Probing the Seesaw Mechanism at 250 GeV ILC

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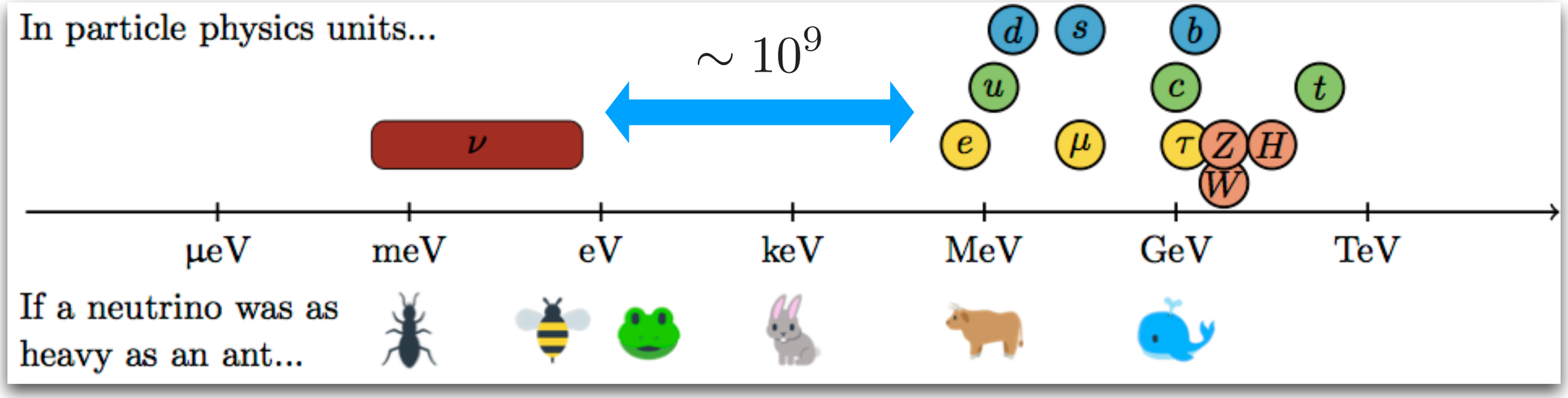
Theoretical work has been done by
N. Okada, A. Das, S. Okada, D. Raut

https://arxiv.org/pdf/1812.11931.pdf

Motivation



https://ghostsintheuniverse.org/theory/

Even comparing within same generation…

Why neutrino masses are so small?

SM extension with gauged B-L symmetry

Baryon - Lepton number is known as the unique anomaly free global symmetry in SM.

One can consider to extend this symmetry as local symmetry.

$U(1)_{B-L}$ symmetry

Anomaly free requirement leads to Right-handed neutrinos
—> Explain small neutrino mass by seesaw mechanism

(Bonus : Right-handed neutrino can be a dark matter)

