Study of $\tilde{\tau}$ pair production in SPS1a'

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Outline

Introduction

What can be done if SUSY exists, and is "next to LEP", and we use a real detector ?

- Study SPS1a'
- Full simulation: LDC' (non-signal SUSY missing in ILD_00 ...)
- Study μ channels (Philip's talk)
- Study τ channels (This talk)

People involved

- Peter Schade (Polarisation)
- Olga Stempel (Mass)
- Supervisors: J. List, P. Bechtle, M.B.

SPS1a'

Pure mSUGRA model:

$M_{1/2} = 250\ GeV, M_0 = 70\ GeV, A_0 = -300\ GeV, \tan\beta = 10, sign(\mu) = +1$

Just outside what is excluded by LEP and low-energy observations.
Compatible with WMAP, with $\tilde{\chi}_1^0$ Dark Matter.

- All sleptons available.
- No squarks.
- Lighter bosinos, up to $\tilde{\chi}_3^0$ (in $e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_3^0$)

Features of $\tilde{\tau}$:s in SPS1a'

- In SPS1a', the $\tilde{\tau}$ is the NLSP.
  $M_{\tilde{\tau}_1} = 107.9\ \mathrm{GeV}/c^2$, $M_{\tilde{\chi}_1^0} = 97.7\ \mathrm{GeV}/c^2$, so
  $\Delta(M) = 10.2$ *GeVcc*.
- $P_{\tilde{\tau},min} = 2.2\ \mathrm{GeV}/c$, $P_{\tilde{\tau},max} = 42.8\ \mathrm{GeV}/c$: $\gamma\gamma$ background.
- Plays an important role for DM: $M_{\tilde{\tau}_1}$ important.
- The $\tilde{\tau}$ mass-e.s. $\neq$ chiral-e.s. Off-diagonal term of mass-matrix: $-M_\tau(A_{\tilde{\tau}} - \mu \tan\beta)$.
- With $M_{\tilde{\mu}_L}$ and $M_{\tilde{\mu}_R}$, a measurement of θ_{mix} gives $A_{\tilde{\tau}} - \mu \tan\beta$.
- If $\tilde{\chi}_1^0$ is purely bino - it is in SPS1a' - P_τ depends only on θ_{mix}.
- $\tilde{\tau}$ NLSP $\rightarrow \tau$:s in most SUSY decays $\rightarrow$ SUSY is background to SUSY.
- For pol=(-1,1): $\sigma(\tilde{\chi}_2^0\tilde{\chi}_2^0)$ and $\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^-)$ = several hundred fb and BR(X$\rightarrow \tilde{\tau}) > 50$ %. For pol=(1,-1): $\sigma(\tilde{\chi}_2^0\tilde{\chi}_2^0)$ and $\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^-) \approx 0$.

Polarisation = (0.8,-0.6) assumed.

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Extracting the $\tilde{\tau}$ properties

- $M_{\tilde{\tau}_1}$ from $M_{\tilde{\chi}_1^0}$ and end-point of spectrum = $P_{\tilde{\tau},max}$.
- In principle: $M_{\tilde{\chi}_1^0}$ turn-over of spectrum = $P_{\tilde{\tau},min}$, but hidden in $\gamma\gamma$ background.
- P from spectrum for exclusive decay-mode(s). Here: $\tau \longrightarrow \pi^{+-}\nu_\tau$

$\gamma\gamma$ suppression

$\Delta(M) = 10.2\mathrm{GeV}/c^2 \rightarrow \gamma\gamma$ background ...

- Correlated cut in ρ and θ_{acop}: $\rho > 3 \sin\theta_{acop} + 1.7$. ($\rho = P_T$ of jets wrt. thrust axis, in x-y projection.)
- no significant activity in the BeamCal
- ϕ_{pmiss} not in the direction of the incoming beam-pipe. (Will be better with ILD_00)

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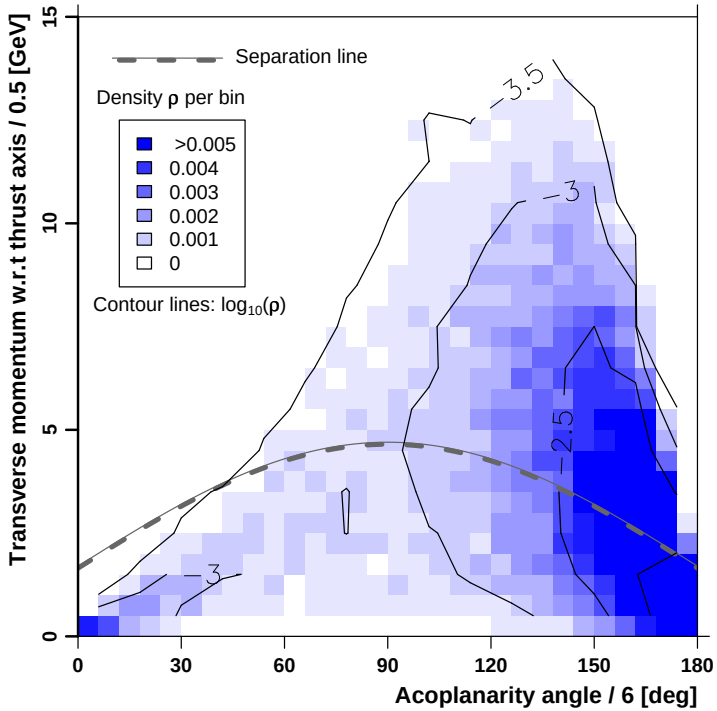

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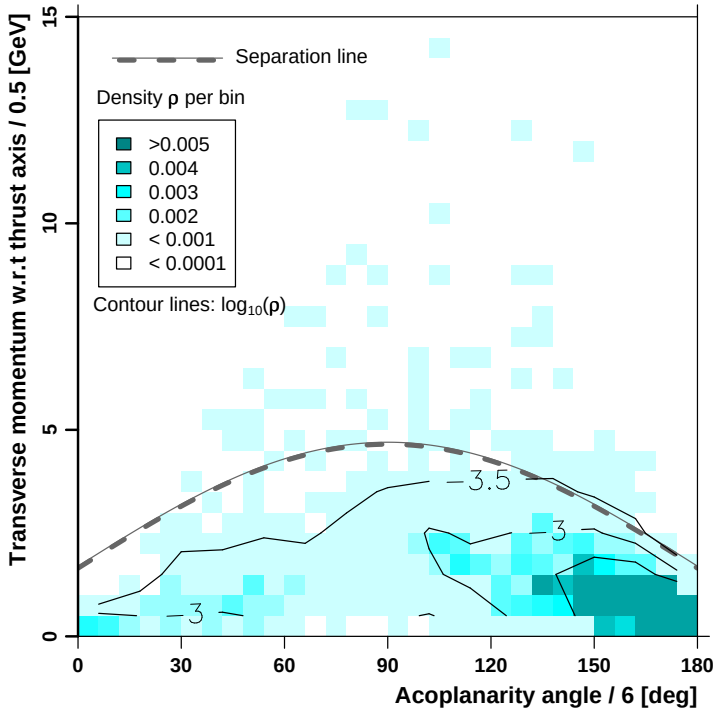

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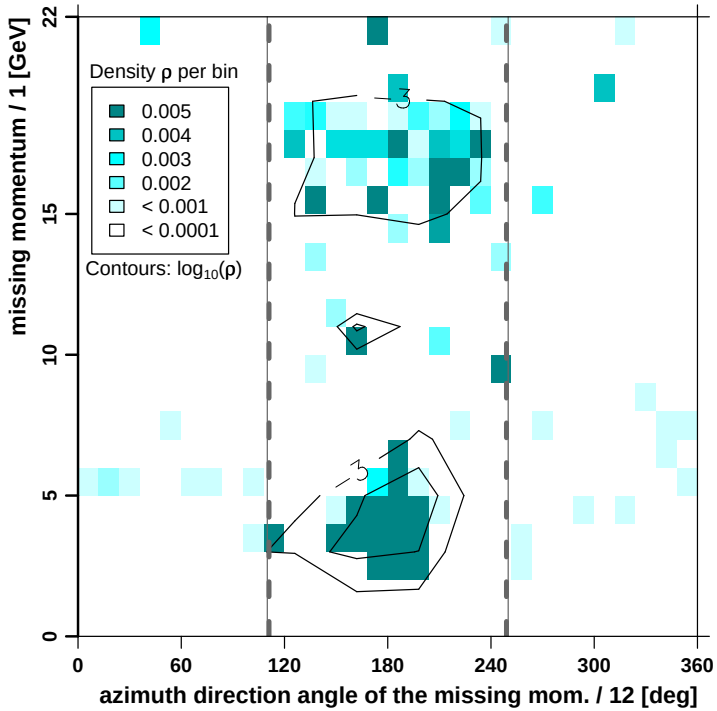

