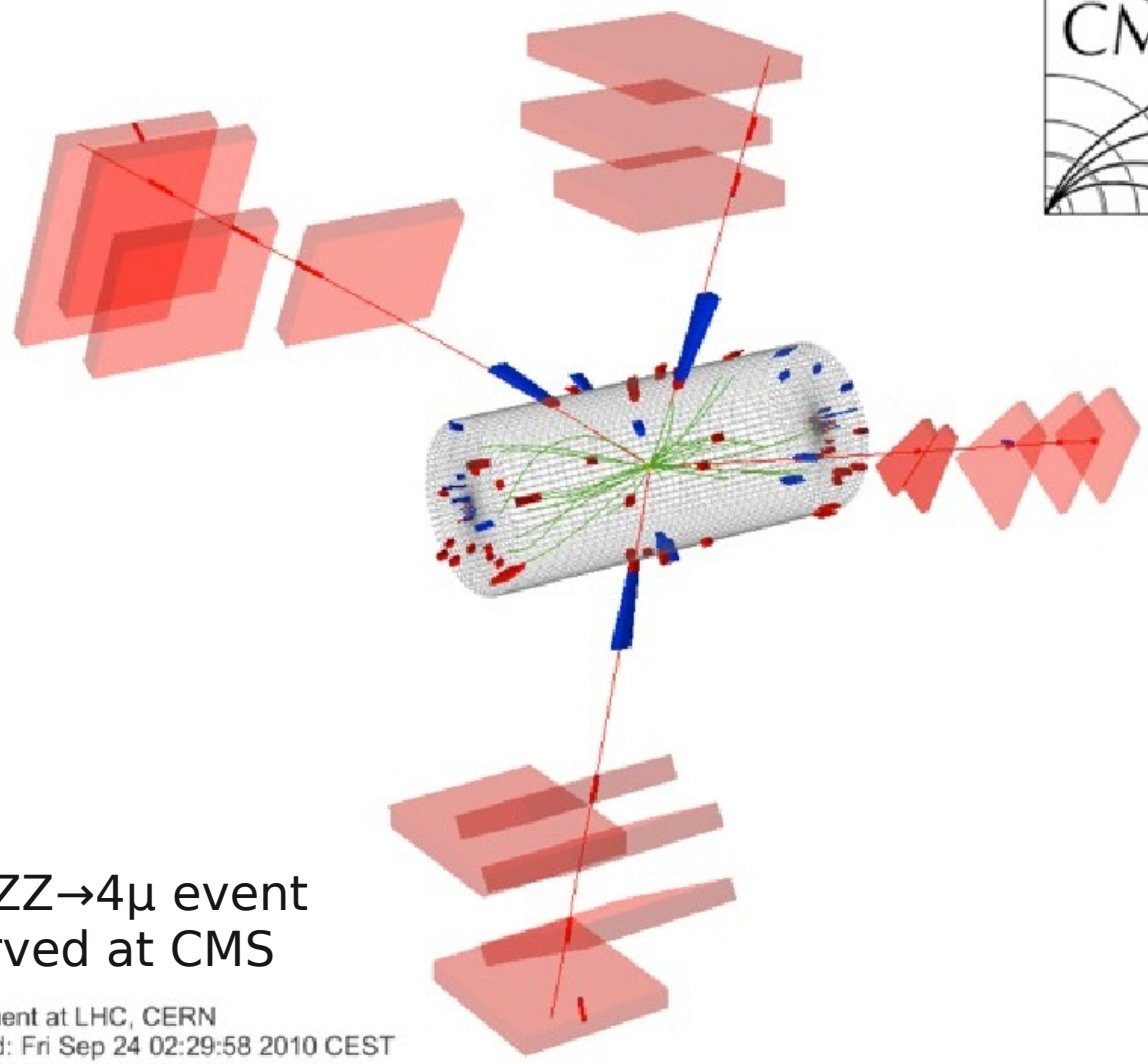
CMS potential for the Higgs boson discovery with 1 fb^{-1}

Artur Kalinowski
(Faculty of Physics
University of Warsaw)
on behalf of
CMS Collaboration

Cracow Epiphany Conference
On the First year of the LHC
Cracow, 10 - 12 January 2011

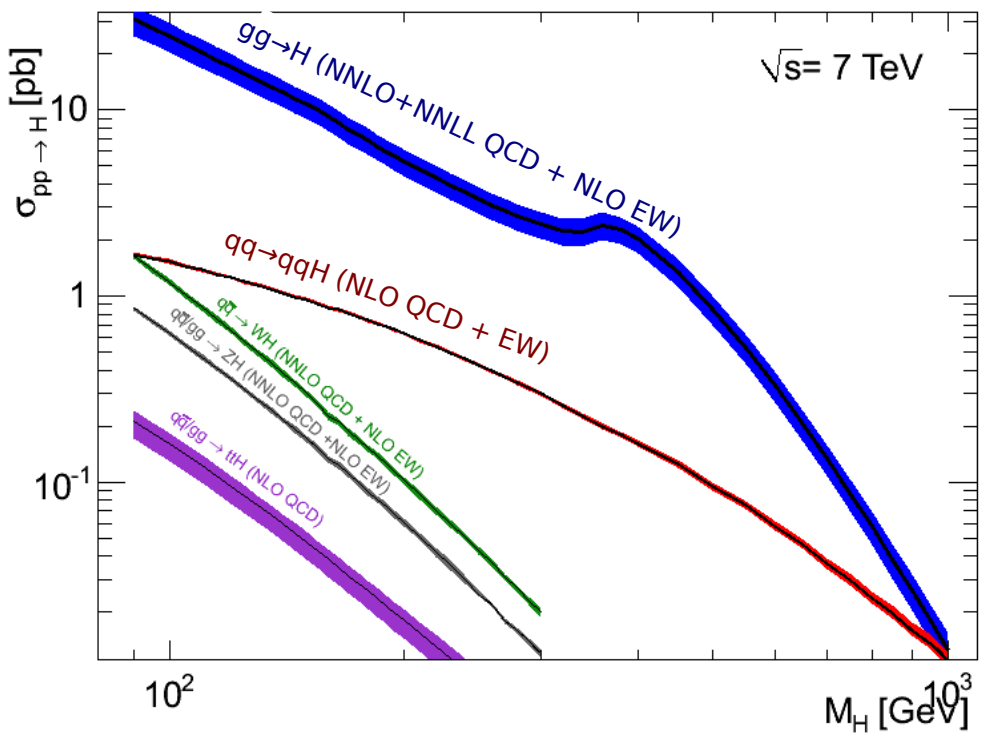
Outline

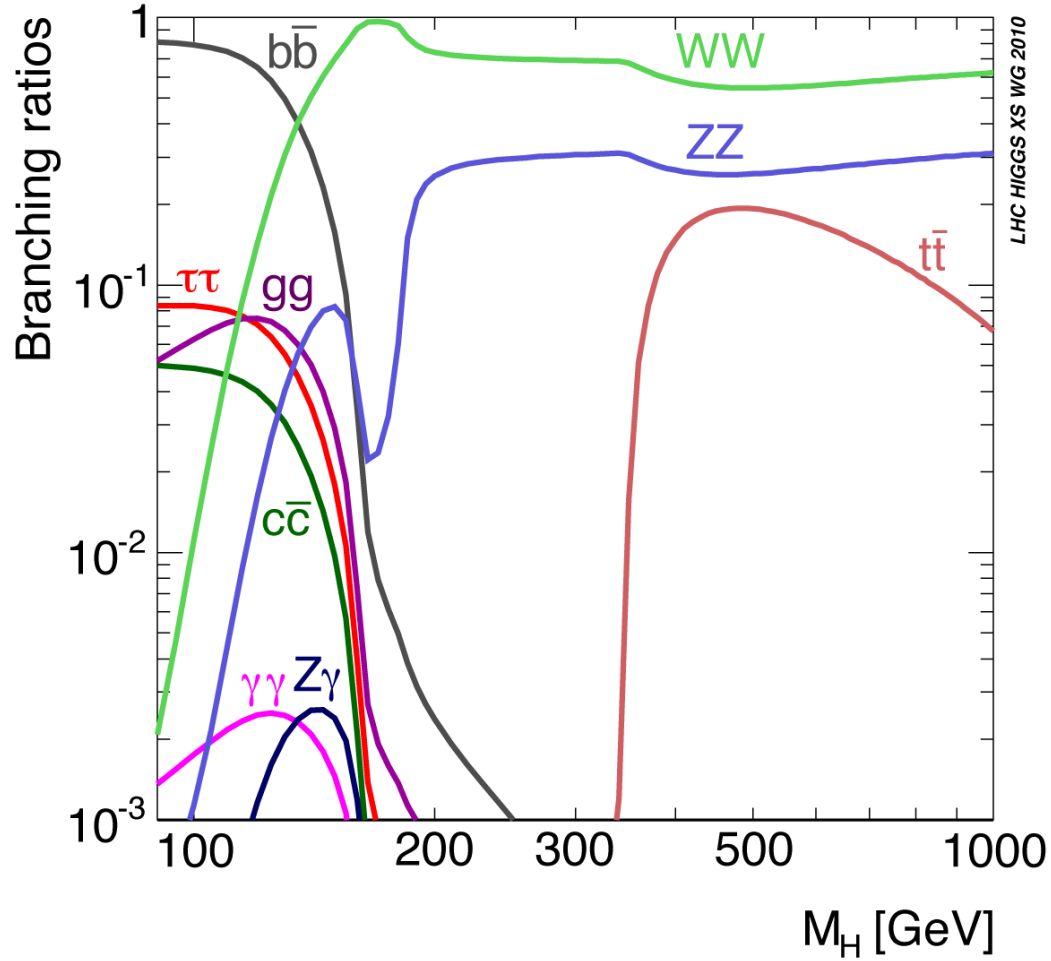
- Standard Model Higgs boson searches
- MSSM Higgs bosons searches
- Conclusions



First ZZ→4μ event observed at CMS

SM Higgs production at LHC





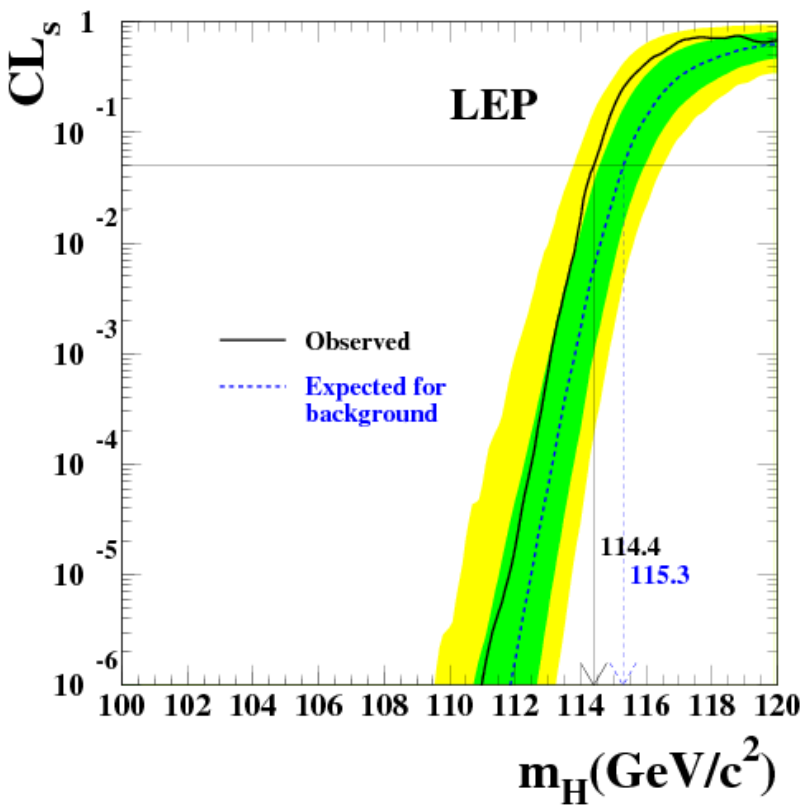
- Main production channels: gg→H, qq→qqH
- Main decay modes used for early searches: VV,ττ,γγ

