Study of Final States with τ - Leptons in GMSB Models at ATLAS

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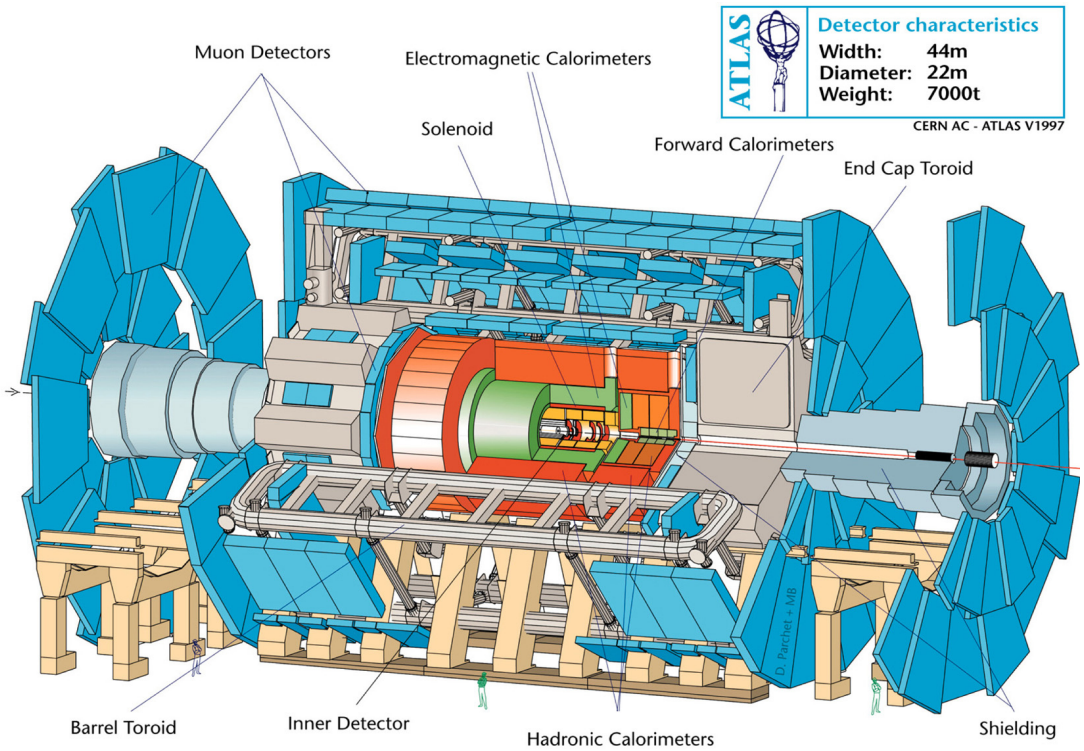
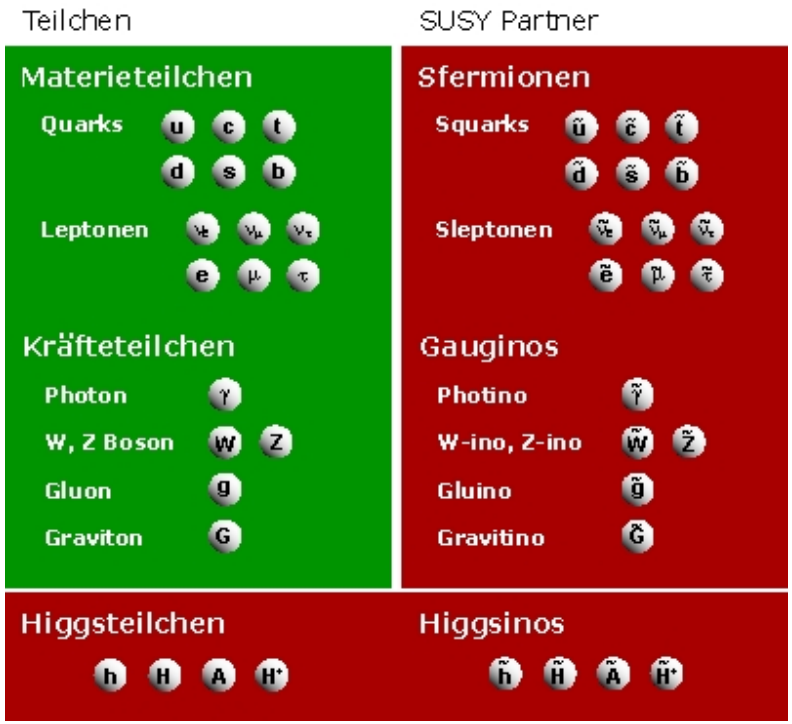
Outline



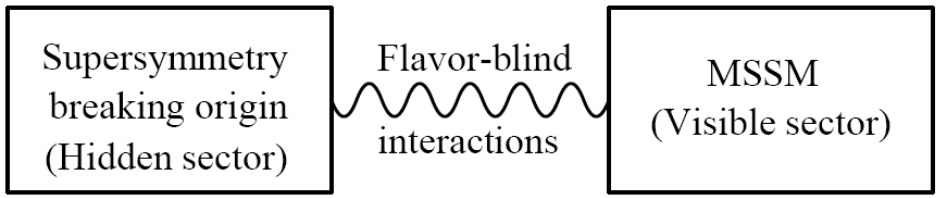
Motivation for SUSY

- Standard Model very successful - but incomplete
- SUSY - promising extension
  - explanation for Dark Matter
  - unification of the coupling constants at the GUT scale $\approx 10^{16}$ GeV
  - solution to the Hierarchy Problem of the Higgs mass
- breakingmechanisms: mSUGRA, **GMSB**, AMSB
  - reduction to a few parameters
  - sufficient for
    - mass spectra
    - physical processes (branching ratios, cross sections)



