

H/A \rightarrow $\tau\tau$ at ATLAS

- Introduction
 - Higgs Sector: SM and SUSY
 - A/H Production and Decay
- Atlas Detection Strategy
 - Trigger
 - Reconstruction Techniques
 - Backgrounds
- Sensitivity

Higgs Sector

- **Standard Model:**

- One complex scalar doublet

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$$

- Gives mass to W,Z and all fermions
- 4 dof: 3 become W and Z longitudinal components
- One physical Higgs

- **MSSM**

- Two complex scalars

$$\phi_u = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \quad \phi_d = \begin{pmatrix} \phi^0 \\ \phi^- \end{pmatrix}$$

- 8 dof: still 3 for W and Z
- 5 physical Higgs :
 - h, H : CP even
 - A: CP odd
 - H \pm

MSSM Higgs Phenomenology

- Tree level: All higgs masses and BR determined by 2 parameters
 - typically use $M(A)$ and $\tan\beta$: ratio of vev's
- Loop corrections with top or Susy particles can modify this
- For wide range of SUSY parameters:
 - $m(h) < 150 \text{ GeV}$
 - $m(A) \sim m(h)$ for $m(A) < 120 \text{ GeV}$
 - $m(A) \sim m(H)$ for $m(A) > 120 \text{ GeV}$

MSSM Higgs Couplings

- Comparison with SM Higgs:

Higgs Type	$d\bar{d}, s\bar{s}, b\bar{b}$	$e\bar{e}, \mu\bar{\mu}, \tau\bar{\tau}$	WW ZZ
	$e^+e^-, \mu^+\mu^-, \tau^+\tau^-$		
h	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$	$\sin(\beta - \alpha)$
H	$\cos\alpha/\cos\beta$	$\sin\alpha/\sin\beta$	$\cos(\beta - \alpha)$
A	$-i\gamma_S \tan\beta$	$-i\gamma_S \cot\beta$	0

$$\frac{\sin 2\alpha}{\sin 2\beta} = -\frac{m_A^2 + m_Z^2}{m_H^2 - m_A^2}$$

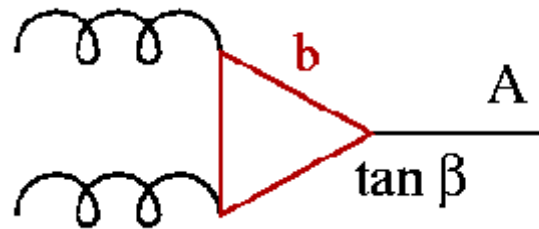
$$\frac{\cos 2\alpha}{\cos 2\beta} = -\frac{m_A^2 - m_Z^2}{m_H^2 - m_A^2}$$

Table 2.1: The Standard Model Higgs couplings need to be multiplied by these factors, at tree level, to get the appropriate MSSM couplings.

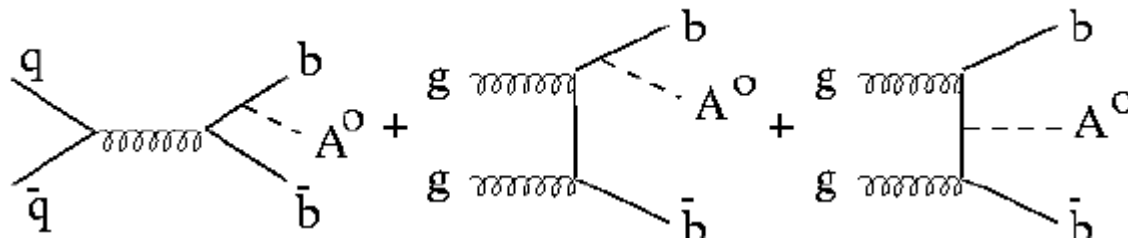
- At large $\tan\beta$, $\alpha \rightarrow \beta - \pi/2$
- A does not couple to W and $Z \rightarrow$ even at high mass BR to $b\bar{b}$ and τ substantial

