Search for New Physics with Boosted Tau Pairs

David Kirchmeier

16th Block Course of the GRK 1504
“Mass, Spectrum, Symmetry”
13 Mar 2017

TECHNISCHE UNIVERSITÄT DRESDEN

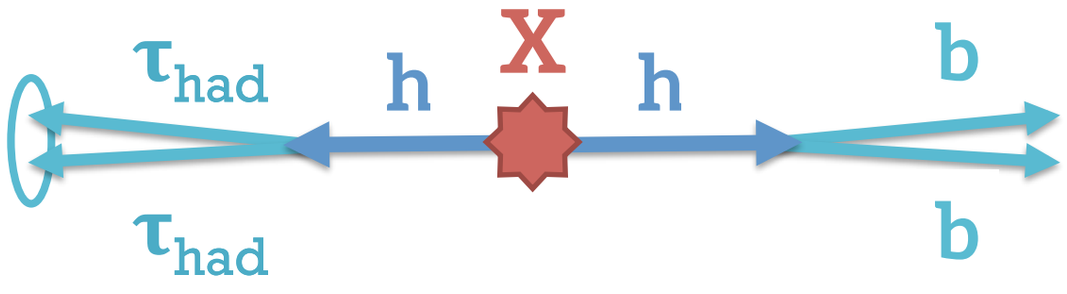
ATLAS EXPERIMENT

FSP 103 ATLAS

GRADUIERTEN KOLLEG Masse-Spektrum-Symmetrie

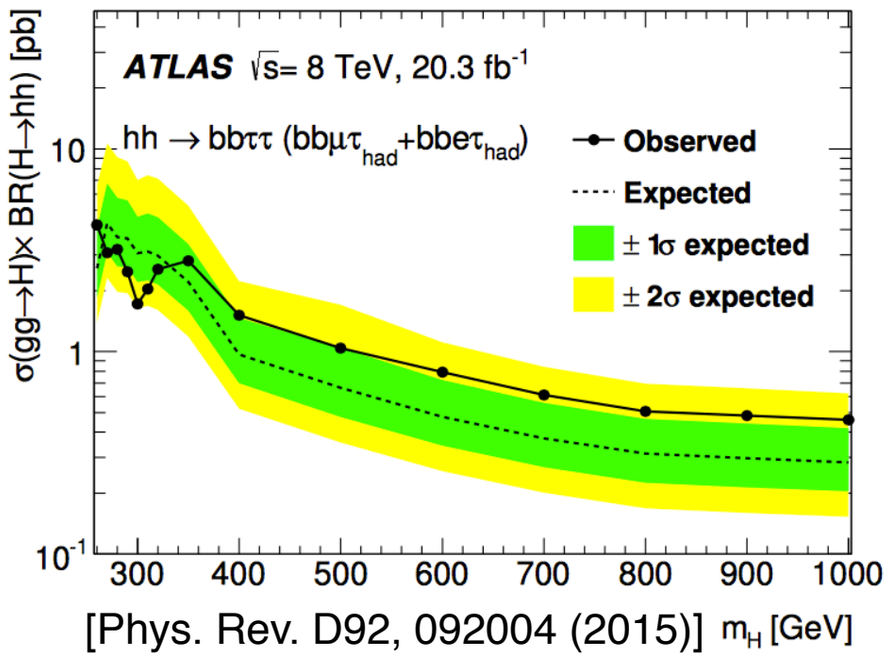
ıktp

Motivation

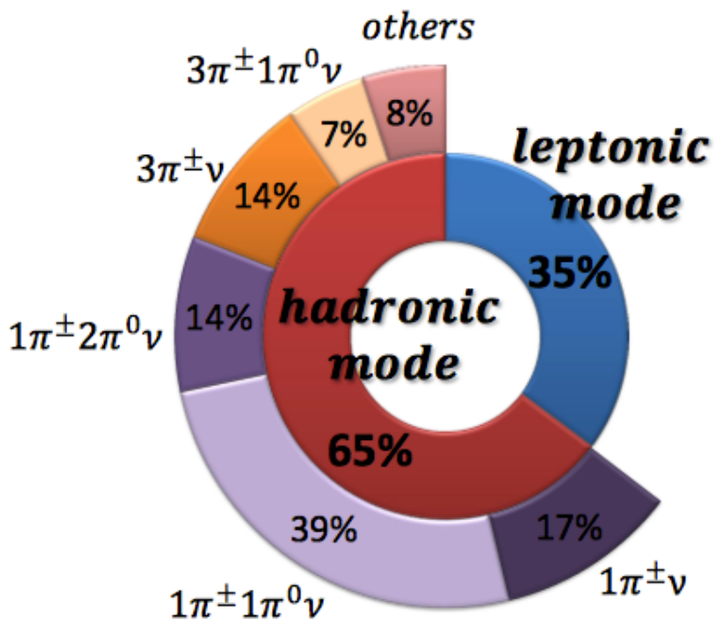


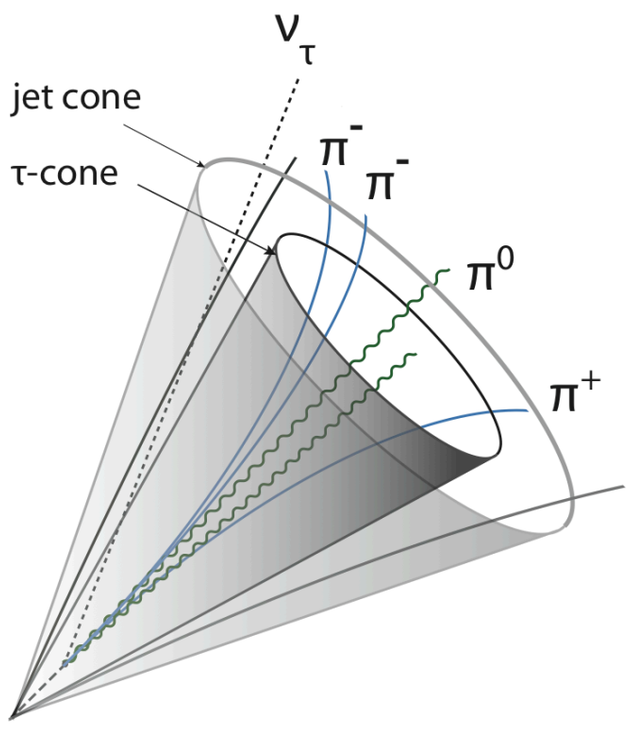
- Since discovery of h significant progress in measuring its coupling strengths, spin and CP properties

