Extraction of $\tilde{\tau}_1$ mass and τ-polarization in 2-body $\tilde{\chi}_2$ decays

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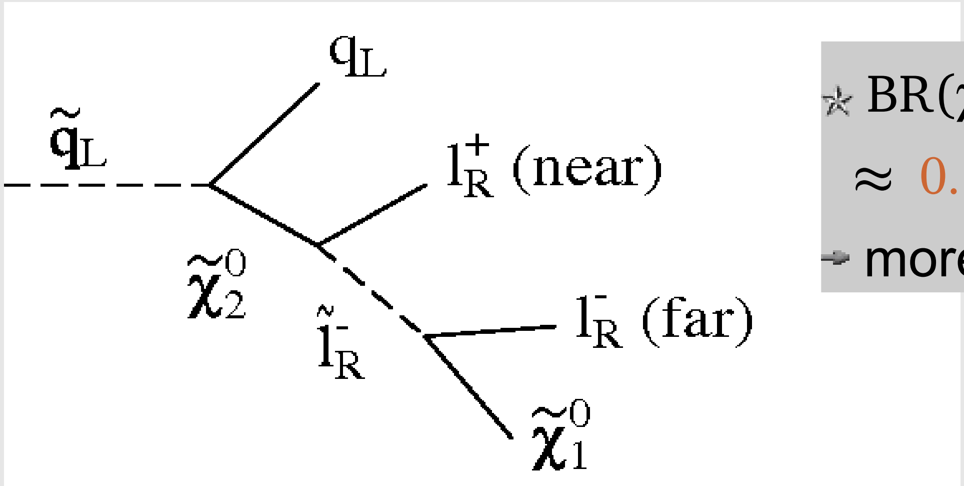
$m_{\tau\tau}$ workshop 21.07.08

outline

- Introduction
- Endpoint determination with “low” integrated luminosity (<10 fb^{-1})
- Endpoint and polarization measurement with “high” integrated luminosity (several 10 fb^{-1})
- Conclusions
- Discussion

introduction



- $BR(\chi_2^0 \to e^+e^- \chi_1^0) \approx BR(\chi_2^0 \to \mu^+\mu^- \chi_1^0) \approx 0.1 * BR(\chi_2^0 \to \tau^+\tau^- \chi_1^0)$ for SU3
- → more τ than e, μ due to R,L-mixing

what kind of SUSY are we dealing with?

Ditau mass spectrum holds information about stau mass and mixing angle:

- Endpoint of $m_{\tau\tau}$ spectrum: $$m_{\tau\tau}^{max} = \sqrt{\frac{(m(\tilde{\chi}_2^0)^2 - m(\tilde{\tau}_1)^2)\cdot(m(\tilde{\tau}_1)^2 - m(\tilde{\chi}_1^0)^2)}{(m(\tilde{\tau}_1)^2)}}$$
- → if $m(\tilde{\chi}^0_{1,2})$ known -> $m(\tilde{\tau}_1)$
- Sum of tau polarizations -> stau mixing angle

invariant mass spectrum

- LSP not detected
  - no mass peak, kinematic endpoint
- $m_{\tau\tau}^{vis}$: sharp edge washed out due to escaping ν
- little statistics left at edge
  - need to approximate shape

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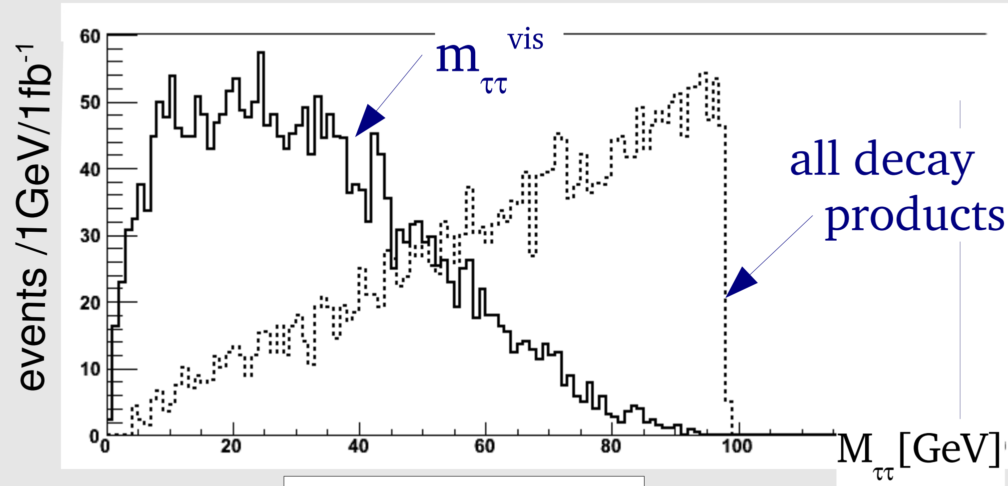


generator level

- **SU3:** $m(\tilde{\tau}_2) > m(\tilde{\chi}_1^0)$
  - only decays via $\tilde{\tau}_1$

