Performance of the tau reconstruction at ATLAS

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Outline

The ATLAS detector

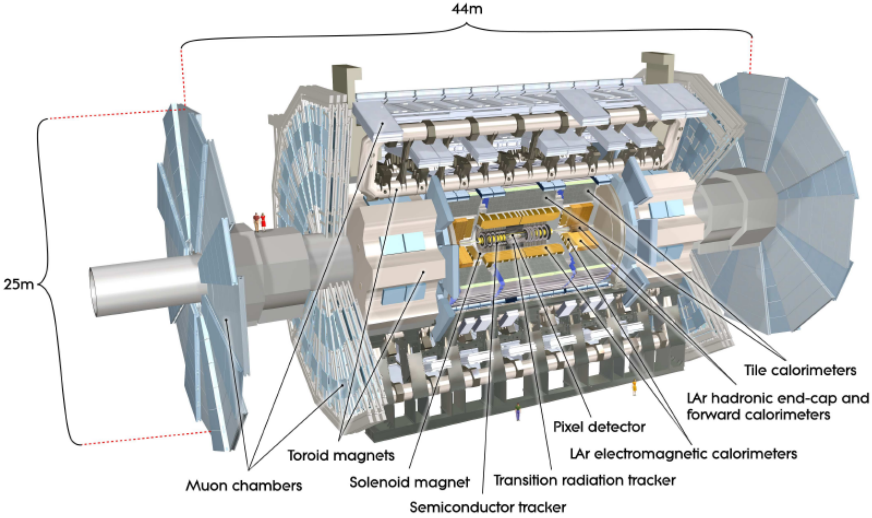
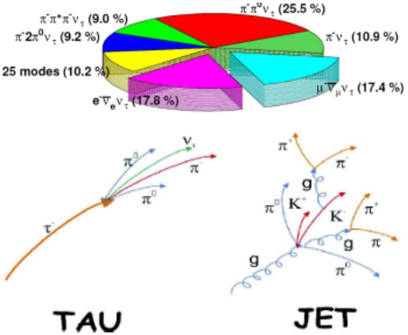


Figure: ATLAS detector overview

Tau characteristics

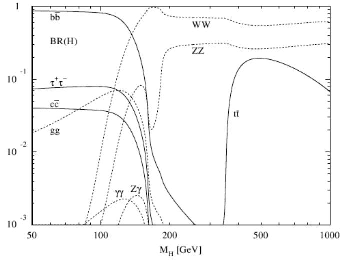
- $m_\tau \sim 1.7$ GeV
- $c\tau = 87\mu m$
- Hadronic decays are well collimated collection of charged and neutral pions/kaons
- Mostly 1 or 3 charged tracks
- Leading pion reproduces τ direction well

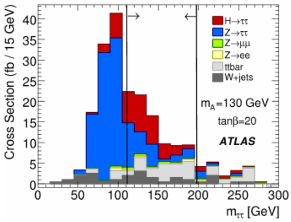


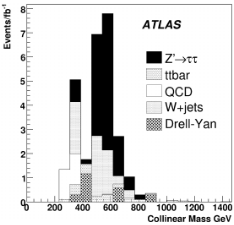
- τ decays well understood
- Provides an excellent probe of 'New Physics' ...
- ... if contribution of QCD background is well understood

Physics with tau leptons in many areas

- **Standard Model**
  - Measurement of W/Z production cross section
  - Discovery of Higgs bosons in H $\rightarrow \tau\tau$ final states
- **Minimal Supersymmetric Standard Model (MSSM)**
  - h/H/A $\rightarrow \tau\tau$ excellent discovery potential
  - Searches for charged Higgs bosons: $H^{\pm} \rightarrow \tau\nu$
- **Exotic scenarios**
  - E.g. searches for heavy gauge bosons

