Analysis of Invisible Higgs production in the $t\bar{t}h$ channel

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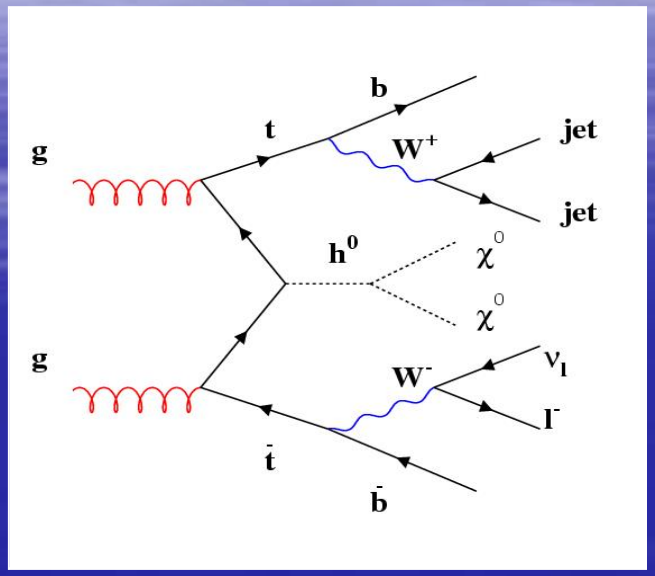
Introduction

- Motivation:
  - Several scenarios for physics BSM predict a significant invisible branching ratio
  - Complementary to the VBF channel with invisible Higgs
- Build upon work done at Royal Holloway:

  (E.Brambilla, talk at Higgs WG meeting, May 2002; T.L.Cheng, MSc.Thesis, available at: http://www.pp.rhul.ac.uk/~ctehlee/)
- Aim to reproduce and build upon results from previous analysis:

  (B.Kersevan, M.Malawski, E.Richter-Was, Eur. Phys. J C29 (2003) 541, ATL-COM-PHYS-2003-016; M.Malawski, MSci Thesis, hep-ph/0407160)

Analysis overview



Process	σxBR
tth	330 (*) fb
tt	490 000 fb
bbW, W → lν	73 000 fb
bbZ, Z → l+l-	61 400 fb
ttW, W → lν	420 fb
ttZ, Z → ν	190 fb

Cut-based analysis

Only signal and tt backg so far

Difficulties:

- Two components of missing momentum: can't reconstruct t→bνl
- ttbar is the most significant background and is very similar to signal
- Signal/Background ~10^{-3}

(*) σ=520 fb in reference analysis, with SM couplings

Cuts

Reference analysis cuts:

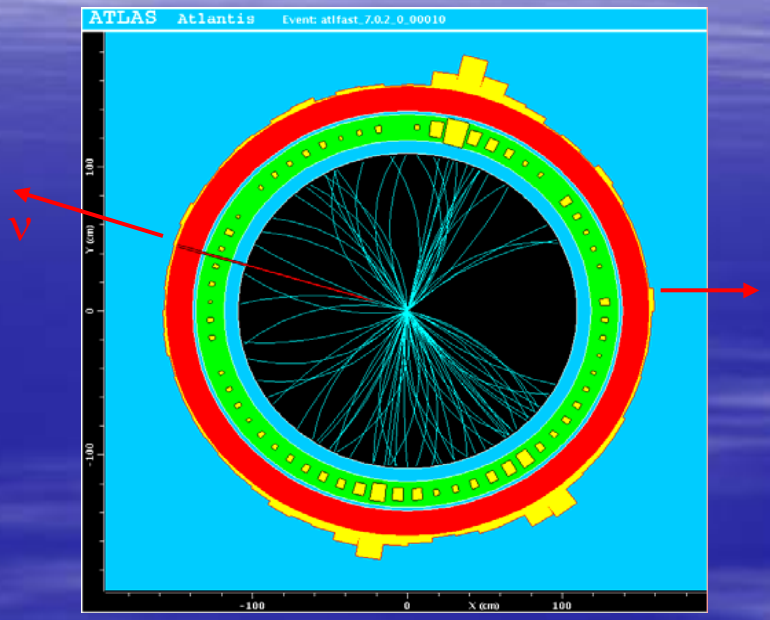
- 1 electron (p_T>25GeV; $|\eta|$<2.5)

or 1 muon (p_T>20GeV; $|\eta|$<2.5)

- Veto on additional electron (p_T>10GeV)

or additional muon (p_T>6GeV)

- 2 b-tagged jets
- 2 or more un-tagged jets
- t→bjj reconstruction:
  - $|m_{jj}-m_W|$<15GeV; $|\eta|$<2.0 for jets in W→jj
  - $|m_{bjj}-m_t|$<25GeV
- m_T > 120 GeV
- Missing E_T > 150GeV
- Scalar sum of p_T of reconstructed l j j b b: ΣE_T>250GeV
- In reconstructed W → jj: $R_{jj} = \sqrt{(\eta^2_{jj}+\varphi^2_{jj})}$ < 2.2 (to reject lep-tau decays)

