Modelindependent WIMP Searches at the ILC

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DESY

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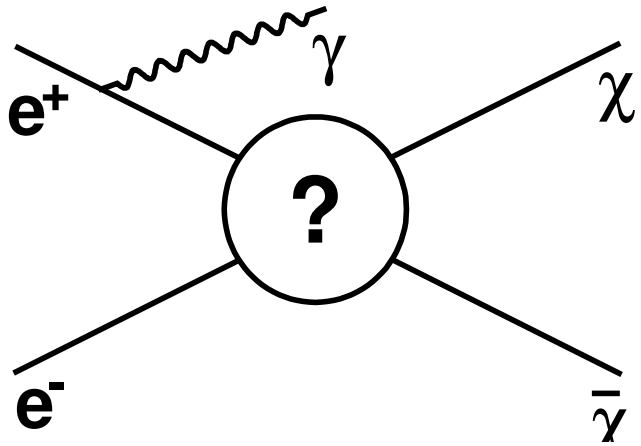
Model-independent WIMP searches

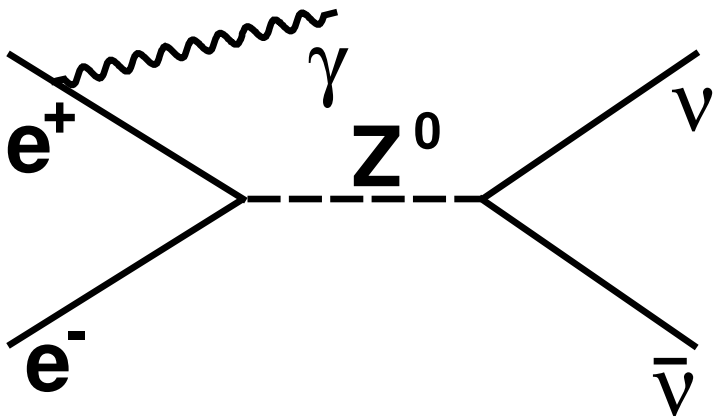
study:

- sensitivity
- mass resolution
- benefits of beam polarisation



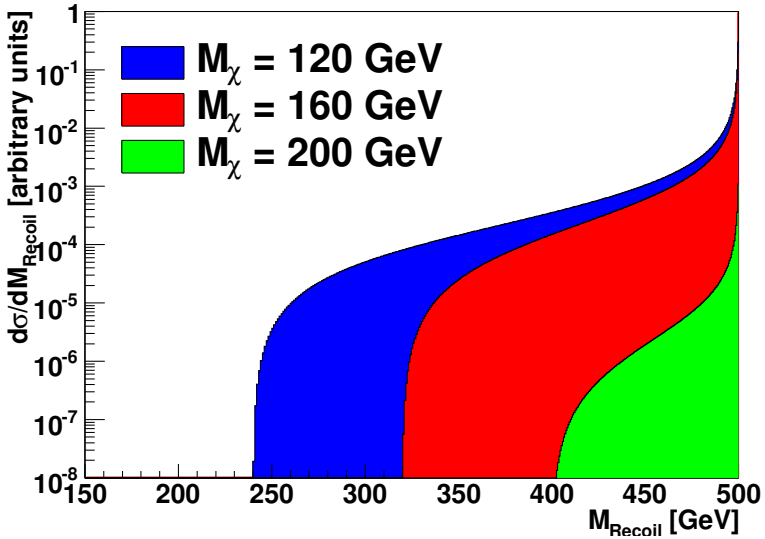
using:

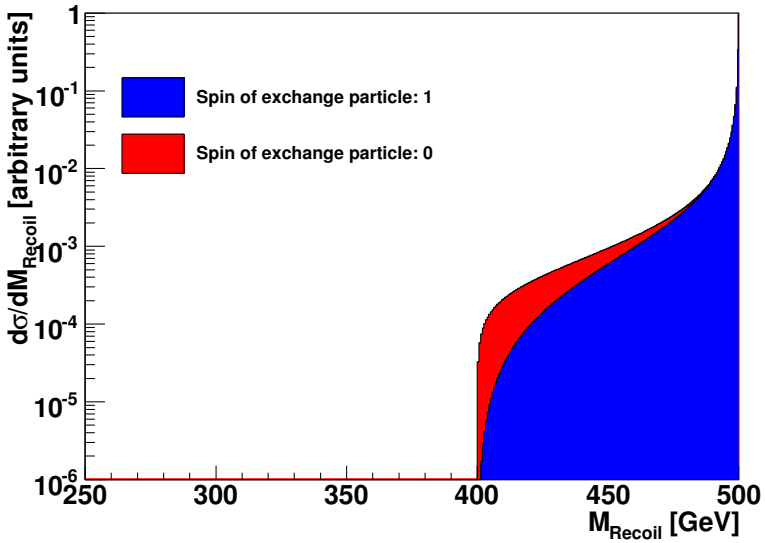
- WIMP pair production with ISR: $e^+e^- \to \chi\bar{\chi}\gamma$
- main background process: $e^+e^- \to \nu\bar{\nu}\gamma$



