Search for heavy neutral Higgs in HZZ4L final state

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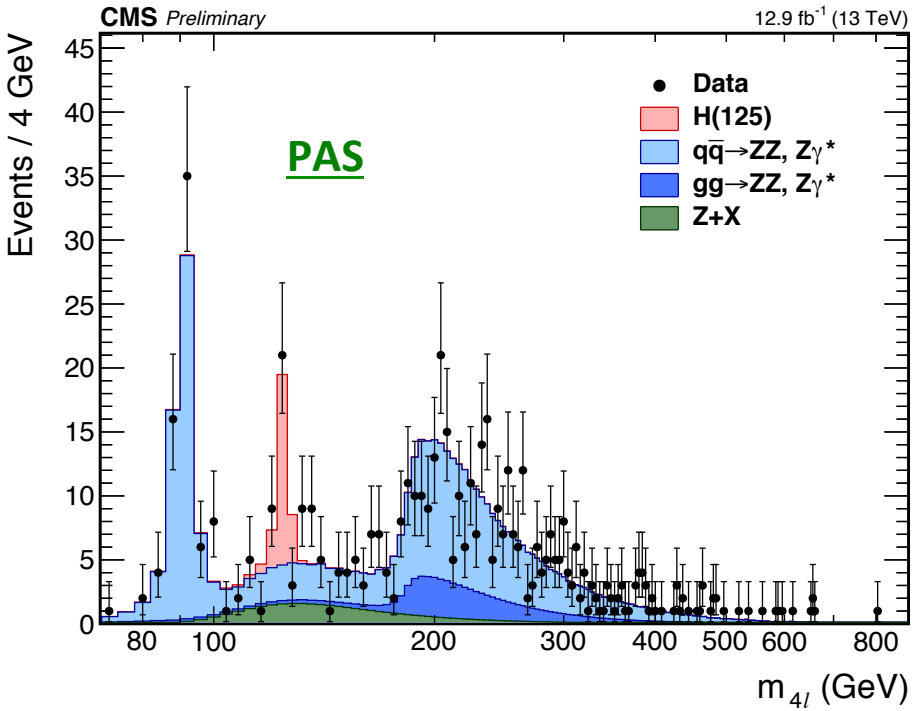
Outline

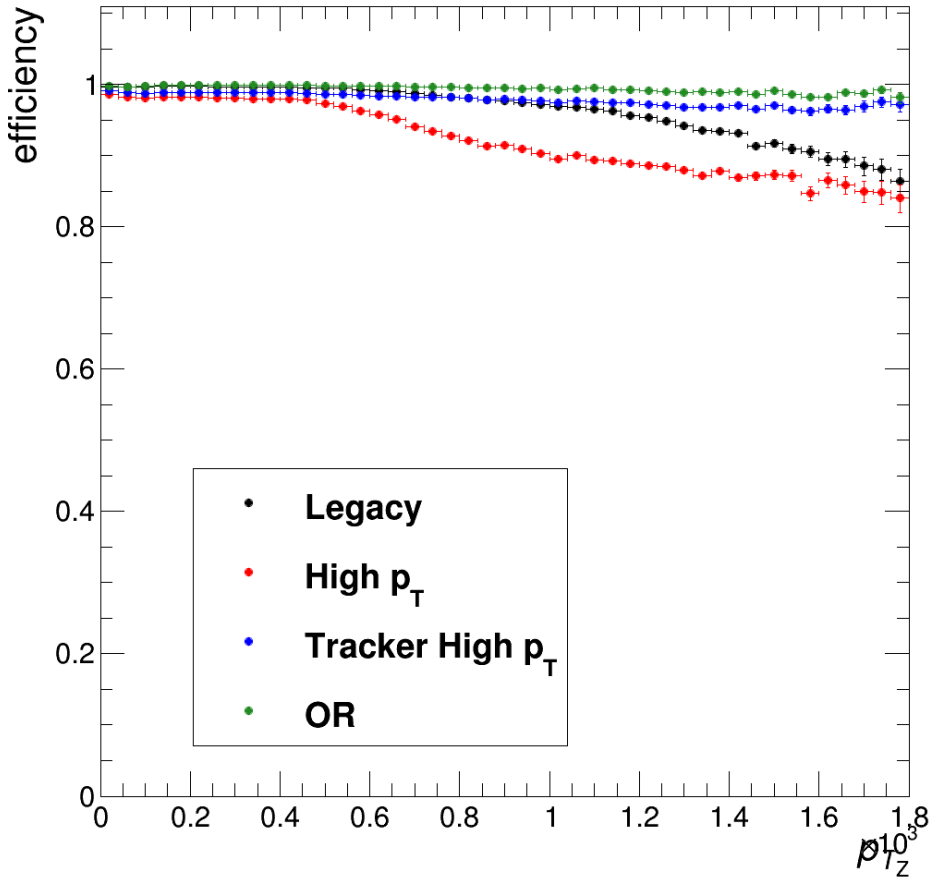
- This talk will present the published results of searching for heavy neutral resonances using CMS 2016 ICHEP data in ZZ4L final state
  - **Higgs to ZZ to four leptons (lepton = e, μ) HIG-16-033**
- Plan targeting end-of-year data will also be discussed

