A τ Reconstruction Algorithm for High Energies at CLIC

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Introduction & Motivation

Why is τ identification important?

- Branching ratio and cross section require identification of lepton flavor.
- For analysis: event topology important
  $\rightarrow$ need to distinguish lepton from jet
  - identification of exclusive final states
  - suppression of background
- SUSY with high tanβ produces many τs in decay cascade
- Polarization measurements (CP violation)
- ...

The Algorithm

Jet like cone algorithm with some specific requirements according to τ properties:

1. Take charged particle with highest energy and test for seed
2. Loop charged particles and add the ones inside search cone to seed adjusting cone to new combined momentum
3. Associate neutral particles in same manner
4. Start from top to find next τ candidate
5. Combine all particles inside τ candidate to τ
6. Check for split τ candidates
7. Reject τ based on ID criteria

Selection Cuts

Reconstruction

- Minimum transverse momentum for a particle to be considered
- Minimum transverse momentum for seed
- Lower and upper limit on impact parameter
- Opening angle of search cone

ID

- $0 <$ number of charged tracks in τ-jet < 4
- Number of particles to form $\tau < 10$
- Opening angle of isolation cone, relative to search cone
- Limit on energy in isolation cone

Data sets without background @ 3TeV:

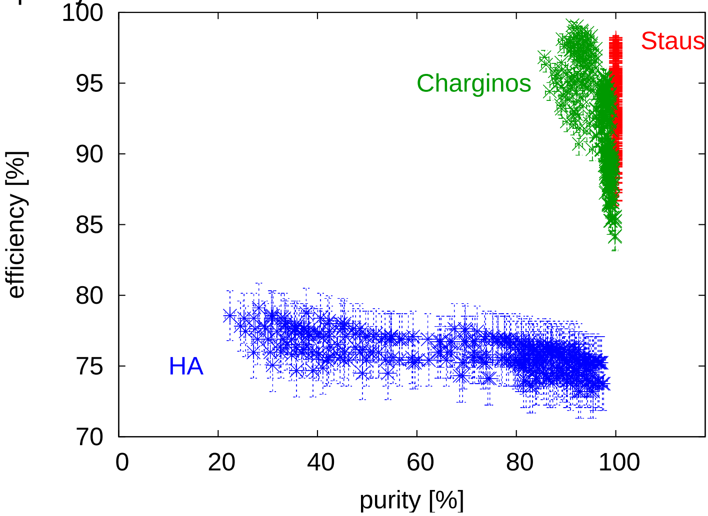
1. $e^+e^- \rightarrow \tilde{\tau}_1^+ \tilde{\tau}_1^-$
2. $e^+e^- \rightarrow \chi_1^+ \chi_1^-$
3. $e^+e^- \rightarrow H^0 A^0$

Parameter Scan:

- p_T of particle $>$ [0, 1] GeV/c
- p_T of seed $>$ [0, 5, 10] GeV/c
- Impact parameter D0 $<$ [0.3, 0.5, 0.7] mm
- Search cone: [0.03, 0.05, 0.07] rad
- Isolation cone: [0.02, 0.04] rad
- Isolation energy $<$ [3, 5, 10] GeV

Results at Generator Level: Efficiency and Purity

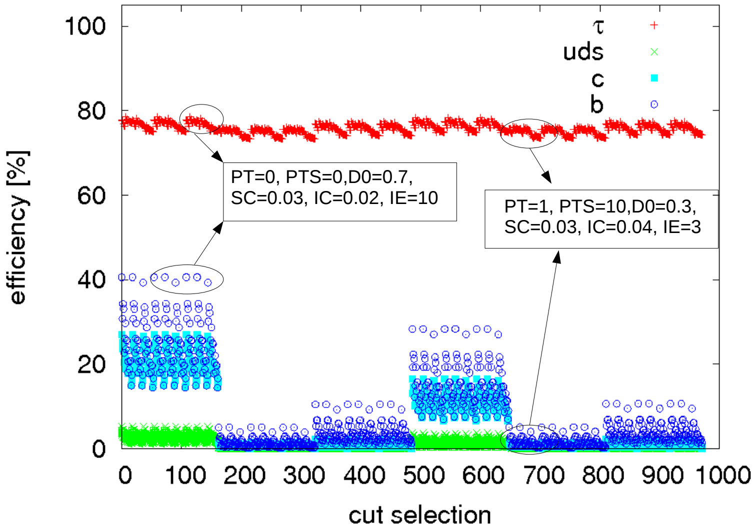
Choice of selection cut is always a trade off between efficiency and purity!



