The search for Z-funnel WIMP at ILC

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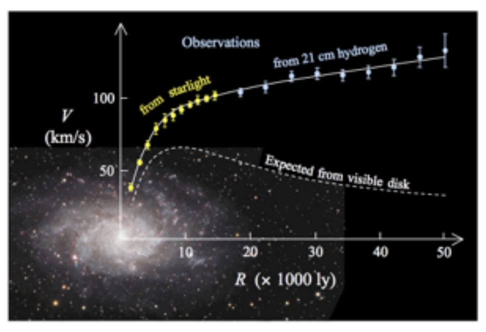
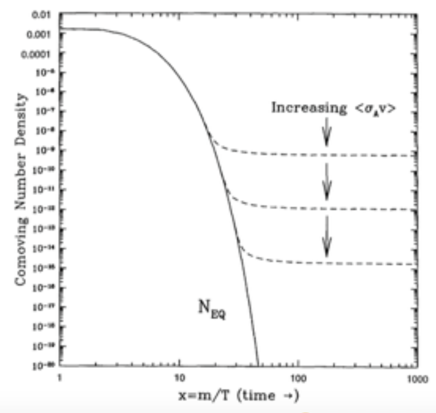
Introduction for WIMP

Many observation suggest the existence of dark matter. (CMB, galaxy rotation curve…)



(Galaxy rotation curve)

WIMP is a good candidate of particle like dark matter. (explanation of relic density, and detectability)

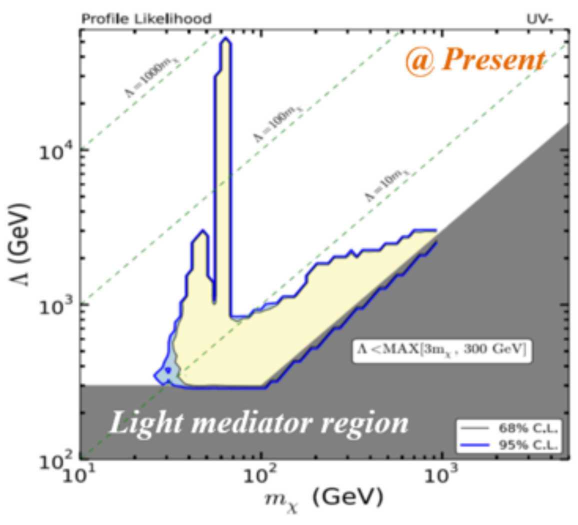


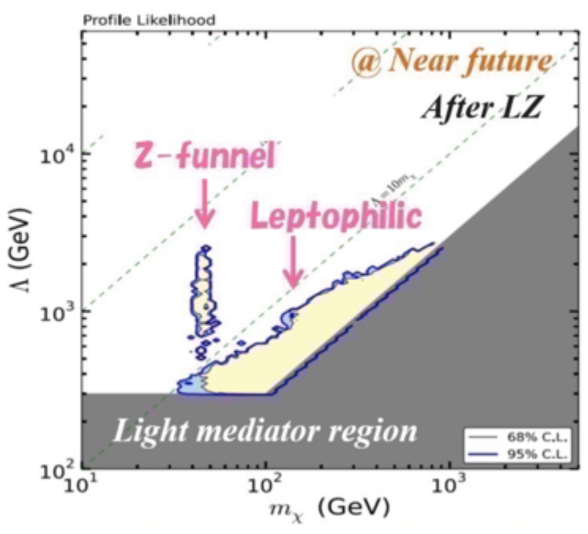
(Freeze out of WIMP)

Constraints from previous work

The figures shows constraints on the m_χ and Λ plane, upper one is the present constraint, and lower one is that of near future assuming the LZ spin independent direct detection.

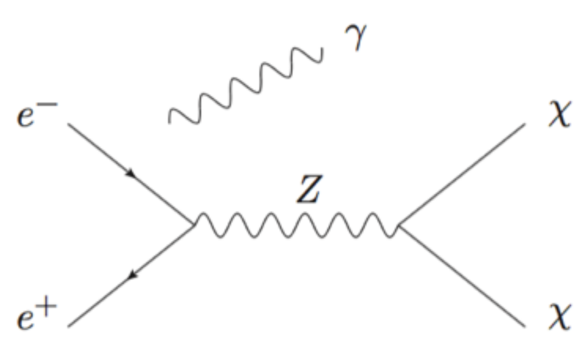
(Yellow area is unexplored region, gray area is where we can't apply EFT)



