The use of beam polarisation in the search for dark matter at the ILC

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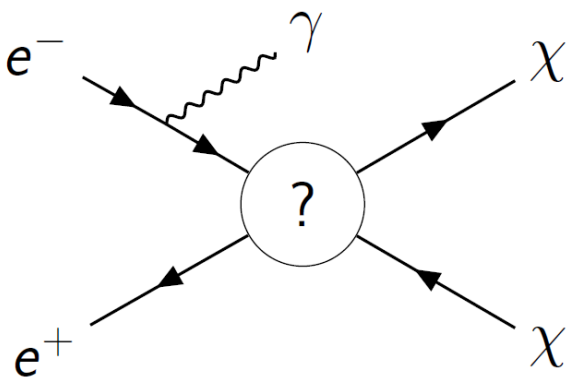
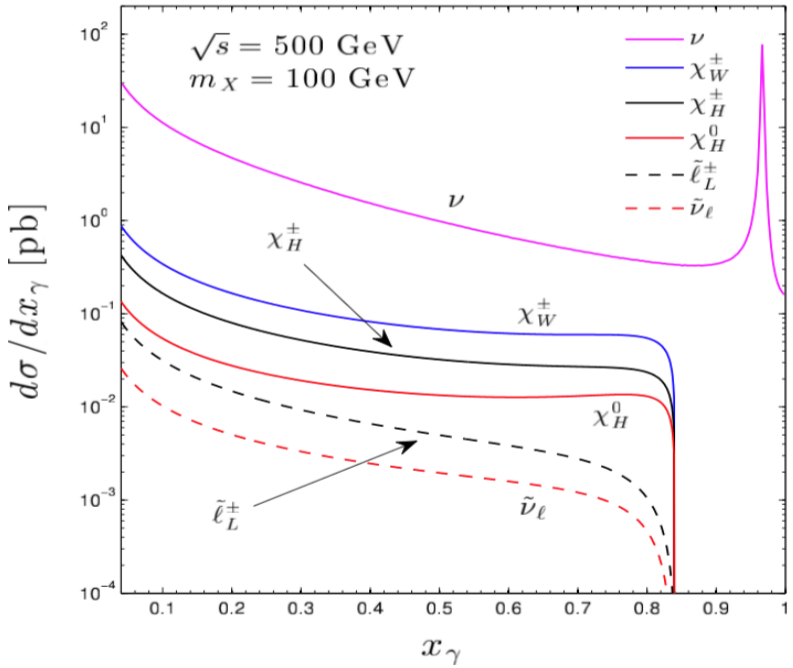
Mono-photon signature

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, which couples to both electrons (SM) and DM states

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

Polarisation in the search for dark matter...

Talk to be given at SPIN'2021

The use of beam polarization in the search for dark matter at the ILC

The International Linear Collider has the opportunity to discover dark matter particles in the monophoton signature $e^+e^- \to \gamma + (\text{missing})$. The sensitivity to new physics in this channel depends crucially on the control and correct estimation of backgrounds. This talk will explain how beam polarization can be used at the ILC to improve the reach of this search.

Impact of polarisation already included in the existing studies:

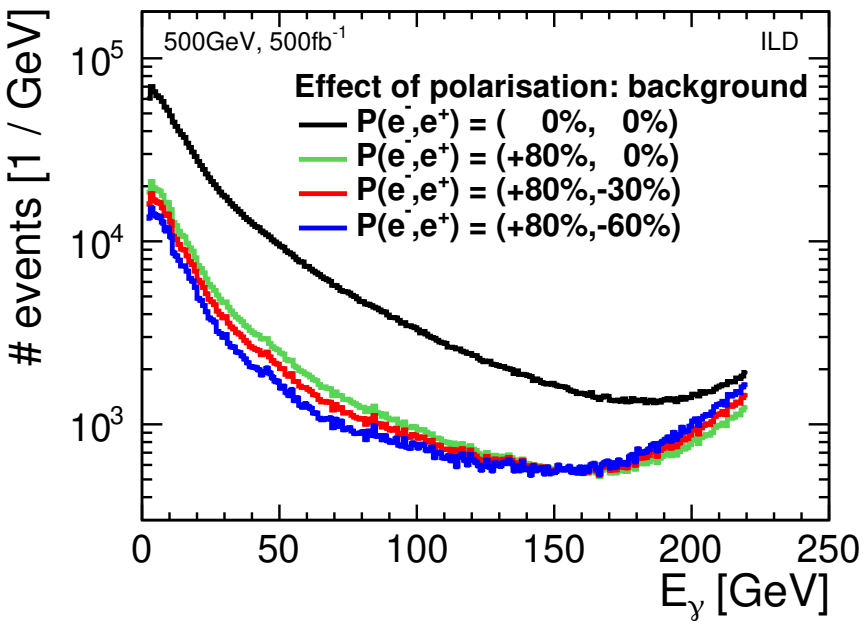
- M. Habermehl, *Dark Matter at the International Linear Collider*, PhD thesis, University of Hamburg, 2018, https://bib-pubdb1.desy.de/record/417605?
- M.Habermehl, M.Berggren, J.List, Phys. Rev. D 101 (2020) 075053, arXiv:2001.03011
- J.Kalinowski, W.Kotlarski, K.Mekala, P.Sopicki, A.F.Z., arXiv:2004.14486, arXiv:2107.11194
  for details see also May 12th presentation: https://agenda.linearcollider.org/event/9223/