Let's suppose a new gauge symmetry $U(1)_{B-L}$

Prospect of HL-LHC

B-L mode context

Das, N.O & Raut, PRD 97 (2018) 115023

Das, N.O & Raut, EPJC 78 (2018) 696

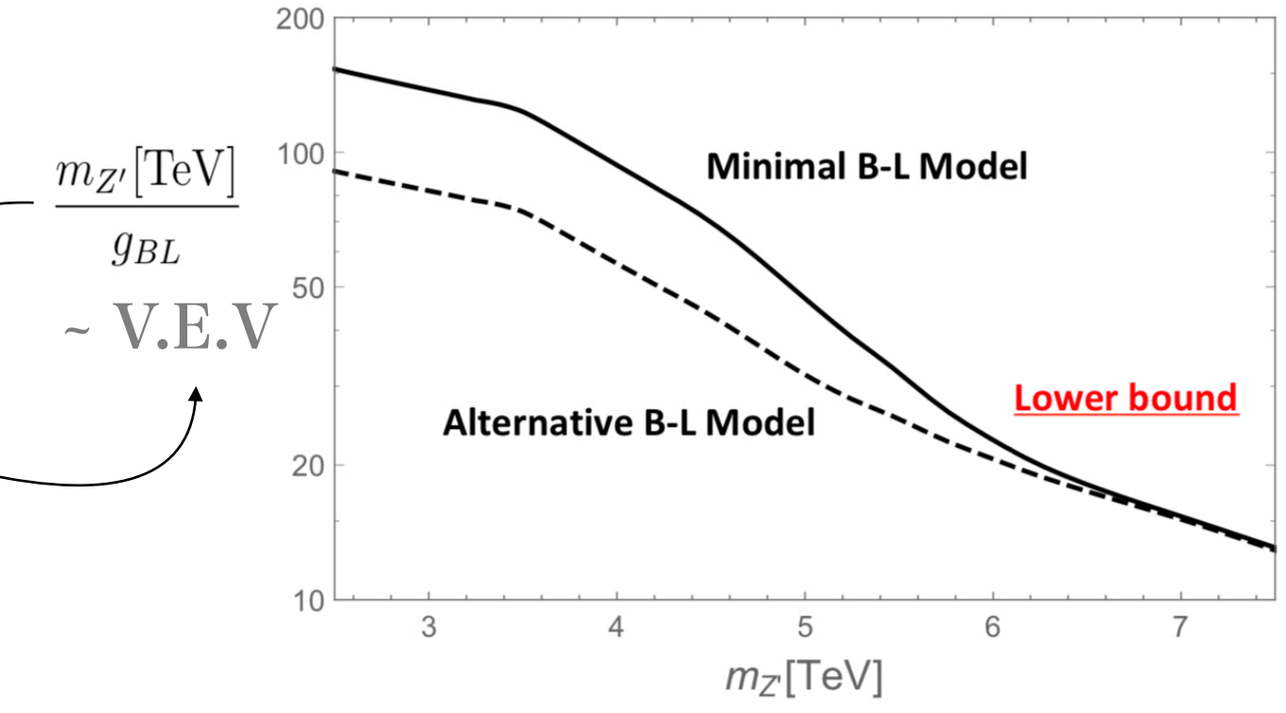
Long-lived RHN production in B-L mode context

Jana, N.O & Raut, PRD 98 (2018) 035023

Das, Dev & N.O, in preparation

Nobuchika Okada @ PHENO2019

HL-LHC prospective bound in terms of $m_{Z'}/g_{BL}$



$\frac{m_{Z'}[\mathrm{TeV}]}{g_{BL}}$ ~ V.E.V

Z' mass and g_{BL} relation

Minimal Model

$m_{Z'} = 2\, g_{BL}\, v_\phi$

Alternative Model

$\simeq g_{BL}\sqrt{64 v_A^2 + 100 v_B^2}$

B-L gauge boson mass

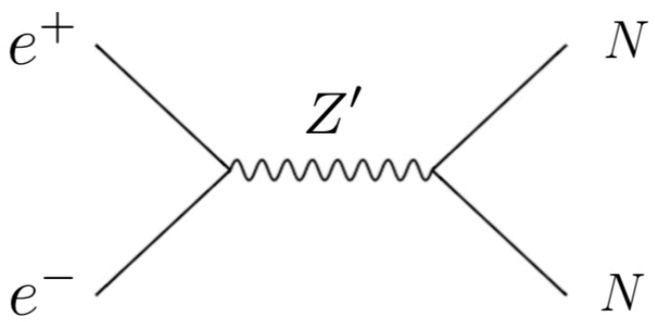
Lower bound on $\frac{m_{Z'}[\mathrm{TeV}]}{g_{BL}}$ is dramatically reducing!

