Type III seesaw Heavy lepton search

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Flavor and CP - Snowmass
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Introduction

- Motivation and Physics Model
- Phenomenology
- Signature
- Signal samples and detector simulation

Caveat: very first look at it to understand how to generate samples and run the detector fast simulation. Only signal sample

Motivation

- Neutrino oscillation experiments have proven that neutrinos of all three generations oscillate and are therefore massive. However, from the theoretical point of view, the origin of this mass is still unknown.
- While it is possible for neutrinos to acquire mass by coupling to the Higgs field, in much the same was as other fermions do, this would require an extremely small Yukawa coupling and is certainly not a natural solution
- To provide answers to these puzzles a number of modifications to the Standard Model have been proposed including seesaw models

Type III Seesaw model

- Introduction of at least two extra matter fields in the adjoint representation $SU(2)_L$: $\left(\Sigma^+ \, \Sigma^0 \, \Sigma^-\right)$
- However unlike Type I, the Type III Seesaw model couples to gauge bosons making studies at the LHC a distinct possibility
- In a simplified model for a single new fermion triplet the Yukawa couplings reduce to a vector:

$$Y_N = (Y_{N_e}, Y_{N_\mu}, Y_{N_\tau})$$

- It generates a single light neutrino mass
- Parameters of the model: Triplet mass and mixing angles

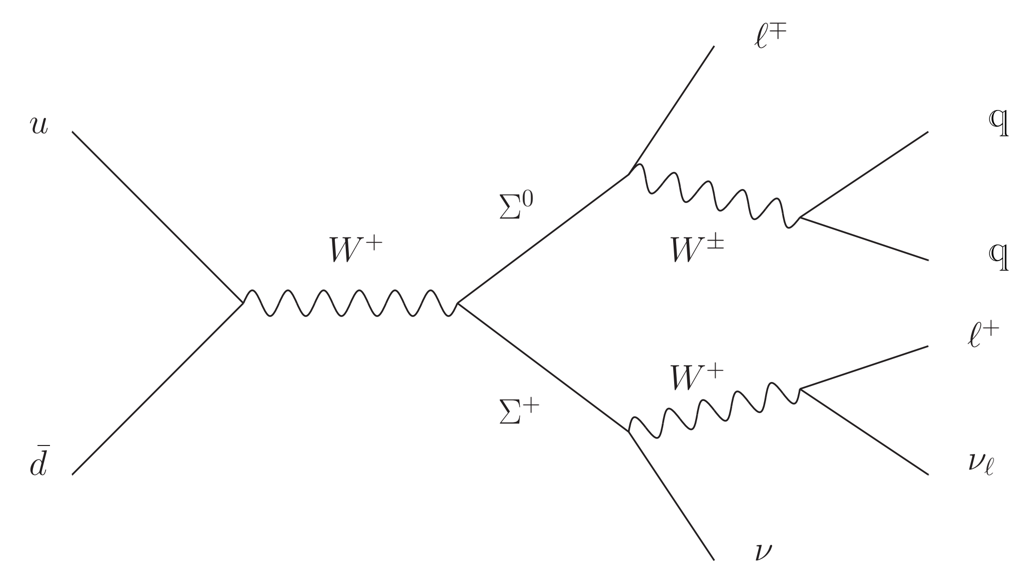
Phenomenology

- Direct production of Σ^0 $\Sigma^\pm$
- Many decay modes
- I general leptonic signature are the cleanest but lower branching ratios
- Hadronic signals has larger yields but also larger backgrounds
- Focus on dominant final state

$$\Sigma^\pm \rightarrow l^\pm Z$$
$$\Sigma^\pm \rightarrow \nu_l W^\pm$$
$$\Sigma^0 \rightarrow l^\pm W^\mp$$
$$\Sigma^0 \rightarrow \nu_l Z$$

