Study of $\tilde{\tau}$ pair production in SPS1a'

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TILC09, Tsukuba, April 2009

Outline

Introduction

What can be done if SUSY exists, and is "next to LEP", and we use a real detector ?

- Study SPS1a'
- Weak-scale parameters with SPheno
- Whizard for event simulation (Produced at DESY)
- GuineaPig for beam-background
- DESY mass-production for both SUSY and SM:
  - Full simulation: ILD_00 in Mokka
  - Reconstruction using Marlin
- Study τ channels

People involved

- Olga Stempel, Peter Schade.
- Supervisors: J. List, P. Bechtle, M.B.

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 $\tilde{\chi}^0_1$ Dark Matter.

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

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

- In SPS1a', the $\tilde{\tau}$ is the NLSP. $M_{\tilde{\tau}_1} = 107.9\ \mathrm{GeV}/c^2$, $M_{\tilde{\chi}^0_1} = 97.7\ \mathrm{GeV}/c^2$, so $\Delta(M) = 10.2\ \mathrm{GeV}/c^2$.
- $P_{\tilde{\tau},min} = 2.2\ \mathrm{GeV}/c$, $P_{\tilde{\tau},max} = 42.8\ \mathrm{GeV}/c$: $\gamma\gamma$ background.
- Plays an important role for Dark Matter: $M_{\tilde{\tau}_1}$ important.
- 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 $\sigma(\tilde{\chi}^+_1\tilde{\chi}^-_1) \approx 0$.

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Extracting the $\tilde{\tau}$ properties

From decay kinematics:

- $M_{\tilde{\tau}_1}$ from $M_{\tilde{\chi}_1^0}$ and end-point of spectrum = $P_{\tau,max}$.
- In principle: $M_{\tilde{\chi}_1^0}$ turn-over of spectrum = $P_{\tau,min}$, but hidden in $\gamma\gamma$ background.

Need to measure end-point of spectrum.

Must get $M_{\tilde{\chi}_1^0}$ from other sources. $\Delta(M_{\tilde{\chi}_1^0}) \approx 1\ \mathrm{GeV}/c^2$ from the $\tilde{\mu}_\mathrm{L}$ analysis - the only studied by ILD up to now.
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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}: $\rho > 3\sin\theta_{acop} + 1.7$. ($\rho$ = P_T of jets wrt. thrust axis, in x-y projection.)
- no significant activity in the BeamCal
- $\phi_{p\ miss}$ not in the direction of the incoming beam-pipe.

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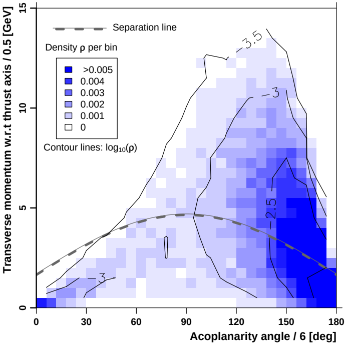

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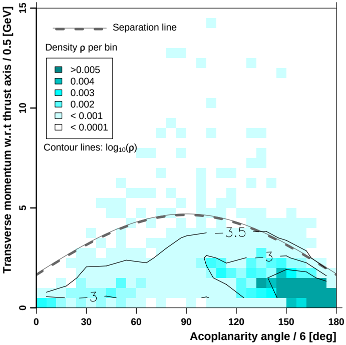

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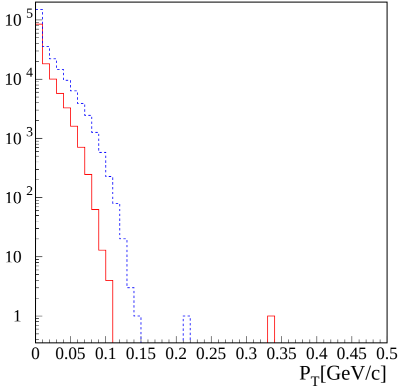
Beam-background

- Generate 1000 bunch-crossings with GuineaPig.
- Signal:
  - For each generated event, pick one bunch crossing at random, and add the beam-strahlung pairs (125 000...) to it.
  - Run through Full Simimualtion and Reconstruction.
- Background:
  - Add simulated and reconstructed beam-background only events on beam-background free, fully simulated and reconstructed physics events → under-estimate pattern rec. problems.

