Boosted CoM H→bb tagger calibration: b-jet

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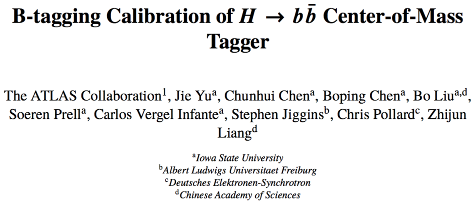
CoM discussion

September 10, 2018

Outline



B-tagging Calibration of $H \to b\bar{b}$ Center-of-Mass Tagger

The ATLAS Collaboration[1], Jie Yu[a], Chunhui Chen[a], Boping Chen[a], Bo Liu[a,d], Soeren Prell[a], Carlos Vergel Infante[a], Stephen Jiggins[b], Chris Pollard[c], Zhijun Liang[d]

[a] *Iowa State University*
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[d] *Chinese Academy of Sciences*

- Analysis twiki: *CoM calibration twiki* .
- Internal note: *ATL-COM-PHYS-2018-1142* (first draft, keep updating).

- Report today:
    - Topological dependence: CoM b-jet tagging efficiency in $H \to b\bar{b}$, $g \to b\bar{b}$ and $t \to W + b$.
    - Publication plan: a more recent target of a CONF note; and a paper for a little later.
        - CONF note: calibration with $t\bar{t}$ events.
        - paper: calibration with $t\bar{t}$ events + validation with $g \to b\bar{b}$ events (similar to what was done for anti-kt2 track jets in the $g \to b\bar{b}$ paper).
    - CoM b-jet calibration status: using $t\bar{t}$ →l+jets events.

Topological dependence

CoM *b*-jet tagging efficiency

- Plots from Bo to show ε_b as a function of CoM jet p_{T} similar in $H \to b\bar{b}$ and $t \to W + b$. (All uses Pythia8 as parton shower.)
- Larger difference might show up in $H \to b\bar{b}$ vs. $g \to b\bar{b}$
- Any difference can be quoted as systematic uncertainty.

Publication plans

Plan for public results: short term

- Short term (in a month or two).
- Aiming for a CONF note (we noticed that PUB plots are only possible when there was CONF note already.)
- Using data 2015 – 2017.
- Description of calibration method and results with $t\bar{t}$.
- The calibration study is almost done: only missing MC/MC SF, topological dependence uncertainty and running the code with flat efficiency working points!
- Urgently needed by a few physics analysis:
  - EXOT $H\gamma$: publication planed for early summer 2019
  - SM VH differential cross section measurements (at boosted region) and BSM search: Carlos' thesis.
  - EXOT VH: Stephen is interested in contributing to this.
  - Inclusive H$\rightarrow b\bar{b}$: Boping's thesis.
- Also needed by myself for searching for jobs starting from now.
- In general good for flavor tagging group in providing new taggers dedicated for boosted $H \rightarrow b\bar{b}$ searches.

Plan for public results: longer term

- Longer term (aiming for Moriond 2019)
- Add validation with $g \rightarrow b\bar{b}$ data. Apply the method used in the antikt2 track jet paper. (No substructure variable study, but only *b*-tagging.)
- Status: Migle's gbb framework @21.2 is tested.
  - Not easy to add other sub-jet / track-jet collections (e.g. VR, ExKt, CoM).
  - OK to modify the code and produce NTuples only for CoM. But, (1) the ntuples are huge (10TB for all MC and data?), (2) link of large-R jet and CoM jets are broken at CxAODMaker level.

