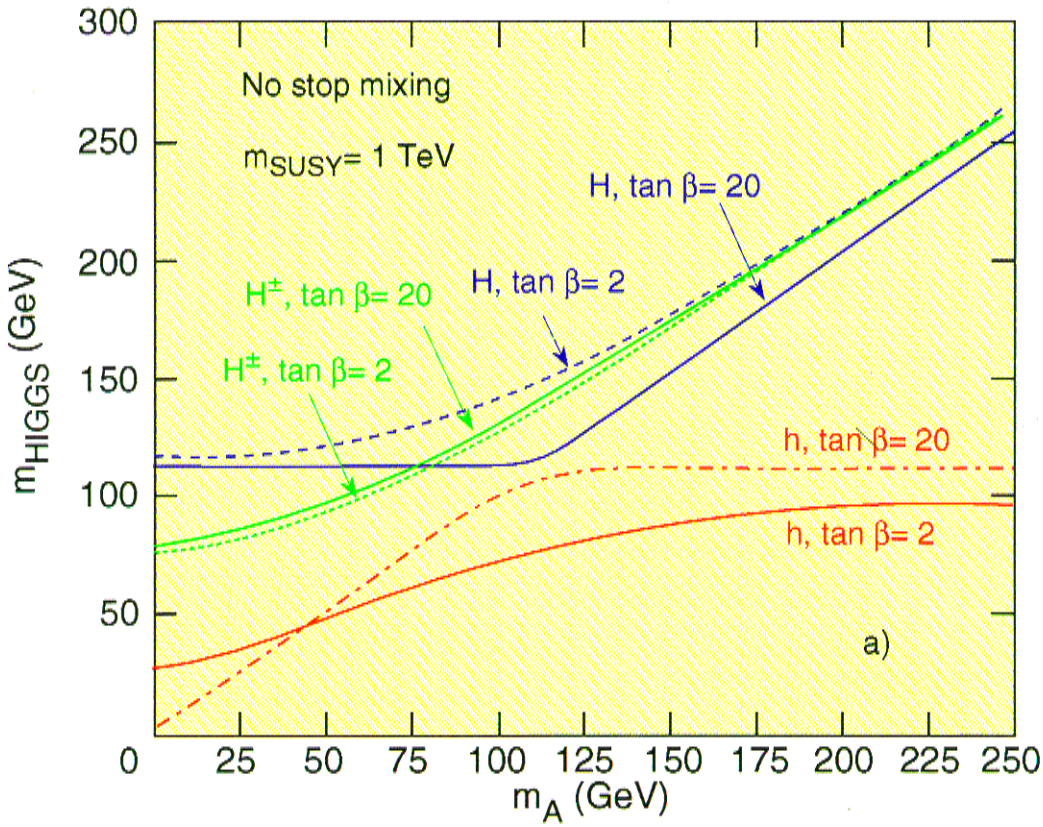
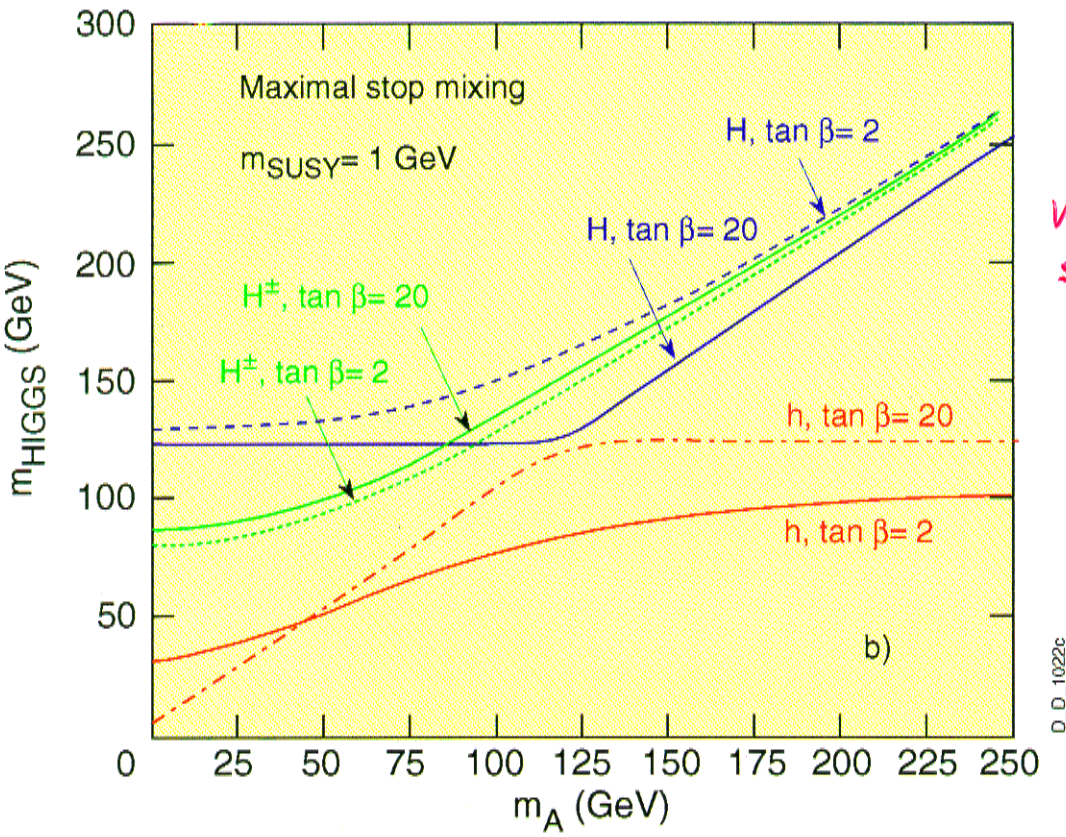
The MSSM Higgses

Masses of MSSM SUSY Higgs bosons as a function of m_A and tan β

Two-loop / RGE-improved radiative corrections

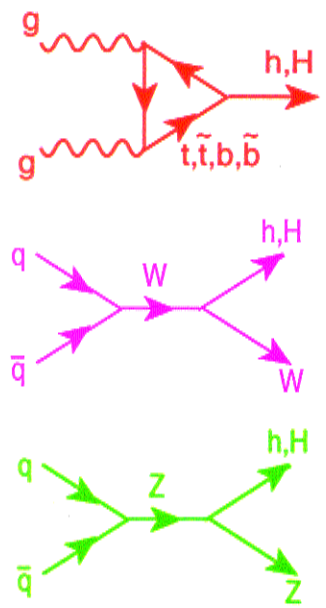


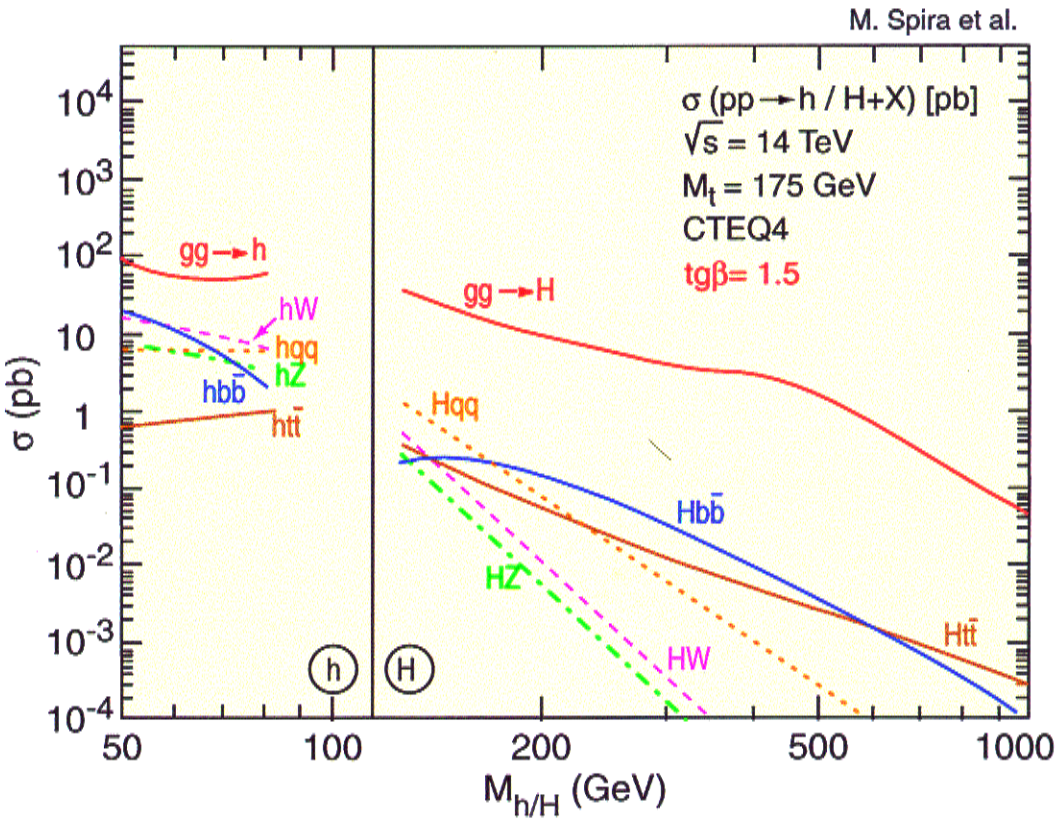
no stop mixing

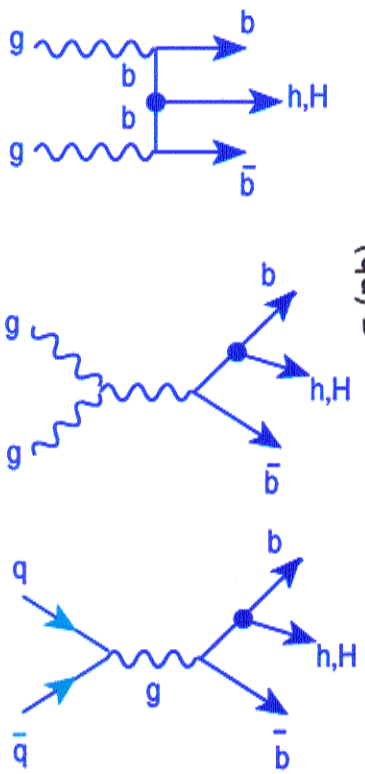


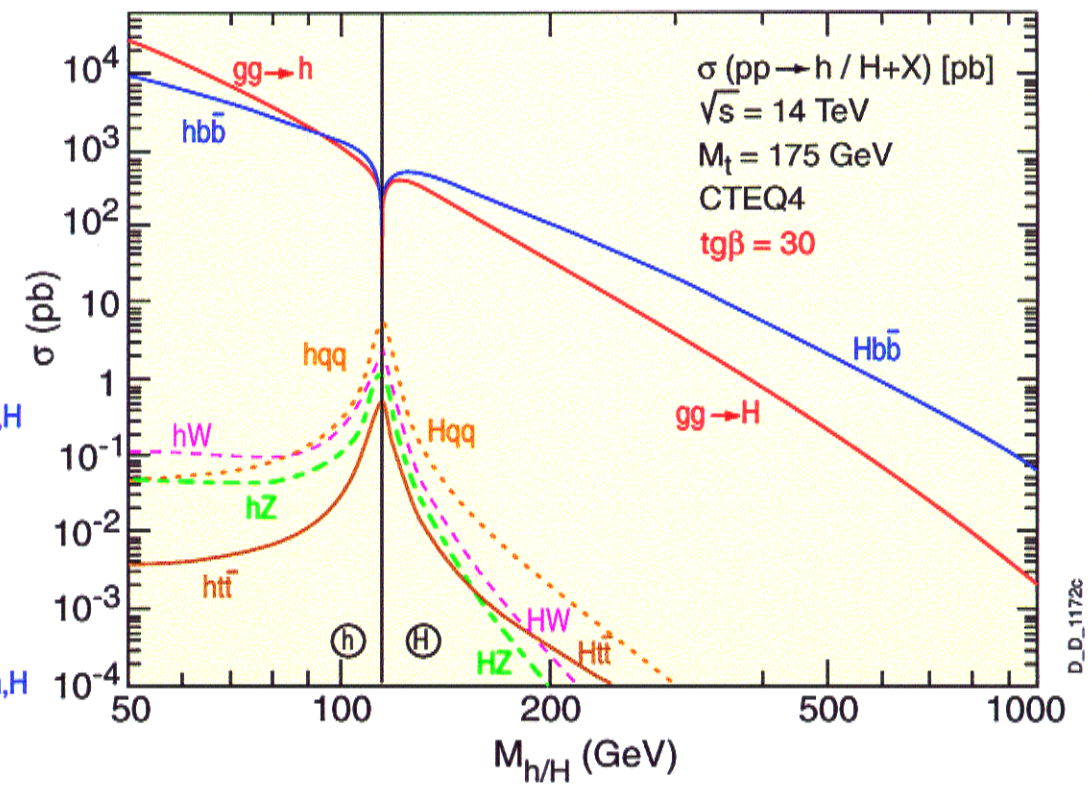
maximal stop mixing

h, H cross sections



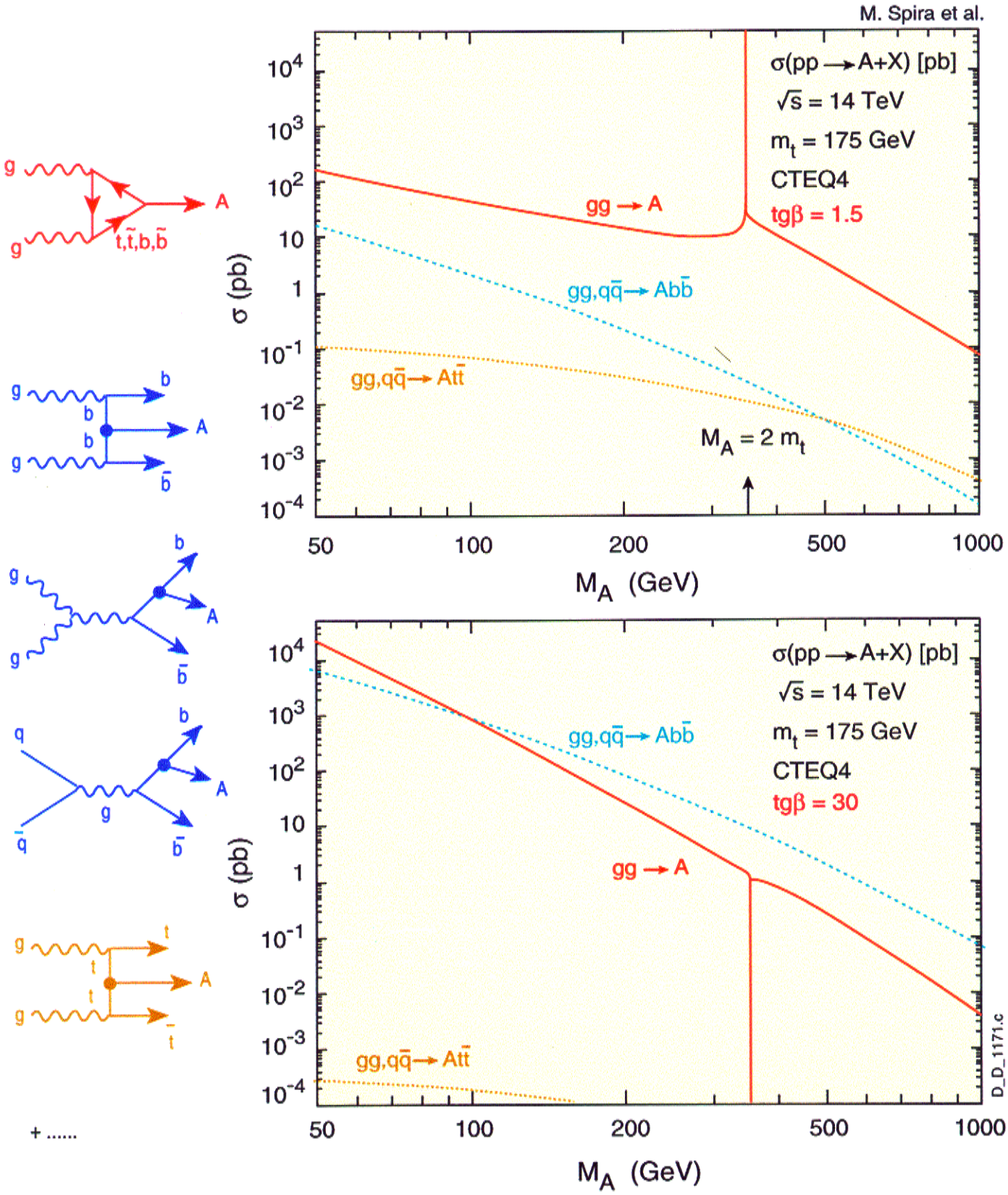






+ .....

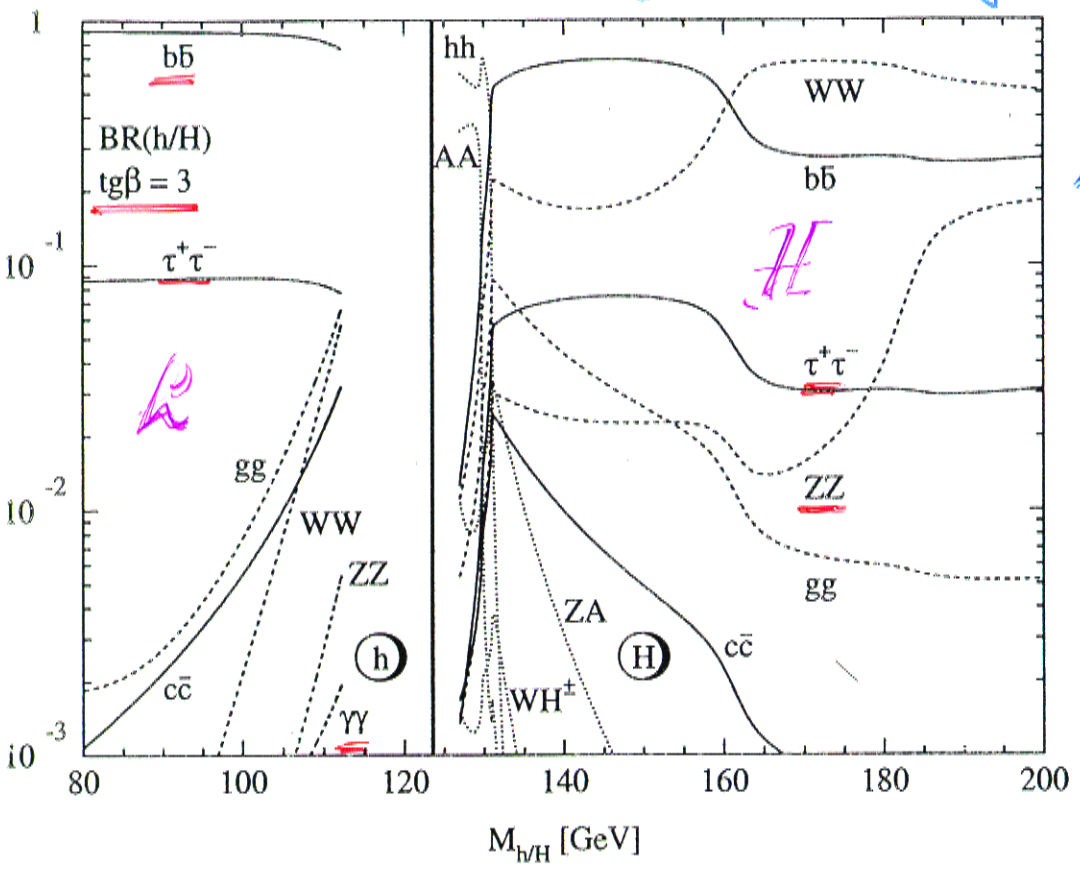
A production

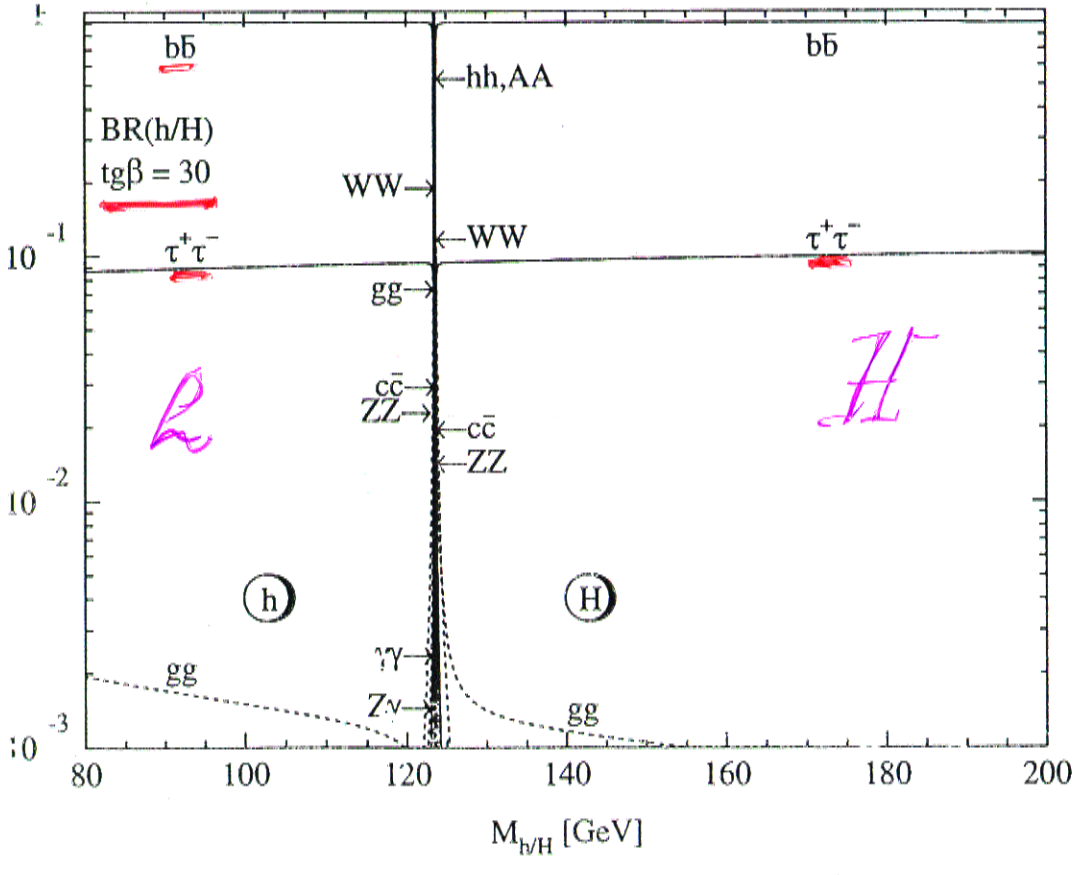


h and H decay branching ratios

HDECAY

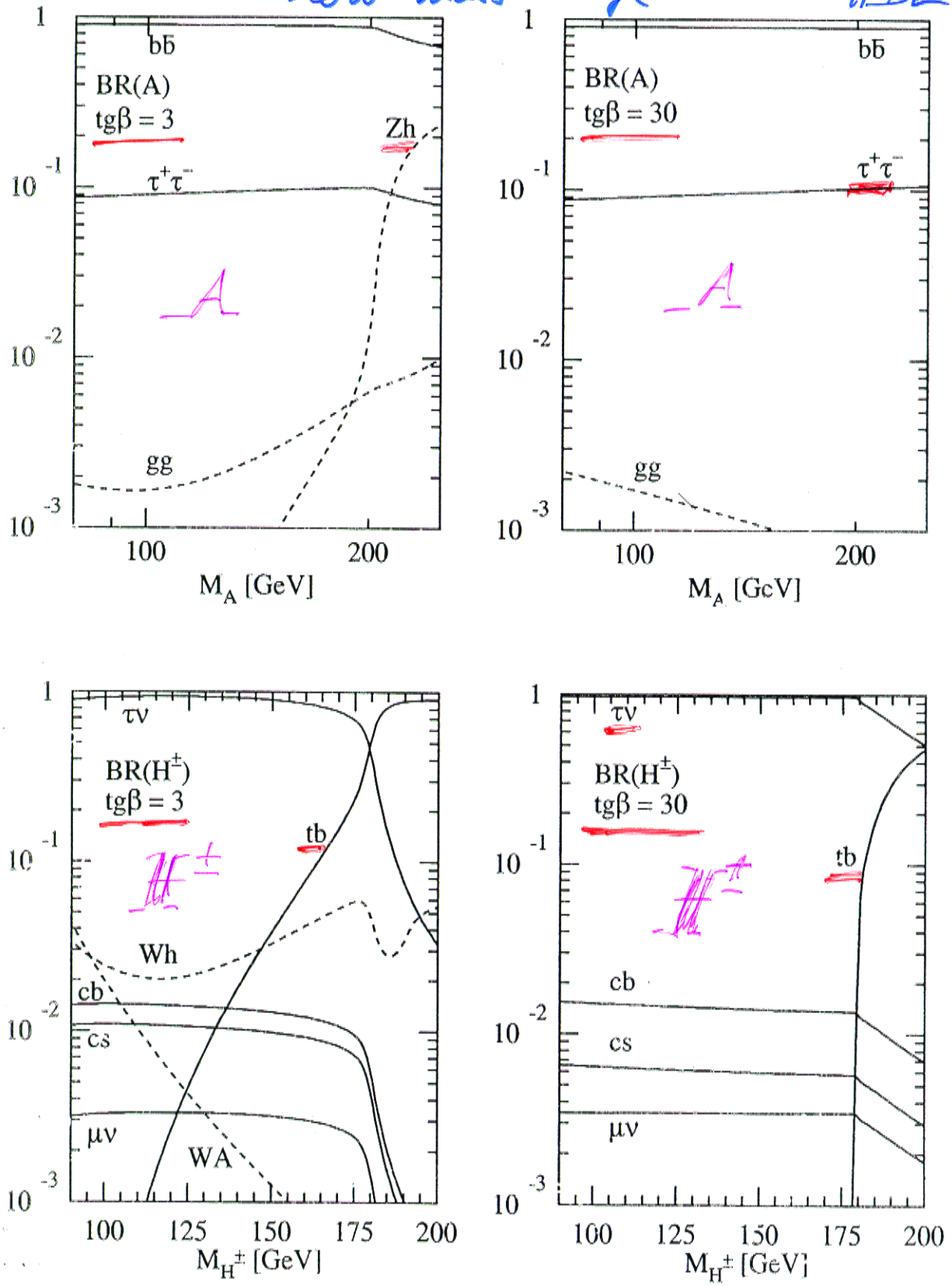
Low-mass Dange





HDECAY

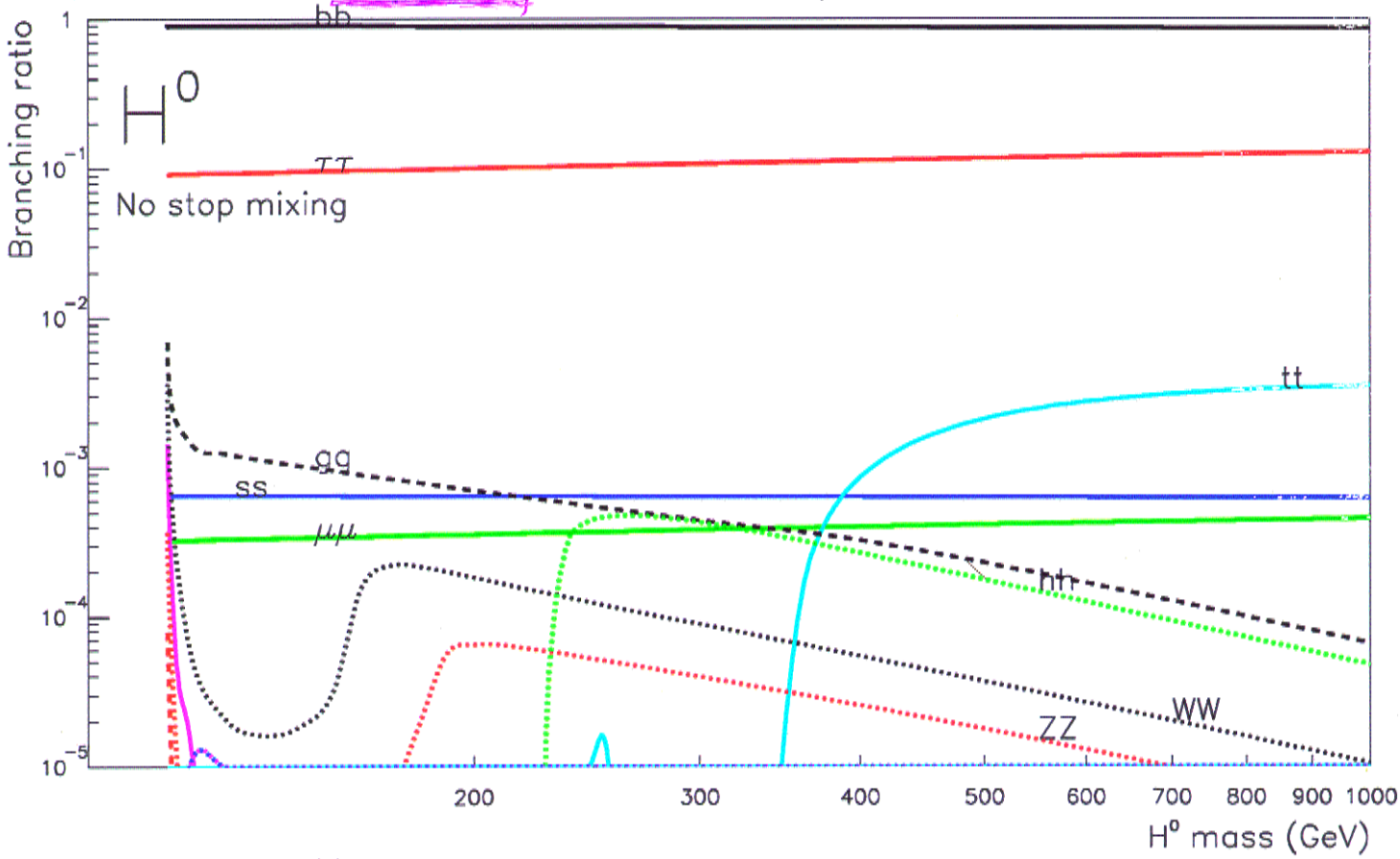
A and $H^\pm$ branching ratios
low mass range HDECAY

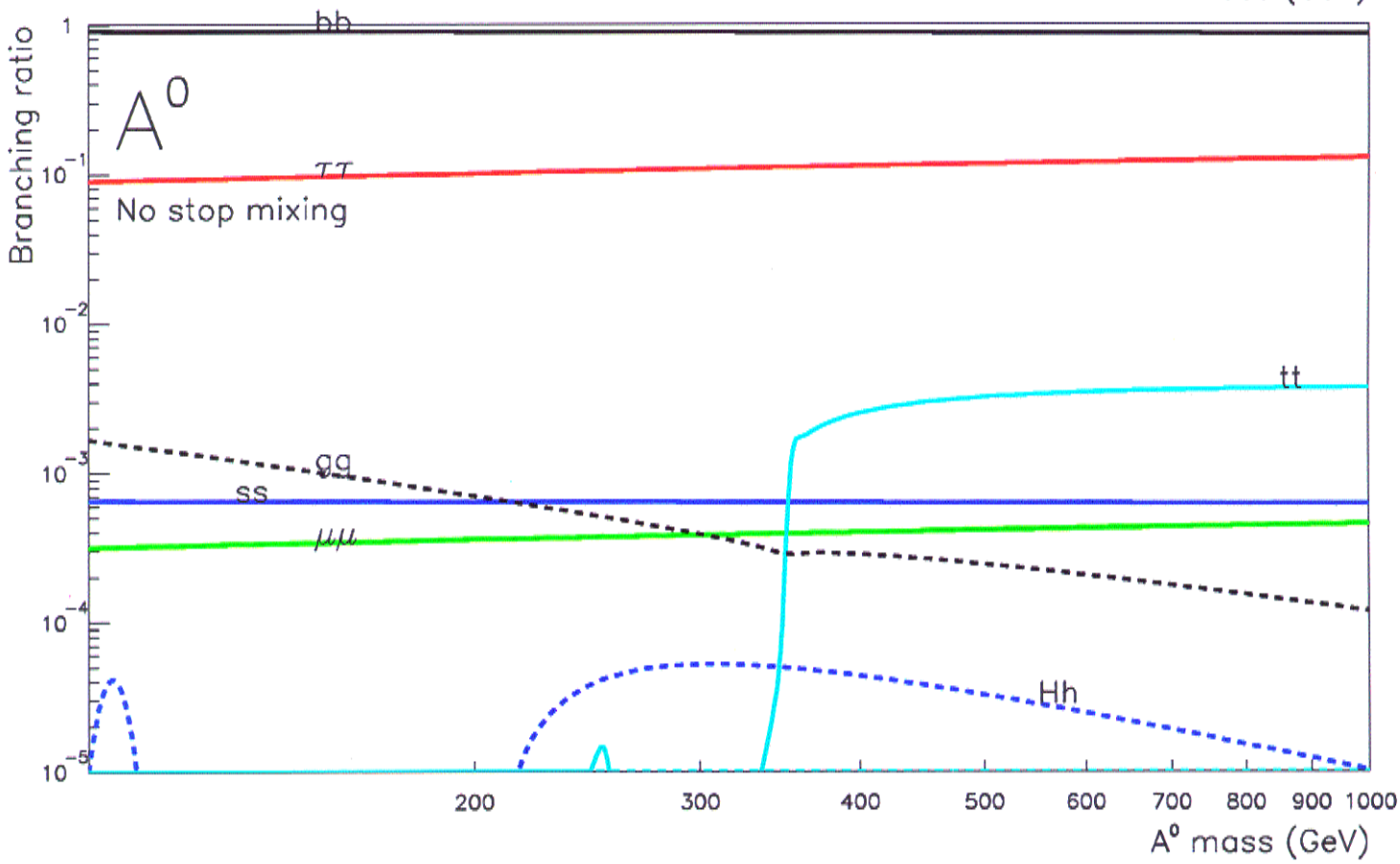


HDECAY

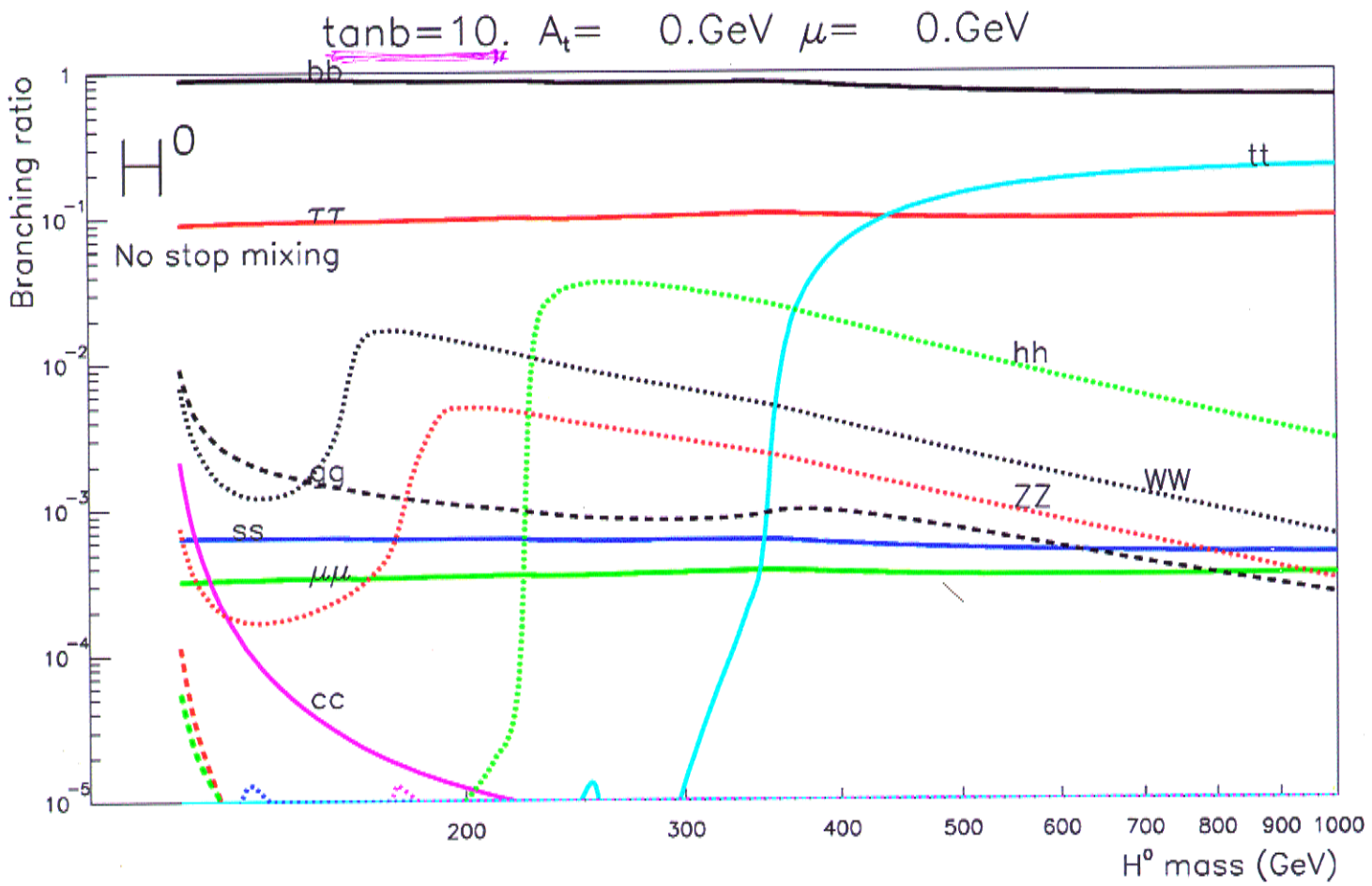
A, H Branching ratios, no stop mixing
full mass range

