Extended scalar sector in DTHM

$H^{\pm\pm} \to W^{\pm} W^{\pm}$

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Associated Production

Parameters

The process: $pp \to H^{\pm\pm}\,(\to W^{\pm}W^{\pm})\,H^{\mp}$.
The parameters were generalized to be non-degenerate while being naturally allowed by the theoretical constraints. Parameters:

- $\sin\alpha = 10^{-4}$
- $M_{H^{\pm\pm}} = 200\,GeV$
- $M_{H^{\pm}} = 192\,GeV$
- $M_{H^0} = M_{A^0} = 163\,GeV$
- $\lambda_5 < 0 \Rightarrow m_{A^0,H^0} < m_{H^{\pm}} < m_{H^{\pm\pm}}$.

$H^{\pm}$ decays to $WZ(64\%)$ or $tb(36\%)$. This can give the same final states as our signal regions.

Overlap between pair-production and associated production

$H^{\pm\pm} \to W^{\pm}W^{\pm} \to 3\ell + 2j + E_T^{miss}$

$H^{\pm} \to W^{\pm}Z$ (64% BR) or $H \to tb$ (36% BR). This could give the same signatures as the concerned pair-production final state.

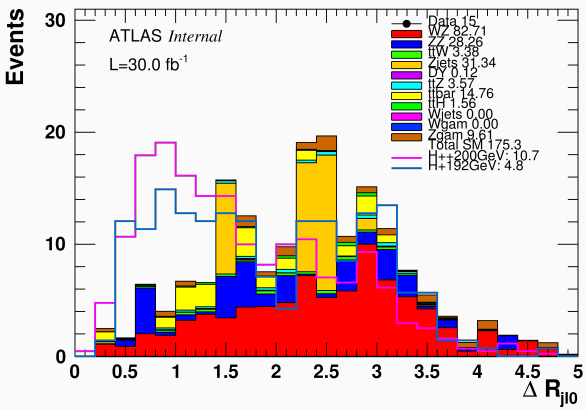


Figure 1: ΔR between leading jet and opposite sign lepton

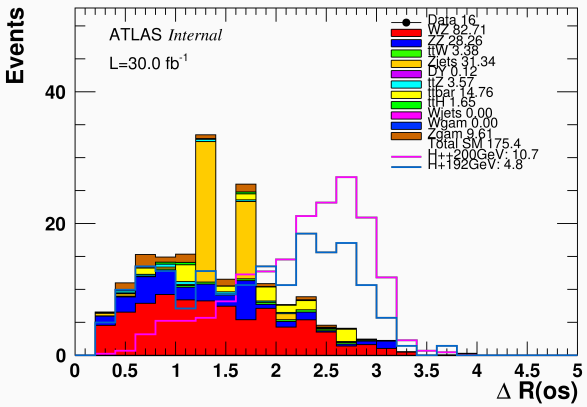


Figure 2: ΔR between opposite sign leptons

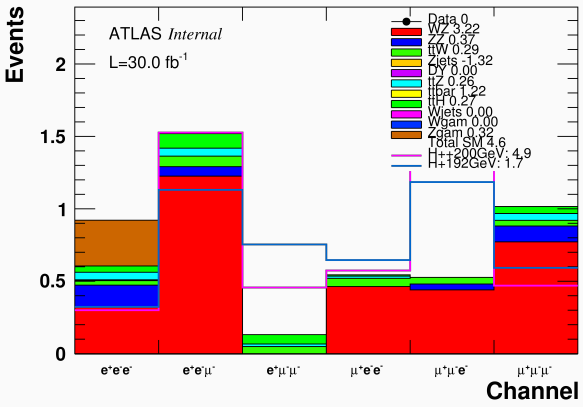
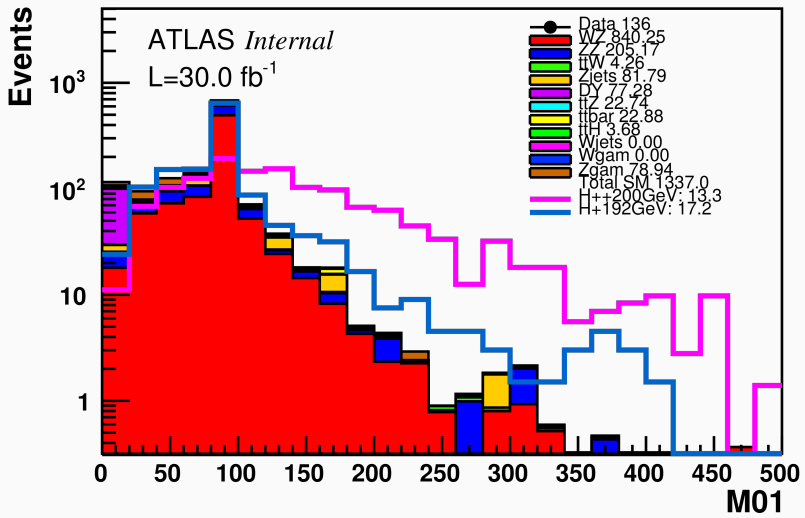


