Mono Photon Searches at 3 TeV With Polarised Beams

Outline

- Introduction
- Background cross-section calculation and event simulation.
- Background cross-sections and Syst errors
- Background dN/dEγ distributions
- 95%CL cross-section calculation method
- 95%CL cross-section plots and results.
- Summary and outlook

Introduction

For the CLICdp Yellow report and for the additional contributions prepared for Granada, the exclusion limits for Dark Matter models were computed using 95% upper limits, computed using backgrounds without polarisation. Right handed polarised e^- beams reduce the main SM background, $\nu \bar{\nu} \gamma$. The goal of this study is to estimate the increase in sensitivy taking into account the systematic errors.

Background Cross-sections 3TeV

Background cross-section values calculated for:
$10° < \theta\gamma < 170°$ and $Pt\gamma/\sqrt{s} > 0.02$, without and with e- beam polarisation.
Cross-section calculation and event generation done using Whizard with beam spectrum, isr function and n(1...3) matrix element photons.
Events with Isr γ's overlapping ME γ's were rejected (Note: CLICdp-2020-004, Filip, Pawel ...).
Fast simulation used to take into acount γ energy resolution and efficiency and e^+ e^- γ veto efficiency.
3 TeV fast simulation based on extrapolation of full simulation.

Background Cross-sections 3TeV

	Polarisation		
	No	Pe-:-80%	Pe-:+80%
Process	σ[fb]	σ[fb]	σ[fb]
$e^+ e^- \rightarrow \nu \bar{\nu} \gamma + \nu \bar{\nu} \gamma \gamma + \nu \bar{\nu} \gamma \gamma \gamma \ (\gamma)$	1058	1880	235
$e^+ e^- \rightarrow e^+ e^- \gamma + e^+ e^- \gamma \gamma + e^+ e^- \gamma \gamma \gamma \ (\gamma)$	1925	1960	1890

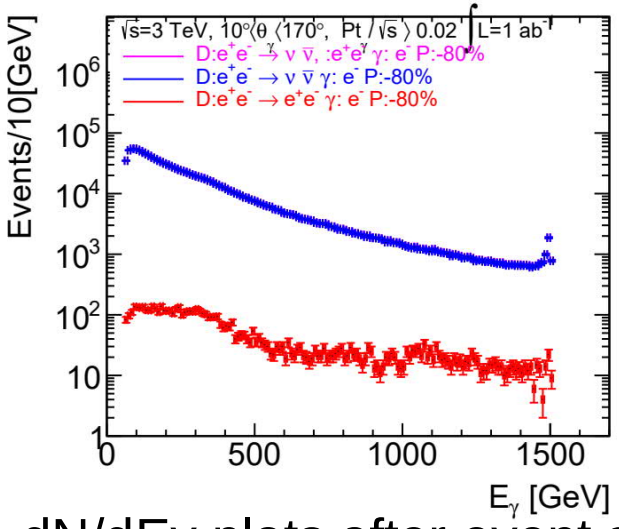
Background cross-section values for: $10° < \theta\gamma < 170°$ and $P_{T\gamma}/\sqrt{s} > 0.02$. $\sigma(\nu \bar{\nu} \gamma)$ for Pe-:+80%, σ reduced by a factor 4.5 w.r.t. no polarisation and a factor 8, w.r.t. Pe-:-80%