Beam-background

- Most beam-background tracks seen in the tracker are low P_T
- .. or fakes.
- Reject by : $E > 500\mathrm{MeV}$
- ... and demand associated TPC hits for charged.



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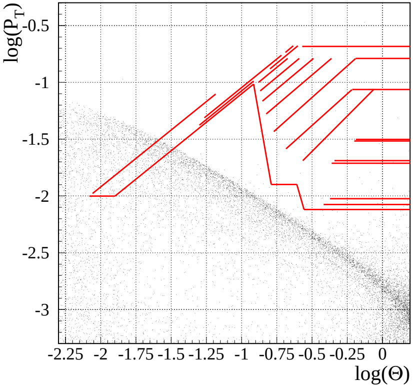

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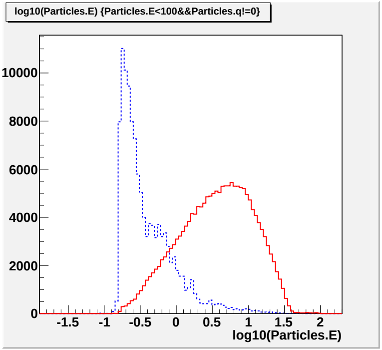

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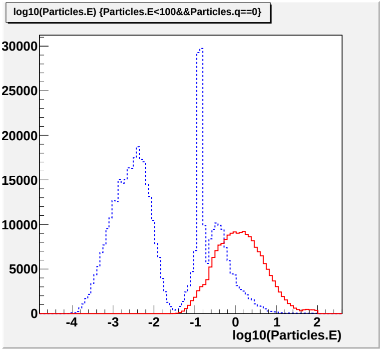

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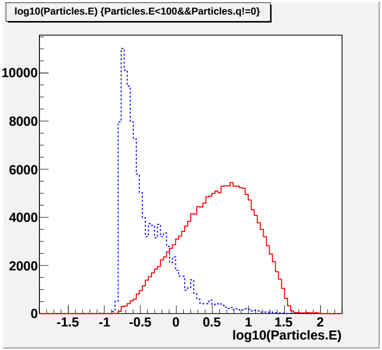

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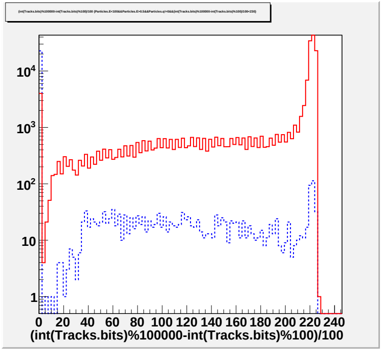

Finding τ:s

In particular in the presence of beam-background, general jet-finders perform poorly when used to find τ:s

Use the DELPHI τ-finder:

1. Test all possible ways to group the charged tracks in the event in collections with $M < 2\ \mathrm{GeV}/c^2$.
2. Prefer the grouping giving the lowest number of groups.
3. If more than one possible, use the one with lowest ΣM.
4. End when no smaller number of groups possible.
5. Then add any neutrals to the groups, always selecting the situation giving the lowest mass
6. If the lowest mass is $> 2\ \mathrm{GeV}/c^2$, leave the neutral to the "Rest-of-event" group

Additional options not yet exploited: Special treatment of leptons, neutral hadrons.

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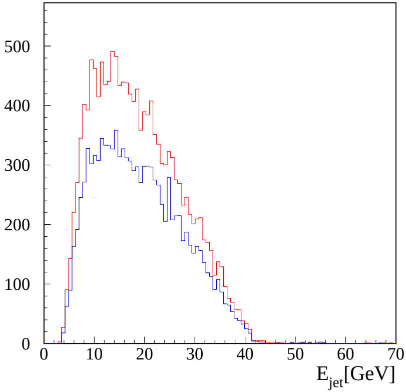
Performs better than Durham forced to two jets already without background:



BLUE: Durham, RED: DELPHI

Extracting the $\tilde{\tau}$ mass

- Extract the signal.
  - Exactly two jets.
  - Charge of each jet = ± 1,
  - $E_{within\ 30^{deg}\ to\ beam} < 4\ \mathrm{GeV}$
  - $M_{vis} > 20\ \mathrm{GeV}/c^2$,
  - anti-$\gamma\gamma$ cut,
  - $E_{vis} < 120\ \mathrm{GeV}$,
  - Two jets with charge $\pm$ 1,
  - $|\cos\theta_{jet}| < 0.9$ for both jets,
  - $\cos\theta_{acop} < -0.2$,
  - $|\cos\theta_{missing\ p}| < 0.75$,

Efficiency 11.2 %.
Without Beam-background: Efficiency 11.8 % (+5%), but: backround +15% (the background *is* two τ:s !)

