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2001.2.10

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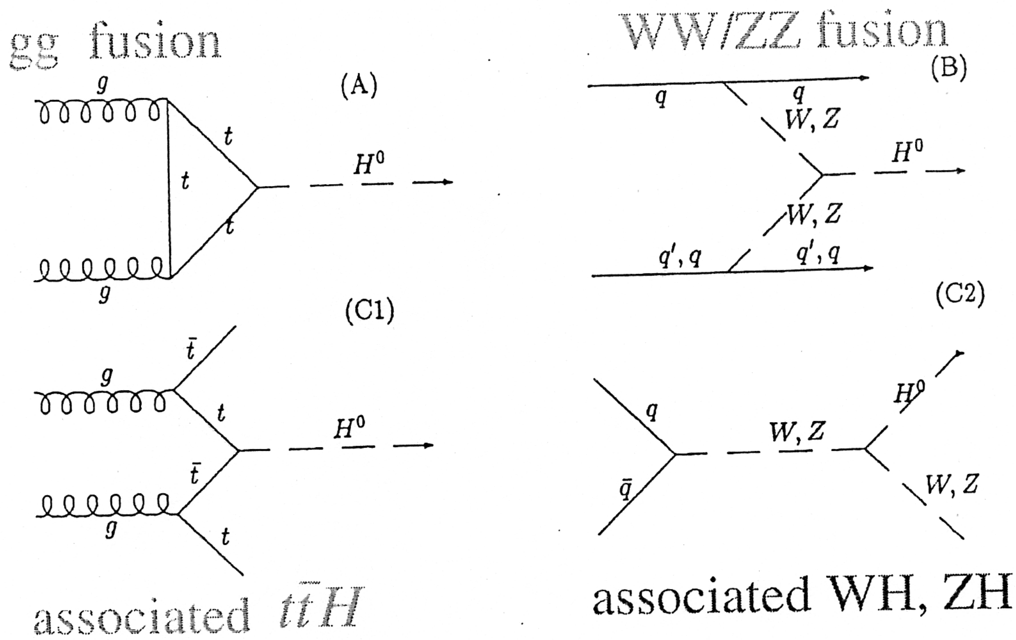
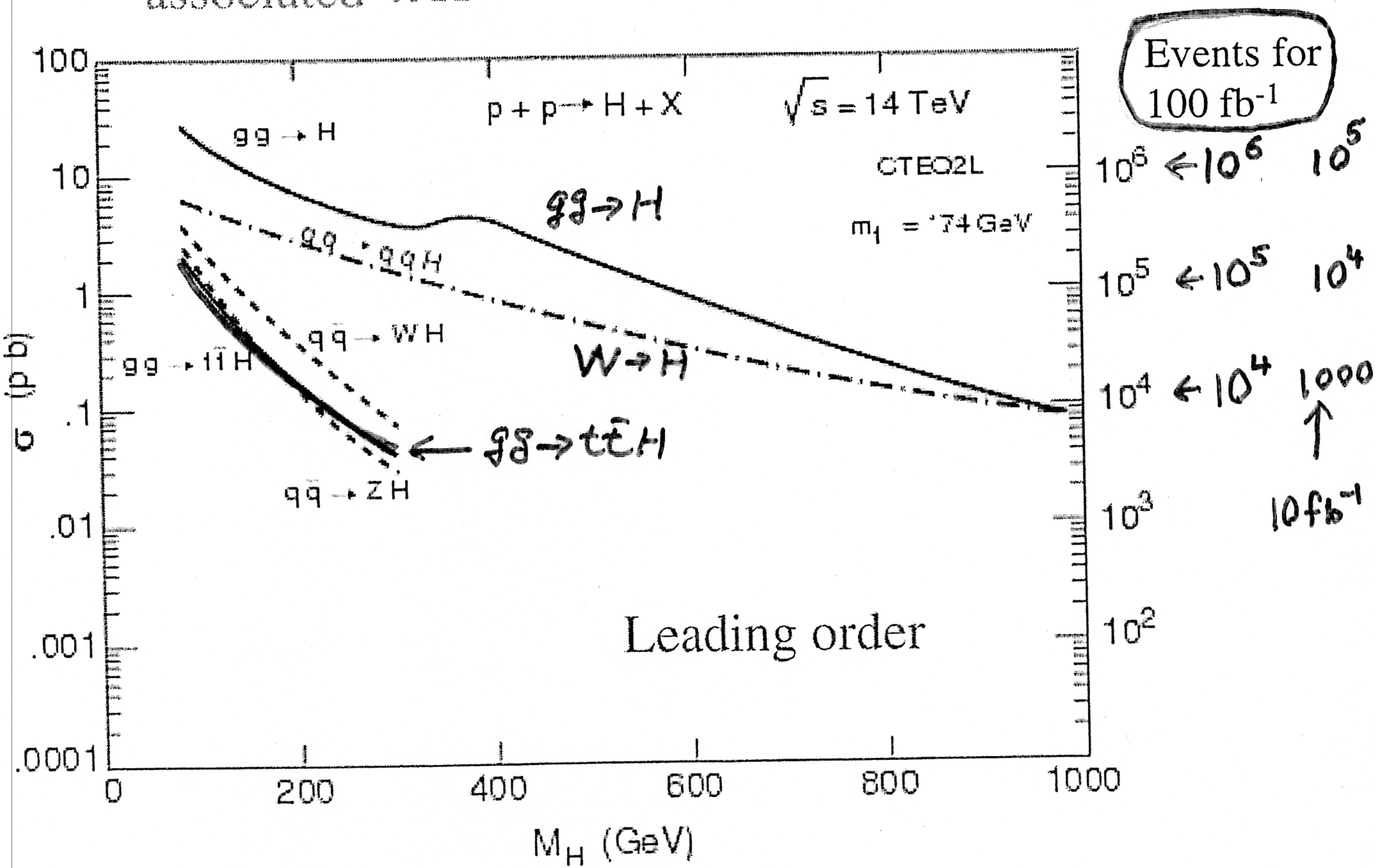
Fabi ola Gianotti

(1)
SM-1

SM Higgs production at LHC





- gg → H : K=1.6– 1.9 (not included)
- residual uncertainties on NLO cross-sections (PDF, NNLO, etc.) ≤ 20% (except ttH)

Fig (2)

SM-2

Main search channels at LHC

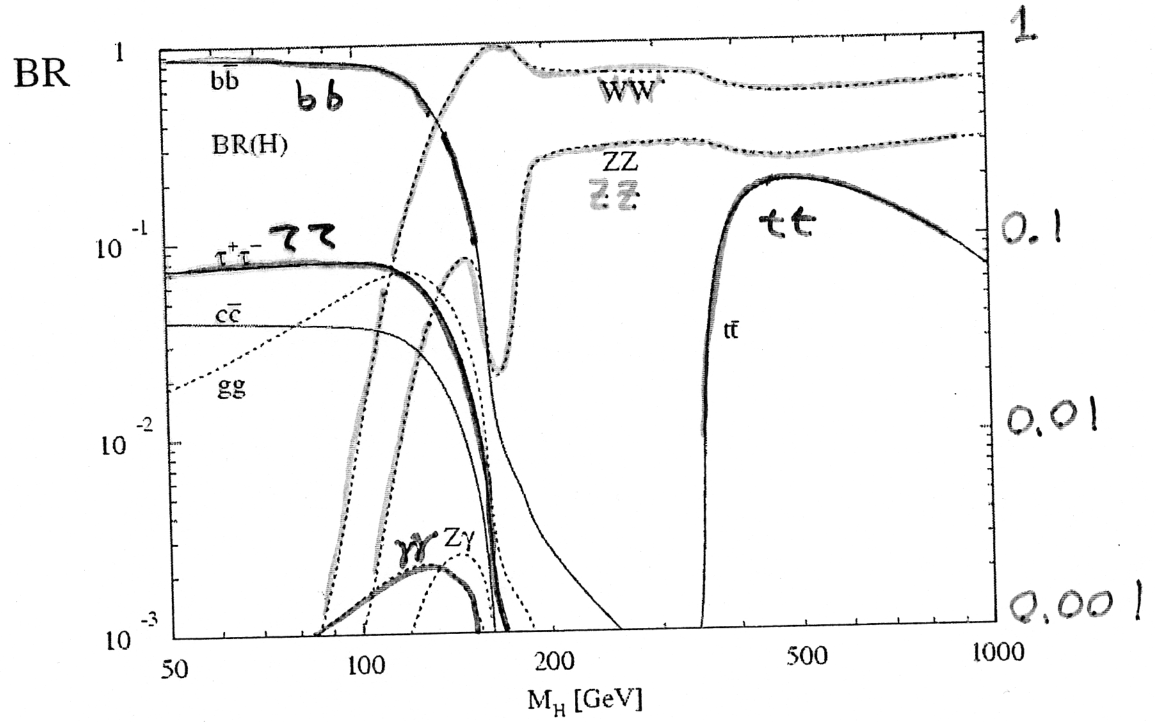
Large QCD backgrounds:

e.g. σ (H $\rightarrow b\bar{b}$) ≈ 20 pb   direct production, m_H =120 GeV

σ ($b\bar{b}$)   ≈ 500 μb

→ no hope to trigger / extract fully hadronic final states

→ look for final states with ℓ, γ (ℓ = e,μ)



$\underline{m_H < 2\, m_Z}$: $t\bar{t}H \rightarrow \ell b\bar{b} + X$, $H \rightarrow \gamma\gamma$,

$H \rightarrow ZZ^* \rightarrow 4\ell$, $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$