b-jet calibration status

Selection efficiency and number of events: MC16a vs. data15+16

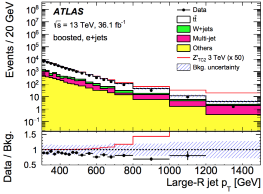
	e+jets channel				μ+jets channel			
pre-selection	8006.2				7478.0			
$t\bar{t} \rightarrow l\nu b, qqb$	6214.1	(77.6%)			6508.0	(87.0%)		
truth channels	matched		top not M	*b*-quark not M	matched		top not M	*b*-quark not M
truth definition	3144.7	(39.3%)	1624.7	1444.8	2998.6	(40.1%)	1903.7	1605.7
$N_{CoM\,jets} == 2$	3144.0	(39.3%)	1620.0	1397.6	2998.6	(40.1%)	1899.0	1603.5
large-R jet $p_{\mathrm{T}} > 350$ GeV	617.7	(7.7%)	395.0	114.9	565.8	(7.6%)	428.0	120.2
MET > 30 GeV	617.7	(7.7%)	395.0	114.9	541.1	(7.2%)	410.1	115.0
$M_T^W > 30$ GeV	608.5	(7.6%)	388.8	113.6	535.6	(7.2%)	404.2	114.0
$1 \leq N_{jets} \leq 4$	533.6	(6.7%)	278.7	101.5	490.7	(6.6%)	286.0	104.2
$N_{b-jets} == 1$	327.3	(4.1%)	139.2	62.1	314.6	(4.2%)	142.7	65.2
ΔR(lep, b-jet) <2	259.1	(3.2%)	110.4	55.8	298.8	(4.0%)	114.6	61.7
$125 \leq M_{ljet} \leq 245$	182.6	(2.3%)	19.7	7.4	210.9	(2.8%)	22.0	7.9
$60 \leq M_{at4em} \leq 105$	89.9	(1.1%)	3.3	3.6	104.4	(1.4%)	3.8	3.9

- In both *e*+jets and μ+jets, the matched $t\bar{t} \rightarrow$l+jets is about 90% out of total MC expectation.
- Very similar selection efficiency and expected number of events found with MC16d.
- Number of events normalized to @1fb^{-1}. Data15+16 has 36.1fb^{-1} and data17 has 43.6fb^{-1}.

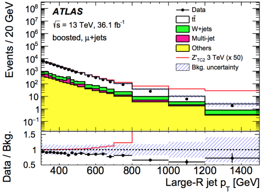
samples	*e*+jets	μ+jets
$t\bar{t} \rightarrow$ dilepton	1.2	1.2
single top (Wt channel)	1.9	1.9
single top (t-channel)	0.1	0.1
single top (s-channel)	<0.1	<0.1
W+jets	<0.1	<0.1
Z+jets	<0.1	0.1
diboson	<0.1	<0.1
Total backgrounds	3.2	3.3

Leading large-R jet p_{T}

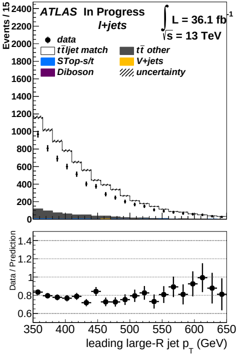
- More MC than data found, which also found in the $t\bar{t}$ resonance paper: arxiv:1804.10823 with same dataset.
- By fitting MC to data, the scale factor for $t\bar{t}$ is found to be: 0.769 ± 0.010 (data15+16) and 0.873 ± 0.010 (data17).



(a) *e*+jets selection.



(b) μ+jets selection.



ε_b calibration as a function of CoM sub-jet p_{T}

- One single SF for $t\bar{t}$ across all p_{T} bins ⇒ can use different SF for every p_{T} bin.
- In CoM sub-jet p_{T} calibration, two CoM jets' index, w_1 and w_2, are ordered according to their p_{T} from low to high.
- If there are two CoM sub-jet p_{T} bins defined, then the two CoM sub-jets p_{T} index would be: 00,01,11, where 0 is the low p_{T} CoM and 1 is the higher p_{T} one.
- Five CoM jet p_{T} bins: 0, 125, 175, 225, 275, 750 ⇒ in total 15 p_{T} regions, while expected number of events lower than 10 is excluded.
- Likelihood:

$$\begin{aligned}
\mathcal{L}(w_1, w_2, p_T^i, p_T^j) = {} & f_{bj}^{t\bar{t}\rightarrow l+jet\ matched} \cdot P_b(w_1|p_T^i) \cdot P_j(w_2|p_T^j) + \\
& f_{jb}^{t\bar{t}\rightarrow l+jet\ matched} \cdot P_j(w_1|p_T^i) \cdot P_b(w_2|p_T^j) + \\
& f_{jj}^{t\bar{t}\rightarrow l+jet\ matched} \cdot P_j(w_1|p_T^i) \cdot P_j(w_2|p_T^j) + \\
& f_{jj}^{t\bar{t}\rightarrow l+jet\ combinatorial} \cdot P_j^{comb}(w_1|p_T^i) \cdot P_j^{comb}(w_2|p_T^j) + \\
& f_{jj}^{bkg} \cdot P_j^{bkg}(w_1|p_T^i) \cdot P_j^{bkg}(w_2|p_T^j)
\end{aligned}$$

