

Search for New Physics with Boosted Tau Pairs

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16th Block Course of the GRK 1504

“Mass, Spectrum, Symmetry”

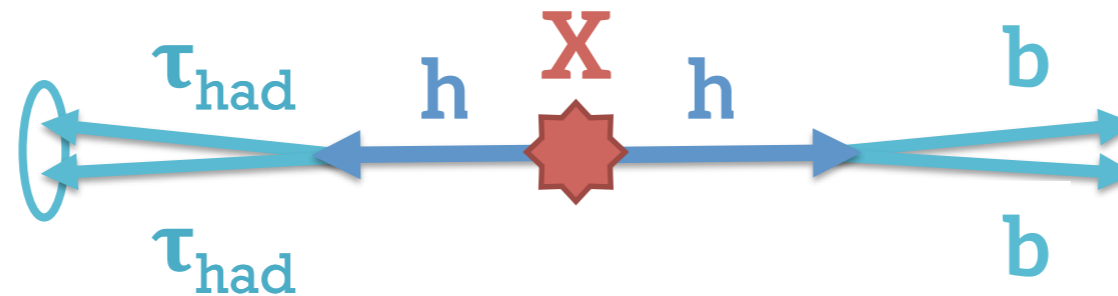
13 Mar 2017



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DRESDEN

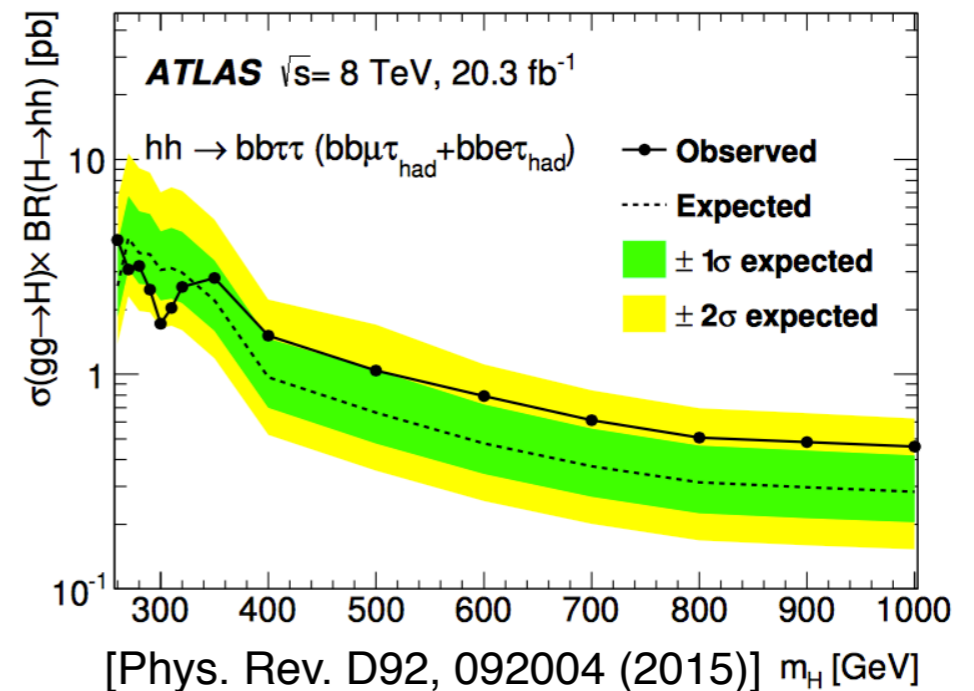


Motivation

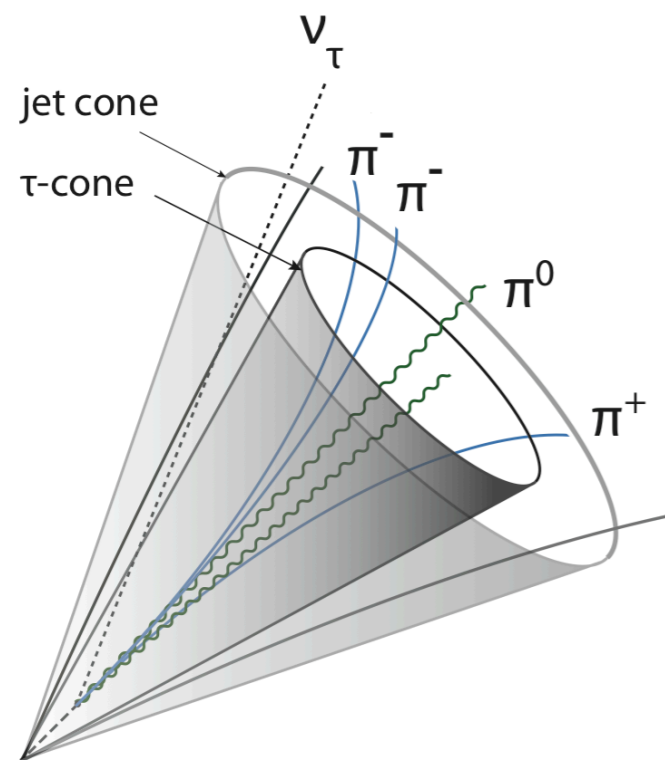
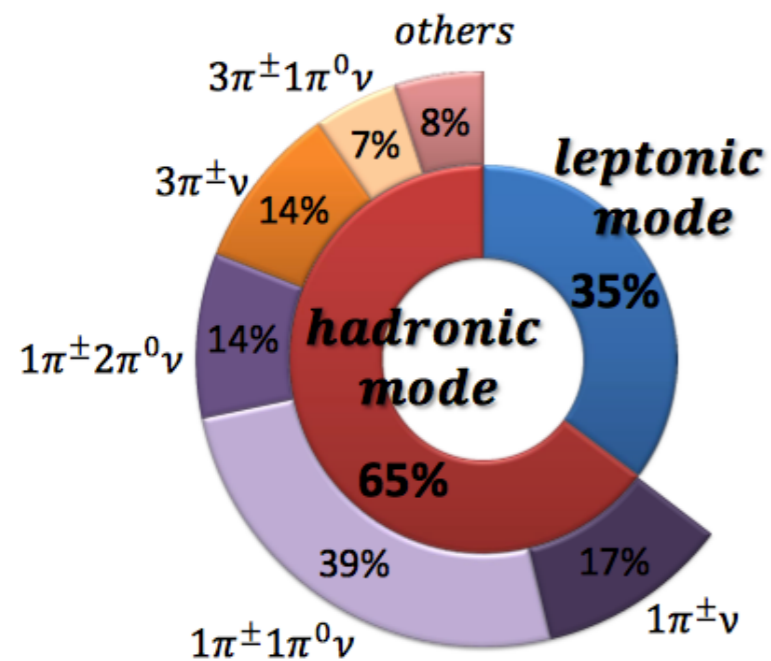


- Since discovery of h significant progress in measuring its coupling strengths, spin and CP properties

