Modelindependent WIMP Searches at the ILC

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DESY

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Model-independent WIMP searches

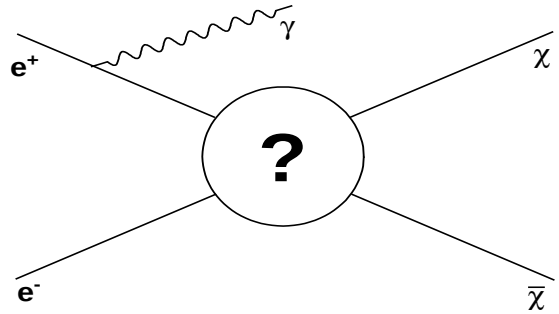
study:

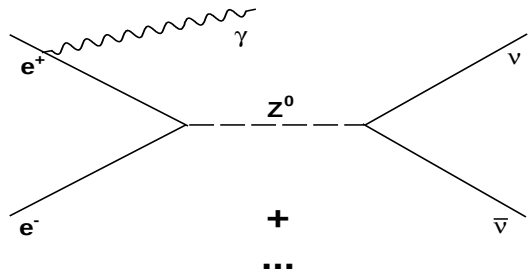
- sensitivity
- mass resolution
- benefits of beam polarisation

... with full detector simulation!

using:

- WIMP pair production with ISR: $e^+e^- \rightarrow \chi\bar{\chi}\gamma$
- main background process: $e^+e^- \rightarrow \nu\bar{\nu}\gamma$





A Model-independent Approach

A. Birkedal et al. [hep-ph/0403004]

What does model-independent mean?:

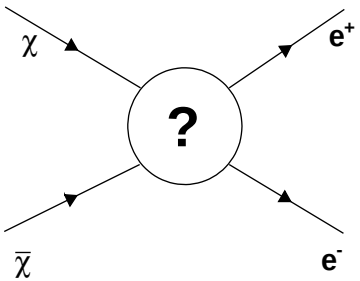
- **No** assumptions on the nature of the WIMP interactions
- Dark Matter consists of only one kind of particle
- WIMP pairs annihilate directly into SM particles $\chi\overline{\chi} \rightarrow X_i\overline{X_i}$ $X_i = e, q, \nu, g, ...$ (no $\tilde{\tau}\tilde{\chi}_1^0$ coannihilation)
- Annihilation cross section σ_{an} determined by Ω_{DM}

A Model-independent Approach

A. Birkedal et al. [hep-ph/0403004]

Cross-section Derivation

- Annihilation cross section σ_{an} determined by Ω_{DM}



A Model-independent Approach

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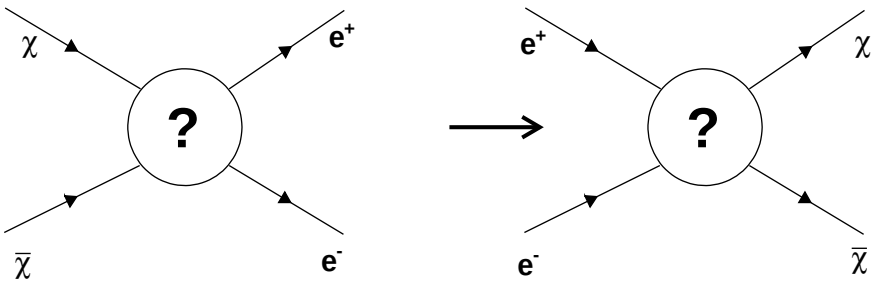
Cross section derivation

- Annihilation cross section σ_{an} determined by Ω_{DM}
- Crossing symmetry: $\sigma_{an} \rightarrow \sigma(e^+e^- \rightarrow \chi\overline{\chi})$



