Summary/Discussion:

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HERAFitter Meeting Marseille Feb 2012

Functionality HERAFitter Beta Release

- Beta release contains a minimum set of tools for its use at the LHC experiments
  - It can produce out of the box HERAPDF1.0
  - Sample data file formats for DY and jets usages

- DATA:
  - DIS ep
    - Inclusive
    - jets
  - DY pp and ppbar
    - W, Z, cross sections
    - Zrapidity
    - W asymmetries
    - jets
  - Error treatment:
    - Correlated, Uncorrelated
    - Hessian Method
    - MC method
- Parametrisation studies:
  - Standard functional form of PDFs
  - CTEQ
  - Chebyshev

- Theory (DIS):
  - ZM-VFNS accessed from QCDNUM
  - GM-VFNS RT from R. Thorne
- Treatment for jets:
  - FastNLO:
    - A wraper around NLOJets++
  - Applgrid:
    - A wraper around MCFM, NLOJets++
- DY cross sections at LO x kfactors
- Output:
  - PDFs at predifined scales
  - LHAPDF grids
  - Theory predictions per data points
  - Pulls per data points

DIS(upol)	✔
DIS(pol)	✔
RT(st)	✔
RT(kfact)	✔
DY	✔
Jets ep	✔
Jets pp,ppbar	✔
Param studies	✔
Error band	✔
MC errors	✔
LHAPDF grids	✔
Drawing Tools	✔

New developments since beta-release

- Data file storage (published Tevatron, LHC data) https://znwiki3.ifh.de/H1Fitter/H1Fitter/downloads/datatables
- New heavy flavour schemes:
  - RT optimal as in MSTW (see G. Watt's talk)
  - ACOT as in CTEQ (see F. Olness's talk)
  - FONLL as in NNPDF (see J. Rojo's talk)
  - FFNS and BMSN as in ABM (see R. Placakyte's talk)

- Developments in the top area: ttbar cross section (see S. Naumann's talk)
- Slightly modified code flow from the beta-release (see K. Nowac's and A. Sapronov's talk)
  - Adjusted wrappers around interfaces
  - Removal of redundancy between NC and CC codes
- Possibility to link to LHAPDF

- Additions to HERAFitter package: HERAaverager
  - Used for combining the measurements
- To be included:
  - Addition of the NNPDF reweighting tool (see A. Guffanti's talk)

  - Additions from ZEUS:
    - Offset method in estimating the uncertainties
    - Diffractive fits
    - Photon PDFs
    - C++ wrappers

HERAFitter: basic interface requirements

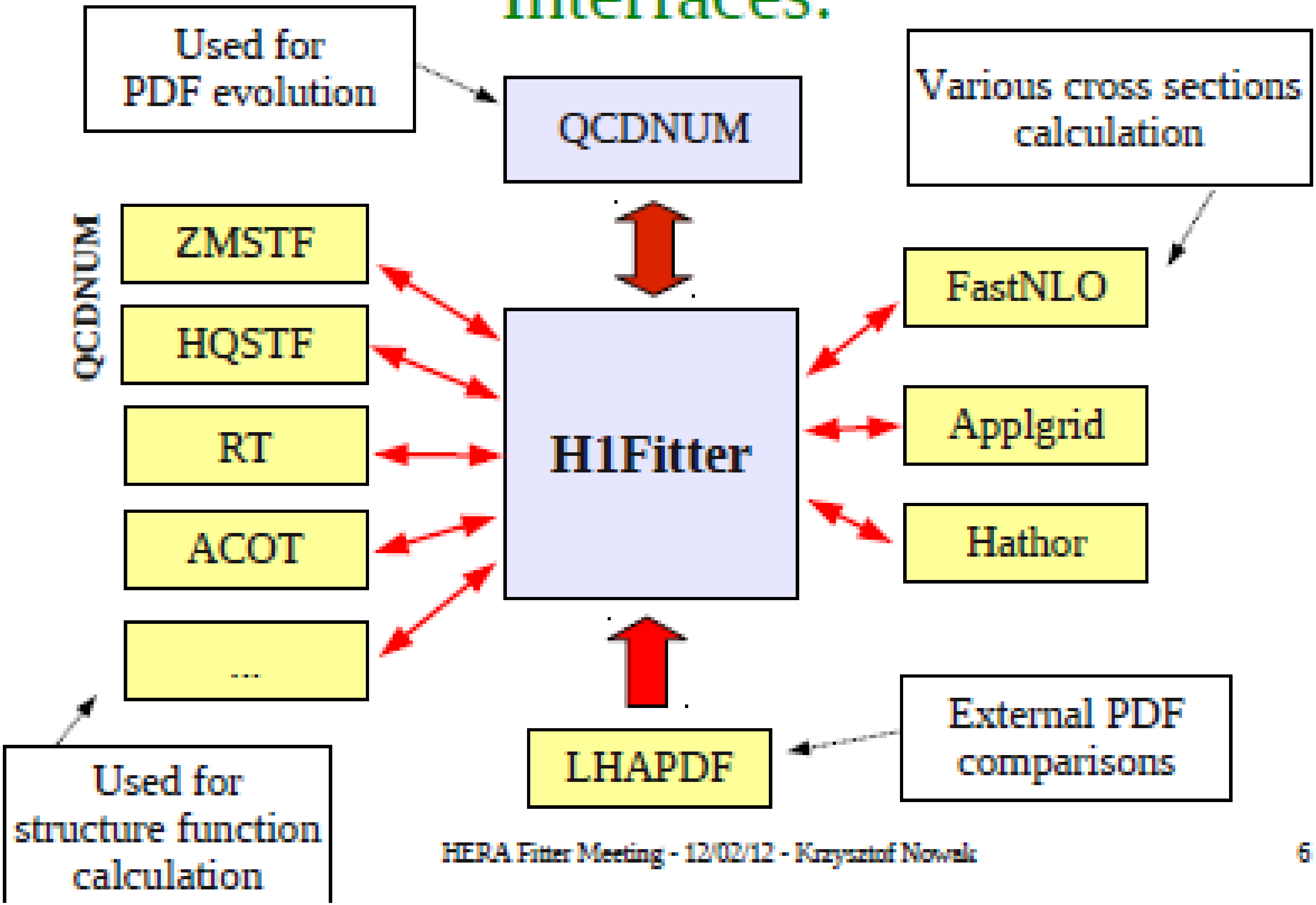
The software code is a mixture of C++ and Fortran codes. The core interfaces are provided in the Fortran part of the code.

