Higgs Analysis in 4mu channel with CMS experiment

The 4th school on High Energy Physics

29-4-2014

Nicola De Filippis – Ahmed Abdelalim – Simranjit Chhibra

- Reham Aly

Outlines

- Introduction
- Background estimation
- Muon Efficiency
- Final result
- P- value test
- Future work

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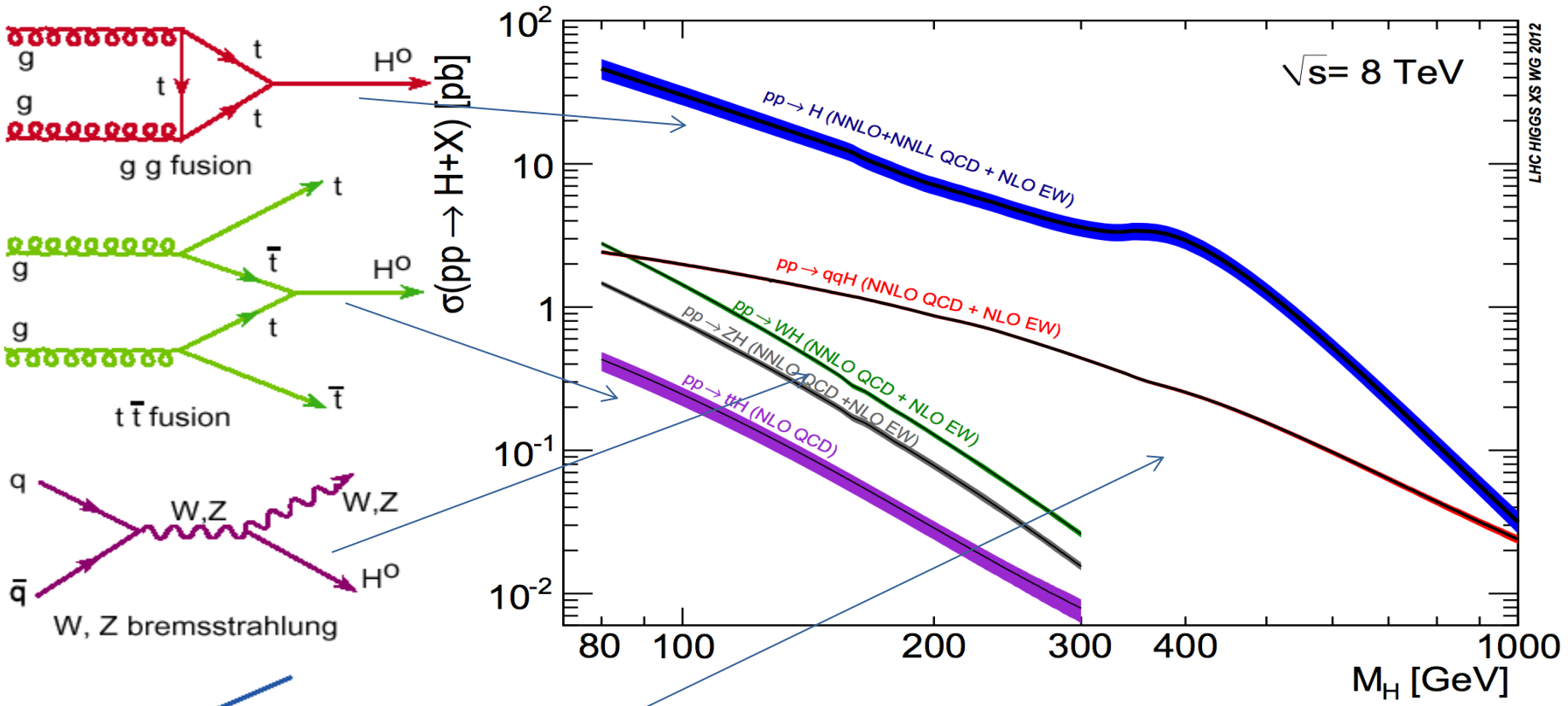
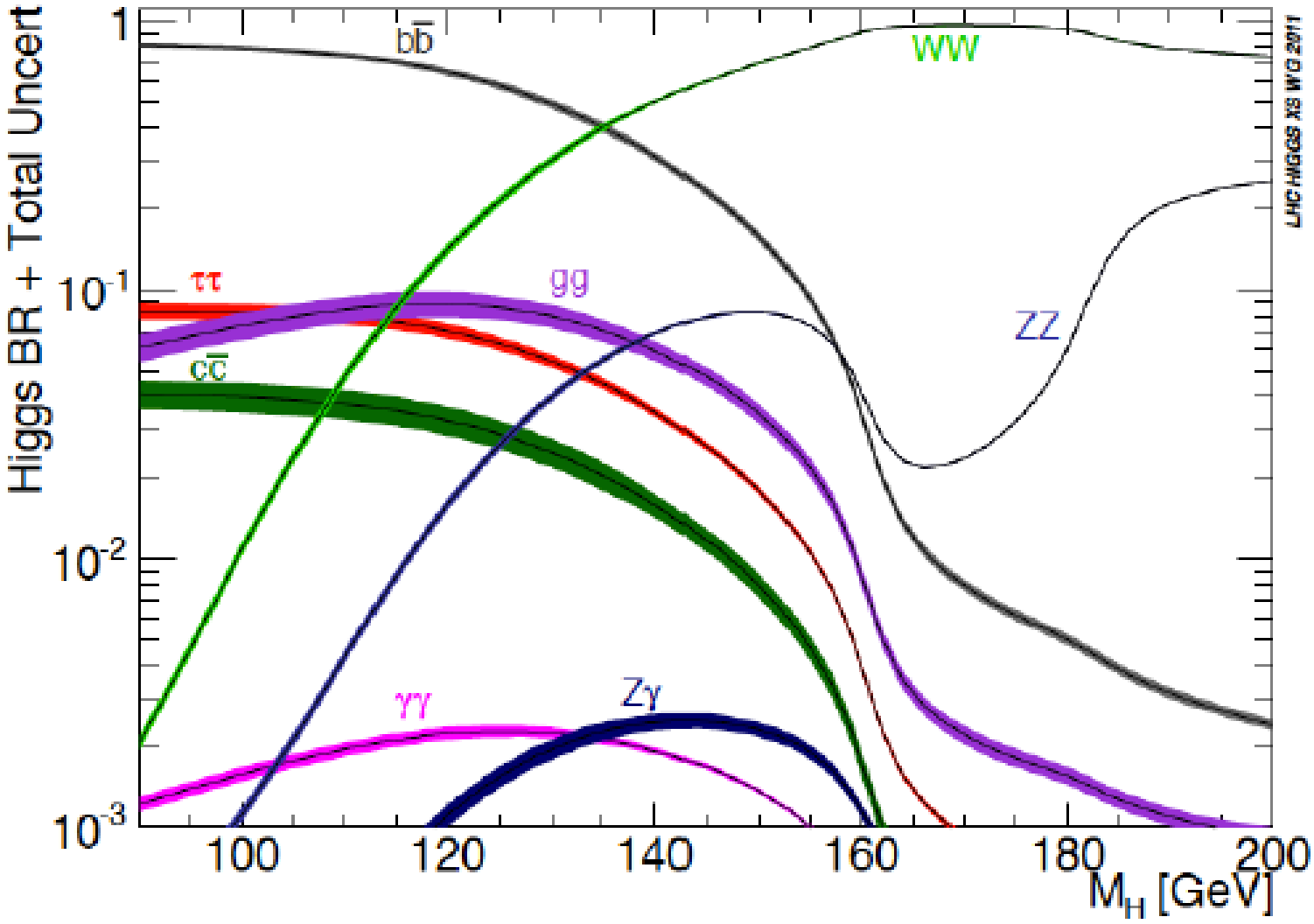
SM Higgs production @ LHC



