Results from the model-independent WIMP analysis

ILD Meeting @ LAL
May 24, 2011
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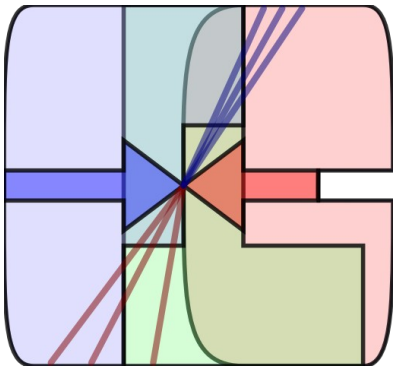
on behalf of C.Bartels



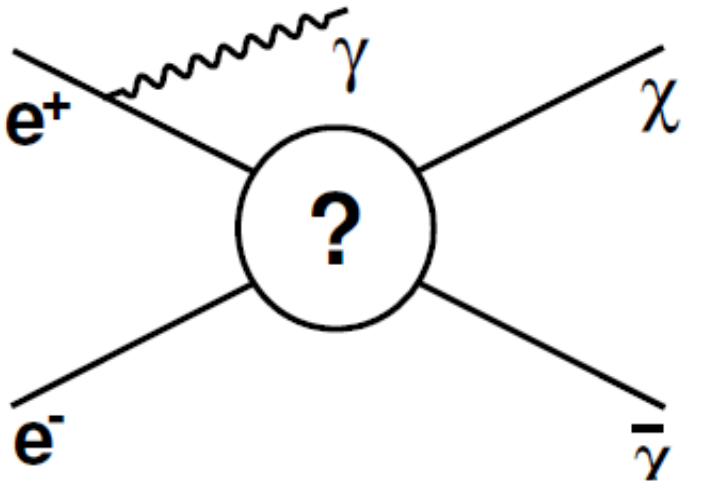
Outline:

- Analysis Principle
- Software & Event Selection
- Results:
  - mass measurement
  - cross-section measurement
- Summary

Model-indpendent WIMPs

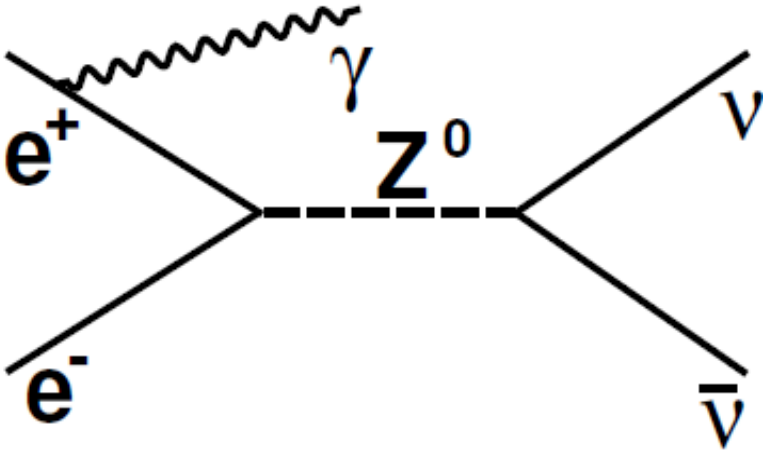
study:

- sensitivity
- mass resolution
- benefits of beam polarisation



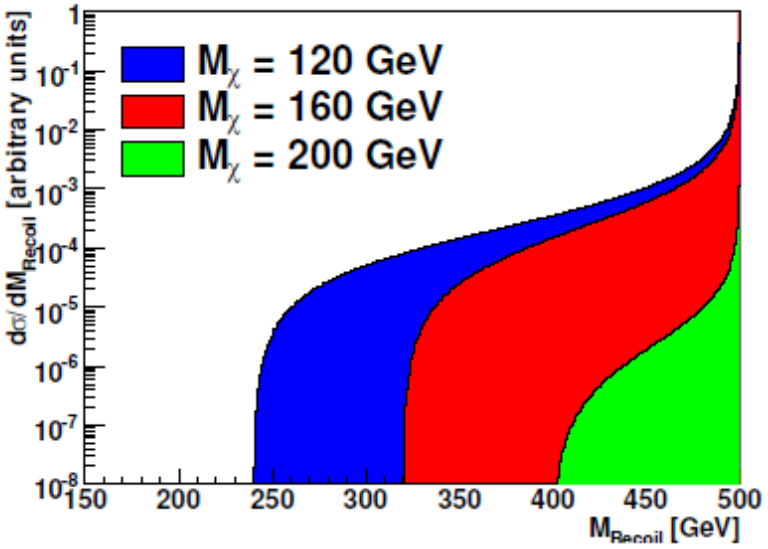
using:

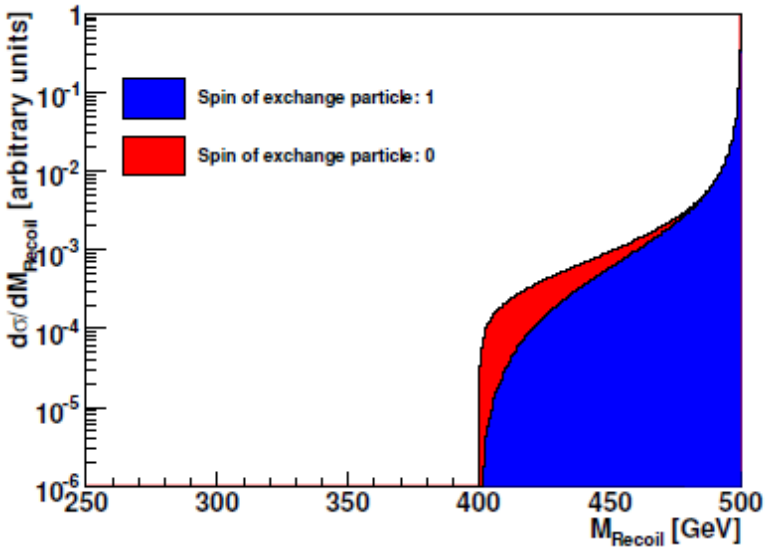
- WIMP pair production with ISR: $e^+e^- \to \chi\bar{\chi}\gamma$
- main background process: $e^+e^- \to \nu\bar{\nu}\gamma$



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?