H/A Production at LHC

Direct Production: Dominates at low $\tan \beta$



Associated Production: Dominates at high $\tan \beta$



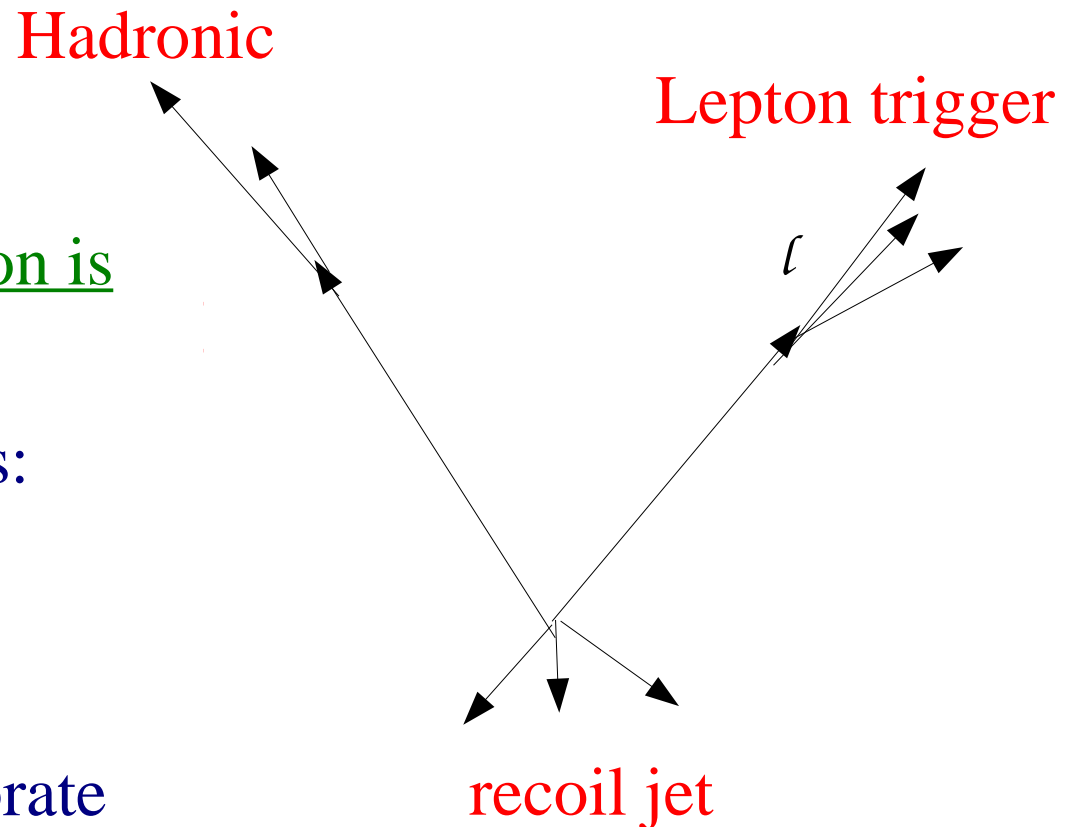
In both cases, production much larger than SM

Why $H/A \rightarrow$?

- For all $\tan \beta$ substantial BR to
- Unlike $b\bar{b}$ channel, not produced strongly
- But can we use this channel to find H/A and reconstruct?
 - Trigger ?
 - Fake ?
 - Missing momentum () ?
- TDR and subsequent work address these issues (see in particular Atlas notes from Cavelli et al)

Topology of Events

- One t decays leptonically
 - This is the trigger
- Other t decays hadronically
 - Here background rejection is important
- Mass reconstruction assumes:
 - Decay products follow direction
- Can use $Z \rightarrow b\bar{b}$ validate/calibrate
- Note: for associated production, also 2 b's

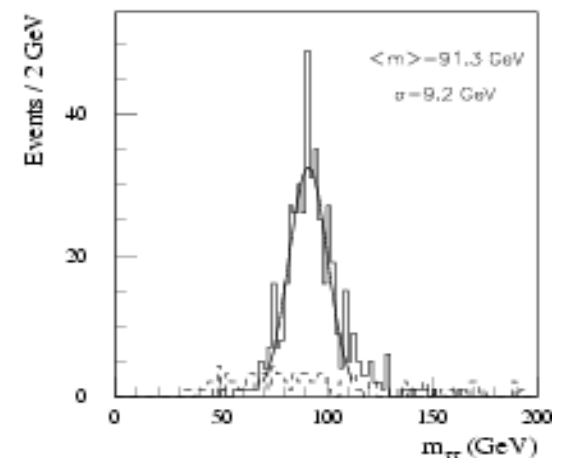
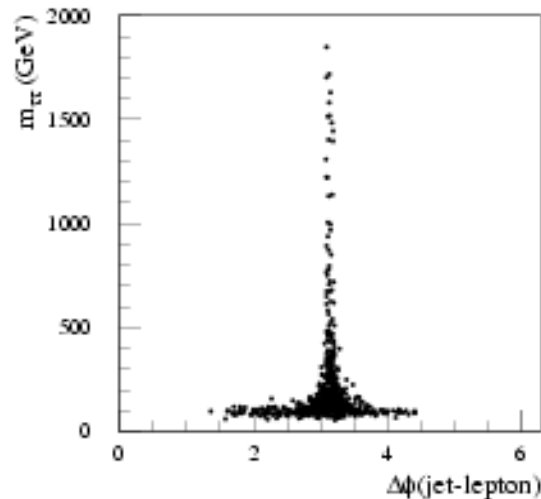


