WIMP benchmark

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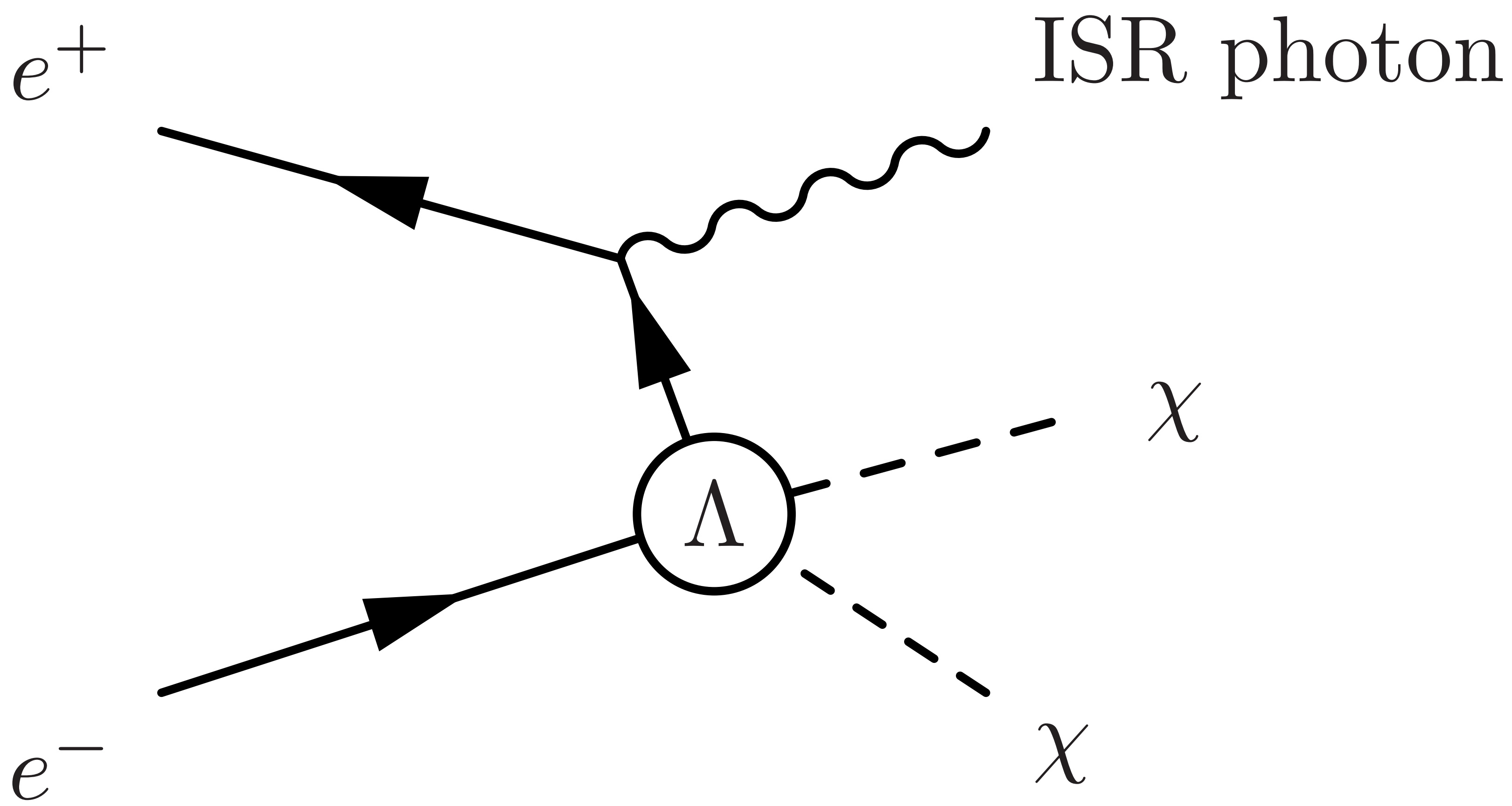
WIMP benchmark for IDR

- 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.
- Key performance : Photon reconstruction, BeamCal veto



