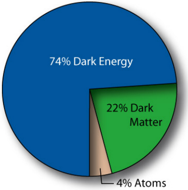

Mono-Photon WIMP prospects at the ILC from $\sqrt{s}$=250 GeV to 1 TeV

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DESY

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Universität Hamburg
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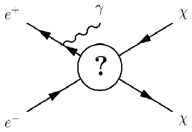
DESY

Mono-Photon WIMP prospects at the ILC from $\sqrt{s} = 250$ GeV to 1 TeV

- Introduction
- Extrapolation of results at 500 GeV to different $\sqrt{s}$, L, polarisation configurations
- Influence of beamspectrum
- Summary and Outlook

Motivation

- **W**eakly **I**nteracting **M**assive **P**articles (WIMPs, χ)
  - Dark Matter Candidate
- Collider Search
  - idea: SM particles $\rightarrow$ pair production of WIMPs
  - ILC: $e^+e^- \rightarrow \chi\chi$



- WIMPs not visible in detector
- Tag particle needed: Mono-X search (**photon**, gluon,...)
- Initial State Radiation (ISR) $\rightarrow$ quasi model-independent / general approach

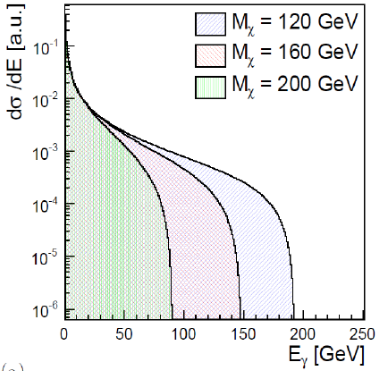
Signal: single photon in an "empty" detector: $\gamma + \not{E}$

Observables

- E_γ, θ_γ
- shape information is used
- E_γ has a maximum
  - rest is carried away by WIMPs
  - depend on M_χ and $\sqrt{s}$

$$E_\gamma = \frac{\sqrt{s}}{2}\left(1 - \frac{4M_\chi^2}{(\sqrt{s})^2}\right)$$

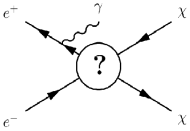
  - well defined initial state needed
  - clean environment
    $\Rightarrow$ ILC



(a)

C.Bartels

Analysis Setup



- $1 \text{ GeV} \leq M_\chi < \sqrt{s}/2$
- Signal events (radiative WIMP pair production, $\chi\chi\gamma$)
  - $\nu\nu\gamma$ cannot be distinguished on an event-by-event basis
  - Idea: use $\nu\nu\gamma$ and reweigh: $w = \frac{d\sigma_{\nu\nu\gamma}}{d\sigma_{\chi\chi\gamma}}$
- Effective operator approach
  - $M_{mediator} \gg \sqrt{s}$
    $\Rightarrow$ interaction can be described by a few parameters
  - Λ: energy scale of new physics ($\sigma \propto 1/\Lambda^4$)
  - types of mediator: vector, axial-vector,...

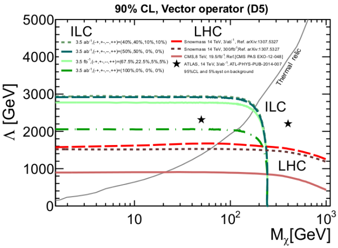
$$\frac{d^2\sigma}{dz d\cos\theta} \approx \frac{\alpha}{12\pi^2}\frac{s}{\Lambda^4}\frac{1}{z\sin^2\theta}(1-z)[4(1-z)+z^2(1+\cos^2\theta)]$$

Chae and Perelstein 2013

$$(z = \frac{2E_\gamma}{\sqrt{s}},\ M_\chi \ll \sqrt{s})$$

Status

- Geant4 based full detector analysis (C.Bartels)
  - EPJC arXiv1206.6639
    - Whizard 1.96
    - beam parameters: RDR
    - ilcsoft v01-06
    - detector models: LDC_PrimeSc_02, ILD_00
  - $\sqrt{s}$ **= 500 GeV**
  - relevant SM mono-photon background processes
  - Bhabha scattering, pairs from beam-beam interaction

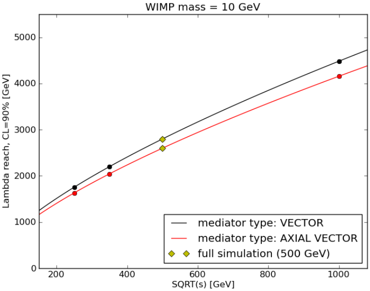


- What about other $\sqrt{s}$, $\int L$, polarisation configurations ?
  $\Rightarrow$ extrapolation of reachable Λ
- influence of luminosity spectrum

Strategy for an extrapolation of Λ^{reach}

- find approximation $\Lambda \sim F(S, B)$
  - S: # signal events, B: # background events
  - these are a function of $\sqrt{s}$, $\int$L and polarisation configuration
- change of sensitivity: $\Lambda^{reach,CL} = \Lambda_0^{reach,CL} \frac{F(S,B)}{F(S_0,B_0)}$
- energy dependence of
  - signal: $S = \sigma_S \cdot \int L \cdot \epsilon$
    $\Rightarrow$ analytical formala for $\frac{d^2\sigma_{pol}}{dzd\cos\theta}(\sqrt{s}, \Lambda)$ with $\sigma \sim 1/\Lambda^4$
  - background: $B = \sigma_B \cdot \int L \cdot \epsilon$
    $\Rightarrow \sigma_B$ calculated with WHIZARD
    main contributions: $\nu\nu\gamma$, $e^+e^-\gamma$
- change of sensitivity: $\Lambda^{reach,CL} = \Lambda_0^{reach,CL} \frac{F(\sqrt{s},\int L,pol)}{F(\sqrt{s_0},\int L_0,pol_0)}$

