Spin measurements in $H \rightarrow WW \rightarrow 2\ell 2\nu$ with CMS

Sten Luyckx (UA)
On behalf of CMS

Higgs Hunting 2013 – Paris

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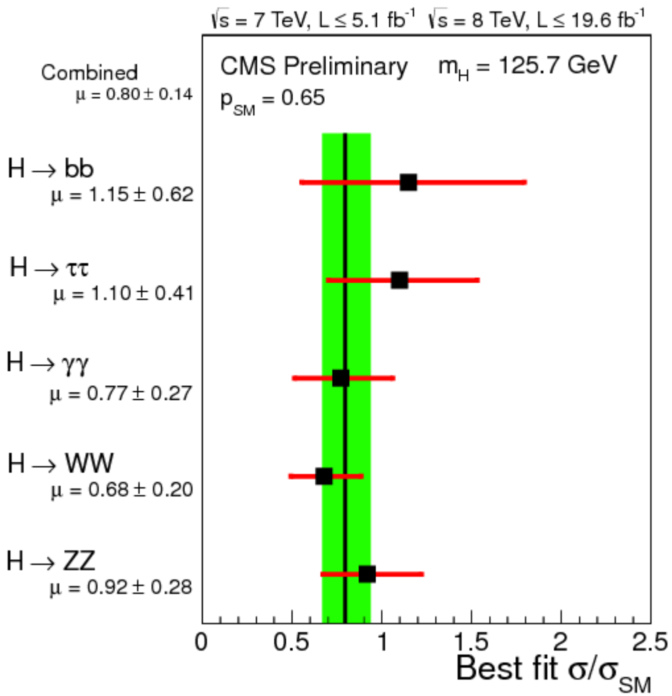
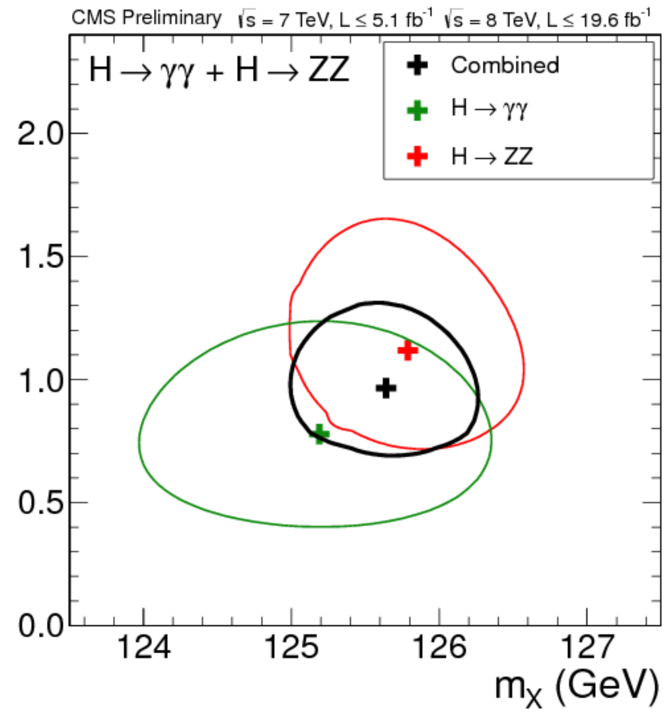
Introduction

- **A narrow resonance was found in multiple channels at a mass of 125 GeV in both ATLAS and CMS**





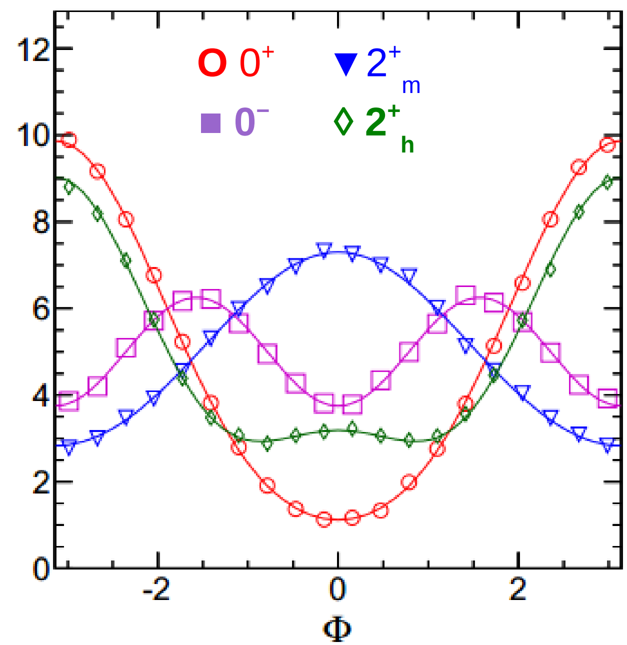
- **Next step : the determination of Quantum Numbers such as Spin and Parity is**