More difficult for heavier Z' cases

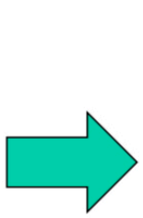
Complementary to HL-LHC

Nobuchika Okada @ PHENO2019

RHN pair production at the 250 GeV ILC



$$E_{\rm ILC} \ll m_{Z'}$$



$$Q_e Q_N \left(\frac{g_{BL}}{m_{Z'}}\right)^2$$

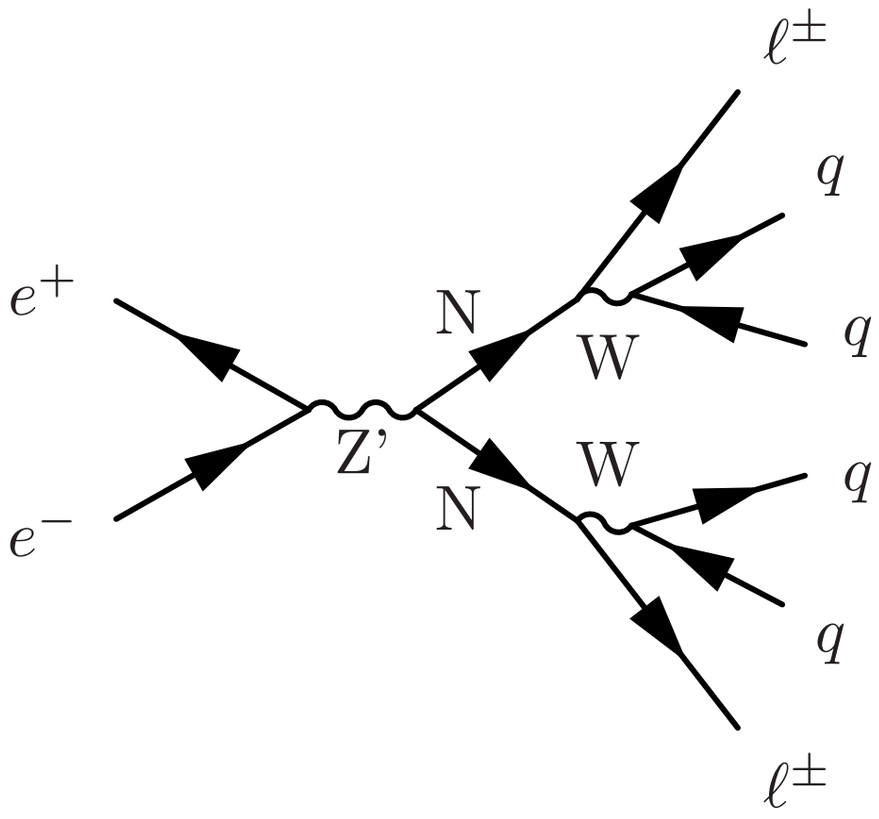
At 250 GeV ILC,
the process can be described as contact interaction.

The effective coupling ~ $(1/\text{V.E.V})^2$

Lower V.E.V is preferable at ILC
(Even for heavy Z')

