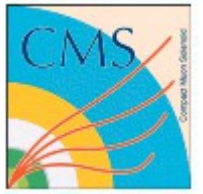


Search For The Higgs Boson in the $H \rightarrow ZZ \rightarrow 2l2j$ mode with CMS

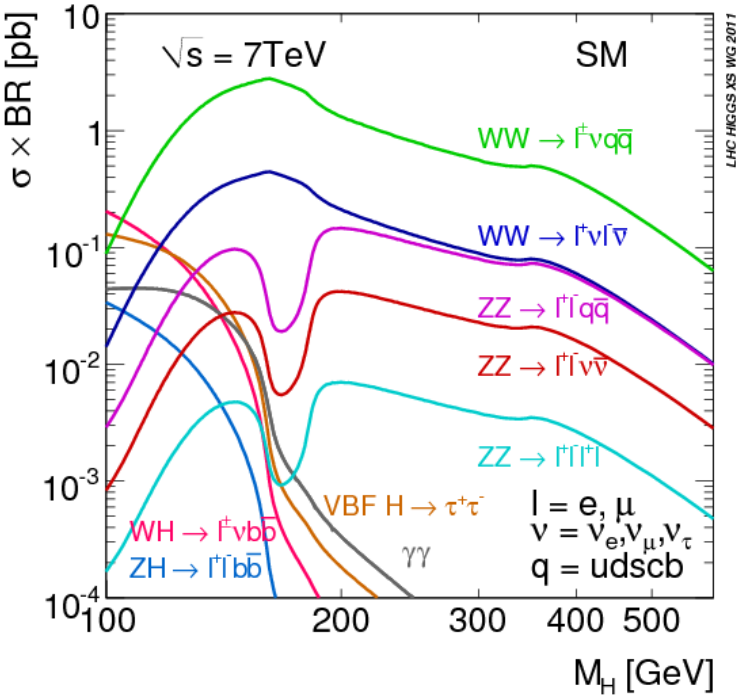
A. Bonato (Johns Hopkins Univ.)
on the behalf of the CMS collaboration

Higgs Hunting 2011
LAL Orsay, 29/07/2011

Public documentation available at:
http://cdsweb.cern.ch/record/1369551/

Introduction to $H \to ZZ \to 2l2j$

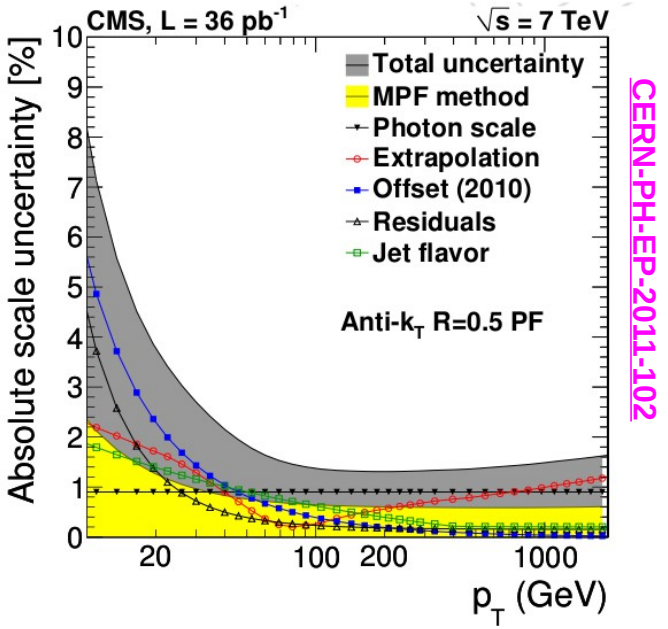
- For $M_H > 200$ GeV,
  $H \to ZZ$ dominant sensitivity
- Historically, focus on 4l final state because of clean reconstruction and low background
- $BR(H \to ZZ \to 2l2q) \sim x20$ than 4l !
- Worse resolution from jets
- Large background
  - SM Z+jets main background
    ($\sigma_{Z+J} \sim O(10^5) * \sigma_H * BR(H \to ZZ \to 2l2q)$
  - smaller contributions from $t\bar{t}$, VV, QCD

