SM/MSSM Higgs production at LHC

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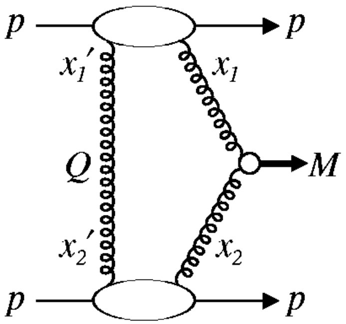
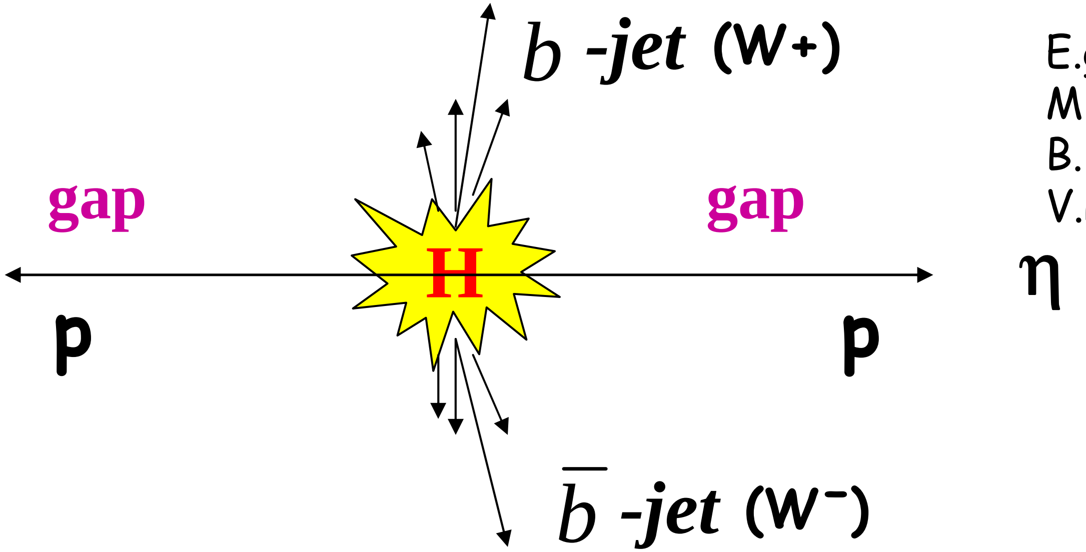
BG+Pile-up effect for DPE processes

MSSM estimates for DPE signal

Double Pomeron Exch. Higgs Production

Exclusive DPE Higgs production pp→ p H p : 3-10 fb
Inclusive DPE Higgs production pp → p+X+H+Y+p : 50-200 fb





E.g. V. Khoze et al
M. Boonekamp et al.
B. Cox et al. …
V.Petrov et al.

Advantages of Exclusive:

Mh^2 measured in RP via missing mass as ξ1*ξ2*s
bb: Jz=0 suppression of gg->bb bg | WW: bg almost negligible

bb: L1-trigger of "central CMS+220 RP" type extensively studied by CMS/Totem group – see Monika's talk.

WW: Extremely promising for Mh>130 GeV. Relevant triggers already exist. Better Mh resolution for higher Mh.