- **This talk covers the spin-parity measurement in H → WW → 2ℓ 2ν with CMS data**

Generator Study

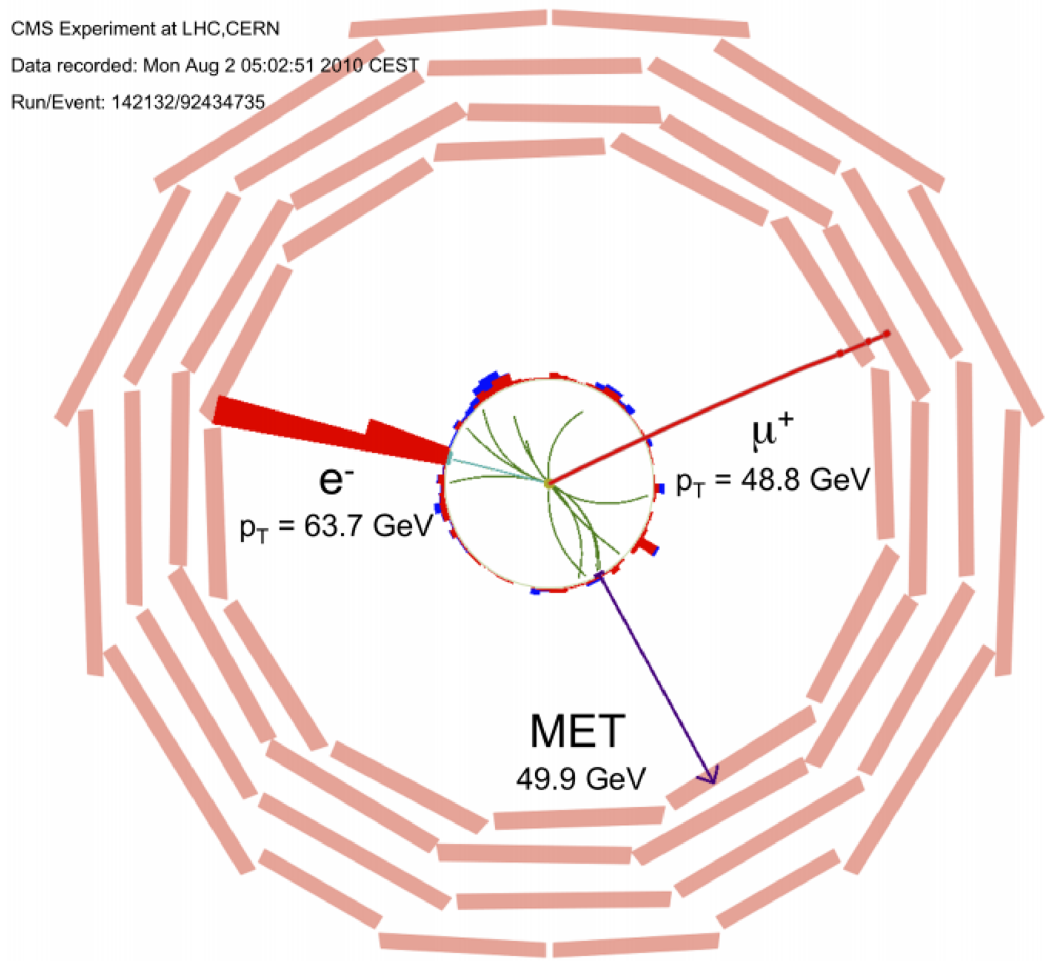
- **As shown in arXiv:1208.4018 (Y. Gao et al.), the WW channel is sensitive to test the tensor structure of the couplings of the new boson to WW :**

scenario	$X \to ZZ$	$X \to WW$	$X \to \gamma\gamma$
0^+_m vs background	5.0	5.0	5.0
0^+_m vs 0^+_h	1.8	1.1	0.0
0^+_m vs 0^-	2.9	1.2	0.0
0^+_m vs 1^+	2.1	2.0	–
0^+_m vs 1^-	2.8	3.2	–
0^+_m vs 2^+_m	1.1	2.8	2.4
0^+_m vs 2^+_h	~5	1.1	3.1
0^+_m vs 2^-_h	~5	2.5	3.1



