τ-ID at D0 and ATLAS

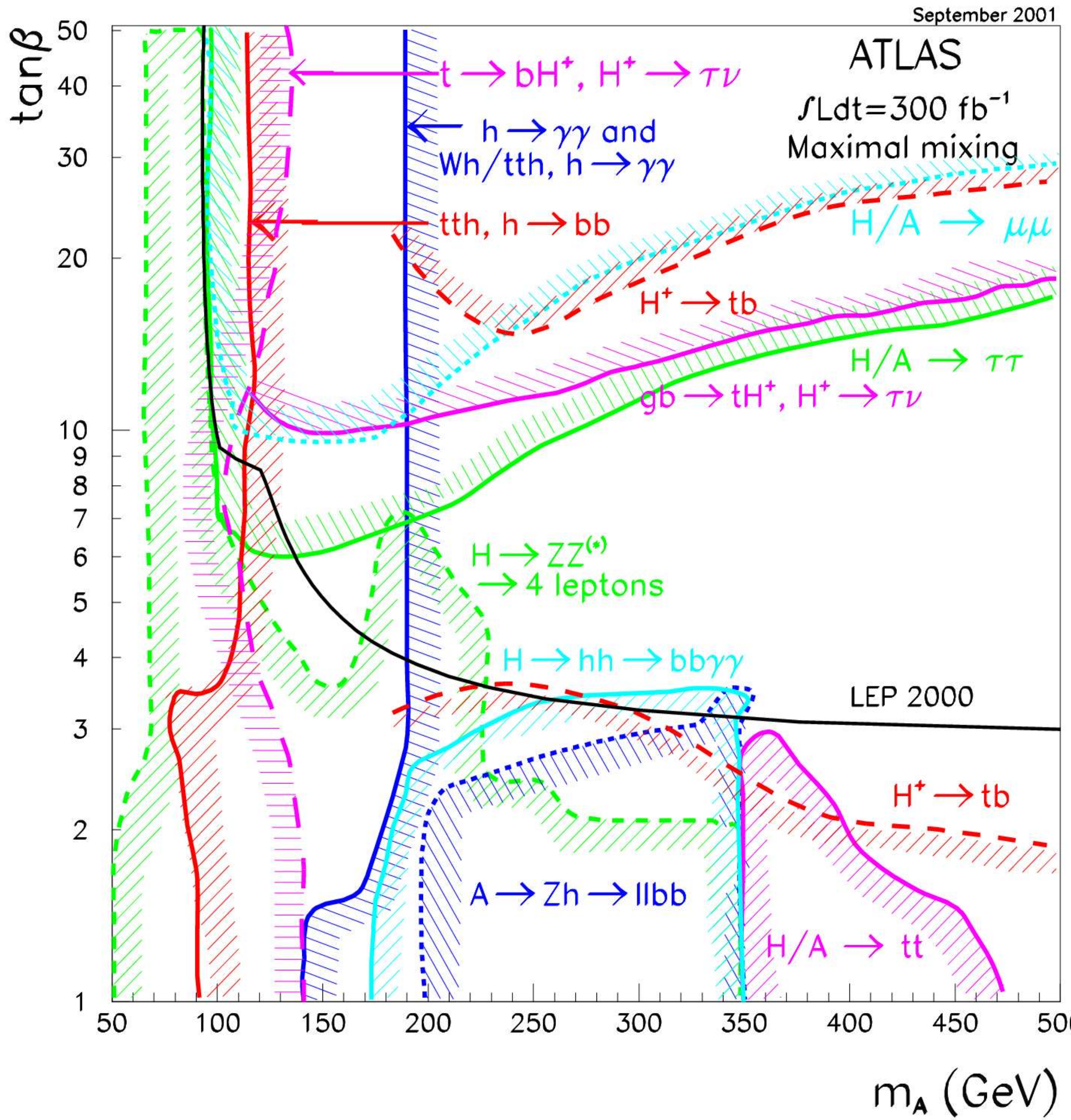
Volker Büscher,
Michael Heldmann,
Ingo Torchiani

University of Freiburg

- Motivation
- D0
- ATLAS
- preliminary comparison
- summary

Motivation

- **At ATLAS we expect a big number of final states involving taus**
- **Channels using taus**
  - $A^0/H^0 \rightarrow \tau\ \tau$
  - $H^+ \rightarrow \tau\ \nu$
  - SUSY with production of $\tilde{\tau} \rightarrow \tau + \chi^0{}_1$
  - Standardmodell Higgs (VBF qq H $\rightarrow$ qq $\tau\ \tau$)
  - Z $\rightarrow \tau\ \tau$ (for comissioning)
  - τ are perhaps the only way to access the chiral structure of SUSY
- $\rightarrow\tau$'s are an important signature



Motivation

- Since this is the TeV4LHC workshop, the questions are:
  - What can ATLAS learn from D0 about tau reconstruction and identification ?
  - How can we transfer this knowledge to ATLAS ?
- The steps we would like to follow are:
  - compare the D0 algorithm to what we use at ATLAS
  - look for input on how we can improve our algorithm
- many ATLAS Analysis rely on the understanding of tau identification
  - will we reach the performance we see on the MC at the moment ?
  - → learn from the D0 comparison between MC and data
- check if the description of MC-Generators of the low multiplicity jets is correct with D0 data
- get input on how to measure the performance using data

Tau Identificaton

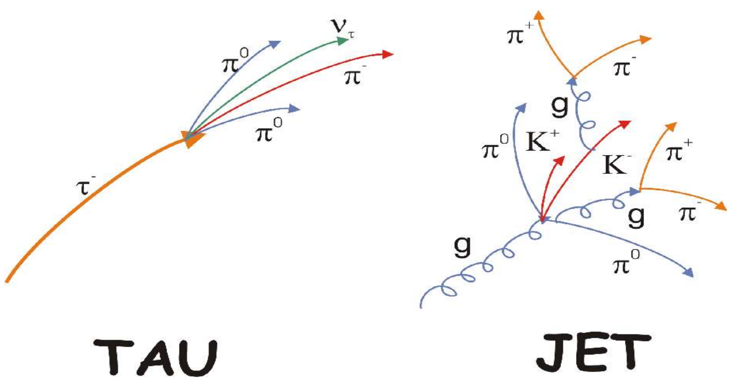
- **How can one identify τ-leptons ?**
- most important decay modes
  - Leptonical decay modes
    - $\tau \rightarrow \nu_\tau + \nu_e + e$ (17.4%)
    - $\tau \rightarrow \nu_\tau + \nu_\mu + \mu$ (17.8%)
  - Hadronical decay modes
    - 1 prong
      - $\tau \rightarrow \nu_\tau + \pi^c$ (11.0%)
      - $\tau \rightarrow \nu_\tau + \pi^c + \times \pi^0$ (36.2%)
    - 3 prong
      - $\tau \rightarrow \nu_\tau + 3 \bullet \pi^c + \times \pi^0$ (15.2%)
      -

1 track
only difference
from prompt leptons:
impact parameter

1 track, impact parameter
shower shape, energy sharing
find the photon cluster

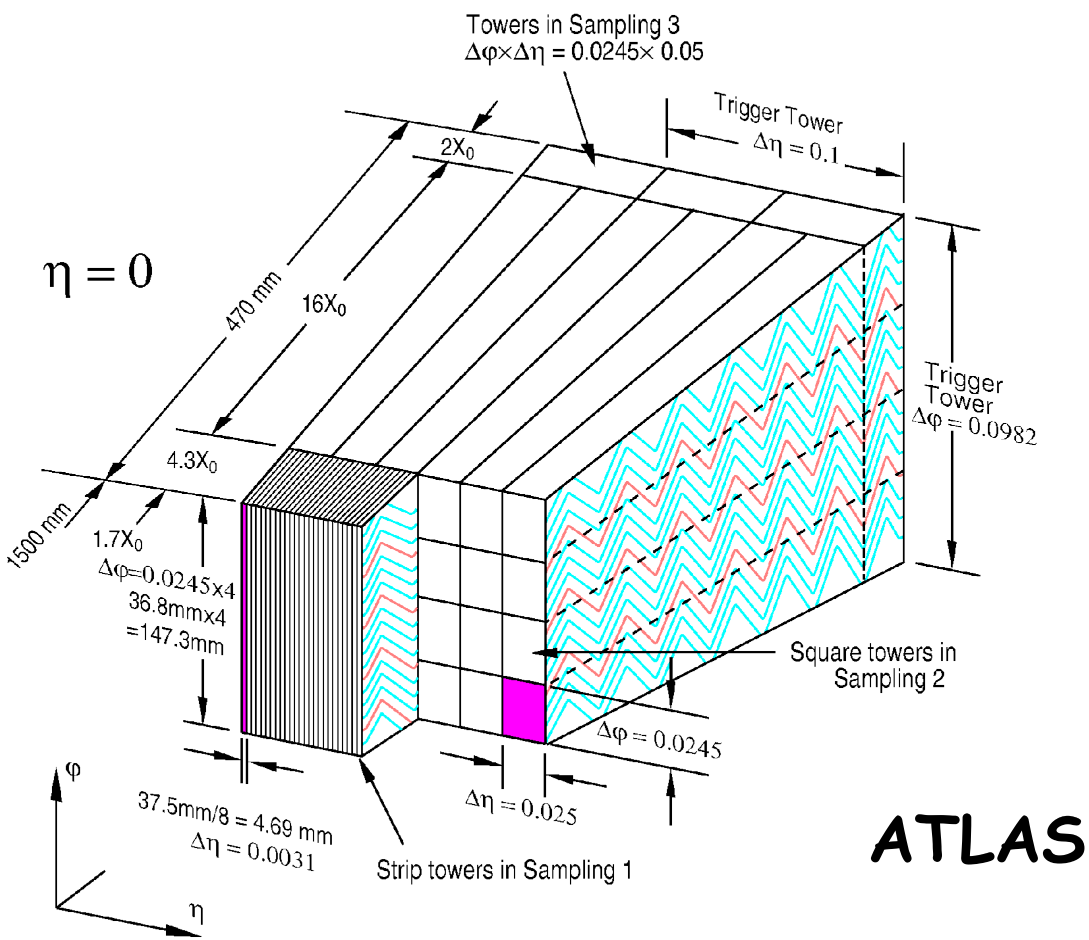
3 track, impact parameters,
secondary vertex

