Flavor tagging at the LHC

PART DEUX

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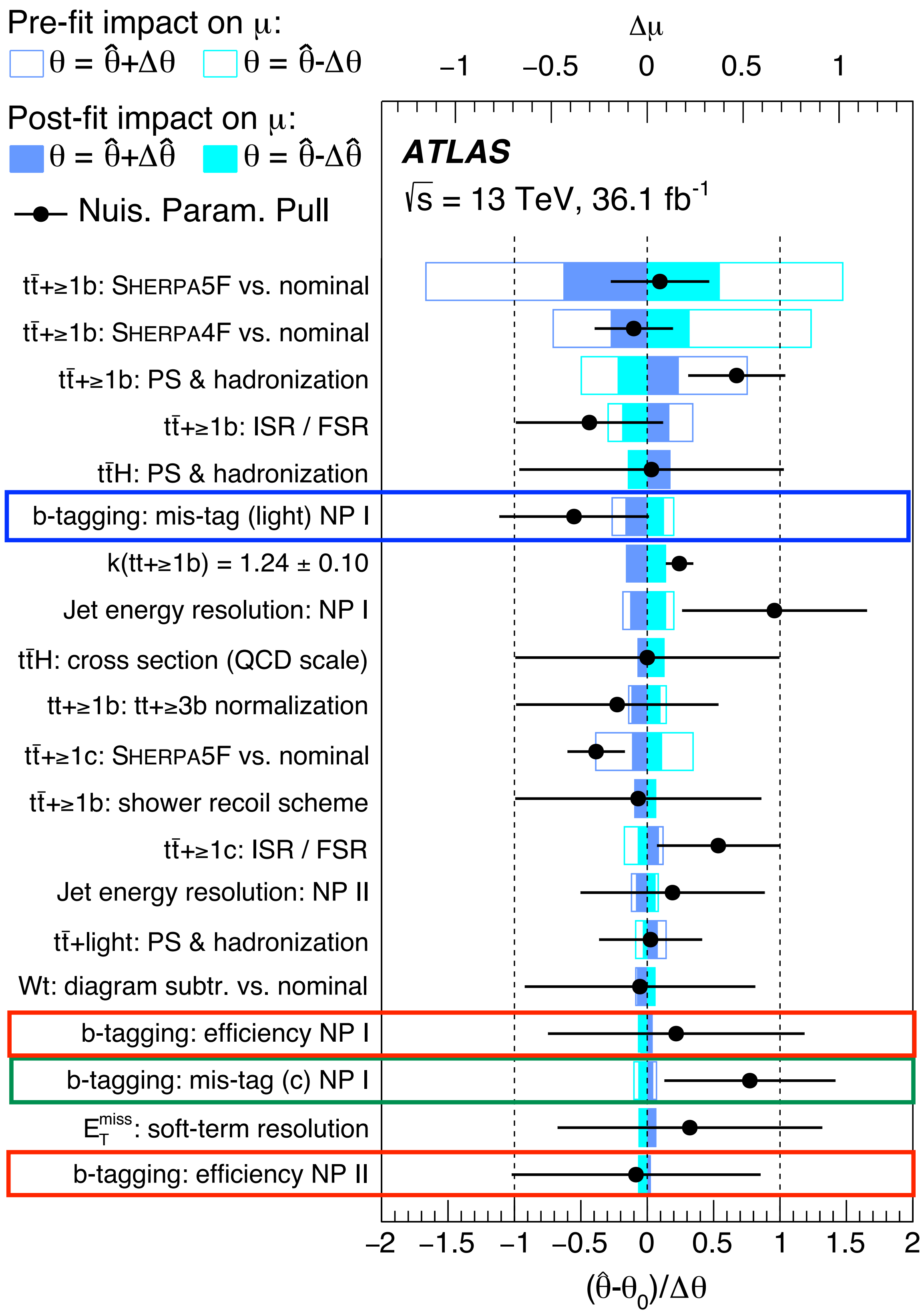
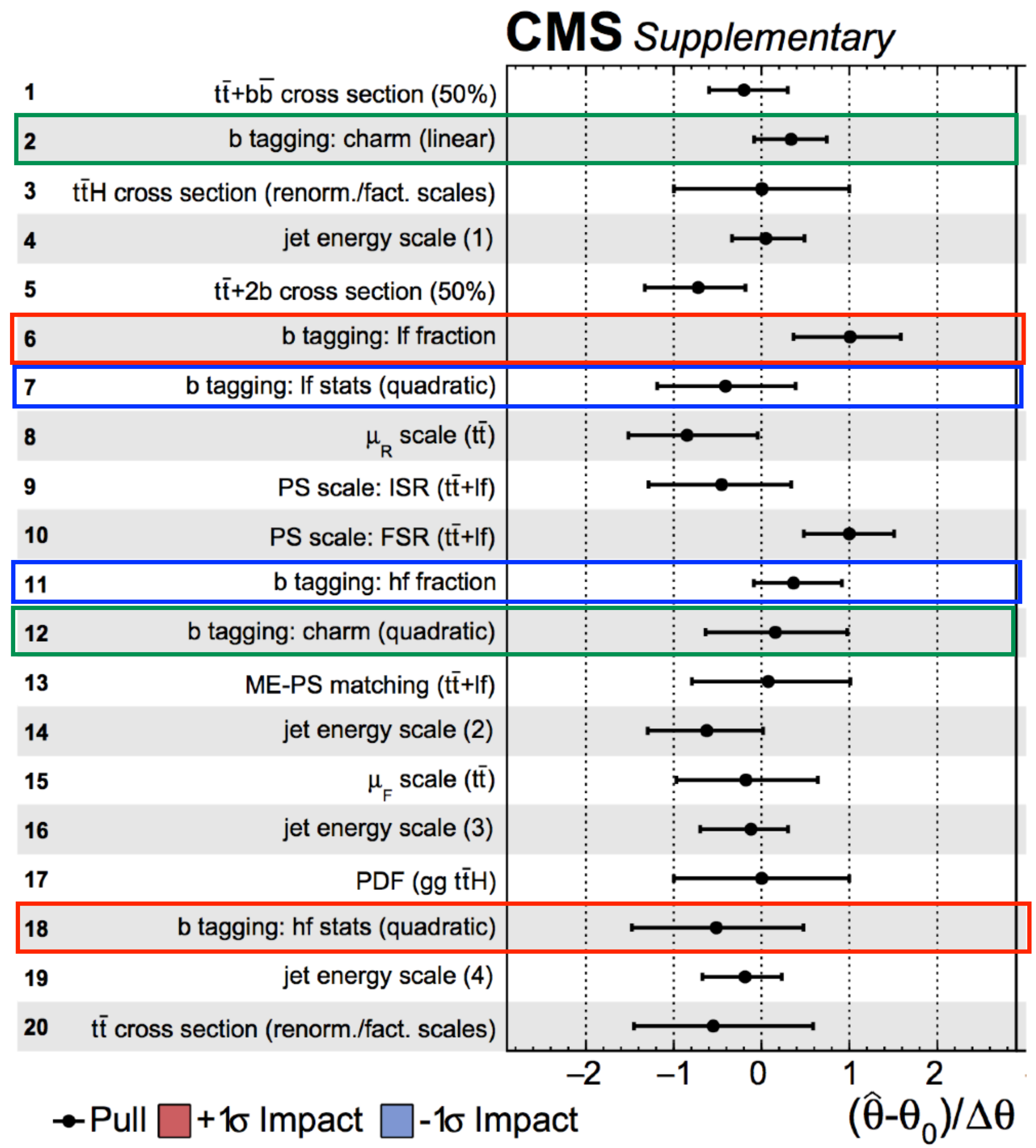
Connection slide



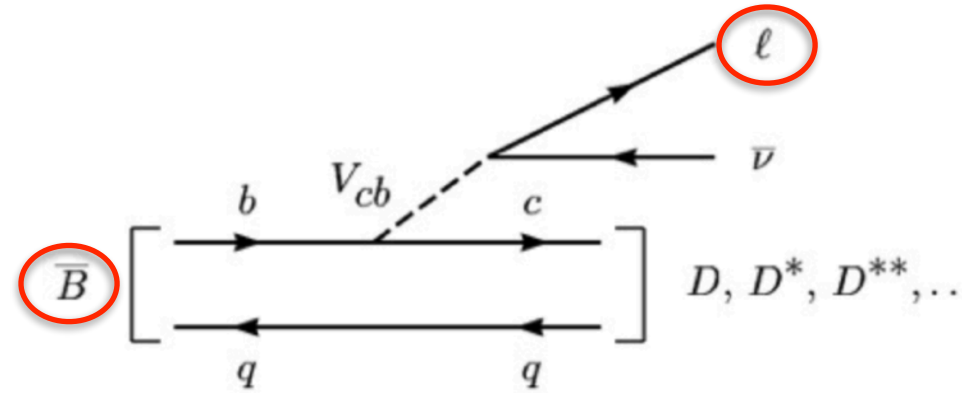


Overview of calibrations

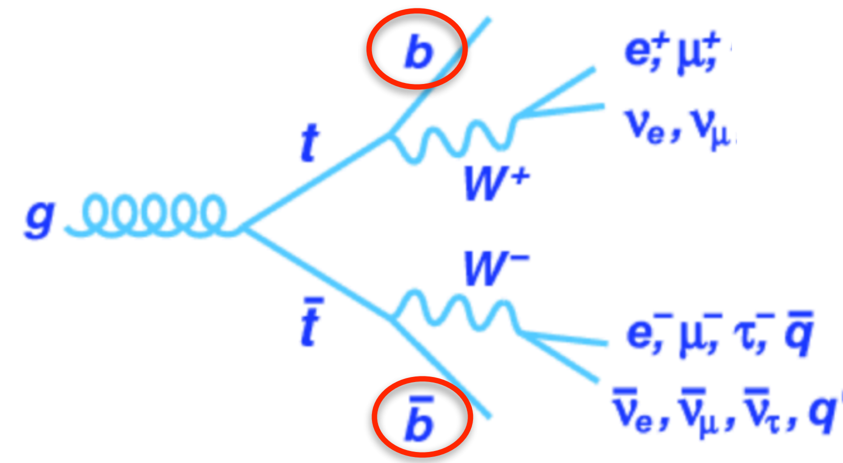
$$SF_f = \varepsilon_f^{\text{data}}(p_\text{T}, \eta)/\varepsilon_f^{\text{MC}}(p_\text{T}, \eta)$$

- Correcting MC for data/MC differences (scale factor):
  - description of detector performance (tracking) and material
  - description of modelling for hadron productions/decays
- In a nutshell: “isolate a sample of a given jet flavour, compute the efficiency on the b-tag selection on data, compare with MC”
- Point of attention:
  - choice of process [choose processes with little theoretical uncertainties]
  - selection efficiency (how to collect events)
  - contamination from other flavours
  - selection bias: should not affect the tagging efficiency
- Two main assumptions [on the SF, NOT on the uncertainties]:
  - SF are universal (sample/process independent)
  - SF are per jet related and independent of what happens around the jet (factorisation)

- 2 preferred samples with enhanced b-jet content:



- *di-jet events with muon-in-jet*:
  - **p_T rel (*)**, **system8 (*)**, **JP template fit**
  - muon requirement significantly enhance b-jet fraction …
  - high cross section (but need to use prescaled triggers), understanding correlation between b-jet efficiency and presence of muon is crucial
  - larger theoretical uncertainties on flavour factions

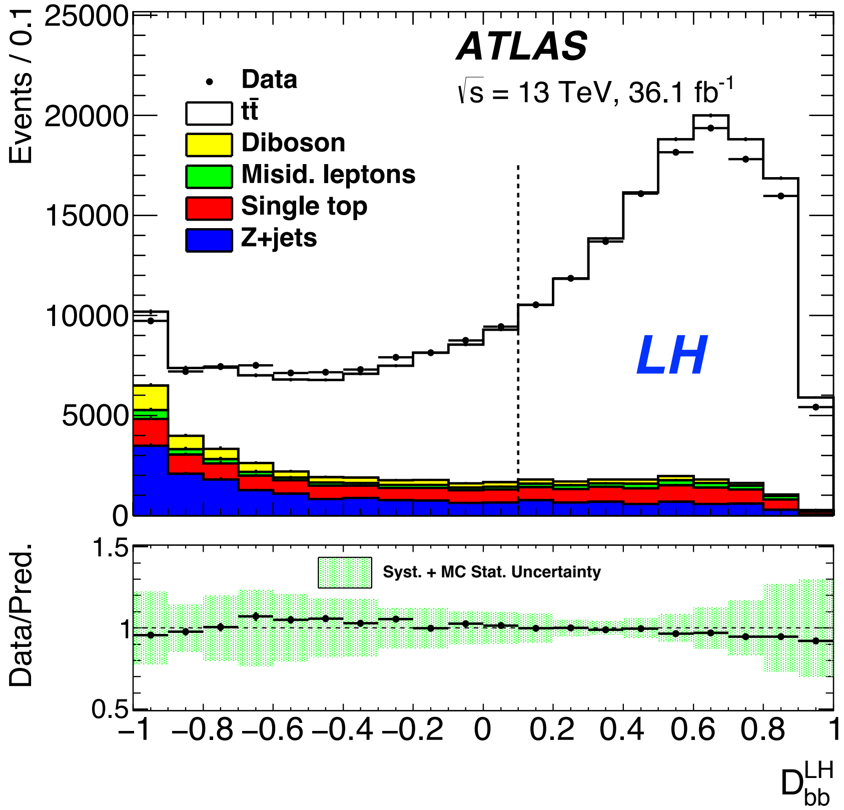


- *ttbar-based methods*:
  - large xSection, characteristic topology: events are easy to collect/identify (l+jets/dilepton selection)
  - decay of b-hadrons FULLY inclusive
  - dileptonic analyses: **tag counting, kin. selection, combinatorial LikeliHood, tag & probe**
  - l+jets analyses: **tag and probe (*)**

difference in the way the efficiency is extracted (how many jets actually considered, etc)

(*) also performed by ATLAS in Run1, but not the leading Run2 method

b-jets: ATLAS

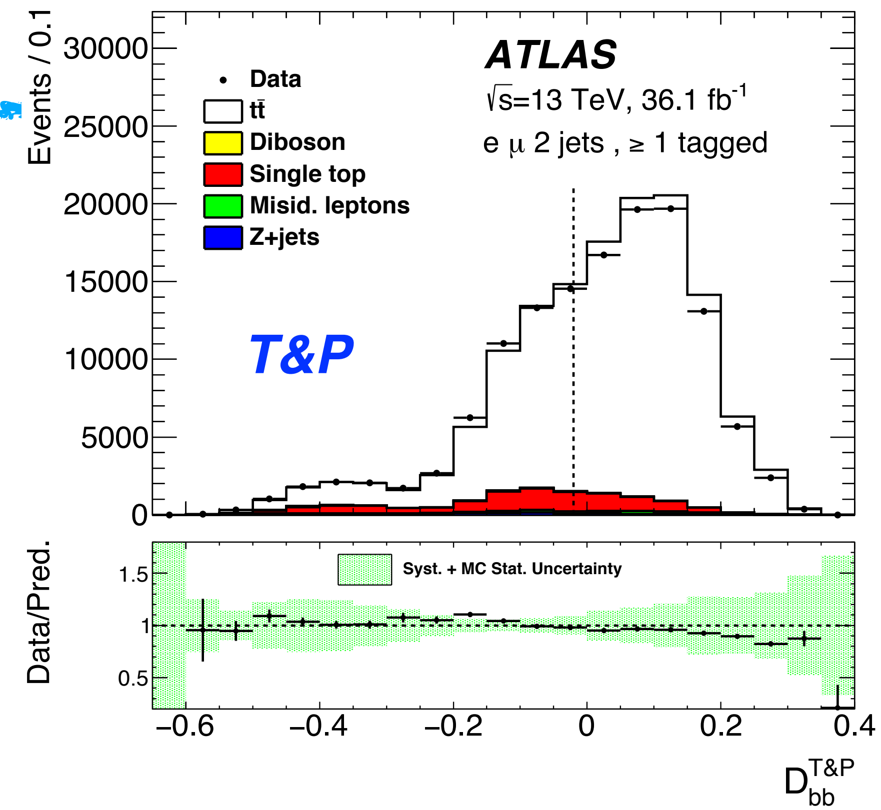


Tag & Probe:

- only em events, considering only 1 b-jet per event

Likelihood method:

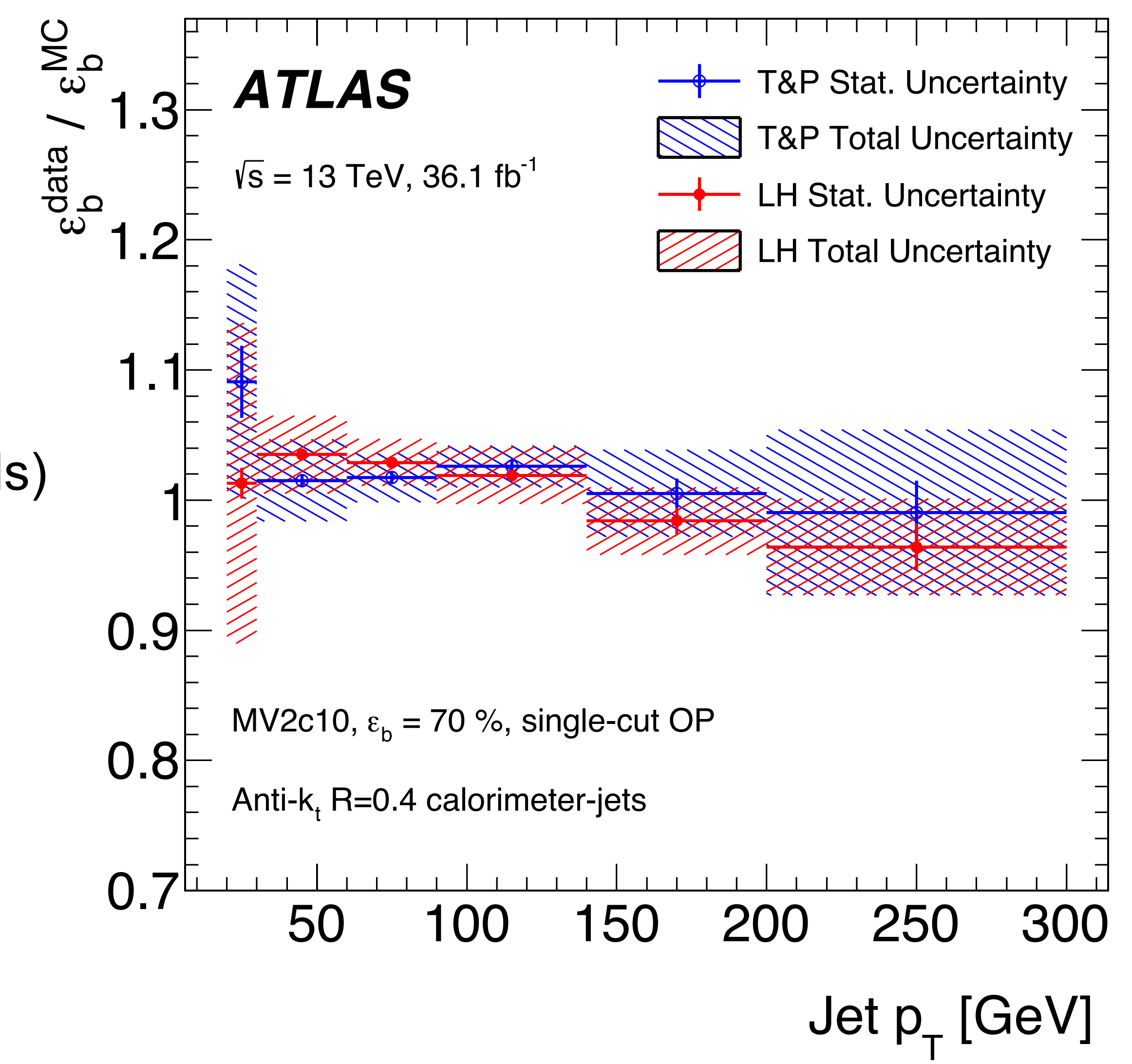
- em and ee/mm events
- considering information from both b-jets in the event (and their correlation)

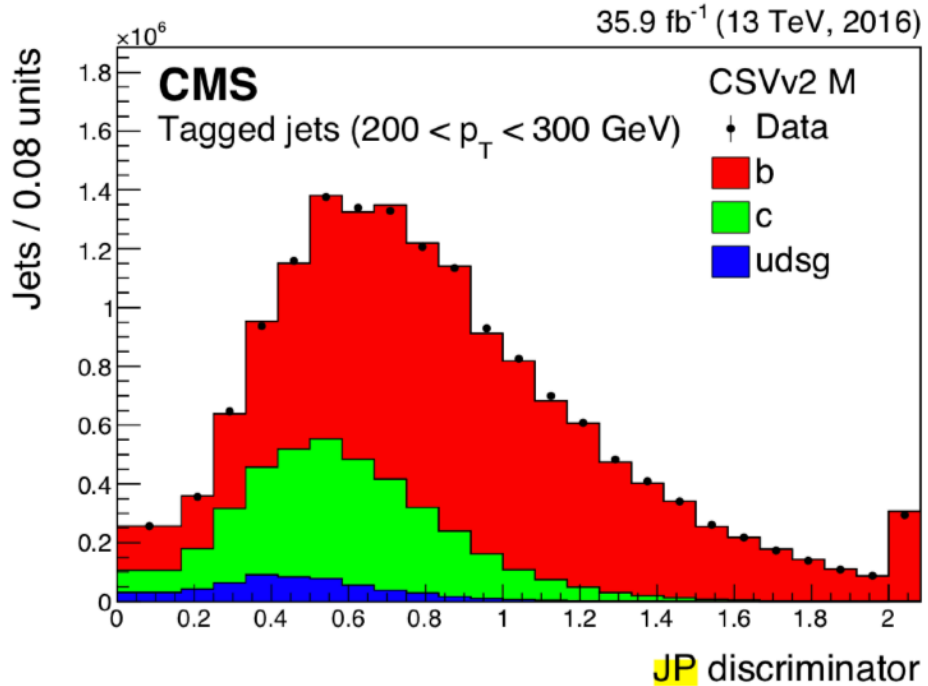


- Purity of b-jet increased by cutting on multivariate kinematic discriminant:
  - >80% purity except very low p_T

- SF quite compatible with unity (and between the 2 methods)

- Uncertainties at 2-3% level except in the low p_T (<30 GeV):
  - dominated by ttbar modelling uncertainties (Powheg+Pythia6 VS Powheg+Herwig++) impacting the non b-jet contamination





b-jets: CMS

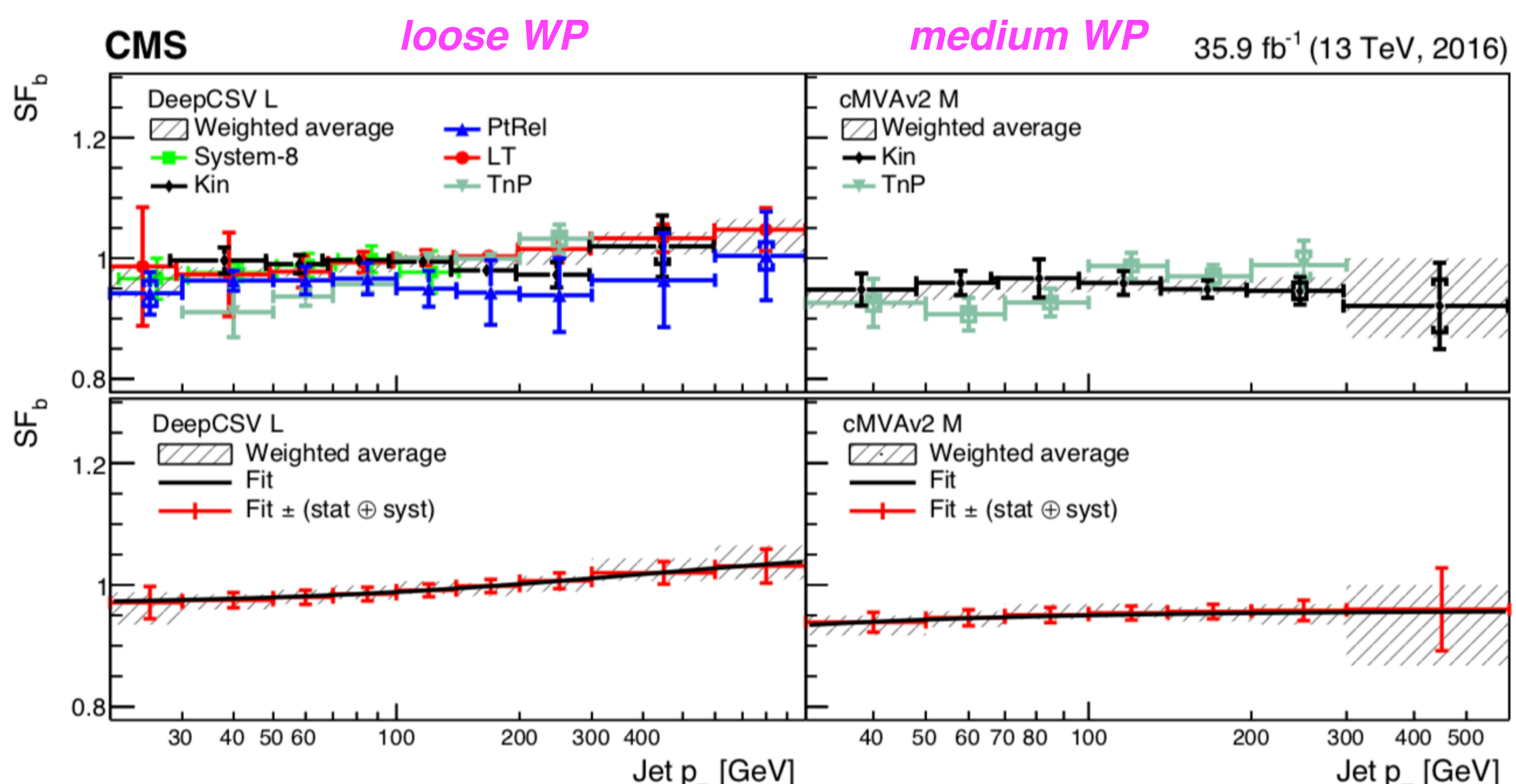
lifetime method:

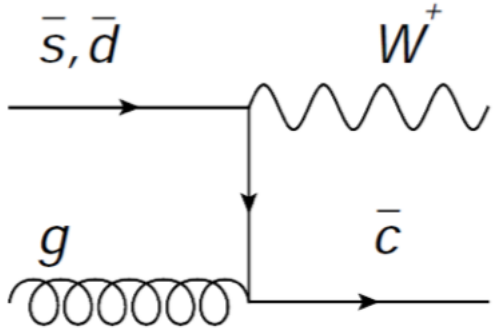
- similar method as p_T^{rel} but fitting output of JP tagger (mildly correlated with the final discriminant) which has better performance at high p_T

ttbar-based calib:

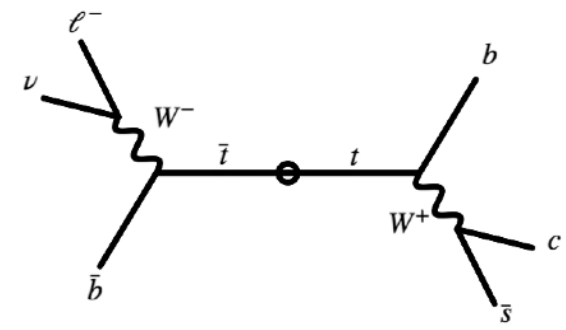
- **dilepton kin selection**: per jet kinematics MVA to separate b and l
- ***l+jet tag and probe***: likelihood-based approach for assigning jets to hadronic or leptonic b-jet

- SF close to 1
- %level uncertainties over a large p_T range:
  - nice complementarity among analyses
  - LT method dominated by tracking uncertainty on JP shape



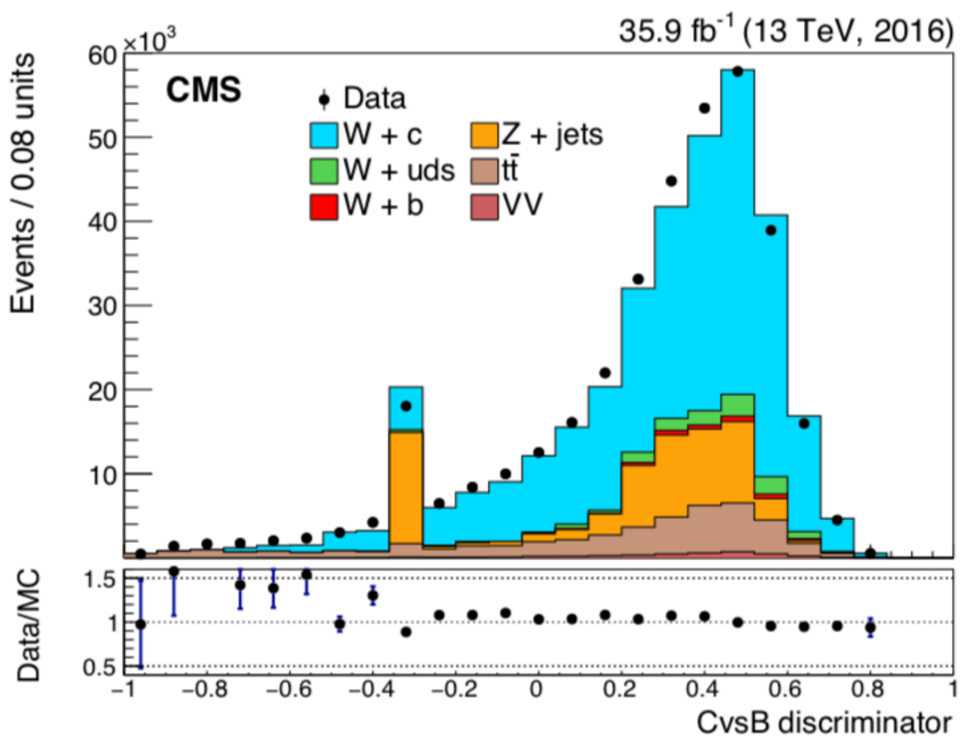


c-jets



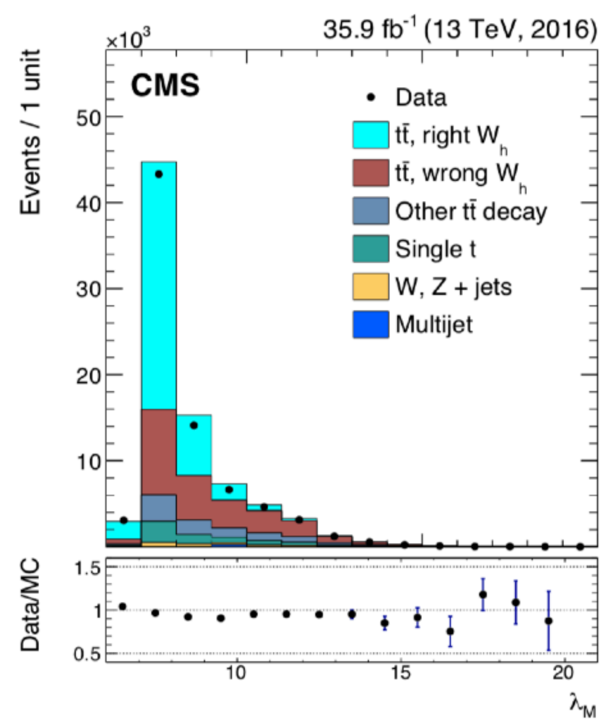
W+c (CMS)

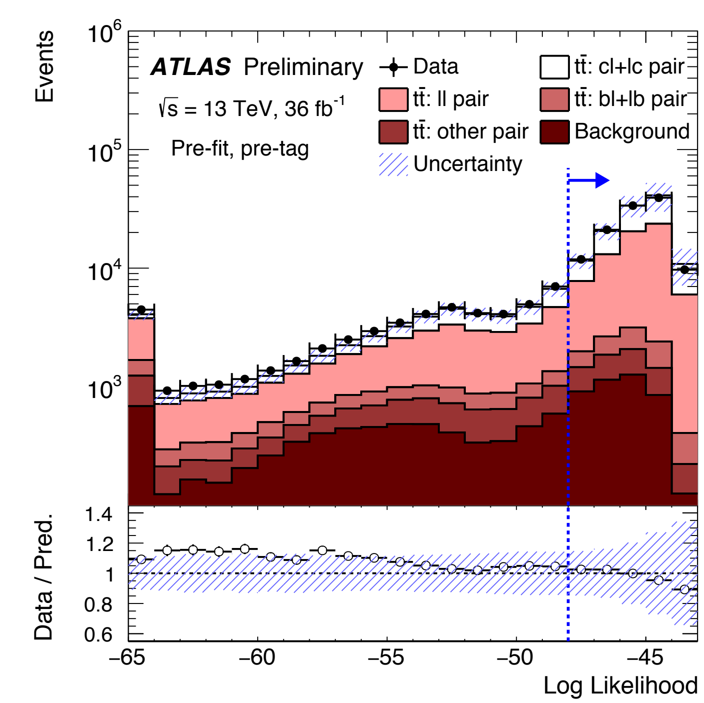
- Select events with 1 lepton + MET + at least one jets containing a soft muon
- Exploit charge correlation to increase purity: signal is OS, background has very similar OS/SS contribution
- High purity but rely on specific c-hadron decays
- mainly cover low p_T



ttbar (ATLAS,CMS)