A Model-independent Approach

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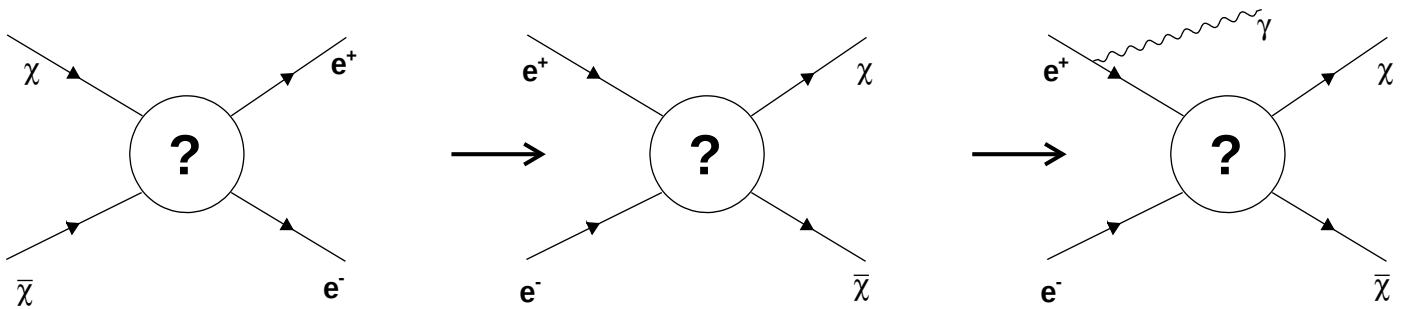
Cross section derivation

- Annihilation cross section σ_{an} determined by Ω_{DM}
- Crossing symmetry: $\sigma_{an} \rightarrow \sigma(e^+e^- \rightarrow \chi\overline{\chi})$
- Inclusion of ISR: $\sigma(e^+e^- \rightarrow \chi\overline{\chi}\gamma)$



A Model-independent Approach

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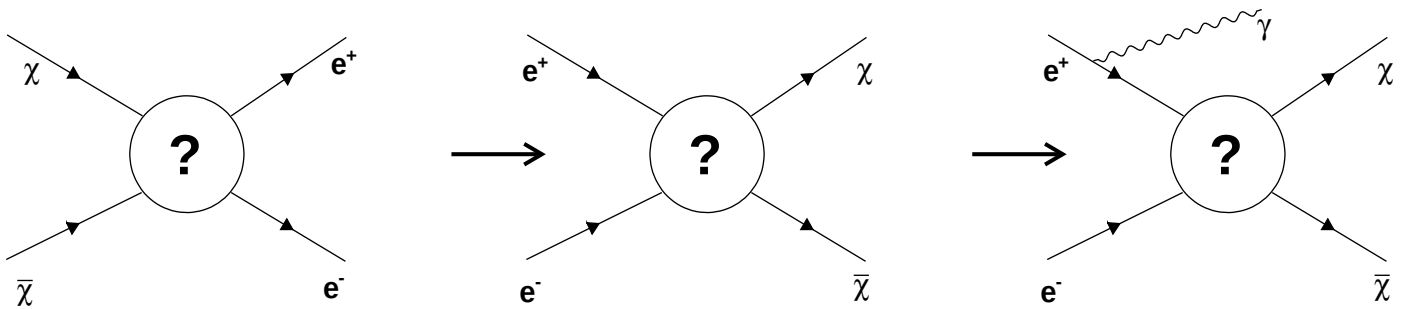
Cross section parameters

- Free:
  - κ_e Fraction of WIMP pair annihilation into e^+e-
  - M_χ WIMP mass
  - S_χ WIMP spin
  - J Angular momentum of dominant partial wave
- From cosmological observation: σ_{an}



Influence of Beam Polarisation

- Main irreducible background: $e^- e^+ \rightarrow \nu\bar{\nu}\gamma$ is strongly suppressed for $e_L^+ e_R^-$
- WIMP couplings to electrons may have different behaviour!

Considered cases for **WIMP** couplings to electrons

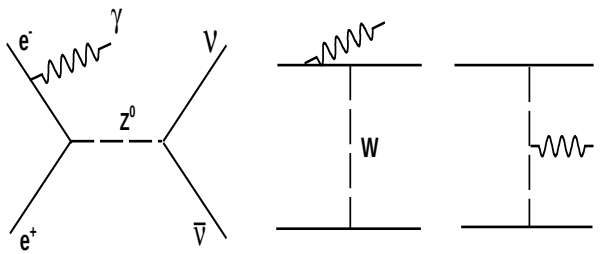
- like SM charged weak interaction $\kappa(e_L^- e_R^+)$
- parity and helicity conserving $\kappa(e_L^- e_R^+) = \kappa(e_R^- e_L^+)$
- opposite SM charged weak interaction $\kappa(e_R^- e_L^+)$

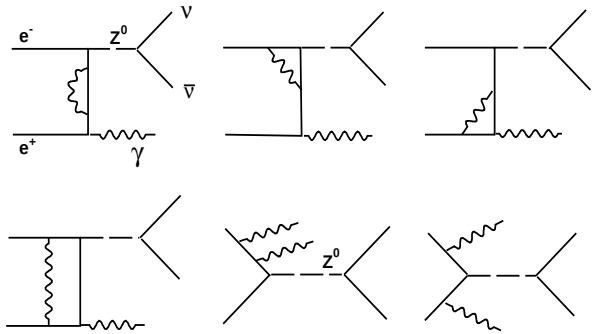
Expect enhancement of S/B ratio by polarisation!

