R-parity violating scenario revisit From mu-e conversion to LHC

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Lepton Flavor

ニュートリノが0質量であることから自動的に出てくる保存「電荷」

電子数、ミューオン数、タウ数

L_e L_μ L_τ

e^- ν_e μ^- ν_μ τ^- ν_τ

L_e 1 1

反粒子は－１

L_μ 1 1

L_τ 1 1

例 $\pi^- \rightarrow \mu^- \bar{\nu}_\mu$

L_μ 0 ＝ 1＋（－1）

Search for LFV with charged lepton

$$\mu^- \rightarrow e^- \quad \gamma$$

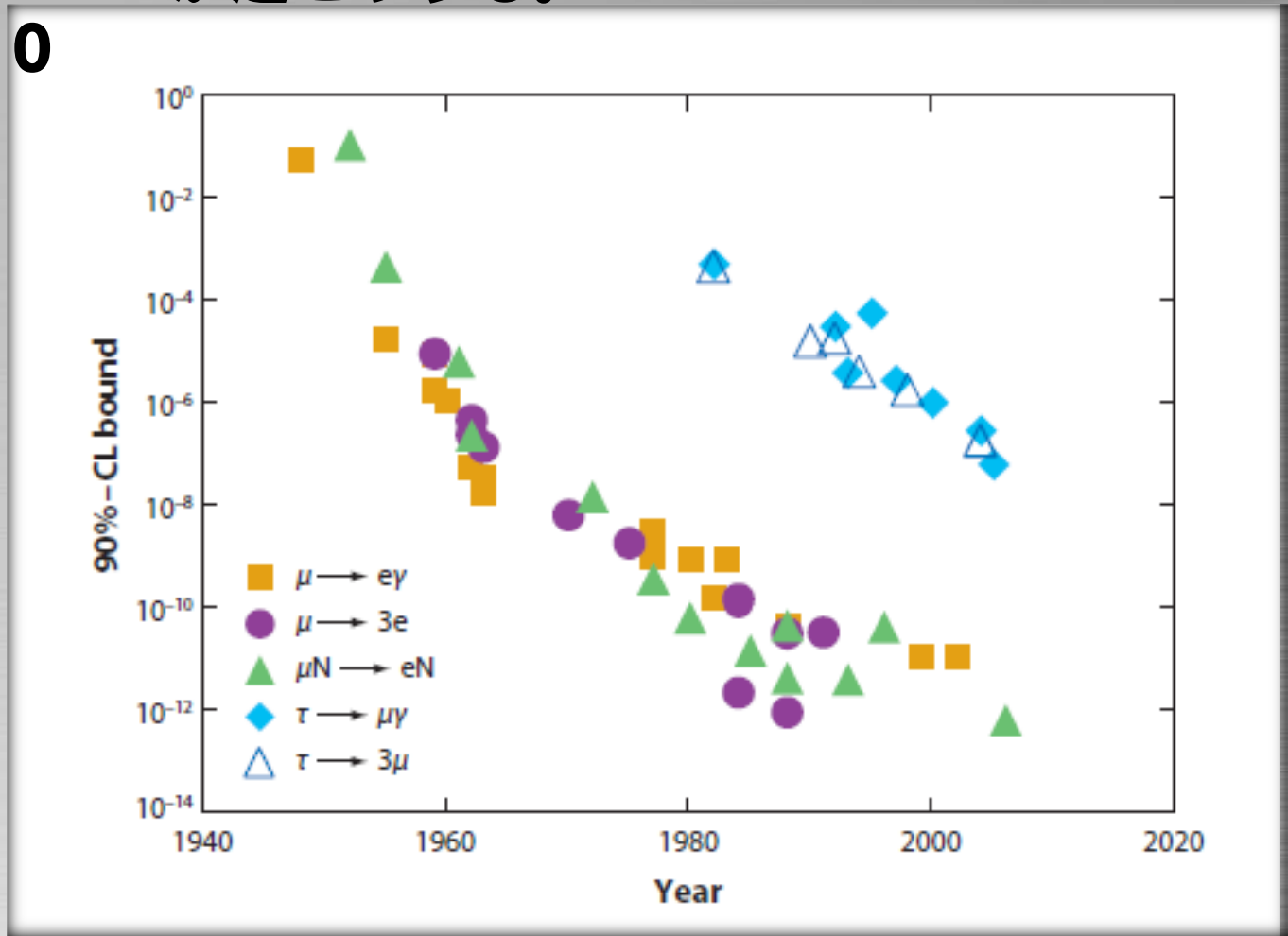
L_μ 1 = 0 + 0

L_e 0 = 1 + 0

ニュートリノに質量があると、一般には
レプトンフレーバーは保存しないので、

が起こりうる。

Annu. Ref. Nucl. Part. Sci. 2008. 58:315-41
W. J. Marciano, T.Mori, and J. M. Roney



LFV from muon decay

Upper limit on Br

$$\mu^+ \to e^+\gamma \quad < \quad 2.4\times10^{-12}$$
$$\mu^+ \to e^+e^+e^- \quad < \quad 1.0\times10^{-12}$$
$$\mu^-\mathrm{Ti} \to e^-\mathrm{Ti} \quad < \quad 6.1\times10^{-13}$$
$$\mu^-\mathrm{Au} \to e^-\mathrm{Au} \quad < \quad 7\times10^{-13}$$