Processes

- Gluon-Gluon fusion
- Vector Boson Fusion
- W/Z Associated production
- Top associated production

Higgs decay channels



H->ZZ*->4l(4μ)

- Data: integrated luminosity of 5 fb-1 at 7 TeV in 2011, 19.8 fb-1 at 8 TeV in 2012
- Signatures: 4l(mu) final state "Golden channel"
- backgrounds:
  - irreducible ZZ
  - reducible Zbb, tt with leptons from b hadrons decays
  - reducible Z+jets, W+jets, QCD with fake leptons
- Selection strategy and observables:
  - 4 well reconstructed and isolated leptons
  - leptons coming from the primary vertex
- Results:
  - 4l invariant mass
  - p-value for discovery
  - sigma95/sigma SM for exclusion
  - discrimination of spin/parity hypotheses

Background

- irreducible ZZ background (From MC)
- Reducible Background

Zbb, tt , Z+jets, W+jets and QCD

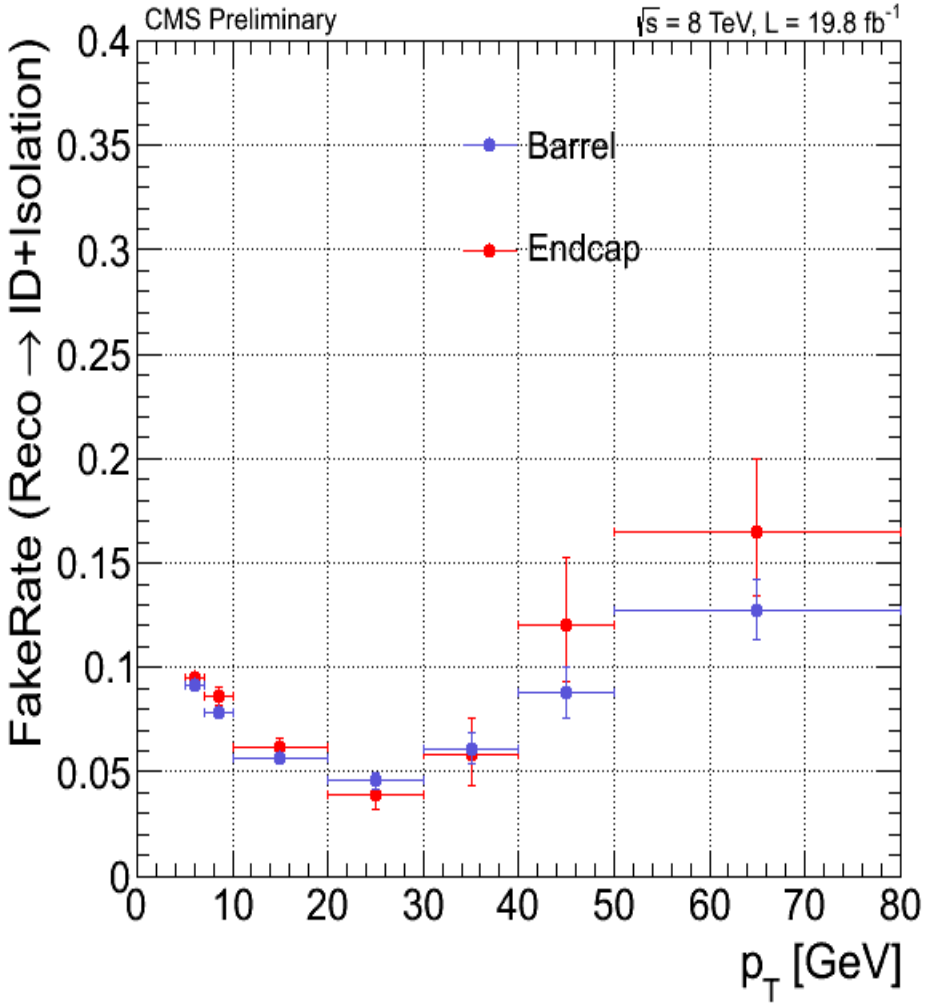
We estimate these background from data by Fake rate method (FR)

Estimation of Z+X background from data using Fake rate method

- Step1: Measuring the fake rate in 3 lepton phase space

(Leading Z + one object)

- FR = No. of Jets passing identification and iso. / Total no. of jets
- Jet $\rightarrow$ μ fake rate: measured using Z $\rightarrow$ μ μ + μ and Z $\rightarrow$ ee + μ events



