$\tau - \tau$-edge and τ-polarisation effects in $\tilde{\chi}_2^0$ decays

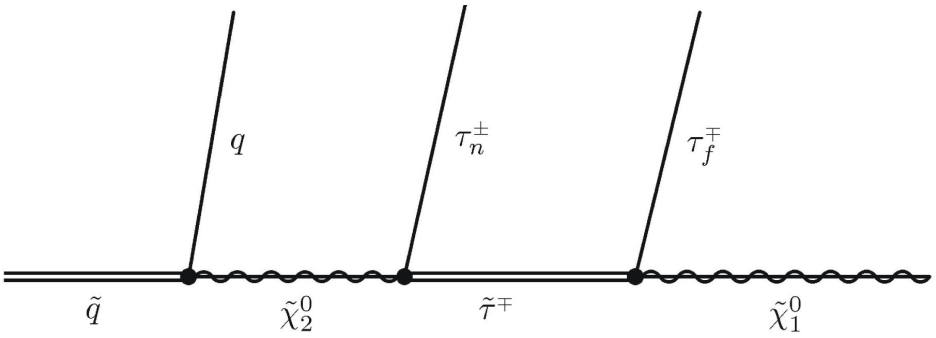
Carolin Zendler, Till Nattermann

Physikalisches Institut
Group Prof. Desch

ATLAS-D Meeting 20./21. September 2007

universitätbonn

motivation

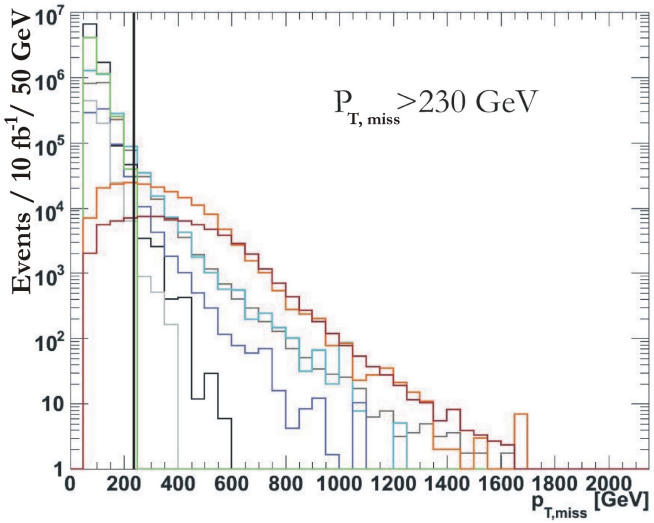


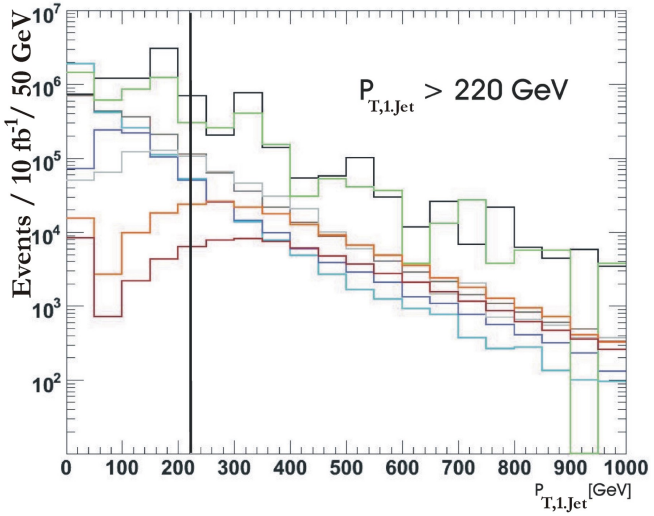
- $m^2_{\ell\ell} = (p_{\ell_n} + p_{\ell_f})^2$-distribution
- endpoint $(m^2_{\ell\ell})_{\max} = m^2_{\tilde{\chi}_2^0}\left(1 - \frac{m^2_{\tilde{\ell}}}{m^2_{\tilde{\chi}_2^0}}\right)\left(1 - \frac{m^2_{\tilde{\chi}_1^0}}{m^2_{\tilde{\ell}}}\right)$
- known neutralino masses $\longrightarrow m_{\tilde{\ell}}$

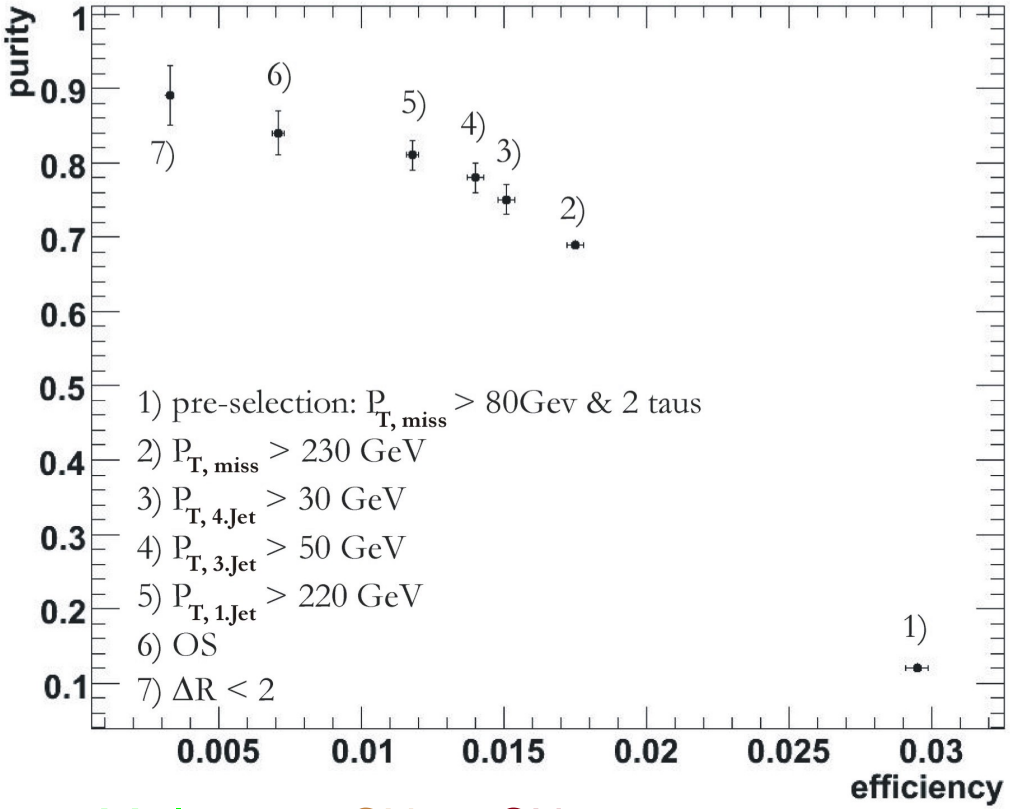
$$\tilde{\chi}_2^0 \longrightarrow \tilde{\tau}^{\pm}\tau^{\mp} \longrightarrow \tau^{\pm}\tau^{\mp}\tilde{\chi}_1^0$$

