ILC beam-parameters and the $\tilde{\tau}$ channel in SPS1a'

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Outline

- $\tilde{\tau}$:s in SPS1a'
- RDR $\rightarrow$ SB2009.
- Conclusions.

$\tilde{\tau}$ in SPS1a'

Pure mSUGRA model:

$M_{1/2} = 250\ GeV, M_0 = 70\ GeV, A_0 = -300\ GeV,$
$\tan\beta = 10, sign(\mu) = +1$

Just outside what is excluded by LEP and low-energy observations.
Compatible with WMAP, with $\tilde{\chi}_1^0$ Dark Matter.

- 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.
- $M_{\tilde{\tau}_1} = 107.9\ \mathrm{GeV}$, $M_{\tilde{\tau}_2} = 194.9\ \mathrm{GeV}$ $M_{\tilde{\chi}^0_1} = 97.7\ \mathrm{GeV}/c^2$
- $E_{\tilde{\tau}_1,min} = 2.6\ \mathrm{GeV}$, $E_{\tilde{\tau}_1,max} = 42.5\ \mathrm{GeV}$: $\gamma\gamma$ background.
- $E_{\tilde{\tau}_2,min} = 35.0\ \mathrm{GeV}$, $E_{\tilde{\tau}_2,max} = 152.2\ \mathrm{GeV}$: $WW \rightarrow l\nu l\nu$ background.
- The $\tilde{\tau}$ mass-eigen states $\neq$ chiral-eigen states. Off-diagonal term of mass-matrix: $-M_\tau(A_{\tilde{\tau}} - \mu \tan\beta)$.
- $\tilde{\tau}$ NLSP $\rightarrow$ τ:s in most SUSY decays $\rightarrow$ 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$\rightarrow \tilde{\tau}$) $>$ 50 %. For pol=(1,-1): $\sigma(\tilde{\chi}^0_2\tilde{\chi}^0_2)$ and $\sigma(\tilde{\chi}^+_1\tilde{\chi}^-_1) \approx 0$.

Polarisation = (0.8,-0.3) assumed.

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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.
- In principle: $M_{\tilde{\chi}_1^0}$ turn-over of spectrum = $P_{\tau,min}$, but hidden in $\gamma\gamma$ background.
- Must get $M_{\tilde{\chi}_1^0}$ from other sources. ($\tilde{\mu}$, $\tilde{e}$, not yet done)

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 $M_{\tilde{\chi}_1^0}$!

Topology selection

$\tilde{\tau}$ properties:

- Only two τ:s in the final state.
- Large missing energy and momentum.
- High acollinearity, with little correlation to the energy of the τ decay-products.
- Central production.
- No forward-backward asymmetry.

Select this by:

- Exactly two jets.
- $N_{ch} < 10$
- Vanishing total charge.
- Charge of each jet = ± 1,
- $M_{jet} < 2.5\ \mathrm{GeV}/c^2$,
- $E_{vis} < 300\ \mathrm{GeV}$,
- $M_{miss} > 250\ \mathrm{GeV}/c^2$,
- No particle with momentum above $180\ \mathrm{GeV}/c$ in the event.

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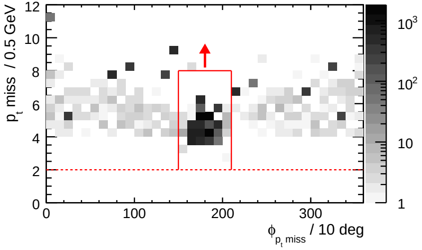
$\gamma\gamma$ suppression

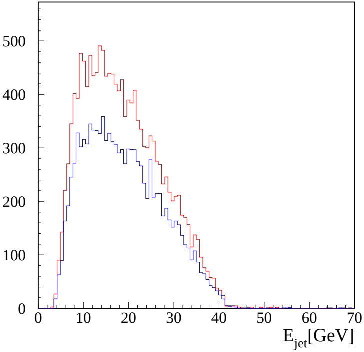
$\Delta(M) = 10.2\ \mathrm{GeV}/c^2 \rightarrow \gamma\gamma$ background ...

- Correlated cut in ρ and θ_{acop}: $\rho > 2.7 \sin\theta_{acop} + 1.8$.
- no significant activity in the BeamCal
- $\phi_{p\ miss}$ not in the direction of the incoming beam-pipe.



