Search for SM Higgs boson in H→ZZ→2l2ν decay channel at CMS

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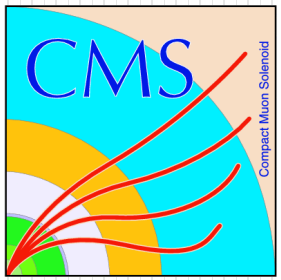
On behalf of the CMS Collaboration



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Outline

- Introduction and Motivation
- Analysis Strategy
- Background Estimation
- Systematics and Limits

Introduction and Motivation

Motivation

- Although SM Higgs excluded in the sensitive range of this analysis at 95% CL but still crucial to understand **vector boson scattering** at high masses
- **VBF** like signature are also under the spotlight
- Channel is sensitive for Higgs masses > 600 GeV where, SM Higgs still not excluded.

Features

- $H \rightarrow ZZ \rightarrow 2l2\nu$ - Most sensitive analysis in high mass Higgs searches
- Pioneering high mass Higgs searches in 2011 along with $H \rightarrow ZZ \rightarrow 2l2q$
- Sensitivity Range : 200 GeV – 600 GeV

Signature of Signal

- Two high p_T isolated leptons of same flavor and opposite charge with di-lepton mass close to Z peak and large MET

Backgrounds

- **Z+Jets** – Most dominant ($\sigma \sim 10^5$ larger than signal)
- Non-Resonant backgrounds like **TT-Jets, Single Top and W+Jets**
- Di-Boson backgrounds – **ZZ, WZ, WW**
- Sub-dominant backgrounds like **QCD**

Analysis Strategy

❑ Analysis Strategy:

- ❑ Analysis is optimized separately for Gluon-Gluon and VBF categories.
- ❑ Selection can be divided into two parts : Pre-Selection + Final Selection

❑ Pre-selection:

- ❑ Events are selected with **2 same flavored, well identified** and **isolated** leptons with **di-Lepton mass** $|M_{ll} - M_Z| < 15$ GeV
- ❑ **Third Lepton Veto:** → to suppress WZ background.
- ❑ **Min $\Delta\phi$(jet,PFMET) < 0.5** → reduce the instrumental background from jet mis-measurements.
- ❑ **P_T (Z) > 55 GeV** → Boosted Z's
- ❑ **Anti b-Tagging**
- ❑ **Soft Muon Veto**

→ To suppress TTbar, Single T

We categorize all events based on the number of jets (P_T >30 GeV) in event.

❑ Final Selection:

- ❑ Missing Transverse Energy: Mass dependent cut for non-VBF category.
- ❑ Mass dependent two sided Transverse Mass of Higgs cut is applied for non-VBF categories.

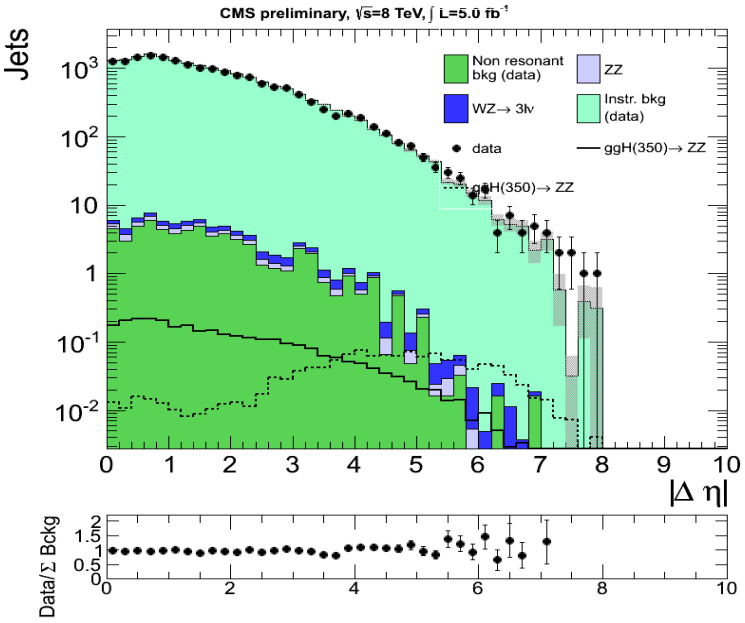
$$M_T^2 = \left(\sqrt{P_{TZ}^2 + M_{ll}^2} + \sqrt{MET^2 + M_{ll}^2}\right)^2 - \left(\vec{P_{TZ}} + \vec{MET}\right)^2$$

