Higgs review @ 7 TeV
(SM, MSSM, NMSSM,...)

Roberto Salerno (LLR)

OUTLINE:
– The SM Higgs World
– The BSM Higgs World

I'm sorry, I will show a no exhaustive list of biased topics

CEA, Saclay, 2nd April 2010, CMS France

As you know, we started ...

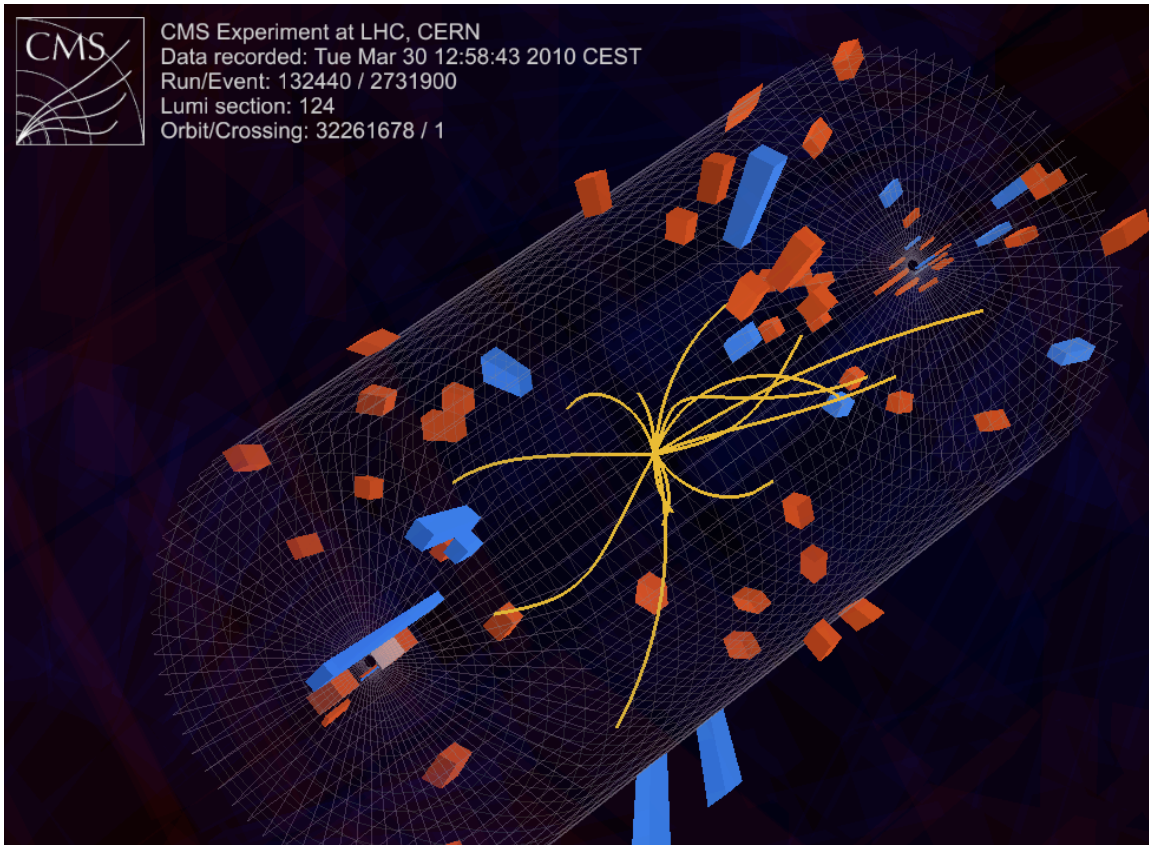
CMS statement for the 7 TeV collisions

Geneva, March 30th 2010.

....

At 12:58:34 the LHC Control Centre declared stable colliding beams: the collisions were immediately detected in CMS. Moments later the full processing power of the detector had analyzed the data and produced the first images of particles created in the 7 TeV collisions traversing the CMS detector

....



... and we know what we have to look for,

at least in the standard way ...

HIGGS BOSON

H

The **HIGGS BOSON** is the theoretical particle of the Higgs mechanism, which physicists believe will reveal how all matter in the universe gets its mass. Many scientists hope that the Large Hadron Collider in Geneva, Switzerland will detect the elusive Higgs Boson when it begins colliding particles at 99.99% the speed of light.

back

$9.75 PLUS SHIPPING

●●●●●●●●●●●●●◐

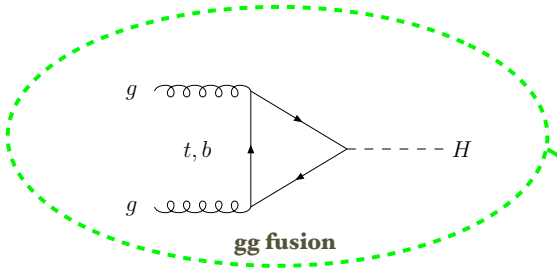
LIGHT HEAVY

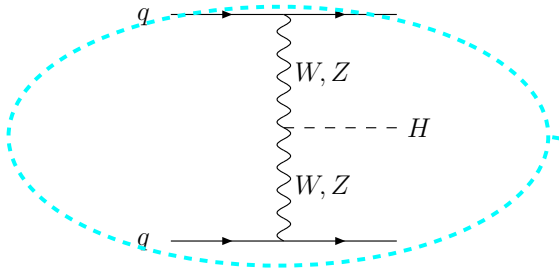
Wool felt, velour with gravel fill for maximum mass. MADE IN CHINA.

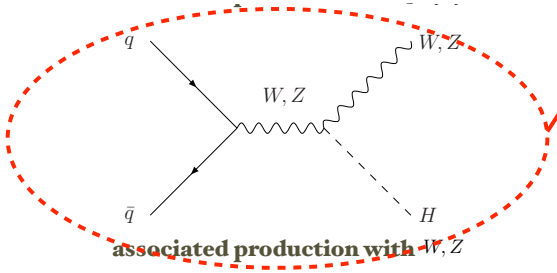
GLUON PHOTON NEUTRINO TACHYON ELECTRON UP QUARK DOWN QUARK TAU NEUTRINO MUON UP Q
NEUTRON DOWN QUARK TAU GLUON **HIGGS BOSON** NEUTRINO TACHYON ELECTRON UP QUARK DOWN
NEUTRINO MUON UP QUARK PROTON NEUTRON DOWN QUARK TAU GLUON PHOTON NEUTRINO TACHY

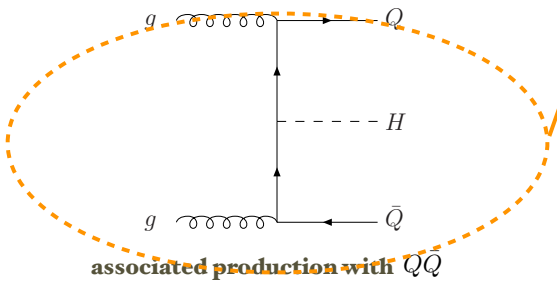
The PARTICLE ZOO

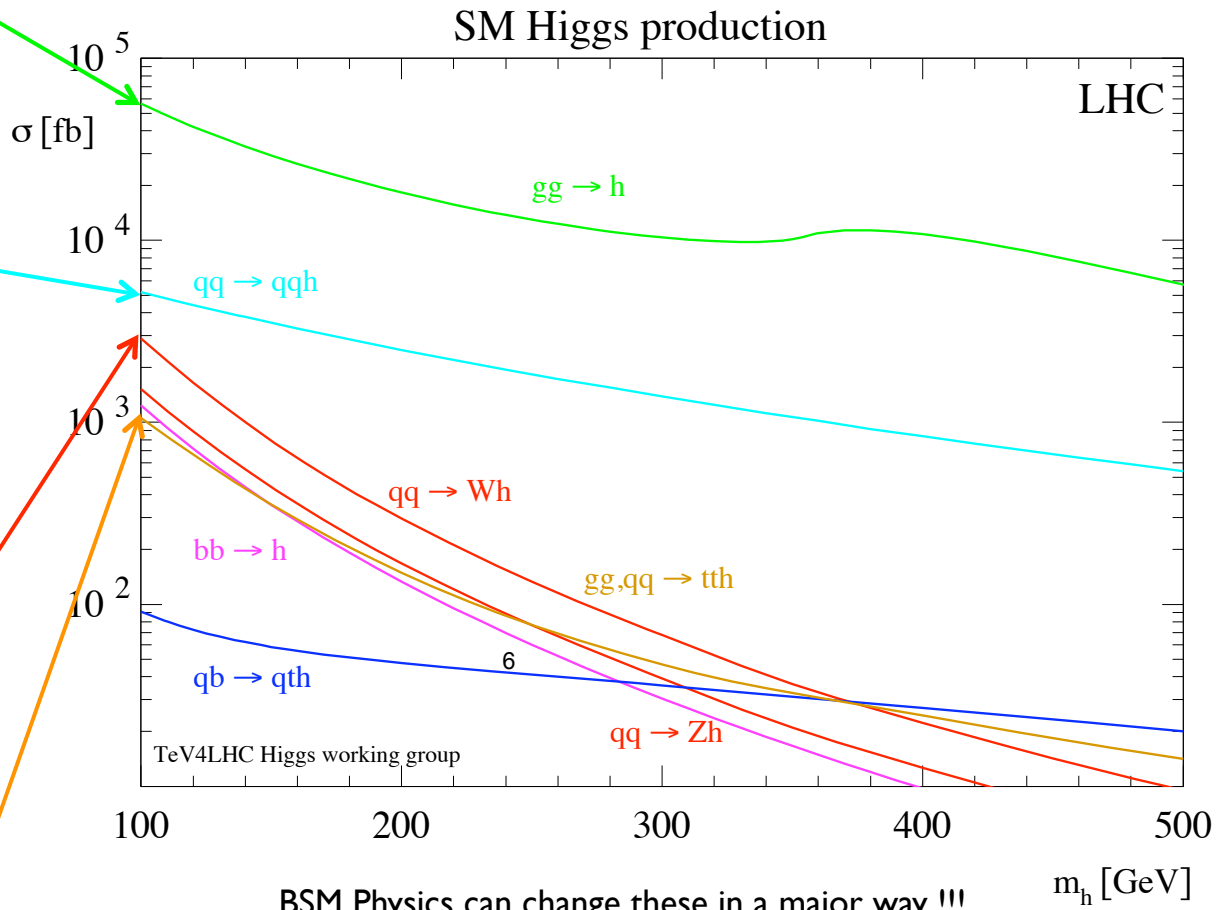
SM: Production and cross sections











BSM Physics can change these in a major way !!!
(e.g. bbH in MSSM)