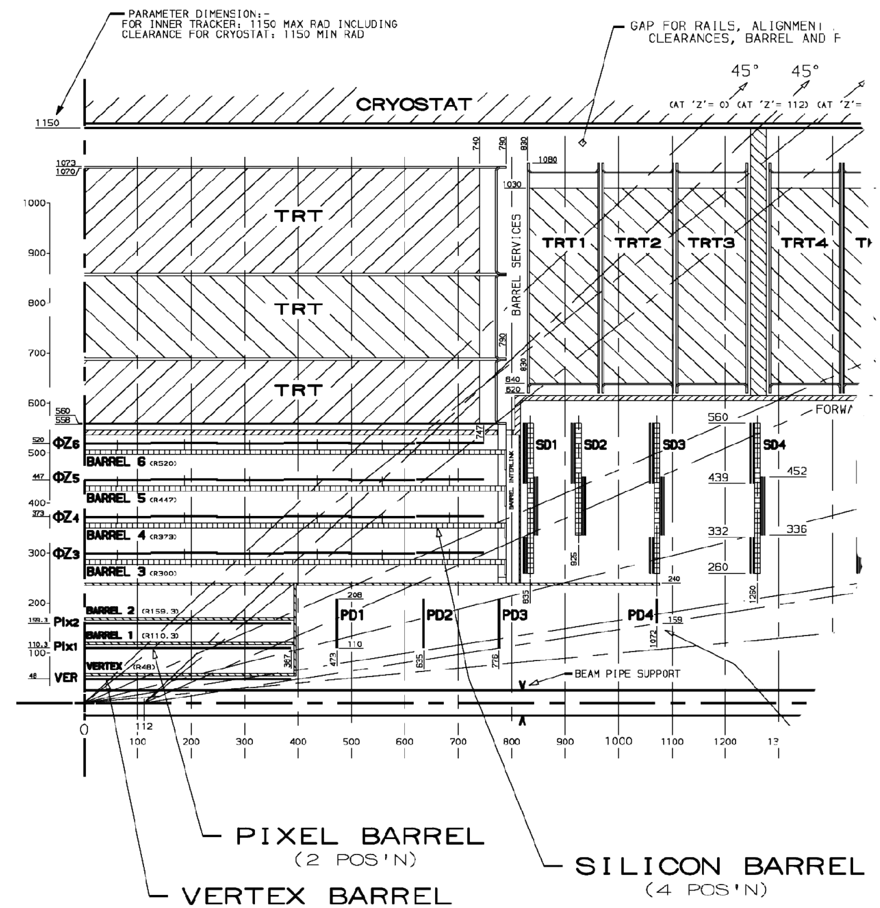
- **$\rightarrow \tau$s are colimated calorimeter objects with one or three associated tracks**



ATLAS Calorimeter and ID

- The tau identification makes use of tracks and calorimeter objects
- Atlas has a presampler (0.025x0.1), eta-strip-layer (0.003x0.1), middle (0.025x0.025) , back layer (0.05x0.025) and three hadronical layers with 0.1x0.1 and 0.2x0.1
- The ID has three pixel layers, four stereo microstrip layers and a straw tube tracker

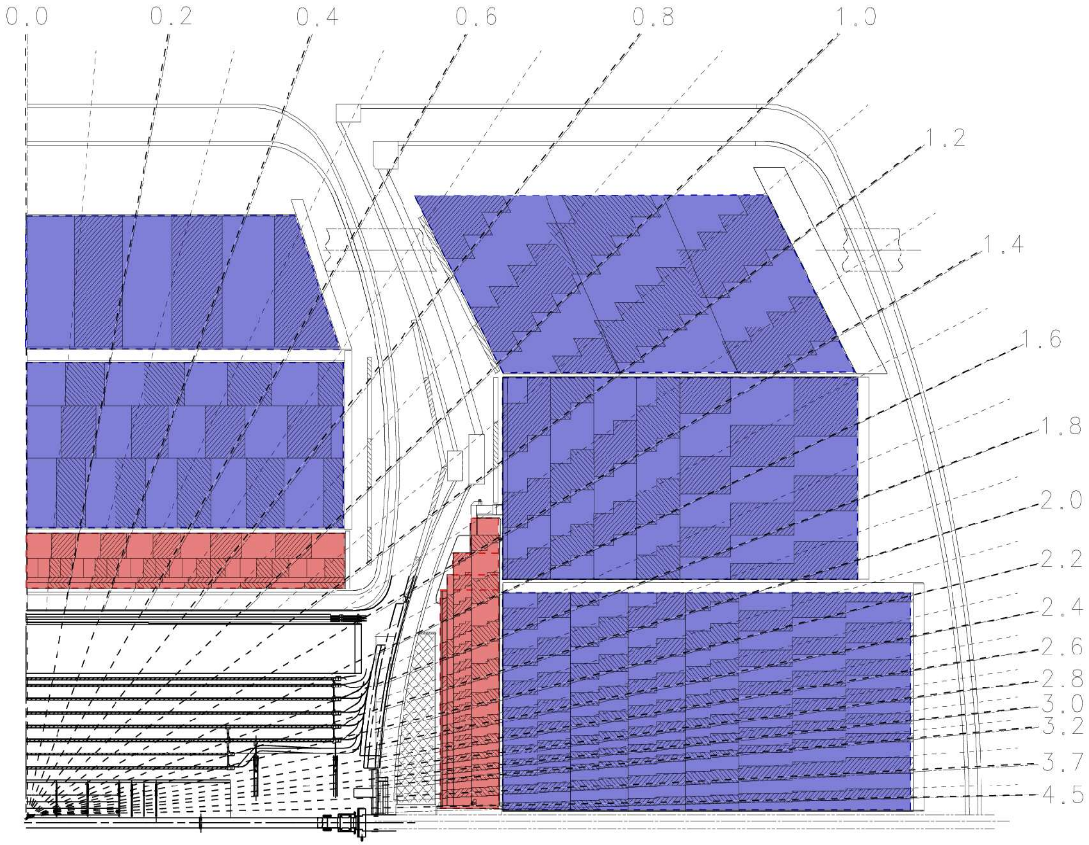


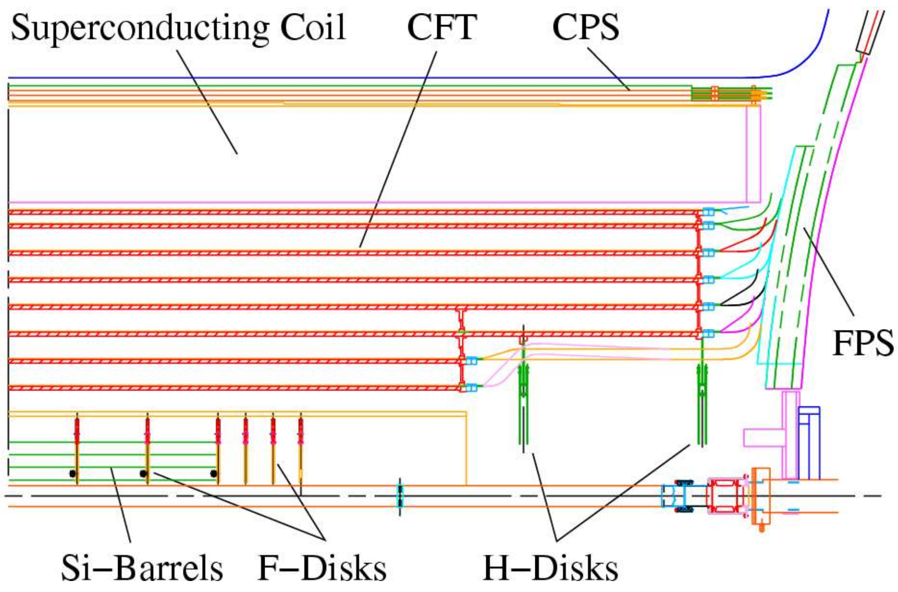


D0 Calorimeter and ID

- D0 has a an EM with four layers of 0.1x0.1, 0.1x0.1, 0.05x0.05, 0.1x0.1 and four hadronical layers 0.1x0.1
- The ID consists of a silicon tracker with four stereo layers and eight stereo layers for the fiber tracker
- the ID of D0 covers $|\eta| < 3.0$!