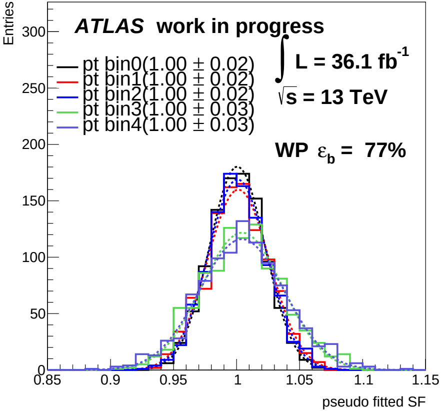
systematic uncertainties (in CoM sub-jet p_{T}): MC16a vs. data15+16

- Dominant contribution from large-R jet energy scale (using ‘Strong‘), but lower than using LJet p_{T}.
- More or less radiation in $t\bar{t}$ has larger effect. More $t\bar{t}$ MC related items to be added.

systematic	CoM sub-jet p_{T} (GeV)					systematic	CoM sub-jet p_{T} (GeV)				
	> 0	>125	>175	>225	>275		> 0	>125	>175	>225	>275
radiationAFII	∓ 0.7%	± 0.4%	∓ 0.4%	∓ 1.5%	± 3.3%	MUON MS	∓ 0.0%	± 0.1%	∓ 0.0%	± 0.1%	∓ 0.1%
herwigAFII	± 0.8%	∓ 0.1%	± 0.4%	∓ 1.3%	∓ 0.1%	MUON SAGITTA RESBIAS	∓ 0.0%	∓ 0.0%	∓ 0.0%	∓ 0.0%	∓ 0.0%
pileup	± 0.0%	± 0.1%	∓ 0.2%	∓ 0.2%	± 0.0%	MUON SAGITTA RHO	± 0.1%	± 0.1%	∓ 0.0%	∓ 0.0%	∓ 0.1%
jvt	± 0.1%	± 0.0%	± 0.0%	± 0.0%	∓ 0.0%	MUON SCALE	∓ 0.0%	∓ 0.0%	± 0.0%	± 0.0%	± 0.0%
bTagSF77 ext	± 0.1%	± 0.0%	∓ 0.0%	∓ 0.0%	∓ 0.1%	JET JER SINGLE NP	± 0.4%	± 0.0%	± 0.3%	∓ 0.4%	± 0.1%
bTagSF77 ext from charm	∓ 0.0%	∓ 0.0%	± 0.0%	± 0.1%	∓ 0.0%	JET BJES Response	± 0.1%	∓ 0.1%	∓ 0.1%	± 0.1%	± 0.1%
LJet Strong JET Comb Baseline All	± 1.4%	± 1.4%	± 0.7%	± 0.9%	± 1.0%	JET EffectiveNP Detector1	∓ 0.0%	± 0.1%	± 0.1%	∓ 0.1%	± 0.3%
LJet Strong JET Comb Modelling All	± 1.6%	± 1.3%	± 0.6%	± 0.7%	± 1.3%	JET EffectiveNP Mixed1	∓ 0.3%	∓ 0.0%	± 0.0%	∓ 0.0%	∓ 0.1%
LJet Strong JET Comb TotalStat All	± 0.1%	∓ 0.0%	± 0.0%	∓ 0.0%	± 0.1%	JET EffectiveNP Mixed2	± 0.0%	∓ 0.1%	∓ 0.0%	± 0.1%	∓ 0.1%
LJet Strong JET Comb Tracking All	± 0.9%	± 0.6%	± 0.4%	± 0.5%	± 0.6%	JET EffectiveNP Mixed3	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%
leptonSF EL SF Trigger	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EffectiveNP Modelling1	± 0.3%	± 0.3%	∓ 0.1%	∓ 0.4%	± 0.5%
leptonSF EL SF Reco	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EffectiveNP Modelling2	∓ 0.2%	∓ 0.0%	∓ 0.0%	± 0.0%	± 0.2%
leptonSF EL SF ID	± 0.0%	± 0.0%	± 0.1%	± 0.1%	± 0.1%	JET EffectiveNP Modelling3	± 0.1%	± 0.1%	∓ 0.1%	± 0.1%	∓ 0.3%
leptonSF EL SF Isol	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.1%	JET EffectiveNP Modelling4	± 0.0%	± 0.1%	∓ 0.0%	∓ 0.0%	∓ 0.0%