Analysis principle

- measure photon's energy and polar angle as precise as possible
- energy / recoil mass give sensitivity to
  - observe or exclude this process
  - measure mass
  - maybe get a clue on dominating partial wave in WIMP annihilation?





Generation, Simulation and Reconstruction and all that

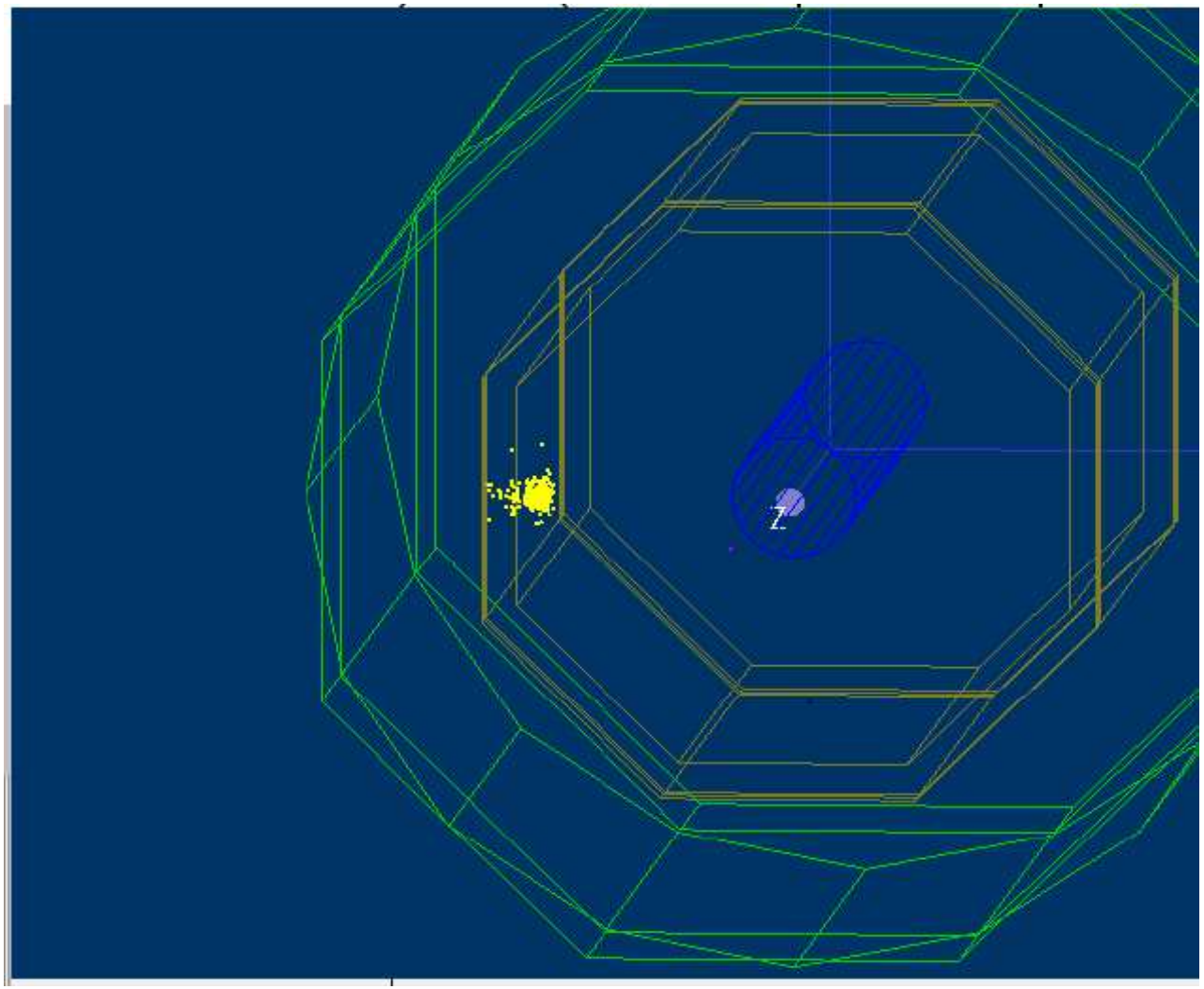
Monte Carlo

- ILD_00 SM DSTs at 500 GeV (today: only missing energy + photon(s) final states)
- signal: reweighting of $\nu\nu\gamma$ process as function of WIMP mass, spin, annihilation partial wave, κ_e= BR($\chi\chi \rightarrow e^+e^-$