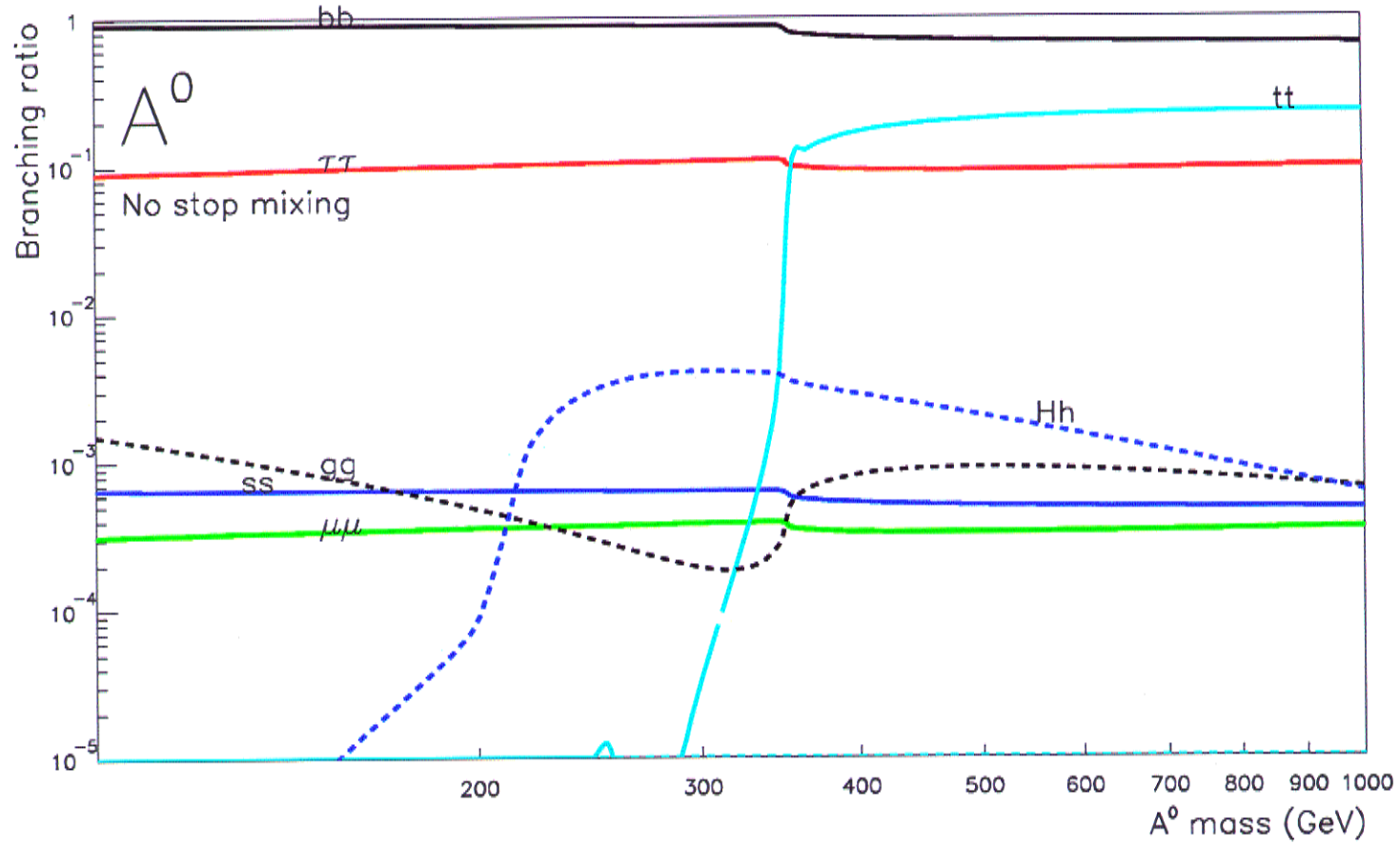
tanb=30. A_t= 0.GeV μ= 0.GeV



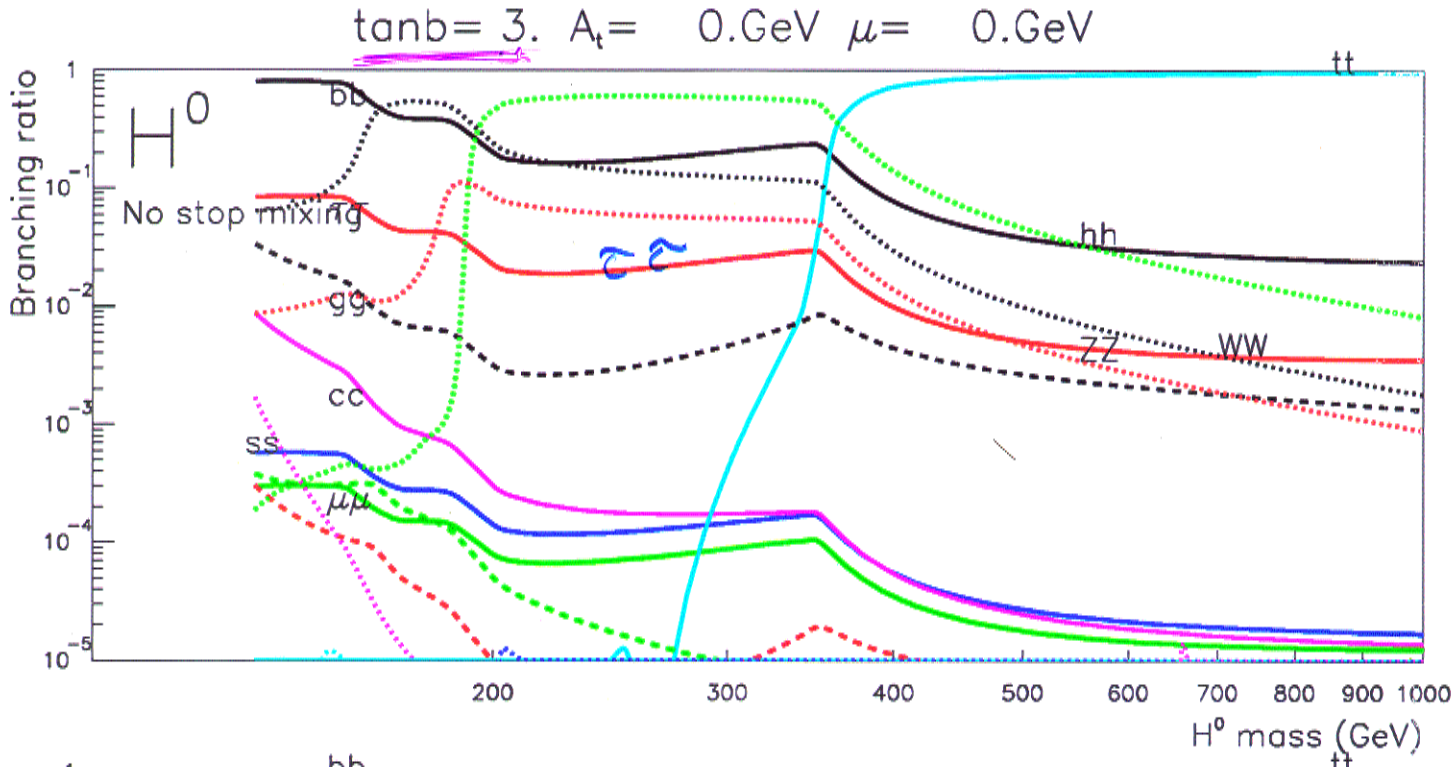


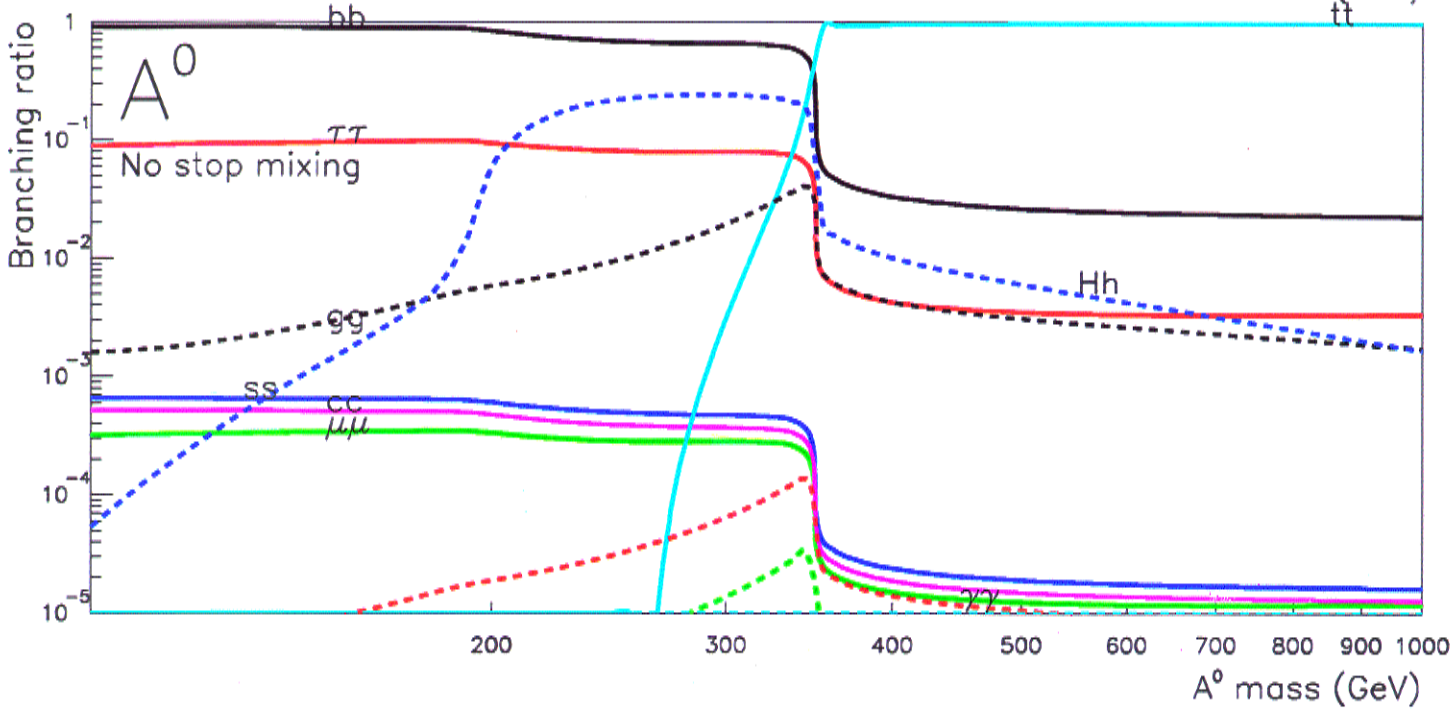
A, H Branching ratios, no stop mixing





A, H Branching ratios, no stop mixing - full mass range low tanβ regime



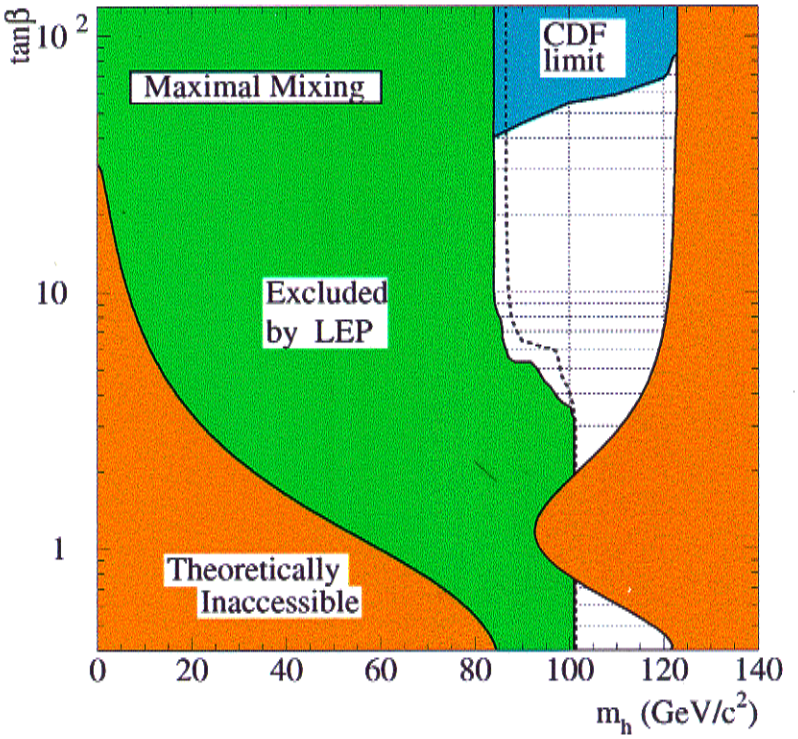


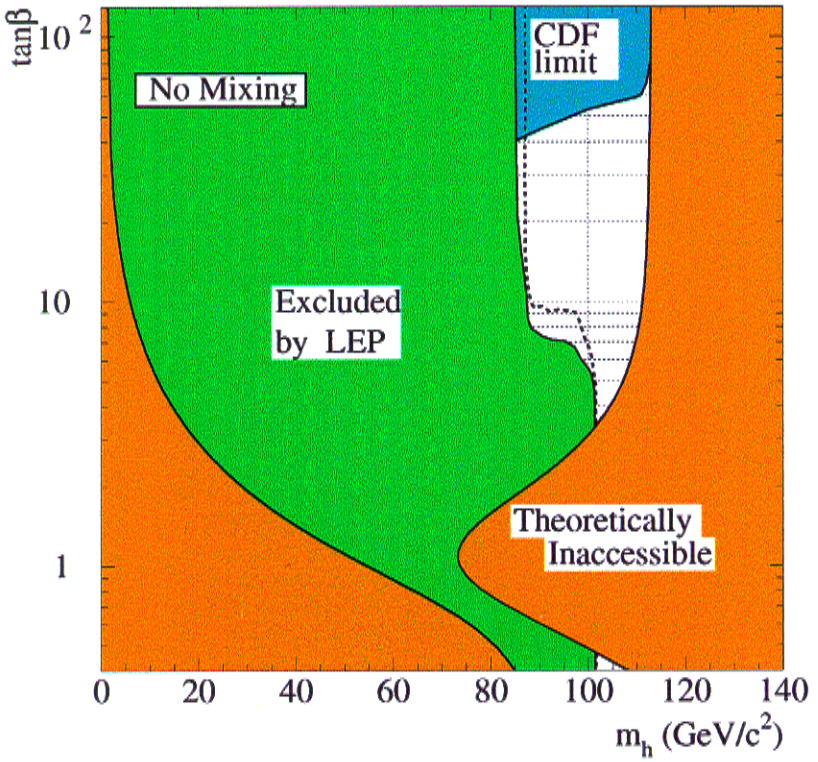
MSSM Limits - m_h vs $\tan\beta$

Maximal mixing:

95% CL Limit on m_h: 84.3 GeV/c^2

Exclude $\tan\beta$: $0.8 - 1.9$





No mixing:

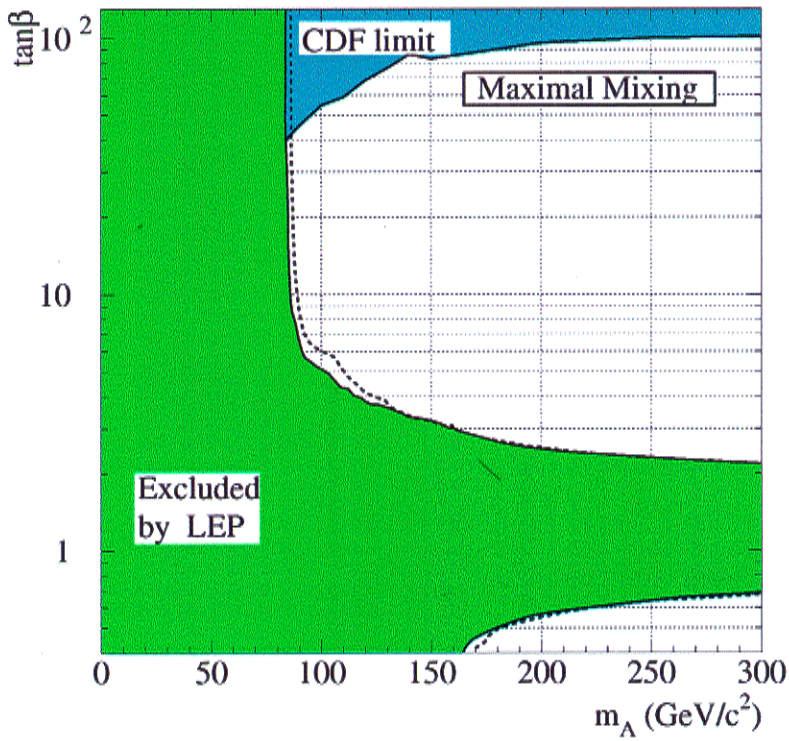
95% CL Limit on m_h: 84.5 GeV/c^2

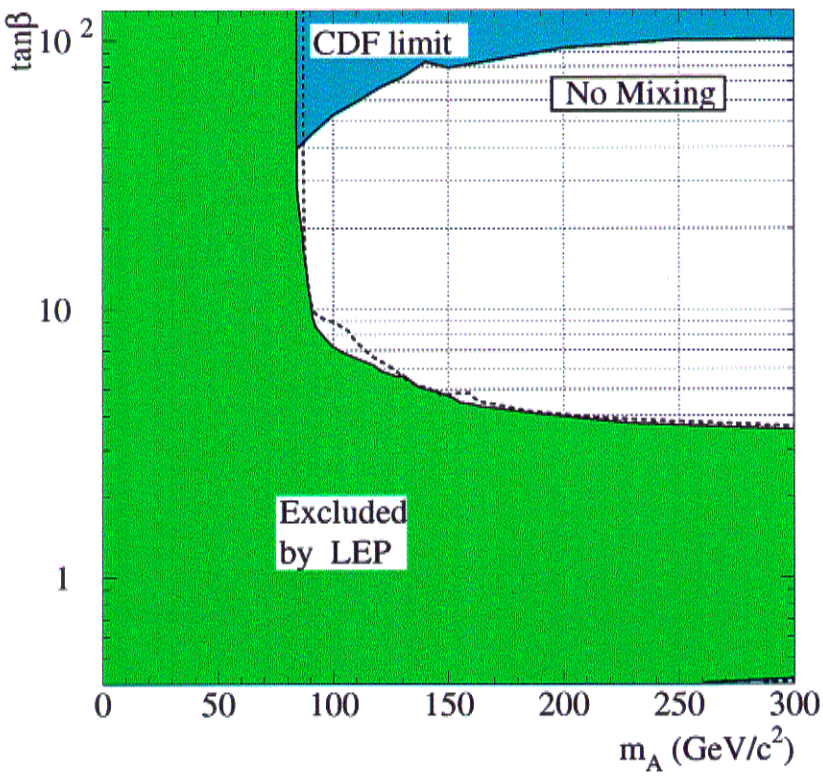
Exclude $\tan\beta$: $0.5 - 3.2$

MSSM Limits - m_A vs $\tan\beta$

Maximal mixing:

95% CL Limit on m_A: 84.5 GeV/c^2



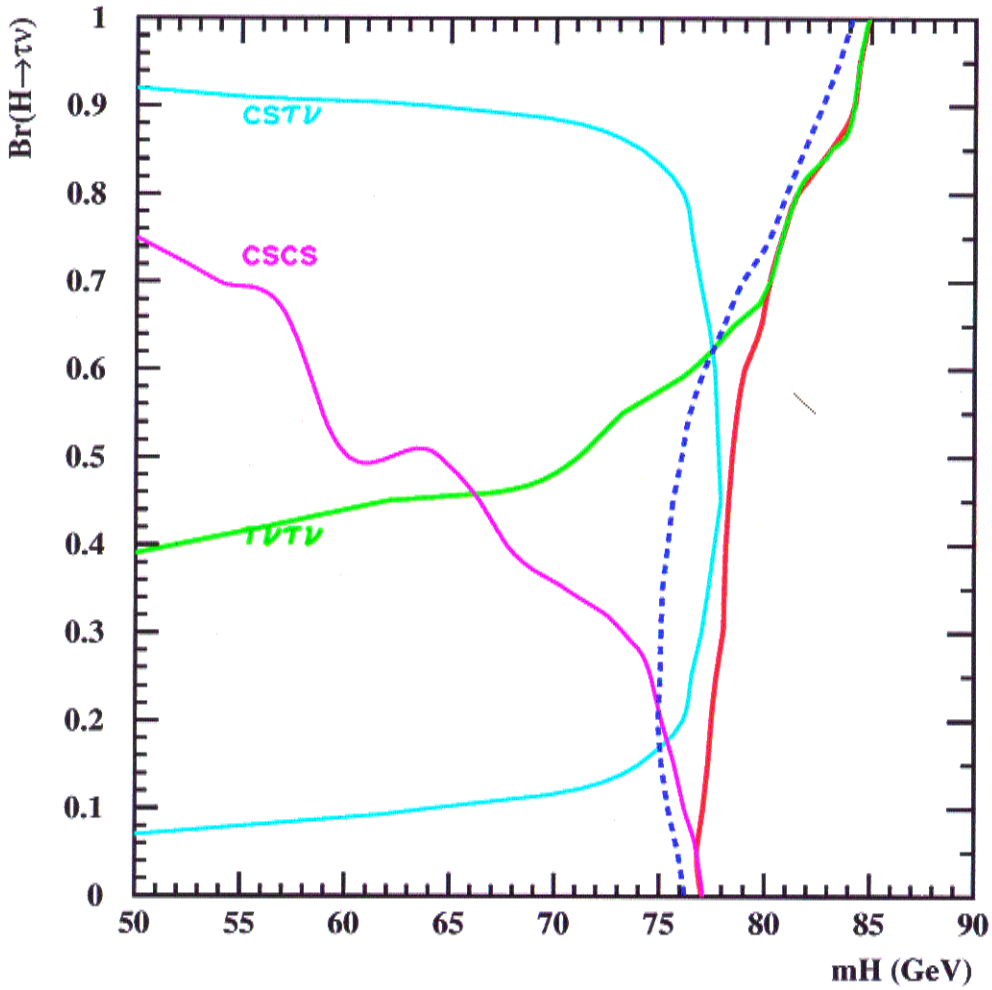


No mixing:

95% CL Limit on m_A: 84.7 GeV/c^2

Charged Higgs Limits

To set limits on $m_{H^\pm}$, look at CL_s:



At 95% Confidence Level:

BR($\tau\nu$=1.0): $m_{H^\pm} > 84.9$ GeV/c^2
BR($\tau\nu$=0.5): $m_{H^\pm} > 78.4$ GeV/c^2
BR($\tau\nu$=0.0): $m_{H^\pm} > 77.1$ GeV/c^2

Any BR($\tau\nu$): $m_{H^\pm} > 77.0$ GeV/c^2

MSSM HIGGS Searches

Channels investigated :

- $h, H \to \gamma\gamma, b\bar{b}$
- $h \to \gamma\gamma$, in Wh, $t\bar{t}h \to \ell^{\pm}\gamma\gamma$ events
- $h \to b\bar{b}$ in Wh, $t\bar{t}h$
- $h, H \to ZZ^*$, $ZZ \to 4\ell^{\pm}$
- $h, H, A \to \tau\tau \to \ell^{\pm} + h^{\pm} + E_T^{miss}$
  $\tau\tau \to e + \mu + E_T^{miss}$
  $\tau\tau \to h^{\pm} + h^{\mp} + E_T^{miss}$
  } inclusively and in $b\bar{b}H_{susy}$ final states
- $h, H, A \to \mu^+\mu^-$ inclusively and in $b\bar{b}H_{susy}$ final states
- $H^{\pm} \to \tau^{\pm}\nu$ from $t\bar{t}$
- $H^{\pm} \to \tau^{\pm}\nu$ and $H^{\pm} \to tb$ for $m_{H^{\pm}} > m_{top}$

$A \to Zh$
$A \to \gamma\gamma$

➡ regions of sensitivity in $(m_A, tg\beta)$

$H \to hh$
$A/H \to tt$
} ATLAS

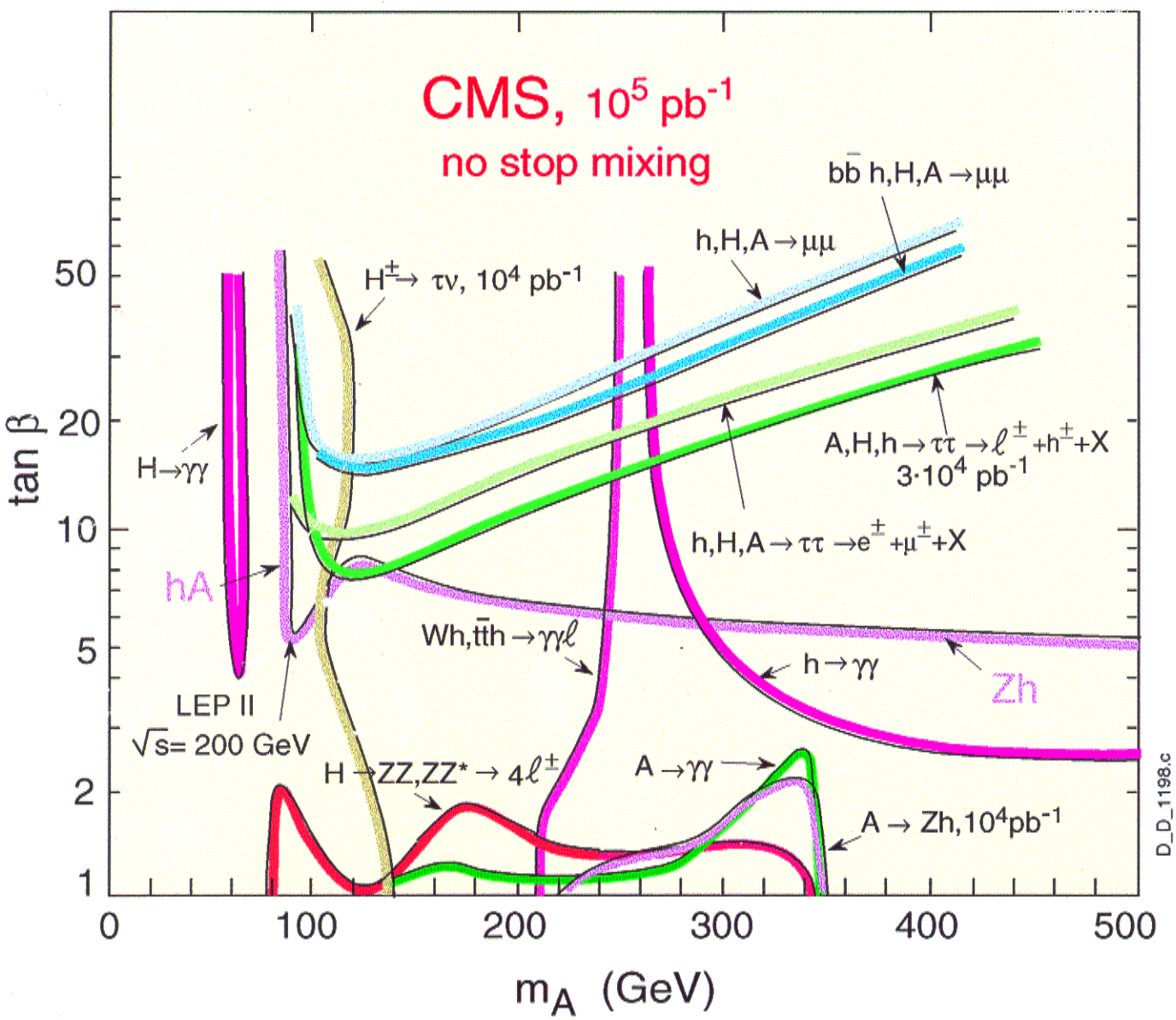
D_D_2036c1

$h, H \rightarrow \gamma\gamma$

Significance contours for SUSY Higgses

Regions of the MSSM parameter space (m_A, tgβ) explorable through various SUSY Higgs channels

- 5 σ significance contours
- two-loop / RGE-improved radiative corrections
- m_{top} = 175 GeV, m_{SUSY} = 1 TeV

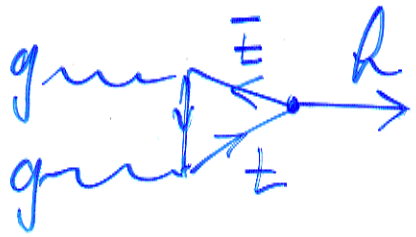


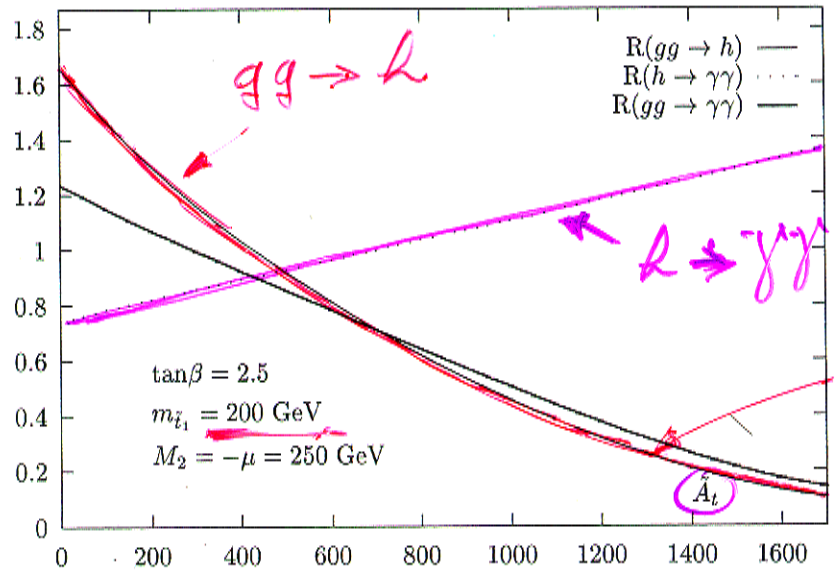
Problems with top-stop interference

and reduction of $h \rightarrow \gamma\gamma$ signal observability

A. Djouadi

MSSM – with sparticle ($\tilde{t}$) in loops



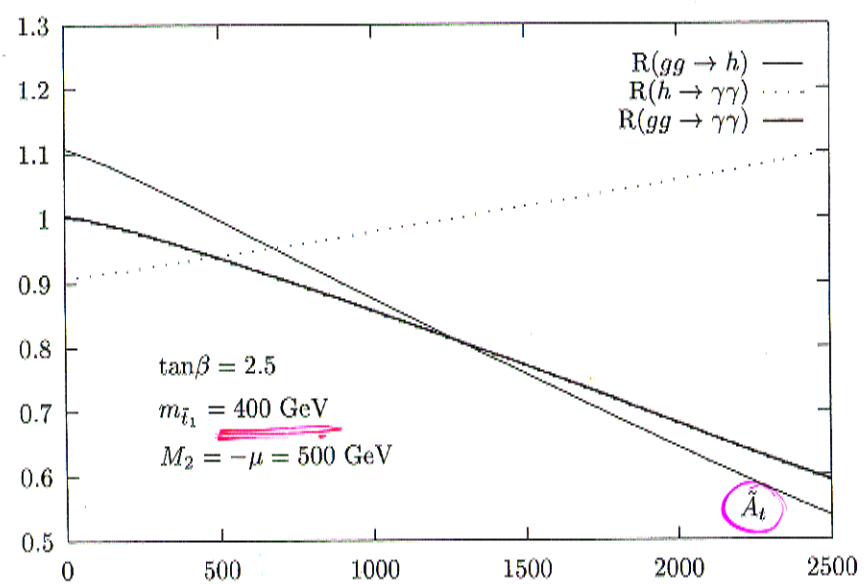


good for Wh, tth channels !!

dangerous for gg → h → γγ

Fig. 1a: SUSY loop effects on $R(h \to \gamma\gamma)$, $R(gg \to h)$ and their product as a function of $\tilde{A}_t$ for $tg\beta = 2.5$ and $m_{\tilde{t}_1} = 200$ GeV; $M_2 = -\mu = 250$ GeV.

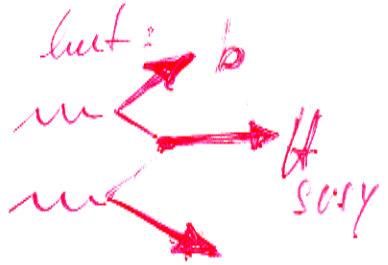
MSSM with $\tilde{t}$ + ... / SM



probably also for gg → h, H, A → ττ, μμ

inclusive searches!

but:

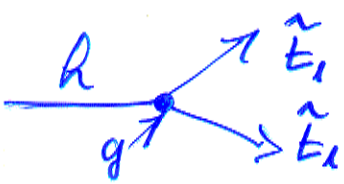


not affected

Fig. 1b: Same as Fig. 1a but with $m_{\tilde{t}_1} = 400$ GeV and $M_2 = -\mu = 500$ GeV.

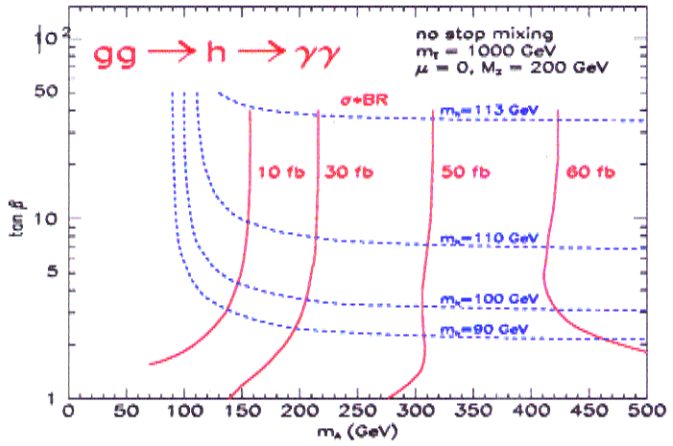
$\tilde{A}_t \equiv A_t - \mu/tg\beta$

stop mixing parameter



$$g_{h\tilde{t}_1\tilde{t}_1} = -\frac{1}{2}\cos 2\beta\left[\cos^2\theta_{\tilde{t}} - \frac{4}{3}\sin^2\theta_W \cos 2\theta_{\tilde{t}}\right] - \frac{m_t^2}{M_Z^2} - \frac{1}{2}\sin 2\theta_{\tilde{t}}\frac{m_t A_t}{M_Z^2}$$

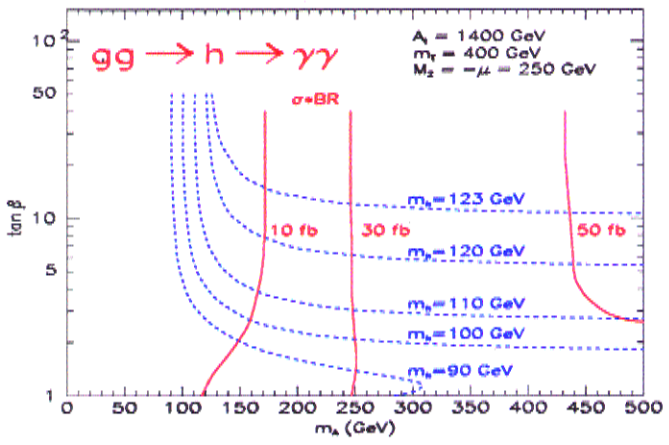
gg -> h -> γγ



no stop mixing

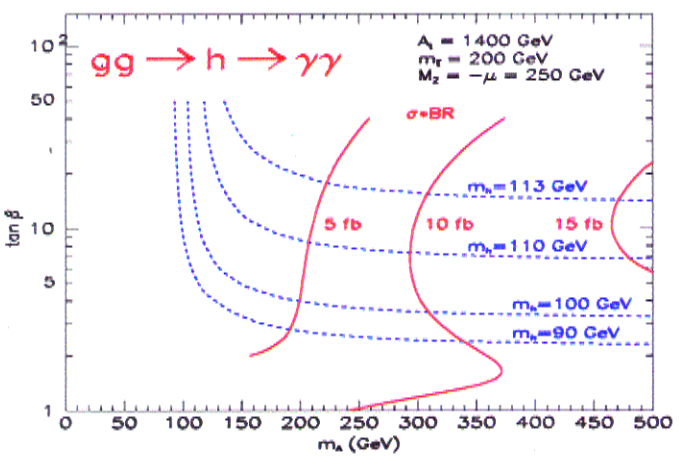
m_{SUSY} = 1000 GeV

$m(\tilde{t}_1) = 1$ TeV



large stop mixing

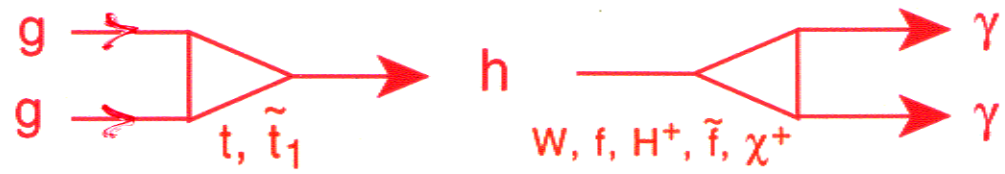
m(stop1) = 400 GeV

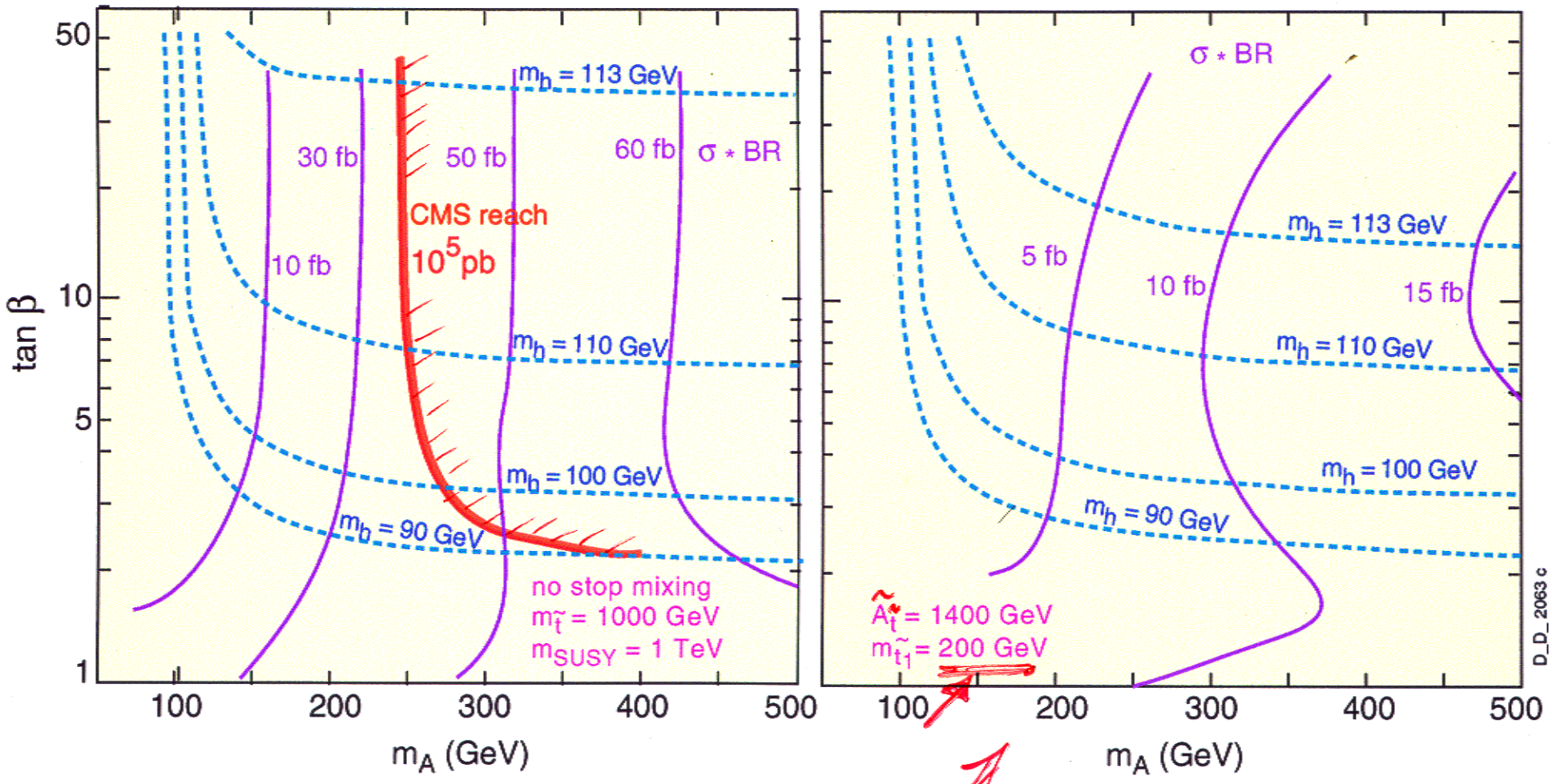


large stop mixing

m(stop1) = 200 GeV

$gg \to h \to \gamma\gamma$ with large mixing and ligth $\tilde{t}_1$

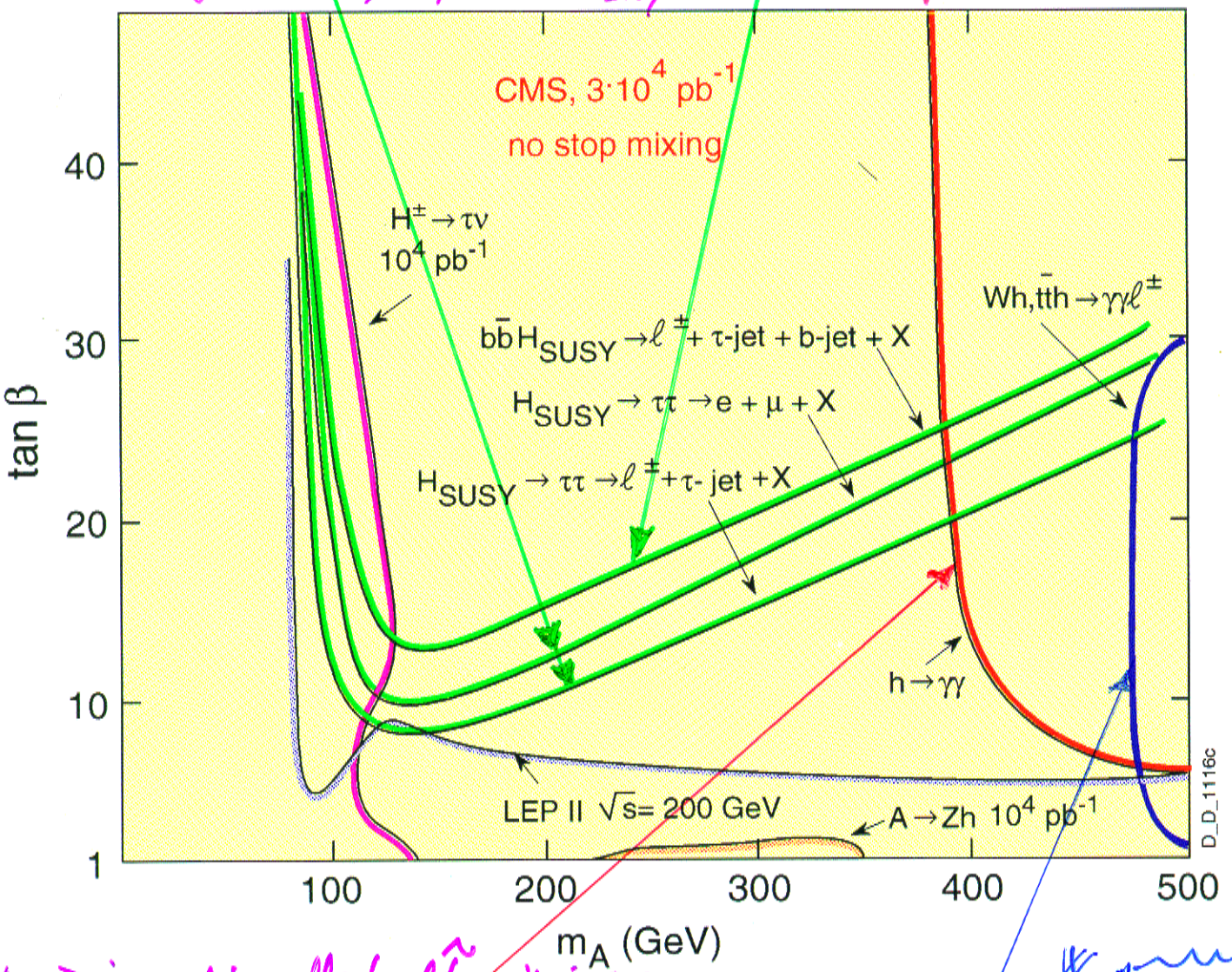




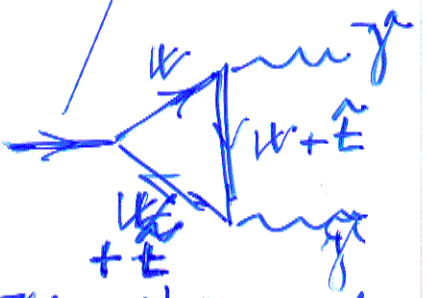
total loss of experimental sensitivity in $gg \to h \to \gamma\gamma$ channel!

could be suppressed by factor ≲ 5 by Djouadi-type interferences / depends on M_{SUSY}

not affected by Djouadi $\tilde{t}\tilde{t}$ compl. interferences!



