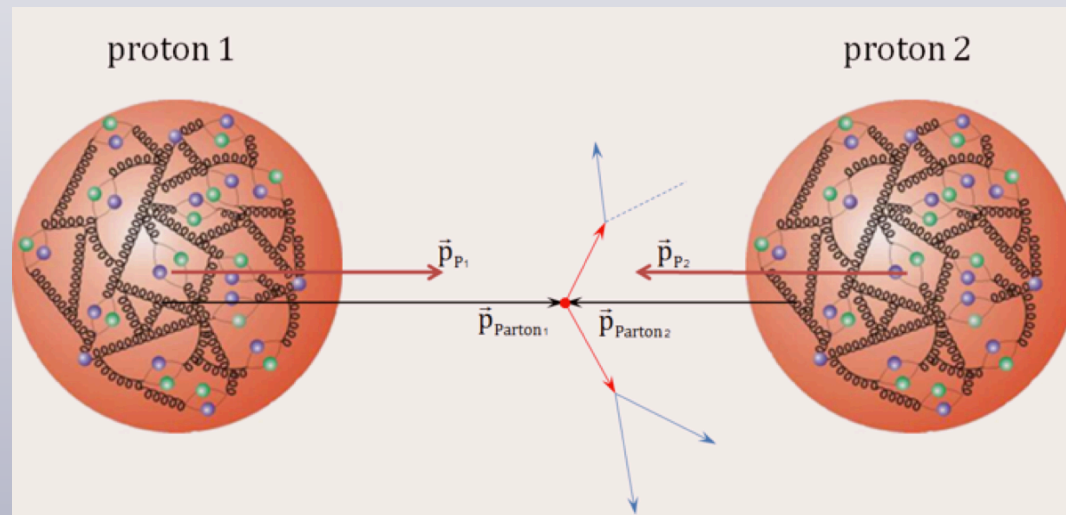


# Parton Distributions in the Higgs Boson Era



Juan Rojo  
CERN, PH Division, TH Unit

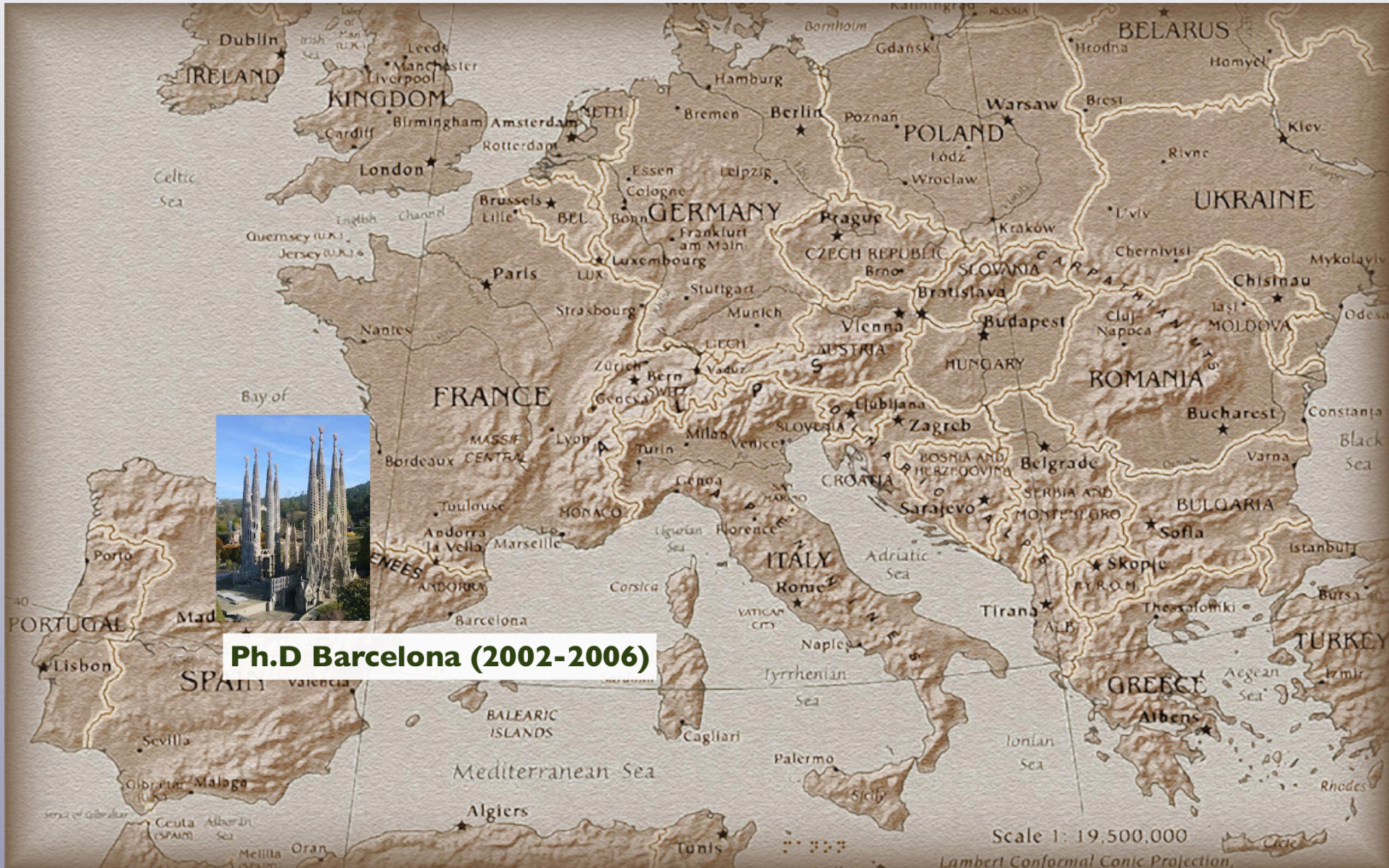
CERN-TH Retreat  
Les Houches, 6th November 2013

