

ATLAS Germany Tau Meeting Hamburg

News from the Explicit Photon Conversion Reconstruction in Hadronic τ Lepton Decays

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April 2th 2009



Outline:

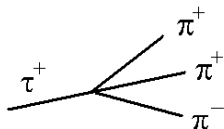
- 1 Photon Conversion Reco & ID
- 2 Implementation in rel. 15
- 3 Results with \approx rel. 15
- 4 Trk Selection & Conv Tagging
- 5 Summary



Motivation: τ -Decay and π^0 -Decay

- τ -decay:

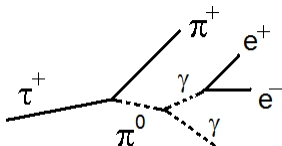
leptonic	(35.2 %)
$\tau \rightarrow e + \nu_e + \nu_\tau$	
$\tau \rightarrow \mu + \nu_\mu + \nu_\tau$	
hadronic	
1 Prong	(46.8 %)
$\tau \rightarrow \pi^\pm + \nu_\tau$	
$\tau \rightarrow \pi^\pm + n \cdot \pi^0 + \nu_\tau$	
3 Prong	(13.9 %)
$\tau \rightarrow \pi^\pm + \pi^\pm + \pi^\pm + \nu_\tau$	
$\tau \rightarrow \pi^\pm + \pi^\pm + \pi^\pm + n \cdot \pi^0 + \nu_\tau$	



τ decays into three charged π 's (3 Prong)

- a π^0 occurs in 40,58% of all τ -decays
- τ -decay with photon conversion:
 - $\tau^+ \rightarrow \pi^+ \pi^0 \nu_\tau \rightarrow \pi^+ \gamma \gamma \nu_\tau \rightarrow \pi^+ \gamma e^+ e^- \nu_\tau$
- numerical example:

process: $Z \rightarrow \tau\tau$	100
τ	200
π^0	353
γ -conversions	185



τ decays into one π^+ (1 Prong) and one π^0 , which decays into two γ 's, one of them makes a e^+e^- pair creation

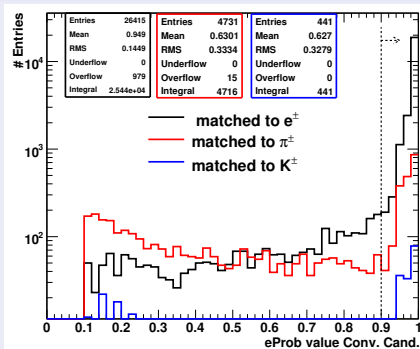
Reconstruction & Identification of Photon Conversions

1. Reconstruction

- investigate all reconstructed tracks
- reject all tracks from IP
- build pos./neg. track pairs
- refit the tracks to a secondary vertex (constraint: inv mass = 0 (m_γ))

2. Identification (modified for τ environment)

- *TRT Electron Particle IDentification Tool* provides:
 - ▶ with a Likelihood method
 - ▶ based on TRT High Threshold Hits
 - ▶ an electron probability for each track
- photon conv. is tagged as identified, if both tracks (eProb > 90%)



Result of τ specific Conversion Identification

1. Reconstruction - Conversion Candidates

e^\pm	$77.8 \pm 0.6 \%$
π^\pm	$20.2 \pm 0.3 \%$
K^\pm	$2.0 \pm 0.1 \%$

- already high fraction of electrons
- large number of π^\pm
 - ▶ often π^\pm pairs from 3Prongs
 - ▶ identification is needed
 - ▶ otherwise suppressing 'good' τ tracks

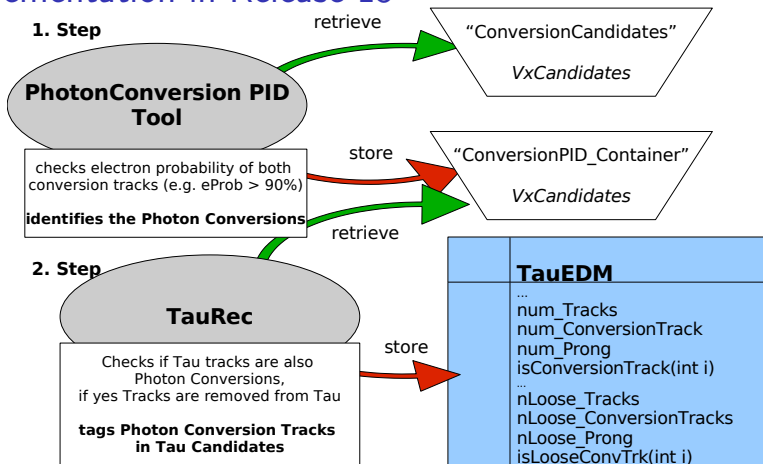
2. Identification - identified Photon Conversions

e^\pm	$92.4 \pm 0.9 \%$
π^\pm	$7.0 \pm 0.2 \%$
K^\pm	$0.6 \pm 0.1 \%$

- many π^\pm could be rejected
- at least an electron purity of 90 % is needed

- Sufficient electron purity to tag photon conversions in τ decays

Implementation in Release 15



- Photon Conversion finding in 2 Steps (impl. in TauRec/run in TauTools)
 - 1 Identify Photon Conversions from Conversion Candidates
 - 2 Check if Trk is used to build Conv. and τ Candidate
- new Transient Container with identified Photon Conversions
- Conversion variables in new TauEDM

