Tau Lepton Identification at the ATLAS Experiment

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PhD Discovery Day

22 May 2012

Motivation

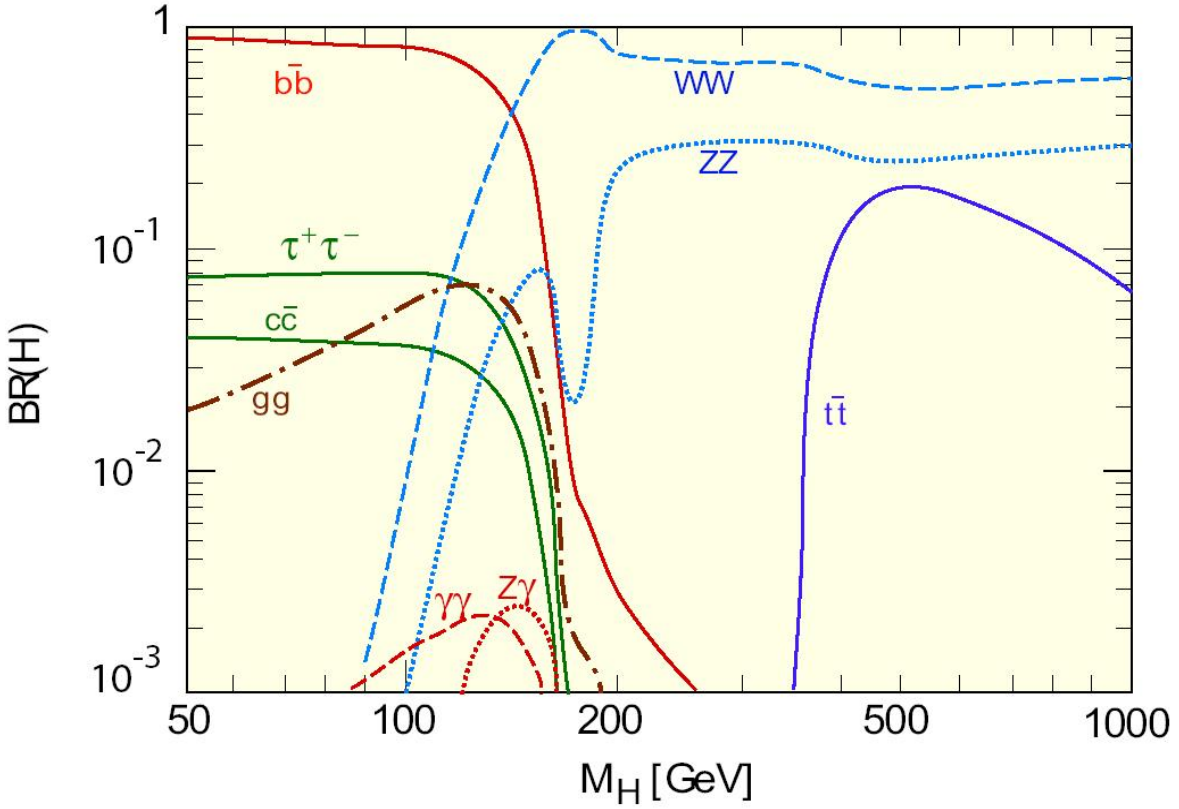
Hadronic Tau Decay

Tau ID and Pileup

Motivation

Tau leptons are important (!!!) ….

- Higgs searches
- Searches for physics beyond the SM



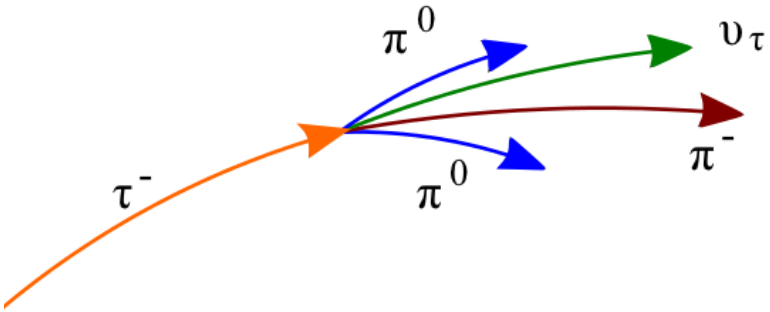
http://www.hep.ph.ic.ac.uk/cms/physics/higgs.html

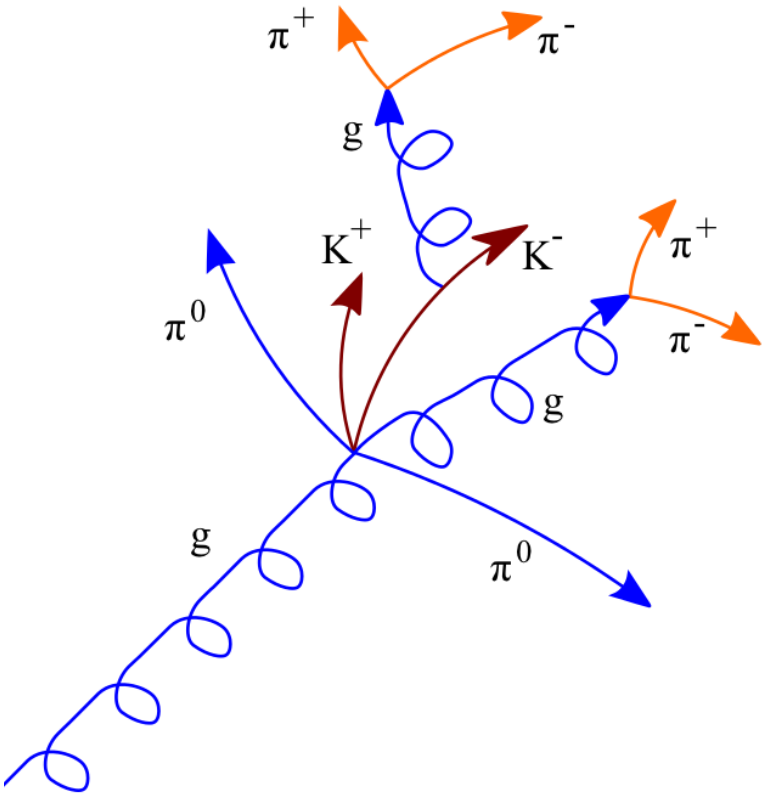
… but really hard to find!