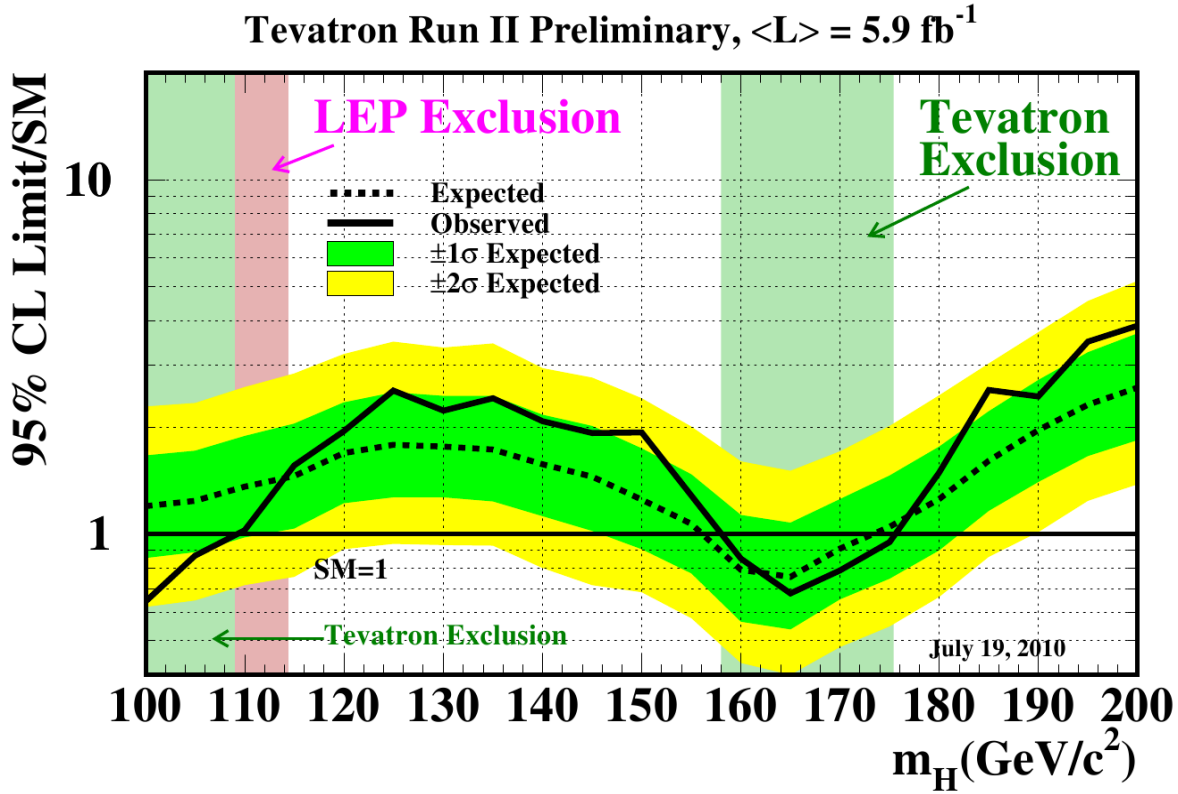
Current status on SM Higgs boson exclusions

- Tevatron exclusion:

$100<m_H<109$ GeV/c²

$158<m_H<175$ GeV/c²



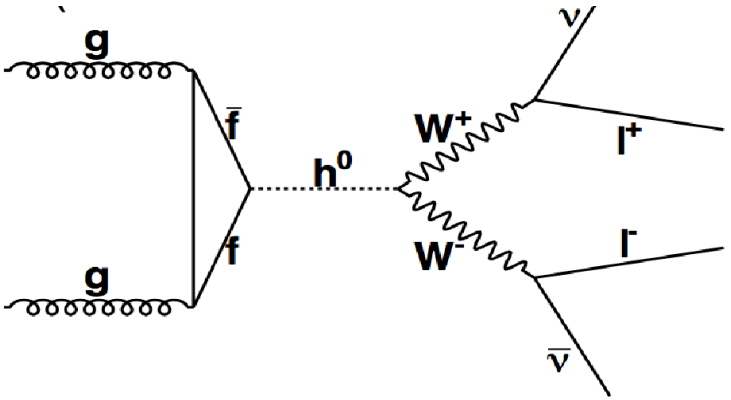


- LEP exclusion:

$m_H>114.4$ GeV/c²

H→WW→2l2ν analysis

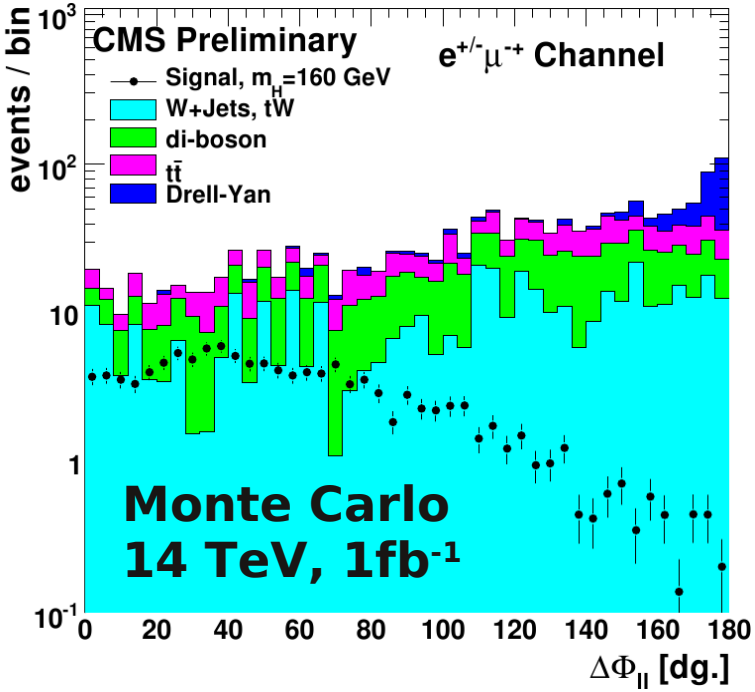
- **Signal signatures:**
  - **two isolated leptons**
  - **large missing E_T**
  - **low jet activity**
  - **lepton azimuthal angle correlations**

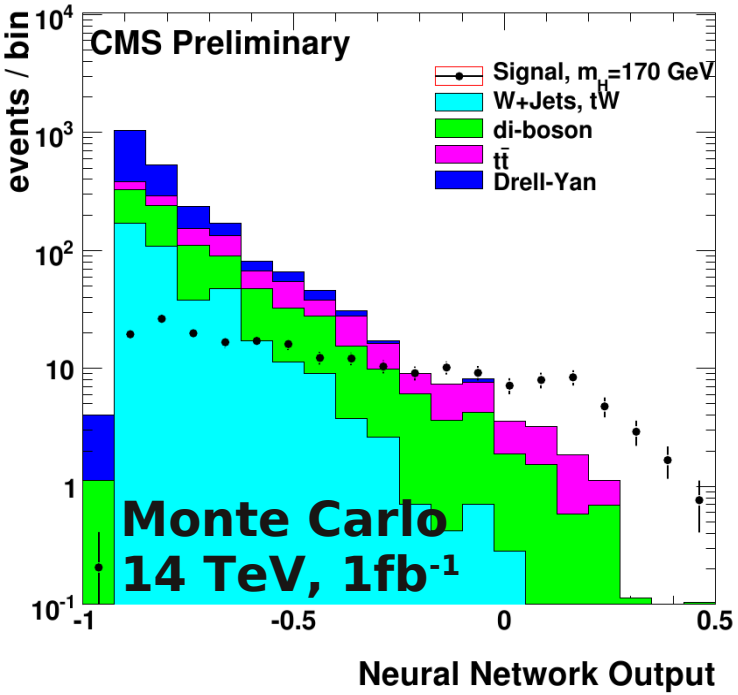


- **Irreducible background: WW**
- **Main reducible backgrounds:**
  - tt, W+t, W+jets
  - Drell-Yan, WZ, ZZ

H→WW→2l2ν analysis

- W+jets background reduced due to different ΔΦ(l,l) distribution
- cuts based and neural network selections are considered

