Exploring Right Handed Neutrinos at ILC

Jurina NAKAJIMA[A], Daniel Jeans[B], Arindam Das[C] ,Keisuke FUJII[B]

SOKENDAI[A], KEK[B], Kyungpook National Univ.[C]

17,March 2021(JST)

SOKENDAI

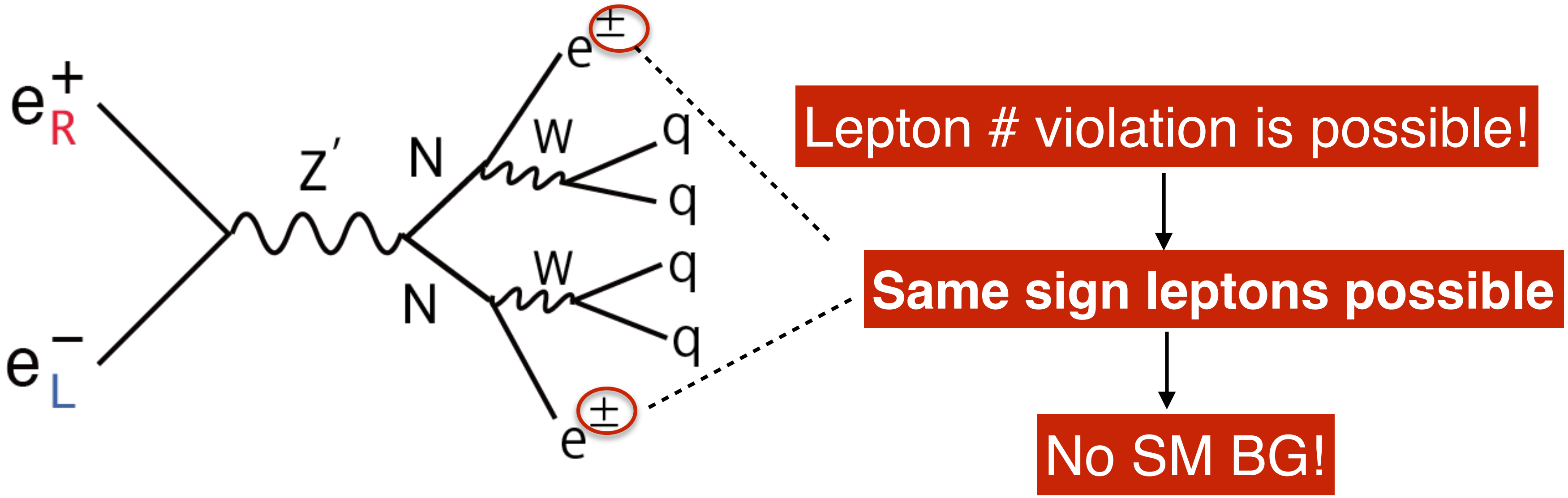
Motivation

The right handed neutrino(RHN) can address the following big questions

- Why does matter dominate anti-matter in our universe?
- Why is neutrino mass so small?
- Do quarks and leptons unifiy?

Right handed neutrino is assumed to be a Majorana particle.($\nu = \bar{\nu}$)

→ RHN **pair** production *OK!*



Model

Gauged B-L extension of Standard Model(SM)

The unique anomaly free global symmetry in the SM

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

Gauge boson : Z'

- Anomaly free requirement → RHNs
- Seesaw mechanism ← automatically include

If B-L symmetry breaks spontaneously → Z' becomes **massive**

minimal B-L model

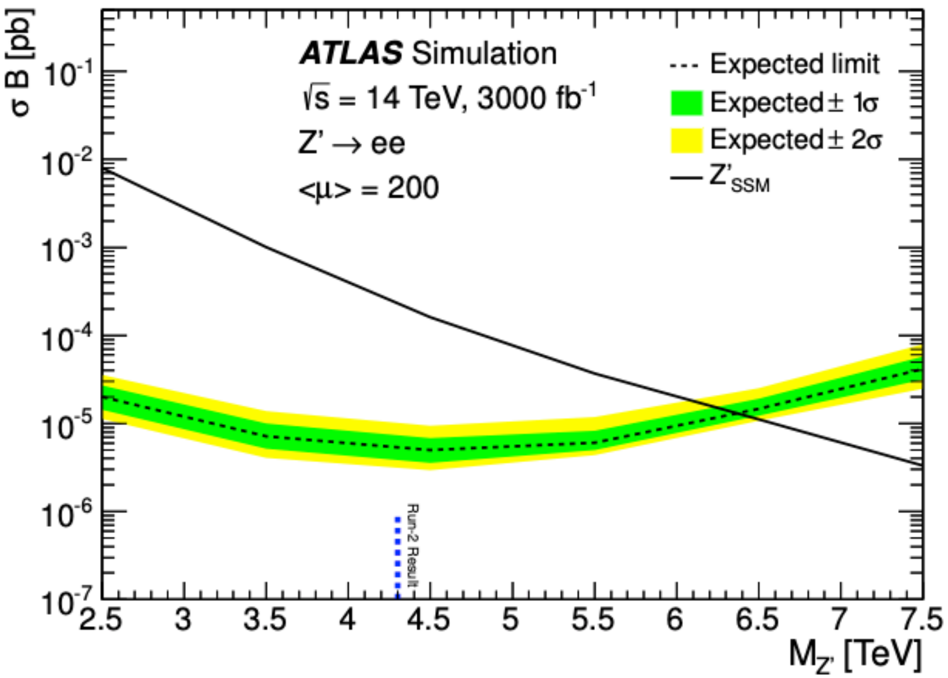
	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_{B-L}$
N_R^i	1	1	0	-1
Φ	1	1	0	2