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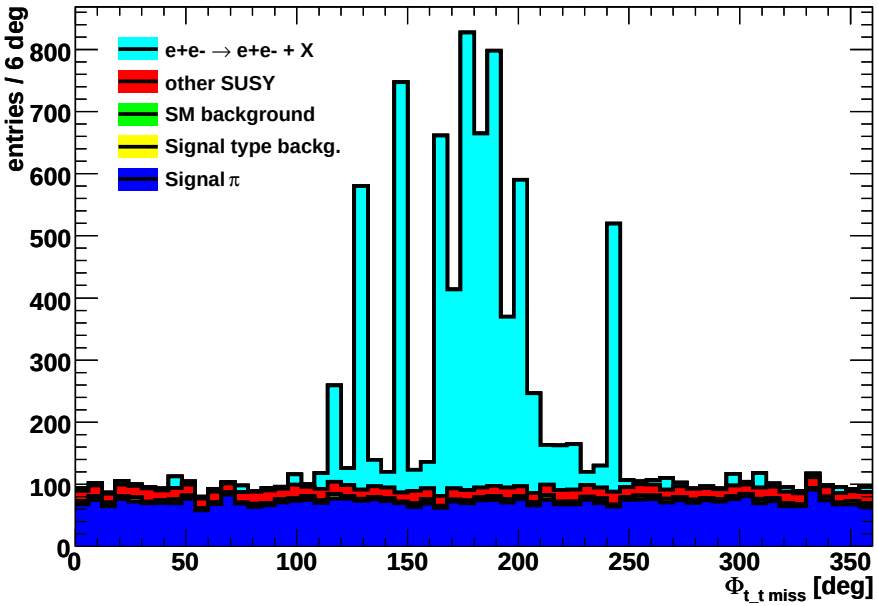
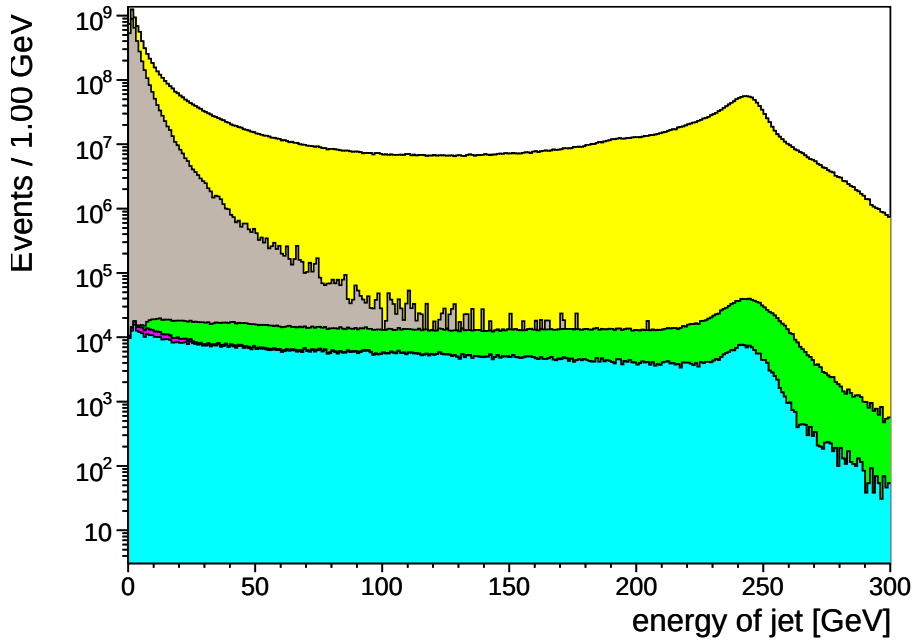


Extracting the $\tilde{\tau}$ mass

- Extract the signal.
  - $E_{miss} \in [430, 490]$ GeV,
  - Two jets with charge ± 1,
  - anti-$\gamma\gamma$ cut
  - $M_{jet} < 2\ \mathrm{GeV}/c^2$,
  - θ_{jet} above 20 degrees,
  - $\theta_{acop} < 160$ degrees,
  - $\theta_{acol} \in [80, 170]$ degrees,
  - $|\cos\theta_{missing\ p}| < 0.9$.
  - $\phi_{missing\ p} \in [50, 310]$ degrees,

  Efficiency 10.2 %
  Tentatively: $M_{\tilde{\tau}_1} = 107.54 \pm 0.12\ \mathrm{GeV}/c^2$



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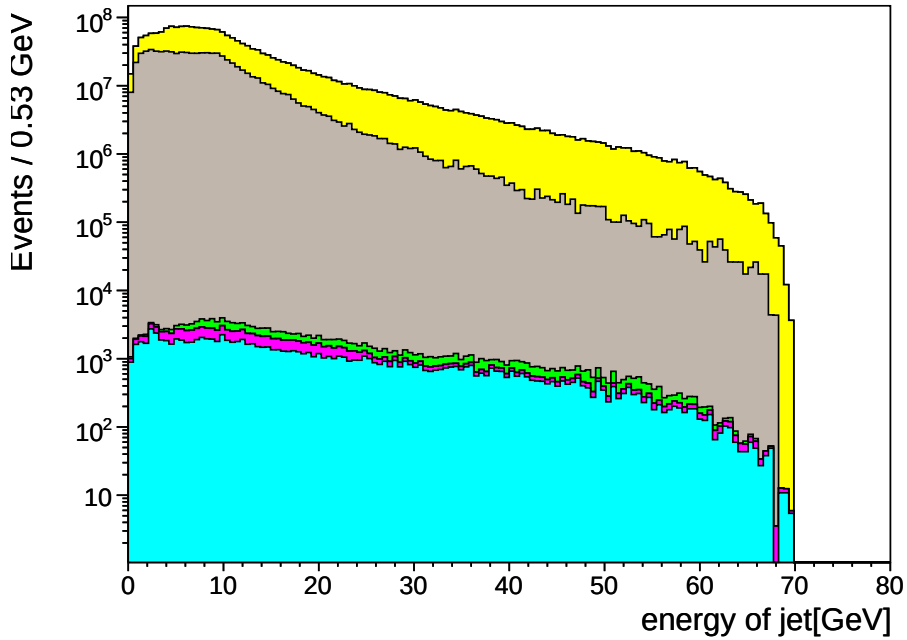

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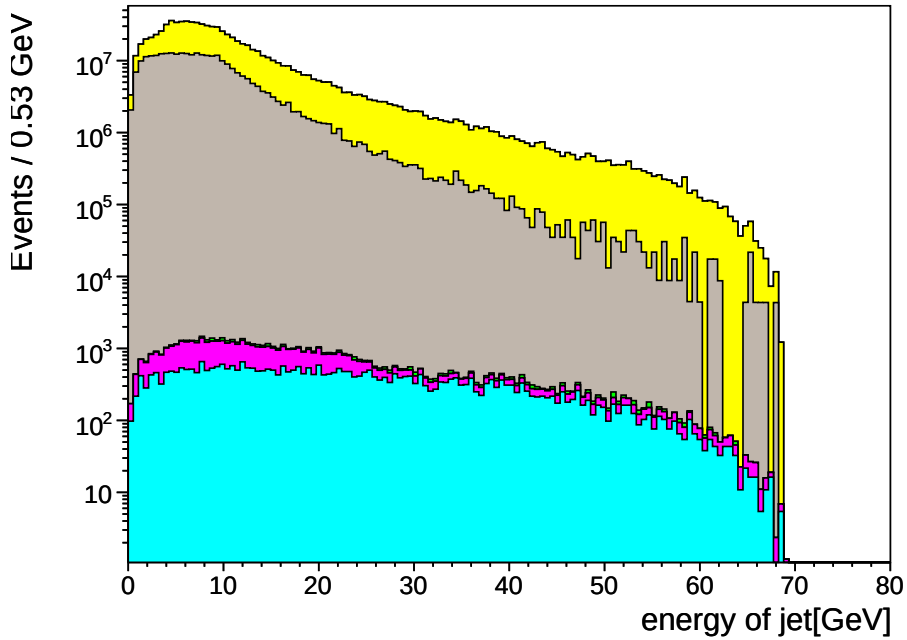

