Search for the Standard Model Higgs boson in H → WW → lνqq decay mode

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on behalf of CMS Collaboration

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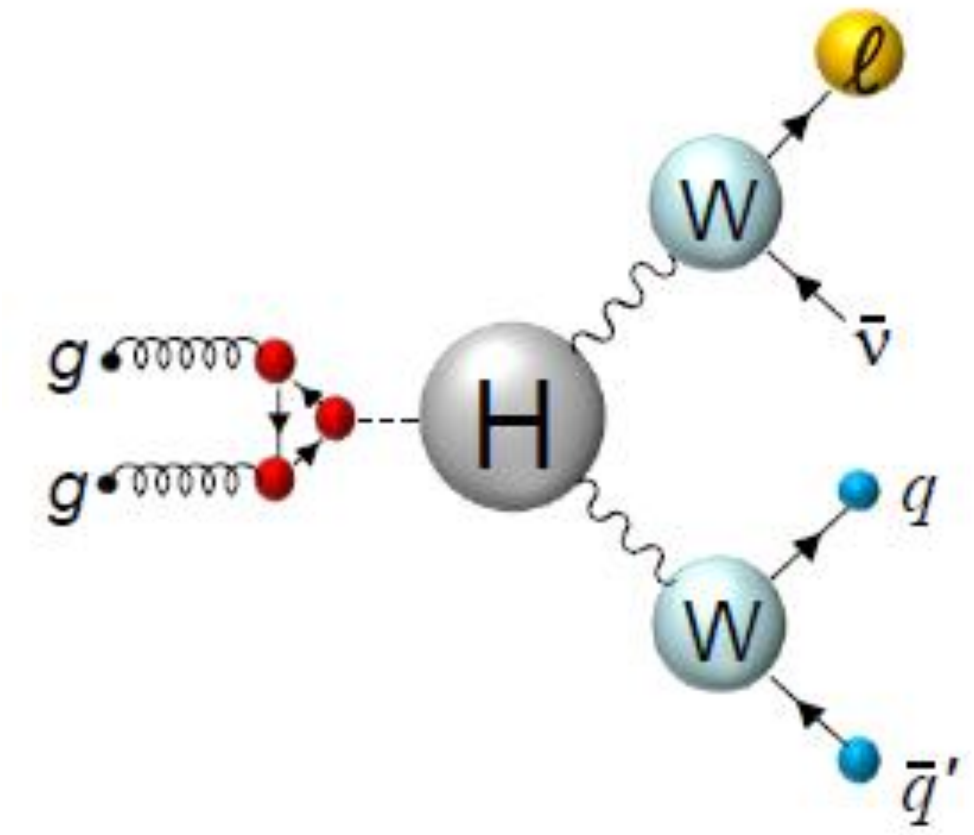
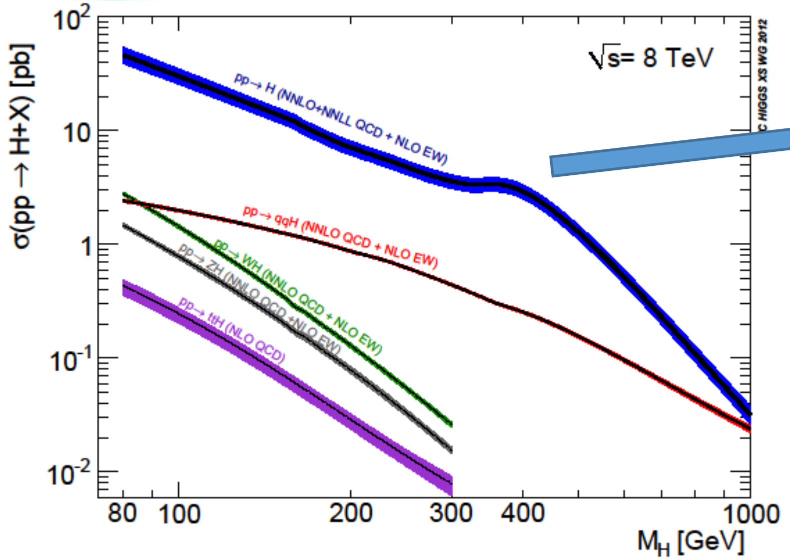
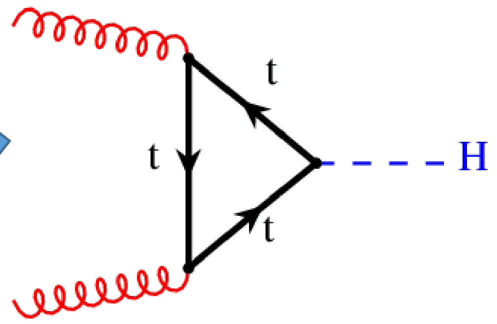
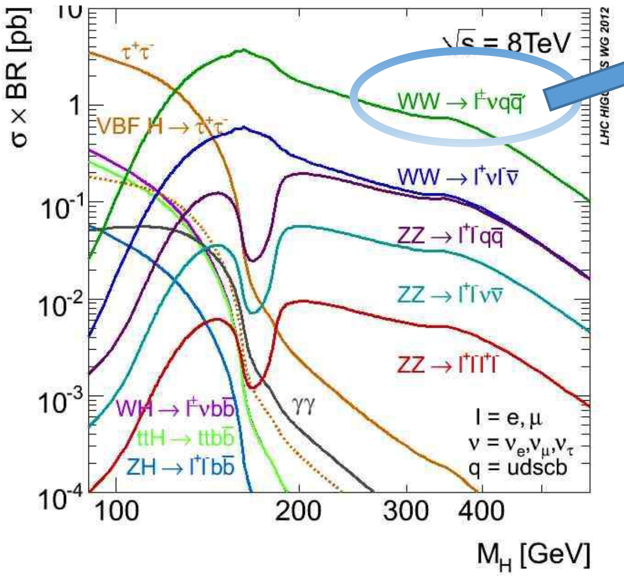