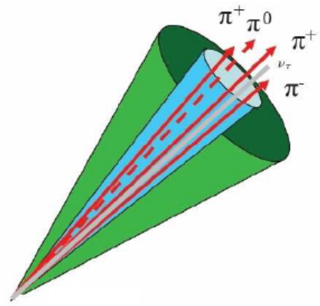


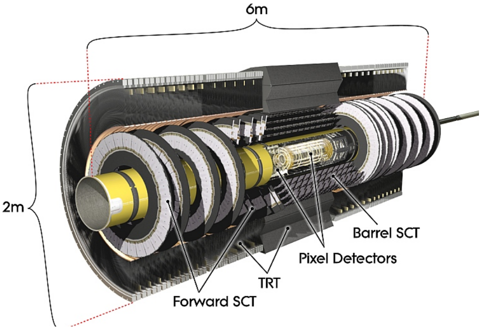




Tracking

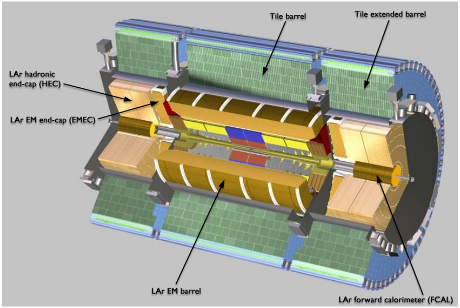
- Low track multiplicity
- Collimated tracks
- Secondary vertex reconstruction for 3-prong τ candidates
- Isolation from other tracks





Calorimetry

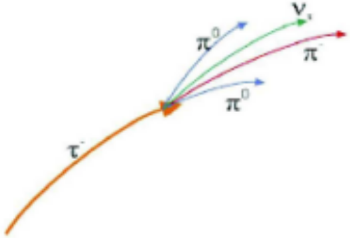
- Collimated energy deposits in calorimeter
- Strong EM component for 1-prongs
- Possibility of π^0 cluster identification ($\pi^0 \rightarrow \gamma\gamma$)
- Use electromagnetic (EM) and hadronic (HAD) component



Reconstruction and Identification done separately

Track- and Calo- seeded tau reconstruction

- Use good quality track ($p_T > 6$ GeV) as seed
- Candidates with ≤ 8 tracks ($p_T > 1$ GeV) in $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < 0.2$
- Reconstruct η, ϕ of τ using p_T weighting of tracks
- Charge consistency check
- Find matching cone-jet with opening $\Delta R = 0.4$ ($E_T > 10$ GeV, $|\eta| < 2.5$) as calo-seed
- E_T using cells from calo-seed
- Energy flow algorithm
- Reconstruct π^0 subclusters

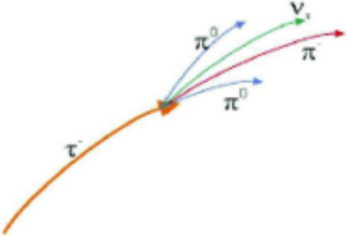


Calorimeter-only seeded reconstruction

- Use remaining clusters as a seed
- Define η, ϕ of τ candidate from cluster
- Loser track quality selection ($p_T > 1$ GeV)

Track-only seeded reconstruction

- Very small fraction of candidates expected in collision data



Identification of tau candidates

- Variety of identification algorithms avaliable
  - Cut-based selection
  - Projective likelihood
  - Neural networks
  - Boosted-Decision-Trees
  - ...
- Based on tracking and calorimetry variables
  $\Rightarrow$ examples later

Robust variable approach

- Safe approach for early data taking
- Based on small number of well understood (robust) variables
- Requirements: variables safe according to experts and largely uncorrelated
- Two approaches:

Calorimeter approach

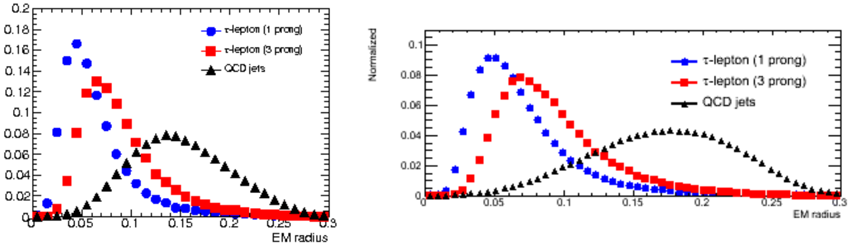
- Shower radius in EM calorimeter
- Isolation fraction
- Width in strip layer
- $E_T(EM)/E_T$

Calorimeter + tracking approach

- Variables from calo-approach
- + width of track momenta
- + E_T/p_T (leading track)
- + $E_T(HAD)/\sum p_T$
- + $E_T(EM)/\sum p_T$
- + $\sum p_T/E_T(EM + HAD)$

