News on Exclusive Production of the BSM Higgs bosons

Marek Taševský

Institute of Physics, Academy of Sciences, Prague

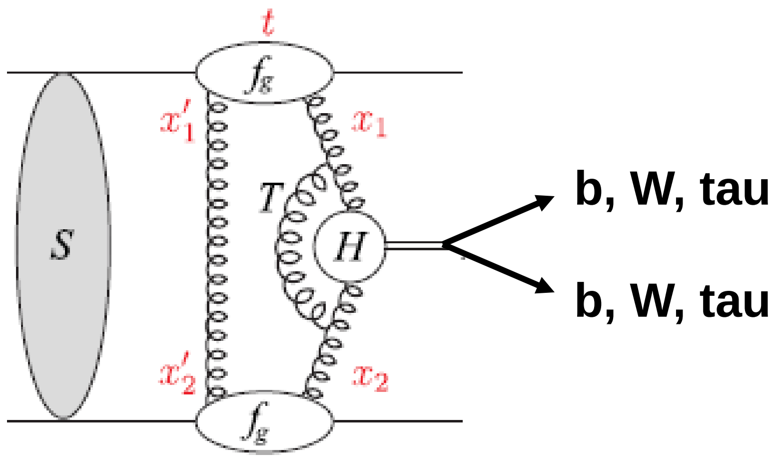
(in collaboration with S. Heinemeyer, V. Khoze, M. Ryskin and G. Weiglein)

Low-x workshop 2012, Paphos, Cyprus - 28/06 2012

EPJC 53 (2008) 231, EPJC 71 (2011) 1649

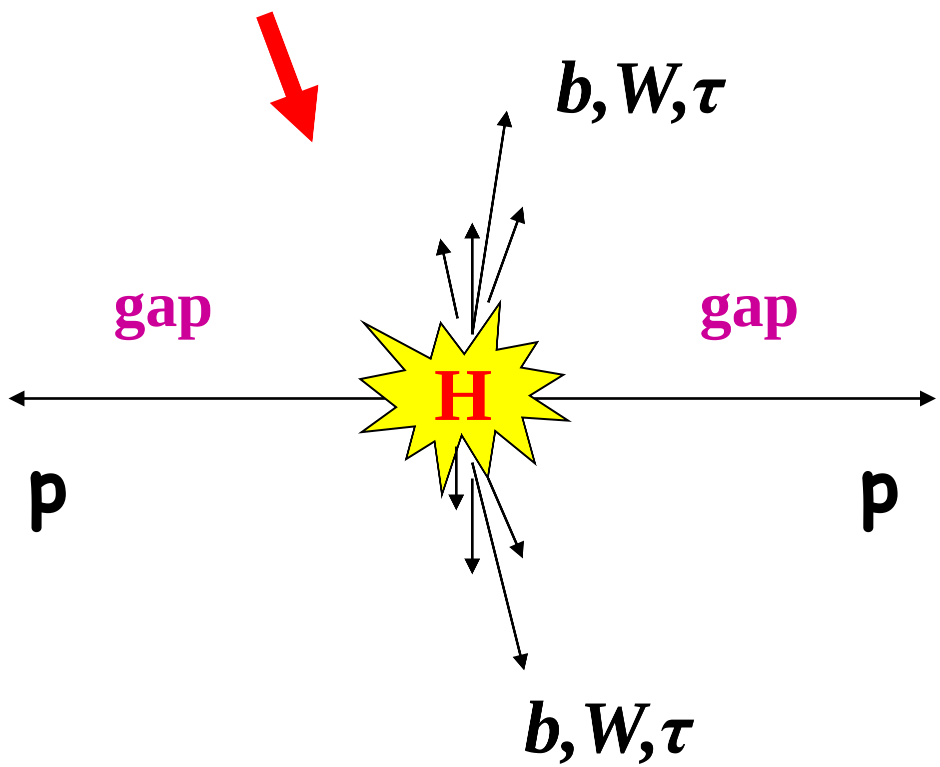
LHC SM Higgs excess and MSSM exclusion bounds! (data 2011)

Central Exclusive Diffraction: Higgs production



1) Protons remain undestroyed, escape undetected by central detector and can be detected in forward detectors

2) Rapidity gaps between leading protons and Higgs decay products



x-section predicted with uncertainty of 3 or more

Huge contribution by KMR group
(but see also Cudell et al.
Pasechnik & Szczurek, Forshaw & Coughlin)

bb: at 120 GeV needs a special diffractive trigger

WW: promising for M>130 GeV use leptonic triggers

ττ : interesting around 100 GeV under study

Central Exclusive Diffraction: Higgs production

Advantages:

I) Forward proton detectors give much better mass resolution than the central detector

II) $J_Z = 0$, C-even, P-even selection rule:

- strong suppression of CED gg→bb background (by $(m_b/M_H)^2$)
- produced central system is dominantly 0^{++} → **just a few events are enough to determine Higgs quantum numbers.** Standard searches need high stat. (φ-angle correlation of jets in VBF of Higgs) and coupling to Vector Bosons

Find a CED resonance and you have confirmed its quantum numbers!!

III) Access to main Higgs decay modes in one (CED) process: bb, WW, tautau

↓

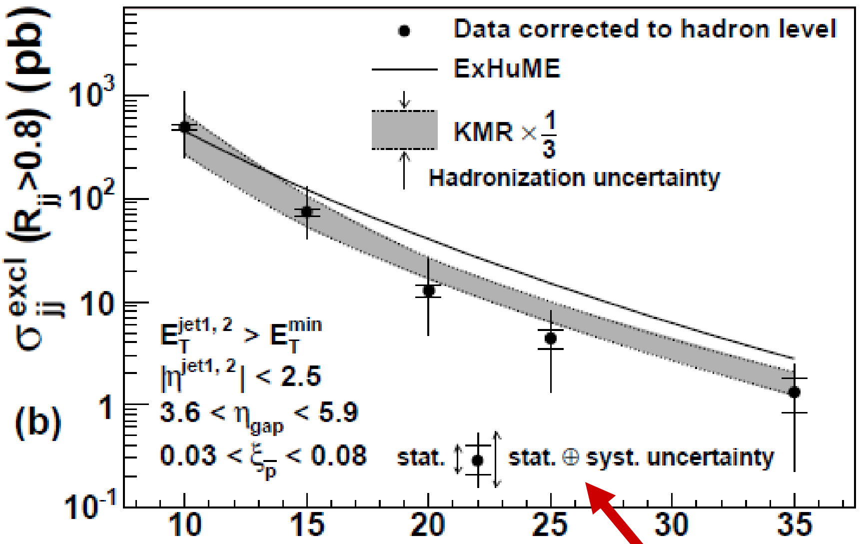
information about Yukawa coupling
(Hbb difficult in standard searches due to huge bg.)

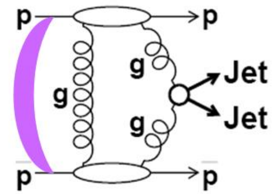
IV) In MSSM, CED Higgs process give very important information on the Higgs sector, and in addition, for sufficiently high tanβ values, it allows direct measurement of the Higgs width.

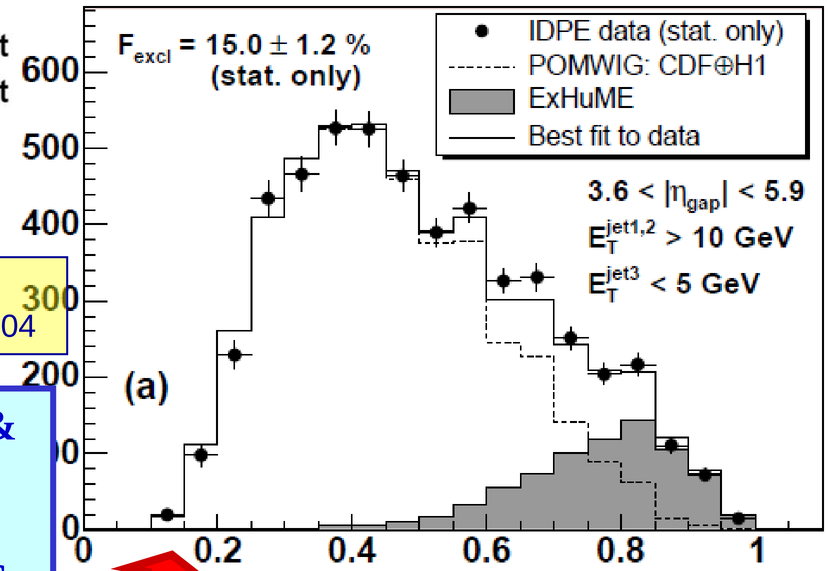
Disadvantages:

- Low signal x-section (but large S/B)
- Large Pile-up

Evidence of exclusive dijets at Tevatron





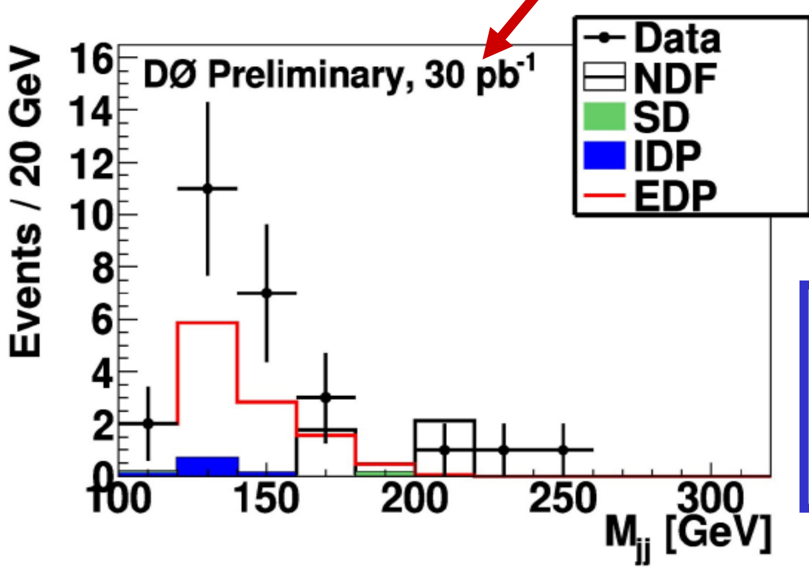


CDF Collaboration
PR D77 (2008) 052004

E_{Tjet} > 10 GeV &
R_{JJ} >0.8:
CED with
significance of 6σ

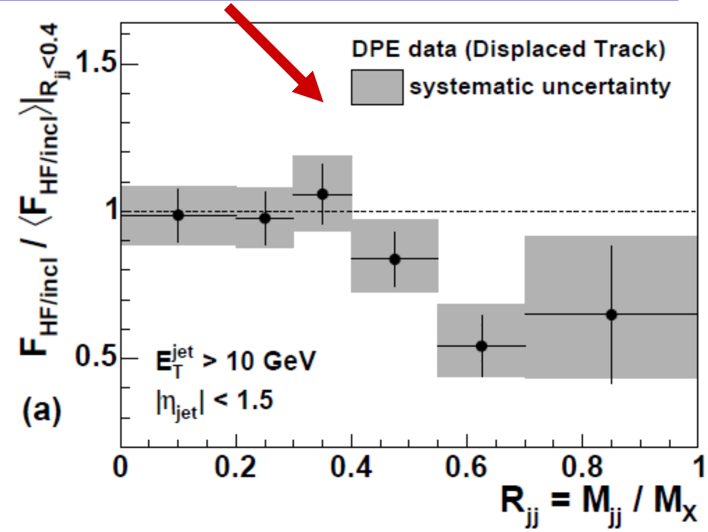
Data consistent with KMR predictions

Suppression of $b\bar{b}$ production as expected



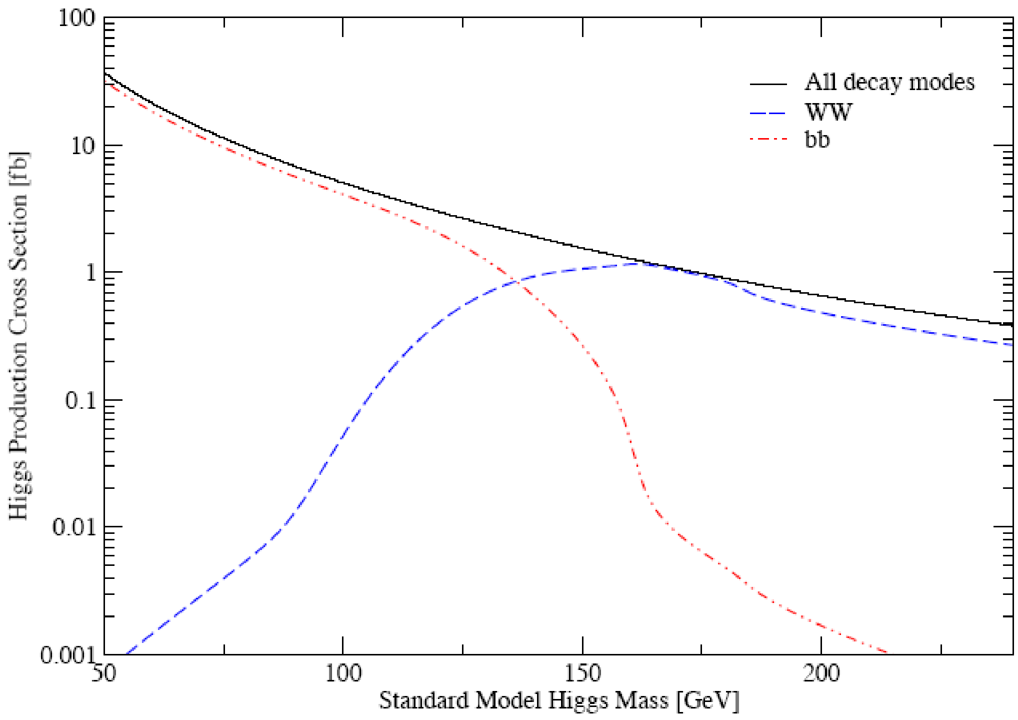
D0 collaboration
PL B705 (2011) 193

M_{JJ} > 100 GeV! &
exp(-ΣE_T) > 0.85:
CED with
significance of 4.1σ

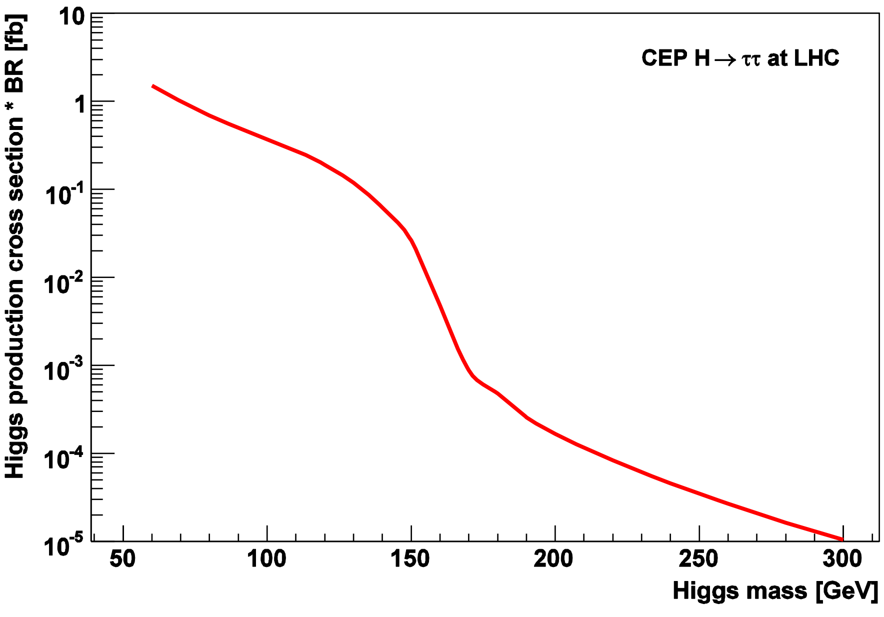


X-sections (KMR) and FD Acceptances for √s = 14 TeV

M_H [GeV]	σ (bb) [fb]	σ (WW^*) [fb]	Acc (420+420)	Acc(420+220)
120	1.9	0.37	0.20	0.17
130		0.70	0.15	0.24
140	0.6	0.87	0.11	0.31
160	0.045	1.10	0.04	0.43
180	0.0042	0.76	0.01	0.53



