Track classification in hadronic tau decay and analysis preparation of the Standard Model H->tau tau signal extraction with LHC-Run2 in ATLAS collaboration

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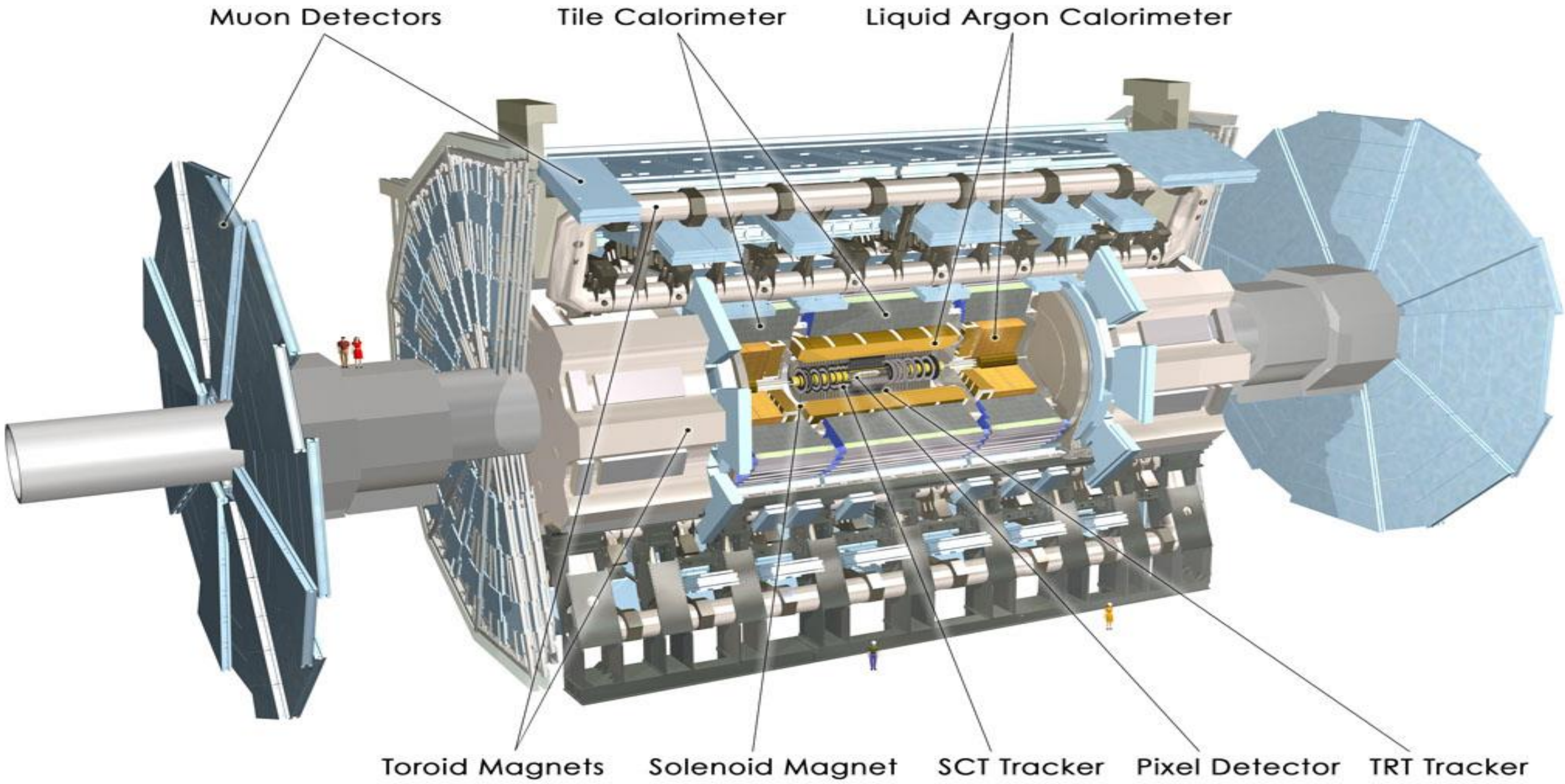
Table of contents

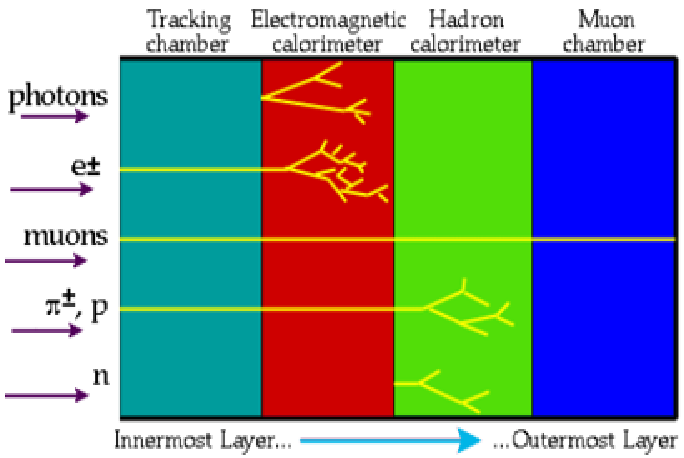
General introduction

- In second year PhD in ATLAS group at LAL
- Member of Higgs->ττ group
- Research domain of my PhD:
  - Participated to the improvement of reconstruction of hadronic tau decay in ATLAS
    - First PhD year
  - Currently working on the preparation of Higgs physics analysis in the di-lepton tau decay channel
  - Analysis will be based on data from the new Run of LHC (Run2)

