WIMP Search at 500GeV ILC

— focusing on possible future improvement in reconstruction —

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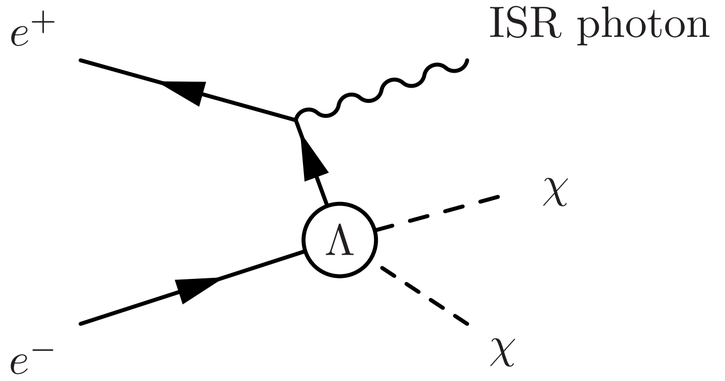
WIMP search at ILC



Signal : Missing four-momentum

But …

Bhabha scattering events can be background when e+/e- go into beam pipe

We should ensure that it is not due to detector inefficiency/geometrical acceptance

We use ISR photons with some requirements :

- Polar angle > 7° so that we can ensure it is not “missing e+/e-”.
- Energy > 2 GeV to avoid noises.
- Pt should be certain values to ensure Bhabha e+/e- to be detectable.

Searching mono photon events but
need to consider the possibility of Bhabha scattering with radiative photons.

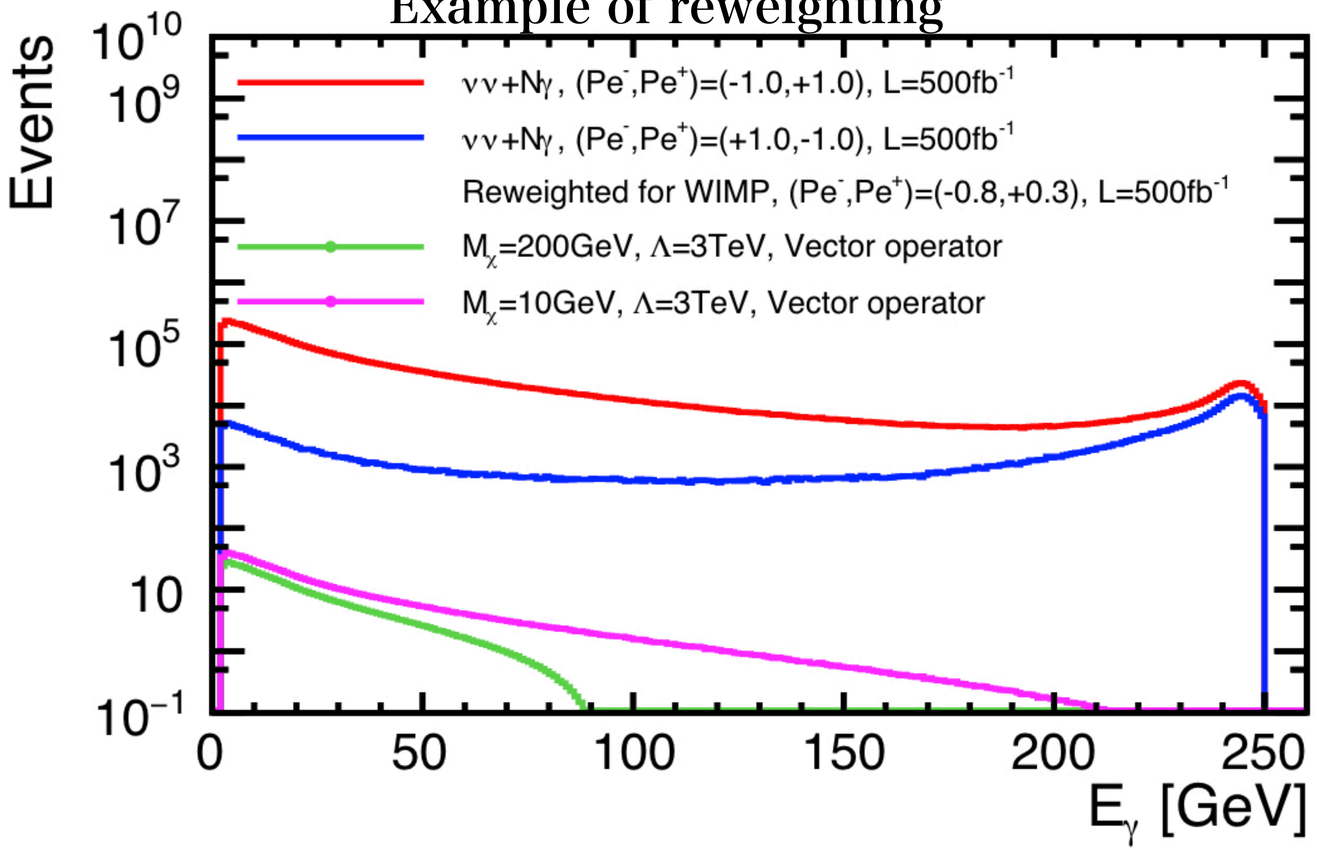
One remark on this analysis

WIMP and neutrino pair production are same event signatures.

—> Divide into 2 :

1. **WIMP signals** by reweighting according to theoretical models
2. **Neutrino pair background**

Example of reweighting



$\nu\nu + N\gamma$ events are taken not only as background but also as signal (after reweighting).

WIMP benchmark for IDR

- WIMP search study is one of benchmark studies that will be in a new document after TDR : ILD Design Rport (IDR).

- Two detector models are compared.
  - Detector radius 7.7 m / 7.4 m
  - Magnetic field 3.5 T / 4 T

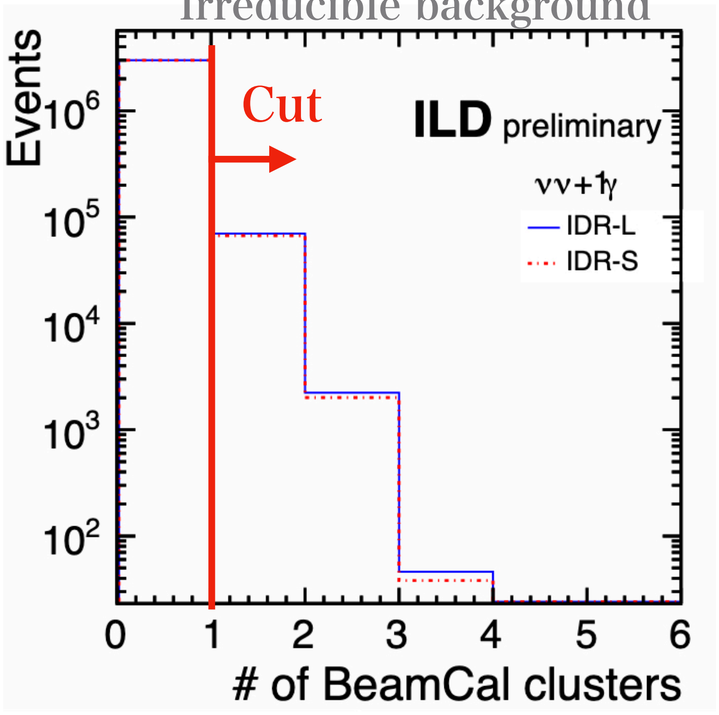
- Key performance to be tested : Photon reconstruction, BeamCal veto

We have tested Photon energy, #of reconstructed photons, # of BeamCal hits.

