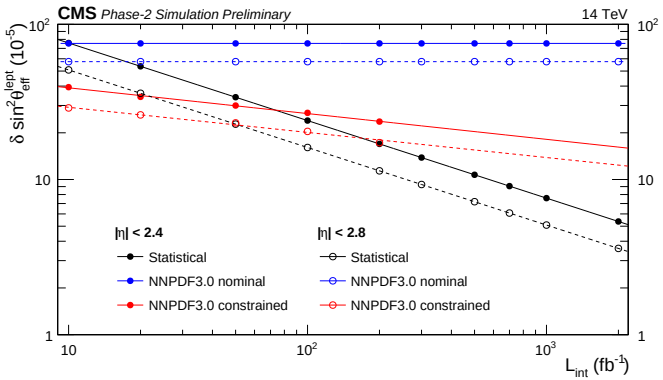
Systematics Limits Measurements/Searches

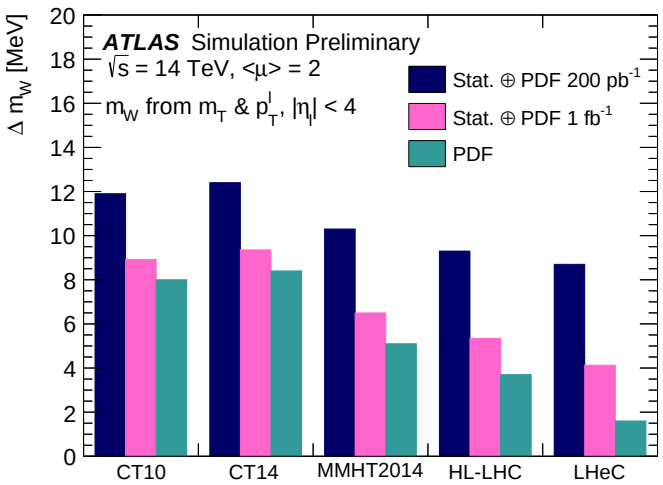
- LHC Run 3 and 4 come with huge amounts of integrated luminosity $\rightarrow$ many existing measurements and searches may become systematics limited (but also new/better measurements and searches become possible)
- A few general classes of systematic uncertainties
  - Detector response related (object reconstruction/identification/trigger efficiencies, energy/momentum scales, etc)
  - Theoretical modelling (PDFs, missing higher orders in QCD/EW calculation, underlying event, hadronization, fragmentation, transverse-momentum dependence of PDFs, etc)
  - Monte Carlo Statistical Uncertainty (more flexible generator cuts/weighting, smarter filters, more condensed analysis formats, faster simulation and reconstruction code, use of heterogeneous computing, supercomputing centers, commercial cloud resources, etc etc)
- Care needed to ensure condensed analysis formats don't create artificial limits on achievable systematic uncertainties
- Better detector and theoretical modelling sometimes costs **more** computing resources

Systematics Limits Measurements/Searches

- Non-trivial interplay: Consider e.g. muon identification/isolation efficiency, typically taken from Monte Carlo and rescaled in bins of η and p_T based on tag and probe measurements with $Z \to \mu\mu$ events in data:
  - Starting point for "identification" (track quality, matching, impact parameter, etc) depends mostly on quality/accuracy of detector simulation
  - Starting point for isolation criteria depends mostly on modelling of underlying event (but at high PU some contamination which depends on MinBias properties, number of additional interactions, longitudinal impact parameter resolution, etc)
  - Scale factor measurements in data depend on theoretical modelling of the DY process (lineshape, UE, additional jet activiity, etc)
  - Extrapolation to other processes, especially $t\bar{t} + X$/BSM scenarios with additional jet activity further sensitive to UE/additional jet modelling in MC
- $Z/\gamma^* \to \ell\ell$ process has a special role for detector calibration (lepton efficiencies, energy/momentum scale, Z/jet balancing for JES, Z/MET balancing for MET calibration, etc, etc, etc)

Precision EW/PDFs/interplay between colliders





(a) CMS $\sin^2\theta_W$ projections (b) ATLAS M_W projections

CMS-PAS-FTR-17-001, ATL-PHYS-PUB-2018-026

- Precision measurements of electroweak parameters at hadron colliders crucially depend on PDFs, but also can heavily exploit in-situ constraints
- More precise PDFs from future DIS experiments → more precise EW parameters from hadron colliders
- More precise EW parameters from FCC-ee or similar → more precise PDF constraints from hadron colliders
- All three → **very** stringent tests of the Standard Model, higher order corrections, etc