Physics studies with polarisation

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Outline

- Introduction.
- Examples
  - $\tilde{\tau}$ in SPS1a'.
  - Model independent WIMPs
  - TGCs and polarisation
  - Near degenerate $\tilde{\mathrm{e}}$
- Conclusions.

Introduction

Polarisation is

- Needed to analyse the chiral structure of interactions
  - Key observable A_{LR}.
  - Relative error goes as that of $P_{eff} = (P_{e^-} - P_{e^+})/(1 - P_{e^-}P_{e^+})$
- Useful to improve S/B:
  - Key-number $\mathcal{L}_{eff} = (1 - P_{e^-}P_{e^+})\mathcal{L}/2$
  - Useful even if S and B depends on P in the same way: error $\propto S/\sqrt{B}$!
- See:
  - Overview in hep-ph/0507011, Phys.Rept., 460 (2008).
  - Sabine's talk.

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$\tilde{\tau}$ in SPS1a' and polarisation

(Work by J. List, P. Bechtle, P. Schade, M.B., PRD 82,no5 (2010), arXiv:0908.0876)

SPS1a' is a pure mSUGRA model, just outside what is excluded by LEP and low-energy observations.
Compatible with WMAP, with $\tilde{\chi}_1^0$ Dark Matter.
At $E_{CMS} = 500$ GeV:

- All sleptons available.
- No squarks.
- Lighter bosinos, up to $\tilde{\chi}_3^0$ (in $\mathrm{e^+e^-} \rightarrow \tilde{\chi}_1^0\tilde{\chi}_3^0$)

Features of $\tilde{\tau}$:s in SPS1a'

- In SPS1a', the $\tilde{\tau}_1$ is the NLSP.
- For $\tilde{\tau}_1$: $E_{\tau,min} = 2.6\ \mathrm{GeV}$, $E_{\tau,max} = 42.5\ \mathrm{GeV}$: $\gamma\gamma - background \Leftrightarrow pairs - background$.
- For $\tilde{\tau}_2$: $E_{\tau,min} = 35.0\ \mathrm{GeV}$, $E_{\tau,max} = 152.2\ \mathrm{GeV}$: $WW \to l\nu l\nu$ background $\Leftrightarrow$ *Polarisation*.
- $\tilde{\tau}$ NLSP $\to$ τ:s in most SUSY decays $\to$ SUSY is background to SUSY.
- For pol=(-1,1): $\sigma(\tilde{\chi}^0_2\tilde{\chi}^0_2)$ and $\sigma(\tilde{\chi}^+_1\tilde{\chi}^-_1)$ = several hundred fb and BR(X$\to \tilde{\tau}$) $>$ 50 %. For pol=(1,-1): $\sigma(\tilde{\chi}^0_2\tilde{\chi}^0_2)$ and $\sigma(\tilde{\chi}^+_1\tilde{\chi}^-_1) \approx 0$.

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Extracting the $\tilde{\tau}$ properties

From decay kinematics:

- $M_{\tilde{\tau}}$ from $M_{\tilde{\chi}_1^0}$ and end-point of spectrum = $E_{\tau,max}$.
- Need to measure end-point of spectrum.
- Must get $M_{\tilde{\chi}_1^0}$ from other sources.

From cross-section:

- $\sigma_{\tilde{\tau}} = A(\theta_{\tilde{\tau}}, \mathcal{P}_{beam}) \times \beta^3/s$, so
- $M_{\tilde{\tau}} = E_{beam}\sqrt{1-(\sigma s/A)^{2/3}}$: no $M_{\tilde{\chi}_1^0}$!

Fitting the $\tilde{\tau}$ mass: Endpoint

- Only the upper end-point is relevant.
- Background subtraction:
  - $\tilde{\tau}_1$: Important SUSY background,but region above 45 GeV is signal free. Fit exponential and extrapolate.
  - $\tilde{\tau}_2$: $\sim$ no SUSY background above 45 GeV. Take background from SM-only simulation and fit exponential.
- Fit line to (data-background fit).

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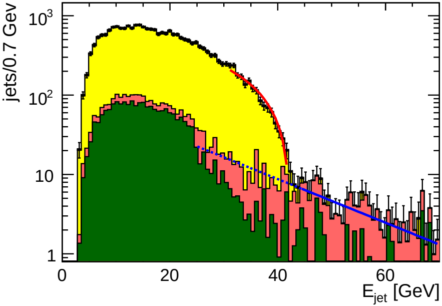

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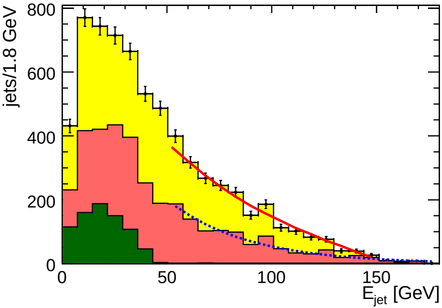