A. Djouadi: effects of $\tilde{t}$ mixing:



$\Gamma(h \to \gamma\gamma)$ increased by ≲ 2

if $m_{\tilde{t}} \lesssim 400$ GeV ⇒ destructive interference $t - \tilde{t}$

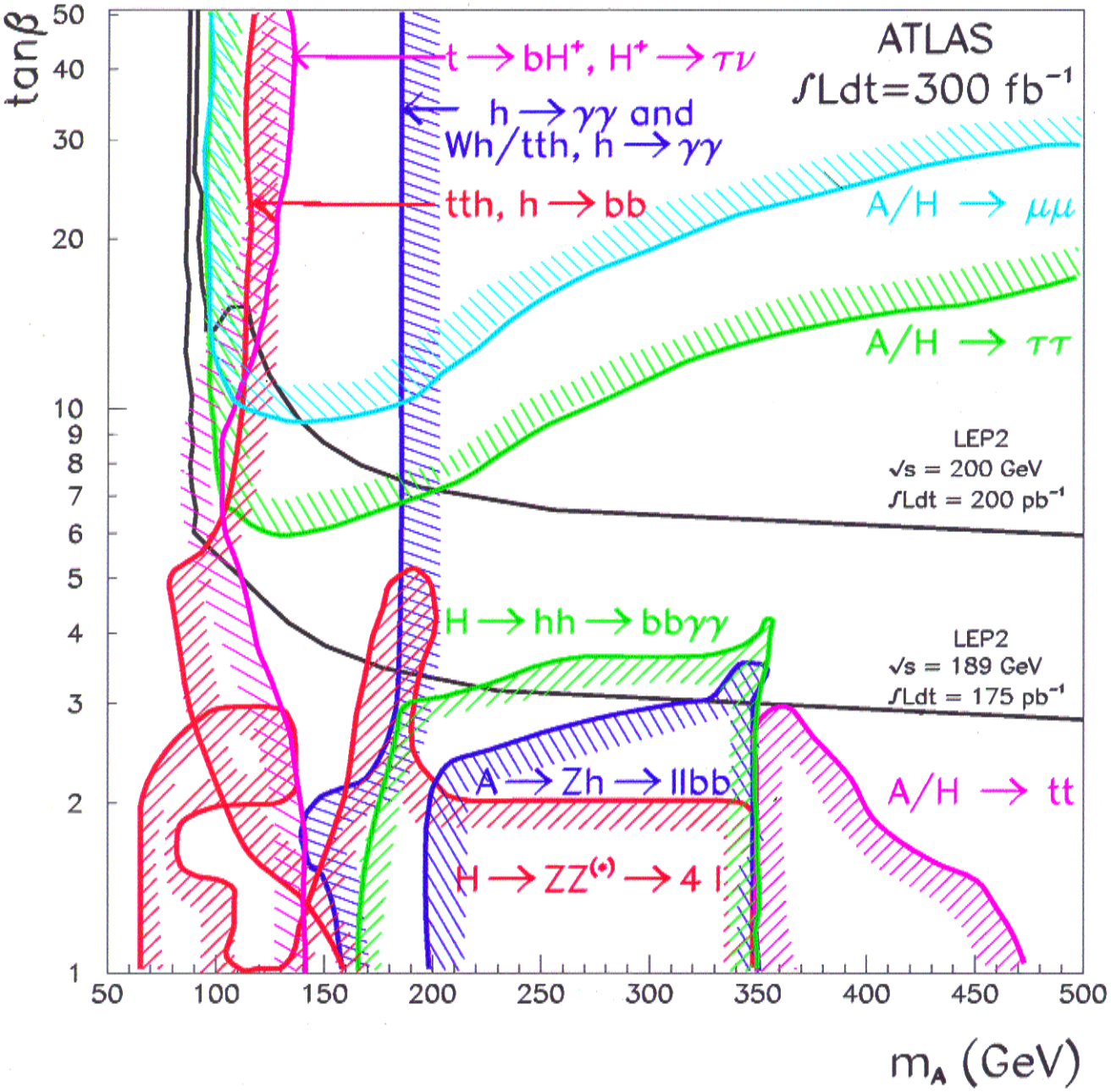
at large $\tilde{t}$ mixing may reduce $\sigma(gg \to h \to \gamma\gamma)$ by ≲ 5!

$h, H \rightarrow Z^*Z, ZZ$

D.D. 74

Discovery reach for MSSM Higgses in ATLAS

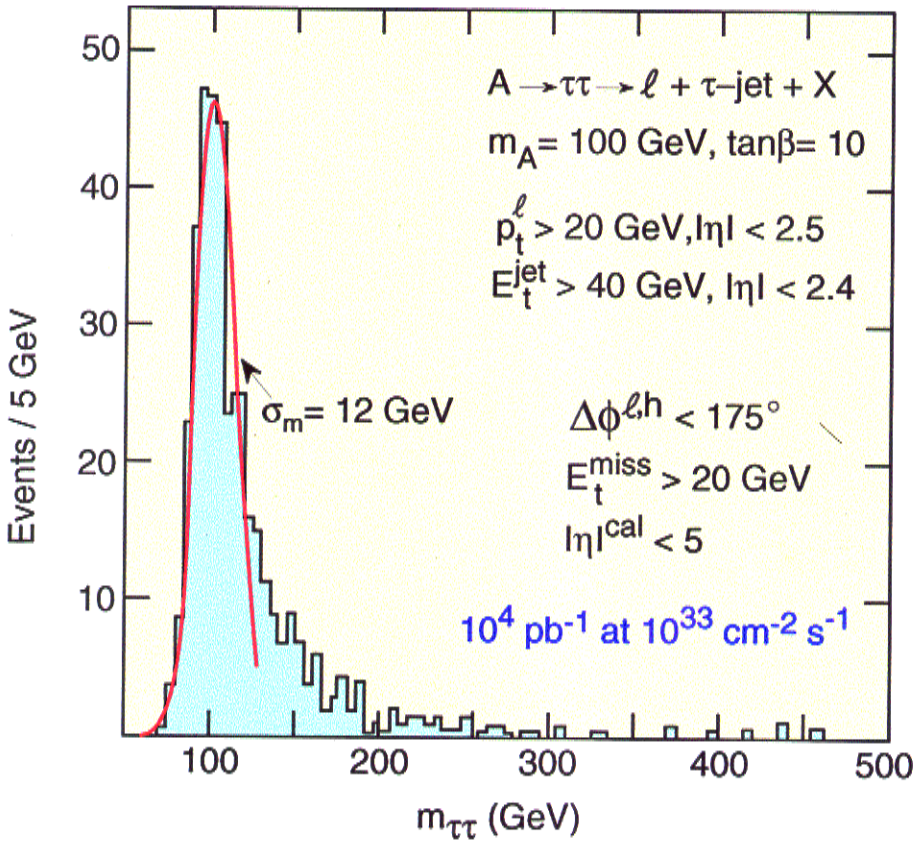
- ultimate reach with 300 fb^{-1}



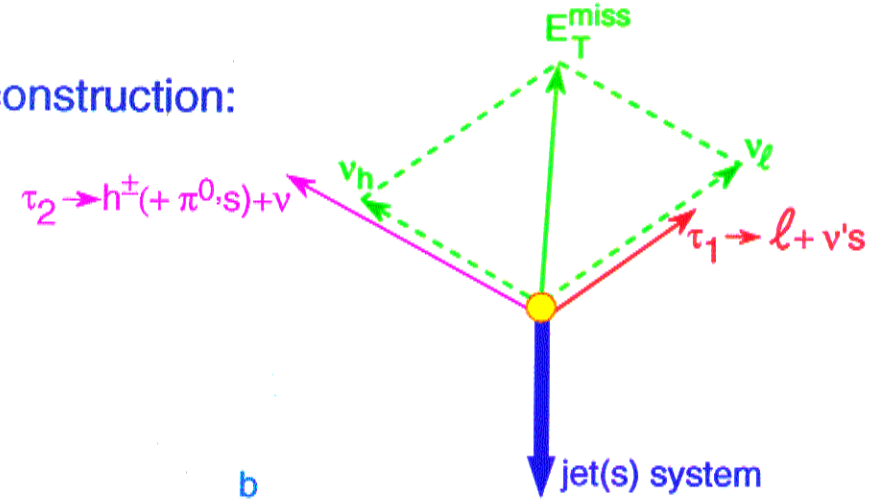
$A,H \rightarrow \tau\tau$

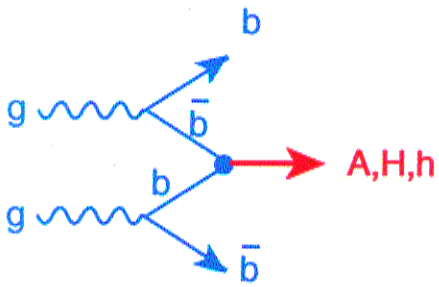
Mass determination in $A \to \tau\tau$

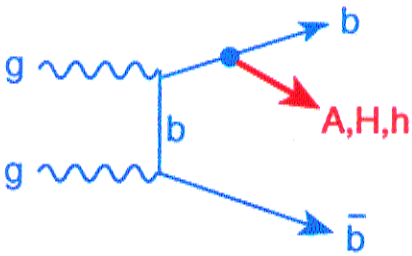
$A \to \tau\tau \to \ell^{\pm} + \tau\text{-jet} + E_t^{miss}$



mass reconstruction:



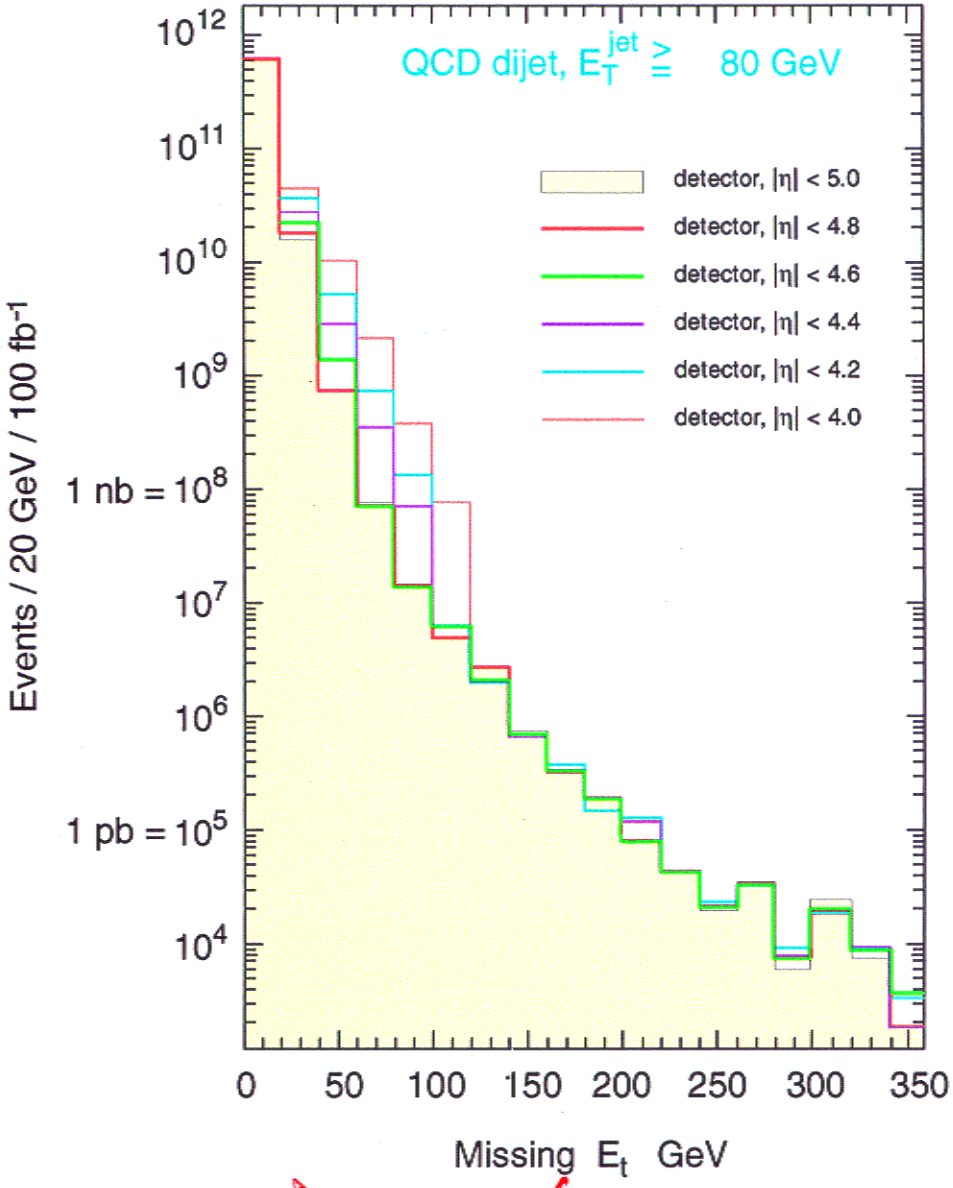




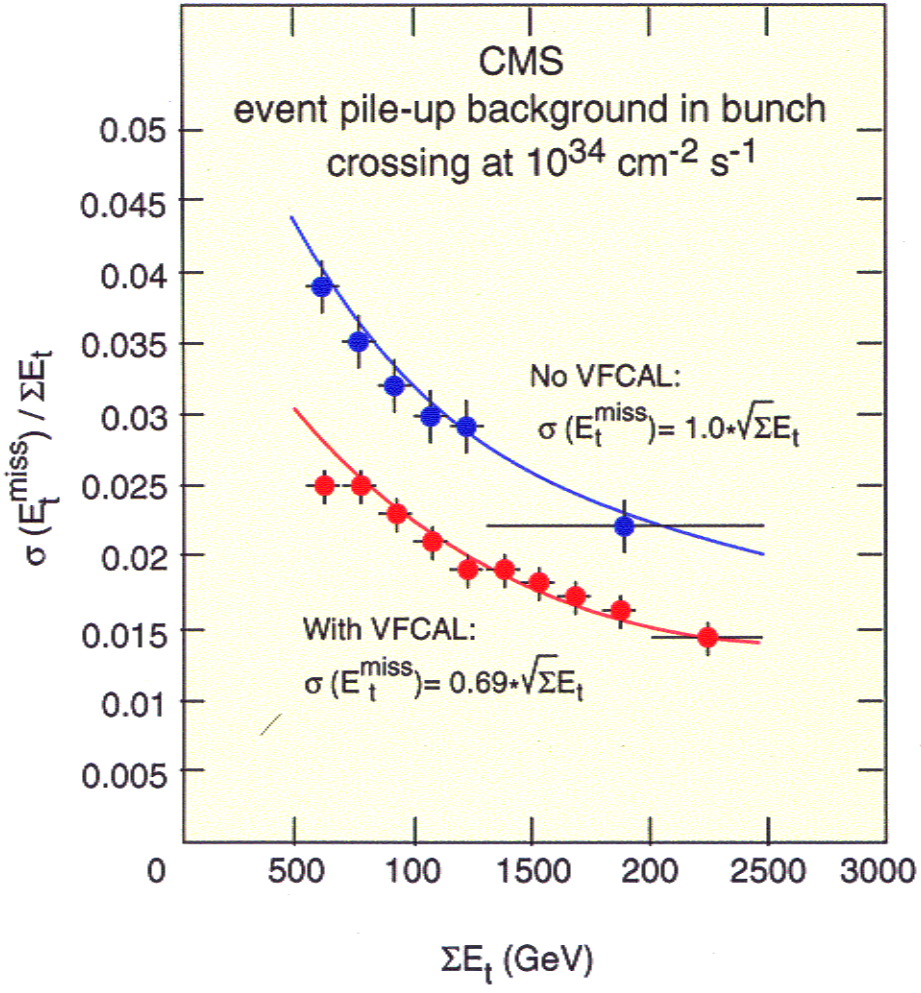
Higgs recoil is significant in this class of events!
thus improved rec. efficiency and mass resolution

D_D_855c

E_t^{miss} dependance on calorimeter coverage



Improvement of E_t^{miss} resolution due to VFCAL in presence of event pile-up

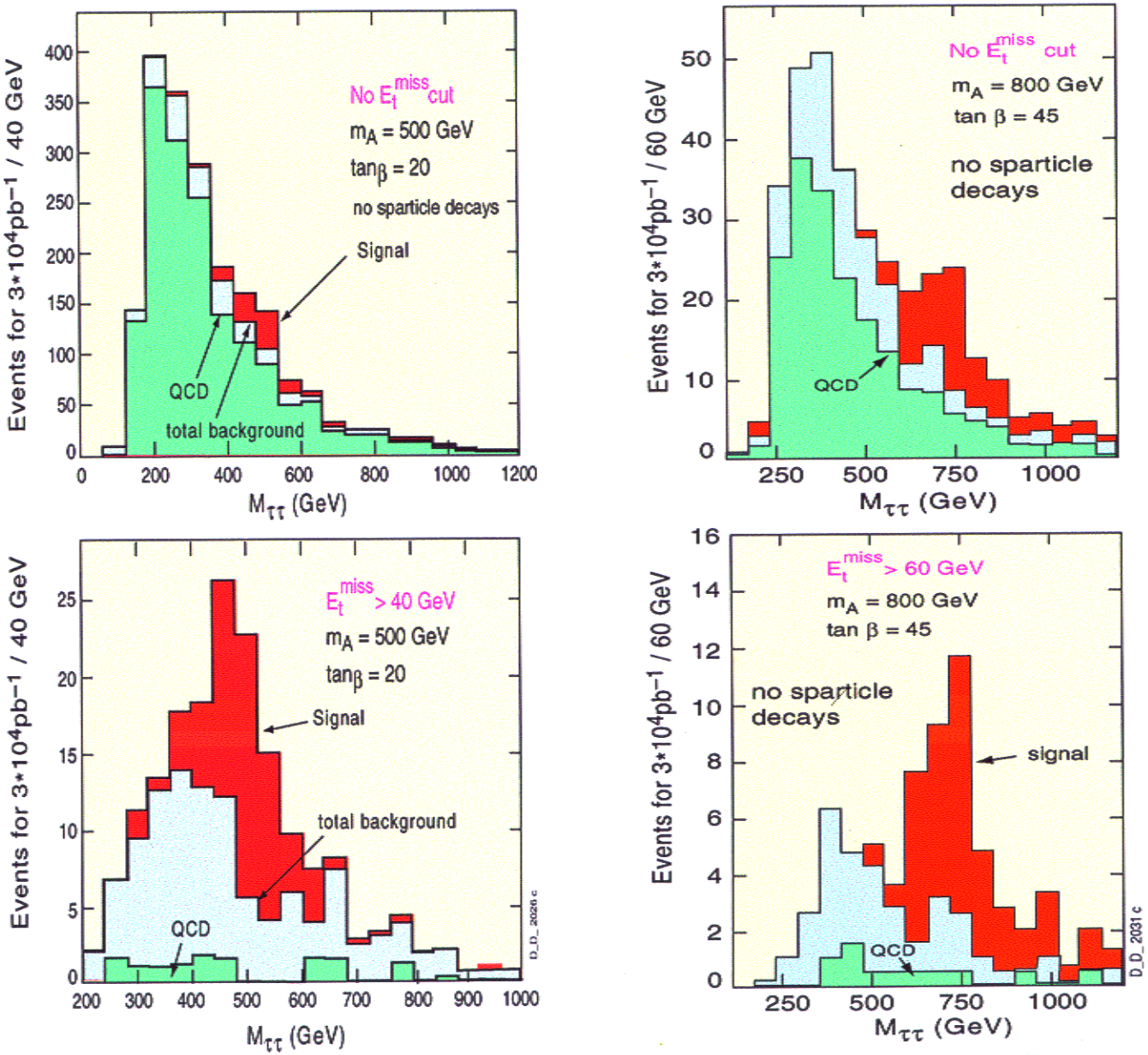


D.D.Gainesville 9

typical E_t^{miss} in $A, H \to \tau\tau$ searches!

$A, H \rightarrow \tau\tau \rightarrow h^+ + h^- + X$

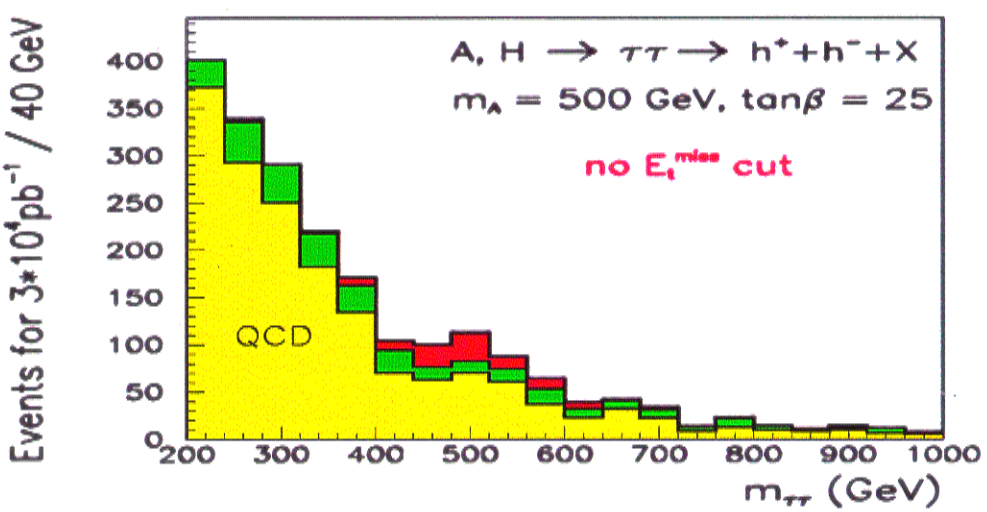
importance of E_t^{miss} cuts and detector hermeticity

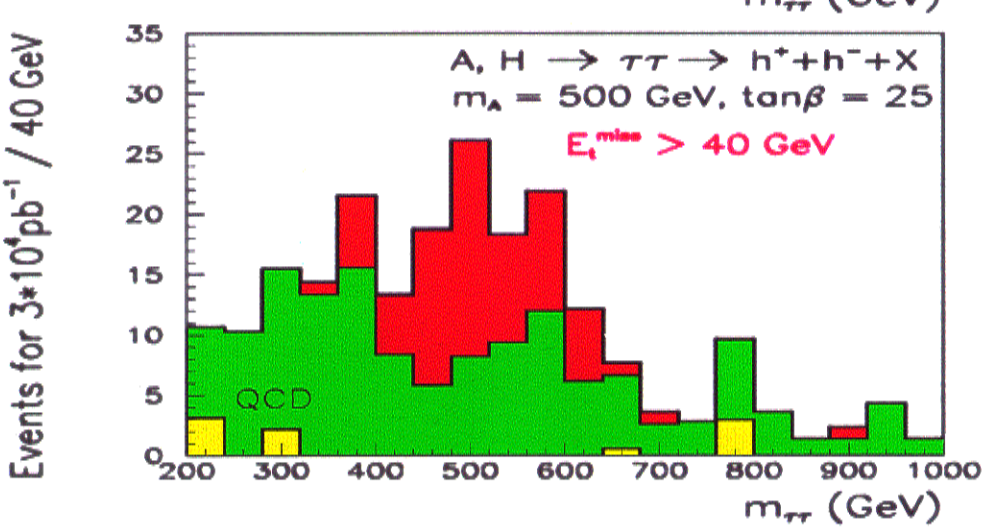


Signal/background with 2selected τ jets, $E_t > 60$ GeV, $\Delta\phi(jj) < 175^0$

Events for 400 GeV < $m_{\tau\tau}$ < 700 GeV:

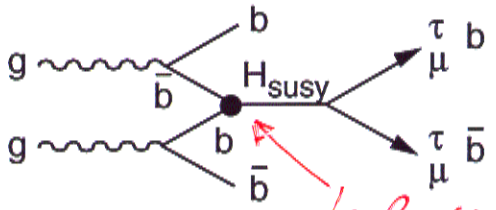
	no E_t^{miss} cut	$E_t^{miss} > 40$ GeV
signal	92	56
Z,γ^*	99	52
QCD	795	8
$t\bar{t}$, $W \to \tau\nu$	31	24
W+jets	24	9
signal/background	0.1	0.6
$S/(S+B)^{1/2}$	2.9	4.6



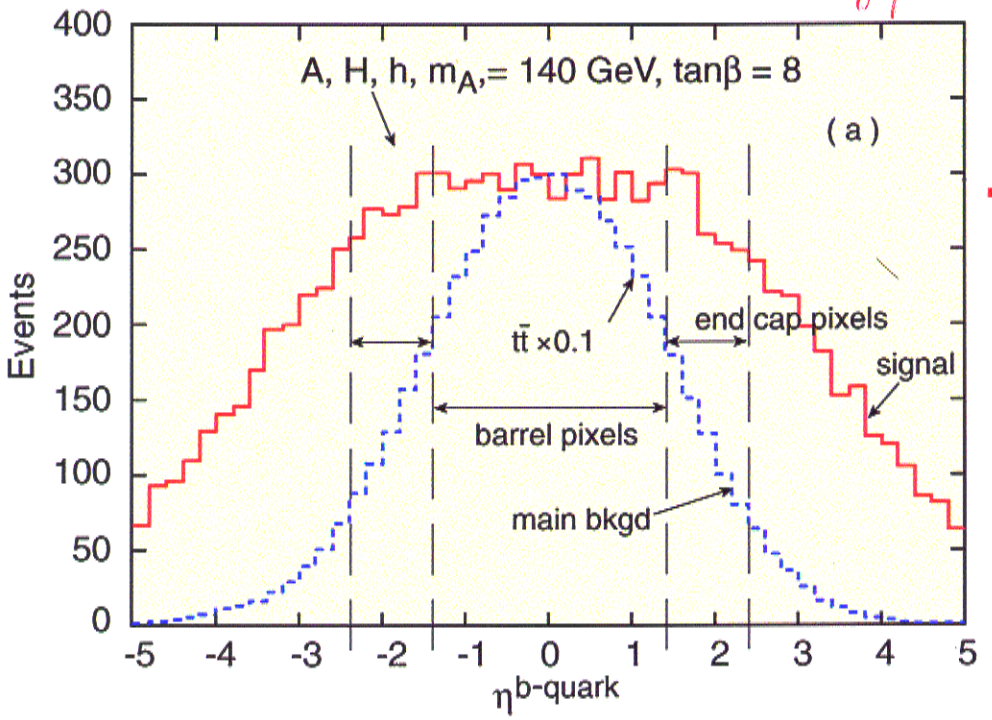


h, H, A → ττ

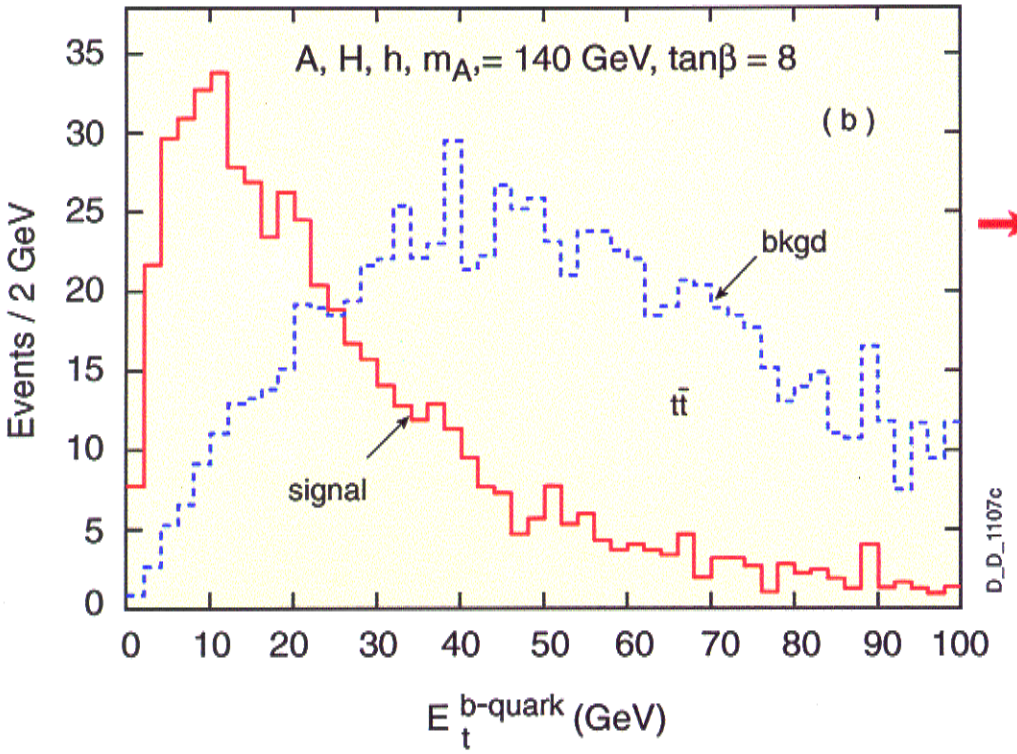
from H_{susy} $b\bar{b}$ final states:



tg β enhancement

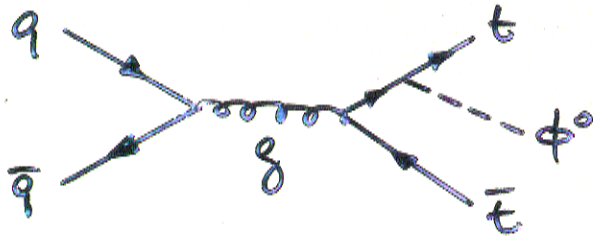


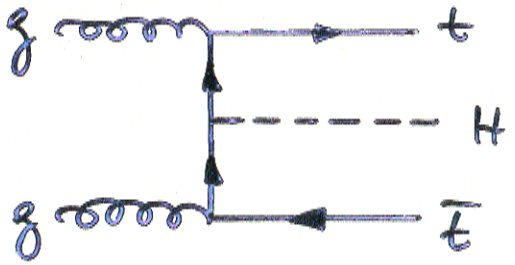
→ maximize b - tagging acceptance



→ soft b - jets

$gg, q\bar{q} \to \phi^0 + t\bar{t}/b\bar{b}$





Kunszt
Gunion
Marciano
Paige

- important for $M_\phi \lesssim 120$ GeV
- QCD corrections: $\sqrt{s} \gg m_t \gg M_H$ (EHA)

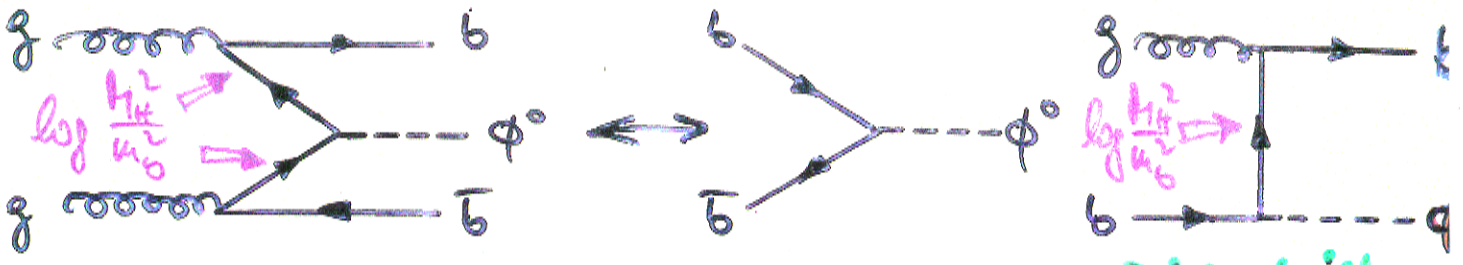
$$\hat{\sigma}(t\bar{t}H) \to \left(f_{H/t} + f_{H/\bar{t}}\right) \otimes \hat{\sigma}(t\bar{t})$$

Dawson, Reina

$$\to +(20-60)\%$$

F

- $b\bar{b}\phi^0$ dominant for large $tg\beta$



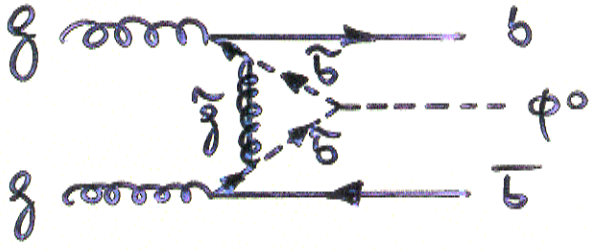
Dicus, Willenbrock

subtractions $\to$ no double counting

$\Rightarrow$ factor 2–3 enhancement from evolution ?

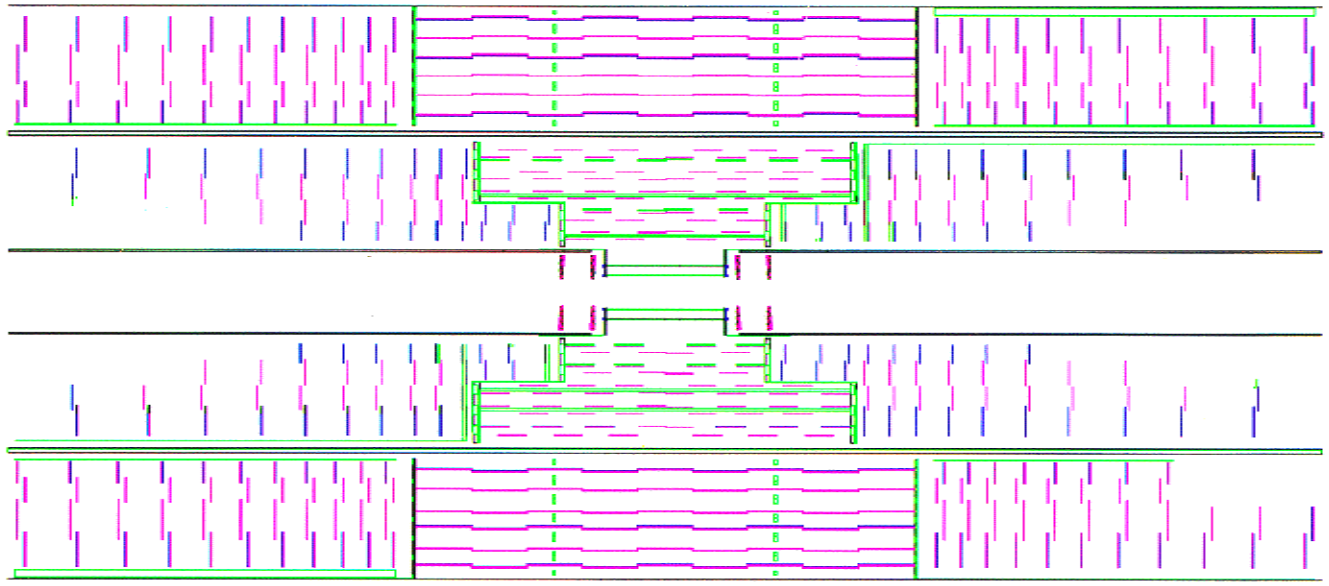
Full calculation in progress ...