Analysis strategy: event selection



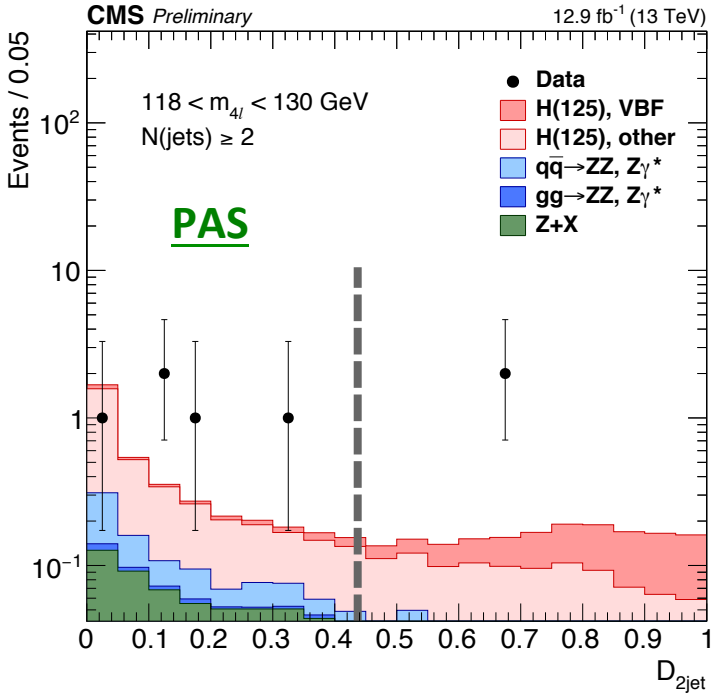
- Analysis uses 12.9 fb^{-1} data collected in 2016 with c.o.m. energy at 13TeV
- Four isolated leptons grouped into 2e2μ, 4e and 4μ final states
  - Electron uses MVA-based ID to gain signal efficiency
  - Muon ID is optimized to avoid loosing efficiency in boost regime (muon p_T >200GeV)
- Include an extra category with relaxed selected electron to gain signal efficiency
- No events are observed with $mass_{4l}$ > 850GeV