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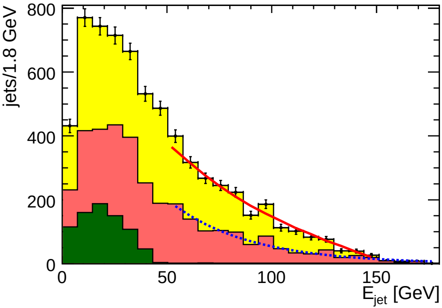

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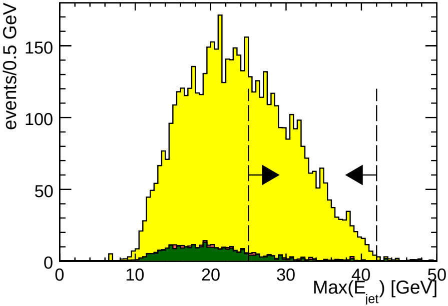

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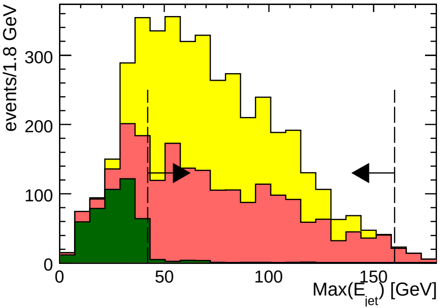

RDR , SB2009 and $\tilde{\tau}$:s

Potential effects on the $\tilde{\tau}$-channels:

- Decrease of $P(e^+)$: Less signal, more background for $\tilde{\tau}_1$, and more signal, but still more background for $\tilde{\tau}_2$
- Incoming energy-spread grows: end-point blurred.
- Luminosity within 1 % of nominal reduced: lower signal.
- Twice as much beam-strahlung:
  - more overlayed tracks (real or fake): Destroys τ topology.
  - Twice as much energy in BeamCal: More $\gamma\gamma$.
- Higher probability for a $\gamma\gamma$ event *in the same BX* as the physics event (this effect has not yet been studied).
- Also: Total luminosity decrease for SB2009 w/o TF.

Evaluating RDR $\Rightarrow$ SB2009 in FullSim

Impossible to re-do fully simulated samples - months of Grid-time - , so a transformation from RDR to SB2009 is needed !

- BeamCal: Double the energy density wrt. numbers from RDR simuation.
- Tracking: Fully simulated and reconstructed BX:es available both for RDR and SB2009. Choose which set to overlay.
- Beam-spectrum Reweight events with Lumi distributions from GP (A. Hartin, T Barklow) (avaiable both for RDR and SB2009) to modify the fully simulated samples to an SB2009 one.
- Polarisation: Straight-forward relative weighting of generated samples with P=(-1,1) and P=(1,-1).

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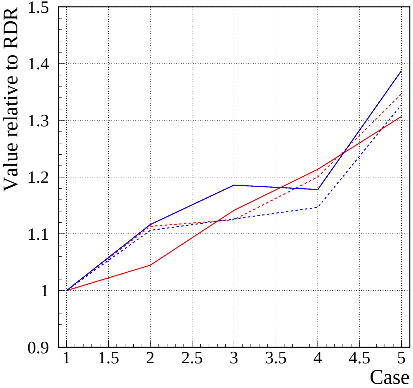
RDR , SB2009 and $\tilde{\tau}$:s: Effect on end-results

Errors on end-point (GeV)

case	#	$\tilde{\tau}_1$	$\tilde{\tau}_2$
RDR	1	0.129	1.83
+SB bck	2	0.144	2.02
+SB ppol	3	0.153	2.06
+SB spect	4	0.152	2.10
+SB noTF	5	0.179	2.42

Errors on cross-section (%)

case	#	$\tilde{\tau}_1$	$\tilde{\tau}_2$
RDR	1	2.90	4.24
+SB bck	2	3.03	4.72
+SB ppol	3	3.31	4.77
+SB spect	4	3.52	5.09
+SB noTF	5	3.79	5.71



Red: cross-section, Blue: end-point, Solid : $\tilde{\tau}_1$, Dashed: $\tilde{\tau}_2$.

Search for WIMPS and polarisation

(Work by C. Bartels, presented at IWLC 2010)

WIMP Dark Matter

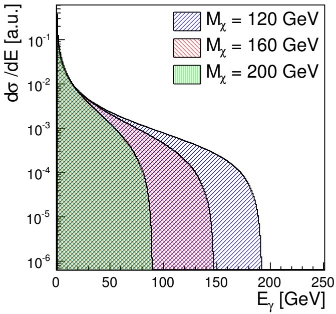
- Masses of 0.1–1 TeV.
- In thermal equilibrium with SM soup after inflation.
- Weak interactions naturally give observed relic density.
- In SUSY with conserved R-Parity: LSP: $\tilde{\chi}^0_1$ or $\tilde{G}$.
- Here: no model assumptions.

Pair production at ILC

- $e^+e^- \to \chi\chi$, WIMPs not detected.
- Detection via ISR: $e^+e^- \to \chi\chi\gamma$.
- Missing $\not{E}$.
- Dominant background: $e^+e^- \to \nu\nu(N)\gamma$.