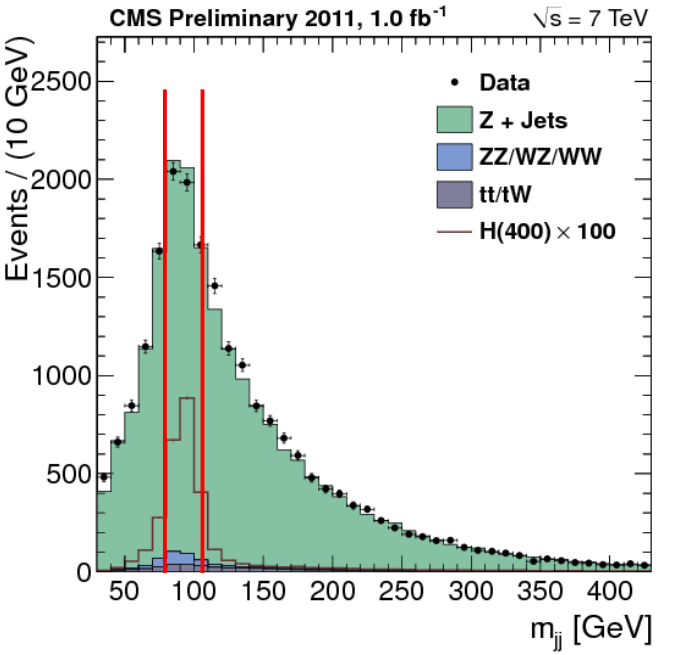


This analysis:
- 1.0 fb^{-1} from 2011 data
- Powheg/JHUgen SM Higgs MC
- Madgraph Z+jets MC
- Pythia VV MC
- Powheg $t\bar{t}$ MC

Physics objects and preselections

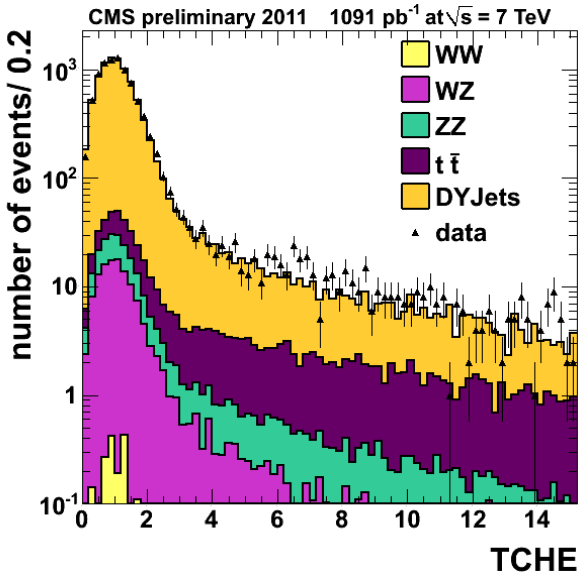
- e and μ:
  - isolated (limited activity in a surrounding cone with ΔR<0.3)
  - d_{xy} < 0.02 cm d_Z < 1 cm (effective against cosmics)
  - η < 2.5 for e (+ exclude ECAL cracks), < 2.4 for μ
  - p_T >40 / 20 GeV
- Jets:
  - anti-k_T clustering algorithm with R=0.5 , PF objects
  - pile-up subtraction included
  - η < 2.4
  - p_T>30 GeV
- Fully reconstructing ZZ final state:
  - one Z → ll (e^+e^- or $\mu^+\mu^-$), one Z → jj
  - 70 < M_{ll} < 110 GeV (effective against $t\bar{t}$)
  - 75 < M_{JJ} < 105 GeV (effective against Z+jets and $t\bar{t}$)
  - sidebands in M_{JJ} ([60, 75] ∪ [105, 130] GeV) used for estimating background