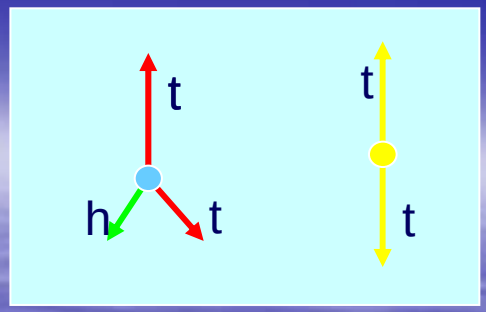


$$m_T = \sqrt{\left(E_T^{miss} + E_T^{lepton}\right)^2 - \left(\vec{p}_T^{\,miss} + \vec{p}_T^{\,lepton}\right)^2}$$

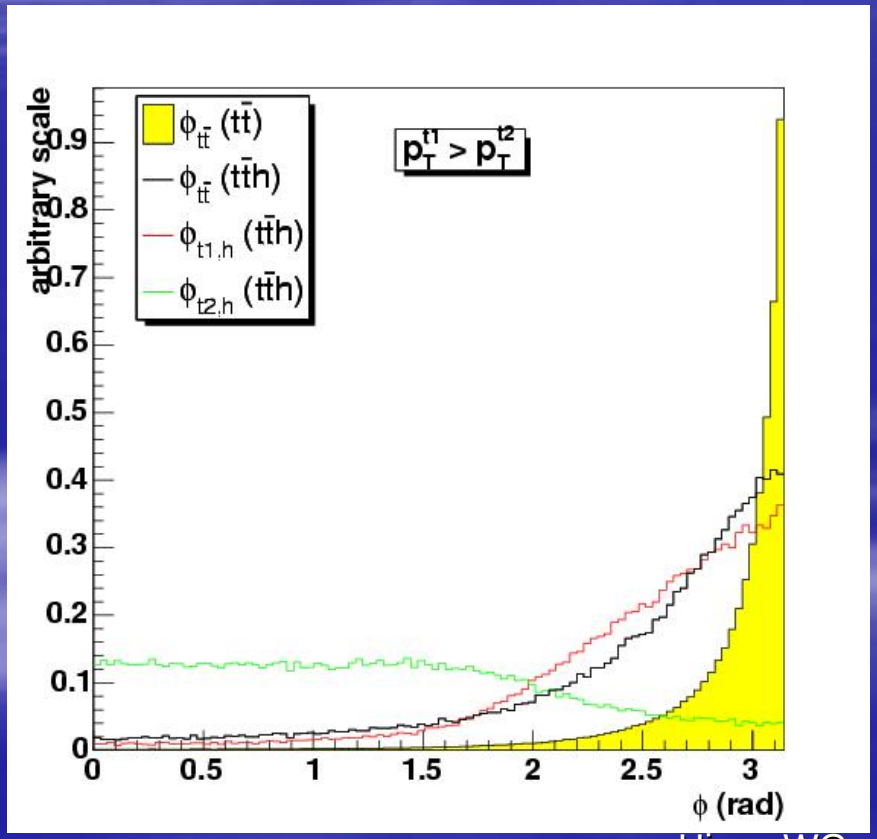
Simulation

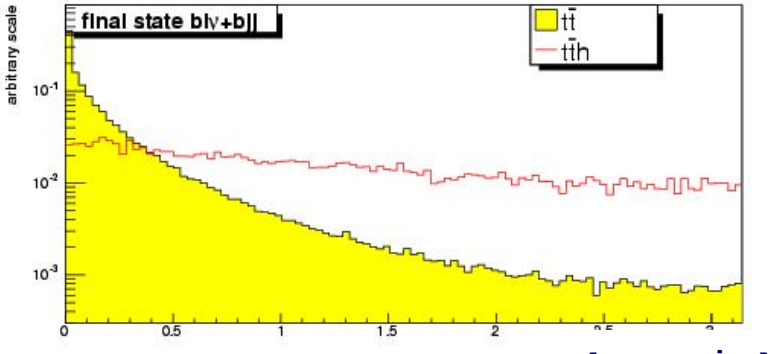
- Channel: Higgs (m_h = 120 GeV) decaying to neutralinos in MSSM
  - ($\tan\beta$= 5, m_A= 1 TeV; M_1= 44 GeV, M_2= 220 GeV, M_3= 1 TeV)
- PYTHIA 6.203 for signal and background
- Generated 60 M tt + 10 M tth
- Atlfast simulation, ATLAS release 7.0.2
  - Low luminosity setting
  - Cone jets (R_{cone} = 0.4)
  - Jet tagging: b jets 60%; c mistag 10%; u,d,s,τ mistag 1%
  - CTEQ5L PDFs
  - m_{top} = 175 GeV (..historical)
- Interfaced code to Atlfast within Athena to produce dedicated ntuple

The truth!