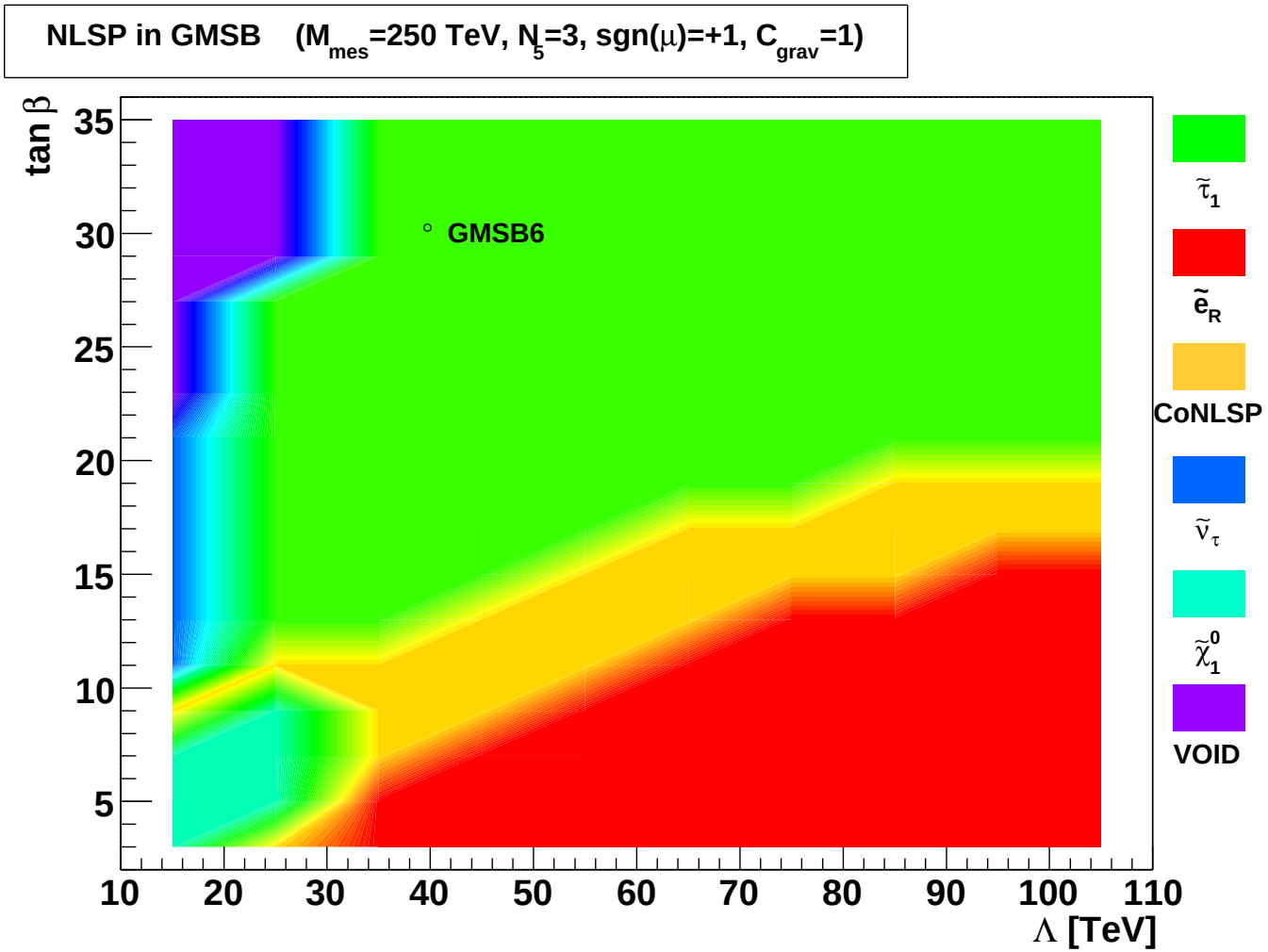
GMSB

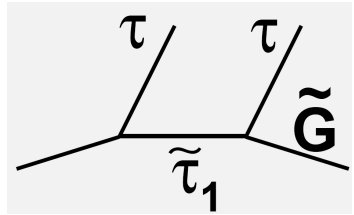
- Gauge Mediated Supersymmetry Breaking
- breaking: coupling of messenger particles
- messenger particles give mass to the super partners of the gauge bosons, quarks and leptons
  $\Rightarrow$ mass of the superpartners through gauge interaction

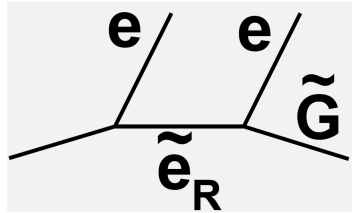


- assumption: R-Parity conservation
- parameters
  - Λ - the SUSY breaking mass scale
  - M_{mes} - messenger mass
  - N_5 - number of equivalent messenger fields
  - $\tan\beta$ - ratio of vacuum expectiation values of the Higgs fields
  - sgnμ - sign of the Higgsino mass term
  - C_{grav} - scale factor for the gravitino mass (determines the NLSP lifetime)

- LSP (Lightest Supersymmetric Particle)
  - nearly massless, neutral Gravitino $m(\tilde{G}) = O(\text{eV})$
- NLSP (Next-to-Lightest Supersymmetric Particle)
  - determines phenomenology





