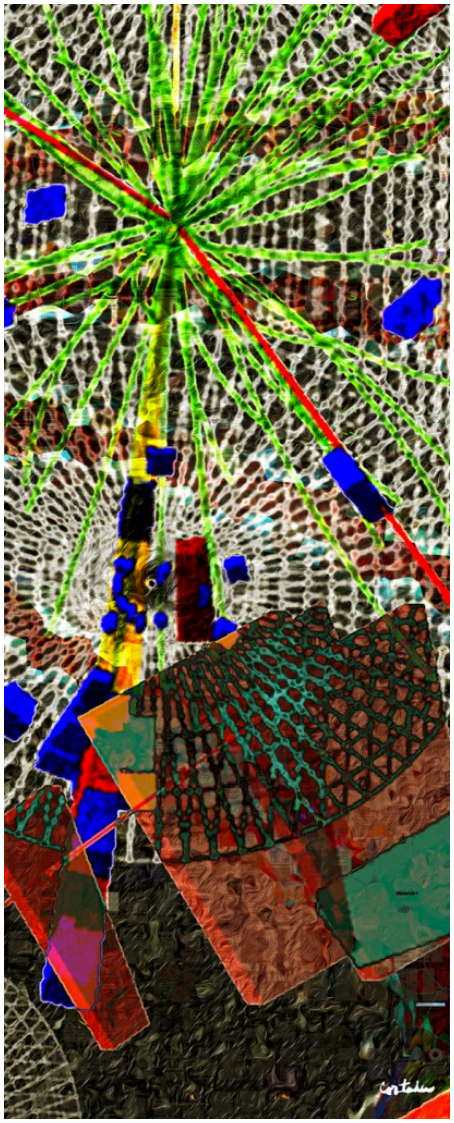
H(125) boson measurements at CMS

M. Malberti (Universita` & INFN Milano Bicocca)
on behalf of the CMS Collaboration



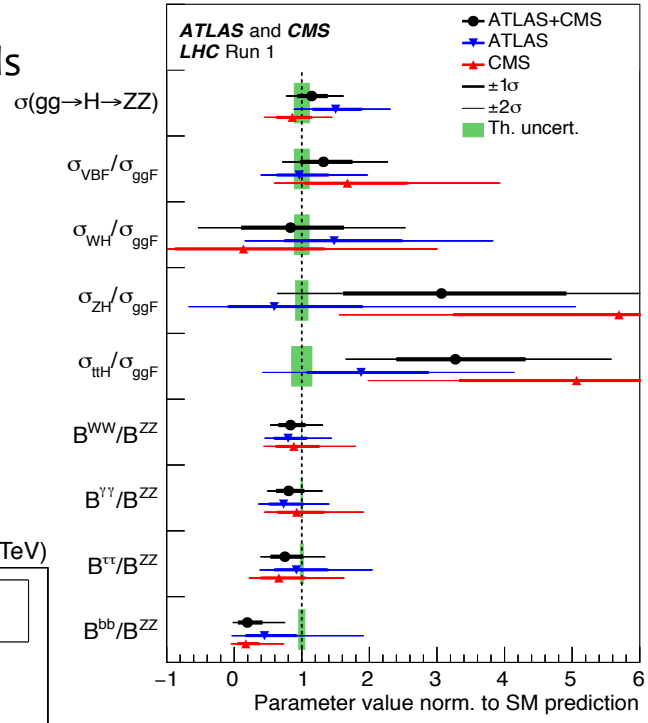
Les Rencontres de Physique de la Vallee d'Aoste
La Thuile, Aosta Valley, Italy
March 5-11, 2017

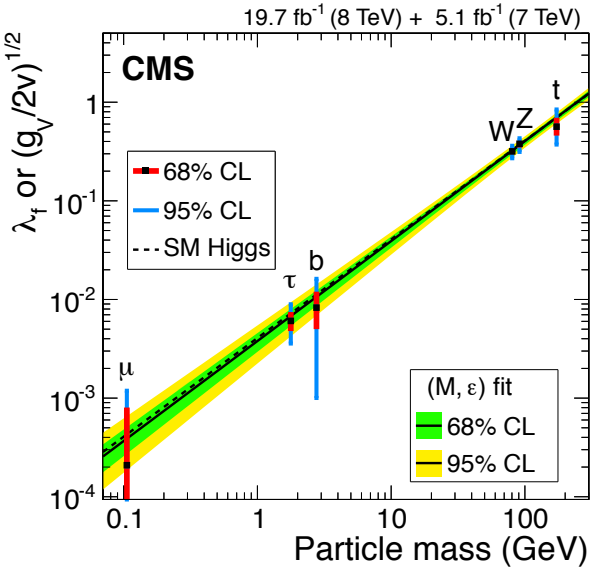
Outline

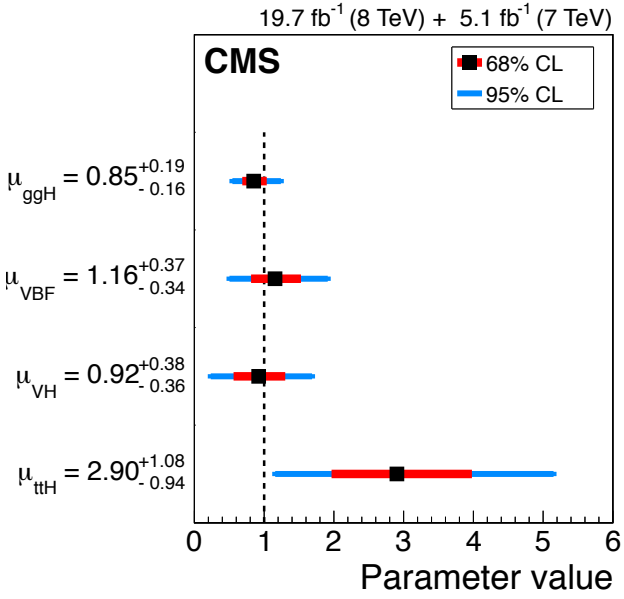
- Brief summary of Run1 results
- Preliminary Run2 results: H → ZZ, H →γγ , ttH (multileptons, bb, γγ)
- Future prospects
- Summary and outlook

Run1 legacy results

- Studied a wide range of Higgs production and decay channels
- Couplings consistent with SM Higgs boson
- Mass measured with 0.2% precision
- No additional Higgs bosons so far
- Small excess in ttH