ATLAS detector



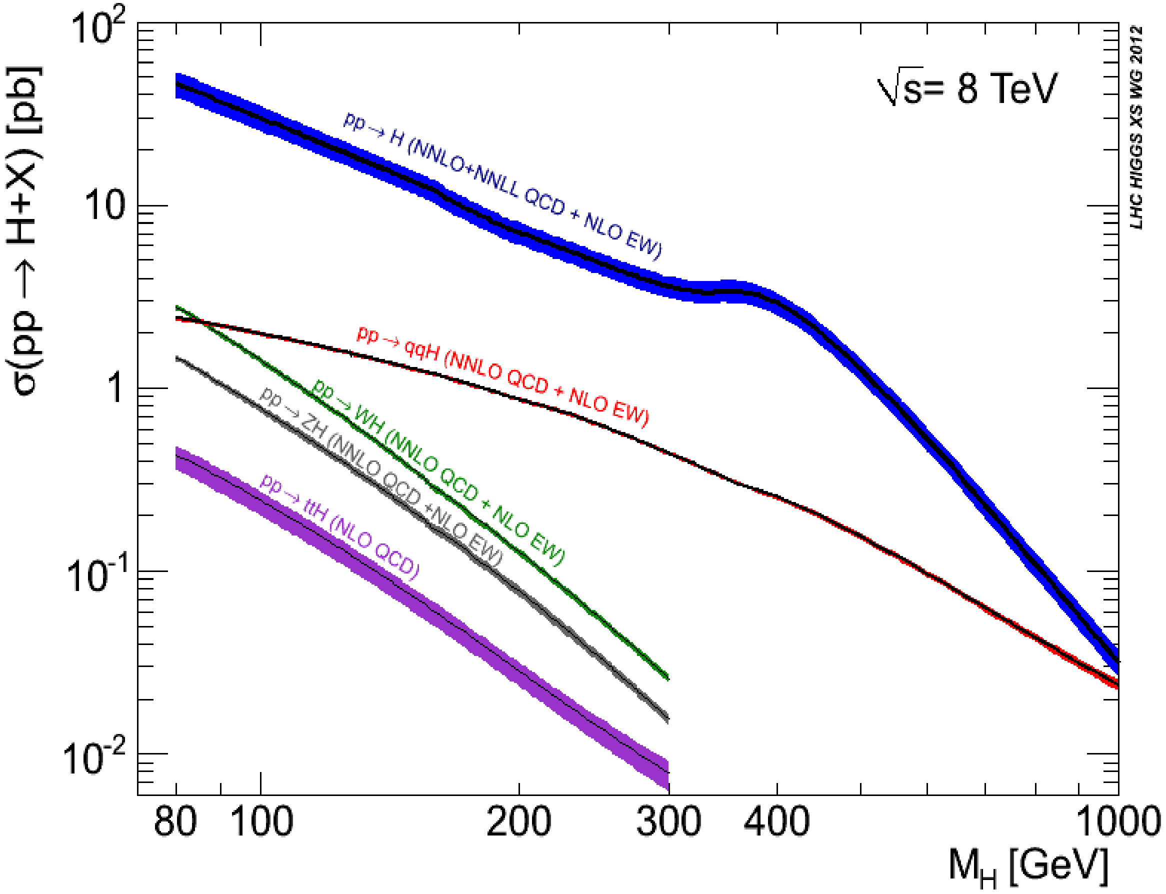
Particle detection principle



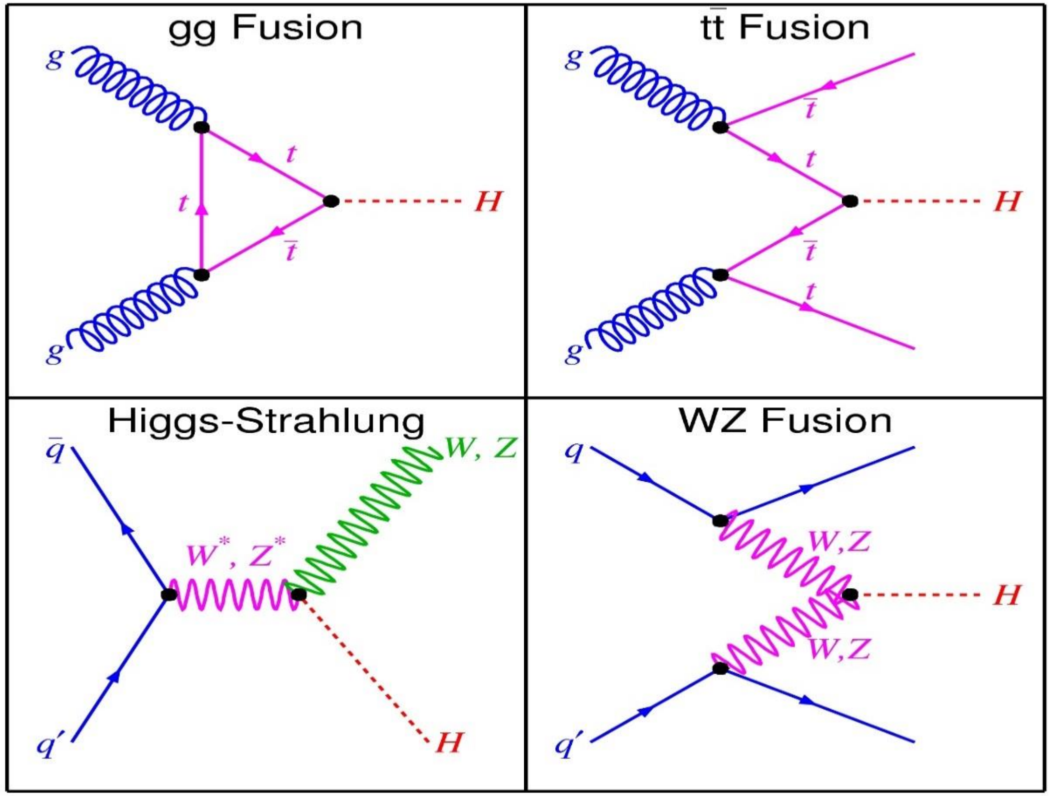
- Overall length = 42 m, diameter = 22 m, weight = 7000 tons
- Components were constructed in over 35 countries around the world