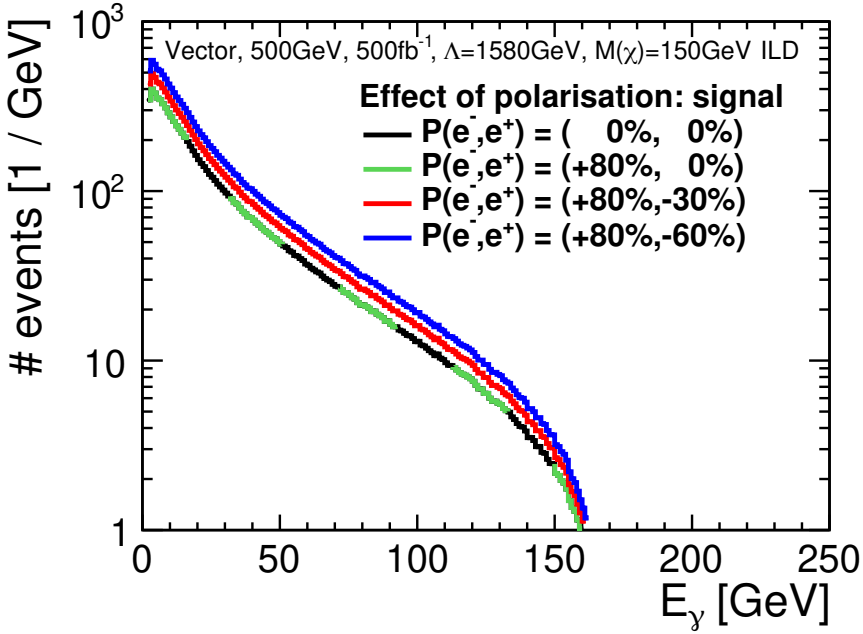
But maybe some more information can be extracted?

WIMP Dark Matter at the 500 GeV ILC

Heavy mediator (EFT limit), full simulation arXiv:2001.03011

Beam polarisation can be used to suppress/control background levels
combination of different polarisations helps to reduce the systematics





It can also enhance mono-photon signal (depending on the scenario).

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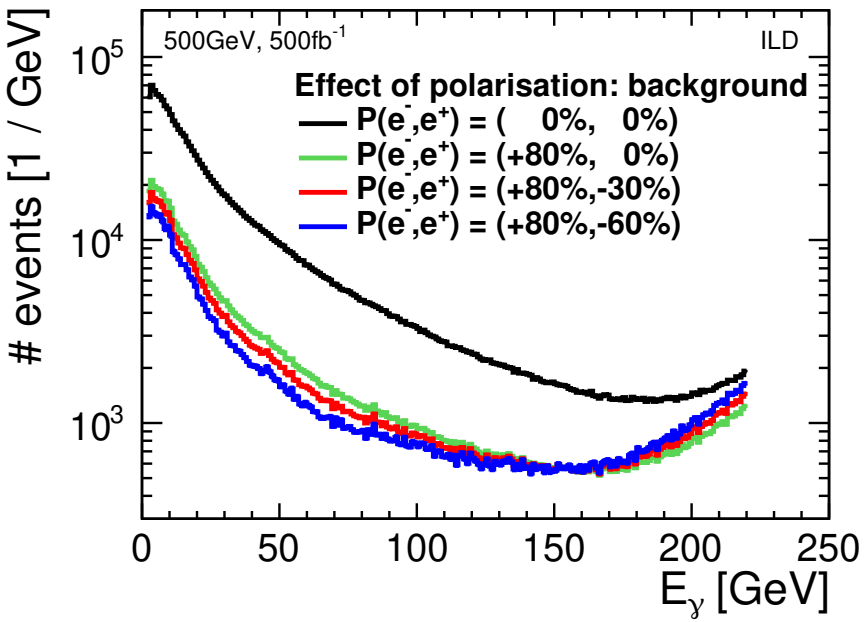