- SUSY-QCD:

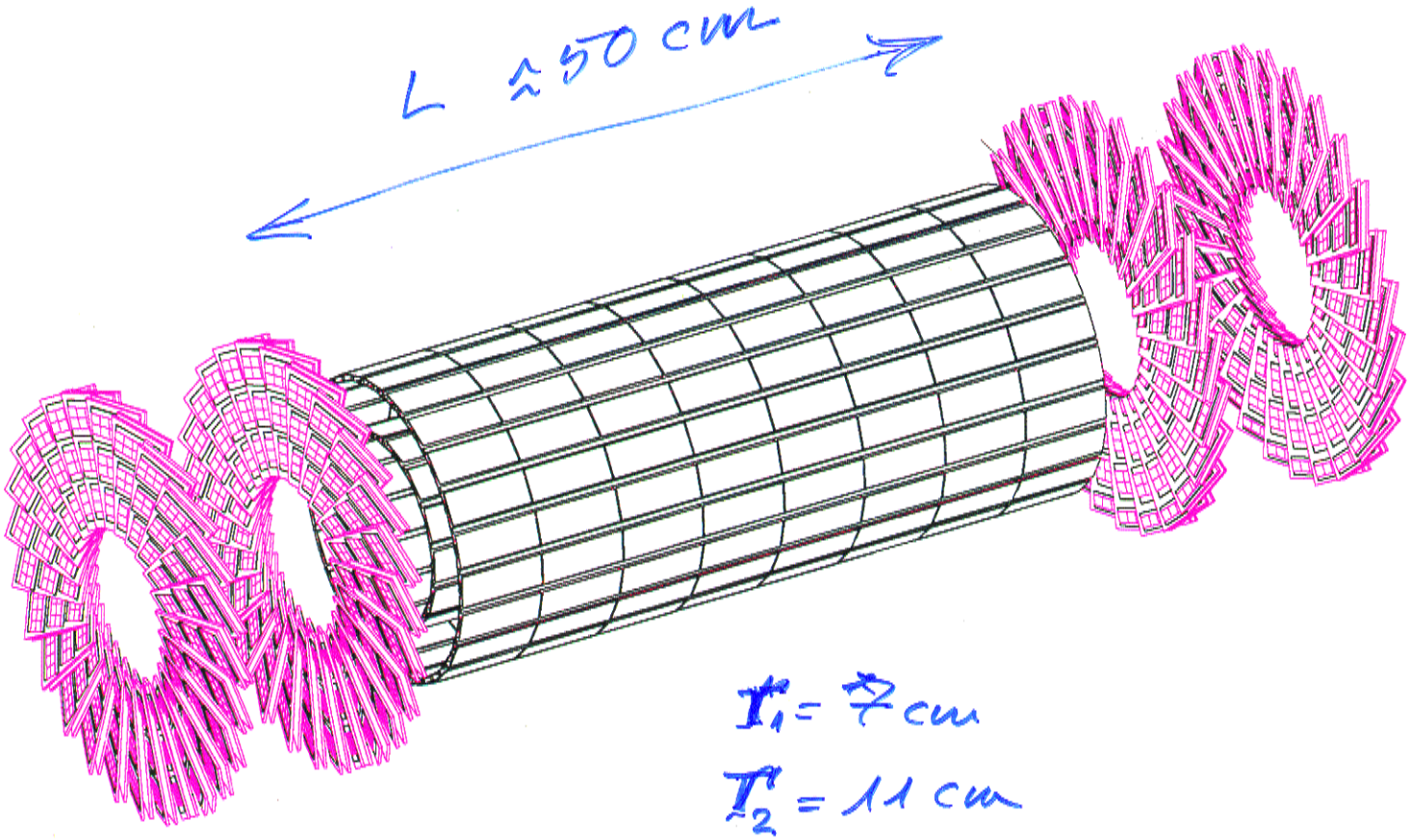


$\to$ large corrections expected [$\to$ suppression]

CMS Tracker Layout



	Channels ($\times 10^6$)	R-ϕ pitch (μm)	Stero pitch (μm)
Pixels	39.2	150×150	
Silicon strips	5.2	62/83/125	125/250
MSGC	6.5	200	400



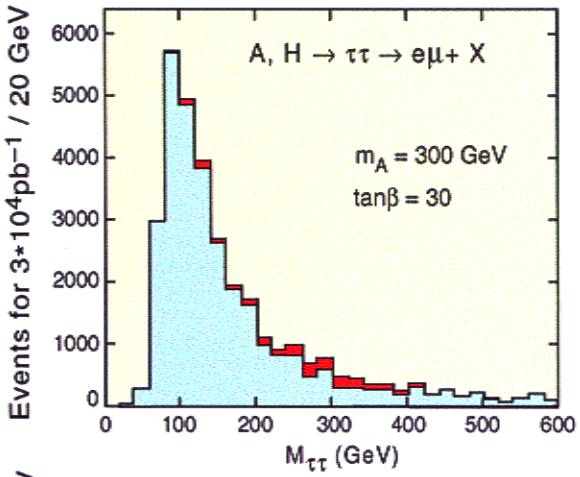
$r_1 = 7$ cm

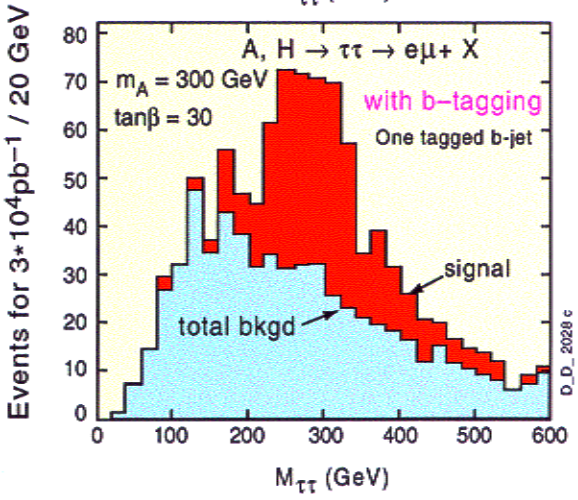
$r_2 = 11$ cm

$r_0 \approx 4$ cm

$H_{SUSY} \rightarrow \tau\tau \rightarrow e^+ + \mu^- + X$

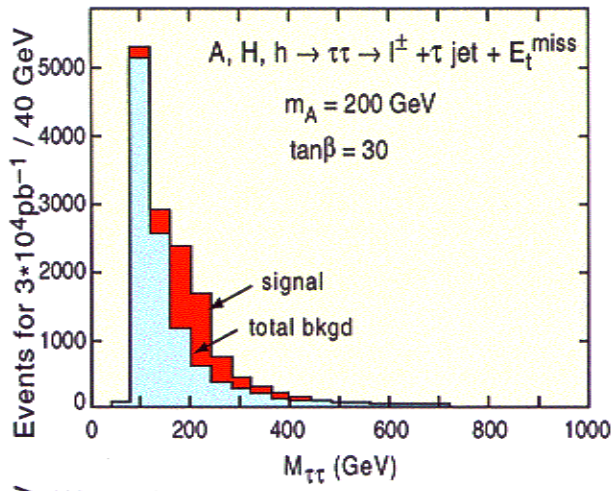
Events selected as:
$p_t^{e,\mu} > 20$ GeV, isolated leptons, $\Delta\phi(e,\mu) < 175^o$

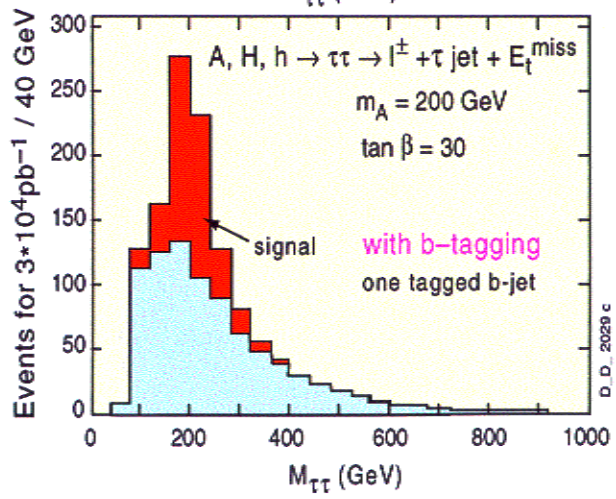




$H_{SUSY} \rightarrow \tau\tau \rightarrow l^{\pm} + h^{\mp} + X$

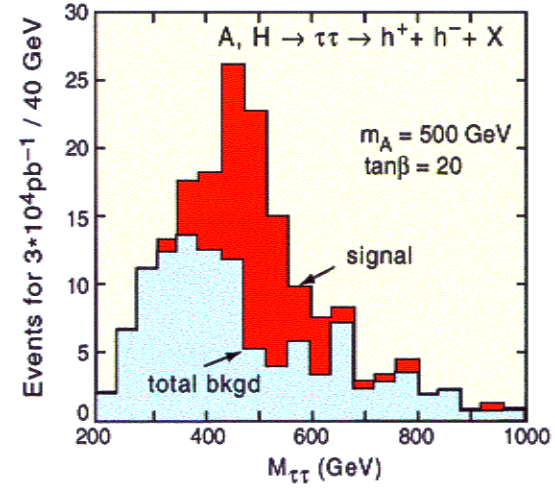
Events selected as : $E_t^{jet} > 40$ GeV,
$p_t^l > 15$ GeV, $\Delta\phi(jl) < 175^o$, $E_t^{miss} > 20$ GeV



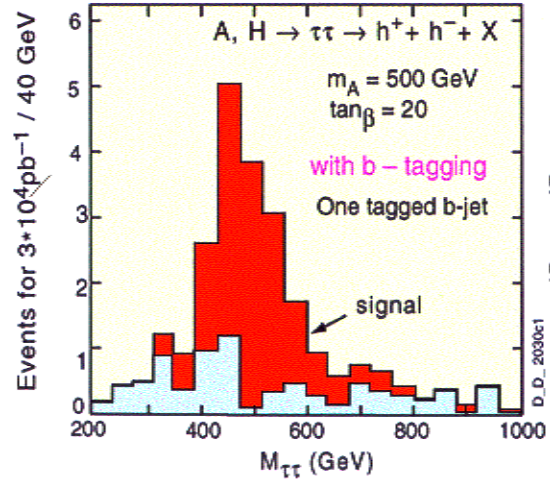


$H_{SUSY} \rightarrow \tau\tau \rightarrow h^+ + h^- + X$

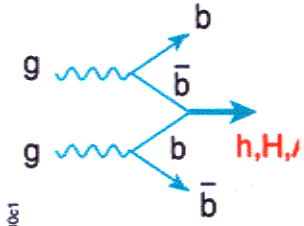
Events selected as: $E_t^{jet} > 60$ GeV
$p_t^h > 40$ GeV, $\Delta\phi(jj) < 175^o$, $E_t^{miss} > 40$ GeV



Inclusive H_{SUSY} search



Search in bbH_{SUSY} channels:

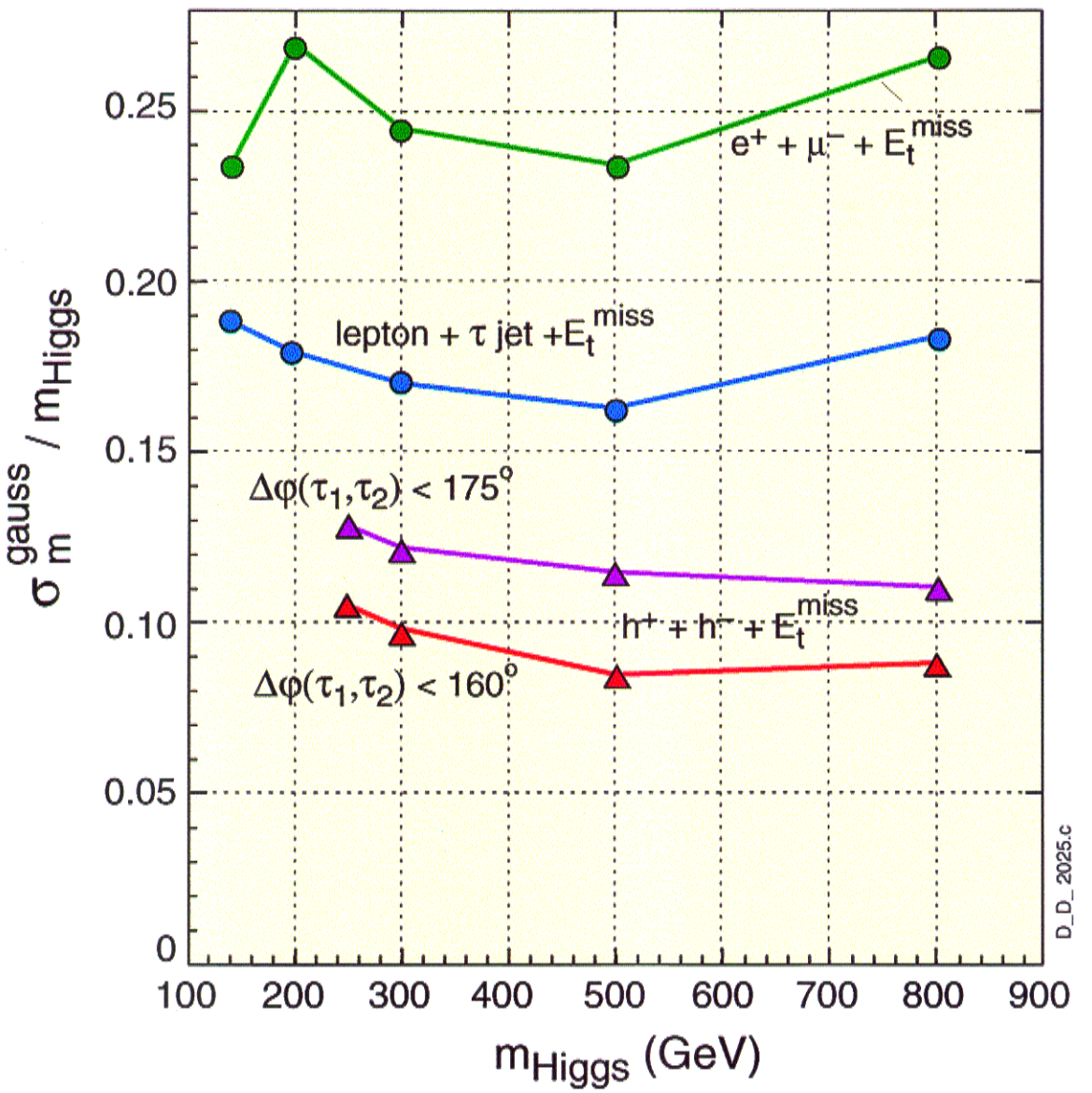


Higgs mass resolution in $H \rightarrow \tau\,\tau$

Higgs mass reconstruction in

$A, H, h \rightarrow \tau\,\tau$

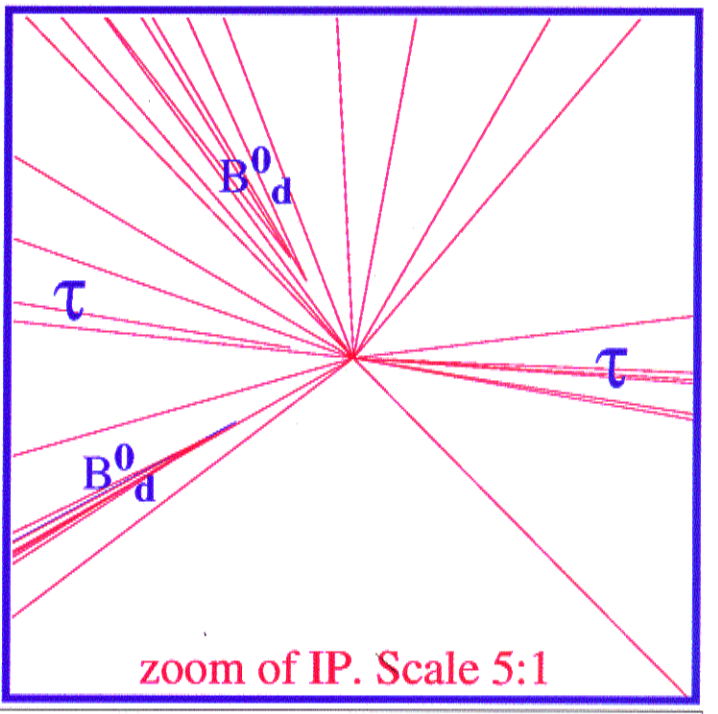
$\Delta\varphi(\tau_1,\tau_2) < 175^\circ$

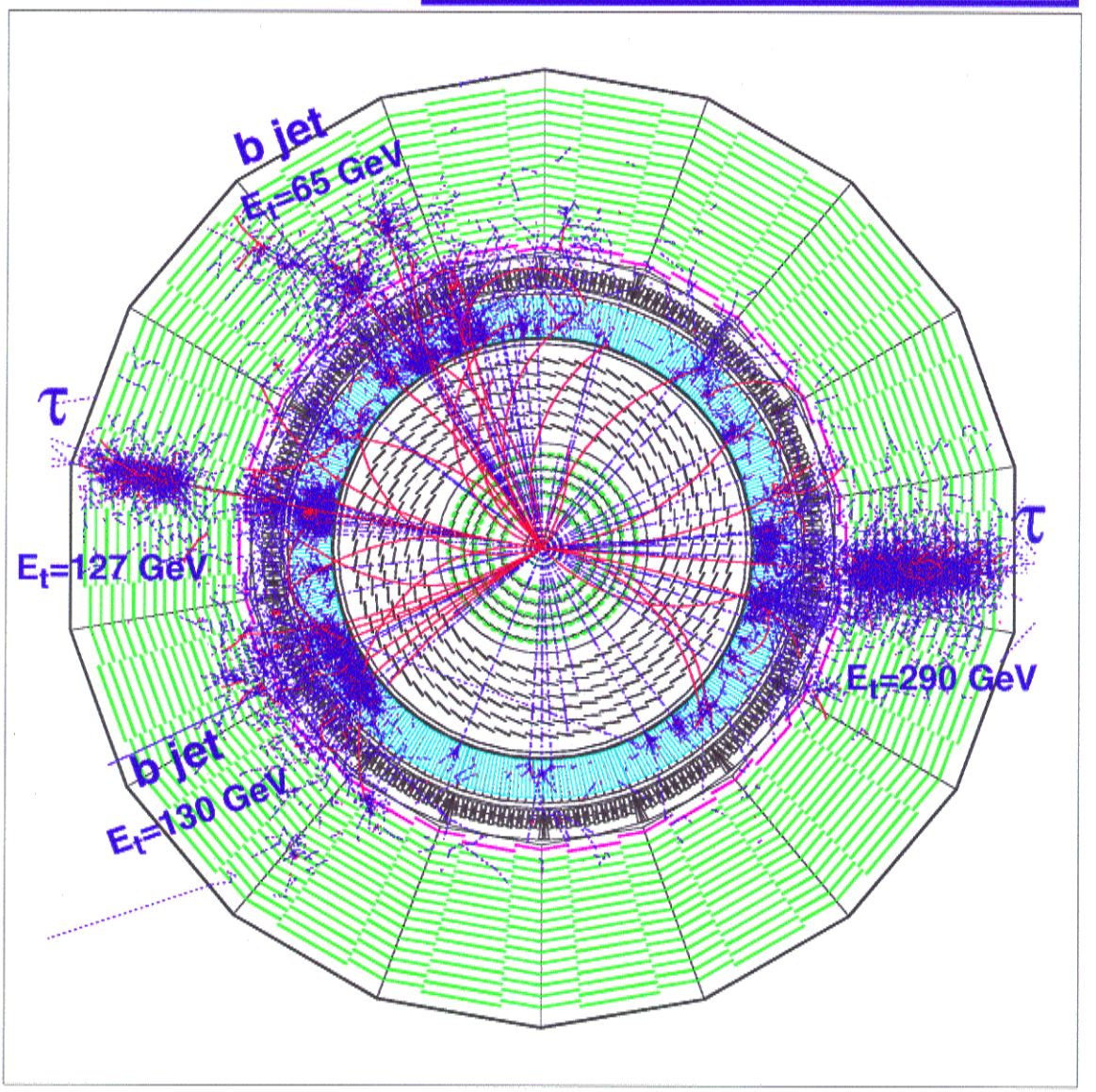


gg->A^0bb in MSSM

M_A=500 GeV

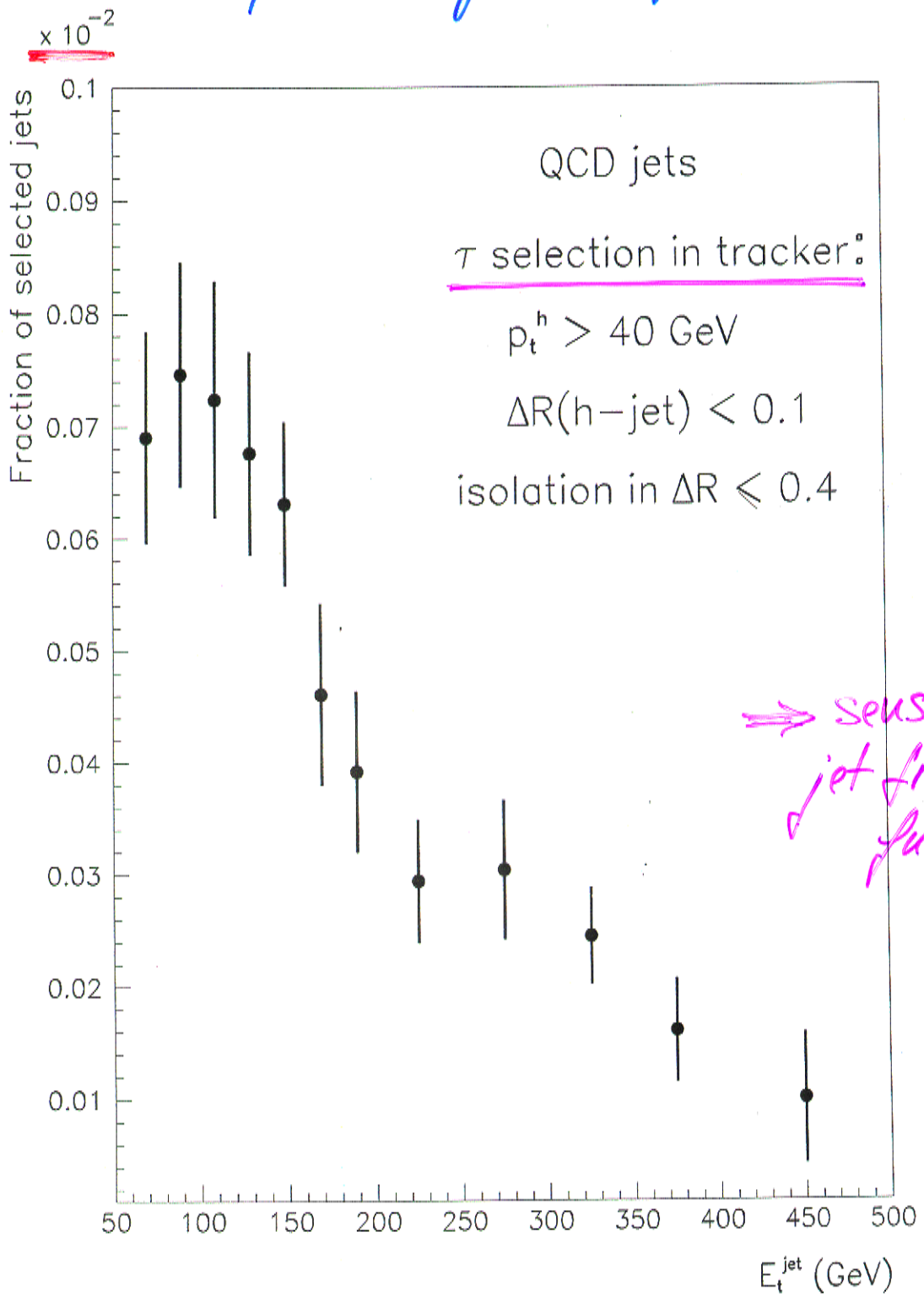
$A^0 \to \tau\tau \to \pi^+\pi^- + X$





QCD jet vs "τ-jet" selection

Rejection factor for QCD jets vs E_t



⇒ sensitive to jet fragmentation function

Figure 3: Rejection factor for QCD jets as a function of E_t^{jet}. τ selection is performed in the tracker by requiring an isolated track with $p_t > 40$ GeV within $\Delta R < 0.1$ around the calorimeter jet axis. The isolation with a p_t threshold of 1 GeV is extented to a larger cone of $\Delta R < 0.4$.

Further improvements possible:

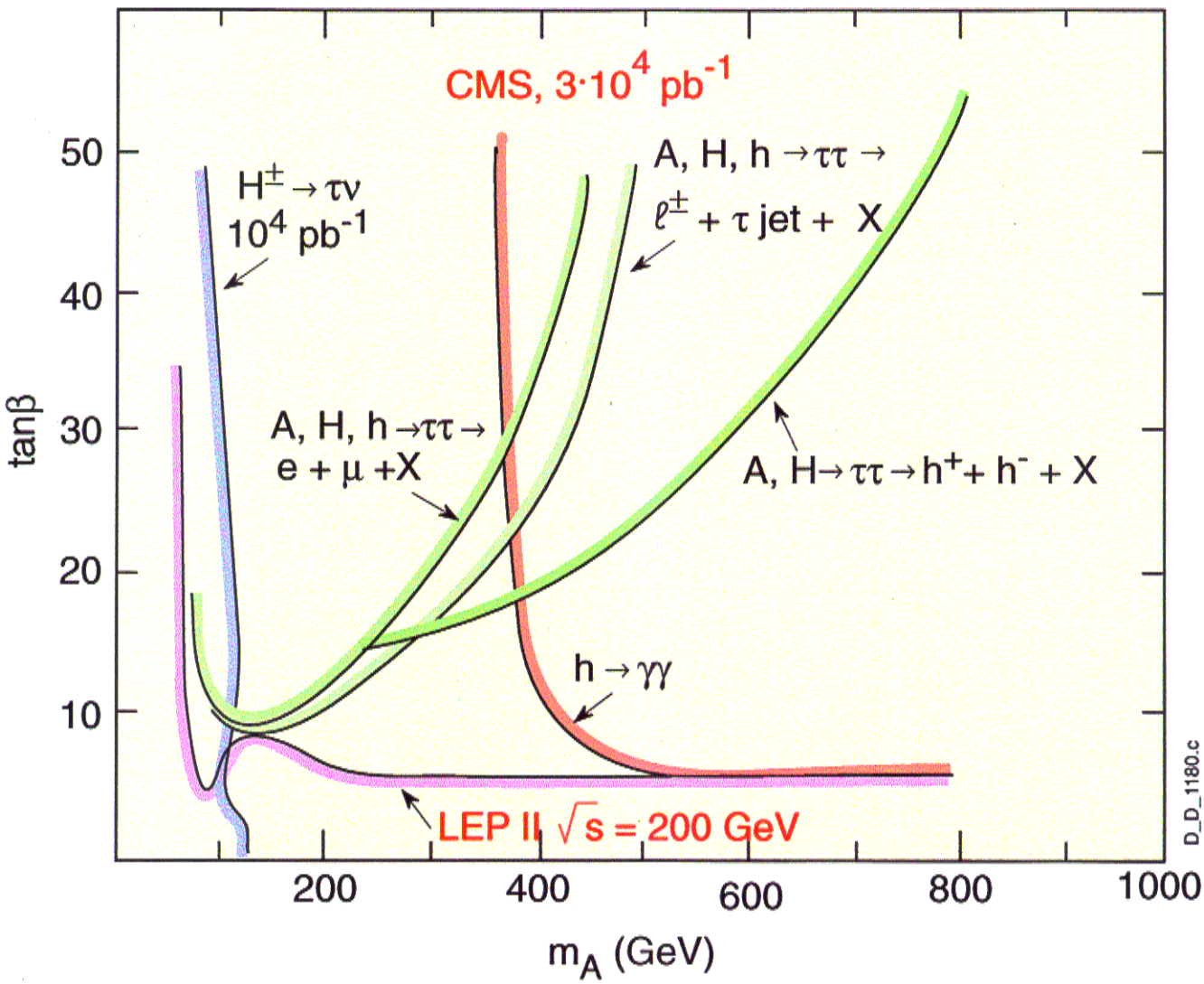
i) calo.-algorithm exploiting granularity for "spot size" for calo-collimation & isolation

ii) Impact parameter cut on hard tau-track

Significance contours for SUSY Higgses

Regions of the MSSM parameter space (m_A, tgβ) explorable through various SUSY Higgs channels

- 5 σ significance contours
- two-loop / RGE-improved radiative corrections
- m_{top} = 175 GeV, m_{SUSY} = 1 TeV;



Significance contours for SUSY Higgses

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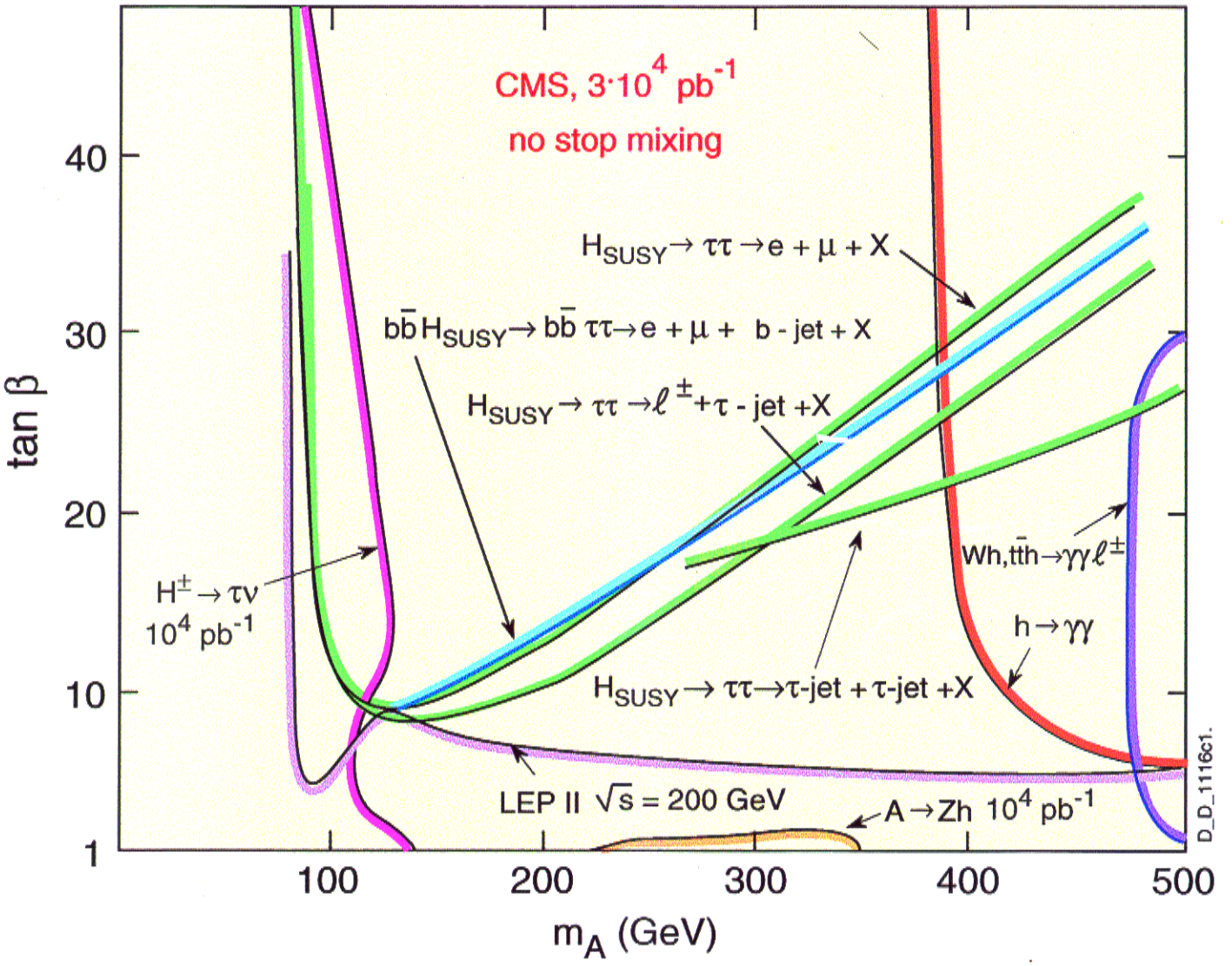
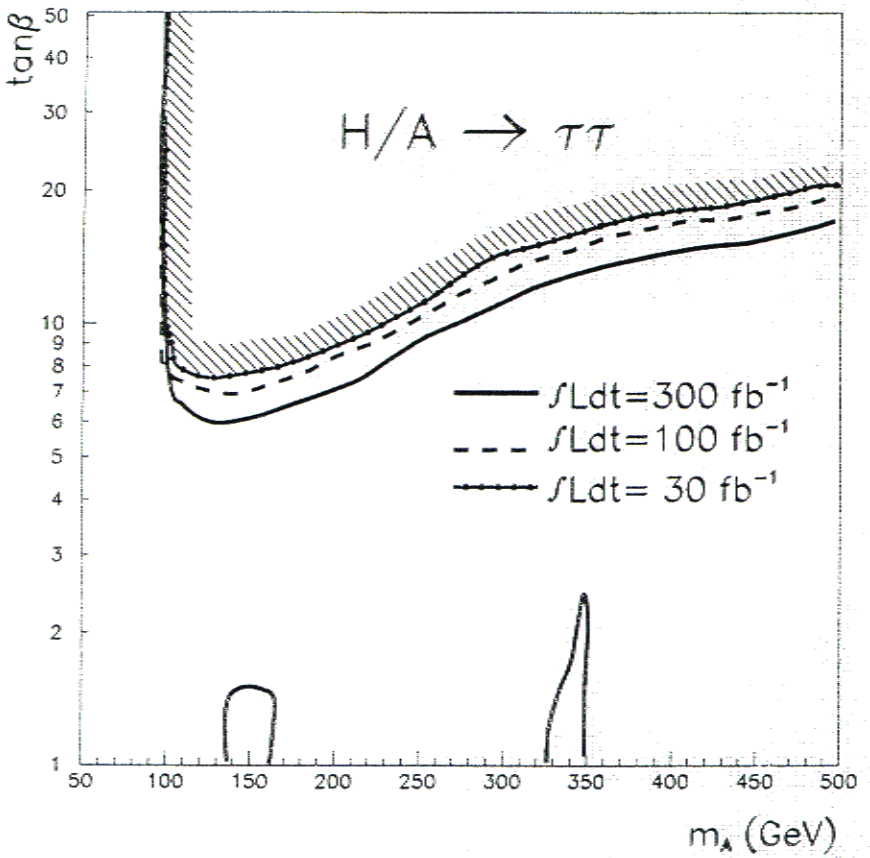
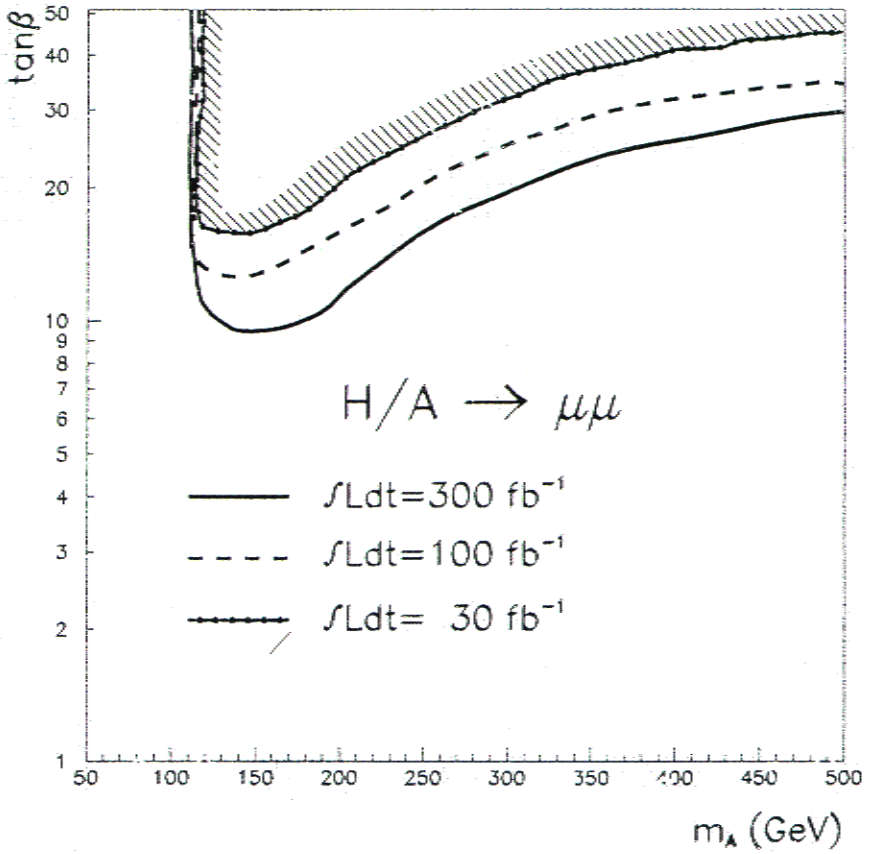


Variation of parameter space coverage with integrated luminosity, $H_{SUSY} \to \tau\tau$ and $\mu\mu$

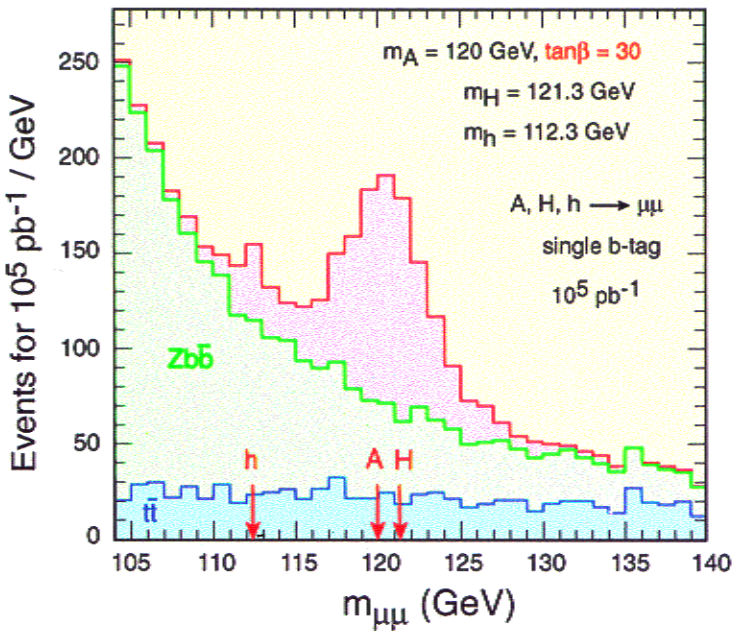
ATLAS

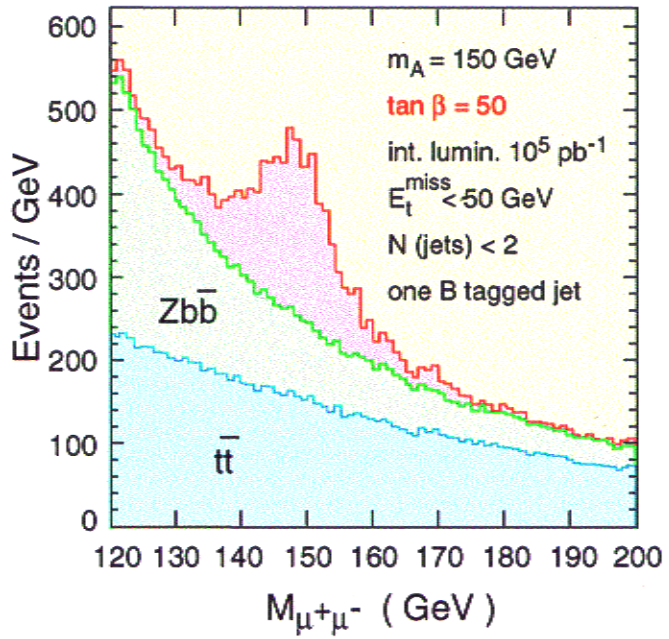


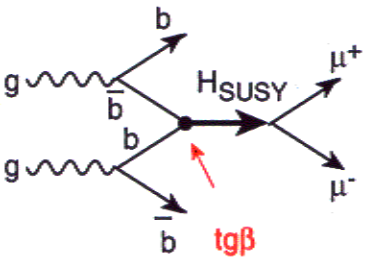


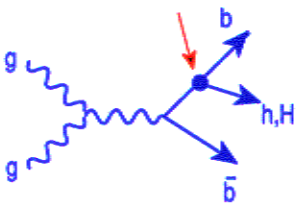
$h, A, H \rightarrow \mu\mu$

$H_{SUSY} \longrightarrow \mu^+\mu^-$ in $\bar{b}b\,H_{SUSY}$ final states

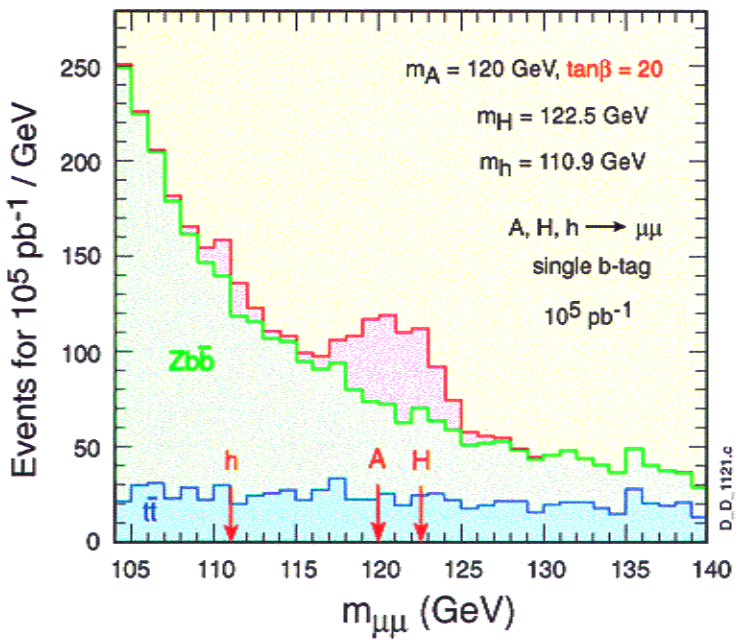


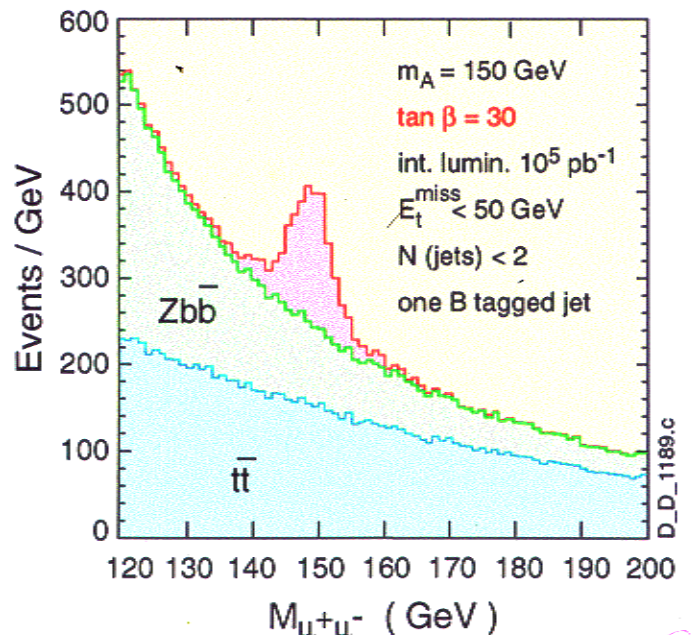






+....