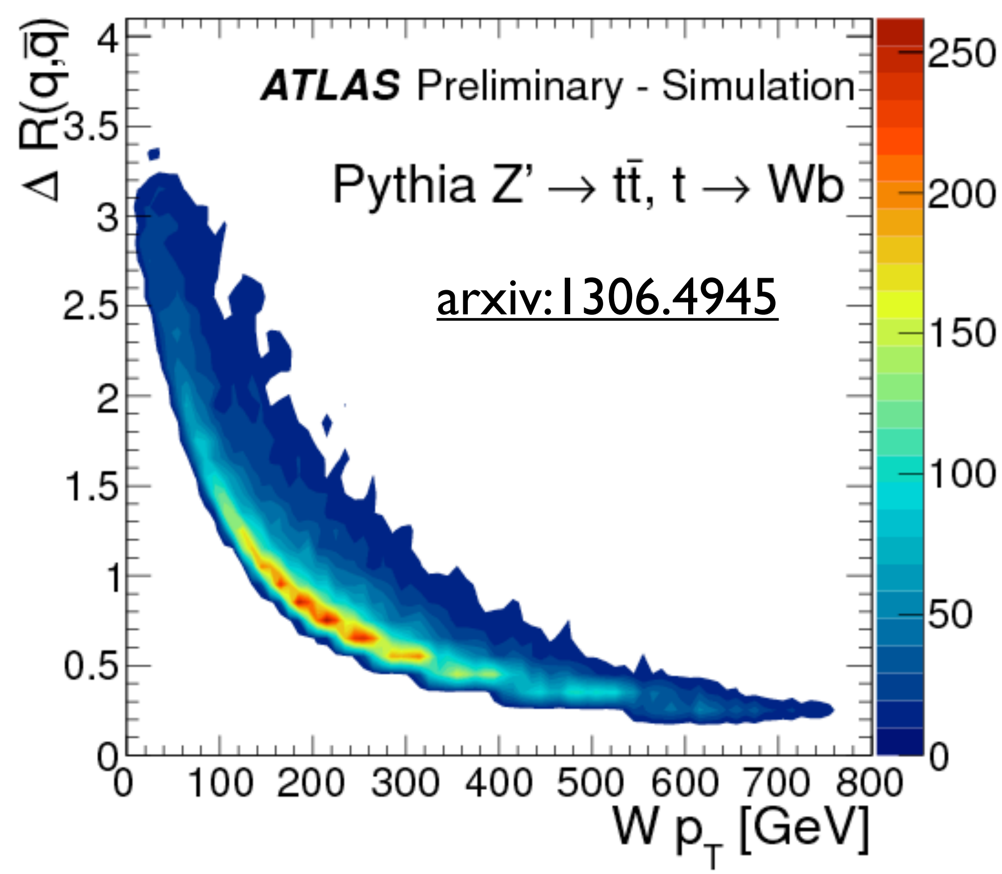
$$pp \rightarrow \Sigma^\pm + \Sigma^0 \rightarrow \nu W^\pm l^\pm W^\mp$$

Signature: 2 leptons + W-jet
Lep+jet -> full reconstruction of the Σ^0 mass



Boosted topology

- One W decays leptonically
- The other W decays hadronically:
  - for massive Σ the W is boosted and its decay products can be collected in a single jet
- Hadronic W can be tagged using jet shape/substructure techniques
- $p^W{}_T \sim 320$ GeV $\Delta R \sim 0.5$



$$\Delta R(qq) = \frac{2m_W}{p_T^W}$$

Signal samples

- 4-vectors generated with Madgraph
  - Feynrules code provided by Biggio, Bonnet, arXiv:1107.3463
- $\sqrt{s}$= 33 TeV
- 3 different mass points 600,900,1200 GeV
- Maximal mixing angles of the new heavy fermions to electrons and muons: $|v_e|$ = 0.055 $|v_e|$ = 0.063
  (other elements set to 0)
- Pythia8 for parton shower, ISR/FSR, UE etc.
- Detector simulation: Delphes - Snowmass Combined LHC detector
- Pileup 140