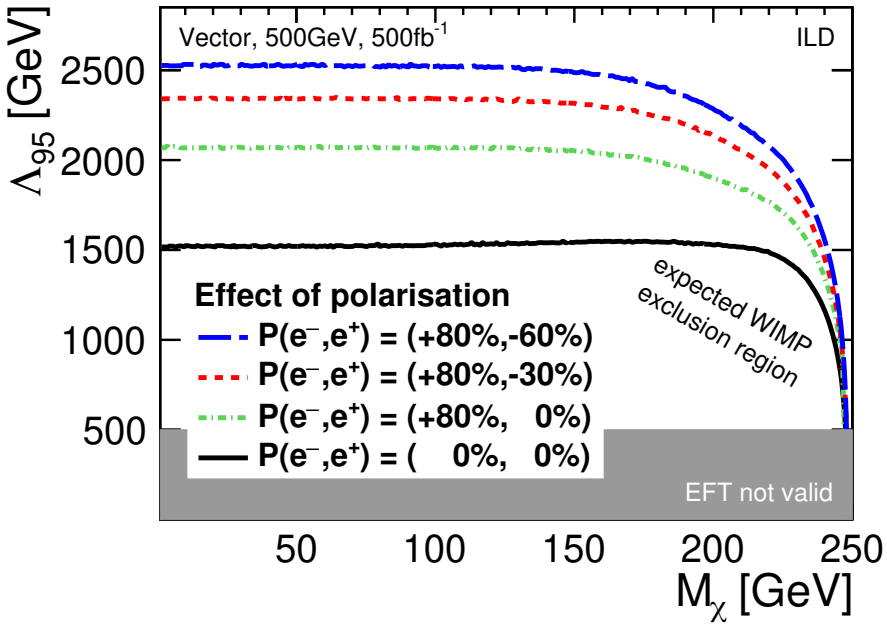

Mass scale limits improve significantly with proper choice of polarisation.

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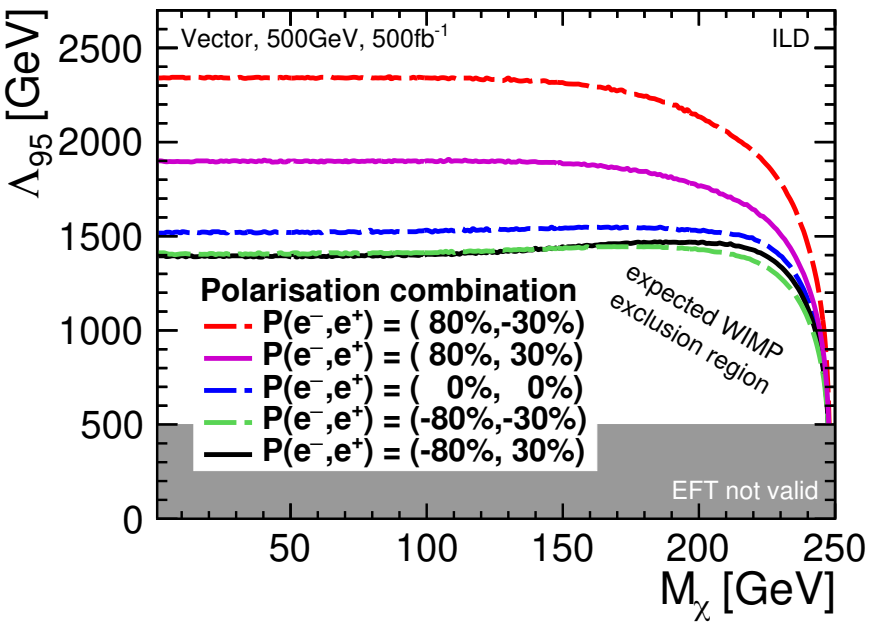

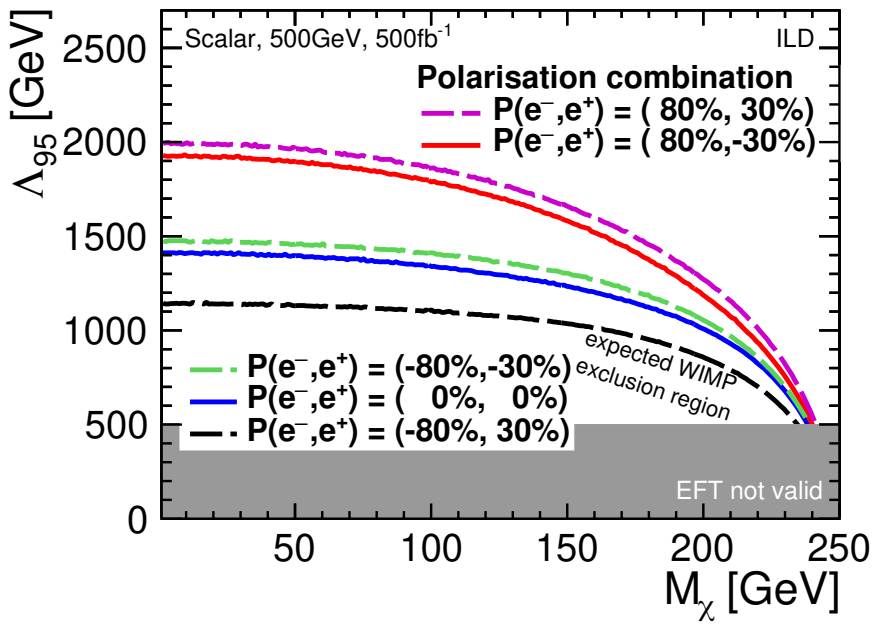

Polarisation choice depends on the BSM scenario...