i=1,2,3

arXiV[1812.11931]
Arindam Das, Nobuchika Okada, Satomi Okada, Digesh Raut

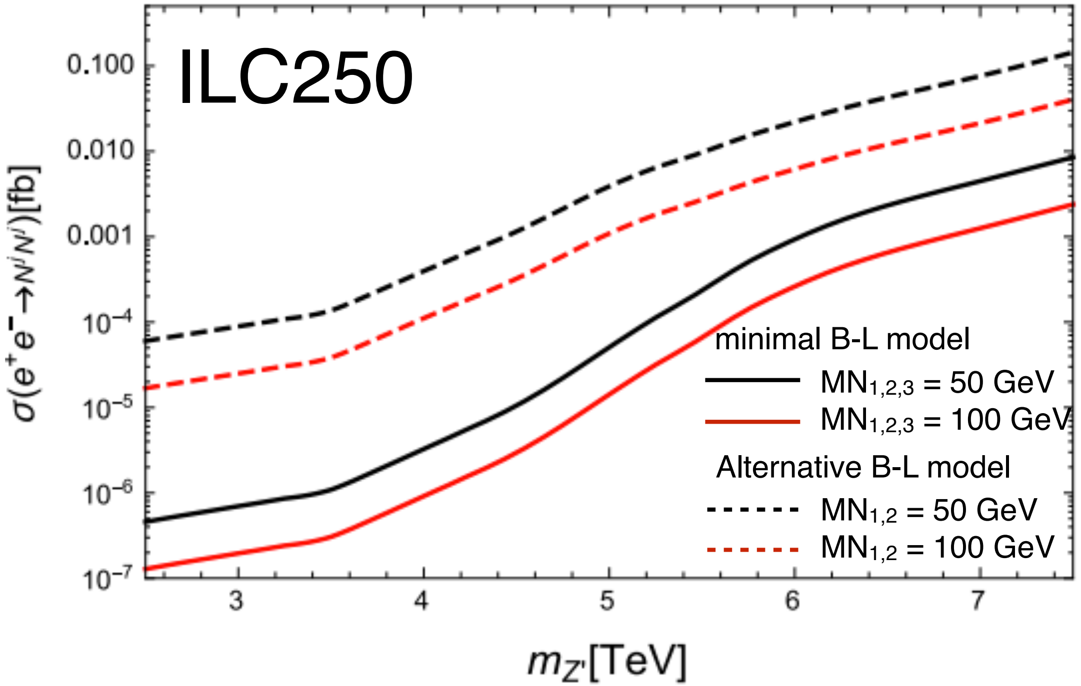
Current limits - Z' mass

SM like Z' coupling



ATLAS-TDR-LHCC2017-2018

HL-LHC prospects limit for $U(1)_{B-L}$ model



arXiV[1812.11931]

The heavier Z' mass less constrained by LHC

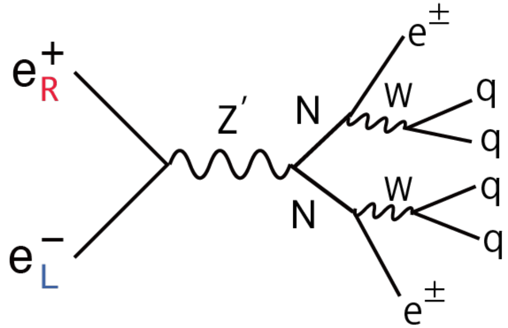
2 benchmark points

Not excluded by LHC

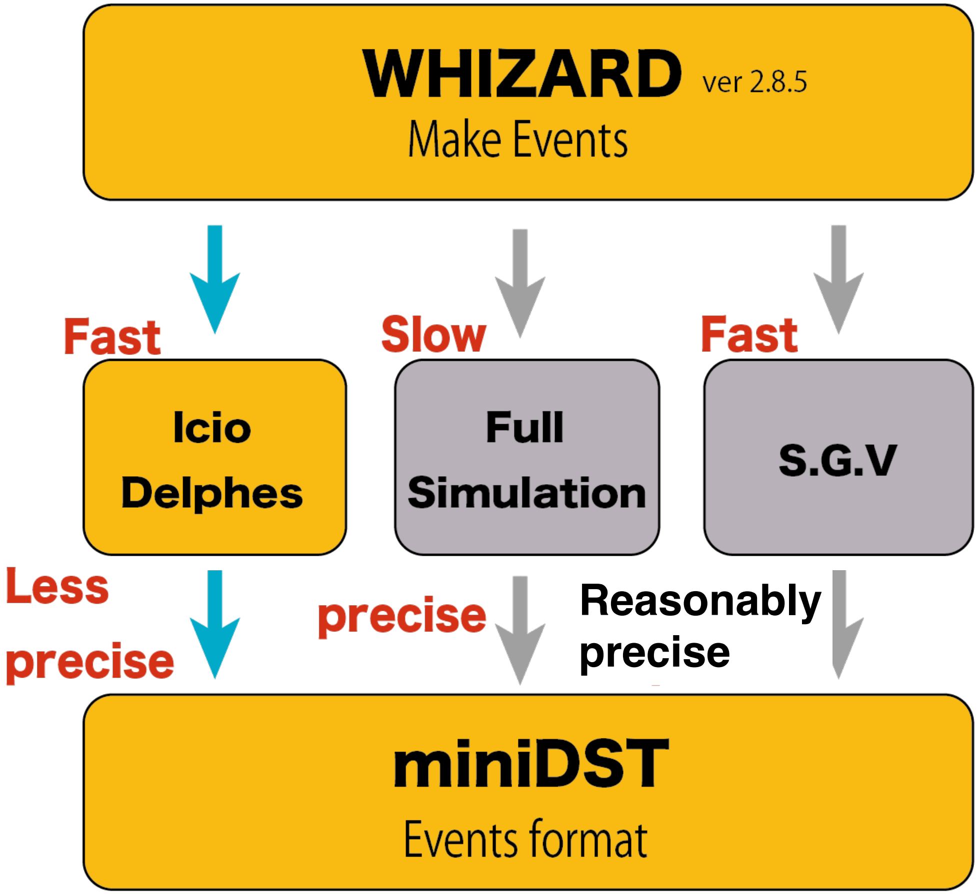
M_N [GeV]	$M_{Z'}$ [TeV]	G1'	$\|V_{eN}\|^2$	σ LR (ee→NN)	Event # [4000fb-1]
100	7	1	0.001	7.05E-01	**1613**
200	7	1	0.005	1.61E-01	**368**
100	3	0.05	0.001	1.34E-04	0.3
200	3	0.05	0.005	2.66E-05	0.06

$$\mathrm{Pol}(-0.8,+0.3),(+0.8,-0.3):\mathcal{L}=1600\,[\mathrm{fb}^{-1}]$$
$$\mathrm{Pol}(+0.8,+0.3),(-0.8,-0.3):\mathcal{L}=400\,[\mathrm{fb}^{-1}]$$

- minimal $U(1)_{B-L}$ model
  - ✦ $\sigma_{LR} = \sigma_{RL}$(100%)
- ILC 500 with ISR / BS
- Generated event # = 5000



