Dark matter searches with mono-photon signature at future e^+e^- colliders

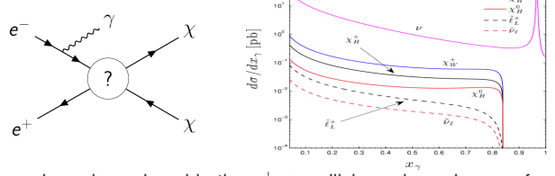
Aleksander Filip Żarnecki (filip.zarnecki@fuw.edu.pl)

FACULTY OF PHYSICS, UNIVERSITY OF WARSAW

NATIONAL SCIENCE CENTRE POLAND

1. Mono-photon signature

The mono-photon signature is considered to be the most general way to look for **DM particle production** in future e^+e^- colliders.

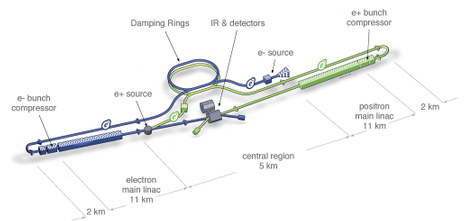


DM can be pair produced in the e^+e^- collisions via exchange of a new mediator particle, coupling to both electrons (SM) and DM states

This process can be detected, if additional hard photon radiation from the initial state is observed...

2. International Linear Collider

Technical Design completed in 2013 arXiv:1306.6328

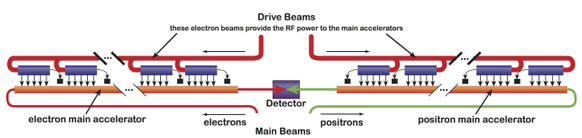


- superconducting accelerating cavities
- 250–500 GeV (baseline), 1 TeV upgrade possible
- footprint 31 km
- polarisation for both e^- and e^+ (80%/30%)

Total of 4000 fb^{-1} assumed at 500 GeV arXiv:1903.01629

3. Compact Linear Collider

Conceptual Design presented in 2012 CERN-2012-007



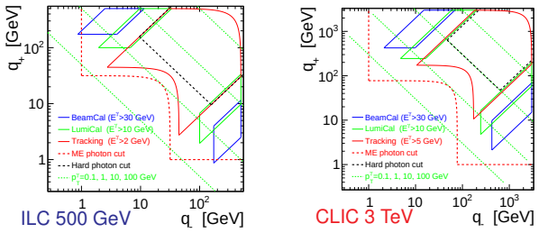
- high gradient, two-beam acceleration scheme
- staged implementation with energy from 380 GeV to 3 TeV
- footprint of 11 to 50 km
- e^- polarisation only (80%)

Total of 5000 fb^{-1} assumed at 3 TeV arXiv:1812.06018

4. Simulating mono-photon events in Whizard

Detected photons need to be simulated on the matrix-elememt level.

Dedicated matching procedured developed to avoid double-counting of ISR and hard photons emission. arXiv:2004.14486



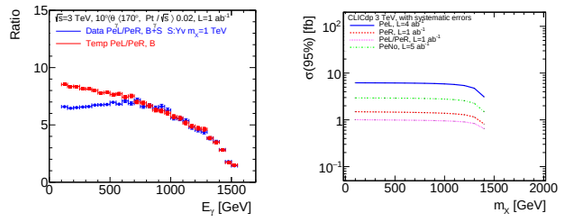
5. Dark Matter searches at 3 TeV CLIC

Generator level study for CLIC arXiv:2103.06006

Signature:
high energy, isolated photon no other "hard" activity

Main backgrounds: radiative Bhabha and neutrino pair-production

Highest sensitivity to DM production from the ratio of photon energy distributions for two electron beam polarisations

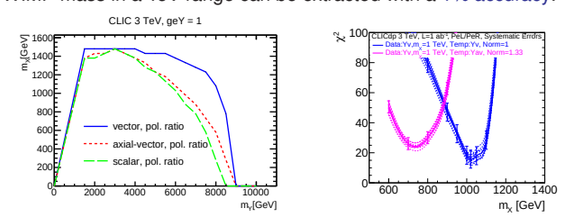


Ratio ⇒ cancelation of systematic uncertainties, but results model-dependent

Limits on the mono-photon cross section can be translated to the expected exclusion range in the DM-mediator mass space.

For a light WIMP mass the exclusion range extends up to 9 TeV

If significant excess of mono-photon events is observed, WIMP mass in a TeV range can be extracted with a 1% accuracy.