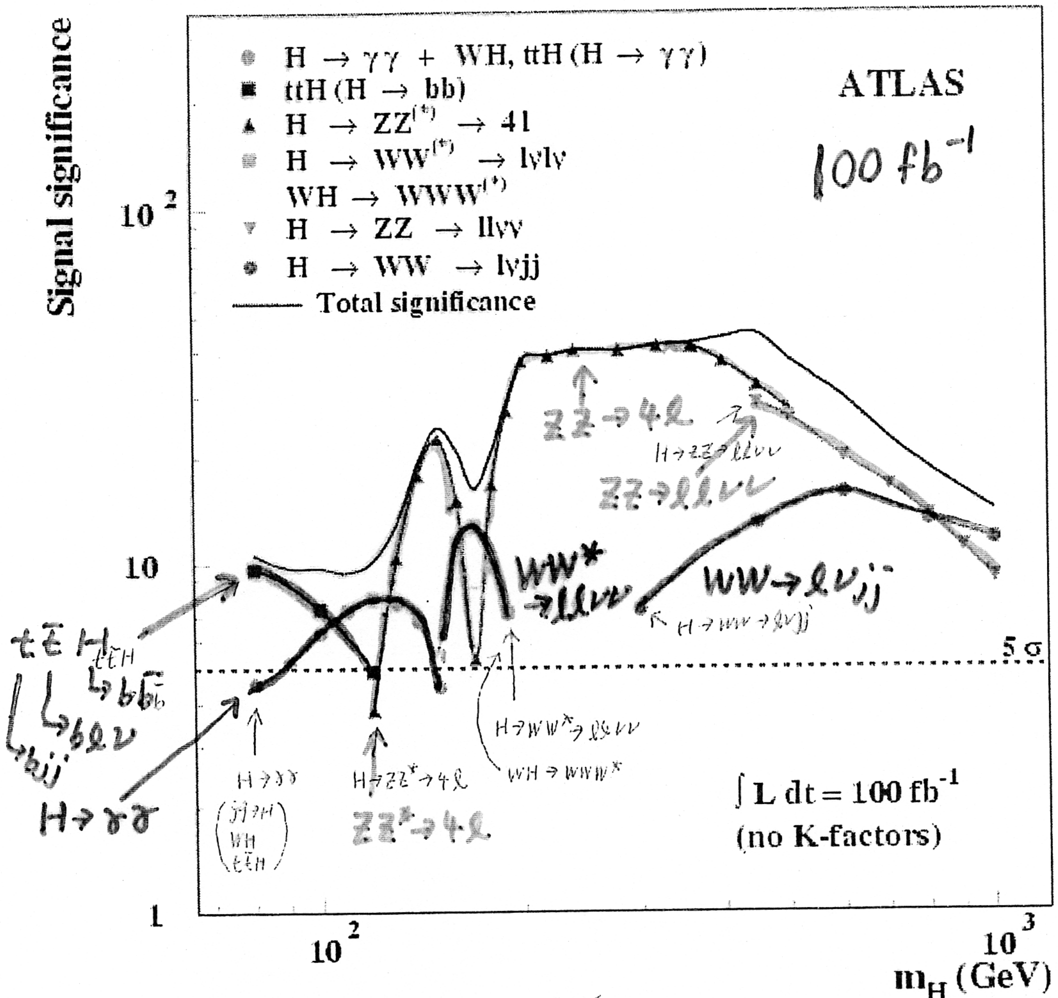
$\underline{m_H > 2\, m_Z}$: $H \rightarrow ZZ \rightarrow 4\ell$ (gold-plated)

$H \rightarrow ZZ \rightarrow \ell\ell\, \nu\nu$
$H \rightarrow ZZ \rightarrow \ell\ell\, jj$
$H \rightarrow WW \rightarrow \ell\nu jj$
} m_H > 300 GeV, forward jet tag

Detector performance is crucial: b-tag, ℓ/γ E-resolution, γ/j separation, E_T^{miss} resolution, forward jet tag, etc.

Fig (3) SM-3

Overall discovery potential for SM Higgs



VV Fusion: 100 – 130 GeV H → τ⁺τ⁻ → e^±μ^∓ p̸_T ; 130 – 200 GeV H → WW* → e^±μ^∓ p̸_T } D. Zeppenfeld et al.

m_H < 180 GeV : many complementary channels (γγ, bb, 2 , 3 , 4 , etc.)

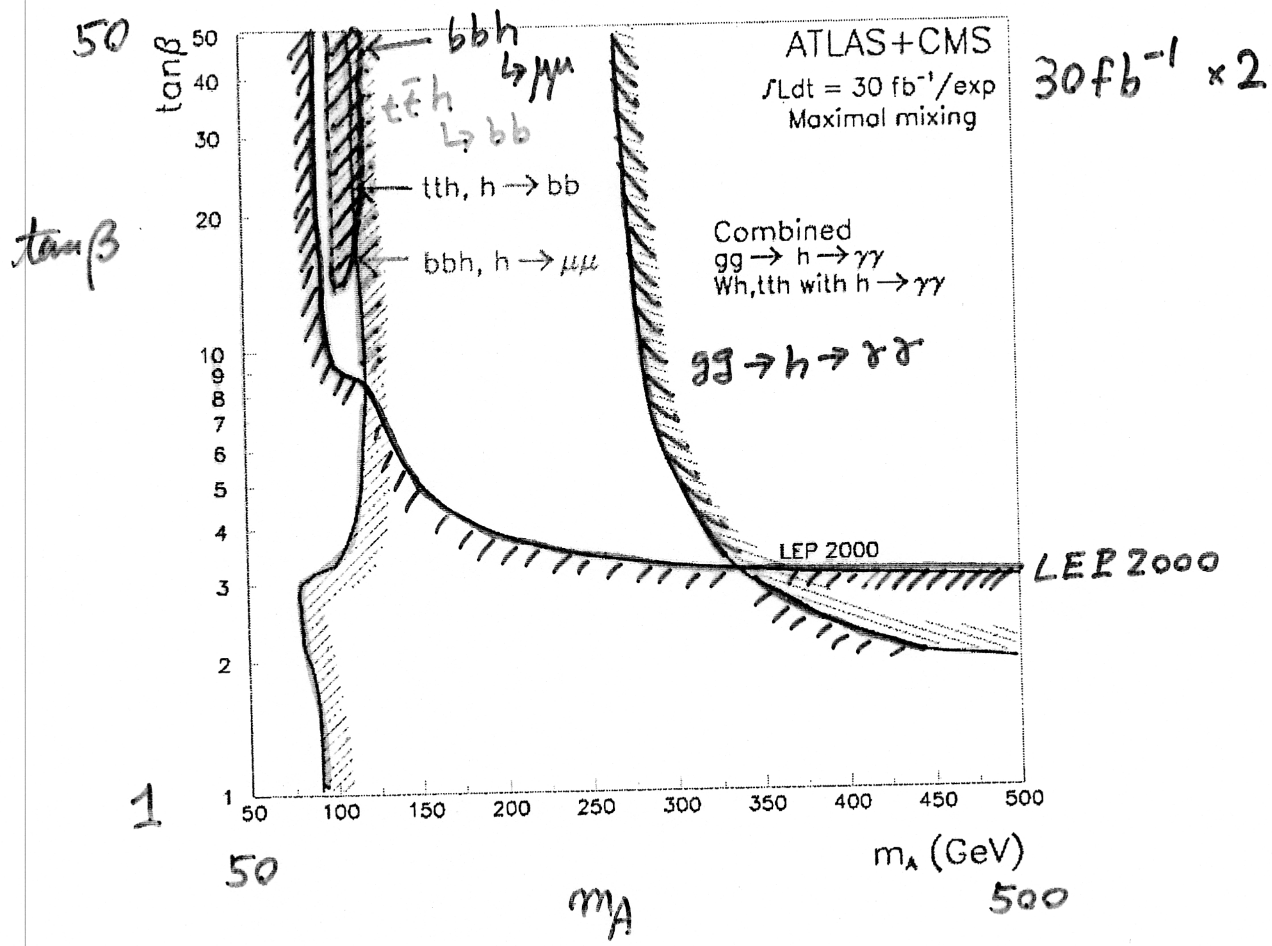
m_H > 180 GeV : discovery is straightforward with gold-plated H → ZZ → 4 (S/B > 5). Complemented by H → WW → ν jj, H → ZZ → νν, jj (forward jet tag)

> 1 channel observable over most of range → robustness, measurement of couplings

MSSM-1

Fig (4)

h boson



m_A > 100 GeV:

-- h mass close to max value (~ 130 GeV)

-- h behaves as SM Higgs → SM production and decay modes

m_A < 100 GeV:

-- h mass decreases

-- BR (h → γγ) and $t\bar{t}h$ production suppressed

-- large tanβ : bbh production enhanced → bb μμ channel observable

Robust coverage:

-- different production mechanisms : gg → h (loops), Wh, $t\bar{t}h$

-- different decays : h → γγ (loops), h → $b\bar{b}$

h/H couplings in the MSSM

Michael Spira

Michael Spira

hep-ph/9705337 (1)

