Probing heavy Majorana neutrino pair production at ILC in a $U(1)_{B-L}$ extension of the Standard Model

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Introduction & Model

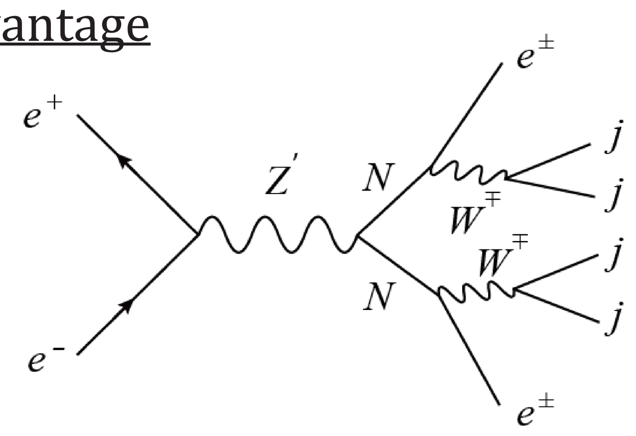
Extending SM with a minimal $U(1)_{B-L}$ (Baryon - Lepton number) gauge symmetry:

$$G_{B-L} \equiv SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_{B-L}$$

- three SM gauge singlet **Majorana Right Handed Neutrinos(RHNs)**
- gauge boson Z'
- explain tiny neutrino mass and mixing

➡ We investigate RHN pair production at ILC 500

Advantage



Lepton number violation is possible

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Same sign leptons are possible

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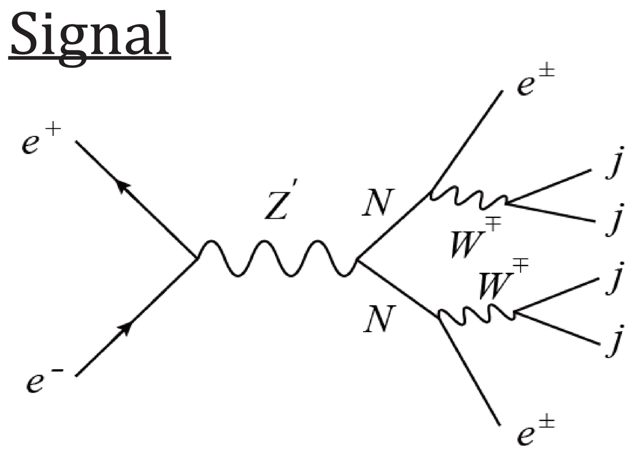
very small SM backgrounds

Signal & Background

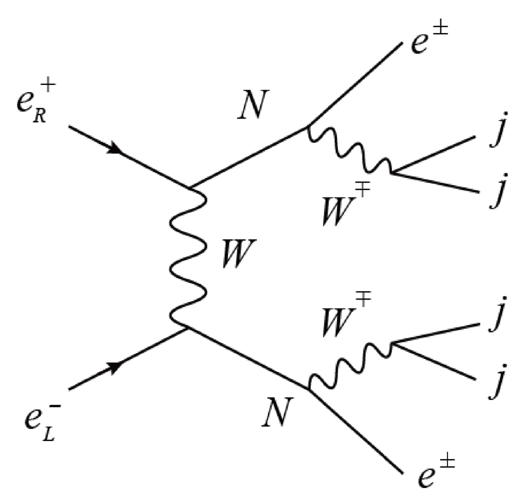
consider the decay of lightest $N \to e^{\pm}W^{\mp}$.