Higgs boson production

σ (13TeV/8TeV) ~2.2

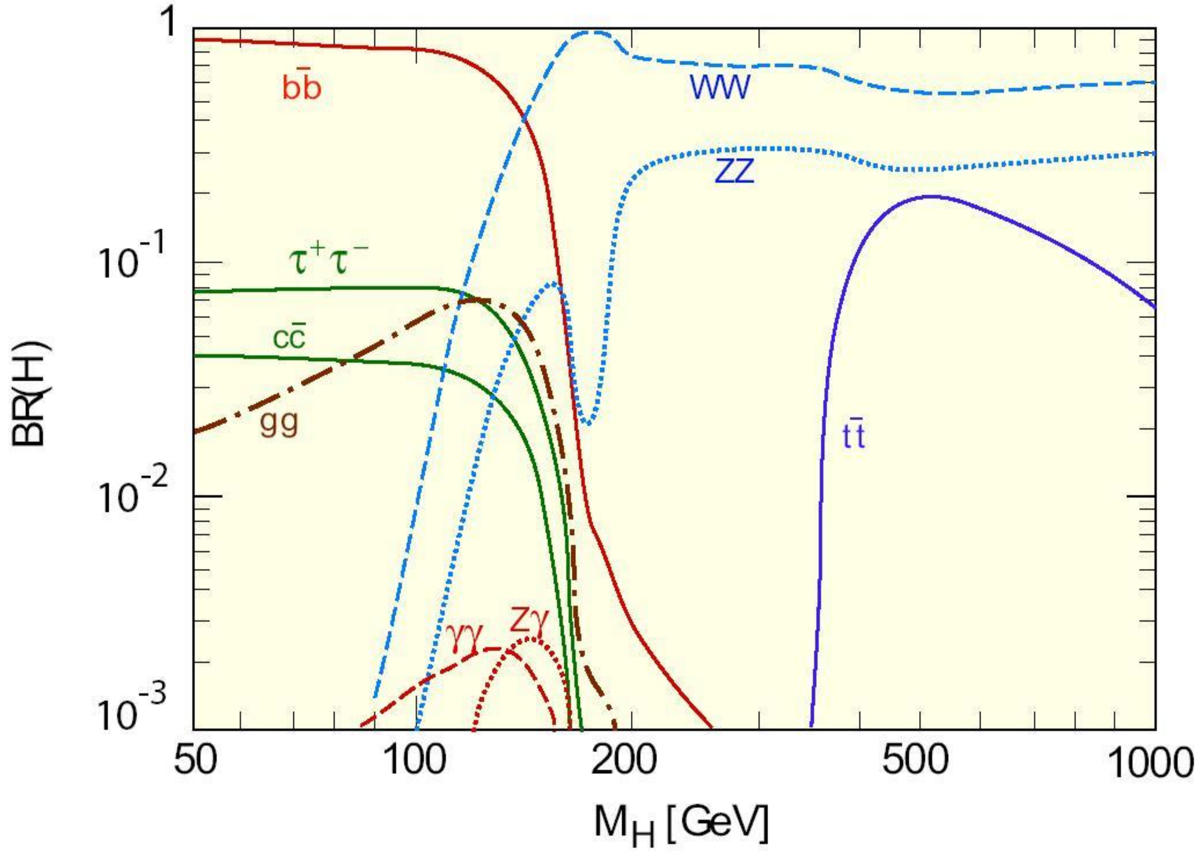


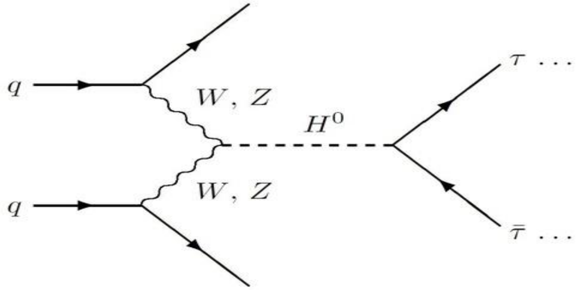
Dominant **Small**



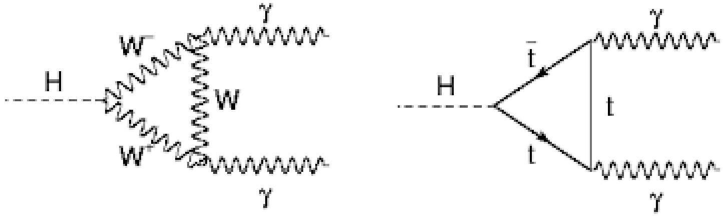
Small **Most sensitive**

Higgs decay modes

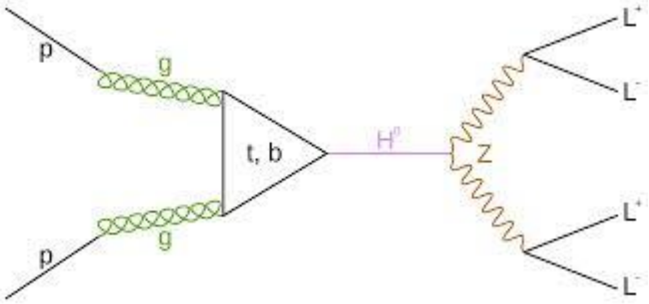




H->ττ



H->γγ



H->ZZ->4l

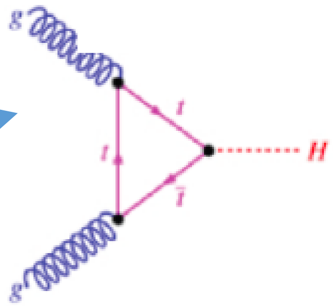
@ 125 GeV, dominant modes are: bb & ττ

Higgs discovery and searches

- The Higgs boson has been discovered in 2012 by ATLAS and CMS
- It has been seen in bosonic decay channels
  - $\gamma\gamma$, WW and ZZ
- Activity:
  - Measure Precisely the properties of the Higgs Boson
    - Higgs Spin/CP measurement
    - Precise mesearement of production modes and couplings
  - Evidence has been observed in the ditau channel in Run 1 analysis
    - To be confirmed as a standalone discovery channel

H→τ⁺τ⁻ channel (1)

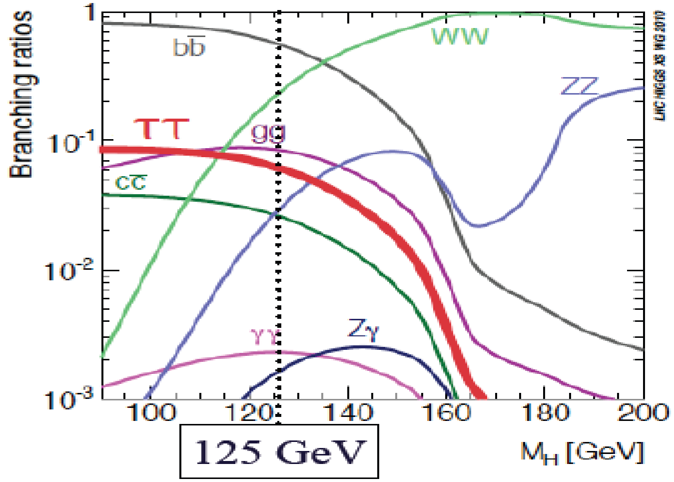
- Coupling of the new discovered particle to fermions:
  1. Quarks:
     - bbar: No evidence yet
     - ttbar: Indirect evidence from gg fusion through top loop



  2. Leptons:
     - μμ: Low statistic
     - H→ττ has one of the largest branching ratios for low mass Higgs

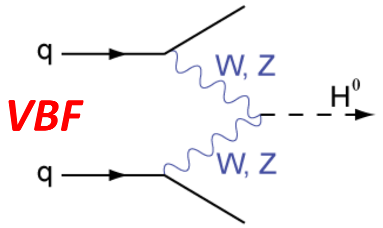
Branching ratios at 125 GeV:

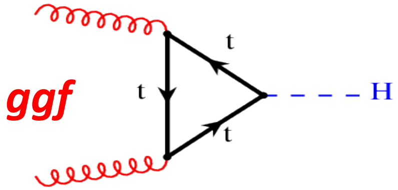
bb:	***57.7%***	***ZZ:***	***2.6%***
WW:	***21.5%***	***γγ:***	***0.23%***
ττ:	***6.3%***		



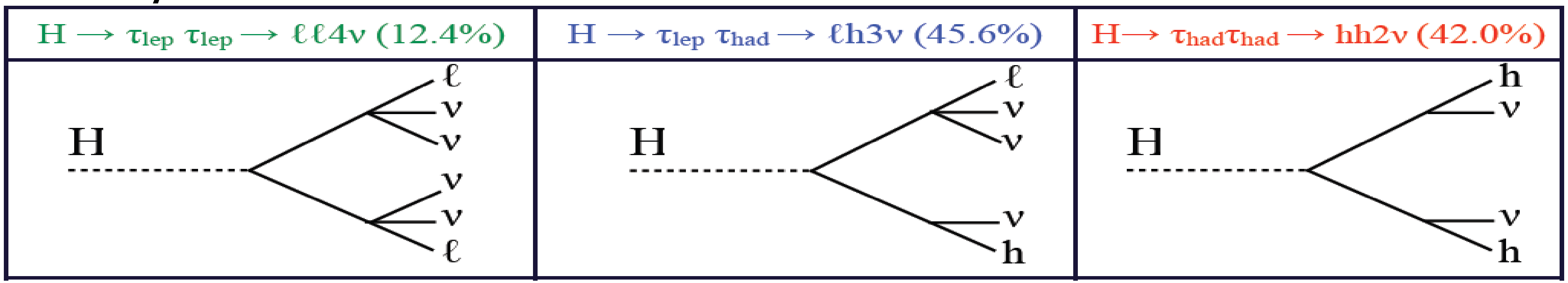
$H \rightarrow \tau^+\tau^-$ channel (2)

