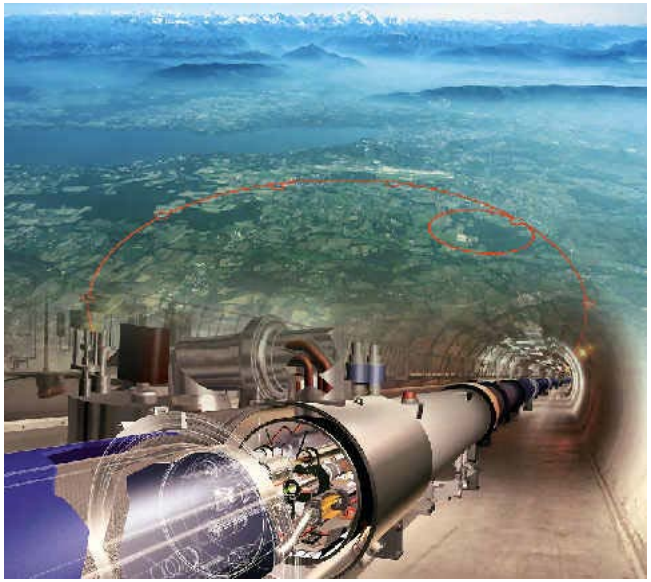
Highlights of the MCTP Symposium on Higgs Boson Physics



Howard E. Haber

West Coast LHC Theory Meeting

SCIPP at UCSC, May 21, 2010

MCTP Higgs Symposium webpage:
http://www.umich.edu/~mctp/SciPrgPgs/events/2010/Higgs/Home.html

I would appreciate if you could inform our theory colleagues attending the West Coast LHC meeting in Santa Cruz about the LHC Higgs Cross section working group that was formed this year and had its kickoff meeting in Frieburg. This working group, consisting of several theorists and ATLAS+CMS experimentalists, is poised to play an important role in many Higgs related deliberations at the LHC in the coming years.

The Twiki page for this working group is at
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections

I am puzzled to see from the list of theorists involved in this working group that there are very few from the US and probably none from the West Coast. Please urge our West Coast colleagues to get involved. Physical presence at CERN is not required since most meetings are on EVO video conf system which your ATLAS/CMS experimental colleagues use on a daily basis and can help you with.

It would be wonderful to see our theory colleagues begin to participate and influence the work of this group, and hopefully take leadership positions in the future.

Please let me know how I can help.

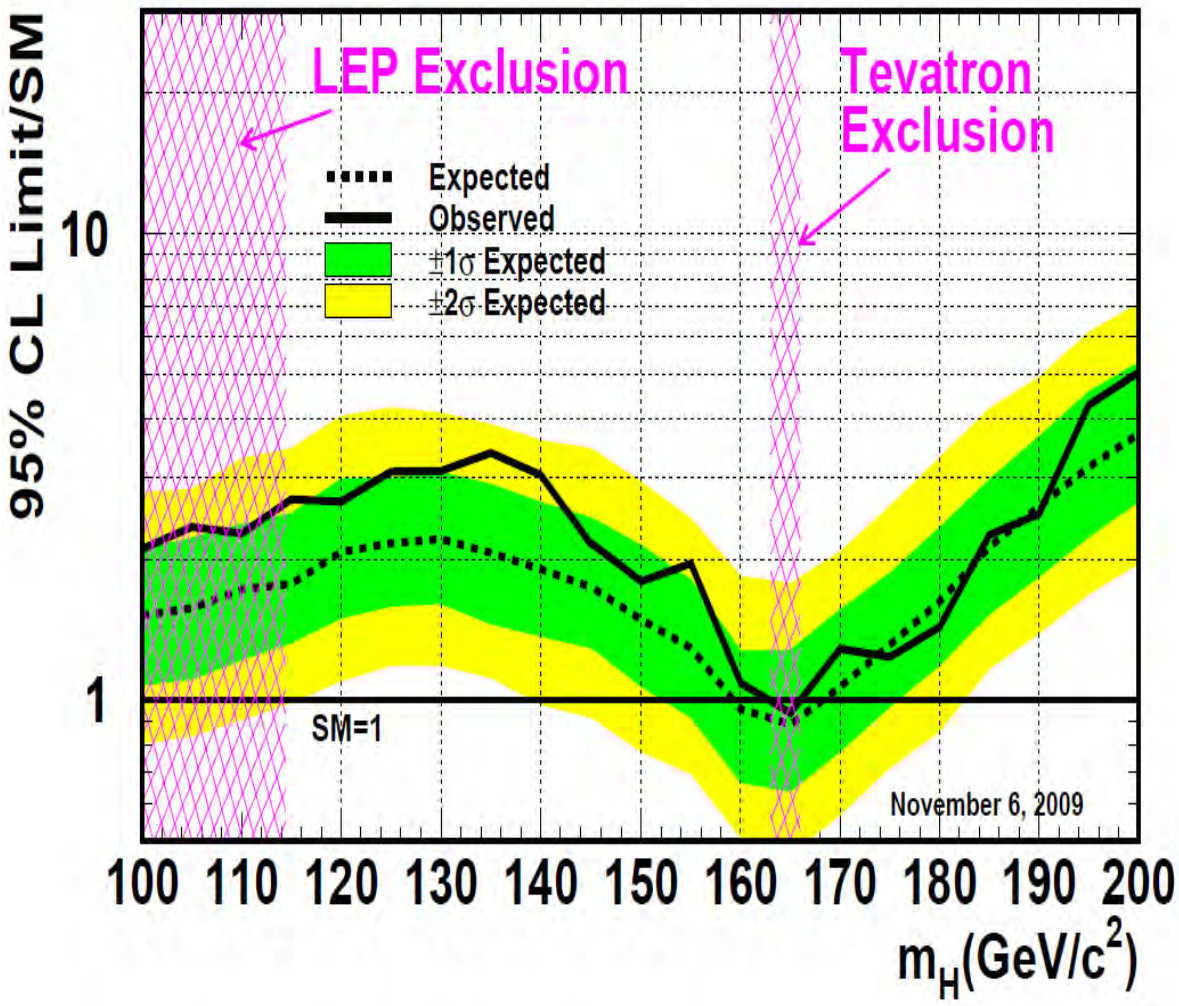
Best Regards ,
Vivek Sharma

Pursuing the Higgs Boson in 2010--2011

- Present Experimental Limits on the Higgs Boson---status of the Tevatron search
- Prospects for the Tevatron in 2010—2011
- The LHC Higgs boson search at $\sqrt{s}$=7 TeV with 1 fb^{-1} of data
  - The Standard Model Higgs boson
  - The MSSM Higgs bosons (neutral and charged)
- Higgs or not Higgs