Signal



s-channel via Z'

\+ Destructive interference



t-channel via W (only eLpR)

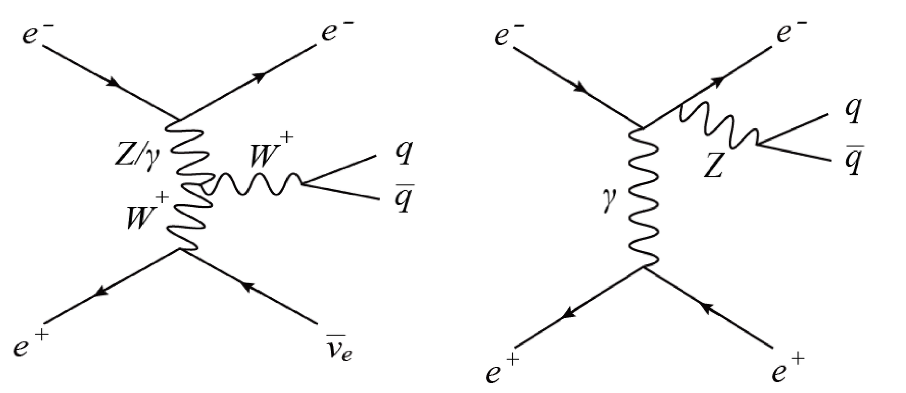
Benchmark points in this analysis

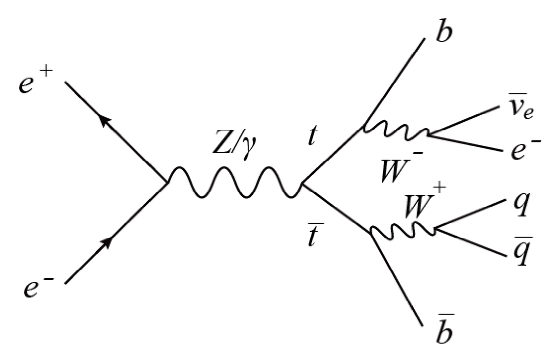
M_N [GeV]	$M_{Z'}$ [GeV]	g'_{B-L}	$\lvert V_{eN}\rvert$	$BR(N \to eW)$	σ_{LR} [fb]	σ_{RL} [fb]
100	7	1	0.03	0.44	0.55	0.71
150	7	1	0.03	0.33	0.36	0.45
200	7	1	0.03	0.30	0.14	0.16
225	7	1	0.03	0.29	0.046	0.0052

Consistent with LHC and HL-LHC bounds

Backgrounds

- 4-fermion: $e^+e^- \to e\nu q\bar{q}$ and $e^+e^- \to e^+e^- q\bar{q}$
- $e^+e^- \to t\bar{t}$

