Università degli Studi di Milano

Istituto Nazionale di Fisica Nucleare

Predizioni teoriche a LHC

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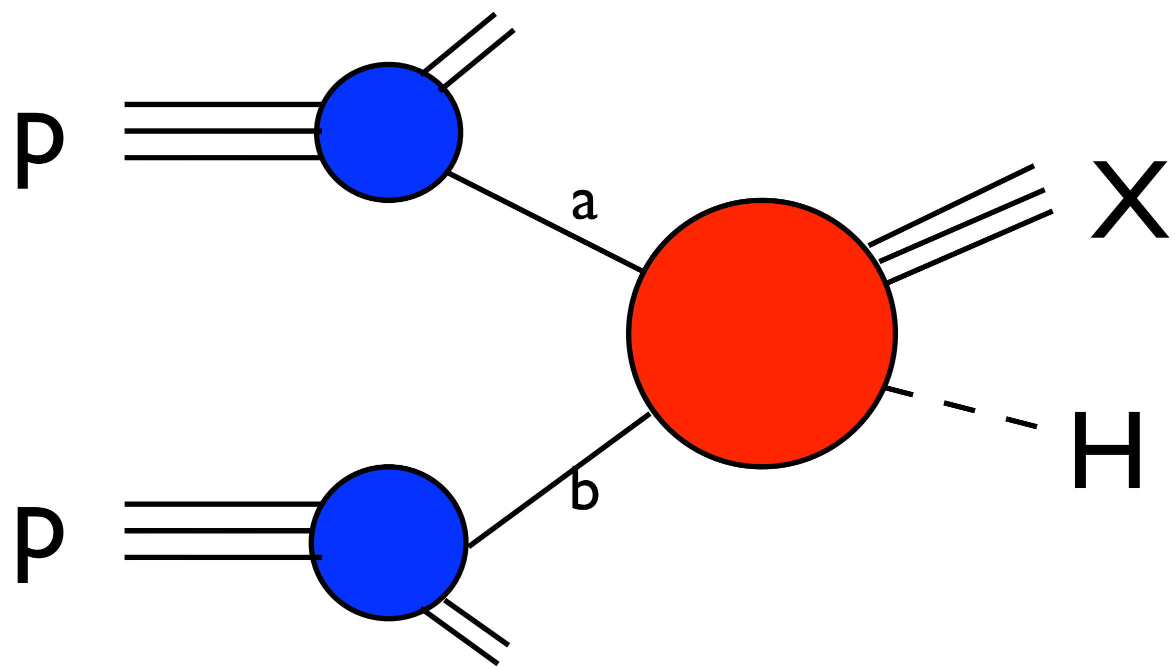
Cross section at hadron colliders: the factorized expression

$$\sigma(P_1, P_2; m_H) = \sum_{a,b} \int_0^1 dx_1 dx_2\, f_{h_1,a}(x_1, M_F) f_{h_2,b}(x_2, M_F)\, \hat{\sigma}_{ab}(x_1 P_1, x_2 P_2, \alpha_s(\mu), M_F)$$



Factorization hypothesis:

inelastic hadron-hadron scattering, to produce a given final state, can be factorized in the convolution of proton parton densities with the partonic cross section that yields the final state

the hadron-level cross section is obtained by summing over all partonic subprocesses that can bring to the desired final state

the parton densities, defined in the collinear limit of additional initial state radiation, are universal i.e. can be measured in one process and used to compute the prediction of a different reaction

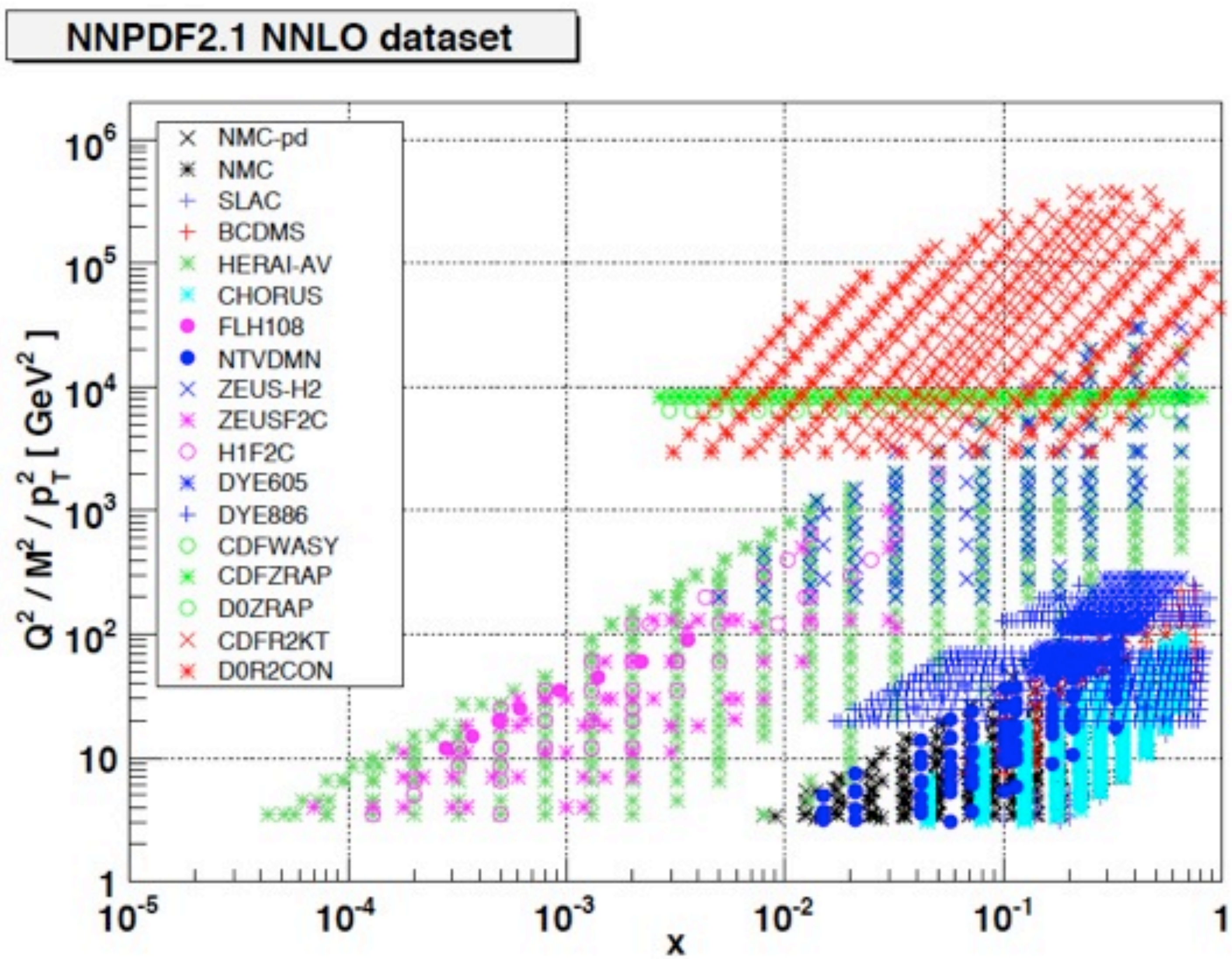
Phenomenology group in Milano

Stefano Forte	PDFs, pQCD, analytical resummations NNPDF
Alessandro Vicini	EW physics, Higgs searches, 1- and 2-loop, MC generators HORACE, POWHEG
Giancarlo Ferrera	EW physics, QCD corrections and analytical resummation DYqT, DYNNLO, HqT, 2γNNLO
Giuseppe Bozzi	EW physics, QCD corrections and analytical resummation HqT, DYqT, VBFNLO
Stefano Carrazza	PDF determination at NLO-(QCD+EW) NNPDF
Emanuele Nocera	polarized PDF determination

Proton parton densities determination

Comparison between data and hadron-level cross sections

global fit: simultaneous fit of experimental data of different scattering processes
DIS (electron-proton at colliders, electron-nucleon and neutrino-nucleon at fixed target),
Drell-Yan (neutral-current at low and at high invariant masses,
asymmetries in charged-current)
inclusive jet production



Proton parton densities determination

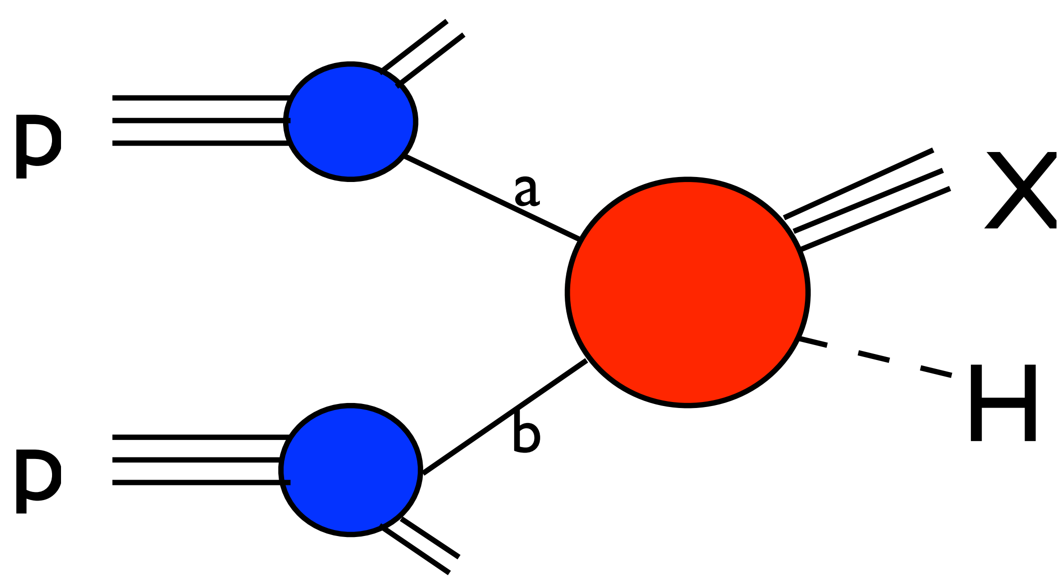
Comparison between data and hadron-level cross sections

theoretical accuracy:
the expressions used in the fit are based on partonic matrix elements;
if the latter are all consistently computed at LO-QCD or at NLO-QCD or at NNLO-QCD
then the extracted parton densities share the same accuracy
and satisfy the Altarelli-Parisi equations at the same order

NLO-QCD matrix elements are available for all the relevant processes (also in a fast-simulation implementation)

NNLO-QCD results are more cumbersome, slower and not fully available for all the observables

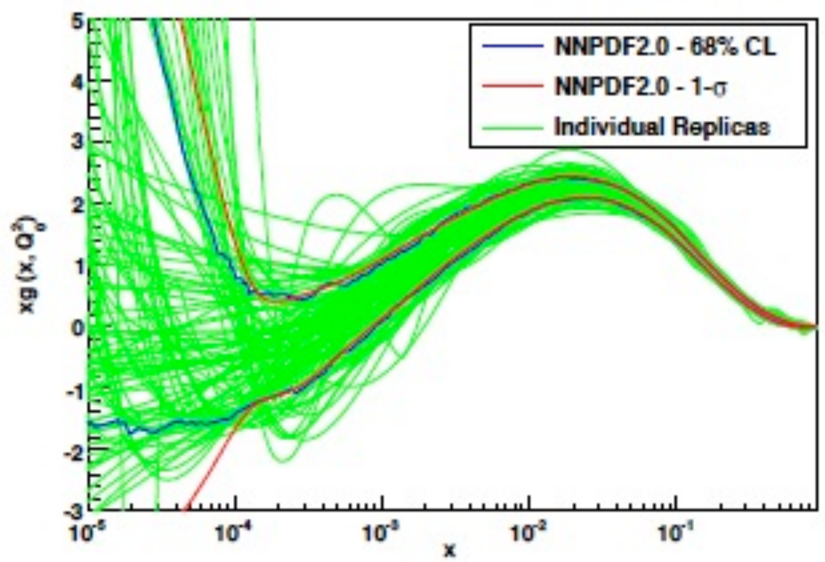
in progress: inclusion of NLO-EW matrix elements to extract a more refined set of PDFs



NNPDF

In NNPDF the parametrization (the functional form) of the parton densities is not chosen *a priori* but is instead determined by means of a neural network

The propagation of the error of the data used to extract the PDFs is represented by a sample of 100 (1000) PDF replicas that span the infinite dimensional space of functions that contain all the possible PDFs compatible with data.

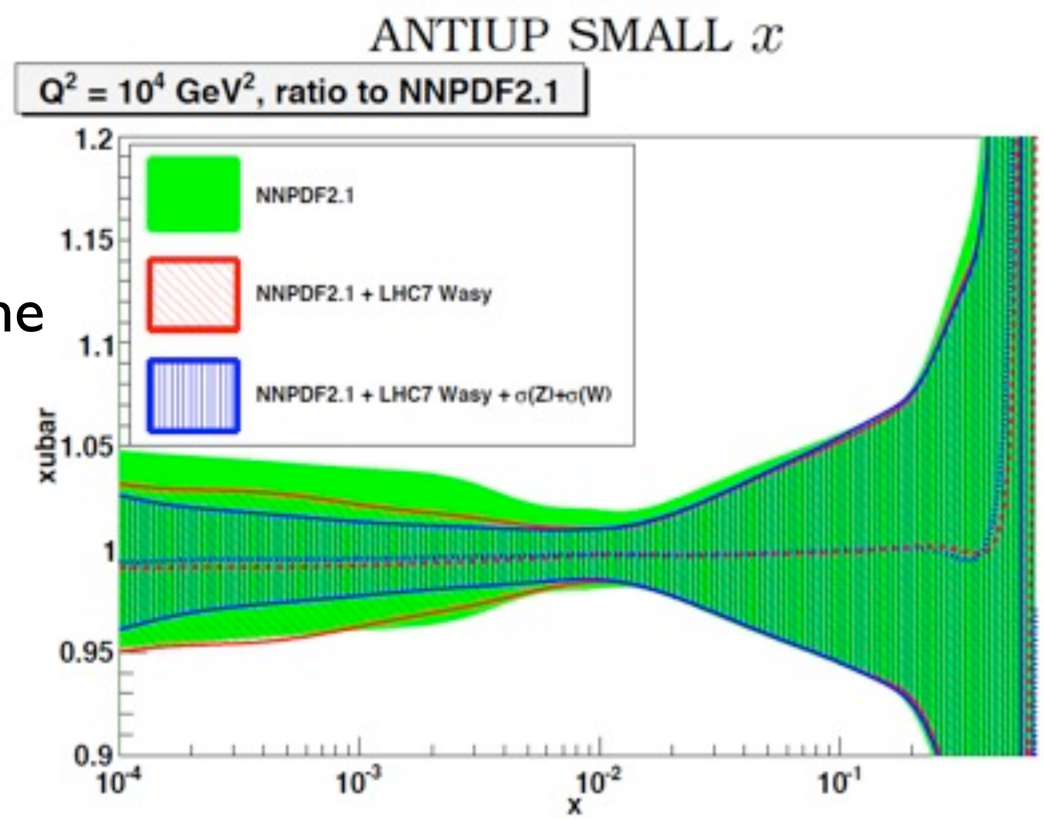


The error due to the experimental data can be obtained by evaluating the desired observable with all the 100 (1000) PDFs and by computing average and standard deviation, with a faithful statistical interpretation of the result