- **X** = SM Higgs boson h
  = Heavy Higgs boson H
  = Graviton G^*_{KK}



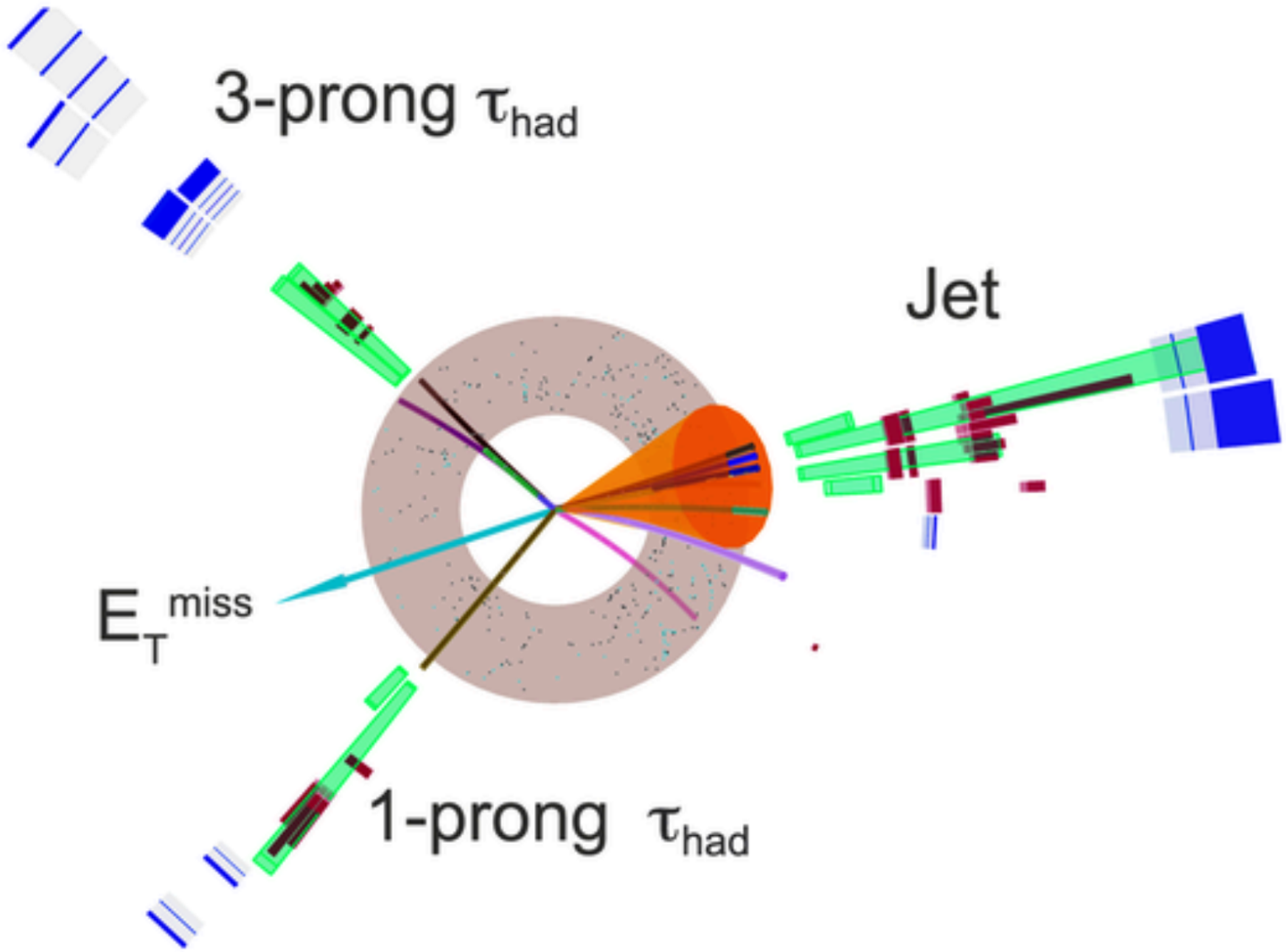
Tau Lepton Decay



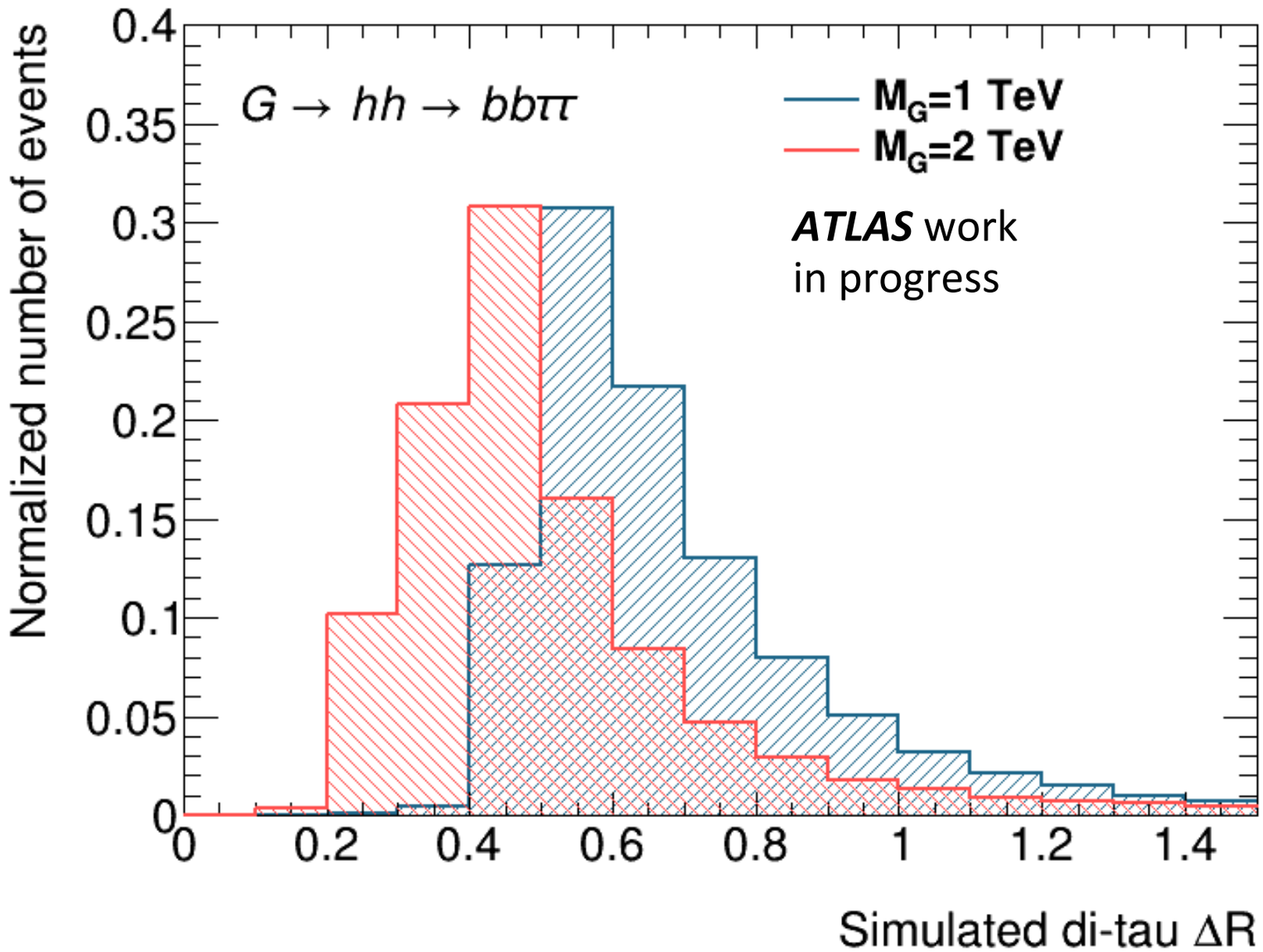


- Higgs decay in tau pairs with third highest branching ratio
- Hadronic mode with 65% BR
- Reconstruction of τ_{had} based on jet seeds
- QCD jet background separation achieved with Boosted Decision Trees

Tau Lepton Decay



Decay in Boosted Tau Pairs



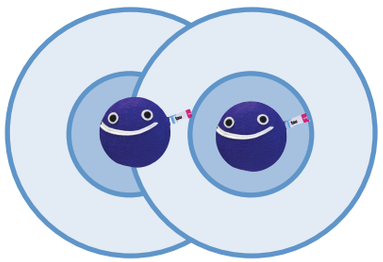
$$\Delta R = \sqrt{(\eta_1 - \eta_2)^2 + (\phi_1 - \phi_2)^2}$$

Single Tau Reconstruction

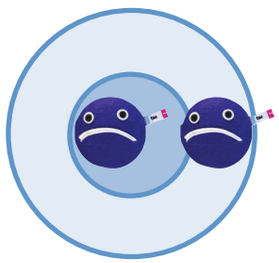
- Standard tau reconstruction in ATLAS is based on anti-k_T algorithm with distance parameter $R = 0.4$

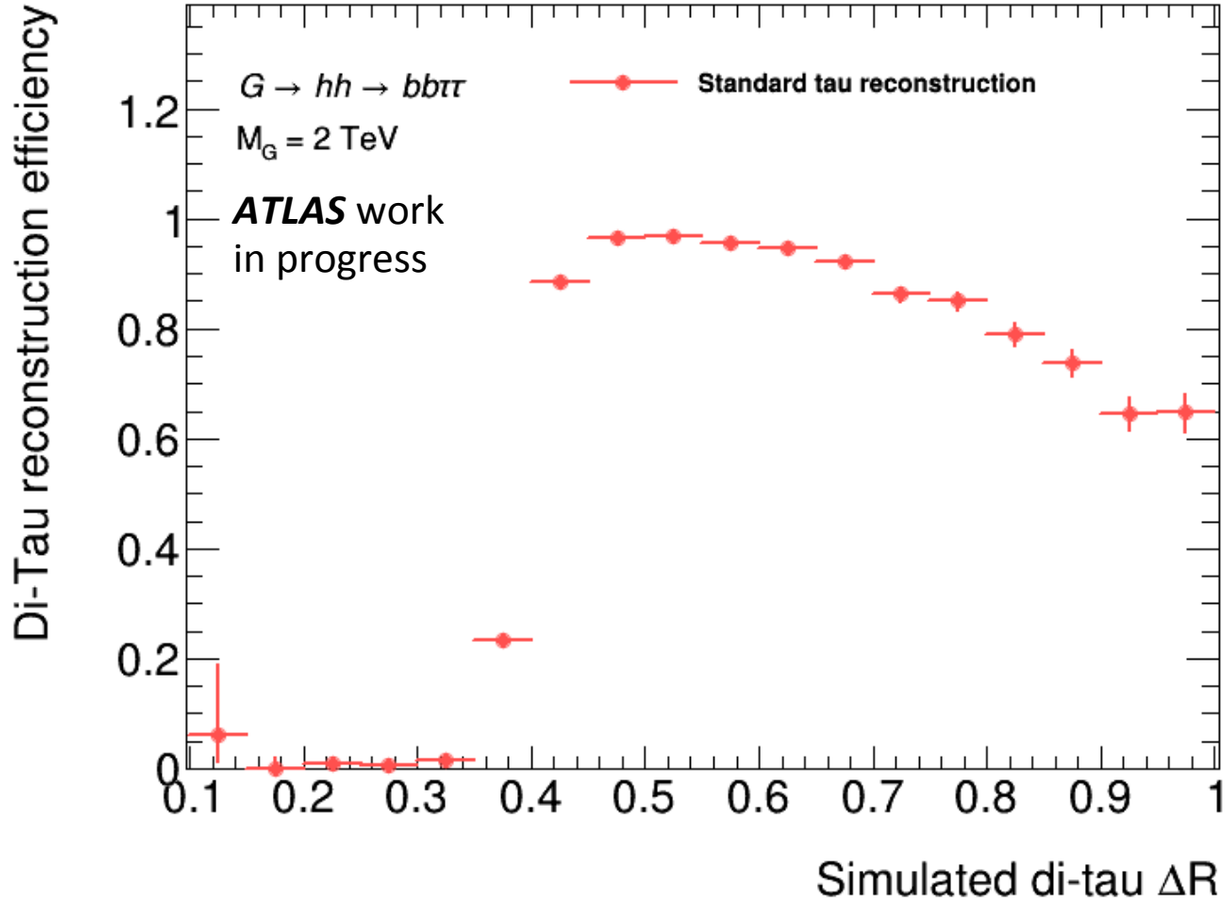
- Tau pairs closer than $\Delta R = 0.4$ tend to merge into one tau candidate