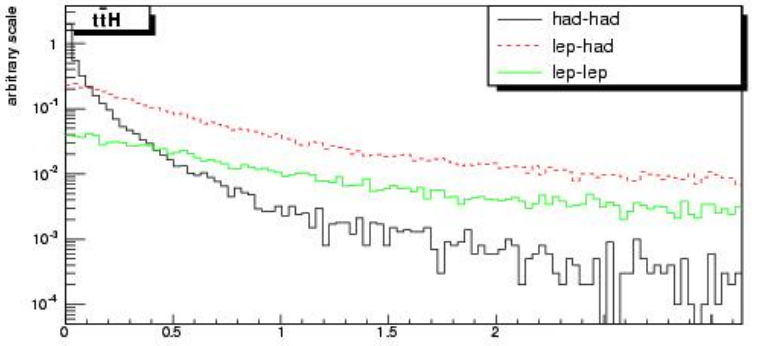


- At parton level:
  - tops back-to-back in background
  - more “mercedes star”-like in signal
  - Most missing p_T from Higgs decay (especially in had-had channel)





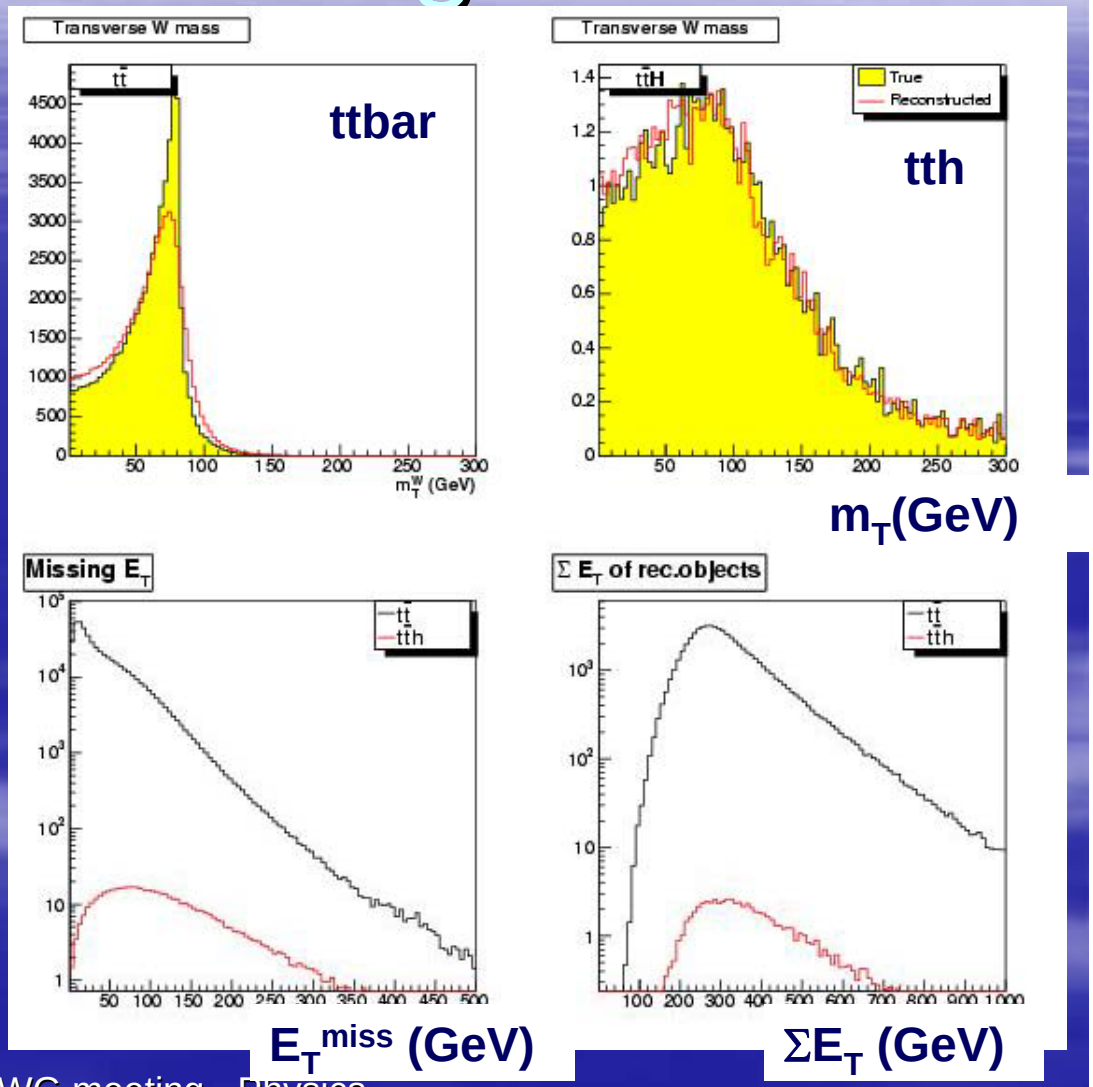
$\varphi(\nu, E_T^{miss})$



$\varphi(h, E_T^{miss})$

Signal and tt background

- Transverse mass, ΣE_T and E_T^{miss} are good discriminating variables
- m_T has sharp edge for tt background at ~m_W
- But background xsection ~1000 times higher than signal
- Tails of background distributions very large