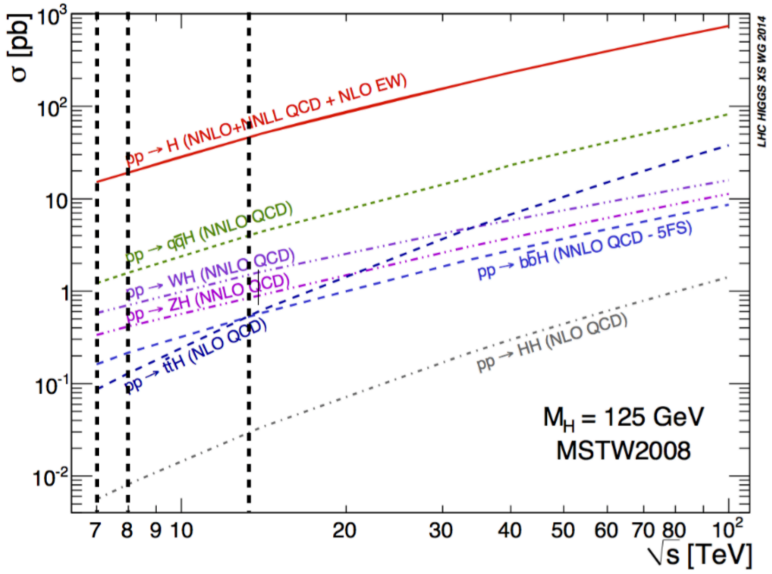




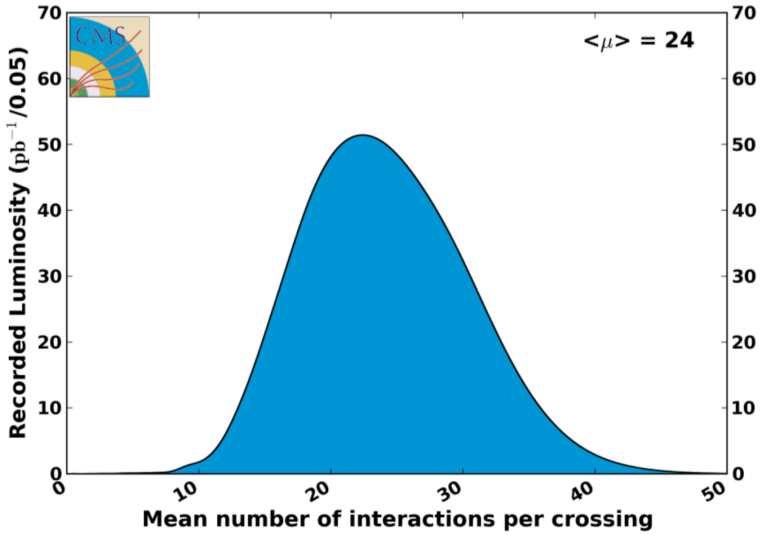
From Run1 to Run2

- 8 TeV → 13 TeV: increase in Higgs production cross section
  - opens the way towards precision and differential measurements, observation of rare production modes

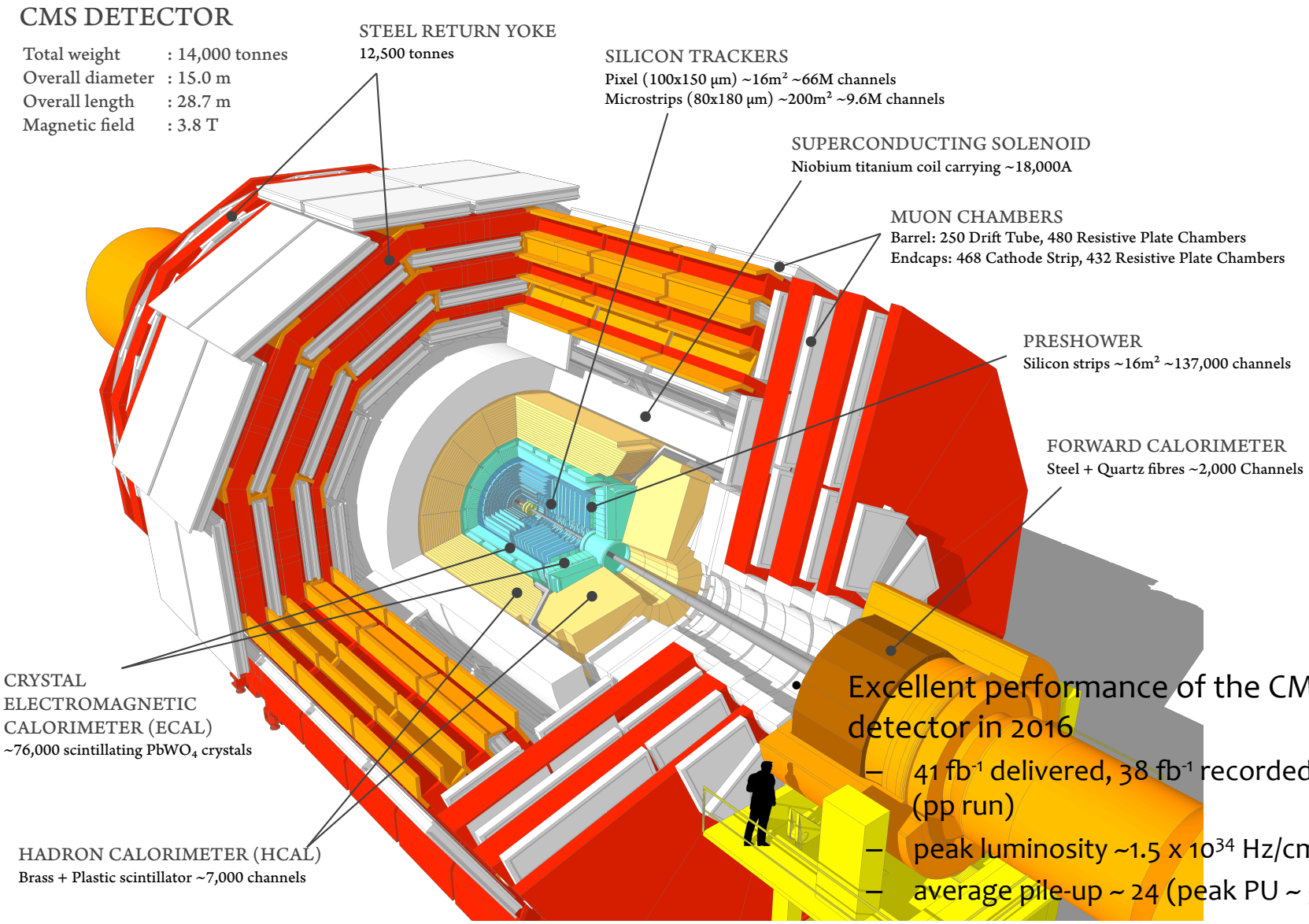
ggH: 19.3 pb → 43.9 pb (x2.3)
VBF: 1.57 pb → 3.75 pb (x2.3)
VH: 1.12 pb → 2.25 pb (x2.0)
ttH: 0.13 pb → 0.51 pb (x3.9)