- information about $\tilde{\tau}$-mass
- $BR(\tilde{\chi}_2^0 \longrightarrow \tau^{\pm}\tau^{\mp}\tilde{\chi}_1^0) \approx 10\ BR(\tilde{\chi}_2^0 \longrightarrow e^{\pm}e^{\mp}(\mu^{\pm}\mu^{\mp})\tilde{\chi}_1^0)$ for $SU3$
- $BR(\tilde{\chi}_2^0 \longrightarrow \tau^{\pm}\tau^{\mp}\tilde{\chi}_1^0) \approx 4\ BR(\tilde{\chi}_2^0 \longrightarrow e^{\pm}e^{\mp}(\mu^{\pm}\mu^{\mp})\tilde{\chi}_1^0)$ for $SU1$
- information about τ_n and τ_f polarisation

event selection – SM & SUSY background







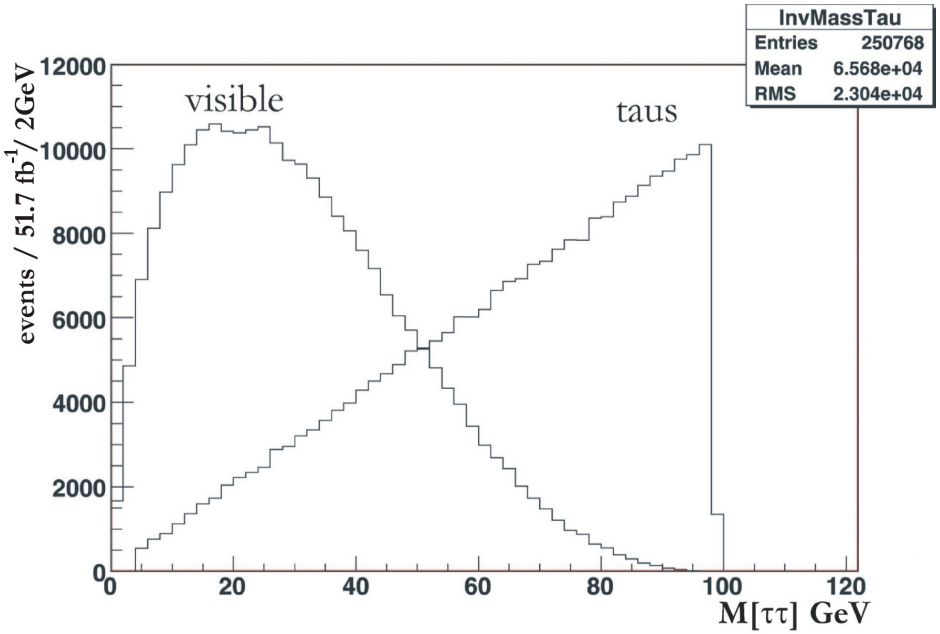
Multijets · SU3 · SU1

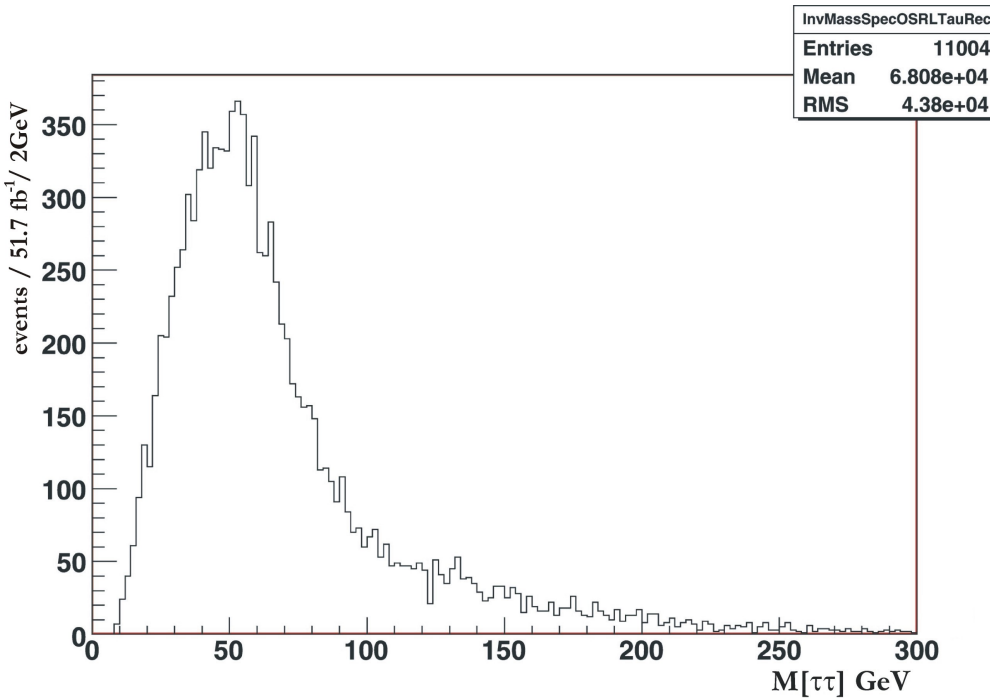
Z+jets · $t\bar{t}$ + jets

$b\bar{b}$ + jets · W+jets · di-jets

$$s = \frac{N_{\mathrm{SUSY}}}{\sqrt{N_{\mathrm{BG}}}} = 100 \pm 4 \text{ SU3}(10\text{fb}^{-1})$$

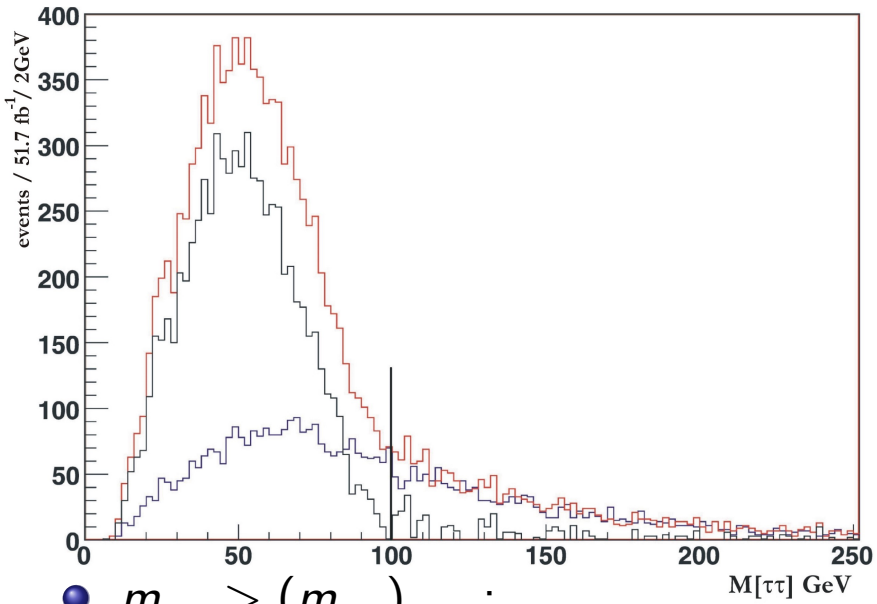
$\tau\tau$-mass spectra



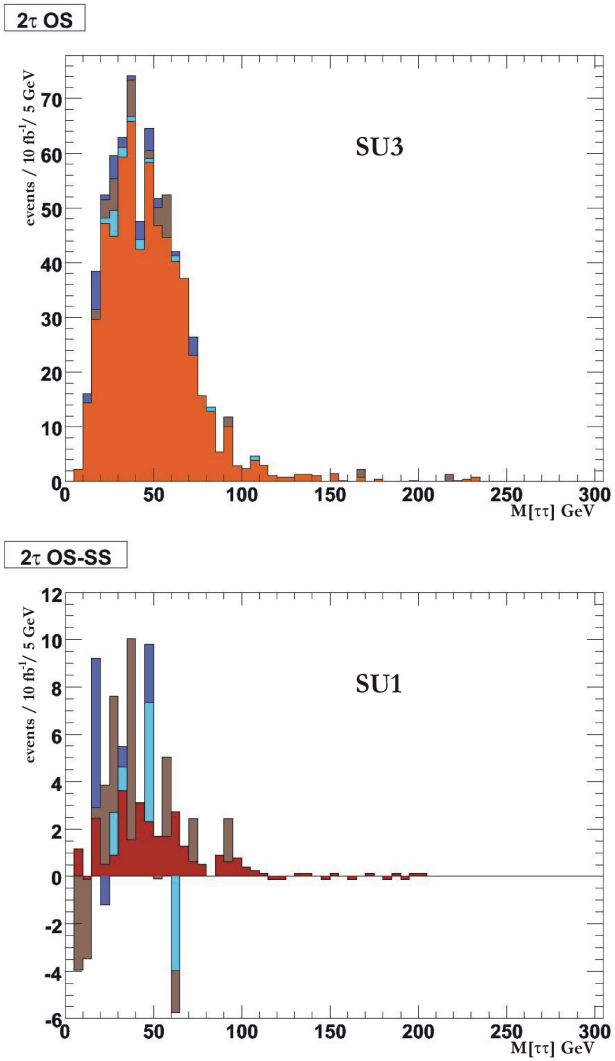


- 1 000 000 SU3 events $\widehat{=} 51.7\mathrm{fb}^{-1}$
- ν not detected
- τ reconstruction
- $m_{\tau\tau} > (m_{\tau\tau})_{\max} \approx 99 GeV \Rightarrow$ fakes and combinational background

