Imperial College London

Prospects for H→γγ measurements with the CMS experiment at the HL-LHC

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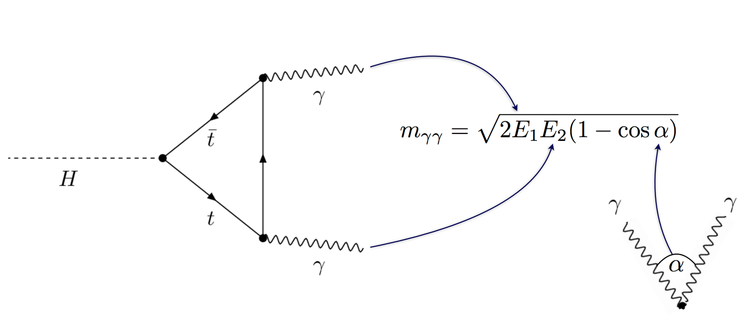
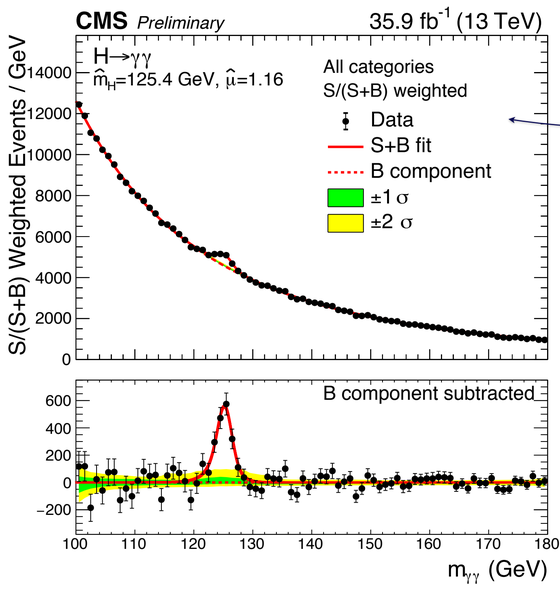
The diphoton decay mode

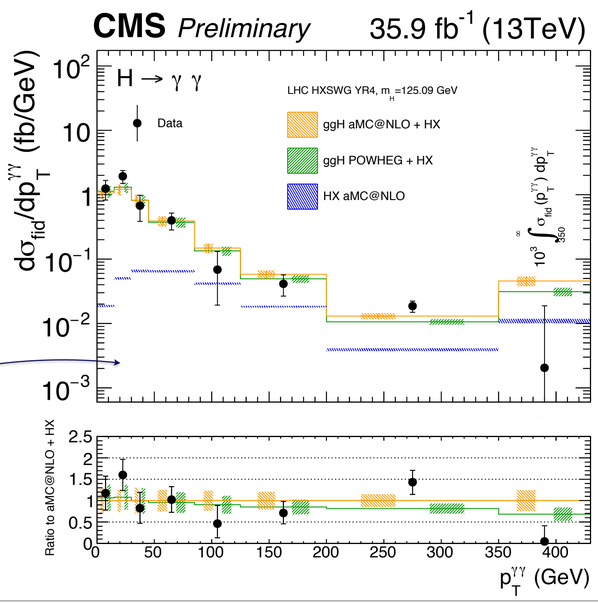


- Low branching ratio (~0.2%), but high resolution
  - key to discovery
    → now perform precision measurements
  - resolution depends on photon energy and angle
    → correct choice of vertex is crucial
- Can probe various Higgs couplings
  - sensitive to ggH, VBF, ttH, and VH modes
  - presence of fermions & bosons
    (and BSM particles?) in decay loop

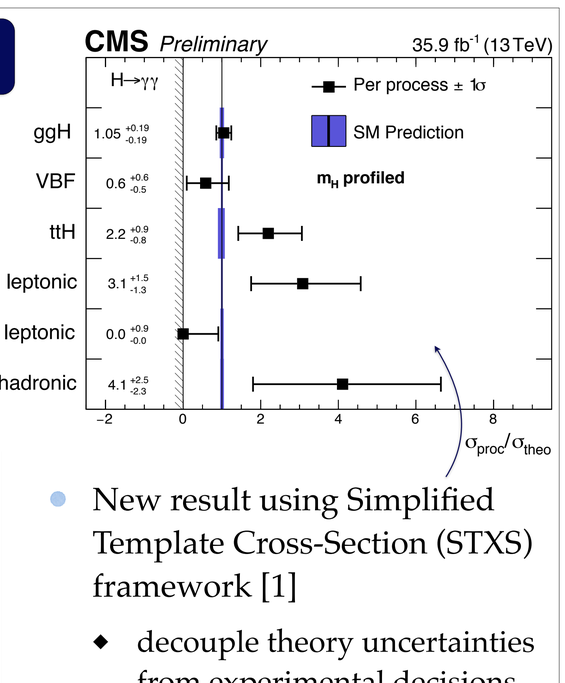
Recent CMS results



- Preliminary result with 2016 dataset of 35.9 fb^{-1} [1]
  - overall $\mu = 1.16\ ^{+0.15}_{-0.14}$
    $= 1.16\ ^{+0.11}_{-0.10}$ (stat.) $^{+0.09}_{-0.08}$ (syst.) $^{+0.06}_{-0.05}$ (theo.)