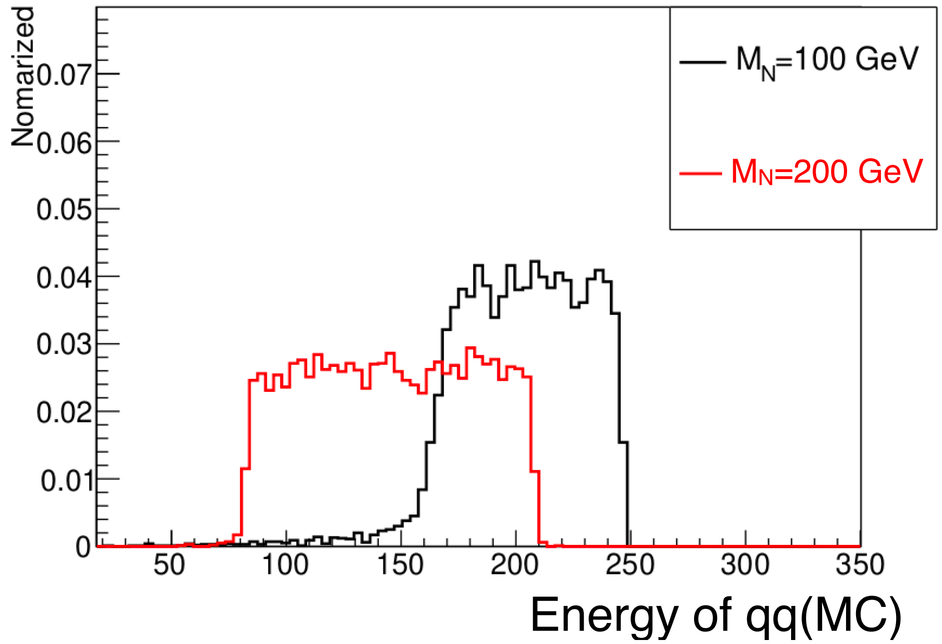
Analysis tool

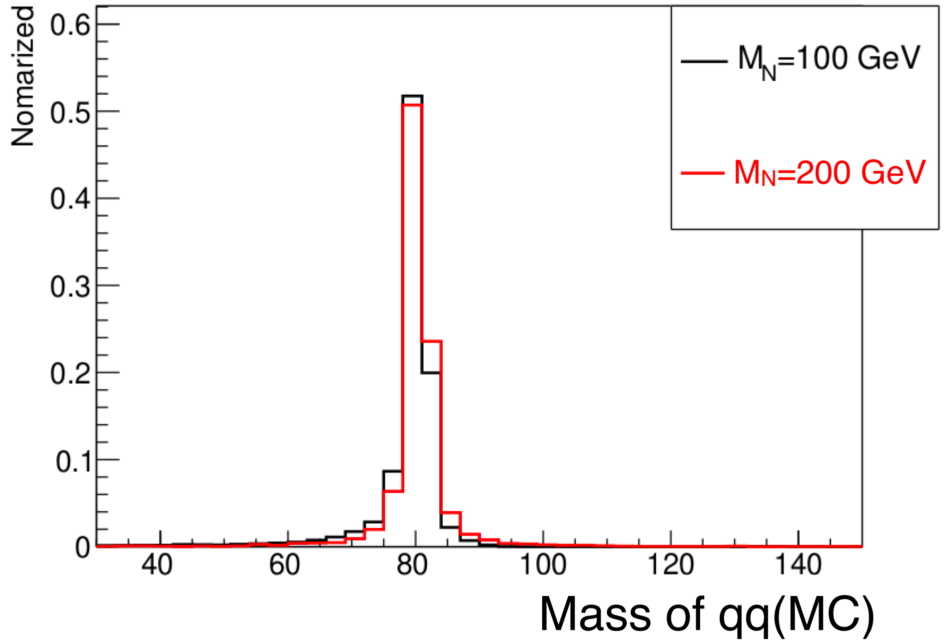


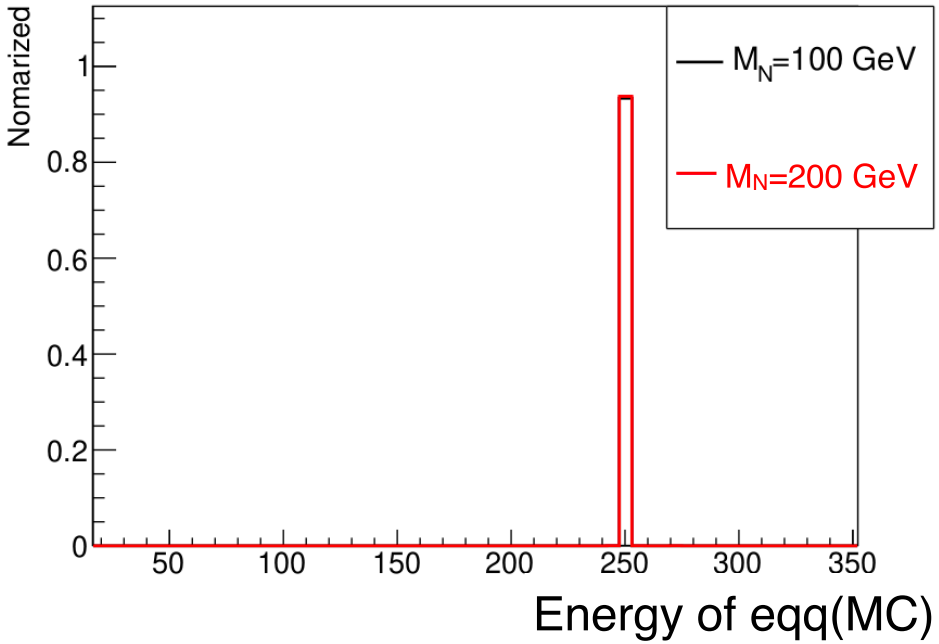
Fast simulation

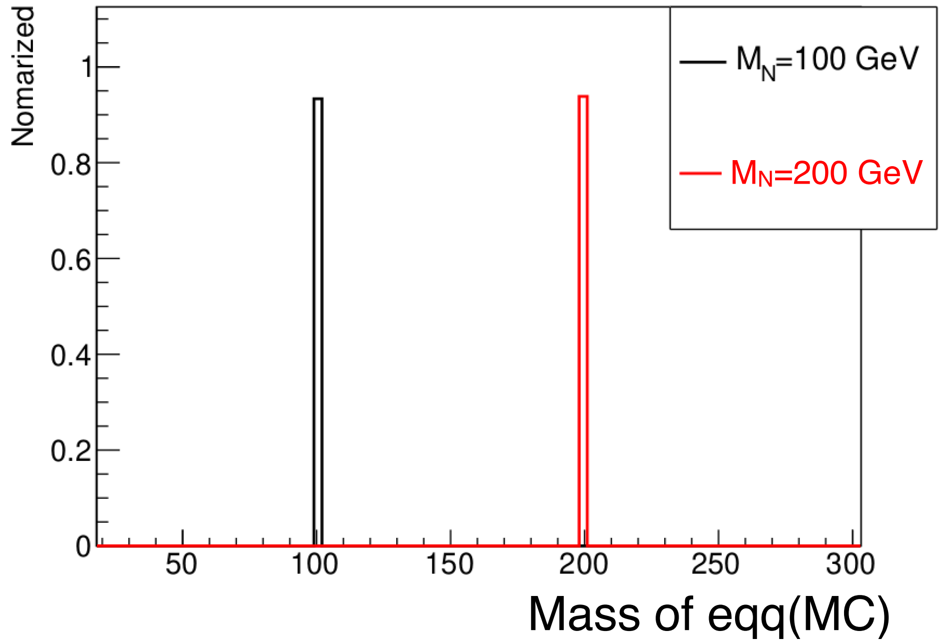
- using Delphes with the “**generic ILC detector card**” *recently prepared for the US Snowmass study*
  →***Friendly to newcomers***

