Search for medium-high mass Higgs bosons in the H$\rightarrow$ZZ channel

Daniel Domínguez Vázquez

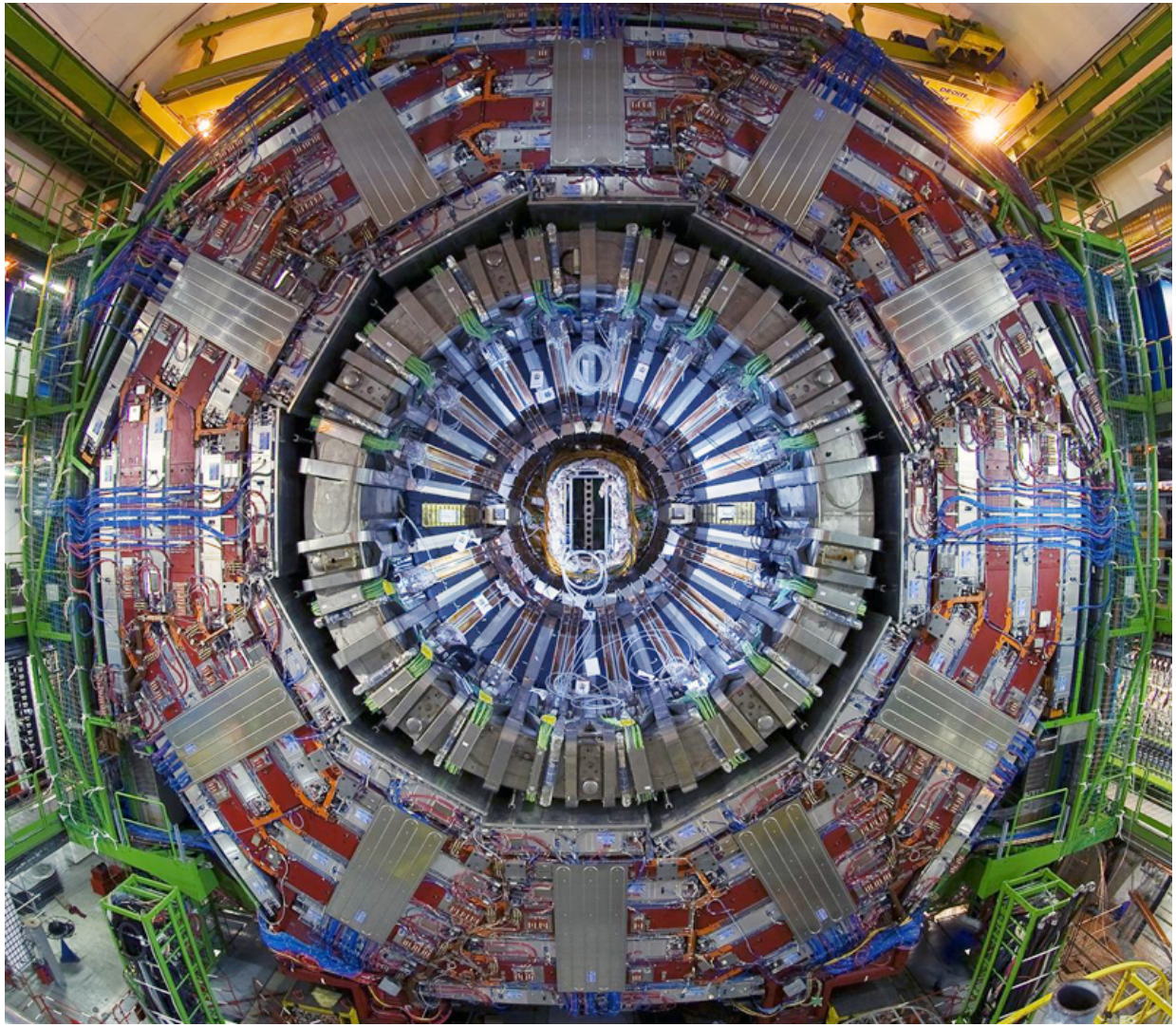
CIEMAT

November 22, 2012

IV Jornadas CPAN

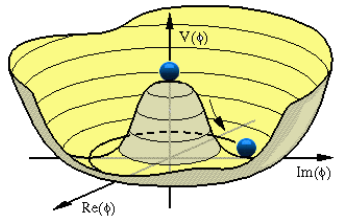
Index

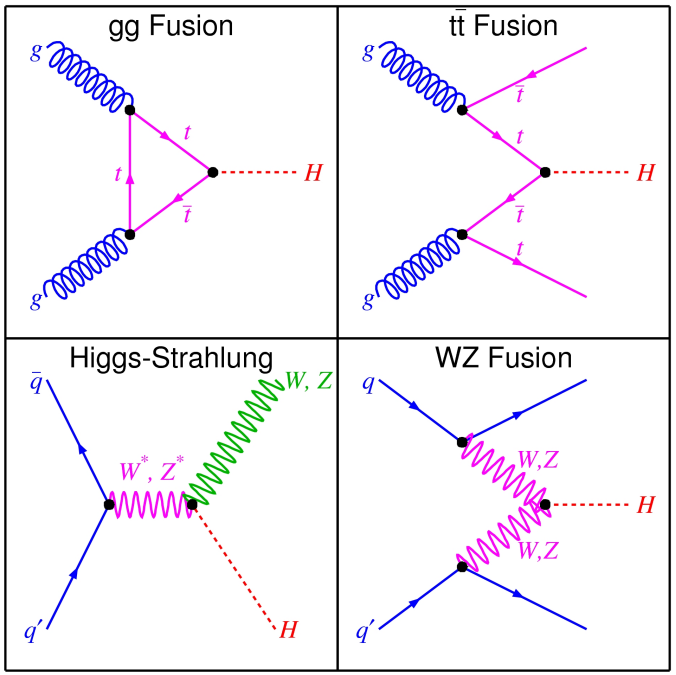
1. Motivation
2. H→ZZ→2l2q search
3. Other H→ZZ searches
4. Conclusions

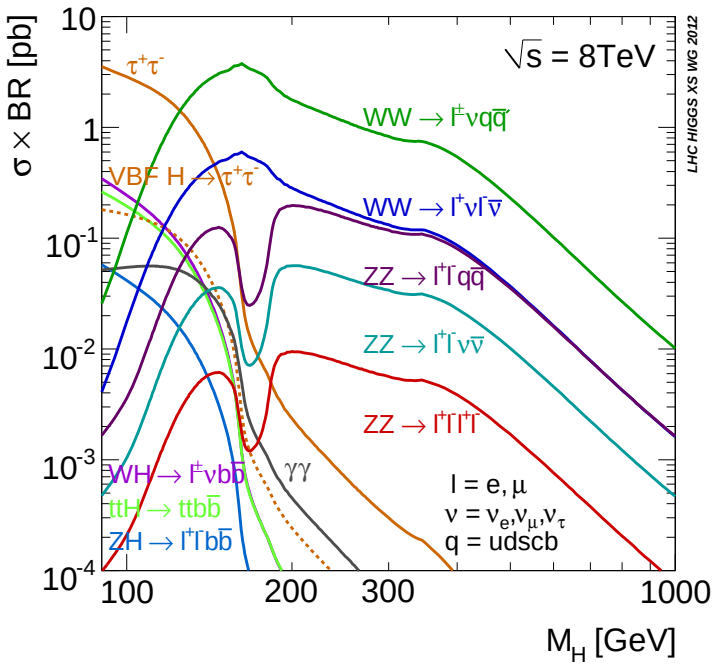


Motivation

- The Higgs boson is an essential element of the Standard Model of Particle Physics (SM).
- It explains the origin of mass and plays a key role in the physics of electroweak symmetry breaking.
- Its search is one of the main goals of the LHC and the CMS Collaboration