What has been shown before

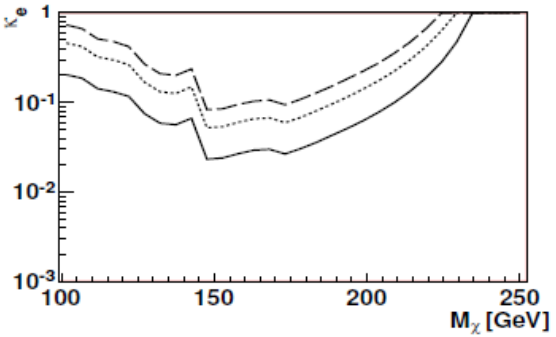
x-section fixed by relic-density → branching fraction to e^+e^- ?

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

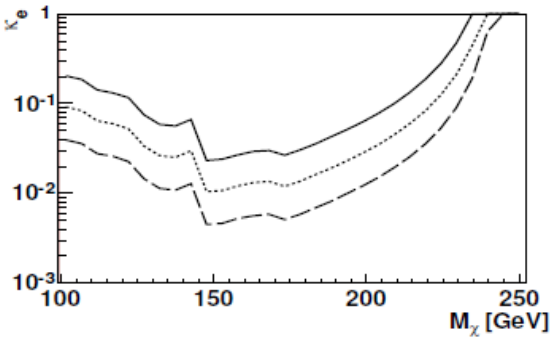
Polarisation:

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

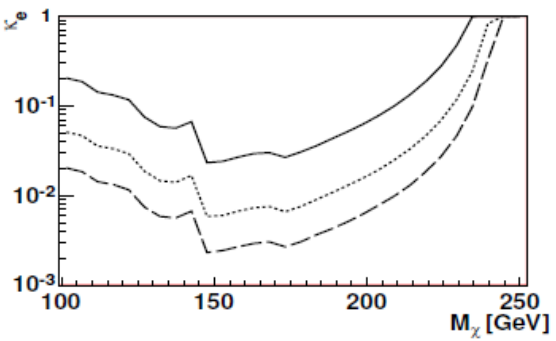
coupling: e_L^- / e_R^+



coupling: P & H conserving



coupling: e_R^- / e_L^+



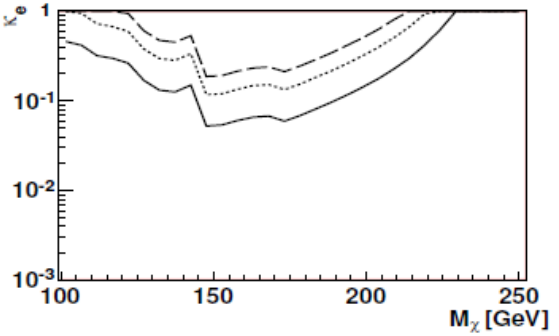
What has been shown before

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

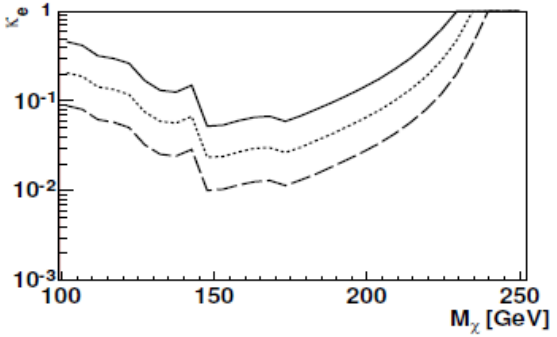
Polarisation:

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

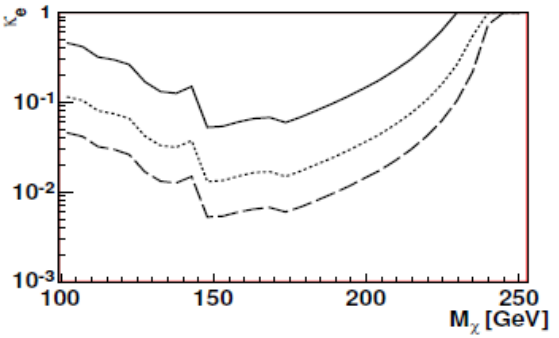
coupling: e_L^- / e_R^+



coupling: P & H conserving



coupling: e_R^- / e_L^+



=> accessable at ILC down to $\kappa_e \approx$ few percent

Generation, Simulation, Reconstruction and all that

Monte Carlo

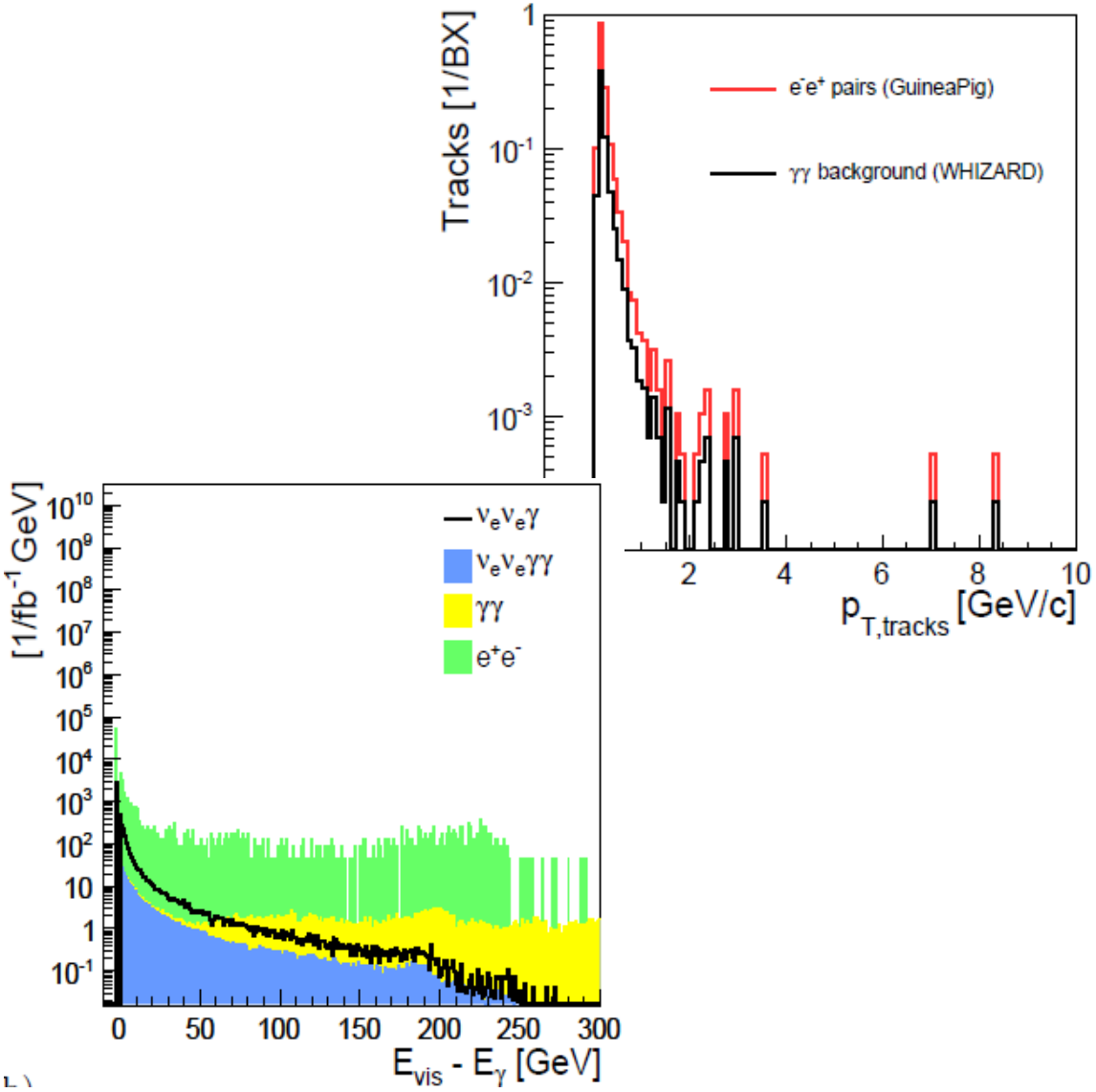
- ILD_00 SM DSTs at 500 GeV
- signal: reweighting of $\nu\nu\gamma$ process as function of WIMP mass, spin, annihilation partial wave, κ_e= BR($\chi\chi \rightarrow e^+e^-$)

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

Event Selection in presence of backgrounds

- for LoI:
  veto *any* additional activity in detector
- new:
  cuts stable against beam background:
  - no track with $p_T > 3$ GeV
  - $E_{vis} - E_\gamma < 20$ GeV
  - no tag in BeamCal



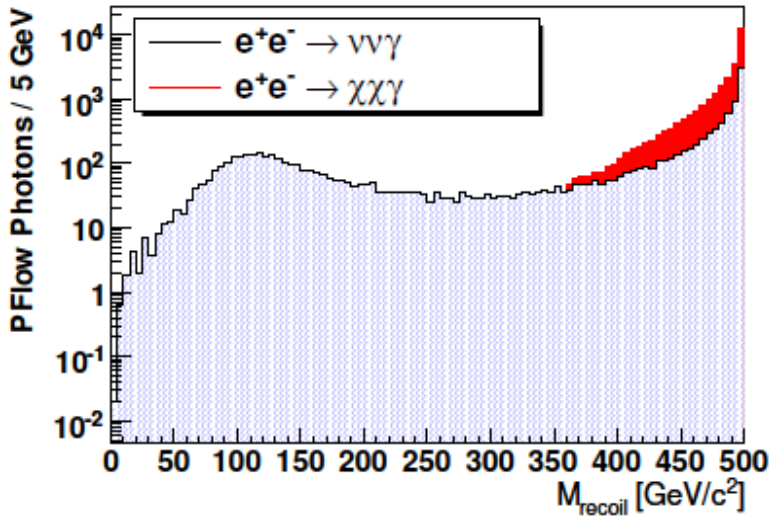
Cut flow (1 fb^{-1})

irreducible!

