# Theoretical Uncertainties---PDF+AlphaS

- Nominal PDF set is 90400(PDF4LHC)
- PDF uncertainties(PDF4LHC, 30items, Hessian symmetric) set: 90401-90430
- AlphaS up/down uncertainties(PDF4LHC)set: 90431/90432
- $\sigma$ is the given cross section(=expected yield).

https://arxiv.org/pdf/1510.03865.pdf

**$\alpha_S$ Uncertainties:**

$$\delta^{\alpha_s}\sigma = \frac{\sigma(\alpha_s^{down}) - \sigma(\alpha_s^{up})}{2}$$

**$PDF$ Uncertainties:**

$$\delta^{\mathrm{pdF}}\sigma = \sqrt{\sum_{k=1}^{N_{mean}} (\sigma^{(k)} - \sigma^{(0)})^2}$$

**$PDF + \alpha_S$ Uncertainties:**

$$\delta^{\alpha_s+PDF}\sigma = \sqrt{(\delta^{PDF}\sigma)^2 + (\delta^{\alpha_s}\sigma)^2}$$

| PDF set | definition |
|---|---|
| 90400 | alternative weights(PDF4LHC15_nlo_30_pdfas): alphas($M_z$)=0.118 central value |
| 90401-90430 | PDF4LHC15_nlo_30_pdfas => PDF symmetric eigenvectors |
| 90431 | alphas($M_z$)=0.1165 |
| 90432 | alphas($M_z$)=0.1195 |

| ME provider | Pythia8 | MG5aMC, Powheg, Herwig7 | Sherpa |
|---|---|---|---|
| ME order | LO | LO/NLO | LO/NLO |
| Baseline | NNPDF23_lo_as_0130_qed (247000) | NNPDF30_nlo_as_0118 (260000) | NNPDF30_nnlo_as_0118 (261000) |
| | | NNPDF30_nlo_as_0118_mc (260800) | NNPDF30_nnlo_as_0118_hessian (303200) |
| Alternative baseline | x | PDF4LHC15_nlo_30_pdfas (90400) | PDF4LHC15_nnlo_30_pdfas (91400) |
| $\alpha_s$ variations | NNPDF23_lo_as_0119_qed (246800) | NNPDF30_nlo_as_0119 (266000) | NNPDF30_nnlo_as_0119 (270000) |
| | | NNPDF30_nlo_as_0117 (265000) | NNPDF30_nnlo_as_0117 (269000) |
| Alternative PDFs | CT14llo (13205) | CT14nlo (13100) | CT14nnlo (13000) |
| | MMHT2014lo68cl (25000) | MMHT2014nlo68clas118 (25200) | MMHT2014nnlo68cl (25300) |

# Theoretical Uncertainties---QCD

- Take the envelope of the scale variations as prescribed in the PMG recommendations. PMG Twiki
- Considered diagonal variations of the renormalization($\mu_r$) and the factorization scale ($\mu_f$):

$$\{\mu_r, \mu_f\} \times \{0.5,0.5\}, \{1,0.5\}, \{0.5,1\}, \{1,1\}, \{2,1\}, \{1,2\}, \{2,2\}$$

- How to apply: (choose the max variation with sign)

$$\max[\mathcal{O}(\mu_{R,i}, \mu_{F,i}) - \mathcal{O}((\mu_{R,0}, \mu_{F,0})]$$

# Theoretical Uncertainties——AOD/DAOD weight metadata

AOD:

| location | type |
|---|---|
| MetaData/StreamAOD/m_eventTypes/m_mc_event_weights | EventStreamInfo_p3 |
| CollectionTree/McEventInfo/m_event_type/m_mc_event_weights | PileUpEventInfo_p5 |
| CollectionTree/TruthEventsAux/weights/values | xAOD::TruthEventAuxContainer_v1 |
| CollectionTree/EventInfoAuxDyn.mcEventWeights | vector<float> |
| MetaData/_Generation_Parameters | IOVMetaDataContainer_p1 |
| MetaData/TruthMetaDataAux.weightNames | vector<vector<string> > |