Analysis Overview





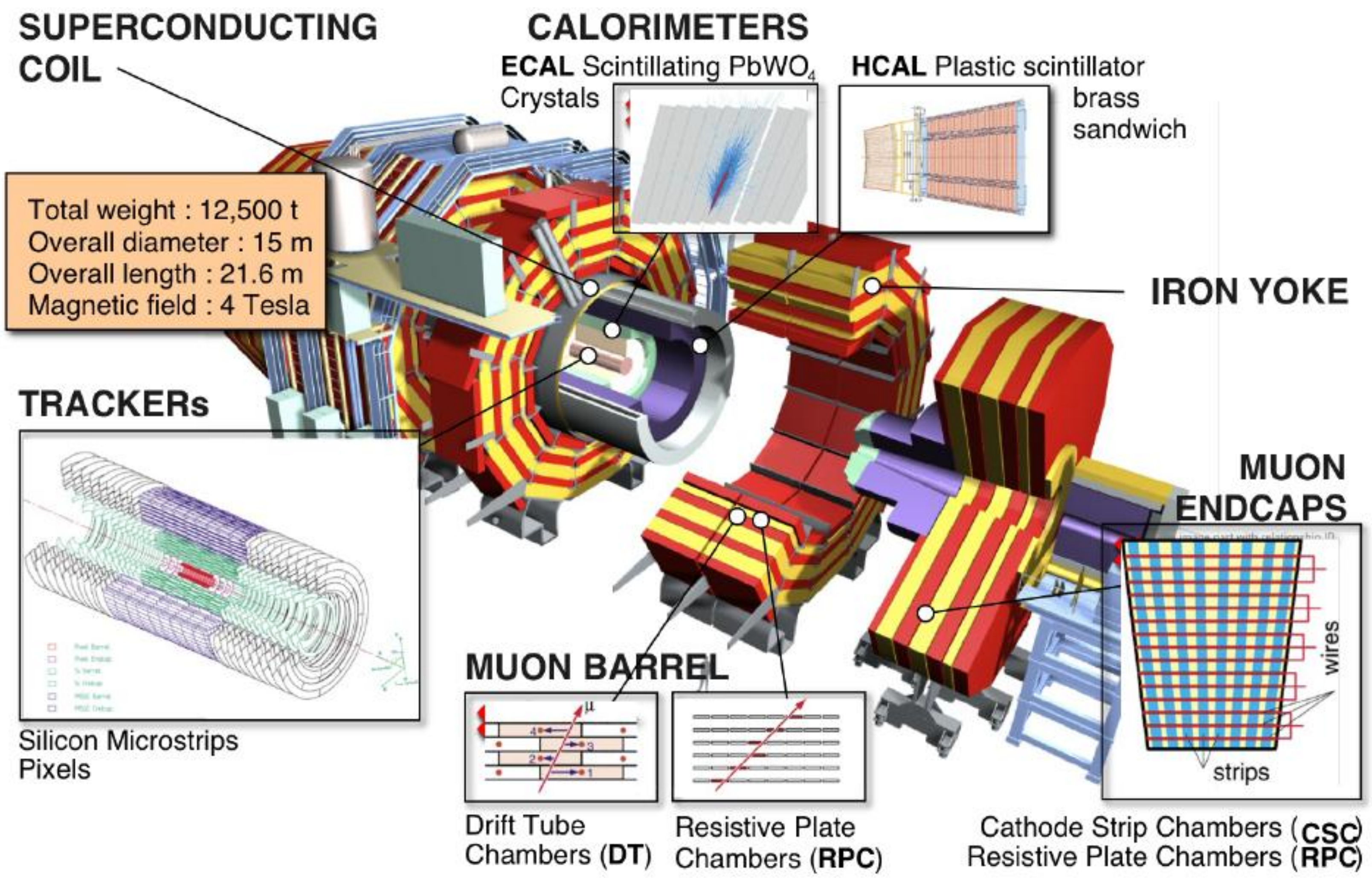
Higgs production through gluon-gluon fusion has highest Prod Cross-section at LHC



- **Highest Branching Ratio in high mass region**
- **Higgs mass peak can be reconstructed by reconstructing neutrino P_Z from W-mass constraint**

- **Huge W+jets background, QCD contamination ,**
- **Presence of a neutrino worsen resolution,**
- **Other backgrounds ttbar, WW, WZ, single top, DY etc.**

CMS Detector and Object reconstruction



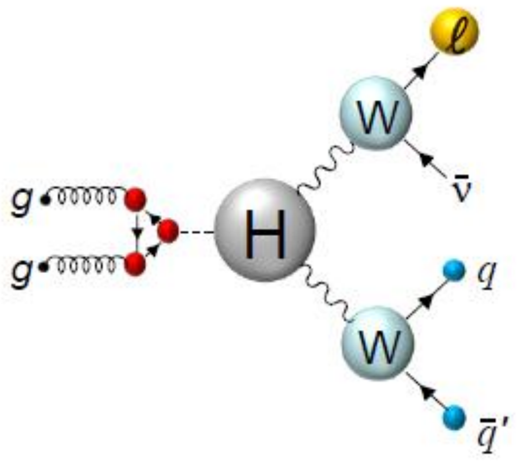
Jets **are reconstructed from calorimeter and tracker information using a particle flow algorithm.**

Muons **are measured with the tracker and the muon system.**

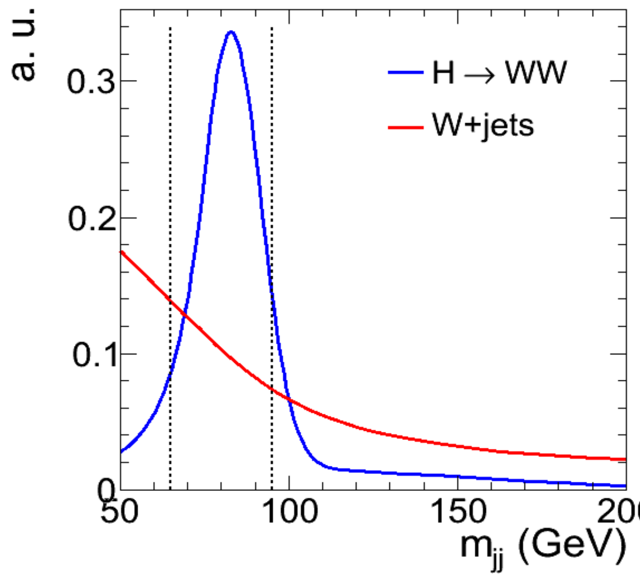
Electrons **are detected as tracks in the tracker pointing to energy clusters in the ECAL**