- Tau reconstruction is improved continously
  $\Rightarrow$ each version has to be checked
- Here:
  $\rightarrow$ study performance of tau reconstruction and identification with Pythia Monte-Carlo 08 samples
  signal: Z$\rightarrow \tau\tau$
  background: QCD di-jet

Figure: EM radius for calo-seeded candidates (fake-taus from QCD di-jet)



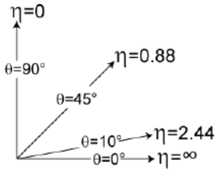
(a) Rel. 14.2.20
QCD: 35 GeV $\leq p_T \leq$ 70 GeV

(b) Rel. 15.3.1; QCD: 0 GeV $\leq p_T \leq$ 140 GeV

EM radius

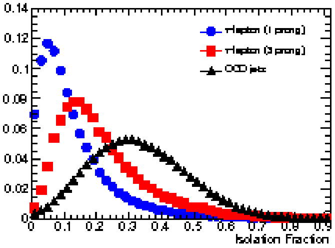
$$R_{em} = \frac{\sum_{i=1}^{n} E_{T,i} \sqrt{(\eta_i - \eta_{cluster})^2 + (\phi_i - \phi_{cluster})^2}}{\sum_{i=1}^{n} E_{T,i}}$$

where i runs over EMCal cells in $\Delta R < 0.4$



no change in shape for tau signal
different background shape → new QCD MC sample is more complete (J0-J3)

Figure: Isolation fraction of calo-seeded candidates (fake-taus from QCD di-jet)



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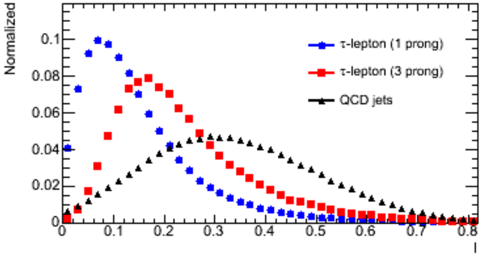


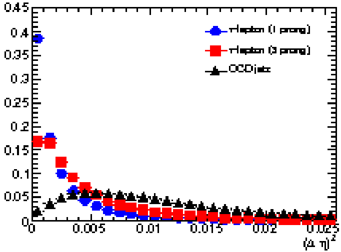
(b) Rel. 15.3.1; QCD: 0 GeV $\leq p_T \leq$ 140 GeV

Isolation fraction

$$I = \frac{\sum_i^{0.1<\Delta R<0.2} E_{T,i}}{\sum_j^{\Delta R<0.4} E_{T,j}}$$

where i, j runs over EM calo cells

Figure: Strip-Layer width of calo-seeded candidates (fake-taus from QCD di-jet)



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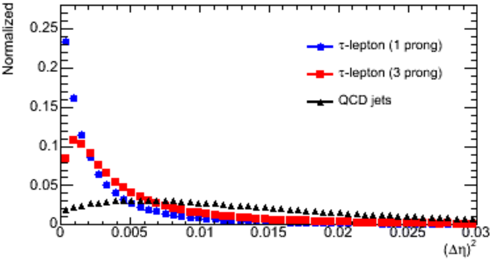


(b) Rel. 15.3.1; QCD: 0 GeV $\leq p_T \leq$ 140 GeV

Strip-Layer width

$$\Delta\eta = \sqrt{\frac{\sum_i^{\Delta R<0.4} E_{T,i}(\eta_i - \eta_{cluster})}{\sum_i^{\Delta R<0.4} E_{T,i}^{strip}}}$$

where i runs over strip cells in associated topoclusters

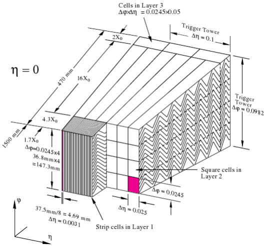
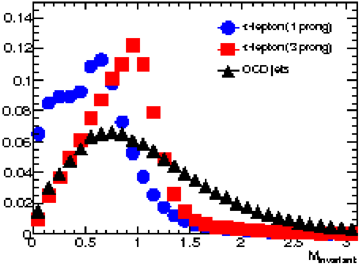


Figure: Invariant visible mass spectrum for track-seeded cand. (fake-taus from QCD di-jet)