τ_{had} Decay

- One or three tracks
- Opening angle of decay cone limited by ~m_τ / E_τ
  - -> little spread of tracks
  - -> small shower width
- Secondary vertex for three prong decay

--> use discriminating variables to distinguish taus from QCD jets





Tau ID and Pileup

My work in the last half year:

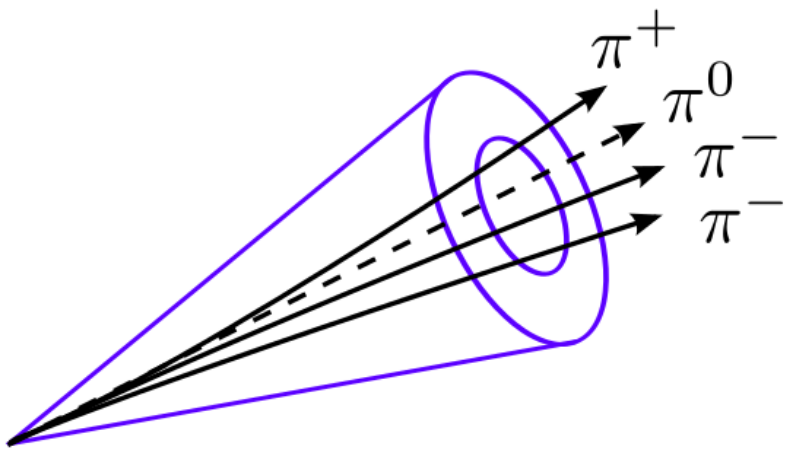
Pileup Robustness of the Tau ID for 2012

- Multiple interactions per bunch crossing: pileup
- More pileup
  - more QCD jets per event
  - more activity in the detector
- Discriminating variables need to be optimised to be robust agains pileup

Tau ID and Pileup

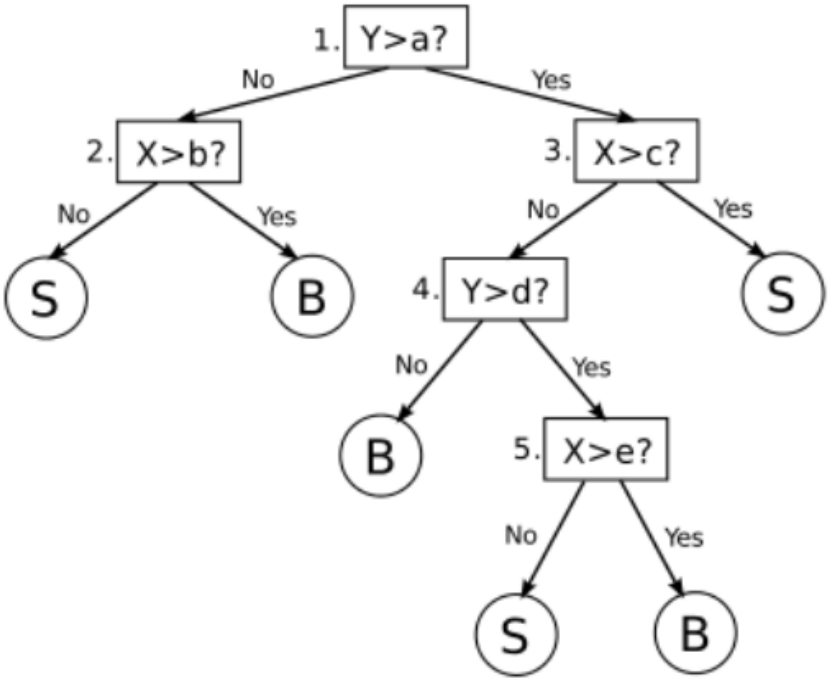
How to achive pileup robustness?

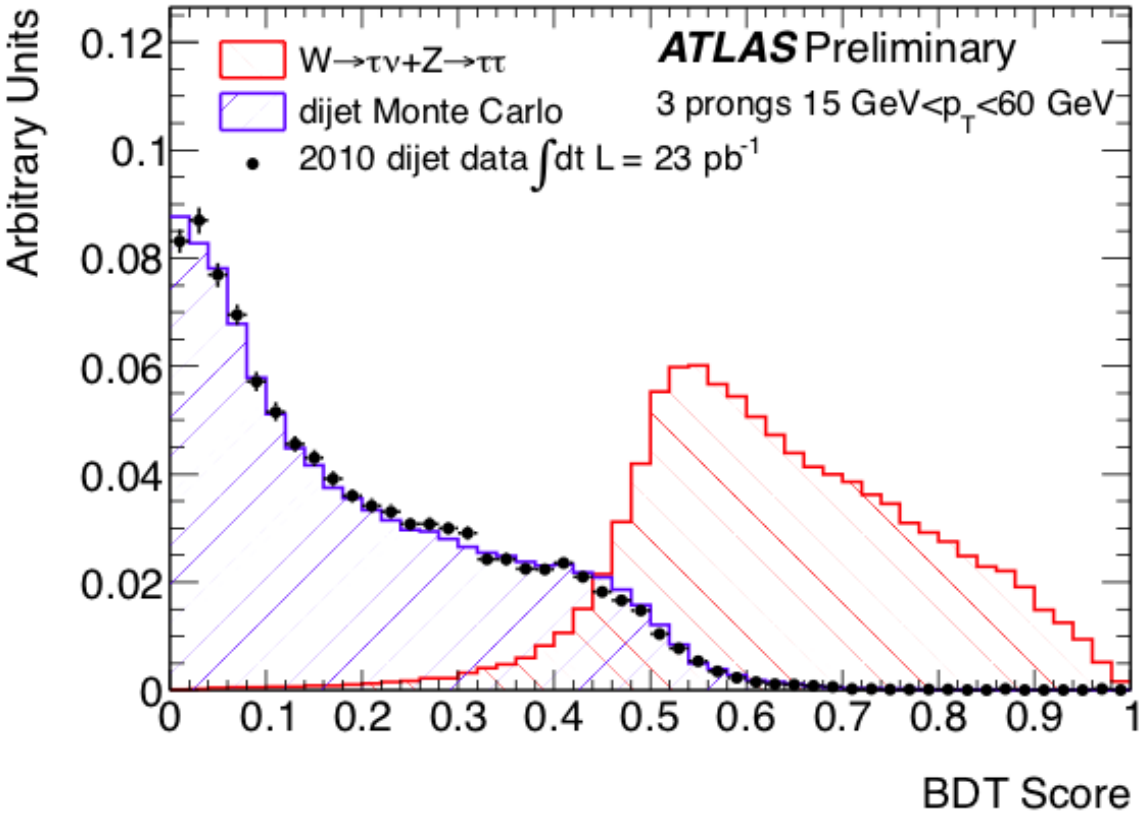
- Reduce number of variables
- Reduce cone size
- Correction of pileup dependend variables



