Track classification in hadronic tau decay and photon conversion tracks finding for H->tautau channel

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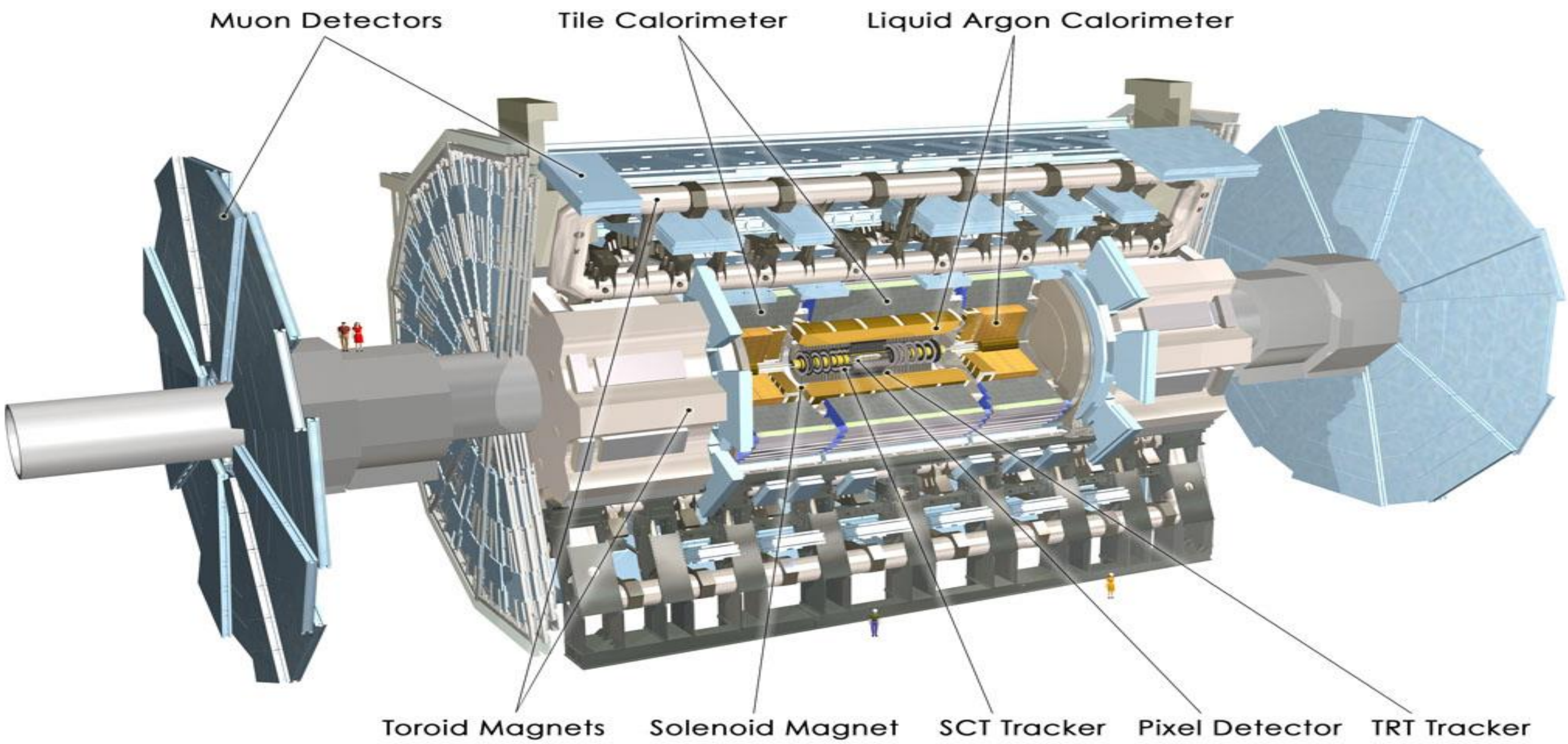
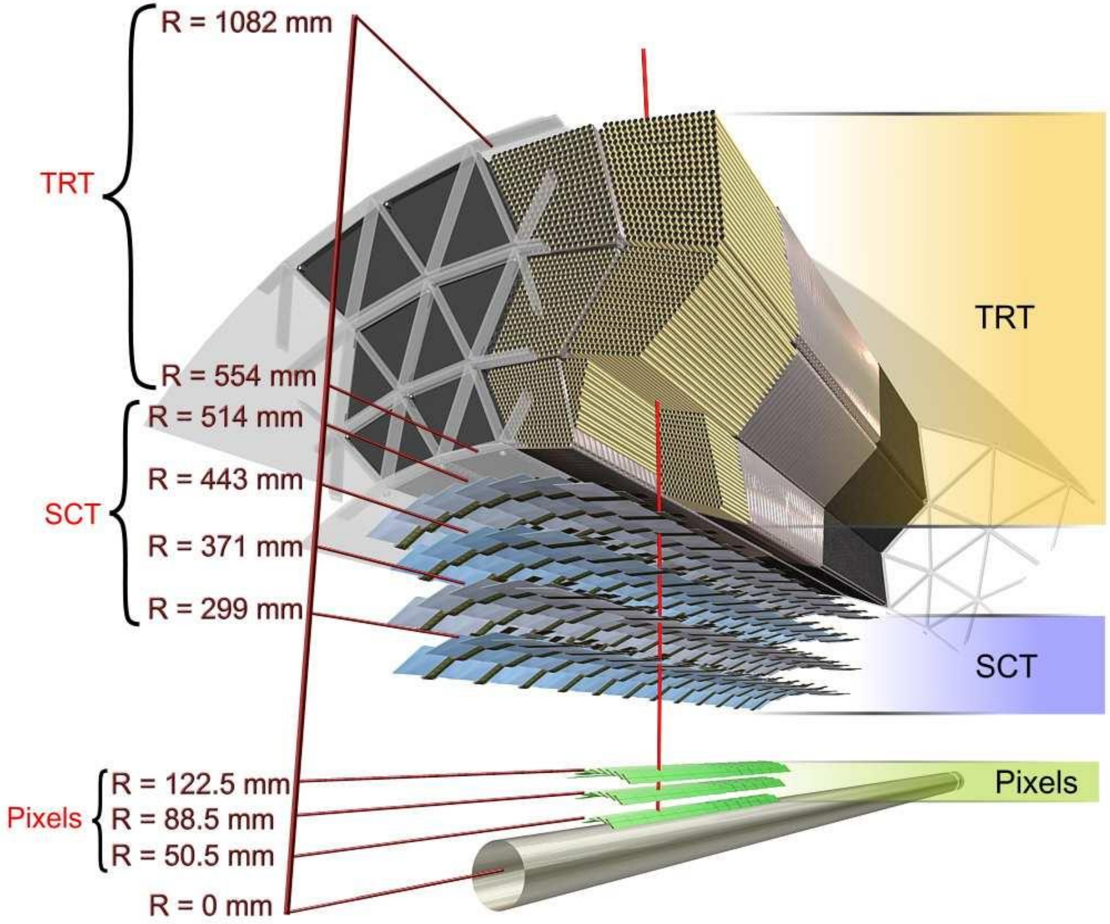
  - ➢ Performance on 13 TeV MC
- Summary

ATLAS detector



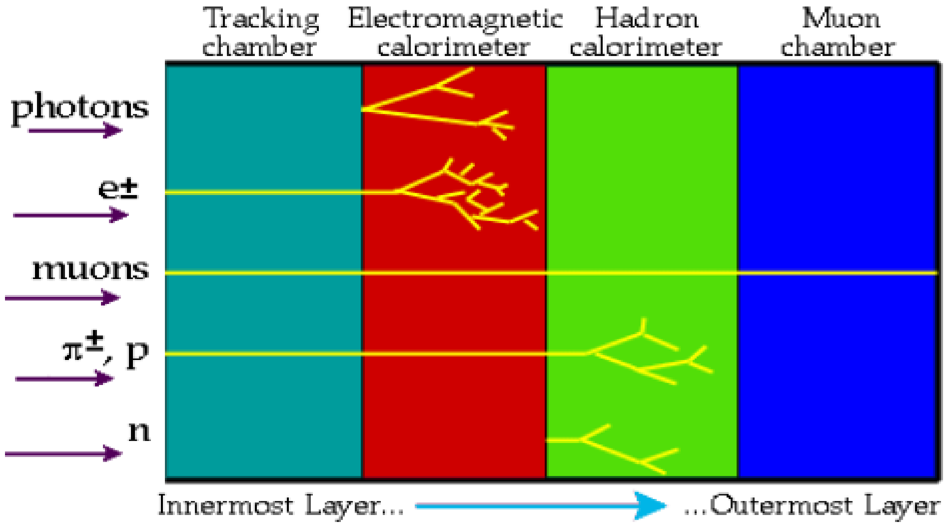
- Overall length = 42 m, diameter = 22 m, weight = 7000 tons
- Components were constructed in over 35 countries around the world