Acceptances for AFP detectors at (220,420) m and 2.5mm,4mm from the beam (1mm dead space)



Experimental analyses on CED Higgs production

CMS:

H→bb: fast simulation, 100 < M_H < 300 GeV, d_{220}~1.5mm, d_{420}~4.5mm, Acc=Acc(ξ,t,φ)

- track variables (N_C, $N_C^{\perp}$) not used →PU bg overestimated
- L1 trigger: single-sided FD220 .AND. Etjet1>40.AND. Etjet2>40. No efficiencies applied
- published in CMS-Totem document **CERN/LHCC 2006-039/G-124**
- signal selection efficiencies used in MSSM study (EPJC 53 (2008) 231, EPJC 71 (2011) 1649)

ATLAS:

H→bb: 1) gen.level + smearing of basic quantities, M_H = 120 GeV

- L1 trigger: fixed rates of dijet triggers with prescales
- one MSSM point (tanβ = 40): JHEP 0710 (2007)090

2) fast simulation, M_H = 120 GeV: ATLAS internal note (common with H→WW)

3) L1 trigger: a dedicated H→bb trigger (ATLAS internal note)

All analyses on H→bb get very similar yields for signal and background

H→WW: fast + full simulation, M_H = 160 GeV: ATLAS internal note (common with H→bb)

H→tautau: full simulation, 100 < M_H < 300 GeV (designed for a MSSM study)

All ATLAS analyses use d_{220}~2-3mm, d_{420}~4-5mm, Acc=Acc(ξ,t)

Experimental analysis strategy for H→bb

1) Proton detection: in Forward proton taggers at 220m and 420m

2) jets: two b-tagged jets: $E_{T1} > 45$ GeV, $E_{T2} > 30$ GeV, $|\eta_{1,2}| < 2.5$, $3.0 < |\varphi_1 - \varphi_2| < 3.3$

3) Exclusivity cuts: $0.75 < R_j < 1.2$, $|\Delta y| < 0.1$

4) L1 triggers (not included in CMS+Totem analysis)**:**

420+220: J20J40 + FD220 + $\bar{\eta} < 0.5$ + $|\Delta\eta| < 2$ + $f_T > 0.45$ → special diffractive trigger

420+420: J20J40 + $\bar{\eta} < 0.5$ + $|\Delta\eta| < 2$ + $f_T > 0.45$ → FD420 cannot be included in L1

5) Mass windows: $117.6 < M_{420} < 122.4$,

$114.2 < M_{420+220} < 125.8$ (3σ – windows)

6) Pile-up combinatorial bg suppressors:

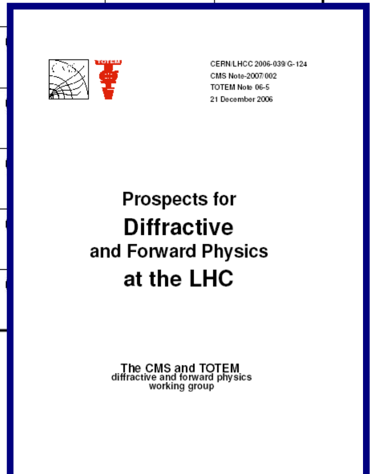
Few tracks outside the dijet

reduction factor ~20 from fast timing detector

Due to stringent cuts to suppress PU bg, experimental efficiencies for SM Higgs and hence significances are modest. **Try MSSM !**

Efficiencies for SM H→bb (CMS+Totem)

Mh [GeV]	Acc_{420}	Acc_{comb}	Acc_{220}	ε_{420}	ε_{comb}	ε_{220}
100	0.37	0.13	0.0	0.012	0.008	0.0
120	0.31	0.25	0.0	0.017	0.025	0.0
140	0.25	0.37	0.0			
160	0.19	0.49	0.0			
180	0.14	0.60	0.0			
200	0.09	0.69	0.0			
300	0.0	0.76	0.13			


CERN/LHCC 2006-039/G-124
CMS Note-2007/002
TOTEM Note 06-5
21 December 2006

Prospects for
Diffractive
and Forward Physics
at the LHC

The CMS and TOTEM
diffractive and forward physics
working group

MSSM and CED go quite well together

Extended Higgs sectors: "typical" features

Search for heavy MSSM Higgs bosons ($M_A, M_H \gg M_Z$):

Decouple from gauge bosons

$\Rightarrow$ no HVV coupling

$\Rightarrow$ no Higgs production in weak boson fusion

$\Rightarrow$ no decay $H \to ZZ \to 4\mu$

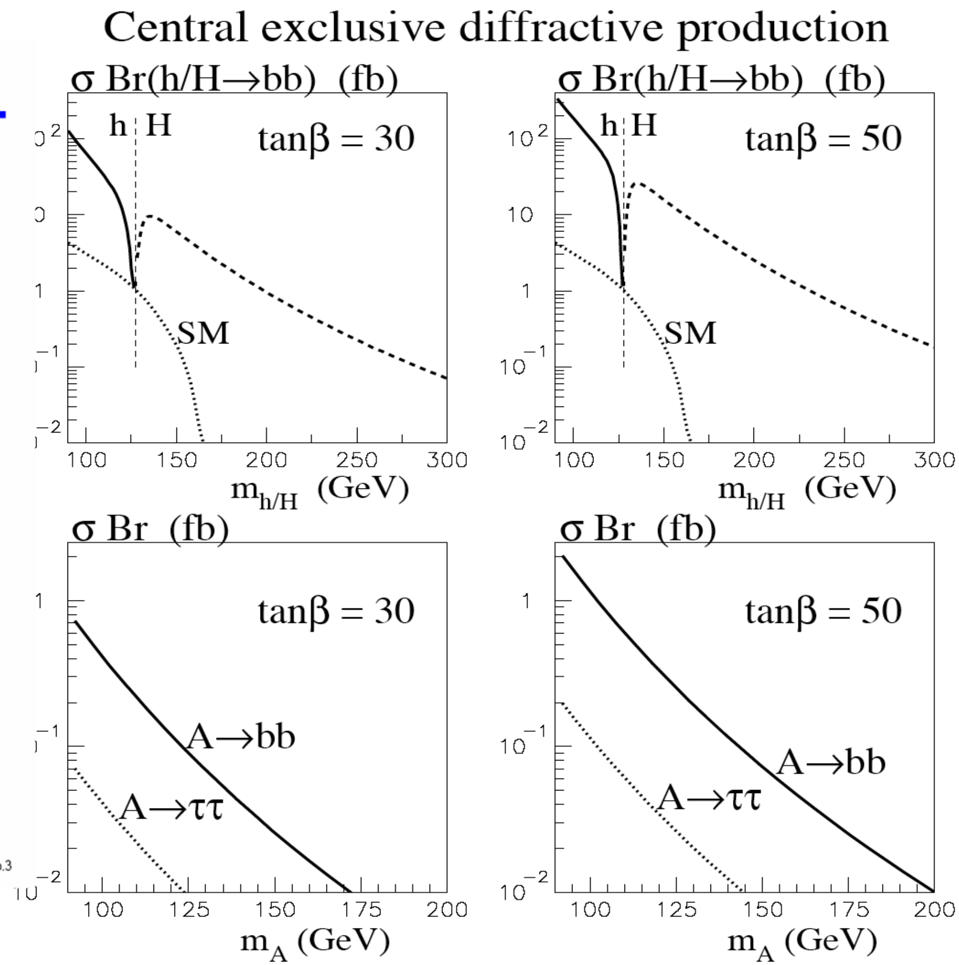
Large enhancement of coupling to $b\bar{b}$, $\tau^+\tau^-$ for high $\tan\beta$

$\Rightarrow$ Decays into $b\bar{b}$ and $\tau^+\tau^-$ play a crucial role

"Typical" features of models with an extended Higgs sector:

- A light Higgs with SM-like properties, couples with about SM-strength to gauge bosons
- Heavy Higgs states that decouple from the gauge bosons

Studying the MSSM Higgs Sector by Forward Proton Tagging at the LHC, Georg Weiglein, EPS07, Manchester, 07/2007 – p.3



[Kaidalov+KMR, EPJC 33 (2004) 261]

Signal and Background calculation

Take the experimental efficiencies **ε** and calculate

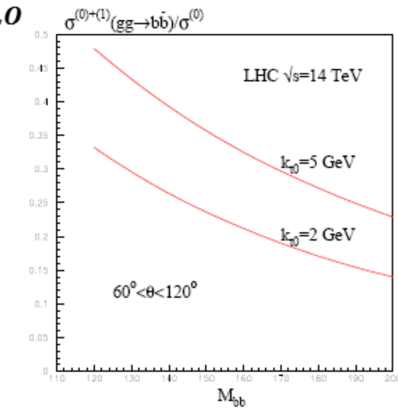
Signal processes: use approximate formula

$$\sigma^{\rm excl} = 3{\rm fb} * \left(\frac{136}{16+m}\right)^{3.3} \left(\frac{120}{m}\right)^{3} \cdot \frac{\Gamma(h/H \to gg)}{0.25\,{\rm MeV}} \cdot \frac{{\rm BR}^{\rm MSSM}}{{\rm BR}^{\rm SM}} * \varepsilon$$

$\Gamma(h/H \to gg)$, ${\rm BR}^{\rm MSSM}$, ${\rm BR}^{\rm SM}$ evaluated with *FeynHiggs* [T. Hahn, S. Heinemeyer, W. Hollik, H. Rzehak, G. Weiglein] (1998-2010)

Background for $h, H \to b\bar{b}$ obtained from

$$\sigma_{\rm B} \approx 2{\rm fb} \left[\frac{3}{4}\frac{\Delta M}{(4\ {\rm GeV})}\left(\frac{120}{M}\right)^{6} + \frac{1}{4}\frac{\Delta M}{(4\ {\rm GeV})}\left(\frac{120}{M}\right)^{8} C_{NLO}\right] * \varepsilon$$



The mass dependence of the ration of the NLO exclusive $b\bar{b}$ cross section to that calculated in Born approximation.

Backgrounds intensively studied by KMR group:

[DeRoeck, Orava+KMR, EPJC 25 (2002) 392, EPJC 53 (2008) 231]

1) Admixture of |Jz|=2 production

2) NLO gg→bbg, large-angle hard gluon emission

3) LO gg→gg, g can be misidentified as b

4) b-quark mass effects in dijet processes, HO radiative corrections

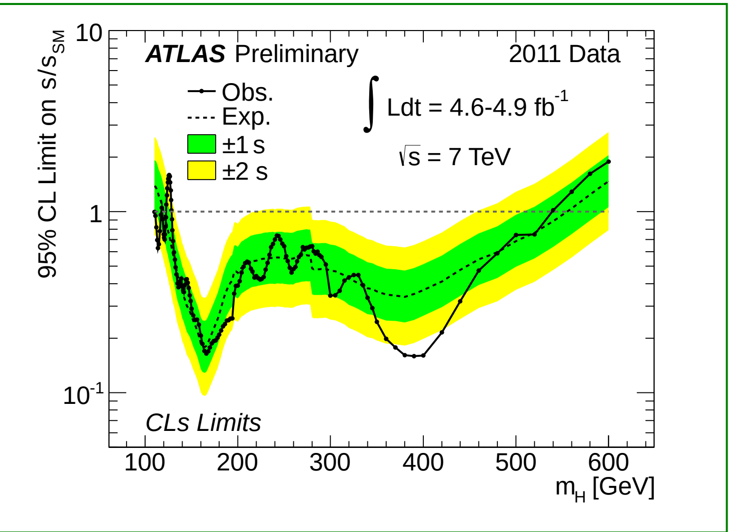
b-jet angular cut applied: 60°< θ <120° ($|\Delta\eta_{\rm jet}|$ <1.1) P(g/b)~1.3%(ATLAS)

Four major bg sources: ~(1/4+1/4+1.3²/4 +1/4) fb at M_h=120 GeV, ΔM=4 GeV

Pile-up background is heavily reduced after applying stringent cuts.

Remaining Pile-up bg considered to be negligible.

