Imperial College London

Status update from RA1

(Multijet estimate, T2cc efficiencies, trigger plans for 2015)

M. Baber, R. Bainbridge, O. Buchmueller, D. Burton, Y. Eshaq, H. Flaecher, E. Laird, C. Lucas, J. Marrouche, B. Mathias, Z. Meng, S. Rogerson, P. Sphicas, D. Smith

(Bristol, Brown, CERN, Imperial, Rochester)

Multijet background estimation

Introductory comments

- Aim is a legacy result based on full 2012 dataset and parked data
  - This analysis is based largely on the published result with 11.7/fb
- Focus is on mass-degenerate models (ie, on or near the "diagonal")
  - Acceptance from ISR jets balancing MET from "invisible" sparticle production/decay
  - Expect signal to populate bins with largest bkgds (ie, low HT, low N_{jet}, low N_b)
- Hence, recent work concerns improved control of backgrounds (ie, reduce B and σ_B)
  - Developments concern both multijet and other "non-multijet" backgrounds
- Analysis strategy is to be "QCD free": achieved with the AlphaT variable
  - This talk outlines a new procedure to measure any potential multijet contribution

- Acronyms:
  - **MJ**: multijet background from QCD
  - **NMJ**: non-multijet backgrounds (eg, WJets, Znunu, TTbar, ...)