- **We considered 2 different possibilities :**
  - **- Spin-0 scalar : $J^P = 0^+$**
    SM predicted value
  - **- Spin-2 tensor : $J^P = 2^+$**
    The minimal couplings spin-2 model

Briefly : $H \to WW \to 2\ell\ 2n$



Signature:

- 2 isolated high p_T leptons (e, μ)
- Large missing E_T
- Small $\Delta\phi_{\ell\ell}$ and low $M_{\ell\ell}$ for low M_H
- No resonance peak

Backgrounds:

- WW : continuum
- tt / tW : b-jets
- W+jets : « fake » lepton
- Z / γ^* : mis-measured MET
- $W / Z+\gamma^{(*)}$: $\gamma^{(*)} \to \ell\ell$
- WZ / ZZ : V+jj/$\nu\nu$ or missing lepton

Spin Analysis

- Try to separate the SM hypothesis (0^+) and the spin-2 minimal coupling graviton (2^+)

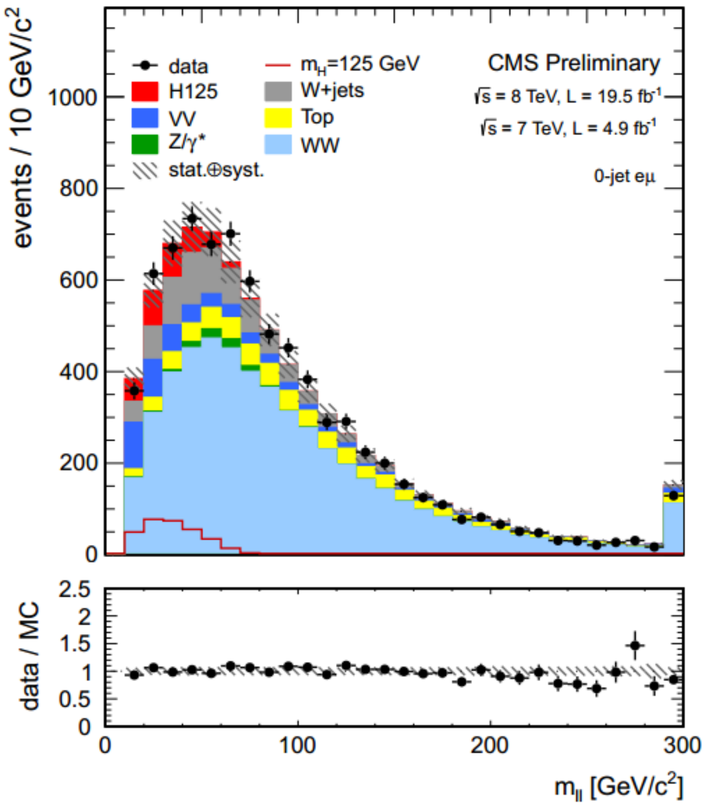
- Set ZH, WH and qqH components to 0 in all hypotheses
  → tested ggH processes against each other :
    - 0^+ from POWHEG (NLO)
    - 2^+ from JHU (LO generator)

- Fix the 2^+ normalization to the same values as the 0^+

- Let the signal event rate float and threat it as a nuisance parameter

Briefly : Analysis overview

- **Analysis optimized in different categories to reach better sensititvity**
  - Lepton flavour pairs : DF (eμ) (and SF (ee/μμ) in main analysis)
  - Exclusive jet multiplicity (0, 1 -jet)
  - Use the full 7 + 8 TeV datasets (4.9 and 19.5 invfb)



Most sensitive in low m_H search

Dominant backgrounds

	0-jet	1-jet
DF	WW W+jets, V+γ$^{(*)}$ (low m_H)	WW, Top

- **The spin analysis is based on the same selection as the 2D shape analysis but only uses DF !**