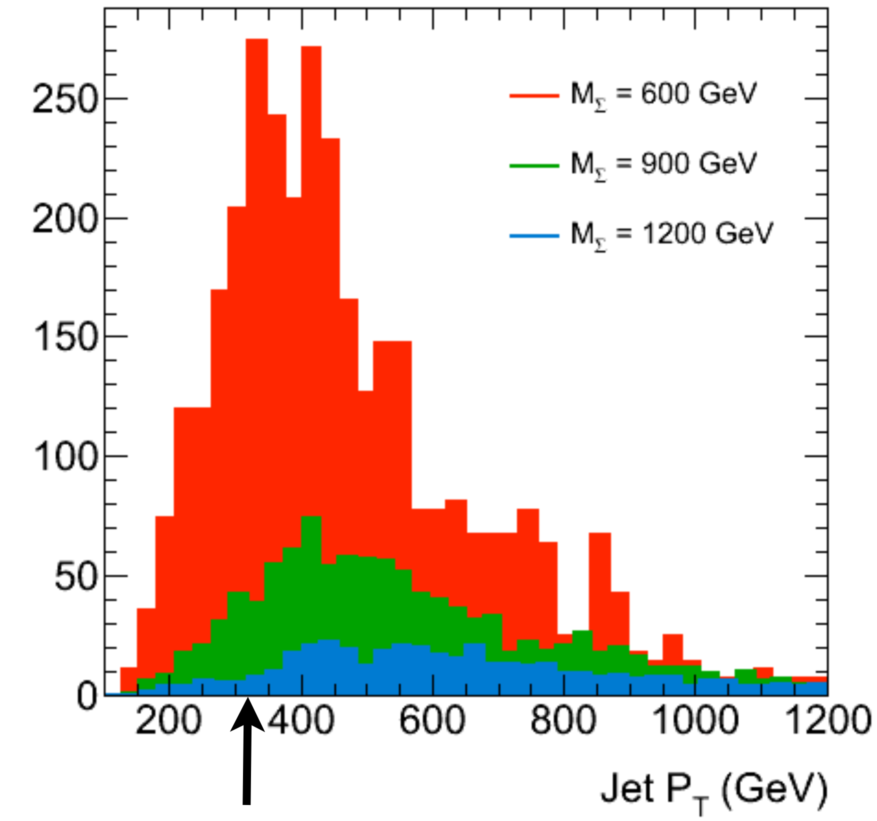
Object reconstruction

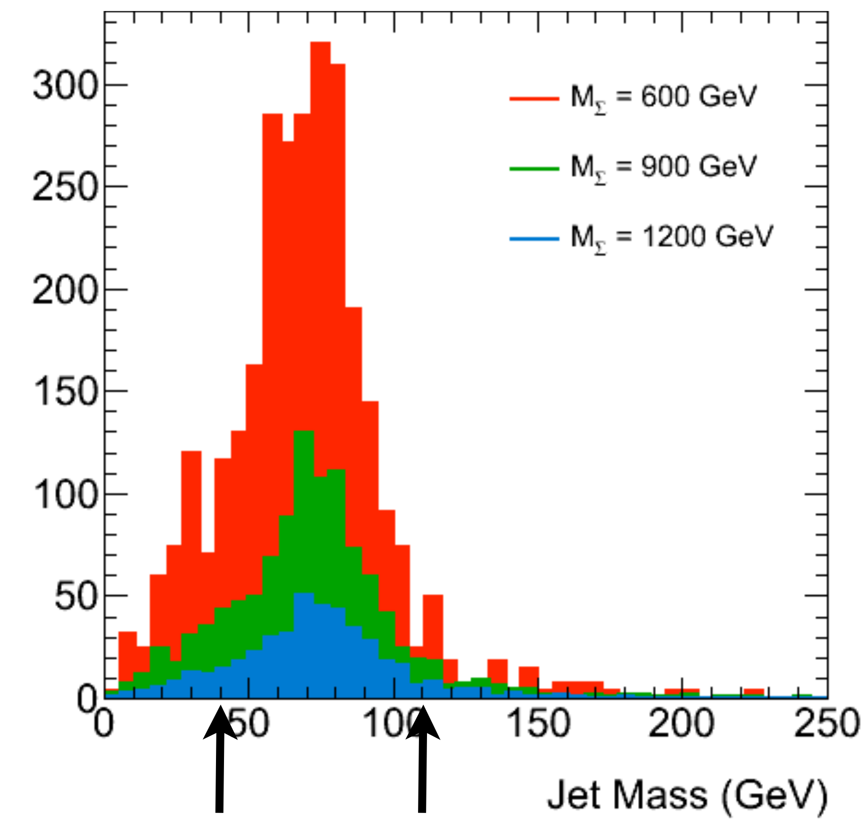
- Using default object stored in Delphes nutples
- Jets:
  - kt algorithm $\Delta R = 0.5$
  - pileup-subtracted
  - No jet/substructure info at the moment
- Electron and muons (default)
- No MET requirements (sensitivity also to $\Sigma^{\pm} \to Z + l^{\pm}$)