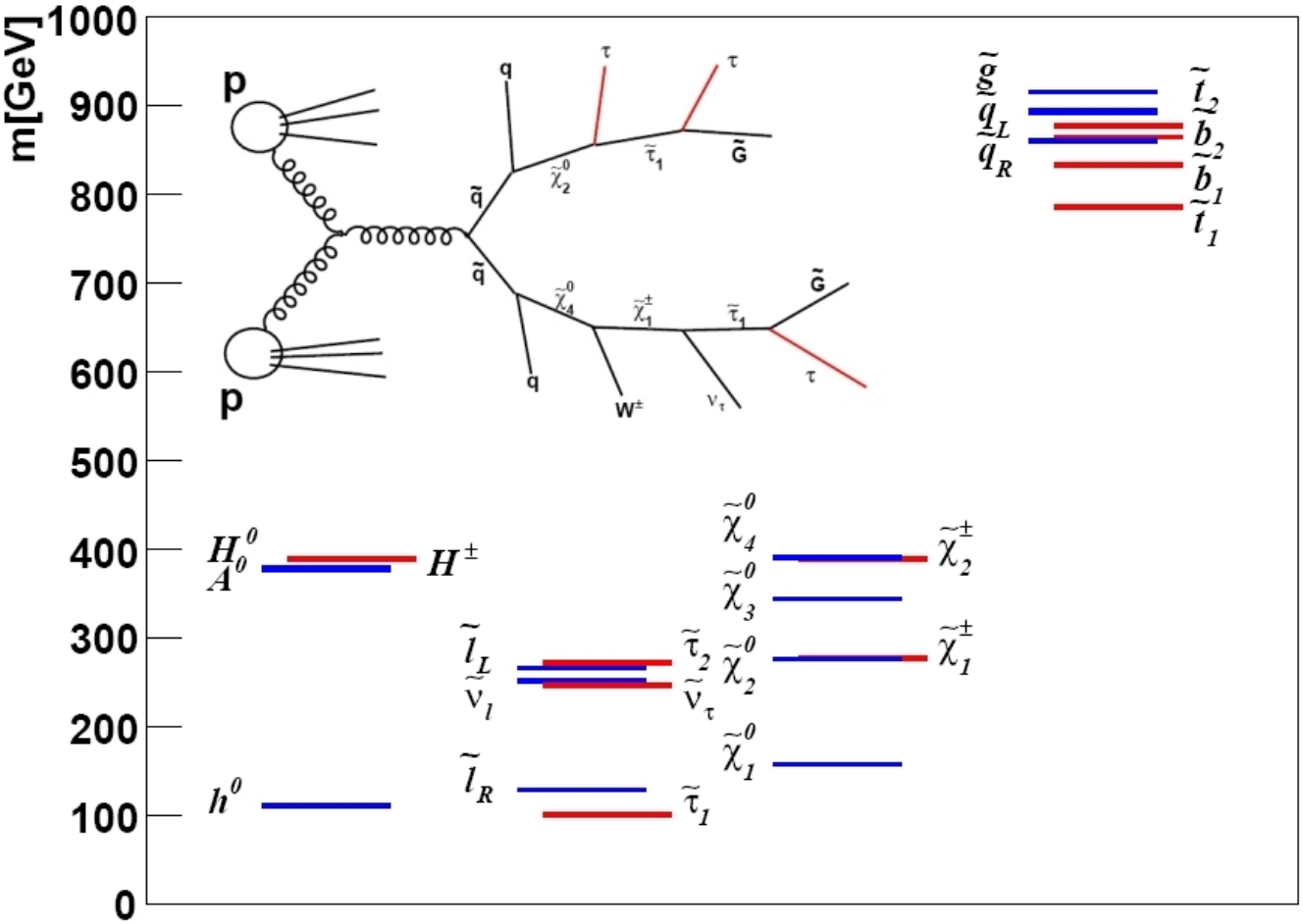


GMSB 6:
$\Lambda = 40\,\text{TeV}$
$\tan\beta = 30$
$M_{\text{mes}} = 250\,\text{TeV}$
$N_5 = 3$

GMSB 6

$(\Lambda = 40\,\mathrm{TeV}, \tan\beta = 30\,, \mathrm{M_{mes}} = 250\,\mathrm{TeV}, \mathrm{N_5} = 3\,)$

Mass spectrum for GMSB 6



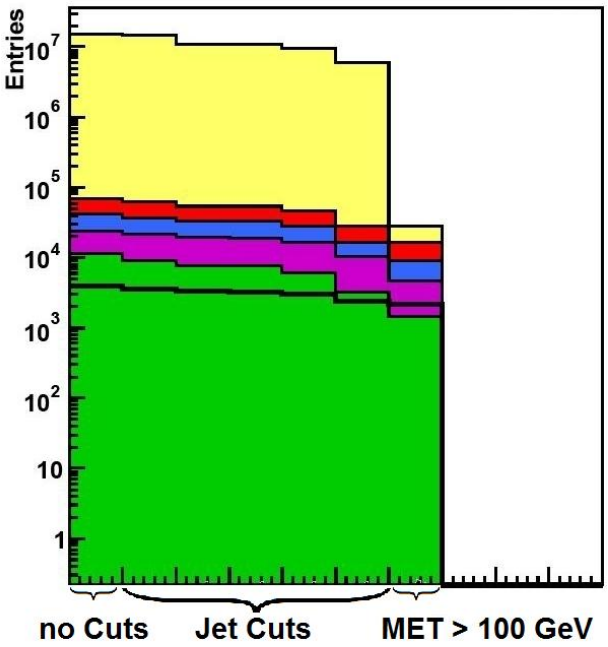
- final state: up to 4τ
- neutral gravitinos cause missing transverse energy (MET)

$\Longrightarrow$ unusual in SM processes

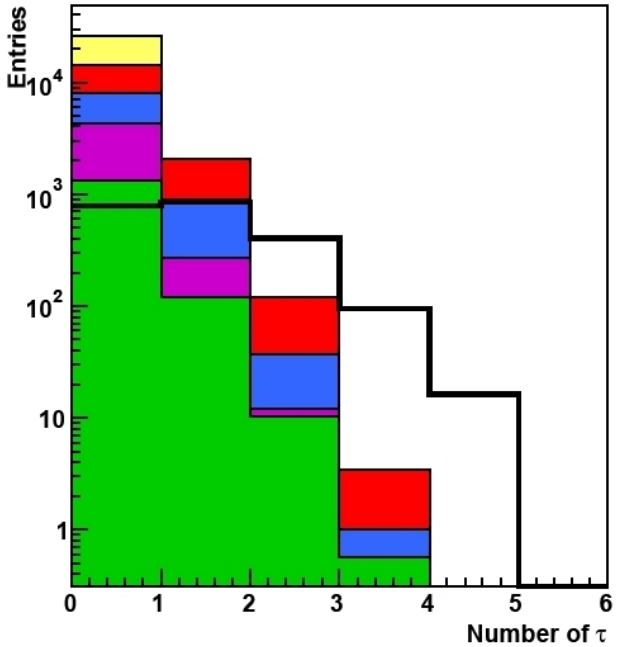
Cuts

- cuts:
  - number of jets > 3
  - 1 jet: $p_T > 100\,\text{GeV}$
  - 3 jets: $p_T > 50\,\text{GeV}$
  - $\not{E}_T > 100\,\text{GeV}$
- reconstruction of hadronic τ-decays
- signal dominates in region of many τ (and much MET)
- $\mathcal{L} = 1\,\text{fb}^{-1}$