DAOD:

| location | type |
|---|---|
| MetaData/StreamDAOD_HIGG1D1/m_eventTypes/m_mc_event_weights | EventStreamInfo_p3 |
| CollectionTree/McEventInfo/m_event_type/m_mc_event_weights | PileUpEventInfo_p5 |
| CollectionTree/EventInfoAuxDyn.mcEventWeights | vector<float> |
| MetaData/_Generation_Parameters | IOVMetaDataContainer_p1 |
| MetaData/TruthMetaDataAux.weightNames | vector<vector<string> > |

# Theoretical Uncertainties——DAOD weight metadata

| location | type |
|---|---|
| MetaData/StreamDAOD_HIGG1D1/m_eventTypes/m_mc_event_weights | EventStreamInfo_p3 |
| CollectionTree/McEventInfo/m_event_type/m_mc_event_weights | PileUpEventInfo_p5 |
| CollectionTree/EventInfoAuxDyn.mcEventWeights | vector<float> |
| MetaData/_Generation_Parameters | IOVMetaDataContainer_p1 |
| MetaData/TruthMetaDataAux.weightNames | vector<vector<string> > |

- EventStreamInfo only contains weights of one example event.
- All weights stored twice in CollectionTree.
- Weight names only stored in Metadata tree.

For example →

Of course, different DAOD samples will store different weights (the order and types of weight_names will change, maybe depend on derivation?)

```
0 *        0 *                          Default *
0 *        1 *                                  *
0 *        2 *     renscfact=0.5 facscfact=1.0  *
0 *        3 *     renscfact=2.0 facscfact=1.0  *
0 *        4 *     renscfact=0.5 facscfact=0.5  *
0 *        5 *     renscfact=1.0 facscfact=0.5  *
0 *        6 *     renscfact=1.0 facscfact=2.0  *
0 *        7 *     renscfact=2.0 facscfact=2.0  *
0 *        8 *                   lhapdf=260000  *
0 *        9 *                   lhapdf=266000  *
0 *       10 *                   lhapdf=265000  *
0 *       11 *                    lhapdf=13100  *
0 *       12 *                    lhapdf=25200  *
0 *       13 *                    lhapdf=90400  *
0 *       14 *                    lhapdf=90401  *
0 *       15 *                    lhapdf=90402  *
0 *       16 *                    lhapdf=90403  *
0 *       17 *                    lhapdf=90404  *
0 *       18 *                    lhapdf=90405  *
0 *       19 *                    lhapdf=90406  *
0 *       20 *                    lhapdf=90407  *
0 *       21 *                    lhapdf=90408  *
0 *       22 *                    lhapdf=90409  *
0 *       23 *                    lhapdf=90410  *
0 *       24 *                    lhapdf=90411  *
0 *       25 *                    lhapdf=90412  *
0 *       26 *                    lhapdf=90413  *
0 *       27 *                    lhapdf=90414  *
0 *       28 *                    lhapdf=90415  *
0 *       29 *                    lhapdf=90416  *
0 *       30 *                    lhapdf=90417  *
0 *       31 *                    lhapdf=90418  *
0 *       32 *                    lhapdf=90419  *
0 *       33 *                    lhapdf=90420  *
0 *       34 *                    lhapdf=90421  *
0 *       35 *                    lhapdf=90422  *
0 *       36 *                    lhapdf=90423  *
0 *       37 *                    lhapdf=90424  *
0 *       38 *                    lhapdf=90425  *
0 *       39 *                    lhapdf=90426  *
0 *       40 *                    lhapdf=90427  *
0 *       41 *                    lhapdf=90428  *
0 *       42 *                    lhapdf=90429  *
0 *       43 *                    lhapdf=90430  *
0 *       44 *                    lhapdf=90431  *
0 *       45 *                    lhapdf=90432  *
```


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# Theoretical Uncertainties——calculate