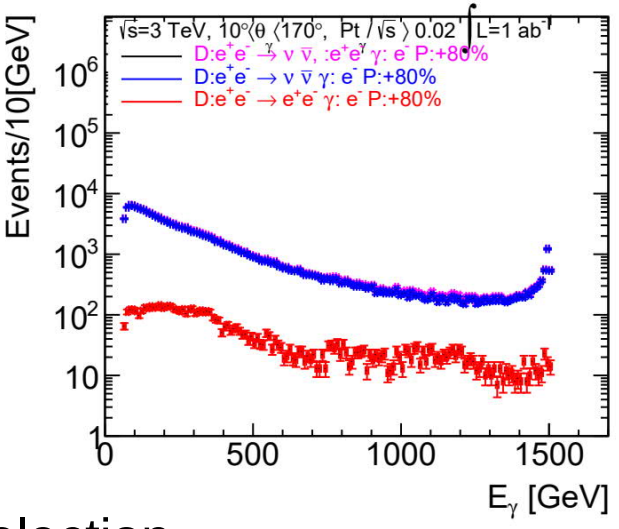
Systematic errors

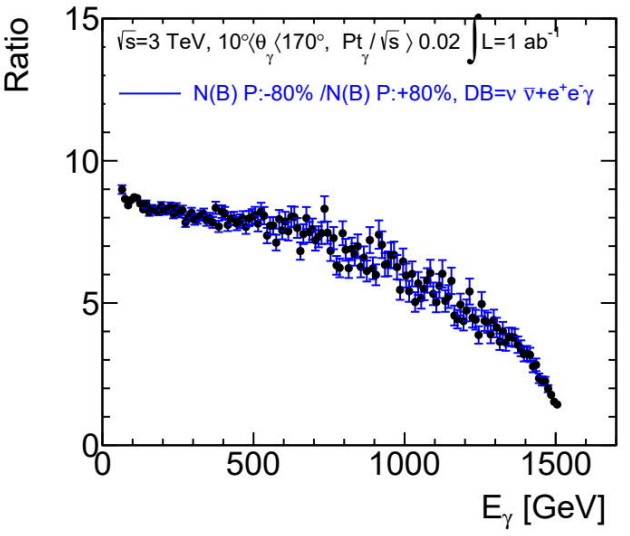
Systematic error	Value
Event selection $\nu \bar{\nu} \gamma$	0.002
Event selection $e^+ e^- \gamma$	0.01 *
Luminosity	0.002
Polarisation	0.0025 **

The values are those used in the ILC paper arXiv:2001.03011v1.
* ILC does not assign a systematic error on the $e^+ e^- \gamma$ veto.
**The sign of polarisation can be reversed at each bunch train, => experimental uncertainties will be strongly correlated.

Background dN/dEγ ∫L=1ab^{-1}







dN/dEγ plots after event selection.

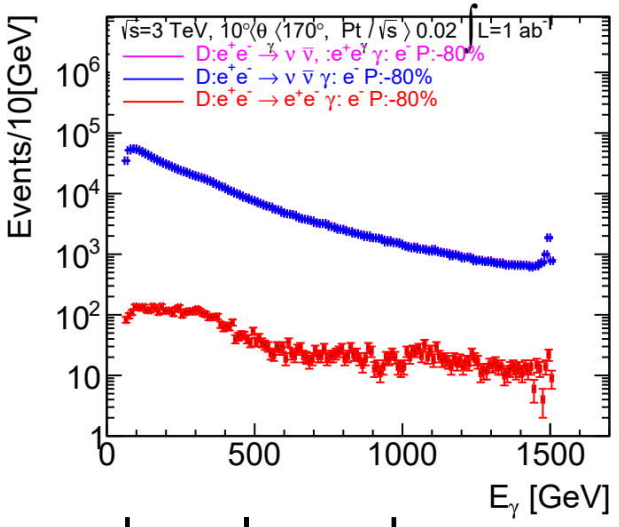
Left : dN/dEγ (Pe-:- 80%) $\nu\bar{\nu}\gamma$, $e^+ e^- \gamma$ events and sum: $N(e^+ e^- \gamma)/N(\nu\bar{\nu}\gamma)=0.005$

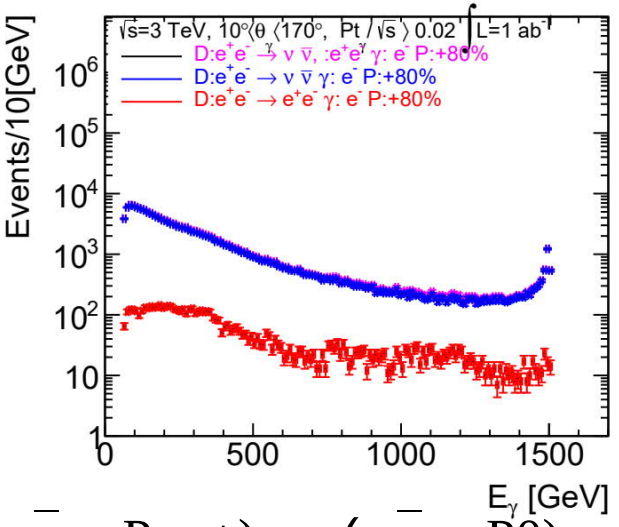
Midle: dN/dEγ (Pe-:+80%) $\nu\bar{\nu}\gamma$, $e^+ e^- \gamma$ events and sum: $N(e^+ e^- \gamma)/N(\nu\bar{\nu}\gamma)=0.04$