leptonSF MU SF Trigger STAT	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EffectiveNP Statistical1	± 0.0%	± 0.0%	∓ 0.0%	± 0.0%	∓ 0.0%
leptonSF MU SF Trigger SYST	± 0.1%	± 0.1%	± 0.0%	± 0.1%	± 0.1%	JET EffectiveNP Statistical2	∓ 0.0%	± 0.0%	∓ 0.0%	± 0.0%	∓ 0.1%
leptonSF MU SF ID STAT	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EffectiveNP Statistical3	± 0.1%	± 0.0%	∓ 0.0%	± 0.1%	∓ 0.1%
leptonSF MU SF ID SYST	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EffectiveNP Statistical4	± 0.0%	∓ 0.0%	± 0.0%	± 0.1%	∓ 0.0%
leptonSF MU SF ID STAT LOWPT	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EffectiveNP Statistical5	± 0.0%	∓ 0.0%	± 0.0%	± 0.1%	∓ 0.0%
leptonSF MU SF ID SYST LOWPT	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EffectiveNP Statistical6	± 0.0%	± 0.0%	± 0.0%	± 0.1%	∓ 0.0%
leptonSF MU SF Isol STAT	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EtaIntCalib Modelling	± 0.2%	± 0.2%	∓ 0.1%	∓ 0.1%	± 0.2%
leptonSF MU SF Isol SYST	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EtaIntCalib NonClosure highE	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%
leptonSF MU SF TTVA STAT	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EtaIntCalib NonClosure negEta	∓ 0.0%	∓ 0.0%	± 0.0%	± 0.0%	± 0.0%
leptonSF MU SF TTVA SYST	∓ 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EtaIntCalib NonClosure posEta	± 0.0%	± 0.0%	∓ 0.0%	∓ 0.0%	∓ 0.0%
EG RESOLUTION ALL	± 0.0%	∓ 0.0%	± 0.0%	± 0.0%	± 0.0%	JET EtaIntCalib TotalStat	± 0.0%	± 0.1%	∓ 0.0%	± 0.0%	∓ 0.1%
EG SCALE ALL	± 0.0%	± 0.0%	± 0.0%	± 0.0%	± 0.0%	JET Flavor Composition	± 0.1%	± 0.3%	± 0.1%	∓ 0.3%	± 0.6%
MET SoftTrk ResoPara	∓ 0.1%	± 0.1%	∓ 0.1%	∓ 0.1%	± 0.1%	JET Flavor Response	± 0.2%	± 0.3%	∓ 0.1%	∓ 0.2%	± 0.6%
MET SoftTrk ResoPerp	∓ 0.2%	∓ 0.0%	∓ 0.0%	± 0.0%	± 0.0%	JET Pileup OffsetMu	∓ 0.0%	∓ 0.2%	± 0.1%	± 0.1%	± 0.2%
MET SoftTrk Scale	∓ 0.0%	± 0.0%	∓ 0.0%	± 0.1%	∓ 0.1%	JET Pileup OffsetNPV	∓ 0.1%	± 0.0%	∓ 0.1%	∓ 0.1%	± 0.2%
MUON ID	∓ 0.0%	∓ 0.0%	± 0.0%	± 0.0%	∓ 0.1%	JET Pileup PtTerm	∓ 0.0%	± 0.0%	∓ 0.0%	∓ 0.1%	± 0.1%
total	± 2.6%	± 2.1%	± 1.3%	± 2.5%	± 3.9%						