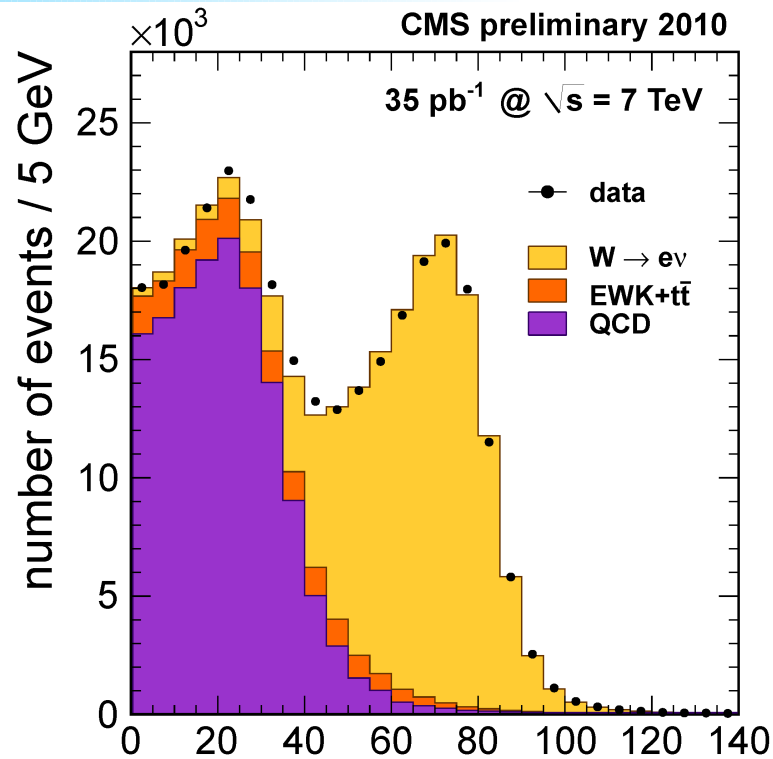


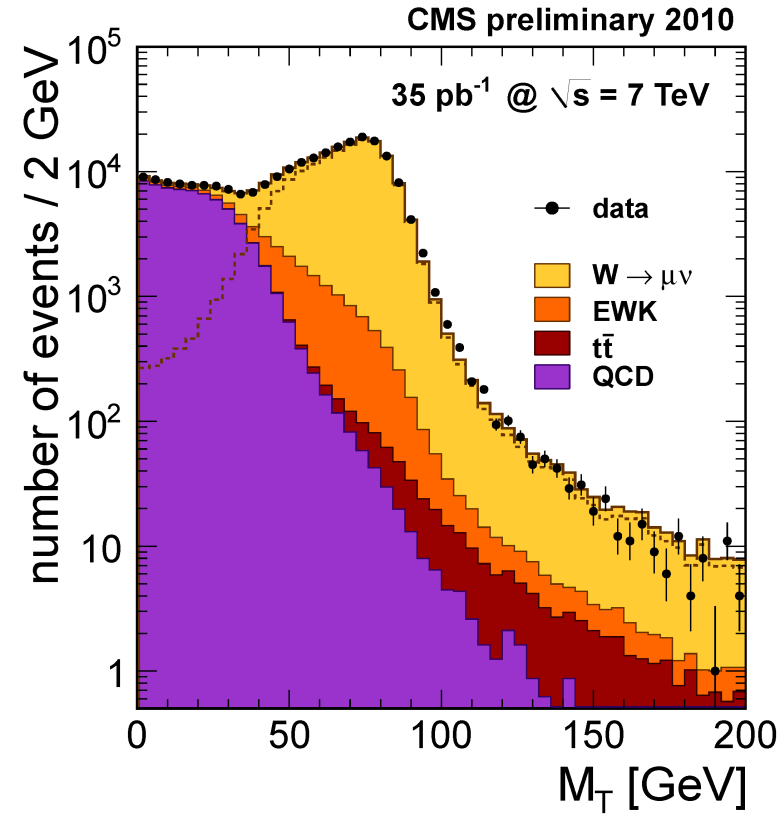


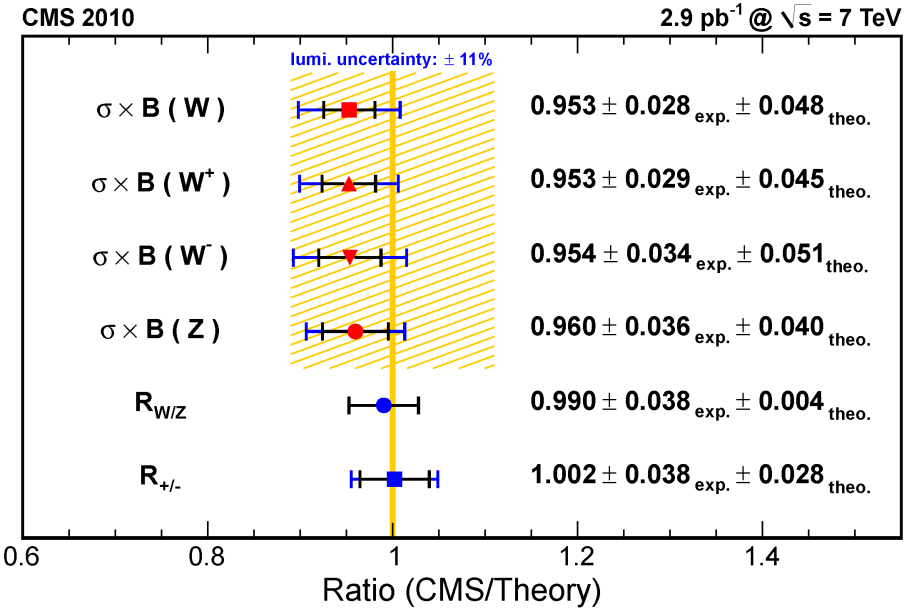
- no peak in m_H due to presence of neutrinos in final state → **counting experiment only**

W→lν analysis

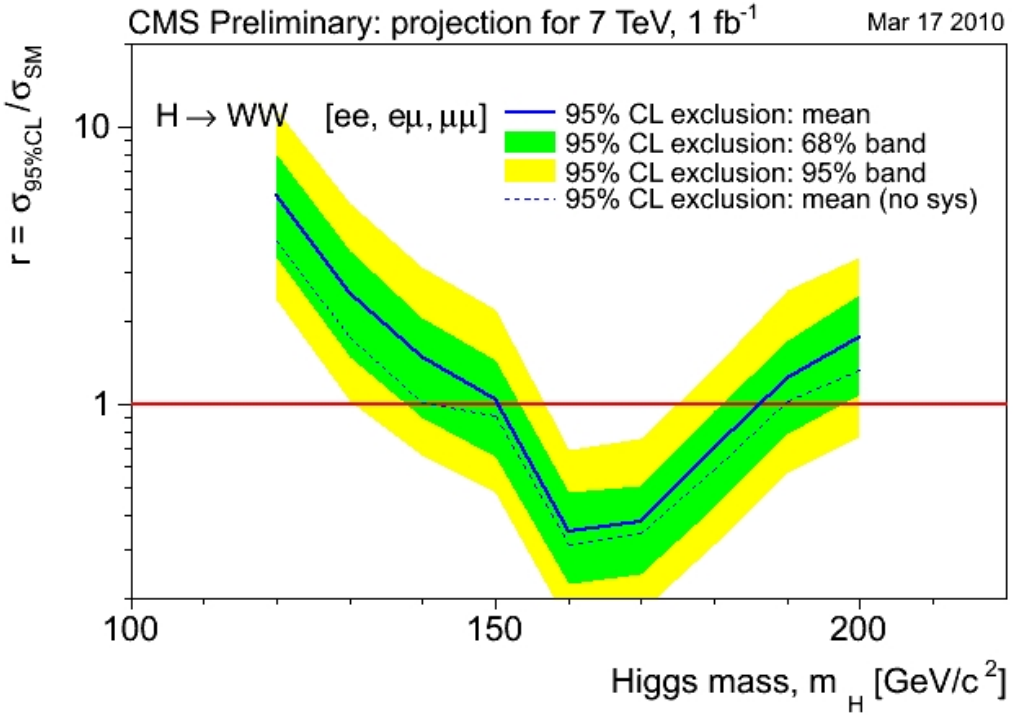
- **W→lν analysis validates physics objects used by the H→WW analysis**
- **Excellent MC-Data agreement**
- **Extracted W cross section agrees well with known values(more details in talk by M. Konecki)**

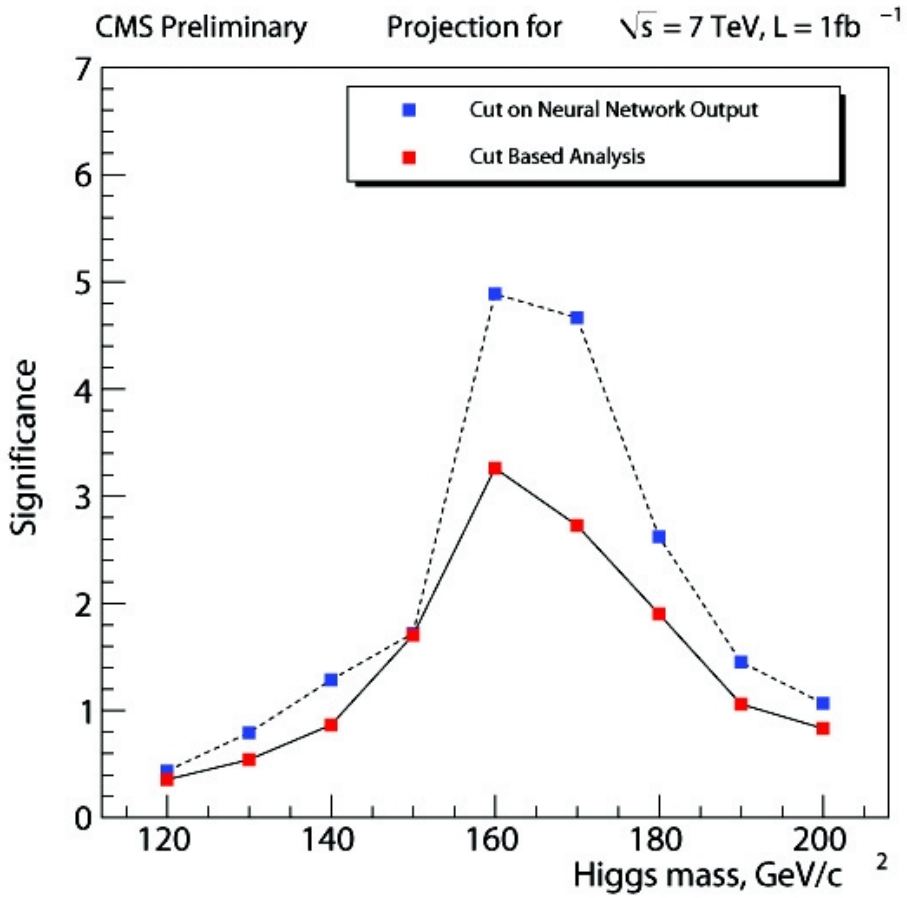






H→WW→2l2ν expectations

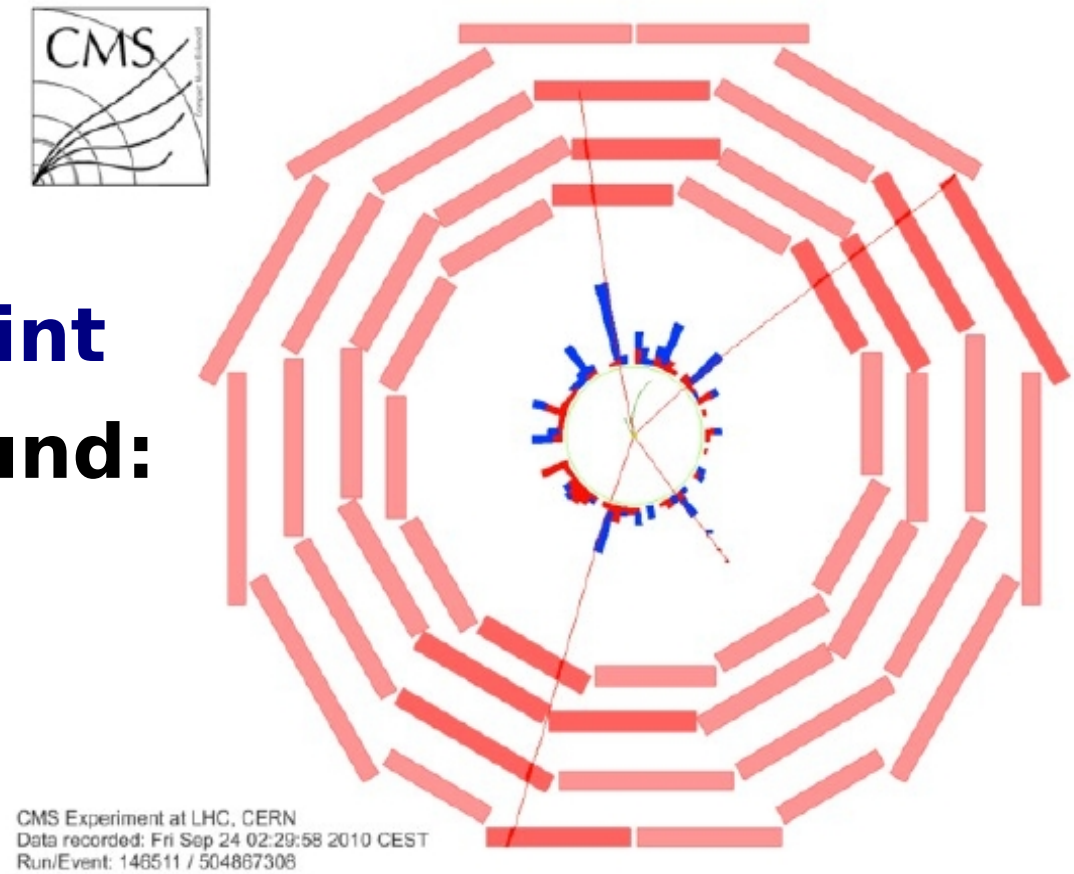




- Expected exclusion with 1 fb^{-1}: **$150<m_H<185$ GeV/c^2**
- Using the NN, close to discovery limit with 1 fb^{-1}: **$160<m_H<170$ GeV/c^2**

