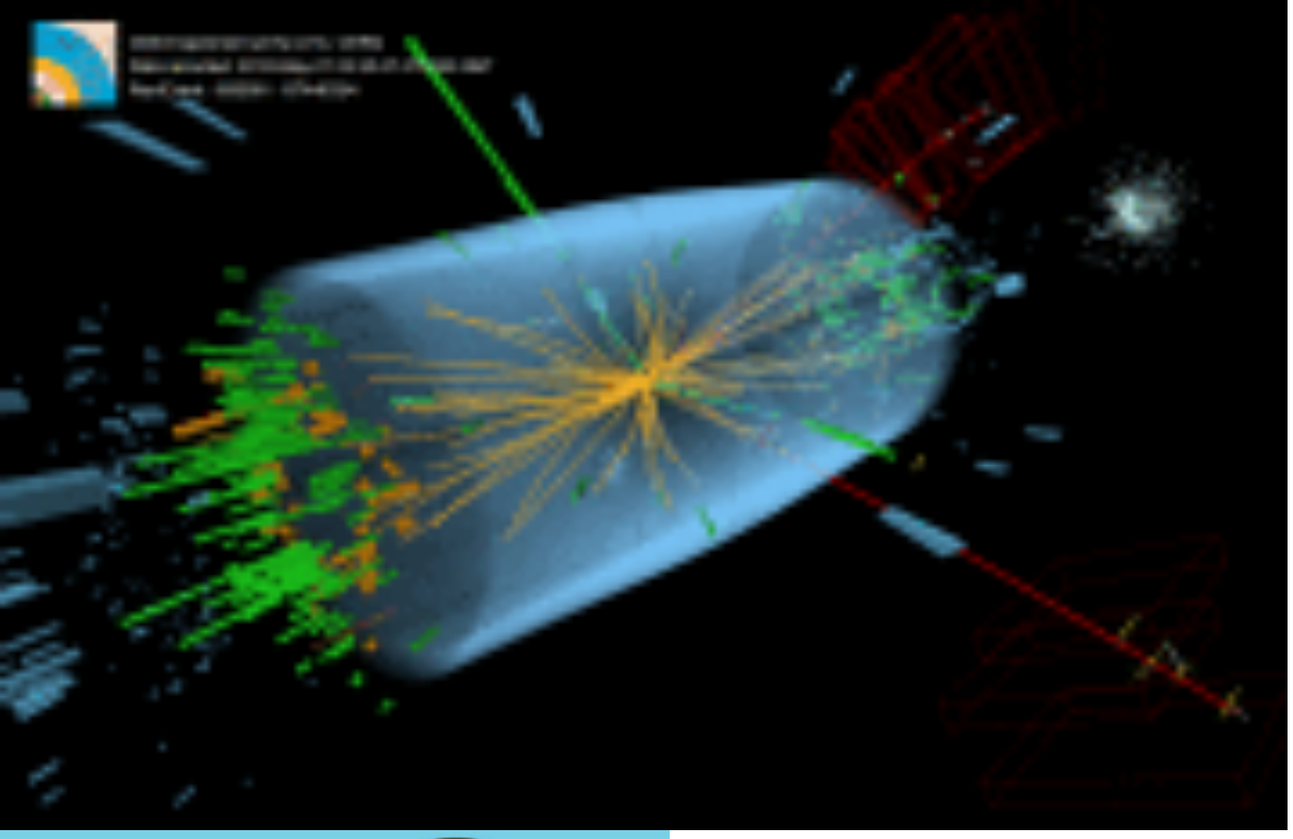
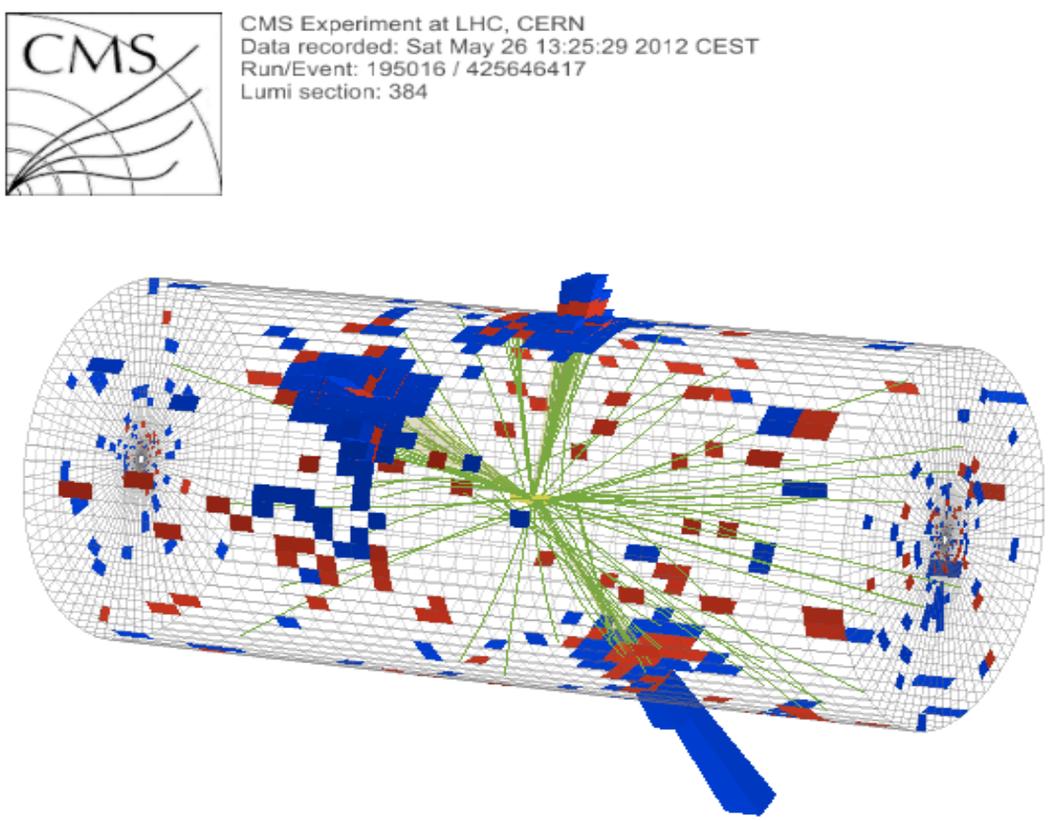
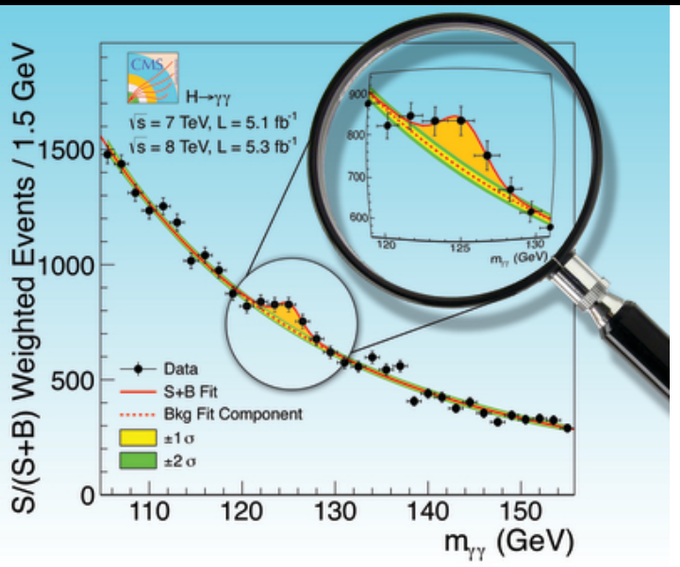






SM Higgs boson search at LHC: CMS summary

Victor T. Kim

Session of Scientific Council of High Energy Physics Division
PNPI NRC KI, Gatchina, December 24, 2013

Search for Higgs at LHC

Outline

Highlights of CMS results on search for SM Higgs boson:

*** CERN, July 4, 2012**
ICHEP, Melbourne

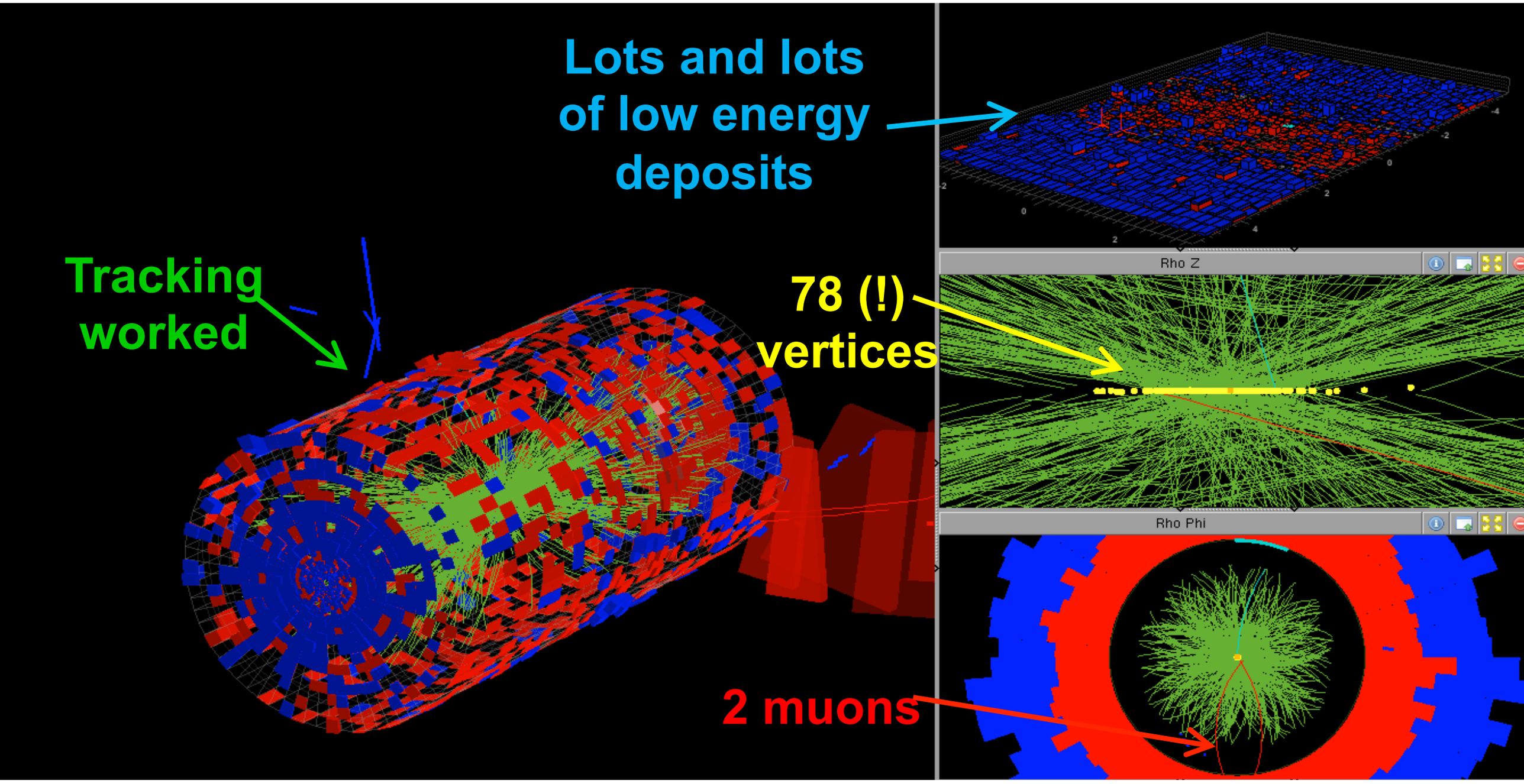
*** Recent updates of CMS results on search for SM Higgs boson:**

- EPS Conference, Stockholm, July 2013

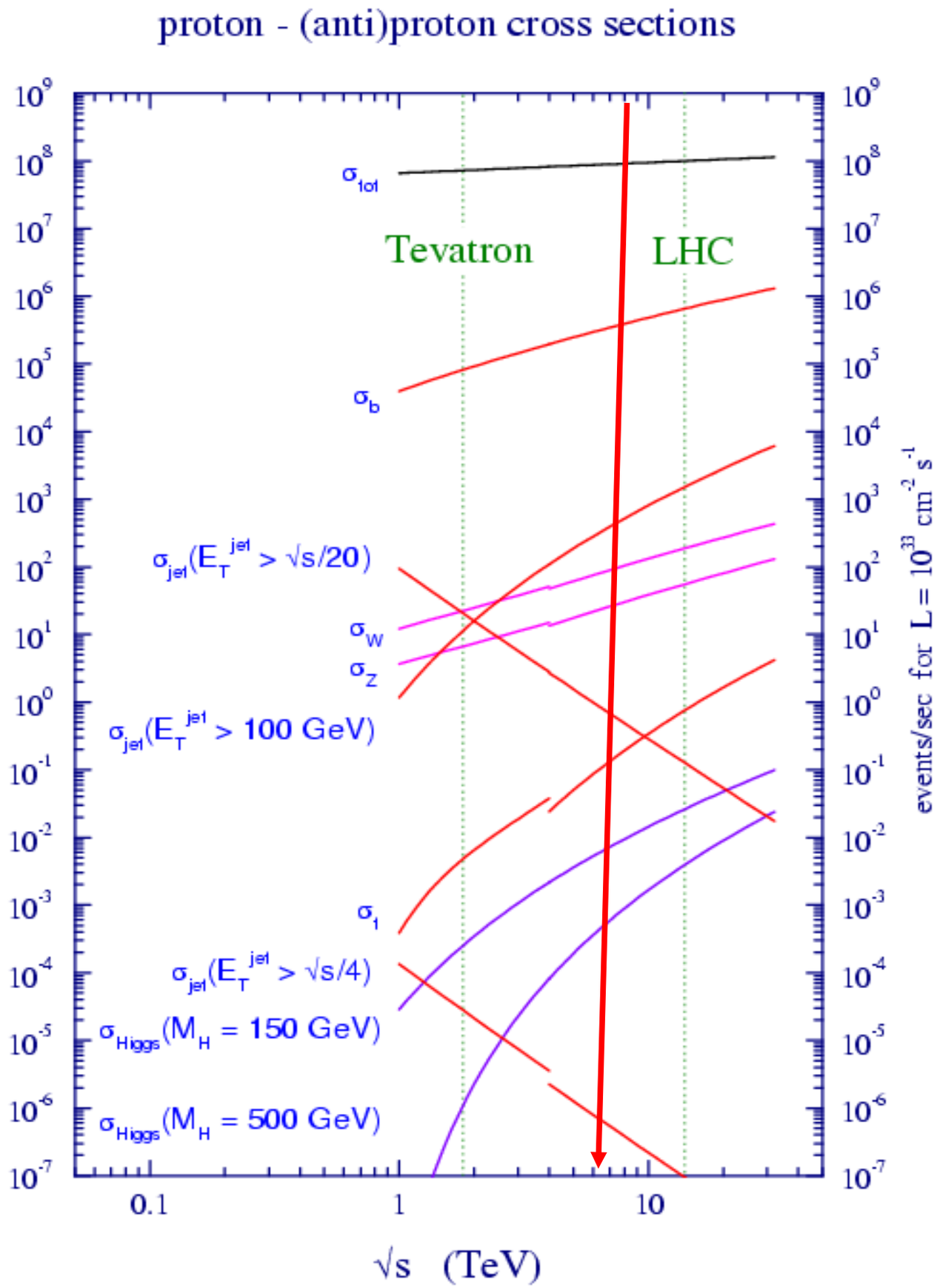
- LPCC, CERN, December, 2013

2012 challenges at 8 TeV: high pile-up!