- Use standard Fortran method to input information: `namelist` files.
- Central steering file to define input data, fitting parameters `steering.txt` containing several namelists.
- Inclusion of new data tables for existing processes should be possible without code recompilation. Data are provided as text files with a namelist header and the main body, as a table.
- Various models for treatment of correlated systematic uncertainties are available, steerable
- Inclusion of new theory in a standardized, modular way.
- Output contains basic text information to
  - Control consistency of the input data/fit parameters (error logging).
  - Report quality of the fit: χ^2, pulls, etc.
  - Report resulting PDFs: simple text and HERAGRID LHAPDF format.

- `HERAFitter` is a modular code with reduced depenence to external packages.
- Data files can be added without code recompilation.
- New theory modules can be added in a modular way.
- `HERAFitter` can be used for PDF benchmarking.

The code is open for further developments. Your input/suggestions are very welcome !

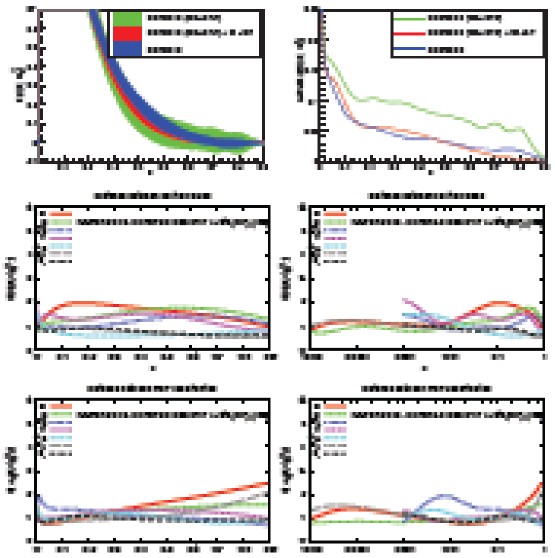
Interfaces:


Used for
PDF evolution
QCDNUM
Various cross sections
calculation
QCDNUM
ZMSTF
HQSTF
RT
ACOT
...
H1Fitter
FastNLO
Applgrid
Hathor
LHAPDF
External PDF
comparisons
Used for
structure function
calculation

Reweighting (NN)PDFs

Proof-of-concept: Inclusive Jet data, reweighting vs. refitting

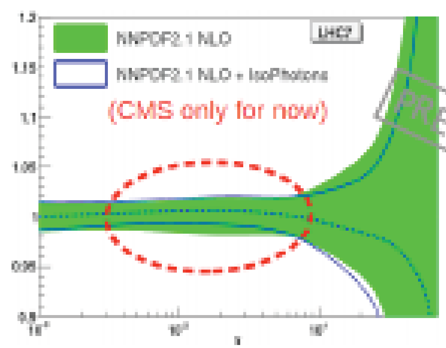
- Use **DIS+DY-fit** as **prior** probability distribution
- Add Tevatron Inclusive Jet data through refitting and through reweighting
- **Reweighting** and **refitting** yield **statistically equivalent** results