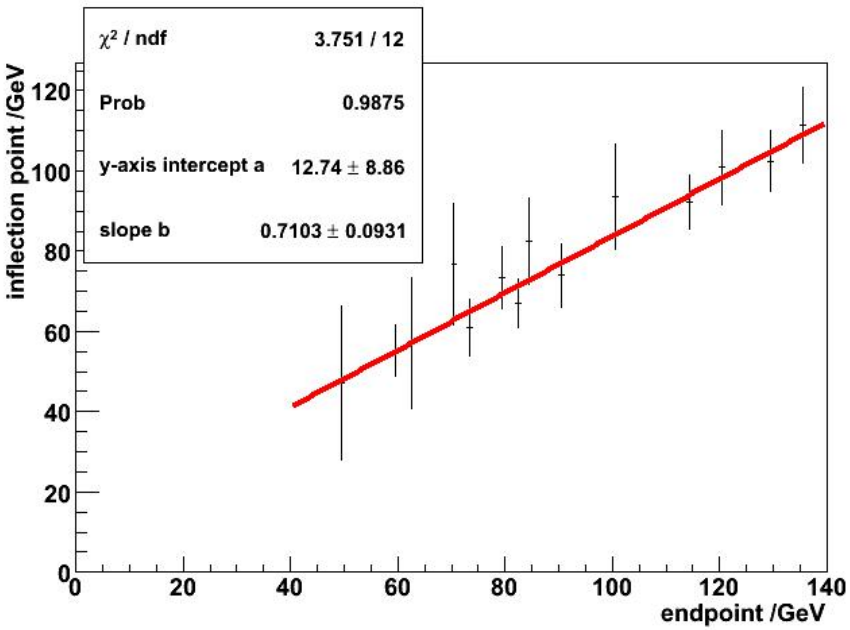
$[\tau^+\tau^-] - [\tau^\pm\tau^\pm]$-distribution



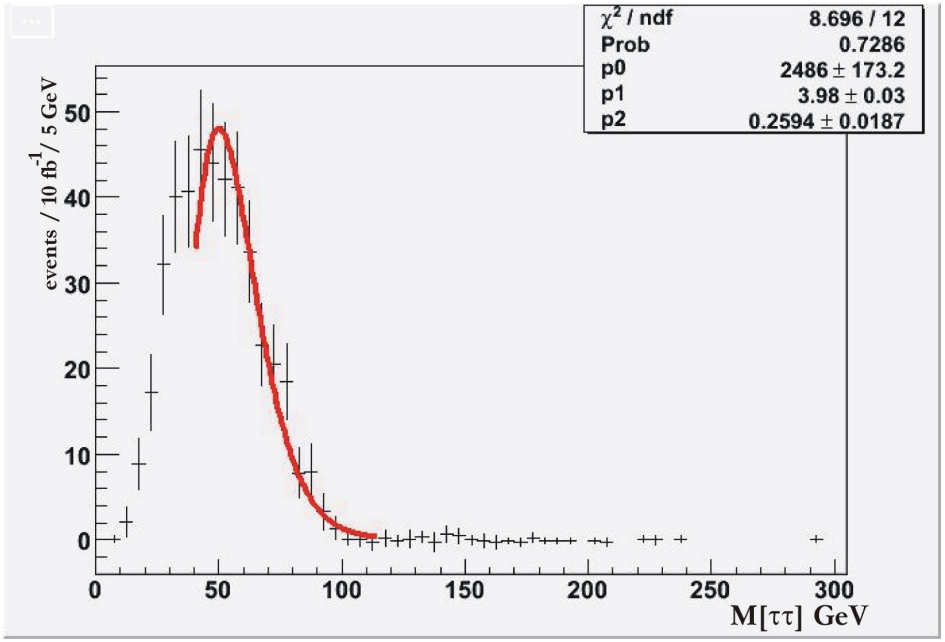
- $m_{\tau\tau} > (m_{\tau\tau})_{\max}$:
  $[\tau^-\tau^+] \approx [\tau^\pm\tau^\pm]$
- $[\tau^-\tau^+] - [\tau^\pm\tau^\pm]$ without combinational background of uncorrelated τs
- $\tilde{\chi}_4^0 \to \tilde{\chi}_1^\pm \tau^\mp \nu_\tau \to$
  $\tilde{\tau}^\pm \nu_\tau \tau^\mp \nu_\tau \to \tau^\pm \tilde{\chi}_1^0 \nu_\tau \tau^\mp \nu_\tau$



inflectionpoint - endpoint



- 14 combinations of $m_{\tilde{\tau}}$, $m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_1^0}$
- 14 different endpoints and inflection points
- measured inflection point $\Rightarrow$ endpoint



$$f(x) = \frac{p_0}{x} \exp\left(\left(\frac{1}{2p_2^2}(\ln(x) - p_1)^2\right)^a\right)$$

SU3: endpoint
$97 \pm 9^{\text{stat}} \pm 6^{\text{syst}}\, GeV$ with
$L = 10 fb^{-1}$

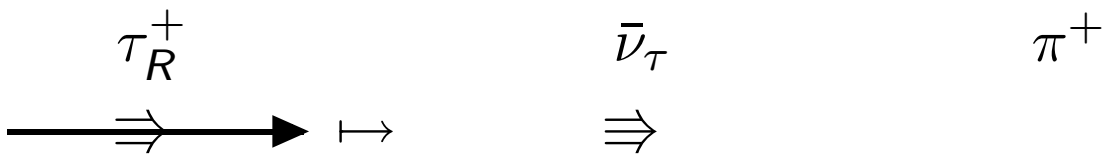
---

[a] modified adoption from
CMS NOTE 2006/096 (2006)

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

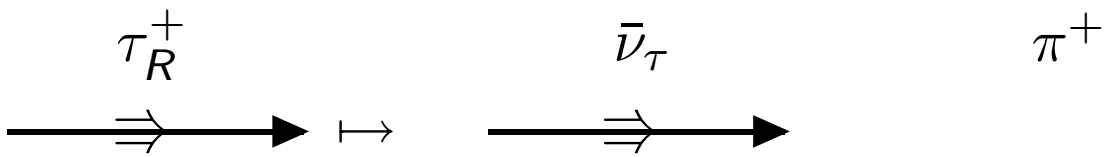
- angular momentum conservation
- handness of neutrino
- momentum conservation

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



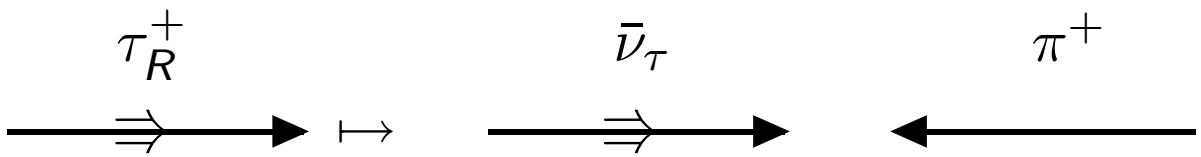
- angular momentum conservation
- handness of neutrino
- momentum conservation

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



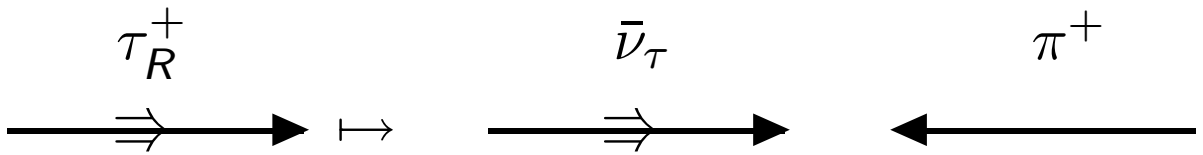
- angular momentum conservation
- handness of neutrino
- momentum conservation