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

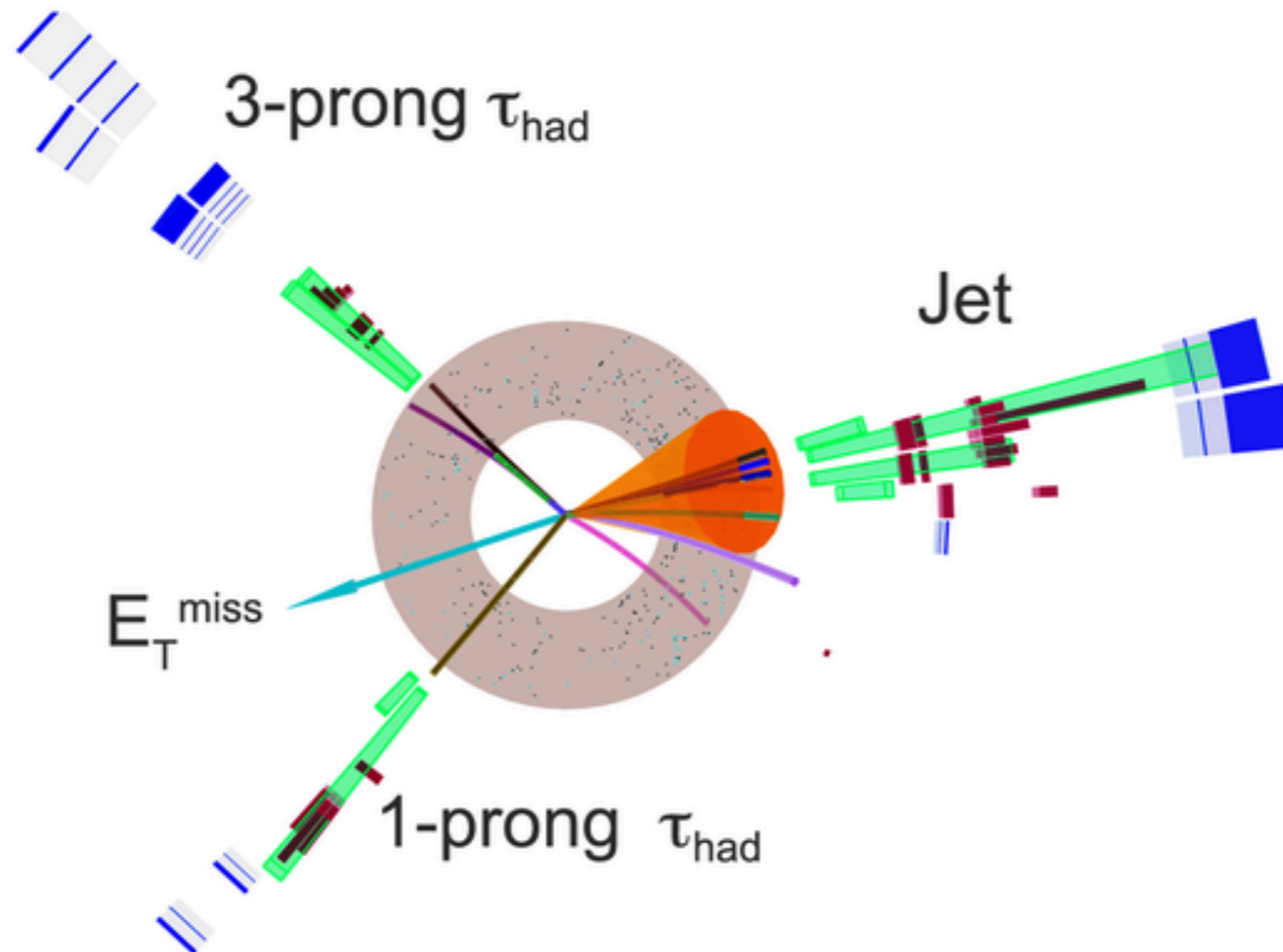


Tau Lepton Decay

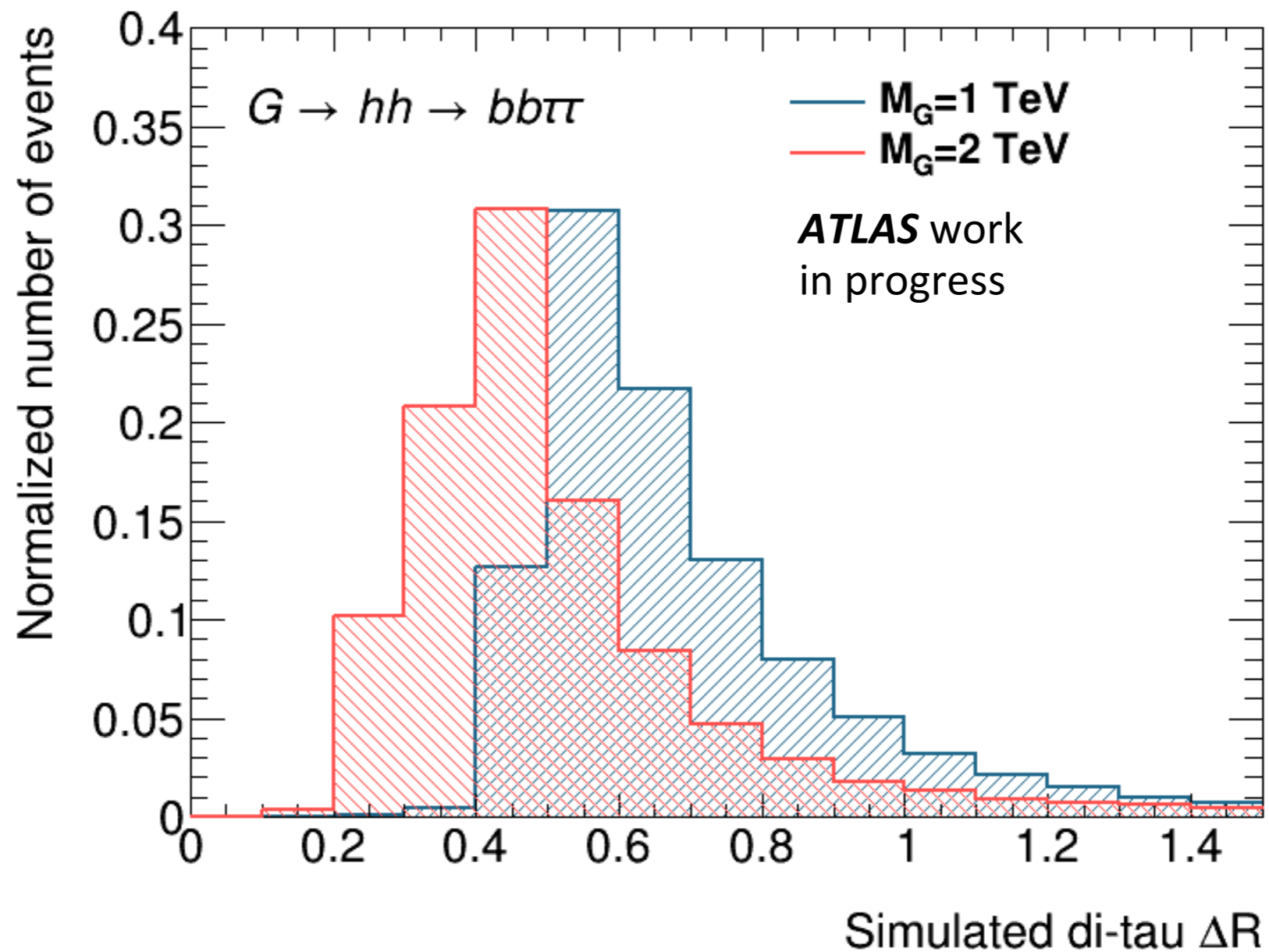


- Higgs decay in tau pairs with third highest branching ratio
- Hadronic mode with 65% BR
- Reconstruction of τ_{had} based on jet seeds
- QCD jet background separation achieved with Boosted Decision Trees

Tau Lepton Decay



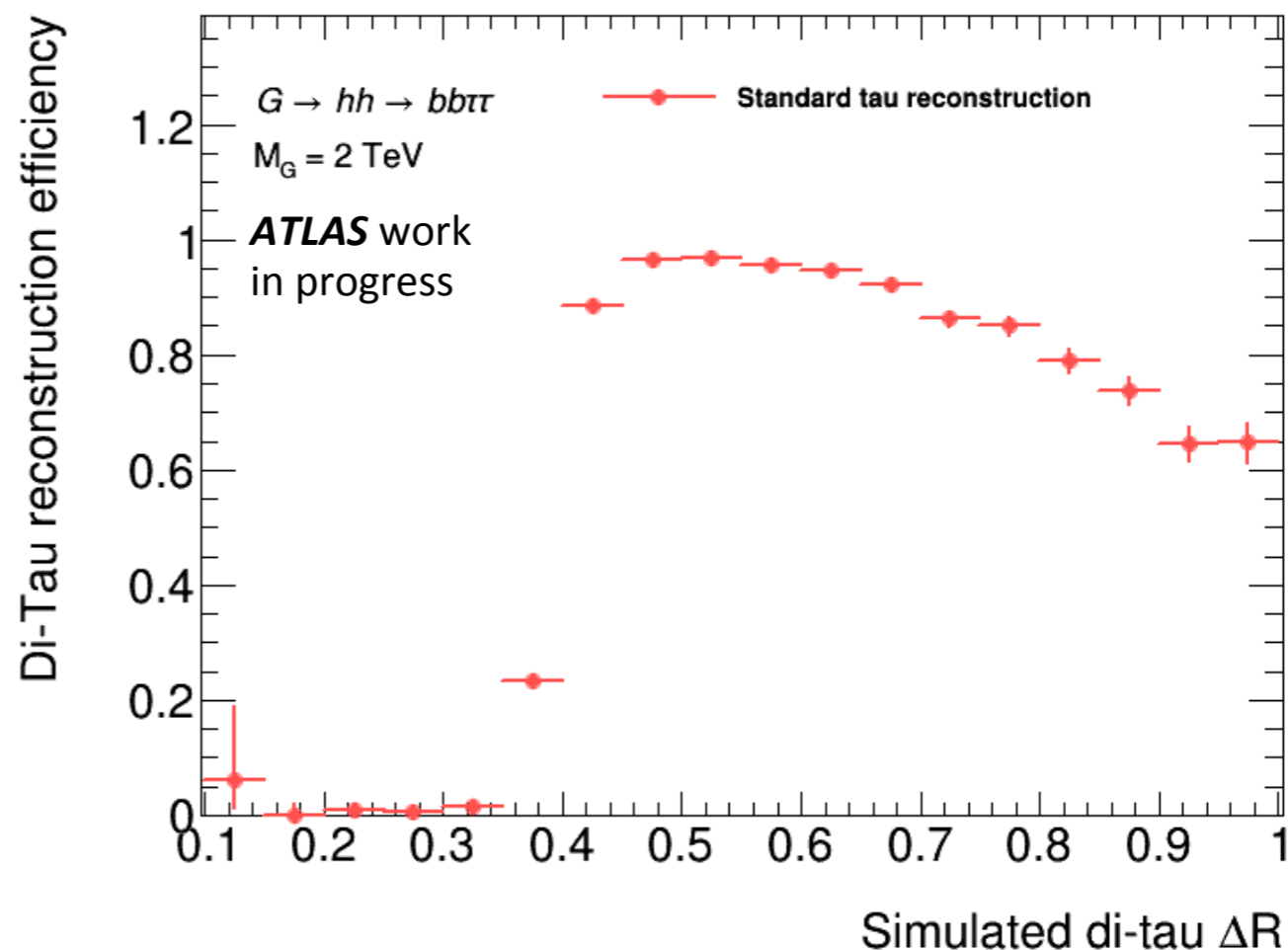
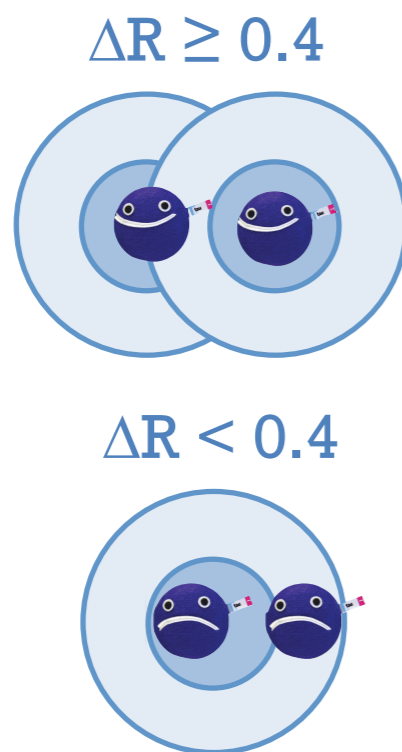
Decay in Boosted Tau Pairs



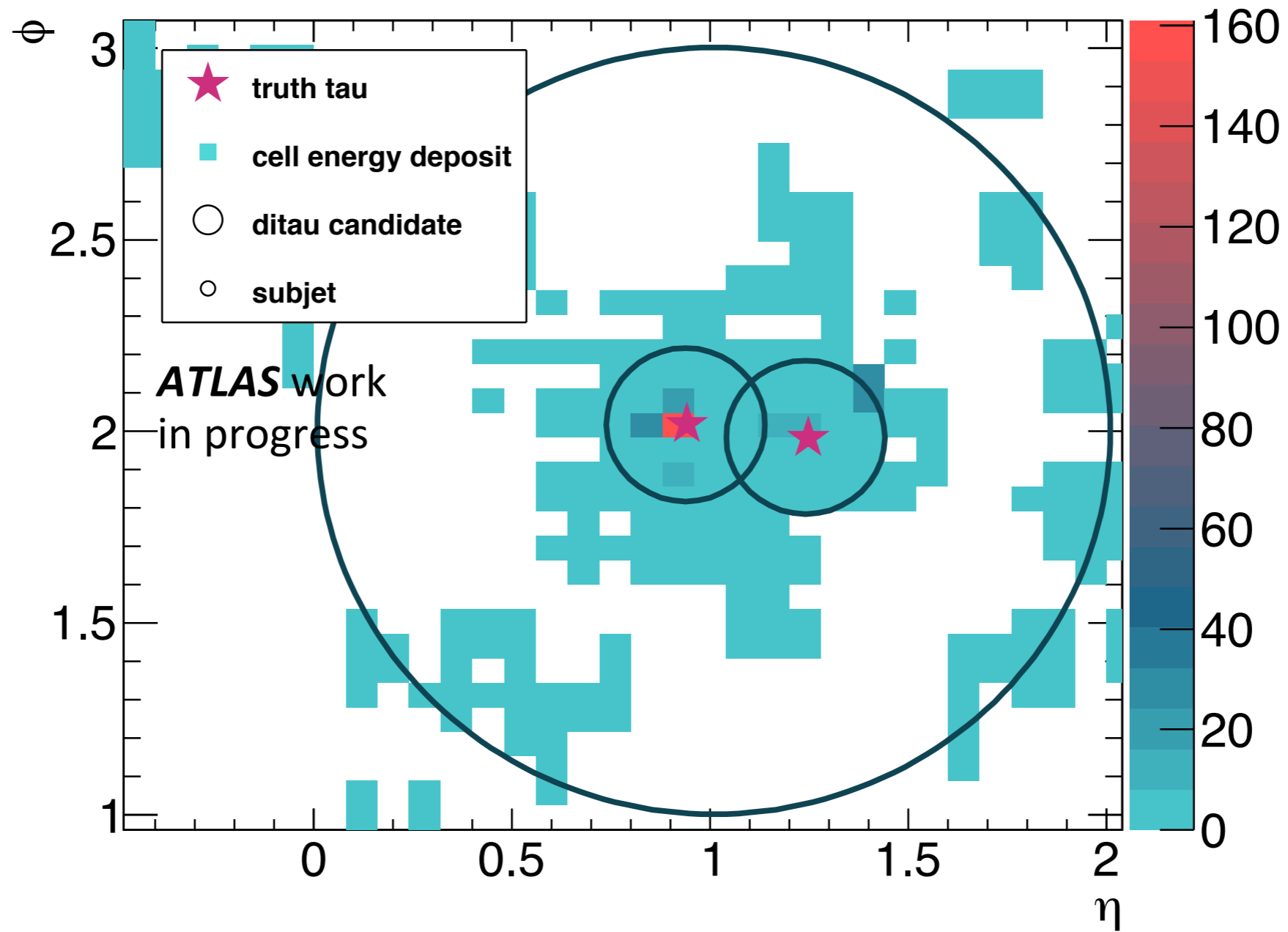
$$\Delta R = \sqrt{(\eta_1 - \eta_2)^2 + (\phi_1 - \phi_2)^2}$$