Estimation of Z+X background from data using Fake rate method

Applying the measured FR in the regions defined as

- Leading Z + 2 opposite charge objects
- M 4l > 70 GeV

➢ Cat 0 (2P2F) : Leading Z + 2 fakeable objects (O1 and O2)

- Both O1 and O2 should fail ID or ISo

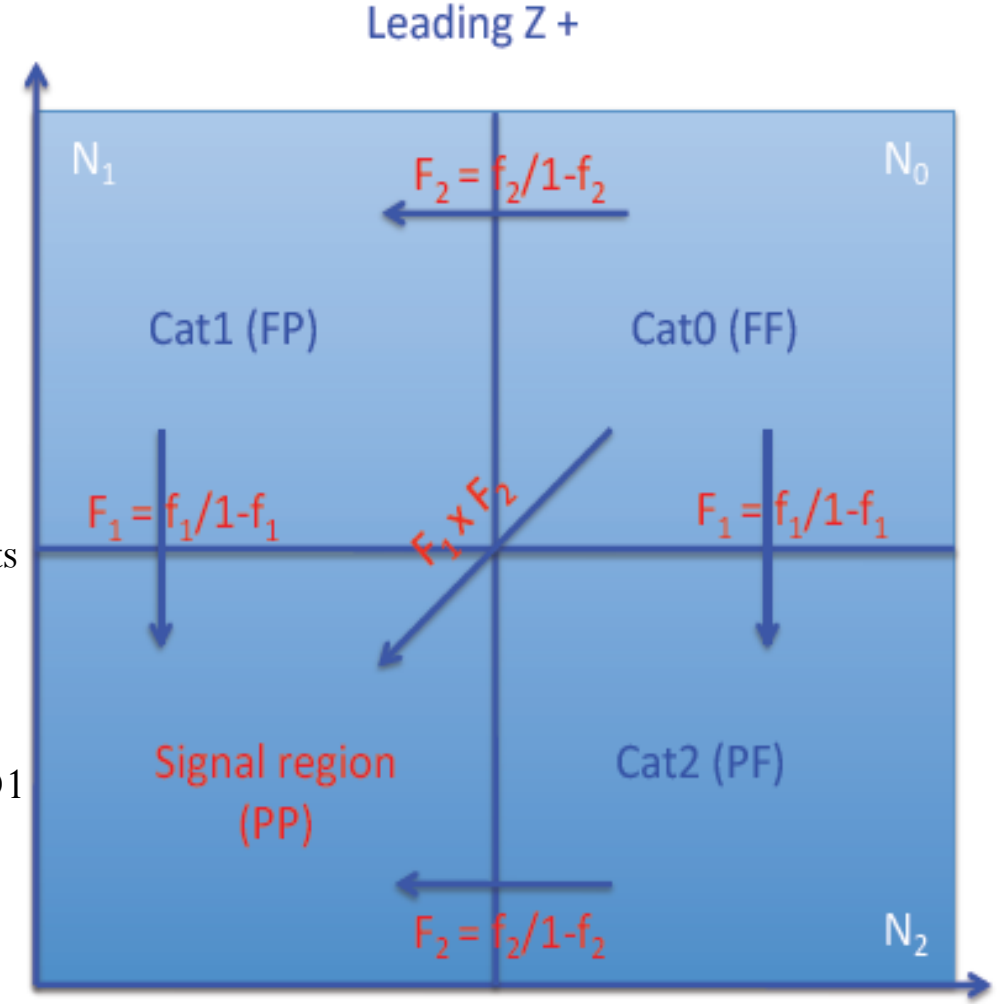
➢ Cat 1 (3P1F) : Leading Z + 1fakeable objects (O1) + 1 real object (O2)

- O2 should pass ID and ISO & O1 should fail eithe ID or ISO

➢ Cat 2 (3P1F) : Leading Z + 1 real objects(O1) + 1 fakeable object (O2)

- O1 should pass ID and ISO & O2 should fail eithe ID or ISO

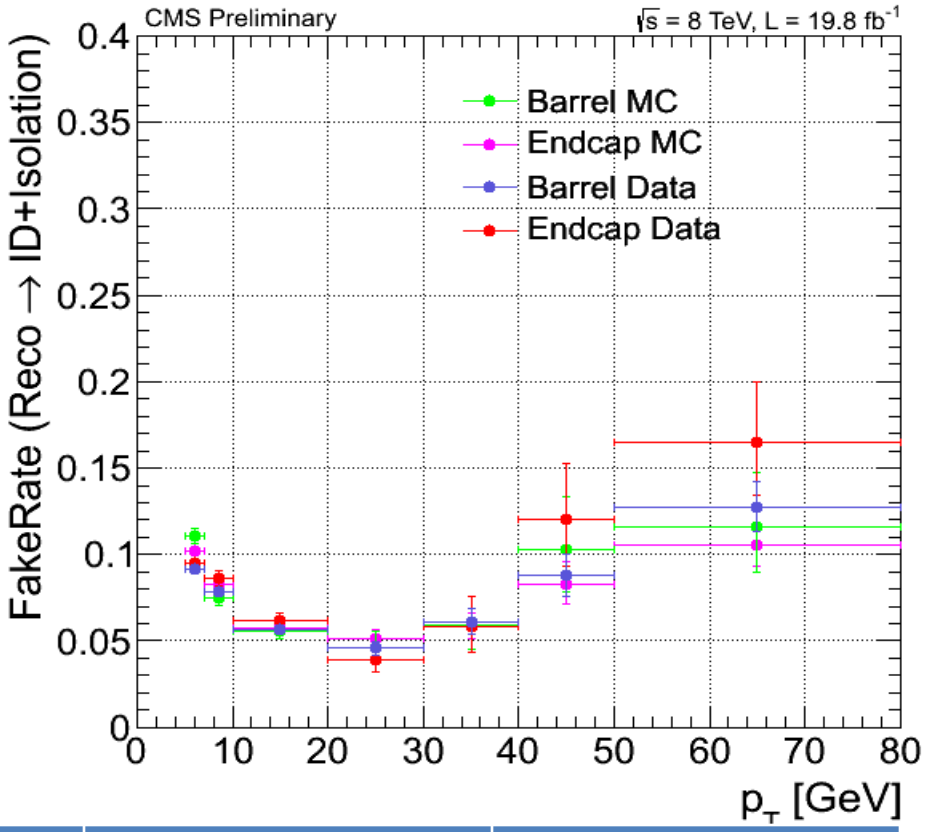
Final Estimation :



$$N_{tot}^{est} = N_0 \times F_1 \times F_2 + (N_1 - N_0 \times F_2) \times F_1 + (N_2 - N_0 \times F_1) \times F_2 = N_1 \times F_1 + N_2 \times F_2 - N_0 \times F_1 \times F_2$$

Estimation of Z+X background from data using Fake rate method

- ZZ part is the fraction of zz estimated by the same FR method from MC and subtracted from data
- Then we calculate the fake rate also for MC by same way
- Similar behavior but Not good agreement between Data & MC .