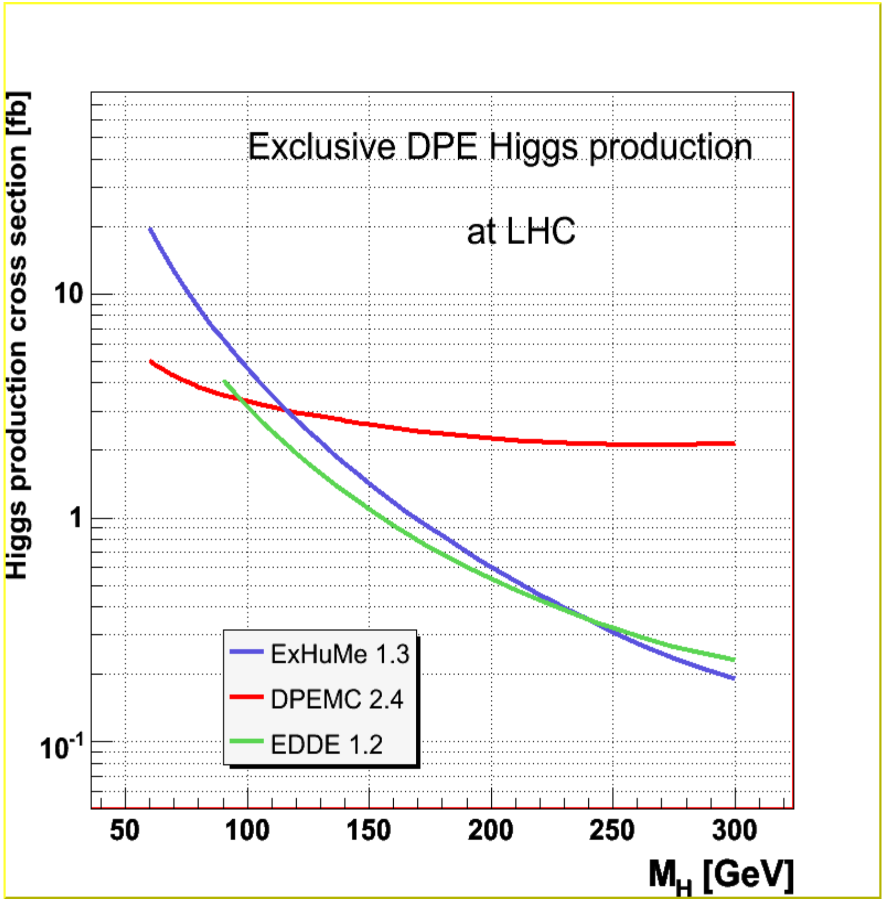
DPE Higgs event generators

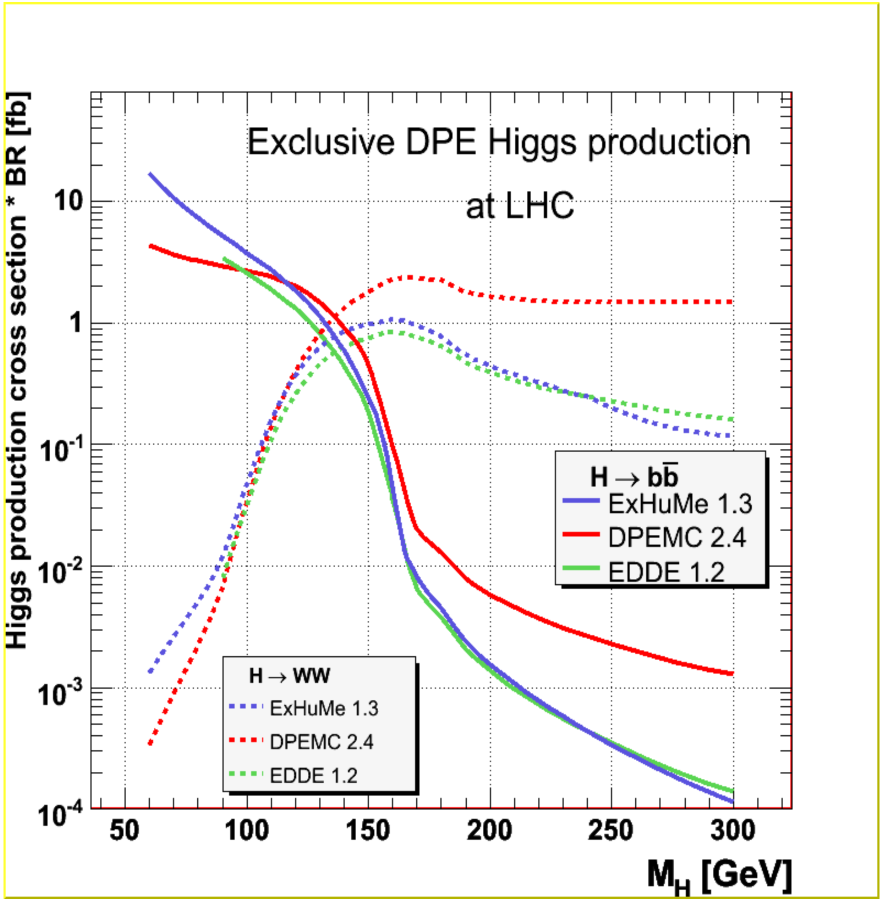
All three models available in the fast CMS simulation

1. **DPEMC 2.4** (M.Boonekamp, T.Kucs)
   - Bialas-Landshof model for Pomeron flux within proton
   - Rap.gap survival probability = 0.03
   - Herwig for hadronization

2. **EDDE 1.2** (V.Petrov, R.Ryutin)
   - Regge-eikonal approach to calculate soft proton vertices
   - Sudakov factor to suppress radiation into rap.gap
   - Pythia for hadronization

3. **ExHuMe 1.3.1** (J.Monk, A.Pilkington)
   - Durham model for exclusive diffraction (pert.calc. by KMR)
   - Improved unintegrated gluon pdfs
   - Sudakov factor to suppress radiation into rap.gap + rap.gap survival prob.=0.03
   - Pythia for hadronization





Difference between DPEMC and (EDDE/ExHuMe) is an effect of **Sudakov suppression factor** growing as the available phase space for gluon emission increases with increasing mass of the central system

Models predict different physics potentials !

H->bb and H->WW in SM

Both the signal and bg studied at detector level using FAMOS.

The following packages used in the analyses:

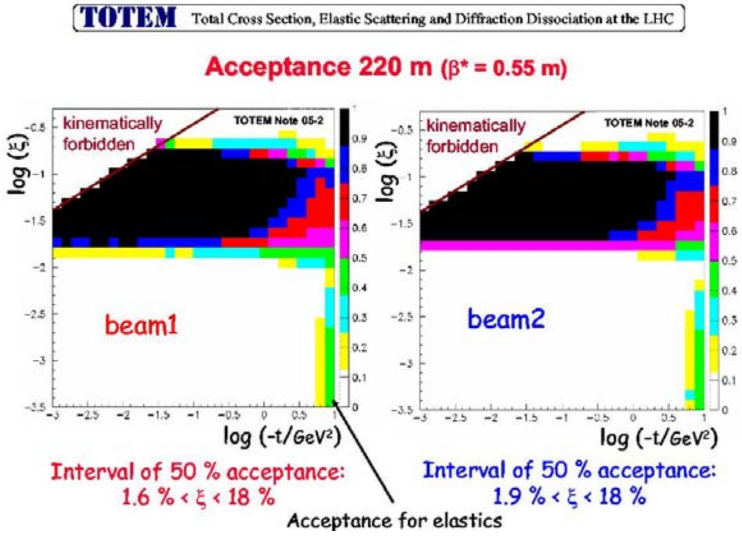
- Fastcalorimetry
- FastTsim, FastBtag
- FastJets,
- FastMuon, FastMuonTrigger
- FastTotem (just Roman Pots)