LHC hints and exclusions data 2011 only



DIS12 talk (March 2012)

SM studies

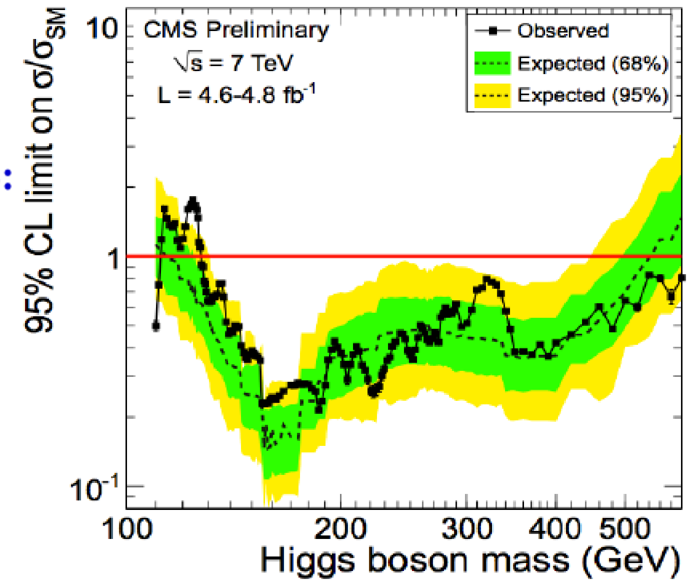
Excluded mass ranges at 95% C.L.:

ATLAS: 110-117.5, 118.5-122.5, 129-539 GeV

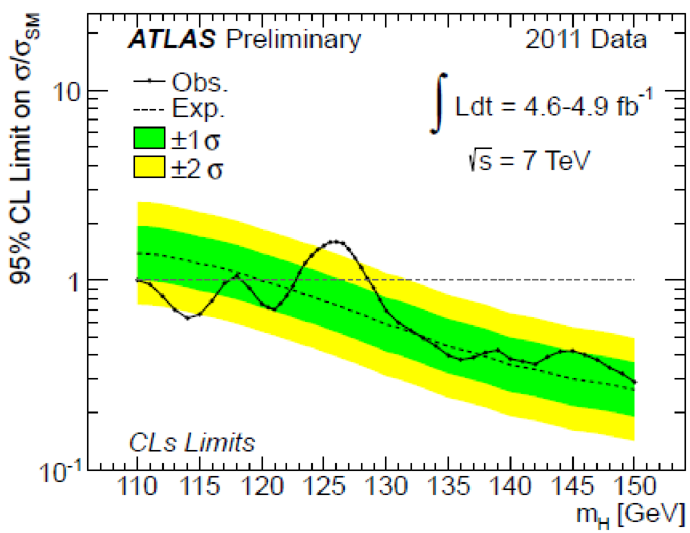
CMS: 127-600 GeV

Allowed mass region:

$122.5 < M_H < 127.5$ GeV

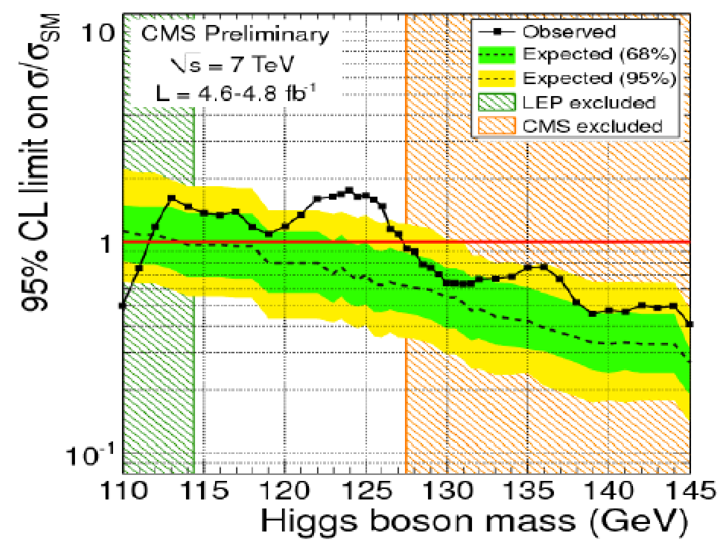


DIS12 talk (March 2012)



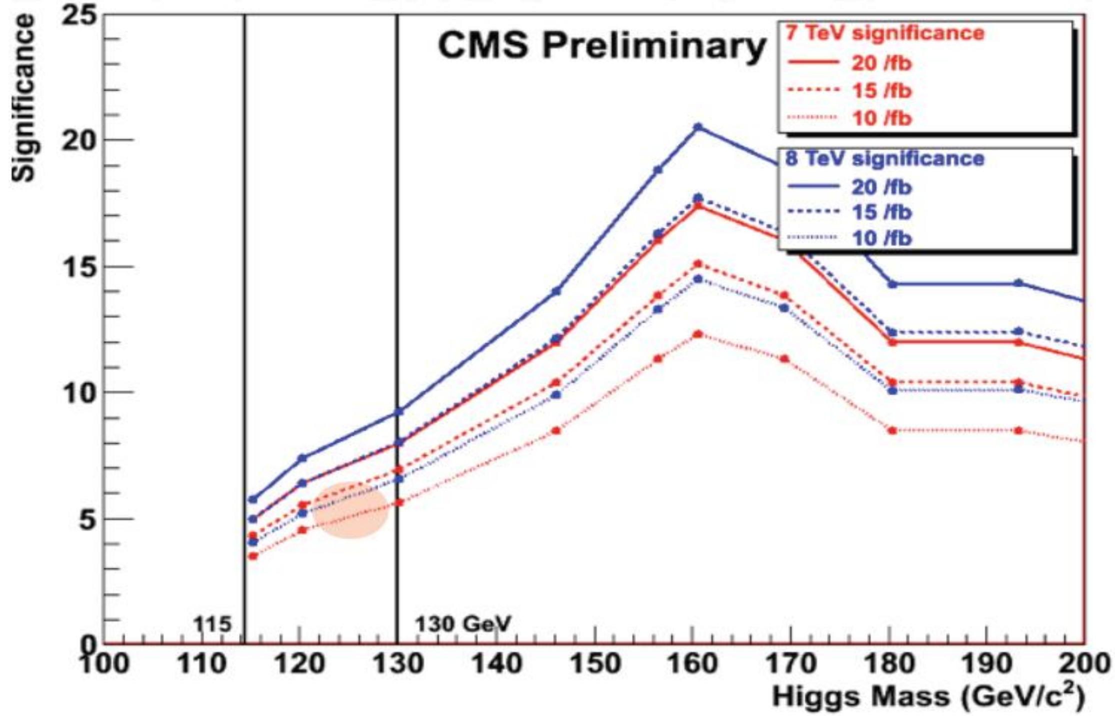
Excess:

Experiment	Mass [GeV]	Local sig	Global sig
ATLAS	~ 126	2.5	2.2
CMS	~ 124	2.8	2.1



Data 2012?

Reminder: CMS Input for Chamonix



You are HERE ?

Y. Sirois: LHCC, June 2012

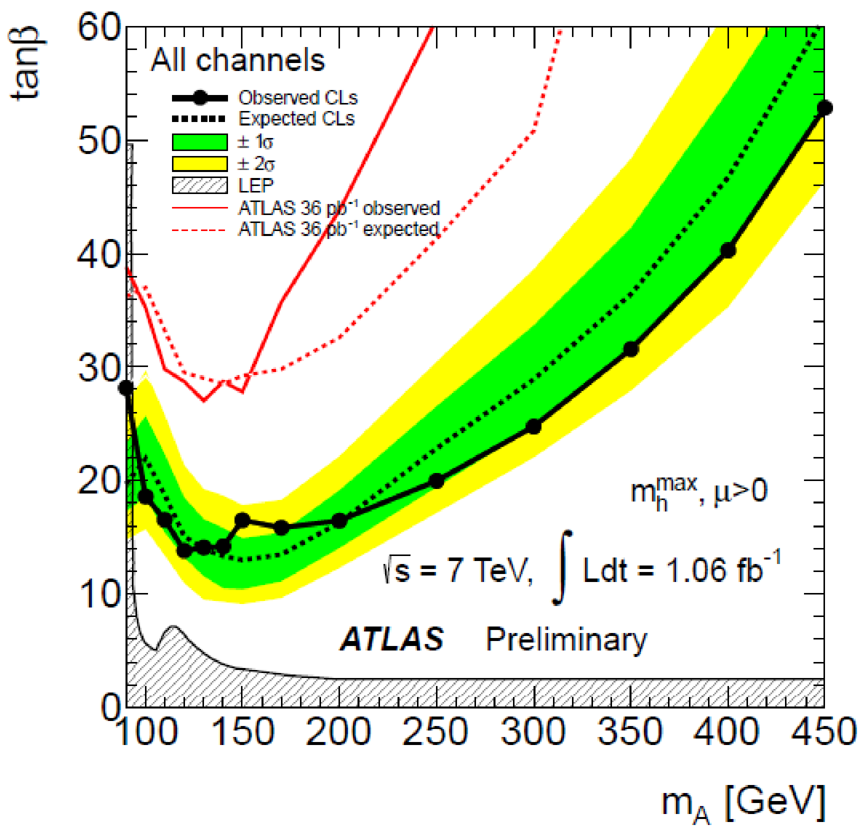
Note: Very roughly, for M_H ~125 GeV, one expects 3 to 4 signal events per 5 fb^{-1} in H → 4ℓ for a S/B of ~ 2

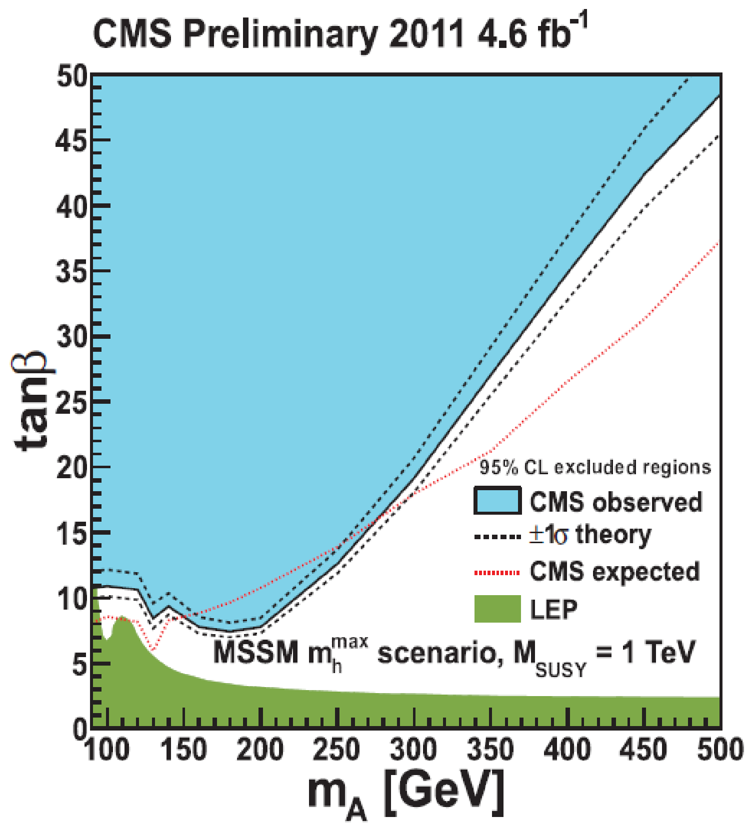
⇒ Requires about 20 fb^{-1} for 5σ in stand-alone

⇒ We should see something starting to build-up already now

Watch the special CERN seminar on 4.7.2012 !
First ATLAS and CMS results on 8 TeV data will be shown.

MSSM exclusions





LHCC talks in Dec.2011

LHC + LEP start to narrow down the region of very low mass

LHC hints and exclusions

Imagine Higgs candidates are found at LHC at ~ 125 GeV. Then natural questions arise:

1) Is it SM or BSM? Look at quantum numbers, especially parity.

2) What is its direct coupling to bb?

Central Exclusive Diffraction may help to answer

J_Z = 0, C-even, P-even selection rule leads to a clear determination of quantum numbers of the centrally produced resonance. A few events are enough.

MSSM: large enhancement for H/h→bb enables to measure Hbb Yukawa coupling!

In the following, we show:

a) LHC MSSM exclusion regions (red area) [**HiggsBounds**: P. Bechtle et al., Comput. Phys. Comm. 181 (2010) 138]

b) One possible region of interest (green area): SM Higgs at **M=125 GeV +- 1 GeV (exper.)**.

If theory uncertainties added: **122 < M < 128 GeV** [S. Heinemeyer et al., arXiv:1112.3026[hep-ph]]

Four luminosity scenarios considered (ATLAS+CMS):

1) 60 fb^{-1} – low inst. lumi (no pile-up)

2) 60 fb^{-1} x 2 – low inst. lumi (no pile-up) but improved signal efficiency

3) 600 fb^{-1} - high inst. lumi (pile-up suppressed)

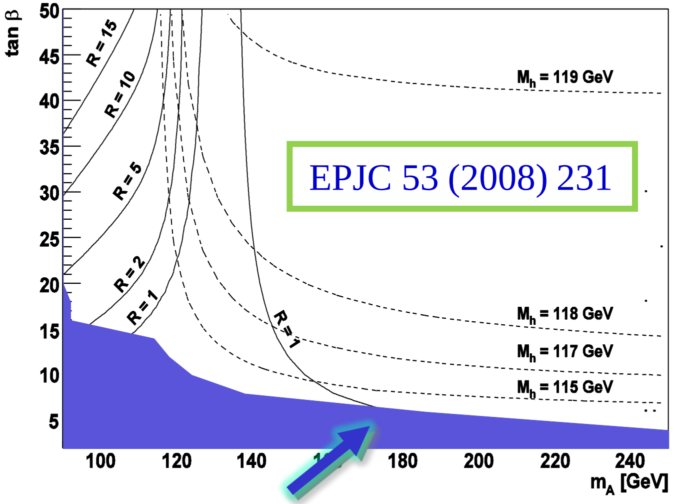
4) 600 fb^{-1} x2 – high inst. lumi (pile-up suppressed) but improved signal efficiency

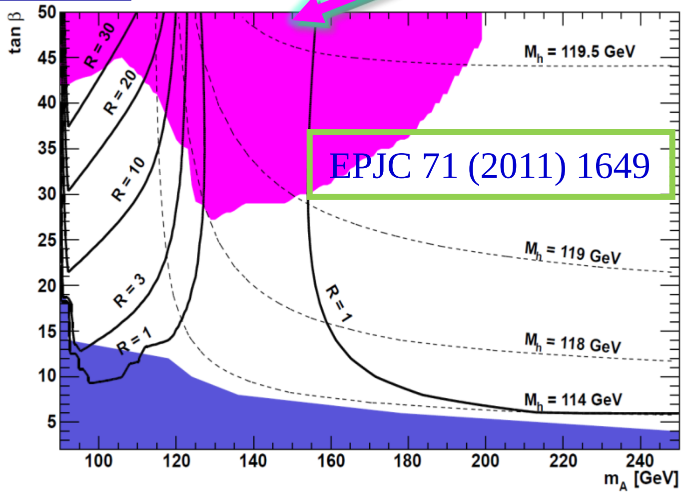
Ratios R=MSSM[M,tanβ] / SM[M]