	8TeV	Data	ZZ part	Final Estimation
Data	4 μ	4.03	1.26	2.77 ±0.67

	8TeV	Final Estimation
MC	4 μ	1.41 ± 0.53

Selection Strategy

- Firstly : Muon selection "Good Muons"
  - PF muon
  - Global || tracker
  - PT > 5 GeV
  - $|\eta| < 2.4$
  - Significance of the Impact Parameter SIP < 4
  - Relative PFIso < 0.4

Muon efficiency
Tag & probe method

- This method for measuring the efficiency of muon in different stages of muon identification, SIP, Isolation and trigger for the muons used in the 4mu final state.
- Tag muon :Pass tight selection (PT>20)
- Probe :Loose selection (PT>5)
- Tag&&Probe Pair

Tag &Probe (TnP) pair with opposite charge & inv.Mass in70<M<130GeV

- Typical decomposition of Muon efficiency

$$\varepsilon = \varepsilon(\text{Tracking}) \times \varepsilon(\text{ID}|\text{Tracking}) \times \varepsilon(\text{SIP}|\text{ID}) \times \varepsilon(\text{ISO}|\text{SIP}) \times \varepsilon(\text{trg}|\text{ISO})$$

  - Tracking efficiency $\longrightarrow$ provided by Tracking POG
  - Loose Muon ID efficiency
  - SIP efficiency
  - Isolation efficiency
  - Trigger efficiency

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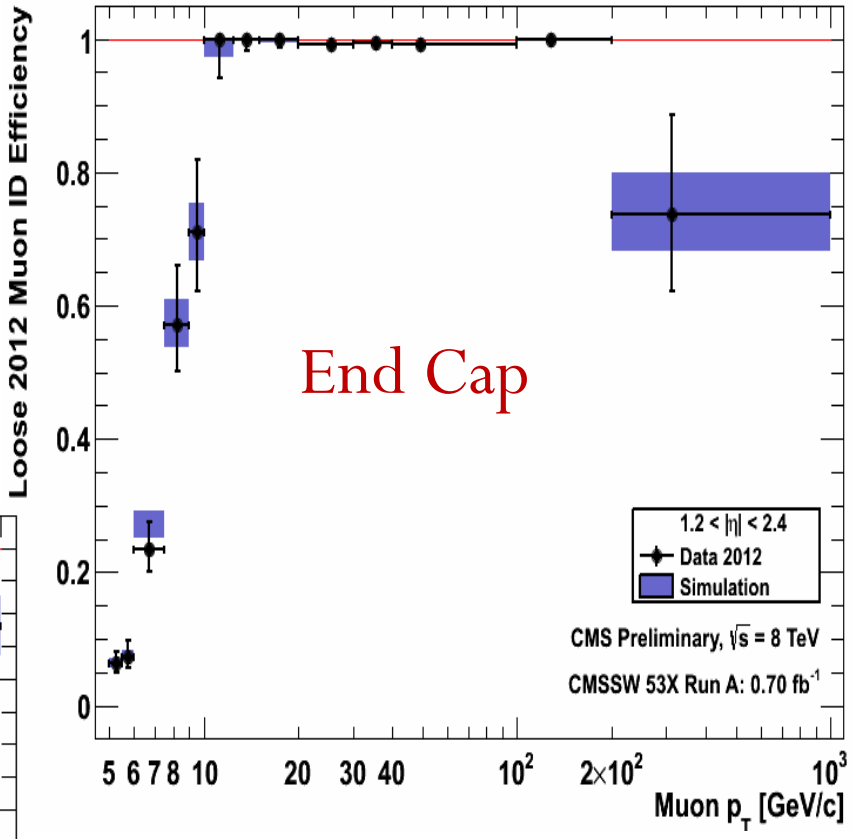
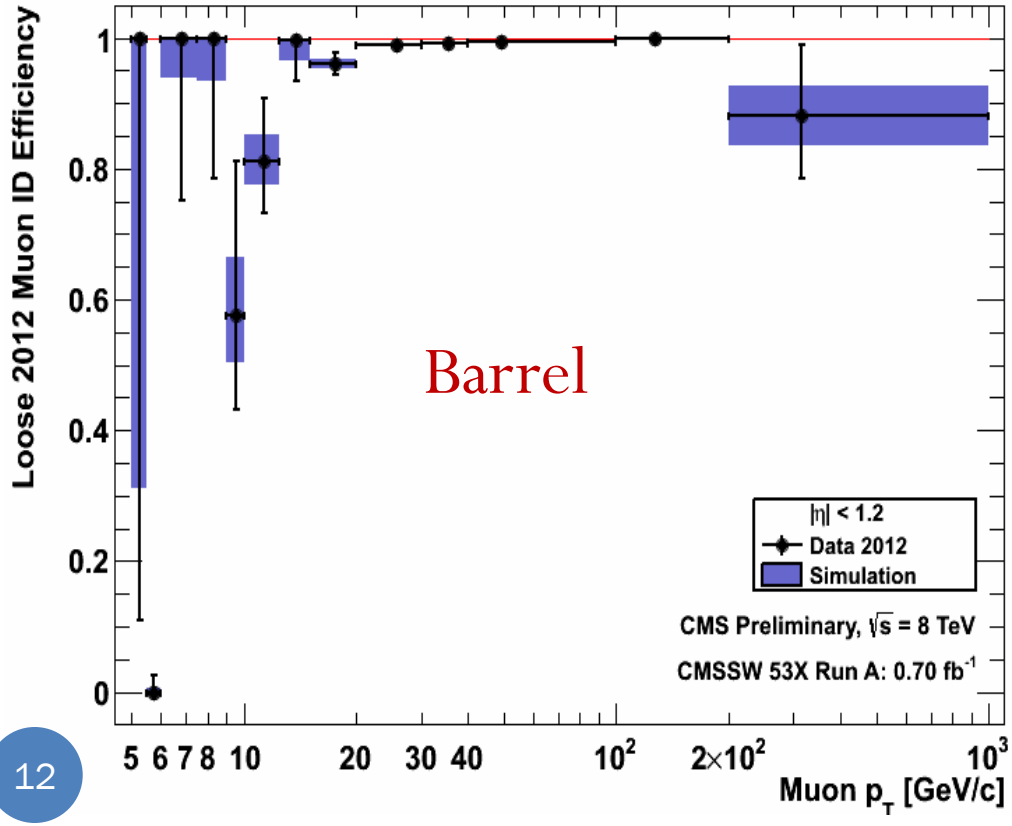
➢Loose 2012 Identification (ID)