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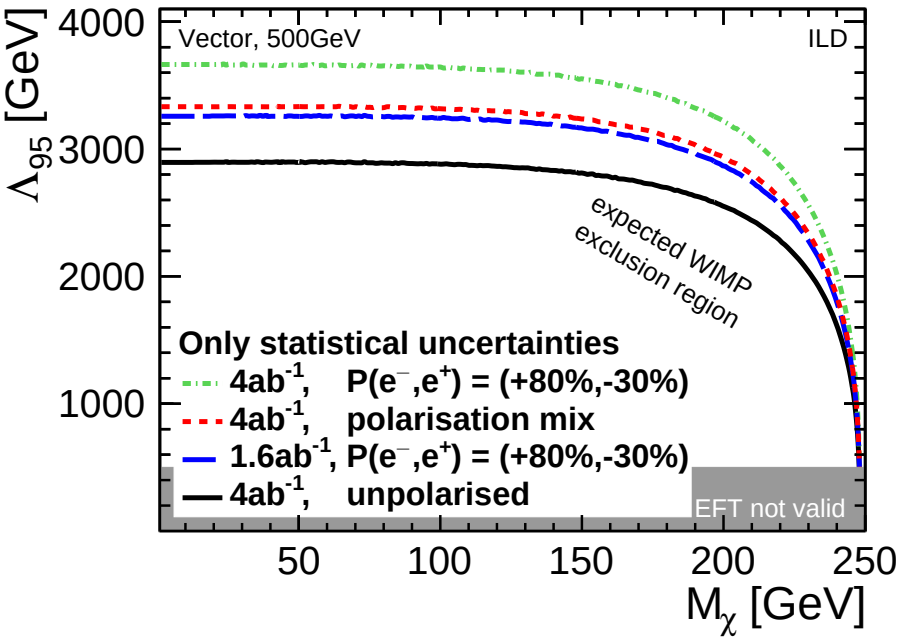
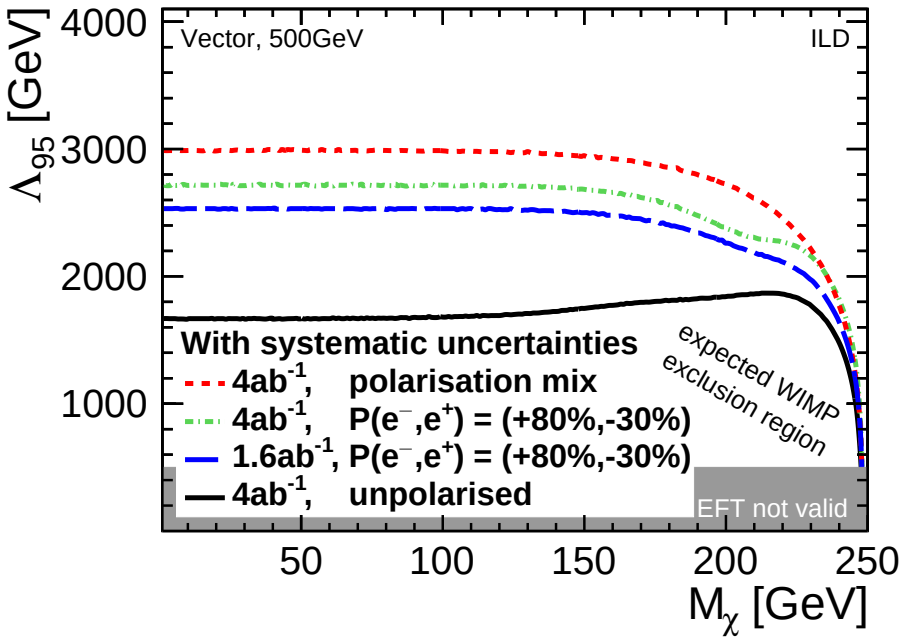