Story So Far: Direct Searches For Higgs

arXiv:1001.4162



Fall 2009 results

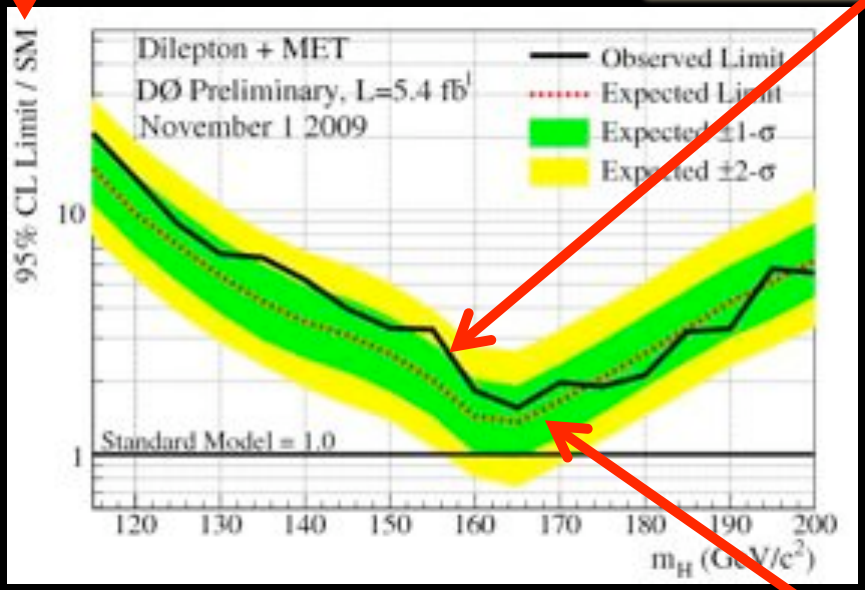
At Mh=165 GeV

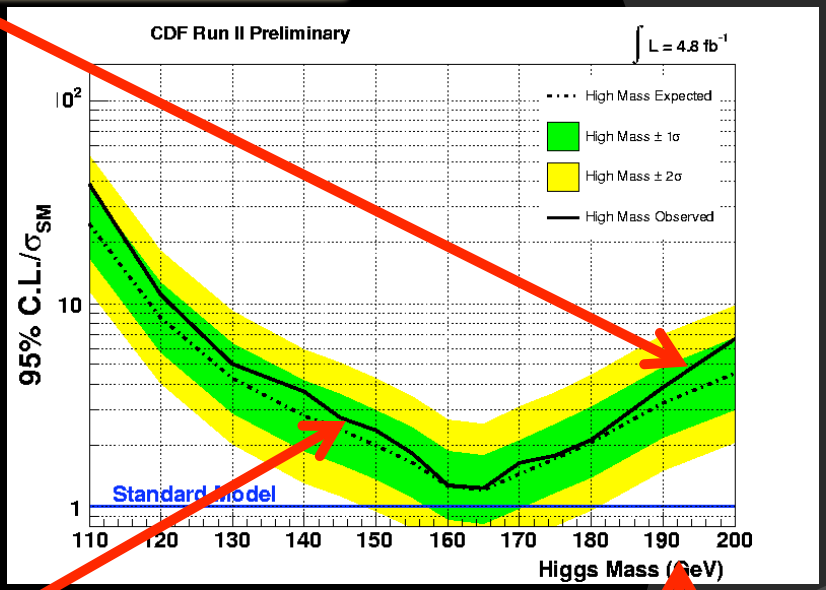
CDF: Exp/σ_{SM}: 1.19
Obs/σ_{SM}: 1.18

DO: Exp/σ_{SM}: 1.36
Obs/σ_{SM}: 1.55

Upper cross section limit for Higgs production relative to SM prediction

Observed limit (solid line) from data

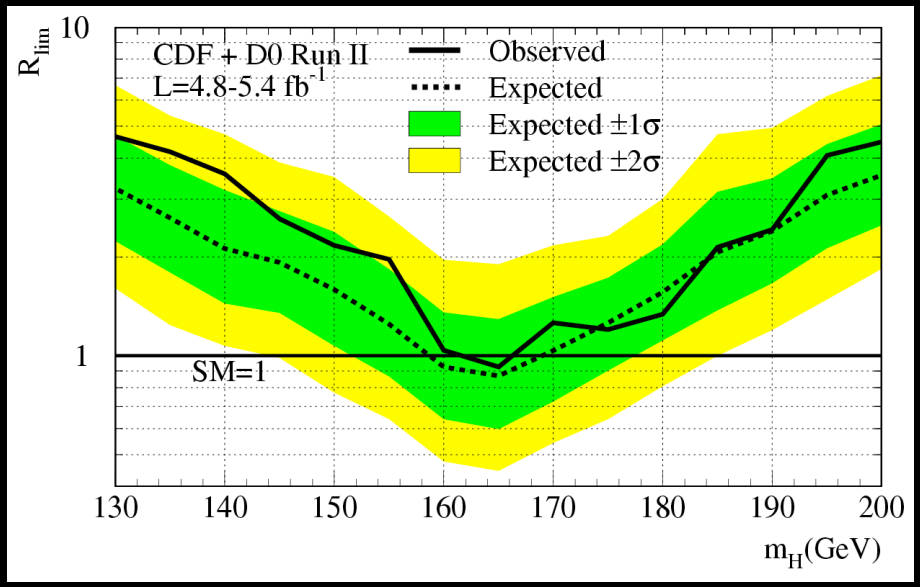


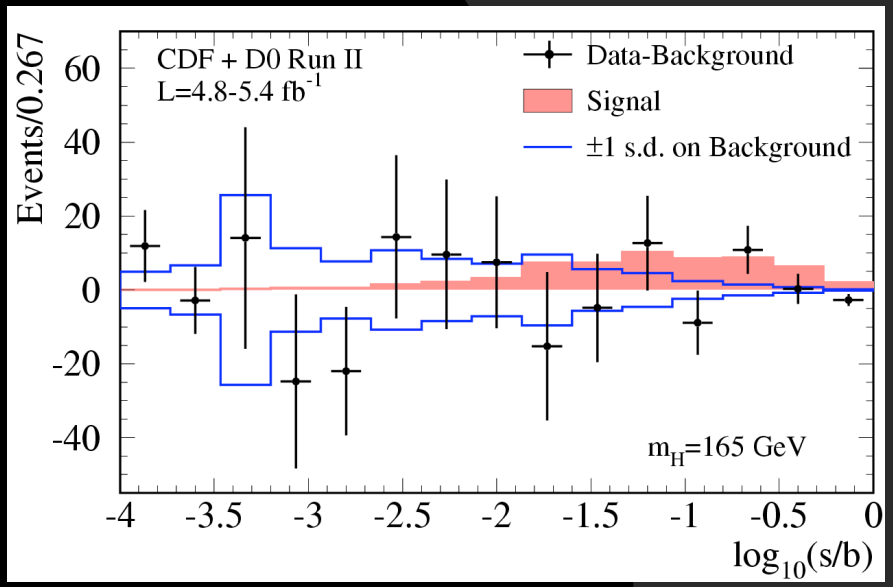


Median expected limit (dot-dashed line) and predicted 1σ/2σ (green/yellow bands) excursions from background only pseudo-experiments

Analysis repeated using different signal templates for each m_H between 100 and 200 GeV in 5 GeV steps

Fall 2009 combination:



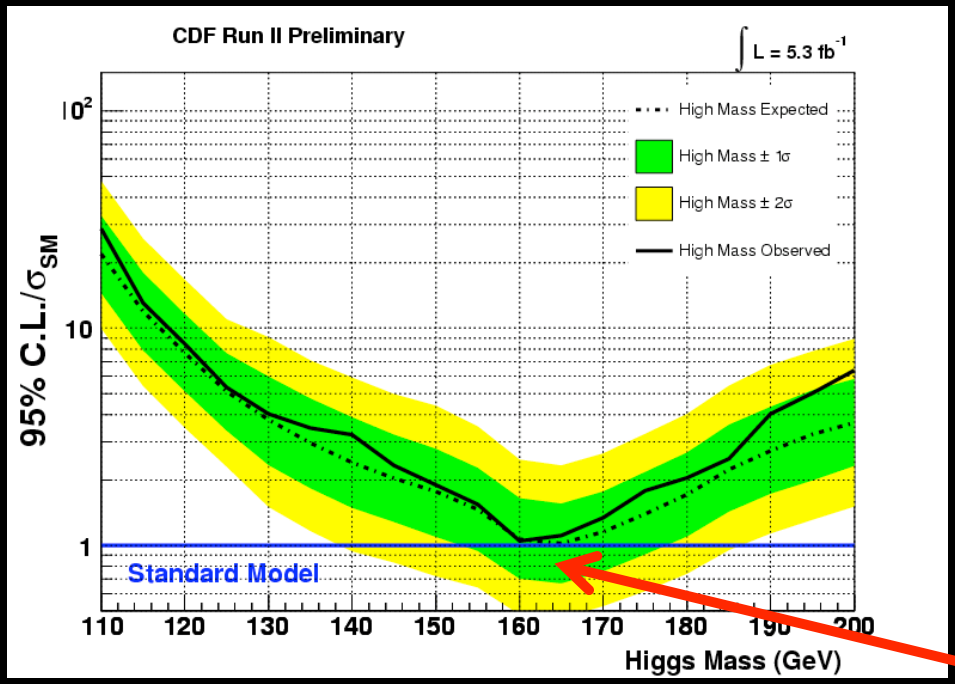


- Phys. Rev. Lett. 104, 061802 (2010)
- Observed exclusion 162 < m_H < 166 GeV
- Expected exclusion 159 < m_H < 169 GeV

Updated CDF high mass combination:

With all channels and 5.3 fb^{-1} of data

Better analysis techniques contribute to more than 50% of the improvement

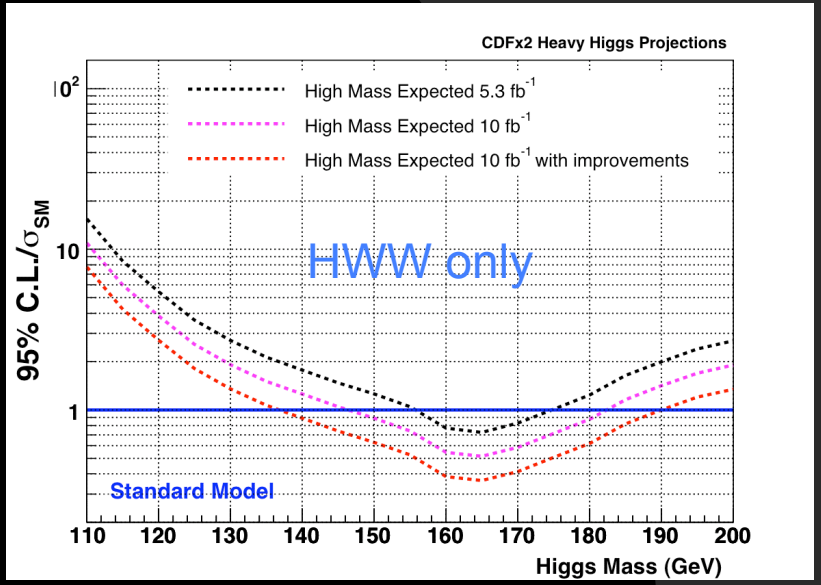


At m_H = 165 GeV,
1.02xSM expected
1.11xSM observed
(Spring 2010)

Looking into the future

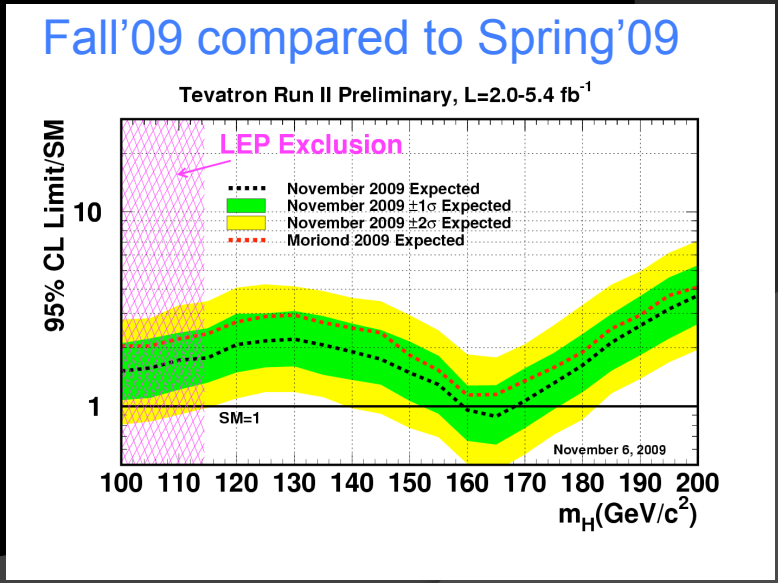
More data

- up to 10 fb-1 recorded data is expected per experiment by the end of run II (20 fb-1 combined!)