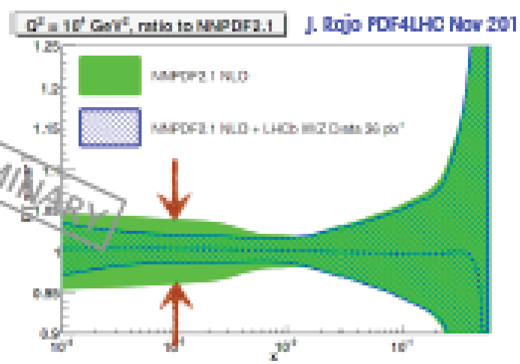
Reweighting NNPDFs

Reweighting at work - Other examples

D'Enterria, PDF4LHC Nov 2011

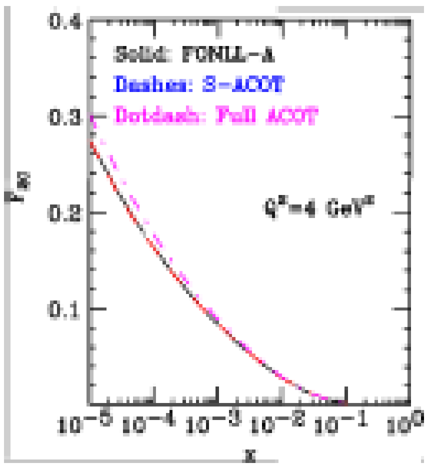


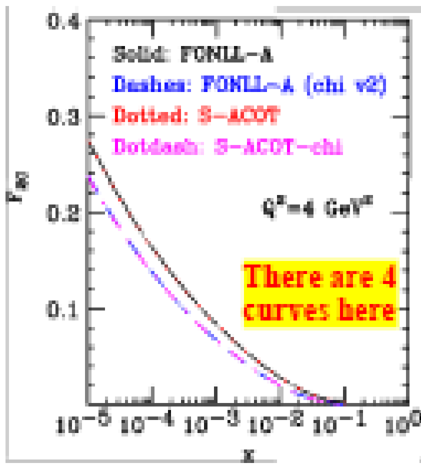
J. Rojo PDF4LHC Nov 2011

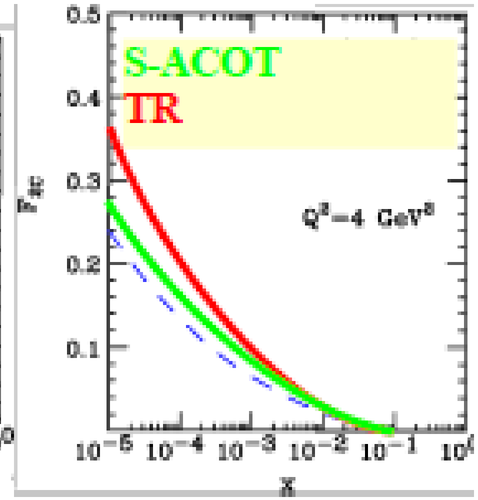


- W lepton asymmetry data from ATLAS and CMS → medium, small-x region light quarks/antiquarks
- Direct photon → medium-x gluon
- LHCb high rapidity data (still preliminary) → small-x region

LHC data already have a non-negligible impact!!







ACOT & S-ACOT essentially identical

... scheme differences are higher order

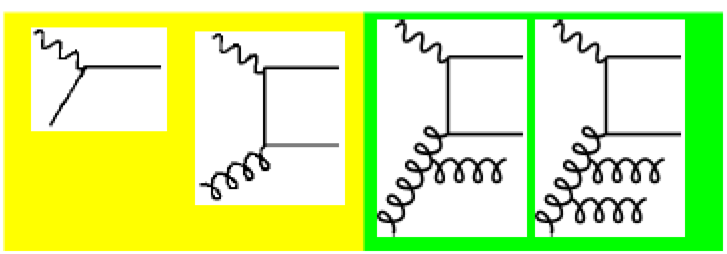
FONNL & S-ACOT

Numerically similar

MSTW09

We can quantify <u>theoretical</u> scheme diffferences

LO **NLO** **N2LO** **N3LO**



Full ACOT

Extensible to any order

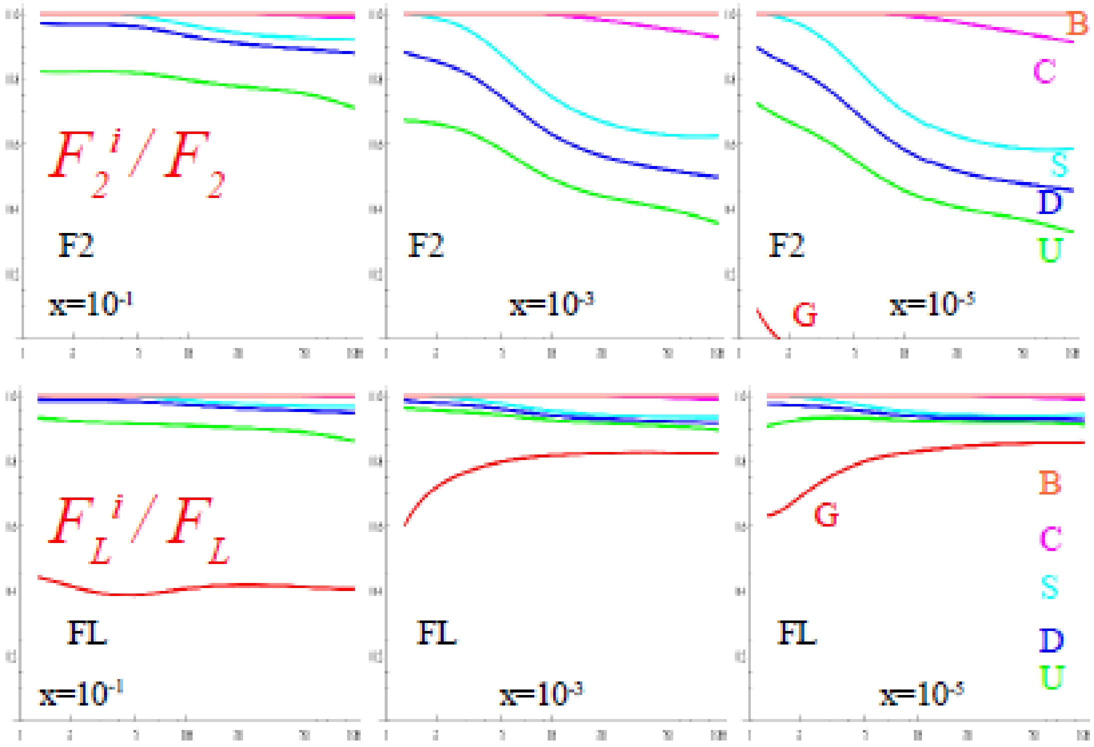
$$\sigma = f(\xi(x, m_{ps}), Q) \otimes \hat{\sigma}(m_{dyn})$$

