Heavy MSSM Higgses at the LHC

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Outline

- **LHC, Atlas and CMS**
- **A,H**
- **H^+**
- **Conclusions**

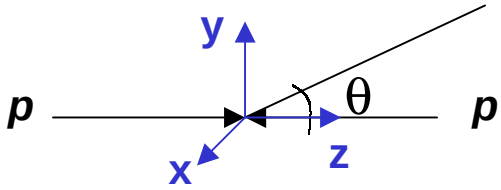
LHC, Atlas and CMS

LHC schedule

- **April 2007: first collisions**
- **August 2007 - February 2008:**
  - $L = 5.10^{32} \rightarrow 2.10^{33}\ cm^{-2}s^{-1}$
  - $Lt = 10\ fb^{-1}$
- **2008 $\rightarrow$:**
  - $L = 10^{34}\ cm^{-2}s^{-1}$
  - $Lt = 100\ fb^{-1}$ / year

Atlas and CMS

- **construction well under way**
- **design parameters:**
  - e,μ,γ: σ_E/E ~ 1% @ 100 GeV
  - calorimeter coverage $|\eta| \leq 5$
  - tracking coverage $|\eta| \leq 2.5$

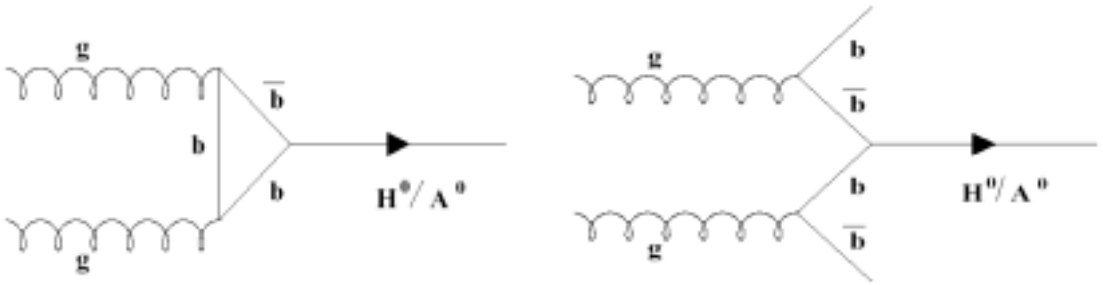


$\eta = -\ln \tan(\theta/2)$

- event rate:
  - ~100 kHz from L1 trigger
  - ~100 Hz stored for offline analysis

Heavy neutral Higgses A, H

Production cross-sections

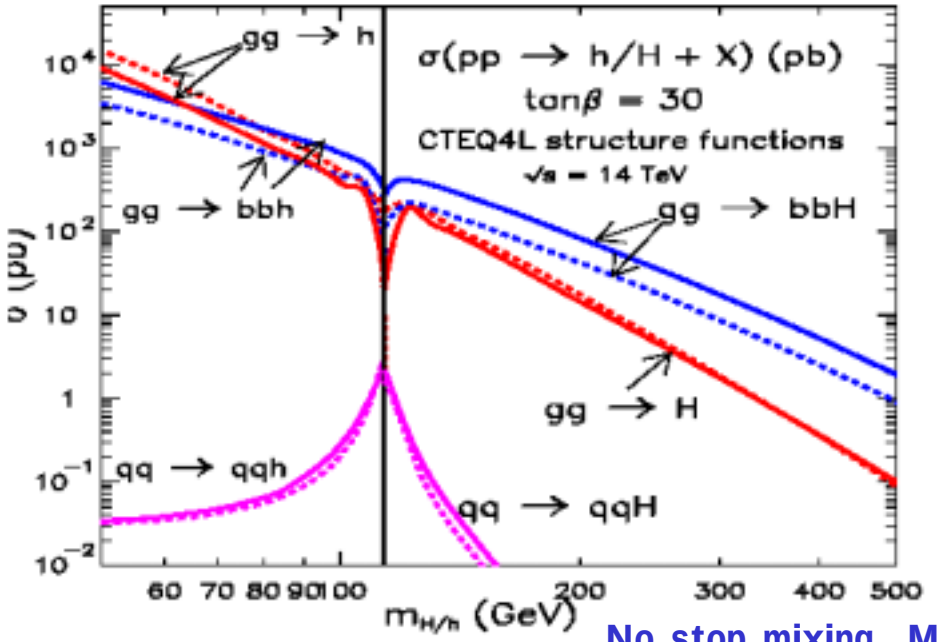


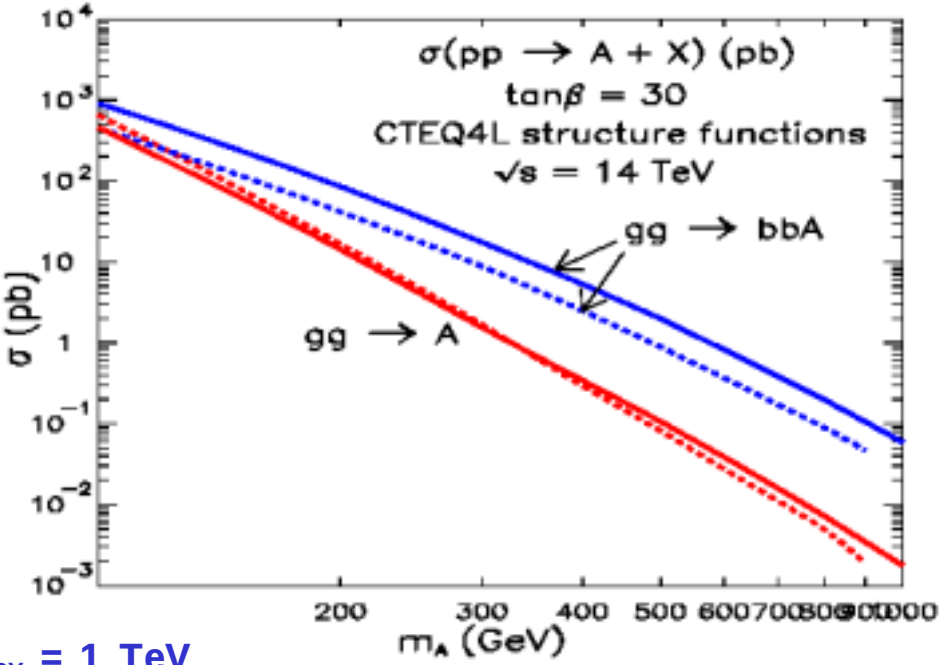
High tanβ:

- Hbb, $H\tau^+\tau^-$, $H\mu^+\mu^-$ enhanced
- $gg \rightarrow bbH/A$ dominating

Monte-Carlo's:

- **A/H:** HIGLU, HQQ (full lines) / Pythia6.1 (dashed)
- **SUSY loop corrections:** from partial decay widths from HDECAY





No stop mixing, M_{SUSY} = 1 TeV

A, H

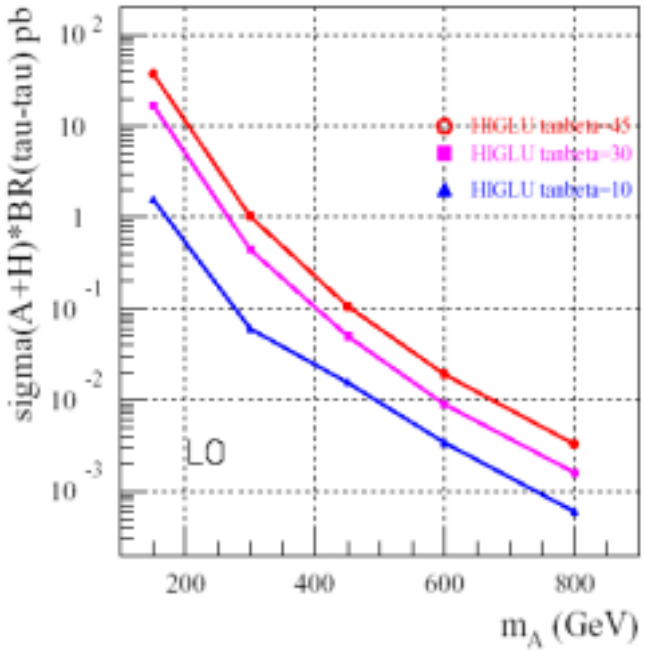
large background, studies going on

Important decay modes: $A/H \rightarrow \tau^+\tau^-$, $\mu^+\mu^-$, $b\bar{b}$, $\chi\chi$

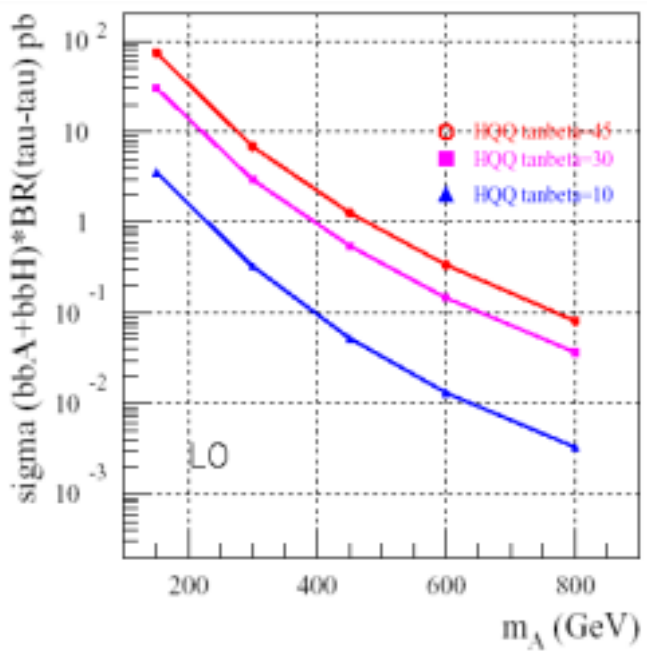
m_A resolution ~ 2%; see R.Kinnunen

$A/H \rightarrow \tau^+\tau^-$

$\sigma(A+H)*BR(\tau^+\tau^-)$



$\sigma(bbA+bbH)*BR(\tau^+\tau^-)$



$m_A \geq 150$ GeV: A, H unresolved

Atlas

3 final states: **l+l+ν's**: BR ~ 12 %, **l+τ-jet+ν's**: BR ~ 35 % (see R.Kinnunen)
2τ-jets+2ν: BR ~ 25 % (1+1 prong), ~ 44 % (1+3 prong)
Use of b-tagging to improve significance

A, H $\rightarrow \tau^+\tau^- \rightarrow$ 2 τ-jets + 2ν

Main backgrounds:

- **QCD jets:**
  - **rate overwhelming**
    - L1 trigger jet (di-jet) thresholds: $E_T \geq 120$ (90) GeV (CMS)
    - efficiency for light A, H too low
    - need dedicated τ-jet trigger
- **W+jets with W$\rightarrow\tau\nu$, jet faking τ**
- **Z/$\gamma^*\rightarrow\tau\tau$, tt with W$\rightarrow\tau\nu$**

Atlas τ-trigger

- **L1+L2 CALO τ-jet**
  - narrow + narrower EM deposit in $\Delta\eta\times\Delta\varphi = 0.4\times0.4$ calo trigger tower
- **L2 tracking**
  - $1 \leq N_{tk} \leq 3$ in cone