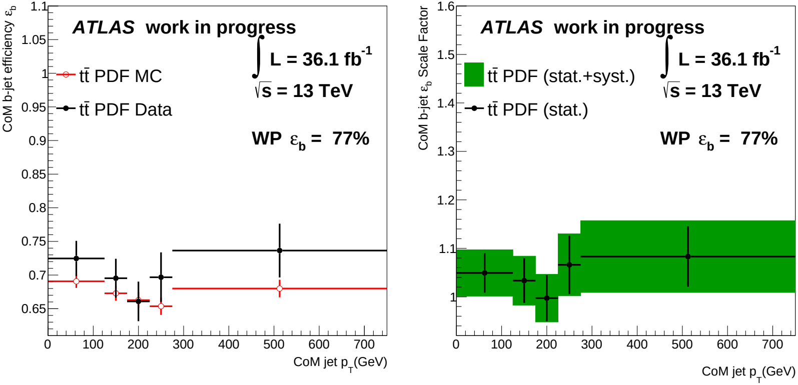
fit to pseudo data: MC16a vs. data15+16

- 1000 binned pseudo data, Poisson variated bin by bin from the PDF model built above.
- The SF found in each of the p_{T} bins are averaged at 1.0



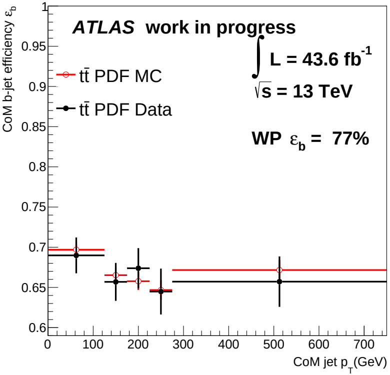
Result of binned in CoM jet p_{T}: MC16a vs. data15+16

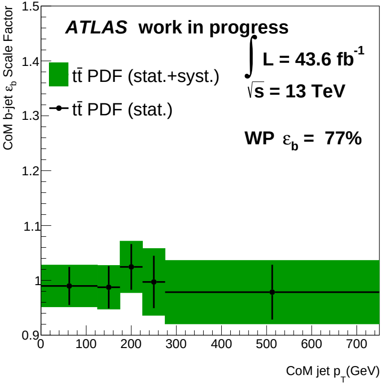
- Using 2015-2016 data, SF close to 1 as in CoM sub-jet p_{T}.



Results with MC16d vs. data17

- Using 2017 data, SF close to 1, similar stat+syst uncertainties compared to data15+16 fit.





Summary and to do

- Summary:
  - Topological dependence: comparison of CoM *b*-jet tagging efficiency similar in $H \to b\bar{b}$ vs. $top \to W + b$ and a larger difference seen $H \to b\bar{b}$ vs. $g \to b\bar{b}$.
  - Motivation to have a quick public result for *b*-jet calibration with boosted top and add CoM SF into flavor tagging CDI: needed for various physics analyzes and job searching.
  - Validation with $g \to b\bar{b}$ events is ongoing. To be included in the CoM paper.
  - Status of *b*-jet calibration with $t\bar{t}$ events: ε_b quite flat as a function of p_{T}; dominant systematic uncertainties ∼2–3%; INT note available. Majority of the work done. No major issue found.
  - Calibrated data 2015-2016 and data 2017 separately.
- To do:
  - Run working points other than 77%, as well as flat efficiency ones.
  - MC/MC SF for higher p_{T} bins $\sim$ TeV region. ⇒ automatically done in CDI?
  - Note to be further updated to include all the studies we did.
  - Use the gbb framework to validate the calibrated SF (ongoing).


THANK
YOU

Backup

fit to pseudo data: correlation of SF in p_{T} bins

- To answer one of the comments earlier: No correlation observed in the SF from different p_{T} bins.

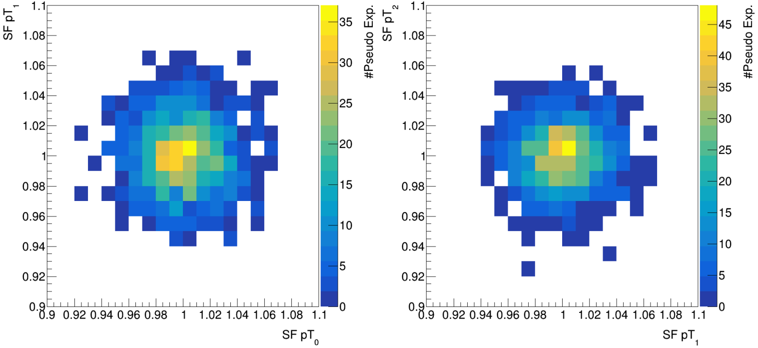


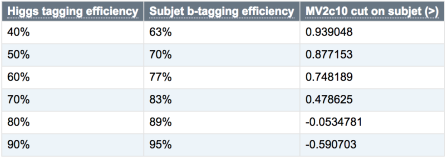
Figure: Left: X-axis: SF from 0th p_{T} bin; Y-axis: SF from 1st p_{T} bin. Right: X-axis: SF from 1st p_{T} bin; Y-axis: SF from 2nd p_{T} bin.