Checking generated MC particles

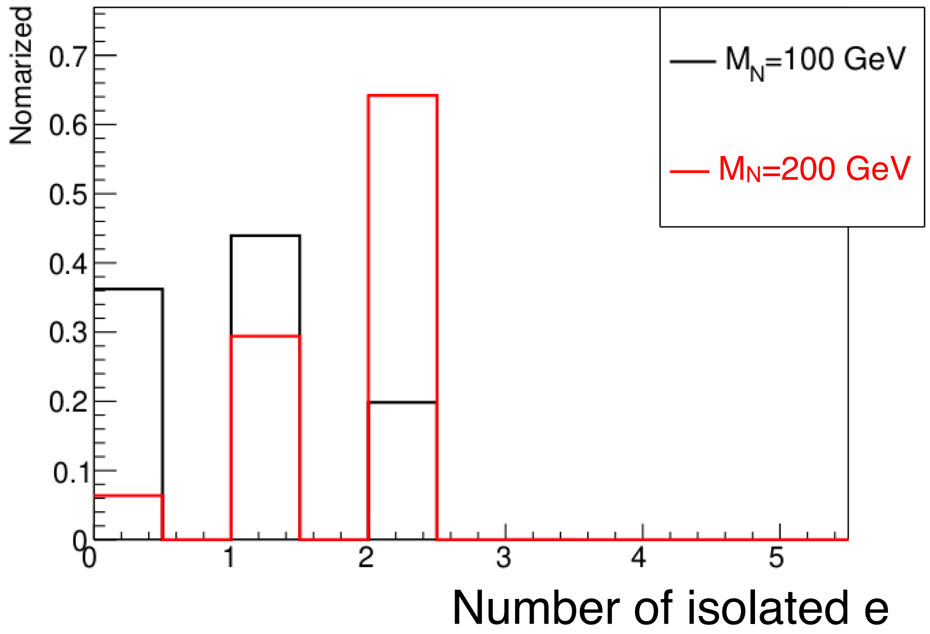


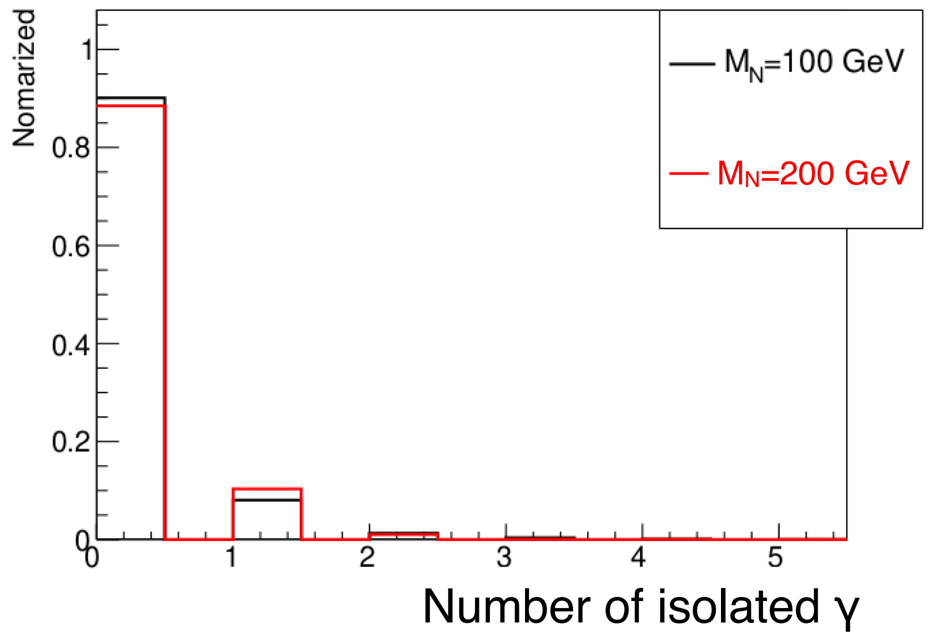


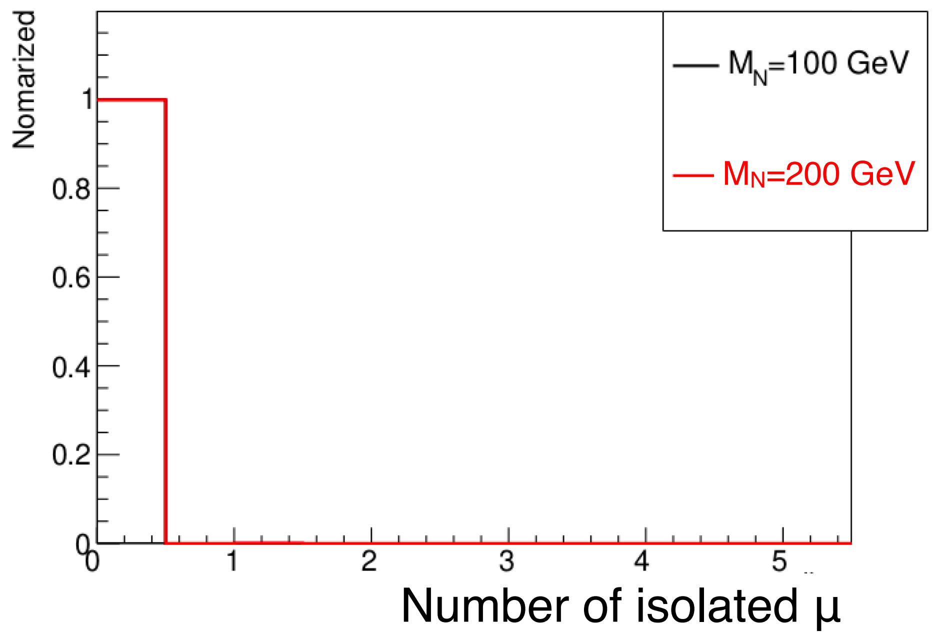




Reconstructed particles - Isolated e,γ,μ



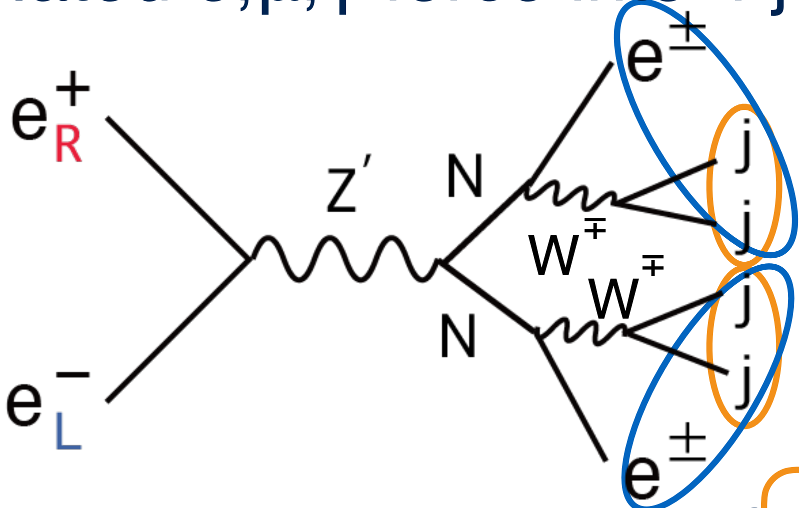




\# isolated electrons = 2
\# isolated photons = 0

Reconstruction methods