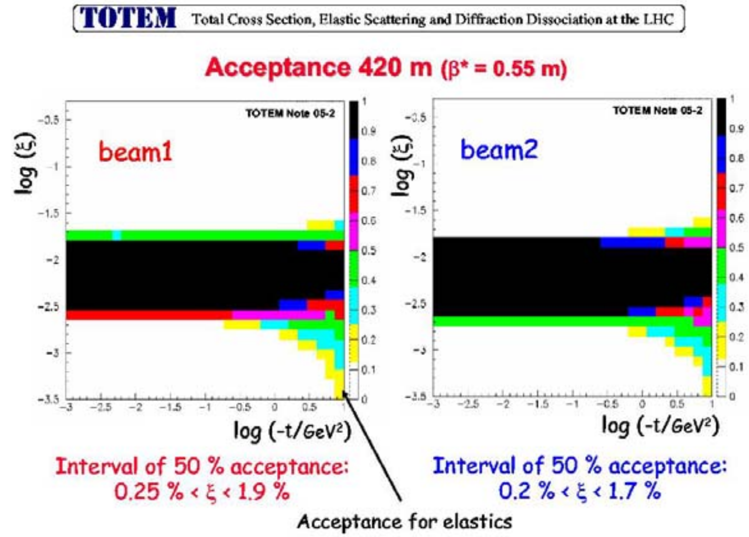
Jet algorithm:

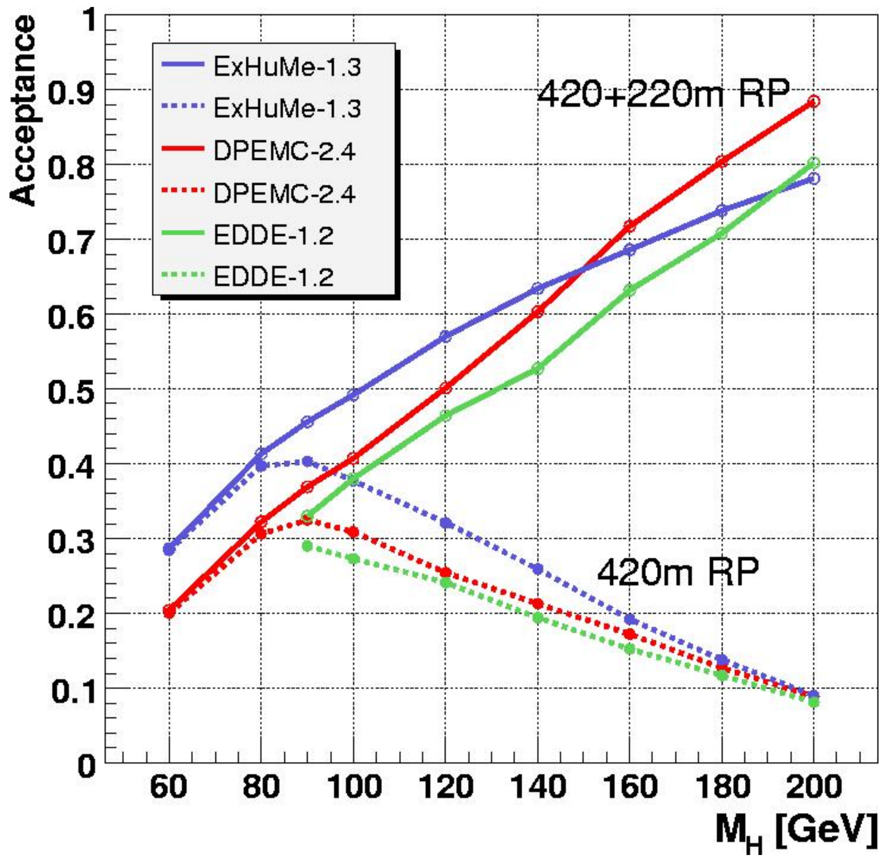
o) Iterative cone, Cone radius = 0.7

o) Jet energy scale corections applied to detector level jets

Roman Pot acceptances







Excl.DPE H->WW:Event yields per L=30 fb-1

- **Both protons accepted in one of two RP's (220, 420)**
- (L1 muons taken from FAMOS. El.+quarks correspond to parton level)
- Various cut scenarios acc.to current CMS L1 thresholds:

- Semi-leptonic W decay:
- 1e (pt>29 GeV, |η|<2.5) or 1μ (pt>14 GeV, |η|<2.1) or
- 1e (pt>20 GeV, |η|<2.5) + 2 quarks (pt>25GeV,|η|<5) or
- 1μ (pt>10 GeV, |η|<2.1) + 2 quarks (pt>25GeV, |η|<5)