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



- angular momentum conservation
- handness of neutrino
- momentum conservation

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

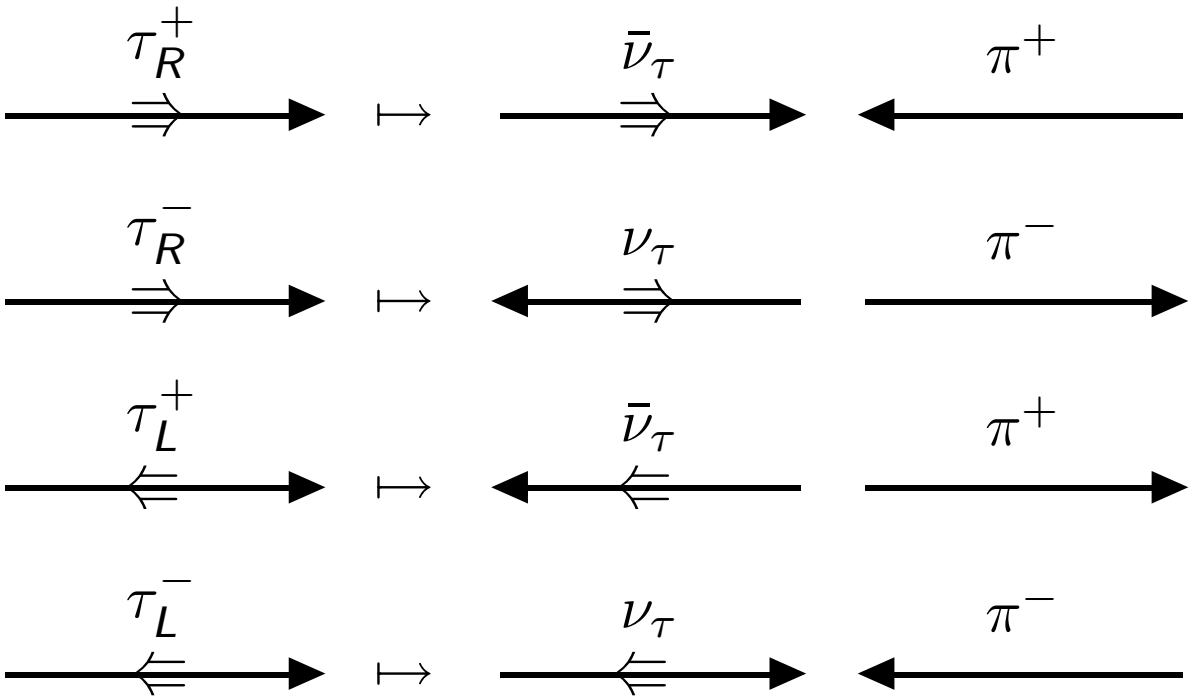


- angular momentum conservation
- handness of neutrino
- momentum conservation

reult

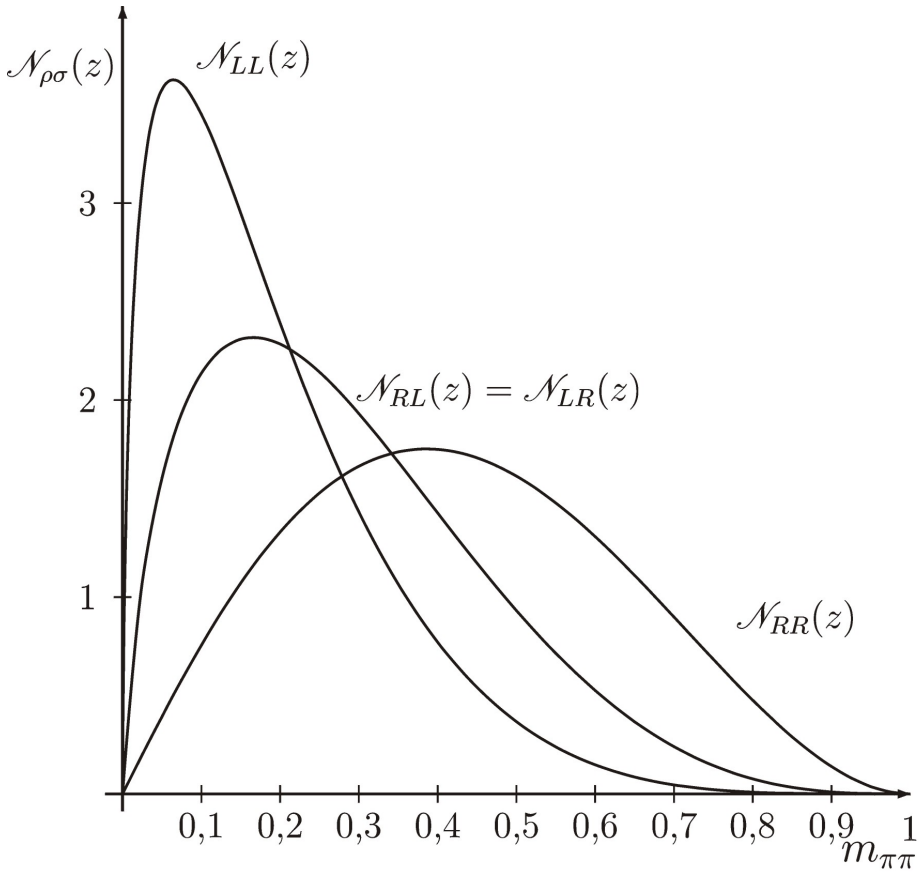
π momentum direction in τ-restframe specified by τ charge and helicity (chirality)

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



- spin-quantisation axis$(\vec{p}_\tau)_{\text{LAB}}-$direction
- LORENTZ-boost τ-restframe $\longrightarrow$ LAB-system
- low and high energy πs