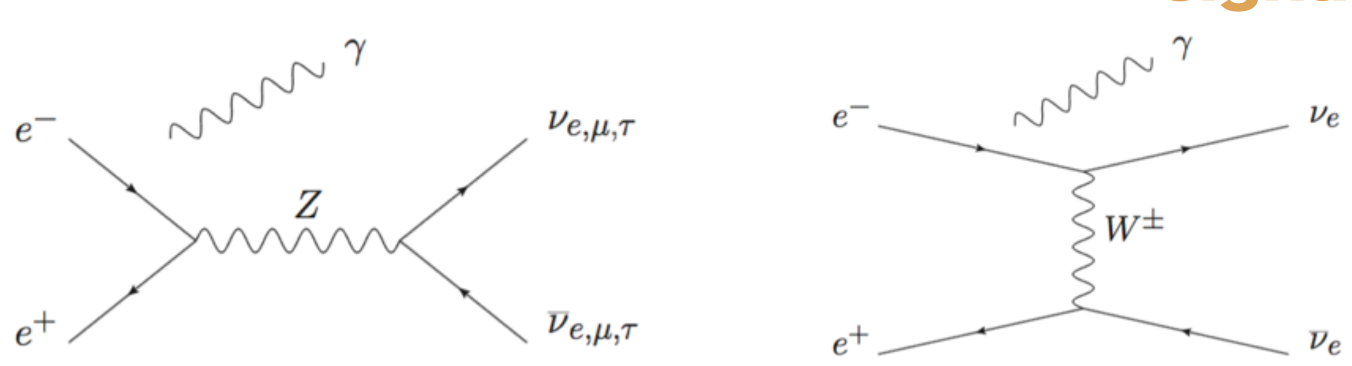


Mono-photon search at lepton collider

Mono-photon channel is the best at lepton collider. Looking the energy dependence of this photon.



signal



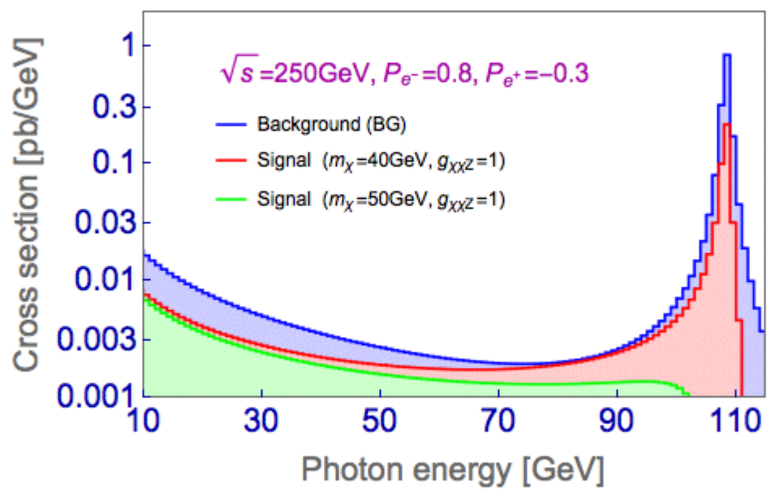
main background

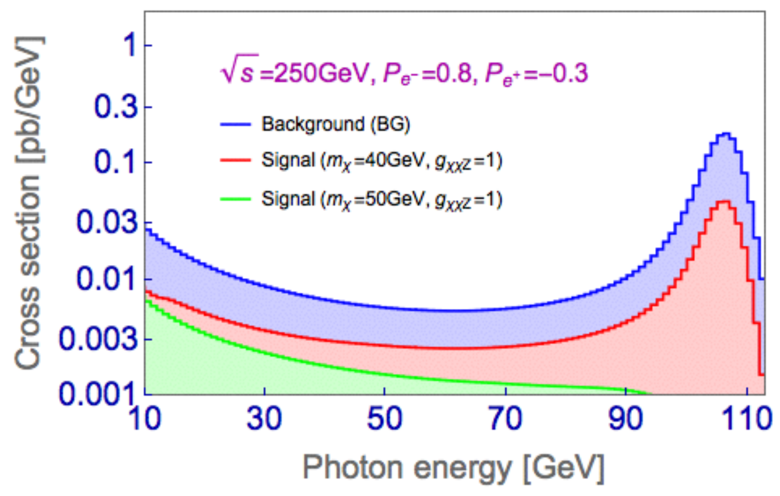
The effects from beam and detector

These two figure show the differential cross section of signal and background.

Left : monochromatic beam energy, no detector error

Right : smeared beam energy, including detector error





SU(2)-singlet fermionic WIMP

Classifying the WIMP by their quantum number for the systematic search.
No electric charge, No SU(3) color.

Lorentz	SU(2)$_L$	U(1)$_Y$
Scalar	Singlet	0
Fermion	Doublet	±1 /2
Vector	Triplet	0 or ±1
…	…	…

Focussing on the Majorana fermion and SU(2) singlet WIMP.