Event reconstruction

- Particle Flow: Pandora algorithm
- require at least one photon with
  - $E_\gamma > 10$ GeV
  - $|cos(\theta_\gamma)| < 0.99$
  - for resolution studies: angular match to generated photon
- no tracks

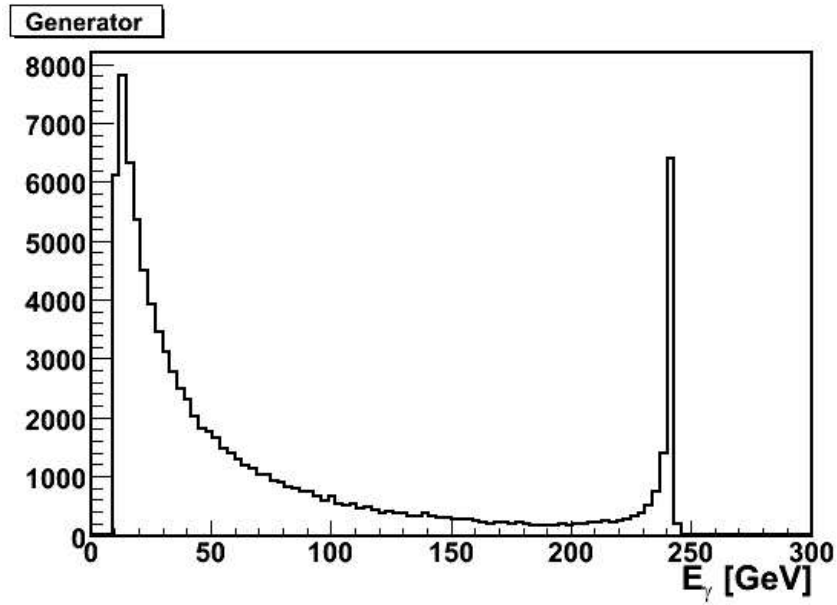
A simulated event

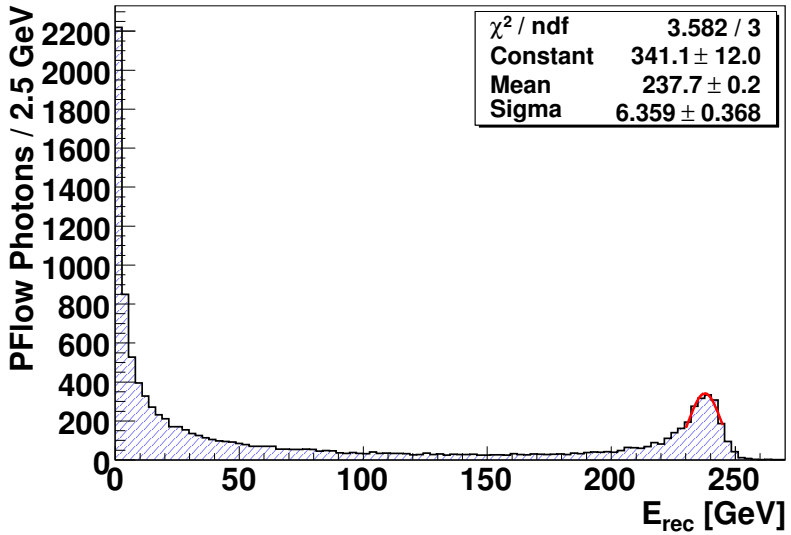


Photon Energy Reconstruction

Energy of most energetic photon

- Z^0-resonance recoil at 240 GeV
  - at generator level...
  - ... and after simulation and reconstruction
- width of reconstructed Z recoil peak 6.4 GeV
- but not out of the box.....