Testing Setup:

To run recent developments this setup has been used:

- rel. 14.5.1 plus additional tags:
 - ▶ RecExCommon-00-10-38
 - ▶ tauRec-03-08-16
 - ▶ tauEvent-00-04-08
 - ▶ TauDiscriminant-00-00-32
 - ▶ RecTPCnv-00-05-14-04 (+ cvs update of Tau* to 00-05-20)
 - ▶ RecAthenaPool-00-05-02-05
 - ▶ TauTools-00-04-02
 - ▶ AtlfastConversionTools-00-05-00

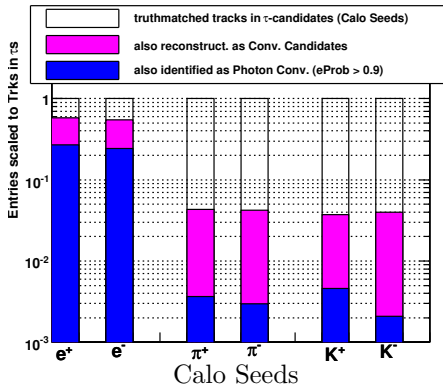
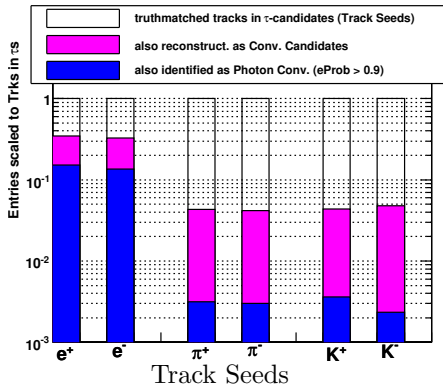
To dump all new variables into D3PD those tags have to be changed:

- ▶ EventViewUserData-14-05-00-02
- ▶ TauDPDMaker-00-04-03

This is work in progress! For easy runing just wait for rel. 15!

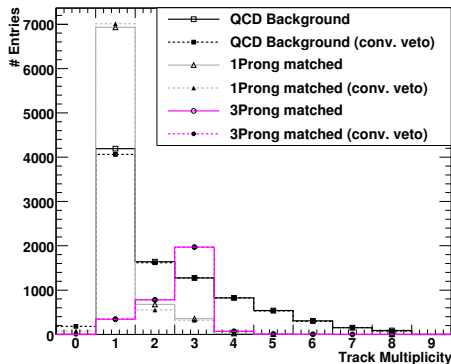
Reconstructed Photon Conversions in τ Decays

Overlap of τ trks, conv cand trks, and photon conv trks

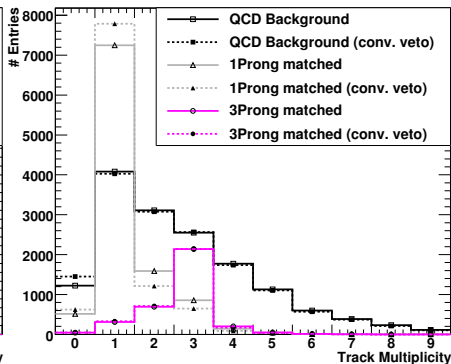


- 29.4 % of e^\pm tracks (*Calo Seed*) of τ cand. are tagged as ID conv tracks (≈ 17 % *Track Seed*)
- both Seeds: < 0.45 % of π^\pm tracks and < 0.35 % of $^\pm$ tracks are tagged wrongly

Corrected Track Multiplicities



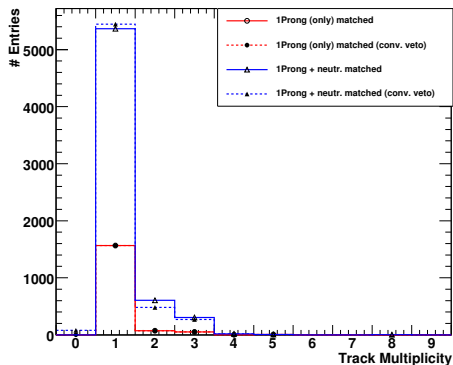
Track Seeds



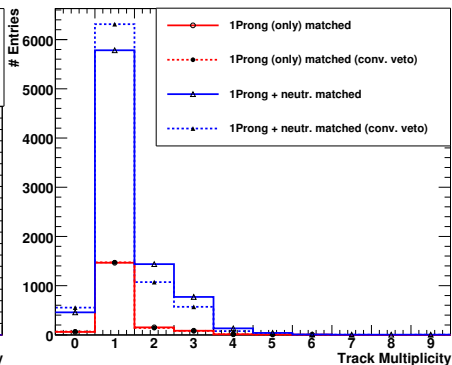
Calo Seeds

- *Track Seed* much lower fraction of QCD background (tighter selection)
- more corrections for matched τ s than for QCD background
- much more 1 Prong reconstructed by *Calo Seed* alg.
- conversion tagging much more useful for *Calo Seeds*