- Fully leptonic W decay:
- 2e (pt>17 GeV, |η|<2.5) or 2μ (pt>3 GeV, |η|<2.1) or
- eμ (pte>17 GeV, |η|<2.5 and ptμ>3 GeV, |η|<2.1) or
- 2e (ptmax>29 GeV,|η|<2.5) or 2μ (ptmax>14 GeV,|η|<2.1) or
- eμ (pte>29 GeV, |η|<2.5 or ptμ>14 GeV, |η|<2.1)

Excl. DPE H->WW: Event yield for L=30 fb-1 ExhuMe 1.3 and new RP acceptances

			fully-lept		semi-lept		
Mh[GeV]	σXBR[fb]	Acc.[%]	cms	atlas	cms	atlas	Total
120	0.37	57	0.2	0	1.2	1	1.3
135	0.77	62	0.6		3.1		3.4
140	0.87	63	0.6	1	3.5	3	3.8
150	1.00	66	1.0		4.9		5.3
160	1.08	69	1.0	1	6.0	5	6.6
170	0.94	71	1.0		5.4		5.9
180	0.76	74	0.8	1	4.5	4	4.9
200	0.44	78	0.6	1	2.9	2	3.2

Excl.DPE H->bb: Mh dependence

High Lumi selection cuts at detector level (for all Mh!):

0) Both protons detected in RPs (420+420 or 420+220 or 220+420)
1) $N_{jet} > 1$
2) 45 < Etj1*JESCor < 85 GeV, Etj2*JESCor > 30 GeV
3) $|\eta_{j1,2}| < 2.5$
4) $|\eta_{j1} - \eta_{j2}| < 1.8$
5) $2.8 < |\varphi_{j1} - \varphi_{j2}| < 3.48$
6) $M_{j1j2}/M_{miss.mass} > 0.8$
7) Both jets b-tagged

Excl. DPE H->bb: Mh dependence

Signal numbers come from ExHuMe (DPEMC gives similar predictions for Mh=120 GeV). BG numbers come from DPEMC (just for technical reasons).
EDDE gives 10x smaller xsections for BG.

BG processes studied: DPE gg->bb + QCD gg->gg

Mass windows (ΔM) used only for S/B studies.
Two window widths used: narrower for (420+420) and
broader for combined RP configs.

Mh=120: resolution=1.6%->ΔM=4GeV for 420+420 config.
resolution=5.6%->ΔM=10GeV for combined config.

Excl. DPE H->bb: Mh dependence, L=30 fb-1

Mh[GeV]	σ[fb]	S_ideal	Acc[%]	ε_btag[%
120	1.9	57	57	33
140	0.6	18	63	37
160	0.045	1.35	69	40
180	0.0042	0.13	74	42
200	0.00156	0.047	78	43

WITHOUT PILE-UP

The event yields at higher masses negligible in SM. But in MSSM the xsections sometimes enhanced by a factor of 100 wrt SM.

Event selection eff. grows from 7% (Mh=120) to 14% (Mh=200).
Loss of stat.at Mh = 120 GeV:
Etjet cut (55%), b-tag (67%) and RP Acc. (43%).

Effect of pile-up events

What is the number of fake signal events per bunch crossing (N^{fake}/BX) caused by PU events?

Selection criteria for signal events (Higgs in DPE):

[2 protons in RPs, each on opposite side] x [Jet cuts] x [Mass window]

For the moment (till I get the final results), assume we can factorize the task the above way:

$$N^{fake} = N^{RP} * [\text{Jet cuts}] * [\text{Mass window}]$$

Estimate of N^{RP}: 1.Rough-but-Fast

2.Precise-but-Slow

All RP acceptances are taken as means.

Phojet generation of PU events

All processes	118 mb
Non-diff.inelastic	68 mb
Elastic	34 mb
Single Diffr.(1)	5.7 mb
Single Diffr.(2)	5.7 mb
Double Diffr.	3.9 mb
DPE	1.4 mb

Number of pile-up events per bunch crossing (BX) $\equiv N^{PU}$ =
Lumi x cross section x bunch time width = LHC bunches/filled bunches =

$10^{34}cm^{-2}s^{-1} x 10^4 cm^2/m^2 \times 10^{-28} m^2/b \times 110mb \times 10^{-3} b/mb \times 25*10^{-9}s$
X 3564/2808 ~ 35

$5*10^{33}$ ~ 17.6 , $2*10^{33}$ ~ 7.0, $1*10^{33}$ ~ 3.5, $1*10^{32}$ ~ 0

N^{RP} estimate – fast method

1. Derived only from PU events, no mixing with signal nor bg events

There are 2 cases: "DD" – 2 protons from one DD event
"2SD" – 2 protons from a sum of 2 SD events

$$N^{RP}(1) = N^{DD} + N^{2SD} = \langle N^{PU}\rangle * A^{DD} + \langle N^{PU}\rangle * (\langle N^{PU}\rangle - 1) * A^{SD-L} * A^{SD-R}$$

$$A^{DD} = A_{420} + A_{220} + A_{comb} - A_{overlap}$$

$$= A^{L}_{420} * A^{R}_{420} + A^{L}_{220} * A^{R}_{220} + A^{L}_{420} * A^{R}_{220} + A^{R}_{420} * A^{L}_{220} - A_{overlap}$$

$$= 1.9\%$$

$A^{SD-L} = A^{L}_{420} + A^{L}_{220} = 12.1\%$, $A^{SD-R} = A^{R}_{420} + A^{R}_{220} = 12.6\%$

$$N^{RP}(1) = \langle N^{PU}\rangle * 0.019 + \langle N^{PU}\rangle * (\langle N^{PU}\rangle - 1) * 0.0152$$

N^{RP} estimate – precise method

2. Mix PU events with signal or bg – using FAMOS

- Sum RP acceptances over all possible proton pairs in all PU events in one BX and then look at mean over all signal or bg events. N^{PU} properly smeared using Poisson dist.

