A Search For The Higgs Boson in the VBF $H \to WW \to 2l2\nu$ Mode with the CMS Detector

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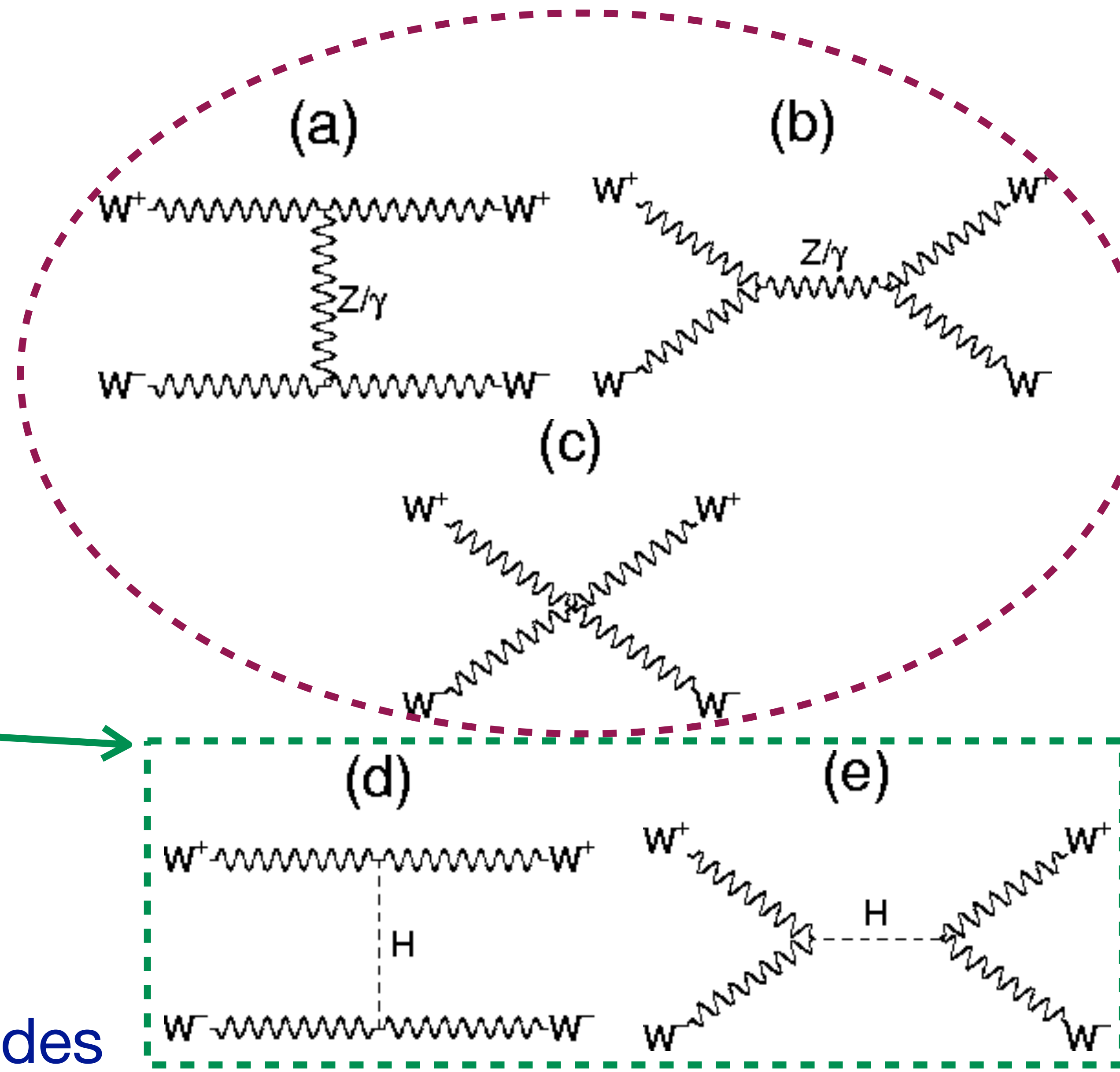
- Motivations for the VBF channel
- Description of the Higgs boson search in the $WW \to 2l2\nu$ mode:
- Results and exclusion limits with 1.1 fb^{-1}
- Conclusions