	0 jet	*1 jet*
DF	2D	2D

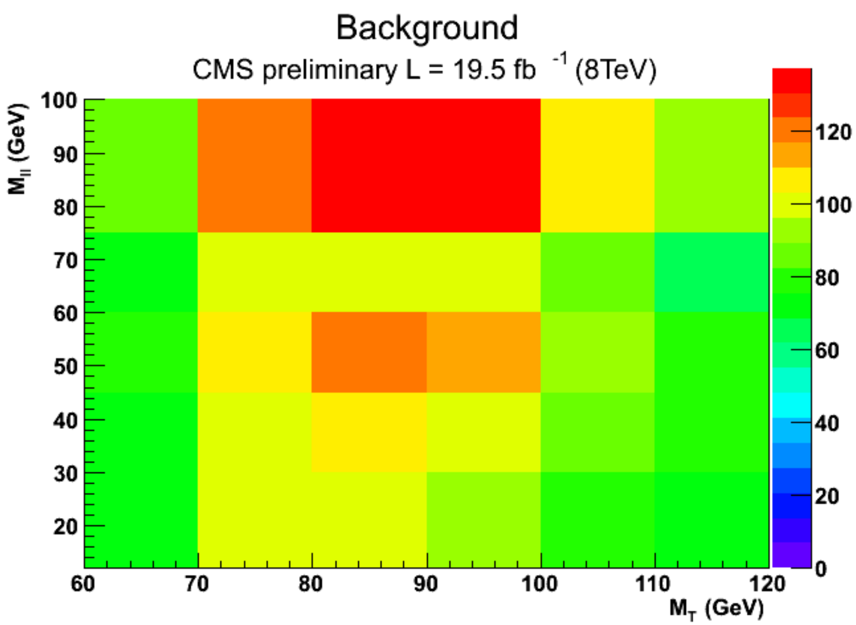
2D Shape analysis M_T:$M_{\ell\ell}$

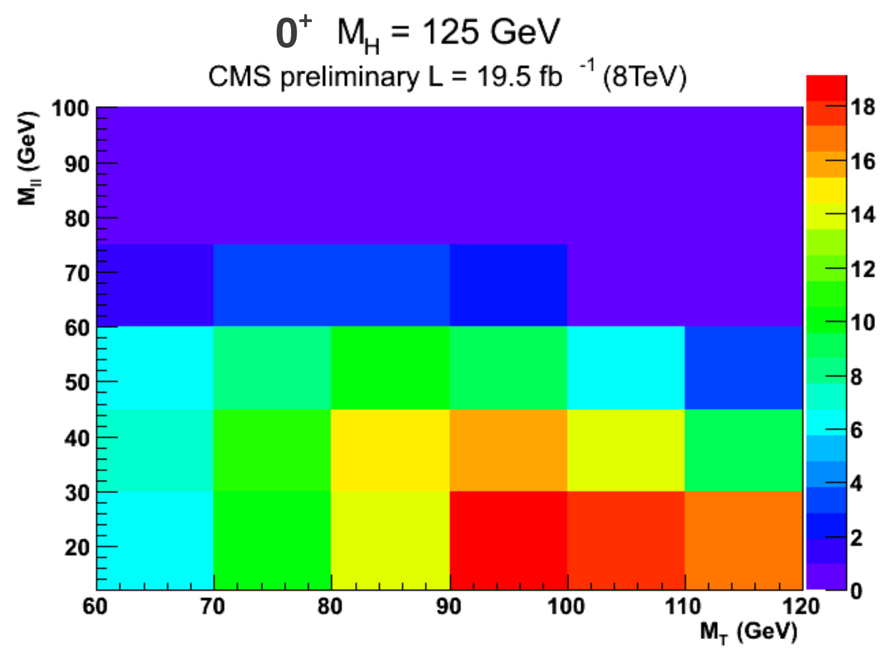
- **Binning in mass-like variables :**
  - m_T : higgs transverse mass
  - $m_{\ell\ell}$: di-lepton invariant mass
    - → These 2 variables are both correlated to the angles of the leptons
  - binning chosen to ensure sufficient statistics
    - is a bit finer in signal region

$$m_T = \sqrt{2 p_T^{\ell\ell} E_T^{\rm miss} \left(1 - \cos \Delta\phi_{E_T^{\rm miss}\ell\ell}\right)}$$