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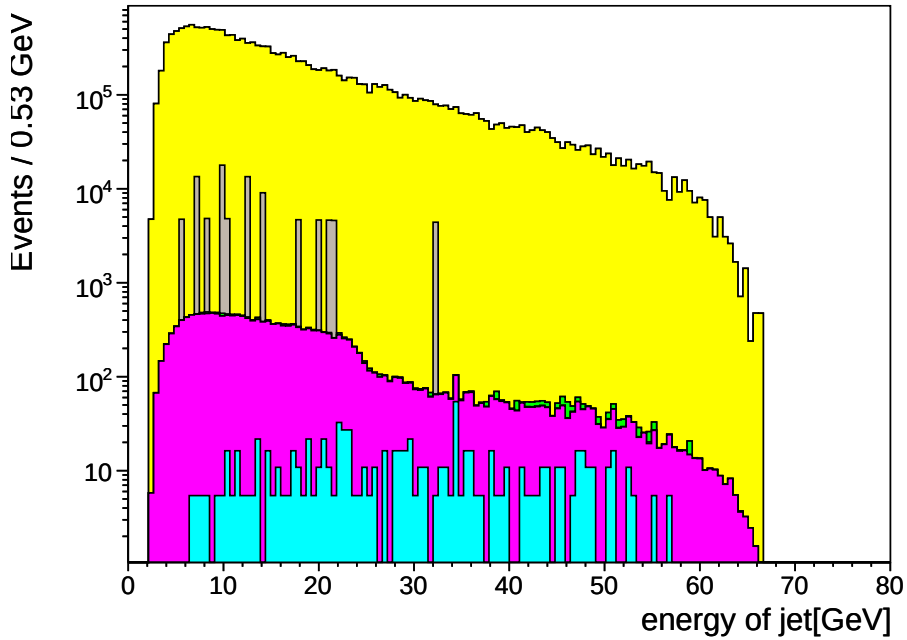

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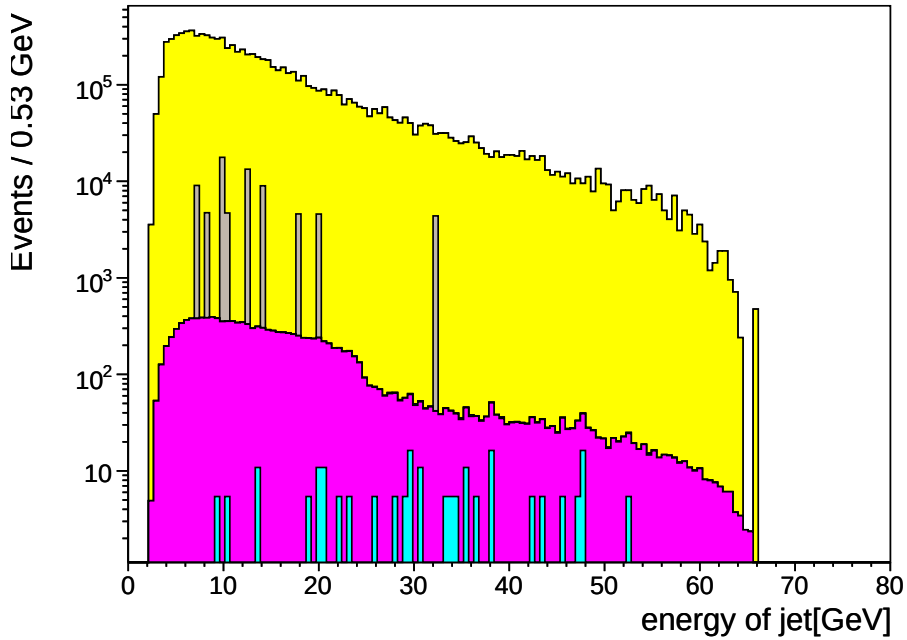

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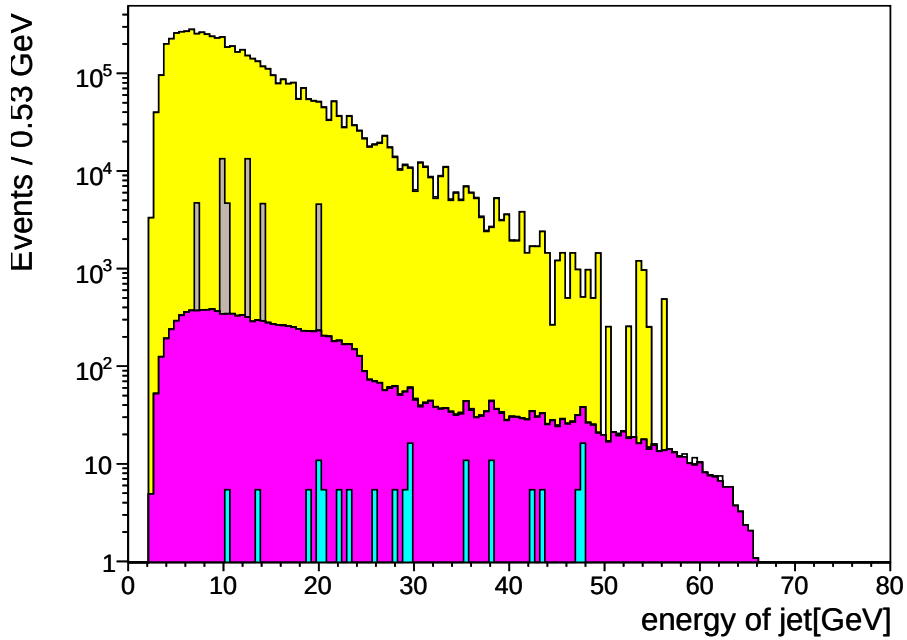

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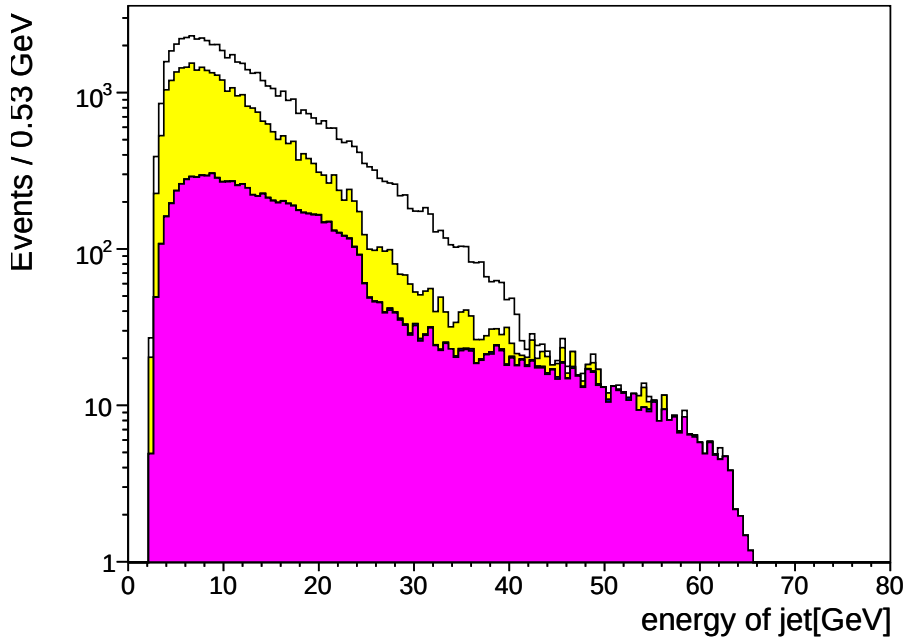

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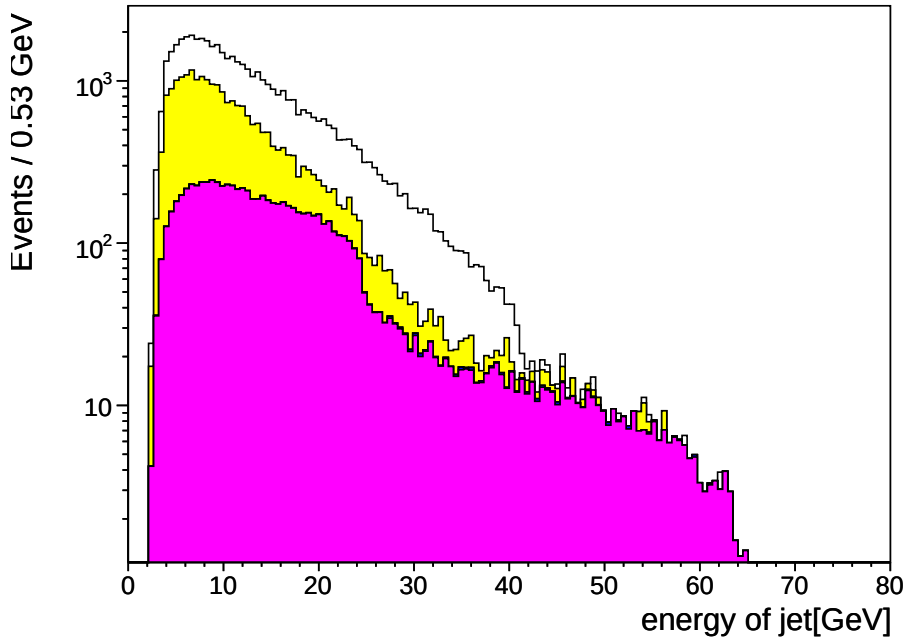