Analysis Strategy

- Higgs searches in the mass range of 170 – 600 GeV
  - Signal corrected for Higgs line shape and interference with the SM gg→WW production (500-600 GeV)



- Define signal region m_{jj} = [65,95] GeV
- Force W_{lep} → lν & W_{had} → *qq* on-shell
- Reconstruct $m_{WW} = m_{l\nu qq}$ *its shape used to extract limit*
- 4 categories (e | μ) x (2j | 3j) (apply the same techniques)
- Form Likelihood , 12 mass points × 2 flavours (e/μ) × 2 jet bins (2j/3j) = 48 different likelihoods
- Data-driven techniques for high rate backgrounds (W+Jets & QCD)

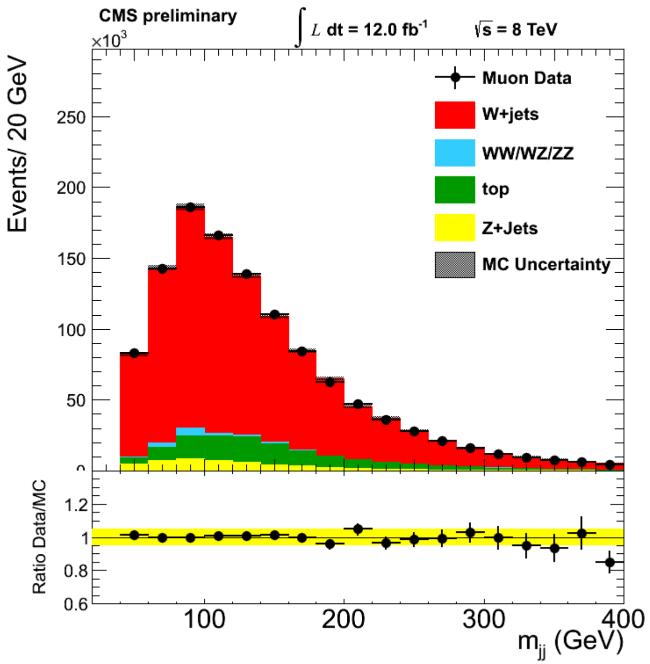


Integrated Luminosity = 12 fb^{-1} @ centre-of-mass energy = 8 TeV
Results are combined with 7 TeV data as well

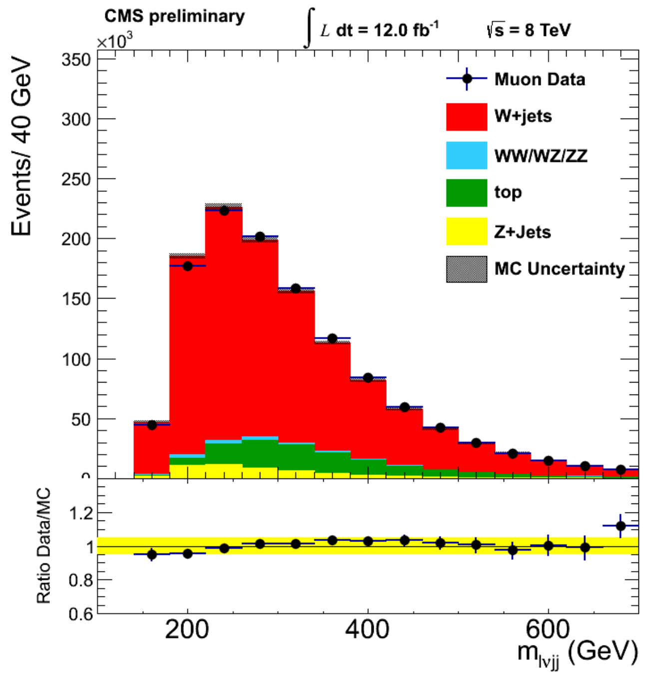
Event Selection

Preselection

- One high-p_T isolated lepton was selected with P_T > 35 (25) GeV and $|\eta|$< 2.5, excluding transition region (2.1) for electrons (muons)
- MET > 30 (25) GeV for electrons (muons)
- M_T (l+MET) > 30 GeV
- Two highest P_T jets for W_{had} , P_T > 30 GeV & $|\eta|$< 2.4
- Veto the presence of other lepton to reduce DY and Diboson



Muons 2j



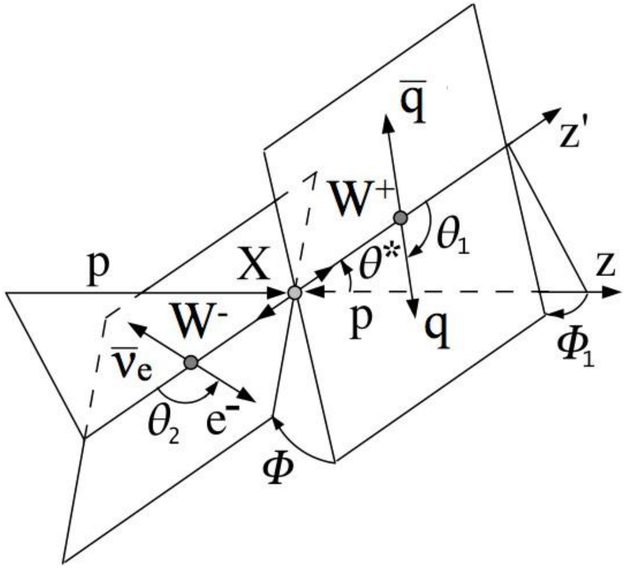
Input Variables for MVA

Optimization of Selection

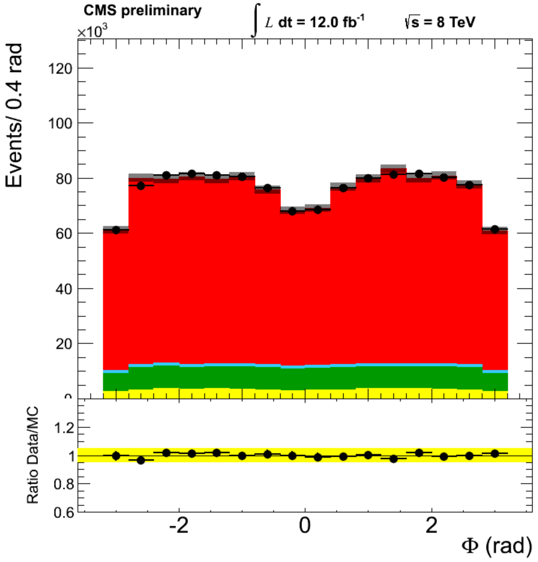
- **The higgs boson decay kinematics is fully described →**