MEGII experiment updates/discovers(?)

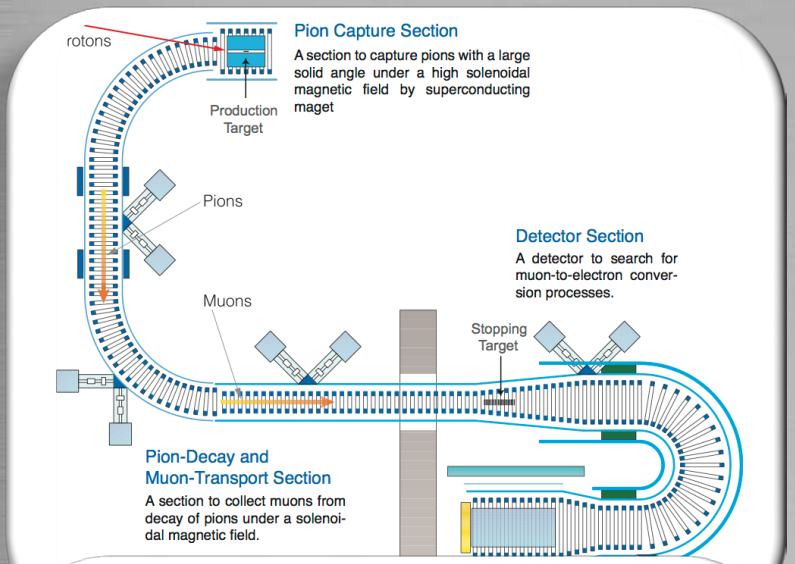
$$\mu^+ \to e^+\gamma$$

COMET/DeeMe/Mu2E will discover(?)

$$\mu^+ \to e$$

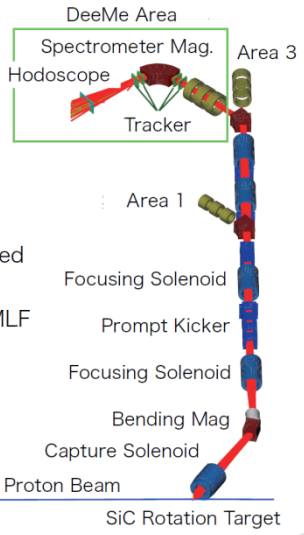
In near future

Waiting for μ-e conversion



DeeMe

- Search for μ-e conversion in nuclear field at 10^{-14}
- J-PARC RCS
  - High Power High Quality Pulsed Proton Beam
- H-Line, multipurpose beamline, in MLF
  - Large Acceptance
- SiC Muon Production/Stop Target
  - $\mu^- + Si \rightarrow e^- + Si$
- Electron Spectrometer
- Prompt Kicker



- ☑ COMET and DeeMe launch at J-PARC in the near future

Example: SUSY models

- ☑ In various models

  Discovery of μ-e conversion

  ⇕

  Discovery of other cLFV

- ☑ cLFV correlations is an evidence and probe of new physics

Waiting for μ-e conversion

If μ-e conversion is found, while other cLFV processes will never be found

We have to discard SUSY models???