$\Delta R \geq 0.4$

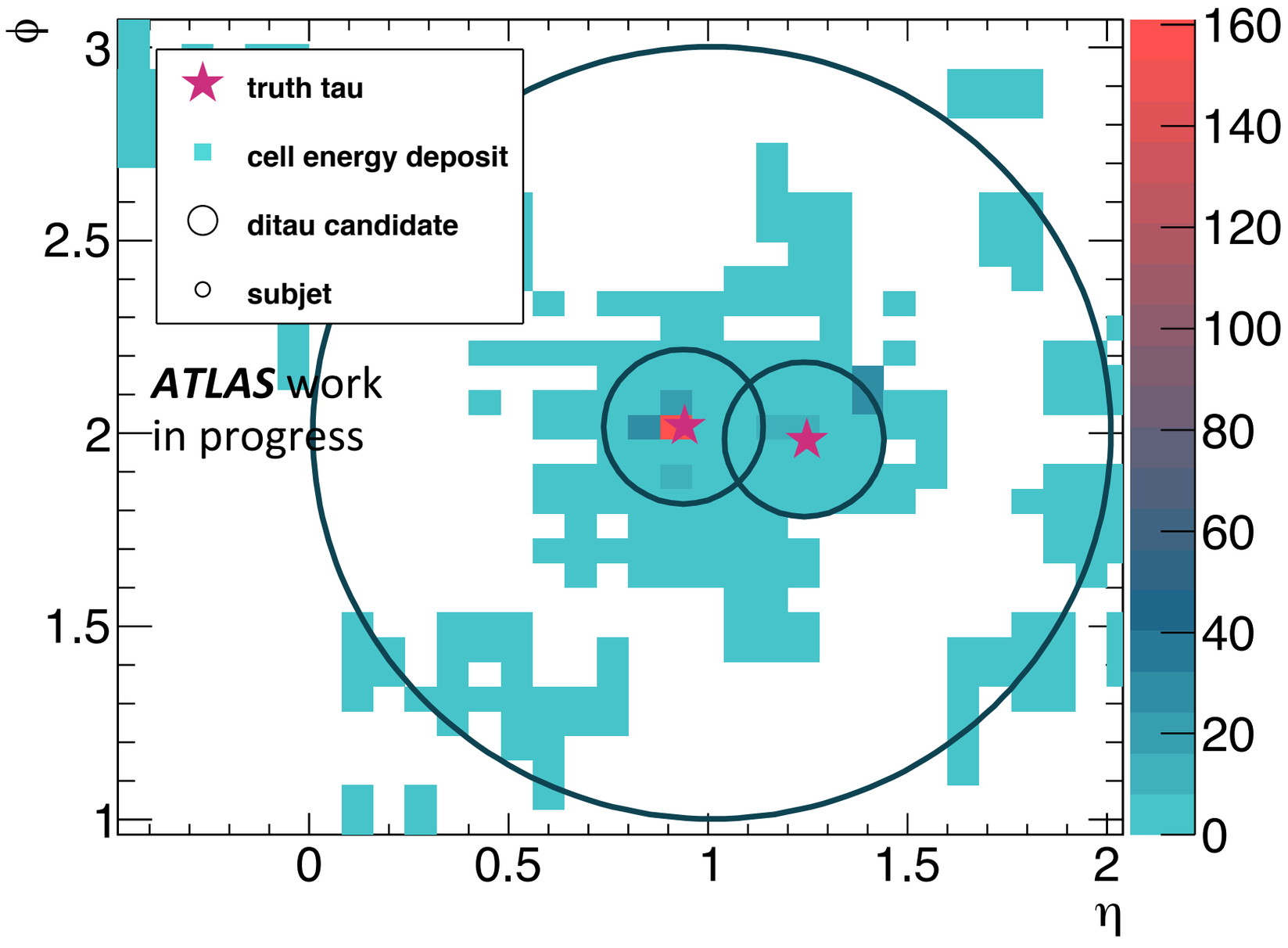


$\Delta R < 0.4$





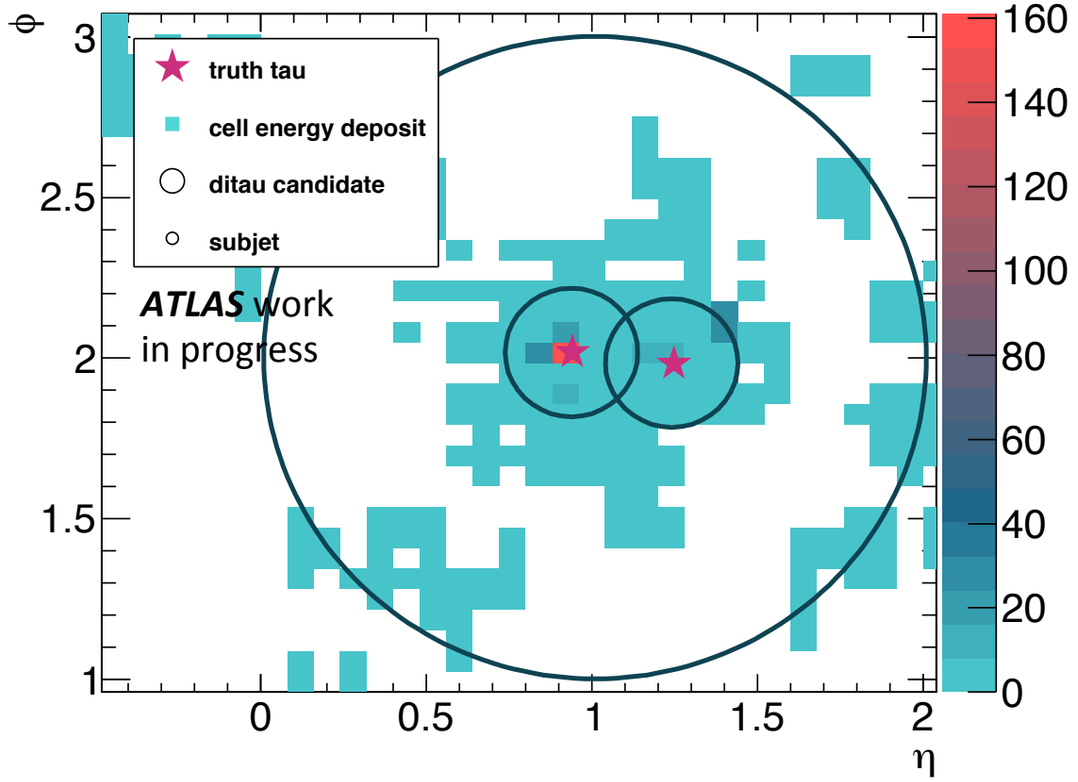
Di-Tau Reconstruction



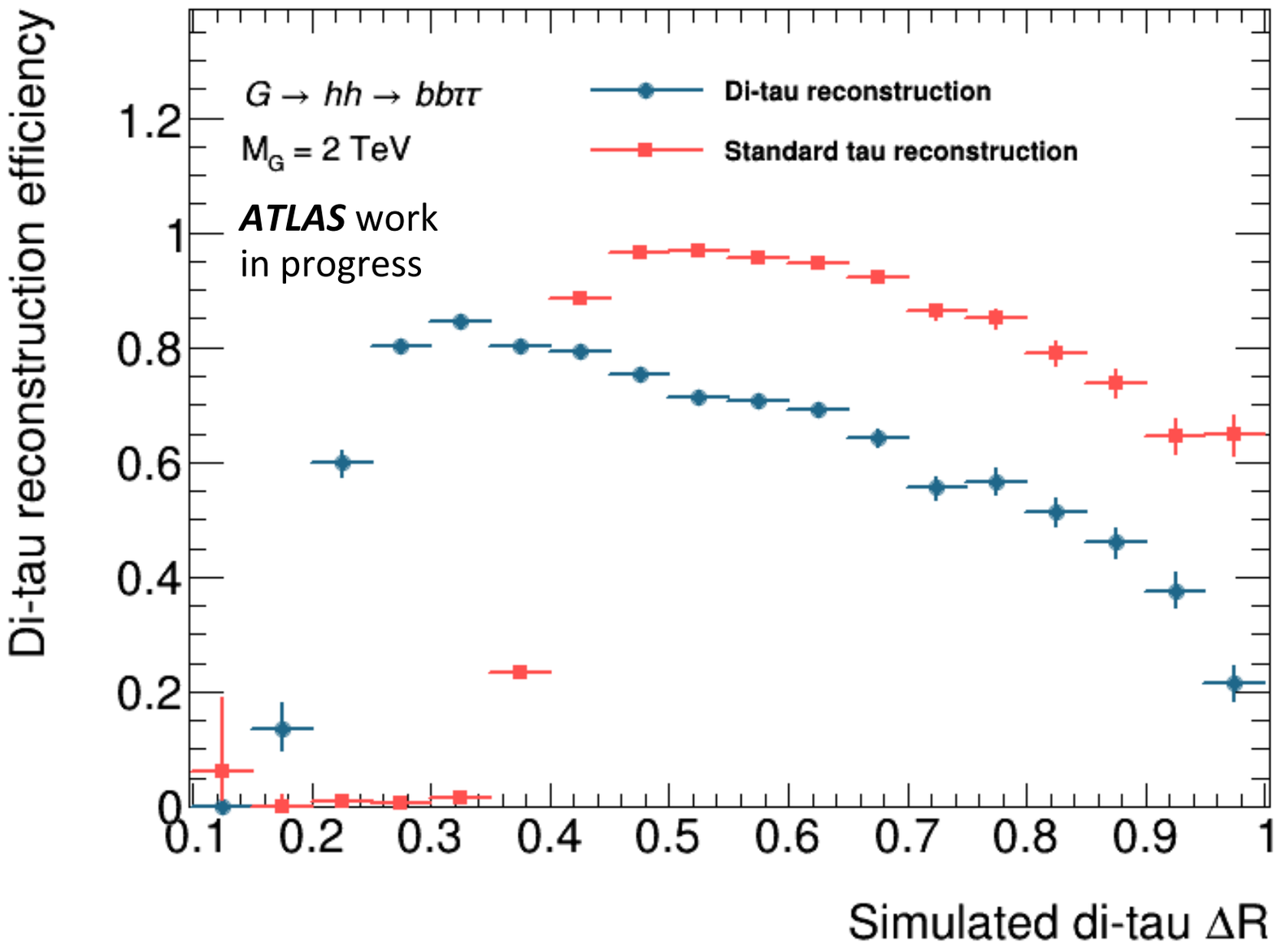
Di-Tau Reconstruction

- High-p_T anti-k_T jet seeds (R = 1.0, p_T > 300 GeV)

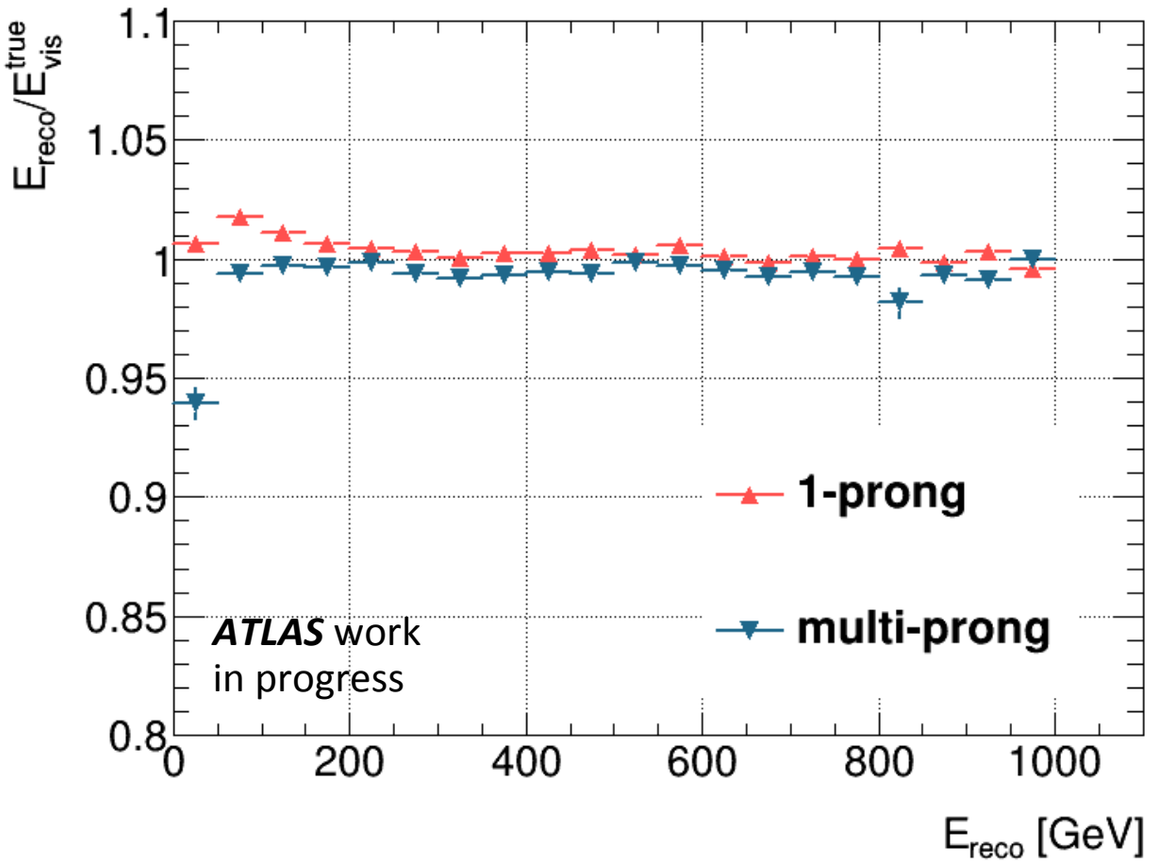
- Anti-k_T subjets (R = 0.2)
- At least 2 subjets with at least one associated track
- Track and primary vertex association
- Calorimeter cell based identification variable calculation