Boosted W-jet

- Jet p_T > 320 GeV
- Jet mass: distinctive peak at ~M_W
- Jet mass cut to select W-jets
- Additional techniques can be used to:
  - Reject background: PRD 85 052005
  - Recover resolution

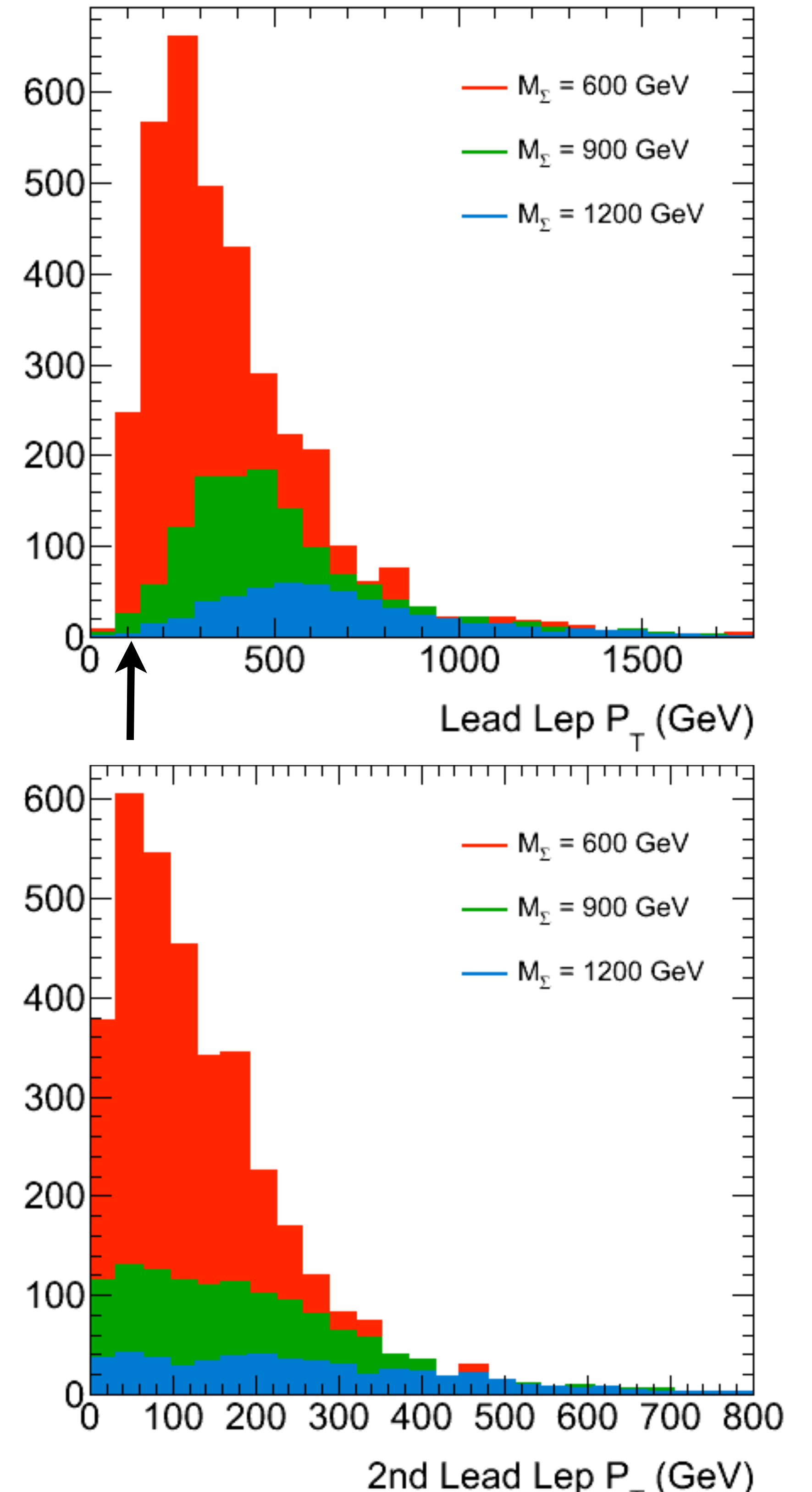
N.B. optimization of p_T cut and jet ΔR required