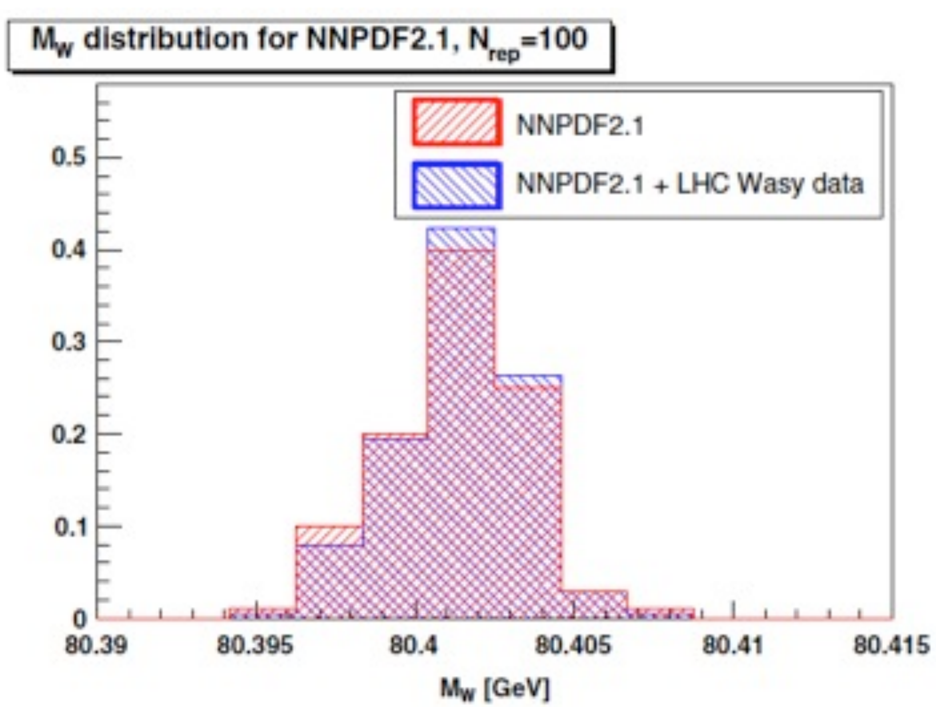
$$\sigma_{\mathcal{F}} = \left(\frac{1}{N_{\rm set}-1} \sum_{k=1}^{N_{\rm set}} \left(\mathcal{F}[\{q^{(k)}\}] - \langle \mathcal{F}[\{q\}] \rangle \right)^2 \right)^{1/2}$$

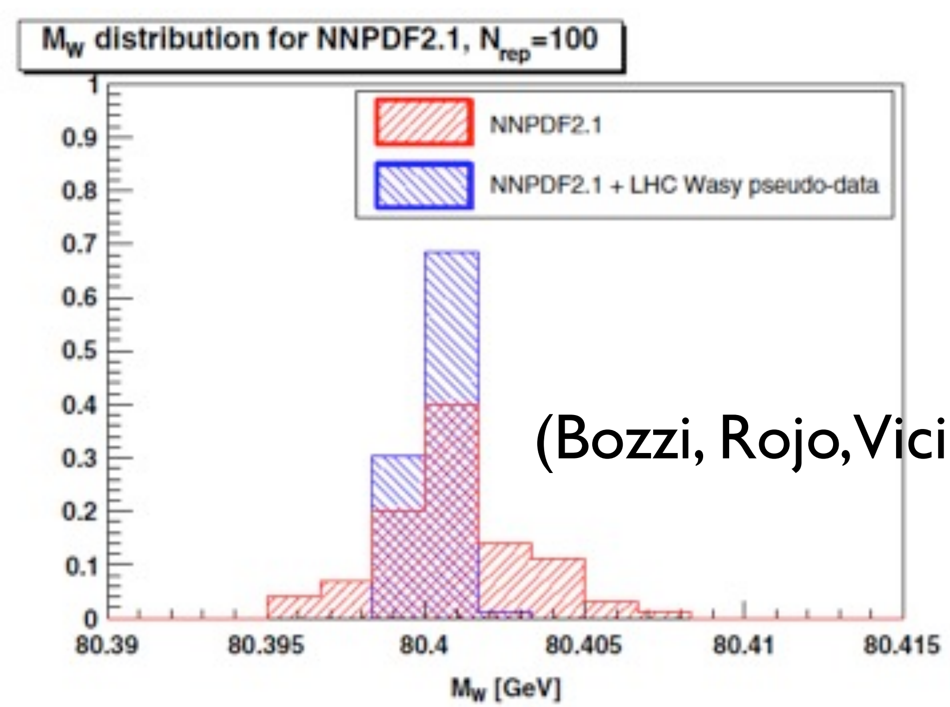
NNPDF

In NNPDF the inclusion of the information due to new data can be included in the PDFs by means of a reweighting technique, which "chooses" which replica are preferred by the new data points



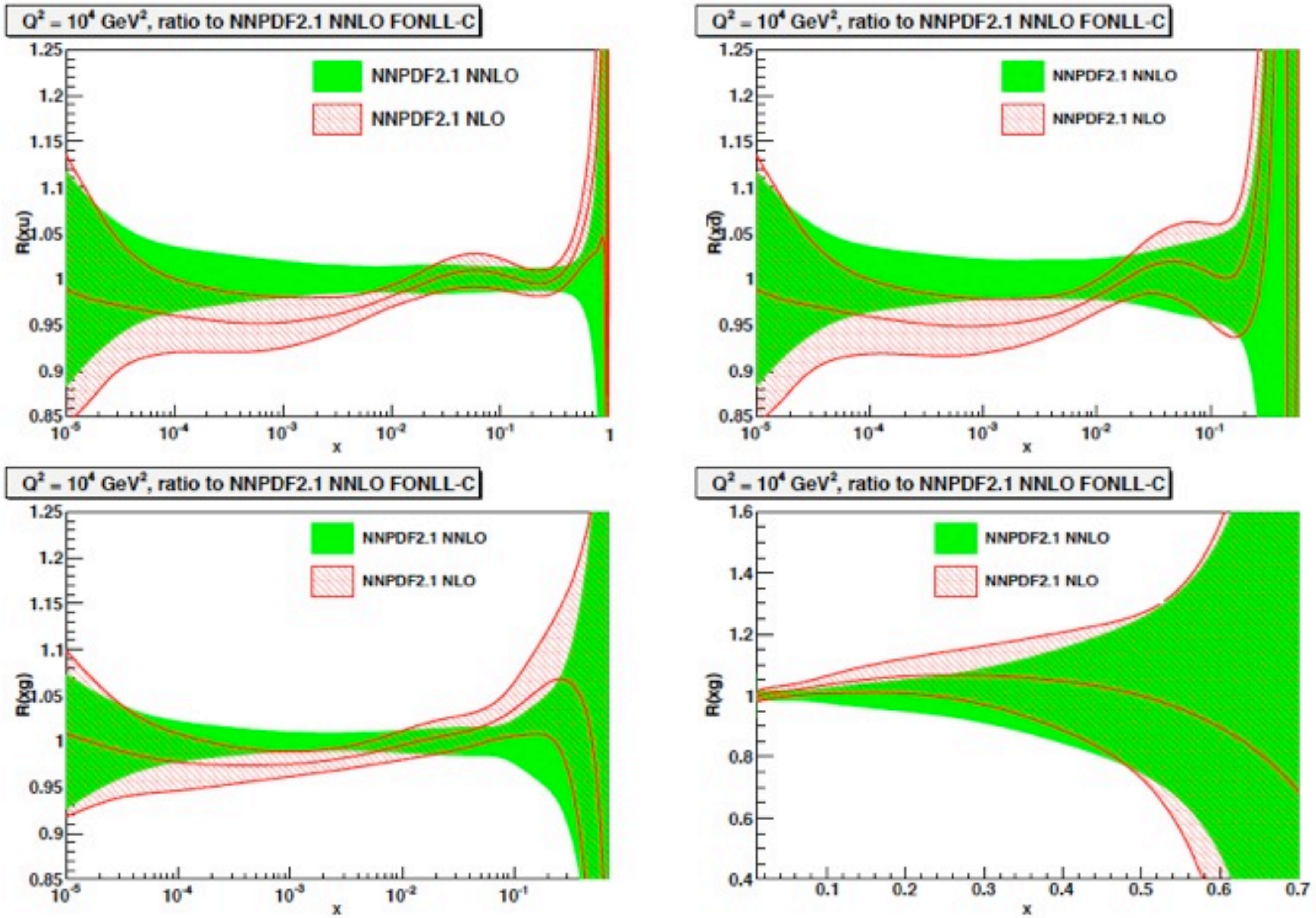
The reweighting does not replace a full new fit, but provides a powerful tool for phenomenological studies to investigate the improvement that future LHC measurements will give e.g. to precision measurements of EW observables





(Bozzi, Rojo, Vicini)

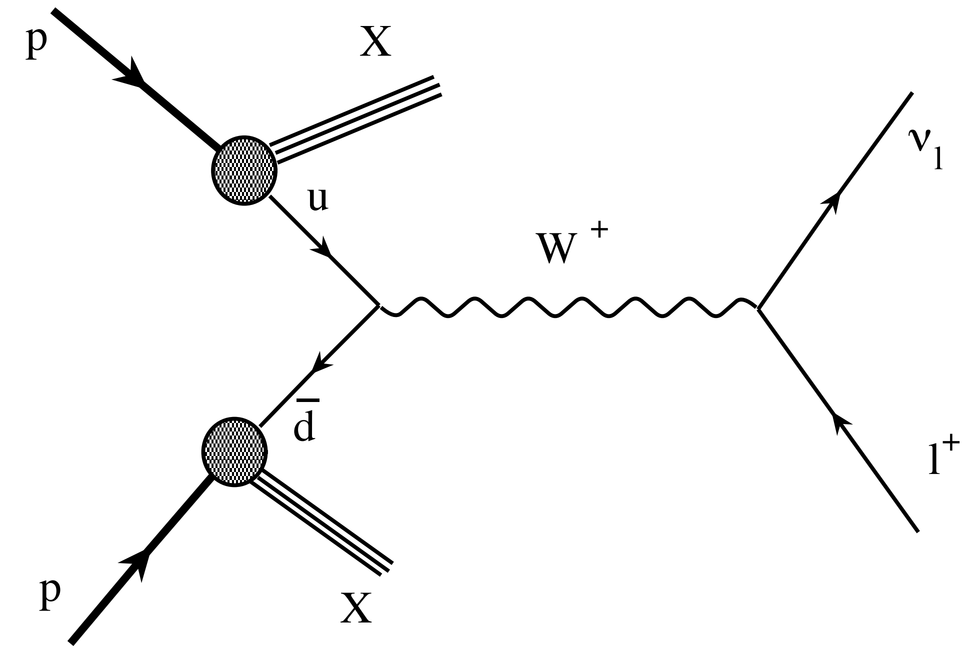
NNPDF is now @ NNLO-QCD



Many high precision observables (Higgs, DY) are known with NNLO-QCD accuracy and require a consistent use of PDFs at this same order

Along the same lines, a consistent calculation of hadron-level observables including EW effects in the partonic cross section would require PDFs extracted with the same accuracy
(in progress in Milano)

The Drell-Yan processes



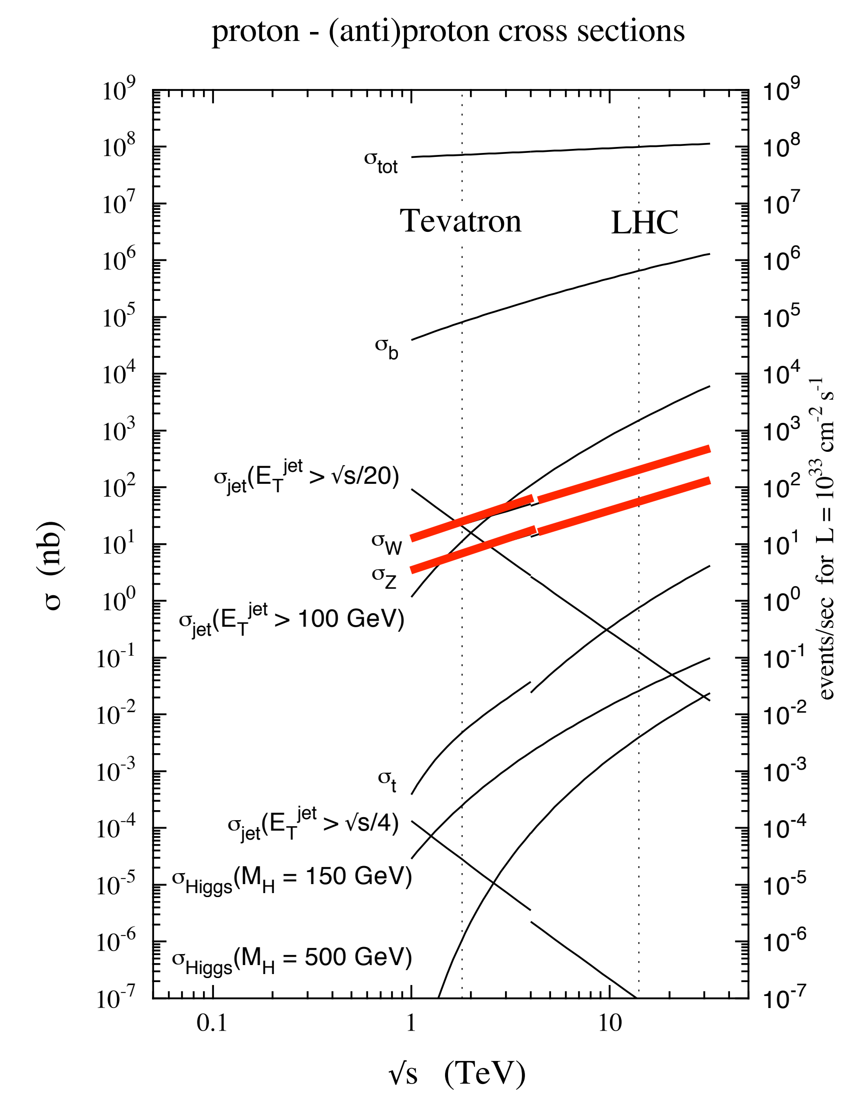
- easy detection
  high pt lepton pair or high pt lepton + missing pt

  typical cuts at the LHC (central detector region)

$$p_{\perp,l} \text{ and } p_{\perp,\nu} > 25\text{GeV}, \quad |\eta_l| < 2.5$$

- large cross section
  at LHC σ(W) = 30 nb i.e. 3 10^8 events with L=10 fb^-1
  at LHC σ(Z) = 3.5 nb i.e. 3.5 10^7 events with L=10 fb^-1

→ no statistical limitation to perform high precision EW measurements



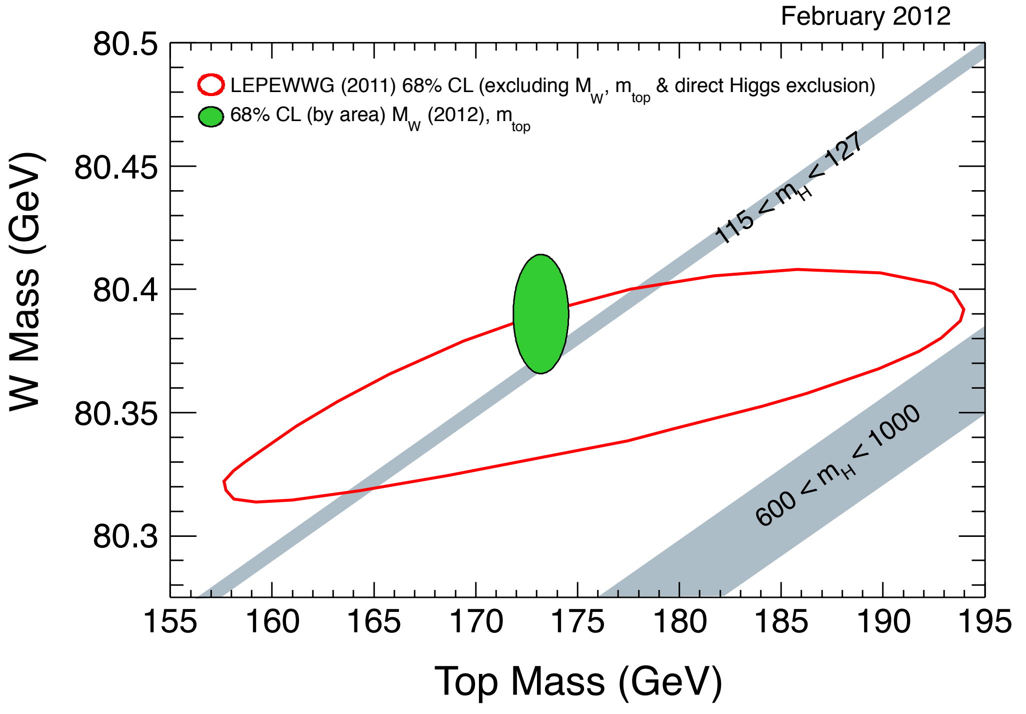
- W mass and width → lepton distributions
  W transverse mass
  ratios W/Z distributions