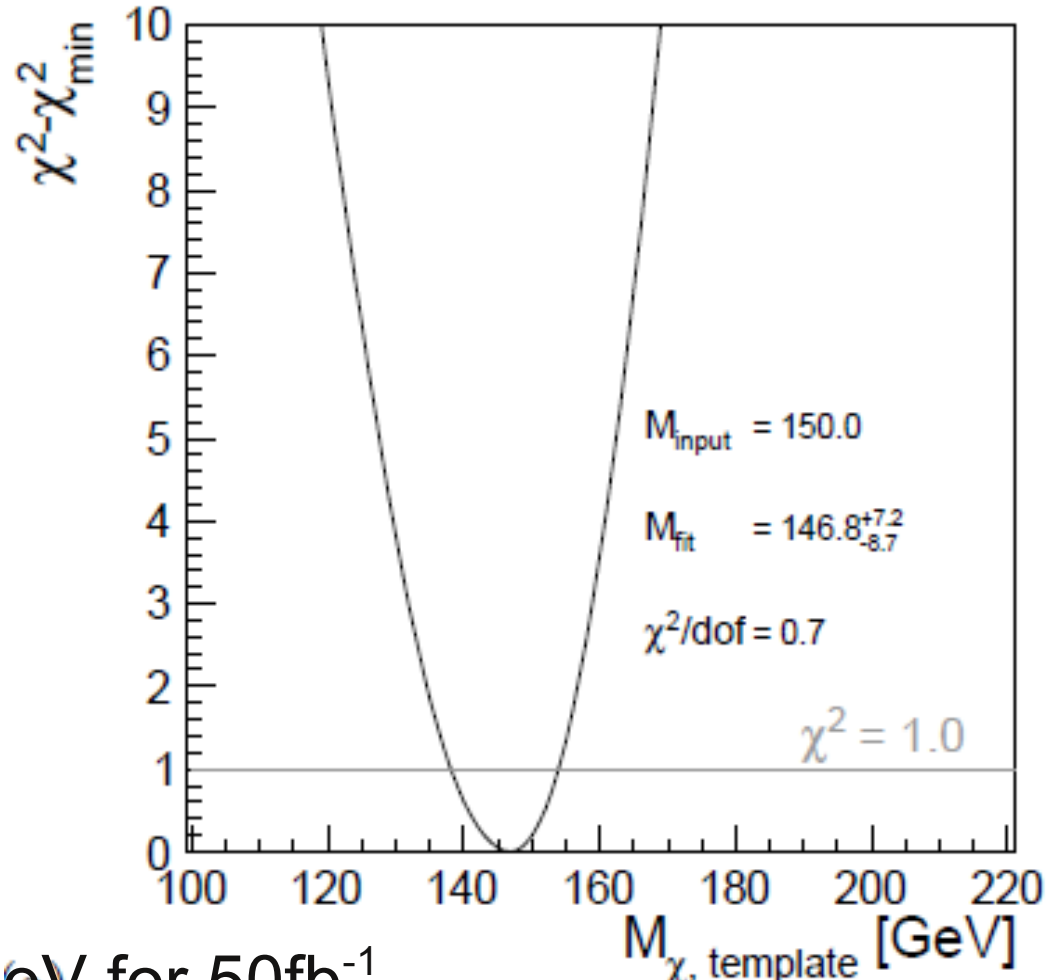
$(P_{e^-}; P_{e^+}) = (0.0; .0.0)$					
Process	simulated	signal def.	$p_{T,track}$	$E_{vis} - E_\gamma$	BeamCal tag
$\nu\nu\gamma$	8101.85	4795.46	4692.25	4429.18	4356.12
$\nu\nu\gamma\gamma$	613.27	344.31	325.44	238.68	228.58
$\nu\nu\gamma\gamma\gamma$	45.32	25.37	23.19	11.82	11.05
$\gamma\gamma$	6497.38	577.76	456.27	60.91	5.77
$\gamma\gamma\gamma$	1079.35	149.97	112.72	4.65	0.10
$\gamma\gamma\gamma\gamma$	97.08	19.50	14.65	0.15	0.03
Bhabha	17383825.0	425800.0	94305.9	71375.4	901.7

High background analysis → systematics will be important!

Mass determination



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



Example: M = 150 GeV,
dom. partial wave J = 1

=> $M_{fit} = 146.8^{+7.2}_{-8.7}$ GeV for 50fb^{-1}

Mass resolutions for 500 fb^{-1}

- **statistics:**
  0.3 % ….4.7 %
  depending on mass, coupling structure and polarisation

"Equal"	$\Delta M/M$ [%]			
Mass	$(P_{e^-}; P_{e^+})$			
	(0.0/0.0)	(0.8/0.0)	(0.8/-0.3)	(0.8/-0.6)
120	4.7	2.5	3.2	3.4
150	3.4	1.8	2.6	2.7
180	2.2	1.2	1.9	2.0
210	0.9	0.5	1.3	1.3

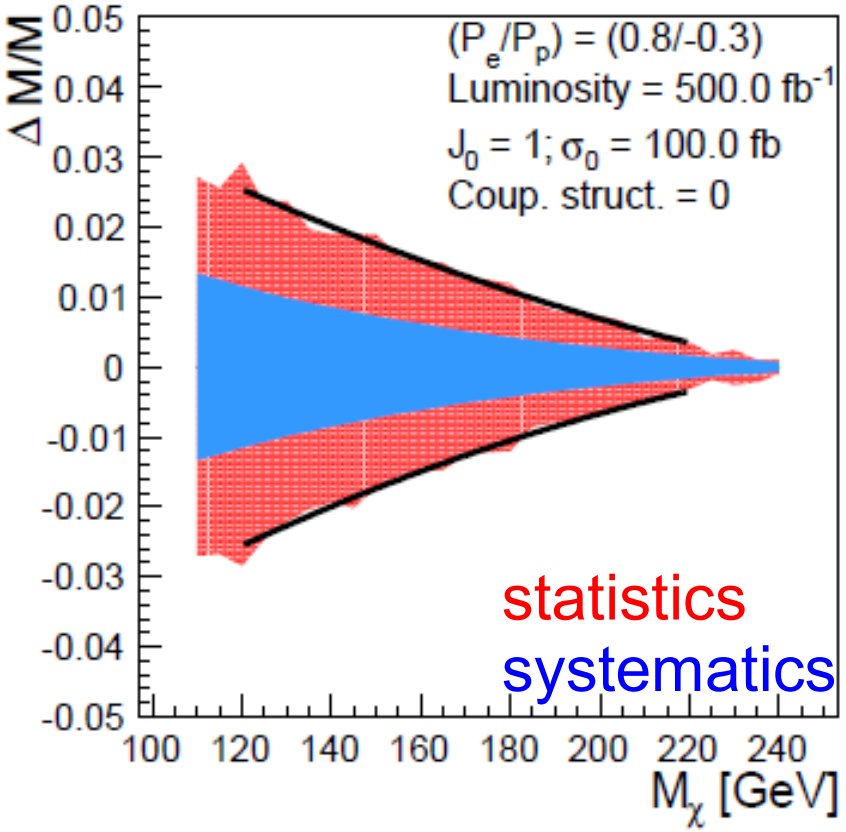
"Helicity"	$\Delta M/M$ [%]			
Mass	$(P_{e^-}; P_{e^+})$			
	(0.0/0.0)	(0.8/0.0)	(0.8/-0.3)	(0.8/-0.6)
120	4.5	2.5	2.5	2.2
150	3.2	1.8	2.0	1.8
180	2.1	1.2	1.5	1.3
210	0.8	0.5	1.0	0.9