SU3: mSUGRA bulk region point

m_0 = 100 GeV   tanβ = 6

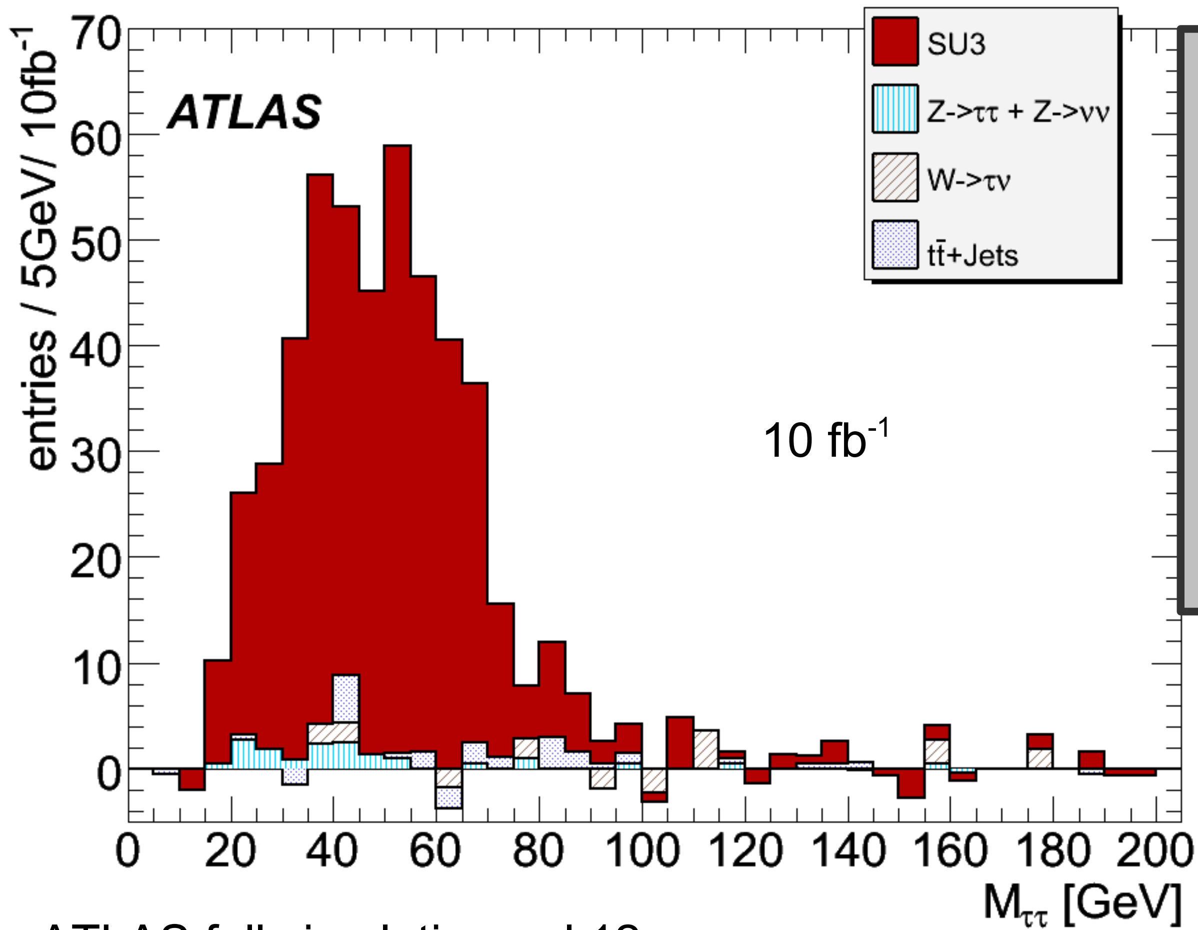
$m_{1/2}$ = 300 GeV   sgnμ = +

A_0 = -300 GeV

Technicalities for ATLAS people:

all results obtained with athena rel. 12 and TauRec or ATLFAST TauRec parameterization

mass spectrum II

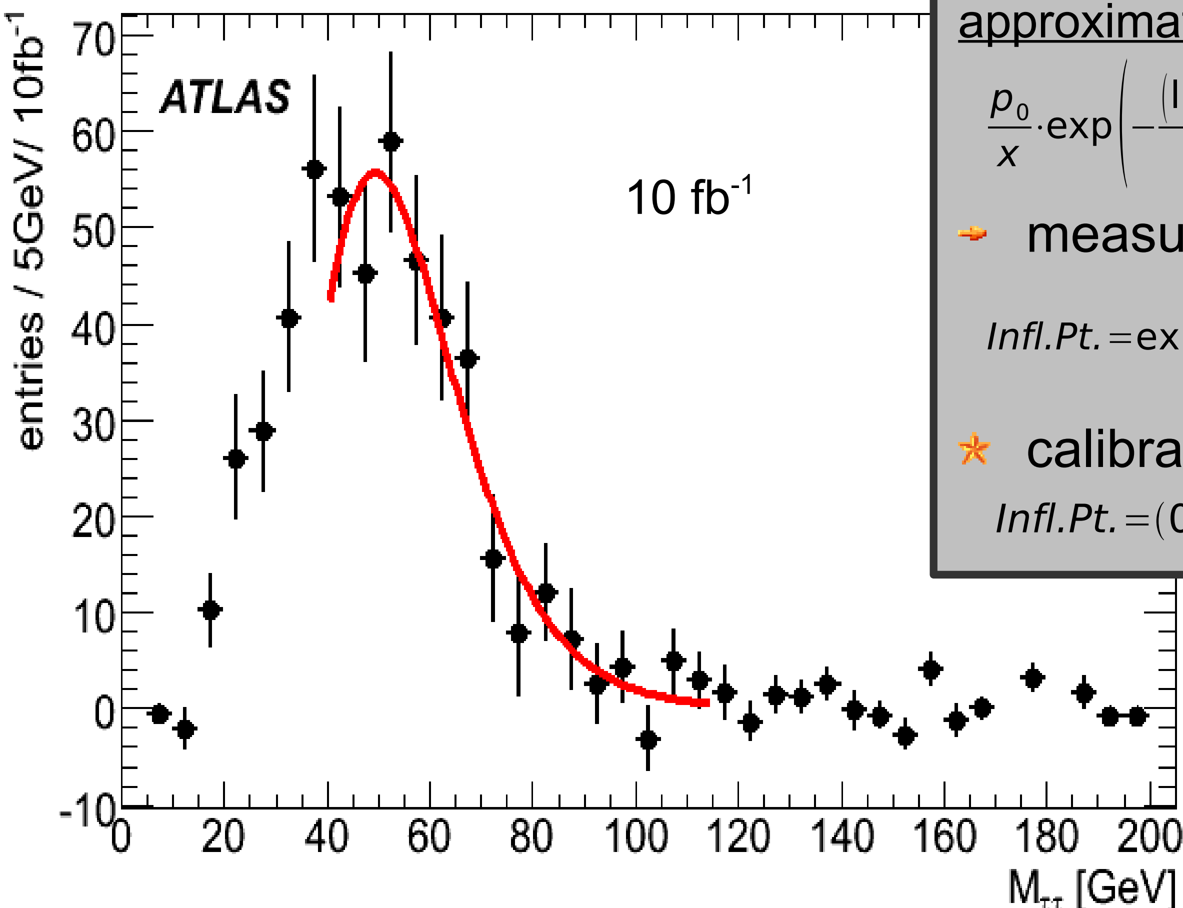


ATLAS full simulation, rel.12

selection cuts:

- p_T^{miss} > 230 GeV
- 4 Jets: p_T > 40 GeV
- 3 Jets: p_T > 50 GeV
- 1 Jet: p_T > 220 GeV
- $\Delta R(\tau\tau) < 2$
- OS-SS

endpoint measurement method



ATLAS full simulation, rel.12

approximate shape:

$$\frac{p_0}{x} \cdot \exp\left(-\frac{(\ln(x-p_1))^2}{2p_2^2}\right)$$

- measure inflection point:

$$Infl.Pt. = \exp\left(\frac{-1}{2} p_2^2 \left(3 - \sqrt{\left(1 + \frac{4}{p_2^2}\right)}\right) + p_1\right)$$