# Curriculum Vitae



**Born in Barcelona, AD 1980**

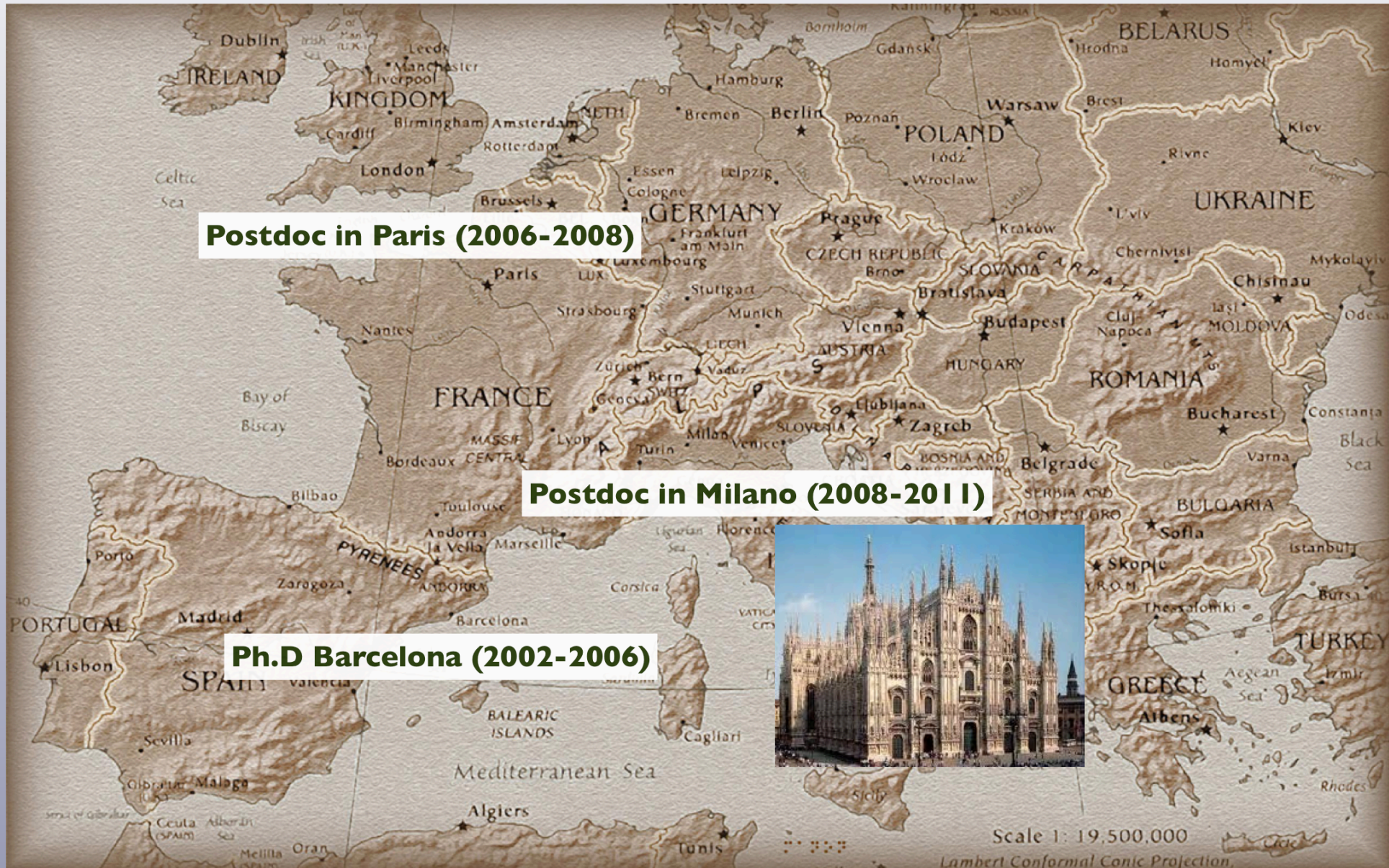
# Curriculum Vitae



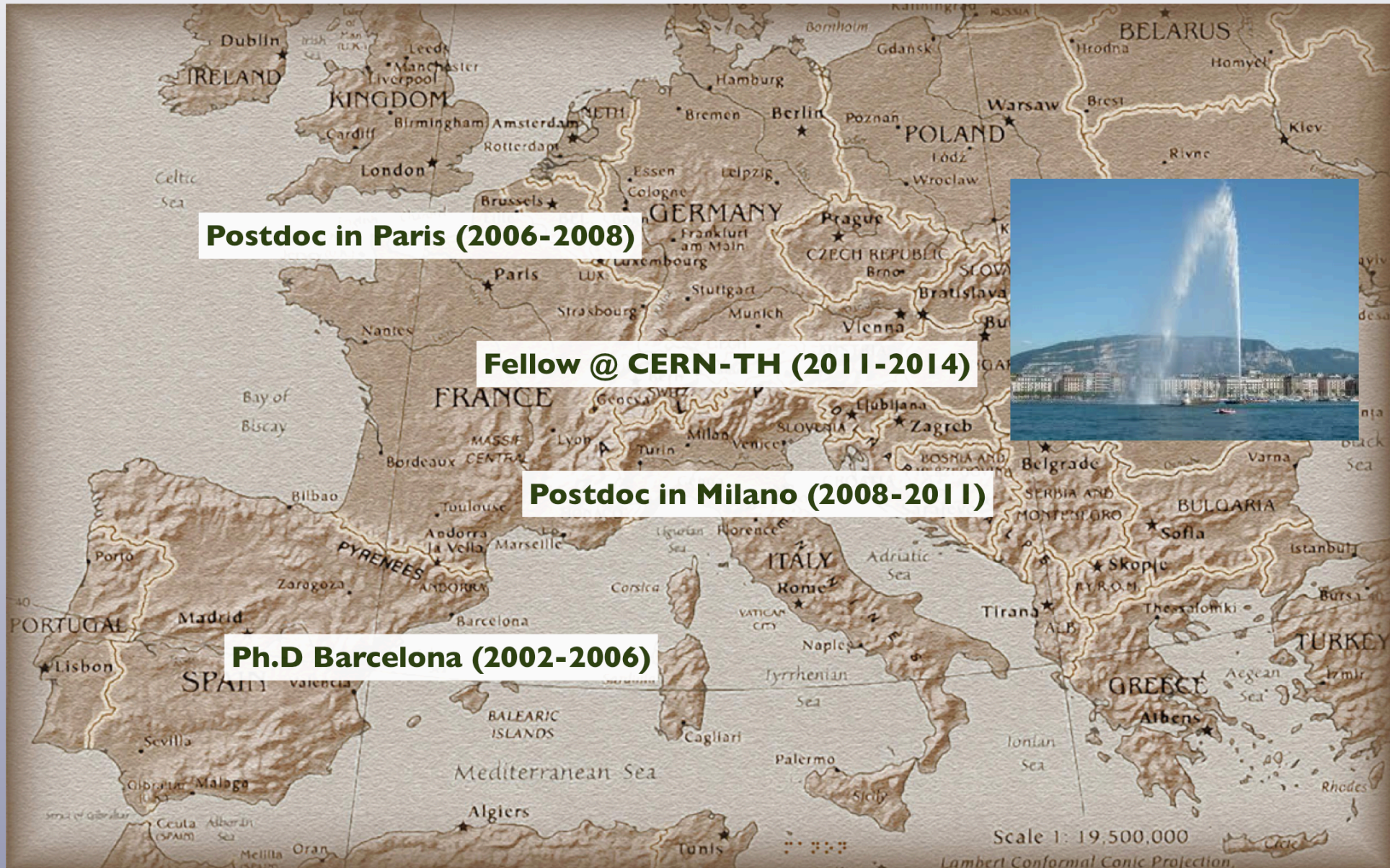
# Curriculum Vitae



# Curriculum Vitae



# Curriculum Vitae



# Curriculum Vitae

**Junior Faculty @ Oxford (from April 