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





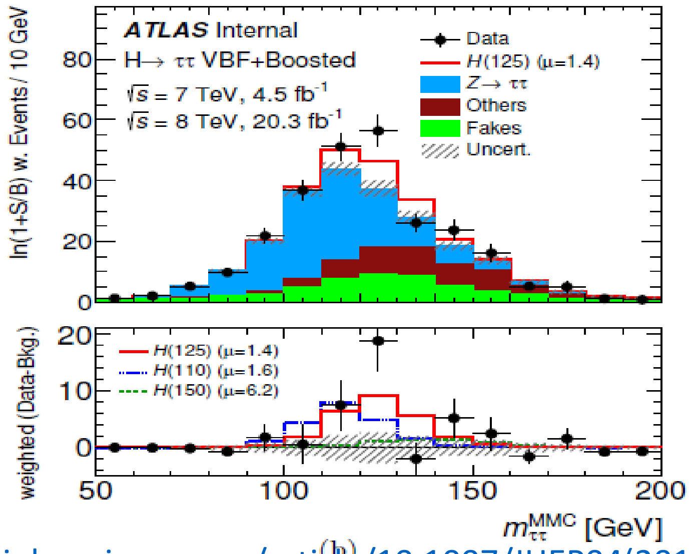
- Decay modes



Less signal – less background | **Best compromise S-B** | **More signal – more background**

$H \rightarrow \tau^+\tau^-$ 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
  - Others: Z->ll, WW, ZZ, top ...

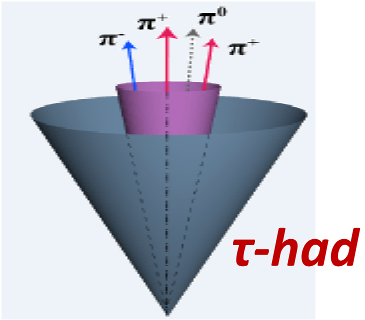


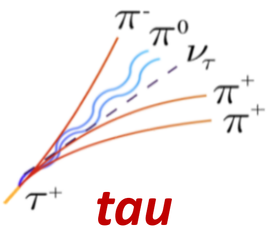
http://link.springer.com/article/10.1007/JHEP04(2015)117

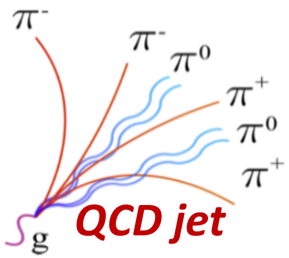
- Analysis method: Boosted decision tree (cut based analysis has been also done)
- Accurate treatment of systematics
- Mass calculation method: "MMC" (missing mass calculator)
- Final significance results: 4.5σ (observed) , 3.4σ (expected)

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

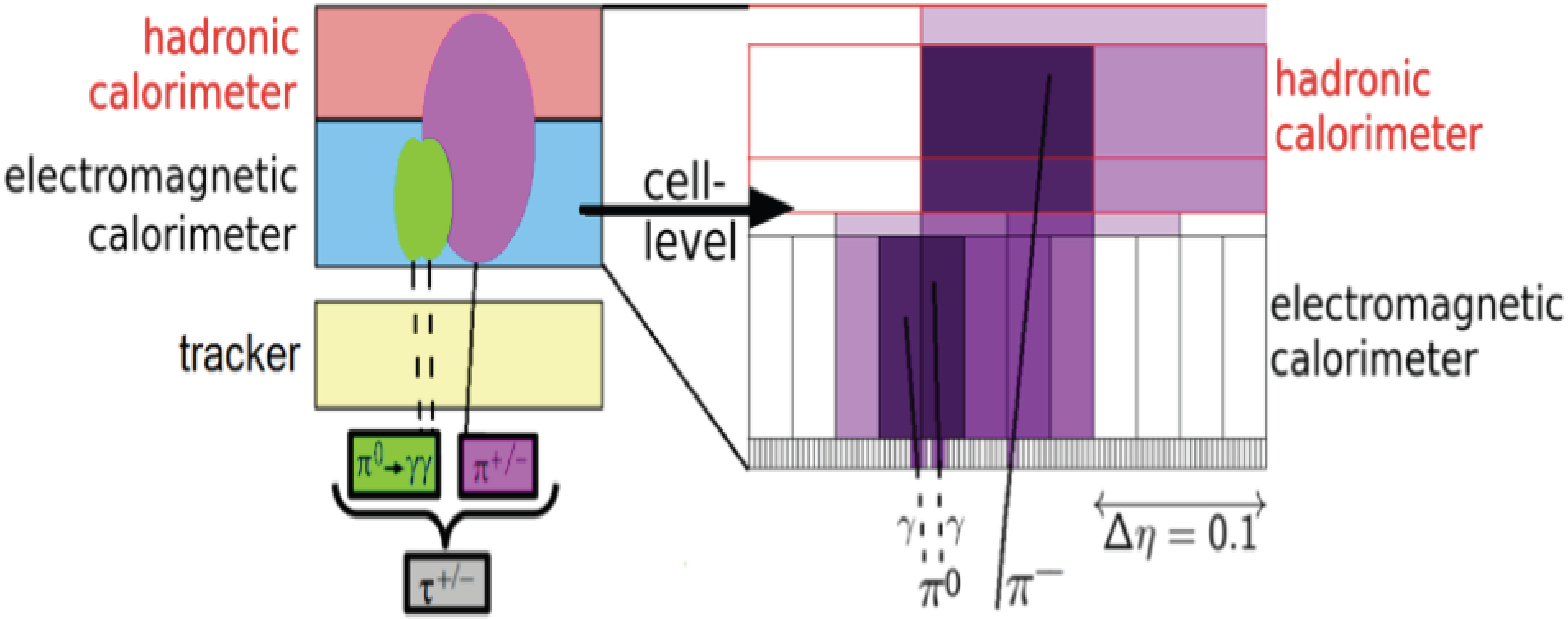






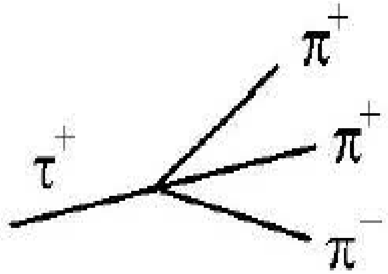
  - Improve the reconstruction of ττ invariant mass

Tau signature

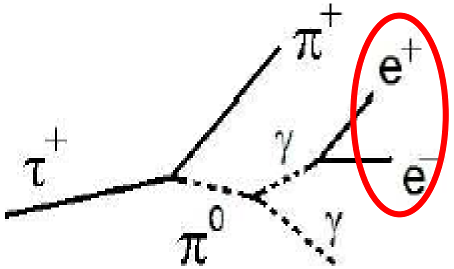


Photon conversion in hadronic tau decay

- 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

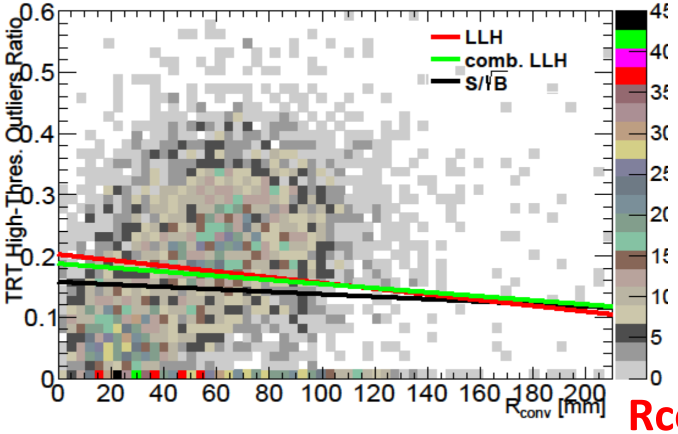
- Need photon conversion tagging to avoid misidentification e-π