ILC can cover heavy Z' region

Event signature



RHN decays W+lepton

- Focusing hadronic W decay
- Same sign isolated leptons

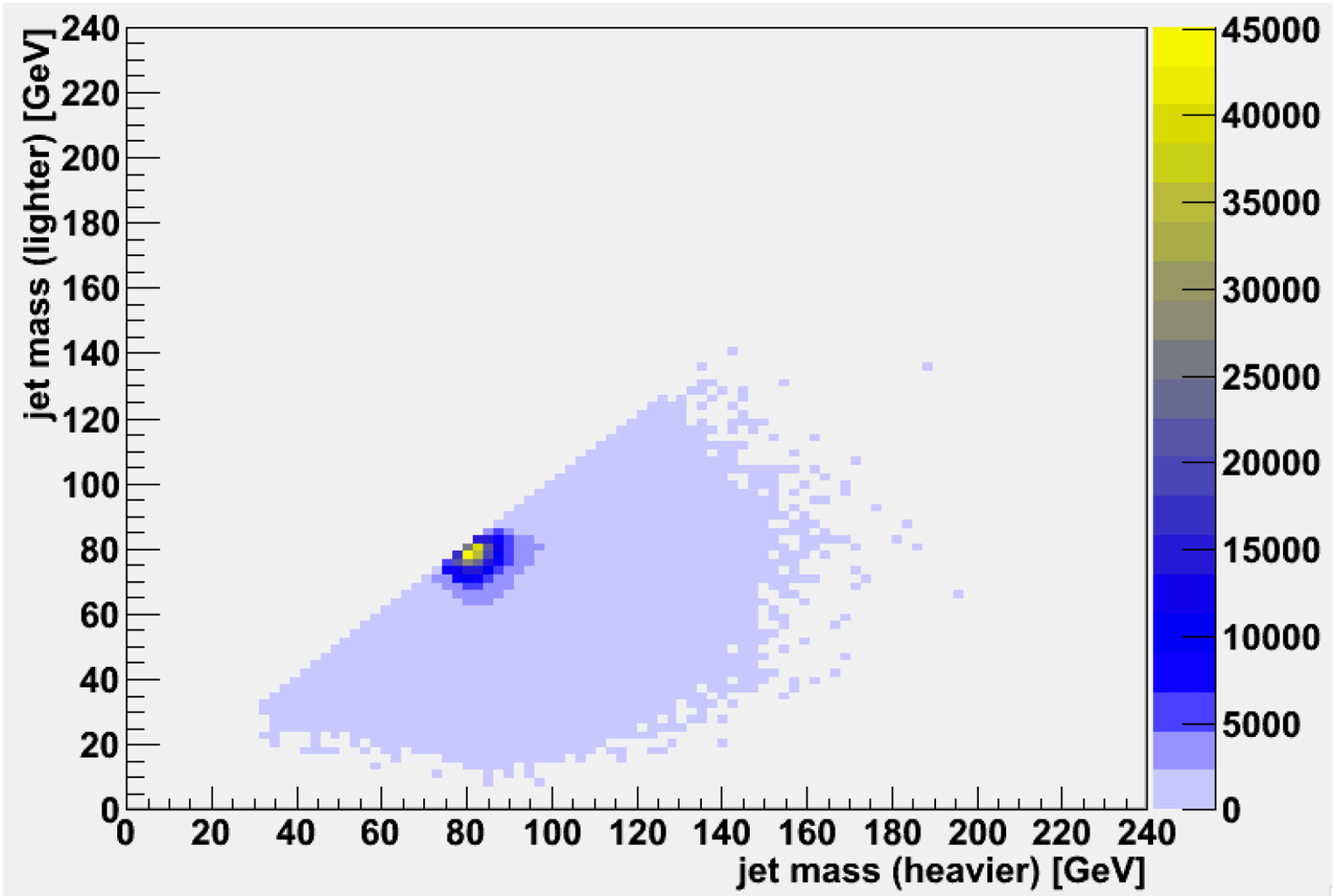
⇒

Final state :
2 same sign isolated leptons +
4 jets (2W)

Isolated lepton finder + Jet combination would be the key

Quick test 1 : Identifying W bosons

DBD sample: WW hadronic decay



Reco :

- Forced 4-jet clustering
- Min chi2 to find a best combination

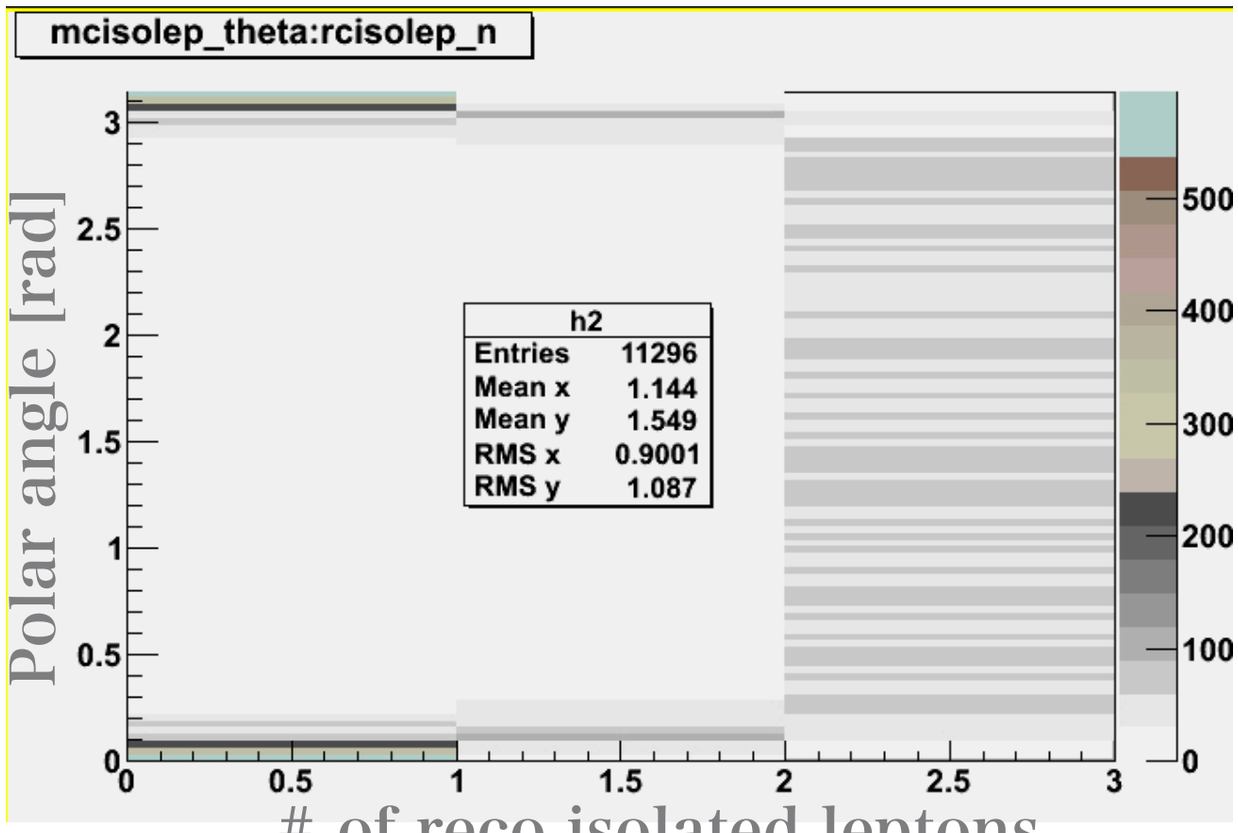
$$\text{chi2}=(M_{j1}-M_W)^2+(M_{j2}-M_W)^2$$