D0

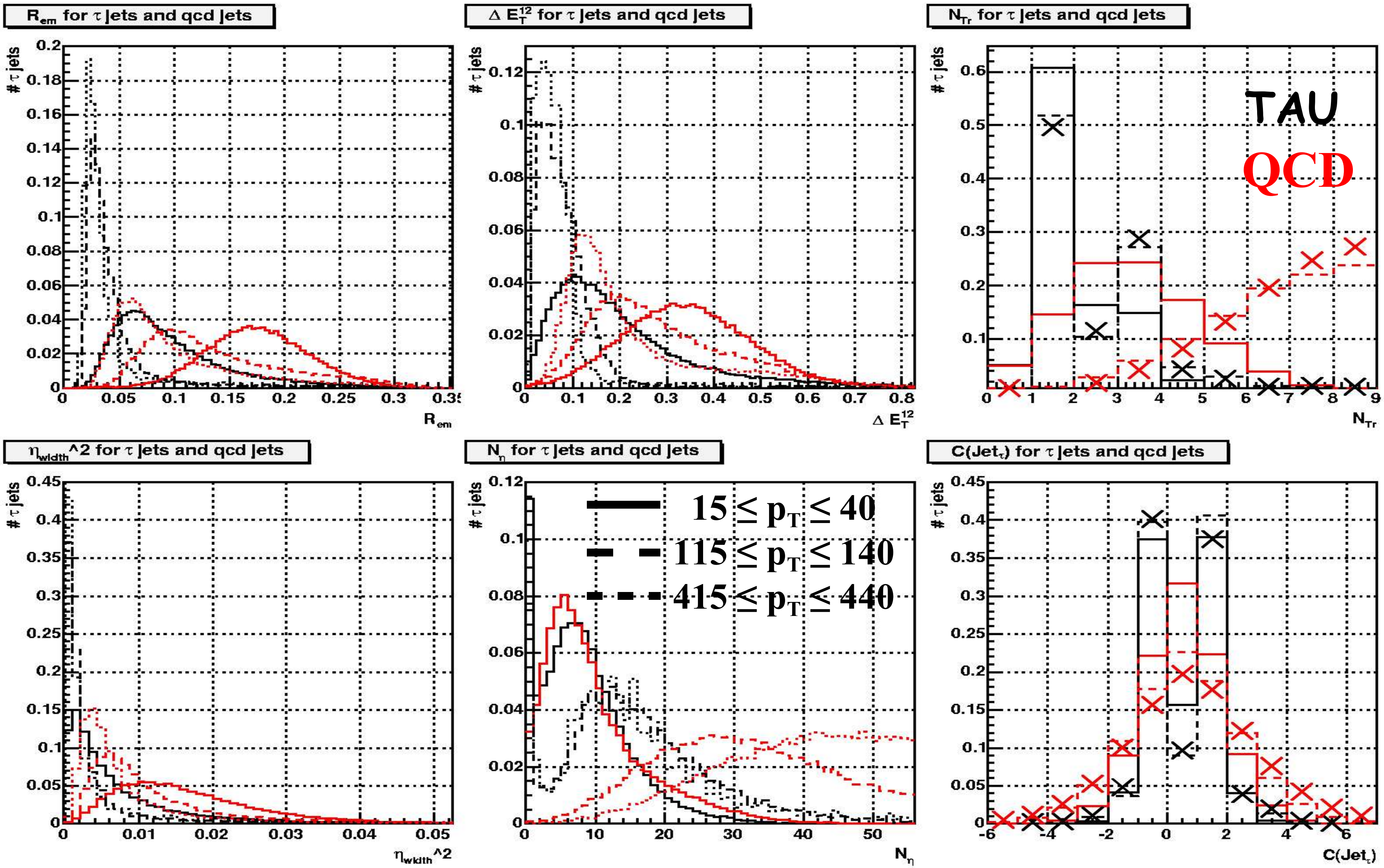




TauID at ATLAS

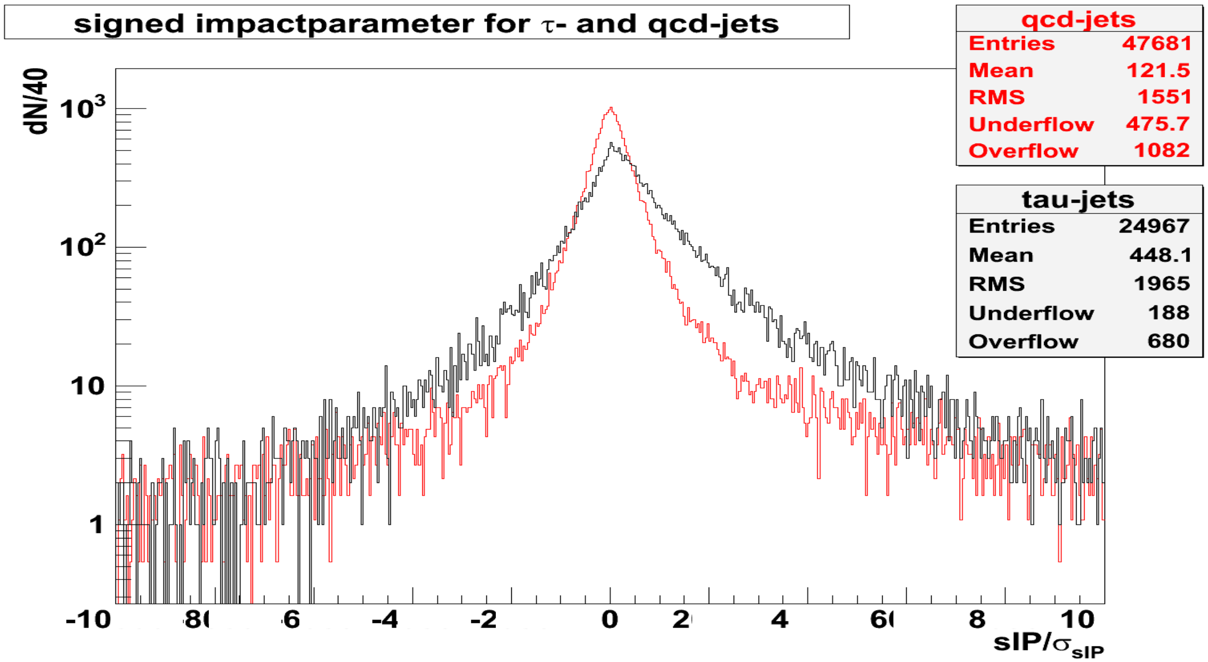
- Half a year ago a tau group has formed for ATLAS -> there is very much work in progress
- I will show only the “standard” way at the moment because we are more interested on D0 side anyway but there exist other algorithms as well
- Our τ-reconstruction package tauRec starts from clusters found by a sliding window algorithm
- We use the following quantities to discriminate taus against jets
  - R_{em} = Radius of the cluster in the em-calorimeter $\Delta R=0.4$
  - ΔE_T^{12} = Fraction of the transverse Energy between $\Delta R=0.2$ and $\Delta R=0.1$ around the center of the cluster
  - N_{tr} = Number of Tracks within 0.3, $p_T>2\mathrm{GeV}$
  - N_{em} / N_{strip} = Number of Hits in EM calo/η-Strip, $E_T>200\mathrm{MeV}$
  - $E_{T,width,strip}$ = Width in the η-Strip
  - $E_{T,em}/E_T$, Charge, $E_{T,had}/\Delta p_{T(tracks)}$
  - Lifetime Signed Impact Parameter
  - for 3 prong decays: secondary vertex