1 Prong Track Multiplicities



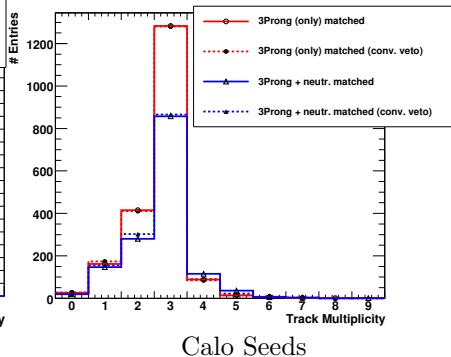
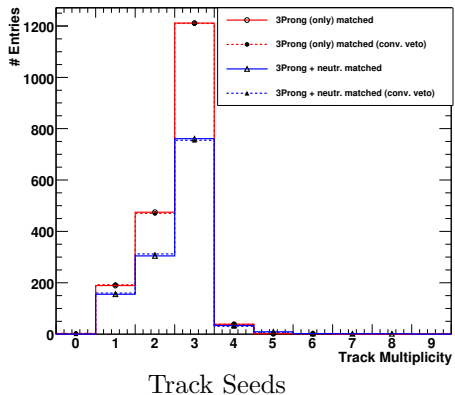
Track Seeds



Calo Seeds

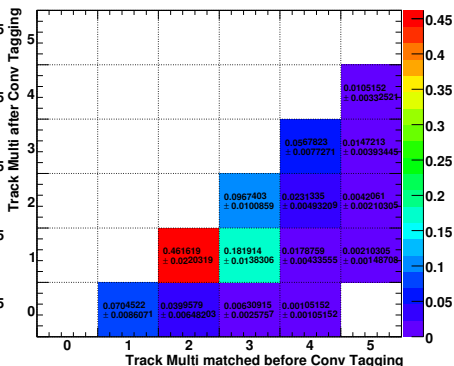
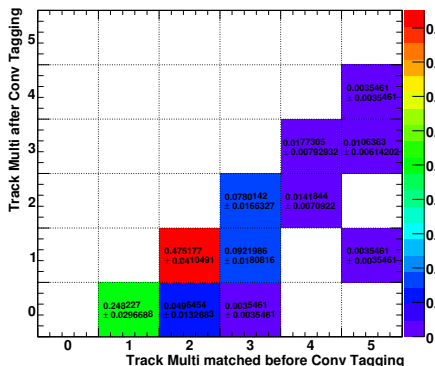
- corrections only in τ decays with π^0 (blue)
- good improvement for *Calo Seed* 1 Prong decays

3 Prong Track Multiplicities



- less entries and corrections than in 1 Prong decays
- theoretically understood
 - ▶ only in 25.6 % of 3 Prong decays occur π^0 (blue)

Correction Overview



Track Seed:

- 2.0 % of all truthmatched τ candidates are corrected
 - ▶ 54.5 % correction $X \rightarrow 1$ Prong (tot.: 1.1 %)
 - ▶ 33.1 % miss correction in total $X \rightarrow 0$ Prong (tot.: 0.7 %)

Calo Seed:

- 6.7 % of all truthmatched τ candidates are corrected
 - ▶ 67.0 % correction $X \rightarrow 1$ Prong (tot.: 4.5 %)
 - ▶ 12.0 % miss correction in total $X \rightarrow 0$ Prong (tot.: 0.8 %)

Summary Table

- Reconstruction efficiency of 1 and 3 Prong τ candidates
- Definition:

$$eff = \frac{\text{reco (1 Trk) matched to truth 1 Prong}}{\text{truth 1 Prong}}$$

		Calo Seeds		Track Seeds	
		def.	conv veto	def.	conv veto
1 Prong	tot.	68.87	74.03	65.86	66.65
	no π^0	80.05	80.60	85.52	85.57
	π^0	66.51	72.64	61.72	62.67
3 Prong	tot.	61.09	61.26	56.29	56.09
	no π^0	63.45	63.30	59.89	59.84
	π^0	57.87	58.47	51.38	50.98
total		66.92	70.84	63.47	64.01

- Improvement for 1 Prong decays (most γ conversions expected)
- Increase reco. efficiency of *Calo Seed* τ candidates by 3.9 %

Track Selection Criteria

Track Seeds

Seed building cuts:

ΔR Core Track Cut	0.2
pTLeadTrackCut [GeV]	6.
ΔR OtherTrackCut	0.2
NOther Tracks Cut	7
Reco Other Eta Cut	2.5
ΔR Isol Track Cut	0.4

Calo Seeds

Seed building cuts:

CellEthreshold [GeV]	0.2
StripEthreshold [GeV]	0.2
EMSumThreshold [GeV]	0.5
EMSumRadius	0.2
Track Isol Cone Low	0.1
Track Isol Cone High	0.4

Tracks selection cuts:

Cut	Tau1P	Tau3P
pTMin	1000	1000
IPd0Max	2.	1.
IPz0Max	10.	1.5
nHitBLayer	0	1
nHitPix	0	2
nHitSct	0	0
nHitSi	7	7
nHitTrt	0	0
$\chi^2 ndf$	99999.	99999.

