Direct and indirect searches of light gauge boson in $L_\mu - L_\tau$ symmetry

Niigata Univ. Yuya KANETA, Univ. of Miyazaki Takashi SHIMOMURA

Based on arXiv : 1701.00156

Introduction

There are no New Physics signals up to *O(1)*TeV
- NP is at higher mass region
- NP is at lower mass region

New Physics with MeV is interesting !!

New particles which is *O(100)*MeV can expect to be detected @ High luminosity frontier
Some deviations are reported by low energy measurements like a $(g\text{-}2)_\mu$, Atomki anomaly and so on…
Planned to search for NP at MeV scale like a Muon g-2/EDM@J-PARC, SHiP, some Dark Photon search and so on…

Gauged $L_\mu - L_\tau$ model

The Lagrangian is written as following

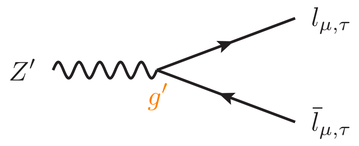
$$\mathcal{L} = \frac{1}{2} M_{Z'}^2 Z'^\mu Z'_\mu$$

$$+ g' Z'_\mu (\bar{\mu}\gamma^\mu \mu + \bar{\nu}_\mu \gamma^\mu \nu_\mu - \bar{\tau}\gamma^\mu \tau - \bar{\nu}_\tau \gamma^\mu \nu_\tau)$$

new interactions for μ and τ

R. Foot, Mod.Phys.Lett. A6, 527 (1991)

	l_e	e_R	l_μ	μ_R	l_τ	τ_R
L_μ	0	0	1	1	0	0
L_τ	0	0	0	0	1	1



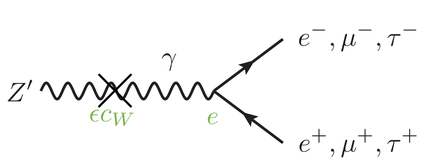
- Anomaly free
- $(g\text{-}2)_\mu$ can be explained
- Large neutrino flavor mixing
  Choubey, Rodejohann, Eur.Phys.J,(2005)
  Ota, Rodejohann, Phys.Lett. (2006)

Recently
- IceCube gap can be explained
  Araki, Kaneko, Ota, Sato, Shimomura,PRD93 (2016)
- $B \to K^* \mu\mu$ anomaly can be explained
  Altmannshorfer, Gori, Pospelov, Yavin, Phys.Rev.D (2015)

In general, there are no reasons to forbid the kinetic mixing
We consider including the kinetic term

$$-\frac{1}{4} B^{\mu\nu} B_{\mu\nu} - \frac{1}{4} Z'^{\mu\nu} Z'_{\mu\nu} - \frac{\epsilon}{2} B^{\mu\nu} Z'_{\mu\nu}$$