$\tau\tau$ mass spectra

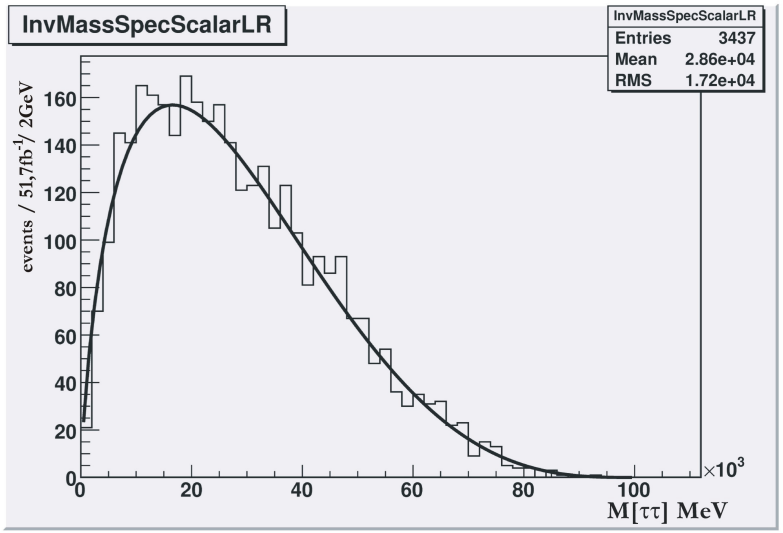


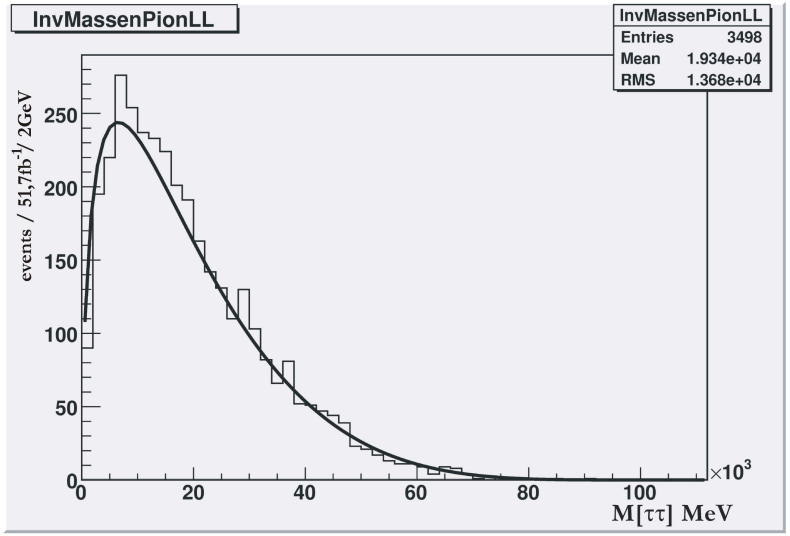
1

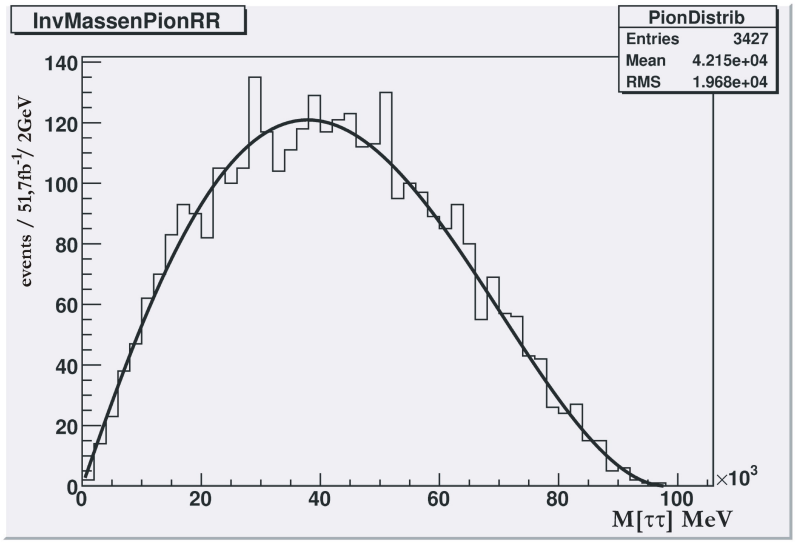
- $\tau \longrightarrow \pi\nu_\tau$
- $m^2_{\pi\pi} = (p_{\pi_n} + p_{\pi_f})^2$
- $m_{\pi\pi}$ sensitive to polarisation
- allows distinction between $RL = LR$, LL and RR (chiralitys)
- but: relation endpoint to inflection point differ

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

spectra of generated $\tau \longrightarrow \nu_\tau \pi$-decays

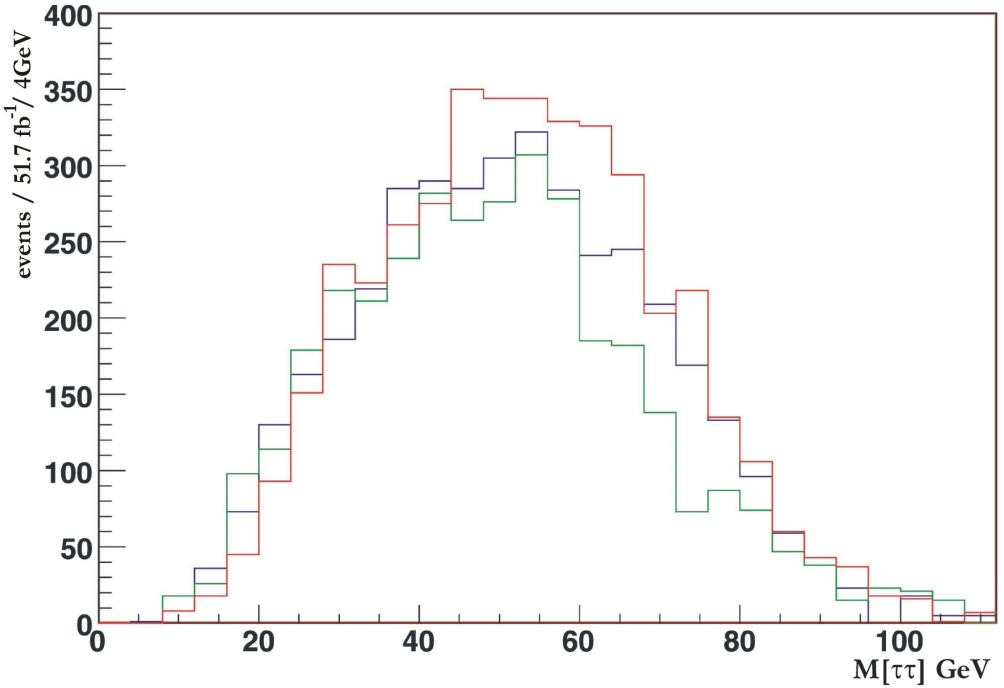






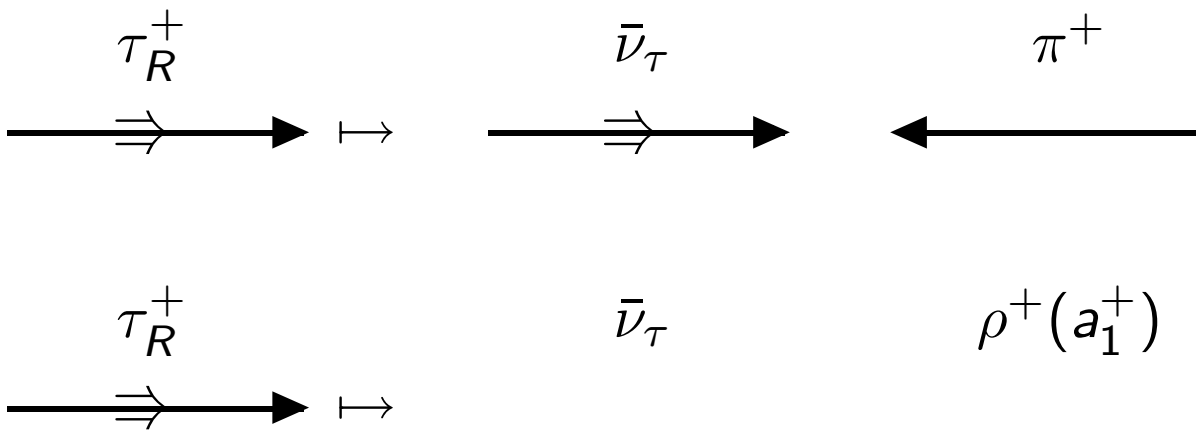
- RR: $(m_{\pi\pi})_{\max} = 98.12 \pm 0.562$ GeV
- LL: $(m_{\pi\pi})_{\max} = 101.3 \pm 1.14$ GeV
- $RL = LR$: $(m_{\pi\pi})_{\max} = 99.97 \pm 0.95$ GeV
- no detector effects

