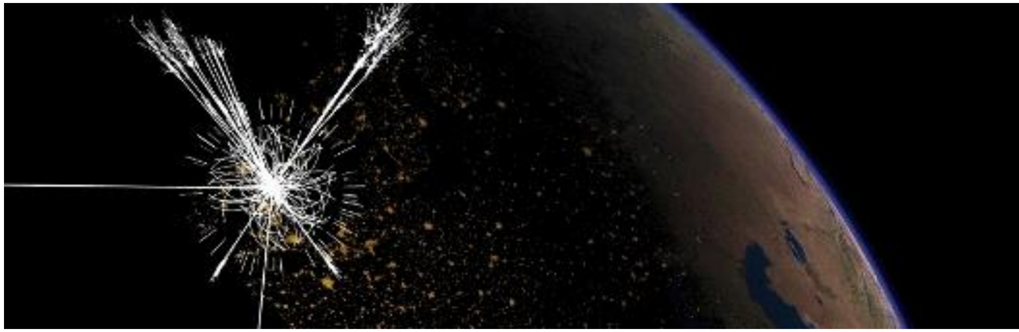
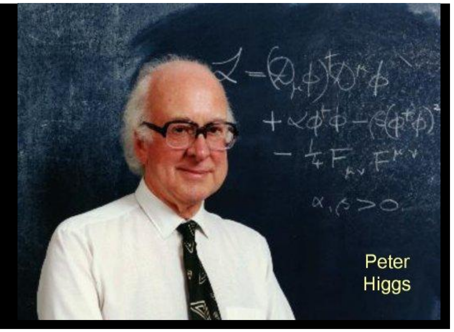


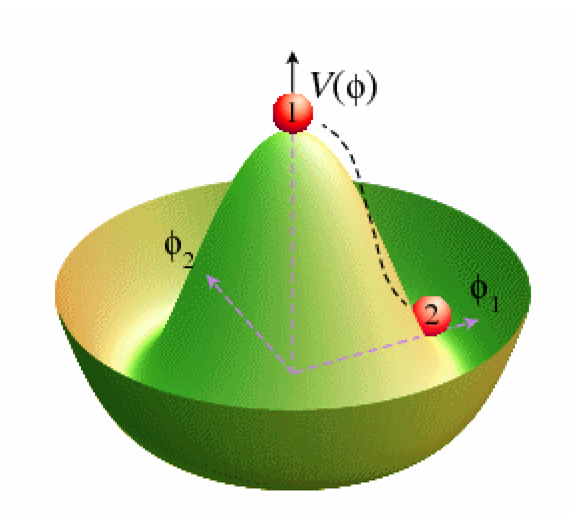


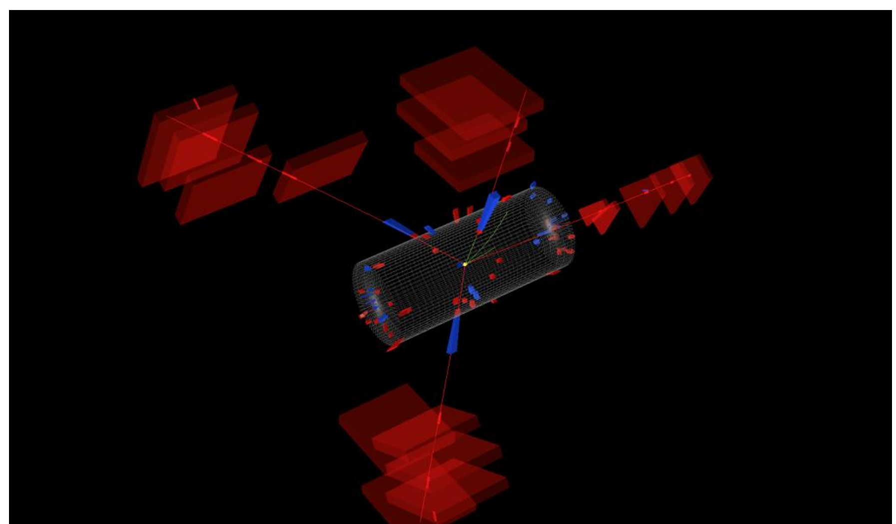
Higgs boson(s) at LHC (CMS)

A. Nikitenko, Imperial College

Seminar in Hamburg and Zeuthen

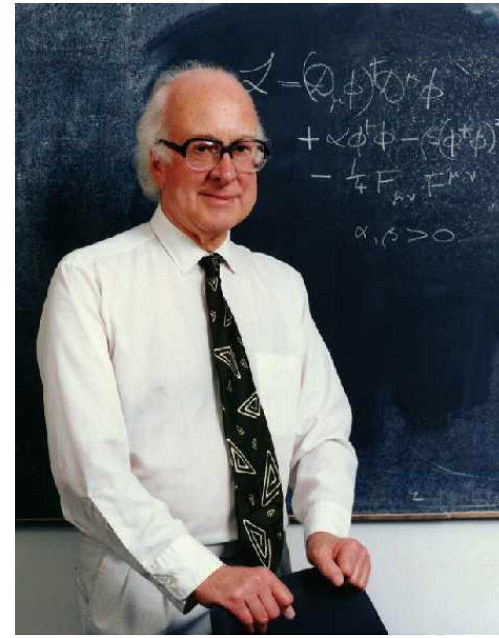
15-16th March 2011





J. J. Sakurai Prize for Theoretical Particle Physics

2010: (L to R) Kibble, Guralnik, Hagen, Englert, Brout, Higgs



"For elucidation of the properties of spontaneous symmetry breaking in four-dimensional relativistic gauge theory and of the mechanism for the consistent generation of vector boson masses."

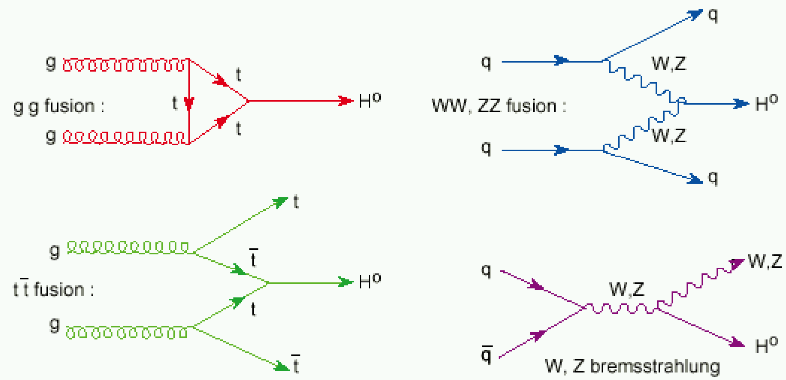
Higgs boson is the only not discovered particle in Standard Model

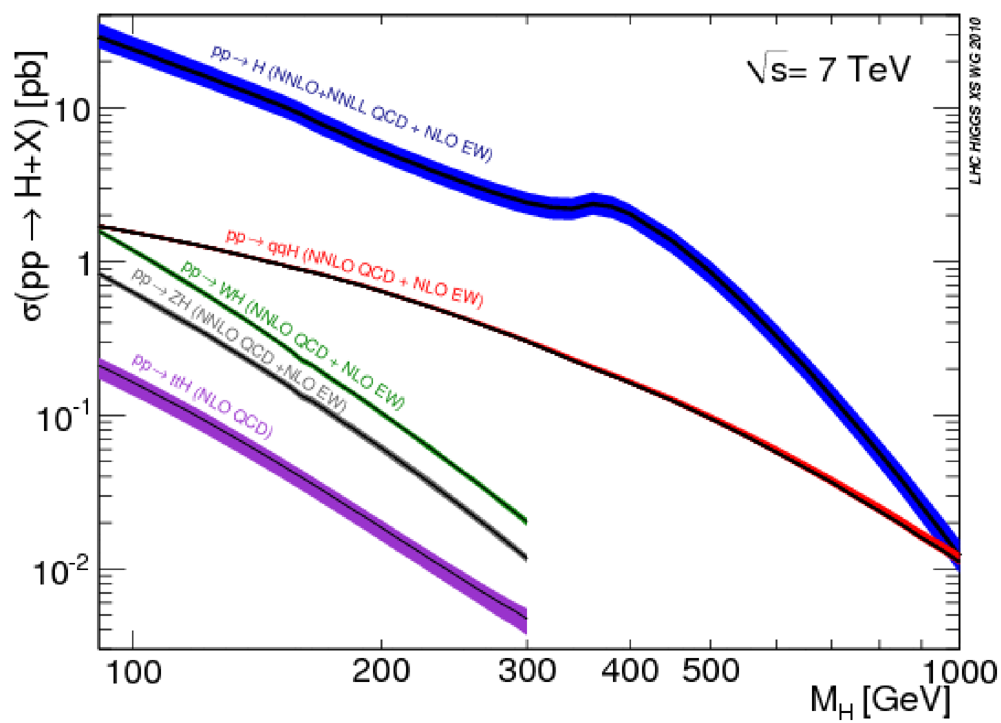
are all these brilliant theorists right about mechanism of generation of particle masses ?

LHC has been build manly for Higgs boson discovery

Phenomenology : Standard Model Higgs at LHC (I)

H^o production at hadron colliders:

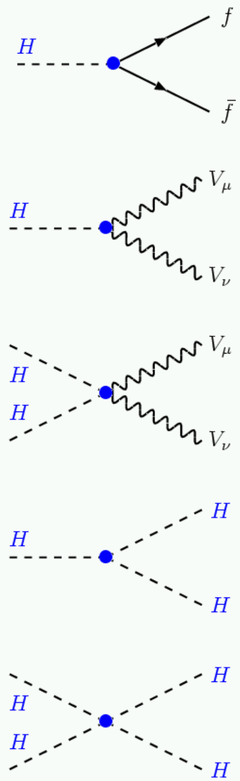




"Handbook for LHC Higgs Cross Sections"
S. Dittmaier et al.
arXiv 1101.0593

SM Higgs boson couplings and Br. ratios

tree level couplings



$$g_{Hff} = m_f/v = (\sqrt{2}G_\mu)^{1/2}\, m_f \qquad \times\ (i)$$

$$g_{HVV} = 2M_V^2/v = 2(\sqrt{2}G_\mu)^{1/2}\, M_V^2 \qquad \times\ (-ig_{\mu\nu})$$

$$g_{HHVV} = 2M_V^2/v^2 = 2\sqrt{2}G_\mu\, M_V^2 \qquad \times\ (-ig_{\mu\nu})$$

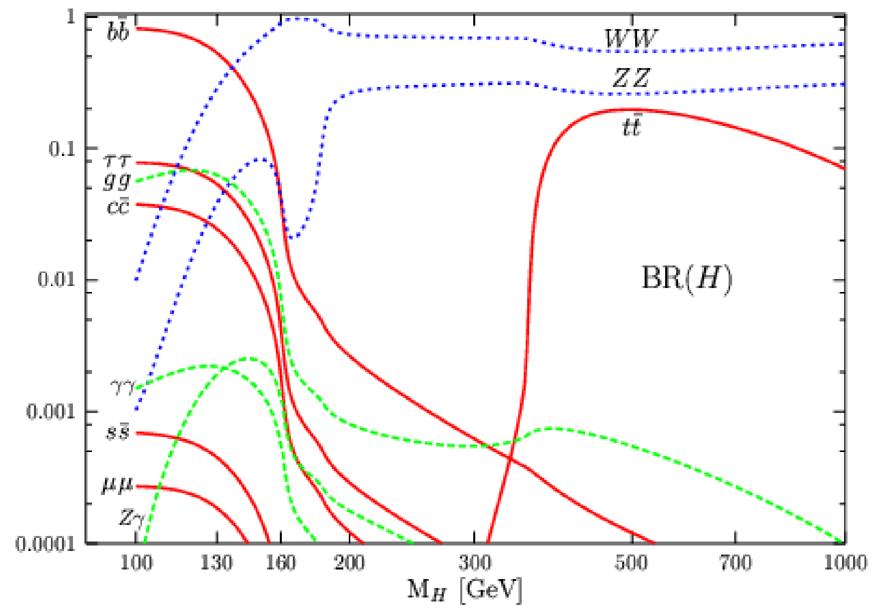
$$g_{HHH} = 3M_H^2/v = 3(\sqrt{2}G_\mu)^{1/2}\, M_H^2 \qquad \times\ (i)$$

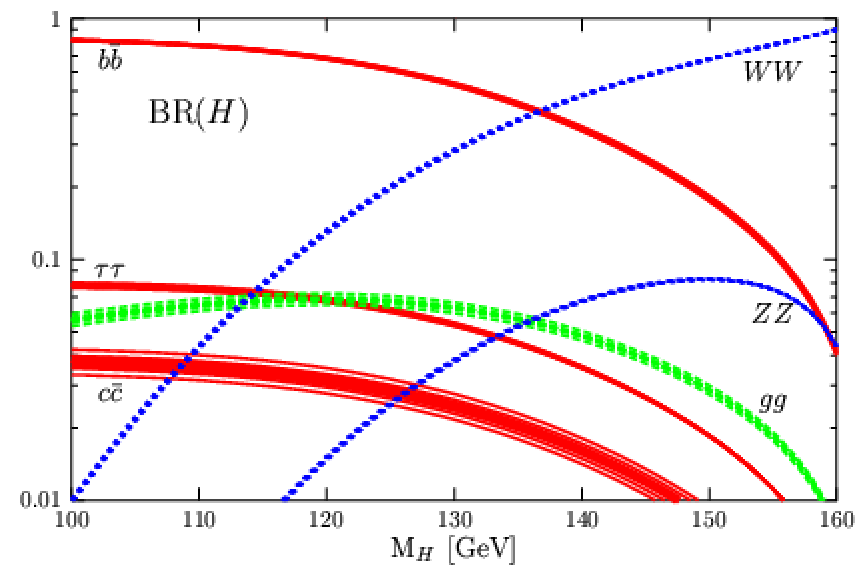
$$g_{HHHH} = 3M_H^2/v^2 = 3\sqrt{2}G_\mu\, M_H^2 \qquad \times\ (i)$$

v is vev of Higgs field = 246 GeV

Right bottom plot includes uncertainties from the quark masses m_t, m_b, m_c and $\alpha_s(M_Z)$

Djouadi, Kalinowski, Spira





What is the mass of Higgs boson in Standard Model ?

$m^2_H = \lambda v^2$ – free parameter

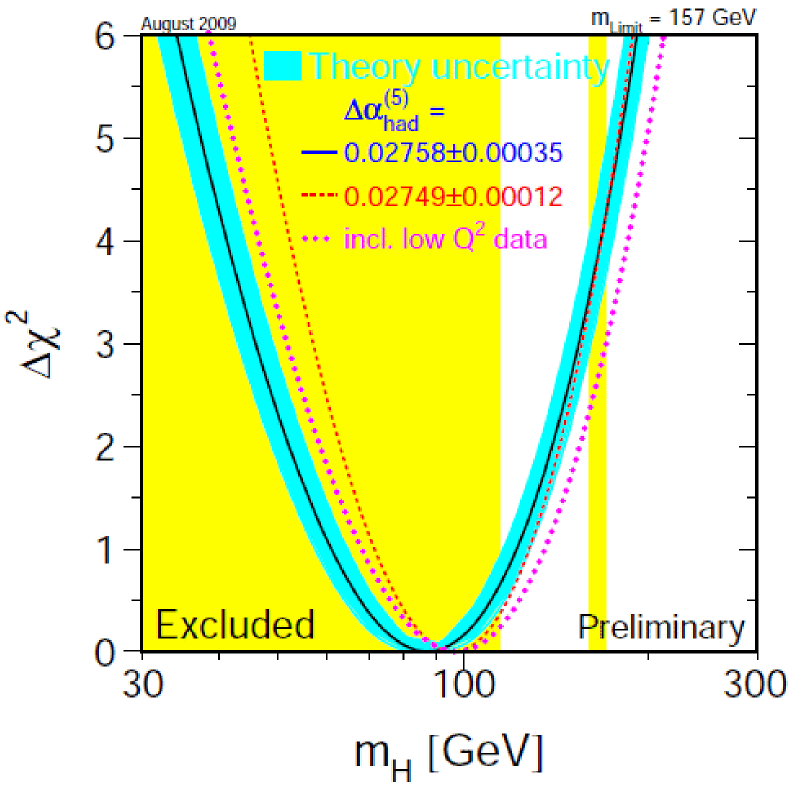
SM Higgs mass constraints from the data and theory

Experiment

Indirect constraints from precision EW data :

- $M_H < 260$ GeV (2004)
- $M_H < 186$ GeV (2005)
- $M_H < 166$ GeV (2006)
- $M_H < 154$ GeV (2008)
- $M_H < 157$ GeV (2009)

Direct limit from LEP:
$M_H > 114.4$ GeV

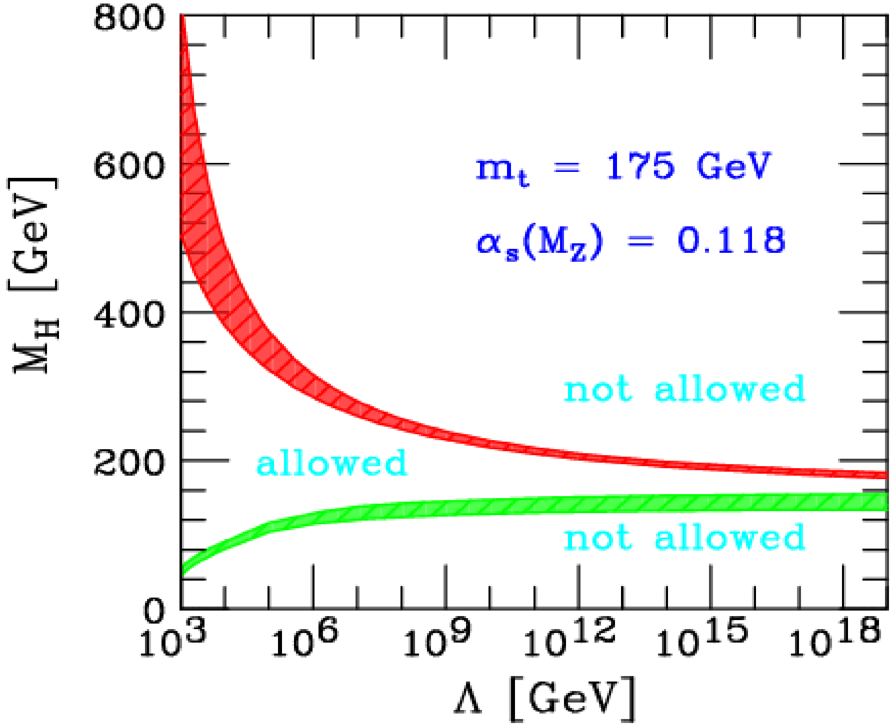


SM theory

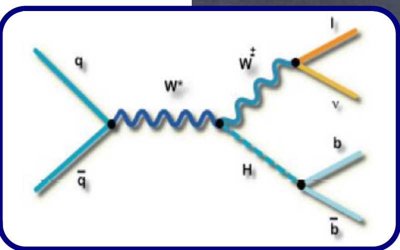
The triviality (upper) bound and vacuum stability (lower) bound as function of the cut-off scale Λ

"triviality" :

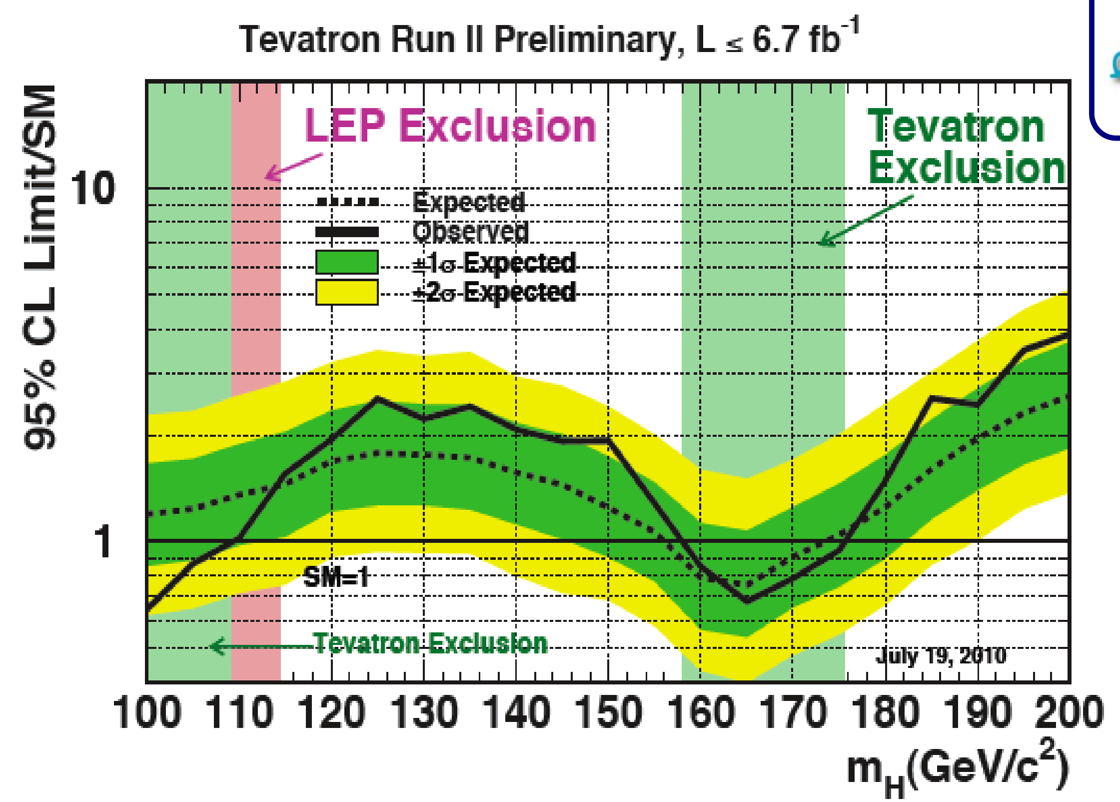
Higgs self-coupling remains finite

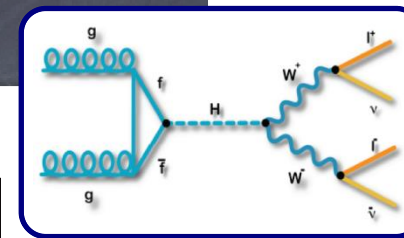


Tevatron exclusions of SM Higgs



Tevatron combination

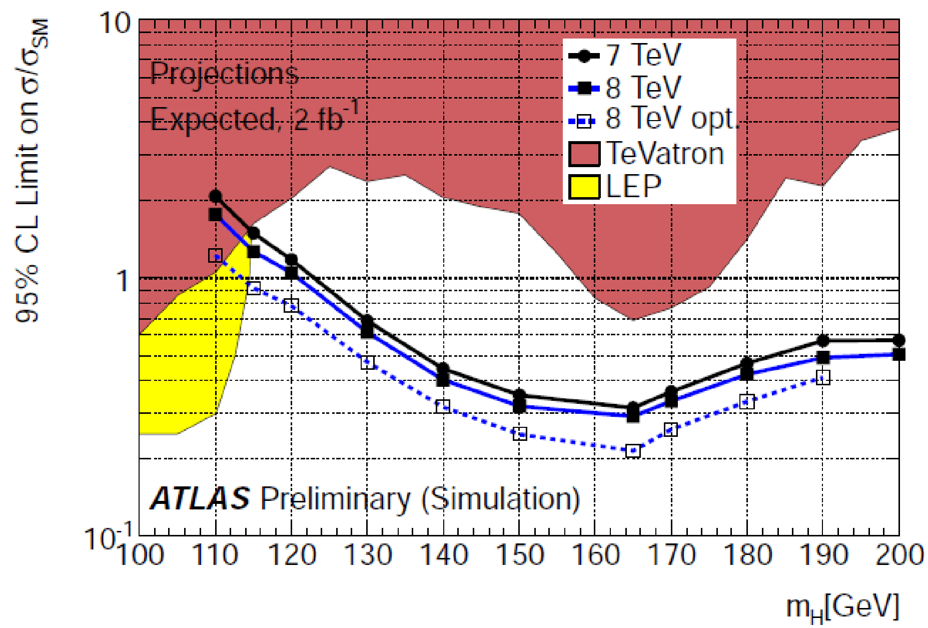




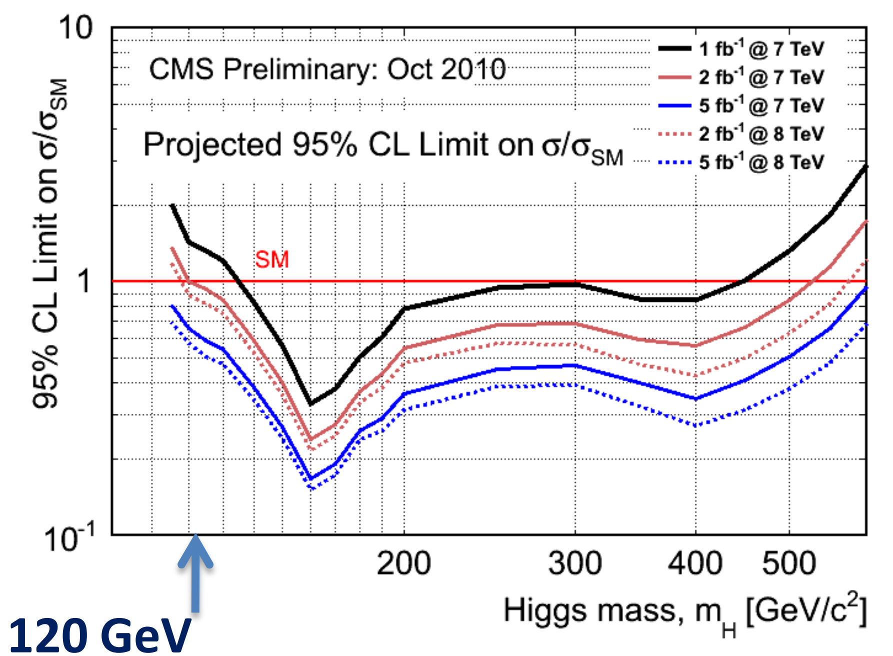
"Expected sensitivity"