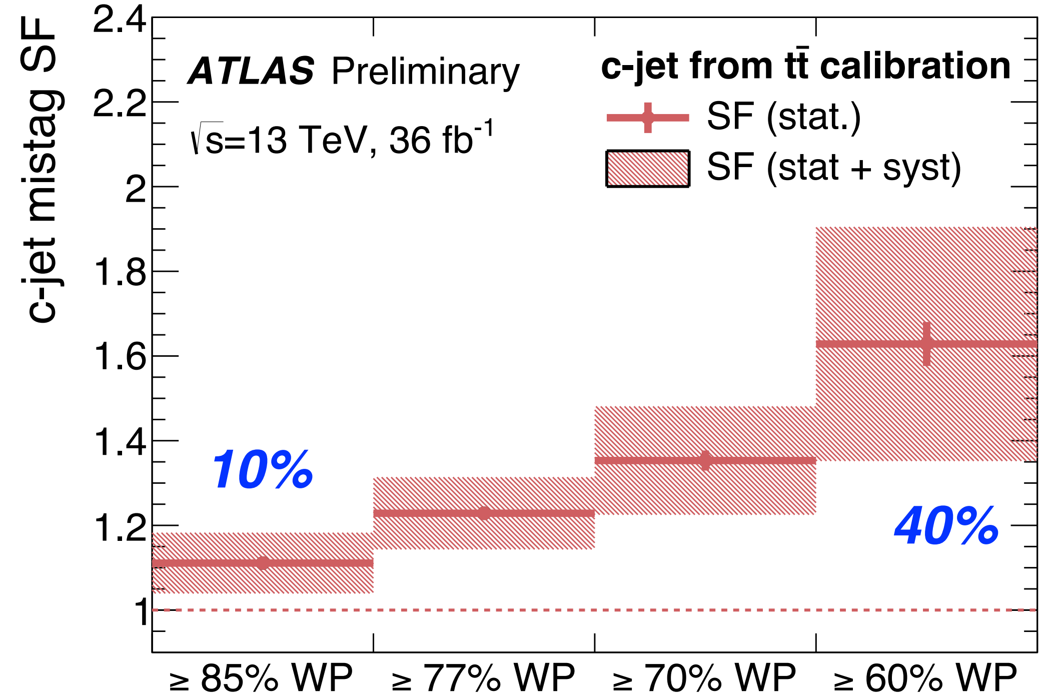
- Select events with 1 lepton + MET + at least 4 jets
- identify pair of jets compatible with hadronic W boson decay:
  - ATLAS: cut & count on kinematic fit output
  - CMS: template fit to 2D mass probability
- lower purity but main background (light jets from W) as similar modelling source as signal jets
- **NO assumptions on c-hadron decay**

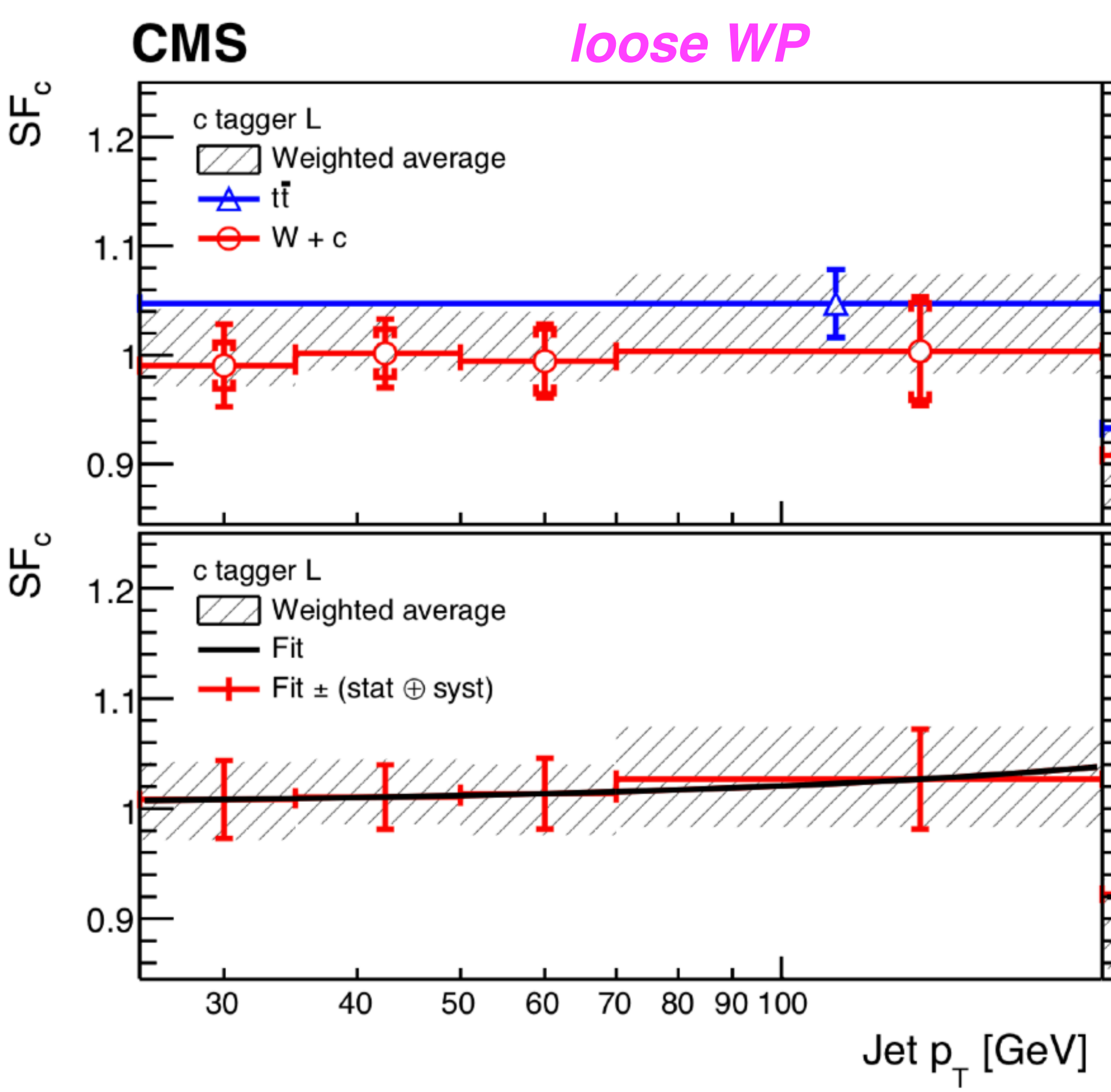


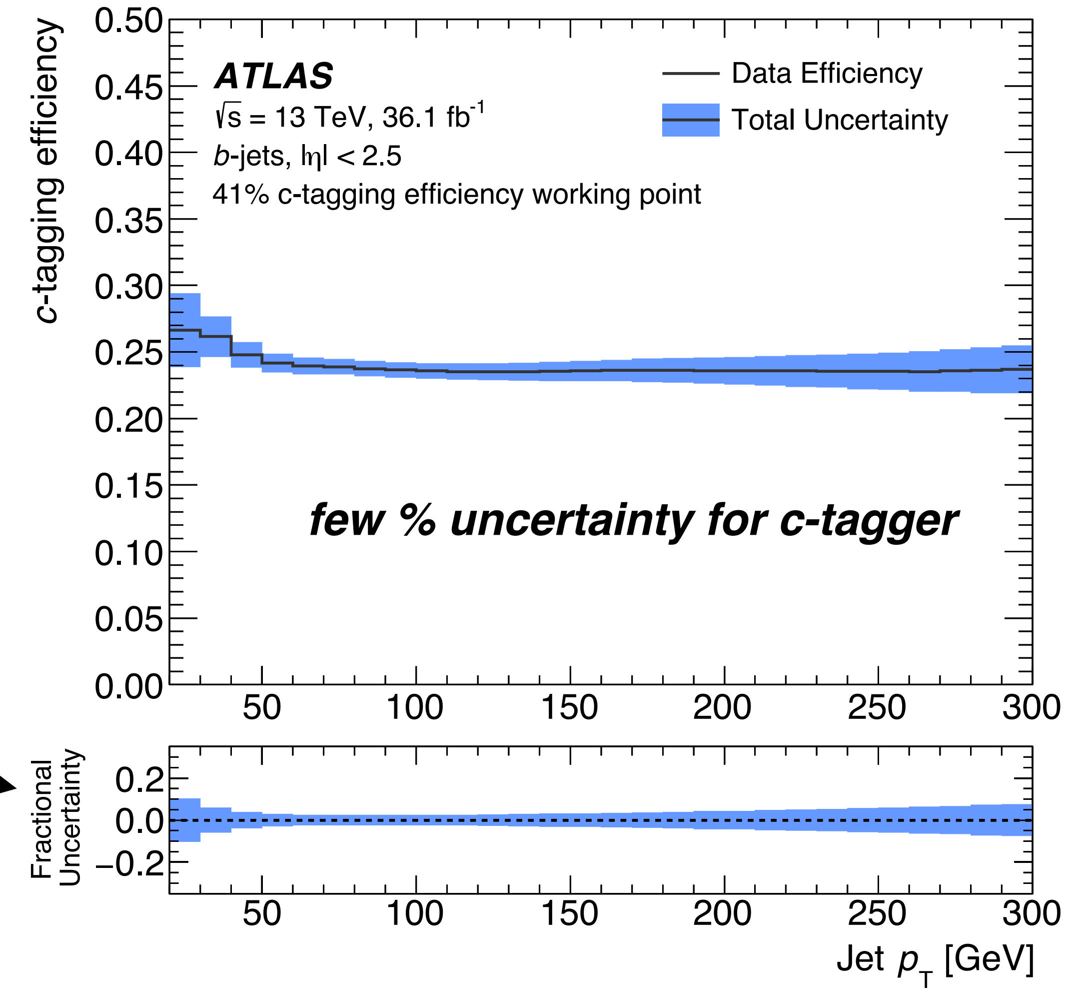


c-jets: uncertainties

- W+c method uncertainties dominated by extrapolation from semileptonic to inclusive decay (few %)
- ***TTbar***: different leading uncertainties if the method is applied to b-tagger (c-mis-tag) or c-tagger:
  - c-tagger / loose b-tagger: dominated by l-tag uncertainties from W->LL events
  - tight b-tagger: larger impact from mis-assigned permutation containing b-jets [extra dependence to ttbar modelling uncertainties]

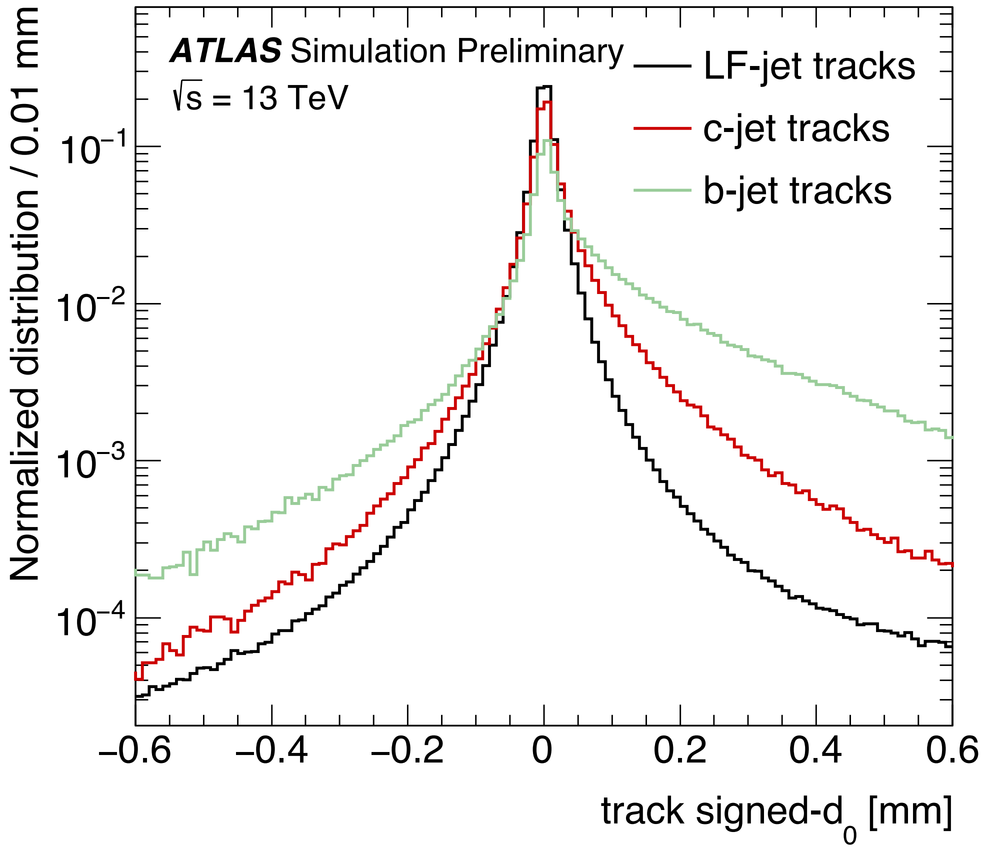


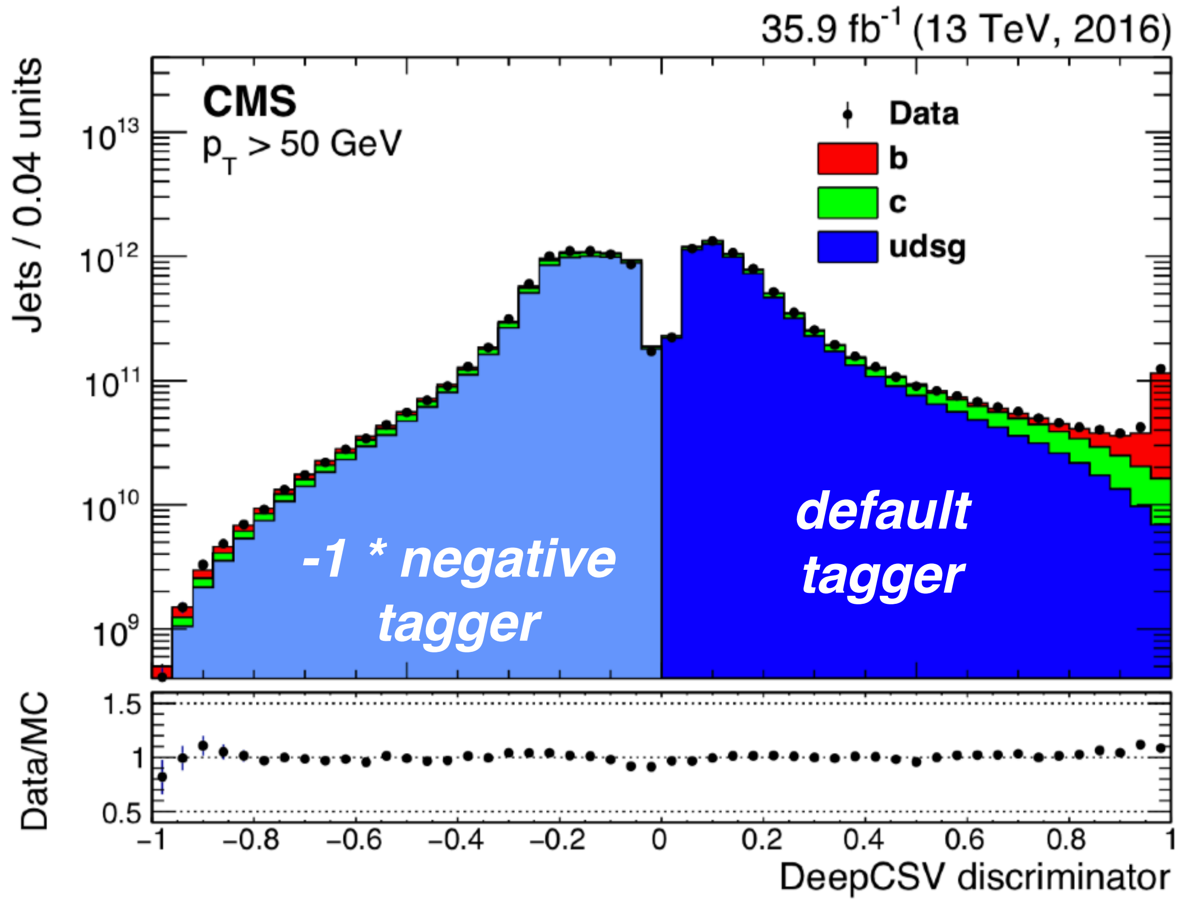


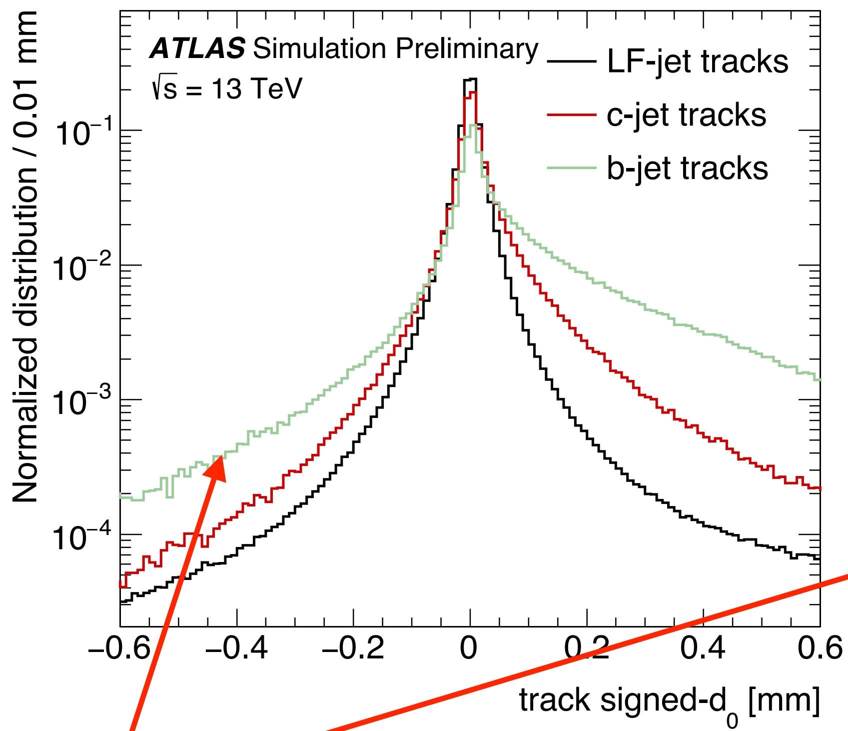


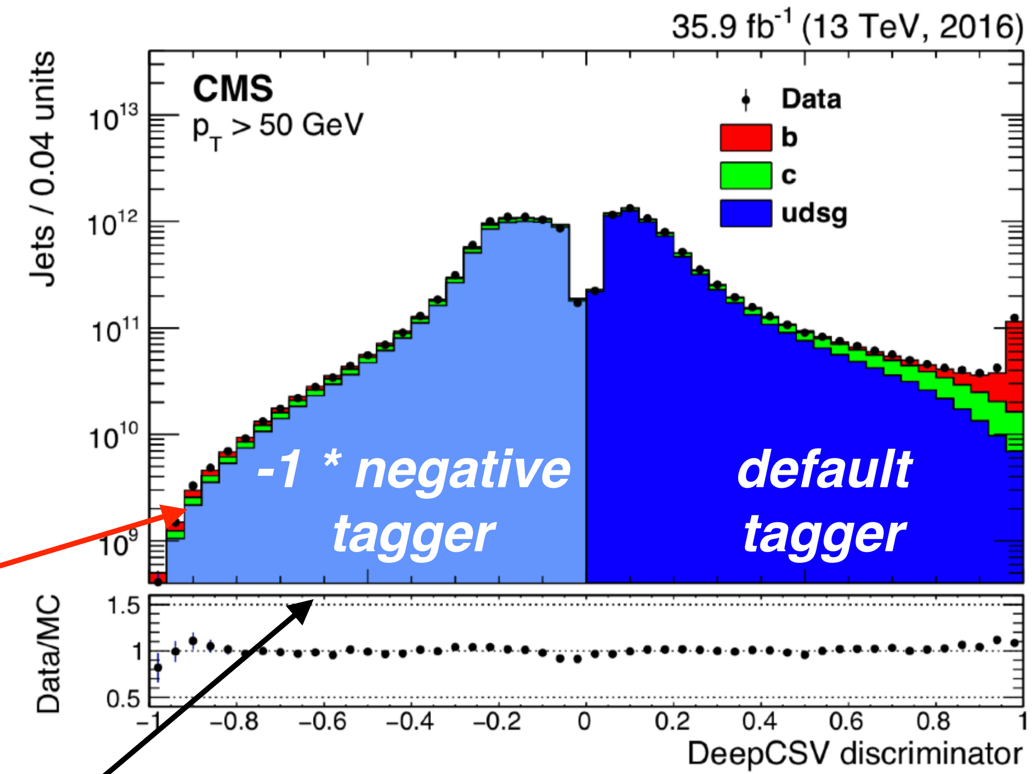
light-jets

- Relying on di-jet events (triggers heavily pre-scaled)
- “Negative tag method"
  - impact parameter of tracks is approx symmetric for light jets
  - build a version of the tagger only considering tracks with negative impact parameter [with reversed sign] or flipping the sign of the tracks as input to the algorithms]









HF contamination

$$K_{\mathrm{HF}}^{\mathrm{MC}} = \left(\frac{\varepsilon_{\mathrm{LF,neg}}}{\varepsilon_{\mathrm{all,neg}}}\right)^{\mathrm{MC}}$$

[0.06 - 0.6]

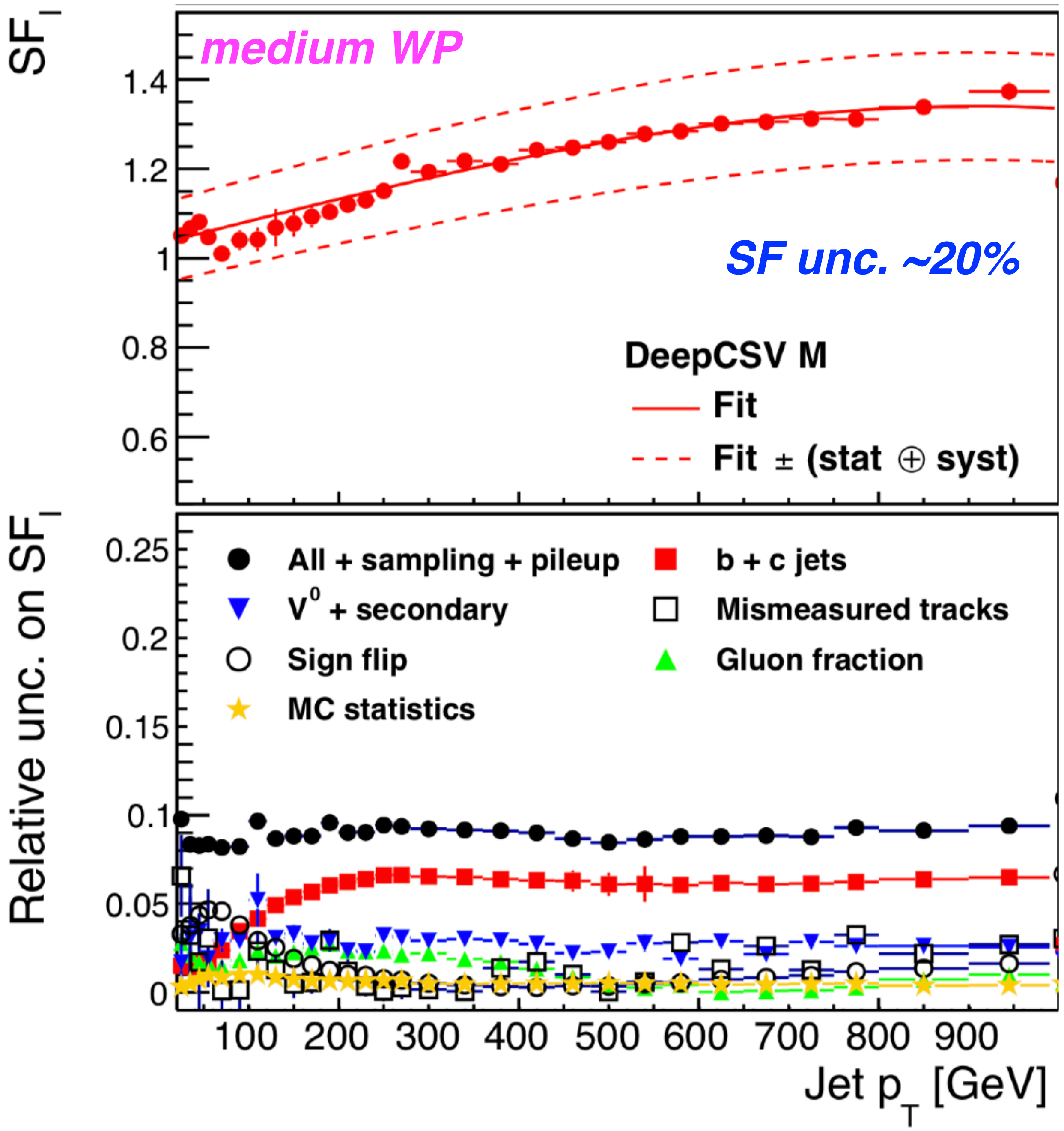
$$\varepsilon_{\mathrm{LF}} = \varepsilon_{\mathrm{neg}}^{\mathrm{data}} \cdot K_{\mathrm{HF}}^{\mathrm{MC}} \cdot K_{\mathrm{LL}}^{\mathrm{MC}},$$

difference between default and neg algo for light jets

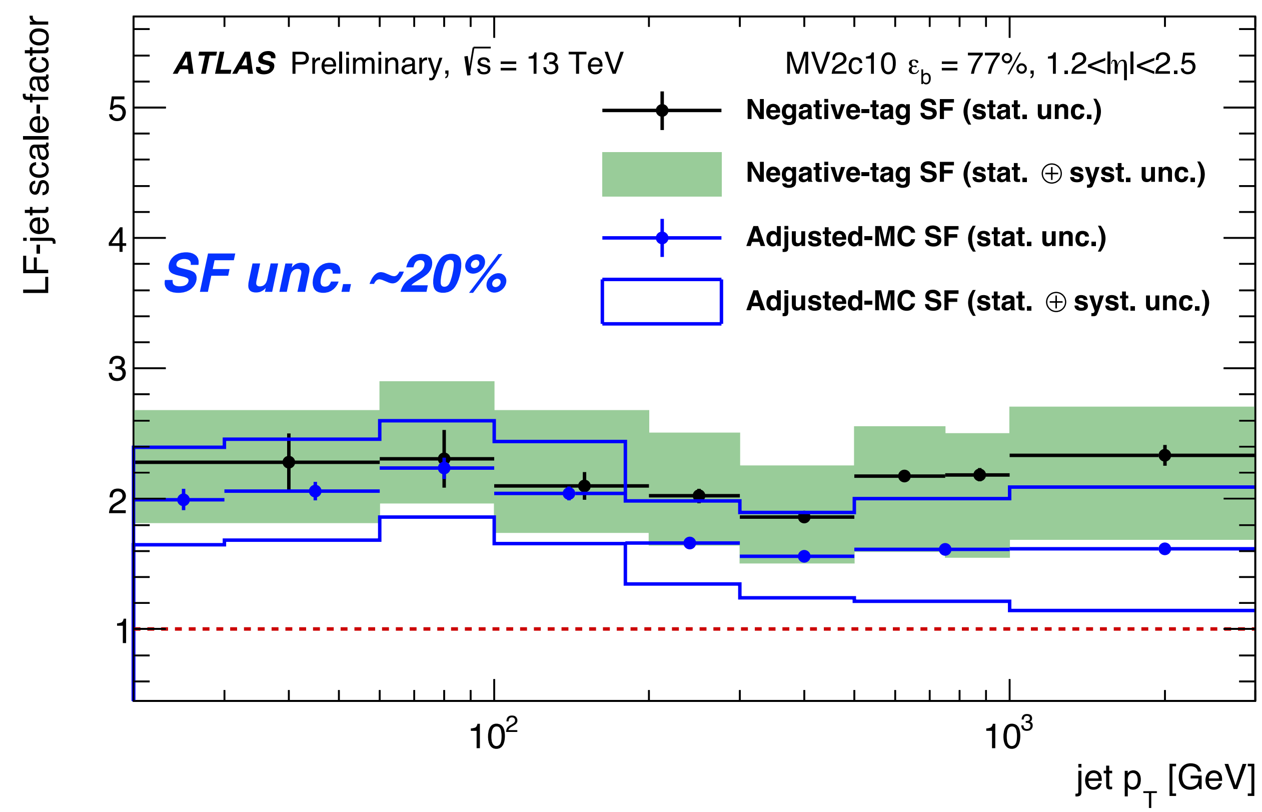
$$K_{\mathrm{LL}}^{\mathrm{MC}} = \left(\frac{\varepsilon_{\mathrm{LF}}}{\varepsilon_{\mathrm{LF,neg}}}\right)^{\mathrm{MC}},$$

[1.3 - 45]

- With tighter working points:
  - large increase of b/c contamination (especially for light rejection < 1%), K_{HF} —> *decreases*
  - mis-tag originates more from decay in flight/material interaction and not track IP smearing, K_{LL} -> *increases*
  - effects compensate for central value … but uncertainties increases substantially



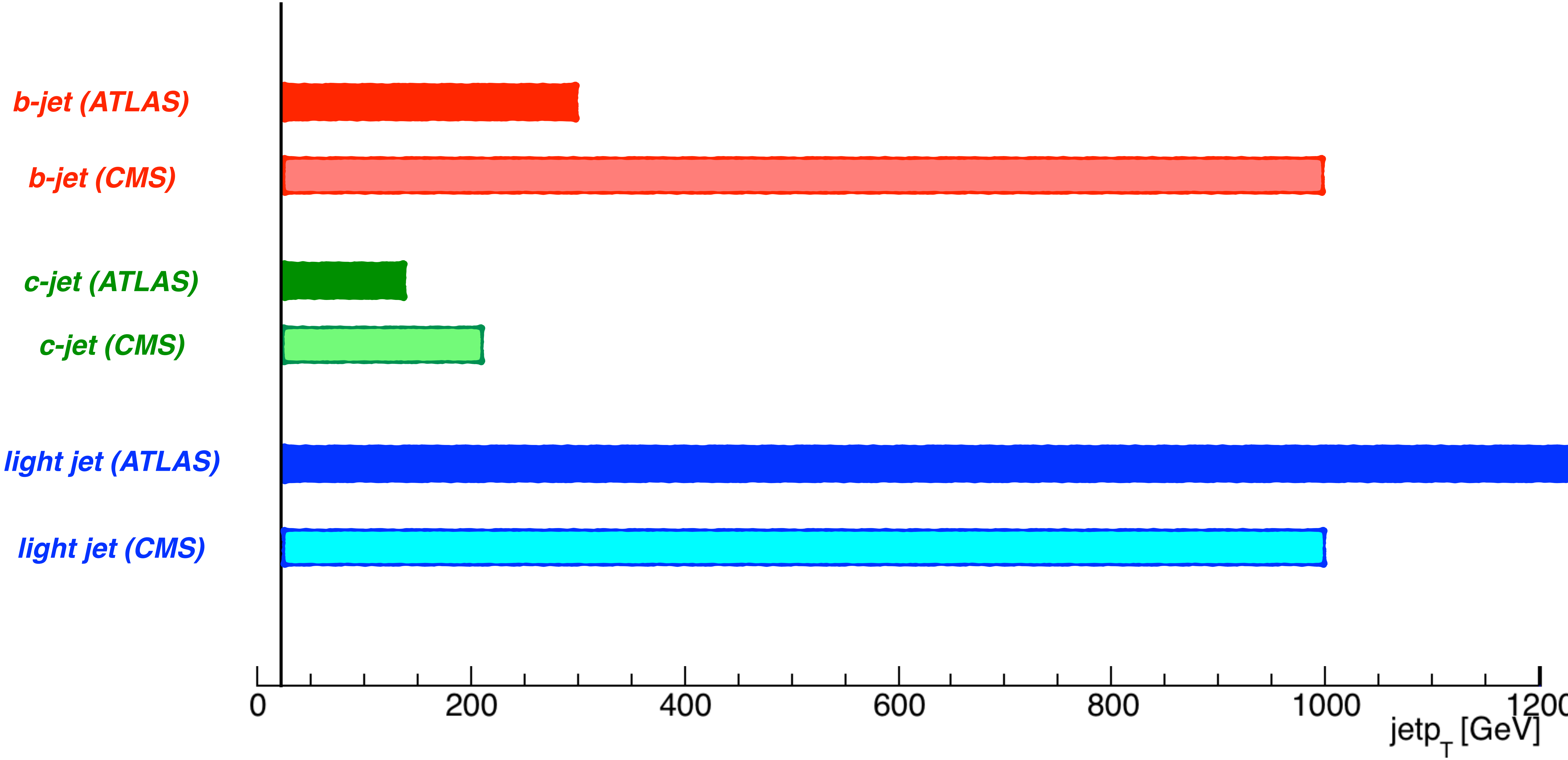
- Similar performance between ATLAS and CMS:
  - uncertainties dominated by HF contamination and IP modelling
  - SF is ~1.2 for CM and ~2.0 for ATLAS