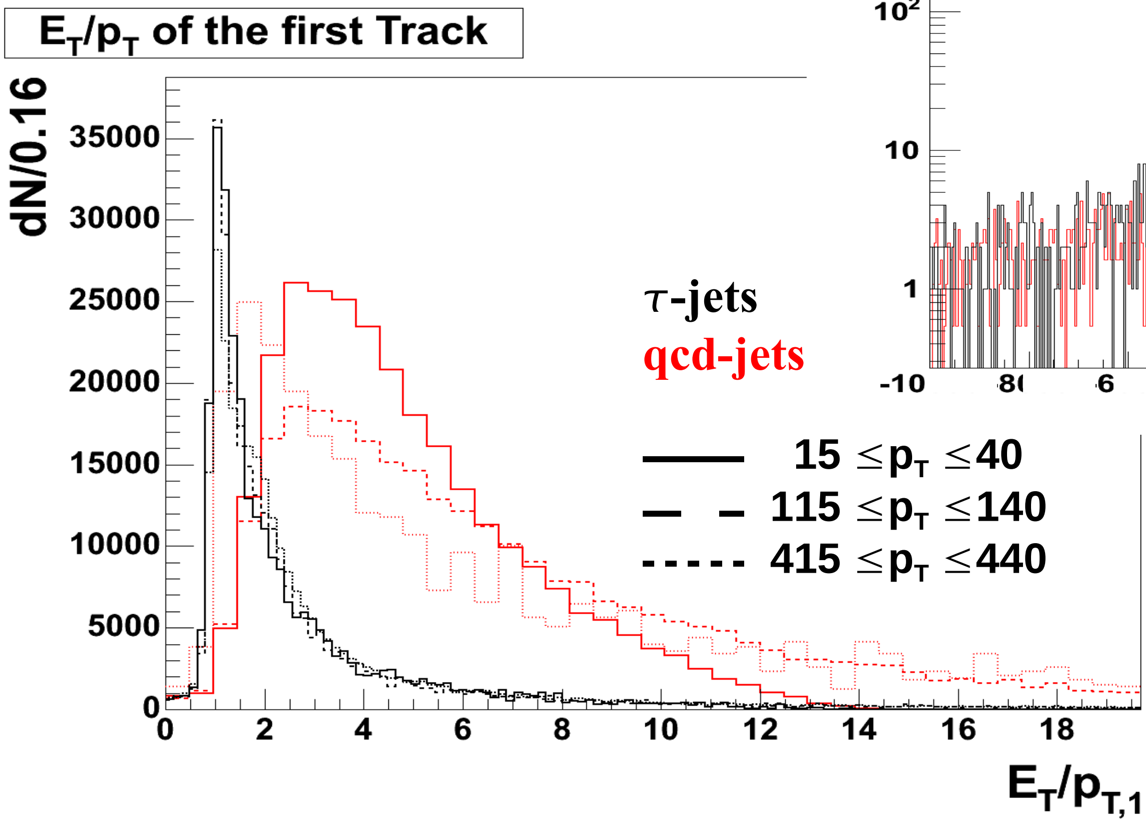
TauID at ATLAS



TauID at ATLAS

- Impactparametersignificance A_0/σ_{ip} : only 2d information, no reconstructed primary vertex (soon to come)
- Sign is defnied as $\mathrm{sign}(\sin(\varphi_{track} - \varphi_{cluster}))$

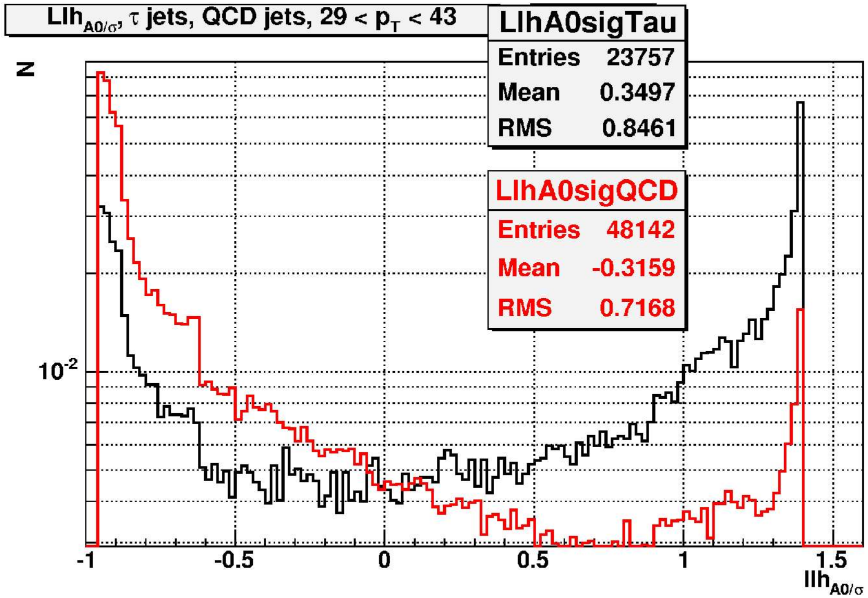


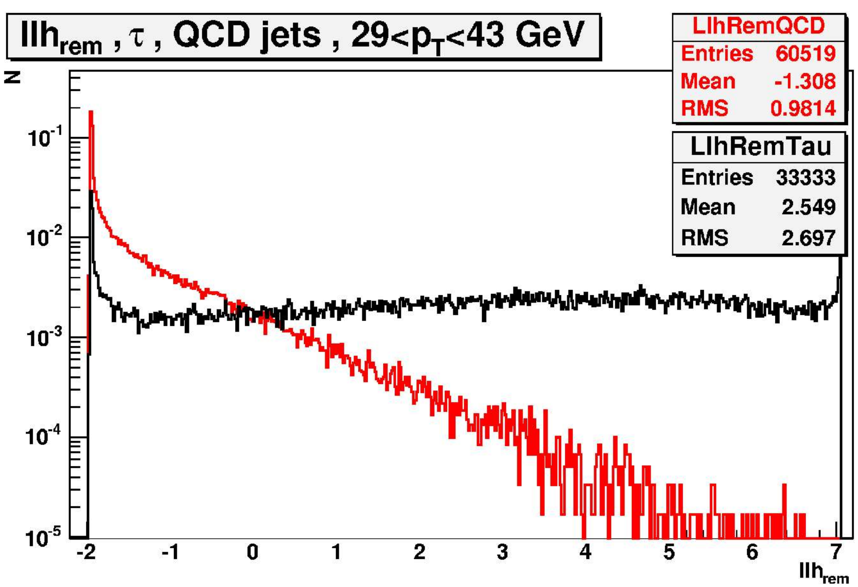


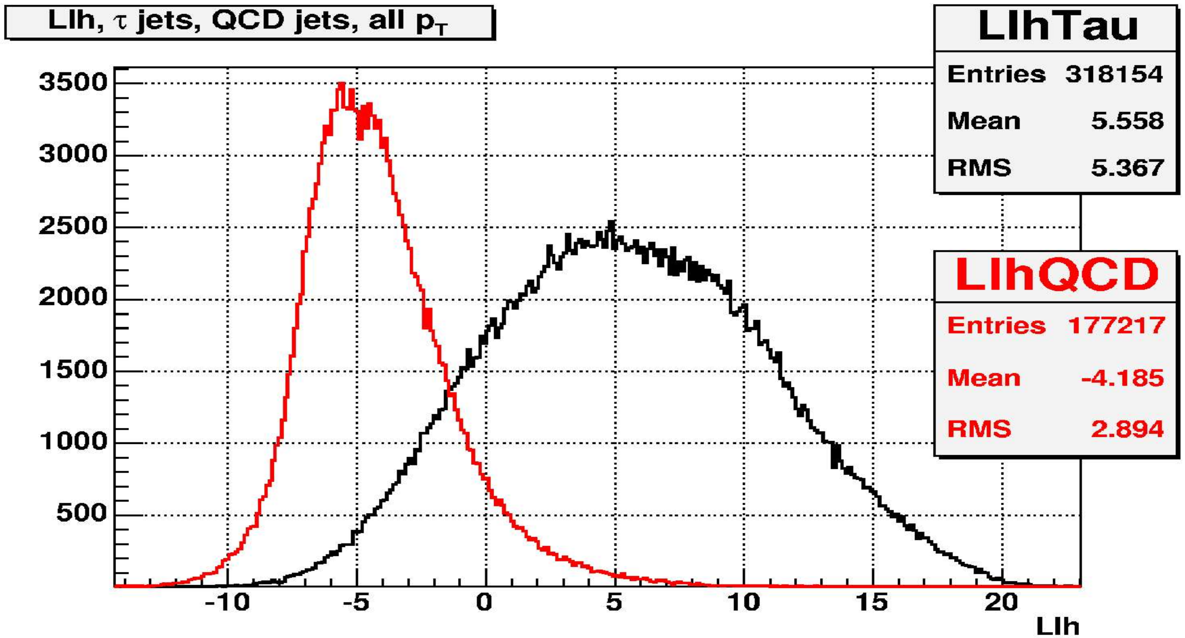
- E_T/p_T : Ratio of total to charged transverse Energy of the Jet
- Shows E_T dependance for QCD-Jets but none for τ-Jets

TauID at ATLAS

- All variables are then combined into a LikelihoodRatio
- preselection cut before the Llh: $1 \leq N_{Tr} \leq 3$
- 3 discreet variables, N_{tr}, N_{strip}, Charge, Llh directly from histograms
- 4 continous variables, R_{em}, ΔE_T^{12}, $E_{T,width,strip}$, $A0/\sigma\sigma$, fitted with arbitrary functions (normaly gaus*polynom)
- 10 p_T bins from 15 to 600 GeV, for Noise and NoNoise