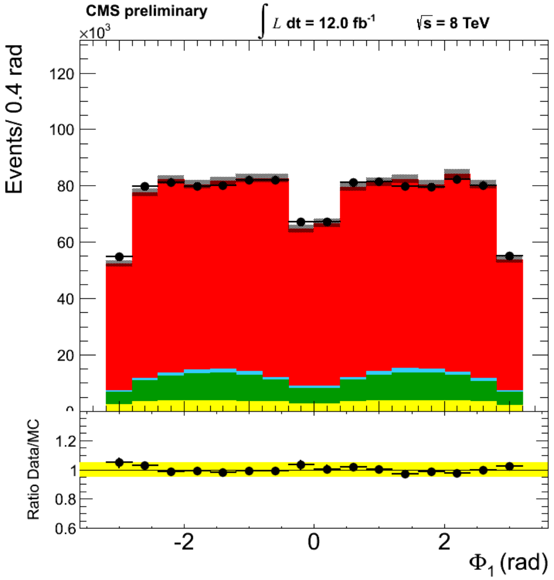
$\{m_{WW}, m_{jj}, \theta_1, \theta_2, \theta^*, \varphi, \varphi_1\}$

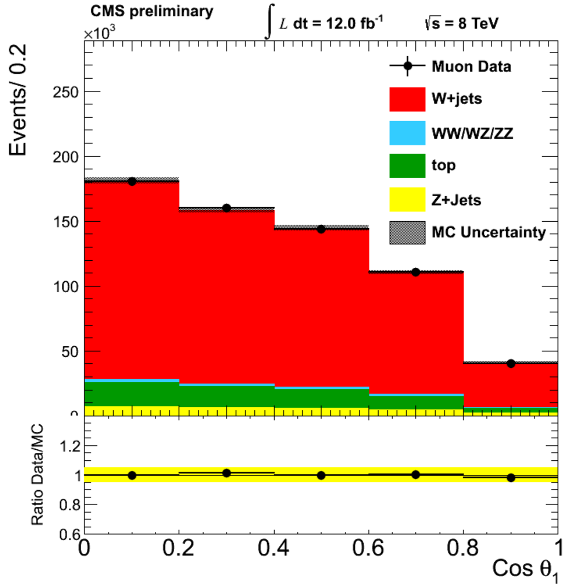
- **Likelihood Discriminators build with 5 decay angles, lepton charge, and P_T^{WW} and η^{WW}**