- Low mass sensitivity approaching LEP exclusion :
  - Expected 1.45*SM @ 115 GeV
  - Expected 1.24*SM @ 105 GeV
- High mass 95% CL exclusion :
  - $158 < m_H < 175$ GeV
    - 4 times previous (162 – 166 GeV)
    - Expected ($156 < m_H < 175$ GeV)

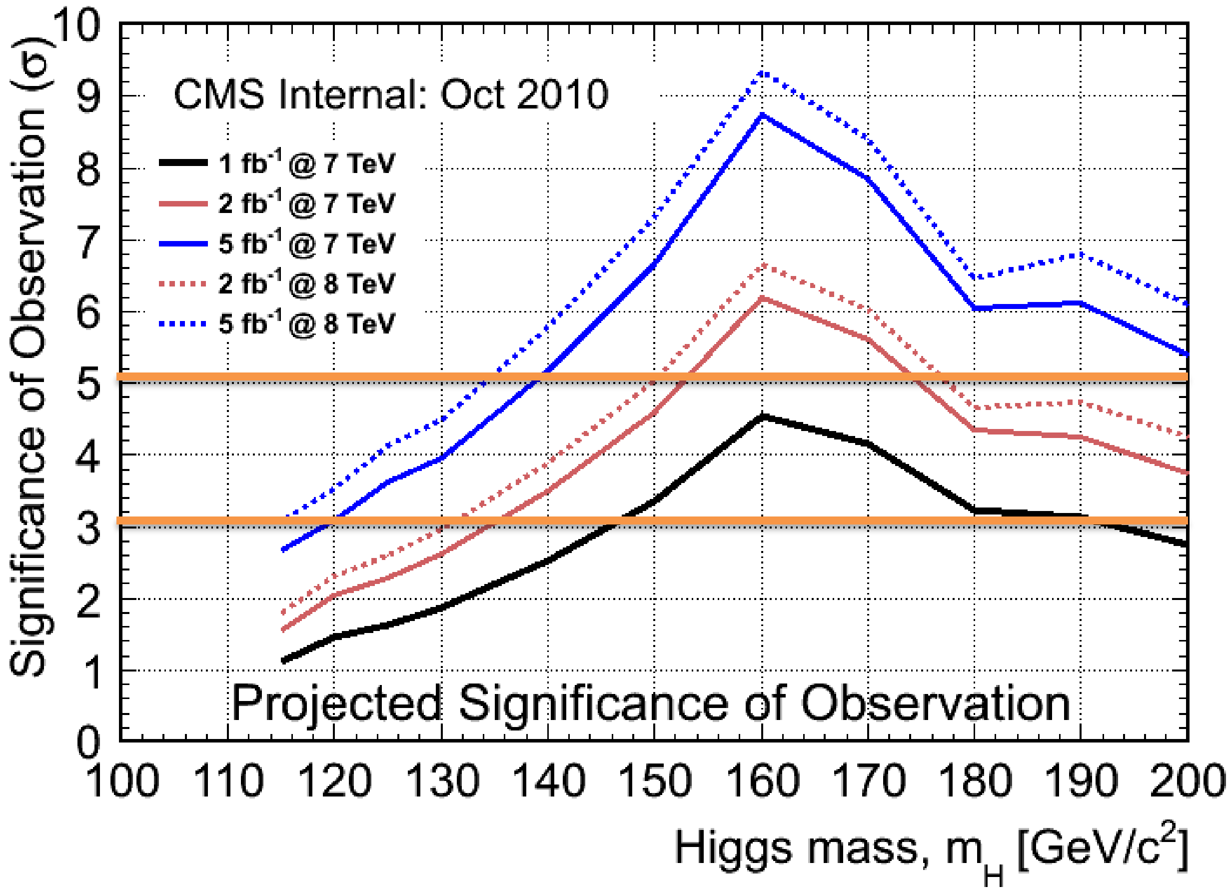
ATLAS /CMS projections for SM Higgs boson exclusion



Channels included	Higgs mass range used in analyses (GeV)
H→γγ	115-150
VBF H→ττ	115-145
VH, H→bb (highly boosted)	115-125
VH, H→WW→lvjj	130-200
H→WW→2l2v + 0/1 jets	120-600
VBF H→WW→2l2v	130-500
H→ZZ→4l	120-600
H→ZZ→2l2v	200-600
H→ZZ→2l2b	300-600

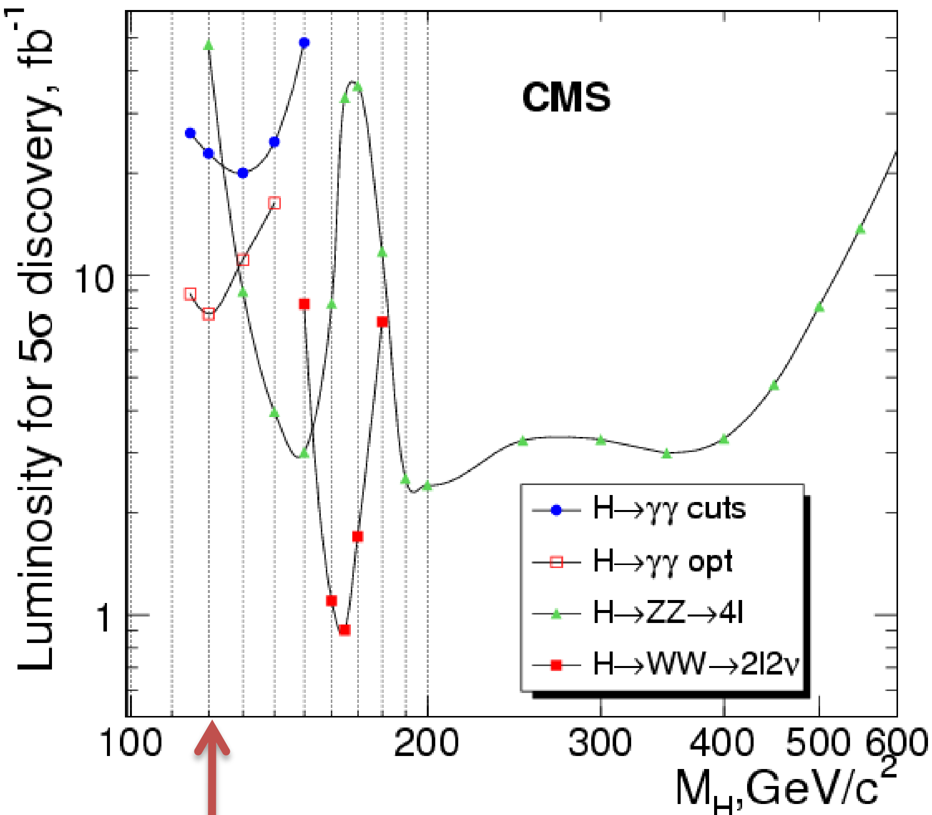


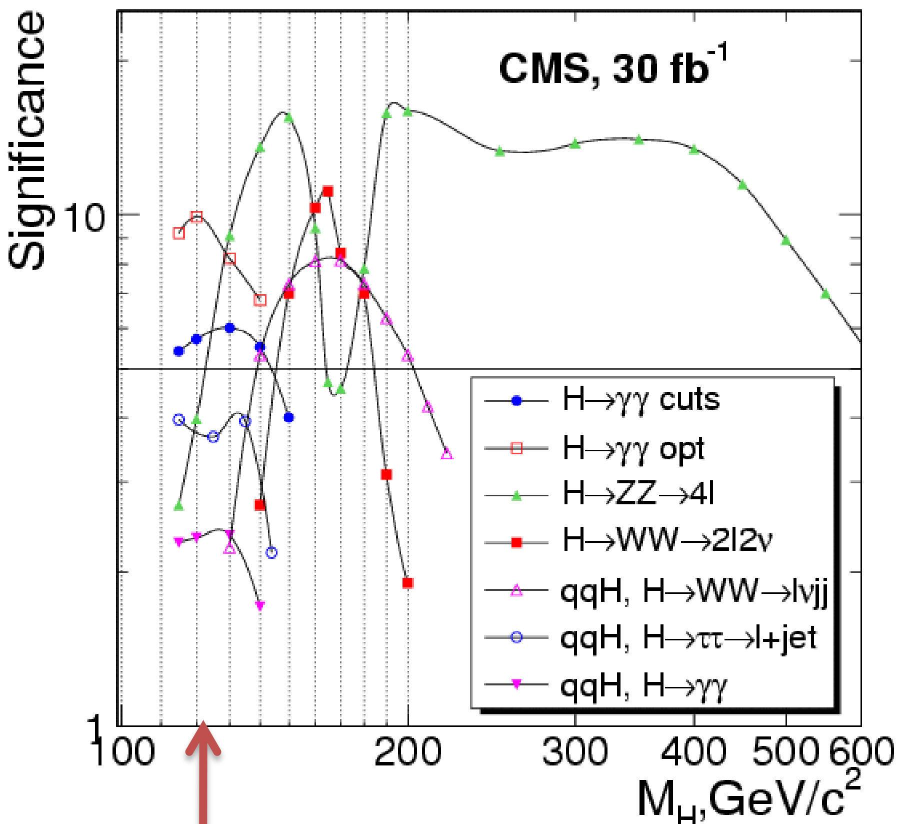
Prospects for CMS SM Higgs boson discovery with at 7 TeV



Ultimate performance at 14 TeV
(CMS PTDR 2006)

Difficult low mass region (~ 115 – 120 GeV):
H->γγ, VBF H->ττ, VH, H->bb (new)





120 GeV

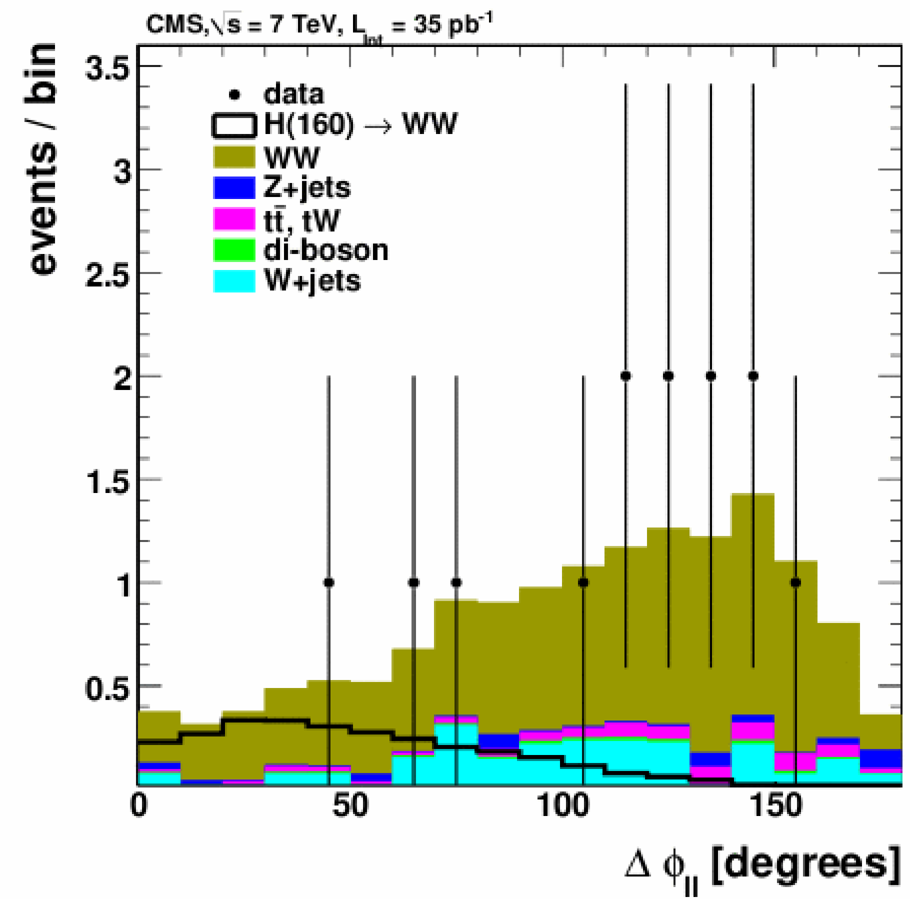
120 GeV

CMS H->WW->lνlν with 36 pb^{-1} (I)

Basic "WW" Selections

- Two opposite sign leptons e or μ p_T > 20 GeV
- m_{ll} > 12 GeV
- DY rejection
  - $|m_{ll} - m_Z|$ > 15 GeV
  - $E_T^{proj.\ miss}$ > 20 (35) GeV for eμ (ee, μμ)
- tt~ and tW rejection
  - no jets with E_T > 25 GeV
  - no soft muons and b-tagged jets E_T < 25 GeV

13 ev selected: 1μμ, 2ee, 10 eμ



CMS H->WW->lνlν with 36 pb^{-1} (II)

- **Higgs boson selections:**

m_H (GeV/c^2)	$p_T^{\ell,max}$ (GeV/c) >	$p_T^{\ell,min}$ (GeV/c) >	$m_{\ell\ell}$ (GeV/c^2) <	$\Delta\phi_{\ell\ell}$ (degree) <
130	25	20	45	60
160	30	25	50	60
200	40	25	90	100
210	44	25	110	110
400	90	25	300	175

- **Signal and bkg. after all selections:**

m_H (GeV/c^2)	data	SM $H \to W^+W^-$	SM with 4th gen. $H \to W^+W^-$	all bkg.	$qq \to W^+W^-$	$gg \to W^+W^-$	all non-W^+W^-
cut-based approach							
130	1	0.30 ± 0.01	1.73 ± 0.04	1.67 ± 0.10	1.12 ± 0.01	0.10 ± 0.01	0.45 ± 0.10
160	0	1.23 ± 0.02	10.35 ± 0.16	0.91 ± 0.05	0.63 ± 0.01	0.07 ± 0.01	0.21 ± 0.05
200	0	0.47 ± 0.01	3.94 ± 0.07	1.47 ± 0.09	1.13 ± 0.01	0.12 ± 0.01	0.23 ± 0.09
210	0	0.34 ± 0.01	2.81 ± 0.07	1.49 ± 0.05	1.09 ± 0.01	0.10 ± 0.01	0.30 ± 0.05
400	0	0.19 ± 0.01	0.84 ± 0.01	1.06 ± 0.03	0.79 ± 0.01	0.04 ± 0.01	0.23 ± 0.03

CMS H->WW->lνlν with 36 pb^{-1} (III)

- **Signal and bkg. systematics:**

Source	Relative Uncertainty (%) $H \to W^+W^-$	$qq \to W^+W^-$	$gg \to W^+W^-$	WZ/ZZ	top	$Z/\gamma^* \to \ell^+\ell^-$	$W + $jets
Luminosity	11	—	—	11	—	—	—
Trigger efficiencies	1.5	1.5	1.5	1.5	—	—	—
Muon efficiency	0.7	0.7	0.7	0.7	—	—	—
Electron id efficiency	2.4	2.4	2.4	2.4	—	—	—
Reconstruction efficiency	1.4	1.4	1.4	1.4	—	—	—
momentum scale	1.3	1.3	1.3	1.5	—	—	—
pile-up	0.5	0.5	0.5	0.5	—	—	—
E_T^{miss} resolution	1.0	1.0	1.0	1.0	1.0	3.0	—
Jet veto	5.3	—	5.4	5.4	—	—	—
PDF uncertainties	3.0	2.6	—	2	—	—	—
NLO effects	2.0	1.1	—	3.5	—	—	—
Fakes	—	—	—	—	—	—	50
WZ/ZZ cross-section	—	—	—	3.0	—	—	—
$qq \to WW$ normalization	—	55	—	—	—	—	—
$gg \to WW$ normalization	—	—	50	—	—	—	—
tX normalization	—	—	—	—	100	—	—
DY normalization	—	—	—	—	—	100	—
statistics	1	1	1	4	6	50	30

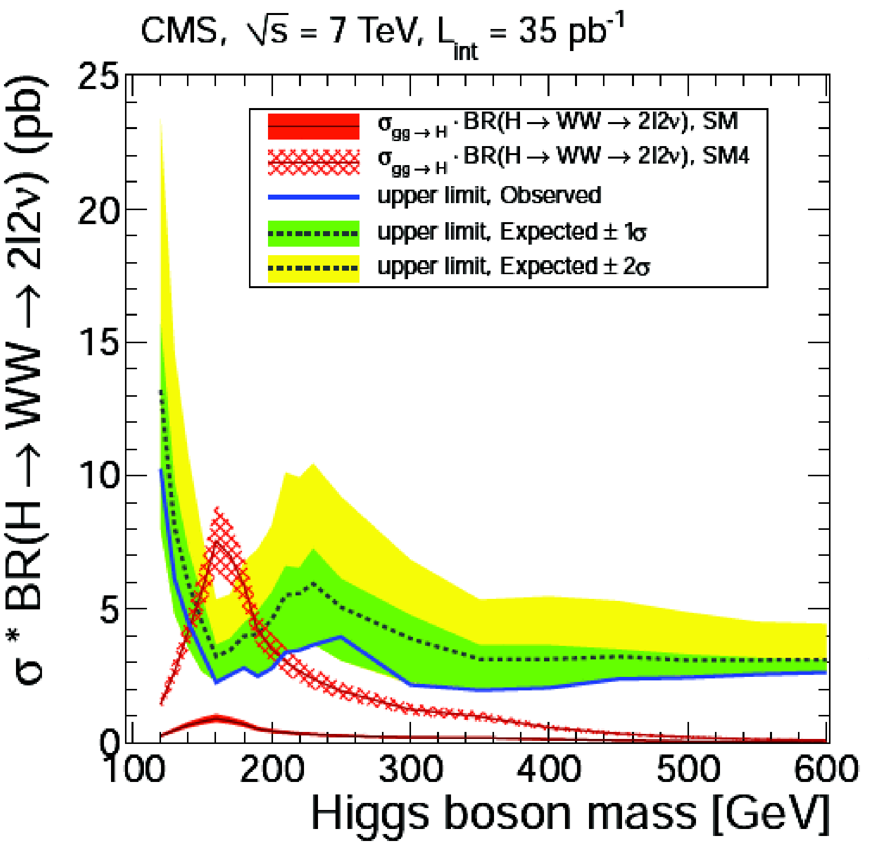
- **Generators used:**
  - Higgs, DY: POWHEG+PYTHIA
  - qq->WW, tt, tW, W+jets: MadGraph
  - gg->WW : GG2WW (T.Binoth et all)
  - WZ,ZZ : PYTHIA

CMS H->WW->lνlν with 36 pb^{-1} (IV)

- **In SM with 4th generation**
  - EPJ C(2010) 66:119 (2010),
  - arXiv:1011.4484v2 (2010)