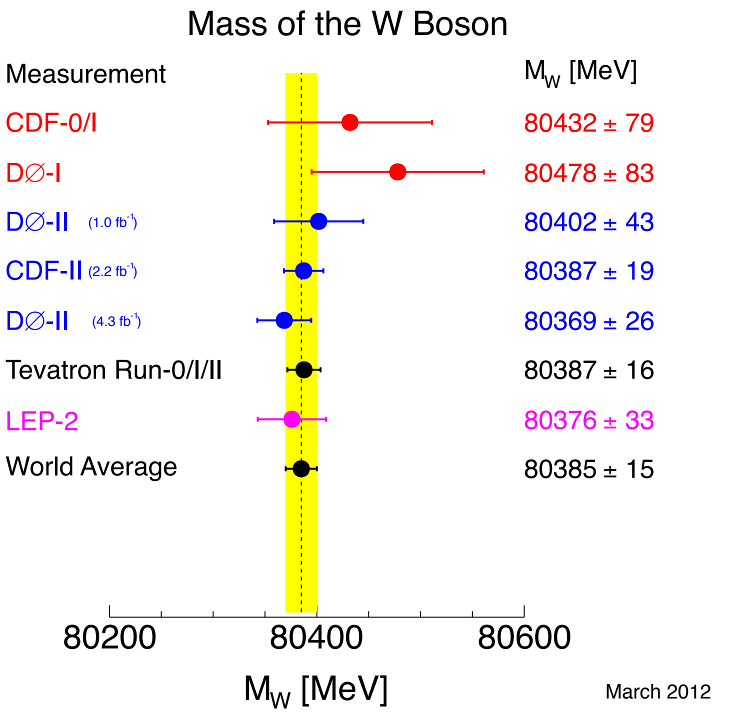
- *pdf* validation
  collider luminosity → total cross section
  W, Z rapidity
  lepton pseudo-rapidity
  acceptances

- detector calibration → W, Z mass distributions

Drell-Yan physics

A precise measurement of MW provides a crucial test of the SM





Drell-Yan physics

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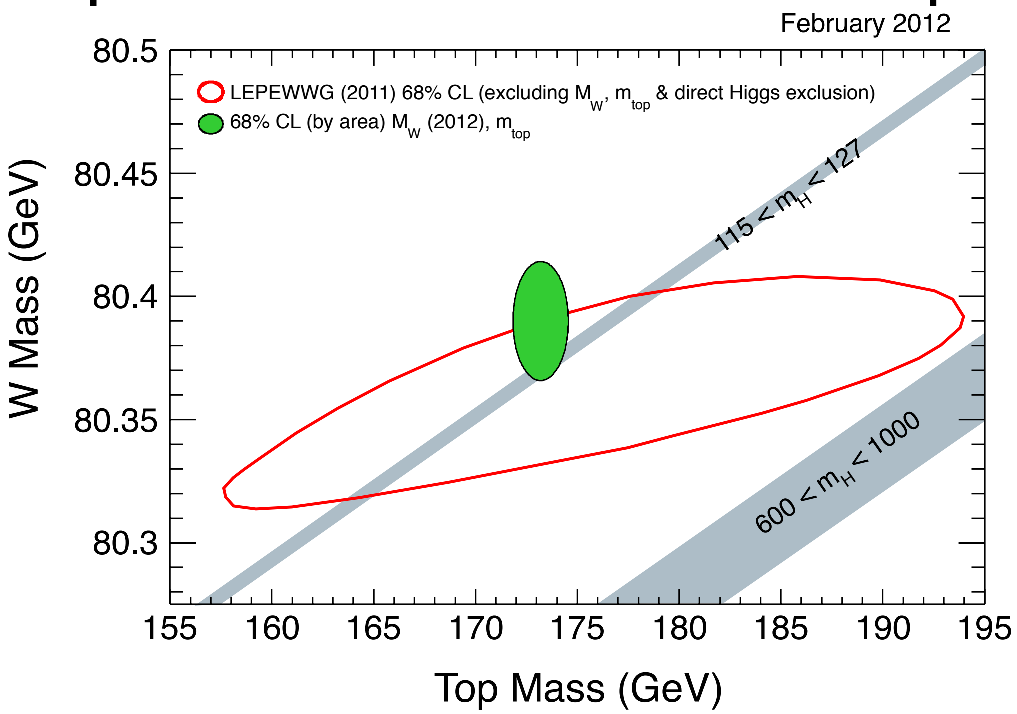
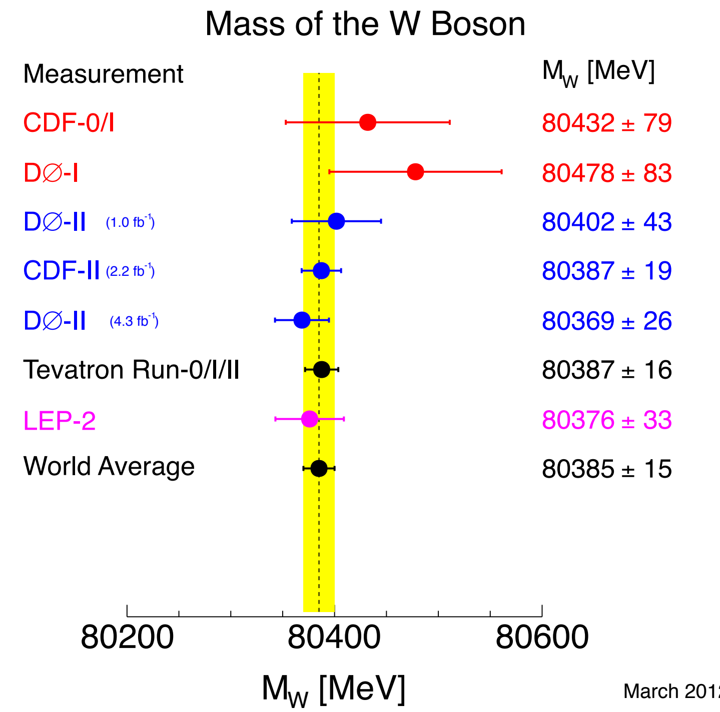
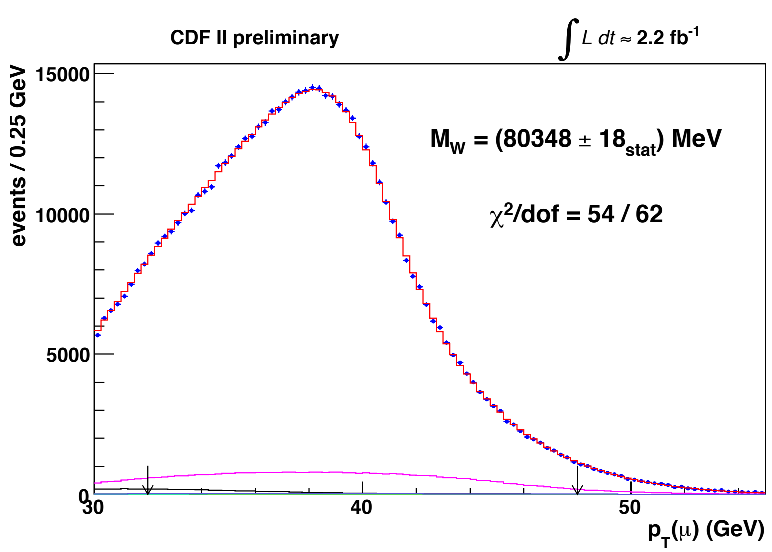
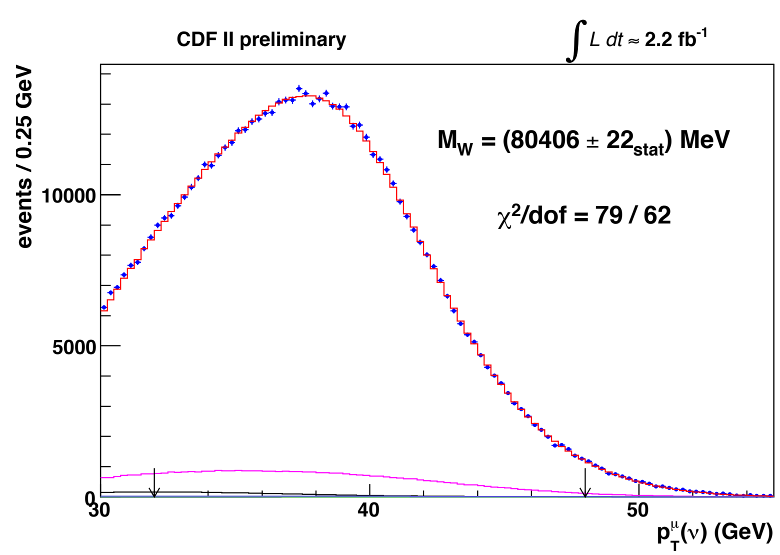


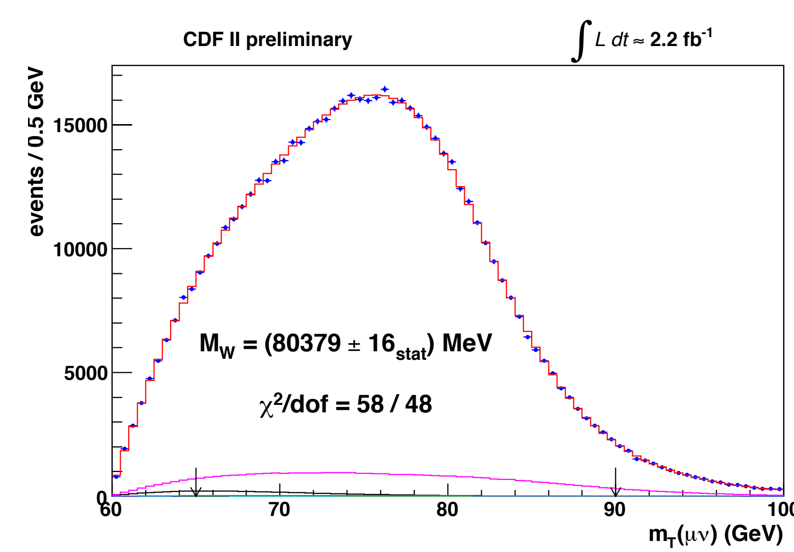


MW is extracted with a template fit technique of various distributions of CC-DY

An event generator that includes the best available results in terms of radiative corrections is necessary to minimize the theoretical systematic error in the fit







Drell-Yan physics

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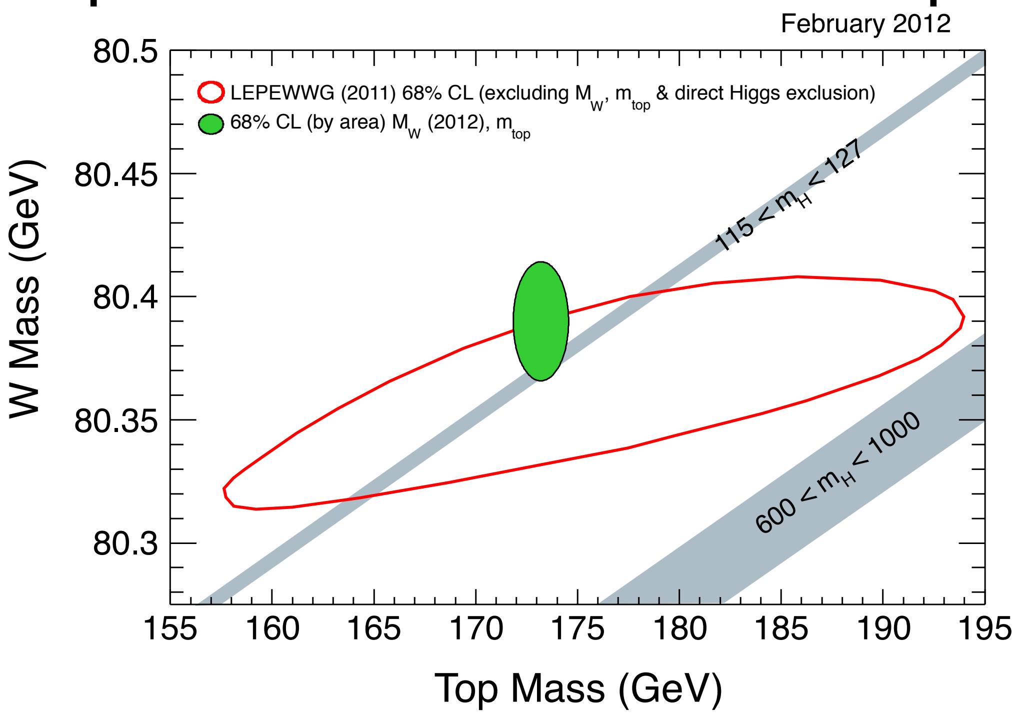

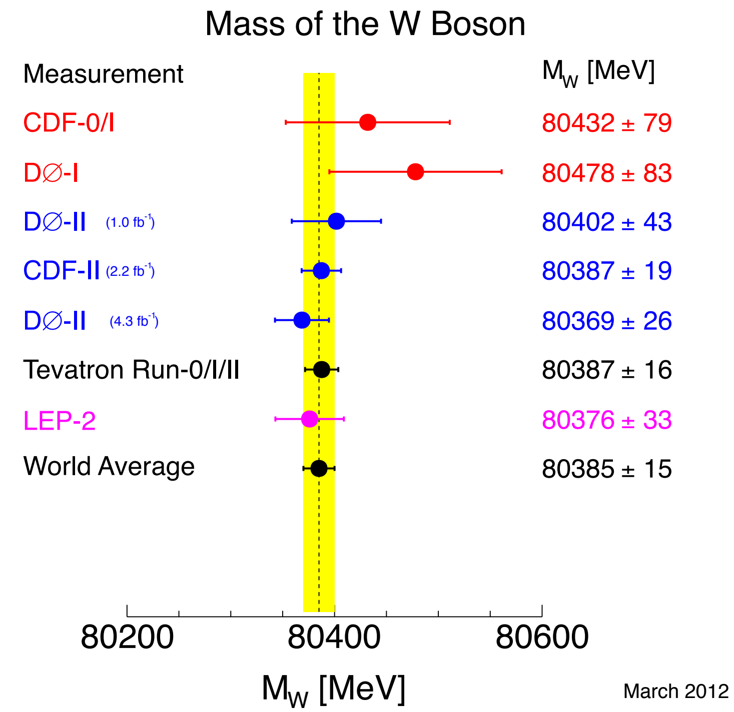

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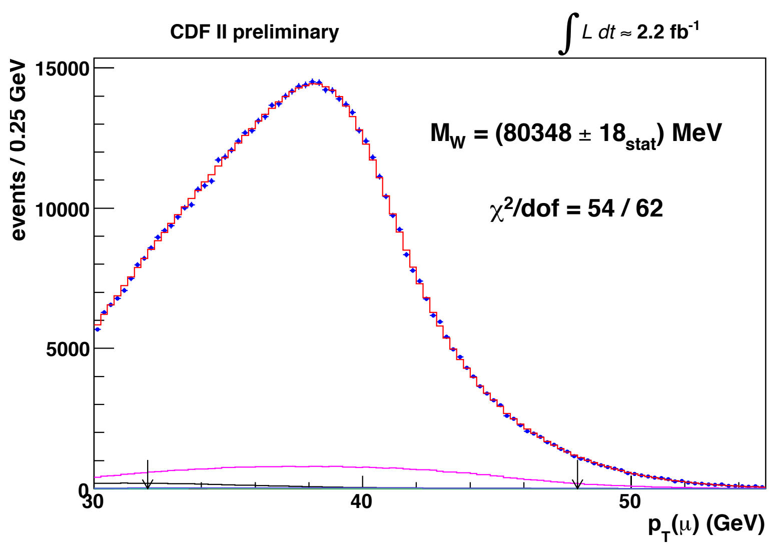
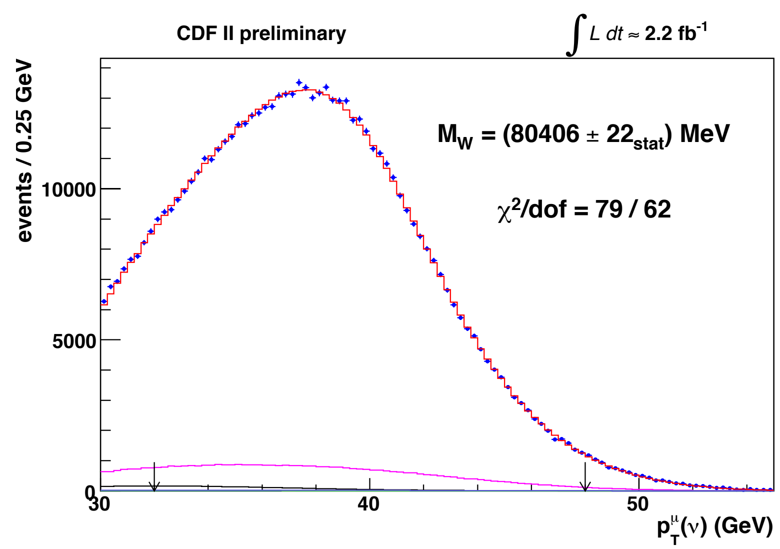
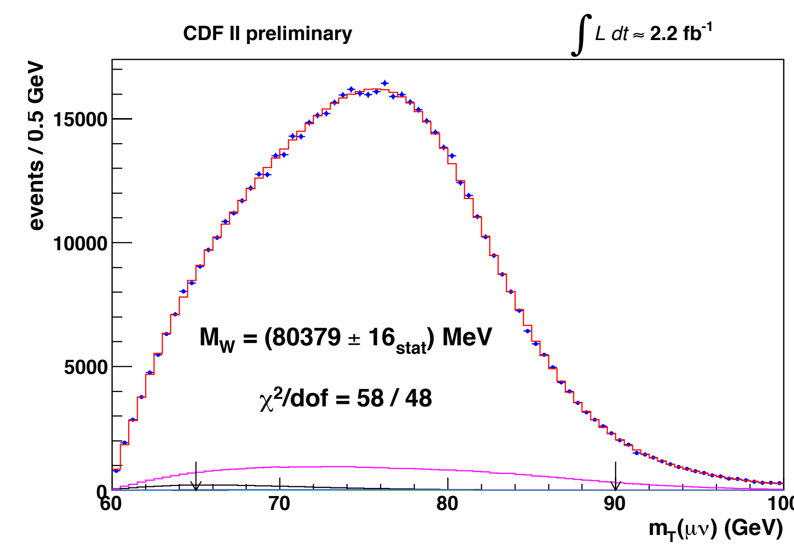