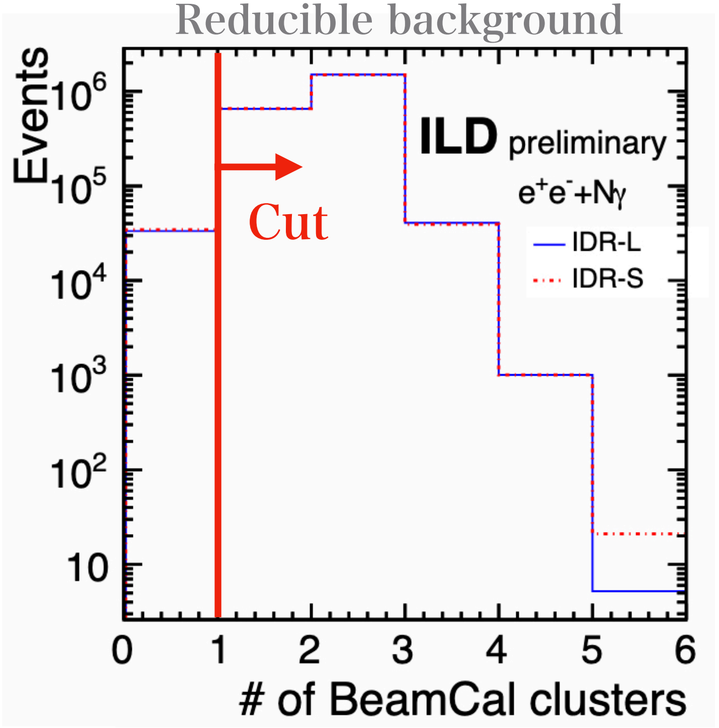
Conclusion of WIMP benchmark

More details can be found at https://confluence.desy.de/display/ILD/ILD+notes?preview=/42357928/138008183/ILD-PHYS-PUB-2019-010.pdf

Irreducible background



Reducible background



√s = 500GeV

L=500fb^{-1}, no beam polarization

Left : Irreducible background (νν+1 γ)
(taken also as signal by reweighting)

Right : Main reducible background (ee++N γ)

0 BeamCal cluster can distinguish signal and reducible background

⇒

BeamCal veto is crucial for this study.
But no difference between two detector models.

No significant difference found between two detector models

Conclusion of WIMP benchmark

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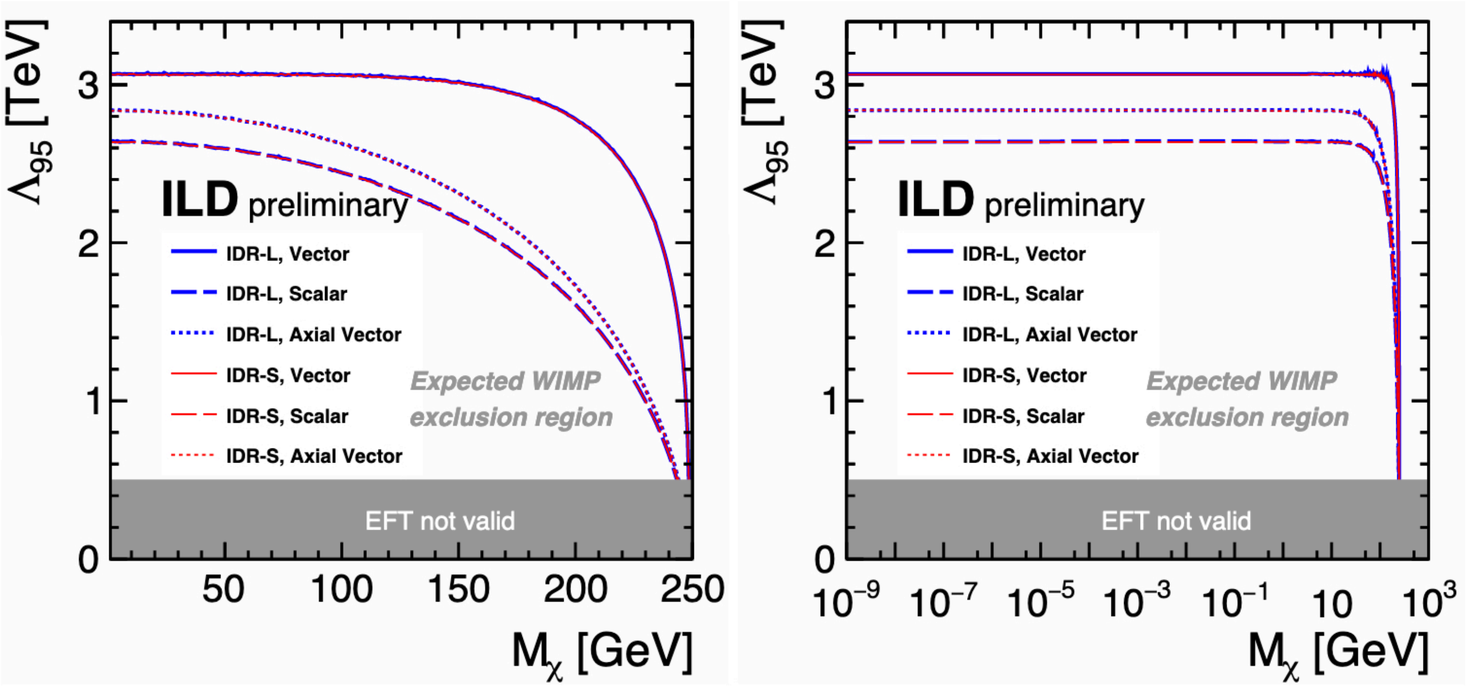


500GeV

beam polarization (P_{e^-}, P_{e^+})	(-80%,-30%)	(-80%,+30%)	(+80%,-30%)	(+80%,+30%)
Integrated Luminosity [fb^{-1}]	400	1600	1600	400