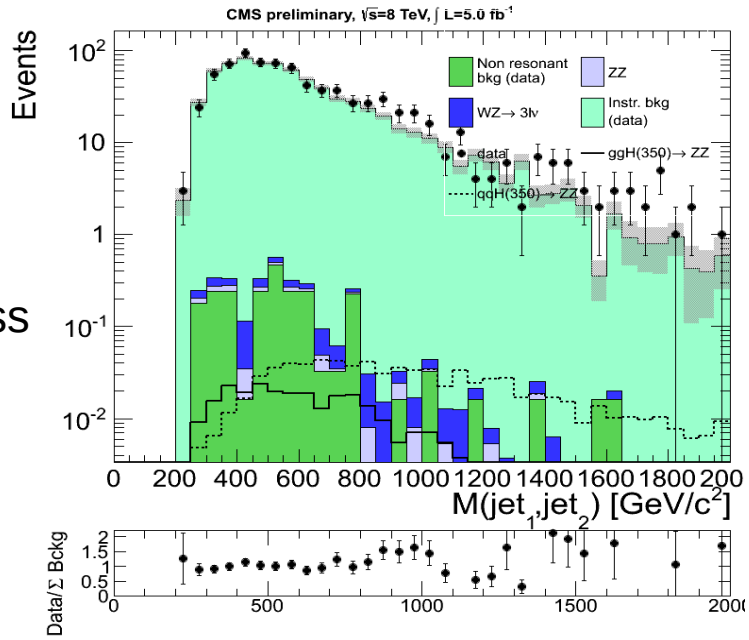
VBF Category

An Event is VBF Tagged if it has:

- ❑ 2 non-b-tagged jets with P_T > 30 GeV
- ❑ $|\Delta\eta|$ > 4.0 between jets
- ❑ di-jet mass M_{jj} > 500 GeV
- ❑ di-lepton between jets
- ❑ Central Jet Veto

Final Selection: PFMET > 70 GeV





- ➢ Including VBF improves sensitivity greatly at low mass
- ➢ Overall increase in sensitivity 2% – 50 %

Background Estimation

In this analysis backgrounds are estimated as follows:

- Z +Jets (mostly instrumental background with fake missing energy) is estimated from data using γ+jets events.
- Non resonant backgrounds (Top/WW/W+Jets, have real MET) are estimated using eμ events
- Irreducible electroweak ZZ background and fully leptonic WZ decays are estimated from Monte Carlo.