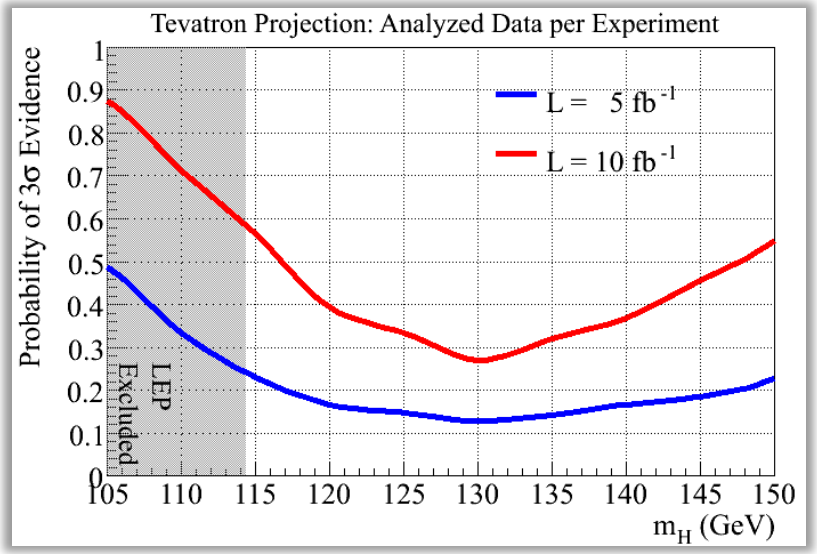
Many possible analysis improvements:

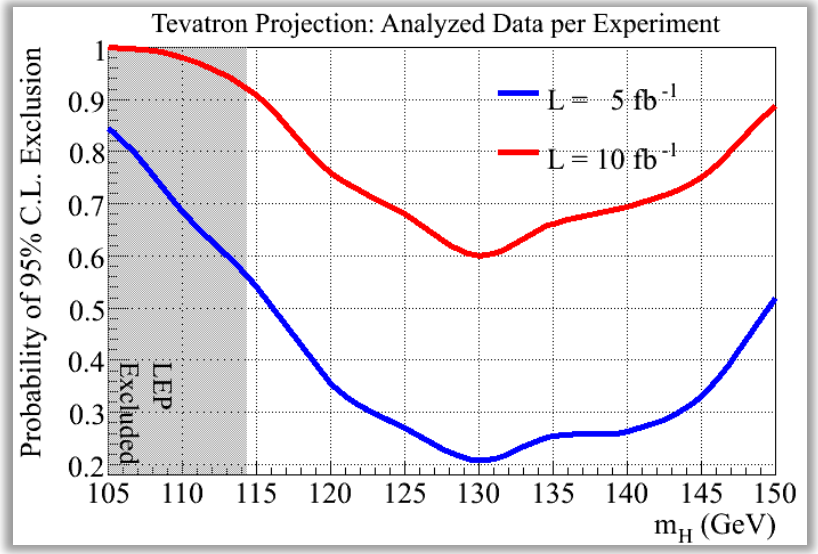
- Smarter lepton isolation
- H->WW->jjlν
- H->ZZ at higher Higgs masses
- new triggers
- ….



SM Higgs Prospects

- Summer 2010
  - Experiments will report results based on data of ~6 fb^{-1}
  - 9 fb^{-1} will be delivered before 2010 shutdown (July 19)





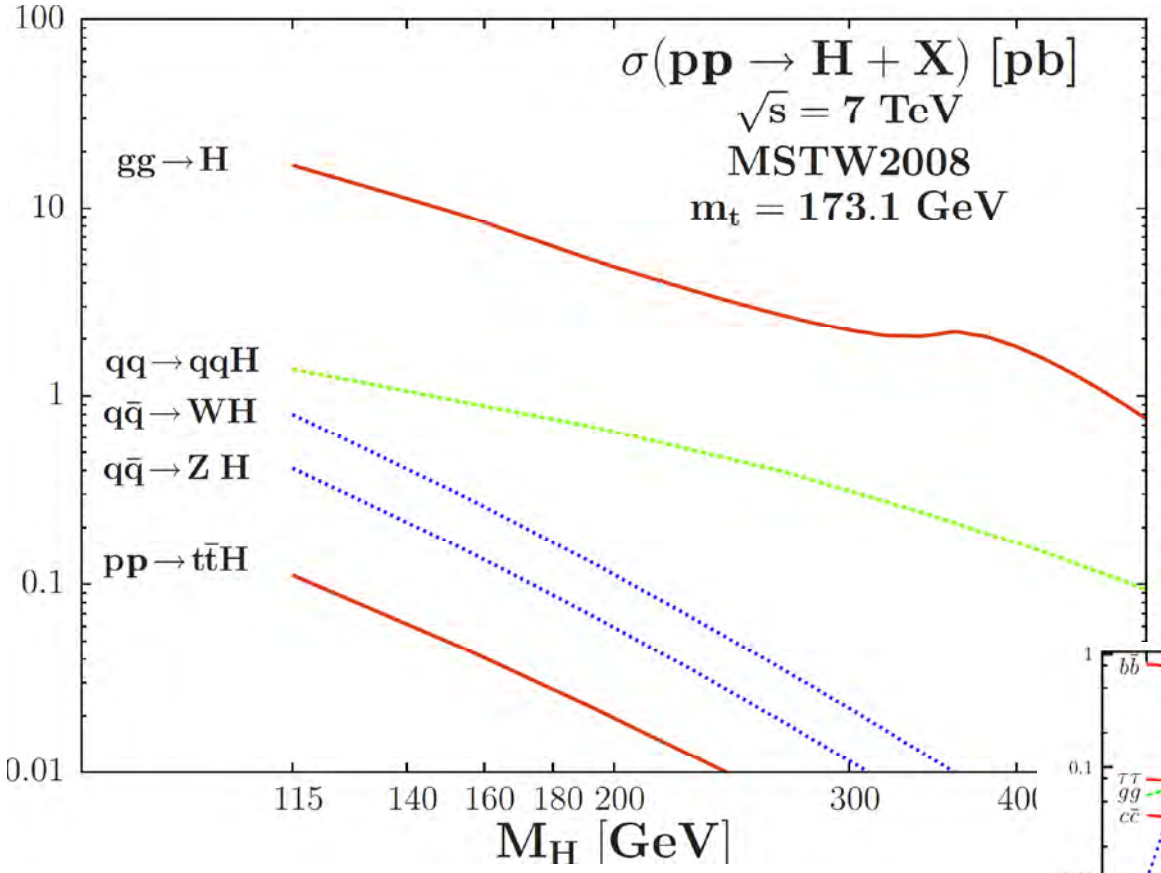
Higgs Boson Searches With The Early LHC Data

Vivek Sharma

University of California, San Diego

(On behalf of ATLAS & CMS Experiments)

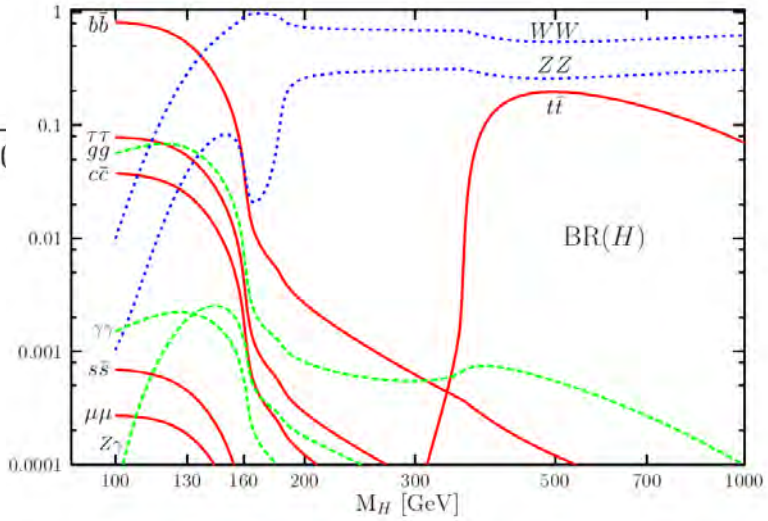
Higgs Production in 7 Tev pp Collsions



Dominant production:
gg→ H

Dominant decay mode
At high H mass

H→ WW, ZZ



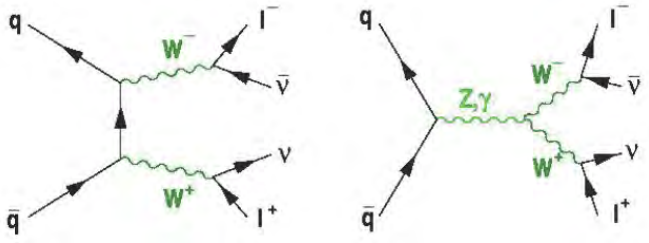
LHC & Tevatron : A Basic Comparison

For $M_X > 140$:

gg σ at 7 TeV > 15x that at Tevatron

Higher rate for Higgs production

Irreducible backgrounds (WW, ZZ)



originate from qqbar which rises relatively slowly

⇒ S/N rises , ⇒ LHC competitive with 1fb^{-1}

For $M_X < 140$: slow rise in qqbar σ

Compared to at Tevatron, Higg-sstrahlung (pp → VH) rate @ 7 TeV not much larger

Major backgrounds are W/Z+bbbar & ttbar which rise sharply due to rapid rise in gg σ