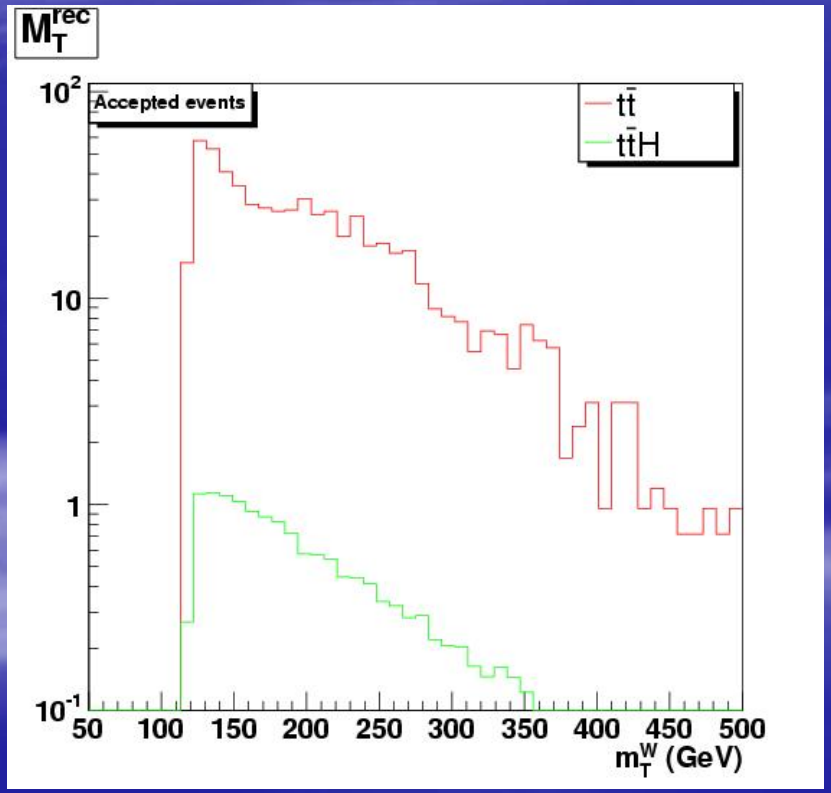


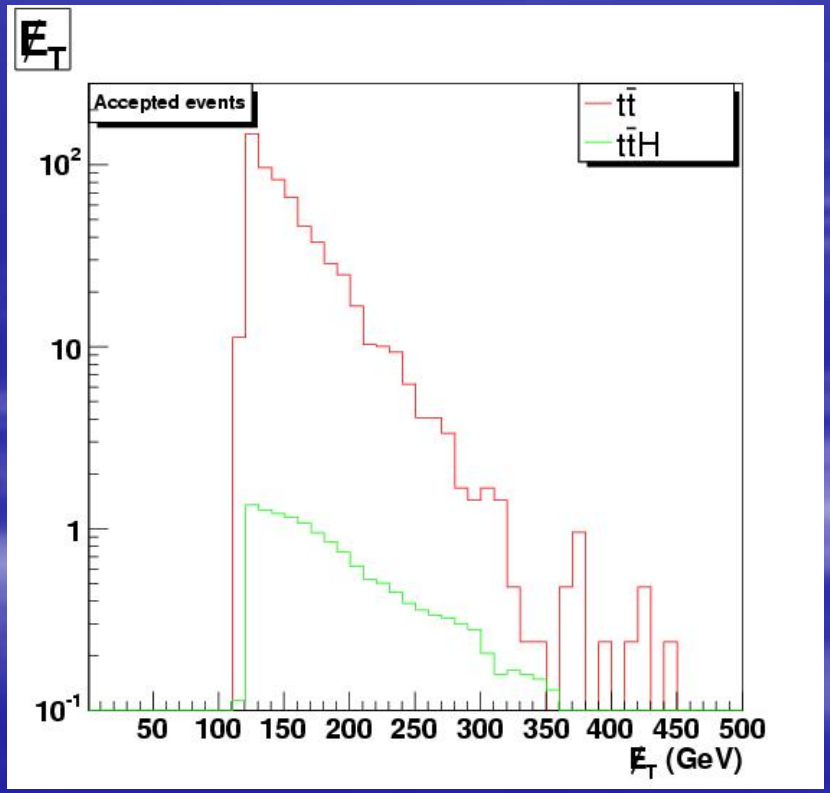
$$m_T = \sqrt{\left(E_T^{miss} + E_T^{lepton}\right)^2 - \left(\vec{p}_T^{\,miss} + \vec{p}_T^{\,lepton}\right)^2}$$