Analysis strategy:
muon ID in the boost regime



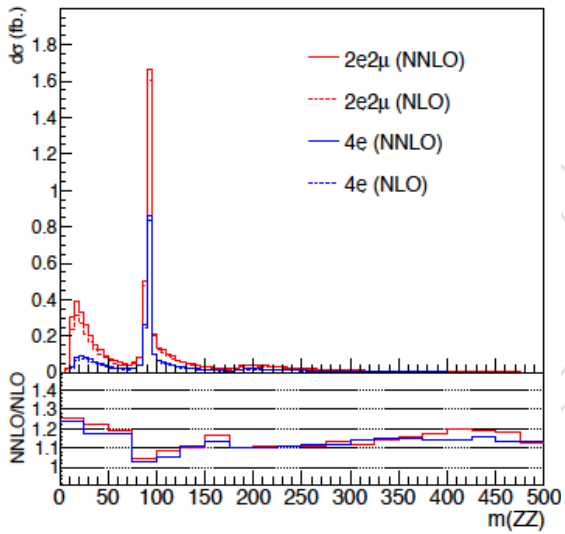
Analysis strategy: event categorization

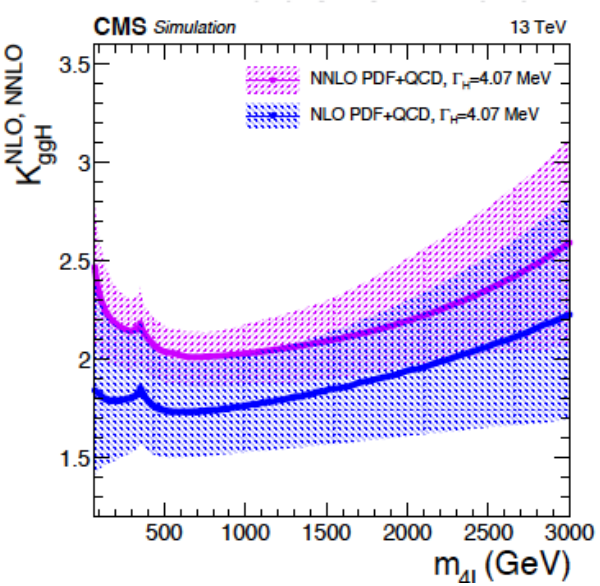
- To separate gluon fusion and VBF production, a matrix-element based discriminant is used.
- The discriminant is used for both measurements for ~125GeV Higgs and high mass resonance search.
- VBF category is defined by events satisfy cut on D_{2jet}
  - $mass_{4l}$ – dependent cut is used for high mass search

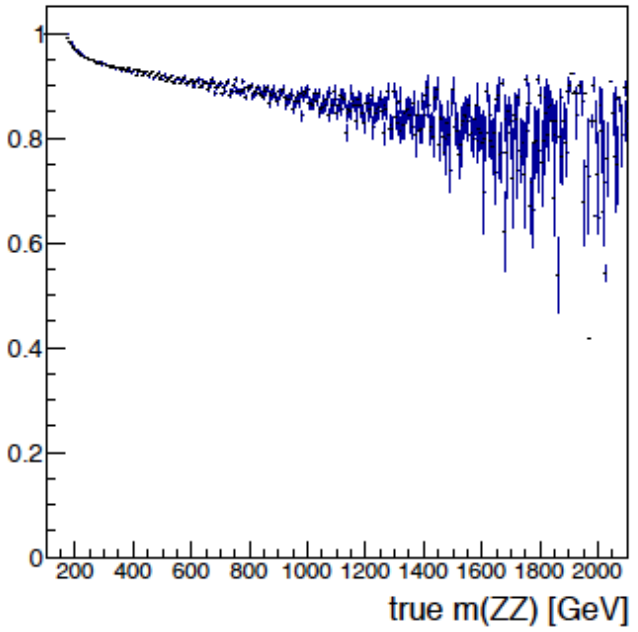


Analysis strategy: background estimation

- qqZZ + ggZZ : estimate from MC
  - Mass dependent K factor (NNLO/NLO for qqZZ, NNLO/NLO for ggZZ) are applied
  - NLO electroweak corrections are applied on qqZZ