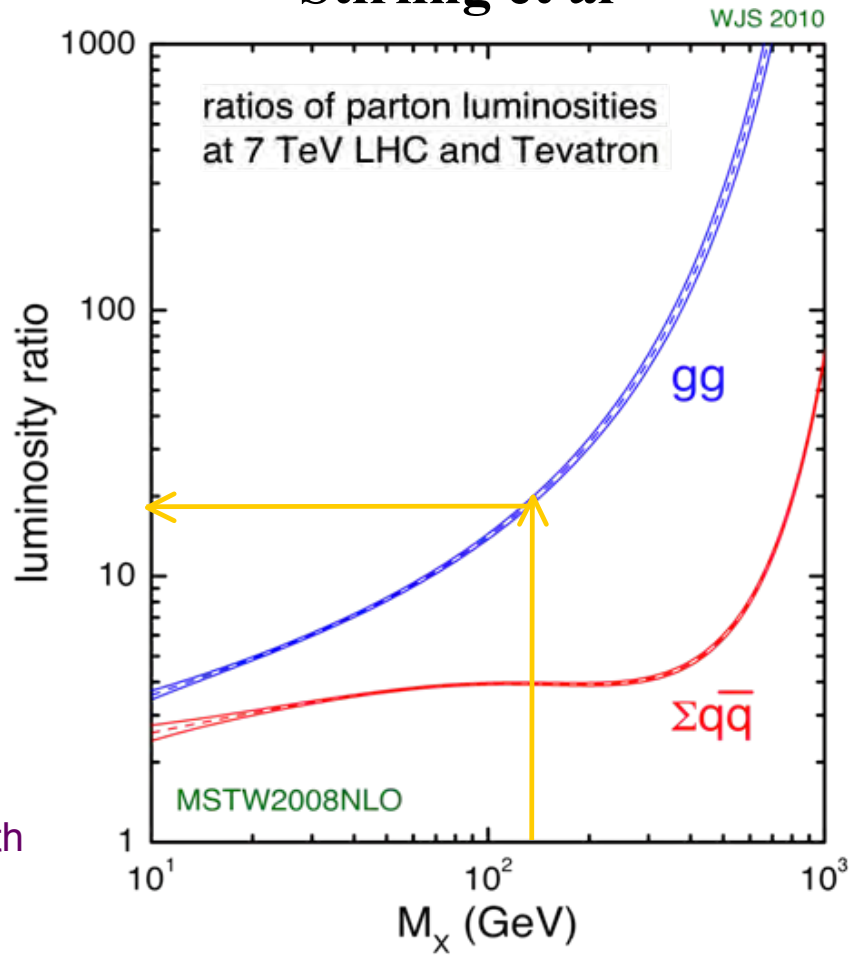
⇒ small signal rate & poor S/N

gg → H →γγ favored in production and even with Br(H →γγ) ≅ 0.2%

large QCD γγ background

⇒ Poor S/N

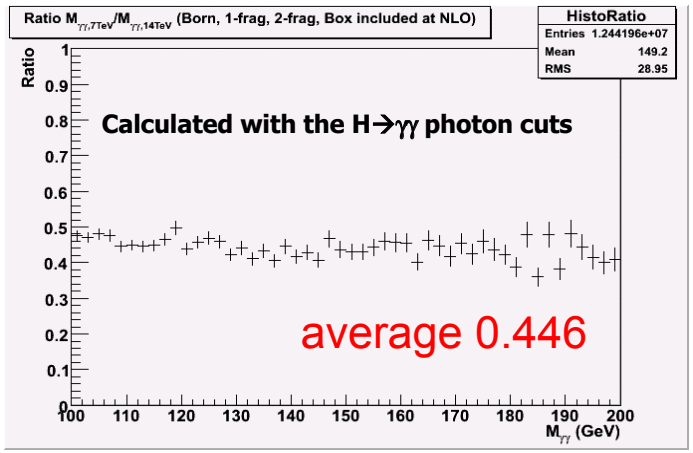
Stirling et al



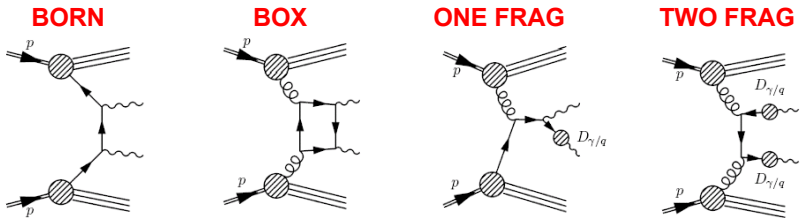
Background Cross Sections used

General background sources

process	$\sqrt{s} = 14$ TeV	$\sqrt{s} = 10$ TeV	$\sqrt{s} = 7$ TeV	comment
$W \to \ell\nu$	3*20283.7	3*14253.7	3*9679.9	MCFM NLO
$DY(20-\infty) \to \ell\ell$	3*3259.7	3*2323.6	3*1606.6	MCFM NLO
WW	112.5	71.4	42.9	MCFM NLO
WZ	51.0	31.4	18.3	MCFM NLO
ZZ	15.6	9.9	5.9	MCFM NLO
$t\bar{t}$	918	415	165	MCFM NLO
Wt	56.1	26.0	10.5	MCFM NLO
tq-t channel	244.6	130.5	62.8	MCFM NLO
tq-s channel	11.9	7.6	4.6	MSTW 2008 NNLO
$W(\to \ell\nu) + \gamma$	54.7*1.8	35.4*1.8	23.2*1.8	NLO k-Factor from Bauer
$Z(\to \ell\ell) + \gamma$	17.5*1.8	11.3*1.8	7.3*1.8	NLO k-Factor from Bauer



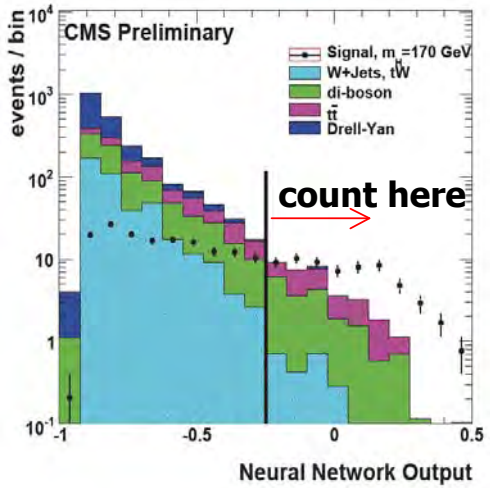
Background Estimate for H→γγ mode



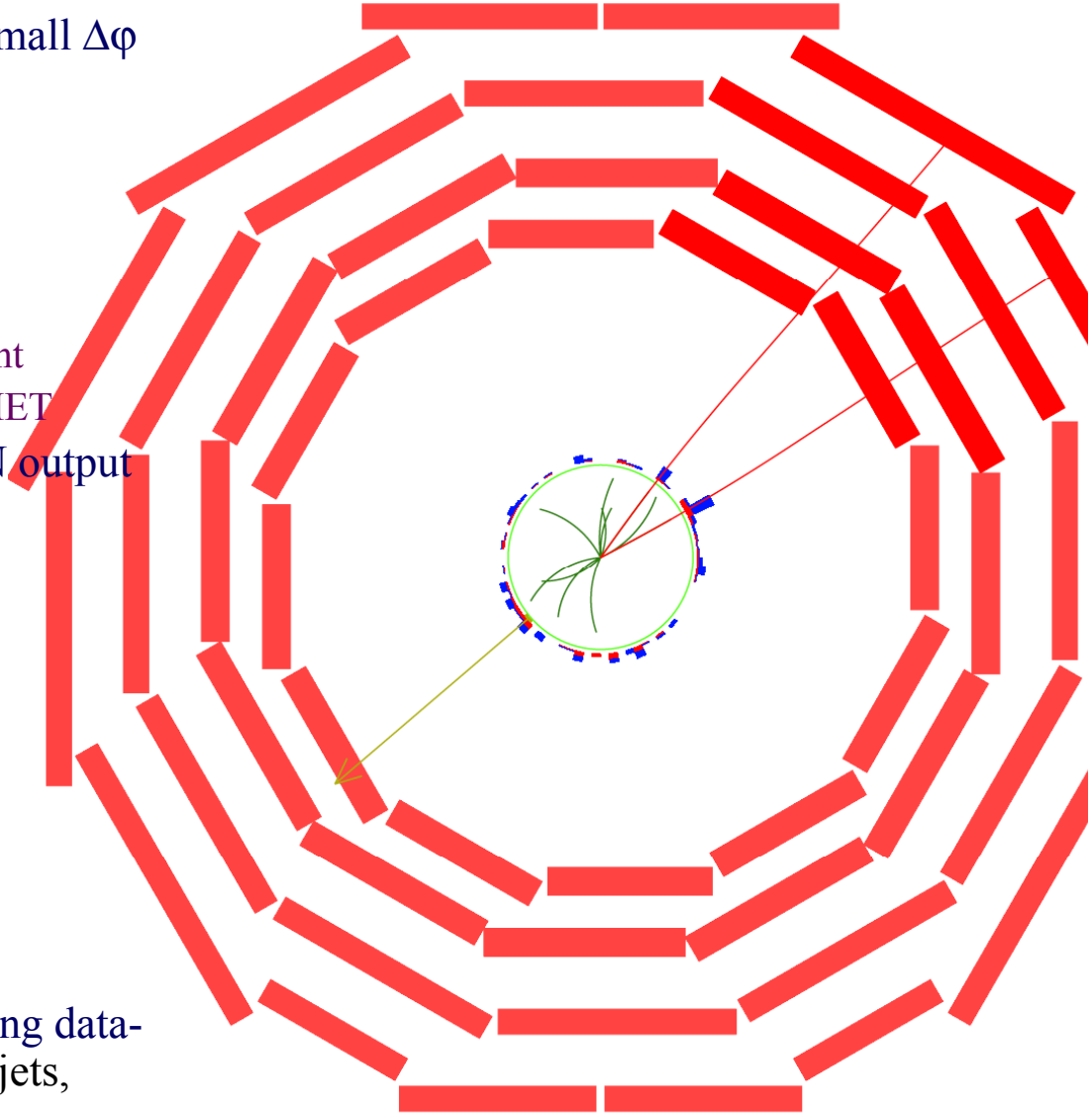
Diphox, Gamma2MC:
born+1frag +2frag + box **[all at NLO]**