Conversion taggers in ATLAS

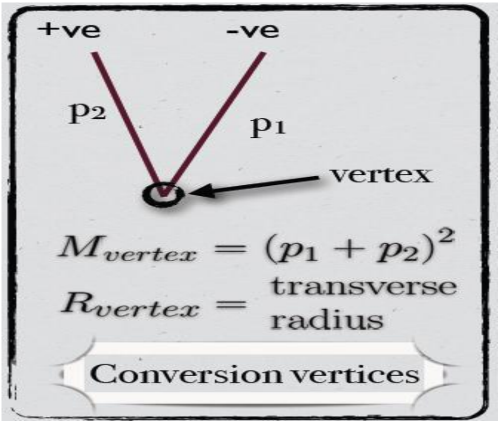
- Two conversion taggers in Tau software
  1. Single track conversion tagger S.T.T.
     - Tag conversions track by track
     - Use variables in the inner detector: Rconv, nbLayer, TRT
     - Combine these variables in a 2 dimension plot and use a simple cut to select conversions

  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

TRT



Rconv



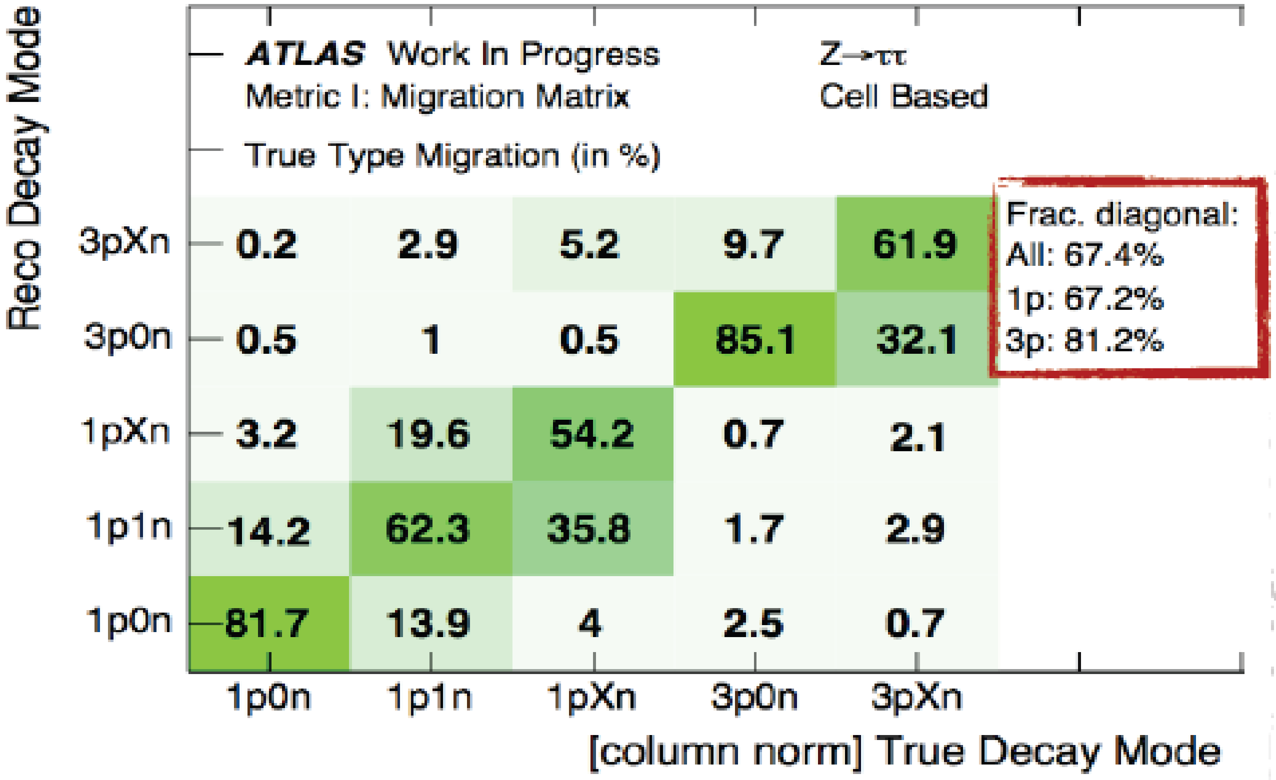
Performance results

Single track tagger	
Conversion efficiency (%)	66 ± 1.4
Fake rate (%)	5 ± 0.2

Double track tagger	
Conversion efficiency (%)	65 ± 5
Fake rate (%)	5 ± 1

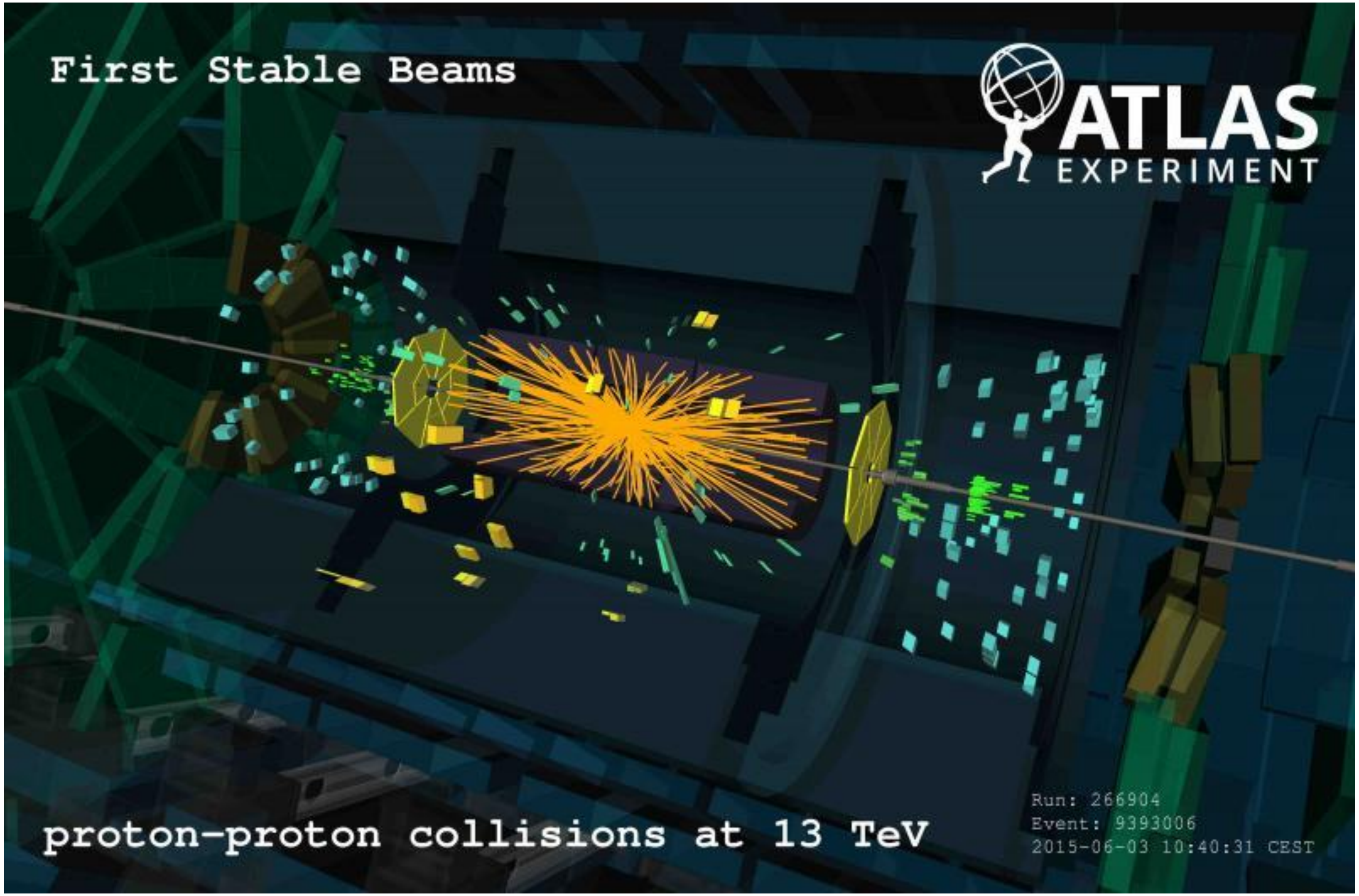
- The 2 algorithms show a comparable performance by running on 13 TeV simulation samples
- The single track tagger is faster in term of running time
- S.T.T. Is the default tagger now is Tau reconstruction ATLAS software
- It has been implemented in the new software for Run2 analysis
- All this is one ingredient of the overall tau identification in ATLAS