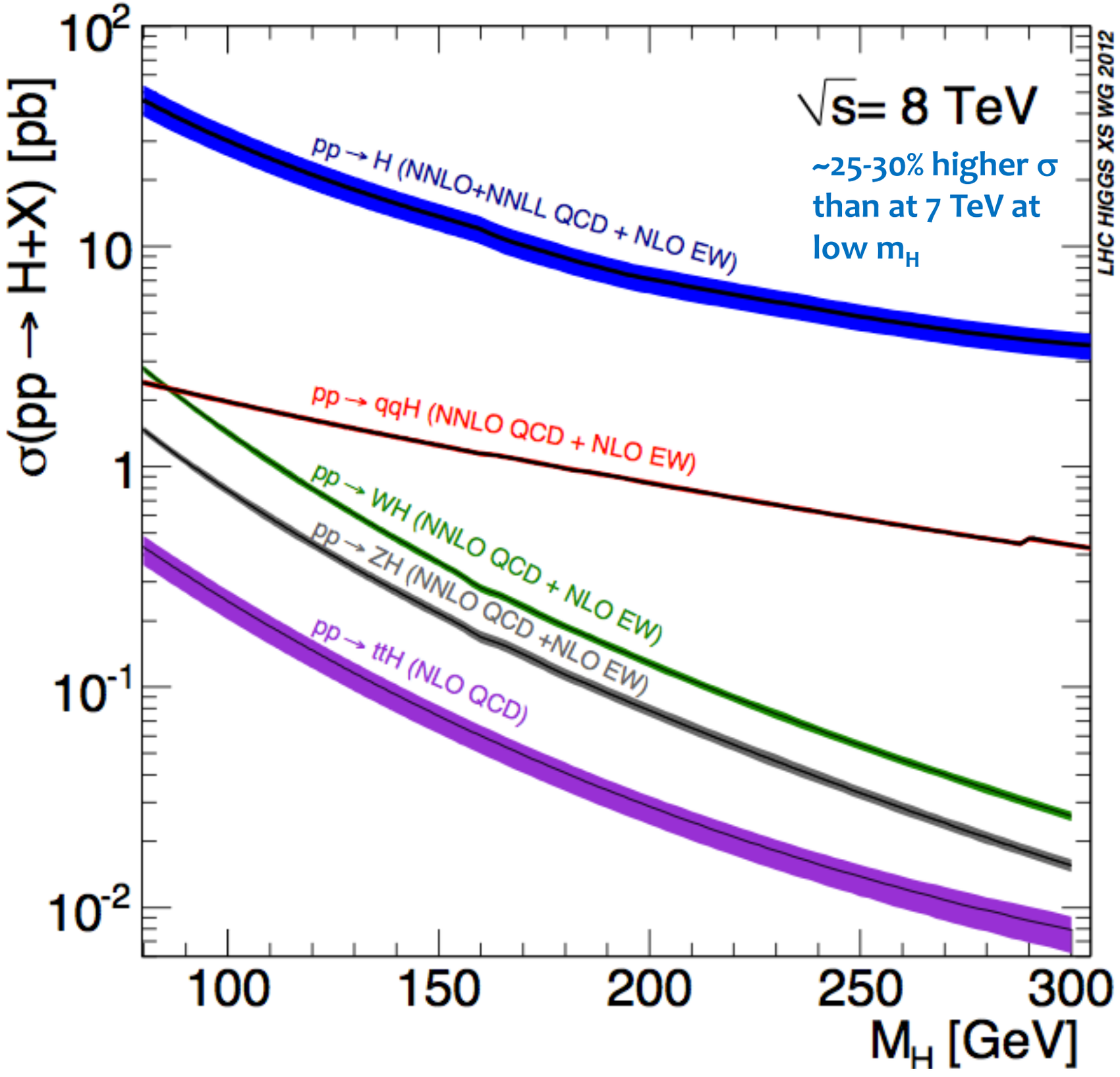
Reconstructed 78-vertices dimuon event at CMS

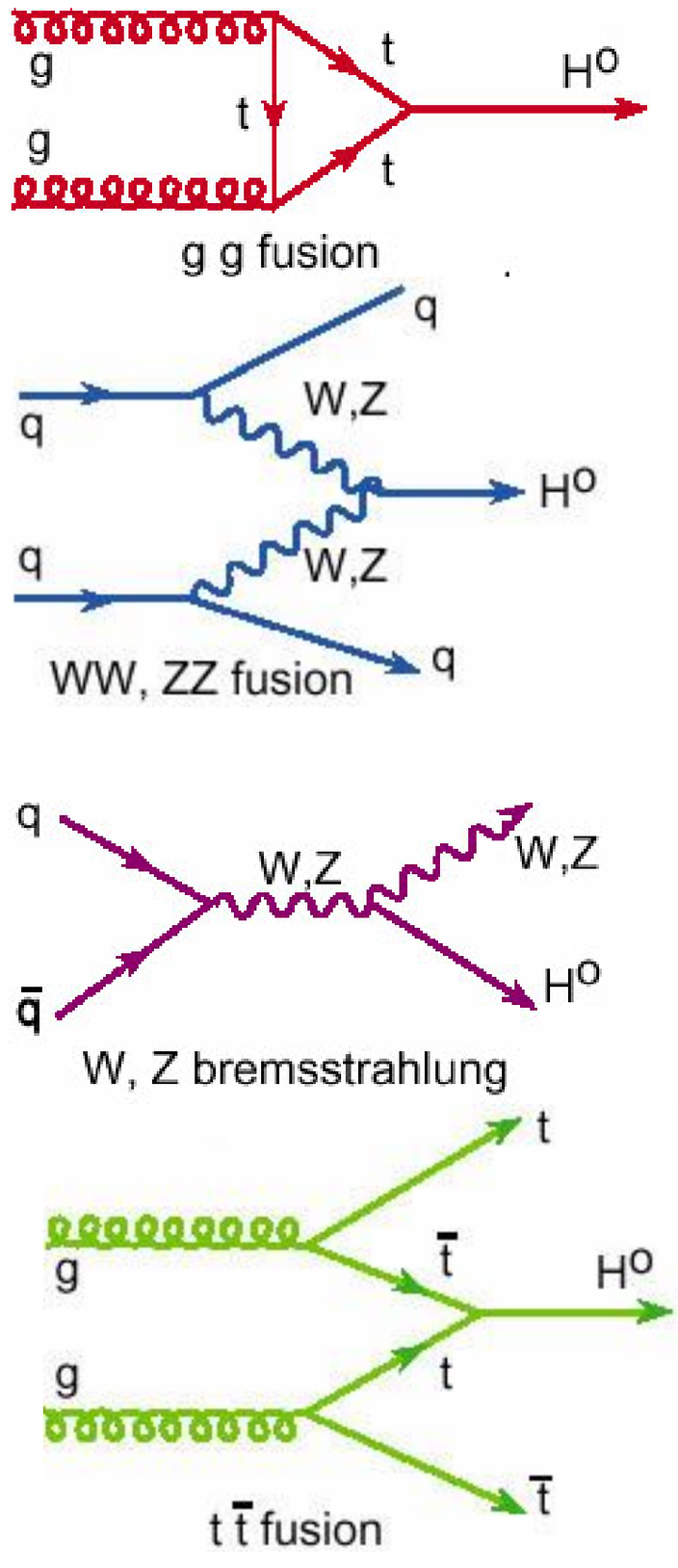


Search for SM Higgs boson: cross sections



Search for SM Higgs boson: production





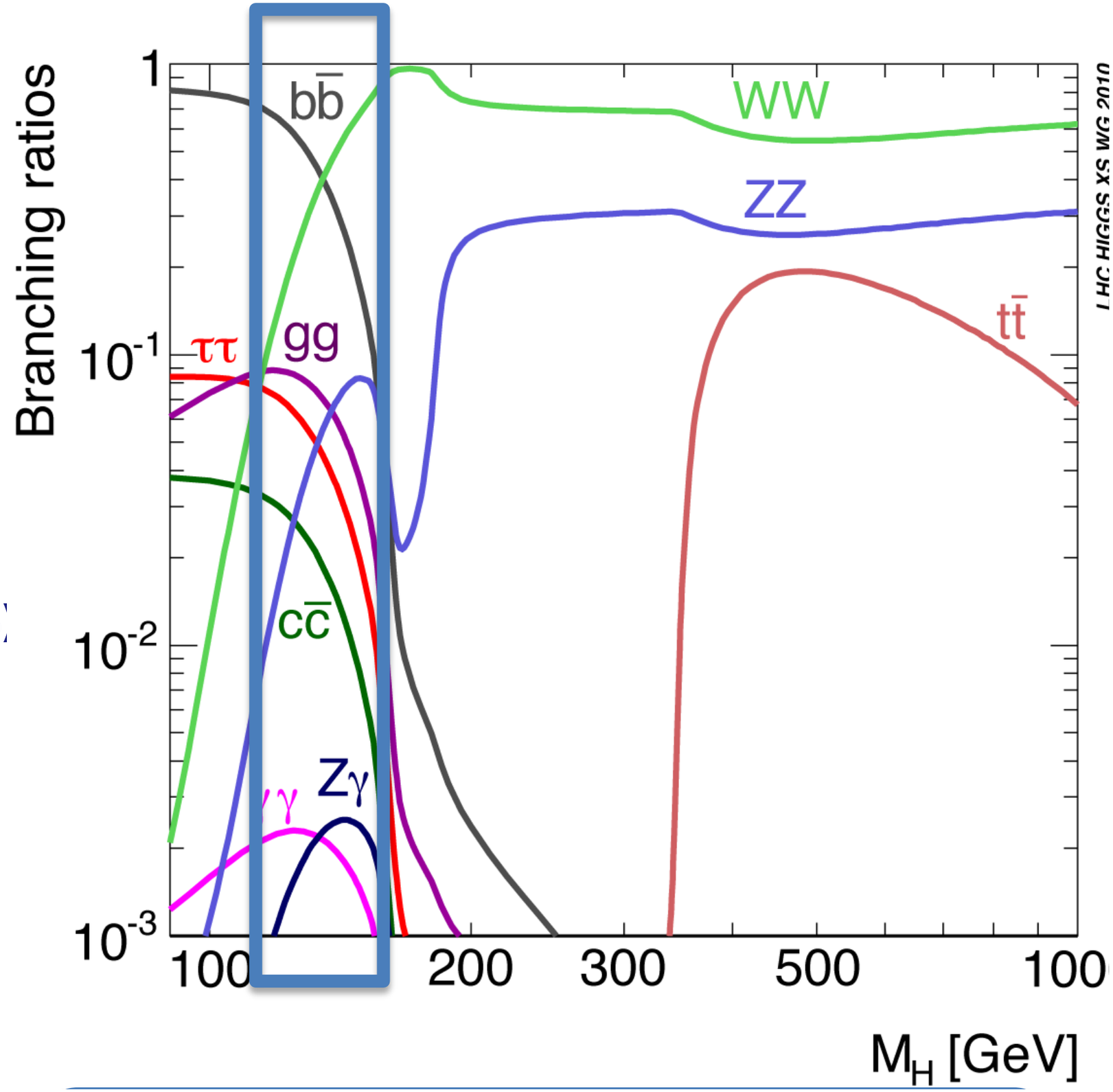
Search for SM Higgs boson: decay modes

* SM Higgs decay modes
  - high mass: WW-, ZZ-
  - low mass: γγ-, ττ-, bb-, ZZ*-, WW*-