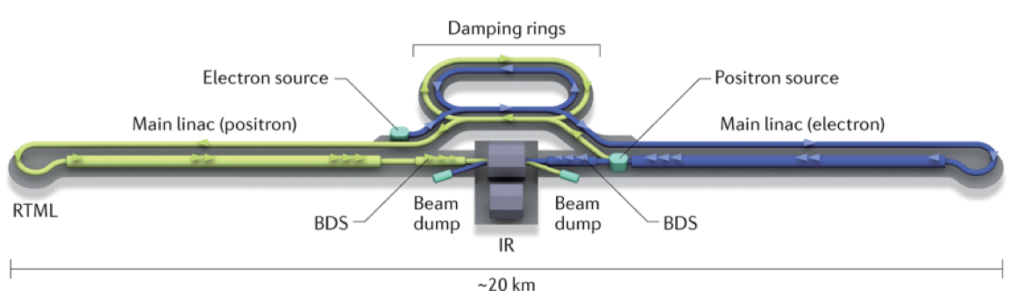


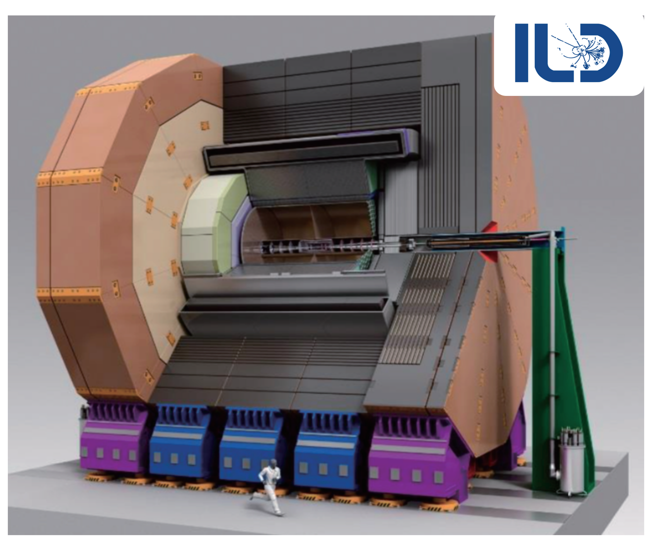


- 6-fermion: $e^+e^- \to e^+e^- q\bar{q}q\bar{q}$

Simulation Setup

WHIZARD Event generator → **ILD Full Simulation & Reconstruction**





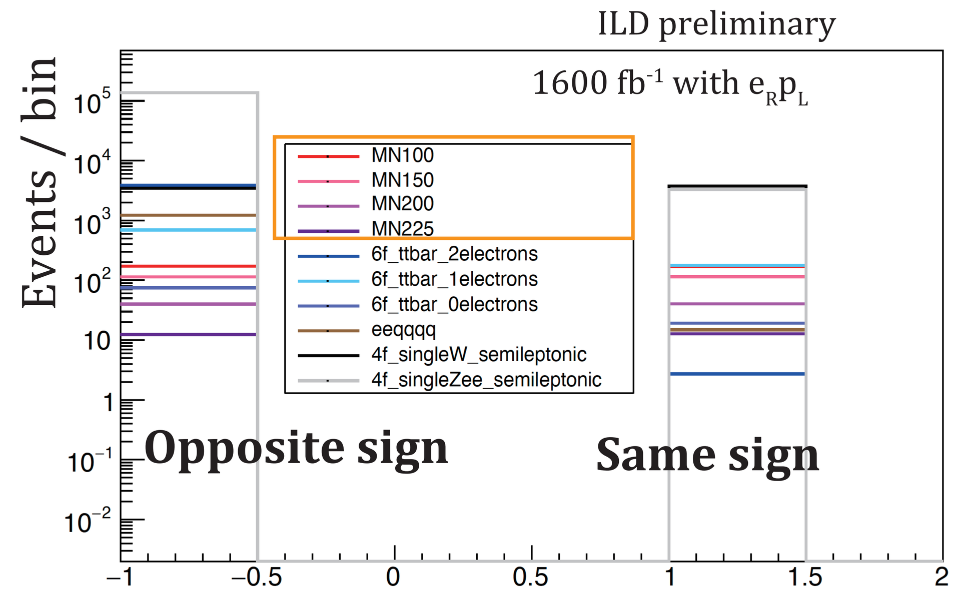
Detector for particle flow reconstruction

- e+e- linear collider
- $\sqrt{s}$ = 250 GeV (Extend to 500, 1000GeV)
- Polarized beams e^-: 80%, e^+: 30%
- "eLpR" = (e^- −80, e^+ +30) "eRpL" = (e^- +80, e^+ −30)