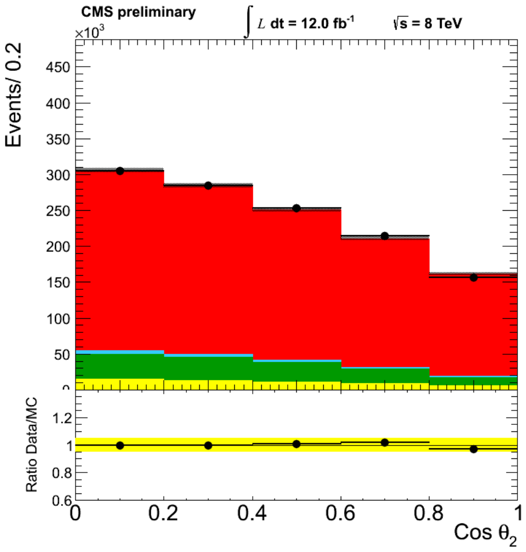


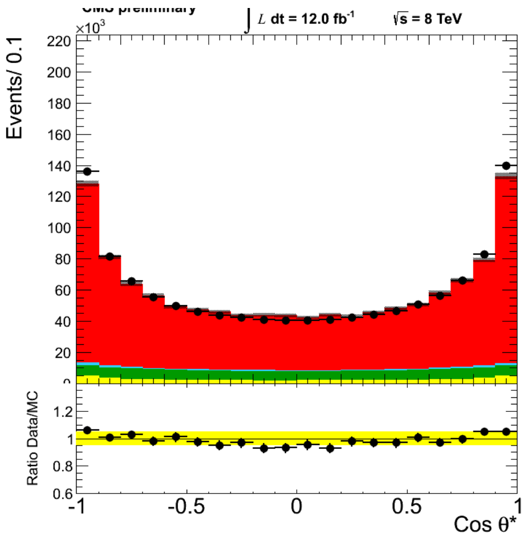
Muons 2j







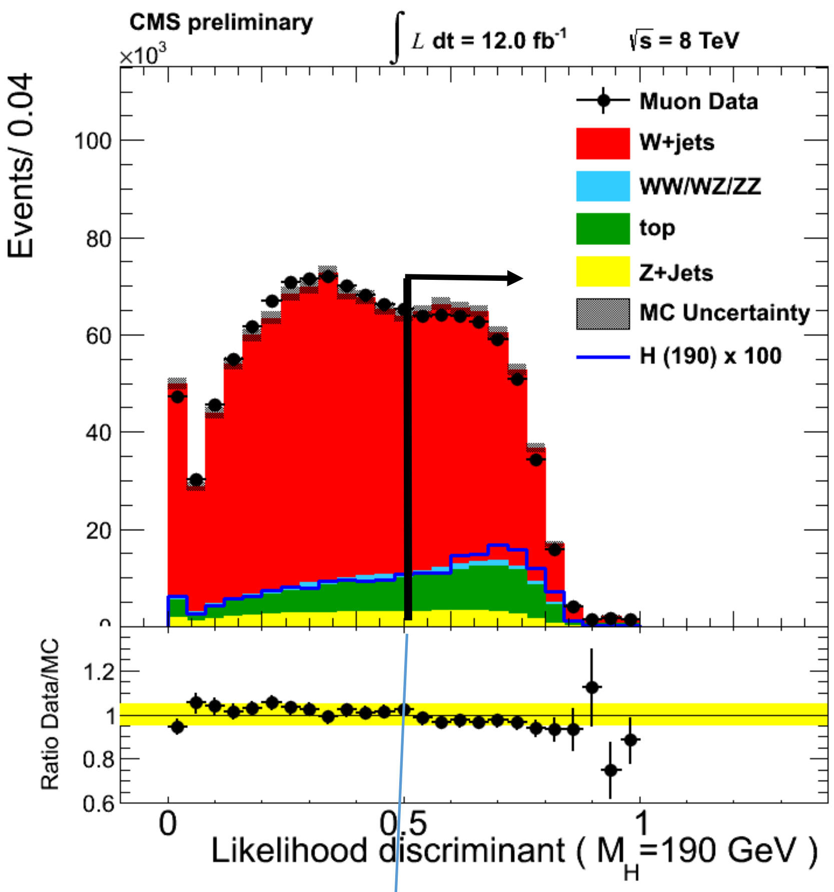


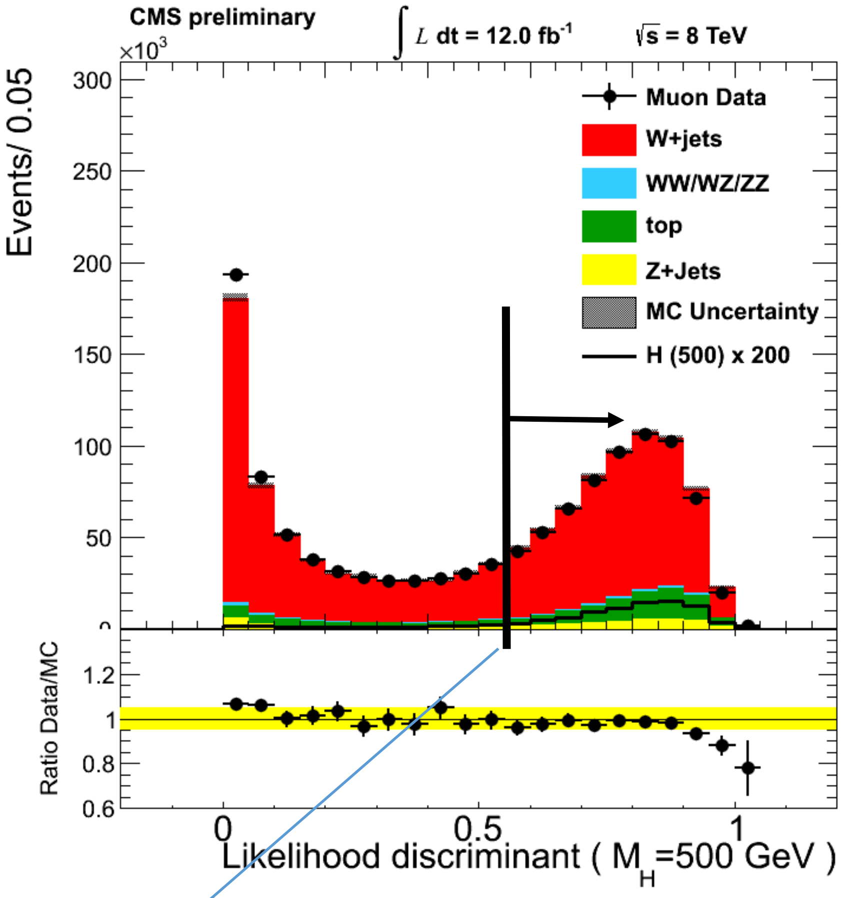


Reasonable agreement gives us confidence in the qualitative aspects of the MC modeling

MVA – Likelihood Discriminators

Muons 2j





MVA cut applied on likelihood discriminant for optimized limit expectation

Background estimations

M_{jj} shape:

- QCD fraction is estimated by fitting data over W+Jets and QCD enriched samples using template method in MET distribution.
- W+Jets shape in signal region is determined in some case from MC while in some from empirical function (comb of error and power law fun)

W+Jet shape in $m_{l\nu jj}$:

$$M_{l\nu jj}{}^{i} = \alpha \cdot m_{SBL}{}^{i} + (1-\alpha) \cdot m_{SBH}{}^{i}$$

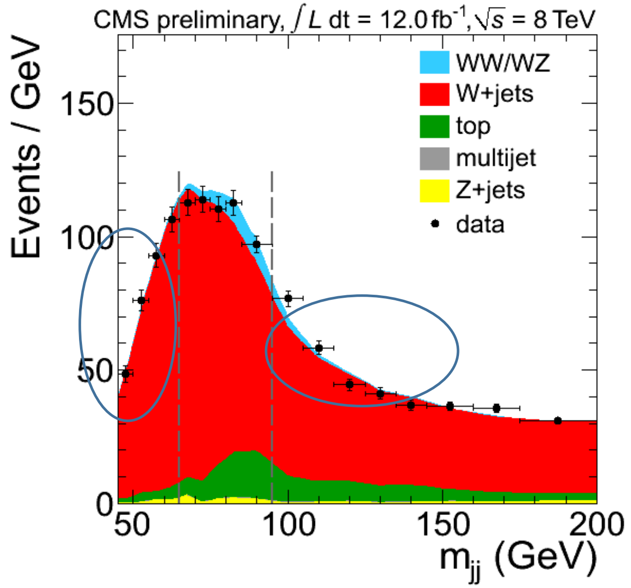
- In MC, $m_{l\nu jj}$ shape in upper and lower sidebands are

Compared to one in sig region, to find best mix of first two to produce latter, so, such α parameter is searched.

Det. Of Normalization:

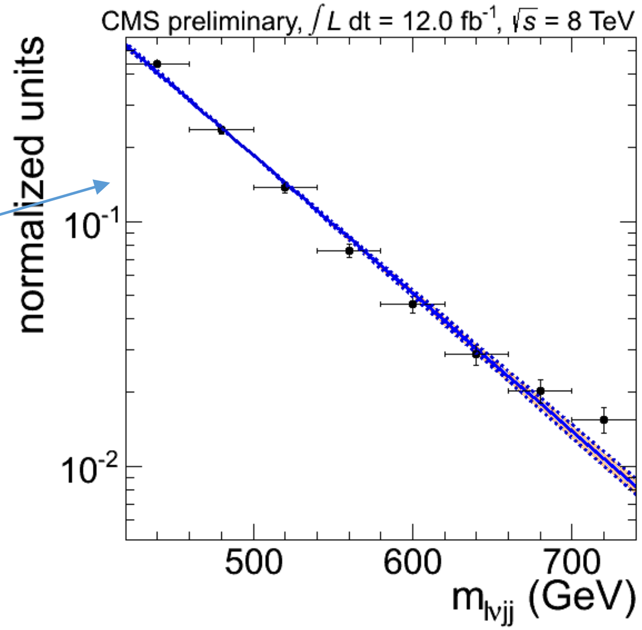
- Stack backgrounds, perform unbinned maximum likelihood fit to m_{jj} data
- Exclude 65-95 GeV signal region from the fit
- Data in sidebands of m_{jj} are fitted to get background normalization, which are then extrapolated to the signal region
- The background yields in the fit are:
  - Constrained to the MC cross-section for all minor backgrounds
  - QCD Constrained to data fraction obtained by the MET fit.
  - Unconstrained for W+jets

