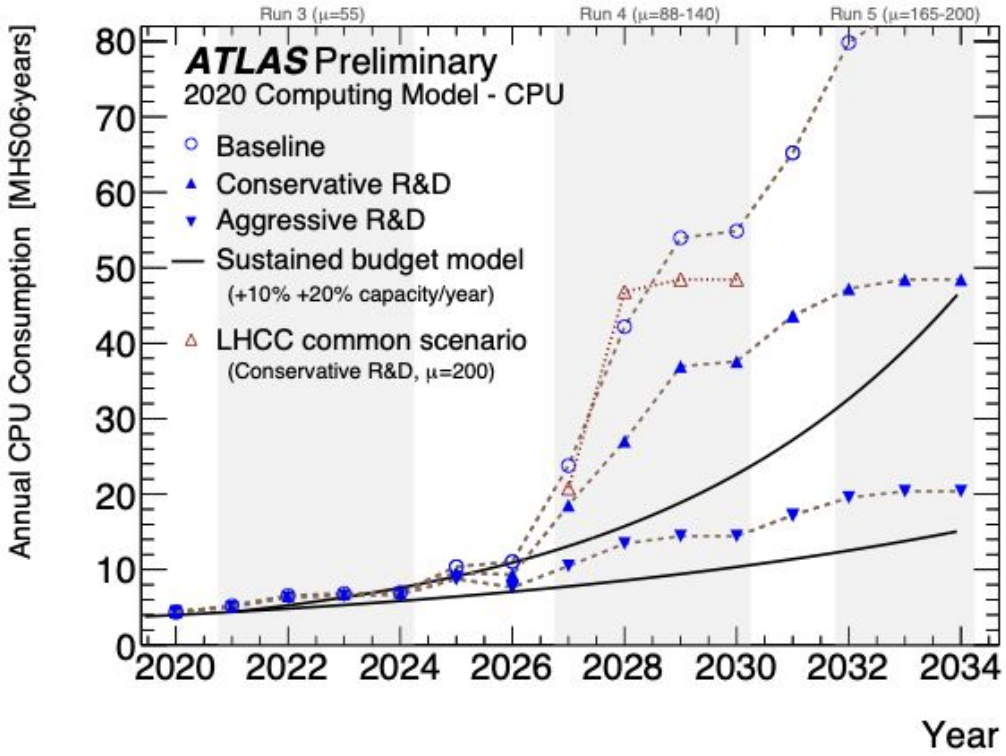
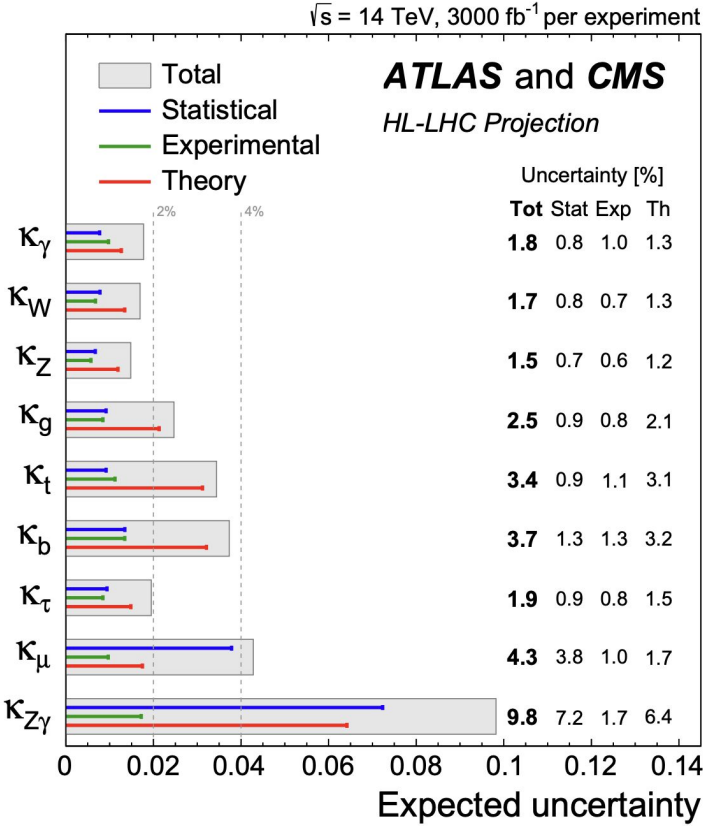
Generators WG plans for the LHCC review