- calibration done with ATLFAST:

$$Infl.Pt. = (0.47 \pm 0.02) m_{\tau\tau}^{max} + (15 \pm 2) GeV$$

- measured endpoint:

(theory: **99** GeV)

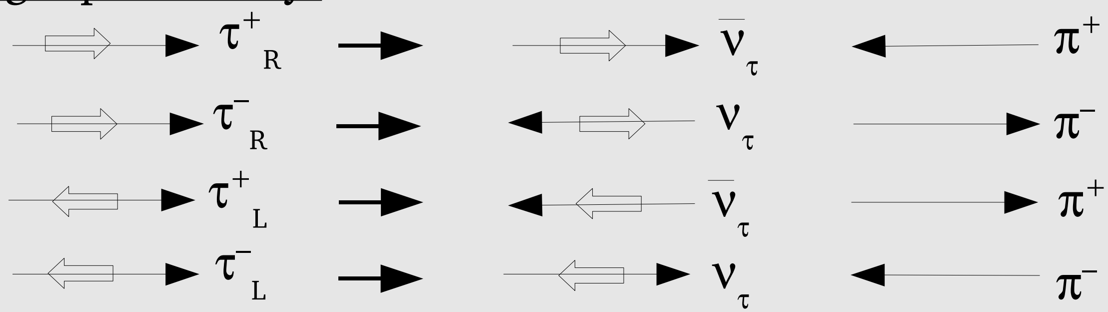
103 ± 5^{stat} ± 4.5^{syst*} GeV

for 10 fb^{-1}

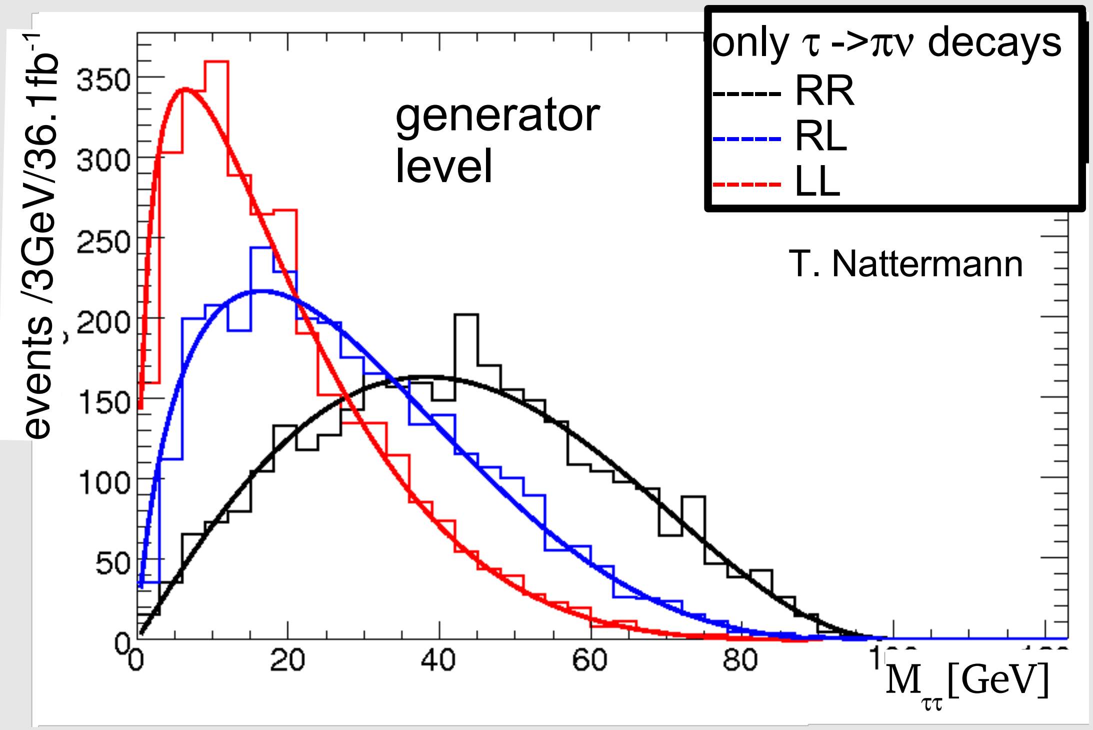
* syst. error: fast simulation

polarization effects

single pion decay:

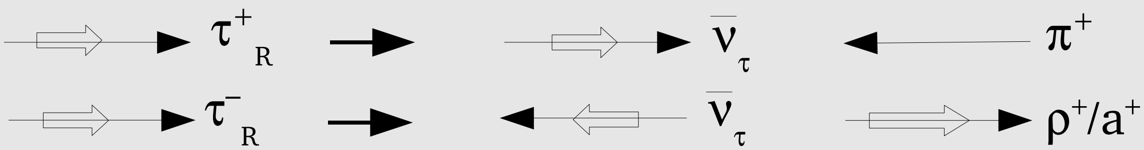


- angular momentum / momentum conservation + helicity of neutrino
- pion momentum direction determined by tau charge and helicity
- pion boosted (anti)parallel to tau momentum direction