Why we are interested in VBF

- The **Spontaneous Symmetry Breaking** (SSB) mechanism is essential to give mass to the weak bosons while preserving the fundamental gauge symmetry

- The **VVH coupling** is (almost) sacred:
  - it is a **direct consequence of SSB**, while fermion masses arise indirectly through arbitrary Yukawa couplings
  - it **prevents** the WW scattering amplitude from **violating unitarity** at ~1 TeV

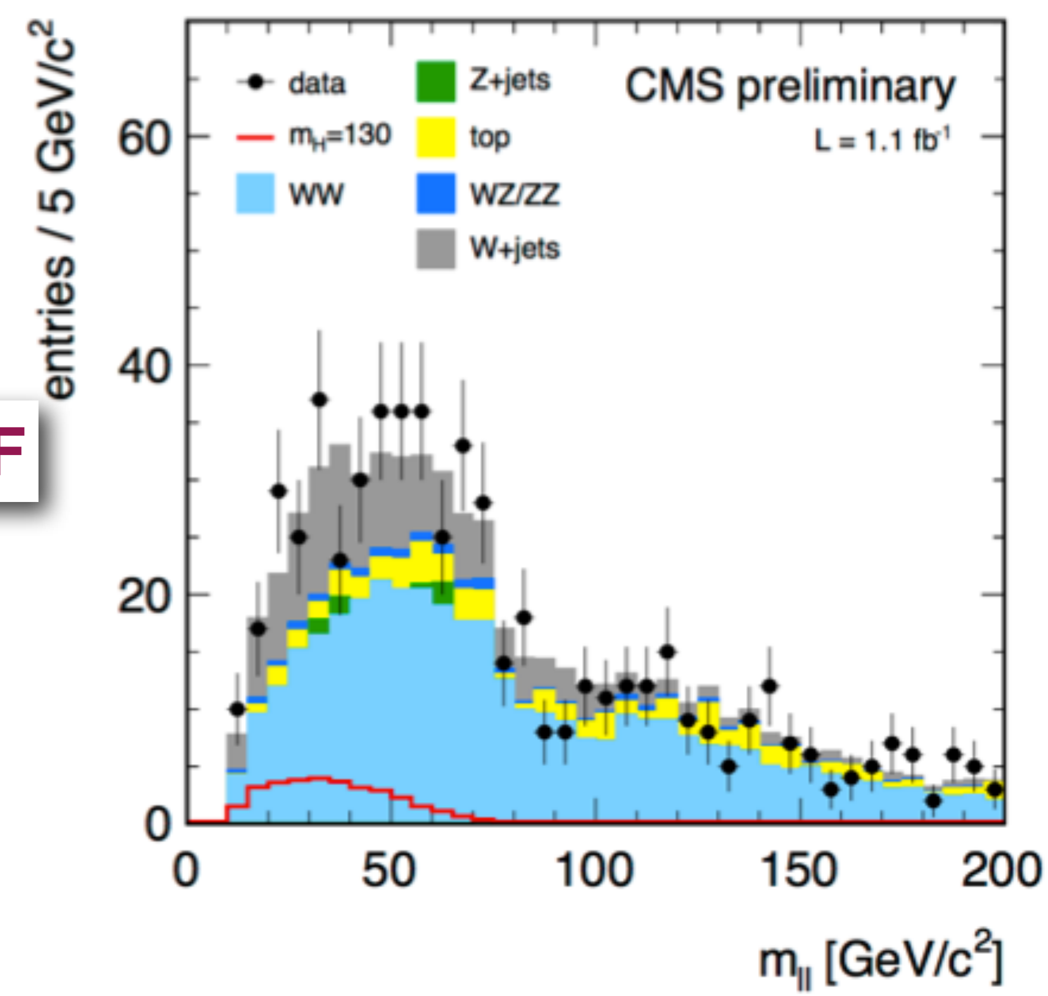


- The qqH, H→WW→2l2ν channel provides **direct access** to the **VVH coupling**
  - both on the production and on the decay side