$$\xi(x, m_{ps}) = x\left(1 + \left[\frac{n\, m_{ps}}{Q}\right]^2\right)$$

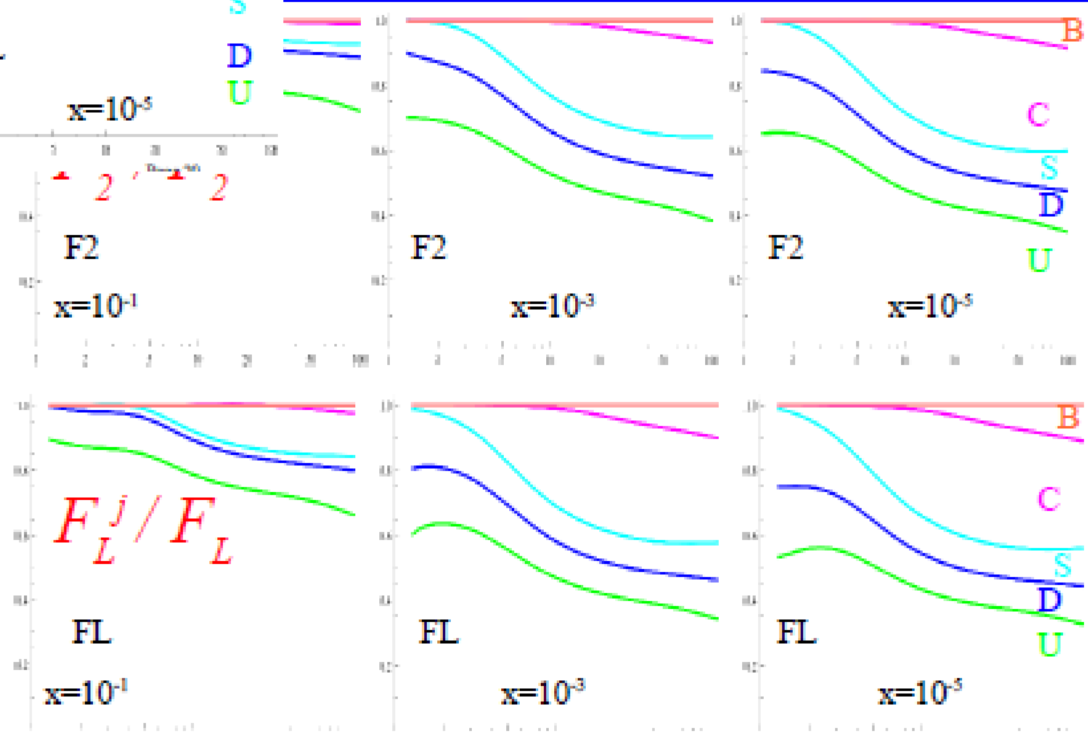
$$n = \{0, 1, 2\}$$

Distinguish "phase space" mass from "dynamic" mass

FLAVOR DECOMPOSITION: Initial State Quark:

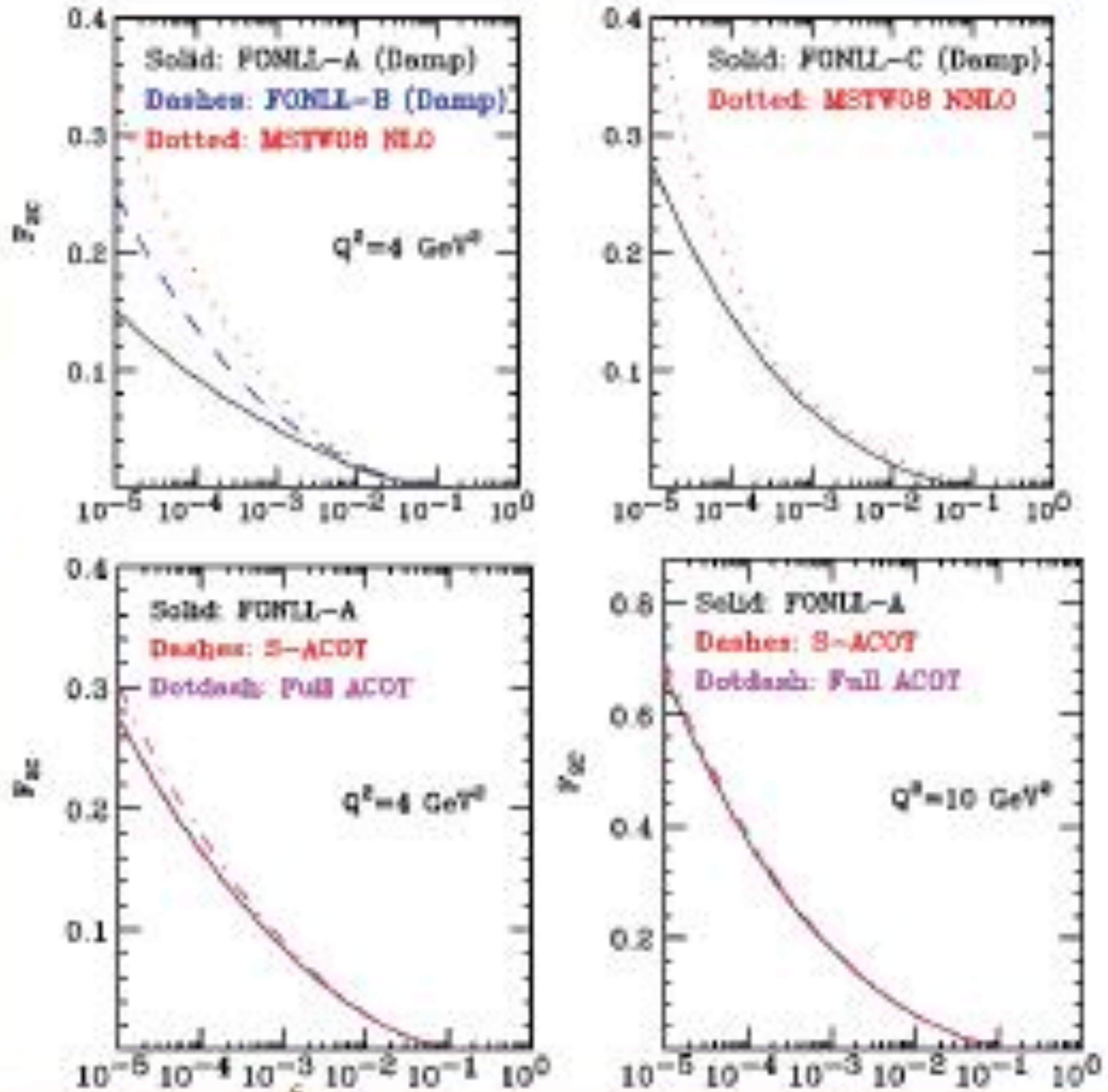


R DECOMPOSITION: Final State Quark:

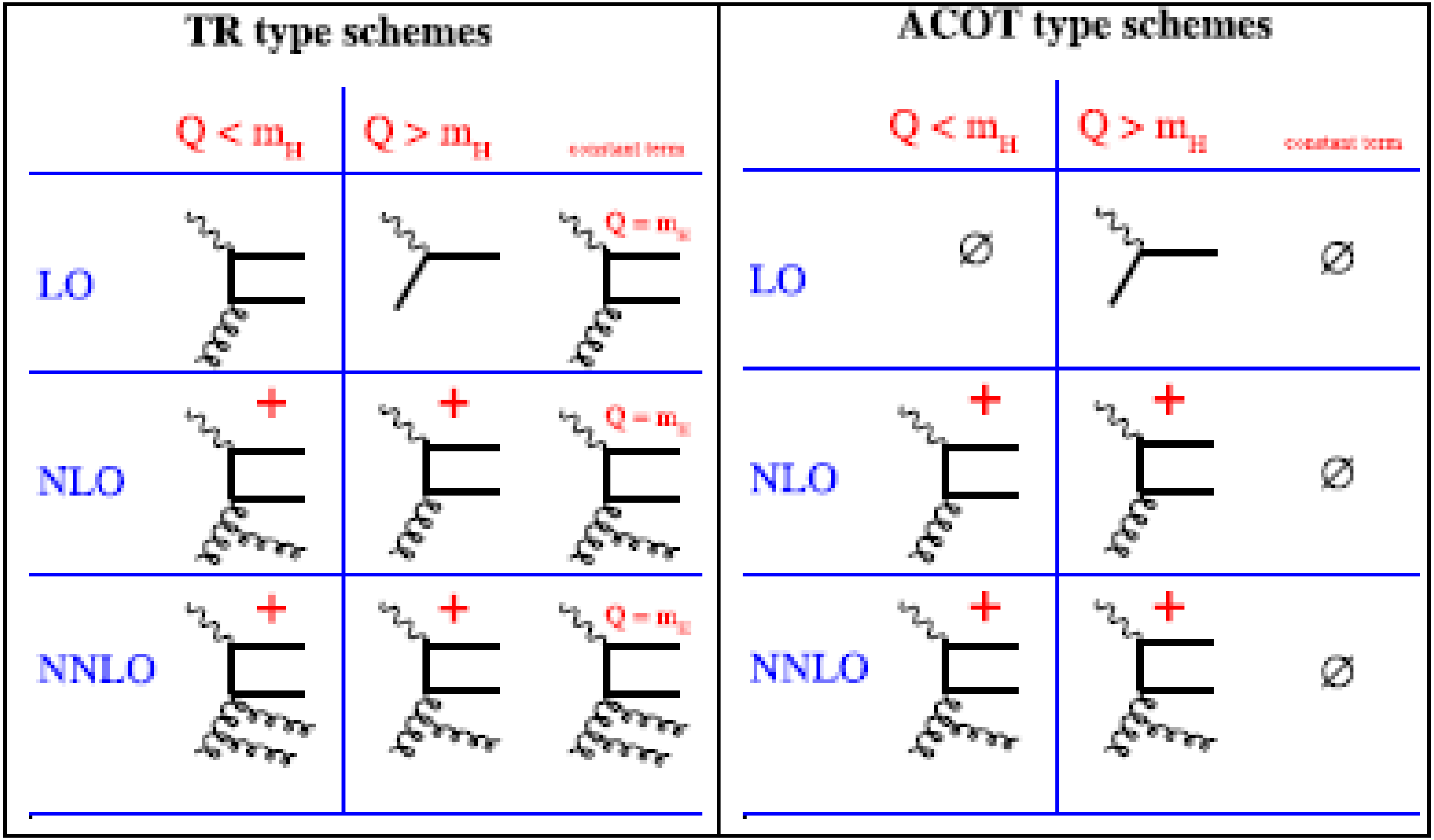


- FONLL variants: FONLL-A (NLO VFN and LO FFN), FONLL-B (NLO VFN and NLO FFN), and FONLL-C (NNLO VFN + NLO FFN)

- Systematic comparison in the Les Houches 2009 proceedings (arXiv:1003.1241)
- FONLL-A identical to S-ACOT if same threshold prescription chosen
- MSTW08 NLO/NNLO identical to FONLL A/C up to a Q^2 independent (subleading) term
- More recently: FONLL-C numerically similar to S-ACOT NNLO, to be used in CT NNLO fits (arXiv:1108.5112)
- Relation between different GM-VFN schemes well understood

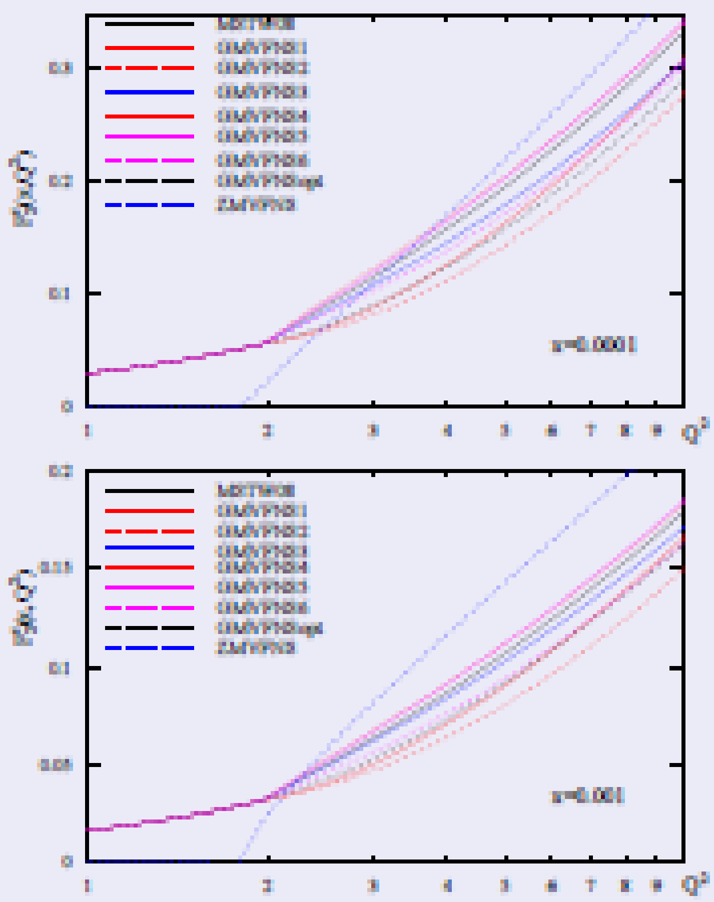


Perturbative expansion for F_2^H (TR/TR′ versus ACOT)