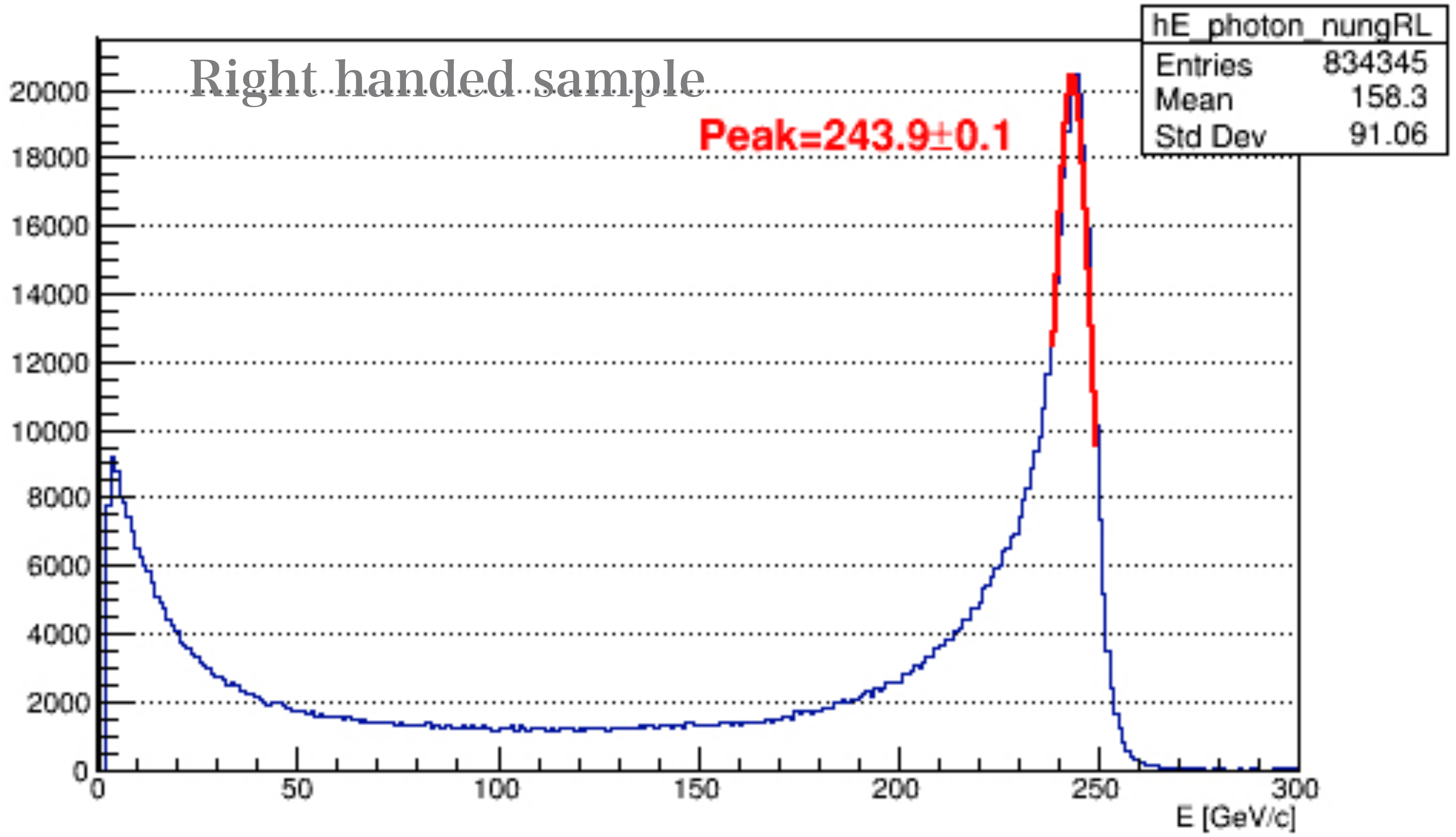
- Status :
  - Input plots for IDR —> Done.
  - Git repository —> Up-to-date.
  - Supporting document (ILD note) —> Under circulation.

https://agenda.linearcollider.org/event/8317/

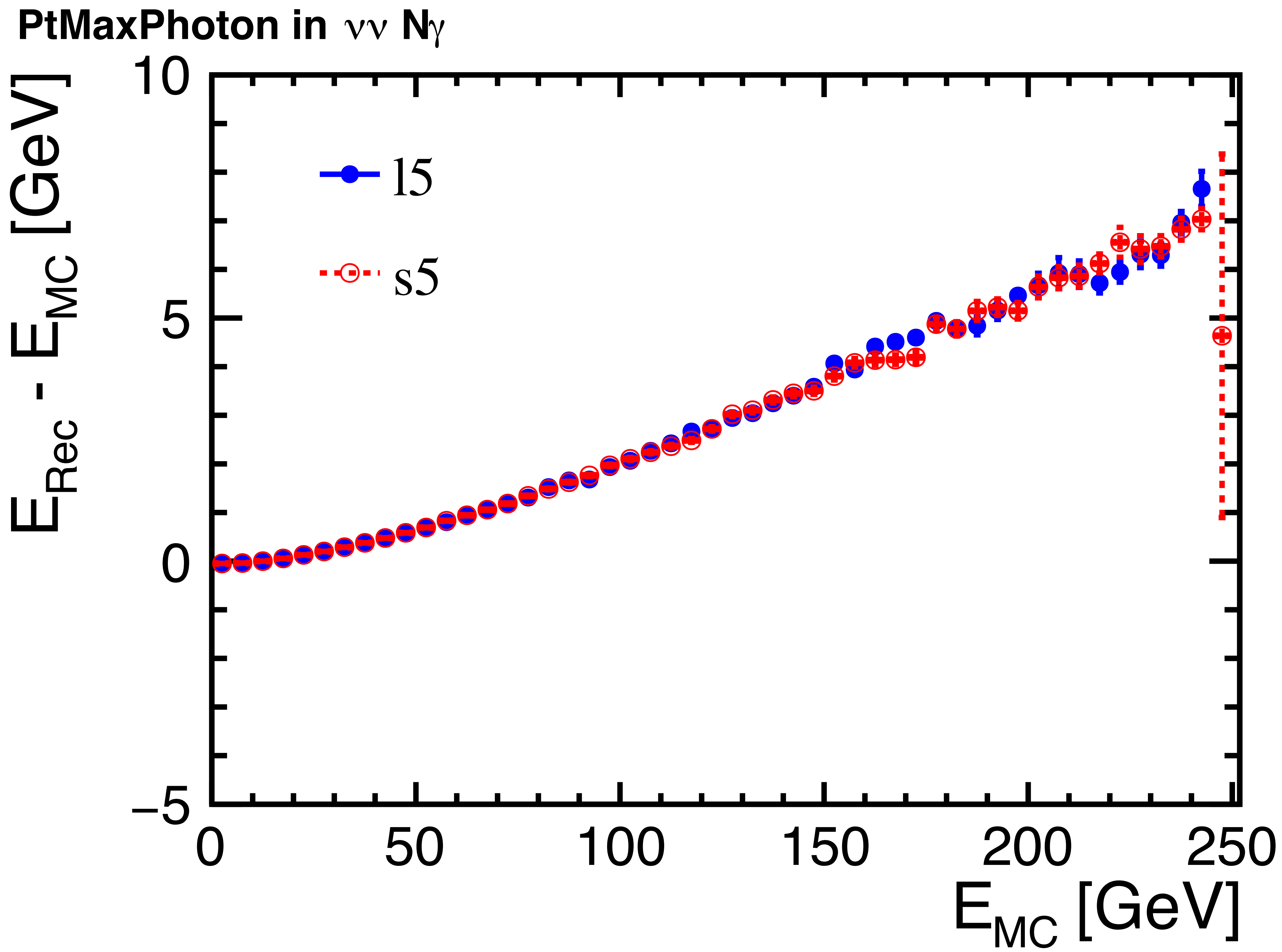
We're almost there!