After removing isolated e,μ,γ force into 4 jets (Durham)



Search for the correct combination of jj and jje

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

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

Best jet pair 1 + iso e → M_{jje1}

Best jet pair 2 + iso e → M_{jje2}

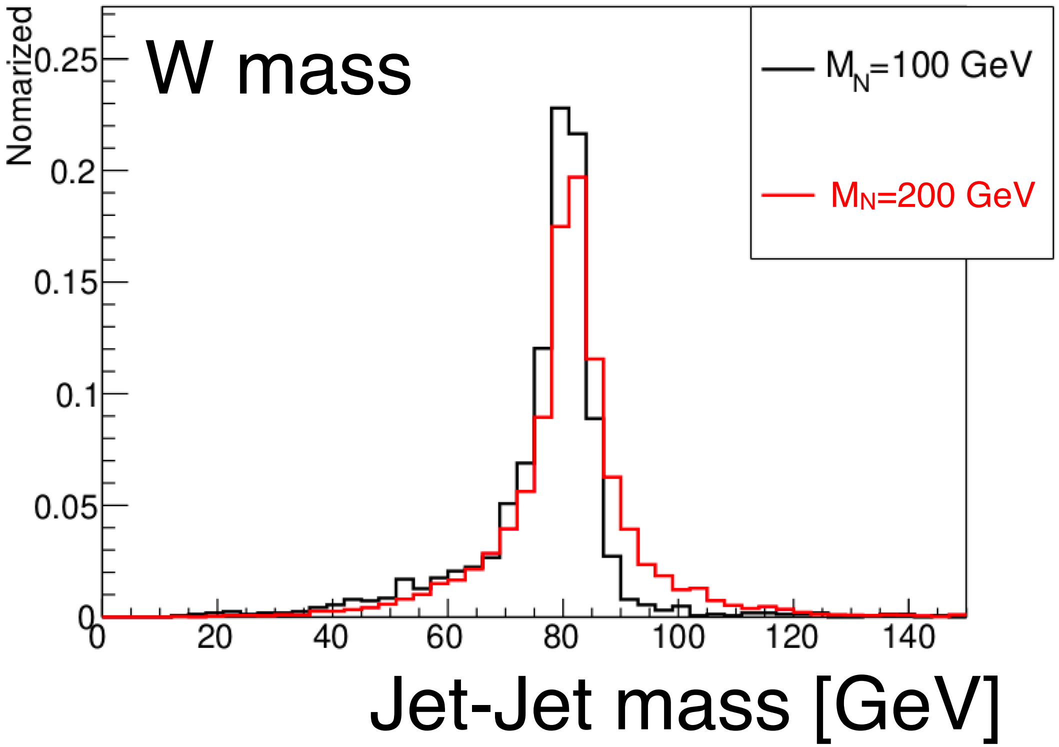
We expect for "$M_{jje1} = M_{jje2}$"