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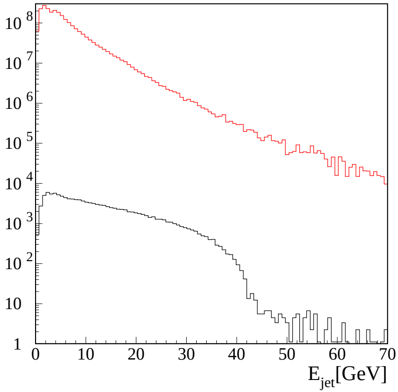

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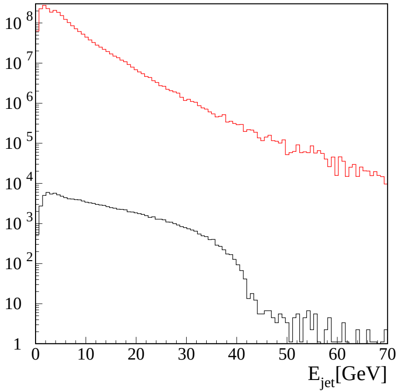

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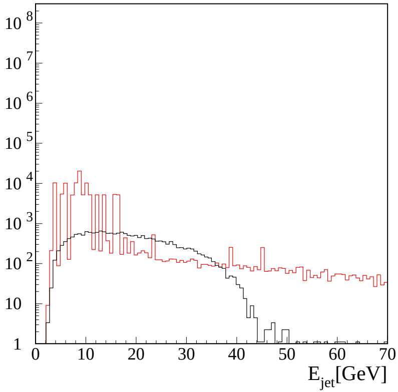

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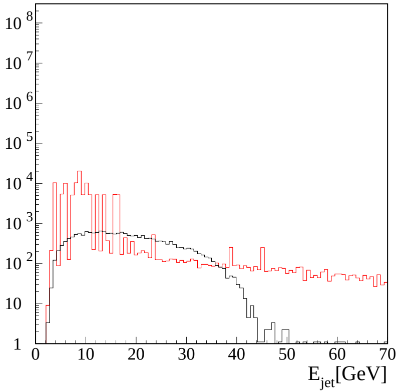

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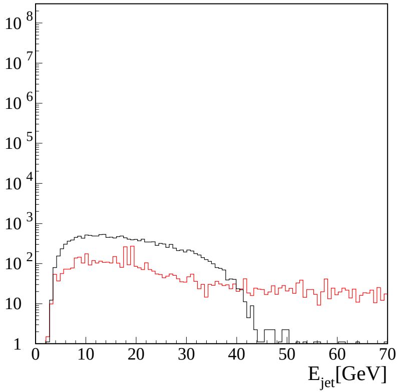

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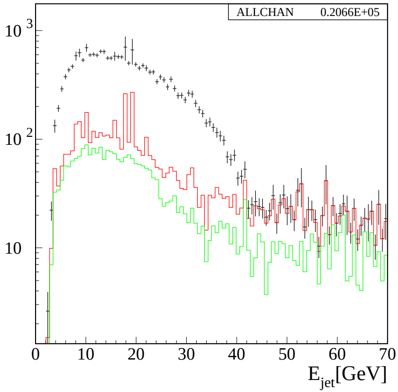

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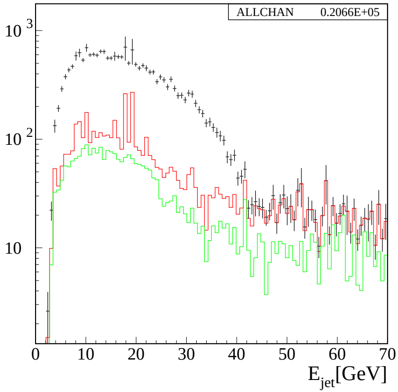