- In ATLAS SF confirmed by adjusted MC method:
  - correcting MC for known differences in tracks performance (+full set of tracking uncertainties)
  - large SF are a consequence of mis-modelling in track impact parameter resolution

p_T coverage

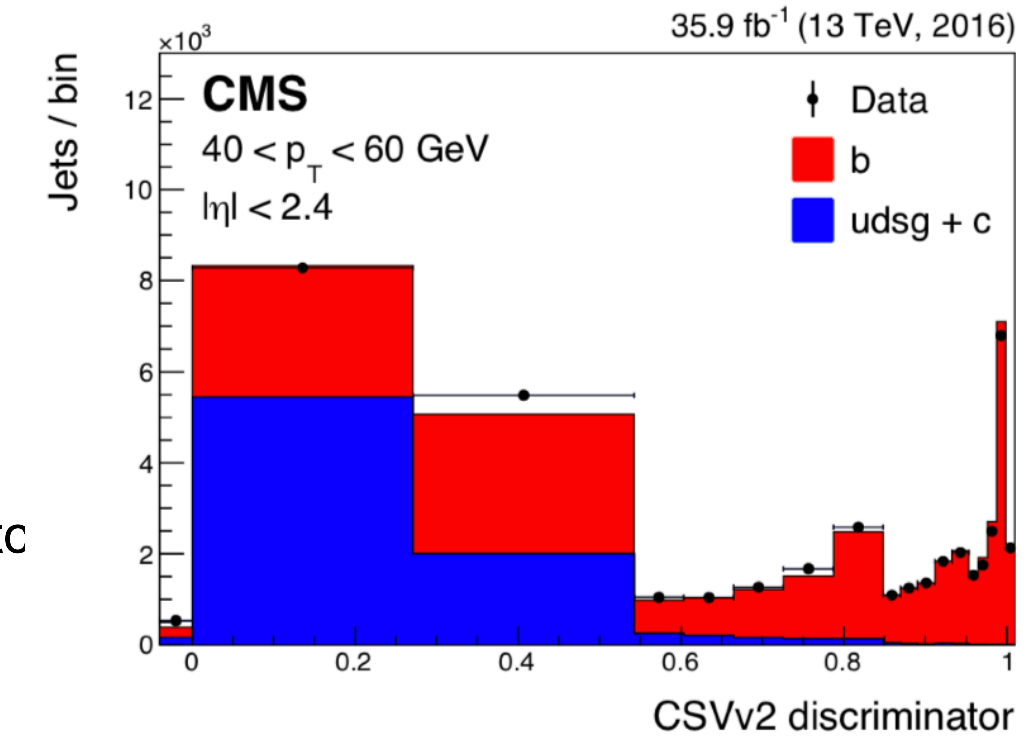
- Reach of data-driven calibration



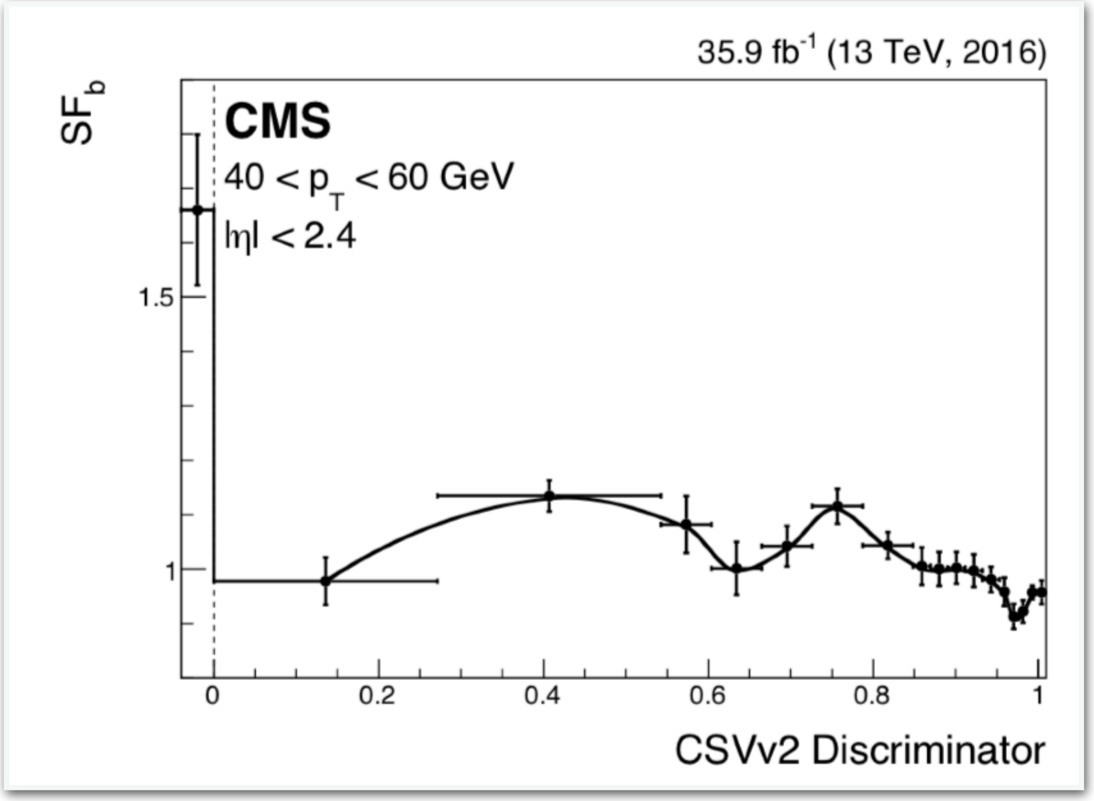
- Outside the measured boundaries:
  - ***ATLAS***: additional extrapolation uncertainties obtained from varying tracking / jet related uncertainties: 5% - 40%
  - ***CMS***: doubling the SF uncertainty

fully continuous distribution in CMS

- ***calibration of continuous tag weight distribution***
- ***Iterative approach***:
  - b-jet enriched region from T&P in dilepton events
  - light-jet enriched region from Z+2jets events (one anti b-tagged)
  - fitting SF in tag weight bins in one region, applying to the other etc
  - fast convergence (3-4 iterations)
  - smoothing the output result for ***fully continuous SF***



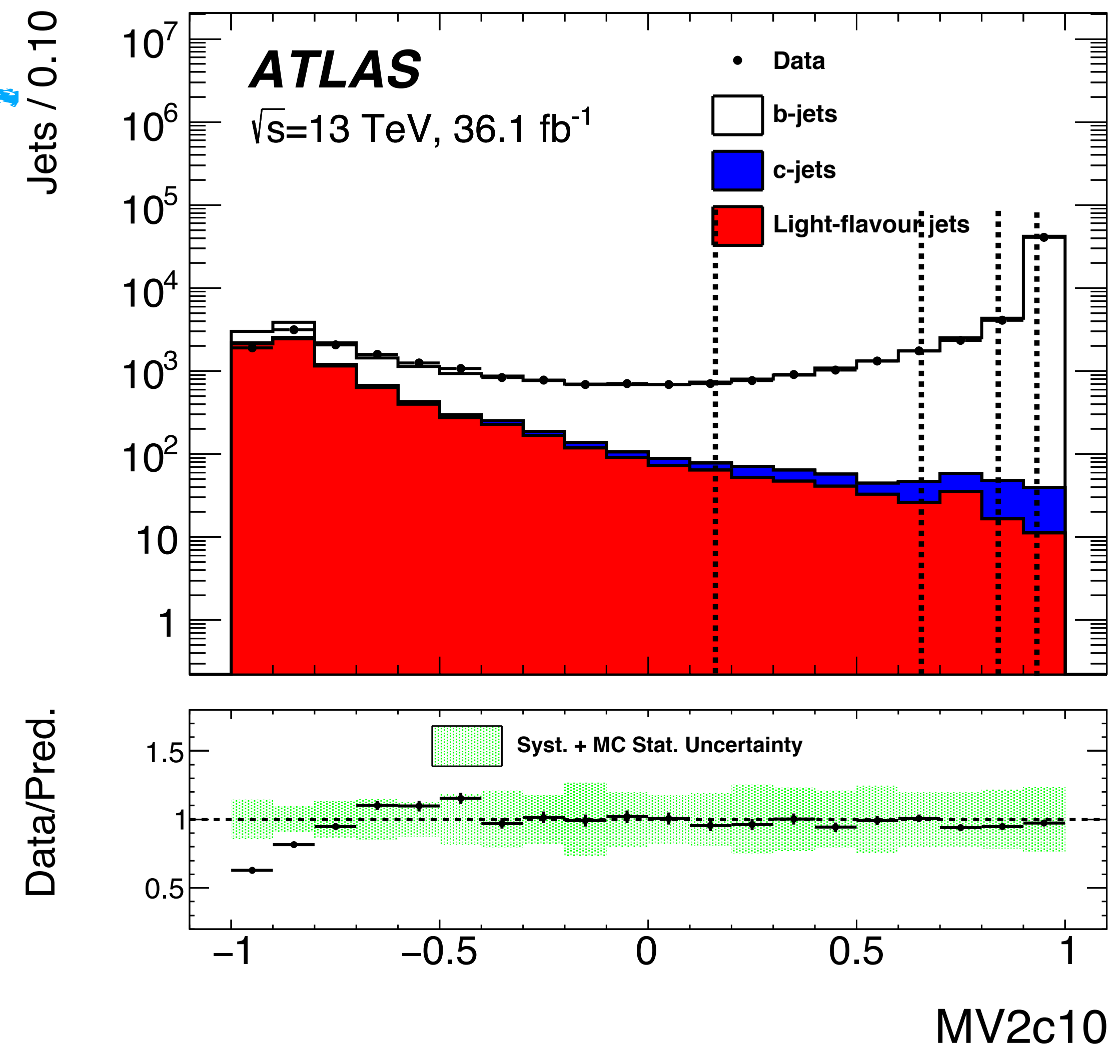
- Source of uncertainties:
  - data stat. implemented as 2 independent variations: linear and parabolic
  - largest sources of unc. from modelling and HF contamination in light jet region: 1 nuisance parameter per flavour
  - yes uncertainties correlated with the rest of the analysis
  - c-jet have same SF as b-jets but with doubled (and uncorrelated) uncertainties



pseudo continuous distribution in ATLAS

- SF measured as a function of p_T 4 WP corresponding to 4 (large) bins in tag weight distribution:
  - for b-jets: SF in tag weight directly extracted from the LH method
  - for c/light jets: SF in tag weight obtained by “subtracting” information from consecutive WP

$$SF_{60-70} = \frac{SF_{70} \cdot \epsilon^{70}_{MC} - SF_{60} \cdot \epsilon^{60}_{MC}}{\epsilon^{70}_{MC} - \epsilon^{60}_{MC}}$$



- Information of tag weight distribution **only available in these 5 macro bins** (pseudo continuous):
  - no shape interpolation inside each bin (not smoothing versus p_T)

- Estimation of uncertainties follows the diagonalisation of the full (pt-tag weight) covariance matrix, taking into account correlation of sys uncertainties:
  - ***pro***: fully correct approach with no extra assumptions on variations shapes/correlations (allows for any arbitrary shape variation compatible with the input systematic uncertainties. Create orthogonal variations for ProfileLikelihood fit
  - ***cons***: can only use binned information, many nuisance parameter O(100) (# pt bins x # tag weight bins)

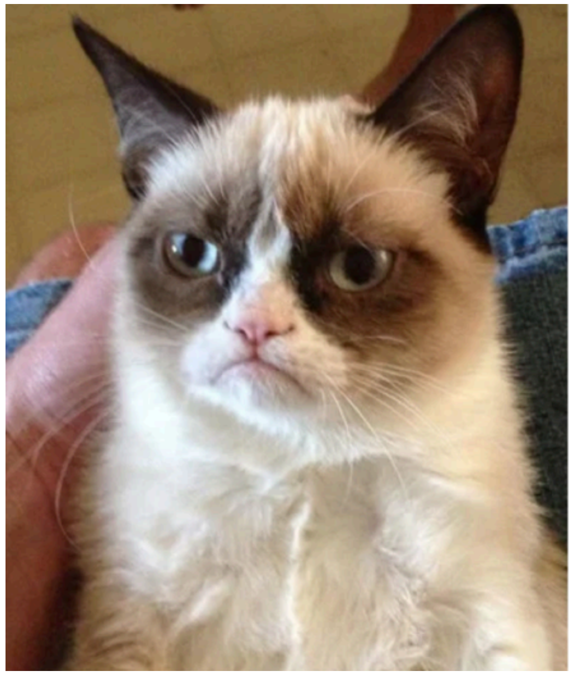
Intermezzo

CMS

left hep

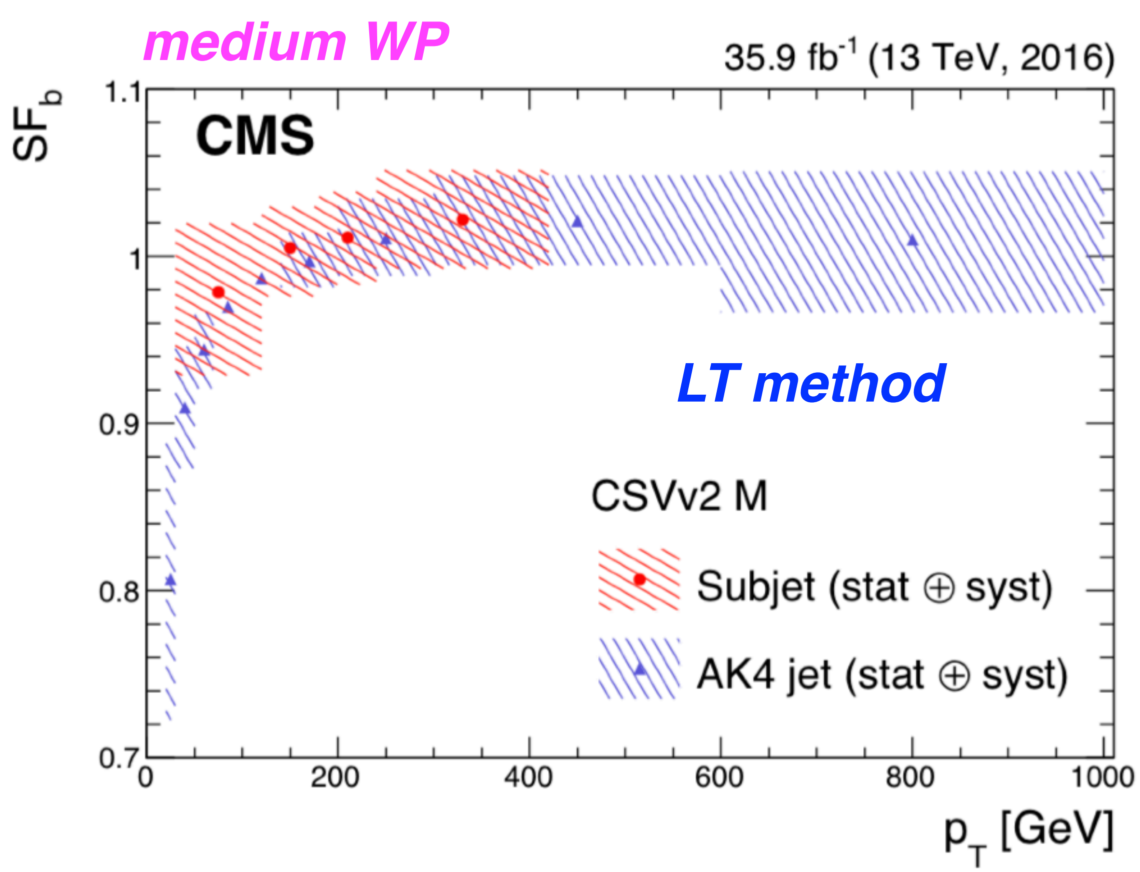
ATLAS

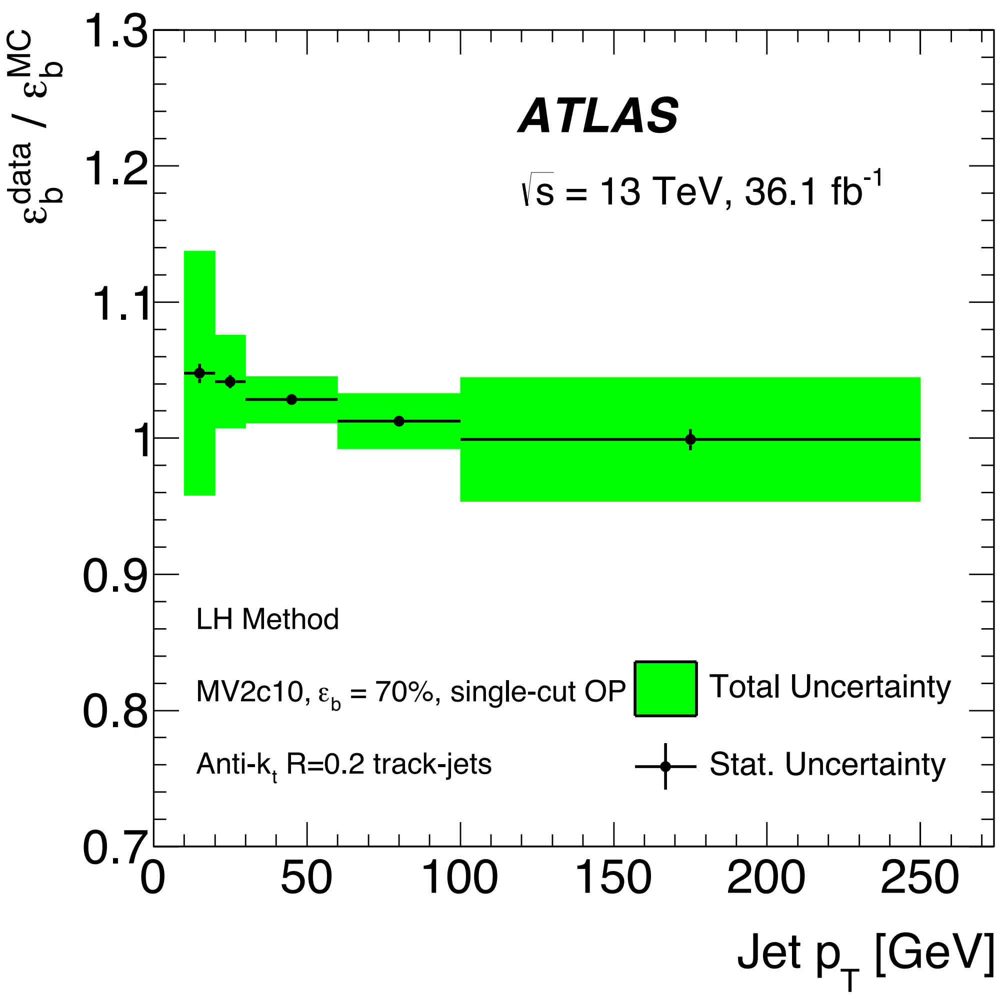
V.D.



Boosted regime (1)

- When using sub-jet for b-tagging need to calibrate sub-jet response [then uncertainties can be propagated to the X->bb tagger]:
  - ***CMS***: performing calibration of subject in high p_T largeR jet environment the SF uncertainty
  - ***ATLAS***: performing b-jet calibration of track jets with same ttbar method, using same SF as standard jets for c/light with additional extrapolation uncertainties.





- Similar performance as for calo jets (although larger uncertainties in certain cases)

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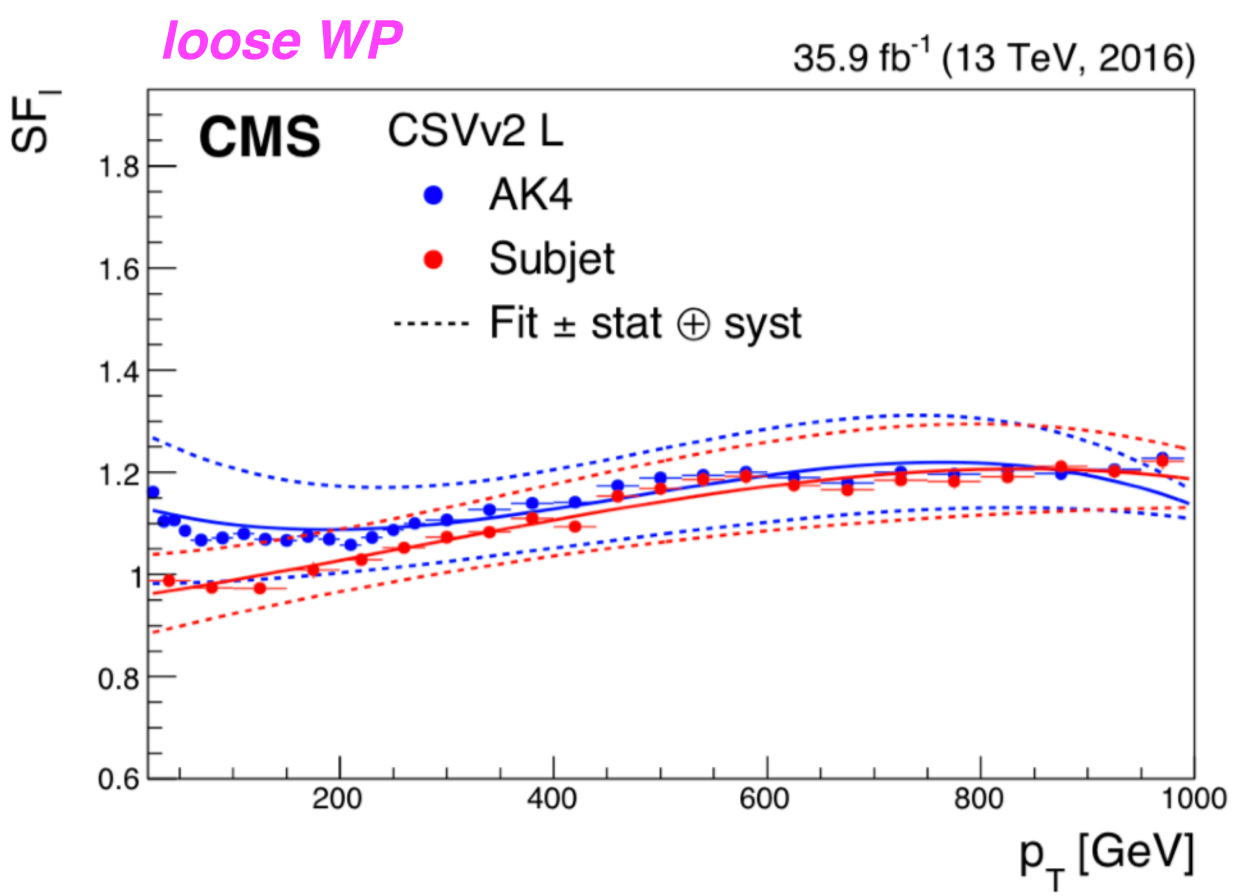

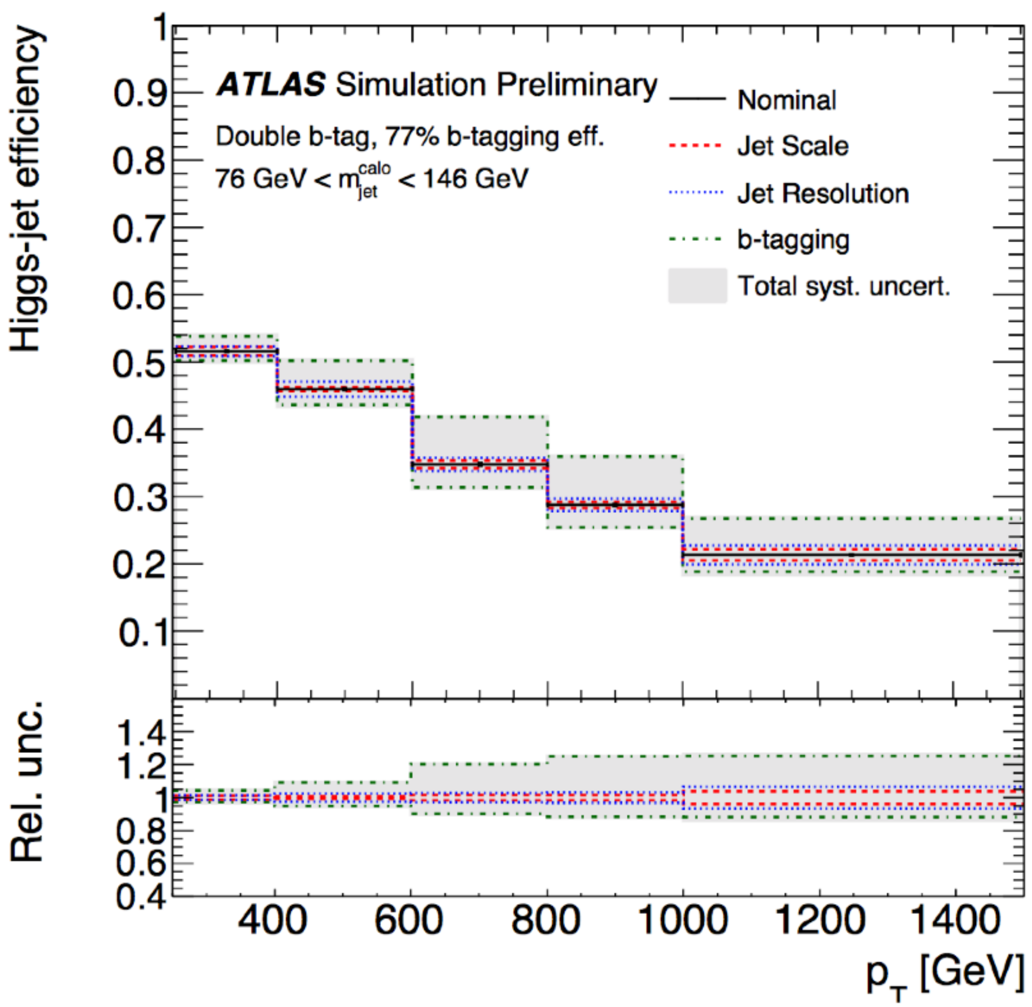

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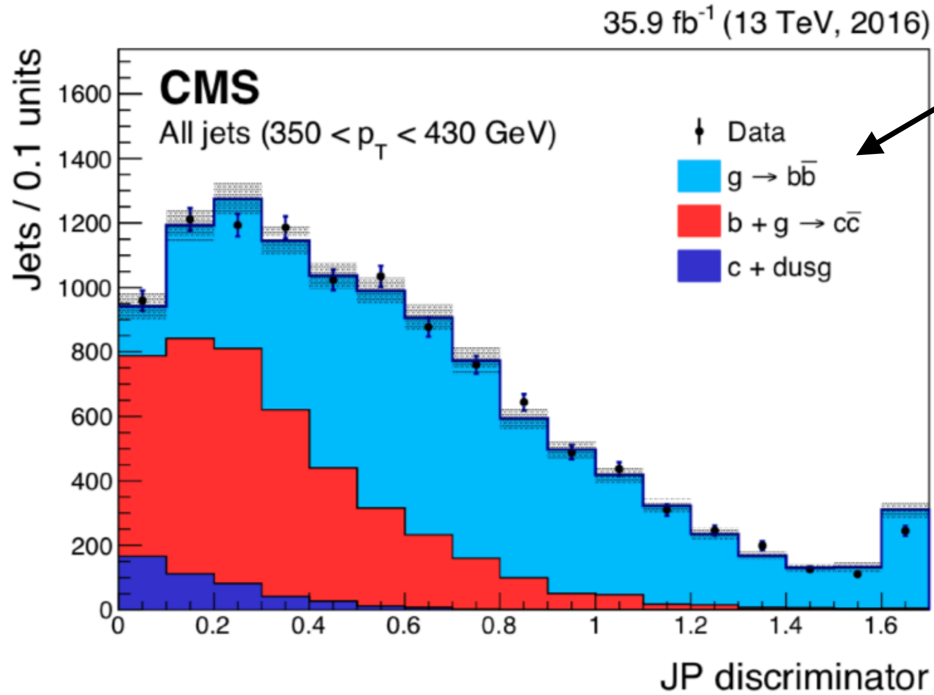
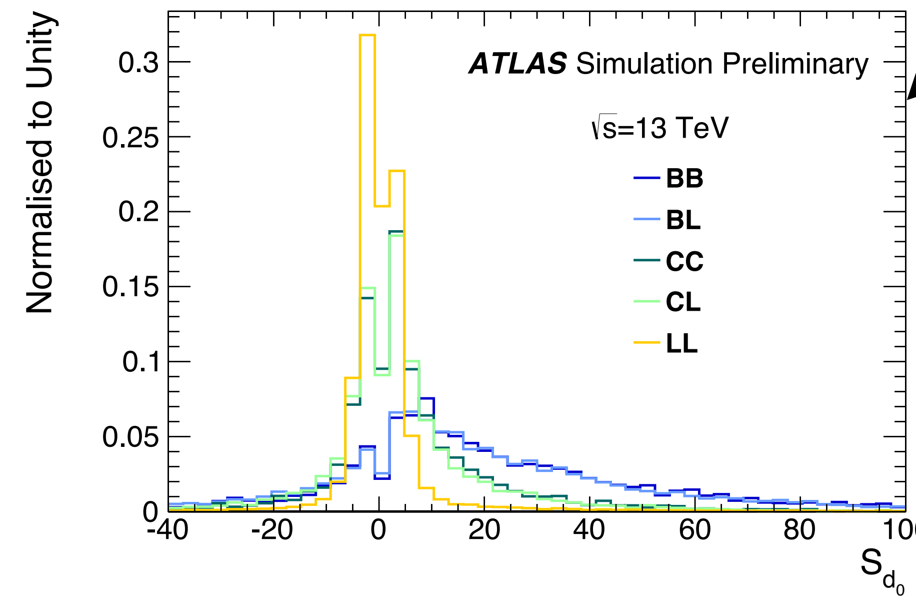
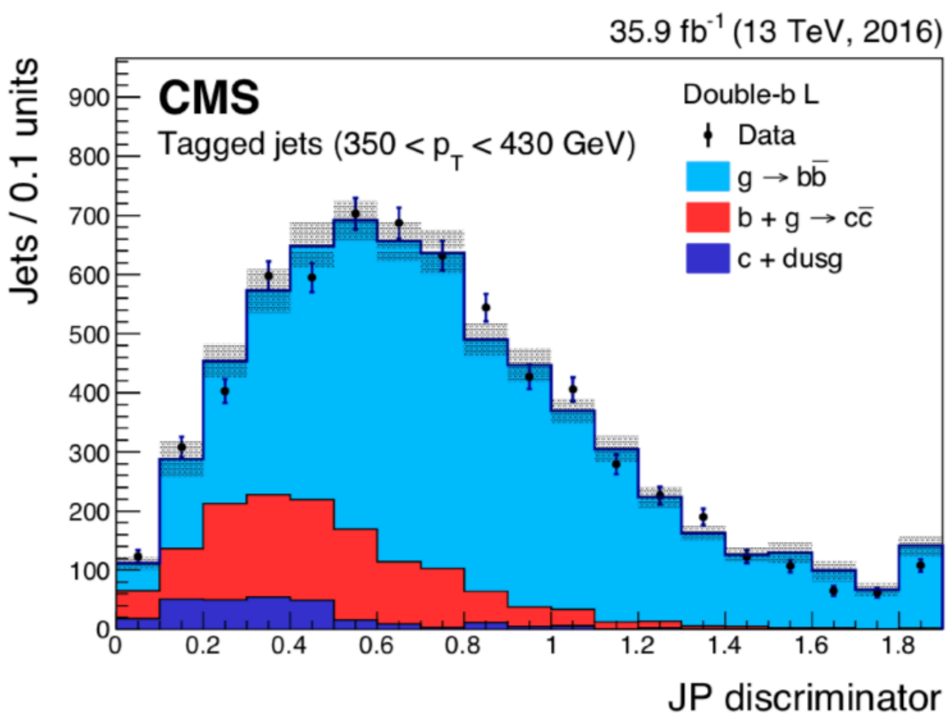
Boosted regime (2)

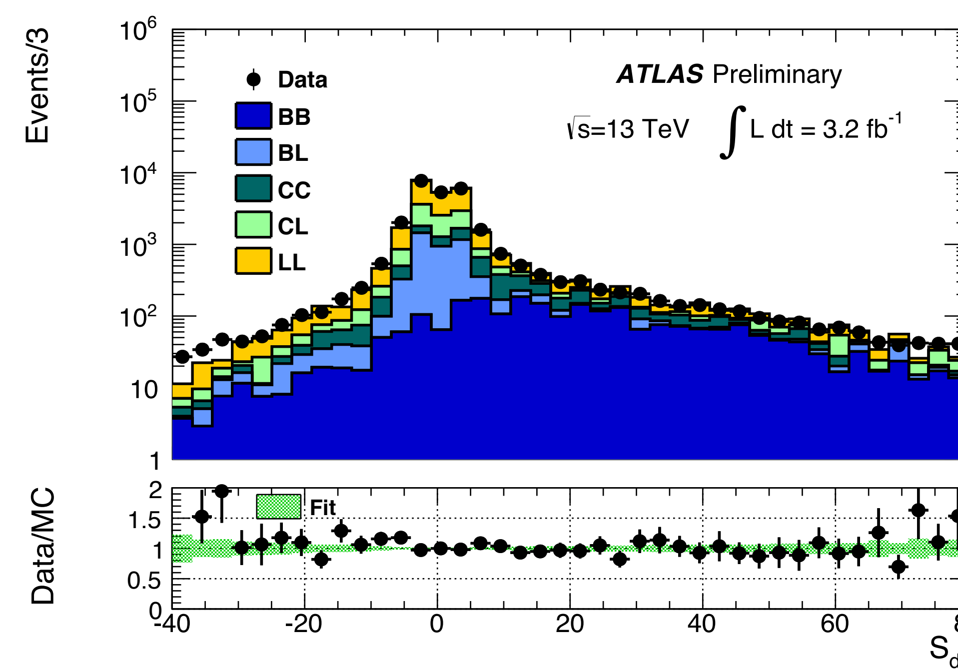
- When the boosted tagger needs more complex information —> *need full double b-tagging calibration*
- *Selecting g->bb events with a largeR jet containing 2 muons* or 2 subjects and at least 1 with a mu





largest impact parameter significance of the three leading tracks (for both sub-jets)