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

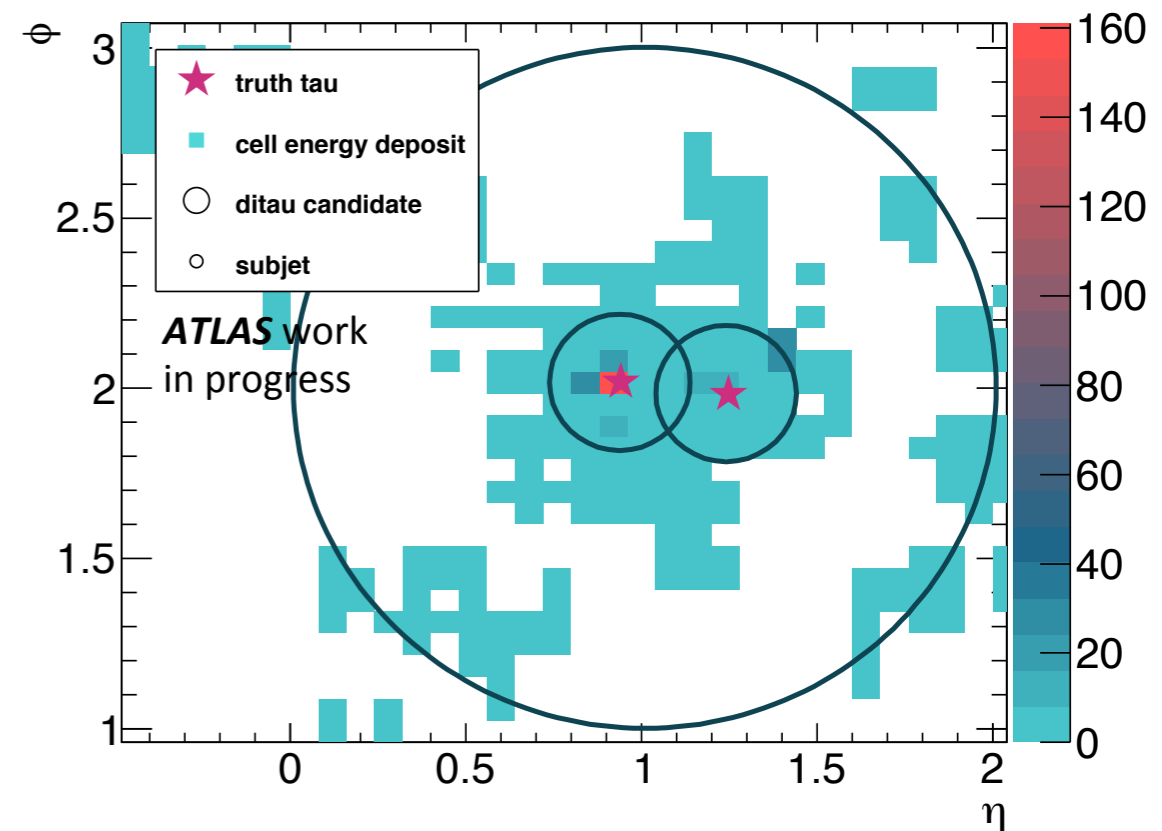
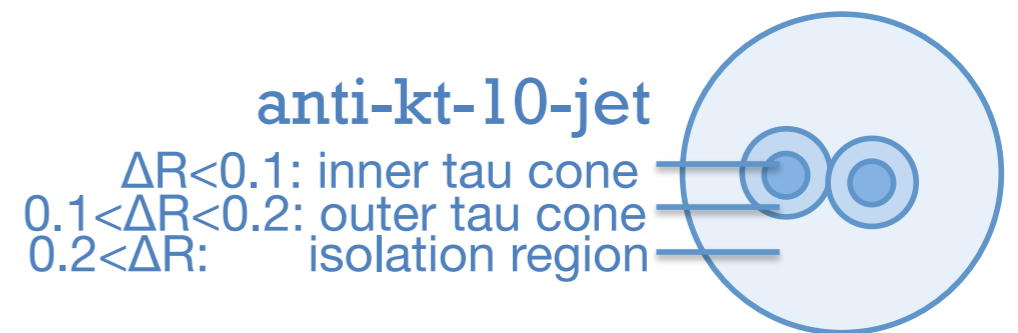


Di-Tau Reconstruction

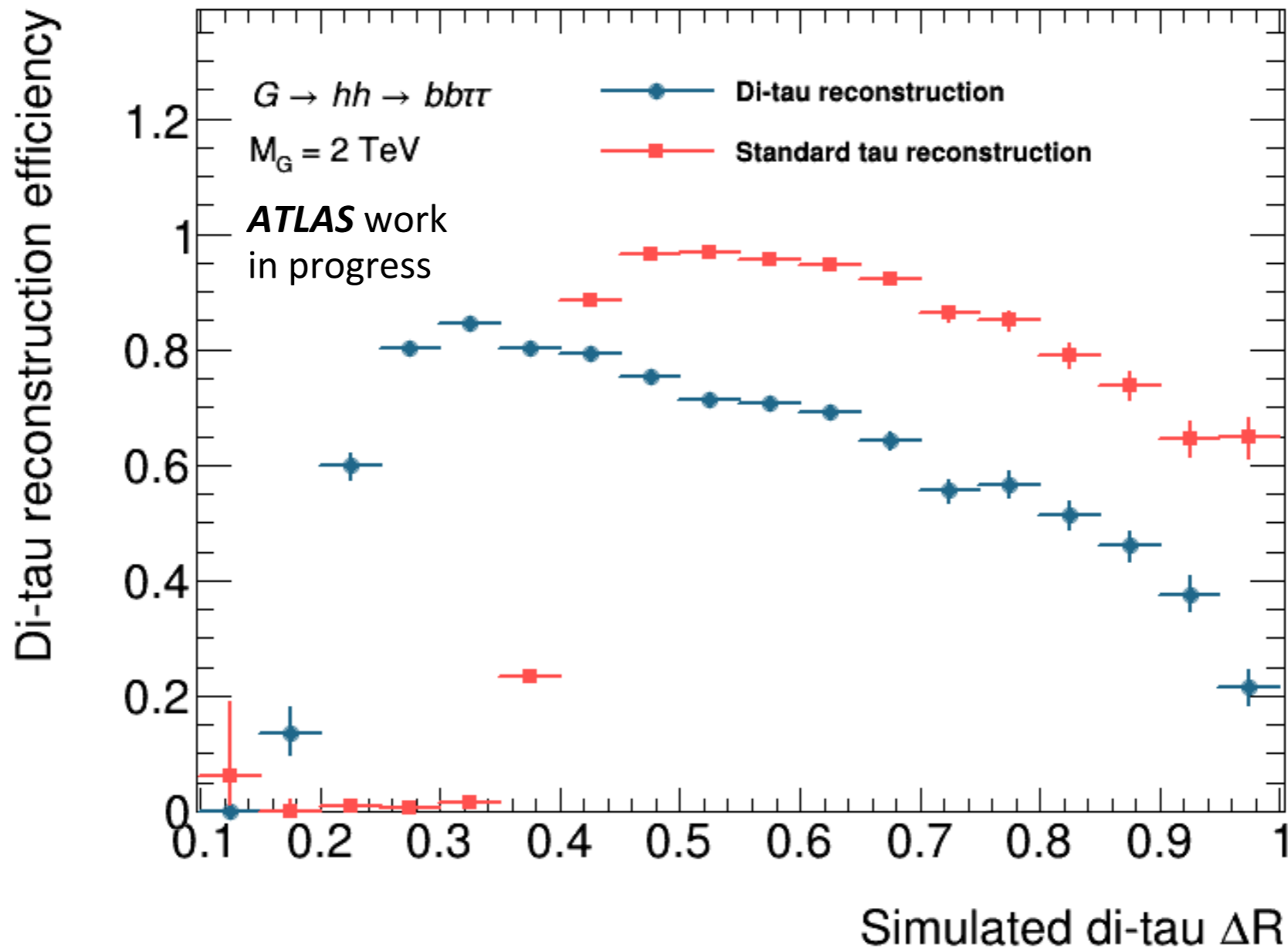


Di-Tau Reconstruction

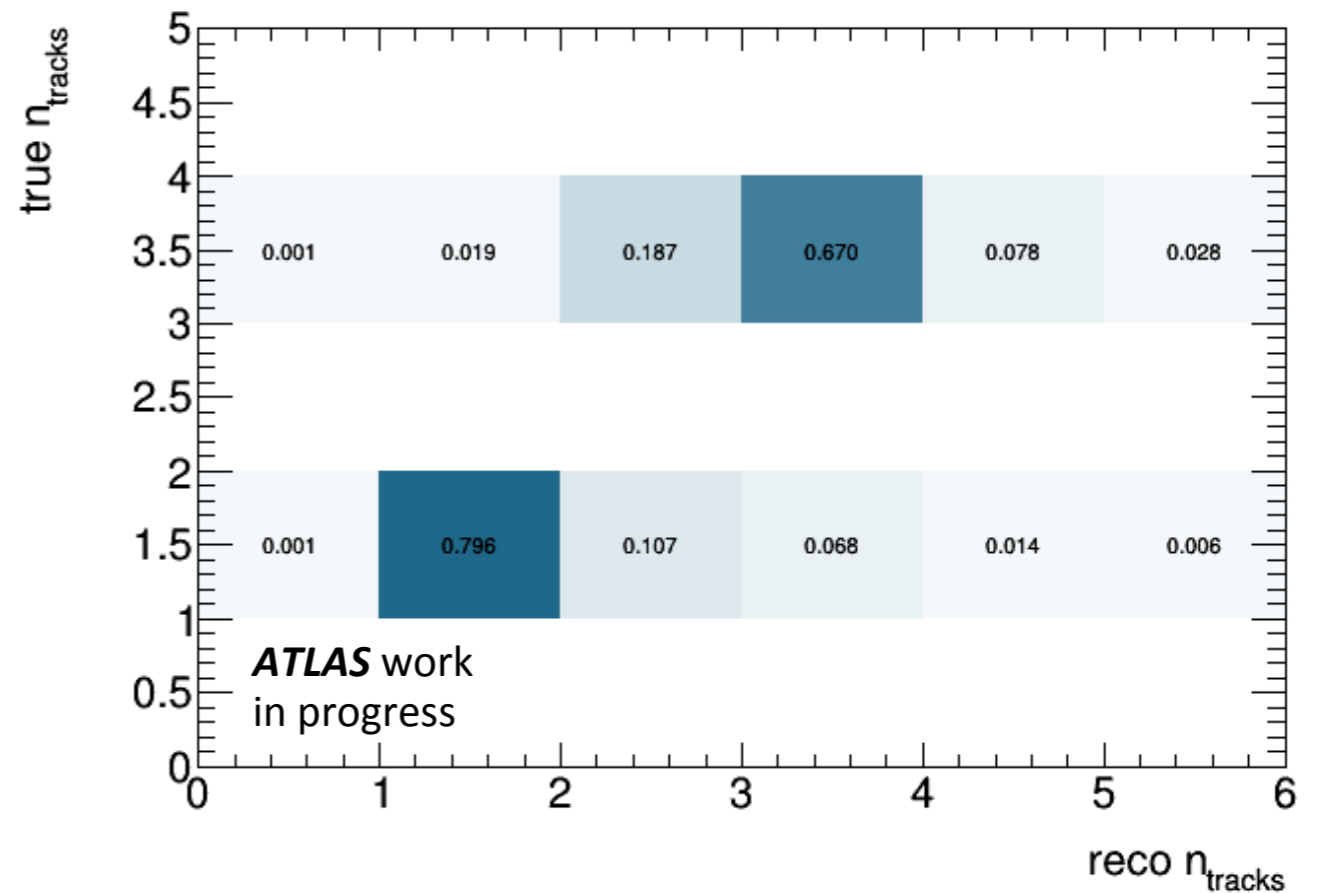
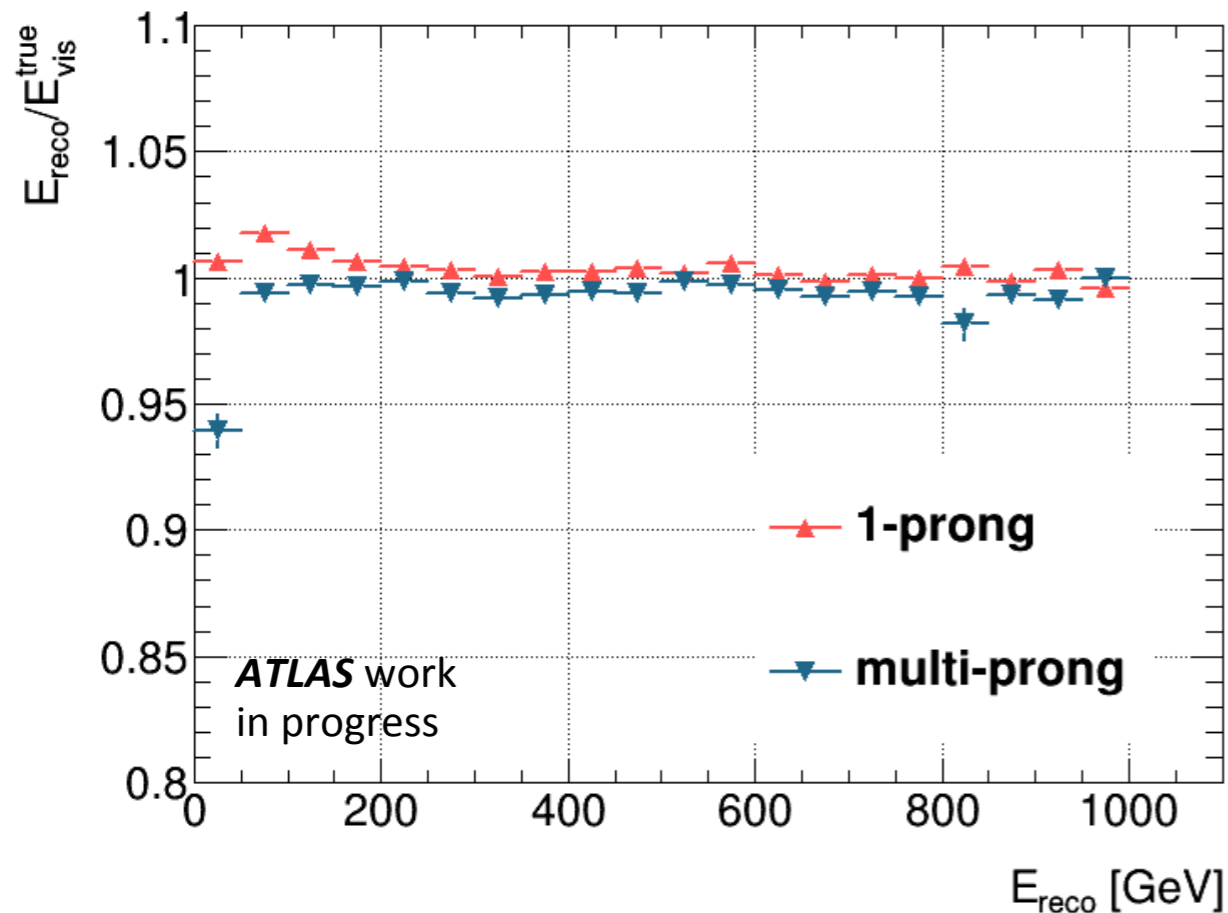
- High- p_T anti- k_T jet seeds ($R = 1.0$, $p_T > 300$ GeV)
- Anti- k_T subjets ($R = 0.2$)
- At least 2 subjets with at least one associated track
- Track and primary vertex association
- Calorimeter cell based identification variable calculation



