τ-polarization in the SUSY decay chain $\widetilde{\chi}_2^0 \longrightarrow \widetilde{\tau}_1\tau \longrightarrow \widetilde{\chi}_1^0\tau\tau$

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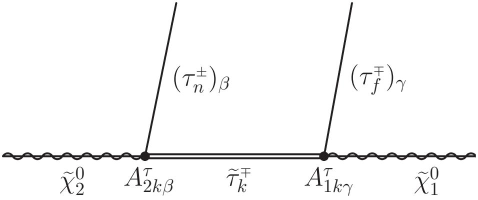
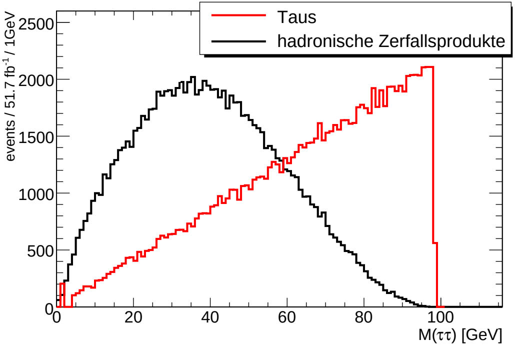
$m_{\tau\tau}$-distribution

- $m^2_{\tau\tau} = [p(\tau_n) + p(\tau_f)]^2$
- endpoint $\leftrightarrow (m_{\tilde{\chi}^0_2}, m_{\tilde{\chi}^0_1}, m_{\tilde{\tau}})$
- shape $\leftrightarrow \beta, \gamma$ (Pol.)

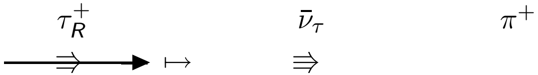




τs important:

- decays in τ favoured:
  - $m_{\tilde{\tau}_1} < m_{\tilde{\ell}}$ (mixing)
  - SU3: $\approx \times 10$
- pol. sensitivity (β, γ)
- $\tilde{\tau}$ properties $(m_{\tilde{\tau}}, \vartheta_{\tilde{\tau}})$:
  - $m_{\tilde{\tau}} \rightarrow m^{\max}_{\tau\tau}$
  - $\vartheta_{\tilde{\tau}} \rightarrow \beta, \gamma$ (Pol.)

- angular momentum conservation
- handness of neutrino
- momentum conservation



- angular momentum conservation
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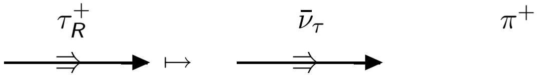
single $\tau \longrightarrow \nu_\tau\ \pi$ decays



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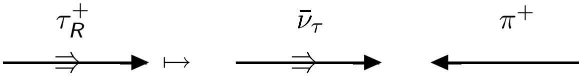

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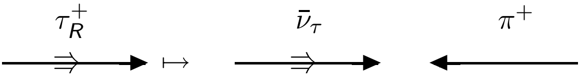

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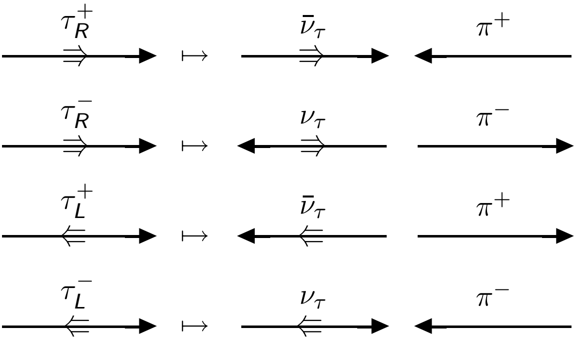
result

π momentum direction in τ-restframe specified by τ charge and helicity (chirality)