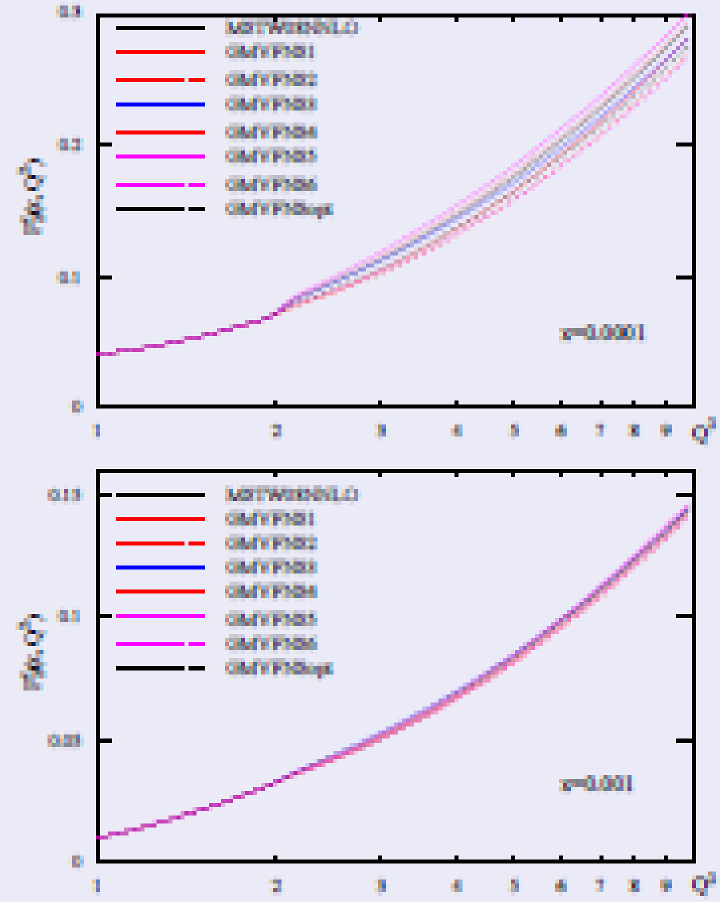


Impact of TR′ variations on $F_2^{\rm charm}$ [R. S. Thorne, arXiv:1201.6180]

$F_2^{\rm charm}$ at NLO (fixed PDFs)



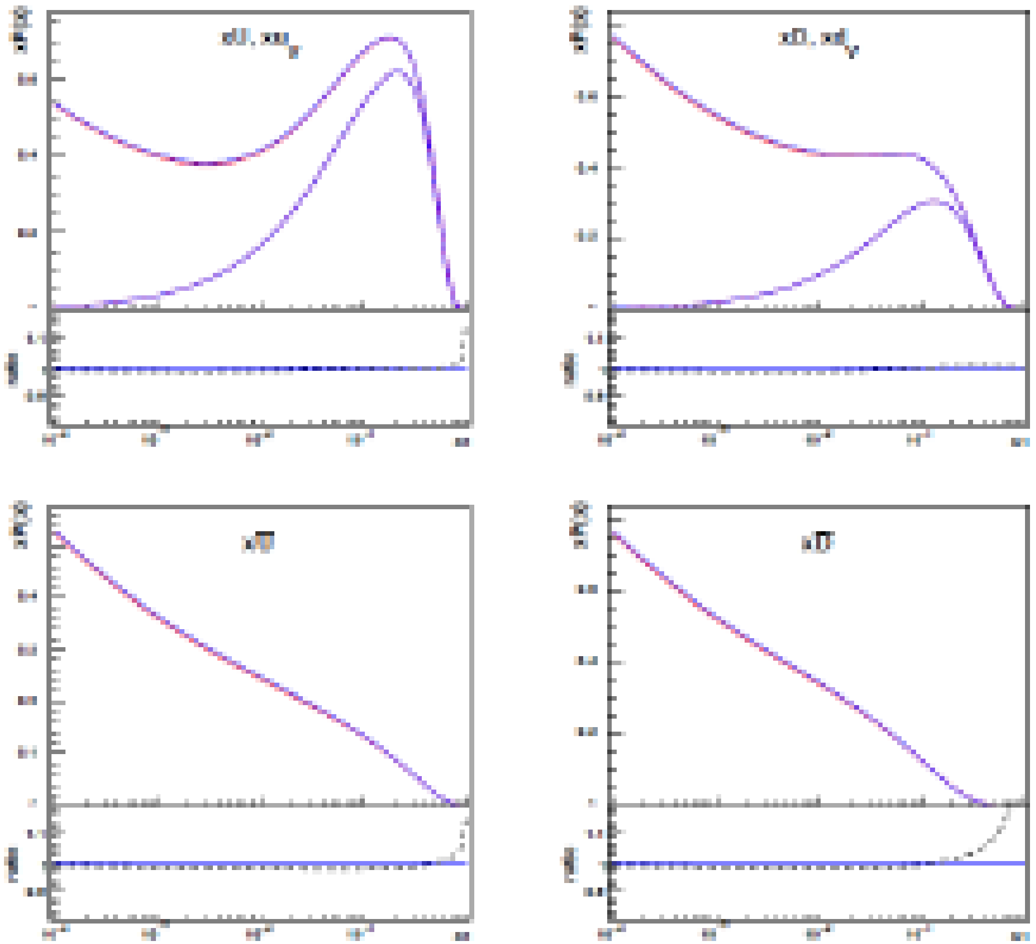
$F_2^{\rm charm}$ at NNLO (fixed PDFs)