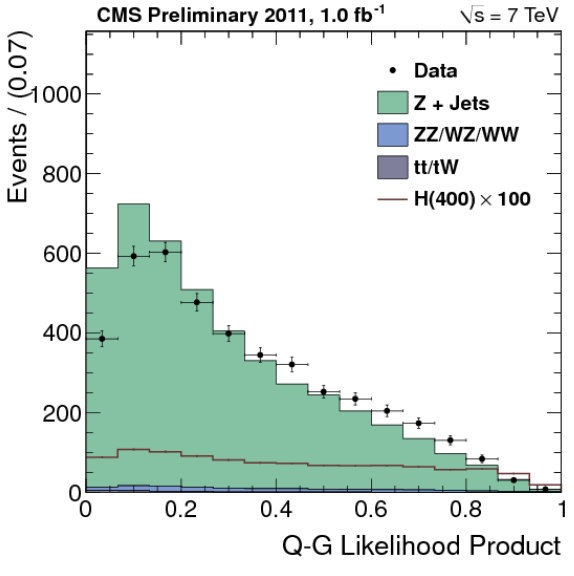


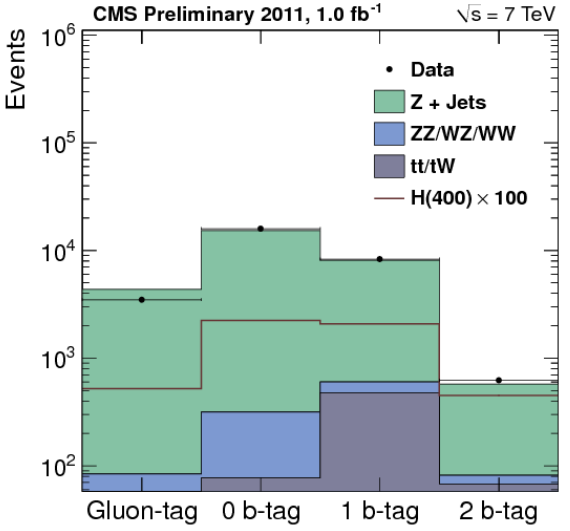


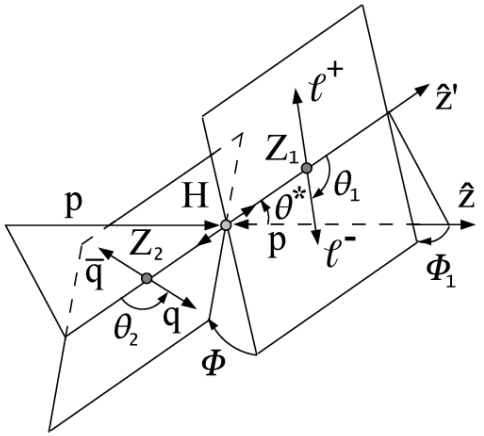
Jet flavor tagging

- Separate events in three categories according to b-tag
  - 2 b-tag: high purity, low efficiency (include MET cut against $t\bar{t}$)
  - 1 b-tag & (!"2 b-tag"): larger background from Z+jets, low purity, efficiency > 2 b-tag
  - 0 b-tag: all other events, large Z+jets background, low purity, higher efficiency
- Quark/gluon discrimination
  - Jets from Z come from quarks, jets from Z+jets background come also from gluons
  - Gluons typically radiate more (higher PF multiplicity, broader cone)
  - Build discriminant for each jet, select $Z \rightarrow jj$ with product of discriminant > 0.1
  - only for 0 b-tag (b-jets behave similarly to g-jets)