M_T (GeV)	M_{ll} (GeV)
[60 - 280]	[0-200]

0-jet

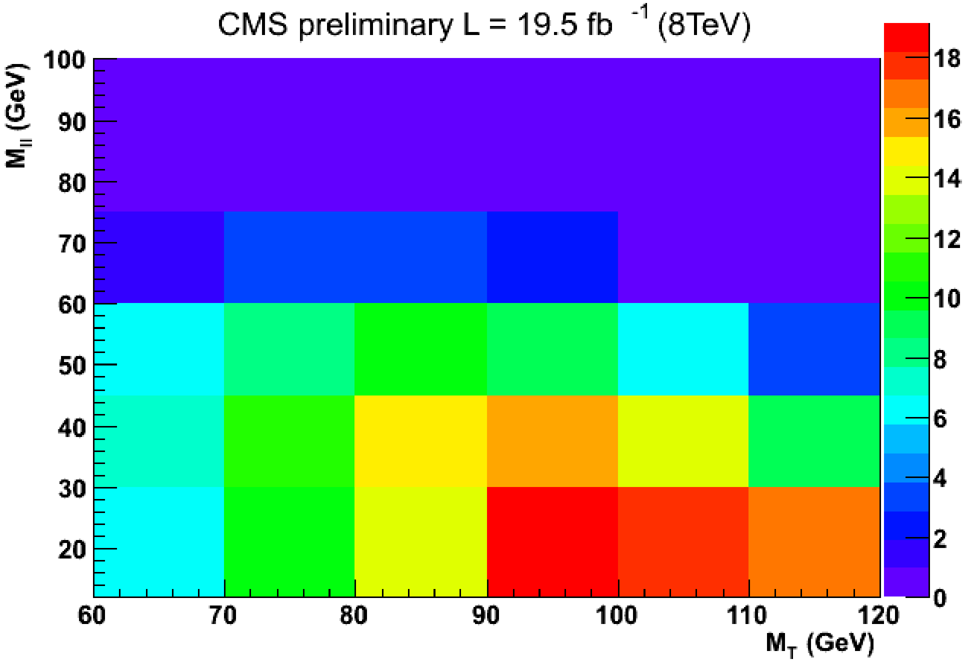




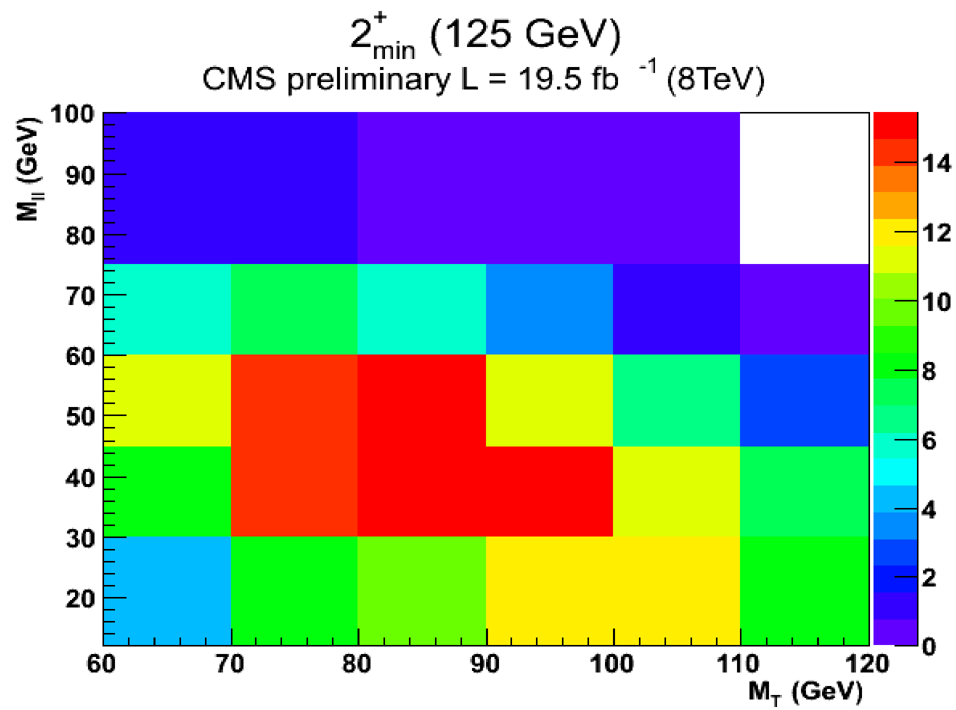
- **Different backgrounds peak at different locations**