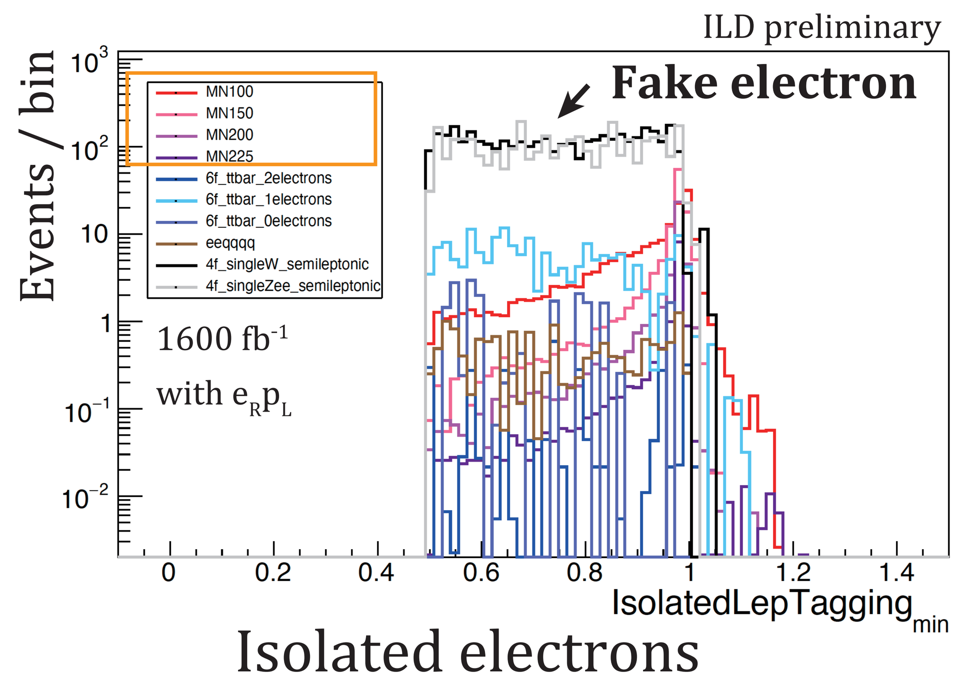
Cut based Analysis

Cut conditions

- 2 same sign isolated electrons
  E < 200 GeV, |cosθ| < 0.95
- IsolatedLepTagging(min) > 0.9
- Small missing momentum
- Remove 2 Jet-like events



Product of electron charges



Isolated electrons Neural Network output

Jet pairing → RHN reconstruction

4 jets + 2 electrons in the final state

Choose combination most consistent with W mass and equal RHN masses

Jet pair 1 → M_{jj1}, Jet pair 2 → M_{jj2}

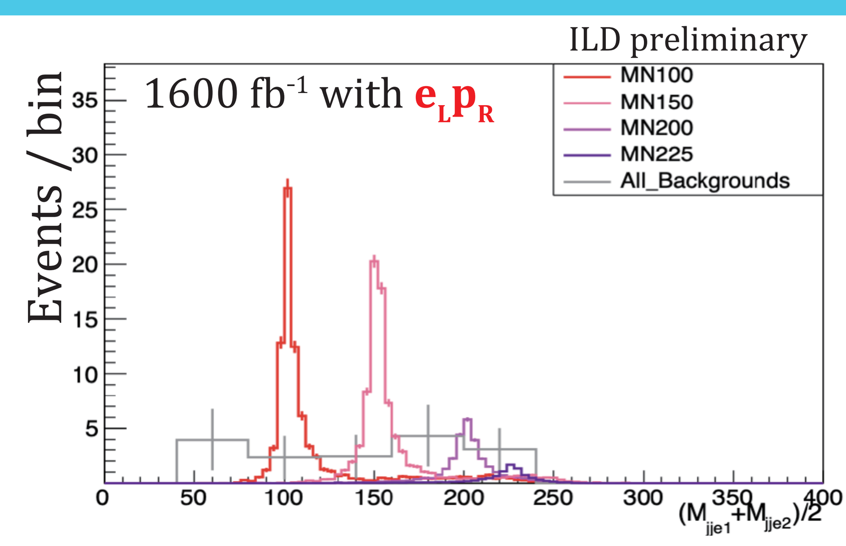
$$F_1 = (M_{jj1} - M_w)^2 + (M_{jj2} - M_w)^2$$