E.g. $N^{RP}_{420} = \langle \Sigma_i^{NPU(n)} \Sigma_j^{NPU(n)} A^L_{420}(i) \times A^R_{420}(j) \rangle_{n=5k}$ ← signal or bg events

Mean nr.of PU events with 2 p's seen in opposite 420 RPs

$\langle N^{PU} \rangle$	N^{RP}_{420}	N^{RP}_{220}	N^{RP}_{comb}	$N^{RP}(2)$	$N^{RP}(1)$
3.5	0.015	0.08	0.08	**0.17**	0.20
7.0	0.05	0.23	0.23	**0.47**	0.65
17.6	0.18	0.96	0.93	**1.99**	4.78
25.0	0.32	1.78	1.57	**3.49**	9.61
35.0	0.61	3.04	2.77	**5.73**	18.79

How PU events affect jets

Just indications derived from signal sample DPE H->bb (because of sufficient statistics): compare nr. of selected events in two samples: one with, the other without PU events mixed. Both have the same RP acceptances. Calculate $K_{jets} = N_{ev}(PU)/N_{ev}(\text{no PU})$.

$\langle N^{PU} \rangle$	N^{RP}_{420}	N^{RP}_{220}	N^{RP}_{comb}	$N^{RP}(2)$	$N^{RP}(1)$	K_{jets}
3.5	0.015	0.08	0.08	**0.17**	0.20	1.03
7.0	0.05	0.23	0.23	**0.47**	0.65	1.01
17.6	0.18	0.96	0.93	**1.99**	4.78	1.00
25.0	0.32	1.78	1.57	**3.49**	9.61	0.82
35.0	0.61	3.04	2.77	**5.73**	18.79	0.42

H->WW,bb,tautau in MSSM

- Valery Khoze's talk at FP420 meeting on 16.02.06:

Diffractive processes at the LHC as a means to study SUSY Higgs sector

FP420

Durham University V.A. Khoze (IPPP, Durham)

(in collaboration with S. Heinemeyer, M. Ryskin, W.J. Stirling, M. Tasevsky and G. Weiglein)

Main aims -to demonstrate that Double Proton Tagging @LHC is especially beneficial for the detailed studies of the MSSM Higgs bosons

-to illustrate and to compare the salient features of the three main decay channels (bb, WW, ττ) for studies in the forward proton mode

- hunting the CP-odd Higgs in the diffractive environment

If the potential experimental challenges are resolved, then there is a very real chance that for some areas of the MSSM parameter space the DPT could be the LHC Higgs **discovery channel** !

Disclaimer : some of the results are (very) preliminary and should be taken only as a snapshot of the current understanding. Studies are still ongoing.

1

(KMR- based estimates)