Spin : 0j DF (8 TeV)

SM Hypothesis



Spin-2 Hypothesis



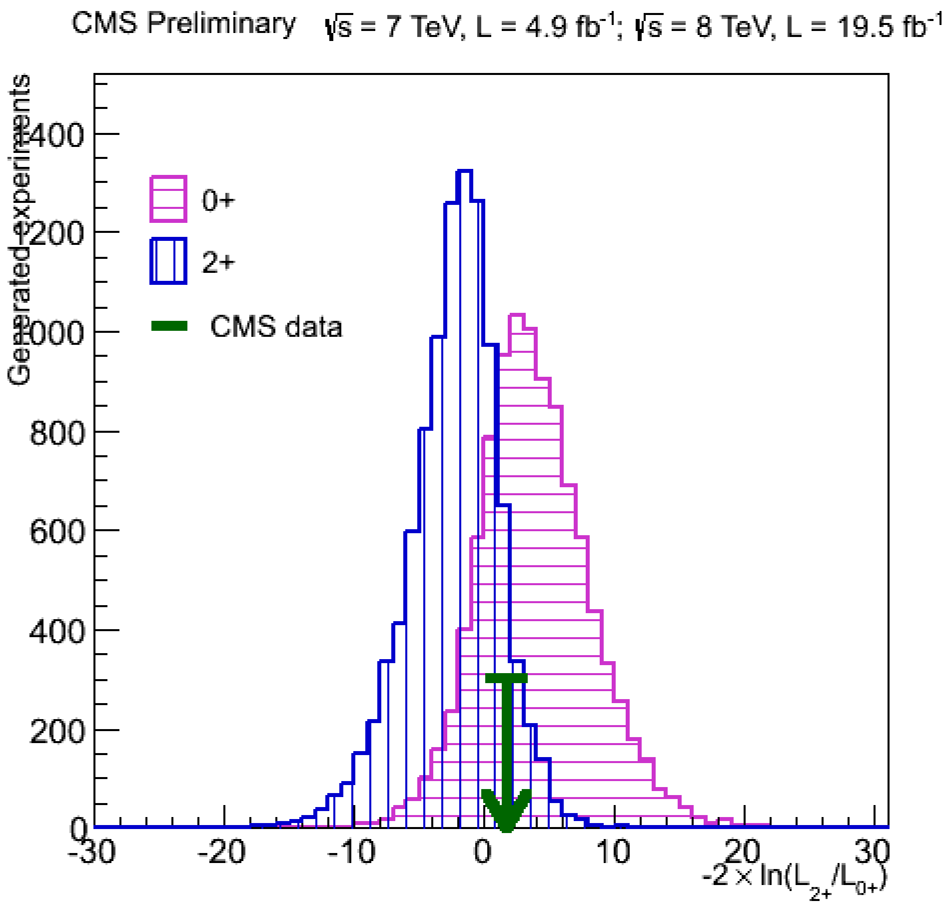
- **Only difference between spin and main analysis is 2 different signal shapes**

  The kinematic of the final leptons is sensitive to spin structure of the resonance