Left : Exclusion limit (95%C.L.) for different coupling structures and two detector models as a function of WIMP masses

Right : Same but more focusing on lower WIMP masses

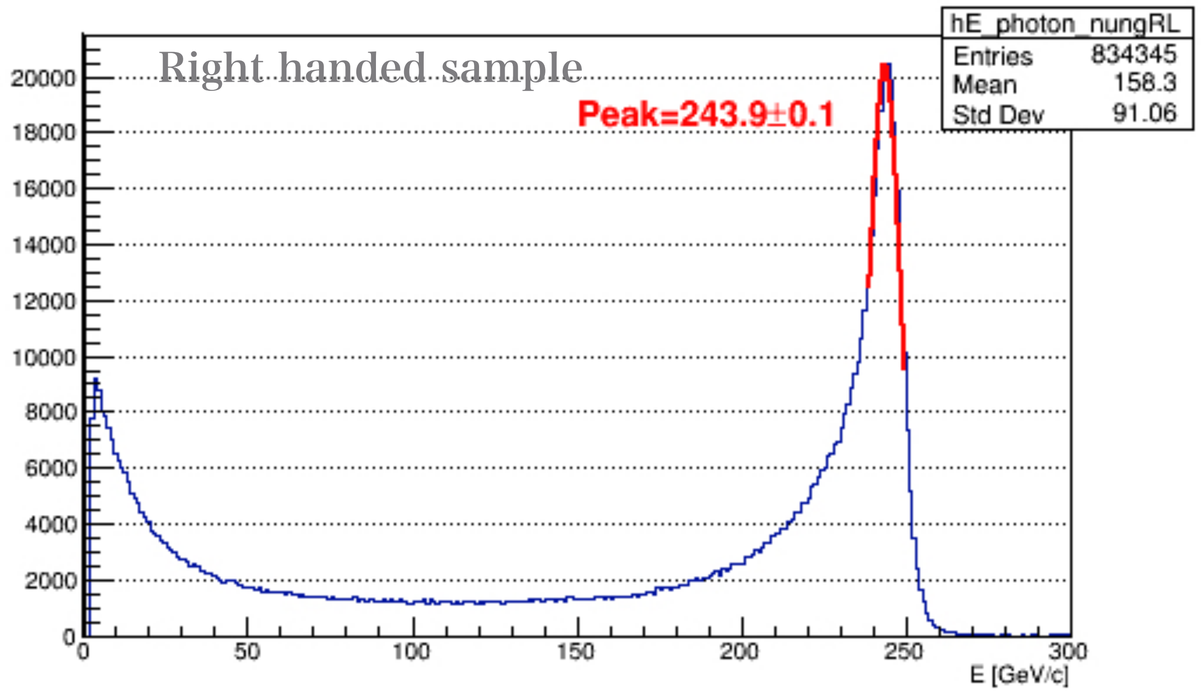
⇒

Testable energy scales are in range of $\Lambda \sim 2.6 - 3.1$ TeV

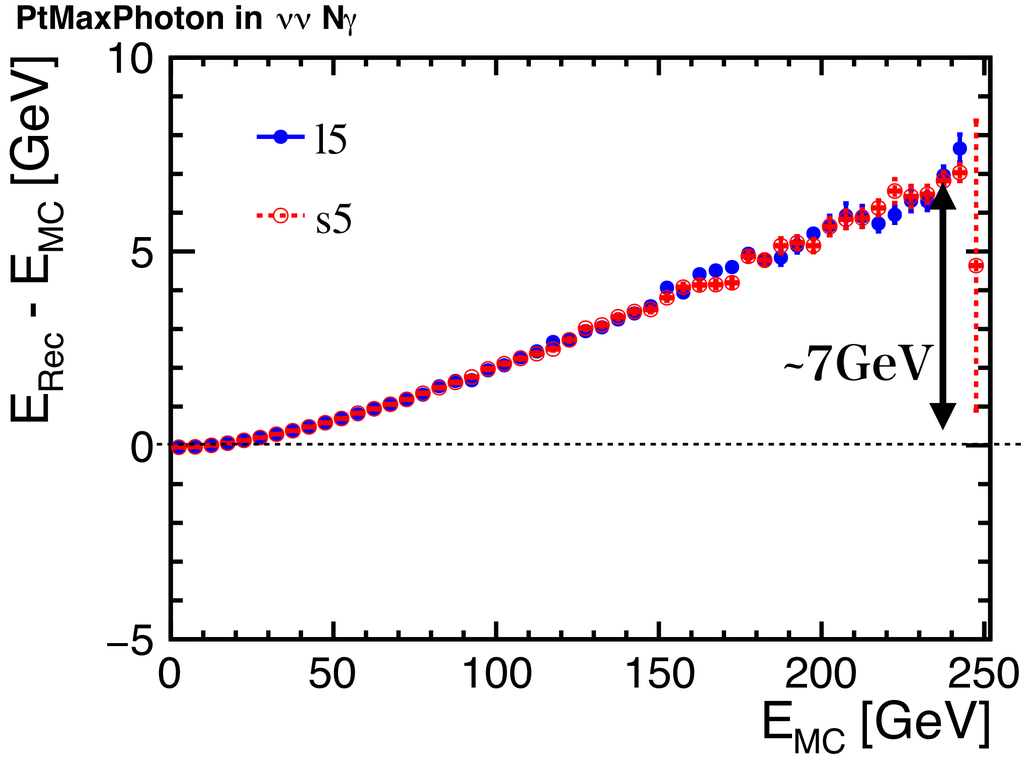
No significant difference found between two detector models

Two different observations on photon energy

Takahiro Mizuno and Wang Yan reported photon energy is overestimated at high energies.
Cross-check with MC samples used in WIMP search study.



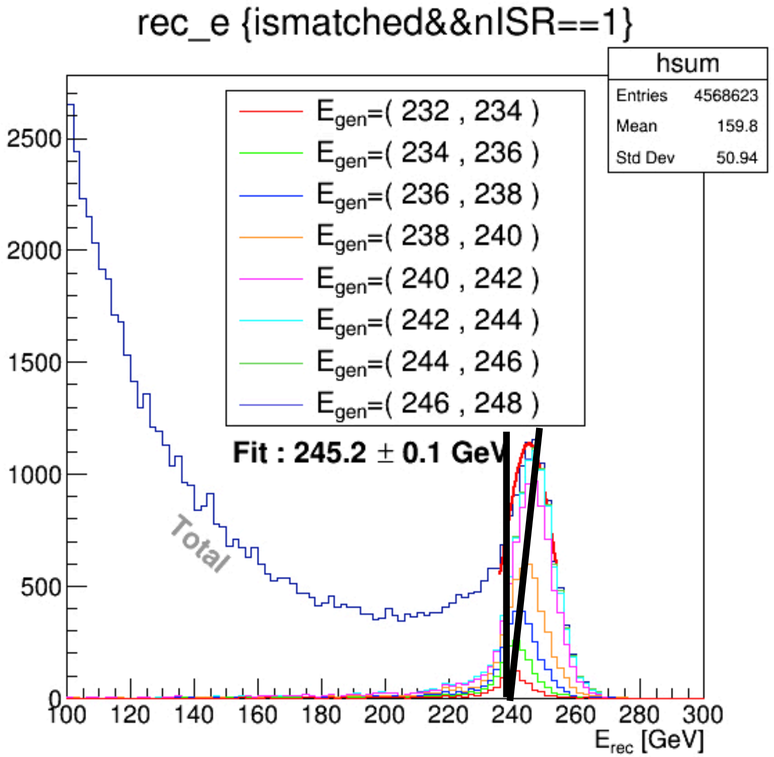
Reconstructed photon energy distribution (Z return)
241.7 GeV expected —> **2.2 GeV shift**