Di-Tau Reconstruction



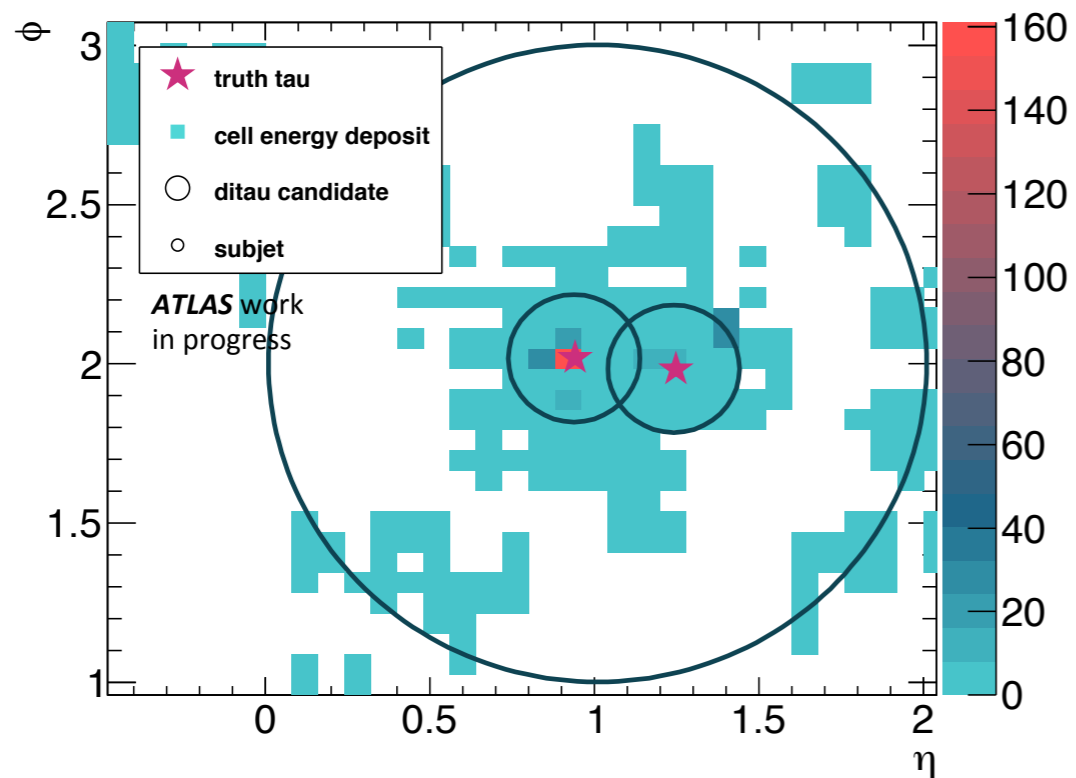
Energy and Track Reconstruction



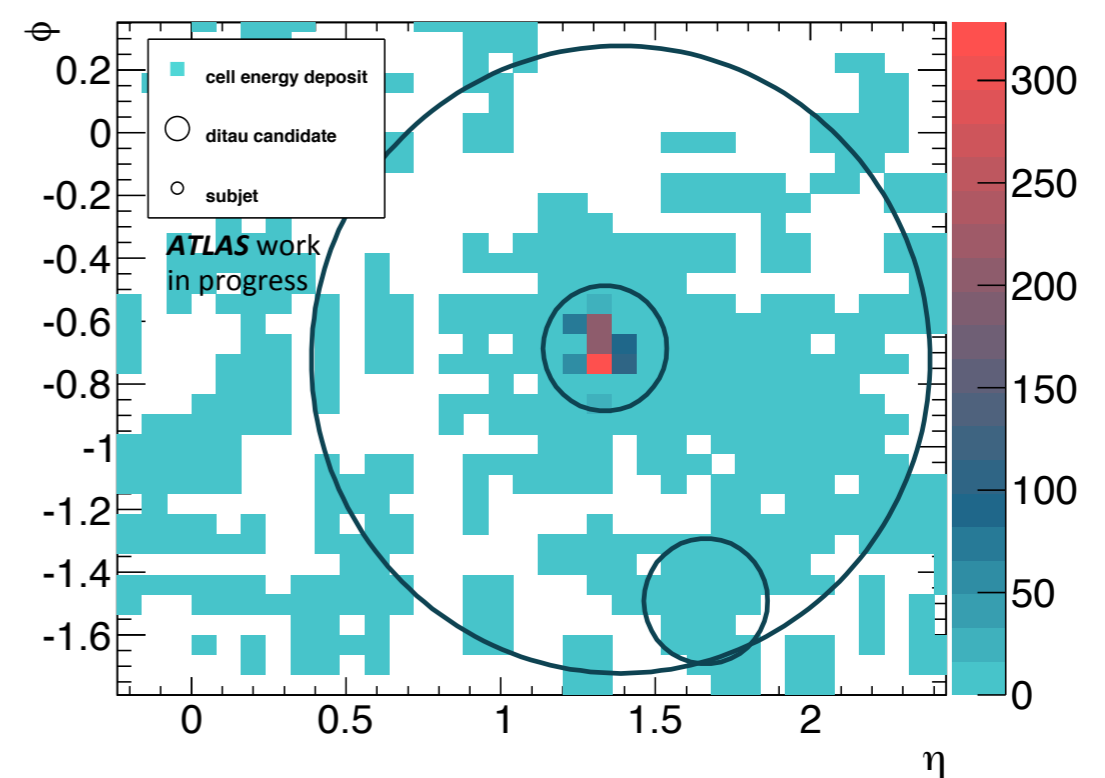
- Energy accuracy $\sim 2\%$
- Efficiency of correct reconstruction of track multiplicity $\sim 67\%-80\%$