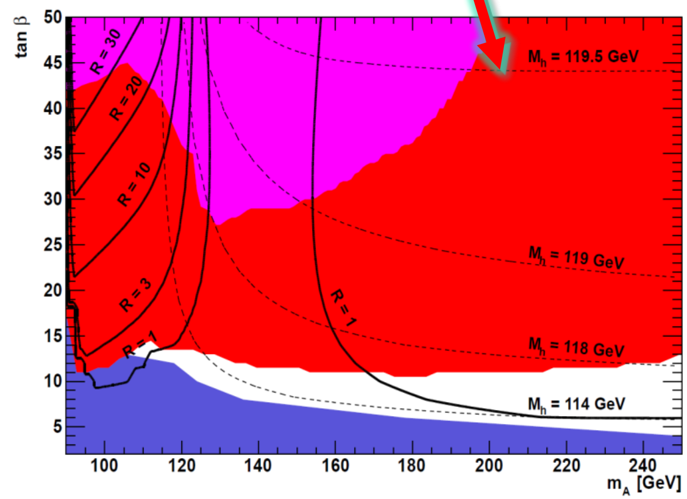
h→bb, nomix, μ=200 GeV

Tevatron exclusion region

LHC exclusion region

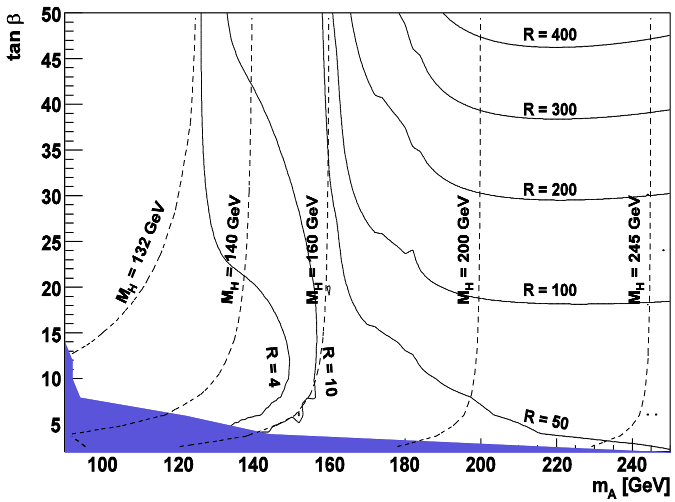


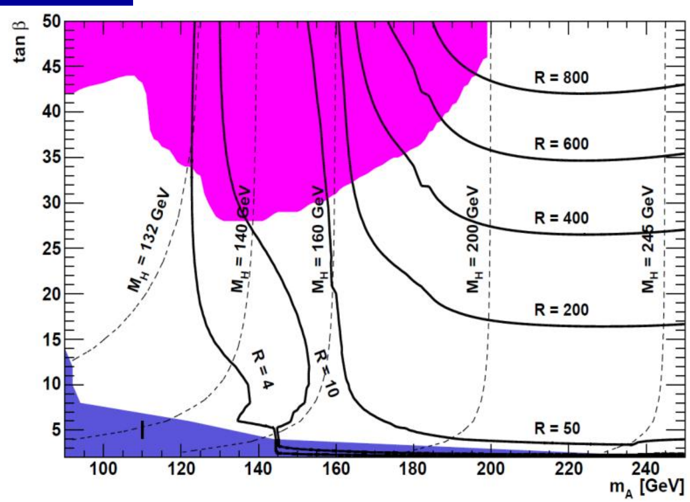


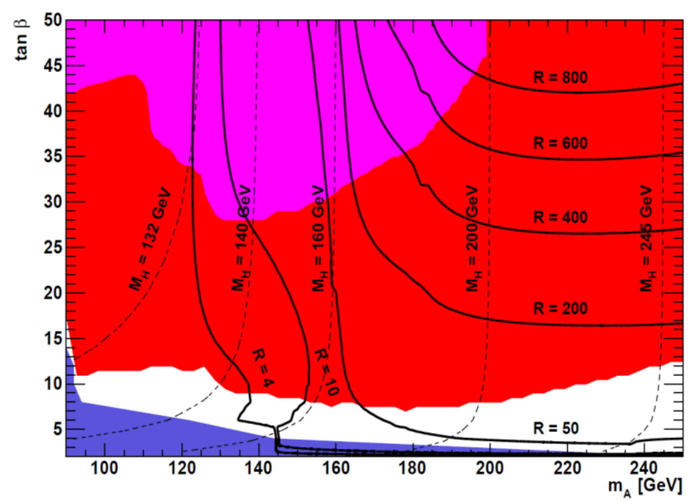


LEP exclusion region

H→bb, mhmax, μ=200 GeV

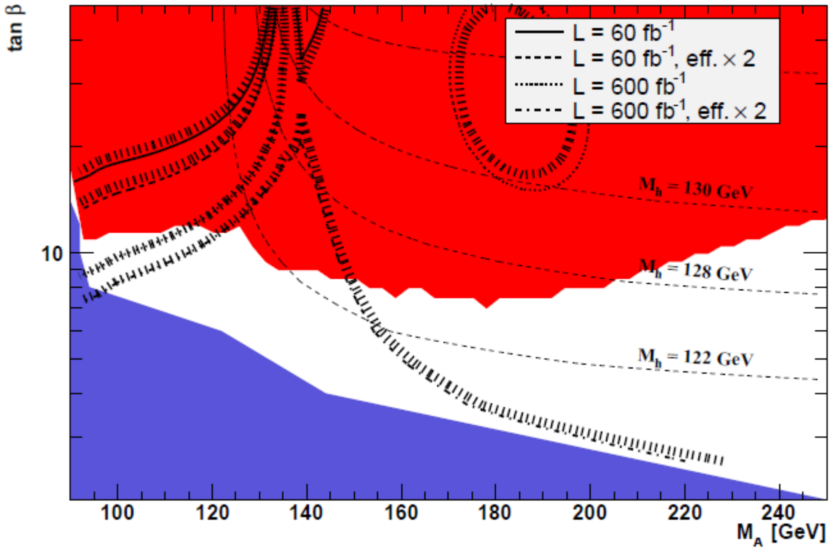




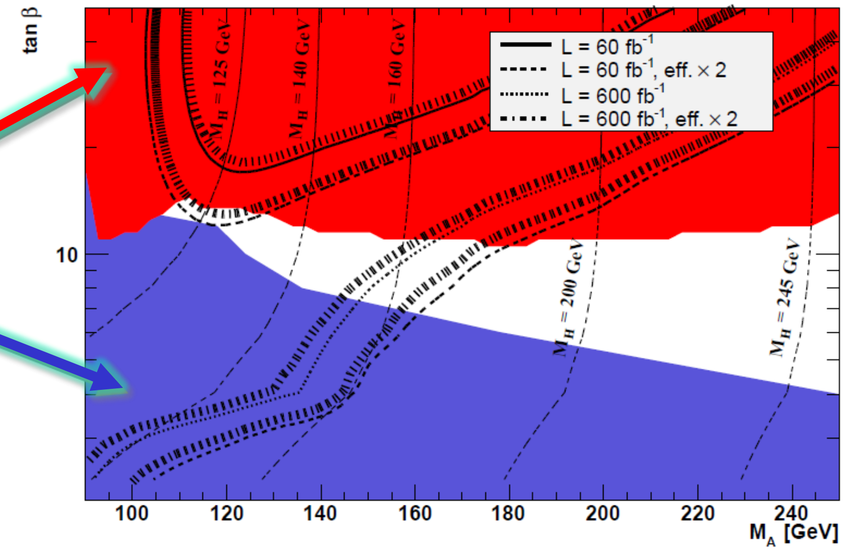


3σ-contours

h→bb, mhmax, μ = 200 GeV



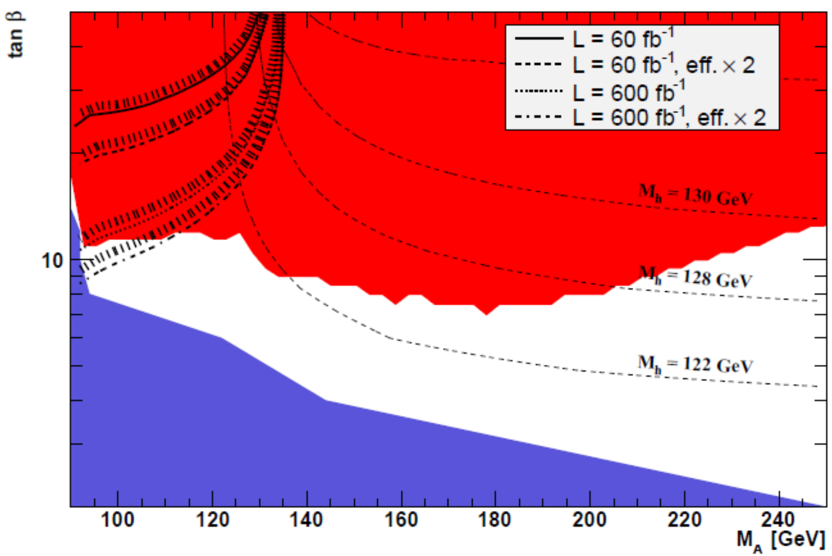
H→bb, nomix, μ = 200 GeV



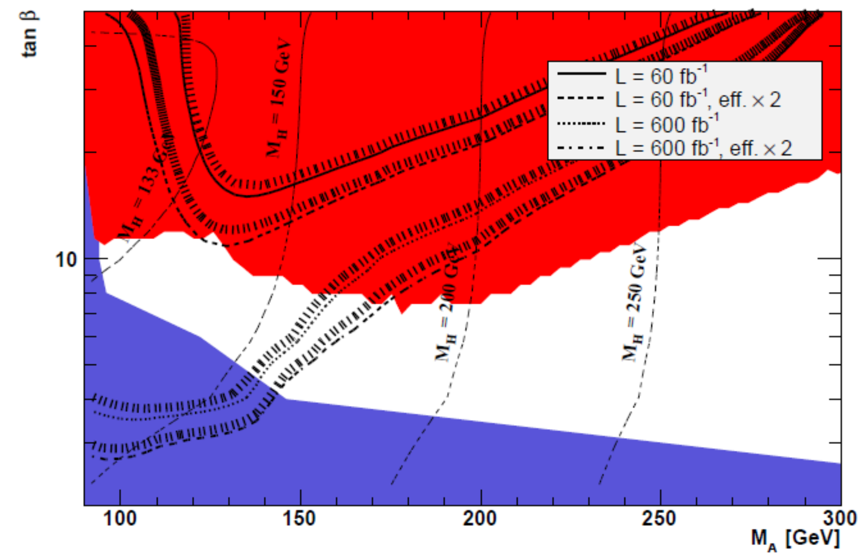
LHC exclusion region

LEP Exclusion region

h→tautau, mhmax, μ = 200 GeV

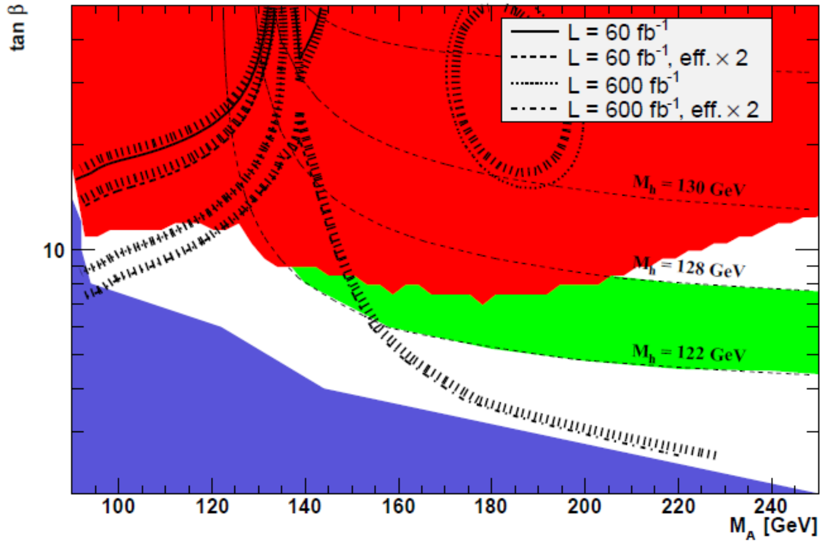


H→bb, mhmax, μ = -500 GeV

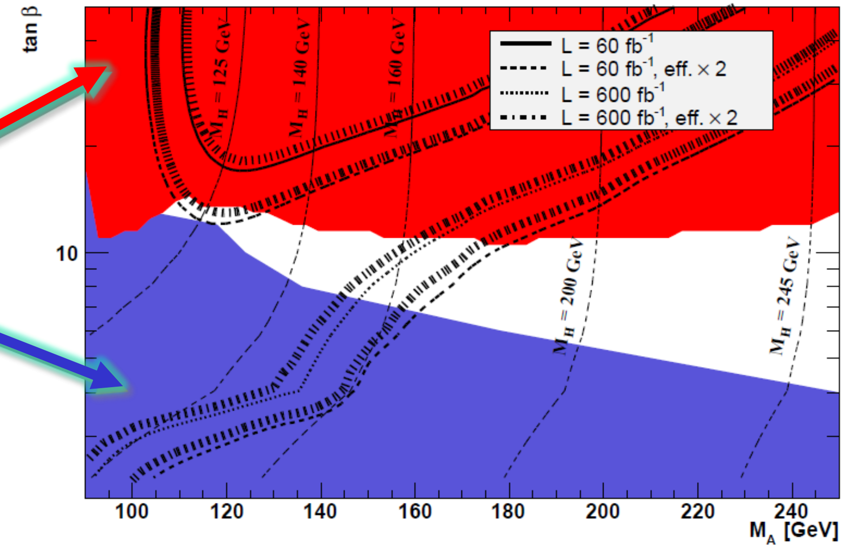


3σ-contours

h→bb, mhmax, μ = 200 GeV



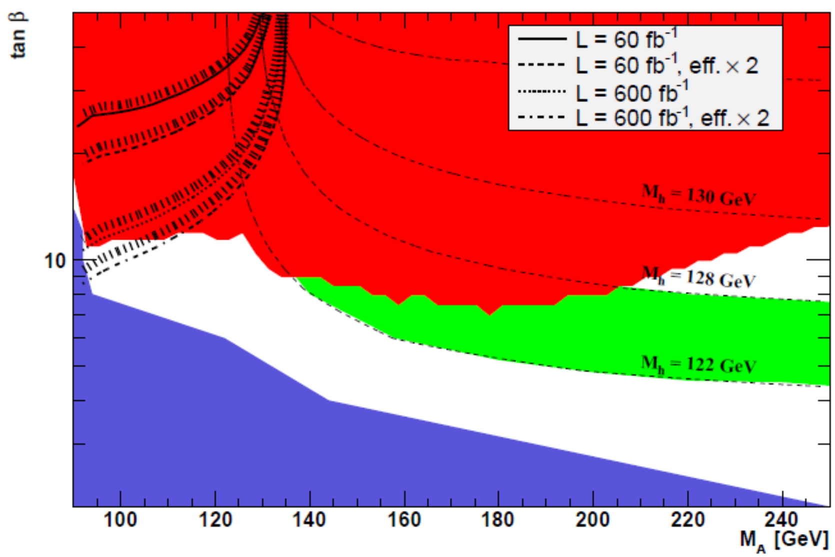
H→bb, nomix, μ = 200 GeV



LHC exclusion region

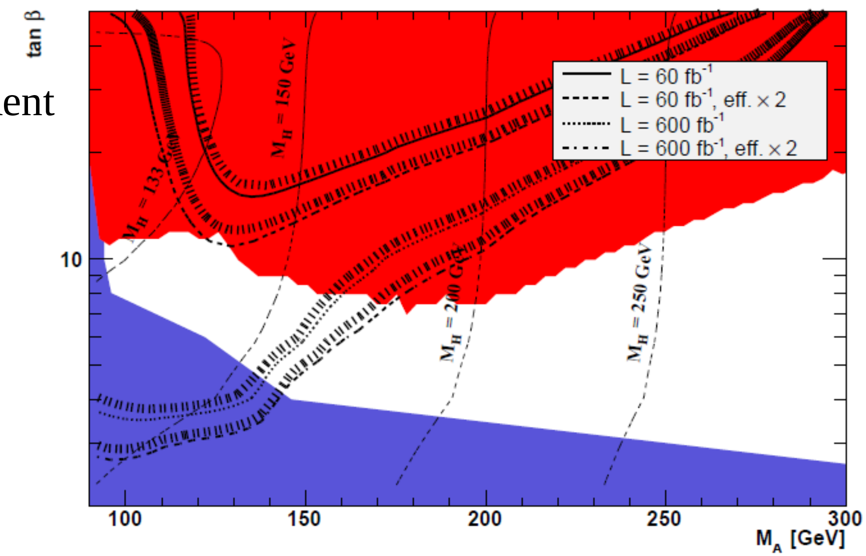