Fermilab3

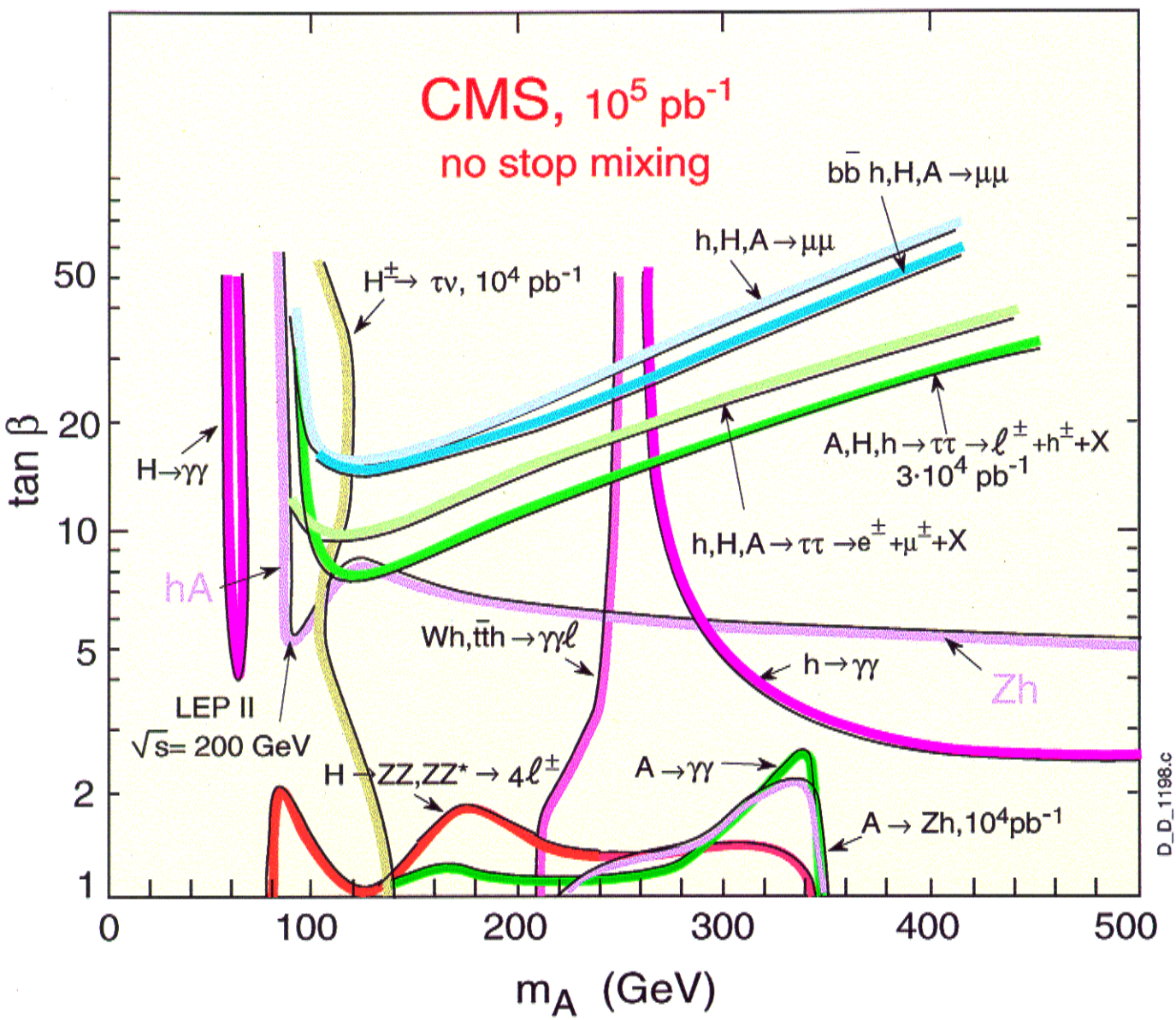
$m_A = 120$ GeV

$m_A = 150$ GeV

Significance contours for SUSY Higgses

Regions of the MSSM parameter space (m_A, tgβ) explorable through various SUSY Higgs channels

- 5 σ significance contours
- two-loop / RGE-improved radiative corrections
- m_{top} = 175 GeV, m_{SUSY} = 1 TeV



$$h \rightarrow bb$$

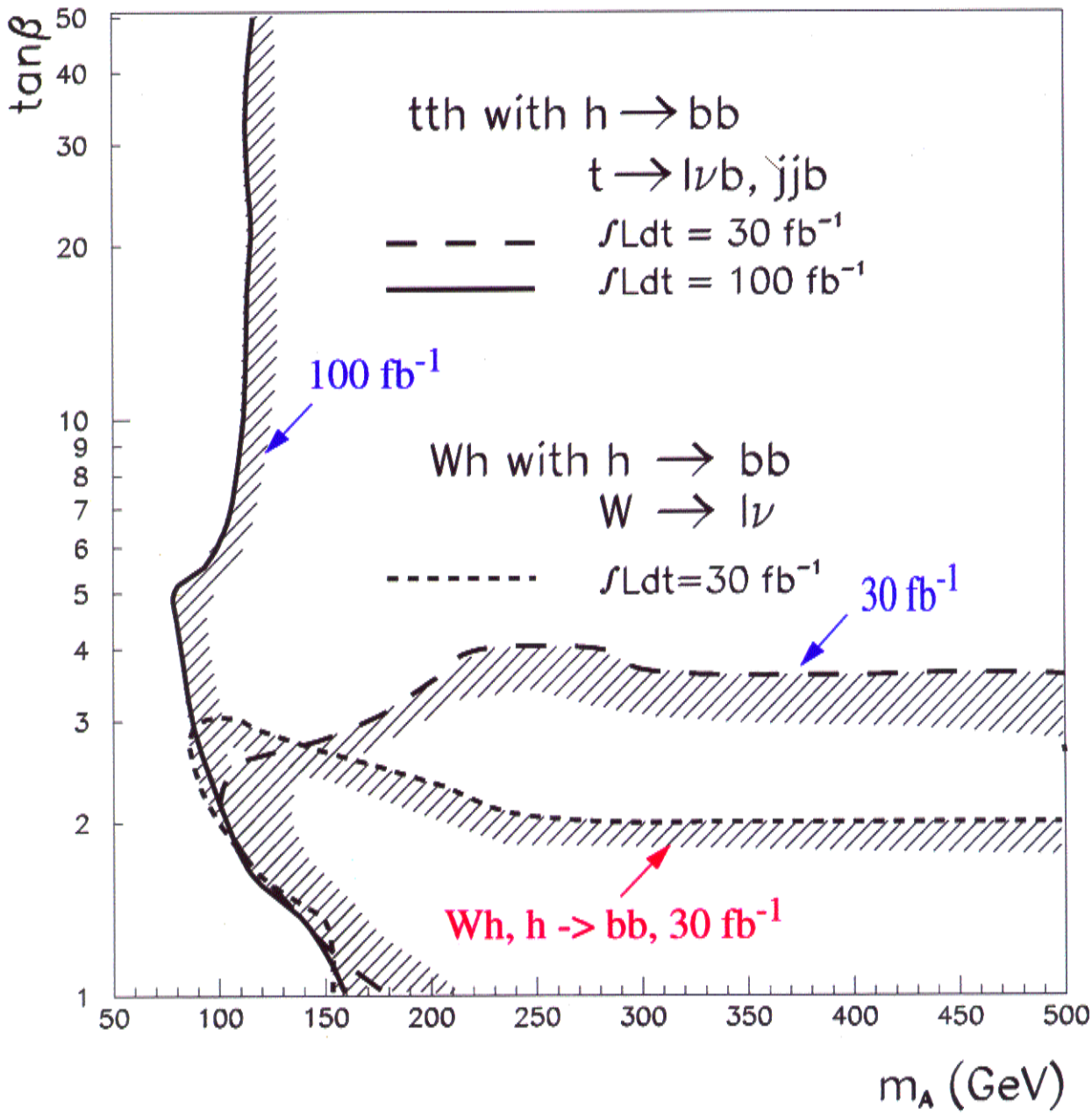
D.D. 90

h_{MSSM} -> $b\bar{b}$ in tth and Wh in ATLAS

from the results obtained for SM search

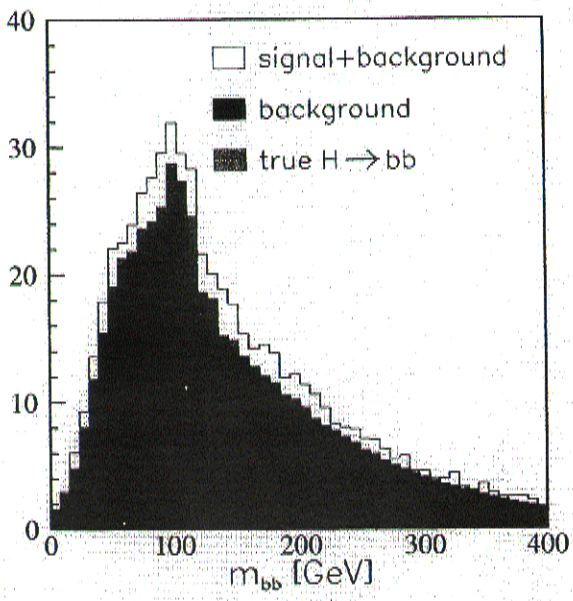
rates can be enhanced by 20-30% compared to SM

5σ discovery contours for the $t\bar{t}h$ and Wh with h -> $b\bar{b}$



Search for SM/MSSM Higgs boson through ttH production with H → bb

- Shape of combinatorial background requires reconstruction of both top quark decays : t→ jjb and t→ lνb (l=e,μ for trigger)
- Require 4 b-tagged jets + 1 lepton + 2 non-b jets (ε_{rec} = 3.5%)
- Reconstruct H → bb mass peak above background from tt+jets



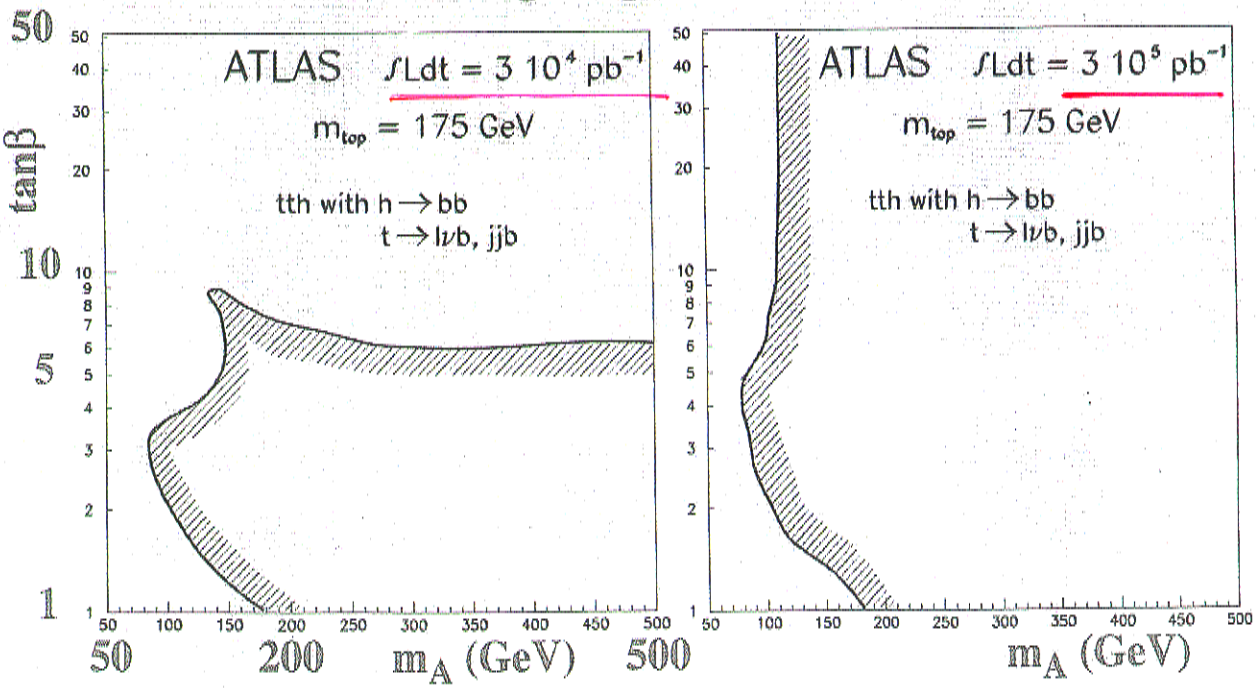
For 3 10^4 pb^{-1} (low luminosity) and for m_H = 100 GeV in SM, expect to observe in a mass bin from 80 GeV to 120 GeV :

67 signal events above
145 background events
(mainly from ttbb and ttjj)

→ Significance above 5 for 80 < m_H < 120 GeV

Possible also at high luminosity

This channel covers a large region of MSSM parameter space



$A/H \to t\bar{t}$

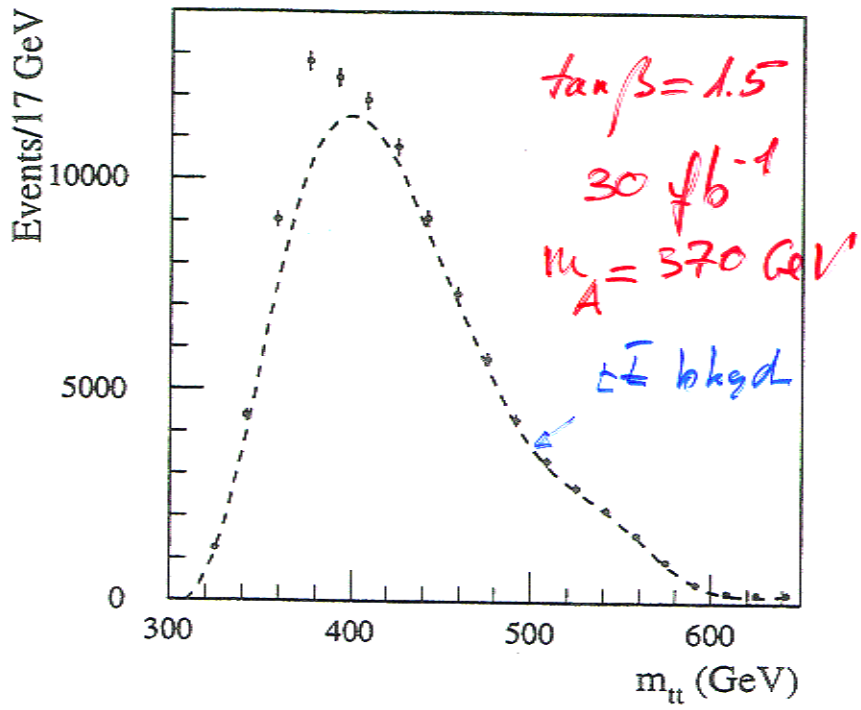


Figure 19-65 For an integrated luminosity of 30 fb^{-1} and for $\tan\beta = 1.5$, distribution of $m_{t\bar{t}}$ for the $t\bar{t}$ background (dashed histogram) and for the sum of the $H/A \to t\bar{t}$ signal with $m_A = 370$ GeV and of the total background (points with error bars).

parameter space coverage vs L_{int}

ATLAS Apr 8'

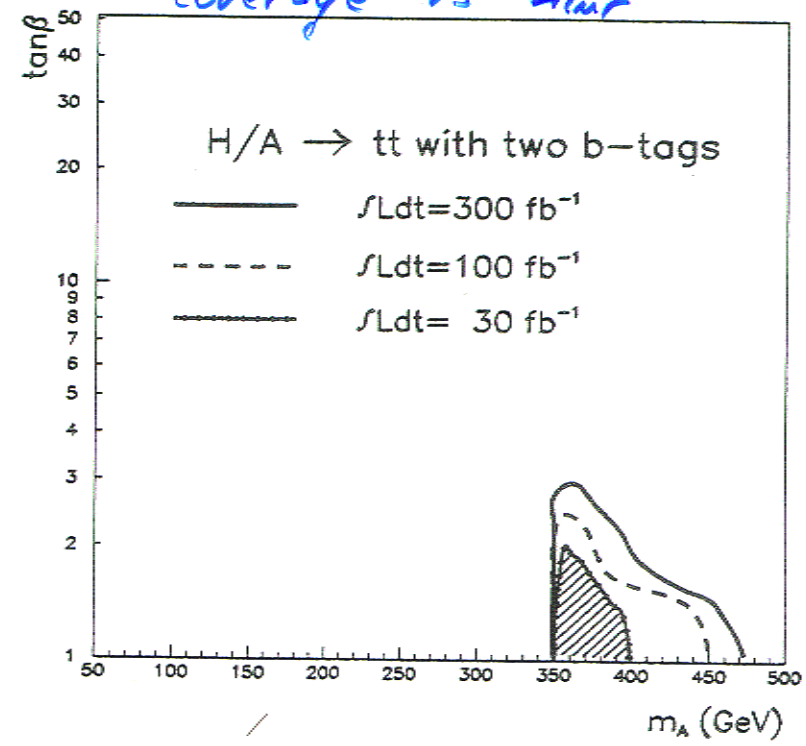
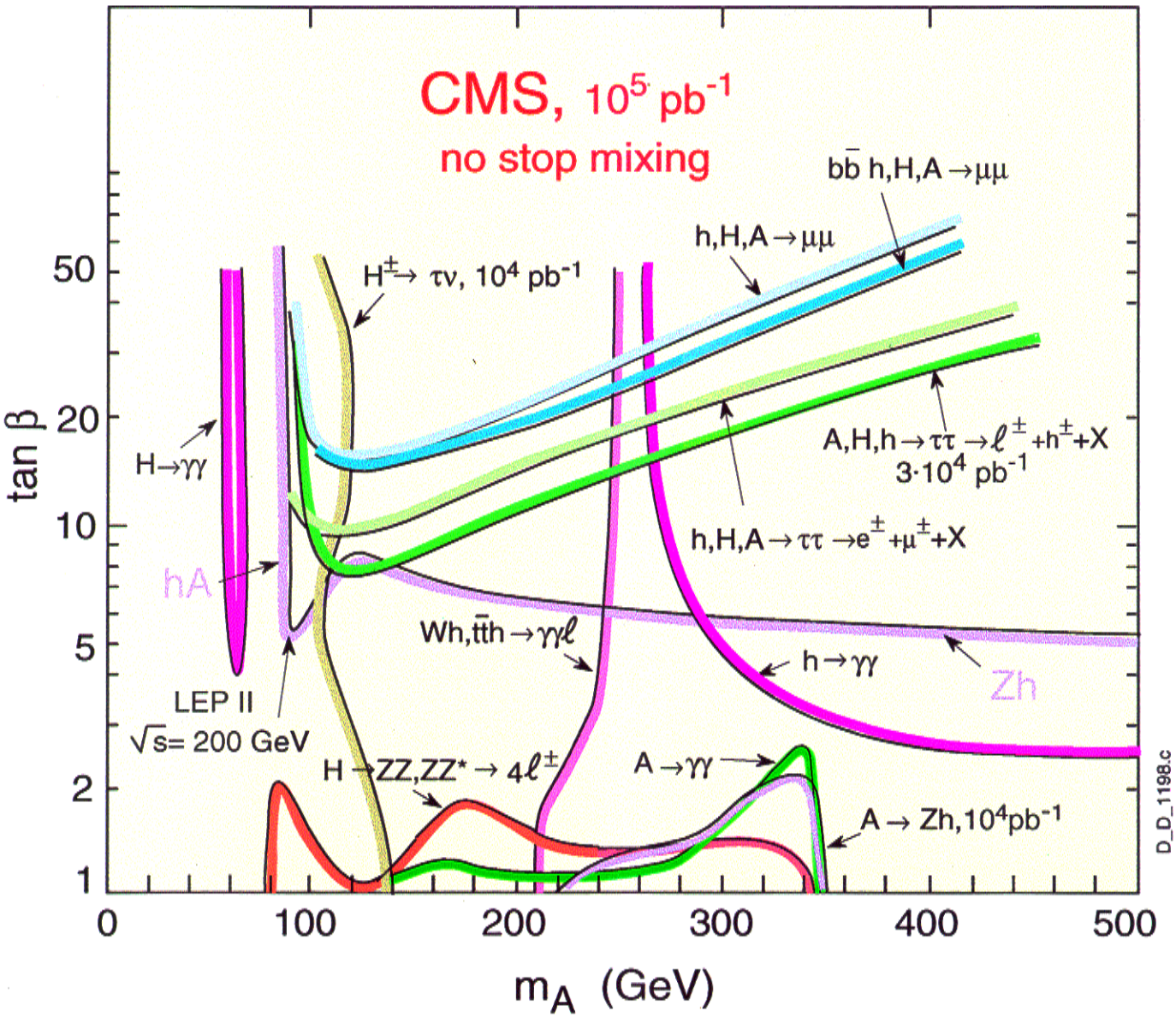


Figure 19-66 For integrated luminosities of 30 fb^{-1}, 100 fb^{-1} and 300 fb^{-1}, 5σ-discovery contour curves for the $H \to t\bar{t}$ channel in the (m_A, tanβ) plane.

Significance contours for SUSY Higgses

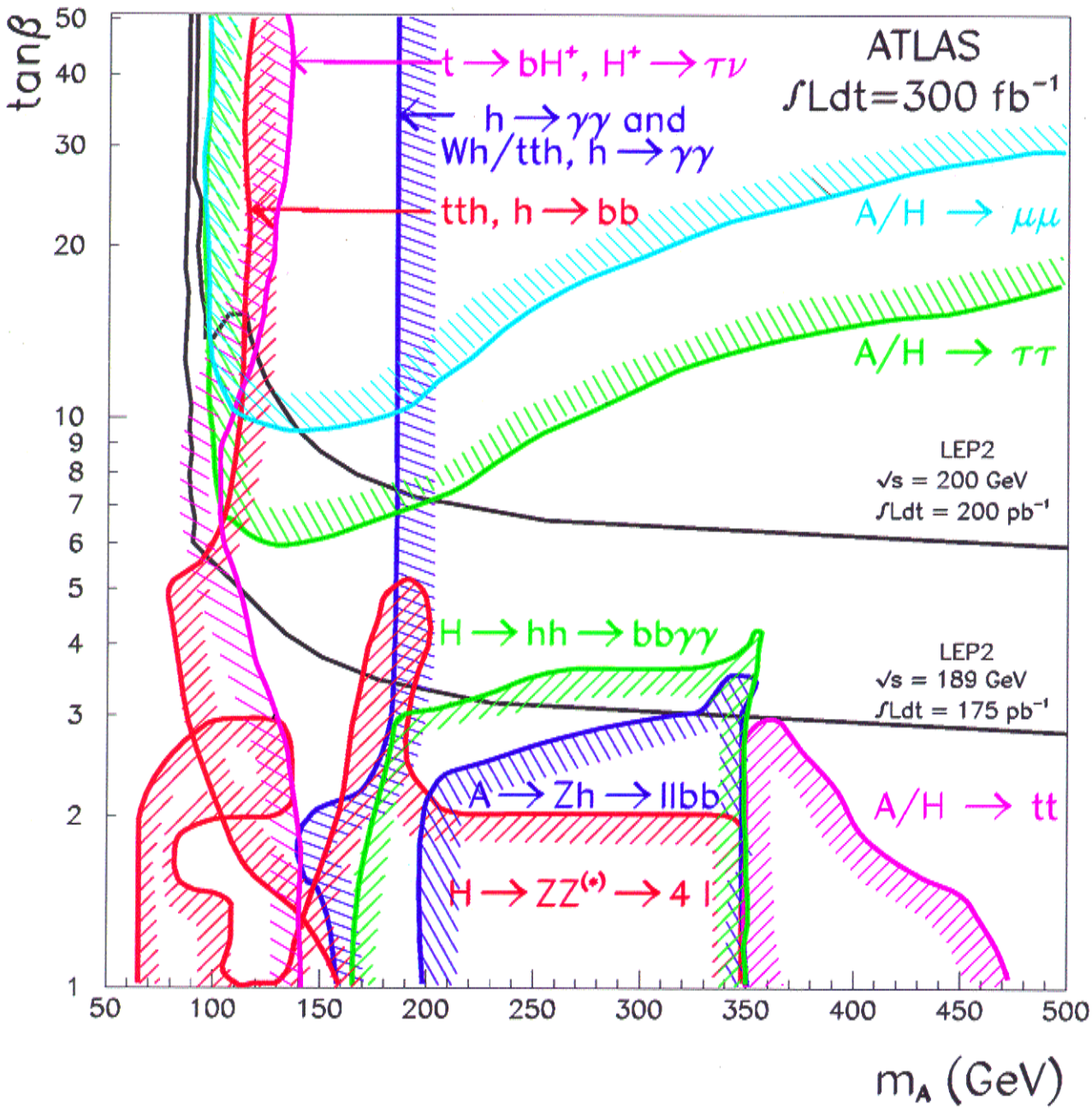
Regions of the MSSM parameter space (m_A, tgβ) explorable through various SUSY Higgs channels

- 5 σ significance contours
- two-loop / RGE-improved radiative corrections
- m_{top} = 175 GeV, m_{SUSY} = 1 TeV



Discovery reach for MSSM Higgses in ATLAS

- ultimate reach with 300 fb^{-1}



Most recent studies

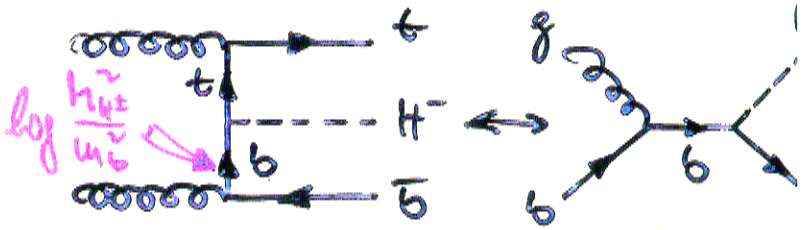
$H^{\pm}$ with $H \rightarrow \tau\nu$ for $M_H > m_{top}$

D.D95

I Charged Higgs Bosons

- production:

(i) $q\bar{q}, gg \to tbH^\pm$
$gb \to H^\pm t$

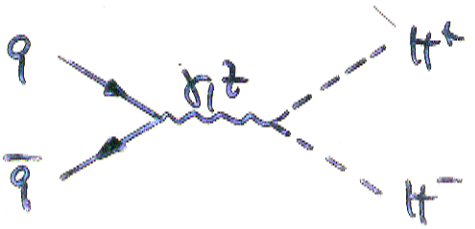


Borzumati

(ii) $bq \to bq'H^\pm$

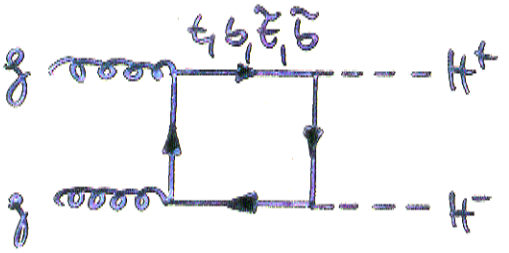
Moretti, ...

(iii) $q\bar{q} \to H^+H^-$



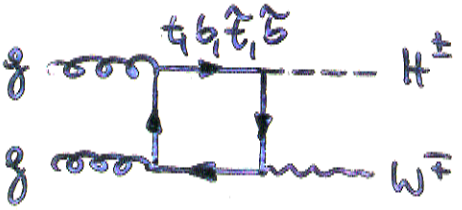
[QCD ~ +30%]

(iv) $gg \to H^+H^-$



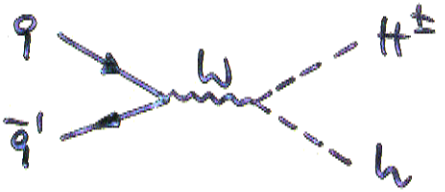
Krause, ...
Dress, ...
Kniehl, ...

(v) $gg \to W^\pm H^\mp$



Dicus, ...
Kniehl, ...

(vi) $q\bar{q}' \to hH^\pm$



[QCD ~ +30%]

- decays: $H^+ \to \tau^+\nu_\tau, t\bar{b}, hW^*, AW^*$
  τ-polarisation?

Roy

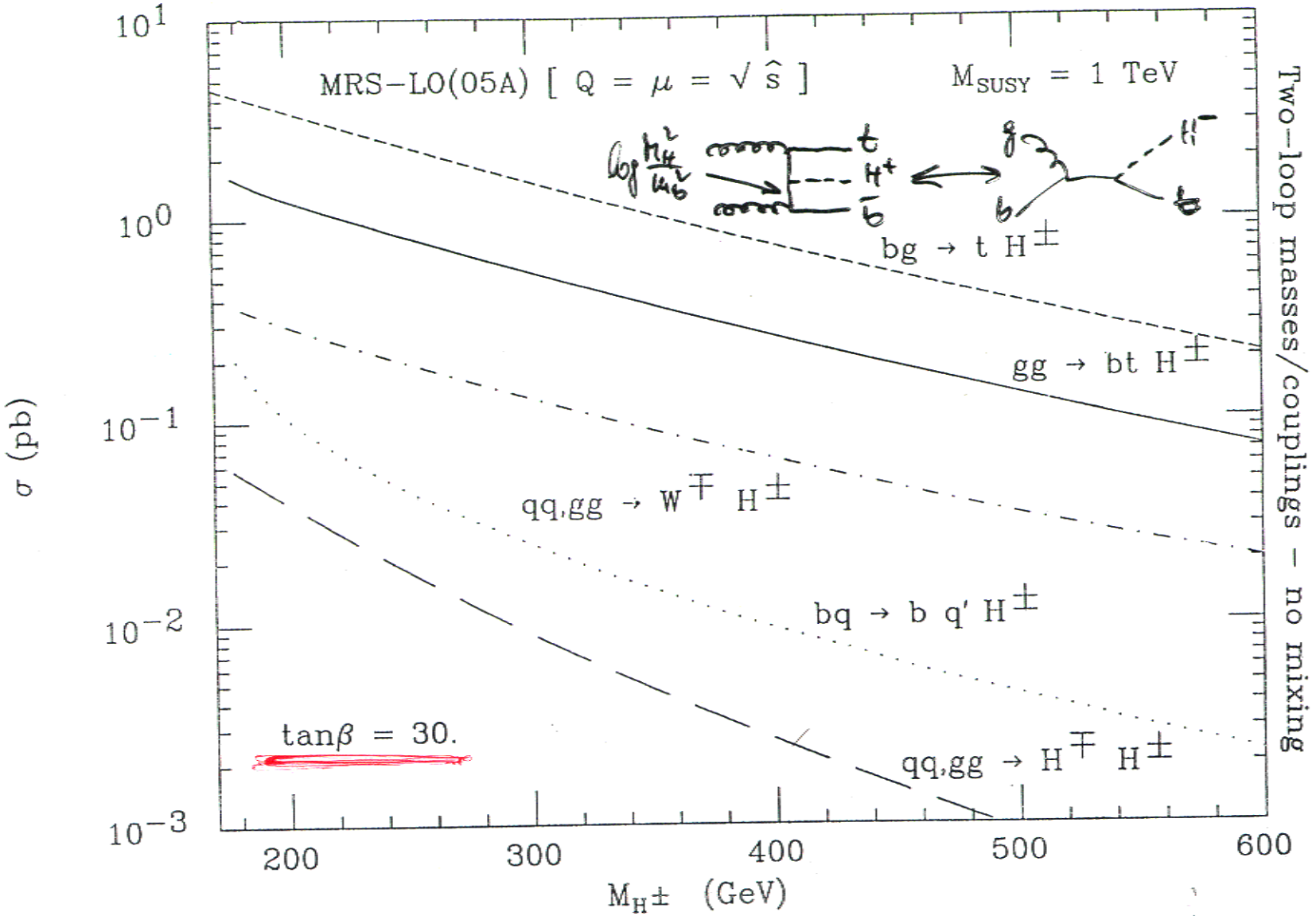
- PYTHIA: $gg \to t\bar{t} \to (H^\pm b)(W^\mp b)$
  $\hookrightarrow hW^*$

Assamagan

in progress...

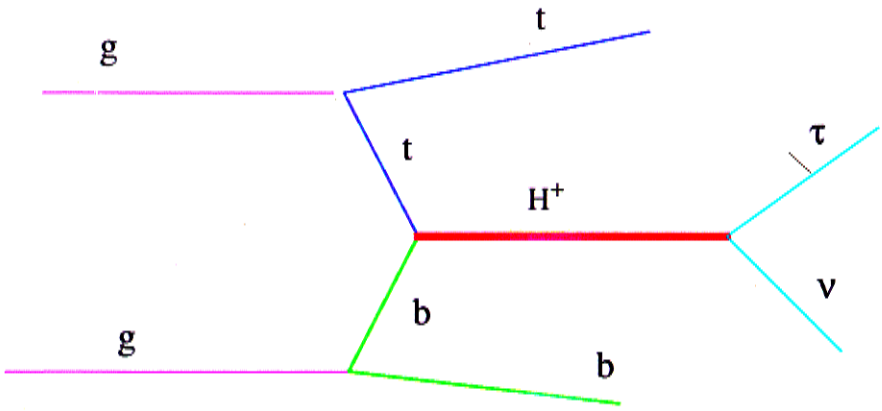
$H^{\pm}$ production

MSSM heavy charged Higgs production at 14 TeV

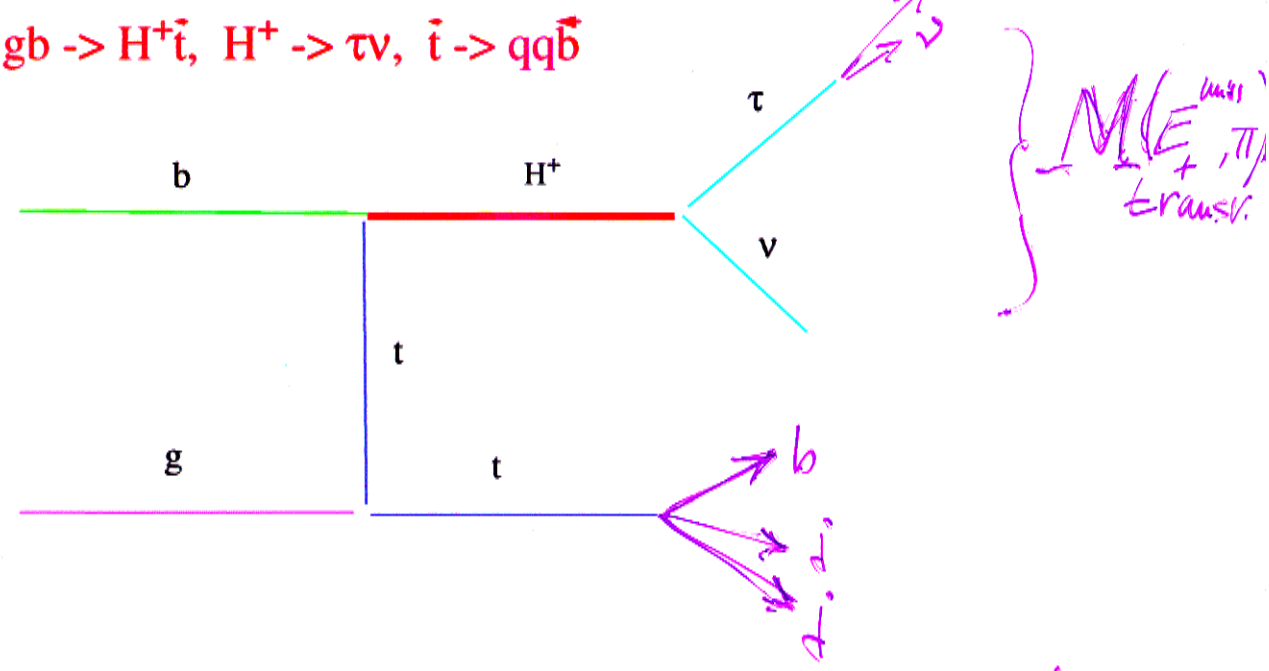


Moretti & Odagiri

$gg \to H^+\bar{t}b,\ H^+ \to \tau\nu,\ \bar{t} \to qq\bar{b}$



$gb \to H^+\bar{t},\ H^+ \to \tau\nu,\ \bar{t} \to qq\bar{b}$



$\Rightarrow$ use $\bar{t} \to b q \bar{q}'$ so that $\not{E}_T^{miss}$ get contribution "only" from $H^\pm$ decay $\Rightarrow$ Jacobian peak

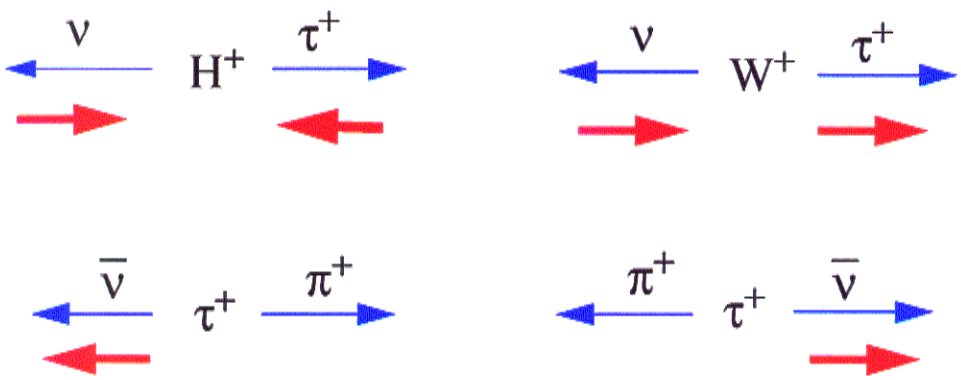
τ polarization in

$gb \to H^+\bar{t}$; $H^+ \to \tau^+\nu$, $\bar{t} \to \bar{b}q\bar{q}$

Main contributions to 1-prong decays

$\tau \to \pi^+\nu$	12.5%
$\tau \to \rho^+\nu \to \pi^+\pi^0\nu$	26%
$\tau \to a_1\nu \to \pi^+\pi^0\pi^0\nu$	7.5%

Effect of τ polarization in $H^\pm$ compared to $W^\pm$ decays:

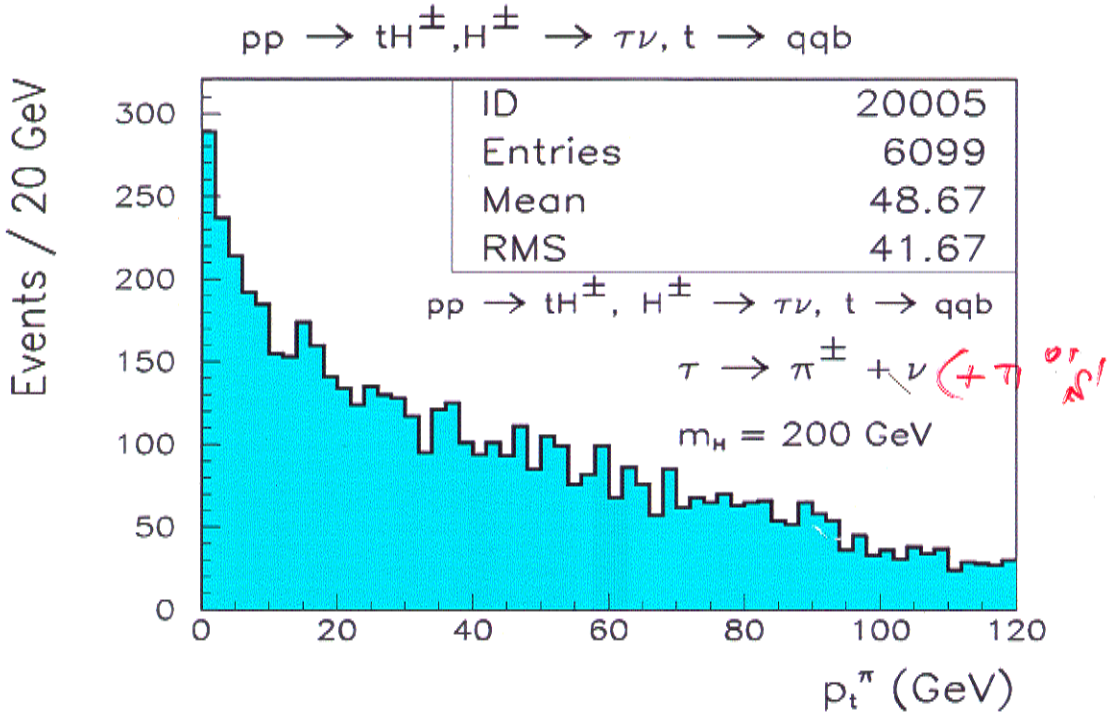


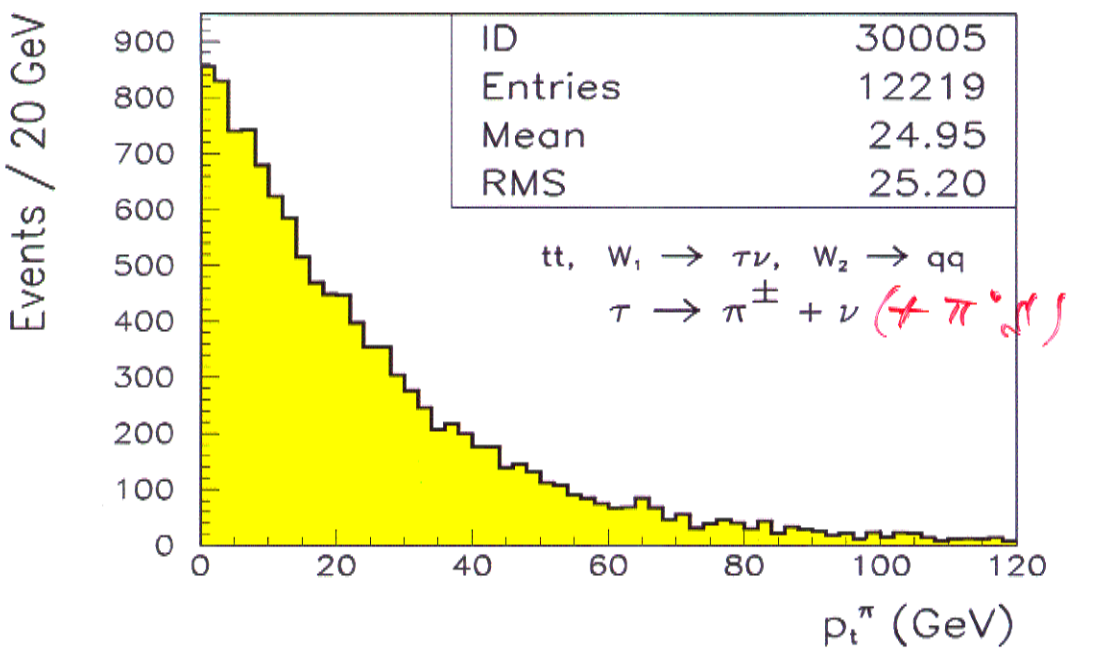
harder pions from $\tau^+ \to \pi^+\nu$ and longitudinal components of ρ and a_1 in $H^\pm$ than in $W^\pm$

Polarization included with TAUOLA package by Z. Was et al.

