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# Higgs Cross Section Calculation at 7 and 8 TeV for RUN-1

This is the instruction for Higgs cross section calculations at centre-of-mass energy of 7 and 8 TeV.

Complete inclusive cross sections at LO, NLO and NNLO(+NNLL) should be calculated.

## Centre-of-mass Energy = 7 and 8 TeV

## Standard Model input parameter

- Input parameters for 8TeV calculations are the same as YR1.
- <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGSMinputParameter>

## Higgs mass range and step:

- $M_H = [80, 300]$  GeV for ggF, VBF, WH/ZH and ttH with the same method as YR1.
- $M_H = [300, 1000]$  GeV for ggF and VBF with Passarino prescription as discussed in YR2 (Section 15).
- Scanning points is defined by the LHC Higgs combination WG's note, ATL-PHYS-PUB-2011-11, CMS NOTE-2011/005, Table 1.
- EXPs need numbers down to  $M_H = 80$  GeV as benchmark numbers for possible BSM physics.

Higgs Mass range	step size	# of points
[ 80, 110] GeV	1 GeV	31 points
[ 110, 140] GeV	0.5 GeV	60 points
[ 140, 160] GeV	1 GeV	20 points
[ 160, 290] GeV	2 GeV	65 points
[ 290, 350] GeV	5 GeV	12 points
[ 350, 400] GeV	10 GeV	5 points
[ 400, 1000] GeV	20 GeV	30 points

+ 450, 550, 650, 750, 850, 950 GeV (6 points)

- 229 points in total

## QCD scale uncertainty

- It should be discussed in each subgroup how to estimate QCD scale uncertainty.
- As these uncertainties change smoothly, it would be enough to do the coarse scan with following points.
- Please carry out the interpolation with spline fit (or 3rd order polynomial fit) for other Higgs mass points.

\* Scan example:

Higgs Mass range	step size	# of points
[ 80, 200] GeV	5 GeV	25 points
[ 200, 300] GeV	10 GeV	10 points
[ 300, 1000] GeV	20 GeV	35 points

- 70 points in total
- The factorization and the renormalization scales are process dependent and should be defined by each subgroup.
- The scale uncertainty should also be defined by each group, (e.g.  $1/2M_H < \mu_R, \mu_F < 2M_H$  do 2D scan with  $1/2 < \mu_R/\mu_F < 2$ )

## PDF+<sub>s</sub> uncertainty calculations (a la PDF4LHC prescription)

- How to estimate PDF+<sub>s</sub> uncertainty for 8TeV is under discussion by PDF experts.

### PDF sets

- PDF sets: CTEQ6.6, MSTW2008, NNPDF2.0, HERAPDF1.0, ABKM09, GJR08/JR09.
  - All these PDF sets are on LHAPDF.
  - PDF prescriptions can be found here.
  - QCD<sub>s</sub>(M<sub>Z</sub>): Use default values of each PDF set.
1. For NLO calculations, CTEQ6.6, MSTW2008 and NNPDF2.0 are the default sets. Others, e.g. HERAPDF, ABKM and (G)JR are optional, but we recommend to calculate with these PDF sets as well.
  2. For NNLO calculations, MSTW2008 is the default set. We also recommend to compare MSTW with ABKM and (G)JR at NNLO.

### Cross section central values

1. For NLO, take the midpoint of CTEQ6.6, MSTW2008 and NNPDF2.0 envelope following the recommendation from PDF4LHC group.
2. For NNLO, take MSTW2008 result.

### PDF+<sub>s</sub> uncertainties (PDF4LHC group recommendation)

- $\delta_{s=+/-0.0012}$  for 68% C.L. and  $\delta_{s=+/-0.0020}$  for 90% C.L.
  - If calculations only at 90% C.L. calculation exist (CTEQ), we shall translate (i.e., by dividing 90% C.L. error by 1.645).
  - PDF+<sub>s</sub> uncertainties should be calculated both at 68% C.L. (priority) and at 90% C.L..
1. The total PDF+<sub>s</sub> uncertainty can be evaluated by adding the variations in PDFs due to  $\delta_s$  uncertainty in quadrature with the fixed  $\delta_s$  PDF uncertainty,
  2. For NNPDF, more efficiently taking a Gaussian distribution of PDF replicas corresponding to different values of  $\delta_s$ .

3. For MSTW the PDF+<sub>s</sub> uncertainties should be evaluated using their prescription which better accounts for correlations between the PDF and <sub>s</sub> uncertainties when using the MSTW dynamical tolerance procedure for uncertainties. Adding the <sub>s</sub> uncertainty in quadrature for MSTW can be used as a simplification but generally gives slightly smaller uncertainties.
1. For NLO, use the envelope provided by the central values and PDF+<sub>s</sub> errors from the MSTW08, CTEQ6.6 and NNPDF2.0 PDFs, using each group's prescriptions for combining the two types of errors. Take the symmetric error following the recommendation from PDF4LHC group.
2. For NNLO, multiply the MSTW uncertainty at NNLO by the factor obtained by dividing the full PDF+<sub>s</sub> uncertainty obtained from the envelope of MSTW CTEQ and NNPDF results at NLO by the MSTW PDF+<sub>s</sub> uncertainty at NLO (~ factor 2 at 7 TeV).

## ● Recipe from PDF4LHC

The official PDF4LHC recommendations on NLO/NNLO cross sections and PDF uncertainty estimations:

1. Recommendation for LHC cross section calculations (June 22, 2010)

## Practical guide on PDF+<sub>s</sub> error calculation

1. Suggestions on calculating the PDF4LHC prescription (September 21, 2010)
  - Also please check PDF prescriptions.
1. MSTW Check the first two paragraphs of section 6 in arXiv:0905.3531.
  - ◆ However adding in quadrature is a pretty good approximation if one is attempting to be quicker.
2. CTEQ: Check section III-B in arXiv:1004.4624.
3. NNPDF: Check arXiv:1004.0962.

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-- Rei Tanaka - 21-May-2010

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