HSF Generators WG meeting
25/3/2021

Landscape


Run 3 (μ=55)
Run 4 (μ=88-140)
Run 5 (μ=165-200)
ATLAS Preliminary
2020 Computing Model - CPU
Baseline
Conservative R&D
Aggressive R&D
Sustained budget model
(+10% +20% capacity/year)
LHCC common scenario
(Conservative R&D, μ=200)
Annual CPU Consumption [MHS06-years]
Year
0
10
20
30
40
50
60
70
80
2020
2022
2024
2026
2028
2030
2032
2034

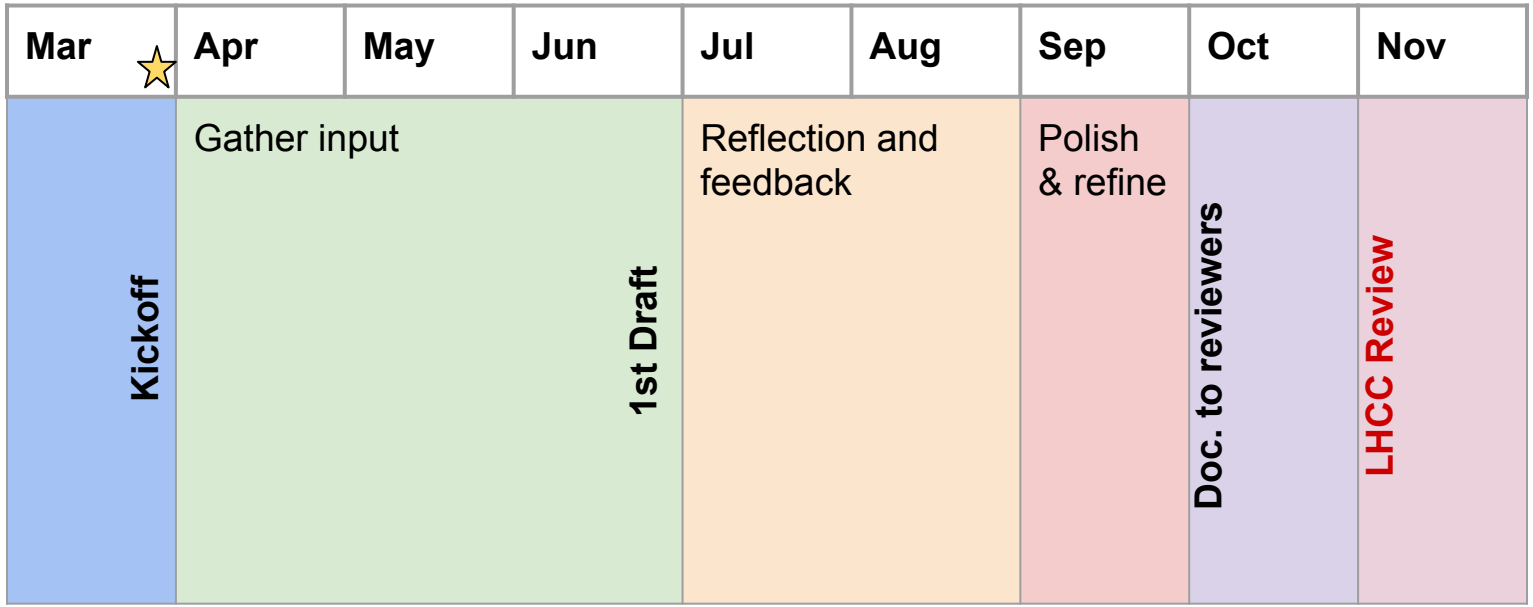

√s = 14 TeV, 3000 fb-1 per experiment
Total
Statistical
Experimental
Theory
ATLAS and CMS
HL-LHC Projection
Uncertainty [%]
Tot Stat Exp Th
κγ 1.8 0.8 1.0 1.3
κW 1.7 0.8 0.7 1.3
κZ 1.5 0.7 0.6 1.2
κg 2.5 0.9 0.8 2.1
κt 3.4 0.9 1.1 3.1
κb 3.7 1.3 1.3 3.2
κτ 1.9 0.9 0.8 1.5
κμ 4.3 3.8 1.0 1.7
κZγ 9.8 7.2 1.7 6.4
2%
4%
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Expected uncertainty

Overview

- The motivation and general plans for the review were already outlined by Graeme.
- Focus for generators:
  - The starting point is the topics/potential issues identified in our recent paper from the WG: https://arxiv.org/abs/2004.13687
  - Our hope for this process is to take these identified topic areas and start making a roadmap of how the issues can be addressed.
  - We have started to flesh out some of the specific points in the following slides
    - None of this is set in stone! We strongly welcome feedback!
  - What the generators provide depends on the needs of the experiments
  - We are considering to pull out a few example analyses at extremes of modelling needs, e.g. *ZpT, mW/mtop, Higgs couplings, high pT search, etc.* and review their needs based on existing HL-LHC projections.

Timeline

- We will start inviting each of generator/tool groups to present in meetings over the next few weeks to start collecting the required information



General questions for all generators

- Are there plans/funds in place to continue support through HL-LHC?
- What major physics updates do you foresee for HL-LHC?
  - Could be NLO→NNLO ME+PS, or improved shower models, etc.
- What major software updates are foreseen for HL-LHC?
  - What will be the main bottlenecks?
- Are there issues or areas of work where help from HSF or from the experiments may be needed?
- Are there generators/tools not listed here today that you hope/expect to become heavily used by the experiments?

ME+PS generators | General