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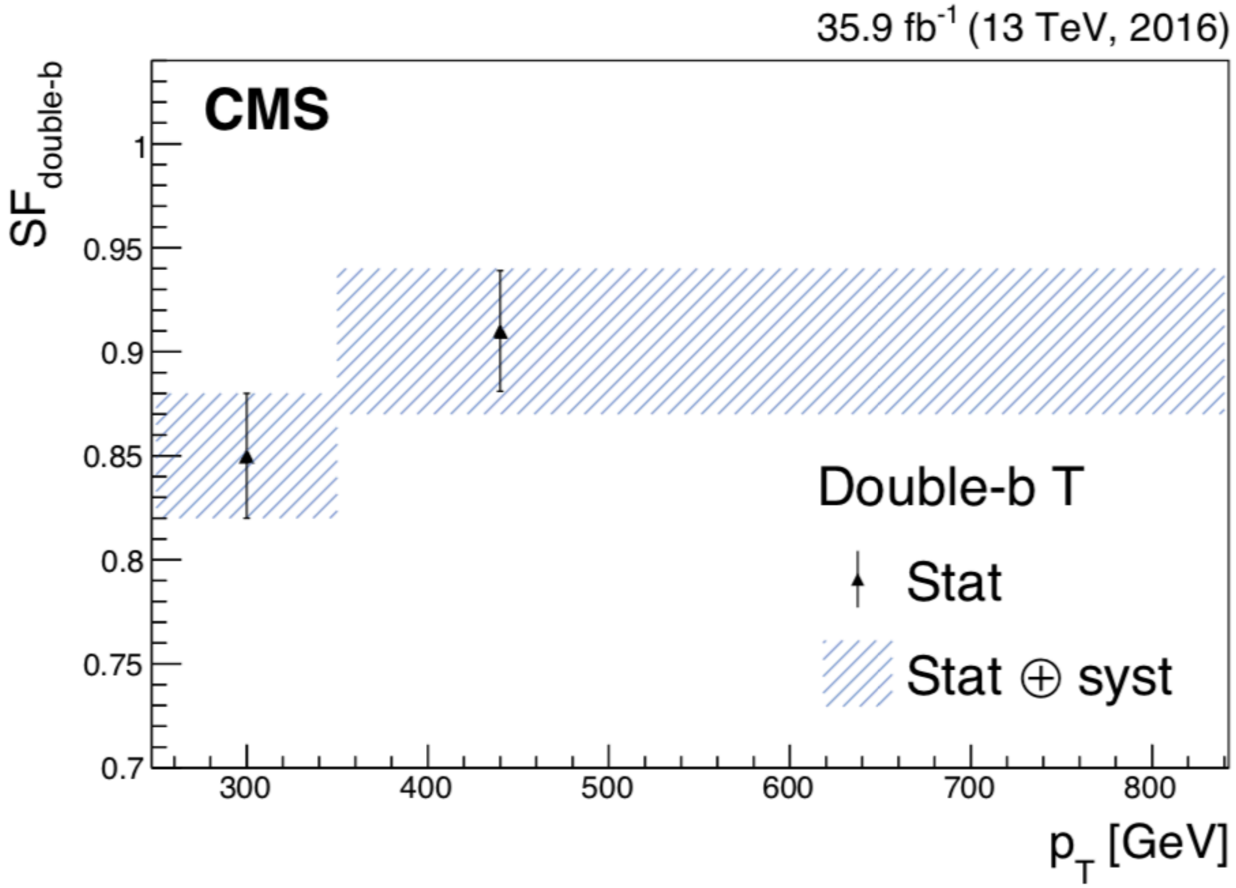
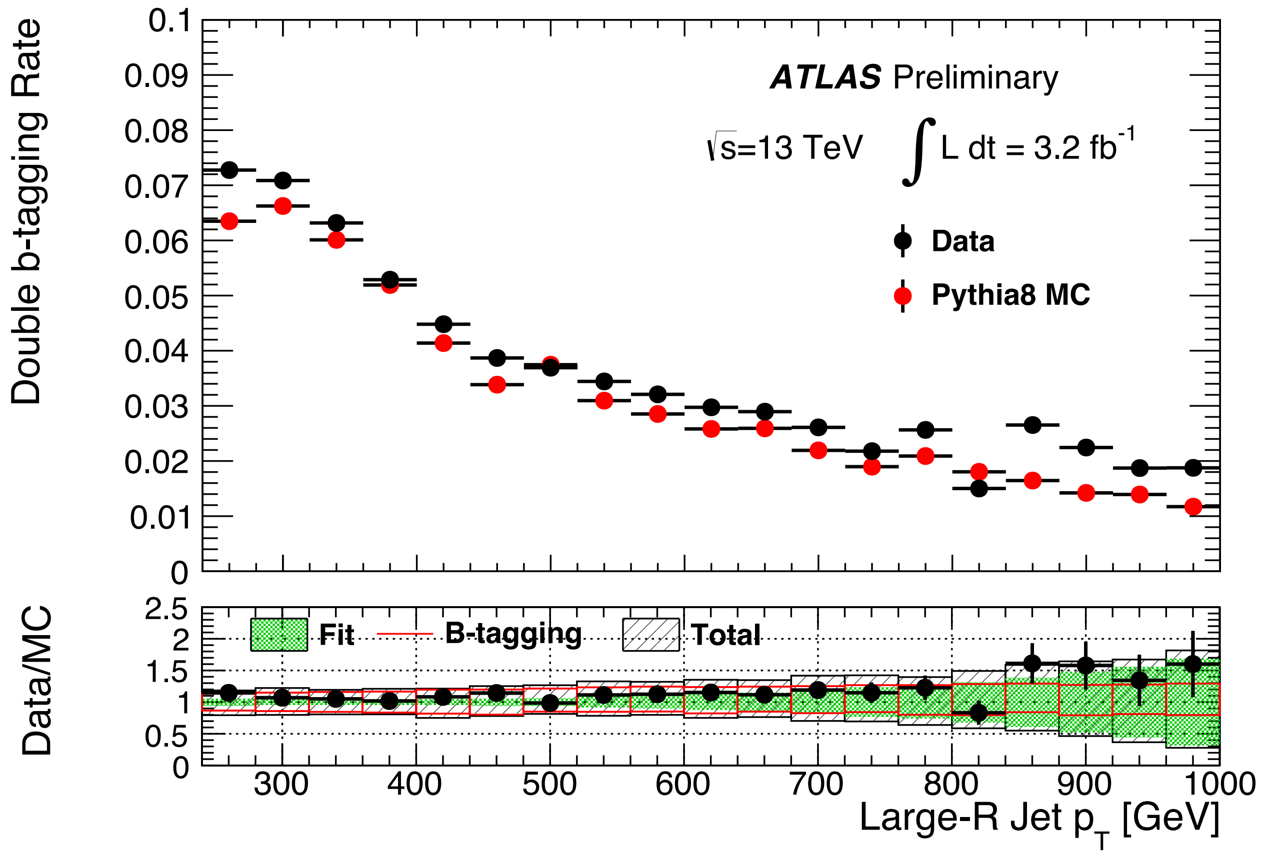




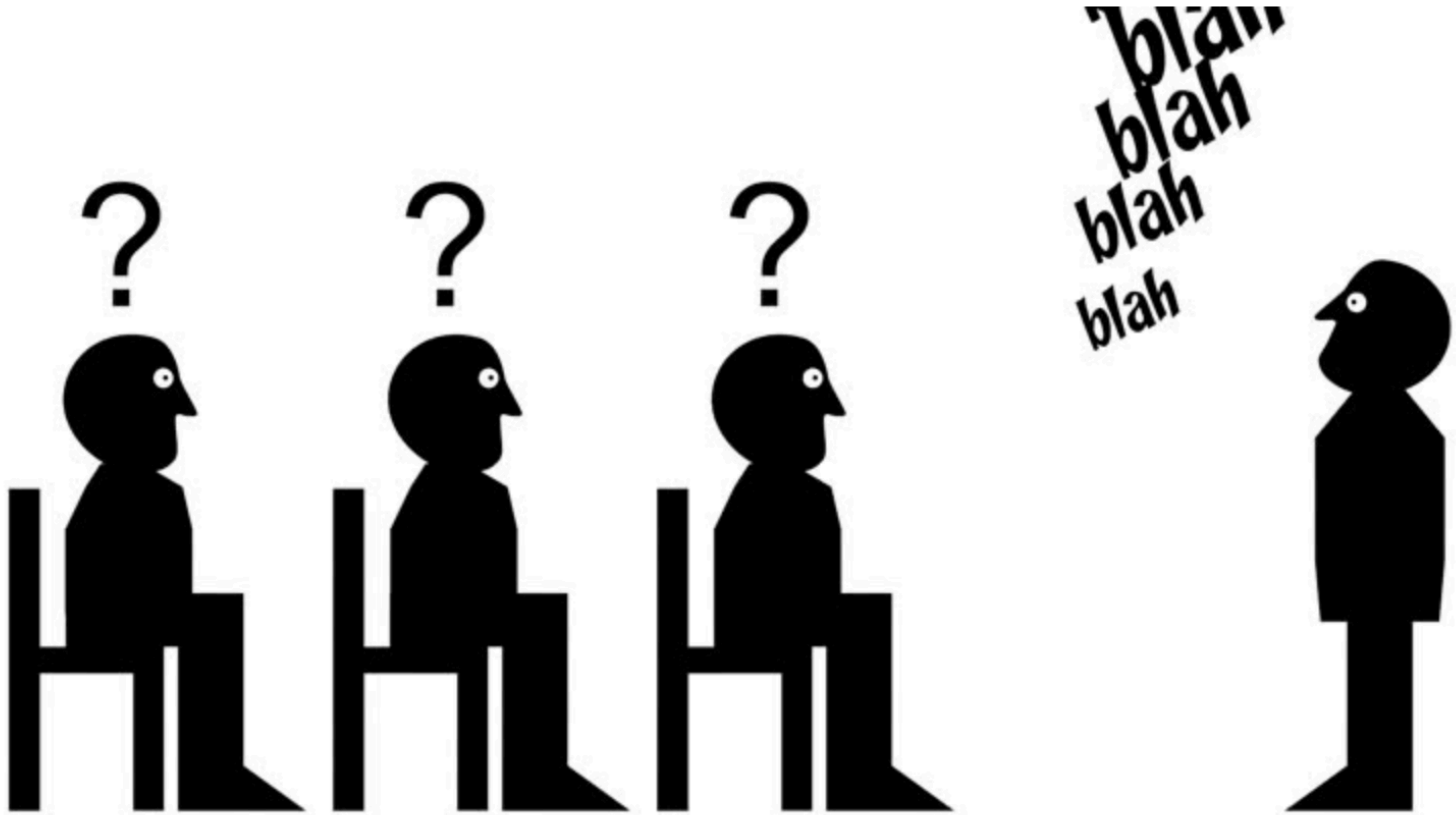
- SF: ratio of tagging efficiency for ***double b-hadron jets*** (background subtracted)
- rate: probability of events passing double b-tagger for ***ALL jets*** (no background subtraction)

WOULD YOU LIKE TO KNOW MORE?

- ***CMS***:
  - *"Identification of heavy-flavour jets with the CMS detector in pp collisions at 13 TeV"*
  - JInst: http://dx.doi.org/10.1088/1748-0221/13/05/P05011

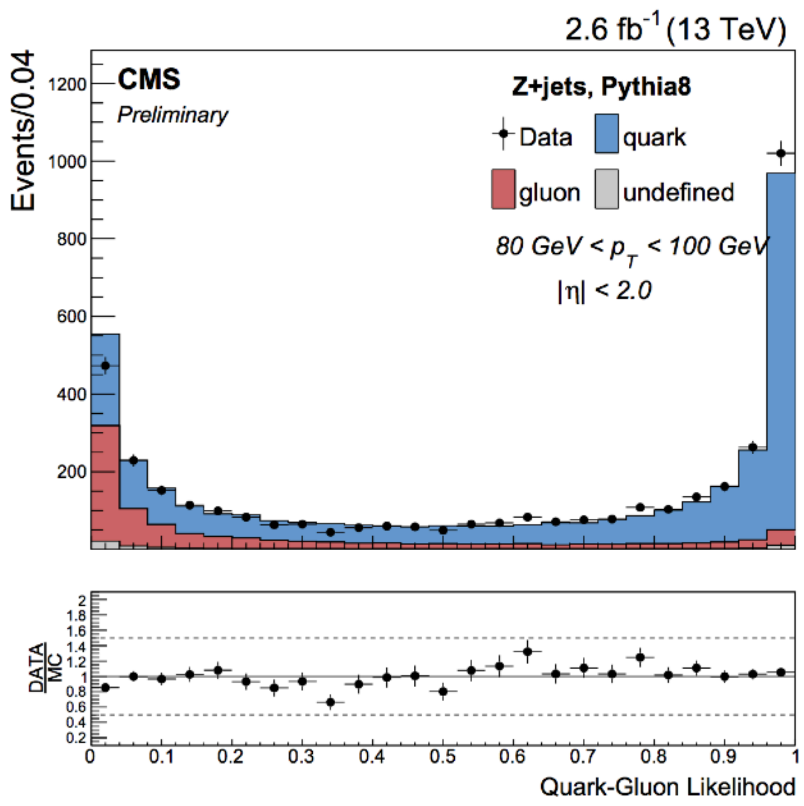
- ***ATLAS***:
  - *" Measurements of the b-jet tagging efficiency with the ATLAS detector using tt events at \sqrt= 13 TeV"* arXiv:1805.01845
  - *"Calibration of light-flavour b-jet mis tagging rates using ATLAS proton-proton collision data at \sqrt=13 TeV" ATLAS-CONF-2018-006*
  - *"Measurement of b-jet tagging efficiency of c-jets in tt events using a likelihood approach with the ATLAS detector" ATLAS-CONF-2018-001*
  - *"Boosted Higgs (→ bb) Boson Identification with the ATLAS Detector at \sqrt=13 TeV" ATLAS-CONF-2016-039*

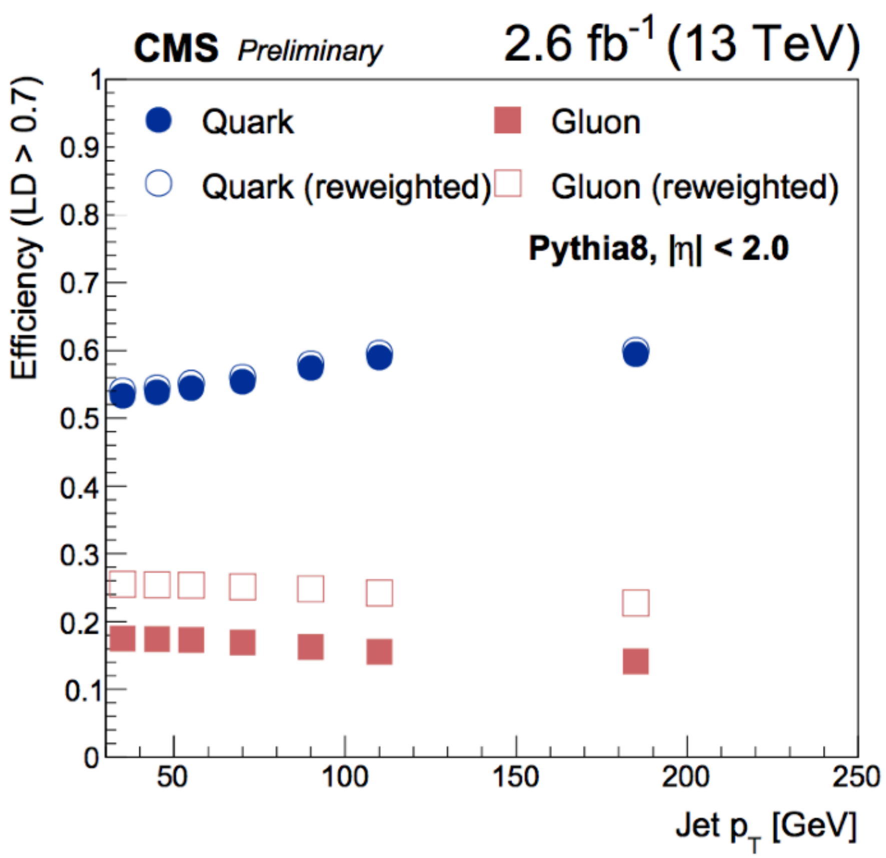
Question time

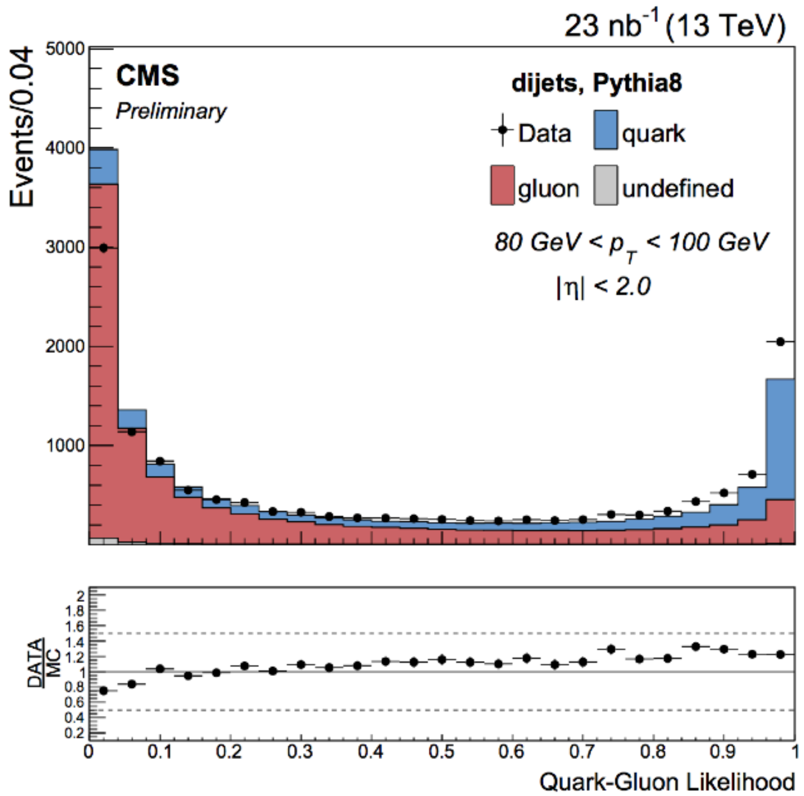


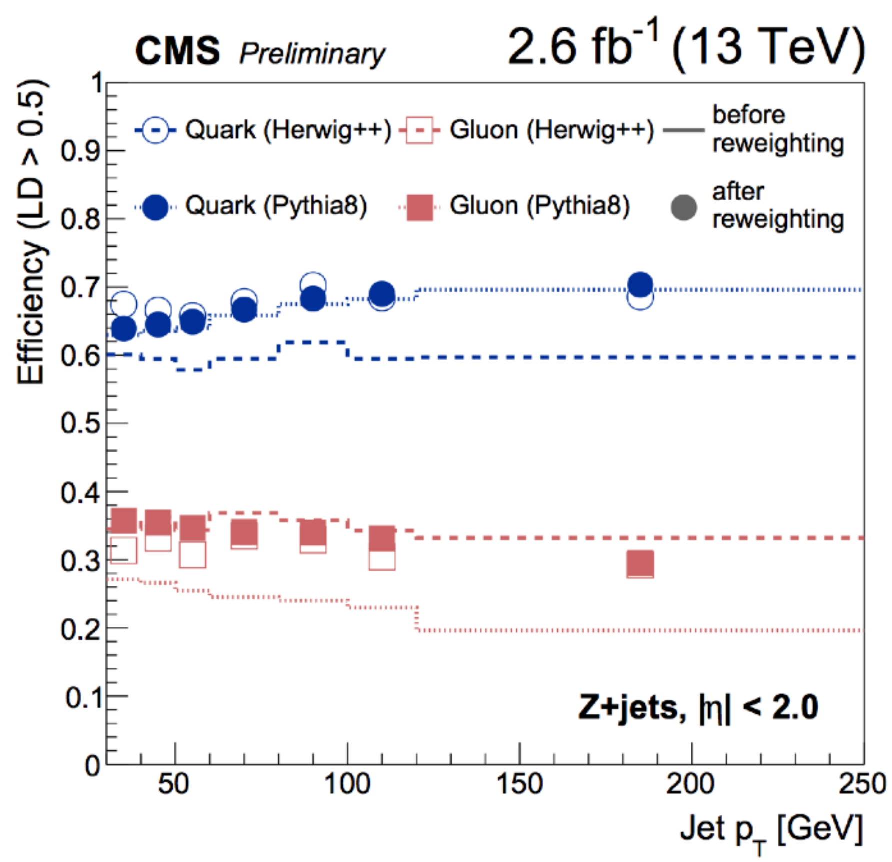
backUp

q-g tagger: CMS



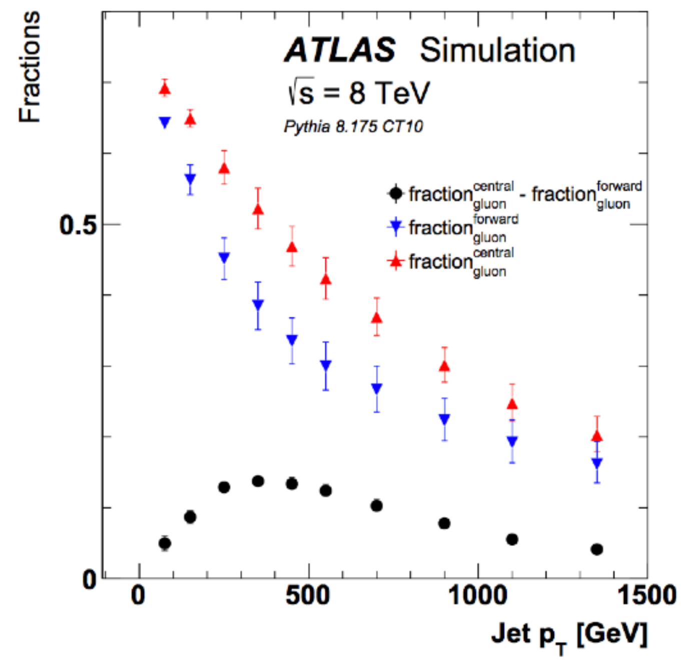


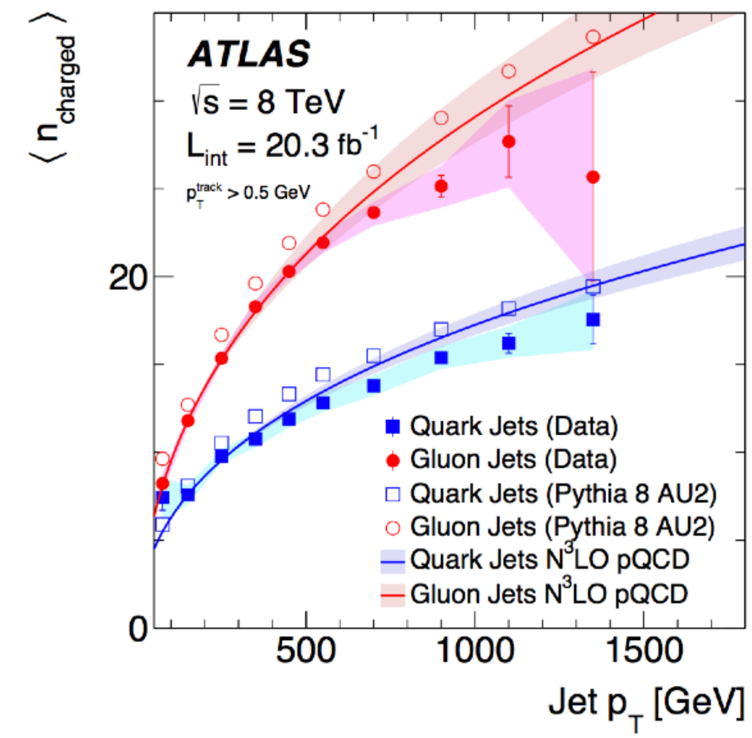




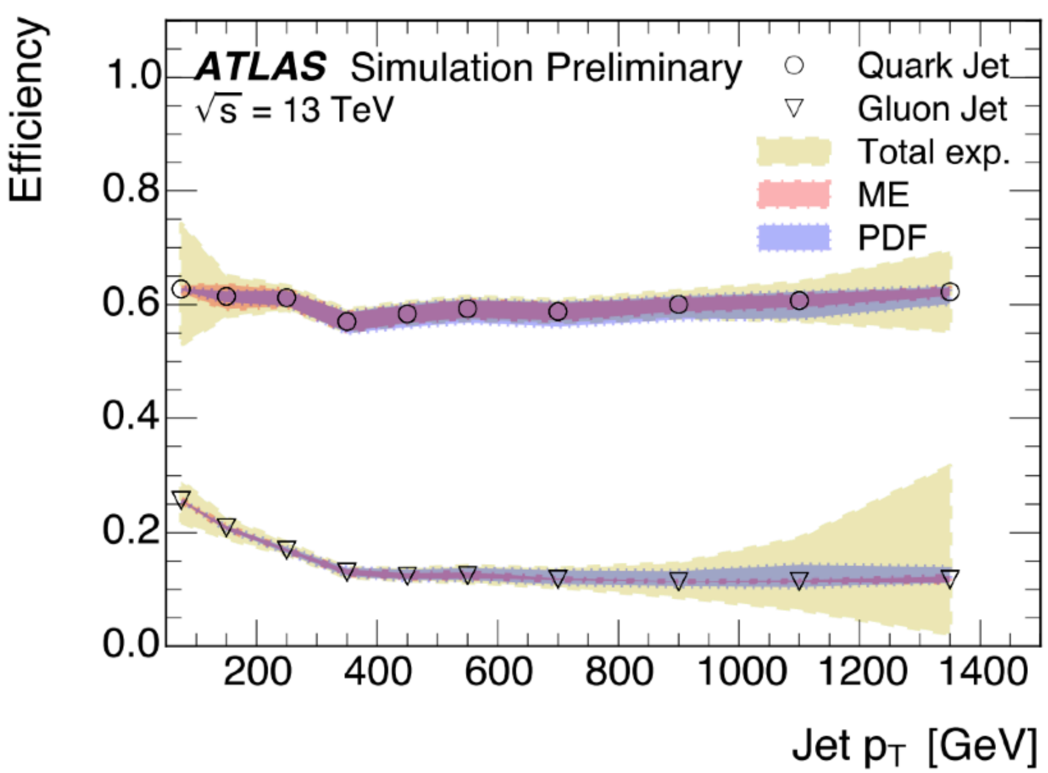
q-g tagger

$$\langle n^{f}_{\text{charged}}\rangle = f^{f}_{q}\langle n^{q}_{\text{charged}}\rangle + f^{f}_{g}\langle n^{g}_{\text{charged}}\rangle$$
$$\langle n^{c}_{\text{charged}}\rangle = f^{c}_{q}\langle n^{q}_{\text{charged}}\rangle + f^{c}_{g}\langle n^{g}_{\text{charged}}\rangle,$$