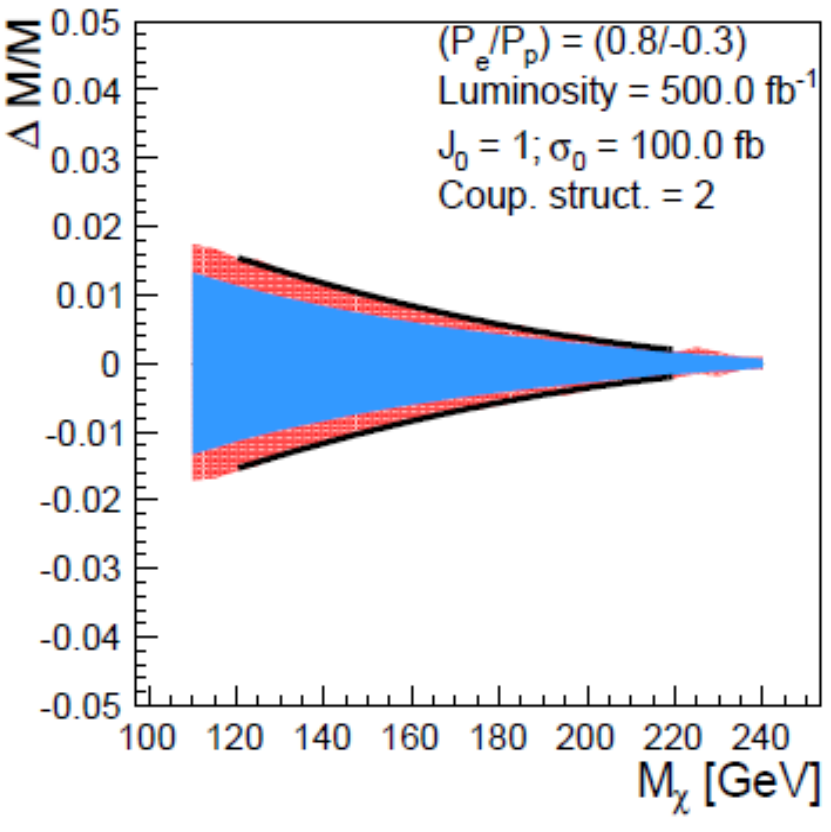
"Anti-SM"	$\Delta M/M$ [%]			
Mass	$(P_{e^-}; P_{e^+})$			
	(0.0/0.0)	(0.8/0.0)	(0.8/-0.3)	(0.8/-0.6)
120	4.5	1.4	1.3	1.1
150	3.3	1.0	1.0	0.9
180	2.0	0.6	0.8	0.7
210	0.8	0.3	0.5	0.4

What about Systematics?

- **systematics:**
  - mean beam energy: monitor from radiative return peak
  - **shape of E_{beam}:** influence estimated from RDR vs SB2009

→ 2.5% (@ 120 GeV)....0.1% (@ 240 GeV)