Di-Tau Identification

Di-tau signal

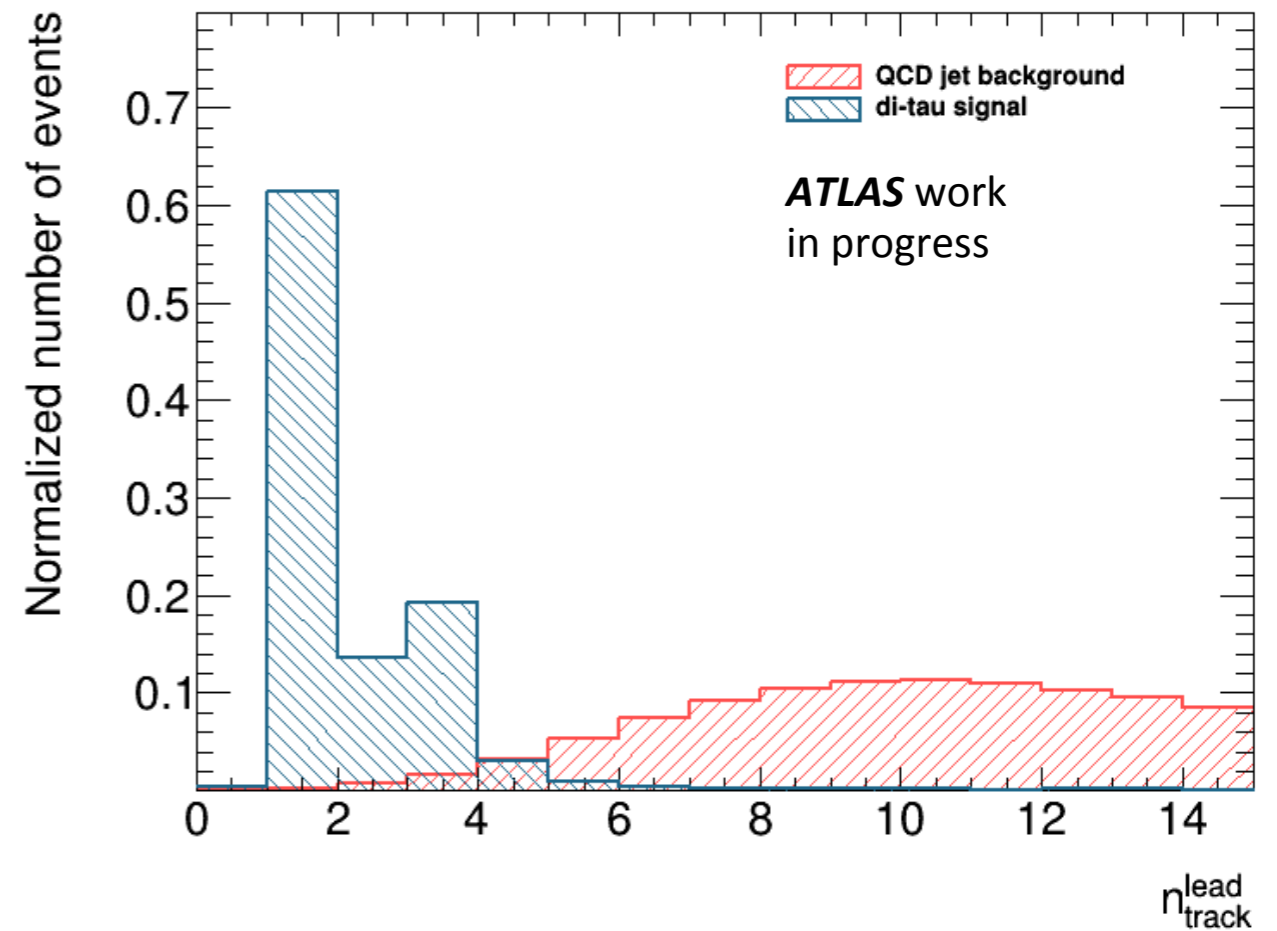
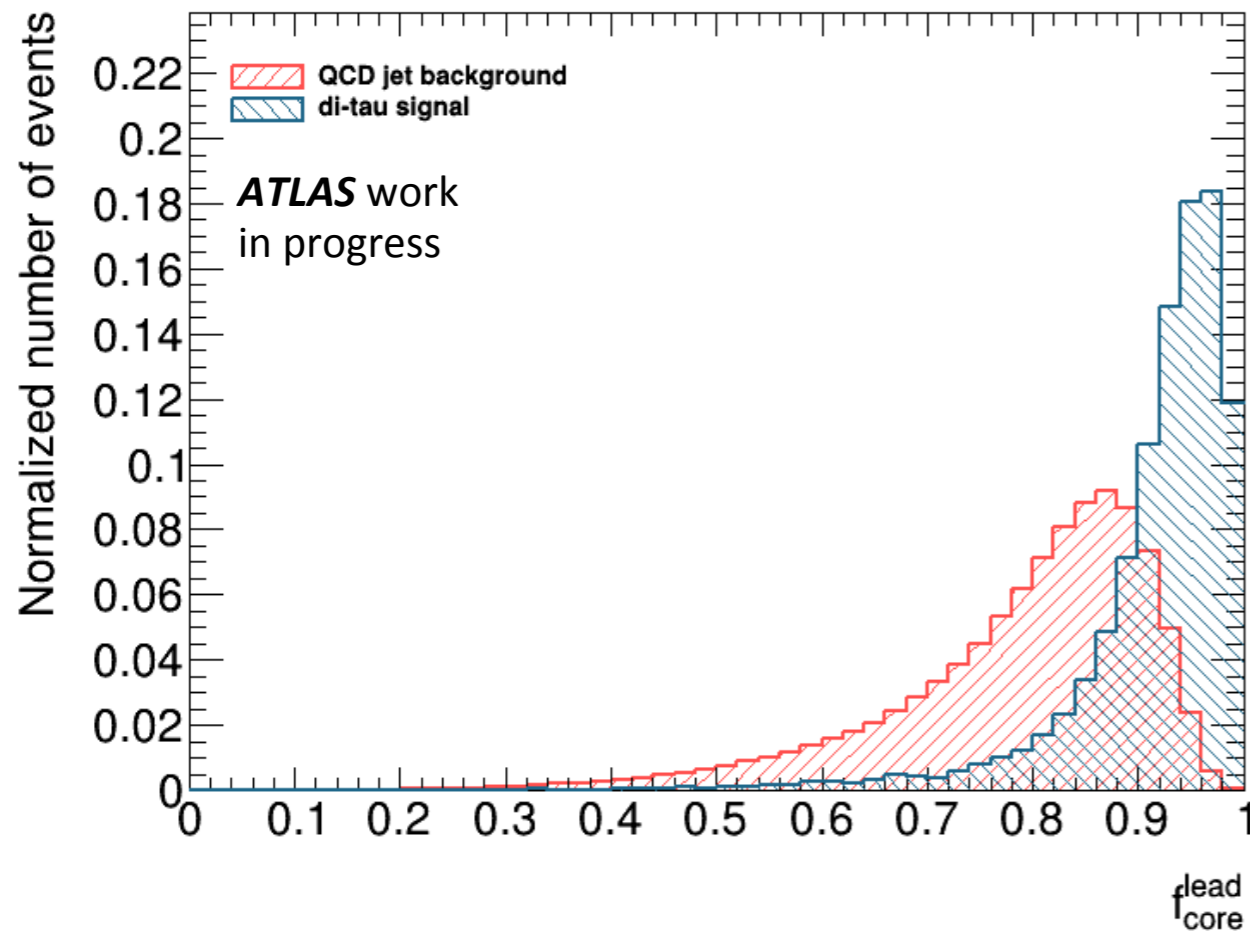
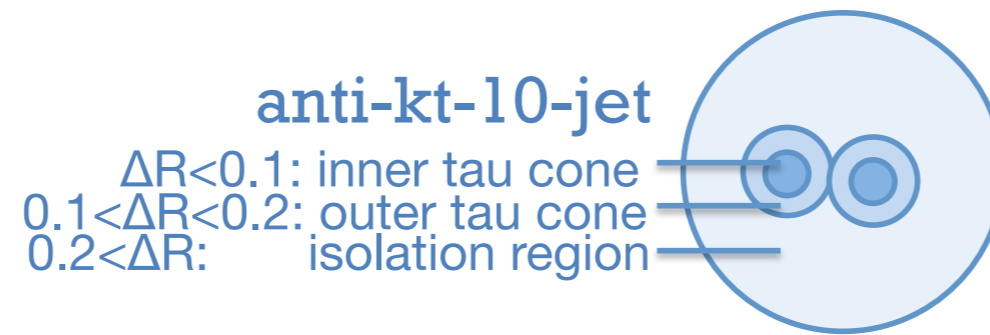


QCD background



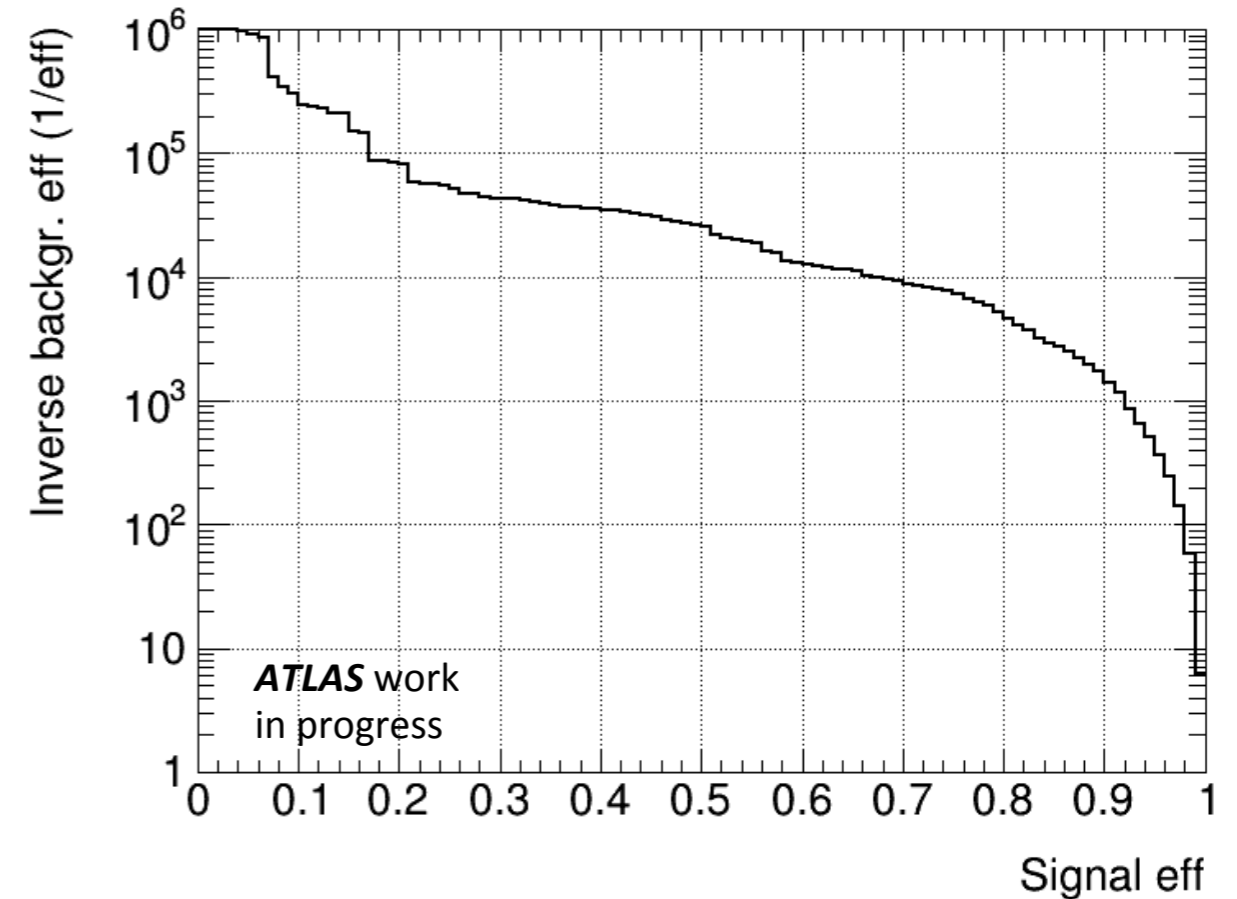
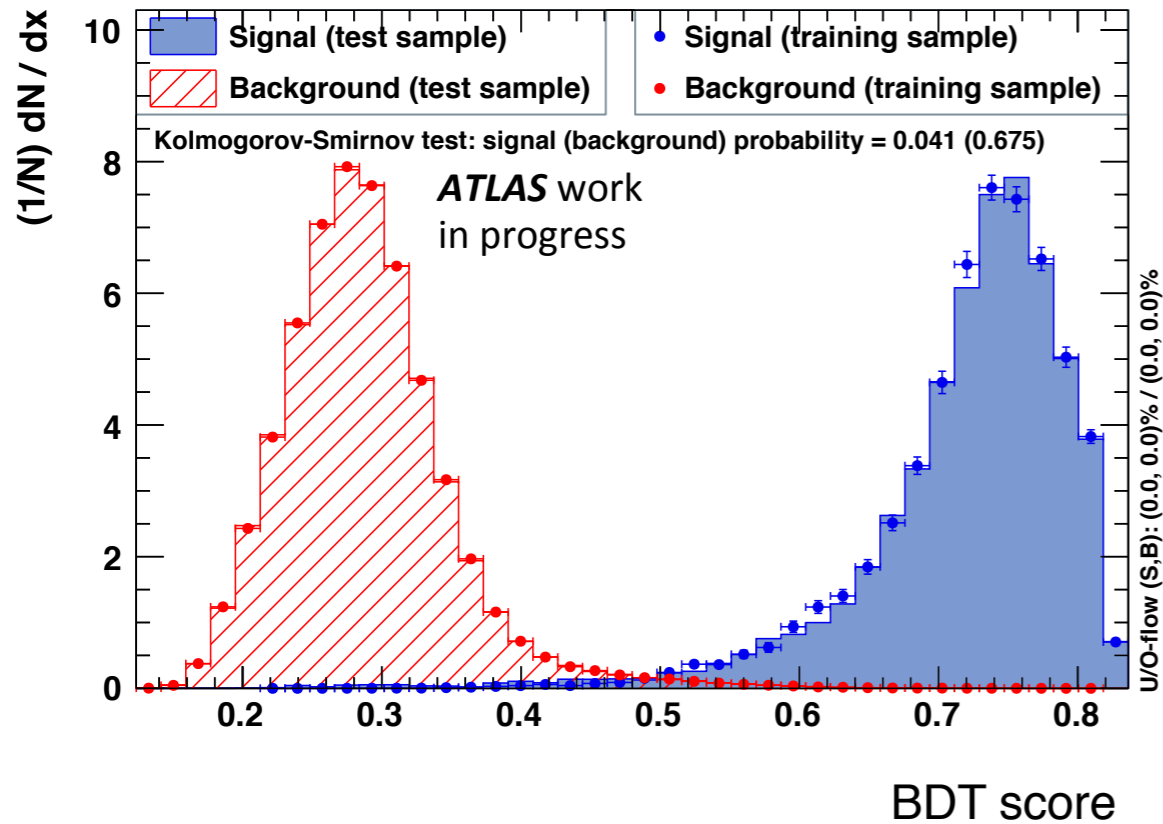
- Multivariate QCD background separation using Boosted Decision Trees
- Combines tracker and calorimeter information within 17 variables