Identification

- What distinguishes from QCD jets?
 - have low multiplicity: 1 or 3 charged tracks
 - are narrow: light particle, highly boosted
- Default ATLAS selection:
 - $R(\text{em}) < 0.07$ (jet radius using EM cells only)
 - $t(1,2) < 0.1$ (difference in E_t between $R=0.2, 0.1$)
 - $N_{\text{tr}} = 1$ (count $p_t > 2$ GeV tracks only, $R < 0.3$)
- efficiency 25% at $m(A) = 150$ GeV
- Jet rejection 170 ($p_t=30$ GeV) to 1700 ($p_t=150$ GeV)

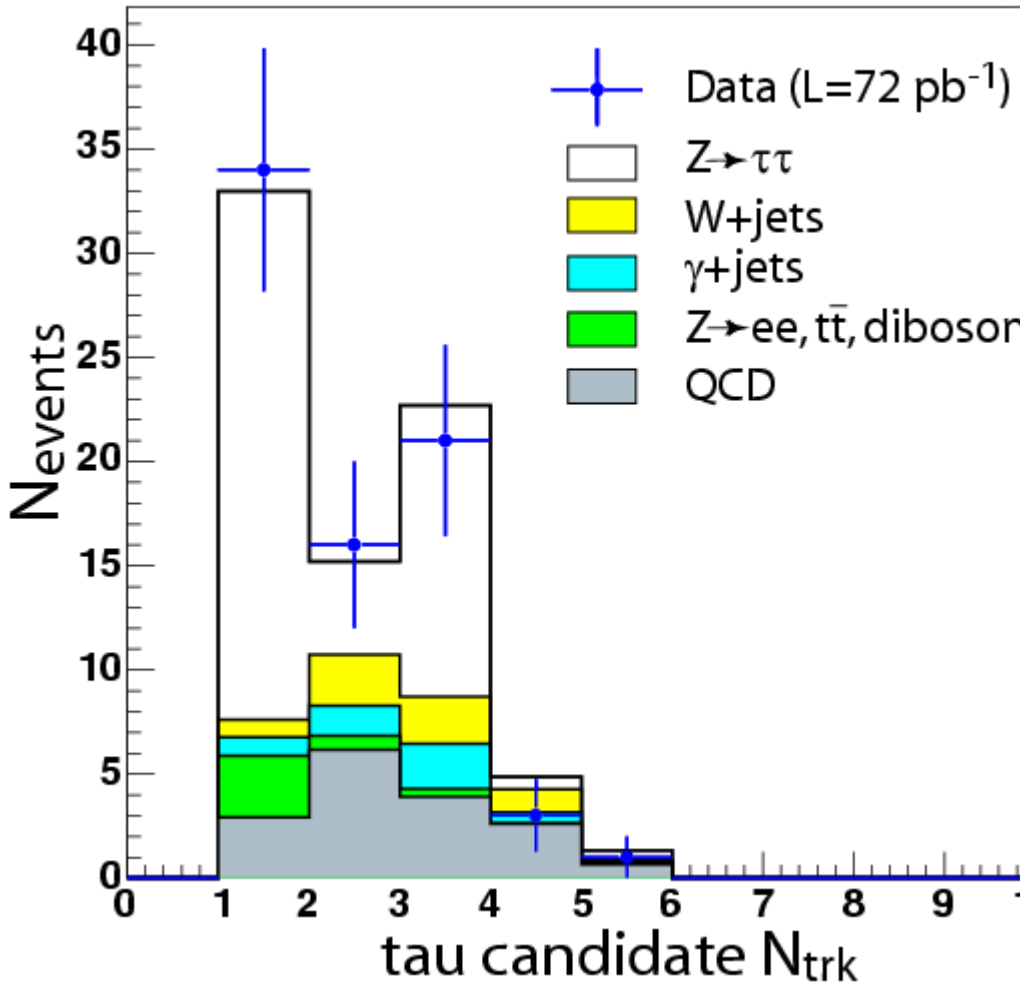
Mass Reconstruction

- Reconstruct $m_{\tau\tau}$ assuming all decay products in τ direction
 - Each τ has unknown missing momentum from ν_{τ}
- Measure missing E_t : x and y components: two constraints
- Can solve for missing τ momenta as long as the two τ are not back-to-back