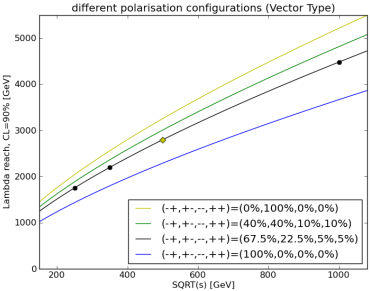
Λ^{reach} at different center-of-mass energies



- accessible Λ rises with energy ($=\sigma$ becomes smaller)
- assumptions:
  - polarisation configuration: (-+,+-,- -,++) = (67.5%,22.5%,5%,5%)
  - $\int L \propto \sqrt{s}$ (e.g. at $\sqrt{s} = 500$: $\int$ L = 500 fb^{-1})
- vector (axial-vector) mediator only possible for LR,RL (LL,RR) $\Rightarrow \Lambda^{reach}_{vector} > \Lambda^{reach}_{axial-v}$

Λ^{reach} for different polarisation configurations

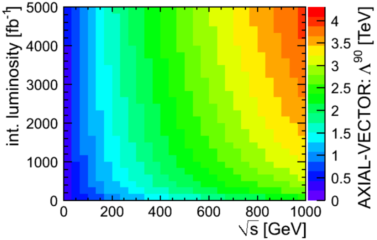
- mediator type: vector
- e^- 80% polarised, e^+ 30% polarised

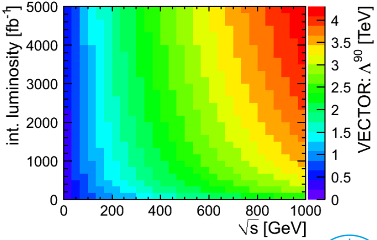


- signal and background depend on polarisation of electron and positron
  - Vector: only possible for LR, RL
  - Background: suppressed for RL
- crucial part is RL
- best case: (-+,+-,- -,++) = (0%,100%,0%,0%)
- extrapolation of $\int L_{RL}$ only

Λ^{reach} at different $\sqrt{s}$ and integrated luminosities

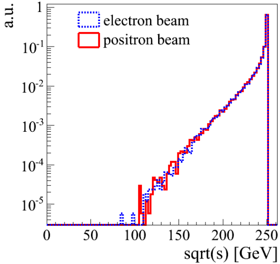
- for (-+,+-,- -,++) = (67.5%,22.5%,5%,5%)
  $\Rightarrow \Lambda^{reach}_{vector} > \Lambda^{reach}_{axial-v}$
- allows to give estimates for Λ^{reach}
  - for different time scales
  (- for different running scenarios)
- e.g.: after 4 years (500 fb^{-1} at $\sqrt{s}$=250 GeV: $\Lambda^{reach} \approx 1.5$ TeV

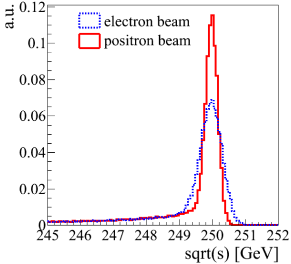




Influence of Beamspectrum

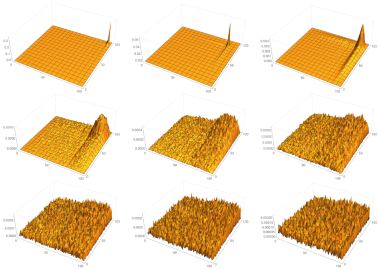
- DBD beamspectrum
- generated with GuineaPig





Parametrization in WHIZARD: CIRCE2

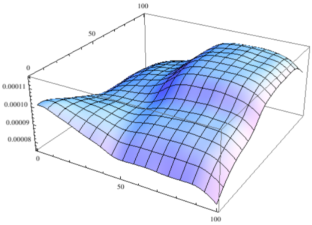
- 2D grid: electrons and positrion distributions depend on each other (100 x 100 bins)
- bin size is adapted to variance
  $\Rightarrow$ descibes well part around nominal beam energy
  $\Rightarrow$ huge bins in tail

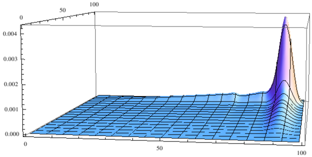


Two different beamspectrum parametrizations

- 20 GuineaPig lumi files ⇒ 3.5 million pairs of e^+e^-
- 100 x 100 bins
- one describes the peak well, the other one the tail

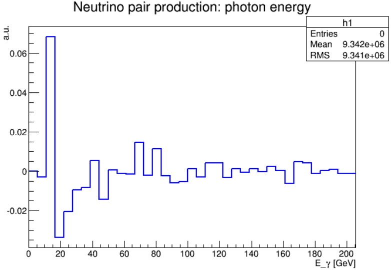
CIRCE2 options	**PEAK**	**TAIL**
iterations	10	2
smooth	5	1





Influence of beamspectrum

- $\nu\nu\gamma$
- two test samples, using the two parametrizations of the beam spectrum
- rough estimation of the influence of the beamspectrum: subtract the distributions of E_γ



preliminary !!!

- huge effect at low energies (6%)
- mc level
- small statistics

Summary

- WIMP search with a general approach: mono-photon (ISR)
- Effective operator approach
  - Λ: suppression scale
  - full simulation at 500 GeV
- extrapolation of reachable Λ for different running scenarios:
  - full ILC energy range (250 GeV - 1 TeV)
  - integrated luminosities
  - polarisation configurations
    (background suppression more important than signal enhancement)
- Crucial to understand luminosity spectrum

Thank you !