# WSIP STATUS

## Weak and Strong Interactions Phenomenology

Stefano Carrazza

Consiglio di Sezione INFN - July 9, 2015

# GROUP OVERVIEW

## Topics:

- LHC phenomenology
- Determination of the structure of the nucleon
- Precision physics of strong and electroweak interactions

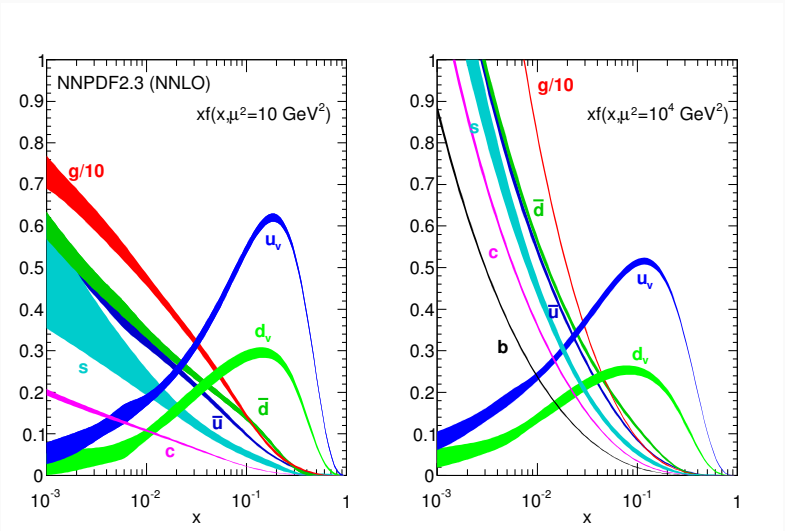
## Organization:

- Local responsible: **Stefano Forte**
- National Network: Genova, Milano & Roma III
- CERN groups: PDF4LHC, LHeC, Higgs WG, EW WG
- Collaborations:
  - *Univ. Pierre et Marie Curie, Univ. Wuppertal, Univ. Hamburg, PV, MIB, SUNY Buffalo, CERN, Oxford Univ., Cambridge Univ., FI, RM1, MIT, Univ. Barcelona, NA, Univ. Zurich, Univ. Buenos Aires*

- **PDFs** are **essential** for a **realistic computation** of a hadron collider **observable**, $\sigma$, thanks to the factorization theorem

$$\sigma = \hat{\sigma} \otimes f,$$

  where the elementary **hard cross-section** $\hat{\sigma}$ is convoluted with $f$ the **PDF**.
- **PDFs** are **not calculable**: reflect non-perturbative physics of confinement, are **extracted** by comparing theoretical predictions to real data.
- The **hard scattering cross section** is process **dependent**, **calculable** with a **perturbative** expansion.



# GROUP MEMBERS

| *Name* | *INFN position* | *Time percentage* | *Details* |
|---|---|---|---|
| Vito Antonelli | Associato | 50% | - |
| Stefano Carrazza | Associato | 100% | Assegnista |
| Giancarlo Ferrera | Incarico di ricerca | 100% | Ricercatore |
| Stefano Forte | Incarico di ricerca | 100% | Prof. Ordinario |
| Elisa Mariani | Associato | 100% | Dottorando |
| Claudio Muselli | Associato | 100% | Dottorando INFN |
| João Pires | Associato | 100% | Assegnista |
| Alessandro Vicini | Incarico di ricerca | 100% | Prof. Associato |

**Table 1:** Current WSIP-MI members

# PUBLICATIONS

Research output:

| *Name* | *WSIP-MI* | *WSIP-all* | % |
|---|---|---|---|
| Publications | 23 | 45 | 51 |
| Talks | 35 | 47 | 74 |
| Thesis | 6 | 10 | 60 |