H → WW : Most Prolific Decay mode

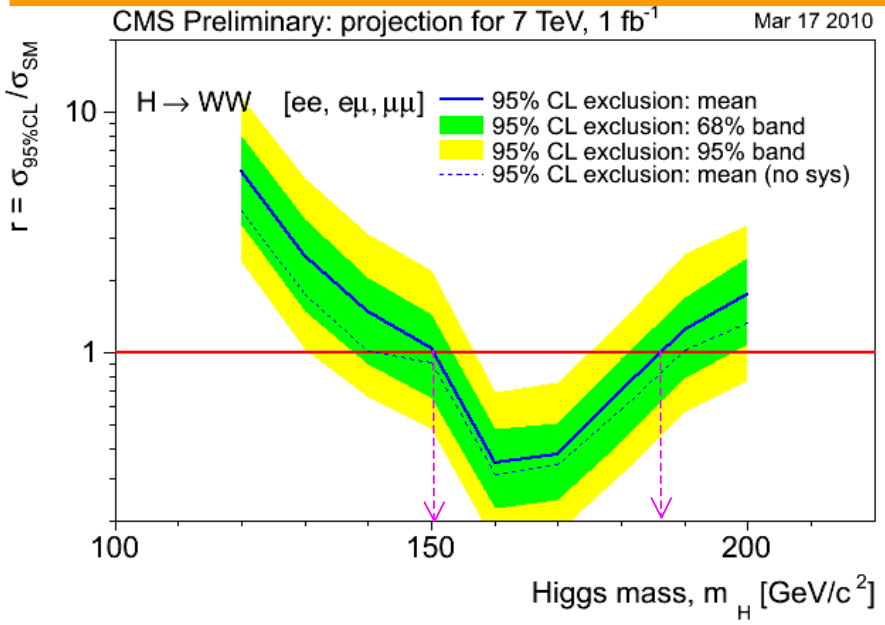
- Signal: two isolated leptons with small Δφ + MET + no central jets (jet veto)
- Backgrounds reduction:
  - WW: Δφ & m_{ll}
  - ttbar: cental jet veto, Δφ & m_{ll}
  - W+jets: lepton id
  - DY alleviated by MET requirement
  - WZ/ZZ: 2 leptons in final state, MET
- look for excess above a cut on NN output

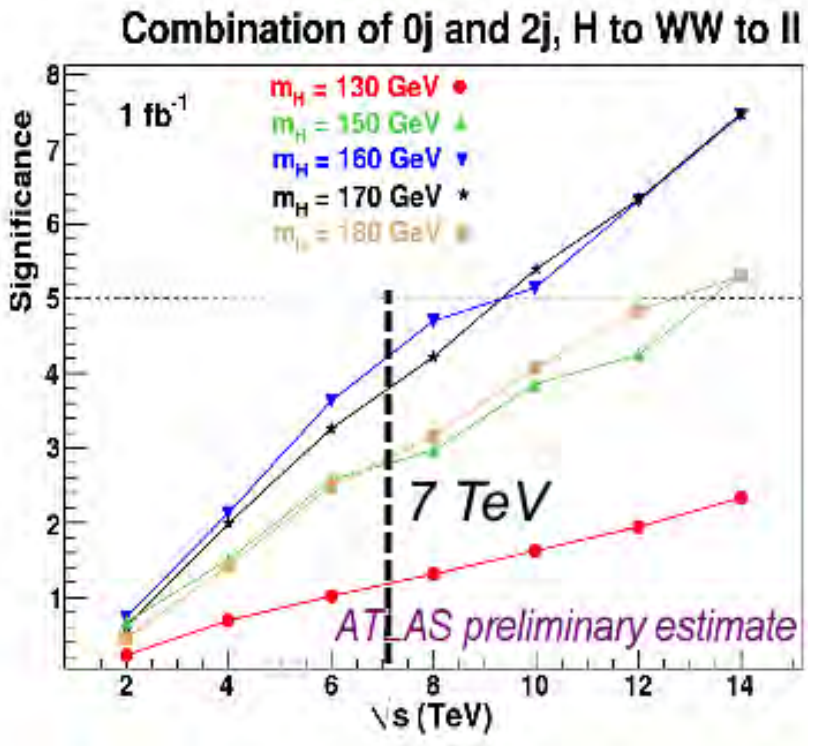


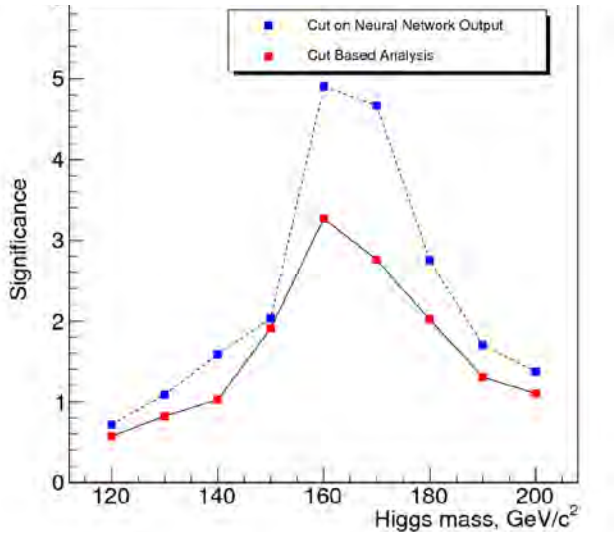
- main backgrounds are assessed using data-driven techniques: WW, ttbar, W+jets, Drell-Yan



SM H→WW→2l2ν





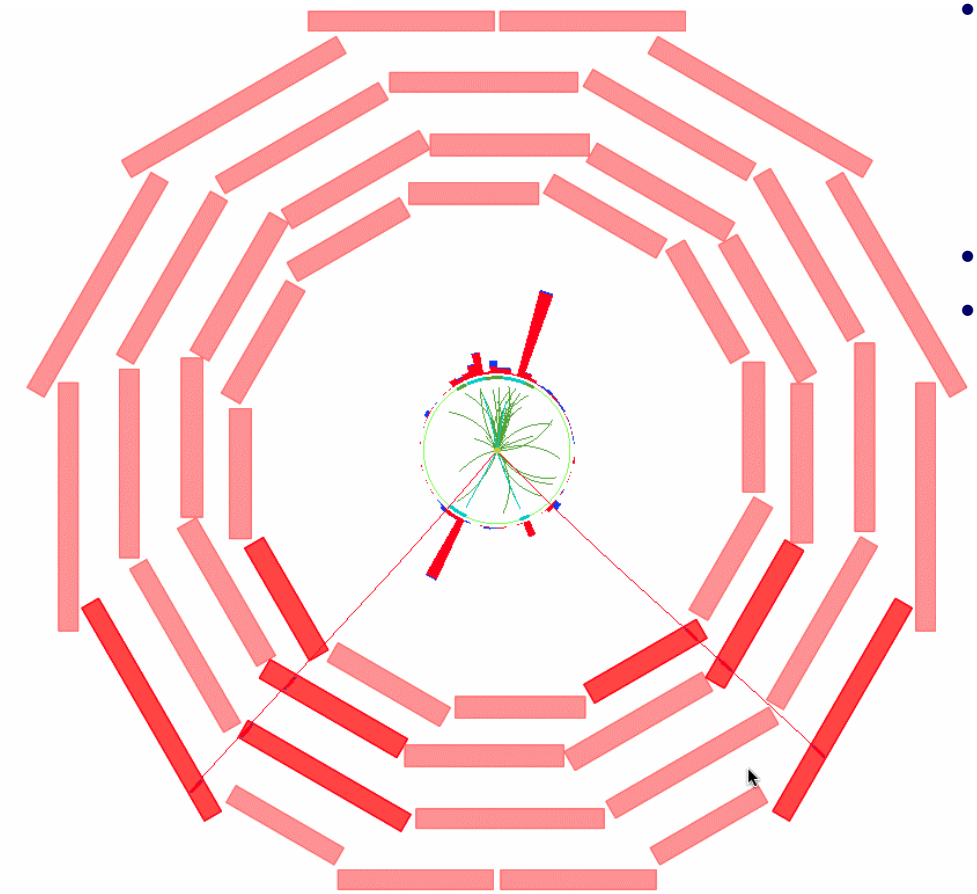


CMS expected exclusion range :[150-185]
ATLAS expected exclusion range : [140-185]

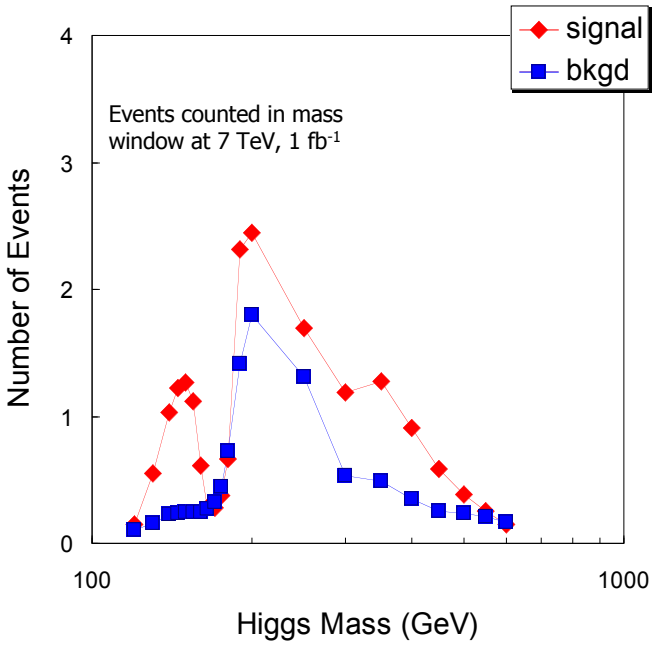
CMS discovery 3-5σ sensitivity : near 160 GeV