2014)**



**Postdoc in Paris (2006-2008)**

**Fellow @ CERN-TH (2011-2014)**

**Postdoc in Milano (2008-2011)**

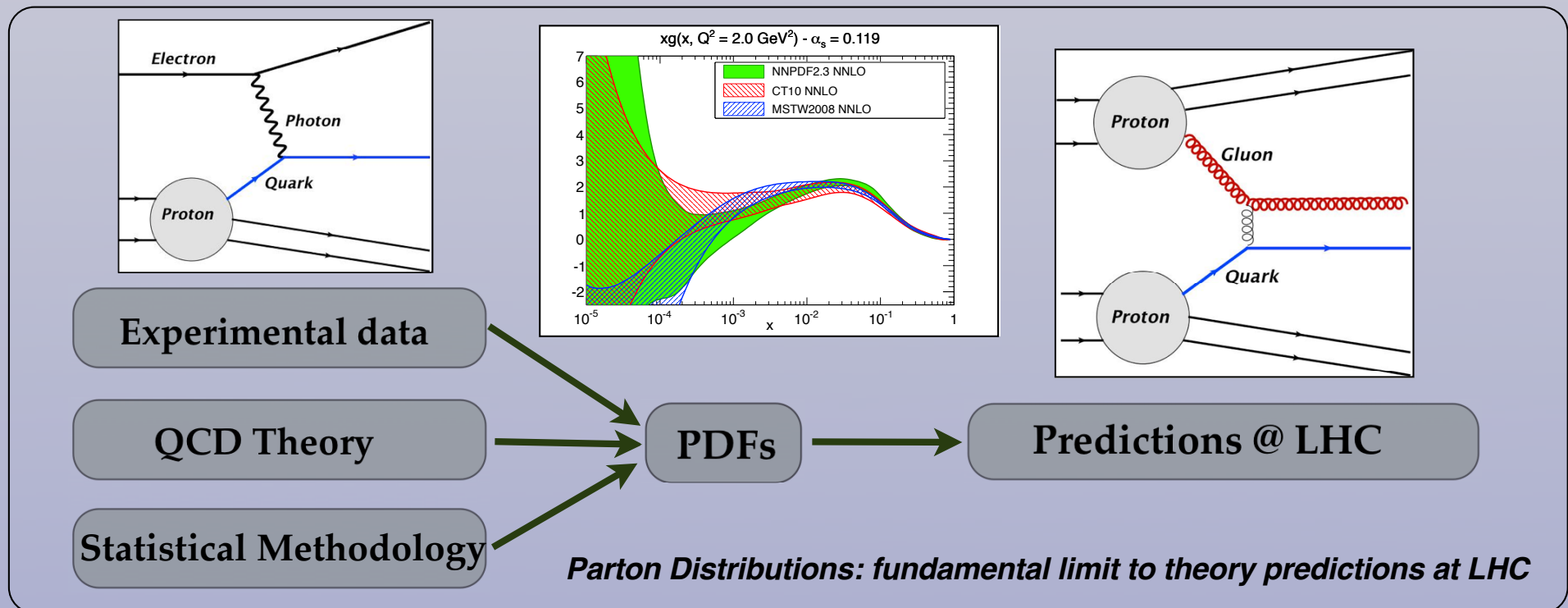
**Ph.D Barcelona (2002-2006)**



# Parton Distribution Functions (PDFs)

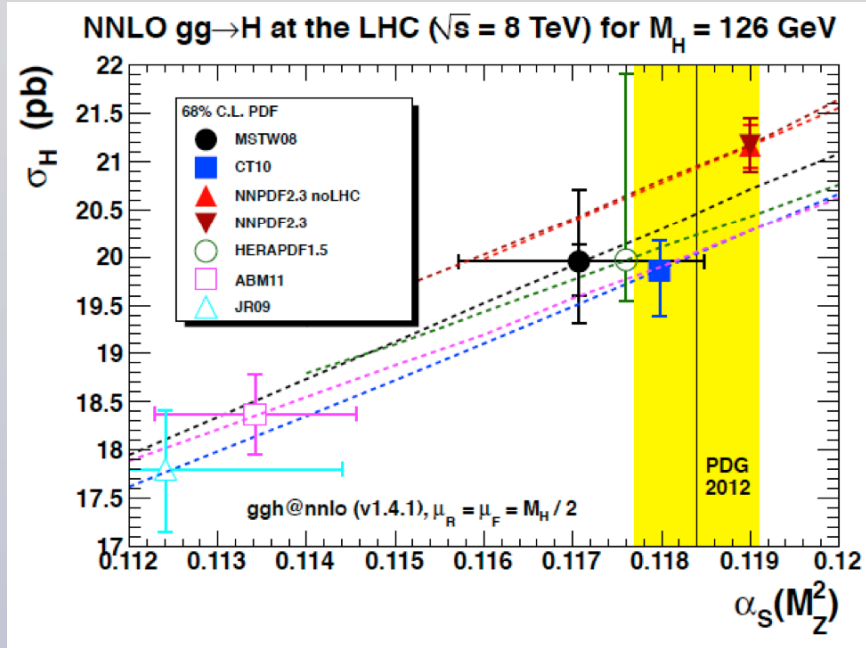
- Event rates at the LHC depend on the **Parton Distribution Functions** (PDFs) of the proton
- PDFs encode **non-perturbative dynamics** that determine the **distribution of energy** that **quarks and gluons** carry within the proton
- Computation of PDFs from first principles not *competitive*