Finding τ:s

In particular in the presence of beam-background, general jet-finders perform poorly when used to find τ:s Use the DELPHI τ-finder: Performs better than Durham forced to two jets already without background:



BLUE: Durham, RED: DELPHI

End-point and cross-section

Additional cuts against $\gamma\gamma$

- $|\cos\theta_{missing\ momentum}| < 0.8$
- Low fraction of "Rest-of-Event" energy at low angles.
- Good agreement p_{track} - E_{calo}

From now on: Different cuts for $\tilde{\tau}_1$ ($\gamma\gamma$ background), and $\tilde{\tau}_2$ (WW background).

- $E_{vis} < 120\ \mathrm{GeV}$,
- $|\cos\theta_{jet}| < 0.9$ for both jets,
- $\theta_{acop} > 85°$,
- $(E_{jet1} + E_{jet2})\sin\theta_{acop} < 30\ \mathrm{GeV}$.
- $M_{vis} > 20\ \mathrm{GeV}/c^2$.

- $E_{vis} > 50\ \mathrm{GeV}$.
- $\theta_{acop} < 155°$.
- Other side jet not e or μ
- Most energetic jet not e or μ
- Cut on Signal-SM LR of f($q_{jet1}cos\theta_{jet1}$,$q_{jet2}cos\theta_{jet2}$)

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.
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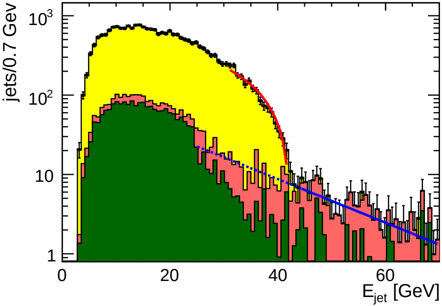

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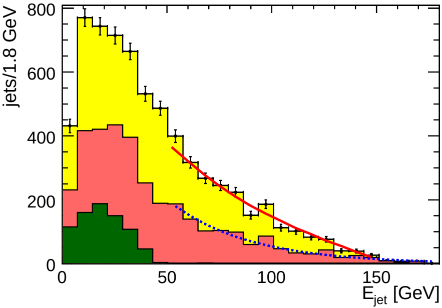

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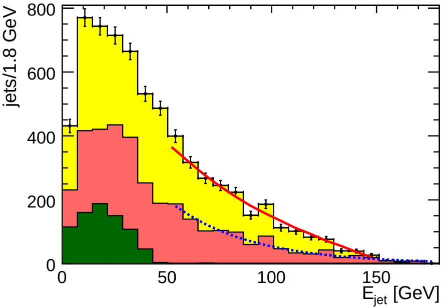

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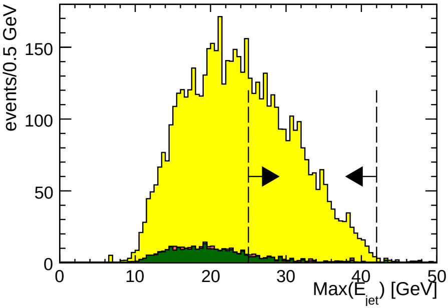

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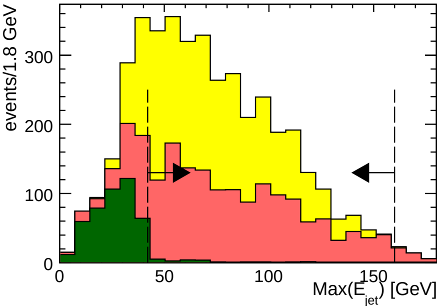

RDR , SB2009 and $\tilde{\tau}$:s

Main items for physics

- Half RF power:
  - The free parameter is N_{bunch}. Fringe benefit: Allows for smaller damping rings
  - To keep L: decrease beam-size.
  - But: . $\rightarrow$ increases δ_{BS}
  - Doubled luminosity/BX $\rightarrow$ doubled probability for a $\gamma\gamma$ event *in the same BX*.
- Undolator move :
  - Higher energy-spread at 500 GeV.
  - Lower positron polarisation at 500 GeV.
  - Also: Lower lumi below 250 GeV, not relevant here.