SM: Branching ratio

$M_H \leq 145$ GeV

$H \to b\bar{b}$
Dominant mode … but crippling QCD background

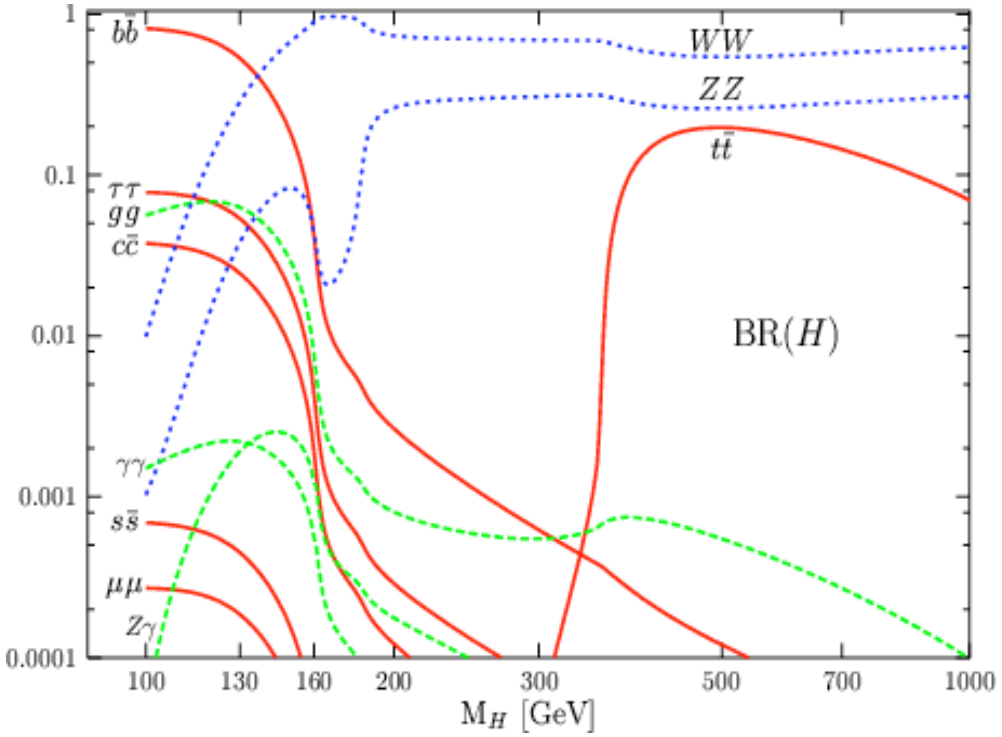
$H \to \tau^+\tau^-$
Exploitable at low M_H in the VBF production mode

$H \to \gamma\gamma$
Complementary mode at low M_H via loop diagrams, low BR but excellent γ/Jet (γ ID, γ Iso., $M_{\gamma\gamma}$) separation

$M_H > 125$ GeV

$H \to WW^{(*)}$
Dominant mode, $l^+\nu l^-\bar{\nu}$ channel optimal for $M_H = 2\,M_W$; $l^+\nu qq'$ channel exploitable at large MH or through VBF

$H \to ZZ^{(*)}$
Small BR but "golden mode" for a discovery $l^+l^-\,l^+\,l^-$



BSM Physics can change these in a major way !!!
(e.g. ττ, bb in MSSM)

SM: Branching ratio

$M_H \leq 145$ GeV

$H \to b\bar{b}$
Dominant mode … but crippling QCD background

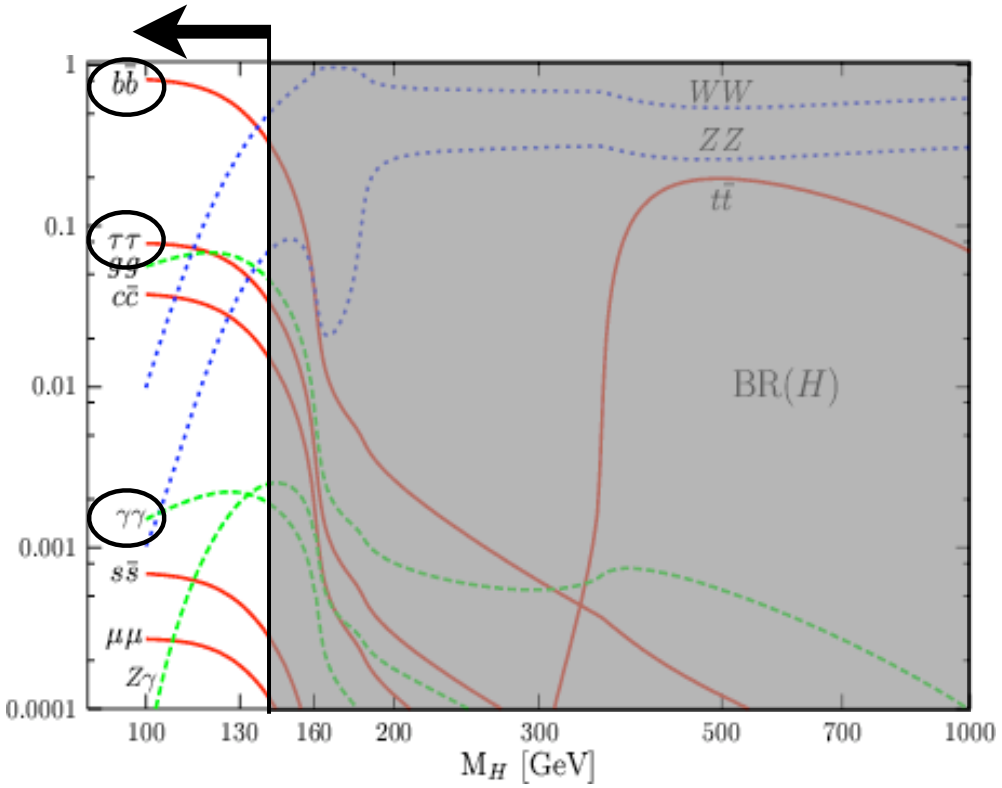
$H \to \tau^+\tau^-$
Exploitable at low M_H in the VBF production mode

$H \to \gamma\gamma$
Complementary mode at low M_H via loop diagrams, low BR but excellent γ/Jet (γ ID, γ Iso., $M_{\gamma\gamma}$) separation

$M_H > 125$ GeV

$H \to WW^{(*)}$
Dominant mode, $l^+\nu l^-\bar{\nu}$ channel optimal for $M_H = 2\,M_W$; $l^+\nu qq'$ channel exploitable at large MH or through VBF

$H \to ZZ^{(*)}$
Small BR but "golden mode" for a discovery $l^+l^-\,l^+\,l^-$



BSM Physics can change these in a major way !!!
(e.g. ττ, bb in MSSM)

SM: Branching ratio

$M_H \leq 145$ GeV

$H \to b\bar{b}$
Dominant mode … but crippling QCD background

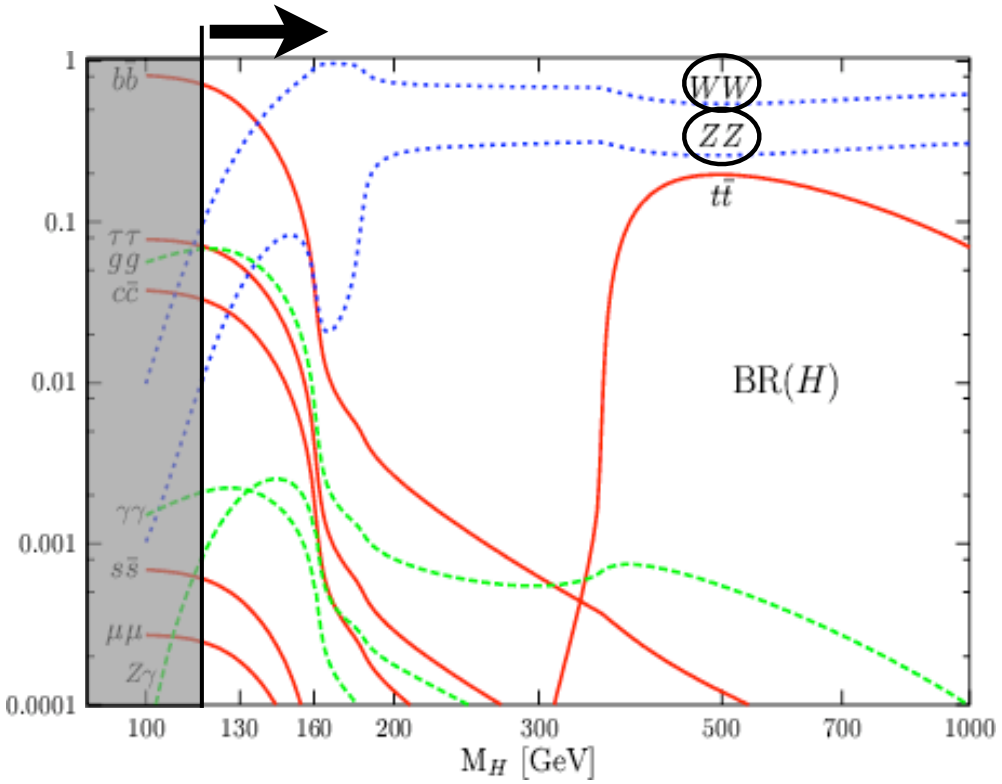
$H \to \tau^+\tau^-$
Exploitable at low M_H in the VBF production mode