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We have to discard SUSY models???

No!

R-parity violating SUSY gives such a situation

- ☑ No correlations of cLFV
- ☑ Lack of evidence and probes to confirm the scenario
- ☑ Misunderstanding of signals

Aim of this work

To find out distinctive signals to discriminate the scenario and other new physics models

To show the feasibility to determine the parameters in the RPV scenario through observing the signals

- ☑ No correlations of cLFV
- ☑ Lack of evidence and probes to confirm the scenario
- ☑ Misunderstanding of signals

R-parity violating SUSY

- Candidate of new physics: R-parity violating SUSY
- Consistent with experimental/theoretical status
  - New physics is required to cancel Higgs quadratic divergence
  - TeV scale SUSY predicts grand unification of interactions
  - So far no typical SUSY signals have been observed@LHC
- RPV terms in superpotential in SUSY

Omit the term to avoid proton decay

$$\mathcal{W}_{\not R} = \lambda_{ijk} L_i L_j E^c_k + \lambda'_{ijk} L_i Q_j D^c_k + \lambda''_{ijk} U^c_i D^c_j D^c_k$$

Framework of our scenario

Naturally realized by RG evoltion
with universal masses@GUT scale

- Slepton contribution to RPV: only 3rd generation
- Different generation of left- and right-handed leptons
  λ_{ijk} ($i \neq k$ and $j \neq k$)

Assumption to realize
the interesting situation

- RPV terms in superpotential in SUSY

$$\mathcal{W}_{\not R} = \lambda_{ijk} L_i L_j E^c_k + \lambda'_{ijk} L_i Q_j D^c_k + \lambda''_{ijk} U^c_i D^c_j D^c_k$$

Framework of our scenario

Naturally realized unless we introduce additional sources of flavor violation

- For quarks, flavor diagonal components are much larger than off-diagonal components

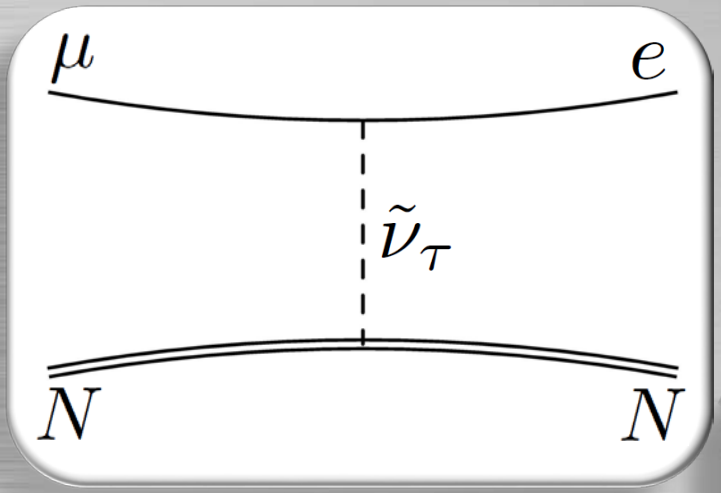
$$\lambda'_{ijj} \gg \lambda'_{ijk} \quad (j \neq k)$$