- What updates in physics precision are foreseen for HL-LHC (e.g NNLO, higher jet multiplicities)?
- What are the current CPU performance bottlenecks & how are they being worked on?
- What improvements in computing performance are planned/expected on the timescale of Run 4/5?
  - CPU and (to a lesser extent) memory consumption.
  - Negative weight fractions and mitigation strategies.
  - Improvements in phase space sampling and unweighting efficiency
  - Any other relevant developments
- What work is in progress to adapt the software to GPUs and heterogeneous architectures for HL-LHC?
- Is there any work in progress to include machine learning tools as part of the generator workflow?

ME+PS generators | Specific

- **MG5_aMC**
  - Progress report and expectation on the GPU and CPU/vectorization ports.
  - Plans to include MC@NLO-Delta, for instance, to reduce negative weights.
- **Sherpa**
  - Is there active development on porting Sherpa to GPUs and heterogeneous architectures (beyond previous HPC work)?
  - There has already been technical work on -ve weights and other performance improvements, it would be useful to have them summarised in one place.
- **POWHEG**
  - There has been recent progress on NNLO+PS setups, what is the performance in terms of CPU time per event and negative weights?
  - Could you remind us for which processes MiN(N)LOPS prescriptions already exist for NLO-merged setups?

ME+PS generators | Specific

- **Herwig7**
  - Some issues with large negative weights seen in the past.
  - Also lacking some systematics functionality as weights.
  - Are there development plans here?
- **Pythia8**
  - There doesn’t seem to be have been a significant take-up in experiments of Vincia and DIRE - why not?

PS, hadronisation and decay

- **General:**
  - What is the progress with NLO showers?
- **EvtGen**:
  - There seem to be difficulties with the multithreaded environments that experiments are moving to due to issues with thread safety. Are these planned to be addressed?
- **Pythia8**
  - Also seem to be some issues with thread safety.
- **Herwig7 (& Sherpa)**
  - Comparisons with Pythia8 dominate systematics in several areas - would a dedicated effort to understanding/improve this be useful?
- **Experiments**
  - Would help to describe more in detail what is done in MT frameworks and what the current issues are?

