SPCS2022

Monojet Search for Heavy Neutrino at Future Z-Factory

Yin-Fa Shen

School of Physics,
Huazhong University of Science and Technology

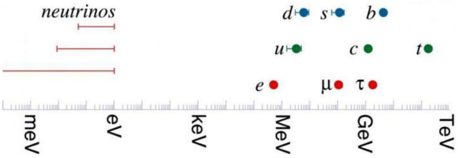
Outline

Introduction

- The neutrino oscillation implies that the neutrino has a non-zero but tiny mass compared to other kinds of elementary fermions.
- For the sake of naturalness, a right-handed Majorana mass term has been suggested to be added to the neutrino sector:

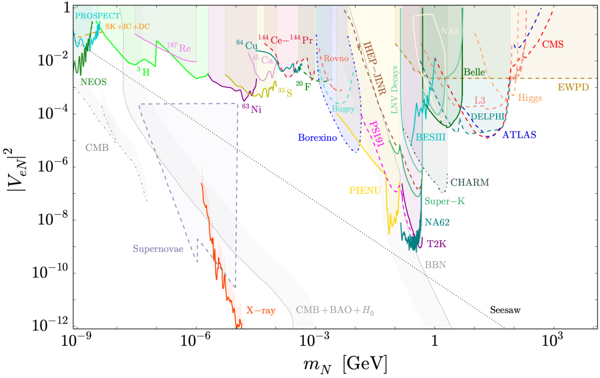
$$\mathcal{L}_\nu \ni \frac{1}{2} i \bar{R}_i^C \not{\partial} R_i - y_{ij} \bar{R}_i^C \tilde{\Phi} L_j - \frac{1}{2} (M_N)_{ij} \bar{R}_i^C R_j + h.c. \qquad (1)$$

- After diagonalizing the mass matrix, the mass eigenvalues might be adjusted suitably through the Majorana mass M_N in a way.



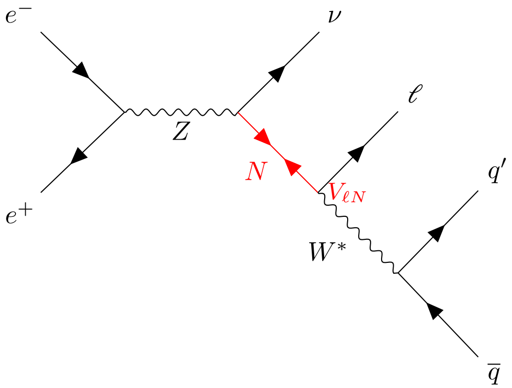
Introduction

- In such a model, two kinds of important parameters are introduced: the Majorana mass M_N and the mixing parameters $V_{\ell N}$ which will *suppress* the interaction with W boson.
- Considering current experimental results (JHEP 03 (2020) 170), we mainly focus on the mass range: $M_N \sim \mathcal{O}(10\,\text{GeV})$.



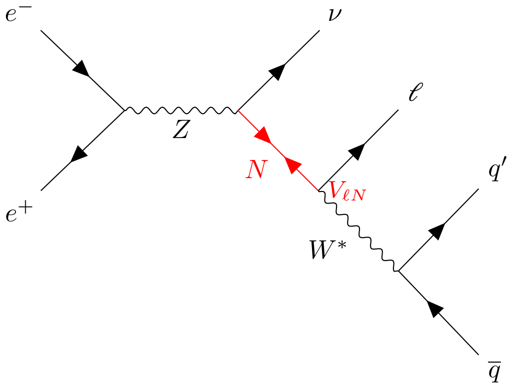
Process

- At future Z-factory, the heavy neutrino are mainly produced through the decay of the *on-shell* Z boson, and can be completely reconstructed by the decay channel as shown below:



Process

- For heavy neutrino in such mass range ($M_N \sim \mathcal{O}(10\,\text{GeV})$), it is relatively lighter than Z boson ($M_Z = 91.2\,\text{GeV}$), hence the *boost* of it will be relatively larger, and the two quarks can "see" each other, to form a *monojet*.



Simulation

- We performed Monte-Carlo simulation, and found that the decay products of heavy neutrino indeed always form a monojet as expected.
- Such character will be useful for distinguishing signal from background.

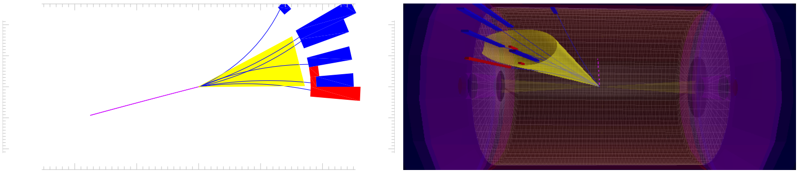


Figure 1: Simulation of a representative signal. The left figure is in the ϕ-plane while the right one is 3D situation.

Simulation

- We found that the main background comes from $e^- e^+ \rightarrow \tau\bar{\tau}$ events.
- For excluding such background, we analyzed the monojet's substructure and observed some interesting features: it always contains one hard charged lepton and has a special energy (momentum) distribution as shown below.

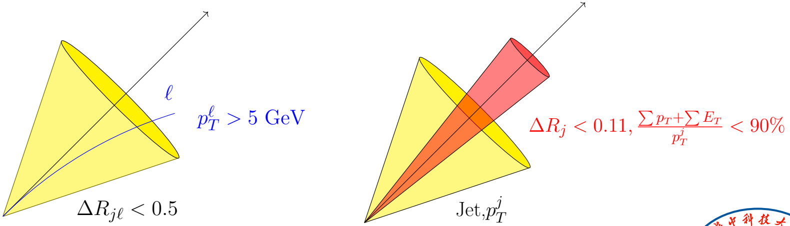
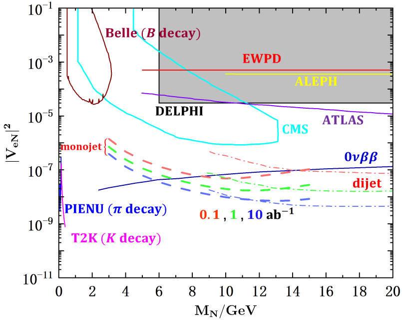


Figure 2: Sketches to visualize the substructure of monojet.

Result

- We finally use the above selection conditions to distinguish the signal from the background. In our estimation, about 99% background events will be excluded, while 50% signal will survive.
- We also estimate the upper bound of the mixing parameter $V_{\ell N}$ at 95% confidence level. The results are shown below.



Summarize

- Therefore, we have analyzed the features of the heavy neutrino with such mass range produced at Z factory, and conclude that the sensitivity to the mixing parameters $|V_{\ell N}|^2$ could reach approximately $\mathcal{O}(10^{-7})$ even with a conservative integrated luminosity, improving the current direct experimental searches by one to two orders of magnitude.
- For more details, please note the paper:
  - Eur.Phys.J.C 82 (2022) 5, 398
  - arXiv: 2201.05831
- This project is finished through collaboration with Jian-Nan Ding (LZU) and my advisor Prof. Qin Qin.
- We are also grateful to Manqi Ruan for his enthusiastic discussion and encouragement

Acknowledgement

Thank You