CMS τ-trigger

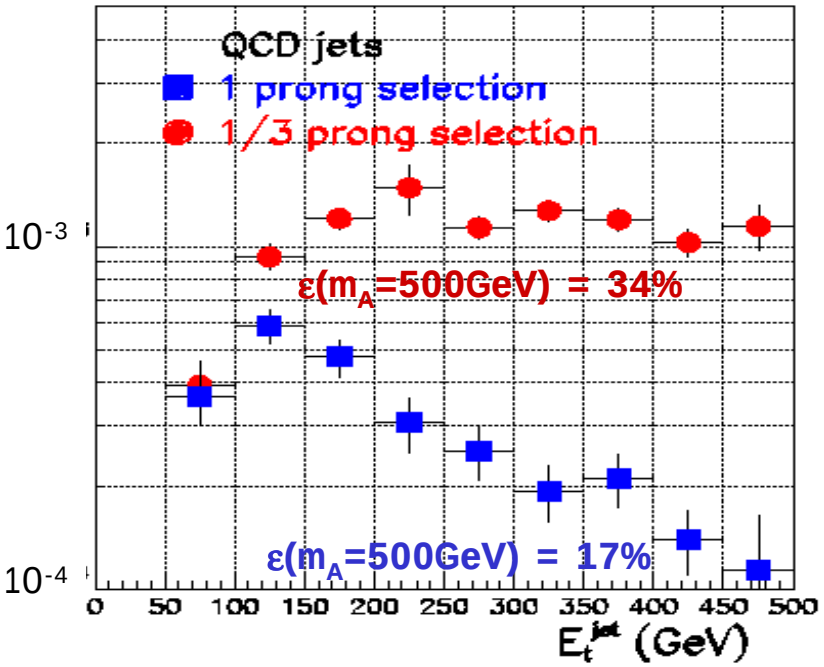
- **L1 CALO τ-jet**
  - narrow + isolated
  - L1 τ-jet: $E_T \geq 100$ (67) GeV; $\varepsilon = 76\%$ for $m_A = 200$ GeV
- **L2 ECAL isolation**
- **Tracking (pixel detector)**
  - $1 \leq N_{tk} \leq 3$ in narrow cone

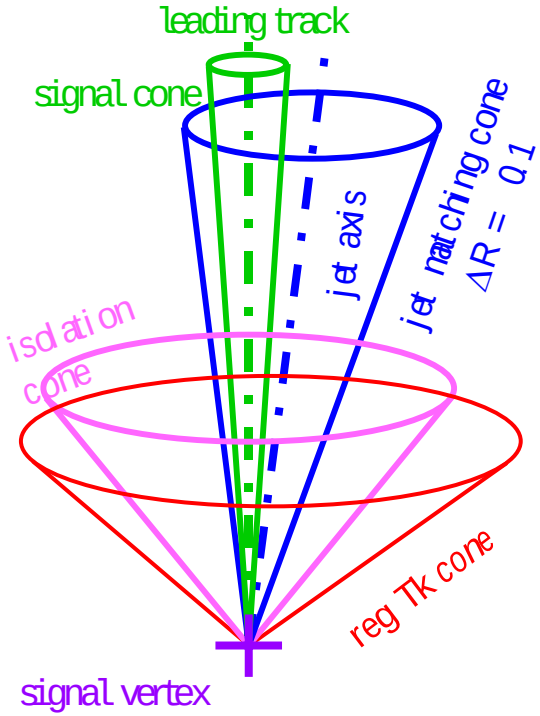
NB: H$^+\rightarrow\tau\nu$: trigger requires full tracking

A, H $\rightarrow \tau^+\tau^- \rightarrow$ 2 τ-jets + 2ν (cont.)

Analysis

- **τ-jet identification >< fake τ-jets from QCD, W+jets…**
  - $E_t^{jet} > 60$ GeV
  - Hard track with $p_T > 40$ GeV/c within $\Delta R = 0.1$ from CALO jet axis
  - Isolation: no track with $p_T > 1$ GeV/c within $0.03 < \Delta R < 0.4$ from hard track





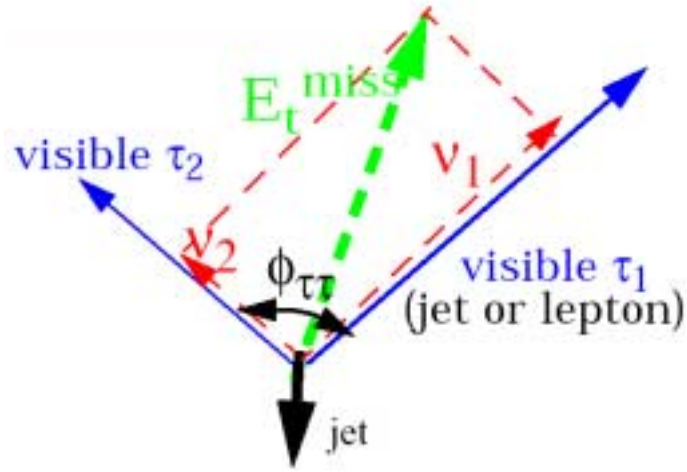
ε QDC jets CMS
(≤ 50% uncertainty from jet fragmentation)