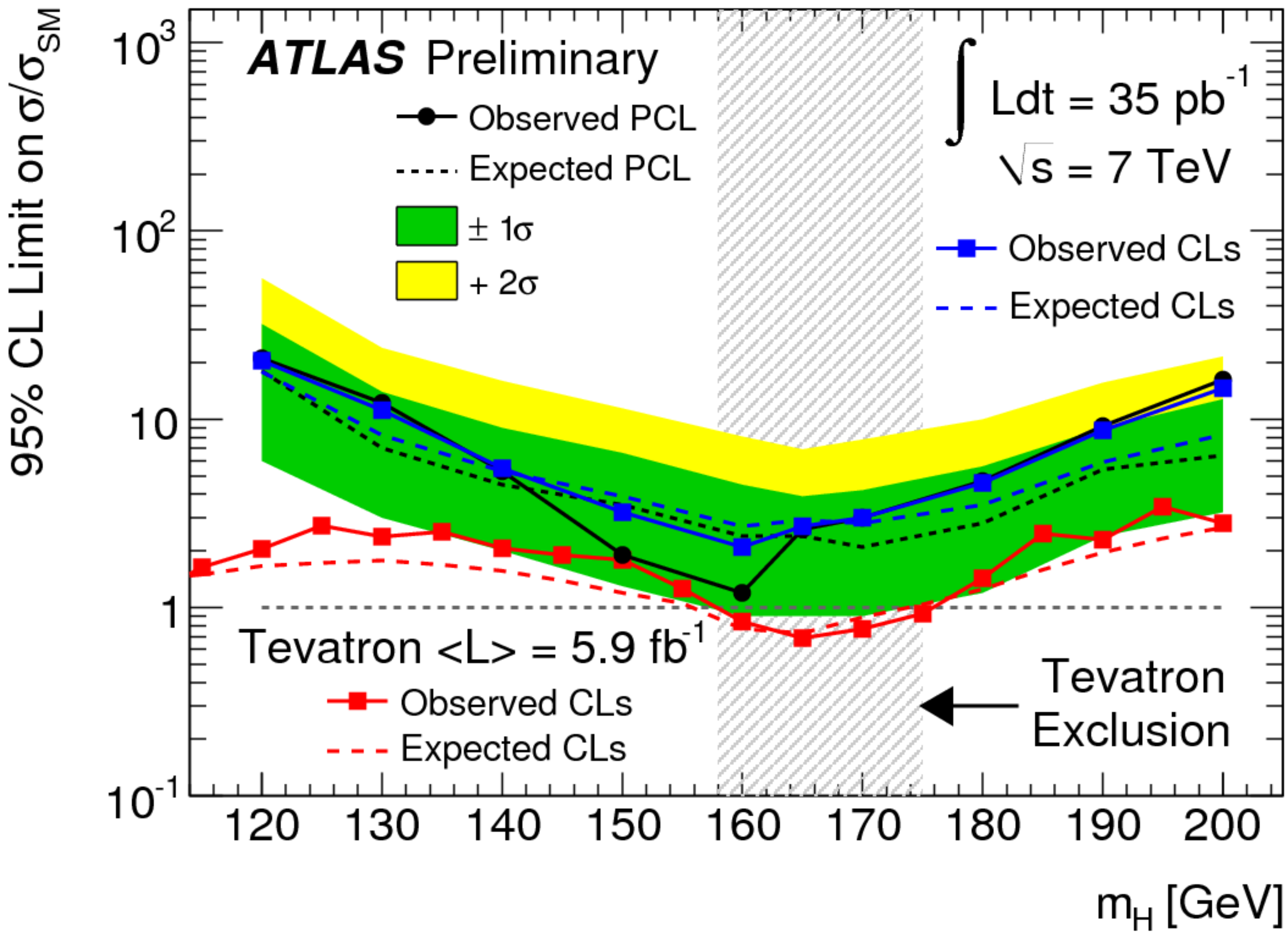
Higgs boson is excluded in region

M_H = (144-207) GeV



m_H (GeV/c^2)	$\sigma \cdot BR$ SM (pb)	$\sigma \cdot BR$ 4th gen. (pb)	lim. obs. cut-based (pb)	lim. exp. cut-based (pb)	lim. obs. BDT-based (pb)	lim. exp. BDT-based (pb)
130	0.45	2.66	6.30	8.07	5.66	6.57
160	0.90	7.54	2.29	3.22	1.93	2.72
200	0.42	3.50	2.80	4.59	2.32	3.72
210	0.37	3.04	3.41	5.53	2.76	4.43
400	0.13	0.55	2.08	3.12	1.94	2.93

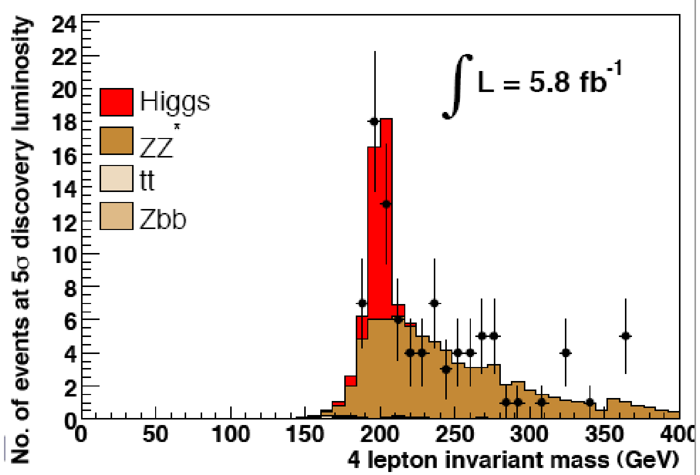
ATLAS H->WW->lνlν with 36 pb^{-1}

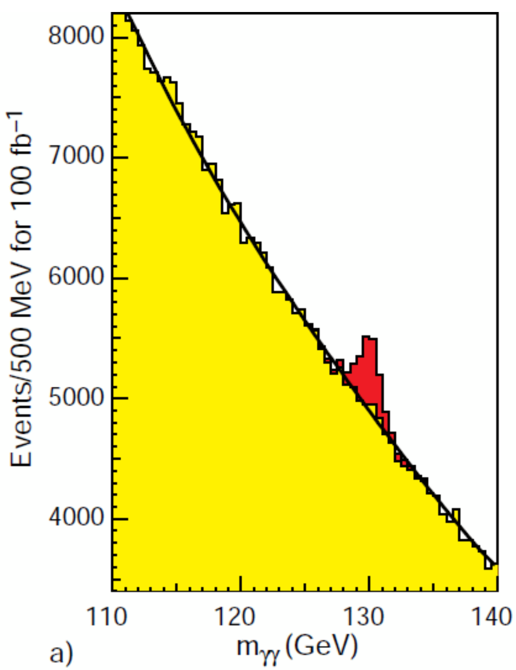


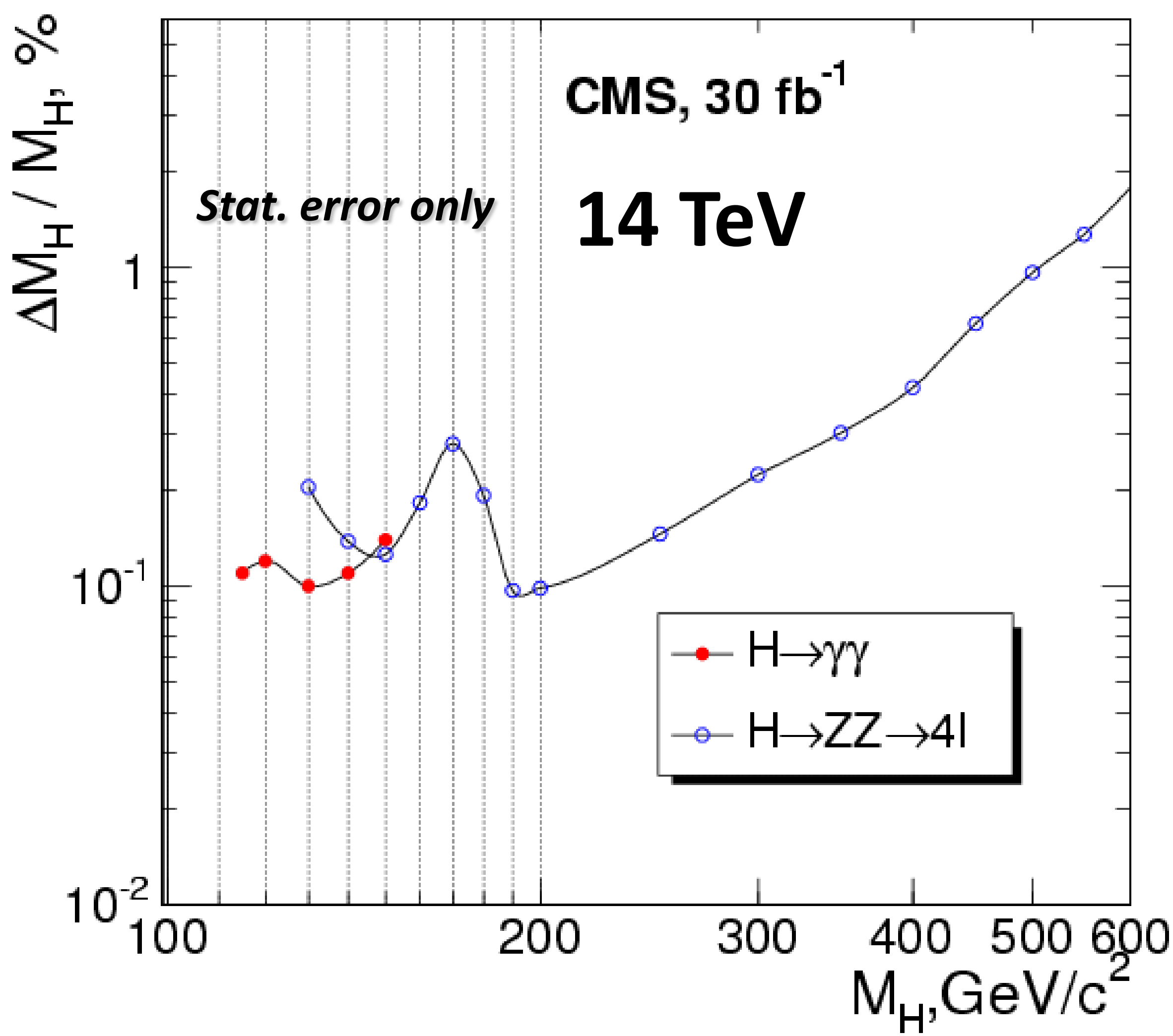
Discovery is not the end, but just beginning of “Higgs story”

Want to measure Higgs boson properties

Accuracy of the Higgs boson mass measurement with H->ZZ->4l and H->γγ



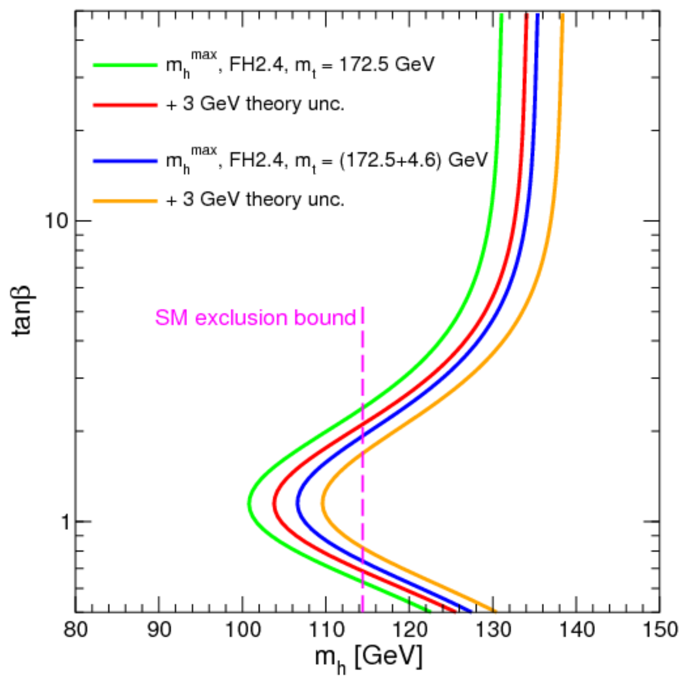




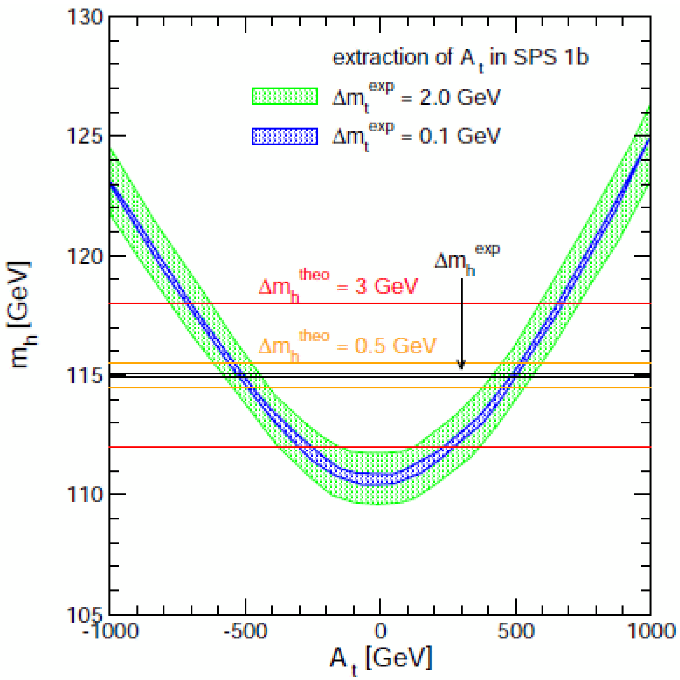
Why Higgs boson mass should be known with great precision ?

- **In MSSM - to constrain other parameters , especially from top/stop sector via the loop corrections**

S. Heinemeyer at al. hep-ph/9909540



S. Heinemeyer at al. hep-ph/0306181

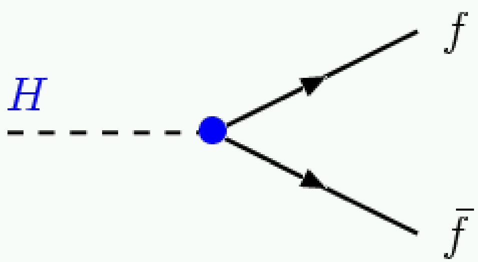


- **In SM: 1-2 GeV is enough to compare measured Higgs couplings with SM predictions at a given M_H**

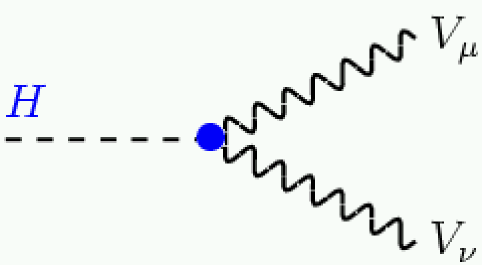
Measurement of Higgs boson couplings

and qqH associated production

(Weak Boson Fusion: VV->H)



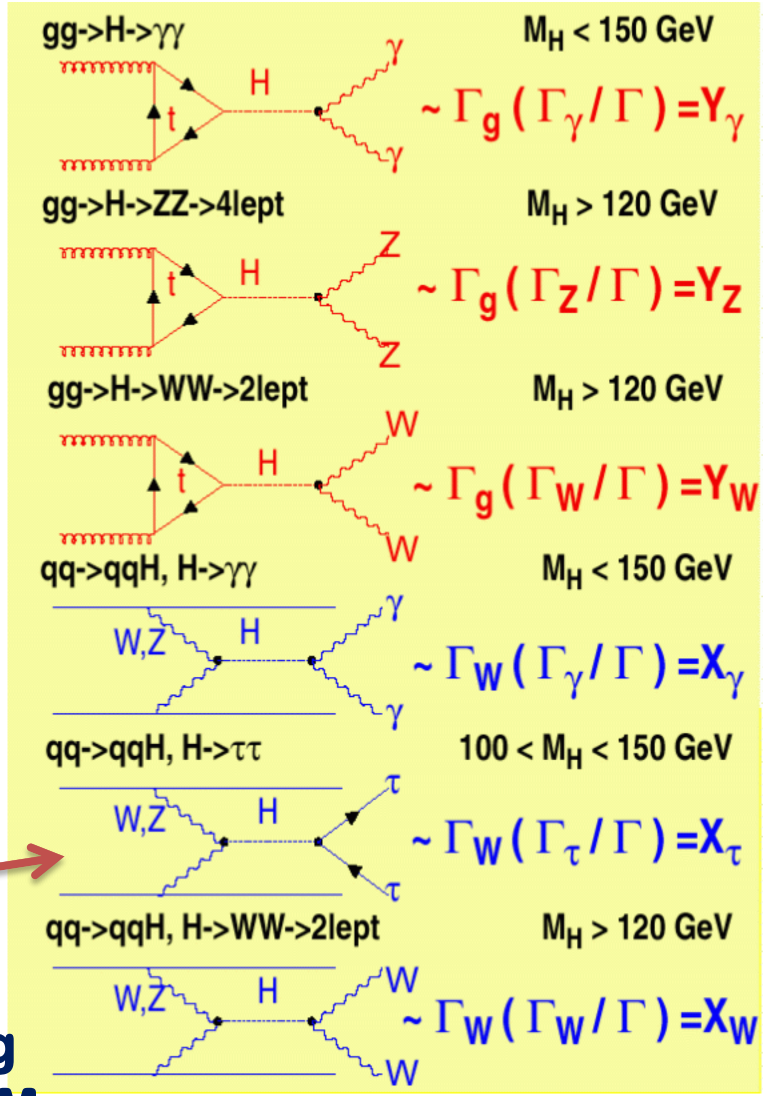
$$g_{Hff} = m_f/v = (\sqrt{2}G_\mu)^{1/2}\, m_f \qquad \times\ (i)$$



$$g_{HVV} = 2M_V^2/v = 2(\sqrt{2}G_\mu)^{1/2}\, M_V^2 \qquad \times\ (-i g_{\mu\nu})$$

Why VBF (qq->qqH) channels are very important ?

- **Significantly extend the possibility of Higgs coupling measurements**
- **Provide possibility of the indirect measurement of the light Higgs boson width**
  - D. Zeppenfeld, R. Kinnunen, A. Nikitenko and E. Richter-Waz, Phys.Rev. D62 (2000) 013009
  - M. Duehressen et al., Phys.Rev. D70 (2004) 113009



H->ττ: the way to measure Higgs coupling to down type fermions; Important in MSSM

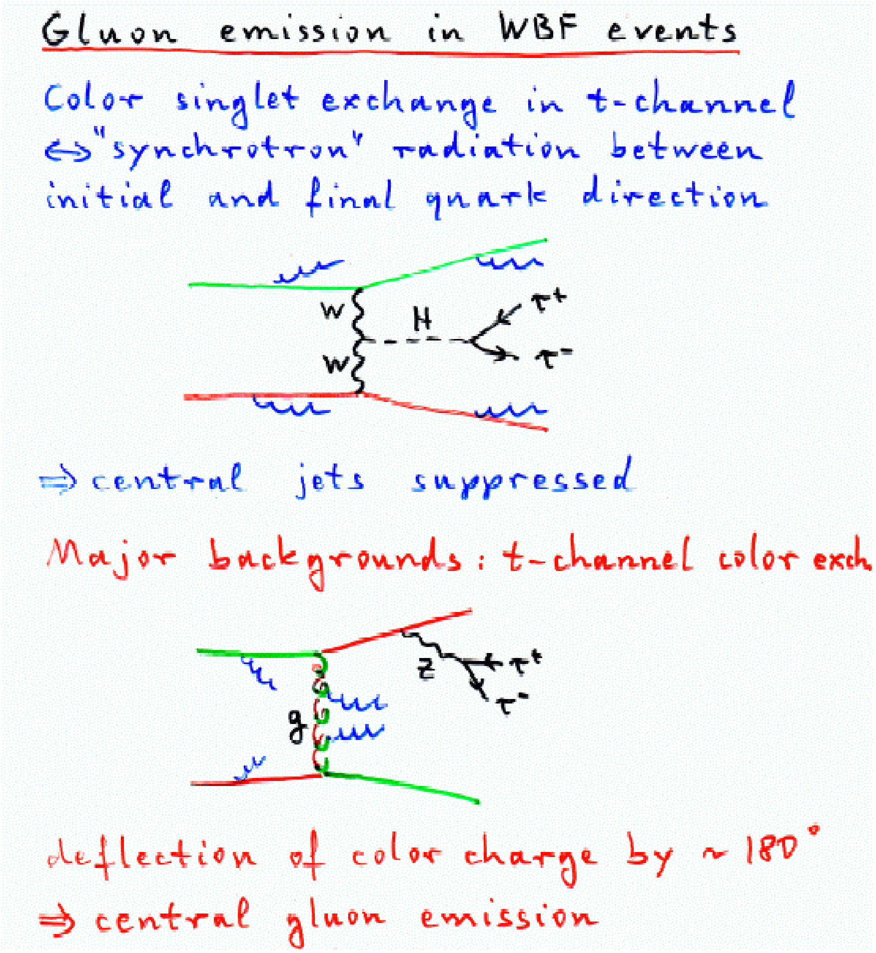
Jet veto ("rapidity gap") in VBF (WW->H) production

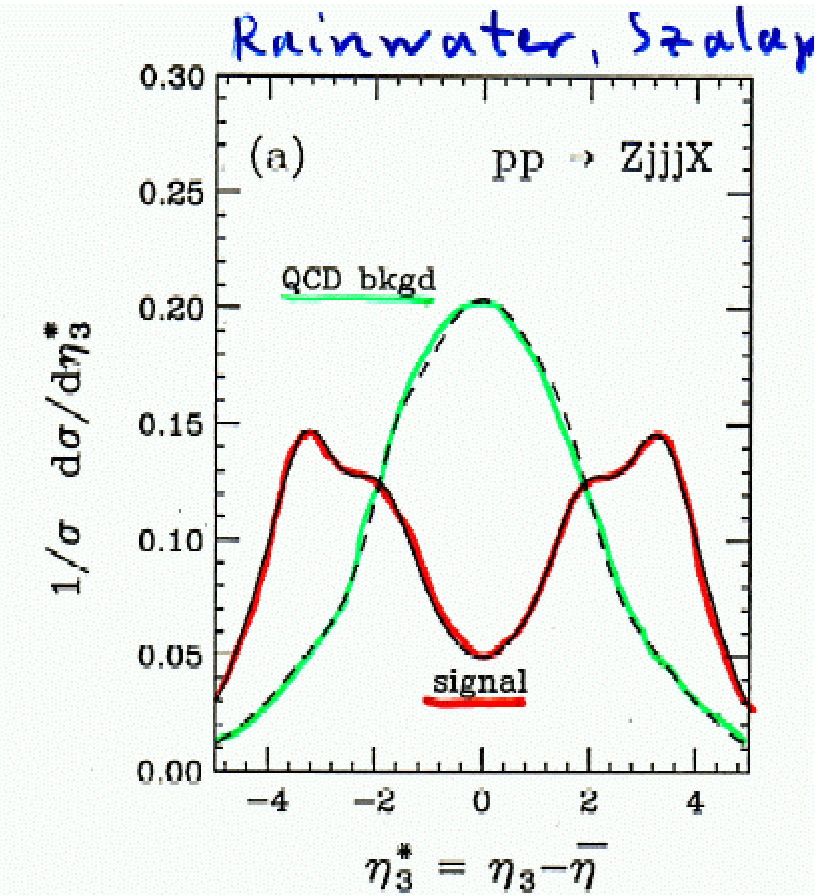
first discussed in :