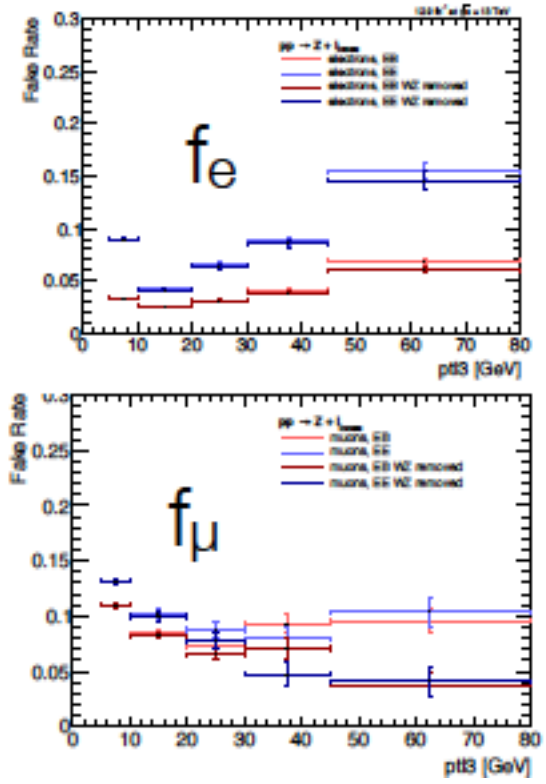




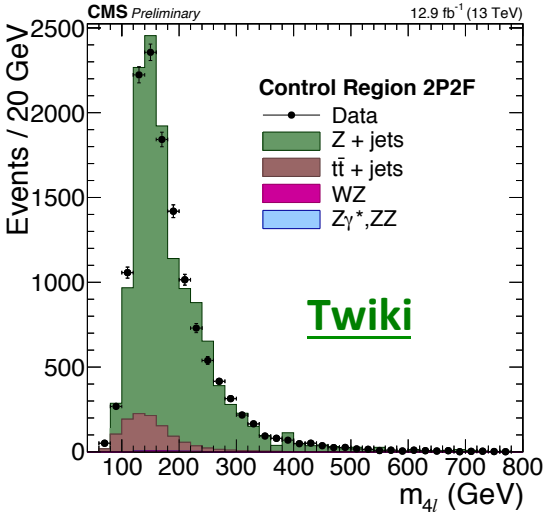
Analysis strategy: background estimation

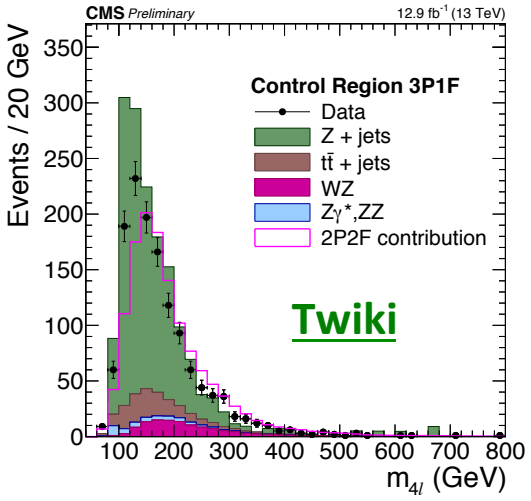
- Z+X : fake rate method using data in the control region
  - Control region is defined as
    two leptons from (leading) Z decay satisfy the final HZZ4L selection, plus two additional either opposite-sign(OS) or same-sign (SS) leptons satisfy relaxed requirements.
  - Electron/muon fake rates are defined correspondingly as the efficiency of "relaxed" lepton passing the final selection criteria are measured for OS/SS method separately.
  - Fake rate is measured in Z+1 "relaxed" lepton region in data
    - OS : Z is selected as m_{ll} tightly around Z mass peak
    - SS : Z is selected as the leading Z in Higgs decay (40GeV<m_{ll}<120GeV)

Analysis strategy: Z+X background estimation – OS method



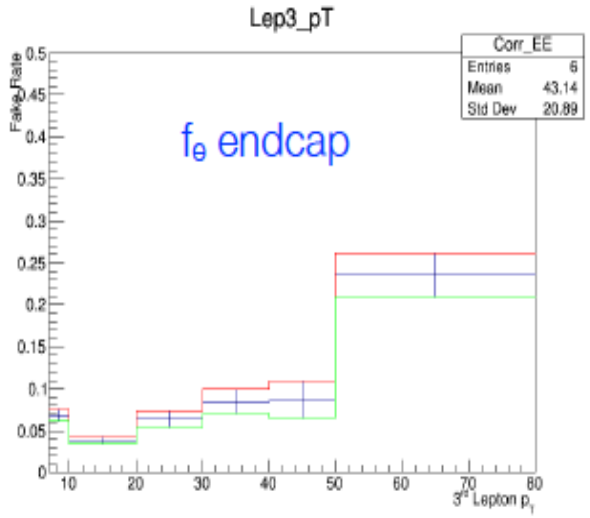
$$N_{SR}^{bkg} = \sum \frac{f_i}{(1-f_i)}(N_{3P1F} - N_{3P1F}^{bkg} - N_{3P1F}^{ZZ}) + \sum \frac{f_i}{(1-f_i)}\frac{f_j}{(1-f_j)}N_{2P2F}$$