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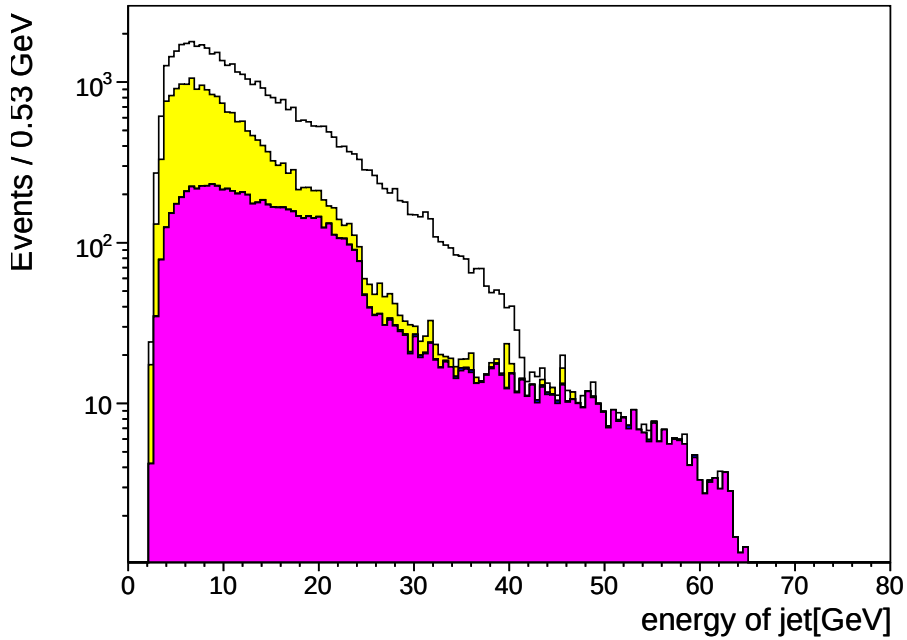

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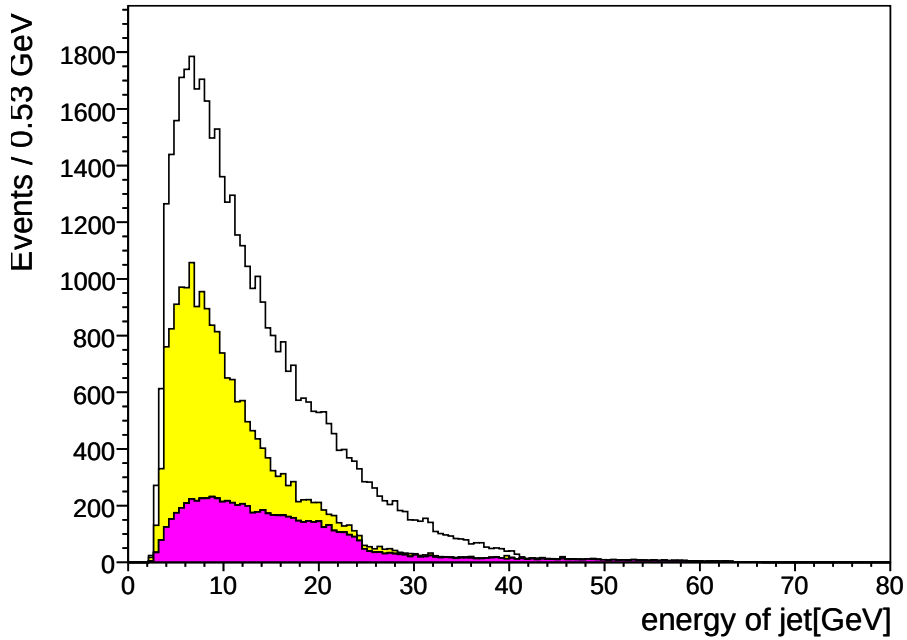

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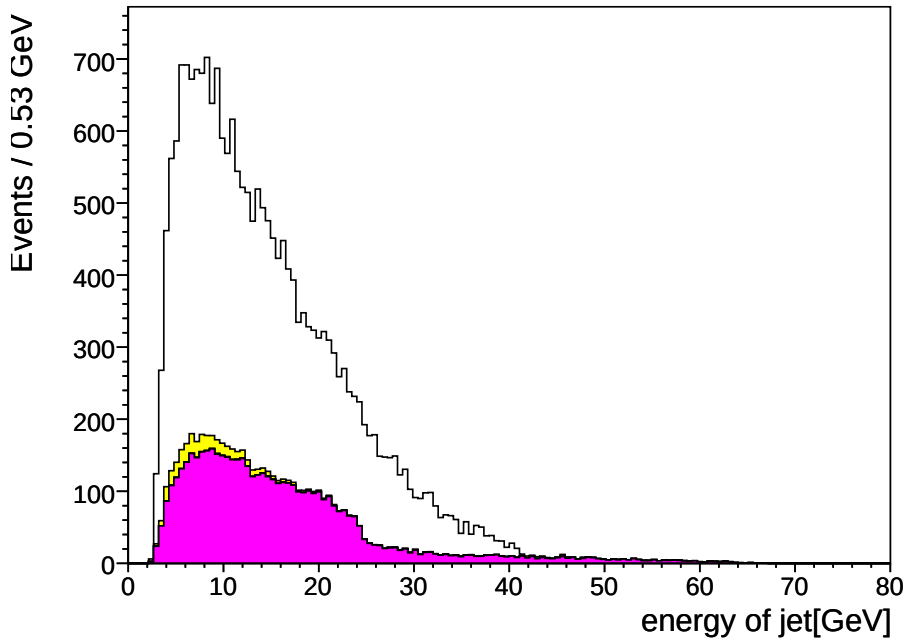

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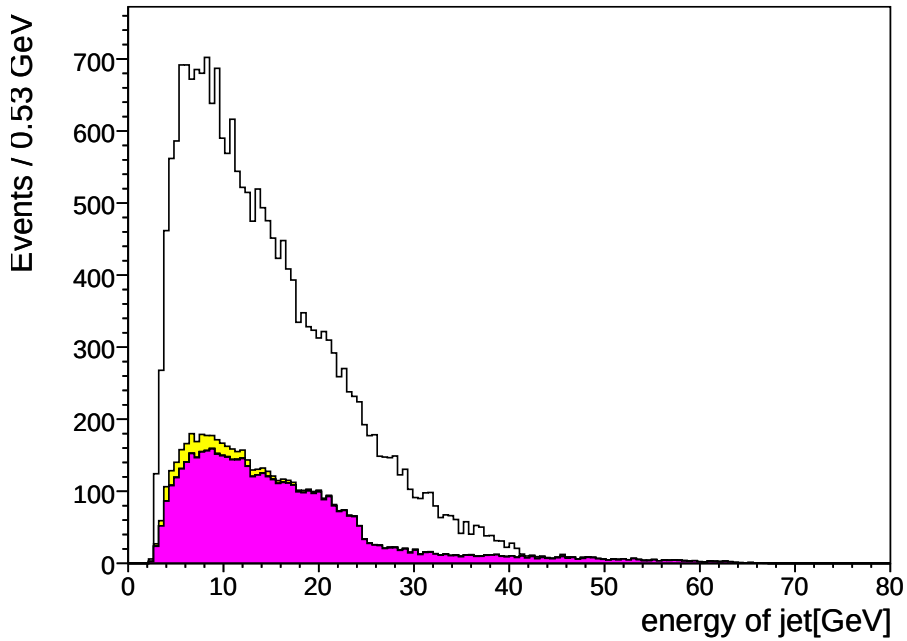

