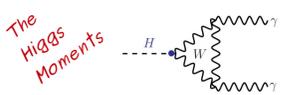# Differential measurement of signal strength of the Higgs boson in diphoton decay channel with the CMS detector
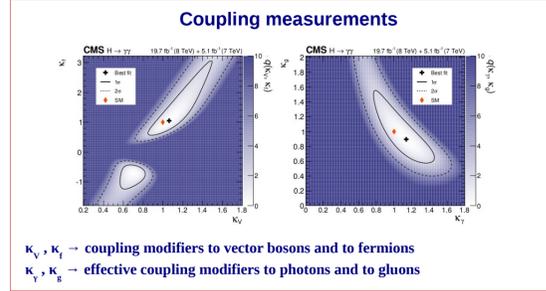
Swagata Mukherjee, Saha Institute of Nuclear Physics, Kolkata, India
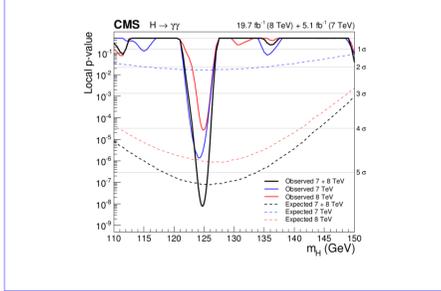
On behalf of CMS collaboration

The Higgs Moments   *The Higgs Moments*

Run1 Legacy Results

Data samples : 5.1 fb^{-1} at 7 TeV & 19.7 fb^{-1} at 8 TeV

Coupling measurements

κ_V , κ_f → coupling modifiers to vector bosons and to fermions
κ_γ , κ_g → effective coupling modifiers to photons and to gluons

Signal observed in the γγ channel at a mass of 124.7 GeV
Local significance : 5.7 σ
Expected : 5.2 σ

Best-fit signal strength relative to the standard model prediction is
1.14 (+0.26 / -0.23) = 1.14 (+0.21 / -0.21)(stat.) (+0.09 / -0.05)(syst.) (+0.13 / -0.09)(theory)
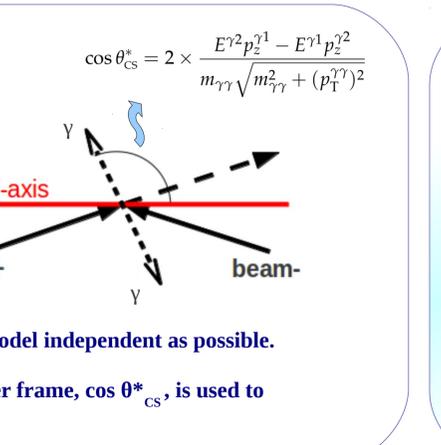
Measured mass : 124.70 ± 0.34 GeV = 124.70 ± 0.31 (stat.) ± 0.15 (syst.) GeV
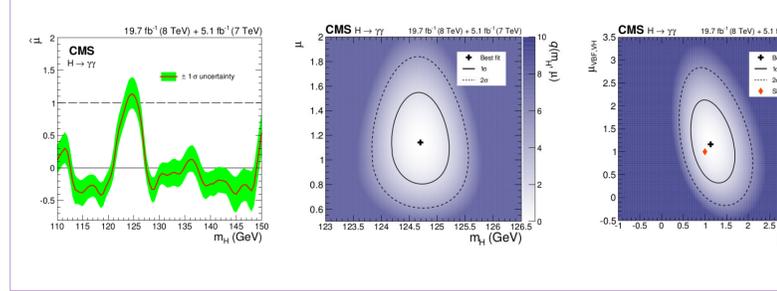
Results are consistent with SM Higgs boson

Spin Analysis with H → γγ

Introduction

- Landau–Yang theorem forbids the direct decay of a spin-1 particle into a pair of photons.

- We want to compare the hypothesis of a spin-2 "graviton-like" model with minimal couplings (2+), to that of a spin-0 SM-Higgs-boson-like (0+) model.

- 2+ is just one of many possible realizations of the spin-2 tensor structure. So, attempt has been made to make the analysis as model independent as possible.

- The cosine of the scattering angle in the Collins–Soper frame, cos θ*$_{CS}$, is used to discriminate between the two hypotheses.

$$\cos\theta^*_{CS} = 2 \times \frac{E^{\gamma 2} p_z^{\gamma 1} - E^{\gamma 1} p_z^{\gamma 2}}{m_{\gamma\gamma}\sqrt{m_{\gamma\gamma}^2 + (p_T^{\gamma\gamma})^2}}$$

CS-axis
beam+   beam-

Pre-selection Cut

- **Barrel : |η| < 1.4442**
  Endcap : 1.566 < |η| < 2.5

- **Leading photon : $p_T / m_{\gamma\gamma}$ > 1/3**
  Sub-leading photon : $p_T / m_{\gamma\gamma}$ > 1/4

- **Electron veto**

- **Cut on the amount of hadronic leakage of the shower**

- **Loose cut on shower shape variable**

- **Loose pre-selection based on isolation**

Cut based photon identification

Photon identification is performed by applying a set of cuts in categories. Four categories defined in terms of pseudorapidity and R9. Cuts are applied on the following variables

- **Isolation variables**

- **Amount of hadronic leakage of the shower (H/E)**

- **shower shape variables**

Event Categorization

To increase the sensitivity, the events are categorized in four diphoton event classes

Category 0	$|\eta|_{max} < 1.5$	and	$R9_{min} > 0.94$
Category 1	$|\eta|_{max} < 1.5$	and	$R9_{min} \leq 0.94$
Category 2	$|\eta|_{max} > 1.5$	and	$R9_{min} > 0.94$
Category 3	$|\eta|_{max} > 1.5$	and	$R9_{min} \leq 0.94$