$H \to \gamma\gamma$
Complementary mode at low M_H via loop diagrams, low BR but excellent γ/Jet (γ ID, γ Iso., $M_{\gamma\gamma}$) separation

$M_H > 125$ GeV

$H \to WW^{(*)}$
Dominant mode, $l^+\nu l^-\bar{\nu}$ channel optimal for $M_H = 2\,M_W$; $l^+\nu qq'$ channel exploitable at large MH or through VBF

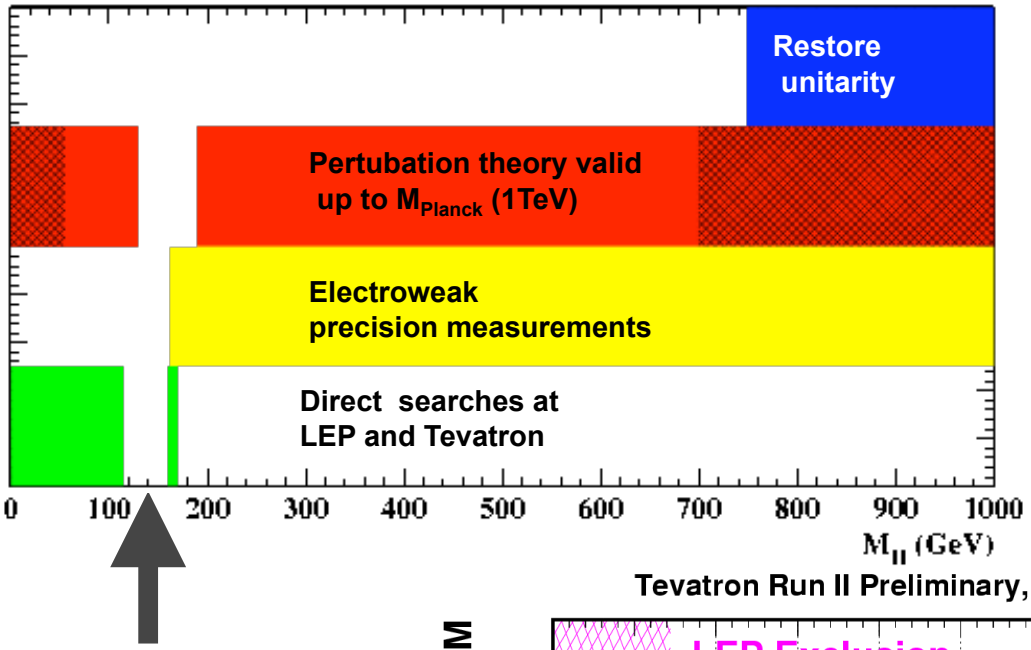
$H \to ZZ^{(*)}$
Small BR but "golden mode" for a discovery $l^+l^-\,l^+\,l^-$



BSM Physics can change these in a major way !!!
(e.g. ττ, bb in MSSM)

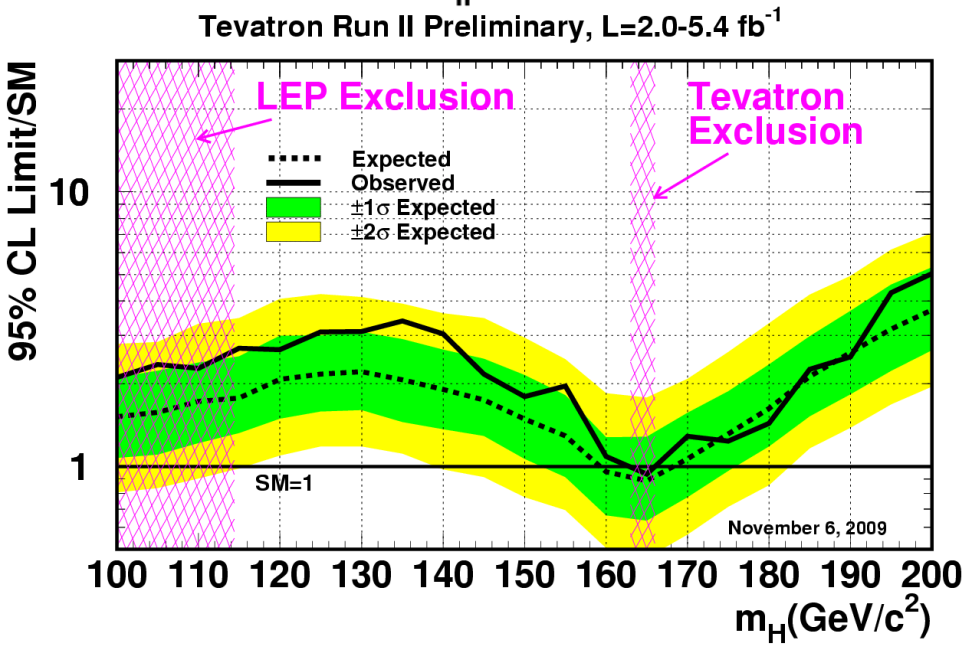
SM: Mass range...

... and if Standard we prefer it light

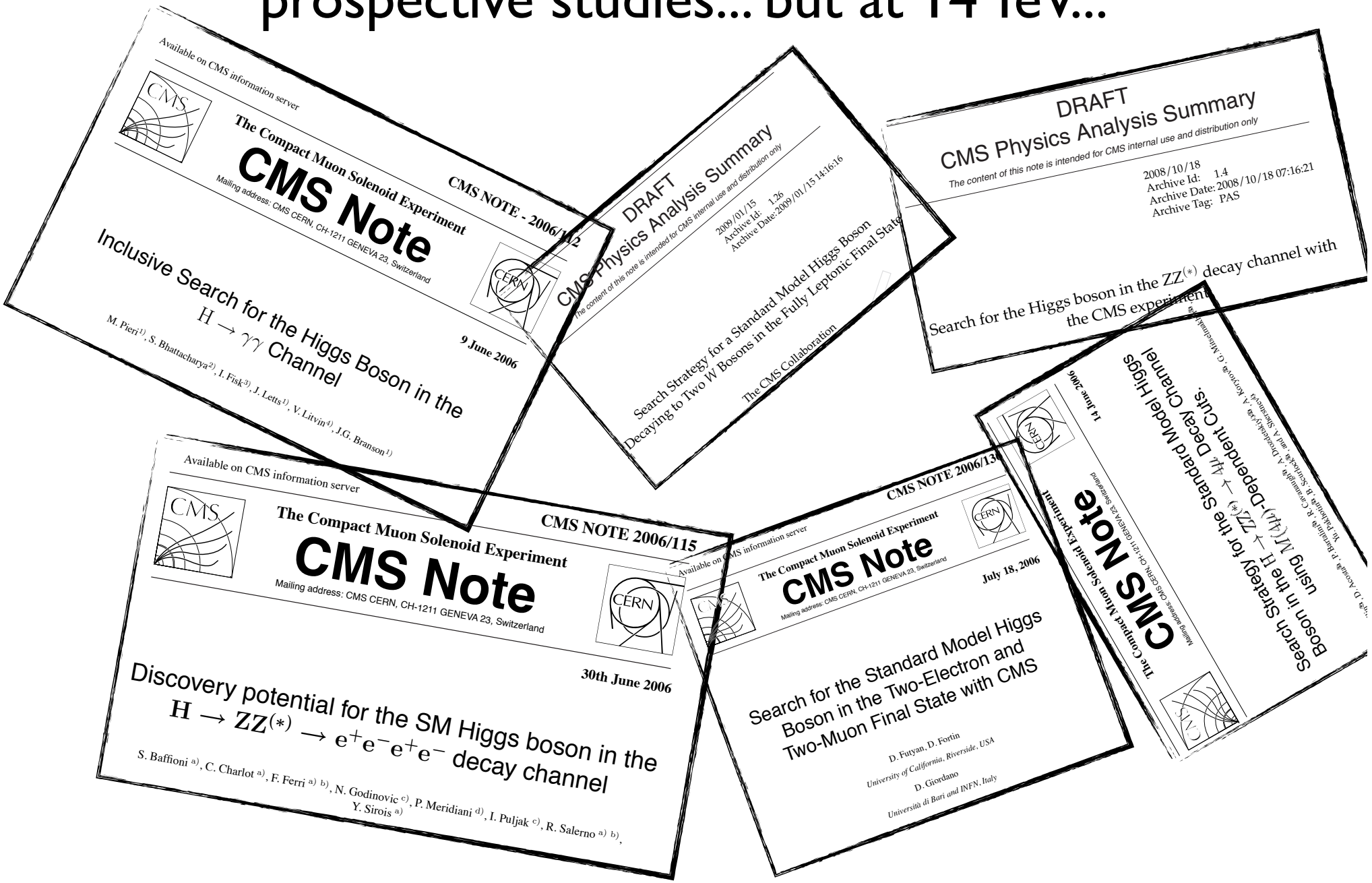


Experimental bounds from TeVatron

162-166 GeV @95%CL
(159-169 GeV expected)



CMS have plenty of SM Higgs published prospective studies... but at 14 TeV...