Muons 2j – m_H =500



$m_{l\nu jj}$ shape

The distribution of the extrapolated background shape in the signal region for the Higgs mass hypothesis of 500 GeV,
Points represent extrapolated points, blue line shows fitting function



W+jets $m_{l\nu jj}$ shape is a linear combination of the shapes from higher sidebands (SBH) & lower sidebands (SBL) m_{jj} data

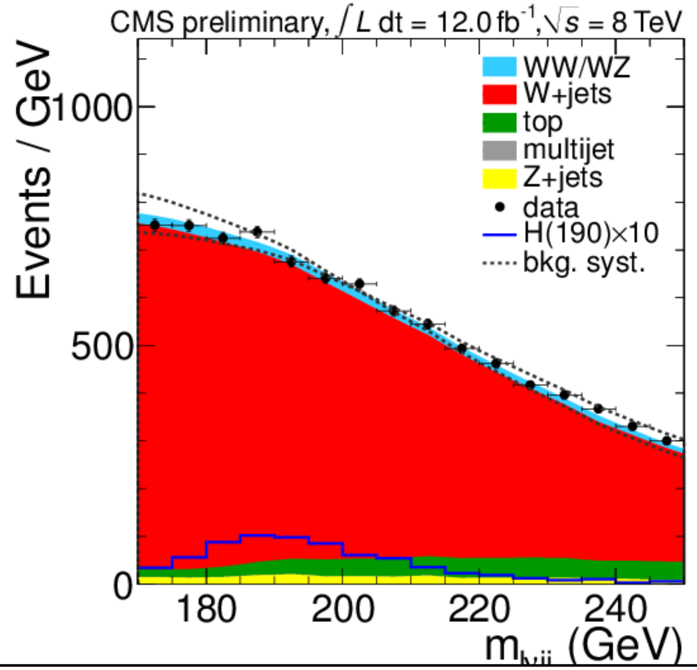
- $m_{jj} \in [55,65]$ GeV : SBL
- $m_{jj} \in [95,115]$ or $[95,200]$ GeV for $m_H <$ or ≥ 250 GeV : SBH

The shape is extracted , in each four body mass bin *i*, using α from previous fit:

$$M_{l\nu jj}{}^{i} = \alpha \cdot m_{SBL}{}^{i} + (1-\alpha) \cdot m_{SBH}{}^{i}$$