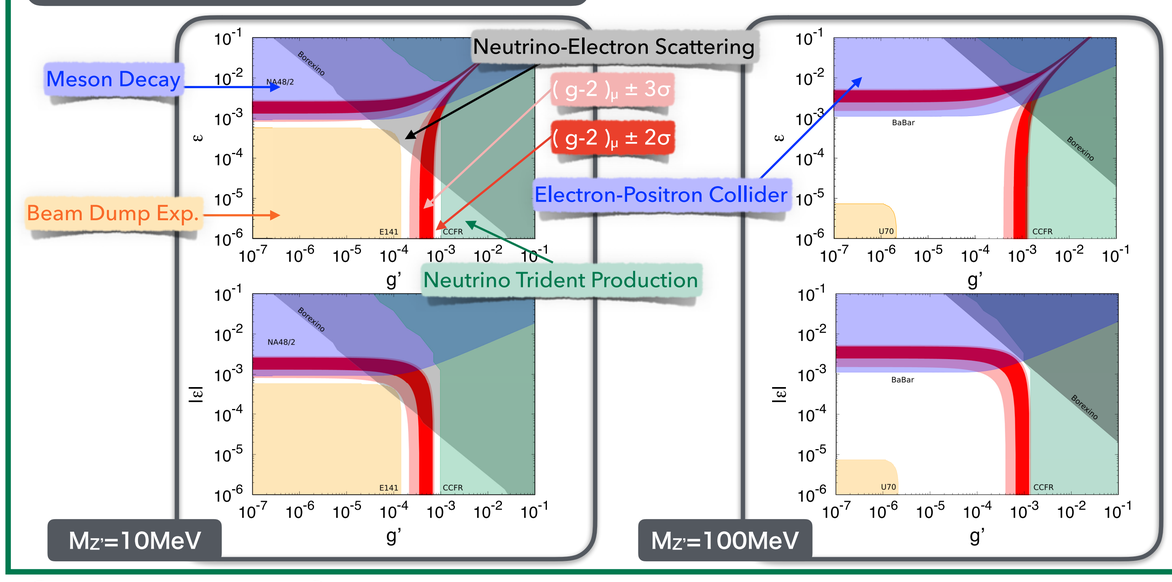
kinetic mixing term between Z′ and γ



It is important that this model has the three free parameters,

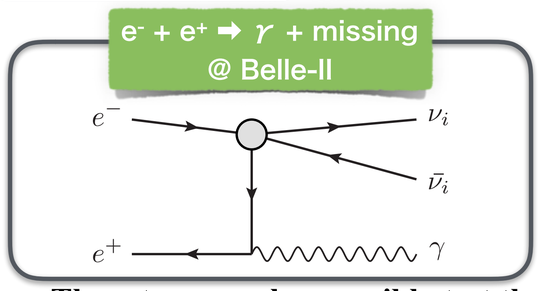
$M_{Z'}$ g' ϵ

Allowed Parameters Region

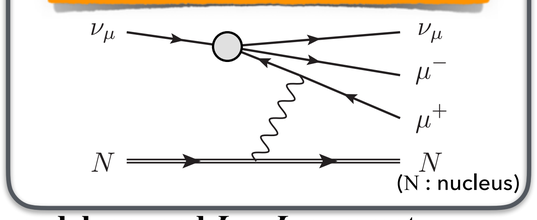


Our Proposal

$e^- + e^+ \to \gamma$ + missing @ Belle-II



Neutrino Trident Production
(ν_μ + N → ν_μ + μ^- + μ^+ + N)
@ Neutrino Beam Experiments



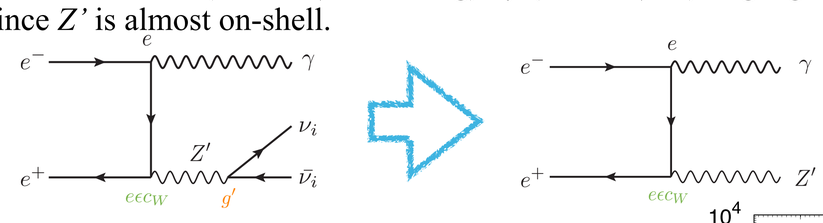
These two searches possibly test the out model, gauged L_μ - L_τ symmetry.

$e^- + e^+ \to \gamma$ + missing @ Belle-II

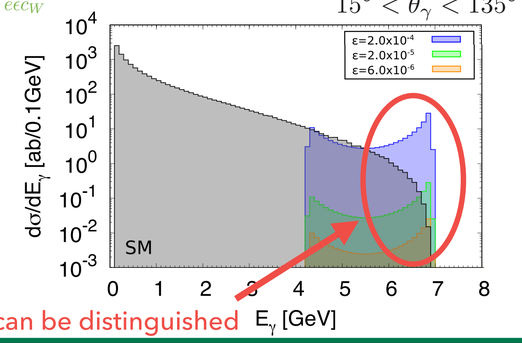
Belle-II is the e^+,e^- collider experiment

$$\int dt\mathcal{L} = 50 \quad [\text{ab}^{-1}] \qquad \sqrt{s} = 10.58 \quad [\text{GeV}] \qquad \begin{matrix} E_{e^-} = 7\text{GeV} \\ E_{e^+} = 4\text{GeV} \end{matrix}$$