Available on CMS information server

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

CMS NOTE - 2006/112

9 June 2006

Inclusive Search for the Higgs Boson in the $H \to \gamma\gamma$ Channel

M. Pieri[1], S. Bhattacharya[2], I. Fisk[3], J. Letts[1], V. Litvin[4], J.G. Branson[1]

DRAFT

CMS Physics Analysis Summary

The content of this note is intended for CMS internal use and distribution only

2009/01/15
Archive Id: 1.26
Archive Date: 2009/01/15 14:16:16

Search Strategy for a Standard Model Higgs Boson Decaying to Two W Bosons in the Fully Leptonic Final State

The CMS Collaboration

DRAFT

CMS Physics Analysis Summary

The content of this note is intended for CMS internal use and distribution only

2008/10/18
Archive Id: 1.4
Archive Date: 2008/10/18 07:16:21
Archive Tag: PAS

Search for the Higgs boson in the $ZZ^{(*)}$ decay channel with the CMS experiment

Available on CMS information server

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

CMS NOTE 2006/115

30th June 2006

Discovery potential for the SM Higgs boson in the $H \to ZZ^{(*)} \to e^+e^-e^+e^-$ decay channel

S. Baffioni [a], C. Charlot [a], F. Ferri [a] [b], N. Godinovic [c], P. Meridiani [d], I. Puljak [c], R. Salerno [a] [b], Y. Sirois [a]

Available on CMS information server

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

CMS NOTE 2006/136

July 18, 2006

Search for the Standard Model Higgs Boson in the Two-Electron and Two-Muon Final State with CMS

D. Futyan, D. Fortin

University of California, Riverside, USA

D. Giordano

Università di Bari and INFN, Italy

The Compact Muon Solenoid Experiment

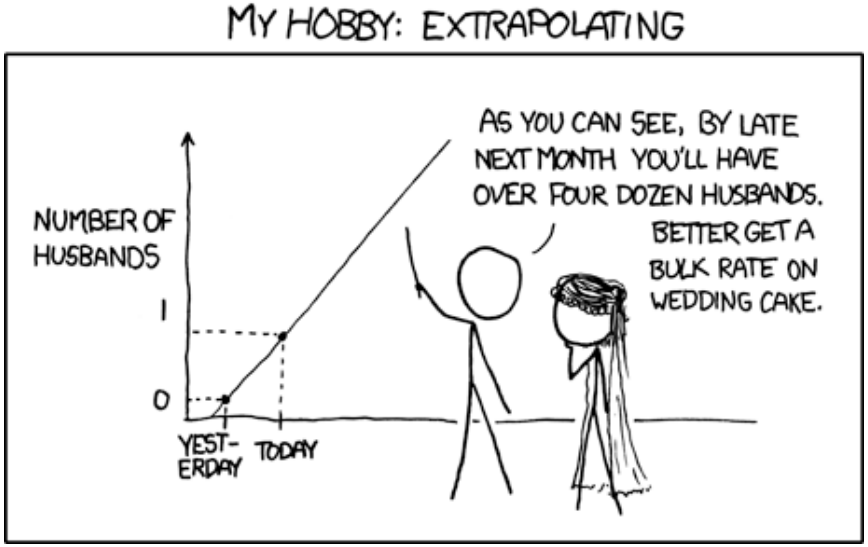
CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

14 June 2006

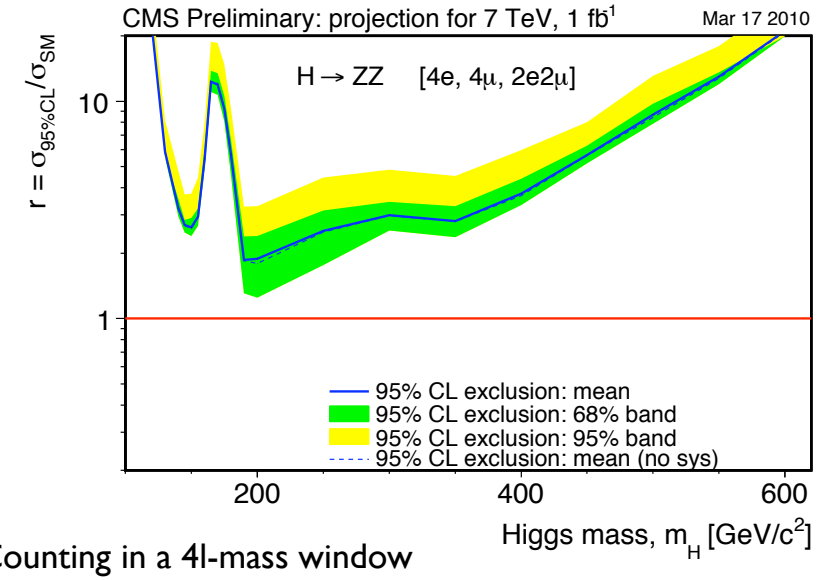
Search Strategy for the Standard Model Higgs Boson in the $H \to ZZ^{(*)} \to 4\mu$ Decay Channel using $M(4\mu)$-Dependent Cuts.

SM: Extrapolating from 14TeV to 7TeV

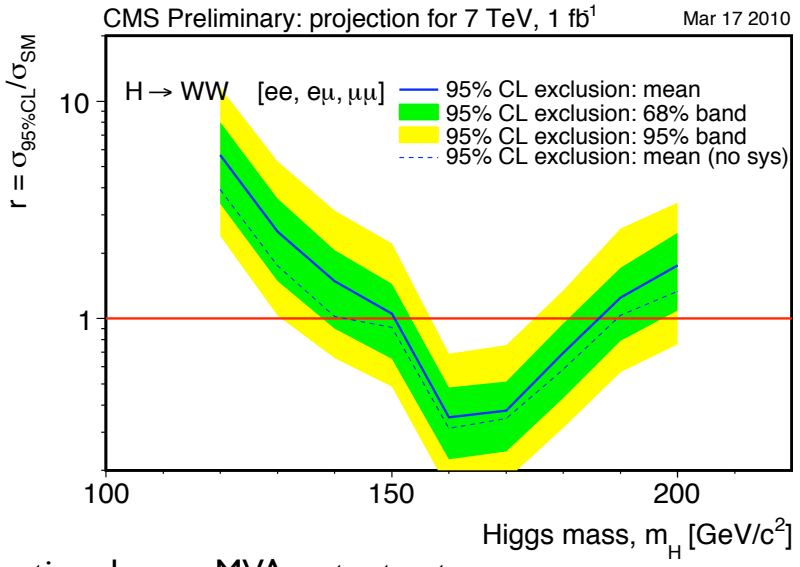


– Use only published results
– Assume the same signal and background efficiencies for 14 TeV and 7 TeV
  efficiencies are actually a bit larger at 7 TeV
– Scale signal and backgrounds by the cross-section ratio at 14 TeV and 7 TeV
– Assume the same systematic uncertainties, take into account different background composition
– Limits are computed using Modified Frequentist (CLs) method

SM: H→ZZ/WW/γγ

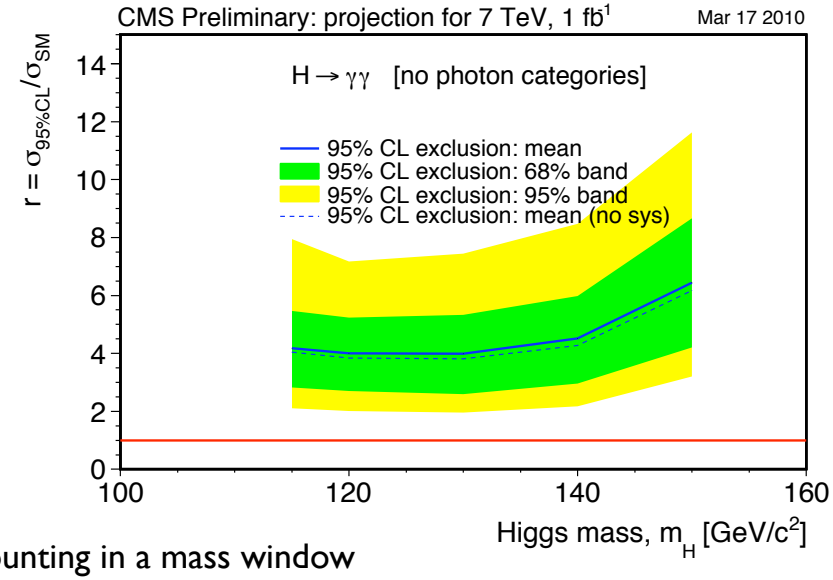


Counting in a 4l-mass window
Three sub-channels: 4e, 4μ, 2e2μ



Counting above a MVA-output cut
Three sub-channels: 2e, 2μ, eμ

Excluded range:
150-185 GeV



Counting in a mass window
No photon categories

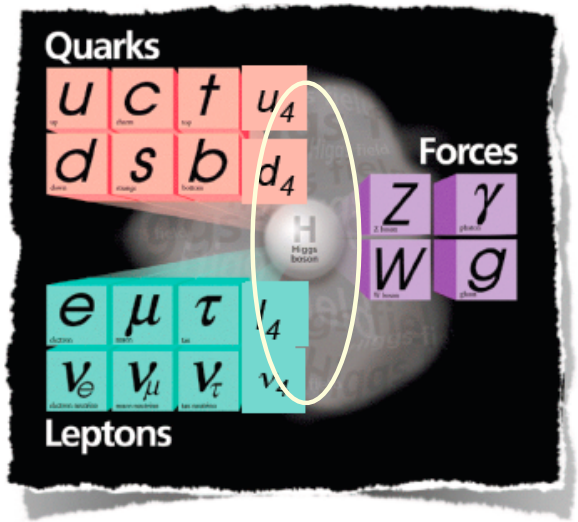
Combing the 3 channels the CMS SM Higgs expected excluded range is **145-190 GeV**

We are going to competitive with TeVatron but our main channel is based on a MVA-analysis

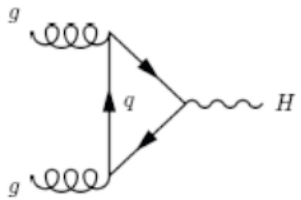
... but if we will look for something
no standard that has
a **standard** topology ...

