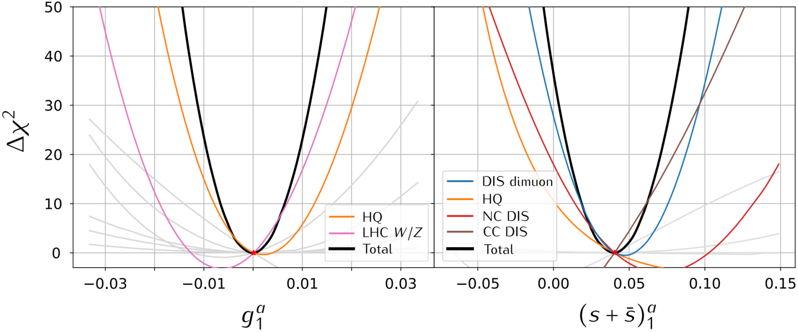
Preliminary results - Parameter Scans

- Valence quark parameters are still mostly constrained by Neutral Current DIS



Preliminary results - Parameter Scans

- Gluon parameters are constrained by heavy quark and W/Z production
- Strange quark parameters are a compromise between various experiment types
  - Tensions remain between CC DIS and others



Summary

Modern nuclear PDF analyses require a vast number of different components to come together to gain comprehensive understanding

Data

- Vector bosons
- Inclusive hadrons
- Heavy quarks
- Neutrino DIS
- High-x DIS
- (Direct photons)
- (Dijets)

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- FF dependence of single inclusive hadrons
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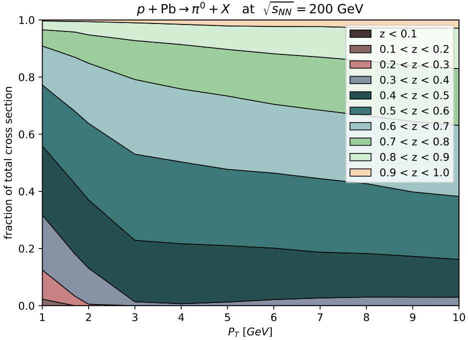
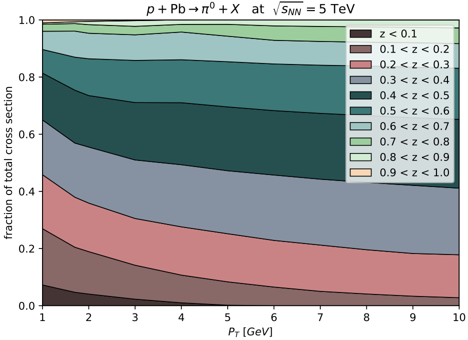
Technical

- New CJ proton baseline
- A-dependence parameterization
- Compatibility criteria
- Increasing number of open parameters

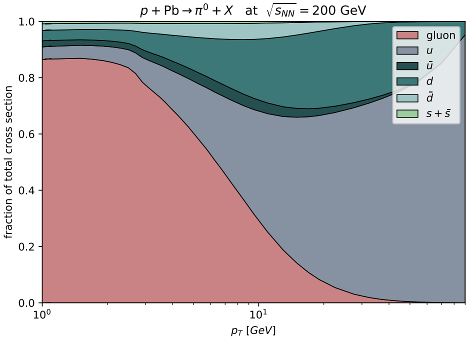
Backup slides

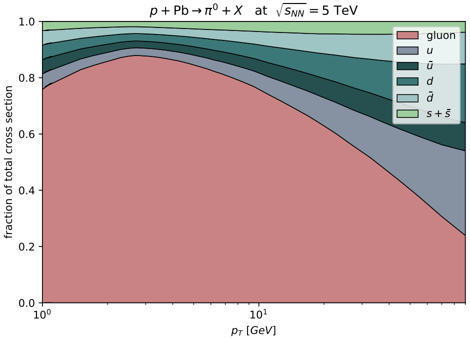
Backup – z dependence





Backup – FF parton dependence

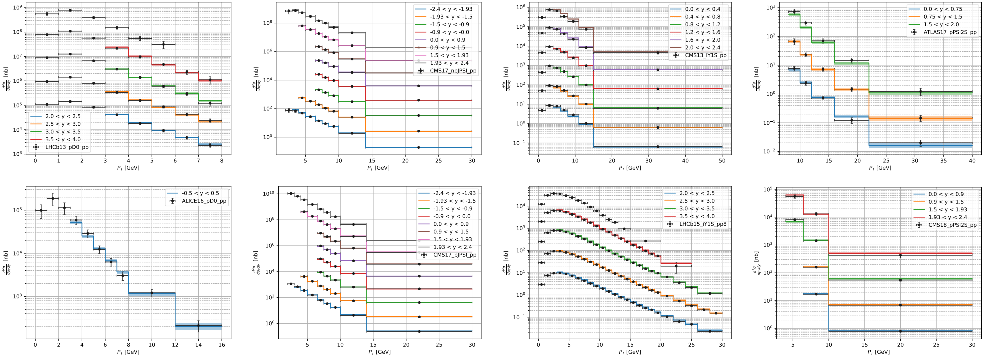




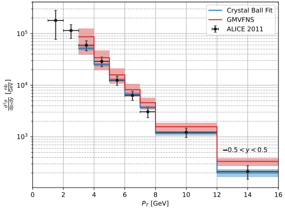
Heavy quarks - Proton-proton baseline

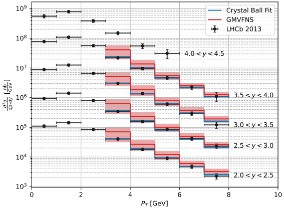
- Impose cuts to remove data with $p_T < 3\,\text{GeV}$ and outside of $-4 \leq y_{\text{c.m.s.}} \leq 4$