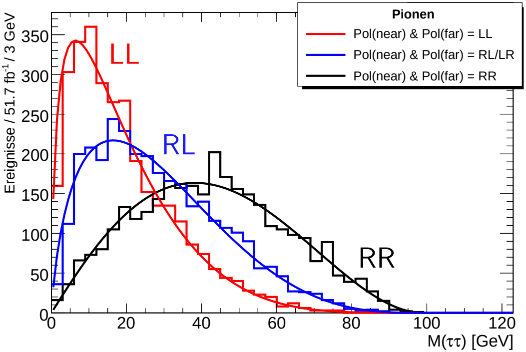
$\tau \longrightarrow \nu_\tau\ \pi$ decays



τ rest system $\longrightarrow$ lab system

- spin-quantization-axis $[\vec{p}(\tau)]_{\mathrm{LAB}}$−direction
- LORENTZ-boost τ-rest system $\longrightarrow$ lab-system
- high and low energy πs

$[\pi\pi]$-spektra on generator level



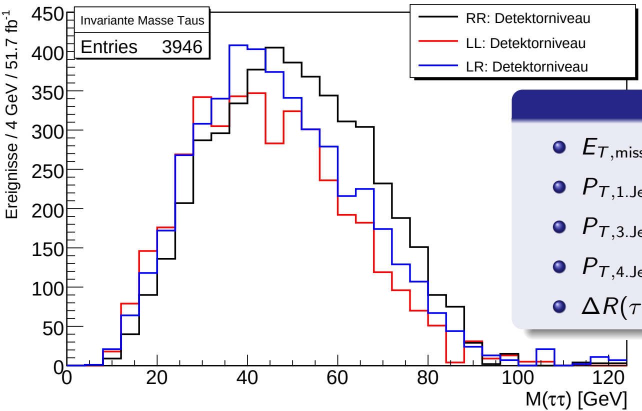
$\tau \longrightarrow \pi\nu_\tau$

- $m^2_{\pi\pi} = [p(\pi_n) + p(\pi_f)]^2$
- $m_{\pi\pi}$ sensitive to polarization
- allows distinction between $RL = LR$, LL, RR (chirality)
- but not τ_n and τ_f $[P(\tau_n) + P(\tau_f)]$

result:

comparison theory[a] $\leftrightarrow$ measurement $\Rightarrow$ polarization

[a] S.Y. Choi, K. Hagiwara, Y.G. Kim, K. Mawatari, P.M. Zerwas, τ *Polarization in SUSY Cascade Decays*, hep-ph/0612237

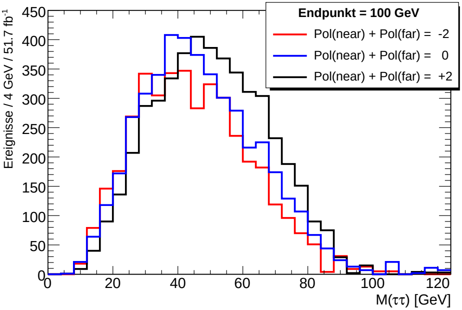


cuts

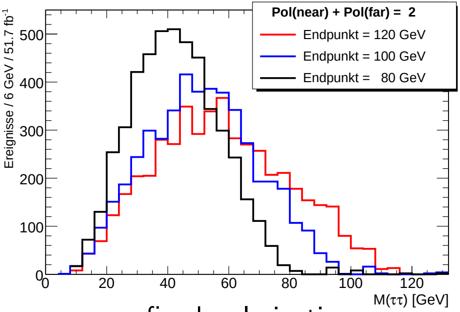
- $E_{T,\text{miss}} > 230$ GeV
- $P_{T,1.\text{Jet}} > 220$ GeV
- $P_{T,3.\text{Jet}} > 50$ GeV
- $P_{T,4.\text{Jet}} > 30$ GeV
- $\Delta R(\tau^+;\tau^-) < 2$

detector level

- fakes and combinatorial background: OS-SS suppressed
- poor τ-reconstruction for small $M(\tau\tau)$
- endpoint (SUSY-masses) $\leftrightarrow$ shape (polarization)