CED production processes for h, H

Signal processes: use approximate formula

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

$\Gamma(h/H \to gg)$, BR^{MSSM}, BR^{SM} evaluated with *FeynHiggs*

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

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

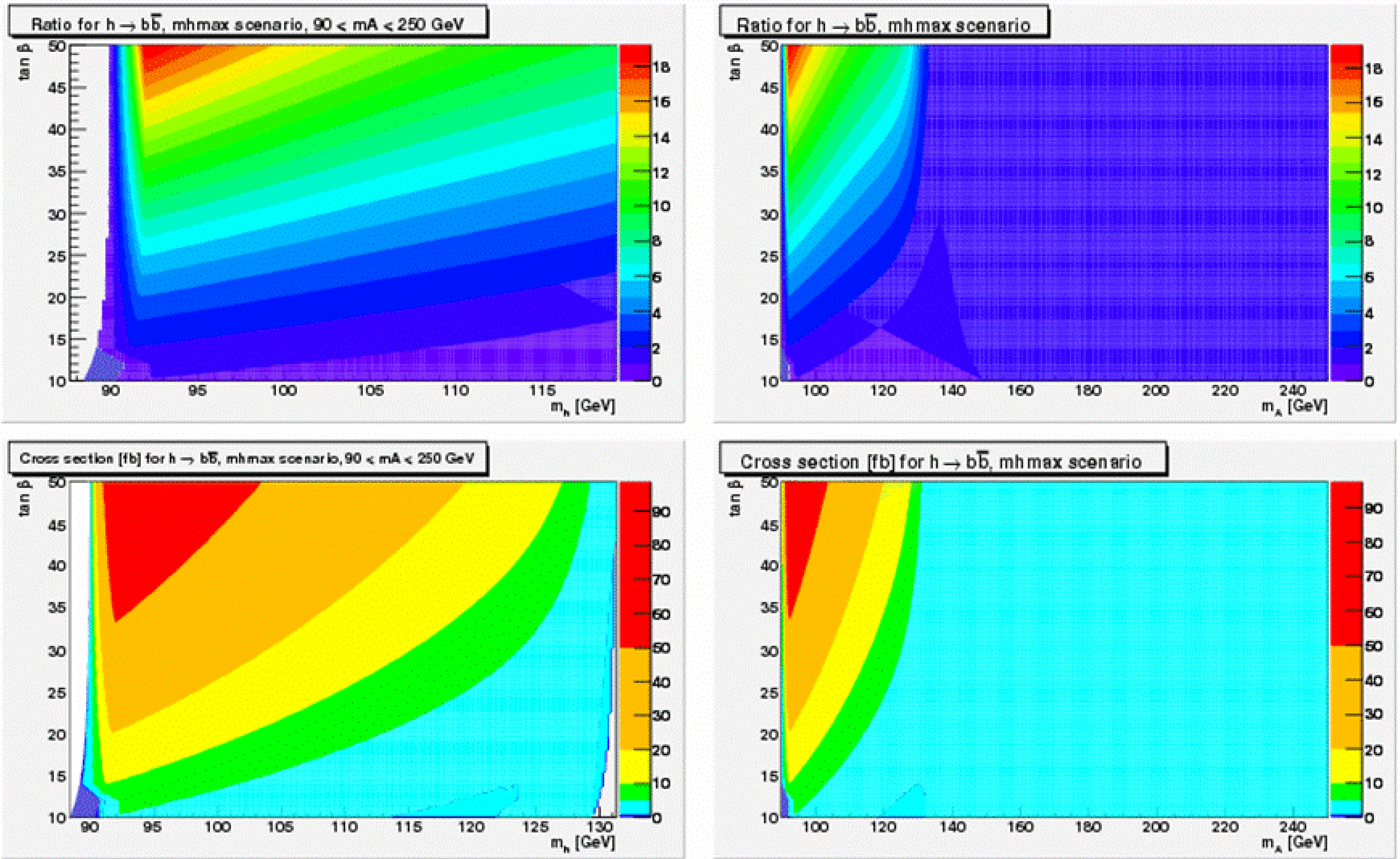
Background for $h, H \to \tau^+\tau^-$ neglected in the following

Show "5σ" contours, where $S/\sqrt{S+B} = 5$

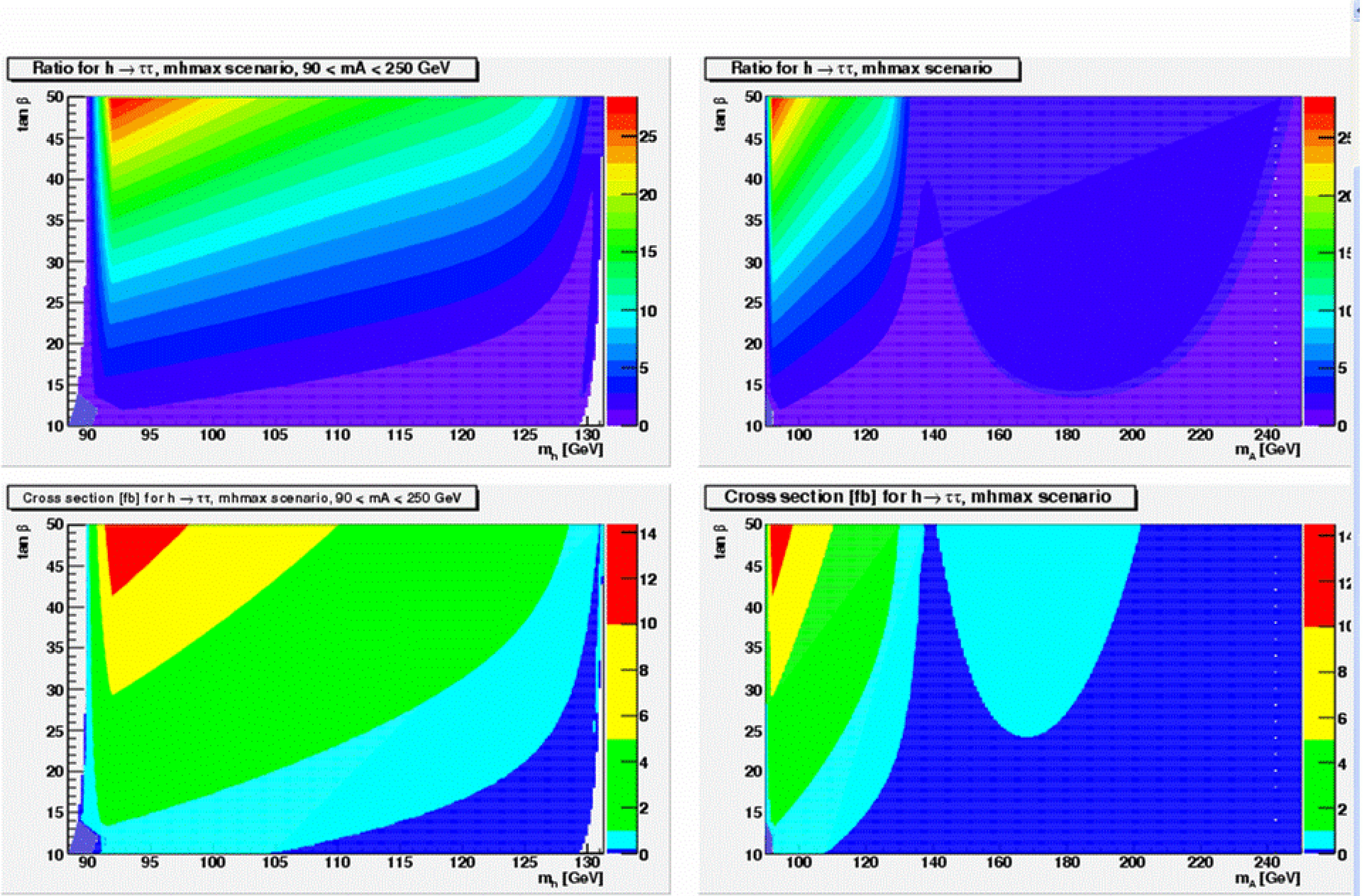
(more on the pessimistic side, studies based on the CMS Higgs group procedure –still to come)