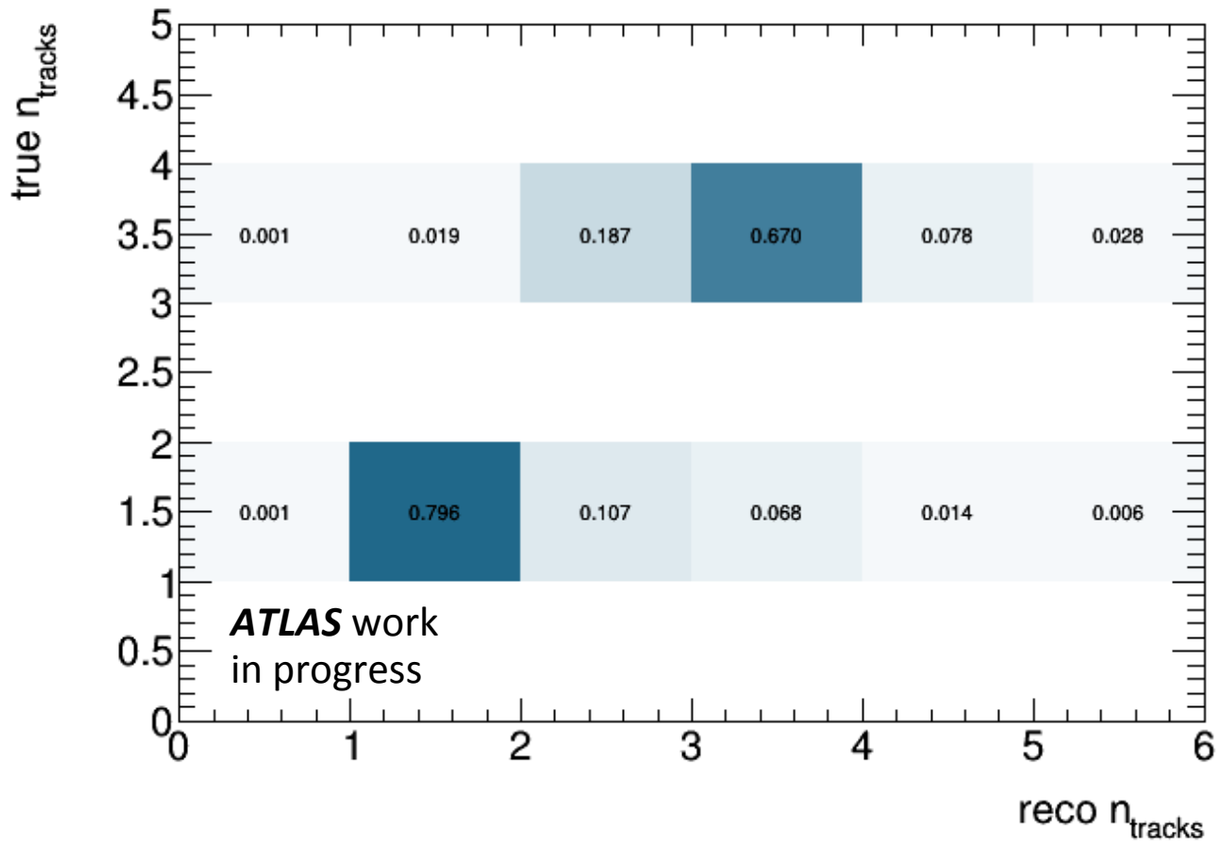


Di-Tau Reconstruction



Energy and Track Reconstruction

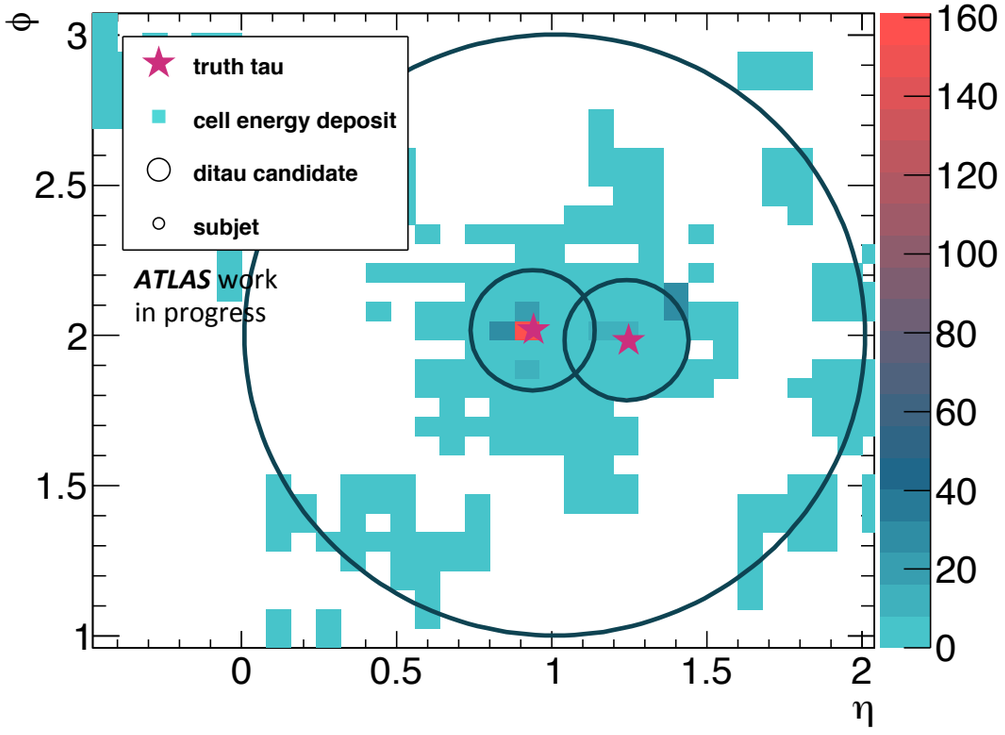




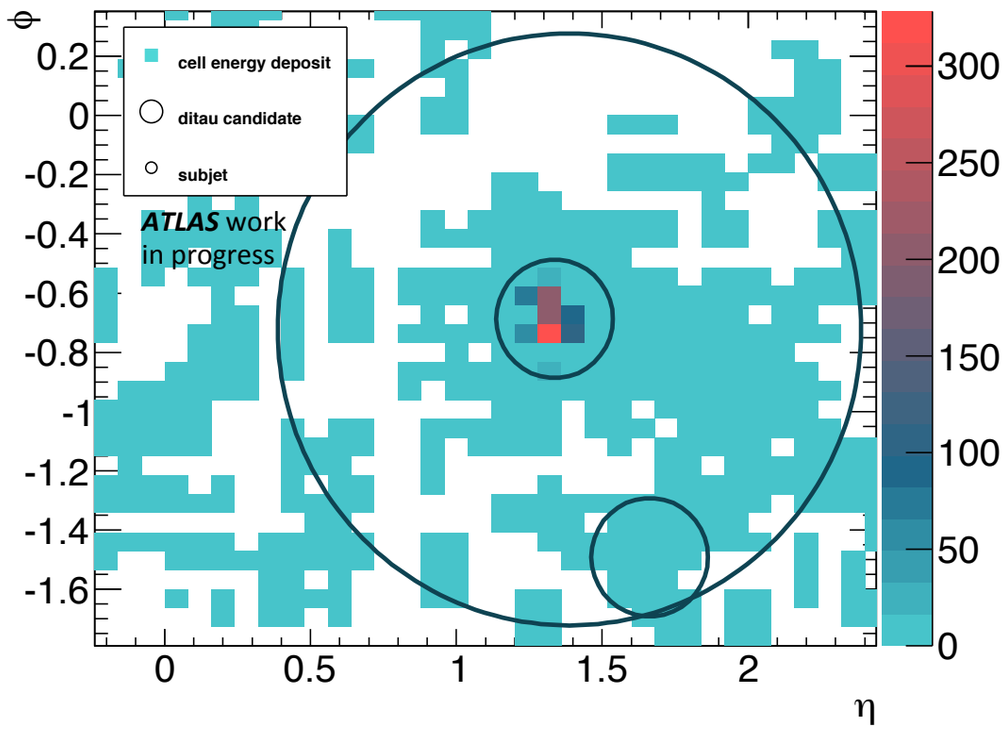
- Energy accuracy ~2 %
- Efficiency of correct reconstruction of track multiplicity ~67%-80%

Di-Tau Identification

Di-tau signal

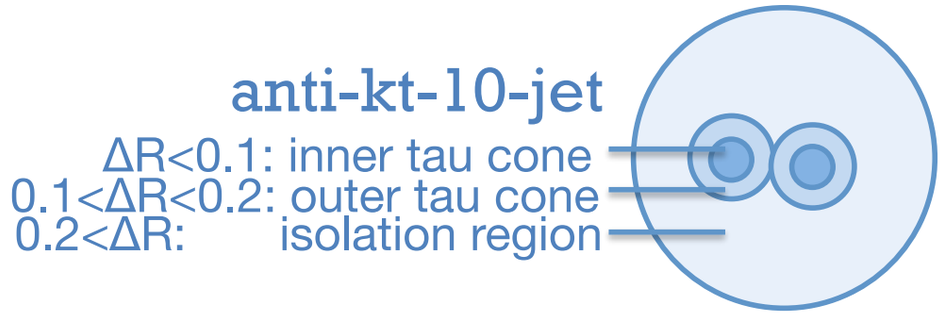


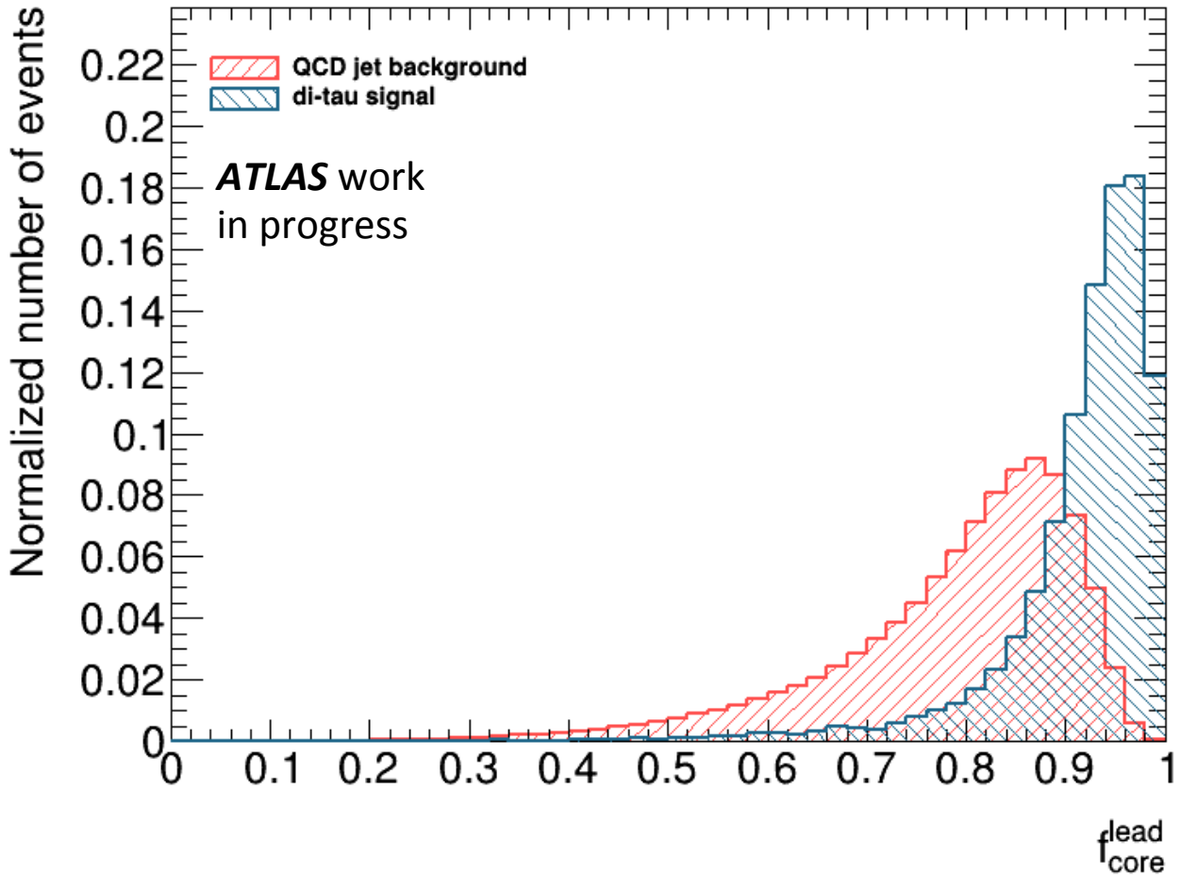
QCD background

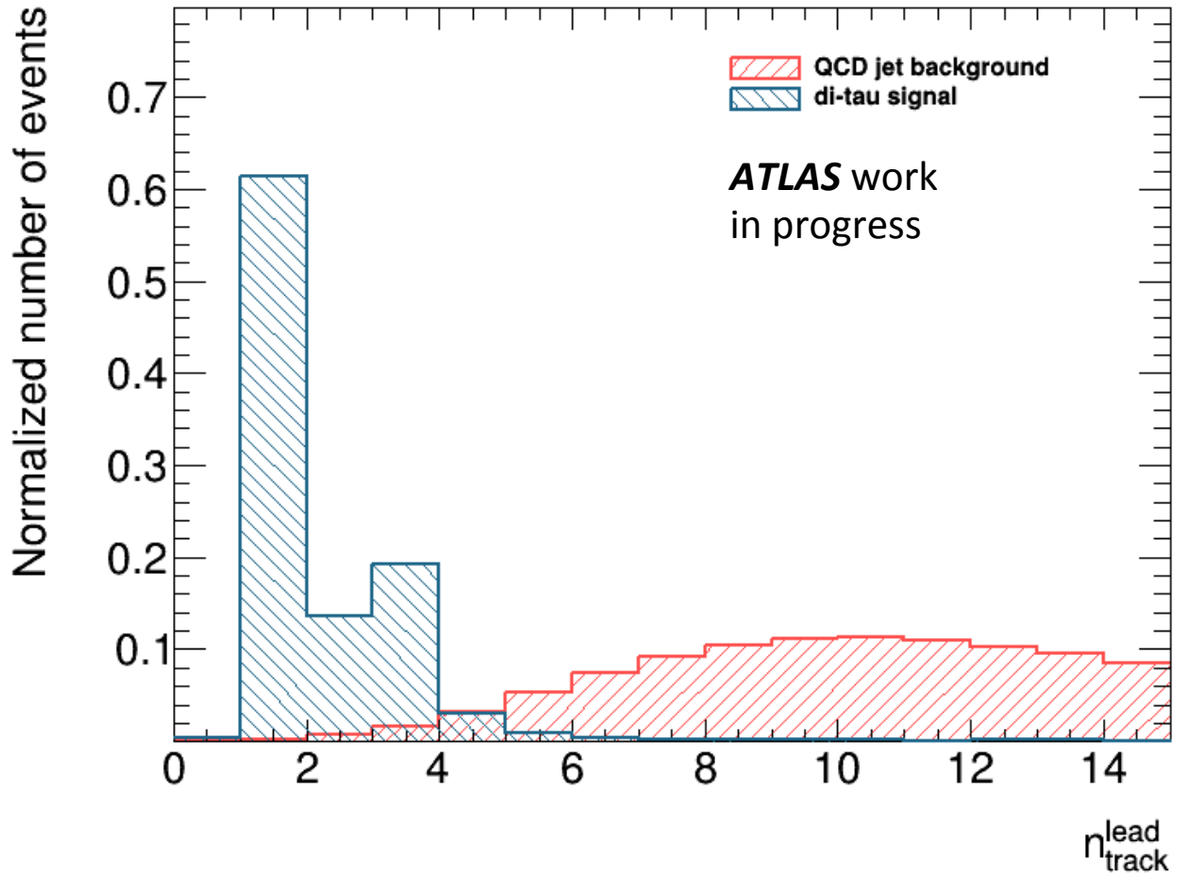


- Multivariate QCD background separation using Boosted Decision Trees
- Combines tracker and calorimeter information within 17 variables