Model Independent Production Cross Section

Mass dependent signal cut-off.

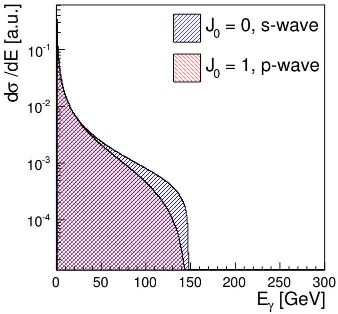


Parameters:

- $\kappa_e(P_e, P_p)$: Helicity dependent annihilation fraction to e^+e^-.
- S_χ: Spin, scale factor.
- M_χ, J_0 $\rightarrow$ shape, J_0 dominant partial wave.

Model Independent Production Cross Section

Signal shape at threshold provides information on partial wave (s- or p-wave).



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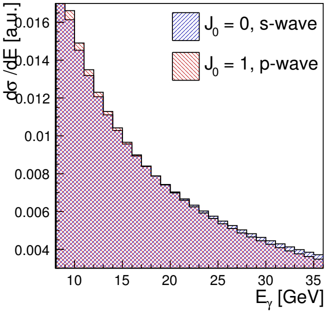
Model Independent Production Cross Section

Crossover for s-wave and p-wave signal with same cross section.
(⇒ important later)



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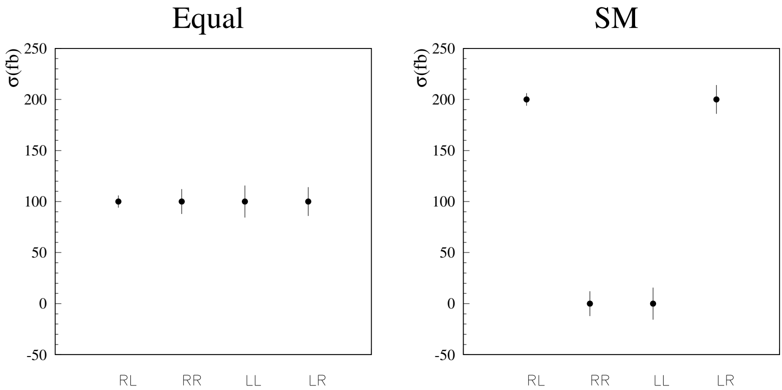
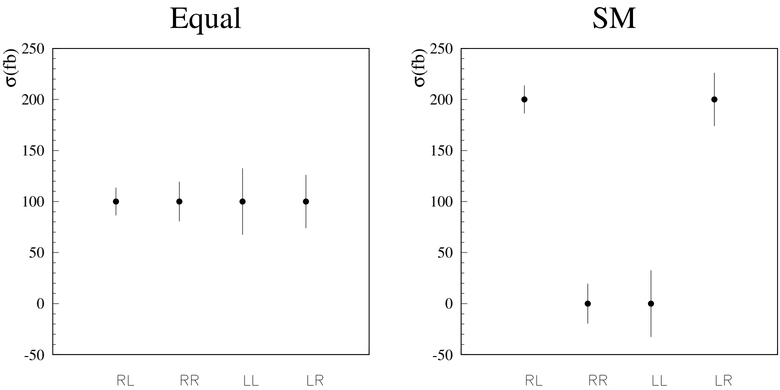
Polarised Cross Sections



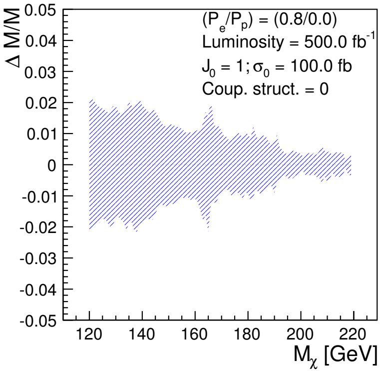
- 500 fb^{-1} with $(P_{e^-}/P_{e^+}) = (0.8/-0.6), (-0.8/0.6), (0.8/0.6), (-0.8/-0.6)$ (devided as 200, 200, 50, 50 fb^{-1}).
- 150 GeV p-wave WIMP

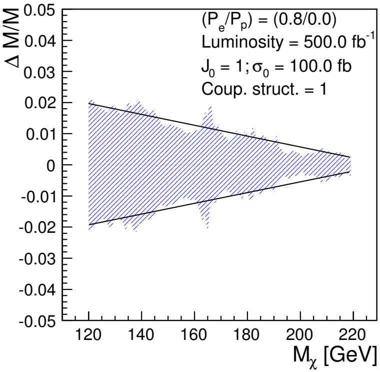
Polarised Cross Sections



- 500 fb^{-1} with $(P_{e^-}/P_{e^+}) = (0.8/-0.3), (-0.8/0.3), (0.8/0.3), (-0.8/-0.3)$ (devided as 200, 200, 50, 50 fb^{-1})
- 150 GeV p-wave WIMP