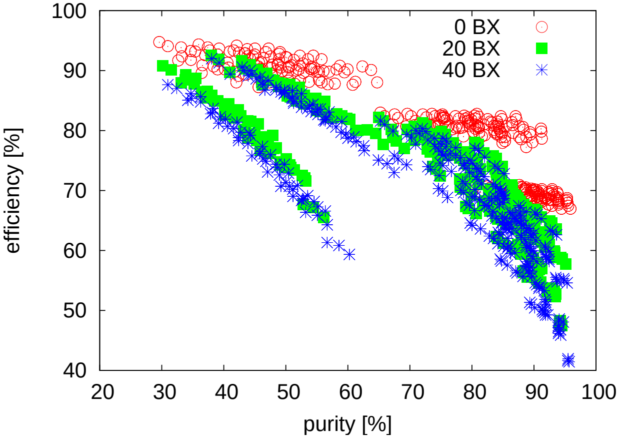
Jets from quarks are biggest source of mis-identification!

Results at Generator Level: Mis-Identification due to quarks

$e^+e^- \rightarrow H^0A^0$

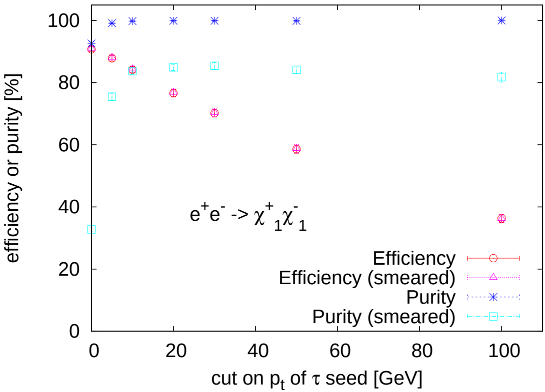


Process: $e^+e^- \rightarrow W^+W^-$ @ 3TeV
overlayed with different number of bunch crossings (BX) of
$\gamma\gamma \rightarrow hh$ background (3 ev/BX).



Effects of Detector Resolution: D0, E and p

- Only impact parameter resolution effects the algorithm.
- The resolution value itself is not that important.
- The efficiency is unaffected.
- The purity drops. It can partly (depending on physics process) be recovered by increasing the cut on the p_t of the τ seed.



Input & Output: LCIO

Input Information from ReconstructedParticle

- getMomentum()
- getCharge()
- getEnergy()
- getTracks(): charged particles need to have at least one track which is used to compute the impact parameter for the seed

also B field required

Output

- τ as ReconstructedParticle (as seen by the detector, not corrected for missing energy)
- Link back to the ReconstructedParticles that formed the τ.

Summary

- Framework (ILD/SiD) dependence minimal:
  runs on LCIO ReconstructedParticles.
- Independent of τ decay:
  works for hadronic and leptonic decays.
- Small drop in efficiency with $\gamma\gamma$ background.

Outlook

So far:
Implemented as MARLIN processor.
Evaluation done at generator level (MCParticles, no full detector simulation).
Next:
Evaluation based on PandoraPFA output once PFA performance is satisfactory at high energies.