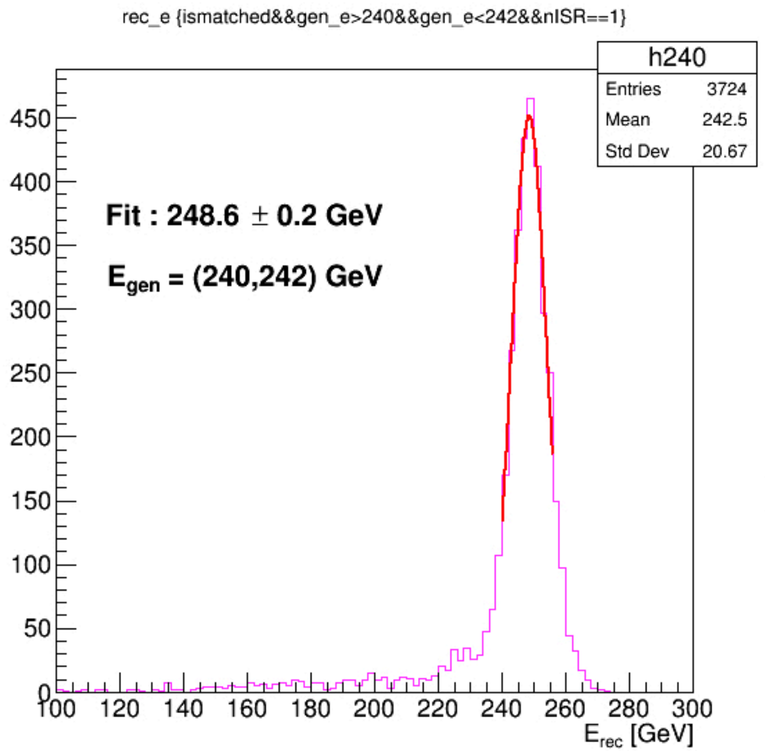


Residual (Erec - Egen) vs Egen
The shift seems to be larger (~7GeV)

Is something wrong with one of them or both?

Both of them are correct!





Left :

Reconstructed photon energy distribution

Histograms are divided by original (generator-level) energies (2 GeV interval)

Right :

Focusing on Egen=(240,242) GeV only

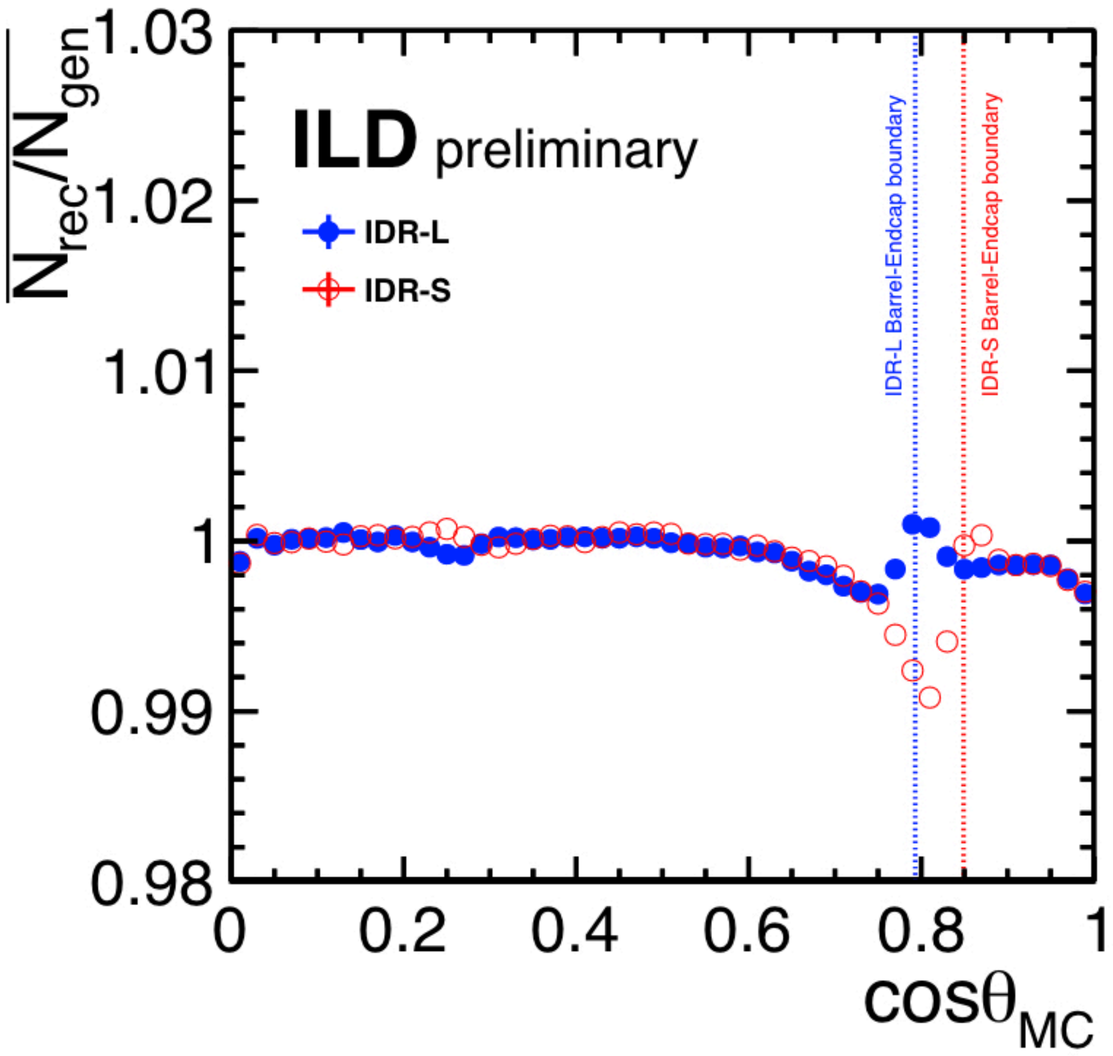
Z return peak :

Total —> 245.2 GeV (241.7 expected) —> 3.5 GeV difference

Egen(240,242) —> 248.6 GeV (241 expected) —> 7.6 GeV difference

Z return peak is shifted (obscured) due to contributions from several energies

Photon reconstruction failure at 1% level only for IDR-S



Using 1 photon events (Ngen=1)

Nrec : number of reconstructed photons

Why Nrec is not always 1 ?