Mass Determination, $P_{e^-} = 80\%$ $P_{e^+} = 0\%$





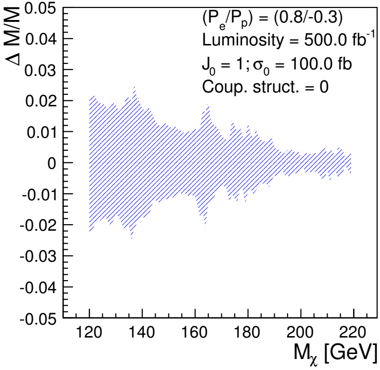
$\sigma_{RR} = \sigma_{LL} = \sigma_{LR} = \sigma_{RL}$

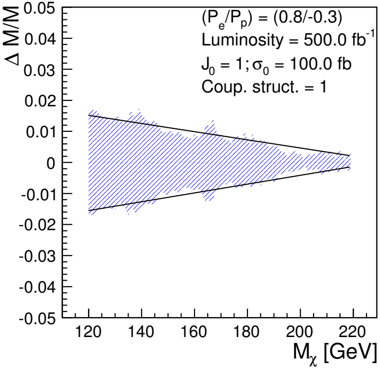
- $\Delta M/M$ from $\sim 1.7\%$ at $M = 120$ to 0.3% at $M = 220$.

$\sigma_{LR} = \sigma_{RL}; \sigma_{RR} = \sigma_{LL} = 0$

- $\Delta M/M$ from $\sim 1.7\%$ at $M = 120$ to 0.3% at $M = 220$.

Mass Determination, $P_{e^-} = 80\%$ $P_{e^+} = -30\%$





$\sigma_{RR} = \sigma_{LL} = \sigma_{LR} = \sigma_{RL}$

- Only small change in resolution with positron polarisation.

$\sigma_{LR} = \sigma_{RL}; \sigma_{RR} = \sigma_{LL} = 0$

- Additional resolution increase by 3/4.

TGC:s and Polarisation

(Work by I. Marchesini, presented at IWLC 2010)

Polarisation measurement from data with the Blondel scheme:

$$\sigma \;=\; \sigma_u \left[1 - P_{e^+} P_{e^-} + A_{LR}(P_{e^+} - P_{e^-})\right], \tag{1}$$

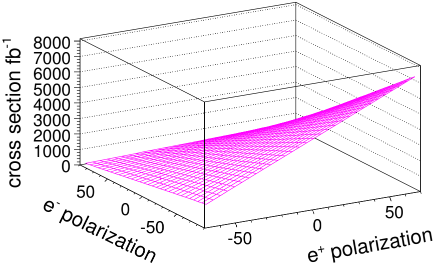
hence

$$P_{e^\pm} \;=\; \sqrt{\frac{(\sigma_{+-} + \sigma_{-+} - \sigma_{++} - \sigma_{--})(\mp\sigma_{-+} \pm \sigma_{+-} - \sigma_{++} + \sigma_{--})}{(\sigma_{-+} + \sigma_{+-} + \sigma_{++} + \sigma_{--})(\mp\sigma_{-+} \pm \sigma_{+-} + \sigma_{++} - \sigma_{--})}}$$

However: 100:s of fb^{-1} needed to get to 0.2 %.

WW and Polarisation

Enter *WW* production : a high cross-section, polarisation dependent process



Ideally suited to make polarisation measurements, with less data than the Blondel scheme.

TGC:s in *WW*

There is a catch, however:

Triple Gauge Couplings

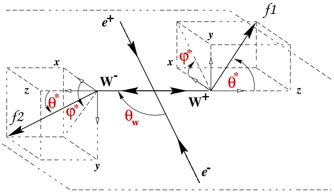
TGC:s :

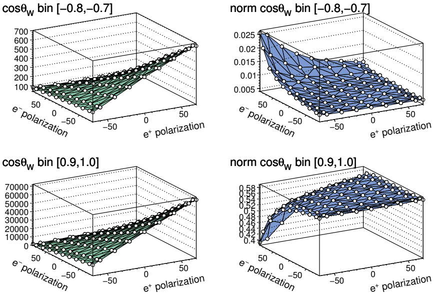
- 14 complex parameters, 8 CP conserving.
- In the SM: only 4 real parameters non-zero, all equal to unity
- Deviations from SM loop-corrections and beyond SM physics

Deviations from the SM still allowed (by LEP), affecting the polarisation measurement up to the % level.

TGC:s+Polarisation in *WW*

TGC:s modifies angular diff. cross-sections $\rightarrow$ % level corrections to polarisation measurement $\rightarrow$ fit simultaneously.