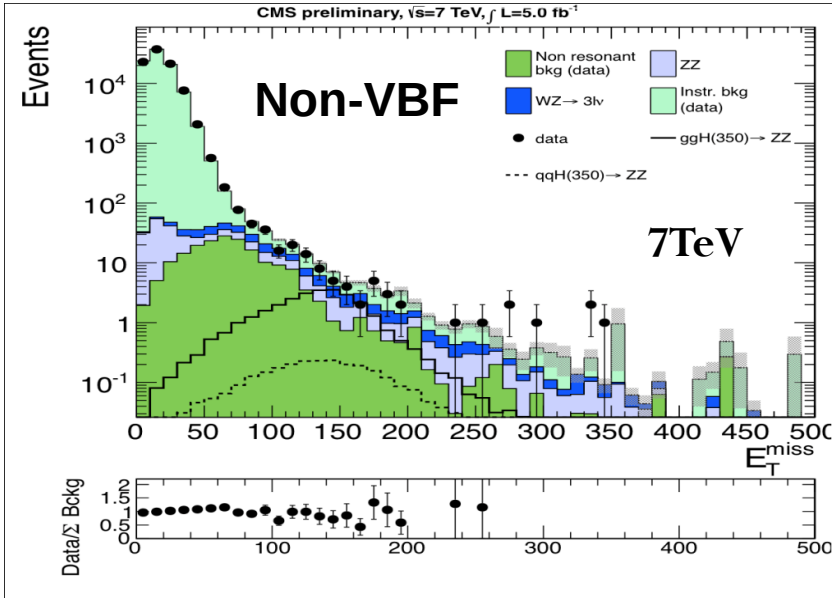
Z+Jets Background Estimation

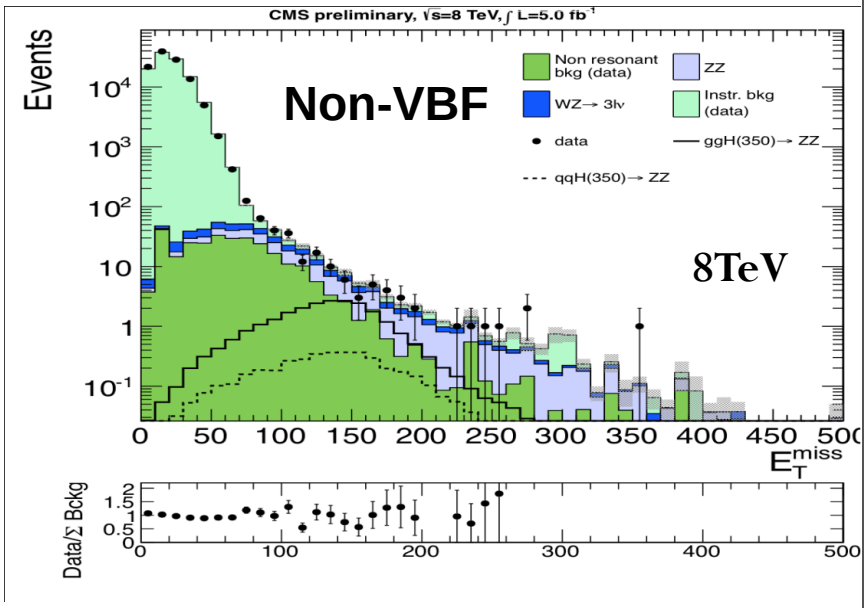
- γ+jets events are used to model Z+Jets from data.
  - γ+jets has similar kinematic distributions as Z+Jets
  - Larger Statistics

➢ **Procedure**

- ➢PT distribution of γ's reweighted to match to Z's
- ➢ Number of primary vertex distribution in γ's is reweighted to match to Z's
- ➢ Each photon is assigned a mass by sampling Z line shape from data
- ➢done separately for each event category

Final estimate is taken as half of the prediction from photon events with 100% systematic error on prediction





Non-Resonant Background Estimation

- Estimation of non-resonant backgrounds is performed with standard technique, using eμ events passing analysis selection ($N_{e\mu}^{SIG}$)

- Using sidebands ($55 < m_{ll} < 70$ and $110 < m_{ll} < 200$ GeV) of the Z peak a scale factor a is determined from ratio of ee/μμ and eμ events passing MET > 70 GeV and requiring at least one b-tagged jet.

$$\alpha_e = \frac{N_{ee}^{SB}}{N_{e\mu}^{SB}}; \quad \alpha_\mu = \frac{N_{\mu\mu}^{SB}}{N_{e\mu}^{SB}}$$

- Predicted number of background events is given then as

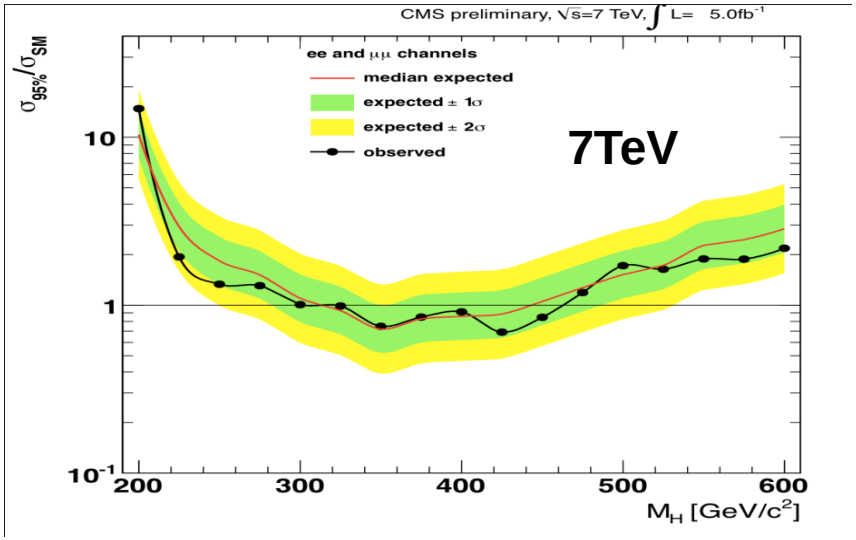
$$N_{ee}^{SIG} = \alpha_e \cdot N_{e\mu}^{SIG}; \quad N_{\mu\mu}^{SIG} = \alpha_\mu \cdot N_{e\mu}^{SIG}$$