- QCD: $\max[\mathcal{O}(\mu_{R,i},\mu_{F,i})-\mathcal{O}((\mu_{R,0},\mu_{F,0})]$

**$PDF$ Uncertainties:**

$$\delta^{\mathrm{pdF}}\sigma=\sqrt{\sum_{k=1}^{N_{mean}}(\sigma^{(k)}-\sigma^{(0)})^2}$$

**$\alpha_S$ Uncertainties:**

$$\delta^{\alpha_s}\sigma=\frac{\sigma(\alpha_s^{down})-\sigma(\alpha_s^{up})}{2}$$

**$PDF+\alpha_S$ Uncertainties:**

$$\delta^{\alpha_s+PDF}\sigma=\sqrt{(\delta^{PDF}\sigma)^2+(\delta^{\alpha_s}\sigma)^2}$$

- Evaluation of the theoretical systematics uncertainties on the efficiency: (= normalize variated and nominal weight.)
- $\varepsilon_{syst}=1-\frac{\varepsilon_{variated}}{\varepsilon_{nominal}}$
- Where $\varepsilon_{variated}=\frac{SumWeights_{Aftercuts}^{variated}}{SumWeights_{Beforecuts}^{variated}}$ , $\varepsilon_{nominal}=\frac{SumWeights_{Aftercuts}^{nominal}}{SumWeights_{Beforecuts}^{nominal}}$
- After_cuts means pass select cut (select different channels).
- Before_cuts means only use the basic cut in HgamCore. (MxAOD selection, exactly 2 photons)

# Theoretical Uncertainties——results

| | Parton shower(%) | PDF(%) | $\alpha_s$(%) | PDF+$\alpha_s$(%) |
|---|---|---|---|---|
| $1l + jets$ | +2.51 | 3.87 | 0.93 | 4.29 |
| $1\tau_{had} + jets$ | -1.18 | 3.93 | 0.95 | 4.36 |
| $2(l + \tau_{had})$ | -2.85 | 3.94 | 0.93 | 4.36 |

- Question for QCD: PMG Twiki

We need to take envelope of variations, but how to do that?

(Now we have the different QCD_weight with $\{\mu_r, \mu_f\} \times \{0.5,0.5\}, \{1,0.5\}, \{0.5,1\}, \{1,1\}, \{2,1\}, \{1,2\}, \{2,2\}$.)

If we just calculate the $\max[\mathcal{O}(\mu_{R,i}, \mu_{F,i}) - \mathcal{O}((\mu_{R,0}, \mu_{F,0})]$

The yield variation ~13%.

# Theoretical Uncertainties——For SH signal/Single Higgs

- Can’t find weight name in SH signal samples, both in AOD/DAOD

- In Single Higgs:  (180 weight names in ggH)

```
' PDF set = 90400 '   111
' PDF set = 90401 '   112
' PDF set = 90402 '   113
' PDF set = 90403 '   114
' PDF set = 90404 '   115
' PDF set = 90405 '   116
' PDF set = 90406 '   117
' PDF set = 90407 '   118
' PDF set = 90408 '   119
' PDF set = 90409 '   120
' PDF set = 90410 '   121
' PDF set = 90411 '   122
' PDF set = 90412 '   123
' PDF set = 90413 '   124
' PDF set = 90414 '   125
' PDF set = 90415 '   126
' PDF set = 90416 '   127
' PDF set = 90417 '   128
' PDF set = 90418 '   129
' PDF set = 90419 '   130
' PDF set = 90420 '   131
' PDF set = 90421 '   132
' PDF set = 90422 '   133
' PDF set = 90423 '   134
' PDF set = 90424 '   135
' PDF set = 90425 '   136
' PDF set = 90426 '   137
' PDF set = 90427 '   138
' PDF set = 90428 '   139
' PDF set = 90429 '   140
' PDF set = 90430 '   141
' PDF set = 90431 '   142
' PDF set = 90432 '   143
```