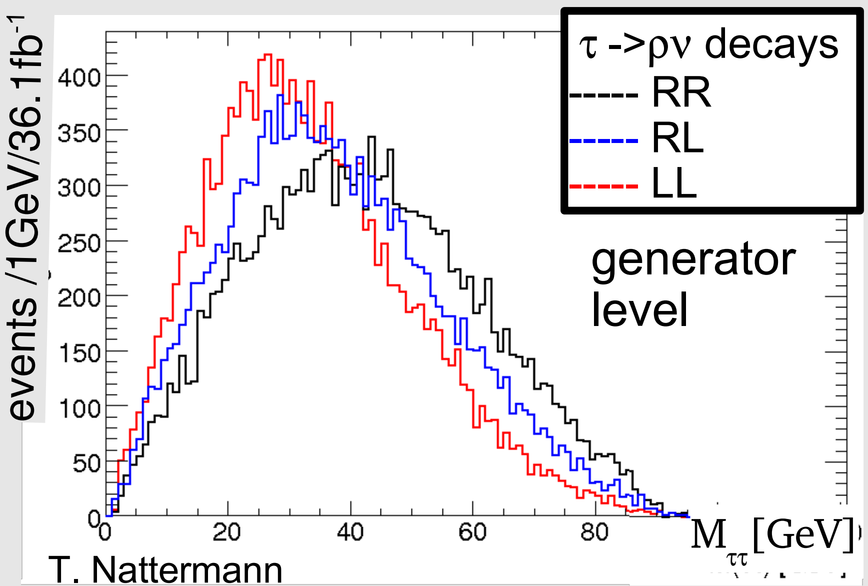


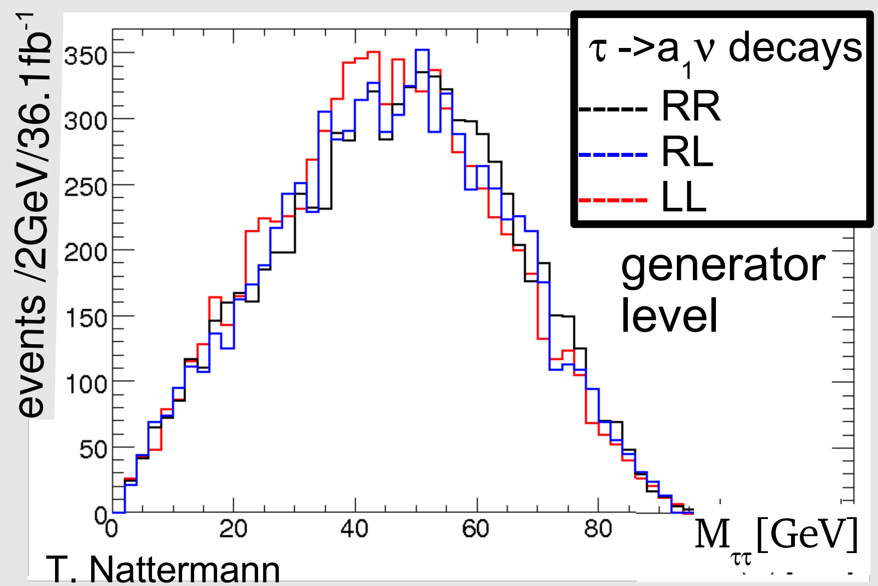
- shape of mass spectrum depends on tau polarization
- inflection point shifted

tau decays via vector mesons

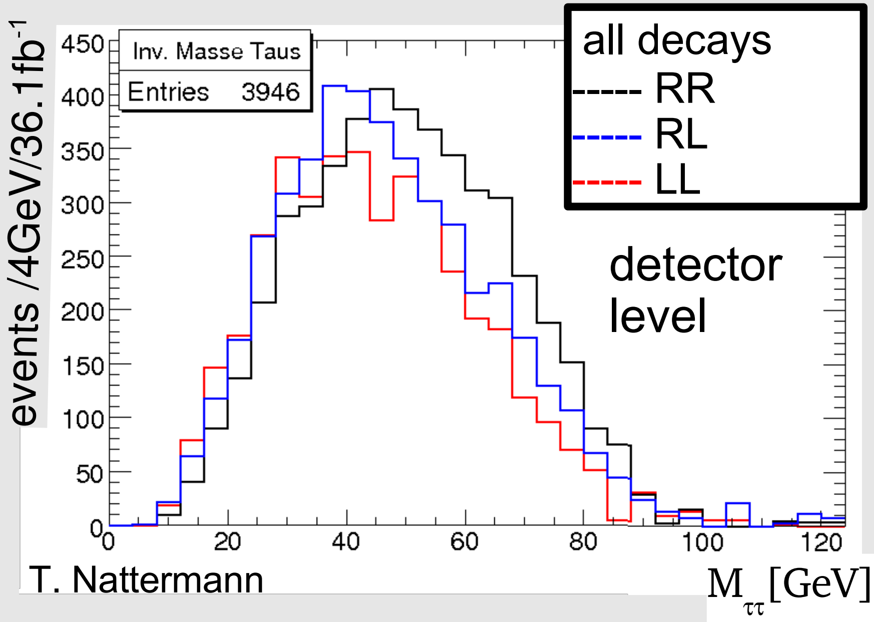


- ρ/a_1: same (opp.) momentum direction as π for long. (transv.) meson
  - ρ: longitudinal share bigger than transversal
  - a_1: longitunal and transversal share equal -> mass spectrum not shifted





detector effects: ATLFAST (fast simulation)



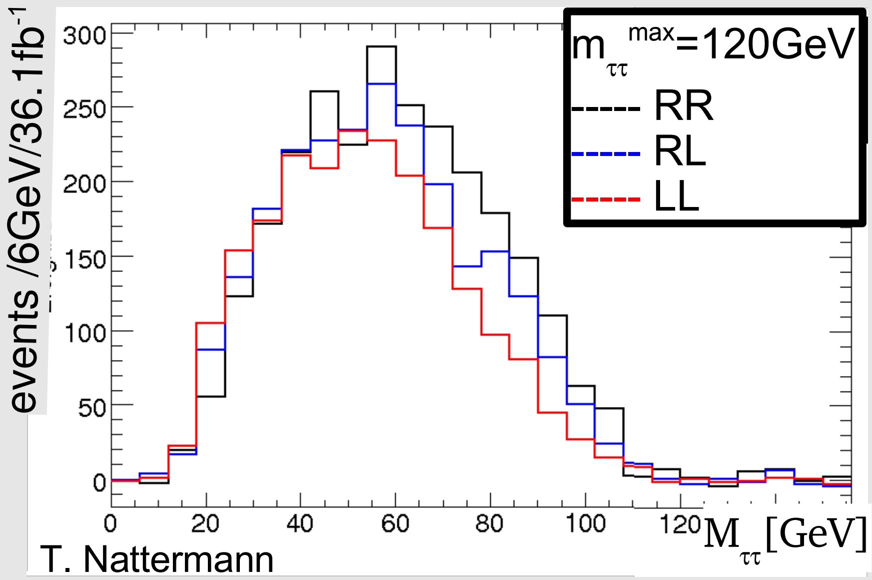
- shape deformed by low tau reconstruction efficiency at low p_T
- reduced shape information, rising edge determined by τ ID

- shift in trailing edge affects inflection point but not endpoint
- additional uncertainty on calibration showed before
- add. error on endpoint measurement: **$\pm$ 3.5$^{(pol)}$ GeV**