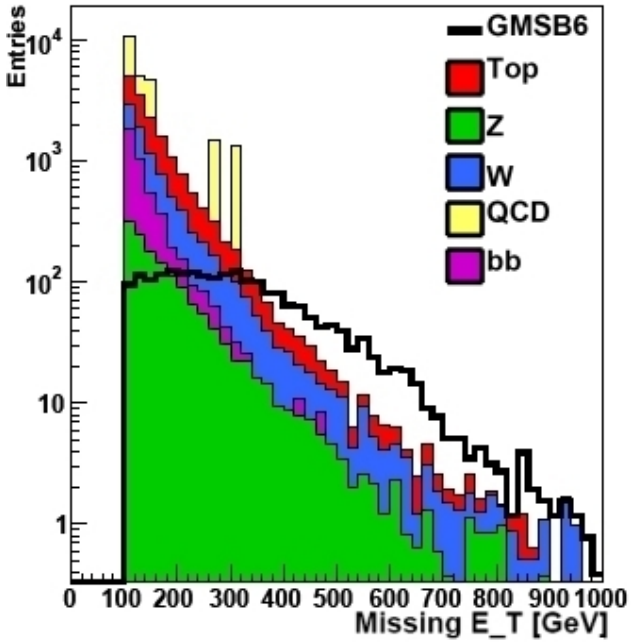
Cut-Flow



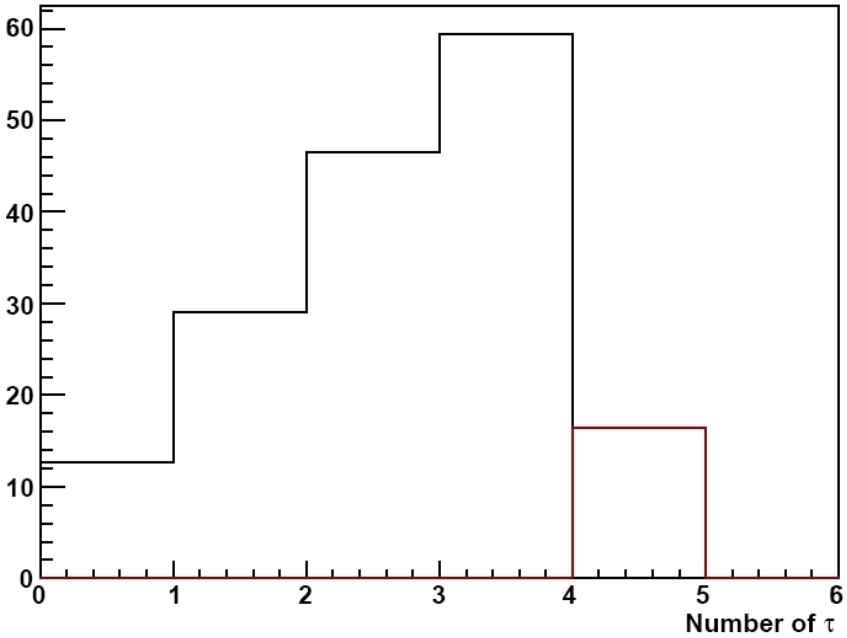
Number of τ



MET

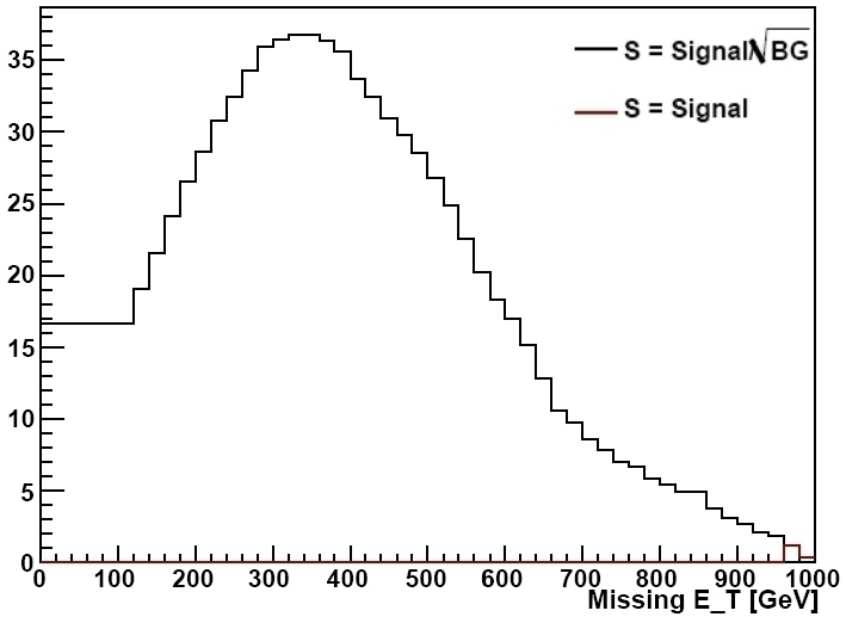


Significance in Number of τ

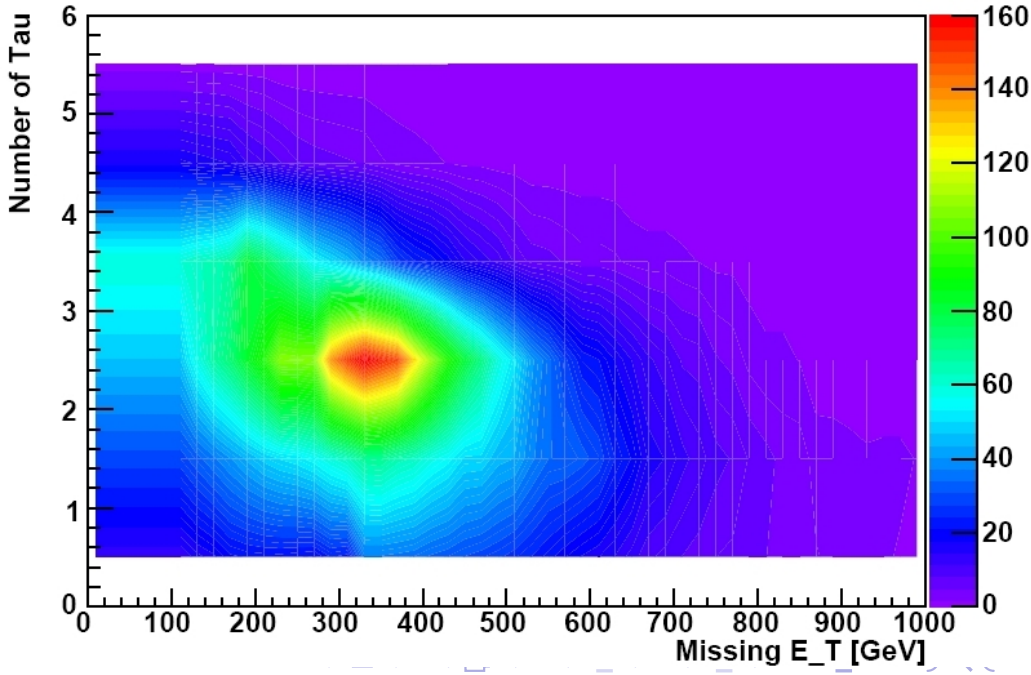


- significance $\sigma = \frac{\#\text{ of Signal events}}{\sqrt{\#\text{ of BG events}}}$
- rises with number of τ
  (no background events with 4τ)
- maximum in MET at $\approx 300\,\text{GeV}$
- 2dim: max. at 2τ, MET $> 320\,\text{GeV}$
  $\Rightarrow \sigma = \frac{196}{\sqrt{1.5}} \approx 160$

Significance in MET



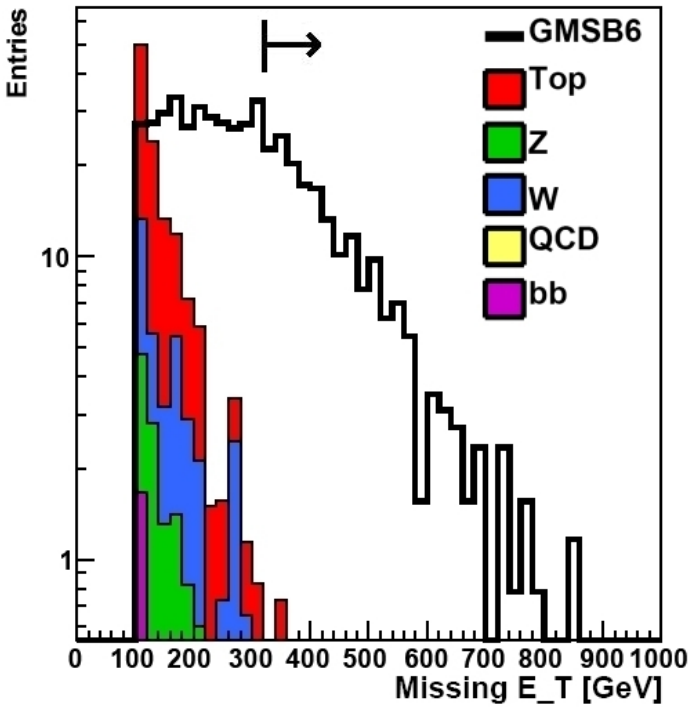