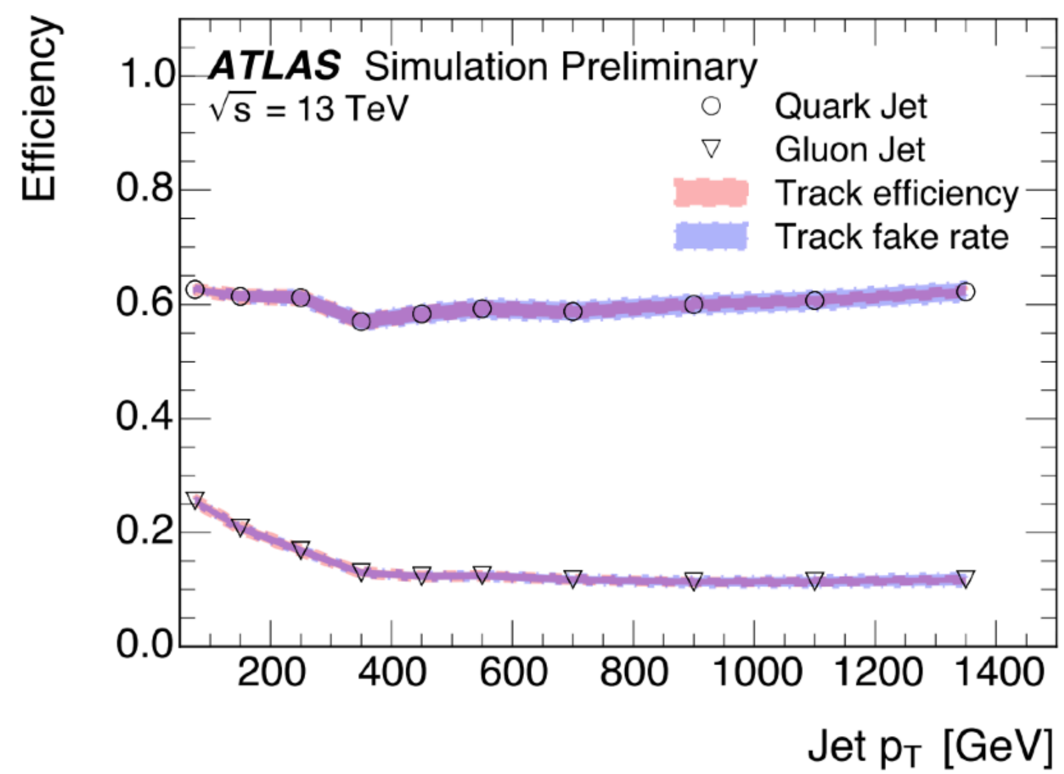




theory sys

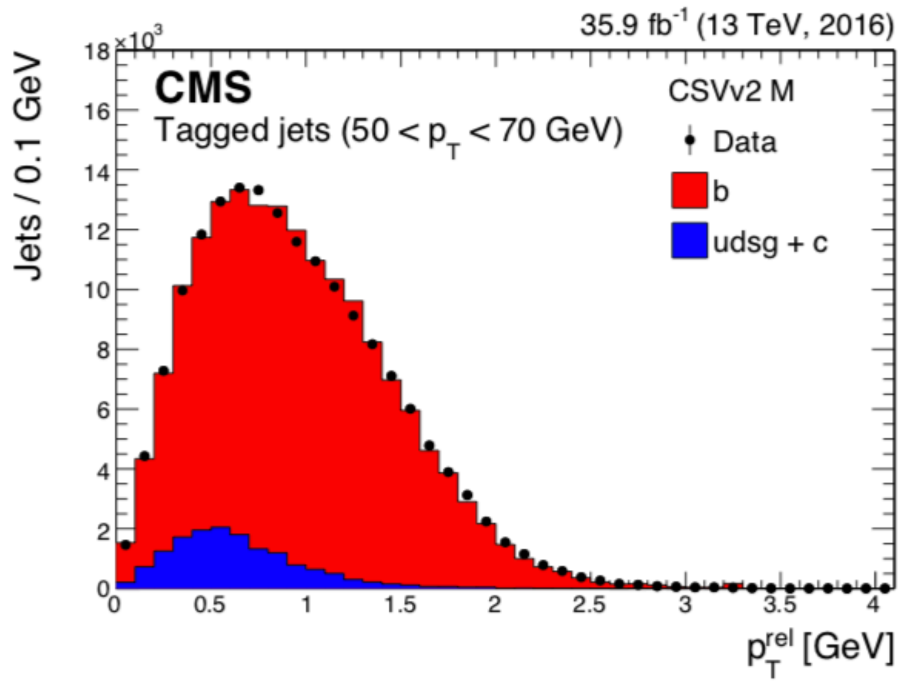


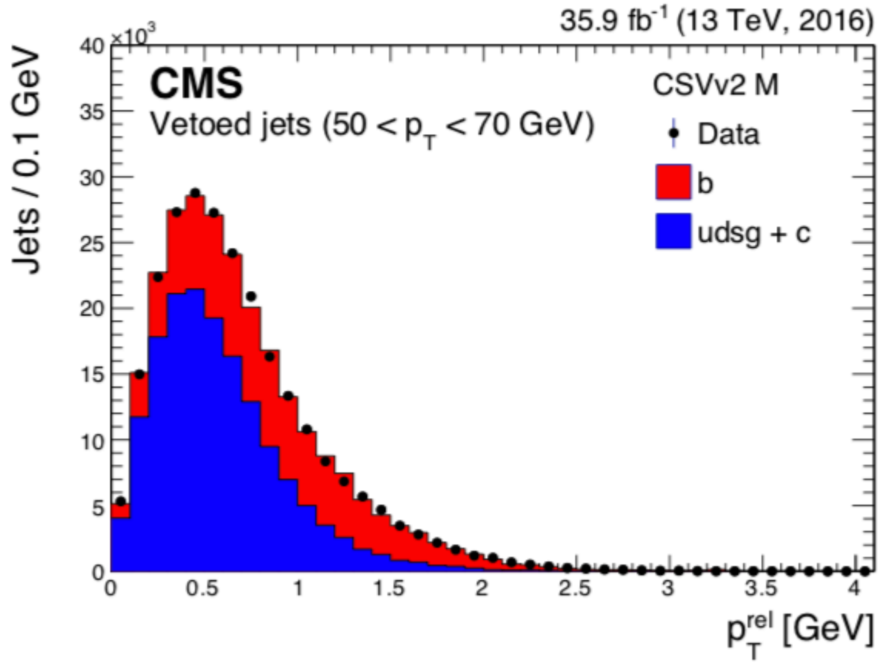
exp sys



data/mc plots

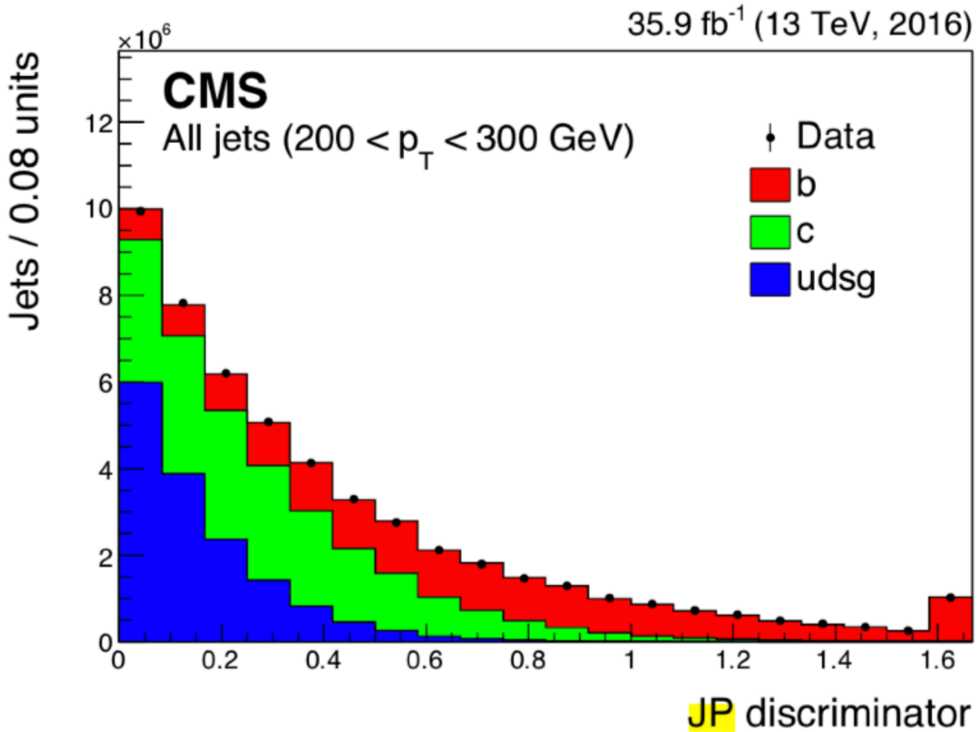
b-jets CMS: muon in jets

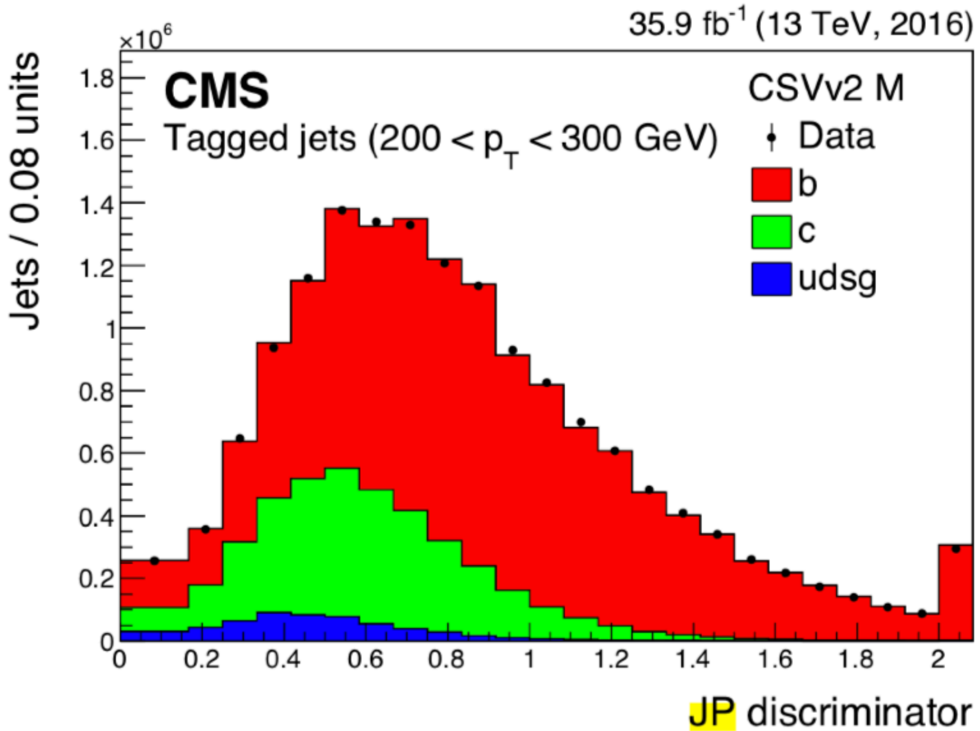




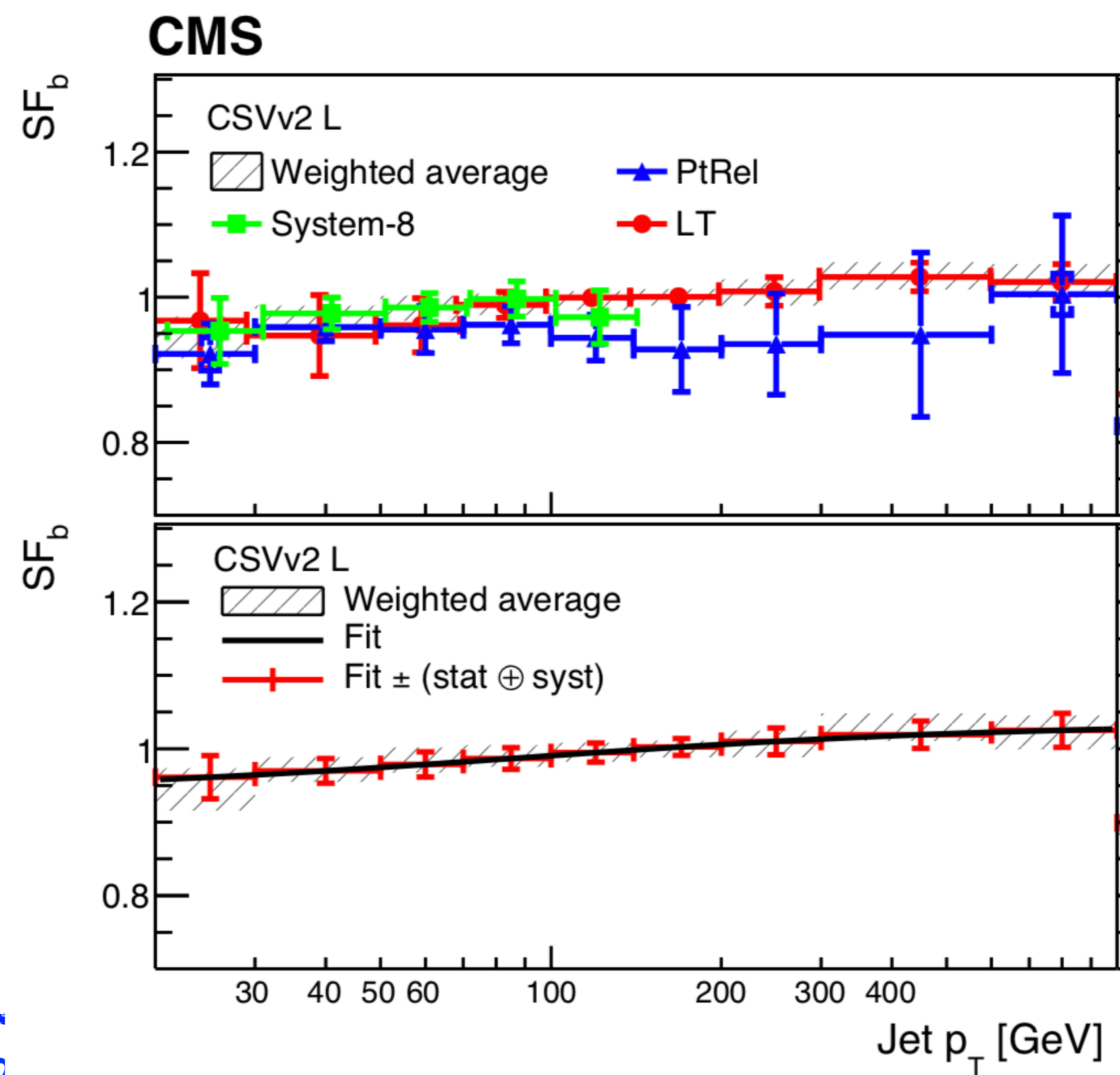
Systematic effect	PtRel	LT	System-8
Gluon splitting to $b\bar{b}$	x	x	x
b quark fragmentation	x	x	x
Branching fraction of $D \rightarrow \mu X$	n/a	x	n/a
$c \rightarrow D$ fragmentation rate	n/a	x	n/a
K^0_S (Λ) production fraction	n/a	x	n/a
Muon p_T and ΔR	x	—	x
Away jet tag	x	n/a	x
Fraction of jets with JP	n/a	x	n/a
JP calibration	n/a	x	n/a
JP bin-by-bin correlation	n/a	x	n/a
p_T^{rel} requirement	n/a	n/a	x
udsg-to-c jet ratio	x	n/a	n/a
Non-b template correction	x	n/a	n/a
b template correction	x	n/a	n/a
JES	x	x	x
Pileup	x	—	x

- JP: likelihood based discriminant using track from primary vertex probability (only positive IP tracks)

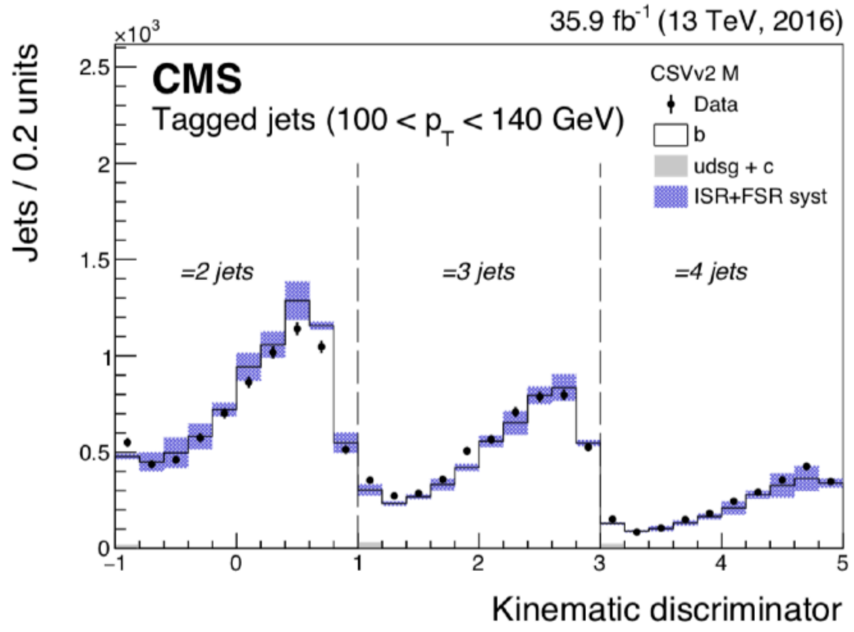


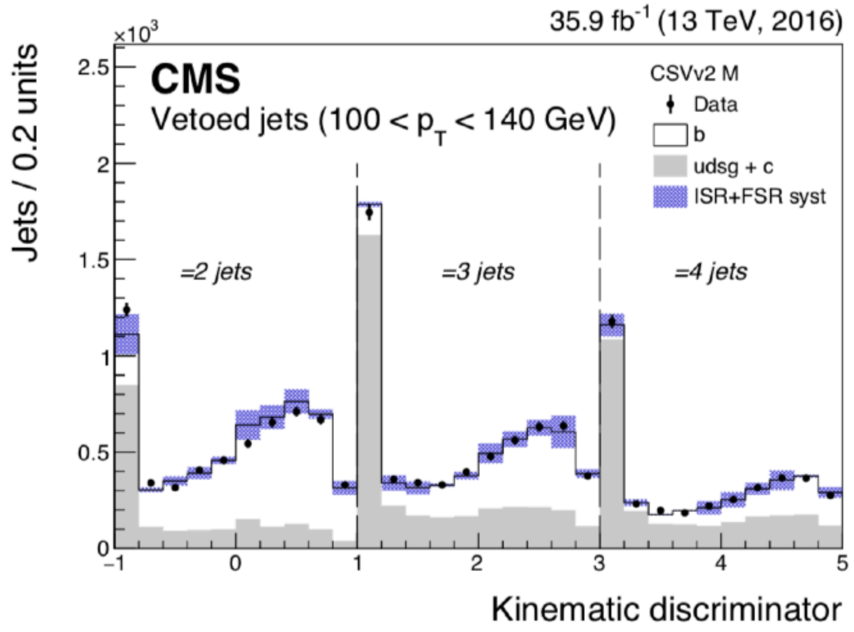


$$\varepsilon_b = C_b \frac{N_b^{\text{tagged}}}{N_b}.$$

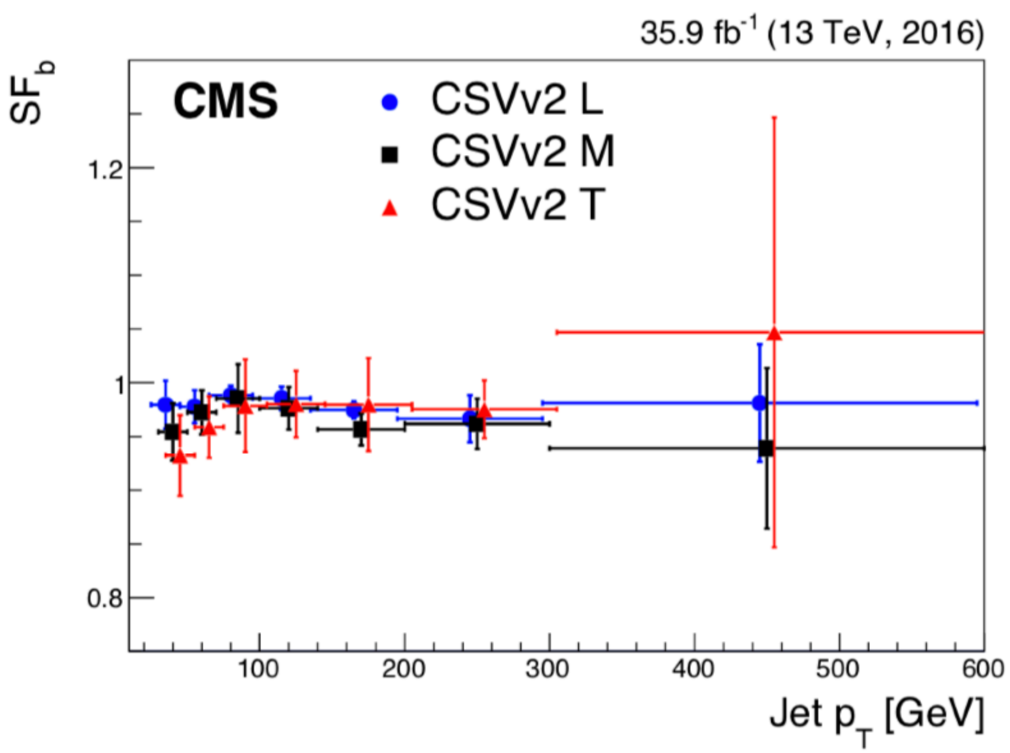


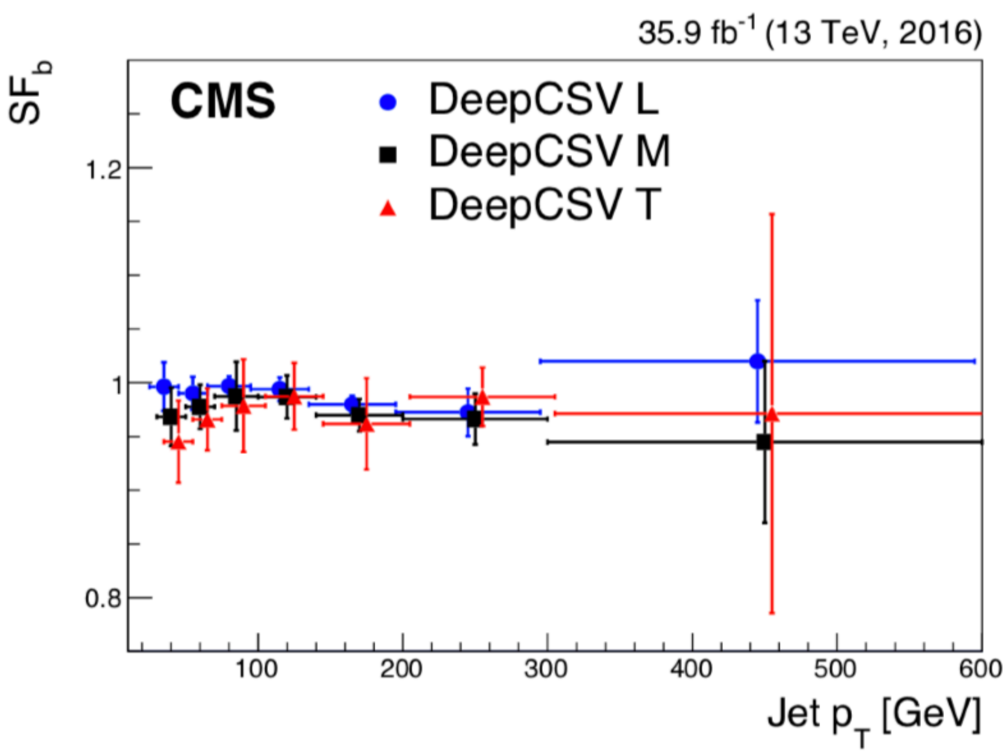
b-jets CMS: ttbar dilepton

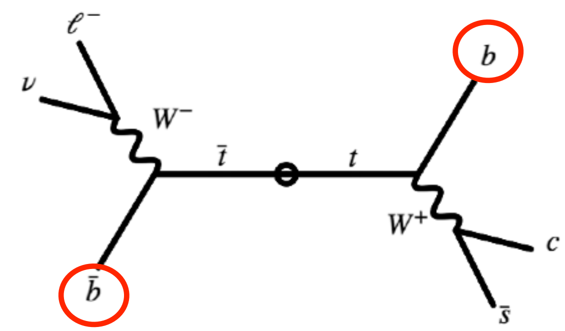




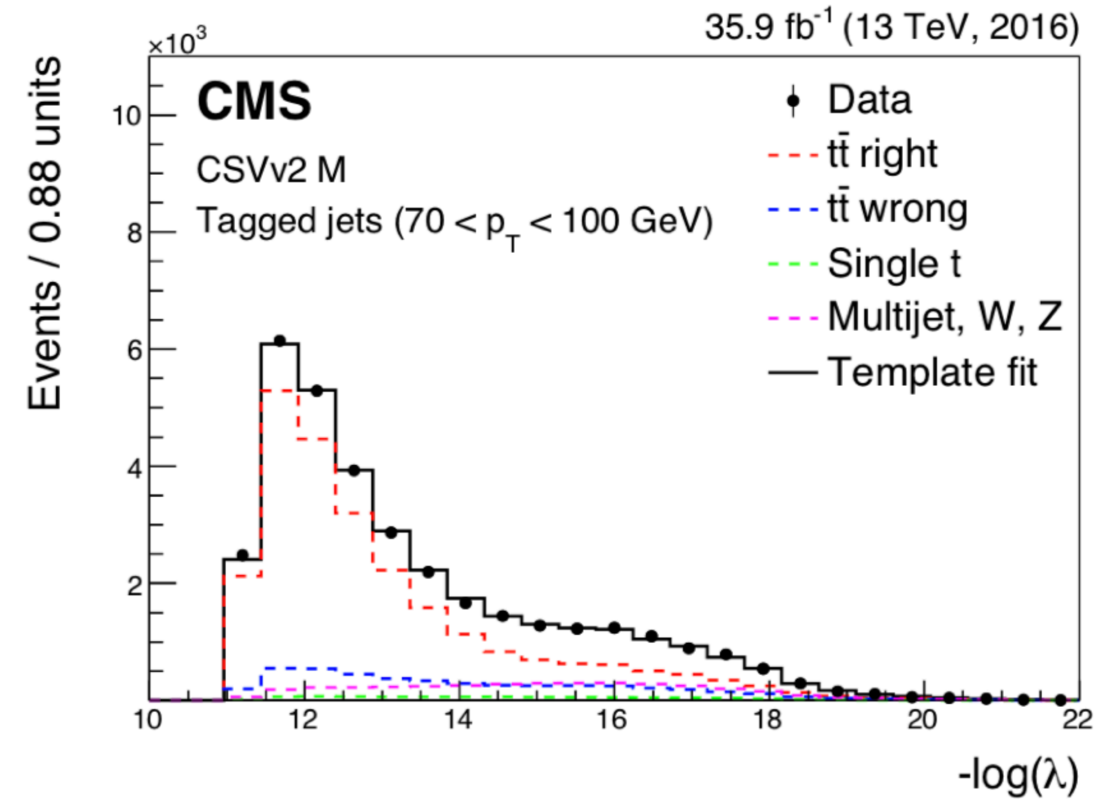
- fitting kinematic discriminator to obtain the fraction of correctly reconstructed b-jets (discriminator only includes per-jet quantities)

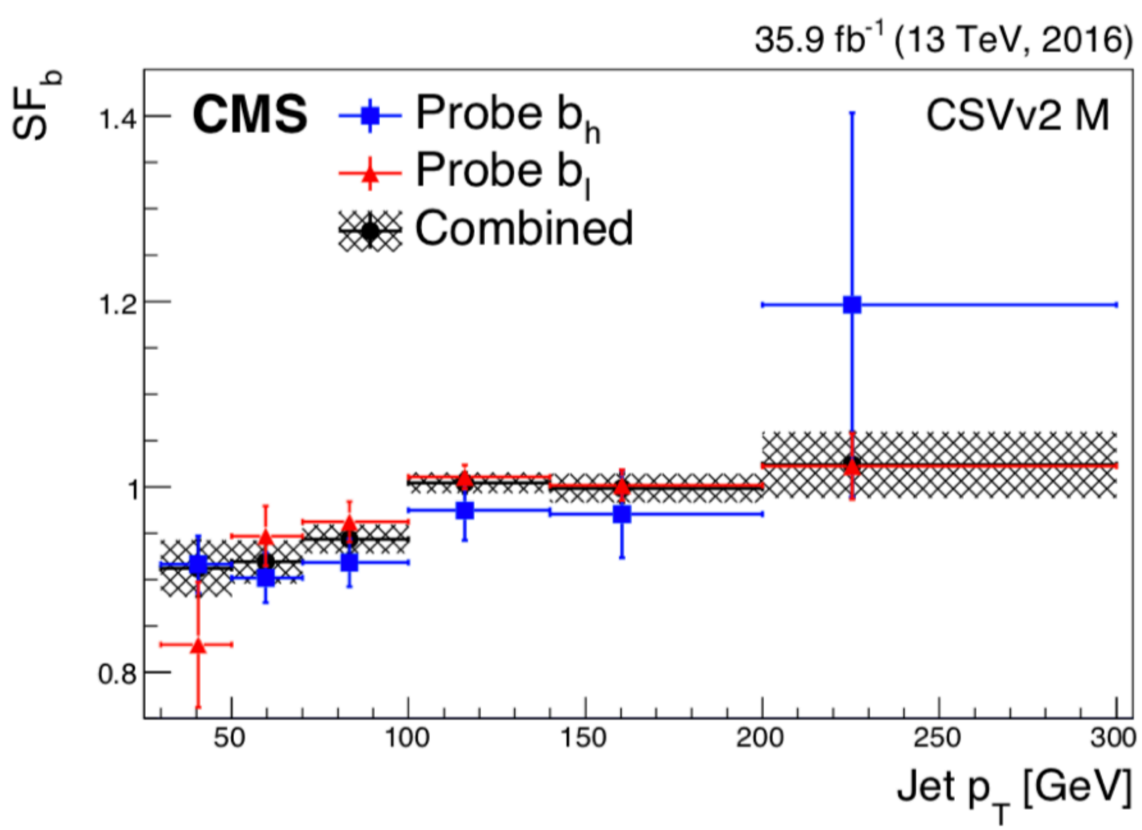


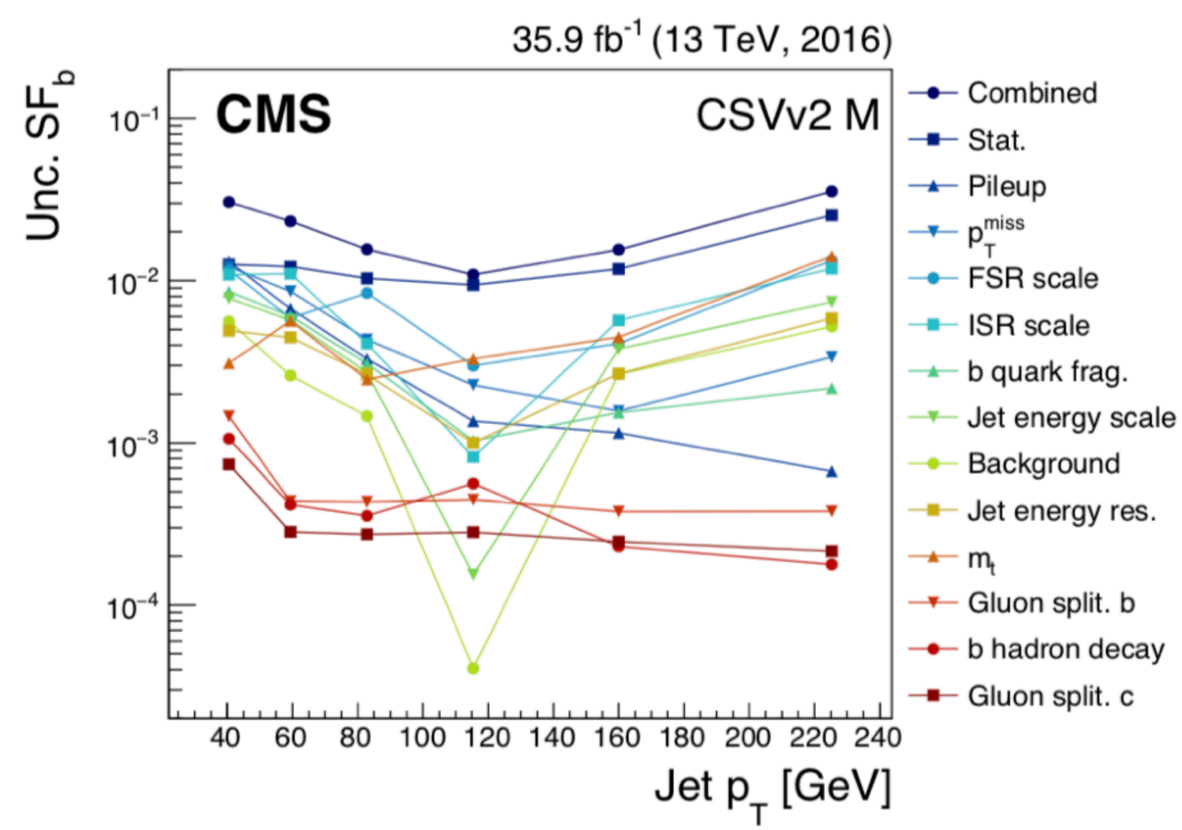




- ***l+jets tag and probe***:
  - considering both leptonic and hadronic side
  - using 2D likelihood mass template to choose the best permutation
  - fitting the likelihood output to obtain the number of correctly assigned events

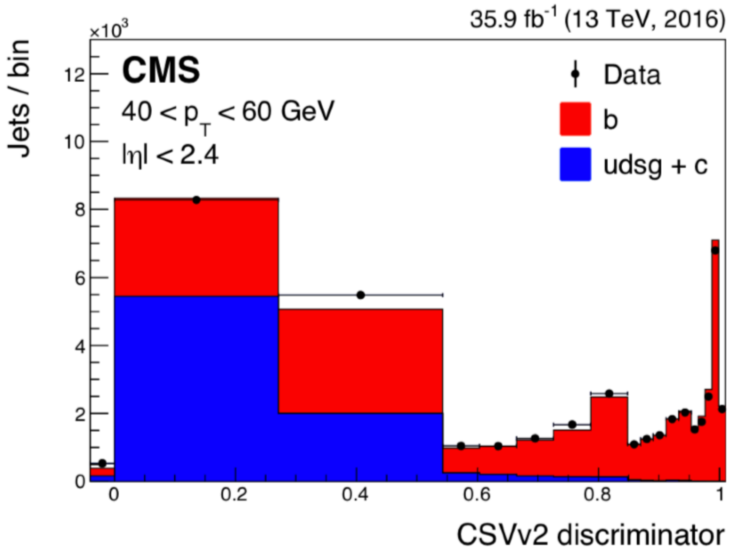


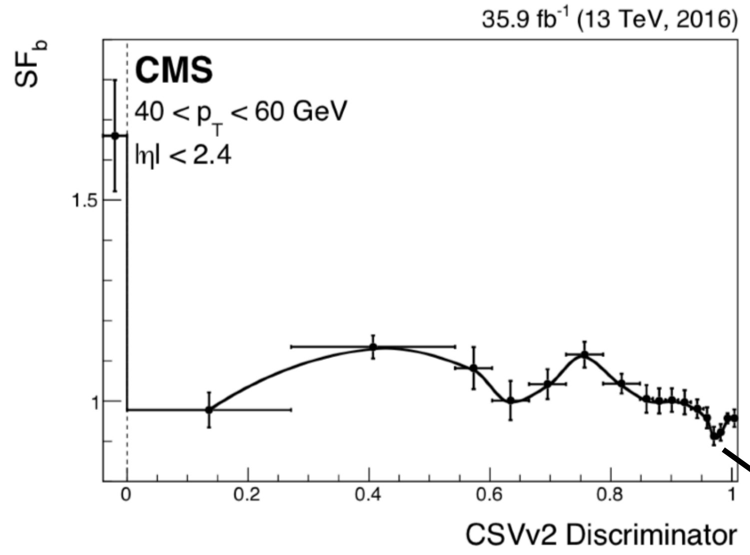


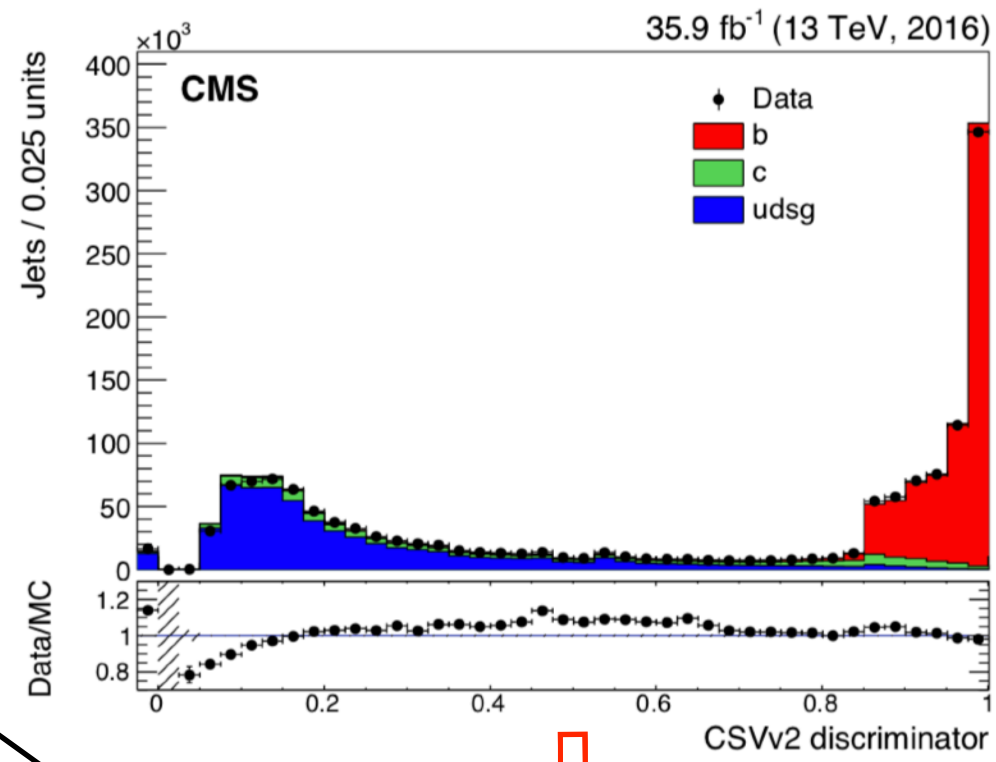


b-jets CMS: continusous

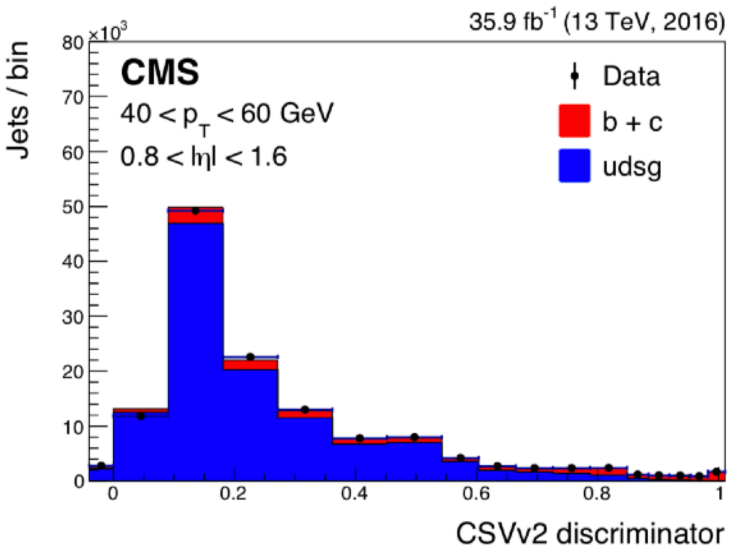
ttbar e/mu + 2jets (one b-tagged)