Event generation with PYTHIA

τ decay with TAUOLA





R. Kinnunen

$gb \to H^+\bar{t}$; $H^+ \to \tau^+\nu$, $\bar{t} \to \bar{b}q\bar{q}$

CMS preliminary

Production in PYTHIA through:

$g\bar{b} \to H^+\bar{t}$

For m_A=400 GeV, m_{H+}=407 GeV, $\tan\beta = 30$:

$\sigma = 1.3$ pb

overestimated by ~30% according to Spira

BR($H^+ \to \tau\nu$) from HDECAY:

m_{H+}=407 GeV, $\tan\beta = 30$	14.1%
m_{H+}=214 GeV, $\tan\beta = 15$	36.8%

Event selection for tH^+, $H^+ \to \tau\nu$, $\tau \to h^+ + X$

1) τ selection:

jet, $E_t > 100$ GeV, $|\eta| < 2.5$ containing

one track with $r = p_t^h / E_t^{jet} > 0.8$, $\Delta R(\text{jet,track}) < 0.1$

no other track, $p_t > 1$ GeV, in $\Delta R(\text{jet,track}) < 0.4$

2) $E_t^{miss} > 50$ GeV

3) W mass reconstruction, $|m_{jj} - m_W| < 20$ GeV

4) one tagged b -jet, $E_t > 30$ GeV, $|\eta| < 2$
containing ≥ 3 tracks, $p_t \geq 0.9$ GeV, $\sigma^{ip} \geq 2$

5) top mass reconstruction, $|m_{jjb} - m_{top}| < 20$ GeV

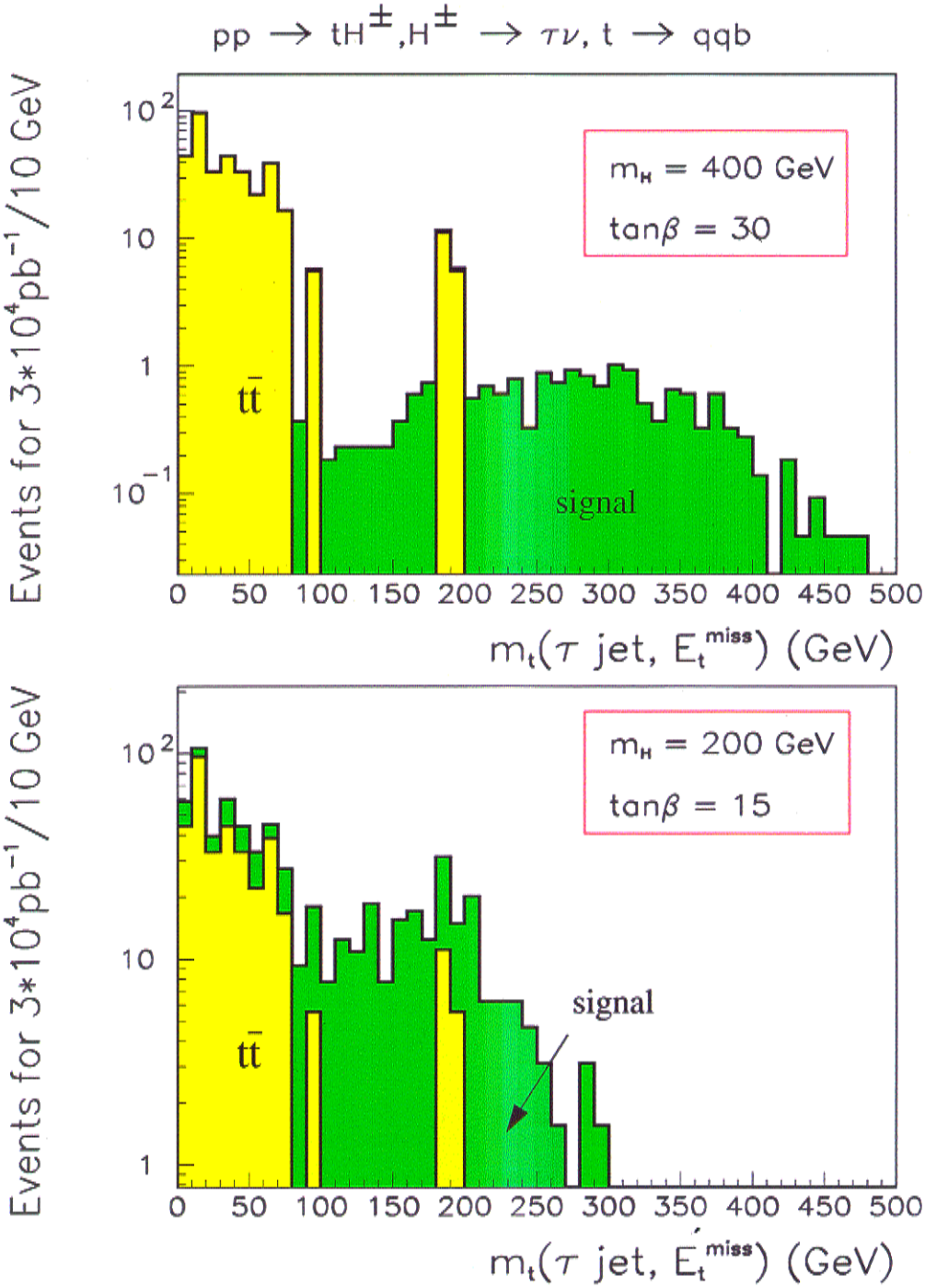
6) $m_t(\tau \text{ jet}, E_t^{miss})$

$H^{\pm}$ signal visibility in transverse mass $\tau - E_t^{miss}$ for $H^{\pm} \to \tau \nu$ mode

$m_t(\tau\ \text{jet}, E_t^{miss})$

signal / background for $3 * 10^4\ pb^{-1}$

no $\Delta\phi(\tau\ \text{jet}, E_t^{miss})$ cut



Discovery domain for $H^{\pm}(\to \tau\nu)$ for $3 \cdot 10^4 pb^{-1}$ – preliminary

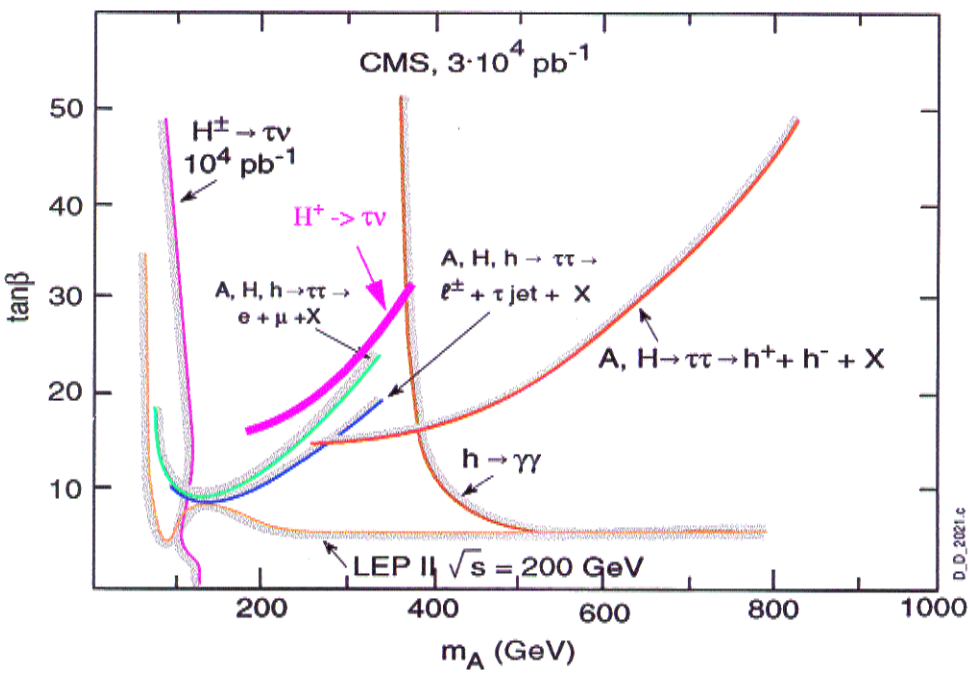
$H^+ \to \tau\nu$ for $m_{H+} > m_{top}$ from $pp \to tH^+$

- Interesting discovery channel for H^+, $m_{H+} > m_{top}$
- Preliminary results:

Events for $m_t(\tau\,\text{jet}, E_t^{miss}) > 150$ GeV, $3 * 10^4\ pb^{-1}$

signal, $m_A = 400$ GeV ($m_{H+} = 410$ GeV), $\tan\beta = 30$	16
signal, $m_A = 200$ GeV ($m_{H+} = 217$ GeV), $\tan\beta = 20$	15
$t\bar{t}$, $W_1 \to \tau\nu$, $W_2 \to qq$	17

- parameter space coverage for 30 fb^{-1}



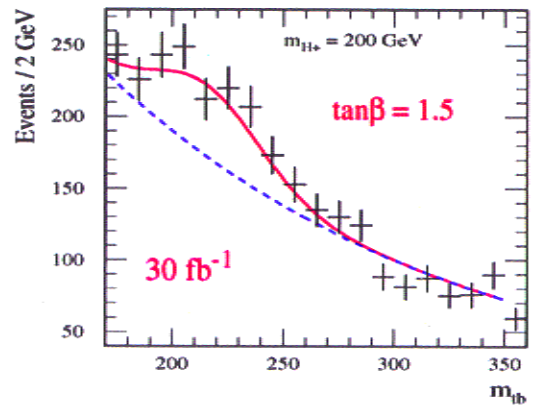
- W + jets background and optimisation of signal selection efficiency under study

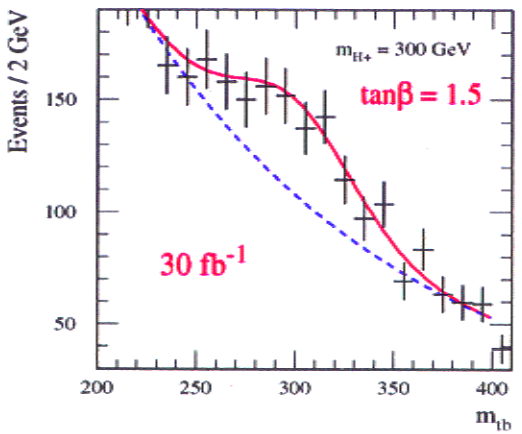
R. Kinnunen

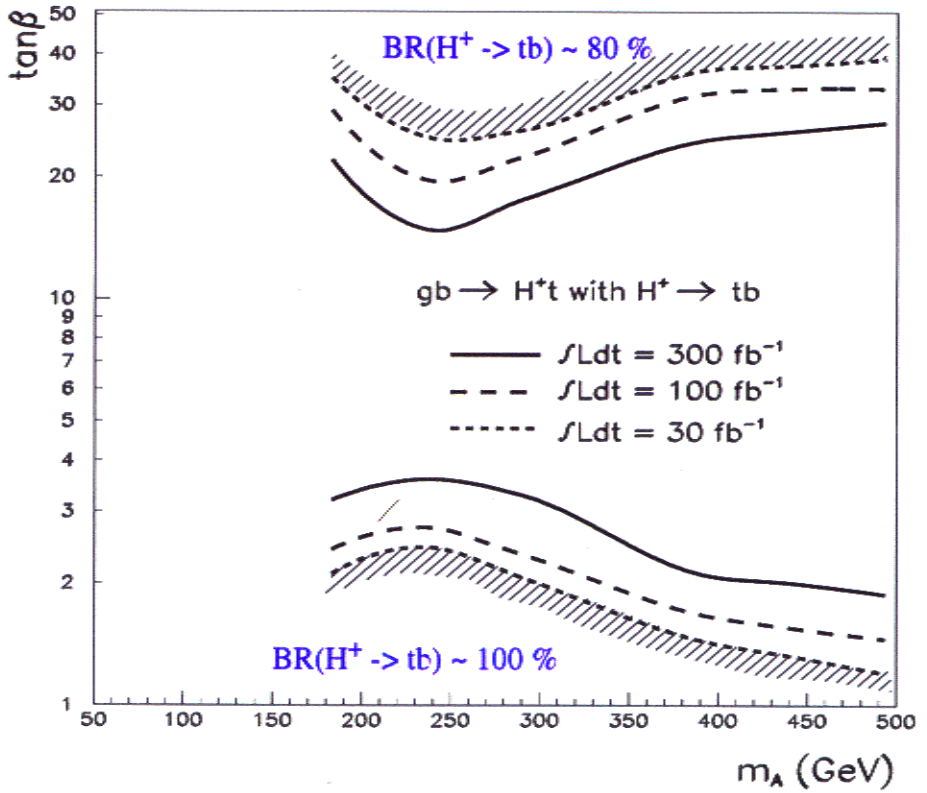
Charged Higgs heavier than top quark in ATLAS

bg -> H^+t, gg -> H^+tb with H^+ -> tb

- One isolated lepton, 3 tagged b jets
- Reconstruction of 2 top-quarks
- Higgs mass reconstruction in the m_{tb} distribution from H^+ -> tb decay



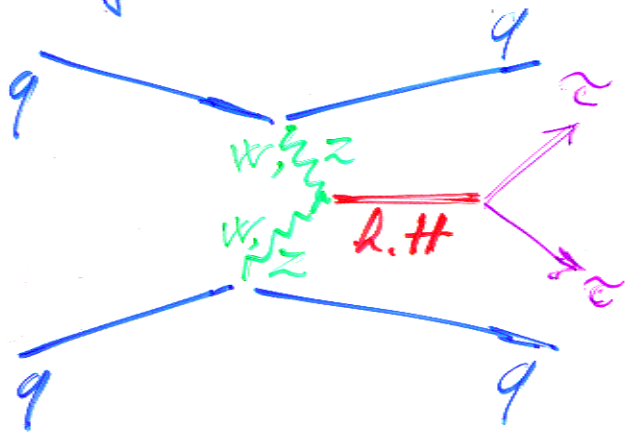




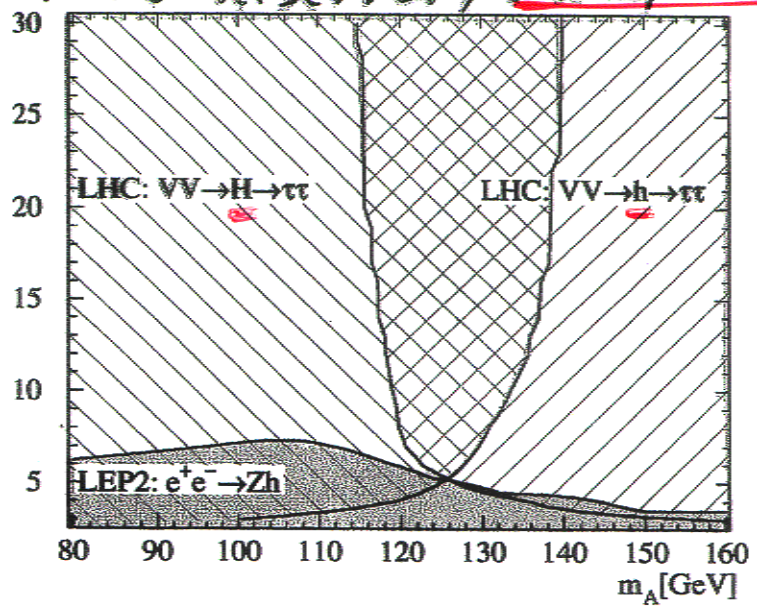
An interesting suggestion – from Workshop at Les Houches June 99

100 fb^{-1}

signal:



5σ discovery [Plehn, Rainwater, Zeppenfeld]

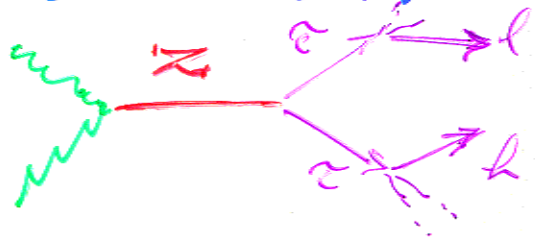


maximal mixing

$m_{SUSY} = 1$ TeV

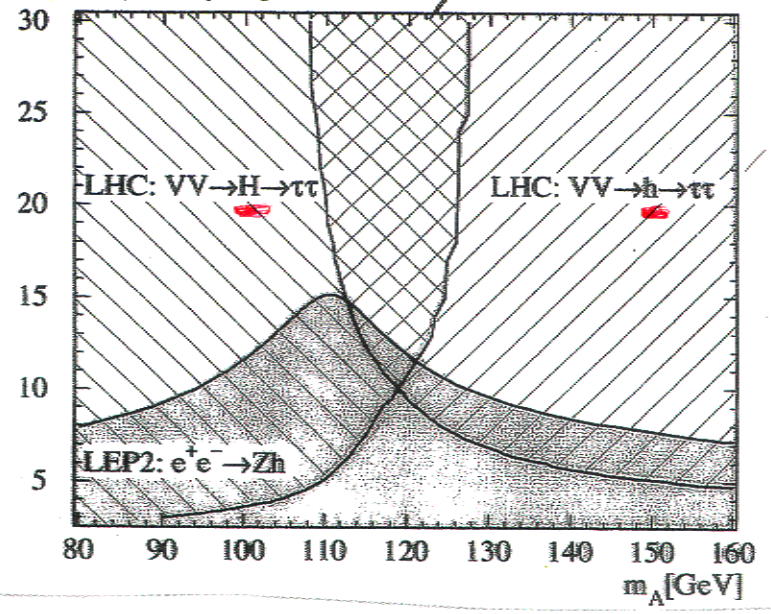
backgrounds to $\tilde{\tau}\tilde{\tau}$:

in $\tilde{\tau}\tilde{\tau} \to \ell^{\pm} + h^{\mp}$



100 fb^{-1}

5σ discovery



no mixing

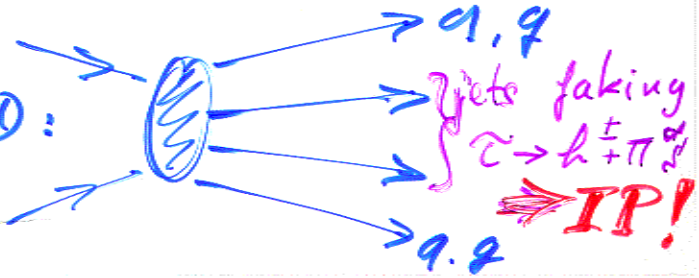
$m_{SUSY} = 1$ TeV

background:

in $\tilde{\tau}\tilde{\tau} \to h^{+} + h^{-}$

Z + QCD

QCD:



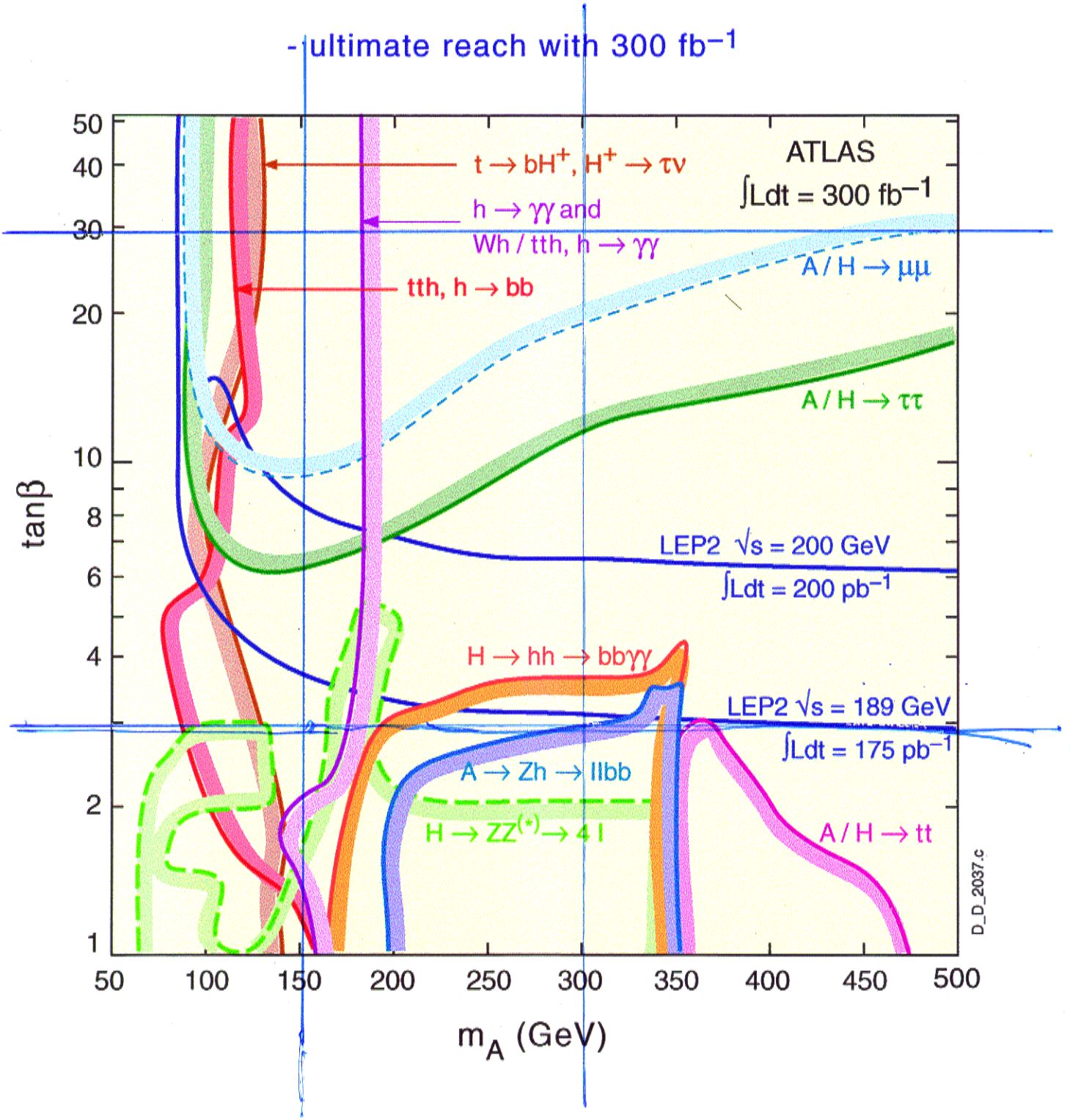
A. Nikitenko + ...

Precision meaurements on MSSM Higgs bosons

- masses
- tg β

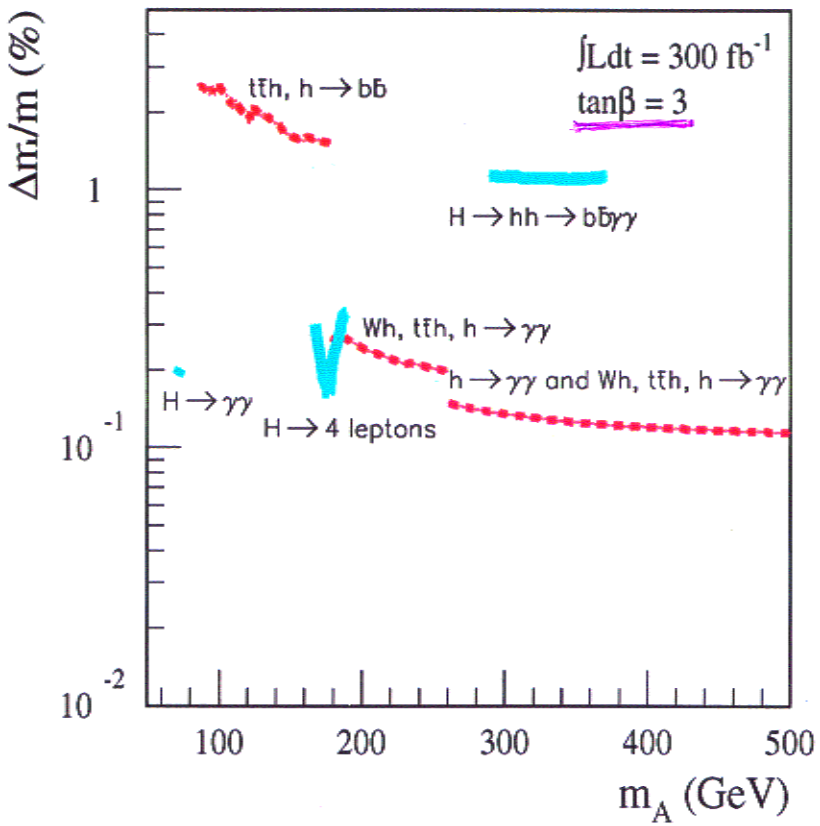
To illustrate achievable precision on theory
- MSSM masses and tg β determinations
⇒ cuts at fixed tg β and m_A :

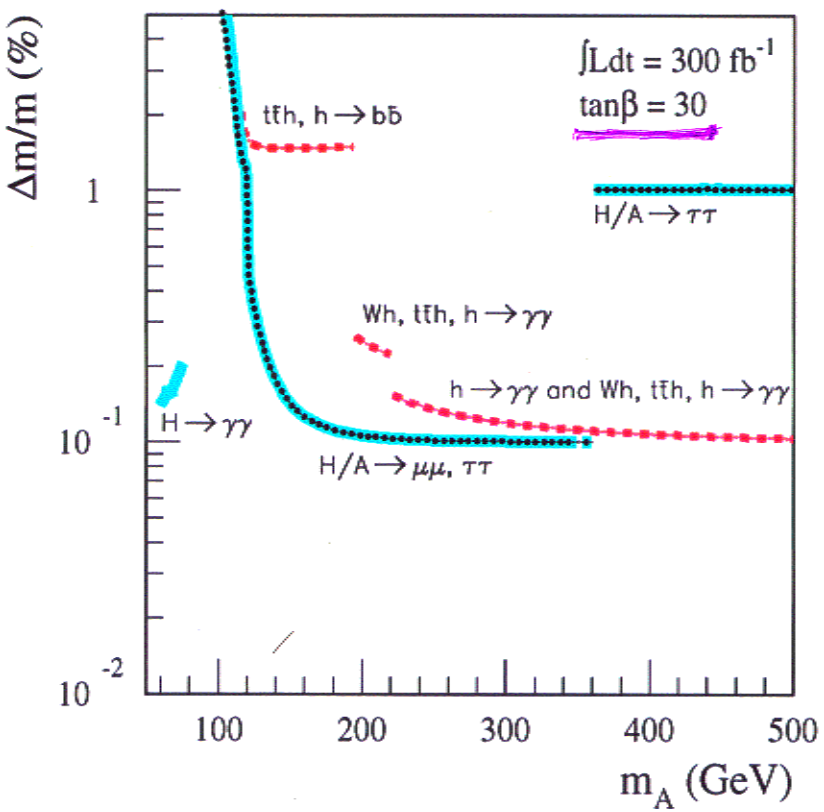
Discovery reach for MSSM Higgses in ATLAS



MSSM Higgs

Precision of mass measurement

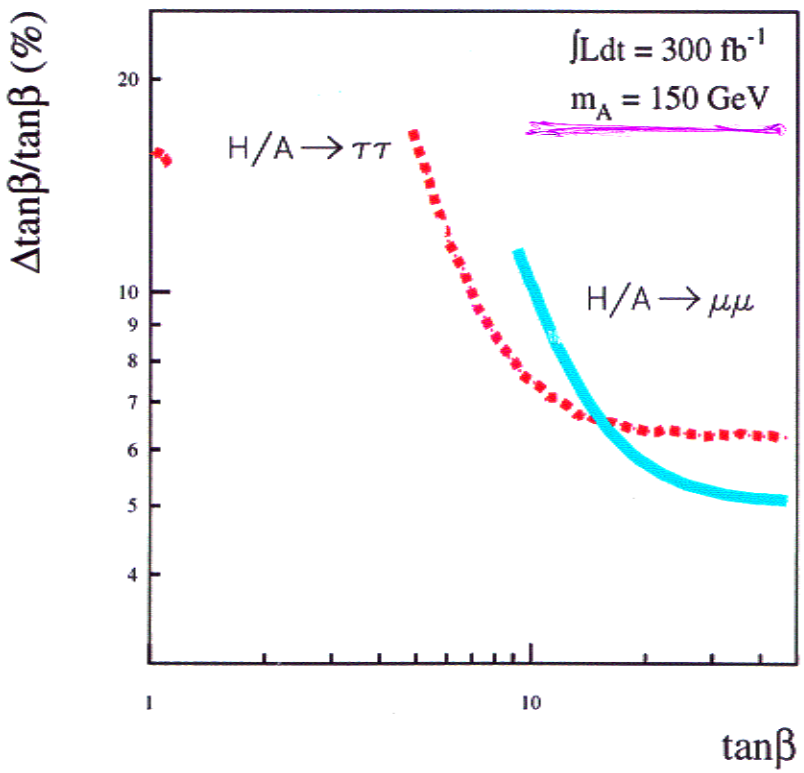


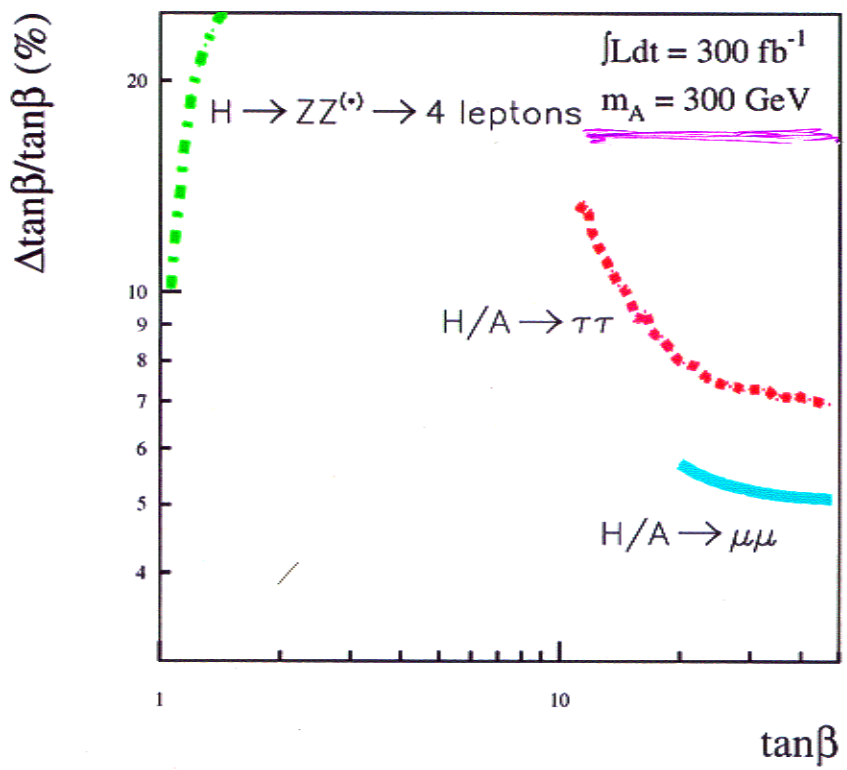


Systematic uncertainty on the absolute energy scale : 0.1% for e, μ, γ (!)
: 1% for jets

MSSM Higgs

Precision of tanβ measurement

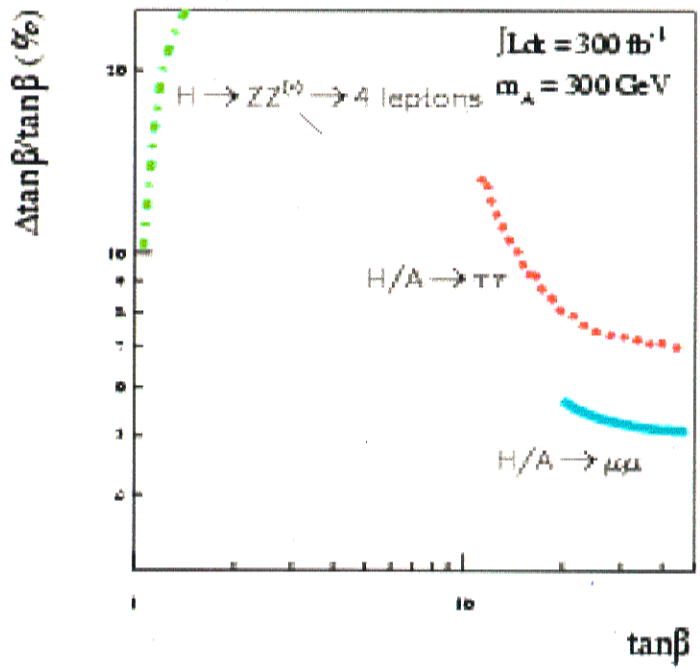




❷ Higgs production rates: σ x BR

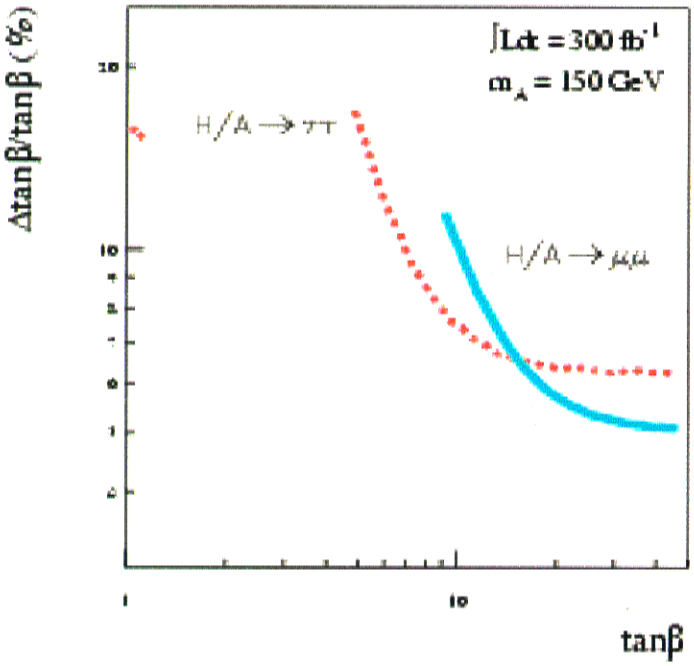
- typical precisions: 7% -20% (depending on mass and MSSM parameters)
- dominant systematics: luminosity (5-10%)
- rate of $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ allows disentangling SM/MSSM (~10 times smaller in MSSM)
- rate of $A/H \rightarrow \tau\tau$, $\mu\mu$ allows measurement of tgβ

ATLAS



m_A=300 GeV

ATLAS

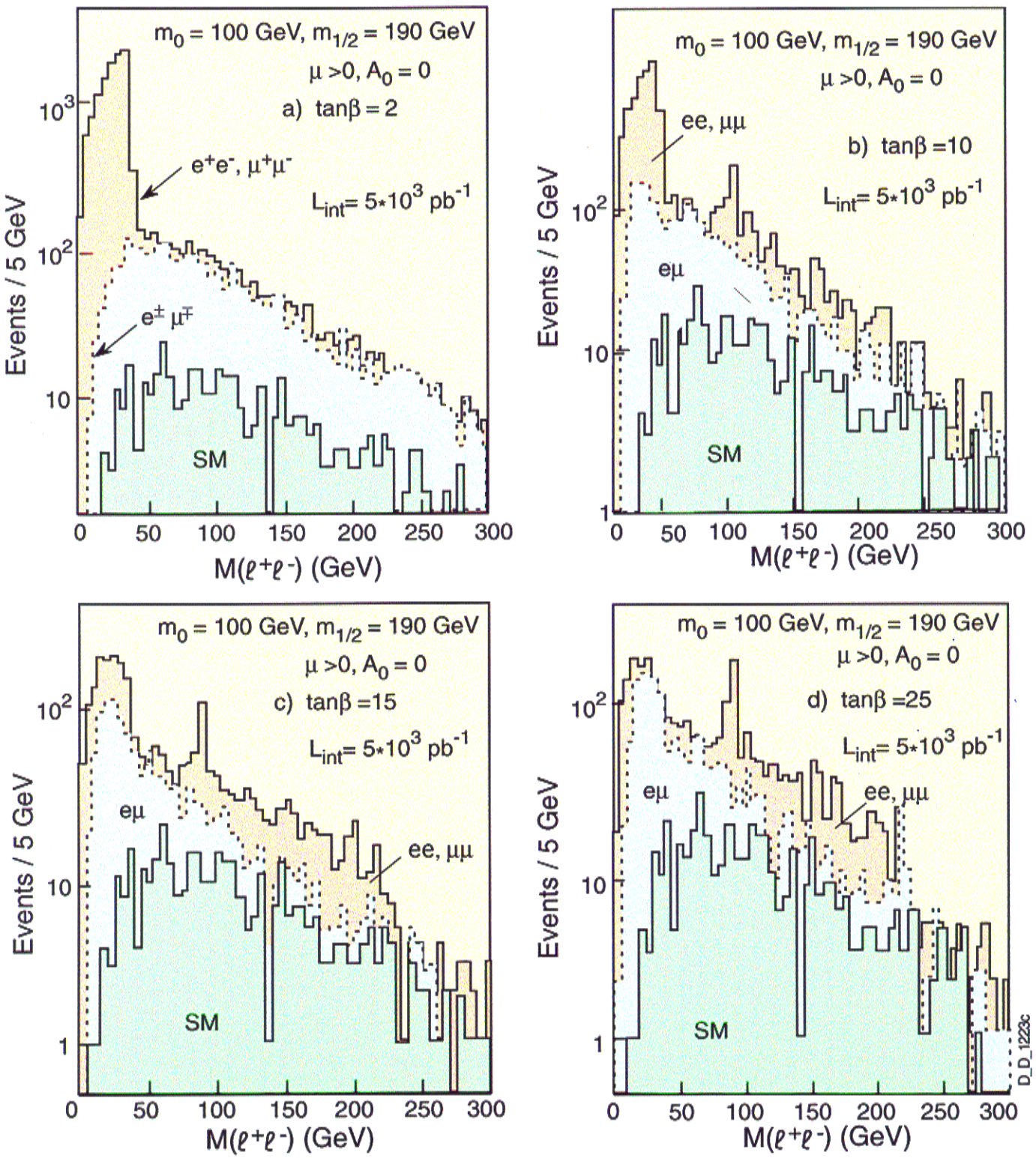


m_A=150 GeV

Other ways to address tanβ determination
- from dilepton spectra i.e. outside Higgs sector

Dilepton invariant mass vs tan β

at fixed m_0 = 100 GeV, $m_{1/2}$ = 190 GeV, A_0 = 0, μ < 0

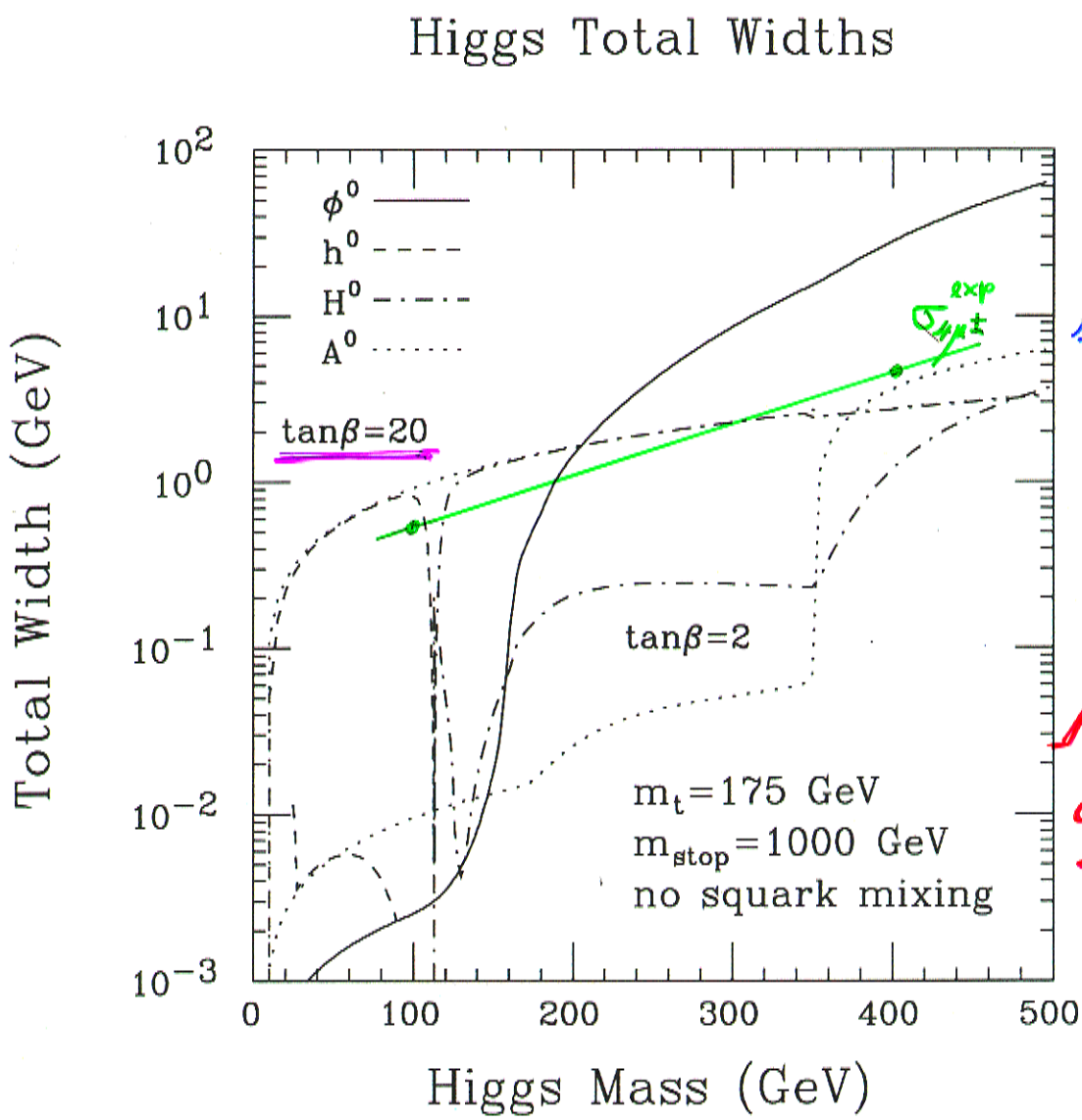


MSSM H_{SUSY} widths

and disentangling A/H ?