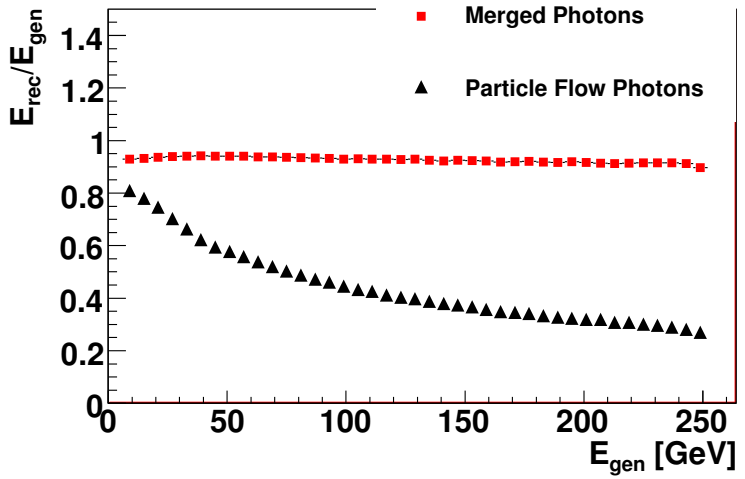




Cluster Splitting

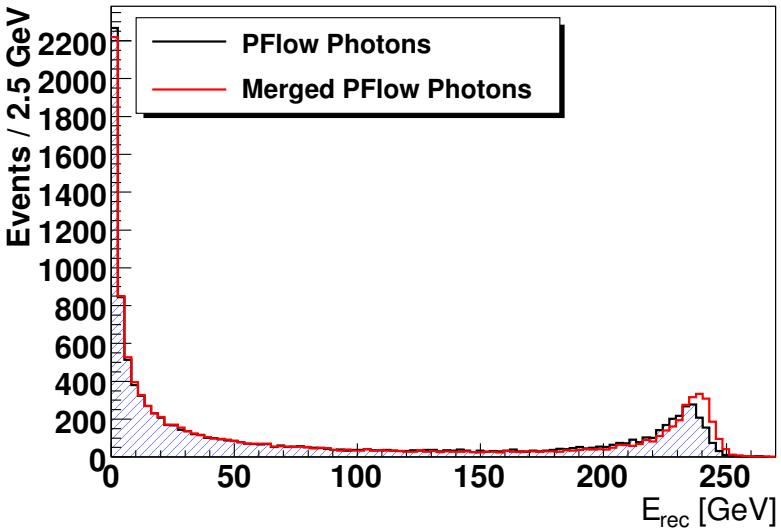
Particle Flow...

- leads to splitting of high energy clusters and identifies them as individual photons
- $\Rightarrow$ Photon deficit at high energies



Merging of photons

- recombine neighboring photons
- $\Rightarrow$ significant improvement at high E_γ



Sensitivity

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

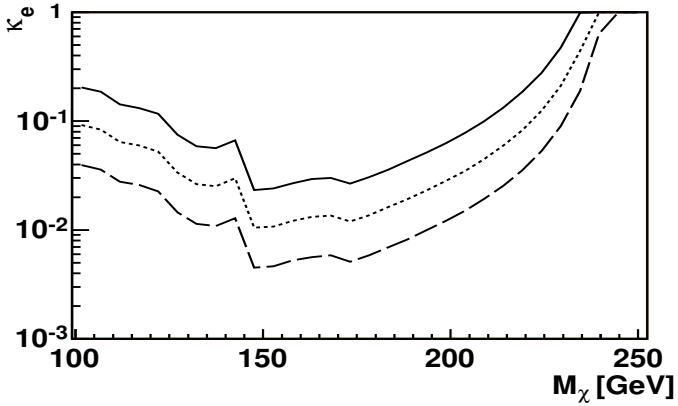
- Method: fractional event counting implemented in ROOT::TLimit
- WIMP spin
  - **Case 1:** P-wave (J=1), $S_\chi = 1$ WIMP
  - **Case 2:** P-wave (J=1), $S_\chi = \frac{1}{2}$ WIMP
- WIMP couplings
  - coupling to e^-_L and e^+_R
  - coupling to e^-_R and e^+_L
  - parity and helicity conserving couplings
- 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