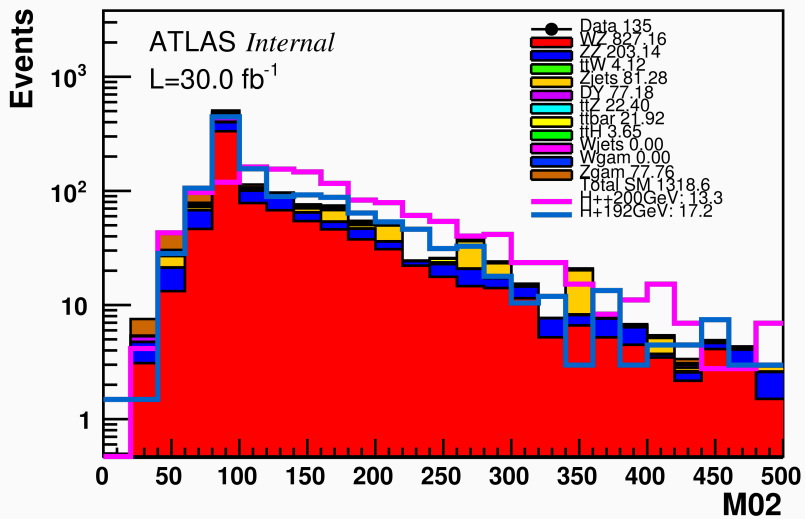
Figure 3: Signal and background yields at 30 fb^{-1}

Overlap can be seen in the signal regions of the discriminating variables. Associated production contributes roughly 30% of the events compared to pair-production if the masses of $H^{\pm\pm}$ and $H^{\pm}$ are nearly degenerate.

Invariant Masses

The cross-section of associated production is roughly twice that of the pair-production. The invariant mass of opposite sign leptons in the associated production channel resembles that of WZ. The Z-veto kills a lot of these events.





To be investigated further.

Fake factor

Fake factor

The fake factor method is used to estimate the number of fakes in the signal region. The factor is defined in the control region as,

$$\theta = \frac{N_{TTT} - N_{TTT}^{prompt}}{N_{TT\bar{T}} - N_{TT\bar{T}}^{prompt}}$$

The prompt contribution is evaluated from MC. Where $\mathbf{T}$ and $\bar{\mathbf{T}}$ are obtained by applying a set of tight criteria or inverting them, respectively. To extrapolate to the signal region, a new region, SR', is obtained using the same kinematics as the signal region but a set of ID/isolation cuts inverted.
The number of fake estimates in the signal region are given by,

$$N_{\text{SR, estimate}} = (N_{\text{data, SR'}} - N_{\text{prompt, SR'}}) \times \theta$$

Region definition

- 3ℓ (looseID) with total charge ± 1
- $P_T > 20 GeV$ for SS leptons
- $P_T > 10 GeV$ for OS lepton (0th lep)
- nJets > 0, nbJets > 0
- Z-mass veto: ± 10 GeV of Z mass are rejected.
- $E_T^{miss} > 20 GeV$
- $M_{\ell\ell}^{os} > 15$ GeV
- IP:
  - $|z_0 \sin\theta| < 0.5$ mm
  - $\sigma_{d_0} PV < 5.0$ for e
  - $\sigma_{d_0} PV < 3.0$ for μ

Tight

- Electrons:
  - TightLH
  - ptvarcone20/pt < 0.06
  - topoetcone20/pt < 0.06
- Muons: ptvarcone30/pt< 0.06

Anti-Tight

- Electrons:
  - not(TightLH)
  - Relax isolation
- Muons: Invert isolation

Fake factors: Electrons

Channel	Data	Prompt	Num
xee	10	3.11	6.89
xeμ	26	7.15	18.85

Table 1: TTT

Channel	Data	Prompt	Den
xee	8	0.68	7.32
xeμ	7	0.6	6.4

Table 2: Electrons: TT$\bar{\text{T}}$

$\theta = \frac{25.39}{13.72} = 1.85 \Rightarrow$ Too high

Fake factors: Muons

x, in the following tables, denotes either an electron or a muon.