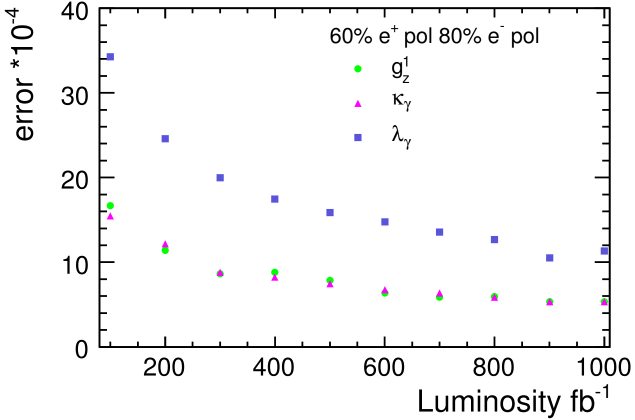




If individually C and P conserving and real: 6 TGC:s, but one fixed by EM-gauge invariance. Gauge conditions: some relations $\rightarrow$ 3 TGC parameters + 2 polarisations to fit.

Simultaneous fit : TGC:s

Result of simultaneous fit: TGCs



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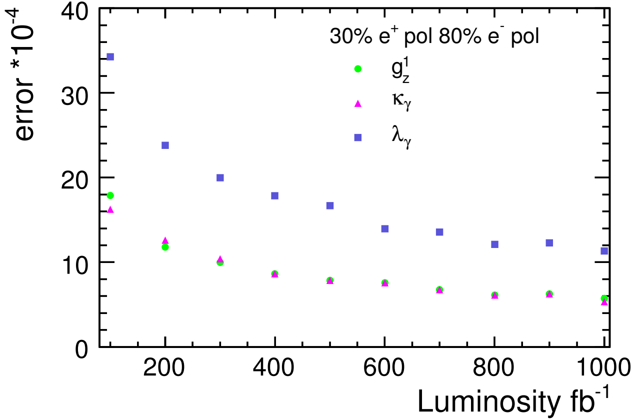

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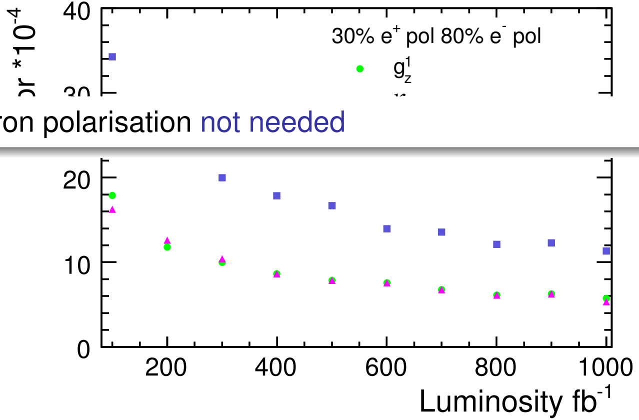
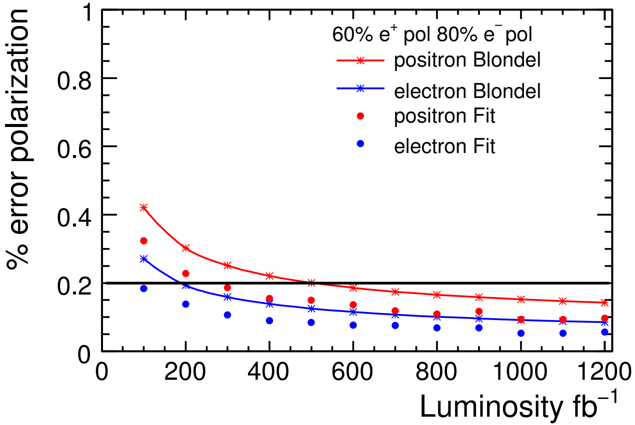


- Positron polarisation not needed

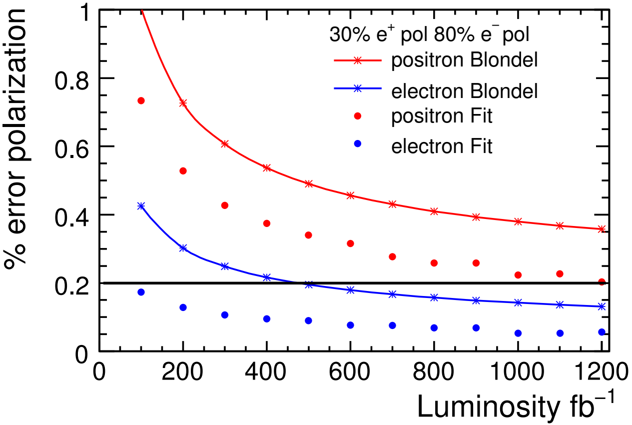
Simultaneous fit: Polarisation

Result of simultaneous fit: polarisation



Simultaneous fit: Polarisation

Result of simultaneous fit: polarisation



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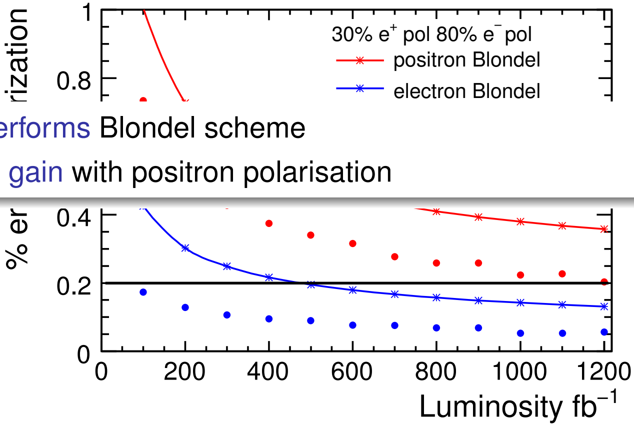