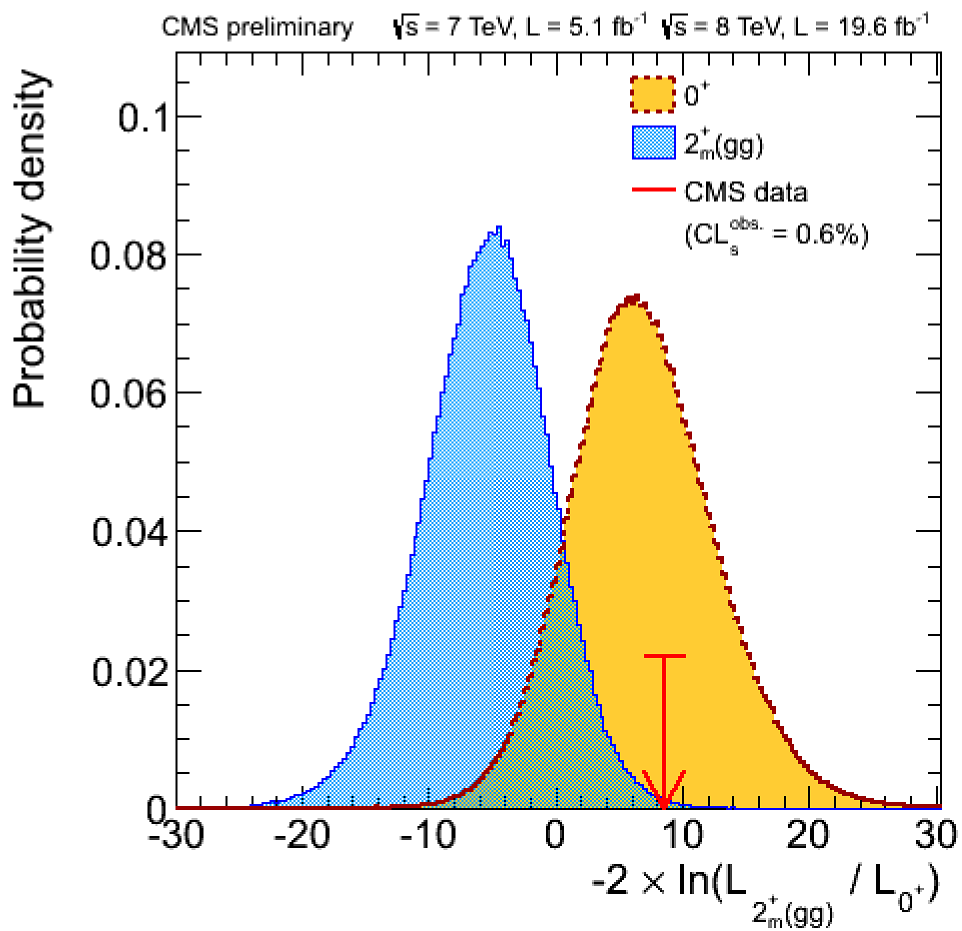
Spin hypothesis separation

- **Perform a maximum likelihood fit to extract the best fit signal strength for each model**
- **Compare the best fit likelihoods to determine the consistency of each hypothesis with the data**
- **Test** $q = -2\ ln(L_{2+} / L_{0+})$
- **Expect hypothesis separation at the 2-sigma level**

case	expected	observed
assuming $\sigma/\sigma_{SM} \equiv 1$		
0^+	1.9	0.9
2^+_{min}	2.4	1.3
assuming $\sigma/\sigma_{SM} \approx 0.8$		
0^+	1.5	0.5
2^+_{min}	1.9	1.3



Spin separation combined with H → ZZ



Combining H → WW with H → ZZ disfavours the 2^+ signal hypothesis with a CLs value of 0.6 %

See Talk : S. Bolognesi , Properties of the Higgs-Like resonance

Summary

- **Spin Parity result for the H → WW → 2ℓ2ν analysis with full 7 and 8 TeV datasets (4.9 and 19.5 invfb) is performed in the DF 0/1 jet channel**

- **The 2^{+} hypothesis is disfavored with a CLs value of 0.6 % in the combined H → WW and H → ZZ observed data.**