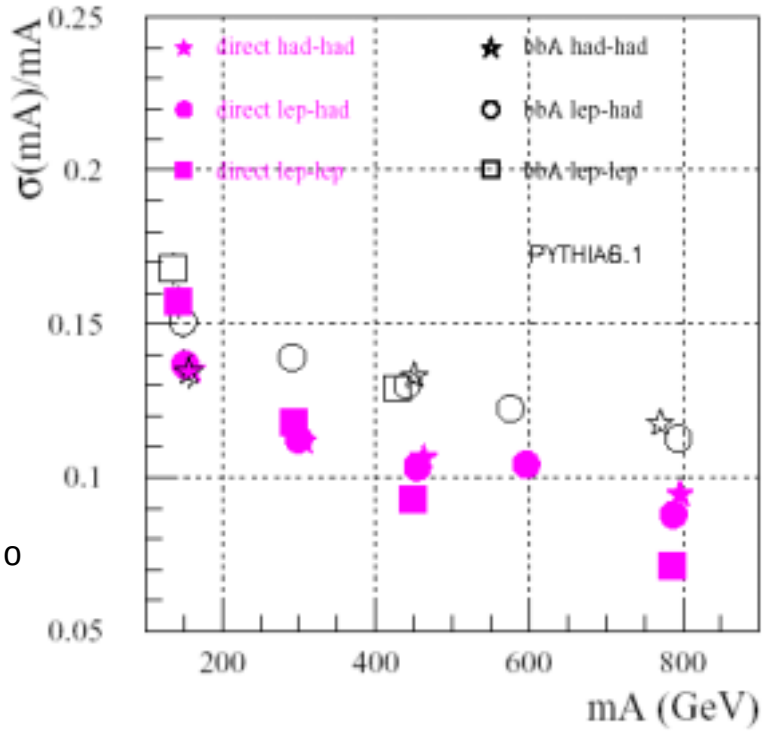
A, H → $\tau^+\tau^-$ → 2 τ-jets + 2ν (cont.)

Analysis (cont.)

- **τ-tagging >< QCD, Z→ll, tt…**
  - impact parameter, secondary vertex
- **central non-τ jet veto >< tt**
- **E_t^{miss} > 40 GeV (60 GeV for m_A = 500 GeV)**
- **b-tagging >< Z/γ*, QCD**
  - soft b-jets, flat η distribution
    - CMS: ε_b = 35% with 1% mistag per Z/ γ*-event

- **Mass reconstruction**
  - assume ν_i collinear to visible τ_i
  - project E_t^{miss}
  - $\sigma(m) \sim \sigma(E_t^{miss})/\sin(\phi_{\tau\tau})$ while τ's tend to be back-to-back