- Loose2012 =
  PF muon &&(Global | | TrackerMuon)
- ϵ (Loose2012 Muon ID | Tracks) =
  Loose2012 Muon ID / All Tracks





➢ Binning

- abseta = (0.0, 1.2, 2.4)
- pt = (5.0, 5.5, 6.0, 7.5, 9.0, 10, 12.5, 15, 20, 30, 40, 100, 200, 1000)

Selection Strategy

Secondly : Full selection

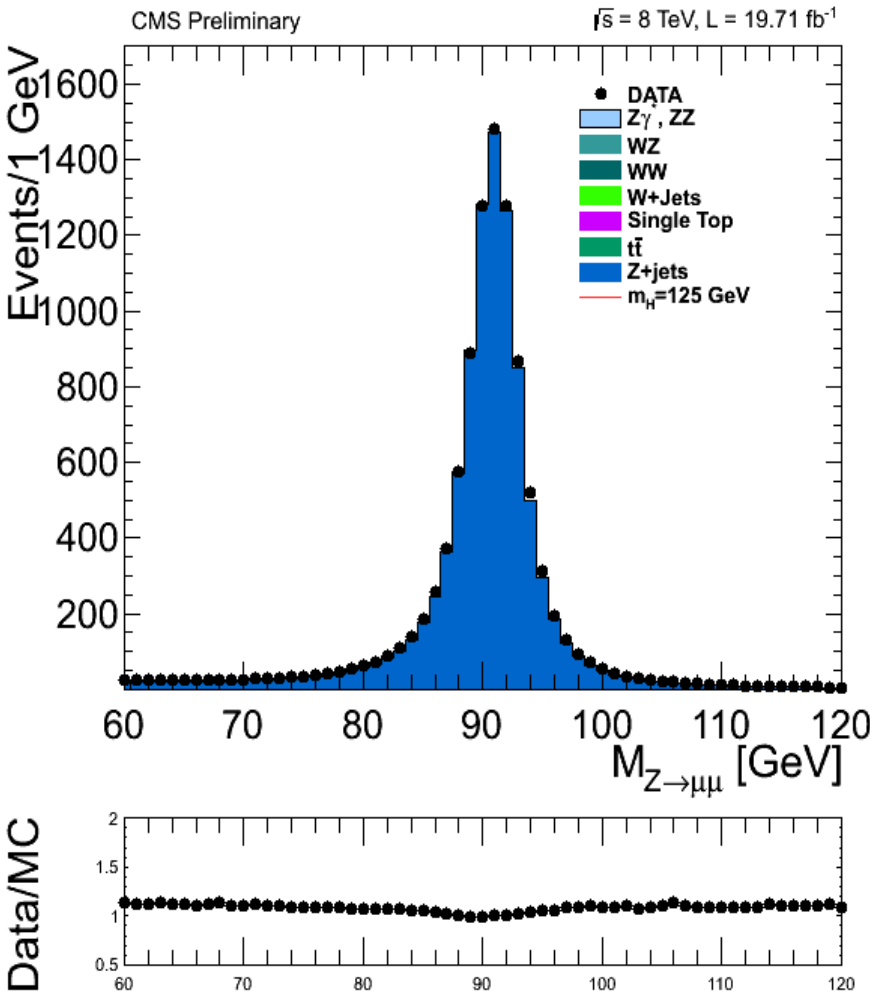
- Select best Z1candidate: opposite charge, same flavor leptons satisfying pT1 > 20GeV ,pT2> 10GeV, satisfying PFISo and SIP (in object selection)
- Z1 lept. cuts" - Good leptons with mll closest to mZ
- Z1+#gamma" - Include FSR in mll
  - Photon cleaning: (if photon –electron deltaR<0.15 photon is removed, select closest mass to Z (mll or mllgamma)).
- m_{Z1} cut" - 40 < mll < 120 (Step 3)
- at least 4l" - Four good leptons
  - Add third lepton of any charge to make Z1+ L
  - Add fourth Lepton of same flavor and opposite charge as third lepton to form Z2
  - (if there exists more than one candidate, choose one with highest pT leptons)
- Off shell Z bosson with mass <40
- m4l > 100