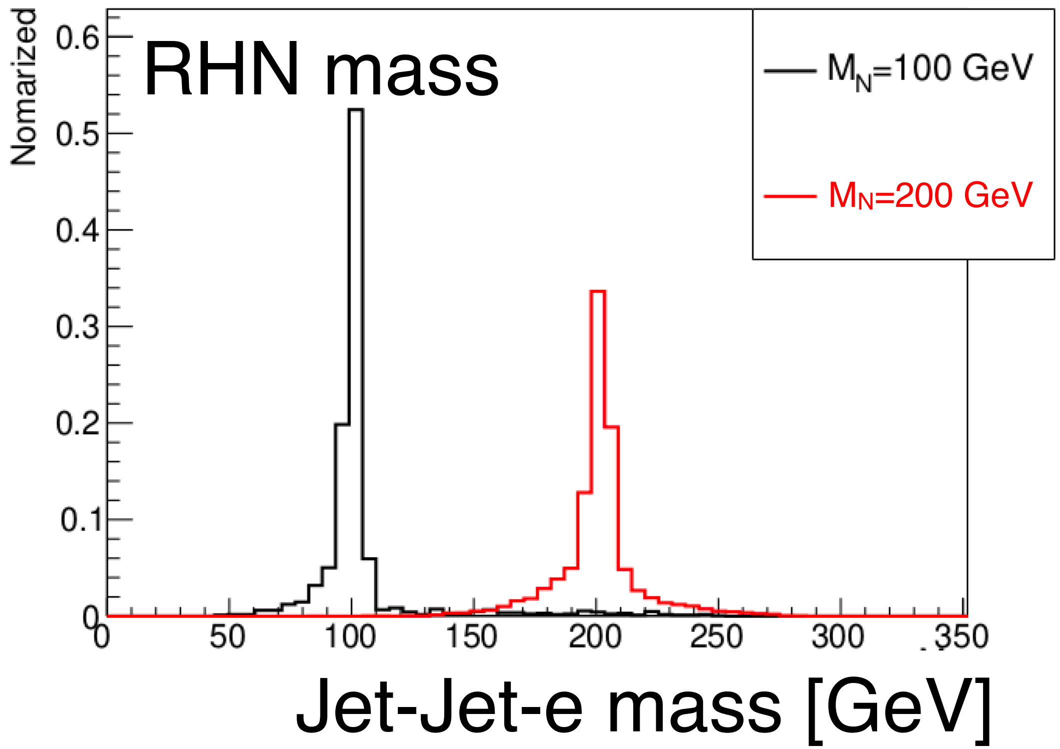
$$F = (M_{jje1} - M_{jje2})^2$$

Choose combination with minimum F

Reconstruction of W and RHN

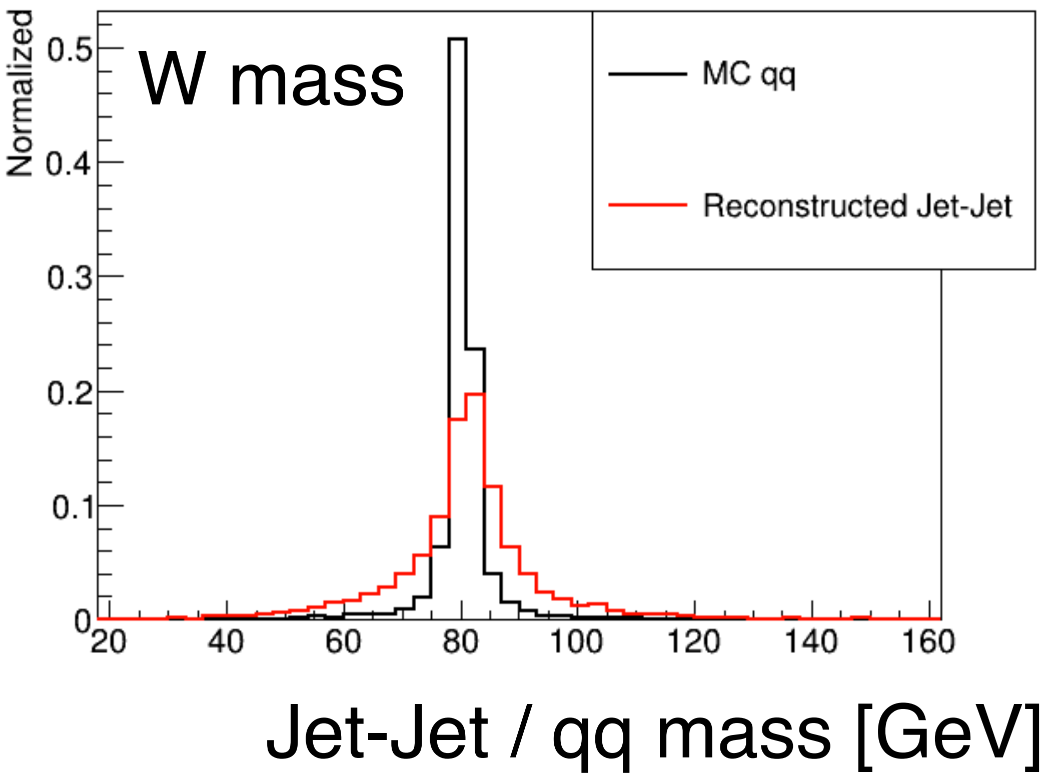
- # isolated electrons =2 && # isolated photons = 0
- Choose the **best** combination