* Low mass challenges:
  ττ-, bb- huge background

* High resolution mass (~1%)
  ZZ->4l and γγ- modes

* ZZ->4l low background



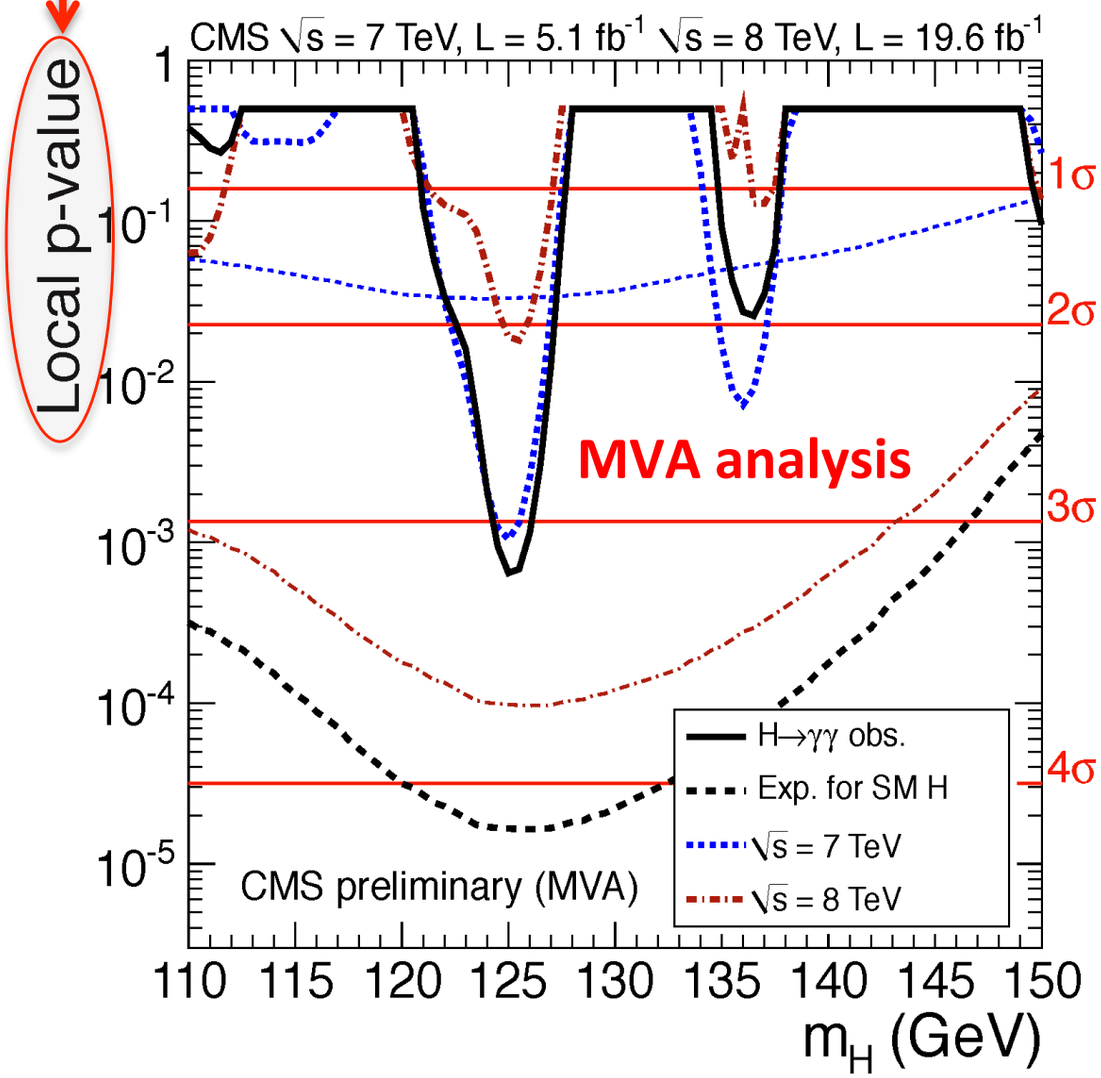
H -> γγ @CMS

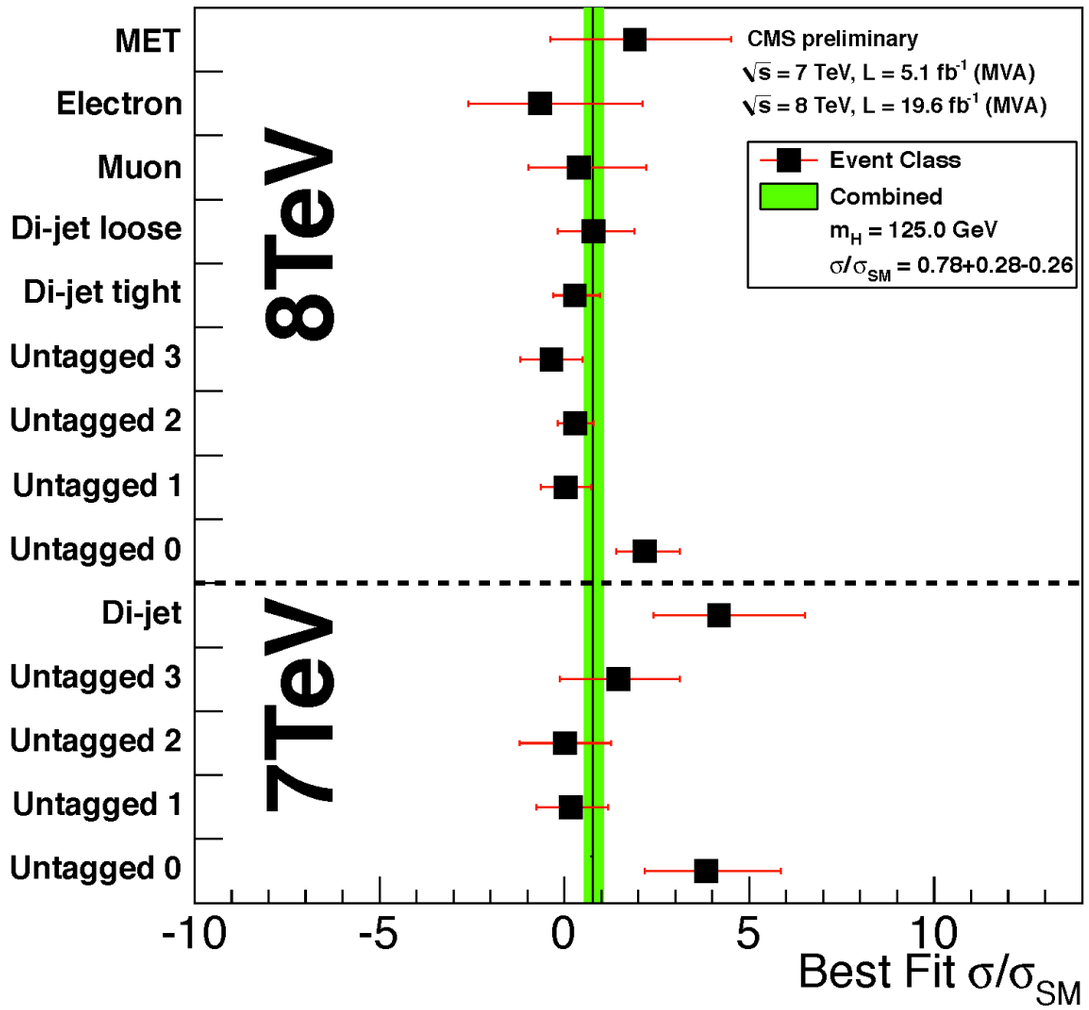
Ratio of the production cross section times the relevant branching fractions over the SM expectation: σ/σ_{SM} = 0.78 ± 0.27 (m_H = 125 GeV)

profile likelihood ratio

Significances (σ) for m_H = 125 GeV:

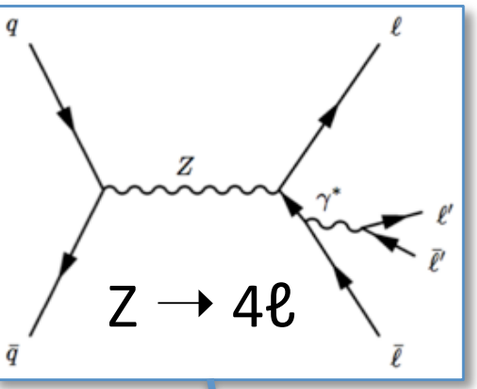
- MVA: observed 3.2, expected 4.2
- Cut-based: observed 3.9, expected 3.5





H -> 4l @CMS

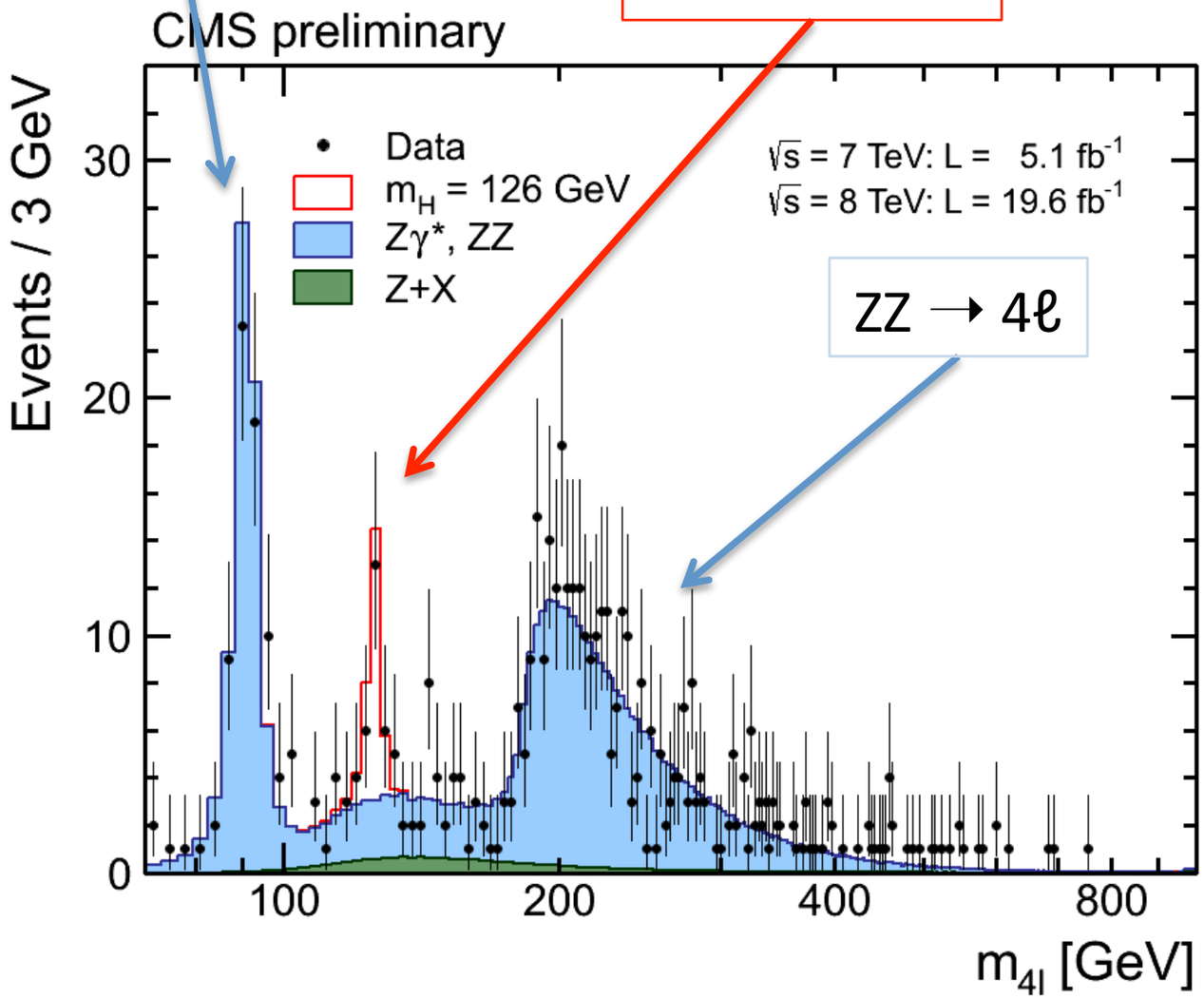
4ℓ mass distribution

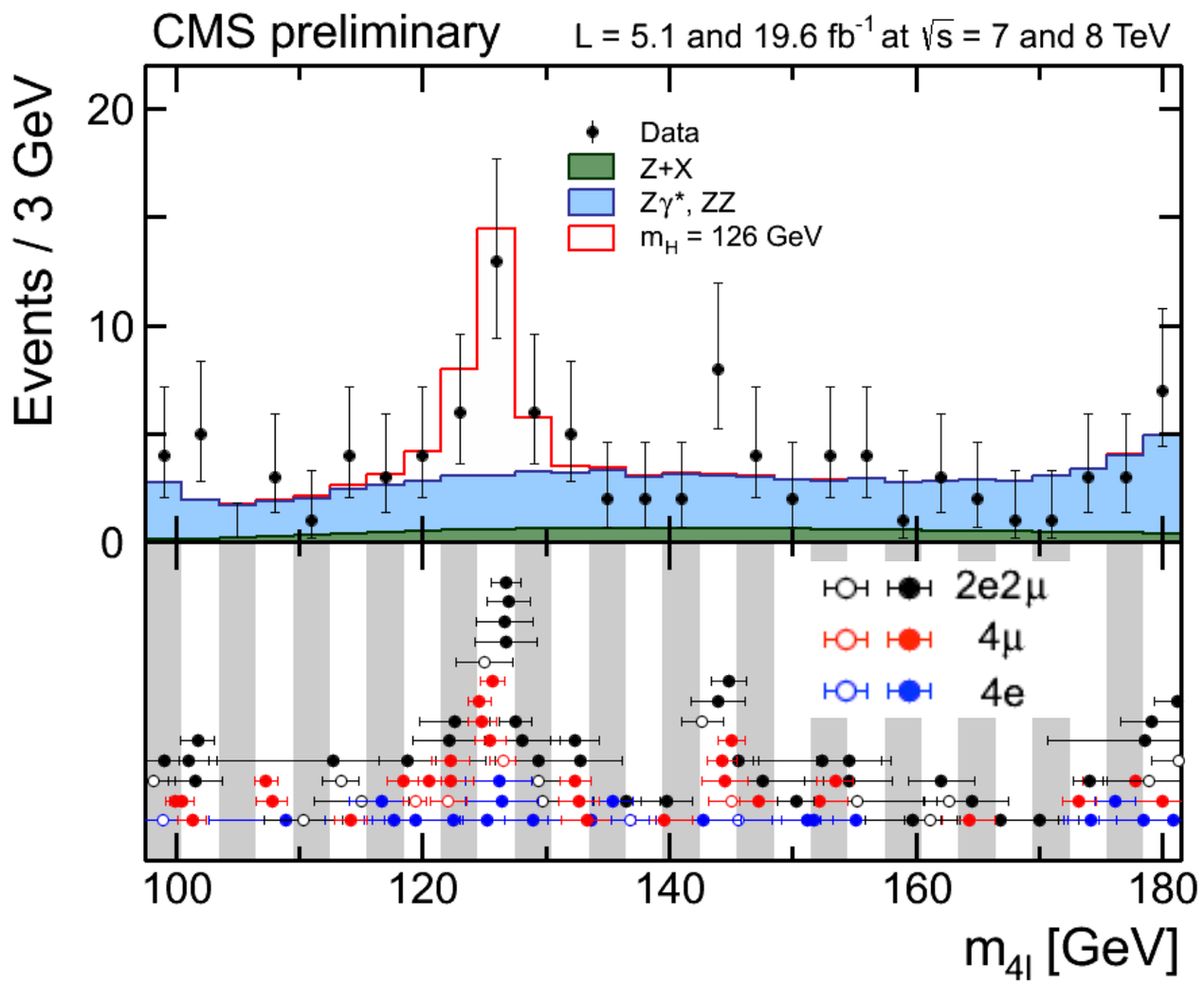


X → ZZ → 4ℓ

ZZ → 4ℓ

mass of the candidates





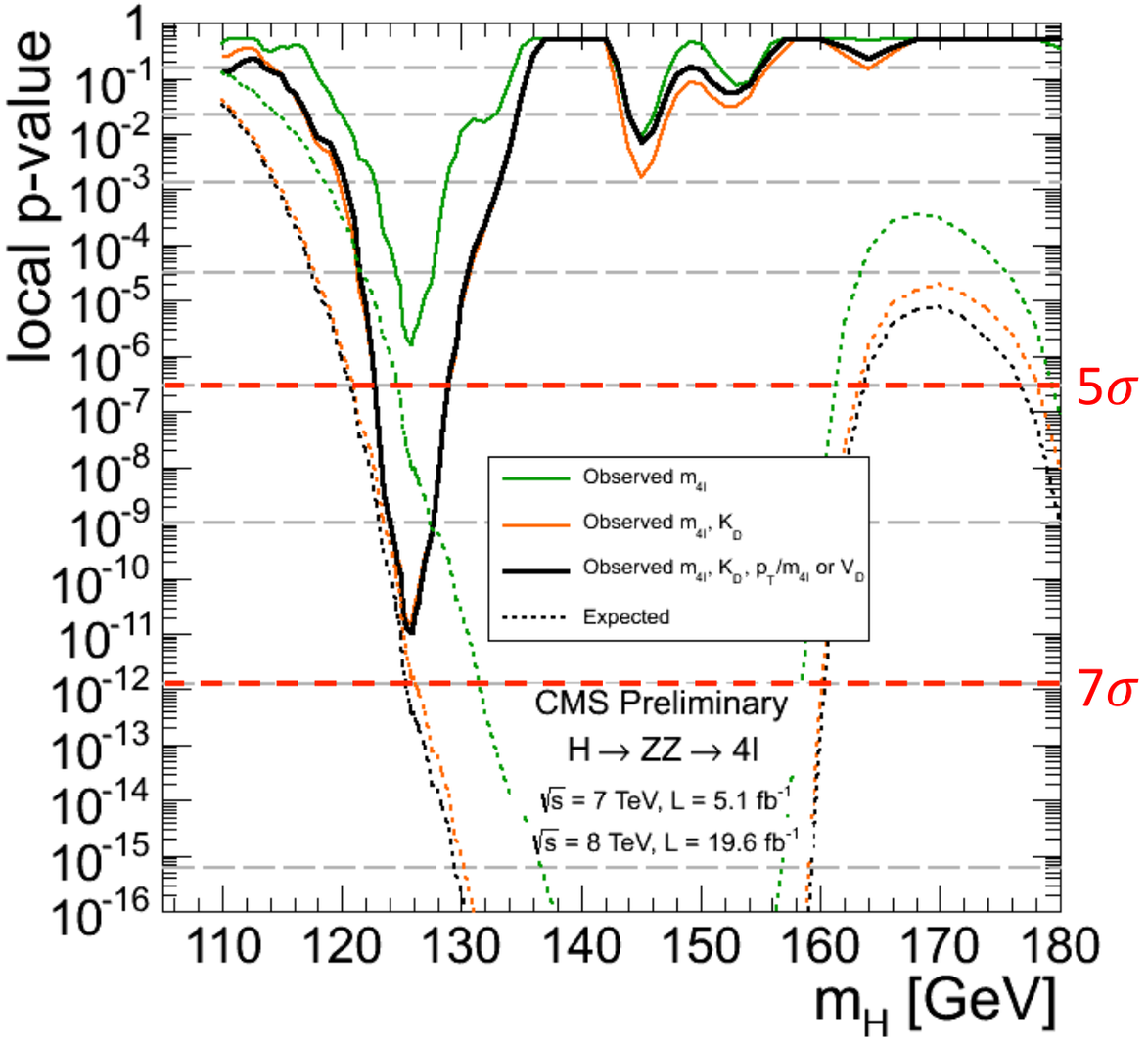
H -> 4l @CMS

Significance (σ) for m_H = 125.8 GeV:

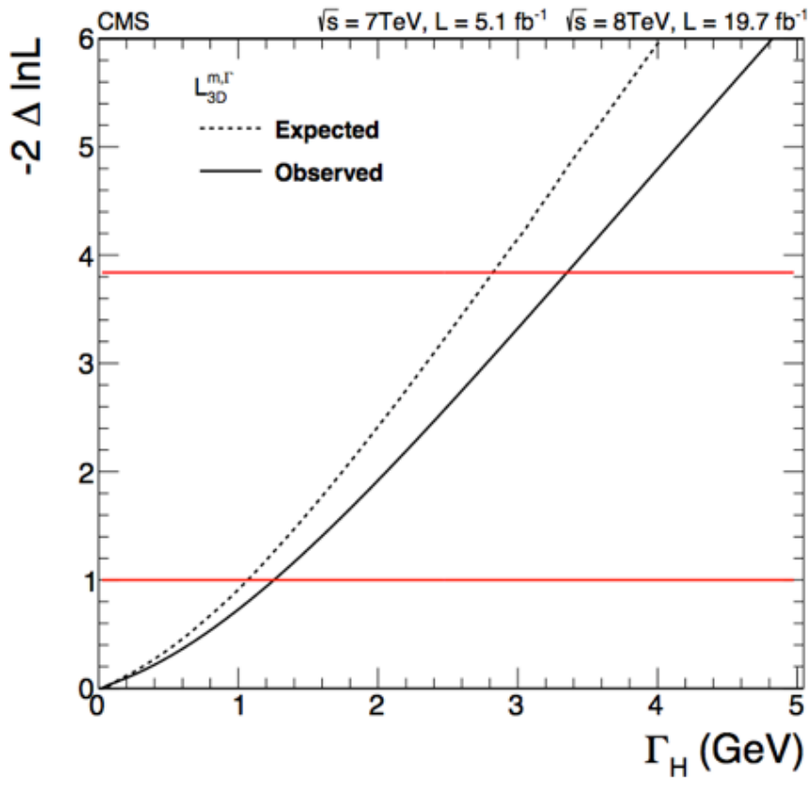
observed 6.7, expected 7.2

$\sigma/\sigma_{SM} = 0.91\ ^{+0.30}_{-0.24}$

$m_H = 125.8 \pm 0.5\ (stat.) \pm 0.2\ (sys.)$ GeV

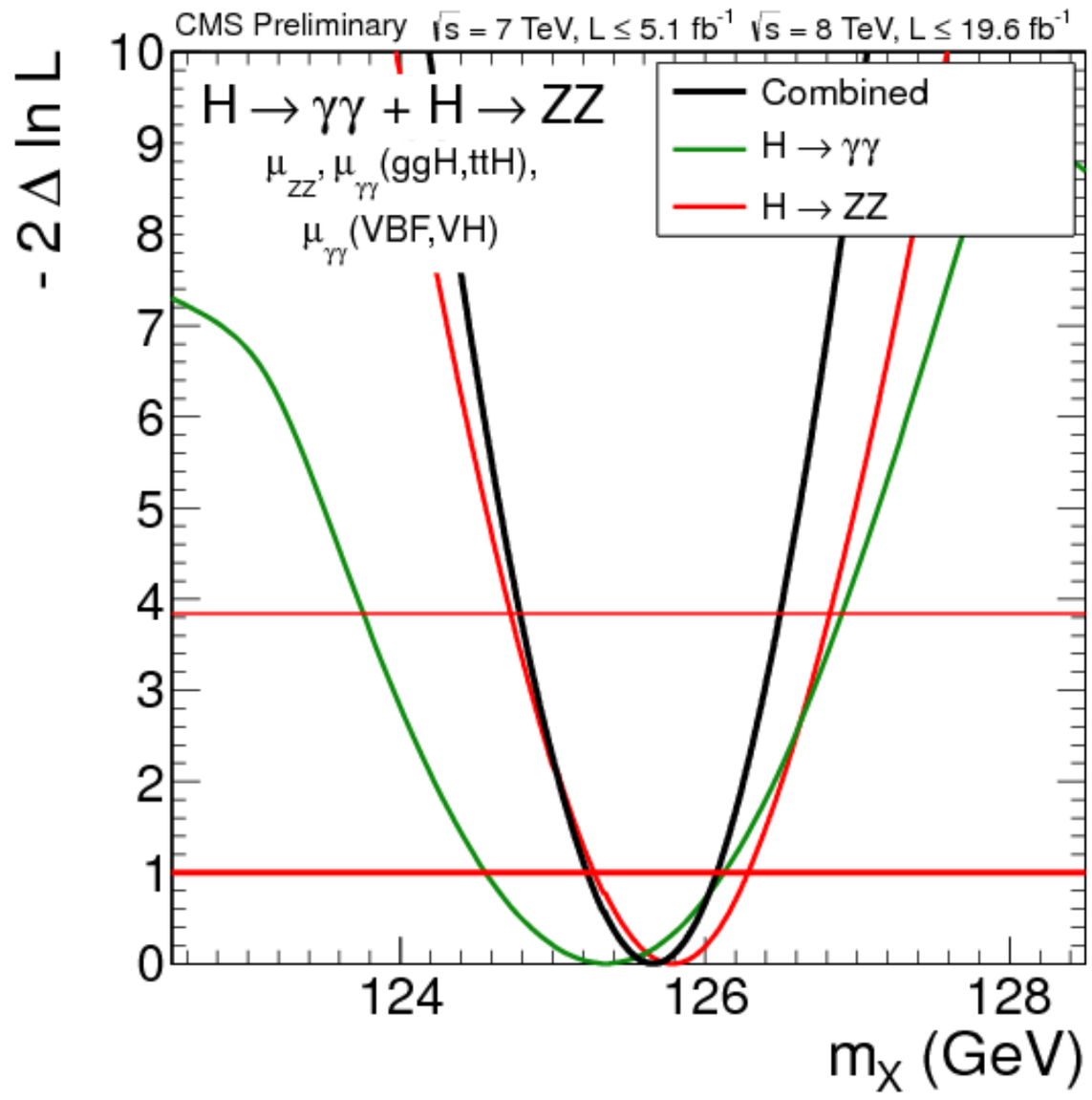


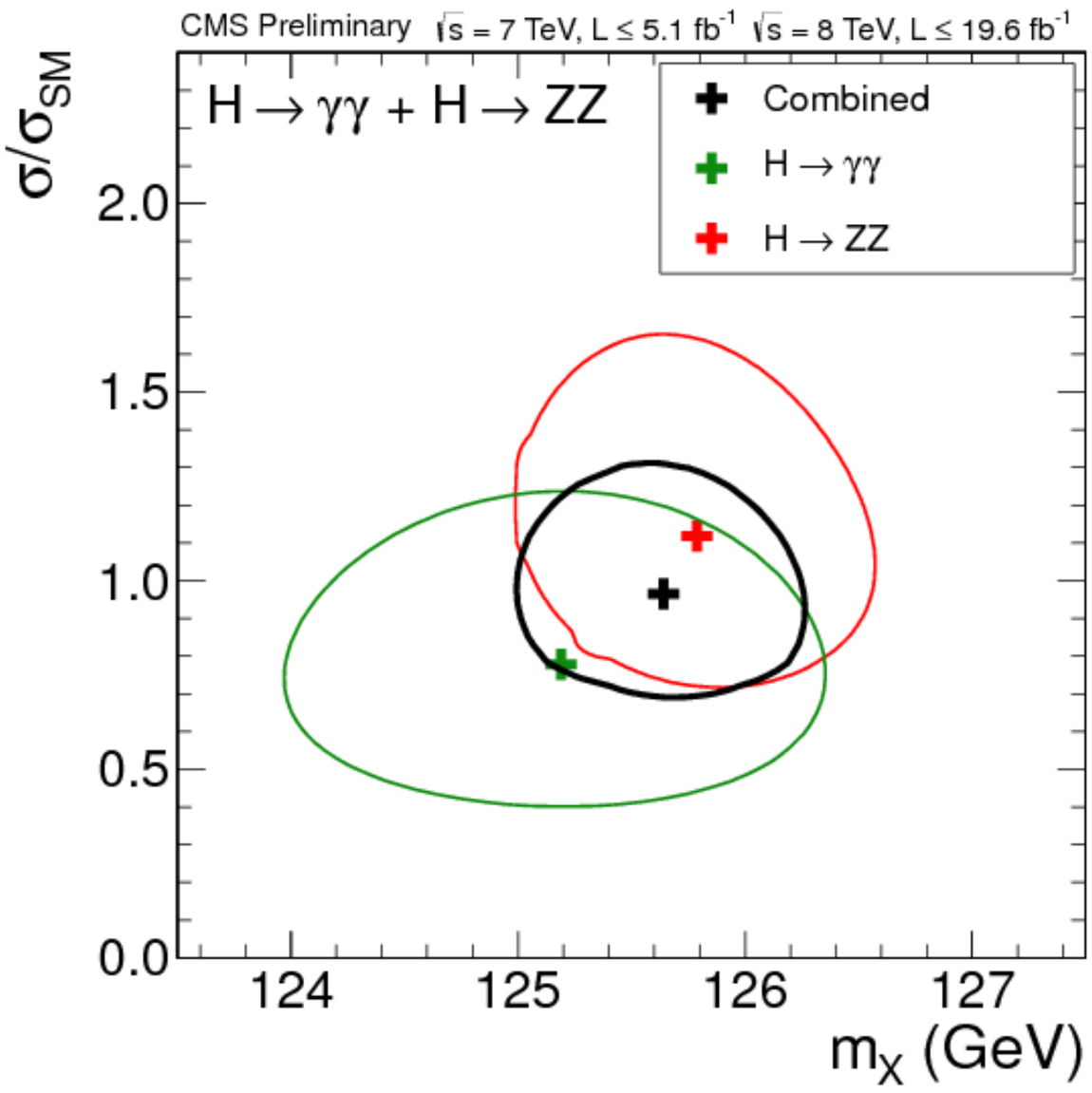
Data compatible with a narrow-width resonance: Γ_H < 3.4 GeV (at 95% CL), expected 2.8 GeV.



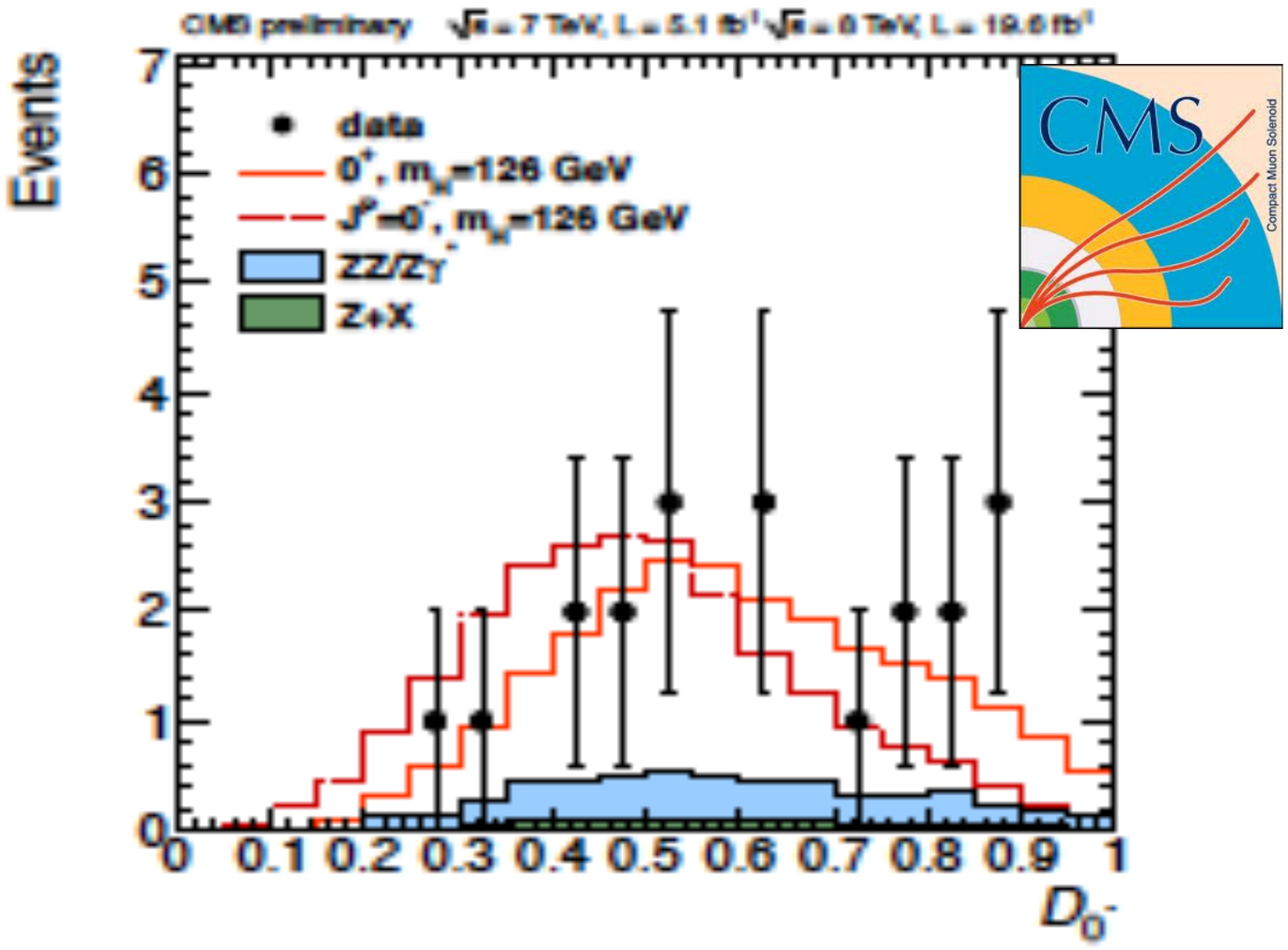
Mass of the state H -> γγ and μZZ @CMS

$$m_x = 125.7 \pm 0.3\ (stat.) \pm 0.3\ (sys.)\ \text{GeV}$$
$$= 125.7 \pm 0.4\ \text{GeV}$$