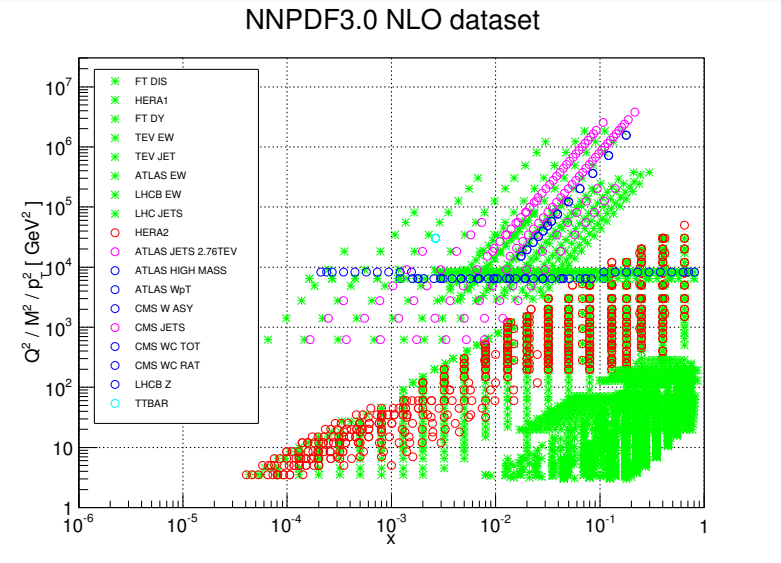
**Table 2:** Data from July 2013 to July 2015

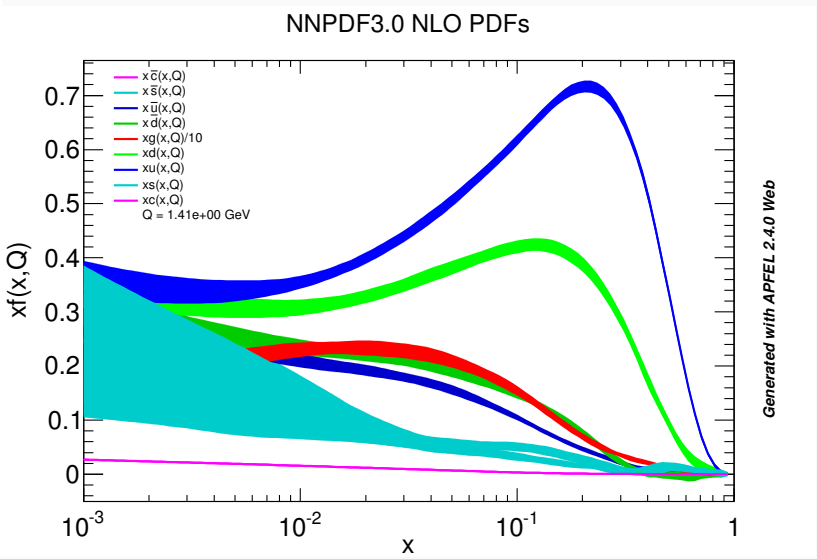
# Parton distribution functions (Carrazza-Forte)

# PARTON DISTRIBUTION FUNCTIONS (CARRAZZA-FORTE)

NNPDF

- **Determination** of **NNPDF3.0** set of PDFs (Carrazza, Forte)

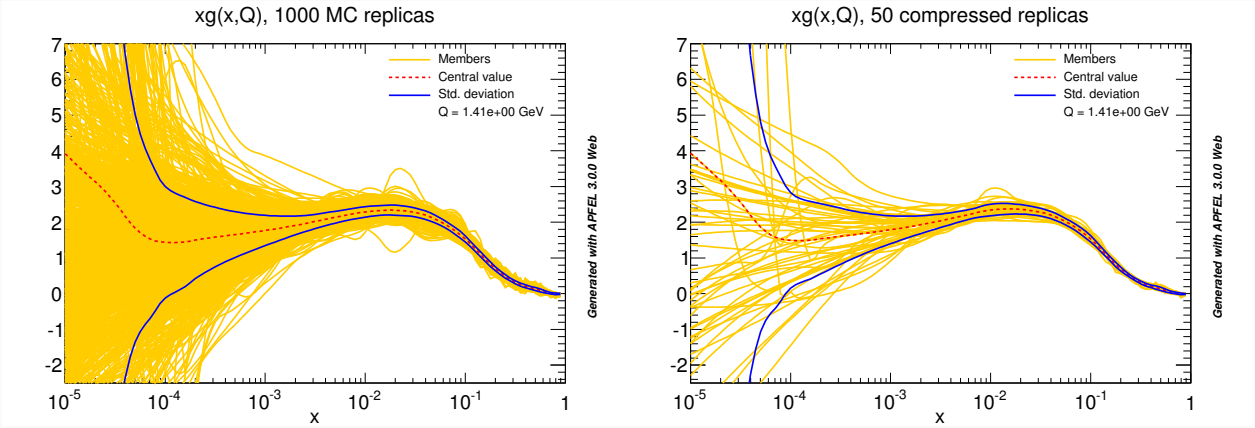



- Parton distributions with large-*x* threshold resummation (Carrazza)
- A first global determination of spin-dependent PDFs and their uncertainties: **NNPDFpol1.1** (Forte)