TauID at D0

- D0 makes use of sometimes similar variables but all are defined in slightly different way
- D0 defines a τ – **Type** as follows
  - Type 1 : 1-prong – no em subcluster ($\tau \rightarrow \pi + \nu$)
  - Type 2 : 1-prong – with em subcluster ($\tau \rightarrow \pi + \nu + x\, \pi^0$)
  - Type 3 : 3-prongs (more than one τ track)
- The em subcluster is found by the following algorithm
  - Find the leading cells in the em layer with finest granularity
  - collect all neighbour cells
  - around the leading neighbour cell, in turn collect all its neighbour cells
  - collect all em cells (from other layers) which have an overlap with any of the so far collected cells
  - if their energy > 800 MeV they are called the em subcluster
- τ-Tracks are defined in the following way
  - only tracks with $\Delta R < 0.5$, $p_T > 1.5$ GeV are considered, and sorted in p_T
  - the first track is always a τ track, the second/third tracks are τ tracks if their invariant mass together < 1.1 / 1.7 GeV

TauID at D0

- all variables act within a cone of 0.5 around the calo center
  - definition variablename(x) means variable calculated using objects within dR < x around the calo center
- Profile = (E_T(Tower1) + E_T(Tower2))/E_T(0.5), Towers defined on deta x dphi=0.1x0.1 granularity
- Isolation = (E_T(0.5) + E_T(0.3)) / E_T(0.3)
- M(Track1, em subcluster)
- p_{T1} / E_T = p_T of the leading tracks divided by the calorimeter energy
- EM12Frac = (E_T(EM1) + E_T(EM2)) / E_T , where ET(EM1) means trans.energy in the first em layer
- trkiso = p_T(τ tracks) / p_T(all tracks)
- e1e2/E_T = sqrt(sum(τ tracks p_T) * E_T(EM)) / E_T(0.3)
- em3iso = E_T(em subcluster) / E_T(EM3)
- ntr1030 = number of tracks within 10° – 30° around the calo center

Preliminary comparison

- The goal is to understand what difference we can expect from the results in MC to performance with real data
  - We think we can accomplish establishing a chain of understanding
  - ATLAS Algorithm on ATLAS MC → D0 Algorithm on ATLAS MC →
  - → D0 Algorithm on D0 MC → D0 Algorithm on D0 data
- Therefor we need to implement all variables D0 uses at ATLAS
- Of course because of differences in the detector design the “translation” of variables is not unambiguous
- our convention:
  - D0 EM3 (finely granulated layer in the EM) → ATLAS EM2
  - D0 EM1, EM2 → ATLAS eta-strip layer
  - tower granularity in both cases 0.1x0.1
- energy thresholds have to be adjusted

Preliminary comparison

- because of time constraints the samples are not as similar as they could be, so some differences (beside detector design) are to be expected
  - D0: signal sample is Z→tau tau, background is W→μ MC, W→μ data, QCD data (with muon trigger → mainly bbbar)
  - ATLAS: signal sample is Z->τ τ, background is QCD – dijet events (no trigger)
- with time and more statistics at ATLAS we will try to implement all cuts + triggers

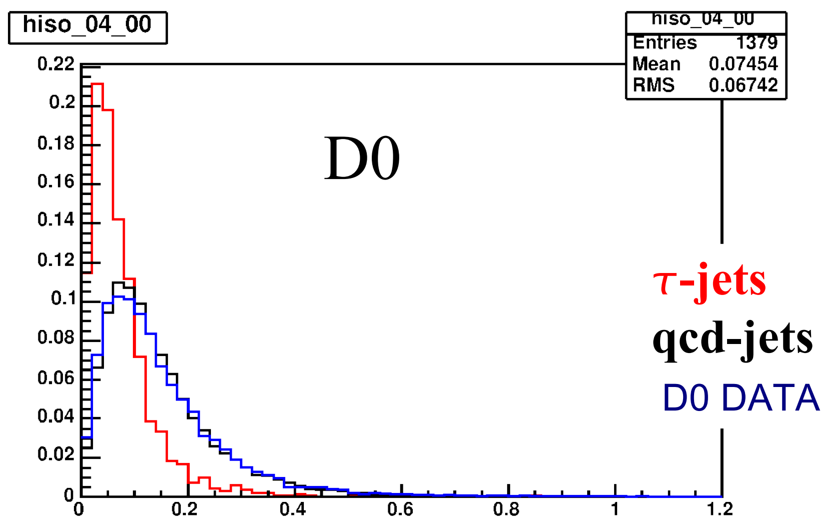
Comparison - Isolation

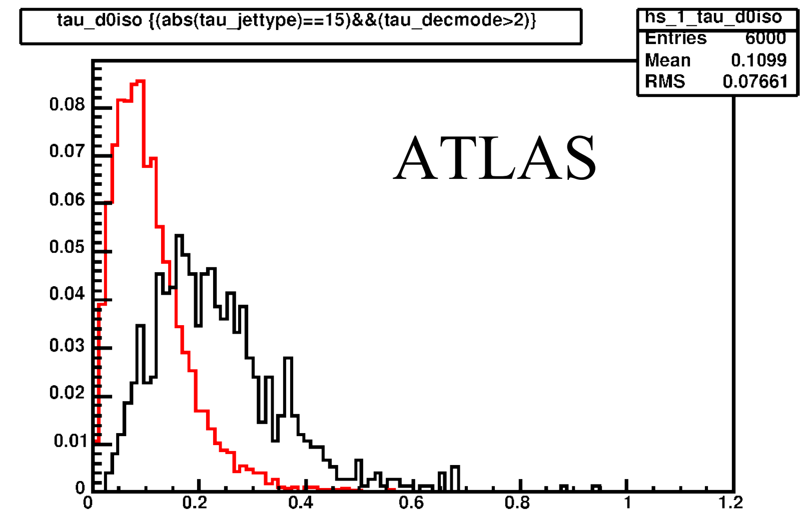
- These comparisons are meant as consistency checks and not as real performance comparisons because of the stated difficulties !

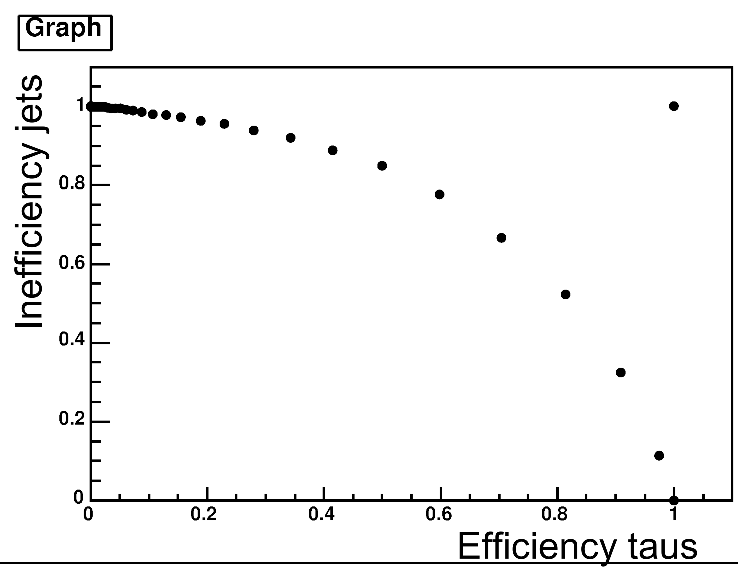
- Isolation is an important criteria both at D0 and at ATLAS

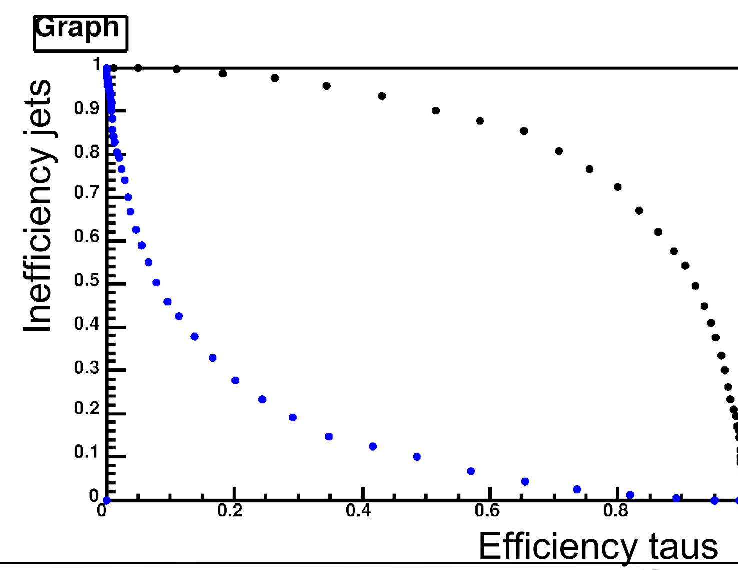
- the comparison shows that both D0 and ATLAS give similar distributions for taus and jets