- Changes in data-taking conditions
  - more challenging experimental environment due to increase in instantaneous luminosity and pile-up



The CMS detector

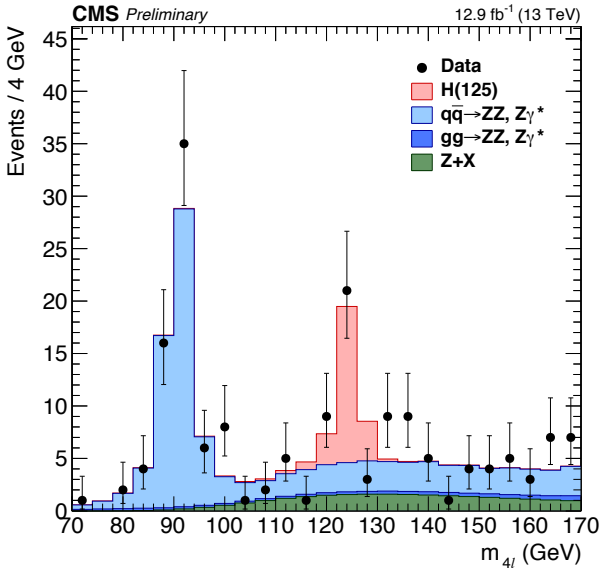


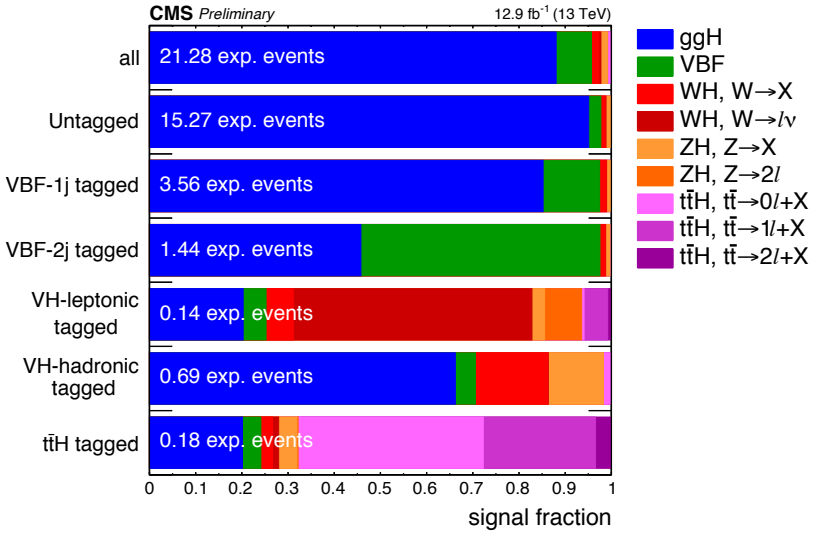
- Excellent performance of the CMS detector in 2016
  - 41 fb^{-1} delivered, 38 fb^{-1} recorded (pp run)
  - peak luminosity ~1.5 x 10^{34} Hz/cm^2
  - average pile-up ~ 24 (peak PU ~ 50)

Preliminary Run2 results (based on 12.9 fb^{-1})

H→ZZ→4leptons

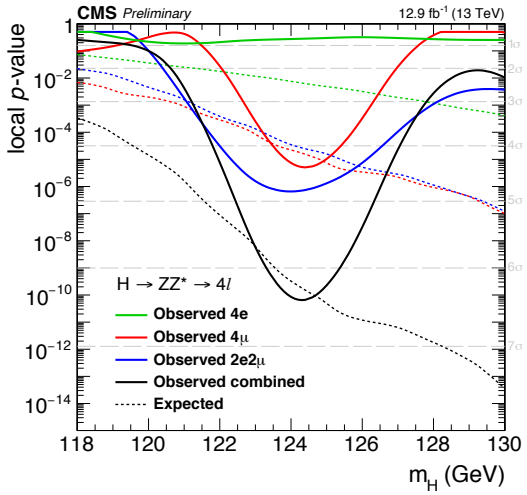
- Fully reconstructed mass peak, large S/B, excellent lepton (e,μ) momentum resolution
- Analysis strategy
  - 6 exclusive categories based on number of (b-)jets, additional leptons and selections on kinematic discriminants (K_D) Matrix Element based (JHUGen, MCFM)
  - Discriminate ggH vs ZZ ("untagged"), VBF/VH/ttH vs ggH ("production-mode-tagged")
- Signal extraction
  - 2D likelihood fit (m4l, K_D) in each category
- Main backgrounds
  - qq→ZZ*, gg→ZZ*: from MC
  - "Z+X": fakes from Z+jets, Z+bb, ttbar, …: from data control samples