Significance in MET and Number of τ



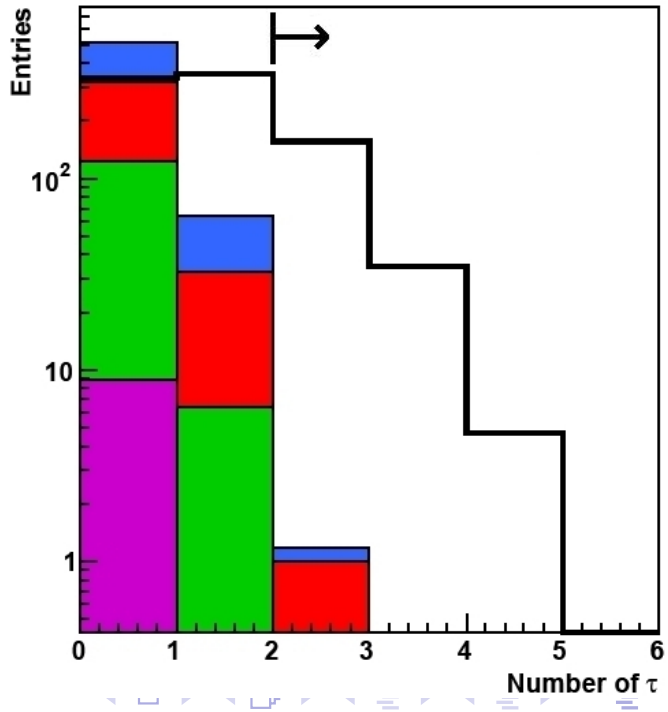
Final Cuts

- cuts applied one by one
  - MET requiring 2τ
  - number of τ requiring MET $> 320\,\text{GeV}$
- biggest residual background: Top
- very high discovery potential

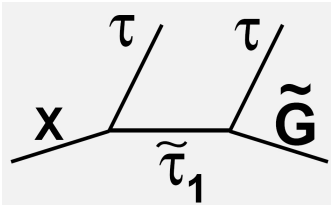
MET (more than 1τ)



Number of τ (MET $> 320\,\text{GeV}$)



Invariant Mass



- invariant mass of $2\tau \rightarrow$ mass edge

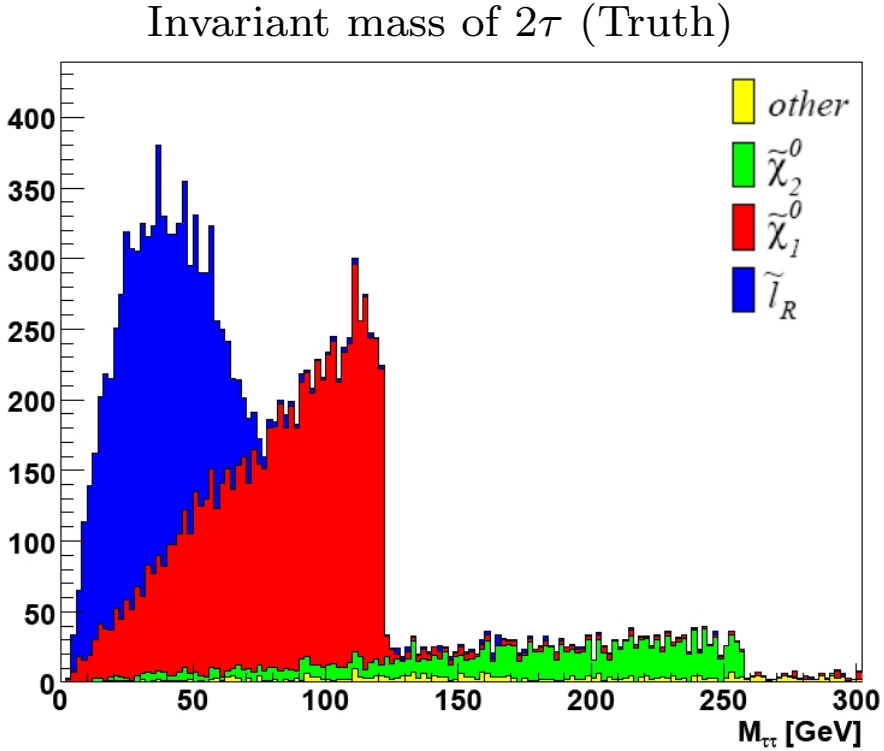
$$M^2_{\tau\tau,\max} = \frac{(m^2_X - m^2_{\tilde{\tau}_1})(m^2_{\tilde{\tau}_1} - m^2_{\tilde{G}})}{m^2_{\tilde{\tau}_1}}$$