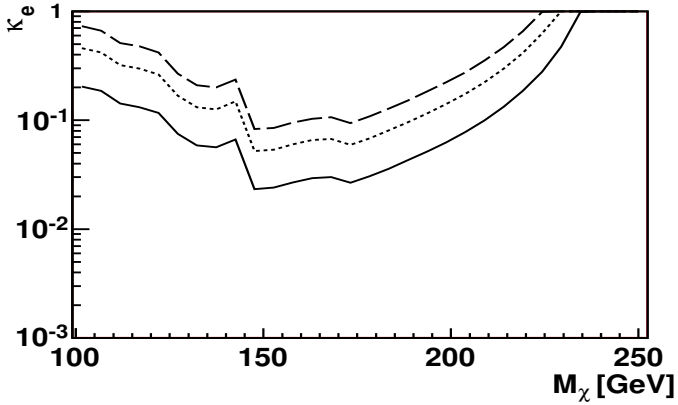
Polarisation:

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

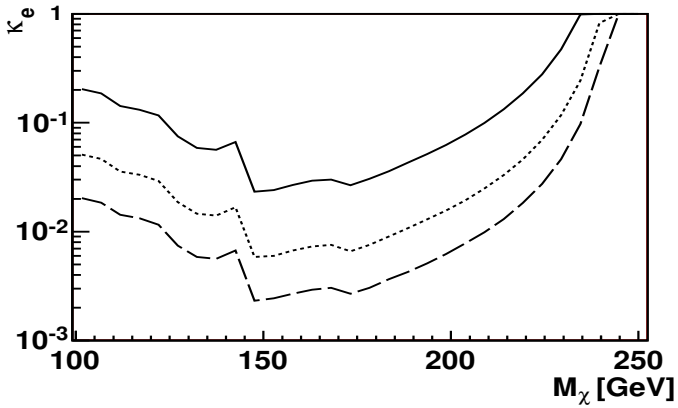
coupling: P & H conserving



coupling: e_L^- / e_R^+



coupling: e_R^- / e_L^+

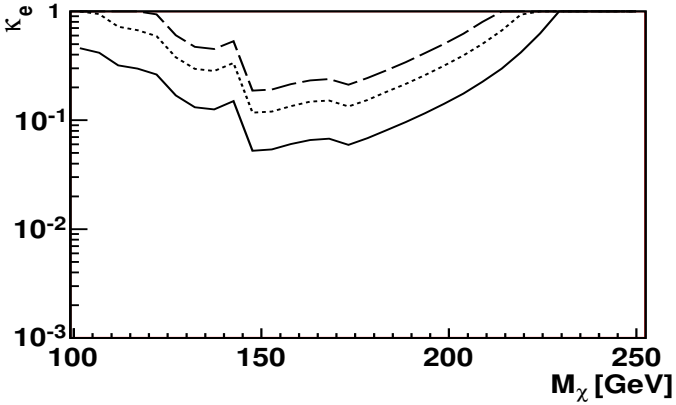


Case 2: P-wave (J=1), $S_\chi = \frac{1}{2}$ WIMP

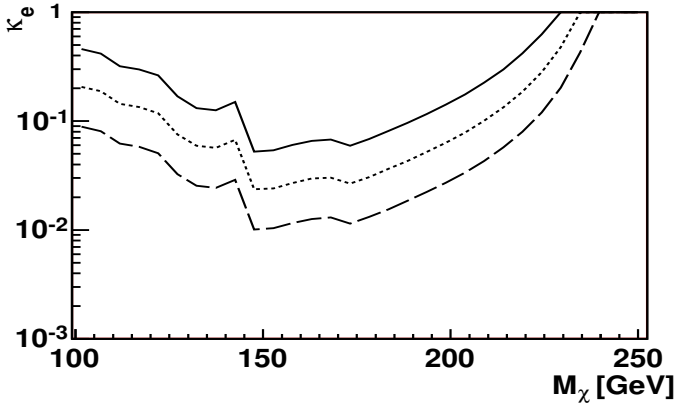
Polarisation:

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

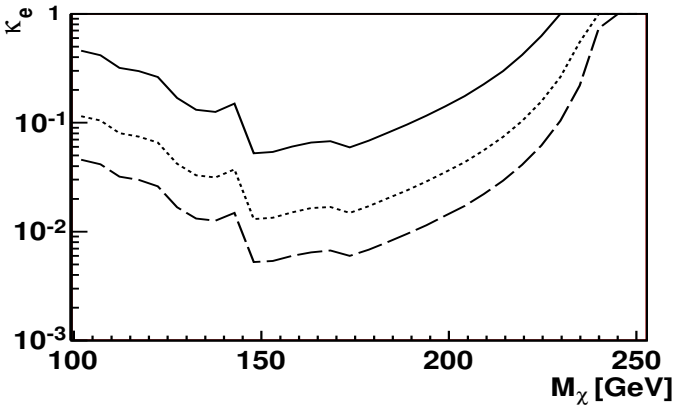
coupling: $e_L^- / \ e_R^+$



coupling: P & H conserving



coupling: $e_R^- / \ e_L^+$



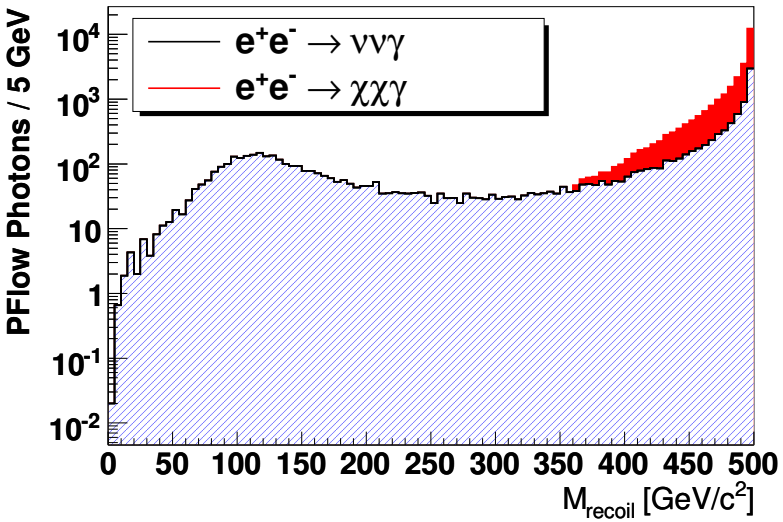
Recoil Mass Spectrum

WIMP:

- P-wave annihilator (J=1)
- $M_\chi = 180$ GeV
- $S_\chi = 1$
- $\kappa_e = 1$

$$M^2_{recoil} = s - 2\sqrt{s}E_\gamma$$

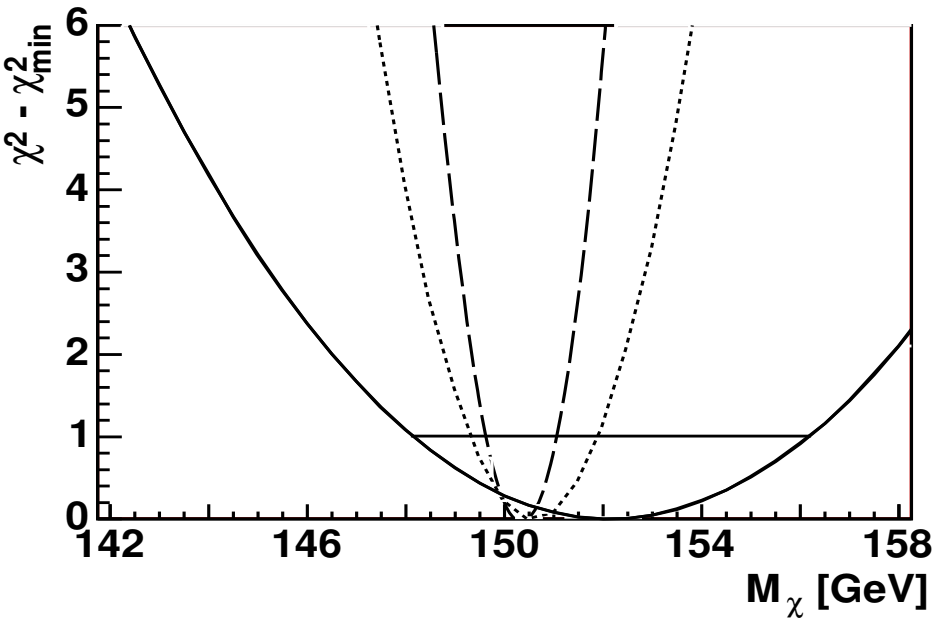
WIMP signal kicks in at $M_{recoil} = 360$ GeV



- for sensitivity calculation, E and θ are used instead of recoil mass
- **the following results have not yet been updated!**

Mass Resolution

- χ^2 test on recoil mass distributions
- $\int Ldt = 200 fb^{-1}$
- again for the three polarisation scenarios



WIMP (Case 1):

- P-wave annihilator (J=1), $S_\chi = 1$
- couplings P & H conversing
- $M_\chi = 150$ GeV
- $\kappa_e = 0.3$