ATLFAST sample including detector effects



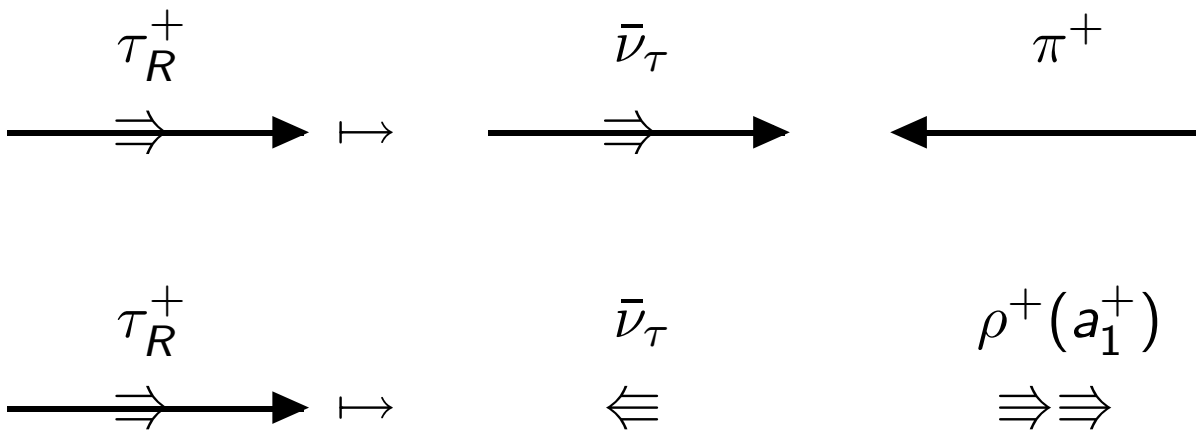
- 1 000 000 events for *RR*, *LL* and $RL = LR$
- cuts: $P_{\mathrm{T,miss}} > 200\,GeV$ $P_{\mathrm{T,1.Jet}} > 200\,GeV$, $P_{\mathrm{T,4.Jet}} > 50\,GeV$
- opposite sign τs - same sign τs
- decay dominated by vector mesons (ρ, a_1)

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



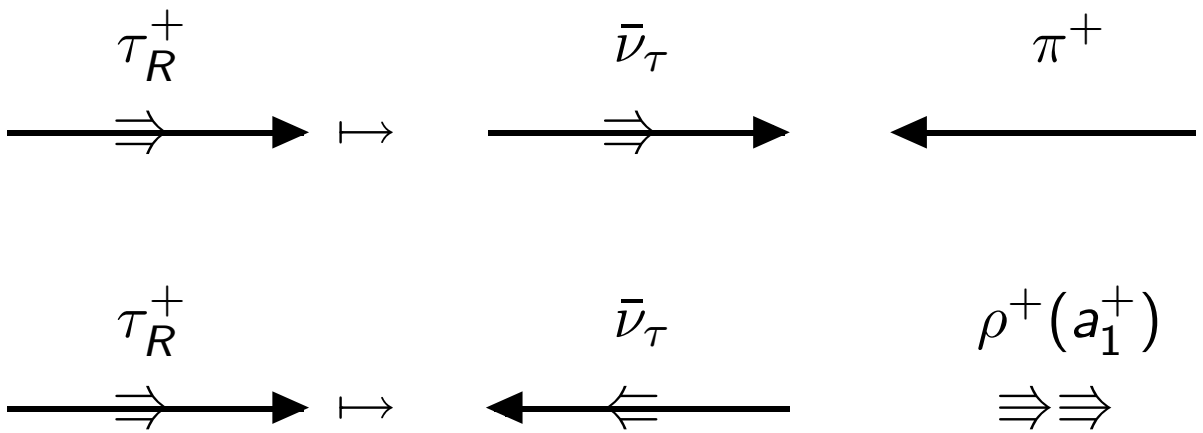
- angular momentum conservation
- handness of neutrino
- momentum conservation

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



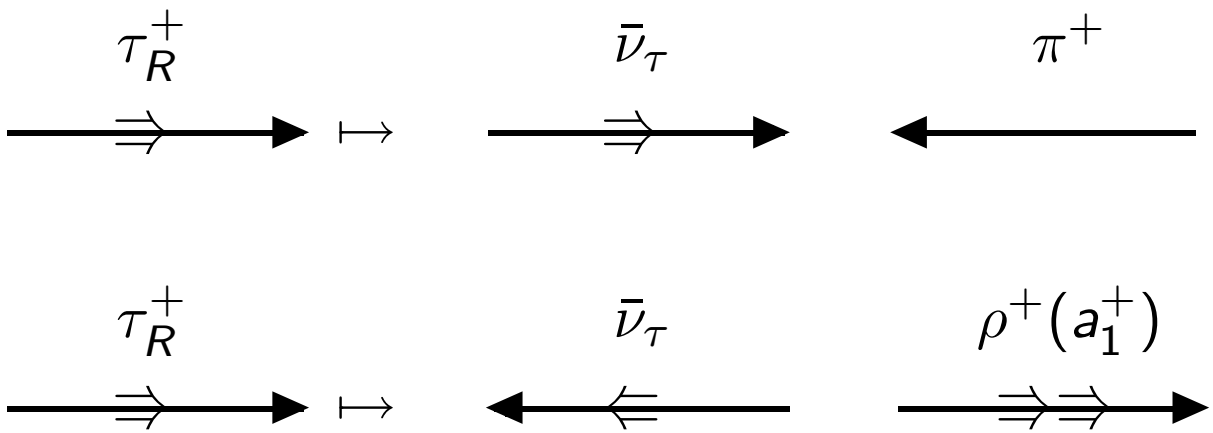
- angular momentum conservation
- handness of neutrino
- momentum conservation

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



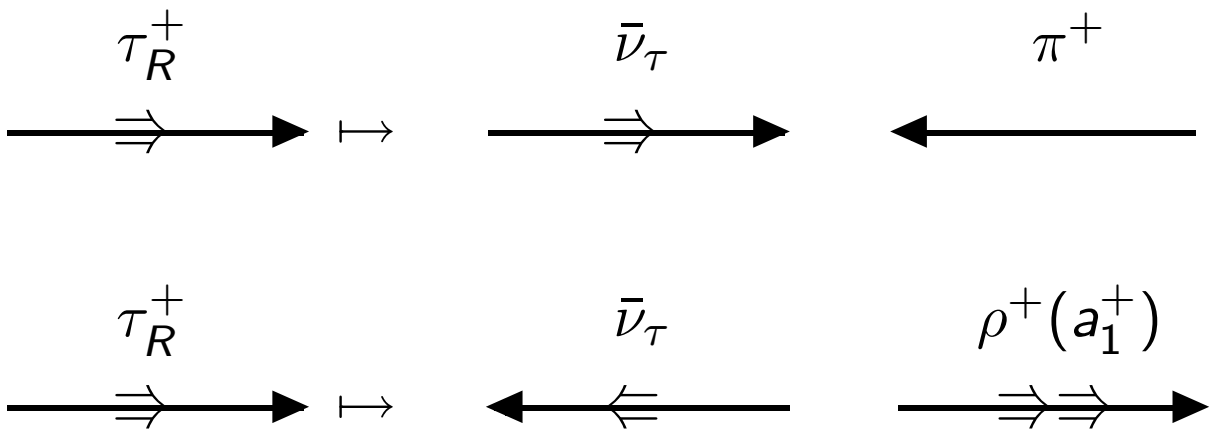
- angular momentum conservation
- handness of neutrino
- momentum conservation