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

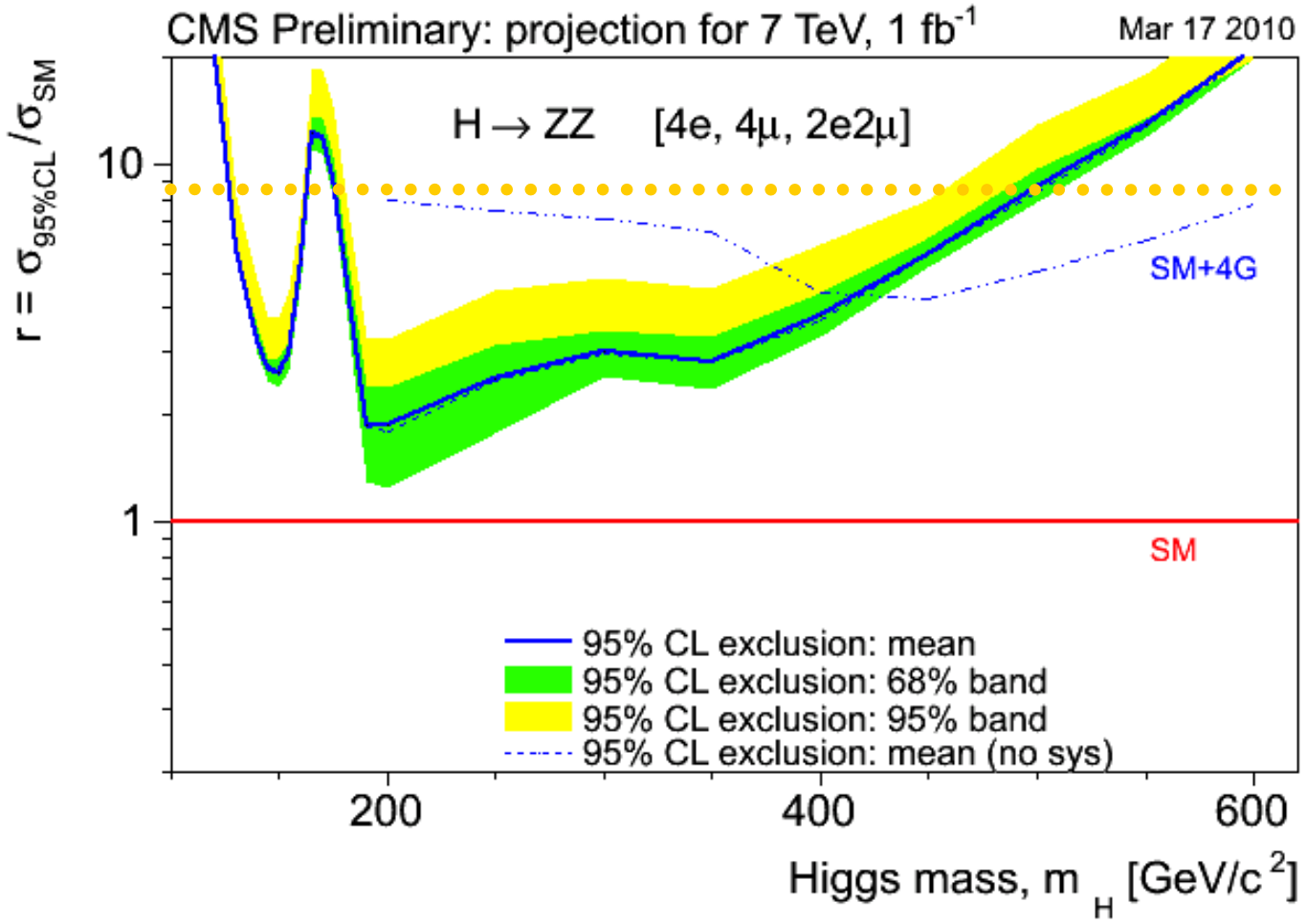
$H \rightarrow ZZ^* \rightarrow e^+e^-\mu^+\mu^-$



- Signal: four isolated leptons, look for 4l-mass peak [count in sliding mass window]
- Backgrounds:
  - ZZ : irreducible background, [rate assessed from data—Z events]
  - ttbar & Zbbbar removed by lepton isolation & impact parameter veto
- Narrow mass peak, low background
- But low yield ⇒ need to push lepton id



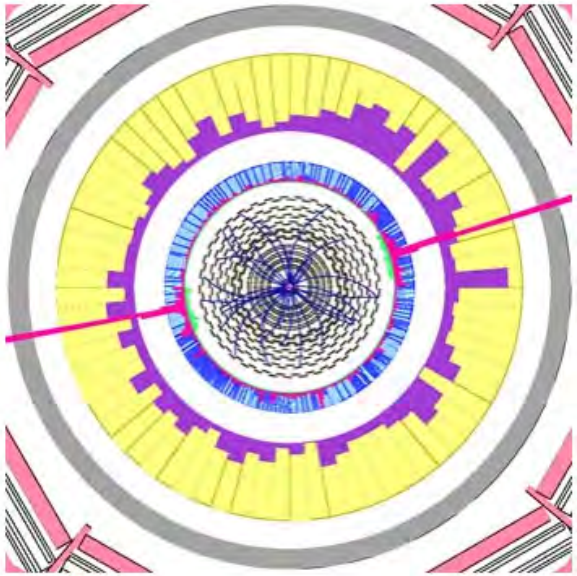
$H \rightarrow ZZ$

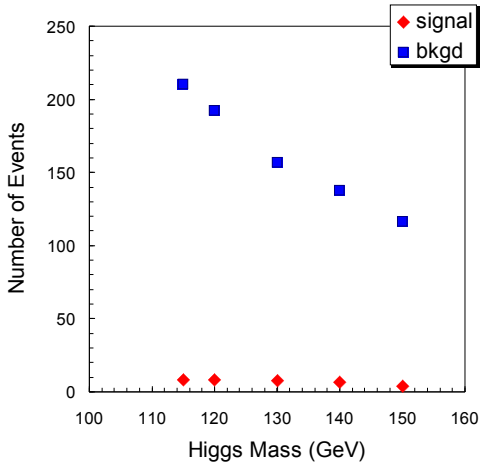


For SM Higgs with 4 fermion generations

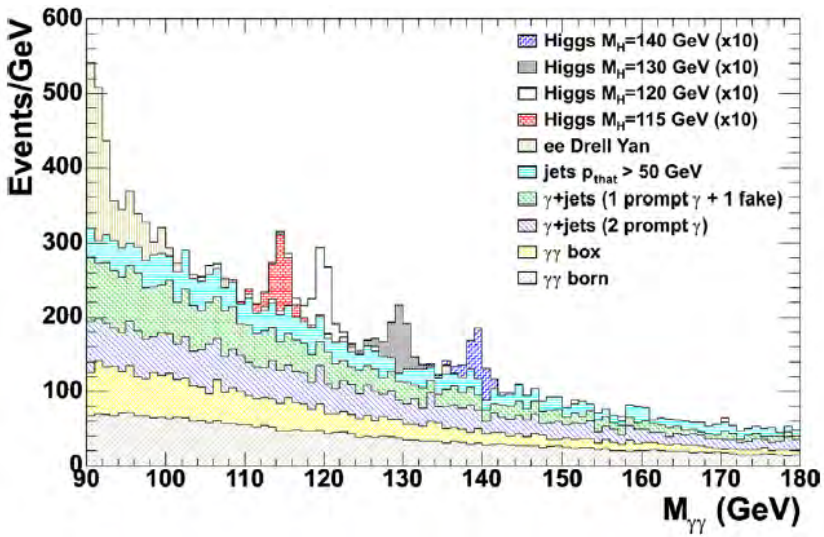
- gg→H cross section increases naively by a factor ~ 3^2=9
- Less naive exclusion limit (based on Kribs et al) **➔ ~ 420 GeV**