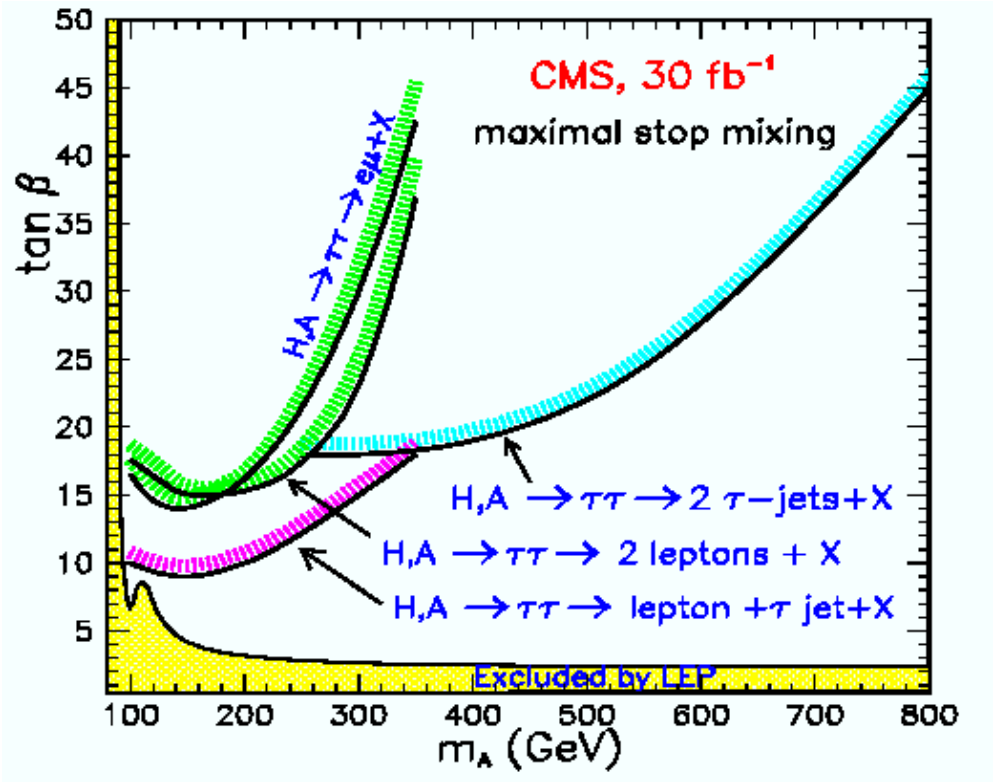


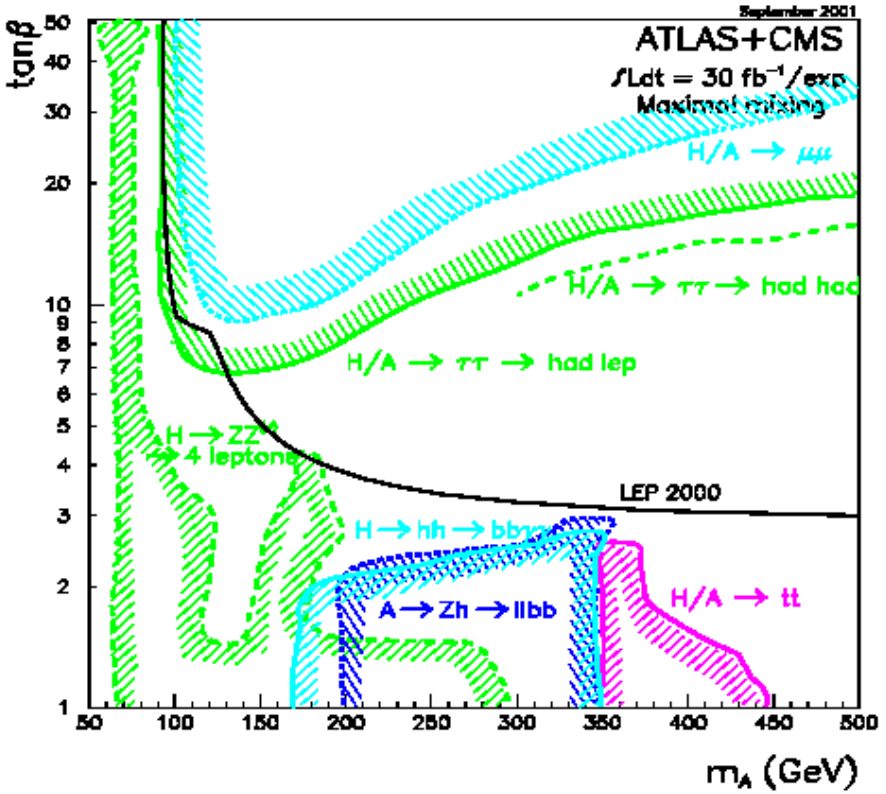


Atlas, $\phi_{\tau\tau} < 165^o$
fast simulation

5σ discovery reach for A, H → $\tau^+\tau^-$

M_2 = 200 GeV, μ = -200 GeV, $M_{\tilde{g}}$ = 800 GeV,
$M_{\tilde{q},\tilde{l}}$ = 1 TeV, A_t = 2.4 TeV





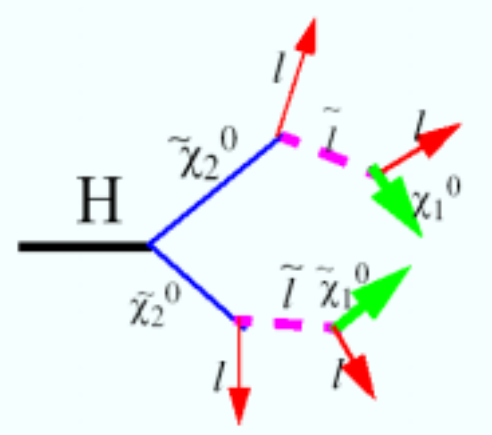
Sensitivity to MSSM parameters:

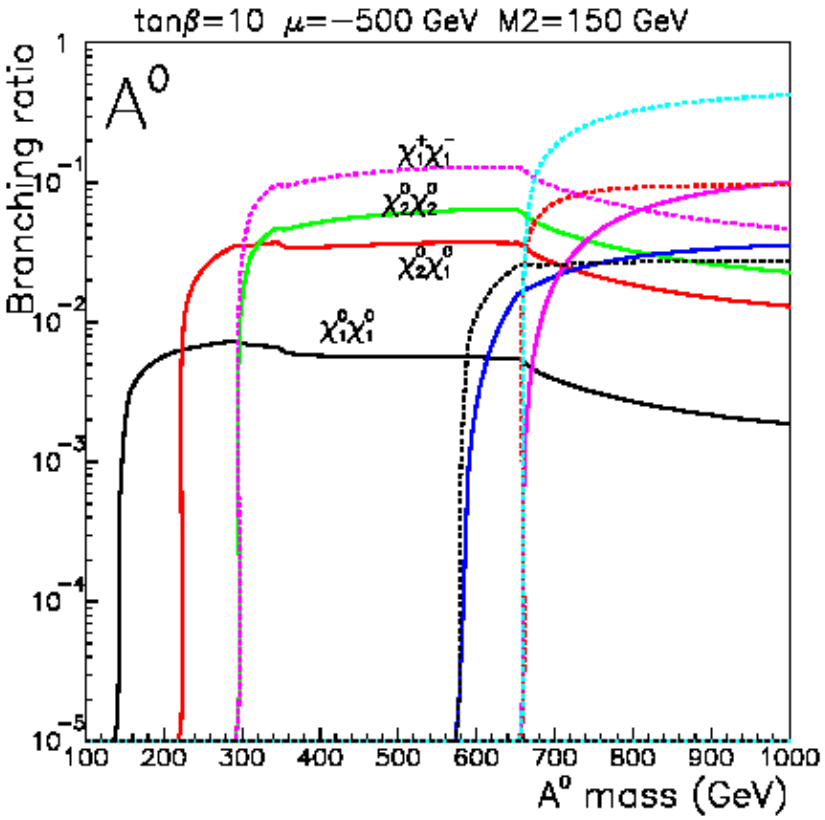
- σ*BR insensitive to stop mixing
  - SUSY loops only affect gg→H
- light SUSY spectrum ⇒ BR(H/A→ττ) can be reduced at high masses
- large μ ⇒ BR(H/A→ττ) can be enhanced at high masses

A, H → χχ

Decay into sparticles

- **MSSM, RG relation $M_2=2M_1$**
- **large $|\mu|>M_2$** (favoured if χ^0_1 dark matter)
  - $m(\chi^0_1) \cong M_1$; $m(\chi^0_2) \cong M_2$
- **sleptons light**
- **$A,H \rightarrow \chi^0_2\chi^0_2 \rightarrow 4l^{\pm}+X$**





Analysis

- **SM backgrounds: ZZ, ZW, Zbb, Zcc, Wtb, tt**
- **MSSM backgrounds: $\tilde{q}/\tilde{g}$, $\tilde{l}\tilde{l}$, $\tilde{\nu}\tilde{\nu}$, $\tilde{q}\chi$, $\chi\chi$**