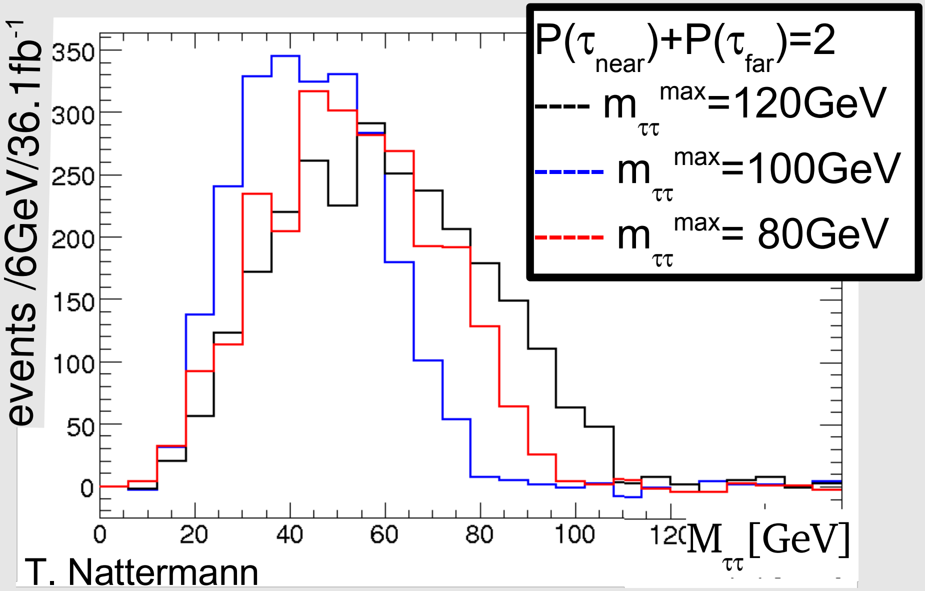
mass and polarization

- to measure both endpoint and polarization: disentangle mass and polarization effects
- search traits with max. different sensitivity to mass / polarization:

polarization effect: fixed masses



mass effect: fixed polarization

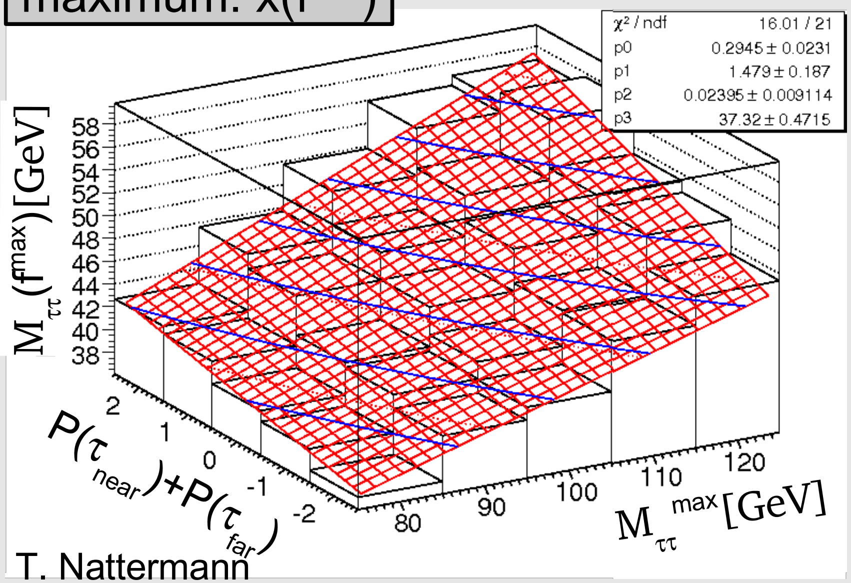


- max. difference close to maximum
- max. difference at high $m_{\tau\tau}$
- traits for calibration: maximum plus position of 0.1*maximum

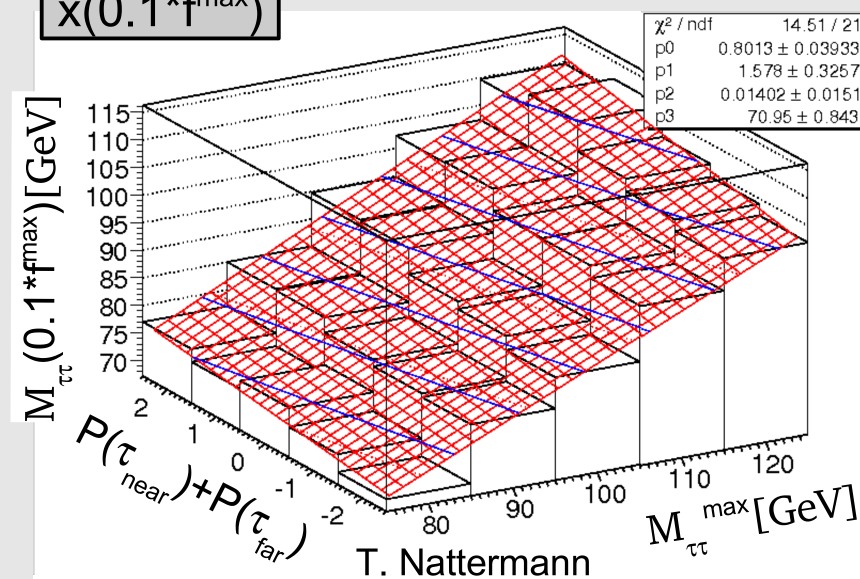
2dim calibration

Calibration: measure x(f^{max}), x(0.1*f^{max}) with 1dim gauss fit: $f(x)=p_0 \cdot \exp\left(-\frac{(p_1-x)^2}{2p_2^2}\right)$

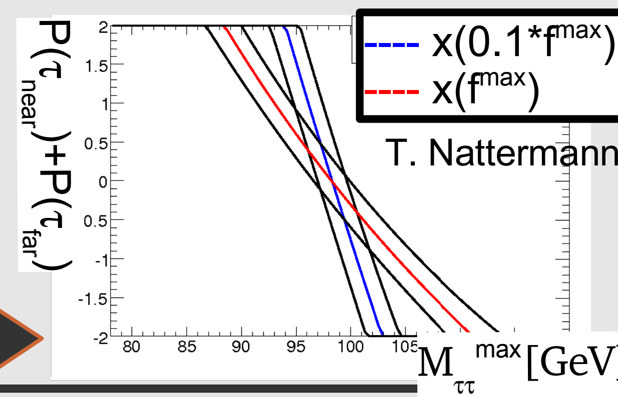
maximum: x(f^{max})



