



H → ZZ^(*) → 4 leptons status and prospects

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LLR – Ecole Polytechnique



Outline



- Higgs boson research in diboson decays
- Lepton reconstruction
- $H \rightarrow ZZ^(*) \rightarrow 4\ell$ analysis
 - An M_H independent cut-based selection
- Prospects of the analysis
 - Improvements of the analysis strategy
 - Analysis at 10 TeV

AN 2008-050
PAS HIG-08-003
(14 TeV, 1fb^{-1})



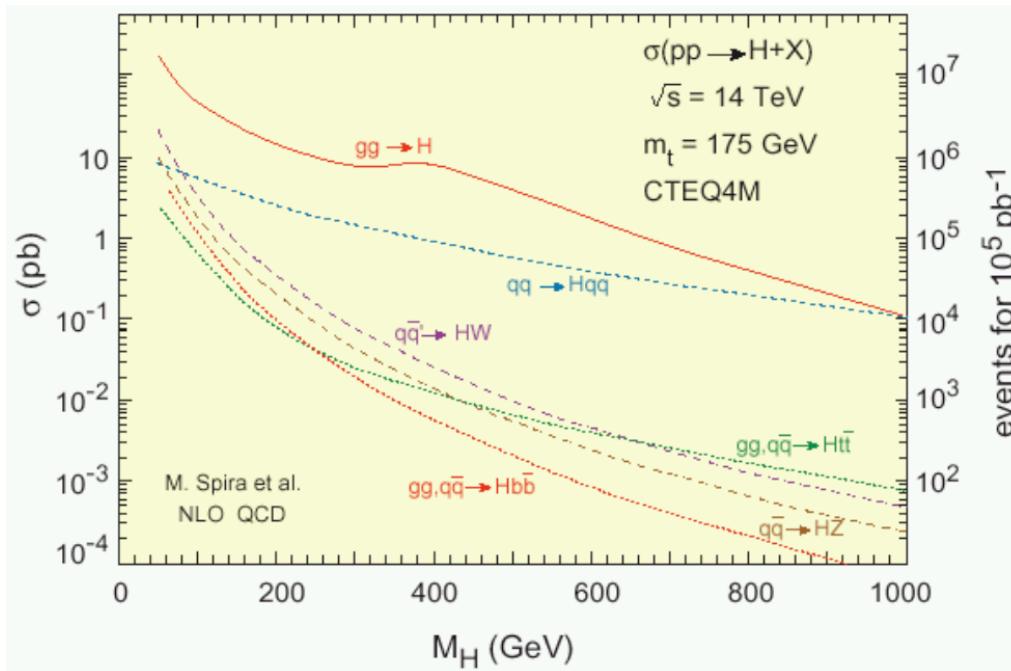
Higgs boson research



Higgs boson production

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- Inclusive production



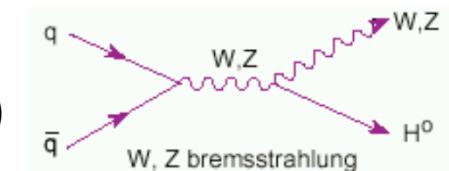
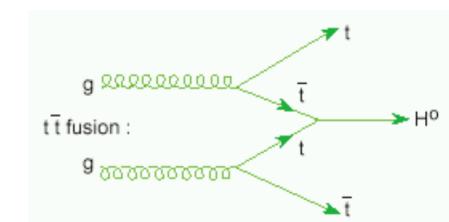
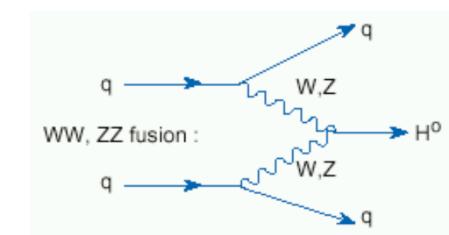
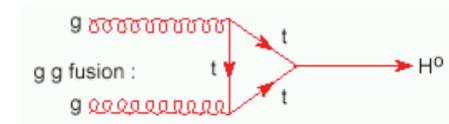
A. Djouadi

- gg fusion

- vector boson fusion

- $t\bar{t}$ fusion

- associated production (W,Z)



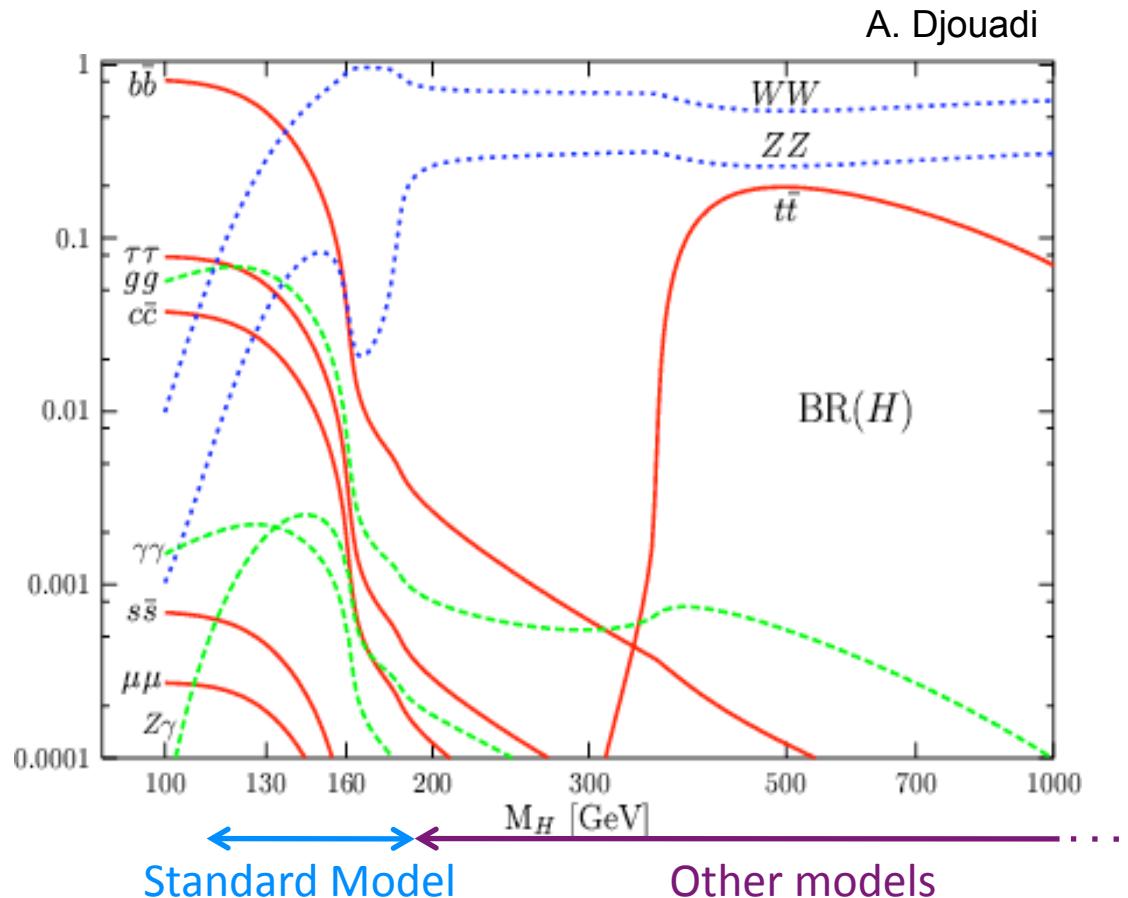


Higgs boson decays

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- Lower masses:
 $H \rightarrow \gamma\gamma, \tau\tau$
- Higher masses:
 $H \rightarrow WW \rightarrow \ell\nu\ell\nu$
 $H \rightarrow ZZ \rightarrow 4\ell$

