

$$e^+e^- \rightarrow \tilde{\tau}\tilde{\tau} \rightarrow \chi_1\tau\chi_1\tau$$

with $\tau \rightarrow \pi + \nu_\tau$

... and what one could learn from it

Task

- measurement of $\tan \beta$, the mixing parameter in the Higgs sector
 - ↳ can be done for moderate values in chargino/neutralino sector
 - ↳ for large values ($\tan \beta \approx 10$ or bigger) only bounds can be set
- an alternative measurement is possible
 - ↳ via the measurement of polarisation in sfermion decays (hep-ph/0303110)
- signal: $e^+e^- \rightarrow \tilde{\chi}_2\tilde{\chi}_1 \rightarrow \chi_1\tau\chi_1\tau \rightarrow \tilde{\tau}_1^\pm + \pi^\pm\nu\chi_1^0$
 - ↳ the energy spectrum of the pions is measured
 - ↳ for positive τ helicity the pion is emitted preferentially in forward direction
 - large fraction of τ energy
- decay in \tilde{b} or \tilde{t} also possible, but not treated by me

Idea of the measurement

- search for single pions coming from $e^+e^- \rightarrow \tilde{\tau}_1\tilde{\tau}_1 \rightarrow \tilde{\tau}_1^\pm + \pi^\pm \nu\chi_1^0$ and measure their energy

$$\frac{1}{\sigma} \frac{d\sigma}{dy_\pi} = \frac{1}{x_+ - x_-} \begin{cases} (1 - P_\tau) \log \frac{x_+}{x_-} + 2P_\tau y_\pi \left(\frac{1}{x_-} - \frac{1}{x_+} \right) & \text{for } 0 < y_\pi < x_- \\ (1 - P_\tau) \log \frac{x_+}{x_\pi} + 2P_\tau \left(1 - \frac{y_\pi}{x_+} \right) & \text{for } x_- < y_\pi < x_+ \end{cases}$$

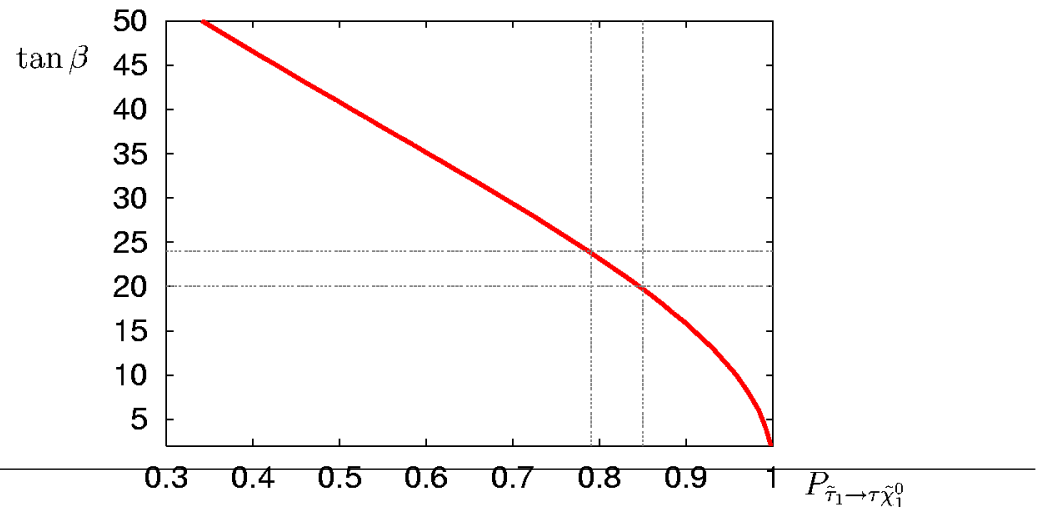
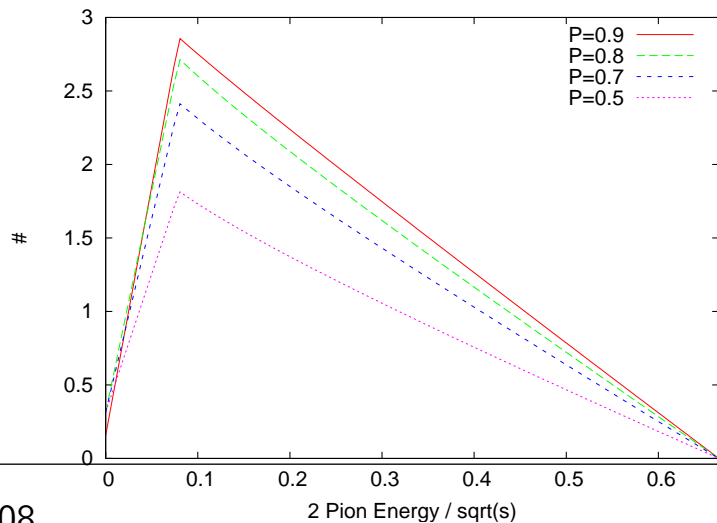
$$\text{with } x_\pm = \frac{m_{\tilde{\tau}}}{\sqrt{s}} \left(1 - \frac{m_\chi^2}{m_{\tilde{\tau}}^2} \right) \frac{1 \pm \beta}{\sqrt{1 - \beta^2}} \text{ and } \beta = \sqrt{1 - 4m_{\tilde{\tau}}^2/s} \text{ and } y_\pi = 2E_\pi/\sqrt{s}$$