$$\xrightarrow{m_{\tilde{G}}=2.41\text{eV}}$$

$$M^2_{\tau\tau,\max} = m^2_X - m^2_{\tilde{\tau}_1}$$

$$M_{\tau\tau,\max} = \sqrt{m^2_{\tilde{\chi}^0_1} - m^2_{\tilde{\tau}_1}}$$

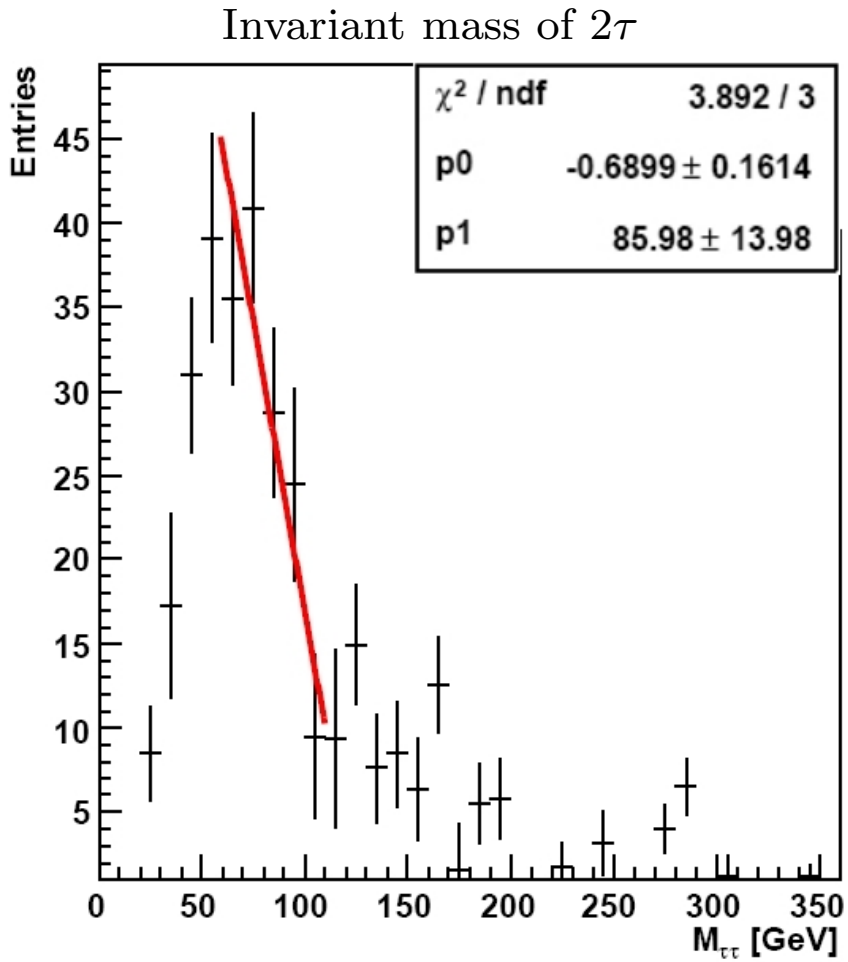
$$= 121.57\,\text{GeV}$$



Fit of mass edge

- apply analysis cuts
- plot invariant mass of 2τ
- distribution smeared out compared to truth because of neutrinos

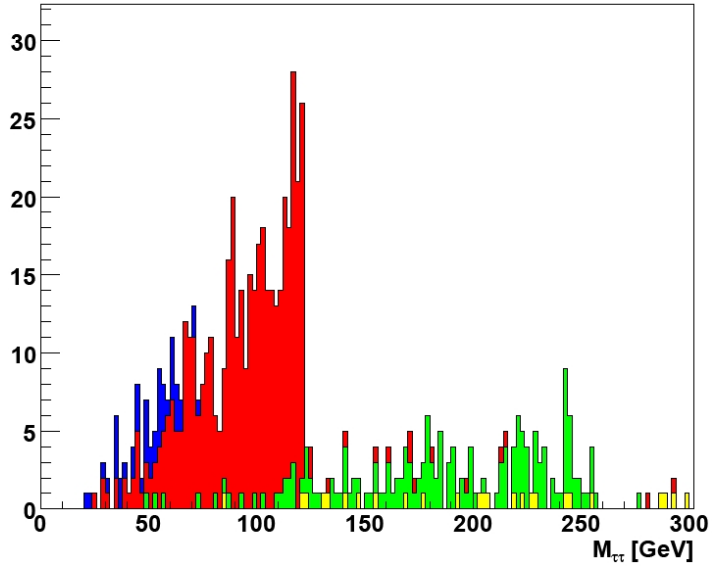
- first approximation: linear fit
- very sensitive to fit range
- $M_{\tau\tau,\max} = \frac{85.98\,\text{GeV}}{0.6899} = 124.6\,\text{GeV}$