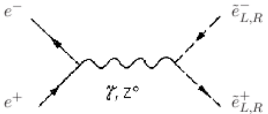
- Outperforms Blondel scheme
- Much gain with positron polarisation

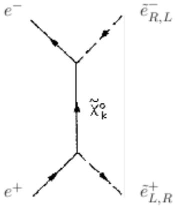
Near Degenerate $\tilde{e}$ and polarisation

(Preliminary work by M.B., G. Moortgat-Pick)

SUSY associates scalars to chiral (anti)fermions

$$e^-_{\mathrm{L,R}} \leftrightarrow \tilde{e}^-_{\mathrm{L,R}} \quad \text{and} \quad e^+_{\mathrm{L,R}} \leftrightarrow \tilde{e}^+_{\mathrm{R,L}}. \tag{2}$$





$\tilde{e}$:s with same helicity

Helicity for $\tilde{e}^\pm$ same as $e^\pm$

What if $M_{\tilde{e}_L} \approx M_{\tilde{e}_R}$, so that thresholds can't separate $e^+e^- \to \tilde{e}_L\tilde{e}_L, \tilde{e}_R\tilde{e}_R$ and $\tilde{e}_R\tilde{e}_L$?

RDR , SB2009 and Near Degenerate $\tilde{\mathrm{e}}$

Model: SPS1a' like, but:

$M_{\tilde{\mathrm{e}}_\mathrm{L}}$ = 200 GeVand $M_{\tilde{\mathrm{e}}_\mathrm{R}}$ = 195 GeV. Both decay 100 % to $\tilde{\chi}^0_1$ *e*.

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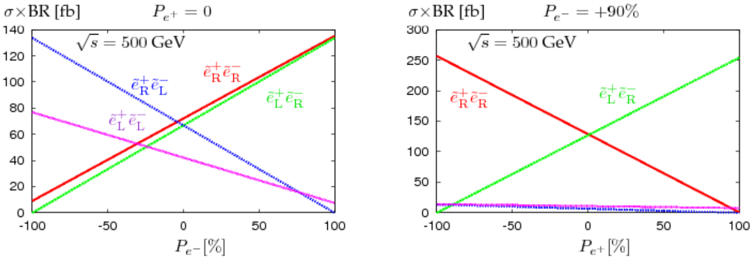

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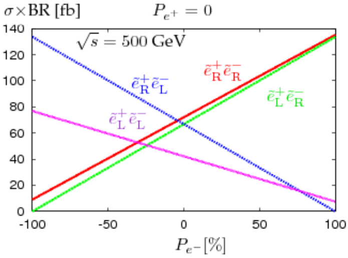

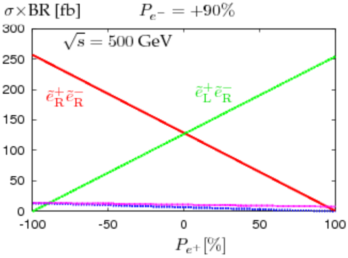

Polarised positrons a must !

RDR , SB2009 and Near Degenerate $\tilde{e}$

Background and efficiency from Full-sim SPS1a' sample, kinematics from Whizard simulation of the model.

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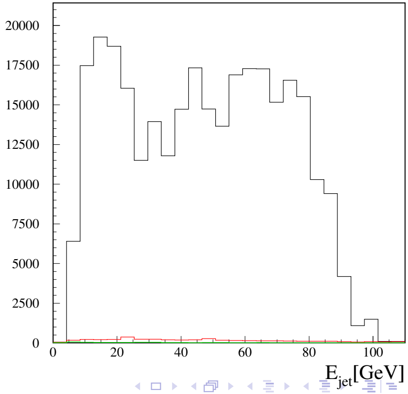

RDR , SB2009 and Near Degenerate $\tilde{e}$

Background and efficiency from Full-sim SPS1a' sample, kinematics from Whizard simulation of the model.

For the signal:

- Generate (with Whizard 1.95) the modified model.
- Apply the kinematic cuts used for the full simulation analysis.
- Scale down the over-all event-weight so that the efficiency agrees with the full simulation.