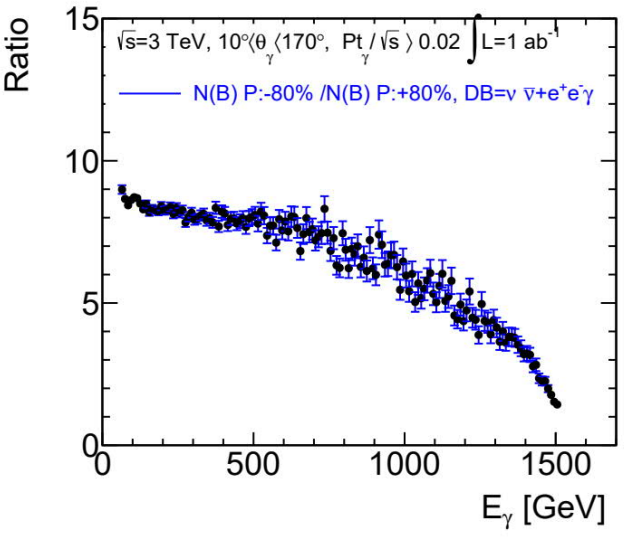
Right :dN/dEγ(Bsum) (Pe-:-80%) / dN/dEγ B(sum) (Pe-:+80%)

The shape of dR/dEγ is due to the $\nu\bar{\nu}\gamma$ s and t-channel contributions changing with Eγ.

Background dN/dEγ ∫L=1ab^{-1}







s-chanel γ exchange : $\sigma(\nu\bar{\nu}\gamma, Pe\text{-}:\pm) = \sigma(\nu\bar{\nu}\gamma, P0)$

s-chanel Z exchange : $\sigma(\nu\bar{\nu}\gamma, Pe\text{-}:\text{-}/+) = \sigma(\nu\bar{\nu}\gamma, P0)*(1 +/- P*ALR)$, νe, νμ, ντ

t-chanel W exchange : $\sigma(\nu\bar{\nu}\gamma, Pe\text{-}:\text{-}/+) = \sigma(\nu\bar{\nu}\gamma, P0)*(1 +/ P)$, only νe

The Z s-chanel and t-chanel contributions change with Eγ because the Z return is increasing when Eγ increases.

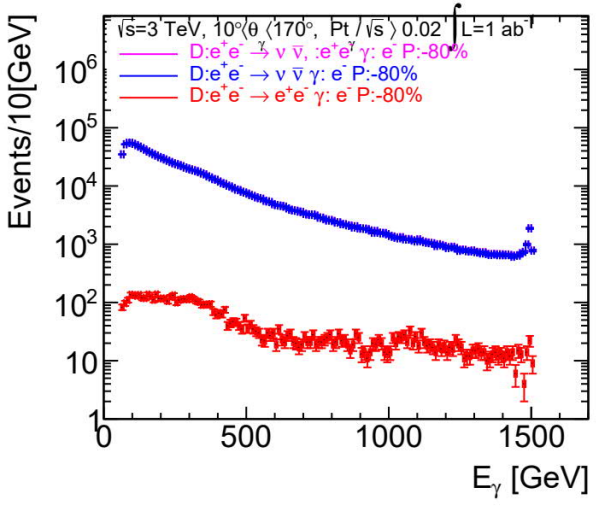
95% Upper Limit Calculation

Definitions (Reminder)

To compute the 95% CL upper limit the likelihood ratio test statistic p=p(s+b)/p(b) (F1) is used:
Nobs=number of observed events, b=number of background events
b+s = number of background + signal events.
p=probability, CL=Confidence Level, CL=1-p
Significance (z)=F(1-2p)
A 1 sided 95% CL upper limit corresponds to p >= 0.025 and z <= 2

$$p = \frac{\sum_{n=0}^{Nobs} (b+s)^n \frac{e^{-(b+s)}}{n!}}{\sum_{n=0}^{Nobs} (b)^n \frac{e^{-b}}{n!}} \quad \text{(F1)}$$