- Differential analysis [2]:
  - binned in Higgs p_T and nJets
  - also measure fiducial cross-section: 84 $^{+13}_{-12}$ fb

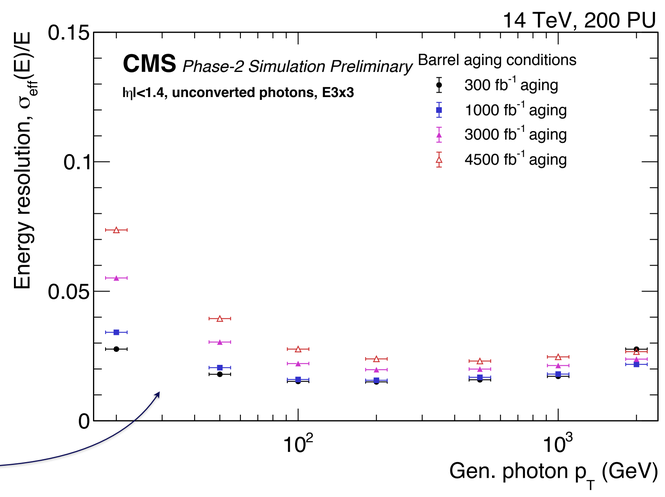


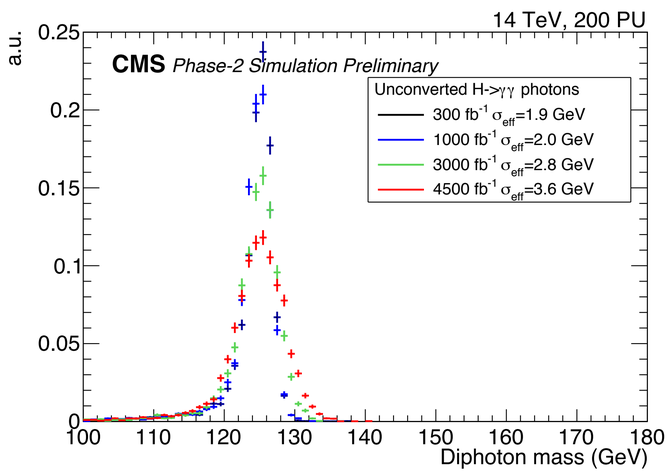
- New result using Simplified Template Cross-Section (STXS) framework [1]
  - decouple theory uncertainties from experimental decisions
  - binning scheme staged
    → Stage 0 above
    → Stage 1 splits by p_T and number of jets
- Key component of future Higgs strategy

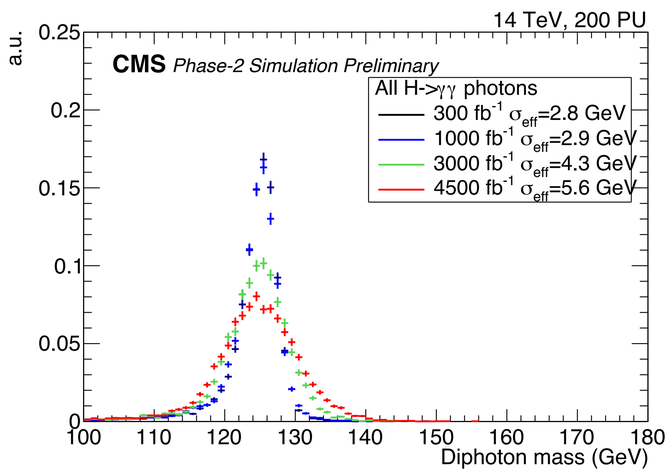
Detector upgrade studies

HL-LHC priorities

- Increasing L_{inst} to ~ 5×10^{34} cm^{-2}s^{-1}
  → total dataset >= 3000 fb^{-1}
  - <PU> 140 - 200
  - aim for Run 2-level performance
- Suite of upgrades needed
  - also replace damaged components
- For H→γγ analysis, vital to maintain diphoton mass resolution
  - excellent per-photon energy resolution
    → determined by upgraded barrel calorimeter
  - fine vertex position reconstruction
    → tracker upgrade and precision timing

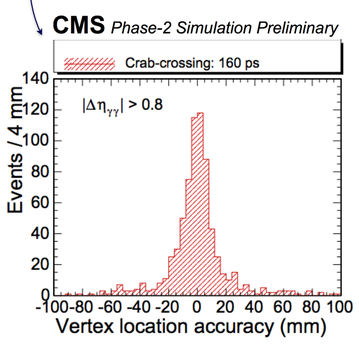


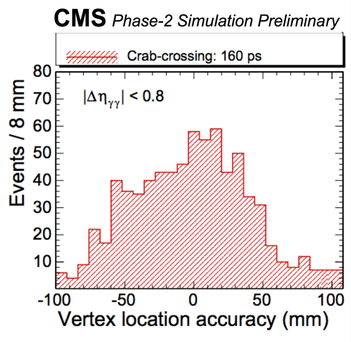




Timing Information

- Vertex position has no impact on mass resolution if < 10mm from true value
  - Run 2 efficiency ~80%
  - down to 40% (30%) at PU of 140 (200)
- If photon $|\Delta\eta| > 0.8$, 30ps timing
  → correct vertex identification
- If $|\Delta\eta| < 0.8$, need track timing instead