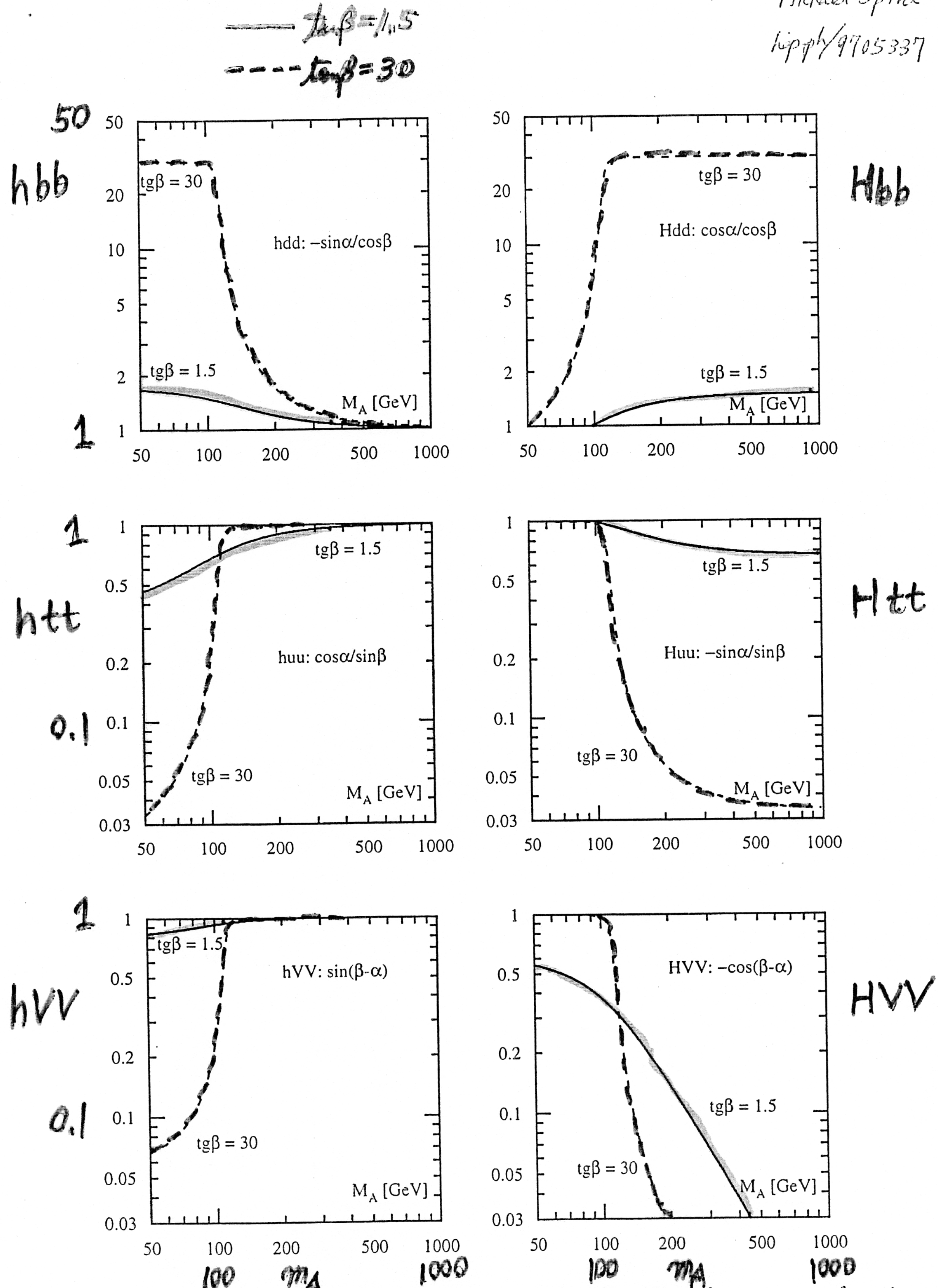


Figure 2: *The coupling parameters of the neutral MSSM Higgs bosons as a function of the pseudoscalar mass M_A for two values of $tg\beta = 1.5, 30$ and vanishing mixing. They are defined in Table 1.*

6

h/H production cross sections in the MSSM

MS (5)

$\tan\beta = 1.5$

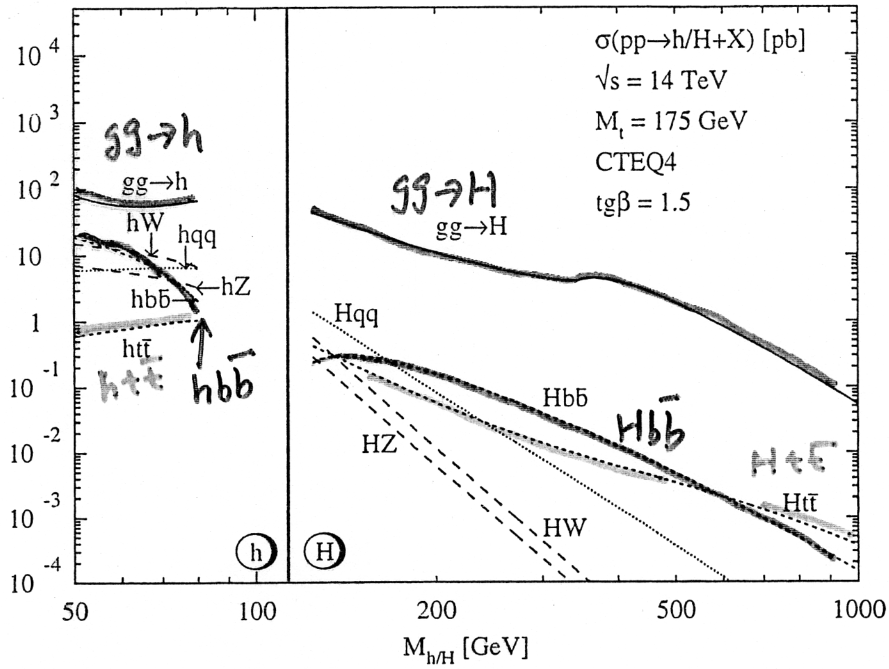


Fig. 54a

$\tan\beta = 30$

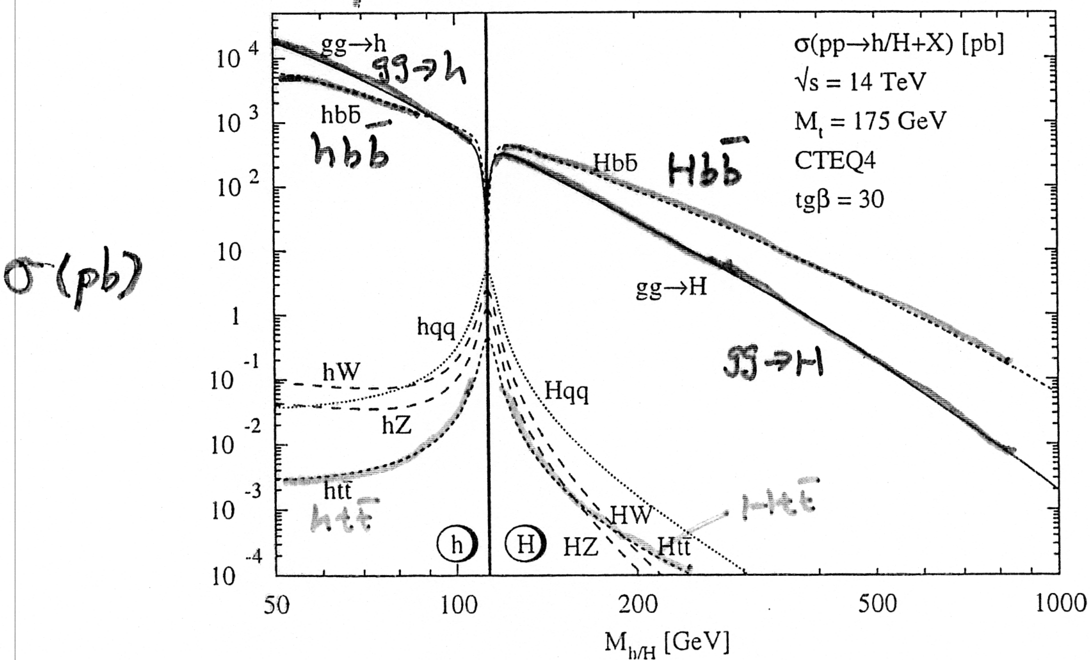


Fig. 54b

Figure 54: *Neutral MSSM Higgs production cross sections at the LHC [$\sqrt{s} = 14$ TeV] for gluon fusion $gg \to \Phi$, vector-boson fusion $qq \to qqVV \to qqh/qqH$, vector-boson bremsstrahlung $q\bar{q} \to V^* \to hV/HV$ and the associated production $gg, q\bar{q} \to \Phi b\bar{b}/\Phi t\bar{t}$ including all known QCD corrections. (a) h, H production for $tg\beta = 1.5$, (b) h, H production for $tg\beta = 30$, (c) A production for $tg\beta = 1.5$, (d) A production for $tg\beta = 30$.*

h/H decay branching in MSSM

MS(2)