Mass resolution

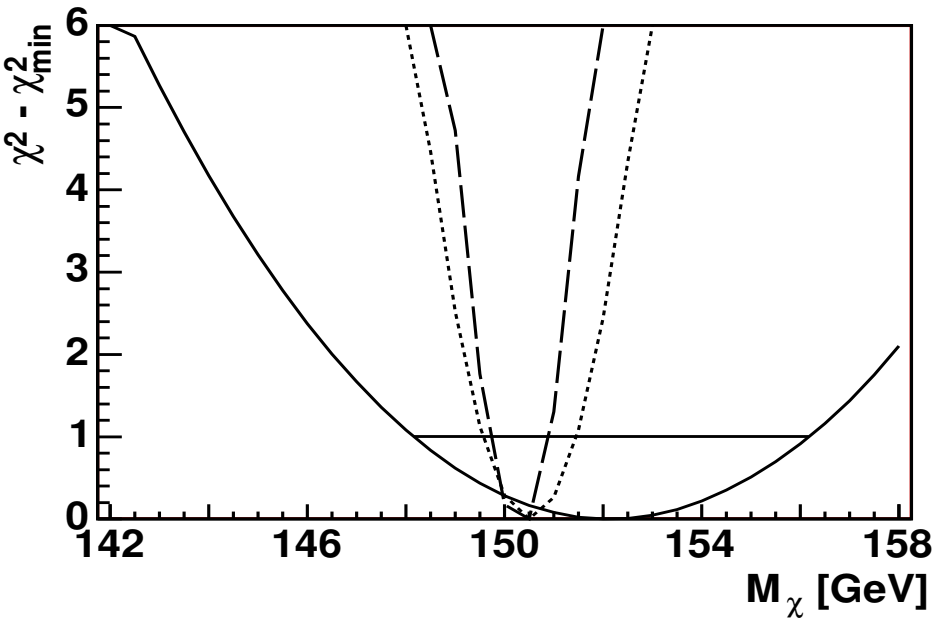
- $P_{e^-} = 0.8, P_{e^+} = 0.0$:

  $M_\chi = 150.5 \pm 1.3$ GeV
- $P_{e^-} = 0.8, P_{e^+} = 0.6$:

  $M_\chi = 150.4 \pm 0.7$ GeV

Mass Resolution

- χ^2 test on recoil mass distributions
- $\int Ldt = 200 fb^{-1}$
- again for the three polarisation scenarios



WIMP (Case 1):

- P-wave annihilator (J=1), $S_\chi = 1$
- couplings: e^-_R / e^+_L
- $M_\chi = 150$ GeV
- $\kappa_e = 0.3$

Mass resolution

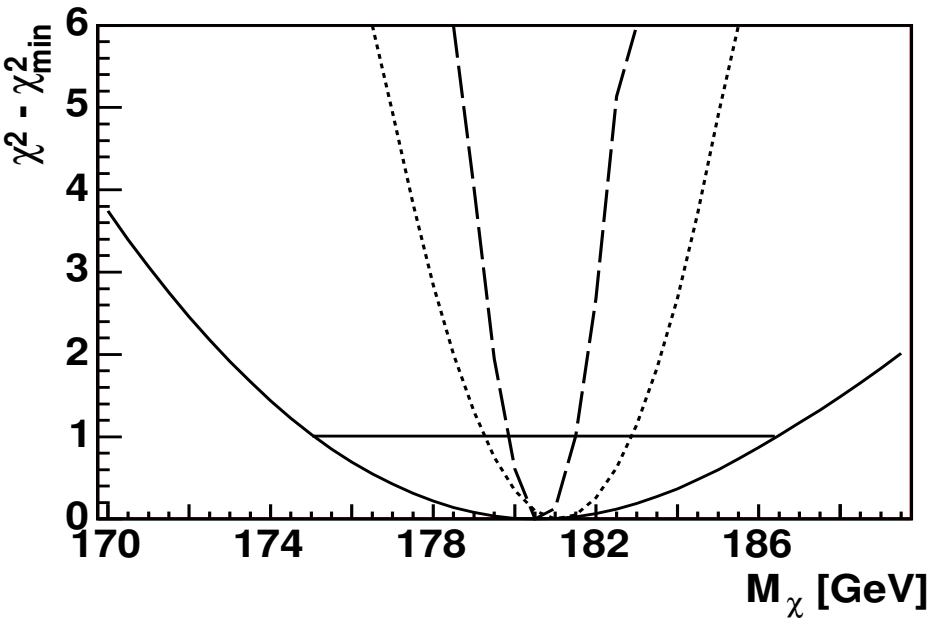
- $P_{e^-} = 0.8, P_{e^+} = 0.0$:

  $M_\chi = 150.5 \pm 1.0$ GeV
- $P_{e^-} = 0.8, P_{e^+} = 0.6$:

  $M_\chi = 150.3 \pm 0.6$ GeV

Mass Resolution

- χ^2 test on recoil mass distributions
- $\int Ldt = 200 fb^{-1}$
- again for the three polarisation scenarios



WIMP (Case 2):

- P-wave annihilator (J=1), $S_\chi = \frac{1}{2}$
- couplings: P & H conserving
- $M_\chi = 180$ GeV
- $\kappa_e = 0.3$

Mass resolution

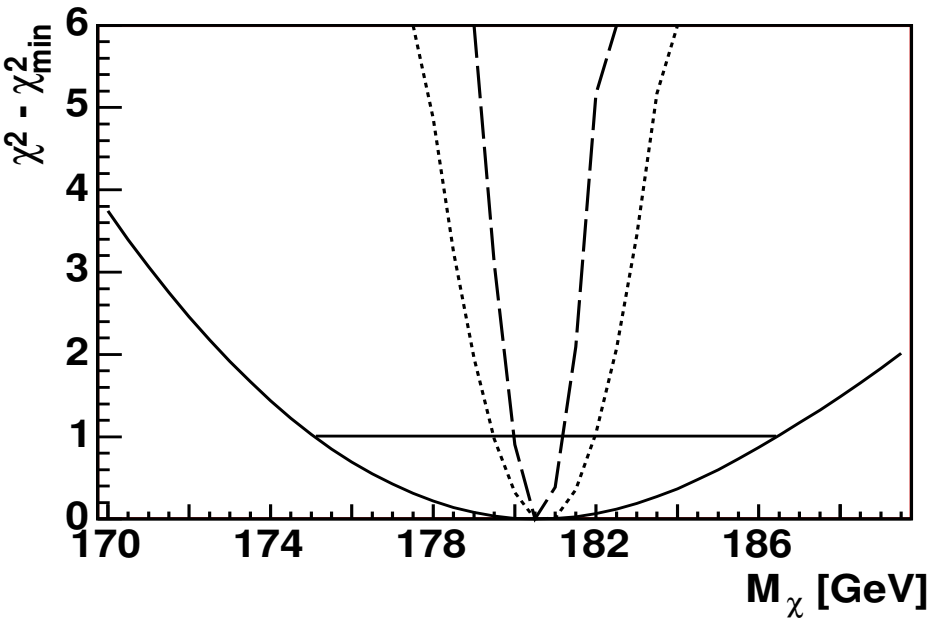
- $P_{e^-} = 0.8, P_{e^+} = 0.0$:

  $M_\chi = 181.0 \pm 1.7$ GeV
- $P_{e^-} = 0.8, P_{e^+} = 0.6$:

  $M_\chi = 180.5 \pm 0.9$ GeV

Mass Resolution

- χ^2 test on recoil mass distributions
- $\int Ldt = 200 fb^{-1}$
- again for the three polarisation scenarios



WIMP (Case 2):

- P-wave annihilator (J=1), $S_\chi = \frac{1}{2}$
- couplings: e^-_R / e^+_L
- $M_\chi = 180$ GeV
- $\kappa_e = 0.3$

Mass resolution

- $P_{e^-} = 0.8, P_{e^+} = 0.0$:

  $M_\chi = 180.7 \pm 1.3$ GeV
- $P_{e^-} = 0.8, P_{e^+} = 0.6$:

  $M_\chi = 180.5 \pm 0.6$ GeV

Benefits Of Beam Polarisation

Benefits

- 80% Polarisation of the e^- beam increases the sensitivity by a factor of 2 to 3
- Additionally 60% e^+ polarisation gives another increase in sensitivity by a factor of 2 as well as in the mass resolution (compared to e^- polarisation)

Summary

- previous analysis (LDC) is being upgraded to ILD_00
- reconstruction improvements
- Good chance of model-independent WIMP detection at ILC
- Beam polarisation enhances significantly the reach as well as the mass resolution
- mass resolutions down to 0.6 GeV (c.f. SUSY LSP mass from cascade decays: about 0.1 GeV)
- Additional e^+ polarisation increases the sensitivity by the same factor as e^- polarisation alone
- first look into new detector model & reconstruction upgrades promisses improved results

Outlook

- finish ILD update of analysis with irreducible backgrounds
- Include reducible backgrounds if time
- write note...