



WG1 outlook

Alexander Karlberg (on behalf of WG1)

Current and future plans

13.6 TeV update

- For now *interpolated* interim numbers on sub-group Twiki pages. Will become a CDS document before the end of the year for experiments to cite.
- Full SM update slow but steady. Some production channels more or less there. Will add to TWiki as they become available so the experiments can start using them. Plan is to submit a report to SciPost early to mid-2024.
- For BSM the agreement with WG3 is to provide official interpolations of the YR4 numbers on the TWiki.
- Some sub-groups working on more extensive recommendations (cf. e.g. Mathieu Pellen's talk)

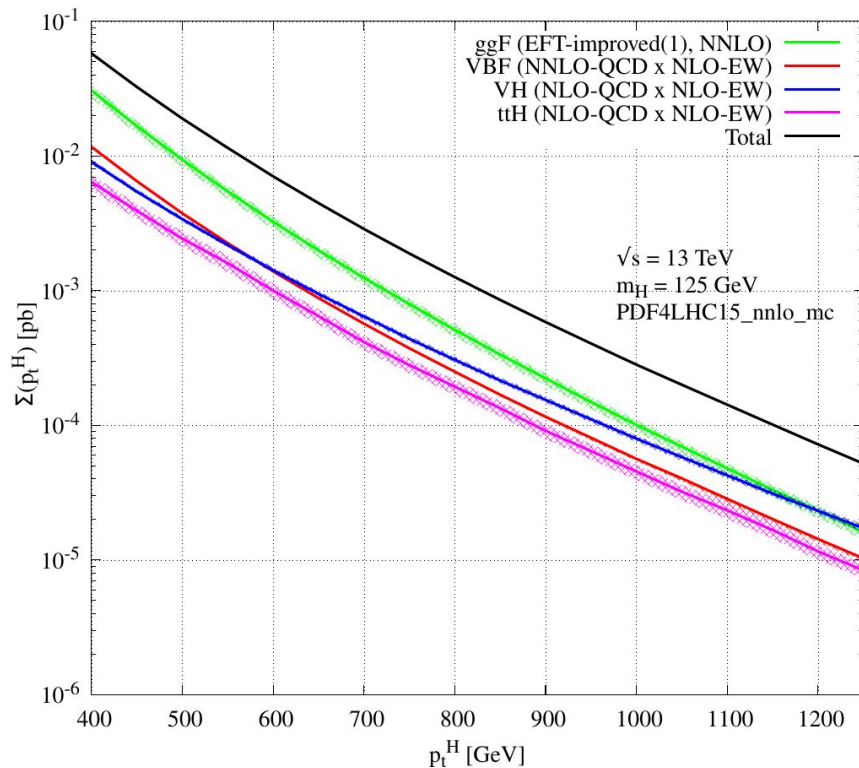
SM Higgs cross section and associated uncertainties at 13.6 TeV

ggF (N3LO QCD + NLO EW)								VBF (N3LO QCD + NLO EW) + sub-eikonal non-factorisable NNLO-QCD							
MH [GeV]	Cross Section [pb]	Uncertainty						MH [GeV]	Cross Section [pb]	Uncertainty					
		Theory			PDF+ α_s [%]	PDF [%]	α_s [%]			Scale		TU [%]	PDF+ α_s [%]	PDF [%]	α_s [%]
		pos [%]	neg [%]	Gauss [%]						pos [%]	neg [%]				
120.00	5.59E+01	2.6	-1.3	± 0.0	± 2.5	± 1.7	± 1.8	120.00	4.267E+00	+0.1	-0.1	± 0.6	± 2.2	± 2.1	± 0.4
122.00	5.43E+01	2.6	-1.3	± 0.0	± 2.5	± 1.7	± 1.8	122.00	4.201E+00	+0.1	-0.1	± 0.6	± 2.2	± 2.1	± 0.4
124.00	5.28E+01	2.6	-1.3	± 0.0	± 2.5	± 1.6	± 1.8	124.00	4.136E+00	+0.1	-0.1	± 0.6	± 2.2	± 2.1	± 0.4
124.60	5.24E+01	2.5	-1.3	± 0.0	± 2.5	± 1.6	± 1.8	124.60	4.117E+00	+0.1	-0.1	± 0.6	± 2.2	± 2.1	± 0.4
124.80	5.22E+01	2.5	-1.3	± 0.0	± 2.5	± 1.6	± 1.8	124.80	4.110E+00	+0.1	-0.1	± 0.6	± 2.2	± 2.1	± 0.4
125.00	5.21E+01	2.5	-1.3	± 0.0	± 2.5	± 1.6	± 1.8	125.00	4.104E+00	+0.1	-0.1	± 0.6	± 2.2	± 2.1	± 0.4
125.09	5.20E+01	2.5	-1.3	± 0.0	± 2.5	± 1.6	± 1.8	125.09	4.101E+00	+0.1	-0.1	± 0.6	± 2.2	± 2.1	± 0.4

