



# CLIC DM studies

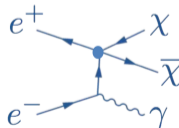
**Ulrike Schnoor**, J.-J. Blaising, P. Roloff

2020-06-17

- ▶ Simplified **Dark Matter** model introduces **dark matter candidate**  $\chi_d$  and **mediator** particle:
  - ▶ spin-1: vector or axial-vector
  - ▶ spin-0: scalar

Whizard model file prepared by Andrea Wulzer according to <http://feynrules.irmp.ucl.ac.be/wiki/DMSimp>

- ▶ Couplings in the model:
  - ▶ **dark matter** coupling to **mediator**
  - ▶ couplings of **mediator** to **leptons** and quarks
- ▶ Process:  $e^+e^- \rightarrow \chi_d\chi_d\gamma$ 
  - ▶ Cross section depends on masses of **mediator** and **dark matter particle**
  - ▶  $\Rightarrow$  **mono-photon signature**



Study by J.-J. Blaising [CLIC Physics potential YR 1812.02093, ch. 5.1]

▶ Full simulation including beamspectrum and ISR

▶ Relevant backgrounds:

$$e^+e^- \rightarrow \nu\bar{\nu}\gamma \text{ and } e^+e^- \rightarrow e^+e^-\gamma$$

▶ Based on  $1 \text{ ab}^{-1}$  at 380 GeV

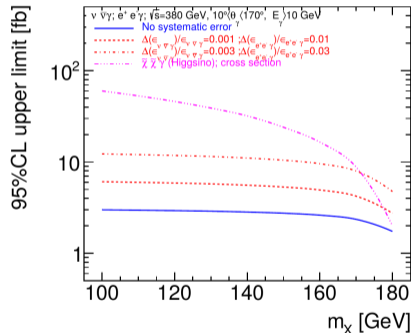
▶ Cuts on the final state photons:

$$E > 10 \text{ GeV}, 10^\circ < \theta < 170^\circ$$

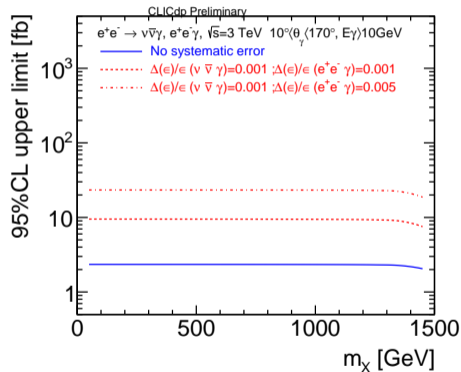
▶ Systematic uncertainty: Bhabha scattering normalisation

- ▶ dominated by forward electron tagging efficiency
- ▶ here considered for the total background

▶ Exclusion limits based on the cases with uncertainty of 0.3% and without systematics



- ▶ Use generator-level cross sections to extrapolate to 3 TeV (J.-J. Blaising)
- ▶ radiative Bhabha background  $e^+e^- \rightarrow e^+e^-\gamma$  decreases by **a factor of 10** between 380 GeV and 3 TeV
- better reach is expected at 3 TeV
- ▶ Exclusion limits based on the cases without and with larger systematics



J.-J. Blaising

# Recast to exclusions in the plane of mediator vs. DM mass

- ▶ Obtain different cross sections for

$$e^+e^- \rightarrow \chi_d\chi_d\gamma$$

for different masses of the **mediator** and the **dark matter** candidate

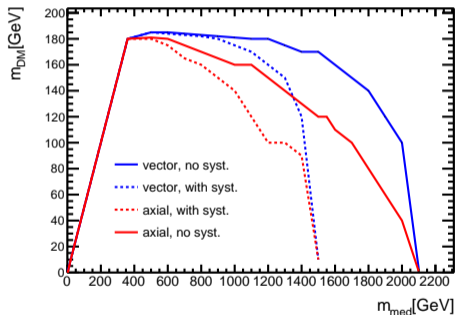
- ▶ Recast the limits on cross sections obtained in the existing monophoton analyses at 380 GeV and 3 TeV to this model
- ▶ Cross sections determined with Whizard 2.7 including ISR and CLIC beam spectrum
  - ▶ Using the same cuts, i.e. on the final state photons:  $E > 10$  GeV,  $10^\circ < \theta < 170^\circ$
  - ▶ No beam polarisation
- ▶ Width of the **mediator** always fixed to the default value of  $WY1 = 10$  GeV
- ▶ Various cases of couplings considered:

**Lepton to mediator**  $g_{\text{lep}} = 0.1, 0.25, 1$

**Mediator to dark matter**  $g_{\text{DM}} = 1$

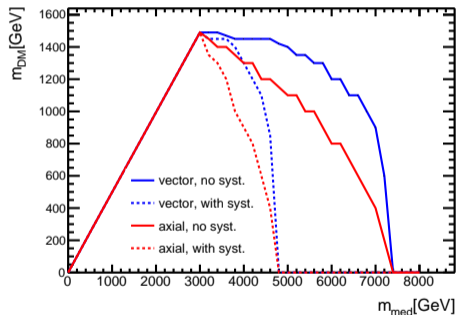
## gDM=glep=1, spin 1 at 380 GeV

exclusion limits gDM=glep=1 for CLIC-380



## gDM=1, glep=1, spin 1 at 3 TeV

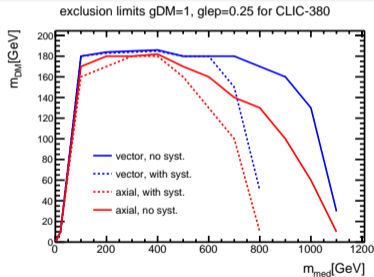
exclusion limits gDM=1, glep=1 for CLIC-3000



- ▶ Exclusion range increases from 1500 GeV to almost 5000 GeV from CLIC-380 to CLIC-3000
- ▶ Systematic uncertainties have a large effect in particular for light DM

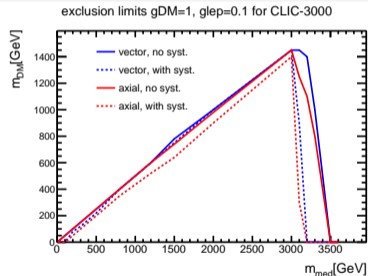
- ▶ LHC DM limits:  $g_q = 0.25 \rightarrow$  transferred to lepton colliders:  $g_{lep} = 0.25$  (for prospects comparison only; not the same point in the model)

## gDM=1; g<sub>lep</sub>=0.25, spin 1 at 380 GeV



For light DM incl. systematics:  
 $m_{DM} = 1 \text{ GeV}$ :  $m_{axial} = 800 \text{ GeV}$

## gDM=1, g<sub>lep</sub>=0.1, spin 1 at 3 TeV

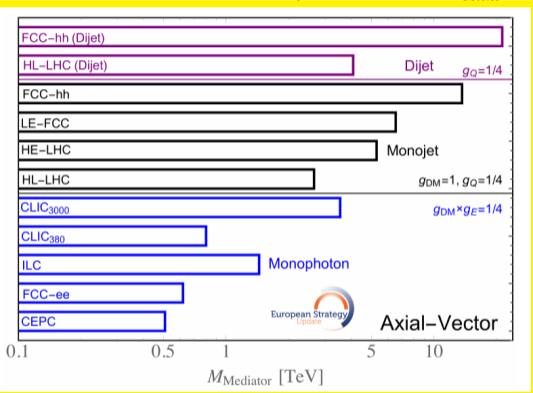
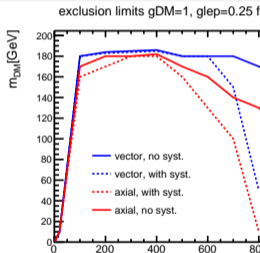


For light DM incl. systematics:  
 $m_{DM} = 1 \text{ GeV}$ :  $m_{med} = 3200 \text{ GeV}$   
 extrapolated to  $g_{lep}=0.25$ :  $m_{axial} = 3800 \text{ GeV}$

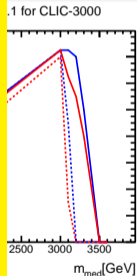
# LHC-like coupling points

- LHC DM limits:  $g_a = 0.25 \rightarrow$  transferred to lepton colliders:  $g_{lep} = 0.25$  (for prospects comparison only; ...)