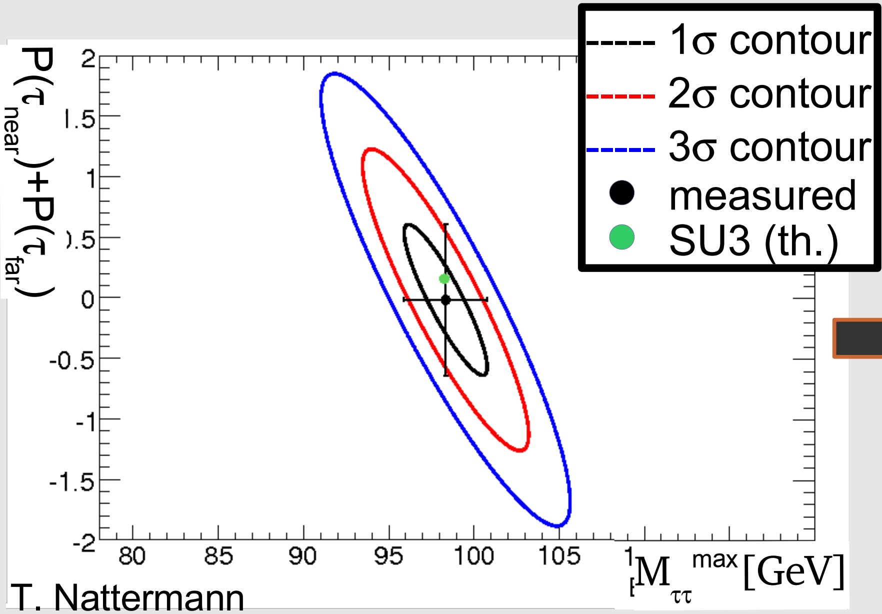
x(0.1*f^{max})



- 2dim fit function: $g(P,m)=p_0P+p_1m+p_1Pm+p_3$
- equipotential line from each of the two observables
- determine intersection in endpoint-polarization plane



- measured SU3 values:



*systematic error inculded

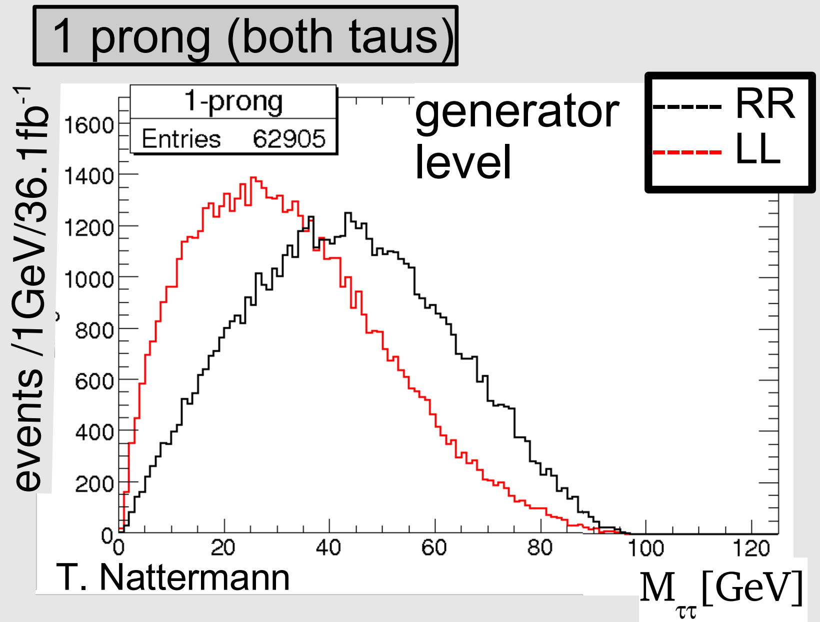
$m_{\tau\tau}^{max}$ = (98.3 ± 2.5*) GeV
$P(\tau\tau) = P(\tau_{near})+P(\tau_{far})$
= (-0.02 ± 0.6*) GeV
for 36 fb^{-1}

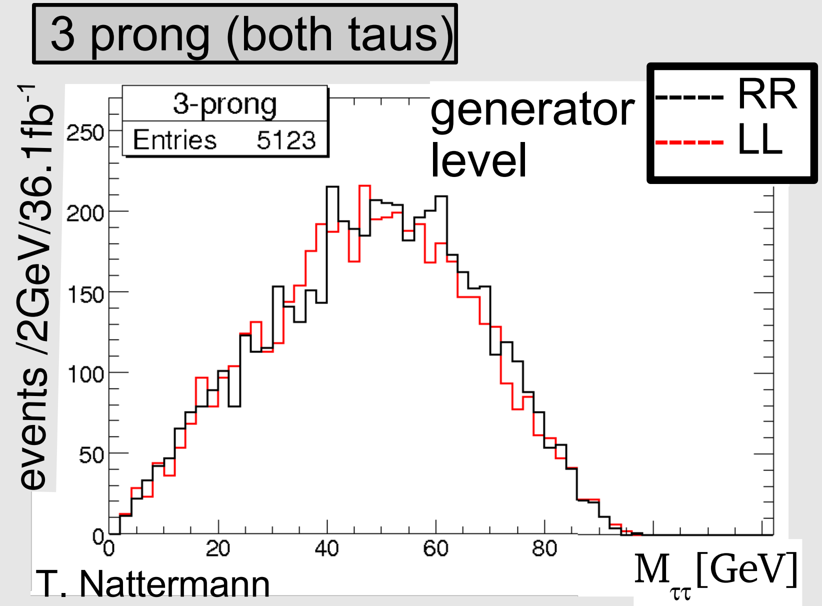
theory: $m_{\tau\tau}^{max}$ = 99 GeV
$P(\tau\tau)$= +0.08

- Can results be improved by separation of different tau decay modes?
  remember: **a_1 decays not affected by polarization effects**

separation via 1p/3p

- <u>separation of 1prong and 3prong decays:</u>
  3p dominated by a_1 (~2/3) and "others" (=not ρ,π,a_1) -> indepent of polarization





<u>but:</u> only 5% of double-hadronic decays are double-3prong
+ some a_1 also decay 1prong