Current and future plans

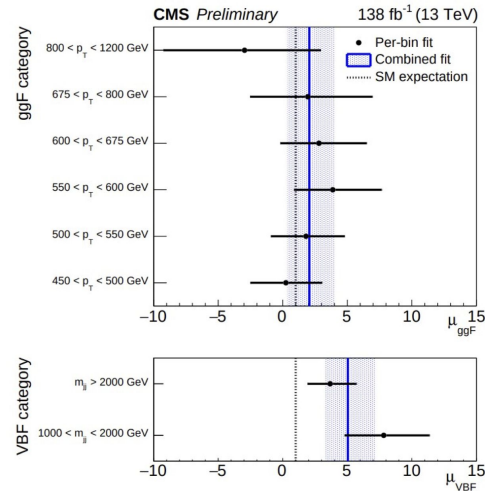
- **Boosted Higgs production**

- Interesting and challenging regime to study!
- Note submitted to SciPost. Currently in review.
- Plan for second report to include momentum ranges requested by experiments, plus more thorough generator study (including also Sherpa).
- Question about size of EW ggF corrections in the boosted regime. Ideally they should be included.
- Will need input from all sub-groups due to all production modes becoming of the same order.
- Also a candidate for SciPost!



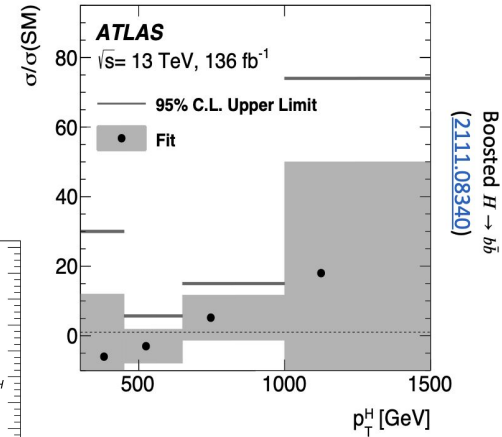
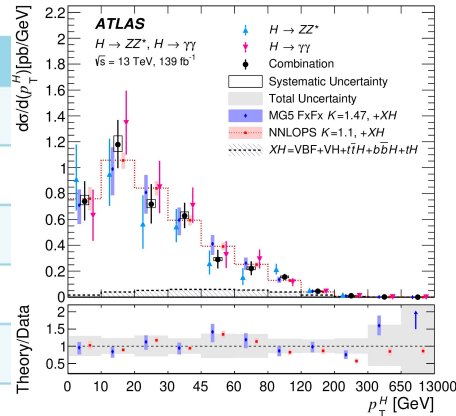
New boosted Higgs results

- Both ATLAS and CMS have reported new results in the boosted regime
- Done in ggF, VBF and VH categories, and multiple decay channels including $H \rightarrow \gamma\gamma$.
- Clear need for finer binning (STXS?) -> organise a meeting early 2024 to discuss and converge (together with WG2).
- 3σ excess seen by CMS in VBF channel...
- See talks by Dickinson and Zheng



	Lumi [fb^{-1}]	μ_{VBF}		
Early 2016	19.5	2.9	+5.8	-4.5
Late 2016	16.8	5.8	+6.3	-4.7
2017	41.5	-0.7	+2.8	-2.6
2018	59.8	10.0	+4.4	-3.4
Combined	137.6	5.0	+2.1	-1.8

