Measurement of the Higgs Boson mass and width at CMS

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On behalf of the CMS collaboration

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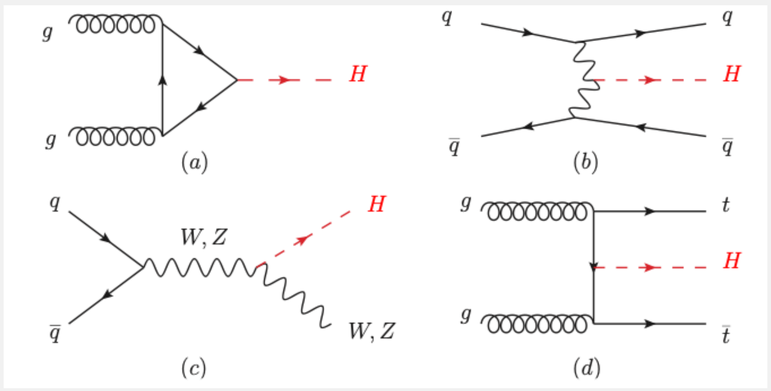
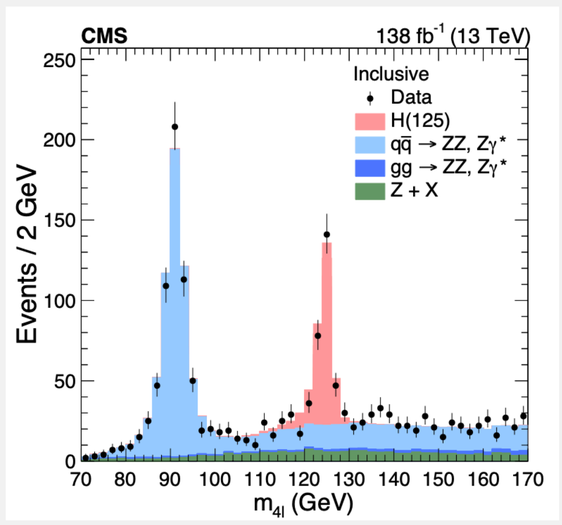
$H \to ZZ \to 4l$

Introduction

Production channels : ggH, VBF, WH/ZH, ttH





- The Higgs boson mass is a free parameter of the Standard Model
- Clean final state with large S/B ~ 4:1 at peak
- Categorised in 4μ, $4e$, $2\mu 2e$, $2e2\mu$ final states (different resolutions, different S/B)
- In $2\mu 2e$, the $\mu\mu$ pair forms Z_1 (closest to nominal Z), in $2e2\mu$, the ee pair forms Z_1

Triggers and selections

- Single lepton, di-lepton, and tri-lepton triggers with relaxed pT requirements
- Select prompt muons/electrons with impact parameter and isolation criteria
- Leptons are dressed with final state radiation recovered photons
- To build Higgs candidate - select opposite-sign and same-flavour lepton pairs $(4\mu, 4e, 2\mu 2e, 2e2\mu)$ with 12< m_{ll} <120 GeV

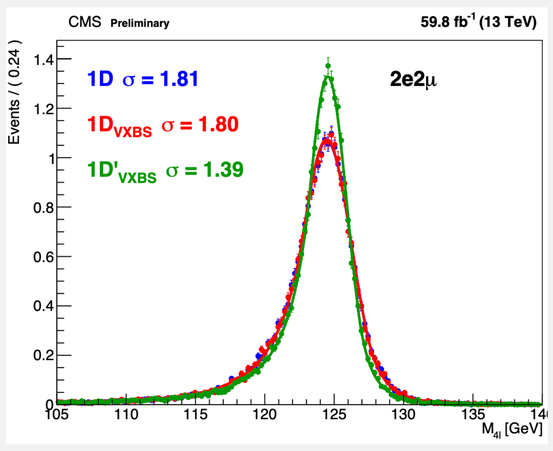
Improvements in measurement

Beam Spot (BS) constraint for muons

- Constrain muon tracks to come from BS, with transverse size (σ) ~ 10 μm
- Improves muon momentum resolution by 8%
- Overall improvement in the Higgs mass measurement ~ 5%