Filtering strategies

- There have been cases with large inefficiency in the experiment workflows due to complicated filtering needs. What are there improvements foreseen on the generators/tools side to facilitate/mitigate this on top of the existing one(s)?

Back-ups

Higgs Couplings

Dominant uncertainties related to modelling

- Signal acceptance dominated
- Background TH dominated
- TH comparable to Exp/Stat
- TH much larger than Exp but stats

ATLAS						
		3000 fb^{-1} uncertainty [%]				
		Total	Stat	Exp	SigAcc	BkgTh
$\sigma^{\gamma\gamma}_{ggH}$	S1	5.2	1.7	4.7	1.1	1.2
	S2	3.6	1.7	3.0	0.9	0.5
σ^{ZZ}_{ggH}	S1	4.9	2.0	3.7	1.8	1.9
	S2	3.9	2.0	3.0	1.0	1.0
σ^{WW}_{ggH}	S1	6.0	1.2	3.2	3.7	3.4
	S2	4.3	1.2	2.7	2.1	2.4
$\sigma^{\tau\tau}_{ggH}$	S1	10.6	3.3	5.0	7.5	4.4
	S2	8.2	3.3	4.4	5.4	2.7
$\sigma^{\mu\mu}_{ggH}$	S1	19.9	17.9	2.8	8.0	0.1
	S2	18.5	17.9	2.7	3.8	0.1
$\sigma^{Z\gamma}_{ggH}$	S1	33.3	31.1	4.9	10.1	0.3
	S2	33.3	31.1	4.9	10.1	0.3
$\sigma^{\gamma\gamma}_{VBF}$	S1	12.0	4.4	7.3	8.2	2.1
	S2	8.9	4.4	5.5	5.4	0.9
σ^{ZZ}_{VBF}	S1	13.0	9.6	5.1	6.8	2.1
	S2	11.8	9.6	5.1	4.5	1.2
σ^{WW}_{VBF}	S1	10.3	3.3	3.9	7.7	4.5
	S2	6.6	3.3	2.9	4.0	2.8
$\sigma^{\tau\tau}_{VBF}$	S1	8.7	3.7	4.1	5.5	3.8
	S2	7.8	3.7	4.8	3.2	3.6
$\sigma^{\mu\mu}_{VBF}$	S1	38.7	32.5	11.7	17.1	0.2
	S2	36.1	32.5	11.7	10.4	0.3
$\sigma^{Z\gamma}_{VBF}$	S1	68.2	62.2	10.9	25.0	0.5
	S2	68.2	62.2	10.9	25.0	0.5
$\sigma^{\gamma\gamma}_{WH}$	S1	14.8	13.1	5.2	4.0	1.3
	S2	13.8	13.1	3.3	2.8	0.7
σ^{ZZ}_{VH}	S1	18.7	17.3	4.2	5.4	2.2
	S2	18.1	17.3	3.4	4.1	1.7
σ^{bb}_{WH}	S1	14.1	4.3	4.9	7.3	10.1
	S2	10.1	4.4	4.1	4.2	6.9
$\sigma^{\gamma\gamma}_{ZH}$	S1	17.0	14.9	5.1	6.3	1.3
	S2	15.7	14.9	3.2	3.7	0.6
σ^{bb}_{ZH}	S1	7.0	3.5	2.7	4.0	3.6
	S2	5.2	3.5	2.0	2.1	2.4
$\sigma^{\gamma\gamma}_{ttH}$	S1	10.0	4.6	5.9	6.4	1.5
	S2	7.4	4.6	4.1	3.9	0.5
σ^{ZZ}_{ttH}	S1	20.5	18.6	4.1	7.3	1.7
	S2	19.3	18.6	3.1	3.8	0.9
$\sigma^{WW\tau\tau}_{ttH}$	S1	22.1	6.3	18.2	7.0	8.1
	S2	20.2	6.3	17.9	4.3	5.1
σ^{bb}_{ttH}	S1	19.9	3.2	4.2	7.4	17.8
	S2	14.2	3.2	3.4	4.4	12.7