4th generation (I)

- Sequential 4th generation of fermions
- Main constraints:
  - Invisible Z width at LEPI: $M_{\nu 4}$>50 GeV
  - Direct searches at TeVatron: M_{u4}>256 GeV
  - LEP2 bounds for unstable ν4 : $M_{\nu 4}$>100 GeV



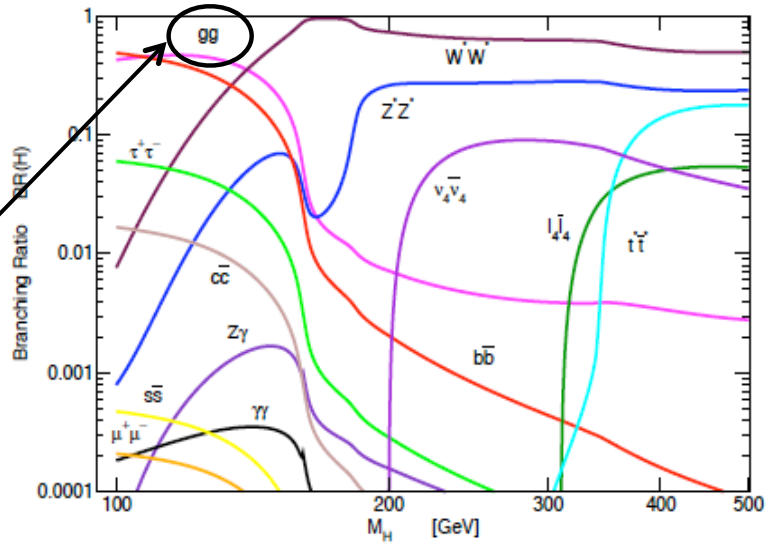
- Additional quarks enhance by x3 ggH coupling



- Higgs production cross sections:
  - •gg→H enhanced by ~x9!
  - •VH and VBF remain at SM rate

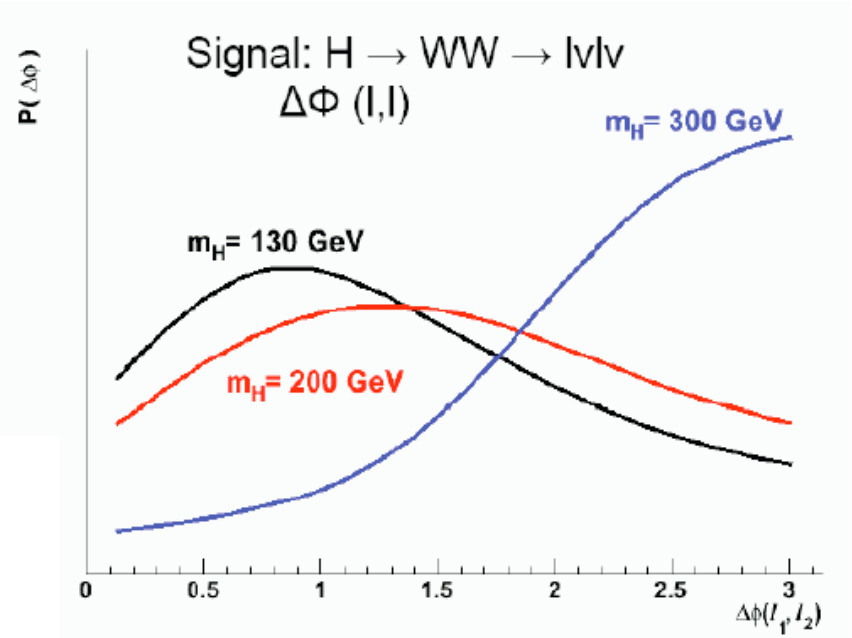
- Higgs decay BRs:
  - •H→gg significantly increased at low mass
  - •H→WW dominant mode for m_H>135 GeV

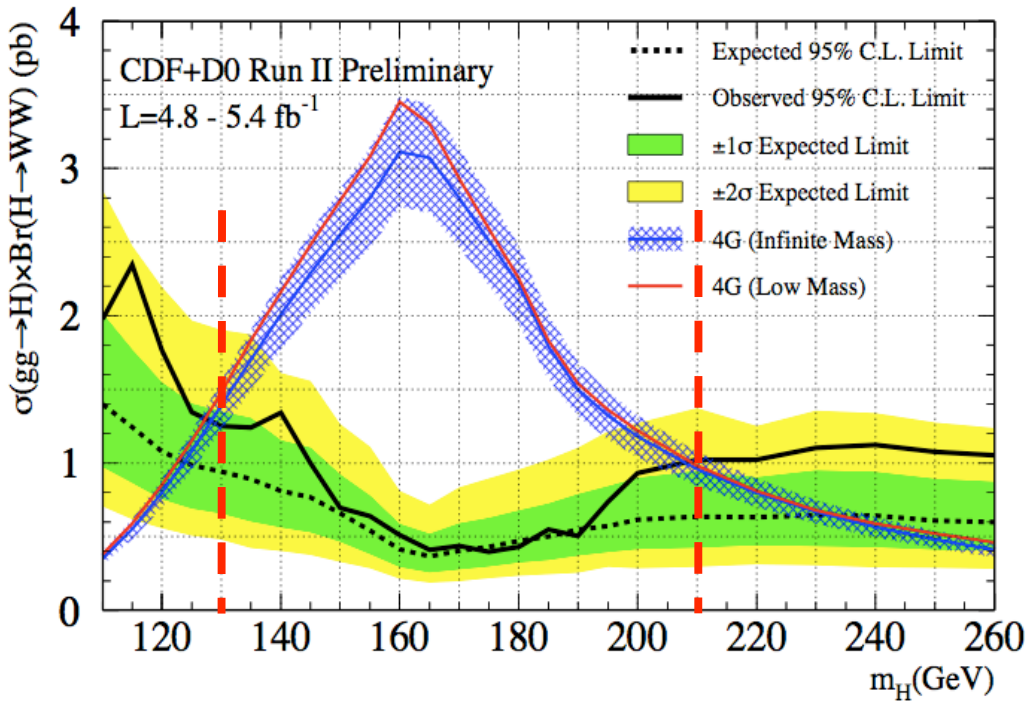
PRD 76, 075016 (2007)



4th generation (II)

- Reinterpretation of SM high mass searches:
  - Consider gg→H→WW signal only
  - Extend mass range to 260 GeV
  - Re-optimize analysis (relax Δϕ cuts, retrain NNs)





- Assuming a 4th generation of fermions masses beyond currently experimental bounds:

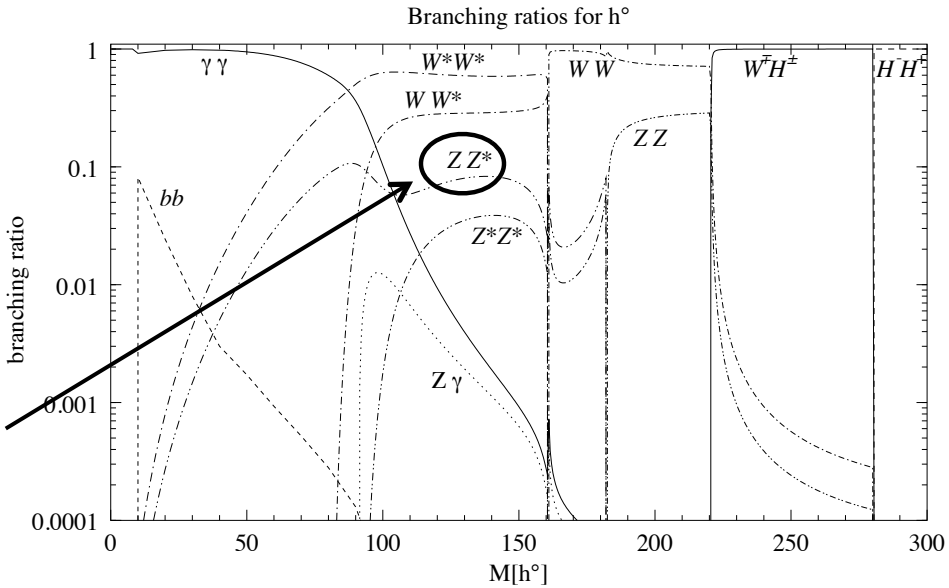
$130 < m_H < 210$ GeV

is excluded at 95% CL

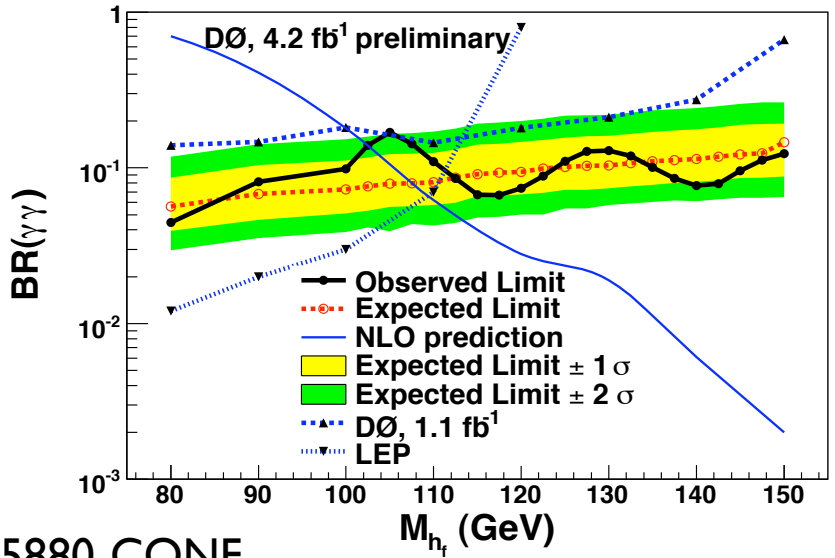
Ref: CDF Note 10101, DØ Note 6039

Fermiophobic Higgs

- In Two Higgs-Doublet Models (2HDMs) two complex scalar doublets are postulated and five Higgs bosons are predicted
- Assuming no Higgs couplings to fermions
- In this case, the BR(h→γγ) is much bigger than the SM one
- Same coupling to W and Z bosons as in the SM case but in the low mass region the BRs increase