The base WW event selection

- The strategy to look for **$H \to WW \to 2l2\nu$ events** relies on:
  - two energetic, isolated leptons (e or μ) with $p_T > 20/10$ GeV/c
  - large missing energy from undetectable neutrinos, i.e. $E_T^{miss} > 40$ (20) GeV (S.F./O.F.)
  - **Z veto**: invariant mass of ee and μμ pairs must lay outside a $m_Z \pm 15$ GeV/c^2 mass window
  - **top veto**: reject events with top-tagged jets
  - **WZ/ZZ veto**: reject events with a 3rd (4th) good lepton candidate

more details in E. Di Marco's talk



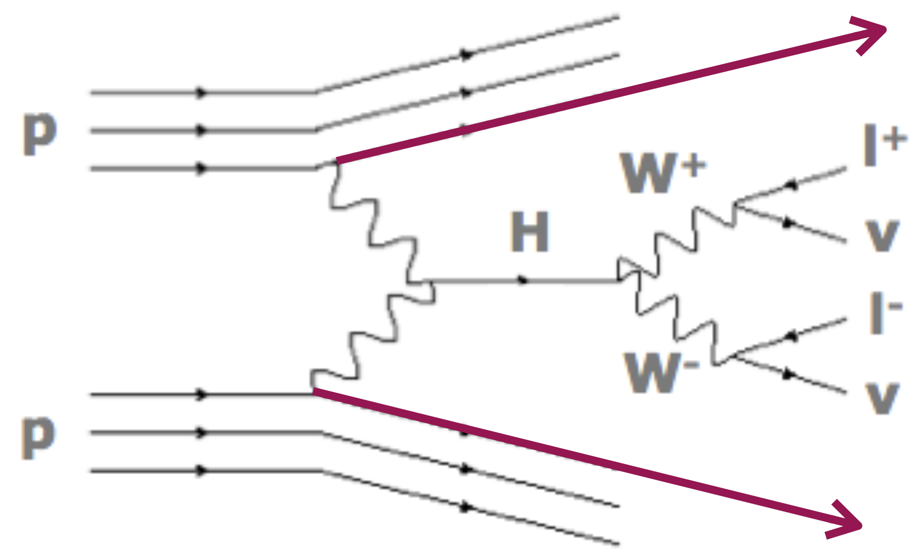
relevant for VBF

- Analysis is divided into 0, 1 and **2-jet bin**
  - count ParticleFlow anti-k_T jets with R=0.5 that have $p_T > 30$ GeV/c and $|\eta| < 5$

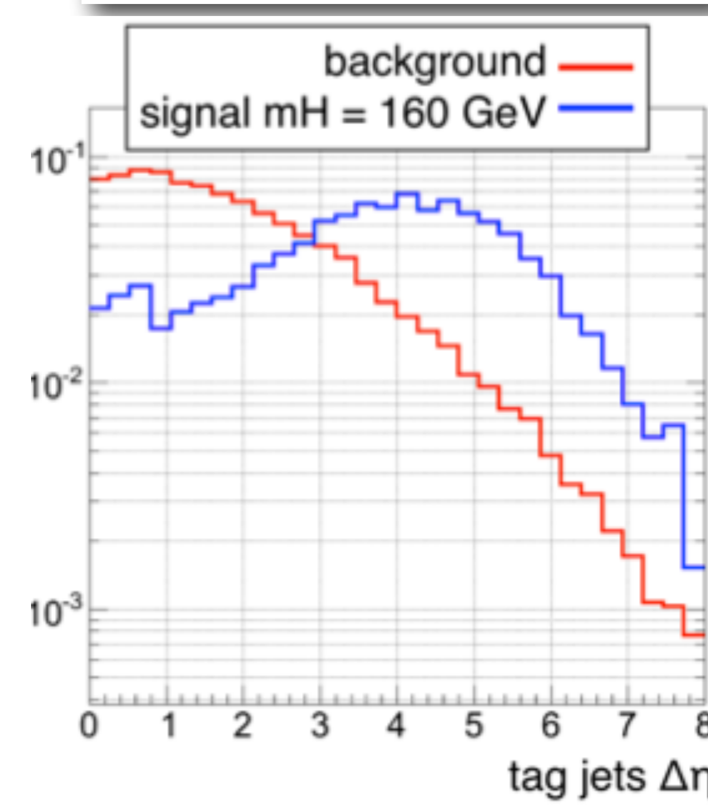
The VBF topology

- Despite $\sigma_{VBF}/\sigma_{gg\text{-}fusion} \approx 1/10$, the **VBF contribution** can be **enhanced** applying specific **topological selections**

