Preliminary Study of the Search for χ_2^0 in sps 1a via Decays into taus

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- Introduction
- Process 1 ($e^+e^- \to \chi_1^0\chi_2^0$):
  - 500 GeV
  - 345 GeV
- Process 2 ($e^+e^- \to \chi_2^0\chi_2^0$)
- Conclusion

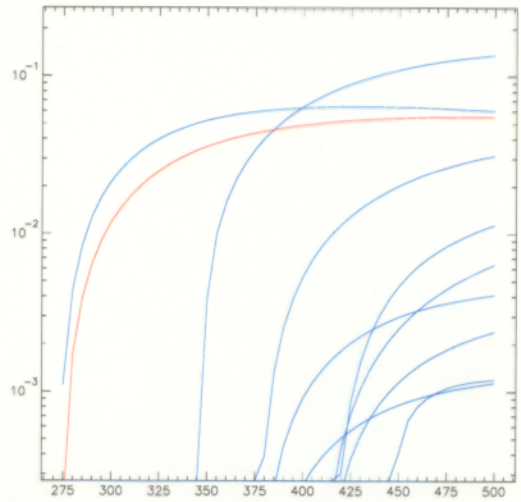
- *SPS 1a is the point in parameter space corresponding to the mSUGRA parameters:*
  - $m_0 = 100GeV$
  - $m_{\frac{1}{2}} = 250GeV$
  - $A_0 = -100GeV$
  - $\tan\beta = 10$
  - $\mu > 0$
- *Decays into taus are dominant:*
  - $\chi_2^0 \to \tilde{\tau}_1\tau$ 84.86%
- *Only two processes at 500 GeV:*
  - $e^+e^- \to \chi_1^0\chi_2^0$
  - $e^+e^- \to \chi_2^0\chi_2^0$
- *Either 2 or 4 taus with missing energy and* P_T

Since tau decays are dominant this was a very common signal. It was thought that the other processes would form an irreducible background and that it may be profitable to look at an inclusive measurement of all processes of the form:

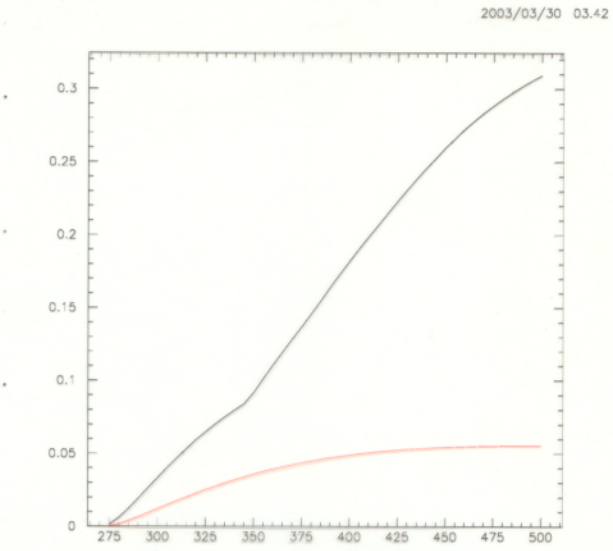
$$e^+e^- \rightarrow \text{SUSY intermediate state} \rightarrow \tau^+\tau^- + \text{invisible}$$

There are several processes contributing:

$\chi_1^0\chi_2^0$
$\tilde{\tau_L}^+\tilde{\tau_L}^-$
$\chi_1^+\chi_1^-$
$\tilde{\nu_\tau}\tilde{\nu_\tau}$
$\tilde{\nu_e}\tilde{\nu_e}$
$\tilde{\nu_\mu}\tilde{\nu_\mu}$
$\tilde{e_L}^+\tilde{e_L}^-$
$\tilde{\mu_L}^+\tilde{\mu_L}^-$
$\tilde{\tau_R}^+\tilde{\tau_R}^-$
$\chi_1^0\chi_3^0$
$\chi_1^0\chi_4^0$



One might expect to observe a kink in such a total inclusive cross section at the threshold of a new process.



- *No such kink was observed at the threshold for the signal process, however, one was observed for the process* $e^+e^- \rightarrow \chi_1^+\chi_1^-$.
- *It is noteworthy that the signal to background ratio is higher at lower energies (345 GeV).*

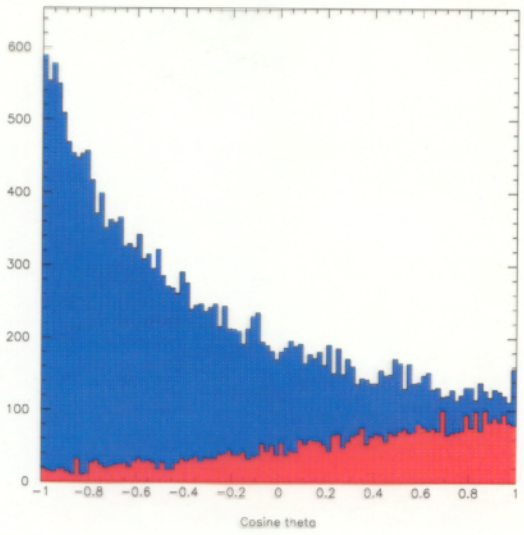
At 500 GeV, topological selection cuts (two charged particles with impact parameters $> 8\mu m$ *in the final state) were made which achieved:*