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



- angular momentum conservation
- handness of neutrino
- momentum conservation

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

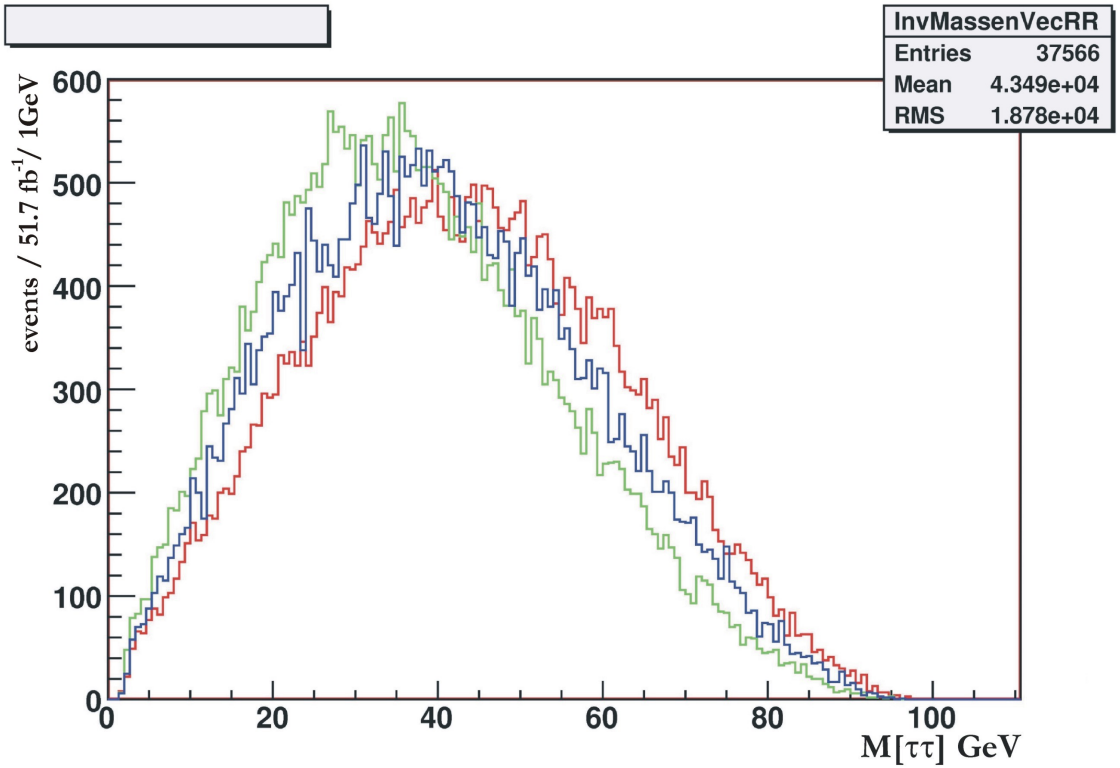


- angular momentum conservation
- handness of neutrino
- momentum conservation

result:

$\rho(a_1)$ has same (opposite) momentum direction as π for longitudinal (transversal) polarisation

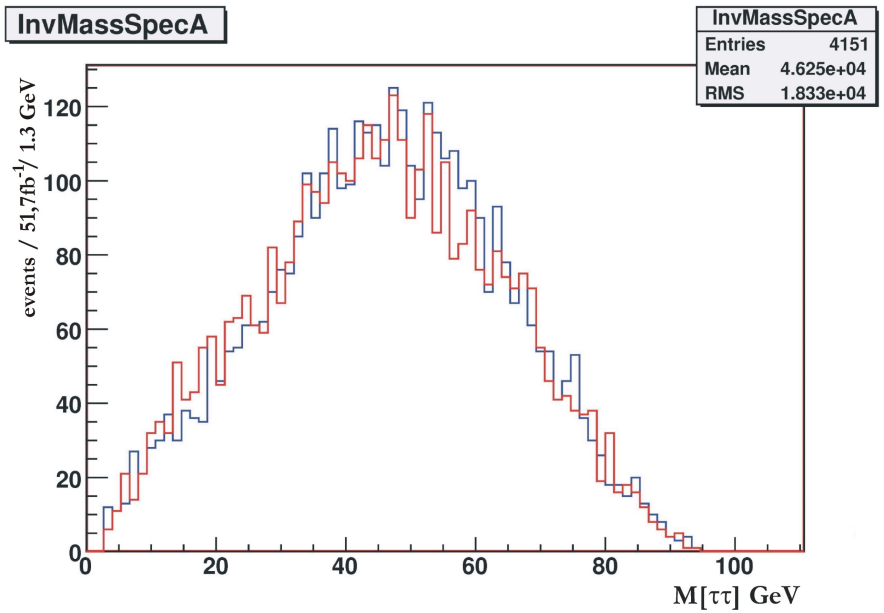
vectormeson spectra of generated events

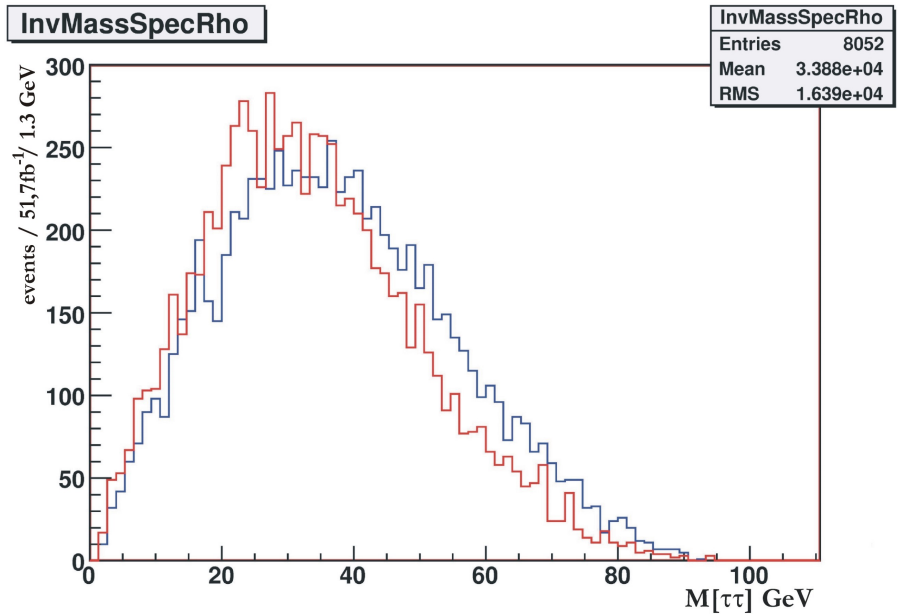


- RR
- LL
- $RL = LR$

- $BR(\rho\&a_1) \approx 0.44\,\&\,BR(\pi) \approx 0.11 \Rightarrow N(\pi\pi) \approx \frac{1}{16} N(\text{vector})$
- $\frac{d\Gamma}{d\cos\vartheta} \propto \left(\frac{m_\nu^2}{m_\tau^2+2m_\nu^2}\left(1 - P_\tau \cos\vartheta\right)\right)_T \quad \left(\frac{\frac{1}{2}m_\tau^2}{m_\tau^2+2m_\nu^2}\left(1 + P_\tau \cos\vartheta\right)\right)_L$