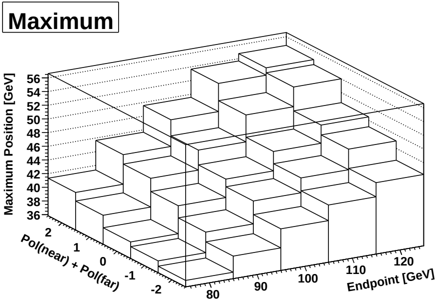
fixed endpoint
different polarizations



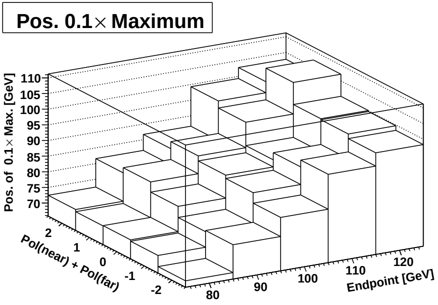
fixed polarization
different endpoints

strategy

- SUSY-masses and polarization show up differently in spectra
- fit spectra: $f(x) = \frac{p_0}{p_1\sqrt{2\pi}} \exp\left(-\frac{1}{2}\left(\frac{x-p_2}{p_1}\right)^2\right)$
- compare calibration $\leftrightarrow$ measurement



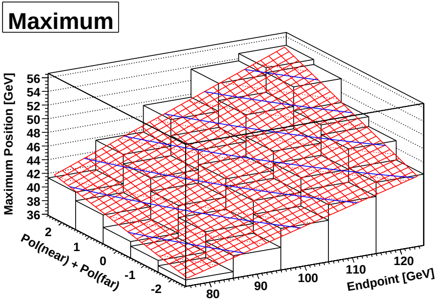
Pos of maximum of spectra



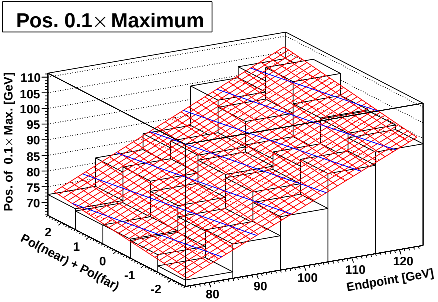
Pos with $f(x) = \frac{1}{10} f_{\mathrm{max}}$

Fit of calibration spectra

- grid of 5 $P(\tau_n) + P(\tau_f)$ and 5 endpoints $\widehat{=}\ 51.7 fb^{-1}$
- Obs.: maximum and position with $\frac{1}{10}$ of maximum
- calibration $\rightarrow$ maps of observables



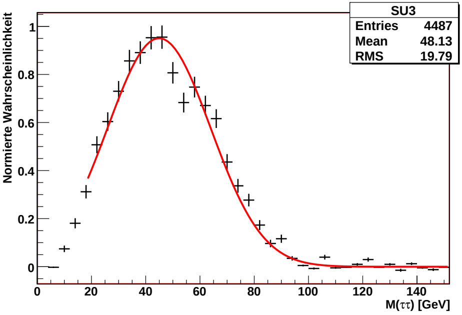
Pos of maximum of spectra



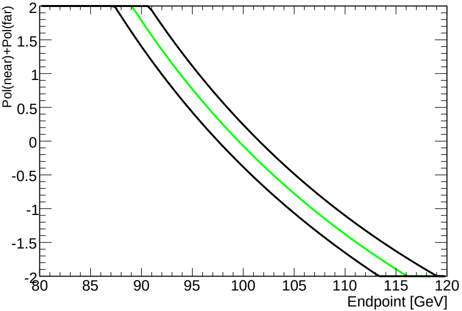
Pos with $f(x) = \frac{1}{10} f_{\max}$

Fit of observables

- $g\left(P(n) + P(f) = y, EP = x\right) = p_0 y + p_1 x + p_2 xy + p_3$
- measured observable → equipotential line
- intersection → polarization and endpoint