Event Generation

Background:

- NUNUGPV: $e^+e^- \rightarrow \nu\bar{\nu}\gamma(\gamma\gamma)$ (used at LEP2)





- $1.2 \cdot 10^6$ events generated at $\sqrt{s} = 500 GeV$
- At least one photon with 8 GeV $< E_\gamma <$ 250 GeV and $15^o < \Theta_\gamma < 165^o$ in each event

Signal:

- Reweighting background according to WIMP cross section
- Benefit: only one MC production needed

Detector Simulation and Reconstruction

Full GEANT 4 based detector simulation

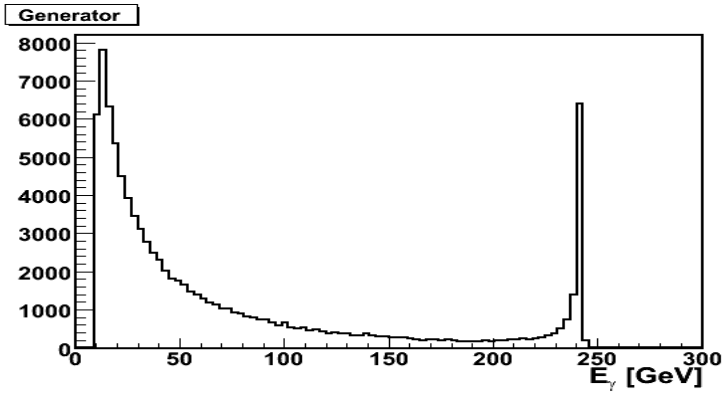
- Large Detector Concept
  - LDC01Sc
  - 4 Tesla magnetic field
- Mokka 6.1

Reconstruction with MarlinReco

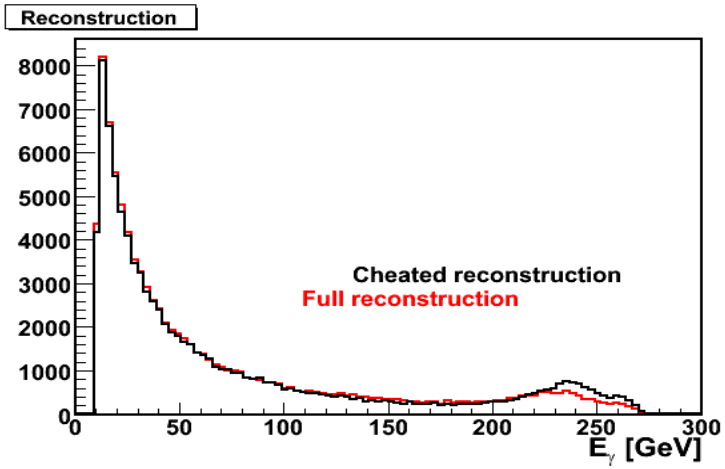
- Particle Flow as implemented in WOLF algorithm
- require:
  - $E_\gamma > 10$ GeV
  - $20^\circ < \theta_\gamma < 160^\circ$
  - for resolution studies: angular match to generated photon

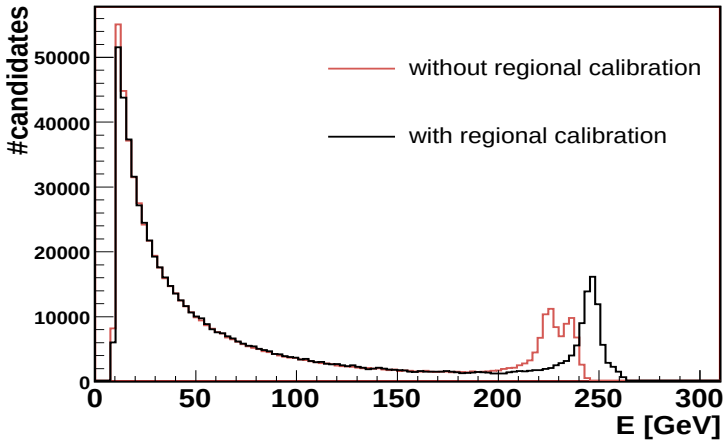
Photon Energy Spectrum

Generator level:



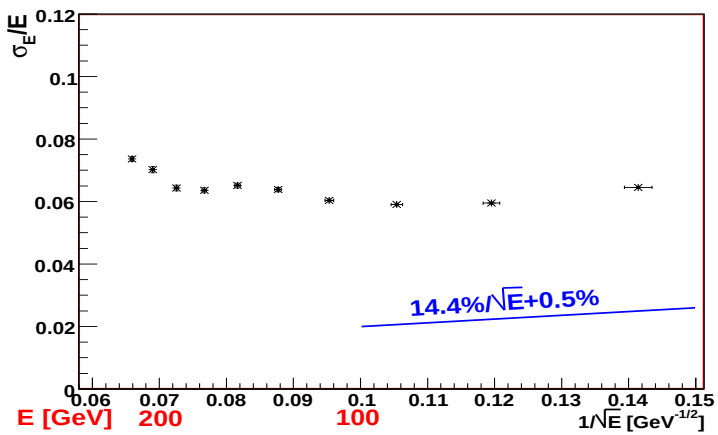
Full reconstruction old vs new:

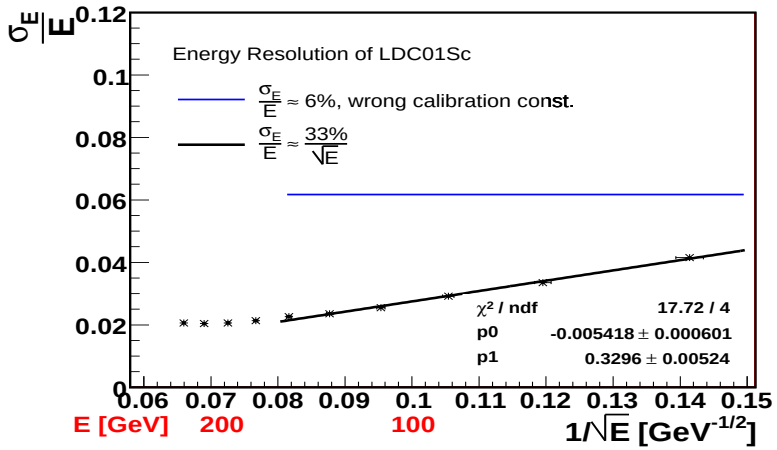




- Difference: bug fix plus „regional“ calibration (endcap/barrel)

Improved Energy Resolution





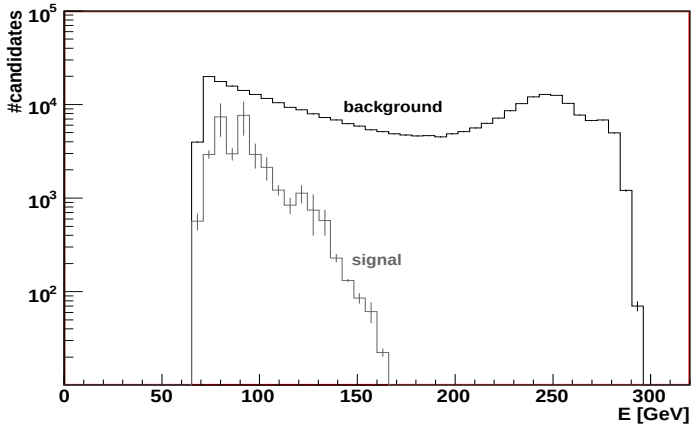
- with new calibration significantly better resolution $\Rightarrow$ better sensitivity
- remaining difference to design goal vanishes when looking at particle gun events in Mokka 6.4
- leads to less migration from kinematic region of relativistic WIMP production into signal region $\Rightarrow$ „less“sensitivity