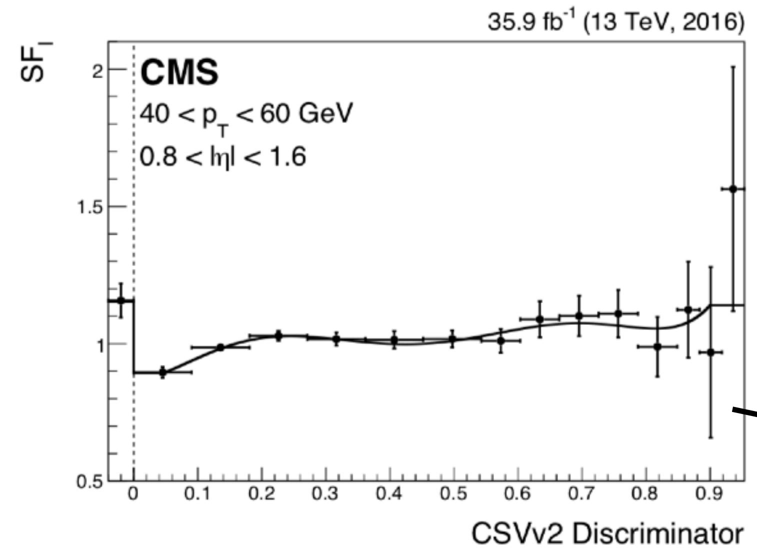


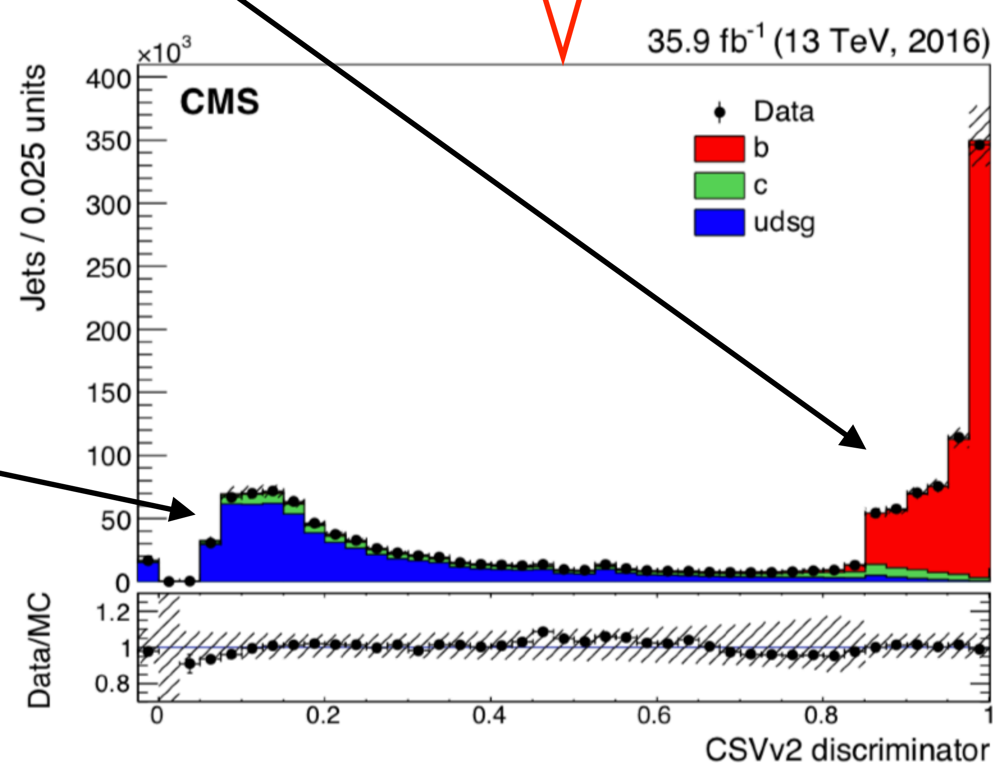




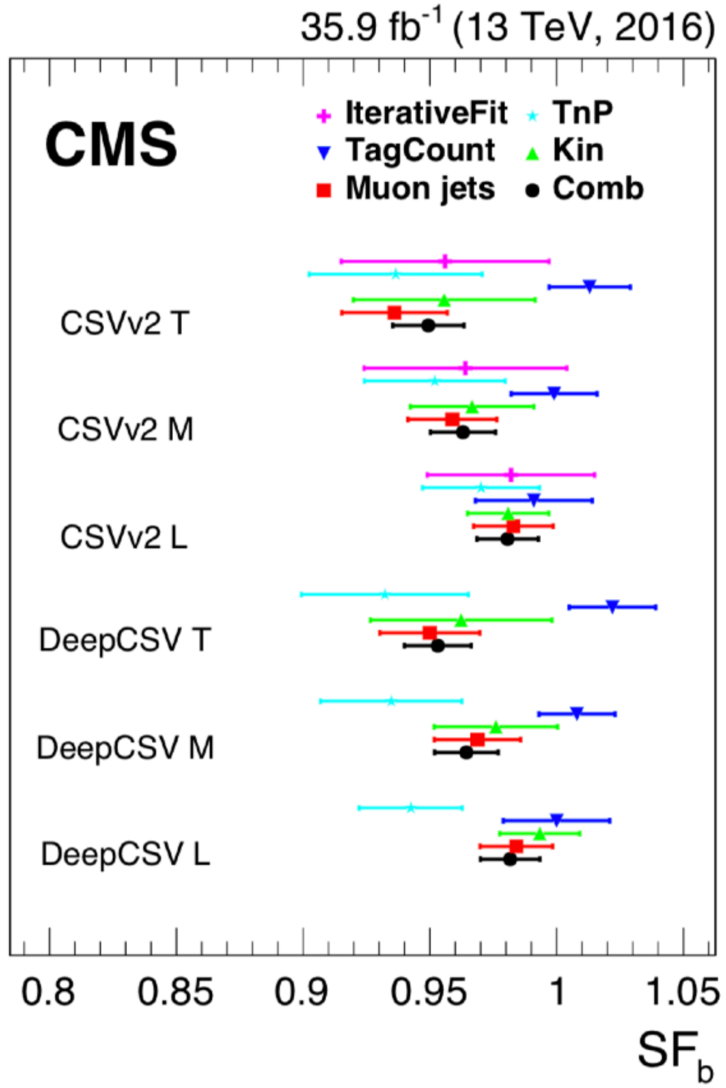
Z(ll/mm) + 2 jets (one anti b-tagged)

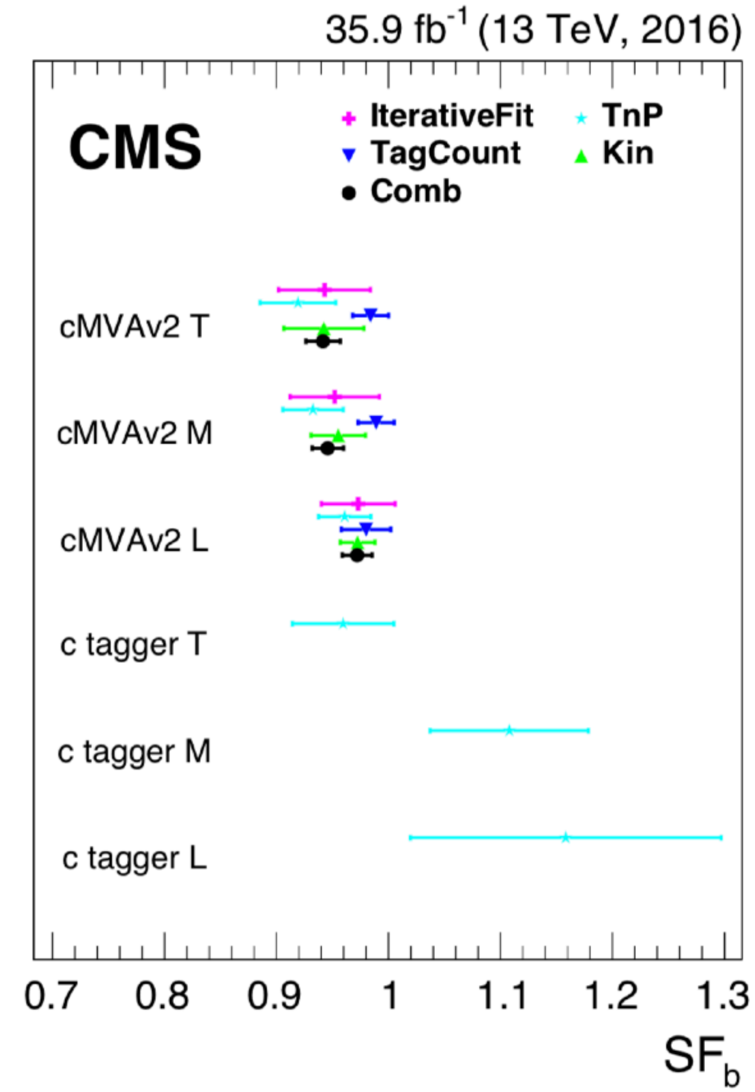


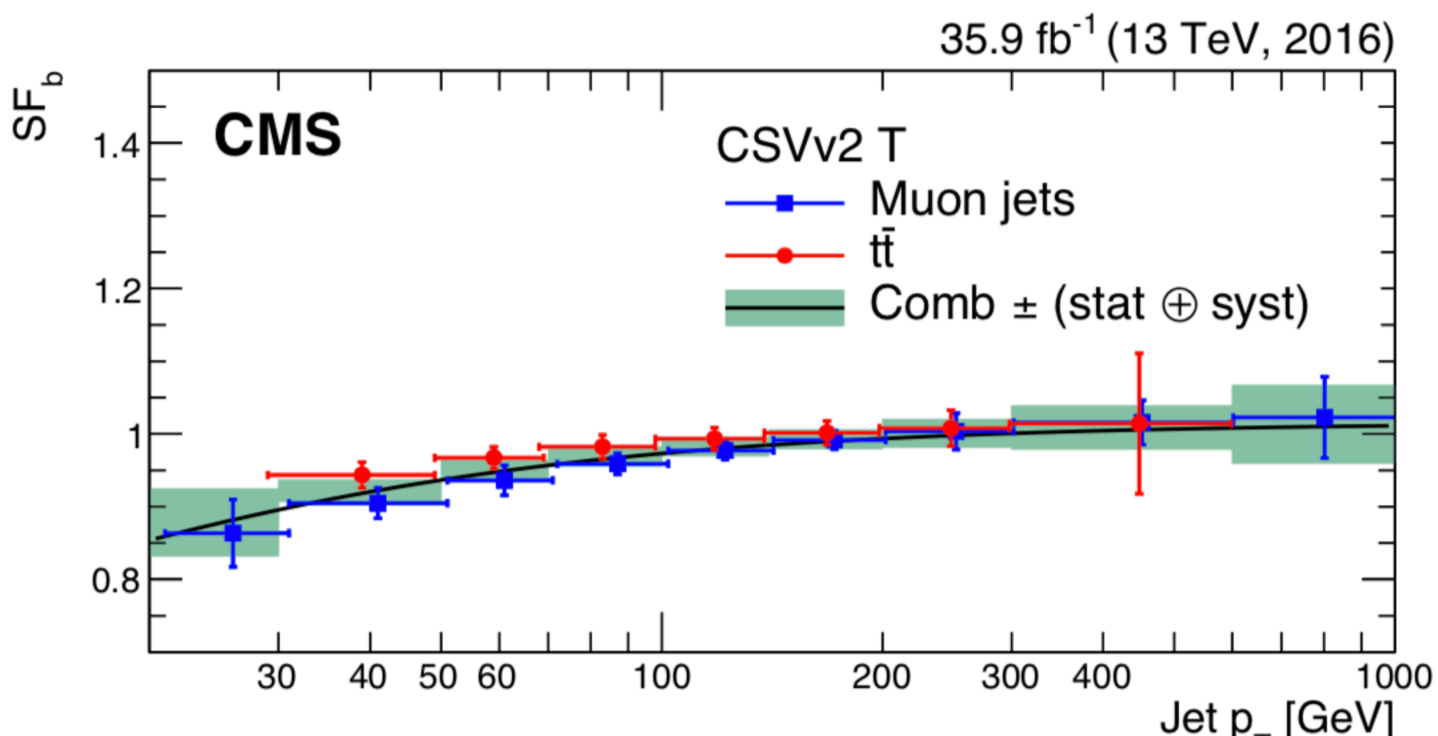




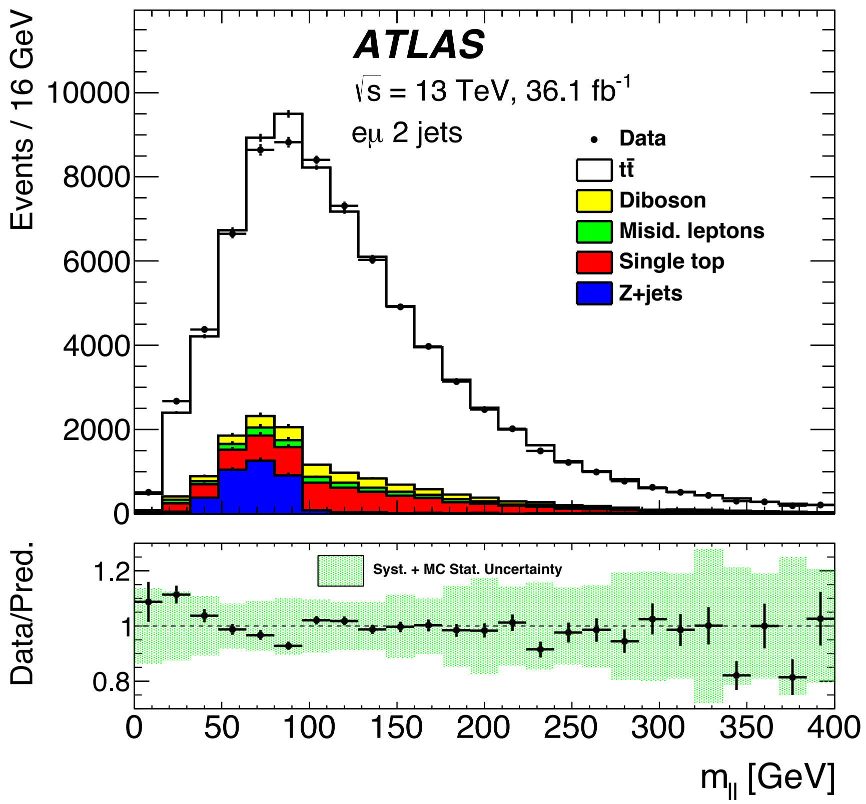
b-jets CMS: combo



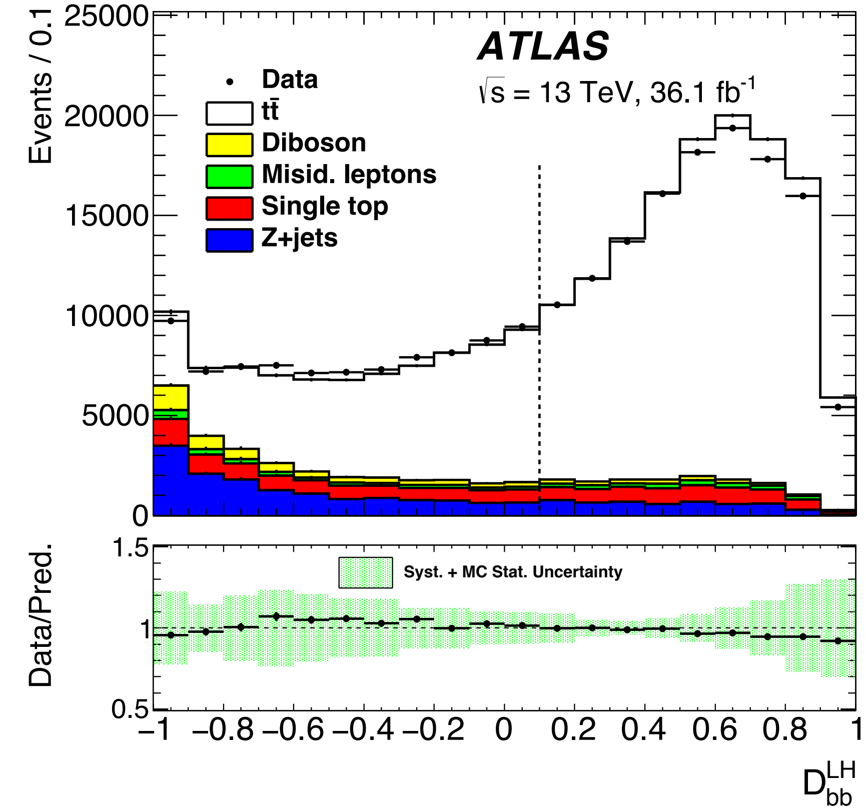




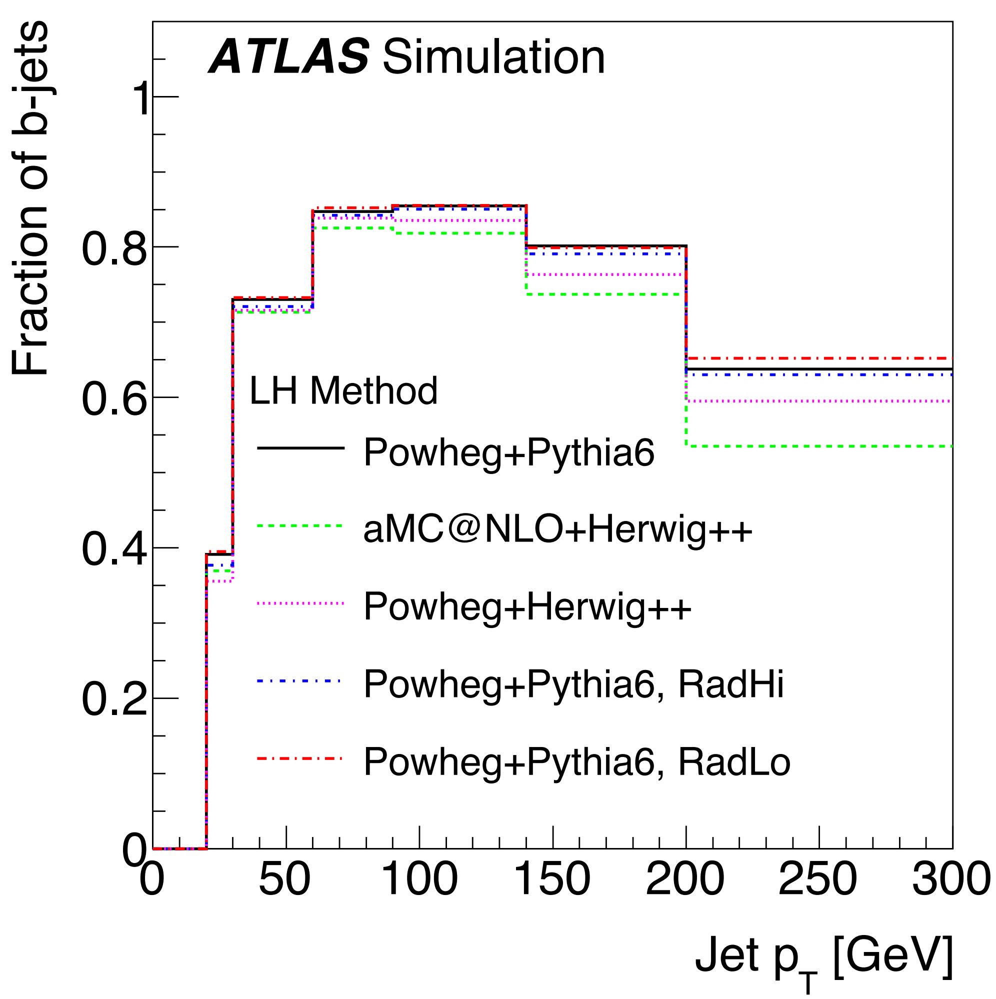
b-jets ATLAS



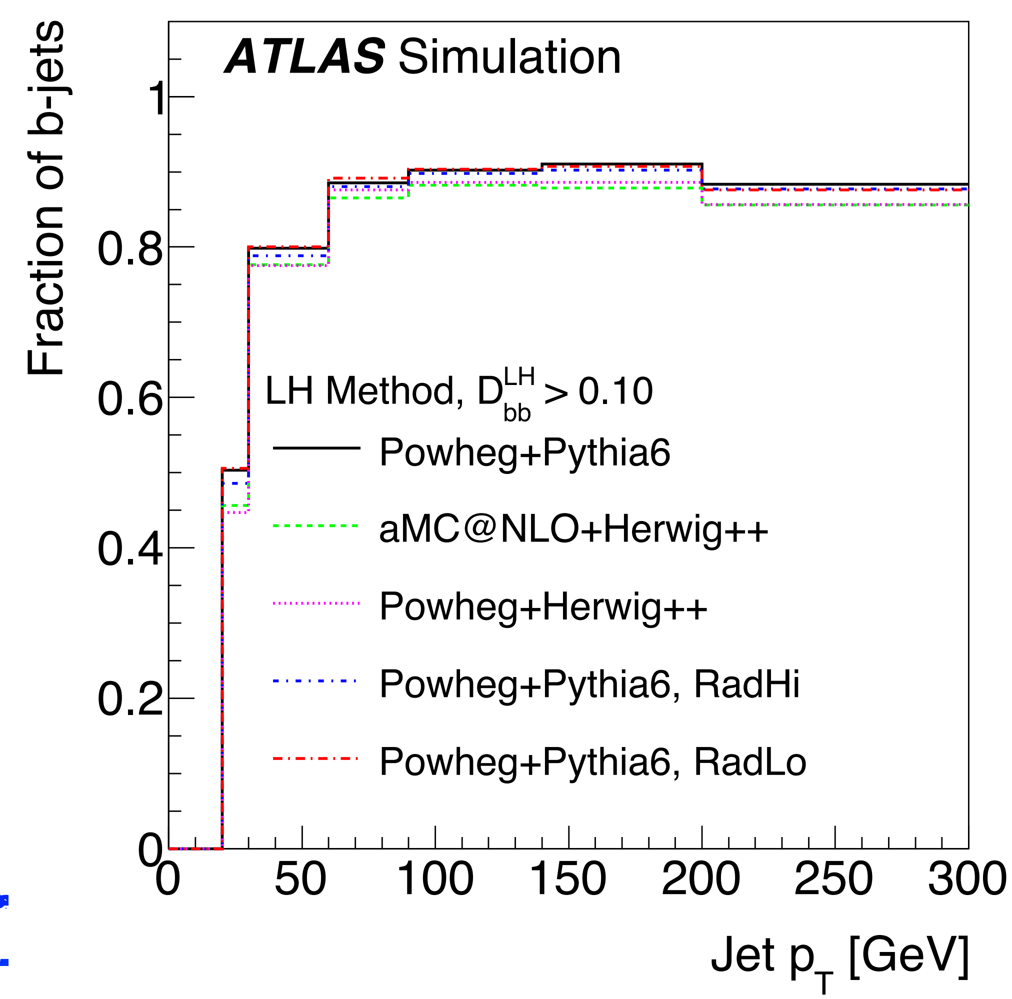
ATLAS
√s = 13 TeV, 36.1 fb-1
eμ 2 jets
Data
tt̄
Diboson
Misid. leptons
Single top
Z+jets
Events / 16 GeV
Syst. + MC Stat. Uncertainty
Data/Pred.
m_ll [GeV]



ATLAS
√s = 13 TeV, 36.1 fb-1
Data
tt̄
Diboson
Misid. leptons
Single top
Z+jets
Events / 0.1
Syst. + MC Stat. Uncertainty
Data/Pred.
D_bb^LH



ATLAS Simulation
Fraction of b-jets
LH Method
Powheg+Pythia6
aMC@NLO+Herwig++
Powheg+Herwig++
Powheg+Pythia6, RadHi
Powheg+Pythia6, RadLo
Jet p_T [GeV]



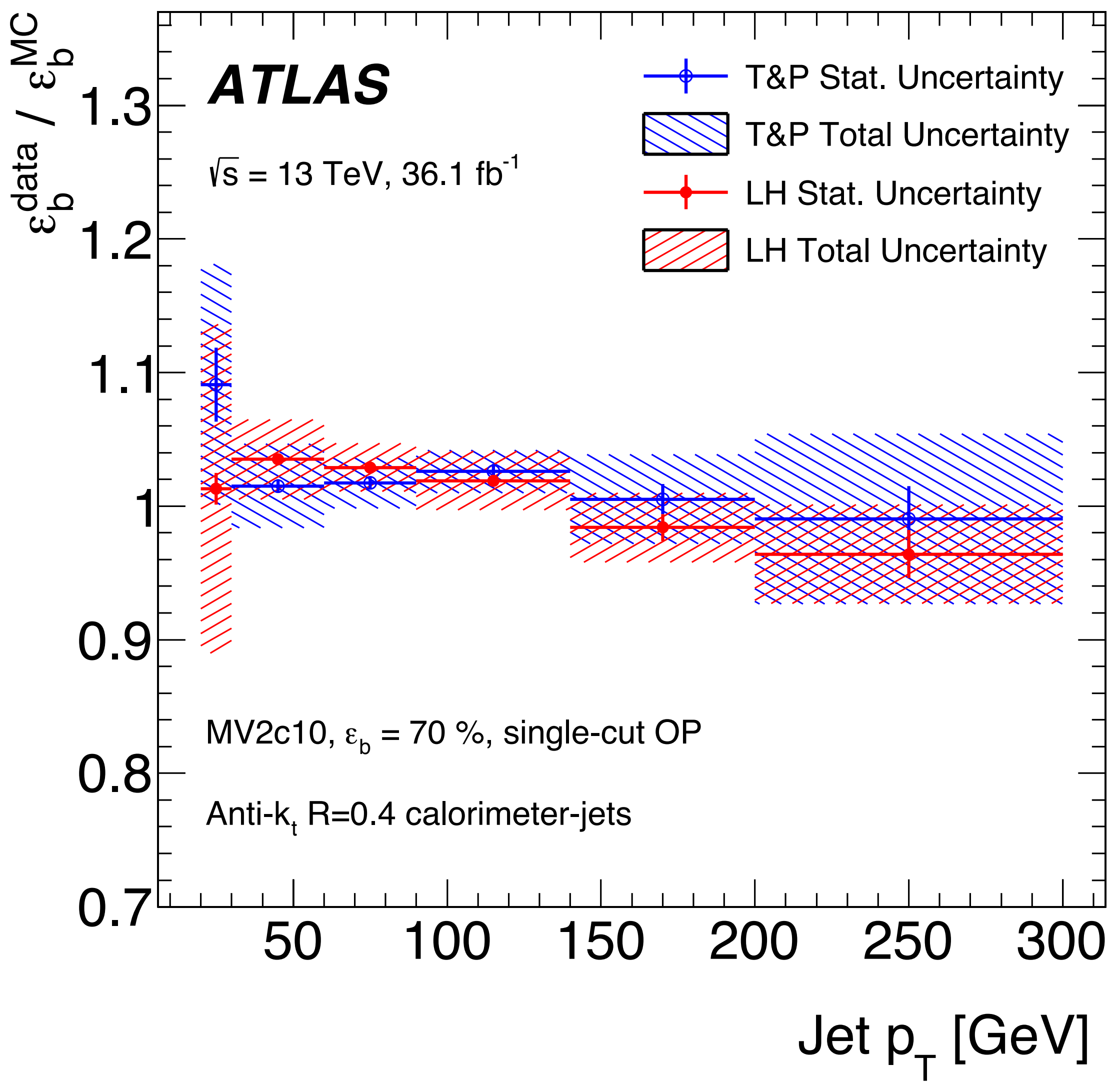
ATLAS Simulation
Fraction of b-jets
LH Method, D_bb^LH > 0.10
Powheg+Pythia6
aMC@NLO+Herwig++
Powheg+Herwig++
Powheg+Pythia6, RadHi
Powheg+Pythia6, RadLo
Jet p_T [GeV]

b-jets ATLAS

$$
\begin{aligned}
\mathcal{L}_{\text{event}}\left(p_{\mathrm{T},1}, p_{\mathrm{T},2}, w_1, w_2\right) = \ & \Big[\ f_{bb}\mathcal{P}_{bb}\left(p_{\mathrm{T},1}, p_{\mathrm{T},2}\right)\mathcal{P}_b\left(w_1|p_{\mathrm{T},1}\right)\mathcal{P}_b\left(w_2|p_{\mathrm{T},2}\right) \\
& + f_{bj}\mathcal{P}_{bj}\left(p_{\mathrm{T},1}, p_{\mathrm{T},2}\right)\mathcal{P}_b\left(w_1|p_{\mathrm{T},1}\right)\mathcal{P}_j\left(w_2|p_{\mathrm{T},2}\right) \\
& + f_{jj}\mathcal{P}_{jj}\left(p_{\mathrm{T},1}, p_{\mathrm{T},2}\right)\mathcal{P}_j\left(w_1|p_{\mathrm{T},1}\right)\mathcal{P}_j\left(w_2|p_{\mathrm{T},2}\right) \\
& + 1 \leftrightarrow 2 \ \Big]/2\,,
\end{aligned}
$$

LH Method

p_{T} interval [GeV]	20-30	30-60	60-90	90-140	140-200	200-300
$\varepsilon_b^{\text{data}}$	0.577	0.716	0.761	0.767	0.739	0.711
Total uncertainty	0.070	0.021	0.013	0.016	0.020	0.027
Statistical uncertainty	0.007	0.002	0.003	0.004	0.008	0.013
Systematic uncertainty	0.070	0.021	0.013	0.016	0.018	0.024

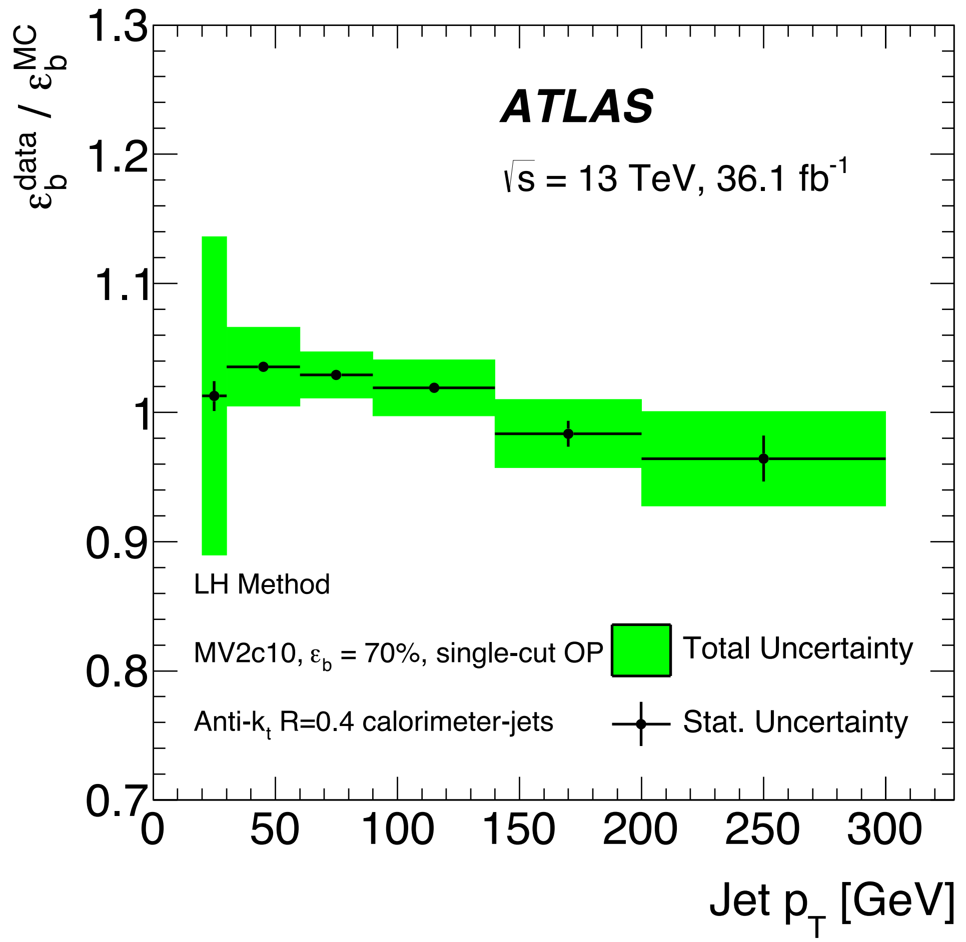


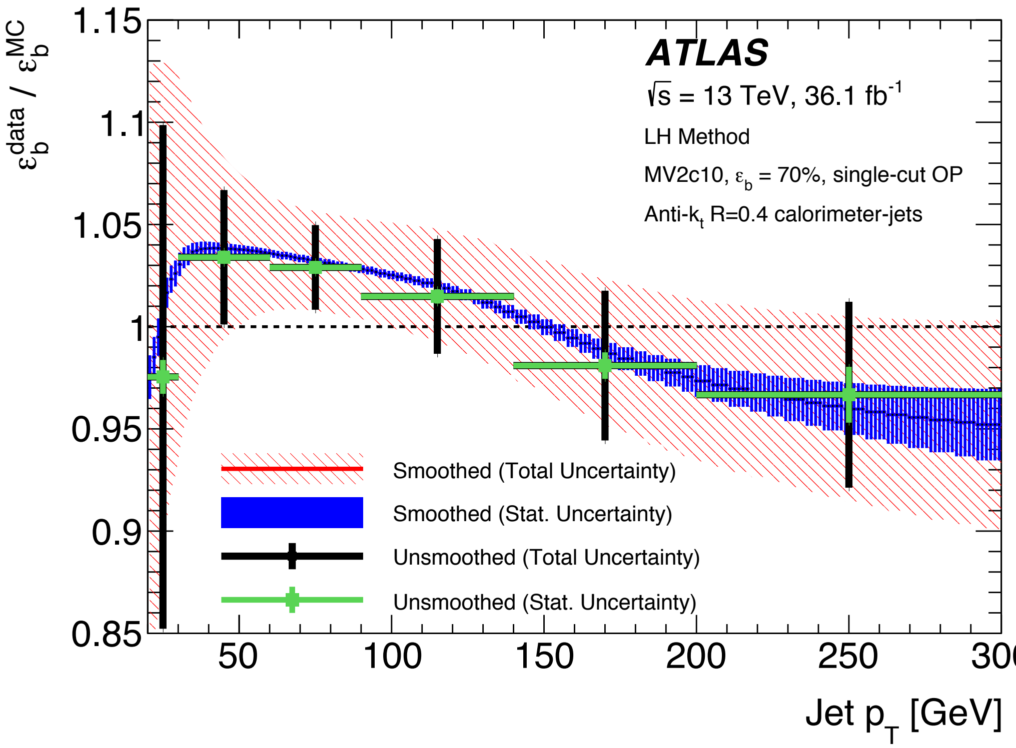
$$\varepsilon_b = \frac{f_{\text{tagged}} - (1 - f_b)\varepsilon_j}{f_b}.$$