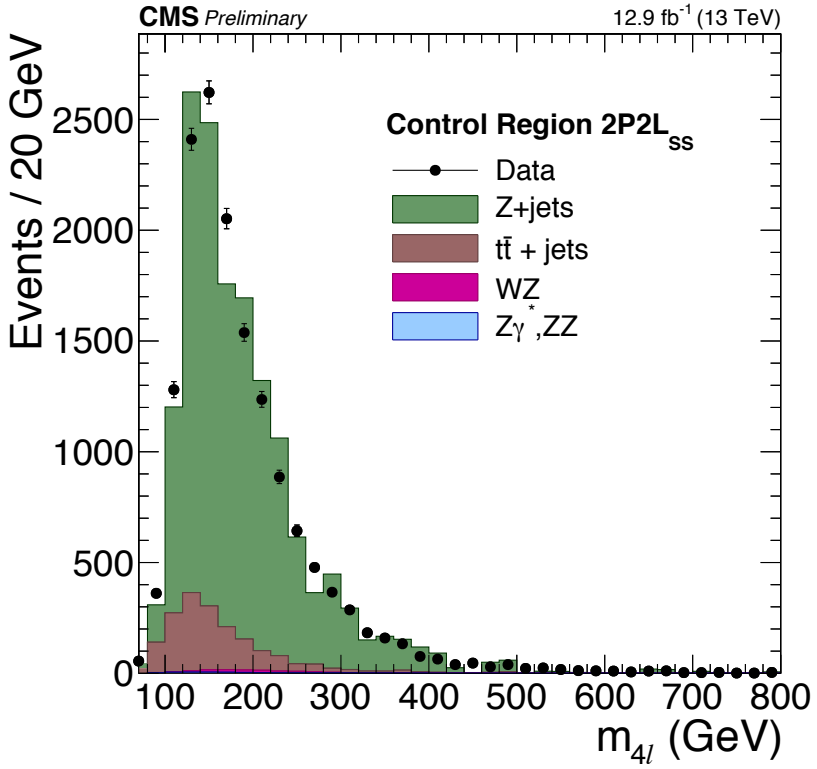


Analysis strategy: Z+X background estimation – SS method

Electron fake rate is corrected with number of missing hits.

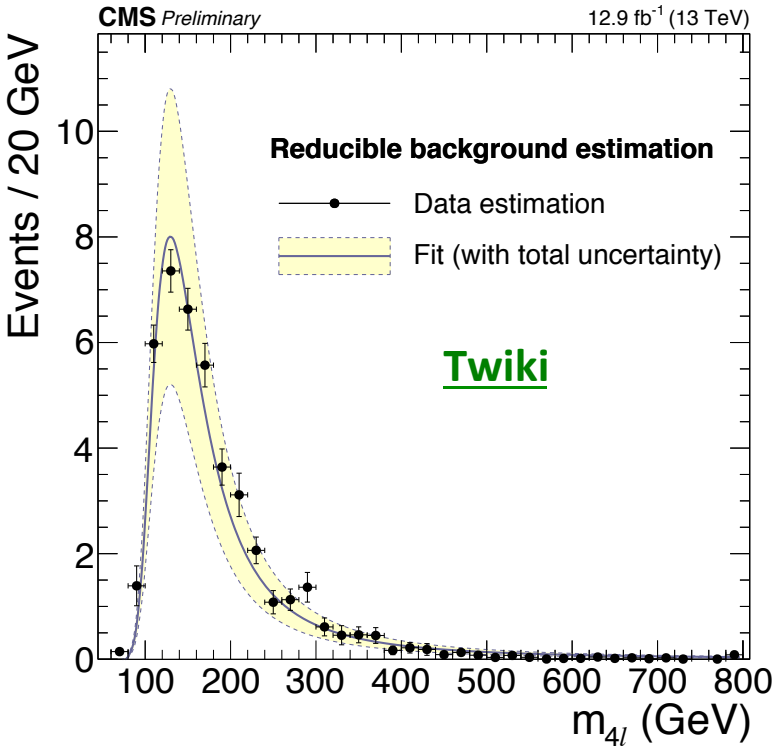


$$N^{Z+X}_{expect} = N^{DATA} \times \left(\frac{OS}{SS}\right)^{MC} \times f_1 \times f_2$$