- Exploit VBF process requiring **2 jets** (*tag* jets):
  - no other hadronic activity between them (in η)
  - leptons lie within tag jets (in η)
  - $|\Delta\eta_{jj}| > 3.5$ and $m_{jj} > 450\ \text{GeV}/c^2$
  - for $m_H < 200\ \text{GeV}/c^2$, require that $m_{ll} < 100\ \text{GeV}/c^2$



tag jets in fwd/bwd regions of detector



mass	**Higgs**	WW	top	Zjets	Wjets	**Σ bkg**	**data**
140	**1.8±0.1**	0.5±0.2	2.0±1.2	0.6±0.6	0.5±0.4	**3.6±1.4**	**3**
160	**4.0±0.1**	0.5±0.2	2.0±1.2	0.6±0.6	0.5±0.4	**3.6±1.4**	**3**
200	**2.5±0.1**	0.5±0.2	2.0±1.2	0.6±0.6	0.5±0.4	**3.6±1.4**	**3**
400	**0.7±0.0**	0.6±0.2	2.8±1.6	0.6±0.6	0.4±0.4	**4.5±1.8**	**4**

Control of backgrounds

- Dominating background after full selection comes from **top events**:

$$N^{qqH}_{non\ tagged} = N^{qqH}_{tagged} \times (1 - \epsilon_{central\ jet})/\epsilon_{central\ jet}$$

N^{qqH}_{tagged}: number of events with the most central jet **top-tagged**

$\epsilon_{central\ jet}$: **top-tagging eff(p_T,η)** for the most central jet measured in data

a 10% correction factor is applied to account for **most central jet outside tracker acceptance**

- Second leading background comes from **DY events**:

$$N^{\ell\ell,\mathrm{exp}}_{\mathrm{out}} = R^{\ell\ell}_{\mathrm{out/in}}(N^{\ell\ell}_{\mathrm{in}} - N^{\mathrm{non-Z}}_{\mathrm{in}} - N^{ZV}_{\mathrm{in}})$$

$N^{\mathrm{non-Z}}_{\mathrm{in}}$: opposite-flavour VZ events **measured** in Z peak

$N^{\ell\ell}_{\mathrm{in}}$: same-flavour events **measured** in Z peak

N^{ZV}_{in}: same-flavour VZ contribution **exp. from MC**

$R^{ll}_{out/in}$ is measured in data and MC as well; systematics from its dependence on E_T^{miss} cut

Systematic uncertainties

- **Theoretical** uncertainties on **jet-bin fractions** →

$f_0 = (\sigma_{\geq 0\text{-jets}} - \sigma_{\geq 1\text{-jets}}) / \sigma_{\geq 0\text{-jets}}$
$f_1 = (\sigma_{\geq 1\text{-jets}} - \sigma_{\geq 2\text{-jets}}) / \sigma_{\geq 0\text{-jets}}$
$f_2 = \sigma_{\geq 2\text{-jets}} / \sigma_{\geq 0\text{-jets}}$

• compute $\sigma_{\geq 0\text{-jets}}$ (ggH) at NNLO, and $\sigma_{\geq 1\text{-jets}}/\sigma_{\geq 1\text{-jets}}$ (ggH+1/2 jets) at NLO with MCFM
• syst. from **$\mu_R(\mu_F)$ variation** between $m_H/4$ and m_H

• syst. from relative differences in f_0, f_1, f_2 with **different PS** (Pythia/Herwig)