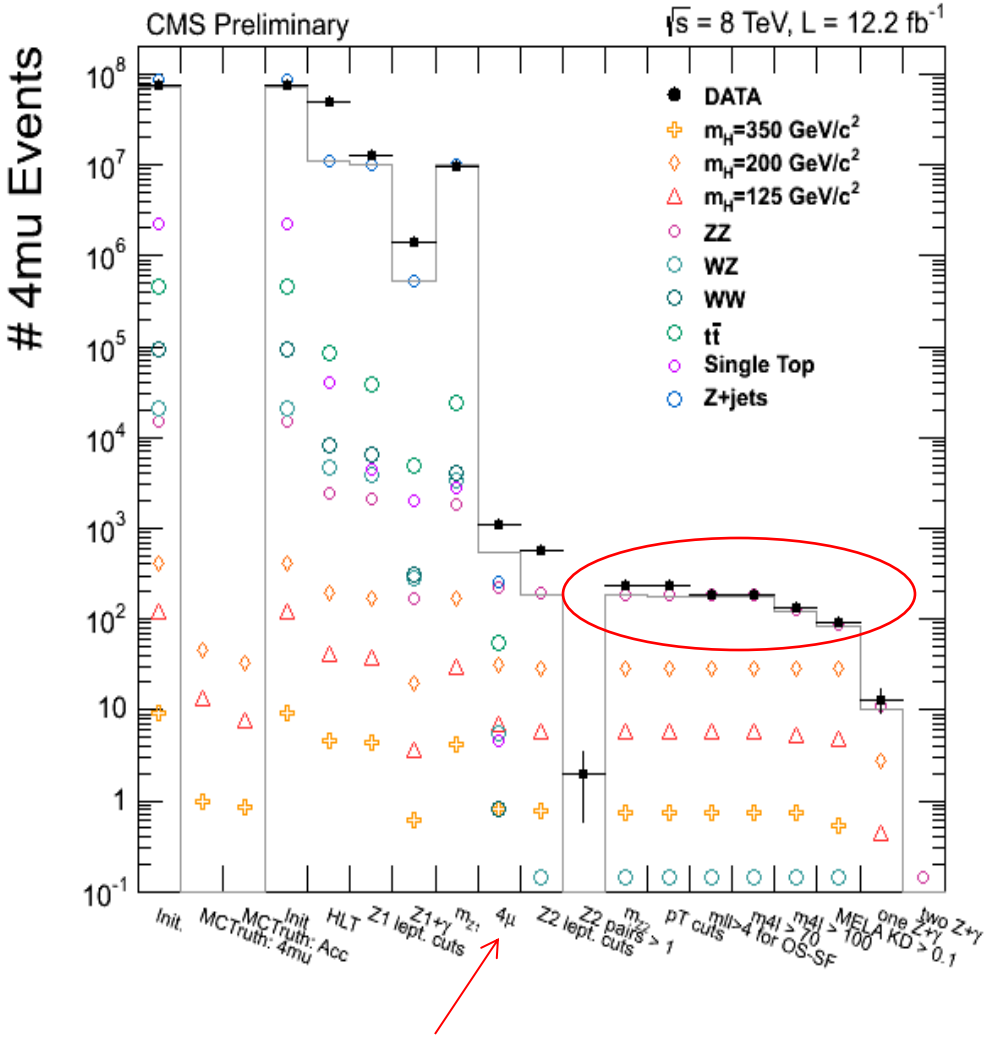
➢ Step 3

- Good leptons with mll closest to mZ

(1st Z candidate)

- 40 < mll < 120





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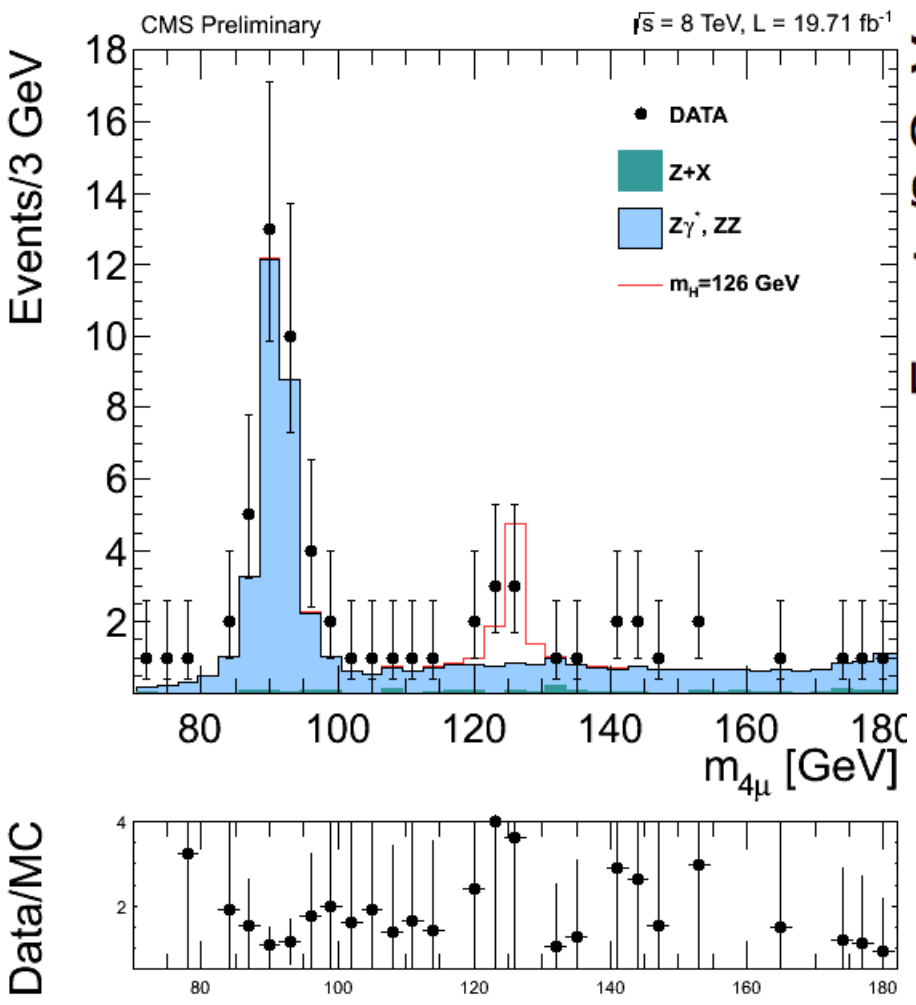
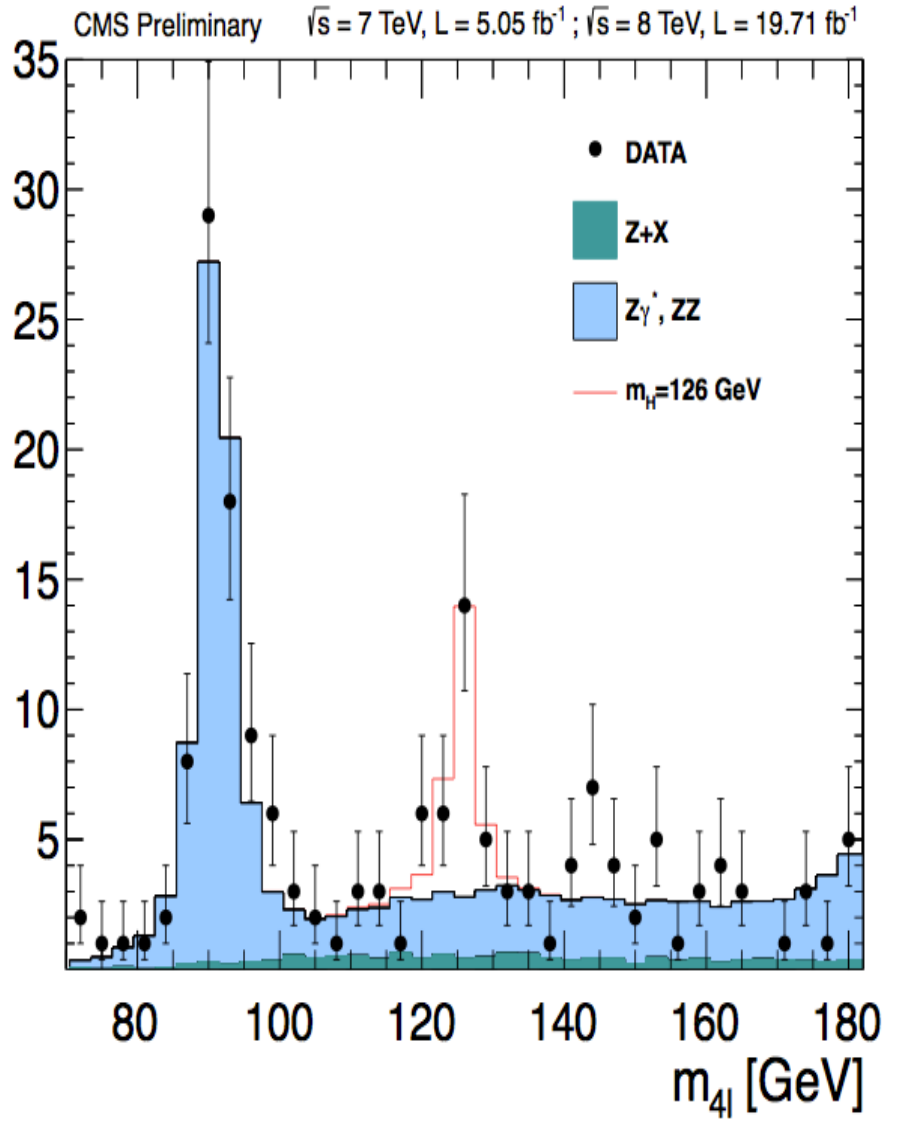
Final Result @ 7+8 TeV (4L)