No cuts; Lumi = 1fb^{-1}

Results so far…

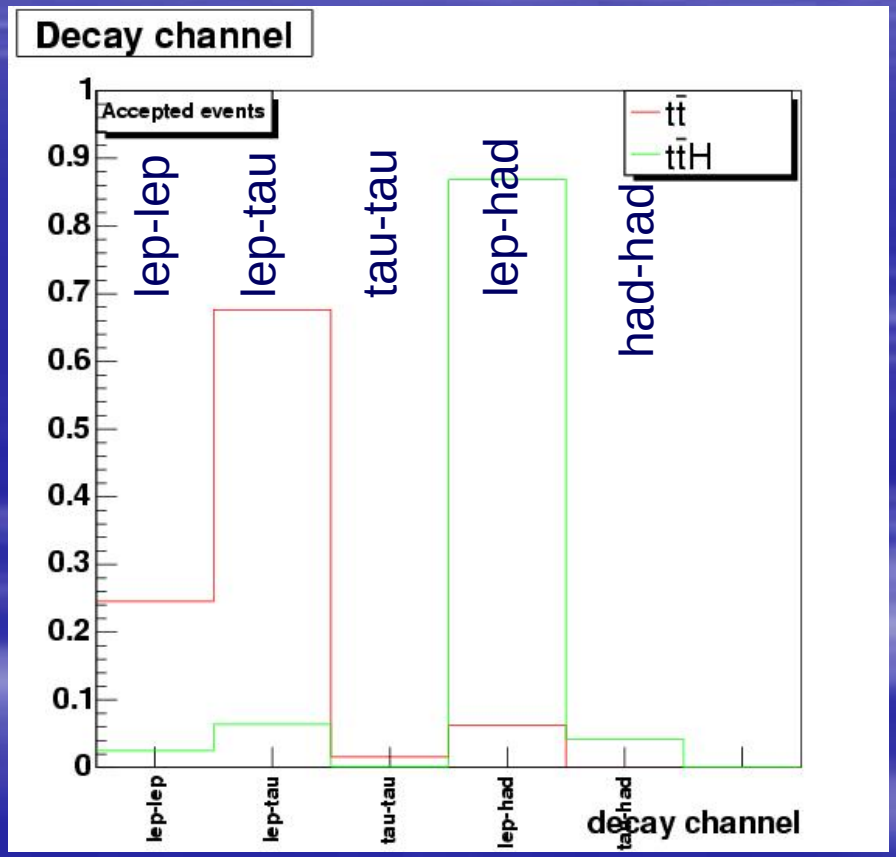
- Relaxed E_T^{miss} cut to 120GeV wrt reference analysis
- Background much higher than tth
- Signal and background normalized to 30 fb^{-1}





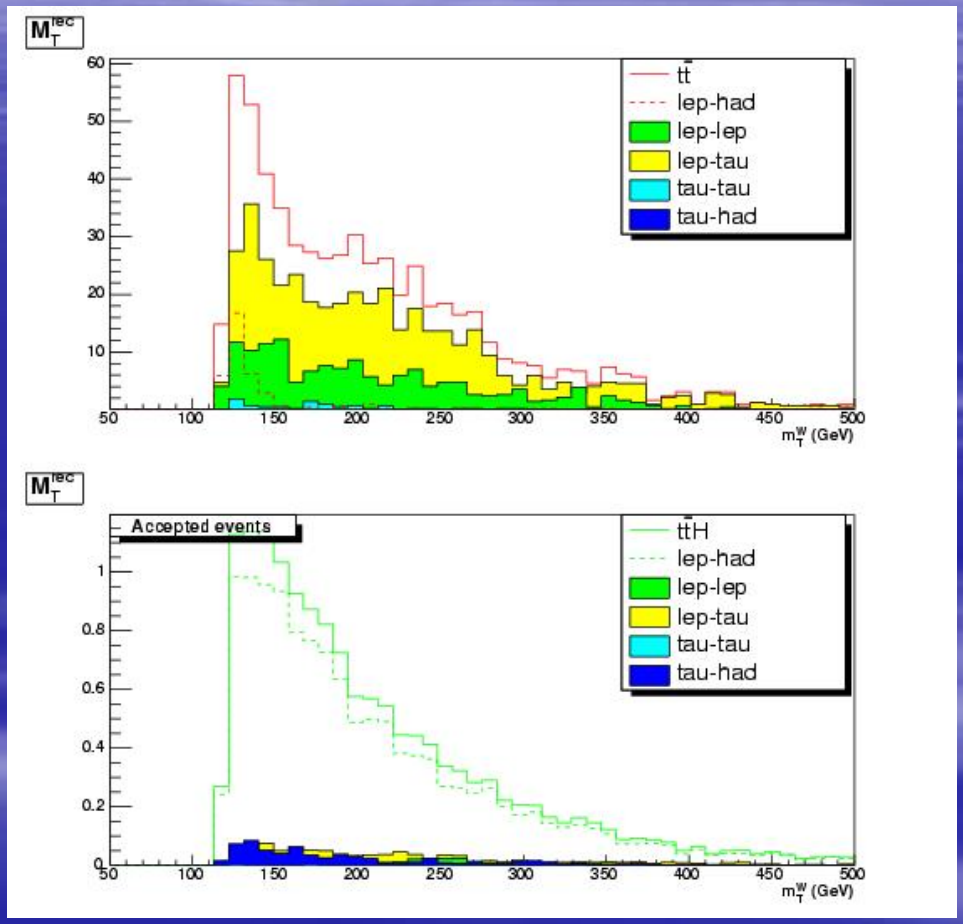
Results so far…

- Most background comes from lep-tau and lep-lep decays of tt, as concluded in reference paper
- τ decays increase the missing E_T
- $W \rightarrow jj$ reconstructed from ISR/FSR jets in lep-tau and lep-lep events