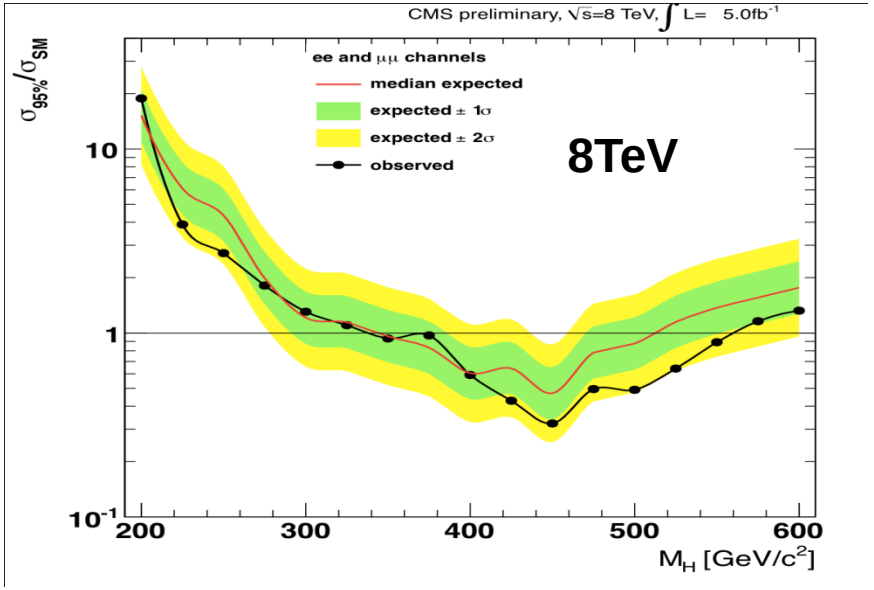
- We treat contribution from H→WW*→2l2ν as background and properly accounts on it.

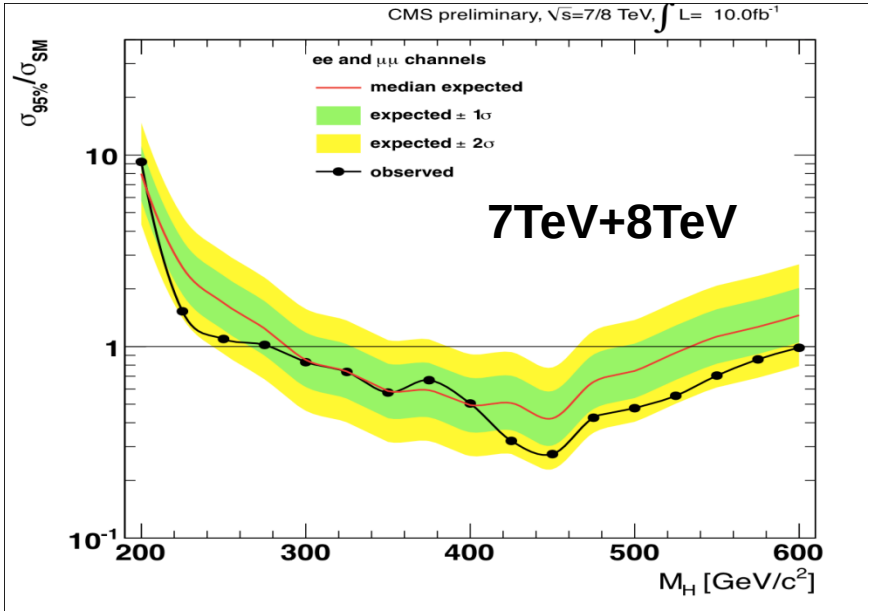
Systematic Uncertainties

Source	Uncertainty [%]
Luminosity	2.2 (7 TeV), 5.0 (8 TeV)
pdf, gluon-gluon initial state	6-11
pdf, quark-quark initial state	3.3-7.6
QCD scale, gluon-gluon initial state (ggH)	7.6-11
QCD scale, quark-quark initial state (VBF)	0.2-2
QCD scale, gluon-gluon initial state (ggZZ)	20
QCD scale, quark-quark initial state (qqVV)	5.8-8.5
Higgs boson line shape	10-30
Signal rescaling (from 7 TeV)	25 (8 TeV VBF)
Anti b-tagging	1-3
Lepton ID+Isolation	2
Lepton momentum scale	1-2
Jet energy scale	1
PU effects, MET	1-3
Trigger	2
non-resonant background estimation from data	25
$Z + jets$ estimation from data	100

Results







- **Expected Limit:** 291 – 534 GeV/c^2
- **Observed Limit:** 278 – 600 GeV/c^2

Back Up

Systematic Uncertainties (1/2)

- We use QCD scale and PDF uncertainties recommended by the LHC Higgs Cross-Section Working group for signal cross-sections.
- We assign a systematic error of 10-30% on signal due to line shape uncertainty on high mass Higgs.
- 25% systematic uncertainty due to rescaling of 7TeV samples to 8TeV .
- The cross-sections and theoretical uncertainties for ZZ→2l2ν and WZ→3lν were calculated using MCFM with LHAPDF PDFs according to PDF4LHC recommendations.
- The systematic uncertainty on small non-resonant background estimate is given by 25% error on α.