We can estimate ($e^+ e^- \to \gamma$ + missing) by ($e^+e^- \to \gamma Z'$) in gauged L_μ - L_τ symmetry, since Z' is almost on-shell.



cut of final state :
$E_\gamma > 0.1$ GeV
$15^\circ < \theta_\gamma < 135^\circ$

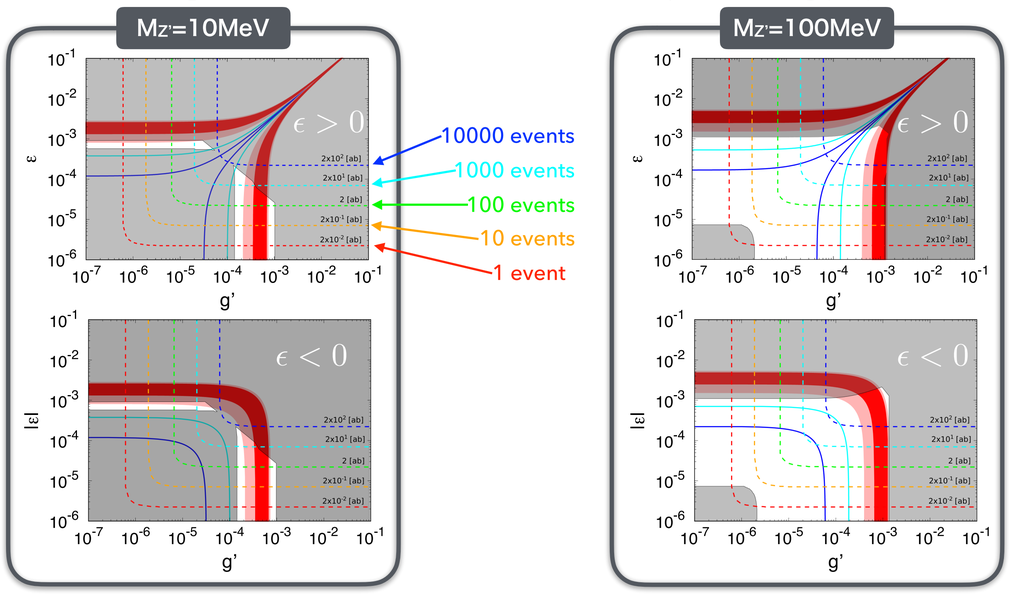


It can be distinguished

The total cross section including Z' is lager than the SM one

The differential cross section has a characteristic shape different from the SM.

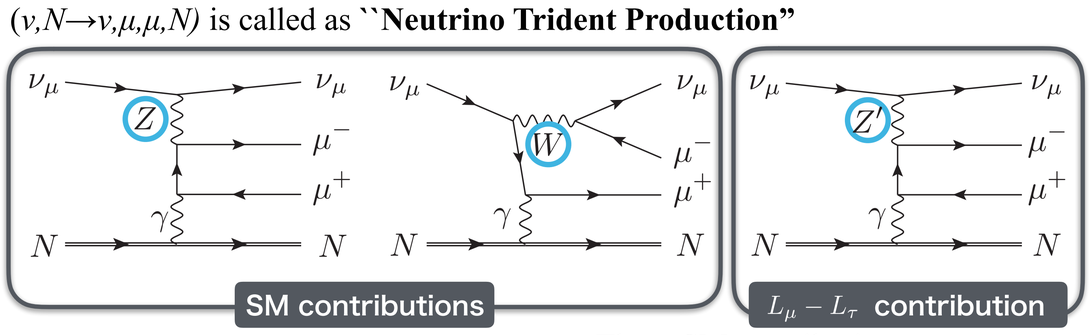
We show the expected number of events of $e^- + e^+ \to \gamma$ + missing(ν,ν) in Belle-II



This process is worthwhile to be searched at Belle-II !!