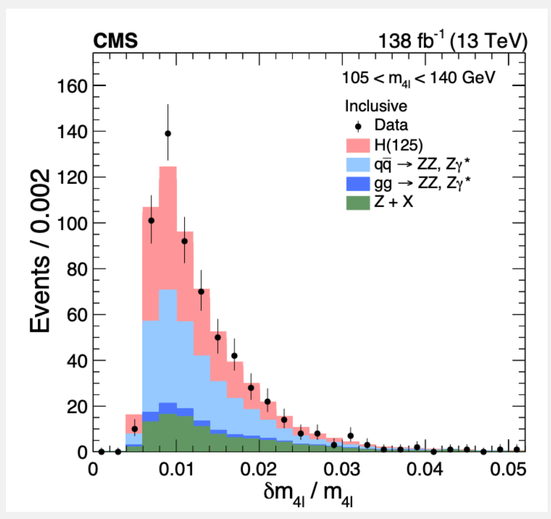
Z1 lineshape constraint

- $H \to Z_1 Z_2 \to 4l$, Z_1 is mostly on-shell with $m(Z_1) \sim m(Z)$
- Use pdf(m_{2l}) for the Z_1 lepton pair to refit the leptons momenta
- Works the best for di-electrons that have a worse momentum resolution
- Overall improvement in the Higgs mass measurement ~ 8%



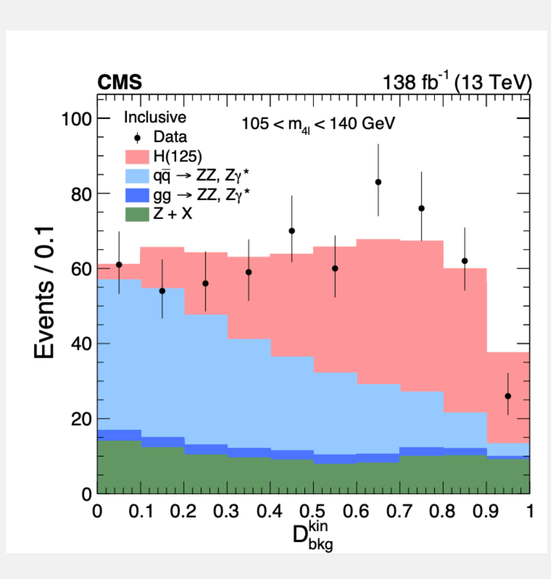
Categorisation based on relative mass resolution ($\delta m_{4l}/m_{4l}$)

- In each of the four-lepton categories, events are further divided into 9 sub-categories based on $\delta m_{4l}/m_{4l}$ to isolate events with better mass resolution
- Per-event lepton momentum resolutions are validated using $Z \to 2l$ events
- Overall improvement in the Higgs mass measurement ~ 8%



Matrix Element (ME) based Kinematic discriminant

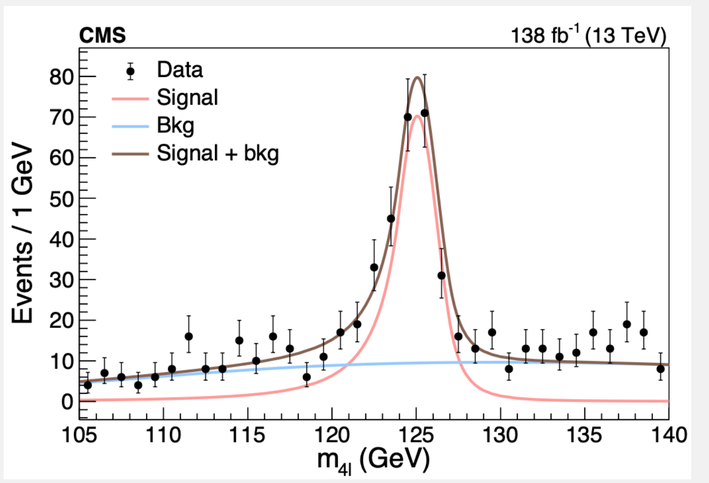
- Built using Kinematic of leptons in the four-lepton COM frame :
  - Ratio R = $|\mathrm{ME}(\mathrm{event}|\tilde{H})/\mathrm{ME}(\mathrm{event}|ZZ)|^2$
  - $\tilde{H}$ - Higgs with mass $m_{\tilde{H}} = m_{4l}$
    ZZ - background
  - R is transformed to $D^{kin}[0,1]$
- Helps separate signal and background
- Introduced in the mass fit as a second observable : pdf (m_{4l}, D^{kin})
- Overall improvement in the Higgs mass measurement ~ 4%



Signal and background modelling

Signal :

- Double-Sided Crystal Ball function (DSCB) for mass measurement
- DSCB convoluted with Breit-Wigner for width measurement (floating mass)