- RPV terms in superpotential in SUSY

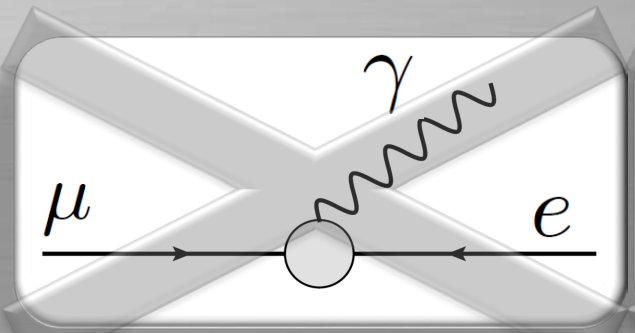
$$\mathcal{W}_{\not R} = \lambda_{ijk} L_i L_j E^c_k + \lambda'_{ijk} L_i Q_j D^c_k + \lambda''_{ijk} U^c_i D^c_j D^c_k$$

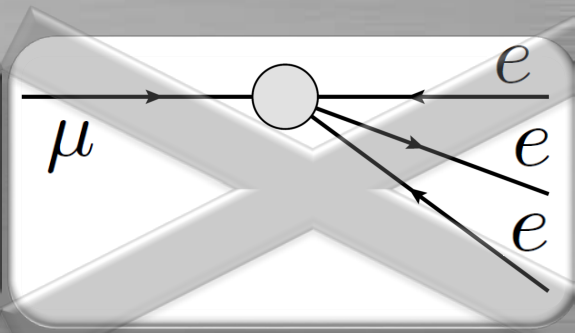
Exotic processes in the scenario

$$\begin{aligned}\mathcal{L}_{\rm RPV} = 2\{ & \lambda_{312}\tilde{\nu}_\tau \bar{\mu}_R e_L + \lambda_{321}\tilde{\nu}_\tau \bar{e}_R \mu_L + \lambda_{132}\tilde{\tau}_L \bar{\mu}_R \nu_e + \lambda_{231}\tilde{\tau}_L \bar{e}_R \nu_\mu \} \\ & + \{ \lambda'_{311}(\tilde{\nu}_\tau \bar{d}_R d_L - \tilde{\tau}_L \bar{d}_R u_L) + \lambda'_{322}(\tilde{\nu}_\tau \bar{s}_R s_L - \tilde{\tau}_L \bar{s}_R c_L) \\ & + \lambda'_{333}(\tilde{\nu}_\tau \bar{b}_R b_L - \tilde{\tau}_L \bar{b}_R t_L) \} + \text{h.c.}\end{aligned}$$



- ☑ μ-e conversion@tree level
- ☑ Negligible rates of other cLFV processes





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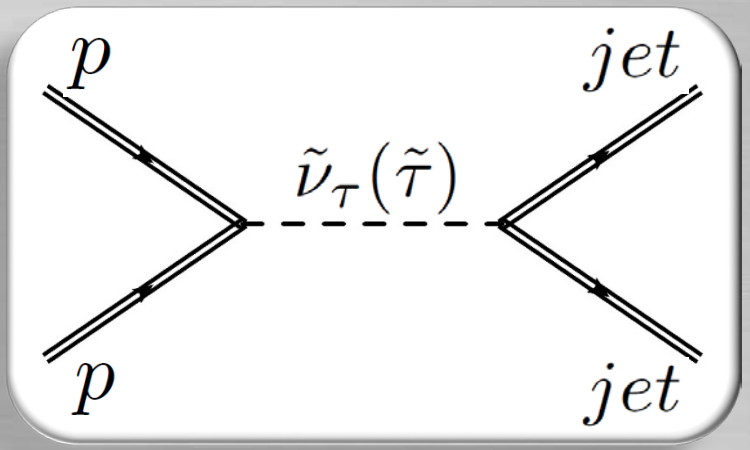
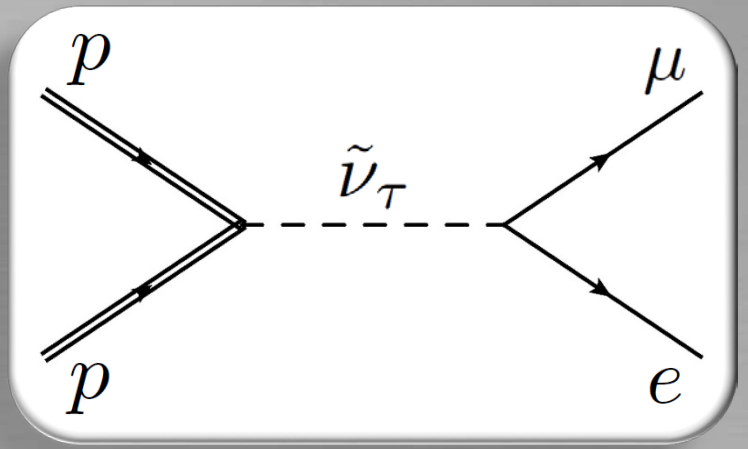
- ☑ High energy dijet and $\mu\bar{e}$ resonances@LHC



