The LHC data at p-Pb collisions (& nPDFs)

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A short digression on nPDFs

The LHC data from Run I (p-Pb)

The (ongoing) work

Re-weighting

Preliminary results

Summary & outlook
the nuclear medium modifies the partonic behaviour, then A dependent PDFs are needed
NUCLEAR PDFS

- Determined as proton PDFs (global fits)
- Several sets available at NLO with theoretical uncertainties (DSSZ, EPS09, HKN, nCTEQ)
- Mostly DIS data (valence well constrained)
- Limited coverage of the kinematic space
- Sea and gluon densities too assumptions dependent
P-Pb: LHC Run I

- Jets (ATLAS)
- Di-jets (CMS)
- W+, W- (CMS)
- Z (ATLAS, CMS, LHCb)
- Hadro-production (ALICE): dependent on (not well understood) FFs
THE WORK

- **Aim:**
  - analyze the impact of these data on nPDFs
  - determine if a new nPDF fit is required

- **Method:**
  - bayesian re-weighting with two proton (MSTW2008, CT10) and two nuclear (DSSZ, EPS09) PDF sets
  - MCFM & FR (Frixione-Ridolfi)

**References**

- **MSTW2008:** EPJC 63 (2009) 189
- **CT10:** PRD 82 (2010) 074024
- **DSSZ:** PRD 85 (2012) 074028
- **EPS09:** JHEP 0904 (2009) 065
- **MCFM:**
  - FR : NPB 467 (1996) 399
  - NPB 507 (1997) 295
  - NPB 507 (1997) 315
- given: $f_{S_0}, f_{S_i^+}, f_{S_i^-}$

- generate MC replicas ($k=1, \ldots, N_{\text{rep}} \sim 10^4$)

$$f_k = f_S + \sum_i^{N_{\text{eig}}} \frac{f_{S_i^+} - f_{S_i^-}}{2} R_{ik}$$

represent the underlying probability distribution of the PDFs

$P_{\text{old}}(f)$

random, gaussian
any PDF dependent quantity is

\[
\langle \mathcal{O} \rangle = \frac{1}{N_{\text{rep}}} \sum_{k=1}^{N_{\text{rep}}} \mathcal{O}(f_k)
\]
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\]

- add new data \( \vec{y} \)
- by Bayes’ theorem:

\[
P_{\text{new}}(f) \propto P(\vec{y}|f)P_{\text{old}}(f)
\]

likelihood
then

\[
\langle \mathcal{O} \rangle_{\text{new}} = \frac{1}{N_{\text{rep}}} \sum_{k=1}^{N_{\text{rep}}} \mathcal{O}(f_k) w_k
\]

proportional to the likelihood
then

\[
< \mathcal{O} >_{\text{new}} = \frac{1}{N_{\text{rep}}} \sum_{k=1}^{N_{\text{rep}}} \mathcal{O}(f_k) w_k
\]

proportional to the likelihood

with

\[
w_k = \exp\left(-\frac{\chi_k^2}{2\Delta}\right)
\]

PDF tolerance, needed for statistical correctness

quantitative estimator of data-theory compatibility

\[
N_{\text{eff}} \equiv \exp\left\{\frac{1}{N_{\text{rep}}} \sum_{k=1}^{N_{\text{rep}}} w_k \log(N_{\text{rep}}/w_k)\right\}
\]
RESULTS

- some data are still preliminary
- adequate data selection under discussion
- shown only for CT10 + EPS09
JETS BY ATLAS

JETS BY ATLAS

ATLAS Collaboration,
JETS BY ATLAS

JETS BY ATLAS

ATLAS Collaboration,
JETS BY ATLAS

GLUONS

$Q^2 = 1.69 \text{GeV}^2$
W’S BY CMS


\[ W^+ \rightarrow l^+ \nu \]

\[ |\eta_{lab}| < 2.4 \]

\[ p_T > 25 GeV \]

\[ \frac{d\sigma(W^+ \rightarrow l^+ \nu)}{d\eta_{lab}} \text{ [nb]} \]

- MCFM (no reweight.)
- Exp. data
$W' \to l^+ \nu$

$|\eta_{lab}| < 2.4$

$p_T > 25 GeV$


$\frac{d\sigma(W^+ \to l^+ \nu)}{d\eta_{lab}} [nb]$
W’S BY CMS


\[ W^- \rightarrow l^- \nu \]
W’s by CMS

$|\eta_{lab}| < 2.4$

$p_T > 20\,\text{GeV}$
$|\eta_{\text{lab}}| < 2.4$

$p_T > 20\text{GeV}$
Z BY ATLAS

ATLAS-CONF-2014-020

CAREFUL! NOT THE LATEST DATA (see T. Balestri’s talk at Hard Probes)

\[ \frac{d\sigma}{dy} \]

- **MCFM (no reweight.)**
- **Exp. data**

![Graph showing the distribution of decay rates](image)
CAREFUL! NOT THE LATEST DATA (see T. Balestri’s talk at Hard Probes)
SEA QUARKS $Q^2 = 1.69 GeV^2$
$C_{\text{asymm}} = \frac{N_l^+ - N_l^-}{N_l^+ + N_l^-}$
\[ C_{asymm} = \frac{N_l^+ - N_l^-}{N_l^+ + N_l^-} \]

CMS W’s

need of flavour decomposition in nPDFs
ASYMMETRIES

\[ FB_{asym} = \frac{N_l(+\eta)}{N_l(-\eta)} \]

predictions show a clear nuclear effect (see A. Zsigmond’s talk in Hard Probes)
SUMMARY

- We analyzed p-Pb data from LHC (~160 points) for EPS09
- Predictions are compatible with data (except ATLAS’ Z, updated data to check): $N_{\text{eff}} \sim 6000$
- For EPS09 the impact seems rather small, except for the gluon density (very unconstrained)
- The trend is a flatter gluon, with less shadowing and anti-shadowing
- Preliminary results do not hint the need for new nPDFs
Incorporate the final ATLAS’ Z data, and LHCb’s Z
Consider charged-particles production from ALICE
Check for (promising) observables, such as asymmetries
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comments and (un) answered questions to:

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& OUTLOOK

- Incorporate the final ATLAS’ Z data, and LHCb’s Z
- Consider charged-particles production from ALICE
- Check for (promising) observables, such as asymmetries

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(the rest of us are on vacation)