4e, 4μ, 2e2μ



Analysis at 14 TeV, 1 fb^{-1}

$M_H = 115\text{-}200 \text{ GeV}; 250 \text{ GeV}$



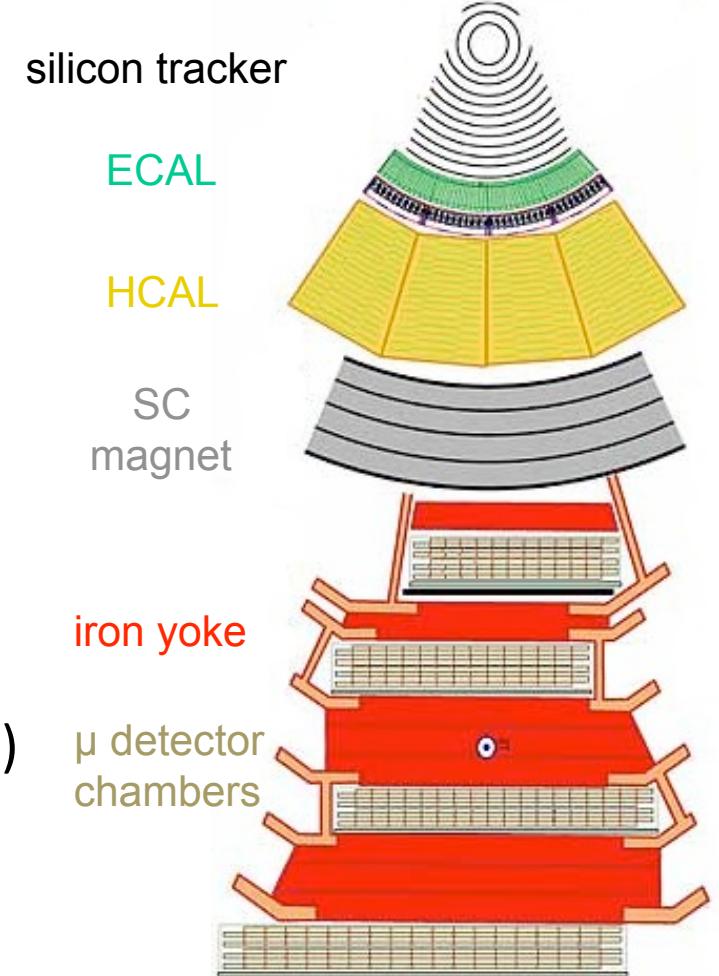
Lepton reconstruction



e/ μ detection with CMS



- Electrons 85-95% efficiency (p_T, η)
 - ECAL-driven reconstruction
 - Energy supercluster in the ECAL
 - Seed and track in the silicon tracker
 - (Si tracker: $|\eta| < 2.5$, ECAL: $|\eta| < 3$)
- Muons 95-99% efficiency (η)
 - Muon chamber-driven reconstruction
 - Hits in the fast muon chambers
 - Outer track (high resolution chambers)
 - Inner track (silicon tracker)
 - (μ chambers: $|\eta| < 2.4$)



Efficiency control via $Z \rightarrow \ell\ell$ measurements



e/ μ detection with CMS

Prospects of improvement



- Electrons
+1-4% efficiency (p_T , η) (e reco)

merging ECAL-driven and

Particle Flow reconstructed electrons

CMSSW 3.1.x

*Ongoing work at level
of e reconstruction*

- Muons
+1-3% efficiency ($H \rightarrow ZZ \rightarrow 4\mu$ skim)

reconstruct all muons

(*global + tracker + standalone muons*)

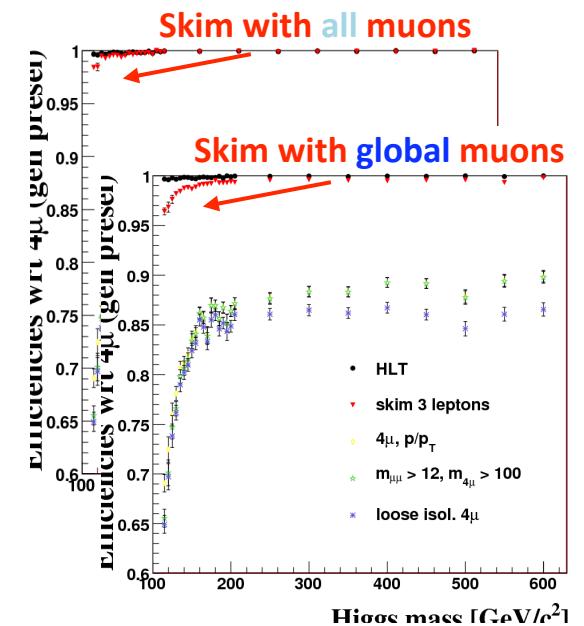
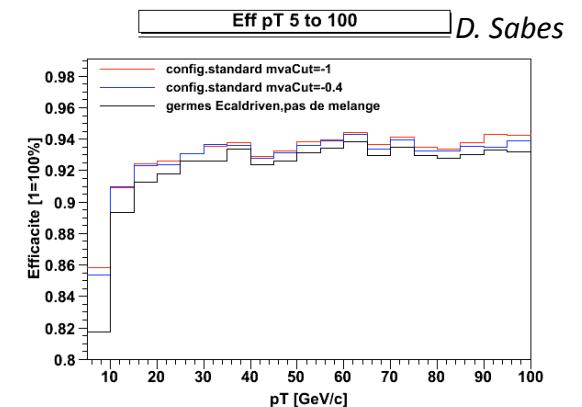
CMSSW 2.2.x

*Ongoing work
In the analysis*

CMS France

28/05/2009

$H \rightarrow ZZ \rightarrow 4l$ analysis: status and prospects





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



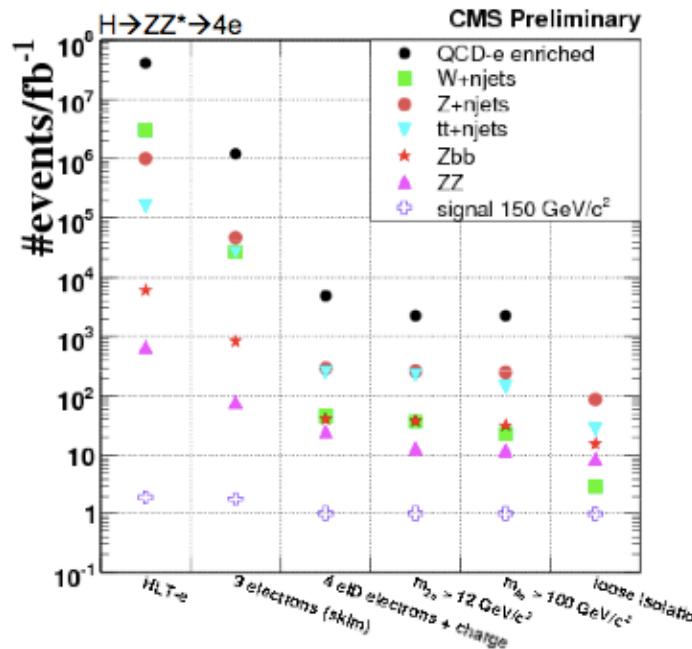
ZZ^(*) channel strategy

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- Preselection (*QCD, Z/W+jets*)

- *at least* 2 pairs of opposite charge, matching flavour leptons
- Lower cuts on p_T^ℓ , $m_{\ell^+\ell^-}$, $m_{4\ell}$; loose isolation

AN 2008-050
CMSSW 1.6.x



- Identification of the « Z pair » and the « Z* pair » [exactly 4ℓ]