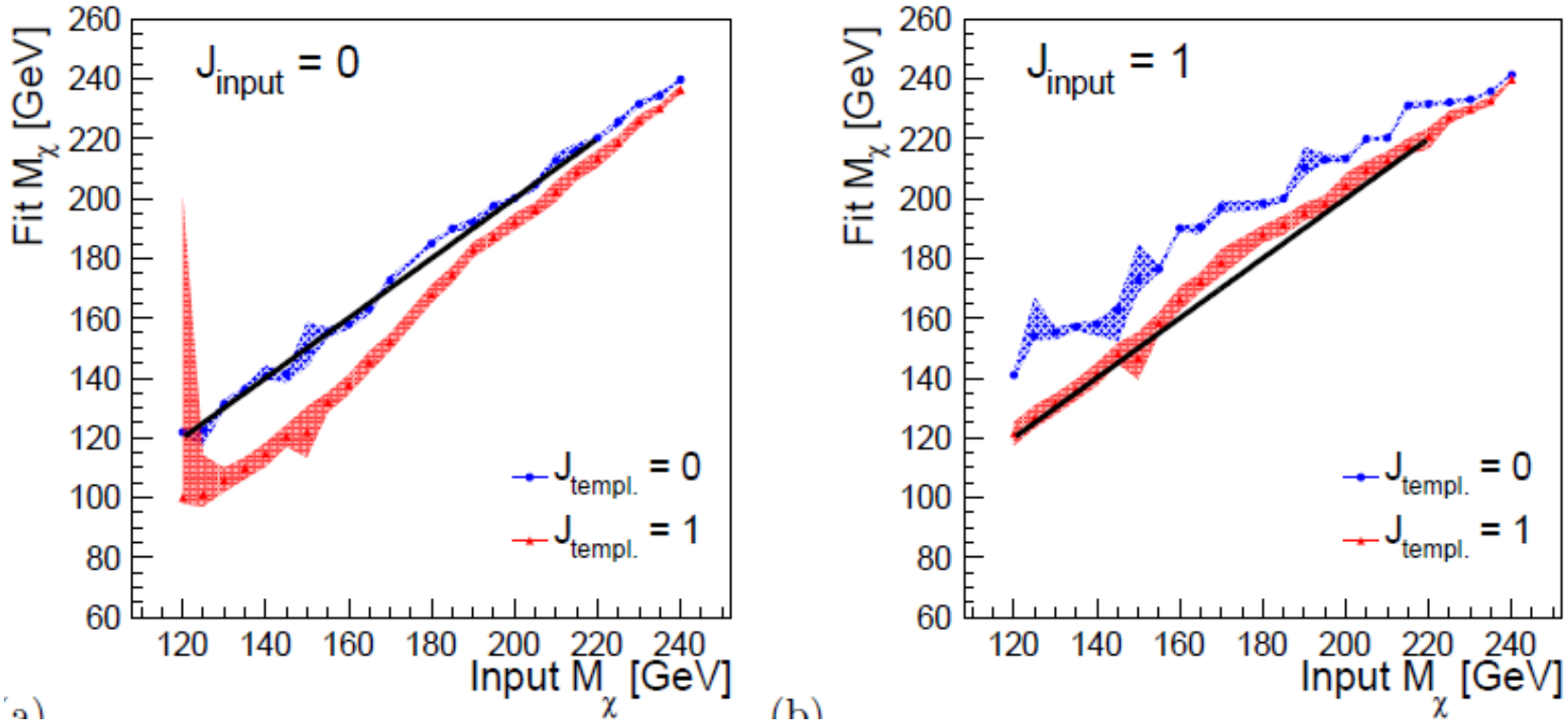




Can we also determine the dominant partial wave?

Wrong J causes shift in mass, but no worse χ^2 ???
→ way too little MC statistics at kinematic edge,
instead sensitive to x-section at high M_{recoil}

→ with more MC: resolve ambiguity, detemine J



Cross-sections

- Measure production cross-section for different beam polarisation combinations
  → figure out helicity structure of SM-WIMP-interaction!
- want to know: σ_{LL}, σ_{LR}, σ_{RR}, σ_{RL},
- measure: σ_{--}, σ_{-+}, σ_{++}, σ_{+-} with e.g. $|P(e^+,e^-)|$ = 30%, 80%
- σ_{--}, σ_{++} are less interesting for other studies
  => assume
  - $200\ \mathrm{fb}^{-1}$ with $(+|P_{e^-}|; -|P_{e^+}|)$
  - $200\ \mathrm{fb}^{-1}$ with $(-|P_{e^-}|; +|P_{e^+}|)$
  - $50\ \mathrm{fb}^{-1}$ with $(+|P_{e^-}|; +|P_{e^+}|)$
  - $50\ \mathrm{fb}^{-1}$ with $(-|P_{e^-}|; -|P_{e^+}|)$

Systematics for cross-section measurement

- calculate σ and statistical error from

$$\sigma_{P_{e^-}P_{e^+}} = \frac{N_D - < N_B >}{\mathcal{L} \times \epsilon} \qquad \Delta\sigma_{P_{e^-}P_{e^+}} = \frac{\sqrt{N_D}}{\mathcal{L} \times \epsilon}$$

$$= \frac{N_D}{\mathcal{L} \times \epsilon} - \sigma_{bg}$$

since S and B indistinguishable on event by event basis!

- => systematics:

$$\delta\sigma^2_{P_{e^-}P_{e^+}} = \delta\sigma^2_{bg} + \frac{\sigma^2_{P_{e^-}P_{e^+}}}{\epsilon^2}\delta\epsilon^2 + \frac{\sigma^2_{P_{e^-}P_{e^+}}}{\mathcal{L}^2}\delta\mathcal{L}^2$$

Dominated by knowledge of polarisation!

Parameter	value	error on σ [fb]
$\delta P/P$	0.25% (0.1%)	8.75 (3.50)
$\delta\epsilon/\epsilon$	1.27%	1.29
$\delta\mathcal{L}/\mathcal{L}$	0.01%	0.01
Total		8.84 (3.73)

Systematics for cross-section measurement

- calculate σ and statistical error from

$$\sigma_{P_{e^-}P_{e^+}} = \frac{N_D - < N_B >}{\mathcal{L} \times \epsilon} \qquad \Delta\sigma_{P_{e^-}P_{e^+}} = \frac{\sqrt{N_D}}{\mathcal{L} \times \epsilon}$$

$$= \frac{N_D}{\mathcal{L} \times \epsilon} - \sigma_{bg}$$

since S and B indistinguishable on event by event basis!