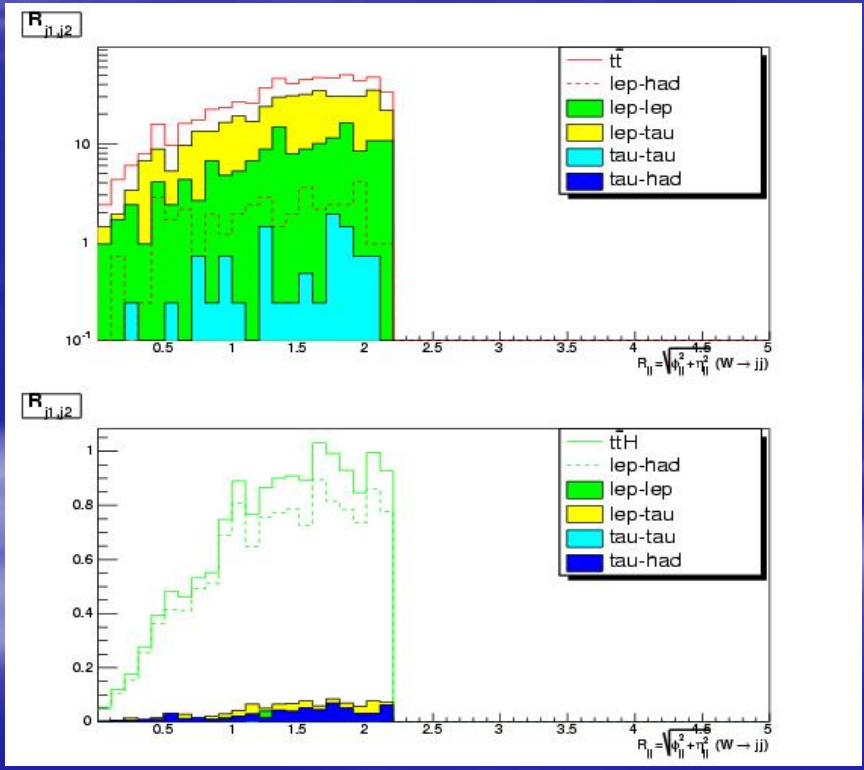
Results so far…

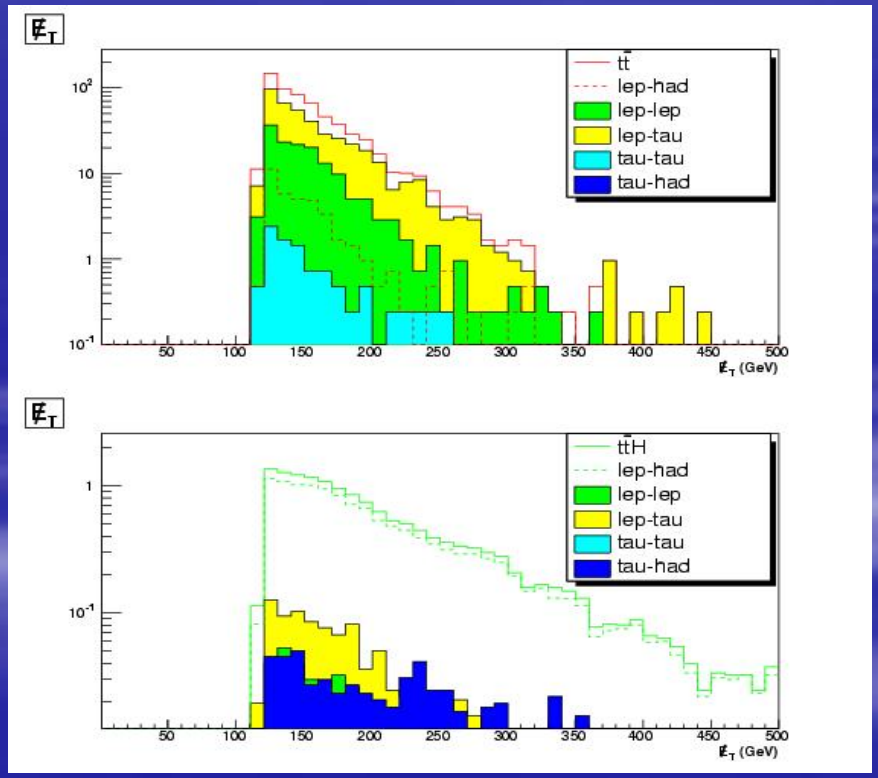
- Main problem in tt background is the “lep-tau” channel decays with fake W→jj
- tth signal much more pure wrt W→jj (we’re looking at the tails of tt background)
- Not much point in rejecting taus in Atlfast, must look for other possibilities