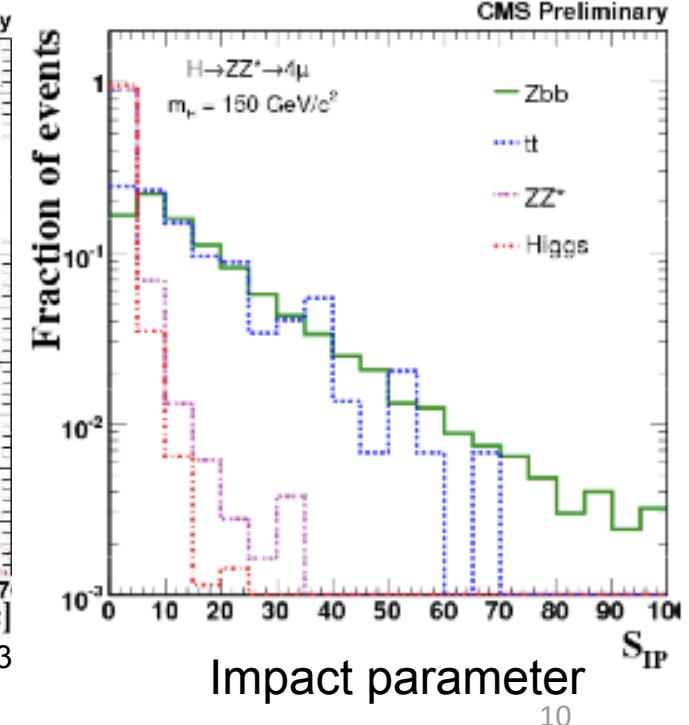
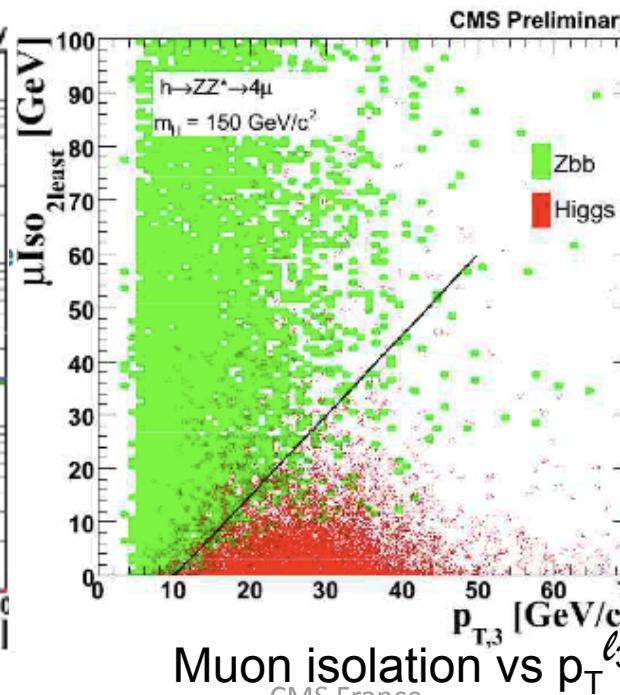
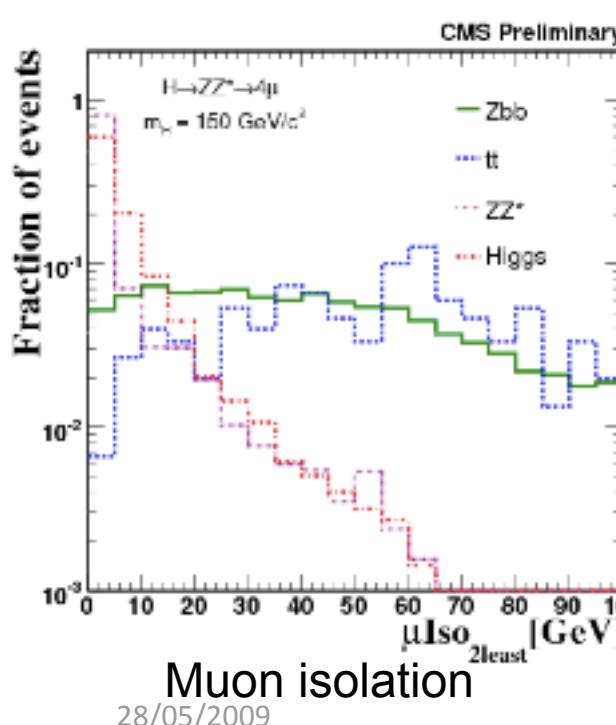
ZZ^(*) channel strategy

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- Further selection ($Z+jets, t\bar{t}, Zbb$)

- isolation, $p_T^{\ell_{\text{lowest}}}$, impact parameter
- Restrictions on the reconstructed « m_Z » and « m_{Z^*} »

AN 2008-050
CMSSW 1.6.x



$H \rightarrow ZZ \rightarrow 4l$ analysis: status and prospects

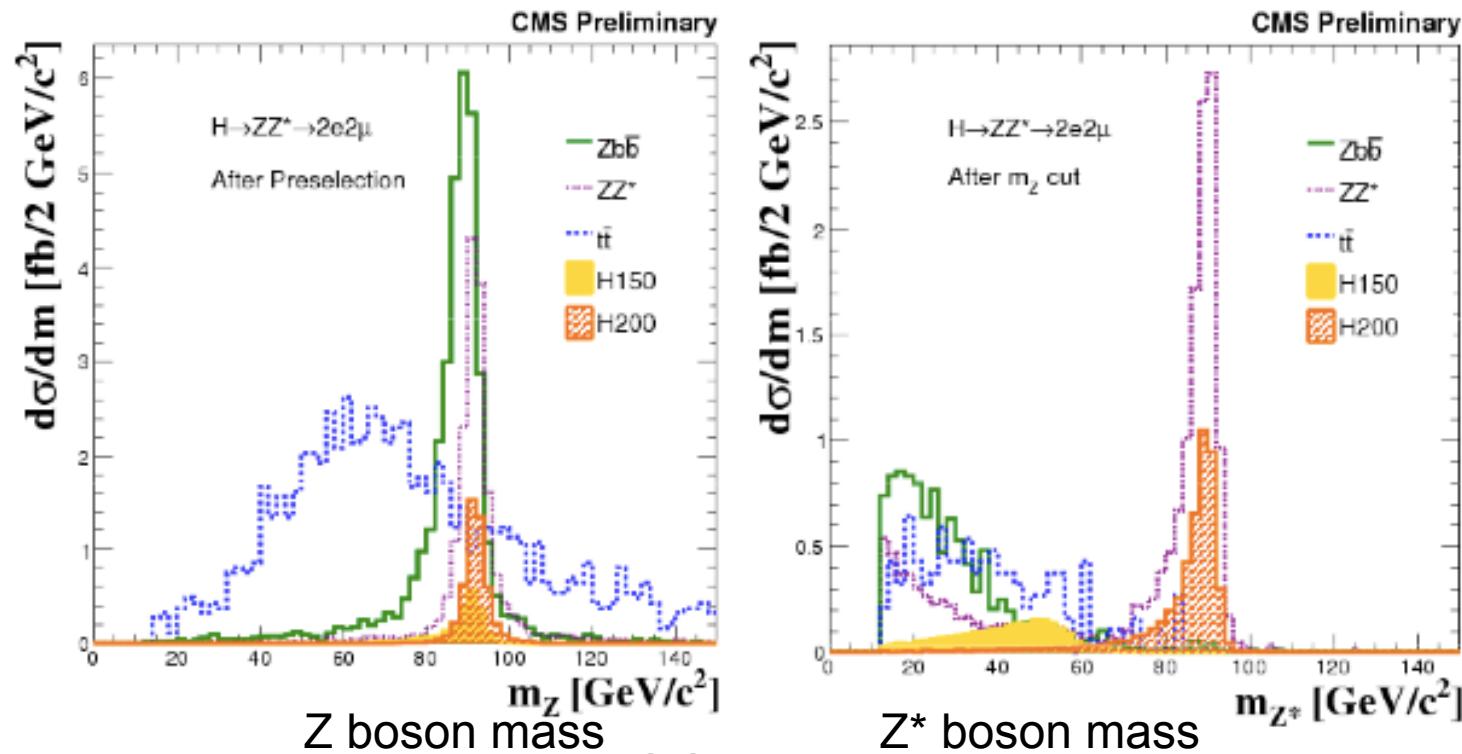


ZZ^(*) channel strategy

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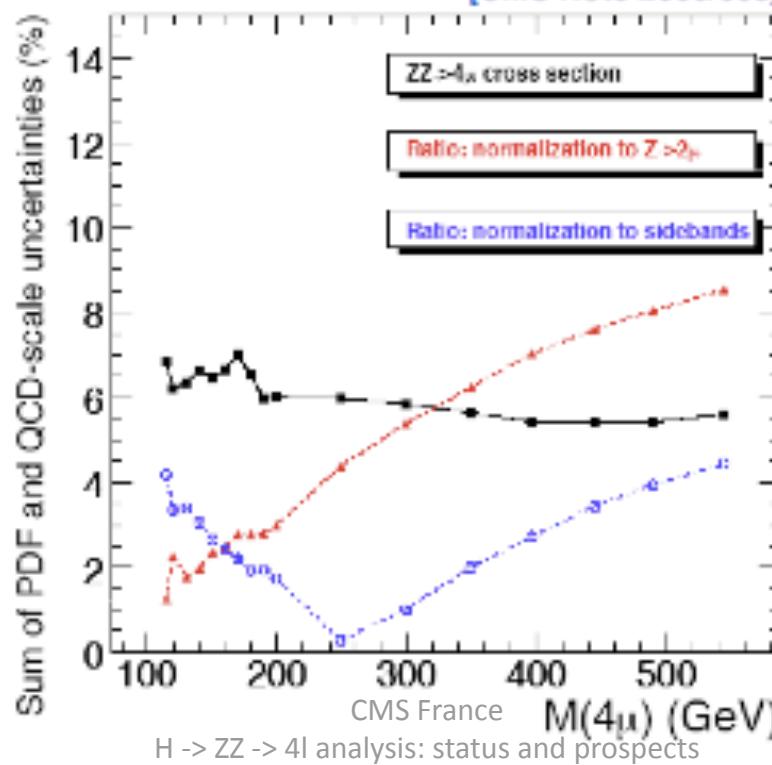
AN 2008-050
CMSSW 1.6.x