Inner detector

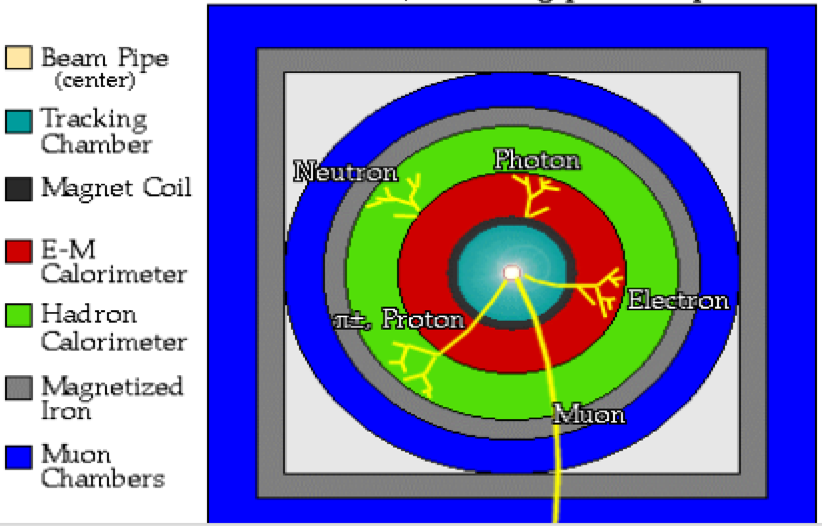


- r =1.15 m, length = 7 m
- 2T solenoidale magnetic field
- Pixel detector: 3 layers with high granulariry
- SCT (semiconductor tracker): 4 layers of silicon microstrip detectors
- TRT (Transition radiation tracker): 36 layers with xenon gas between

Particle detection principle

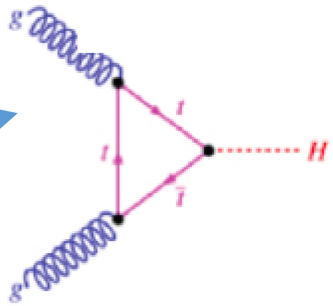


A detector cross-section, showing particle paths



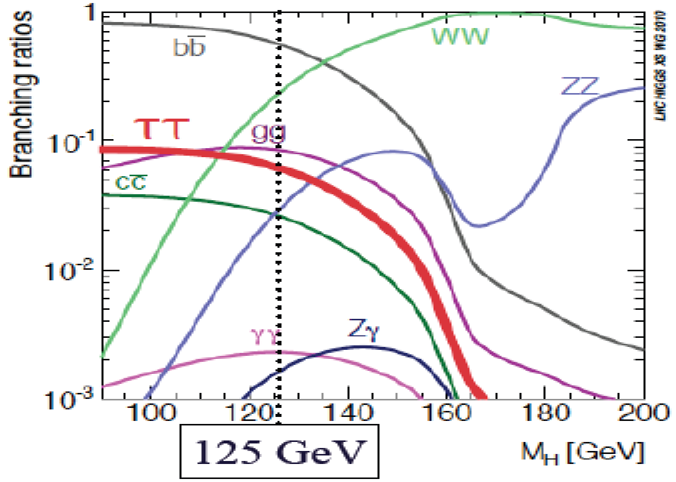
$H \rightarrow \tau^+\tau^-$ channel (1)

- Coupling of the new discovered particle to fermions:
  1. Quarks:
     - bbar: No evidence
     - ttbar: Indirect evidence from gg fusion through top loop
  2. Leptons:
     - μμbar: Low statistic
     - $H \rightarrow \tau\tau$ has one of the largest branching ratios for low mass Higgs



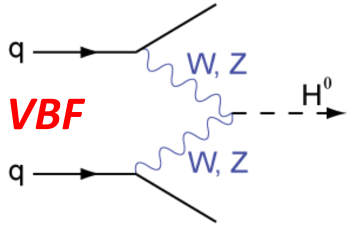
Branching ratios at 125 GeV:

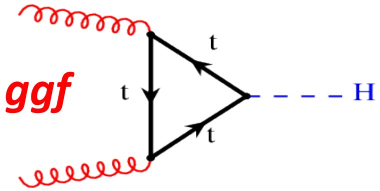
bb:	57.7%	ZZ:	2.6%
WW:	21.5%	γγ:	0.23%
ττ:	6.3%		



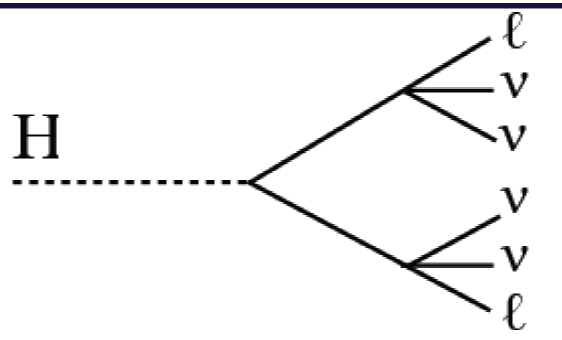
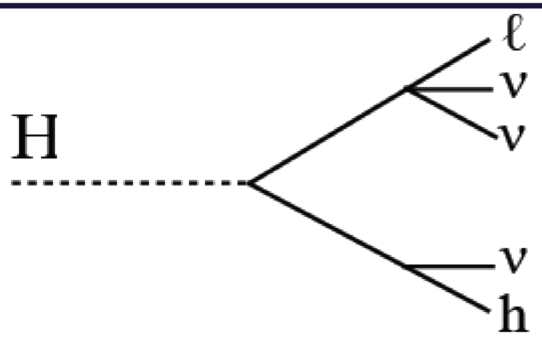
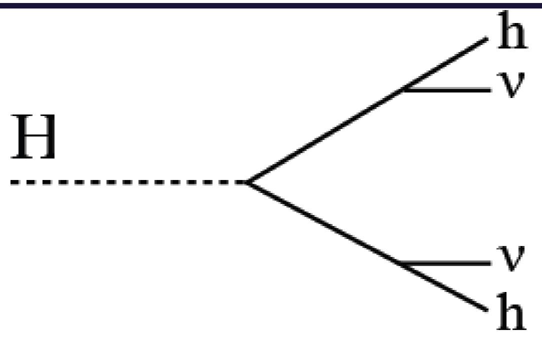
H→τ⁺τ⁻ channel (2)

- Search strategy:
  - Gluon (ggF) fusion is the dominant Higgs production mecanism
  - Background can be reduced by requiring presence of additional forward jets or high pT tau-tau system:
    - Vector boson fusion with 2 additional jets
    - Boosted Higgs category (p_T^H >100GeV)





- Decay modes

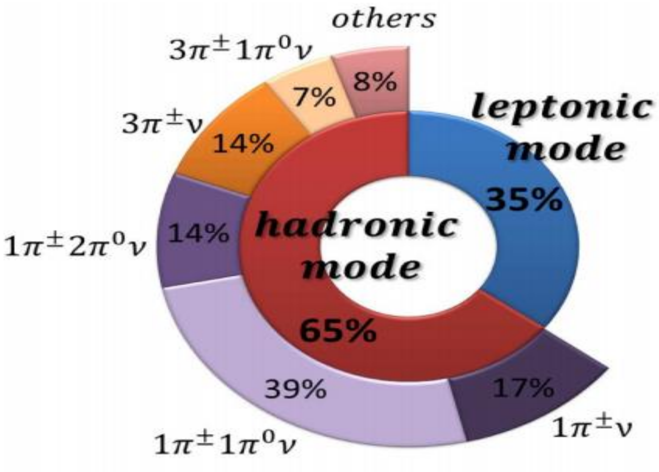
$H \rightarrow \tau_{lep}\,\tau_{lep} \rightarrow \ell\ell 4\nu$ (12.4%)	$H \rightarrow \tau_{lep}\,\tau_{had} \rightarrow \ell h 3\nu$ (45.6%)	$H \rightarrow \tau_{had}\tau_{had} \rightarrow hh2\nu$ (42.0%)
		

$H \to \tau^+\tau^-$ channel (3)

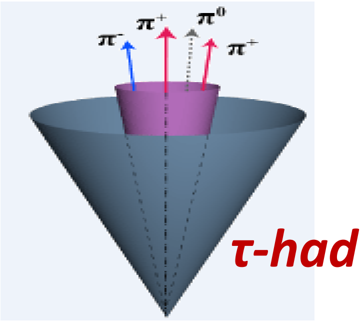
- Analysis channel at LAL: τ_{lep} - τ_{had}
- Background:
  - Z-> ττ : irreducible background (estimated using embedding technique)
  - Fakes: QCD, W+jet, Z+jet (Fake factor method)
  - Others: Z->ll, WW, ZZ, top ...