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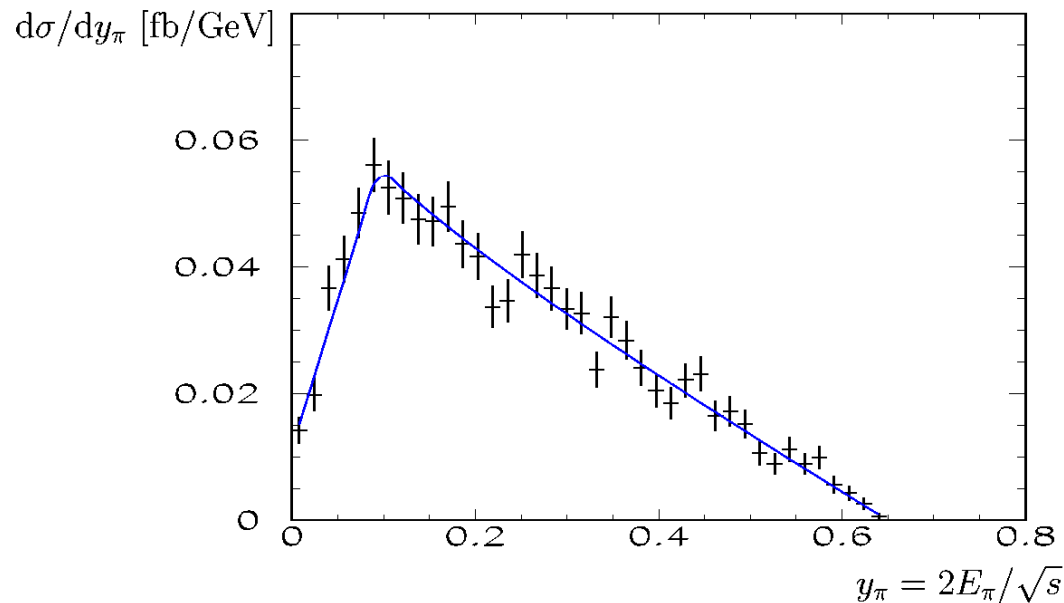
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with $x_\pm = \frac{m_{\tilde{\tau}}}{\sqrt{s}} \left(1 - \frac{m_{\chi_1^0}^2}{m_{\tilde{\tau}}^2} \right) \frac{1 \pm \beta}{\sqrt{1 - \beta^2}}$ and $\beta = \sqrt{1 - 4m_{\tilde{\tau}}^2/s}$ and $y_\pi = 2E_\pi/\sqrt{s}$



Example

- $\sqrt{s} = 500 \text{ GeV}$ and $\mathcal{L} = 500 \text{ fb}^{-1}$ ($P_{e^-} = 0.8$, $P_{e^+} = 0.6$ and masses according to 'paper' in tabular above)
- ↳ assuming an efficiency of 30 % gives 3000 events



- measured $P_\tau = 0.82 \pm 0.03$ with theoretical value of 0.85.
- from above figure reconstructed $\tan \beta = 22 \pm 2$ with a value 20 in the model