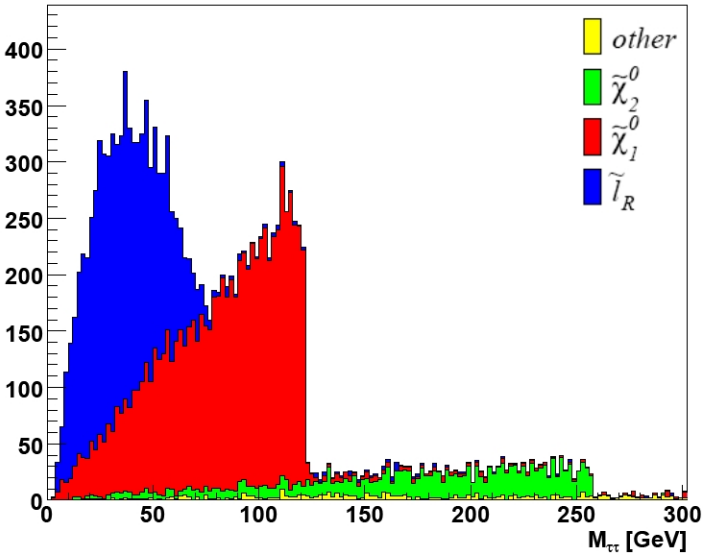
Unfortunately ...

- there is a bug in HERWIG
- TAUOLA ist not correctly called
  $\Rightarrow$ slepton - τ remains stable
- slepton - τ is not reconstructed
- reconstructed τ coming from sleptons due to insufficient matching criteria

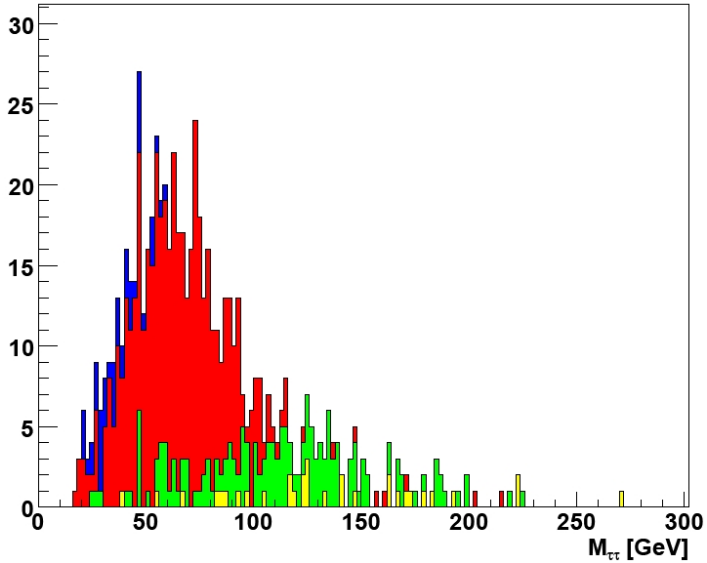
"True" invariant mass of reconstructed τ



Invariant mass of 2τ (Truth)



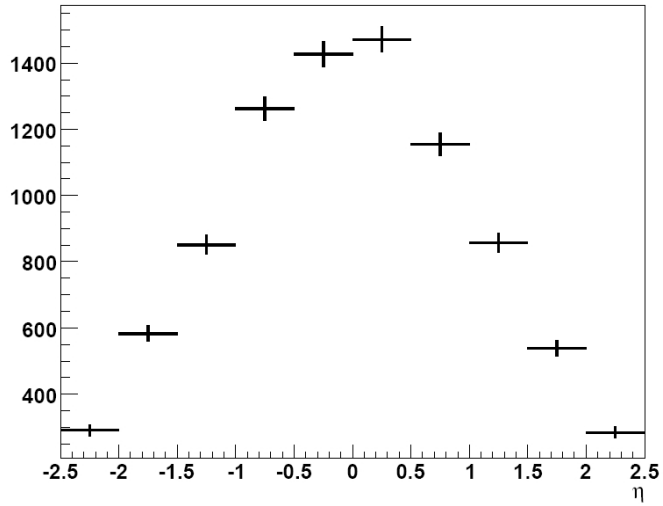
Invariant mass of reconstructed τ



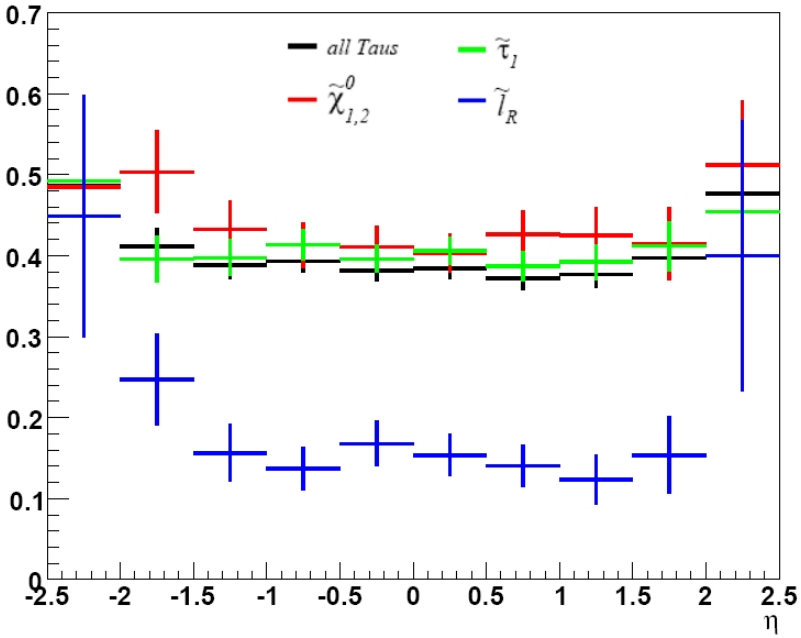
Reconstruction Efficiency and Fakerate in η

- 10000 GMSB events
  (no cuts on jets or MET)
- efficiency: 0.39
- fakerate: 0.15
- same problems with slepton - τ