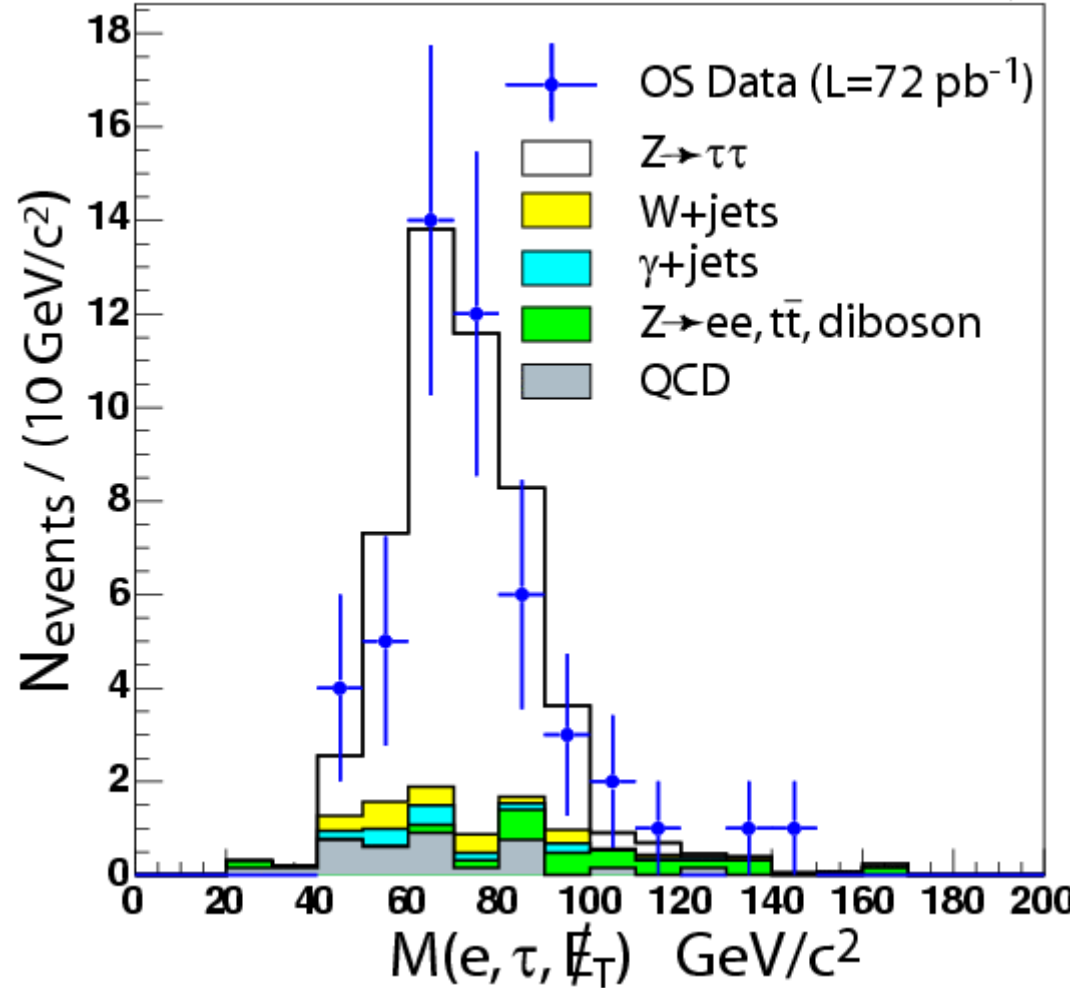


Does this Technique *Really* Work?