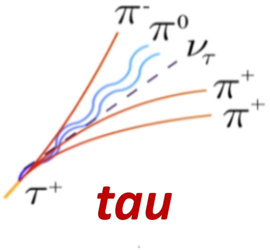
- Analysis method: Boosted decision tree (cut based analysis has been also done)
- Mass calculation method: “MMC” (missing mass calculator)
- Final significance results: 4.1σ (observed) , 3.2σ (expected)

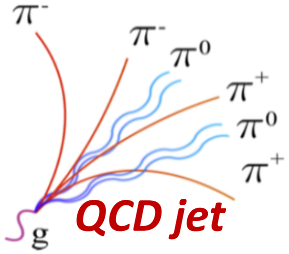
Hadronic tau decay



- Tau is the only massive lepton to decay hadronically
- 65 % of tau decay is hadronic
  - 1-prong (50%): 1 charged pions in the final state
  - 3-prong (15%): 3 charged pions in the final state
  - In ~41% of cases, at least 1 neutral pion
- Reconstruction of hadronic tau is a very important issue
  - Improve identification of hadronic tau against huge QCD background

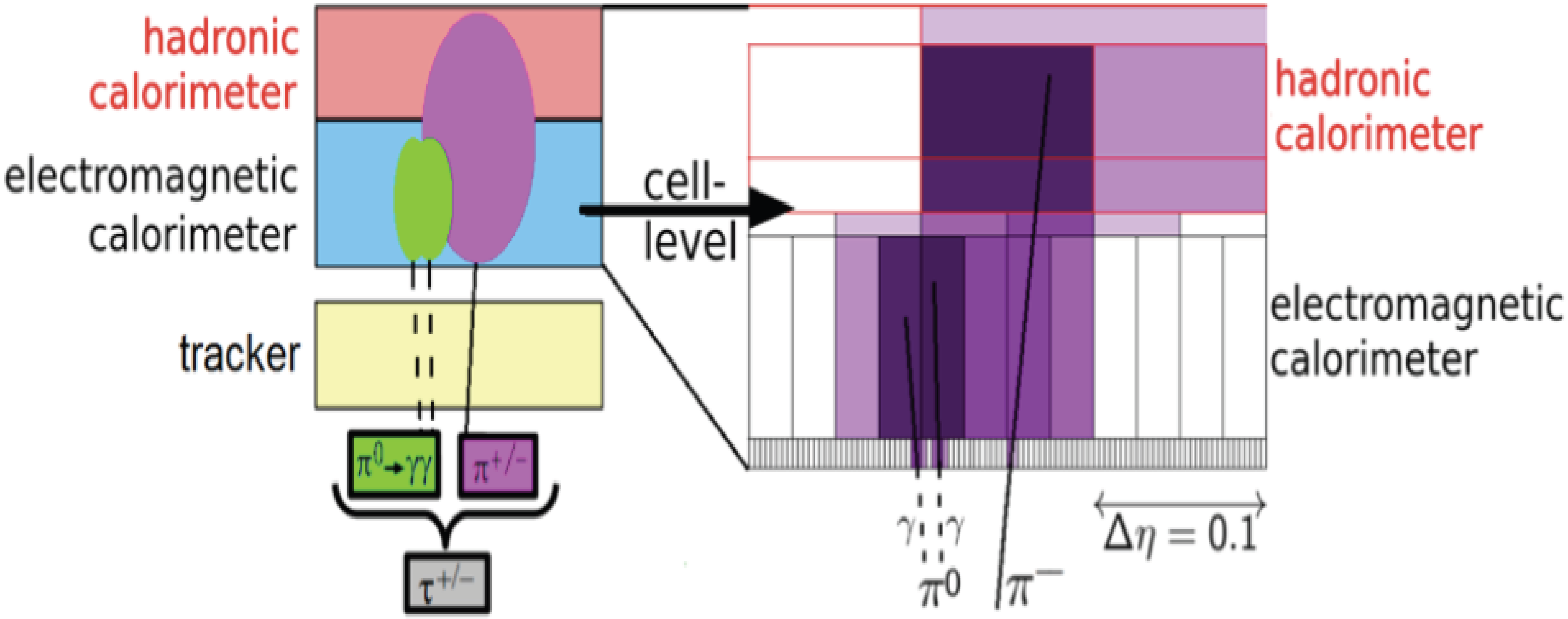






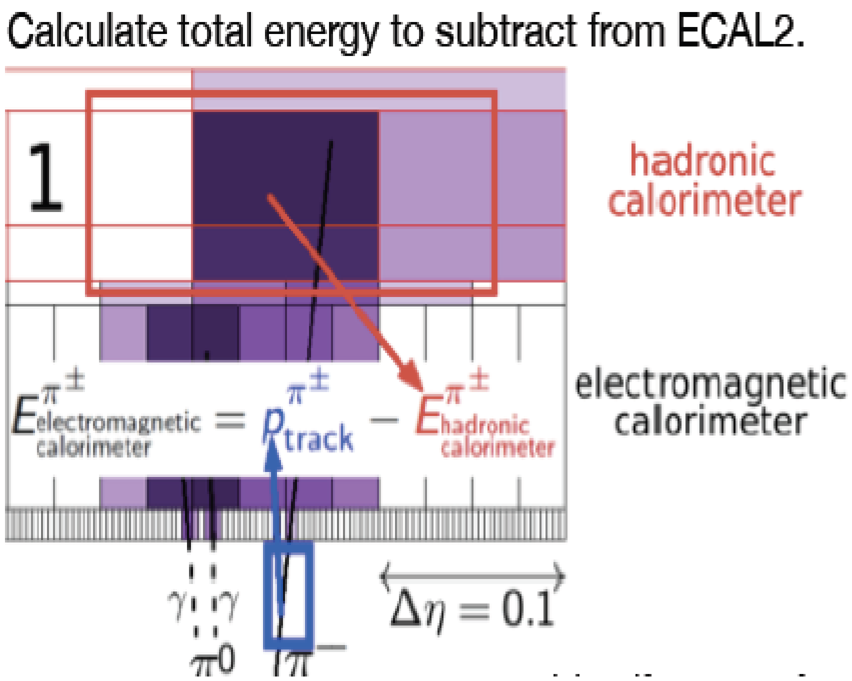
  - Improve the reconstruction of ττ mass invariant