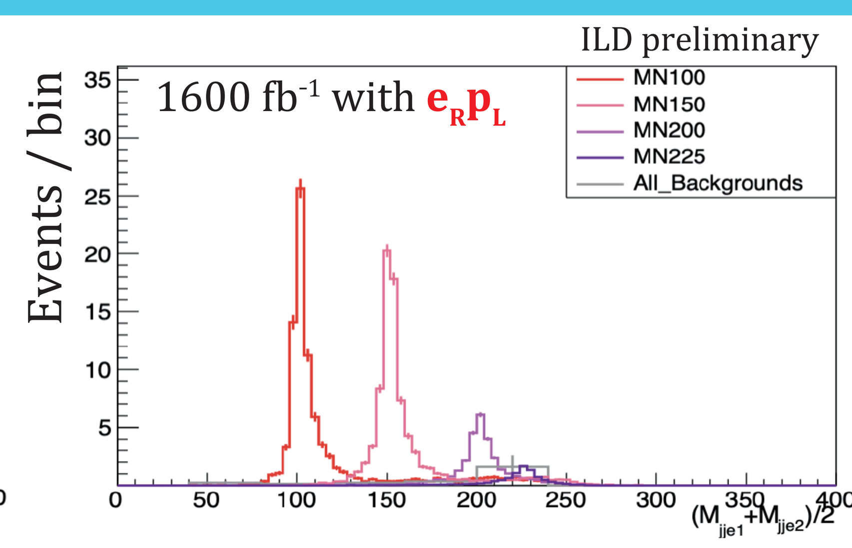
➡ Best jet pair 1,2 + iso e → $M_{jje1,2}$

We expect for "$M_{jje1} = M_{jje2}$"

$$F_2 = (M_{jje1} - M_{jje2})^2$$

Results





Signal efficiency ∼ 20%

Remaining background events ∼ 150 (eLpR), 20 (eRpL)

mass window around each true RHN mass (-10 GeV / +15 GeV)

Assume flat background distribution.

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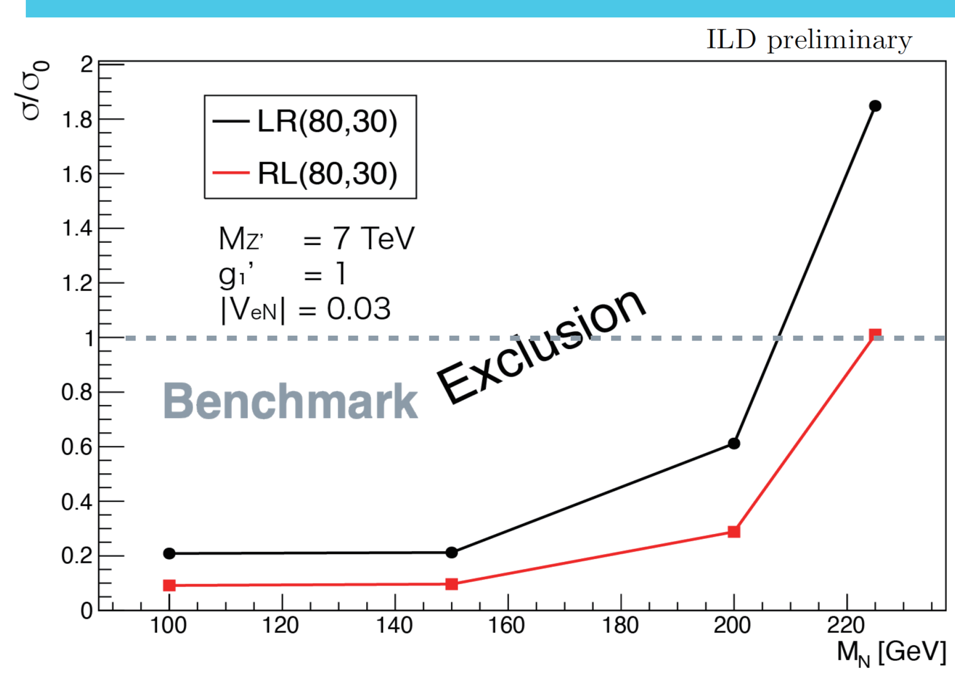
Signal efficiency ∼ 20%

Remaining background events ∼ 20 (eLpR), 3 (eRpL)

Summary



eRpL is better than eLpR

→larger signal and smaller backgrounds

Exclude benchmark points and cross-sections up to 10x smaller

Can use same sign lepton signature to set powerful limits on Majorana RHN at ILC!

Study performed in the framework of the ILD concept