# CMC-PDFs (Carrazza)

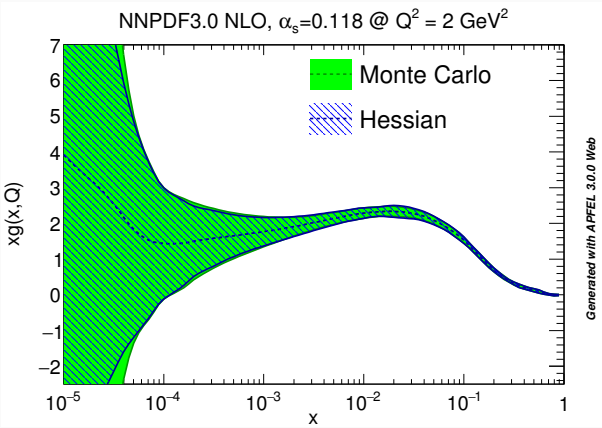
- Development of a **compression algorithm** for the combination of PDF sets: Compressed Monte Carlo PDF.
- **Reduction** of the total number of MC replicas, by means of statistical estimators and genetic algorithm.

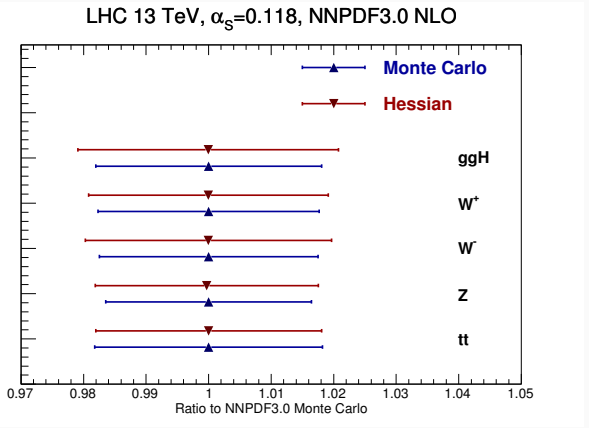



- Simple generalization for the construction of a combined set of PDFs from multiple collaborations.
- It is the MC representation of the **PDF4LHC 2015 recommendation**.

# mc²hessian

- Unbiased **Hessian representation** for Monte Carlo PDFs




- Two methods based on: linear combination of replicas selected by genetic algorithm and principal component analysis.
- Validation with **phenomenology** results.
- Candidate for the **PDF4LHC 2015 recommendation**.

# APFEL & APFEL Web (Carrazza)



- **APFEL** is *"A Parton distribution Function Evolution Library"*
  - up to **NNLO** in **QCD** and **LO** in **QED** combined evolution
  - in the fixed- and variable-flavor number schemes
  - using either Pole or $\overline{\rm MS}$ heavy quark masses

