Measurements of Higgs Parameters with CMS Data

Anna Kropivnitskaya (University of Kansas)

on Behalf of the CMS Collaboration
In 2016, 40.8 fb\(^{-1}\) recorded by CMS
Around 36 fb\(^{-1}\) was certified as good for analysis
Motivation

Detailed measurements of the Higgs boson properties in all possible channels are very important:

- To check Standard Model (SM) prediction
- Test physics beyond SM
In LHC Run 2: the study of Higgs boson reaches "precision" level. The highest resolution channels with full 2016 dataset (36 fb$^{-1}$):

- $H \to ZZ^* \to 4\ell$:
  - Measurements of properties of the Higgs boson in the four-lepton final state at $\sqrt{s} = 13$ TeV
    CMS-HIG-16-041, arXiv:1706.09936, sub. to JHEP
  - Constraints on anomalous Higgs boson couplings in production and decay $H \to 4\ell$
    CMS-HIG-17-011, arXiv:1707.00541, sub. to PLB

- $H \to \gamma\gamma$:
  - Measurements of properties of the Higgs boson in the diphoton decay channel with the full 2016 data set
    CMS-HIG-16-040
  - Measurement of differential fiducial cross sections for Higgs boson production in the diphoton decay channel in pp collisions at $\sqrt{s}=13$ TeV
    CMS-HIG-17-015
(CMS-HIG-16-041)

- Four isolated leptons (e, μ) with excellent momentum resolution: two pairs of same flavour, opposite sign leptons: 4e, 4μ, 2e2μ or 2μ2e
- S/B ratio (~2:1)
- Small background from ZZ and (reducible) from Z+X
- Event Categories are defined to improve sensitivity
Fiducial cross section at $m_H = 125.09$ GeV

$$\sigma_{\text{fid}} = 2.90^{+0.48}_{-0.44}\,(\text{stat})^{+0.27}_{-0.44}\,(\text{sys})\,fb$$

$$\sigma_{\text{fid}}^{SM} = 2.72 \pm 0.14 \, fb$$

Good agreement with SM predictions
Observed values of the signal strength
\( \mu = \sigma / \sigma_{SM} = 1.05^{+0.19}_{-0.17} \)
for the seven event categories

Result of the 2D likelihood scan for
the \( \mu_{ggH,ttH} \) and \( \mu_{VBF,VH} \) signal-strength modifiers

Good agreement with SM predictions
\( m_H = 125.26 \pm 0.20 \text{ (stat.)} \pm 0.08 \text{ (sys.) GeV} \)

Precision at level of Run 1 ATLAS+CMS combination (125.09 ± 0.21 (stat.) ± 0.11 (syst.) GeV)
\( \Gamma_H < 1.10 \text{ GeV at 95\% CL} \)

- Direct measurement with on-shell production, no assumptions on BSM physics
- Measurement limited by \( m_{4l} \) resolution, only sensitive at the \( \sim 1 \text{ GeV} \) level
- Indirect (off-shell measurement) was performed on Run 1 data (\textit{JHEP} 09 (2016) 051) with ZZ&WW combination on observed (expected): \( \Gamma_H < 13 \) (26) MeV at 95\% CL
H→ZZ*→4l: Anomalous Couplings

- Use ME techniques (MELA package) to extract coupling information in H → 4l decays
- Discriminants to suppress background, to separate BSM and SM, and to isolate interference of BSM and SM
- Target associated Higgs boson production with two quark jets in either vector boson fusion or associated production with a vector boson
- Effective cross-section ratios $f_{ai}$ (= 0 for SM) and coupling phases $\phi_{ai}$ allowed 68% CL (central values with uncertainties) and 95% CL (ranges in square brackets) intervals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Observed</th>
<th>Expected</th>
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<tbody>
<tr>
<td>$f_{a3} \cos(\phi_{a3})$</td>
<td>$0.00^{+0.26}_{-0.09} [-0.38, 0.46]$</td>
<td>$0.000^{+0.010}_{-0.010} [-0.25, 0.25]$</td>
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<tr>
<td>$f_{a2} \cos(\phi_{a2})$</td>
<td>$0.01^{+0.12}_{-0.02} [-0.04, 0.43]$</td>
<td>$0.000^{+0.009}_{-0.008} [-0.06, 0.19]$</td>
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<tr>
<td>$f_{\Lambda 1} \cos(\phi_{\Lambda 1})$</td>
<td>$0.02^{+0.08}_{-0.06} [-0.49, 0.18]$</td>
<td>$0.000^{+0.003}_{-0.002} [-0.60, 0.12]$</td>
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<tr>
<td>$f_{Z\gamma} \cos(\phi_{Z\gamma})$</td>
<td>$0.26^{+0.30}_{-0.35} [-0.40, 0.79]$</td>
<td>$0.000^{+0.019}_{-0.022} [-0.37, 0.71]$</td>
</tr>
</tbody>
</table>

Results are consistent with SM prediction.
H→γγ: Couplings

**Results are consistent with SM prediction**

**Events categorized into VBF-like, ttH-like, VH-like and “untagged”**

**ttH-like:** 3.3σ evidence for signal strength $\mu = 2.2^{+0.9}_{-0.8}$
H→γγ: Inclusive Fiducial Cross Section

*(CMS-HIG-17-015)*

Inclusive fiducial cross section
Compared to MADGRAPH_aMC@NLO
prediction normalised to
HXSWG YR4 total cross section

Weighted mass spectrum
by S/(S+B)

19.7 fb⁻¹ (8 TeV) + 35.9 fb⁻¹ (13 TeV)

**CMS Supplementary**

- Data (best-fit $m_\ell$)
- syst. uncertainty
- SM ($m_\ell=125.09$ GeV)
  - norm. LHC Higgs XSWG YR4
  - aMC@NLO

**CMS Preliminary**

All categories
S/(S+B) weighted

- Data
- S+B fit
- B component

B component subtracted

19 August       ICNFP2017                                                A. Kropivnitskaya           “Higgs Parameters at CMS”
Both $p_T^{\gamma\gamma}$ and $N_{\text{jet}}$ differential cross sections are in good agreement with SM prediction.
LHC Run 2 data set allows study of properties of the Higgs boson

Measurements performed using 2016 data show good compatibility with SM prediction, both inclusively and differentially

Precision on $m_H$ from CMS Run 2 is the same as Run 1 ATLAS+CMS combination

The results on HVV anomalous coupling are presented

Other Higgs channels will be covered today by Valeria Botta in her talk: “Measurements of the Higgs H(125) boson at CMS”

We expect much more data coming in 2017
→ we will improve precision of the measurements, which are mostly statistically limited

Thanks to NSF support
Back up slides
Large Hadron Collider
The effective fractional cross sections \( f_{ai} \) and phases \( \phi_{ai} \):

\[
f_{ai} = |a_i|^2 \sigma_i \left/ \sum |a_j|^2 \sigma_j \right. \quad \text{and} \quad \phi_{ai} = \arg \left( \frac{a_i}{a_1} \right)
\]