The LEP/TeVatron γγ results provide strong limits on the production of a fermiophobic Higgs

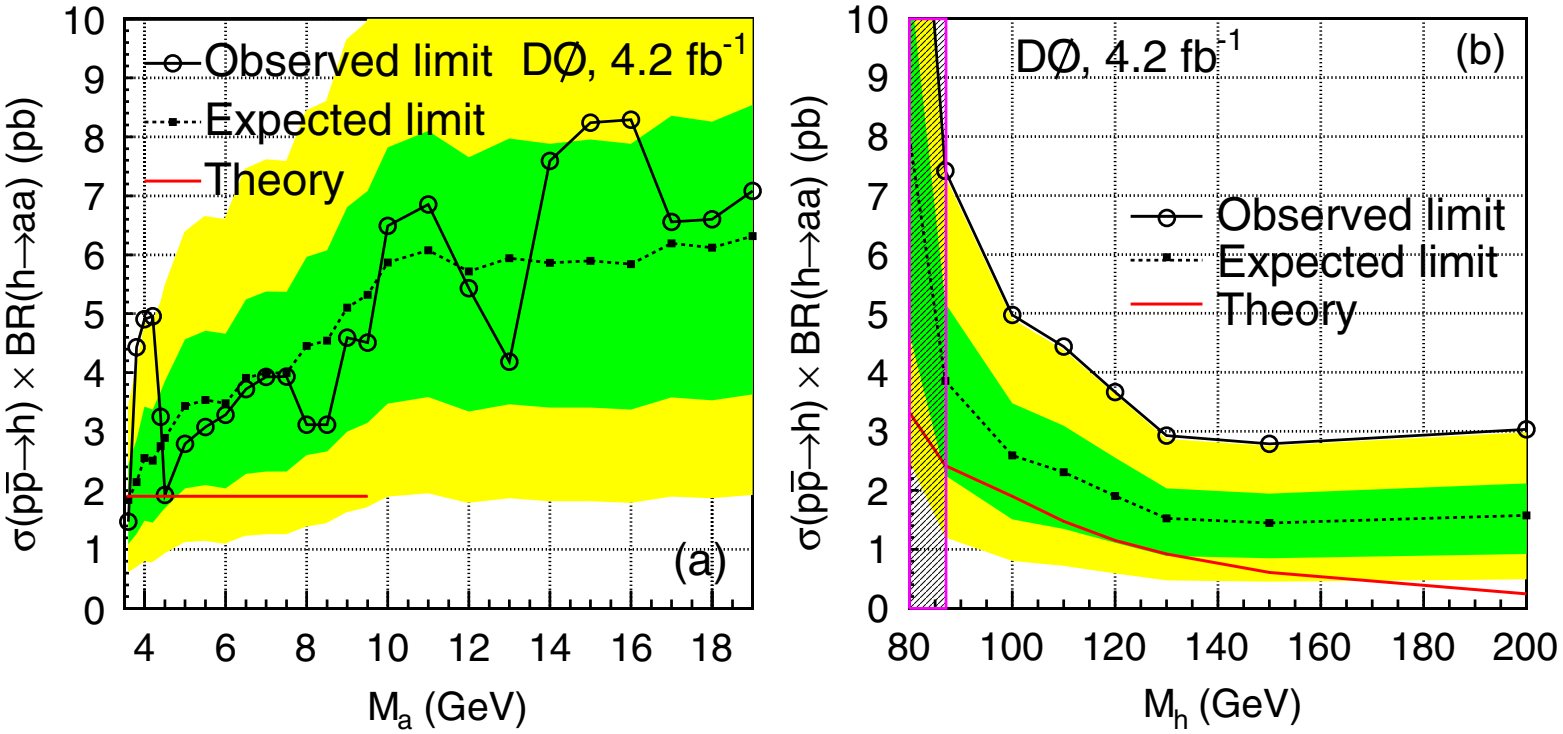


Ref: DØ Note 5880-CONF

NMSSM searches

In the altered Higgs sector two additional pseudo-scalar Higgs bosons (s and a) are added
h →aa dominates

If $m_a < 2m_\tau$, dominant decay aa → μμμμ
If $2m_\tau < ma < 2m_b$, look for: aa → μμττ

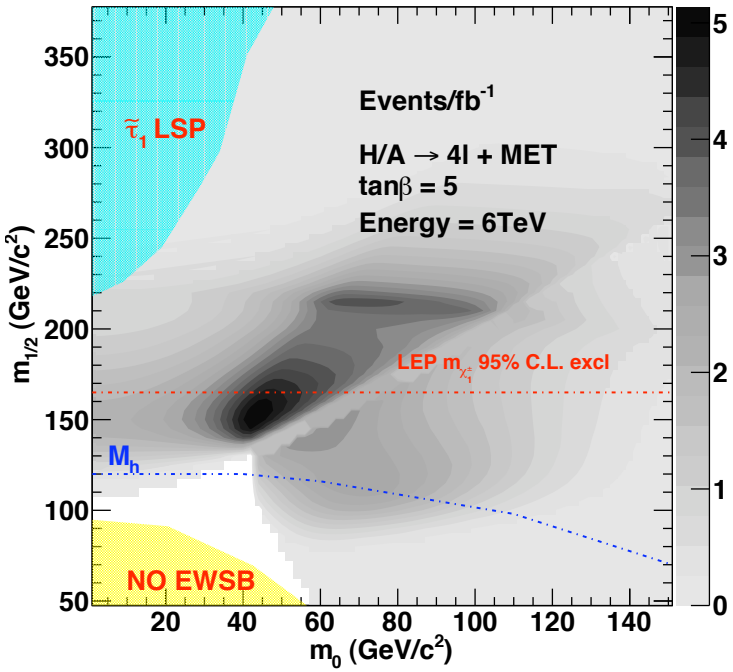


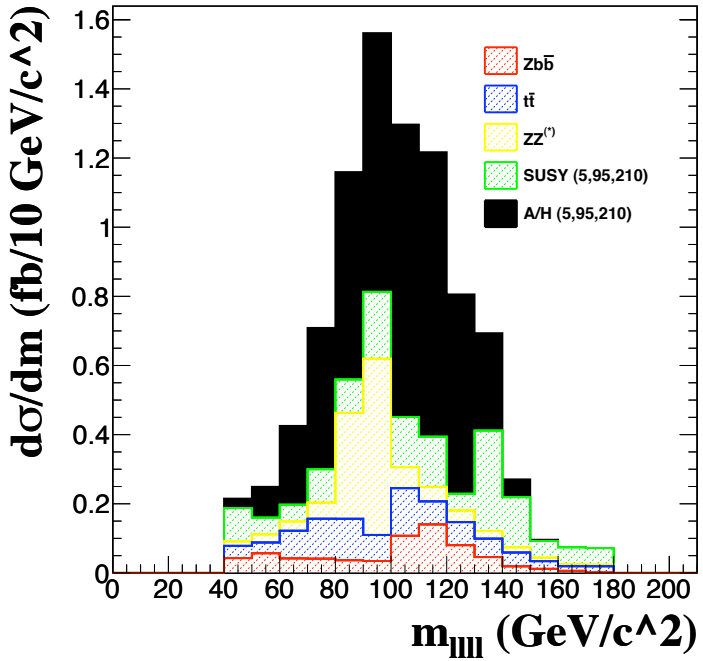
Ref: Phys. Rev. Lett. 103, 061801 (2009)

... but if we will look for something
no standard that has
a **standard** topology **but not quite** ...

Neutral MSSM Higgs (4l+**MET**)

- If sparticles (χ_2^0) are light enough so that SUSY decays of Higgs become kinematically allowed there are low tanβ regions of mSUGRA parameter space where A/H in 4l+MET channel has a sizable yield:
  Focus on the decay of H/A in two next to lightest neutralinos (χ_2^0)
  Consider neutralino decays in two leptons plus missing E_T (LSP χ_1^0)





Upper limits on the production cross-section can easily be established with 1 fb^{-1} 7 TeV data

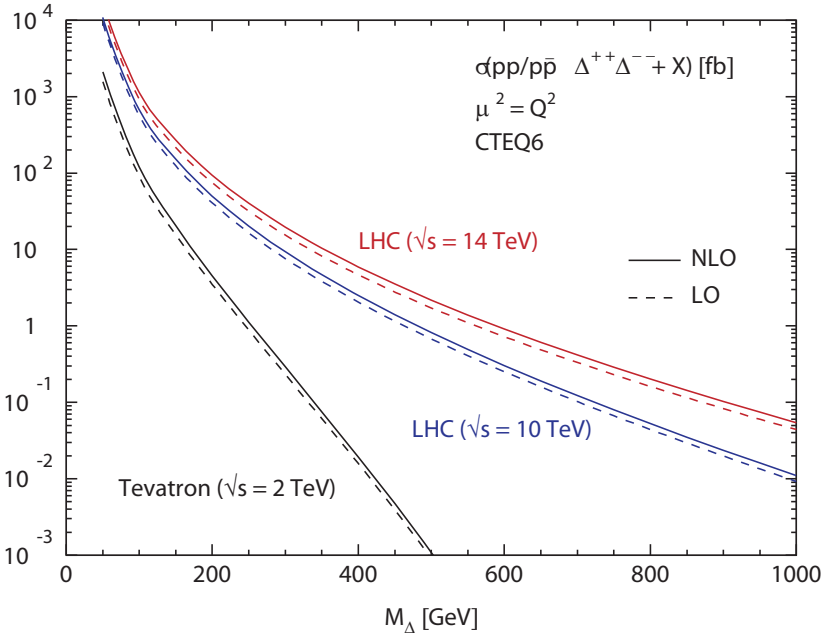
Ref: C.Charlot, R.Salerno, Y. Sirois [J. Phys. G34 (2007) N1-N12]