ZZ^(*) channel strategy

- Systematics and control from data (ZZ)
 - Efficiency measurement with Z production
 - Normalization ZZ/Z
 - Random cone technique [CMS Note 2006/068]





ZZ^(*) channel results

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14 TeV

1 fb⁻¹

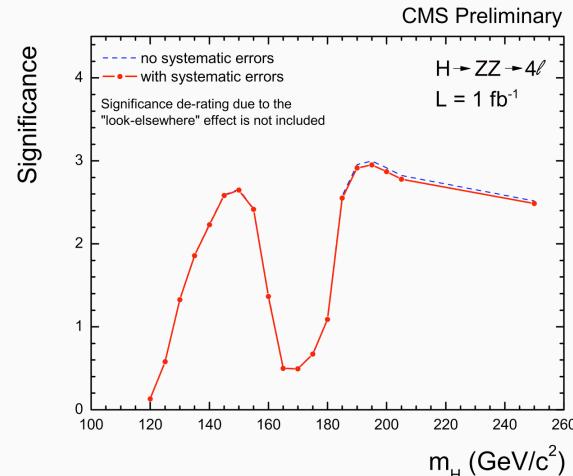
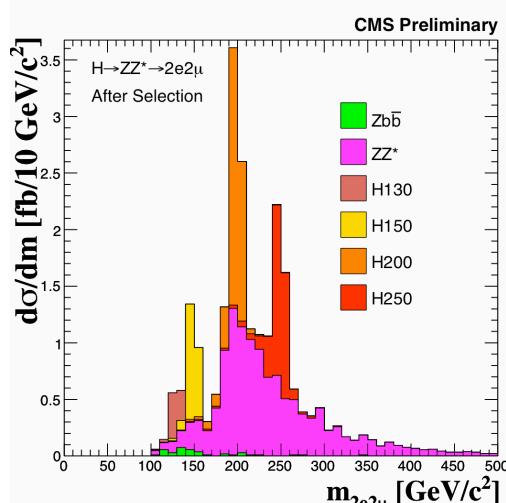
AN 2008-050
CMSSW 1.6.x

(agreement of CMSSW 2.2.x)

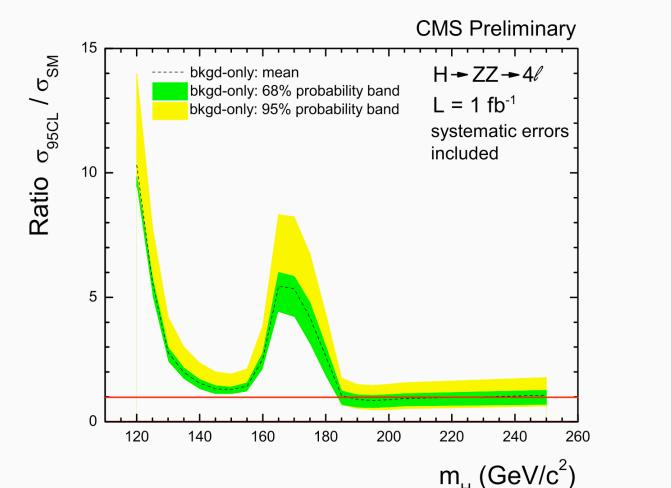


look-elsewhere effects

need to subtract $\sim 1\sigma$ in the significance



Not enough luminosity
for a discovery



\sim exclusion for $M_H \gtrsim 185$ GeV



Combined WW^(*) and ZZ^(*) channels

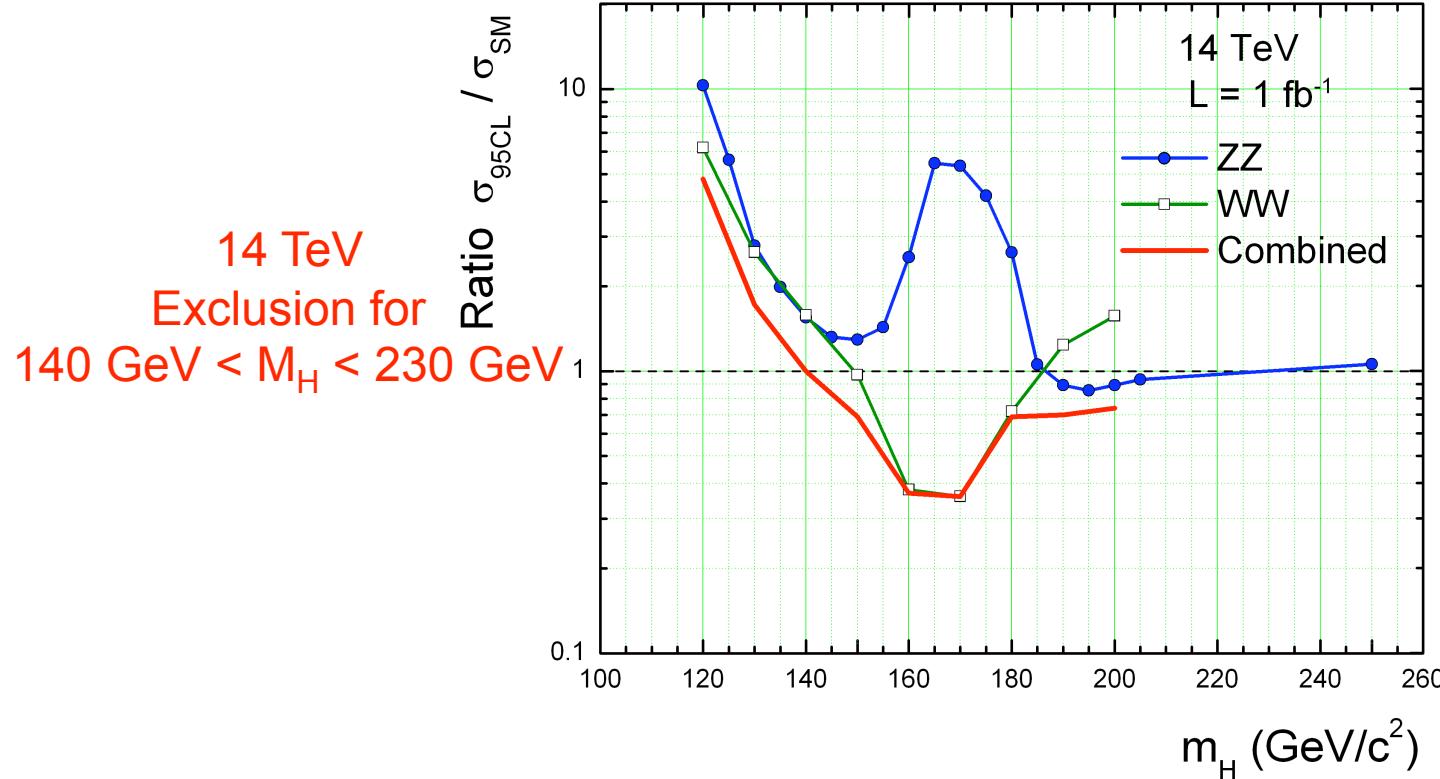
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AN 2009-020

14 TeV

1 fb⁻¹

CMS Preliminary





Prospects



H → ZZ(^{*}) schedule

Start for $\sqrt{s} \sim 10$ TeV
instead of 14 TeV

- 50 pb⁻¹
Study of Z → ee
Study of WZ production

 - 200 pb⁻¹
Study of ZZ continuum
H → ZZ: First exclusion limits for M_H > 200 GeV
H → WW: Exclusion

 - 1 fb⁻¹ AN 2008-050
Start H → ZZ analysis including M_H < 2 M_Z
Exclusion / discovery for H → WW analysis

 - few x 10 fb⁻¹
Higgs boson discovery; properties...
- ~ summer 2010
- ~ autumn 2010
- ~ autumn 2011
- ...