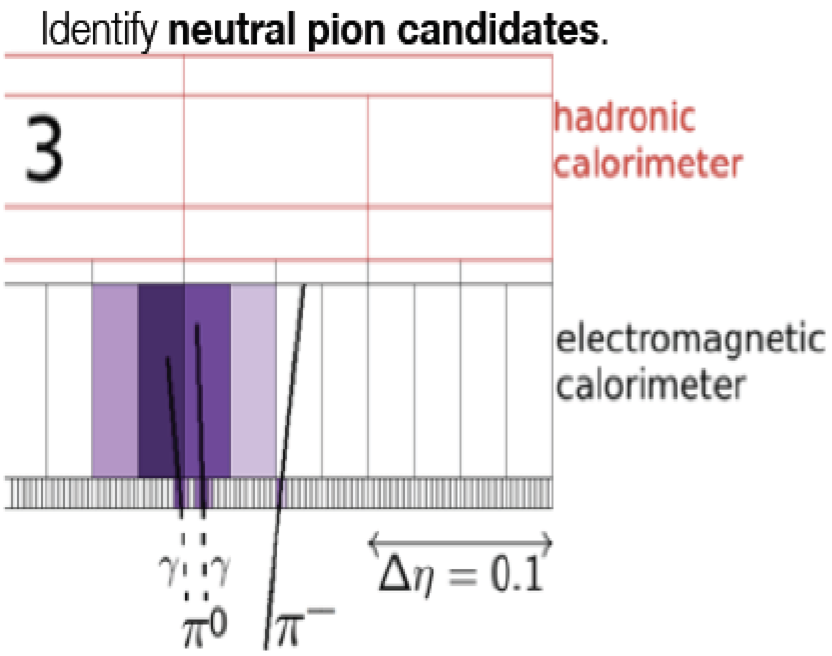
Tau signature



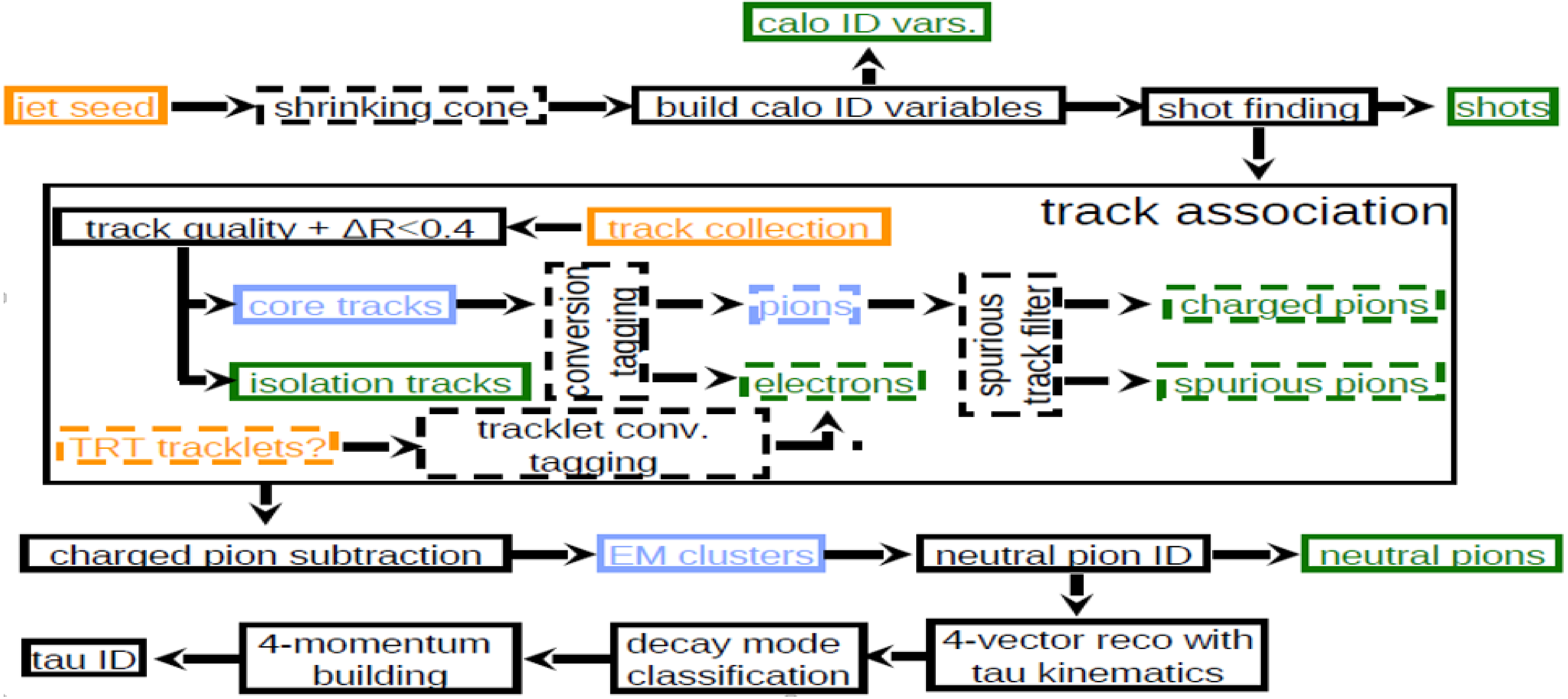
Reconstruction

- Reconstruct charged pion from tracker
- Reconstruct neutral pion from ECAL

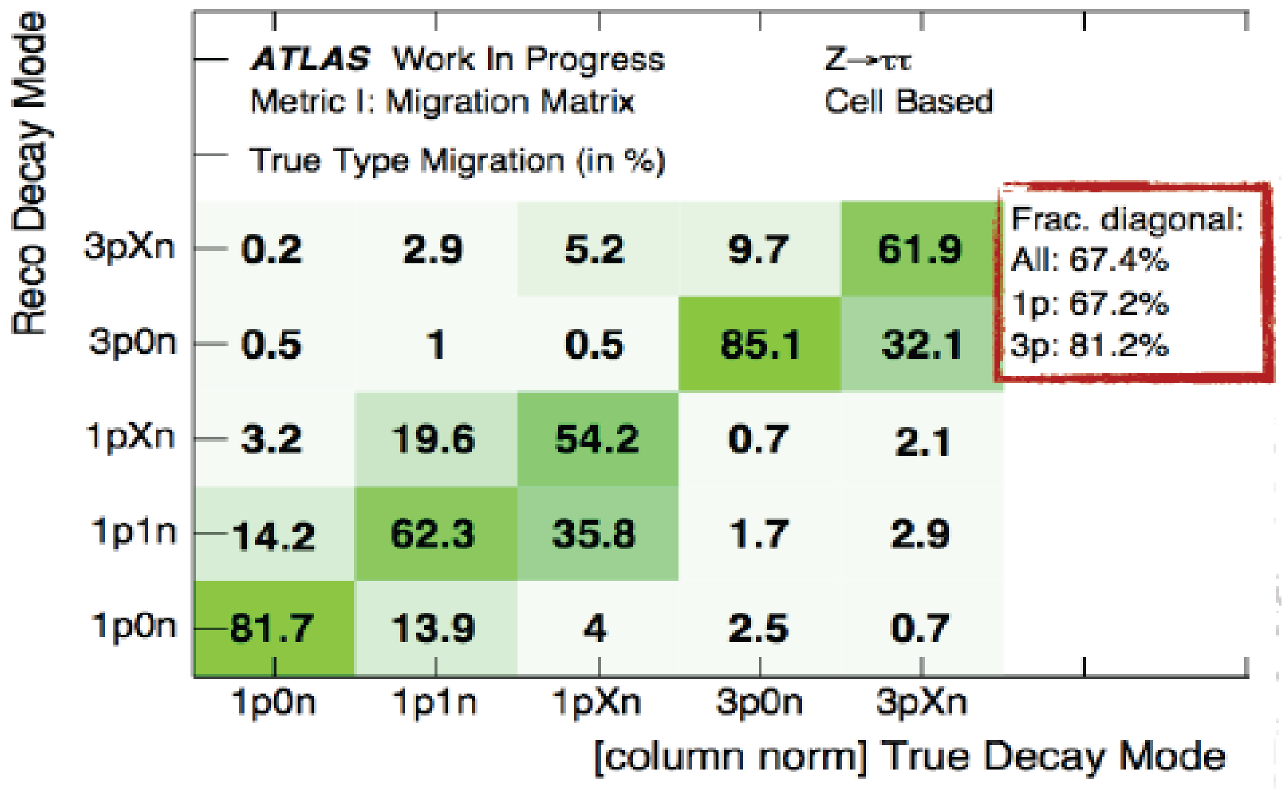




Tau substructure in TauCP group



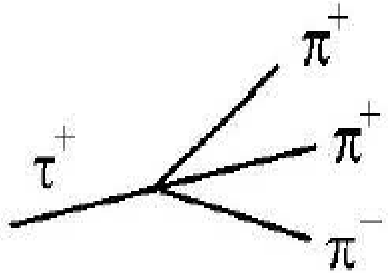
Current reconstruction efficiency



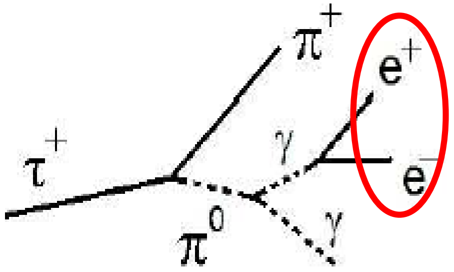
Conversion tagging analysis

Photon conversion in hadronic tau decay

- We have photons from π^0 decay
- Interactions photon-detector material → e^+- e^- pairs production (photon conversion)
- Additional charged tracks are reconstructed as pions from tau decay



3-prong decay

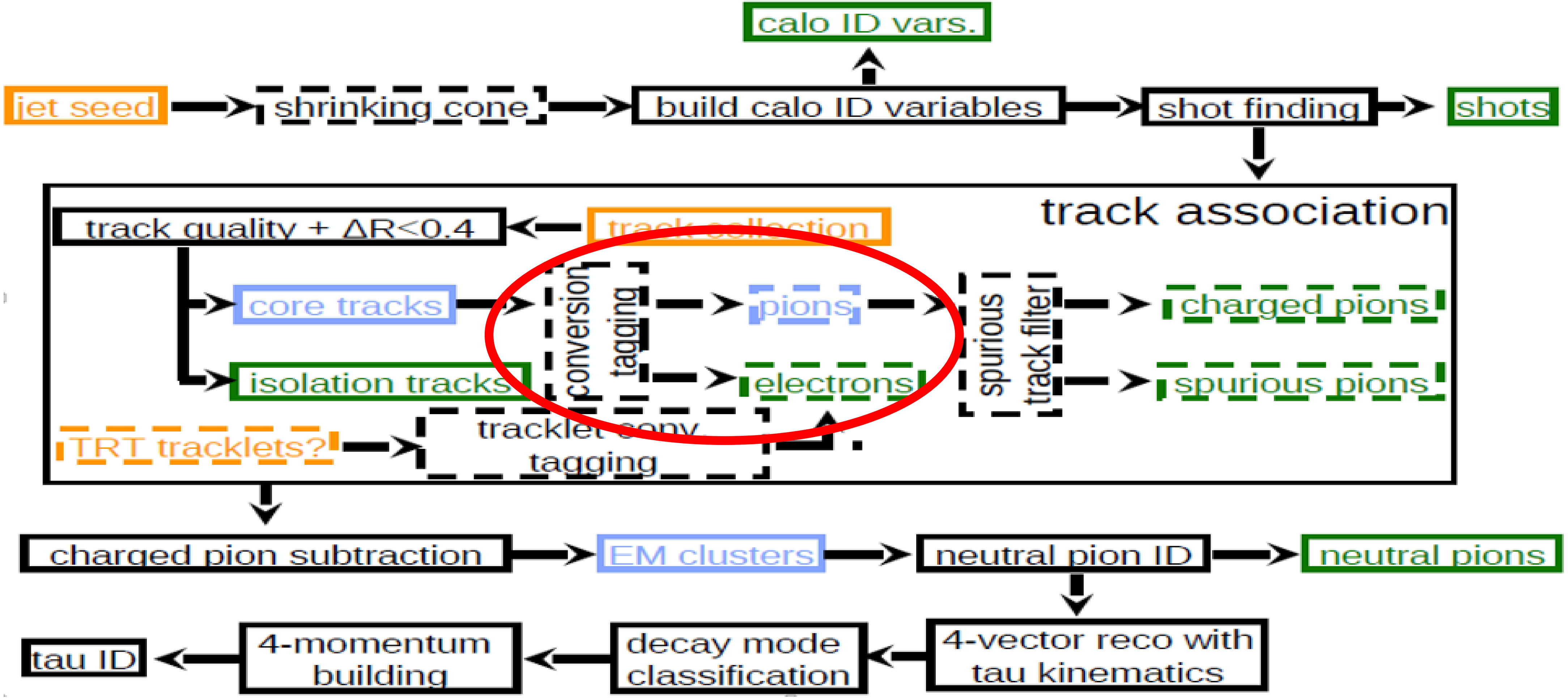


1-prong decay with photon conversion

In run 1: 1prong + 1 electron
=> 2 prong => rejected

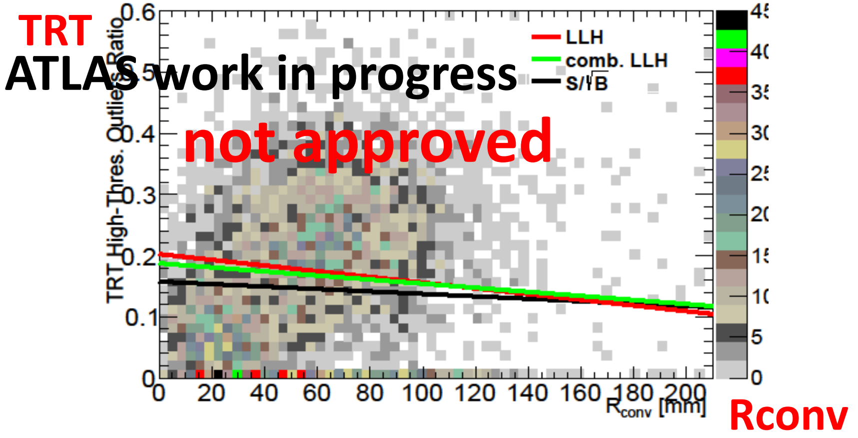
- Need photon conversion tagging to avoid misidentification e-π