➔ Determine PDFs via **global QCD analysis** of hard-scattering data



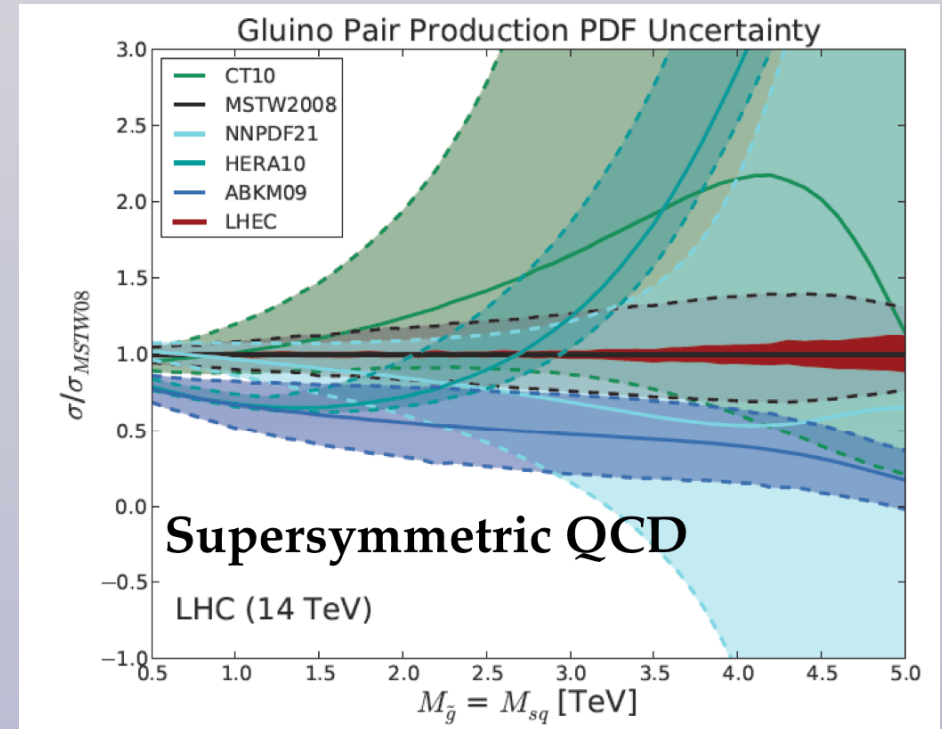


# PDFs and LHC phenomenology



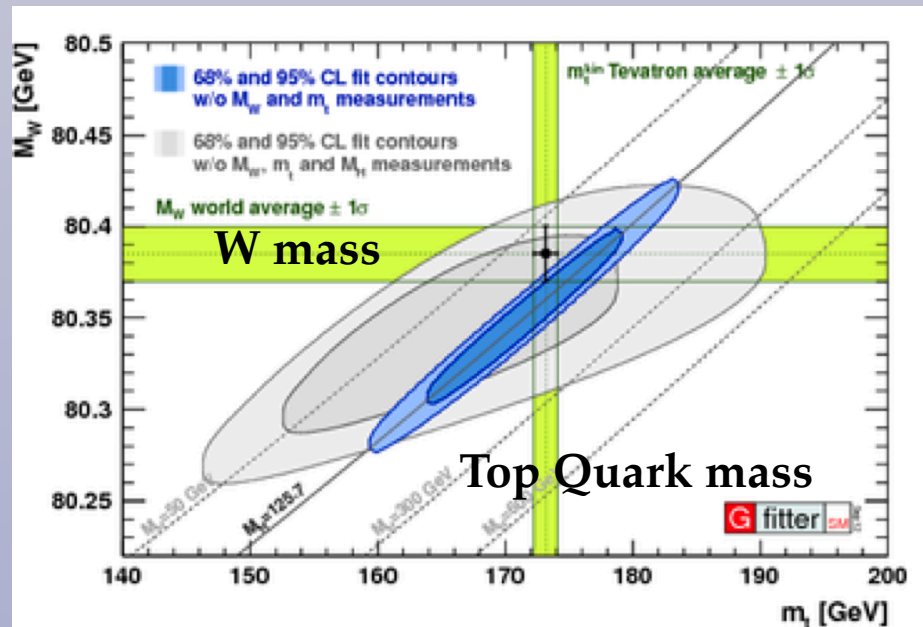
1) PDFs fundamental limit for Higgs boson characterization in terms of couplings

2) Very large PDF uncertainties (>100%) for new heavy particle production



Supersymmetric QCD

LHC (14 TeV)



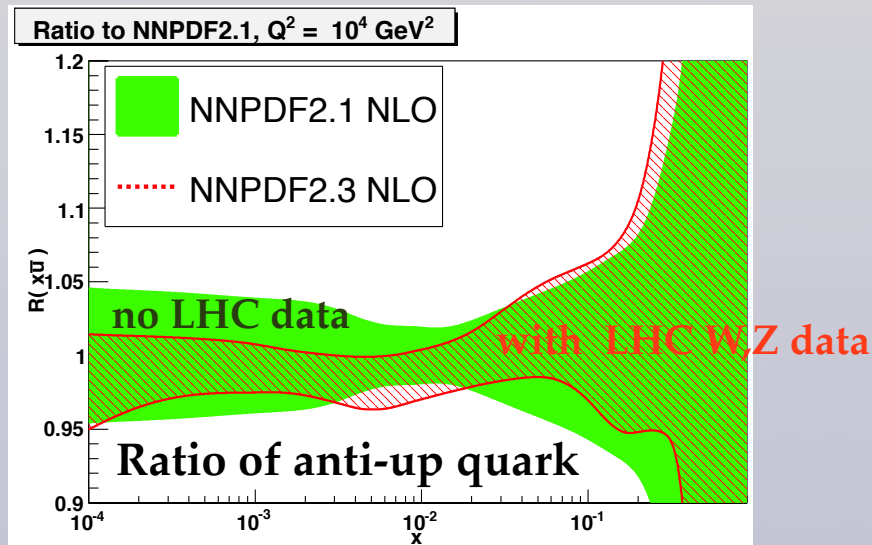
Juan Rojo

3) PDFs dominant systematic for precision measurements, like W boson mass, that test internal consistency of the Standard Model