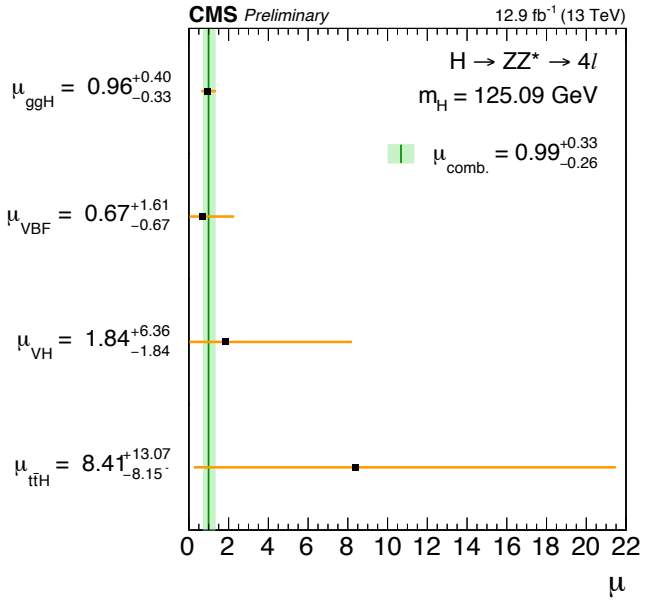


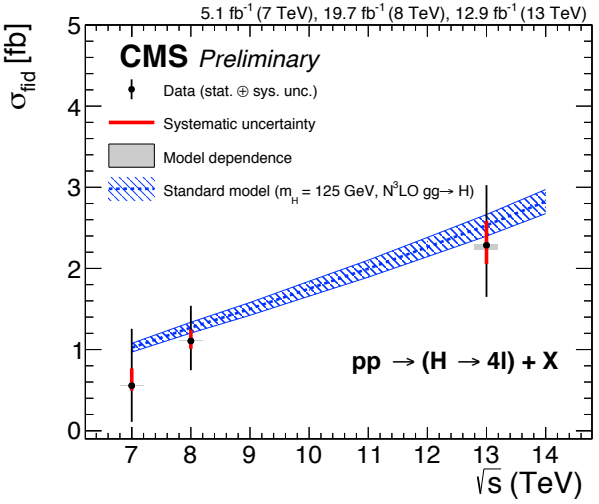


CMS-PAS-HIG-16-033

H→ZZ→4l results







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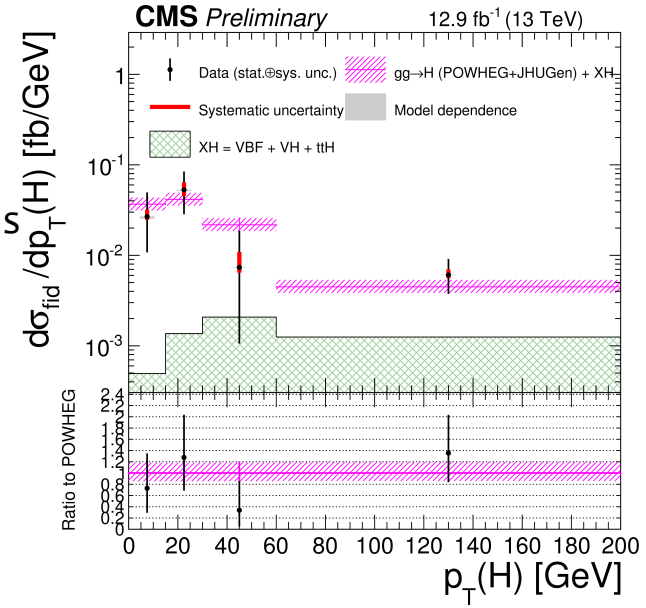
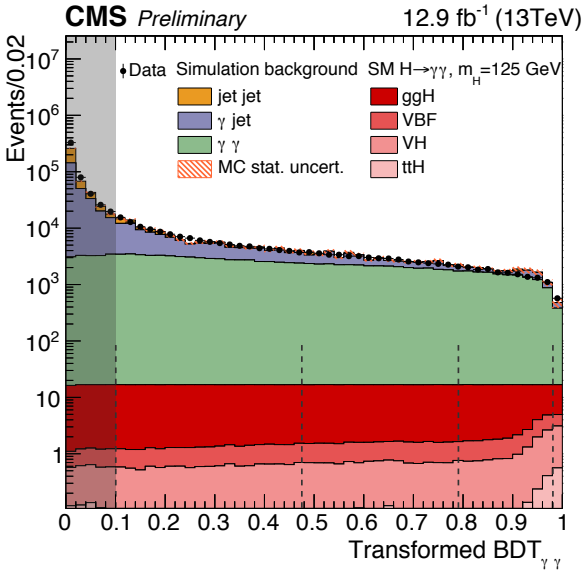


- Obs. (exp.) significance: **6.2σ** (6.5σ)
- Best fit : **μ = 0.99** $^{+0.33}_{-0.26}$ at m_H = 125.09 GeV
- μ by production mechanism **compatible** with SM expectations
- m_H = 124.5 ± 0.47 GeV
- Fiducial cross section in agreement with SM predictions
- Differential measurements: pT(H), Njets

H→ γγ

- Small, narrow mass peak on top of large, smoothly falling background modeled on data
- Clean signature: two high pT isolated photons
  - high precision for mass reconstruction
- Main backgrounds
  - irreducible: prompt di-photons production
  - reducible: γ+jets, QCD multijets
- Analysis strategy:
  - BDTγγ to discriminate H→γγ from background exploiting kinematics, mass resolution, photon ID
  - events categorized exploiting different S/B and mass resolution to achieve maximum sensitivity
  - additional categorization with jets/leptons targeting VBF/VH/ttH production
- Signal extracted from a simultaneous fit to the $m_{\gamma\gamma}$ distribution in different categories