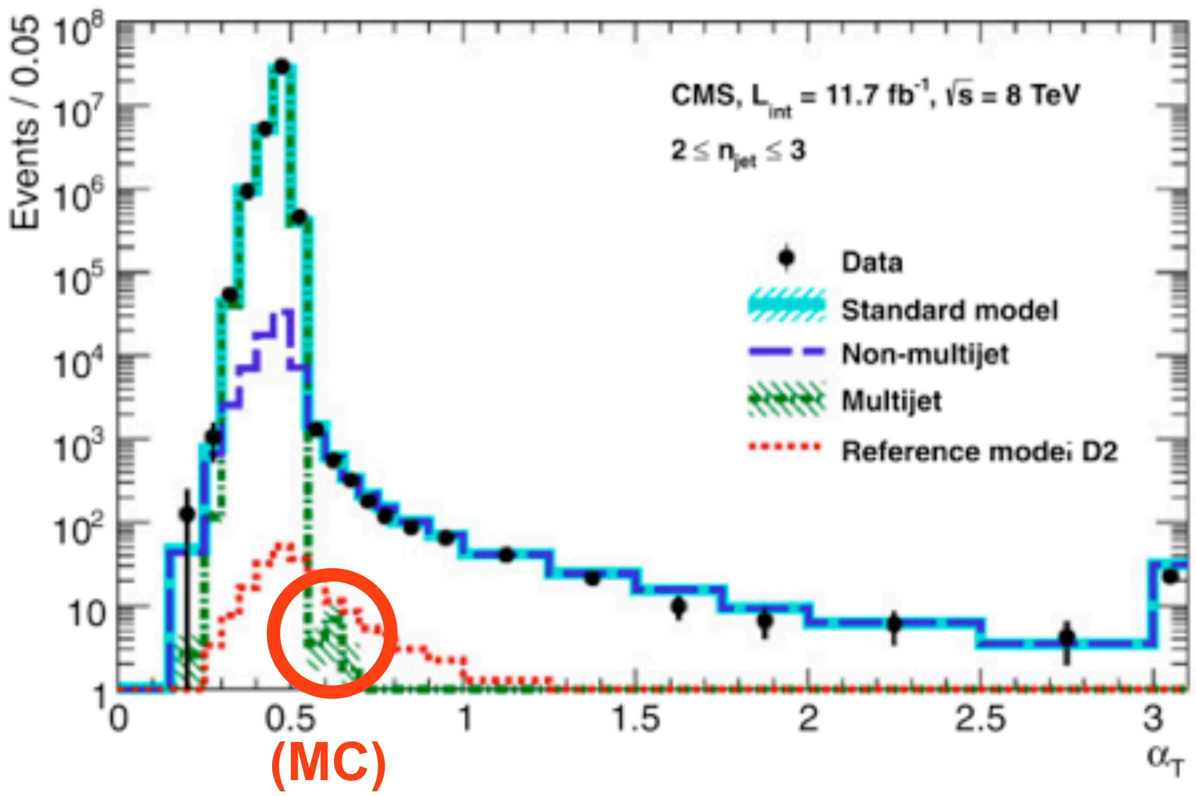
Suppressing multijet events with AlphaT

- Mis-measurement of jet E_T in dijet system is penalised to lower values of AlphaT
  - AlphaT = 0.5 for perfectly measured dijet event
  - AlphaT < 0.5 for mis-measured dijet events
  - AlphaT definition extended to handle multijet systems

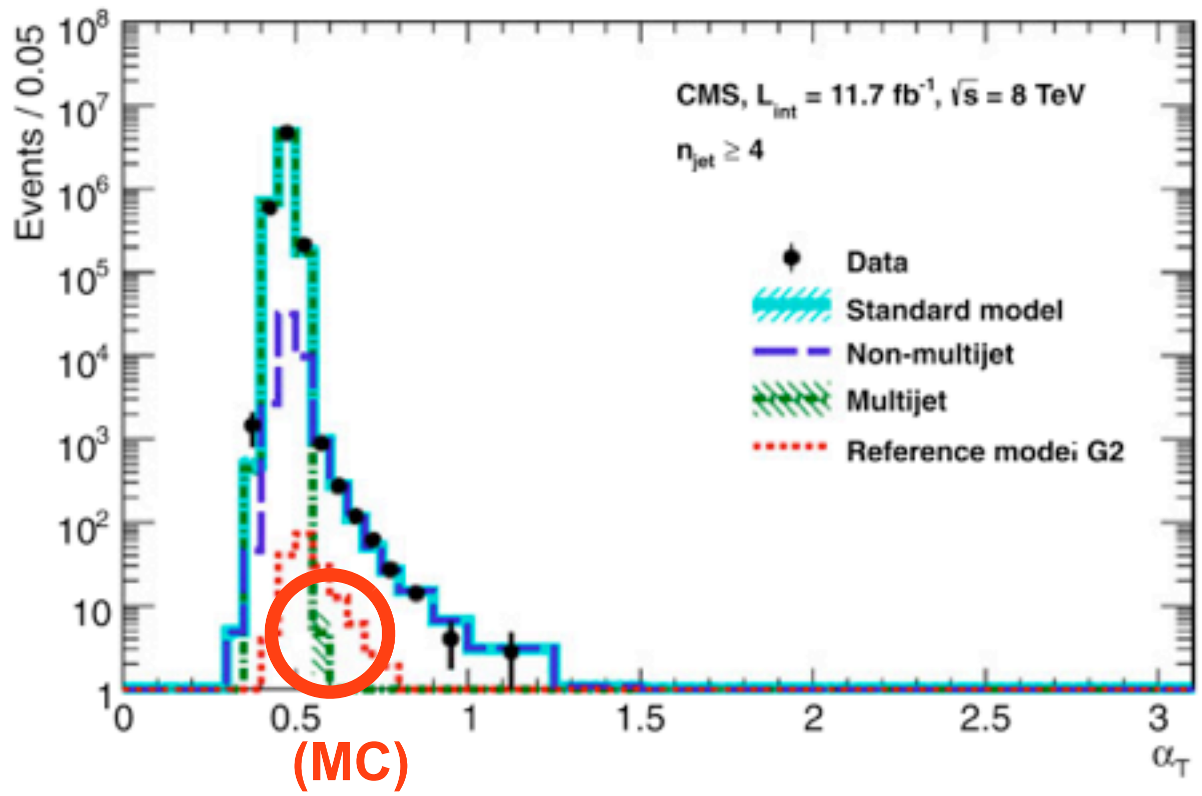
Dijet system

$$\alpha_T = \frac{E_T^{j_2}}{M_T}$$

- Leakage beyond a value of 0.5 is due to:
  - stochastic fluctuations in jet energy measurements (ie, resolutions)
  - severe jet energy mismeasurements (ie, dead ECAL cells)
  - threshold effect due to jet pT requirements (ie, MHT >> MET)