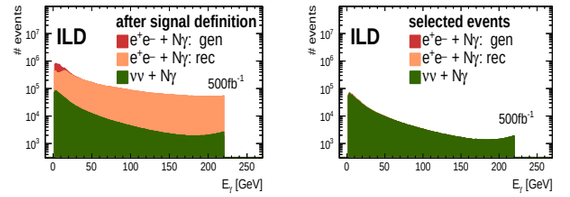


6. WIMP Dark Matter at the ILC

Full simulation study for ILD arXiv:2001.03011

Scenarios with heavy mediator and coupling values $\mathcal{O}(1)$ (EFT limit)

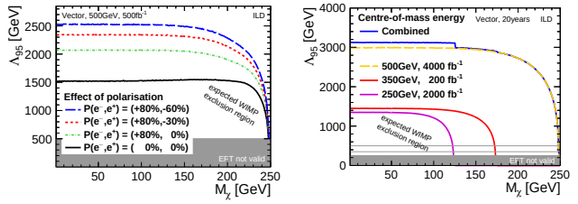
Very efficient background suppression but for "irreducible" background from radiative neutrino pair-production: $e^+e^- \to \nu\nu + N\gamma$



Polarised beams essential for neutrino pair-production background suppression, can also increase the signal (for some scenarios).

Combining different polarisations helps to reduce the systematics.

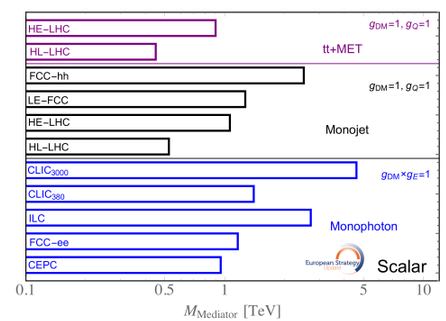
⇒ significant improvement of mass scale limits



Sensitivity to the BSM mass scales up to $\Lambda \sim 3$ TeV $\Lambda^2 = \frac{M_Y^2}{|g_{eeY} g_{\chi\chi Y}|}$

7. EFT limit comparison

Mediator mass limits expected at different colliders in the EFT approach arXiv:1910.11775



ILC and CLIC mass reach better than that of FCC-hh !!!

for the equivalent scenario

8. Sensitivity to light mediator exchange

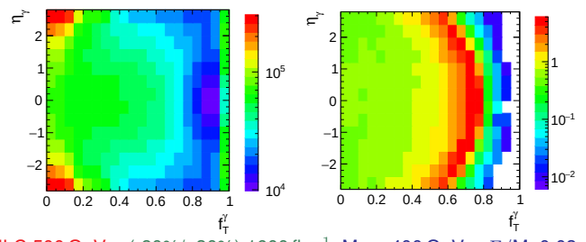
New analysis approach arXiv:2107.11194

based on fast simulation with Delphes

2D distribution in $(f_T^\gamma, \eta_\gamma)$ used to constrain DM production

$f_T^\gamma = \log\left(\frac{p_T^\gamma}{p_T^{min}}\right) / \log\left(\frac{p_T^{max}}{p_T^{min}}\right)$

Background Signal

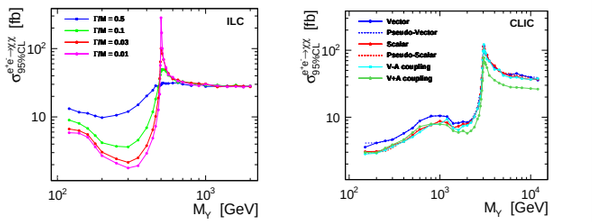


ILC 500 GeV (-80%/+30%) 1600 fb^{-1} M_Y = 400 GeV, Γ/M=0.03

Signal normalised to unpol. DM pair-production cross section of 1 fb

Limits for total DM production cross section
Corrected for probability of hard photon tagging!

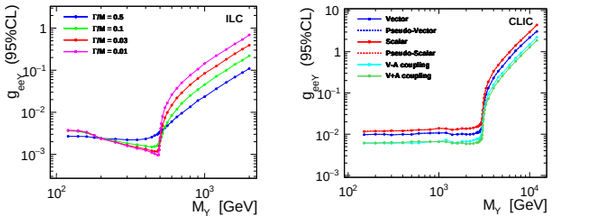
Vector mediator (ILC 500 GeV) Γ/M = 0.03 (CLIC 3 TeV)



ISR suppressed for narrow mediator with $M_Y \sim \sqrt{s} \Rightarrow$ weaker limits

Combined mediator-electron coupling limits

Vector mediator (ILC 500 GeV) Γ/M = 0.03 (CLIC 3 TeV)



Almost uniform sensitivity to mediator coupling g_{eeY} up to kin. limit

For $M_Y \gg \sqrt{s}$ very good agreement with ILD full simulation results!
⇒ reliable extrapolation to low mediator mass domain...