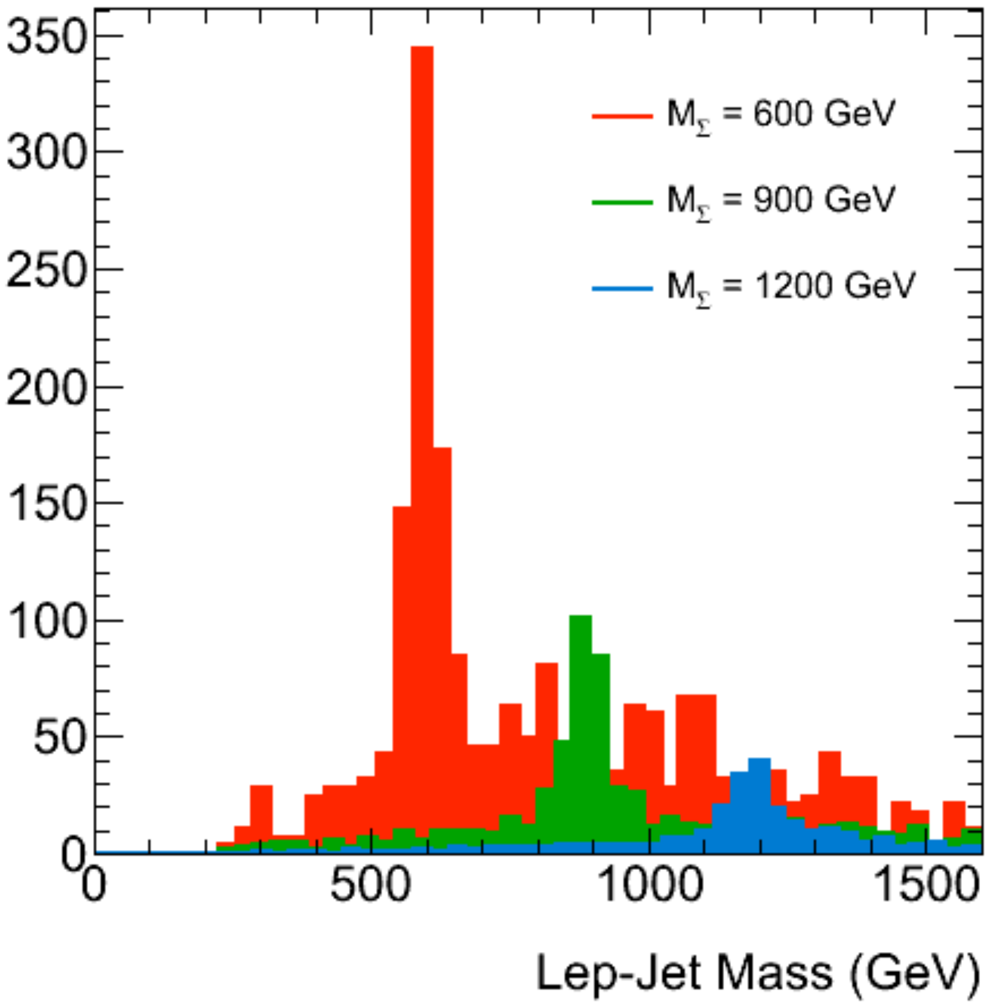
Leptons

- Two high p_T leptons (electron and muons)
- p_T lead > 100 GeV
- 2nd lead p_T > 25 GeV
- M_{ll} > 110 GeV remove Z peak



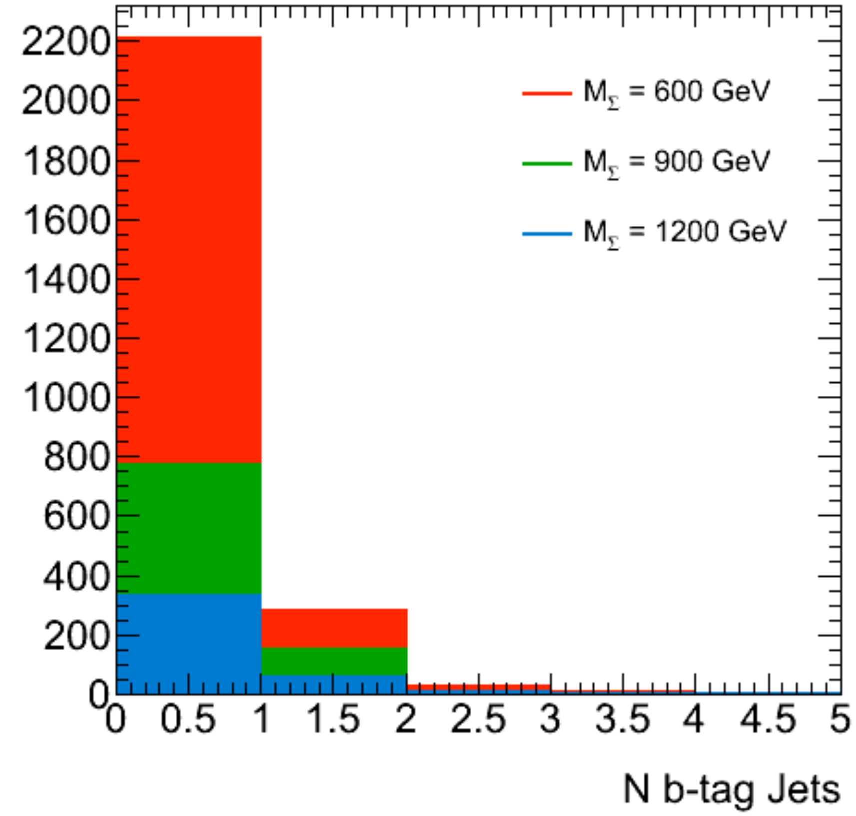
Resonance reconstruction

- Combine the leading lepton with the W-tag jet
- Full reconstruction of the Σ^0 mass
- Expected yields for 3000/fb



Backgrounds

- Very small background
- From preliminary estimate (not shown today) S/B ~ 0.2
- Need to be studied carefully:
  - γ/Z+jet
  - ttbar (reject with b-jet veto)
  - WW/WZ/ZZ (very small)



Conclusion

- First look at heavy lepton production in the type III seesaw model
- Projection for 3000/fb, $\sqrt{s}$= 33 TeV
- Basic signal kinematic variables studied
- Still to do:
  - analysis optimization (jet ΔR, cuts, etc.)
  - run on background samples (centrally produced HT binned samples not ready for 33 TeV)