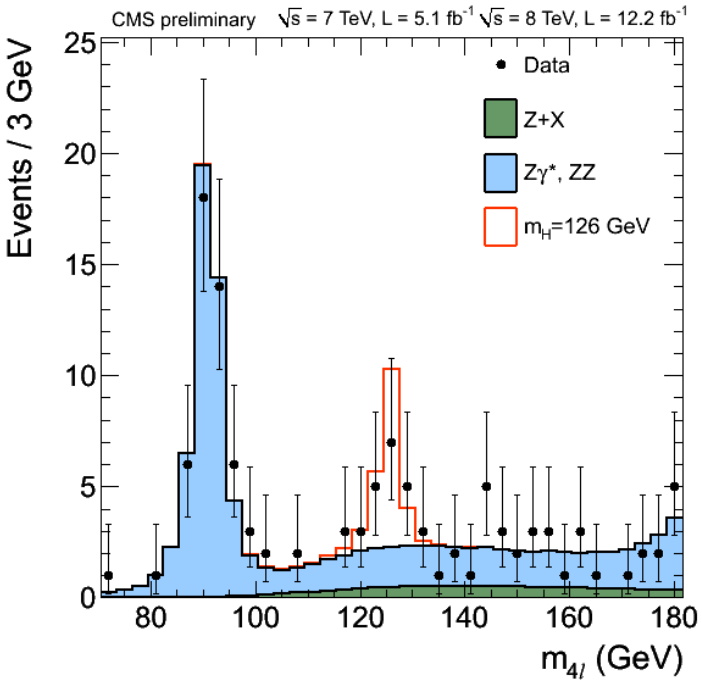


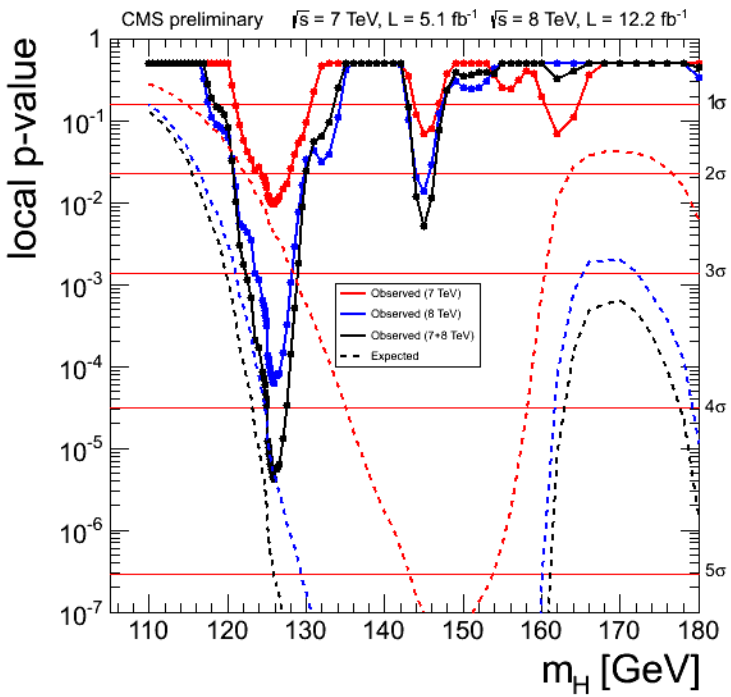




New boson discovered at the LHC!

- A new particle has been recently discovered at a mass of $\sim$ 126 GeV
- It has been observed in H$\longrightarrow \gamma\gamma$ and H$\longrightarrow ZZ \longrightarrow$ 4l with high mass resolution.
- Consistent with SM Higgs boson. Spin different from one.





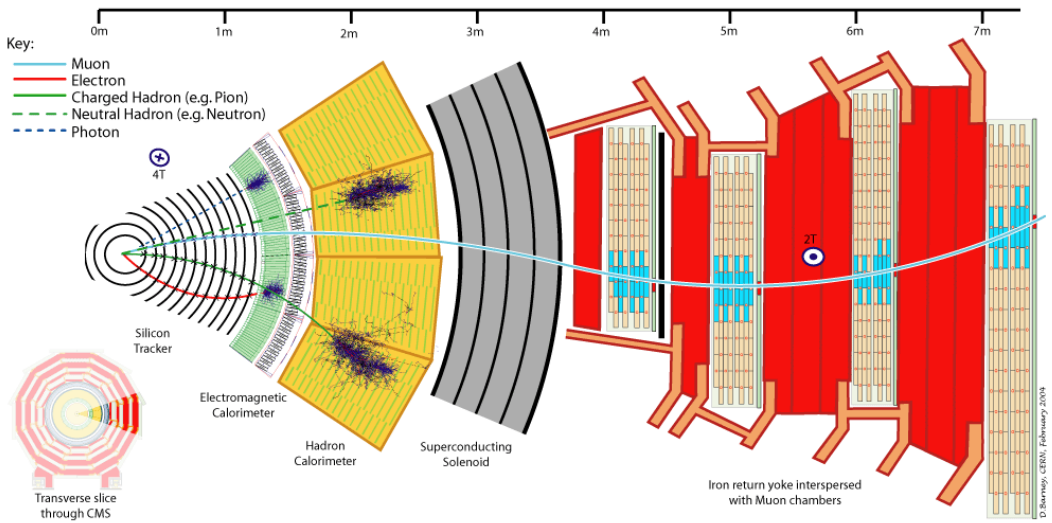
Far from the end in the Higgs sector

- Despite the new boson found at ∼126 GeV, Higgs-like signatures is a **still very interesting search at higher mass**.
- Many models predict **Higgs doublets (2HDM)** or **other Higgs-like resonances at higher mass**.
- Measured signal strength $\sigma/\sigma_{SM} \sim 0.8...$ still room for something else?
- ZZ channel is an optimal final state to perform these searches.

- This talk will refer to the different ZZ channels, but emphasizing the ZZ→2l2q decay channel.
- More information about this topic in plenary sessions (M.Soares and J.Virdee).

CMS Detector

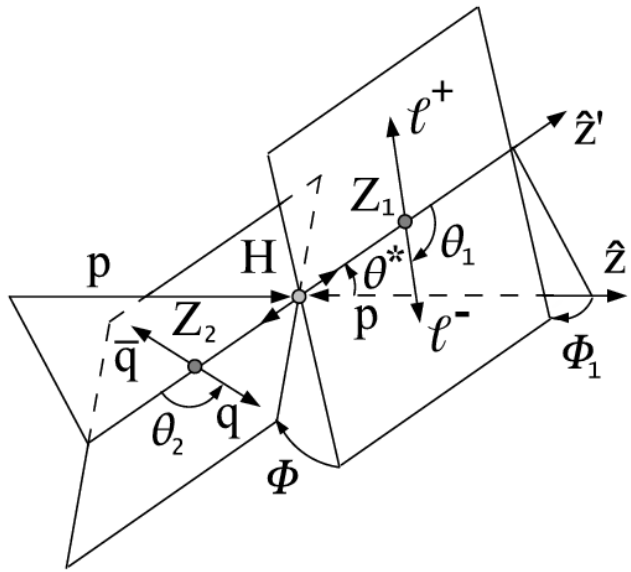
- CMS design allows full coverage to completely reconstruct the event.
- Excellent performance since its start.
- 20 fb^{-1} of data recorded (but not all statistics presented here).
- 3.8T Solenoid and high precision silicon tracker allow to measure p_T of charged particles with high precision.
- Global event description with "particle-flow" algorithm.