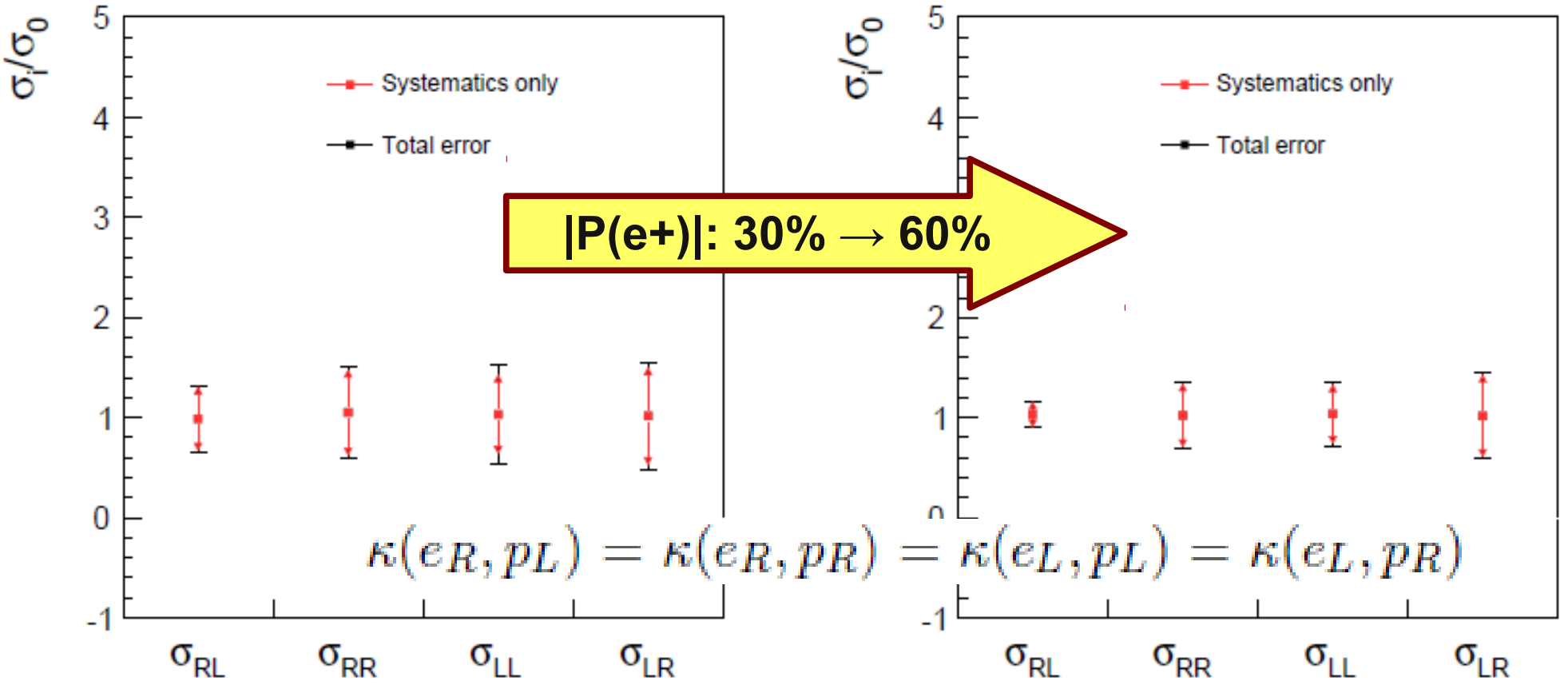
- => systematics:

$$\delta\sigma^2_{P_{e^-}P_{e^+}} = \delta\sigma^2_{bg} + \frac{\sigma^2_{P_{e^-}P_{e^+}}}{\epsilon^2}\delta\epsilon^2 + \frac{\sigma^2_{P_{e^-}P_{e^+}}}{\mathcal{L}^2}\delta\mathcal{L}^2$$

Dominated by knowledge of polarisation!

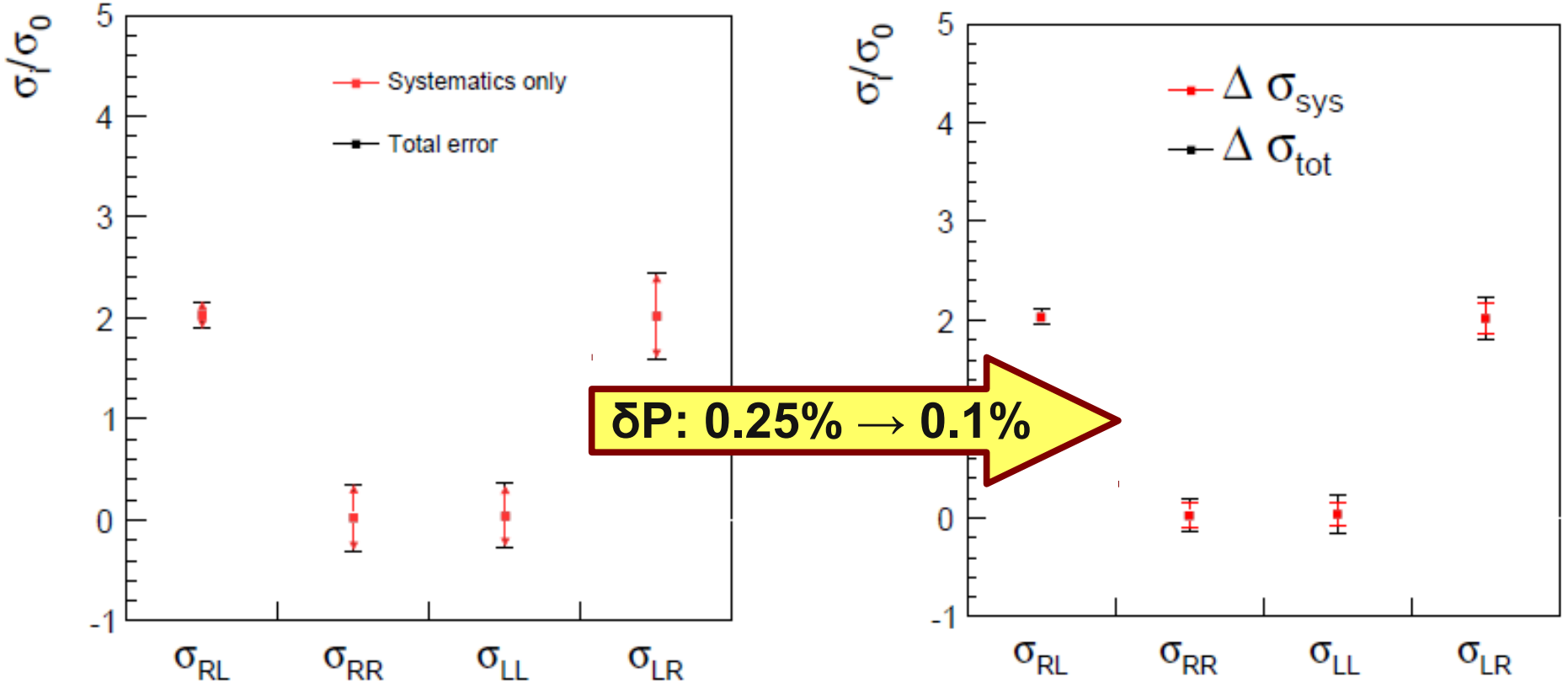
$(P_{e^-}; P_{e^+})$	σ [fb]	$\pm$ stat. [fb]	$\pm$ sys. [fb]	total error [fb]
$(+0.8; -0.3)$	101.3	3.4	8.8	9.5
$(-0.8; +0.3)$	102.3	8.2	18.2	20.0
$(+0.8; +0.3)$	102.9	7.7	16.2	17.9
$(-0.8; -0.3)$	102.6	12.7	12.1	17.5