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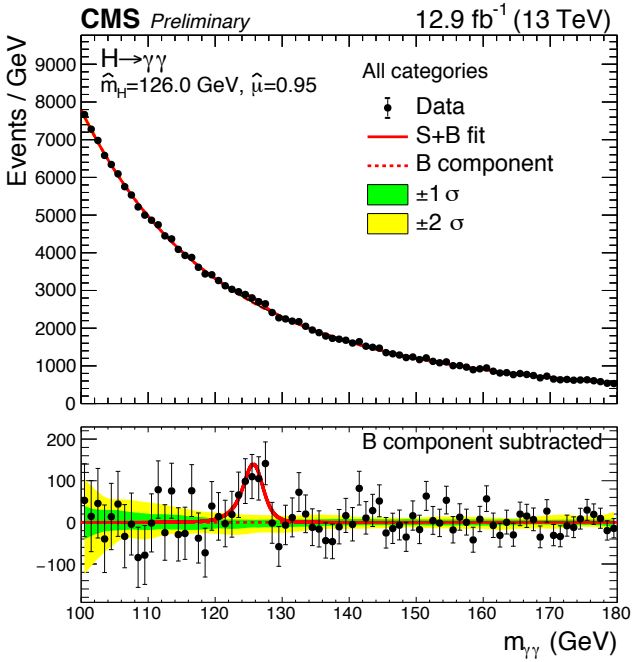
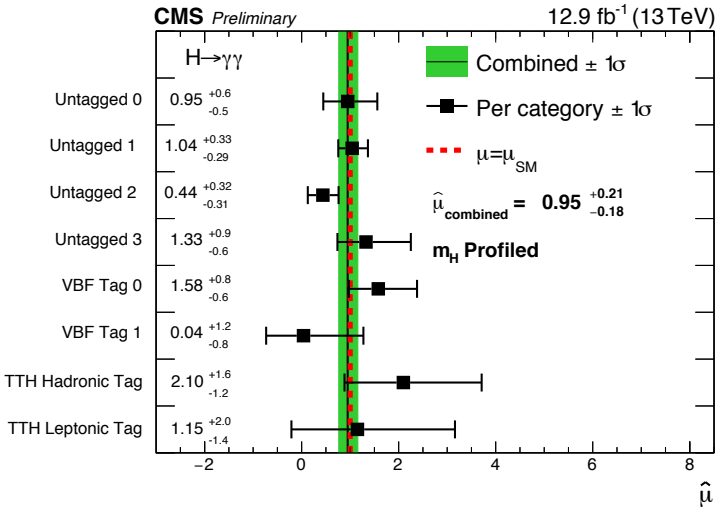
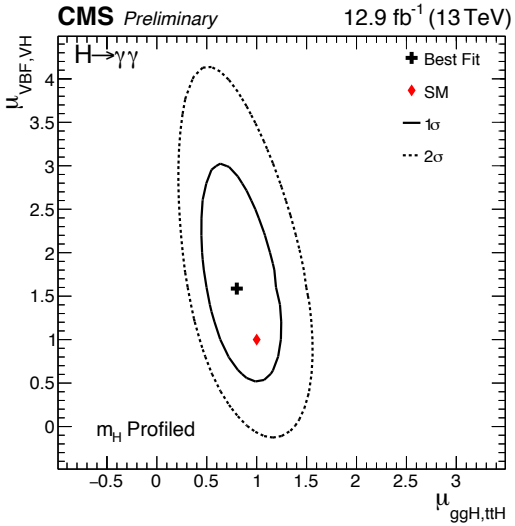
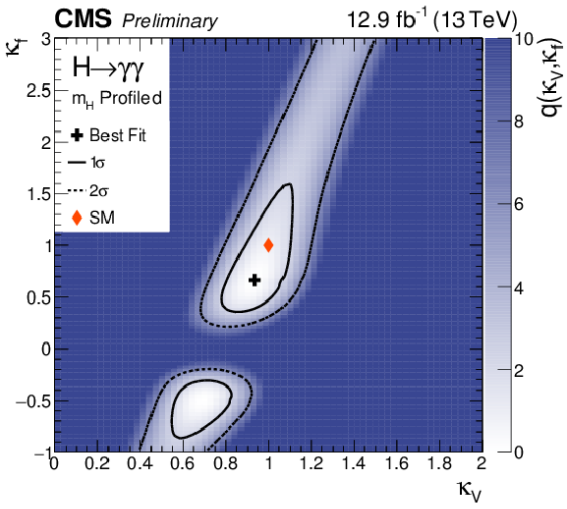


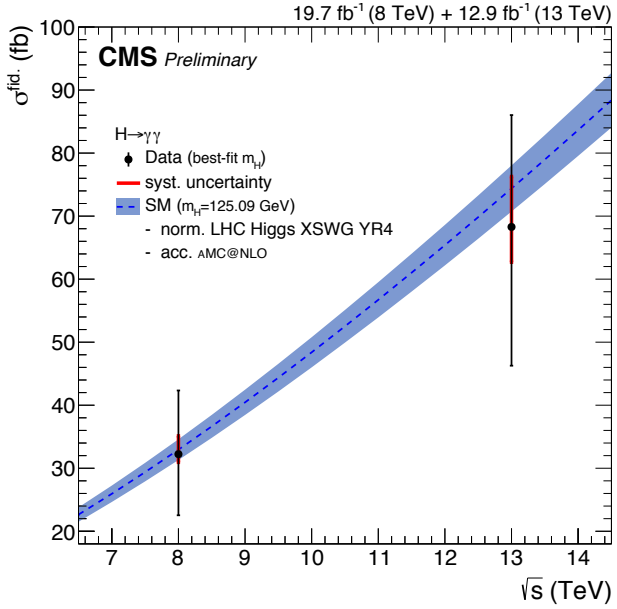
H→γγ results





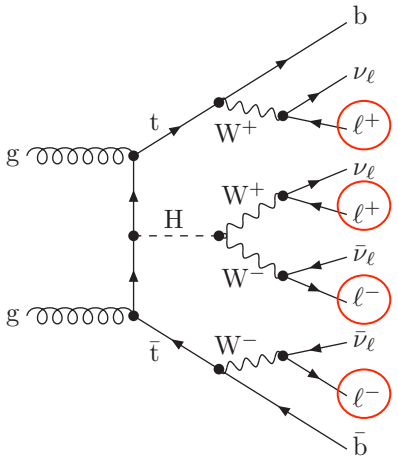


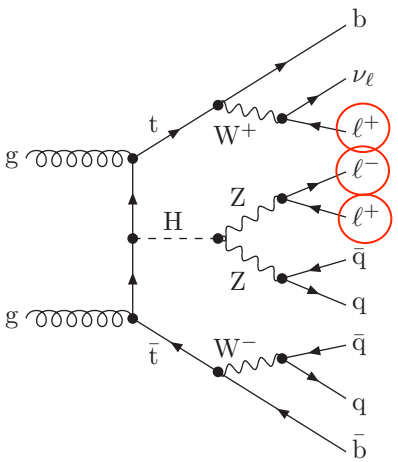
- Obs. (exp.) significance: **5.6σ** (6.2σ)
- Best fit: **μ = 0.95 ± 0.20**
- Signal strength by production mechanism **compatible** with SM expectations
- Fiducial cross section in agreement with SM predictions

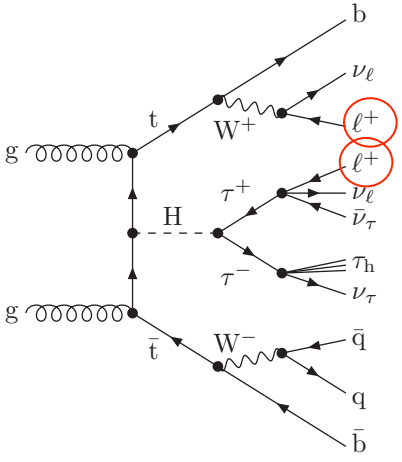


CMS-PAS-HIG-16-020

ttH → multileptons (I)