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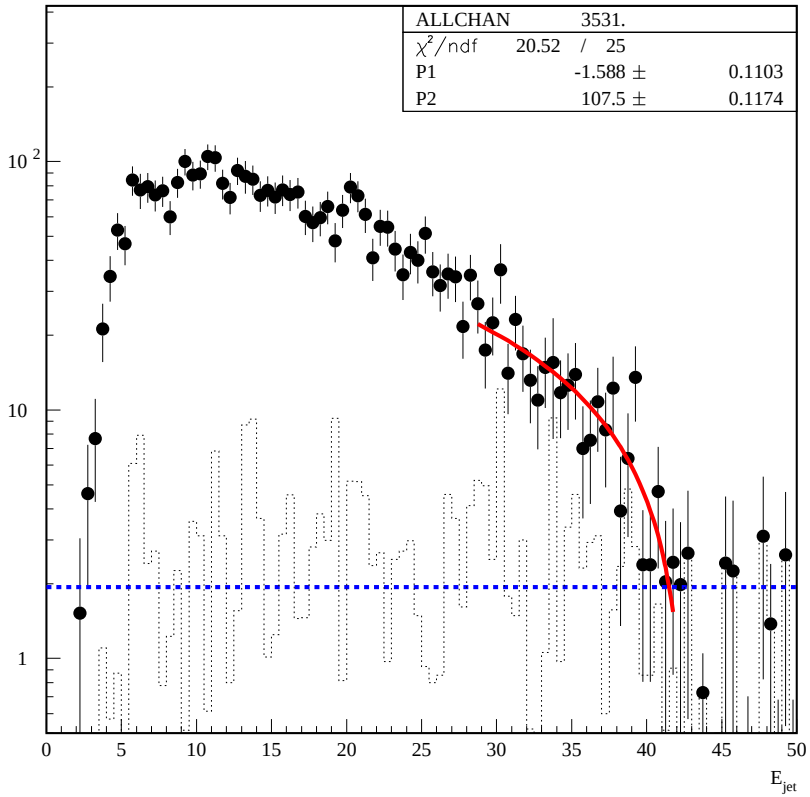
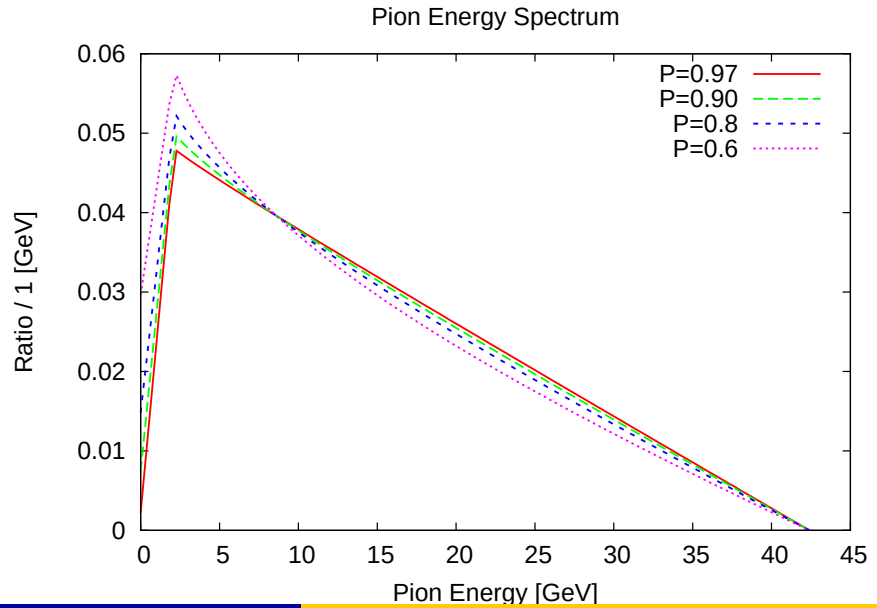


τ Polarisation: formulae and corrections

Spectrum of π:s in $\tau \longrightarrow \pi^{+-}\nu_\tau$:

$$\frac{1}{\sigma}\frac{d\sigma}{dy_\pi} \sim \begin{cases} (1-P_\tau)\log\frac{P_{\tilde{\tau},max}}{P_{\tilde{\tau},min}} + 2P_\tau y_\pi\left(\frac{1}{P_{\tilde{\tau},min}} - \frac{1}{P_{\tilde{\tau},max}}\right) & \text{for } y_\pi < P_{\tilde{\tau},min} \\ (1-P_\tau)\log\frac{P_{\tilde{\tau},max}}{y_\pi} + 2P_\tau\left(1 - \frac{y_\pi}{P_{\tilde{\tau},max}}\right) & \text{for } Y_\pi > P_{\tilde{\tau},min} \end{cases}$$

Note the importance of the region with $Y_\pi < P_{\tilde{\tau},min}$!



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Correct for the spread in E_{beam}:

- Plot spectrum (at generator level), with and without beam-strahlung.
- Do this for P_τ = +1 or -1.
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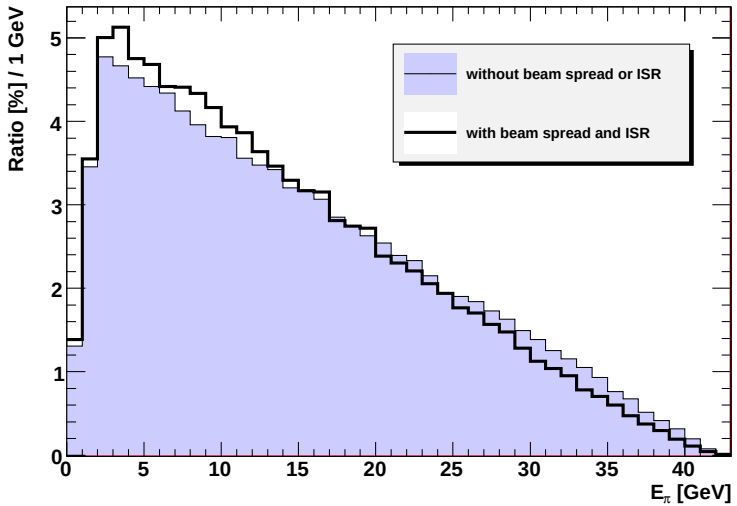

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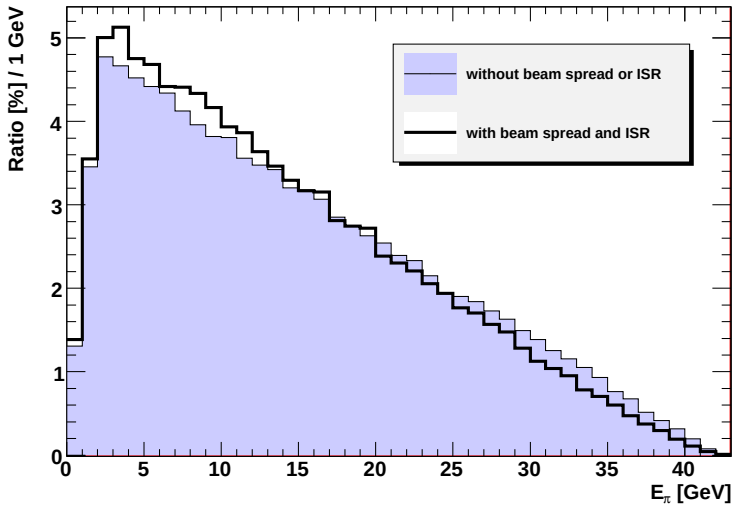

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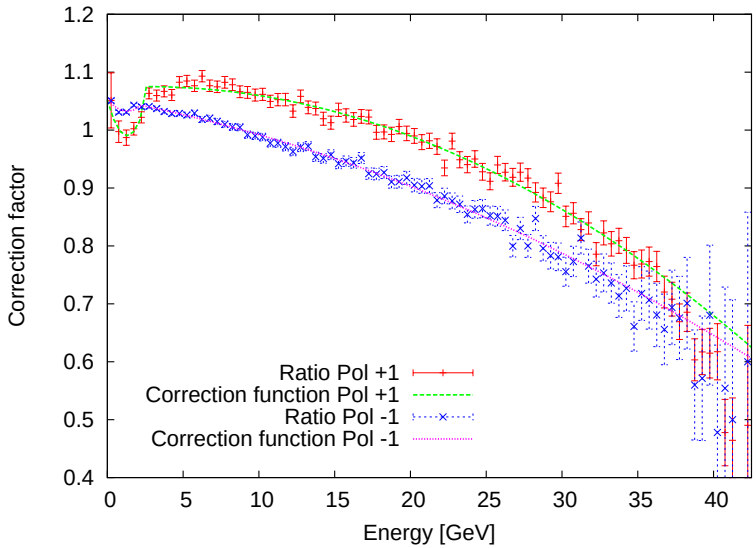

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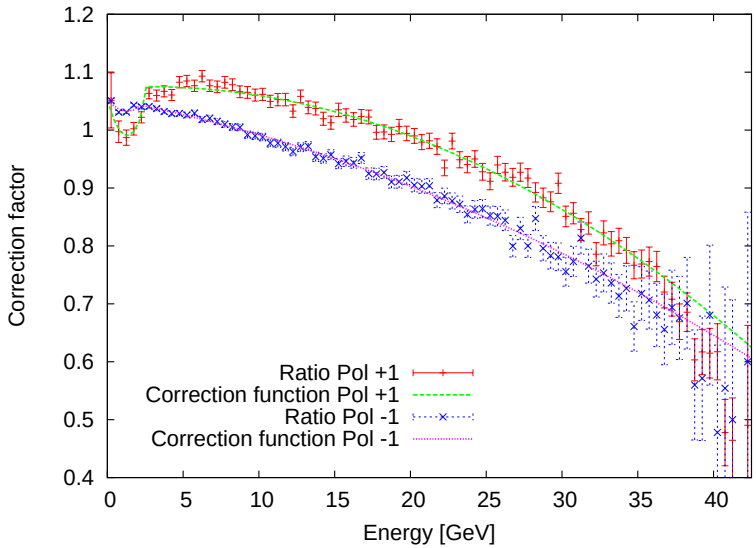

τ Polarisation: Select the signal process

Extract the $\tau \rightarrow \pi^{+-}\nu_\tau$ signal.