ZZ^(*) channel prospects



- Preselection (ℓ selection (QCD))
preserve signal low p_T leptons
- M_H -independent selection
open-up minimal requirements
- Optimization for M_H hypothesis
 m_{Z1}, m_{Z2}, p_T^ℓ in H rest-frame
- Generalized Analysis
 S_{CP} , *hadronic recoil*
- Tag-and-probe & Data-driven tools for systematics
lepton isolation via random cones



ZZ^(*) channel prospects



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preserve signal low p_T leptons
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lepton isolation via random cones



ZZ^(*) channel prospects



CMSSW 2.2.x

- Further selection
 - Cut optimization: impact parameter

Currently use for each track:

Significance of the 3D Impact Parameter : $\text{IP}/\Delta(\text{IP})$

Use also for each track: STIP: $\text{IP}_T/\Delta(\text{IP}_T)$, SLIP: $\text{IP}_L/(\text{IP}_L)$

Geometric discriminator (compatibility) of the 4 tracks



ZZ^(*) channel prospects



CMSSW 2.2.x

- Further selection
 - Cut optimization: lepton isolation

Measurement inside an isolation cone (jets),
except the veto cone (ℓ) inside it:

μ : cut on Σp_T^{cone}

e : cut on $(\Sigma p_T^{\text{cone}}) / p_T^\ell$

- $(\Sigma p_T^{\text{cone}}) / p_T^\ell$ also for muons? (*better except low p_T*)
- Common isolation code
- Tuning of the parameters (*with data, using $Z \rightarrow ee$?*)
- Systematics?



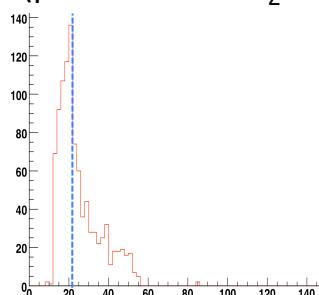
ZZ^(*) channel prospects



CMSSW 2.2.x

- Further selection
 - Cut optimization: m_{Z^*} , $p_T^{\ell \text{ lowest}}$

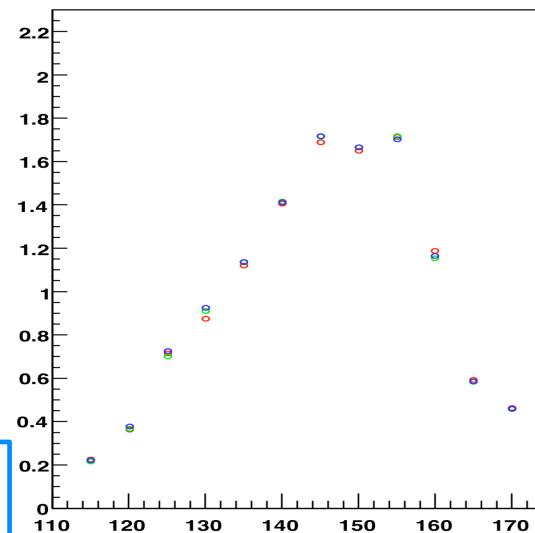
H120: Z* mass
(preselection+ m_Z cut)



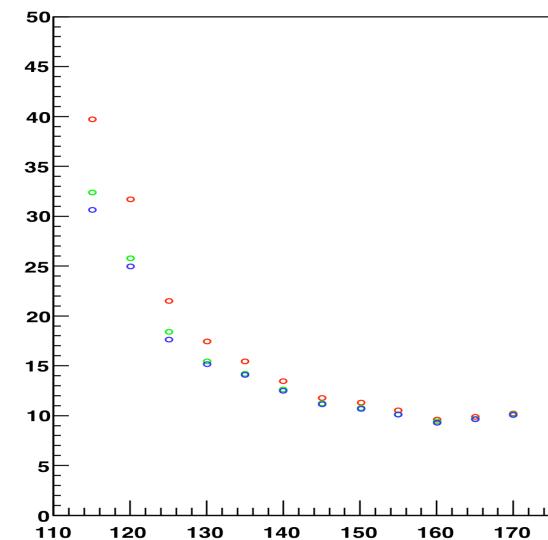
Usual cuts:
 $m_{Z^*} > 20 \text{ GeV}$
 $p_T^{\ell^4} > 7 \text{ GeV}$

Better cuts
 $(M_H < 150 \text{ GeV})$:
 $m_{Z^*} > 12 \text{ GeV}$
 $p_T^{\ell^4} > 6 \text{ GeV}$

Significance for discovery vs M_H :
To be maximized



Upper limit for exclusion vs M_H :
To be minimized



Usual cuts: $m_{Z^*} > 20 \text{ GeV}$, $p_T^{\ell^4} > 7 \text{ GeV}$
New m_{Z^*} cut: $m_{Z^*} > 12 \text{ GeV}$, $p_T^{\ell^4} > 7 \text{ GeV}$
New m_{Z^*} and $p_T^{\ell^4}$ cuts: $m_{Z^*} > 12 \text{ GeV}$, $p_T^{\ell^4} > 6 \text{ GeV}$



ZZ^(*) channel prospects



CMSSW 2.2.x

- Systematics and control from data
 - Side bands (control regions)
to extrapolate background in signal region (Zbb, ZZ)
 - Reliability of the theoretical ZZ/Z ratio
control relaxing flavour/charge conditions
- Weighted experiment strategy
 - Fitting of the Higgs mass shape



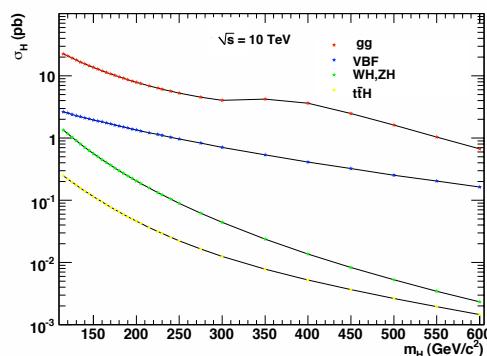
ZZ^(*) channel prospects



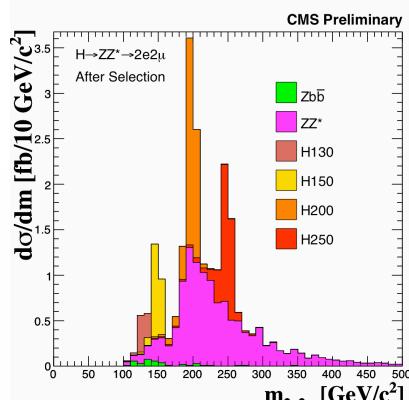
CMSSW 2.2.x

- $\sqrt{s} = 14 \text{ TeV}$ to $\sqrt{s} = 10 \text{ TeV}$

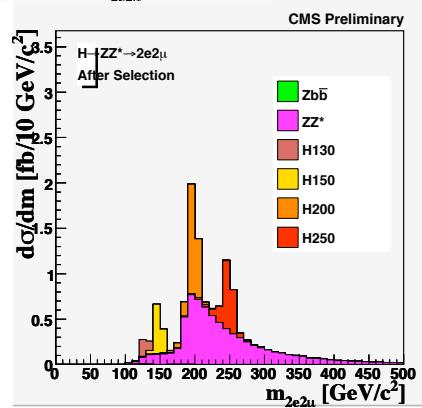
$(M_H \text{ up to } 600 \text{ GeV})$



Higgs boson production cross sections at 10 TeV

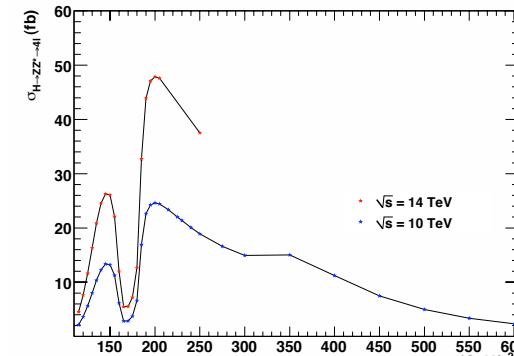


14 TeV

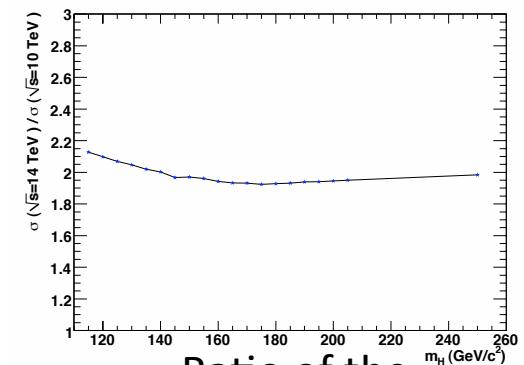


10 TeV

CMS France
H → ZZ → 4l analysis: status and prospects



2e2mu cross sections



Ratio of the
2e2mu cross sections²²



Conclusion



- An already good analysis at 14 TeV, 1 fb^{-1}
- Results at 10 TeV, 1 fb^{-1} to come soon
(in agreement with LHC schedule)
- Plans for improvements within next months
- Next step: 4ℓ workshop on 1st-2nd-3rd of July
at LLR (Ecole Polytechnique, Palaiseau)