Extrapolation to σ_{LL}, σ_{LR}, σ_{RR}, σ_{RL}



- systematically limited by polarisation uncertainty for background subtraction
  → **P(e+)|: 30% → 60% doesn't change much.....**

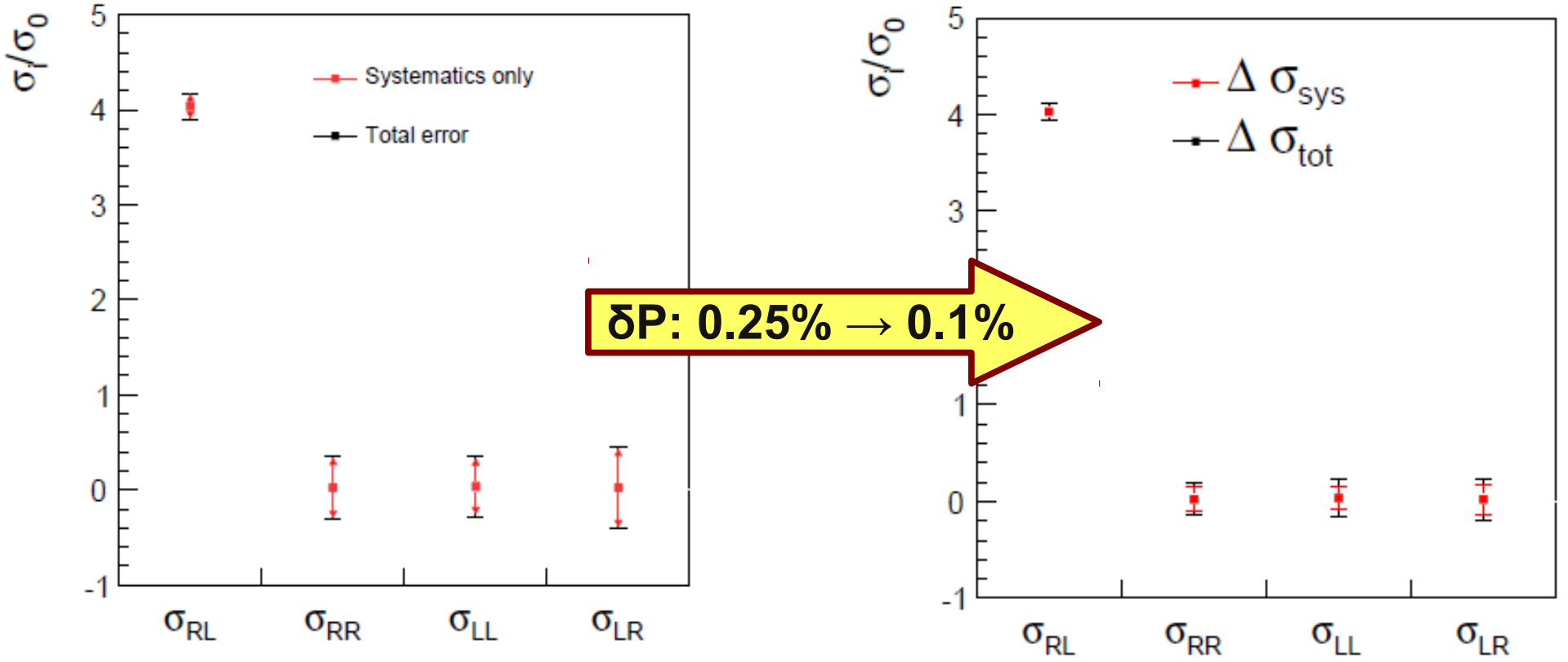
...but δP: 0.25% → 0.1% does!



"Helicity & Parity conserving" scenario

$$\kappa(e_R, p_L) = \kappa(e_L, p_R); \quad \kappa(e_R, p_R) = \kappa(e_L, p_L) = 0$$

...but δP: 0.25% → 0.1% does!



"Anti-SM" scenario

$$\kappa(e_R, p_L);\ \kappa(e_R, p_R) = \kappa(e_L, p_L) = \kappa(e_L, p_R) = 0$$

Summary

- A generic WIMP compatible with observed relic density can be observed at the ILC up to M=240 GeV if BR($\chi\chi \rightarrow ee$) is at least few percent
- mitigated effects of machine bkg / $\gamma\gamma \rightarrow$hadrons
- included systematics from selection efficiency, beam energy spectrum, luminosity & *polarisation*
- mass measurement to typically O(1GeV)
- helicity structure of cross-section can be determined
- Last missing piece: determinationof dominant partial wave currently limited by MC statistics → can be fixed....

BACKUP

Efficiency & Rad. Return