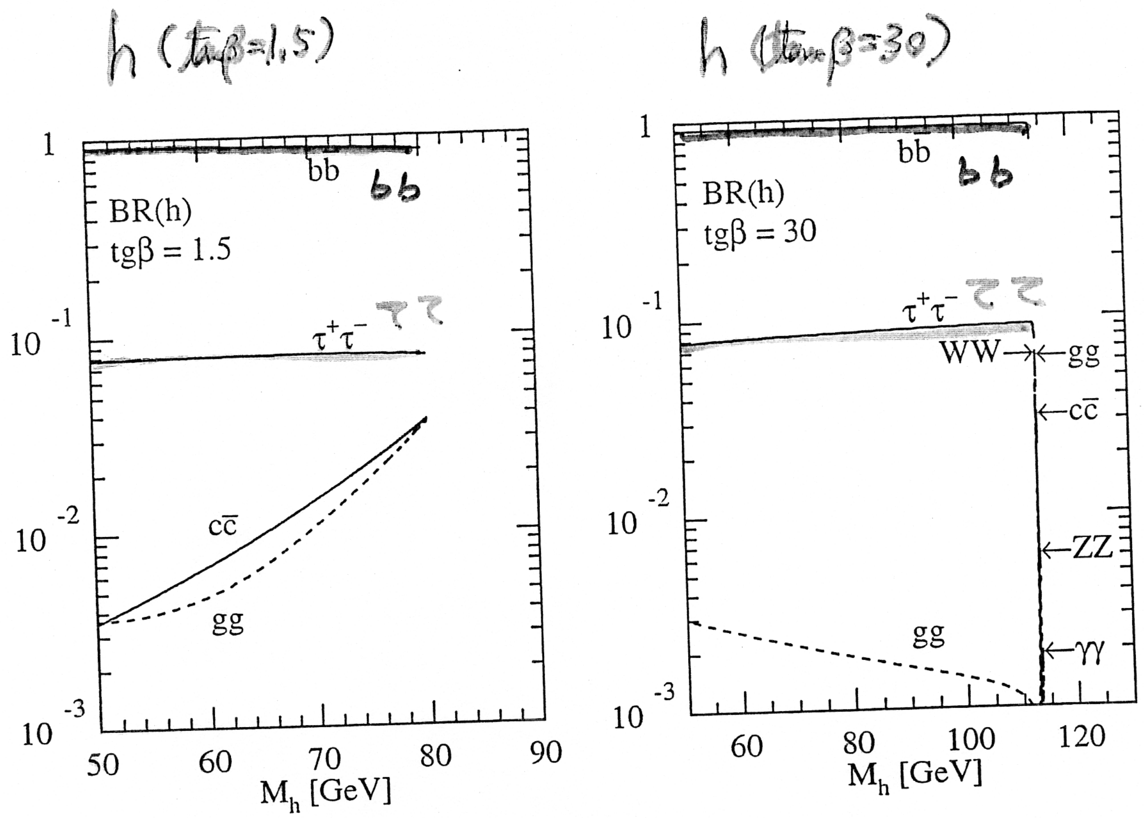


Fig. 42a

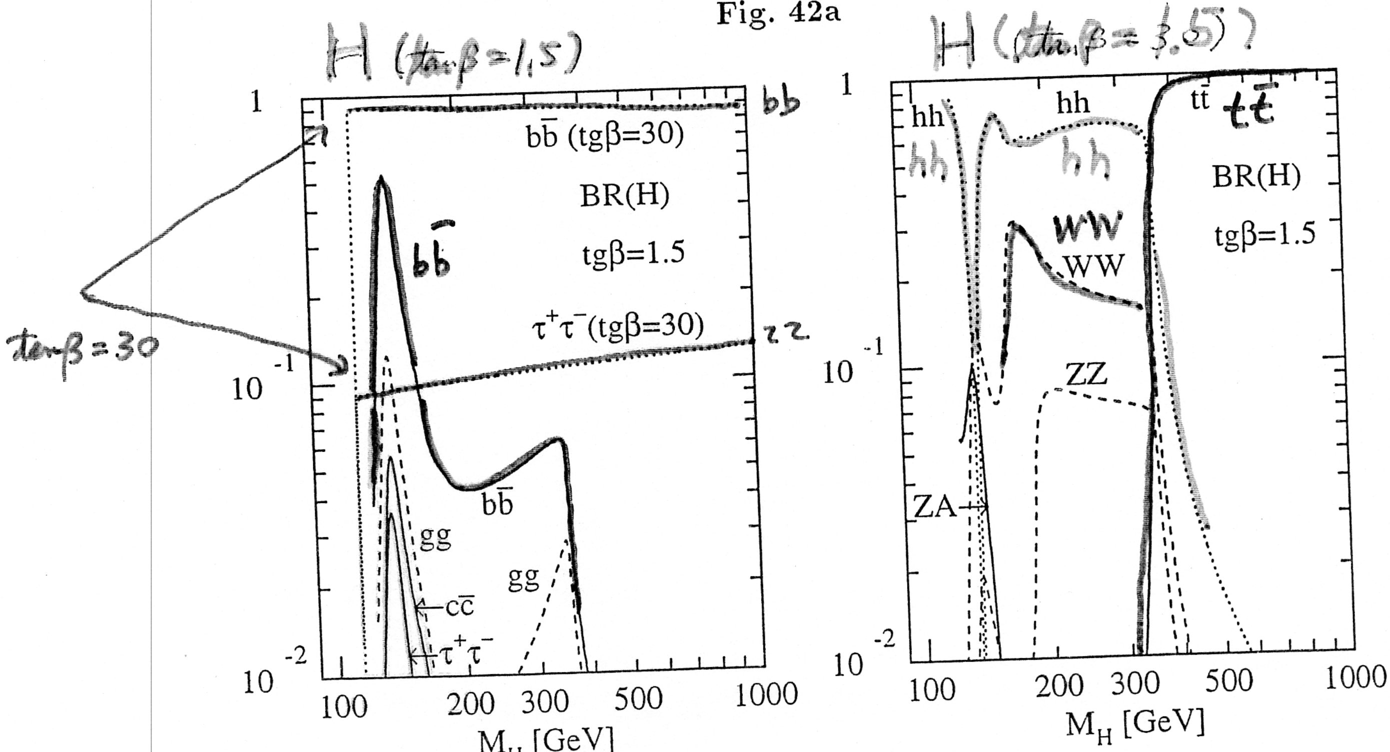


Fig. 42b

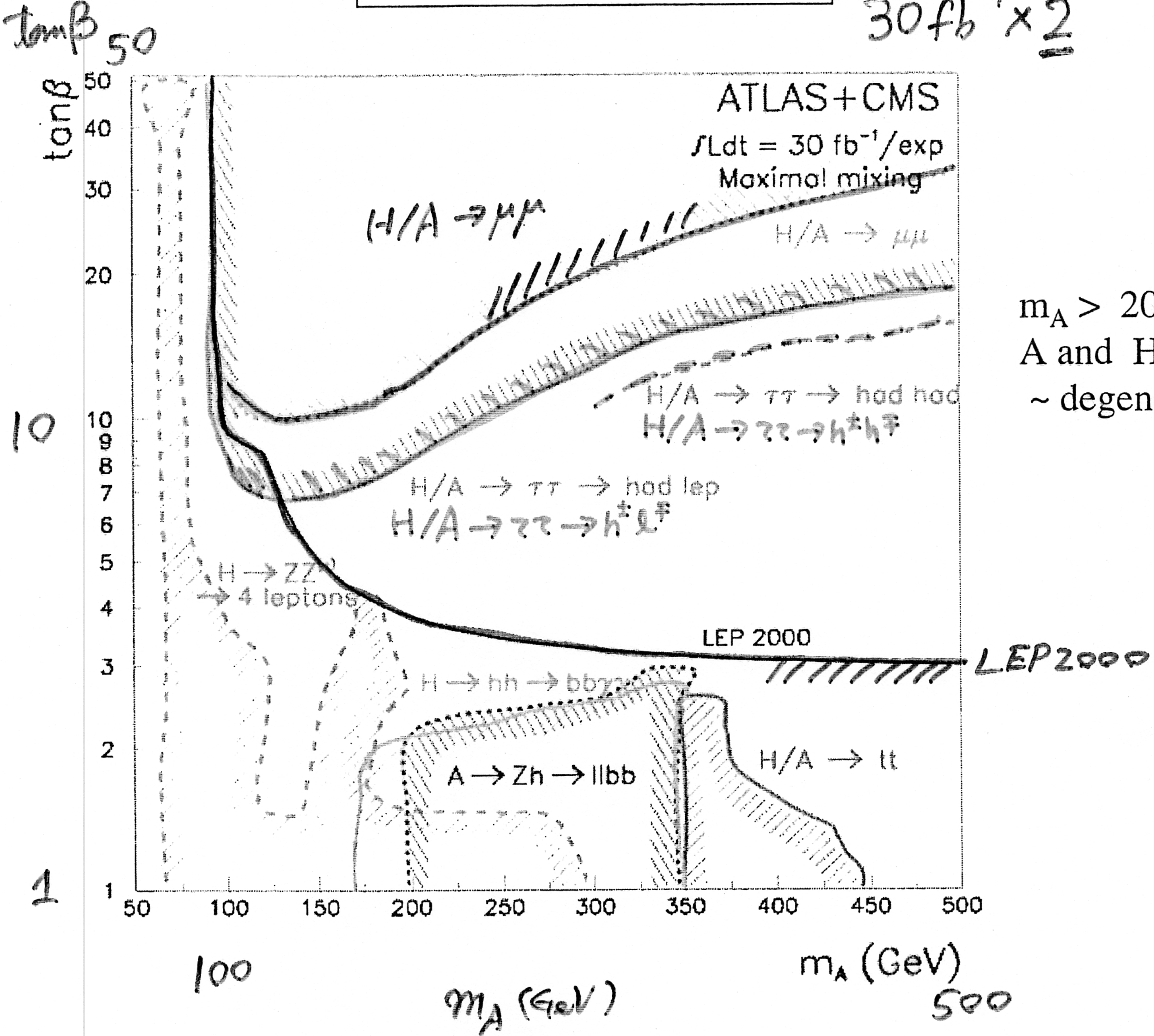
Figure 42: *Branching ratios of the MSSM Higgs bosons $h(a), H(b), A(c), H^{\pm}(d)$ for non-SUSY decay modes as a function of their masses for two values of $tg\beta = 1.5, 30$ and vanishing mixing. The common squark mass has been chosen as $M_S = 1$ TeV.*

FG (5)

MSSM-2

A and H bosons

30 fb^{-1} x 2



$m_A > 200$ GeV: A and H are ~ degenerate

- Large tanβ : $b\bar{b}H, b\bar{b}A$ strongly enhanced
  e.g. σ (MSSM) / σ (SM) ≈ 5000 tanβ =30, m =300 GeV

⇨ H/A → ττ, μμ observable and cover large part of parameter space

- Small tanβ : large number of channels
  → measurement of many couplings including Hhh, AZh