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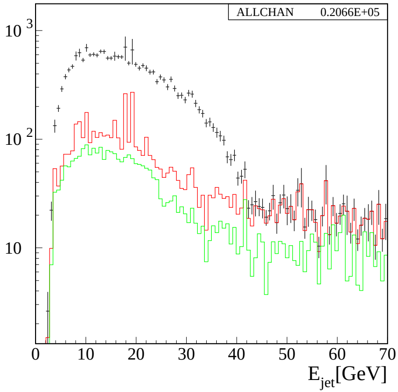

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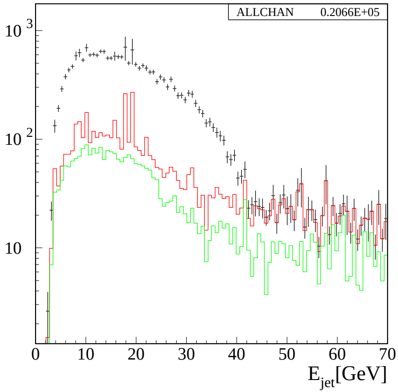
Without Beam-background: Efficiency 11.8 % (+5%), but: backround +15% (the background *is* two τ:s !)

Fitting the $\tilde\tau$ mass

- Only the upper end-point is relevant.
- Region above 45 GeV is signal free. Fit exponential.
- Fit line to (data-background fit extrapolation):
  - MINUIT, ML fit, with MINOS+HESSE.



$M_{\tilde\tau_1} = 107.60 \pm 0.08\ \mathrm{GeV}/c^2$

Without beam-background: $M_{\tilde\tau_1} = 107.65 \pm 0.08\ \mathrm{GeV}/c^2$.

NB: $dM_{\tilde\tau}/dM_{\tilde\chi^0_1} \approx 1.3$, and $\Delta(M_{\tilde\chi^0_1}) \approx 1\mathrm{GeV}/c^2$ from the $\tilde\mu_L$ analysis, so the error from $M_{\tilde\chi^0_1}$ largely dominates.

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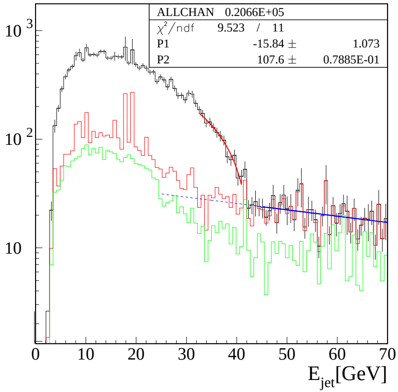

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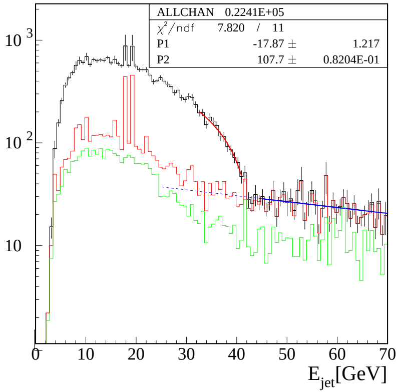

NB: $dM_{\tilde{\tau}}/dM_{\tilde{\chi}_1^0} \approx 1.3$, and $\Delta(M_{\tilde{\chi}_1^0}) \approx 1GeV/c^2$ from the $\tilde{\mu}_L$ analysis, so the error from $M_{\tilde{\chi}_1^0}$ largely dominates.

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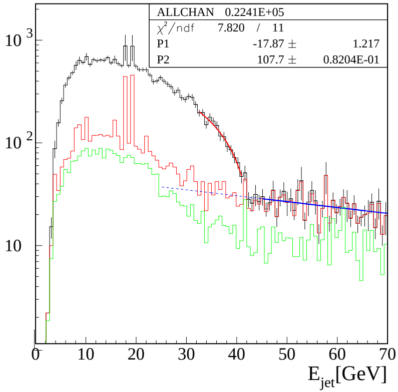

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Summary and outlook

Full simulation of $\tilde{\tau}$ production in SPS1a' in the ILD detector was presented

- All background - SUSY and SM - included. .
- Beam-background included. .
- $\Delta(M_{\tilde{\tau}_1}) = 80\ \mathrm{MeV}/c^2 \oplus 1.3\Delta(M_{\tilde{\chi}^0_1})$.
- Beam-background: decreases signal by %5, but also decreases (physics) background by 15 %.

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