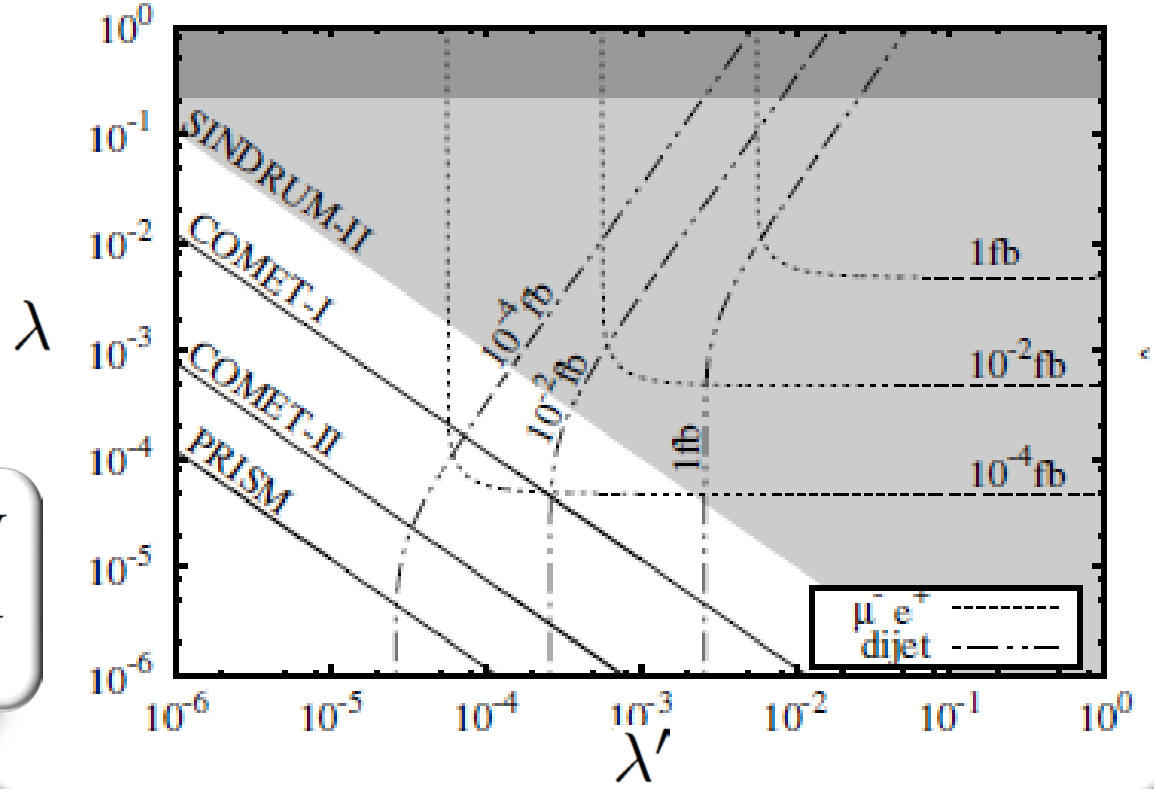


Correlations of distinctive signals

Contour plot of

- $\mathrm{BR}(\mu^- + N \to e^- + N)$
- $\sigma(pp \to \mu\bar{e})$
- $\sigma(pp \to jj)$