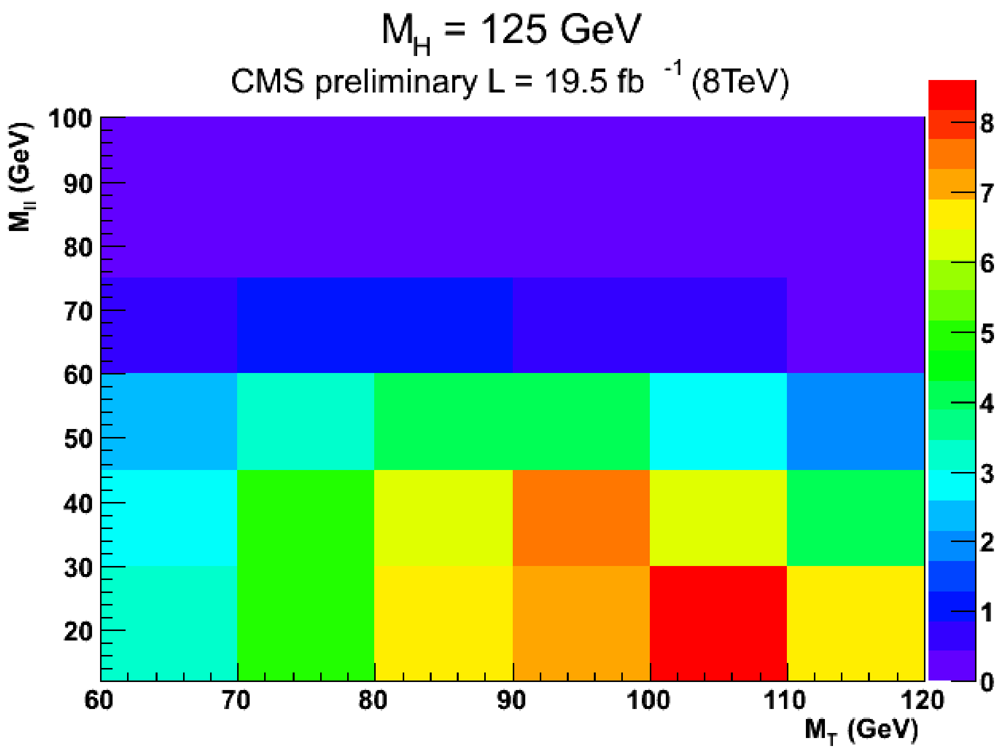
- **Future**

  - add the qqH instead of only ggH

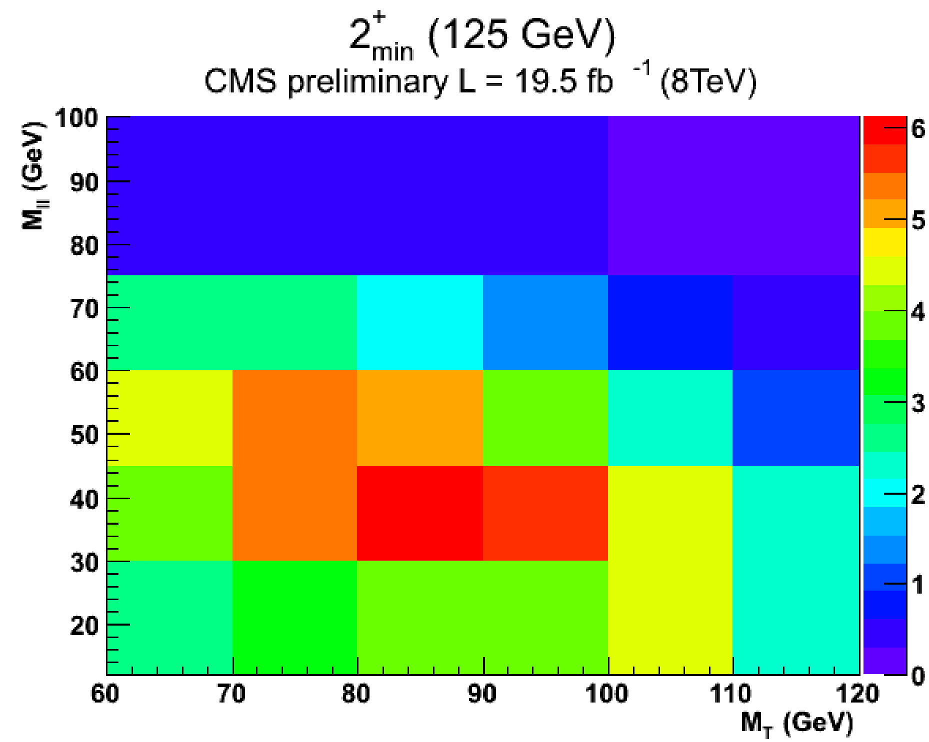
BACKUP

Spin : 1j DF (8 TeV)

SM Hypothesis



Spin-2 Hypothesis



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  The kinematic of the final leptons is sensitive to spin structure of the resonance