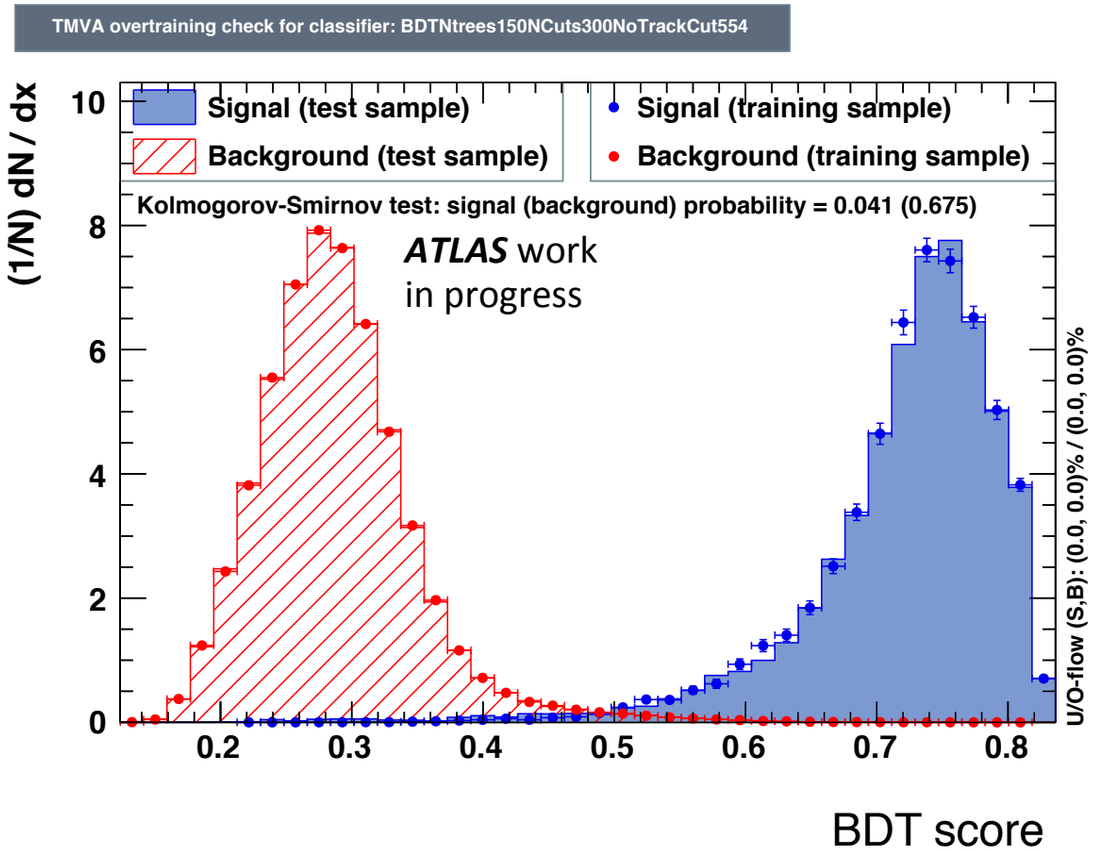
Di-Tau Identification

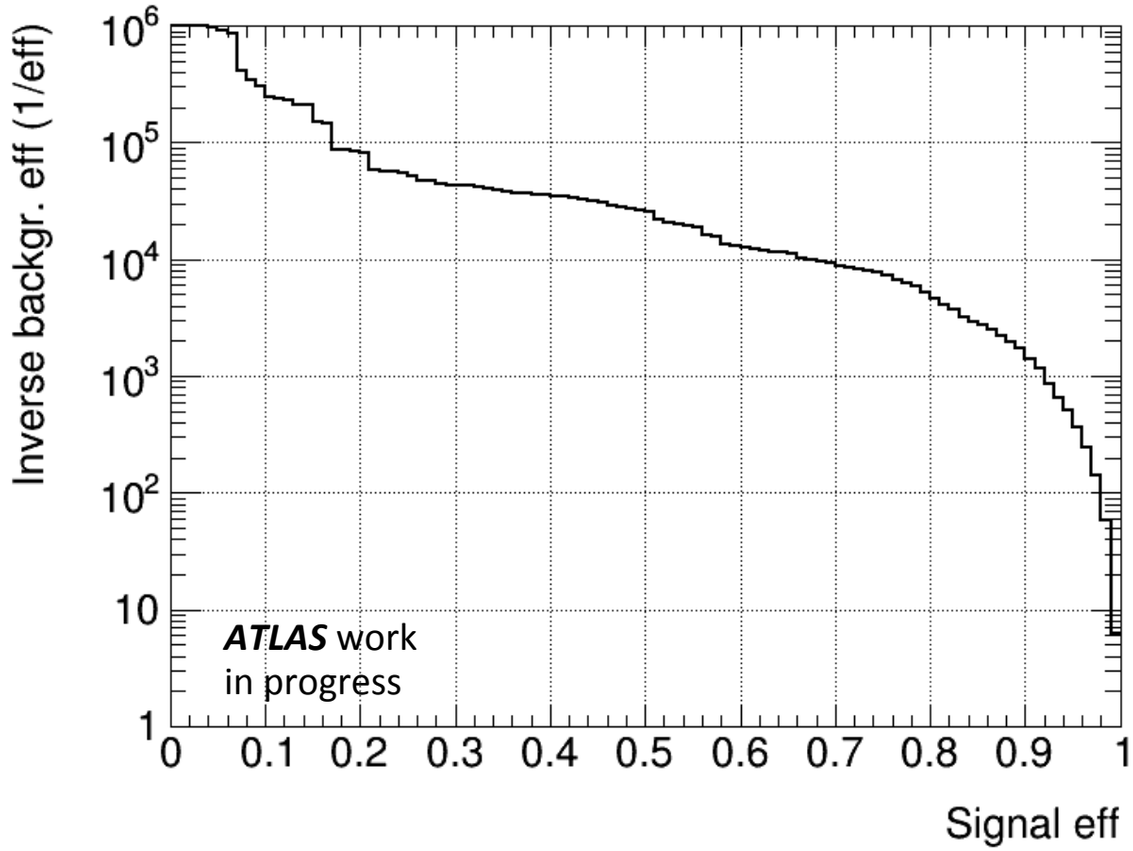






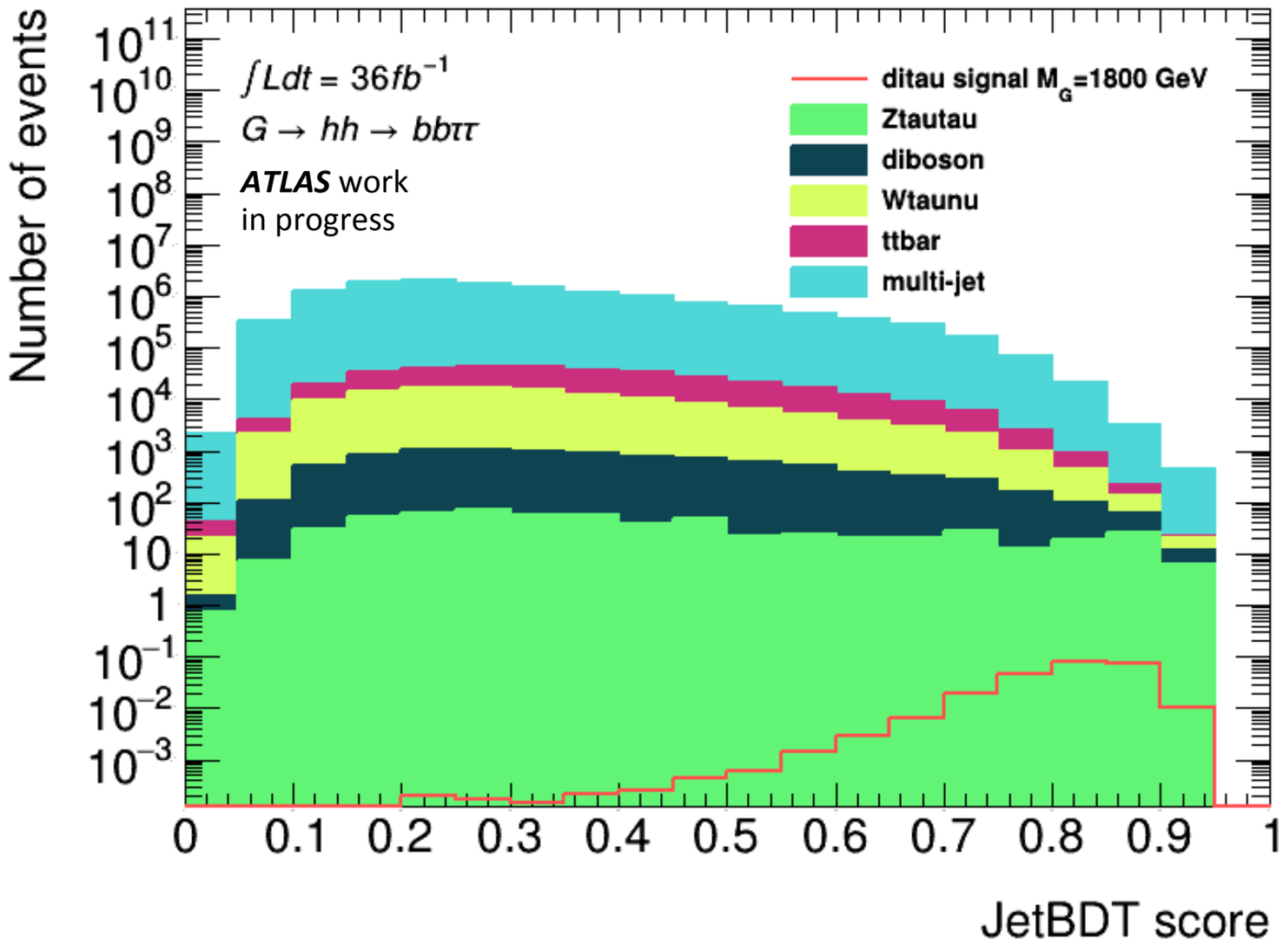
Di-Tau Identification