What we found : Photon energy bias at high energies

Takahiro and Jan reported photon energy is overestimated at high energies.
Cross-check with WIMP samples



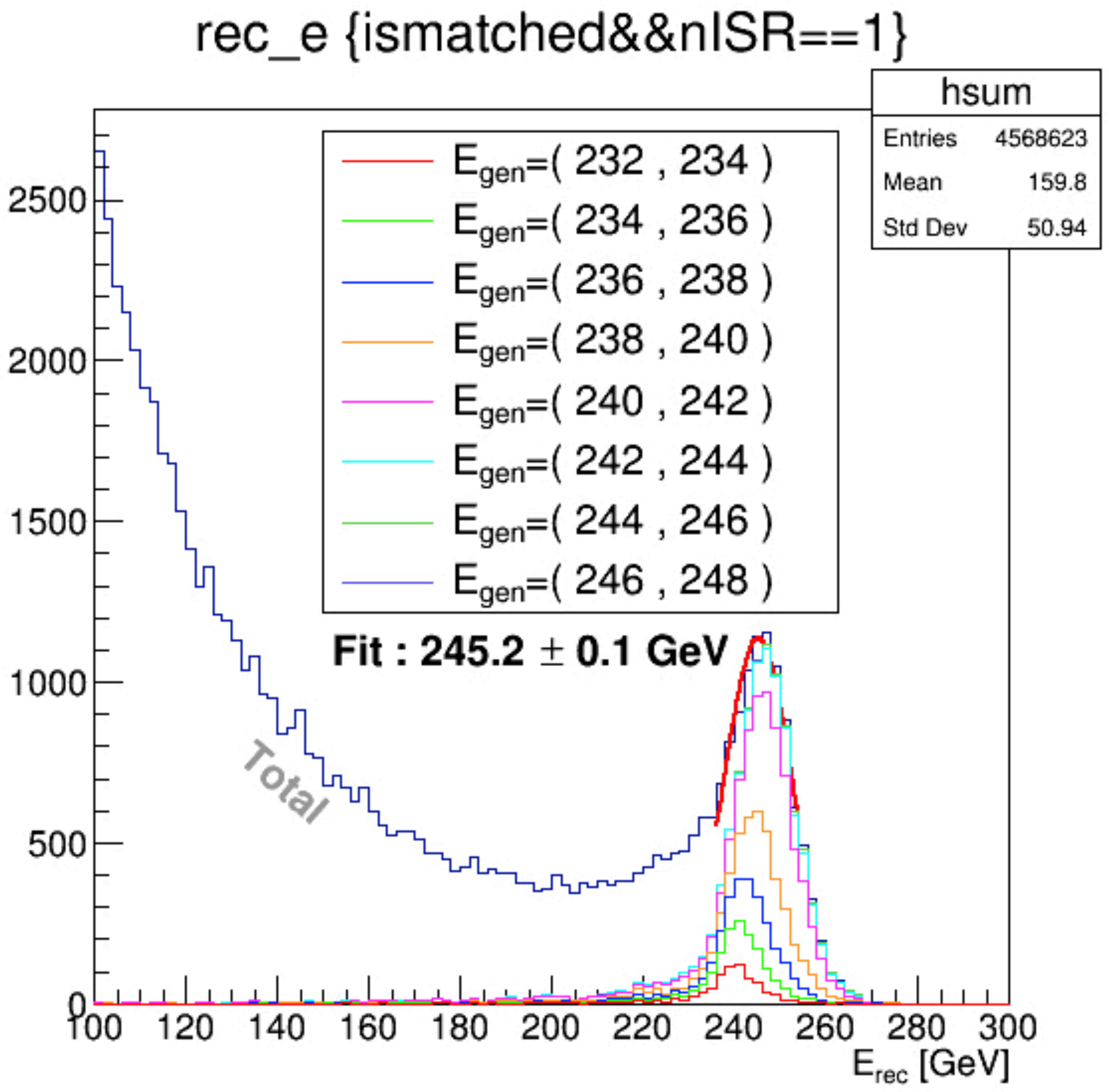
Reconstructed photon energy distribution (Z return)
241.7 GeV expected —> 2.2 GeV shift