- also the performance of the variable is comparable





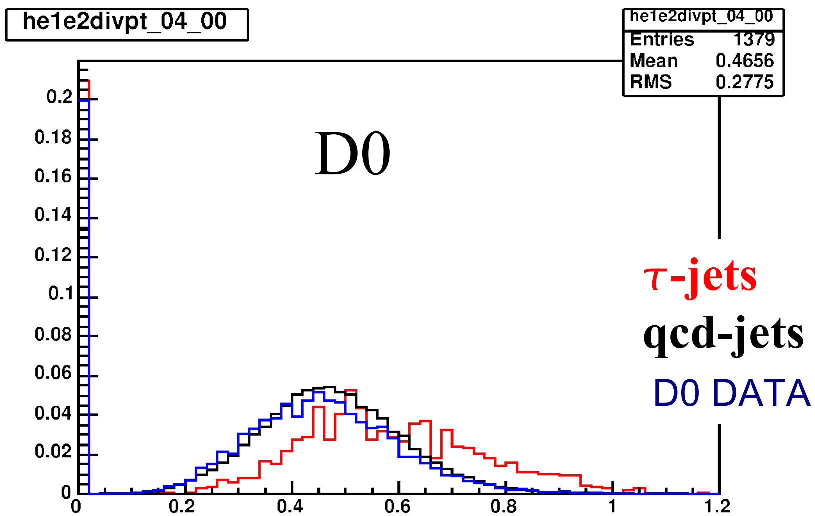


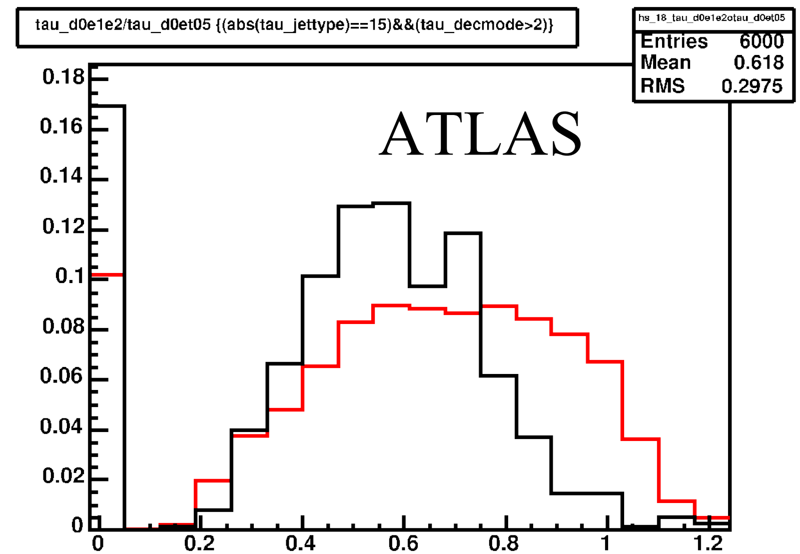


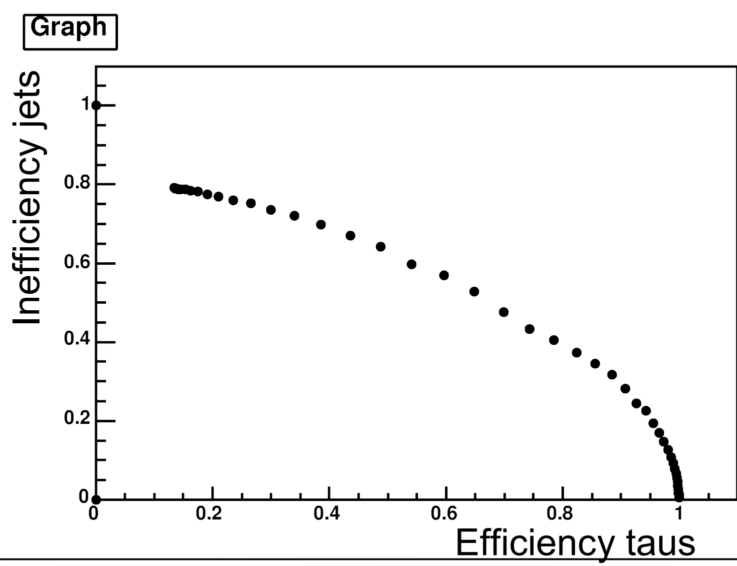
Comparison e1e2/ET(0.3)

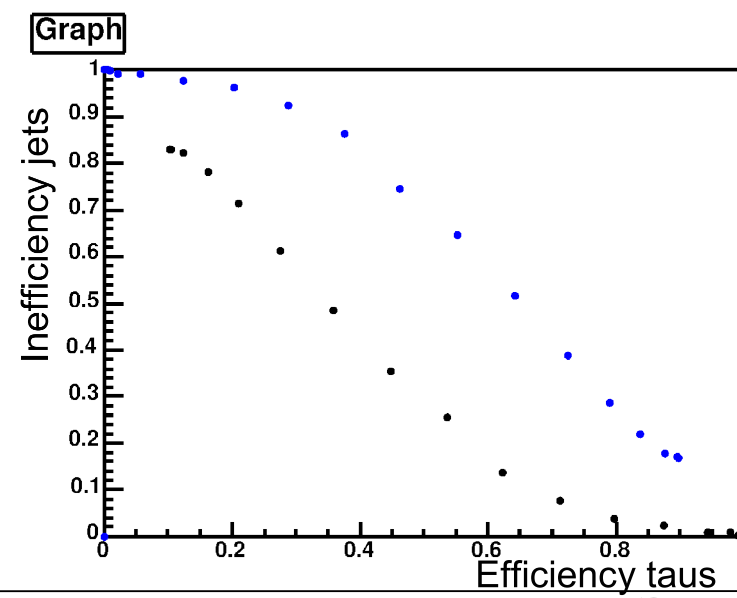
- e1e2/ET is a measure of the difference in energy compared to the em calorimeter

- e1e2/ETshows weaker discrimination for both
- distributions due not match perfectly, ATLAS show cases with very few EM energy
- the performance show different dependency on the efficiency
- but overall trend seems ok





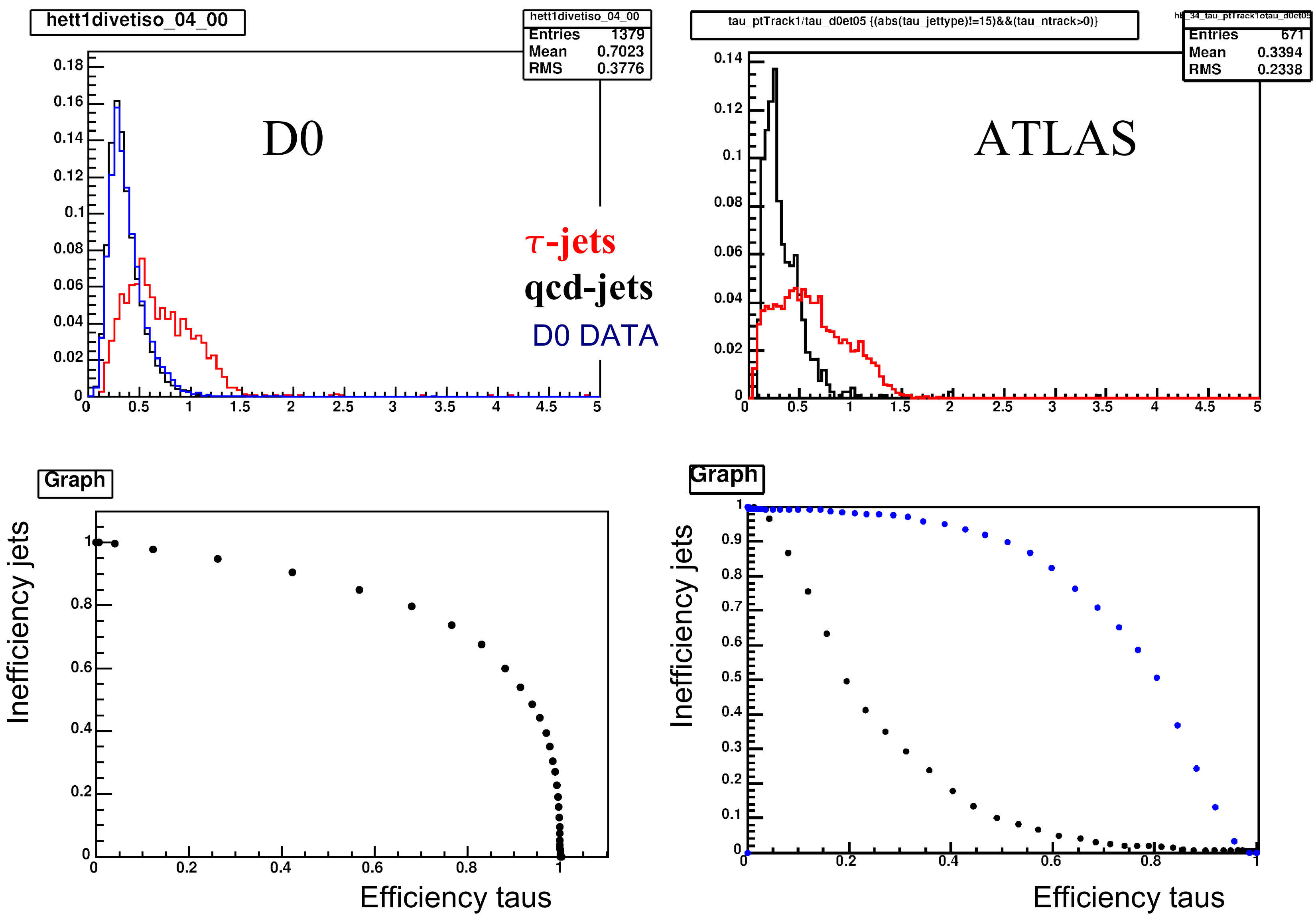




Comparison pT(Tr1)/ET(0.5)