MS ⊕

A production cross section in MSSM

tanβ = 1.5

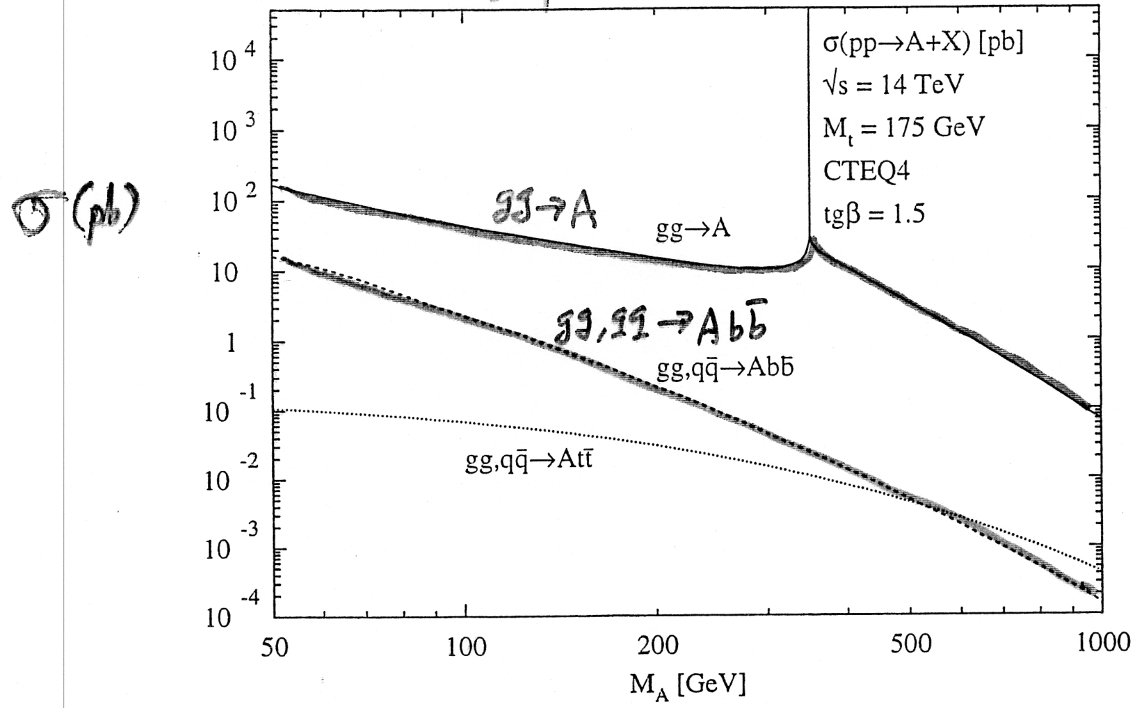


Fig. 54c

tanβ = 30

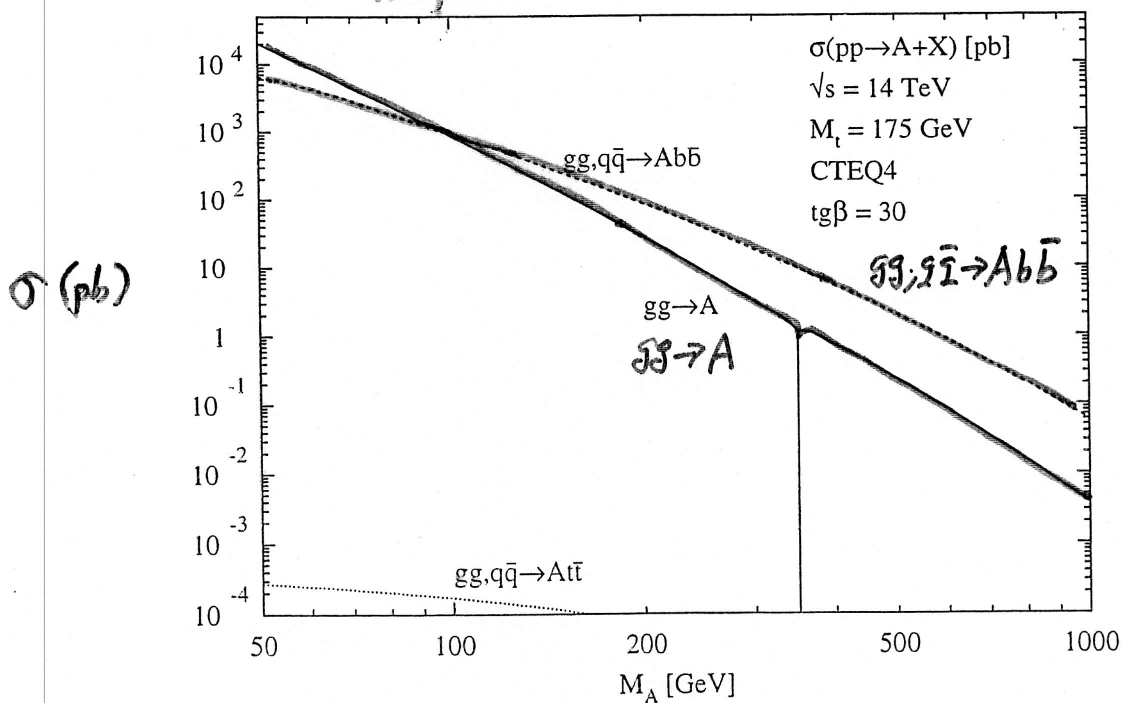


Fig. 54d

Figure 54: *Continued.*

MS ③

A decay branching in MSSM

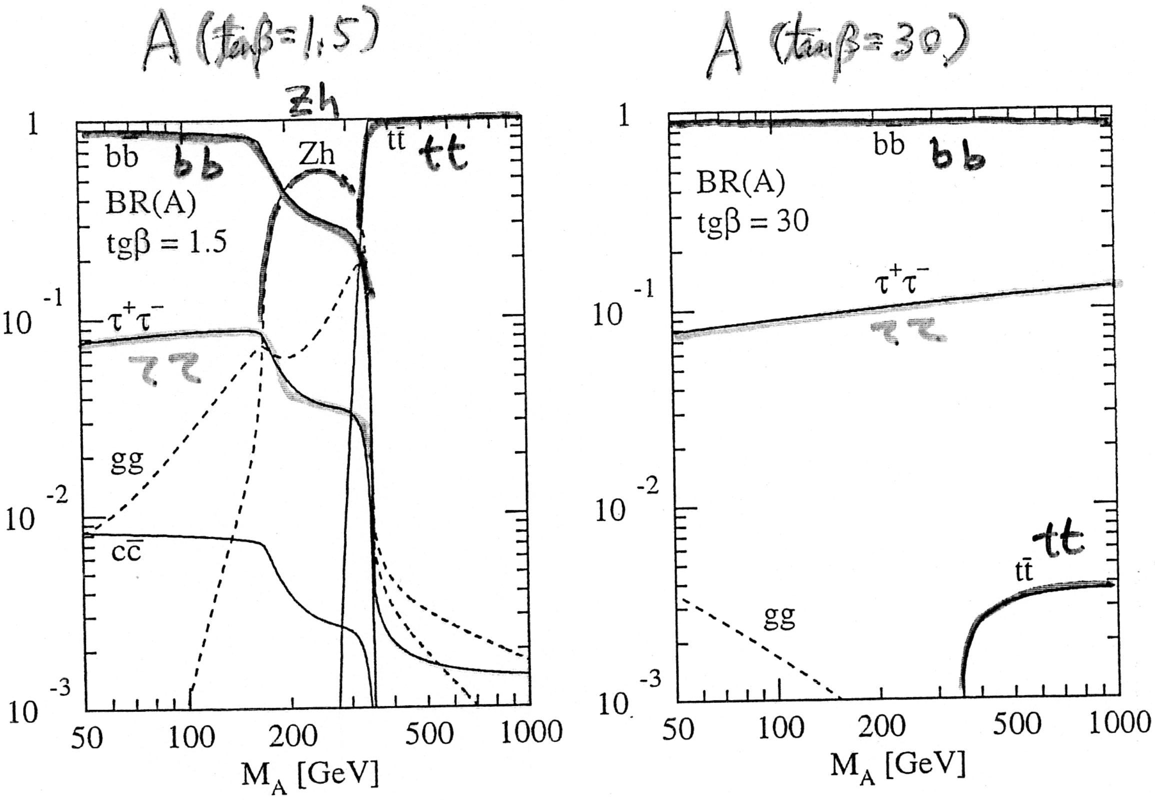


Fig. 42c

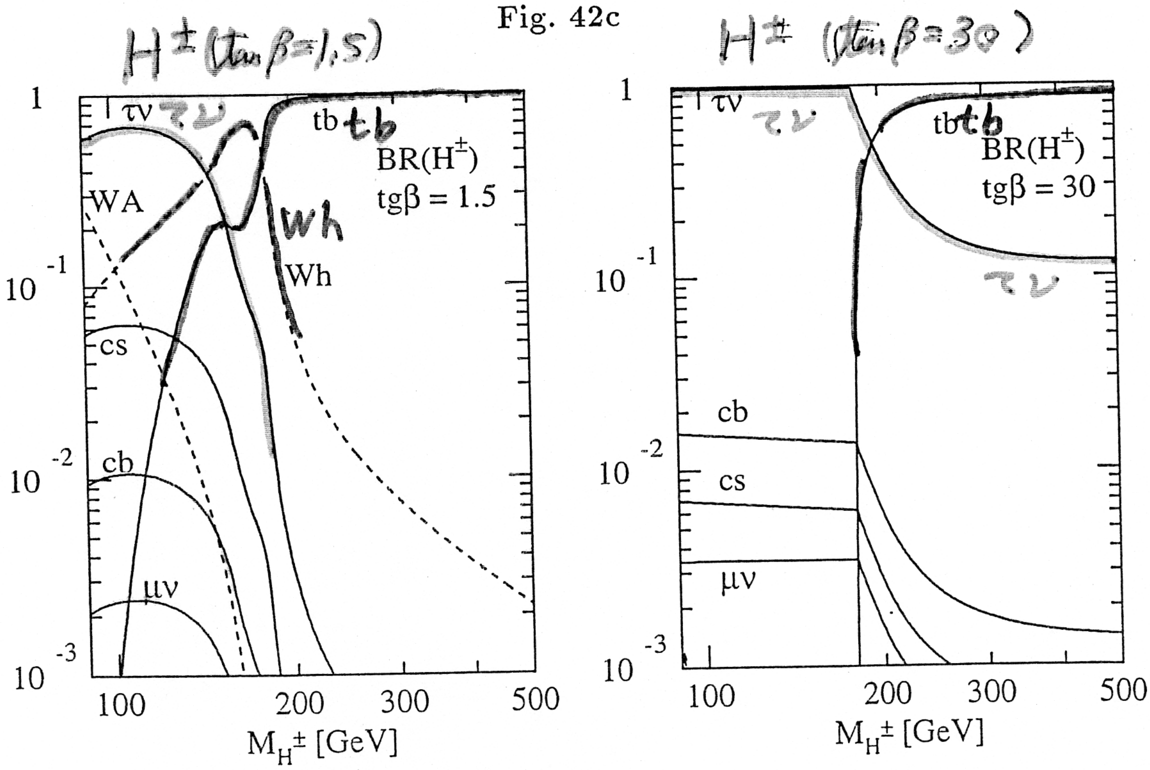
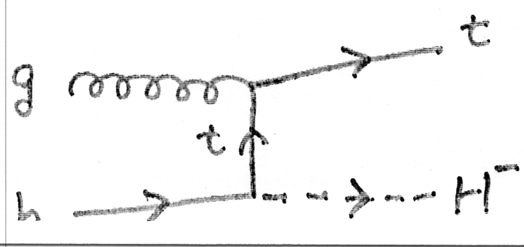