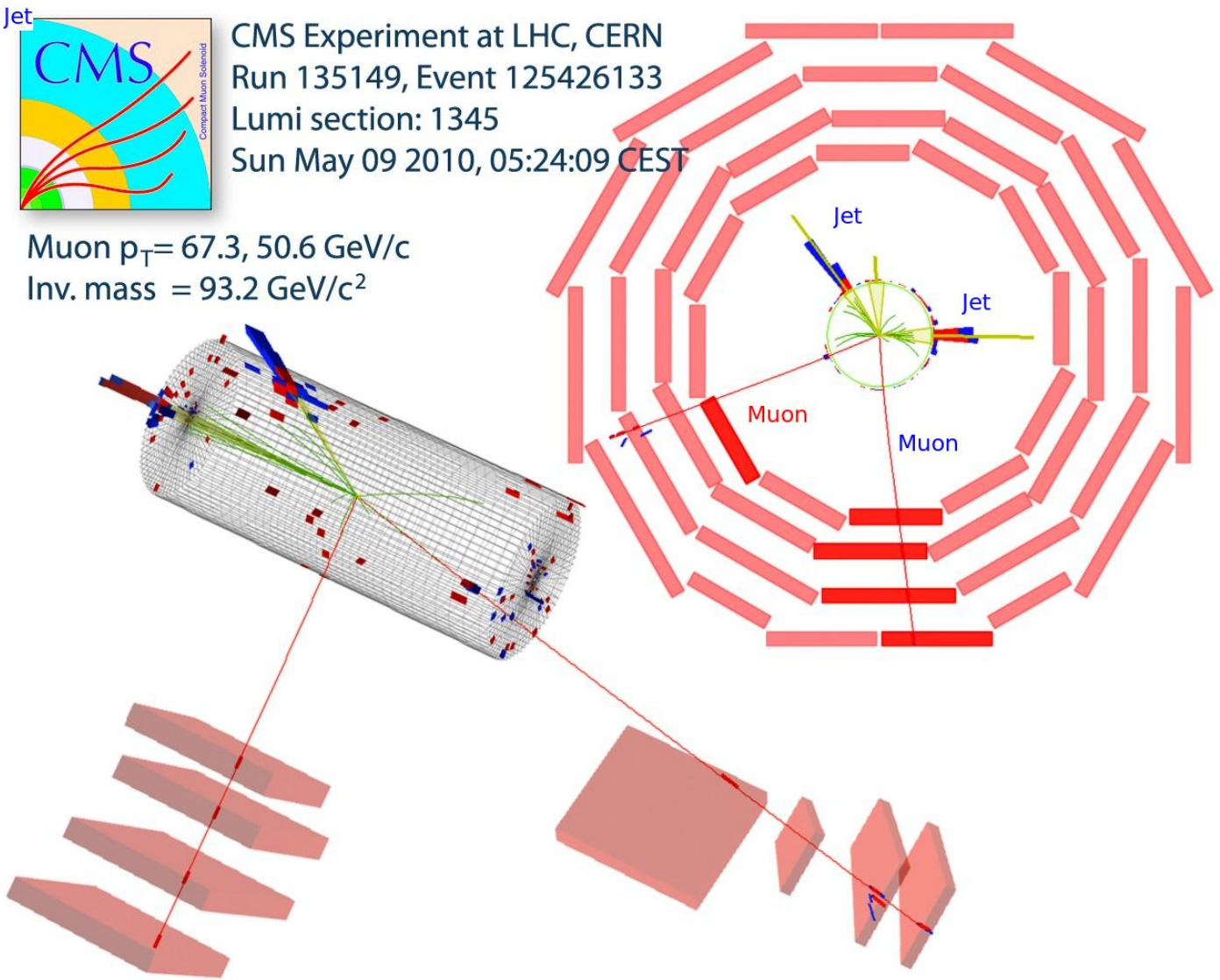
H→ZZ→2l2q

- The semileptonic channel has the advantage of a higher cross section compared to leptonic ones. (BR(ZZ→2l2q) = 20*BR(ZZ→4l) = 3.5* BR(ZZ→2l2ν))
- On the other hand, it suffers from large Z+Jets background(5 orders of magnitude higher).
- Other background processes are $t\bar{t}$ and diboson production.
- Full kinematics of the process described by the five decay angles.

- We divide the sample in 3 categories according to the tagged b-jets (0,1 or 2) to take advantage of the higher sensitivity in the 2l2b channel.
- Light jets will be dominant in Z+Jets background
- More fraction of b-jets in Z decay w.r.t. QCD background.



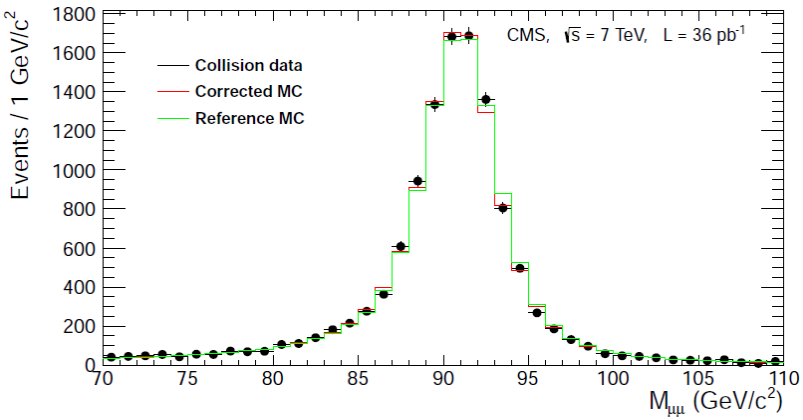
H→ZZ→2l2q

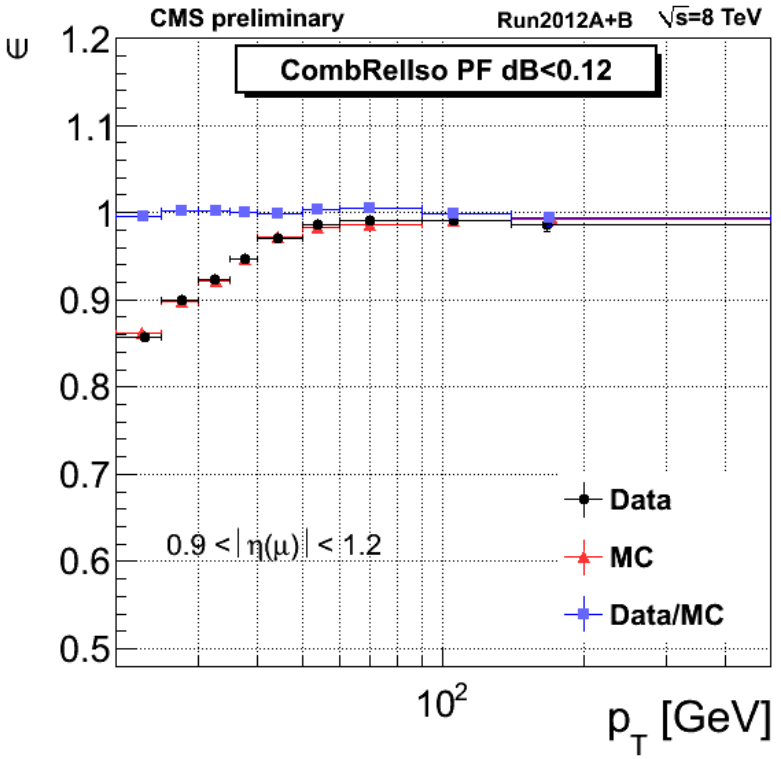

Jet
CMS
CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST
Muon p_T= 67.3, 50.6 GeV/c
Inv. mass = 93.2 GeV/c^2
Jet
Jet
Muon
Muon

Event Selection: Leptons

- We look for 2 leptons (electron, muon) and 2 jets in the detector.