Yu. Dokshitzer, V. Khoze and S. Troyan, Sov.J.Nucl. Phys. 46 (1987) 712

Yu. Dokshitzer, V. Khoze and T. Sjostrand, Phys.Lett., B274 (1992) 116

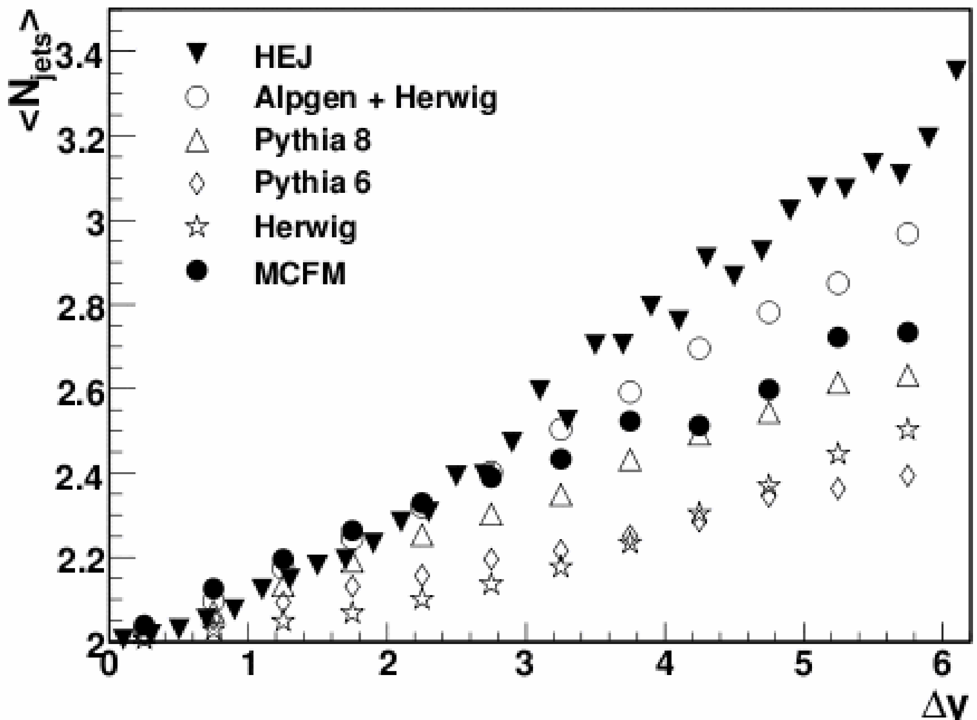
From D. Zeppenfeld talk on TeV4LHC, 2004





… planning to make rapidity gap studies this year

What can 1 fb^{-1} tell us about our perturbative tools

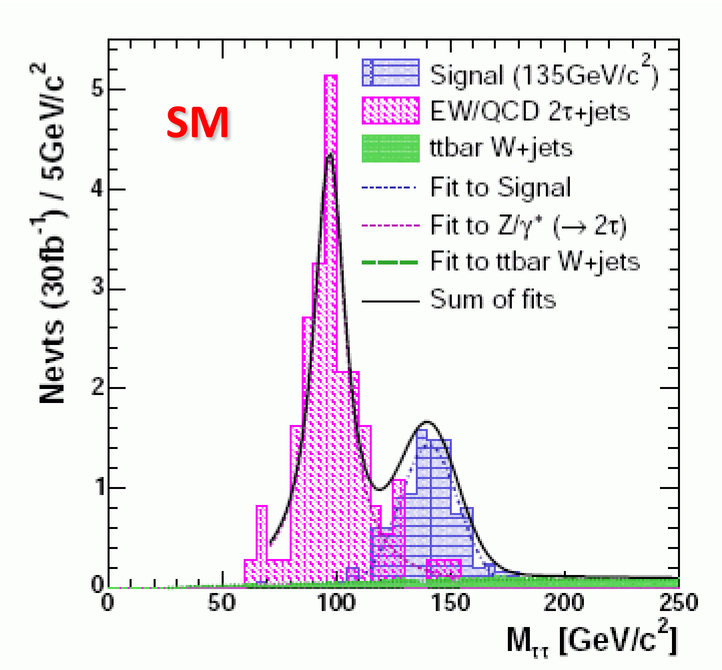


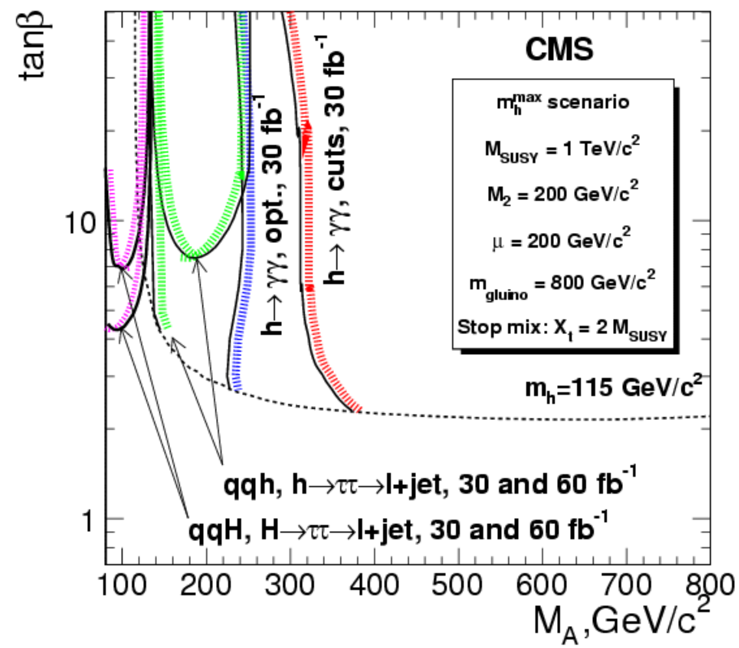
W+dijets, JRA, M. Campanelli, J. Campbell, V. Ciulli, J. Huston, P. Lenzi, R. Mackeprang, arXiv:1003.1241

1 fb^{-1}@7TeV could be enough to tell the predictions apart!

Obviously, similar results for pure dijets with much less data

Full simulation analysis of qqH, H->ττ->l+jet at LHC 14 TeV





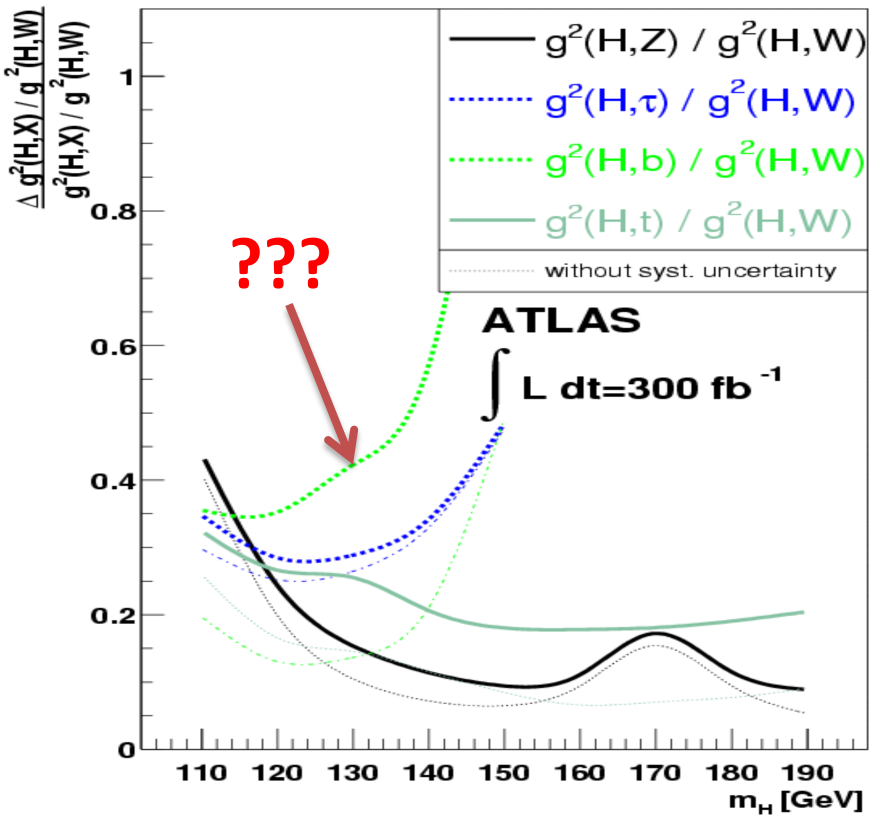
discovery of light h in MSSM

Discovery in Standard Model

M_H [GeV]	115	125	135	145
Production σ [fb]	4.65×10^3	4.30×10^3	3.98×10^3	3.70×10^3
$\sigma\times BR(H\to\tau\tau\to lj)$ [fb]	157.3	112.9	82.38	45.37
N_S at 30 fb^{-1}	10.5	7.8	7.9	3.6
N_B at 30 fb^{-1}	3.7	2.2	1.8	1.4
Significance at 30 fb^{-1} ($\sigma_B = 7.8\%$)	3.97	3.67	3.94	2.18
Significance at 60 fb^{-1} ($\sigma_B = 5.9\%$)	5.67	5.26	5.64	3.19

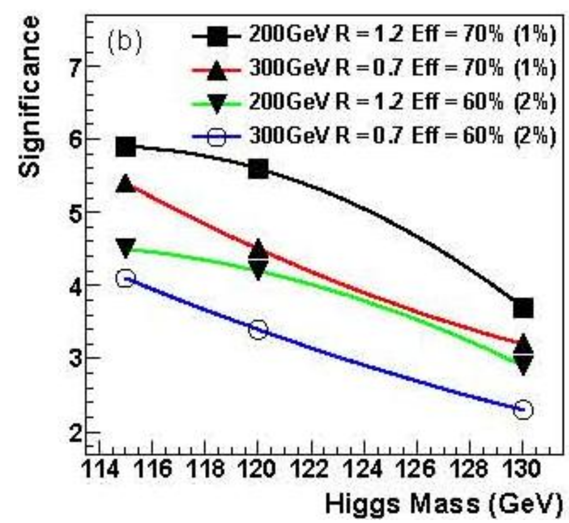
Measurement of Higgs boson couplings and H->bb

ATL-PHYS-PUB-2003/030



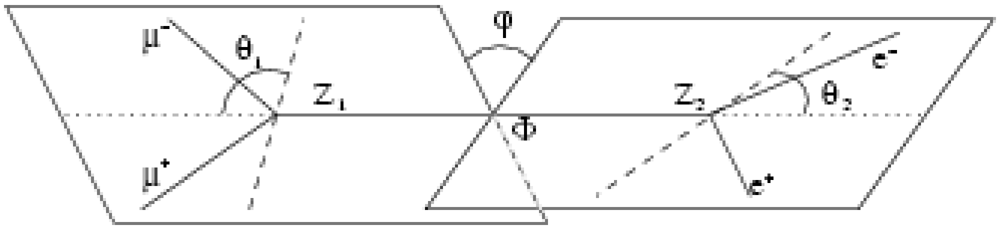
- traditional ttH, H->bb was "dead" since CMS-TDR (same for ATLAS)
- Re-incarnation with
  - "boosted" H->bb in VH analysis;
    - Butterworth at al, 2008
  - "boosted top" in ttH, H->bb
    - Plehn at al, 2010

VH, H->bb; p_T^H > 200 GeV, 30 fb^{-1} at 14 TeV

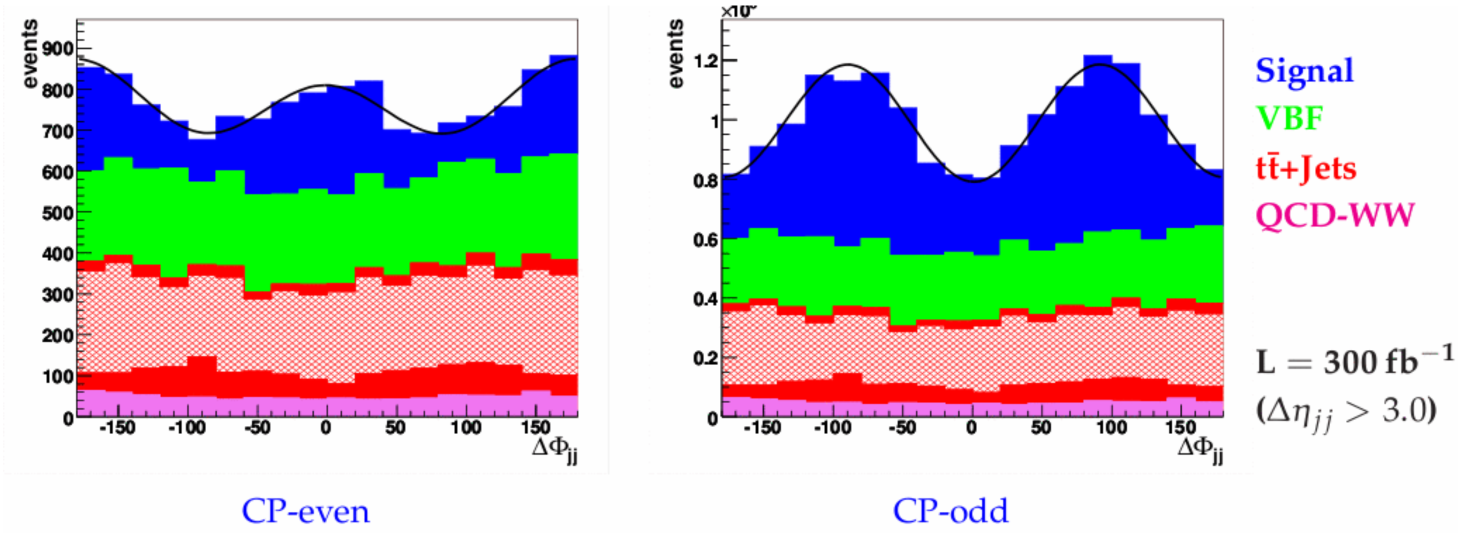


Higgs CP property: need > 200 fb^{-1}

- **Using H->ZZ->4l** (M. Muhlleitner, R. Godbole, D. Miller, …)



- **Using H+jj, Δϕ jj correlation** (D. Zeppendeld, J.R. Andersen, …)

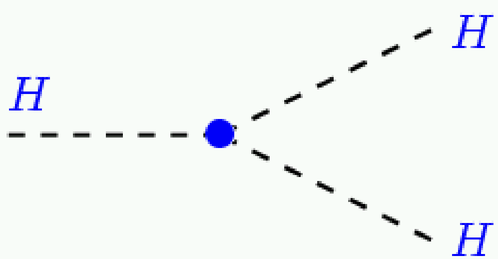


The ultimate goal of Higgs physics:

measure Higgs boson "self-coupling" value $\lambda = m_H^2 / v^2$,
parameter of Higgs boson potential
$V(\Phi) = =-\lambda v^2 (\Phi^+\Phi) + \lambda (\Phi^+\Phi)^2$