Model dependence

- the energy of the π coming from the decay of the τ depends on the mass difference of the $\tilde{\tau}$ and the χ_1

- in the rest frame of the $\tilde{\tau}$:

$$E_{\tau} = \frac{m_{\tau}^2 + m_{\tilde{\tau}}^2 - m_{\chi}^2}{2m_{\tilde{\tau}}}$$

- in the cms-frame: $E_{\tau}\gamma(1 - \beta) < E_{\tau}^{cms} < E_{\tau}\gamma(1 + \beta)$

Model	$m_{\tilde{\tau}}$ [GeV]	$m_{\tilde{\chi}}$ [GeV]	E_{max} [GeV]	$y_{\pi,max}$
Paper	78	155	138	0.55
sps1a	97	136	113	0.45
sps1ap	97	107	42.5	0.17

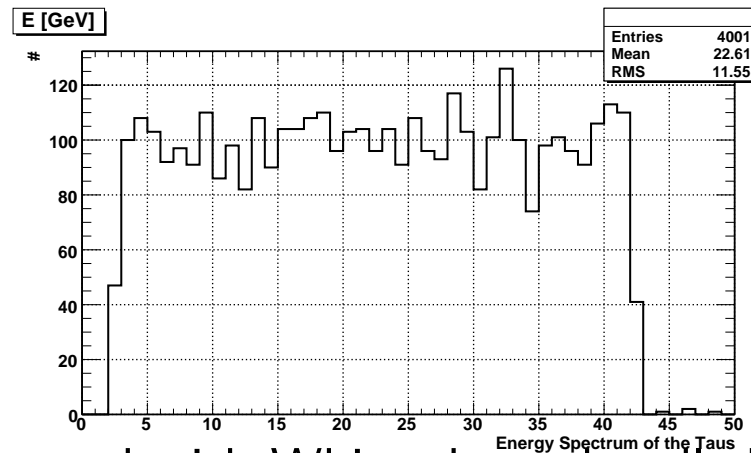
- → talk to H.U. Martyn

Status

- SLAC-Whizard 1.4 running
 - ↪ TAUOLA needed for the correct handling of the τ s
 - ↪ Option 'r' for omega hacked in, thanks to Jörgen, but not ready yet → to be finished
 - ↪ cross check with omega to have control over processes that are generated
- 2000 Events with Whizard 1.5 generated and reconstructed for testing purposes
 - ↪ model: sps1ap as implemented in Whizard
 - ↪ all τ decay channels mixed → Event filter in preparation
- $BP(\tau \rightarrow \pi\nu) = 10\%$: expected 20% with at least one π , 1% with two π
- two classes of events:
 1. decay via W exchange $\tau \rightarrow W \rightarrow \pi$, 163 single π s, 20 double π events
 2. direct decay $\tau \rightarrow \pi$, 338 single π s, 60 double π events

Finger training

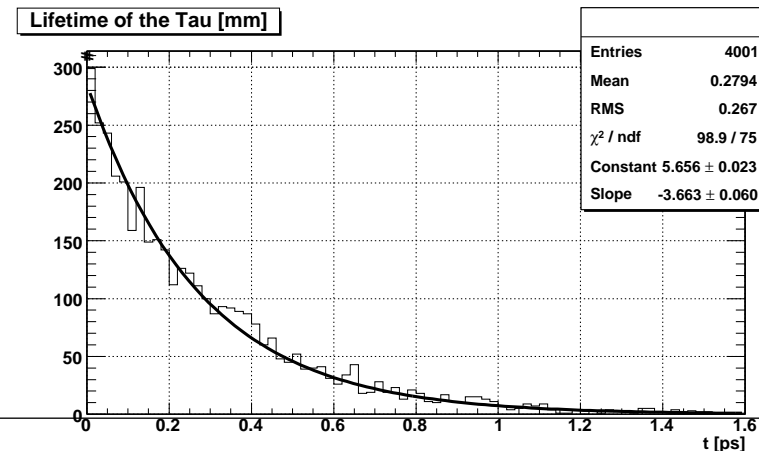
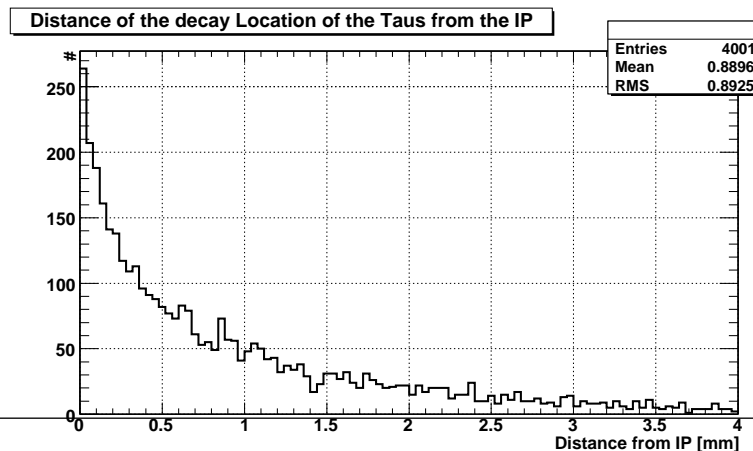
- mass spectrum of the τ looks as expected