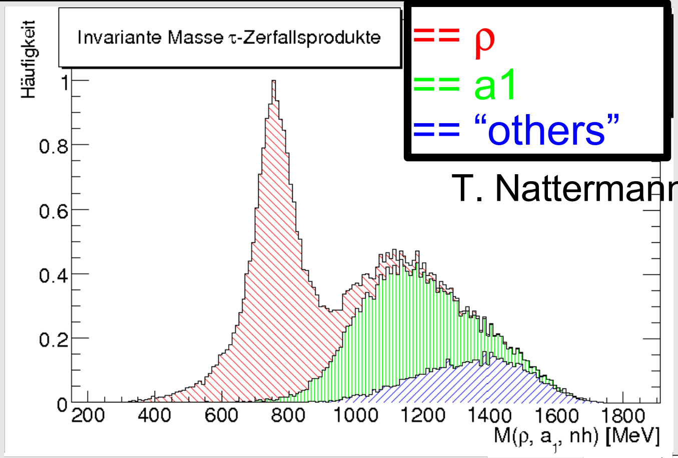
- on detector level and after selection cuts, not enough double-3prongs for endpoint determination

separation via inv. mass

- use invariant mass of single tau decay products:

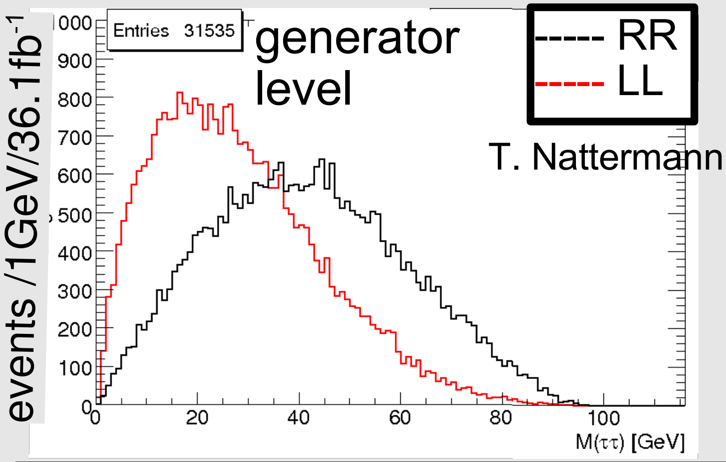
Inv. Mass of tau decay products

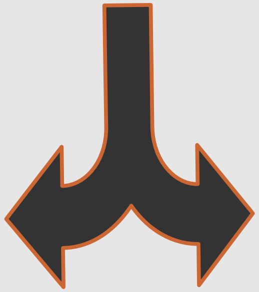
generator level



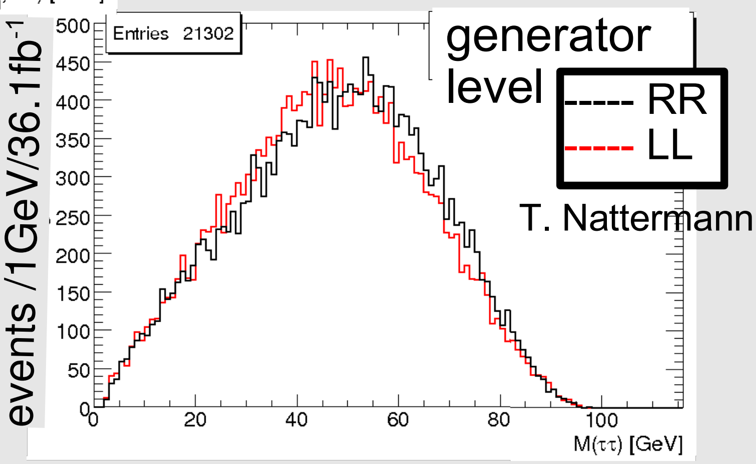
but: need to reconstruct all decay products correctly
- currently not possible
- also not in ATLFAST

$p_\mu p^\mu < 900$ MeV





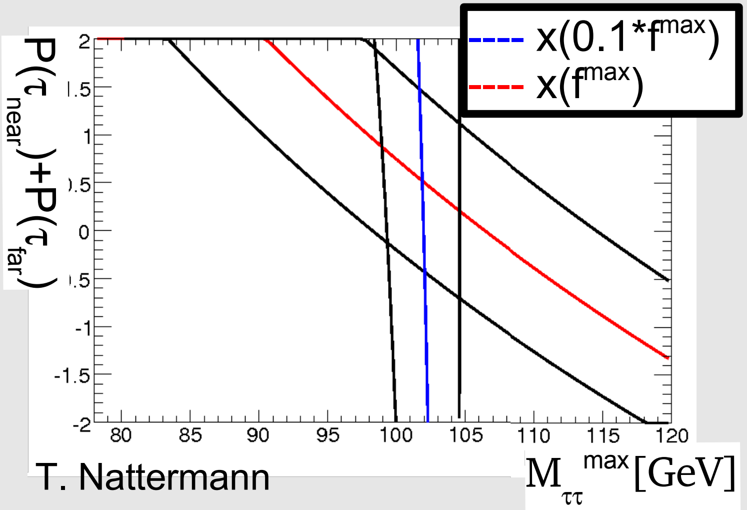
$p_\mu p^\mu > 900$ MeV



...but how much ***could*** be gained by such a separation?

- take reconstructed taus + information about decay mode from truth-match
- fake taus: probability according to branching fraction
- 6 separate calibrations:
  2/1/0 taus decayed in polarization sensitive mode
  x 2 observables

preliminary



T. Nattermann

- 0.1*maximum: from polarization **independent** spectrum (21%)
- maximum: from polarization **dependent** spectrum (50%)

- less parallel, intersection steeper
- error bands broader due to statistics loss

- measurement of $m_{\tau\tau}^{max}$ and $p(\tau\tau)$ could not be improved
- but: used only 2 out of 6 calibrations -> repeat with full information: under study

conclusions

- $m_{\tau\tau}^{max}$ and sum of tau polarizations $P(\tau\tau)$ provide important information for SUSY parameter determination
- can be measured accurately:

  for SU3 ($m_{\tau\tau}^{max}$ = 99 GeV, $P(\tau\tau)$= +0.08) our methods yield

  $\mathbf{m_{\tau\tau}^{max} = (103 \pm 5^{stat} \pm 4.5^{syst} \pm 3.5^{pol})}$ **GeV** for **10 fb^{-1}**

  and

  $\mathbf{m_{\tau\tau}^{max} = (98.3 \pm 2.5)}$ **GeV,**

  $\mathbf{P(\tau\tau) = (-0.02 \pm 0.6)}$ **GeV** for **36 fb^{-1}**
- these results could *principally* be improved by use of tau decay information: under study
- an accurate separation of tau decay modes would be desirable for high luminosity studies

backup

trigger

1 trigger
2 efficiency (SU3)
3 efficiency for SU3 events passing cuts:
met>230GeV, jet pts(220/50/50/40), 2Ntaus DR<2
3b efficiency for SU3 events passing cuts:
met>230GeV, jet pts(220/50/50/40), Ntaus>=2

tau trigger results also not compatible to numbers given for SU3 in Tau Trigger CSC Note

rel. 12 study:

1	2	3
xe120	0.75	1
j70_xe70	0.87	1
j400	0.23	0.31
j160	0.81	0.99
2j120	0.62	0.76
3j65	0.52	0.77
tau10i	0.34	0.86
tau15i	0.28	0.83
tau20i	0.27	0.81
tau25i	0.24	0.77

rel 13:
can not reproduce rel 12 result for tau trigger!