$H \to ZZ^{(*)} \to 4l$ analysis

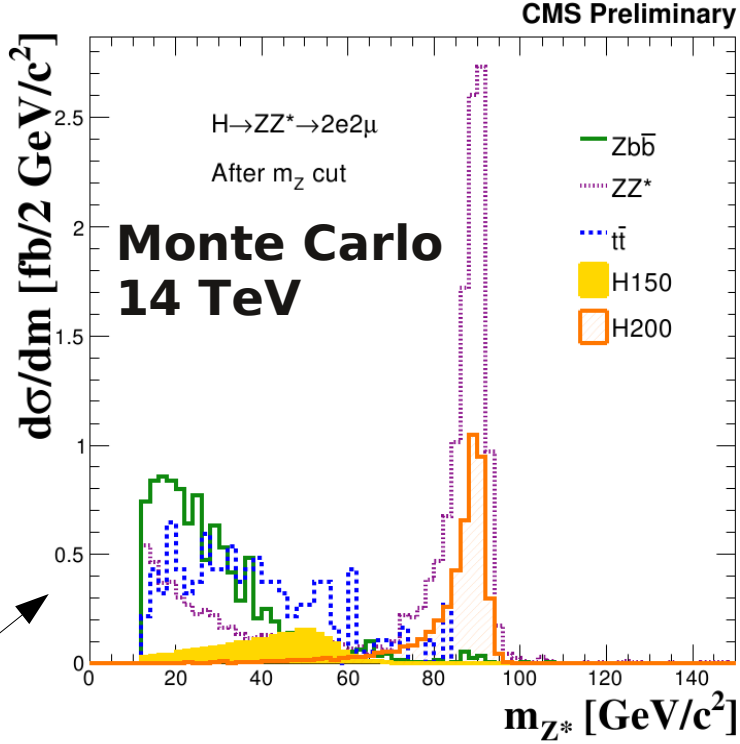
- **Signal signatures:**
  - **two isolated leptons**
  - **Z mass constraint**
- **Irreducible background: ZZ**
- **Main reducible backgrounds:**
  - Zbb, Z+jets, W+jets, tt
  - QCD



First $ZZ \to 4\mu$ event observed in CMS
$m_{4\mu} = 201$ GeV/c^2

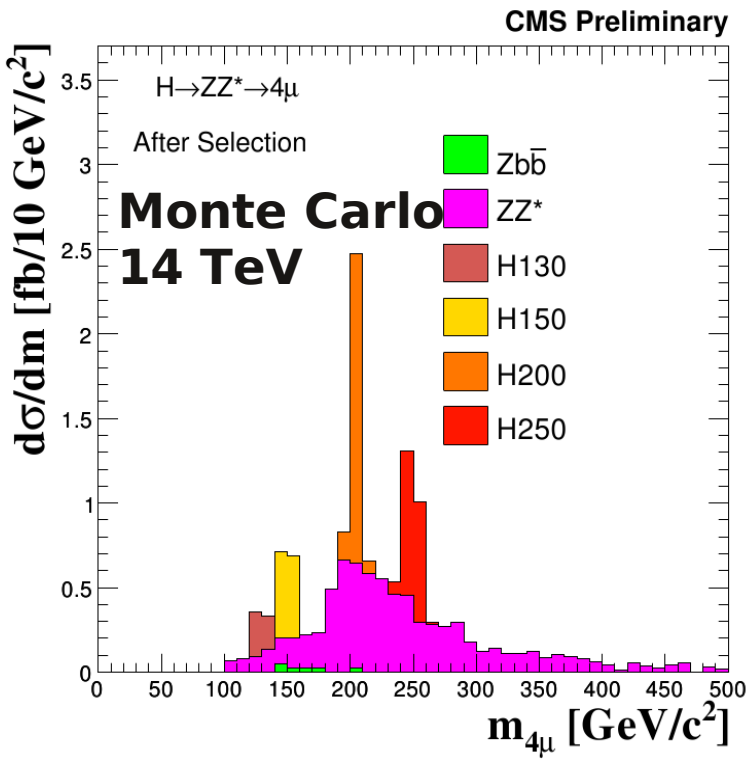
$H \rightarrow ZZ^{(*)} \rightarrow 4l$

- **Event selection:**
  - lepton isolation
  - lepton p_T
  - lepton impact parameter
  - $50 < m(\text{best pair}) < 100$ GeV/c²
  - $20 < \text{mass(second pair)} < 100$ GeV/c²