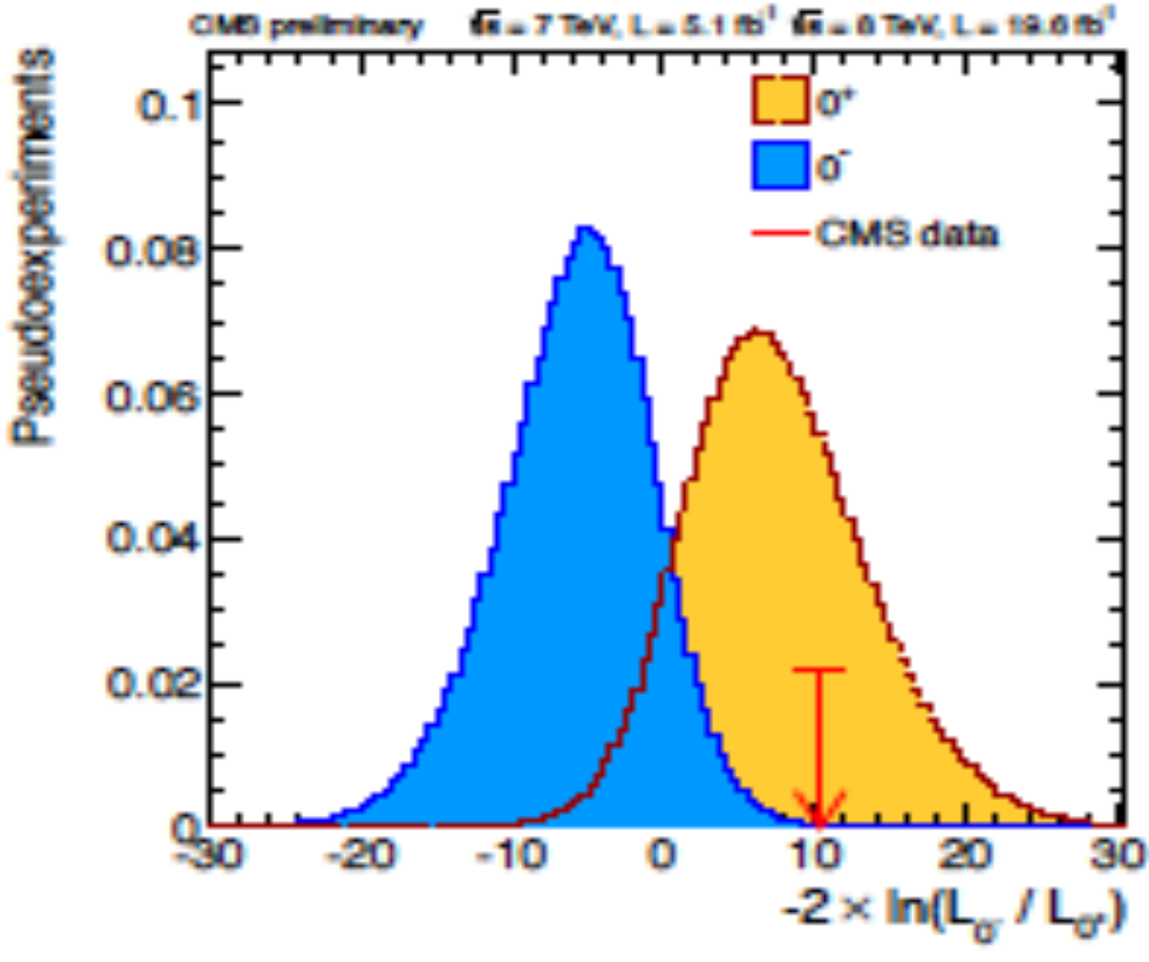




Spin-parity study: test for 0^-

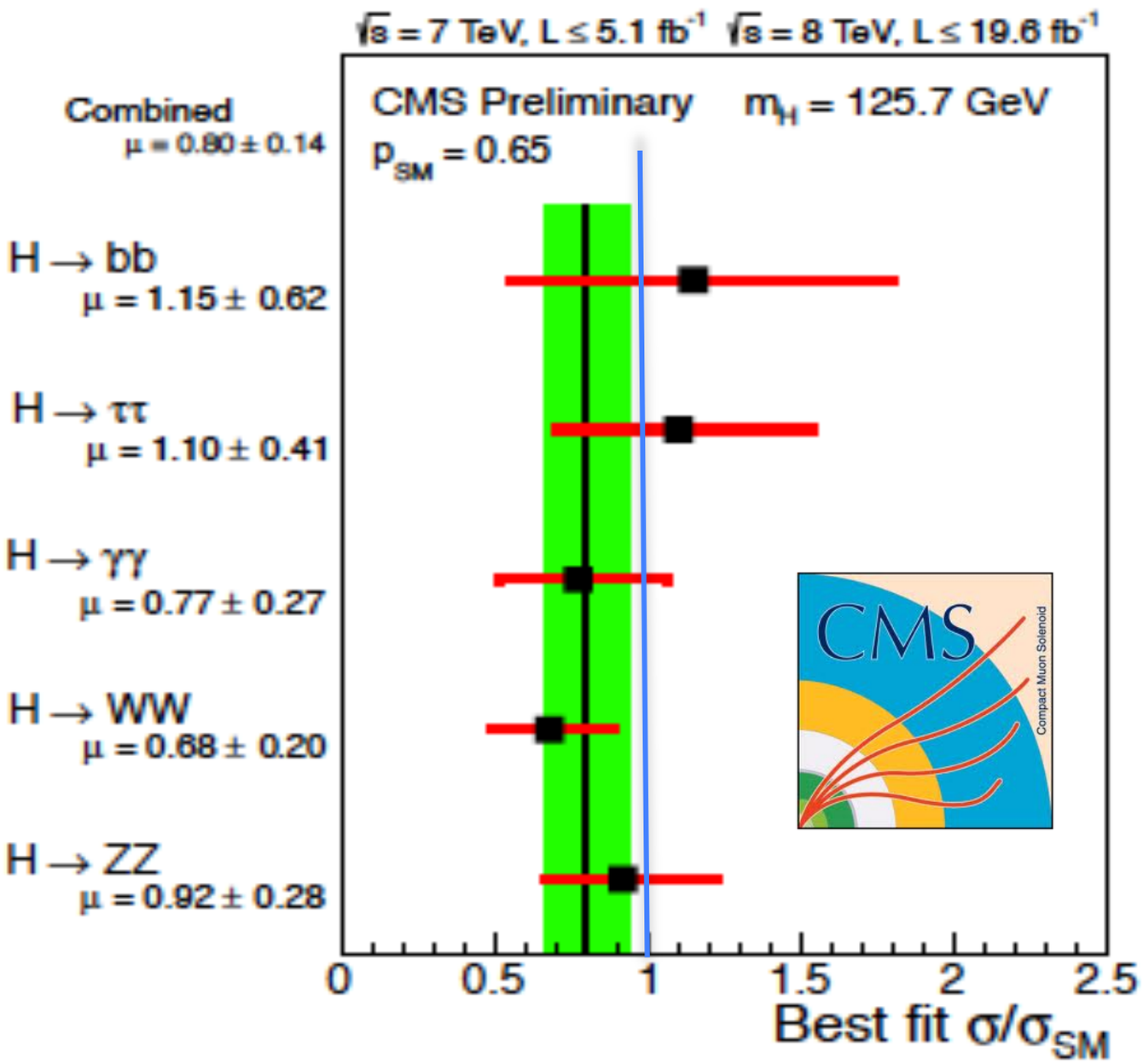


Toy experiments



- Good compatibility with SM
- Only 0.16% compatibility 0^- ➔ 3 sigma exclusion

Search for SM Higgs: signal strength



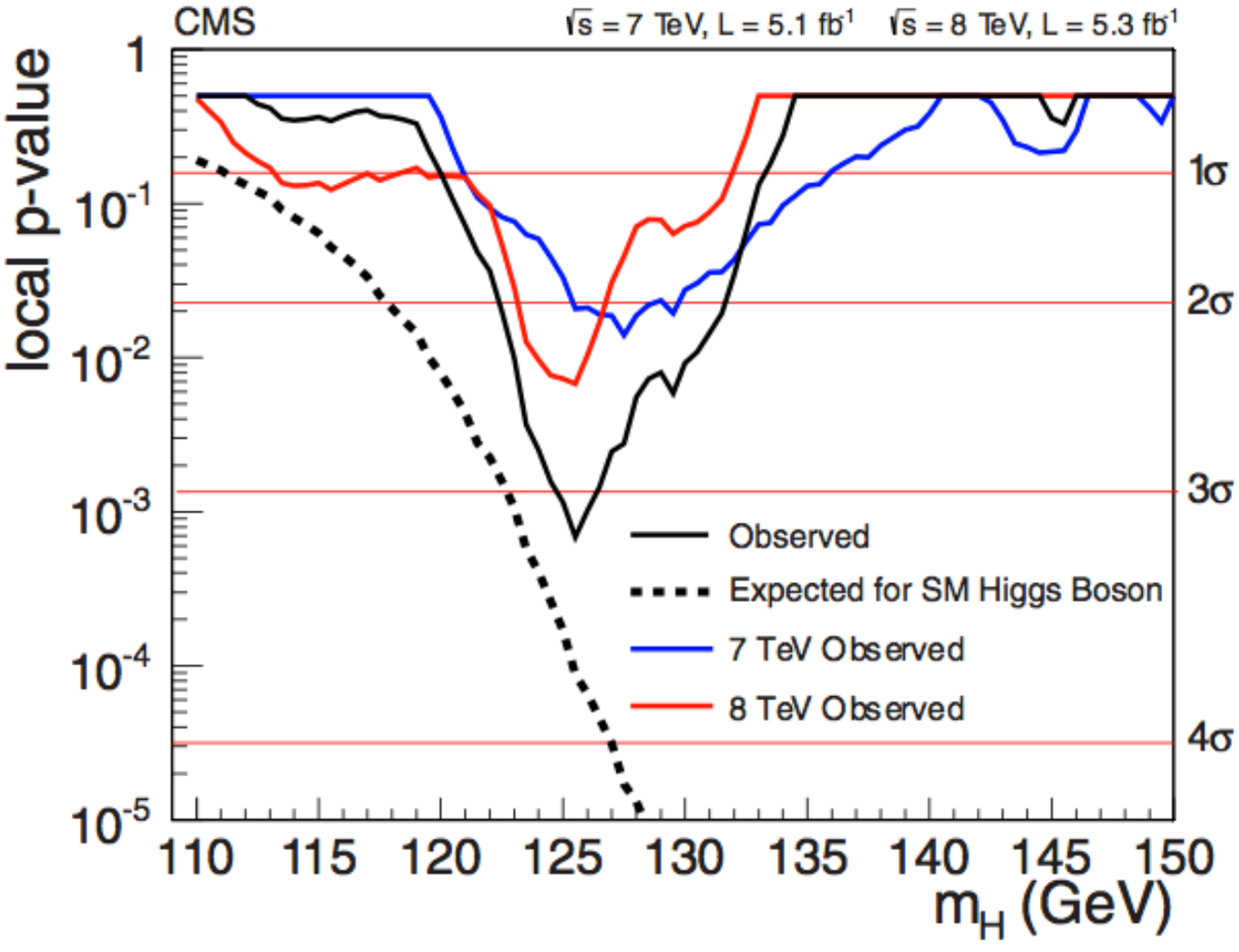
- Average:
$\sigma/\sigma_{SM} = 0.80 +- 0.14$