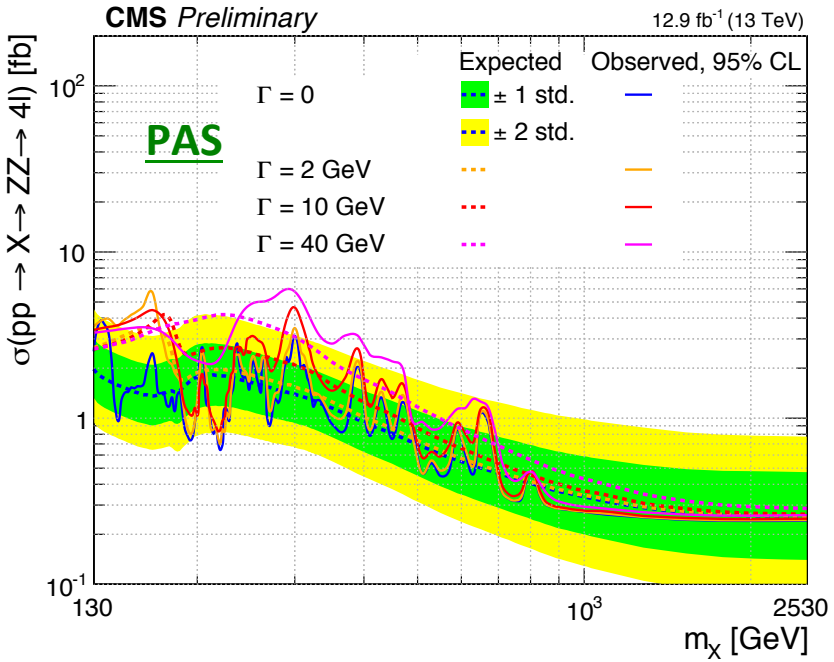
Analysis strategy: background estimation

- Z+X : fake ratio method from data control region
  - Estimations from opposite-sign(OS) or same-sign (SS) are combined to give the final Z+X background estimation



Results:
cross section upper limit

- An unbinned maximum likelihood fit of the m_{4l} distribution is performed over the full range between 100 and 3000GeV.
- The fraction of VBF and VH production f_{VBF} can be either fixed to a certain value or left unconstrained in the fit when scan over of m_{4l} spectrum.
- Limits on the pp->X->ZZ->4l cross section are set as a function of m_X and Γ_X with f_{VBF} unconstrained are scanned from 130GeV to 2.5TeV.



Plan targeting end-of-year: kinematic refitting

- In the high mass regime, Z boson has enough phase space to decay on-shell
  - For 130GeV<$mass_{4l}$<~200GeV: one Z can decay on-shell
  - For $mass_{4l}$>200GeV : both Z can decay on-shell
- Using (Breit-Wigner) Z mass constrain can be applied to refit the lepton momenta

$$L(p_{\mathrm{T}}^{1}, p_{\mathrm{T}}^{2} | p_{\mathrm{T}}^{reco1}, \sigma p_{\mathrm{T}}^{1}, p_{\mathrm{T}}^{reco2}, \sigma p_{\mathrm{T}}^{2}) = \mathrm{Gauss}(p_{\mathrm{T}}^{reco1} | p_{\mathrm{T}}^{1}, \sigma p_{\mathrm{T}}^{1}) \cdot \mathrm{Gauss}(p_{\mathrm{T}}^{reco2} | p_{\mathrm{T}}^{2}, \sigma p_{\mathrm{T}}^{2}) \cdot L(m_{12} | m_{\mathrm{Z}}, \Gamma_{\mathrm{Z}})$$

  - Lepton resolution will be improved.
  - Background shape will not be bias.
  - qqZZ/ggZZ : leptons are also from Z decay.
  - Z+X : much less important when $mass_{4l}$ > 200GeV. The effect of refitting on fake leptons can be studied using control region data.