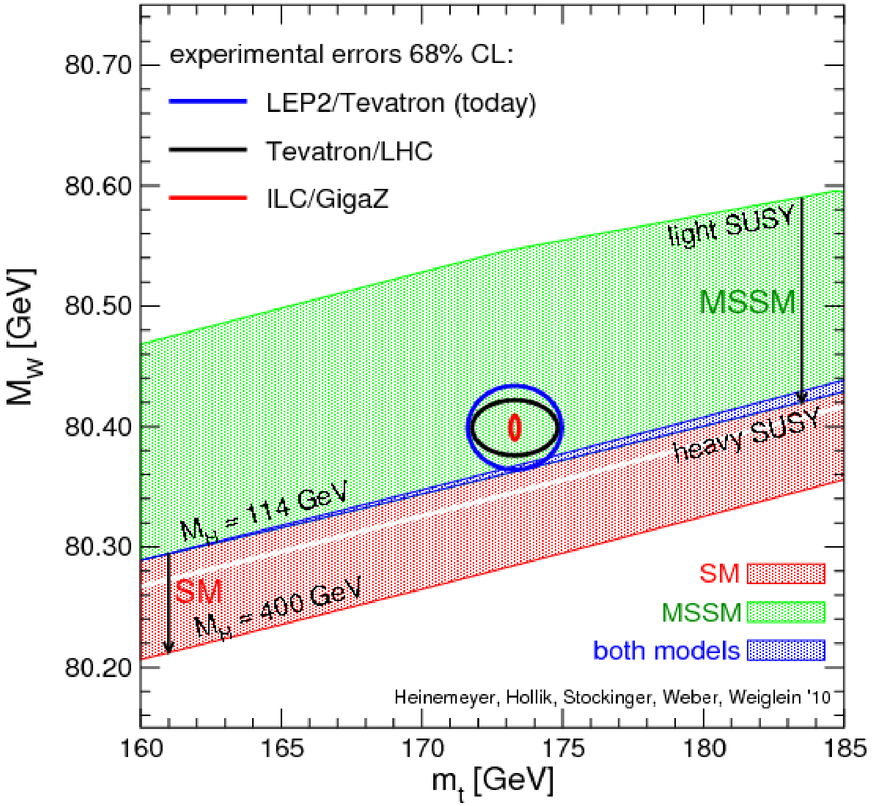
using H->HH

– LHC can not do it. Need linear collider



$$g_{HHH} = 3M_H^2/v = 3(\sqrt{2}G_\mu)^{1/2} M_H^2 \qquad \times (i)$$

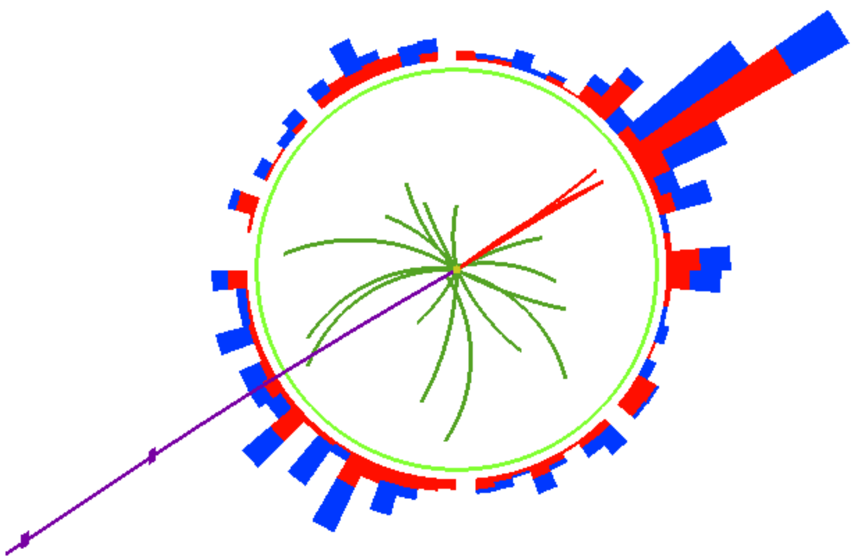
Searches for MSSM Higgs bosons

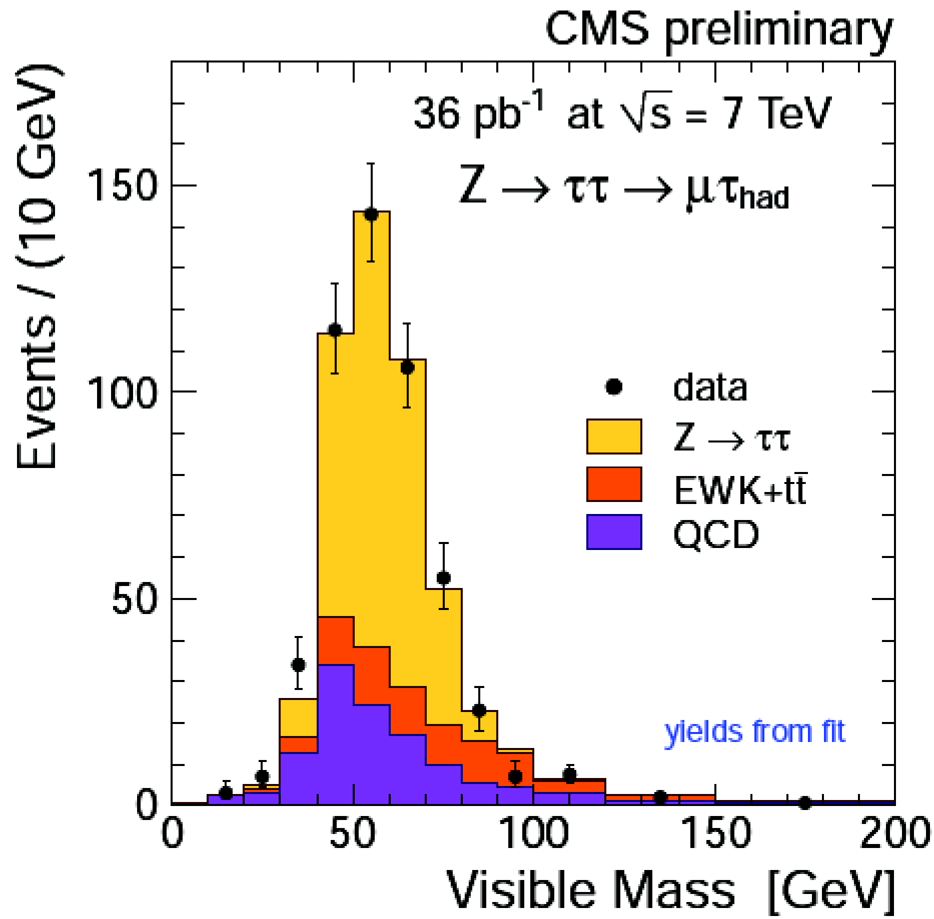


- $\phi \rightarrow \tau\tau$, $\mu\mu$
- $H^{+} \rightarrow \tau\nu$, cs

Preparation for pp->ϕ+X, ϕ->ττ discovery

- “Discovery” of Z->ττ

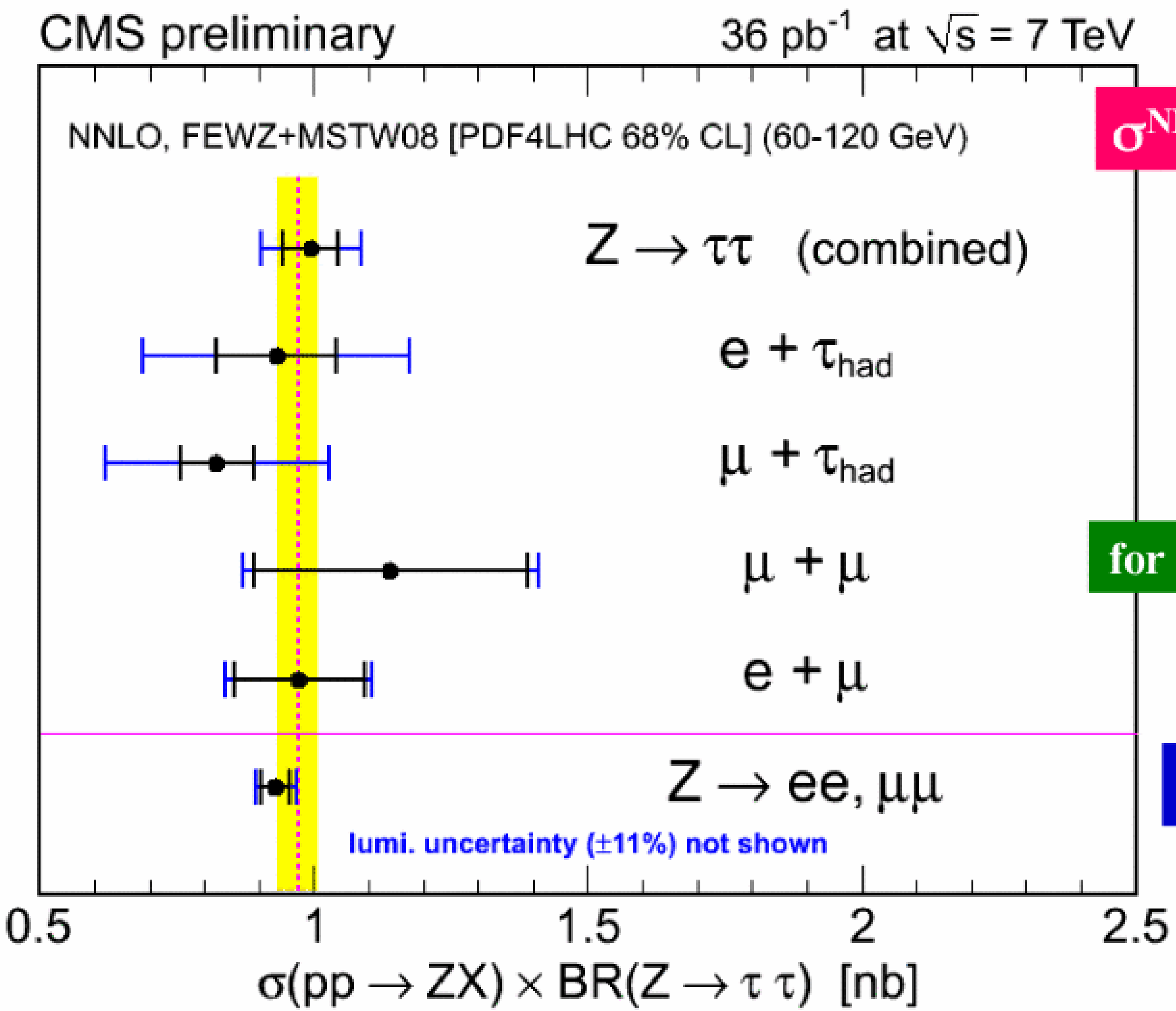




Z→ττ Cross Section Summary

Imperial College London

σ (pp→ZX) BR(Z→ττ) = 1.00 ± 0.05 (stat) ± 0.08 (syst) ± 0.11 (lumi) nb



σ^{NNLO} = 0.972 ±0.042 nb

for approval

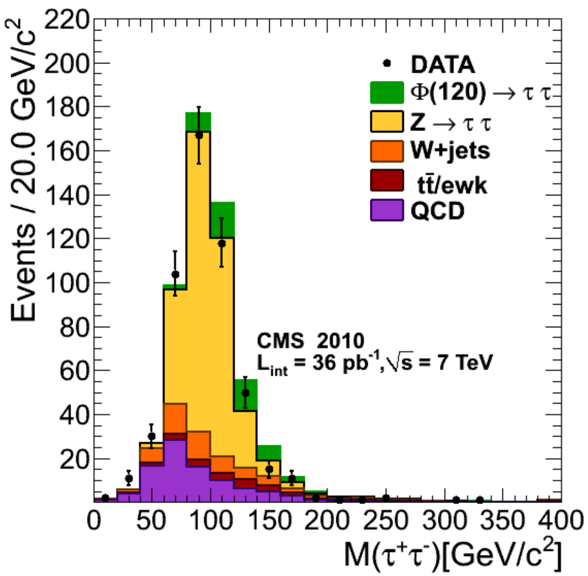
JHEP 01 (2011) 080

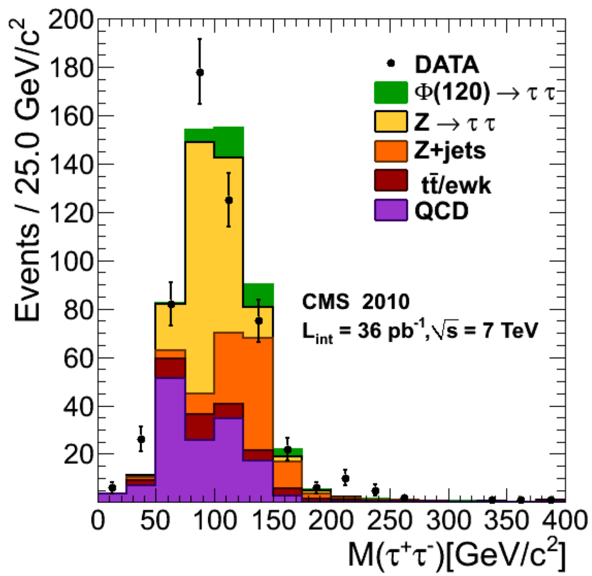
SUSY H->ττ with $36pb^{-1}$

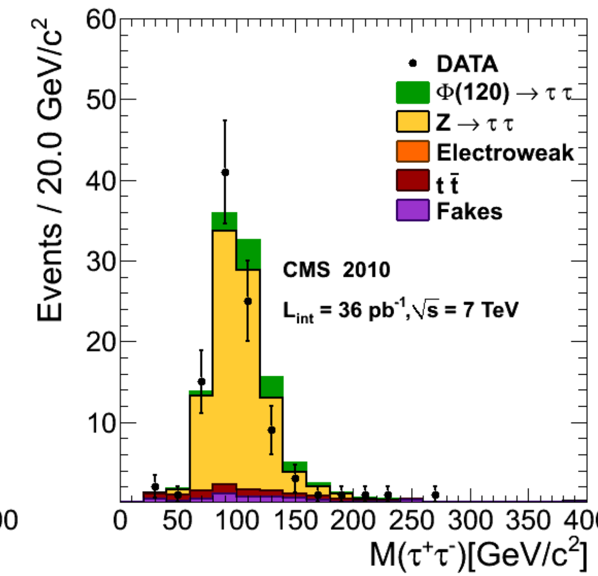
- Fit of ττ mass shape for $\mu\tau_{had}$, $e\tau_{had}$, eμ final states
- Background normalization from data
- QCD, Z->ll shapes from data

$\mu\tau_{had}$ $e\tau_{had}$ eμ

Higgs boson is shown for tanβ=30



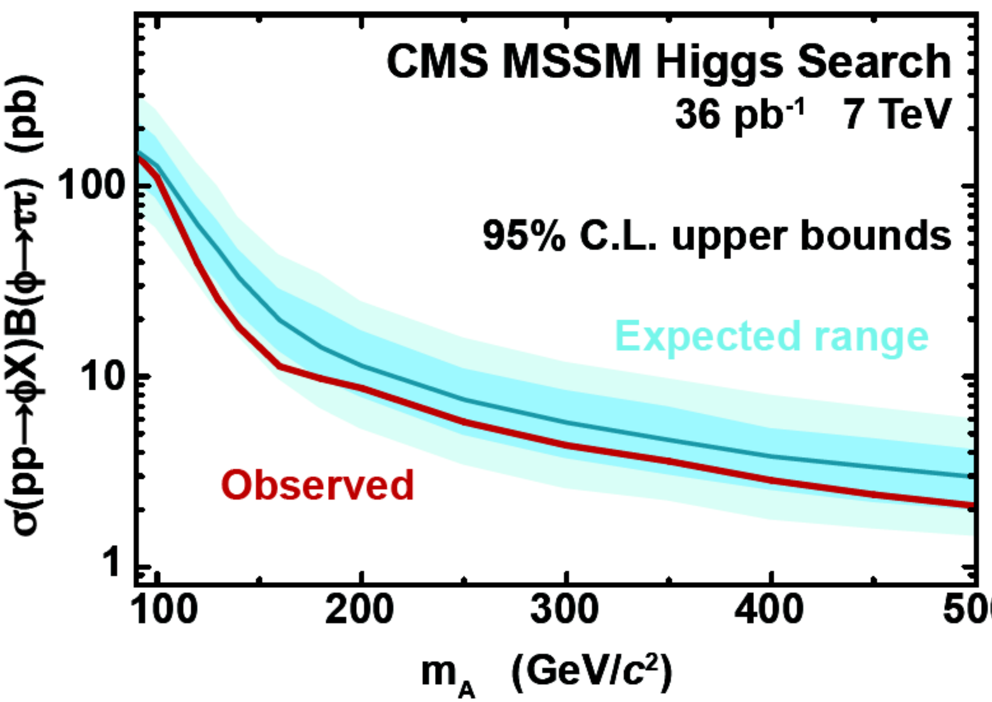




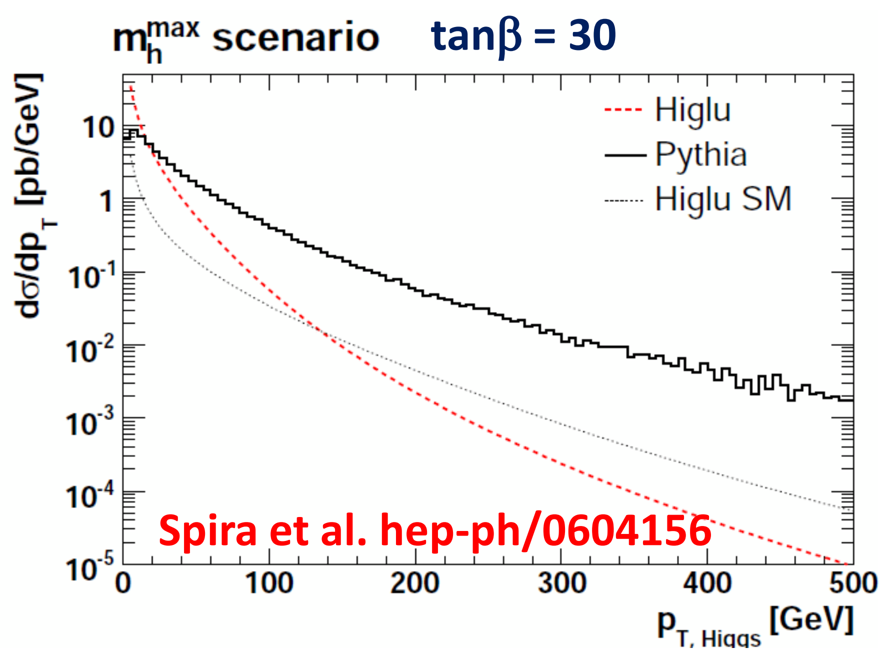
use SUSY Higgs cross-section from LHC XS group report and Br from HeynHiggs

Limits on σ x Br(H->ττ)

- $\sigma^{gg\text{->}A}\,\varepsilon^{gg\text{->}A}_{sel} + \sigma^{\,bbA}\,\varepsilon^{bbA}_{sel} < N_H$
- $\varepsilon^{gg\text{->}A}_{sel} = \varepsilon^{bbA}_{sel}$ within 2-10 % using PYTHIA MC
  - $(\sigma^{gg\text{->}A} + \sigma^{\,bbA})\,\varepsilon_{sel} < N_H$



top-loop vs b-loop in gg->h :
diffeent Higgs p_T !



Tevatron vs CMS exclusion on σ x Br(ττ)

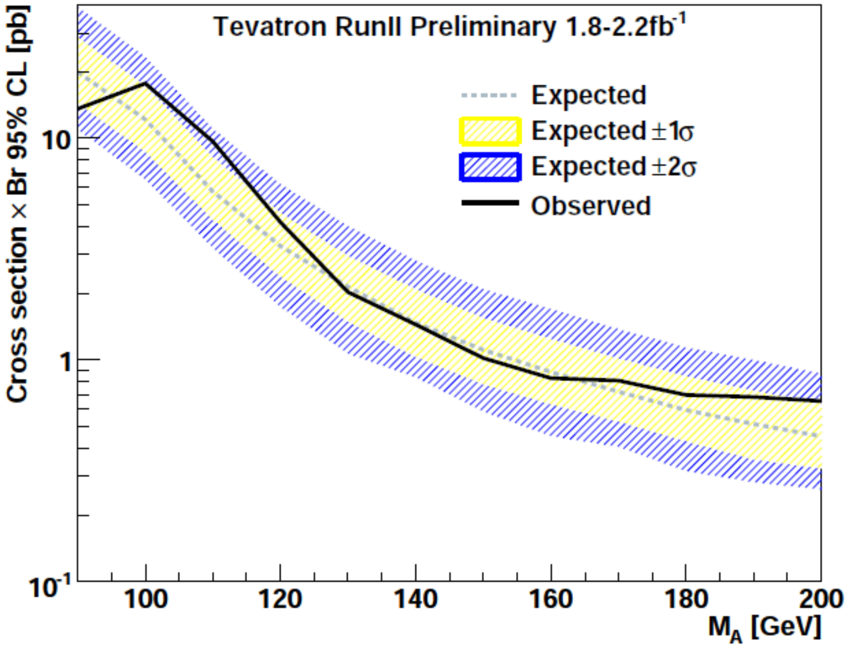
M_A = 140 GeV; Br(ττ)=0.104		
	Tevatron	LHC/CMS
$\sigma_{gg\to A+bb\to A}$	7 fb*	164 fb*
σ x Br $^{exp.}$	1.47 pb	32.8 pb
σ x Br $^{obs.}$	1.45 pb	18.2 pb

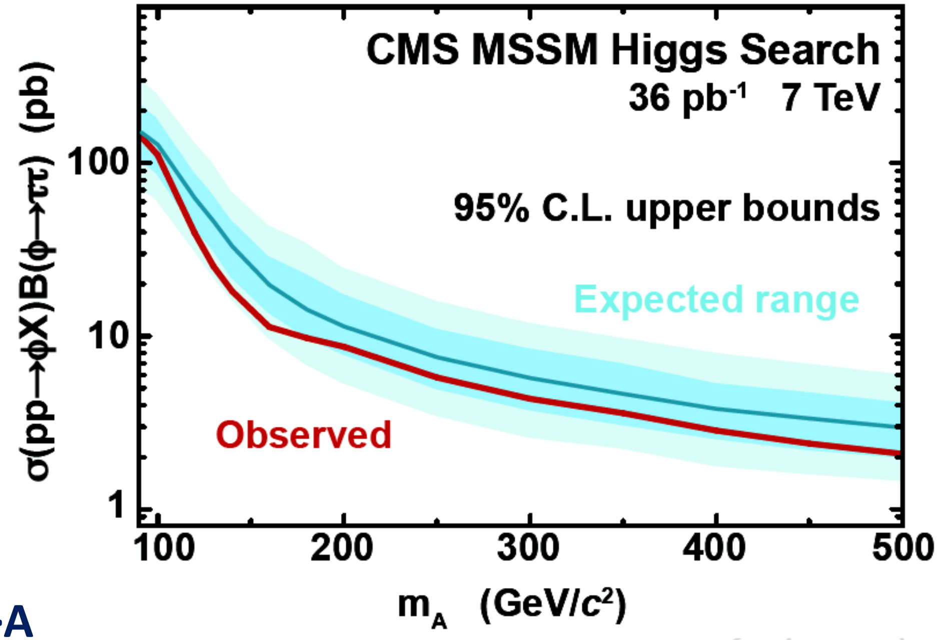
*Baglio, Djouadi arXiv:1012.2748

*Baglio, Djouadi arXiv:1012.0530

$$\sigma^{h(H)+A}_{SUSY} = 2\tan^2\beta\,\sigma_{gg\to A+bb\to A}$$

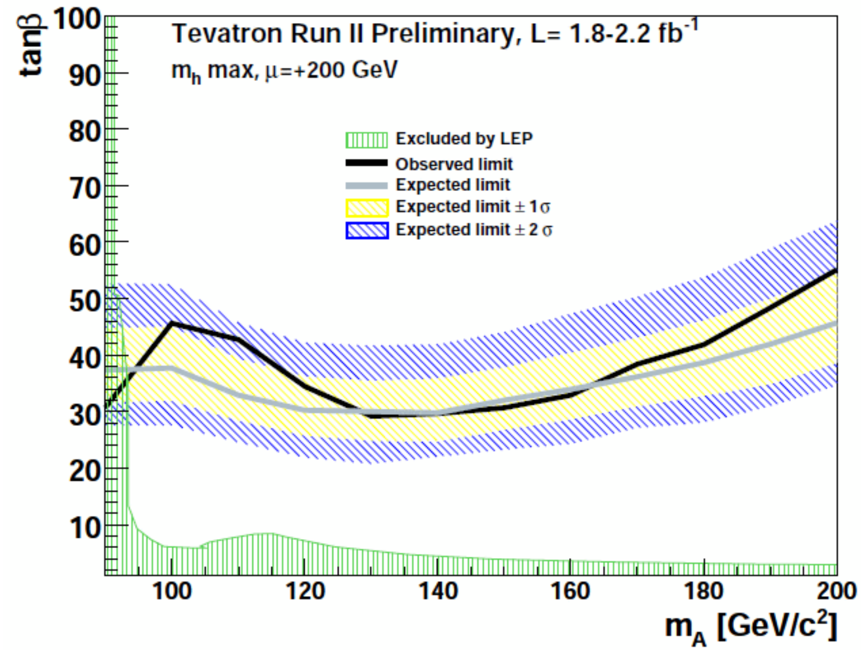
at high tanβ > 25

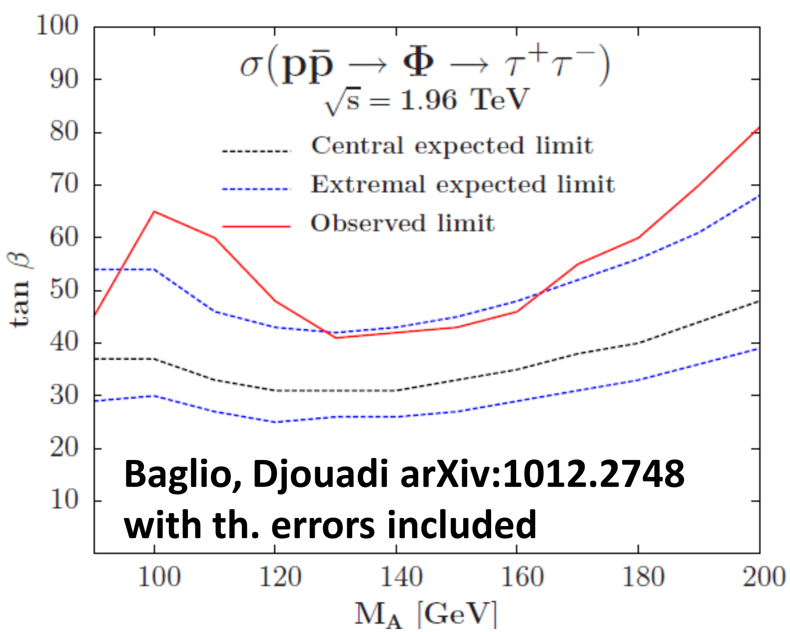


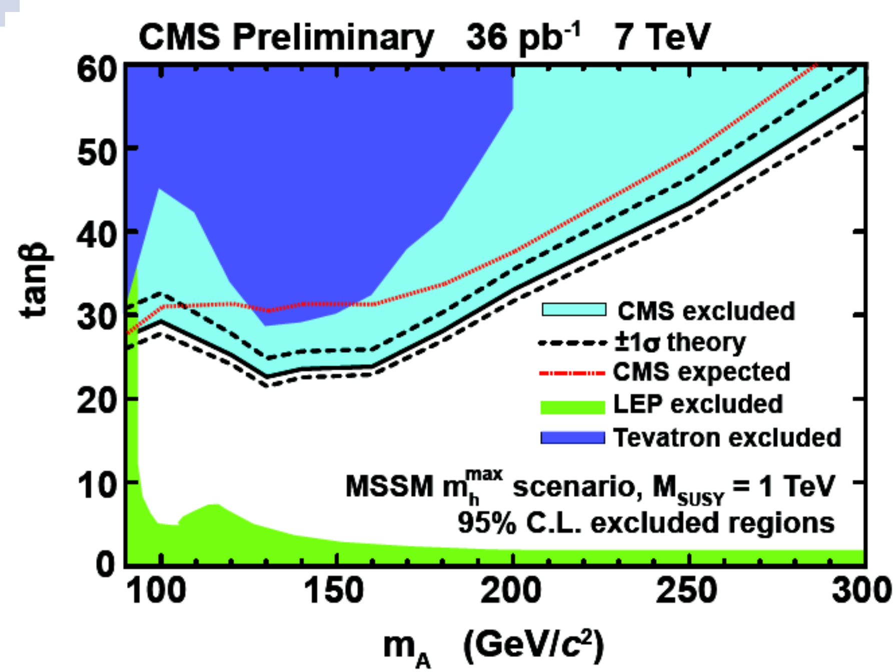


Tevatron vs CMS exclusion on tanβ

M_A = 140 GeV		
	Tevatron	LHC/CMS
tan β $^{exp.}$	30 (32*)	32
tan β $^{obs.}$	30 (32*)	24