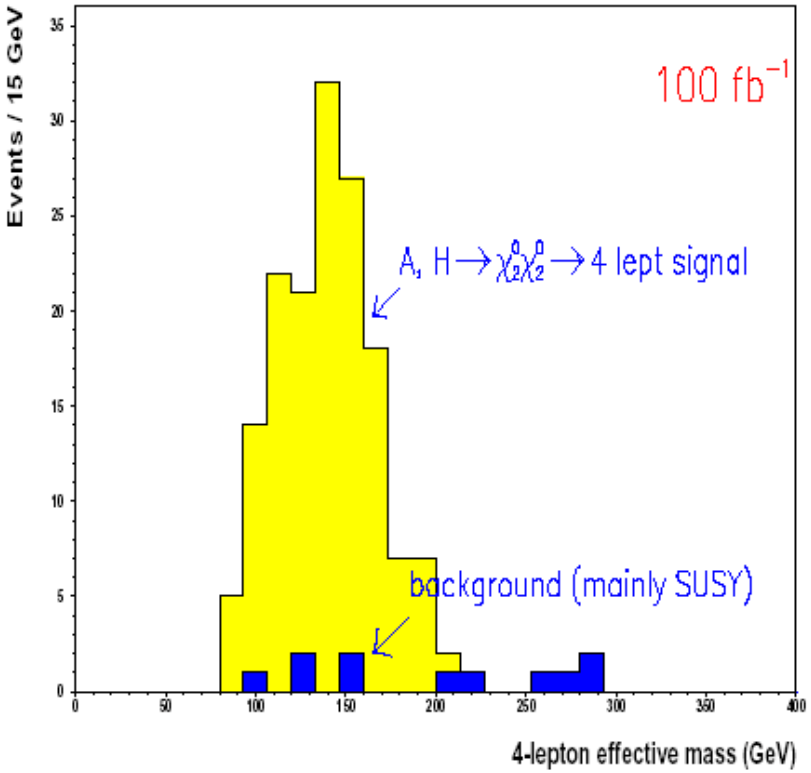
  2 pairs of isolated leptons

  jet veto, Z veto

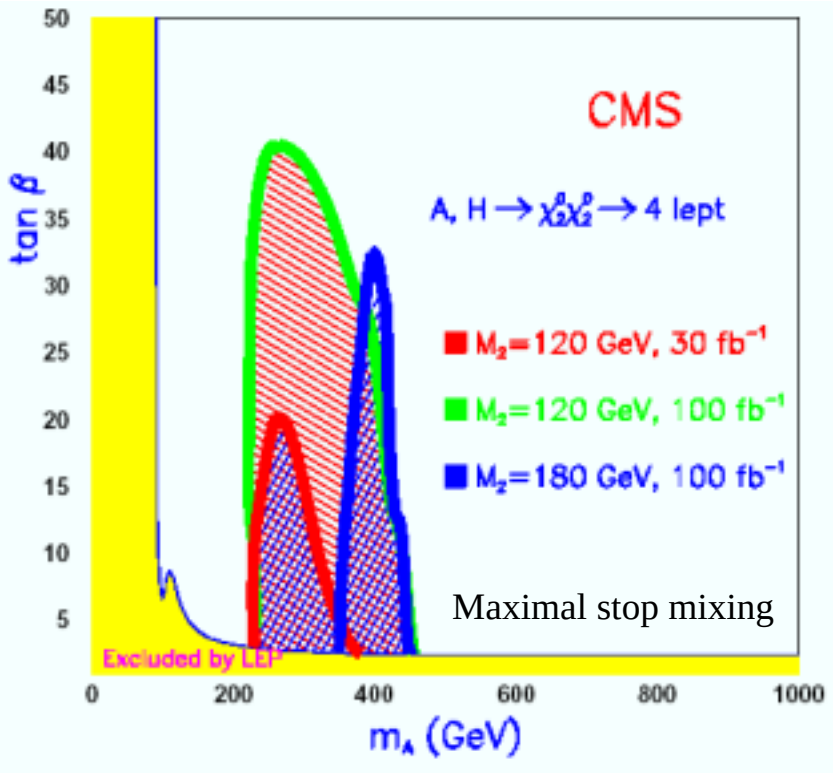
$A, H \rightarrow \chi^0_2\chi^0_2 \rightarrow 4l^{\pm} + \chi^0_1\chi^0_1$

Signal and total background

m_A = 350 GeV, tanβ = 5, M_2 = 120 GeV,
μ = -500 GeV, $M_{\tilde{l}}$ = 250 GeV, $M_{\tilde{q},\tilde{g}}$ = 1 TeV



5σ discovery contours



μ = -500 GeV, $M_{\tilde{l}}$ = 250 GeV, $M_{\tilde{q},\tilde{g}}$ = 1 TeV

Sensitivity to MSSM parameters:

- sensitive to M_1, M_2, μ, $m_{\tilde{l}}$
- small M_1, M_2, $m_{\tilde{l}}$; large μ favourable

Charged Higgs H^+

Production

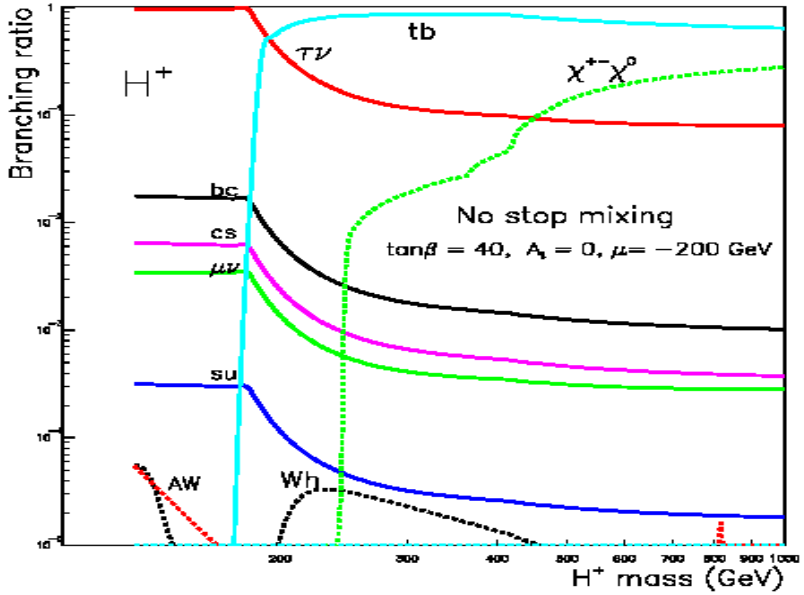
- $gg \rightarrow tbH^+$, $gb \rightarrow tH^+$, $qq' \rightarrow H^+$
- smaller rate from $pp \rightarrow H^+H^- + X$, $\rightarrow H^+W$