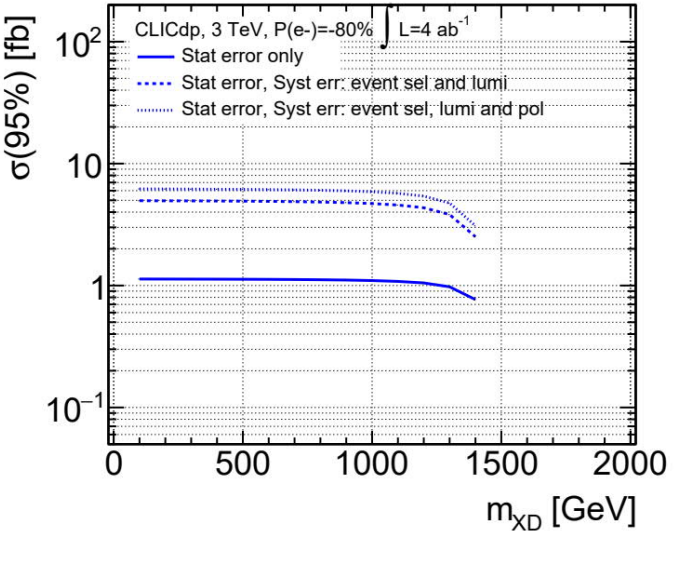
σ(95%) for Pe-:-80%



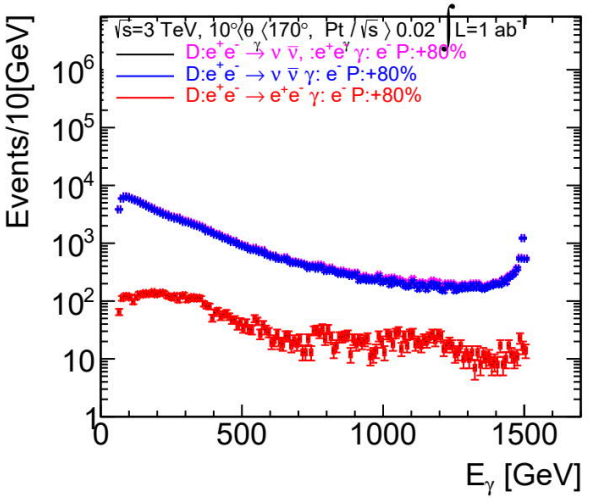
-dN/dEγ for ν ν̄ γ and e^+ e^- γ events and sum for Pe-:-80%.
For a DM mass mXD, Eymax= √s/2-2*mXD²/√s.
The background b is computed for 50 GeV < Eγ < Eymax using F1. The s excluded at 95%CL is computed using F2.
σ(95%) = s/Lumi. σ(95%) is computed for 200 GeV < mXD < 1400 GeV without and with systematic errors.
With systematic errors :
σ(95%)=6 fb.

$$b = \int_{E_{\gamma_{min}}}^{E_{\gamma_{max}}} dN/dE_\gamma \quad \text{(F1)}$$

$$\frac{\sum_{n=0}^{Nobs} (b+s)^n \frac{e^{-(b+s)}}{n!}}{\sum_{n=0}^{Nobs} (b)^n \frac{e^{-b}}{n!}} \geq 0.025 \quad \text{(F2)}$$