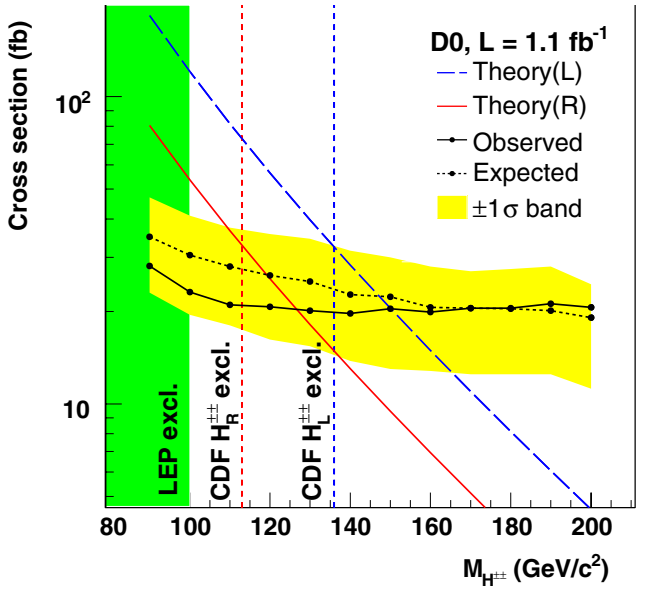
Doubly charged Higgs (4l **but charge**)

- The analysis searches for doubly-charged Higgs H^{++} bosons occur in models that have Higgs triplets
- The Higgs triplet(s) may couple to lepton fields via Yukawa couplings which are not constrained to be small since they are not involved in the mass generation
- The analysis is looking for two pairs of SS leptons or one pair of SS lepton and another additional lepton

It is almost a background free analysis and no evidence for a signal can been easily observed

An upper limits on the production cross-section can be established with O(300pb^{-1})



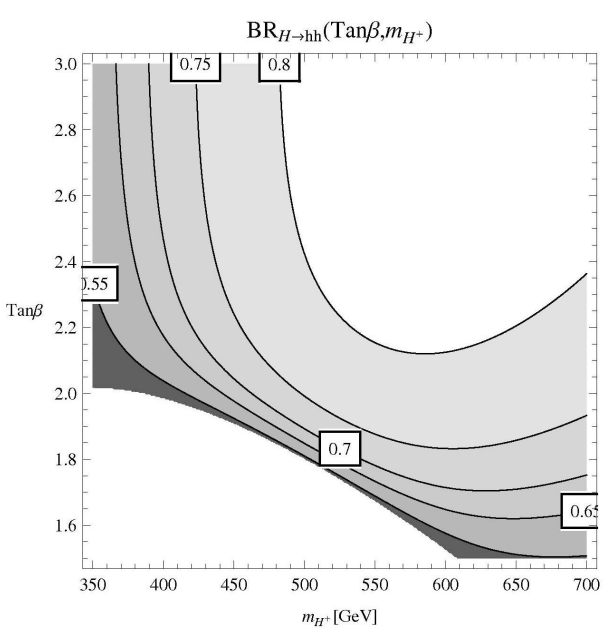


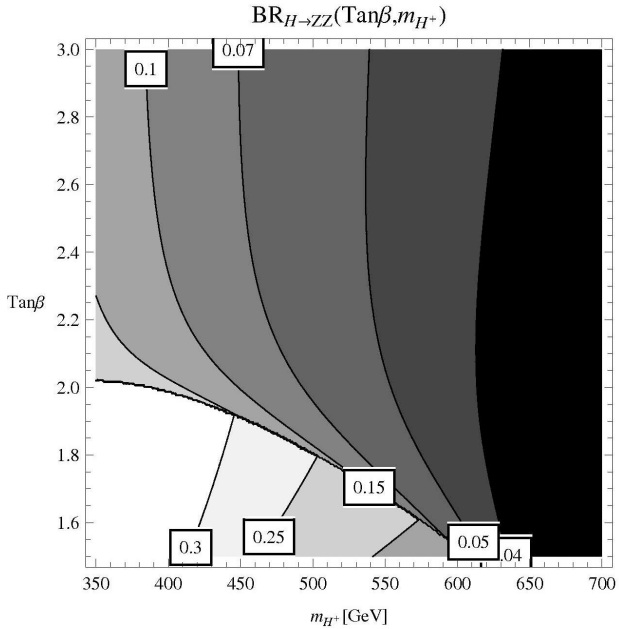
... but if we will look for something
no standard that has a
no standard topology ...

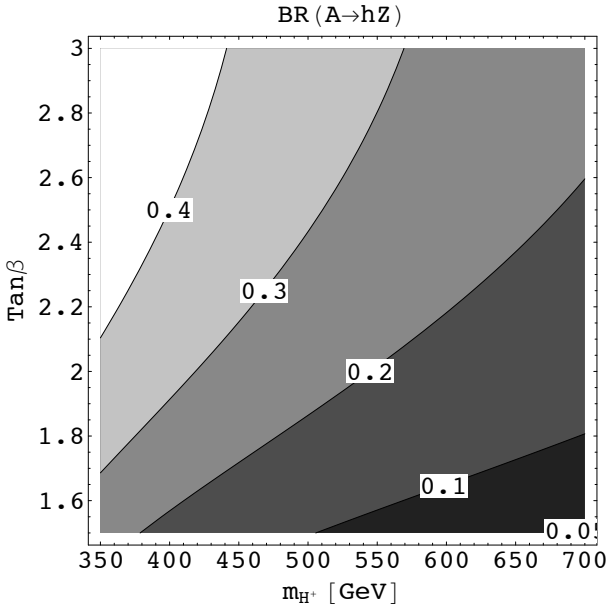
Heavyish Higgs (2l/4l+jets)

The model contains a 200−300 GeV Higgs boson h with Standard-Model like properties, and heavy CP-even and CP-odd Higgs bosons H and A with masses in 500−800 GeV range

Discovery potential of H and A in the decay chains H→hh→4V and A→Zh







Some numbers for 14TeV

gg → H → hh → 2Z2V → ll6J σ × BR = 2.67 fb

gg → A → hZ → VVZ → ll4J σ × BR = 6.9 fb

Ref: L.Cavicchia, R.Franceschini, S. Rychkov [arXiv:0710.5750]

Hidden Higgs (lepton jets)

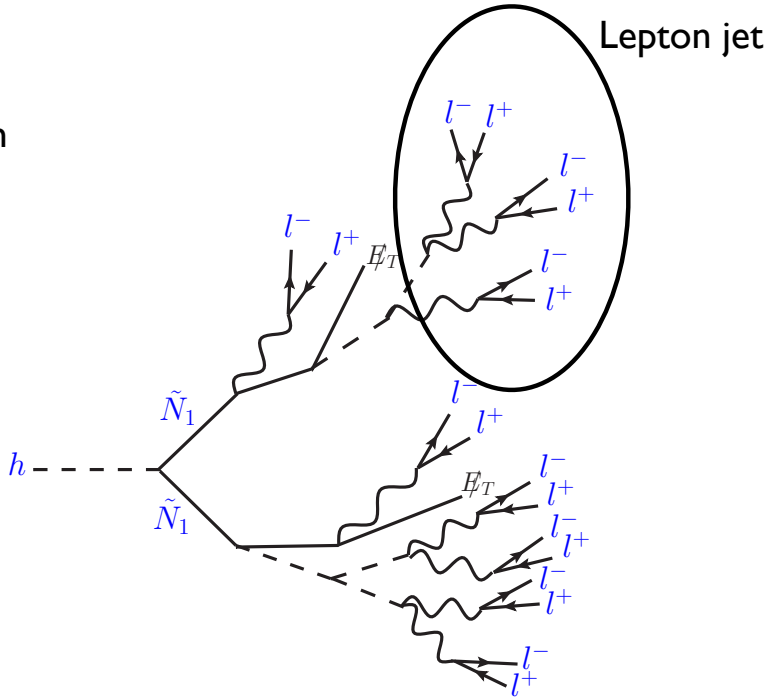
A Hidden Higgs is light and has been produced at LEP, but was missed because of exotic decays

Appealing scenario:

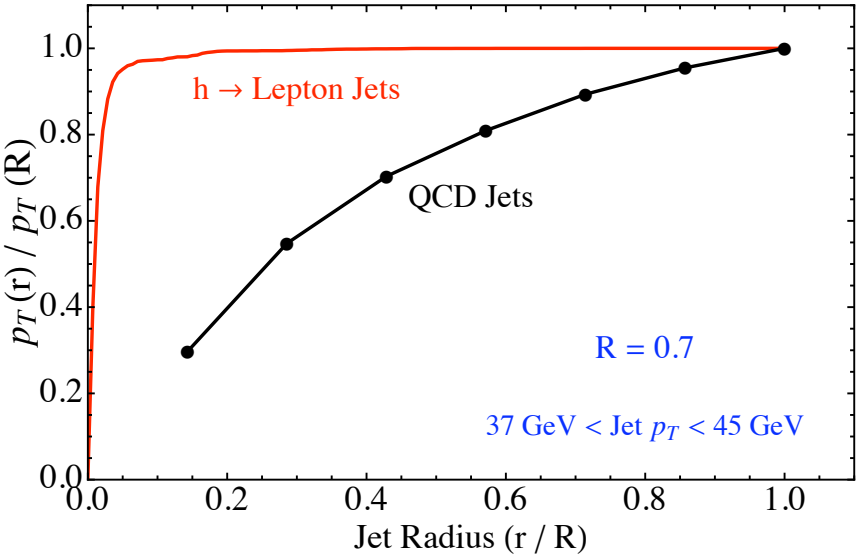
- The precision electroweak fit favors a light Higgs
- A heavy Higgs leads to the SUSY fine tuning problem