# Recent Results

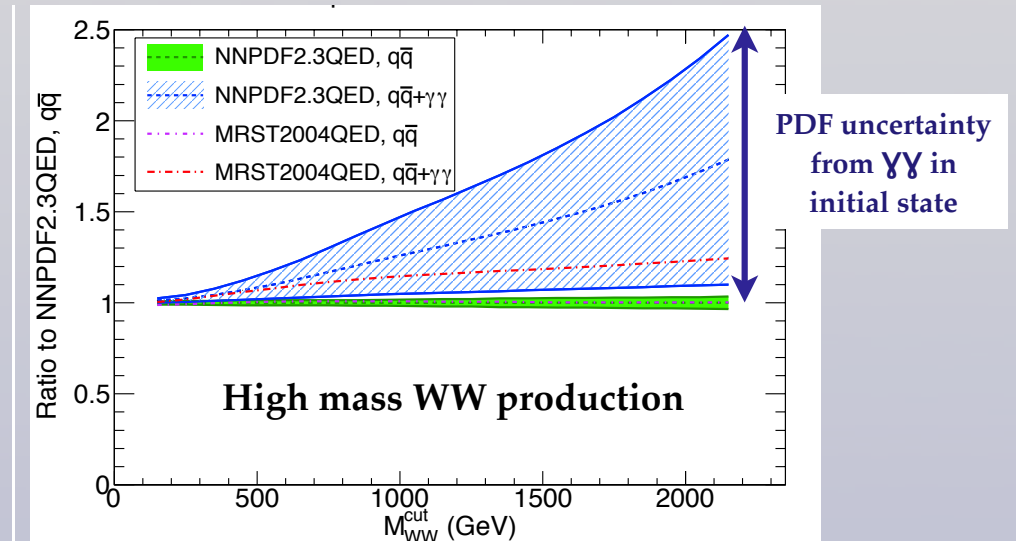
## ✓ Parton Distributions with LHC data

NNPDF2.3: First PDF set to include **constraints from LHC**  
 W,Z data from ATLAS/CMS/LHCb, jet data from ATLAS



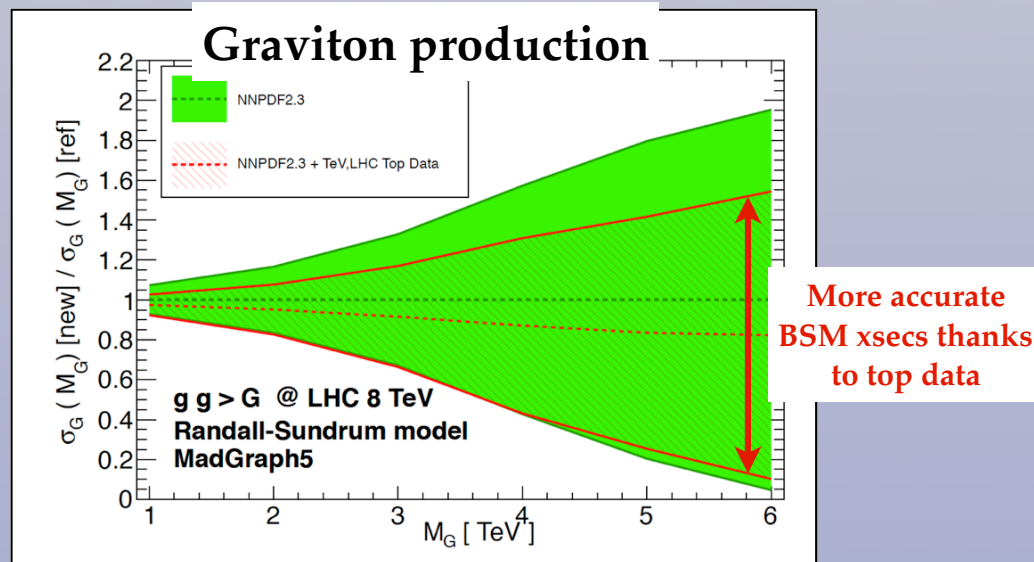
## ✓ Parton Distributions with QED corrections

Direct determination of the **photon PDF** from LHC data  
 Potential impact in **EWPO** and **high-mass BSM**