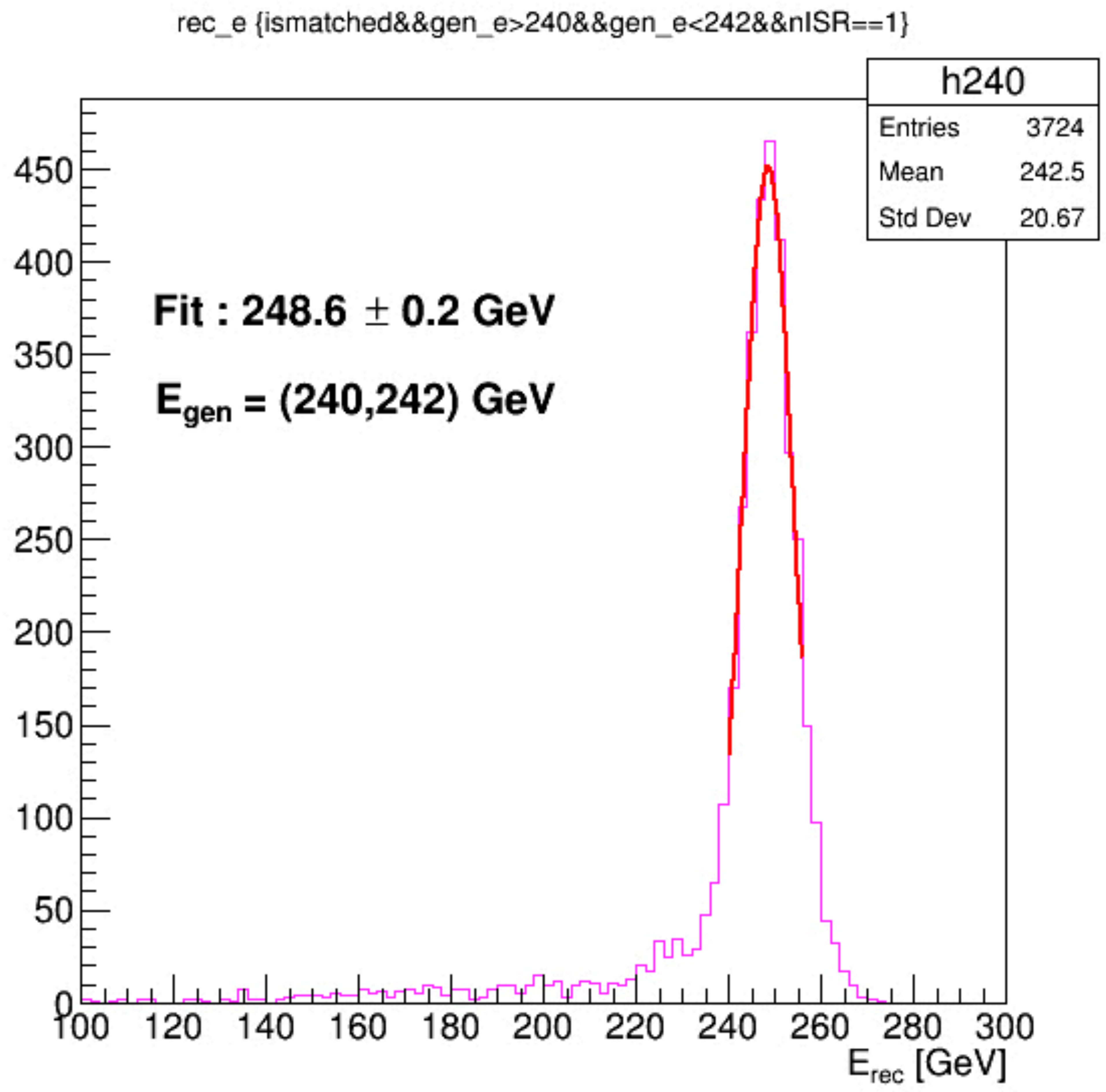


Residual (Erec - Egen) vs Egen
The shift seems to be larger (~7GeV)

Is something wrong with one of them or both?