$g_{DM}=1; g_{lep}=0.25, s_{\theta} = 0.88$



Spin 1 at 3 TeV



In the Briefing Book: Fig. 8.15 incl. systematics:

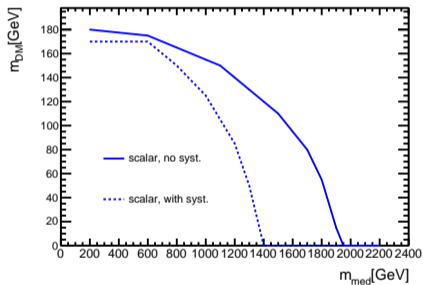
For light DM incl. systematics:  
 $m_{DM} = 1 \text{ GeV}: m_{axial} = 800 \text{ GeV}$

$m_{DM} = 1 \text{ GeV}: m_{med} = 3200 \text{ GeV}$   
 extrapolated to  $g_{lep}=0.25: m_{axial} = 3800 \text{ GeV}$



## gDM=glep=1, spin 0 at 380 GeV

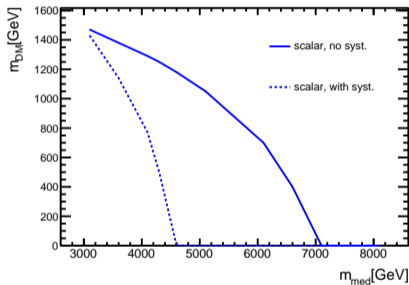
exclusion limits scalar DM for CLIC-380



For light DM incl. systematics:  
 $m_{DM} = 1 \text{ GeV}: m_{med} = 1400 \text{ GeV}$

## gDM=glep=1, spin 0 at 3 TeV

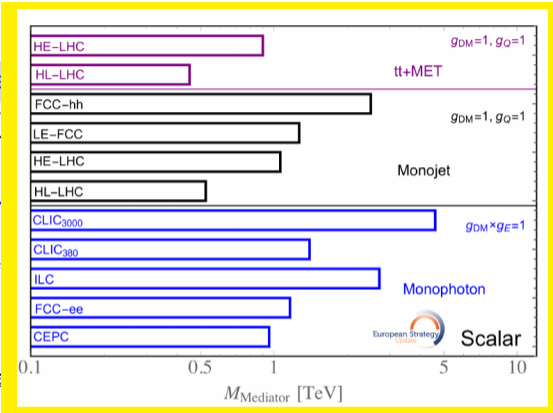
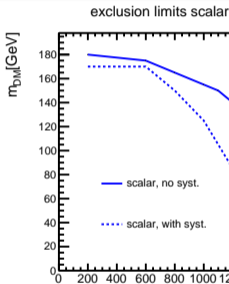
exclusion limits scalar DM for CLIC-3000



For light DM incl. systematics:  
 $m_{DM} = 1 \text{ GeV}: m_{med} = 4600 \text{ GeV}$

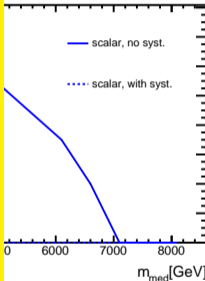
# Scalar Dark Matter candidate

$g_{DM}=g_{lep}=1$ , spin 0



at 3 TeV

scalar DM for CLIC-3000



In the Briefing Book: Fig. 8.15

For light DM incl. systematics:

$$m_{DM} = 1 \text{ GeV: } m_{med} = 1400 \text{ GeV}$$

For light DM incl. systematics:

$$m_{DM} = 1 \text{ GeV: } m_{med} = 4600 \text{ GeV}$$

- ▶ Dark matter sensitivity in monophoton studies for CLIC was provided to the European Strategy based on a fast simulation study
- ▶ Currently:
  - ▶ reviewing the CICdp performance for DM searches at 3 TeV using electron beam polarisation (Jean-Jacques Blaising)
  - ▶ different beam polarizations allow a reduction of systematic errors leading to a significant improvement of the sensitivity
  - ▶ planning to use the same benchmark models (UFO full compatibility Whizard 2.8.2/3)
  - ▶ results will be made public when ready