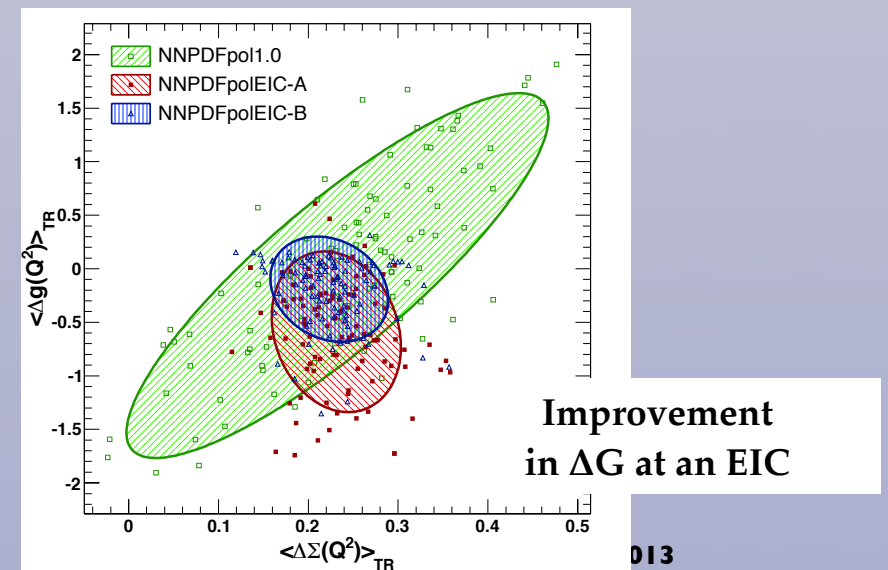
## ✓ Pinning down the gluon PDF with top quarks

NNLO calculations allows to include **top data** in PDF fits  
 Reduced uncertainties in poorly known **large-x gluon**



## ✓ Polarized PDFs and nuclear PDFs

- i) NNPDFpol1.0: first NNPDF polarized set + EIC studies
- ii) Constraints on nuclear PDFs from pPb collisions



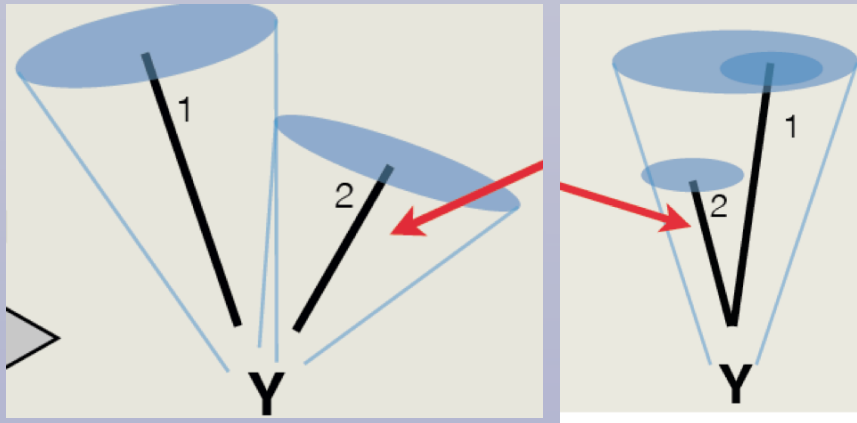
# Ongoing research

## NNPDF3.0: The New PDF Generation



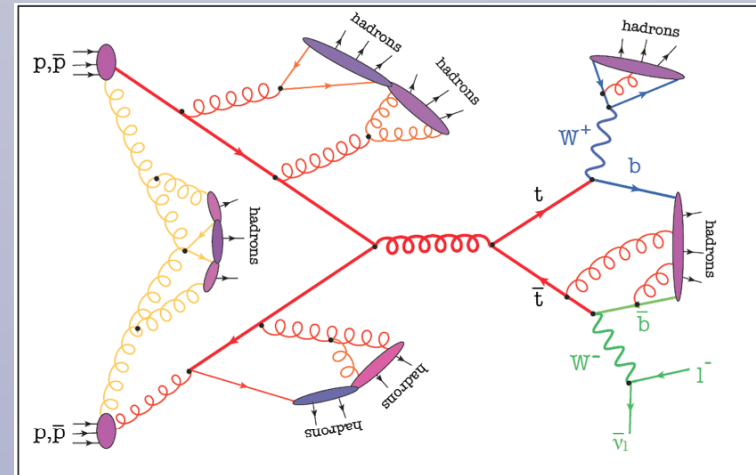
- ✓ Complete rewriting of NNPDF framework in C++/Python, graphical user interface, interface to GPUs
- ✓ Wealth of new HERA and LHC data: CMS jets,  $W$ +charm, top production, 2D Drell-Yan, HERA-II xsecs
- ✓ Improved fitting methodology based on statistical analysis and closure testing with fixed underlying theory
- ✓ Release: Jan 2014, as part of the new C++ LHAPDF6
- ✓ Next: PDFs with resummation, intrinsic charm and PDFs for NLO event generators

## Jet reconstruction and substructure Scale-invariant resonance tagging



New ideas to improve BSM searches  
in boosted final states  
Match boosted and resolved configurations  
Relevant for multijets, boosted tops, ...