What we found : Photon energy bias at high energies



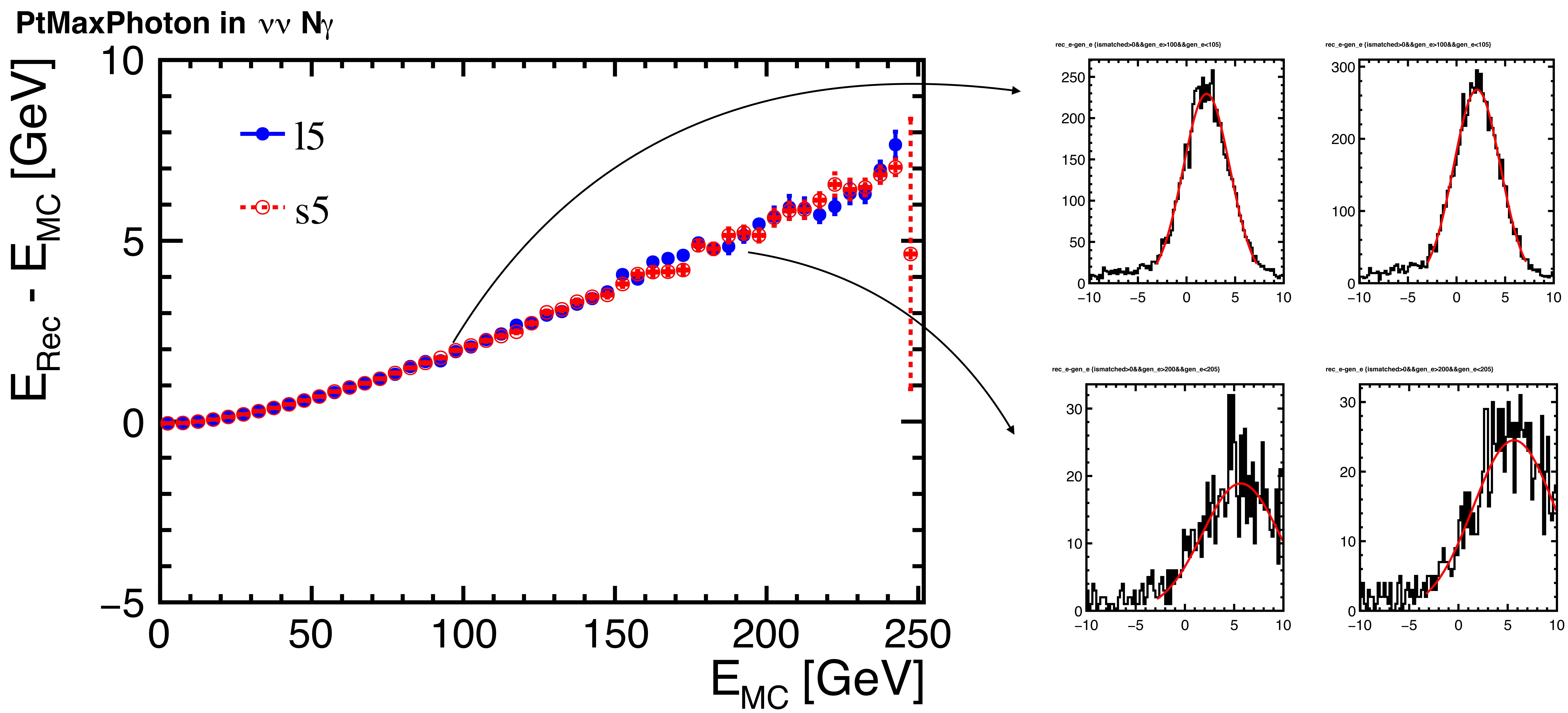


Reconstructed photon energy distribution
Histgrams are divided by original (generator-level) energies (2 GeV interval)

Z return peak ~ 245.2 GeV (241.7 expected) —> 3.5 GeV difference
Egen(240,242) makes a peak around 248.6 (241 expected) —> 7.6 GeV difference

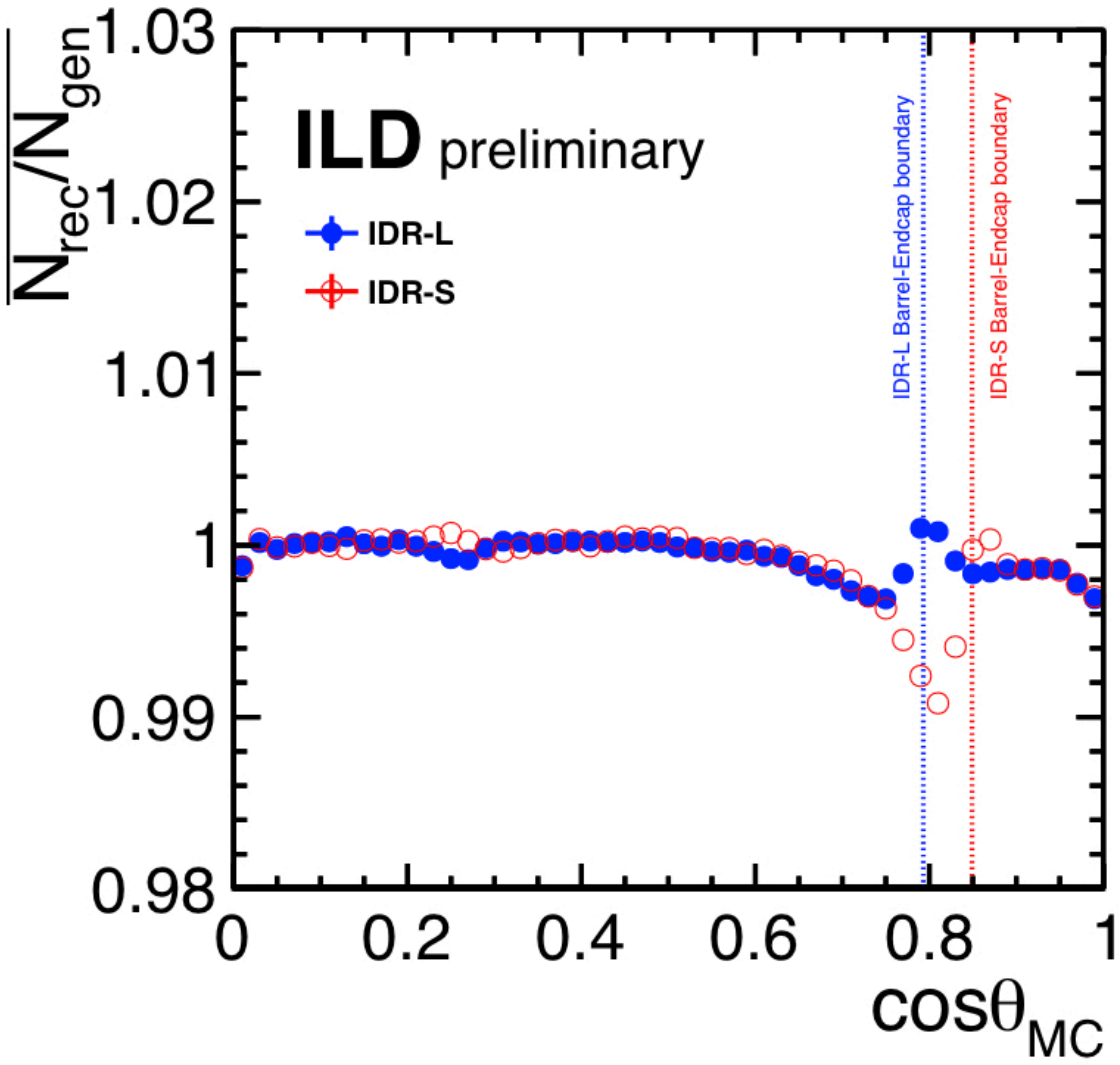
⇨ Shift seen in Z return peak becomes underestimate due to contributions from several energies.