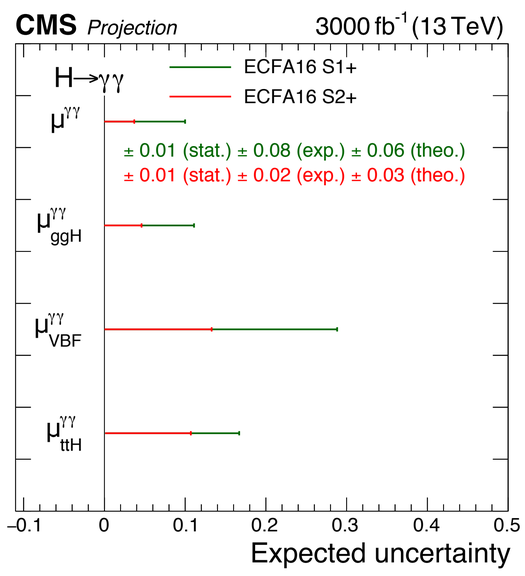


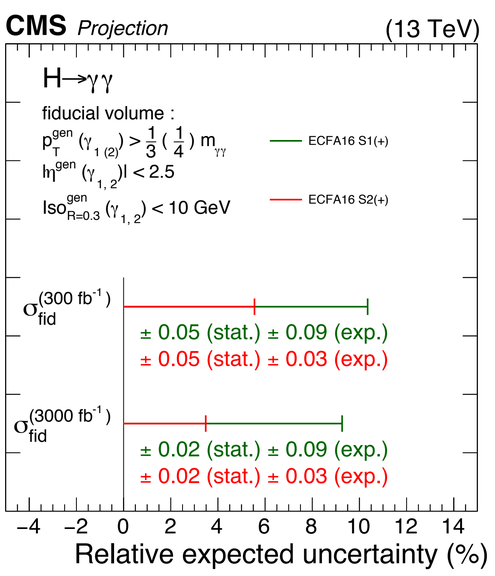
Barrel Calorimeter

- Isolate impact of photon energy resolution
  - use generator vertex for reconstruction
  - 1000fb^{-1} ageing: resolution increase by ~13%
- Full simulation of ggH H→γγ
- p_T > 25 (15) GeV for (sub) leading photon
  - both $|\eta| < 1.45$, and
    matched to generator object
- Unconverted photons improve with E3×3 energy estimate
  - sum of 3×3 crystals around most energetic
  - ineffective for the dispersed showers of converted photons
- No multivariate regression used for corrections
  → results underestimate ultimate performance

Projected Performance

- Extrapolations based on 2016 12.9 fb^{-1} Run 2 result [3]
  - documented at ECFA 2016 [4]
  - inclusive + ggH, VBF, and ttH modes
- Effects of detector upgrades based on Phase 2 upgrade TP [5]
- Dominant experimental uncertainties for S2+:
  - luminosity = 1.5%, and jet energy scale = 1%
- Assume 40% vertex efficiency (pessimistic)





- Scenario S1(+)
  - All systematic uncertainties constant with integrated luminosity
- Scenario S2(+)
  - Theoretical uncertainties halved
  - Experimental uncertainties scaled by square root of int. luminosity
    → until limit defined by upgraded detector performance

Summary

- H→γγ becomes precision channel for Higgs physics at the HL-LHC
  - uncertainty on μ and σ_{fid} projected to reach few per-cent level
- Much future work to achieve ambitious goals upgraded detector
  - and to drive down existing experimental and theoretical uncertainties
- Scope for improvements even on optimistic extrapolation scenario
  - e.g precision timing in 4D reconstruction, novel analysis techniques
- Exciting times ahead!

REFERENCES

[1] CMS Collaboration, "Measurements of properties of the Higgs boson in the diphoton decay channel with the full 2016 data set", CMS Physics Analysis Summary CMS-PAS-HIG-16-040, 2017
[2] CMS Collaboration, "Higgs to diphoton differential and fiducial cross-sections with 2016 dataset", CMS Physics Analysis Summary CMS-PAS-HIG-17-0415, 2017
[3] CMS Collaboration, "First results on H→γγ measurements at √s = 13 TeV", CMS Physics Analysis Summary CMS-PAS-HIG-16-020, 2016
[4] CMS Collaboration, "Projected performance of Higgs analyses at the HL-LHC for ECFA 2016", CMS Physics Analysis Summary CMS-PAS-FTR-16-002, 2016
[5] CMS Collaboration, "Technical Proposal for the Phase-II Upgrade of the CMS Detector", Technical Report CERN-LHCC-2015-010. LHCC-P-008. CMS-TDR-15-02, 2015