$\Rightarrow$ combined analysis of data taken with different polarisations

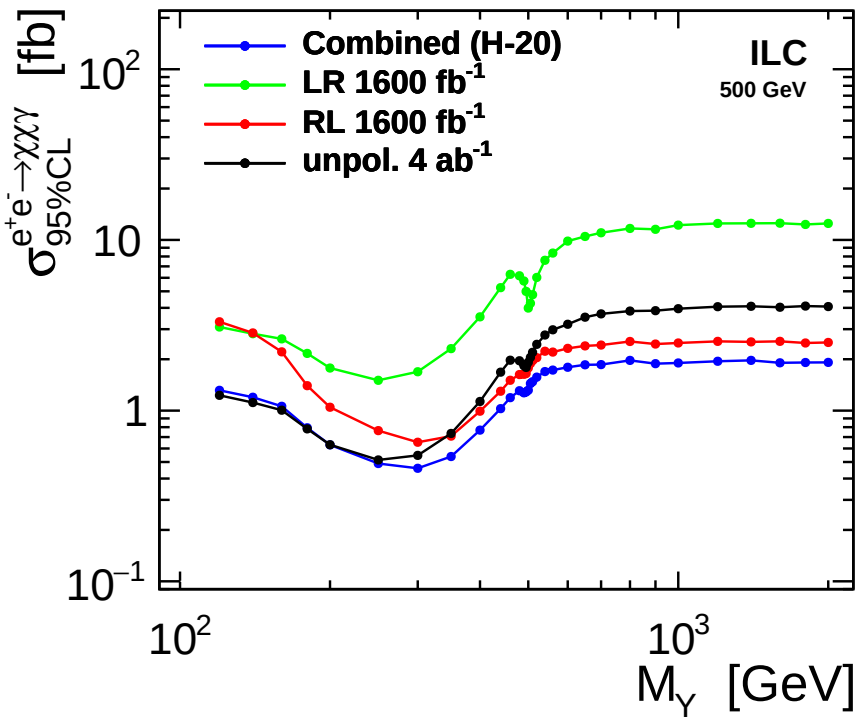
Light mediator exchange

Cross section limits for events with tagged photon arXiv:2107.11194

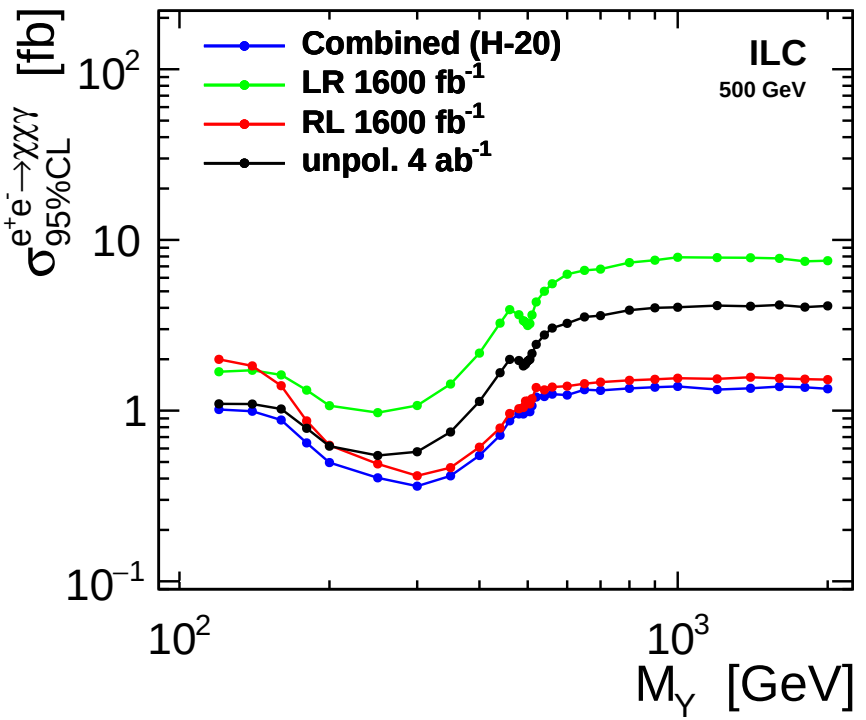
as a function of mediator mass, M_Y
for fixed $\Gamma/M = 0.03$