What we found : Photon energy bias at high energies



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

What we found : Photon ID performance for IDR-S



1 photon events (Ngen=1)

Nrec : number of reconstructed photons

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

< 1 case : photon detection inefficiency

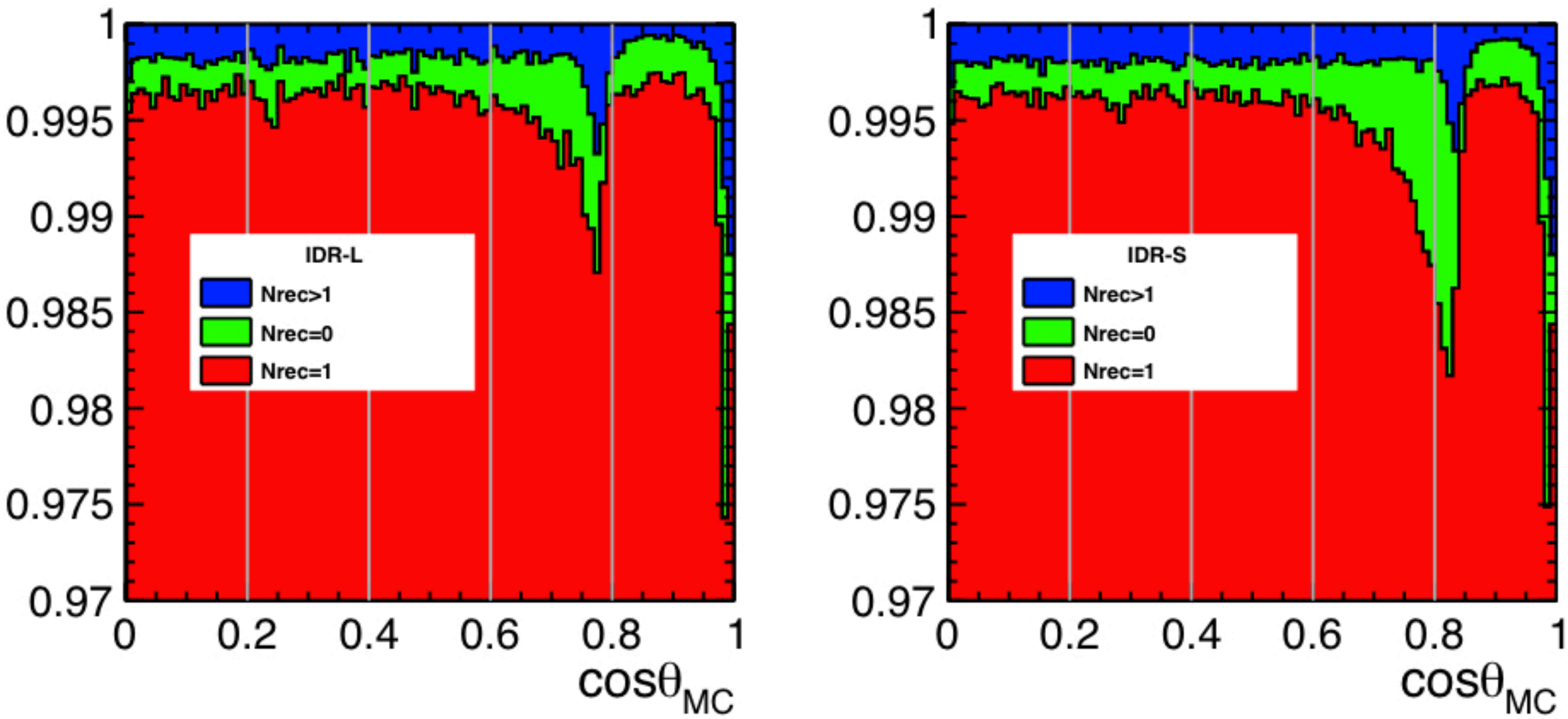
⇨

Photon reconstruction is working well.