CDF Run II Preliminary



CDF Run II Preliminary



Backgrounds for $A/H \rightarrow$

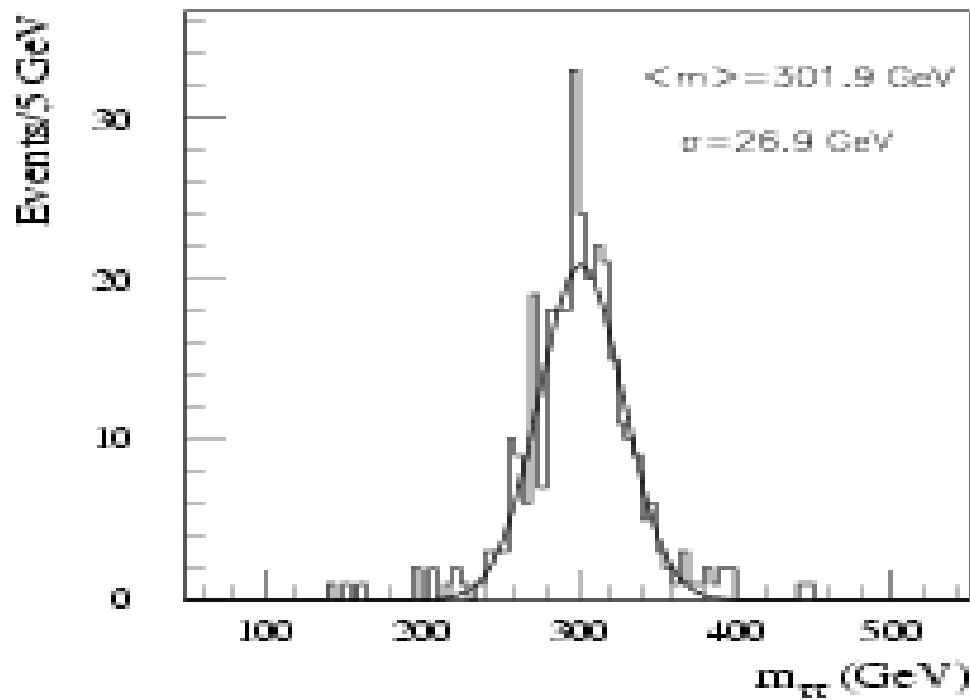
- Irreducible Background: $Z \rightarrow$
 - Good calibration sample, but limits use of this channel for $M(A) < 120 \text{ GeV}$
- Reducible Backgrounds with real leptons:
 - $W + \text{jets}$
 - $t\bar{t}$
 - $b\bar{b}$