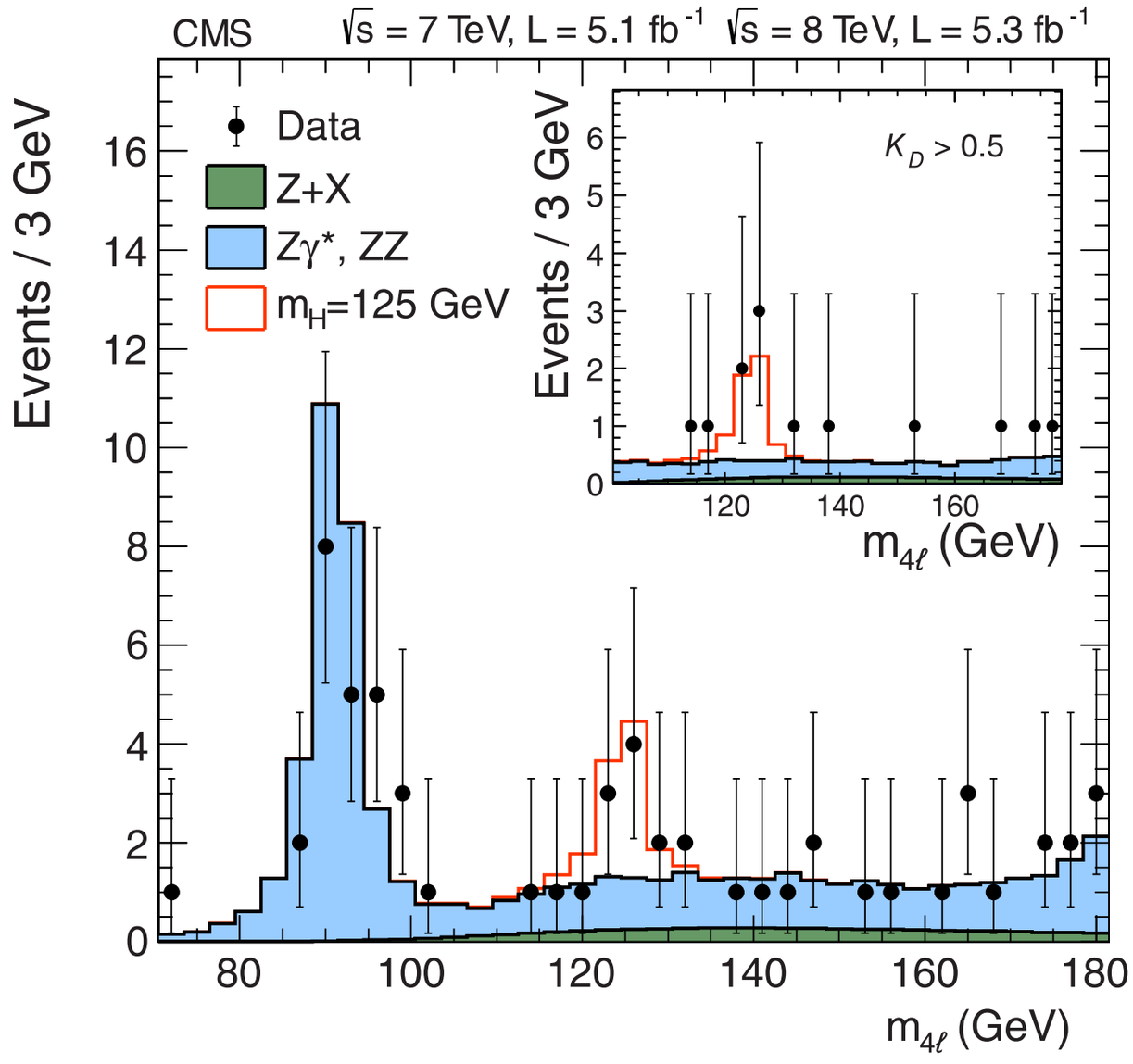
- Good consistency with the SM Higgs

new $H \rightarrow \tau\tau$ result not yet included

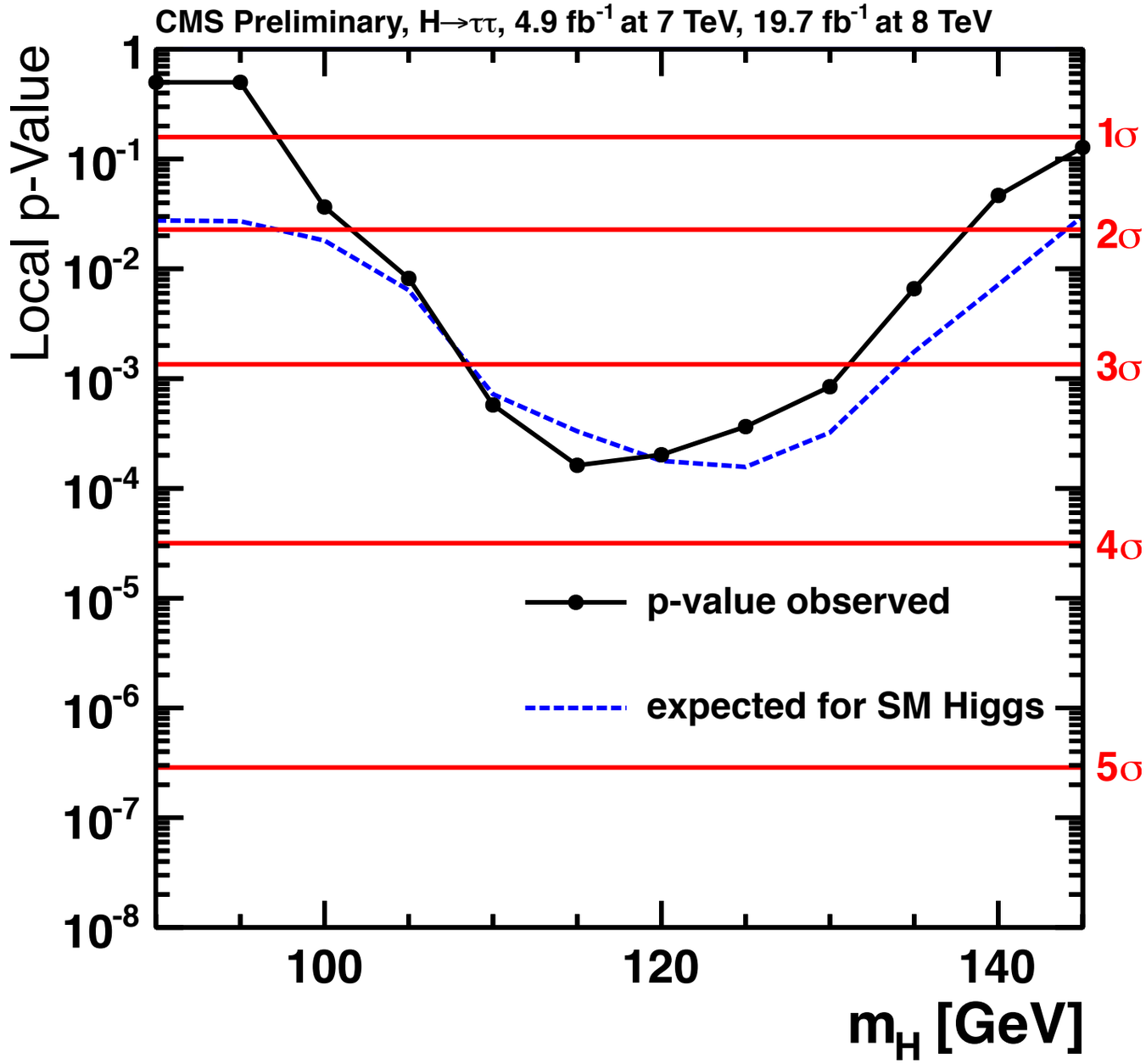
Search for SM Higgs boson: 4 lepton mass

Localized excess at ~126 GeV (July 4, 2012)
Local significance: 3.2σ
SM expectation: 3.8 σ



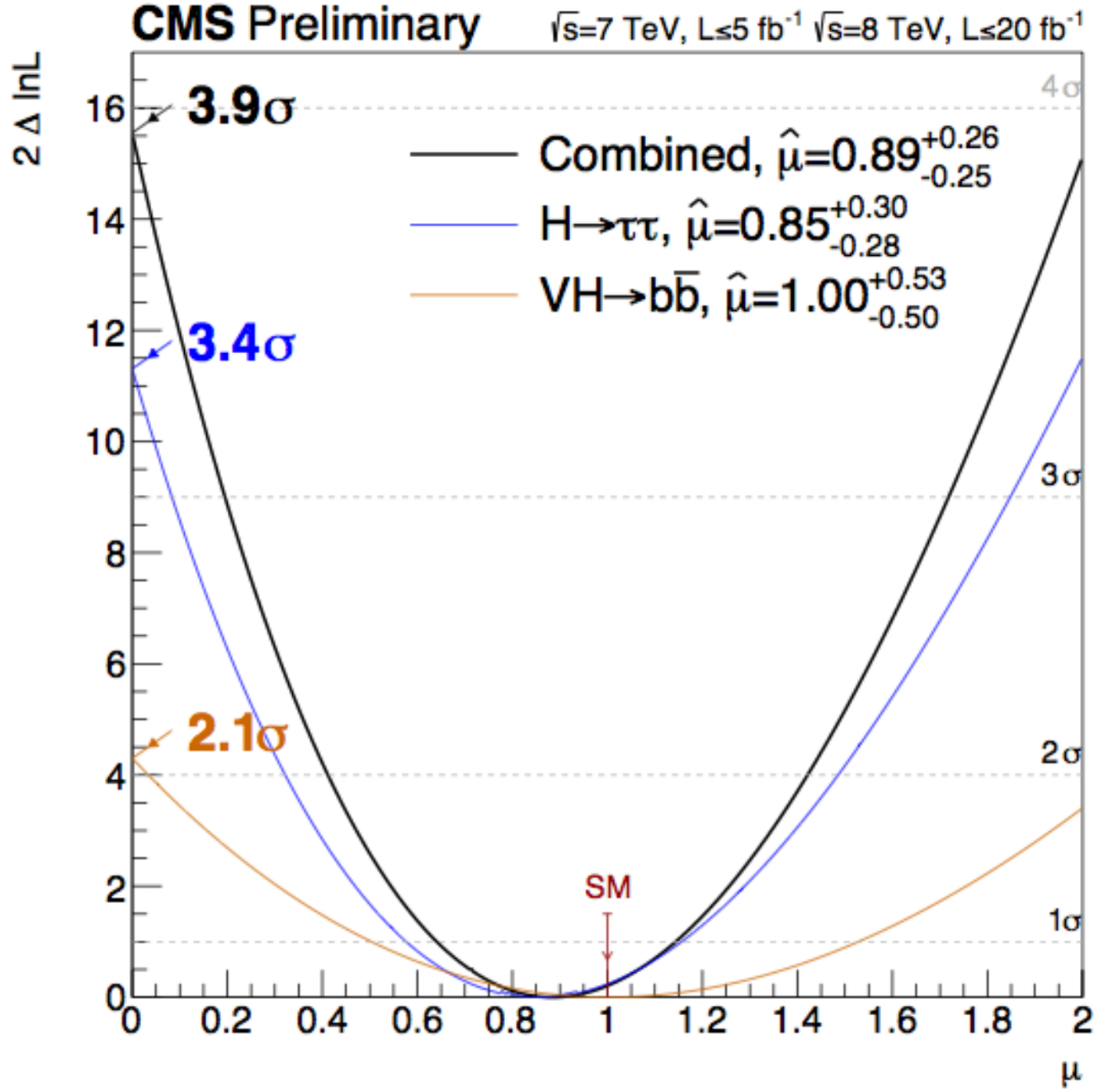


H->ττ: CMS update Dec. 2013



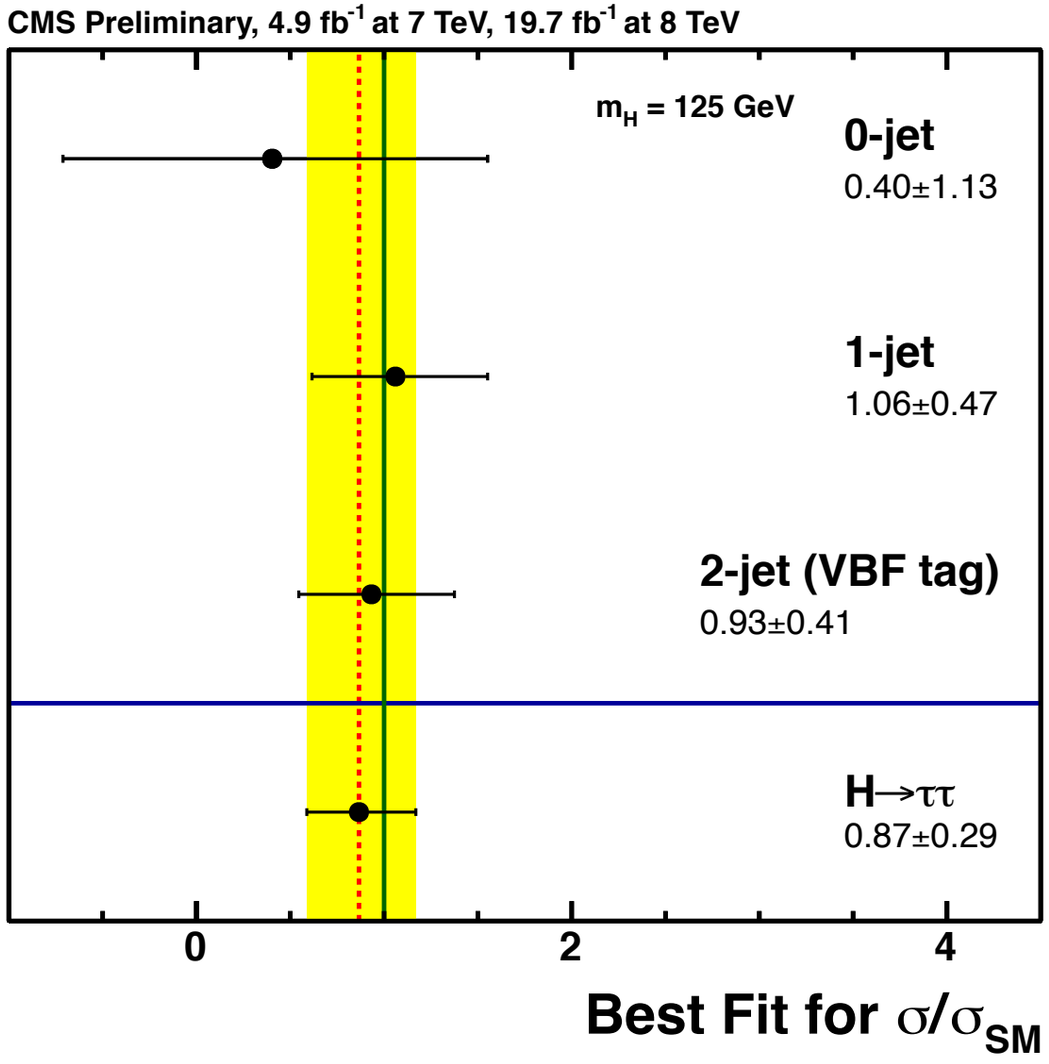
- Observed significance at 125 GeV = 3.38 σ
- Observed significance at 115 GeV = 3.59 σ
- **Excess > 3 σ for 110 < M_H < 130 GeV.**

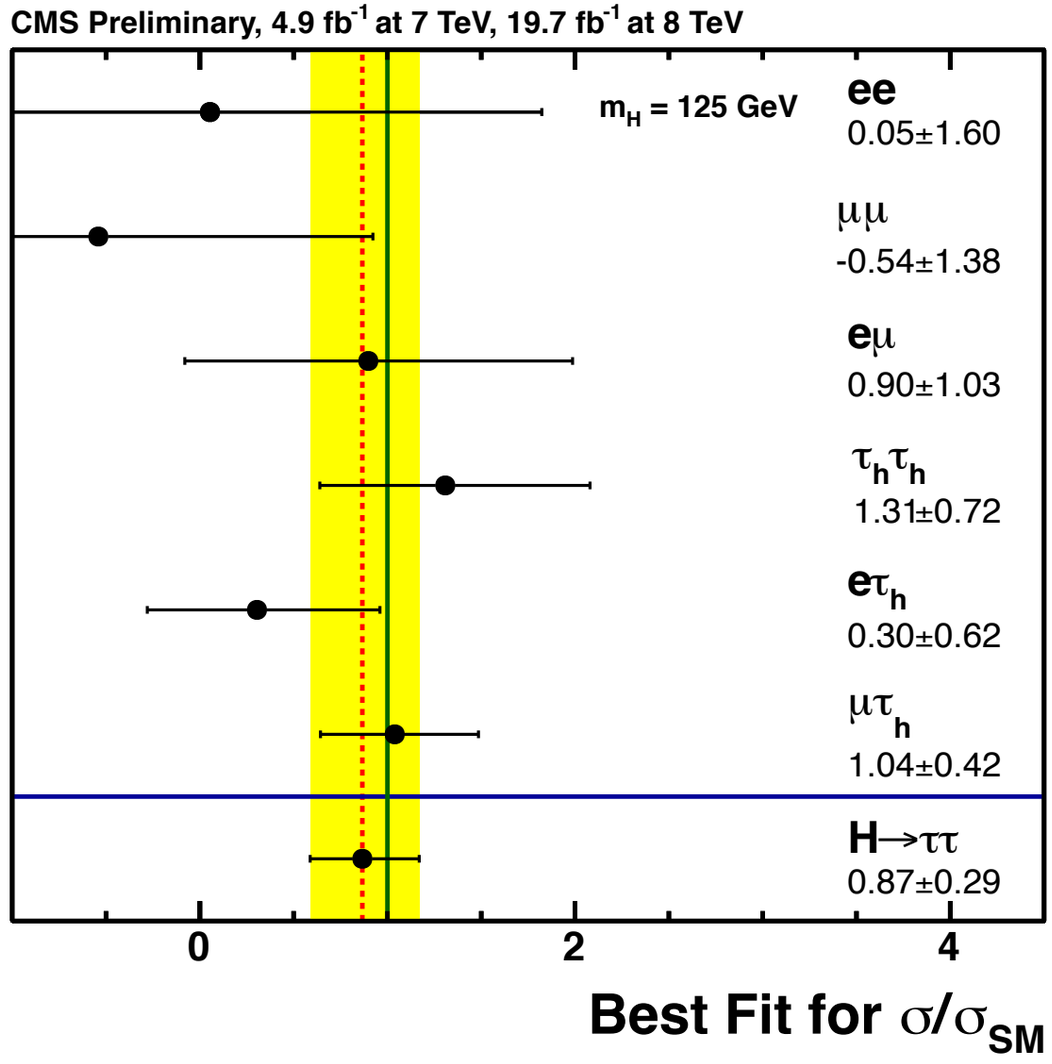
H->(ττ+bb): CMS update Dec. 2013



H→bb observed (expected) significance at 125 GeV = 2.1 (2.3) **σ**
H→**ττ** observed (expected) significance at 125 GeV = 3.4 (3.6) **σ**
Combination observed (expected) significance at 125 GeV = **3.9** (4.3) **σ**