- pT of the leading tracks devided by the total calorimeter energy

- shows a good performance
- distributions are comparable
- the performance shows different behaviour for high efficiency



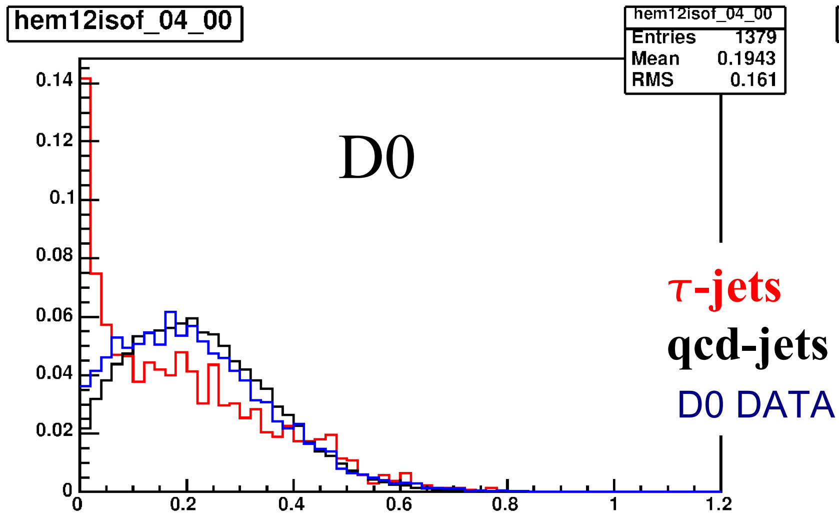
Comparison EM12IsoF

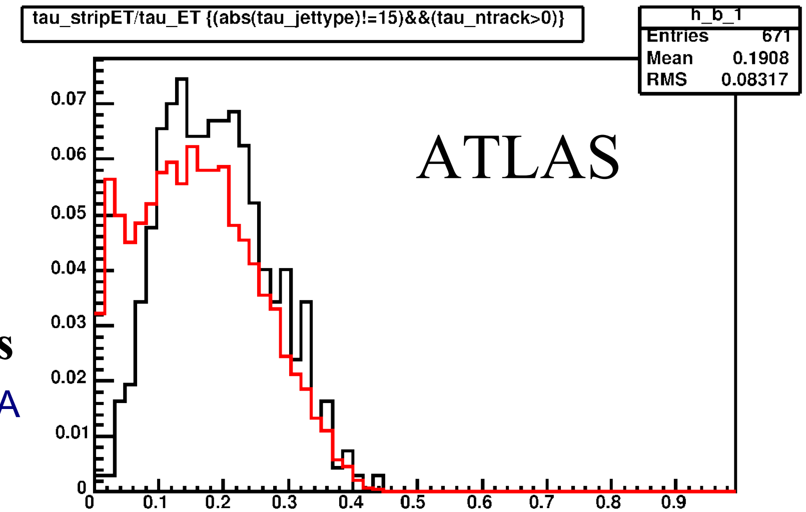
- energy in the first two em layers devided by the total calorimeter energy

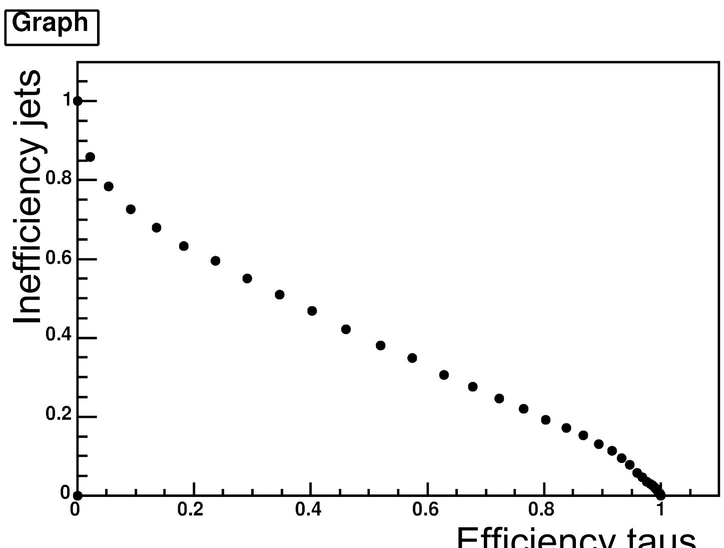
- for ATLAS I used only the eta-strip-layer, but this already has ~4.3X0 → fewer cases were there is no energy

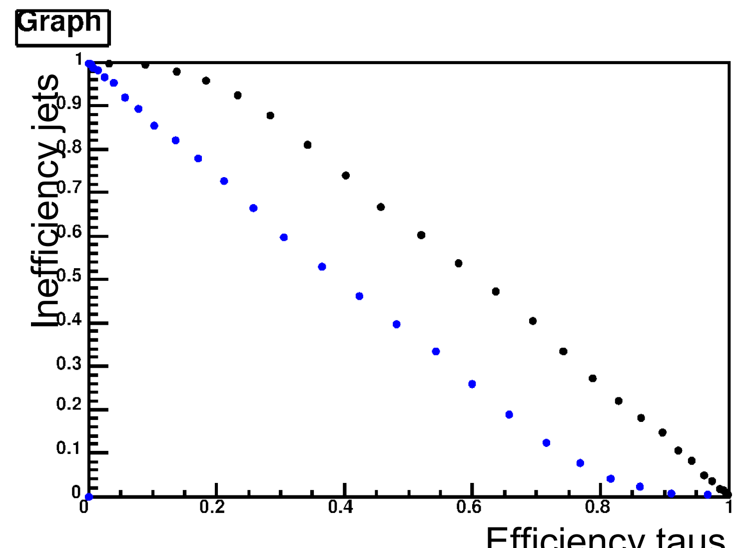
- the resulting distributions are therefore quite different

- the performance shows a different behaviour









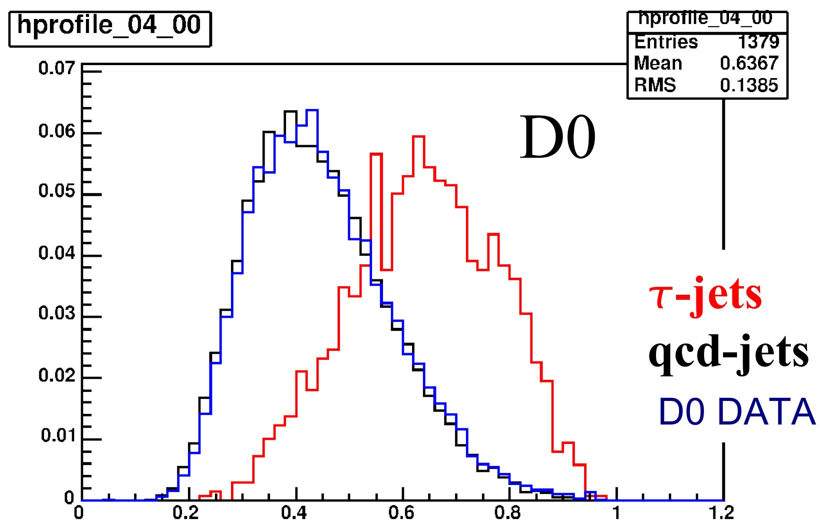
Comparison Profile

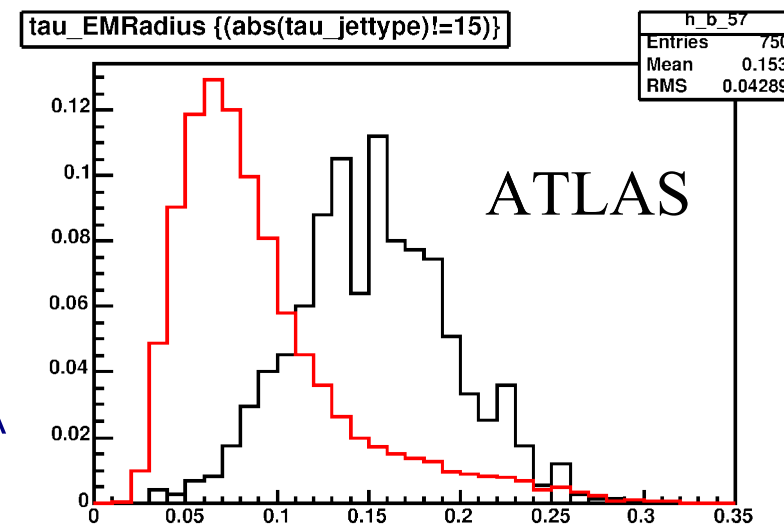
- sorry, don't have the profile for ATLAS yet, the equivalent quantity is EMRadius