Conversion tagging



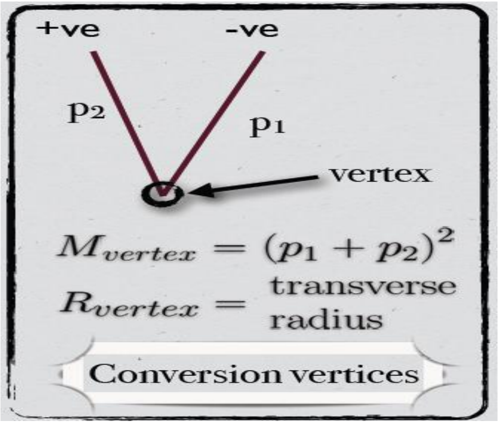
Conversion taggers in ATLAS software (Athena)

Conversion taggers in ATLAS software



- Test actualy 2 conversion taggers in Athena
  1. Single track conversion tagger S.T.T.
     (Initiated by “Dimitris varouchas”)
     - Tag conversions track by track
     - Use 3 variables in the inner detector:
       Conversion radius Rconv, nBLayer Hits, TRTHighThresholdRatio
     - Combine these variables in a 2 dimension plot and use a simple cut to select conversions

  2. Double track conversion tagger D.T.T.
     - Tag conversion vertex (double track)
     - Enumerate each pair of opposite charged tracks pairs
     - Fit a conversion vertex for each pair using tuned parameters



Performance definitions

- The 2 algorithms produce the same type of output (flag per each track)
- Same output => straightforward comparison between 2 taggers
- To examine the performance of each tagger, we define:

  - Efficiency of tagging a conversion track:

$$\text{Eff} = \frac{Tracks\ matched\ to\ true\ conversion\ flagged\ by\ the\ tagger}{Total\ tracks\ matched\ to\ true\ conversion}$$

  - Mis-identification rate:

$$\text{Fake} = \frac{Tracks\ matched\ to\ true\ pion\ (pileup\ or\ UE) flagged\ by\ the\ tagger}{Total\ tracks\ matched\ to\ true\ pions\ (pileup\ or\ UE)}$$

  ➢ Exclude tracks with |η|> 2 (TRT acceptance)

General performance

H(125GeV) -> ττ , 8TeV (mc)

	S.T.T.	D.T.T.
Efficiency (1&3 prong) (%)	65 ± 0.8	68 ± 0.8
Efficiency (1 prong) (%)	67 ± 0.85	71.5 ± 0.85
Efficiency (3 prong) (%)	50 ± 2.4	44.5 ± 2.4

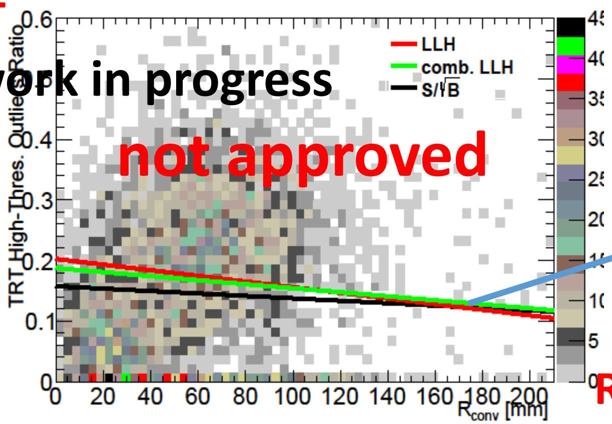
- The 2 taggers have almost same efficiency

Global fake rate	7.5 ± 0.1	0.5 ± 0.1
Fake rate (true pions) (%)	7 ± 0.1	0.36 ± 0.1
Fake rate (pileup) (%)	4 ± 0.5	0.6 ± 0.5
Fake rate (UE) (%)	13 ± 0.6	2.4 ± 0.6

- Fake rate is clearly higher for S.T.T.

High fake rate

- Worked on reducing fake rate (most critical)



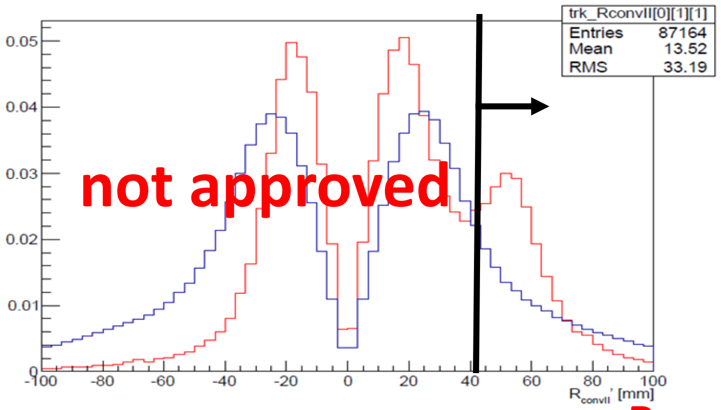
TLAS work in progress

not approved

Rconv

Almost horizontal
=> Rconv does not
play a big role here

=>



not approved

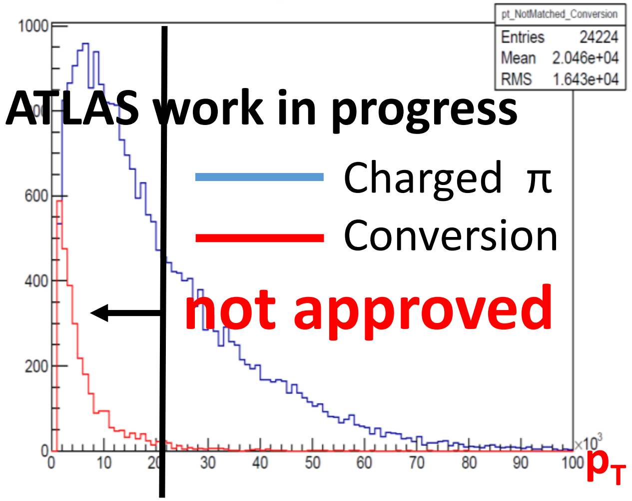
Rconv

Cut on signed
Rconv:
Rconv > 40 mm

	S.T.T.	S.T.T. (Rconv > 40mm)
Efficiency (1 & 3 prong) (%)	65	51
Efficiency (1prong) (%)	67	53
Efficiency (3 prong) (%)	50	40
Globale fake rate(%)	7.5	2
Fake rate (pions) (%)	7	2
Fake rate (PU) (%)	4	0.17
Fake rate (UE) (%)	13	2.3

- Reduce fake by factor 2 using |Rconv| and factor 4 using Rconv (with ~10% loss on efficiency)

Can we gain from p_T ?



➢ Almost all conversion tracks has p_T < 20 GeV

	S.T.T.			D.T.T.	
	Without p_T cut	With p_T cut	With Cut on p_T and Rconv	Without p_T cut	With p_T cut
Efficiency (1&3 prong) (%)	65	62	49	68	66
Efficiency (1 prong) (%)	67	64	50	71.5	69
Efficiency (1 prong) (%)	50	48	38	44.5	43
Global fake rate	7.5	4.7	1	0.5	0.4
Fake rate (true pions) (%)	7	4.2	1	0.36	0.3
Fake rate (pileup) (%)	4	4	0.17	0.6	0.6
Fake rate (UE) (%)	13	12	2.4	44.5	2.4

- p_T cut does not affect mush the performance the D.T.T.
- For S.T.T.: Very small effect on efficiency but reduce ~40% of fake
- Combining p_T and Rconv: (eff=65, fake=7.5) ⟶ (eff=49, fake=1)

Results for new ATLAS release (rel19)

- Since octobre 2014
- New framework and new analysis format (xAOD)

Procedure in the new release

- Conversion taggers migrated to the new release
- Migrate the physics performance test code to run on the new format
- The code has to produce the same results:
  - Conversion tagging efficiency
  - Fake rate

8TeV Z->ττ

Performance results for S.T.T.