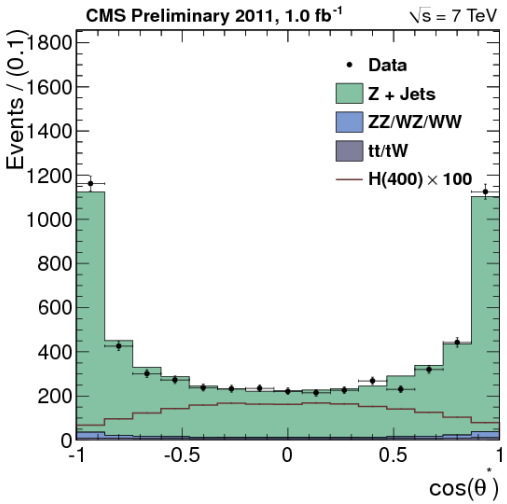


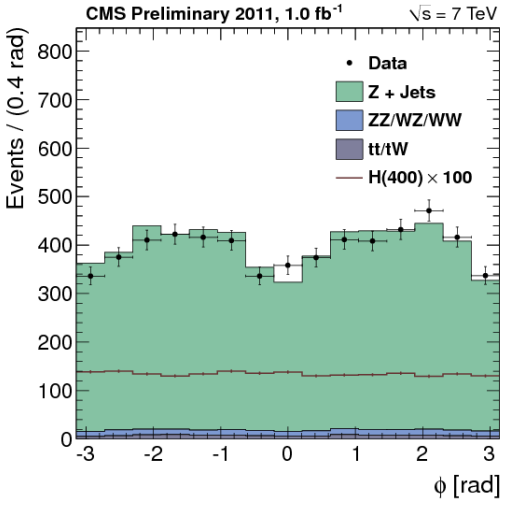


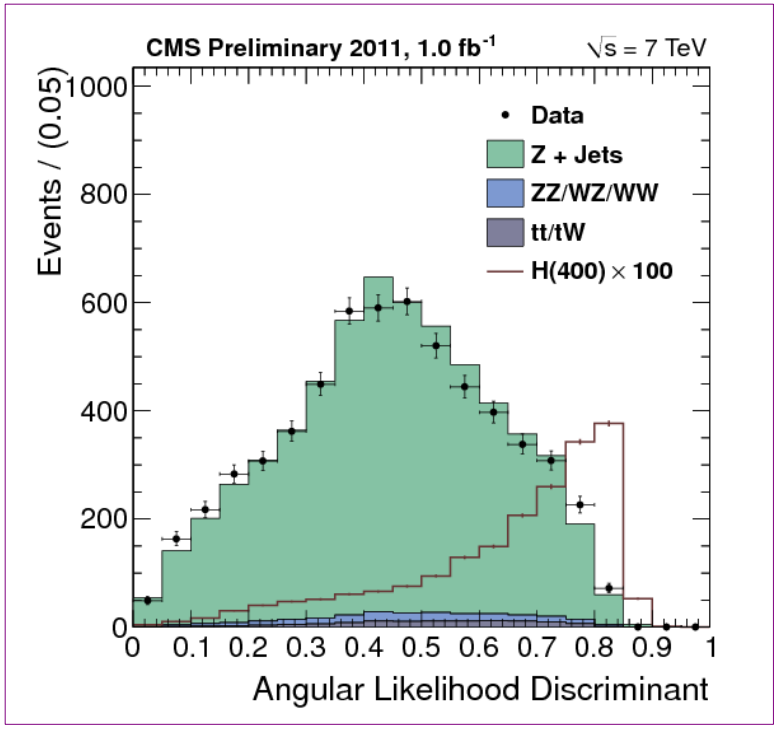
Angular analysis

- Final state fully described by five helicity angles (arXiv:1001.3396v2)
  - invariant mass not biased by cuts on them
  - analytical 5-D p.d.f. for signal, bkgd p.d.f. fitted from MC (both mass dependent)
- Build discriminant, cut dependent on reconstructed mass and flavor

$$D(\theta*, \phi_1, \theta_1, \theta_2, \phi) = \frac{P_{SIG}}{P_{SIG} + P_{BKGD}}$$







Event rates and invariant mass

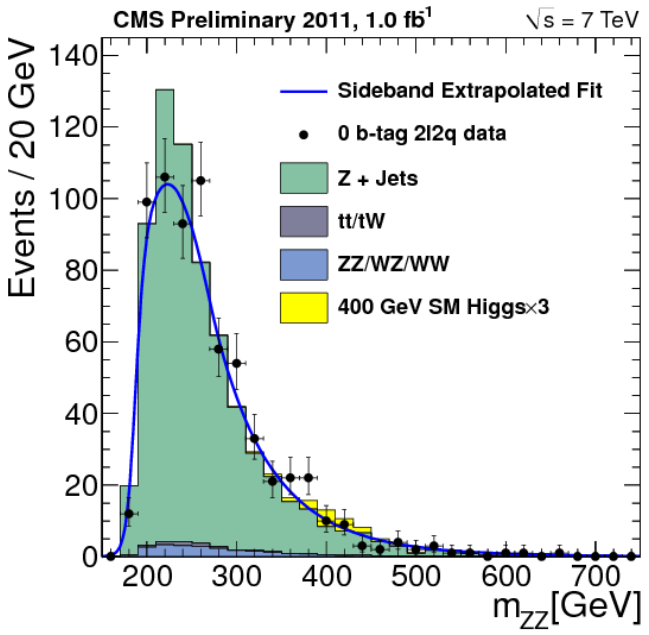
- Background estimated from sidebands in M_{JJ}