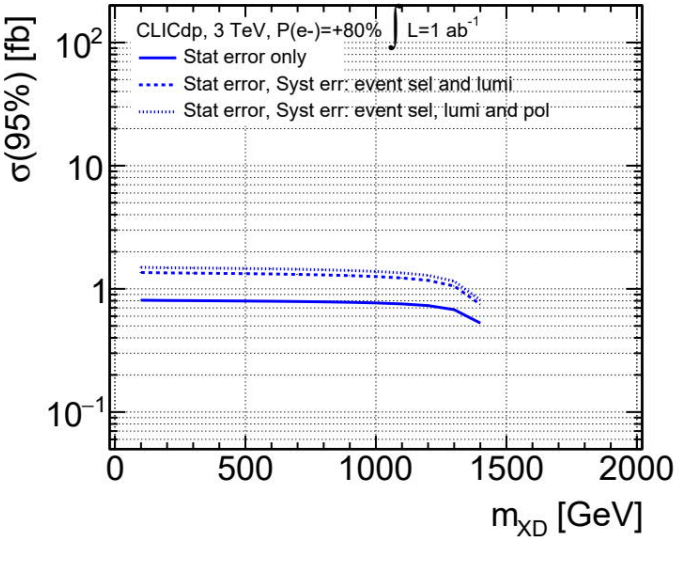
σ(95%) for Pe-:+80%



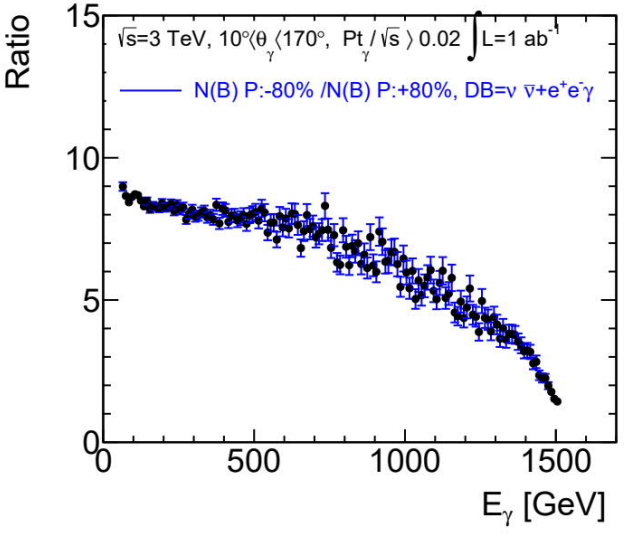
-dN/dEγ for ν ν̄ γ and e^+ e^- γ events and sum for Pe-:-80%.
For a DM mass mXD, Eymax= √s/2-2*mXD²/√s.
The background b is computed for 50 GeV < Eγ < Eymax using F1. The s excluded at 95%CL is computed using F2.
σ(95%) = s/Lumi. σ(95%) is computed for 200 GeV < mXD < 1400 GeV without and with systematic errors.
With systematic errors :
σ(95%)=1.4fb.

$$b = \int_{E_{\gamma_{min}}}^{E_{\gamma_{max}}} dN/dE_\gamma \quad \text{(F1)}$$

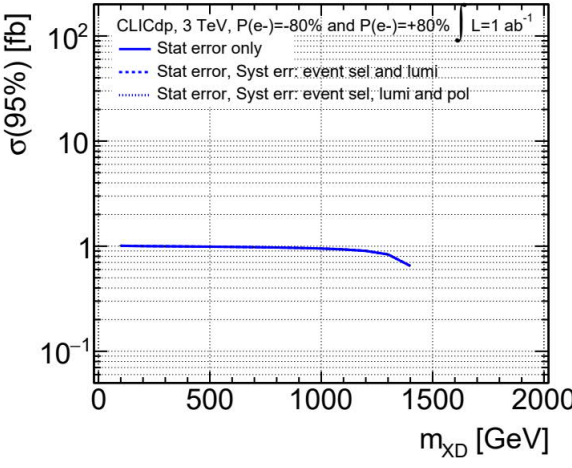
$$\frac{\sum_{n=0}^{Nobs} (b+s)^n \frac{e^{-(b+s)}}{n!}}{\sum_{n=0}^{Nobs} (b)^n \frac{e^{-b}}{n!}} \geq 0.025 \quad \text{(F2)}$$