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

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

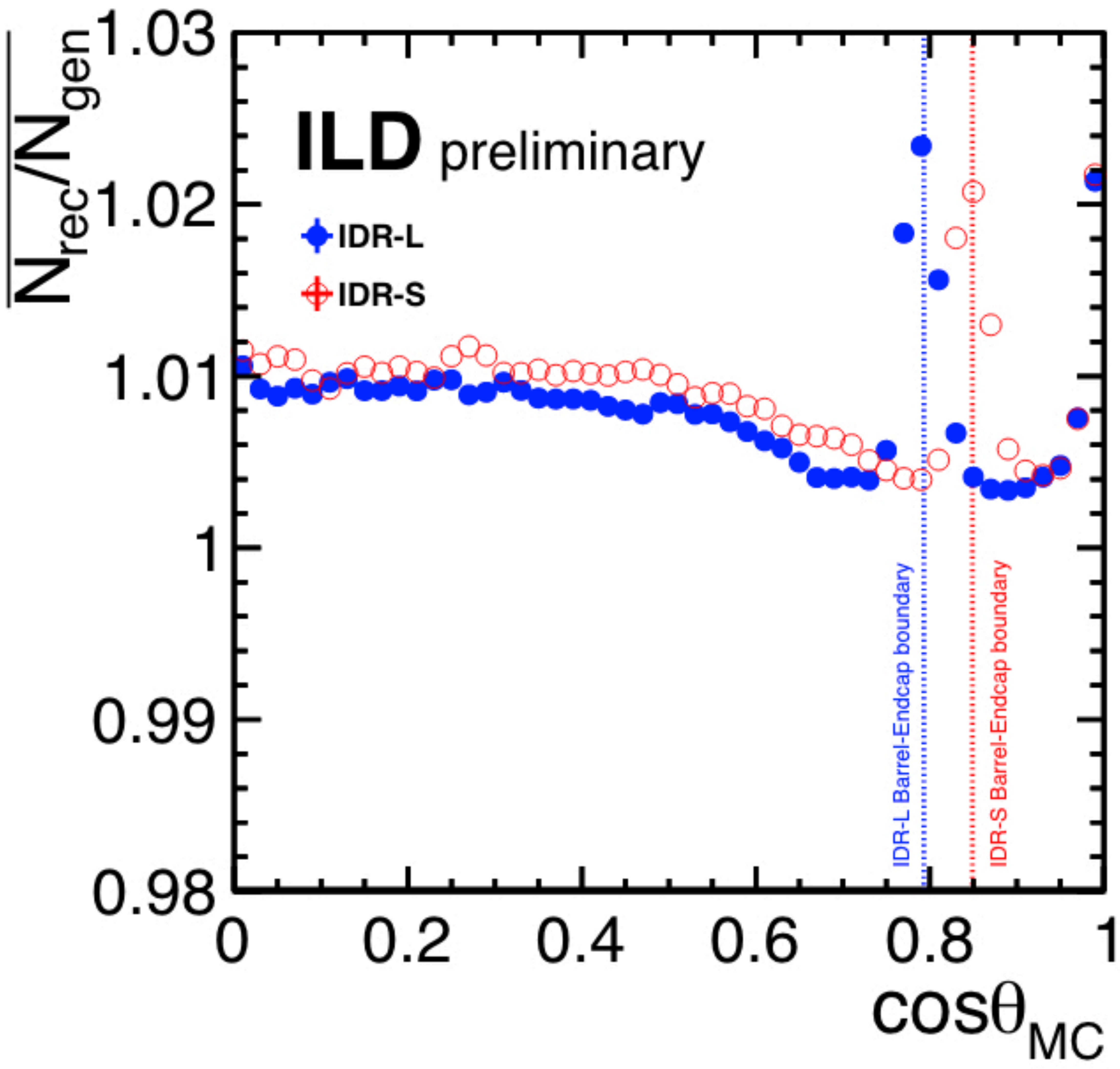
What we found : Photon ID performance for IDR-S



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

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

What we found : 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

BeamCal reconstruction issue(?)

Issue :

BeamCal reconstruction is required to run with BeamCal digitizer.

Cause :

BeamCal reconstruction uses a variable (“cellID1”) which is provided by BeamCal digitizer.
But the variable is not stored in CalorimeterHit collection in REC files.

This may be something to be discussed in the SW expert group.

Summary

- Photon reconstruction and BeamCal veto performance have been checked in context of WIMP search (WIMP benchmark).
- 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.
- BeamCal reconstruction requires BeamCal digitization too. This may be something to be discussed in experts.

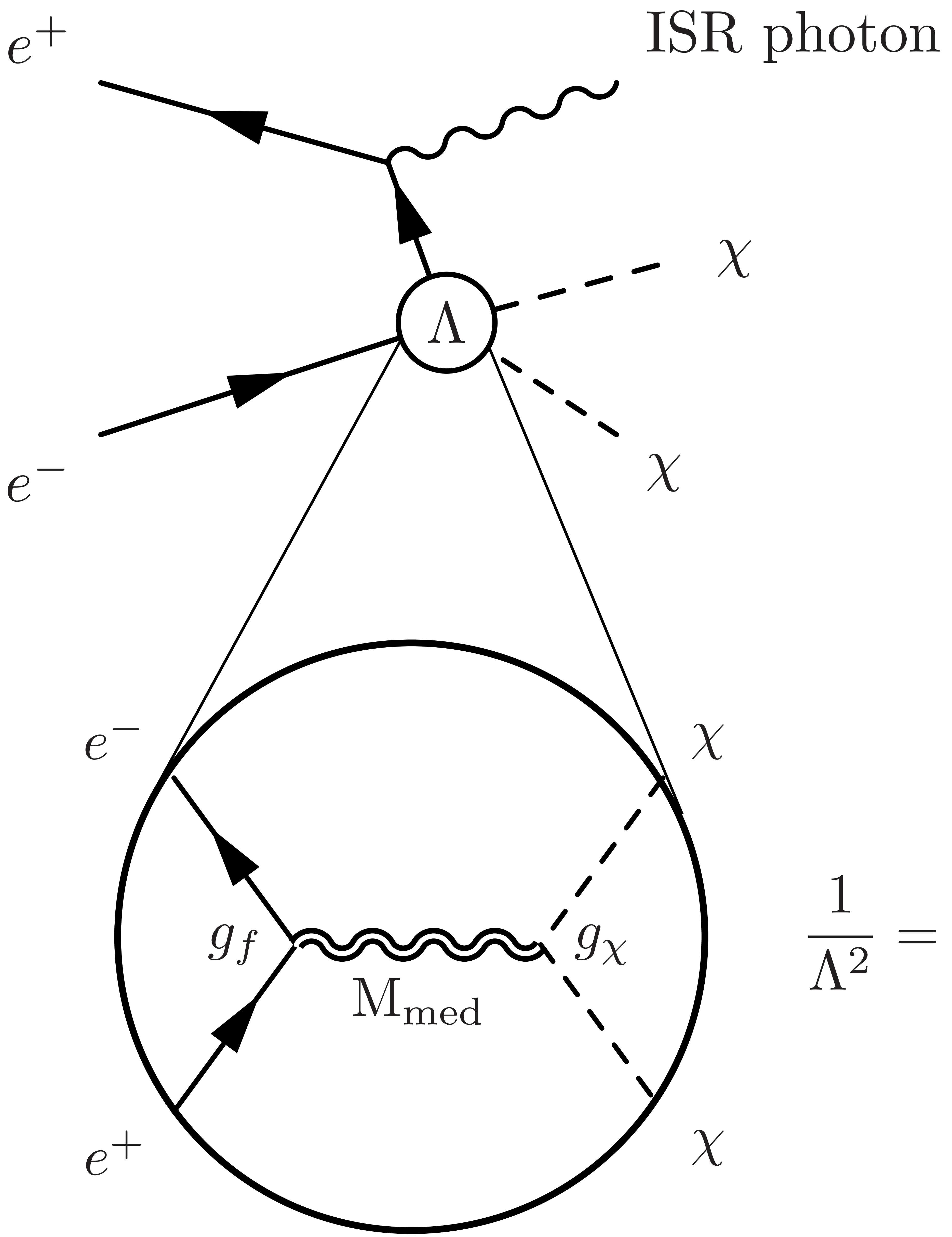
WIMP pair production (EFT approach)

