Introduction to Heavy Neutrinos

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Introduction

- Standard model unanswered questions
  - Dark Matter
  - Baryon Asymmetry
  - Smallness of neutrino masses
- A heavy neutrino could explain the latter using the seesaw mechanism
- The Neutrino Minimal Standard Model (νMSM) could solve all three problems
  - Postulate three new right-handed heavy neutrinos

Introduction: Seesaw Mechanism

- Consider the SM Lagrangian with the addition of a single new RH neutrino

$$L \supset F_\alpha \bar{L}_\alpha H N + \frac{1}{2} M \bar{N}^c N$$

- Only one flavor of N is produced at a time for a given interaction
- After electroweak symmetry breaking the mass eigenstates are

$$M_{\nu\alpha} \sim \frac{F_\alpha^2 \langle H \rangle^2}{M}$$

$$M_N \sim M$$

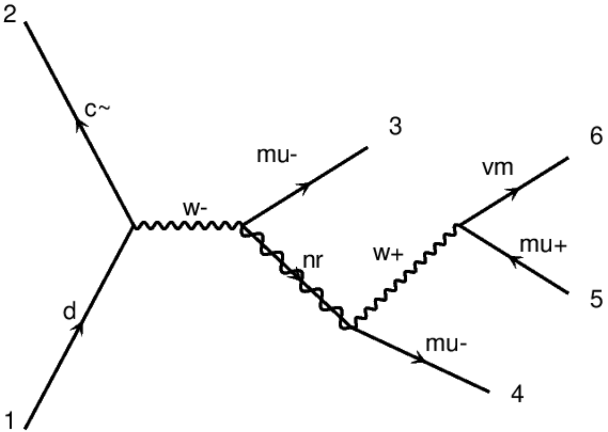
- Then, if one increases the other decreses and viceversa, hence the name seesaw

Introduction

- Issues with seesaw
  - What is the scale of M_R and what determines it?
  - Is there a natural reason for the existence of the right handed neutrinos?
  - Is the seesaw mechanism by itself enough to explain all aspects of neutrino masses and mixings?

Event signature

- Event signature consist of three charged leptons (e, μ) plus missing energy



- item 2

The Analysis

- Consider the case where N mixes only with ν_μ
- Production
  - From W bosons, $W^\pm \rightarrow \mu^\pm N$
  - When allowed, from $B^\pm \rightarrow D\mu^\pm N$
  - N is produced in association with prompt muons and other objects
- Decay
  - N could decay via off-shell W/Z bosons to SM particles
  - Leptonic $N \rightarrow \mu^\pm l^\mp \nu_l$ and $N \rightarrow \nu_\mu l^+ l^-$, with a distinctive final state of multiple charged leptons
  - Semileptonic $N \rightarrow \mu^\pm q\bar{q}$, larger backgrounds

The Analysis

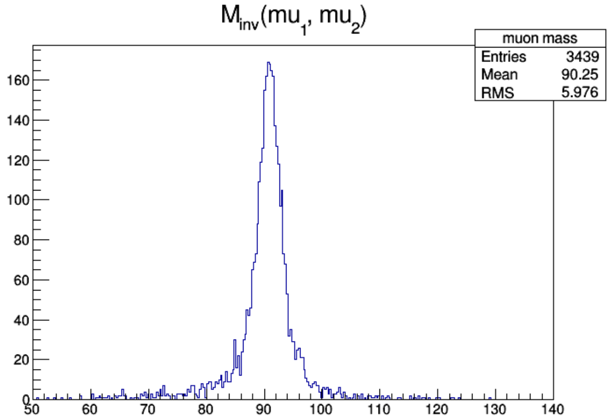
- The search includes
- Displaced lepton jet
  - $\mathrm{M}_N < M_W$
  - RN is boosted in $W^{\pm} \rightarrow \mu^{\pm} N$
  - Signature: prompt lepton + a single displaced lepton jet
- Prompt trilepton
  - For $M_N > 15 GeV$
  - RH is not boosted nor displaced
  - $W^{\pm} \rightarrow \mu^{\pm} N \rightarrow \mu^{\pm}\mu^{\pm}e^{\mp}\nu$

First Simulation

- Used madgraph and pythia to simulate the process
  - $pp \rightarrow w \rightarrow \mu nr(nr \rightarrow w\mu, w \rightarrow \nu_\mu \mu)$
  - Energy 13 TeV
  - $M_N = 30$ Gev
  - 10k events
- Used delphes to make preliminary plots

Reconstructed Z peak

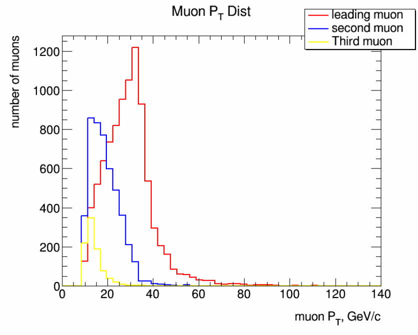
- First simulated $Z \to \mu^+\mu^-$ and reconstructed the Z mass peak



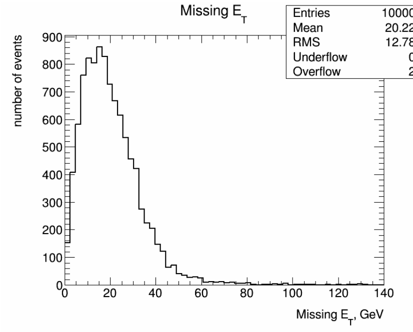
- If things work well move to the RHN

Preliminary Plots

- P_t Distribution of all muons in the event



- Missing energy distribution



References

- arXiv:1504.02470v2 [hep-ph]