Dirac fermion DM, $m_\chi = 50\,\text{GeV}$

Scalar



Vector



Impact of polarisation reduced for small mediator masses

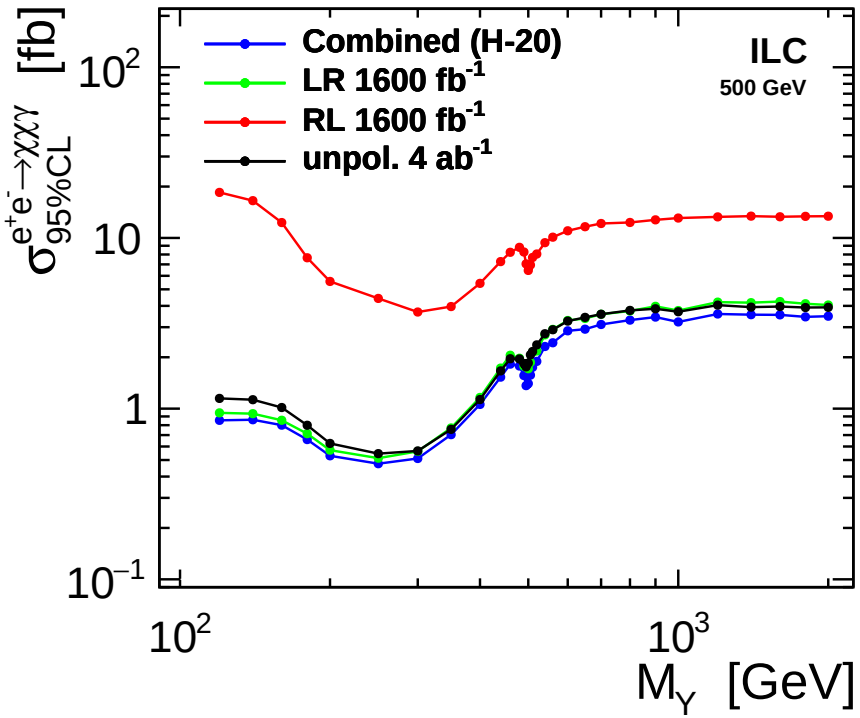
Light mediator exchange

Cross section limits for events with tagged photon arXiv:2107.11194

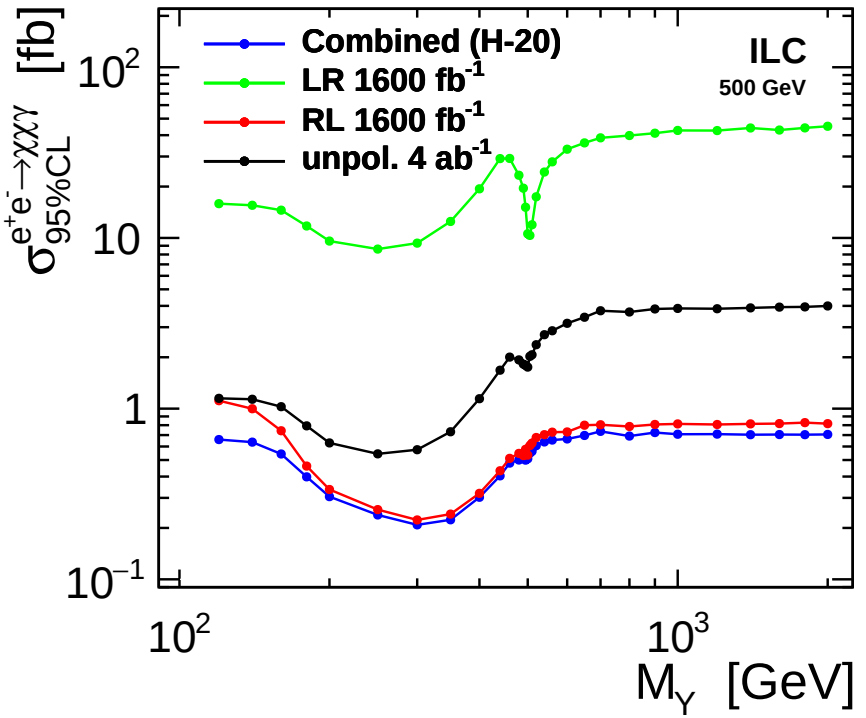
as a function of mediator mass, M_Y
for fixed $\Gamma/M = 0.03$

Dirac fermion DM, $m_\chi = 50\,\text{GeV}$

V−A coupling



V+A coupling



Impact of polarisation reduced for small mediator masses

Light mediator exchange

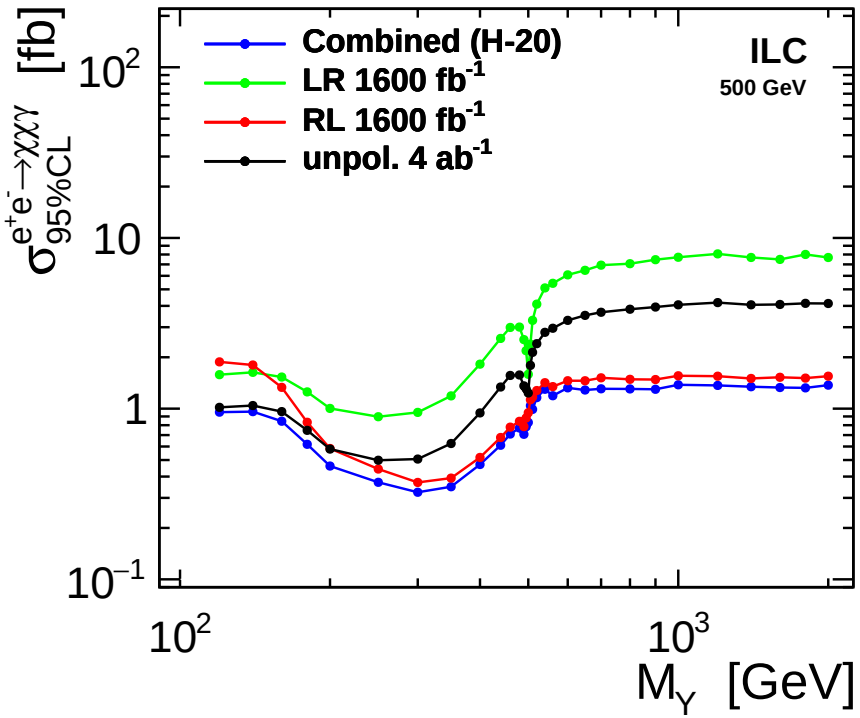
Cross section limits for events with tagged photon arXiv:2107.11194