# APFEL & APFEL WEB (CARRAZZA)

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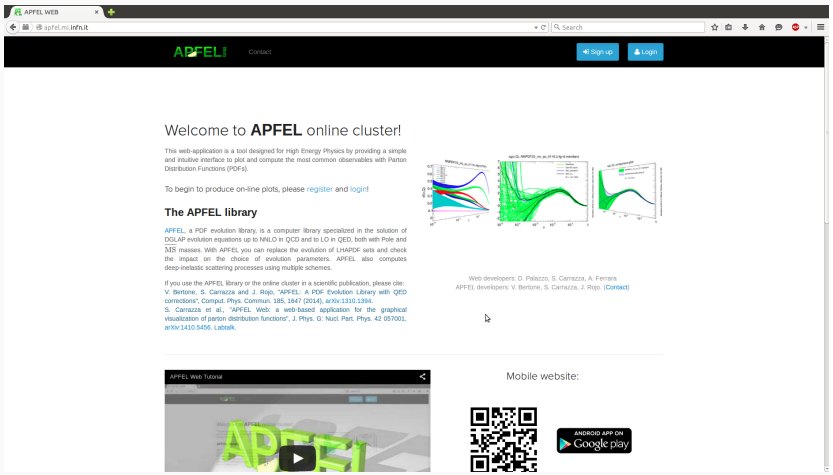
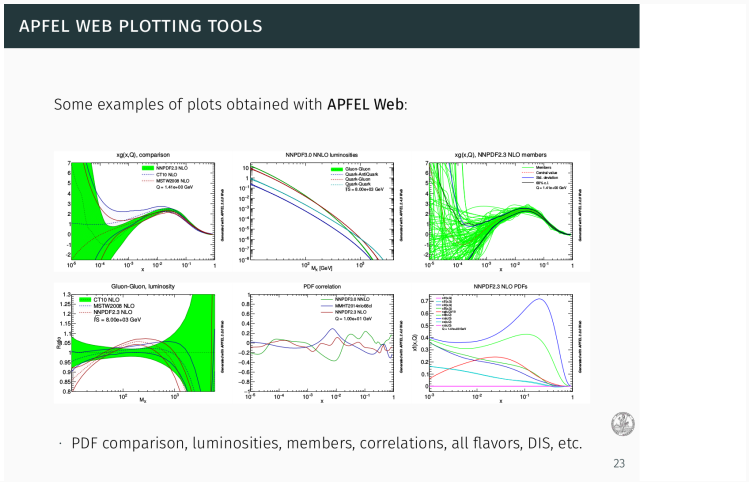
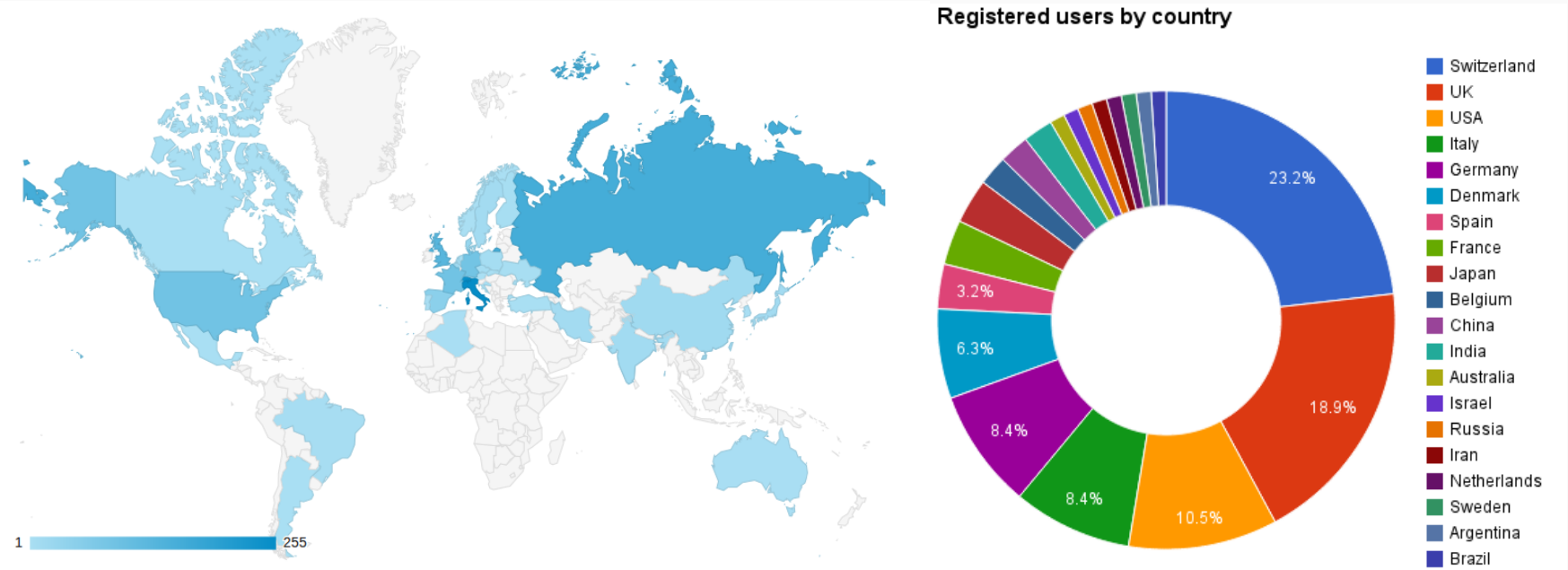
- **APFEL Web:** a web-based application for PDF visualization
  - hosted at: http://apfel.mi.infn.it/