Di-Tau Identification



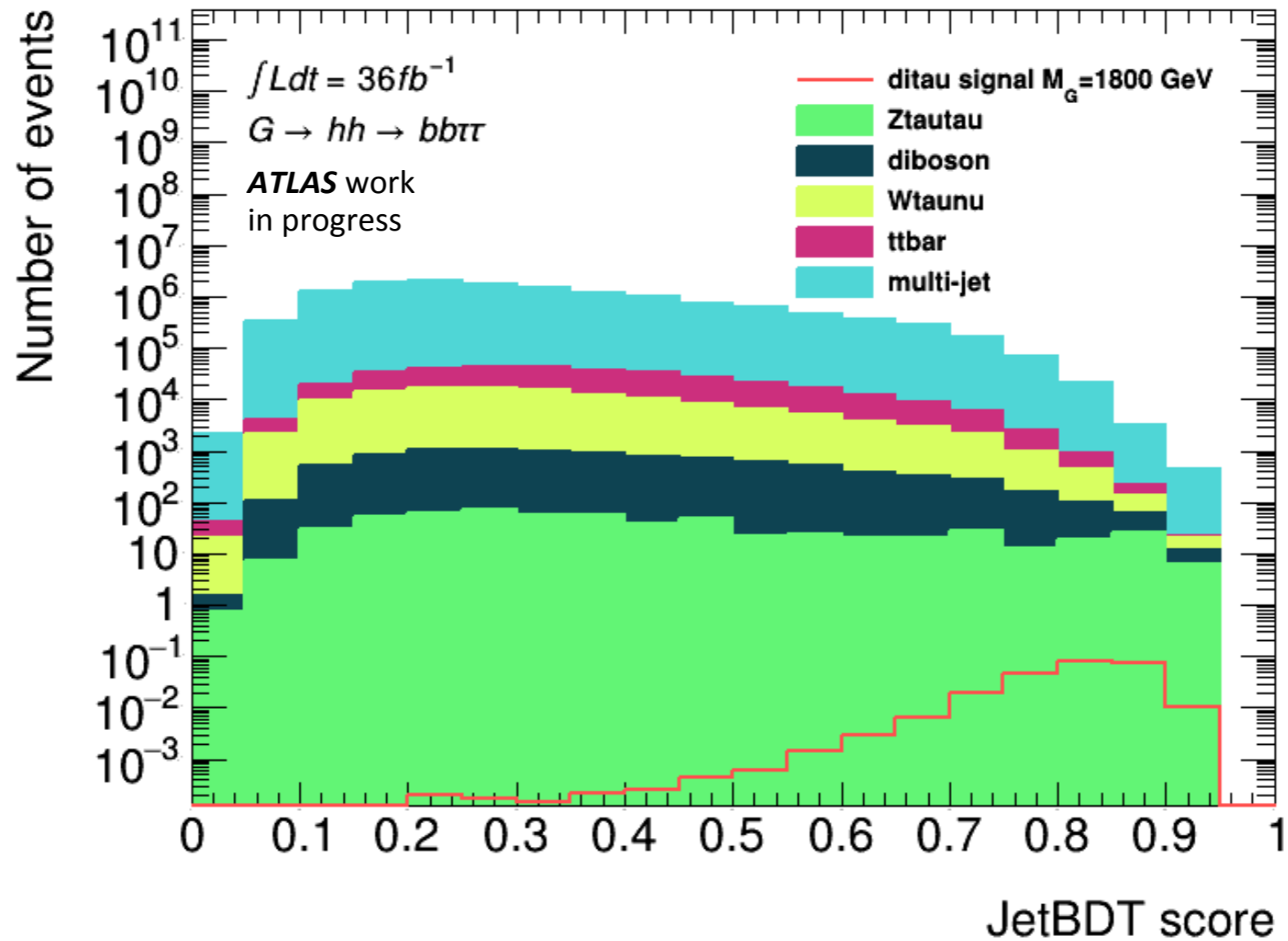
Di-Tau Identification

TMVA overtraining check for classifier: BDTNtrees150NCuts300NoTrackCut554

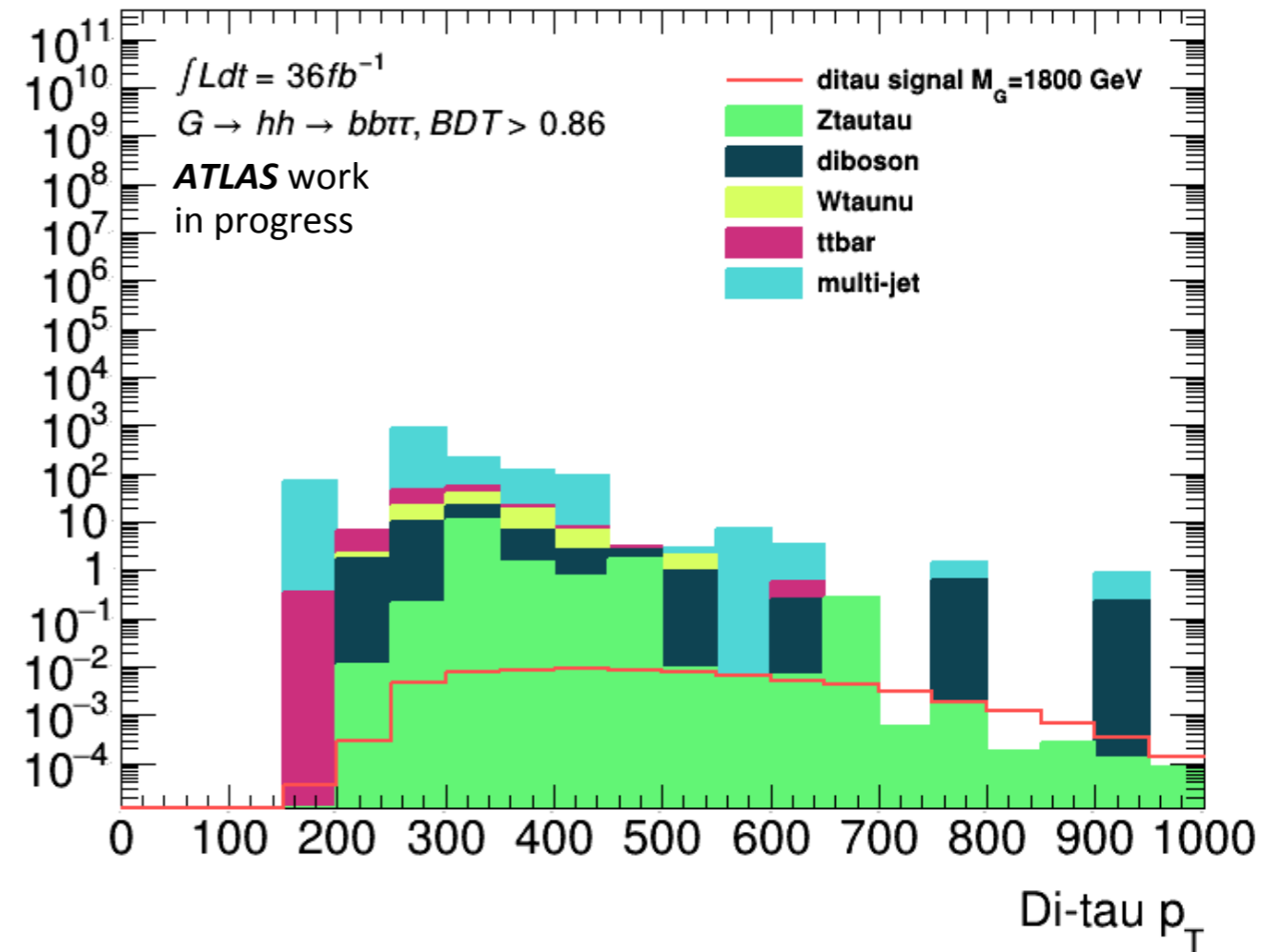
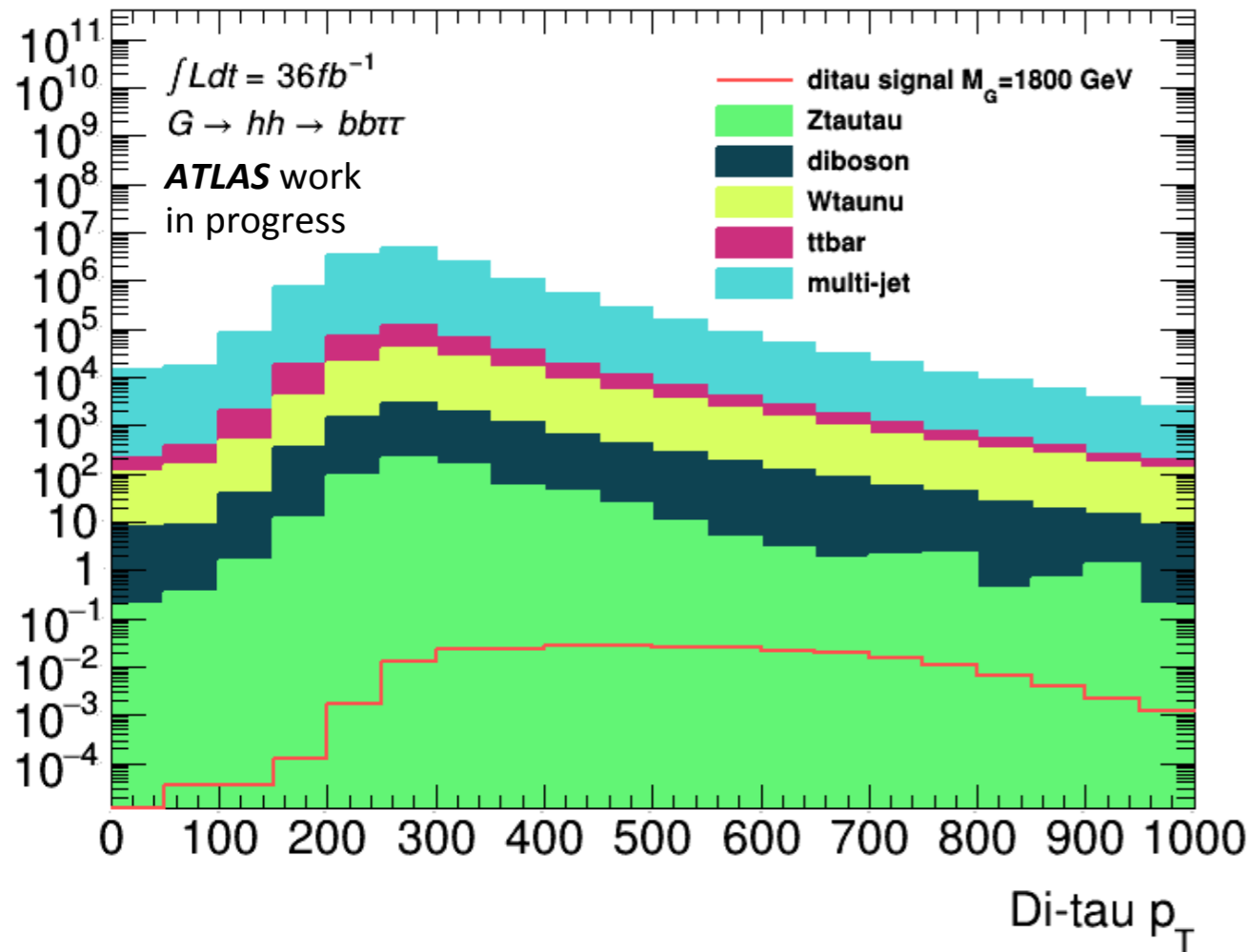


- Signal: $G \rightarrow hh \rightarrow 4\tau$ MC samples, $M_G = 1500-2500$ GeV
- Background: 13 TeV 2015 data