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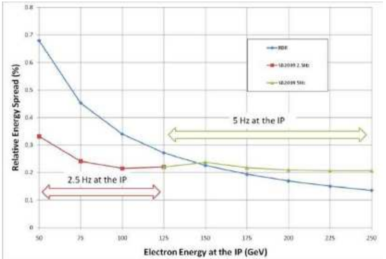

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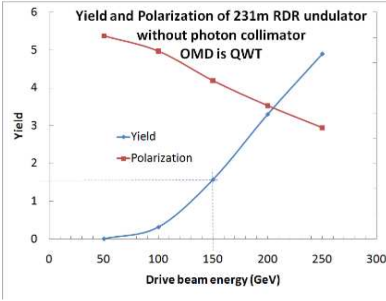

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RDR , SB2009 and $\tilde{\tau}$:s

Specifically:

- Twice as much beam-strahlung:
  - more overlayed tracks (real or fake)
  - Twice as much energy in BeamCal
- Total luminosity unchanged RDR→SB2009 w TF, but reduced by %25 for SB2009 w/o TF.
- $P(e^+)$ goes from 33 % to 22 %.
- Incoming energy-spread grows from 0.16 to 0.21 %.
- Luminosity within 1 % of nominal reduced from 0.83 to 0.72.

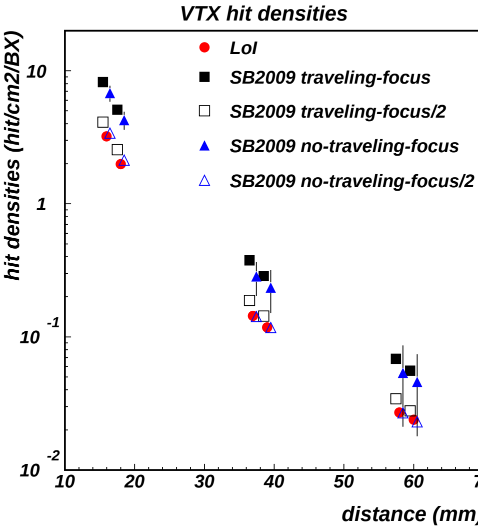
RDR , SB2009 and $\tilde{\tau}$:s

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

- Total luminosity decrease for SB2009 w/o TF.
- Decrease of $P(e^+)$: More background, less-signal for $\tilde{\tau}_1$.
- 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).

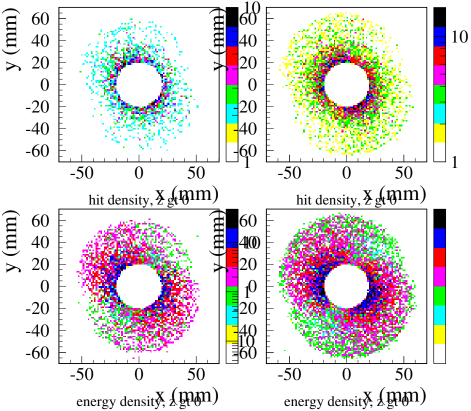
Beam-strahlung: Hits in Vertex detector

- Full simulation (Mokka), with crossing-angle and anti-DID field.
- No reconstruction yet, just count hits.
- The ILD VTX integrates of a certain time-window → Many BX:es overlayed.



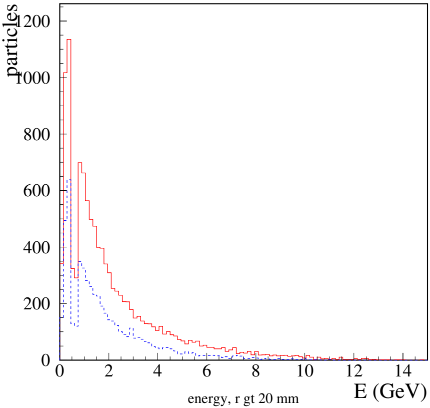
Beam-strahlung: BeamCal

- Only GP, but with crossing-angle and anti-DID.
- Both hit-densities (top) and energy-density (bottom) matters.
- The issue: can one still see a $\approx$ 250 GeV electron from a $\gamma\gamma$ process over the pairs-background?