20%

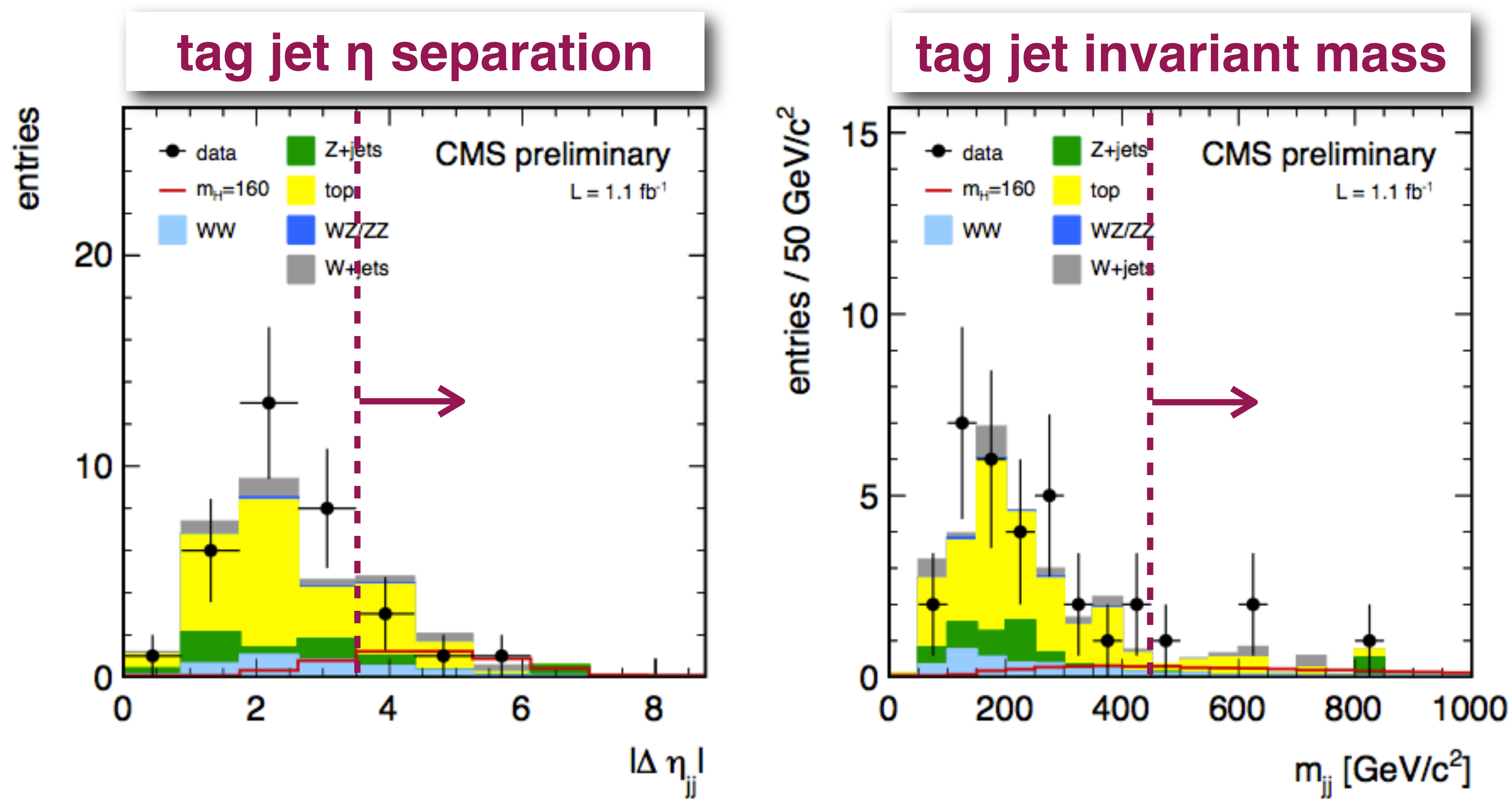
- **Theoretical** uncertainties on **VBF predictions**
  - vary **$t/2 < \mu_R(\mu_F) < 2t$** and **α_S**
  - repeat the procedure for **loose/tight VBF cuts**