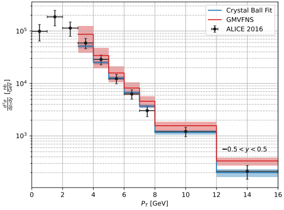
	D^0	J/ψ	$B \to J/\psi$	$\Upsilon(1S)$	$\psi(2S)$	$B \to \psi(2S)$
N_{points}	34	501		375	55	
χ^2/N_{dof}	0.25	0.88		0.92	0.77	



Baseline – comparison with GMVFNS



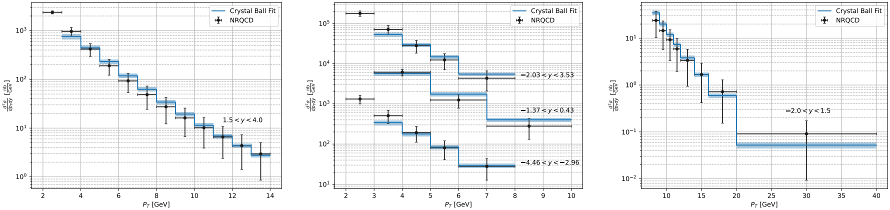




- KKKS08 fragmentation functions
- Base scale $\mu_r = \mu_i = \mu_f = \sqrt{p_T^2 + 4m_c^2}$
- Uncertainties due to individual scale variations by factor 2 or $\frac{1}{2}$

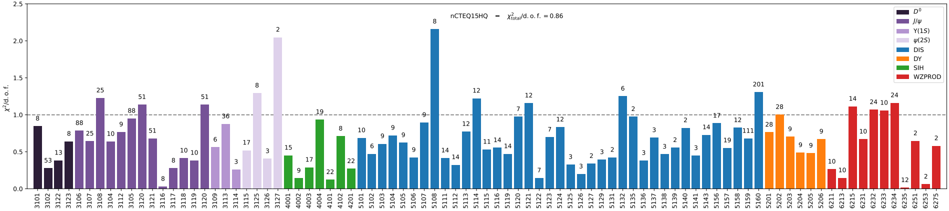
Baseline – comparison with NRQCD

Calculations by Mathias Butenschoen, Bernd Kniehl [M. Butenschoen et al., Nucl.Phys.B Proc.Suppl. 222-224 (2012) 151-161]

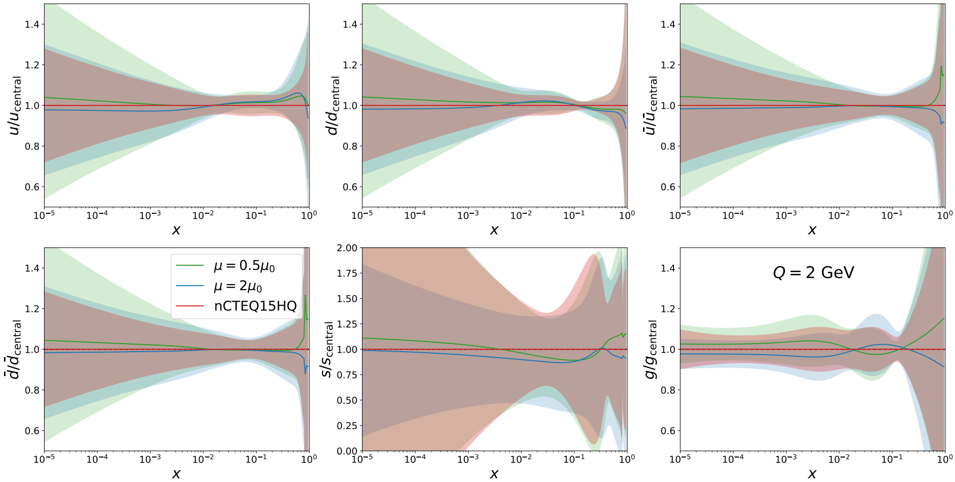


- NRQCD Uncertainties due to scale variations:
  $1/2 < \mu_r/\mu_{r,0} = \mu_f/\mu_{f,0} = \mu_{\mathrm{NRQCD}}/\mu_{\mathrm{NRQCD},0} < 2$
- Base scale $\mu_{r,0} = \mu_{f,0} = \sqrt{p_T^2 + 4m_c^2}$ and $m_{\mathrm{NRQCD},0} = m_c$