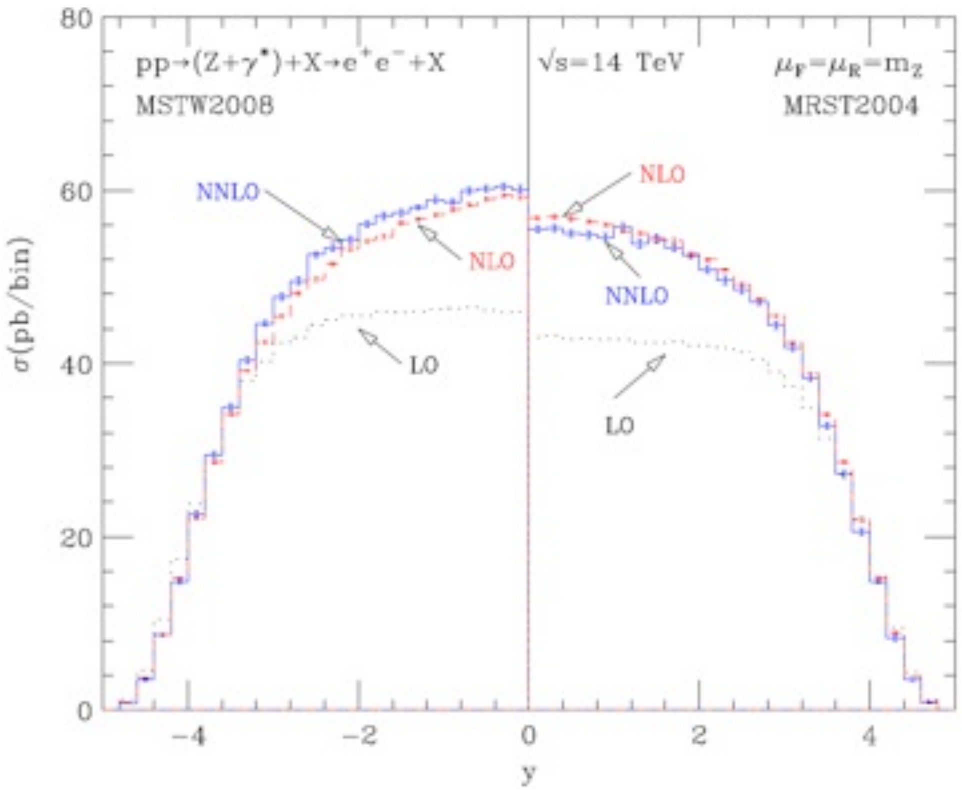


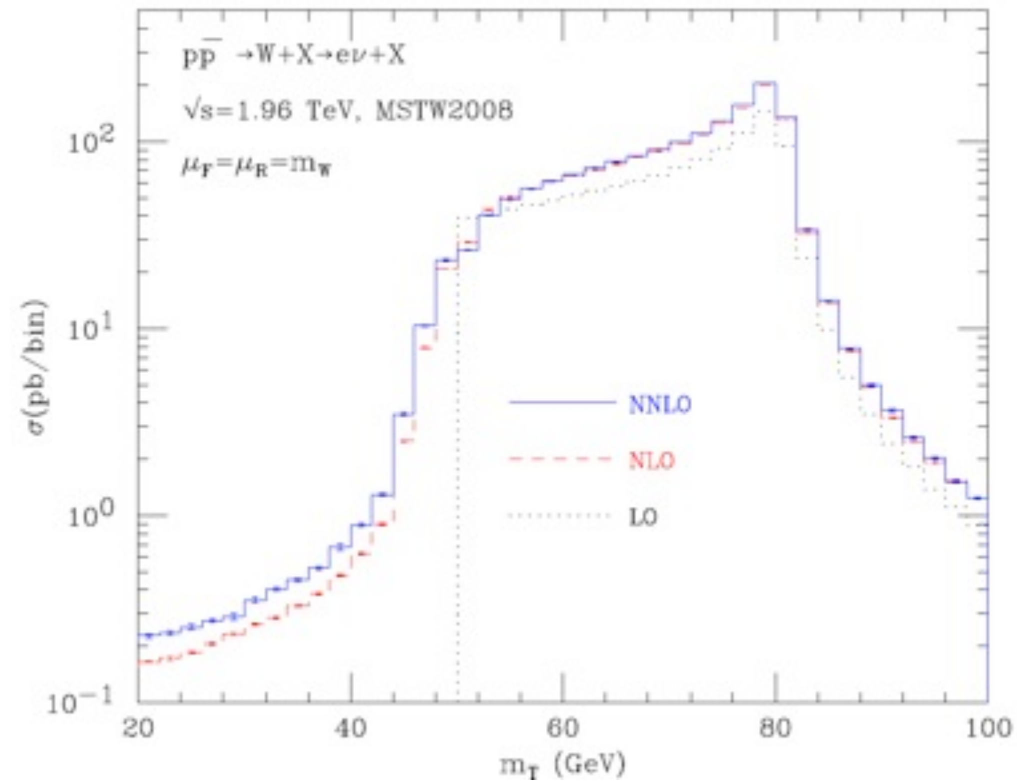
In Milano we are contributing with different tools (HORACE, POWHEG, DYNNLO, DYqT) to the evaluation of the templates that can be used to fit MW from the data
e.g. HORACE has been extensively used by CDF in the last analysis

Drell-Yan physics

DYNNLO (Catani, Cieri, de Florian, Ferrera, Grazzini)

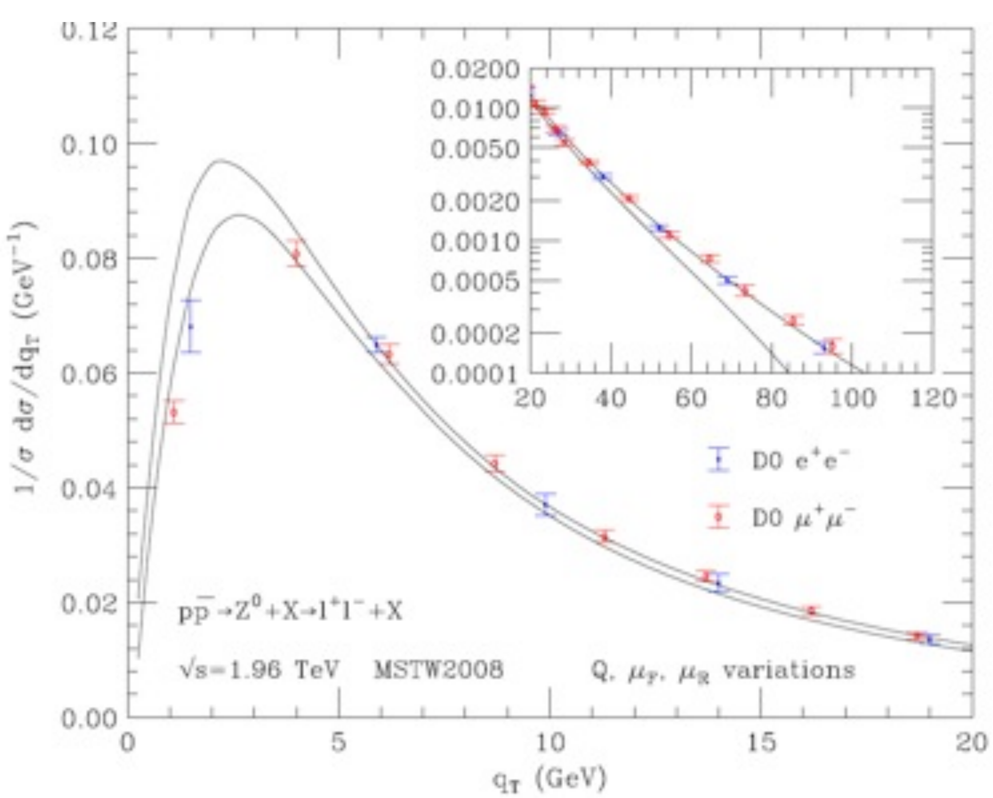
to be compared with FEWZ





DYqT (Bozzi, Catani, Ferrera, de Florian, Grazzini)

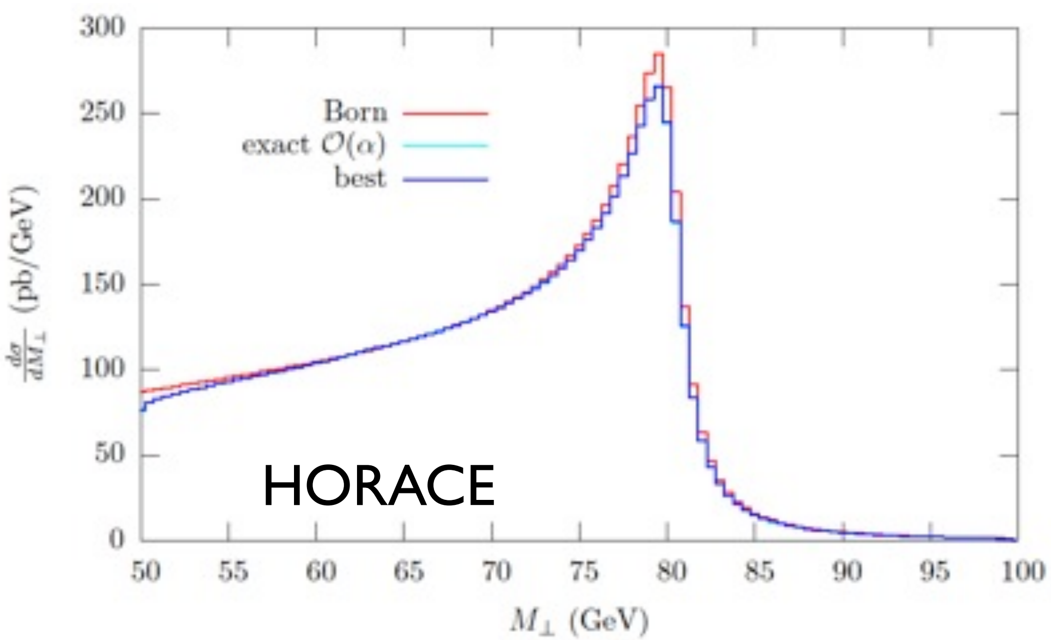
to be compared with ResBos

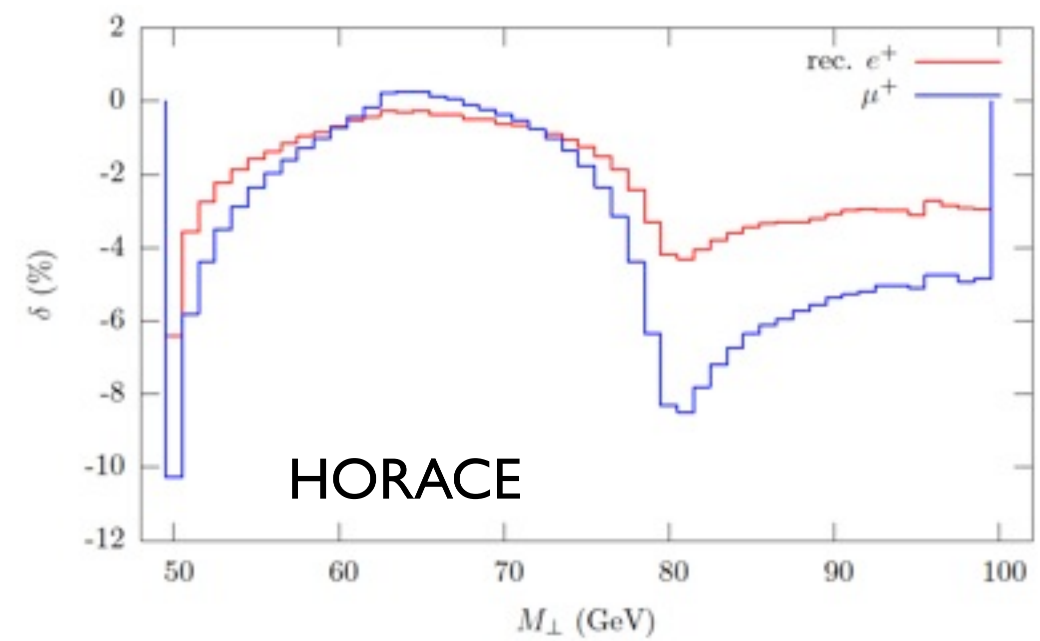


Drell-Yan physics

HORACE (Carloni Calame, Montagna, Nicrosini, Vicini)