Di-Tau Identification



Di-Tau Identification



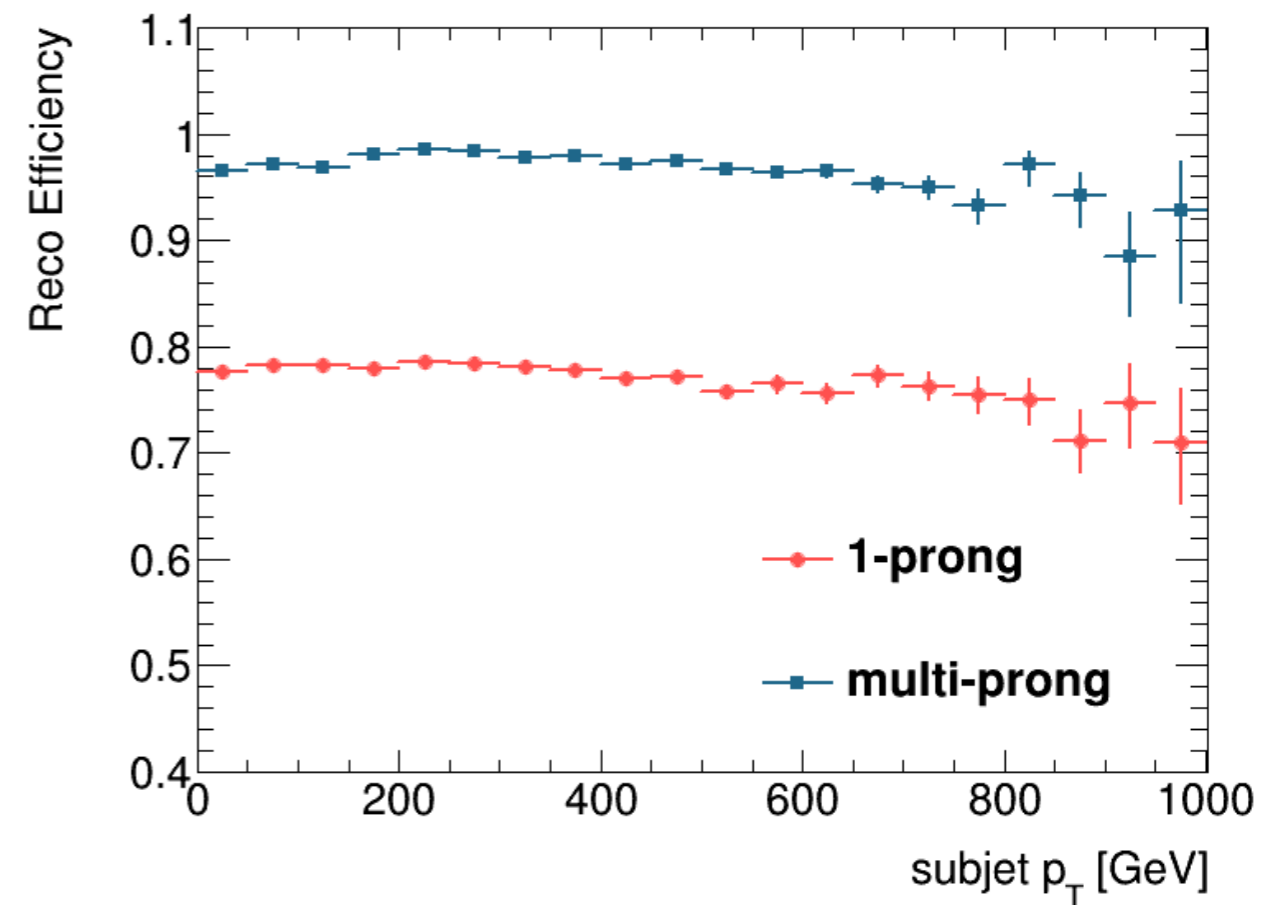
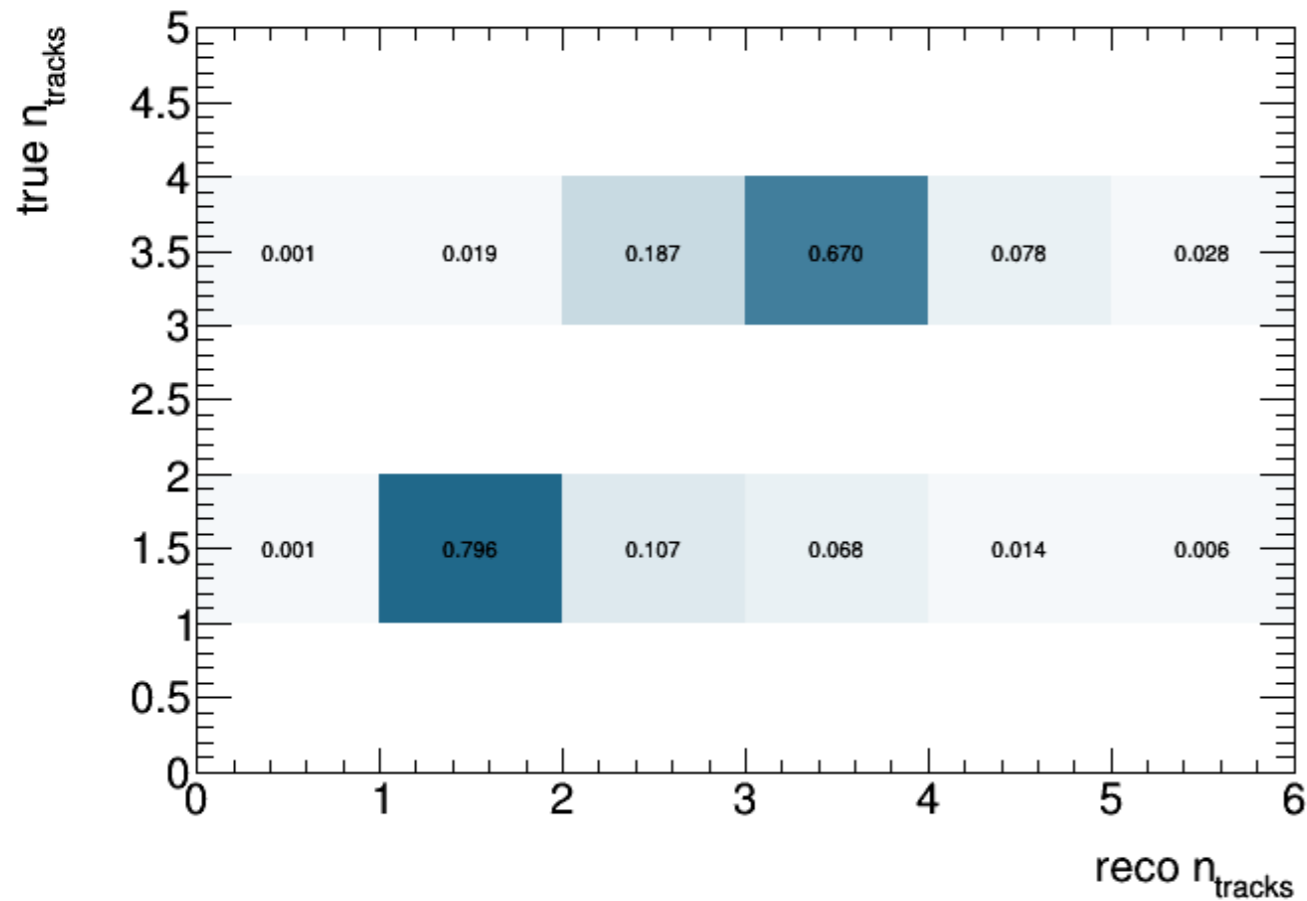
Summary and Outlook

- 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 $hh \rightarrow bb\tau\tau$ analysis with boosted category



**THANK YOU
FOR YOUR ATTENTION**

Di-Tau Track Reconstruction



Event Selection for DiTauID

Di-Tau Signal

- $G \rightarrow hh \rightarrow 4\tau$ 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**

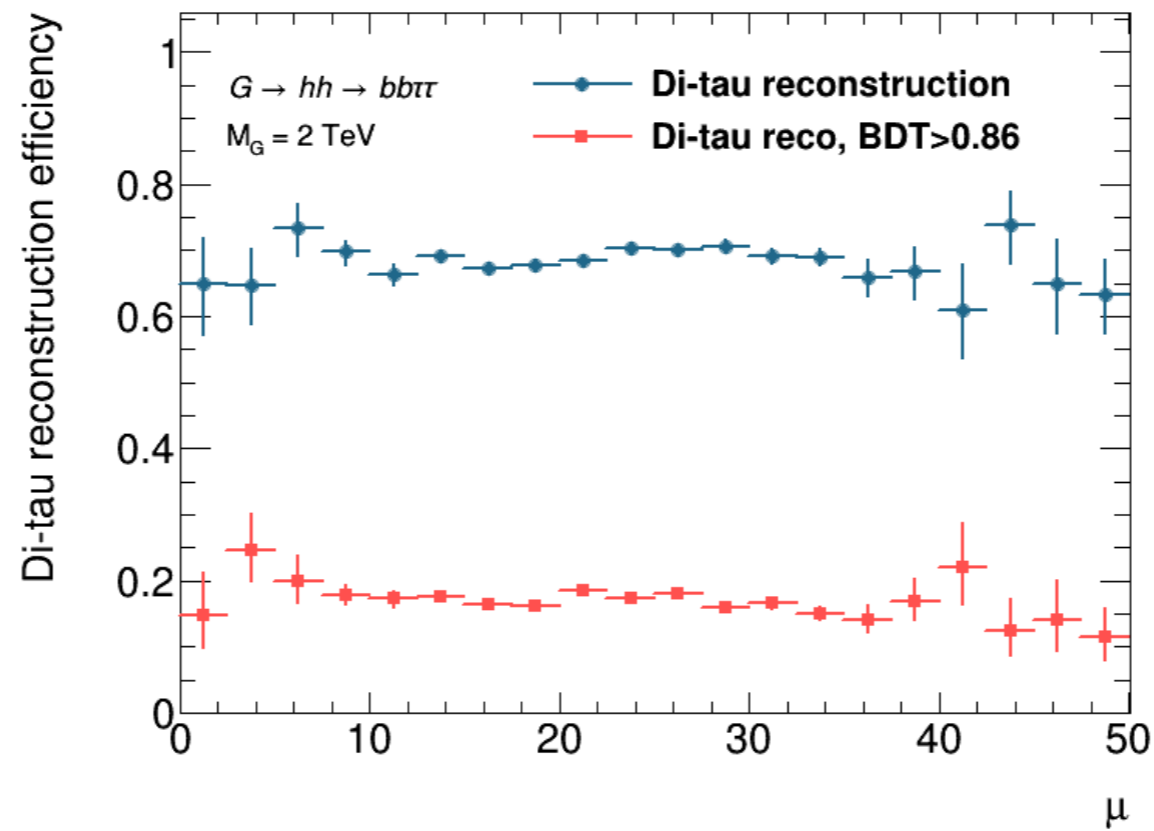
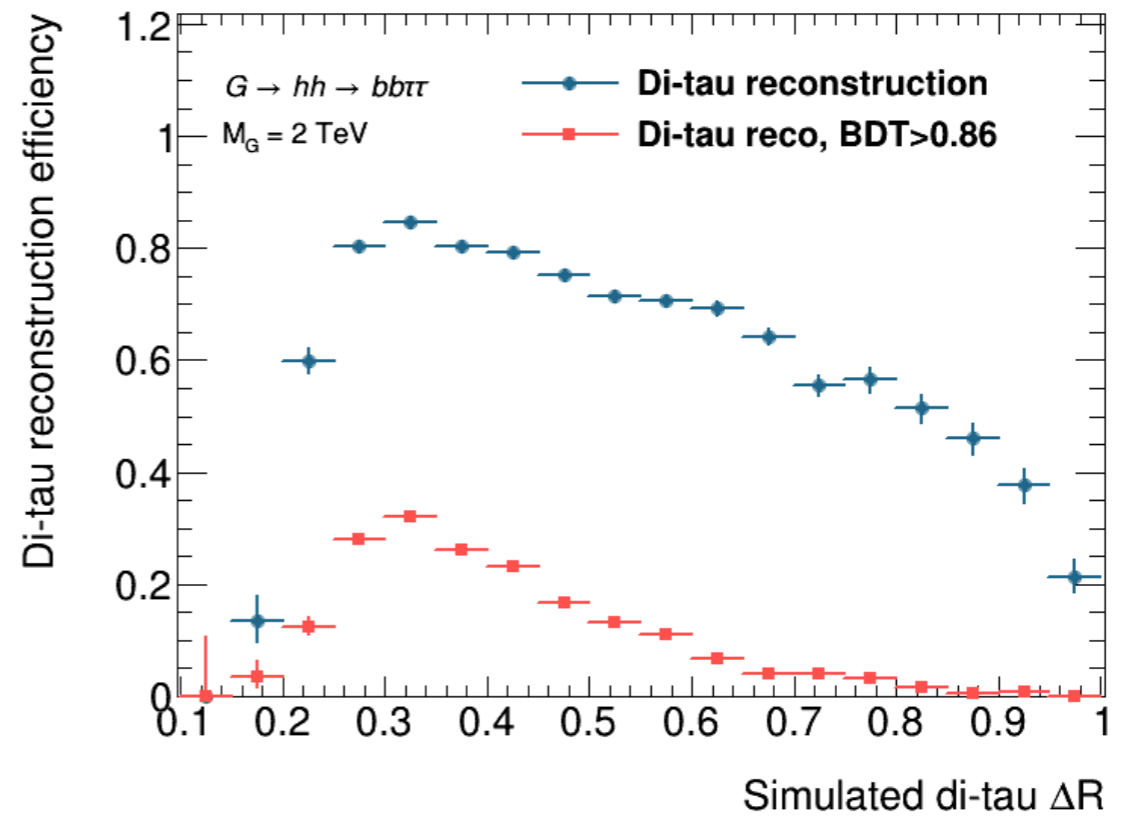
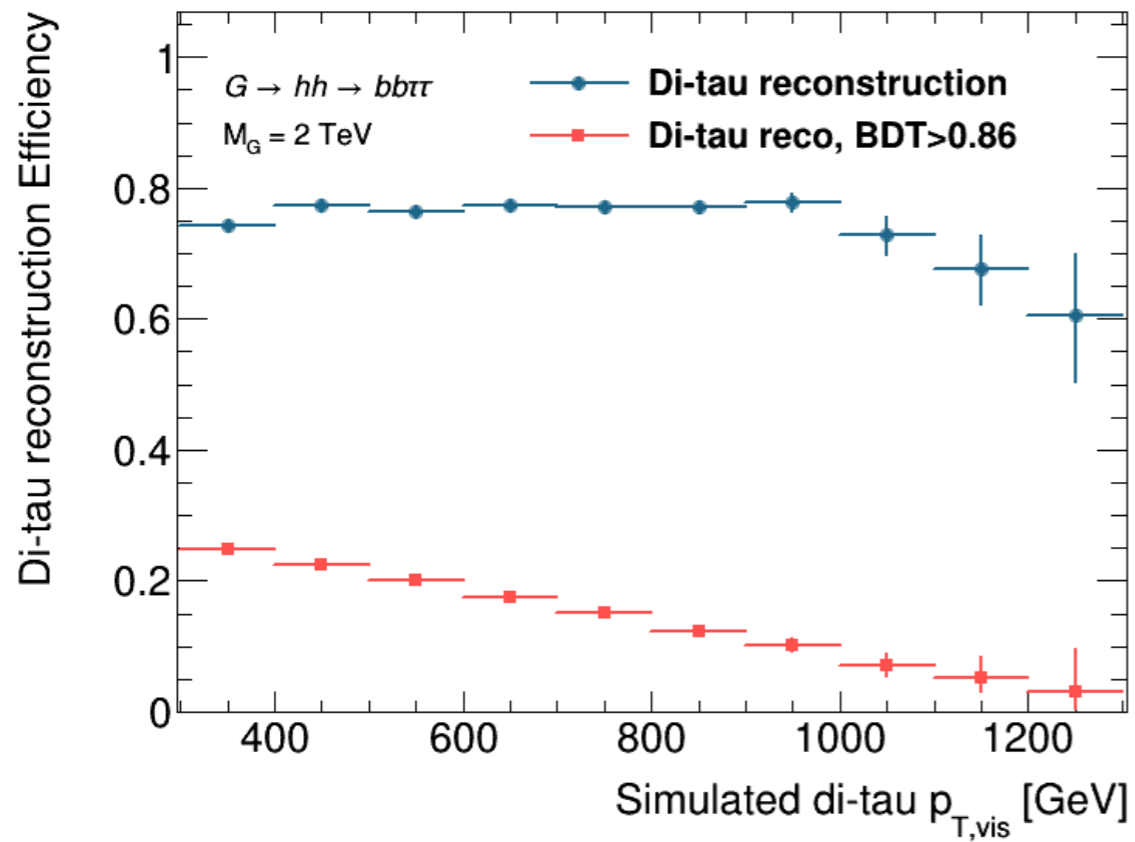
Di-Tau Identification