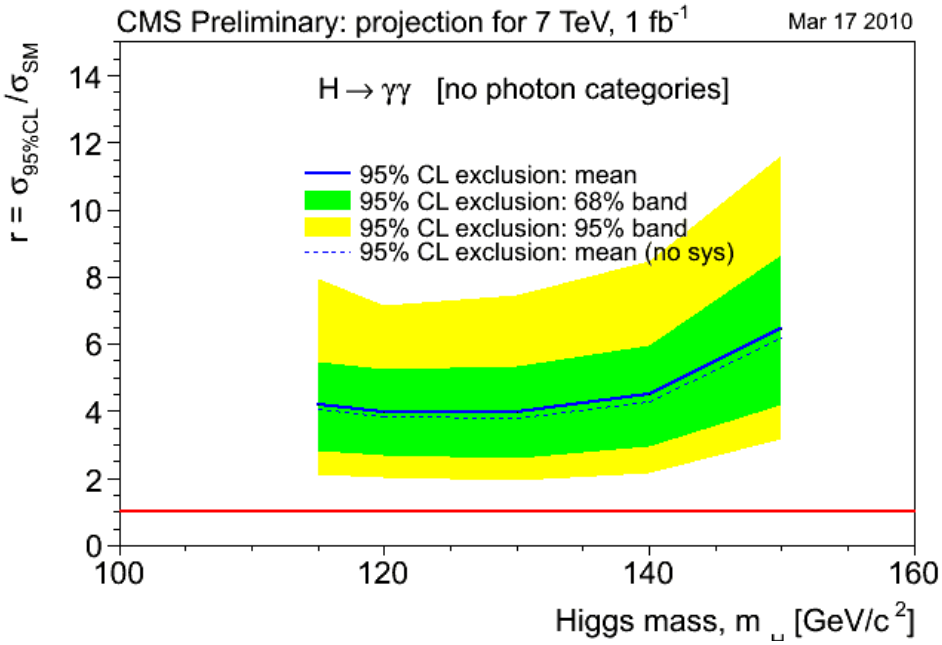
$H \rightarrow \gamma\gamma$



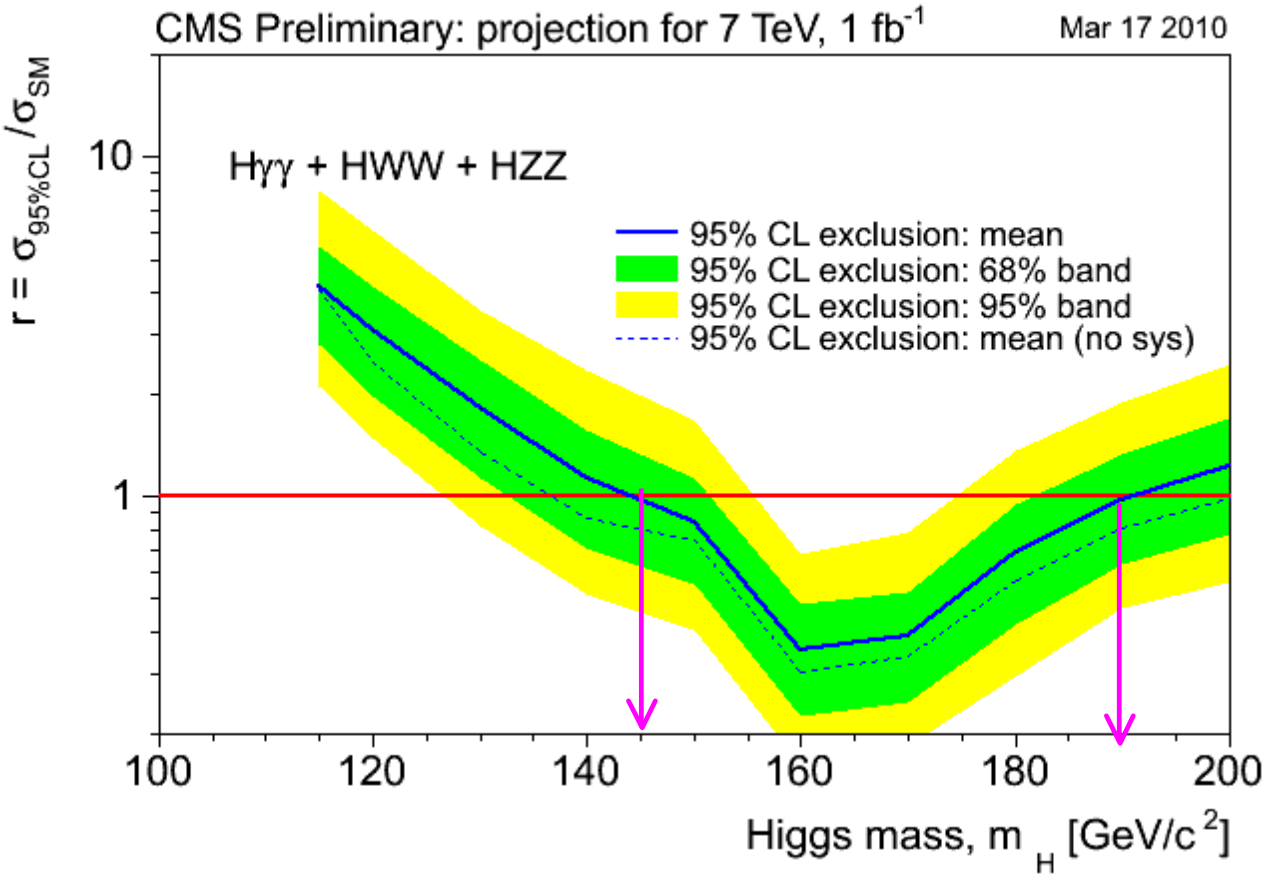


- two isolated photons, search for mass peak
- QCD bkgd is large and partly irreducible,
  - measured from sidebands
- Not a viable mode of low mass SM Higgs in 7 TeV/ 1fb^{-1} run





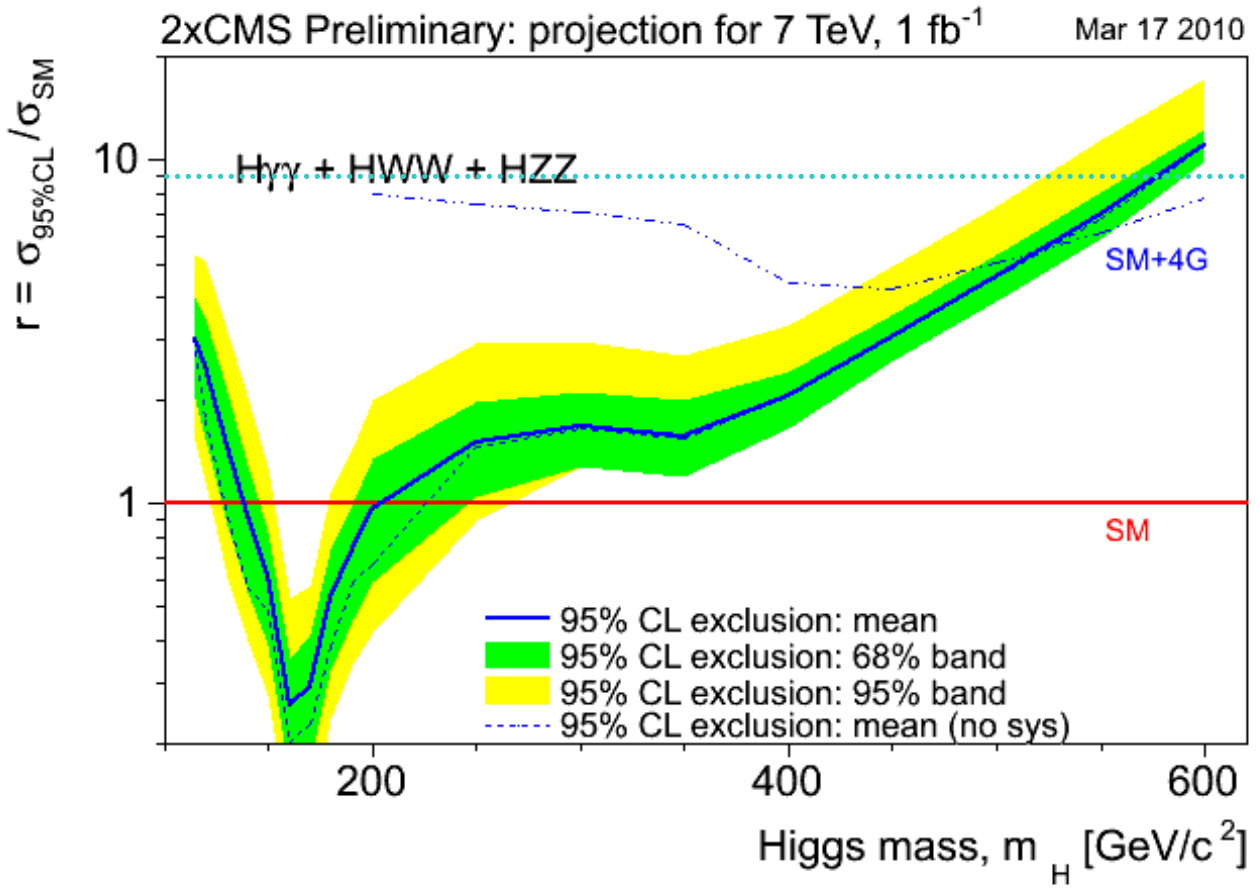
CMS: All Modes Combined



SM Higgs expected excluded range: **145-190 GeV**

SM Higgs with 4 fermion generations: **< ≈ 420 GeV**

[CMS x 2 Projection] ≈ ATLAS+CMS

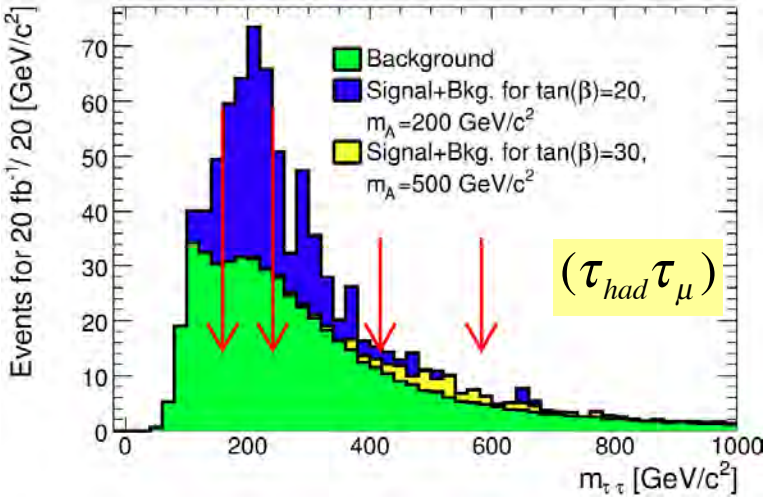


SM Higgs expected excluded range approx: **140-200 GeV**

discovery range approx: **160-170 GeV**

SM Higgs with 4 generations can be ruled out to $M_H \approx 530$ GeV

MSSM Higgs In $pp \to bb\Phi;\ \Phi \to \tau^+\tau^-$



– – Isolated pairs of $(\tau_{had}\tau_{\mu}),(\tau_{had}\tau_{e}),(\tau_{\mu}\tau_{e})$

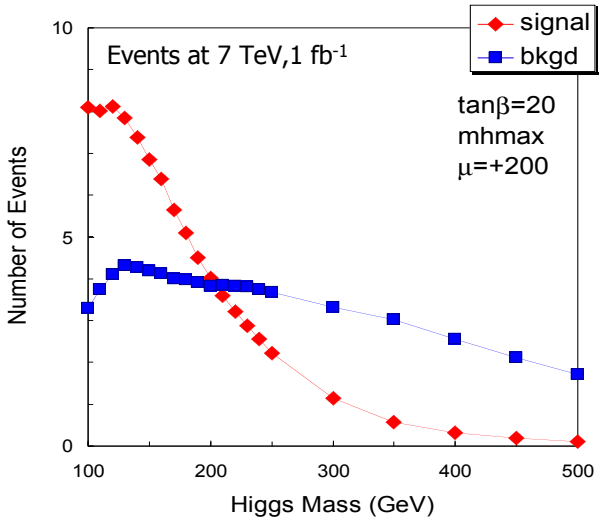
– – With MET, 1 tagged bjet, veto extra jets