LEP Exclusion region

h→tautau, mhmax, μ = 200 GeV



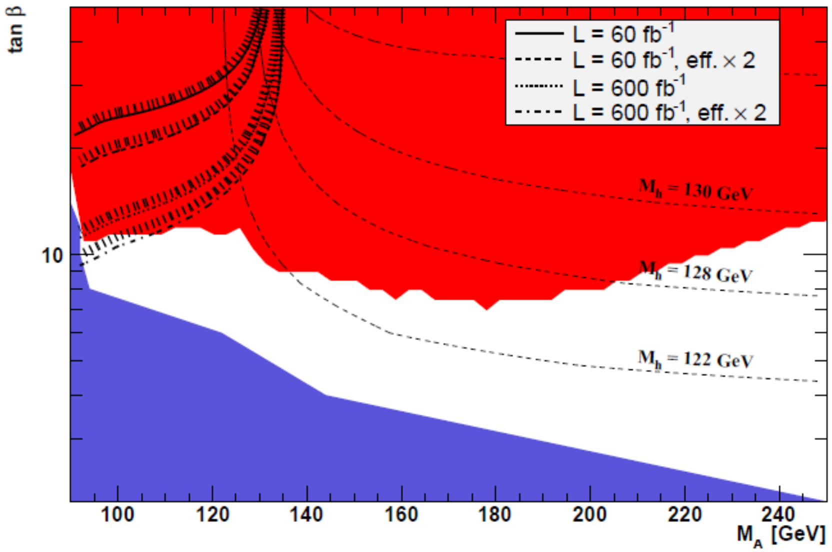
MSSM in agreement with the allowed mass range

H→bb, mhmax, μ = -500 GeV

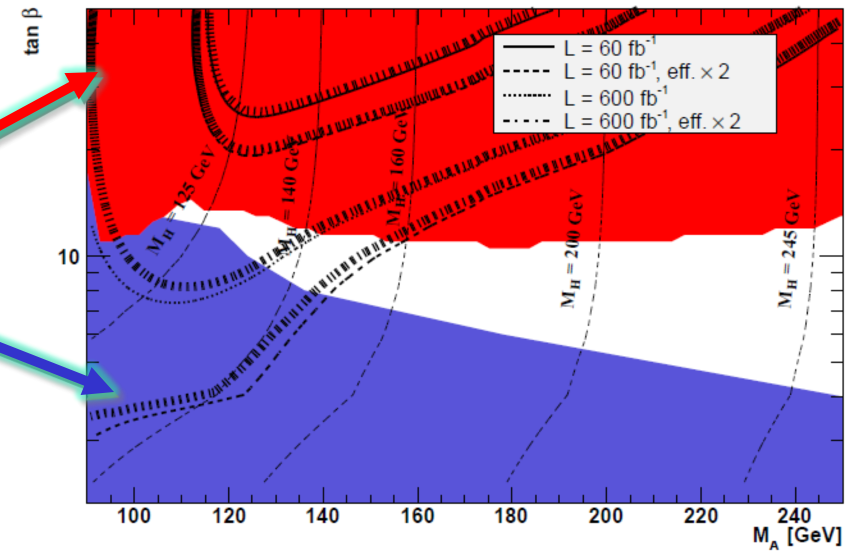


5σ-contours

h→bb, mhmax, μ = 200 GeV



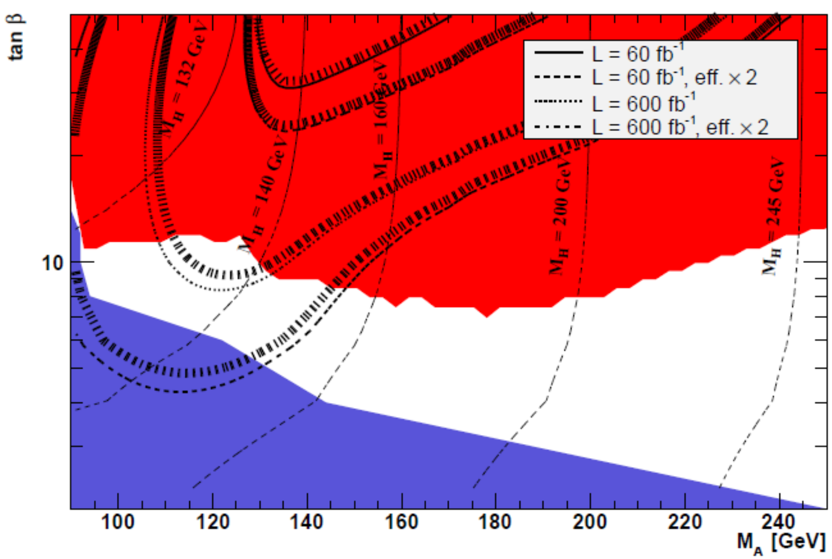
H→bb, nomix, μ = 200 GeV



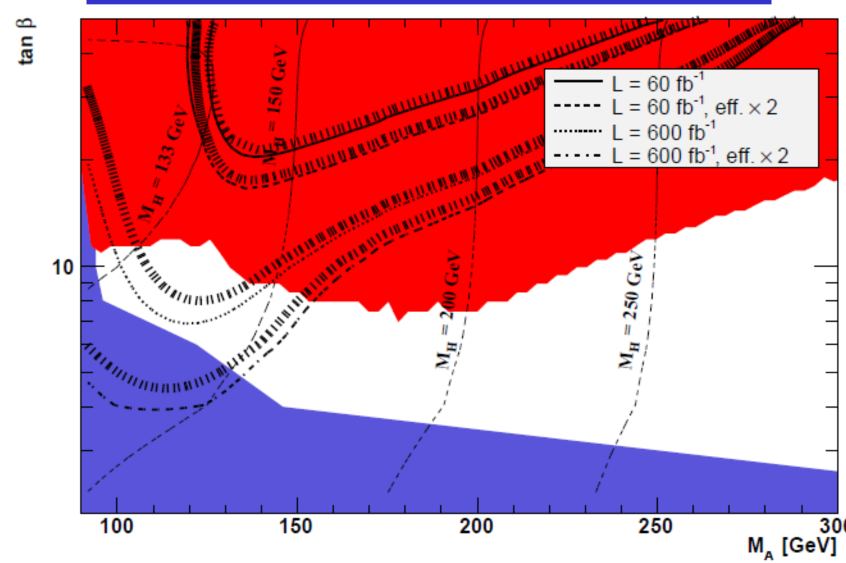
LHC exclusion region

LEP Exclusion region

H→bb, mhmax, μ = 200 GeV

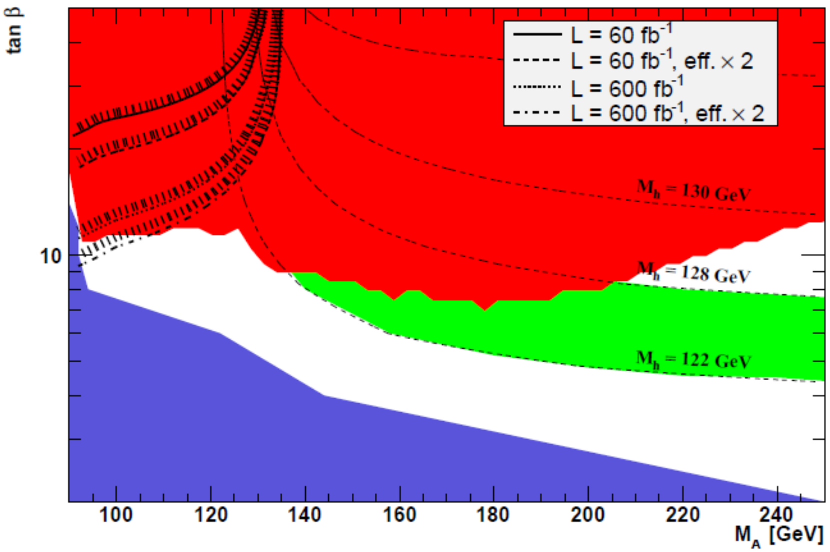


H→bb, mhmax, μ = -500 GeV

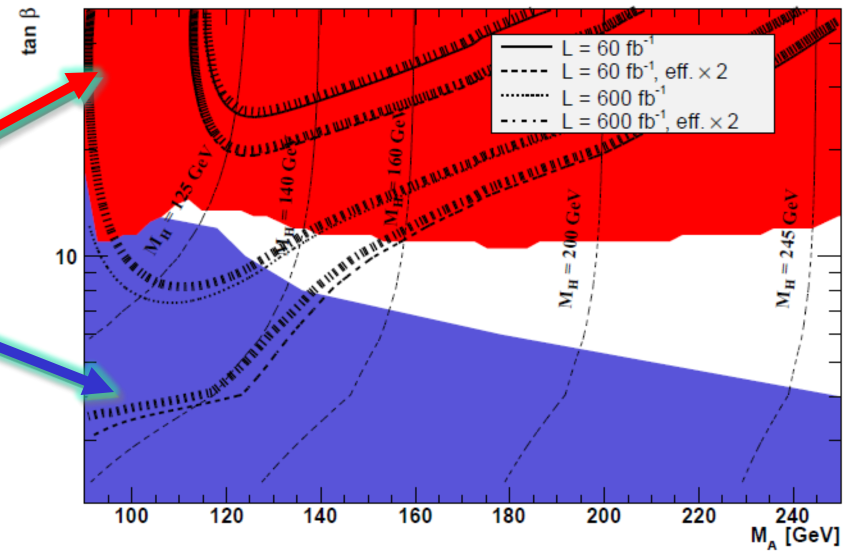


5σ-contours

h→bb, mhmax, μ = 200 GeV



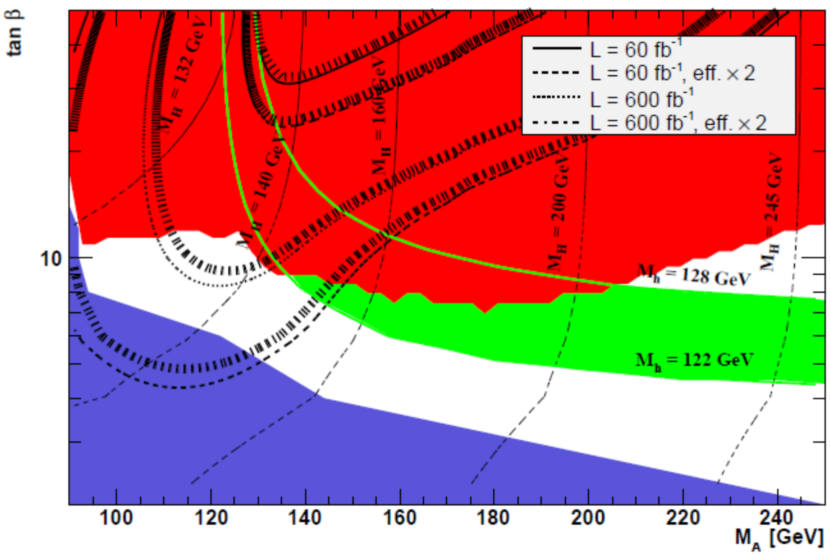
H→bb, nomix, μ = 200 GeV



LHC exclusion region

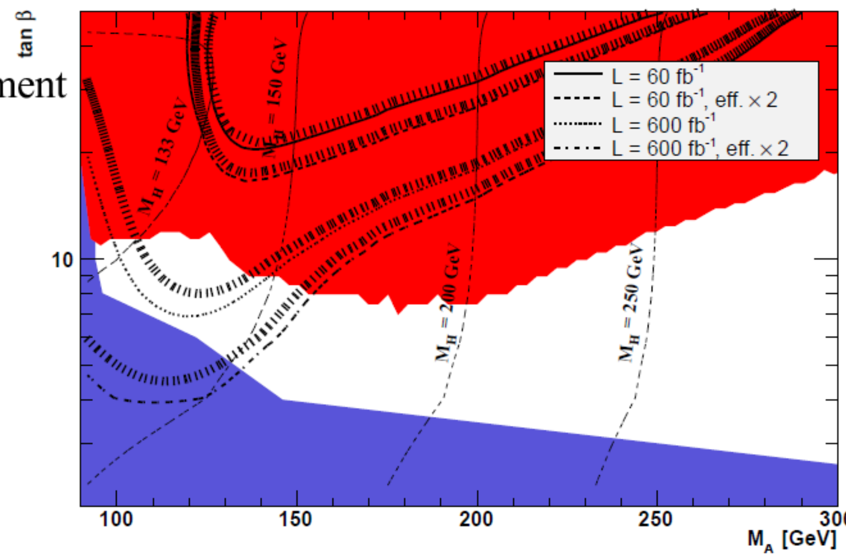
LEP Exclusion region

H→bb, mhmax, μ = 200 GeV



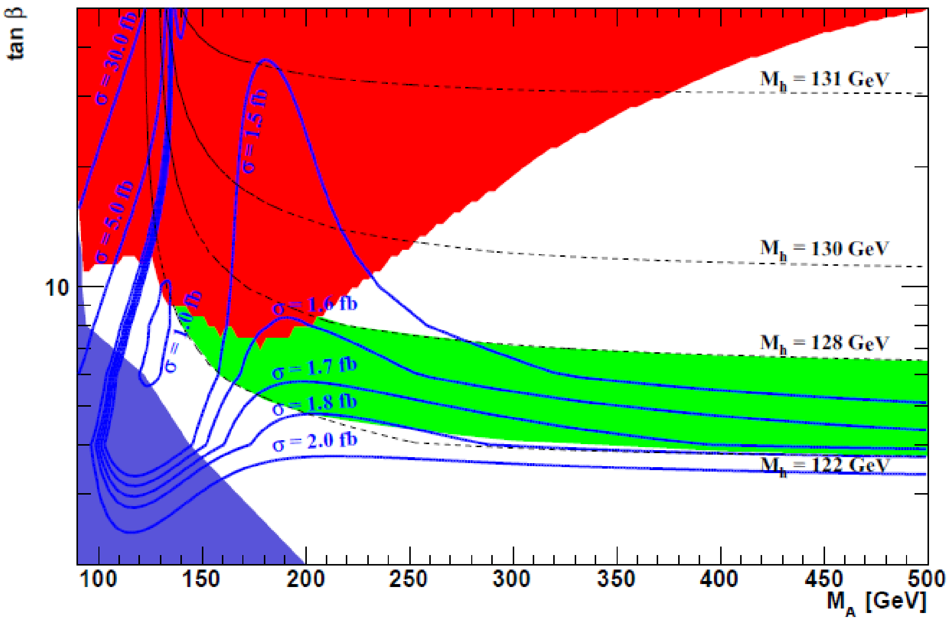
MSSM in agreement with the allowed mass range