Correlation Signal

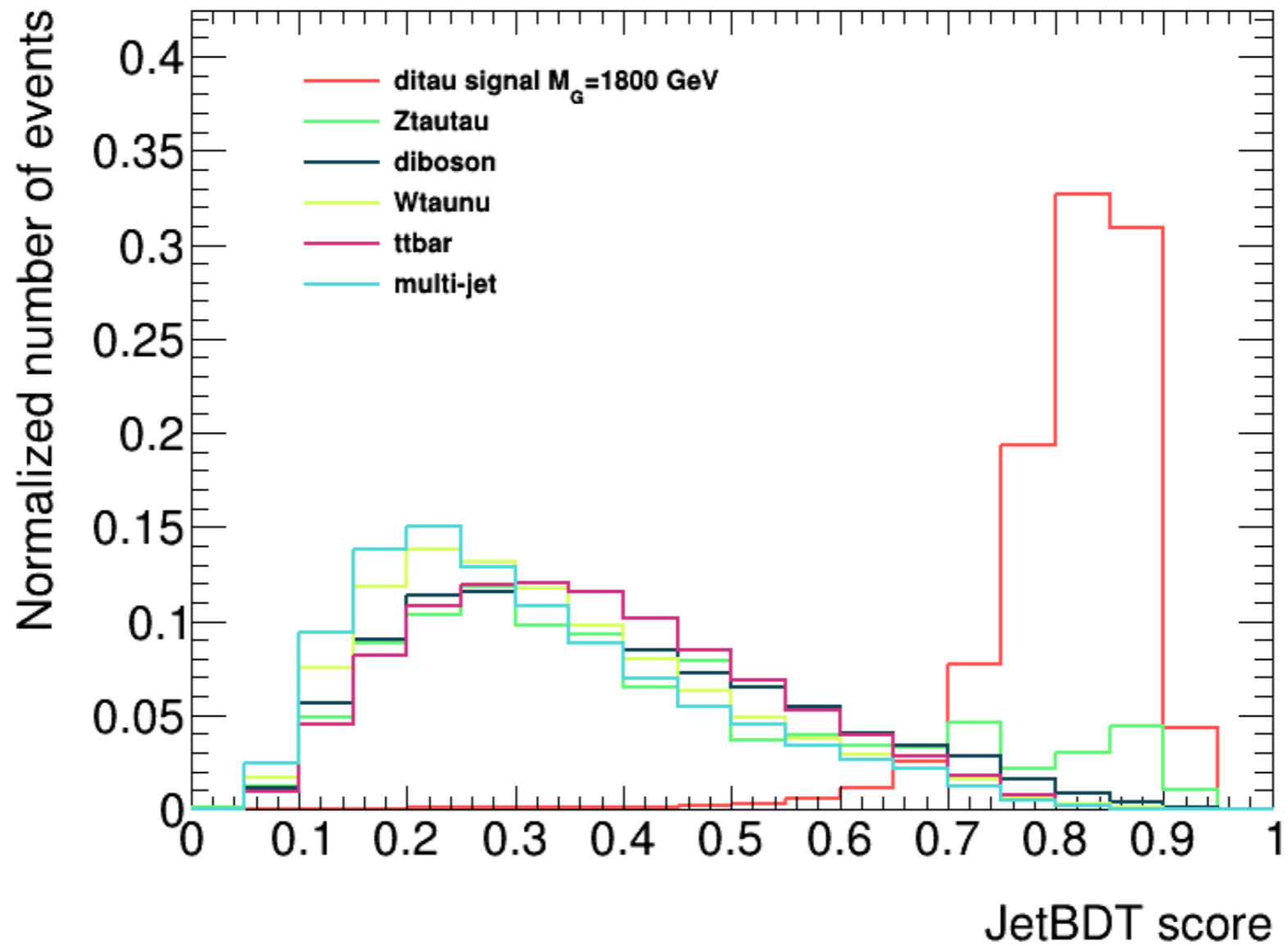
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n_isotrack		2	2	-27	-1	-42	-1	30	3		28	5	5	100	33	
n_tracks_subl			2	6	1	-10	-4	-6	4	1	-11	42		100	5	
n_tracks_lead				1	-1	3	-3	4	2	50	2	41	100		5	
n_track					1	-4	-13	-2	61	22	-3	100	41	42	28	
log(abs(d0_leadtrack_subl))									23		3	100	-3	2	-11	
log(m_tracks_lead)										1	100	3	22	50	1	
R_subjets_subsubl													61	2	4	
R_tracks_subl														30	8	
log(f_isotracks)																
f_track_subl																
f_track_lead																
f_subjets																
f_subjet_subl																
f_core_subl																
f_core_lead																
f_core_lead	100	29	-27	5	-10	-20	-10	-23	-3	-8	-14	-2				
f_core_subl		100	17	-8	-2	-28	-32	1	-21	-9	-2	-7	-2	2	2	
f_subjet_subl			100	-7	-1	-14	-22	2	-9	-7	3	-2	6	2	-6	
f_subjets				100	-2	-2	7	2	-43	8	-4	-40	1	1	-27	
f_track_lead					100	1	12	-2	8	-4	-4	3	-10	-1	-2	
f_track_subl						100	1	12	-2	8	-4	-4	3	-10	-1	
log(f_isotracks)							100	-15	-3	-13	-3	-4	-42	-13		
R_tracks_subl								100	-2	10	23	-2	4	-6	-1	
R_subjets_subsubl									100	1	61	2	4	30	8	
log(m_tracks_lead)										100	3	22	50	1	3	
log(abs(d0_leadtrack_subl))											100	-3	2	-11		
n_track												100	41	42	28	
n_tracks_lead													100		5	
n_tracks_subl														100	5	
n_isotrack															100	
n_iso_ellipse																100

Correlation Background

n_iso_ellipse	5	6	10	-11	2	-4	9		12	5	-9	11	5	12	48	100	
n_isotrack		-5	4	12	-25	1	-4	24	1	19	5	-8	17	5	11	100	48
n_tracks_subl			-7	5	33	-12	4		-3	14	16	16	-52	33	16	100	11
n_tracks_lead				-8	-1	-4		17	7	-7	15	2	60	-8	24	100	16
n_track					-8	-1	-4		17	7	-7	15	2	60	-8	24	100
log(abs(d0_leadtrack_subl))																	
log(m_tracks_lead)																	
R_subjets_subsubl																	
R_tracks_subl																	
log(f_isotracks)																	
f_track_subl																	
f_track_lead																	
f_subjets																	
f_subjet_subl																	
f_core_subl																	
f_core_lead																	
f_core_lead	100	2	-21	39	-2	-2	-9	-8	-9	-12	6	-33	-8	-7	-5	5	
f_core_subl		100	12	-3	-5	-3	5	-1	-5	4	-1	5	4	5	4	6	
f_subjet_subl			100	-27	4	-20	5	-2	28	-3	-30	37	-4	33	12	10	
f_subjets				100	-8	5	-20	-3	-40	1	9	-25		-12	-25	-11	
f_track_lead					100	5	1	3	2	30	-3	-1	17	4	1	2	
f_track_subl						100	5	1	3	2	30	-3	-1	17	4	1	
log(f_isotracks)							100	-2	3	-7	3	-5	-7	-3	24	9	
R_tracks_subl								100	3	20	-3	12	15	14	1		
R_subjets_subsubl									100	2	-14	38	2	16	19	12	
log(m_tracks_lead)										100	-11	28	60	16	5	5	
log(abs(d0_leadtrack_subl))											100	-27	-8	-52	-8	-9	
n_track												100	24	33	17	11	
n_tracks_lead													100		5	5	
n_tracks_subl														100		12	
n_isotrack															100	48	
n_iso_ellipse																100	



Di-Tau Identification



Uncertainties