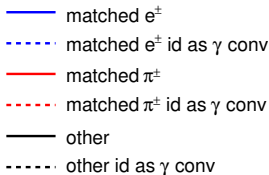
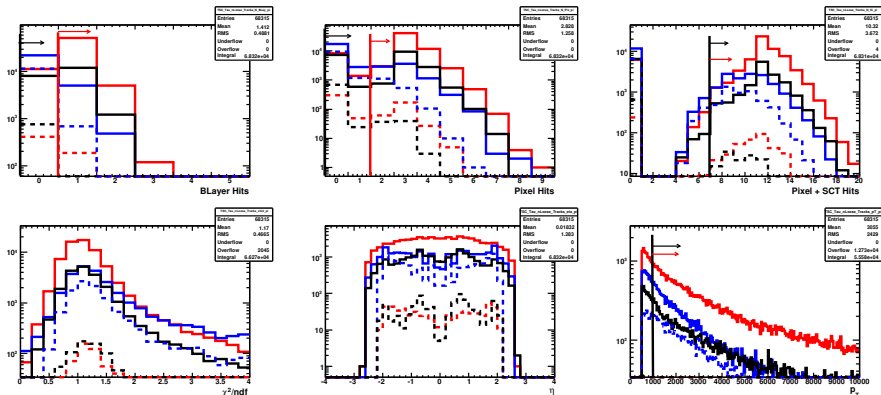
Tracks selection cuts:

Cut	Value
pTMin	1000
IPd0Max	1.
IPz0Max	1.5
nHitBLayer	0
nHitPix	0
nHitSct	0
nHitSi	7
nHitTrt	0
$\chi^2 ndf$	99999.

all cuts are taken from:

/atlas/Reconstruction/tauRec/python/TauMergedGetter.py

Overview of the Track Selection Criteria Distributions



- all trks around *Calo Seed* τ candidates
- cuts: *Track Seeds* and *CaloSeeds*
- cuts are already loosened a lot

Summary & Outlook

Summary:

- A method to identify Photon Conversions in dense environment has been worked out
 - ▶ Based on TRT Electron PID Tool only
- Improvements in the τ track multiplicity have been shown
- Conversion tagging tool for τ candidates is already implemented in rel. 15

Outlook:

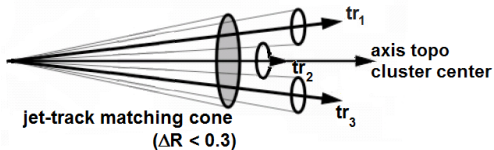
- Investigate impact of tagged conversion tracks on the track selection criteria
 - ▶ Study will be presented by Guilherme N. Hanninger (next talk)
- Provide likelihood pdf with tagged conversion tracks
 - ▶ to study the impact of identified τ s
- An internal note is in preparation

Back-up Slides

Track ID in τ -Candidates / τ -Cone

- truthmatched track ID of τ -jets

	τ -Cone	τ -Cand.(TSC)
π^\pm	58.4 %	74.0 %
e^\pm	25.4 %	6.8 %
K^\pm	7.5 %	11.2 %
other	8.7 %	3.6%

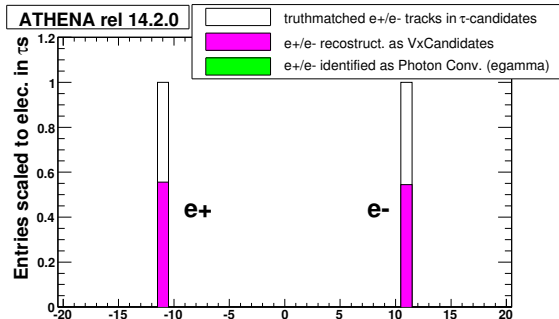


- rel. 14.2.0 def. TauRec **Track Selection Criteria (TSC)** suppress γ conv. (rel 15. TSC are slightly opened)

lower part

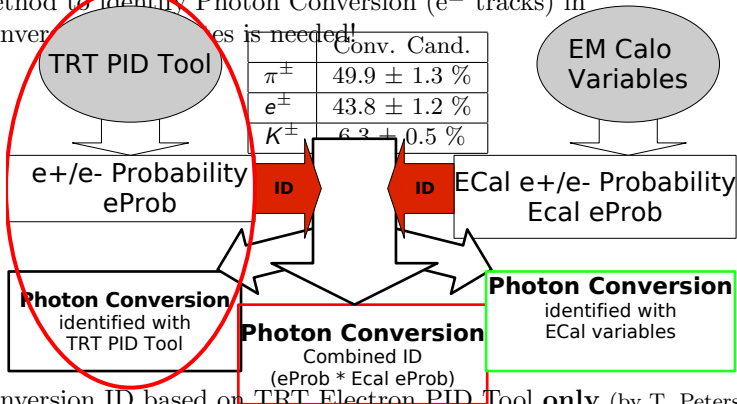
For τ -Candidates with TSC:

- 55 % of e^\pm in τ s have been found by *ConversionFinder*
- since rel. 14
0 % are identified as def. *egamma*-conversion
- γ conv. ID method for dense environment has to be developed



Two Independent Photon Conversion ID Approaches

- Method to identify Photon Conversion (e^\pm tracks) in Conversion Candidates is needed!