MC samples

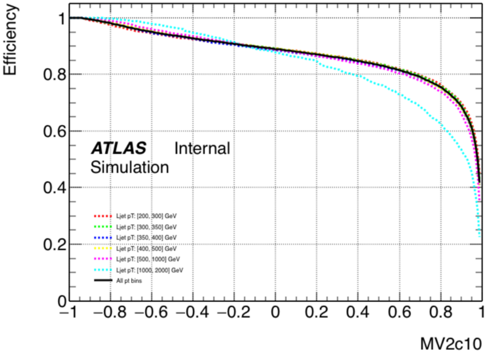
Physics process	DSID	Generator	Shower	PDF(hard process)	Tune	σ norm	Fast/ Full
$t\bar{t}$							
$t\bar{t} \rightarrow l\nu l\nu/qq$	410470	Powheg	Pythia8	CT10	A14	NNLO	Both
$t\bar{t} \rightarrow l\nu qq$(rad.)	410480	Powheg	Pythia8	CT10	A14	NNLO	Fast
$t\bar{t} \rightarrow l\nu qq$	410557	Powheg	Herwig7	CT10	H7UE	NNLO	Fast
$t\bar{t} \rightarrow l\nu qq$	410464	aMCatNlo	Pythia8	MEN30NLO	A14N23LO	NNLO	Fast
single top							
schan $t \rightarrow l\nu b$	410644	Powheg	Pythia8	CT10	A14	NNLO	Full
schan $\bar{t} \rightarrow l\nu b$	410644	Powheg	Pythia8	CT10	A14	NNLO	Full
tchan $t \rightarrow l\nu b$	410658	Powheg	Pythia8	CT10	A14	NNLO	Full
tchan $\bar{t} \rightarrow l\nu b$	410659	Powheg	Pythia8	CT10	A14	NNLO	Full
Wt DR $t \rightarrow inc$	410646	Powheg	Pythia8	CT10	A14	NNLO	Full
Wt DR $\bar{t} \rightarrow inc$	410647	Powheg	Pythia8	CT10	A14	NNLO	Full
Wt DS $t \rightarrow inc$	410654	Powheg	Pythia8	CT10	A14	NNLO	Full
Wt DS $\bar{t} \rightarrow inc$	410655	Powheg	Pythia8	CT10	A14	NNLO	Full
V+jets							
$W^+ \rightarrow e\nu$	361100	Powheg	Pythia8	CT10		NNLO	Full
$W^+ \rightarrow \mu\nu$	361101	Powheg	Pythia8	CT10		NNLO	Full
$W^+ \rightarrow \tau\nu$	361102	Powheg	Pythia8	CT10		NNLO	Full
$W^- \rightarrow e\nu$	361103	Powheg	Pythia8	CT10		NNLO	Full
$W^- \rightarrow \mu\nu$	361104	Powheg	Pythia8	CT10		NNLO	Full
$W^- \rightarrow \tau\nu$	361105	Powheg	Pythia8	CT10		NNLO	Full
$Z \rightarrow ee$	361106	Powheg	Pythia8	CT10		NNLO	Full
$Z \rightarrow \mu\mu$	361107	Powheg	Pythia8	CT10		NNLO	Full
$Z \rightarrow \tau\tau$	361108	Powheg	Pythia8	CT10		NNLO	Full
diboson							
$WZ \rightarrow l\nu\nu\nu$	361602	Powheg	Pythia8	CT10		NLO	Full
$WZ \rightarrow l\nu qq$	361609	Powheg	Pythia8	CT10		NLO	Full
$WW \rightarrow l\nu qq$	361606	Powheg	Pythia8	CT10		NLO	Full
$ZZ \rightarrow \nu\nu qq$	361611	Powheg	Pythia8	CT10		NLO	Full

ε_b calibration as a function of LJet p_{T}

- Using CoM sub-jet MV2c10 working point @77% ($w > 0.748189$) defined by Bo: *CoM Hbb TWiki* with $G \rightarrow hh \rightarrow bbbb$ samples. ⇒ Note: higgs large-R jet $p_{\mathrm{T}} > 250\ \mathrm{GeV}$.