H→bb, mhmax, μ = -500 GeV

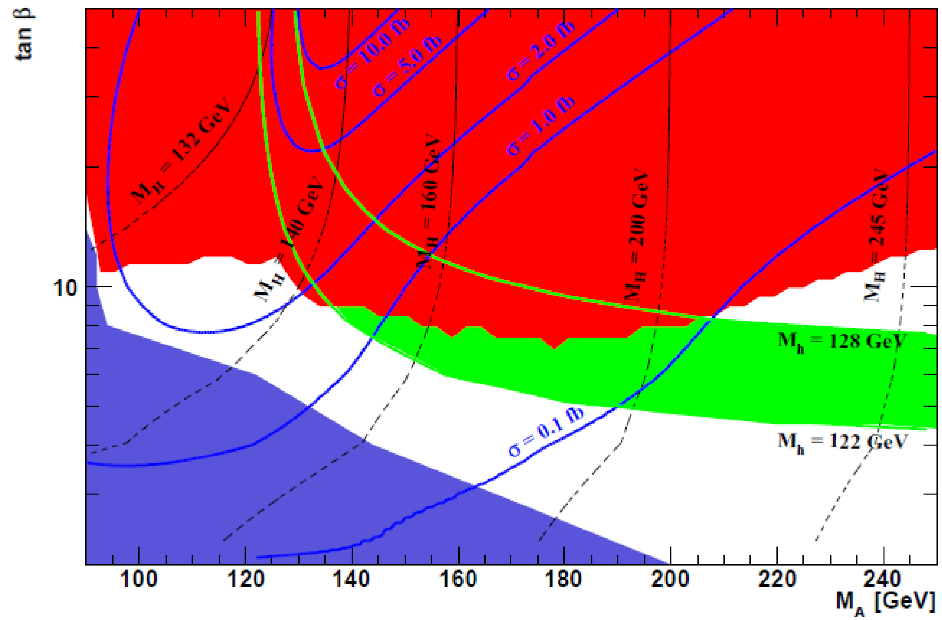


Available MSSM CEP x-sections in Mhmax

h→bb, mhmax, μ = 200 GeV



H→bb, mhmax, μ = 200 GeV



M_h contours stay constant with M_A

Available MSSM CEP x-section stay constant with M_A (because R=MSSM/SM =1 in this region) reaching maximum of 1.8 fb

x-section of 1.5 fb reachable but in a tiny allowed phase-space region. Outside this region the x-section is very small

Determination of Higgs CP properties

Existing SM analyses for LHC:
- rely largely on the coupling of Higgs boson to heavy gauge bosons:

WBF $H \to W^+W^- \to ll\nu\nu$
WBF $H \to \tau^+\tau^-$
WBF $H \to ZZ \to 4l$

Backgrounds: $gg \to H$, WWjj(EW), WWjj(QCD)
tt, tW, Zjj(EW), Zjj(QCD)

Prerequisites for these SM(-like) analyses: Higgs with
- sufficiently large HVV coupling
- sufficiently large BR($H \to VV$) – M_H >140 GeV to suppress $H \to bb$;
- possibly large BR($H \to \tau\tau$)

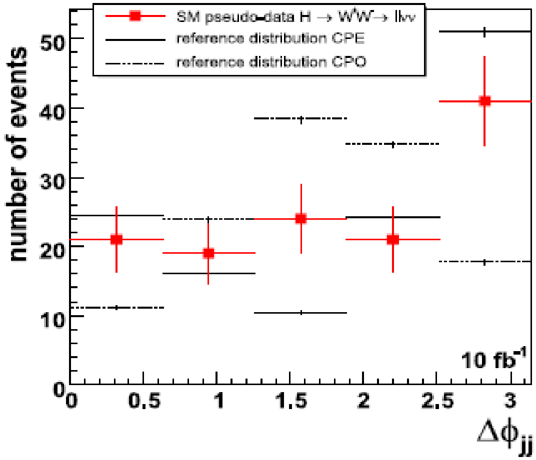
SM analyses of the structure of the HVV coupling: CP-even vs. CP-odd
[T. Plehn et al., 2001] (theory)
[V. Hankele et al., 2006] (theory)
[C. Ruwiedel et al., 2007] (experiment)

Assumption often made: $H^{CP\text{-}even}VV \approx H^{CP\text{-}odd}VV$

MSSM: $H^{CP\text{-}odd}VV / H^{CP\text{-}even}VV \approx 10^{-11}$

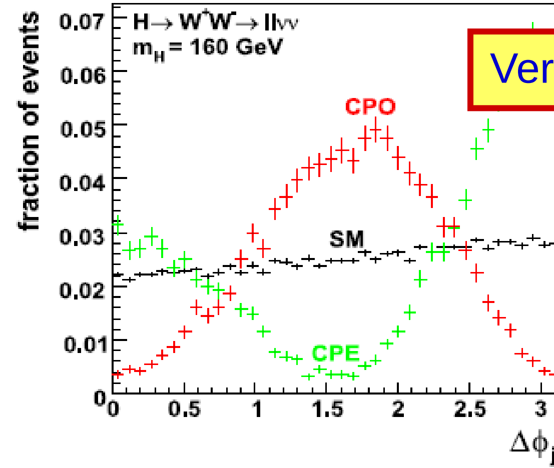
Higgs coupling structure: HWW, HVV

[C. Ruwiedel et al., 2007]: $H \to W^+W^- \to ll\nu\nu$, M_H = 160 GeV (BR(H→WW) is maximal)



10 fb^{-1}

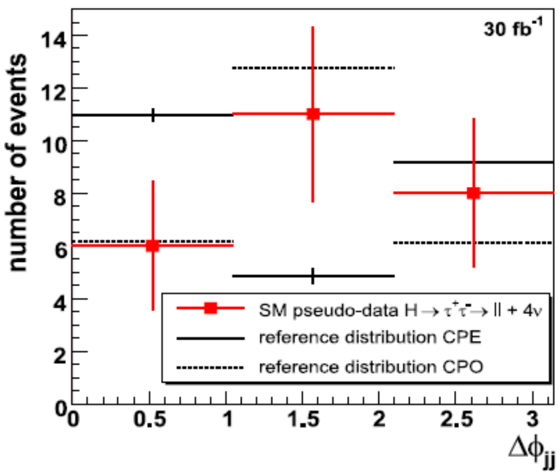
$\Delta\varphi_{jj}$ =
Difference in azimuthal angle of two tagging jets



Very large statistics

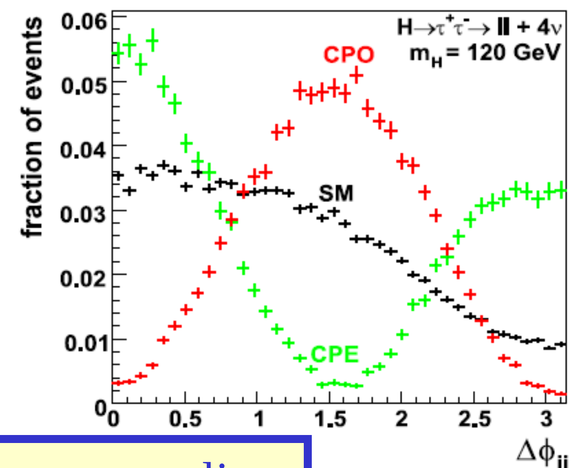
5σ - discrimination of anomalous couplings already with 10 fb^{-1}

SM = signal with SM couplings + backgrounds, **CPE** = signal with CP-even couplings + backgrounds
CPO = signal with CP-odd couplings + backgrounds



30 fb^{-1}

$H \to \tau^+\tau^- \to ll+4\nu$, M_H = 120 GeV



3σ - discrimination of anomalous CP-even coupling

Situation in MSSM

Light Higgs: M_h < 135 GeV: too small BR(h→VV$^{(*)}$)

Heavy Higgses:

$$g_{hVV} = g_{HVV}^{\text{SM}} \times \sin(\beta-\alpha)$$
$$g_{HVV} = g_{HVV}^{\text{SM}} \times \cos(\beta-\alpha)$$
$$g_{AVV} = 0 \qquad \text{at tree-level}$$

$M_H \approx M_A$ > 150 GeV:

β-α → π/2 => h has substantial VV coupling, but not sufficient BR(h→ττ)

H and A have negligible VV coupling

$M_H \approx M_A$ < 130 GeV => |sin(β-α)| << 1 possible:

H has substantial VV coupling, but not sufficient BR(H→ττ)

Heavy Higgses: method relying on H→VV cannot be applied

Light Higgs: no improvement wrt SM analyses

Central Exclusive Diffraction!

J_Z = 0, C-even, P-even selection rule leads to a clear determination of quantum numbers of the centrally produced resonance. A few events are enough.

MSSM: large enhancement for H/h→bb enables to measure Hbb Yukawa coupling!

Summary

CED Higgs production in MSSM

- The signal yields are potentially greatly enhanced
- Gives complementary information about Higgs sector
- Gives information about Yukawa Hbb coupling (which is difficult in standard searches)
- New CDM benchmark planes show consistent results with Mhmax and No-mixing

BUT IN PARTICULAR

A few events are enough to establish quantum numbers of a Higgs candidate. No need for coupling to vector bosons

- BUT high significances need high FD acceptances → all advantages of MSSM CED process can be useful only if forward detector upgrades (AFP, HPS) contain both, the very forward (420 m) and forward (220 m) stations. This is not on the table at the moment.

  AFP and HPS defendable with 220 stations only.

CED MSSM signal still survives the as yet provided exclusion limits. In the allowed region $122.5 < M_h < 127.5$ GeV even 5σ significances may be achieved for the highest luminosity scenarios. Also: MSSM is in agreement with the tentative hints at $M_h = 125$ GeV (although the allowed region may shrink further with time …)

BACKUP SLIDES

Changes wrt 1st paper (EPJC 53 (2008) 231)

1) FeynHiggs 2.3.0 → most recent FeynHiggs 2.7.1

2) NLO formula for CED gg→bb background

3) Tevatron exclusion areas added

4) A few Cold Dark Matter scenarios tried

5) 4th generation model

Theory cross-section:
$\sigma_{SM} \times \Gamma(gg\to H)_{MSSM} / \Gamma(gg\to H)_{SM}$

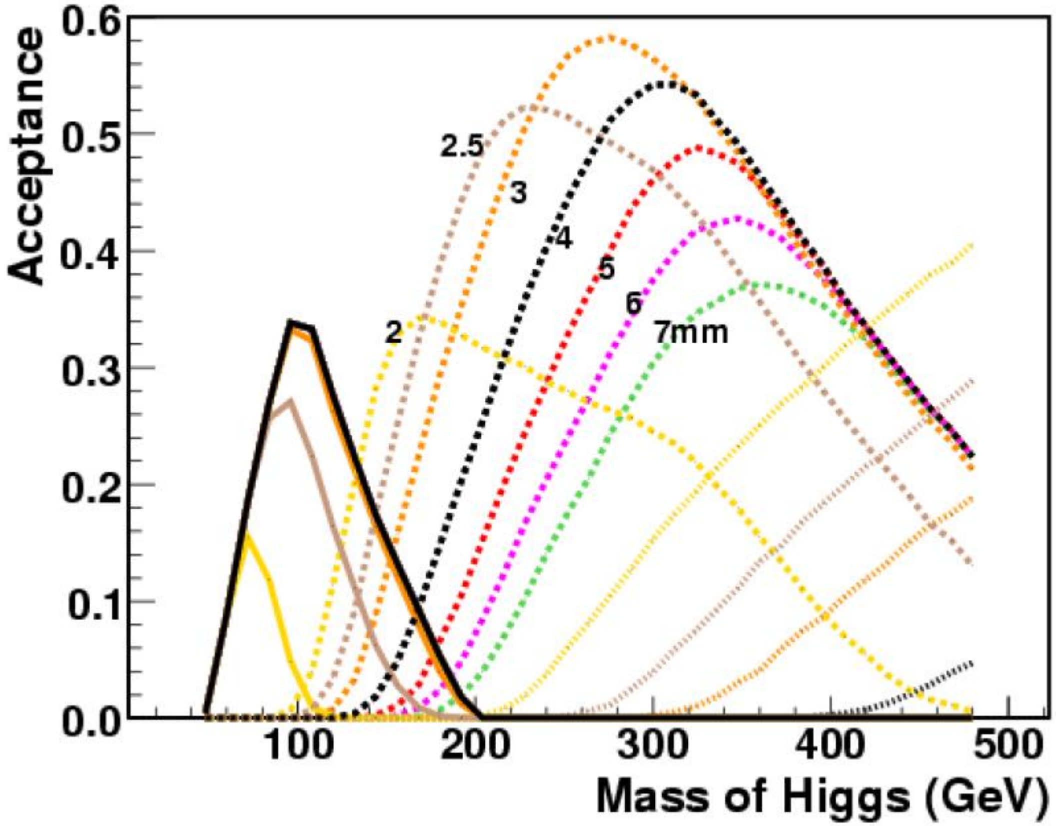
1) $m_b(mt) \to m_b(m_b)$ in Hbb coupling
- reduces HO corrections
- enhances gg→H effective coupling
2) More HO corrections to Δ_b in $\varphi\to gg$
- enhances Hbb coupling and thus also gg→H effective coupling

Four luminosity scenarios (ATLAS+CMS):

1) 60 fb^{-1} – low inst. lumi (no pile-up)
2) 60 fb^{-1} x 2 – low inst. lumi (no pile-up) but improved signal efficiency
3) 600 fb^{-1} - high inst. lumi (pile-up suppressed)
4) 600 fb^{-1} x2 – high inst. lumi (pile-up suppressed) but improved signal efficiency

Acceptances

Acceptances depend heavily on the distance from the beam and dead space!
(if protons hit the dead space in 220 station, they are lost for 420 measurement)
Acceptance for 420+420, 420+220 and 220+220. Numbers mean total distances.
420 at 6 mm everywhere, 220 varying from 2mm to 7mm



Peter

Dead space = 1.1mm

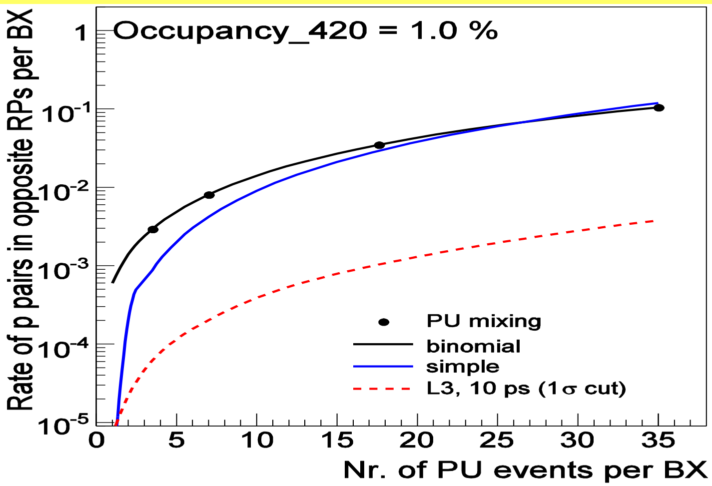
220 at 2mm obstructs the tracking at 420 !