- Ratio between Data && Bkg
- Signal H=126

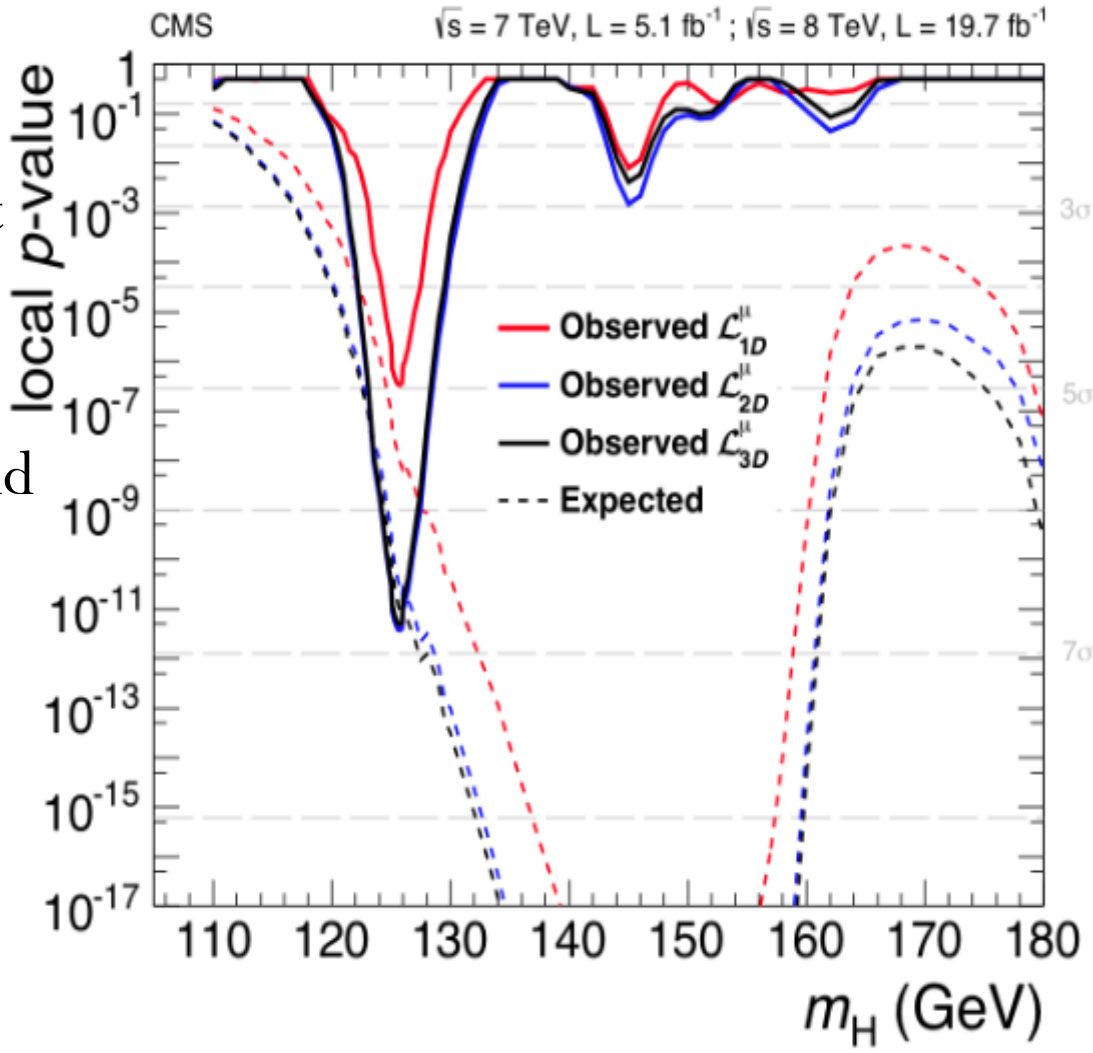
Final Result @ 7+8 TeV (4L)