- Conversion ID based on TRT Electron PID Tool **only** (by T. Peterson)
 - calculates an e^\pm probability for each Trk
 - Likelihood approach based on High Threshold Hits
- Conversion Candidates with eProb. > 90 % (both Trk) are accepted

- TRT Electron PID Tool (by Troels Peterson)

- electron prob. for each Trk

- Based on ECal var. **ONLY**

- lin. uncorrelated from ID var.
- add. information

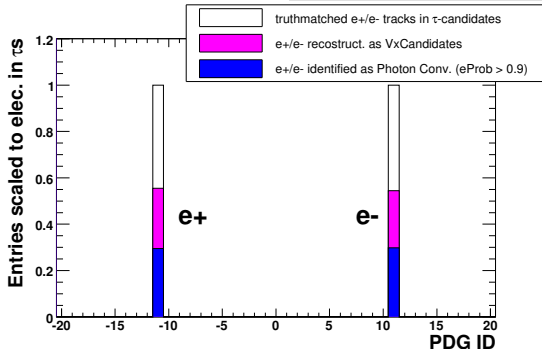
Results Using TRT PID Tool to ID Photon Conversions

- Conversion Candidates before identification:

	Conversions Candidates
π^\pm	$49.9 \pm 1.3 \%$
e^\pm	$43.8 \pm 1.2 \%$
K^\pm	$6.3 \pm 0.5 \%$

- Identified with the TRT PID Tool (cut: $e\text{Prob} > 90\%$)

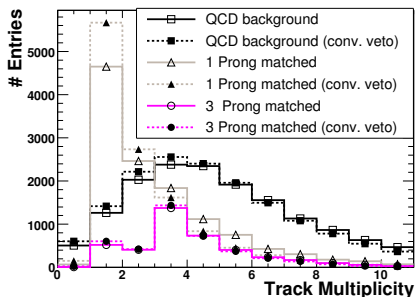
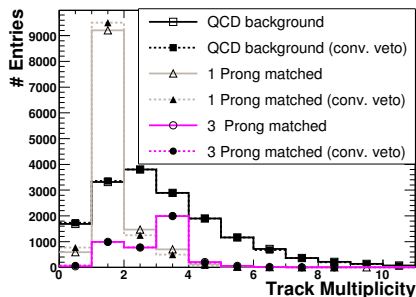
	Photon Conversions
π^\pm	$9.1 \pm 1.0 \%$
e^\pm	$89.5 \pm 3.1 \%$
K^\pm	$0.9 \pm 0.3 \%$



- Identification of Conversion Candidates with TRT PID Tool
 - 29.7 % of e^\pm of τ candidate tracks are tagged as Photon Conversions

Corrected τ Track Multiplicity

def. *TauRec* Track Selection Criteria: all Trks with $dR < 0.3$ around τ -axis:

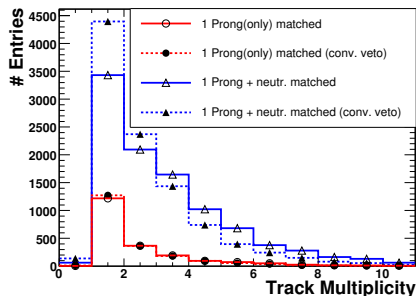


- Even if the TSC are applied a slight improvement can be observed
- Rel. 15 some of the TSC are loosened
→ we expect something between the two plots

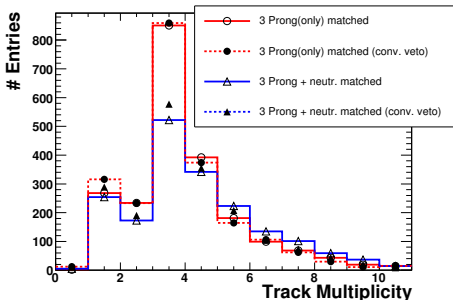
Corrected τ Track Multiplicity

With opened Tracks Selection Criteria (all Trks with $dR < 0.3$ around τ -axis), Track Multiplicities are matched to truth hadronic...

... 1-Prong decays:



... 3-Prong decays:

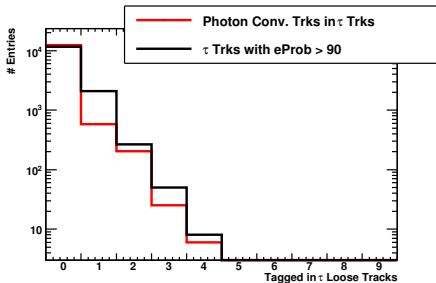
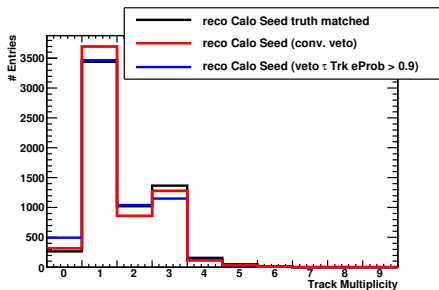
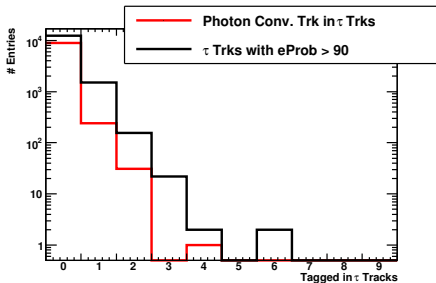
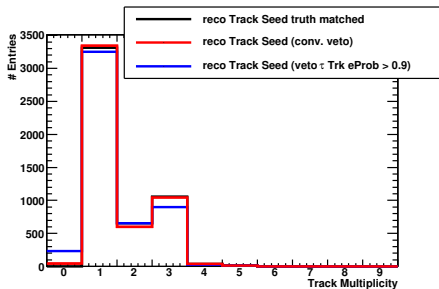


- (in blue) photon conversions are only expected in decays with neutral π_0
 - ▶ mainly in these decays corrections due to conversion track veto can be seen
- less entries / corrections for 3 Prong decays
 - ▶ only 25.6 % of 3 Prong decays are with neutral π_0

Summary of the Study

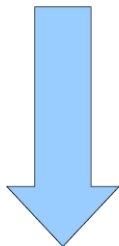
- Def. photon conversion ID method does not work in τ environment
- τ specific conversion ID has been worked out
- Photon conversions are identified with an e^\pm purity of $\approx 90\%$
- Corrections in τ track multiplicity have been shown
- Corrections mainly in decay modes with π_0
(where corrections are expected)

Veto with TRT electron PID Tool only

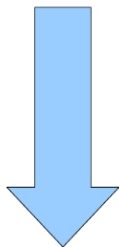


Steps of Photon Conversion Reconstruction

Tracks



VxCandidates



Photon Conversions

1. Step building VxCandidates *InDetConversionFinder*

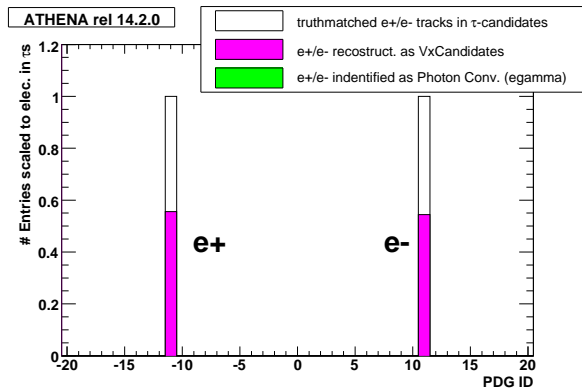
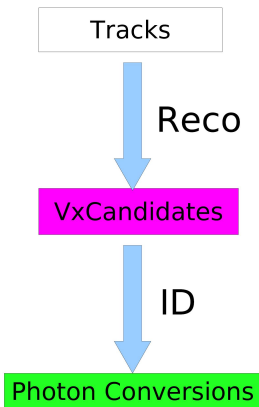
- builds pos/neg trk pairs
- refits secondary vertices
- constraints and cuts like $p_{T,min}$ have to be opened for τ -environment
- This step will be optimized by M. Donega et al. at University of Pennsylvania

2. Step identify e^+/e^- of photon conversion *EMConversionBuilder*

- extrapolates trks to ECal surface and identify e^+/e^- via CaloCluster informations
- makes add. cuts like $\text{trk}_{\text{min}p_T} > 2 \text{ GeV}$ (which is too tight for low p_T conversions from τ)
- A τ specific photon conv. ID has to be implemented (this is what we will present now)

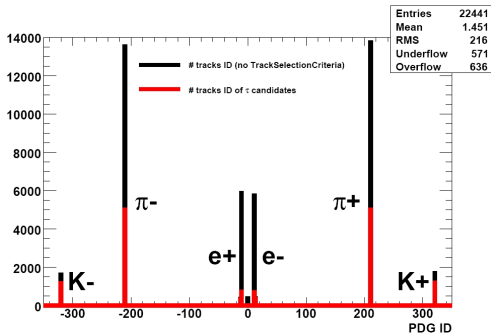
Problems Reconstructing Conversions in τ tracks

- Default Photon Conversion Reconstruction and Identification in τ environment



- After ID no Photon Conversion is found within the τ tracks
 - ▶ τ specific Conversion ID is needed!