- $m_{l\nu jj}$ shapes are fed to the limit setting tools

Muons 2j – m_H 190

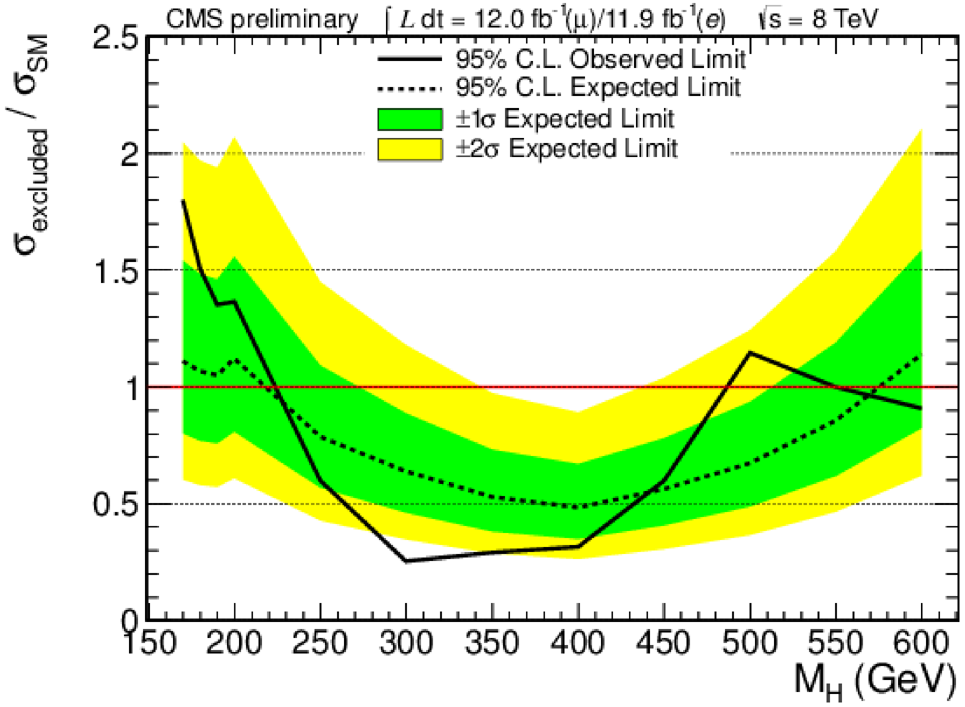


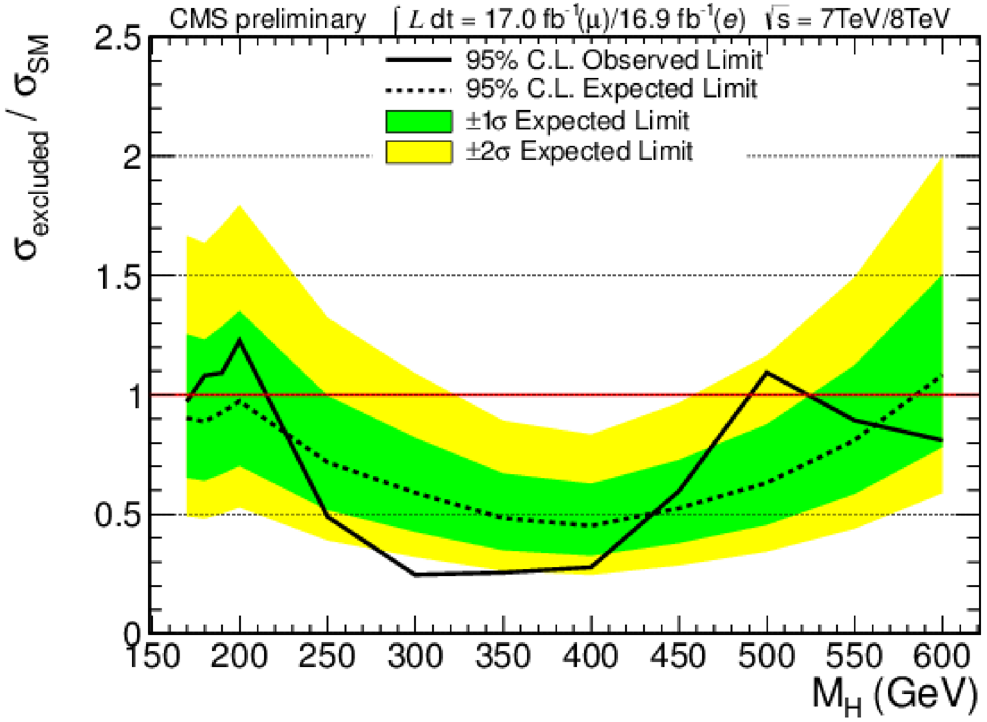
The four body invariant mass distribution with the fit projection after selection optimized for the Higgs mass hypotheses of 190 GeV

Systematics uncertainties

normalization uncertainty	<= 2 %
W+jets fit uncertainty	shape
inclusive cross-section	13-15%
scale uncertainties from jet binning	4-28%
acceptance uncertainty due to pdfs	1-2%
luminosity	4.4%
jet energy scale and MET	1%
Lepton efficiencies	2%
Lepton trigger efficiencies	1%
Pile up	<1%
Likelihood selection	10%
interference	shape

Limits on SM Higgs cross-section





8 TeV at 12fb^{-1} of Data:

- **expected exclusion 95% CL: 220–560 GeV**
- **observed exclusion 95% CL: 225–485 GeV and 550–600 GeV**

7TeV of 5fb^{-1} +8TeV of 12fb^{-1} of Data

- **expected exclusion 95% CL: 170–585 GeV**
- **observed exclusion 95% CL: 215–490 GeV and 525–600 GeV**

Conclusion and outlook

- A search for the SM Higgs boson decaying into two W bosons with semi-leptonic final state has been presented.
- The analysed data correspond to the p-p collisions at centre-of-mass energy of both 7TeV (2011) and 8TeV (2012).
- No evidence for an additional Higgs-like boson is found and 95% exclusion limits on its production cross section have been obtained.
- With 8 TeV data, we exclude the Standard Model Higgs boson in the mass ranges 225–485 GeV and 550–600 at 95% confidence level
- With 7+8 TeV data, we exclude the Standard Model Higgs boson in the mass ranges 215–490 GeV and 525–600 at 95% confidence level
- working on including Vector Boson Fusion production mode as well to increase sensitivity

- Working on extending analysis up to 1 TeV with a separate event category called boosted regime in which Jet-substructure technique is used, targeting Moriond EW-2013.

Backup

Physics Objects

Muons : Using the official mu-POG recommendation

- https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideMuonId
- Using "thigh" and "loose" (for veto) definitions
- PF based isolation with PU correction

Electrons : Using the official e/γ-POG recommendation

- MVA ID: https://twiki.cern.ch/twiki/bin/viewauth/CMS/MultivariateElectronIdentification
- Conversion rejection
- PF based isolation (ΔR0.3) with PU correction with Effective Area
- Tight electron: WP80 triggering MVA
- Veto : WP90 non-triggering MVA
- WP definitions: https://twiki.cern.ch/twiki/bin/view/Main/HVVElectronId2012

Jets:

- AK5 PF jets with CHS, JEC: L1,L2,L3(residual for data)
- PU jet ID: https://twiki.cern.ch/twiki/bin/view/CMS/PileupJetID

Missing Transverse Energy:

- PF MET : type-I and shift (phi modulation) corrections

Interference corrections

• Interference is playing a major role in the signal cross section modeling for an
heavy Higgs ($m_H > 600$ GeV)

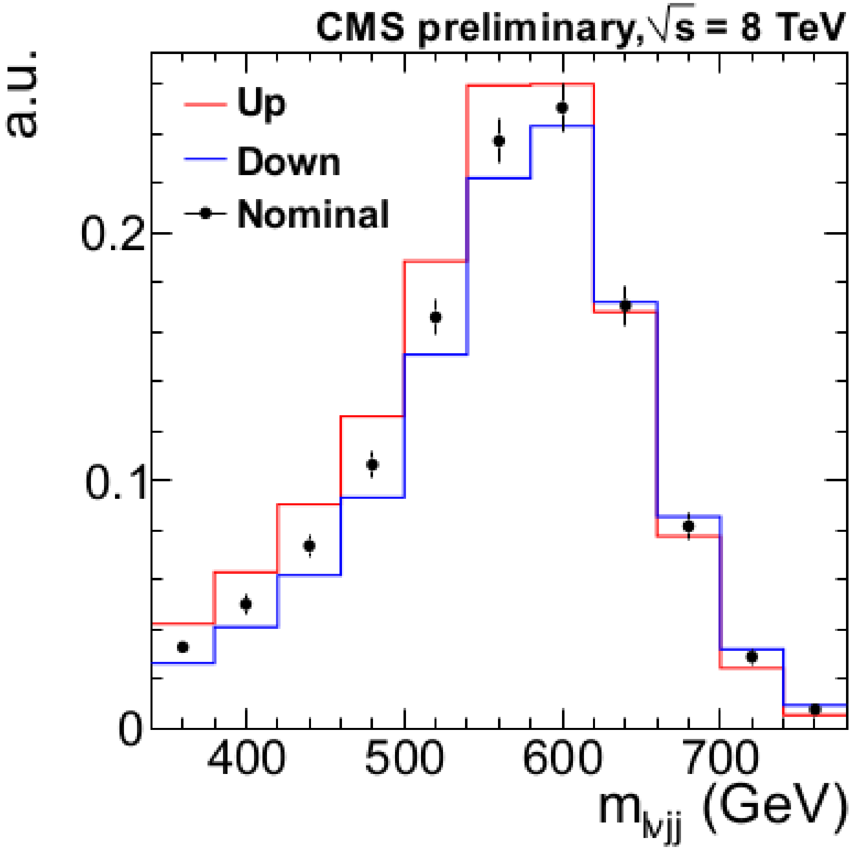
• A final recipe was presented at Higgs High Mass WG meeting on Oct. 12
meeting by Qiang Li and approved by theorists.