High concentration around m~80GeV as expected.

W reco for WW hadronic decay is ready.

Quick test 2 : Identifying isolated leptons

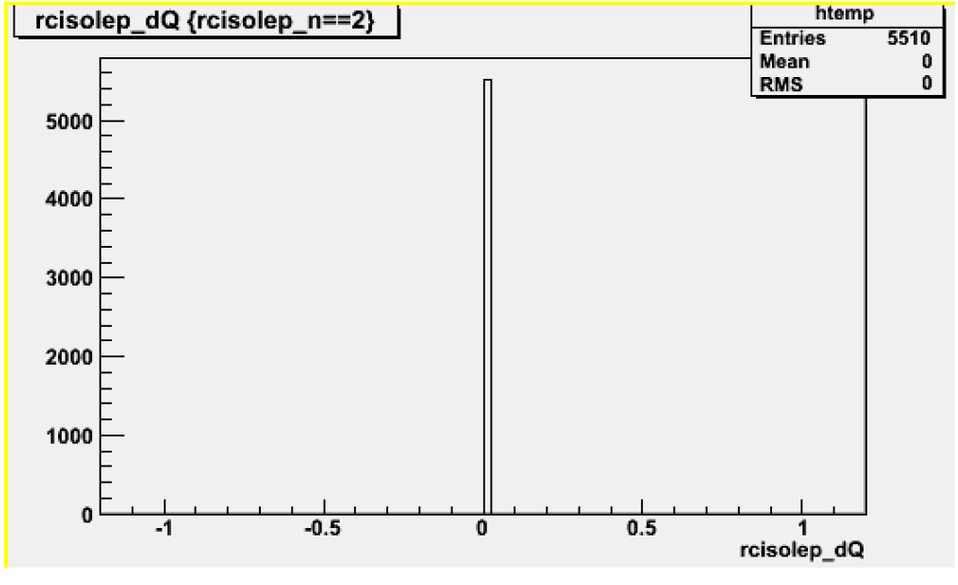
Polar angle vs #of isolated leptons found



DBD sample : ZZ semi-leptonic decay samples

Most of the failed cases are muons going very forward.

—> The inefficiency is just detector acceptance.



Reconstructed charge - MC charge

No problem with charge identification.

Signal event generator (Physsim)

RHN production from Z (not Z') —> Done (Thanks to Fujii-san)

Since there is no difference between left- and right-couplings for Z',
we will cheat a bit for the event generation.

We generate events with 100% left polarized electron beam,
and normalize number of events later. This should be equivalent to Z' events.

Next step : event generation

Summary

* $U(1)_{B-L}$ symmetry can explain small neutrino mass (and dark matter)
* ILC plays an important role even the case HL-LHC find no clue.
* Theoretical study has been done while simulation study has just started.
* Signal event generator is the next step.