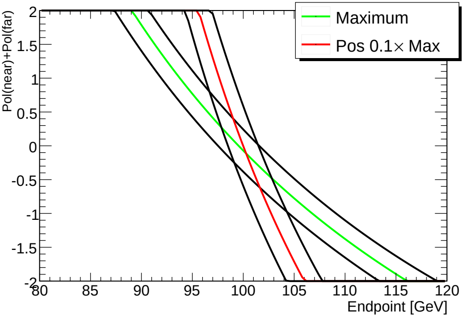
fit (SU3 spectrum)



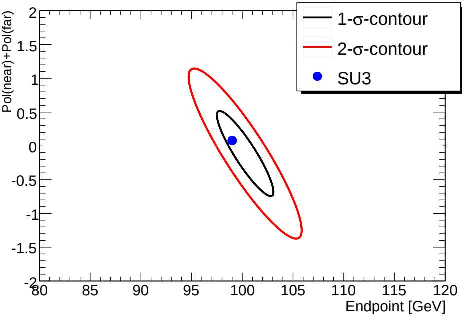
maximum with 1-σ-lines

measurement of observables of unkonown spectum (SU3)

- observables: $\sigma_{\text{stat.}}$ from fit, $\sigma_{\text{syst.}}$ with 3 binnings $\times$ 5 fit-ranges
- $\sigma^2 = \sigma^2_{\text{stat.}} + \sigma^2_{\text{syst.}}$
- $\sigma_y^2 = \left(\frac{\partial y}{\partial O}\sigma\right)^2 + \sum_{i,j=1}^4 \text{cov}(p_i, p_j)\frac{\partial y}{\partial p_i}\frac{\partial y}{\partial p_j}$



Maximum and $\frac{1}{10} \times$Max

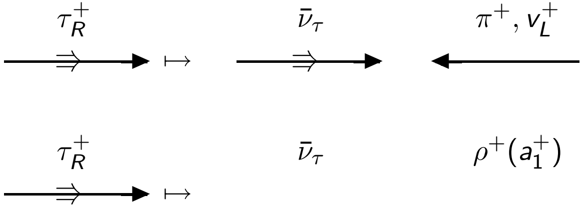


error contours and theoretical SU3 values

result of measurement of SU3

- $M_{\tau\tau}^{\max} = 100 \pm 3$ GeV (99GeV), $P(\tau_n) + P(\tau_f) = -0.11 \pm 0.63$ (0.08)
- 1-σ-contour: $\left(\frac{x}{\sigma_x}\right)^2 + \left(\frac{y}{\sigma_y}\right)^2 - 2\rho\frac{xy}{\sigma_x\sigma_y} = 1 - \rho$ with $\rho = -0.9$
- strong experimental correlation

single $\tau \to \nu_\tau \, \rho(a_1)$ decays



- angular momentum conservation
- handness of neutrino
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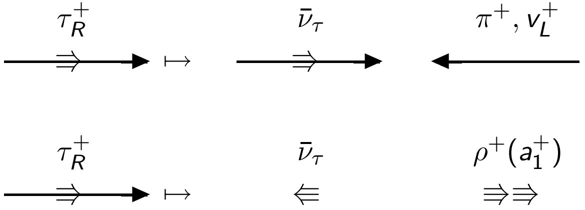
single $\tau \to \nu_\tau\ \rho(a_1)$ decays



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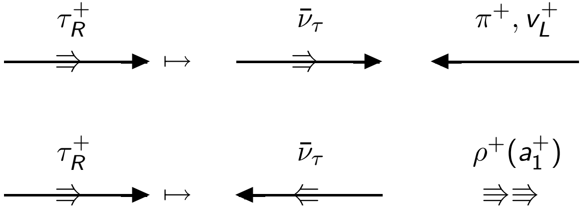