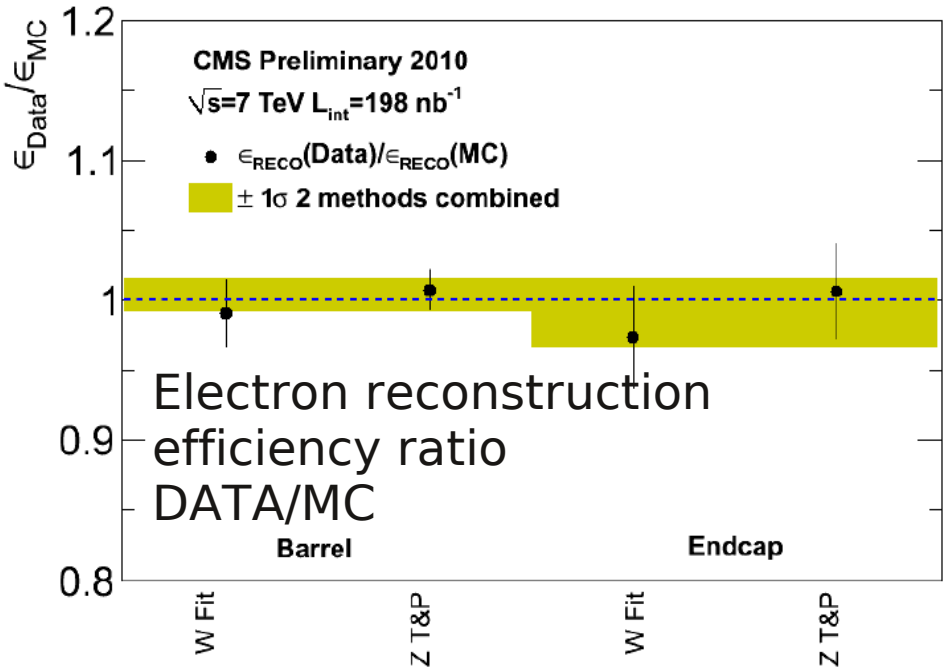
- **Exclusion limits:**

  event counting in a mass window $m_{4l} \pm 2\sigma_{m4l}$

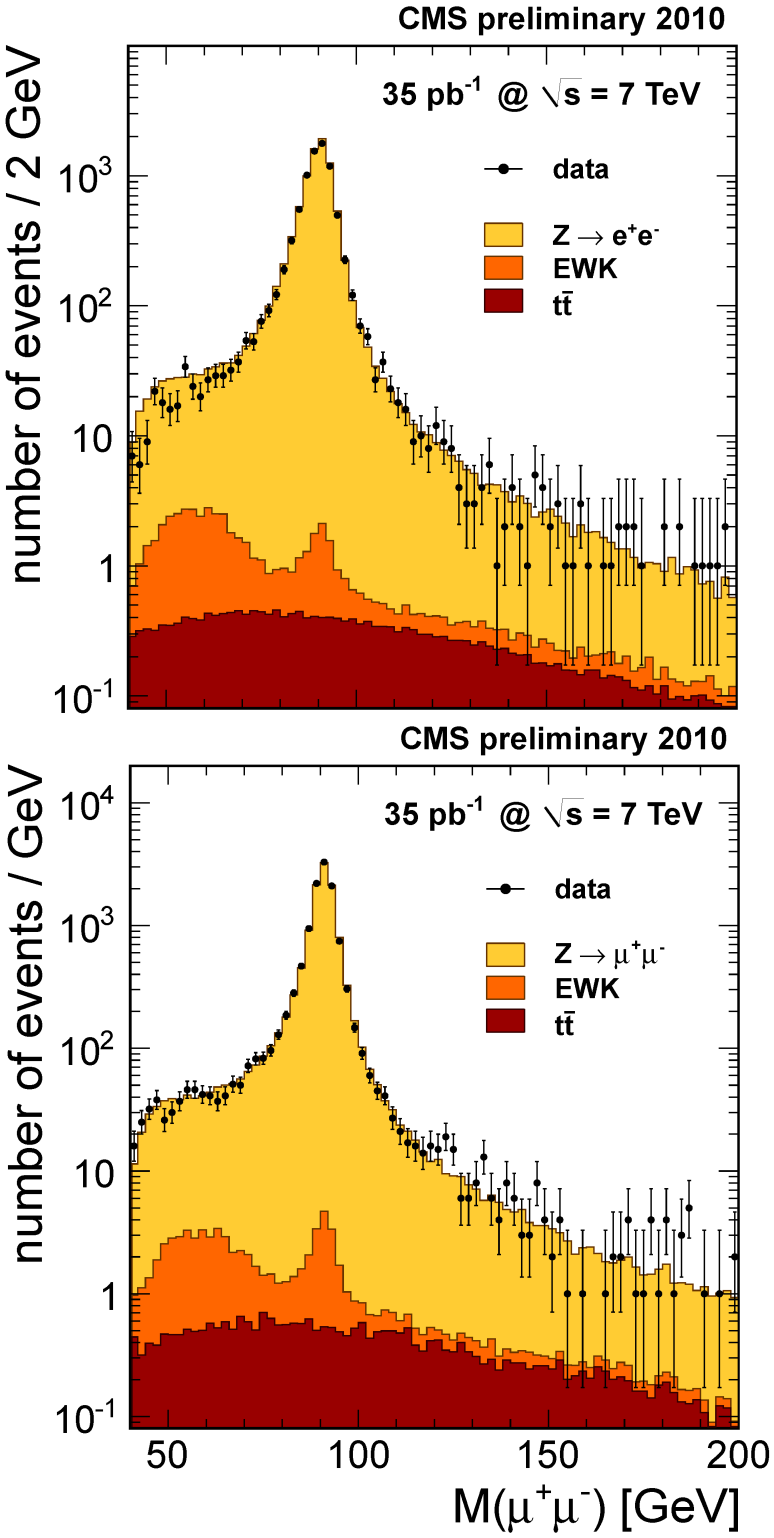


Z→ll analysis

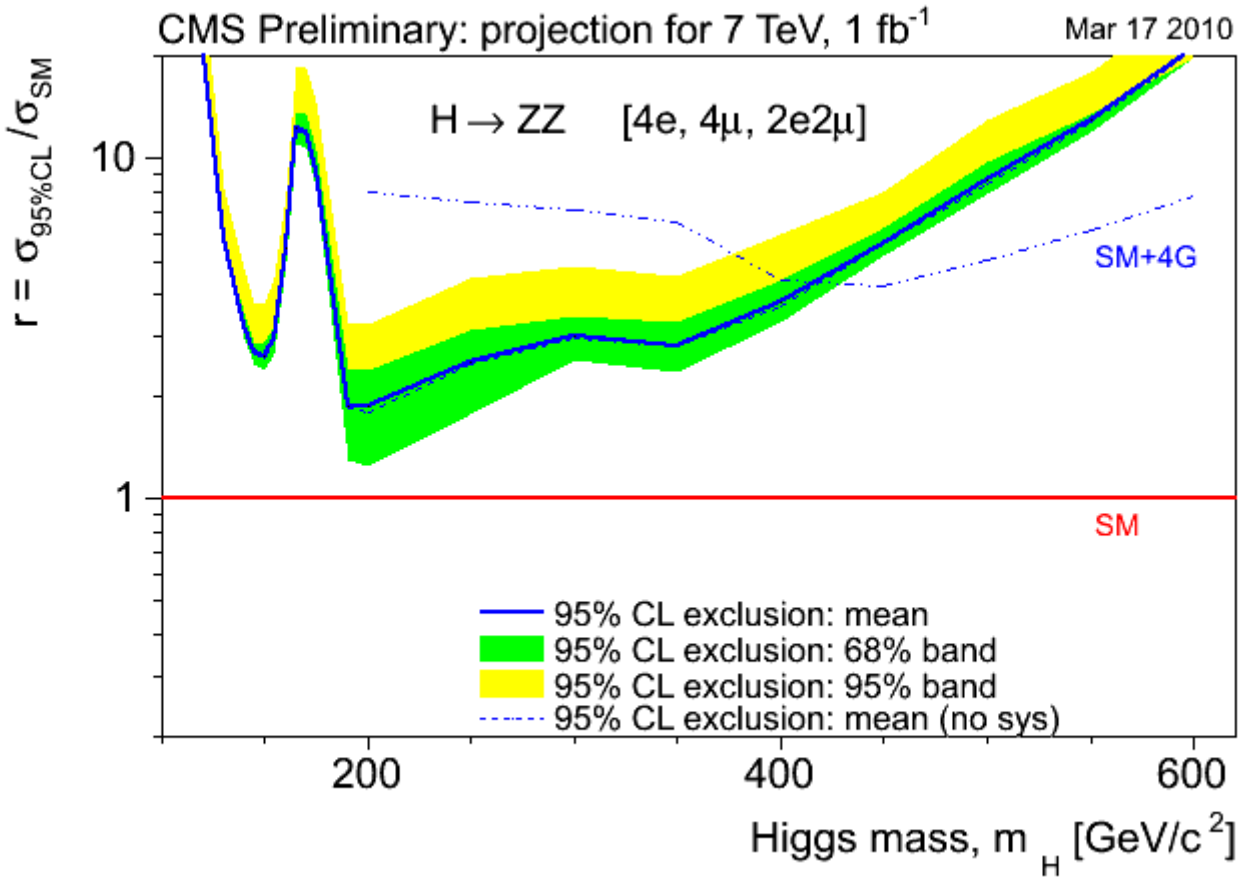
- **Z→ll analysis used as standard candle for the H→ZZ→ll analysis**
- **Z→ll is used for data-driven measurement of the lepton reconstruction and identification performance.**
- **Excellent MC-DATA agreement**



Electron reconstruction efficiency ratio DATA/MC



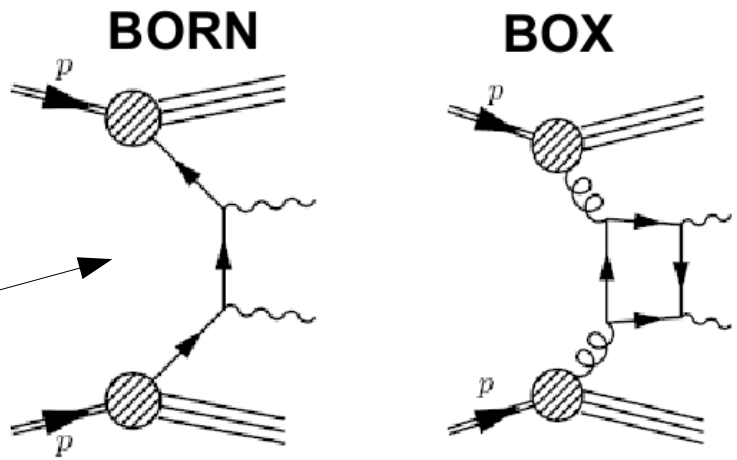
H→ZZ→4l expectations

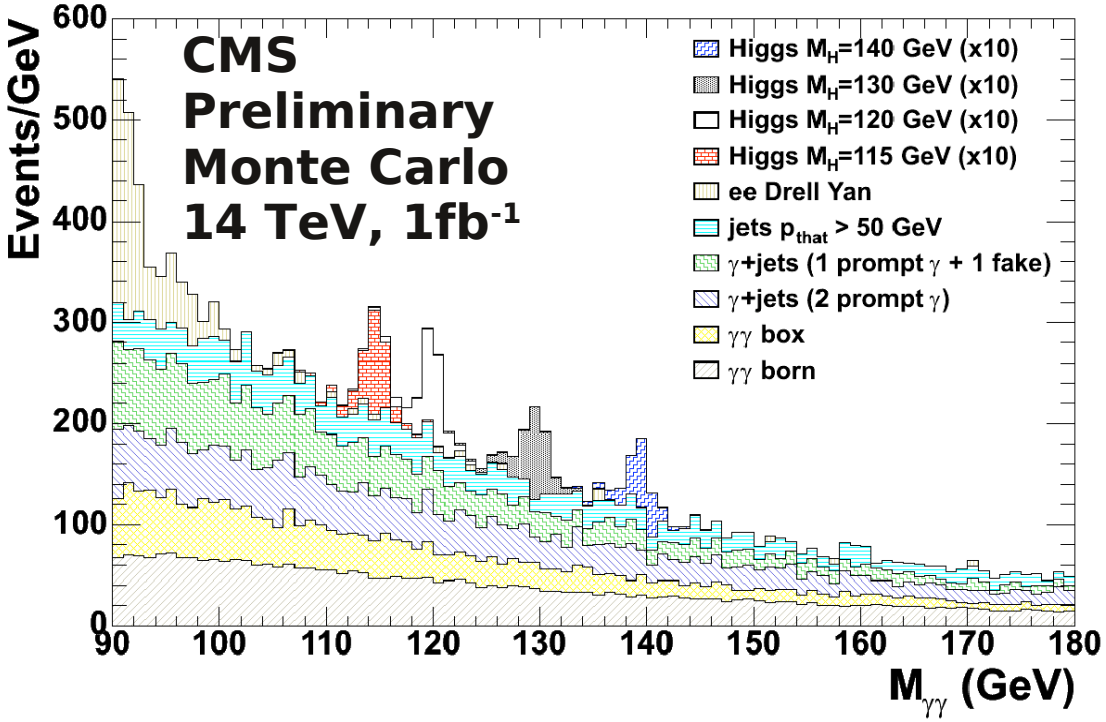


- no SM exclusion in this channel alone
- SM with additional fourth quark generation: expected exclusion with 1 fb^{-1}: **m_H<400 GeV/c^2**

H→γγ analysis

- **Signal signatures:**
  - **two isolated photons**
  - **excellent mass resolution: 0.7%**
- **Irreducible background: di-photon production**
- **Main reducible backgrounds:**
  - **photon+jet (mis id. as second photon)**
  - **jet+jet (both jets mis id. as photons**