1	2	3b
xe120	0.72	0.92
j70_xe70	0.85	0.99
j400	0.34	0.52
j160	0.82	1
2j120	0.64	0.78
3j65	0.53	0.84
tau10i	0.7	0.99
tau15i	0.67	0.99
tau20i	0.46	0.96
tau25i	0.41	0.92

rel. 12: SusyView
rel. 13: TauDPDMaker

selection cuts: efficiency

a: met>230GeV, jet pts>(220/50/50/40)GeV
b: a + Ntaus>=2

+ n jets ↓

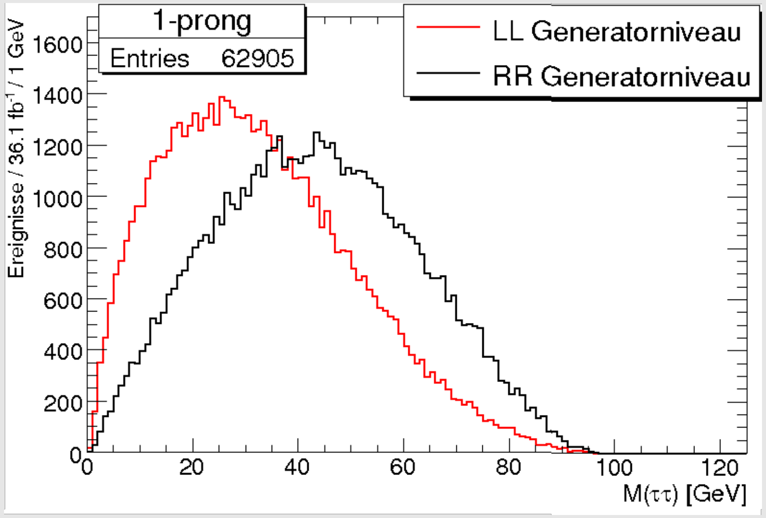
	n jets	a	b
ttbar			
->lnulnu	0	1*10-5	2*10-6
	1	3*10-4	3*10-5
	2	1*10-3	9*10-5
	3	4*10-3	4*10-4
->lnuqq	0	5*10-5	1*10-6
	1	3*10-4	2*10-5
	2	8*10-4	6*10-5
	3	2*10-3	8*10-5
->qqqq	1	4*10-7	0
	2	7*10-7	0
	3	4*10-6	0
Z			
->tautau	2	8*10-5	1*10-5
	3	4*10-4	7*10-5
	4	7*10-4	1*10-4
	5	1*10-3	7*10-5
->nunu	4	5*10-4	9*10-6

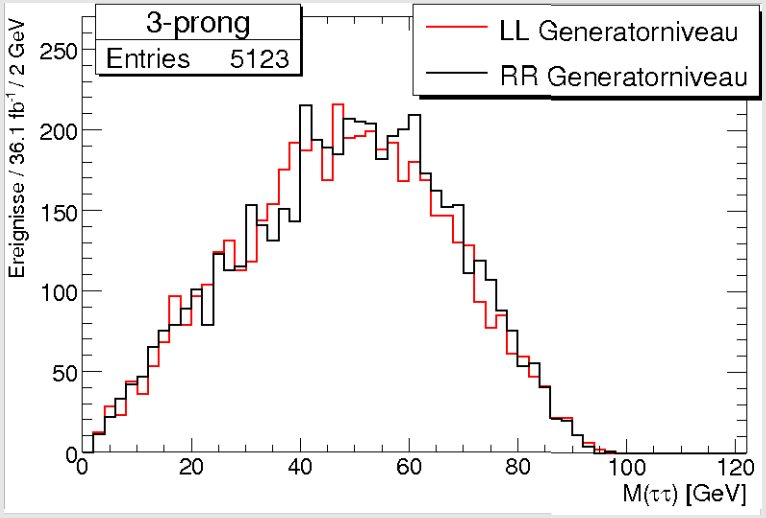
		a	b
SU3		**0.26**	**0.01**
W			
->taunu	2	3*10-5	7*10-7
	3	7*10-4	3*10-5
	4	2*10-3	9*10-5
	5	3*10-3	9*10-5

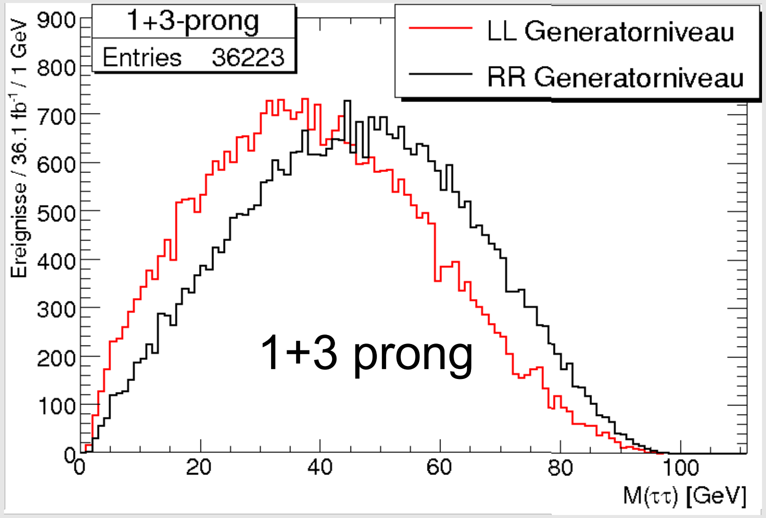
- rho/a1 difference:

$$\frac{d\Gamma}{d\cos\theta} \propto \underbrace{\left(\frac{m_V^2}{m_\tau^2+2m_V^2}(1-P_\tau \cos\theta)\right)_T}_{\text{transversal}} \underbrace{\left(\frac{(1/2)m_\tau^2}{m_\tau^2+2m_V^2}(1+P_\tau \cos\theta)\right)_L}_{\text{longitudinal}}$$

separation of 1p/3p







inv mass dec prod