- The events should pass the anti-$\gamma\gamma$ cut.
- $E_{vis} < 120$ GeV.
- $N_{PFO} < 20$.
- At least one jets should contain a single particle.
- The single particle should have a π-id, and have $E < 43$ GeV.
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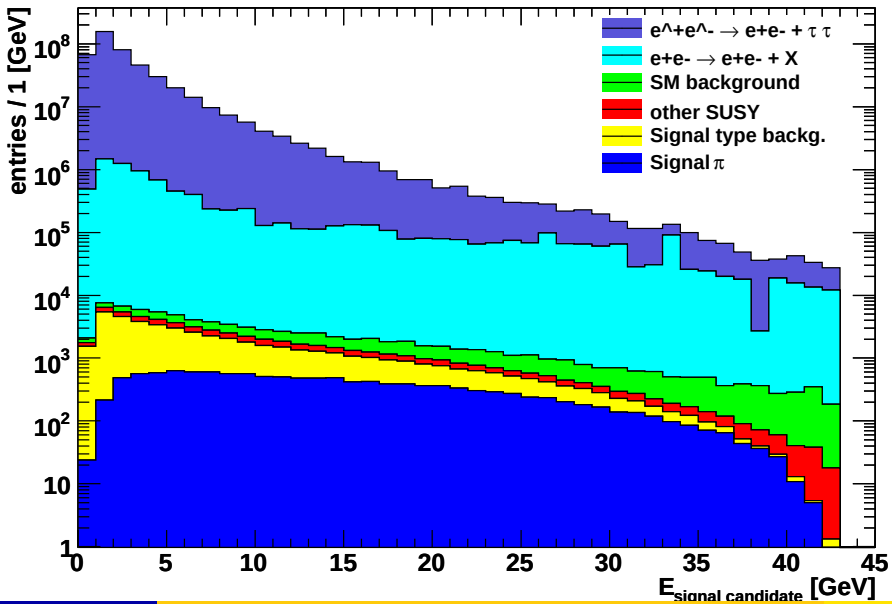
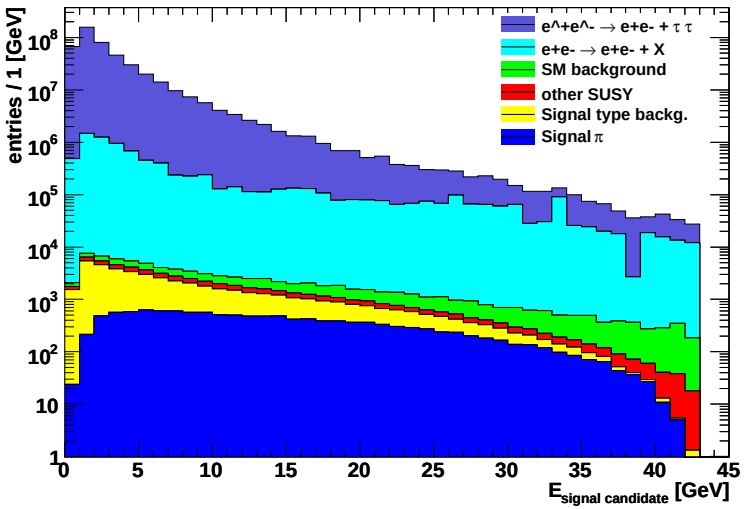


τ Polarisation: Isolate the signal process

Furthermore:

- $M_{rest\ of\ event} < 2.5\ \mathrm{GeV}/c^2$.
- $|\cos\theta| < 0.9$ (both jets).
- $\theta_{acop} > 85$ degrees.
- The sum over the two jets of the p_T of one jet wrt. the direction of the other $< 30\ \mathrm{GeV}/c$.



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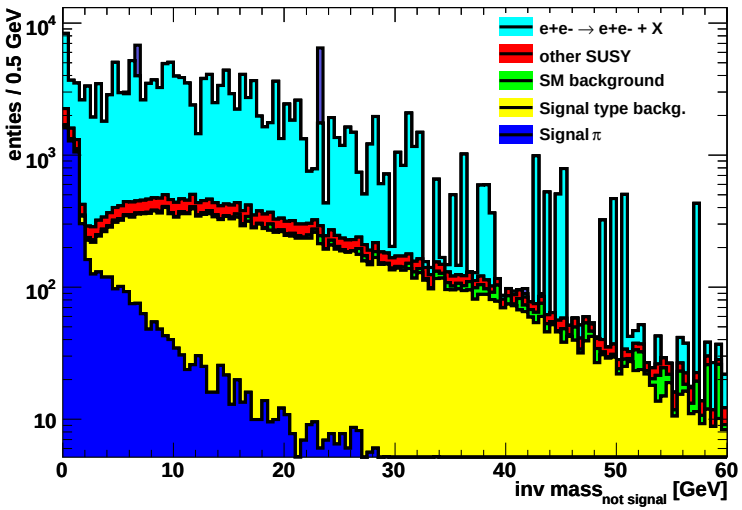

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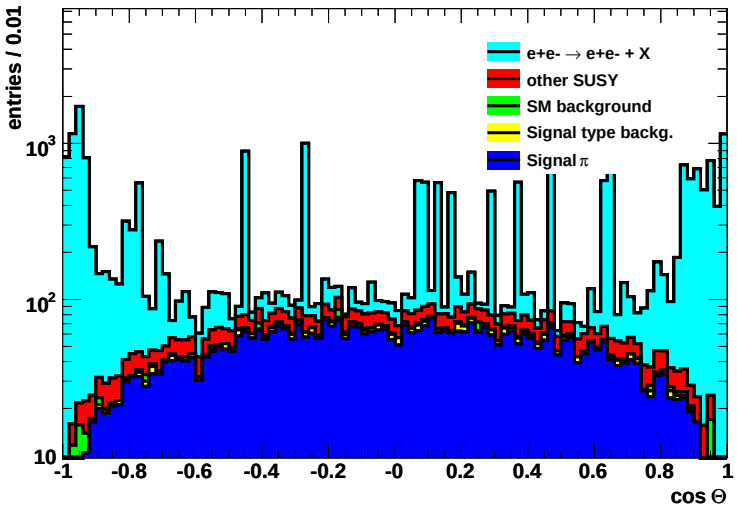

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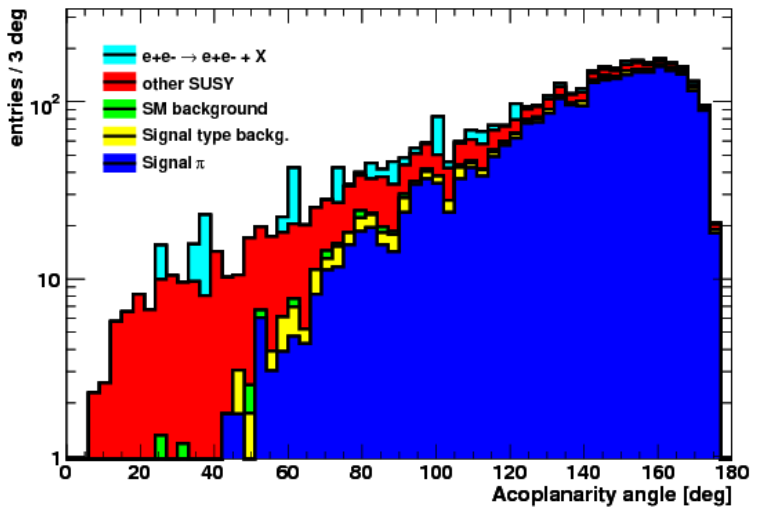