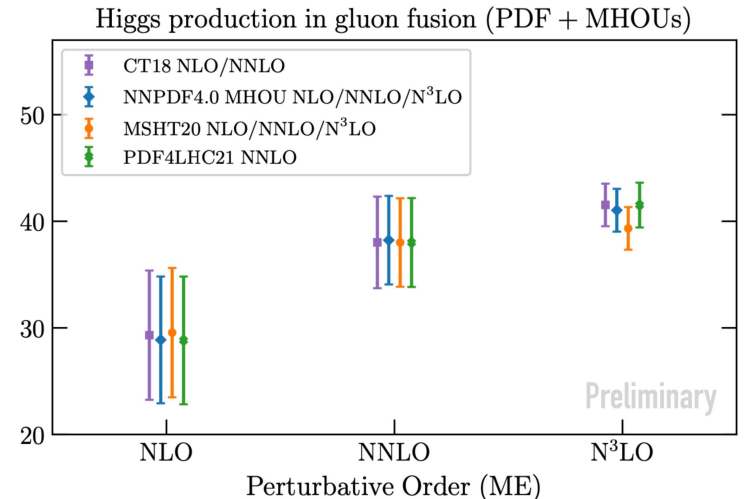
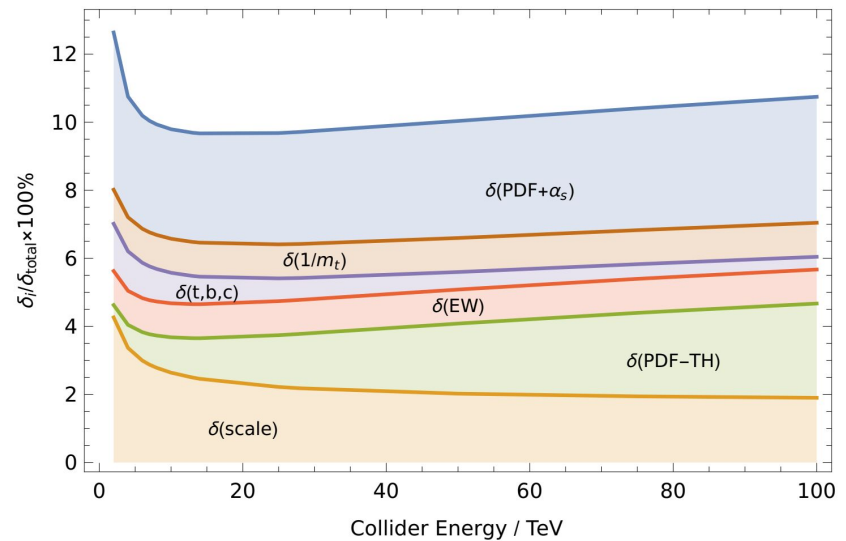
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N3LO PDFs are coming!

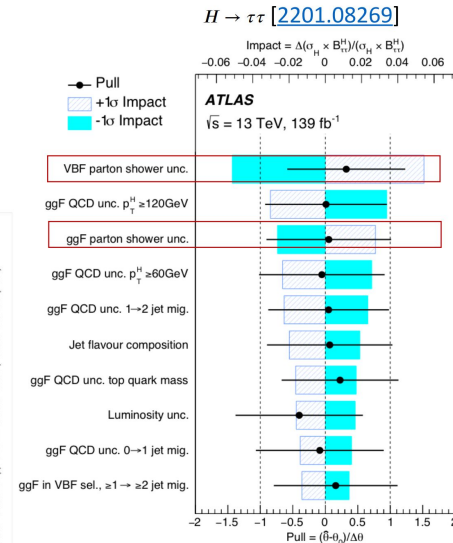
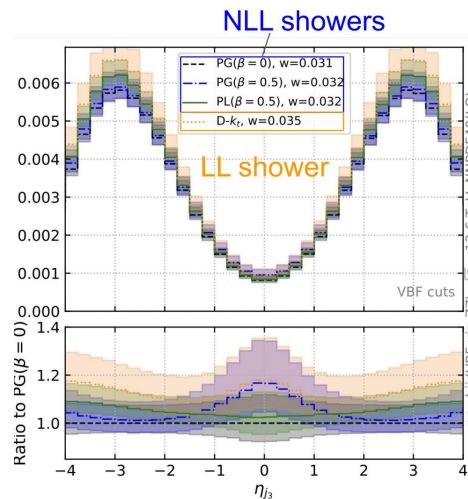
- N3LO has been available for ggF and VBF for some time (in various approximations), but formally N3LO PDFs also needed
- Their emergence this year has already lead to cross section and benchmarking studies (cf. PDF4LHC meeting on Friday)
- Still debate about whether results so far are only instructive ([Houston](#)) or definitive ([Tackmann](#))
- Release of NNPDF will hopefully settle this question

See also talks by [M. Ubiali](#) and [S. Jones](#)



The WG1 evergreen: PS uncertainties...

- A recurring theme over the last half decade has been event generator/parton shower uncertainties
- Has now become a limiting systematic in many analyses. Pythia tuned using the “default” shower. How does this impact Pythia dipole or Vincia?
- Not something we will solve on a short time scale, but progress outside of the WG will propagate:
 - Parton showers with controlled logarithmic accuracy (and uncertainties!)
 - Emerging understanding of non-perturbative physics (renormalons)
- For now some sub-groups are studying recommendations for the short term -> stay tuned!
- Monte Carlo harmonisation going on within the experiments (cf. talk by X. Sun), to try and go beyond 2-point systematic agreed upon for Run-2.