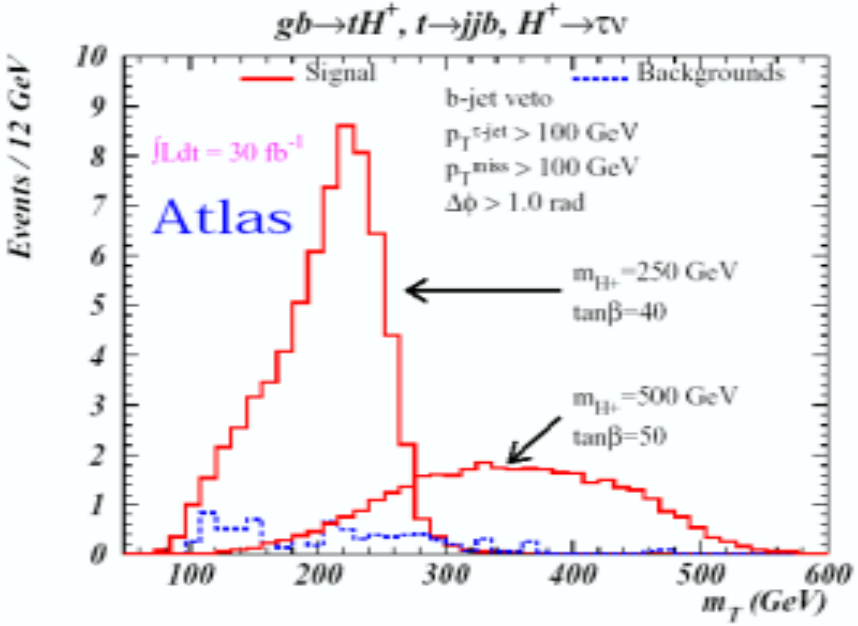
(see next talks)

- 1pb @ $m_{H^+} = 400$ GeV

Most promising decay channels

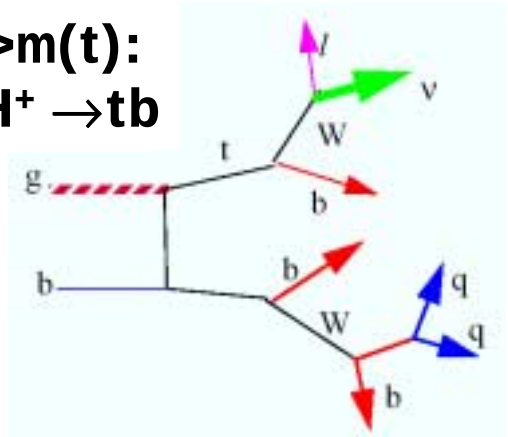
- $\tau\nu$
  - BR=10% at high tanβ
  - harder $p^{\pi}/E^{\tau\text{-jet}}$ in $H^+ \rightarrow \tau\nu$ than in tt bkg with $W \rightarrow \tau\nu$ (simulation with TAUOLA)
  - m_T reconstruction
- **tb**
  - discovery could be possible for small (<3) and large tanβ (>20)