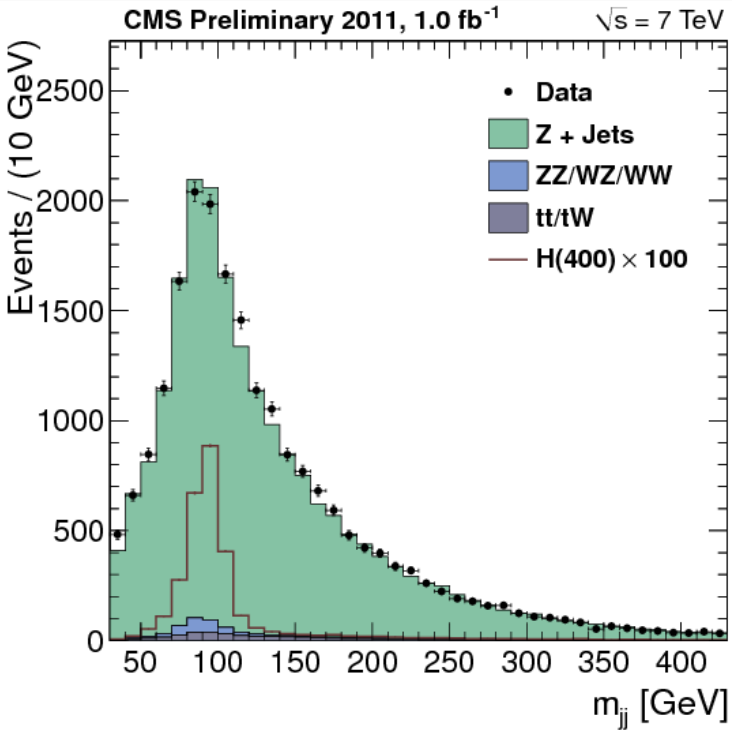
  - Selected electron/muons pairs with quality cuts
  - $p_T > 40$ / 20 GeV
  - $|\eta|$ <2.4 (muons) / 2.5 (electrons)
  - Isolation & vertex requirements
  - Dilepton triggers (p_T >17/8)GeV

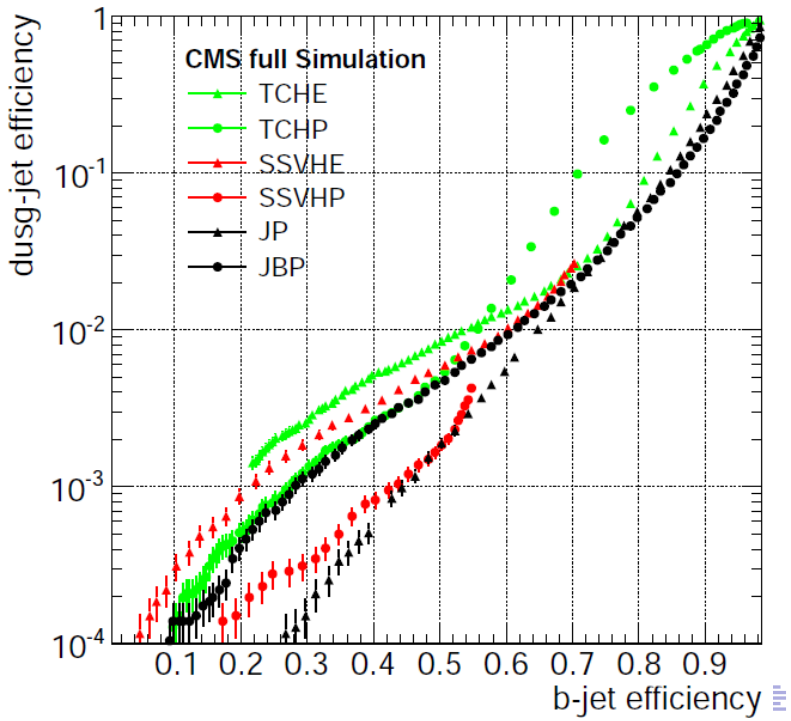




Event Selection: Jets & btagging

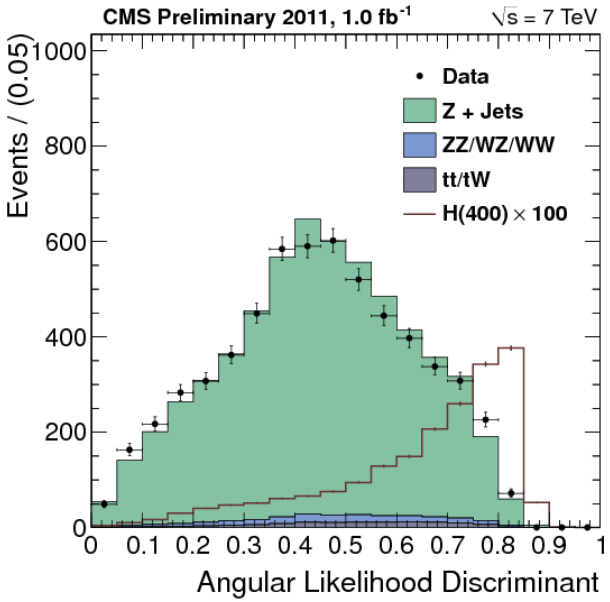
- **anti-kt algorithm with R=0.5**.
- $p_T > 30$ GeV and $|\eta| < 2.4$.
- **Particle-flow algorithm** combine information from various detectors to make the best combined estimation of particle properties.
- Pile-up rejection using charged particle tracks inside the jet.
- Final 4-object resolution dominated by jet resolution.
- Exploit the long lifetime of B hadrons to identify jets coming from b quarks.

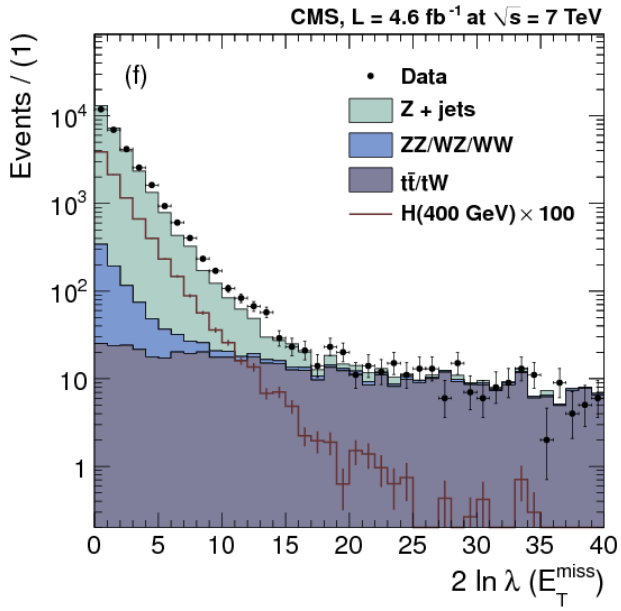




Final Selection

- Require lepton and jet pairs to have an invariant mass around the Z nominal mass ($m_{ll} \in [70,110]$ && $m_{jj} \in [75,105]$ GeV)
- Different optimized cuts for each category (0,1,2 b-tagged jets).
- Angular likelihood discriminant from 5 angles in decay.
- Missing Transverse Energy veto to reject $t\bar{t}$ in the 2 b-tag category.
- Kinematic Fit to constrain di-jet mass to nominal Z mass, improving mass resolution.