BACKUP

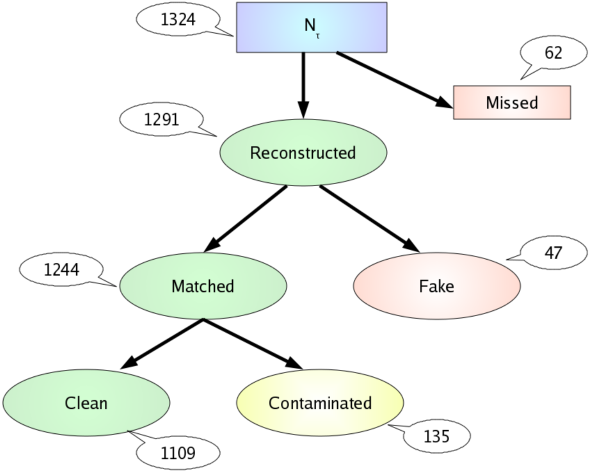
Evaluation: Definitions

$$\text{Efficiency}: \quad E = \frac{\textit{Matched}}{N_\tau}$$

$$\text{Purity}: \quad P = \frac{\textit{Matched}}{\textit{Reconstructed}}$$

- N_τ: Number of τs in the MC truth.
- *Missed*: Number of τs not recognized
- *Reconstructed*: Number of τs reconstructed.
- *Matched*: Number of reconstructed τs where at least one of the particles used to form the τ links back to a τ in the MC truth.
- *Fake*: *Reconstructed - Matched*
- *Clean*: Number of reconstructed τs where all the particles used to form the τ link back to a τ in the MC truth.
- *Contaminated*: *Matched - Clean*.

Evaluation: Nomenclature



τ Decay Channel Dependence

Process	Decay	Eff. [%]	tot. Eff.[%]	Purity [%]
$e^+e^- \longrightarrow W^+W^-$	$\tau \longrightarrow \mu$ $\tau \longrightarrow e$ $\tau \longrightarrow \pi$ $\tau \longrightarrow \pi\pi\pi$ $\tau \longrightarrow \pi\pi^0$	77.1 $\pm$ 3.1 81.1 $\pm$ 3.0 82.9 $\pm$ 2.0 84.2 $\pm$ 3.3 70.6 $\pm$ 4.3	80.3 $\pm$ 1.3	91.1 $\pm$ 1.0
$e^+e^- \longrightarrow tt$	$\tau \longrightarrow \mu$ $\tau \longrightarrow e$ $\tau \longrightarrow \pi$ $\tau \longrightarrow \pi\pi\pi$ $\tau \longrightarrow \pi\pi^0$	42.9 $\pm$ 7.4 52.0 $\pm$ 6.8 56.0 $\pm$ 5.1 45.9 $\pm$ 7.9 36.0 $\pm$ 9.1	49.1 $\pm$ 3.1	69.5 $\pm$ 3.3
$e^+e^- \longrightarrow \tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tau \longrightarrow \mu$ $\tau \longrightarrow e$ $\tau \longrightarrow \pi$ $\tau \longrightarrow \pi\pi\pi$ $\tau \longrightarrow \pi\pi^0$	98.6 $\pm$ 0.3 97.5 $\pm$ 0.4 98.6 $\pm$ 0.5 98.4 $\pm$ 0.4 98.2 $\pm$ 0.4	98.2 $\pm$ 0.1	100
$e^+e^- \longrightarrow \chi_1^+\chi_1^-$	$\tau \longrightarrow \mu$ $\tau \longrightarrow e$ $\tau \longrightarrow \pi$ $\tau \longrightarrow \pi\pi\pi$ $\tau \longrightarrow \pi\pi^0$	97.0 $\pm$ 1.2 98.0 $\pm$ 1.0 99.2 $\pm$ 0.4 100 96.3 $\pm$ 2.0	98.3 $\pm$ 0.4	95.0 $\pm$ 0.6
$e^+e^- \longrightarrow H^0A^0$	$\tau \longrightarrow \mu$ $\tau \longrightarrow e$ $\tau \longrightarrow \pi$ $\tau \longrightarrow \pi\pi\pi$ $\tau \longrightarrow \pi\pi^0$	80.2 $\pm$ 3.7 80.4 $\pm$ 3.8 69.2 $\pm$ 3.4 75.8 $\pm$ 5.2 77.5 $\pm$ 5.9	75.2 $\pm$ 1.8	97.1 $\pm$ 0.8