to be compared with W/ZGRAD

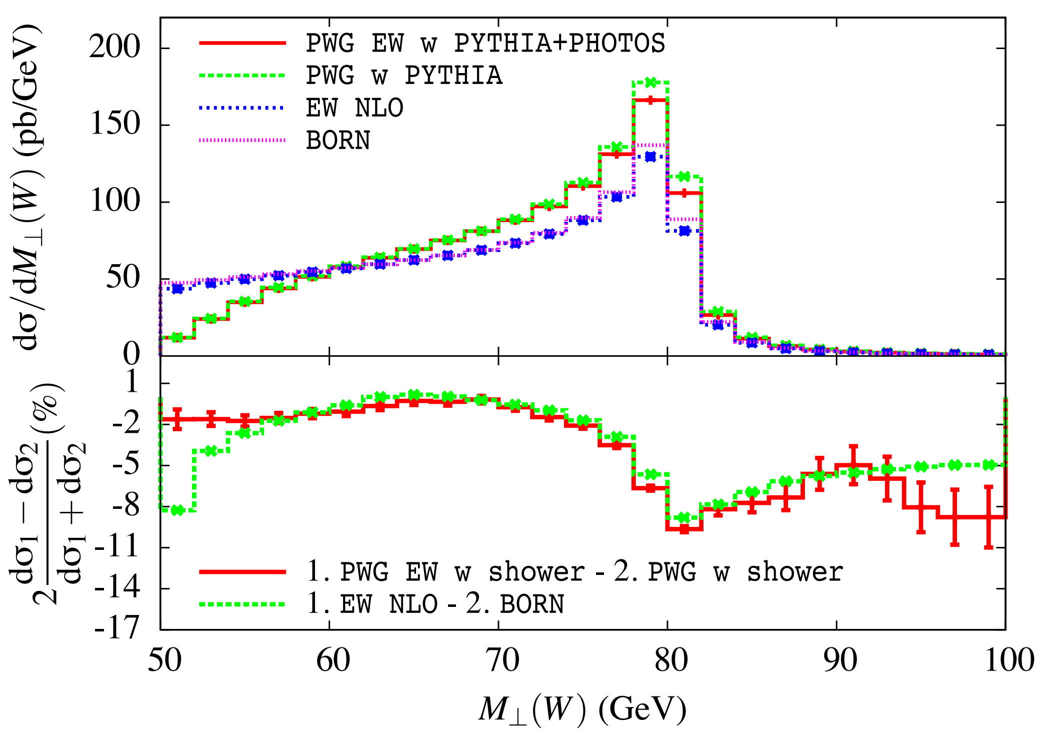


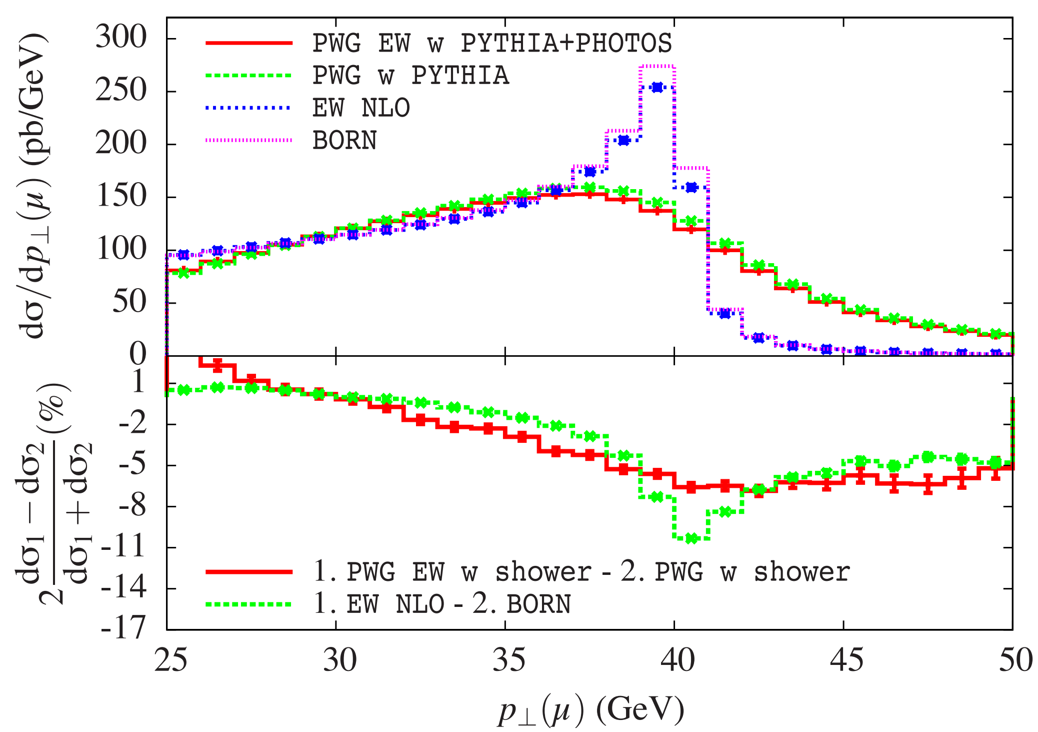


The change of the final state lepton distribution yields a huge shift in the extracted MW value

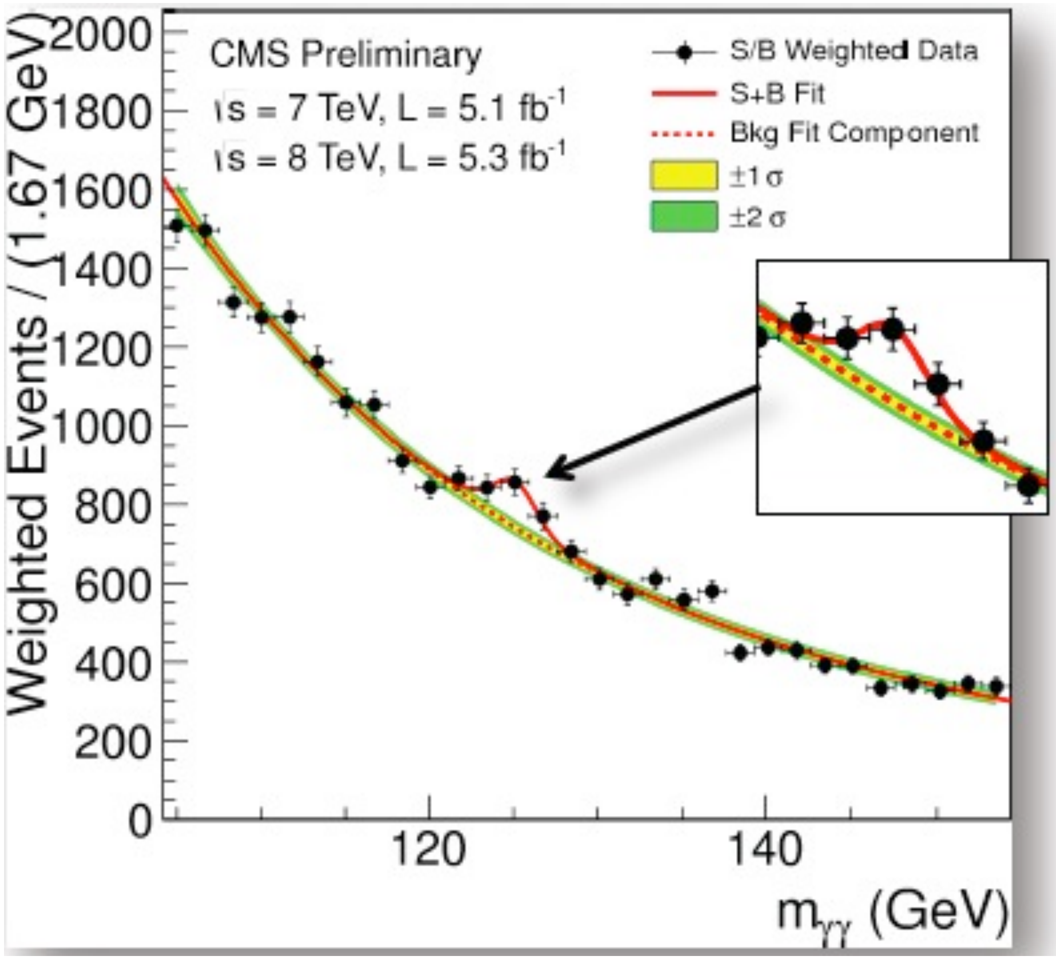
$$\Delta M_W^\alpha = 110 \text{ MeV}$$

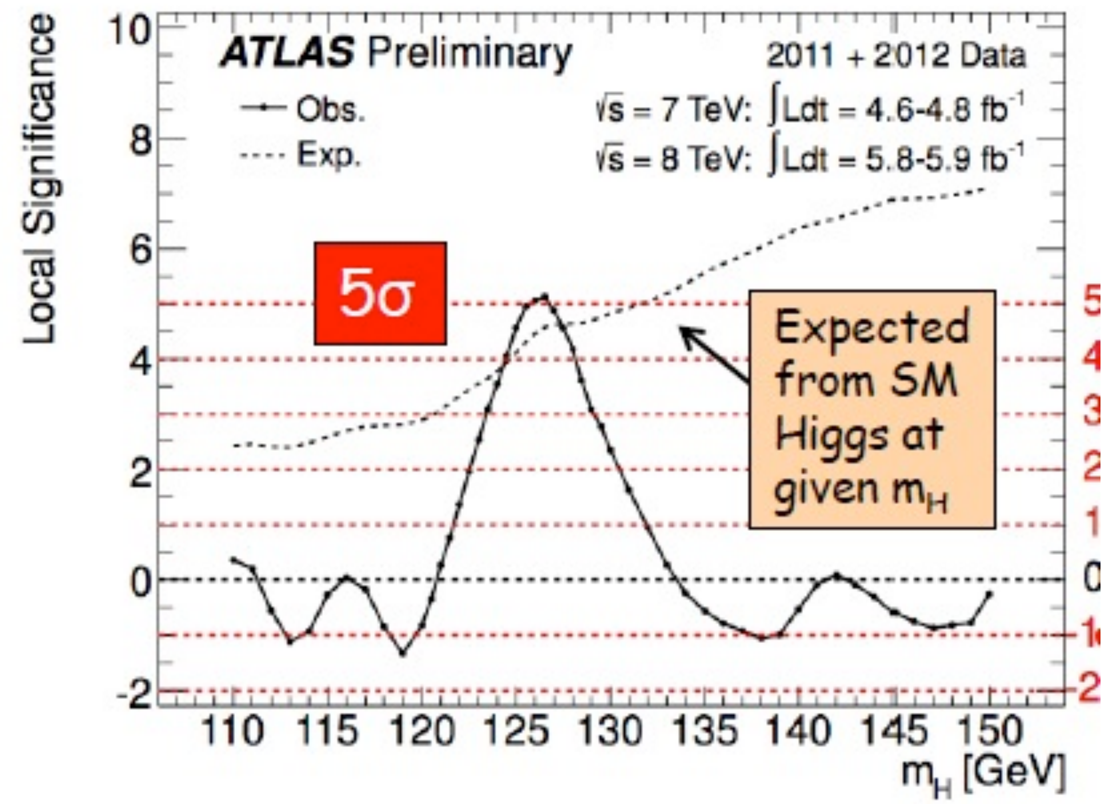
POWHEG+HORACE: CC-DY (Barzè, Montagna, Nason, Nicrosini, Piccinini)





Higgs physics





the searches for the Higgs boson require

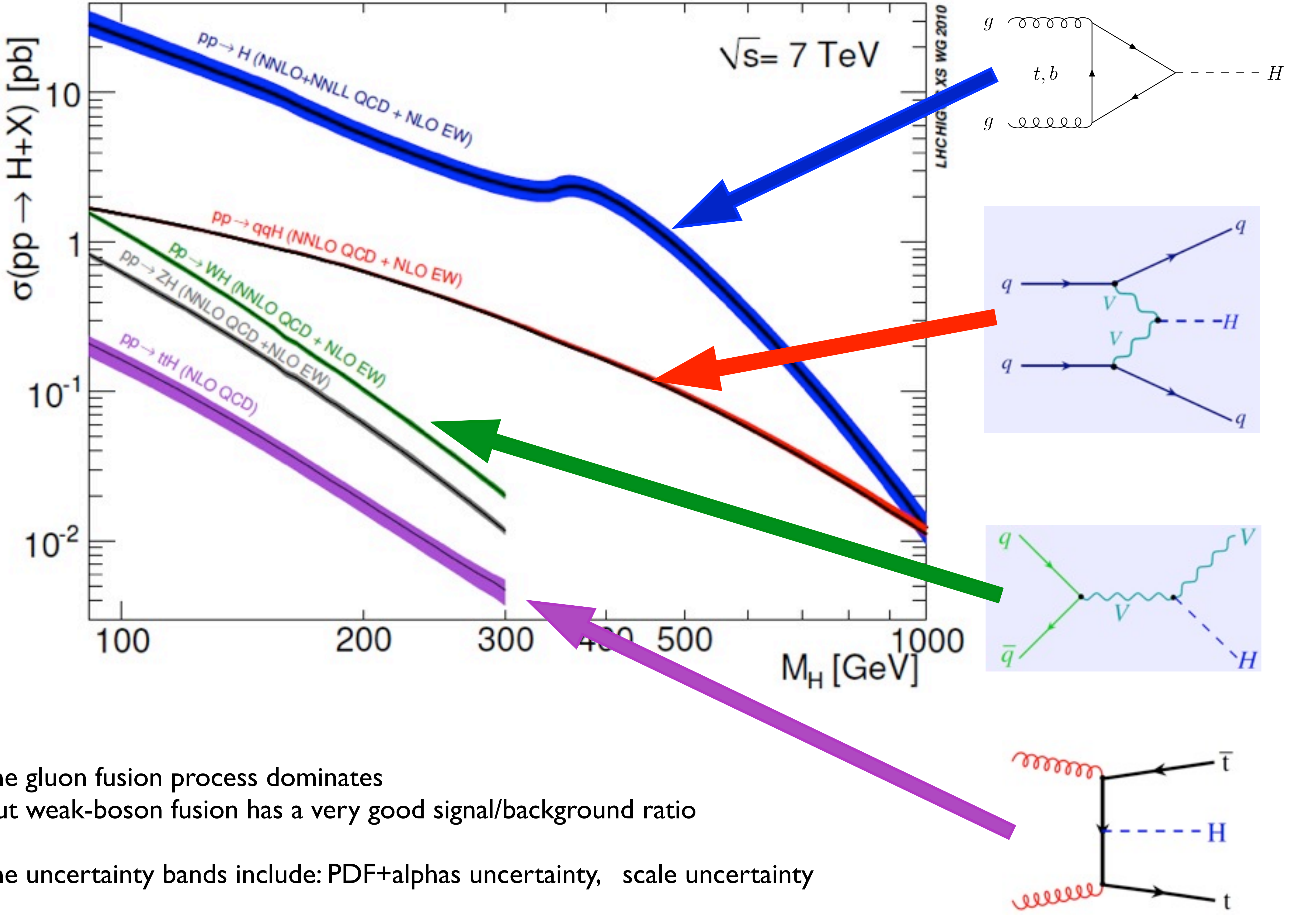
accurate evaluation of the cross sections, of the branching ratios and of their uncertainties

accurate MC tools to simulate signals and backgrounds

evaluate detector acceptances

Higgs physics: the total production cross section

- Yellow Report 1 of the Higgs Cross Section Working Group, arXiv:1101.0593

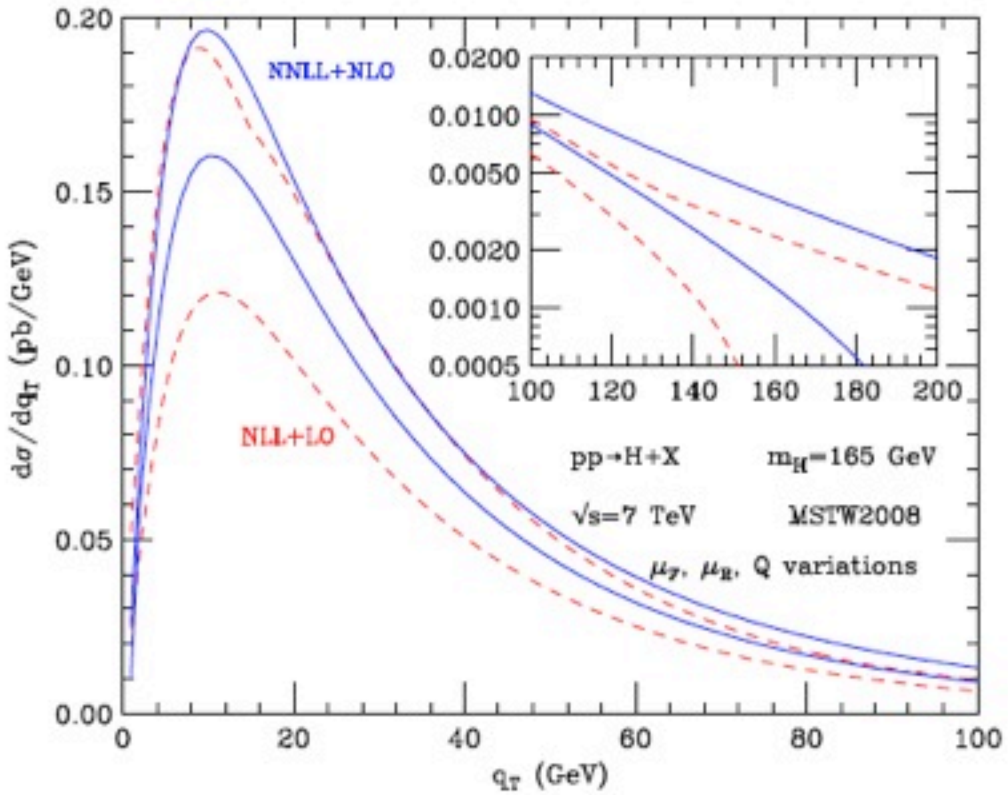


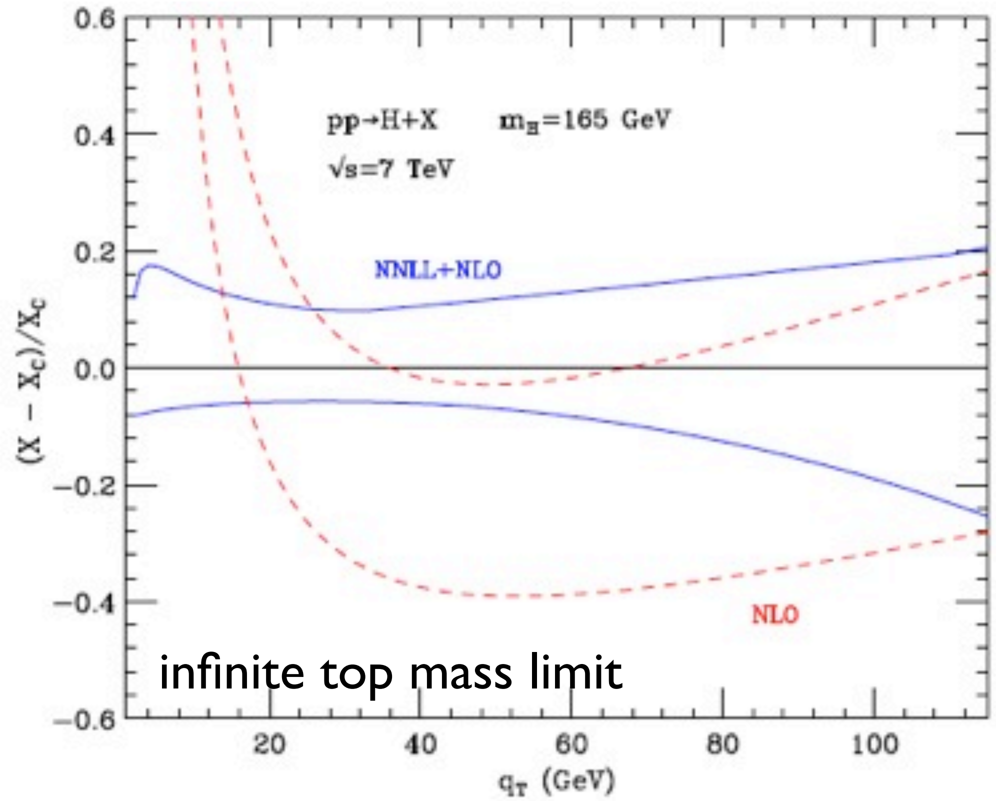
- the gluon fusion process dominates
  but weak-boson fusion has a very good signal/background ratio