Table 1: The number of estimated background and signal events and number of observed candidates, after final inclusive selection, in the full measurement range $121.5 < m_{4l} < 130.5$ GeV. Signal and ZZ background are estimated from Monte Carlo simulation, while Z+X is estimated from data

Channel	$4e$	4μ	$2e2\mu$
$5.05\,\text{fb}^{-1}$ @ 7 TeV			
ZZ background	0.3 ± 0.0	0.5 ± 0.0	0.7 ± 0.0
Z + X	0.1 ± 0.0	0.0 ± 0.0	0.2 ± 0.0
All background expected	0.3 ± 0.0	0.6 ± 0.0	0.9 ± 0.0
$m_H = 125$ GeV	0.5 ± 0.0	1.1 ± 0.0	1.3 ± 0.0
$m_H = 126$ GeV	0.5 ± 0.0	1.1 ± 0.0	1.4 ± 0.0
Observed	0	2	3
$19.71\,\text{fb}^{-1}$ @ 8 TeV			
ZZ background	0.9 ± 0.0	2.2 ± 0.1	2.9 ± 0.1
Z + X	0.3 ± 0.0	0.2 ± 0.0	0.6 ± 0.0
All background expected	1.2 ± 0.0	2.4 ± 0.1	3.5 ± 0.1
$m_H = 125$ GeV	2.3 ± 0.0	5.0 ± 0.0	6.1 ± 0.0
$m_H = 126$ GeV	2.6 ± 0.0	5.6 ± 0.0	7.1 ± 0.1
Observed	4	6	10
$5.05\,\text{fb}^{-1}$ @ 7 TeV and $19.71\,\text{fb}^{-1}$ @ 8 TeV			
ZZ background	1.1 ± 0.0	2.8 ± 0.1	3.6 ± 0.1
Z + X	0.4 ± 0.0	0.2 ± 0.0	0.8 ± 0.0
All background expected	1.5 ± 0.0	3.0 ± 0.1	4.4 ± 0.1
$m_H = 125$ GeV	2.8 ± 0.0	6.0 ± 0.0	7.4 ± 0.0
$m_H = 126$ GeV	3.1 ± 0.0	6.7 ± 0.0	8.4 ± 0.1
Observed	4	8	13

Final Result @ 7+8 TeV

- P- value test :
- "What are the chances that the higgs boson doesn't exist given my data "
- Probability that background fluctuate to give an excess of events equal or larger than what observed

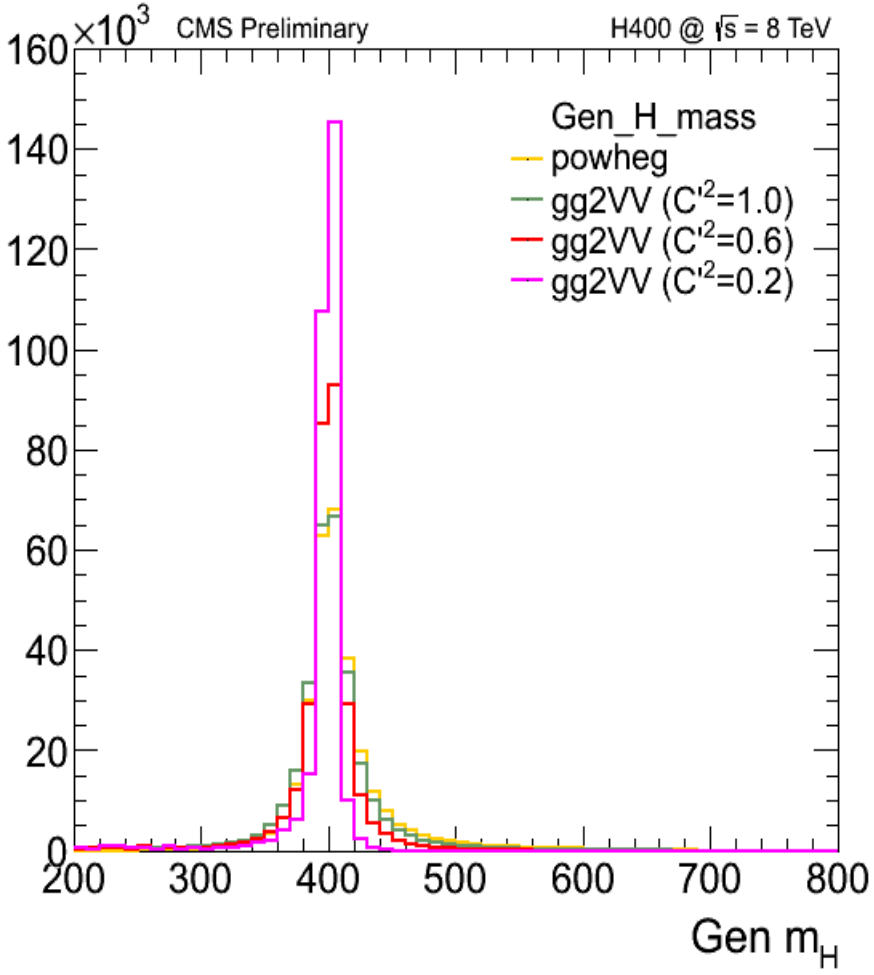


Future plan

- High mass Higgs boson

- For This analysis :
- The same selection will be used.
- We will use the existing lineshape
- Re-weight for the width of the signal
- Re-weight for the interference is needed
  - Different C' values from 0.1 t0 1.0 with Interval 0.1
  - BR new =0

- Data cards for Significance of discover and exclusion



Thanks To

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Thank You!