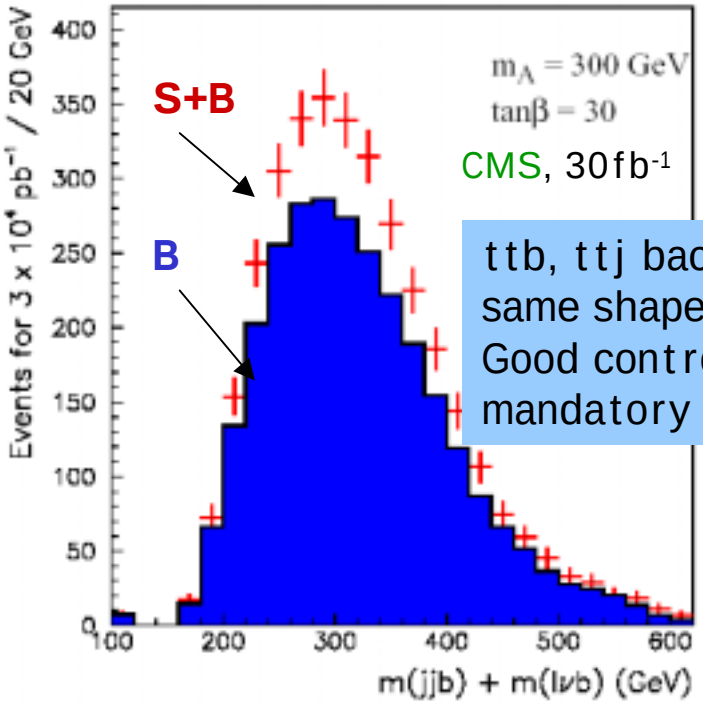




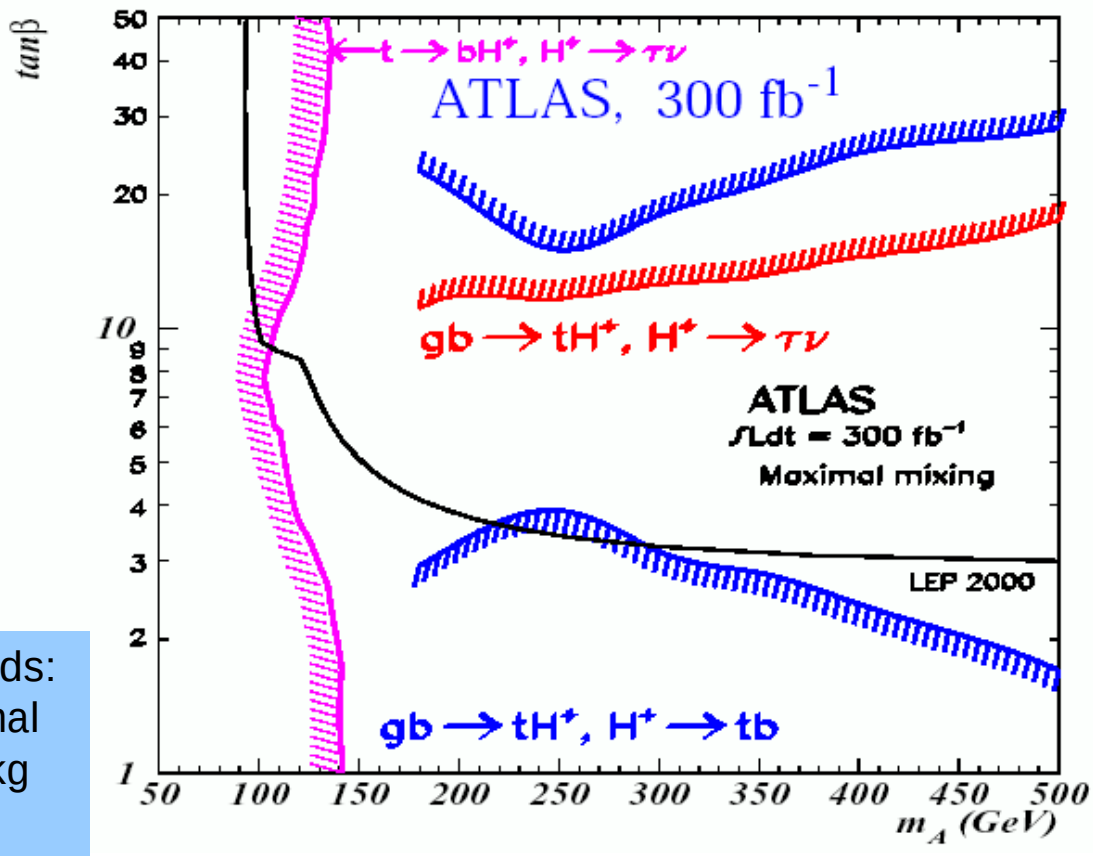
H^+

$m(H^+)>m(t)$: tH^+, $H^+ \rightarrow tb$





ttb, ttj backgrounds:
same shape as signal
Good control of bkg mandatory

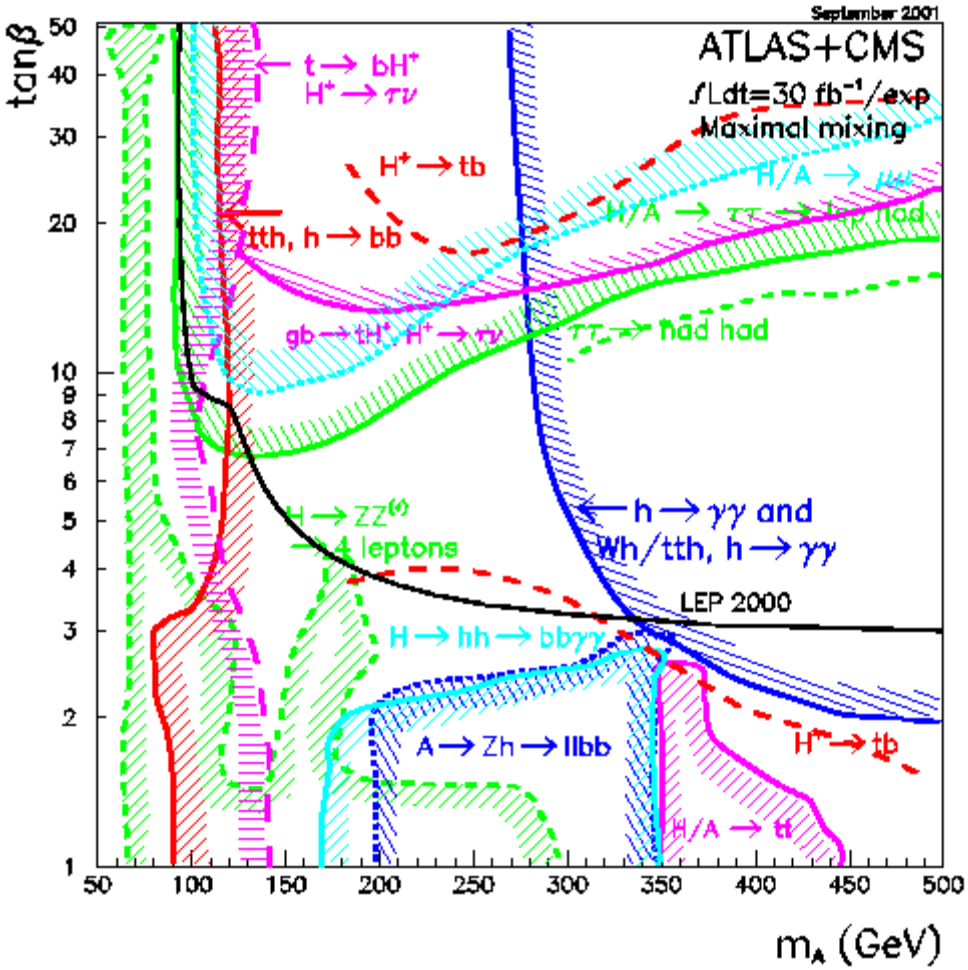


Intermediate tanβ?

- H^+ in cascade decays looks promising

Conclusions

- **The discovery range for heavy MSSM Higgses at the LHC is studied in a large fraction of the parameter space (not all channels shown)**
- **The intermediate tanβ region remains difficult**
  - complementarity from decays into SUSY particles, new ideas welcome
- **Work is ongoing on techniques to measure Higgs parameters at the LHC (masses, widths, tanβ, couplings)**



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