- the uncertainty bands include: PDF+alphas uncertainty, scale uncertainty

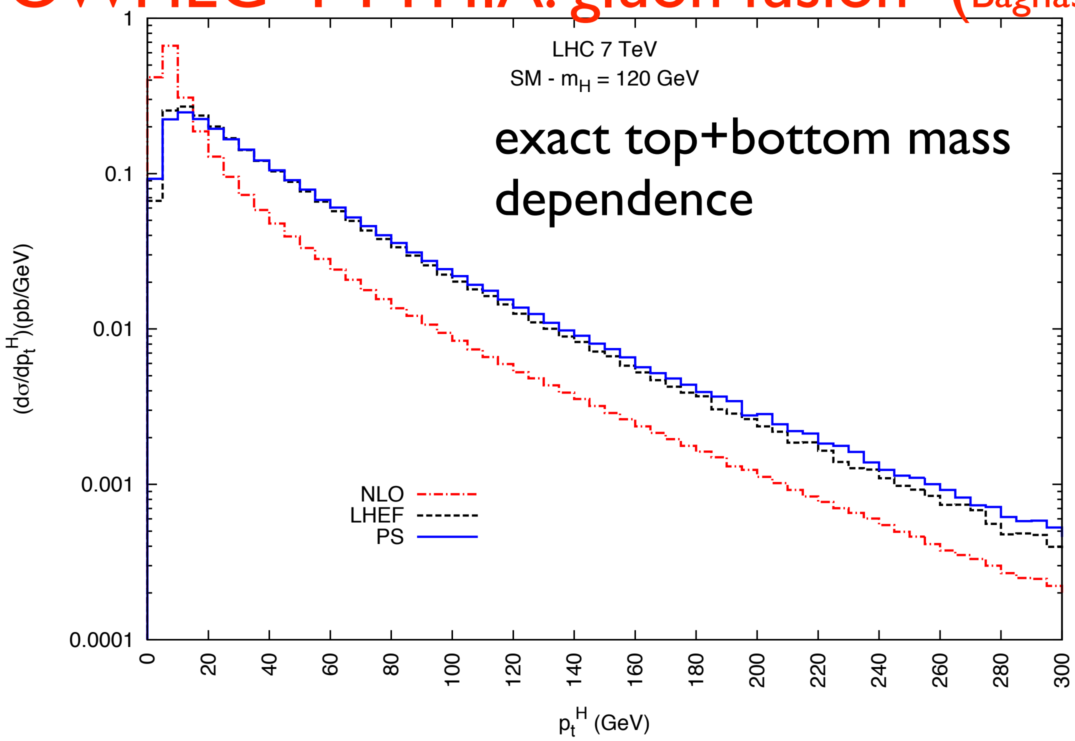
Higgs physics

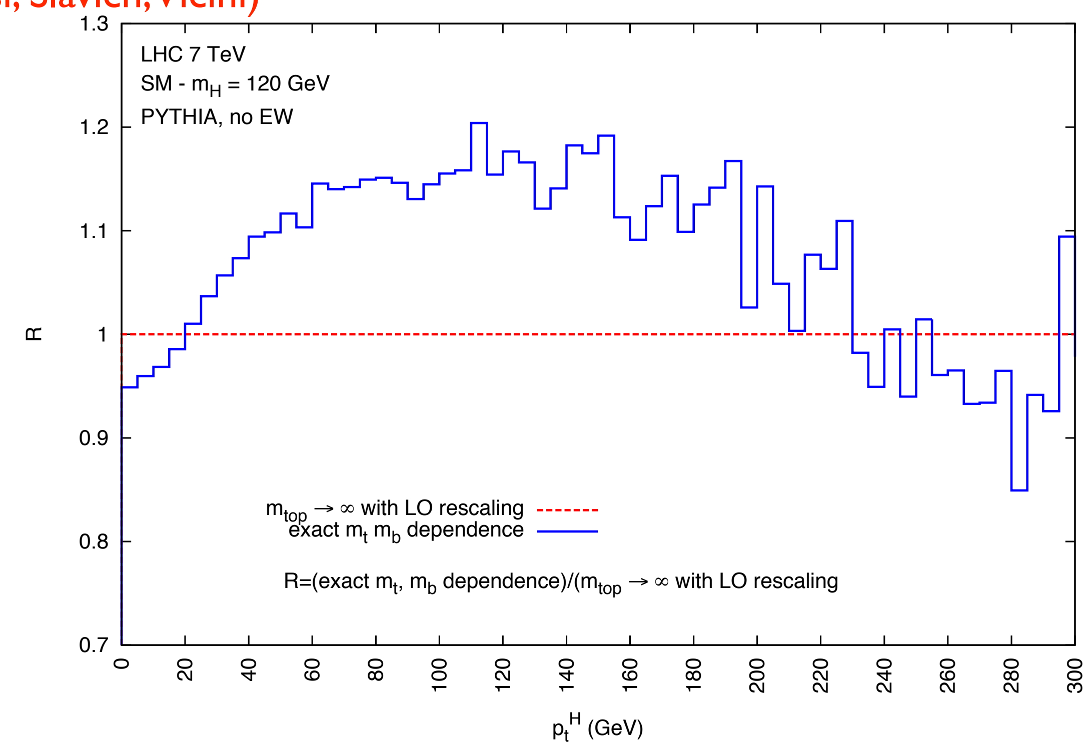
HqT (Bozzi, Catani, de Florian, Ferrera, Grazzini, Tommasini)





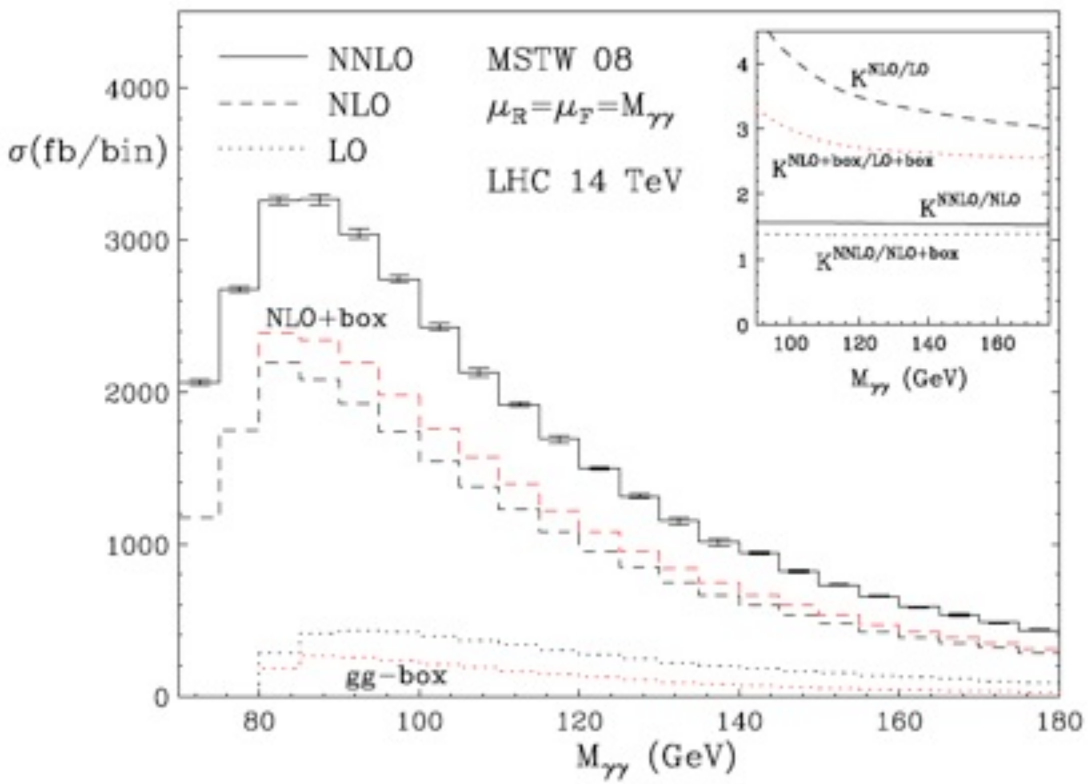
POWHEG+PYTHIA: gluon fusion (Bagnaschi, Degrassi, Slavich, Vicini)





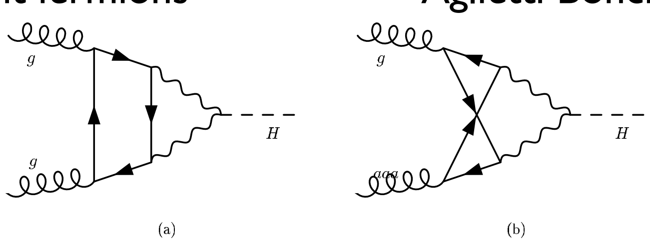
Higgs physics

2γNNLO (Catani, Cieri, de Florian, Ferrera, Grazzini)