as a function of mediator mass, M_Y

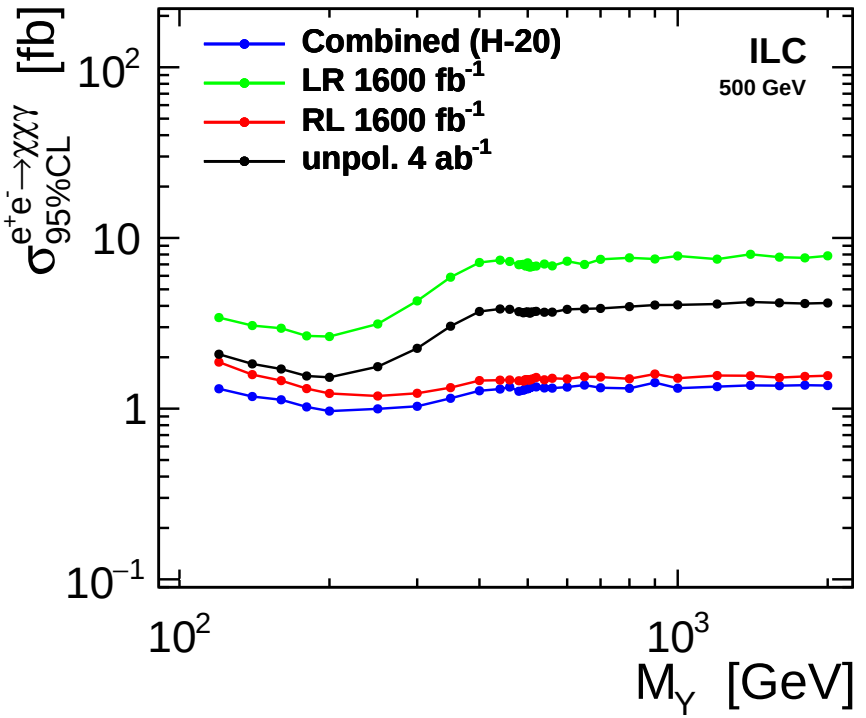
for vector mediator

Dirac fermion DM, $m_\chi = 50\,\text{GeV}$

$\Gamma/M = 0.01$



$\Gamma/M = 0.5$



Impact of polarisation reduced for narrow mediator

Light mediator exchange

Systematic uncertainties

following ILD study: Phys. Rev. D 101, 075053 (2020), arXiv:2001.03011

Considered sources of uncertainties:

- Integrated luminosity uncertainty of 0.26%
  uncorrelated between polarisations
- Luminosity spectra shape uncertainty
  correlated between polarisations
- Uncertainty in neutrino background normalisation of 0.2% (th+exp)
  correlated between polarisations
- Uncertainty in Bhabha background normalisation of 1% (th+exp)
  correlated between polarisations
- Uncertainty on beam polarisation of **0.02–0.08%**
  correlated for runs with same beam polarisation at ILC

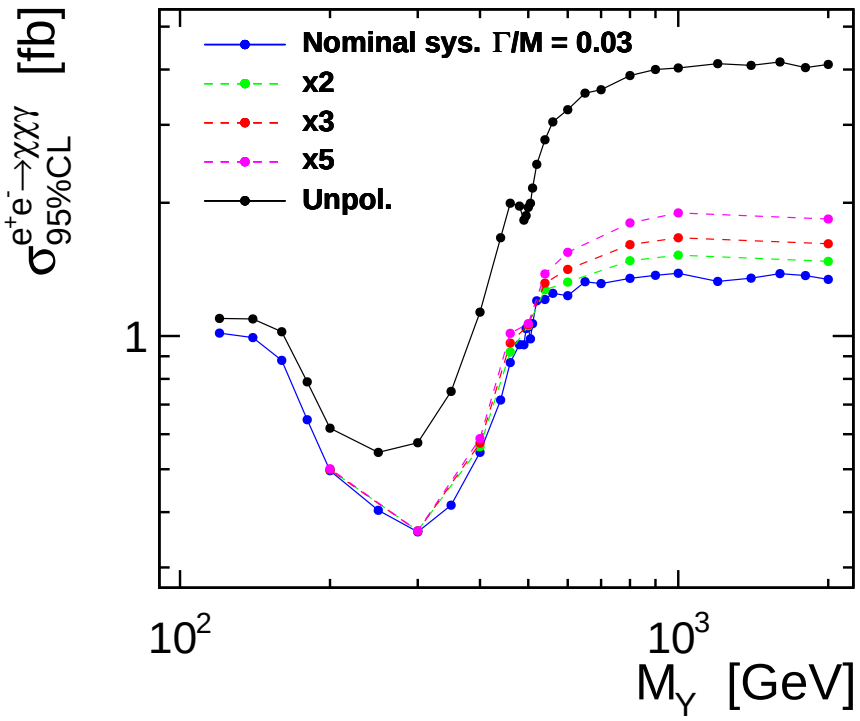
$\Rightarrow$ 11 nuisance parameters in the model fit