Dead space of 1.1 mm is too cautious.
Peter will make this plot for dead space of 0.5mm.
In the following analyses, dead space=0mm

15 σ^{beam} ~ 1.5 mm
(thin window (400μm) + safety offset (300μm) + edge (5μm) + alignment) ~ 0.7 mm
Conservative guess of distance between beam center and first sensor : **2.2 mm**

CED experimental challenges: Pile-up

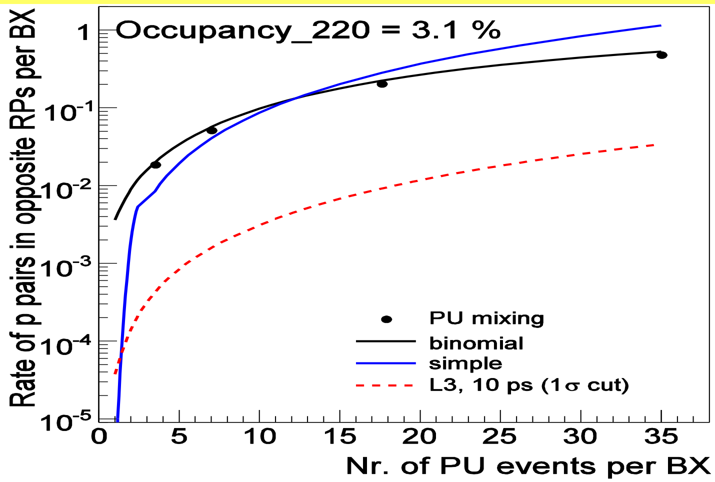
Overlap of three events (2xSD+non-diffr.dijet) in one BX can fake Higgs Signal. Matching measurements in Central vs. Forward detectors reduces the overlap bg significantly. BUT: Due to large cross sections for SD (~20mb) and non-diffr.dijets (~μb), additional rejection necessary: REDUCE BY FAST TIMING DET



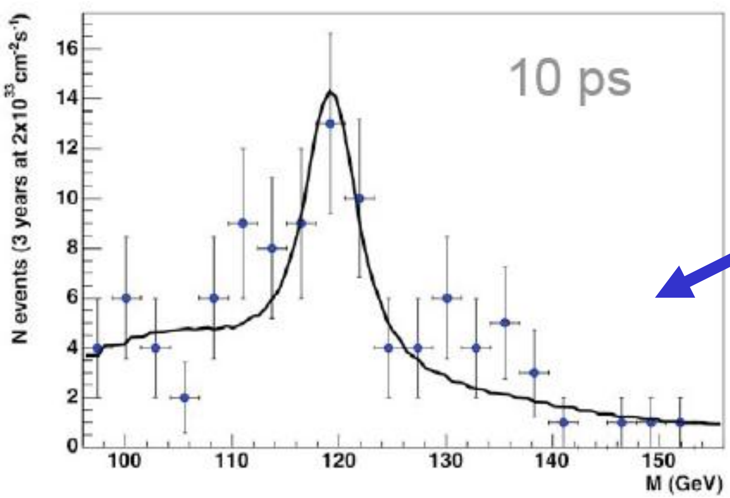
Huge rates

Reduced by

Fast timing Detectors (factor ~20)



h→bb, mhmax scenario, standard ATLAS L1 triggers, 420m only, 5 mm from beam

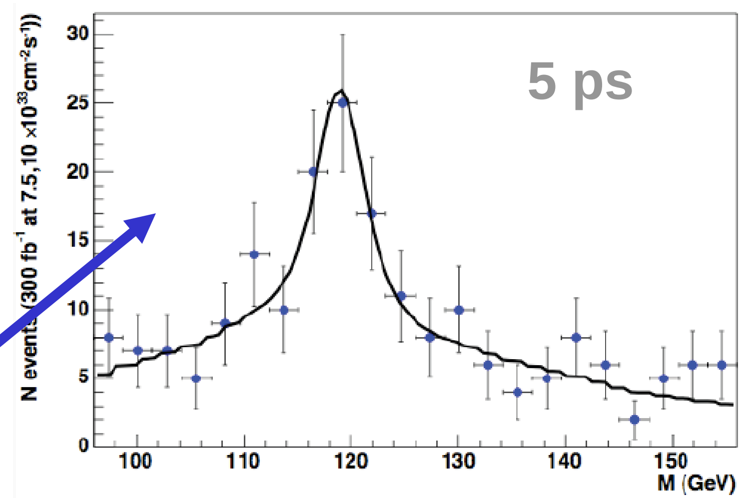


JHEP 0710:090,2007

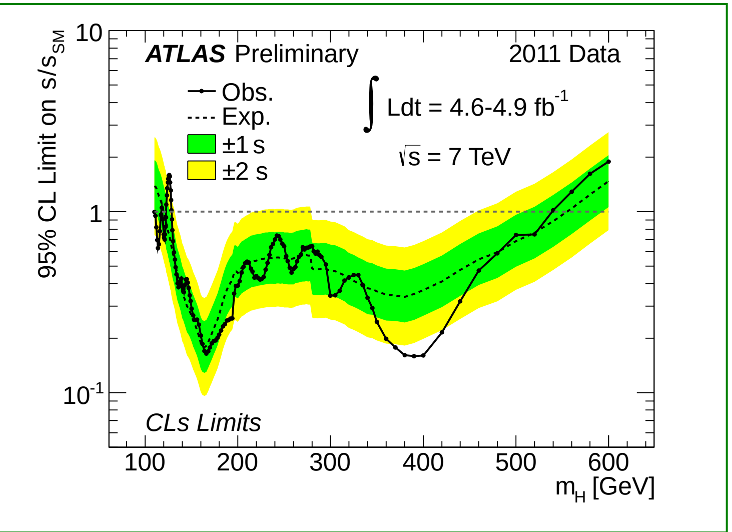
m_A=120 GeV, tanβ=40
$\sigma_{h\to bb}$=17.9 fb

60 fb^{-1} collected at $2\times10^{33} cm^{-2}s^{-1}$

150 fb^{-1} at $7.5\times10^{33} cm^{-2}s^{-1}$ plus 150 fb^{-1} at 10^{34} $cm^{-2}s^{-1}$



LHC hints and exclusions 2011 data only



DIS12 talk (March 2012)

SM studies

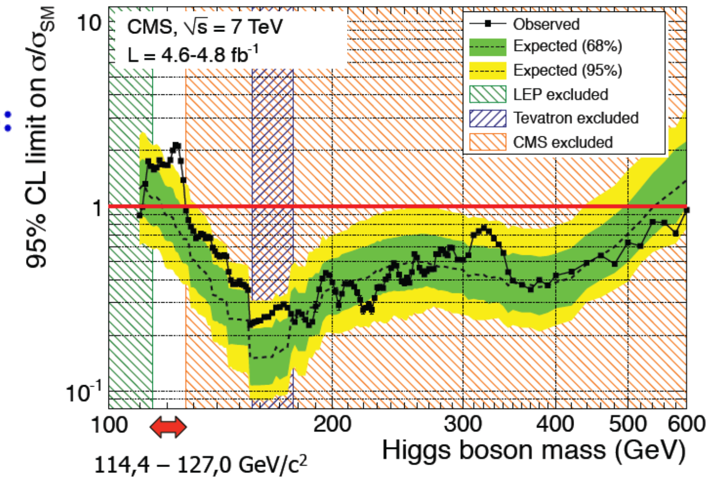
Excluded mass ranges at 95% C.L.:

ATLAS: 110-117.5, 118.5-122.5, 129-539 GeV

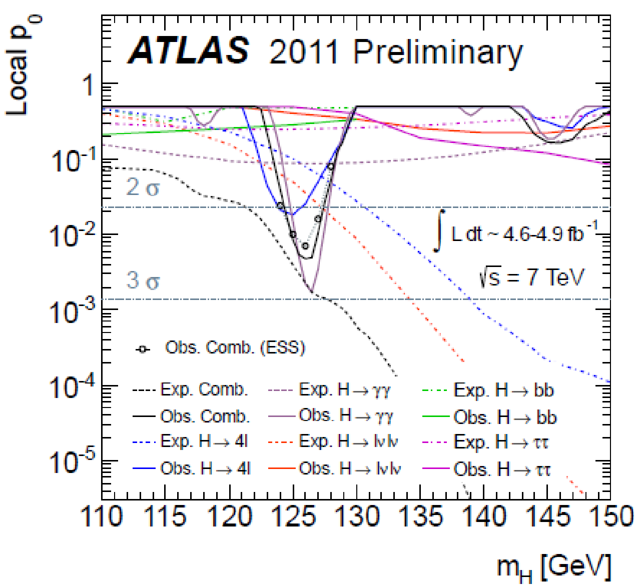
CMS: 127-600 GeV

Allowed mass region:

$122.5 < M_H < 127.0$ GeV

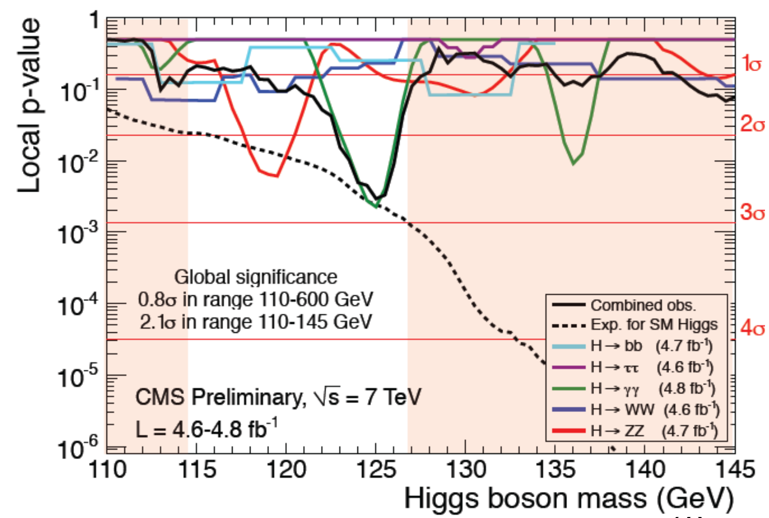


LHCC talk (June 2012)



Excess:

Experiment	Mass [GeV]	Local sig	Global sig
ATLAS	~ 126	2.5	2.2
CMS	~ 124	2.8	2.1



Basics of MSSM

Enlarged Higgs sector: Two Higgs doublets

$$H_1 = \begin{pmatrix} H_1^1 \\ H_1^2 \end{pmatrix} = \begin{pmatrix} v_1 + (\phi_1 + i\chi_1)/\sqrt{2} \\ \phi_1^- \end{pmatrix}$$

$$H_2 = \begin{pmatrix} H_2^1 \\ H_2^2 \end{pmatrix} = \begin{pmatrix} \phi_2^+ \\ v_2 + (\phi_2 + i\chi_2)/\sqrt{2} \end{pmatrix}$$

$$V = m_1^2 H_1 \bar{H}_1 + m_2^2 H_2 \bar{H}_2 - m_{12}^2(\epsilon_{ab} H_1^a H_2^b + \text{h.c.})$$

$$+ \underbrace{\frac{g'^2 + g^2}{8}}(H_1\bar{H}_1 - H_2\bar{H}_2)^2 + \underbrace{\frac{g^2}{2}}|H_1\bar{H}_2|^2$$

gauge couplings, in contrast to SM

physical states: $h^0, H^0, A^0, H^\pm$ Goldstone bosons: $G^0, G^\pm$

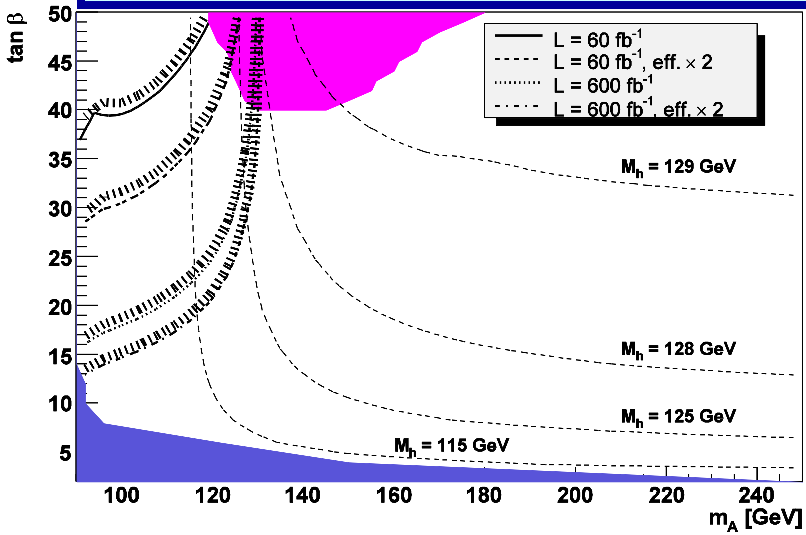
Input parameters: (to be determined experimentally)

$$\tan\beta = \frac{v_2}{v_1}, \qquad M_A^2 = -m_{12}^2(\tan\beta + \cot\beta)$$

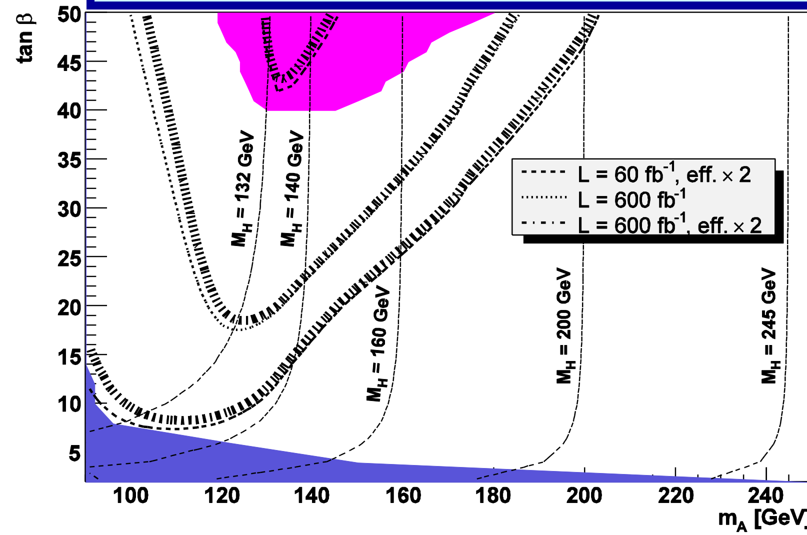
H → tau tau in MSSM

- In MSSM, BR(h,H→ττ) ~ 10%, if decays to SUSY particles not allowed
- Studied in EPJC 53 (2008) 231: the same efficiencies assumed as in the bb case
- Background: QED γγ→ll (suppressed by p_T^{prot} > 0.2 GeV)
  CEP gg→gg (suppressed by $|\eta_{j1} - \eta_{j2}| < 1.1$ and P(g/τ)~1/500)