Current reconstruction efficiency



Preparation of H->ττ analysis for Run2

First proton beams collision at 13 TeV ☺



03-June-2015

From 8 TeV to 13 TeV

- Gain

S (Run2) = S (Run1) * 2.2

B (Run2) = B (Run1) * 1.7

=>

$\sim S/\sqrt{B}$ (Run2) $= \sqrt{2} * S/\sqrt{B}$ (Run1)

- Luminosity

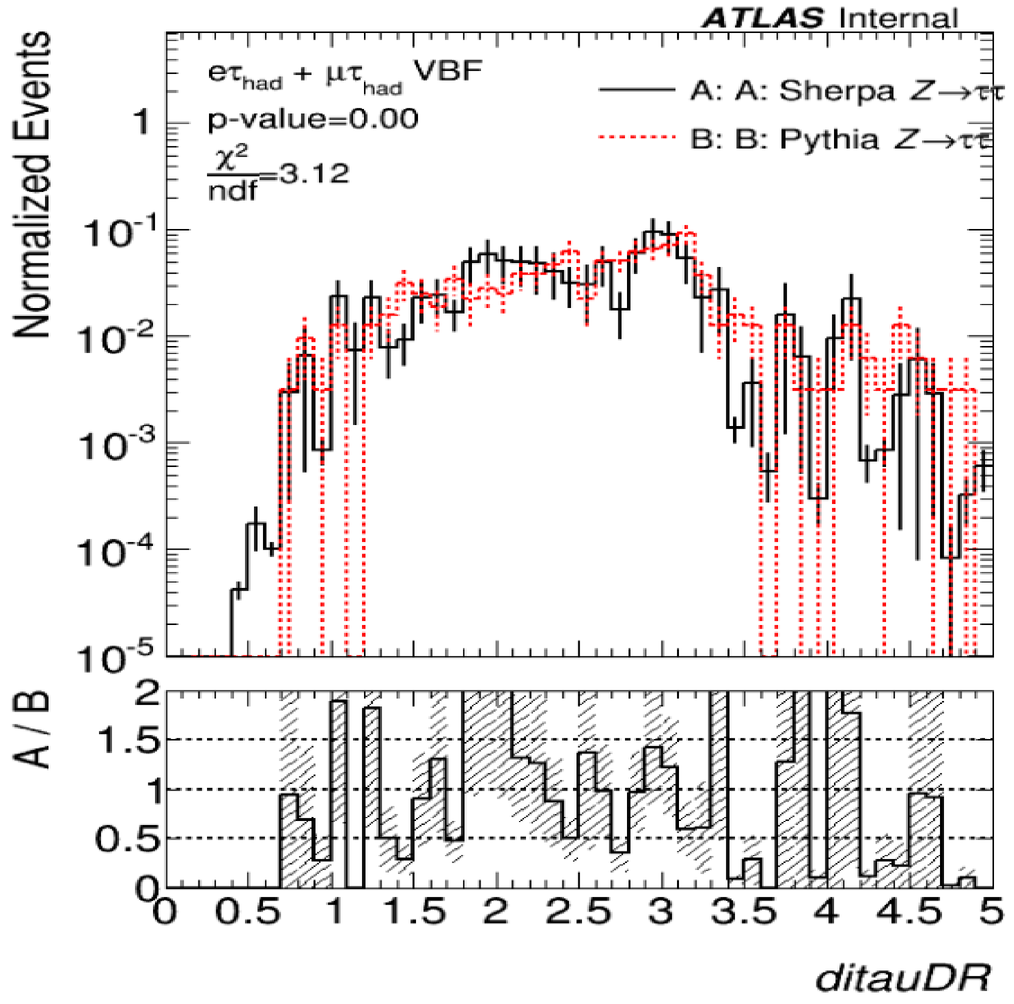
25 fb^{-1} (Run1) → 100 fb^{-1} (Run2 2015-2018) => factor $\sqrt{4} = 2$