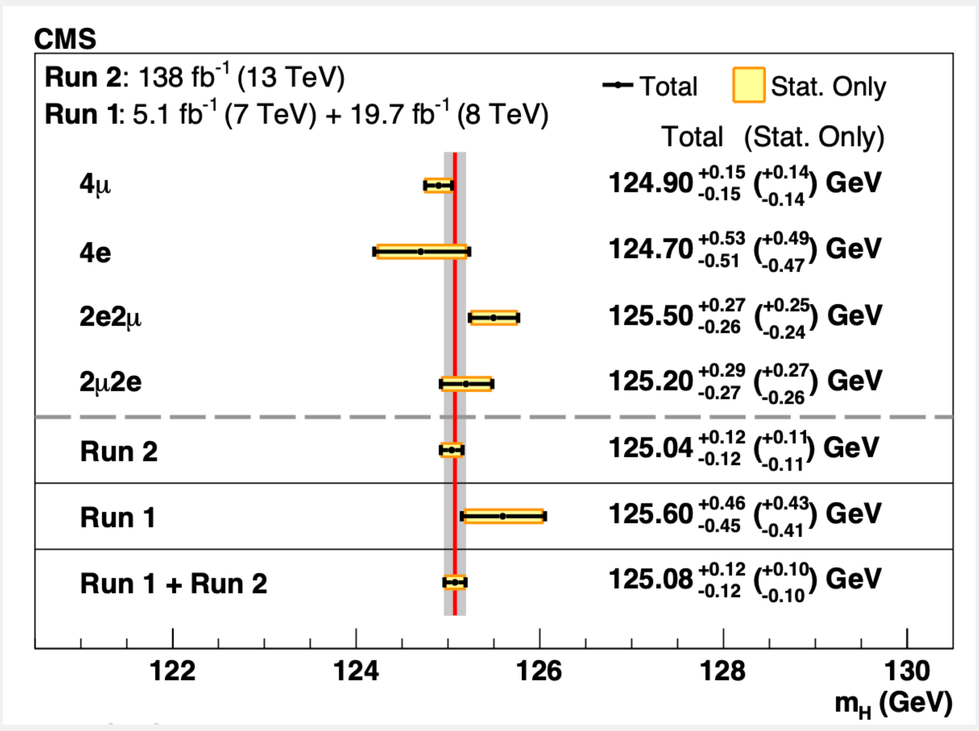


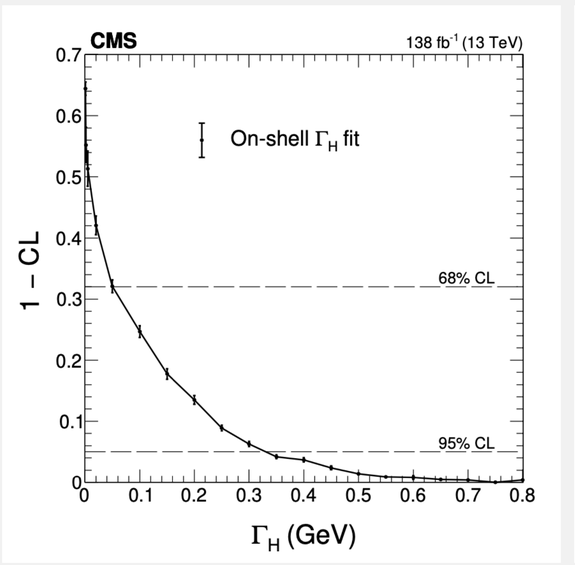
Backgrounds :

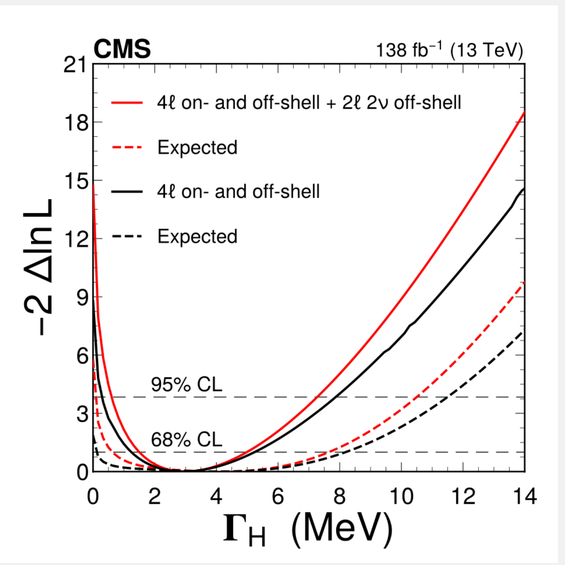
- **Irreducible (qq->ZZ, gg->ZZ)** - estimated from MC
- **Reducible (Z+X),** with at least one non-prompt/misidentified lepton - derived from data

Results

Most precise single-channel measurement of Higgs mass







On-shell width : $\Gamma_H < 50\ (330)$ MeV@68(95)% CL

Indirect width measurement using the **ratio of the off-shell and on-shell Higgs production rates** : $\Gamma_H < 3.0^{+2.0}_{-1.5}$ MeV

Future projections and limitations

- Muon momentum scale (4μ) : 40 MeV
- Electron momentum scale ($4e$) : 200 MeV
- **Future challenge** : If systematic uncertainties remain the same, the Higgs boson mass measurement would be systematic limited before the end of HL-LHC program (3000 fb^{-1})