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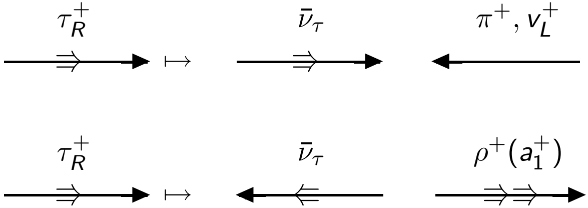
single $\tau \longrightarrow \nu_\tau \, \rho(a_1)$ decays



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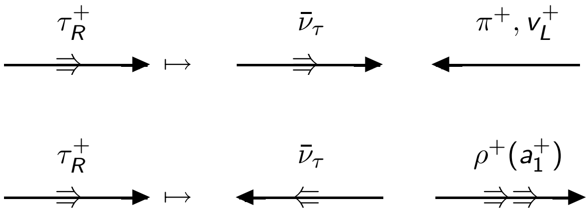
single $\tau \to \nu_\tau\ \rho(a_1)$ decays



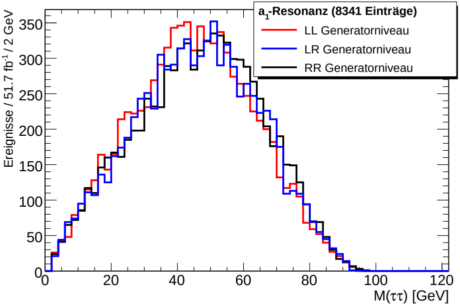
- angular momentum conservation
- neutrino handness
- momentum conservation

result:

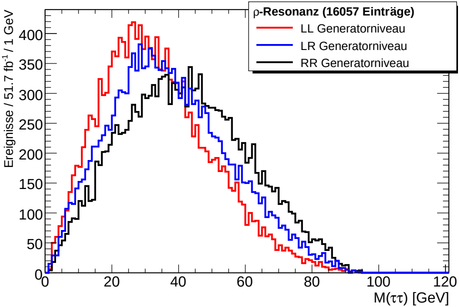
longitudinal (transversal) ρ, a_1: same (opposite) momentum direction as π

$$\frac{1}{\Gamma_v}\frac{d\Gamma_v}{d\cos\vartheta} = \underbrace{\left(\frac{m_v^2}{m_\tau^2 + 2m_v^2}\,(1 - P_\tau \cos\vartheta)\right)}_{\text{transversal}} + \underbrace{\left(\frac{\frac{1}{2}\,m_\tau^2}{m_\tau^2 + 2m_v^2}\,(1 + P_\tau \cos\vartheta)\right)}_{\text{longitudinal}}$$

$\tau \to a_1, \rho$ decays (generator level)



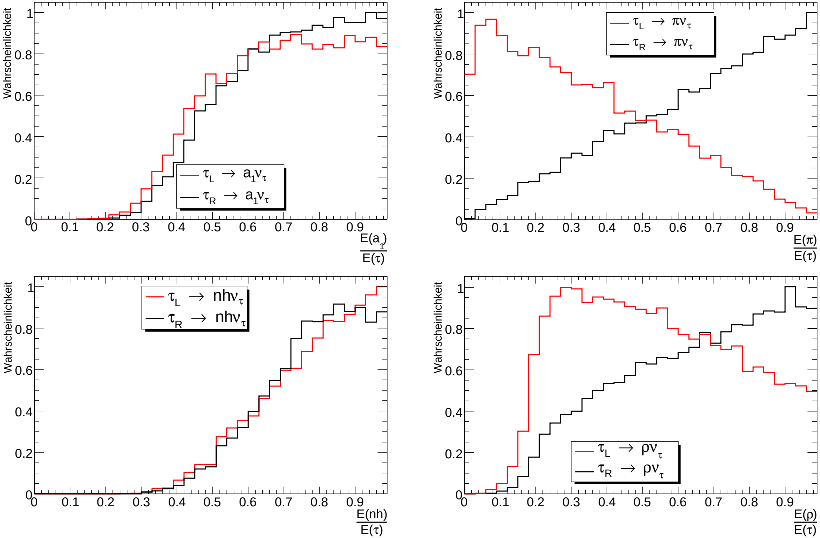
$[a_1 a_1]_{RR} \approx [a_1 a_1]_{LL}$
independent of polarization