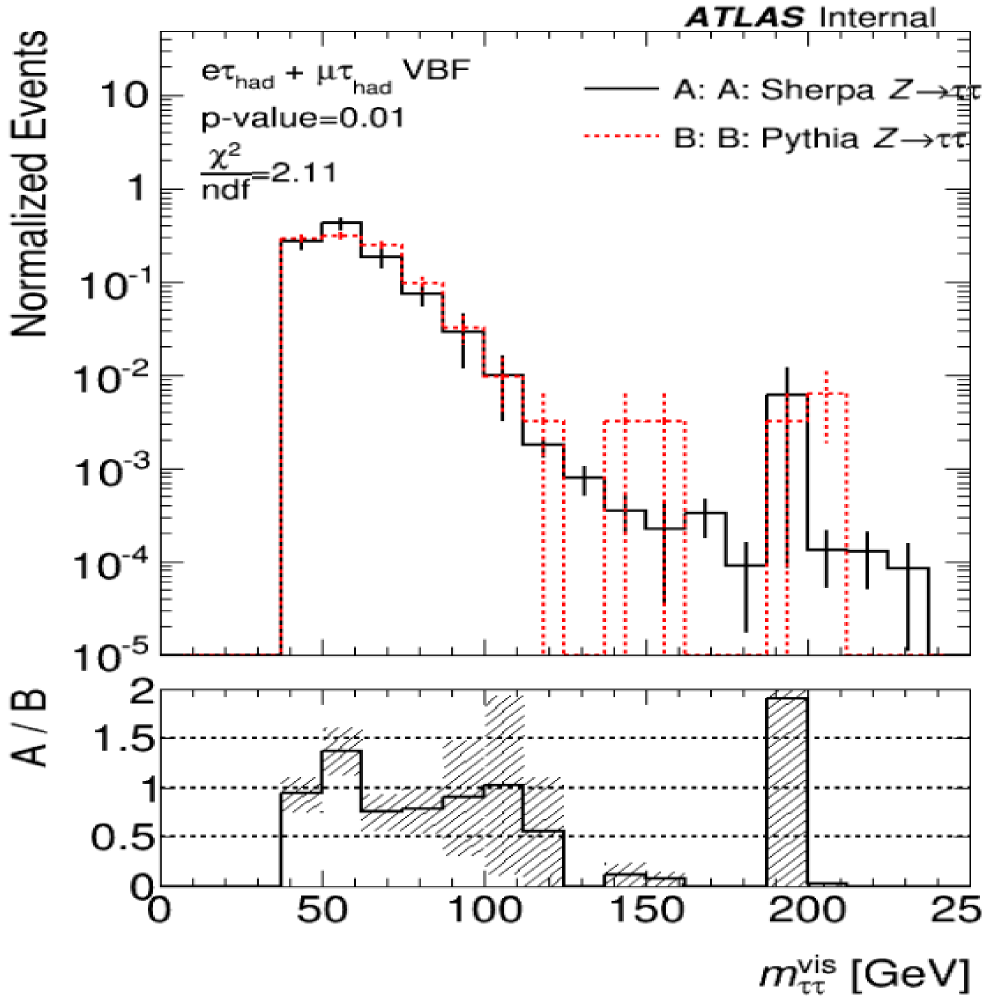
- Higher luminosity vs Pileup ?
  → Idea is to run with 25ns Bunch Crossing
- Detector improved (IBL for primary & secondary vertex)

Events file production for Run2 analysis

- Simulated events files have to be produced for 13 TeV energy collision
  - Background estimation
  - Signal prediction
  - Comparison prediction with real ATLAS data
  - H->tautau signal extraction
- A new production framework is used now by many H->tautau analysis groups
  - Standard Model H->tautau channels, BSM, HCP,...
  - Lal group: implementation and production of lepton-hadron channel
- Fisrt production has been done for the H-> tautau lephad channel

Some output variables





Physics analysis

- Goals:
  - Access the discovery (5σ)
  - Study Higgs properties in ditau channel with Run 2
    - (CP, Coupling, Production)
  - Aim to have public results for Moriond 2016
- Various H->ττ ATLAS groups will be involved in this analysis
  (LAL-Orsay, Melbourne, Goettingen, Bonn,…)

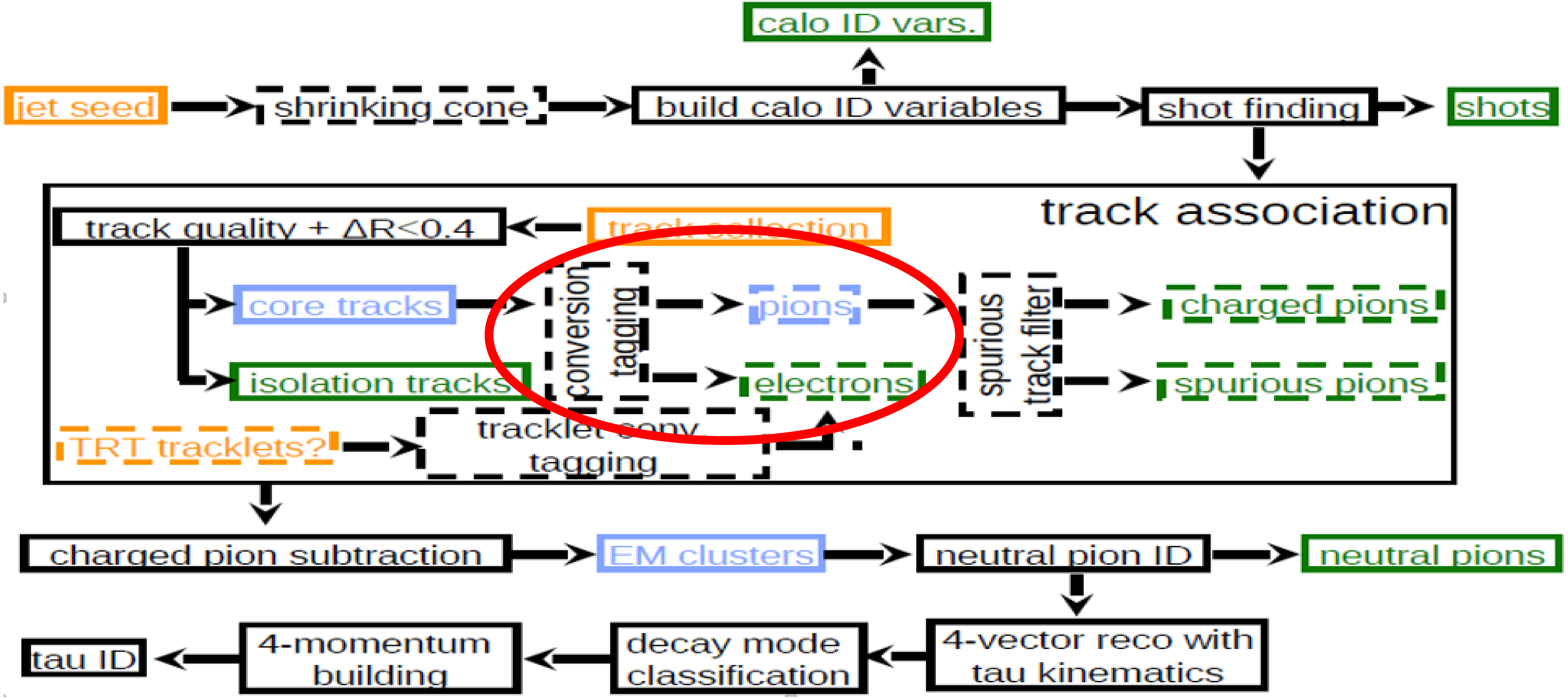
Conclusion

- The Standard Model H->ττ search is a very important channel for Higgs boson physics
  - Only observable mode of coupling to leptons
- Evidence has been seen already from Run1 analysis
  - Very promising analysis with the Run2 energy to improve sensitivity for this channel
- Improvement of hadronic tau reconstruction is ongoing
- Start collecting data with the new LHC energy (13 TeV)
- Analysis preparation for H->ττ Run2 searches has been started and aiming for results in few months