Tau ID and Pileup

Tau Identification using a Boosted Decision Tree

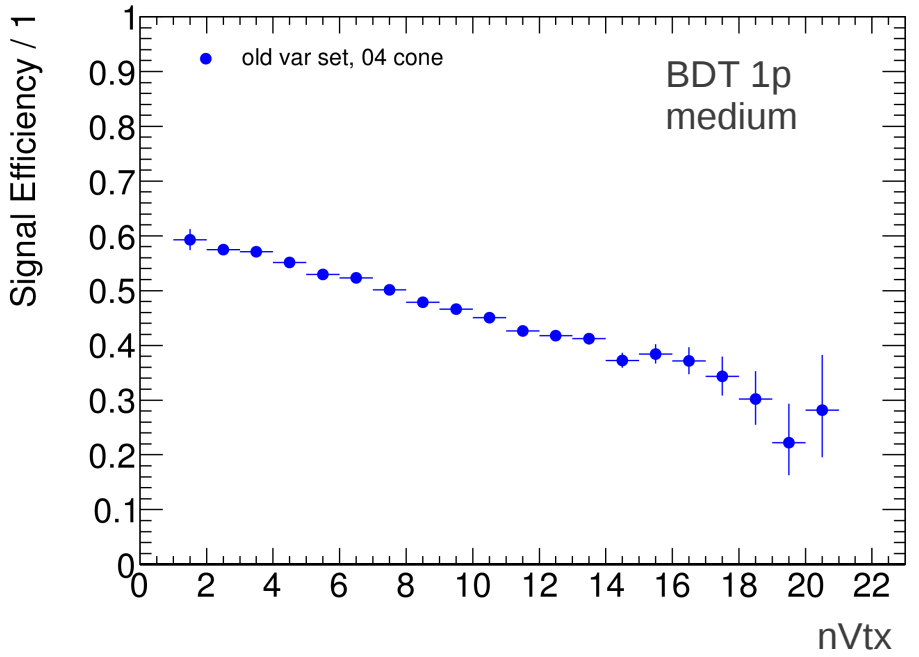


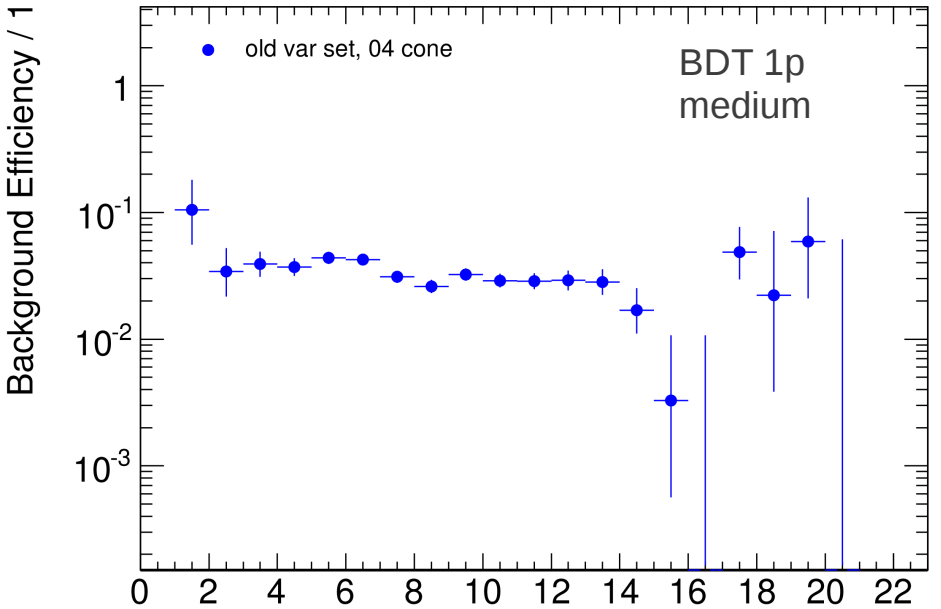


Tau ID and Pileup

old variable set (04 cone):

- centrality fraction
- calo radius
- leading 3 cluster energy over all cluster energy
- eff topo inv mass
- ftrk (etOverPtLeadTrk)
- trk avg dist
- number of wide tracks
- ip sig lead track (1p)
- max dR (3p)
- mass track system (3p)
- track flight path sig (3p)

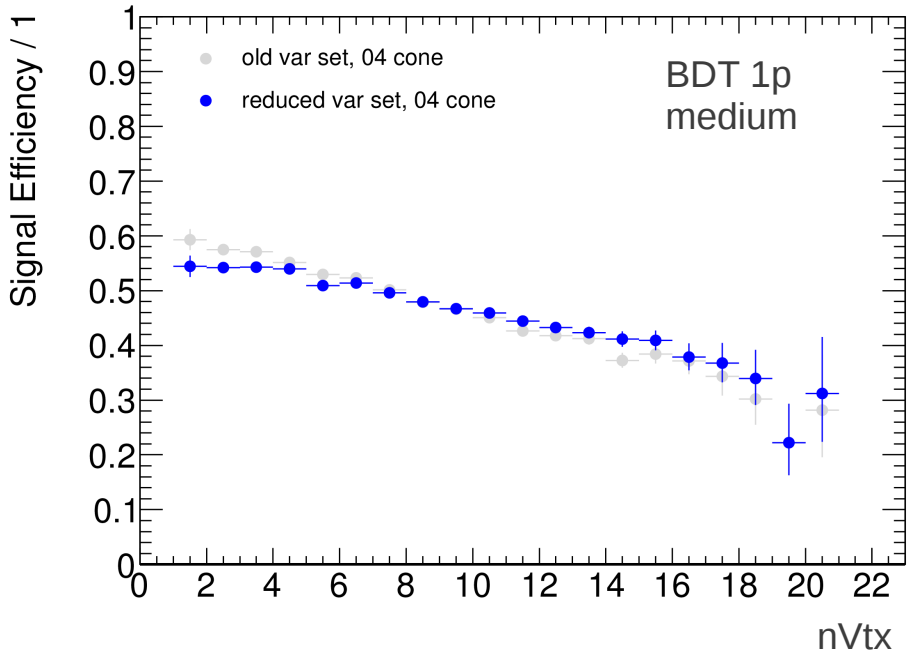


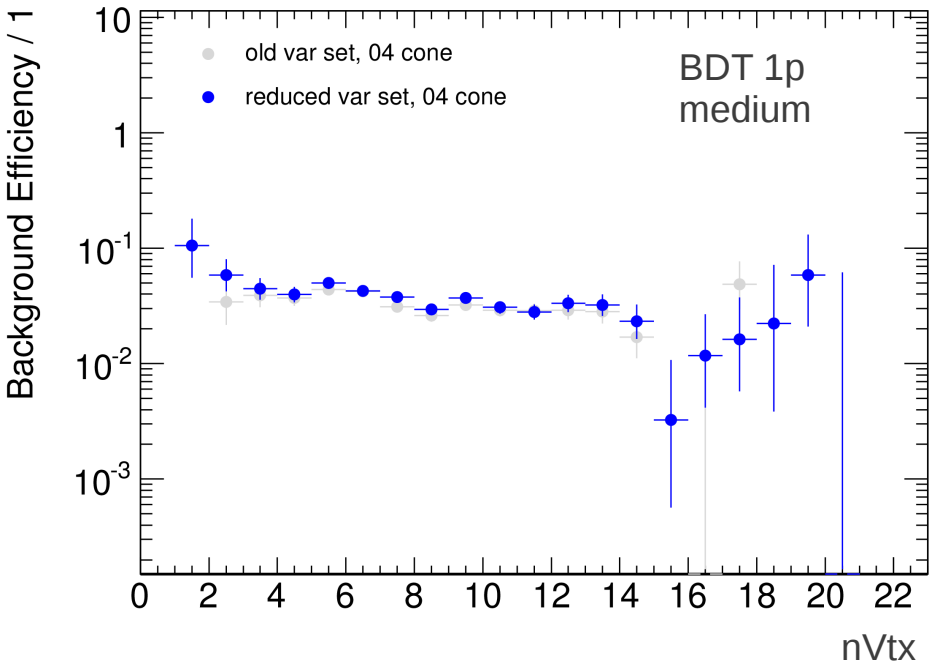


Tau ID and Pileup

reduced variable set (04 cone):