$A/H \to \tau\tau$: no

$A/H \to \mu\mu$: possibly



gunion
Stange
Willenbrock

10 GeV

1 GeV

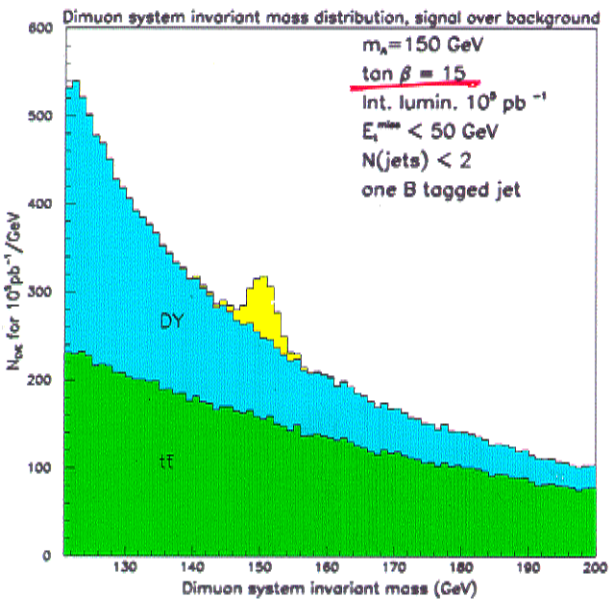
for tg β ≈ 20

A, H → μ⁺μ⁻
could be
sensitive to
$\Gamma_{tot} \lesssim 1$ GeV

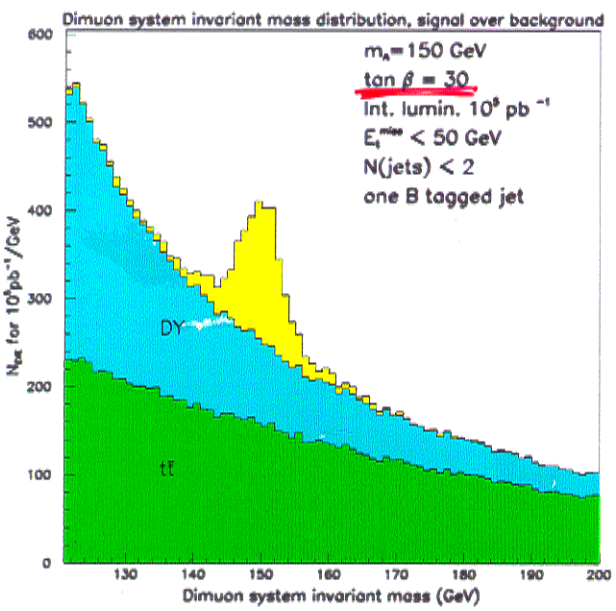
Figure 6: Total width versus mass of the SM and MSSM Higgs bosons for $m_t = 175$ GeV. In the case of the MSSM, we have plotted results for $\tan\beta = 2$ and 20, taking $m_{\tilde{t}} = 1$ TeV and including two-loop/RGE-improved radiative corrections, neglecting squark mixing; SUSY decay channels are assumed to be absent.

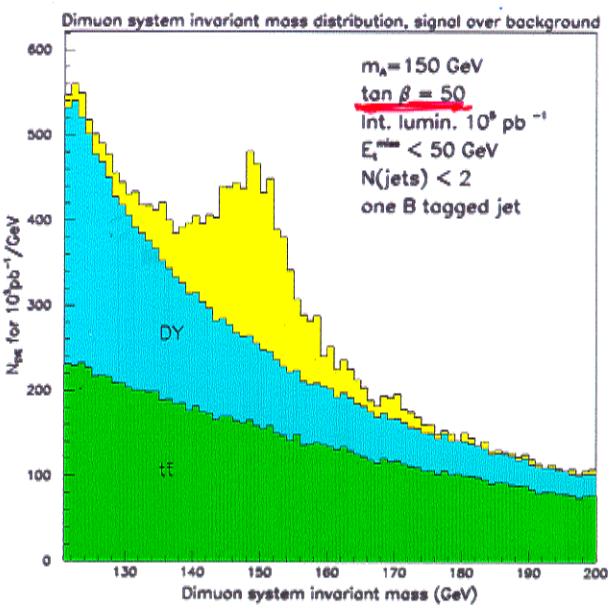
$H_{SUSY} \to \mu^+\mu^-$ in $b\bar{b}H_{SUSY}$

Dimuon system invariant mass distributions, with b-tagging



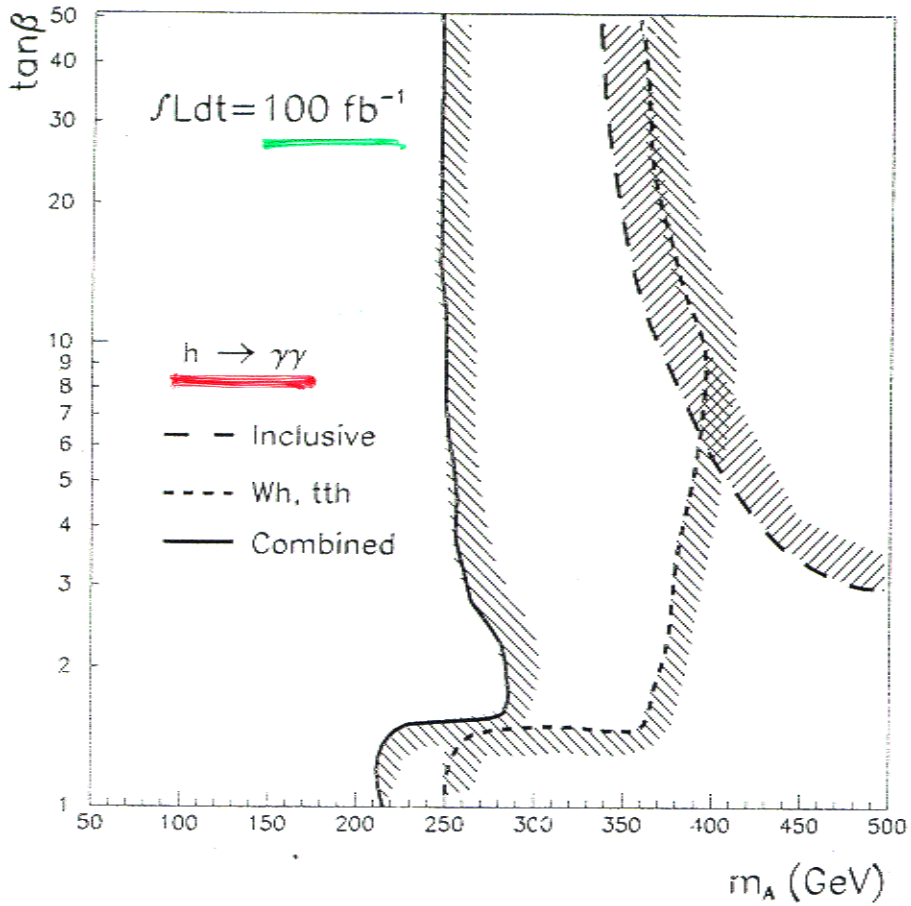
- Search for $b\bar{b}H_{SUSY}$; $H_{SUSY} \to \mu^+\mu^-$
- Signal over background,
- $m_A = 150$ GeV
- $\tan\beta = 15, 30, 50$
- The following cuts are used:
  - $E_T^{miss} < 50$GeV
  - No. of jets with $p_t > 30$GeV is less than 2
  - At least one b-tagged jet:
    - the number of tracks with $\sigma_{ip} > 2$ and $p_t > 2$GeV in the jet is greater than 3

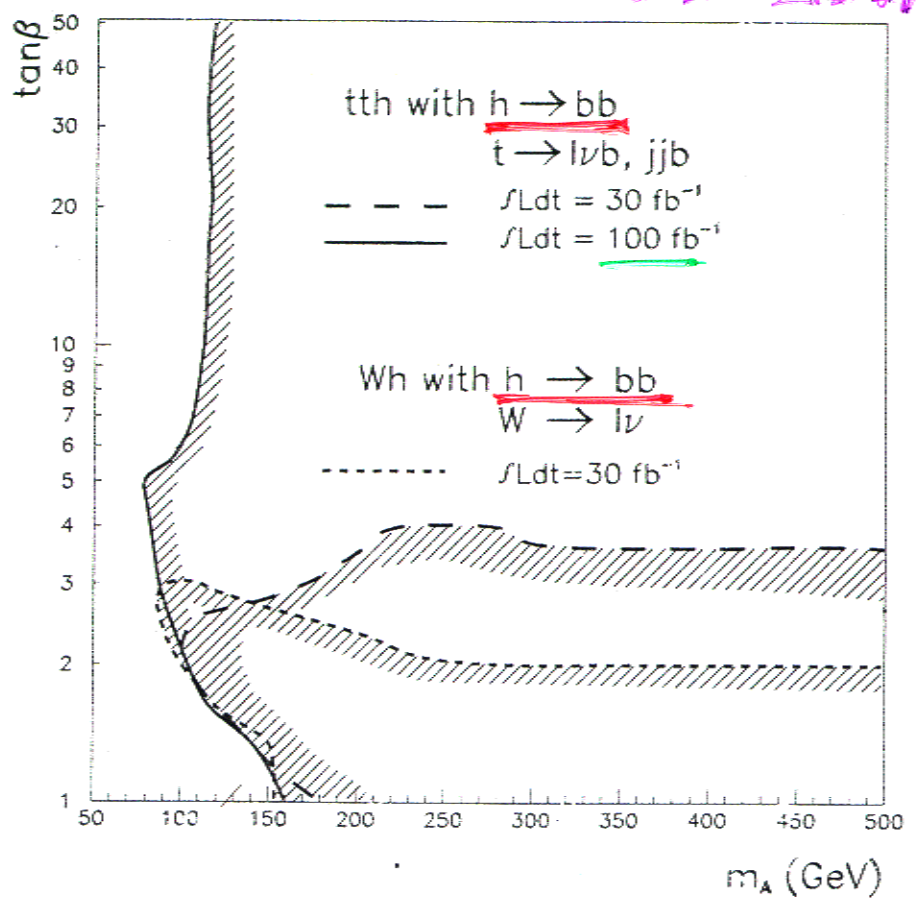




h (MSSM) Higgs detectability at LHC

ATLAS

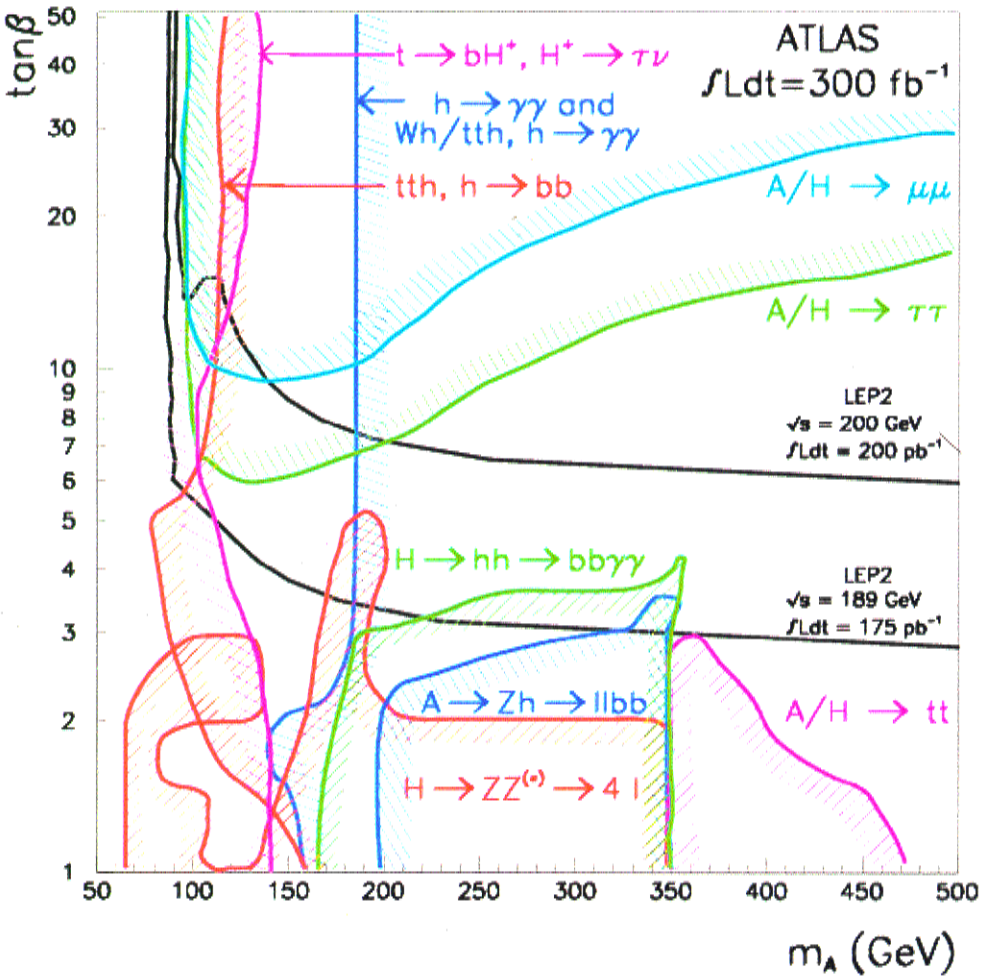




The $t\bar{t}h$, $h \to b\bar{b}$ channel is quite insensitive to loop corrections;
Covers most of the parameter space;
Difficult to disentangle between SM and MSSM scenario.

MSSM Higgs bosons

Assuming SUSY particles do not contribute



5σ contours

Minimal mixing

Not all channels shown !

Plane fully covered after 3 years at low L

Typical MSSM channels: $A/H \to \tau\tau$, $\mu\mu$, tt,

$A \to Zh$, $H \to hh$, $H^{\pm} \to \tau\nu$, cs, tb etc.

Over most space : more than 1 Higgs observable
disentangle SM/MSSM

Difficult region: $m_A > 500$ GeV (~ only h observable)

$h(MSSM)/H_{SM}$ ratios

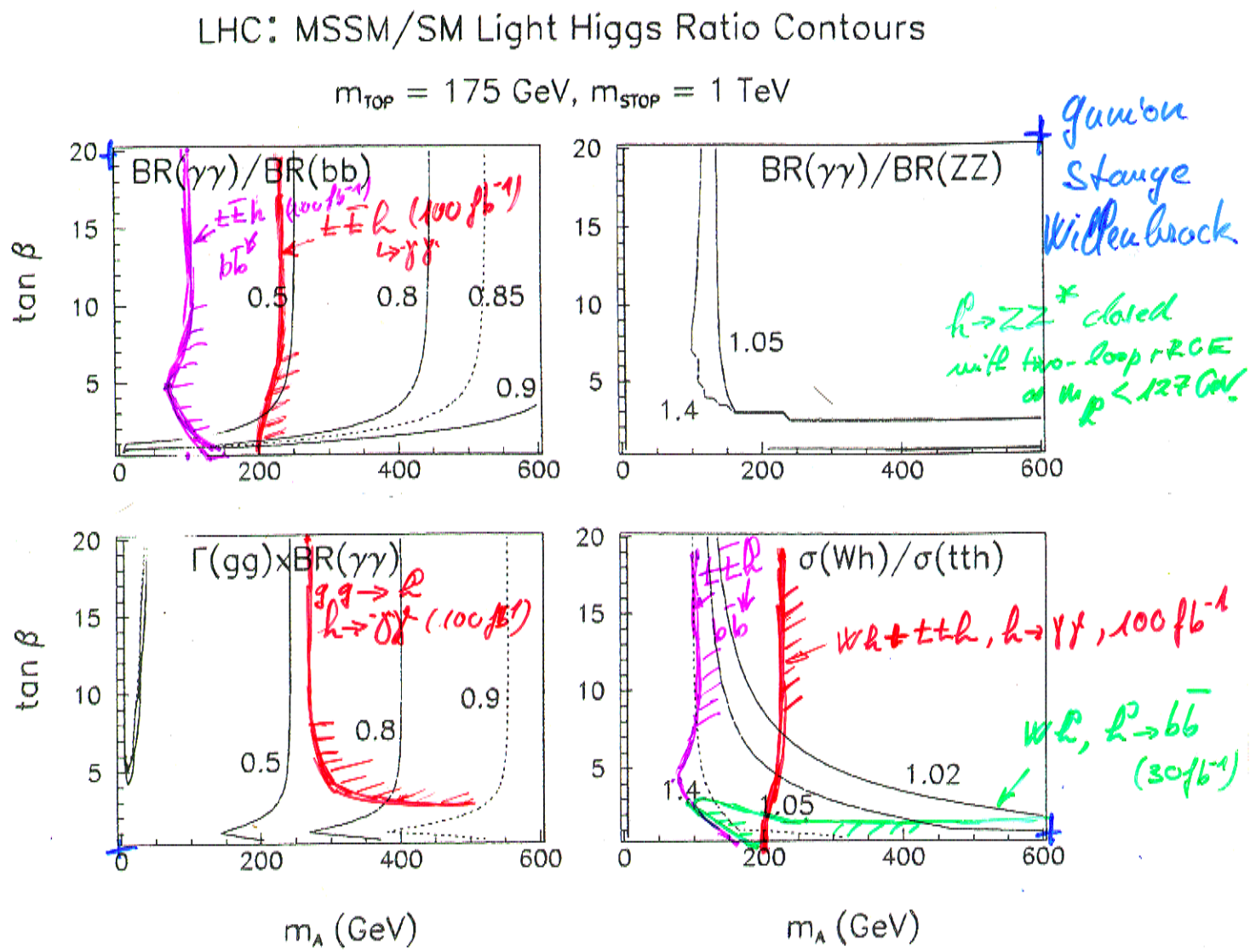


Figure 22: Contours for ratios of MSSM h^0 results to SM ϕ^0 results for $m_{h^0} = m_{\phi^0}$, in $(m_{A^0}, \tan\beta)$ parameter space. We take $m_t = 175\,\mathrm{GeV}$, $m_{\tilde{t}} = 1\,\mathrm{TeV}$, and neglect squark mixing in computing the two-loop/RGE-improved radiative corrections to the MSSM Higgs sector.

$\sigma \cdot B(gg \to h, h \to \gamma\gamma)$ limitations: i) ±10% syst. uncertainty on background subtraction
ii) 5-10% uncertainty on $\int \mathcal{L} dt$.

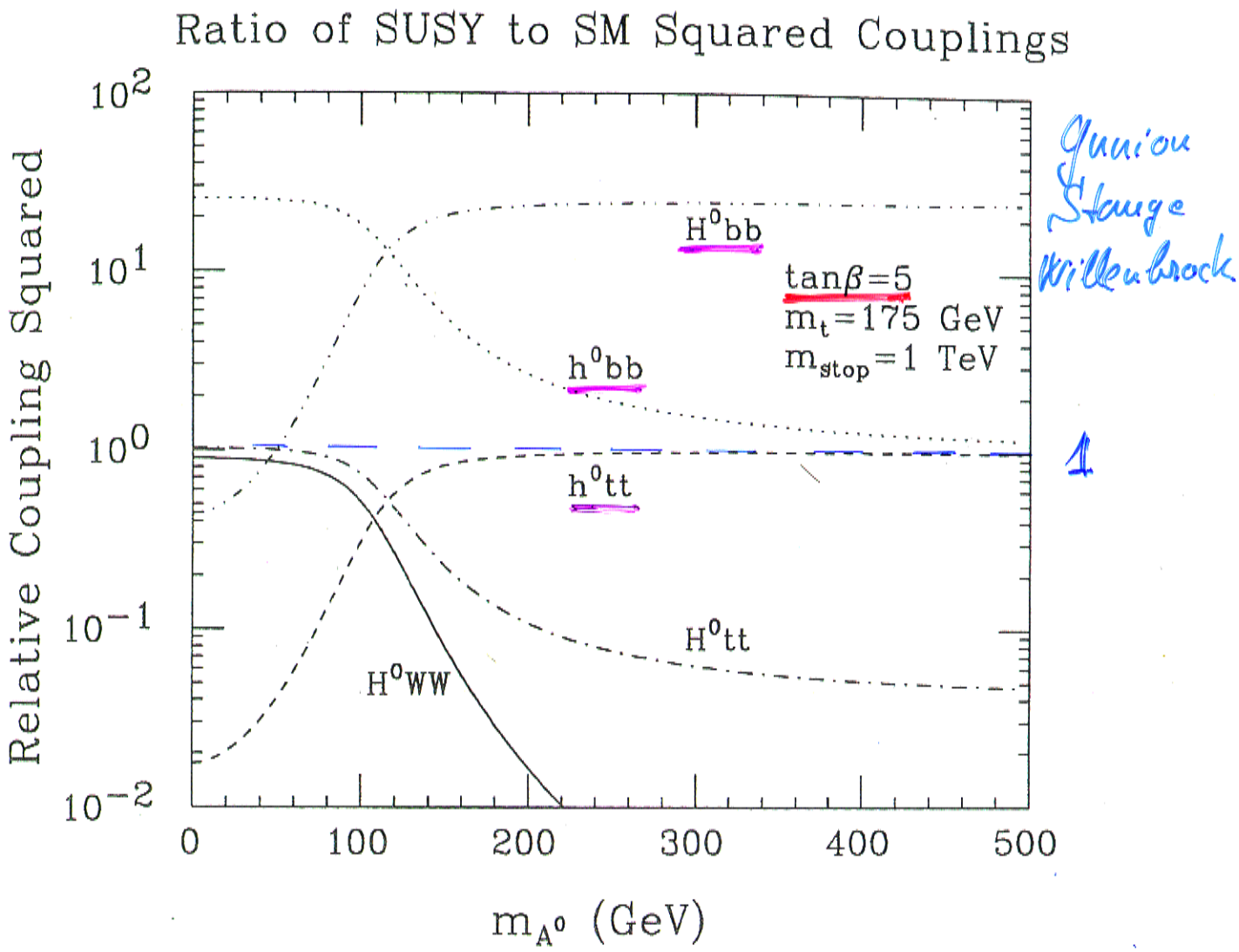
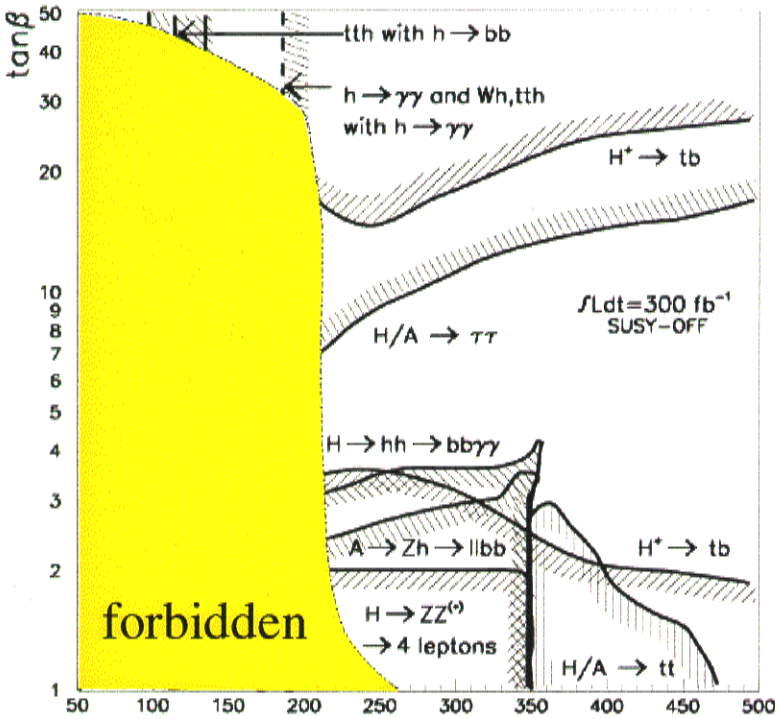


Figure 3: Ratios of SUSY Higgs squared couplings to the corresponding SM values as a function of m_{A^0} for the case of $\tan\beta = 5$, taking $m_t = 175$ GeV and $m_{\tilde{t}} = 1$ TeV. Two-loop/RGE-improved radiative corrections to the CP-even Higgs sector mass matrix are included and squark mixing is neglected.

If SUSY particles contribute (done in mSUGRA)

❶ SUSY-loops can enhance/suppress
$gg \to h/A/H$ and $h \to \gamma\gamma$

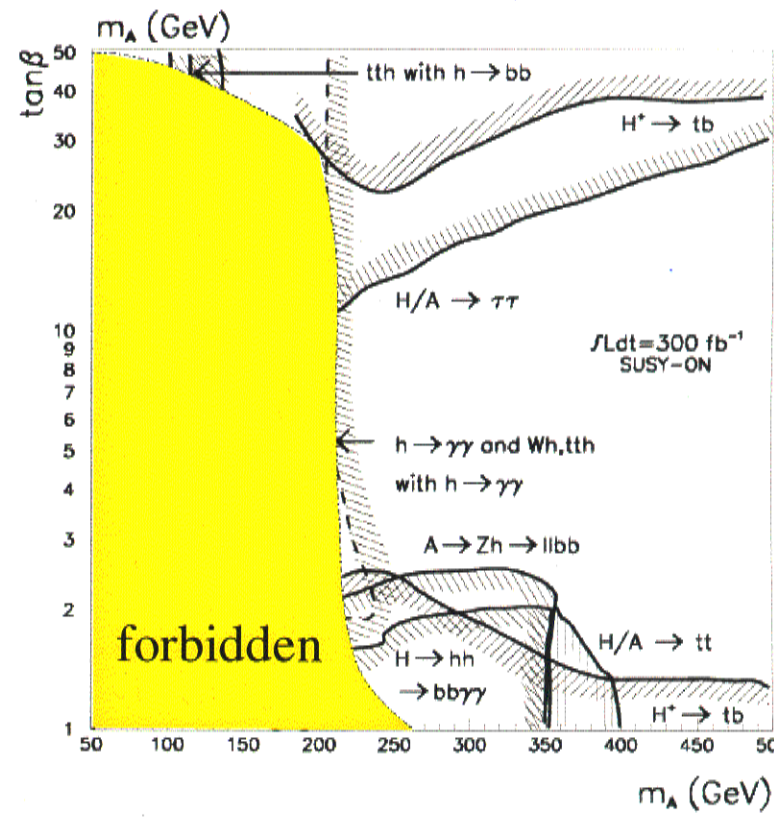


ATLAS , mSUGRA

SUSY OFF

SUSY ON

tt H is unaffected



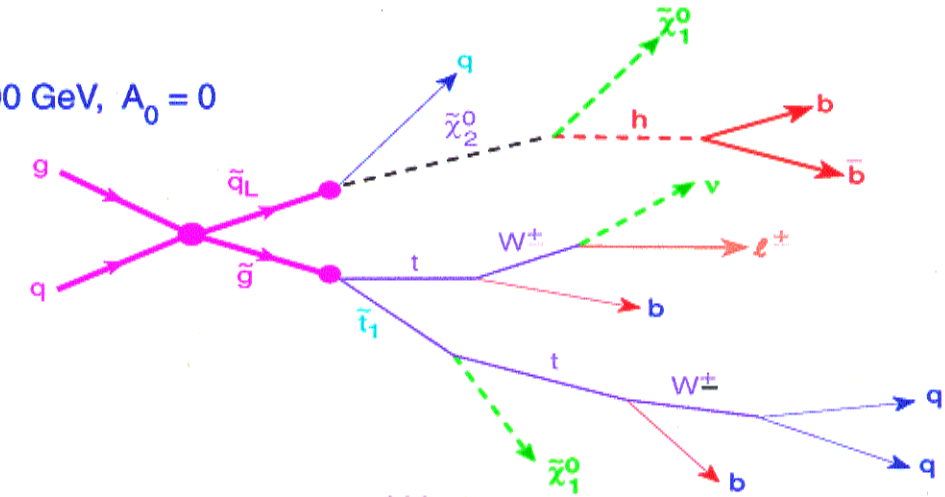
$h \rightarrow b\bar{b}$ production in massive $\tilde{q}$ and $\tilde{g}$ cascade decays

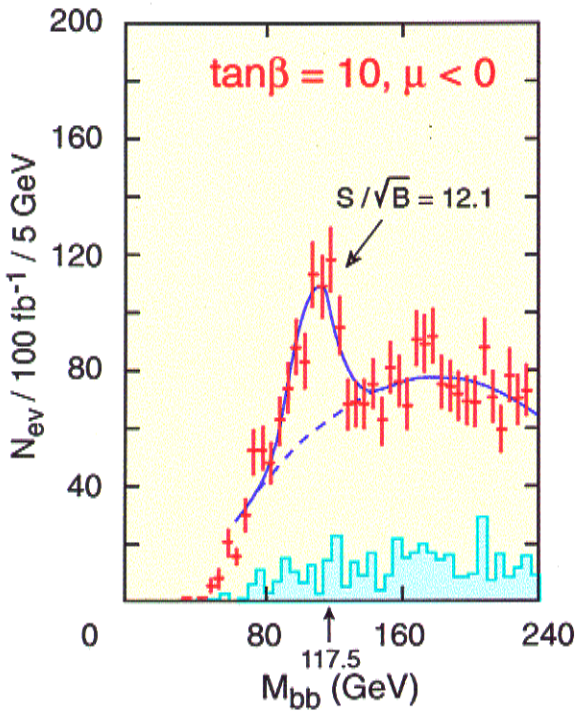
$h \rightarrow b\bar{b}$ production in massive $\tilde{q}$ and $\tilde{g}$ cascade decays

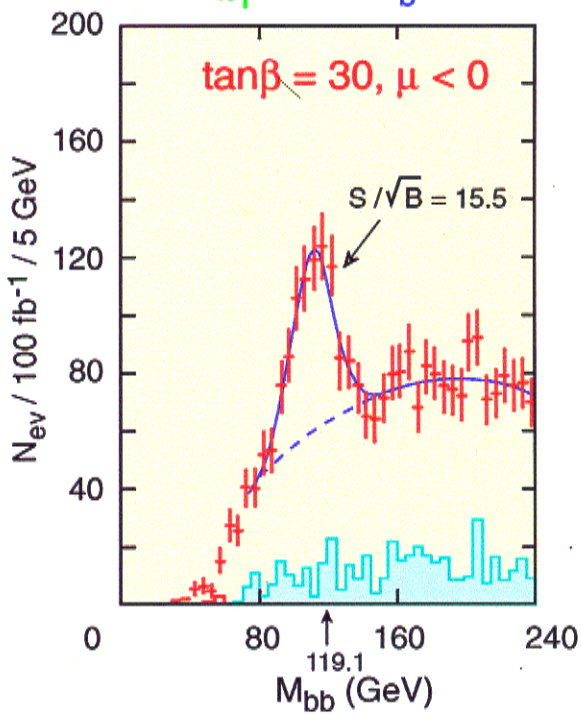
mSUGRA

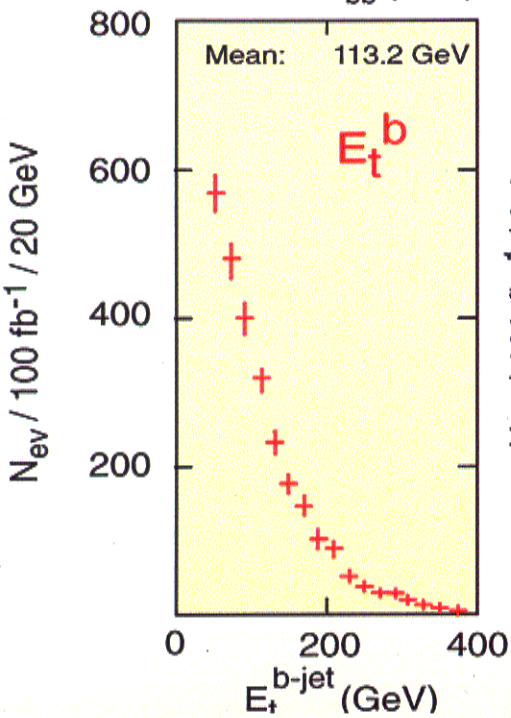
$m_0 = 500$ GeV, $m_{1/2} = 500$ GeV, $A_0 = 0$

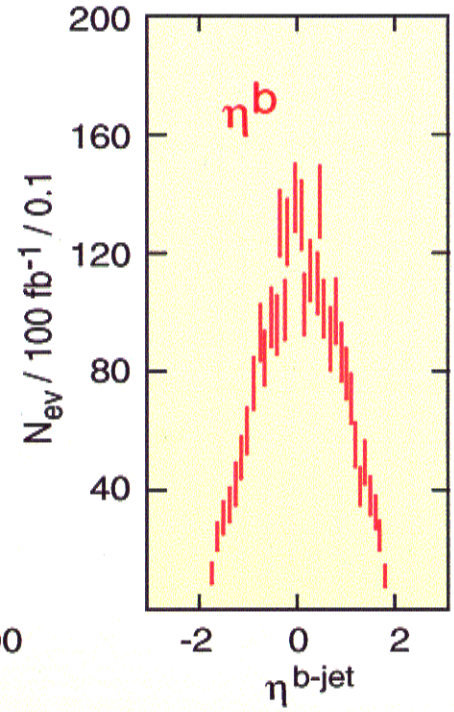
event topology:











→ b-jets are hard and very central

CMS Coll. Meeting 99-28

CMSIM figure

mSUGRA : $m_0 = 1000$ GeV, $m_{1/2} = 500$ GeV, $A_0 = 0$, $\tan\beta = 35$, $\mu > 0$

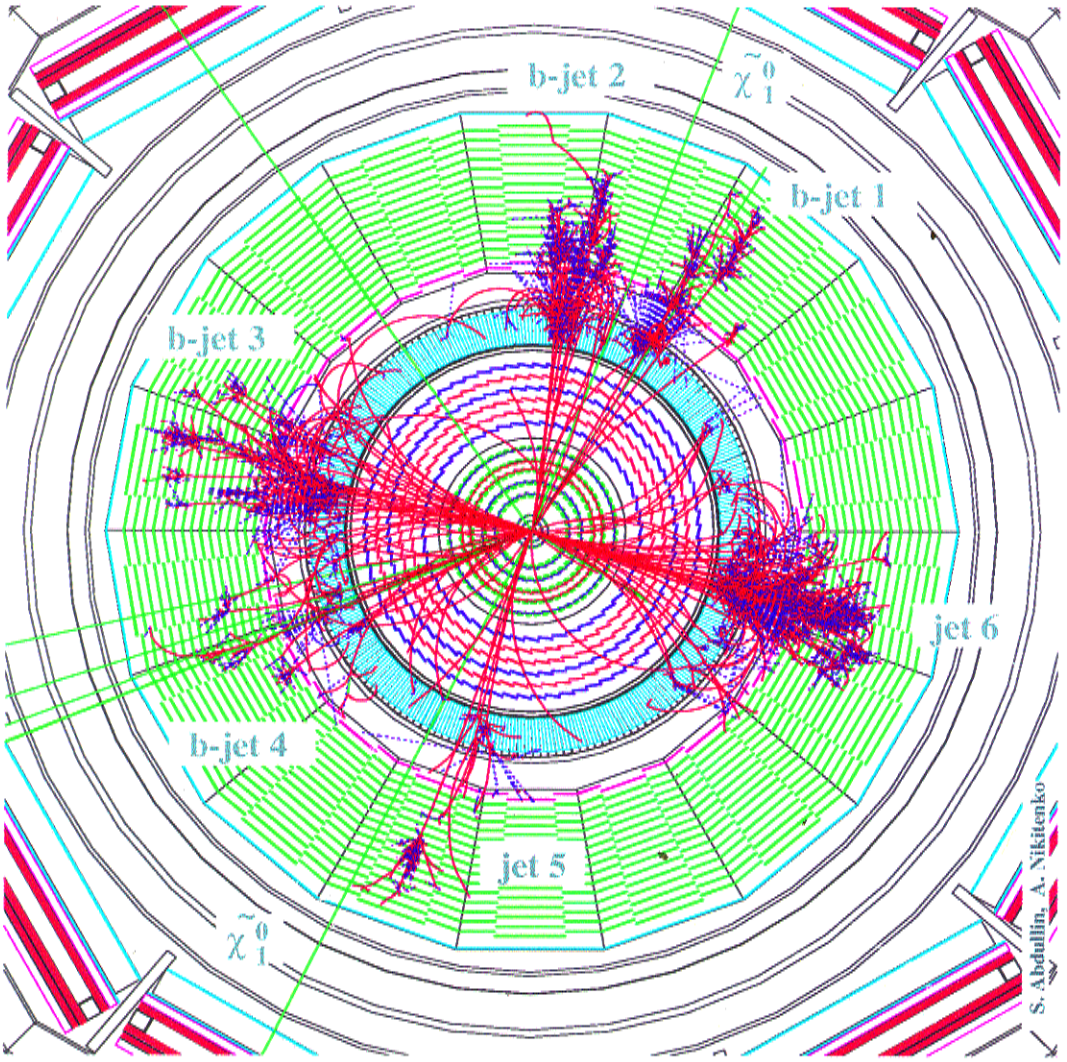
$\tilde{g} \rightarrow \tilde{t}_1 \, \bar{t}$

