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The search for Leptophilic WIMP at ILC

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WIMP

- Well motivated DM candidate by many physics beyond the standard models (SM)
- Thermal equilibrium with SM particles at early universe
- We can estimate the relic density by Boltzmann equation

Motivation

- Direct detection experiments are effective for WIMP search
- Is there any difficult parameter space by direct detection?
  ↪ Leptophilic WIMP
- How effective does ILC work for such region?

Constraint

Theory

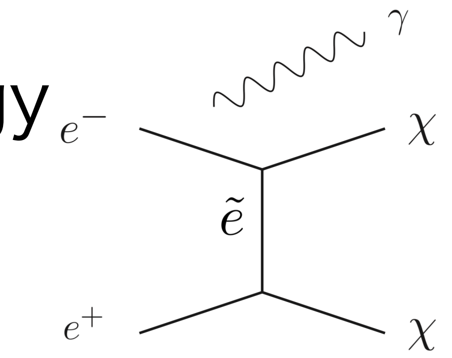
- Vacuum stability condition
- Relic abundance condition

Experiment

- Slepton search at LHC or LEP
- Electroweak precision measurement
(Higgs to diphoton, STU parameter)

Prospect

- Mono-photon search at ILC
- Look at the energy distribution of photon



- $e^+e^- \to \gamma\nu\bar{\nu}$ is main background
- Assuming 250GeV ILC and 500fb^{-1} integrated luminosity

Leptophilic WIMP

Features

- Consider majorana fermionic SM gauge singlet WIMP
- Interacting mainly with SM leptons via mediators
- WIMP : bino like χ
- Mediator : slepton like $\tilde{L}$ $\tilde{R}$
  ↪ can be left/right-handed
  (SU(2)-doublet/singlet)
- Mass range : GeV~TeV
  (both DM and mediators)

Lagrangian

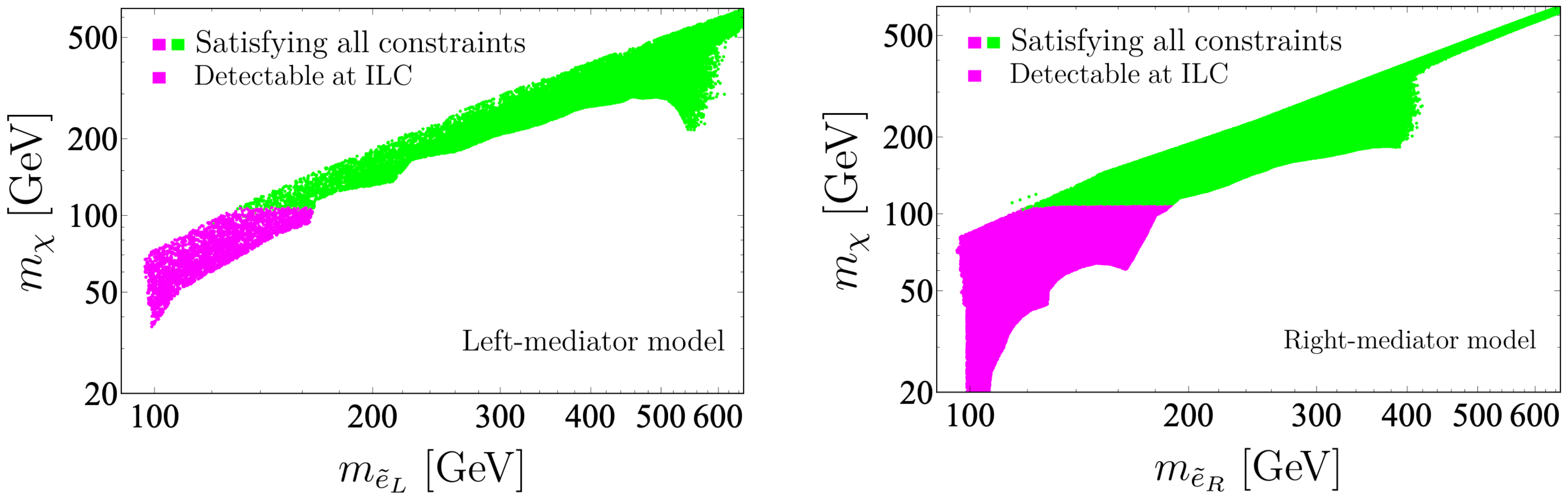
- Yukawa coupling of SM leptons, mediators and DM

$$\mathcal{L}_{\rm DMR} = -y_R \bar{E}_i \tilde{R}_i \chi + h.c.$$

$$\mathcal{L}_{\rm DML} = -y_L \bar{L}_i \tilde{L}_i \chi + h.c.$$

- Assuming flavor blindness
↪ coupling and mass of sleptons are universal over 3 generations
- There are also scalar couplings
  (Details in backup)

Summary



- Surviving parameter space projected onto mediator mass and DM mass plane for left-handed case and right-handed case
- Magenta region is detectable region only by ILC
- Supplement : Left-right mixing can explain muon g-2 anomaly
  (Details in backup)

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Backup : Scalar coupling

Right-mediator (SU(2)-singlet)

$$\mathcal{L}_R = \mathcal{L}_{\rm SM} + \frac{1}{2}\bar{\chi}\left(i\partial\!\!\!/ - m_\chi\right)\chi + (D_R^\mu \tilde{R}_i)^\dagger (D_{R\,\mu}\tilde{R}_i) + \mathcal{L}_{{\rm DM}\,R} - V_L(H, \tilde{R}_i),$$

$$\mathcal{L}_{{\rm DM}\,R} = -y_R \bar{E}_i \tilde{R}_i \chi + h.c,$$

$$V_R = m_{\tilde{R}}^2 |\tilde{R}_i|^2 + \frac{\lambda_R}{4}|\tilde{R}_i|^4 + \lambda_{RH}|\tilde{R}_i|^2|H|^2,$$