> 1 case : signal hit split into two (or more)

< 1 case : photon detection inefficiency

⇒

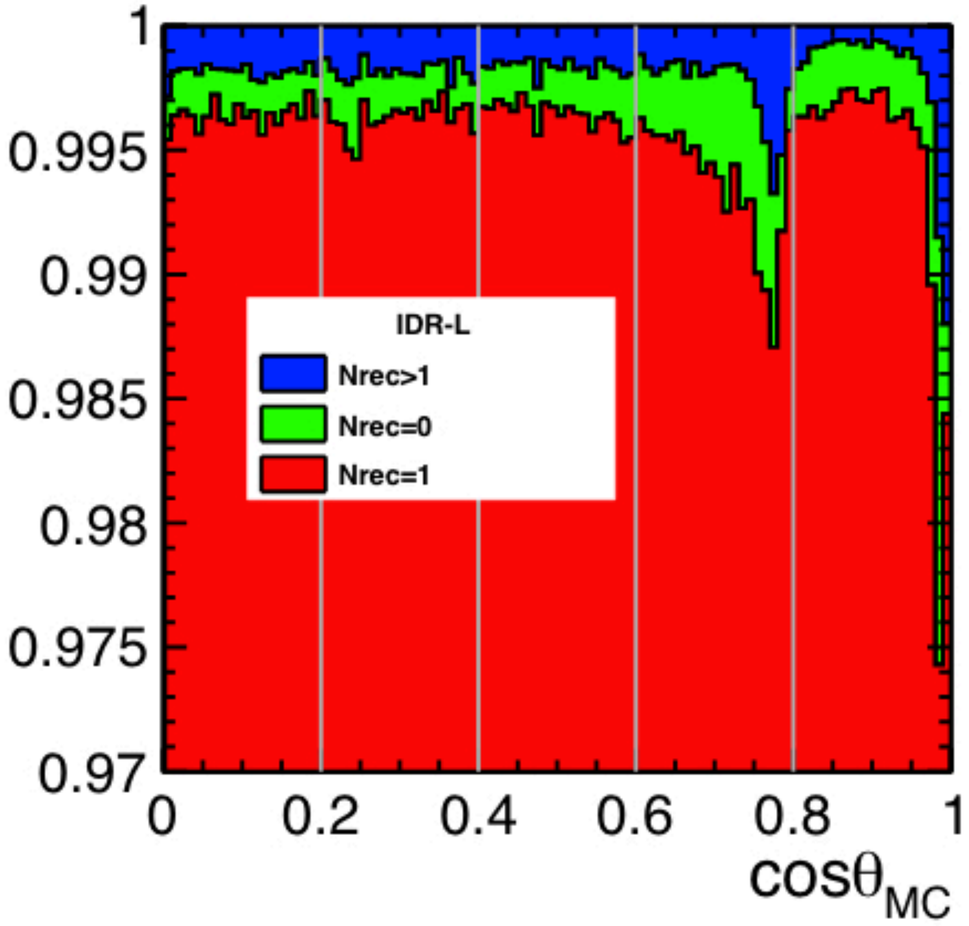
Photon reconstruction is basically working well.

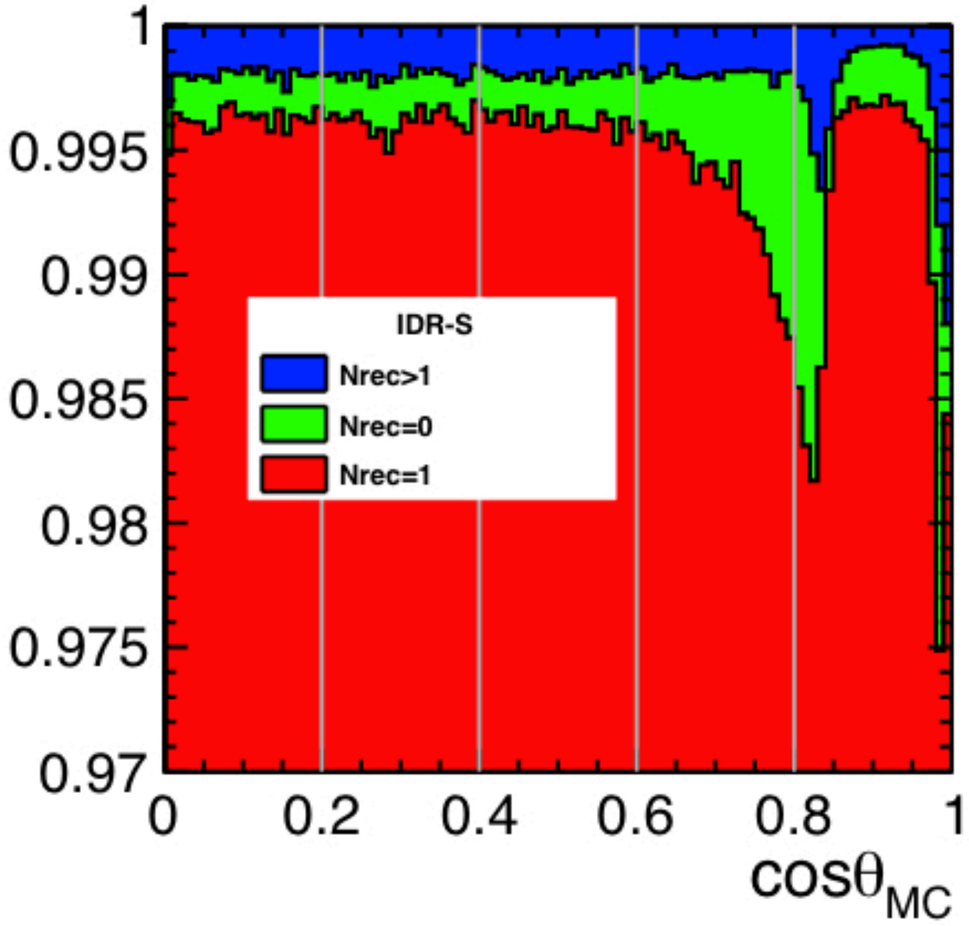
Just 1% degradation at $\cos\theta$ ~0.8 for IDR-S

but why?