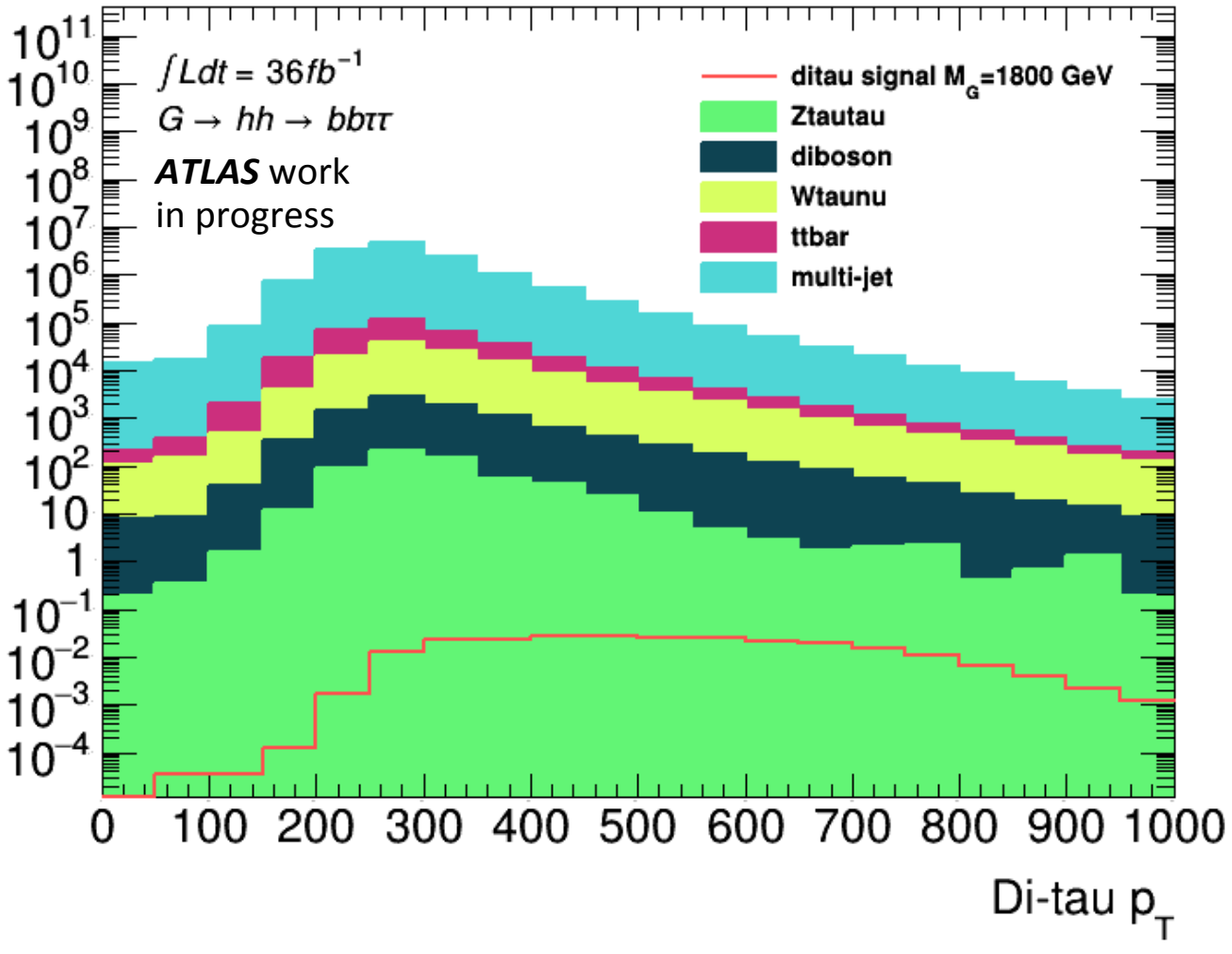


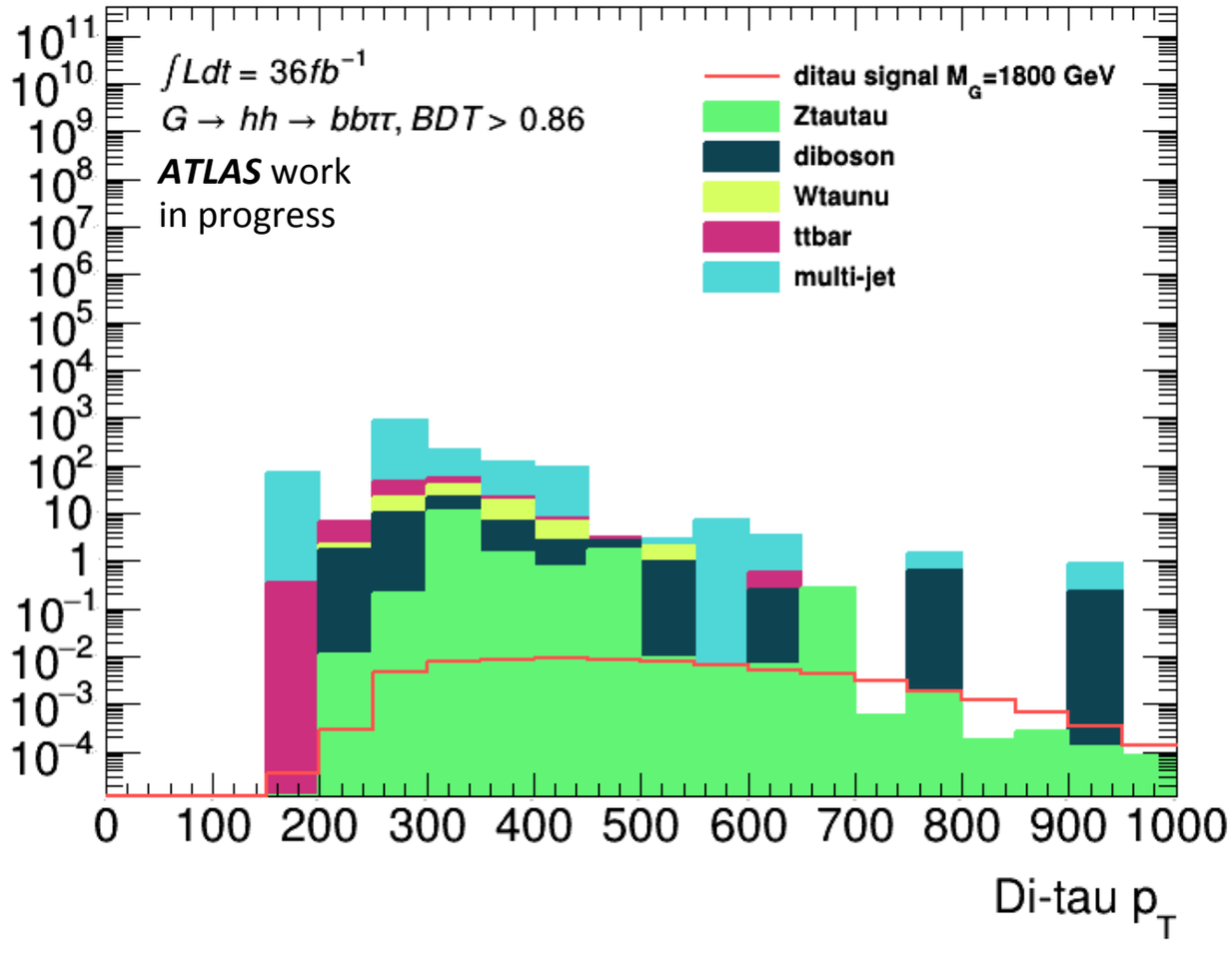
- Signal: $G \rightarrow hh \rightarrow 4\tau$ MC samples, M_G = 1500-2500 GeV
- Background: 13 TeV 2015 data