Channel	Data	Prompt	Num
x$e\mu$	26	7.15	18.85
x$\mu\mu$	10	4.48	5.52

Table 3: TTT

Channel	Data	Prompt	Den
x$e\mu$	8	0.25	7.32
x$\mu\mu$	19	0.2	18.8

Table 4: Electrons: TT$\bar{\text{T}}$

$\theta = \frac{24.37}{26.12} = 0.93 \Rightarrow$ Too high

TTT: Njets

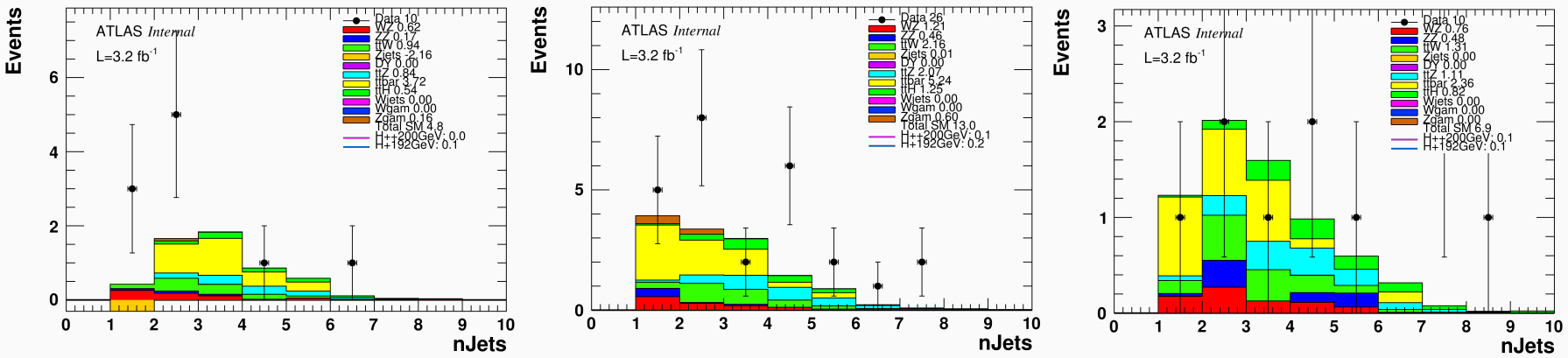


Figure 4: Left to Right: xee, xeμ, x$\mu\mu$