Why IDR-S has a larger drop than IDR-L ?

Photon reconstruction for IDR-S

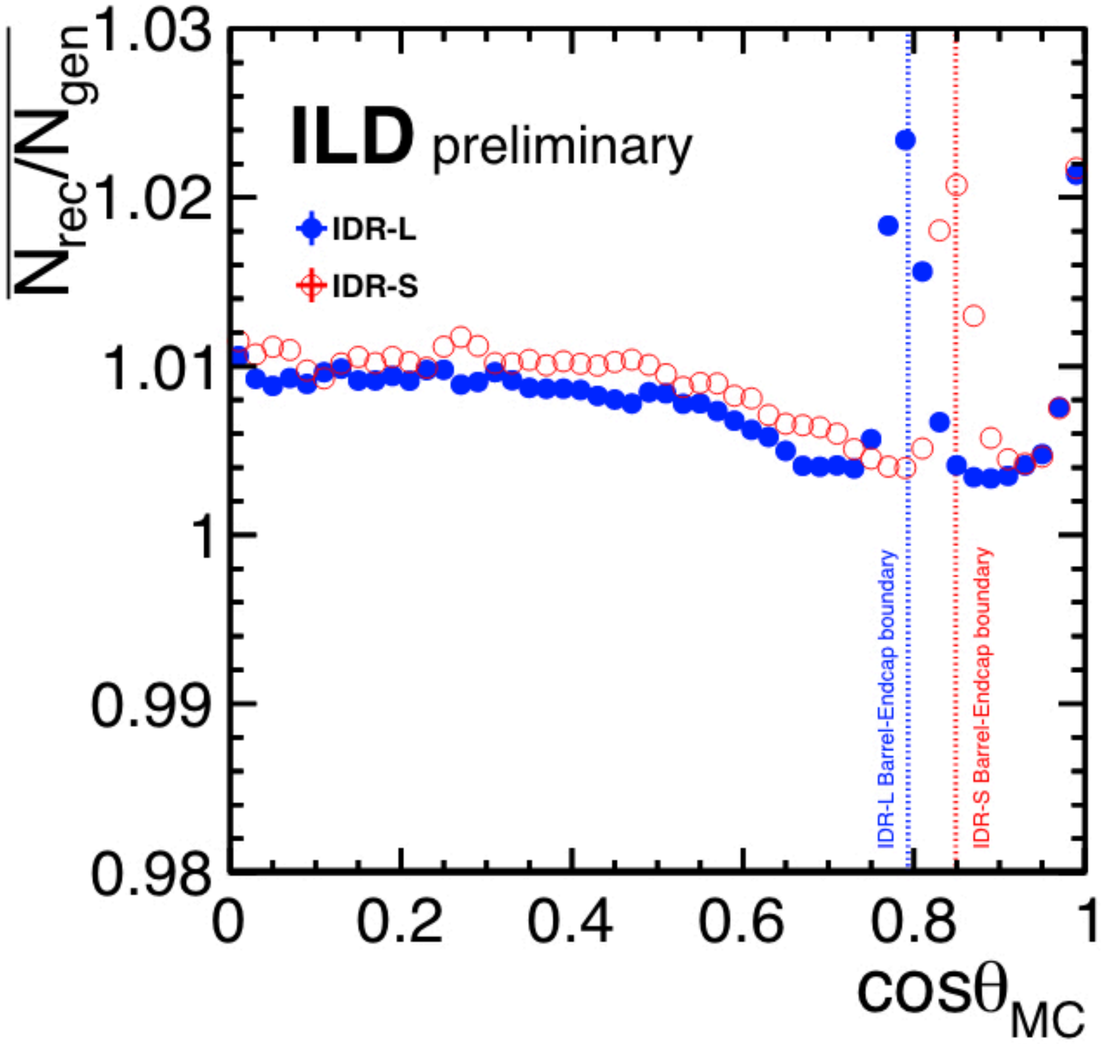




Larger blue fraction indicates larger Nrec.
Larger green fraction indicates smaller Nrec.

Nrec=0 (Green) region around $\cos\theta$ =0.8 is larger in IDR-S. ⇒ IDR-S more likely fails photon reconstruction for some reason.

Photon ID performance for IDR-S



Same plot as p.8 except for the point we do not require signal candidate PFOs to be PID=22 (photon)

The drop at $\cos\theta$ ~0.8 becomes a peak!

⇒

The drop is caused by mis-identification of photon in PandraPFA.

Since degradation is larger in IDR-S,
we may need to tune PandraPFA parameters for IDR-S to get similar performance to IDR-L.

Parameter tuning in PandraPFA may be necessary for IDR-S

Summary

* Photon reconstruction and BeamCal veto performance have been checked in context of WIMP search (WIMP benchmark).
* There is no significant difference between two detector models.
* Photon energy bias at high energies is cross-checked.
* At barrel and endcap region, 1% level degradation on photon identification for IDR-S model is found.