Fig. 42d

Figure 42: *Continued.*

$H^{\pm}$ production

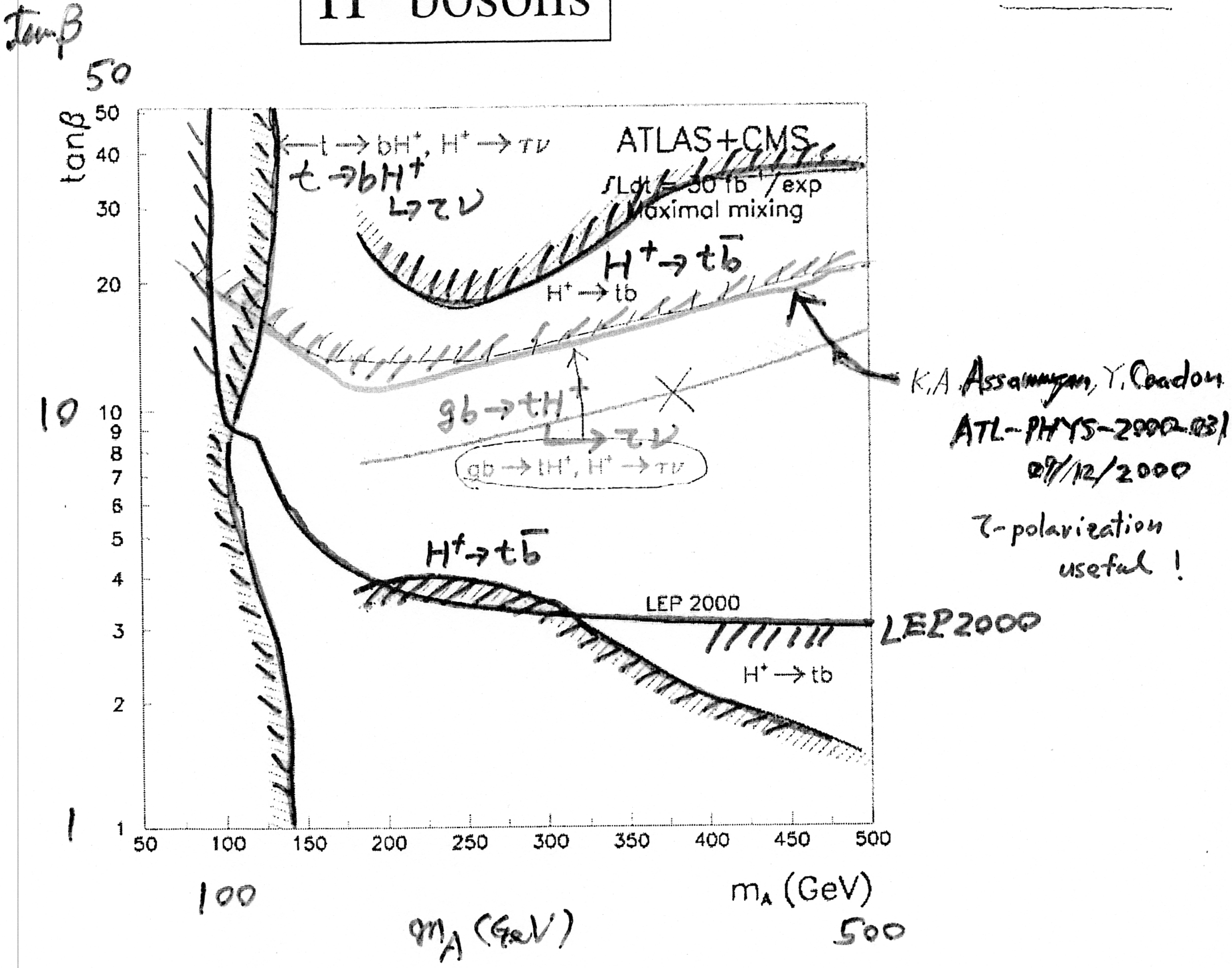


c.f. K.A. Assamagan + Y. Coadou
ATL-PHYS-2000-031 (07/12/2000)

FIG 6

MSSM-3

H± bosons



- $m_{H\pm} < m_t$: $t \rightarrow b H^+$ ($H^+ \rightarrow \tau\nu$) competes with $t \rightarrow bW$
  $\rightarrow$ count excess of τ's in $t\bar{t}$ final states

3000 $W \rightarrow \tau\nu$
1500 $H^\pm \rightarrow \tau\nu$ m=130 GeV tanβ=5
4000 fake τ from $W \rightarrow jj$

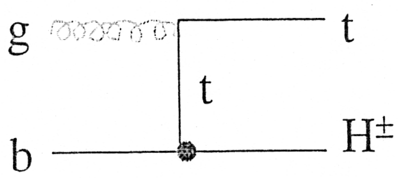
} $t\bar{t}$ events, 30 fb^{-1}

$H^- \rightarrow \tau^-_R \bar{\nu}_\tau$
$W^- \rightarrow \tau^-_L \bar{\nu}_\tau$

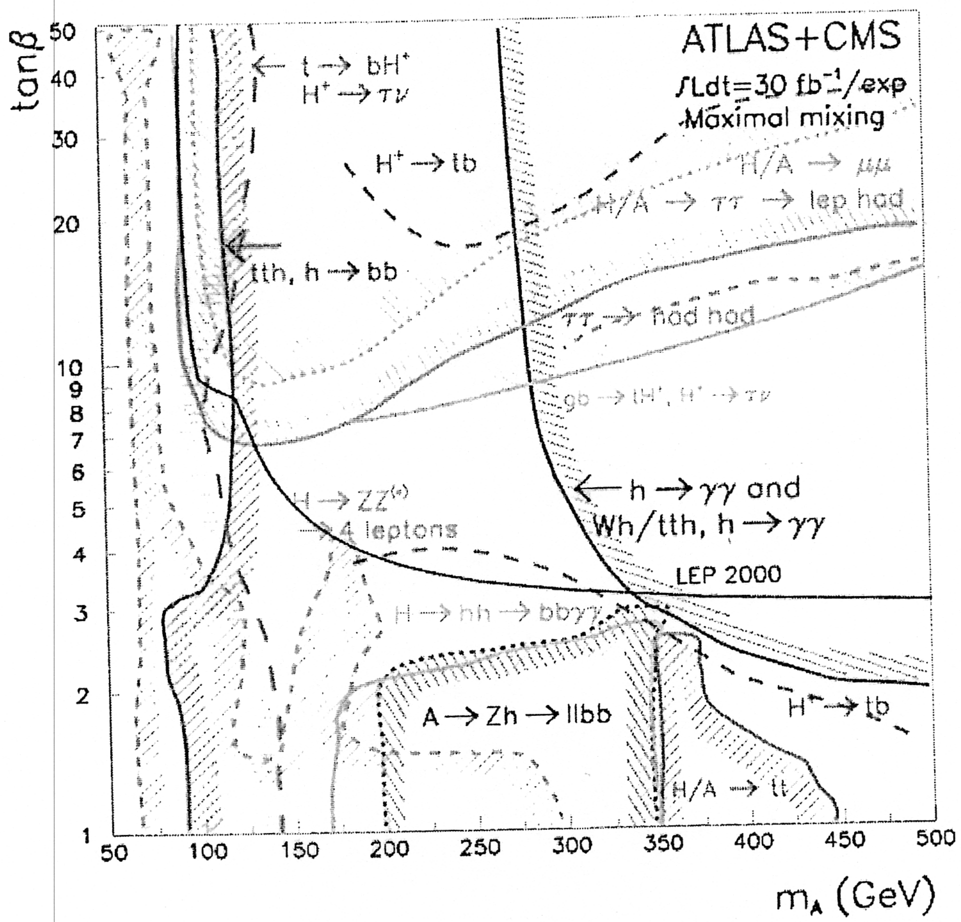
$\tan\beta \leq 1.5$: $H^\pm \rightarrow cs$

- $m_{H\pm} > m_t$:

  -- $gb \rightarrow H^\pm t \rightarrow tb\ t$
  -- $gb \rightarrow H^\pm t \rightarrow \tau\nu\ t$



All (almost …) channels together ….