3σ: h→tautau, mhmax, μ=200 GeV



3σ: H→tautau, mhmax, μ=200 GeV



- In ATLAS the proper efficiencies now being estimated with full sim.
- All tau-decays studied.
- Backgrounds expected to be very low:

 - fully leptonic have high-pt leptons
 - fully hadronic have two tau-jets: very-few-particle jets going sharply back-to-back in φ

No problems expected with triggering

Cold Dark Matter scenarios

- arXiv: 0709.0098v2 (J.Ellis, T.Hahn, S.Heinemeyer, K.Olive and G.Weiglein):

Invent new benchmark scenarios which would comply with constraints not only to the Higgs sector of MSSM but also to EW precision observables, B physics observables and abundance of Cold Dark Matter.

- **Explore new benchmark surfaces for MSSM Higgs phenomenology so that the supersymmetric relic density is compatible with the cosmological density of cold dark matter inferred from WMAP and other observations** [or that abundance of the lightest SUSY particle, the lightest neutralino, is compatible with CDM constraints as measured by WMAP].

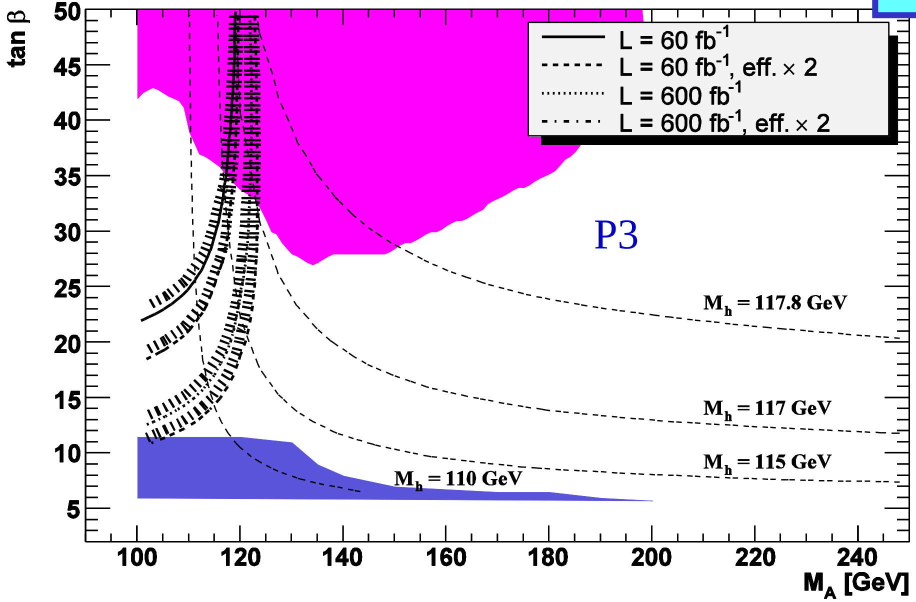
The allowed range of cold dark matter density: $0.0882 < \Omega_{CDM}h^2 < 0.1204$

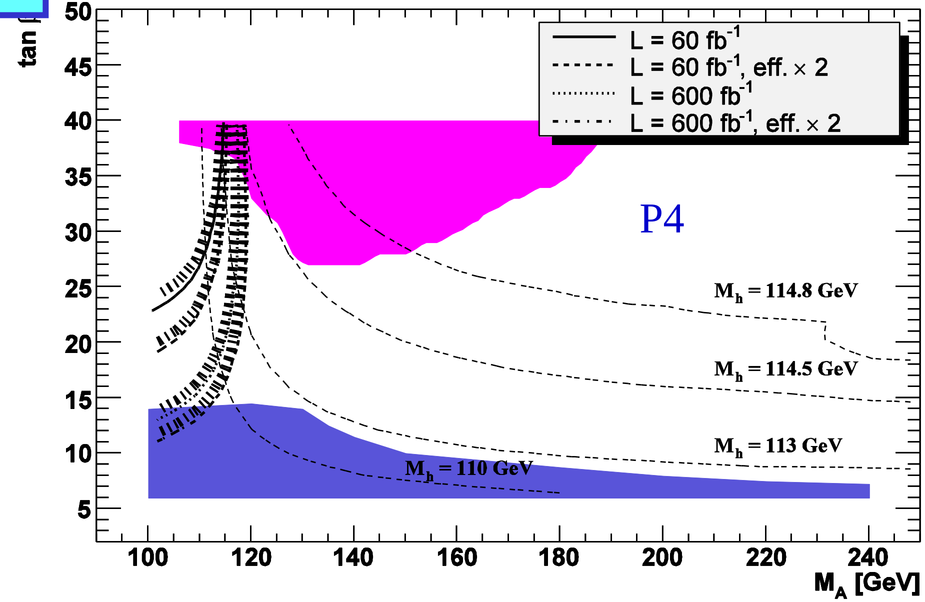
- The benchmark surfaces may be presented as (M_A, tanβ) planes with fixed or systematically varying values of NUHM2 parameters, such as scalar mass m_0, gaugino mass $m_{1/2}$, trilinear parameter A_0 and the Higgs mixing parameter μ.

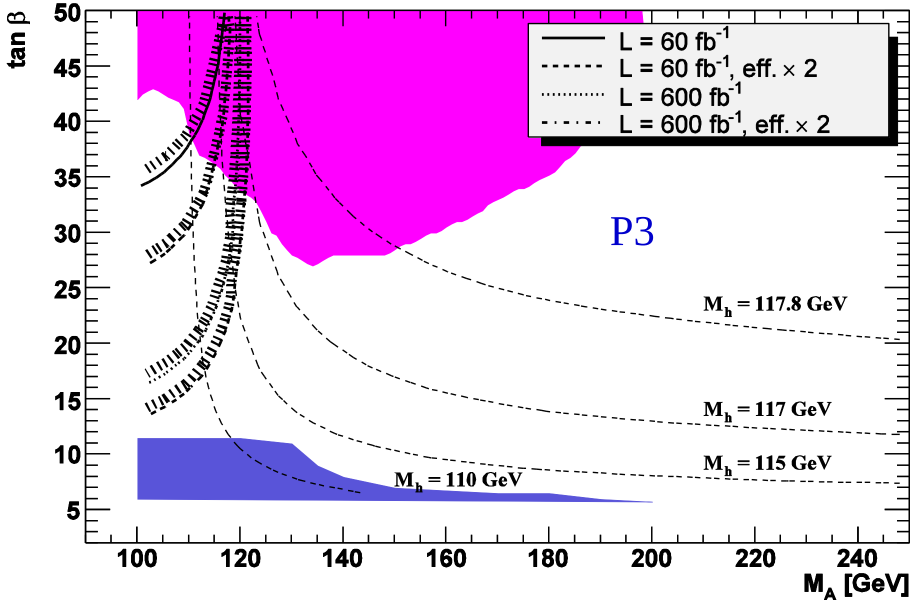
Plane P1: m_0=800 GeV, μ=1000 GeV, A_0=0, varying $9/8M_A-12.5$ GeV$<m_{1/2}<9/8M_A+37.5$ GeV
Plane P2: m_0=300 GeV, μ=800 GeV, A_0=0, varying $1.2M_A$ - 40 GeV $< m_{1/2} <$ $1.2M_A$ + 40 GeV
Plane P3: $m_{1/2}$=500 GeV, m_0=1000 GeV, A_0=0, 200 < μ < 400 GeV
Plane P4: $m_{1/2}$=300 GeV, m_0= 300 GeV, A_0=0, 200 < μ < 350 GeV

Cold Dark Matter: h→bb,tautau, 5σ-contours

h → bb





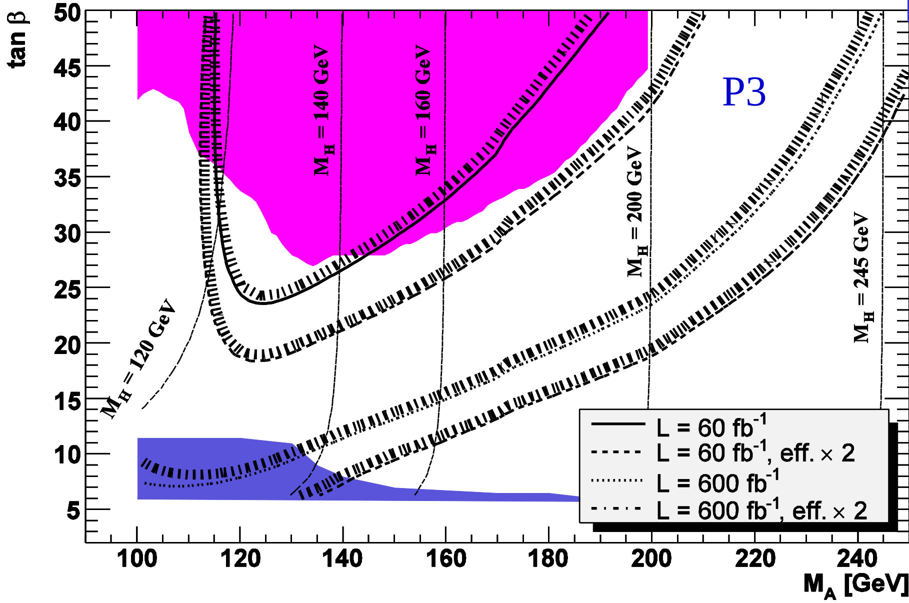


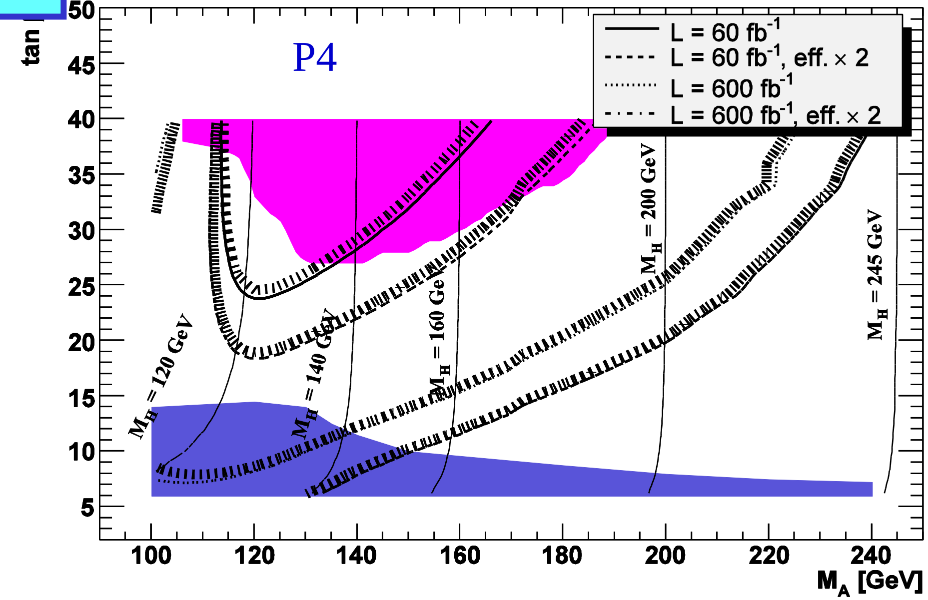
h → ττ

Qualitatively the same features as the conventional Mhmax and No-mixing scenarios

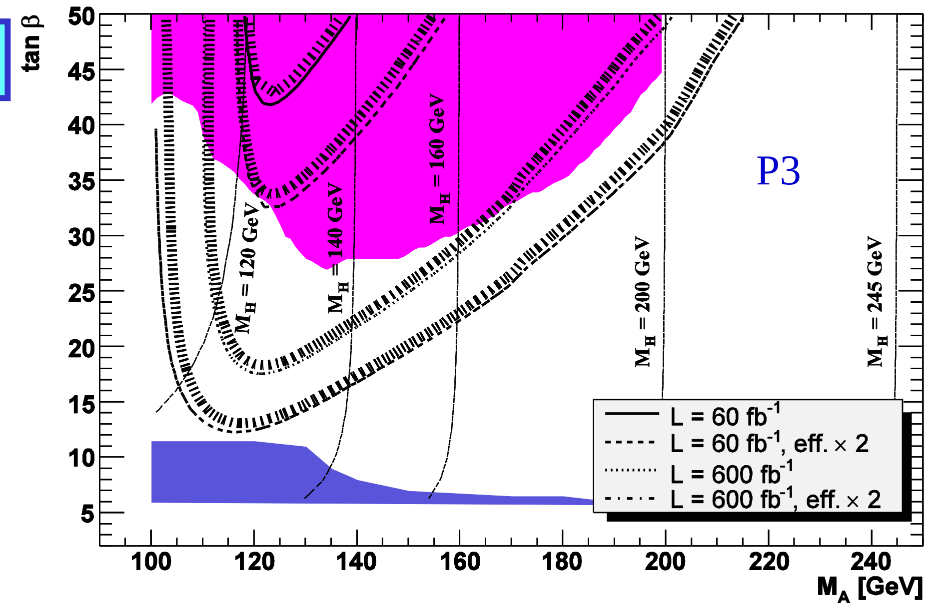
Cold Dark Matter: H→bb, tautau, 5σ-contours

H → bb





H → ττ



Qualitatively the same features as the conventional Mhmax and No-mixing scenarios.

This strengthens the overall validity of findings.