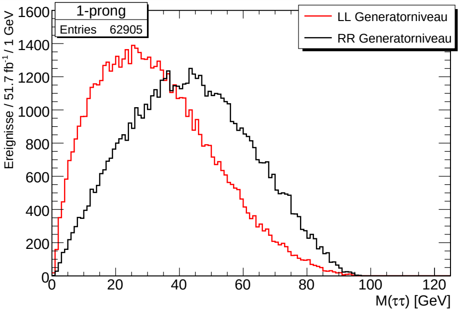
$[\rho\rho]_{RR} > [\rho\rho]_{LL}$
dependent on polarization

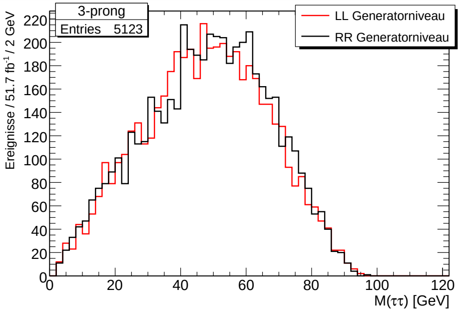
vector mesons

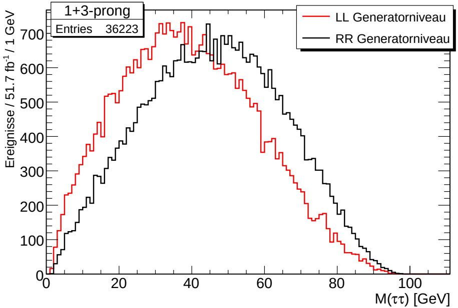
- a_1 pol. independent, ρ depends on pol.
- selection τ-decays $\rightarrow$ spectra with max (min) dependence on pol.
- compare $[\pi\pi]$ and $[a_1 a_1]$-spectra



- fragmentation functions (arbitrary units) $\left(\frac{E(\text{visible})}{E(\tau)} \text{ generator level}\right)$
- decay via ρ and π is polarization dependent, rest not







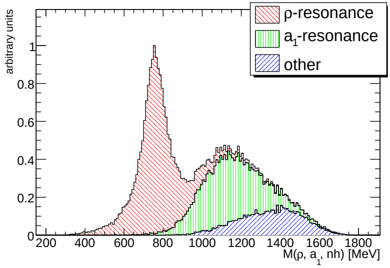
prong selection

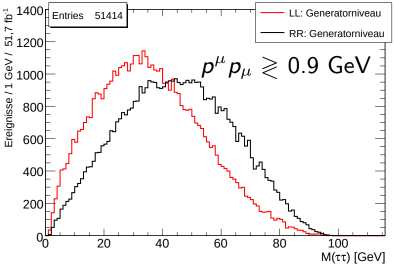
1-prong: ρ, π, K, a_1
mostly dependent on polarization

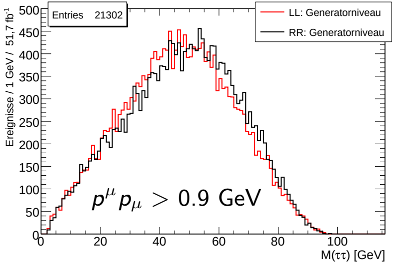
3-prong: a_1, other decays
independent of polarization