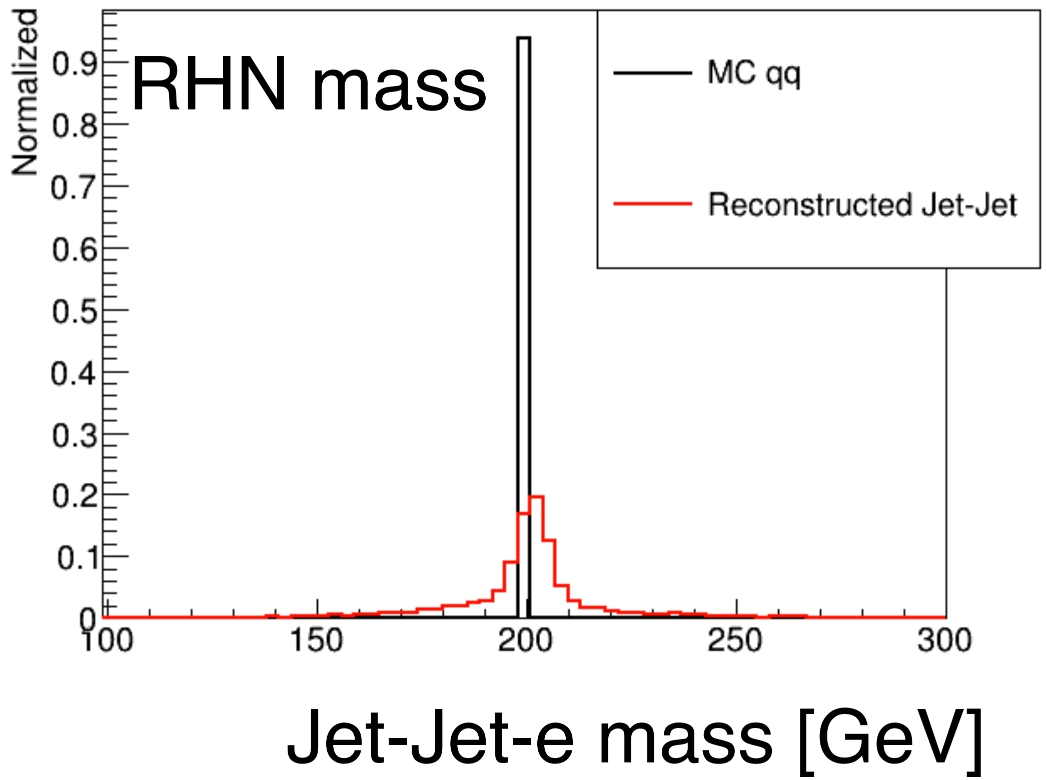




Comparison between MC and Reconstructed W Bosons and RHN

- M_N =200 GeV





Summary

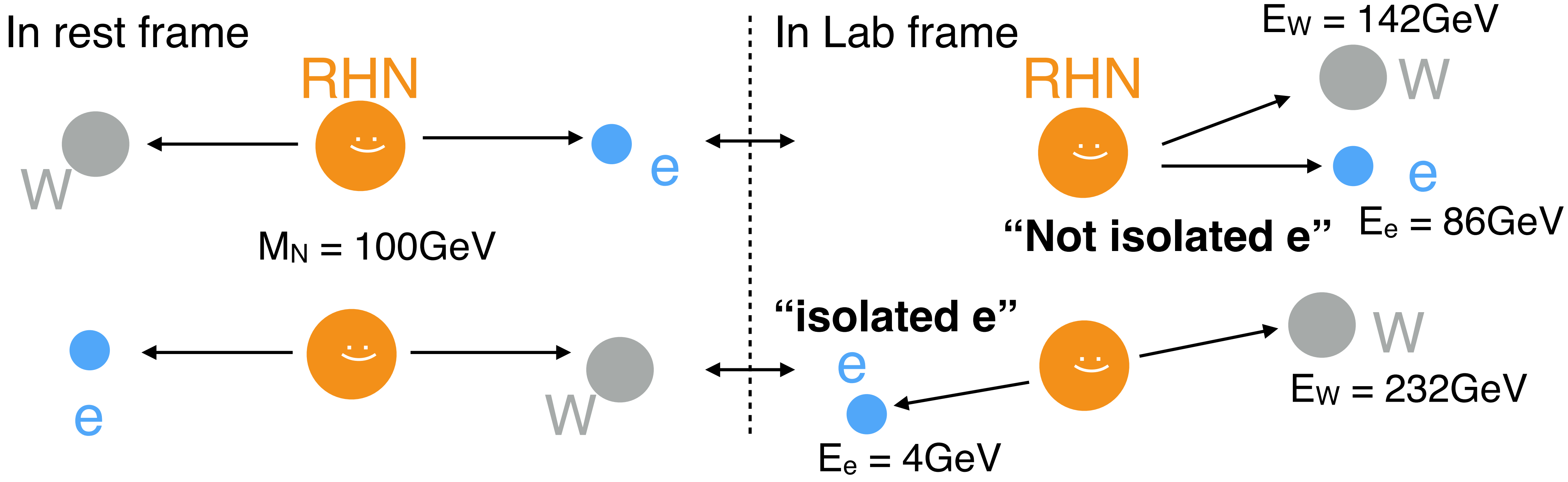
- RHN pair production has a distinctive signature of same sign leptons in the final state
  →Expected to be **almost background free**
- Carried out **fast simulation** for RHN pair production using **Delphes miniDST** framework
- Analyzed detector-simulated particles and tried to reconstruct RHNs → **Looks promising!**

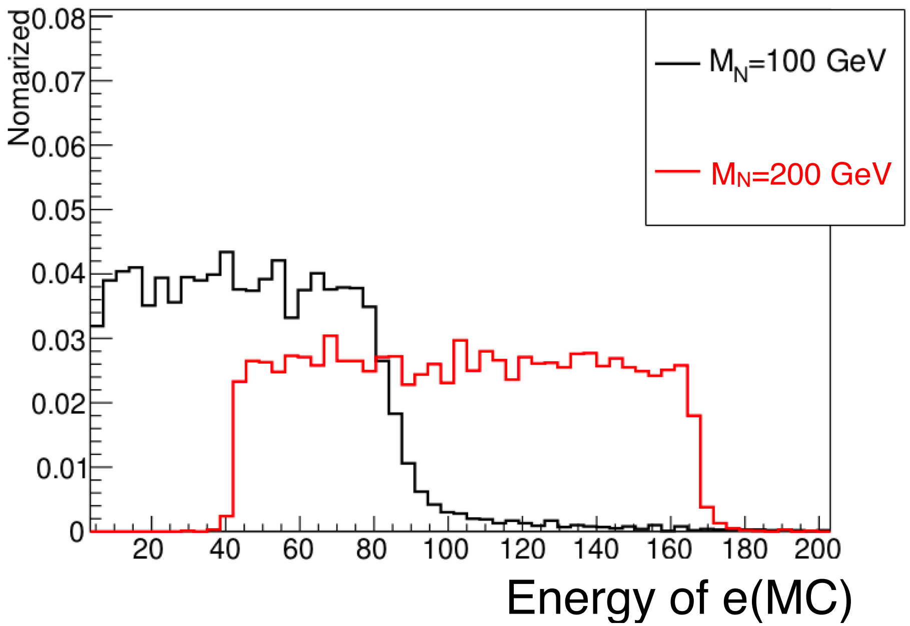
Future plan

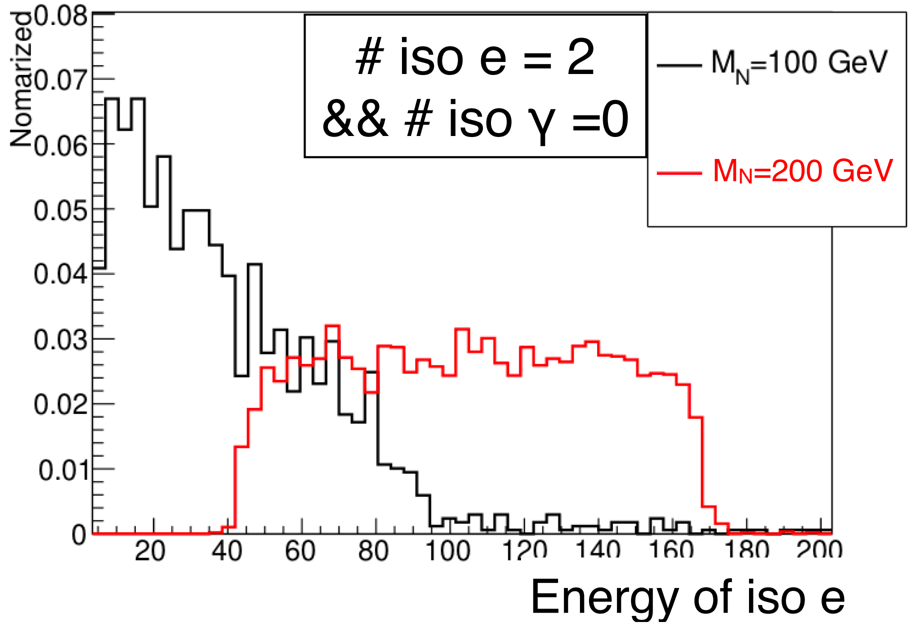
- Include potential backgound processes
- Consider other models of RHN

Backup

Why is an about half of # isolated electrons 1 in M_N=100 GeV?







ILC250

M_N [GeV]	$M_{Z'}$ [TeV]	g1'	$\|V_{eN}\|^2$	σ_{LR} (ee→NN)	Event # [2000fb-1]
100	7	1	0.001	4.53E-02	50