- $\tilde{t}_1 \rightarrow W^- + \bar{b}$ (jet4, $E_T = 113$ GeV)
  - $W^- \rightarrow s$ (jet5, $E_T = 79$ GeV) + $\bar{c}$
- $\tilde{t}_1 \rightarrow \tilde{\chi}_2^+ + b$ (jet3, $E_T = 536$ GeV)
  - $\tilde{\chi}_2^+ \rightarrow \tilde{\chi}_1^+ + Z \rightarrow \nu\,\bar{\nu}$
    - $\tilde{\chi}_1^+ \rightarrow \tilde{\chi}_1^0 + W^+ \rightarrow \tau^+ \nu$
      - $\tau^+ \rightarrow e^+ \nu$

$\tilde{u}_L \rightarrow \tilde{\chi}_2^0 + u$ (jet6, $E_T = 1196$ GeV)

- $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + h$
  - $h \rightarrow b$ (jet1, $E_T = 206$ GeV)
  - $h \rightarrow \bar{b}$ (jet2, $E_T = 320$ GeV)

$E_T^{miss} = 380$ GeV



$m_{\tilde{g}} = 1266$ GeV

$m_{\tilde{u}_L} = 1450$ GeV

$m_{\tilde{t}_1} = 1026$ GeV

$m_{\tilde{\chi}_2^0} = 410$ GeV

$m_{\tilde{\chi}_1^0} = 214$ GeV

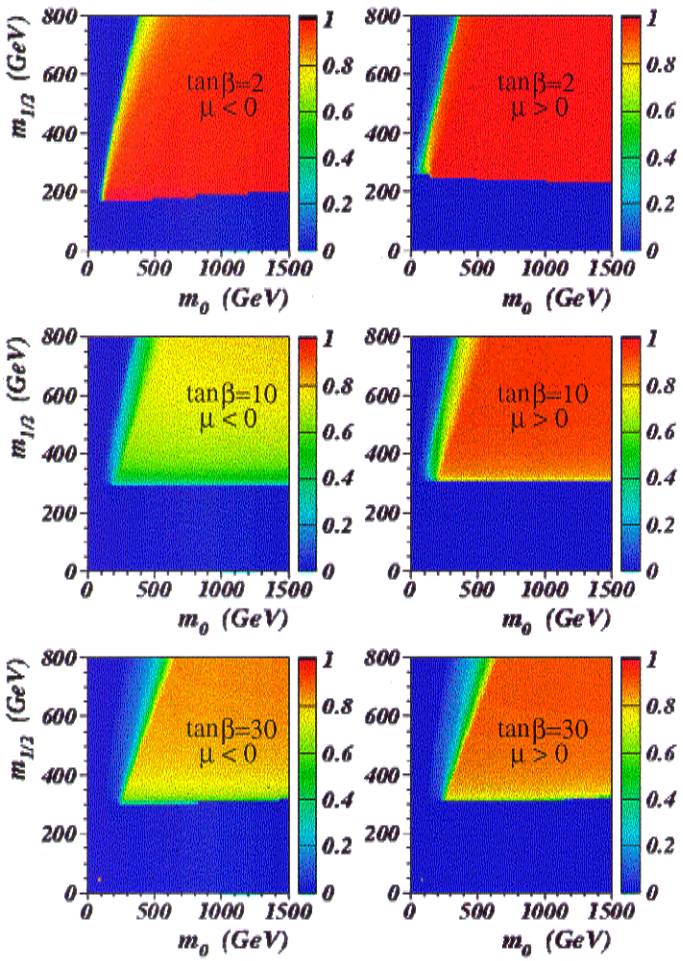
$m_h = 119$ GeV

Higgs production in cascades (mSUGRA)

- Main source : $\tilde{q}_L \xrightarrow{\sim 30\,\%} \tilde{\chi}^0_2\, q \xrightarrow{\sim 90\,\%} \tilde{\chi}^0_1\, h\, q \xrightarrow{\sim 80\,\%} \tilde{\chi}^0_1\, b\bar{b}\, q$

$Br(\tilde{\chi}^0_2 \rightarrow \tilde{\chi}^0_1 h)$

$\sigma Br(\tilde{\chi}^0_2 \rightarrow \tilde{\chi}^0_1 h \rightarrow \tilde{\chi}^0_1 b\bar{b})$ (pb)



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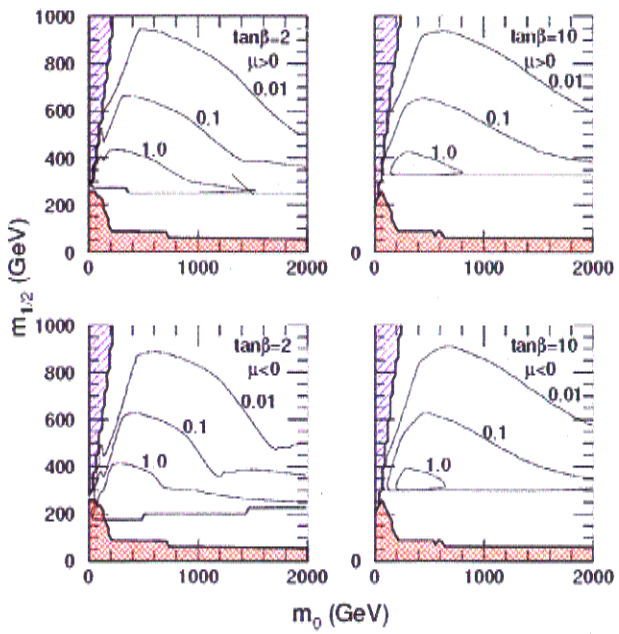
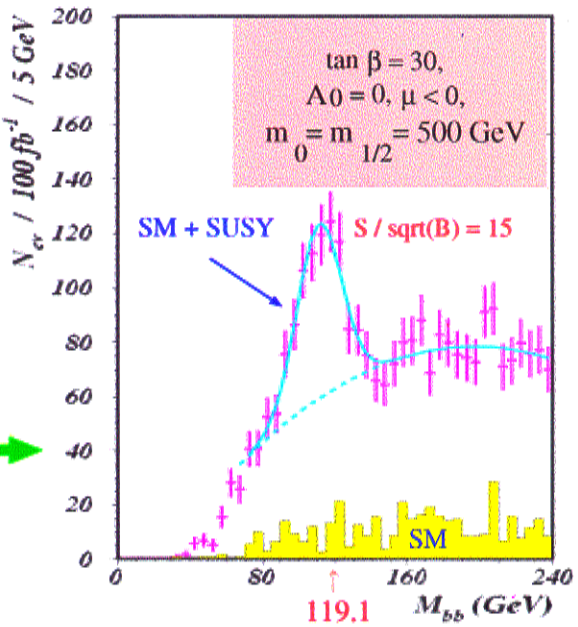


ATLAS TDR

$E_T^{miss} > 400$ GeV

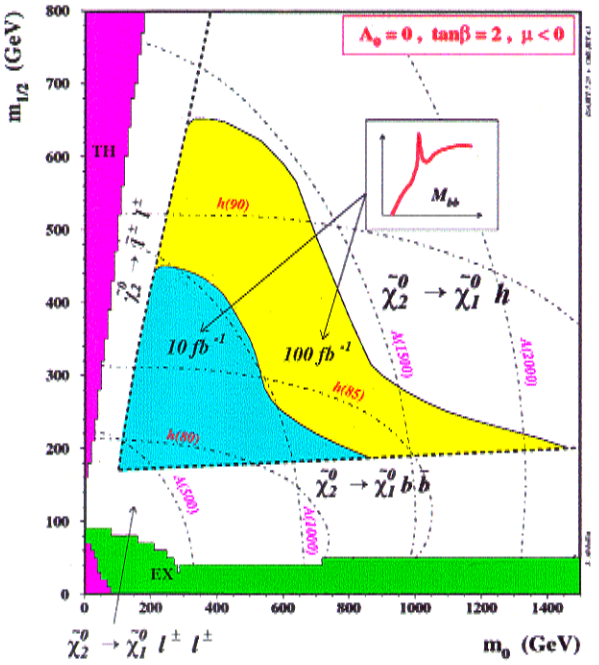
≥ 4 jets with $E_T^{jet} > 40$ GeV, $|\eta^{jet}| < 4.5$

≥ 2 b-jets (nominal CMS tagging performance in $|\eta| < 1.75$)



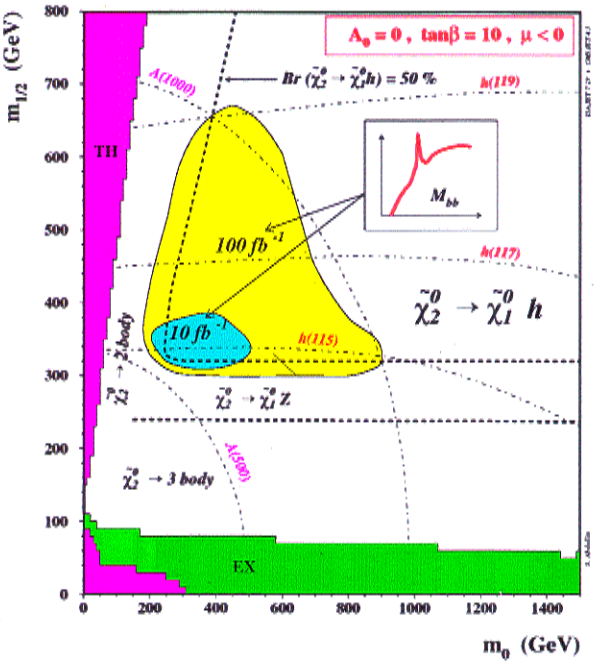
Domains of visibility of the $h \to b\bar{b}$ peak with nominal CMS performance in mSUGRA-SUSY

$S/\sqrt{B} > 5$



Domains of visibility of the $h \to b\bar{b}$ peak with nominal CMS performance in mSUGRA-SUSY

$S/\sqrt{B} > 5$



Domains of visibility of the $h \to b\bar{b}$ peak with nominal CMS performance in mSUGRA-SUSY

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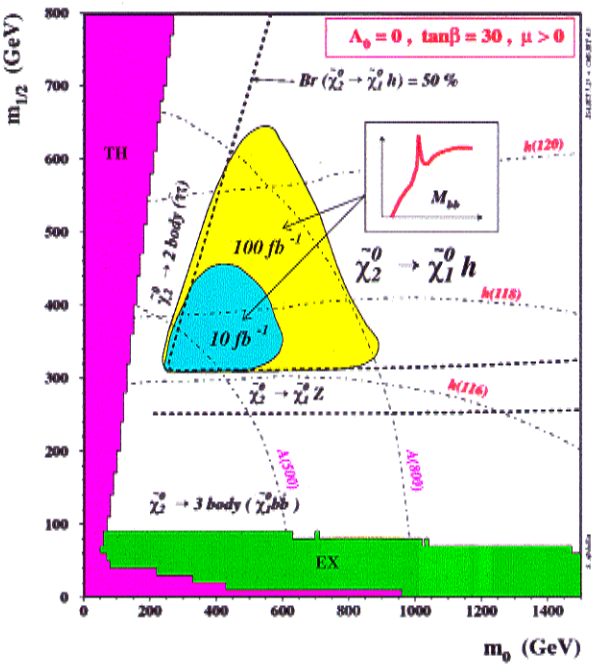
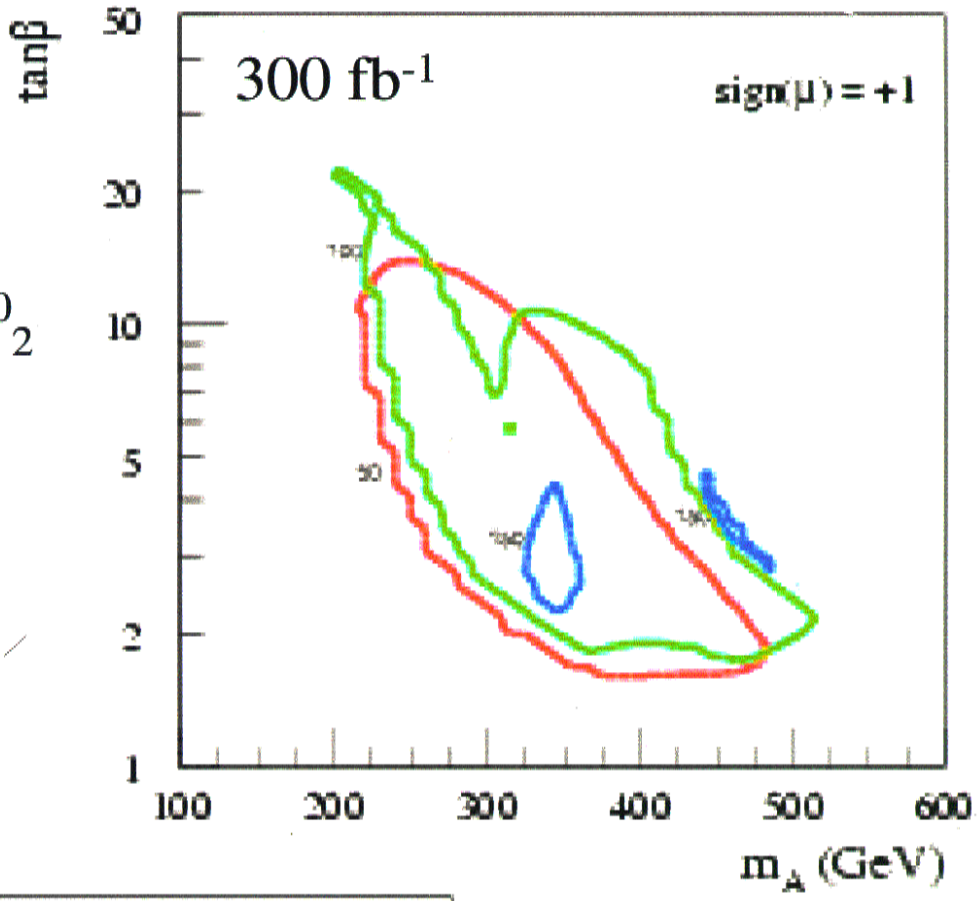


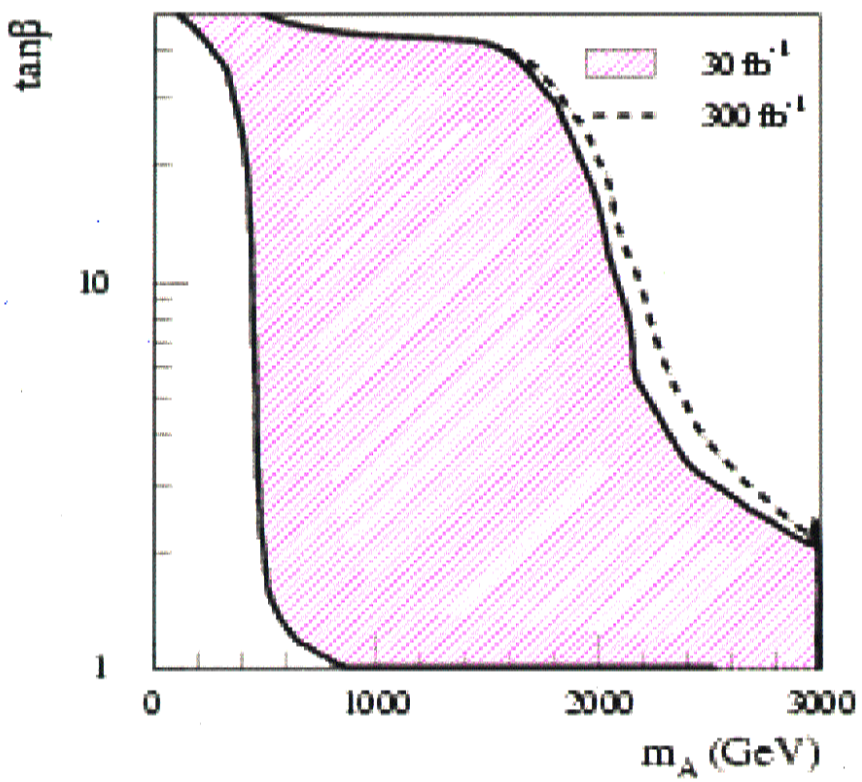
CMS NOTE 1997/ 070

❷ H/A/H± can decay to SUSY particles (h too light)

$H/A \to \chi^0_2 \chi^0_2$
$\to 4\,\ell\, \chi^0_1 \chi^0_1$

ATLAS



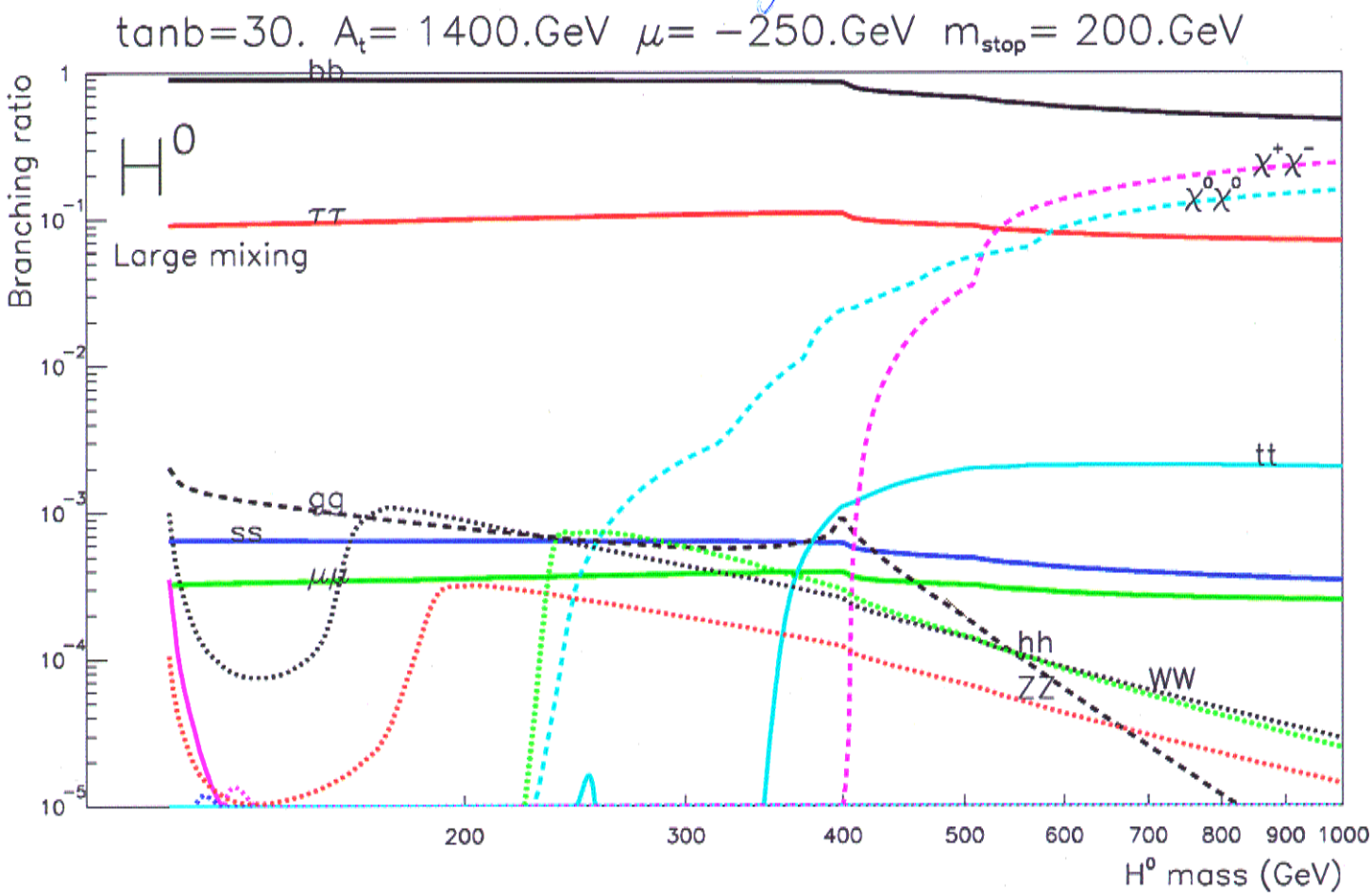


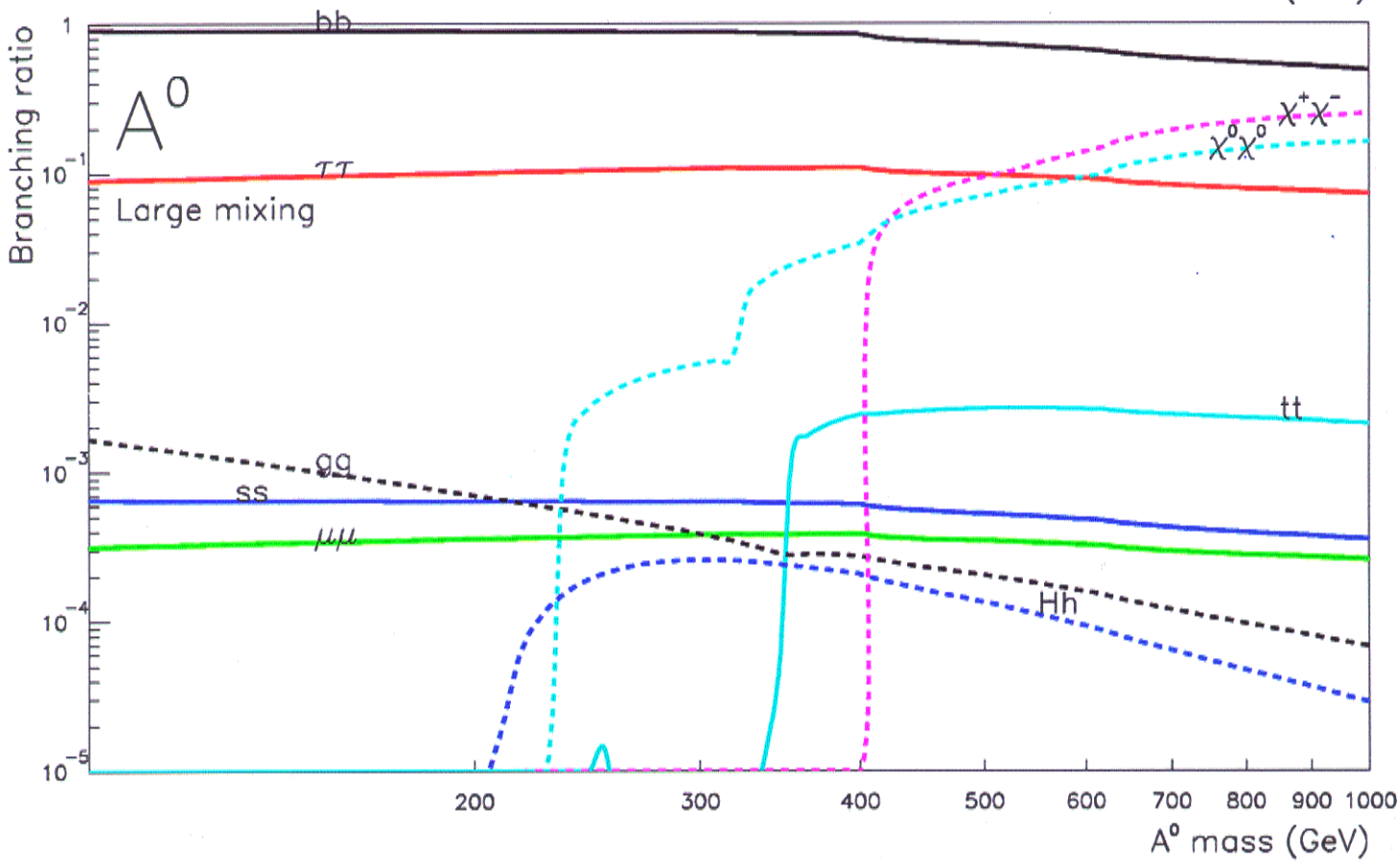
❸ h from SUSY decays (H/A/H± too heavy)

$h \to bb$ from
$\chi^0_2 \to h\, \chi^0_1$

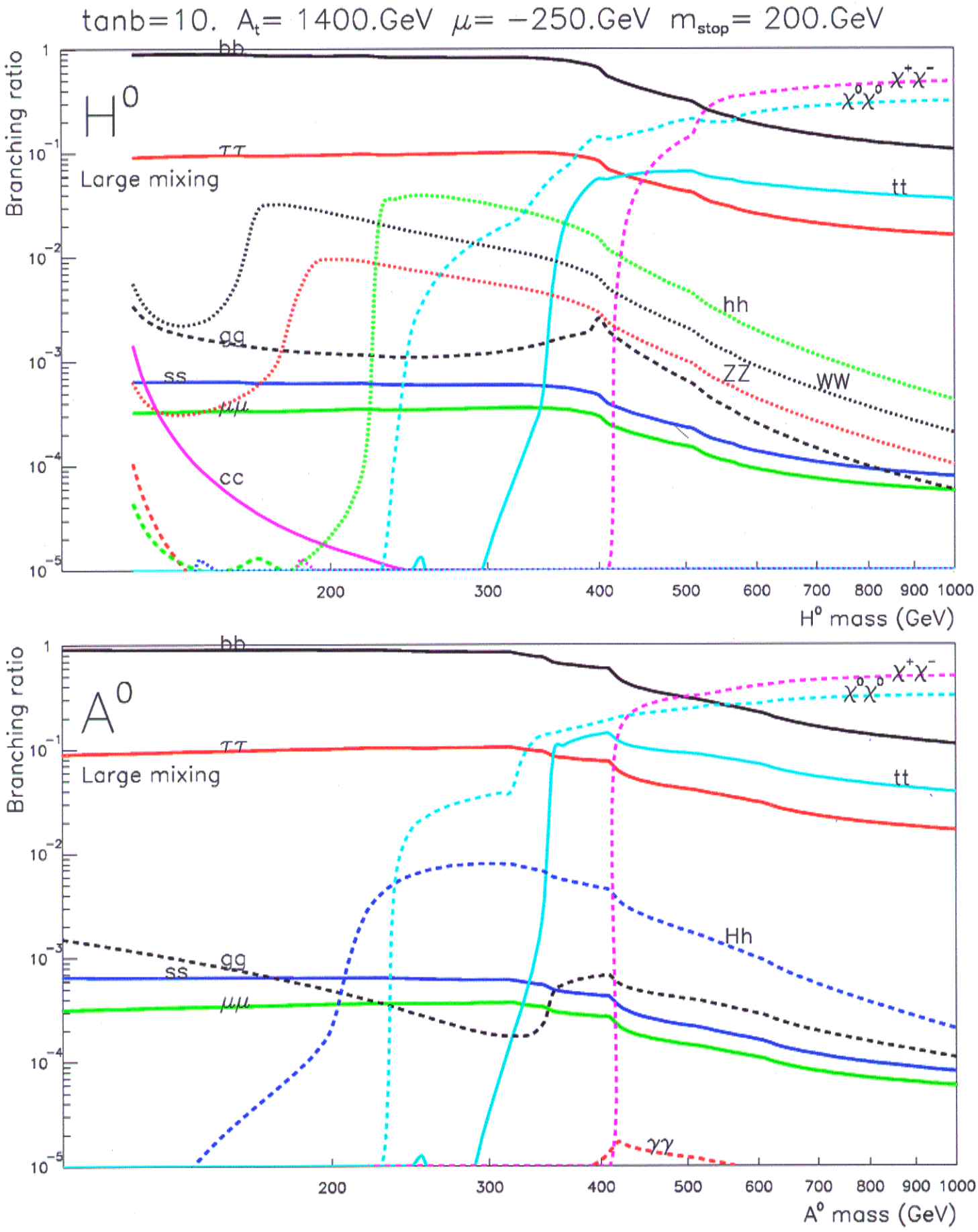
Cover regions where disentangling SM/MSSM difficult

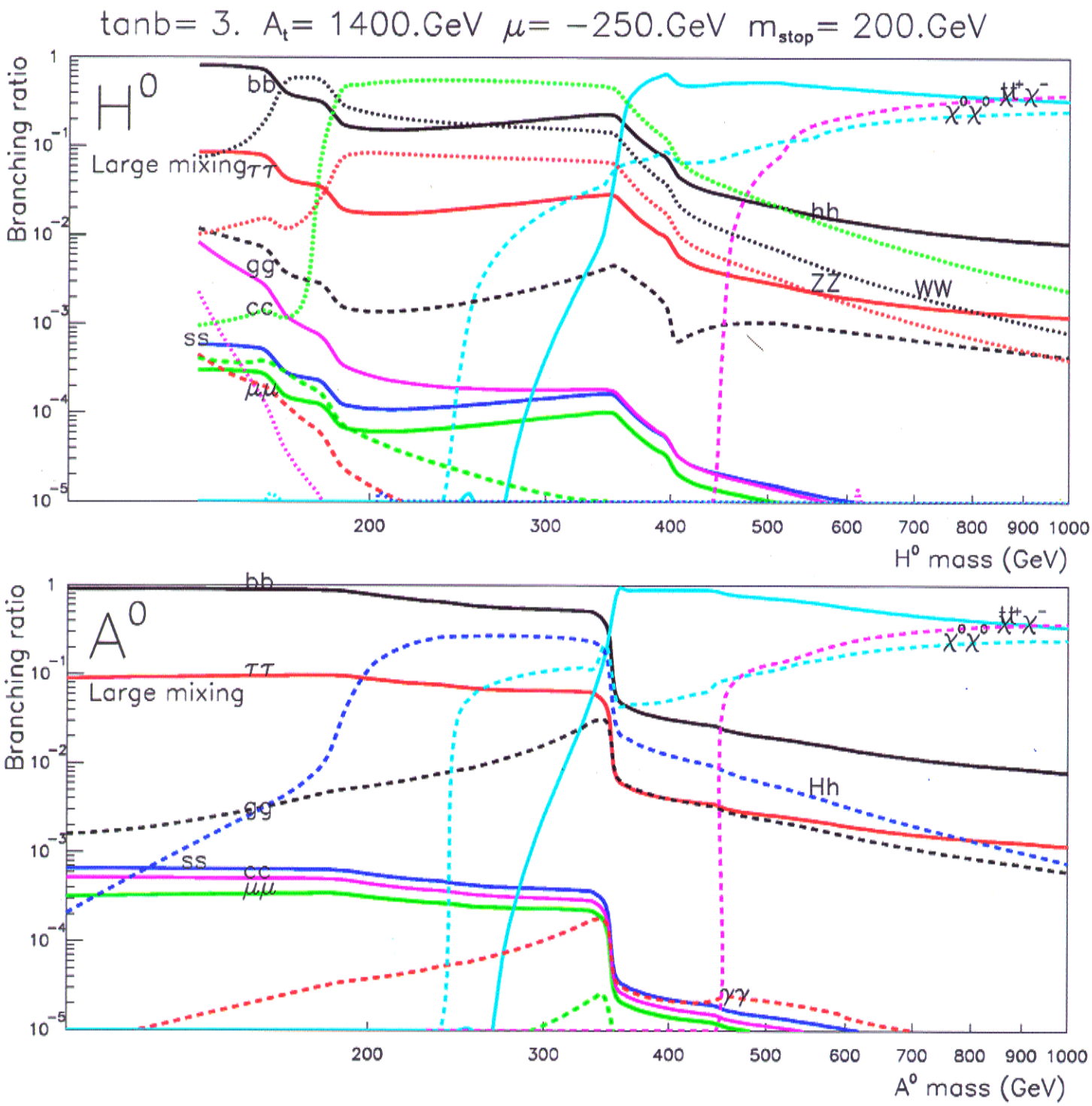
A, H Branching ratios, large $\tilde{t}$ mixing
light $\tilde{t}_1$





A, H Branching ratios, large $\tilde{t}$ mixing
light $\tilde{t}$




tanb= 3. A_t= 1400.GeV μ= −250.GeV m_{stop}= 200.GeV
H^0
Large mixing
bb
ττ
gg
cc
ss
μμ
hh
ZZ
WW
$\chi^0\chi^0$
$\chi^+\chi^-$
Branching ratio
H^0 mass (GeV)
A^0
Large mixing
bb
ττ
gg
ss
cc
μμ
Hh
γγ
$\chi^0\chi^0$
$\chi^+\chi^-$
Branching ratio
A^0 mass (GeV)

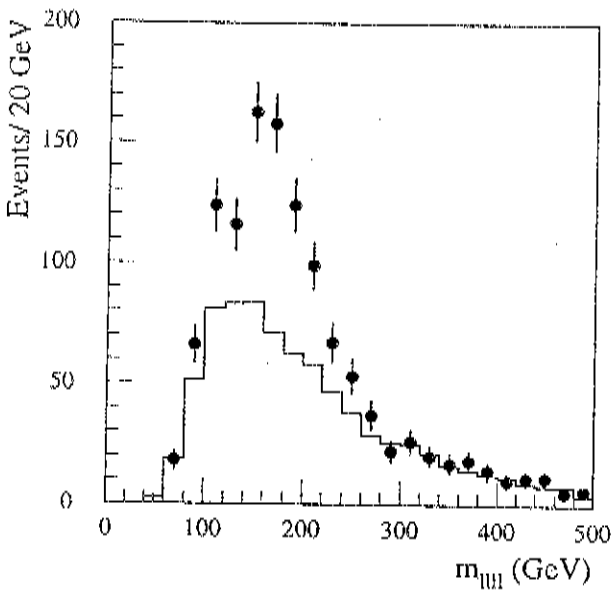
Heavy Higgs H/A decaying into charginos/neutralinos

$H/A \rightarrow \chi\chi \rightarrow$ 4 leptons + χ_0^1 (SUGRA)

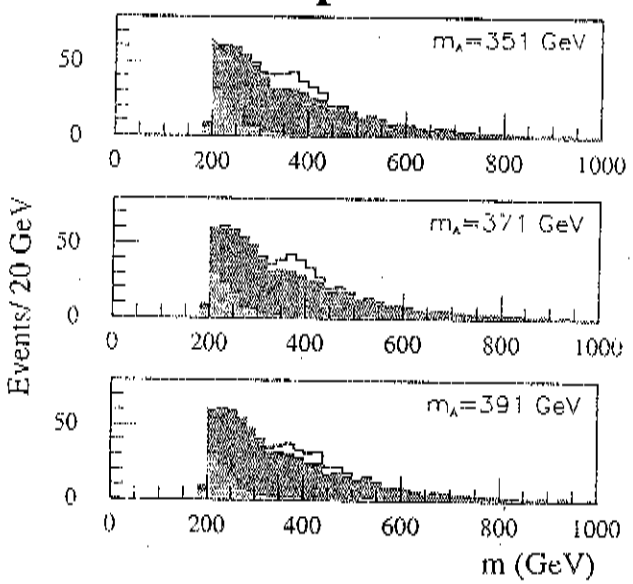
- 2 pairs of OS-SF leptons,
- thight jet veto to supress SM bgd.

for 300 fb^{-1} and SUGRA point3

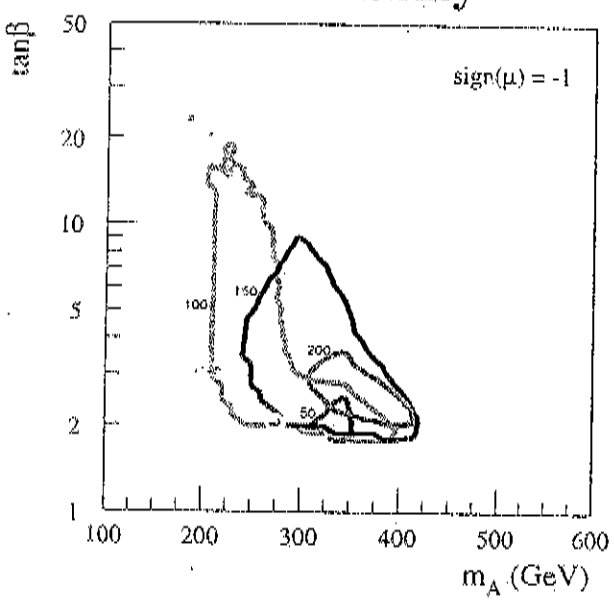
excess of events



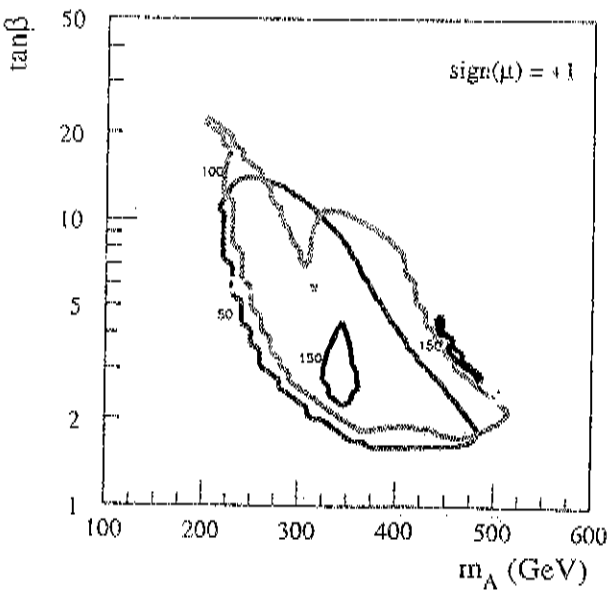
reconstr. possible



5σ observability



5σ observability



Conclusions

- The SM Higgs can be searched over the entire expected mass range ($m_H \sim 0.08$ to 1TeV) with a good safety factor

  - most demanding is $H \rightarrow \gamma\gamma$ for $90 \lesssim m_H \lesssim 130$ GeV
  - there is a "weak spot " at $m_H \approx 165 \pm 5$ GeV where the significance for a completely reconstructed mass peak is marginal, but the WW channel would allow unambiguous observation

  Precision measurements are possible:

  - the Higgs mass can be determined to a ~0.1% level
  - the Higgs width can be determined to a ~5-10% level
  - the σ*BR can be determined to a 5 - 10% level
  - ratios of Higgs couplings to fermions ($t\bar{t}$, $b\bar{b}$, $\tau\bar{\tau}$) and to vector bosons (WW, ZZ) can be determined from $gg \rightarrow H$, WH, qq qqH production, with decays to $\gamma\gamma$, 4l, $\tau\tau$, 2l2ν ...

- In the MSSM Higgs sector most of the parameter space (tgβ, m_A) can be explored with 10^5 pb^{-1}

  the region $3 < tg\beta \lesssim 10$, $120 \lesssim m_A \lesssim 220$ GeV is difficult, would require $> 10^5$ pb^{-1} or exploitation of $h \rightarrow b\bar{b}$ modes to be fully covered

  In the intermediate tgβ region disentangling SM and MSSM from Higgs measurements alone is hard with only h detectable in the decoupling limit

  In large portions of parameter space % level precision measurements of masses and tgβ are possible