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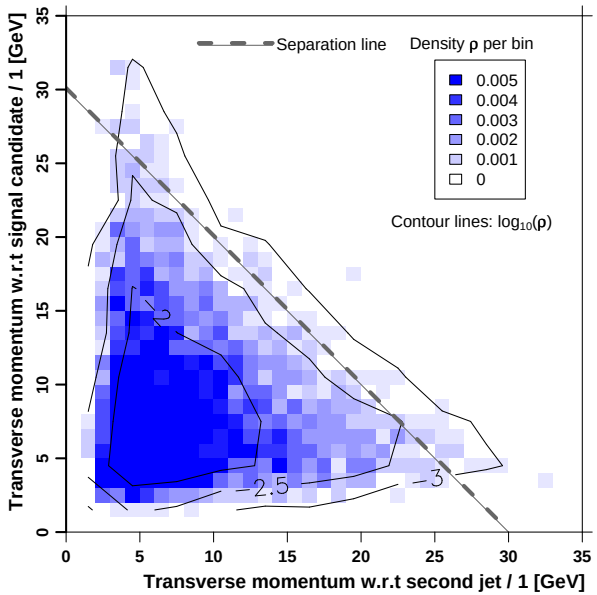

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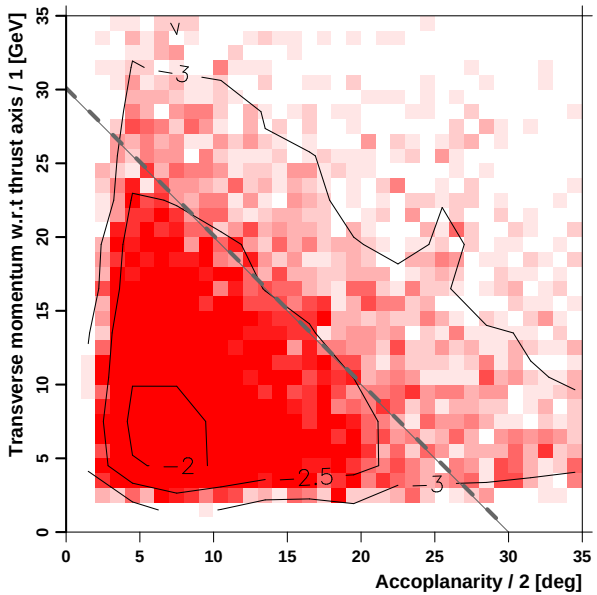

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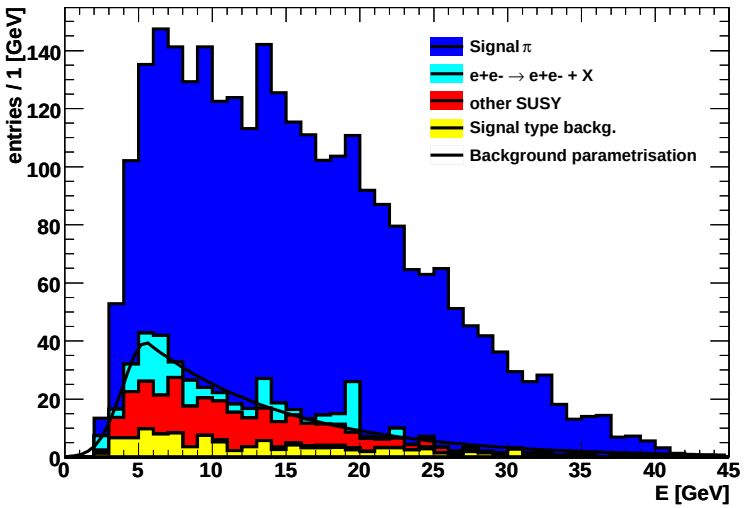
Final spectrum
Efficiency= 13 %



τ Polarisation : background and signal fit

Method to extract the polarisation:

- Fit background MC.
- Check when real data exists: Invert acoplanarity cut, Check if shape is OK.
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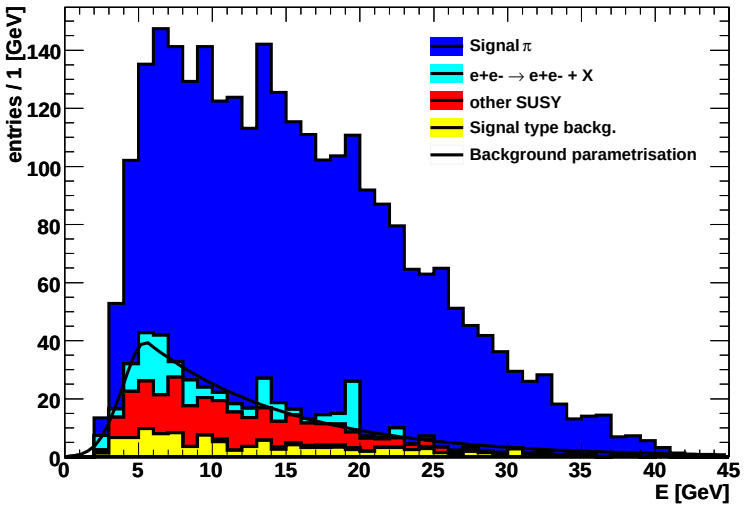
$P_\tau = (93 \pm 13)$ %



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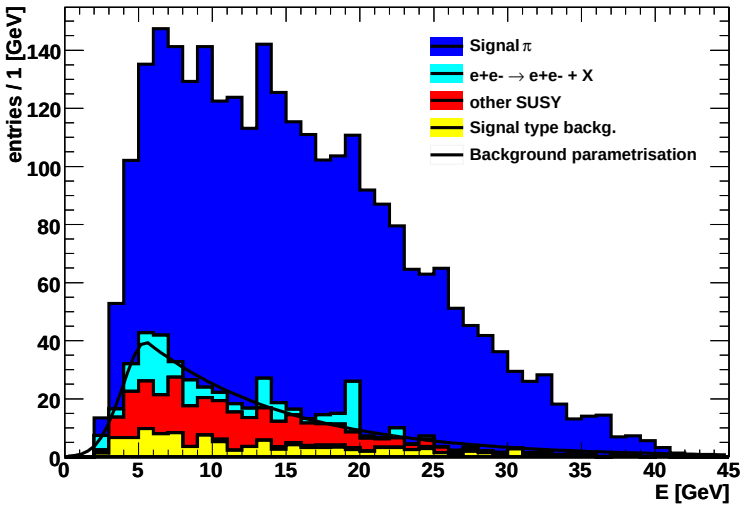

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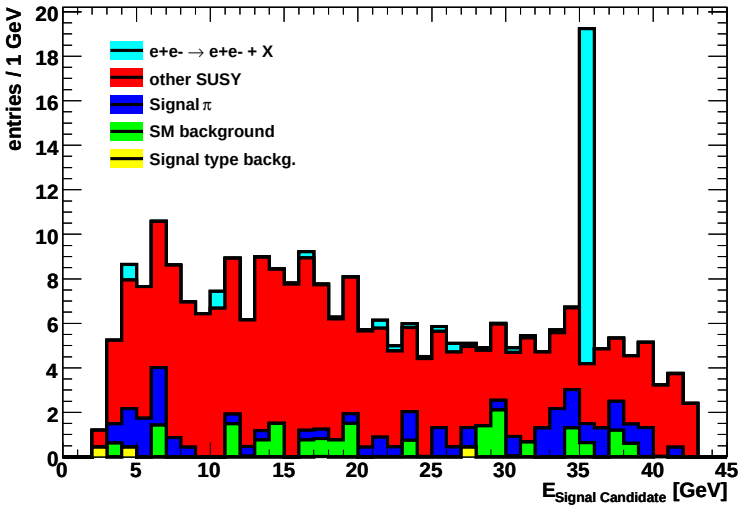