# APFEL & APFEL WEB (CARRAZZA)

- **Web analytics** after **5 months** of activity:

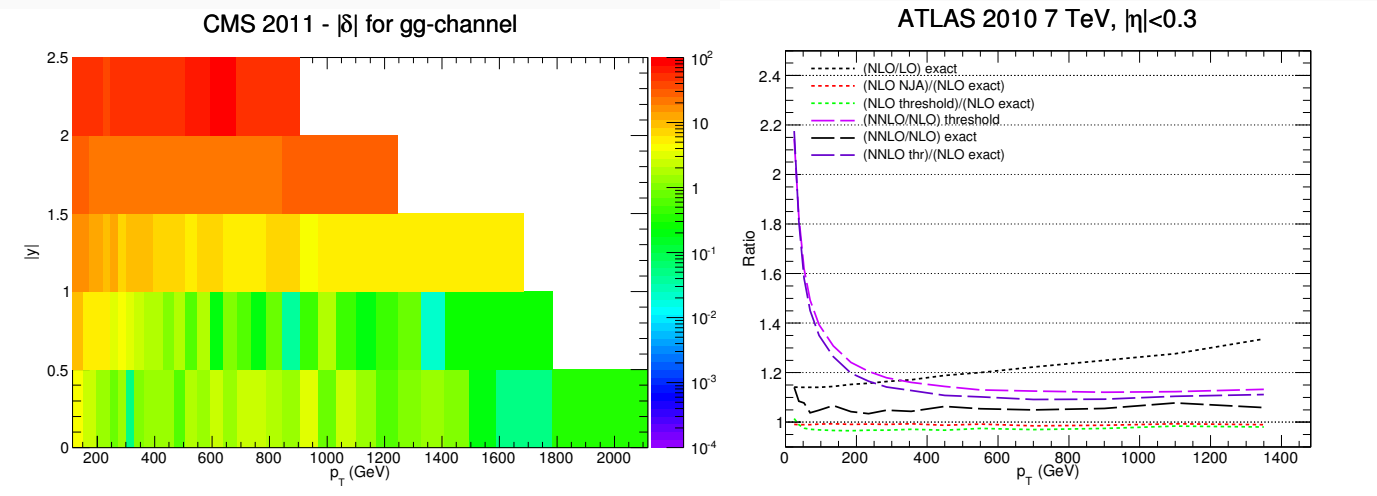



- **131 registered users** from **20 countries**
- Average of **258 visits** monthly
- Completed more than **3500 jobs**

# QCD description of jet data (Carrazza-Pires)

# NNLO JET THRESHOLD APPROXIMATION (CARRAZZA-PIRES)

- **Systematic comparison** of jet predictions at the **LHC** and the **Tevatron** with accuracy up to NNLO.
- The **exact computation** at NNLO for the *gg*-channel is compared to approximation prediction based on **threshold resummation**.

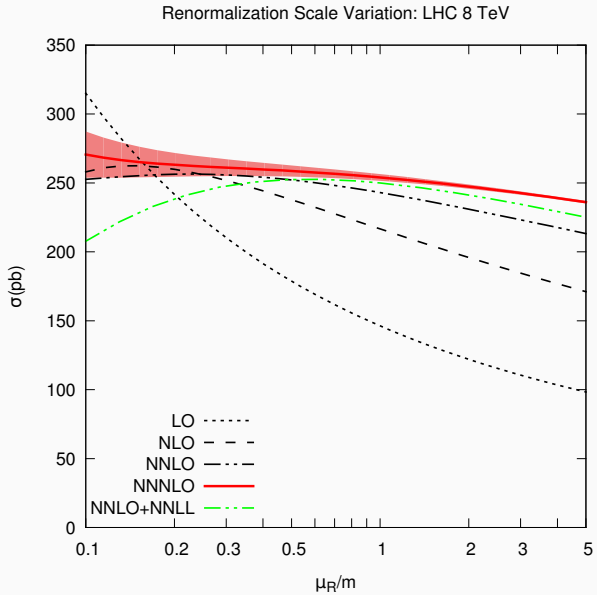



- **Determine** the **regions** where the **approximation** is reliable.
- **Essential** for **NNLO PDF** fits.