Beam-strahlung: BeamCal

- Distribution of particle energy for r $>$ 20 mm.
- Total energy in BeamCal per BX: 24 TeV for SB2009TF, 10 TeV for RDR nom.
- Number of particles per BX 11500 for SB2009TF,5400 for RDR nom.
- Energy density vs Radius. SB2009TF has about twice at any given radius, and extends 5 mm further.
- All the relevant numbers double



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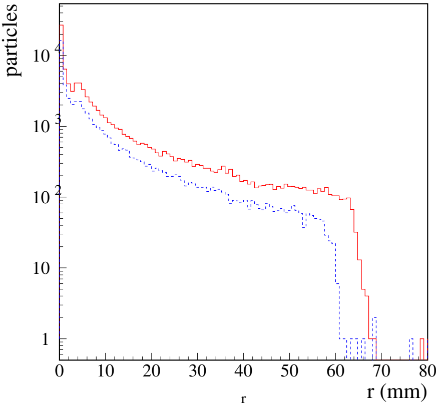

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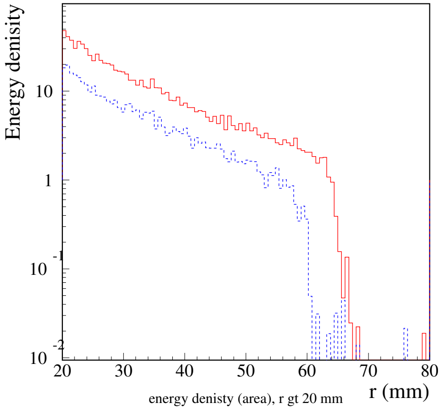

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Beam-background

- Generate 1000 bunch-crossings with GuineaPig.
- Reconstruct these with full ILD reconstruction.
- Add simulated and reconstructed beam-background only events on beam-background free, fully simulated and reconstructed physics events $\rightarrow$ under-estimate pattern rec. problems.

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

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 $p([E_e atx, y], [pairsenergydensityatx, y])$ 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 !
- Beam-spectrum Lumi distributions from GP (A. Hartin, T Barklow) for RDR and SB2009 and $E_{beam1,2}$ used to calculate even-by-event weights, to modify the existing fully simulated sample to an RDR 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: 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

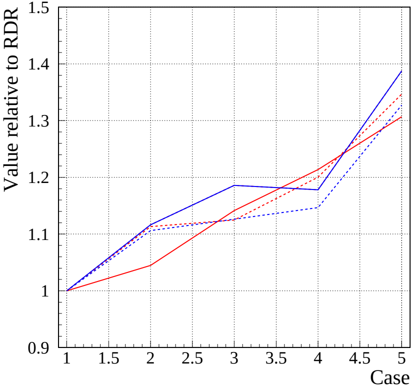
RDR , SB2009 and $\tilde{\tau}$:s: Effect on end-results

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: $\tilde{\tau}_2$.

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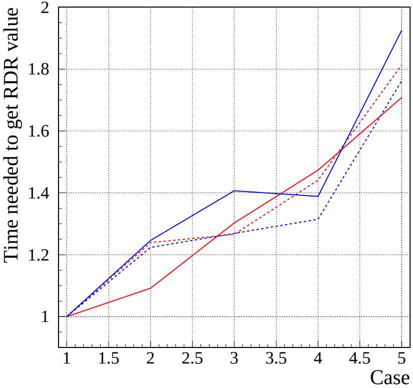

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Solid : $\tilde{\tau}_1$, Dashed: $\tilde{\tau}_2$.

Conclusions

- The effect of the transition RDR $\rightarrow$ SB2009 of the $\tilde{\tau}$ channels in SPS1a' was studied.
  - Less favourable beam spectrum and positron polarisation treated by re-weighting the existing samples with RDR parameters.
  - Increased pairs-background in BeamCal treated by scaling up the RDR energy densities.
  - New GP-generated pairs were fully simulated and reconstructed, and over-layed on the physics events (background and signal).
- 15-20 % degradation both on end-point and cross-section determination, both for $\tilde{\tau}_1$ and $\tilde{\tau}_2$. Increases to 20-30 % if TF scheme would turn out not to be feasible.
- Corresponds to increasing the in running time by 40 % (80 % for noTF) to achieve the same results.
- Half of degradation from the modifications of the positron source: Wider incoming beam-spectrum and lower positron polarisation.