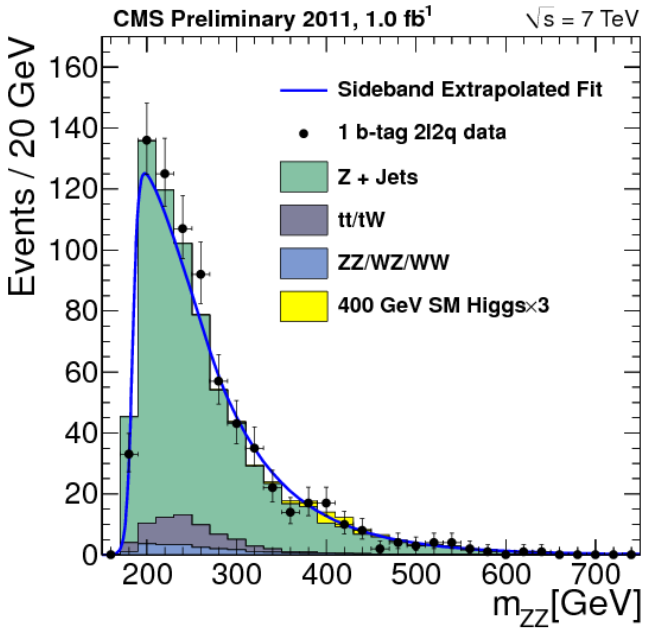
$$\alpha = \frac{N^{MC}_{Sig-Reg}}{N^{MC}_{SB-Reg}}$$

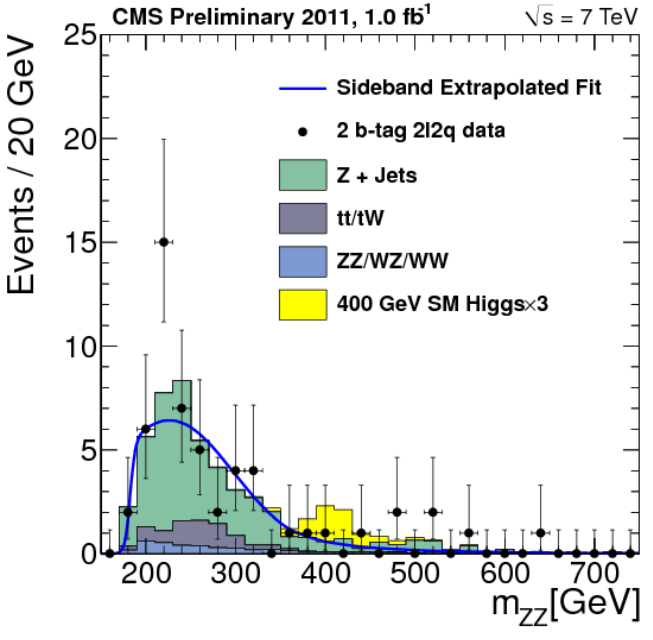
$$N^{BKGD}_{Sig-Reg} = \alpha * N^{DATA}_{SB-Reg}$$

eejj			
	0 b-tag	1 b-tag	2 b-tag
Exp. bkgd	345.7 ± 17.8	376.4 ± 19.3	24.3 ± 3.7
Observed	307	352	30

μμjj			
	0 b-tag	1 b-tag	2 b-tag
Exp. bkgd	286.4 ± 16.2	334.7 ± 18.2	20.3 ± 3.1
Observed	359	396	25







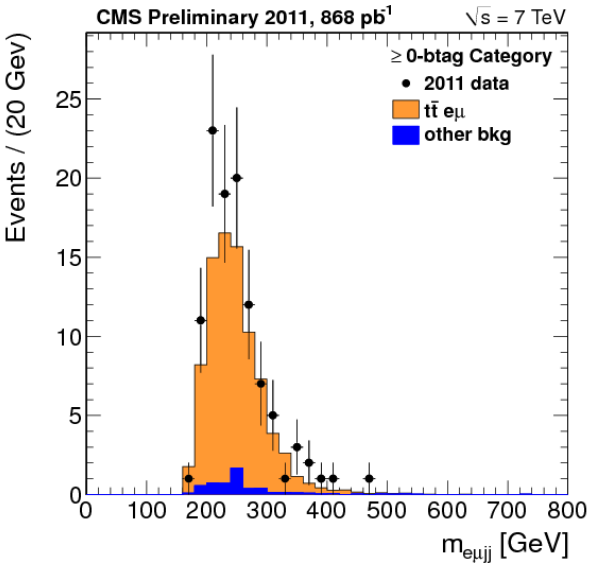
Systematics

Signal systematics

source	0 *b*-tag	1 *b*-tag	2 *b*-tag
muon reco	2.7%		
electron reco	4.5%		
jet reco	1–5%		
pileup	2%		
b-tagging	3%	1%	20%
gluon-tagging	4.6%	–	–
$\not\!\!E_T$	–	–	3%
acceptance (PDF)	3%		
acceptance (HQT)	2%	5%	3%
acceptance (WBF)	1-2%		
luminosity	6%		
Higgs cross section	13–18%		