Effective lagrangian

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

Coupling structure

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



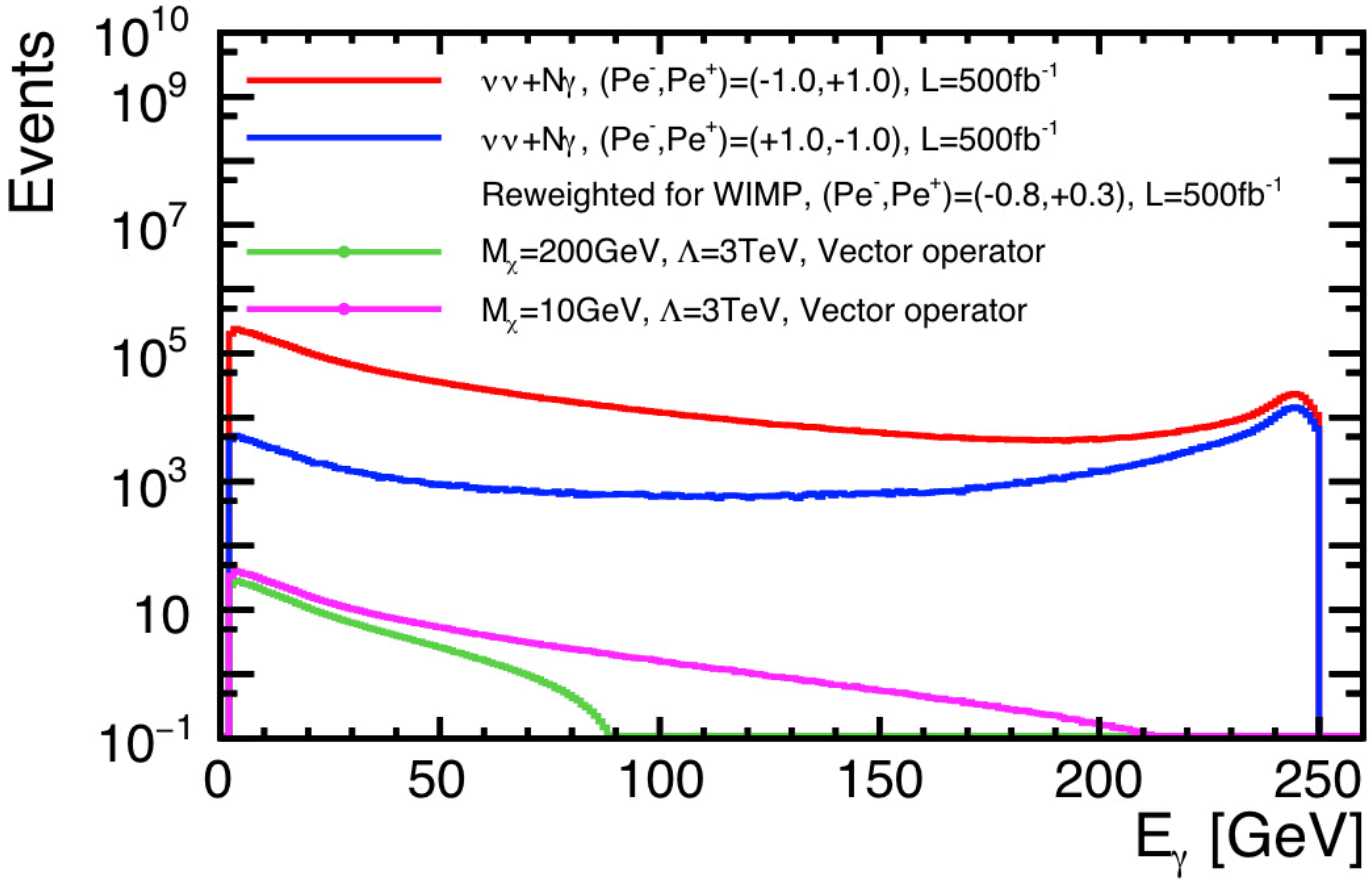
$$\frac{1}{\Lambda^2} = \frac{g_f g_\chi}{M_{\text{med}}^2}$$

WIMP sample from neutrino pair sample

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

WIMP dectection at ILC

- **Signals from undetectable particles : Missing four-momentum**
  - Target process : $e^+e^- \rightarrow \chi\chi\gamma_{\rm ISR}$ 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 $|\phi| \leqq 35^\circ$, $|\phi| > 35^\circ$ in accordance with BeamCal inner rim structure
- **Main background**
  - Neutrino pairs + N $\gamma_{\rm ISR}$ (σ~10 pb, irreducible)
  - Bhabha scattering + N $\gamma_{\rm ISR}$ (σ~100 pb, e+,e- in forward region) BeamCal veto