➡Mediator particle is needed because of symmetries.

If the mediator is enough heavy, we can go effective field theory. This is the Lagrangian up to dimension 6.

$$\mathcal{L} = \mathcal{L}_{\rm sm} + \frac{1}{2}\bar{\chi}(i\partial\!\!\!/ - M_\chi)\chi + \mathcal{L}_{\rm int}$$

$$\mathcal{L}_{\rm int} = \frac{g_S}{\Lambda}\bar{\chi}\chi H^\dagger H + \frac{1}{\Lambda^2}(\bar{\chi}\gamma_\mu\gamma_5\chi)\times\sum_f(g_f\bar{f}\gamma^\mu f) + \frac{g_D}{\Lambda^2}(\bar{\chi}\gamma_\mu\gamma_5\chi)(H^\dagger i\overleftrightarrow{D}^\mu H) + \text{h.c.}$$

Simplified model of Z-funnel WIMP

In Z-funnel region, WIMP mass is almost half of the Z-boson mass and it is enough to think only the coupling WIMP and Z-boson.

$$\frac{g_D}{\Lambda^2}(\bar{\chi}\gamma_\mu\gamma_5\chi)(H^\dagger i\overleftrightarrow{D}^\mu H) + \text{h.c} \xrightarrow{\text{SSB}} \frac{g_{\chi\chi Z}}{2}(\bar{\chi}\gamma_\mu\gamma_5\chi)Z^\mu$$

We can characterize this WIMP by only two parameters (dark matter mass m_χ and coupling constant with Z-boson $g_{\chi\chi Z}$).

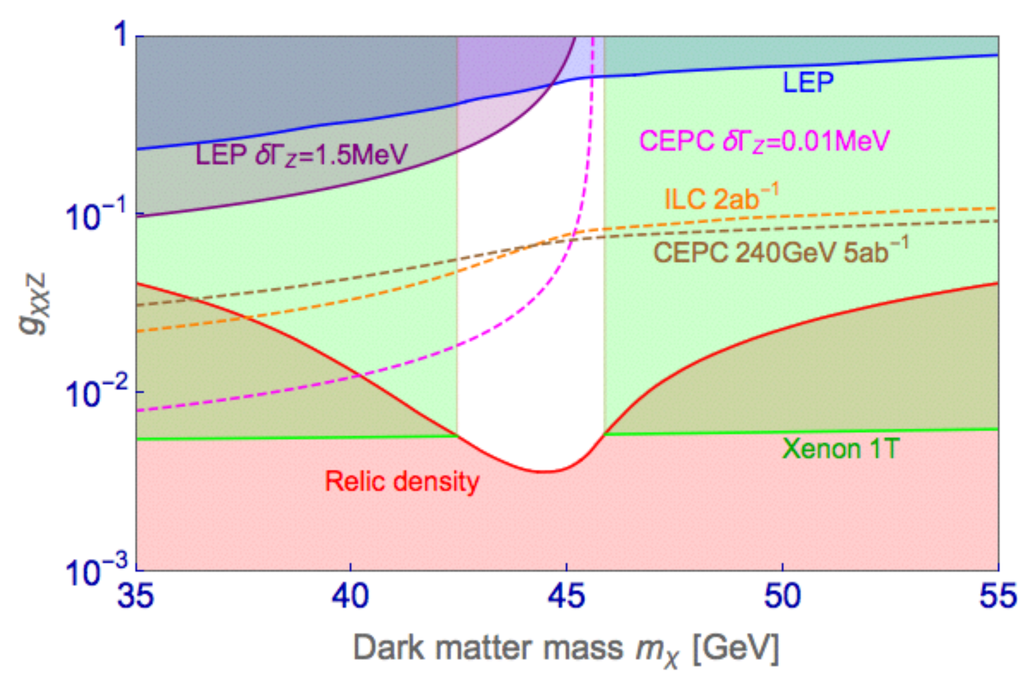
Analysis of mono-photon search

Counting the numbers of the photons in each energy bin (1GeV bin), and make likelihood function.

$$L[m_\chi, g_{\chi\chi Z}] = \prod_i \exp\left(\frac{-(N_i^{exp} - N_i^{th})^2}{2N_i^{th}}\right) \Rightarrow \Delta\chi^2 = \sum_i \frac{(N_i^{SG})^2}{N_i^{BG}}$$

Result and conclusion

This figure shows the 90% constraint on this WIMP from several experiment or observations (LEP, Invisible Z-width from LEP, ILC at 2ab^{-1}, CEPC 240GeV at 5ab^{-1}, Invisible Z-width from CEPC, Xenon 1T, relic density).



Colored regions are ruled out currently, and dotted lines are future prospect by lepton colliders.