- Best-fit values using "standard" TR′ of $m_c = 1.45$ GeV (NLO) and 1.26 GeV (NNLO) [MSTW, arXiv:1007.2624].
- Best-fit values using "optimal" TR′ of $m_c = 1.35$ GeV (NLO) and 1.23 GeV (NNLO) [R. S. Thorne, arXiv:1201.6180].

ABKM FF (running mass)

ABKM FF: pole and running vs mass definition

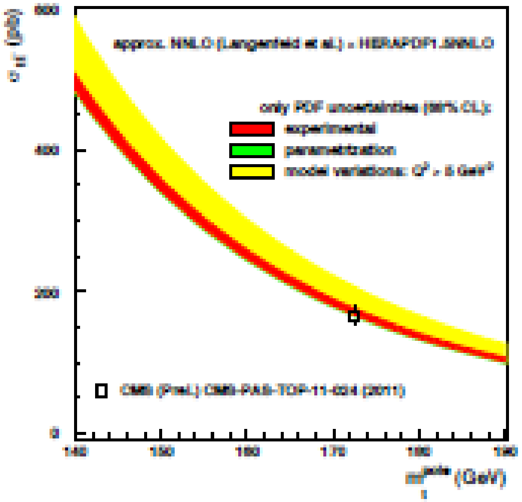


ABKM FF (run mass)

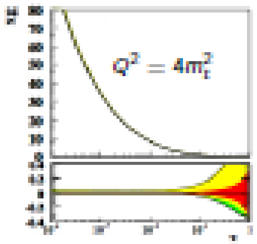
ABKM FF

Q^2 = 1.90 GeV^2

Big impact of model variations ($Q^2 > 5.0$ instead of $3.5\ \mathrm{GeV}^2$) in the PDF fit on the predicted $t\bar{t}$ cross section



Gluon PDF at high x is very sensitive to this:



Side note: Electroweak production of single-top quarks should provide a handle on the b-quark PDF, but that's not what we (currently) look at!

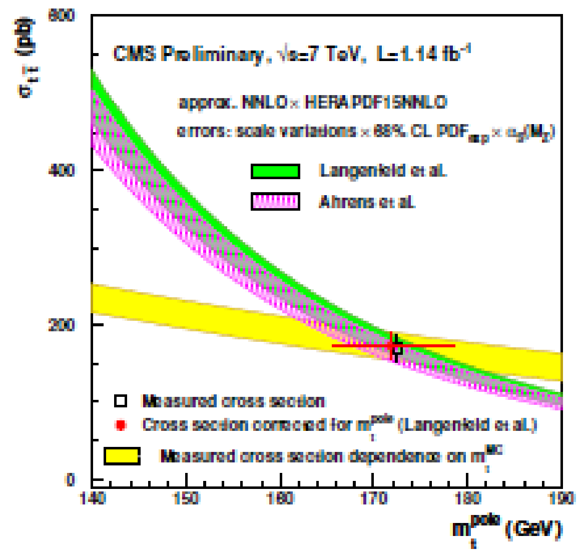
Outlook: Mass Dependence

Predicted $t\bar{t}$ cross section is mass dependent

Measured cross section is mass dependent (due to acceptance correction)

This allows extracting of most-probable mass value - either in pole or $\overline{\mathrm{MS}}$ scheme

See, e.g., CMS-PAS-TOP-11-008



→ Goal: Include $\sigma_{t\bar{t}}$ in a PDF fit performing an m_t scan

DY integration code:

Simple LO cross section formulae: DY NC: $pp \rightarrow Z/\gamma \rightarrow e^+e^-$

$$\frac{d\sigma^2_\gamma}{dMdydcos\theta^*} = N_c C^2_{q\bar{q}} \frac{8\alpha^2}{3M^3}\tau \times \sum_q e_q^2 f_q(x_1, M) f_{\bar{q}}(x_2, M) F_{q\bar{q}}(1+\cos^2\theta^*, \cos\theta^*)$$

DY CC: $pp \rightarrow W^\pm \rightarrow e^\pm \nu$

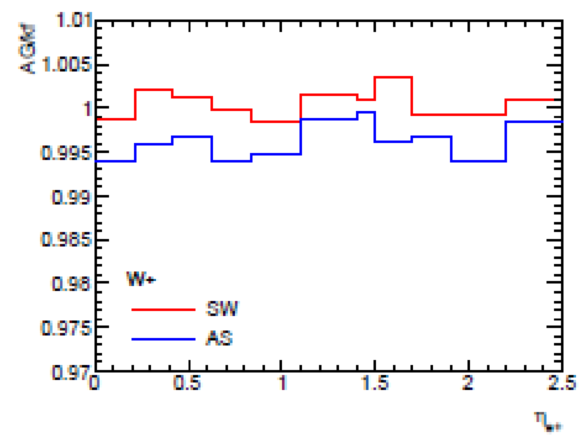
$$\frac{d\sigma^3_{W\pm}}{dMdydcos\theta^*} = \frac{\pi\alpha^2}{48 s_W^4} M\tau \frac{(1-cos\theta^*)^2}{(M^2 - M_W^2)^2 + \Gamma_W^2 M_W^2} \times \sum_{qq'} V_{qq'} f_q(x_1, M) f_{q'}(x_2, M)$$

where $\tau = \frac{M^2}{S_0}$, S_0 - beam energy.