Assuming SUSY particles are heavy

Not all channels shown

- Plane fully covered (no holes) at low L (30 fb^{-1})
- Main channels : $h \rightarrow \gamma\gamma, b\bar{b}$, $A/H \rightarrow \mu\mu, \tau\tau, H^{\pm} \rightarrow \tau\nu$

- Two or more Higgs can be observed over most of parameter space → disentangle SM / MSSM

- If LEP observes hA , LHC will observe $H^{\pm}$ and H
  if LEP observes hZ (disentangling SM / MSSM difficult) LHC will observe h, A, H, $H^{\pm}$ for $m_A < 400$ GeV

Uncertainties : $\Delta m_A \approx \pm 30$ GeV (e.g. from Δm_h ~3 GeV), $\Delta\tan\beta \approx \pm 0.7$
Impact of mixing on couplings studied for minimal mixing but not for all possible mixing (evolving theory predictions)

FIG 5

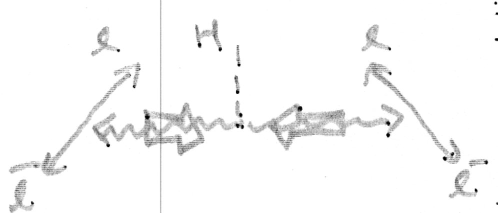
Measurement of the Higgs spin

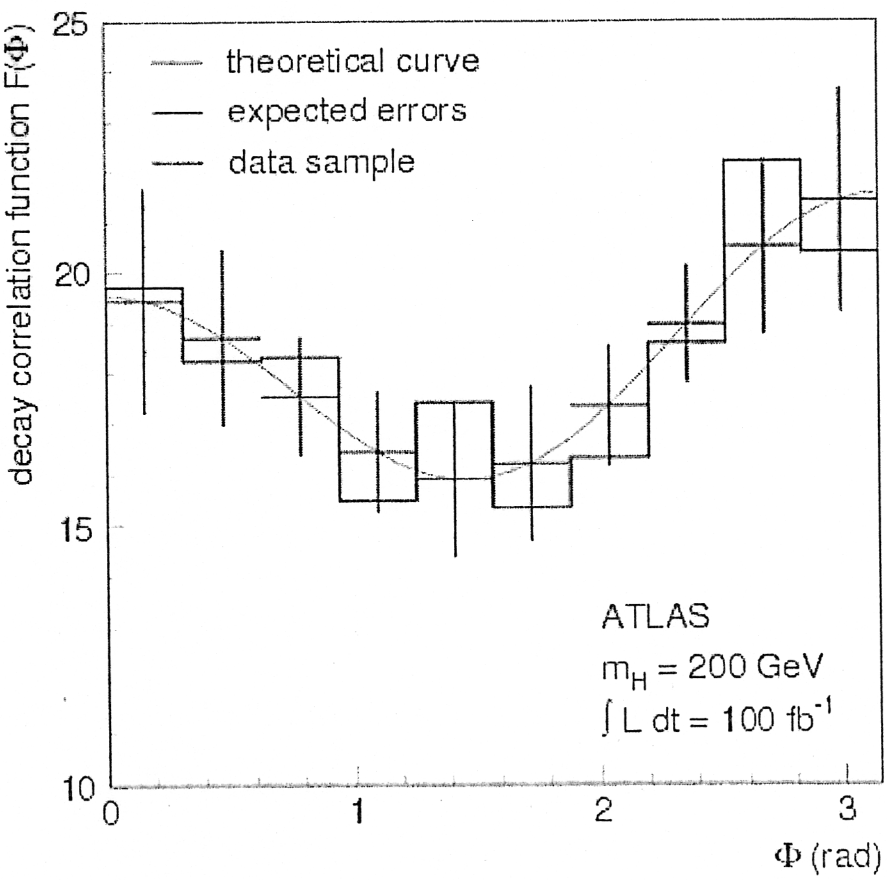
(preliminary)

- From angular distribution of decay products
- Difficult for channels with S/B << 1 (e.g. $H \rightarrow \gamma\gamma$): sensitivity diluted by large backgrounds
- Promising for $H \rightarrow 4\ell$ (S/B $\geq$ 3)

⬇

Angle between decay planes of two Z from Higgs
(theoretical prediction from C.A. Nelson, Phys. Rev. D37 (1998)1220)

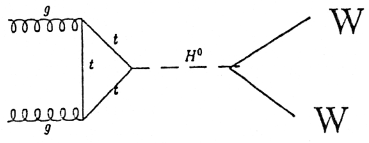




Theoretical predictions for $s \neq 0$ not yet available

A9 (9)

$H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$



$150 \leq m_H \leq 190$ GeV

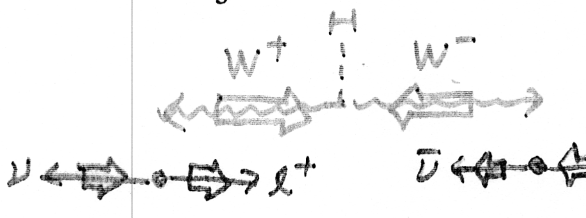
- Large rate : $\sigma \times BR \approx 700$ fb BR ($H \rightarrow WW$) > 70%
  Counting channel (no mass peak) $\rightarrow$ precise knowledge of background needed

- Main backgrounds:
  - -- $WW^{(*)}$ (irreducible) $\sigma \approx 5$ pb
  - -- $WZ \rightarrow \ell\nu\ell\ell$, $ZZ \rightarrow \ell\ell\nu\nu$ $\sigma \approx 1$ pb
  - -- $t\bar{t}$, Wt, $Wb\bar{b} \rightarrow 2\ell + X$ $\sigma \approx 120$ pb

- 2 isolated leptons (e, μ) $p_T > 20, 10$ GeV, $E_T^{miss} > 40$ GeV
  m < 80 GeV (rejects WZ, ZZ)
  no jets $p_T > 15$ GeV (rejects $t\bar{t}$, Wt, $Wb\bar{b}$)

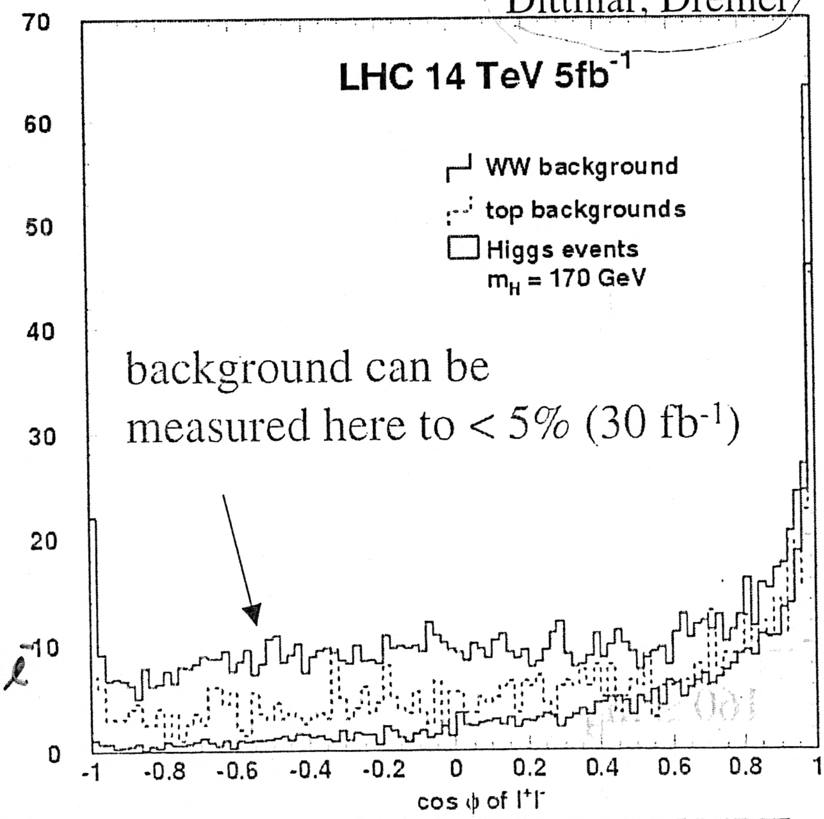
$H \rightarrow W^+W^-$
$\quad \hookrightarrow \ell^+\nu \quad \hookrightarrow \ell^-\bar{\nu}$

Require also small angle between two leptons (WW from Higgs have opposite spins)
$\rightarrow$ rejects WW



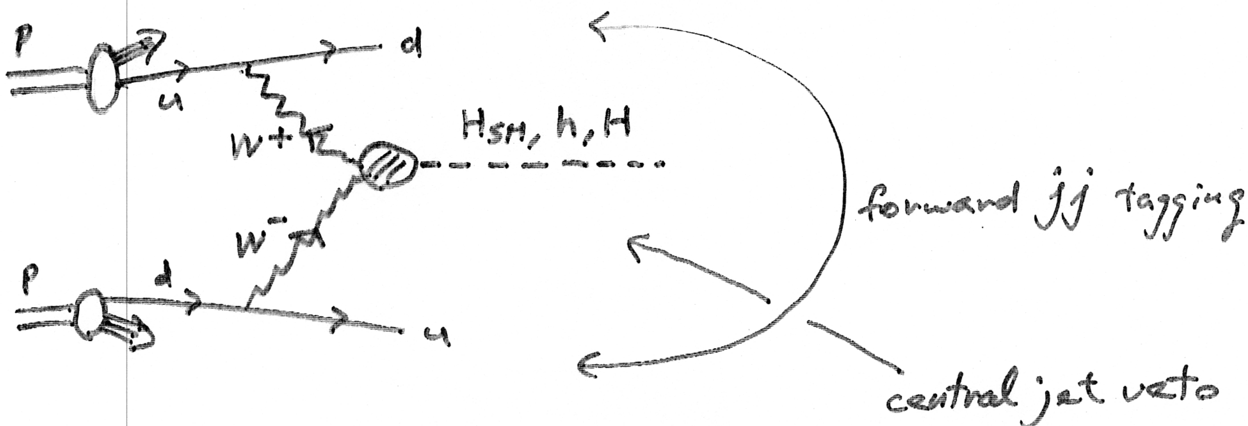
Polar angle correlation

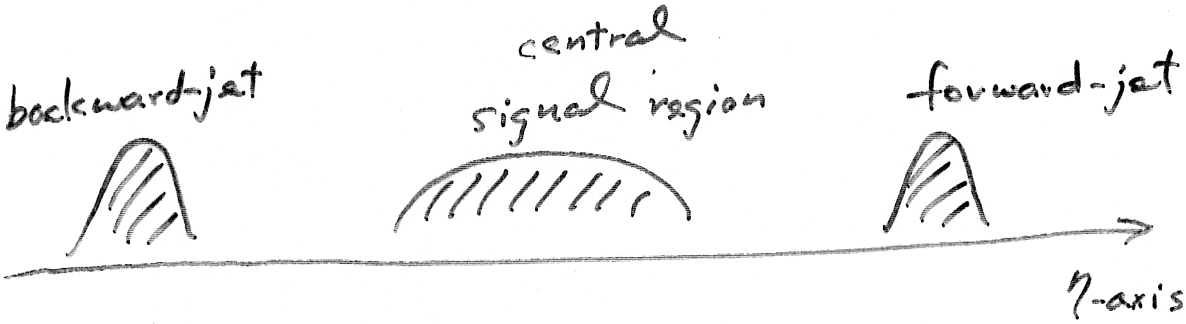
Dittmar, Dreiner



VV (WW/ZZ) fusion processes

Papers by D. Zeppenfeld & collaborators.