TTTbar: Njets

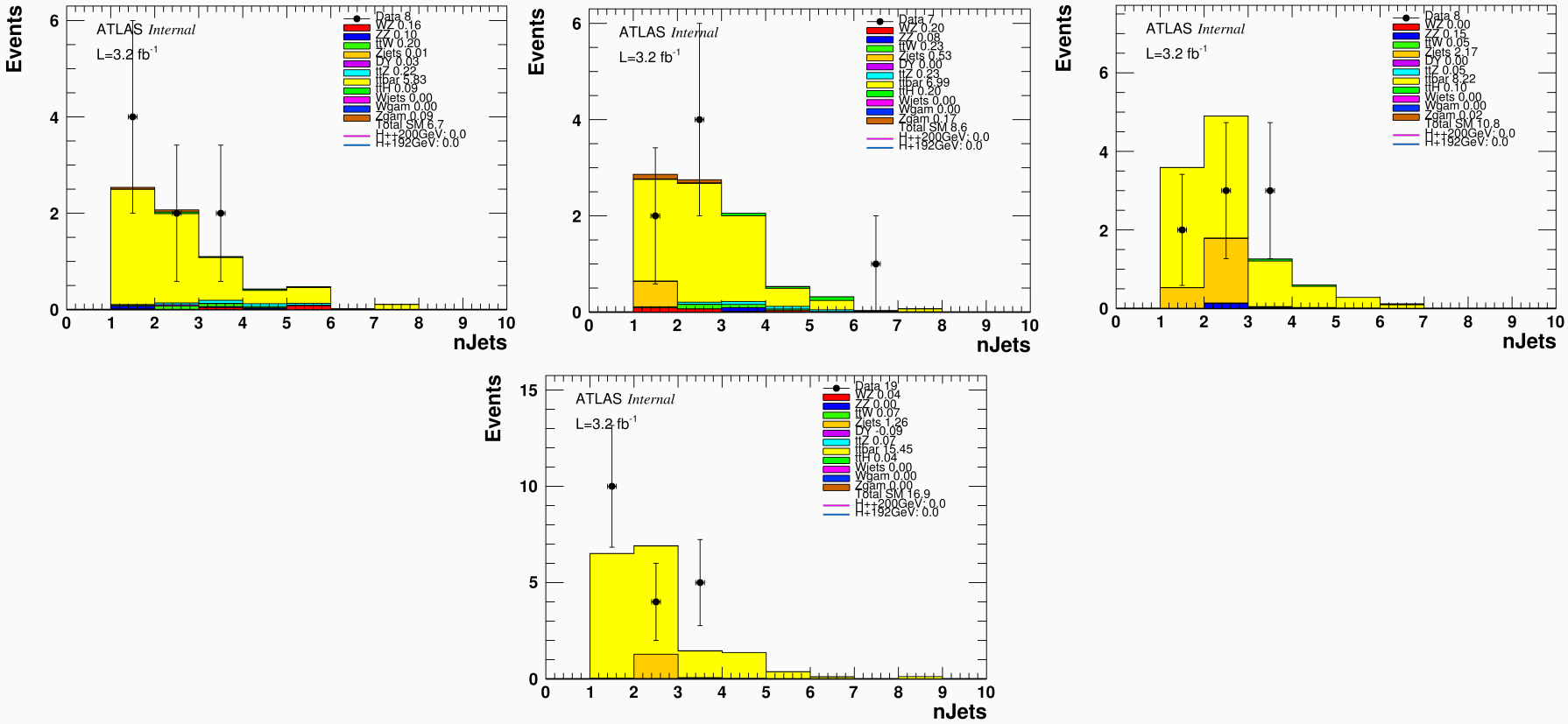


Figure 5: Top Left to Right: xee$_f$, xe$_f\mu$, xeμ_f; Bottom: x$\mu\mu_f$

ℓ_f denotes the lepton which is anti-tight.

To-do in fake factor estimation

- Statistics are too low. One dominant cut is requiring non-zero bjets. Investigations with 2l ongoing.
- Cut flow and jet multiplicity in the backup.