# TOP QUARK PAIR PRODUCTION (FORTE-MUSELLI)

# TOP QUARK PAIR PRODUCTION (FORTE, MUSELLI)

- **Approximate expression** for the total cross section for the production of a **heavy quark-antiquark pair** in hadronic collisions at $N^3LO$ in $\alpha_s$.

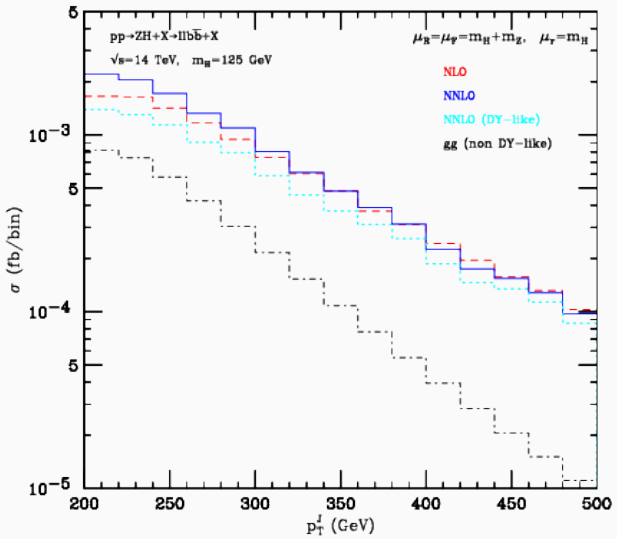



- $N^3LO$ corrections **increase** the predicted top pair cross section at the LHC by about 4% over the NNLO. It decreases the scale uncertainties for the top pair cross section at LHC in comparison to NNLO and NNLO+NNLL.

# HIGHER ORDER CORRECTIONS (FERRERA, VICINI)

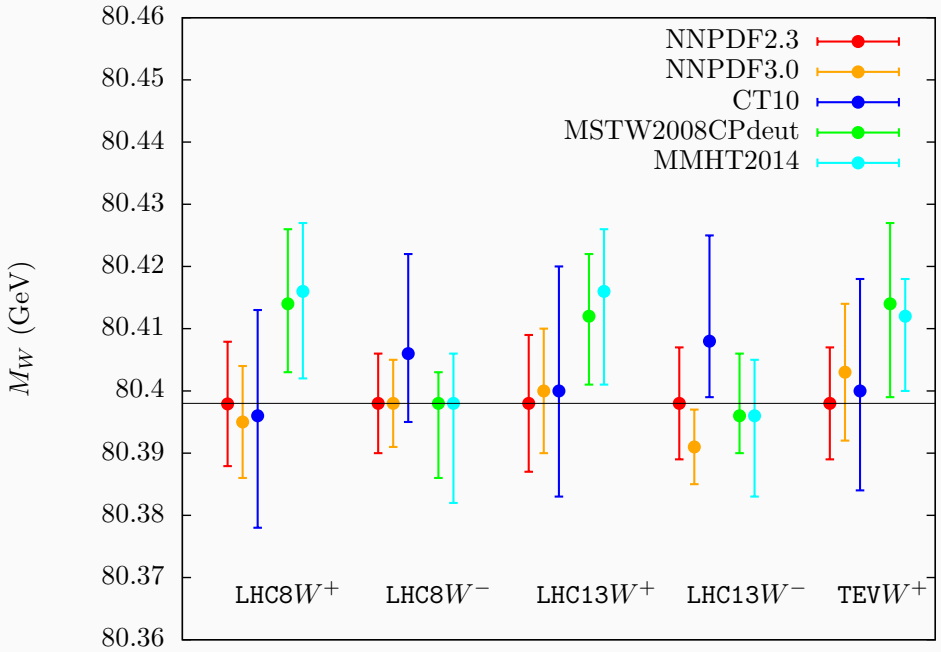
# HIGHER ORDER CORRECTIONS (FERRERA)

- Fully exclusive NNLO QCD calculation for *ZH* and *WH* production at hadron colliders implemented in the parton level Monte Carlo code **HVNNLO**.
- The **impact** of **NNLO QCD corrections** is particularly sizable at the LHC for **high-$p_T$ Higgs boson** events.