- sneutrino mass $m_{\tilde{\nu}_\tau} = 1\mathrm{TeV}$
- collision energy $\sqrt{s} = 14\mathrm{TeV}$



- ☑ μ-e conversion search is a strong tool for exploring RPV
- ☑ PRISM explores all parameter space wherein LHC can survey

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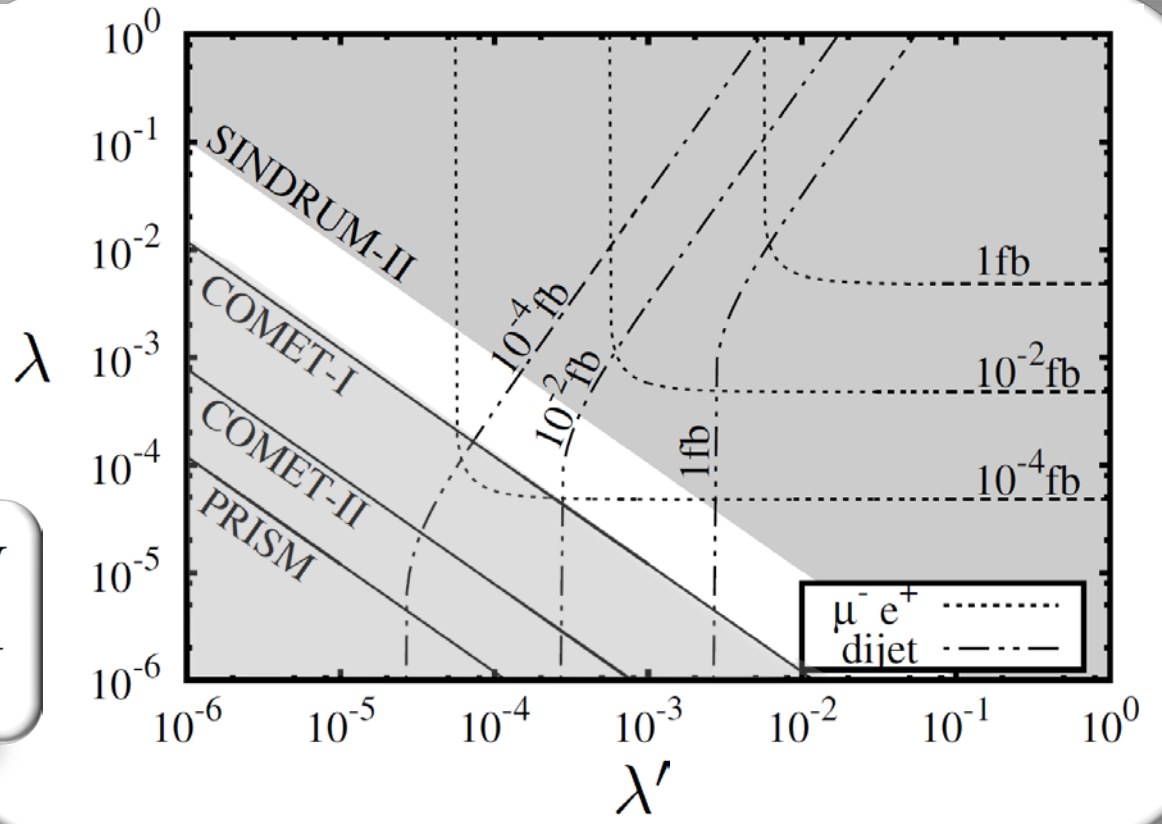