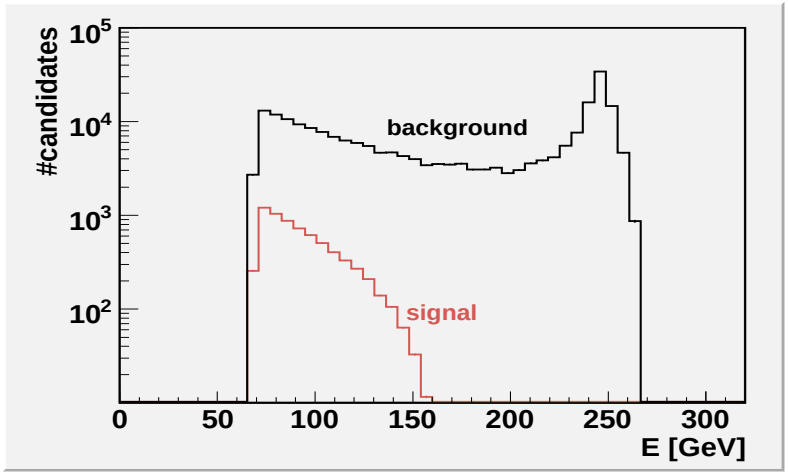
Inputs for Sensitivity Determination

WIMP:

- P-wave annihilator (J=1)
- $M_\chi = 150$ GeV
- $S_\chi = 1$
- $\kappa_e = 0.3$

technical problem with weights fixed $\Rightarrow$ less fluctuations in signal





Sensitivity

Reach for 3σ observation with $\int Ldt = 500 fb^{-1}$

- Method: fractional event counting implemented in ROOT::TLimit
- WIMP spin
  - **TODAY:** P-wave (J=1), $S_\chi = 1$ WIMP
  - not yet: P-wave (J=1), $S_\chi = \frac{1}{2}$ WIMP
- WIMP couplings
  - not yet: coupling to e^-_L and e^+_R
  - not yet: coupling to e^-_R and e^+_L
  - **TODAY:** parity and helicity conserving couplings
- Polarisation
  - unpolarised beams
  - e^- polarisation only ($P_{e^-} = 0.8$)
  - additional e^+ polarisation ($P_{e^+} = 0.6$)

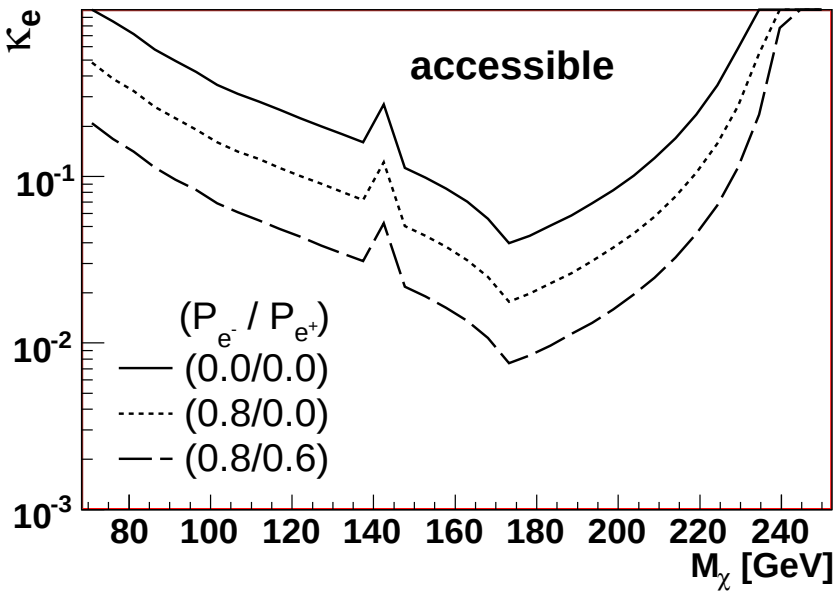
Case 1: P-wave (J=1), $S_\chi = 1$ WIMP

Polarisation:

- **full line:**
  unpolarised beams
- **dotted line:**
  e^- only ($P_{e^-} = 0.8$)
- **dashed line:**
  additional e^+
  ($P_{e^+} = 0.6$)

What's happening at
$M = 140$ GeV?

coupling: P & H conserving



Summary

- Energy resolution significantly improved, expect
  - improved sensitivity through sharper edges
  - worse sensitivity due to reduced migration from relativistic region
- technical problem with weights solved
- new problem at $M = 140$ GeV ?!

Outlook

- Use better photon reconstruction (Pandora, photon finder by P. Krstonosic)
- Include reducible (experimental) backgrounds
- Include beamstrahlung / machine backgrounds
- Move to LDC01Sc_05
- Have a look at SUSY scenarios in which radiative Neutralino production is the only open SUSY channel at the ILC (Started already in cooperation with O. Kittel (Bonn) et al.)