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Determining systematic uncertainties of boosted tau pair reconstruction and identification efficiencies at ATLAS

DPG Frühjahrstagung Würzburg, 22nd of March 2018





Outlook

Data-driven method for scale factors using Z→ττ mass peak $(X \rightarrow \tau_{had} \tau_{had} \text{ and } X \rightarrow \tau_{had} \tau_{lep})$

uncertainties on the

a) reconstruction and identification efficiency

b) energy scale

of boosted τ -pairs in the $X \rightarrow \tau_{had} \tau_{lep}$ channel

Introduction

Motivation



Search for new physics in final states with





Graviton samples

- G \rightarrow hh \rightarrow 4 τ samples (mass-sliced: M_G = 1TeV, ..., 5TeV)
- DiTau identification depends on track reconstruction in inner detector and shower modelling in calorimeter
- Three samples concerning the **inner detector**:
 - Overall increase in material budget in all detector layers
 - Additional 30% material in Insertable B-Layer (IBL)
 - Additional 50% material in patch panel (PP0)
- One sample containing an alternative hadronic shower model
 - (QGSP_BIC instead of FTFP)
- A nominal sample to compare with







Systematic uncertainties for boosted τ-pair topologies IKTP / Fabian Petsch DPG Frühjahrstagung Würzburg, 22.03.2018



Systematic uncertainties for the reconstruction and identification efficiency

$\epsilon = \frac{\text{truth-matched reconstructed/identified DiTaus}}{\text{truth DiTaus}}$

Relative uncertainty = $\frac{\epsilon_{nominal} - \epsilon_{modified}}{\epsilon_{nominal}}$

Kinematic regions:

ΔR	$p_{T}(\tau_{had, vis})$	$p_{T}(\tau_{lep})$
Small	Low	Low
0 - 0.2	0 - 20 GeV	0 - 20 GeV
Medium	Medium	Medium
0.2 - 0.4	20 - 200 GeV	20 - 100 GeV
Large	High	High
0.4 - 1.0	> 200 GeV	> 100 GeV









Efficiency – $\tau\tau \rightarrow$ hadrons + e + neutrinos

ΔR	$p_{T}(\tau_{had, vis})$	$p_{T}(\tau_{lep})$		A	TLAS	Work i	n progr	ess
Large	High	High	95.3%	91.9%	78.0%	60.8%	41.4%	- 90
Large	High	Medium	84.2%	82.6%	77.9%	71.7%	63.0%	- 80
Large	Medium	High	62.4%	57.9%	43.4%	29.8%	18.2%	- 70
Large	Medium	Medium	10.6%	10.0%	8.5%	7.1%	5.6%	-60
Medium	High	High	92.1%	88.5%	75.4%	60.5%	44.4%	50
Medium	High	Medium	85.2%	82.8%	75.3%	67.3%	58.4%	-40
Medium	Medium	High	79.5%	75.3%	60.7%	46.2%	32.1%	— 30
Medium	Medium	Medium	18.2%	16.9%	14.2%	11.6%	9.0%	20
Small or	Low or	Low	34.5%	32.0%	25.7%	20.6%	15.7%	—10
			Reco	VeryLoose	Loose	Medium	Tight	J





Relative Reconstruction/ID uncertainties - $\tau\tau \rightarrow hadrons + e + neutrinos$

ΔR	p _T (τ _{had, vis})	$p_{T}(\tau_{lep})$		ΑΤ	LAS W	/ork in p	orogres	SS	
Large	High	High	0.81%	1.13%	2.90%	4.06%	5.08%		8
Large	High	Medium	1.32%	1.40%	1.49%	1.87%	2.42%		7
Large	Medium	High	- 1.80%	1.85%	2.81%	3.96%	4.63%		, ,
Large	Medium	Medium	8.64%	6.97%	6.62%	7.43%	6.44%		0
Medium	High	High	0.74%	0.77%	1.27%	1.99%	3.09%		5
Medium	High	Medium	0.42%	0.49%	0.78%	1.22%	1.69%		4
Medium	Medium	High	- 1.64%	1.55%	1.49%	2.48%	3.87%		3
Medium	Medium	Medium	7.07%	7.30%	6.40%	6.99%	6.36%		2
Small or	Low or	Low	4.31%	2.30%	1.09%	1.16%	1.45%		1
			Reco	VeryLoose	Loose	Medium	Tight	1	I





Efficiency - $\tau\tau \rightarrow$ hadrons + μ + neutrinos

ΔR	p _T (τ _{had, vis})	$p_{T}(\tau_{lep})$	
Large	High	High	99.
Large	High	Medium	- 99.
Large	Medium	High	94.
Large	Medium	Medium	96.
Medium	High	High	97.
Medium	High	Medium	 96.
Medium	Medium	High	- 85.
Medium	Medium	Medium	92.
Small	High	High	 91.
Small	High	Medium	- <u> </u>
Small	Medium	High	- 81.
Small	Medium	Medium	- 83.
	Low or	Low	

ATLAS Work in progress







Relative Reconstruction/ID uncertainties -

$\tau \tau \rightarrow hadrons + \mu + neutrinos$

ΔR	p _T (τ _{had, vis})	$p_{T}(\tau_{lep})$
Large	High	High
Large	High	Medium
Large	Medium	High
Large	Medium	Medium
Medium	High	High
Medium	High	Medium
Medium	Medium	High
Medium	Medium	Medium
Small	High	High
Small	High	Medium
Small	Medium	High
Small	Medium	Medium
	Low or	Low