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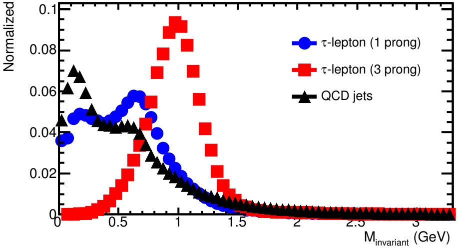


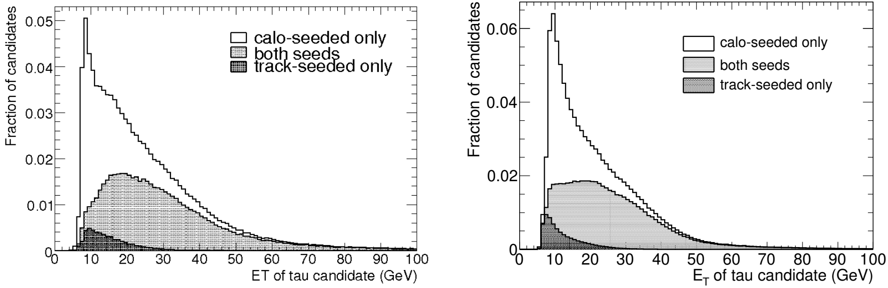
(b) Rel. 15.3.1; QCD: 0 GeV $\leq p_T \leq$ 140 GeV

M_{inv}

using four-momenta of tracks and the barycentre of energy

- 3-prong mass distribution more narrow → better resolution
- New QCD MC Sample has also low-pT jets

Figure: E_T spectra of reconstructed τ candidates



(a) Rel. 14.2.20 (b) Rel. 15.3.1

Comparison

more track-seeded and both-seeded candidates at small E_T

Table: Rel. 14.2.20

	both-seeds candidates	Only track-seeded candidates	Only calo-seeded candidates
Reconstructed Reconstructed an matched with MC tau's	50% 75%	5% $<$1%	45% 25%

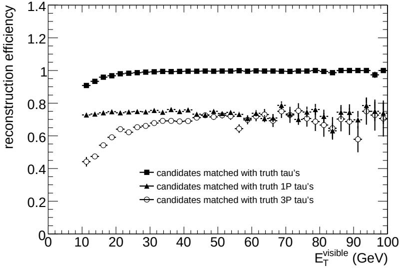
Table: Fraction of reconstructed and truth-matched τ cand. for signal Z$\rightarrow \tau\tau$

Table: Rel. 15.3.1

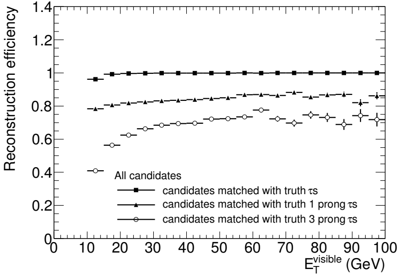
	both-seeds candidates	Only track-seeded candidates	Only calo-seeded candidates
Reconstructed Reconstructed an matched with MC tau's	51.1% 75.8%	7.2% $<$1%	41.7% 23.5%

Table: Fraction of reconstructed and truth-matched τ cand. for signal Z$\rightarrow \tau\tau$

Figure: Reconstruction efficiency for all reconstructed candidates



(a) Rel. 14.2.20



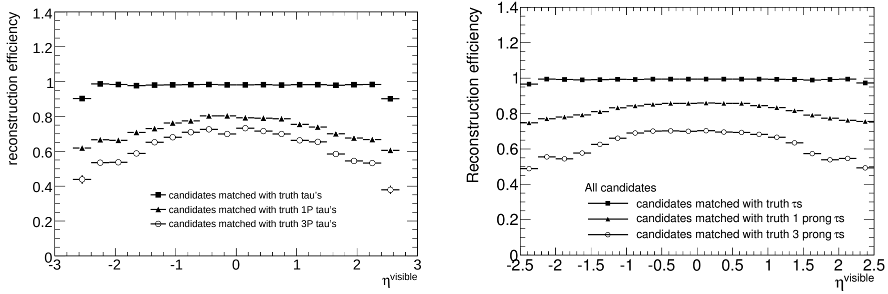
(b) Rel. 15.3.1

Reconstruction efficiency

$$\epsilon_\tau = \frac{N^\tau_{reco-matched}}{N^\tau_{true}}$$

- N^τ_{true} - # true, had. decaying τ's with $E_T{}^{vis} > 10$ GeV, $|\eta| < 2.5$
- $N^\tau_{reco-matched}$ - # of reconstructed τ's matched to N^τ_{true} within $\Delta R < 0.2$
- E_T and η cut on tracks implemented
- higher efficiency for 1-prong τ candidates