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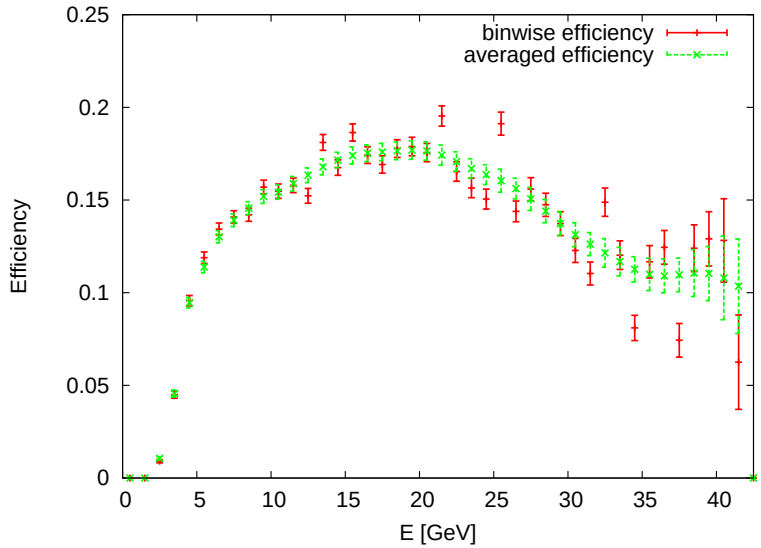

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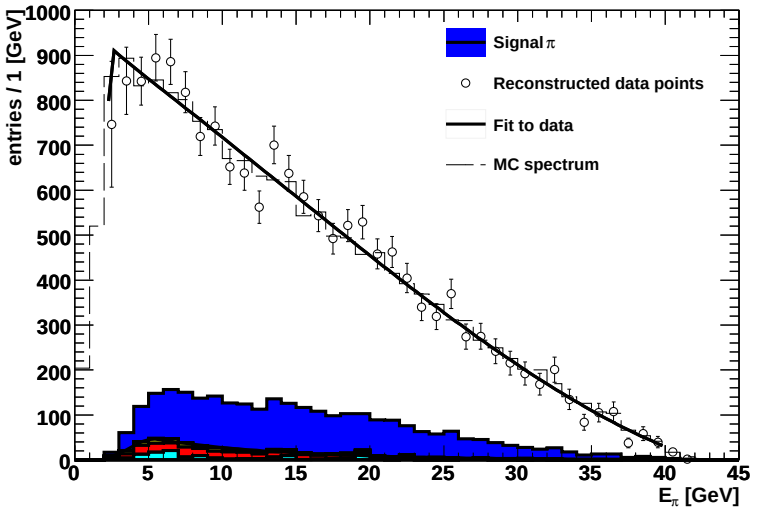

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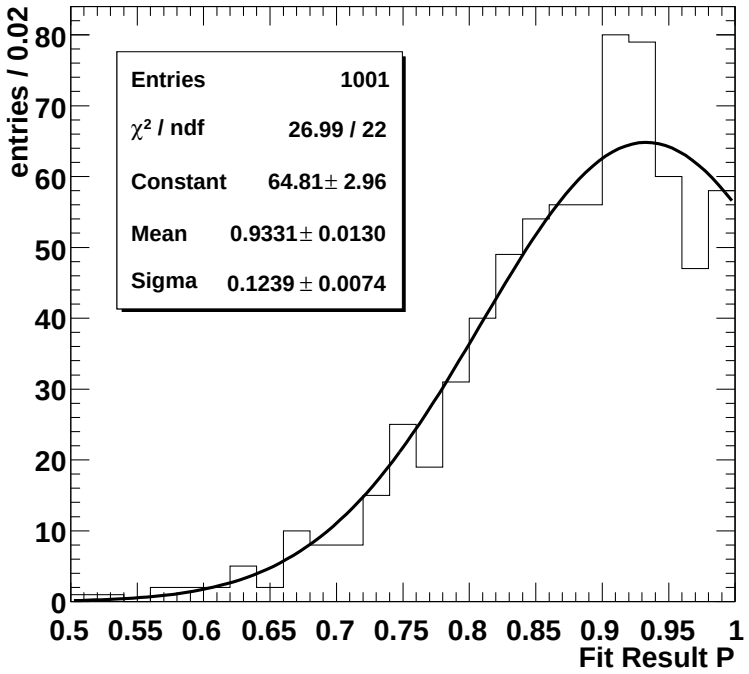

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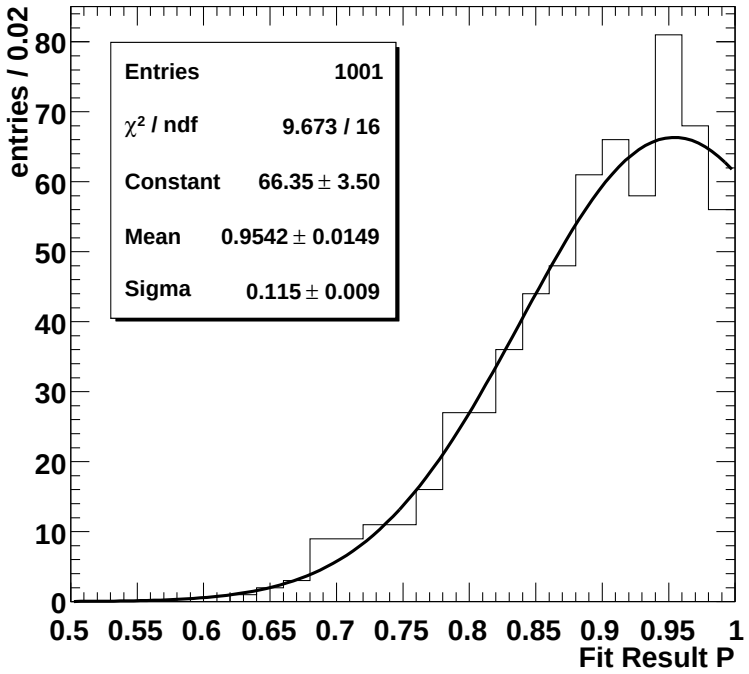

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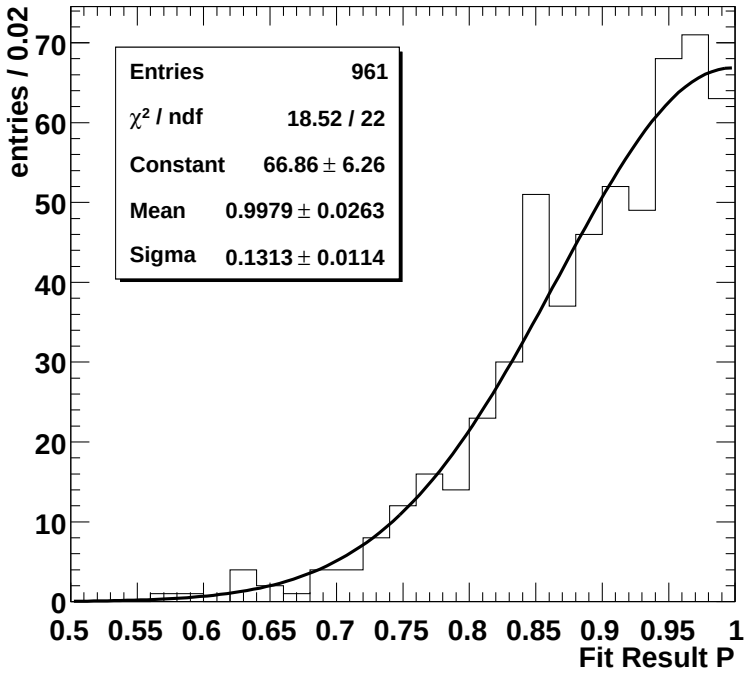

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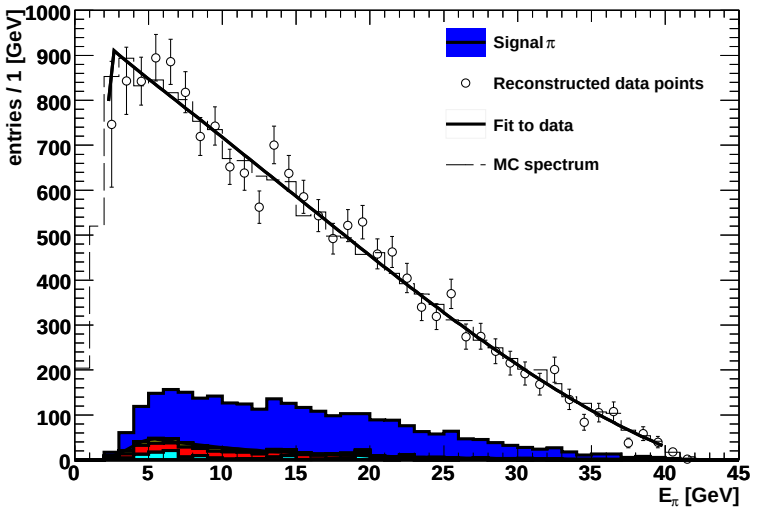

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- Preliminary result: $\Delta(P_\tau) = 13$ %. .
- A very Preliminary result: $\Delta(M_{\tilde{\tau}_1}) = 120\ \mathrm{MeV}/c^2$.
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