☑ COMET/DeeMe found m-e conversion ➡ white band

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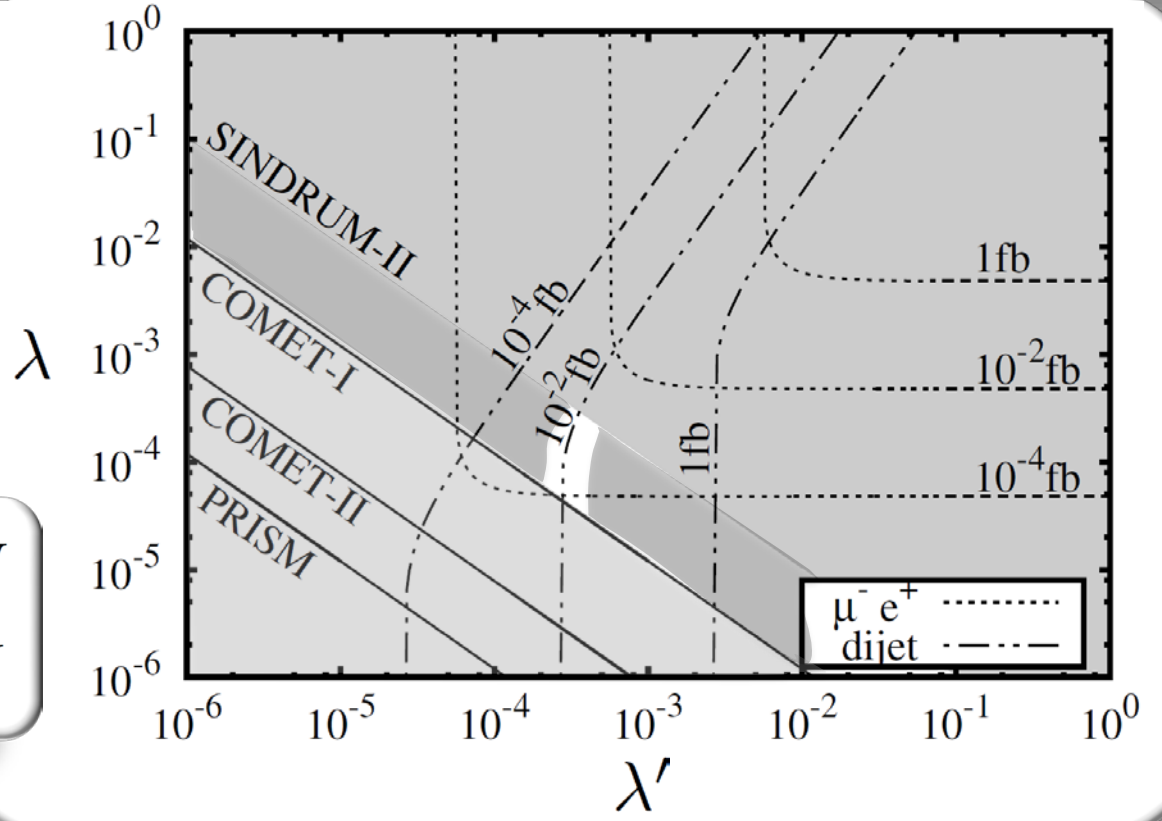

- ☑ COMET/DeeMe found m-e conversion ➡ white band
- ☑ Dijet resonance is found with 10^{-2}fb ➡ white small region

Correlations of distinctive signals

Contour plot of

- $\mathrm{BR}(\mu^- + N \to e^- + N)$
- $\sigma(pp \to \mu\bar{e})$
- $\sigma(pp \to jj)$