Results so far…

- No cut found so far that can be targeted at lep-tau and lep-lep channels in tt production in addition to what was found in the reference analysis





Results so far

Accepted events for 30 fb^{-1}

- tth x-section scaled to SM value as used in reference analysis

- tth: x-section = 520 fb^{-1}
- Signal = 44.3 events

- tt: x-section = 490000.0 fb^{-1}
- Background = 812 events

$S/\sqrt{B} = 1.55$

Comparison with reference analysis

Cumulative efficiency of cuts:

- Reasonable agreement with reference analysis: ~10-20% for signal ("check" column)
- Agreement wrt tt background efficiency becomes worse (factor 1.35 – 2.8) for cuts after m_T cut
- Testing all $t \rightarrow bjj$ combinations against m_W and m_t gives efficiency ~30% better wrt "cross check" ("this analysis" column) both for signal and background $\Rightarrow$ (small) net gain in significance

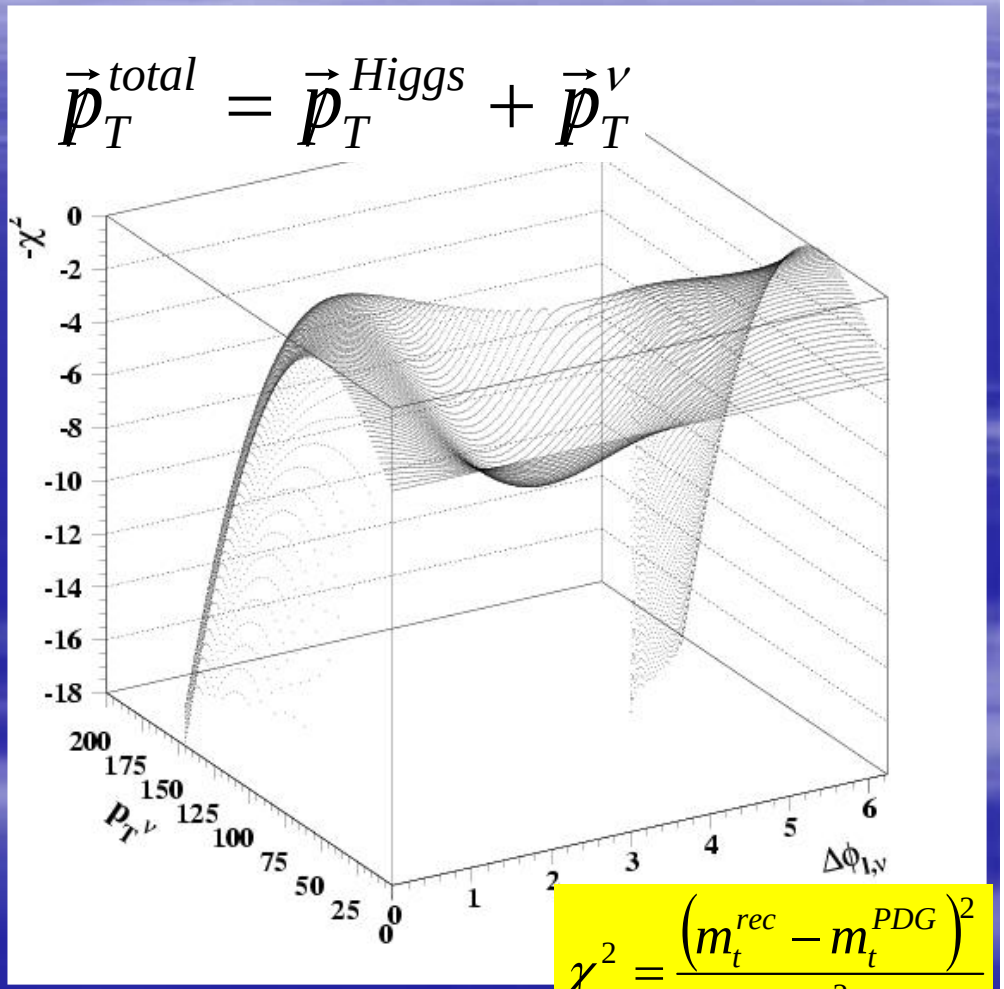
Cut	Reference tth	Cross check tth	this analysis tth	Reference tt	Cross check tt	this analysis tt
Lepton	22%	23.6%	23.6%	22%	23.6%	23.7%
Jets/b jets	5.0%	5.7%	5.7%	4.9%	5.01%	5.02%
$t \rightarrow bjj$	2.6%	2.9%	3.4%	2.4%	2.60%	2.98%
m_T	0.87%	1.12%	1.33%	0.041%	0.055%	0.063%
E_T^{miss}	0.41%	0.51%	0.67%	2.0×10^{-5}	$3.8 \times 10^{-5} \pm 0.6$	4.9×10^{-5}
ΣE_T	0.40%	0.50%	0.67%	2.0×10^{-5}	$3.7 \times 10^{-5} \pm 0.6$	4.6×10^{-5}
R_{jj}	0.28%	0.33%	0.44%	7.5×10^{-6}	$2.1 \times 10^{-5} \pm 0.5$	2.8×10^{-5}