Neutrino Trident Production

(ν,N→ν,μ,μ,N) is called as ``**Neutrino Trident Production**"



This scattering was observed

$$\frac{\sigma_{\text{CCFR}}}{\sigma_{\text{SM}}} = 0.82 \pm 0.28$$

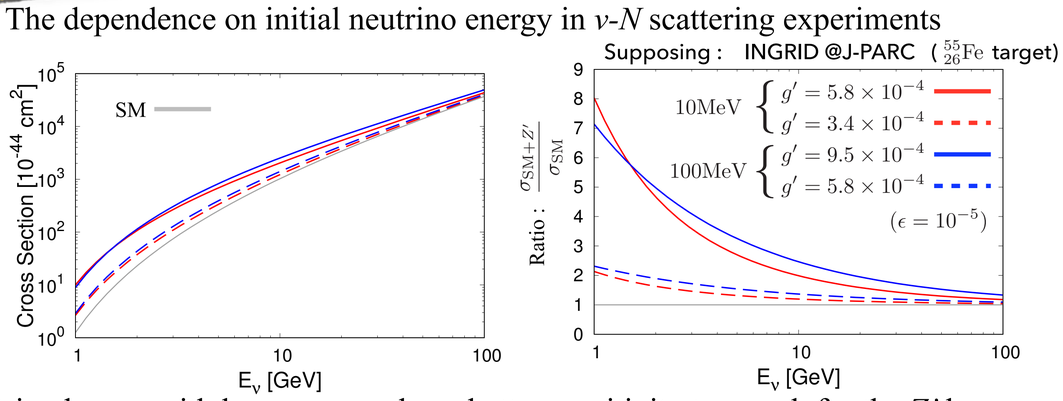
CCFR Collaboration, Phys. Rev. Lett. 66, 3117(1991)

These SM contributions are suppressed since Z and W are heavy

This process is sensitive to
Low mass Z' with small coupling !!
independent of ε ($\varepsilon < O(10^{-4})$) !!

Initial Energy Dependence

The dependence on initial neutrino energy in ν-N scattering experiments



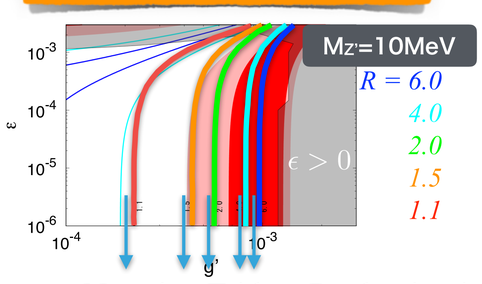
Neutrino beams with lower energy have better sensitivity to search for the Z' boson. Larger flux is needed to produce enough events, since the cross section becomes smaller at the lower energy.

ν oscillation experiments with high intensity beam is Good Target !!

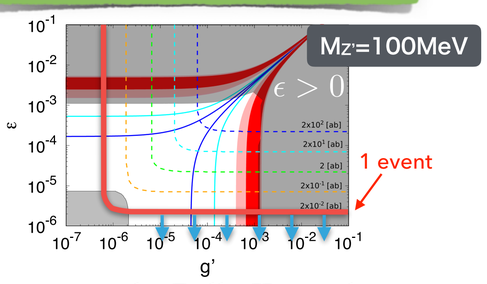
Our Proposal

$E_\nu = 1.5$ GeV

Neutrino Trident Production



$e^- + e^+ \to \gamma$ + missing @ Belle-II



Neutrino Trident Production is complementary to the Belle-II search
The two experiments are important to search for the light gauge boson !!

Summary

- We have proposed two searches for hight Z' .
- The diff. cross section with respect to E_γ has a characteristic shape. Therefore, it can distinguish between L_μ - L_τ process and SM one.
- This process is worthwhile to be searched at Belle-II !!
- Neutrino trident production process $\nu, N \to \nu, \mu, \mu, N$ is sensitive to light Z'.
- To observe the neutrino trident production clearly, it needs the low energy neutrino beam with high intensity.
- ν oscillation experiments is good target for neutrino trident production.
- Neutrino Trident Production is complementary to Belle-II search. The two experiments are important to search for the light gauge boson !!