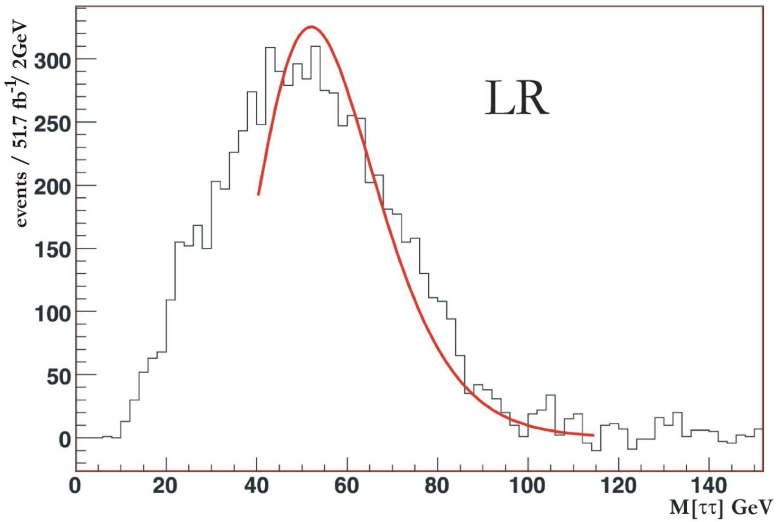
$\tau \longrightarrow a_1, \rho$ decays

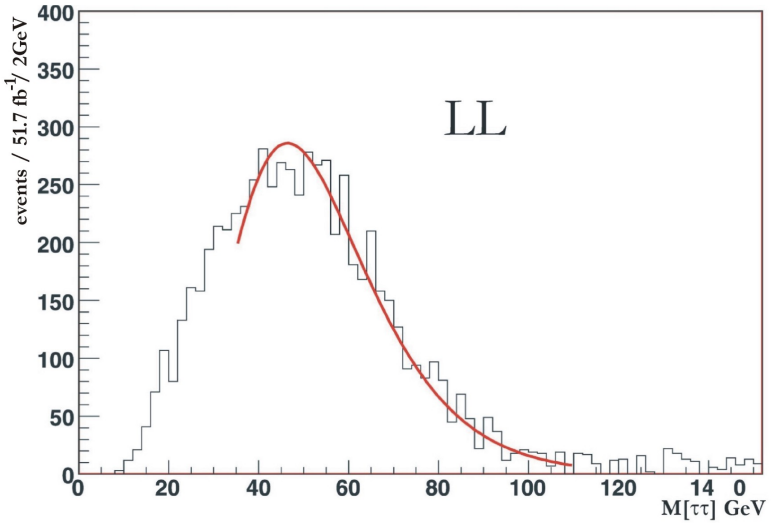


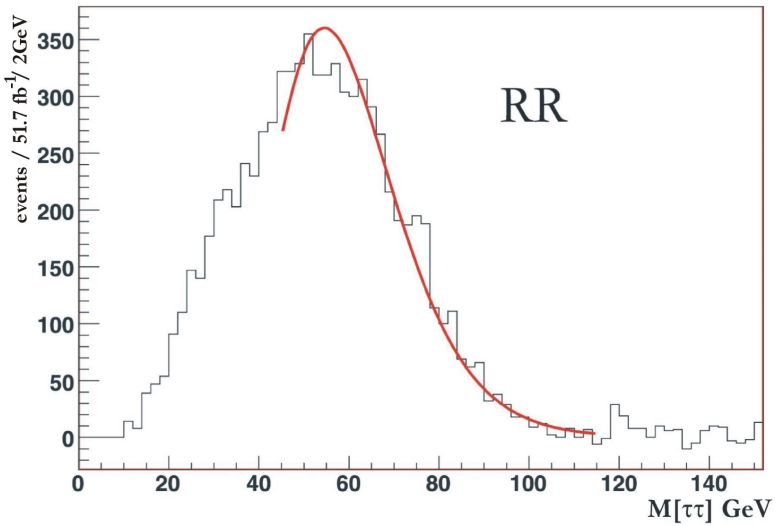


- $[a_1 a_1]_{LL} \approx [a_1 a_1]_{LR=RL}$
- $[\rho\rho]_{LL} < [\rho\rho]_{LR=RL}$
- more longitudinal ρs
- a_1 spectra independent of polarisation, select 3-prong, $BR(\tau \longrightarrow \nu_\tau a_1)_{3-\text{prong}} \approx 9,5\%$

polarisation and inflection point



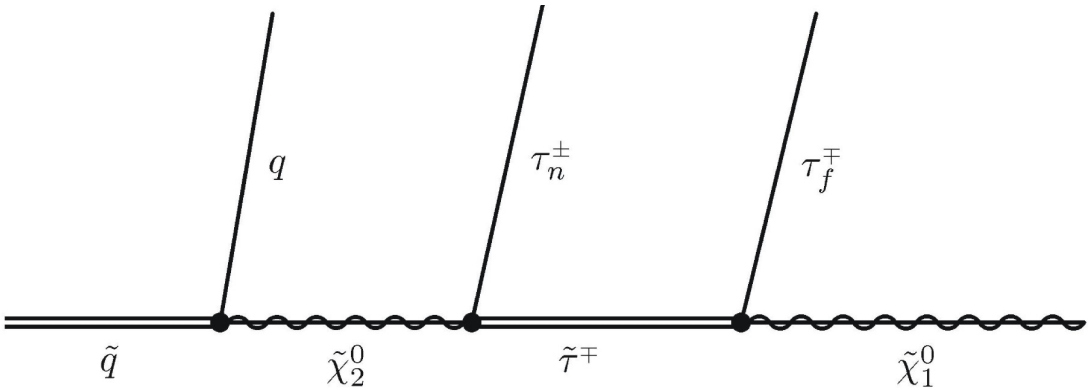




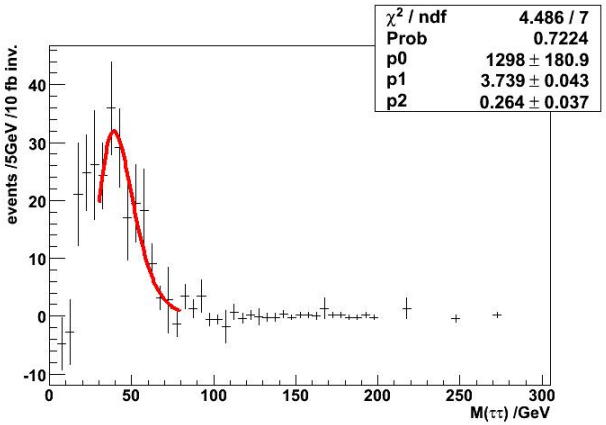
RR: $x_{IP} = 67.6$ GeV
LL: $x_{IP} = 60.9$ GeV
$RL = LR$: $x_{IP} = 64.7$ GeV
systematical error ≈ 7 GeV

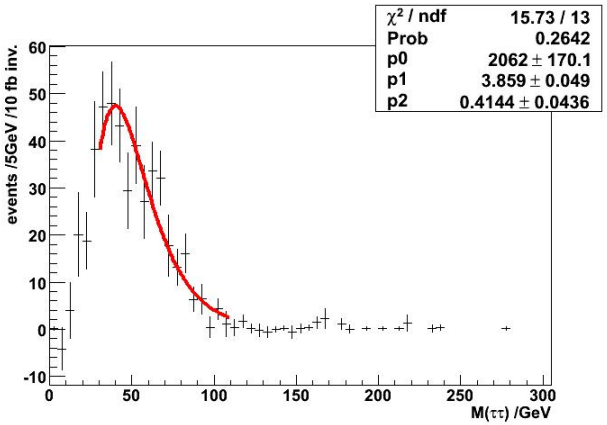
challenges and long term objective

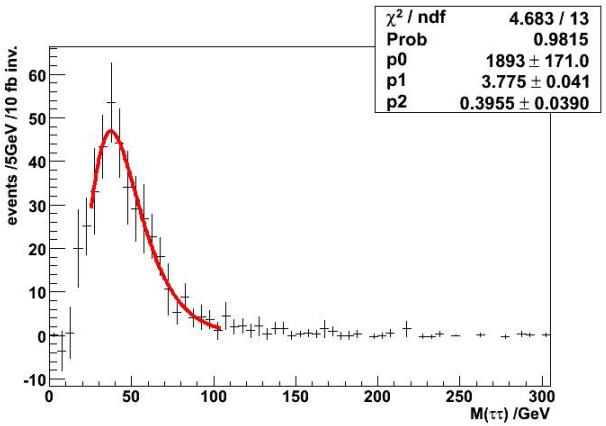
- include polarisation to endpoint determination
- develop strategies polarisation of τ_n and τ_f
  1. fit with more parameters
  2. use intrinsic shape of spectra
- polarisation depends on:
  1. $\tilde{\tau}$-mixing angle
  2. mixing properties of neutralinos

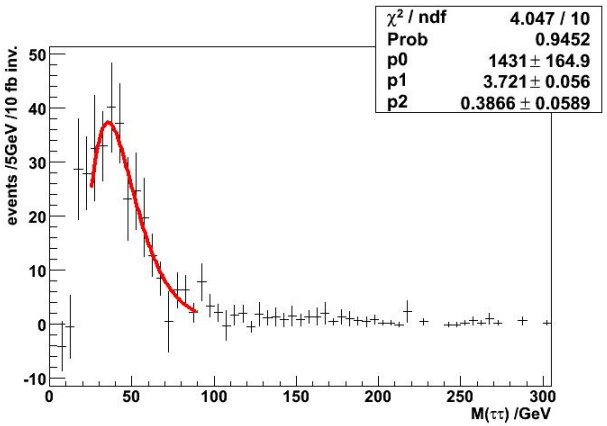


shape of spectra









$m(\tilde{\tau}) = 130\,GeV$
$m(\tilde{\tau}) = 160\,GeV$
$m(\tilde{\tau}) = 190\,GeV$
$m(\tilde{\tau}) = 200\,GeV$

- $f(x) = \frac{p_0}{x}\exp\left(\left(\frac{1}{2p_2^2}(\ln(x) - p_1)^2\right)^2\right) \rightarrow$inflectionpoint

[2] modified proposal from CMS NOTE 2006/096 (2006)