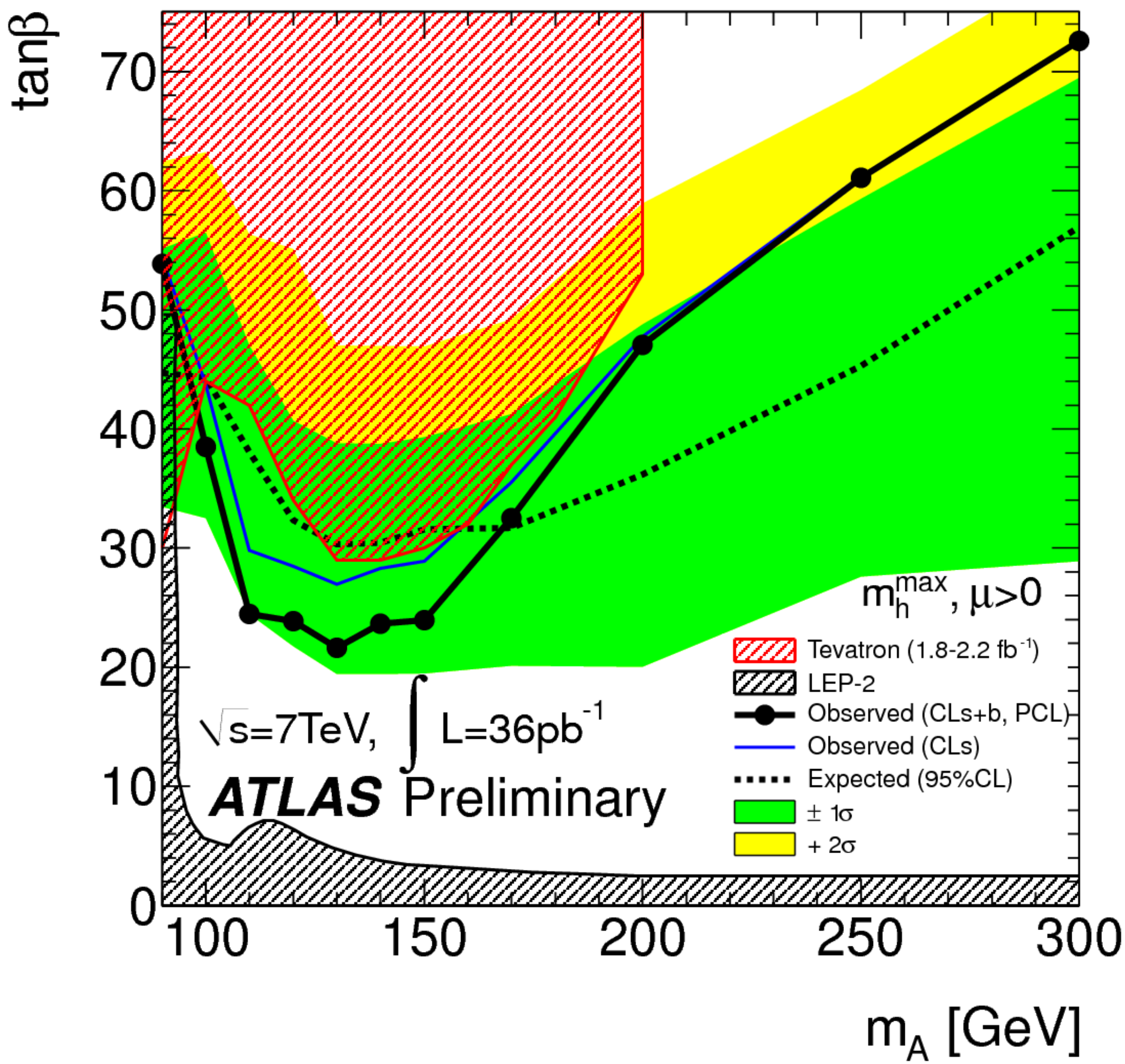




* re-evaluated by Baglio, Djouadi arXiv:1012.2748v1

“YR” th. errors: arXiv 1101.0593

ATLAS exclusion in M_A-tanβ



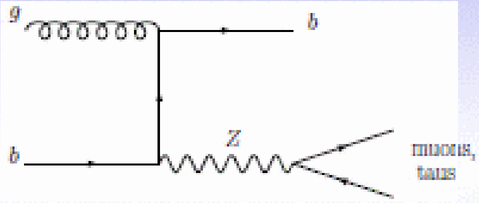
Preparation for pp->bbϕ, ϕ->ττ discovery

- "Discover" Z+b as "benchmark" for ϕ+b

$Z + b$ as a test case

Slide from J. Campbell talk

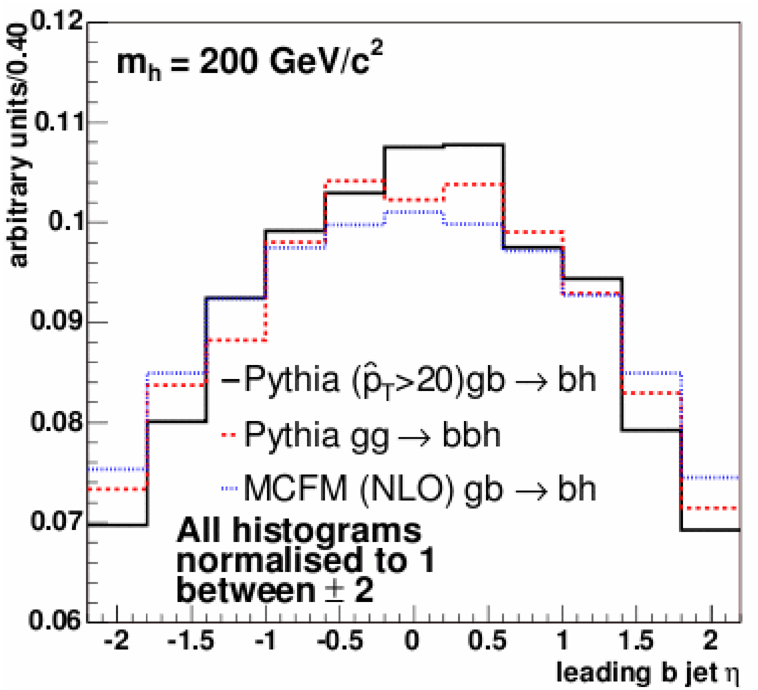
- The production of $Z + b$ is very similar to that of $H + b$, even lying in a similar kinematic region for a low mass Higgs.
- Theoretically, the two processes have the same inputs and uncertainties.
  - same initial state, similar (x, Q^2)
  - the same H and Z decays
- Test the experimental analysis procedure by re-discovering the Z –
  a) $Z+$ one jet which is b-tagged ;
  b) $Z+$ two jets, one or more b-tags.
- Furthermore, for low Higgs masses a significant source of background events could come from the production of a slightly off-shell Z boson and a bottom quark at high p_T.



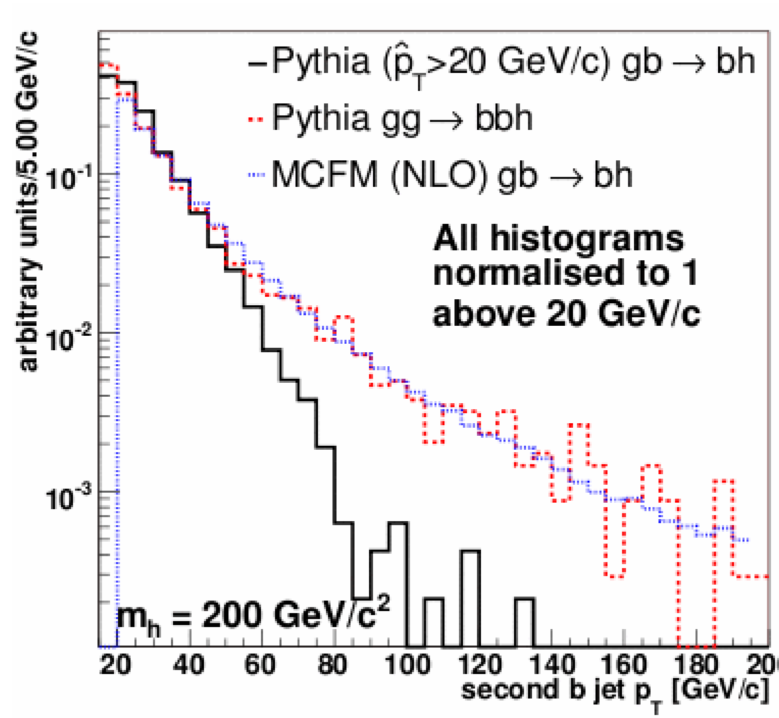
Different MCs for b(b)H production gives different predictions: => need bbZ data to tune/verify Monte Carlo

Campbell, Kalinowski and Nikitenko; Les Houches 2005 hep-ph/0604120

η^b



second b p_T



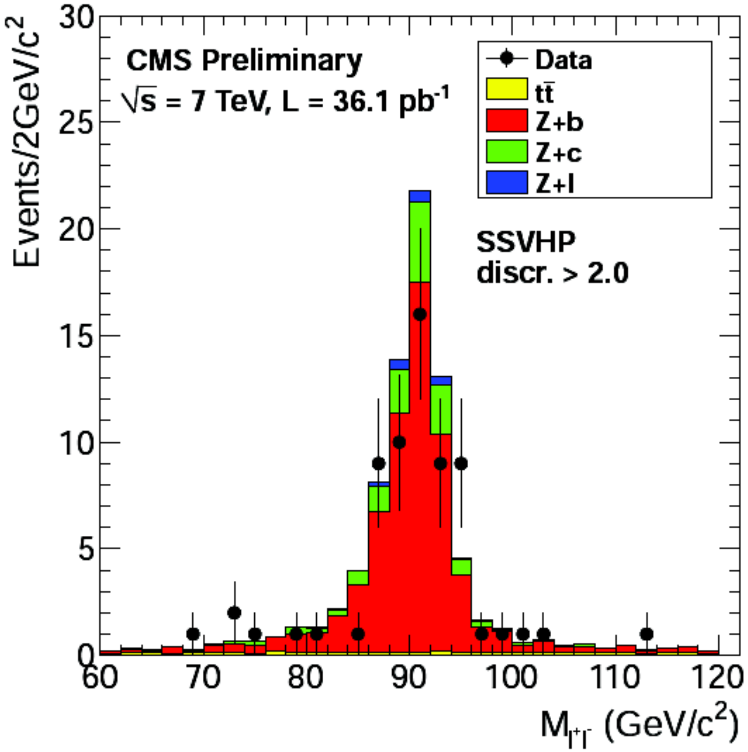
PYTHIA gg->bbH describes p_T^b spectra at NLO within 5-10 %;
Kinnunen, Lehti, Moortgat, Nikitenko, Spira. Eur.Phys.J. C40n5:23-32,2005

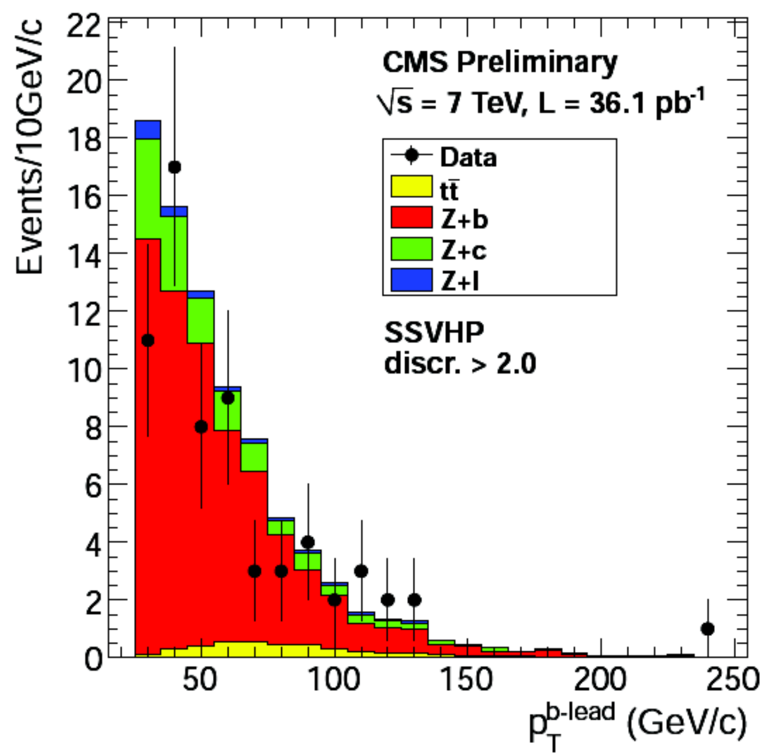
want to measure Z + 1(2) b + X

- at least 1 b tagged jet
  - Campbell, Ellis, Maltoni, Willenbrock, McElmurry hep-ph/0312024, hep-ph/0505014. $m_b = 0$
- at least two jets with at least 1 b-tagged jets
  - Campbell, Ellis, Maltoni, Willenbrock hep-ph/0510362, m_b=0
- at least two jets with 2 b-tagged
  - Cordero, Reina, Wackeroth arXiv:0906.1923 [hep-ph],massive b
- *ME+PS generator preselections (discussed with F. Krauss, M. Mangano, F. Maltoni):*
  - *LO pp->bbZ with massive b; p_T^b > 15 GeV for at least one b.*
  - *Need corresponding σ NLO, L. Reina, F. Cordero – work in progress*

Z+b in CMS with 36 pb^{-1} at 7 TeV

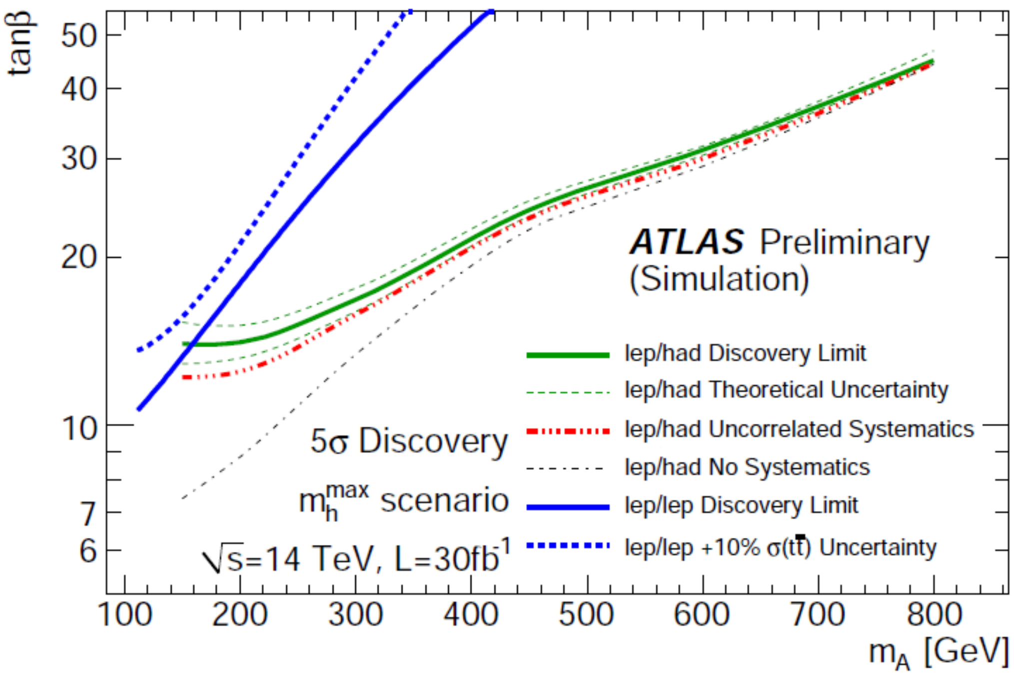
- **First observation of Z+b at LHC**
  - 65 evens with single b-tag jet p_T>25 GeV, $|\eta|$<2.1 (~ 83 % of Z+b)
- **Good agreement with theory/MC for Z+b/Z+j ratio**



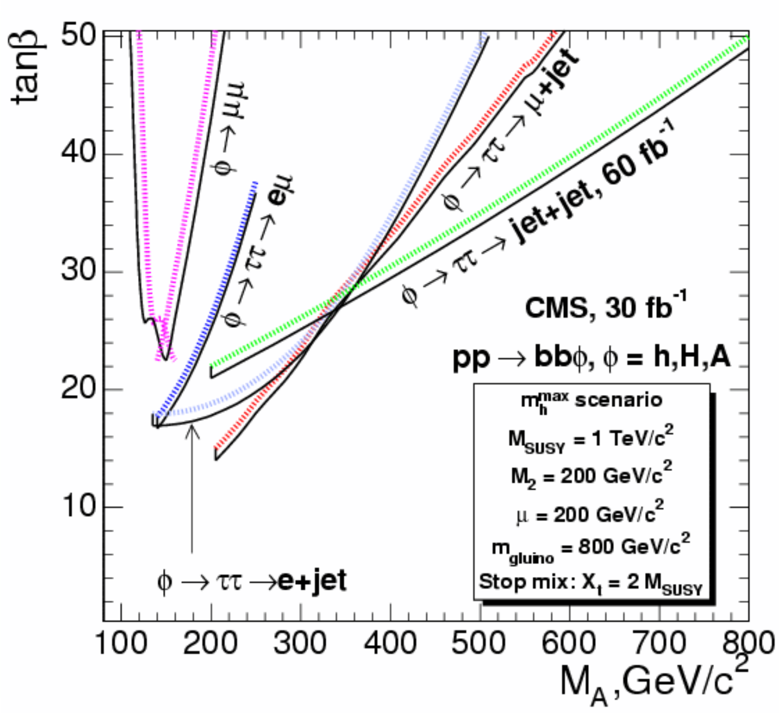


Discovery reach with 30 fb^{-1} at 14 TeV

ATLAS ϕ->ττ

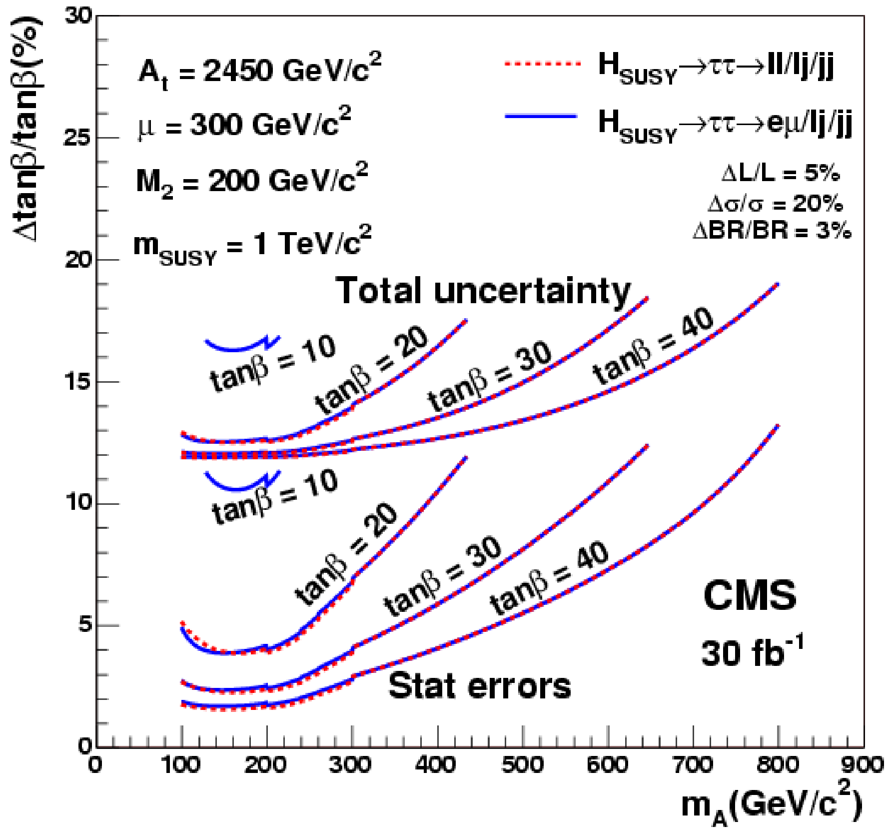


CMS ϕ->ττ, μμ



tan(β) "measurement" with MSSM bbϕ

with ϕ->ττ using cross-section measurement;
with ϕ->μμ using ϕ width (CMS PTDR)



From
Kinnunen, Lehti, Moortgat, Nikitenko, Spira.
Eur.Phys.J. C40n5:23-32,2005

In bbϕ, ϕ–>ττ we used $\Delta\sigma_{th}$=20%, ΔBr=3%

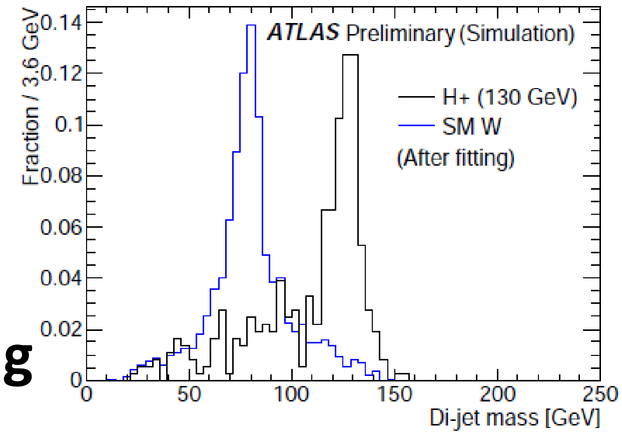
(new: Noth, Spira 2010, NNLO SUSY QCD/EWK : ΔBr(ϕ–>ττ) ~ 1 %)

New ATLAS MC studies for light H+->cs, τν

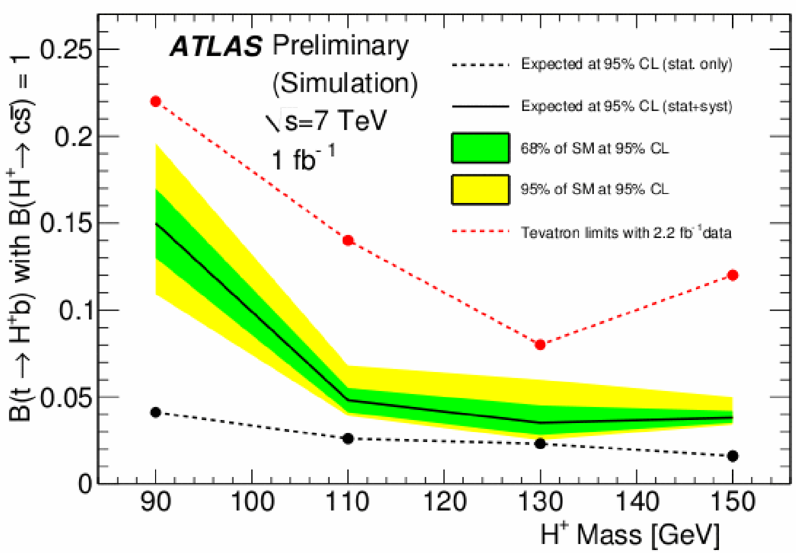
ATL-PHYS-PUB-2010-009, L=1 fb^{-1} at 7 TeV