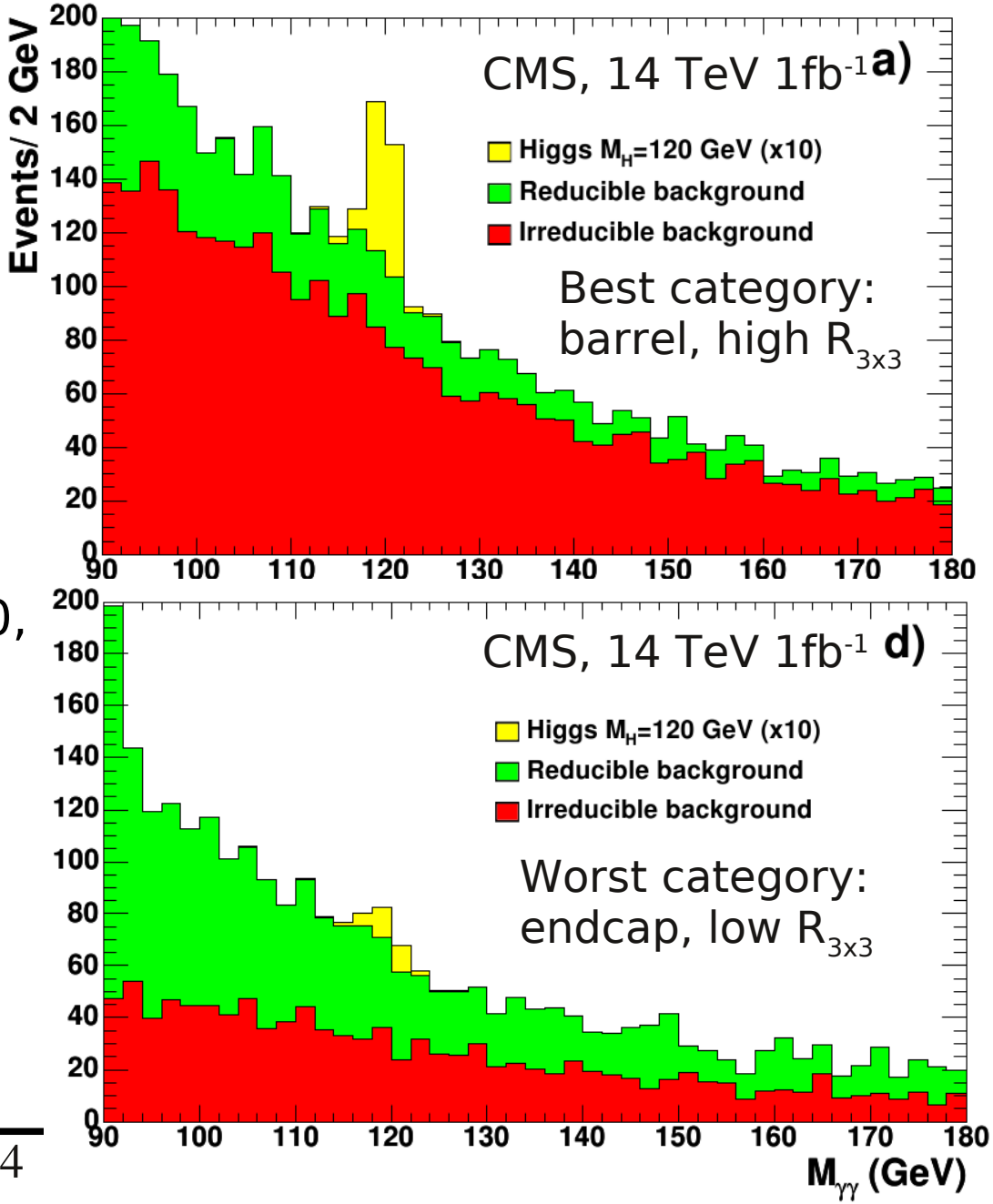


H→γγ analysis

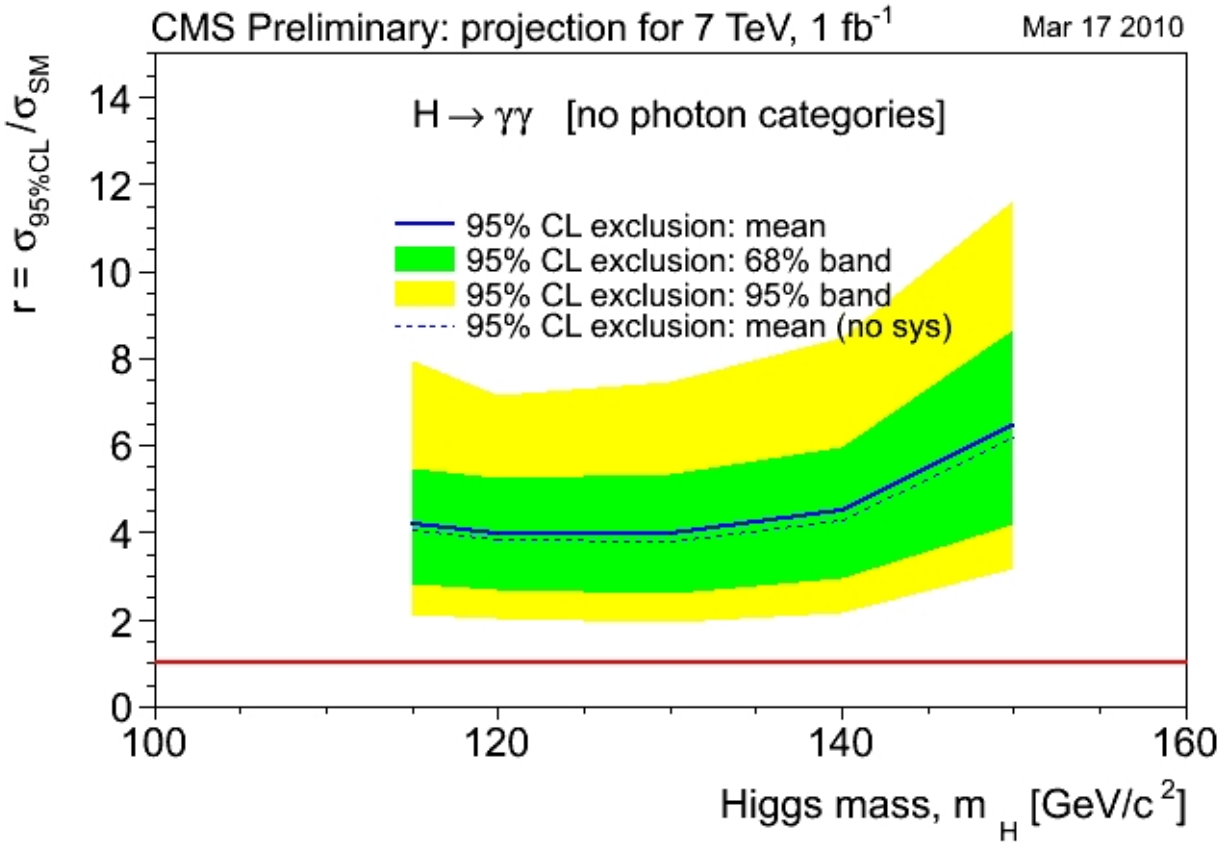
- **Event categorisation**
  - photon shower shape:

$$R_{3x3} = \frac{E_T \, in \, 3x3 \, ECAL \, cell \, block}{total \, E_T}$$

  - photon η
- **Event selection:**
  - cut based: trigger, E_{T1}>40, E_{T2}>35 GeV, photon isolation
  - neural network, variables used: $E_{T1}/M\gamma\gamma$, $E_{T2}/M\gamma\gamma$, $|\eta_1-\eta_2|$,

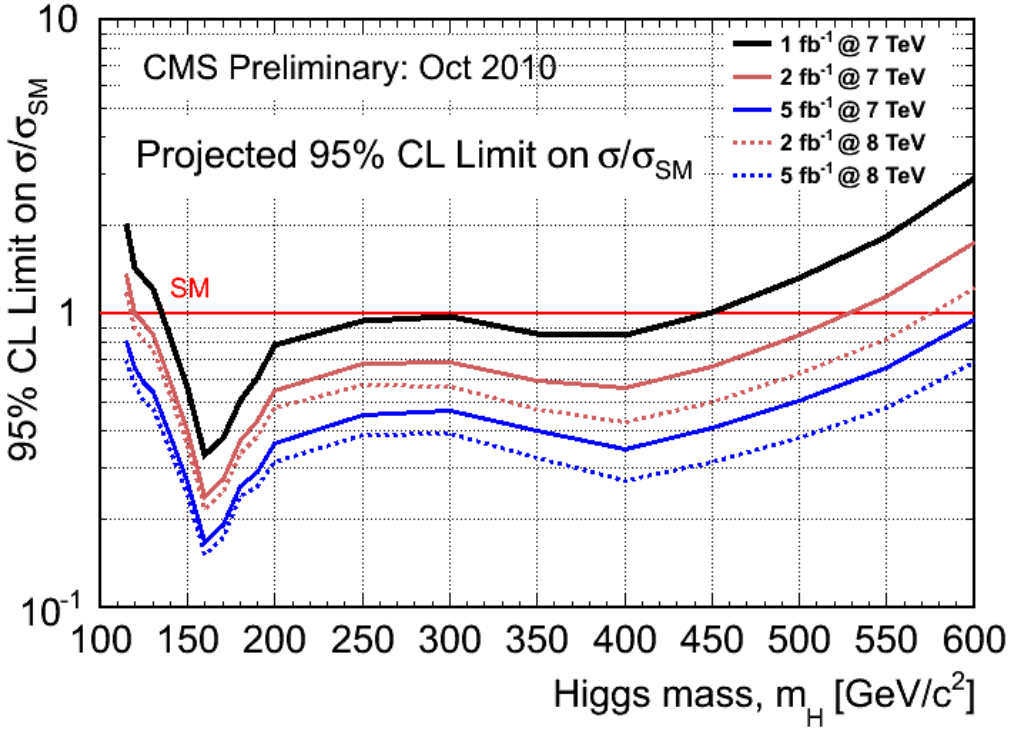


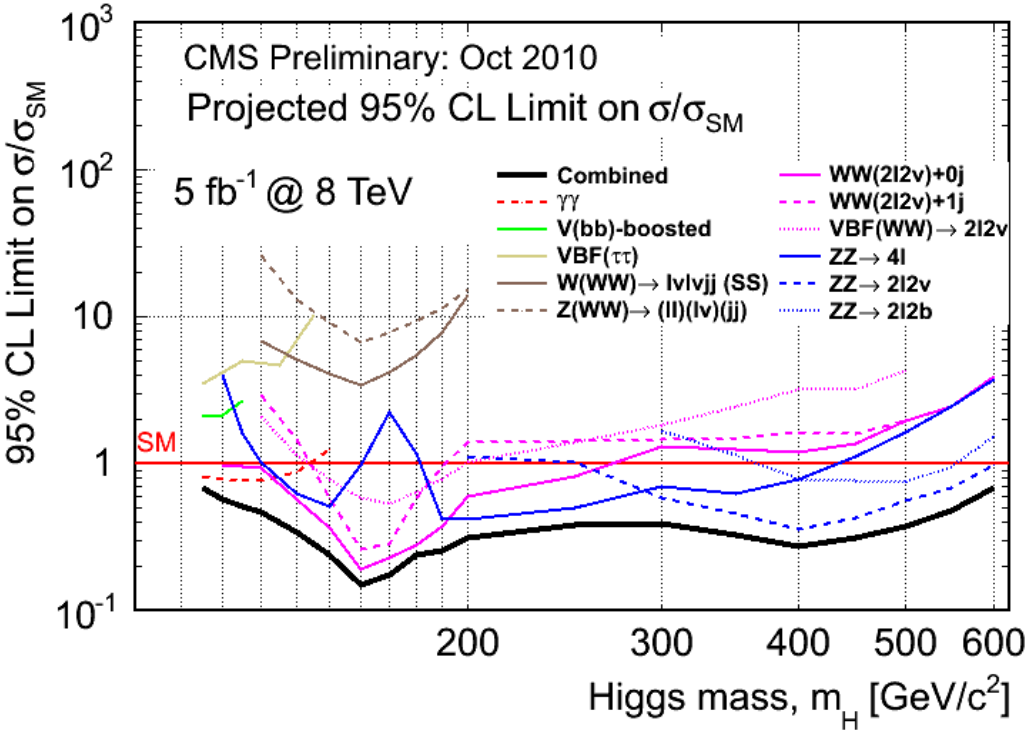
H→γγ expectations



- no SM exclusion in this channel alone
- a fermiophobic Higgs has σ(h)·BR(h→γγ)>4·SM, so it could be excluded for **m_H<110 GeV/c²**