Plan targeting end-of-year: trackless electron (TLE)

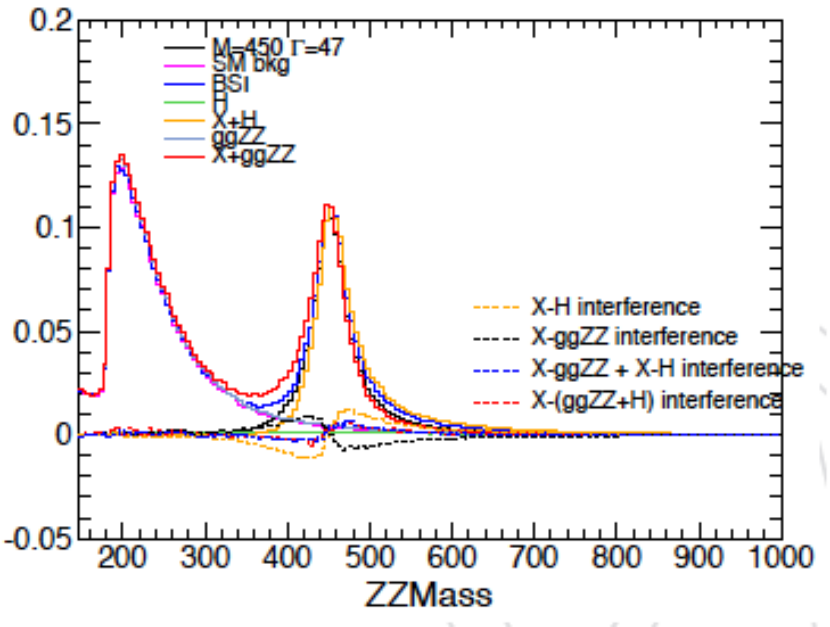
- The major issues with HZZ4L is its low statistics.
- TLE electrons avoid inefficiency due to track finding / sc-track matching
- TLE ID :
  - The same MVA training algorithm as regular electron ID
  - Training variables : cluster shape, PF Iso, pixel veto (conversion)
  - Need to have good control of much larger background due to introducing TLE and estimate the gain

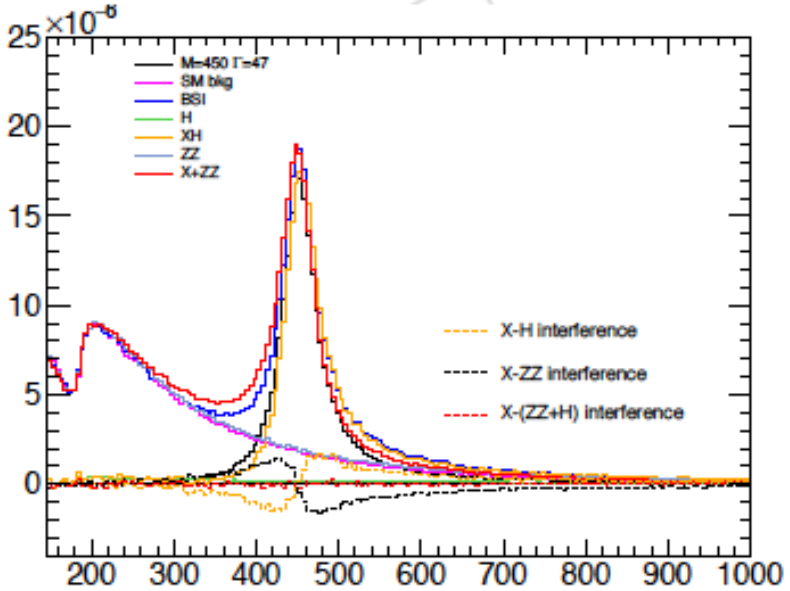
Summary

- Analyses of searching for high mass resonance decay to ZZ-to-four-lepton, are updated with 12.9 fb^{-1} data collected by CMS in 2016.
- No significant excess is observed under a few hundred GeV to TeV resonance assumption. Upper limits on the cross section are set as a function of resonance mass and width.
- Data with full 2016 run are expected to be at least ~30fb^{-1}
  - There is still room for analysis improvement.
  - Stay tune with results with three times statistics in the near future!

Back up

Interference effect





Limits assuming pure VBF production