Di-Tau Identification



Di-Tau Identification



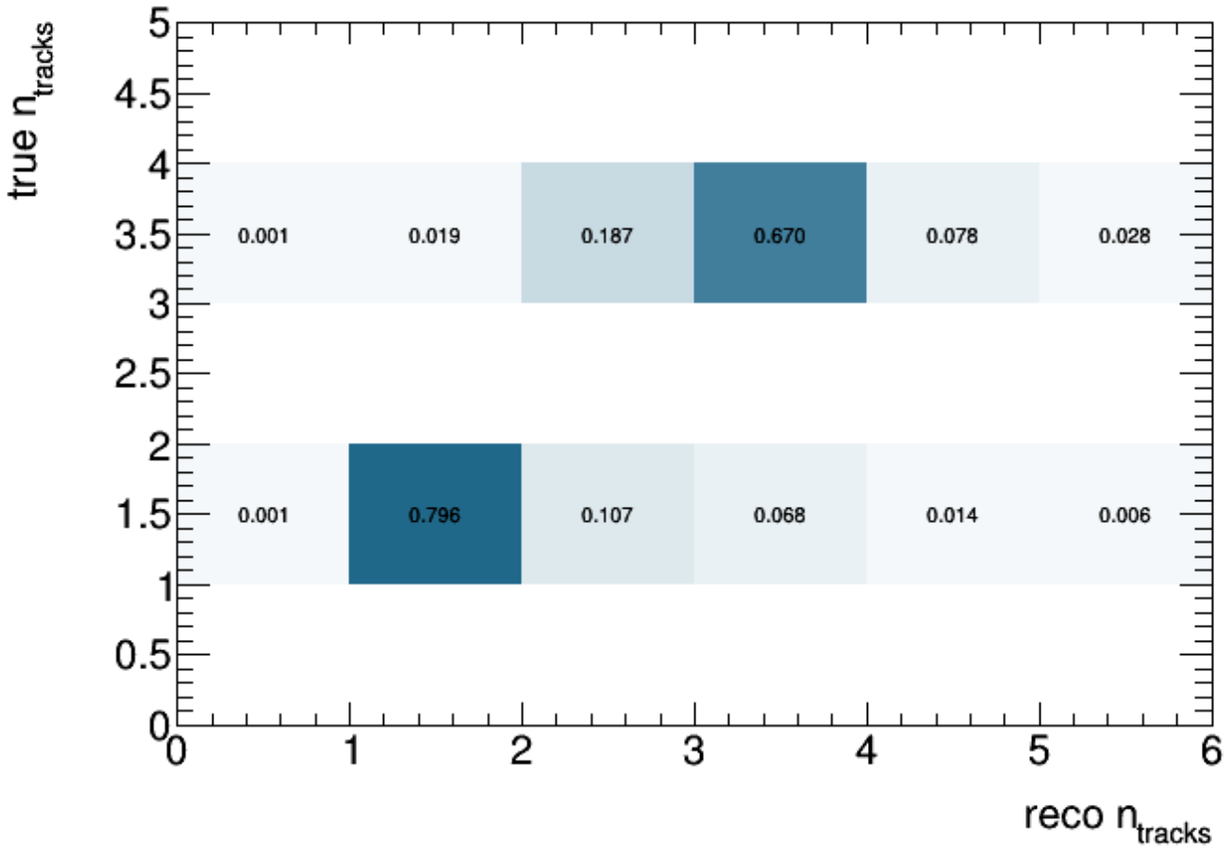


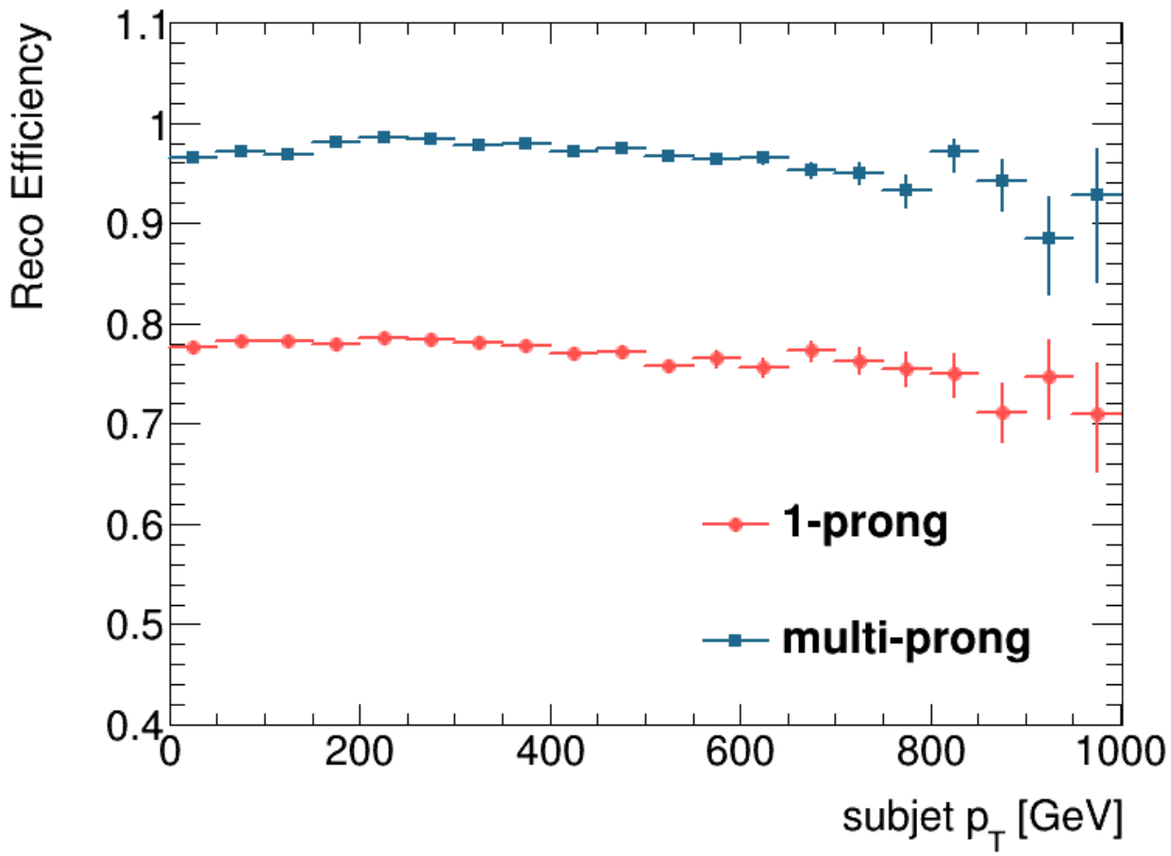
Summary and Outlook

- New method for reconstructing boosted tau pairs
- High background suppression, not only for QCD jets
- Systematic uncertainties need to be determined (e.g. on identification efficiency and energy scale)
- Expanding existing hh → bbττ analysis with boosted category


THANK YOU
FOR YOUR ATTENTION

Di-Tau Track Reconstruction





Event Selection for DiTauID

Di-Tau Signal

- G → hh → 4τ MC samples:

```
MadGraphPythia8EvtGen_A14NNPDF23LO_RS_G_hh_4tau_c10_M1500
MadGraphPythia8EvtGen_A14NNPDF23LO_RS_G_hh_4tau_c10_M1750
MadGraphPythia8EvtGen_A14NNPDF23LO_RS_G_hh_4tau_c10_M2000
MadGraphPythia8EvtGen_A14NNPDF23LO_RS_G_hh_4tau_c10_M2250
MadGraphPythia8EvtGen_A14NNPDF23LO_RS_G_hh_4tau_c10_M2500
```

- GRL and jet cleaning
- Flat p_T re-weighting
- Mix of high-p_T jet triggers
- Ditau p_T > 200 GeV, $|\eta| < 2.5$

→ 300 k boosted di-taus

QCD Jet Background

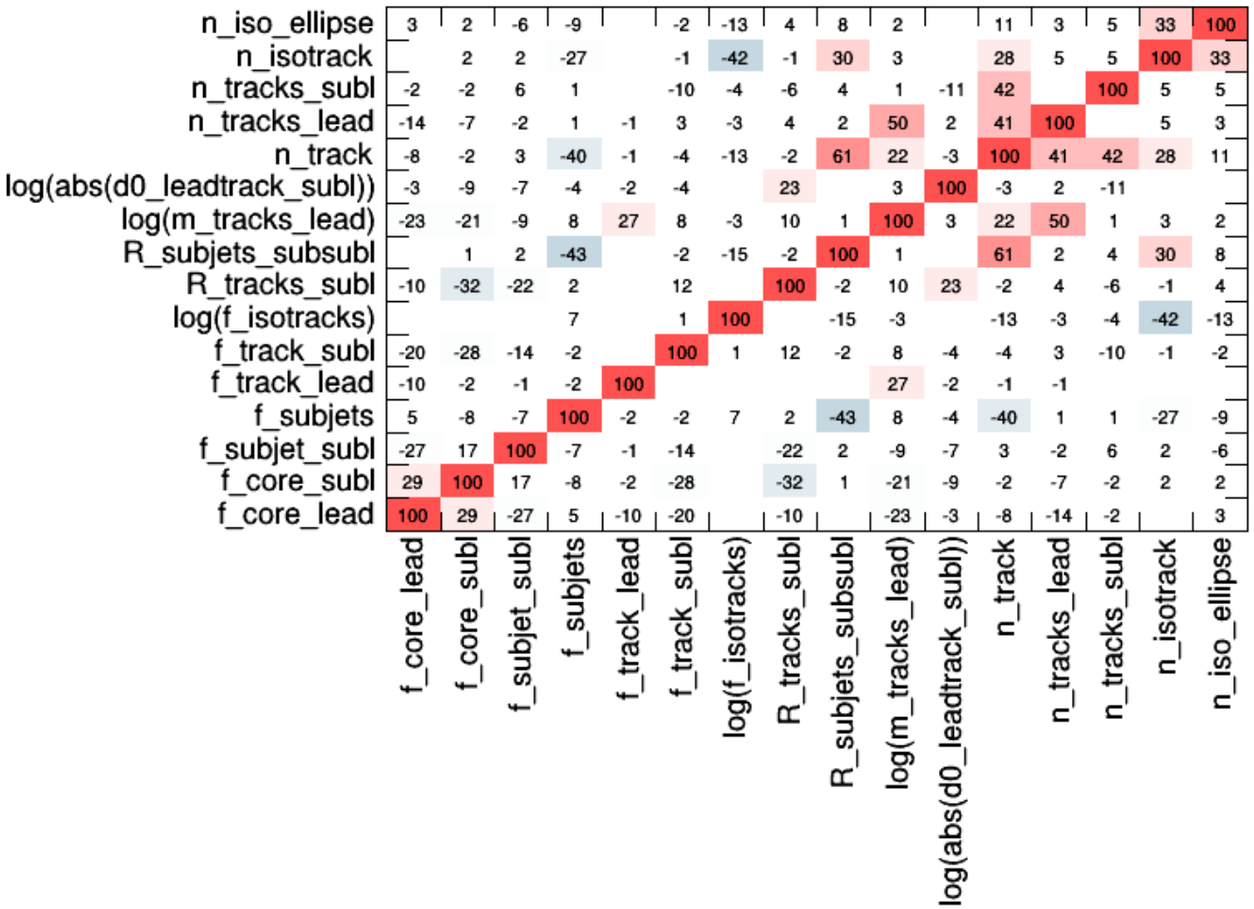
- 13 TeV 2015 data:

```
data15_13TeV.periodAllYear_DetStatus-v75-
repro20-01_DQDefects-00-02-02_PHYS_StandardGRL_All_Good
.xml
```