- centrality fraction
- ftrk (etOverPtLeadTrk)
- trk avg dist
- number of wide tracks
- ip sig lead track (1p)
- max dR (3p)
- mass track system (3p)
- track flight path sig (3p)

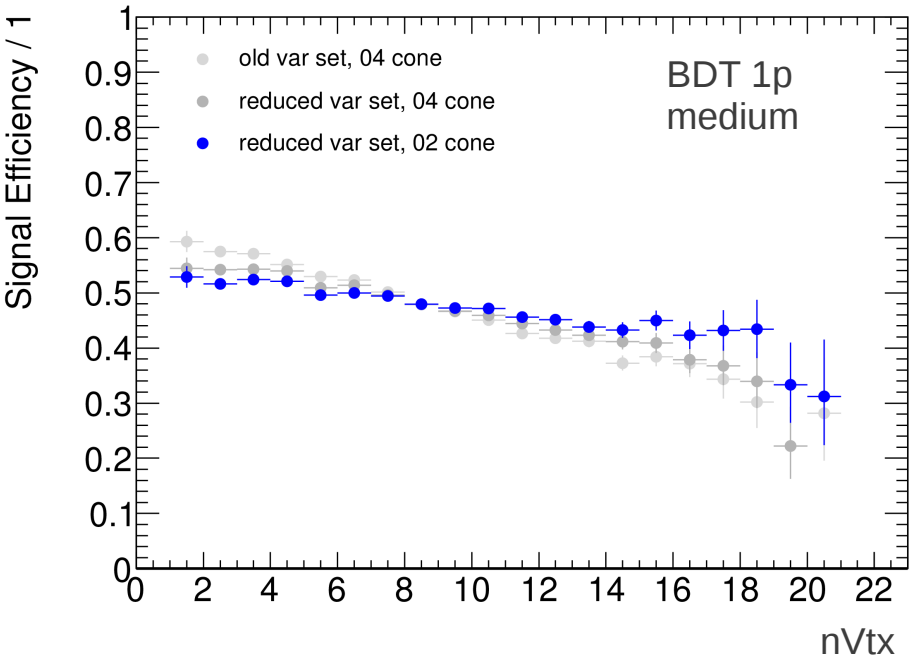


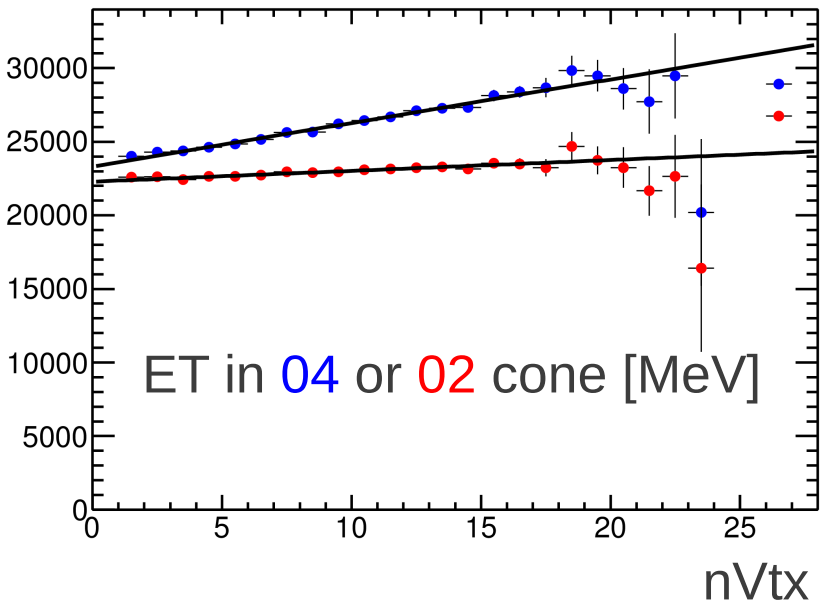


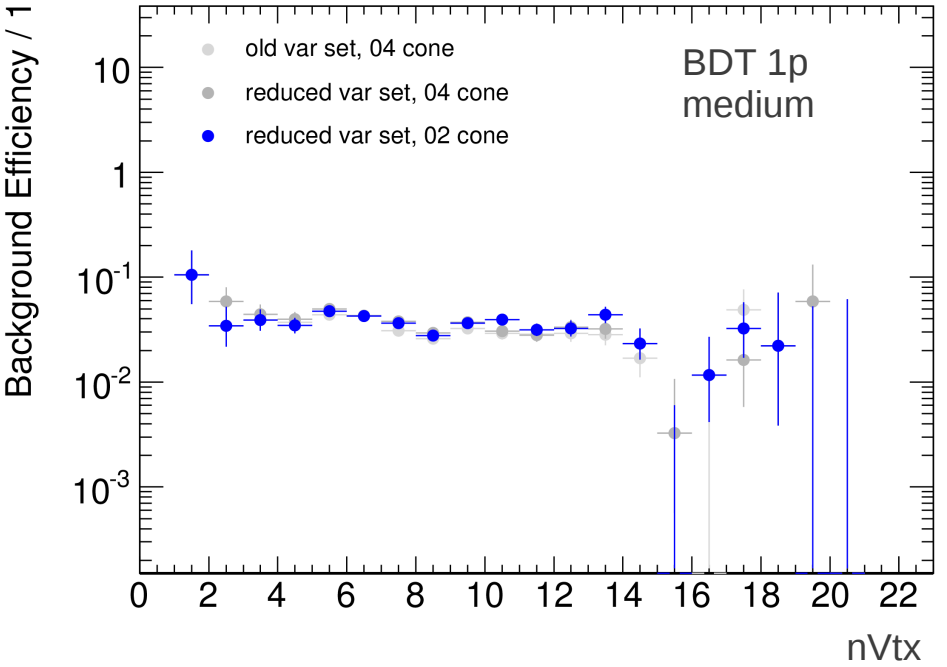
Tau ID and Pileup

reduce cone size:

- calculate calorimeter variables in smaller cone
- keep track variables unchaged