Backgrounds with b's especially relevant for associated production channel

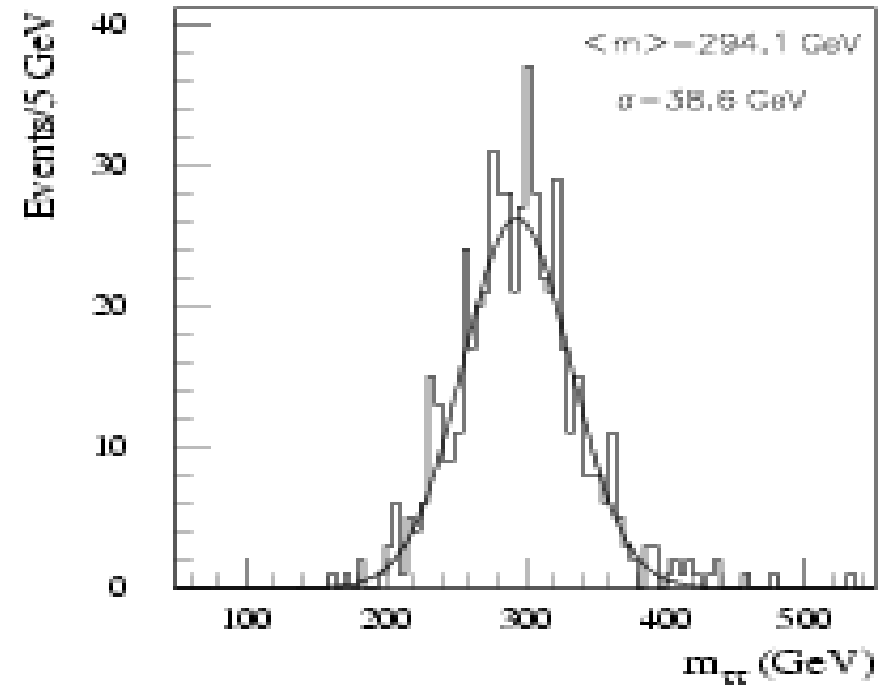
Selection Criteria

- Both Direct and Associated Production
 - 1 isolated lepton $p_t > 24$ GeV (isolation rejects b's)
 - 1 “jet” with $E_t > 40$ GeV (satisfies requirements)
 - Missing $E_t > 18$ GeV
 - $m_t(\text{lepton}-E_{t\text{miss}}) < 25$ GeV (rejects W's)
 - $1.8 < \Delta\phi < 2.9$ or $3.4 < \Delta\phi < 4.5$ ($\Delta\phi$ is angle between jet and lepton) Required for mass reconstruction
- Direct Production
 - Veto b jets $P_t > 15$ GeV
- Associated Production
 - At least one tagged b jet $P_t > 15$ GeV
 - At most 2 additional non-b jets (reject top)

Reconstructed Signals



- direct production

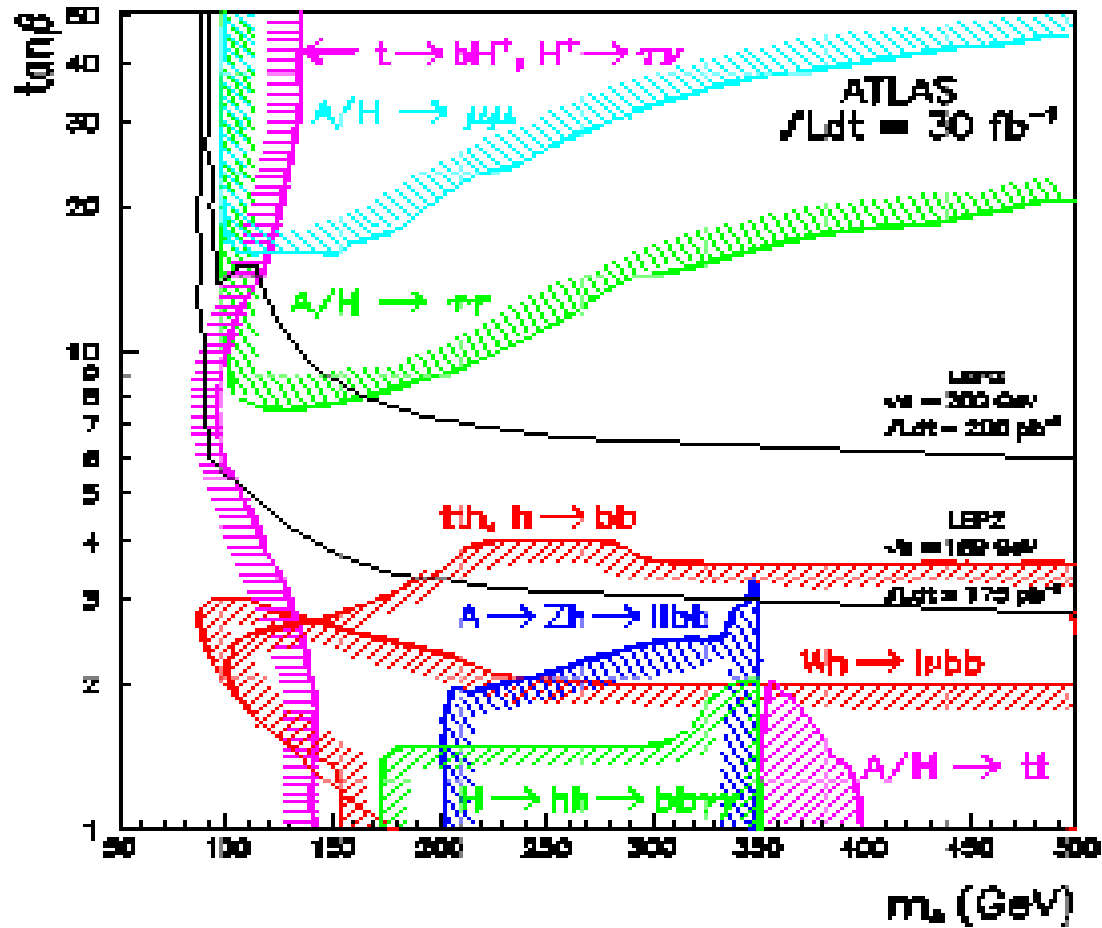


associated production

$$m(A) = 300 \text{ GeV}$$

Atlas Sensitivity

5 Reach



Conclusions

- SUSY Higgs A and H accessible at ATLAS in H/A in $\tau\tau$ decay channel
- Lepton trigger plus offline τ ID