H->(ττ+bb): CMS update Dec. 2013

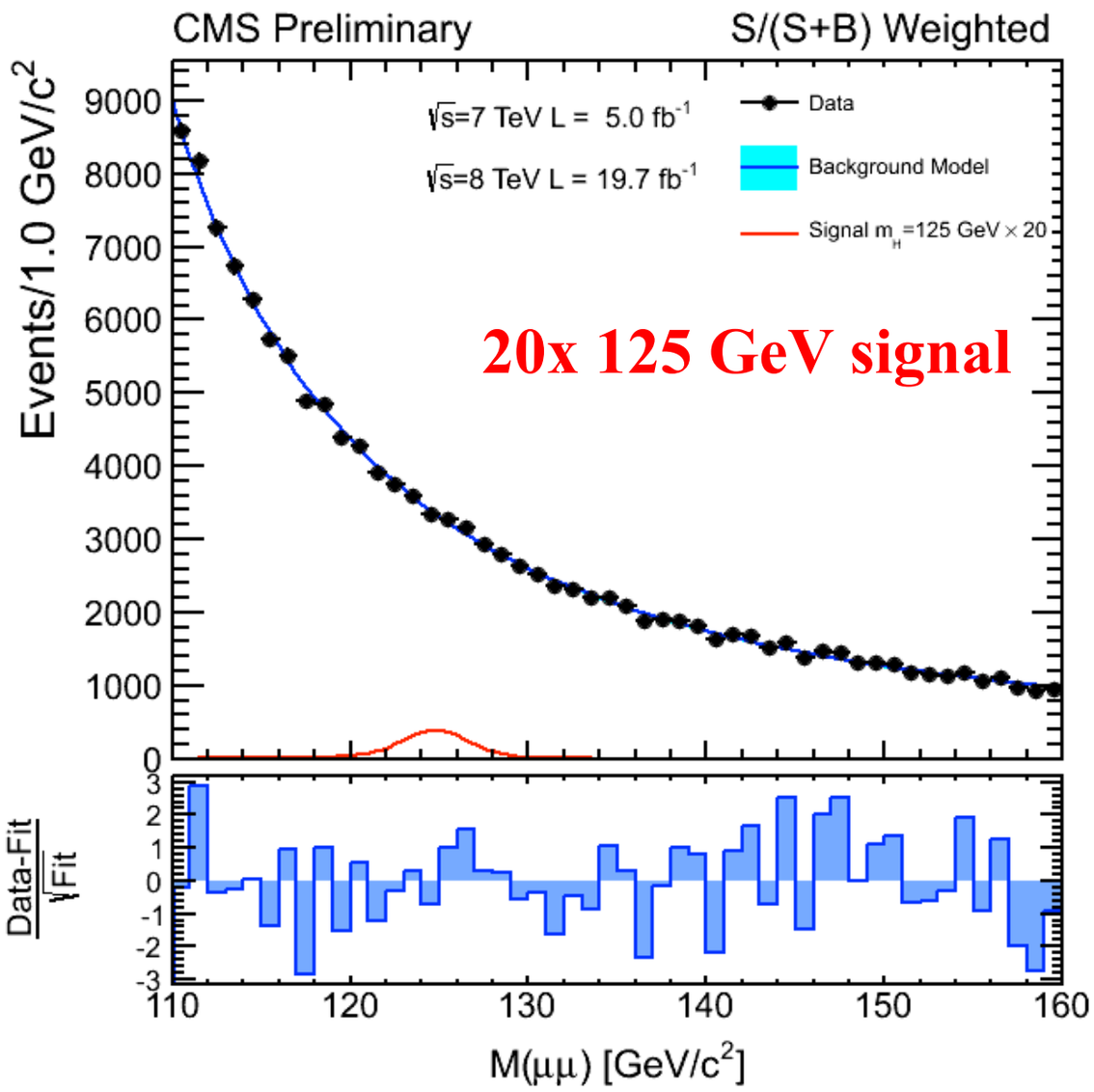


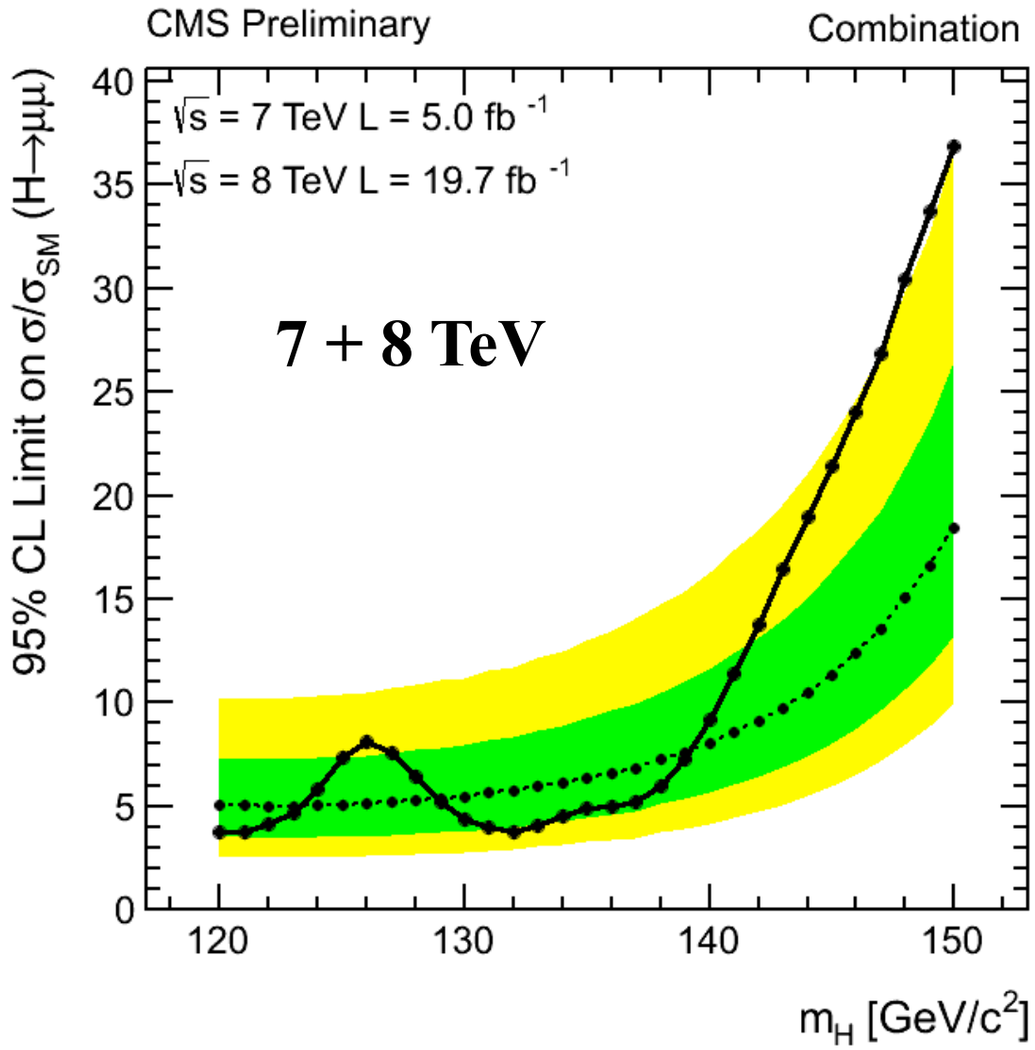


- Best fit $\mu = \sigma/\sigma_{SM} = 0.87 \pm 0.29$
- Compatible with the SM Higgs boson (125 GeV) prediction.

H->μμ: CMS update Dec. 2013

BR(H →μμ) = 2.2 x 10^{-4} at m_H = 125 GeV





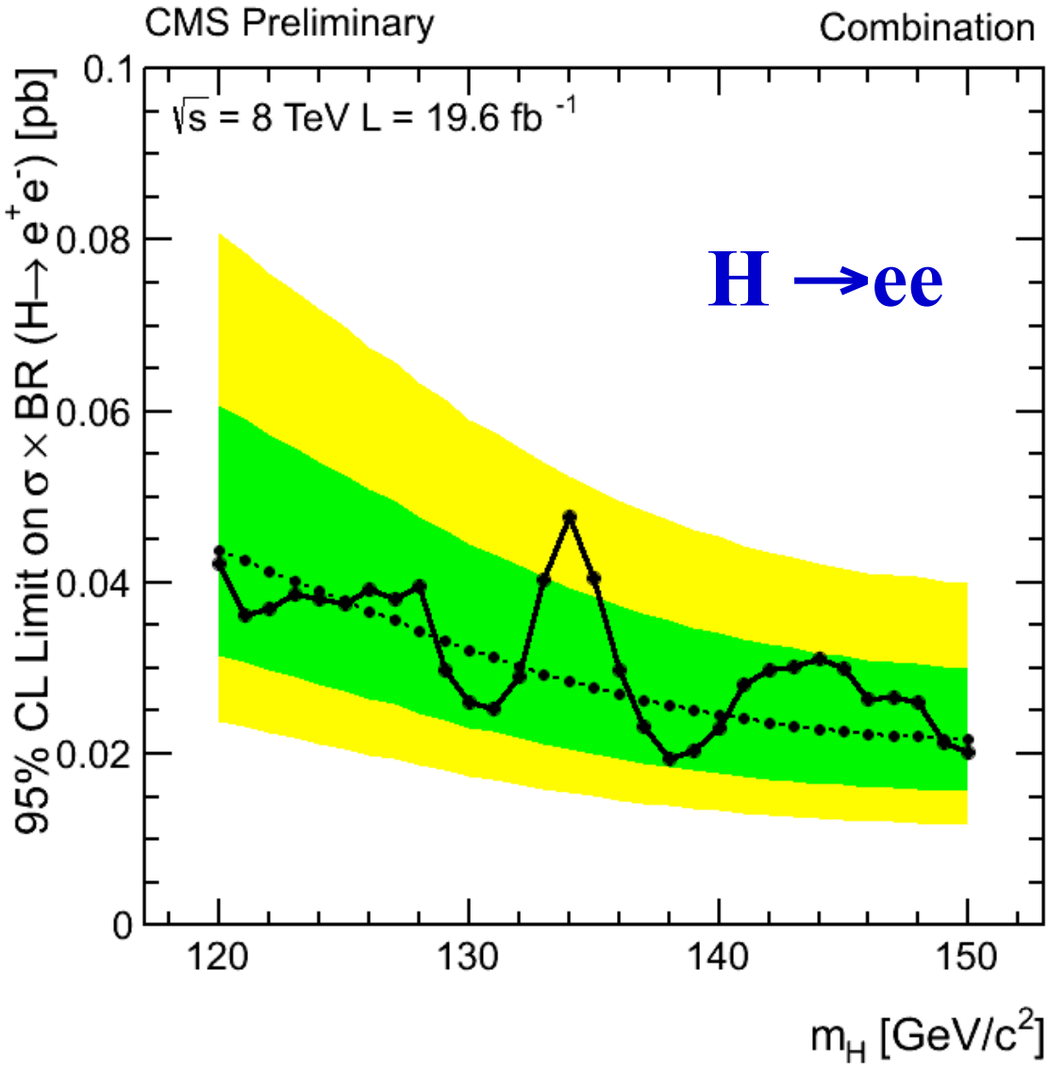
σ($M_{μμ}$): 1.6 GeV (both μ: $η^μ$ <0.8)
2.5 GeV (both μ: 1.6<$η^μ$ <2.1)

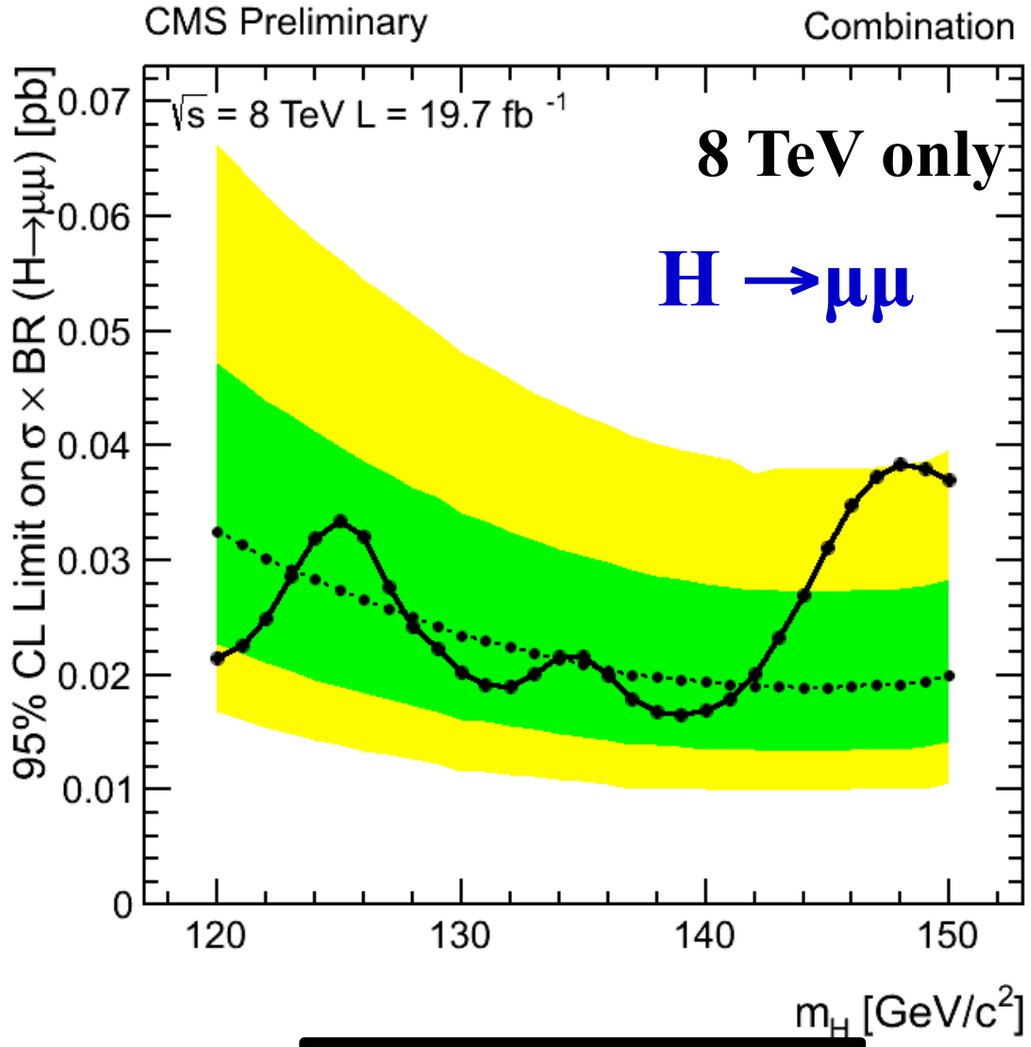
95% CL exclusion at m_H= 125 GeV:

Observed limit: 7.4
Expected limit: 5.1

H->ee: CMS update Dec. 2013

BR(H →ee) ~ 2x10^{-5} *BR(H →μμ)





95% CL observed upper limit σ*BR at m_H= 125 GeV:

H→ee: 0.038 pb
H→μμ: 0.034 pb

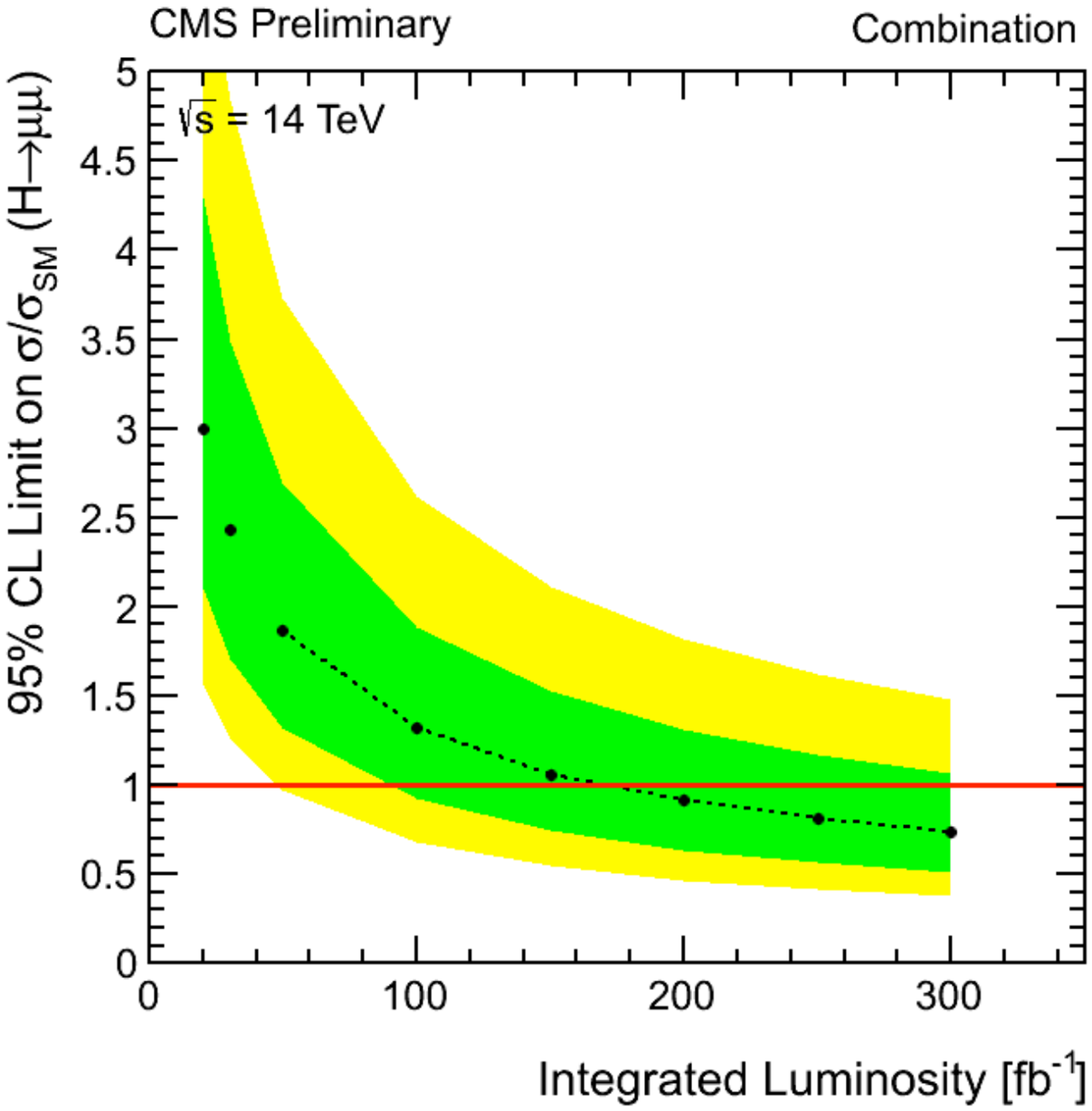
BR(H→ee) <0.0017

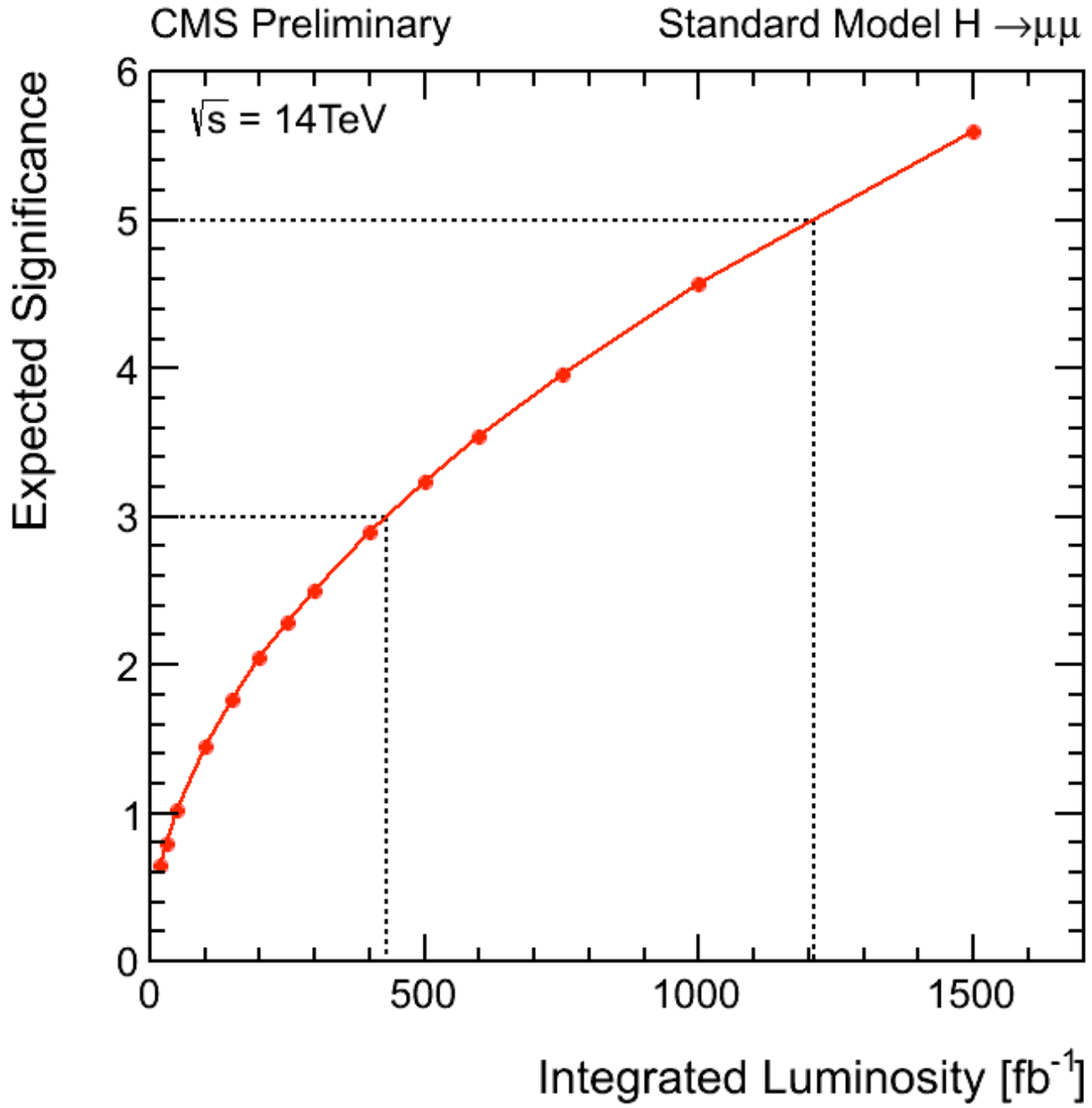
Evidence for flavour non-universality

H->μμ: CMS projection @14 ТэВ

5 σ discovery with ~ 1200 fb^{-1} @ 14 TeV

Measure muon coupling with 8% precision with ~3 ab^{-1} @14 TeV





CMS search for SM Higgs boson: Summary

François Englert and Peter Higgs
Photo: © CERN

2013 Nobel Prize in Physics

- **CMS: 7σ Higgs boson 125.7 ± 0.4 GeV**

  ∗ 0^- excluded at 3.0σ

  December 2013, CERN:

- **Clear evidence for flavour non-universality from H ->ee, H->μμ, H -> ττ**

- **Direct evidence for Higgs boson decays to 3rdgen bottom-type fermions:**

  H -> ττ 3.2σ (3.6σ expected) μ=0.87±0.29

  bb 2.1σ (2.1σ expected) μ=1.0±0.5

  ττ+bb 4.0σ (4.2σ expected) μ=0.89±0.26

SM Higgs boson: Discussion

SM problems:
Naturalness, fine tuning, ierarchy

* **Non-naturalness of scalar fields**

Fermions: Chiral symmetry $m^2=m_0^2 + C\ \mathrm{Log}[\Lambda^2]$
K. Wilson (1970)
Susskind (1979), 't Hooft (1979)

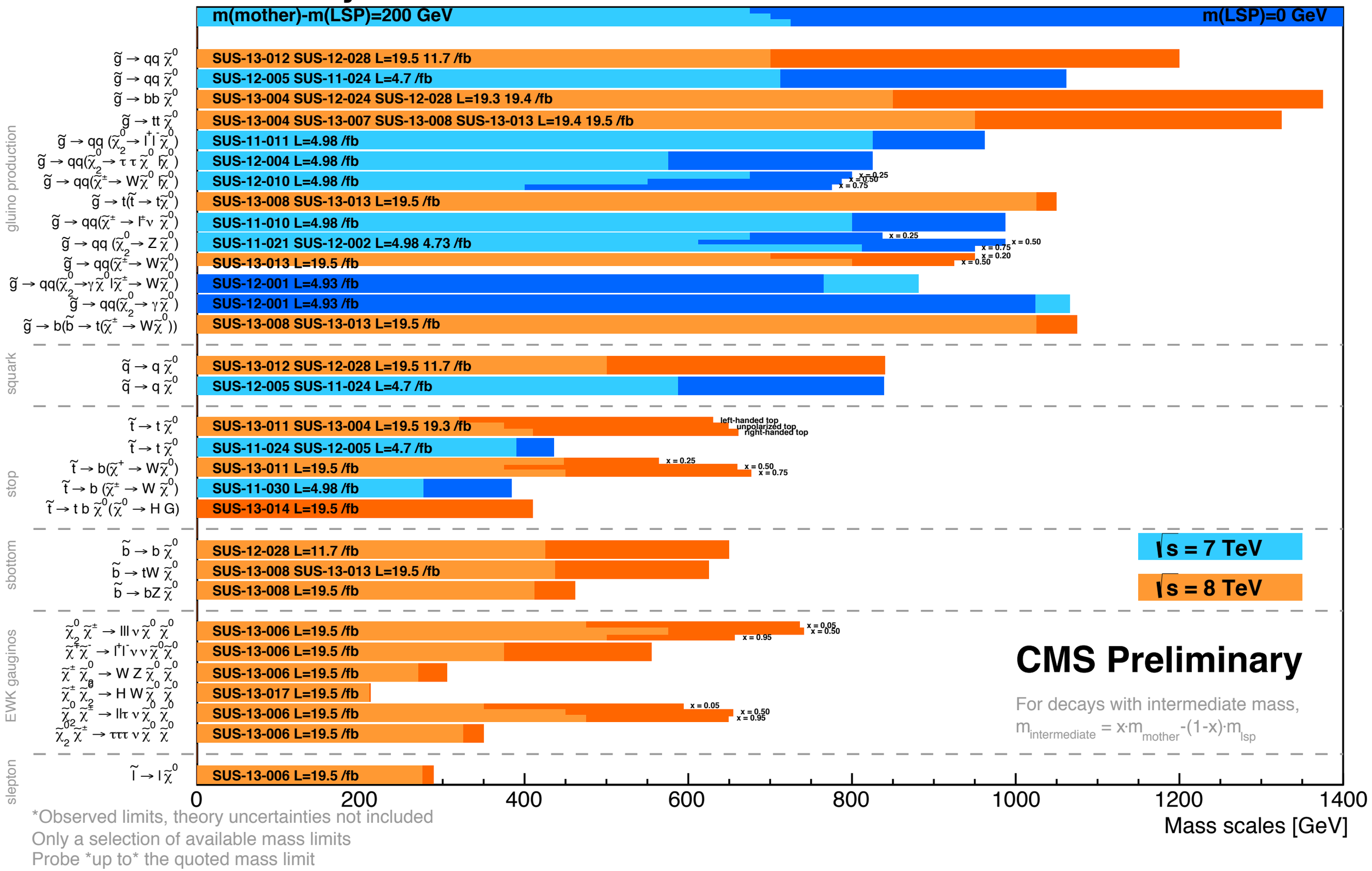
Scalar: mass divergence: $m^2 \sim m_0^2 + \Lambda^2$
Higgs mass ~ Λ^2
in SM strong EW interaction at 2-4 TeV

*** Naturalness in SM extends up to 6-10 TeV**
G. Pivovarov & V. Kim (2009)

If no quadratic divergences -> SM with Higgs boson 125 GeV validity extends up to to Planck mass scale (stable vacuum ...)
M. Shaposhnikov et al

Search for SUSY @CMS

Summary of CMS SUSY Results* in SMS framework SUSY 2013



*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

Search for BSM: CMS