Track ID in τ -Candidates with rel. 13.0.40



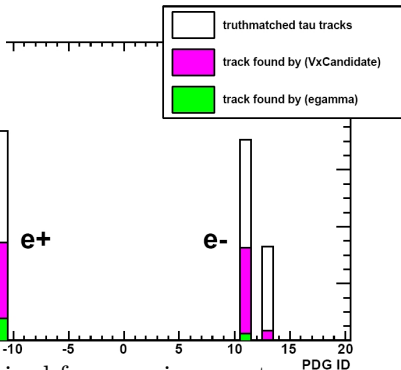
- truthmatched track ID of τ -jets

	τ -Cone	τ -Cand
$\pi^+\pi^-$	59.3 %	75.9 %
e^+e^-	25.3 %	6.4 %
K^+K^-	7.8 %	10.5 %
other	7.6 %	7.2 %

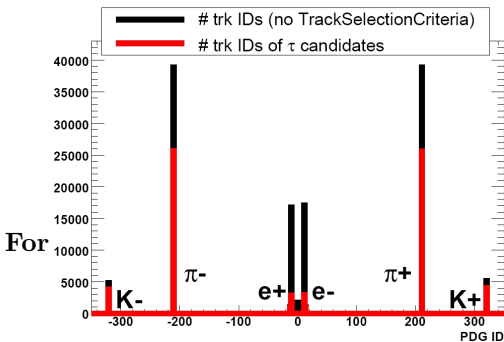
For

(upper plot in red):

- 46.4 % of e^+e^- in τ s have been found by *ConversionFinder*
- 7.1 % are identified as *egamma*-conversion
- *egamma*-conversion definition not optimized for τ -environment

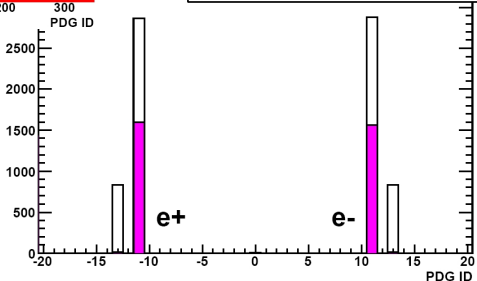
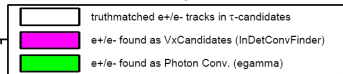


Track ID in τ -Candidates / τ -Cone



Track Selection Criteria

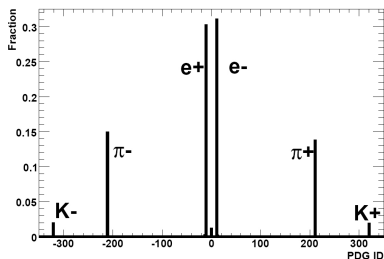
- $\Delta R < 0.3$
- $p_T > 1.0$ GeV
- $d_0 < 1.5$ mm
- $\frac{\chi^2}{ndf} < 3.5$
- # Si Hits (Pixel + SCT) ≥ 6
- # Pixel + B-Layer Hits ≥ 1



(upper plot in red):

- 55.0 % of e^+e^- in τ s have been found by *ConversionFinder*
- after changes in rel. 14.2.x no photon conversions can be identified in τ cone anymore (no green histogram)

VxCandidates have to be cleaned



- 30 % of the VxCand. trks are from π^\pm
- $\Rightarrow \pi^\pm$ will be rejected in the τ 's !
- is the e^\pm purity good enough, VxCand. can be used to suppress photon conv. in the τ -candidates

How to clean VxCandidates from pions determine electron probabilities with two methods:

- *TrackSummaryTool* calculates via inner detector variables (e.g. TRT high threshold hits) an electron probability (**eProb**)
- additionally we decided to define a electron probability calculated out of ECal informations
 - 1 extrapolate trk to ECal surface (similar to *EMConversionBuilder*)
 - 2 via TMVA a BDT value out of ECal infos has been calculated (compare track momentum with ECal cluster)

combine the 2 probabilities to cut on

Identification with the TRT PID tool

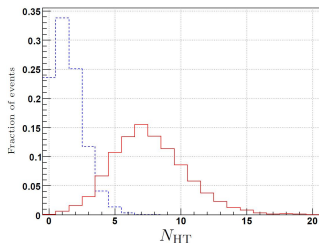
- probability based (eProb)
- applied informations:
 - ▶ High Threshold Hits (HT)
 - ▶ Time-Over-Threshold info (ToT)
- probability evaluated from likelihood (each var.):

$$p_{HT}^e = \frac{\prod_i p_{HT,i}^e}{\sum_{j=e,\pi} \prod_i p_{HT,i}^j}$$

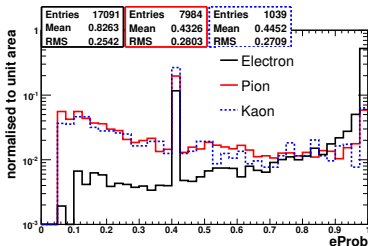
- combined:

$$eProb = \frac{p_{HT}^e p_{ToT}^e}{\sum_{j=e,\pi} p_{HT}^j p_{ToT}^j}$$

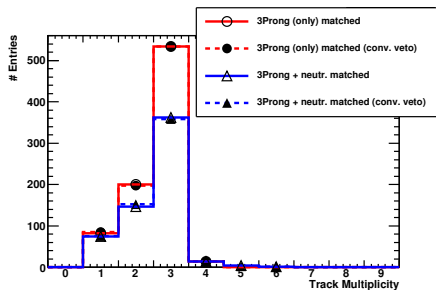
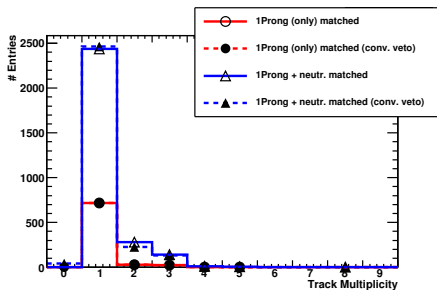
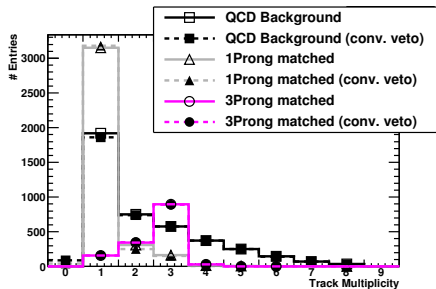
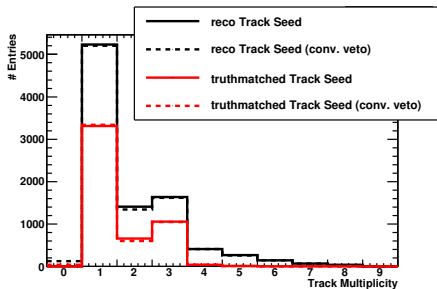
HT hits from e (red) and π (dashed blue)



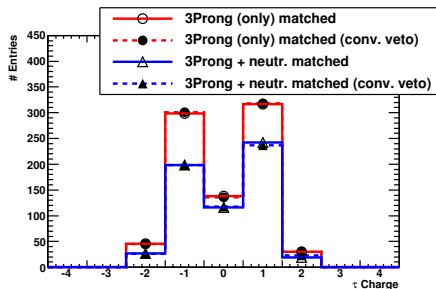
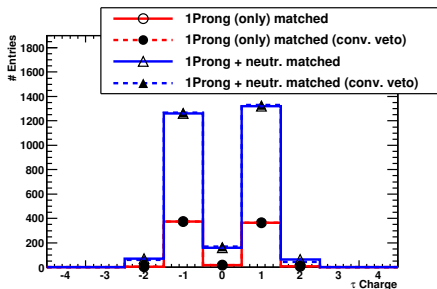
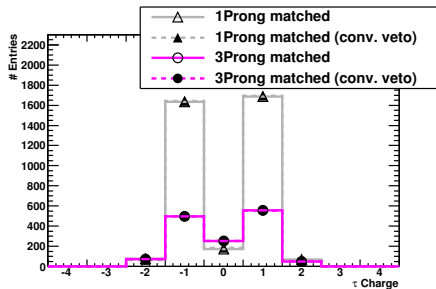
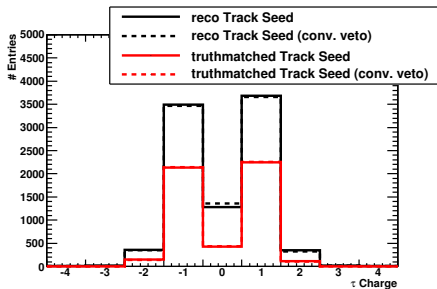
eProb of TRT PID Tool in VxCandidates



Track Seed: Track Multiplicity Preliminary!! (4500 Ev. only!)

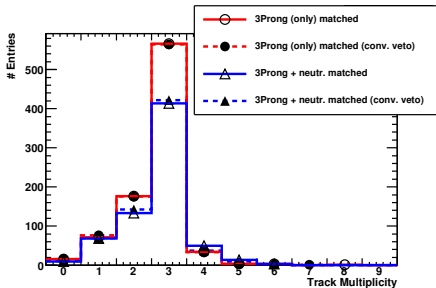
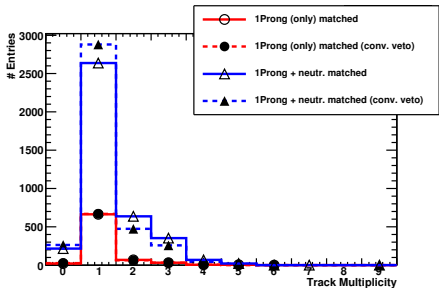
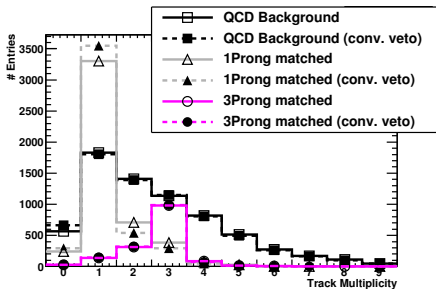
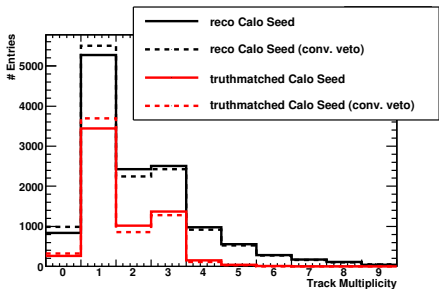


Track Seed: τ Charge Preliminary!! (4500 Ev. only!)



Calo Seed: Track Multiplicity

Preliminary!! (4500 Ev. only!)



Calo Seed: τ Charge Preliminary!! (4500 Ev. only!)