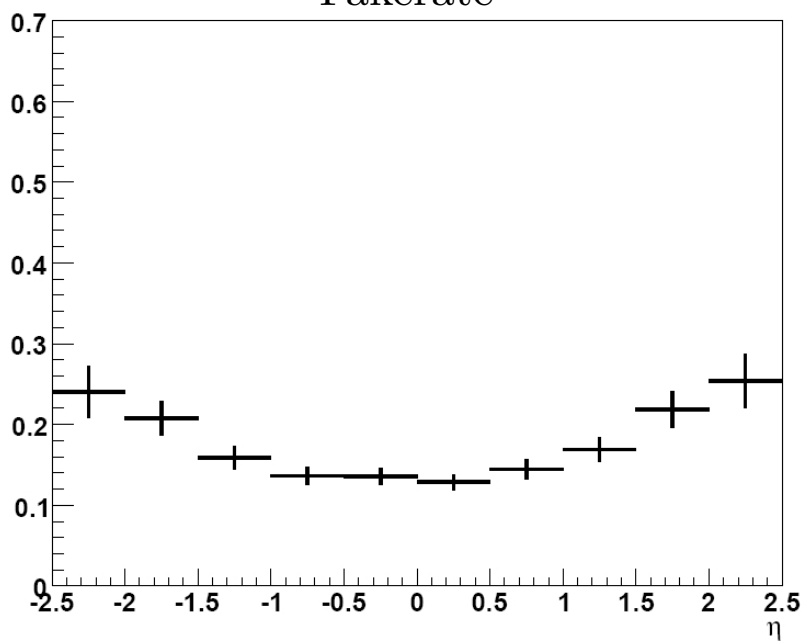
η distribution



Reconstruction Efficiency



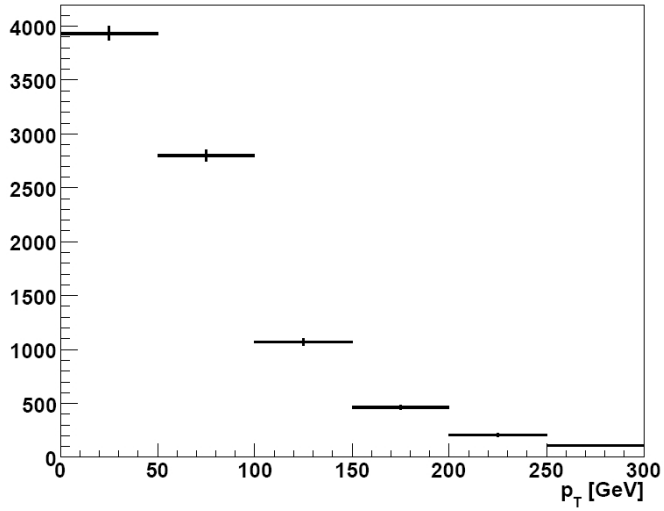
Fakerate



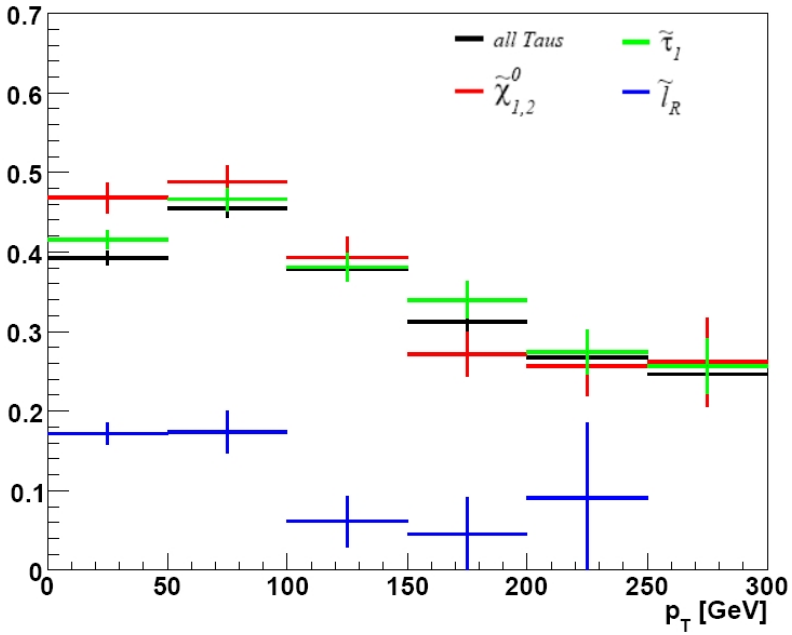
Reconstruction Efficiency and Fakerate in p_T

- studied also efficiency in ϕ
  - distributions are flat in ϕ
- working on comparison with a $Z^0 \rightarrow \tau\tau$ sample

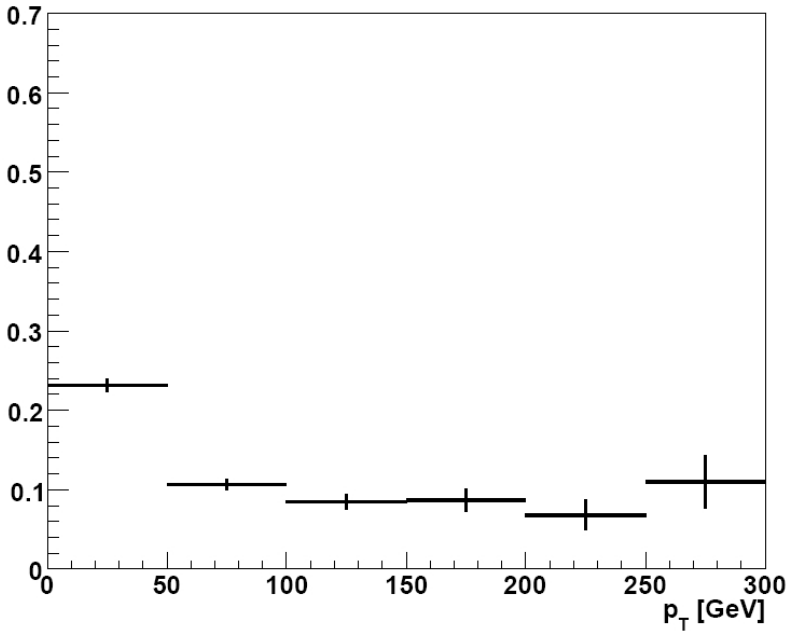
p_T distribution



Reconstruction Efficiency



Fakerate



Conclusion

- GMSB - one possible Supersymmetric model
- number of τ and missing transverse energy seem applicable for isolation of the signal
- GMSB 6 - high discovery potential in first data
- mass edge can be estimated

Outlook

- produce new data (bug is fixed in release 14)
- devise an algorithm to disentangle τ coming from sleptons and those coming from neutralinos
- improve fit of the mass edge
- scan the parameter space