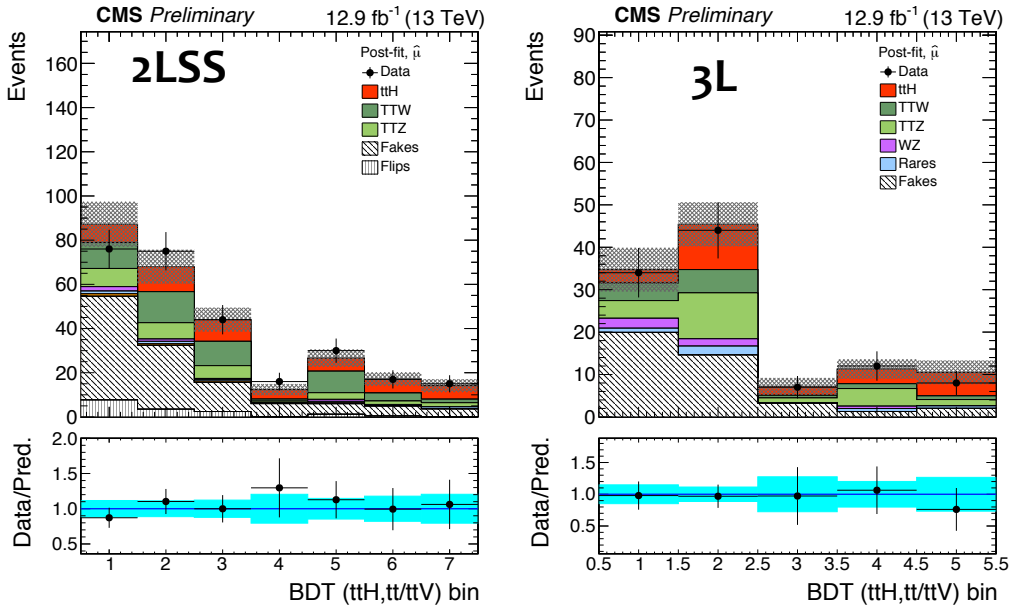


CMS-PAS-HIG-16-022

- Target signature with **H → WW /ZZ /ττ final states + additional products from tt decays**
- Select events with multiple leptons and b-jets
  - 2 same-sign leptons + 4 jets (**2LSS**)
  - >= 3 leptons (with Z veto) + 2 jets (**3L**)
- Dedicated BDT to reject non-prompt leptons, jets and charge mis-ID
- Further categorization based on lepton flavor and charge, n. of b-jets and τ_{had}
- Main backgrounds:
  - Irreducible: ttV (from MC), di-boson (validated in data)
  - Reducible: non-prompt leptons in tt events and charge mis-ID (from DATA)

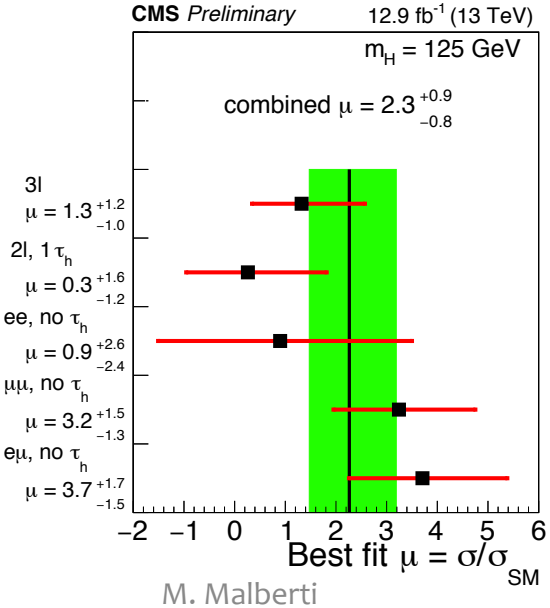
ttH → multileptons (II)

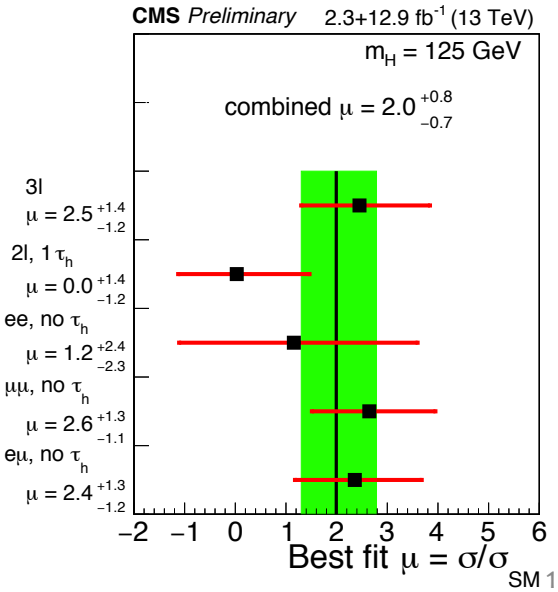
- 2 BDT's: ttH vs tt, ttH vs ttV
  - trained separately for 2LSS and 3L
  - use topological and kinematic differences between signal and backgrounds (inputs: jet multiplicity, lepton/jet angular separation, MET, lepton pTs)
- Signal extracted via simultaneous 2D fits of BDTs in each category



CMS-PAS-HIG-16-022

- Best fit signal strenght:
  $\mu = 2.0^{+0.8}_{-0.7}$ (2015+ 2016)
- **3.2σ observed significance** (expected 1.7σ)