Figure: Reconstruction efficiency for all reconstructed candidates



(a) Rel. 14.2.20

(b) Rel. 15.3.1

Comparison

- higher efficiency for all and 1 + 3-prong τ candidates
- more flat distribution for 1-prong τ candidates

Summary/Outlook

- τ leptons can be reconstructed with high efficiency:
  $> 90\%$ if correct identification of number of tracks is neglected
- Better performance in new reconstruction version
- This comparison will be documented in an ATLAS note
- My Diploma project:
  extend reconstruction and identification of τ leptons to high momentum τ leptons
  - More collimated jets
  - Use energy to categorize τs instead of E_T
  - Development of new selection criteria

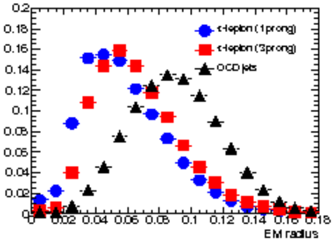
Datasets

- using TauValidation-00-04-05 in ATHENA Rel. 15.6.1
- Signal samples:
  - mc08.106052.PythiaZtautau.merge.AOD.e347_s462_s520_r809_r838
- background samples
  - mc08.105009.J0_pythia_jetjet.merge.AOD.e344_s479_s520_r809_r838
  - mc08.105010.J1_pythia_jetjet.merge.AOD.e344_s479_s520_r809_r838
  - mc08.105011.J2_pythia_jetjet.merge.AOD.e344_s479_s520_r809_r838
  - mc08.105012.J3_pythia_jetjet.merge.AOD.e344_s479_s520_r809_r838

Backup: The energy-flow approach

- energy deposits in cells divided into:
  - pure em. energy E_T^{emcl}
  - charged em. energy E_T^{chrgEM}, $E_T^{chrgHAD}$
  - neutral em energy E_T^{neuEM}
- $E_T^{chrgEM} + E_T^{chrgHAD}$ replaced by track(s) momenta $\rightarrow$ define energy scale of τ_{had}
- contribution of π^0 included in E_T^{emcl} and E_T^{neuEM}
- correction of effects of π^0 and $\pi^\pm$ depositing energy in same cell by $\sum resE_T^{chrgEM}$ and $\sum resE_T^{neuEM}$

Figure: EM radius of track-seeded candidates (fake-taus from J2 (left); J0-J3 (right))



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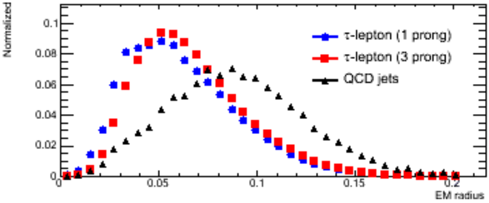
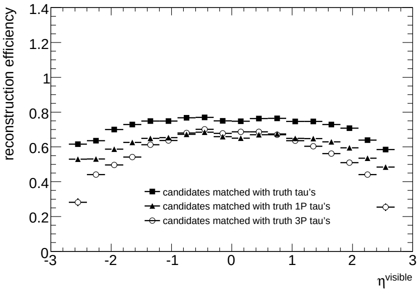


(b) Rel. 15.3.1

Figure: Reconstruction efficiency for reconstructed candidates with both seeds



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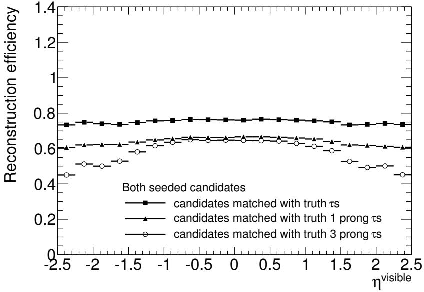

(b) Rel. 15.3.1

Comparison

- higher efficiency for all and 1 + 3-prong τ candidates at high $|\eta|$
- more flat distribution for all and 1-prong τ candidates