Background systematics

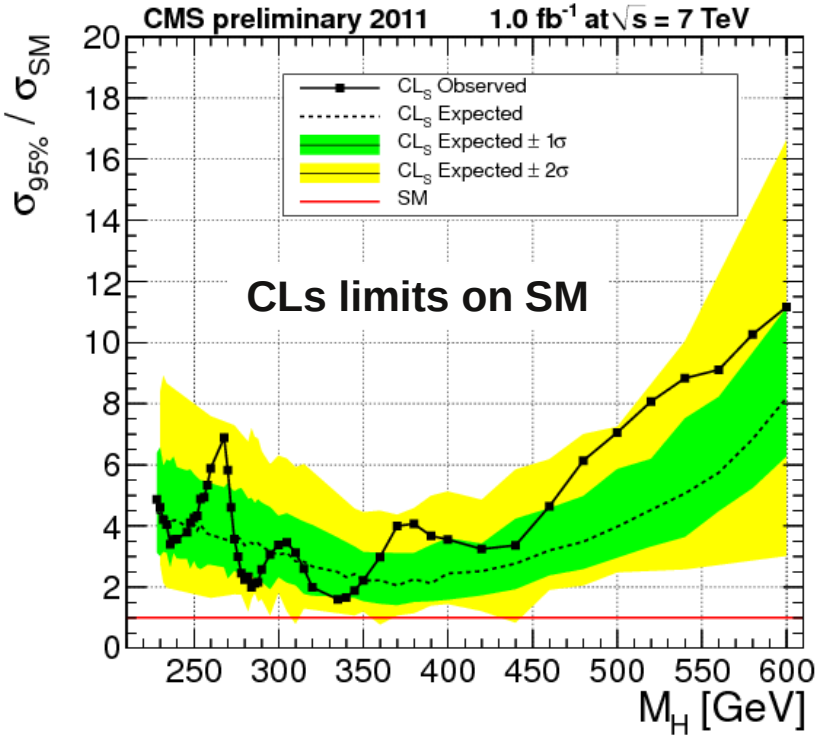
- Normalization uncertainty dominated by statistics in sidebands:
  0/1 b-tag ~ 5% , 2 b-tag ~18%
- Shape uncertainties taken from fit covariance matrix, treated as uncorrelated.
- Additional monitoring of background from γ+jets and $e\mu jj$