- Default conversion tagger => run on standard DC14 samples (25Kevents)

mc14_8TeV.147808.PowhegPythia8_AU2CT10_Ztautau.merge.e2372_s1933_s1911_r5591_r5625

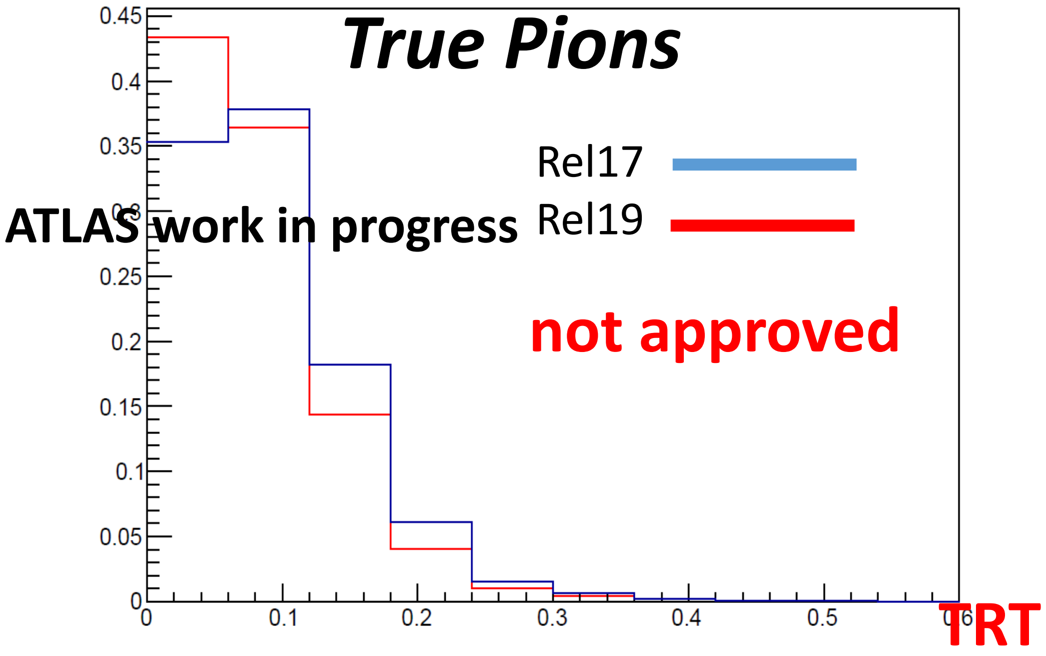
Single track tagger – release 19	
Conversion efficiency (%)	66 ± 1.4
Fake rate (pions) (%)	5 ± 0.2
Fake rate (UE) (%)	4 ± 0.8
Fake rate (PU) (%)	0%(No pileup in the sample)

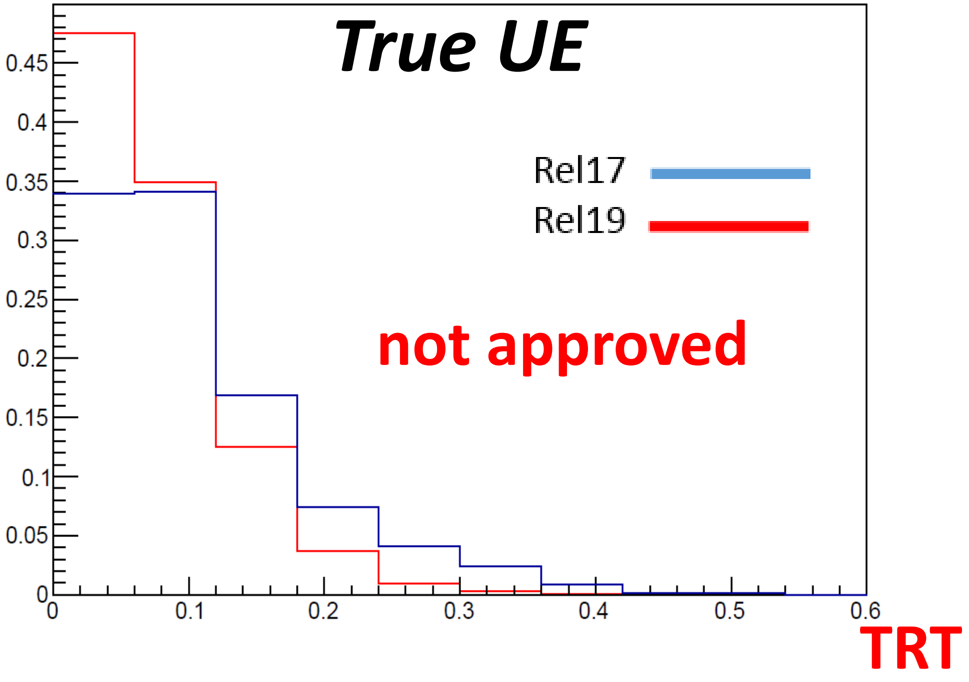
Single track tagger – release 17	
Conversion efficiency (%)	65 ± 0.8
Fake rate (pions (%)	7 ± 0.1
Fake rate (UE) (%)	13 ± 0.6
Fake rate (PU) (%)	4 ± 0.5

➢ Efficiency results are comparable between release 19 (Z->tautau) and release 17 (H->tautau)

Why lower fake rate ?

- Plot the variables for the S.T.T. to understand this origin of this difference between the 2 release
  - Rconv and p_T show same distributions
  - TRT of tracks show a slight decrease in release 19





- Lower TRT => less tracks tagged as conversion => lower fake rate

Results for D.T.T. in rel 19

D.T.T. In release 19	
Conversion efficiency (%)	65 ± 5
Fake rate (%)	5 ± 1

D.T.T. In release 17	
Conversion efficiency (%)	68 ±0.8
Fake rate (%)	0.36 ±0.1

- Efficiency is comparable between the 2 release
- the fake is mush higher in release 19
- On going work to understand this behaviour

Results on 13 TeV dataset

Performance for 13 TeV

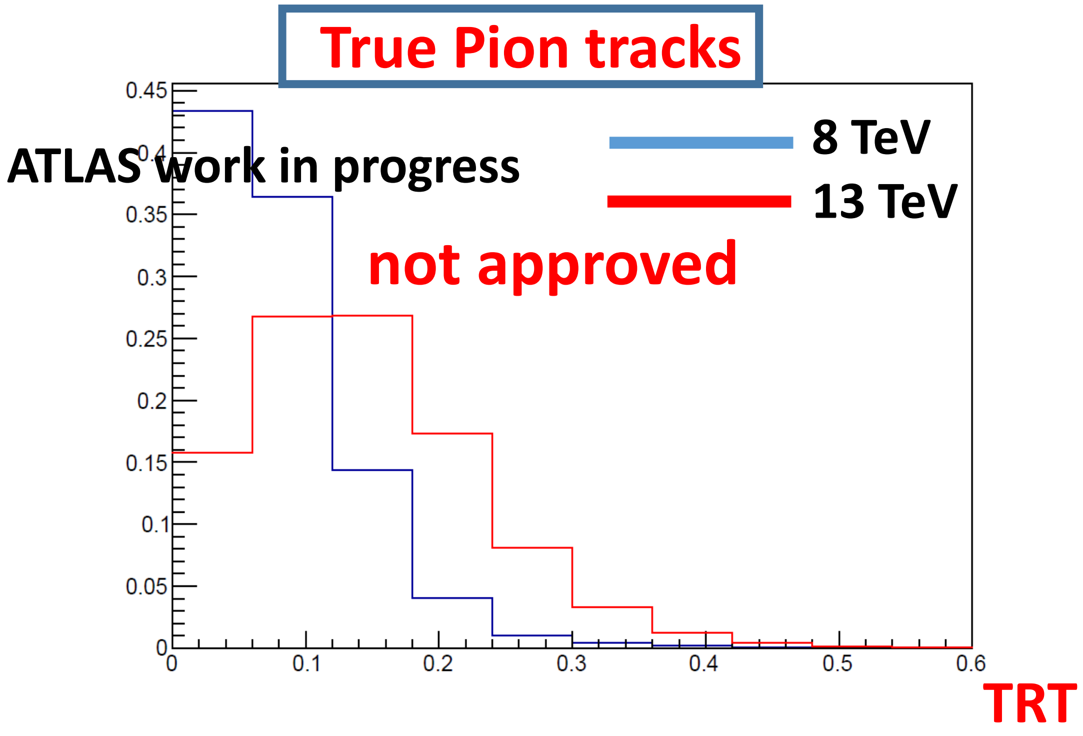
- Start from 13TeV RDO input files to produce the xAOD
  mc14_13TeV.147408.PowhegPythia8_AZNLO_Ztautau.recon.RDO.e3059_s1982_s2008_r5787
- Activate the S.T.T. in the reconstruction software
- Run the performance test code on these xAOD