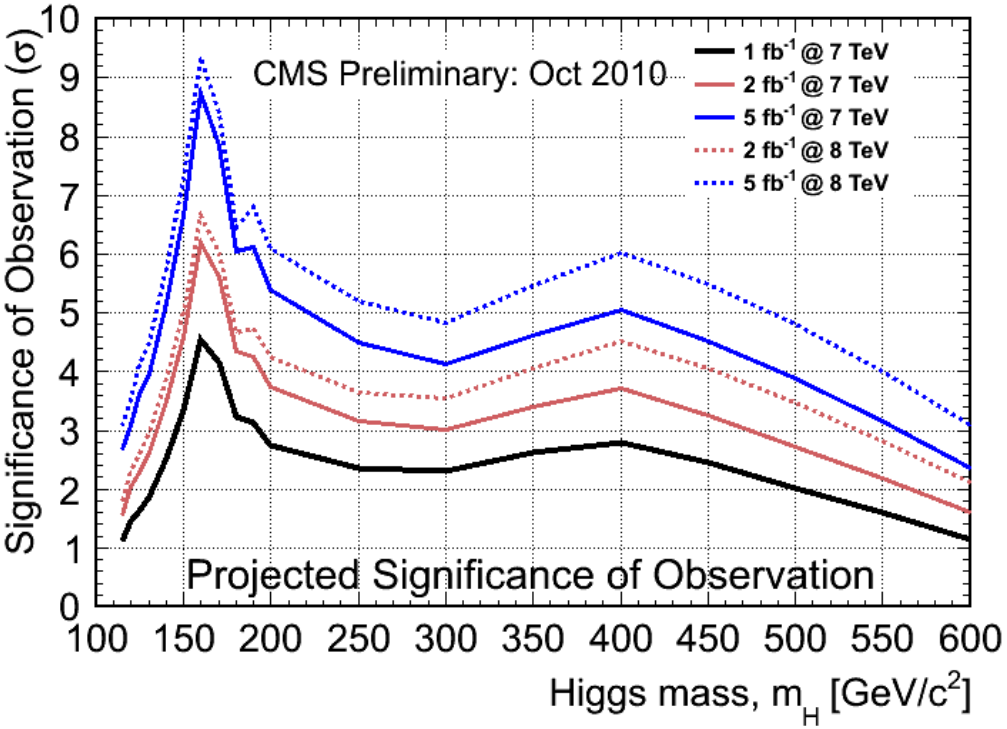
Combined SM expectations

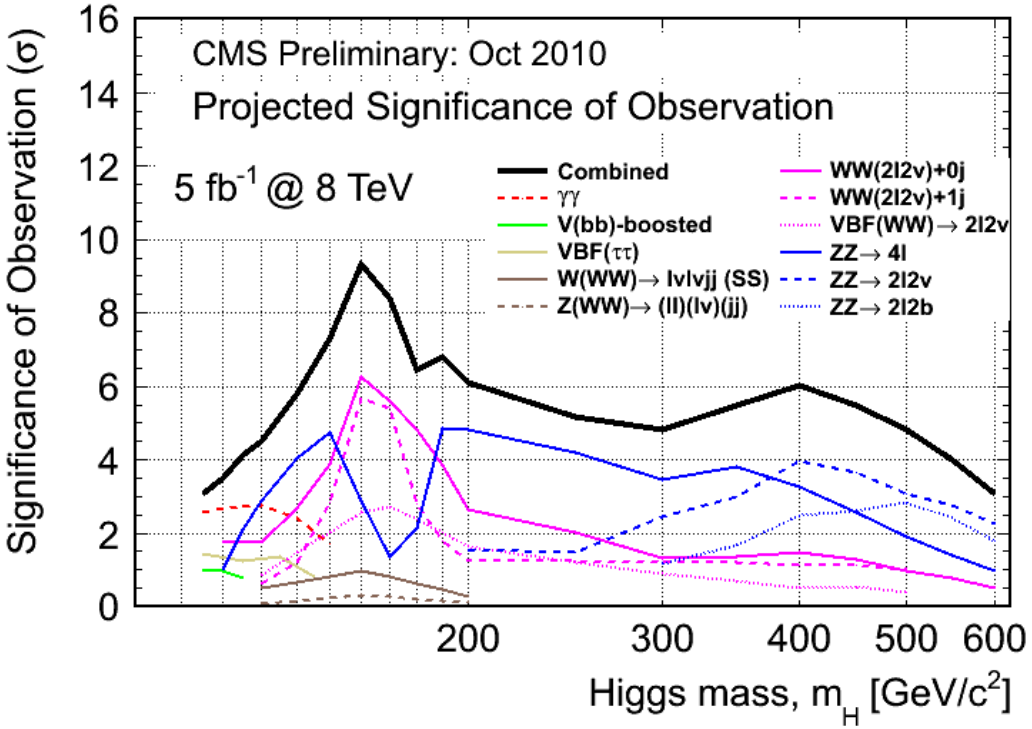




- with 1 fb^{-1} exclusion in range **$145<m_H<300$ GeV/c^2**
- with 5 fb^{-1} exclusion in range **$114<m_H<600$ GeV/c^2**

Combined SM expectations

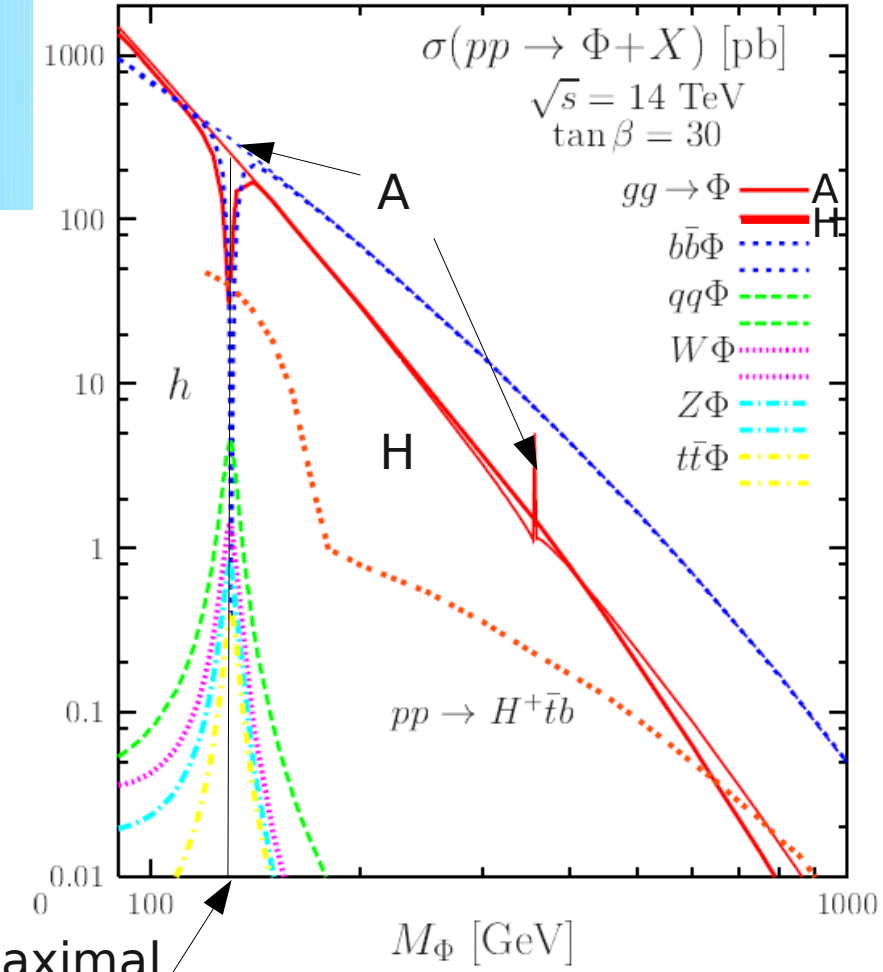




- with 1 fb^{-1} no 5σ discovery is expected
- with 5 fb^{-1} discovery in range **$145<m_H<230$ GeV/c^2**

MSSM h/H/A→ττ

- **Signal signatures:**
  - **isolated lepton from semileptonic tau decay**
  - **Isolated tau-like jet from hadronic tau decay**
- **Irreducible background: Z→ττ**
- **Main reducible backgrounds:**
  - **QCD, tt, W+jets**
  - **Z→ee, γ+jets**
  - **Z→μμ**



maximal h/minimal H mass

$BR(\phi \to \tau\tau) \approx 0.1$

$BR(\tau\tau \to \mu + \tau\,\text{jet} + X) = 0.23$

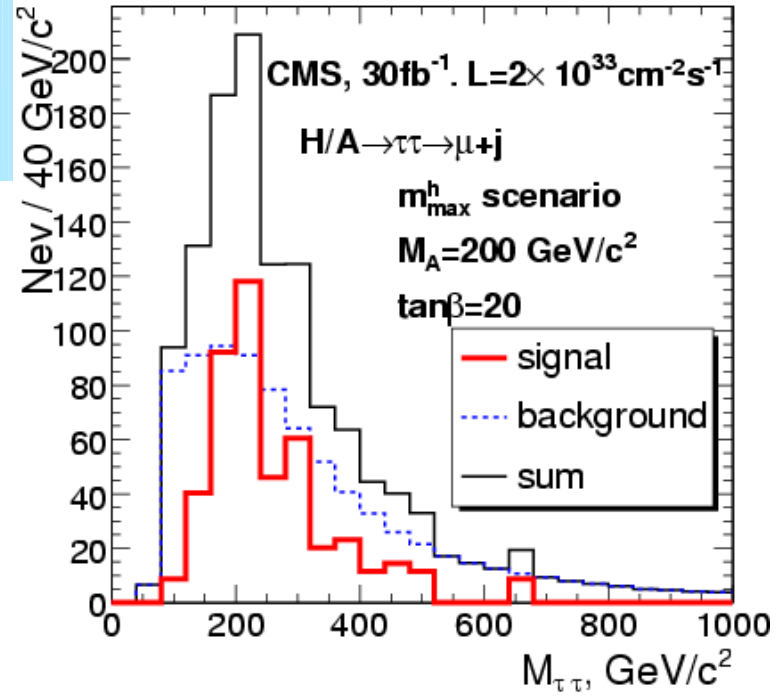
$BR(\tau\tau \to e + \tau\,\text{jet} + X) = 0.23$

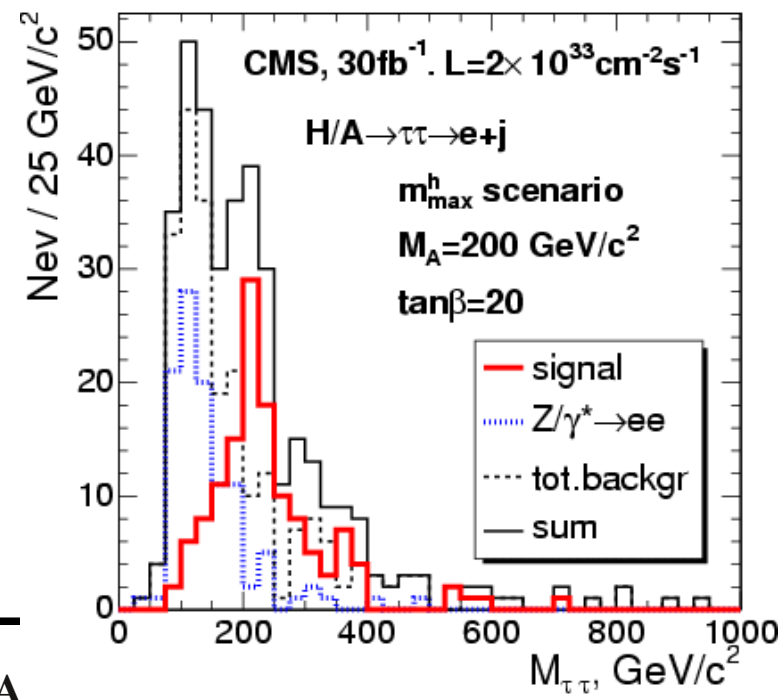
$BR(\tau\tau \to \tau\,\text{jet} + \tau\,\text{jet} + X) = 0.42$