Left-mediator (SU(2)-doublet)

$$\mathcal{L}_L = \mathcal{L}_{\rm SM} + \frac{1}{2}\bar{\chi}\left(i\partial\!\!\!/ - m_\chi\right)\chi + (D_L^\mu \tilde{L}_i)^\dagger (D_{L\,\mu}\tilde{L}_i) + \mathcal{L}_{{\rm DM}\,L} - V_L(H, \tilde{L}_i),$$

$$\mathcal{L}_{{\rm DM}\,L} = -y_L \bar{L}_i \tilde{L}_i \chi + h.c,$$

$$V_L = m_{\tilde{L}}^2 |\tilde{L}_i|^2 + \frac{\lambda_L}{4}|\tilde{L}_i|^4 + \lambda_{LH}|\tilde{L}_i|^2|H|^2 + \lambda'_{LH}(\tilde{L}_i^\dagger \tau^a \tilde{L}_i)(H^\dagger \tau^a H) + [\frac{\lambda''_{LH}}{4}(\tilde{L}_i^\dagger H^c)^2 + h.c.].$$

Supplement

- Scalar couplings are important for vacuum stability
- Also important for electroweak precision measurement
- When DM mass and mediator mass are close, co-annihilation happens
- In such a case, mediators behave like DM, and scalar coupling affect relic abundance
- For left case, λ''_{LH} induce neutrino mass, so we set this value to be 0

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Backup : Combined model, muon g-2

Combined model

- Left-handed mediator and right-handed mediator can exist simultaneously
- In such a case, new scalar coupling emerge in addition to previous scalar couplings

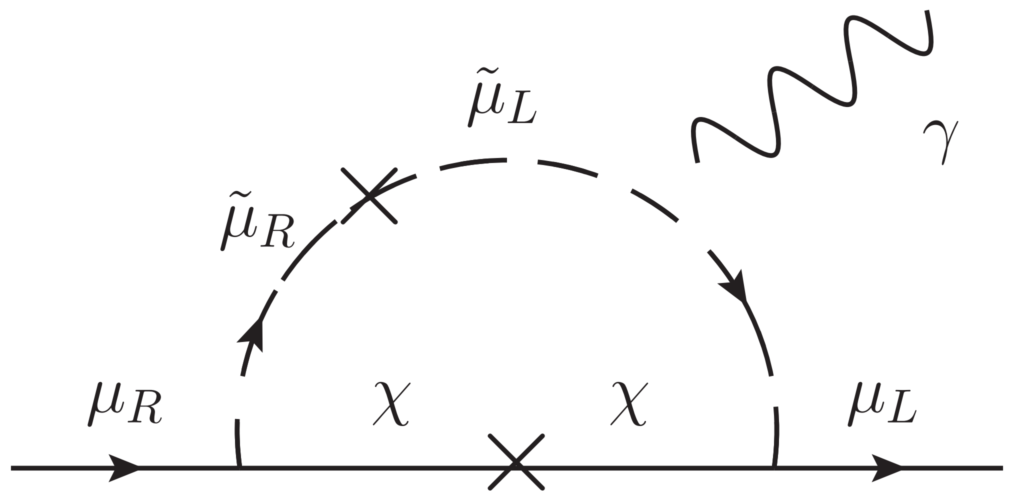
$$\lambda_{LR}(\tilde{L}_i^\dagger \tilde{L}_i)(\tilde{E}_i^\dagger \tilde{E}_i)$$

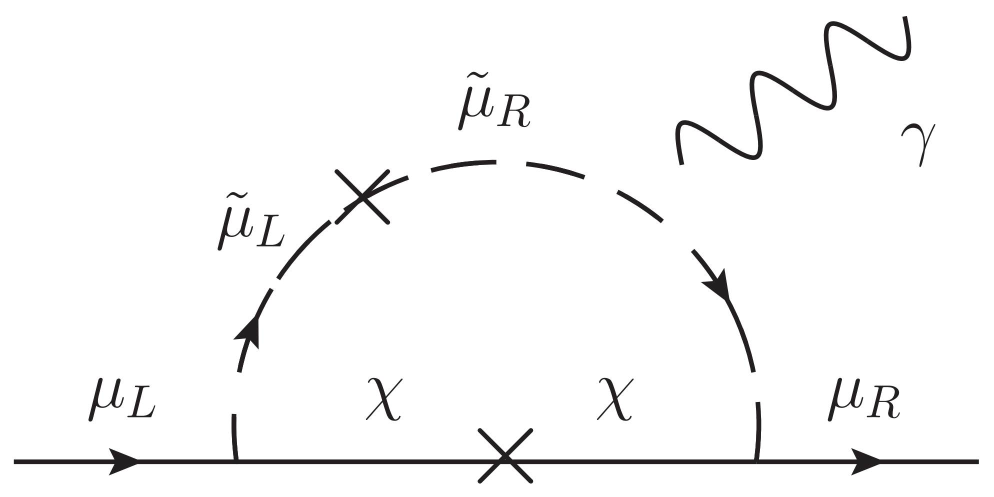
$$A m_i \tilde{E}_i \tilde{L}_i^\dagger H + h.c.$$

- These couplings do not change relic abundance condition or experimental constraint drastically
- Vacuum stability keeps for O(10~100) “A” term

Muon g-2

- “A” term induce muon g-2





- By choosing proper value of “A”, this model can explain muon g-2 anomaly
- The DM in the reach of ILC possibly explain muon g-2 anomaly