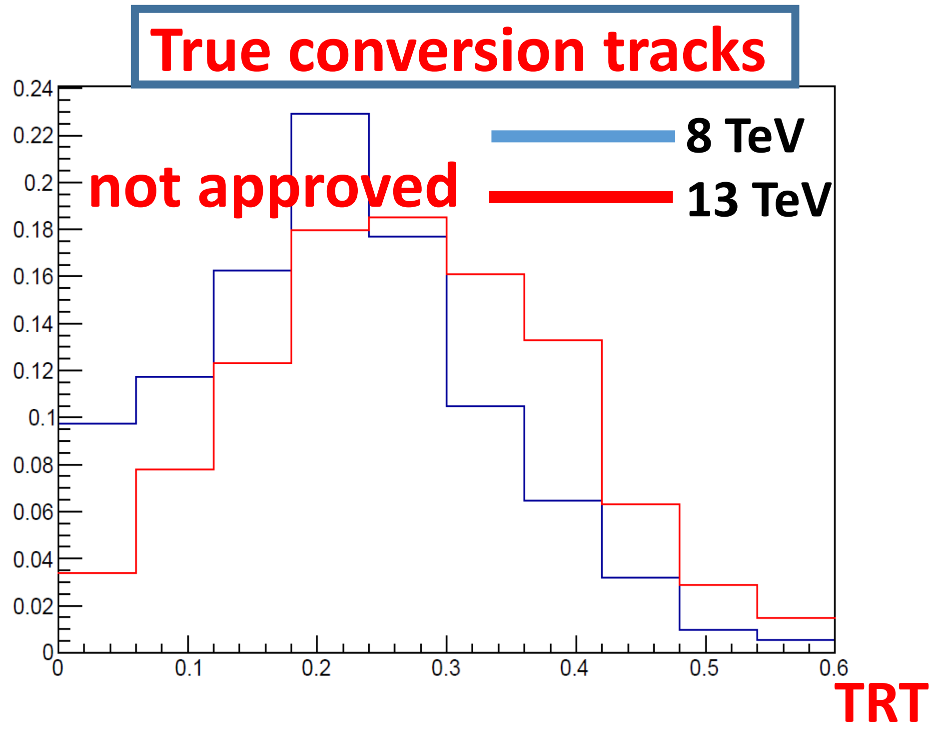
S.T.T. performance (13 TeV)	
Conversion efficiency (%)	81 ± 4.5
Fake rate (%)	39 ± 2

- Both efficiency and fake rate are very mush higher than for 8TeV case

Why different performance?

- Look again on TRT variable and compare between 8 TeV and 13 TeV





- TRT is mush higher in 13 TeV case => higher efficiency and fake rate

Performance improvement (13 TeV)

- Use the cuts on pt and Rconv as shown before to reduce the high fake rate
  - ➢ Rconv > 40 mm
  - ➢ pT < 20 GeV

S.T.T. performance (13 TeV)			S.T.T. Performance (8 TeV)
	Without cuts	With cuts	
Conversion efficiency (%)	81 ± 4.5	60 ± 4.5	65 ± 5
Fake rate (%)	39 ± 2	5 ± 2	5 ± 1

- Very good reduction of fake rate with loss on the efficiency
  - ➢ Comparable to 8 TeV performances

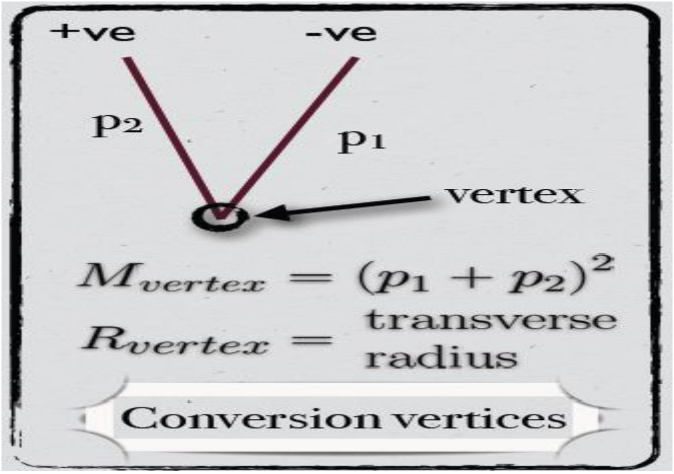
conclusion

- Have to finalize the choice of conversion tagger to be used in the tau substructure code
- Stay involved in conversion studies inside TauCP group
  - ➢ Test and optimize the physics performance of taggers for 13 TeV xAOD files
- From now on:
  - ➢ Strong involvement in the signal extraction in the H->ττ in lep-had decay mode for run 2
    - ➢ New detector, new LHC conditions, new software, new analysis framework
  - ➢ Extra potential studies
    - ➢ Optimization of ττ invariant mass

Backup

Double track tagger

- Photon Conversion Finder
  https://svnweb.cern.ch/trac/atlasoff/browser/Reconstruction/tauRec/branches/tauRec-04-03-12 branch/src/PhotonConversionVertex
  - ➢ From tracks of a reconstructed tau, enumerate every combination of opposite charged track pairs
  - ➢ fit a conversion vertex for each pair using some parameters:
    - Invariant mass of the reconstructed vertex
    - Conversion radius
    - Track pair Δη, Track pair ΔΦ, Track pair ΔR
  - ➢ These parameters are tuned for conversion finding vertices using truth informations



- Tau Conversion Finder

  https://svnweb.cern.ch/trac/atlasoff/browser/Reconstruction/tauRec/branches/tauRec-04-03-12-branch/src/TauConversionFinder

  - ➢ compares fitted VxCandidate tracks with tau tracks
  - ➢ if a track is found which belongs to both subsets

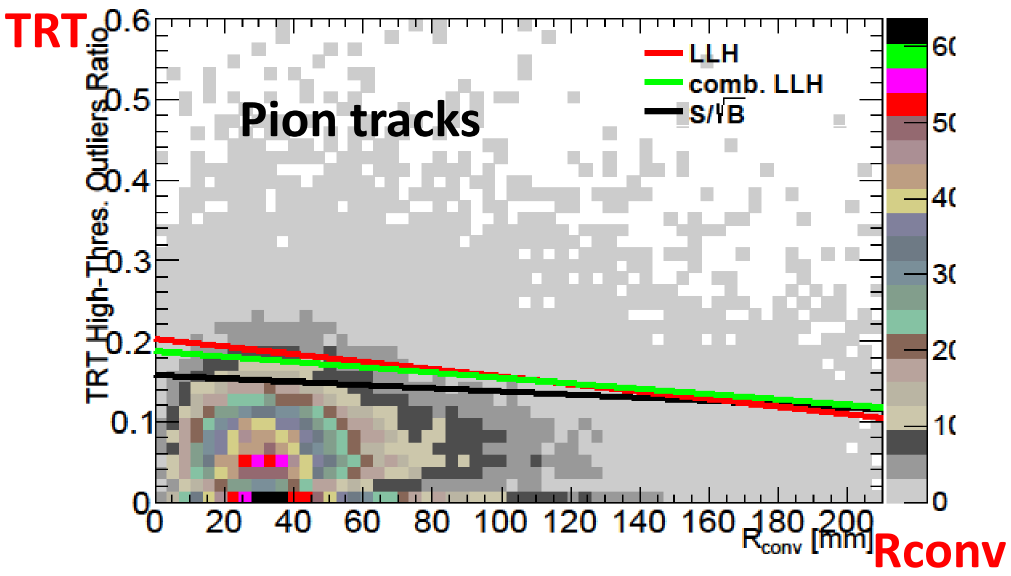
    → track is tagged as conversion track

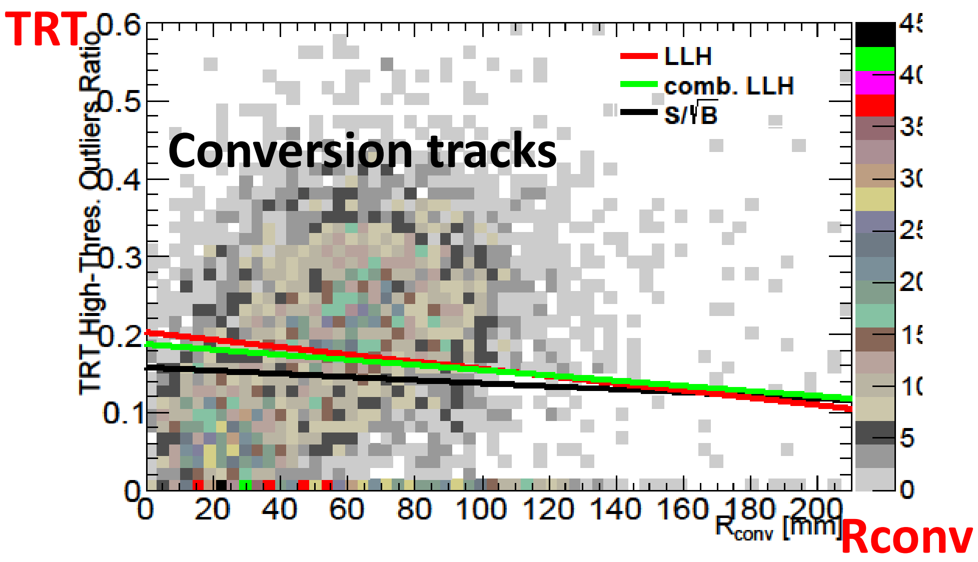
Outline

- In second year PhD in ATLAS group at LAL
- Member of Higgs→ττ group at LAL
- Qualification task just finished
  - ➢ Involved in the tau lepton Combined Performance group
  - ➢ Participate to the improvement of hadronic tau decay reconstruction (photon conversion tracks finding)

Single track tagger(2)

- Combine these variable to extract a simple cut discriminating between matched and unmatched tracks