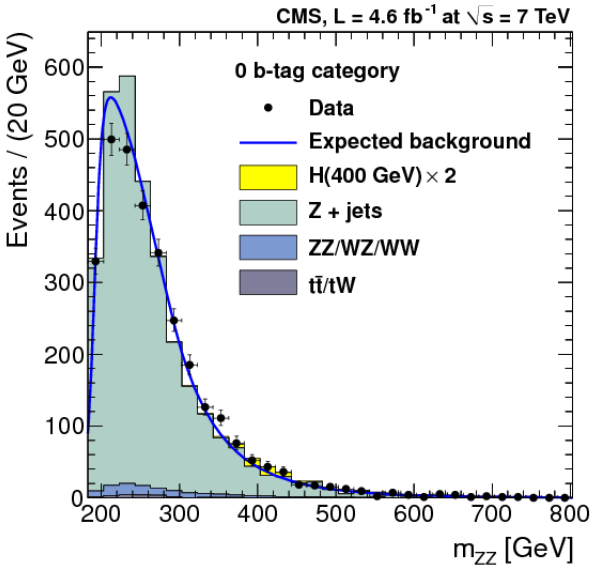
Background estimation

- Data-driven method used to estimate background.
- Control region defined in m_{jj} sidebands ($m_{jj} \in$ ([60,75] $\cup$ [105,130]) around signal region ($m_{jj} \in$ [75,105] GeV)
- Kinematic differences between signal region and sidebands taken from MC simulation.

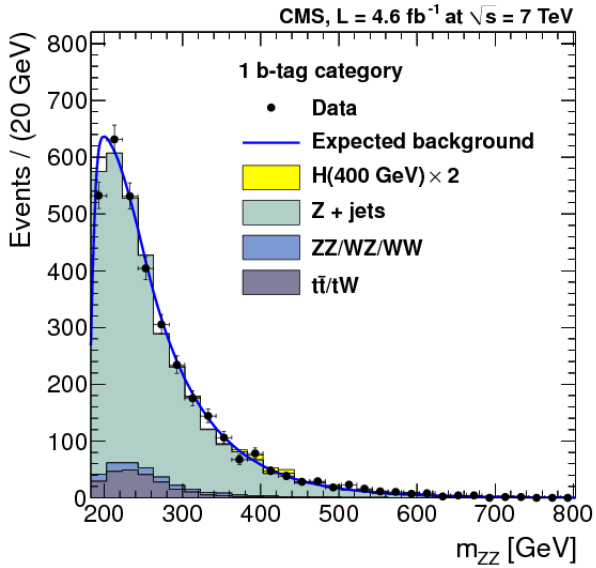
$$N_{\mathrm{bkg}}(m_{ZZ}) = N_{\mathrm{sb}}(m_{ZZ}) \times \frac{N_{\mathrm{bkg}}^{\mathrm{MC}}(m_{ZZ})}{N_{\mathrm{sb}}^{\mathrm{MC}}(m_{ZZ})} = N_{\mathrm{sb}}(m_{ZZ}) \times \alpha(m_{ZZ})$$

- Background parametrized to achieve a more accurate description of the shape, especially in the tail of the distribution where the samples lack of statistics.

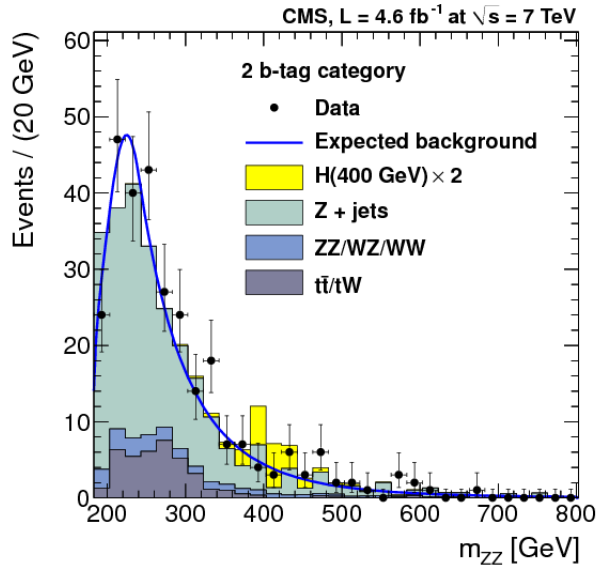
0-tag



1-tag

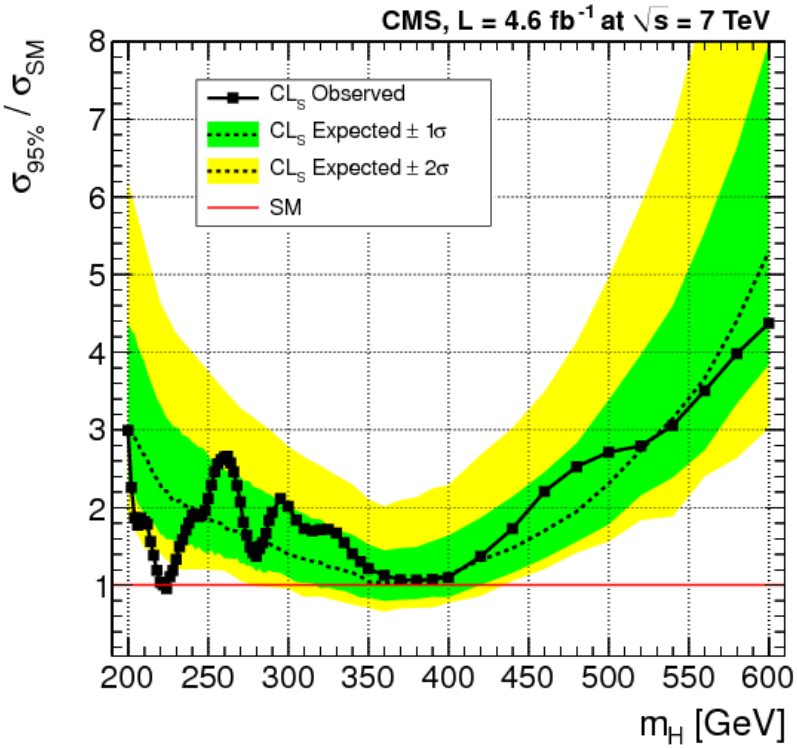


2-tag



2011 Results

- 2012 analyis not yet approved, cannot be shown today.
- 2011 result approved and published (JHEP 04 (2012) 036).
- It has explored the range $m_{ZZ} \in (200,600$ GeV).
- 2012 analyis intended to extend the range up to 1TeV and include improvements over this one.