- efficiency, $\epsilon = 30.0\%$
- purity, $\rho = 17.2\%$

The signal process is asymmetric with respect to the two primary particles, having one particle which doesn't decay and one that does. This is very different to most of the background processes, and one would expect:

- *The angle between the charged particles to be small for signal and peaked at* π *for background.*
- *The missing* P_T *to be larger for signal.*

Distributions of $\cos\theta$ *were plotted for signal (red) and background:*



The selection cut that $\cos\theta > 0.55$ *was made resulting in:*

- efficiency, $\epsilon = 11.2\%$
- purity, $\rho = 38.3\%$

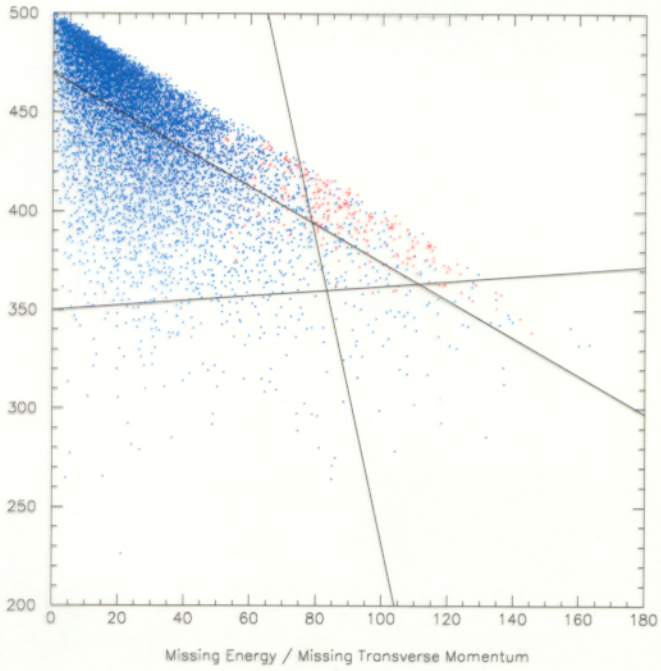
2D distributions of missing energy and missing P_T were used to make scatter plots for regions where the signal is greater than the background (red) and when the background is larger than the signal (blue):

The following selection cuts were imposed:

- $25E^{miss} + 24P_T^{miss} \geq 11750$
- $25E^{miss} - 3P_T^{miss} \geq 8750$
- $13E^{miss} + 100P_T^{miss} \geq 13000$

Resulting in:

- efficiency, $\epsilon = 2.0\%$
- purity, $\rho = 56.2\%$



Finally these two selection cut were combined to give:

FINAL CUTS:

$\rightarrow$2 charged particles with impact parameters $> 8\mu$
$\rightarrow \cos\theta > 0.5$
$\rightarrow 25E^{miss} + 24P_T^{miss} \geq 11750$
$\rightarrow 25E^{miss} - 3P_T^{miss} \geq 8750$
$\rightarrow 13E^{miss} + 100P_T^{miss} \geq 13000$

- efficiency, $\epsilon = 1.5\%$
- purity, $\rho = 75.1\%$

The same analysis was performed at 345 GeV, an energy at which there is only one background process contributing, and the cross section of the process is $0.0336pb$. *After topological selection cuts had been made:*

- efficiency, $\epsilon = 29.5\%$
- purity, $\rho = 39.8\%$

Again the asymmetry of the signal process was exploited:

CUT $\rightarrow \cos\theta > 0.6$

- efficiency, $\epsilon = 5.6\%$
- purity, $\rho = 52.1\%$

CUT $\rightarrow 18E^{miss} + 140P_T^{miss} \geq 14600$

CUT $\rightarrow 100E^{miss} + 97P_T^{miss} \geq 47200$

- efficiency, $\epsilon = 2.1\%$
- purity, $\rho = 57.1\%$

FINAL CUT $\rightarrow$ 2 charged particles with impact parameters $> 8\mu m$

FINAL CUT $\rightarrow \cos\theta > 0.6$

FINAL CUT $\rightarrow 18E^{miss} + 140P_T^{miss} \geq 12640$

FINAL CUT $\rightarrow 100E^{miss} + 97P_T^{miss} \geq 47200$

- efficiency, $\epsilon = 2.5\%$
- purity, $\rho = 62.73\%$

The other process, $e^+e^- \to \chi_2^0\chi_2^0$, has a less common signal: 4 taus. The topological selection cuts that there must be 4 charged particles with impact parameters greater than $8\mu m$ were made, resulting in:

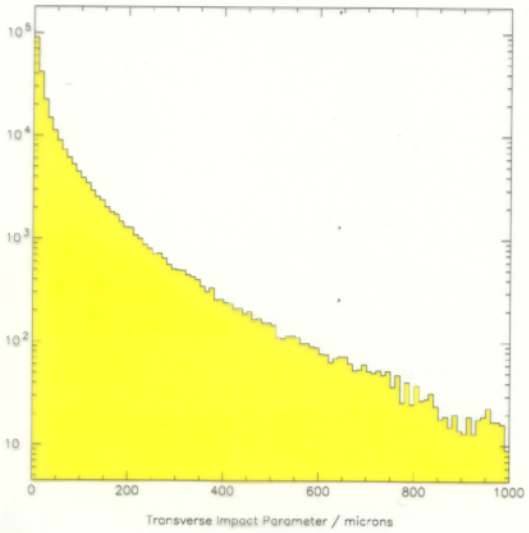
- efficiency, $\epsilon = 8.9\%$
- purity, $\rho = 21.2\%$

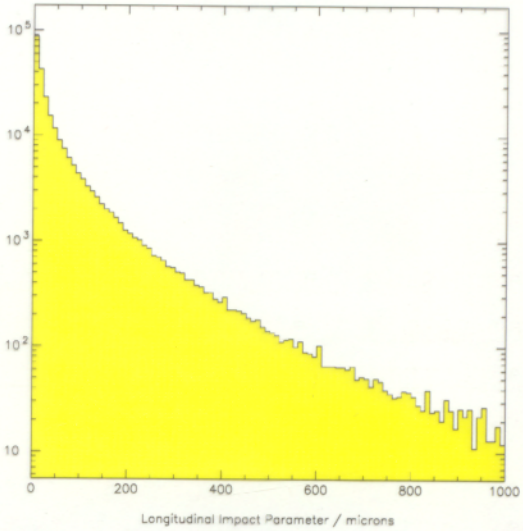
This is so low, since two taus are very common, and one of these may decay into three prongs. There are some other processes which have 4 taus and invisible particles, which make up about 7% of this signature:

$\tilde{\nu}_e\tilde{\nu}_e$
$\tilde{\nu}_\mu\tilde{\nu}_\mu$
$\tilde{\nu}_\tau\tilde{\nu}_\tau$
$\tilde{e}_L\tilde{e}_L$
$\tilde{\mu}_L\tilde{\mu}_L$
$\tilde{\tau}_R\tilde{\tau}_R$

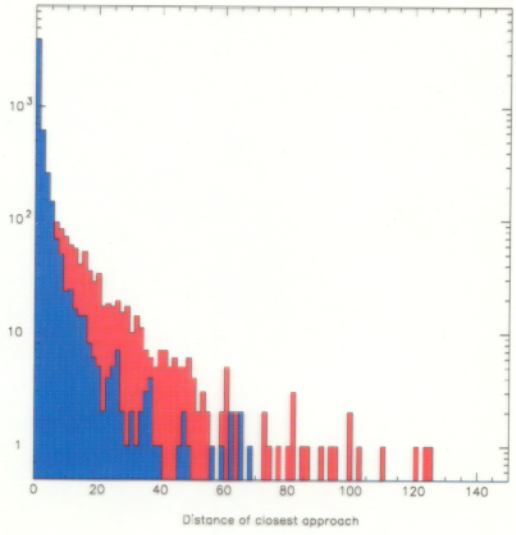
The trajectories of the particles could be reconstructed as a line in 3 dimensions. One would expect that the shortest distance of approach between three such pairs to be smaller for the background than for the signal.

Is the resolution of the APS vertex detector sufficient to distinguish whether these charged particles came from the same tau or not? The resolution of the impact parameters is $\sim 17\mu m$. *Distributions of the transverse and longitudinal impact parameters of all charged particles from single prong decays of taus were plotted:*





Each of the four tracks were reconstructed, and the shortest distance between the 6 pairs were calculated. These were ordered by size and the smallest of these was used to fill a distribution:



The selection cut $distance > 6.0\mu m$ *was made and resulted in:*

- efficiency, $\epsilon = 5.0\%$
- purity, $\rho = 74.4\%$

Another way to remove the background from two tau events is to select higher multiplicity decays of the taus. By altering the topological cuts to accommodate 6 charged particles in the final state the results were:

- efficiency, $\epsilon = 3.2\%$
- purity, $\rho = 60.5\%$

And with 8 charged particles:

- efficiency, $\epsilon = 0.5\%$
- purity, $\rho = 86.82\%$

CONCLUSION

- *We were able to isolate the processes with χ_2^0 with reasonable purity, but low efficiency. With a luminosity of $5 \times 10^{34} cm^{-2} s^{-1}$ after one year of running, collecting data for 50% of the time, one would expect to see these numbers of events:*
  - $N(\chi_1^0 \chi_2^0) \approx 800$
  - $N(\chi_2^0 \chi_2^0) \approx 3000$
- *One would have to be sure that the charged particles were coming from taus. It is a very rare signal to have 4 distinct secondary vertices, and for this reason the high multiplicity tracks are not so promising.*
- *One would also have to perform a more detailed study of other leptonic decay modes.*
- *This is only a preliminary study and it is quite clear that more work is needed.*