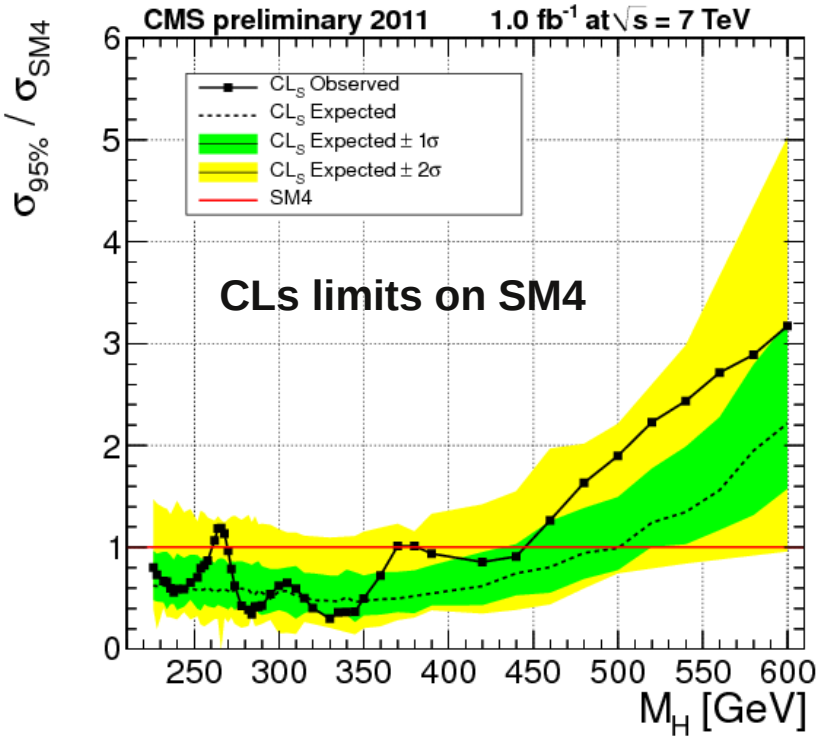


Very conservative approach on background estimation, to be revised soon

Results

- Combined shape analysis of six independent channels
- No evidence for a signal, setting exclusion limits on the SM and SM+4th generation with CLs technique
- Expected 95% exclusion limit: ~2 – 4 * SM in the 230-500 GeV range.
  Observed 95% exclusion limit ~1.6*SM at ~ 350 GeV
- Excluding at 95% the SM4 in a wide range [226, 445] GeV
  (except two narrow windows, [261, 270] and [370, 381] GeV)
- Large coverage of masses, important input for grand combined result