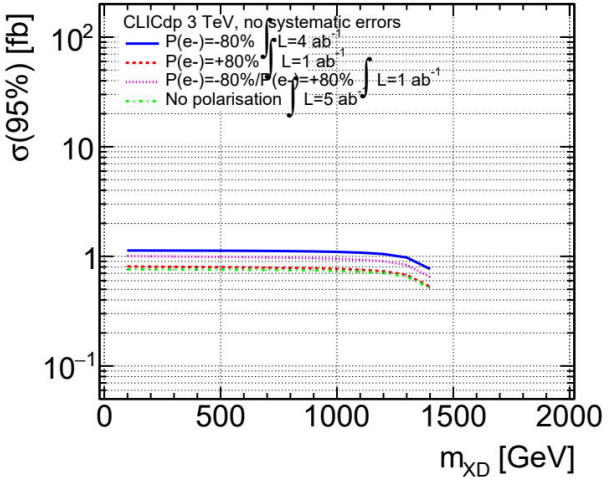
σ(95%) for Pe-:-80%/Pe-:+80%

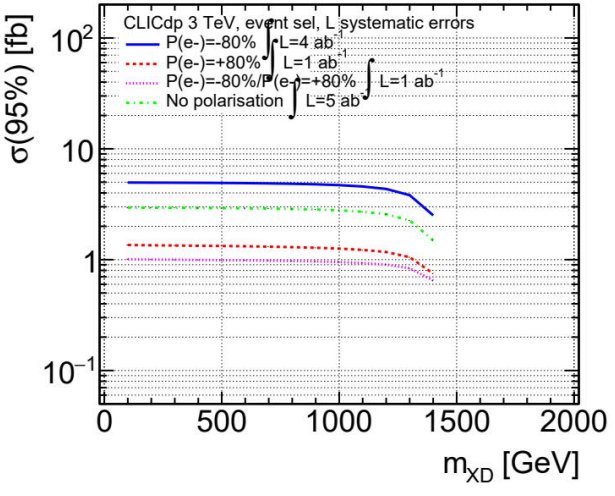


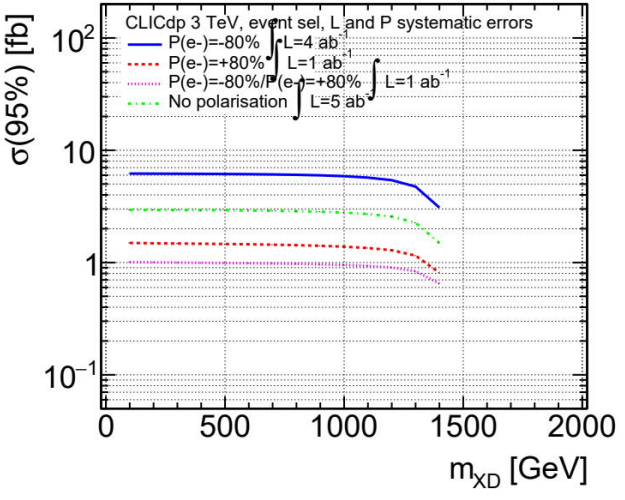
Plot: dRB/dEγ: RB=NB(Pe-:-80%)/NB(Pe-:+80%) (B only)
RB and ΔRB computed for 50 GeV < Eγ < Eγmax
In presence of signal: RBPS=(NB:-80%+NS)/(NB:+80%+NS)
Compute NS to get RBPS=RB-2*ΔRB. σ(95%,RB)=NS/Lumi
Compute σ(95%,RB) for 200 GeV < mXD < 1400 GeV
without and with systematic errors.
With systematic errors:
σ(95%,RB)=1 fb.
It increases by 2% w.r.t No Syst Err



95% CL cross-section values







95% upper limit σ, for different polarisation conditions: L, R, L/R, No.
Left : without systematic errors
Middle: with systematic errors: event selection and luminosity
Right : with systematic errors: event selection, luminosity and polarisation
W.r.t no polarisation, P(e-)=+80% is decrasing the σ(95%) by 2 and RP by 3.

Summary

Right handed e^- polarised beams reduce the main SM background, $\nu\bar{\nu}\gamma$, increasing significantly the sensitivy.
Taking into account the systematic errors:
$\sigma(95\%, Pe^-: -80\%, L=1ab^{-1}) = 1.4$ fb for MXD=1 TeV
$=\sigma(95\%, Pe^-: 0, L=5ab^{-1})/2$
$\sigma(95\%, RP, L=1ab^{-1}) = 0.95$ fb for MXD=1 TeV
$=\sigma(95\%, Pe^-: 0, L=5ab^{-1})/3$

Outlook

Using axial, axial-vector and scalor simplified DM models, study:

- Mass determination and cross-section measurement.
- Chiral properties: couplings identification