RDR , SB2009 and Near Degenerate $\tilde{e}$

The handle:
Opposite polarisation beams produces $\tilde{e}$:s in both s- and t-channel.
Same polarisation produces $\tilde{e}$:s in t-channel only $\Rightarrow$

Modification of Θ distribution with changed positron polarisation

However, the effect is small since t-channel always dominates !
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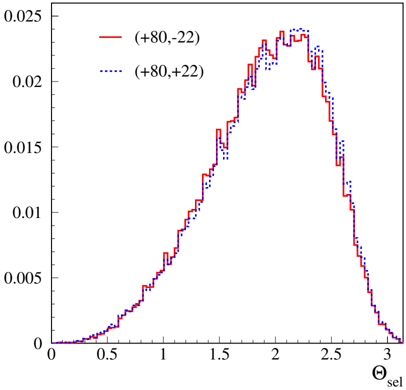

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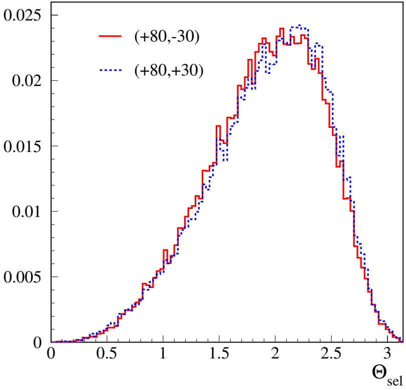

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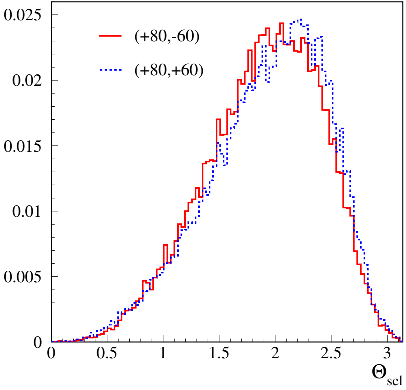

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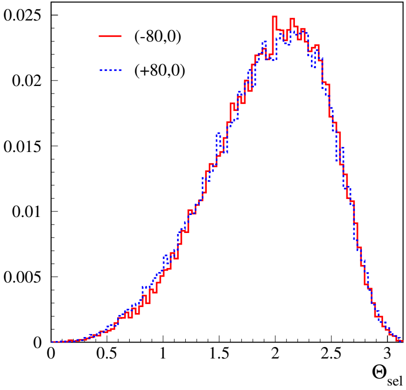

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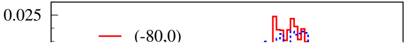
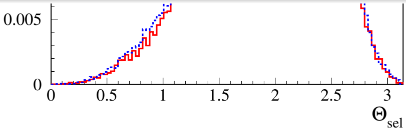


$\|P(e^+)\|$ (%)	significance of shift (σ)	Title of paper
22	2.4	“Limit on ...”
30	3.5	“Evidence for ...”
60	6.6	“Observation of ...”



Conclusions

Also when full simulation of both detector and beams:

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  - Strongly in in $\tilde{\tau}_1$: signal and background have opposite P dependence.
  - But also in $\tilde{\tau}_2$, even though they have the same.
- The polarisation measurement using WW was shown to
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Backup

RDR , SB2009 and $\tilde{\tau}$:s

Main items for physics

- Half RF power:
  - To keep L: decrease beam-size.
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  - Doubled luminosity/BX $\rightarrow$ doubled probability for a $\gamma\gamma$ event *in the same BX*.
- Undolator move :
  - Higher energy-spread at 500 GeV.
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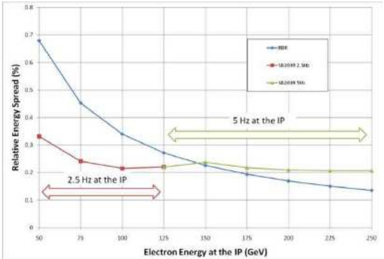

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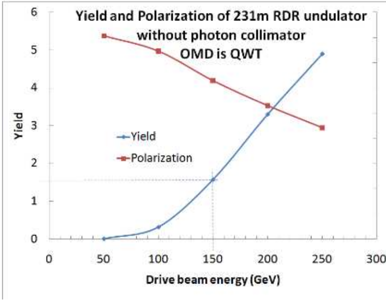

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RDR $\rightarrow$ SB2009 procedure

- BeamCal: From our studies: SB2009(TF) $\approx$ SB2009(noTF) $\approx 2 \times$ RDR. $\rightarrow$ Multiply BeamCal Energy-density map(RDR) by 2. Use same function $p([E_e \text{ at } x, y], [\text{pairs energy density at } x, y])$ as the probability to detect an electron of energy E entering the BeamCal at (x, y) would be seen.
- Tracking Fully simulated and reconstructed BX:es available both for RDR and SB2009 (no TF). Use method outlined above. NB: optimistic when applied to SB2009 with TF !
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RDR , SB2009 and $\tilde{\tau}$:s: Signal and background

Events after cuts, end-point analysis

case	$\tilde{\tau}_1$			$\tilde{\tau}_2$		
	SM	SUSY	signal	SM	SUSY	signal
RDR	317	998	10466	1518	241	1983
SB09(TF)	814	956	8410	1346	223	1555
SB09(nTF)	611	717	6308	1009	167	1166