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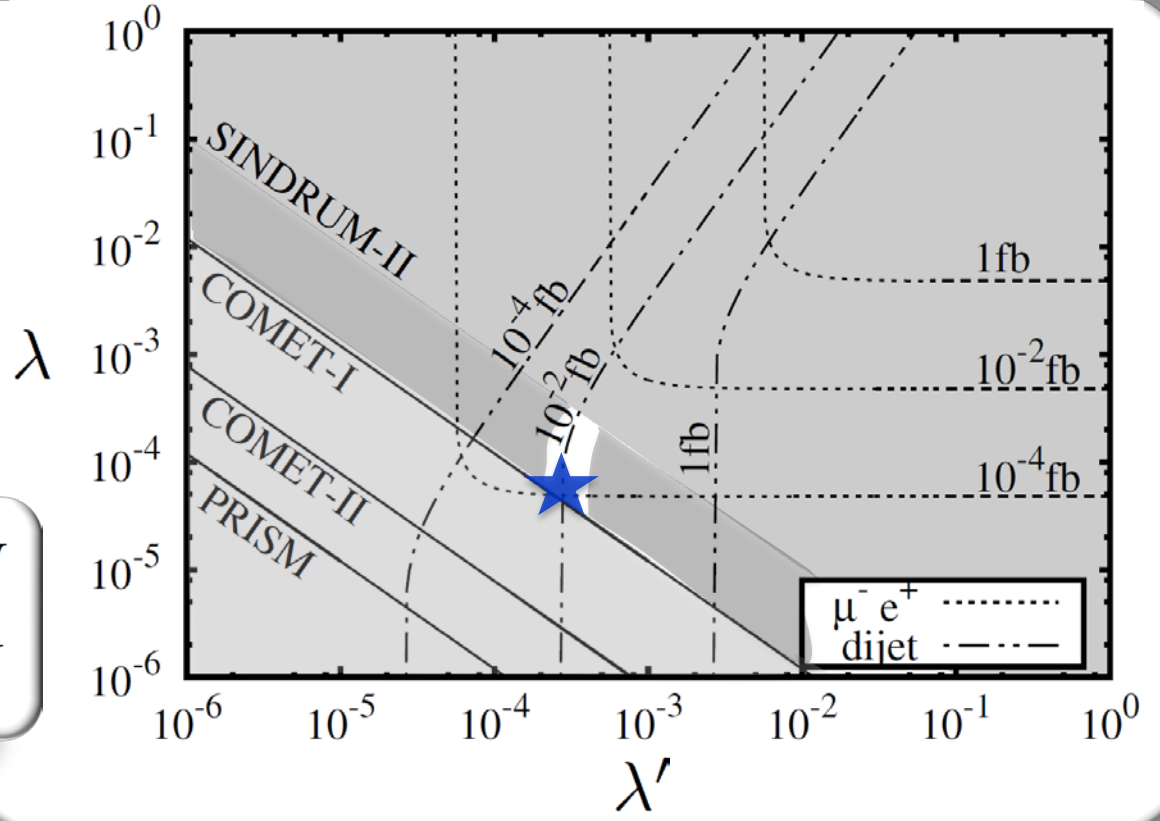

- ☑ $\mu\bar{e}$ resonance is found with 10^{-4}fb ➡ blue star point
- ☑ J-PARC and LHC precisely determine the RPV parameters!

More on coupling discrimination

- Non Standard Interaction

Pion decay in scalar channel – chiral enhancement

Exotic decay $\pi^+ \to \mu^+ \nu_e$

$$\epsilon^S_{\mu e} = \sqrt{2} \frac{m_\pi^2}{m_\mu m} \frac{\lambda^*_{312} \lambda'_{311}}{G_F m^2_{\tilde{\tau}}}$$

312 : LH electron only

- ILC with polarization

LHC signal is same for 312(LH e) and 321 (RH e)

Can you distinguish them ?

Summary

- We studied R-parity violating SUSY model as a benchmark that μ-e conversion is observed prior to other cLFV processes

- Such a RPV scenario are simply realized by 3 settings

1. Slepton contribution to RPV: only 3rd generation
2. Different generation of left- and right-handed leptons λ_{ijk} ($i \neq k$ and $j \neq k$)
3. For quarks, flavor diagonal components are much larger than off-diagonal components $\lambda'_{ijj} \gg \lambda'_{ijk}$ ($j \neq k$)

- Such a RPV scenario is confirmed or rejected from μ-e conversion search@J-PARC and dijet and $\mu\bar{e}$ resonances search@LHC and in future in ILC !?
- More details are shown in our paper arXiv:1407:xxxx

Backup slides

HOGE

- ☑ HOGE