$\gamma\gamma$ DR+DZ, hep-ph/9712271

$\tau^+\tau^-$ DR+DZ+KH, hep-ph/9808468 — SM $60 fb^{-1}$

$\downarrow$ TP+DR+DZ, hep-ph/9902434 — MSSM fully covered by single channel.

$l^\pm l'^\mp \nu\nu$ " " /9911385 — h or H $40 fb^{-1}$

WW^* DR+DZ, hep-ph/9906218

$\downarrow$ NK+TP+DR+DZ, hep-ph/0012351 — 5σ discovery @ $35 fb^{-1}$ for $m_H = 115$ GeV

$l^\pm l'^\mp \nu\nu$

★ Invisible Higgs OJE+DZ, hep-ph/0009158 (5σ discovery up to $m_H < 480$ GeV if $Br(H \to \text{invisible}) = 100\%$

★★ Higgs couplings DZ+RK+AN+ERW, hep-ph/0002036 — $\delta\Gamma \approx 10\text{-}20\%$ $\delta\Gamma_W \approx 10\%$

$gg \to H \to \gamma\gamma$	$\Gamma_g \Gamma_\gamma / \Gamma$	$qq \to qqH;\ H \to \gamma\gamma$	$\Gamma_W \Gamma_\gamma / \Gamma$
$gg \to H \to ZZ^*$	$\Gamma_g \Gamma_Z / \Gamma$	$qq \to qqH;\ H \to \tau\tau$	$\Gamma_W \Gamma_\tau / \Gamma$
$gg \to H \to WW^*$	$\Gamma_g \Gamma_W / \Gamma$	$qq \to qqH;\ H \to WW^*$	Γ_W^2 / Γ

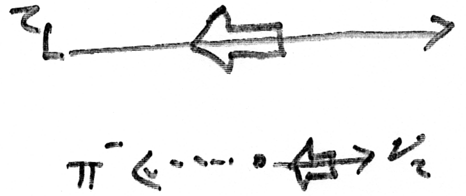
$H \to WW^*$

115 GeV

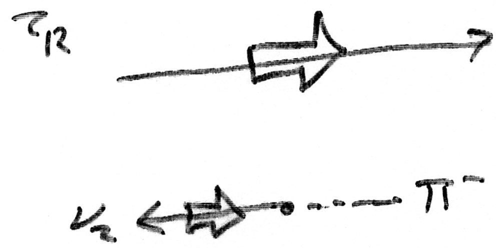
80 GeV   35 GeV

$E_e \approx 40$ GeV $E_e \approx 17$ GeV

$W^- \to \tau_L \bar{\nu}$; $\tau \to \nu_\tau \pi^-$



$H^- \to \tau_R \bar{\nu}$; $\tau \to \nu_\tau \pi^-$



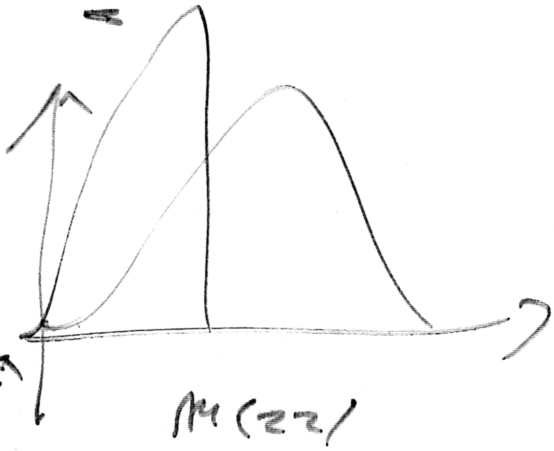
$qq \to q'q'\underline{H}$

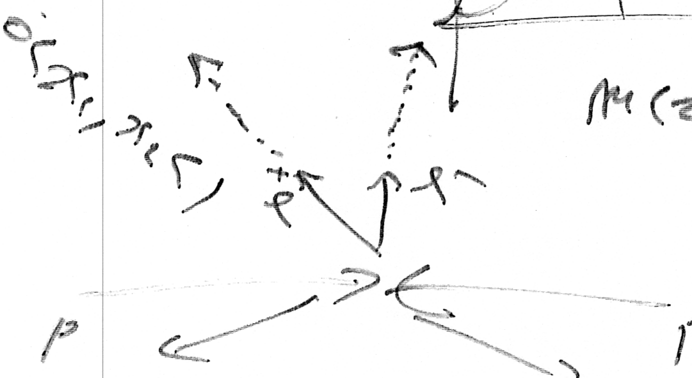
$\hookrightarrow \tau^+\tau^-$

$\hookrightarrow \underline{\ell^+}\nu\nu$ $\hookrightarrow \underline{\ell^-}\nu\nu$

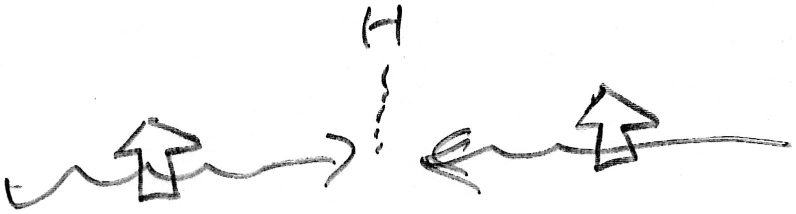
$E_{\tau^-} = \dfrac{E_{\ell^-}}{x_1}$

$E_{\tau^+} = \dfrac{E_{\ell^+}}{x_2}$



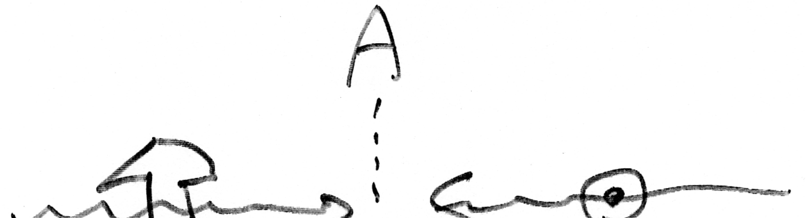


$\gamma\gamma \to H/A$



$H F^{\mu\nu} F_{\mu\nu}$

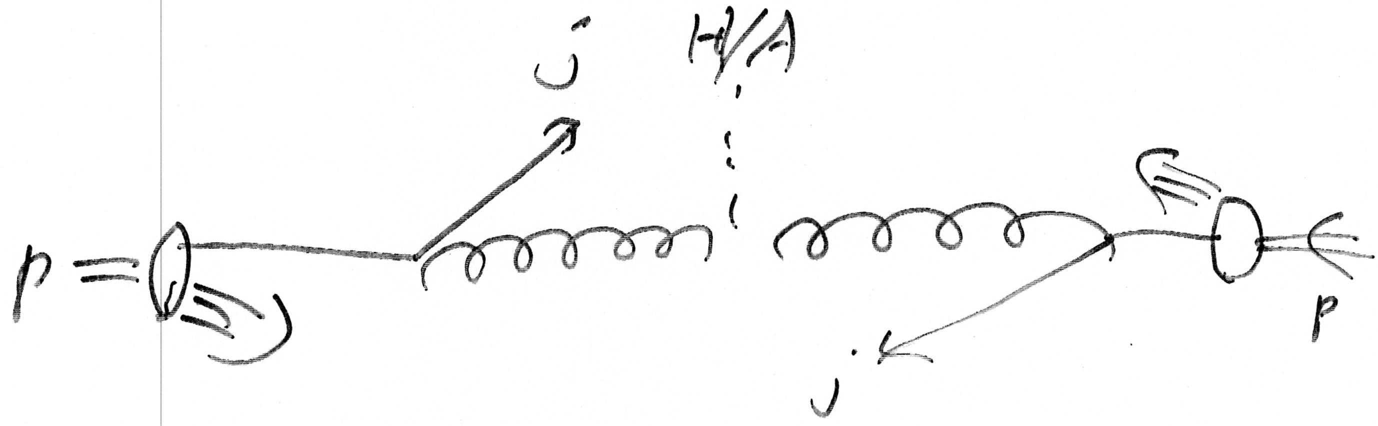
$\mathbb{E}^2 \pm \mathbb{B}^2$

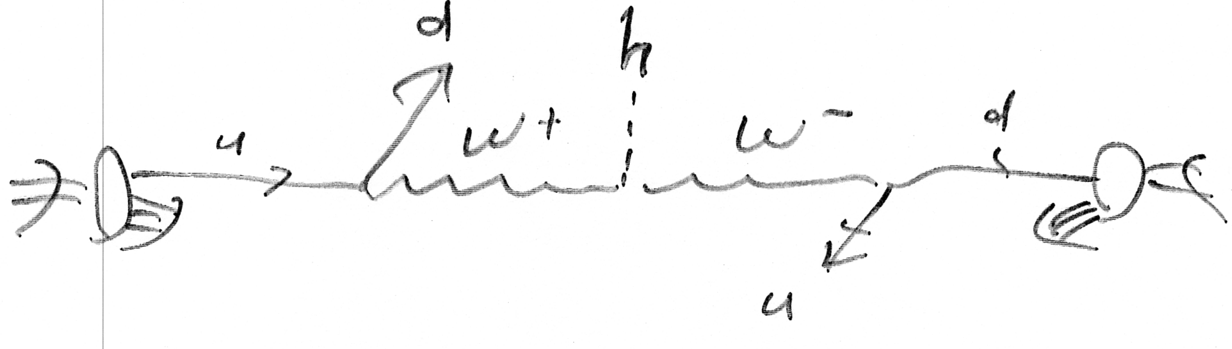


$A F^{\mu\nu} \tilde{F}_{\mu\nu}$

$\frac{1}{2}\epsilon_{\mu\nu\rho\sigma} F^{\rho\sigma}$

$\mathbb{E} \cdot \mathbb{B}$





$y_h > 0$