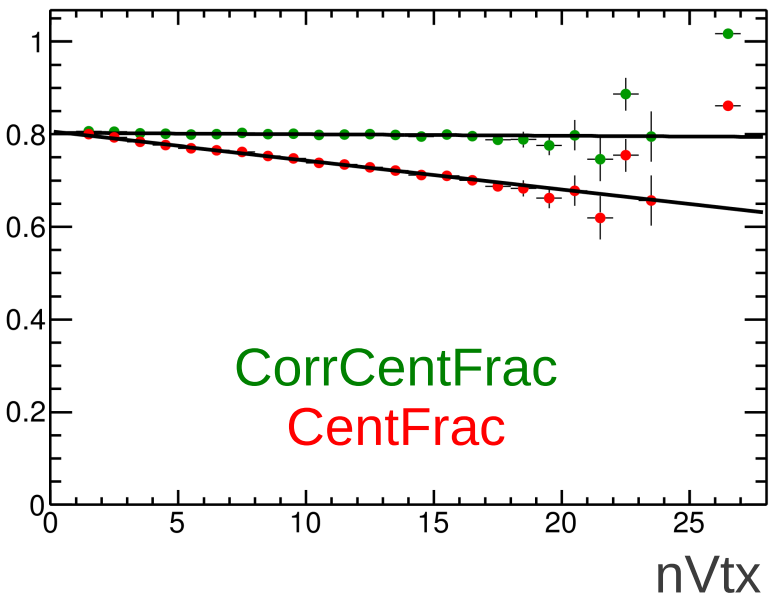
Tau ID and Pileup

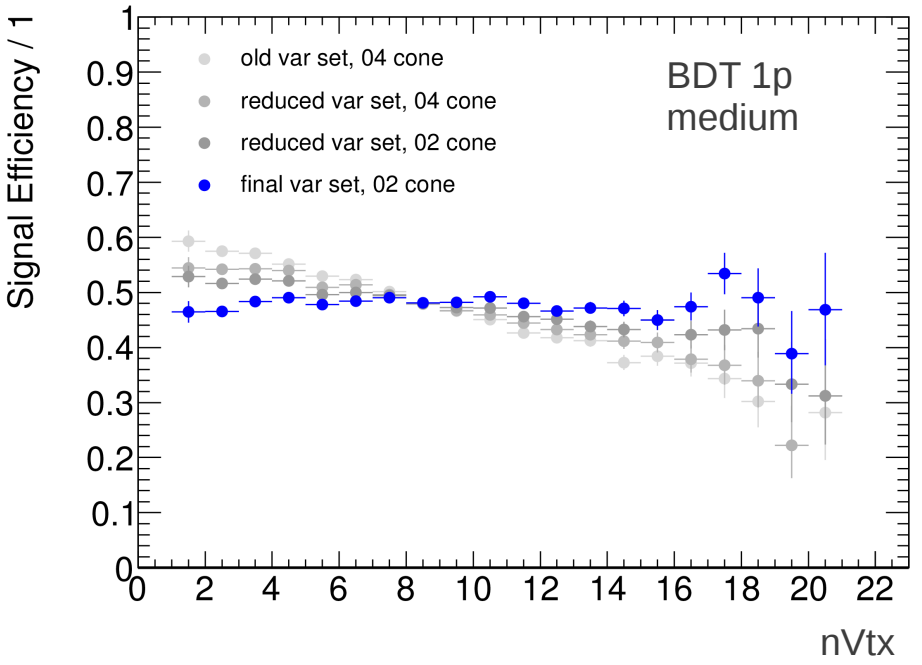
corret variables:

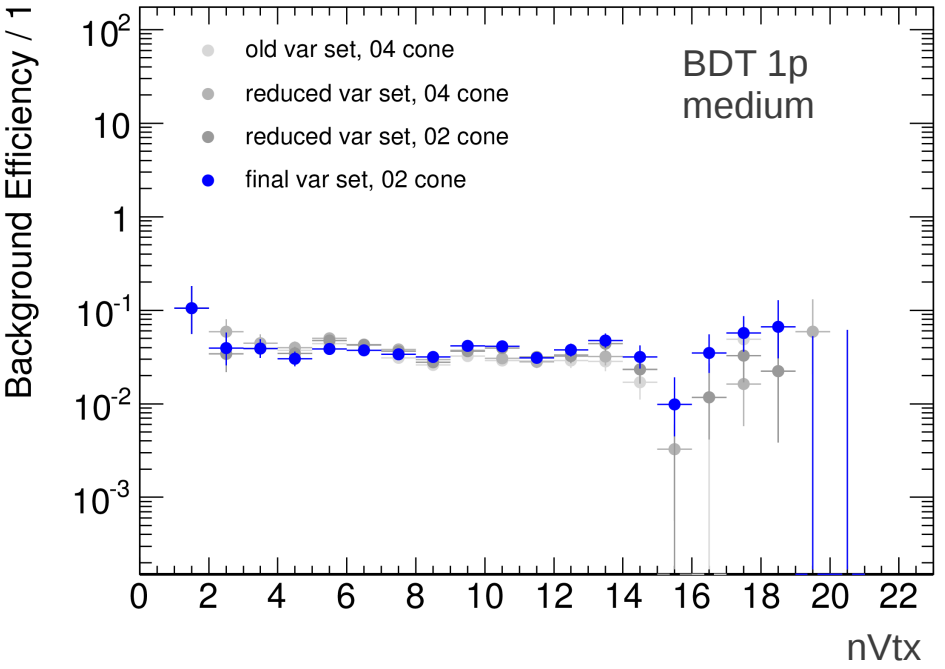
- apply pileup correction to calorimeter variables: eg.