Within each diphoton class, the events are binned in |cos θ*$_{CS}$| to discriminate between the different spin hypotheses

Spin Category 0	$|\cos(\theta^*_{CS})| < 0.2$
Spin Category 1	$0.2 \leq |\cos(\theta^*_{CS})| < 0.375$
Spin Category 2	$0.375 \leq |\cos(\theta^*_{CS})| < 0.55$
Spin Category 3	$0.55 \leq |\cos(\theta^*_{CS})| < 0.75$
Spin Category 4	$0.75 \leq |\cos(\theta^*_{CS})| < 1.0$

In total, the analysis is split into 40 event classes :
(4 η/R9 categories × 5 |cos(θ*$_{CS}$)| categories × 2 center of mass energy (7 and 8 TeV)

Signal Model and Background Model

The signal models are obtained from MC simulation.

- **Spin-0 SM processes (ggH, qqH, VH, ttH) : NLO matrix-element generator POWHEG (interfaced with PYTHIA)**

- **Spin-2 graviton-like processes (gg, qq) : JHU generator at leading-order (interfaced with PYTHIA)**

- **All samples are run through the full CMS simulation using GEANT-4**

Background model is data-driven. It is obtained by fitting the diphoton mass spectrum, in each of the event classes, over the range 100 < m$_{\gamma\gamma}$ < 180 GeV. A bias study has been performed to make sure that any systematic bias incurred by the choice of function is less than 20% of the statistical uncertainty. Polynomials of order 4 or 3 are found to fulfill this criteria for all categories in all cosθ*$_{CS}$ bins.

Systematics

The systematic uncertainties calculated at the single photon level are :
- **Photon selection efficiency**
- **Energy scale and resolution**
- **Photon identification**
- **R9 selection**

The systematic uncertainties calculated at the event level are :
- **Integrated luminosity**
- **Vertex finding efficiency**
- **Trigger efficiency**
- **Higgs p$_T$ spectrum**

The theoretical systematic uncertainties considered are :
- **Production cross section**

Results

The separation between the two models (2+ and 0+) is extracted using a test statistic defined as

$$q = -2\ln(\mathcal{L}_{2_m^+ + bkg} / \mathcal{L}_{0^+ + bkg})$$

The test is made under the assumption that the 2$^+$ state is produced

1) **Either entirely by gluon-fusion**
2) **OR entirely by quark-antiquark annihilation**
3) **OR by three intermediate mixtures of gg and qq**

The fraction of the spin-2 state produced by qq annihilation is parameterized by the variable f$_{qq}$
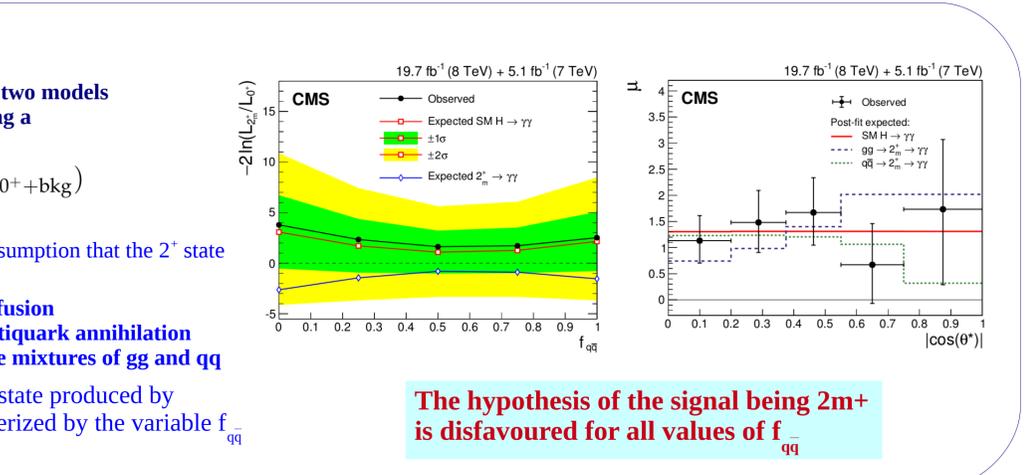
The hypothesis of the signal being 2m+ is disfavoured for all values of f$_{qq}$

The excitement is not over yet ...

"Coming soon" : Differential cross section of Higgs boson

Direct measurement of differential cross section of the Higgs Boson further elucidate its production and decay properties, and thus complement earlier analyses of its spin and couplings.

H → γγ is an ideal channel to measure the differential cross section of Higgs boson because of relatively high signal yield (~ 480 expected at 8 TeV)

Deviation of observed distributions w.r.t the expected ones from the Standard Model may put stress on the properties of the Higgs boson and point to alternate models. Measurement of differential cross section will also allow to test perturbative QCD predictions in the Higgs sector.

Target observables

Higgs p$_T$, Higgs rapidity ——→ Related to production mode of Higgs

Δφ(γ$_1$, γ$_2$) ——→ Related to decay mode of Higgs

leading jet p$_T$, M$_{jj}$, Δφ(j$_1$, j$_2$) ——→ Related to additional jet activity in a Higgs event

etc..

Analysis Strategy

- Divide the dataset into bins of a observable
- Perform a simultaneous (Signal + Background) fit in all bins of the observable
- Report the number of fitted signal events in each bin
- Unfold the data and compare with theory predictions

STAY TUNED!

References

- **CMS Collaboration :** CMS-PAS-HIG-13-001 : Updated measurements of the Higgs boson at 125 GeV in the two photon decay channel
- **CMS Collaboration :** CMS-PAS-HIG-13-016 : Properties of the observed Higgs-like resonance using the diphoton channel