Light mediator exchange

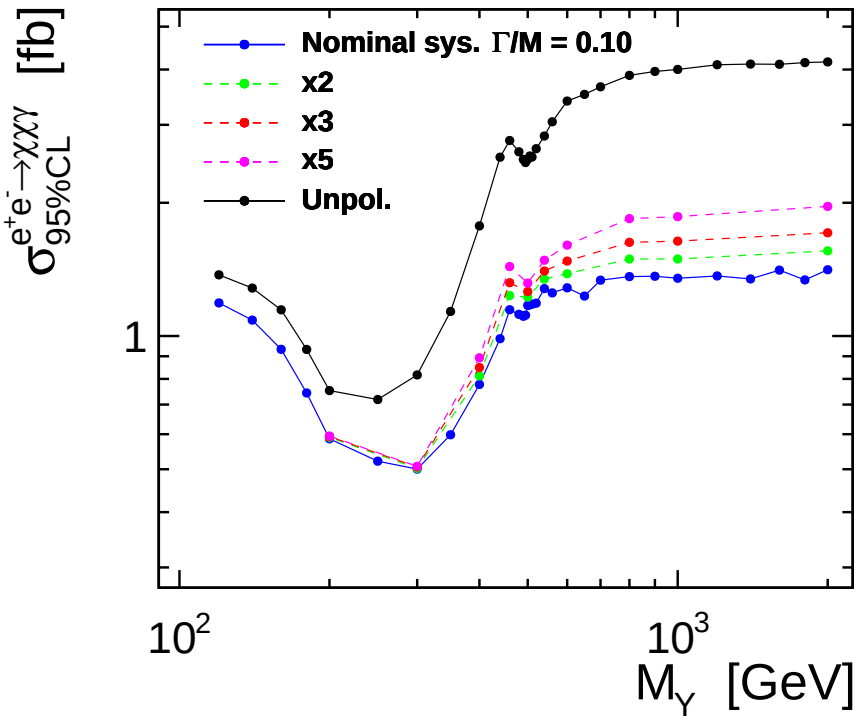
How important is the polarisation uncertainty!?

Radiative cross section limits (for events with tagged photon) as a function of the polarisation uncertainty scaling factor

$\Gamma/M = 0.03$



$\Gamma/M = 0.10$



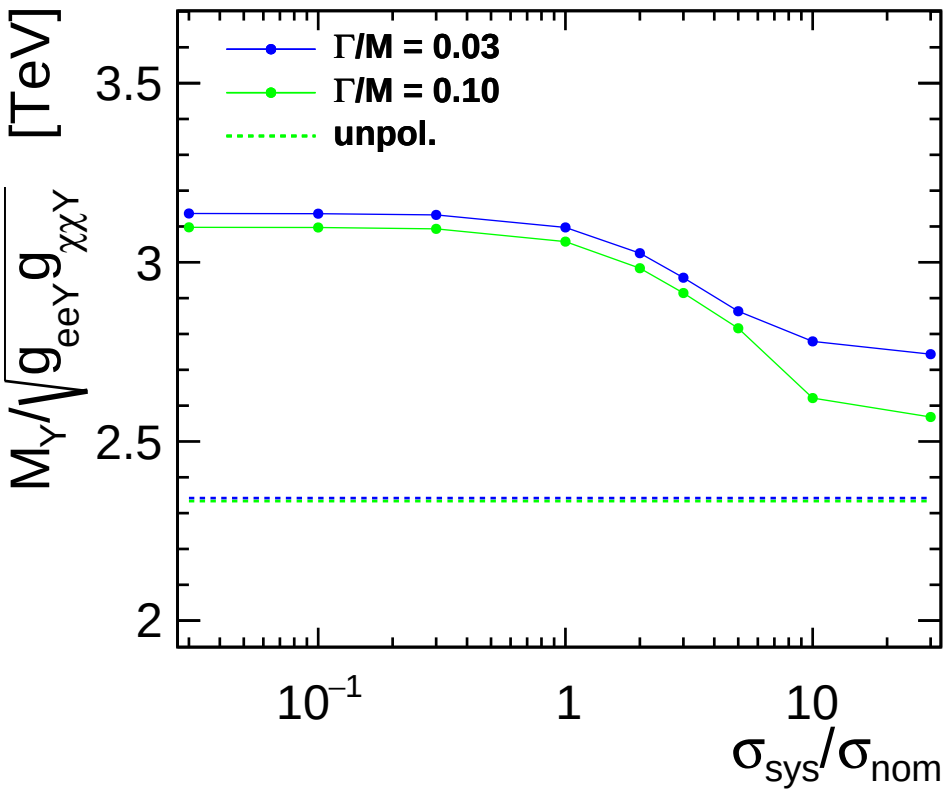
Systematic uncertainties relevant only for heavy mediator exchange

Heavy mediator exchange

How important is the polarisation uncertainty!?

Limits on the EFT mass scale Λ vector mediator, Dirac fermion DM

as a function of the polarisation uncertainty scaling factor



Significant impact of polarisation even with much higher uncertainty

$\Rightarrow$ polarisation constrained by the data itself