(MC)



(MC)

“QCD-free” signal region with AlphaT

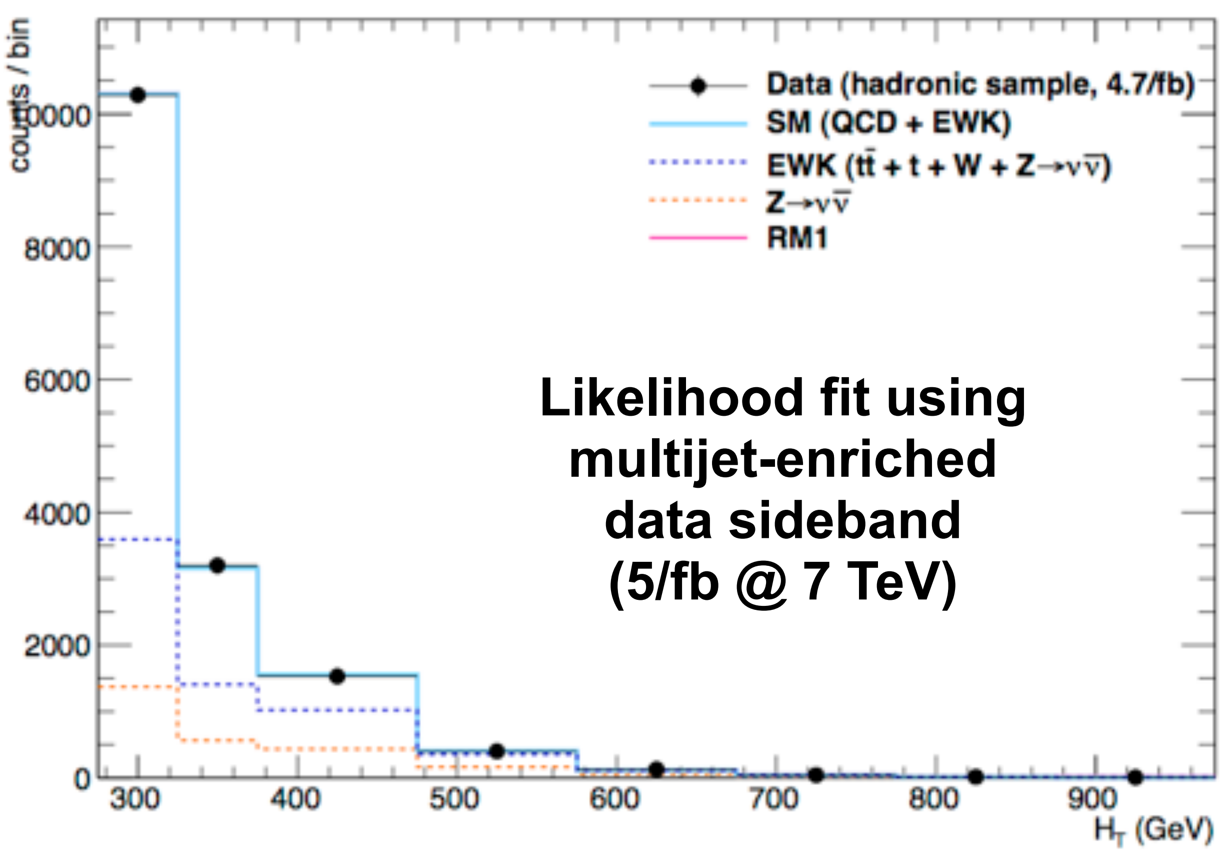
- Hadronic pre-selection for signal region
  - Veto events with isolated leptons and photons
  - $N_{jet} \geq 2$, jet $p_T > 37$ GeV, 2nd lead jet $p_T > 73$ GeV, HT > 200 GeV
- QCD killer: AlphaT > 0.55 (HT > 275 GeV), AlphaT > 0.6 (200 < HT 275 GeV)
- Additional cuts that “clean up” the AlphaT edge
  - MHT/MET < 1.25: vetoes events with jets below threshold contributing to MHT
  - Dead ECAL: veto event if jet coincides with dead cell and $\Delta\varphi$(jet,MHT) ~0
- AlphaT > 0.55 suppresses multijet events by several (5-6) orders of magnitude
  - Cleaning cuts provide further order of magnitude reduction
- Multijet contribution in SR expected to be ~zero (HT > 275 GeV, AlphaT > 0.55)
  - If any contamination, only expected at low HT