Additional slides

Radiative Neutrinos Diagrams

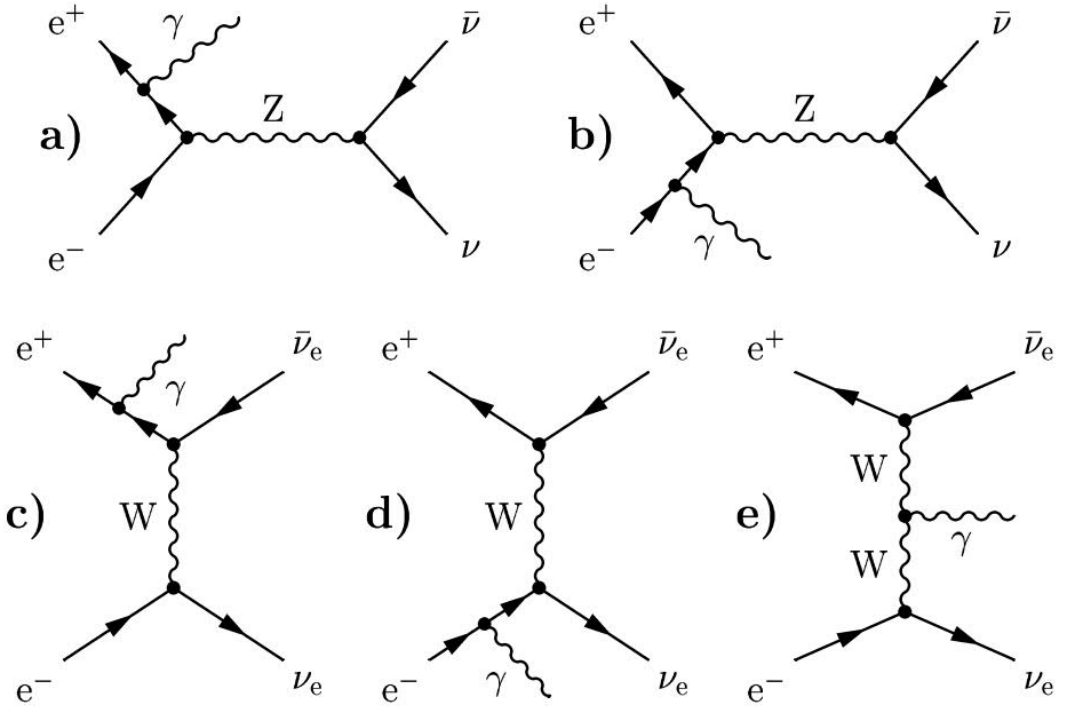
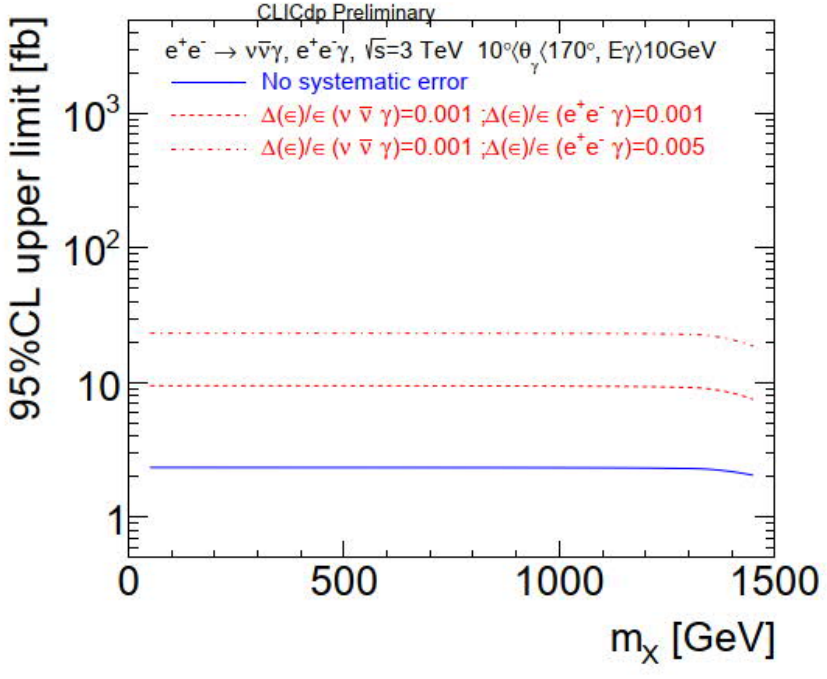


Figure 2.6: Lowest-order Feynman diagrams for the reaction $e^+e^- \to \nu\bar{\nu}\gamma$.

2019 σ(95%CL)



σ(95%CL) values used by Ulrike to compute the DM exclusion limits for Granada.