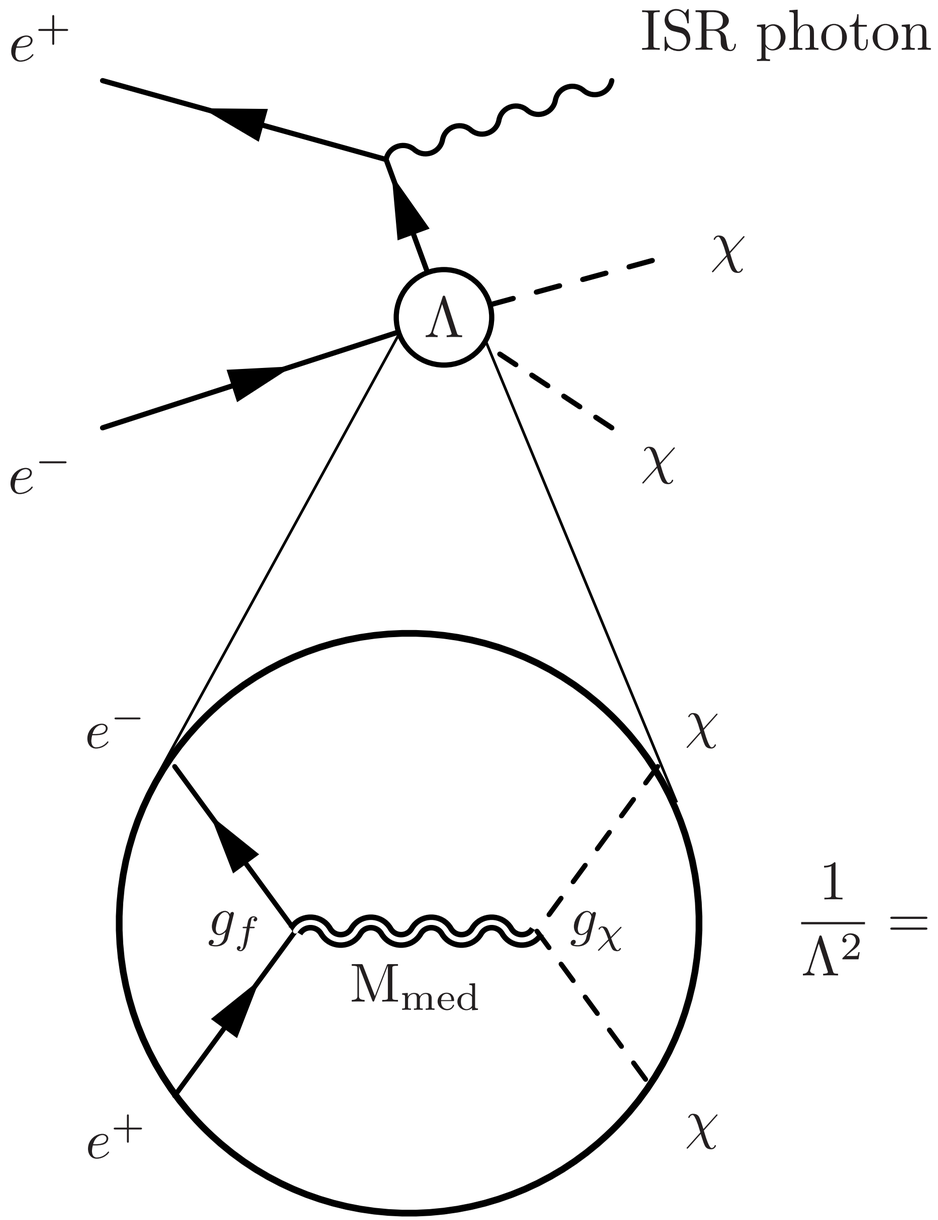
WIMP pair production (EFT approach)

Effective lagrangian

$$\mathscr{L}^{\text{eff}} = \frac{1}{\Lambda^2}(\bar{f}\Gamma f)(\chi\Gamma\chi)$$

Coupling structure

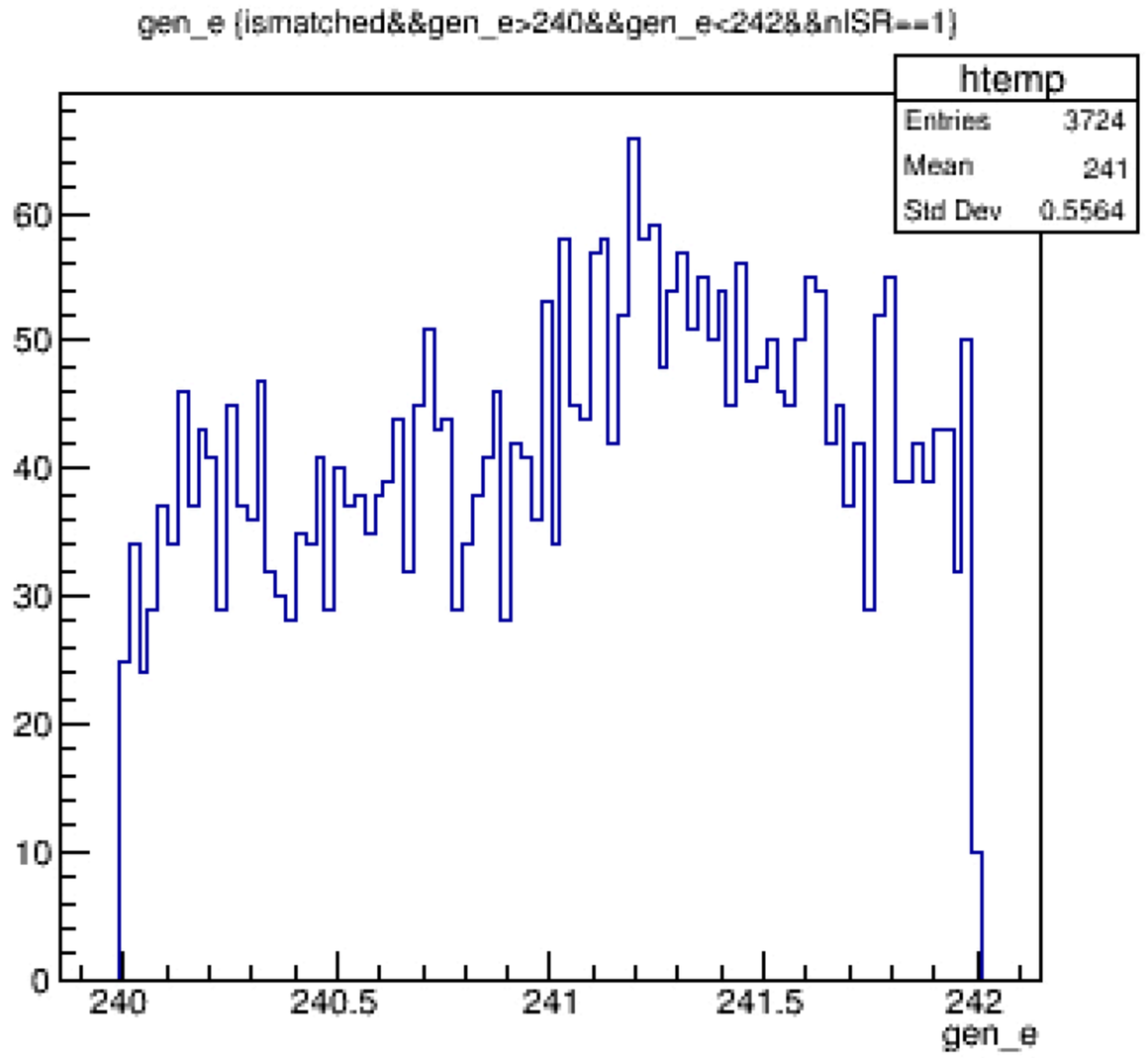
$$\Gamma = \begin{cases} 1 \\ \gamma^\mu \\ \gamma^5\gamma^\mu \end{cases}$$