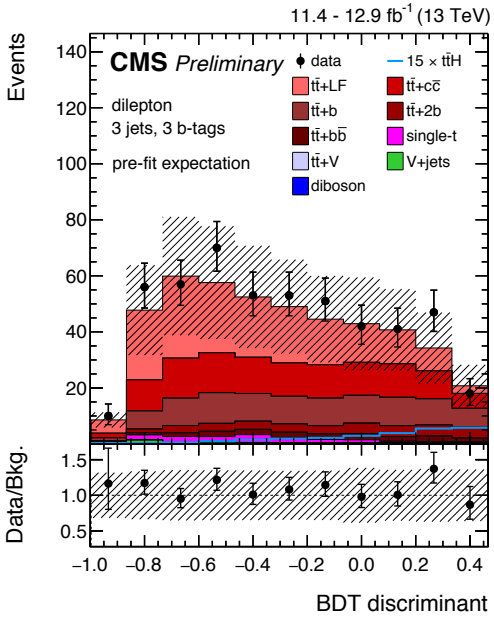


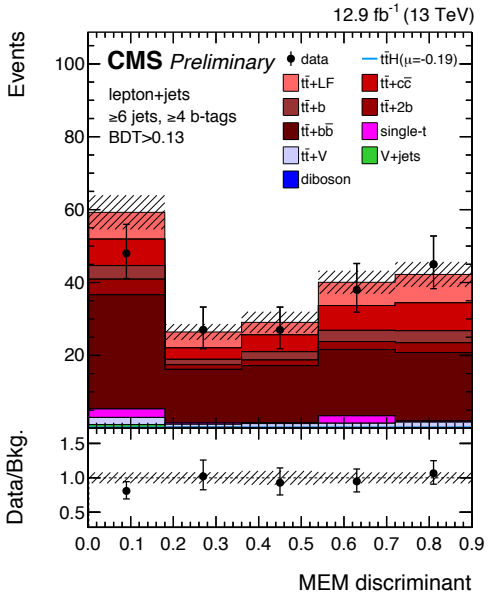


ttH(bb)

- Two channels considered:
  - lepton+jets: 1 lepton + ≥ 4 jets
  - dilepton: 2 OS leptons + ≥ 2 jets
- Further categorization based on n(jets), n(b-jets)
- Sub-categories defined based on BDT and MEM
  - BDT inputs : kinematics, event shapes, b-tag discriminant
  - MEM discriminant optimized to separate ttH(bb) signal from irreducible ttbb background
- Signal extraction from simultaneous fit to data of the final sub-categories discriminant
- Best fit signal strenght:

$\mu = -0.19^{+0.80}_{-0.81}$





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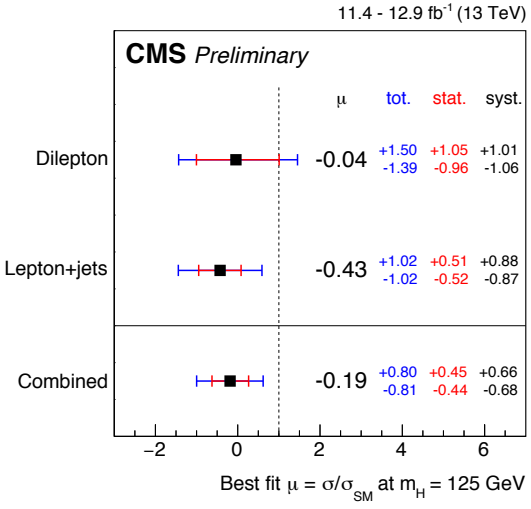
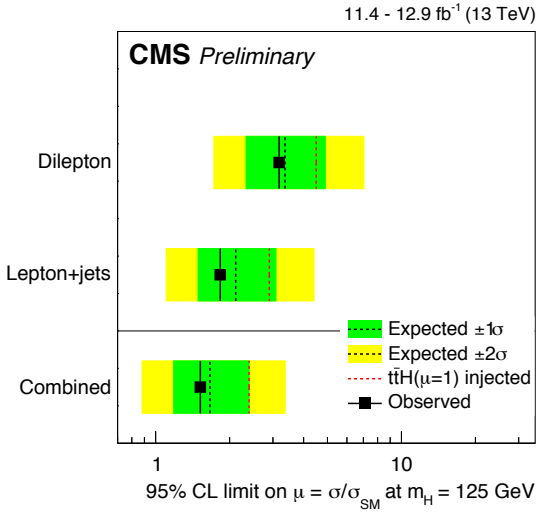
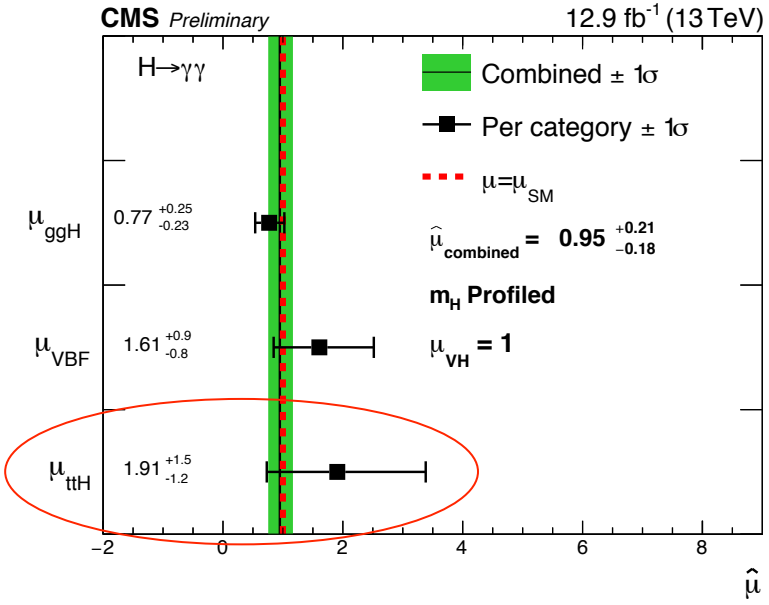
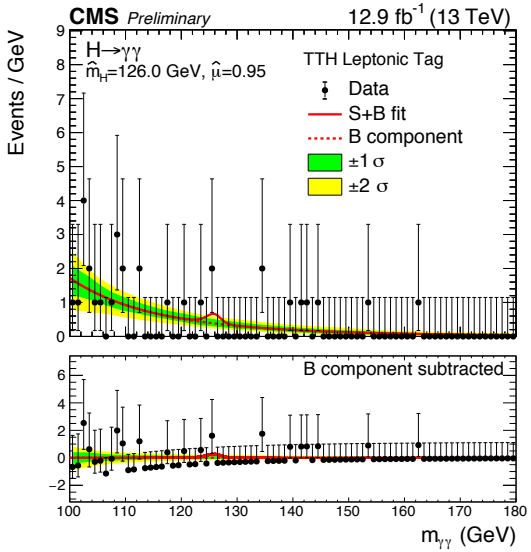