Merci ☺

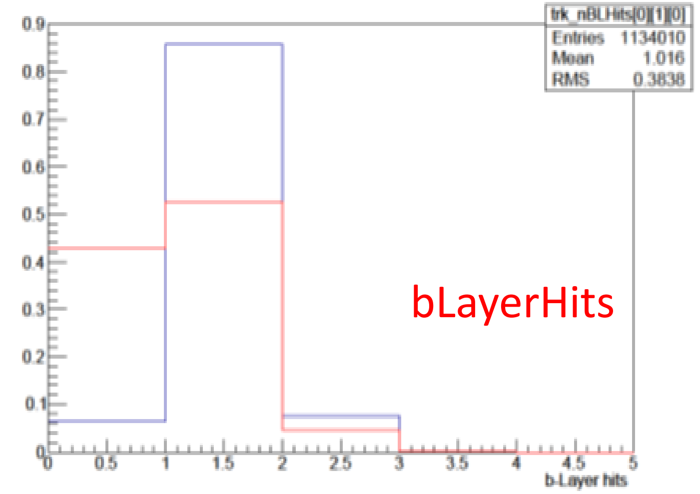
Back up

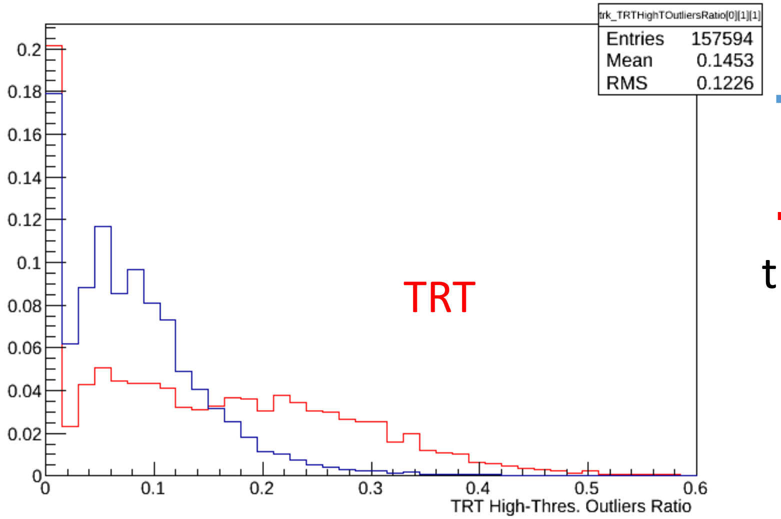
Conversion tagging



Single track tagger(1)

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

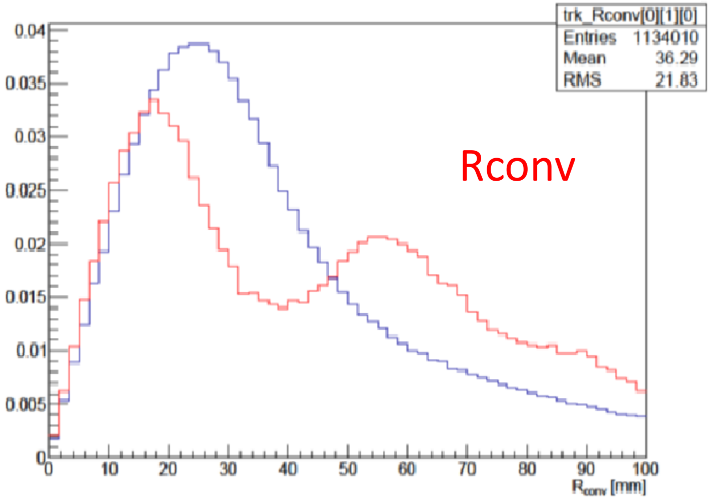




RecNprong=2

Matched to charged pion track (blue line)

Not matched to Charged pion track (conversion candidate) (red line)



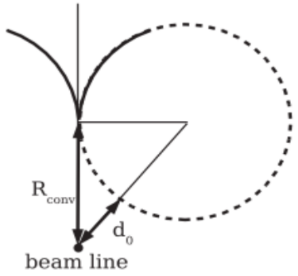


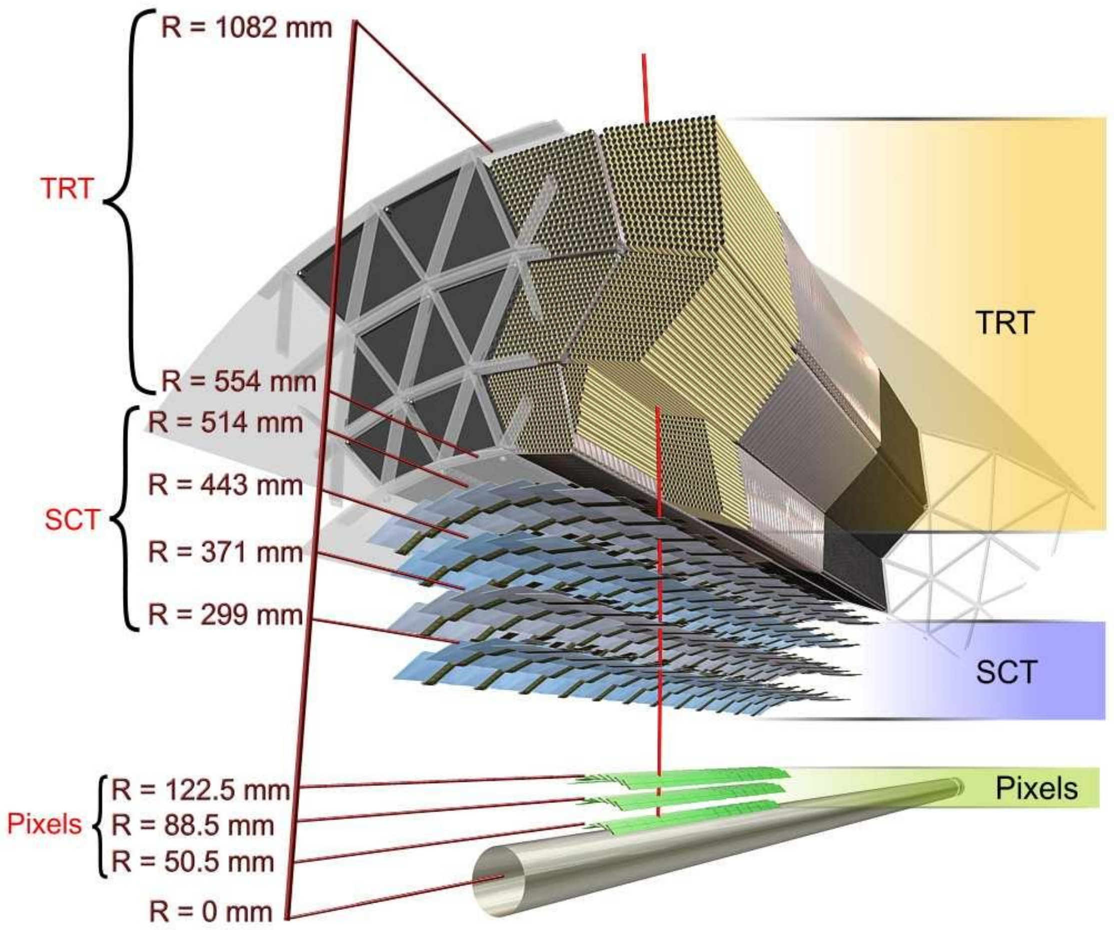
FIG. 4. Schematic illustration of the distance R_{conv} from the beam line to the point where the conversion occurred. Here, d_0 is the impact parameter.

Physical Review D 77, 092001 (2008)

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

Magnetic field in tracker

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

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:

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