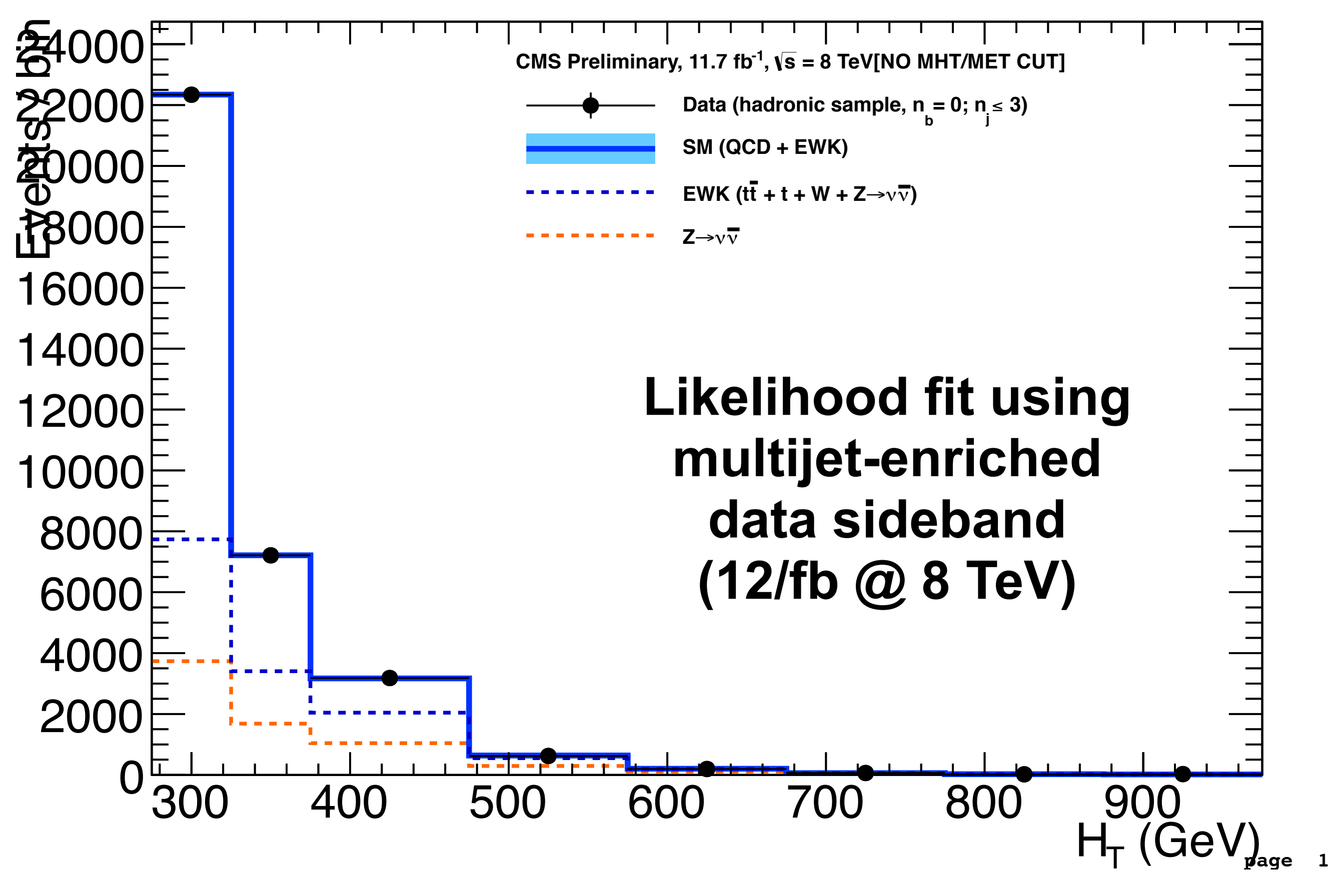
R_{AlphaT} method to estimate multijet background