Theory uncertainty relative sizes in typical VBF measurements

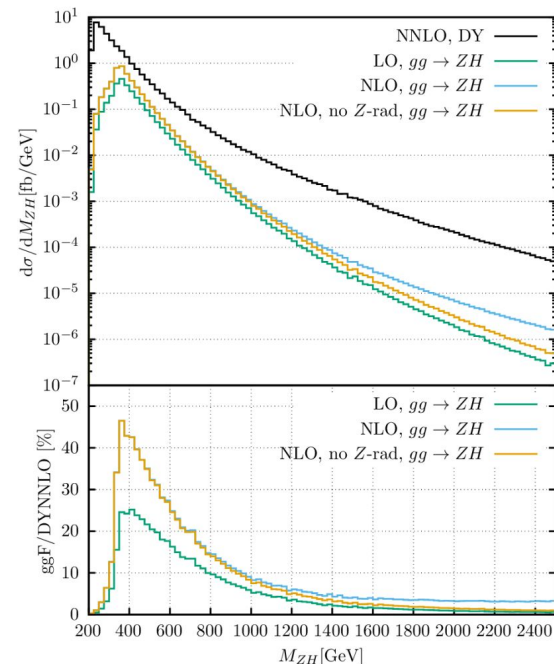
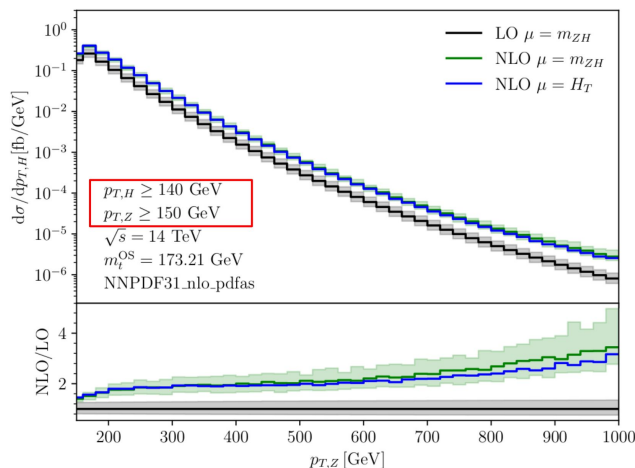
	VBF H	ggH (in VBF-enriched region)
PDF	<1%	<3%
QCD scale	<1%	2-20%
UE	<1.5%	<2-3%
Parton shower	5-15%	4-10%

ggZH

Top-mass scheme	LO [fb]	$\sigma_{LO}/\sigma_{LO}^{OS}$	NLO [fb]	$\sigma_{NLO}/\sigma_{NLO}^{OS}$	$K = \sigma_{NLO}/\sigma_{LO}$
On-Shell	64.01 ^{+27.2%} _{-20.3%}	—	118.6 ^{+16.7%} _{-14.1%}	—	1.85
$\overline{MS}, \mu_t = M_{ZH}/4$	59.40 ^{+27.1%} _{-20.2%}	0.928	113.3 ^{+17.4%} _{-14.5%}	0.955	1.91
$\overline{MS}, \mu_t = m_t^{\overline{MS}}(m_t^{\overline{MS}})$	57.95 ^{+26.9%} _{-20.1%}	0.905	111.7 ^{+17.7%} _{-14.6%}	0.942	1.93
$\overline{MS}, \mu_t = M_{ZH}/2$	54.22 ^{+26.8%} _{-20.0%}	0.847	107.9 ^{+18.4%} _{-15.0%}	0.910	1.99
$\overline{MS}, \mu_t = M_{ZH}$	49.23 ^{+26.6%} _{-19.9%}	0.769	103.3 ^{+19.6%} _{-15.6%}	0.871	2.10

- MC generators only include LO gg->ZH production. Process loop-induced but enhanced by gluon luminosity.
- Leads to 25% uncertainties for ZH@NNLO
- Recent progress in computing NLO corrections to ggZH by several groups
- Very complex computation - various approximations applied (pt and high energy expansions)
- Will be needed for VH precision physics.
- Ongoing work to provide ptZ reweighting before full-fledged MC implementation. SciPost contribution?