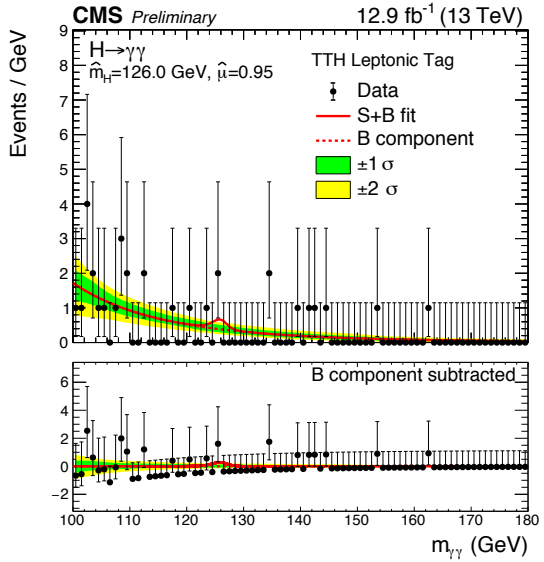


ttH(γγ)

- Two ttH sensitive channels
  - ttH leptonic: 2γ + ≥1 lepton + ≥ 2 jets (≥ 1 b-tag)
  - ttH hadronic: 2γ + ≥ 5 jets (≥ 1 b-tag) , no leptons
- Background estimated from fit of m($\gamma\gamma$) distribution
- Best fit : $\mu_{ttH} = 1.91^{+1.5}_{-1.2}$





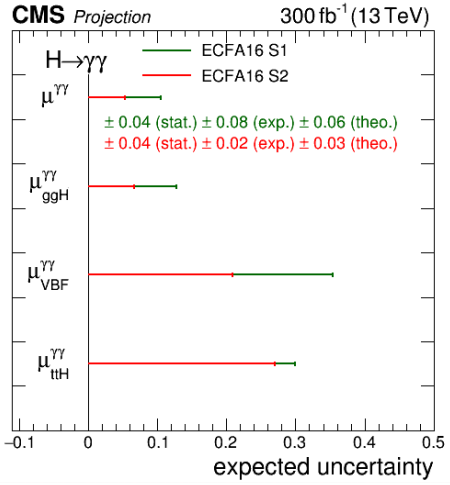


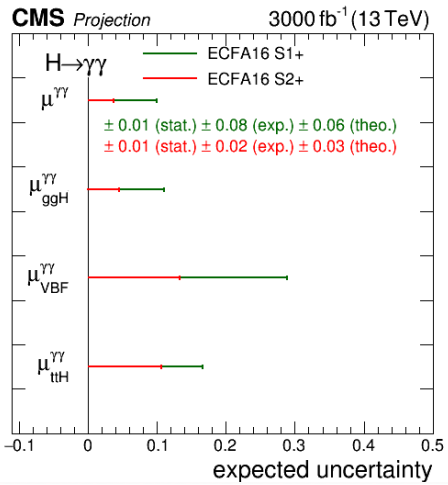
CMS-PAS-HIG-16-020

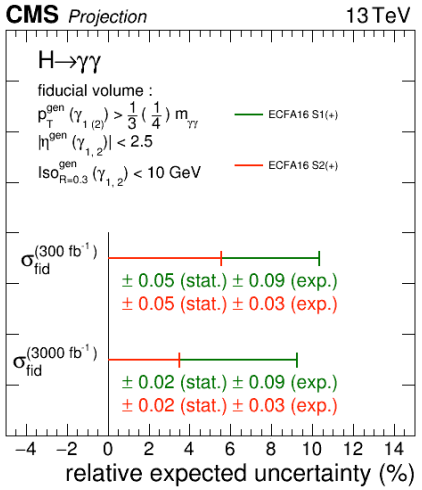
Future prospects

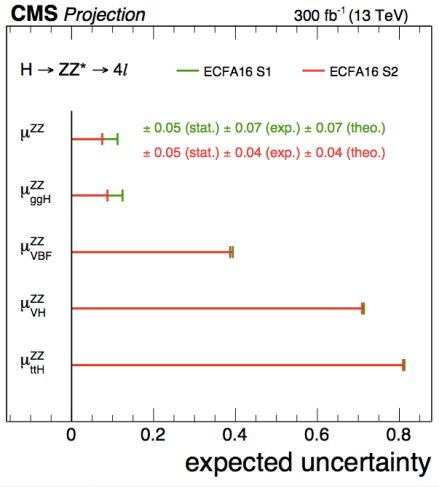
- Results extrapolated to larger dataset (300, 3000 fb^{-1}) and upgraded CMS for the HL-LHC
- Systematics kept constant (S1) or scaled (S2)

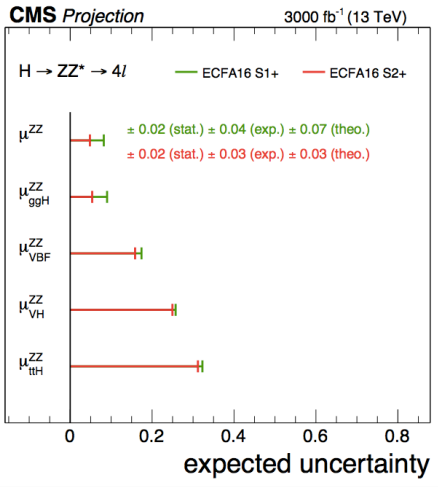
CMS-DP2016-064

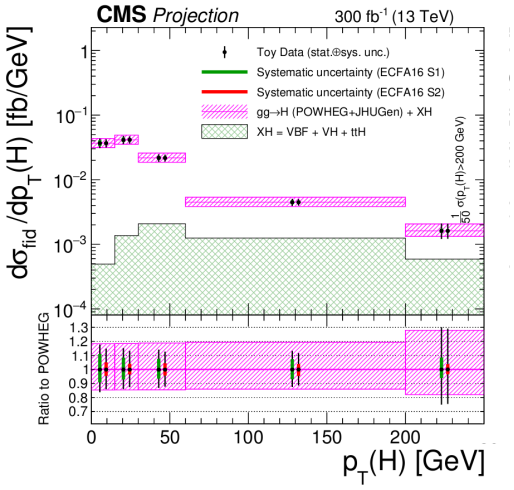












Summary and outlook

- Preliminary Higgs boson measurements performed at CMS using 13 TeV pp collisions data
  - sensitivity already close to Run1 using only 12.9 fb^{-1}
  - measurements are largely compatible with SM expectations

- All analyses are being updated using the full 2016 datasets (~36 fb^{-1})
  - substantial improvements expected

- Expected > 100 fb^{-1} to be delivered by the end of Run2
  - improve precision on couplings, fiducial and differential cross sections