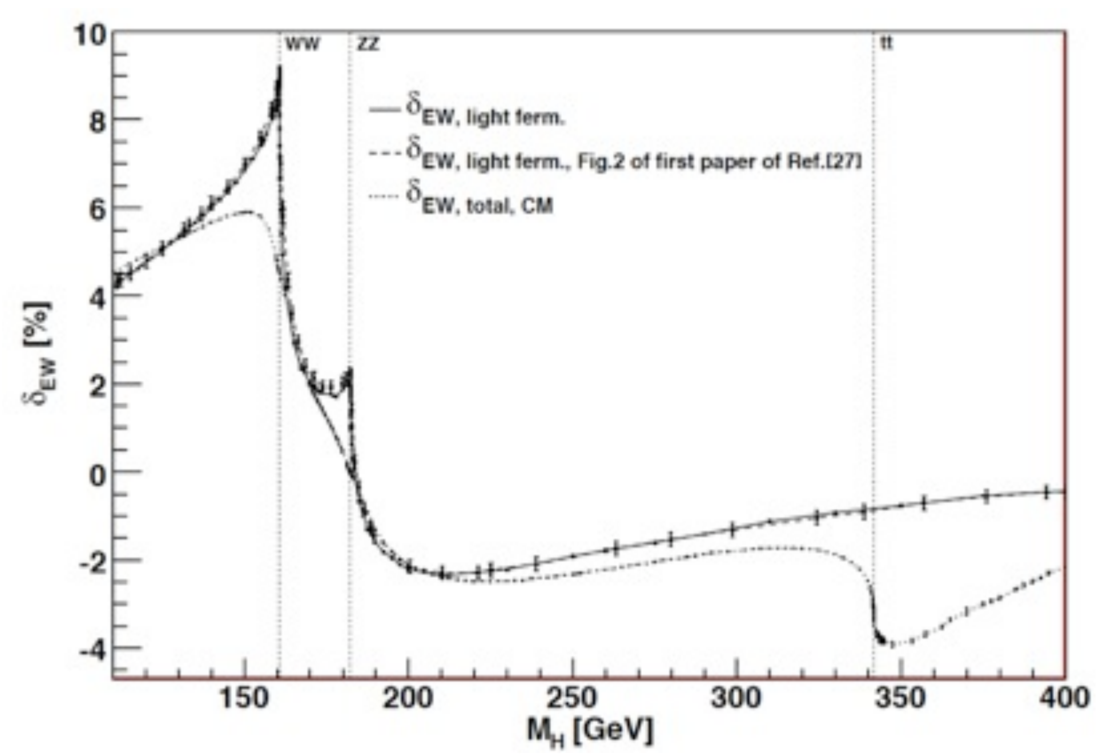
NLO-EW corrections

light fermions — Aglietti Bonciani Degrassi AV 2004

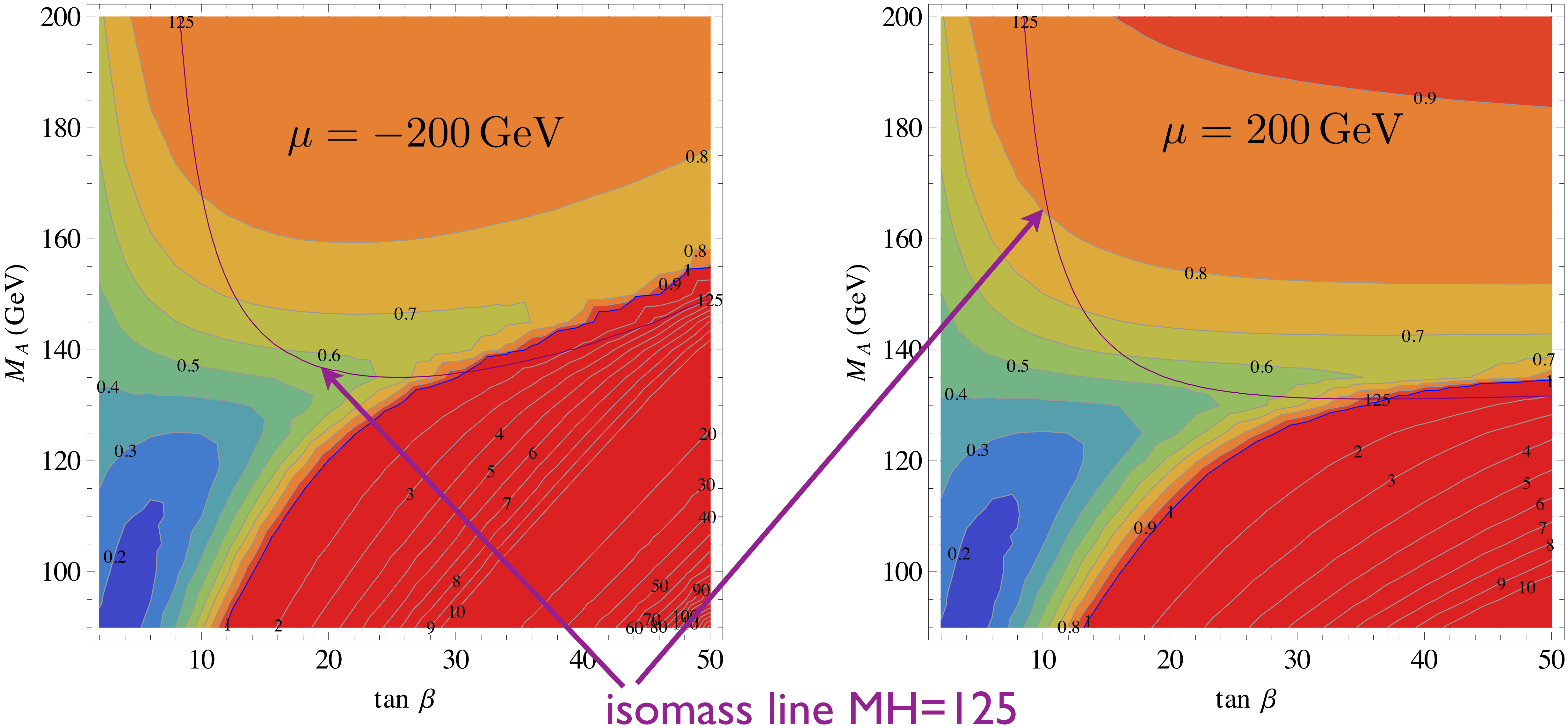


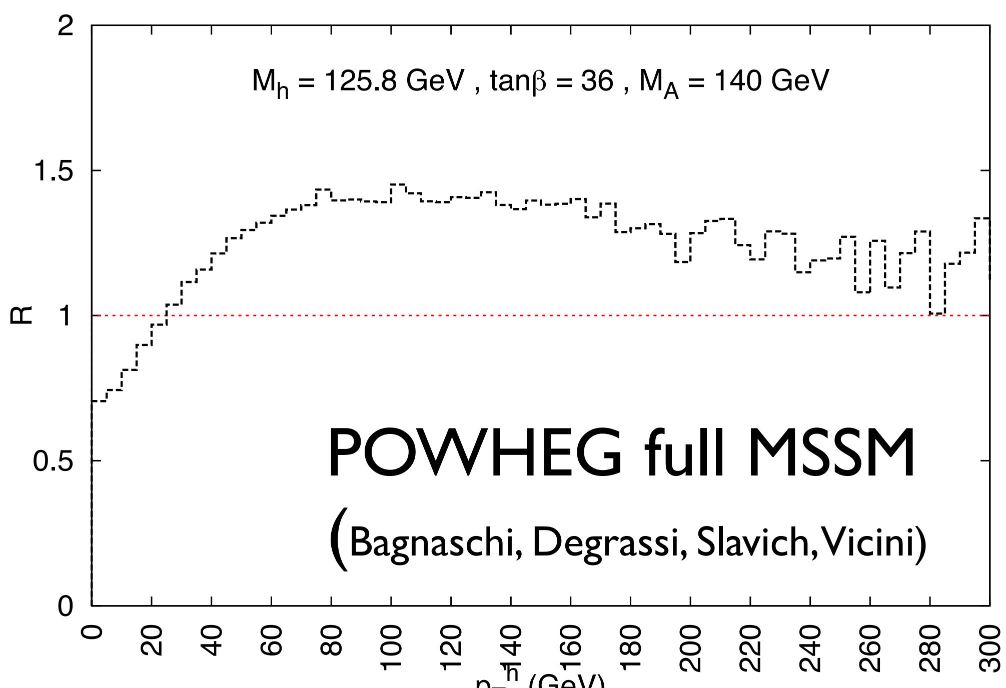
top+bottom — Degrassi Maltoni 2004

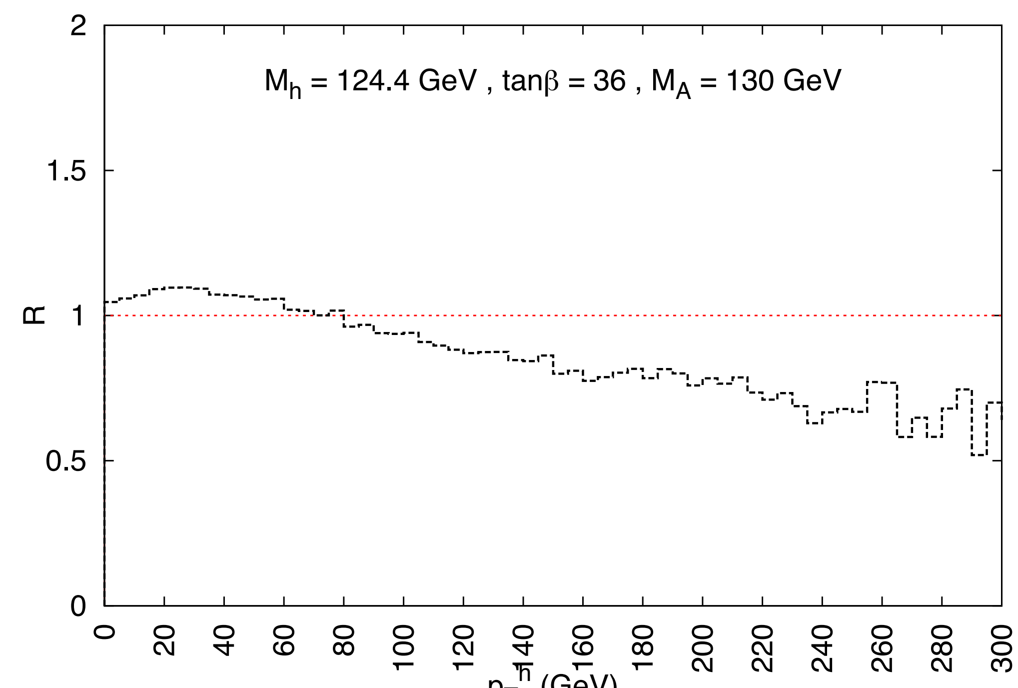
full with complex masses — Actis Passarino Sturm Uccirati 2008



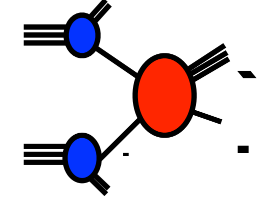
Is a scalar with mass 125 GeV a SM Higgs? Is it a MSSM Higgs?



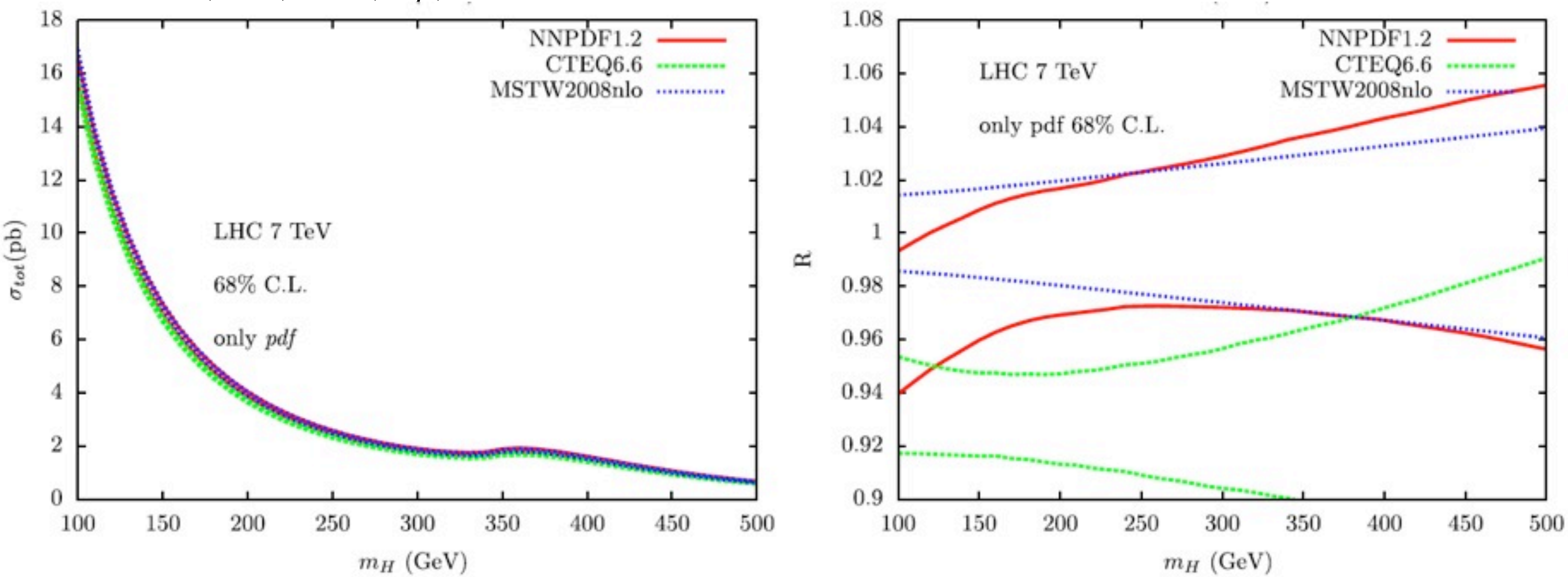




The gluon fusion process: PDF + alpha_s uncertainties



Demartin, Forte, Mariani, Rojo, Vicini 2010



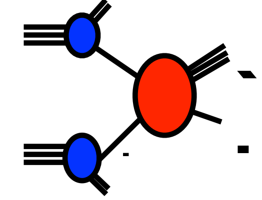
including ONLY the PDF uncertainty, predictions do not overlap at 1-sigma

- different PDF parametrization
- use of different values of alpha_s

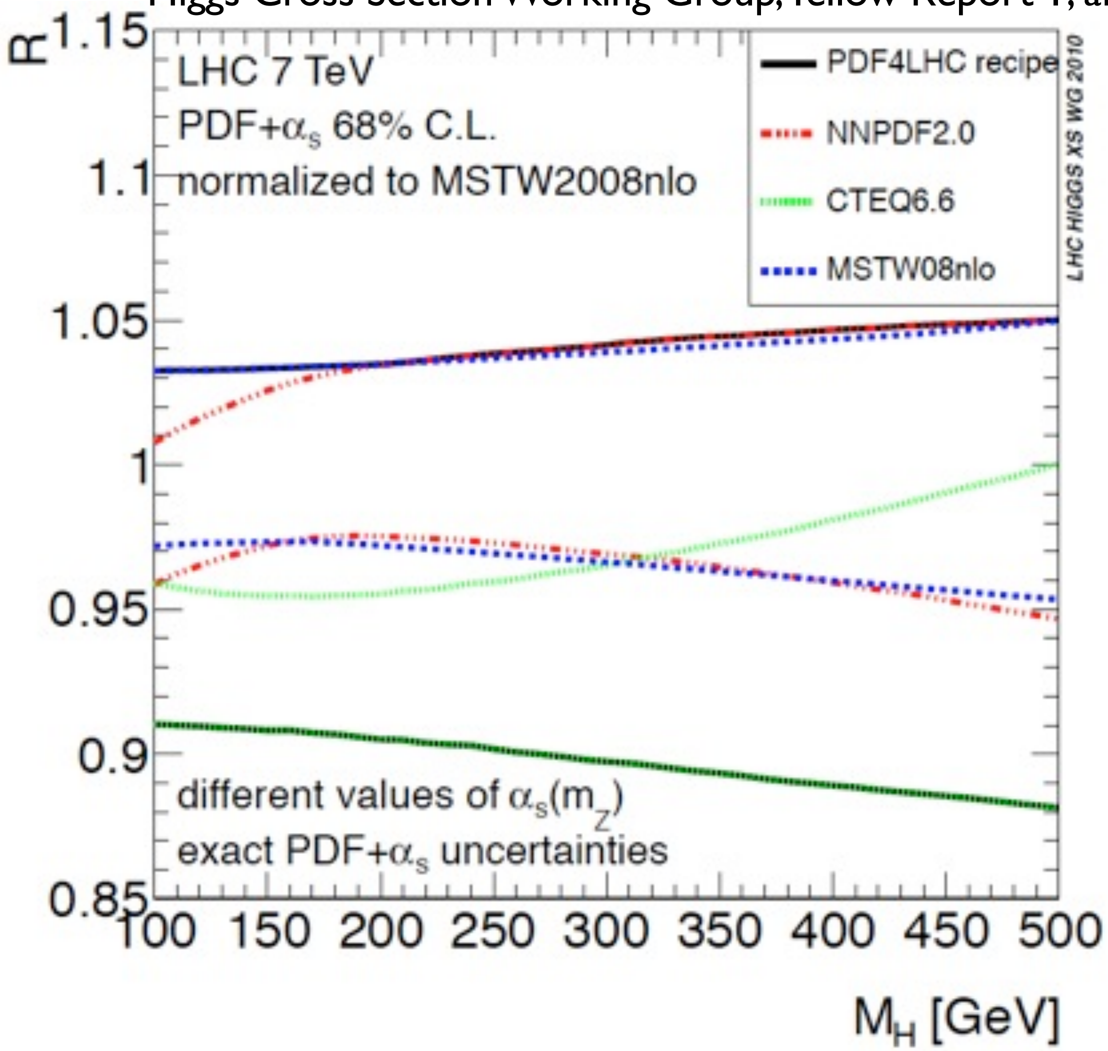
$$\frac{\Delta\sigma_{\alpha_s}}{\sigma} \sim 2.5\, \frac{\delta\alpha_s}{\alpha_s}$$

CTEQ6.6	0.118
NNPDF1.2	0.119
MSTW2008nlo	0.12018

The gluon fusion process: PDF + alpha_s uncertainties

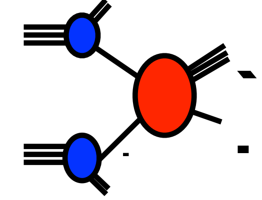


Higgs Cross Section Working Group, Yellow Report 1, arXiv:1101.0593



- estimate of the uncertainty induced by alpha_s combined with the PDF uncertainty
- envelope to identify the spread of the predictions obtained with different PDF sets

The gluon fusion process: PDF + alpha_s uncertainties



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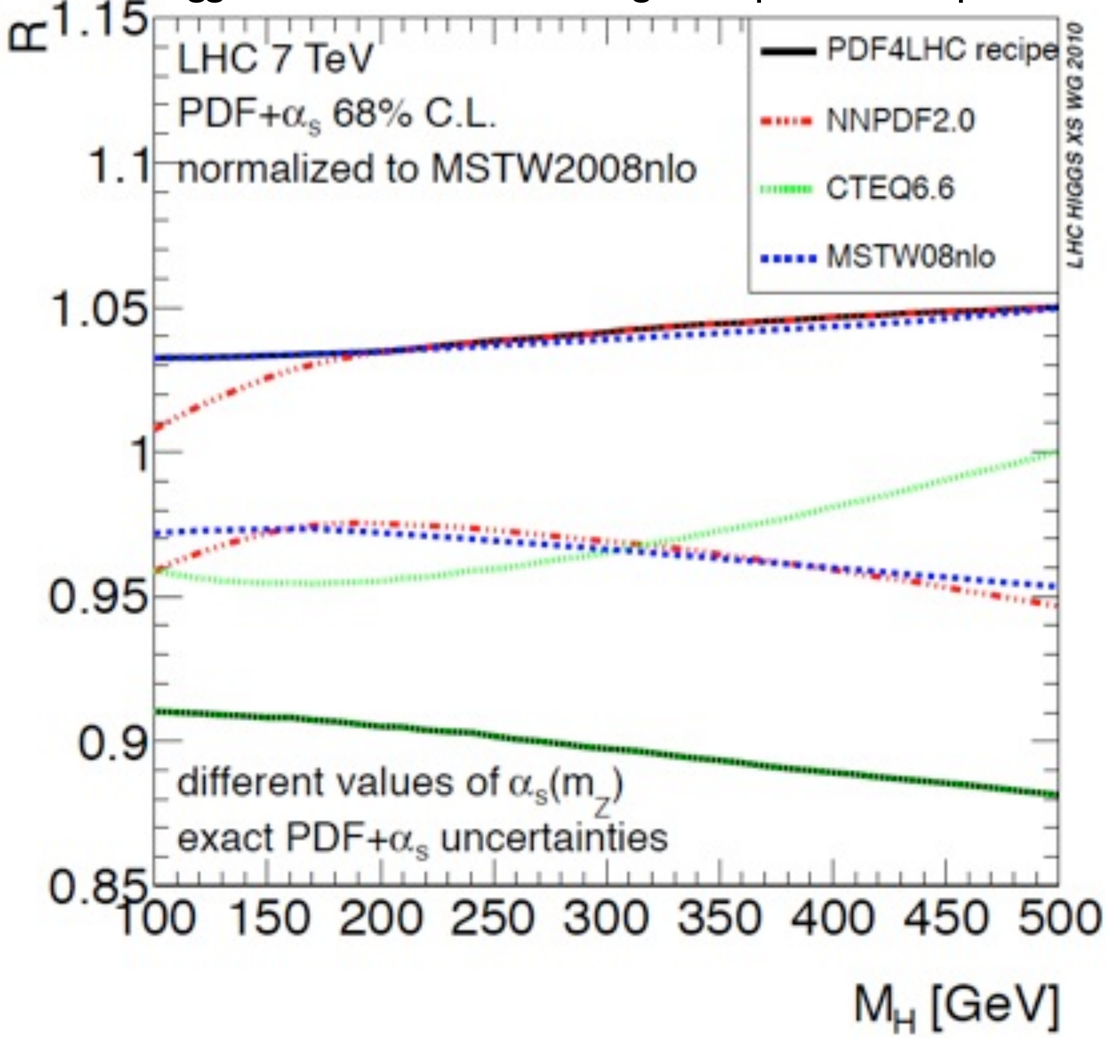