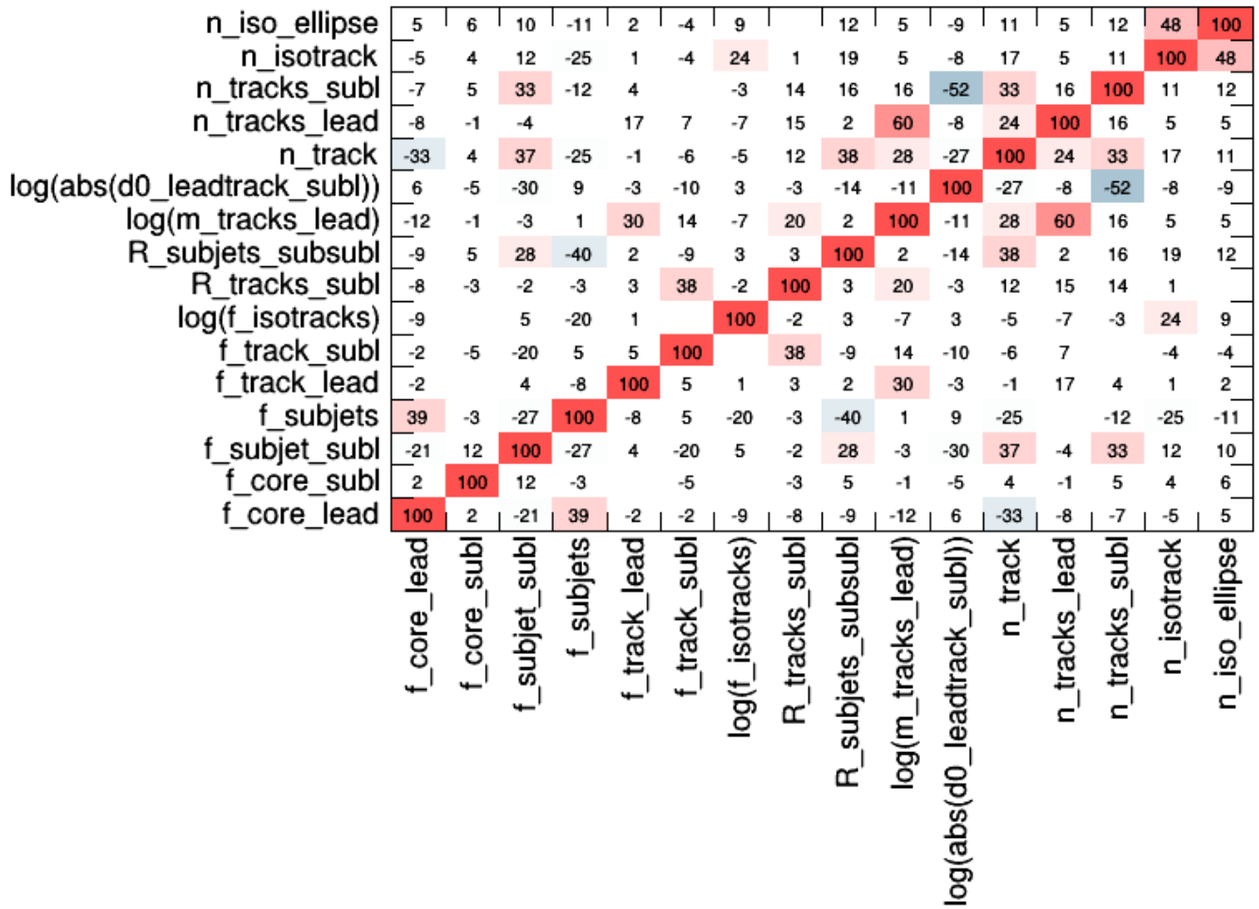
→ 13 M di-tau candidates

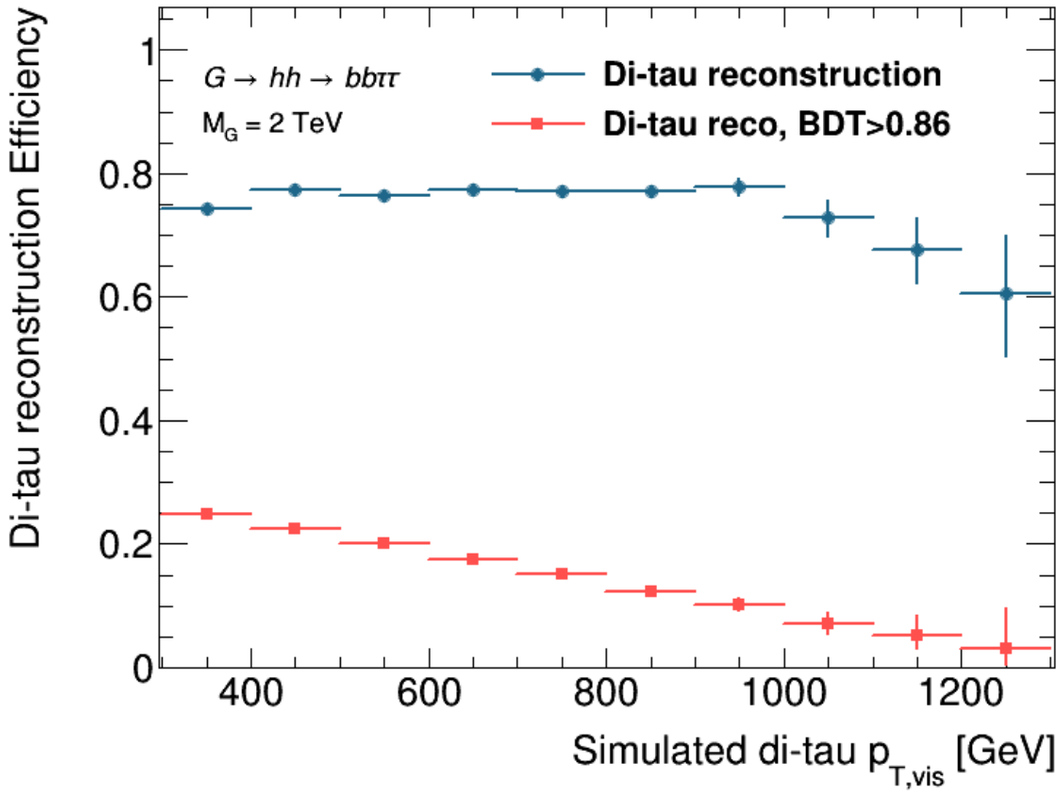
Di-Tau Identification

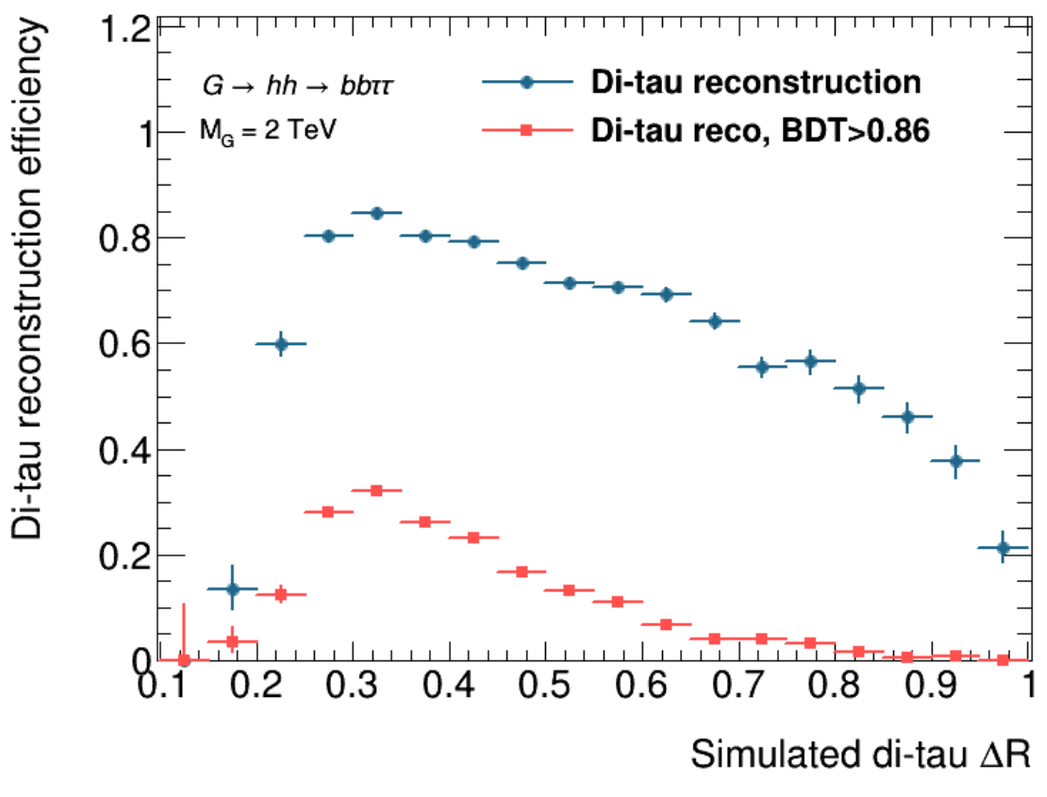
Correlation Signal

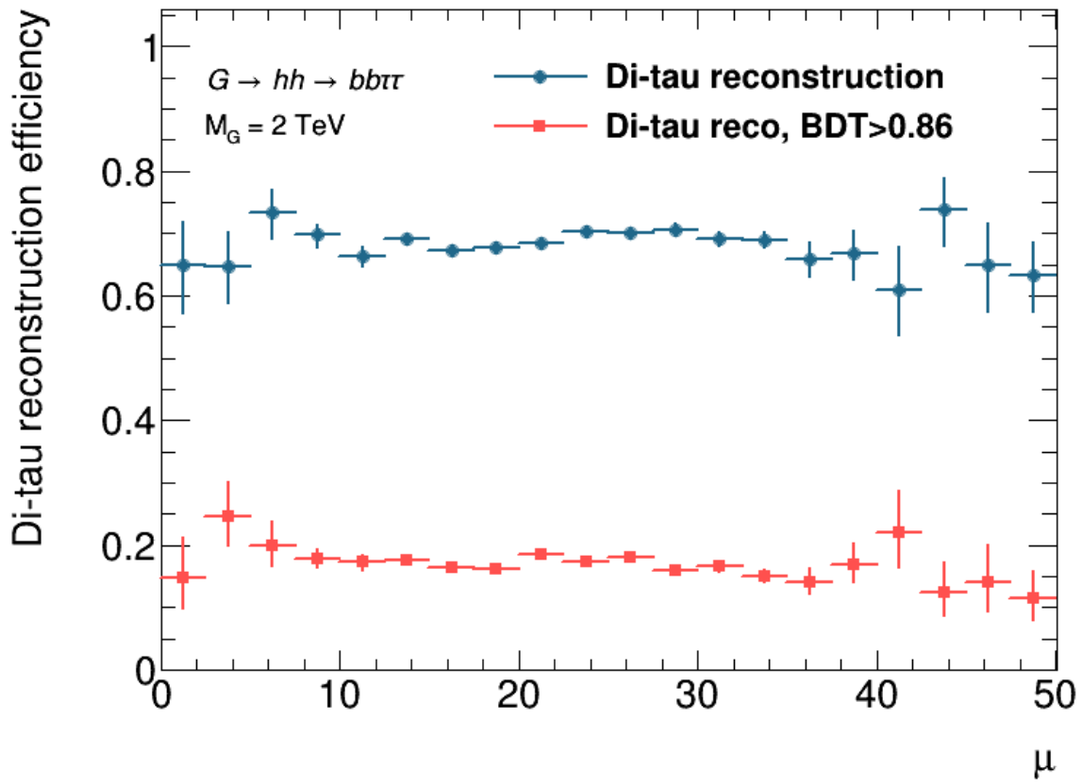


Correlation Background

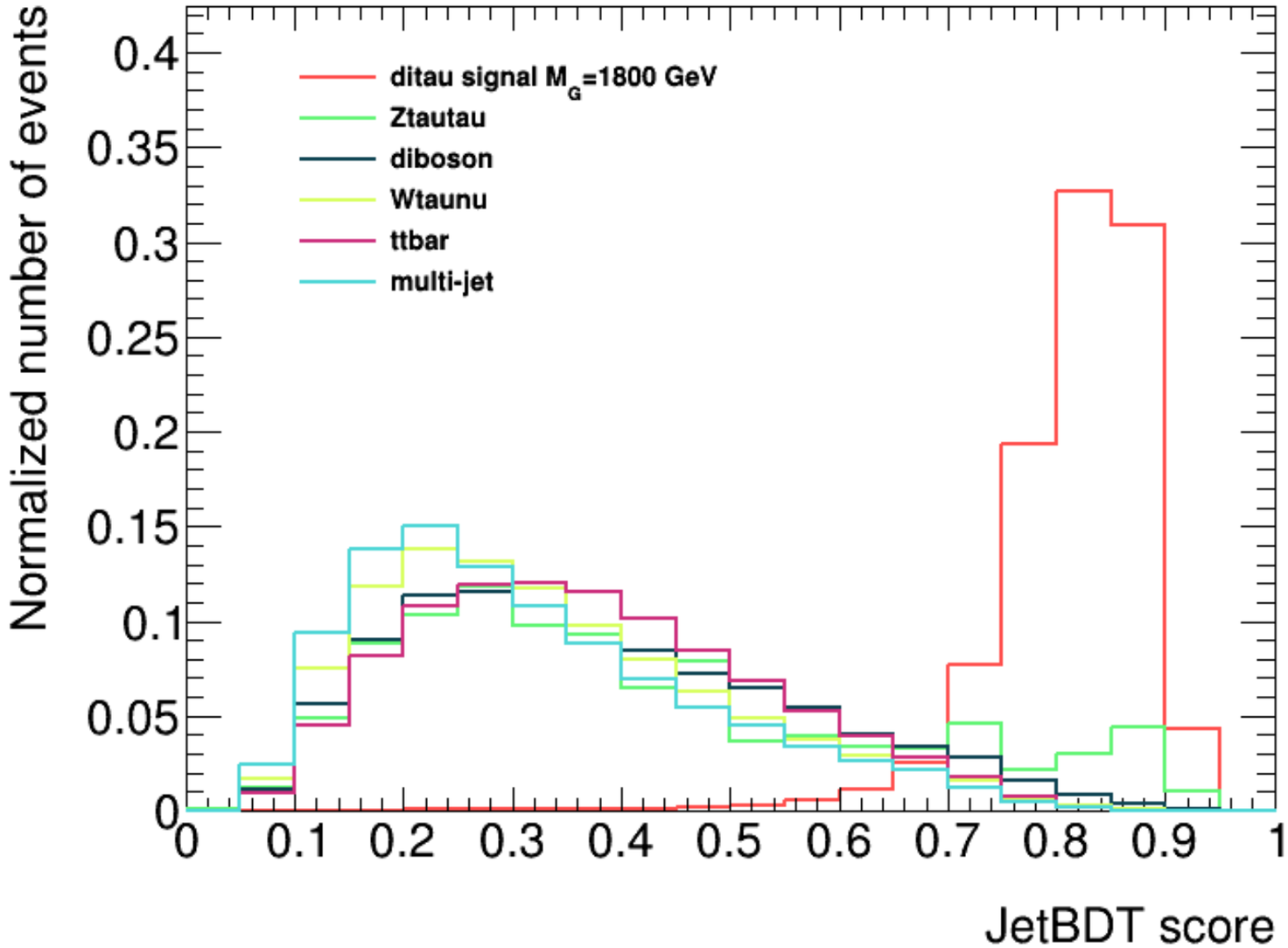



Di-tau reconstruction Efficiency
$G \to hh \to bb\tau\tau$
M_G = 2 TeV
Di-tau reconstruction
Di-tau reco, BDT>0.86
Simulated di-tau $p_{T,vis}$ [GeV]


Di-tau reconstruction efficiency
$G \to hh \to bb\tau\tau$
M_G = 2 TeV
Di-tau reconstruction
Di-tau reco, BDT>0.86
Simulated di-tau ΔR


Di-tau reconstruction efficiency
$G \to hh \to bb\tau\tau$
M_G = 2 TeV
Di-tau reconstruction
Di-tau reco, BDT>0.86
μ

Di-Tau Identification



Uncertainties