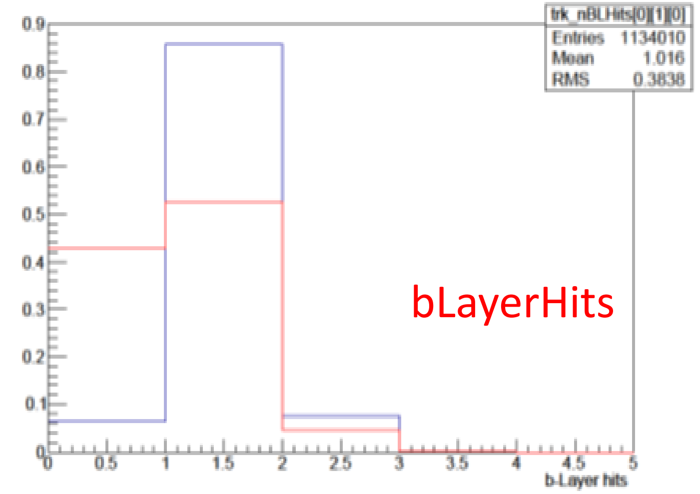


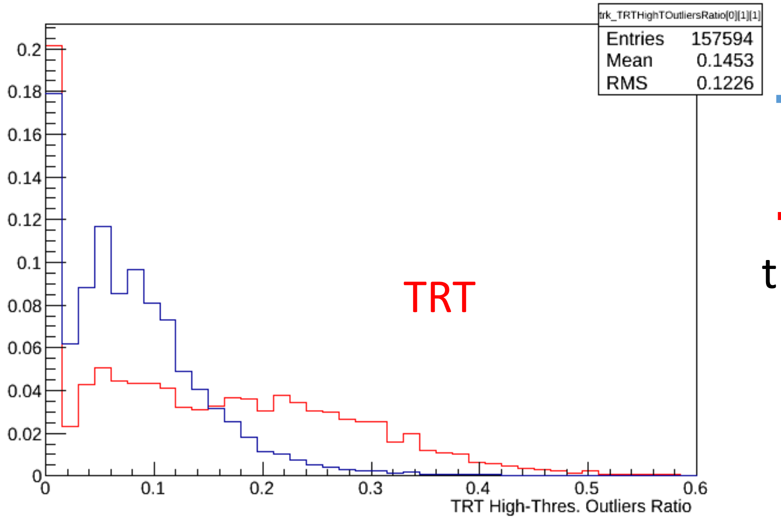
  - ➢ Apply a triangle cut discrminating between matched and unmatched tracks

- Initial goal: correct 2 prong bin to 1 prong (about 50% of recovery from 2p to 1 p in true 1prong bin)
- Now: it is a single track conversion tagger
- It has been implemented and validated in Athena

Single track tagger(1)

- Use 3 variables from the inner detector: nBlayer Hits, Rconv and TRT High threshold ratio

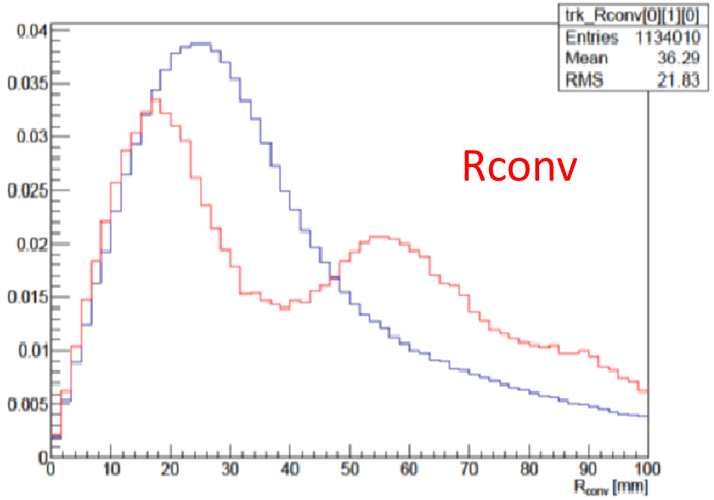




RecNprong=2

Matched to charged pion track

Not matched to Charged pion track (conversion candidate)



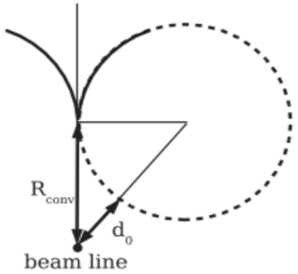


FIG. 4. Schematic illustration of the distance R_{conv} from the beam line to the point where the conversion occurred. Here, d_0 is the impact parameter.

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$$R_{conv}^{approx.} = \sqrt{\frac{d_0 \cdot p_T}{0{,}15B}}$$

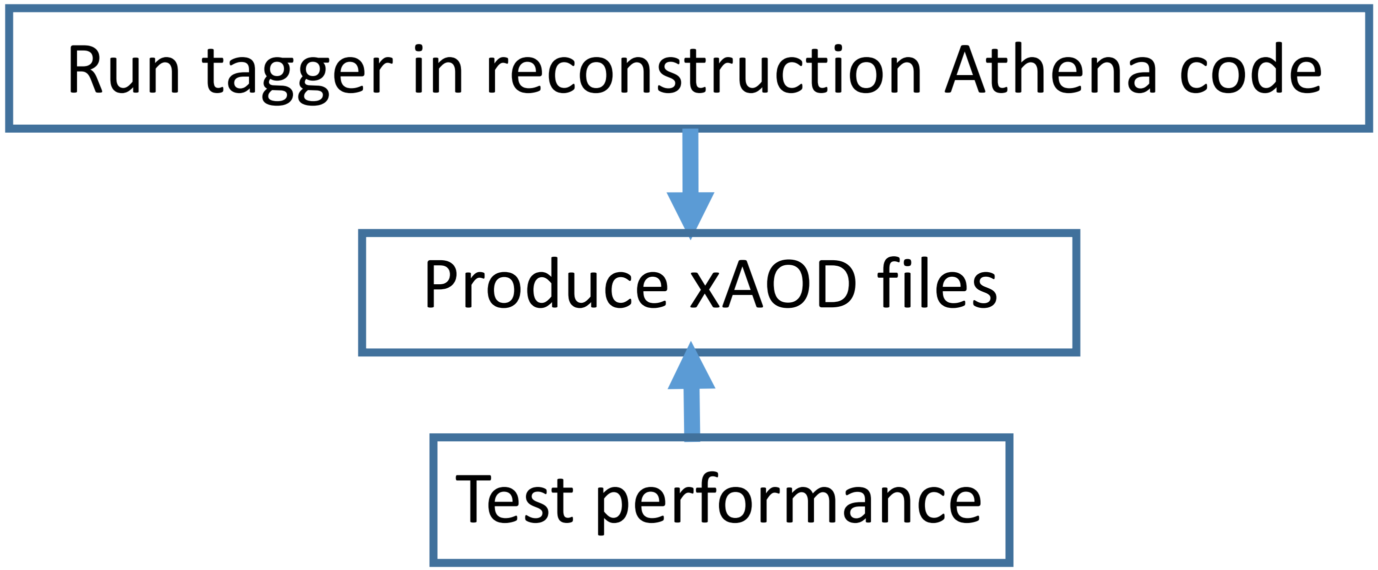
Magnetic field in tracker

Framework in release 17 (2014)

- The 2 algorithms produce the same type of output
  - Flag per each track deciding if it is conversion or not
- The algorithms run on ESD input files
- Implementation:
  - The conversion information is dumped to the finale D3PD
  - Produce 2 D3PD's: activate each time one of the conversion taggers
  - Just change a flag when producing the D3PD to choose one of the 2 taggers
- Examine the performance of each tagger
  - New tool is developed to do truth track matching
  - It give the true origin of each track: charged pion, conversion, pileup or UE

Procedure in release 19

- Conversion taggers are migrated to new Athena software in release 19
- Performances tested again in the new release
- Test strategy:



=> ***produce conversion efficiency and mis-identification rate***

Test performance code migration

- Physics performance test code has been migrated to run on xAOD files
- The code produce the same performance quantities as release17:
  - ➢ Conversion tagging efficiency
  - ➢ Fake rate

- Truth track matching is used also to provide the true origin of each track
- A conversion vector for each tau in the xAOD tau variables
  - ➢ Contain tau tracks tagged as conversion by the tagger in Athena
  - ➢ Use this vector to get the conversion descision for each tau track

CPU time performance (1)

- Time performance study done for the taggers

1 k Events	Total running time (min)	Tau Core Builder Time (s)	Average by event (s)	How many calls to the tool
D.T.T.	80.8	1830	1.83 ± 3.56	553655
S.T.T.	55.4	417	0.41 ± 0.26	13753

- D.T.T. Show higher CPU time (~ factor 4)
  - ➢ Because the algorithm take all combination of opposite charge tracks

CPU time performance (2)

- D.T.T. Run over all tau jet without any selection
- Adding tau selection criteria show a good reduction of cpu time
  - ➢ Only ~1% loss on conversion tagging efficiency

1 K events	Total running time (s)	Tau Core Builder Time (s)	Average time by event (s)	How mush time call the tool
D.T.T.	80.8	1830	1.83 ± 3.56	5536655
D.T.T. (With tau selection)	61.3	672	0.67 ± 0.5	107600
D.T.T. (with tau selec. & maxDR=0.4)	59.6	562	0.56 ± 0.42	66497