Higgs tagging efficiency	Subjet b-tagging efficiency	MV2c10 cut on subjet (>)
40%	63%	0.939048
50%	70%	0.877153
60%	77%	0.748189
70%	83%	0.478625
80%	89%	-0.0534781
90%	95%	-0.590703



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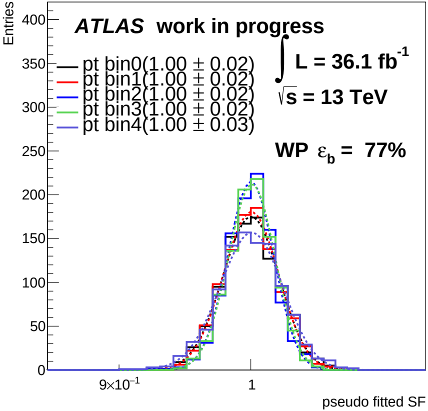
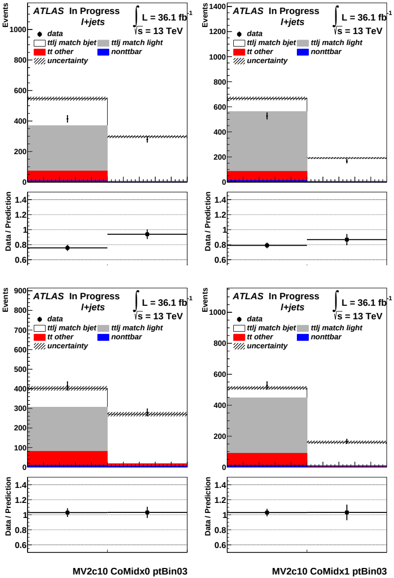


MV2c10 pre-/post-fit (0th p_{T} bin): MC16a vs. data15+16



- Top, left to right: pre-fit MV2 in the p_{T} bin of 03 from **0th** and **1st** CoM jet.
- Bottom, left to right: corresponding post-fit plots.
- Post-fit data-to-MC looks nice.

b-jet calibration: $t\bar{t}$ →l+jets event selection

- Selection of boosted $t\bar{t} \rightarrow l\nu b\, qqb$ decay mode.
- Pre-selection:
  - $\geq$1 boosted large-R jet with $p_{\mathrm{T}} > 200$ GeV, $|\eta| < 2.0$, where the leading p_{T} one considered as a candidate of hadronic top.
  - Exactly one lepton (e or μ) with trigger matched.
- Further selection:
  - Exactly two CoM sub-jets associated to the large-R jet.
  - Leading large-R jet p_{T} >350 GeV
  - $E_{\mathrm{T}}^{\mathrm{miss}}$ >30 GeV, m_T^W >30 GeV
  - $\geq$1 small-R jet (AntiKt4TopoEM) with ΔR(LJet, j) > 1.5
  - $\geq$1 b-tagged small-R jet out of LJet.
  - ΔR(lep, b-jet) < 2.
  - Large-R jet mass $125 < M_{ljet} < 245$ GeV.
  - Mass of small-R jet (AntiKt4TopoEM) in ΔR(LJet, j) < 1 matched to W boson. $60 < M_{ak4} < 105$ GeV Note: ==1 ak4 jet, use its mass; $\geq$2 ak4 jets, use the mass of the two closest ak4 jets.
- Tools:
  - Using FTAG4 (cache: 21.2.34.0) to produce DxAOD containing slimmed large-R jets and 2 CoM sub-jets associated.
  - Using AnalysisTop.21.2.34 to produce the Ntuples (after pre-selection).

$t\bar{t}$ truth definition

- $t\bar{t}$ event classification: using truth top-quark, W-boson and b-quark to classify the $t\bar{t}$ into signal and combinatorial.
    - Matched: large-R jet matched to top-quark and its decay products of W-boson ($\rightarrow$qq) and b-quark.
    - Top not matched: large-R jet not matched to hadronic decaying top-quark.
    - b-quark not matched: large-R jet matched to top-quark but *b*-quark is not matched.
    - Note: when top-quark is matched, W-boson is also matched.

truth definition	$t\bar{t}$ decay	ΔR(LJet, top)	ΔR(LJet, *b*-quark)
$t\bar{t} \rightarrow$ dilepton	$t\bar{t} \rightarrow l\nu b, l\nu b$	N/A	N/A
$t\bar{t} \rightarrow$ ljet, match	$t\bar{t} \rightarrow l\nu b, qqb$	<0.5	<1.0
$t\bar{t} \rightarrow$ ljet, top not match	$t\bar{t} \rightarrow l\nu b, qqb$	>0.5	N/A
$t\bar{t} \rightarrow$ ljet, *b*-quark match	$t\bar{t} \rightarrow l\nu b, qqb$	<0.5	>1.0

- All MC samples are listed in the backup.

Data-to-MC comparison: MC16a vs. data15+16