$BR(\tau\tau \to l + l + X) = 0.12$

MSSM h/H/A→ττ

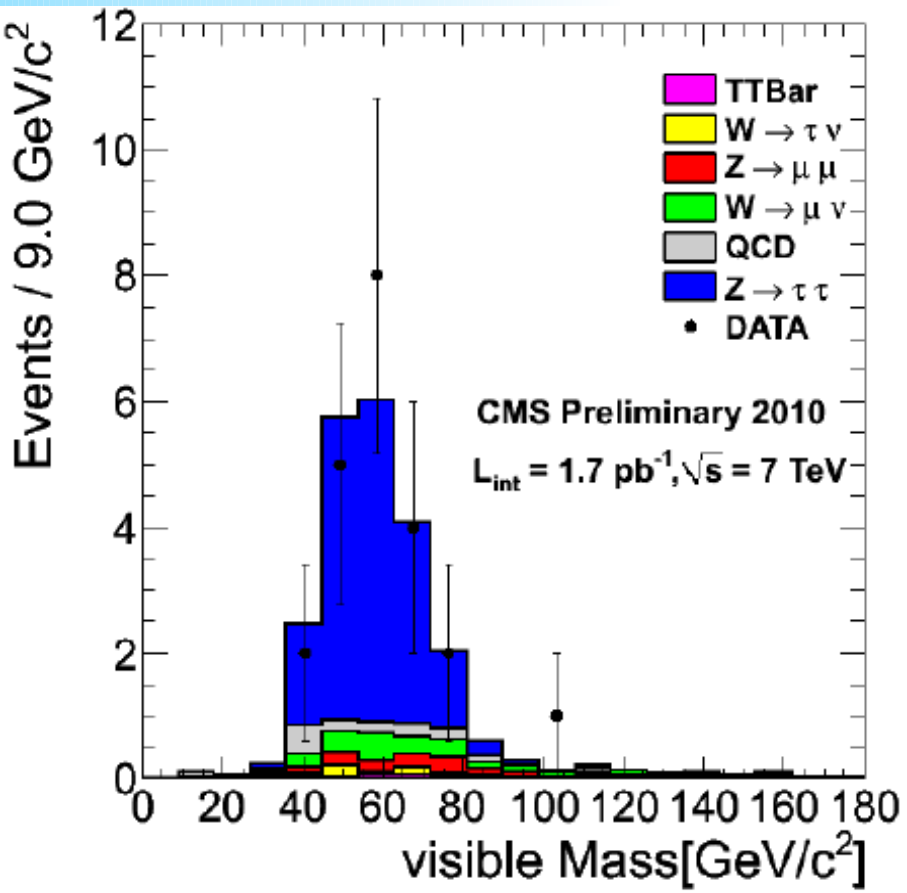
- **Event selection:**
  - lepton isolation
  - lepton p_T
  - hadronic tau identification
  - mT(l,MET) cut against W
  - b-jet tagging
  - veto on extra jets
- **Exclusion limits:**
  - mass reconstructed with collinear approximation
  - event counting in a sliding mass window

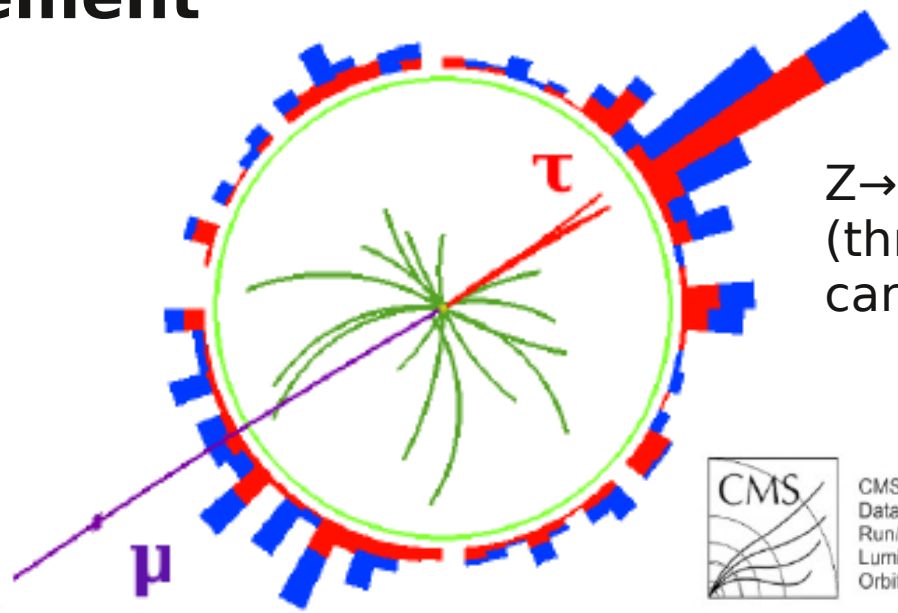




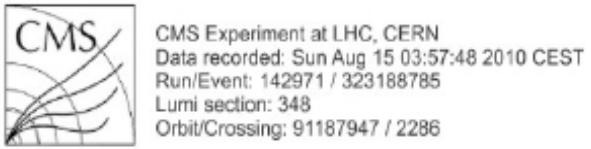
Z→ττ analysis

- **Z→ττ analysis used as standard candle for the H→ττ analysis providing information on performance of tau identification and reconstruction**
- **First Z→ττ candidates observed in CMS**
- **Fair MC-DATA agreement observed**

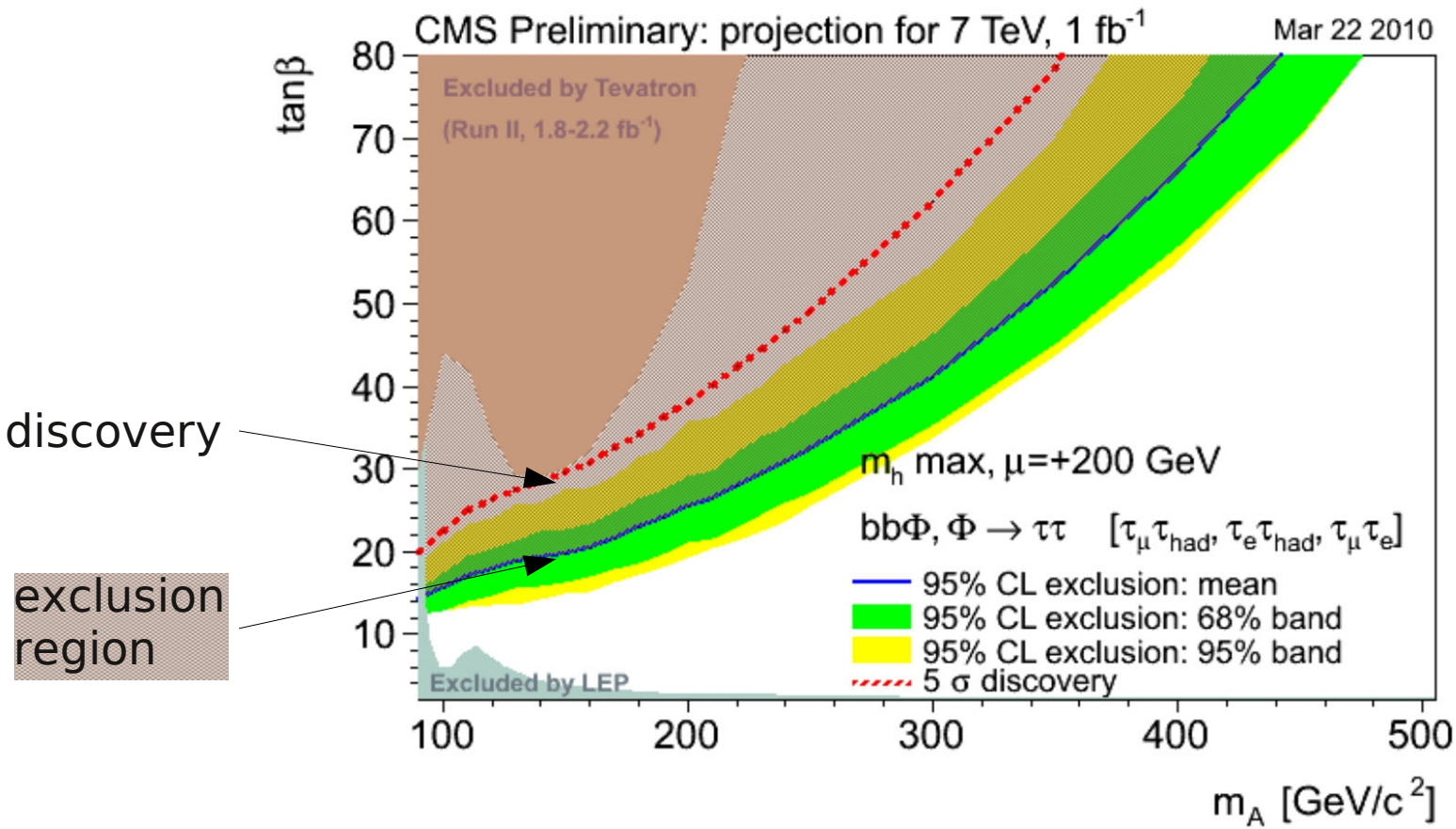




Z→ττ→μ+τ-jet (three prong) candidate event



MSSM A/H→ττ expectations



- with 1 fb^{-1} discovery expected for tanβ>20 for low m_A
- with 1 fb^{-1} exclusion expected for tanβ>15 for low m_A

Conclusions

- **With 1 fb^{-1} at 7 TeV CMS has enough potential to start exploring the Higgs sector:**
  - **SM exclusion range: 145-300 GeV/c^2**
  - **MSSM neutral Higgs discovery starts from tanβ~20 for low masses**
  - **MSSM neutral Higgs exclusion starts from tanβ~15 for low masses**
- **With 5 fb^{-1} at 7 TeV CMS has enough potential to exclude SM Higgs over whole interesting mass range: 115-600 GeV/c^2**

  or discover SM Higgs in the $145<m_H<230$ GeV/c^2 range

References

- 14 TeV results: CMS Physics Technical Design Report: http://cdsweb.cern.ch/record/942733
- 7 TeV Projections: CMS NOTE-2010/008: http://cdsweb.cern.ch/record/1264099
- $H \to WW \to 2l2\nu$ analysis: CMS-PAS-HIG-08-006
- $H \to ZZ \to 4l$ analysis: CMS-PAS-HIG-08-003
- $H \to \gamma\gamma$ analysis: CMS-NOTE-2006-112
- MSSM $H \to \tau\tau$ analysis:CMS-NOTE-2006-075,CMS-NOTE-2006-101, CMS-NOTE-2006-105
- $ZZ \to 4\mu$ event: CMS-DP-2010-038
- Higgs cross section for LHC: LHC Higgs Cross Section Working Group
- Electroweak boson analysis:CMS-EWK-10-002
- Tevatron SM Higgs searches: arXiv:1007.4587v1
- Tevatron MSSM Higgs searches: arXiv:1003.3363v3
- LEP SM Higgs searches: Phys.Lett.B565:61-75,2003

References

- CMS detector: JINST 3:S08004,2008
  http://iopscience.iop.org/1748-0221/3/08/S08004
- Tracking and b-tagging performance:CMS-PAS-TRK-10-005
  CMS-PAS-BTV-10-001
- Jets and missing E_T:
  CMS-PAS-JME-10-003 CMS-PAS-JME-10-004
- Muon ID:CMS-PAS-MUO-10-002
- Electron and Photon ID: CMS-PAS-EGM-10-004 CMS-PAS-EGM-10-005
- Tau ID:CMS-PAS-PFT-10-004

BACKUP SLIDES

14 to 7 TeV projections

- 14 TeV MC CMS results are rescaled to 7 TeV:
  - σ(NNLO+NNLL) is used for gg→H providing 30% increase in the event rate
  - σ(NLO) is used for Vector Boson Fusion (VBF) and V+H
  - σ(NLO) used for background processes
  - no corrections are made for higher acceptance at 7 TeV
  - no correction for improvements in physics object reconstruction and identification
  - systematic errors included. For backgrounds estimated from data, error rescaled by 1/sqrt(N events)