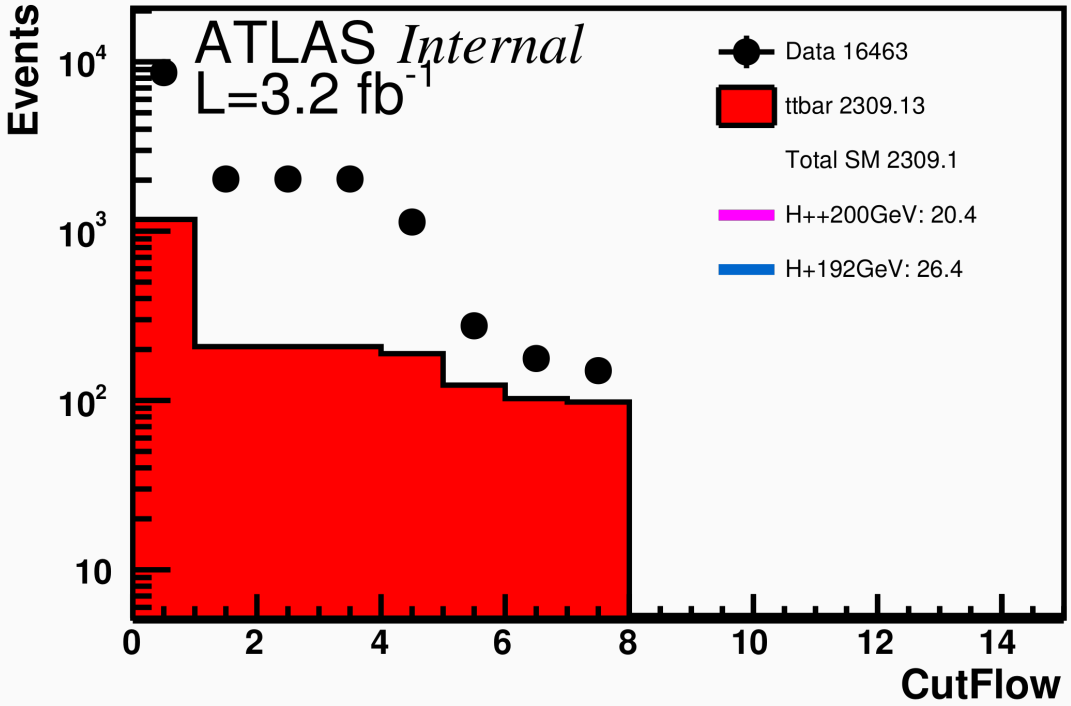
Backup

Allowed mass points (in GeV)

If $H^{\pm\pm}$ and $H^{\pm}$ are degenerate, it is impossible to get the neutral Higgses to have the same mass. A parameter space study considering theoretical constraints show allowed mass points that are nearly degenerate. These will used for the simulations.

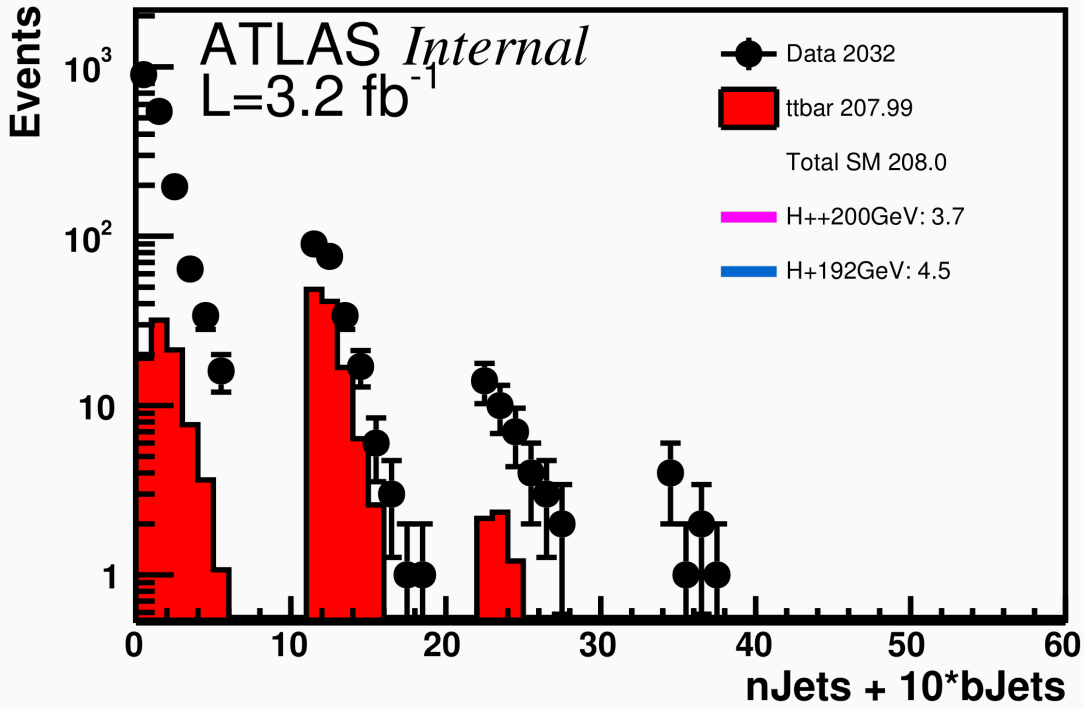
$H^{\pm\pm}$	$H^{\pm}$	H^0	A^0
200	192	163	163
300	294	288	288
400	395	391	391
500	497	494	494

Cutflow



The two cuts which affect the stats the most are 1, and 5. 1 corresponds to the PT cut on the leptons. 5 corresponds to requiring at least one b-jet.

Jet multiplicity



Significant fraction of events with 0 b-jets which should not be the case.