• https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=212297

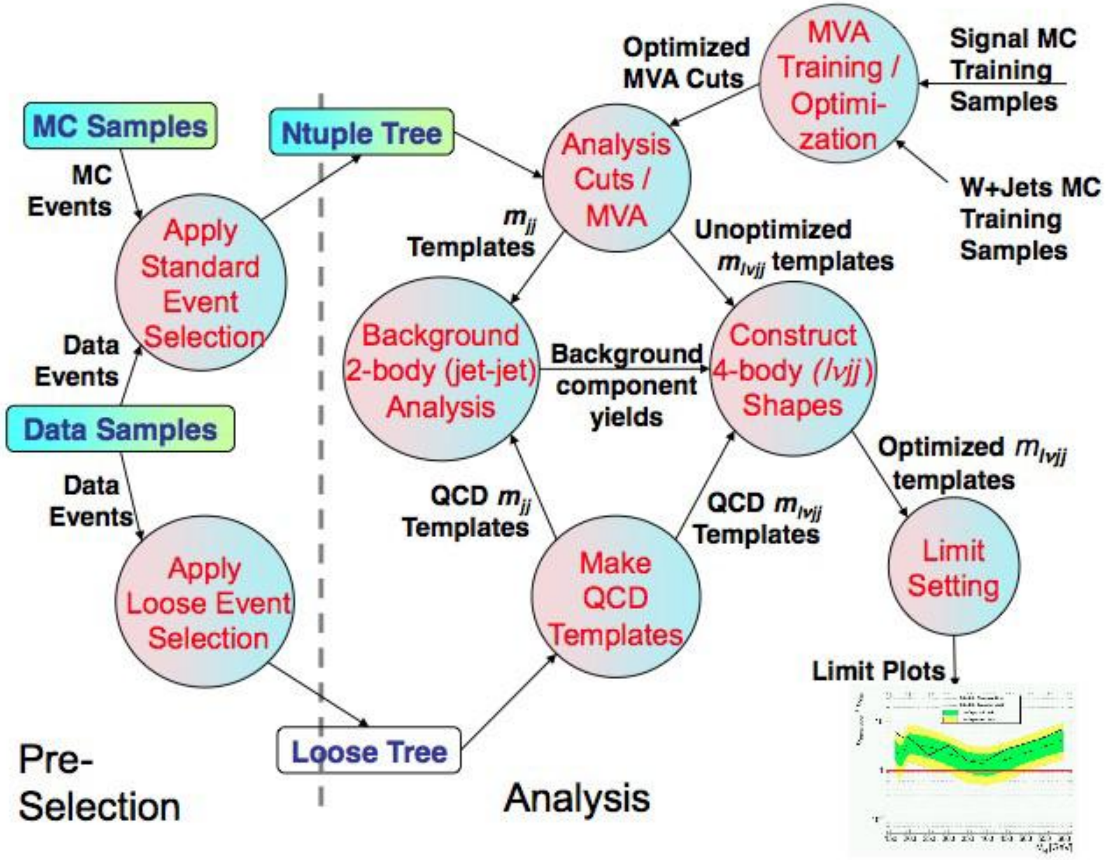
• https://twiki.cern.ch/twiki/bin/viewauth/CMS/HeavyHiggsInterferenceEffects

• The correction is implemented in this version of the analysis

• The error associated to the correction is propagated to the m_{WW} signal shape and given to the combination tool(check also backup



The signal extraction technique



Two main conceptual steps:

- **The two-body mass distribution mjj used to get the background normalization**
- **The four-body mass distribution mlvjj used to extract the limit**

W+jets 2-body shape

- The W+jets shape is described by a kinematic turn-on ⊗ power law tail or, in a few cases, by a mixture of MC shapes:
- for most of mass points, the analytic form is

$$f_{\text{high mass}}^{2j/3j}(x) = \mathrm{erf}(x;m_0,\sigma) \cdot x^{-\alpha-\beta\log(x/\sqrt{s})}$$

- for low-mass Higgs (≤ 200/300 GeV/c2 for the 2j/3j channels), more suitable shapes are given by

$$f_{\text{low mass}}^{2j}(x) = \mathrm{erf}(x;m_0,\sigma) \cdot x^{-\alpha} \cdot e^{x\tau}$$

$$f_{\text{low mass}}^{3j}(x) = x^{-\alpha-\beta\log(x/\sqrt{s})} \cdot e^{x\tau}$$

- for even lower-mass Higgs (≤ 180/200 GeV/c2 for the 2j/3j channels), given the high statistics of these bins, the W+jets shape is given by the MC

Background normalization systematic

- **The errors for the total background normalization are derived from the unbinned maximum likelihood fit on the dijet invariant mass described**
- **The non-Poisson fractional are taken as an additional systematic uncertainty and they are computed with**

$$\text{non-Poisson fractional error} \equiv \frac{\sqrt{\sigma^2_{N_{\text{bkg}}} - N_{\text{bkg}}}}{N_{\text{bkg}}}$$

m_{H} (GeV)	electron 2-jet (%)	electron 3-jet (%)	muon 2-jet (%)	muon 3-jet (%)
170	0.2	0.3	0.2	0.2
180	0.5	0.3	0.5	0.2
190	0.3	0.3	0.3	0.2
200	0.6	0.4	0.4	0.3
250	0.3	0.4	0.3	0.3
300	0.3	0.5	0.3	0.7
350	0.9	0.8	2.5	1.3
400	0.4	0.8	0.5	0.8
450	0.6	2.9	0.7	1.8
500	0.9	1.9	1.0	1.7
550	0.9	4.1	1.2	1.9
600	1.6	0.9	1.3	1.6