– – Build $\tau\tau$-mass using collinear approx

– – Count events in sliding $\tau\tau$-mass window

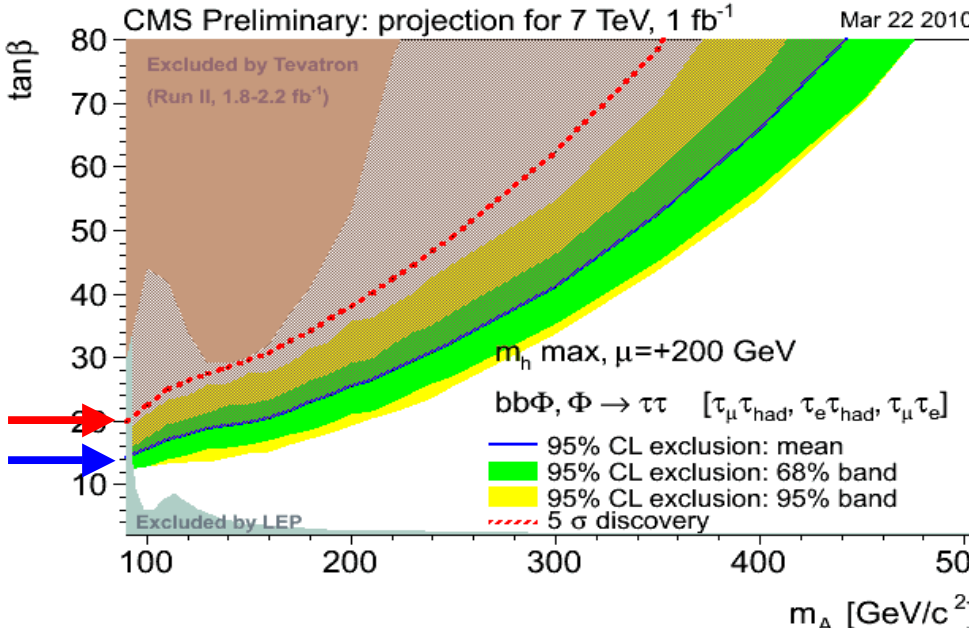
– – Dominant backgrounds: $t\bar{t}$, $Z+b\bar{b}$ & $Z+c\bar{c}$

-- assessed from data

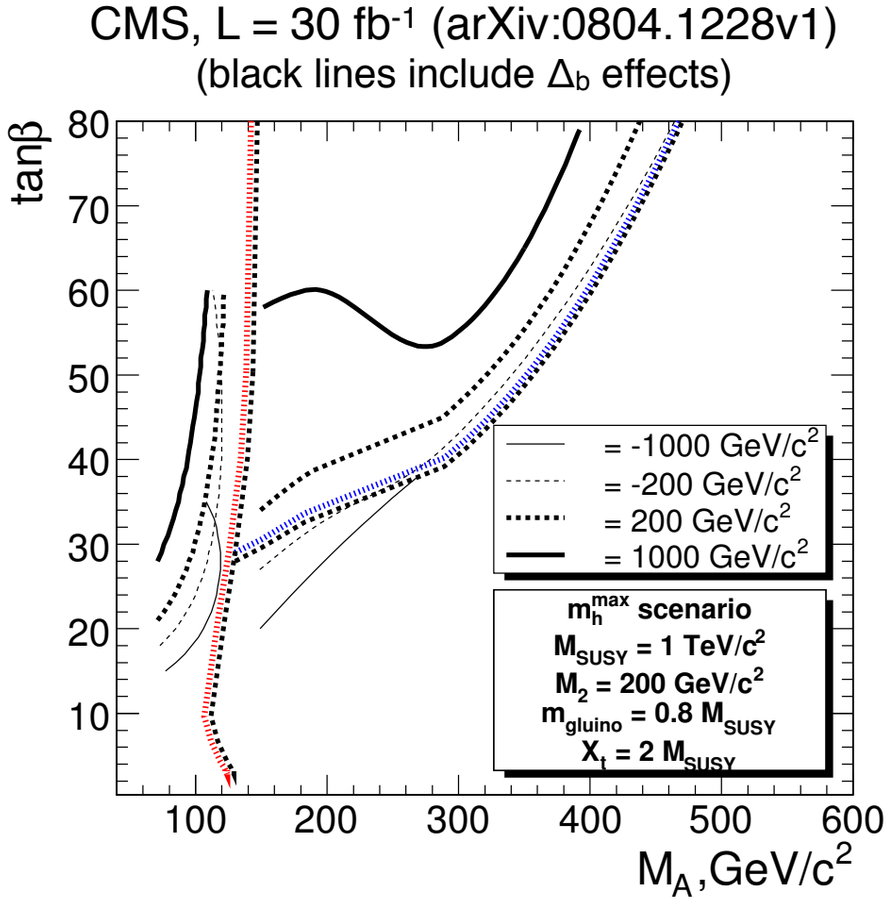


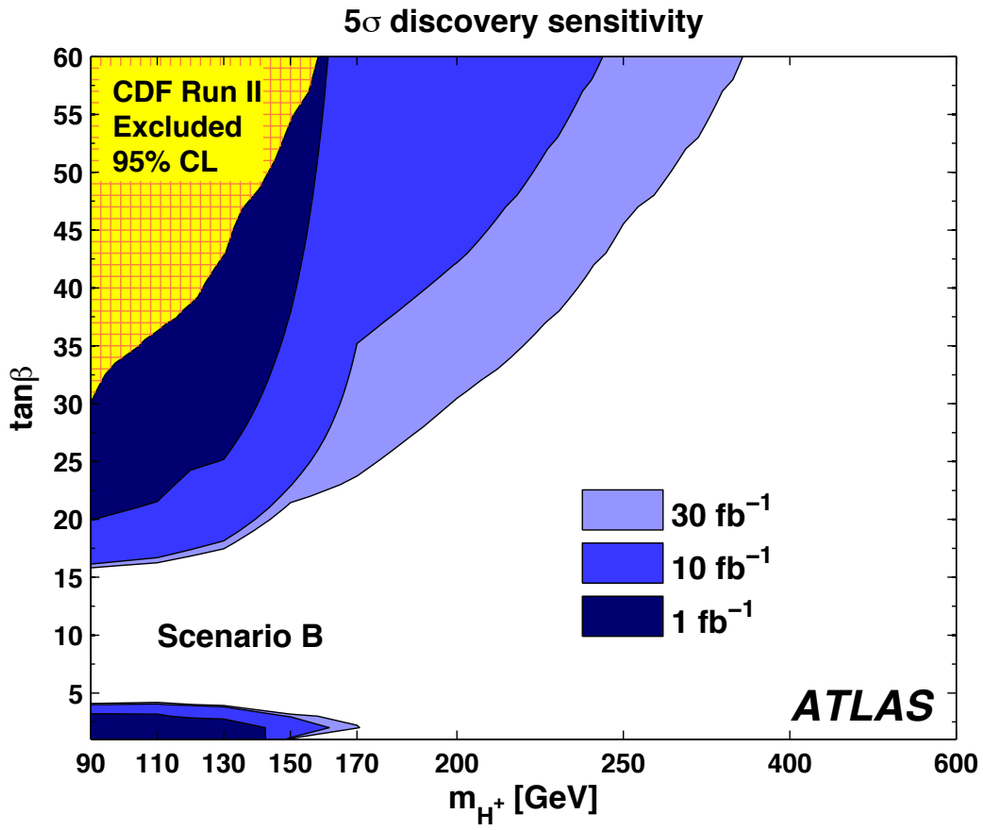
discover

exclude



Charged Higgs boson expected discovery potential





- Good sensitivity at low masses and/or high tan β, dominated by $H^+ \rightarrow \tau\nu$
- Difficult in intermediate tan β
  - Decays to SUSY particles might be an alternative

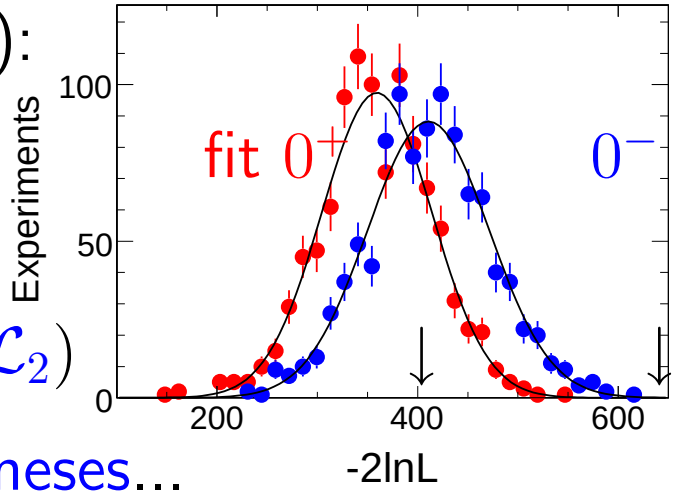
Higgs or not Higgs?

- Three steps in analysis (include mass, yield):

  (1) hypothesis h1 fit self-consistency $\longrightarrow$
  "χ^{2}"=-2 ln($\mathcal{L}_1$) from background & signal

  (2) compare hyp. h1 and h2 with $2\ln(\mathcal{L}_1/\mathcal{L}_2)$

  (>2) determine all parameters for all hypotheses...



- If found resonance is not truly SM Higgs

  and parameters are rather different $\Rightarrow$ exclude SM Higgs

  $\Rightarrow$ quote "range" of allowed hypotheses

- If true SM Higgs is found

  can we exclude all other hypotheses?

  $\Rightarrow$ only very fine-tuned hypotheses cannot be ruled out "easily"

  e.g. unpolarized "graviton" with Higgs-like couplings, rate, width...

  $\Rightarrow$ quote level of consistency and "range" of excluded hypotheses