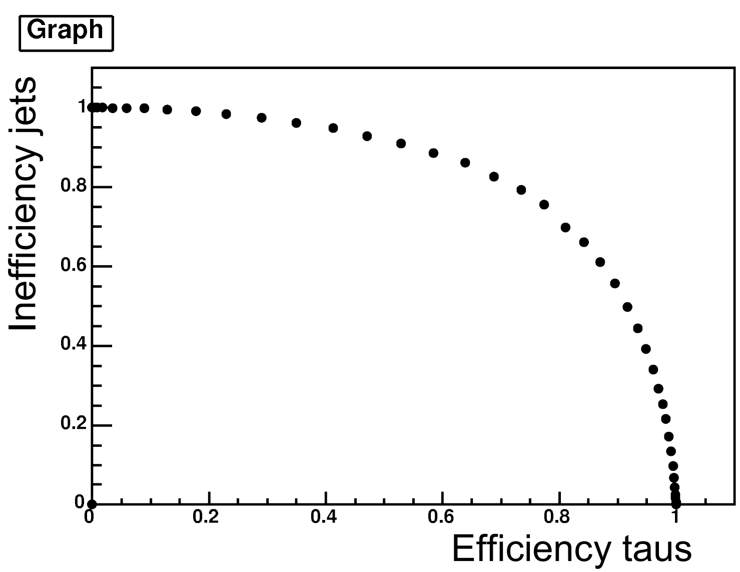
- for both ATLAS and D0 the “profile” is an important variable showing good discrimination

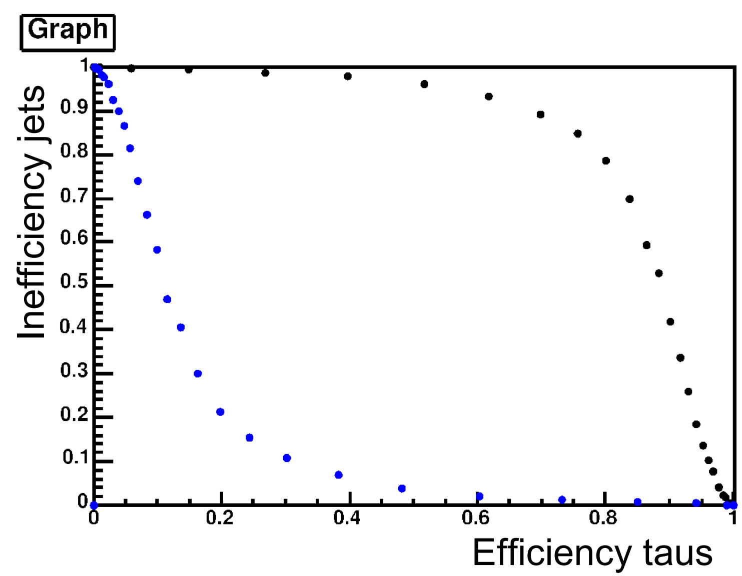
- only for the interest: the distributions are mirrowed but show some similarity

- we will soon have the D0 style profile for ATLAS







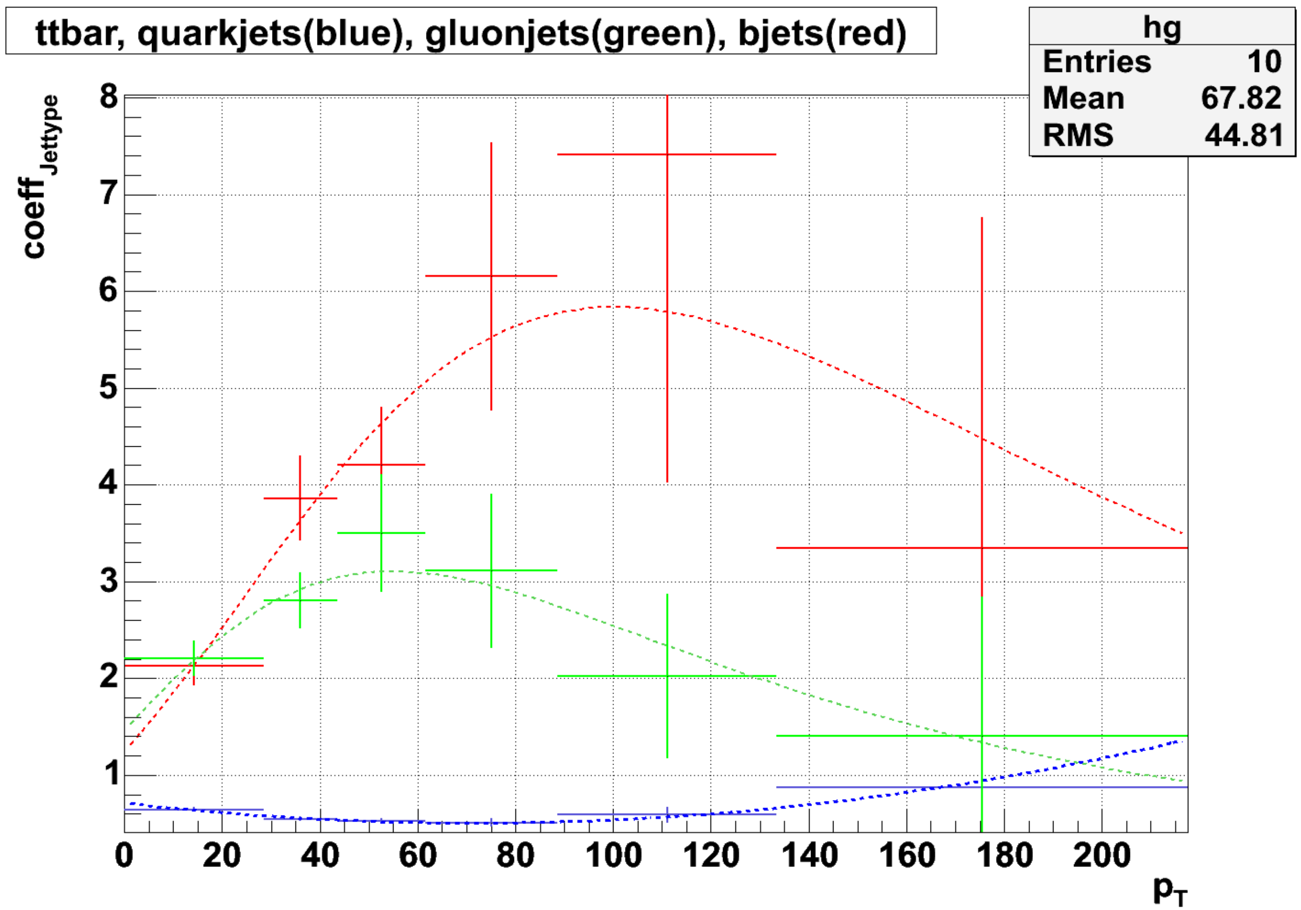


Comparison Performance

- I don't shows plots involving non-tau tracks, because D0 uses tracks down to 200MeV, and I have only > 1.5GeV at the moment
- As stated before the results are not really comparable, but just to give some idea
- we had a first look, cutting on the D0 variables for ATLAS
  - iso < 0.2
  - e1e2/ETt > 0.4
  - pT(Trk1)/ET > 0.25
  - EM12isof < 0.3
  - EMRadius < 0.15
  - **eff = 56%, R=10.6**
- the D0 neural network gives
  - NN eff=57%, R=47 or NN eff=36%, R=125
- for comparison the ATLAS LikelihoodRatio shows
  - LLH eff=57%, R=59 or LLH eff=38%, R=334
- these number are normalized to tau-candidates, so they should be corrected for the reconstruction efficiency for the tau-candidates

Plans

- this project has just begun
- a lot of details have still to be understood and differences made as small as possible (algorithm and samples)
- of course we need to finish the implementation of all variables
- the identification of tau types does not work at ATLAS → need to do something reasonably similar
- the samples have to be choosen carefully and enough statistics has to be available



  - at ATLAS we see that the rejection varies very much with the type of jet you are rejecting

Plans

- → the samples we use for comparisons (also for the backgrounds) should be as similar as possible
- they should match in p_T, η, and jettype

- → will probably use W+jet in the future for jets, sticking to $Z \rightarrow \tau\ \tau$ for τs
- the preselection of D0 data should be imitated selecting the samples for ATLAS
- the p_T and η distribution of taus and jets should be as similar as possible
- the influence of the reconstruction has to be understood (perhaps normalizing to jets, but also the jets may show differences)
- → make a nice comparison between D0 MC, D0 data and ATLAS MC

TeV for LHC(3)