- **Extraction** of the **general expression** of the hard-virtual coefficient that contributes to threshold resummation at N$^3$LL accuracy and soft-virtual N$^3$LO corrections for the hard production of an arbitrary colorless system (for instance Higgs bosons and Drell-Yan lepton pairs).

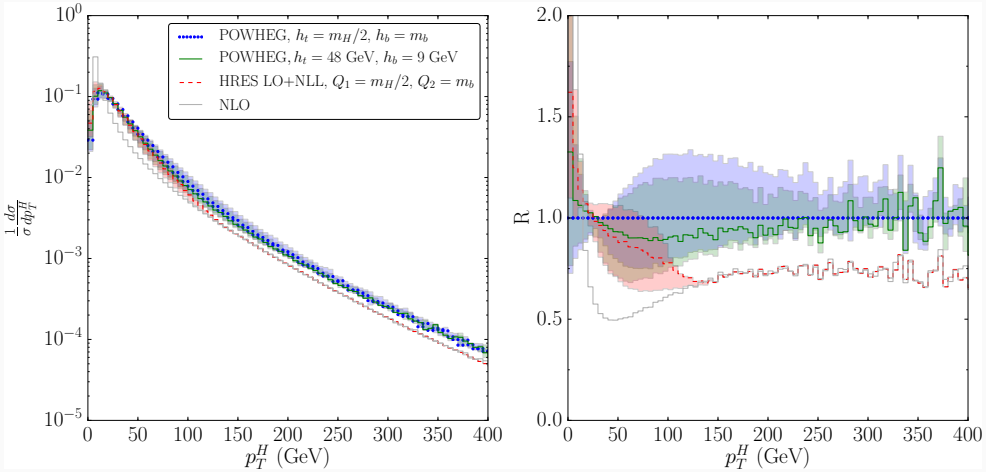
- **PDF uncertainties** on the $W$ boson mass measurement from the lepton transverse momentum distribution.



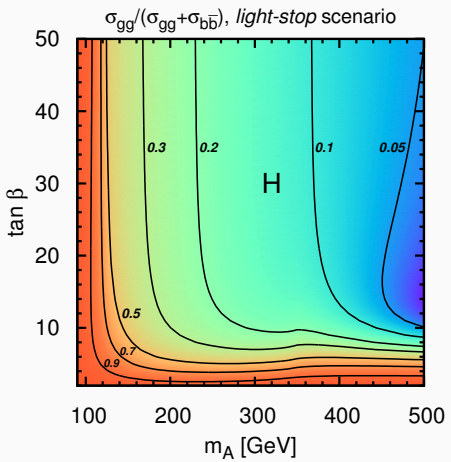

- Large differences between PDFs compared to an accuracy goal of 10 MeV, hope that an improvement of the global PDF analysis will remove this bottleneck towards a precise $m_W$ measurement.

# HIGHER ORDER CORRECTIONS (VICINI)

- Higgs transverse momentum distribution in gluon fusion.

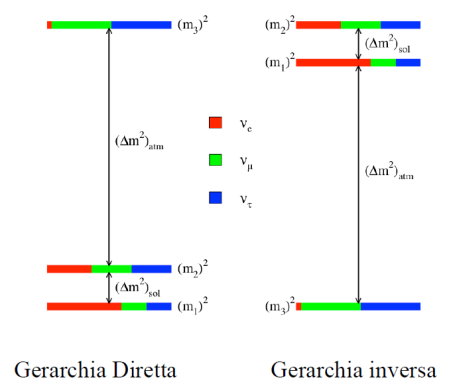



- Precise predictions for Higgs-boson production in the MSSM.



# Theory and phenomenology of neutrinos (Antonelli)

- **Impact** on Astrophysics and Elementary Particle Physics of recent and future data from **natural** (solar) and **artificial** (reactor and accelerator) neutrino sources:
  - study of future **experiments** about **neutrino mass** and **oscillations**
  - test **theoretical models** (SM) with available **experimental data**.




- **Participation** in phenomenological analysis in the JUNO experiment, and in the Yellow Book “Physics at JUNO” (one of the “3 Major Contributors” to section concerning solar neutrinos)
- **Participation** and **report** about “Problemi aperti in fisica dei neutrini solari e sviluppi futuri” in “What Next - INFN”.

Thanks for your attention.