ATLAS Work in progress

0.68%	0.84%	0.78%	2.99%	4.63%	
0.66%	0.46%	0.20%	0.60%	0.97%	 12
2.78%	1.72%	0.87%	0.96%	0.93%	
2.50%	1.89%	0.77%	0.63%	1.28%	 10
1.14%	0.92%	0.60%	0.70%	1.21%	
1.17%	1.01%	1.06%	0.84%	1.05%	 8
5.82%	5.02%	3.41%	2.75%	1.73%	
5.84%	5.21%	4.22%	3.32%	3.33%	 6
0.74%	0.55%	0.98%	1.60%	3.09%	
1.58%	1.41%	1.17%	1.25%	1.87%	 4
8.34%	7.67%	7.23%	5.82%	7.62%	
13.85%	12.33%	8.02%	8.15%	6.83%	 2
7.00%	5.15%	2.28%	1.02%	1.50%	
Reco	VeryLoose	Loose	Medium	Tight	





Systematic uncertainties for the energy scale

Scale ditau- p_T with a small factor α : (1+ α)· p_T (ditau)

Uncertainties for DiTau energy scale:

For each systematic sample

- Apply scaling
- Perform χ²-Test to compare histograms of systematic and nominal sample
- Obtain α for minimal $\,\chi^2\!$ value

SFUncertainty =
$$\sqrt{\sum_{\text{modifications}} \alpha^2}$$







Energy scale uncertainties - $\tau\tau \rightarrow hadrons + e + neutrinos$

ΔR	p _T (τ _{had, vis})	$p_{T}(\tau_{lep})$		A	TLAS	Nork ir	n progr	ess
Large	High	High	1.04%	1.05%	0.82%	1.31%	1.31%	1.0
Large	Medium	High	0.20%	0.28%	0.36%	0.70%	0.66%	1.2
Large	High	Medium	0.60%	0.49%	0.42%	0.65%	0.68%	-1
Large	Medium	Medium	0.14%	1.01%	0.99%	1.09%	1.14%	0.9
Medium	High	High	1.01%	1.01%	1.00%	1.04%	1.03%	-0.0
Medium	Medium	High	0.71%	0.73%	0.85%	0.65%	0.58%	-0.6
Medium	High	Medium	0.91%	1.00%	1.03%	0.59%	0.59%	
Medium	Medium	Medium	0.20%	0.14%	0.57%	1.21%	0.72%	-0.4
Small or	Low or	Low	0.95%	0.99%	0.76%	0.79%	0.88%	-0.2
			Reco	o ^V erj	10050 LOOS	se Mea	lium ^{Tigh}	t





Energy scale uncertainties - $\tau\tau \rightarrow hadrons + \mu + neutrinos$

ΔR	$p_{T}(\tau_{had, vis})$	$p_{T}(T_{lep})$		A	TLAS	Work i	n progi	ress
Large	High	High	1.22%	1.22%	1.22%	0.75%	1.28%	-2.2
Large	Medium	High	0.87%	0.62%	0.95%	0.76%	1.12%	-2
Large	High	Medium	1.50%	1.40%	1.71%	1.41%	1.50%	-1.8
Large	Medium	Medium	1.22%	1.12%	1.11%	1.01%	1.10%	-1.6
Medium	High	High	1.01%	0.92%	1.01%	0.92%	1.07%	1.4
Medium	Medium	High	1.71%	1.71%	1.54%	1.59%	1.39%	-1
Medium	High	Medium	1.51%	1.50%	1.30%	1.30%	1.00%	-0.8
Medium	Medium	Medium	2.35%	2.13%	2.08%	2.18%	2.17%	-0.6
Small	or Low	or Low	1.09%	0.85%	0.37%	1.04%	0.20%	-0.4
			Rec	o Verj	Loose	se Mea	tium ^{Tigh}	<i>t</i> −0.2





Outlook - Scale factors from data

Idea: Use $Z \rightarrow \tau \tau$ mass peak in boosted regime to derive scale factors

- Boosted DiTaus from $7 \rightarrow \tau \tau$ events with $high-p_{_{T}}\ recoil\ jet$
- For both HadHad and LepHad channel
- Data-driven method

Truth-matching:

 Match each of the two subjets in the DiTaulet to a truth tau within $\Delta R < 0.2$ cone







Background composition:

- Dominated by QCD
- Some $t\bar{t}$, $W \rightarrow \tau v$
- Very few single top, WW, WZ

Preliminary cutflow for

signal region:

- DiTauJets with 2 subjets
- High MET cut
- $|\Delta \phi(MET, DiTauJet)| < 1$
- b veto
- DiTau identification with BDT

ABCD method:

 QCD mis-modelling (dijet MC) addressed by estimation from data



A	B
BDT score > 0.6	0.2 < BDT score < 0.6
MET > 150 GeV	MET > 150 GeV
C	D
BDT score > 0.6	0.2 < BDT score < 0.6
50 GeV < MET < 150	50 GeV < MET < 150
GeV	GeV

Other backgrounds are subtracted from data: $N_i^{QCD} = N_i^{data} - N_i^{Z \rightarrow \tau \tau} - N_i^{W \rightarrow \tau \nu} - N_i^{ttbar} - N_i^{singletop} - N_i^{WW} - N_i^{WZ}$

where i = B, C, D





Expected signal purity

- $Z \rightarrow \tau\tau$, $t\bar{t}$, $W \rightarrow \tau v$ taken from MC samples
- QCD calculated by ABCD method
- Normalization of other backgrounds to be verified in control regions
- Work is ongoing



Invariant mass of subjets [GeV]



Summary

- Systematic uncertainties for reconstruction/identification efficiency and energy scale of boosted DiTaus in X→ T_{had}T_{lep} channel have been calculated (MC studies)
- Data-driven approach for scale factors and corresponding uncertainties using Z→ττ (for both X→ τ_{had} τ_{lep} and X→ τ_{had} τ_{had}) may be possible





Thank you for your attention!