<http://indico.cern.ch/confRegistrationFormDisplay.py?confId=59620>

defilip@mail.cern.ch

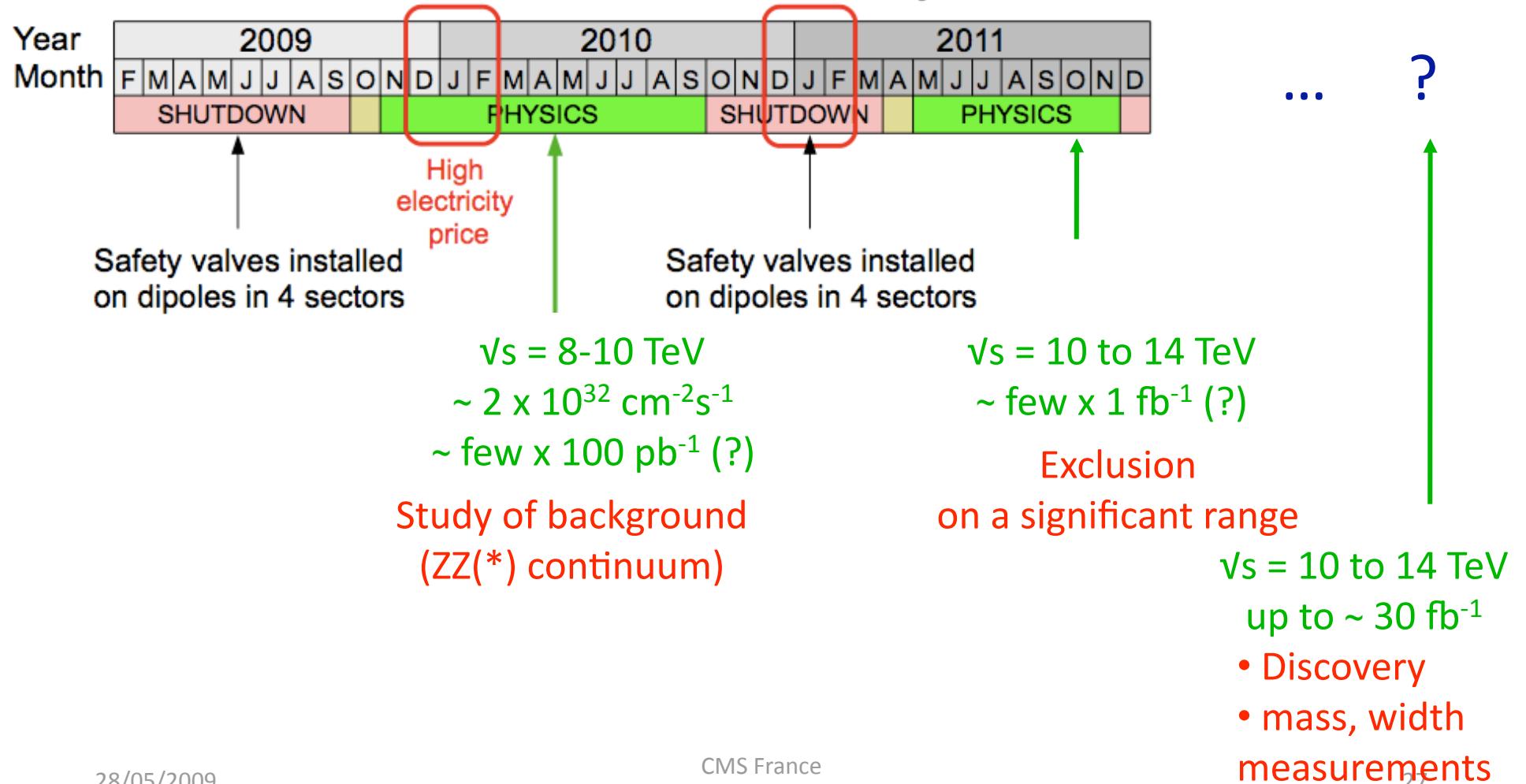
Back-up Slides



Higgs diboson schedule

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LHC Schedule announced on 9 February 2009