h→bb

mhmax scenario, μ=200 GeV, Msusy =1000 GeV



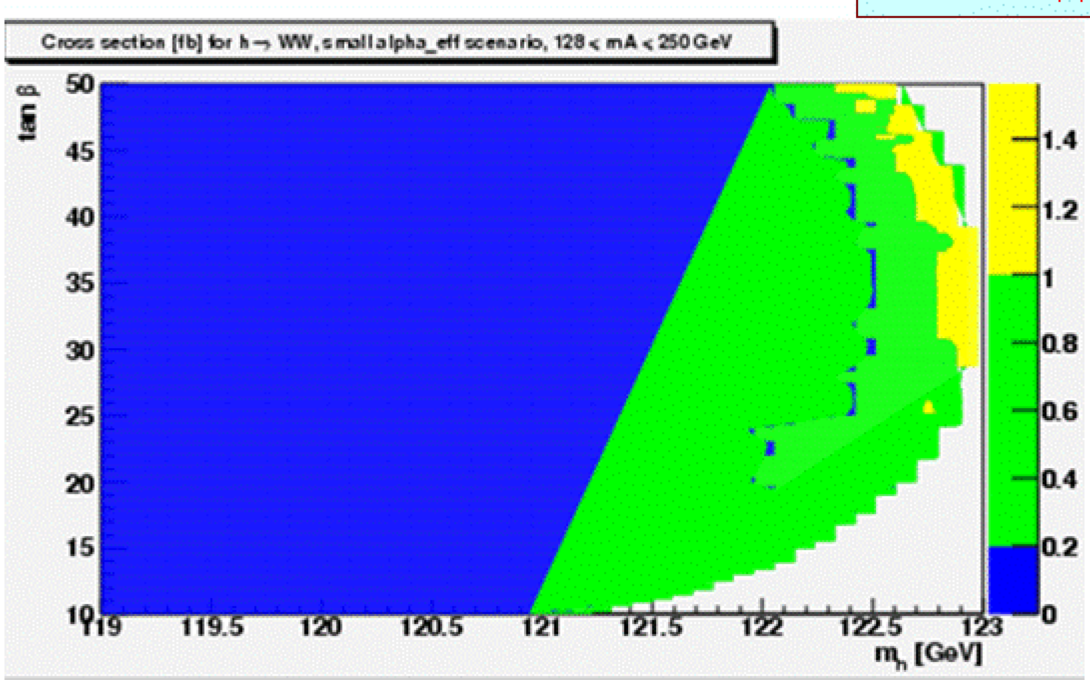
h→ττ



Ratio for h → ττ, mhmax scenario, 90 < mA < 250 GeV
tan β
m_h [GeV]
Ratio for h → ττ, mhmax scenario
m_A [GeV]
Cross section [fb] for h → ττ, mhmax scenario, 90 < mA < 250 GeV
Cross section [fb] for h→ ττ, mhmax scenario