  CorrCentFrac = CentFrac + 0.006 * nVtx

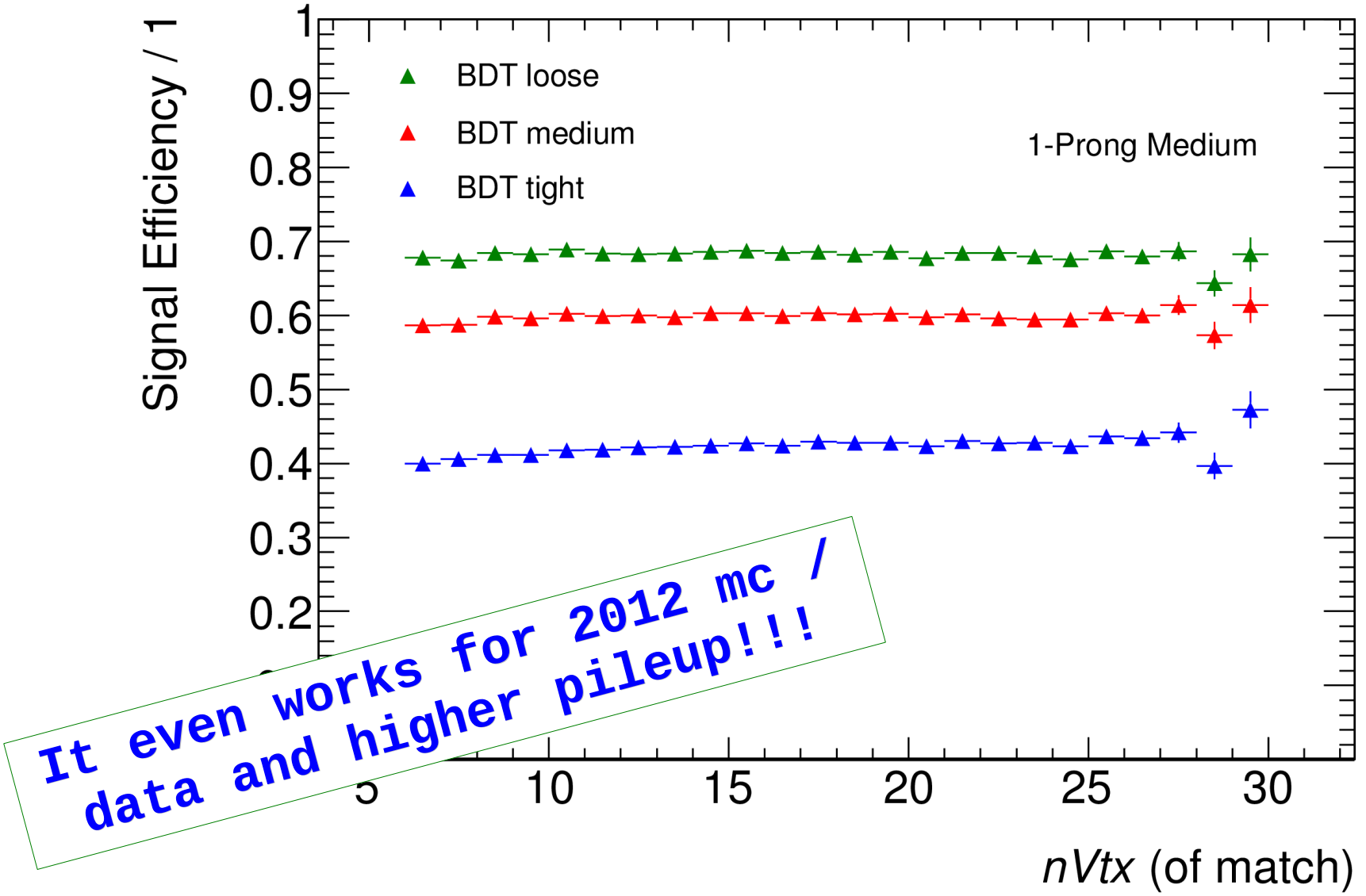
- keep track variables unchaged







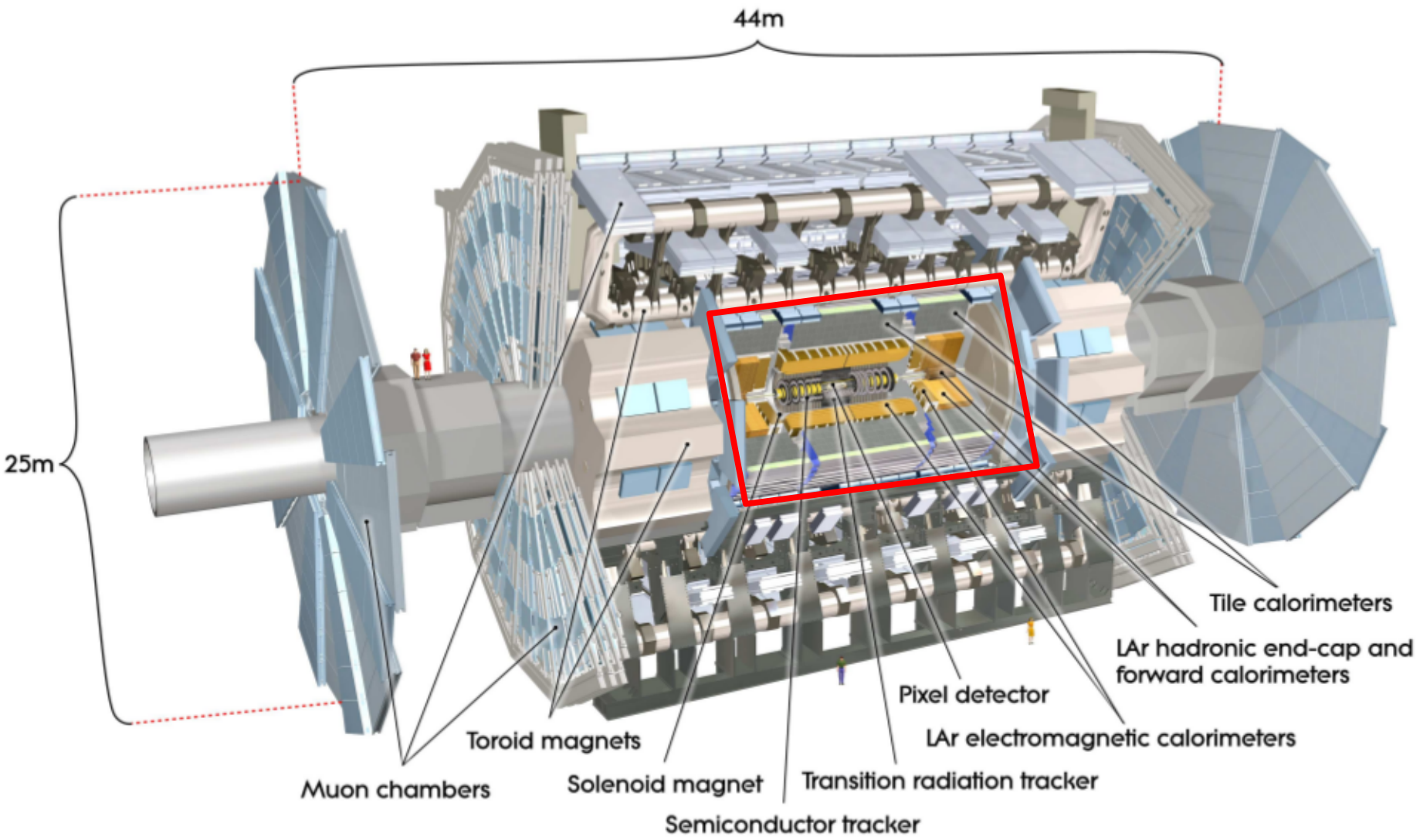
Tau ID and Pileup (2012)



It even works for 2012 mc / data and higher pileup!!!

Backup

The ATLAS Experiment



The ATLAS Collaboration, G. Aad et al.,
The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.

The Tau Lepton

- Heaviest lepton: m = 1777 MeV
- Lifetime: ct = 87 μm
- Decay:
  - Leptonic decay: ~35%
    - $\tau^{\pm} \rightarrow e^{\pm} \nu_e \nu_\tau$
    - $\tau^{\pm} \rightarrow \mu^{\pm} \nu_\mu \nu_\tau$
  - Hadronic decay: ~65%
    - one prong: $\tau^{\pm} \rightarrow \pi^{\pm} X\pi^0 \nu_\tau$
    - three prong: $\tau^{\pm} \rightarrow \pi^{\pm} \pi^{+} \pi^{-} X\pi^0 \nu_\tau$