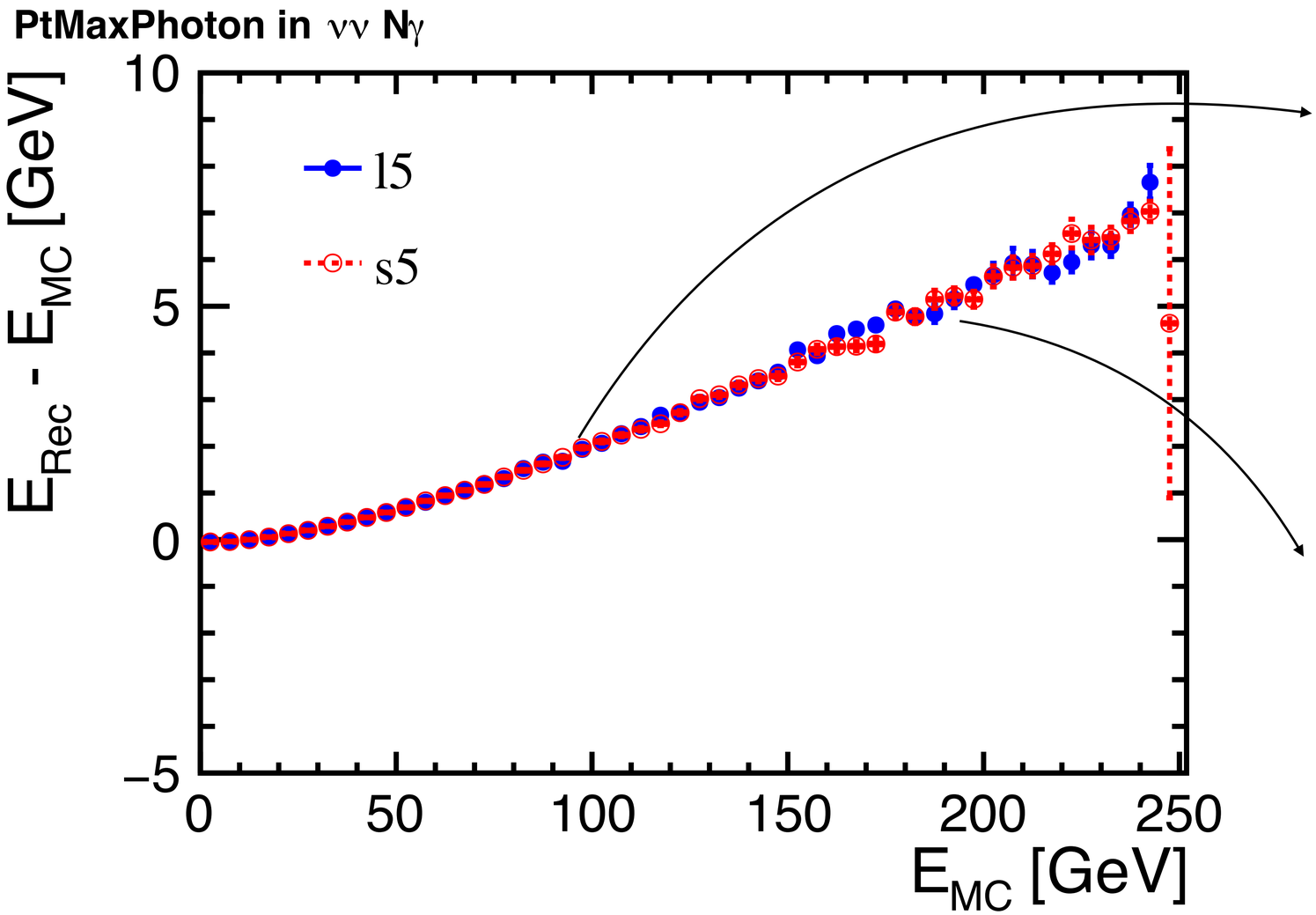
$$\frac{1}{\Lambda^2} = \frac{g_f g_\chi}{M^2_{\text{med}}}$$

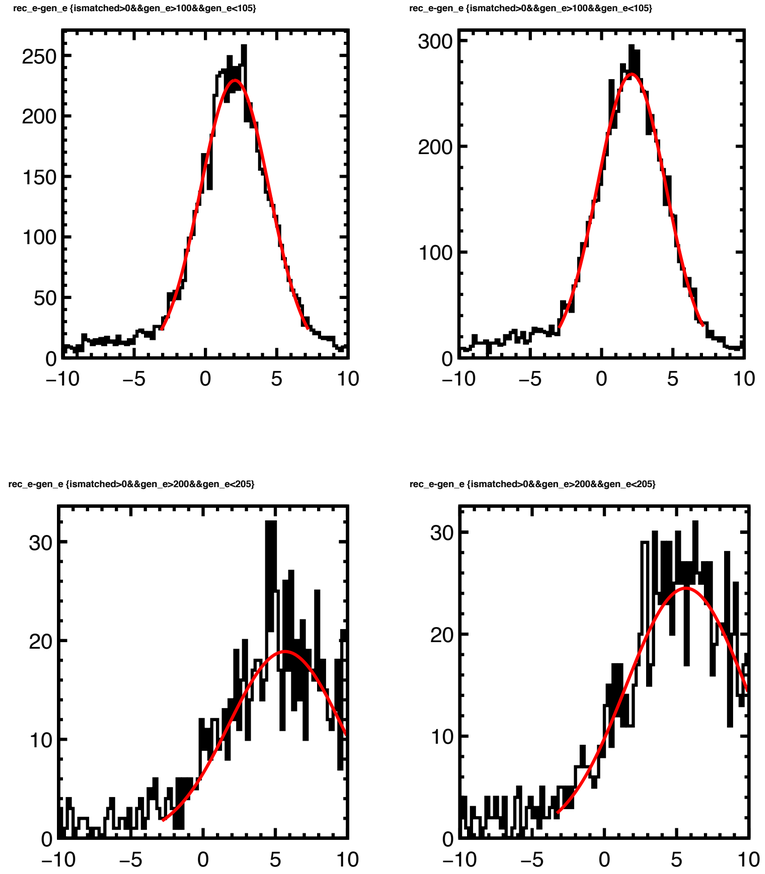
WIMP dectection at ILC

- **Signals from undetectable particles : Missing four-momentum**
  - Target process : $e^+e^- \rightarrow \chi\chi\gamma_{\mathrm{ISR}}$ Empty except for ISR photon
- **Requirement for ISR photon**
  - Distinguish e+/e- and γ —> Require to be tracker region —> polar angle > 7°
  - Avoid noise signals —> E > 2 GeV
  - Ensure not to be Bhabha —> one of e+/e- should be detectable —> pt > 5.7 (1.97) GeV for $|\phi|$ ≦ 35°, $|\phi|$ > 35° in accordance with BeamCal inner rim structure
- **Main background**
  - Neutrino pairs + N γ ISR (σ ~10 pb, irreducible)
  - Bhabha scattering + N γ ISR (σ ~100 pb, e+,e- in forward region) BeamCal veto


gen_e (ismatched&&gen_e>240&&gen_e<242&&nISR==1)
htemp
Entries 3724
Mean 241
Std Dev 0.5564
60
50
40
30
20
10
0
240
240.5
241
241.5
242
gen_e

What we found : Photon energy bias at high energies





This result seems to be valid (consistent with z peak shift)