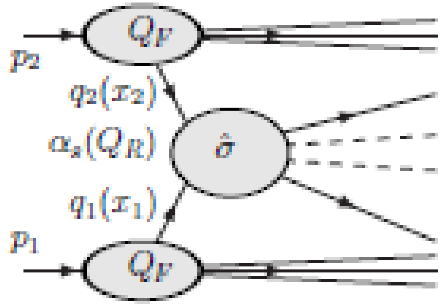
$F_{q\bar{q}}(1+\cos^2\theta^*, \cos\theta^*)$ is a linear homogenious dependence and $\cos\theta^*$.

Crosscheck with APPLgrid

within HERAfitter, with APPLgrid 1.1.6, k-factors from MCFM6.1



NLO QCD cross section



Calculating NLO cross-sections takes a long time ($\sim$ *days*).

$$\frac{d\sigma}{dX} \sim \sum_{(i,j,p)} \int d\Gamma\, \alpha_s^p(Q_R^2)\, q_i(x_1, Q_F^2) q_j(x_2, Q_F^2)\, \frac{d\hat{\sigma}^{ij}_{(p)}}{dX}(x_1, x_2, Q_F^2, Q_R^2;\ S)$$

- Coupling and parton density functions are non-perturbative inputs to calculation (extracted from data)
- Perturbative coefficients are essentially independent from PDF functions due to factorization theorem

$\Longrightarrow$ we can split calculation into two parts

- Jet production cross sections studied using NLOJET++ (up to 3 jets @NLO)
- Electroweak observables included using MCFM ($W^\pm$, Z^0, QQ are already implemented, the rest is straight forward)

Calculation of theoretical uncertainties:

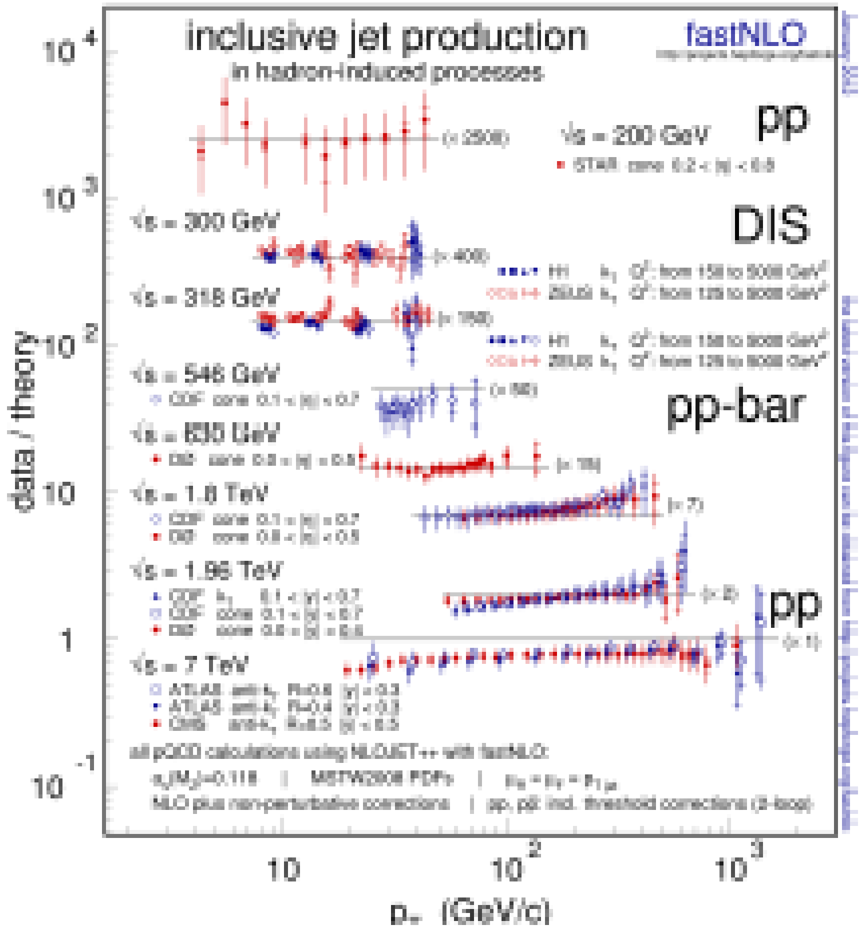
- PDF uncertainty
- Scale uncertainty (Arbitrary simultaneous variation of renormalisation and factorisation scales a posteriori)
- Strong coupling uncertainty
- Can be re-calculated for any PDF and/or α_s on-fly (in $\sim$ *ms*)
- A posteriori variation of centre-of-mass energy and fast evaluation of theoretical uncertainty in total cross section.

- We are starting to work on interface to DYNNLO

Hence benchmarking of different DY codes is possible

Jets Data / Theory

- Comparison of jet data from
  - STAR at RHIC
  - H1 and ZEUS at HERA
  - CDF and D0 at Tevatron
- Compatible with QCD
- Includes measurements from LHC
- New: Updated with ATLAS inclusive jets



fastNLO, to be uploaded, arXiv:1109:1310v2, 2012

So what is the HERAfitter for?

It can make fast PDF fits in the HERAPDF framework to evaluate the impact of new data
But it is also much more flexible in the choice of parametrisation, input data, form of chisq, error treatment etc

The NNPDF reweighting tool will allow fast evaluation of the impact of new data

The data averaging tool which was used to combine H1 and ZEUS data will be incorporated and can be used for other combinations--- like ATLAS e, mu data#

iI also provides a common platform to benchmark fits
It provides common data formats and any PDF can be compared to data via LHAPDF

It provides a common platform from which we can compare heavy quark codes
Theorists are encouraged to provide their codes in user friendly formats which can also be made fast
This code bencharking can be extended -- e.g. NLOcodes for Drell-Yan like DYNNLO and MCFM

and more...