Discriminating Variables

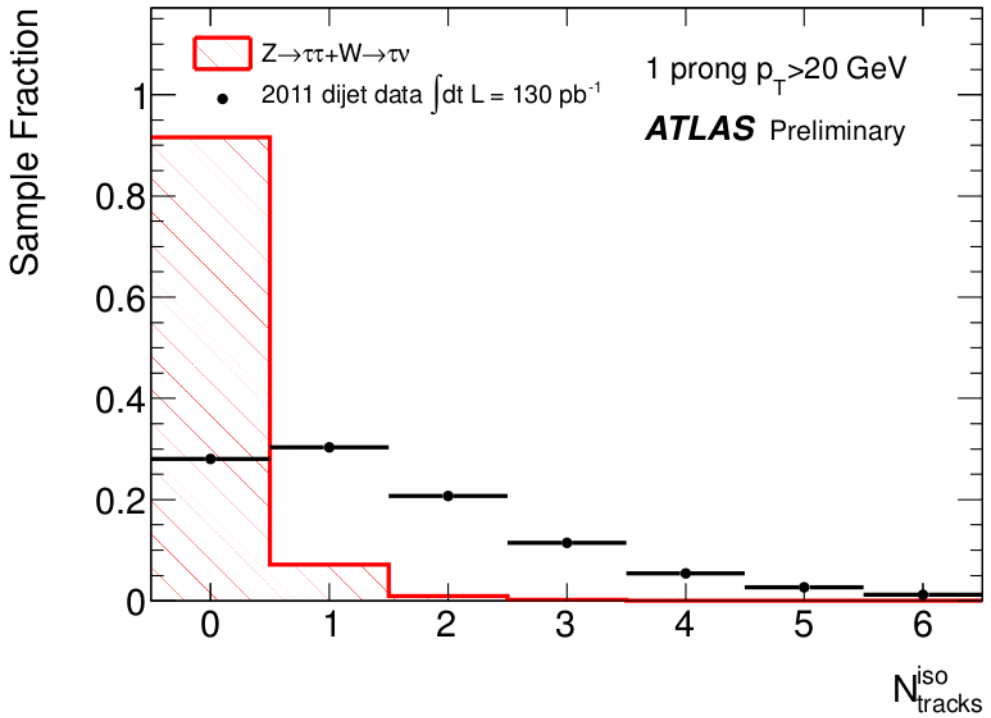
Track radius	p_T weighted track distance
Leading track momentum fraction	Fraction of leading track momentum
Core energy fraction	Fraction of transverse energy within dR < 0.1
Number of isolation tracks	Number of tracks in isolation annulus: 0.2 < dR < 0.4
Calorimetric radius	E_T weighted shower width in the calorimeter
Cluster mass	Invariant mass of clusters
Track mass	Invariant mass of core and isolation tracks
Transvere flight path significance	Decay length significance of the secondary vertex
Leading track IP significance	Impact parameter significance of the leading track
First 2 or 3 leading cluster energy ratio	Fraction of energy in leading two or three clusters
Maximum dR	maximum dR between tau axis and a core track
Corrected cluster isolation energy	transverse energy of calorimeter clusters with pileup correction

Discriminating Variables

Track radius	Cuts, Llh, BDT
Leading track momentum fraction	Cuts, BDT
Core energy fraction	Llh, BDT
Number of isolation tracks	Cut, Llh (1p), BDT
Calorimetric radius	Llh (1p), BDT
Cluster mass	BDT
Track mass	Llh (3p), BDT (3p)
Transvere flight path significance	Cuts (3p), Llh (3p), BDT (3p)
Leading track IP significance	BDT
First 2 or 3 leading cluster energy ratio	Llh (1p), BDT
Maximum dR	Llh (3p), BDT (3p)
Corrected cluster isolation energy	Cuts

$$dR = \sqrt{(\Delta\varphi)^2 + (\Delta\eta)^2}$$

Discriminating Variables

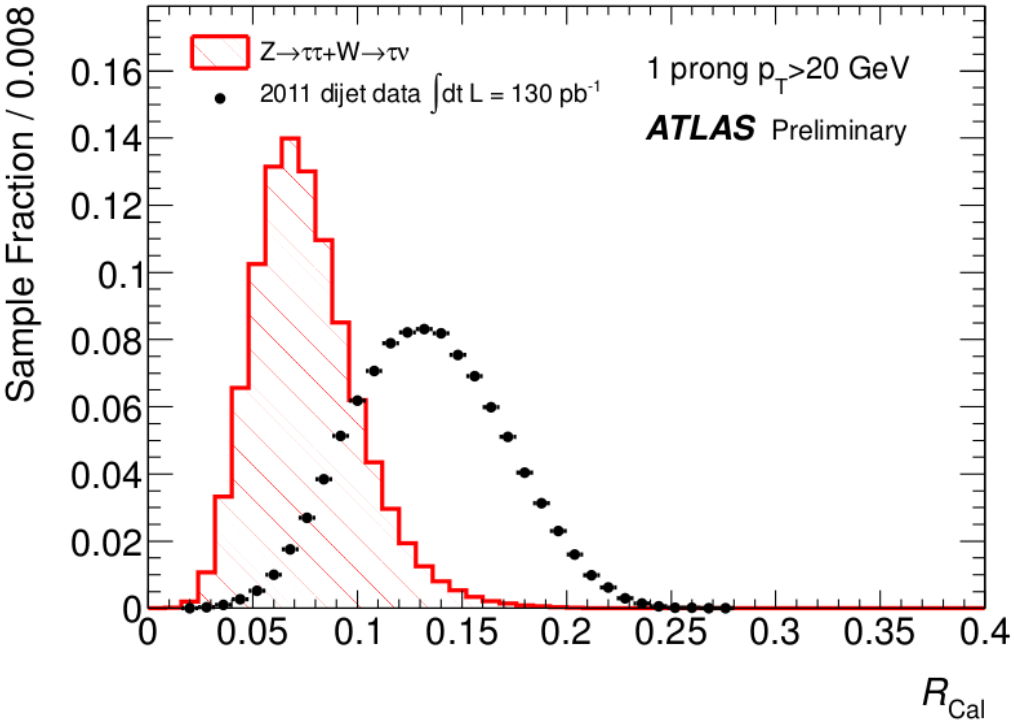


Number of Isolation Tracks

Number of tracks in the isolation annulus
(0.2 < dR < 0.4)

Calorimetric Radius

E_T weighted shower width in the calorimeter



"Performance of the Reconstruction and Identification of Hadronic Tau Decays with ATLAS"
ATLAS-CONF-2011-152

Efficiency Definitions

- signal eff:

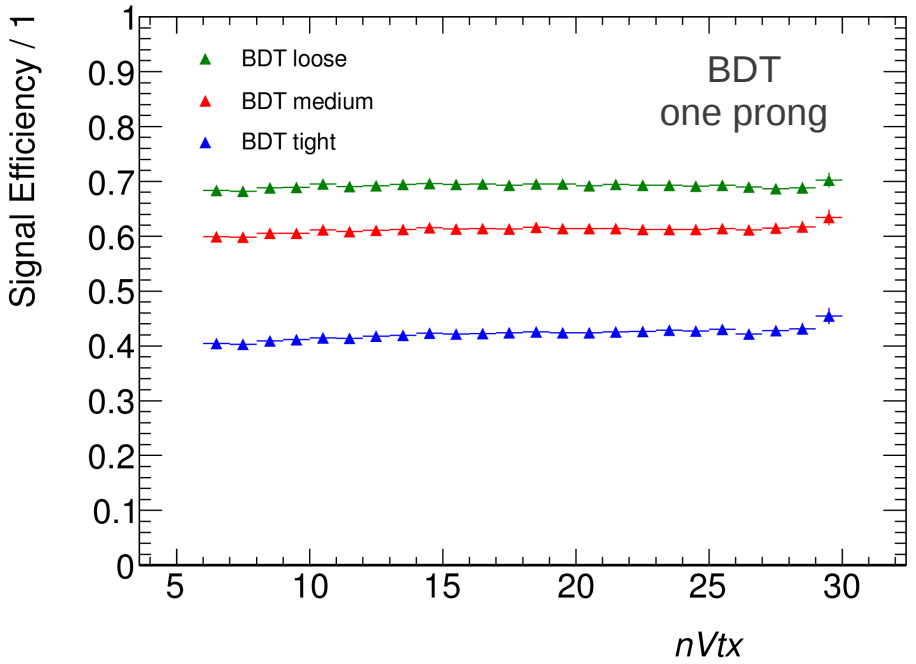
$$\frac{\text{(number of truth matched taus with N tracks, passing ID)}}{\text{(number of true taus with N tracks)}}$$