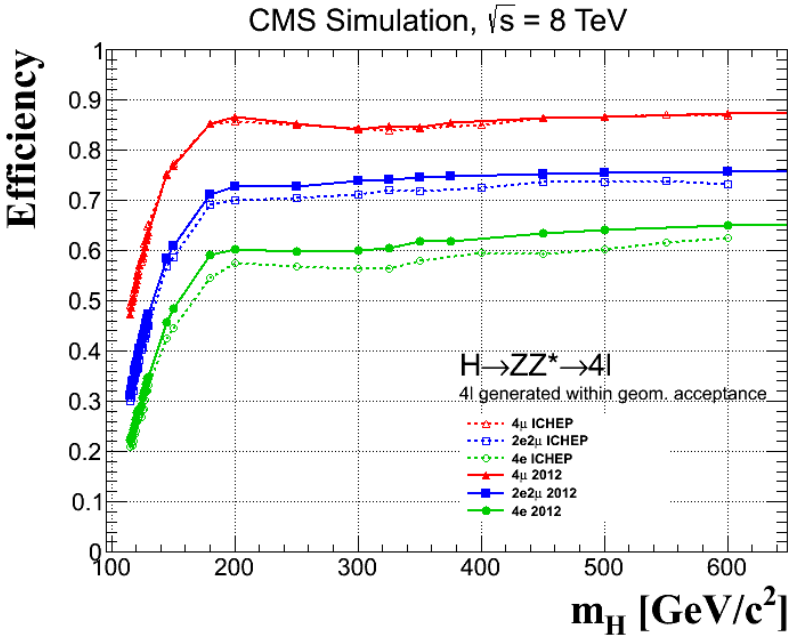


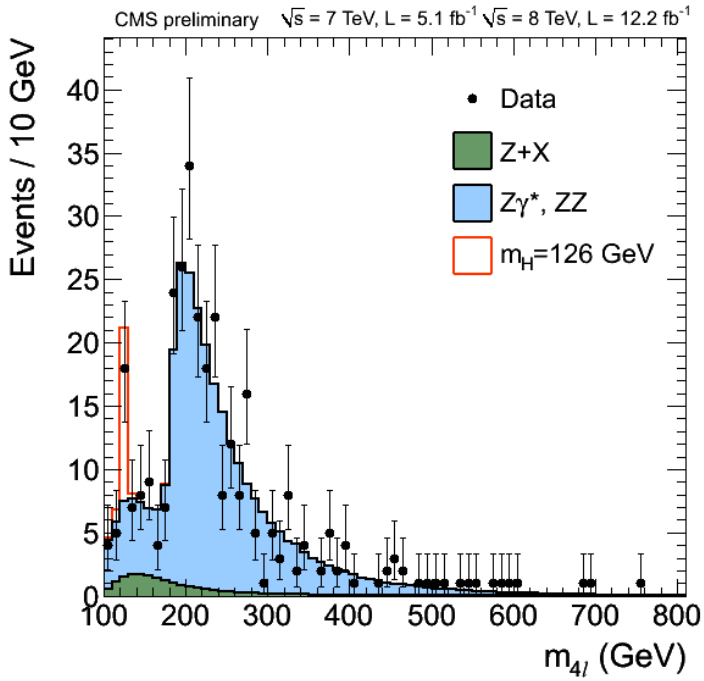
Other analysis

What I can show today...

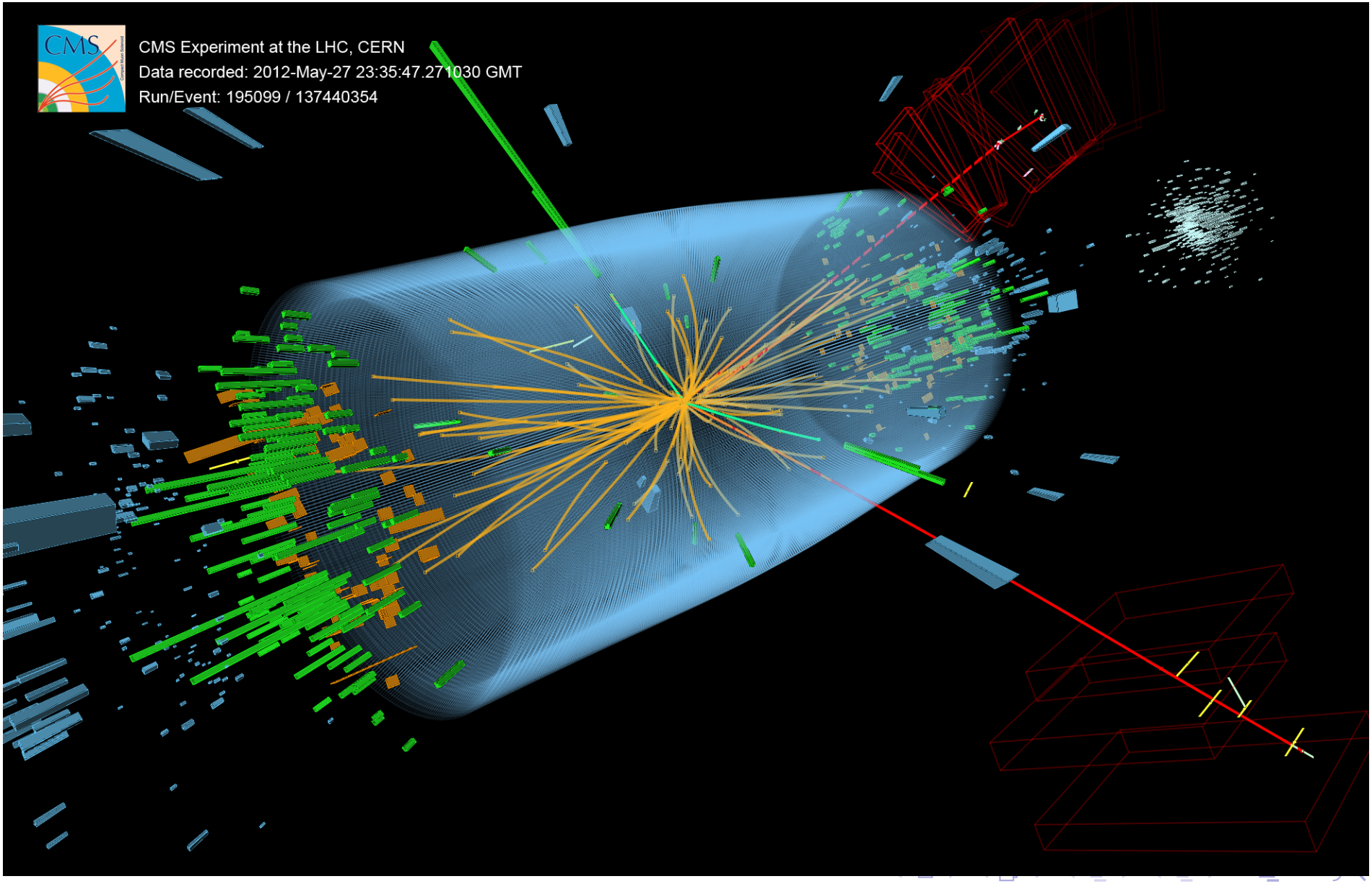
H→ZZ→4l

- This channel takes advantage of low background and very clean identification to get the highest sensitivity.
- Looser lepton cuts to gain efficiency and allow Z's to be offshell.
- ZZ and $Z\gamma^*$ irreducible background. Other reducible backgrounds are $Zb\bar{b}$ and $t\bar{t}$.
- Accurate Higgs lineshape taking into account large width at high mass and interference with ZZ (all ZZ channels).