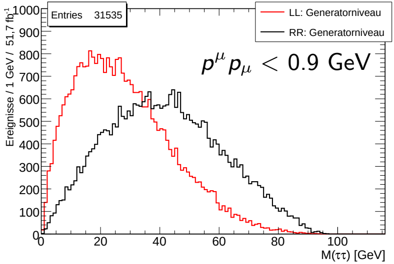
but: 3-prong poor statistics (5%)
$\rightarrow$ poor endpoint determination

invariant mass based τ selection (generator level)

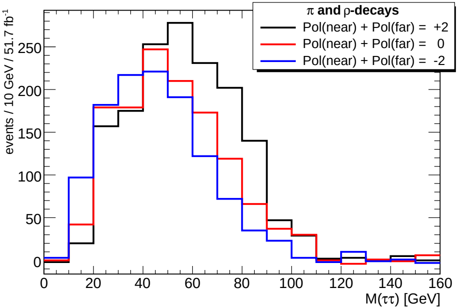




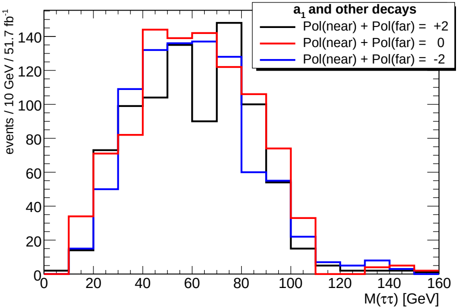




- resonant structure allows decay ID
- more efficient than prong sel.
- reconstruction inv. mass needed
- reality: resonances get broader



ρ and π and K decays
dependent on polarization



a_1 and other decays
independent of polarization

selection of decay modes (from MC truth) on detector level

- a_1 pol. independent, ρ depends on pol.
- 4000 (all dec.) $=$ 800 (a_1&other) $+$ 1500 (ρ, π, K) $+$ 1700 (mixed)
- gain in information compensated by loss of statistics

Conclusion and outlook

improve sensitivity with selection of τ decay modes:

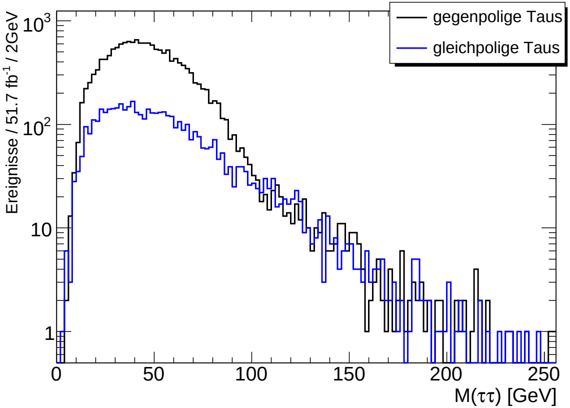
1. compare polarization affected and non-affected spectra
2. but: requires discrimination of decay modes
3. maybe: gain of information is overcompensated by loss of statistics

results with shape related observables for $51.7 fb^{-1}$:

1. endpoint $= 100 \pm 3$ GeV (theoretical: 99GeV)
2. sum of polarization $= -0.11 \pm 0.63$ (theoretical: $+0.08$)
3. strong experimental correlation

backup

fakes and combinatorial background



OS - SS

- $M(\tau\tau) > M(\tau\tau)_{\max} \Rightarrow$ fakes and combinatorial background
- $M(\tau\tau) > M(\tau\tau)_{\max}$: $[\tau^{\pm}\tau^{\pm}] \approx [\tau^{\pm}\tau^{\mp}]$ (uncorrelated)
- $\tilde{\chi}_4^0 \rightarrow \tilde{\chi}_1^{\pm}\tau^{\mp}\nu_\tau \rightarrow \tilde{\tau}^{\pm}\nu_\tau\tau^{\mp}\nu_\tau \rightarrow \tau^{\pm}\tilde{\chi}_1^0\nu_\tau\tau^{\mp}\nu_\tau$