Events after cuts, cross-section analysis

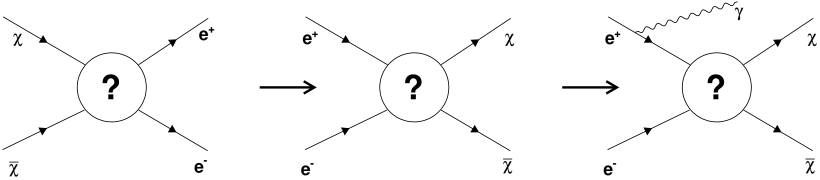
case	$\tilde{\tau}_1$			$\tilde{\tau}_2$		
	SM	SUSY	signal	SM	SUSY	signal
RDR	17.6	47.7	2377	1362	33.7	1775
SB09(TF)	17.6	45.7	1784	1194	32.4	1366
SB09(nTF)	13.2	34.3	1337	895	24.3	1025

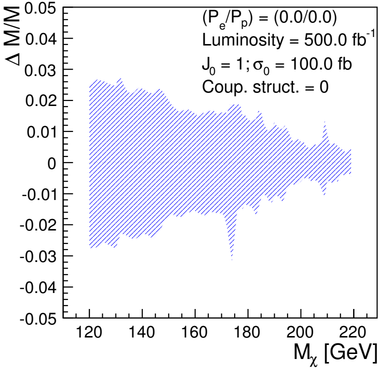
Model-independent search

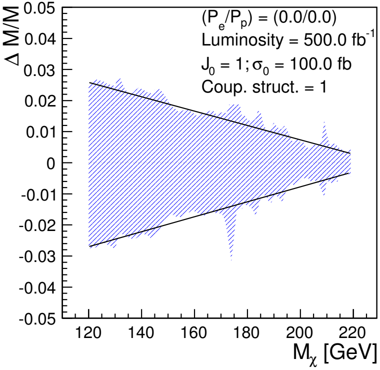
Birkedal *et al.* [hep-ph/0403004]

Model independence

- Assume only one DM candidate, no co-annihilation.
- Constrain WIMP pair annihilation XSec from observation.
- Crossing Symmetry (annihilation $\Rightarrow$ production).
- ISR.







$\sigma_{RR} = \sigma_{LL} = \sigma_{LR} = \sigma_{RL}$

- $\Delta M/M$ from $\sim 2.5\%$ at $M = 120$ to 0.5% at $M = 220$.

$\sigma_{LR} = \sigma_{RL}; \sigma_{RR} = \sigma_{LL} = 0$

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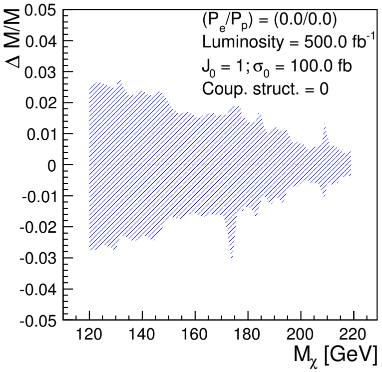
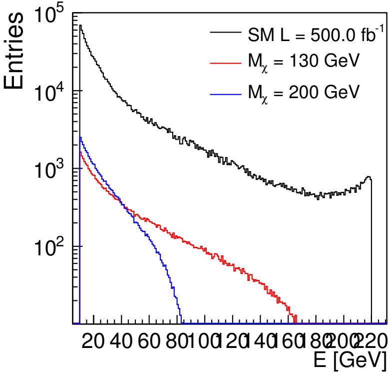
Mass Determination, $P_{e^-} = 0\%$ $P_{e^+} = 0\%$





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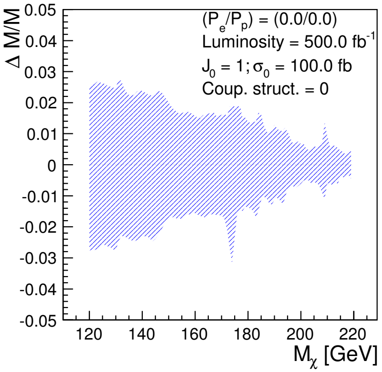

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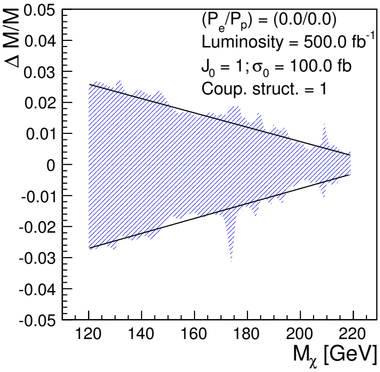

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Need to reconstruct the $\tilde{\mathrm{e}}$ direction:

- 8 unknown $\tilde{\chi}^0_1$ momentum components
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- 8 constraints (E and p conservation, 4 mass-relations)
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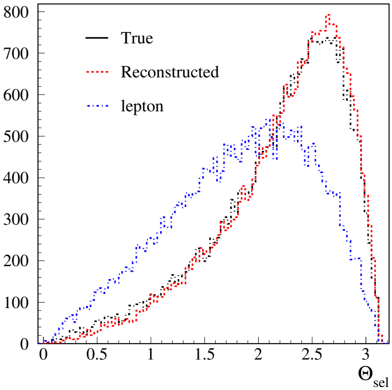

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