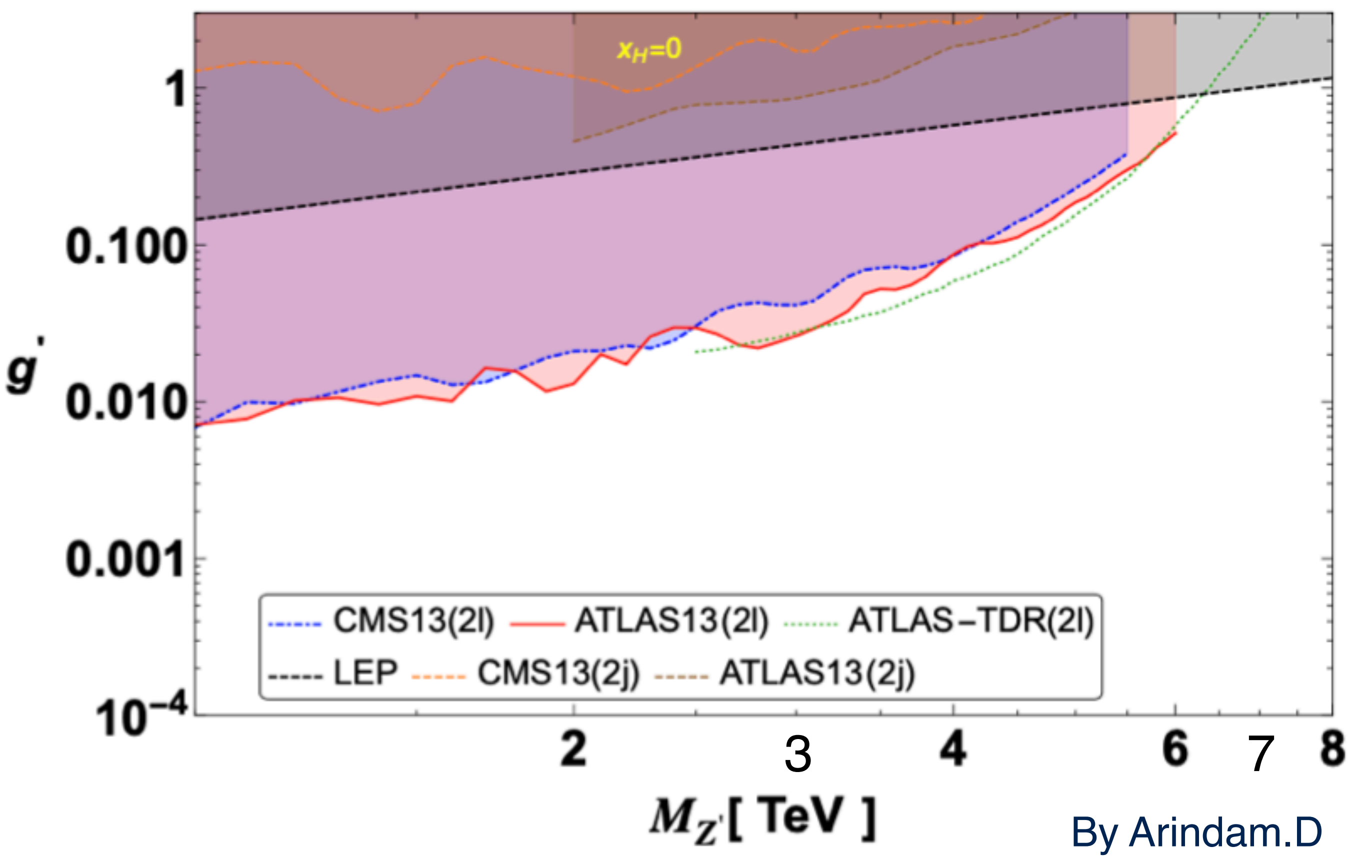
Cross section with the beam polarization

$$\sigma(P_-, P_+) = \left(\frac{1-P_-}{2}\right)\left(\frac{1+P_+}{2}\right)\sigma_L + \left(\frac{1+P_-}{2}\right)\left(\frac{1-P_+}{2}\right)\sigma_R \ (\sigma_L = \sigma_R)$$

$$\mathrm{Pol}(-0.8, +0.3), \mathrm{Pol}(+0.8, -0.3) : \mathcal{L} = 900\ [\mathrm{fb}^{-1}]$$
$$\mathrm{Pol}(+0.8, +0.3), \mathrm{Pol}(-0.8, -0.3) : \mathcal{L} = 100\ [\mathrm{fb}^{-1}]$$

Current Limits and prospects - Z' mass,g1'

G1' :U(1)$_{B\text{-}L}$ gauge coupling constant

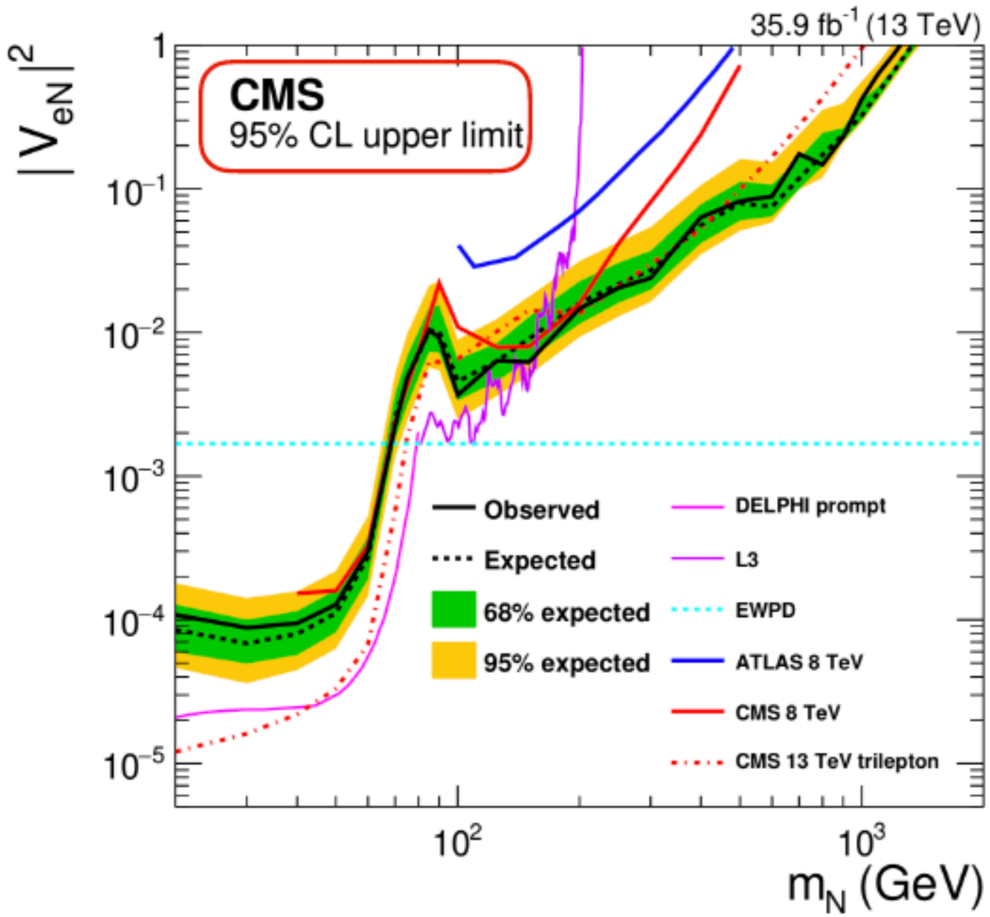


By Arindam.D

M_N [GeV]	$M_{Z'}$ [TeV]	g1'
100	7	1
200	7	1

Current limits $|V_{eN}|^2$

$|V_{eN}|^2$: the "light-heavy" neutrino mixing matrix



CMS PAS EXO-19-019