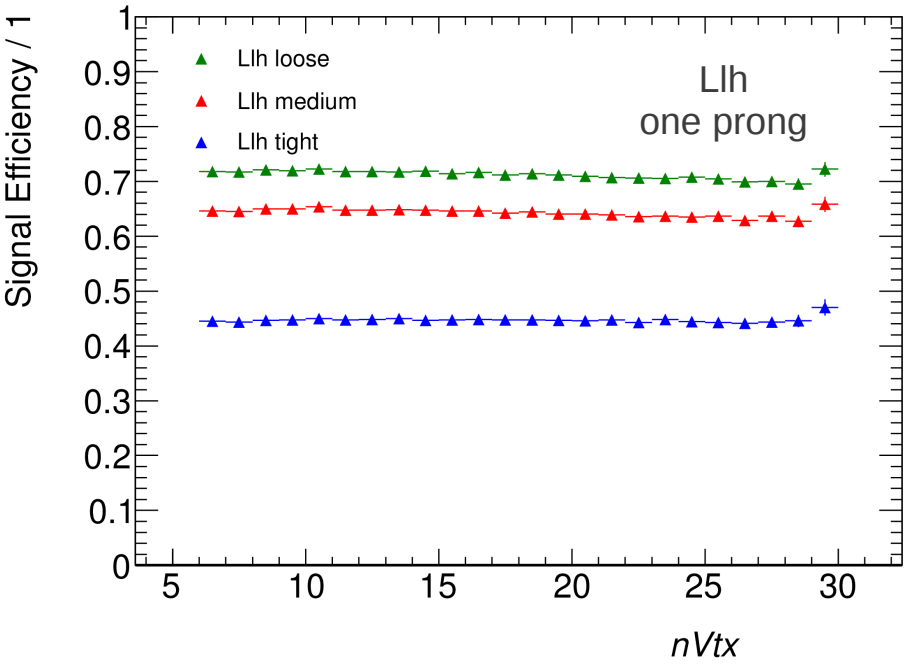
- background eff:

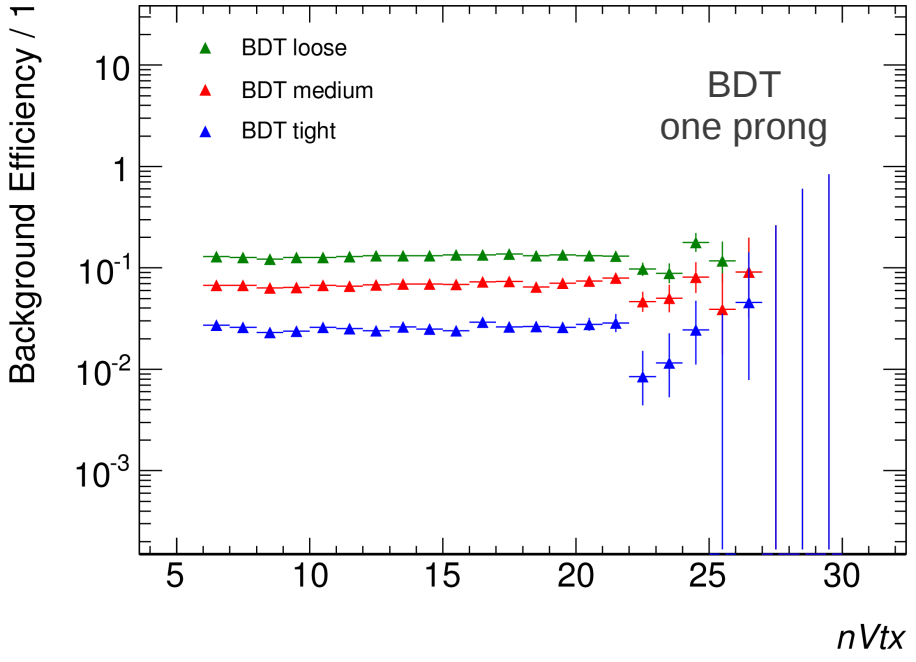
$$\frac{\text{(number of taus with N tracks, passing ID)}}{\text{(number of taus with N tracks)}}$$

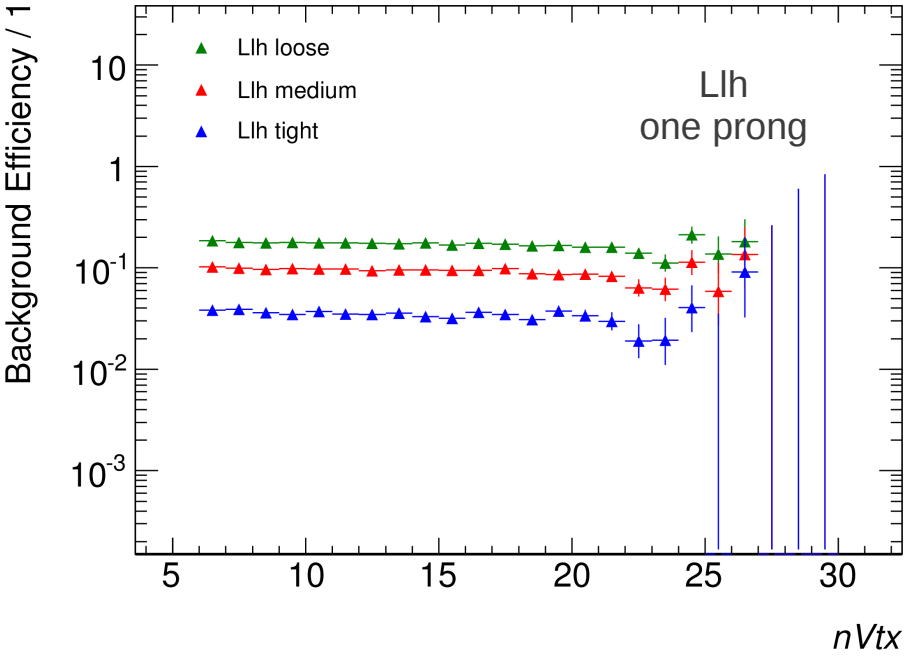
- with N being 1 for one prong taus (1p), and 2 or 3 for multi prong taus (mp)
- target signal efficiencies for loose, medium, tight are 70%, 60%, 40% for 1p and 65%, 55%, 35% for mp

Tau ID – Performance 2012 – 1p









Tau ID – Performance 2012 - mp