Kinematic fit

Tried something different:

- Assume p_T^{miss} comes from ν and h only
- Build grid of points in p_T^{ν} and $\varphi(l,\nu)$ and calculate p_Z^{ν}
- p_Z^{ν} can be found from p_T^{ν} and p^{lep} assuming W on mass-shell
- From p^b , p^{ν} and p^{lep}, calculate m_t for each point
- Propagate errors in m_t from grid spacing to obtain σ_{mt} and calculate χ^2

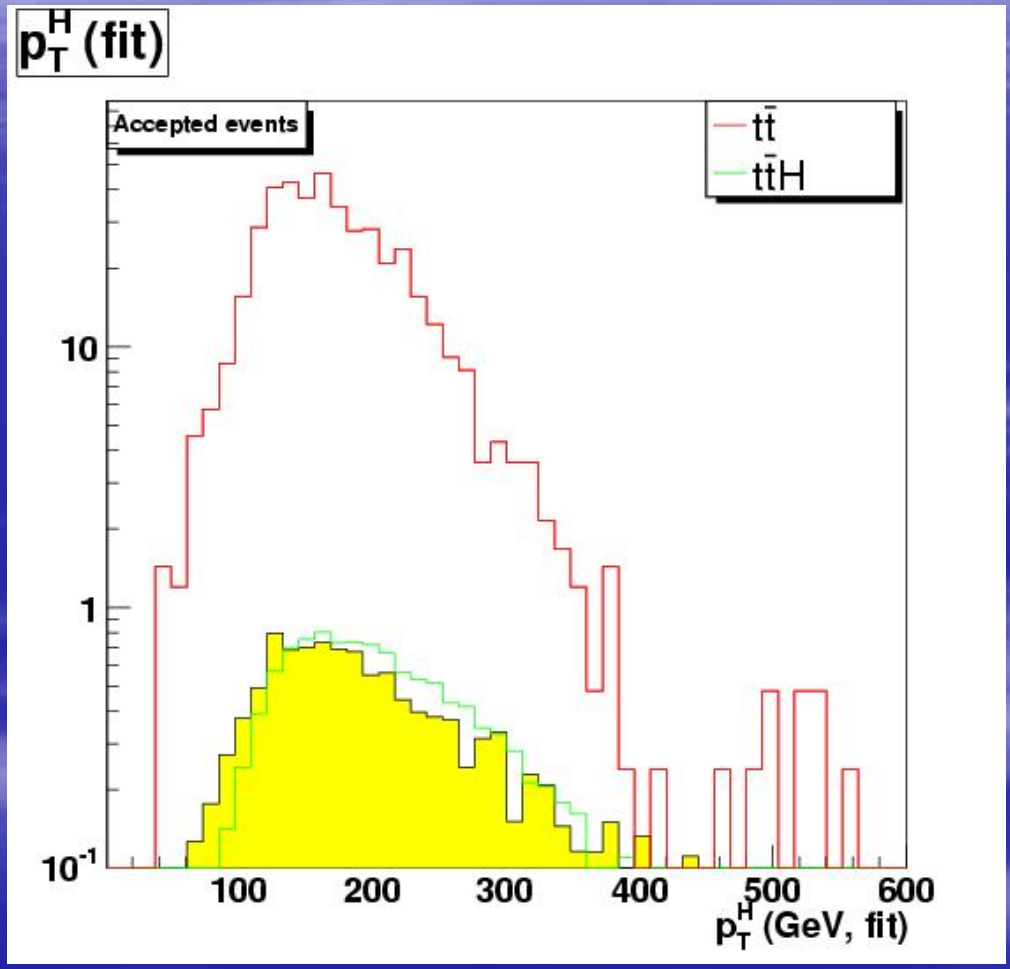
$$\vec{p}_T^{\,total} = \vec{p}_T^{\,Higgs} + \vec{p}_T^{\,\nu}$$



$$\chi^2 = \frac{\left(m_t^{rec} - m_t^{PDG}\right)^2}{\sigma_{mt}^2}$$

Kinematic fit results

- Kinematic fit ~works for signal: $\sigma(p_T^h)$~85GeV
- Will try to use fit results for discrimination against tt background
- The hope is that this allows other cuts to be relaxed
- Correlations to m_T and E_T^{miss} may be important



Conclusions

- Major background to tth has been studied
- Reasonable agreement with reference analysis – still work to be done to find remaining differences
- Some improvement in significance may be achieved by different reconstruction of $t \rightarrow bjj$
- Simple kinematic fit to semileptonic top decay may be useful to discriminate against background