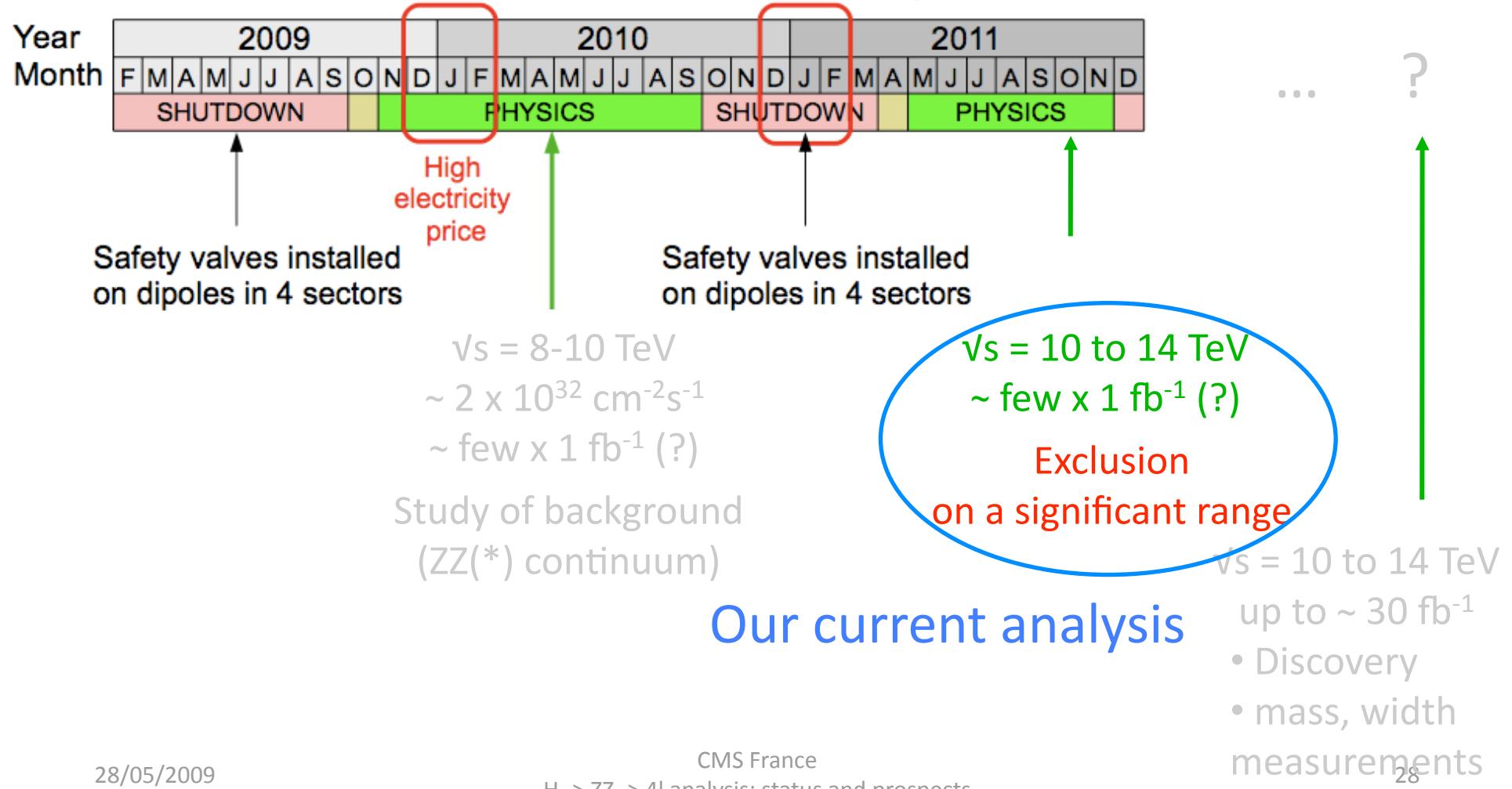




Higgs diboson schedule

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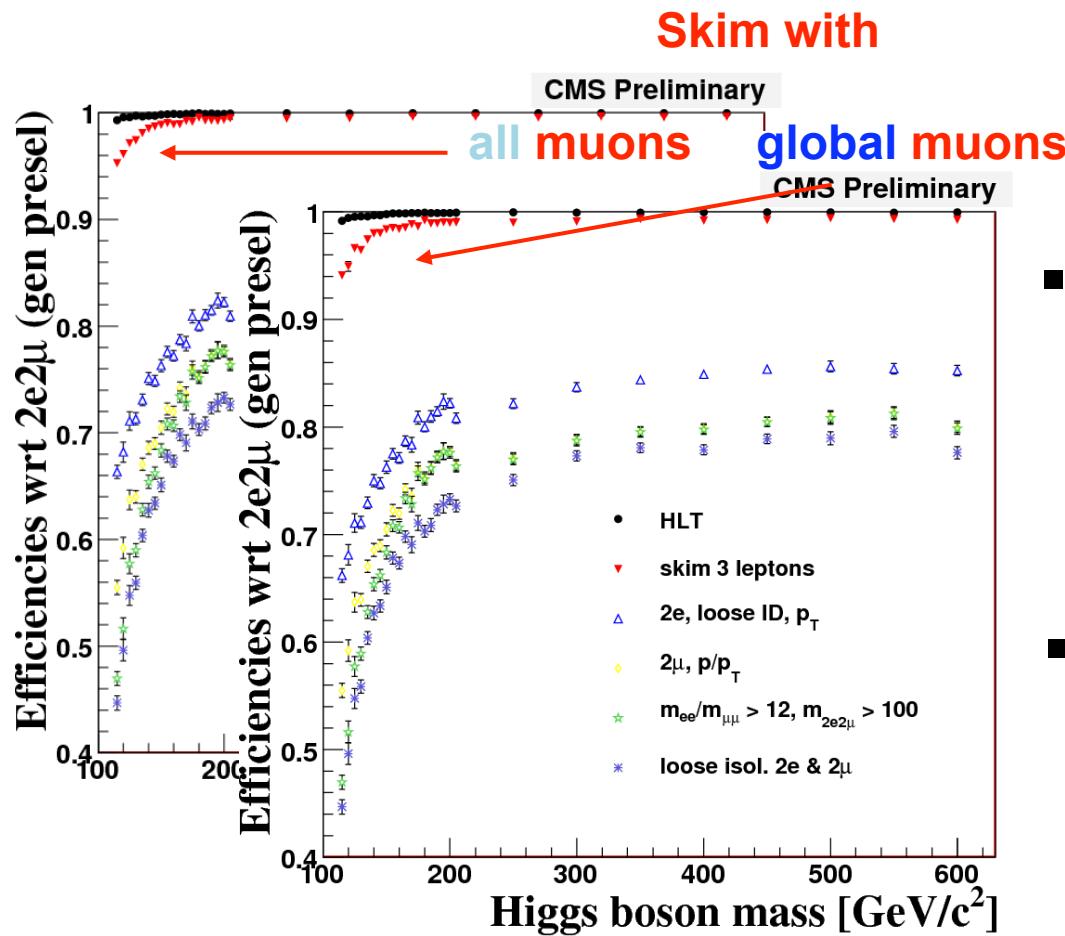
LHC Schedule announced on 9 February 2009



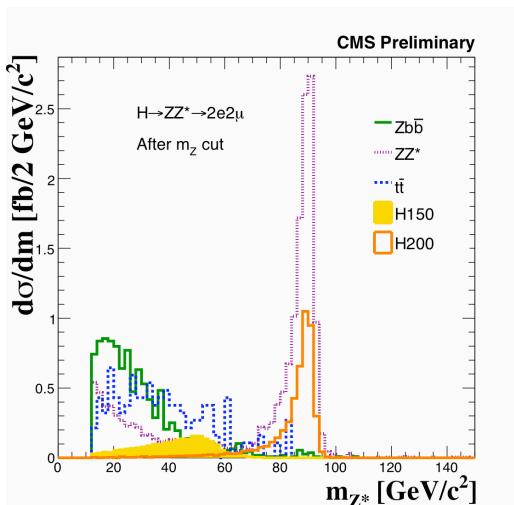
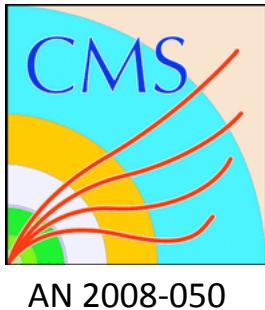


ZZ^(*) channel prospects

CMSSW 2.2.x



- Global muons → All muons
- e/μ ID optimization (choices, constraints on parameters)



ZZ $^{(*)}$ channel prospects

H120

Z * mass cut optimization

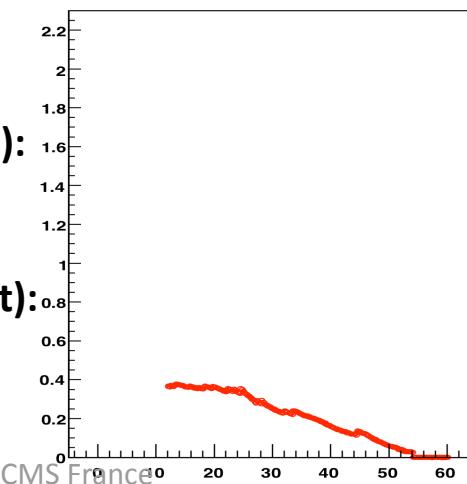
CMSSW 2.2.x



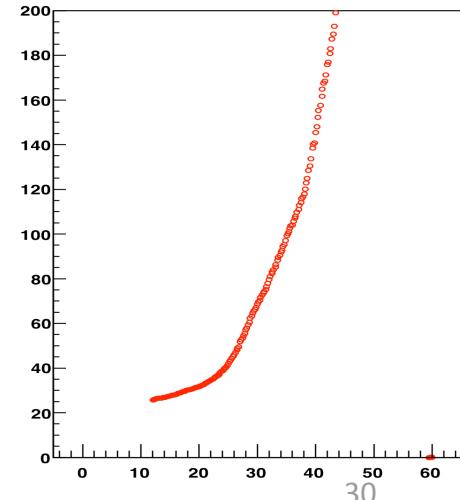
Z * mass (after preselection+m $_{Z^*}$ cut)



Significance vs Minimal Cut in Zstar Mass



N_95 vs Minimal Cut in Zstar Mass



Usual cuts:

$$20 \text{ GeV} < m_{Z^*} < 100 \text{ GeV}$$

$$p_T^{\ell_4} > 7 \text{ GeV}$$

Significance for discovery vs m $_{Z^*}$ cut (left):
To be maximized

Upper limit for exclusion vs m $_{Z^*}$ cut (right):
To be minimized

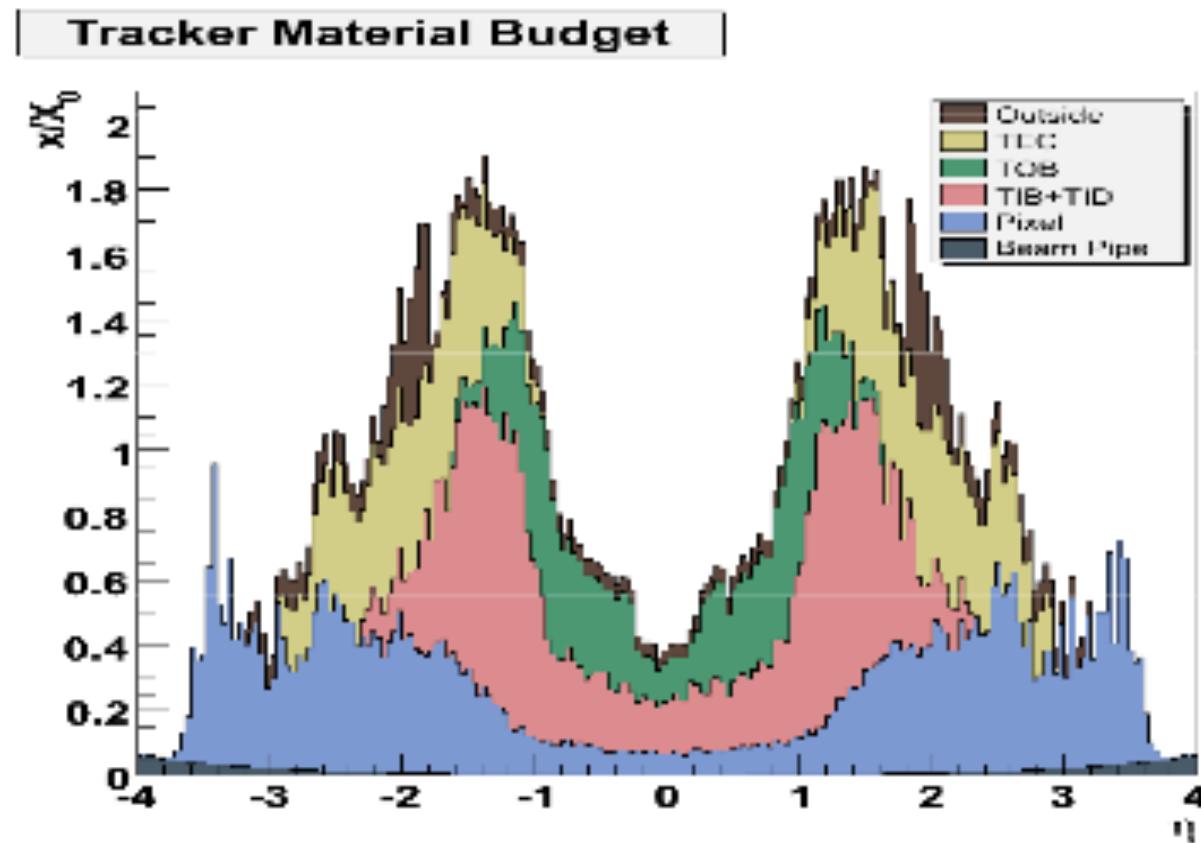
28/05/2009

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e reconstruction: impact of material budget