## Parton Distributions and NLO Event Generators Fast interface to aMCatNLO



Developing APPLgrid interface to aMCatNLO  
NLO+PS computations for global PDF fits

- 2013 [arXiv:1310.1394](#), submitted to **CPC**, *APFEL: A PDF Evolution Library with QED corrections*, V. Bertone, S. Carrazza and J. Rojo.
- 2013 [arXiv:1310.0461](#), submitted to **PLB**, *Polarized Parton Distributions at an Electron-Ion Collider*, R. D. Ball, S. Forte, A. Guffanti, E. R. Nocera, G. Ridolfi, J. Rojo.
- 2013 [arXiv:1309.5371](#), **JHEP in press**, *Bayesian reweighting of nuclear PDFs and constraints from proton-lead collisions at the LHC*, N. Armesto, J. Rojo, C. A. Salgado and P. Zurita.
- 2013 [arXiv:1308.6176](#), **JHEP in press**, *First look at the physics case of TLEP*, M. Bicer, ... J. Rojo, et al.. <http://arxiv.org/abs/arXiv:1308.6176>
- 2013 [arXiv:1308.0598](#), **NPB in press**, *Parton distributions with QED corrections*, R. D. Ball, V. Bertone, S. Carrazza, L. del Debbio, S. Forte, Nathan P. Hartland, A. Guffanti and J. Rojo [The NNPDF Collaboration].
- 2013 **Nucl. Phys. B 874, 36 (2013)**, [arXiv:1303.7236](#), *Unbiased determination of polarized parton distributions and their uncertainties*, R. D. Ball, S. Forte, A. Guffanti, E. R. Nocera, G. Ridolfi and J. Rojo [The NNPDF Collaboration].
- 2013 **JHEP 1307, 167 (2013)**, [arXiv:1303.7215](#), *Constraints on the gluon PDF from top quark pair production at hadron colliders*, M. Czakon, M. L. Mangano, A. Mitov and J. Rojo.
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- 2013 **Physics Letters B, 723 (2013) 330**, [arXiv:1303.1189](#), *Theoretical issues in PDF determination and associated uncertainties*, R. D. Ball, V. Bertone, L. Del Debbio, S. Forte, A. Guffanti, J. Rojo and M. Ubiali [The NNPDF Collaboration].
- 2012 **EPL 101 (2013) 61002**, [arXiv:1212.5511](#), *Sensitivity of the LHC isolated-gamma+jet data to the parton distribution functions of the proton*, L. Carminati, C. Costa, D. d'Enterria, I. Koletsou, G. Marchiori, J. Rojo, M. Stockton and F. Tartarelli.
- 2012 **JHEP 1304 (2013) 125**, [arXiv:1211.5142](#), *Parton Distribution Benchmarking with LHC data*, R. D. Ball, S. Carrazza, L. Del Debbio, S. Forte, J. Gao, N. Hartland, J. Huston and P. Nadolsky, J. Rojo, D. Stump, R. Thorne and C. P. Yuan.
- 2012 **Nucl.Phys.B867 (2013) 244**, [arXiv:1207.1303](#), *Parton Distributions with LHC data*, R. D. Ball, V. Bertone, S. Carrazza, C. Deans, L. Del Debbio, S. Forte, A. Guffanti, J. I. Latorre, J. Rojo and M. Ubiali [The NNPDF Collaboration].
- 2012 **JHEP 1208 (2012) 010**, [arXiv:1206.3357](#), *Cross Section Ratios between different CM energies at the LHC: opportunities for precision measurements and BSM sensitivity*, M. L. Mangano and J. Rojo.
- 2012 **J.Phys.G. 39 (2012) 075001**, [arXiv:1206.2913](#), *A Large Hadron Electron Collider at CERN: Report on the Physics and Design Concepts for Machine and Detector*, J. L. Abelleira Fernandez, ..., J. Rojo et al. [LHeC Study Group]. <http://inspirehep.net/record/1118165?ln=en>
- 2012 **Eur. Phys. Jour. C 72 (2012) 2131**, [arXiv:1203.1043](#), *Linear vs non-linear QCD evolution: from HERA data to LHC phenomenology*, J. L. Albacete, J. G. Milhano, J. Rojo and P. Quiroga-Arias.
- 2012 **Nucl. Phys. B860 (2012) 311**, [arXiv:1202.1762](#), *Quantitative constraints on the gluon distribution function in the proton from collider isolated-photon data*, D. D'Enterria and J. Rojo.

**APFEL PDF  
evolution library**

**nuclear PDFs from pPb data**

**PDFs with QED effects**

**Polarized NNPDFs**

**Top in PDF fits**

**Scale-invariant jet reco**

**Theory issues in PDF fits**

**PDFs with LHC data**

**LHC xsec ratios at different  
CM energy**

**Small-x QCD**

**Photon data for PDFs**