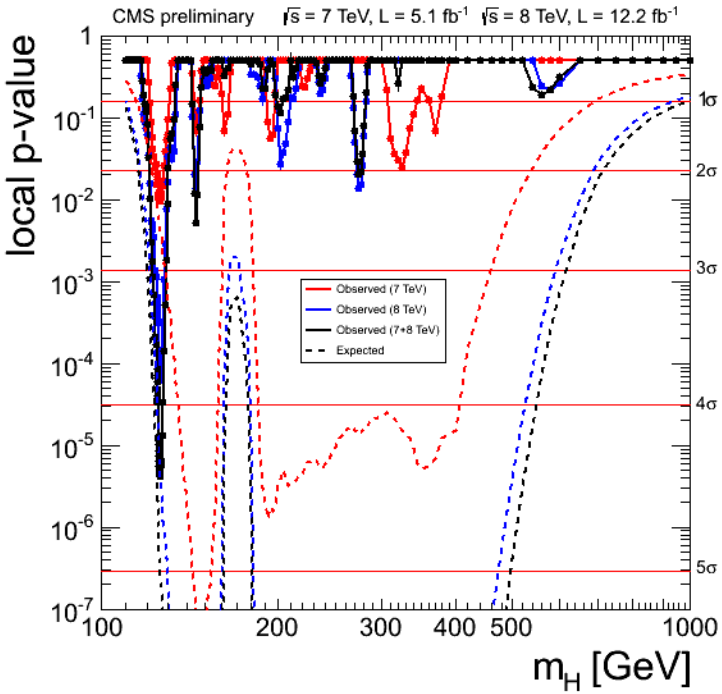


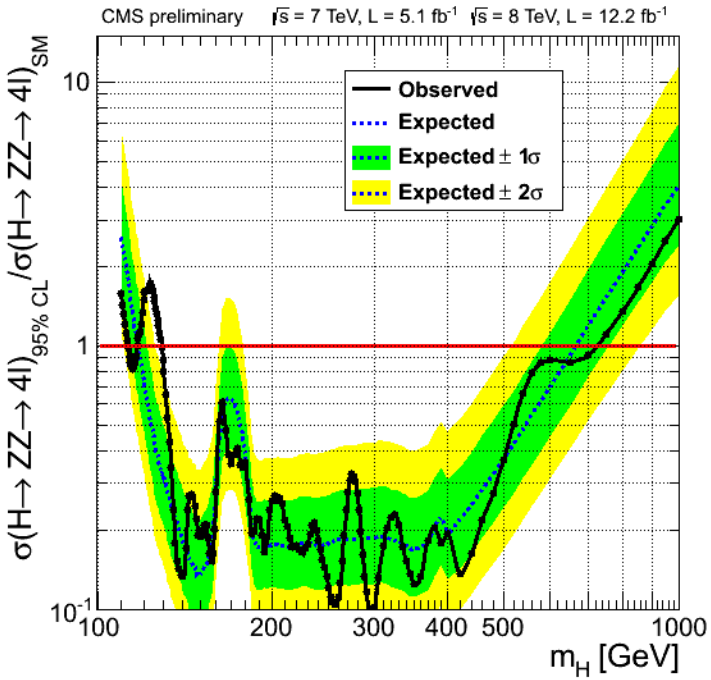
H$\rightarrow$ZZ$\rightarrow$2e2μ Candidate



H→ZZ→4l

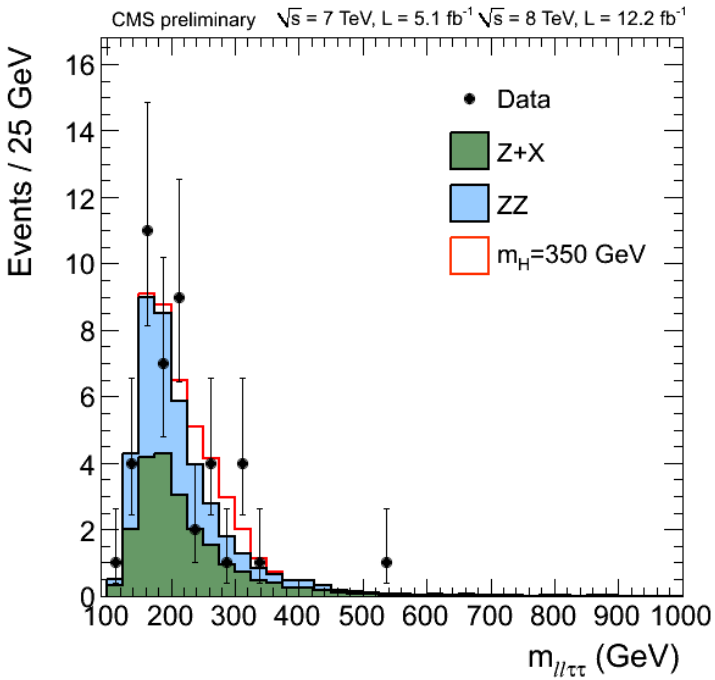
- Recovery photons radiated in the final state (FSR) improve mass resolution.
- Results include **5.1 fb^{-1} at $\sqrt{s}$=7TeV and 12.2 fb^{-1} at $\sqrt{s}$=8TeV**.
- Matrix Elements likehood to discriminate signal and background using 5 angles in decay (previously described) and the 2 Z masses.
- **No excess** in data observed over expected SM background **in the high mass range**.

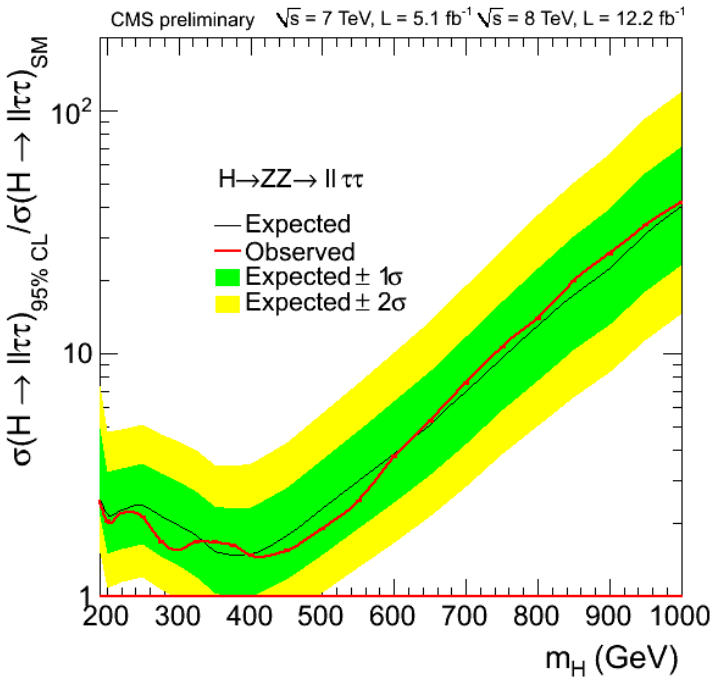




H→ZZ→2l2τ

- Same approach as H→ZZ→4l analysis (4μ,4e,2e2μ).
- Taus are identified both in their leptonic and hadronic decays using particle-flow.
- Only contributes to middle-high mass range ($m_{2l2\tau} > 180$ GeV).
- Overall 4l channel (including taus) **exclude 129-720 GeV at 95% CL**.