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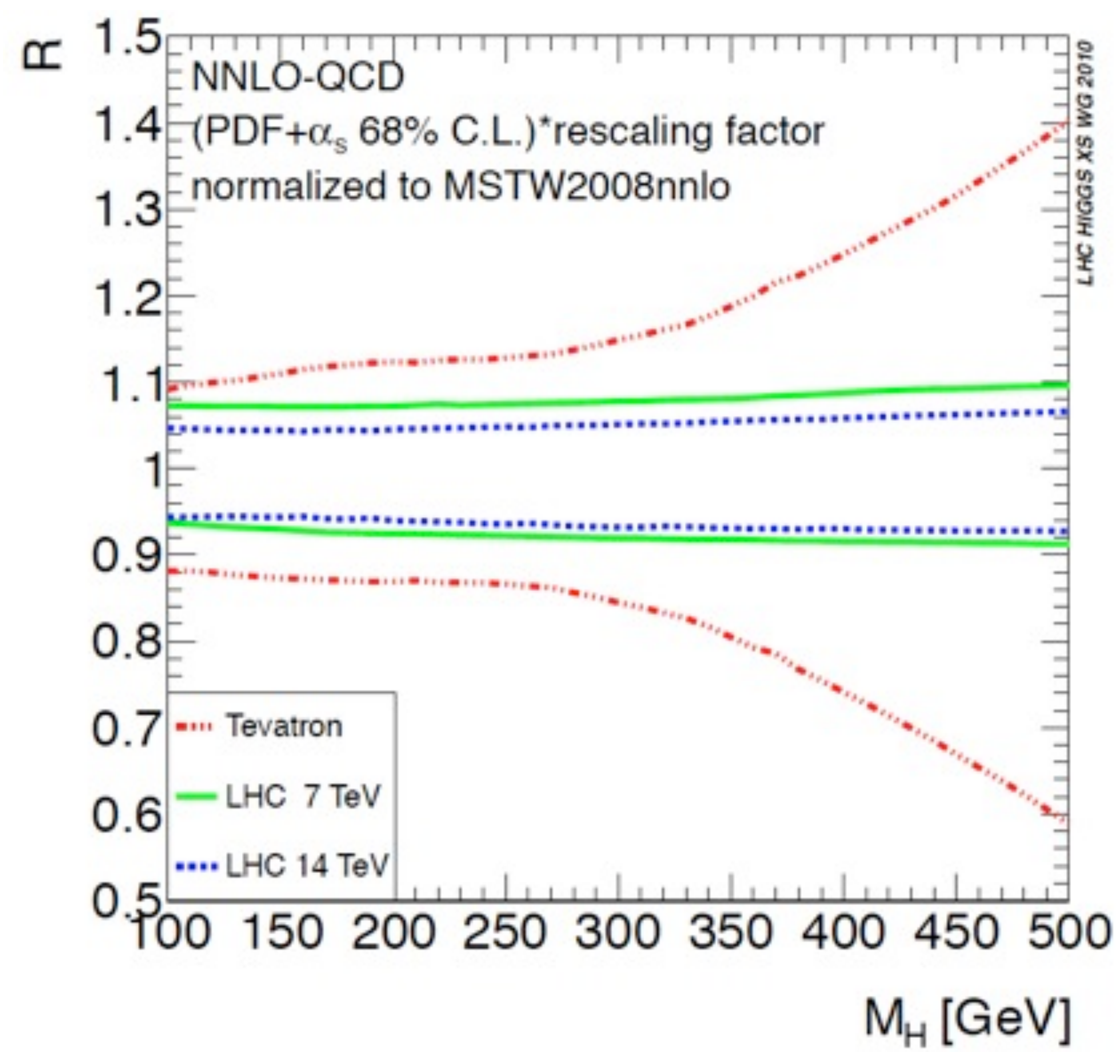


- extrapolation of the NLO uncertainty to NNLO

(almost superseeded by the new CTEQ and NNPDF NNLO-QCD results)

What is behind the development of these tools

- the computing laboratory LCM (Laboratorio di Calcolo e Multimedia)
  where we have installed a high performance linux cluster
  17 nodes, 120 physical cores, 240 simultaneous processes
  5 GPU Tesla C-2070, 1 GPU Tesla C-1060, 10 GeForce GT440
  for a large fraction funded by INFN

- the intensive use of Mathematica as algebraic manipulation tool to prepare the analytical expressions

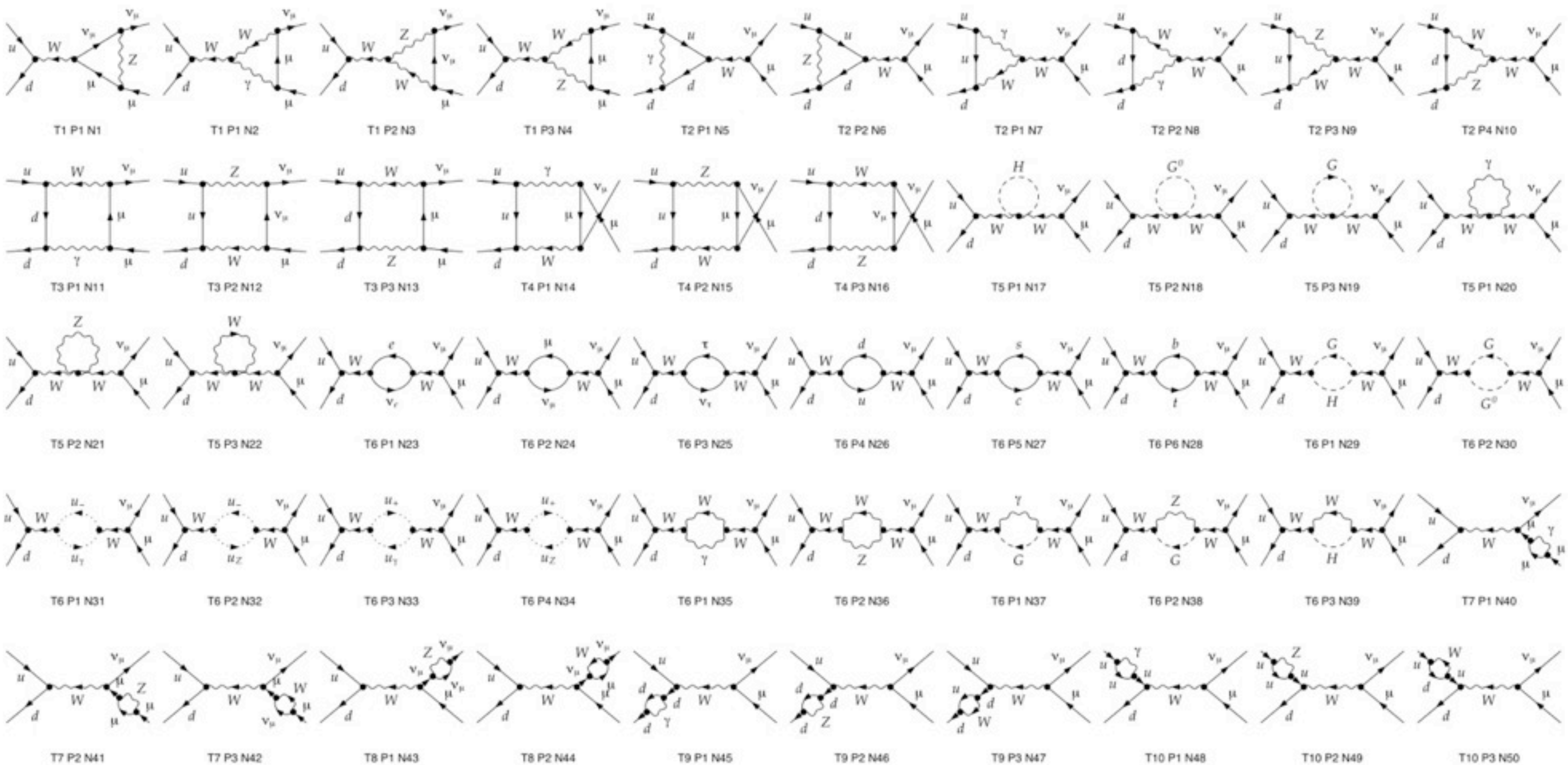
- since January 2012 we started a collaboration with NVIDIA (CUDA research and teaching center)
  to develop simulation codes running on GPU (graphics card)

Which skills are behind the development of these tools

- the ability to run long and very long (weeks) MC simulations, with stable, fast, reliable codes

- a good knowledge of Quantum Field Theory, at formal and at phenomenological level

- the ability to define new classes of mathematical functions and to study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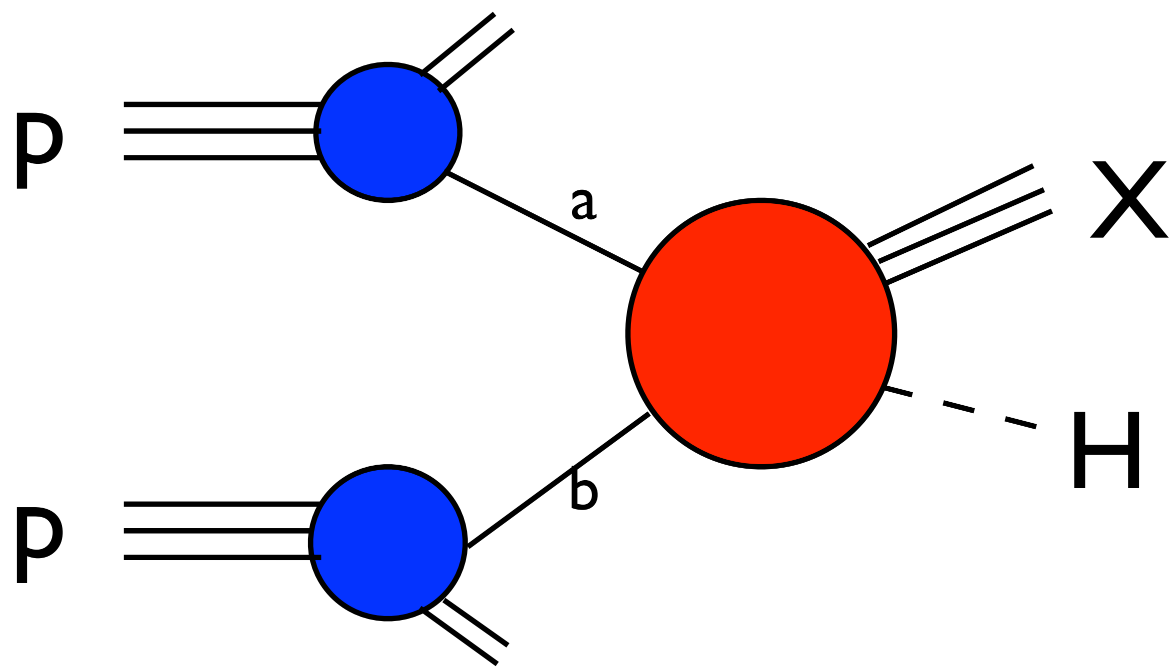
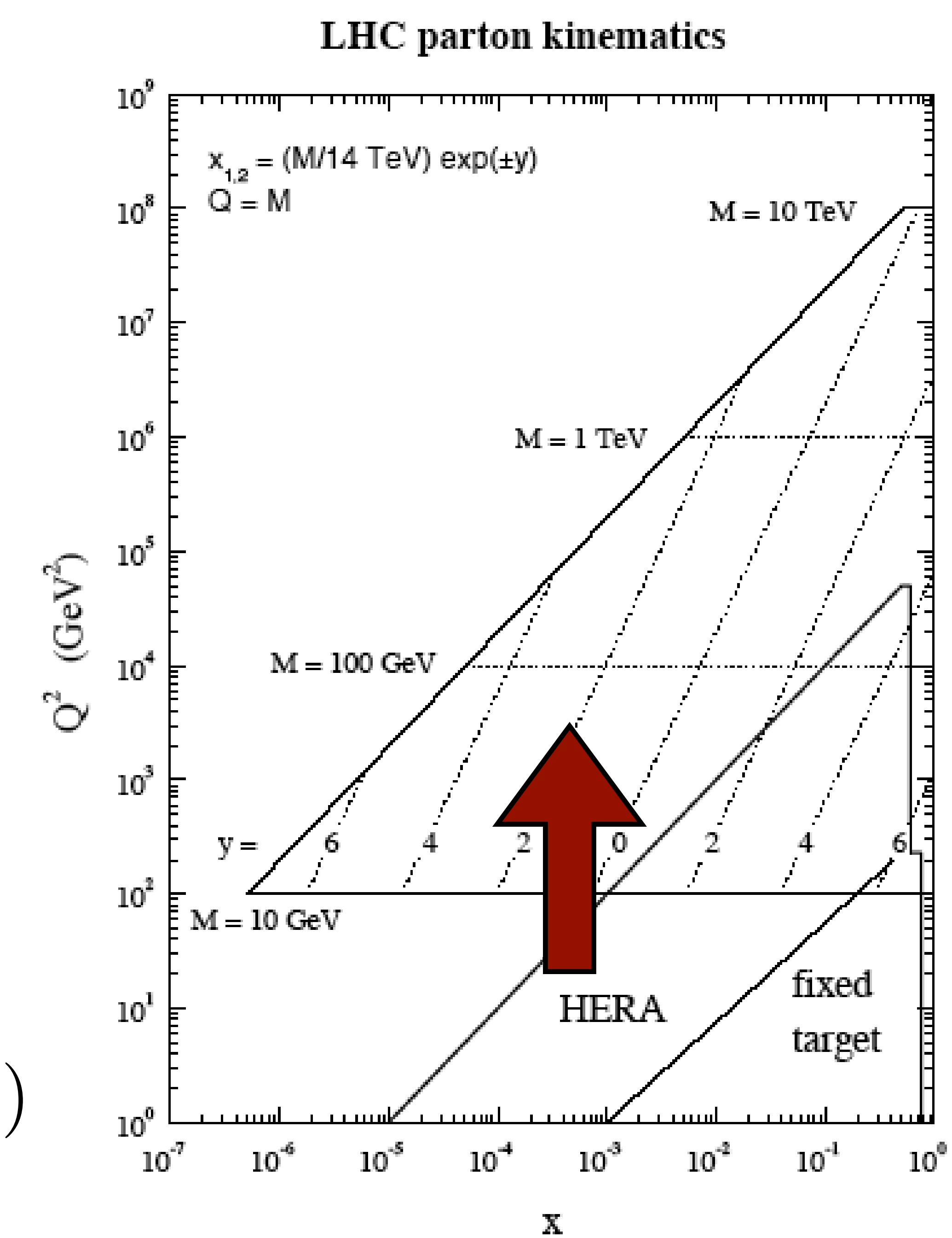
T10 P2 N49
T10 P3 N50

back-up

Direct searches at hadron colliders: kinematics

$$\sigma(P_1,P_2;m_H)=\sum_{a,b}\int_0^1 dx_1dx_2\, f_{h_1,a}(x_1,M_F)f_{h_2,b}(x_2,M_F)\,\hat\sigma_{ab}(x_1P_1,x_2P_2,\alpha_s(\mu),M_F)$$





The parton densities are probed in a new range of x and Q^2

$$y=\frac{1}{2}\log\frac{E+p_z}{E-p_z}\qquad x_{1,2}=\frac{M}{\sqrt{S}}\exp(\pm y)$$