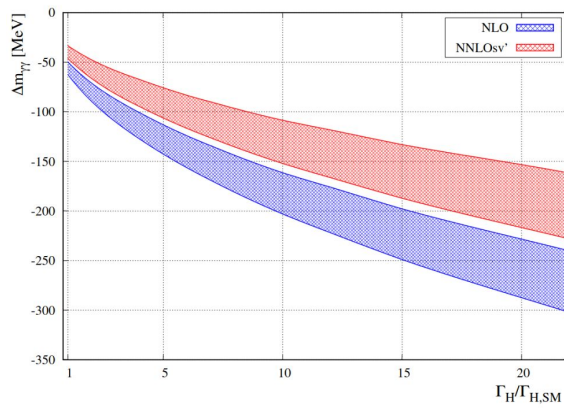
At NLO top mass scheme uncertainties commensurate with scale uncertainties. Need to be properly taken into account!



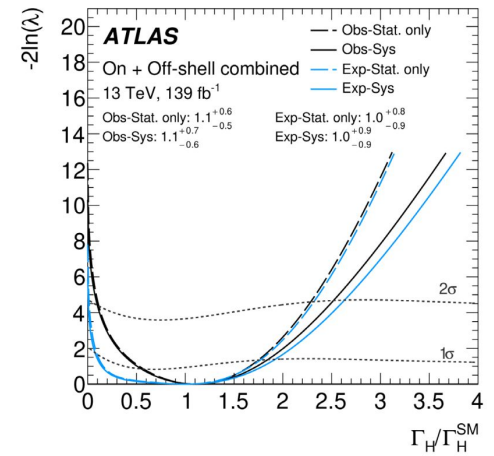
- NLO corrections as sizeable as LO, with only a moderate reduction in scale uncertainties.
- At the differential level the k-factor can become significantly larger than 1!

See talk by M. Vitti

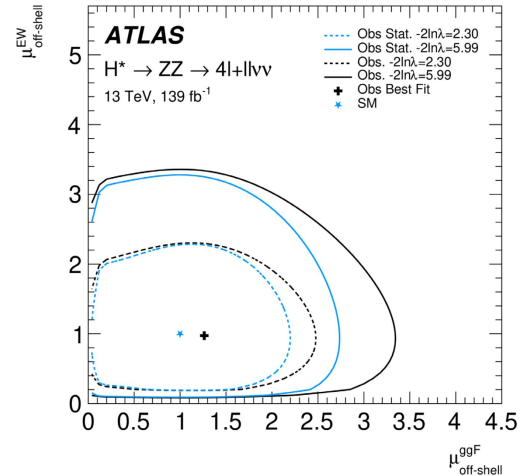
Off-shell



- Both ATLAS and CMS now sensitive to the SM Γ_H .
- Signal samples differ between the two experiments. Aim for Run-3 harmonisation?
- Current extractions make assumptions about width in on- and off-shell region
- Old ideas with new calculations being explored to extract the width in a less model-dependent way measuring mass shift in $m_{\gamma\gamma}$.
- With $\Delta m_{\gamma\gamma} \sim 75$ MeV one can reach $(3-5)\Gamma_{H,SM}$.
- Interference effects in $H \rightarrow \gamma\gamma$ of the order of 2%. Should we start thinking about including them in cross section recommendations?



ATLAS: $\Gamma_H = 4.5^{+3.3}_{-2.5}$ MeV @ 68% CL.
[based on full Run 2 $ZZ \rightarrow 4\ell$ and $ZZ \rightarrow 2\ell 2\nu$]



Improving collaboration between theory and experiment

From talk by S.
Sánchez Cruz

- We have identified a few areas of improvement in the collaboration between theory and experiments
- The community relies on significant work by theorists which is often not rewarding, specially to young scientists
 - Detailed comparisons between different generators as the ones mentioned earlier
 - Producing predictions for a custom fiducial region/binning/center-of-mass energy
- The proposal and actions outlined by Gudrun yesterday go in the right direction to address these points

- Start experiment/theory communication early in the experimental analysis design process
 - Share fiducial region / binning, so predictions can be tailored to the analysis
- Come up with ways to encourage theorists producing predictions for experiments
 - Short term associate figure → allow them to sign specific papers and participate in collaboration meetings

- Pursue collaborations with other working groups, such as the Top LHC WG / EFT LHC WG

Organisation

Thanks to the outgoing conveners [Julie Malcles](#) and [Roberto Di Nardo](#) and welcome [Hannah Arnold](#) and [Alessandro Calandri](#)!

A lot of reshuffling in the sub-groups over this year. We thank all outgoing conveners and welcome the new ones!

Twiki: <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHWG1>

e-group: lhc-higgs-xsbr@cern.ch