5%

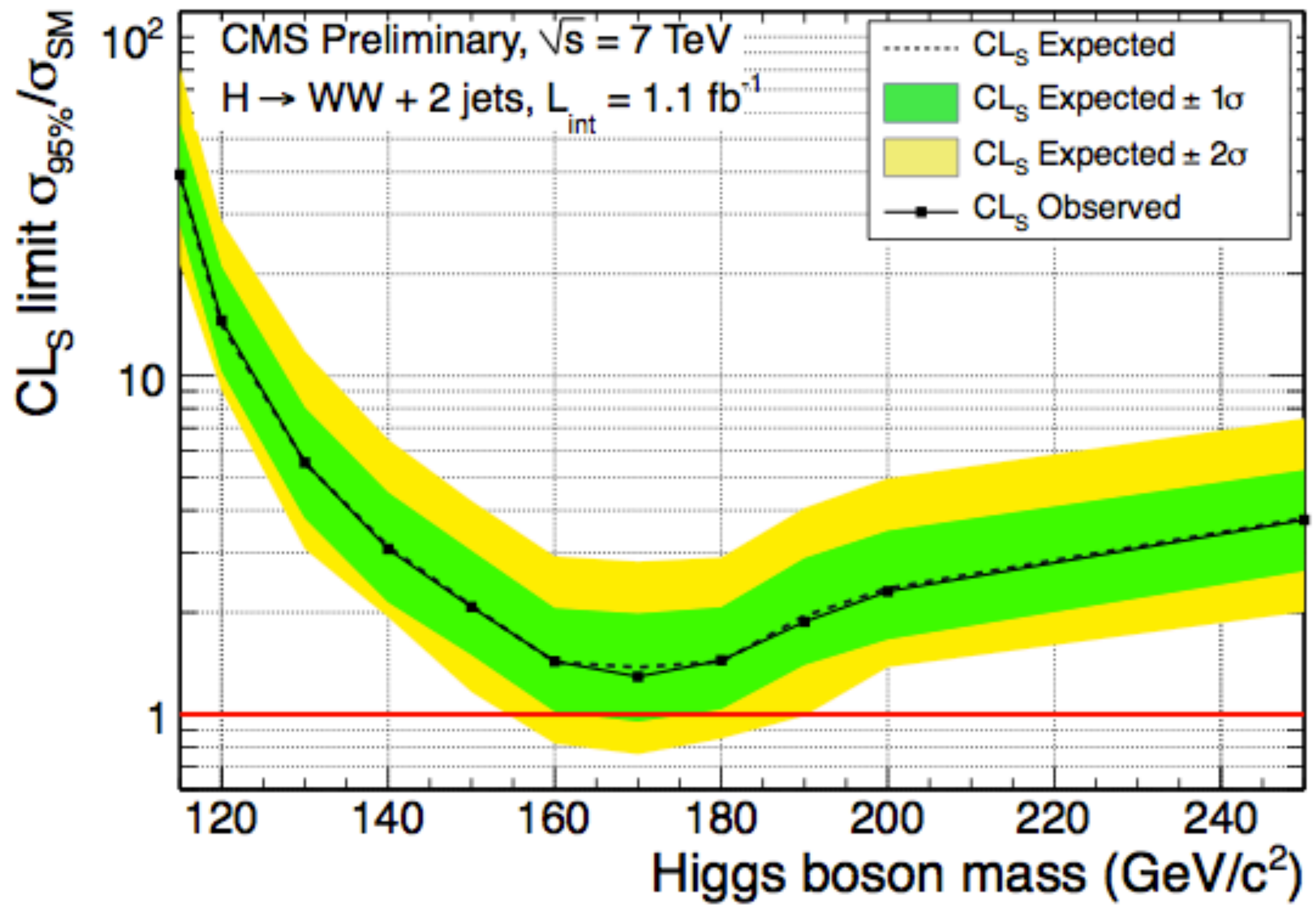
- **Experimental** uncertainties on **background estimation**
  - top: 25%
  - Drell-Yan: 60%

Cut based analysis

- Simply **count number of events** after full selection is applied
- **Drell-Yan**, **top** and **W+jets** backgrounds are evaluated from **data-driven** techniques at the end of the analysis
- **Other backgrounds** are taken from **Monte Carlo** directly (WZ, ZZ,W+γ)



Results with 1.1 fb^{-1}



- Exclusion limit obtained with the CL_s-LHC method
- Observed limit is in very good agreement with SM expectations
- The **VBF channel alone** is sensitive to ≤ **$2\times\sigma_{SM}$** in the range [150-200] GeV/c^2

Conclusions

- CMS searched for the **VBF-produced SM Higgs** in WW fully leptonic final state with 1.1 fb^{-1} of data collected in 2011
  - results in good agreement with SM expectations - no visible excess found

- **Results** for this production channel have been **combined with the 0 and 1-jet bins** (mostly gluon-fusion)

- With more data, and if a SM Higgs exists, this channel will allow to probe the electroweak nature of the **VVH coupling**

Backup