h→WW

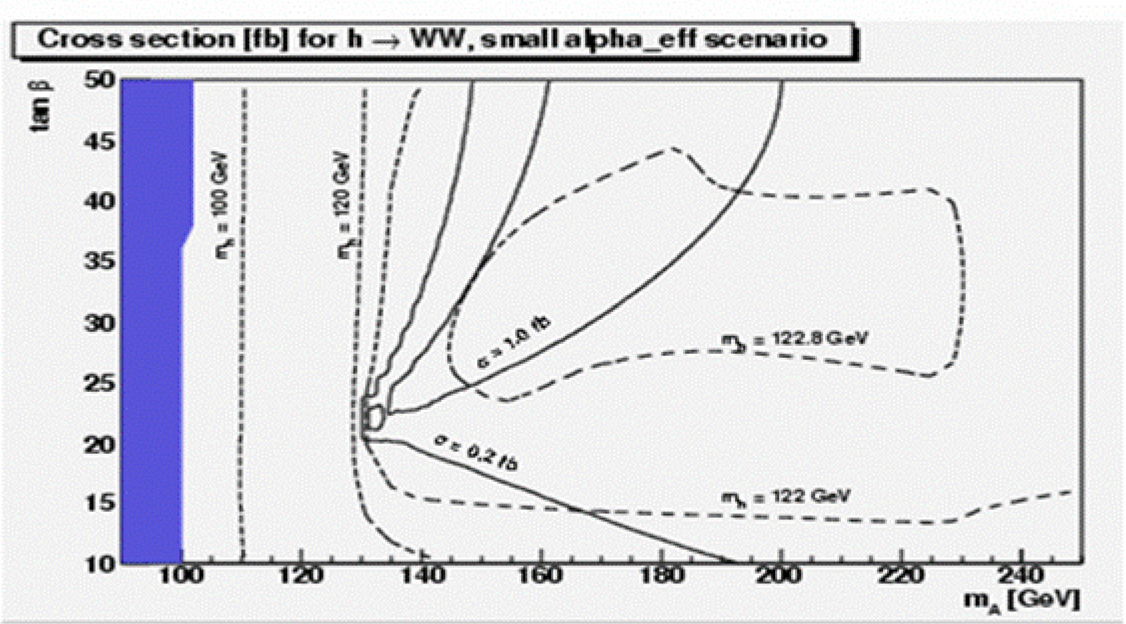
small αeff scenario



mh≈ 121-123 GeV

for the SM Higgs
at M = 120 GeV σ = 0.4 fb,

at M= 140 GeV σ = 1 fb



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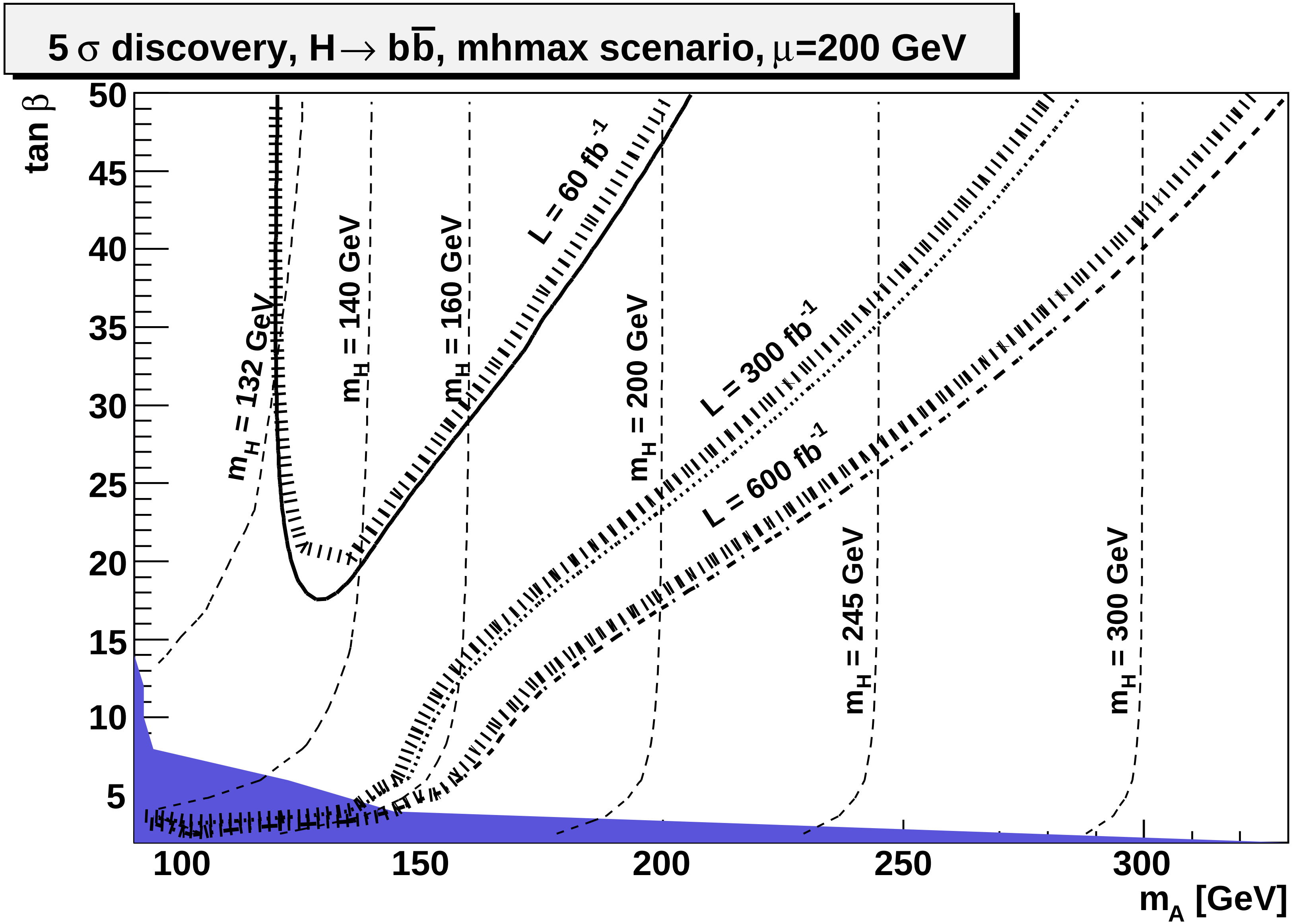
Sigma=5 contours for H->bb (mhmax scenario)



Summary

Diffractive Higgs production is a rich and very interesting chapter. Still many things need to be done:

1. Tune selection cuts – e.g. just one b-tag?
2. Add b->mu processes to the signal H->bb
3. Apply L1 trigger conditions
4. Check W production as bg to H->bb