The Higgs can produce lots of leptons together with missing energy, even in the simplest U(1) model

Multilepton searches are not sensitive to lepton jets because they demand well-isolated leptons



Lepton jets are much narrower than QCD jets



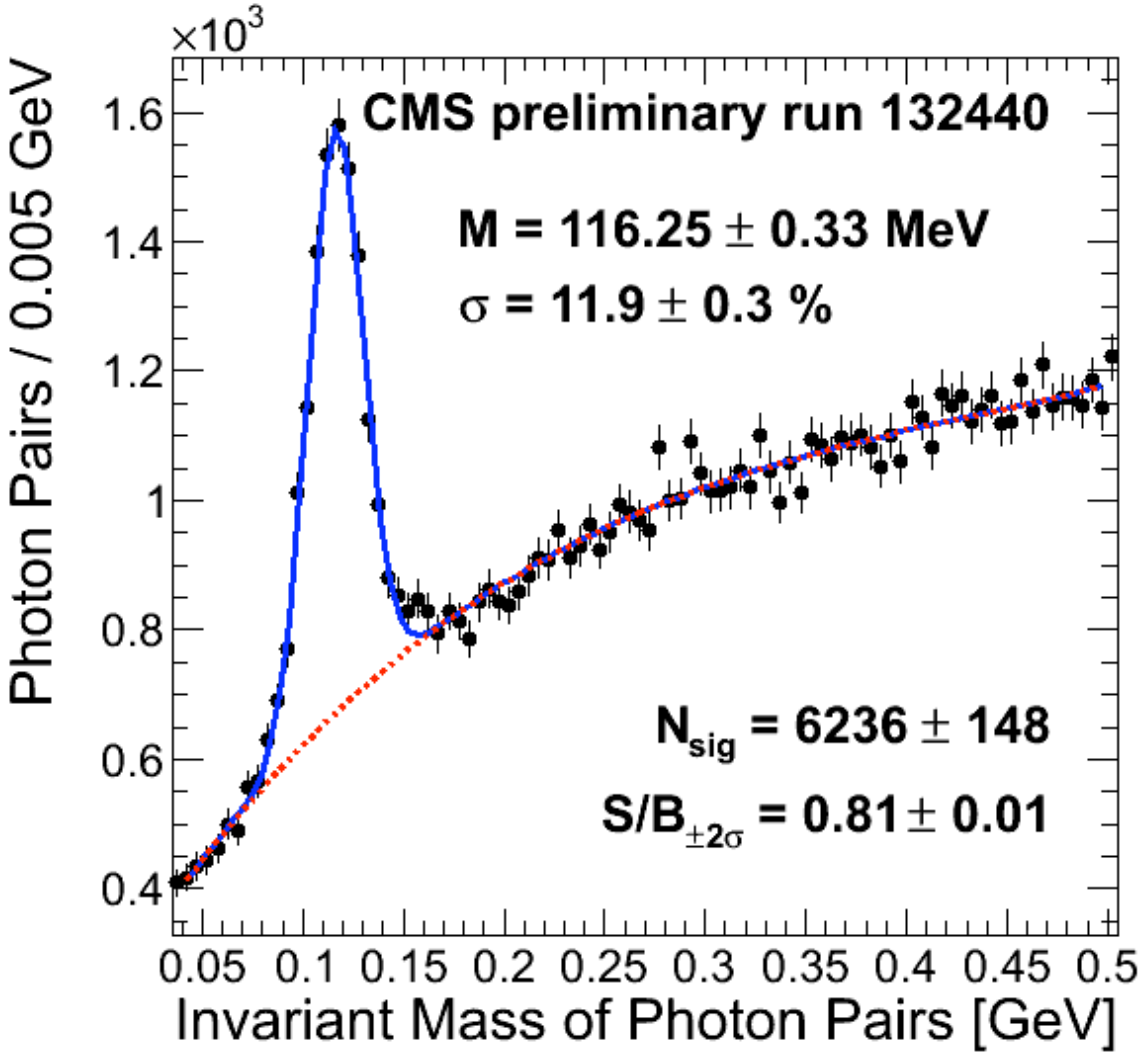
Exclusion limit/discovery reach to be establish

Conclusions

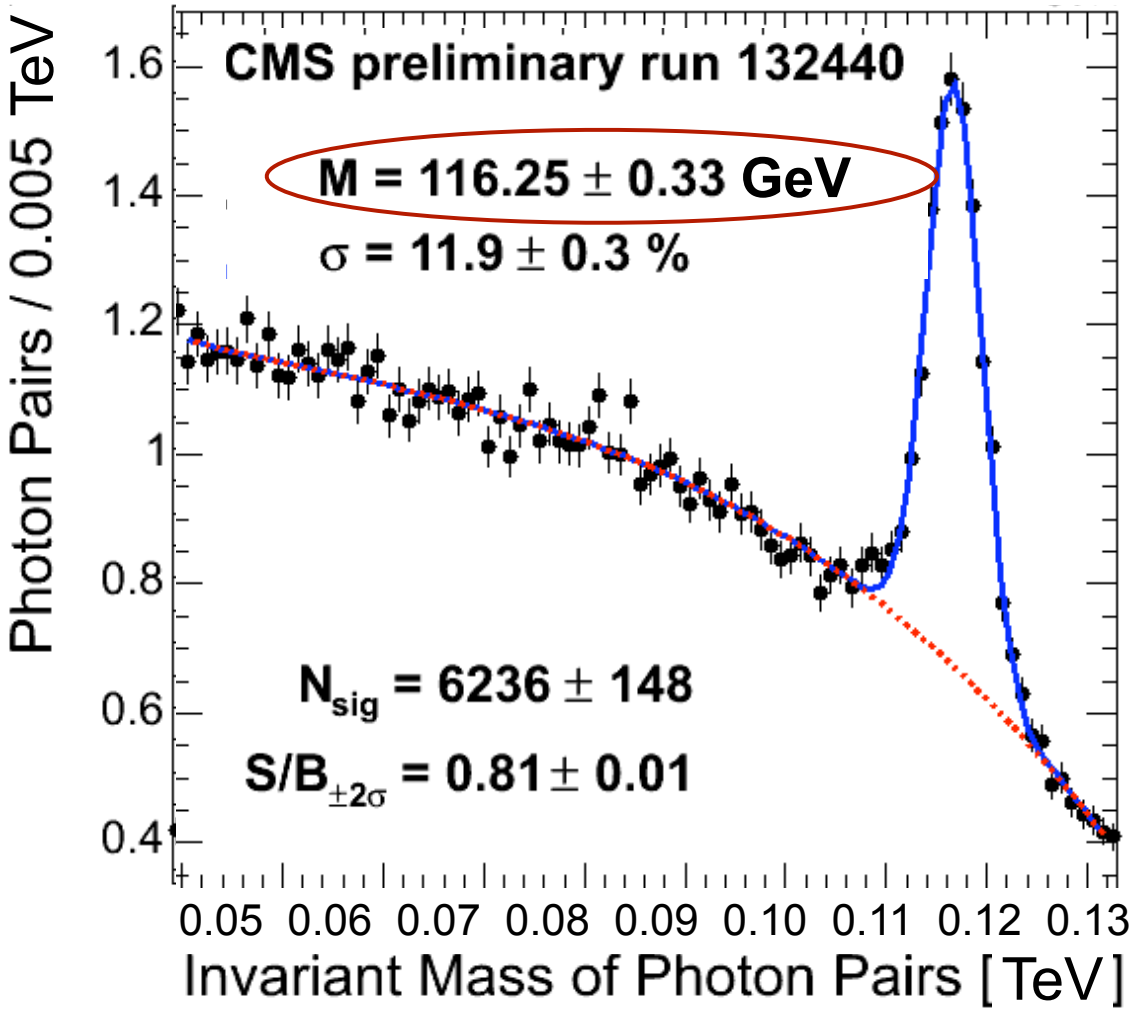
- For the SM Higgs boson @ 7TeV with $1fb^{-1}$ of integrated luminosity CMS is going to be competitive with Tevatron, putting experimental limits more stringent than the actual ones
- In the BSM Higgs world, looking for something with a standard/quite standard/ no standard topology will allow us to exclude(discovery) models

Very exciting time is just around the corner ...

... finger crossed that the following figures ...



... might be very soon ...


CMS preliminary run 132440
M = 116.25 ± 0.33 GeV
σ = 11.9 ± 0.3 %
N_sig = 6236 ± 148
S/B_±2σ = 0.81 ± 0.01
Photon Pairs / 0.005 TeV
1.6
1.4
1.2
1
0.8
0.6
0.4
0.05 0.06 0.07 0.08 0.09 0.10 0.11 0.12 0.13
Invariant Mass of Photon Pairs [TeV]


HIGGS BOSON

BACKUP

Final states to search/exclude...

... a multilepton example

	Final state		xsec	pT spec.
Doubly Charged Higgs	2l (2lSS)	Single H^{++} Prod	up to 10 fb-1	hard lept
	3l (2lSS+1l)	H^{++}/H- Prod	up to 10 fb-1	hard lept
	4l (2lSS+2lSS)	Double H^{++} Prod	up to 10 fb-1	hard lept
MSSM Higgs SUSY decay	3l + MET (2lOS+1l)	H^{+} to Chi2Chi+	up to 5 fb-1	soft lept
	4l + MET (2lOS+2lOS)	A/H to Chi2Chi2	up to 5 fb-1	soft lept
NMSSM Higgs	2l+jets (2lOS)	H to hh to 2Z2V	up to 3 fb-1	lept from Z on shell
	4l +jets (2lOS+2lOS)	A to hZ to VVZ	up to 7 fb-1	lept from Z on shell
Non Abelian Higgs	4l (2lOS+2lOS)	H to Z'Z'	up to 5 fb-1	soft lept