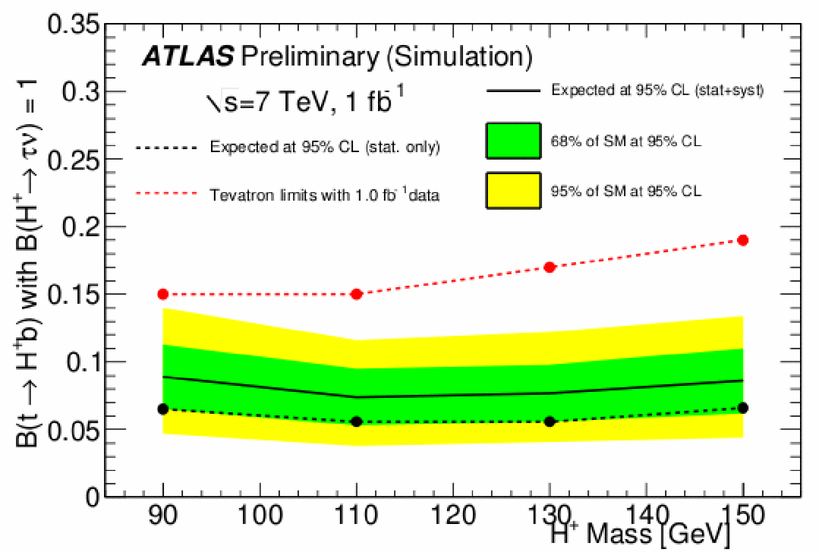
- tt->WbH$^+$b->lνb+csb

M_{jj} for W->jj and H$^+$->cs after fitting



- tt->WbH$^+$b->lνb+τνb
  - τ->lνν
- New variables to separate signal from bkg.:
  - Helicity angle, cos θ^*_l
  - generalized transverse mass m_{T2}^{H+}

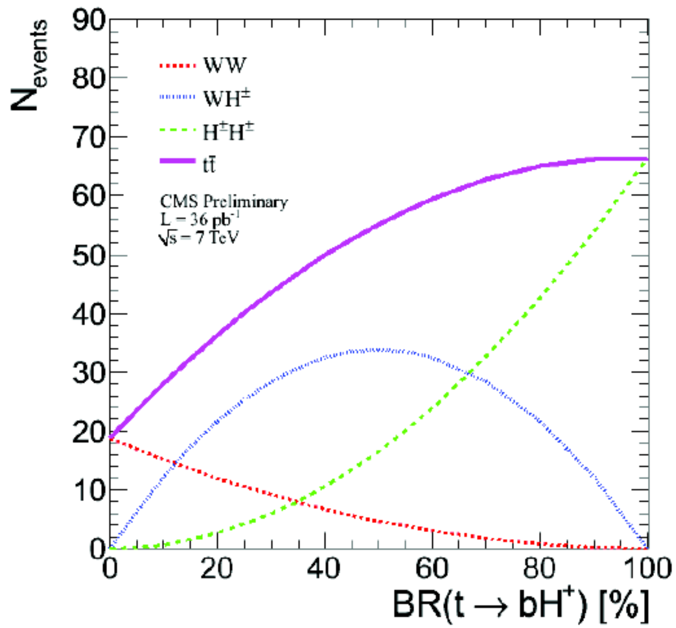


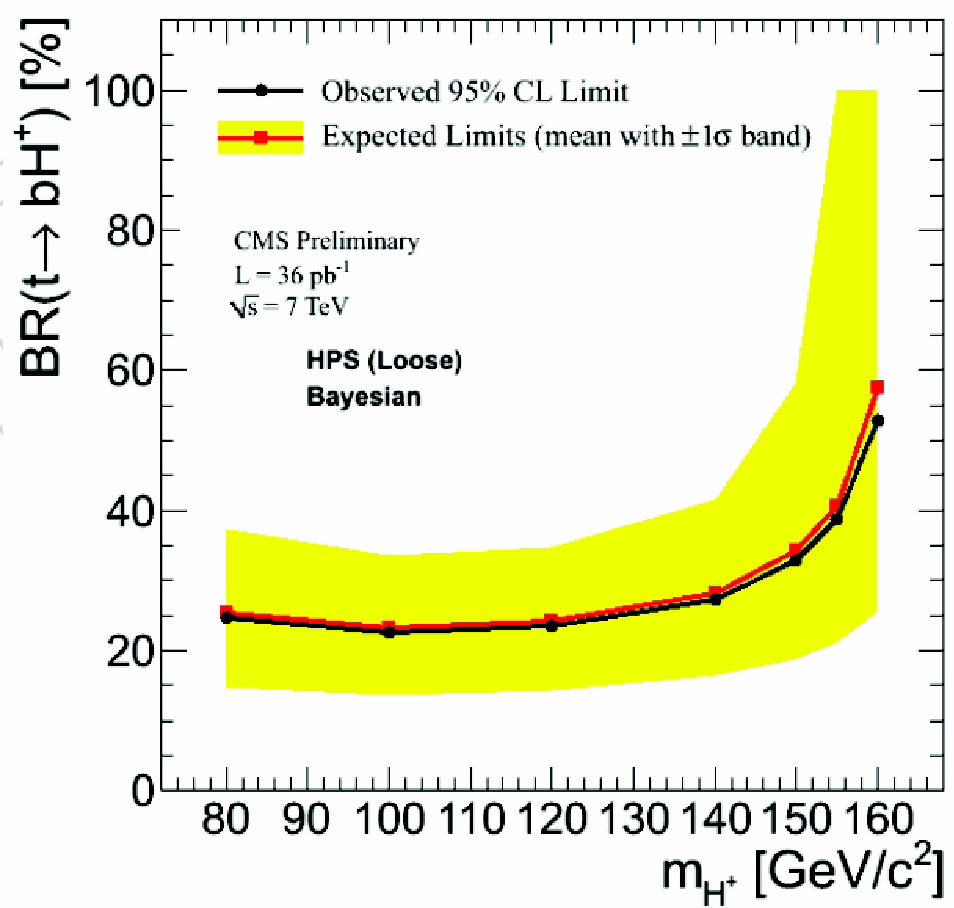


$t \to H^+b$, $H^+ \to \tau\nu$ in CMS with 36 pb^{-1} at 7 TeV

Source	N_{events}
HH, M_{H+}=120 GeV/c^2	$66.5 \pm 1.8 \pm 9.7$
HW, M_{H+}=120 GeV/c^2	$68.1 \pm 1.9 \pm 9.1$
τ fakes	$21.3 \pm 2.5 \pm 5.6$
$t\bar{t} \to WbWb \to \ell\nu b\ \tau\nu b$	$10.7 \pm 0.2 \pm 1.4$
$t\bar{t} \to WbWb \to \ell\nu b\ \ell\nu b$	$1.6 \pm 0.1 \pm 0.3$
$Z/\gamma^* \to ee, \mu\mu$	$0.3 \pm 0.1 \pm 0.2$
$Z/\gamma^* \to \tau\tau$	$3.0 \pm 0.3 \pm 0.6$
Single top	$1.0 \pm 0.0 \pm 0.2$
WW,WZ,ZZ	$0.5 \pm 0.0 \pm 0.1$
Expected from SM	$38.3 \pm 2.5 \pm 5.8$
Data	40

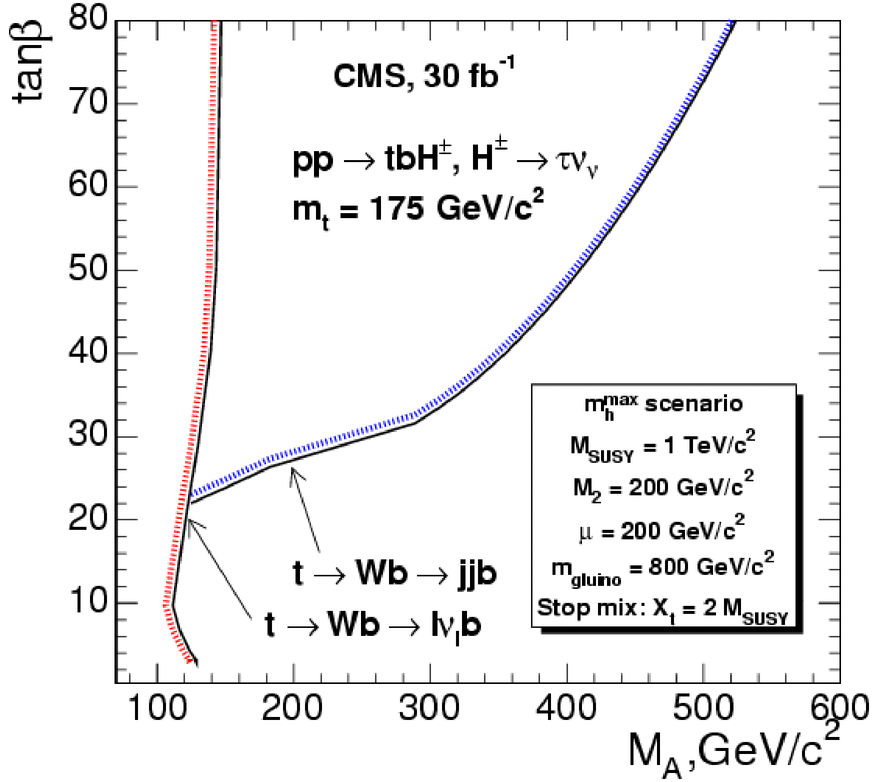
$$N_{up} = N_{WH} \cdot 2(1-x) \cdot x + N_{HH} \cdot x^2 + (N^{\ell\tau}_{SM\ tt} + N^{\ell\ell}_{SM\ tt} + N^{\ell qq'}_{SM\ tt}) \cdot (1-x)^2 - (N^{\ell\tau}_{SM\ tt} + N^{\ell\ell}_{SM\ tt} + N^{\ell qq'}_{SM\ tt}),$$

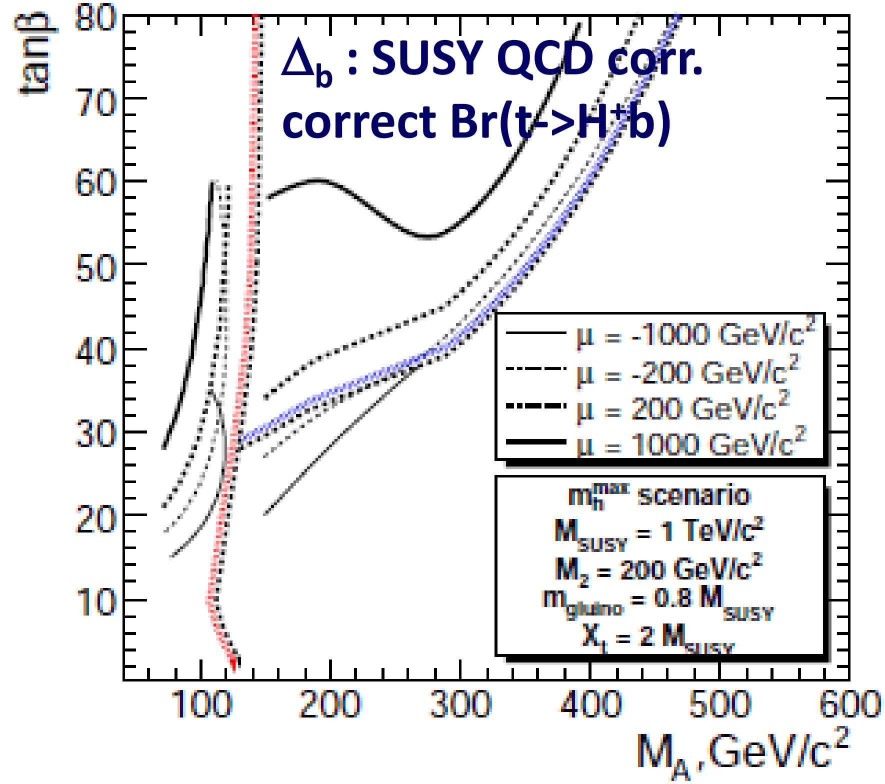




The 5 σ discovery reach of CMS 2006 (PTDR) for MSSM charged Higgs bosons with m_h^{max} scenario.

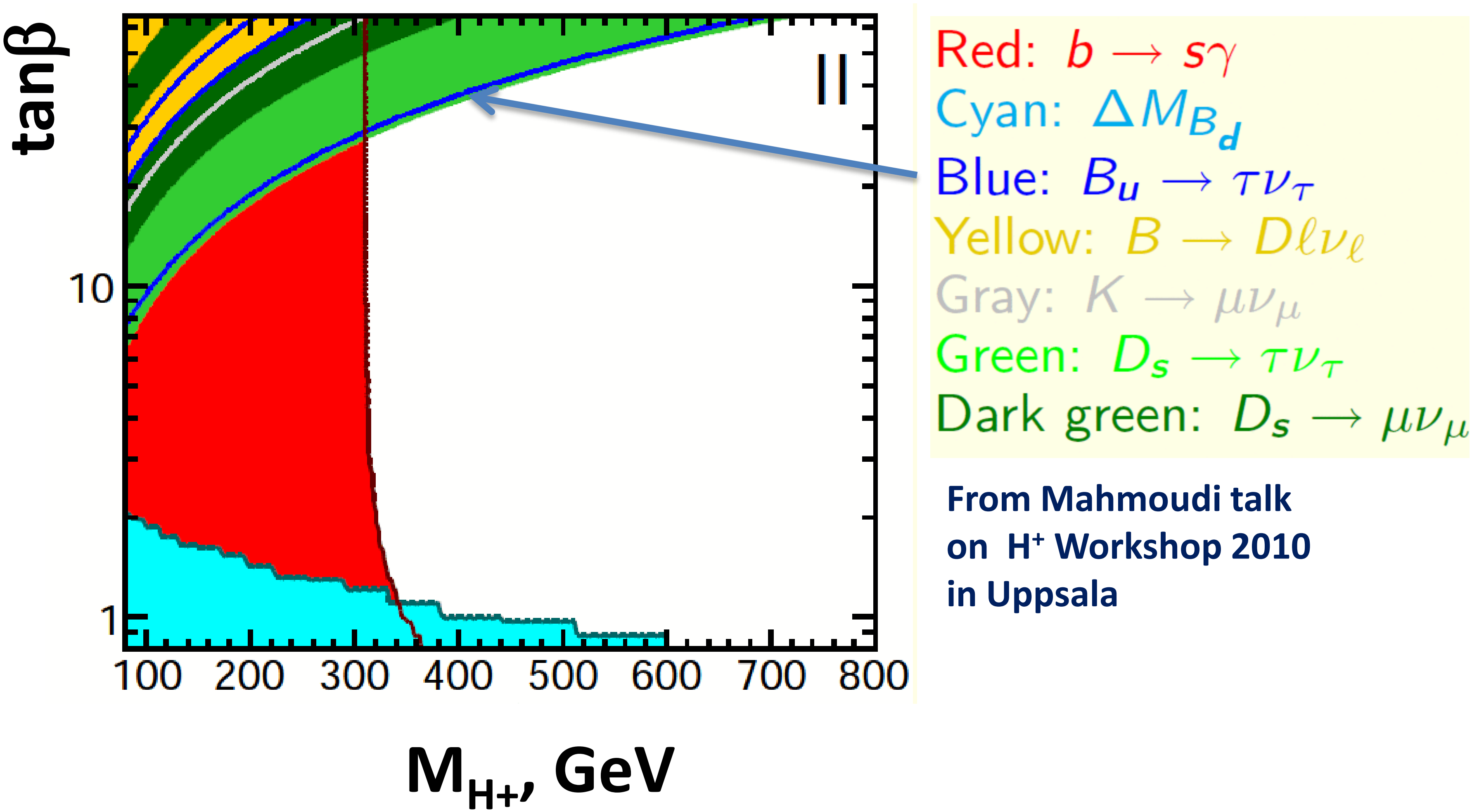
PTDR 2006: NLO cross-section, but no SUSY QCD corrections → ***Post PTDR update 2008 with Weiglein and Heinemeyer arXiv:0804.1228 [hep-ph]***





- **Dittmaier, Kramer, Spira, Walser 2009:** CMS reach for pp->tbH$^+$, H$^+$->τν in SPS 1b scenario: *effect of cross-section uncertainty on discovery reach*

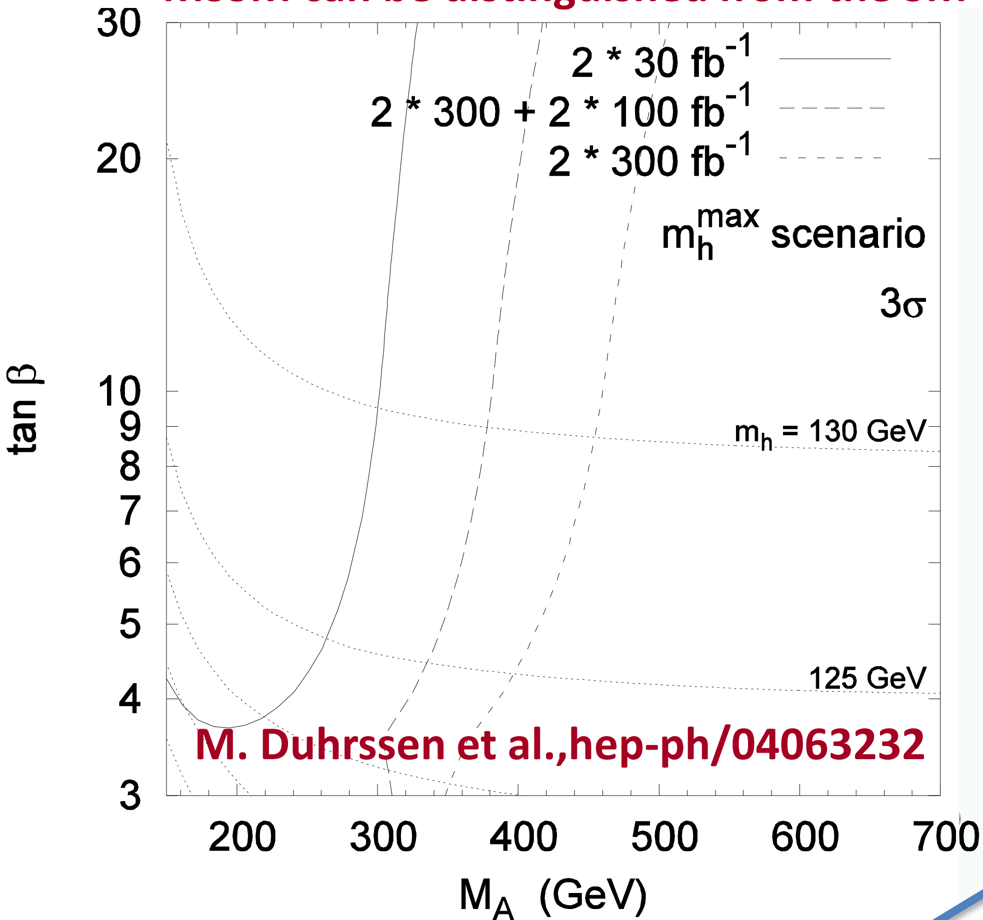
Is $H^+ \to \tau\nu$ (and $\phi \to \tau\tau$) discovery region already excluded by $B \to \tau\nu_\tau$?



From Mahmoudi talk
on H^+ Workshop 2010
in Uppsala

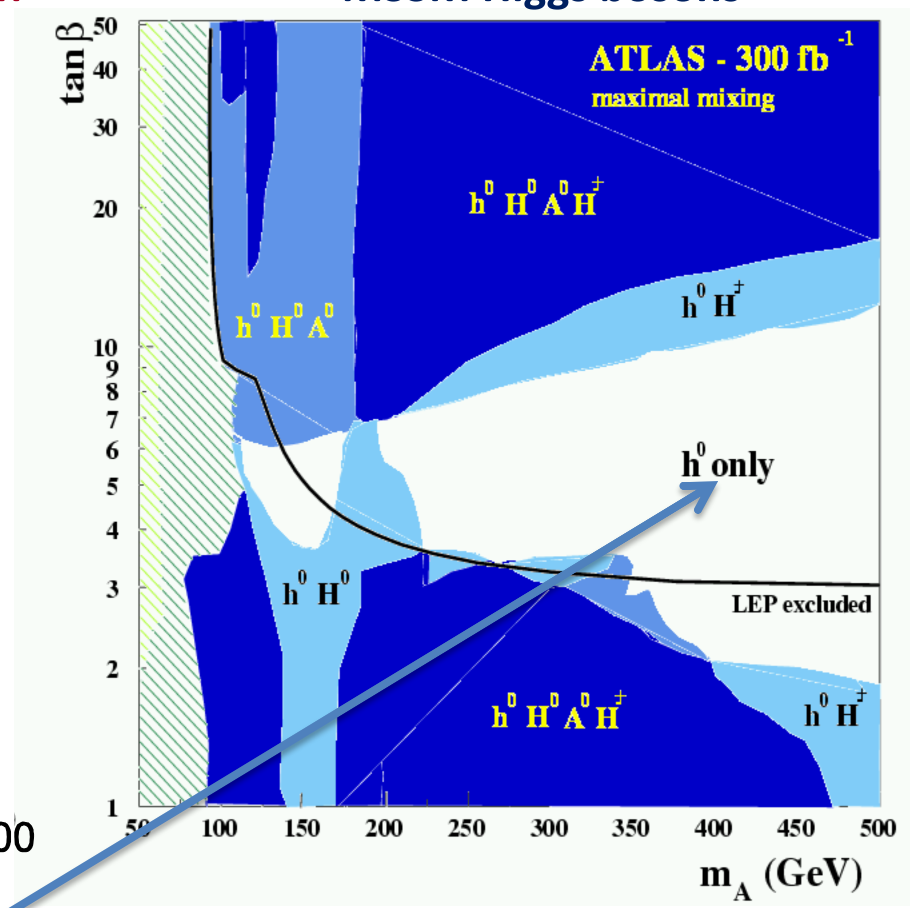
Can MSSM be distinguished from SM if only one, light Higgs is discovered ?

Area on the left of the curves is where MSSM can be distinguished from the SM



M. Duhrssen et al.,hep-ph/04063232

5 σ discovery regions for one or more MSSM Higgs bosons



SM like Higgs… Need linear collider

I did not say about CMS/ATLAS studies on

- *NMSSM H_1->$a_1 a_1$->$\tau\tau\tau\tau$*
  - *arXiv:0805.3505 [hep-ph], arXiv:0801.4321[hep-ph]*
- *$H^{++}H^{--}$ -> $llll$ (l= μ, τ) – CMS 2010 data analysis*
- *NMSSM a1->$\mu\mu$ ATLAS 2010 data analysis*
- *5D Randall-Sundrum model: ϕ->hh->$\gamma\gamma$/$\tau\tau$ +bb*

Conclusions

ATLAS and CMS start producing first results for Higgs physics this year !