- the taus, although generated with Whizard, are handled correctly in Mokka

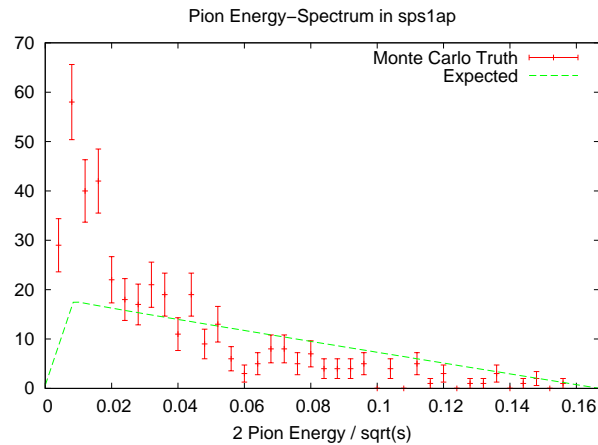
↳ do not come from the IP

↳ reconstructed lifetime is correct: $t_\tau = 0.273 \pm 0.045$ ps

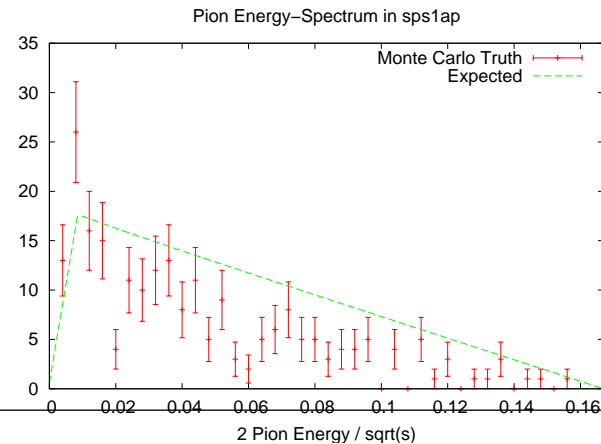
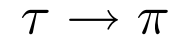
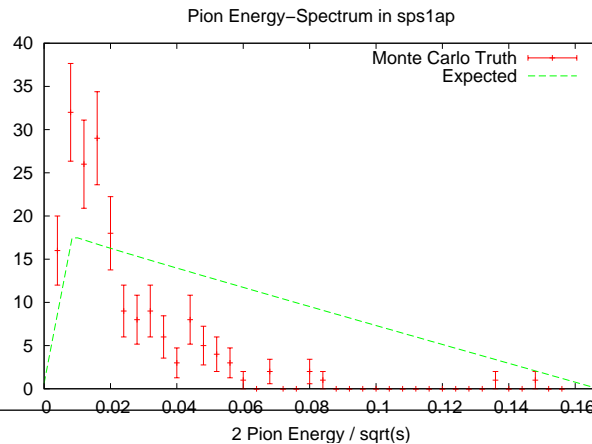


Finger training

- with the event selection the energy spectrum of the π s can already be extracted



↪ unexpected peak for low energies





Next steps

- optimise the event selection
- check the TAUOLA implementation to Whizard
- generate signal and SUSY-background events