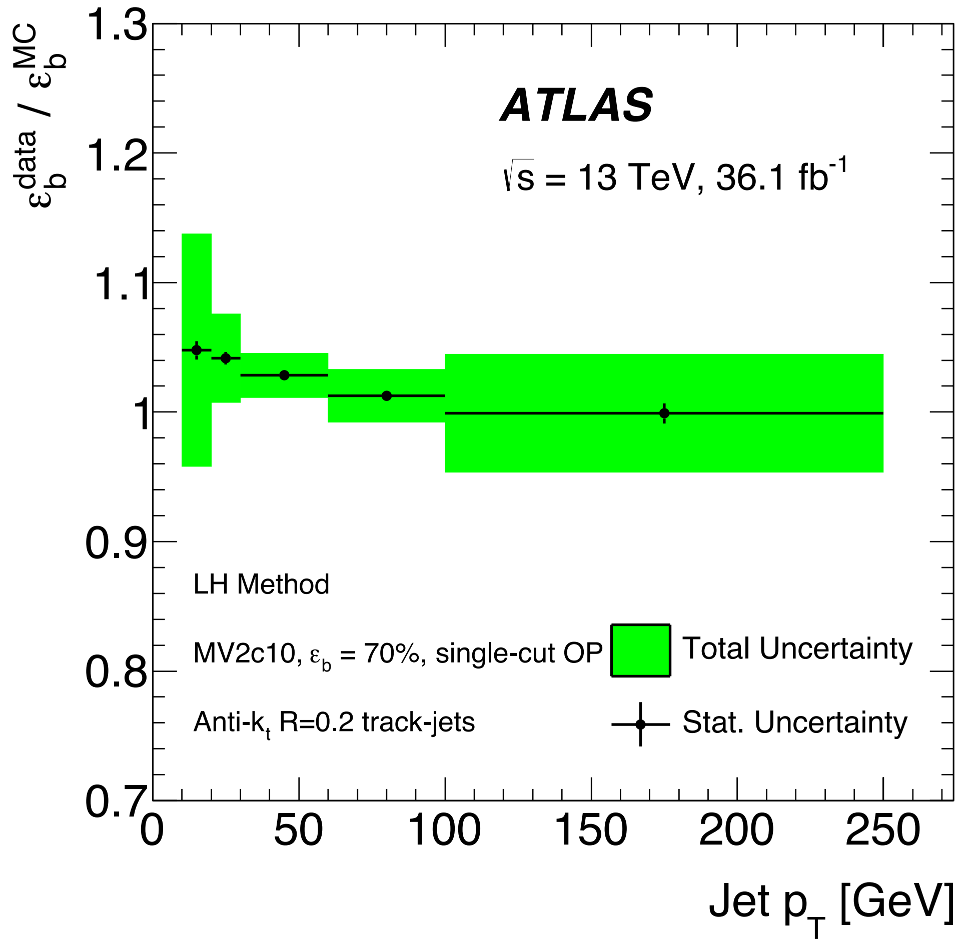
T&P Method

p_{T} interval [GeV]	20–30	30–60	60–90	90–140	140–200	200–300
Scale factor	1.091	1.015	1.017	1.026	1.005	0.990
Total uncertainty	0.091	0.032	0.019	0.016	0.034	0.064
Statistical uncertainty	0.028	0.005	0.005	0.006	0.011	0.025
Systematic uncertainty	0.086	0.031	0.019	0.015	0.032	0.059

b-jets ATLAS


ATLAS
√s = 13 TeV, 36.1 fb-1
LH Method
MV2c10, εb = 70%, single-cut OP
Anti-kt R=0.4 calorimeter-jets
Total Uncertainty
Stat. Uncertainty
εb data / εb MC
Jet pT [GeV]


ATLAS
√s = 13 TeV, 36.1 fb-1
LH Method
MV2c10, εb = 70%, single-cut OP
Anti-kt R=0.4 calorimeter-jets
Smoothed (Total Uncertainty)
Smoothed (Stat. Uncertainty)
Unsmoothed (Total Uncertainty)
Unsmoothed (Stat. Uncertainty)
εb data / εb MC
Jet pT [GeV]


ATLAS
√s = 13 TeV, 36.1 fb-1
LH Method
MV2c10, εb = 70%, single-cut OP
Anti-kt R=0.2 track-jets
Total Uncertainty
Stat. Uncertainty
εb data / εb MC
Jet pT [GeV]

CMS

$$\begin{aligned}
N_{\text{notag}} &= N_{\text{T}}((1-\varepsilon_1^{\text{c}})(1-\varepsilon_2^{\text{LF}})f_1 + (1-\varepsilon_1^{\text{LF}})(1-\varepsilon_2^{\text{c}})f_2 + (1-\varepsilon_1^{\text{LF}})(1-\varepsilon_2^{\text{LF}})(1-f_1-f_2)),\\
N_{\text{leadtag}} &= N_{\text{T}}(\varepsilon_1^{\text{c}}(1-\varepsilon_2^{\text{LF}})f_1 + \varepsilon_1^{\text{LF}}(1-\varepsilon_2^{\text{c}})f_2 + \varepsilon_1^{\text{LF}}(1-\varepsilon_2^{\text{LF}})(1-f_1-f_2)),\\
N_{\text{subtag}} &= N_{\text{T}}((1-\varepsilon_1^{\text{c}})\varepsilon_2^{\text{LF}}f_1 + (1-\varepsilon_1^{\text{LF}})\varepsilon_2^{\text{c}}f_2 + (1-\varepsilon_1^{\text{LF}})\varepsilon_2^{\text{LF}}(1-f_1-f_2)),\\
N_{\text{ditag}} &= N_{\text{T}}(\varepsilon_1^{\text{c}}\varepsilon_2^{\text{LF}}f_1 + \varepsilon_1^{\text{LF}}\varepsilon_2^{\text{c}}f_2 + \varepsilon_1^{\text{LF}}\varepsilon_2^{\text{LF}}(1-f_1-f_2)),
\end{aligned} \tag{8.4}$$

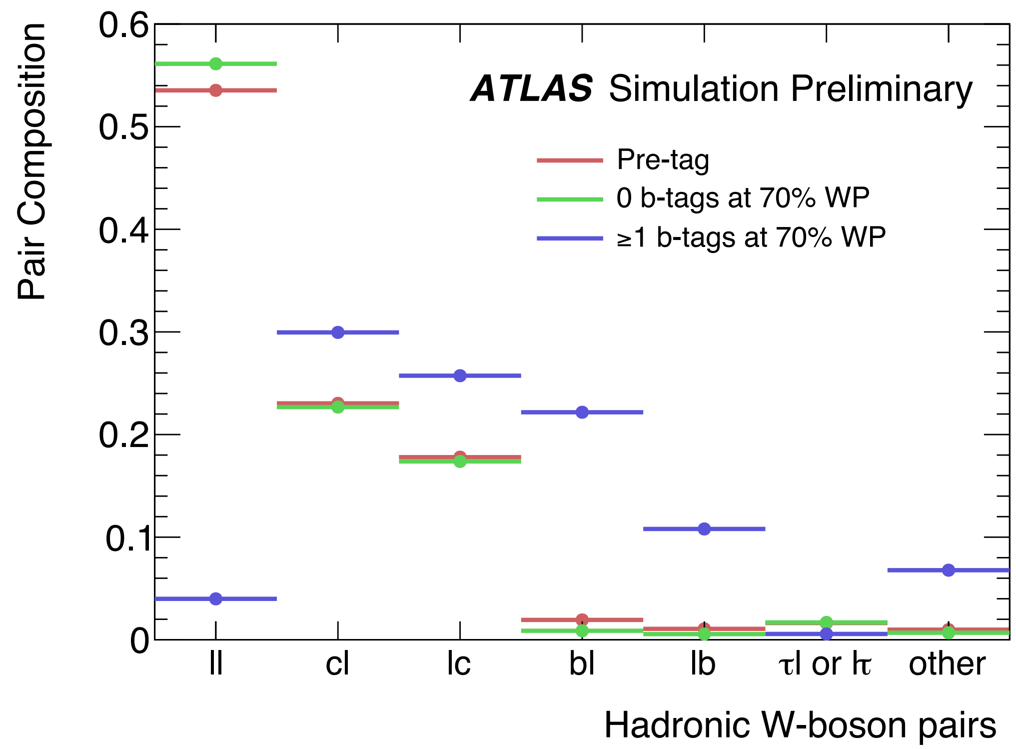
ATLAS

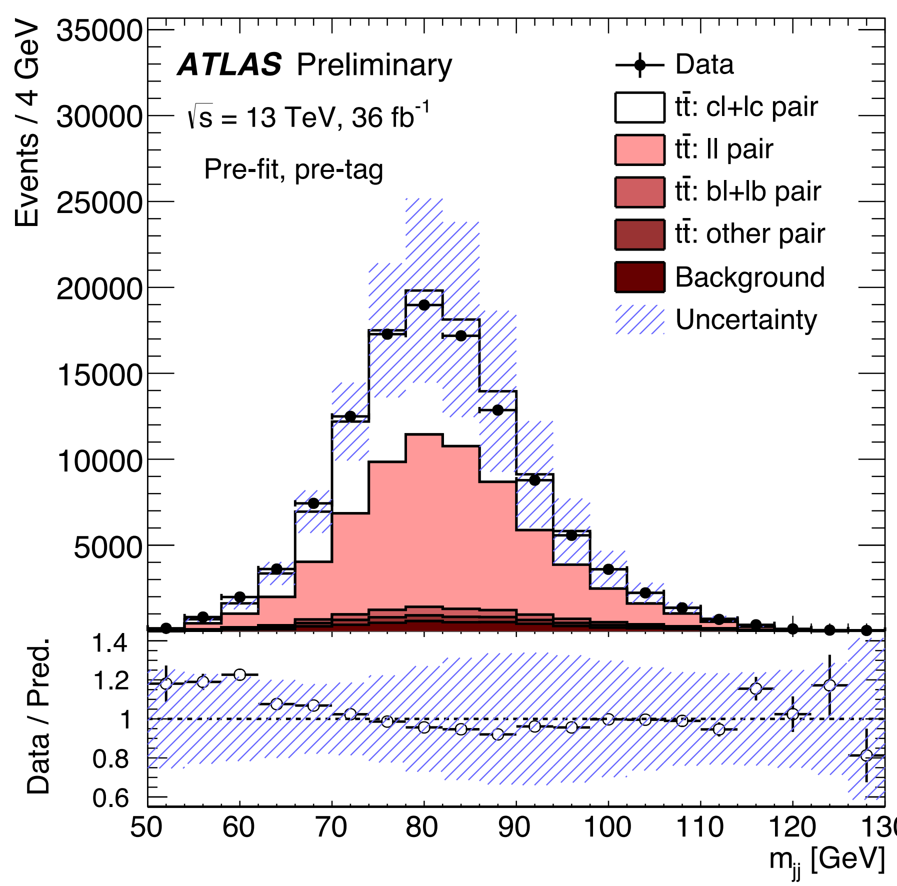
$$\begin{aligned}
N_{\text{exp}}^{0-\text{tag},i,j} = \mu^{i,j}\cdot N_{\text{exp}}^{\text{pretag},i,j}\cdot[(1-\epsilon_l^i)(1-\epsilon_l^j)\cdot f_{ll}^{i,j} + (1-\epsilon_c^i)(1-\epsilon_l^j)\cdot f_{cl}^{i,j} + (1-\epsilon_l^i)(1-\epsilon_c^j)\cdot f_{lc}^{i,j}\\
+(1-\epsilon_b^i)(1-\epsilon_l^j)\cdot f_{bl}^{i,j} + (1-\epsilon_l^i)(1-\epsilon_b^j)\cdot f_{lb}^{i,j}] + \mu^{i,j}N_{\text{other}}^{0-\text{tag},i,j} + N_{\text{bkg}}^{0-\text{tag},i,j}.
\end{aligned}$$

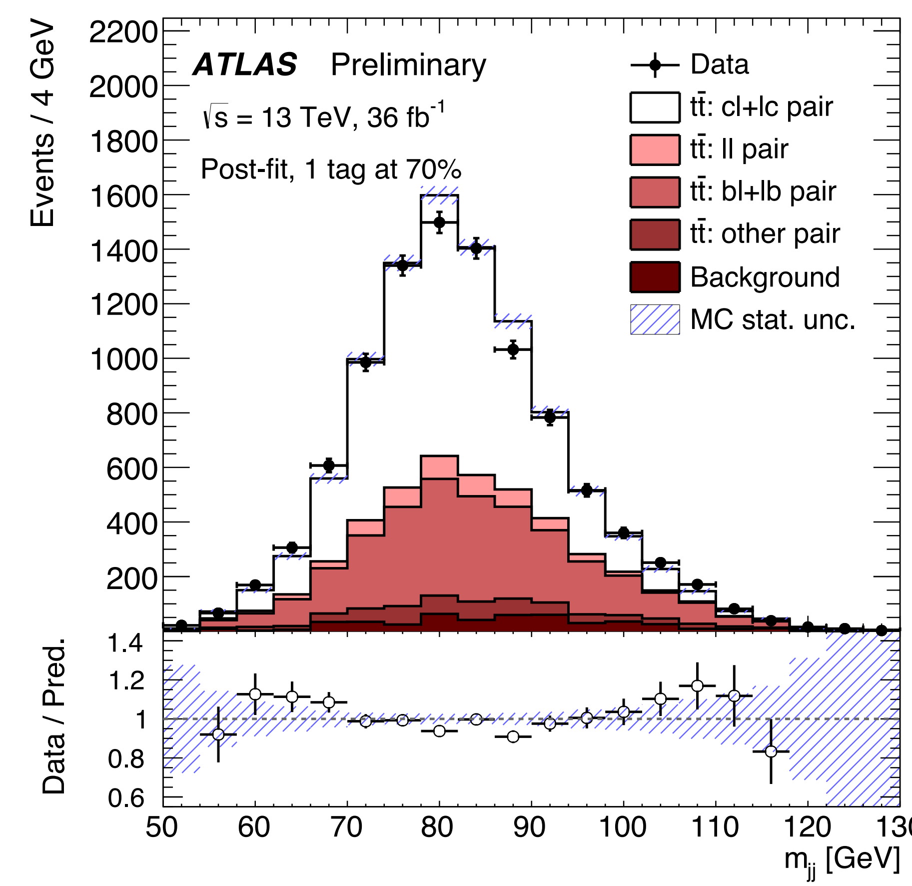
$$\begin{aligned}
N_{\text{data}}^{\text{leadT},i,j} = \mu^{i,j}\cdot N_{\text{exp}}^{\text{pretag},i,j}\cdot[(\epsilon_l^i(1-\epsilon_l^j)\cdot f_{ll}^{i,j} + \epsilon_c^i(1-\epsilon_l^j)\cdot f_{cl}^{i,j} + \epsilon_l^i(1-\epsilon_c^j)\cdot f_{lc}^{i,j}\\
+\epsilon_b^i(1-\epsilon_l^j)\cdot f_{bl}^{i,j} + \epsilon_l^i(1-\epsilon_b^j)\cdot f_{lb}^{i,j}] + \mu^{i,j}N_{\text{other}}^{\text{leadT},i,j} + N_{\text{bkg}}^{\text{leadT},i,j}
\end{aligned}$$

$$\begin{aligned}
N_{\text{data}}^{\text{subT},i,j} = \mu^{i,j}\cdot N_{\text{exp}}^{\text{pretag},i,j}\cdot[(\epsilon_l^j(1-\epsilon_l^i)\cdot f_{ll}^{i,j} + (1-\epsilon_c^i)\epsilon_l^j\cdot f_{cl}^{i,j} + (1-\epsilon_l^i)\epsilon_c^j\cdot f_{lc}^{i,j}\\
+(1-\epsilon_b^i)\epsilon_l^j\cdot f_{bl}^{i,j} + (1-\epsilon_l^i)\epsilon_b^j\cdot f_{lb}^{i,j}] + \mu^{i,j}N_{\text{other}}^{\text{subT},i,j} + N_{\text{bkg}}^{\text{subT},i,j}
\end{aligned}$$

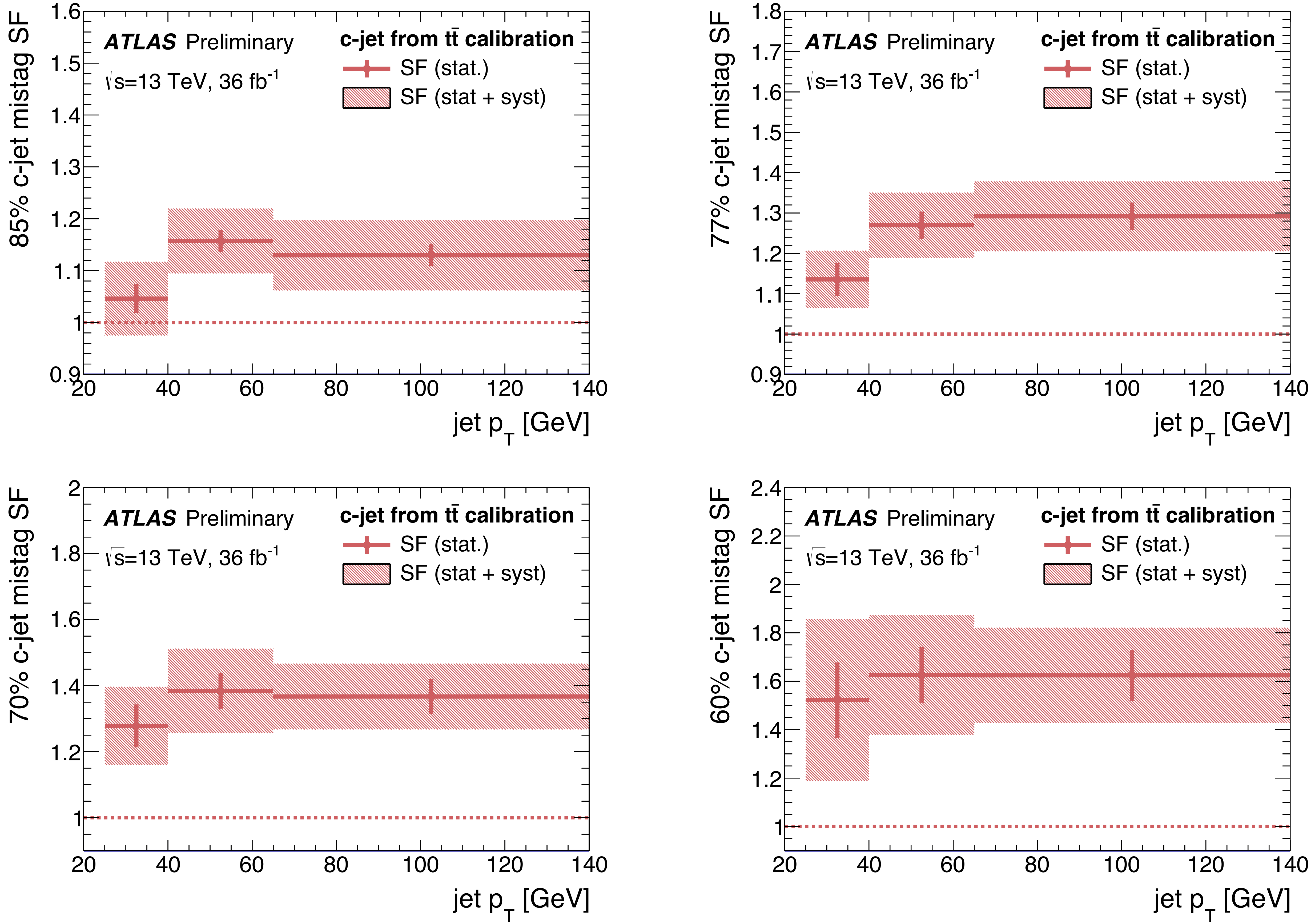
c-jet calib: ATLAS



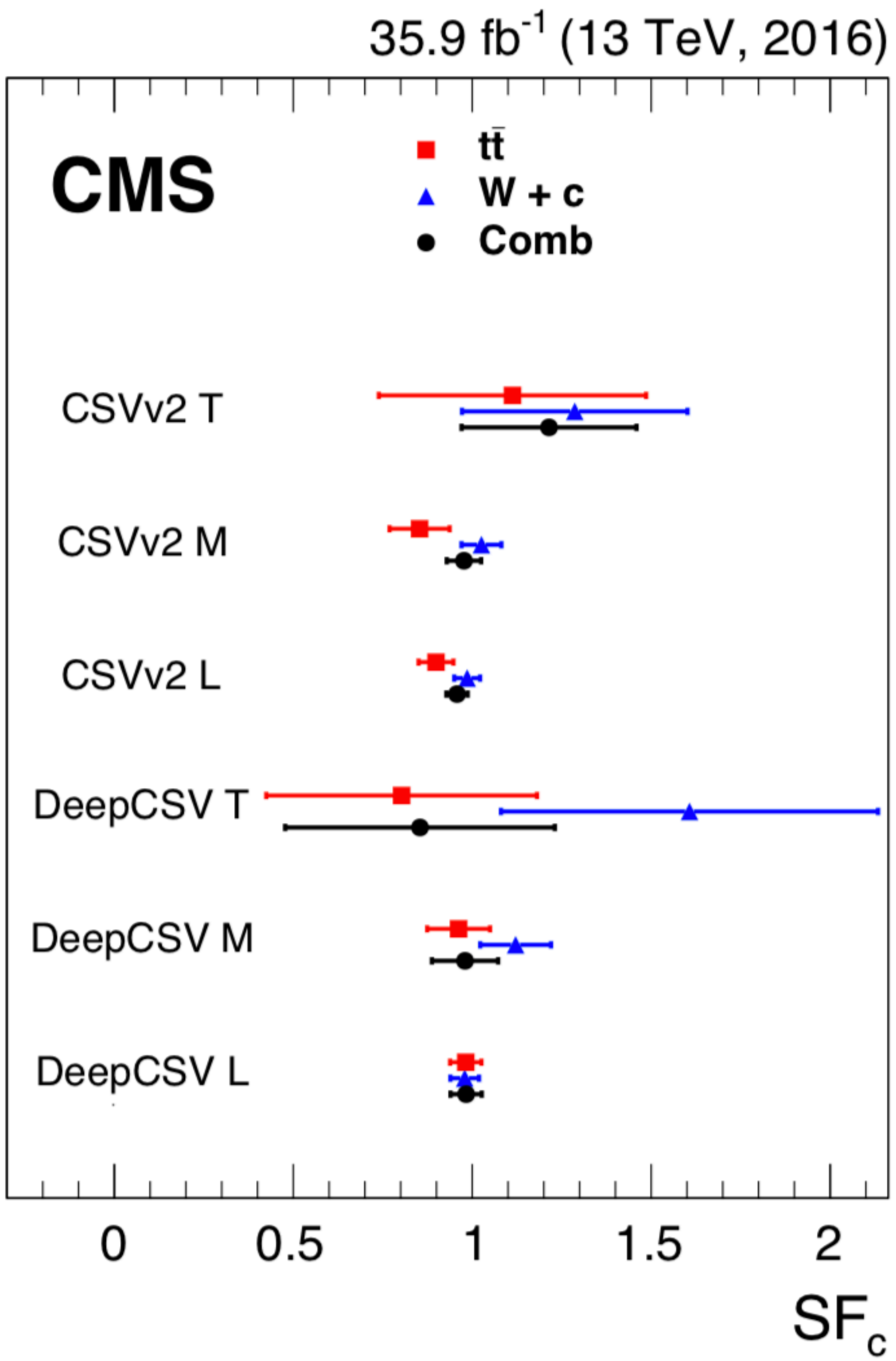


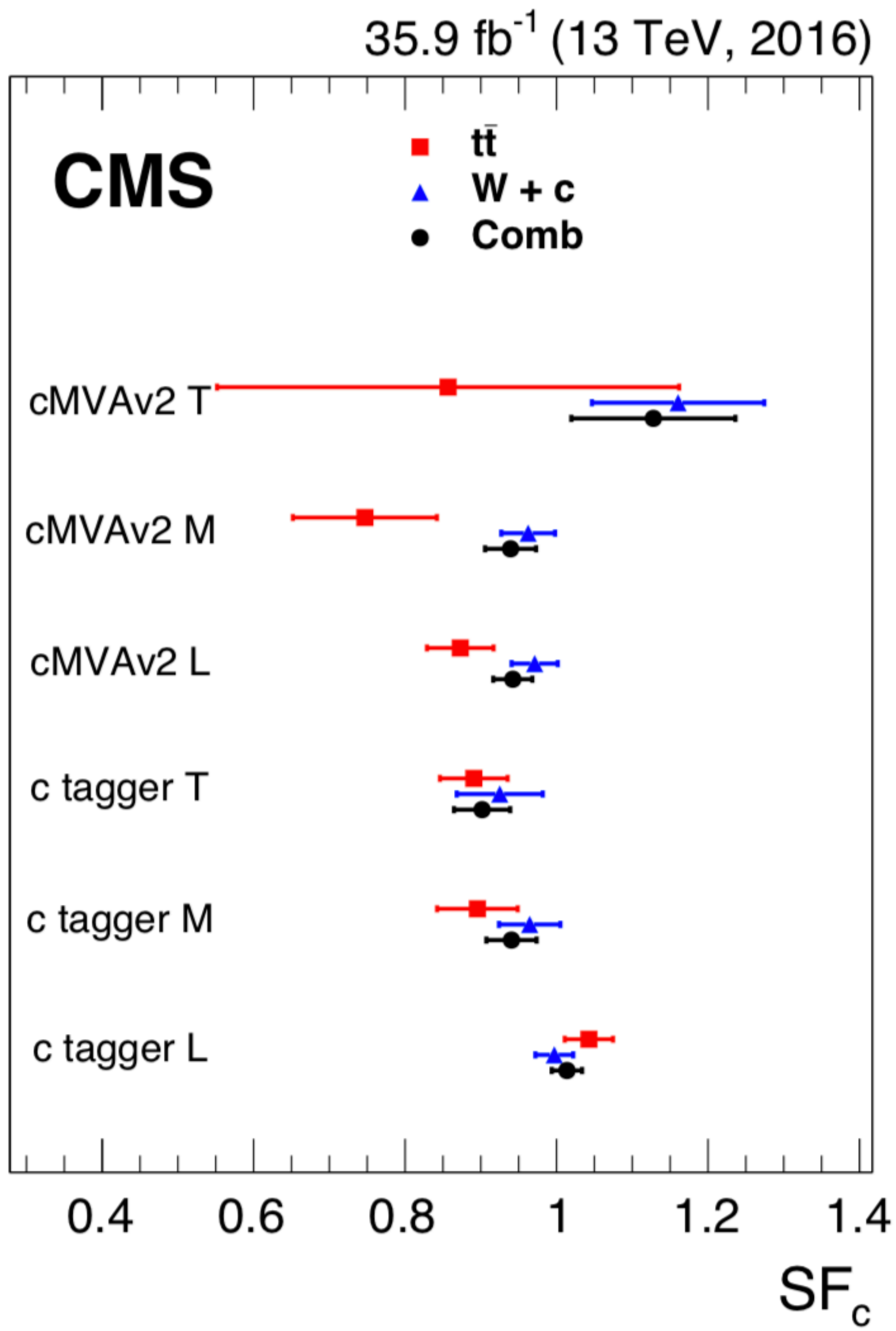


c-jet calib: ATLAS (2)