THE END

Process	$\mu\tau_h$	$e\tau_h$	$e\mu$
$Z \to \tau\tau$	329±77	190±44	88±5
$t\bar{t}$	6±3	2.6±1.3	7.1±1.3
$Z \to \ell\ell$, $jet \to \tau_h$	6.4±2.4	15±6.2	
$Z \to \ell\ell$, $\ell \to \tau_h$	13.3±3.6	119±28	
$W \to \ell\nu$	54.9±4.8	30.6±3.1	
$W \to \tau_\ell\nu$	14.7±1.3	7.0±0.7	3.9±1.2
QCD	132±14	181±23	
$WW/WZ/ZZ$	1.6±0.8	0.8±0.4	3.0±0.4
Total	558±79	546±57	102±5
Observed	540	517	101
Signal Efficiency (m_A=120 GeV/c^2)	0.0253	0.0156	0.00561

- Uncertainty on yields

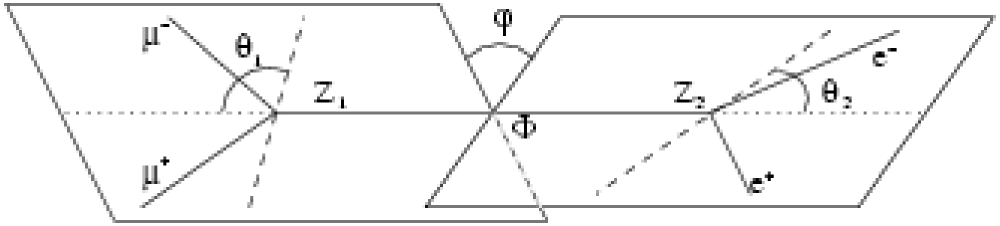
Source	$\tau_\mu\ \tau_{had}$	$\tau_e\ \tau_{had}$	$\tau_e\ \tau_\mu$
trigger	0.971±0.002	0.959±0.022	0.971±0.002
lepton identification and isolation	0.992±0.004	0.968±0.035	0.960±0.035
τ_{had} identification	1.00± 0.23		-
efficiency of OS, M_T and $2nd$ lepton veto	1.00±0.02		
acceptance due to τ_{had} JES, 3 %	2.7 %		-
acceptance due to e energy scale, 1 %	-	1 %	1 %
acceptance due to μ momentum scale, 1%	1 %	-	1 %
luminosity uncertainty	11 %		

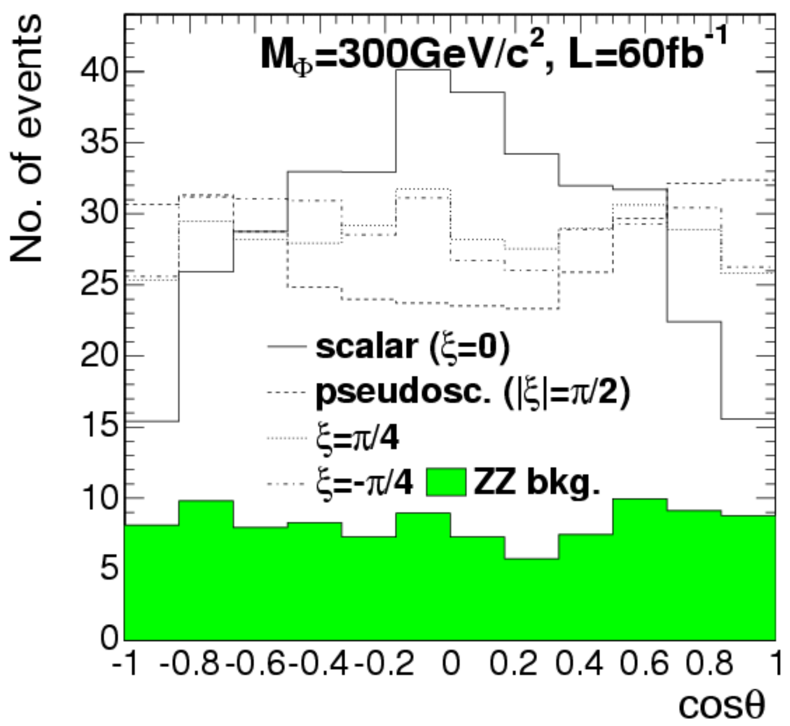
→ can move to 4%

- Uncertainty on shapes
  - tau (3%), muon (1%) and electron (2%) scales
  - Missing transverse energy via jets scale (3%) and unclustered energy (10%)

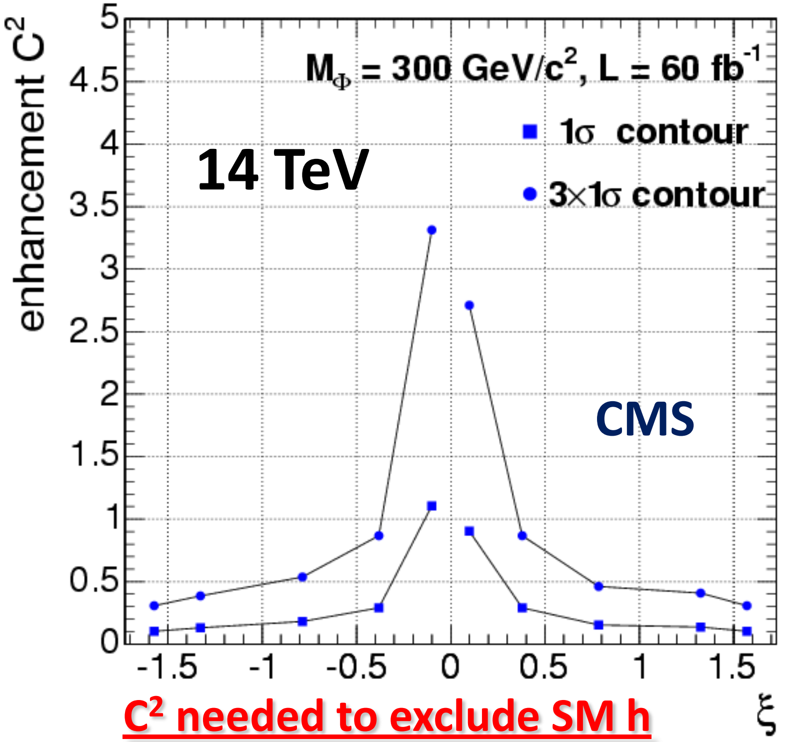
Higgs CP property with H->ZZ->4l

$d\Gamma(\eta) \sim H + \eta I + \eta^2 A$,
H scalar, A – pseudoscalar,
$\eta = \tan(\xi)$, $\xi = +/- \pi/2$ --> A

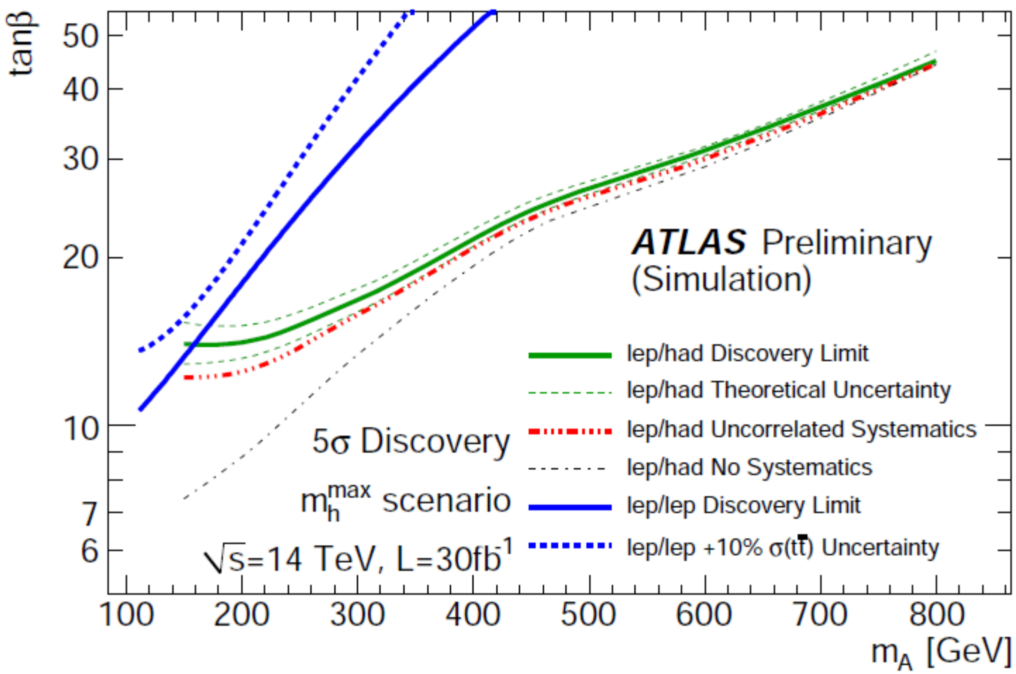




$C^2 = \sigma\, Br / \sigma_{SM}\, Br_{SM}$



C² needed to exclude SM h



tanβ
50
40
30
20
10
7
6
100
200
300
400
500
600
700
800
m_A [GeV]
ATLAS Preliminary
(Simulation)
5σ Discovery
m_h^{max} scenario
$\sqrt{s}$=14 TeV, L=30fb^{-1}
lep/had Discovery Limit
lep/had Theoretical Uncertainty
lep/had Uncorrelated Systematics
lep/had No Systematics
lep/lep Discovery Limit
lep/lep +10% σ($t\bar{t}$) Uncertainty

Uncertainties involved in the $\tan(\beta)$ measurement

At large $\tan(\beta)$, $\sigma \times Br \sim \tan^2(\beta)_{eff}\, f(M_A)$ at fixed μ, M_2, A_t, M_{SUSY}

$$N_S = \tan^2(\beta)_{eff}\ f(M_A)\ L\ \varepsilon_{sel}$$

$$\tan(\beta) = \tan(\beta)_{mes} +/- \Delta_{stat} +/- \Delta_{syst} +/- \Delta_{MCgen}$$

$$\Delta_{syst} = 0.5\ \mathrm{sqrt}(\Delta L^2 + \Delta\sigma_{th}^2 + \Delta Br_{th}^2 + \Delta\sigma(\Delta M_H)^2 + \Delta\varepsilon_{sel}^2 + \Delta B^2)$$

$\Delta\sigma_{th}$ = 20 % due to NLO scale dependence

ΔBr_{th} = 3 % uncertainties of SM input parameters

ΔL = 5 % luminosity uncertainty

$\Delta\sigma(\Delta M_H)$ = 10-12 % due to mass measurement at 5σ discovery limit

$\Delta B = \Delta N_B / N_S$ = 10 % at 5σ discovery limit (preliminary)

$$\Delta\varepsilon_{sel}^2 = \Delta\varepsilon_{calo}^2 + \Delta\varepsilon_{b\ tag}^2 + \Delta\varepsilon_{\tau\ tag}^2$$

$\Delta\varepsilon_{b\ tag}$ = 2.0 % (preliminary)

$\Delta\varepsilon_{\tau\ tag}$ = 2.5 % (preliminary)

$\Delta\varepsilon_{calo}$ = 2.9 % (preliminary)

Uncertainties involved in the $\tan(\beta)$ measurement

At large $\tan(\beta)$, $\sigma \times Br \sim \tan^2(\beta)_{eff}\, f(M_A)$ at fixed μ, M_2, A_t, M_{SUSY}

$$N_S = \tan^2(\beta)_{eff}\ f(M_A)\ L\ \varepsilon_{sel}$$

$$\tan(\beta) = \tan(\beta)_{mes} +/- \Delta_{stat} +/- \Delta_{syst} +/- \Delta_{MCgen}$$

$$\Delta_{syst} = 0.5\ \mathrm{sqrt}(\Delta L^2 + \Delta\sigma_{th}^2 + \Delta Br_{th}^2 + \Delta\sigma(\Delta M_H)^2 + \Delta\varepsilon_{sel}^2 + \Delta B^2)$$

$\Delta\sigma_{th}$ = 20 % due to NLO scale dependence
ΔBr_{th} = 3 % uncertainties of SM input parameters
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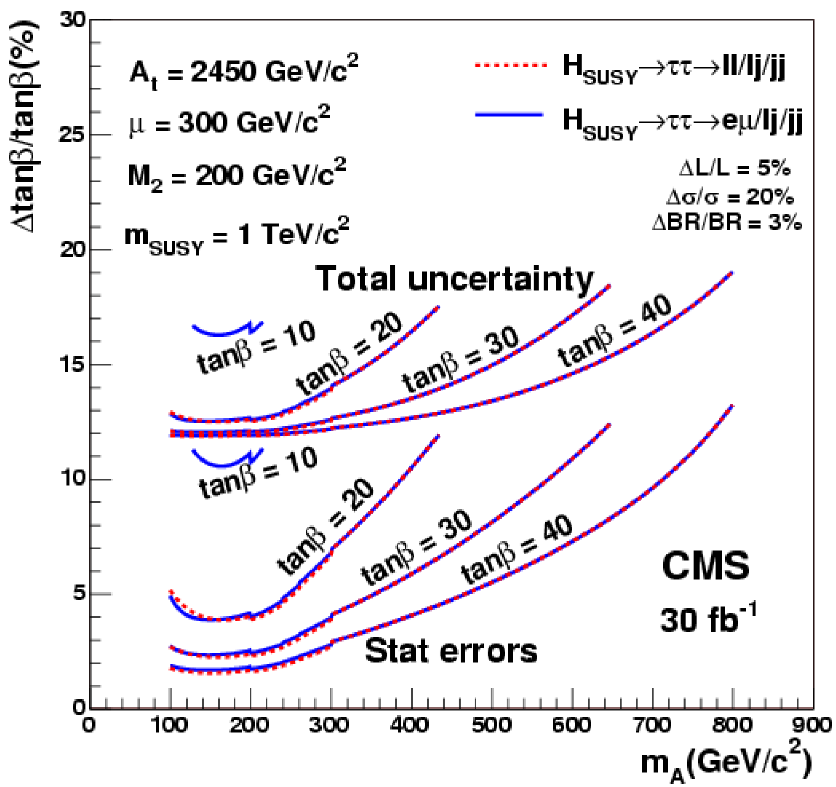
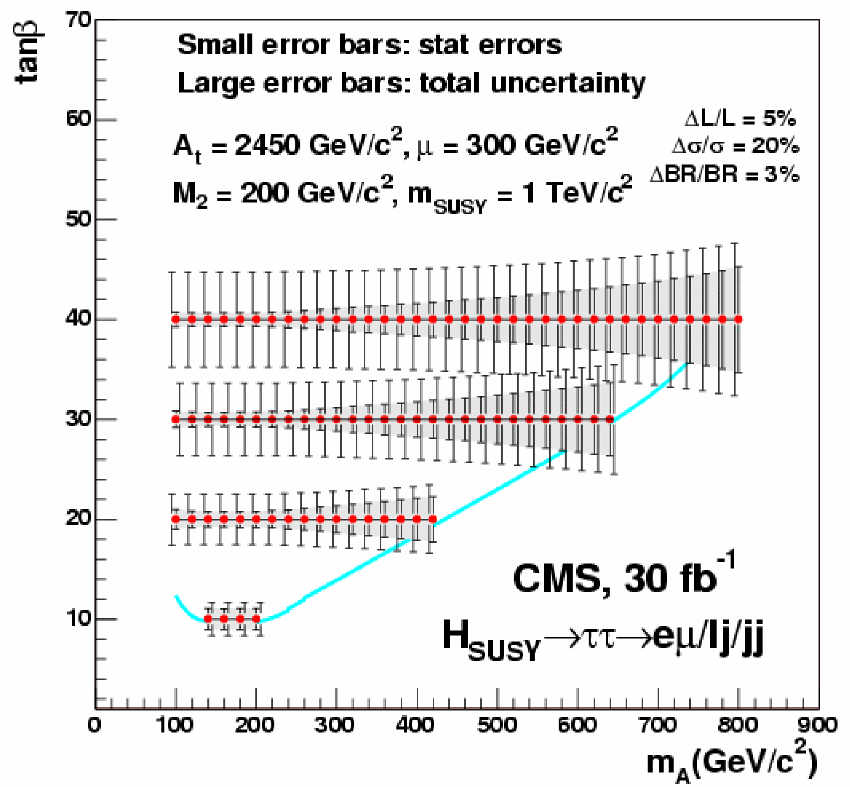
$\Delta\sigma(\Delta M_H)$ = 10-12 % due to mass measurement at 5σ discovery limit
$\Delta B = \Delta N_B / N_S$ = 10 % at 5σ discovery limit (preliminary)

$$\Delta\varepsilon_{sel}^2 = \Delta\varepsilon_{calo}^2 + \Delta\varepsilon_{b\ tag}^2 + \Delta\varepsilon_{\tau\ tag}^2$$

$\Delta\varepsilon_{b\ tag}$ = 2.0 % (preliminary)
$\Delta\varepsilon_{\tau\ tag}$ = 2.5 % (preliminary)
$\Delta\varepsilon_{calo}$ = 2.9 % (preliminary)

MSSM gg->bbA/H, A/H->2τ : accuracy of tan(β) measurement



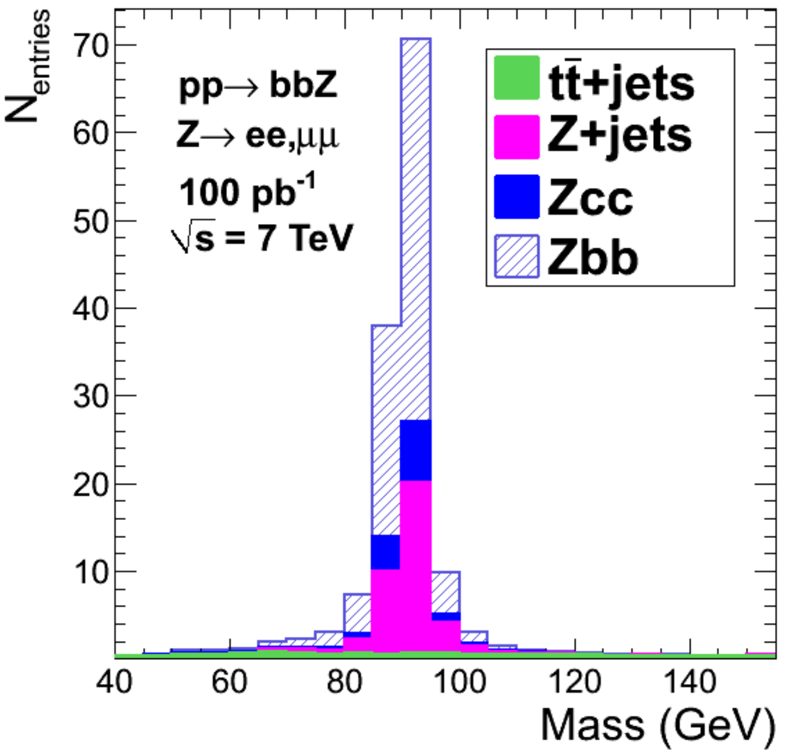


CMS expectations for Z+1b at 7 TeV

(rescaling of 10 TeV result)

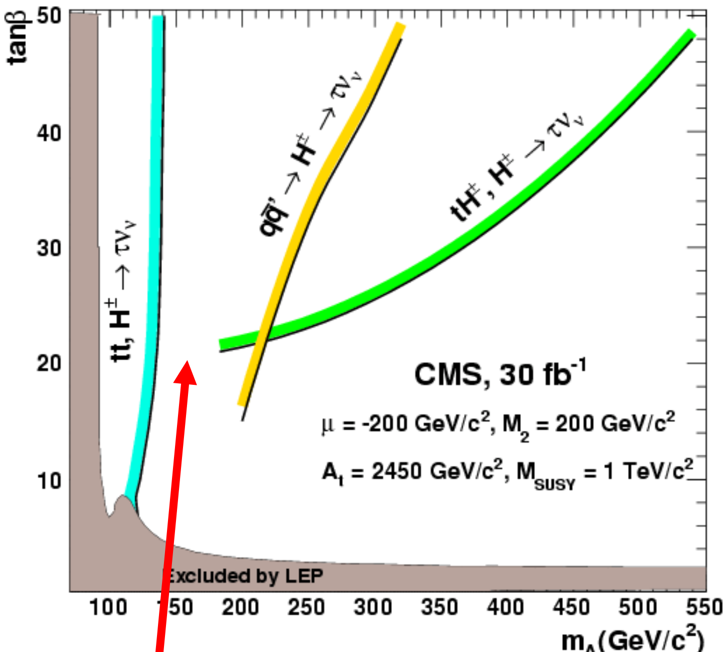
A.M. Magnan, A. Nikitenko . CMS Analysis Note 2010/027
A. Nayak, T. Aziz, A. Nikitenko, CMS Analysis Note 2008/020

- 2 l p_T > 20 GeV, |η|<2.1
- E_T^{miss} < 40 GeV
- >= 1 b-jet, E_T>15 GeV, |η|< 2.1
- N_S = 84 ev.
- *Background:*
  - *Z+jets: 39 ev.*
  - *Z+cc: 14 ev*
  - *tt~: 15 ev*

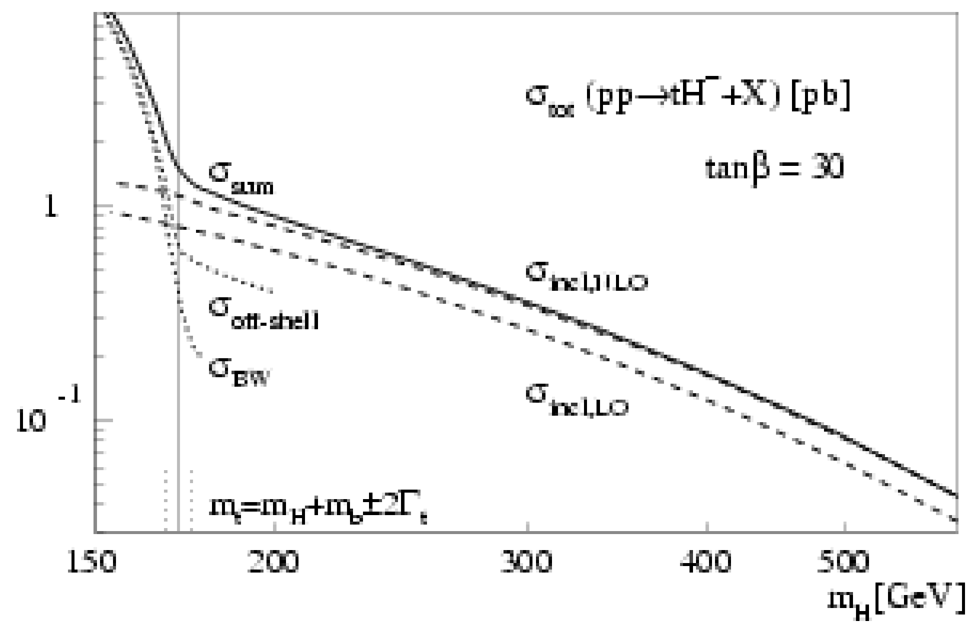


The 5 σ discovery reach of CMS 2003 for MSSM charged Higgs bosons with m_h^{max} scenario.

CMS Note 2003/033



NLO cross section for pp->tH⁻ +X



Gap at M_{H+} ~ M_t is artificial due to usage of gg->tt (NWA) cross section

gg->tbH+ process is available in PYTHIA (S. Moretti et al. Les Houches 2003)

NLO cross section (no Δ_b SUSY corrections) : T. Plehn et al., hep-ph/0312286