- Include all data from nCTEQ15WZ+SIH
- Use the same open parameters as nCTEQ15WZ+SIH
- Cut HQ data below $p_T < 3.0$ GeV and outside $-4 \leq y_{\text{c.m.s.}} \leq 4$
  - Same as proton-proton baseline.
  - 548 new data points
  - Add Crystal Ball uncertainty to data systematics



nCTEQ15HQ PDFs – scale variation



Compatibility Analysis S vs $\bar{S}$

Definition ($\Delta\chi^2_S$-compatibility)

$$\chi^2_S(\text{after}) - \chi^2_S(\text{before}) \leq \Delta\chi^2_S$$

Definition (χ^2-compatibility)

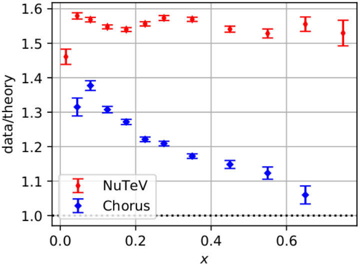
$$p_S \leq 0.9 \quad \text{and} \quad p_{\bar{S}} \leq 0.9$$

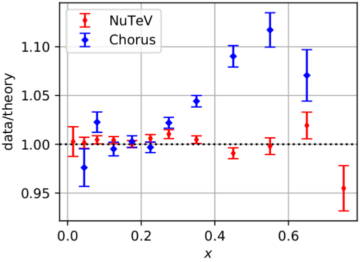
$$p_S = \int_0^{\chi^2_S} P(\chi^2, N_S) d\chi^2$$

Definition (S_E-compatibility)

$$S_E = \sqrt{2\chi^2_E(N)} - \sqrt{2N-1} \sim \mathcal{N}(0,1)$$

Treatment of Normalization Parameters





- The old way to include normalization uncertainties : $\chi^2 = (D-T)^T C_D^{-1}(D-T)$, $C_{D,ij} = C_{ij} + \sigma_{norm}^2 D_i D_j$ lead to d' Agostini bias.
- Standard solution :

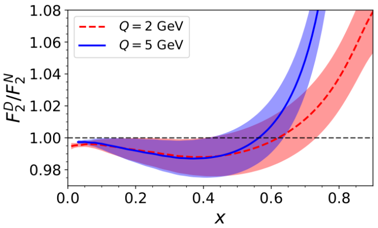
$$\chi^2 = (D - T/r)^T C^{-1}(D - T/r) + \frac{(1-r)^2}{\sigma_{norm}^2}$$

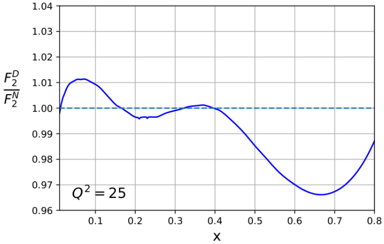
- Drawbacks : (1) Additional fitting parameters. (2) Must be taken into account in the Hessian error analysis.
- Another solution :

$$\chi^2 = (D - rT)^T C_{-1}(D - rT) + \frac{(1-r)^2}{\sigma_{norm}^2}$$

Advantages : (1) No additional open parameters as the optimal r can be calculated analytically. (2) The Hessian method automatically includes the contribution from r.

Treatment of Deuteron Correction





- Without deuteron correction, F_2^D is computed as : $F_2^D = F_2^p + F_2^n \equiv F_2^N$.
- However, $F_2^D \neq F_2^N$.
- How we compute F_2^D :

$$F_2^D = F_2^{p,CTEQ} \times \frac{F_2^{D,CJ}}{F_2^{P,CJ}}$$

where $F_2^{D,CJ}$, $F_2^{P,CJ}$ comes from CJ15 analysis[Accardi *et al*, Phys.Rev.D93 11,(2016) 114017].

Open Parameters in Neutrino Fits

$$a_1^{u_v},\ a_2^{u_v},\ a_4^{u_v},\ a_5^{u_v},\ b_1^{u_v},\ b_2^{u_v},$$
$$a_1^{d_v},\ a_2^{d_v},\ a_4^{d_v},\ a_5^{d_v},\ b_1^{d_v},\ b_2^{d_v},$$
$$a_1^{\bar{u}+\bar{d}},\ a_2^{\bar{u}+\bar{d}},\ a_5^{\bar{u}+\bar{d}},$$
$$a_1^{g},\ a_4^{g},\ a_5^{g},\ b_0^{g},\ b_1^{g}, b_4^{g},\ b_5^{g},$$
$$a_0^{s+\bar{s}},\ a_1^{s+\bar{s}},\ a_2^{s+\bar{s}},\ b_0^{s+\bar{s}},\ b_2^{s+\bar{s}}$$

Combined Fit?

- **Important question** : issue with the data or incomplete understanding of neutrino interactions in nuclear environment?
- Need new neutrino DIS data.
- In the mean time, three strategies :
  - Issue with experimental uncertainties → Ignore correlations, Weight variation, etc.
  - Issue with possibly different shadowing mechanism → Restricting Kinematic region → BaseDimuNeuX.
  - Select data sets that pass the compatibility criteria→ BaseDimuChorus.