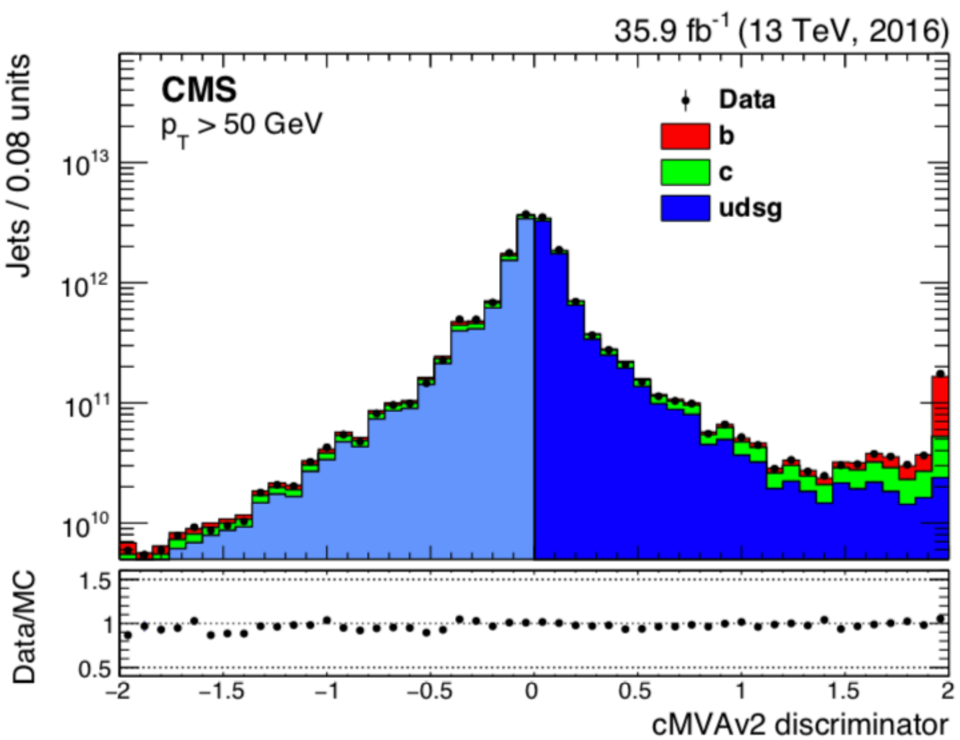


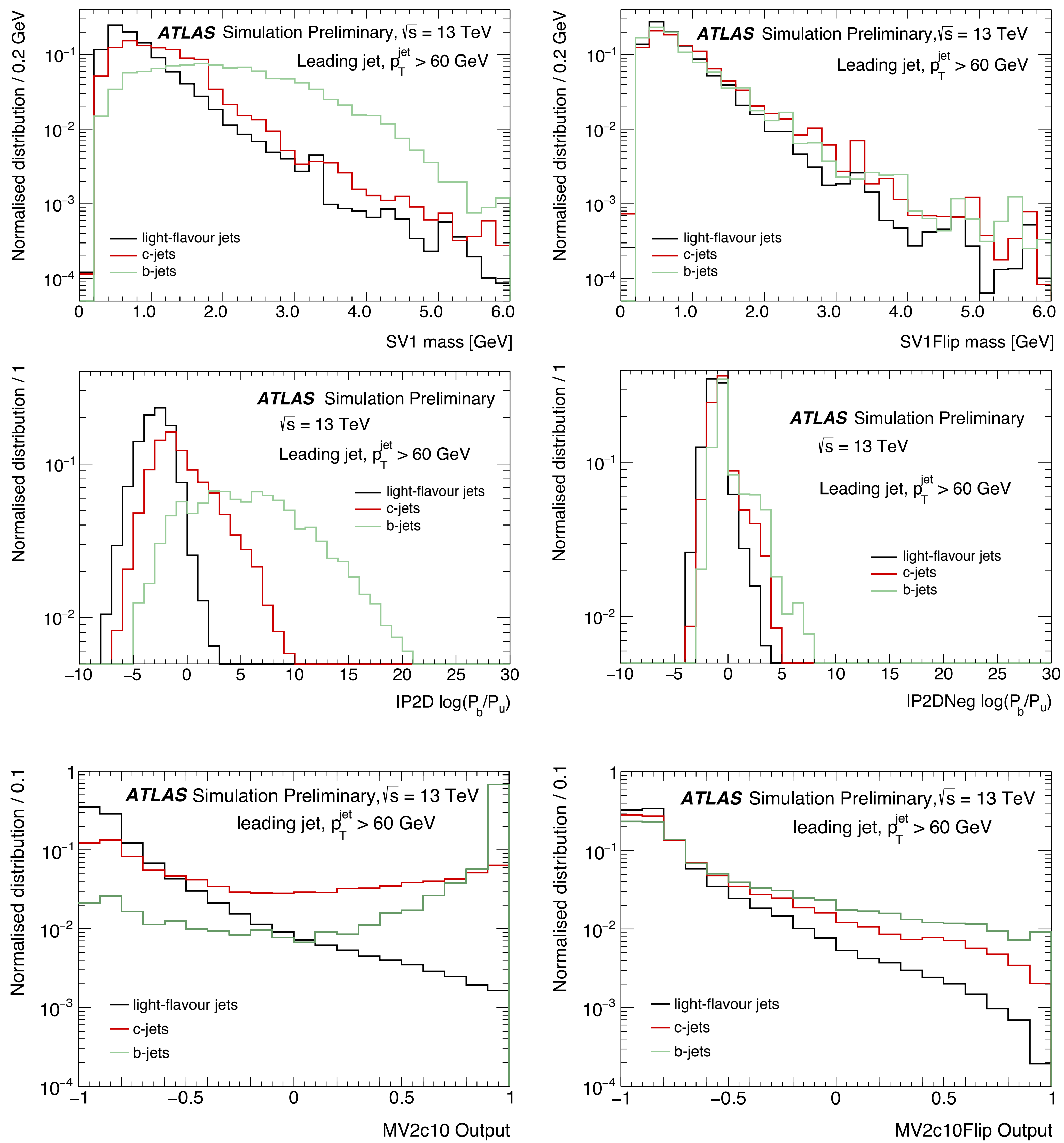
c-jet calib: CMS

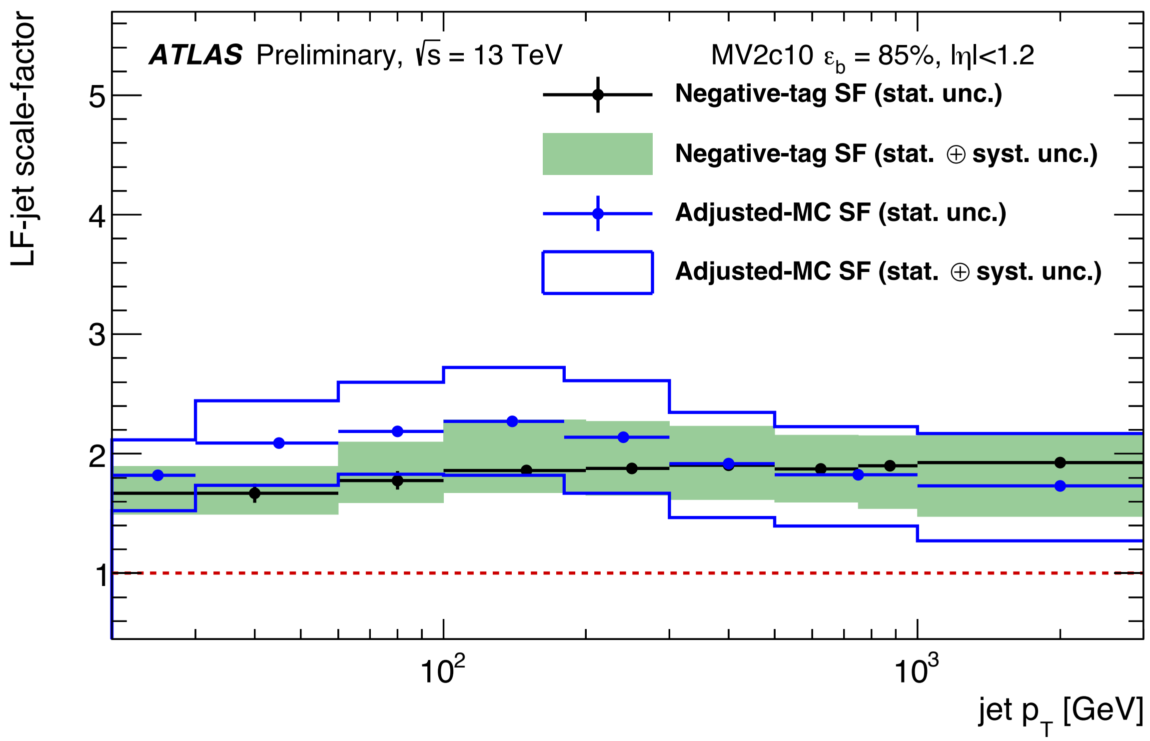


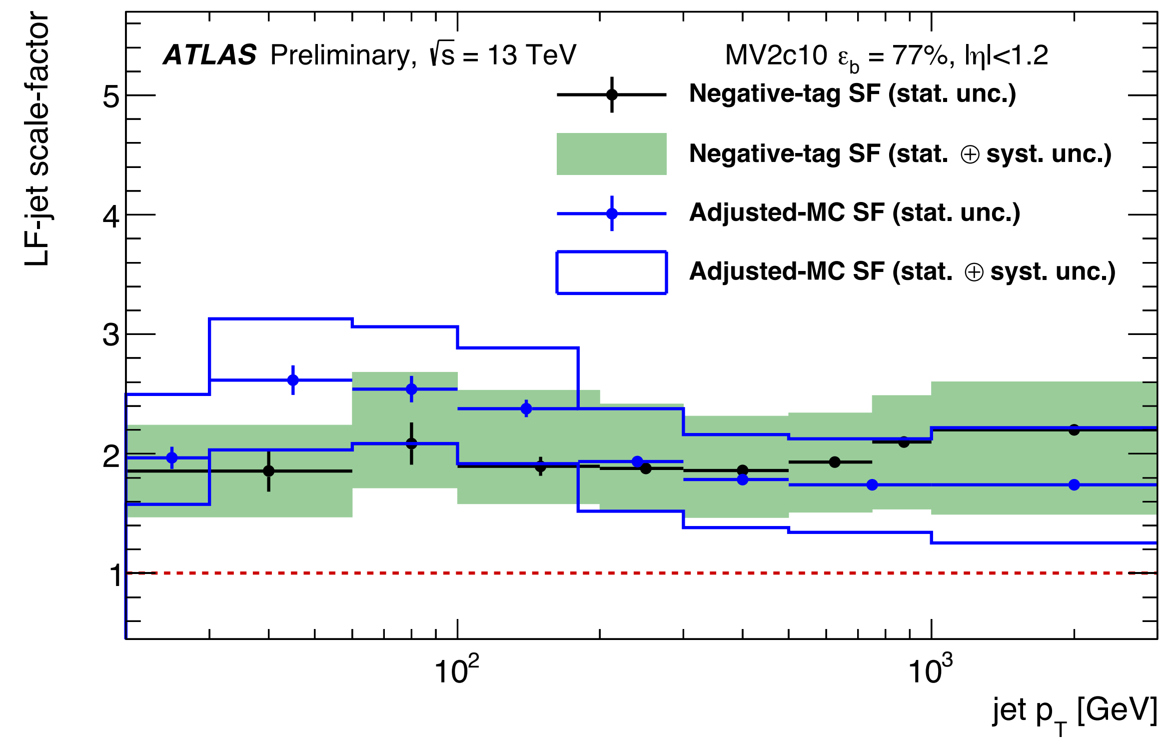


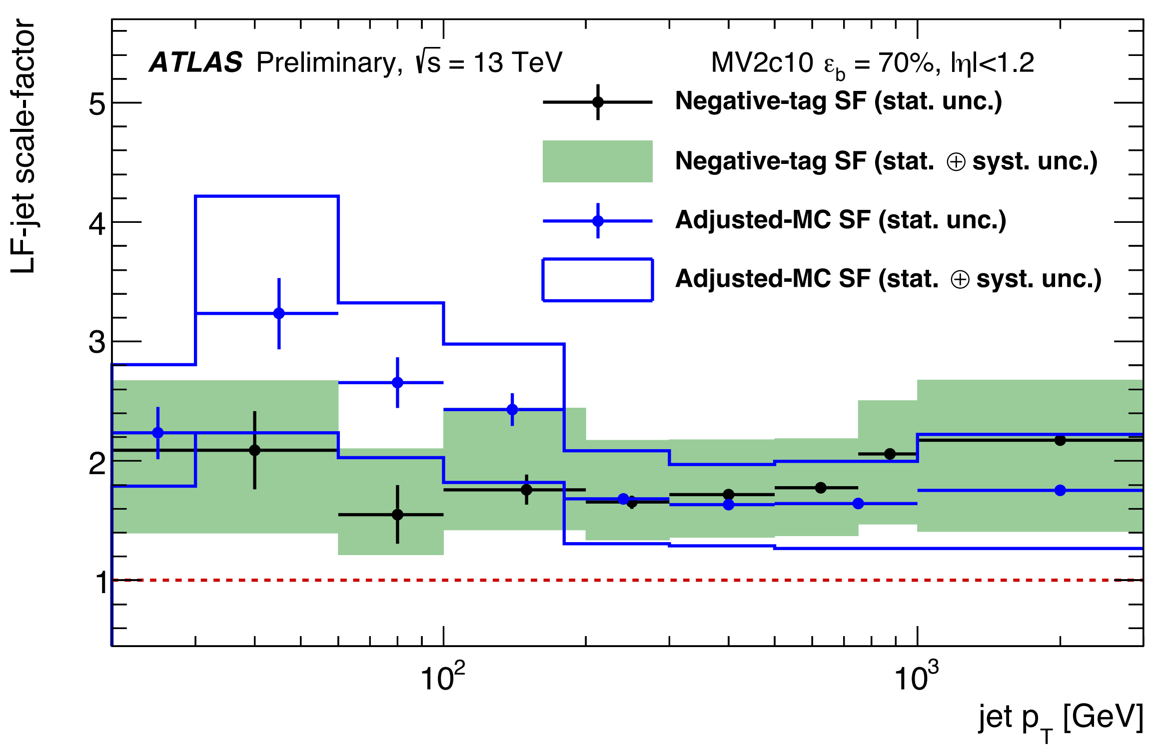
light jets: neg tag method

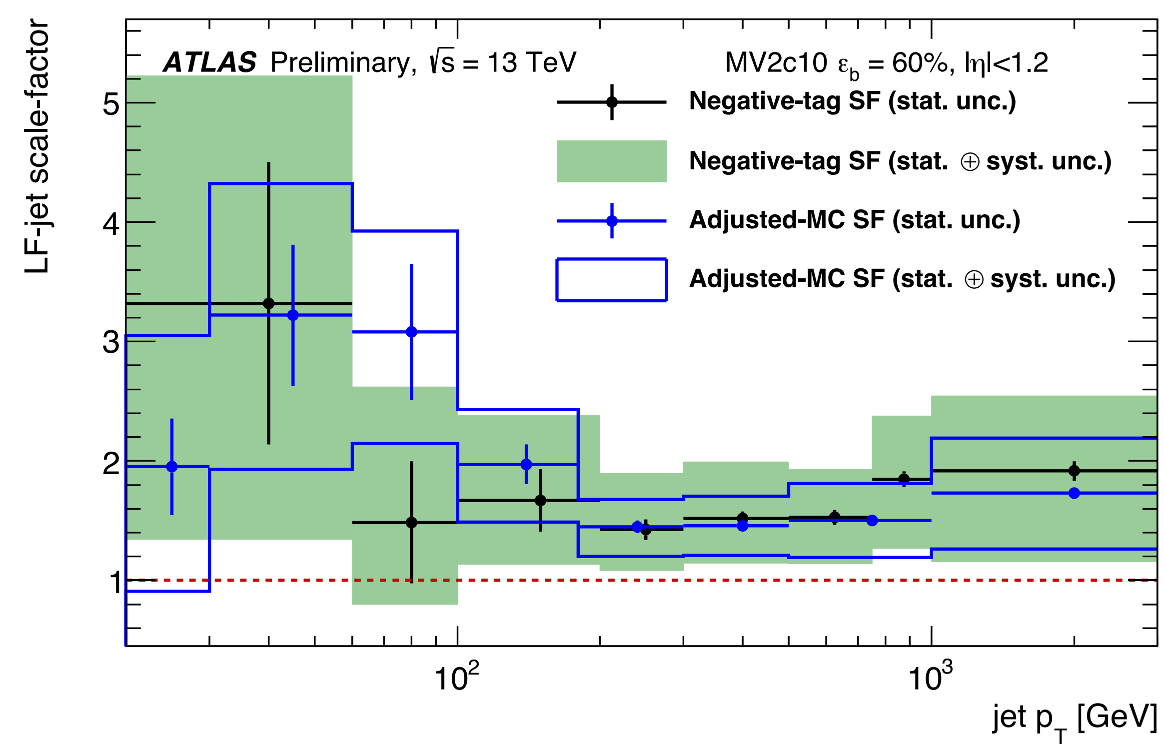




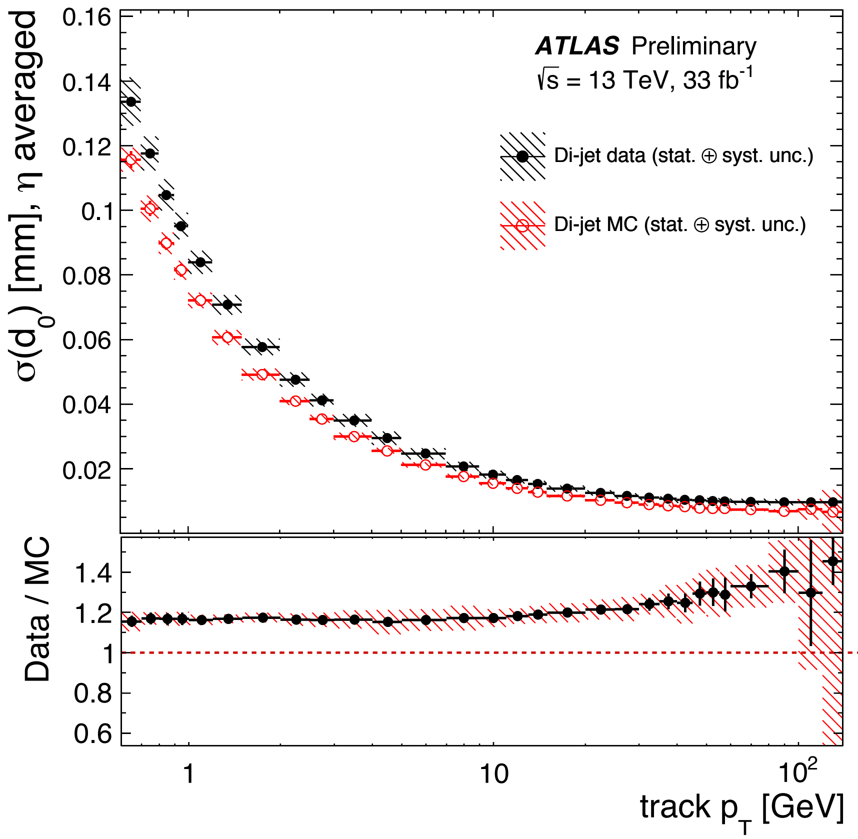

ATLAS Preliminary, √s = 13 TeV
MV2c10 ε_b = 85%, |η|<1.2
Negative-tag SF (stat. unc.)
Negative-tag SF (stat. ⊕ syst. unc.)
Adjusted-MC SF (stat. unc.)
Adjusted-MC SF (stat. ⊕ syst. unc.)
LF-jet scale-factor
jet p_T [GeV]

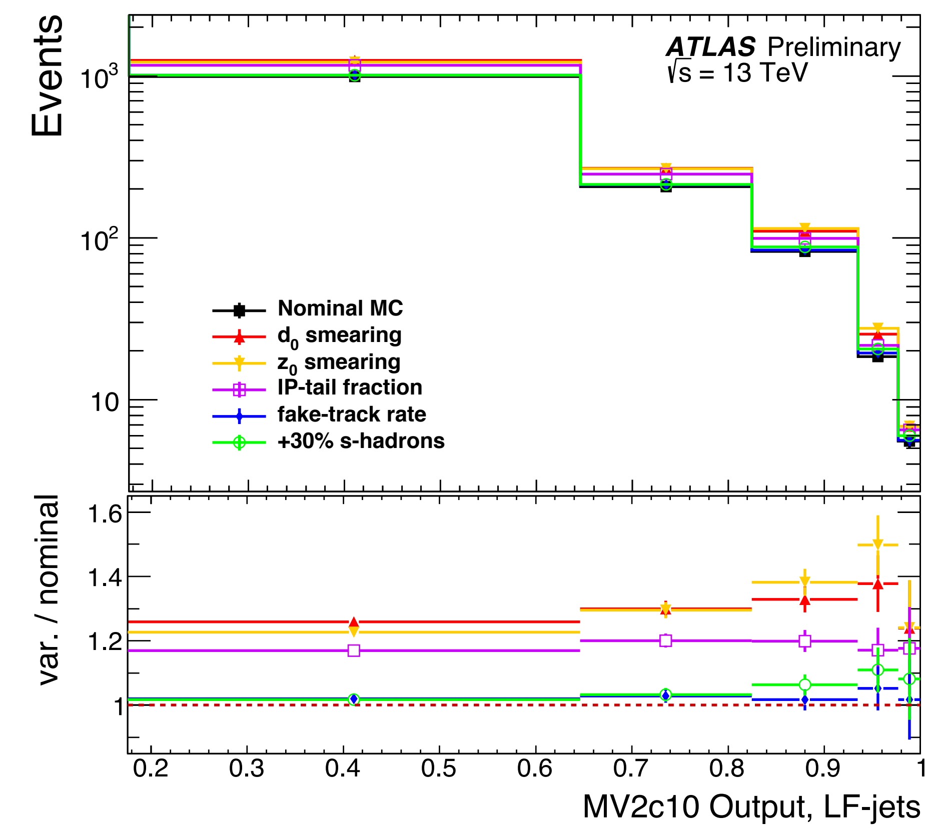

ATLAS Preliminary, √s = 13 TeV
MV2c10 ε_b = 77%, |η|<1.2
Negative-tag SF (stat. unc.)
Negative-tag SF (stat. ⊕ syst. unc.)
Adjusted-MC SF (stat. unc.)
Adjusted-MC SF (stat. ⊕ syst. unc.)
LF-jet scale-factor
jet p_T [GeV]

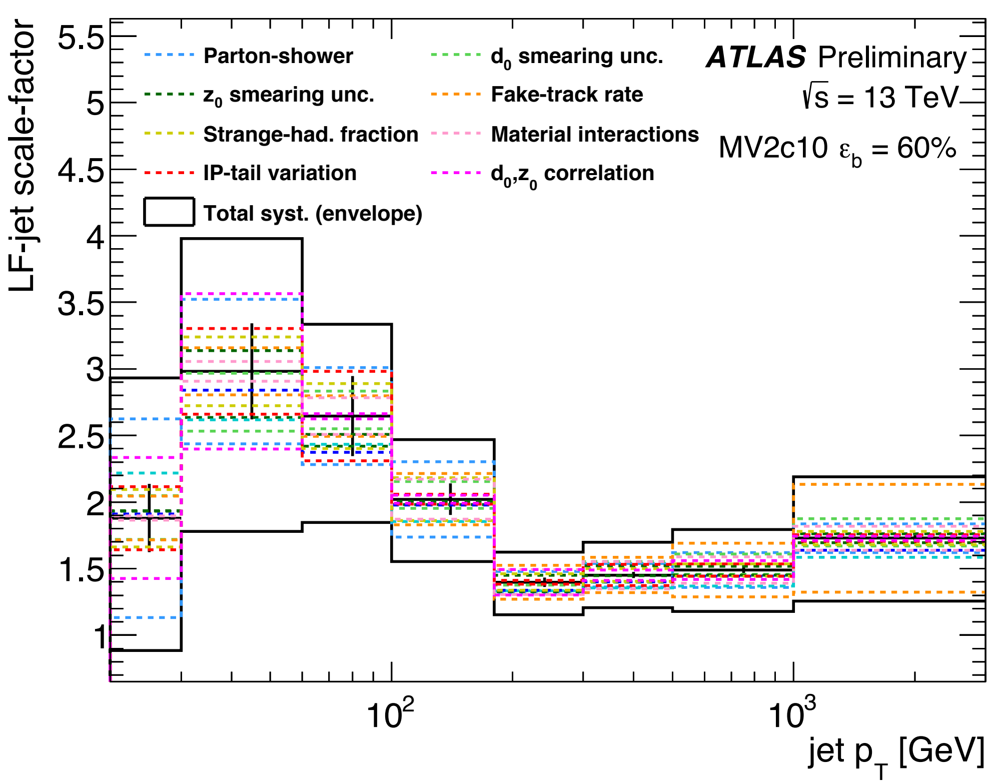

ATLAS Preliminary, √s = 13 TeV
MV2c10 ε_b = 70%, |η|<1.2
Negative-tag SF (stat. unc.)
Negative-tag SF (stat. ⊕ syst. unc.)
Adjusted-MC SF (stat. unc.)
Adjusted-MC SF (stat. ⊕ syst. unc.)
LF-jet scale-factor
jet p_T [GeV]

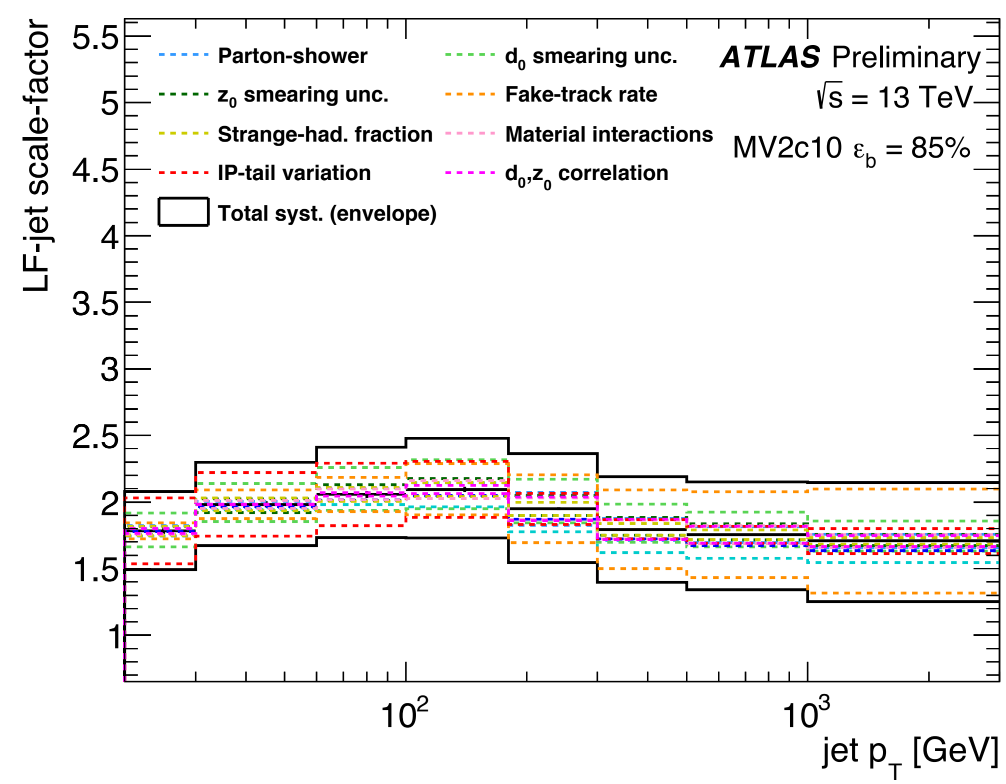

ATLAS Preliminary, √s = 13 TeV
MV2c10 ε_b = 60%, |η|<1.2
Negative-tag SF (stat. unc.)
Negative-tag SF (stat. ⊕ syst. unc.)
Adjusted-MC SF (stat. unc.)
Adjusted-MC SF (stat. ⊕ syst. unc.)
LF-jet scale-factor
jet p_T [GeV]

light SF: adjusted MC





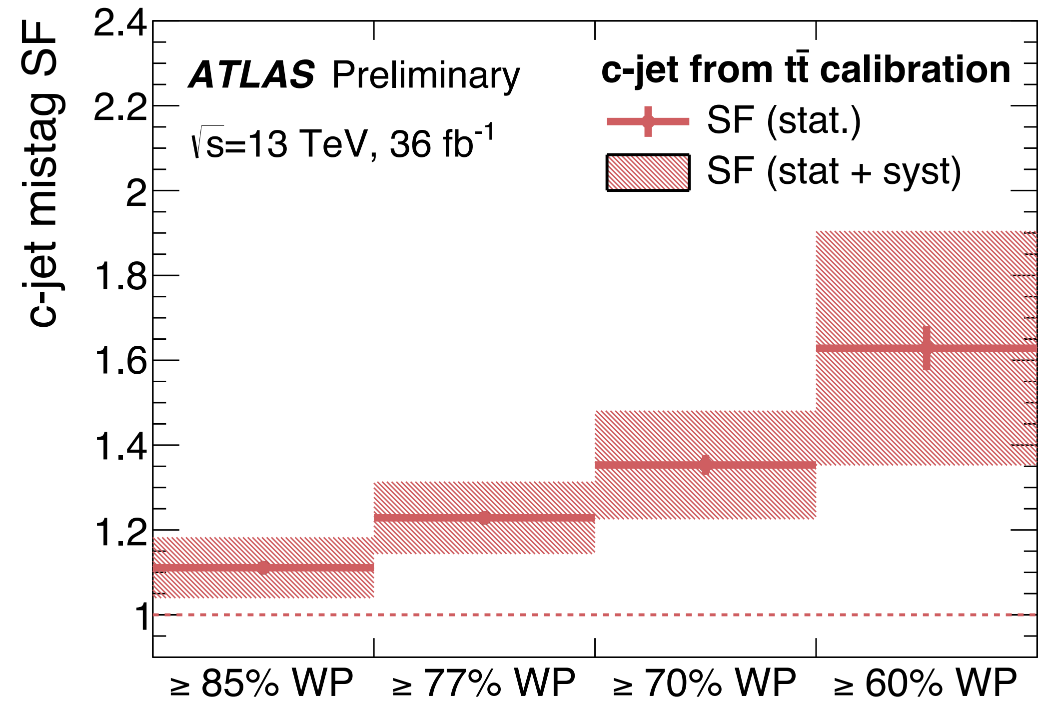




ATLAS: cumulative to pseudo continuous transition

- Extension considering N_{wp} finite WP:
  - effective SF computed with a dedicated calibration **or** by 'subtracting' cumulative calibration of 2 adjacent WP (correctly taking into account the correlation of the uncertainties)
  - more precise adjustment of the shape but ALWAYS within the bin

$$SF_{60-70} = \frac{SF_{70} \cdot \epsilon^{70}_{MC} - SF_{60} \cdot \epsilon^{60}_{MC}}{\epsilon^{70}_{MC} - \epsilon^{60}_{MC}}$$



ATLAS - CMS

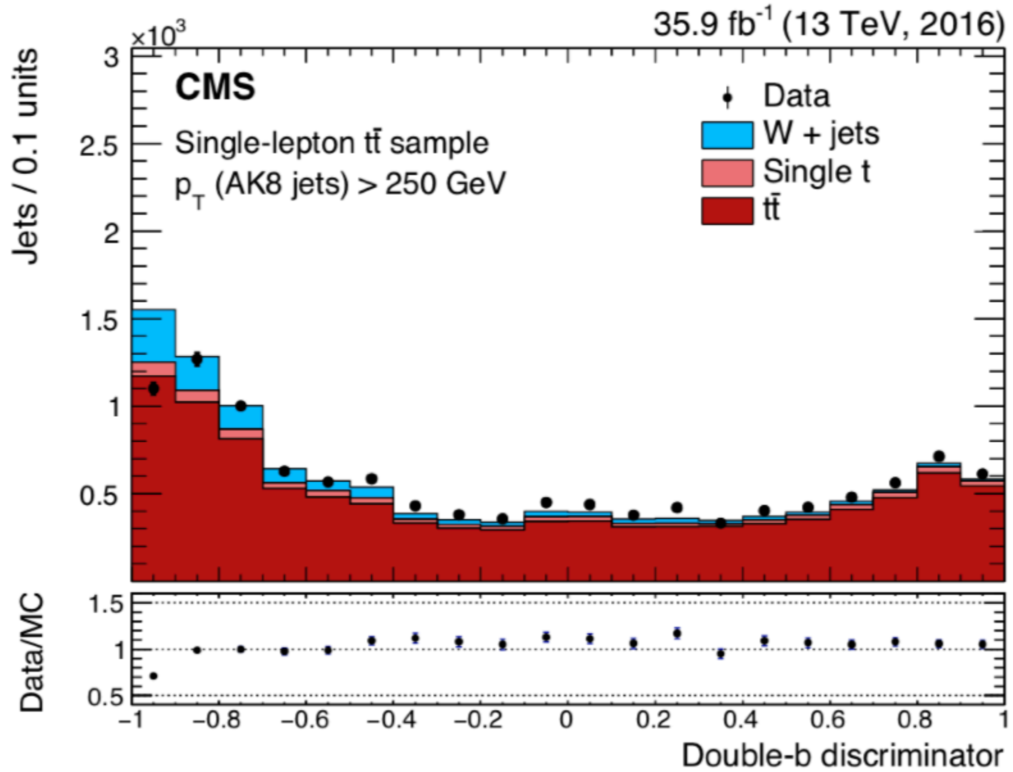
	CMS	ATLAS
tag weight usage	fully continuous	5 macro bins (100%,85%, 77%,70%,60%)
# p_T bins (b / c / l)	5 / 5 / 4*3	6 / 3 / 9*2
number of uncertainties NP	3 / 3 / 3	30 / 20 / 80
comments	2 shapes (stat.) + 1 contamination	full decomposition of covariance matrix
c-jet treatment	same SF as b with doubled unc.	independent calib

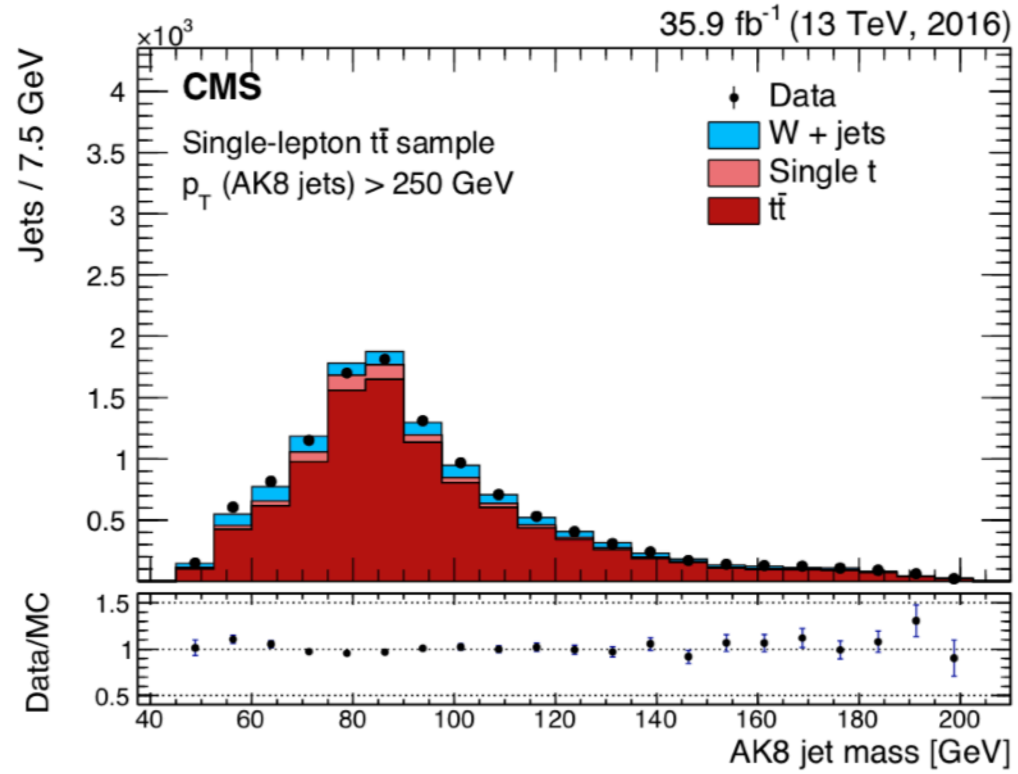
CMS ttHbb note:

b tag hf fraction	shape	Signal and all backgrounds
b tag hf stats (linear)	shape	Signal and all backgrounds
b tag hf stats (quadratic)	shape	Signal and all backgrounds
b tag lf fraction	shape	Signal and all backgrounds
b tag lf stats (linear)	shape	Signal and all backgrounds
b tag lf stats (quadratic)	shape	Signal and all backgrounds
b tag charm (linear)	shape	Signal and all backgrounds
b tag charm (quadratic)	shape	Signal and all backgrounds

CMS: double b-tagging ttbar fakerate

- 1 lepton+1b-tagged jet in one hemisphere , one large jet with substructure cut (tau2/tau1<0.6) in the other





- Leading uncertainty from data stat.

- Systematic dominated by background subtraction (+/-30%), ttbar modelling at % level