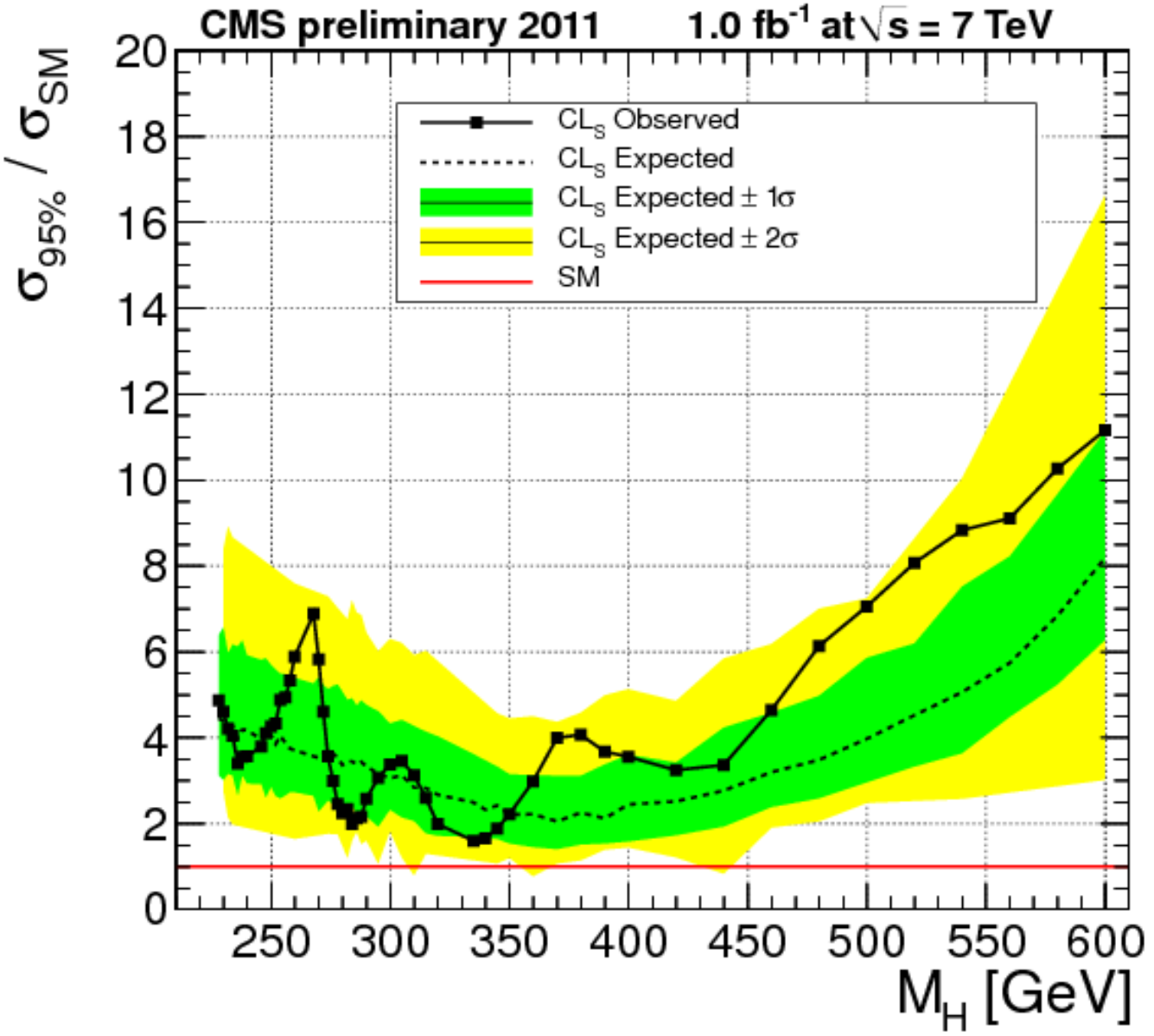




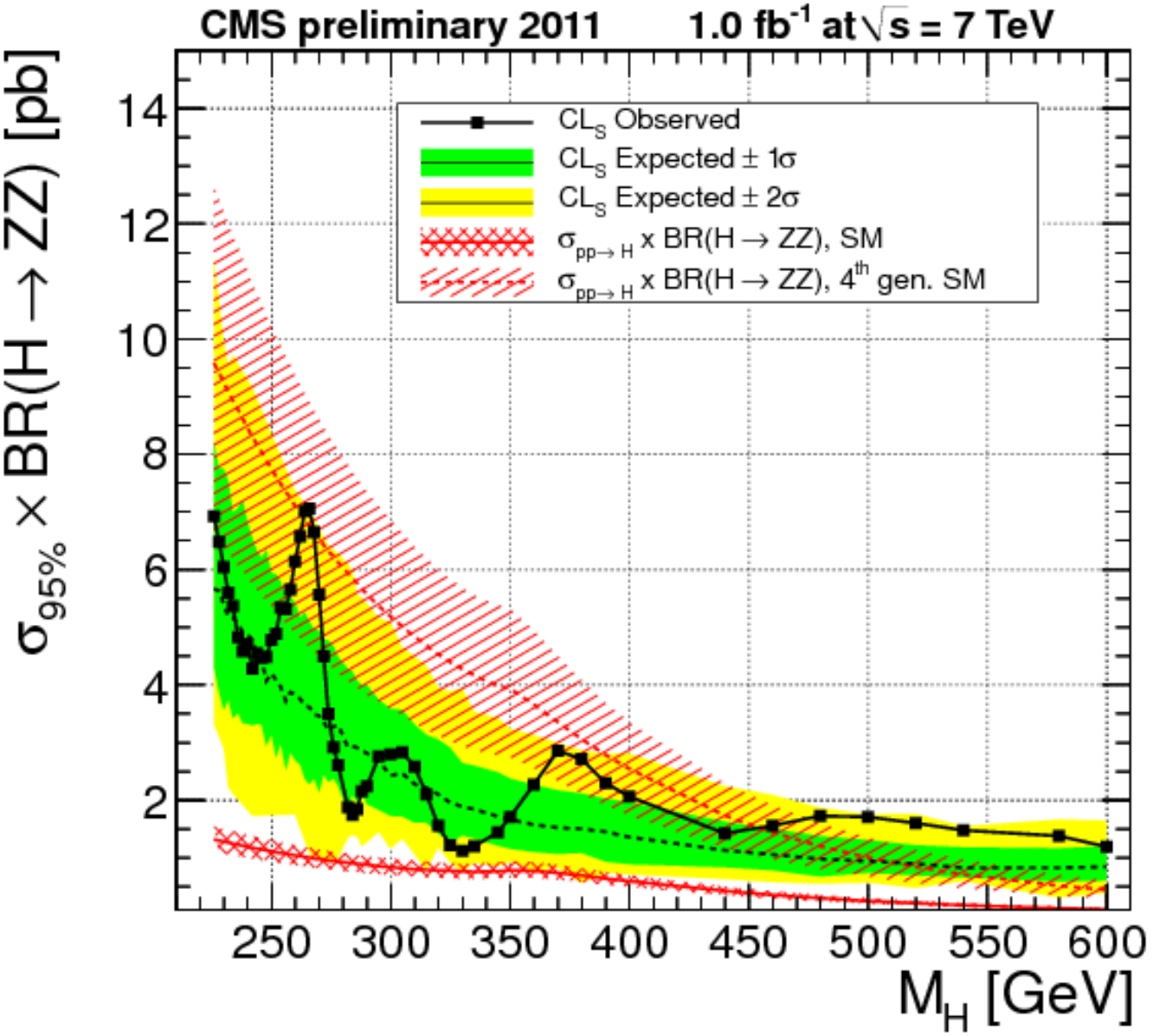
Additional material

Public documentation available at:
http://cdsweb.cern.ch/record/1369551/

Limit on SM signal strength



Limit on SM σ*BR(H → ZZ)



Input to CMS combined limit

http://cdsweb.cern.ch/record/1370076