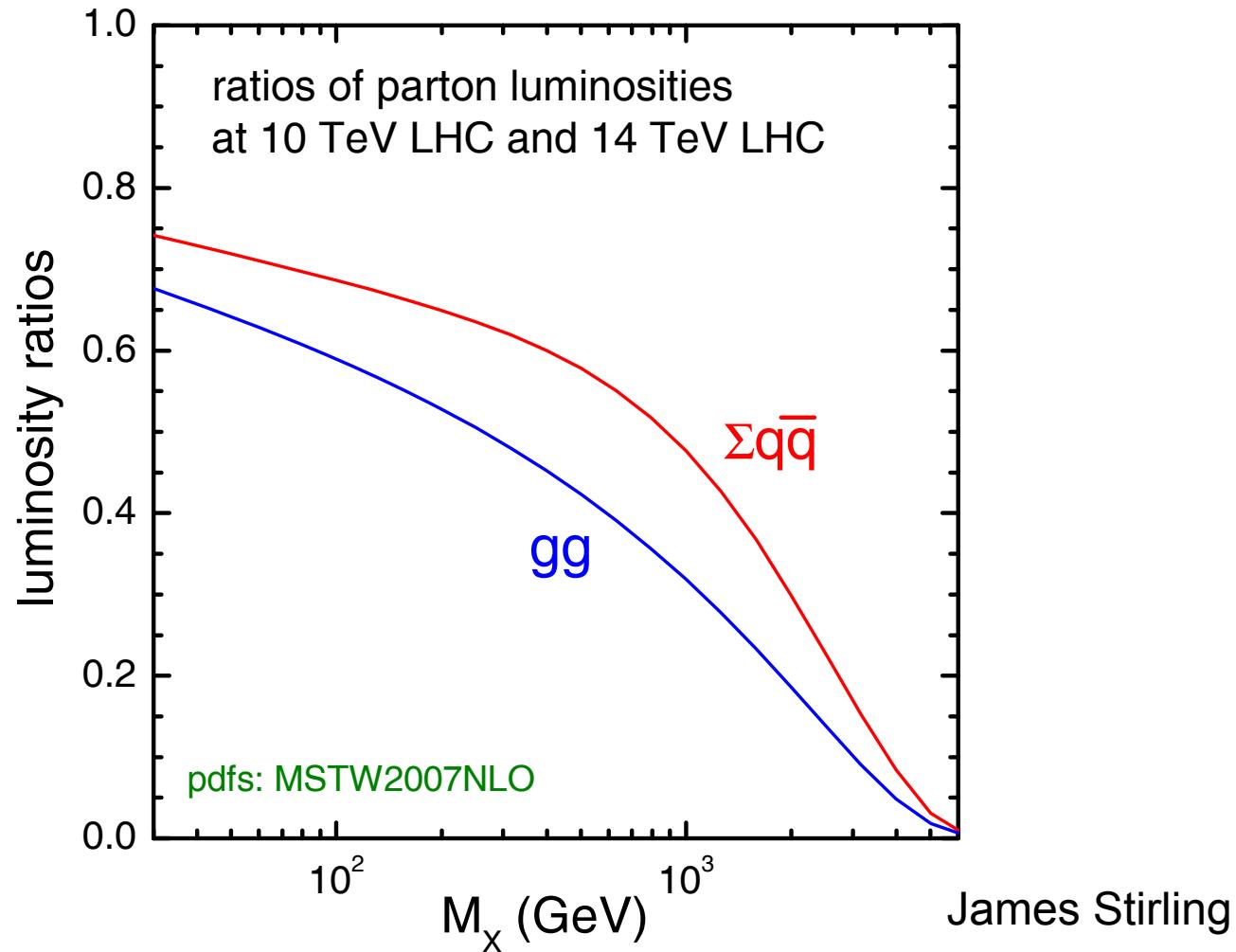
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10 TeV to 14 TeV ratio

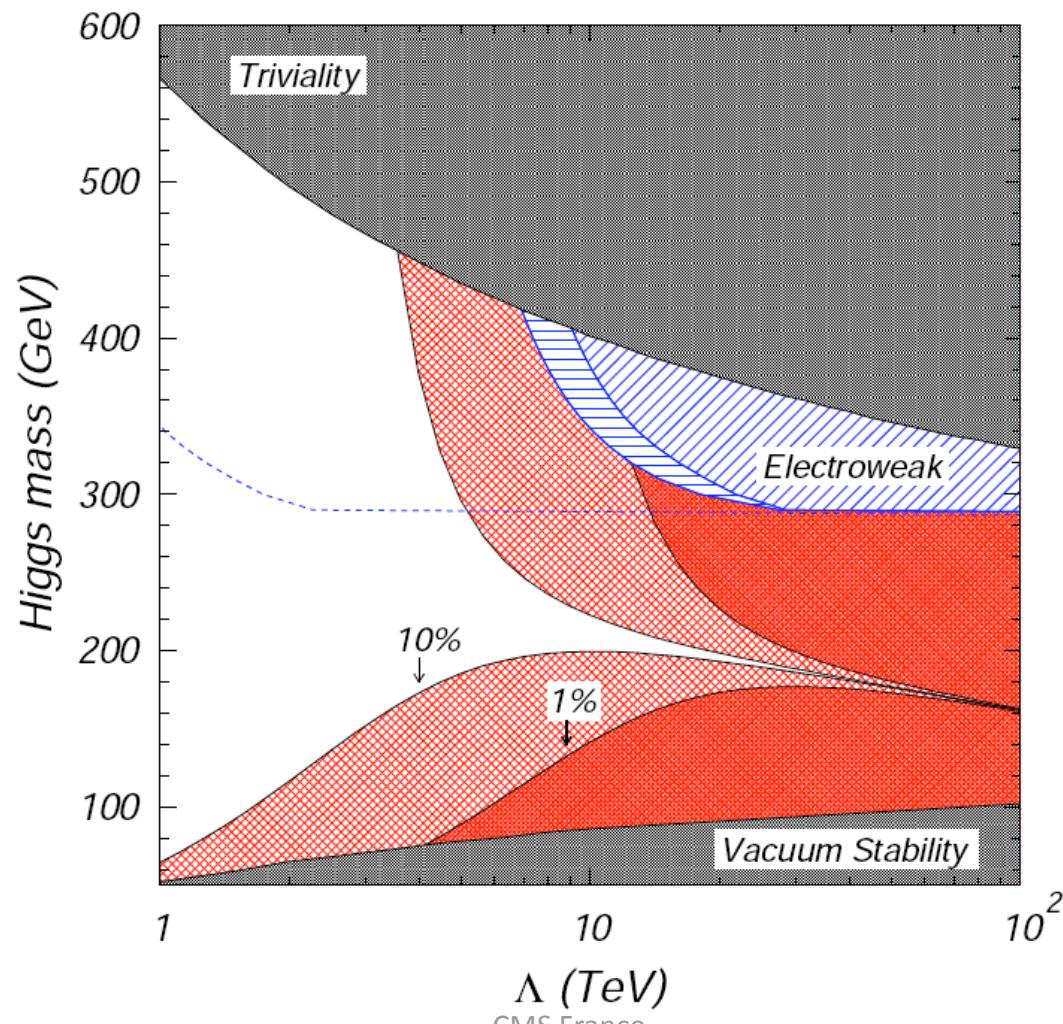
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Constraints on a SM Higgs mass

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The CMS detector

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