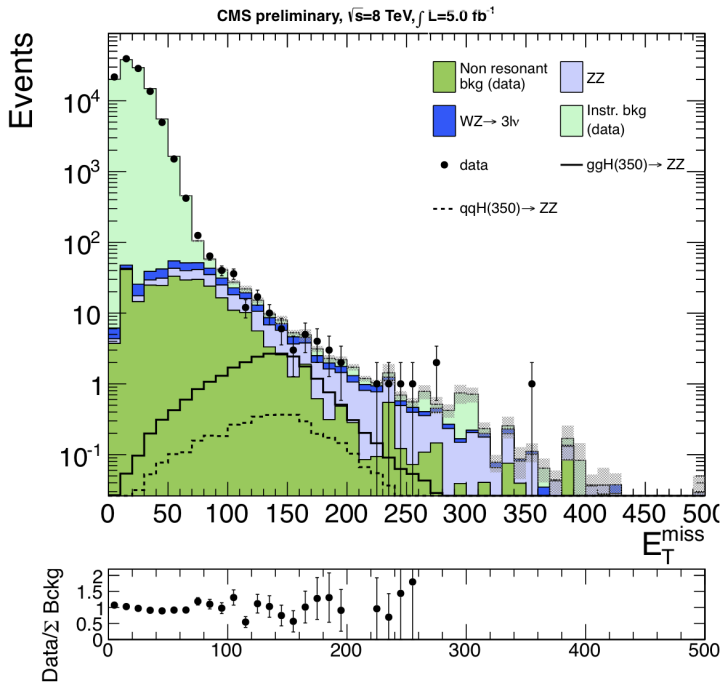


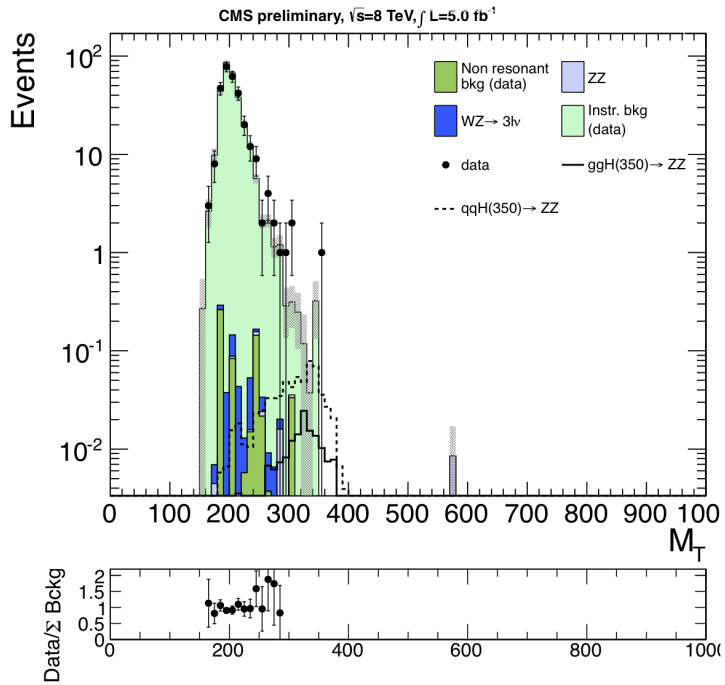


H→ZZ→2l2ν

- Final state with 2 leptons (ee,$\mu\mu$) + large missing energy (ME).
- Main background is Z+Jets. Other are $t\bar{t}$,tW and diboson production.
- b-tagging veto to suppress $t\bar{t}$ background.
- Angular separation between ME and any lepton/jet to avoid energy mismeasurement.
- Search for an excess in the missing transverse energy and the reconstructed transverse mass (M_T).

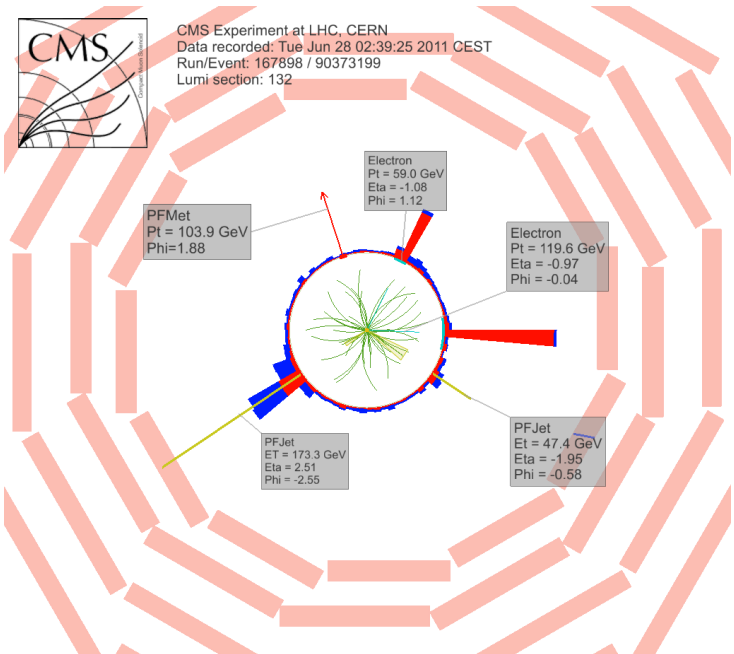
$$M_T^2 = \left(\sqrt{p_T(ll)^2 + M(ll)^2} + \sqrt{E_T^{miss\,2} + M(ll)^2}\right)^2 - (\vec{p}_T(ll) + \vec{E}_T^{miss})^2$$

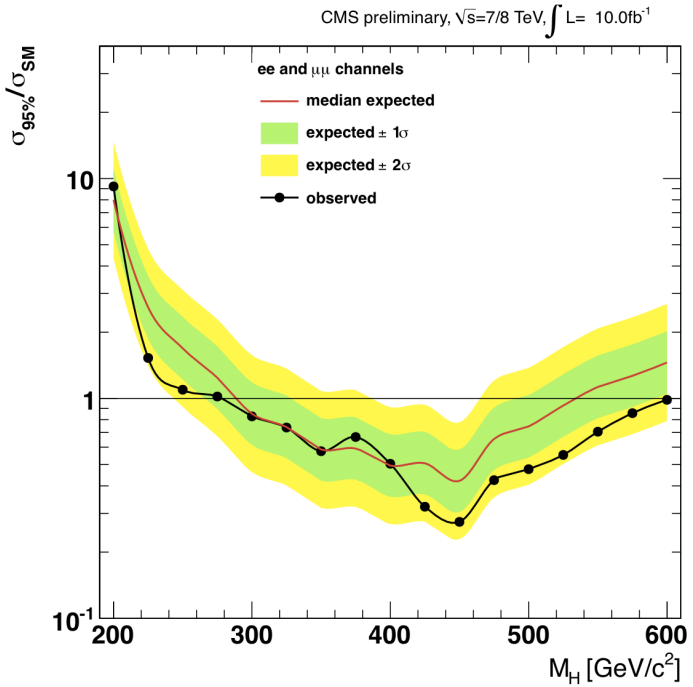




$H \rightarrow ZZ \rightarrow 2l2\nu$

- Categories according to jet multiplicity: Vector Boson Fusion and Gluon Fusion considered separately.
- Results include **5.1 fb^{-1} at $\sqrt{7}$ TeV and 5.0 fb^{-1} at $\sqrt{8}$ TeV**.
- No significant excess observed over the expectation of SM background.
- **278-600 GeV mass range excluded at 95% CL**.





Conclusions

- Search of a Higgs-like signature in the ZZ channel has been performed at CMS.
- New particle discovered at 126 GeV .
- H$\rightarrow$ZZ$\rightarrow$4l and H$\rightarrow$ZZ$\rightarrow$2l2ν results presented with data at $\sqrt{s}$=7TeV and $\sqrt{s}$=8TeV
- 129-720 GeV mass range excluded at 95% CL.
- H$\rightarrow$ZZ$\rightarrow$2l2q very important channel as it is one of the most sensitive at very high mass (over 600 GeV)
- Full statistics results expected soon.