- Assume ratio of multijet events that pass/fail AlphaT has exponential HT-dependence
  - Model incorporated into likelihood function: $R_{AlphaT}(HT) = \boldsymbol{A}e^{-\boldsymbol{k}.HT}$
  - Exponent term ***k*** is constrained using multijet-enriched data sidebands
  - Normalisation ***A*** is not constrained and allowed to float: conservative approach

- Model validated in multijet-enriched data sideband (removed MHT/MET cleaning cut)

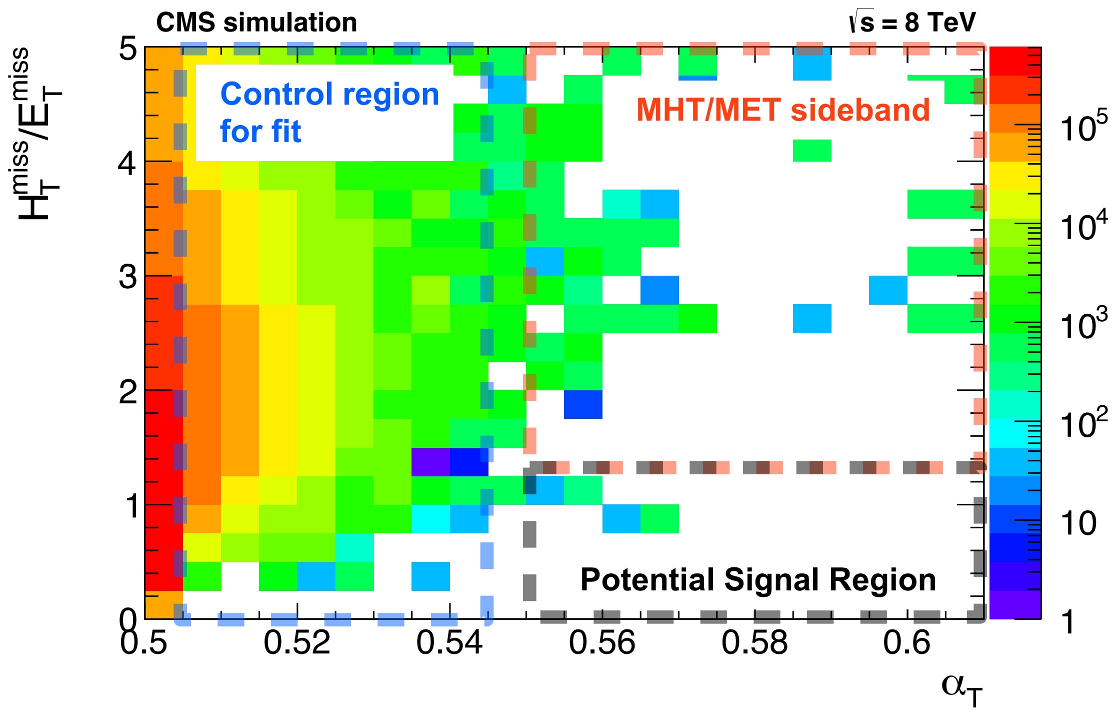
- Historically, multijet estimate for SR is compatible with zero (HT > 275 GeV, AlphaT > 0.55)

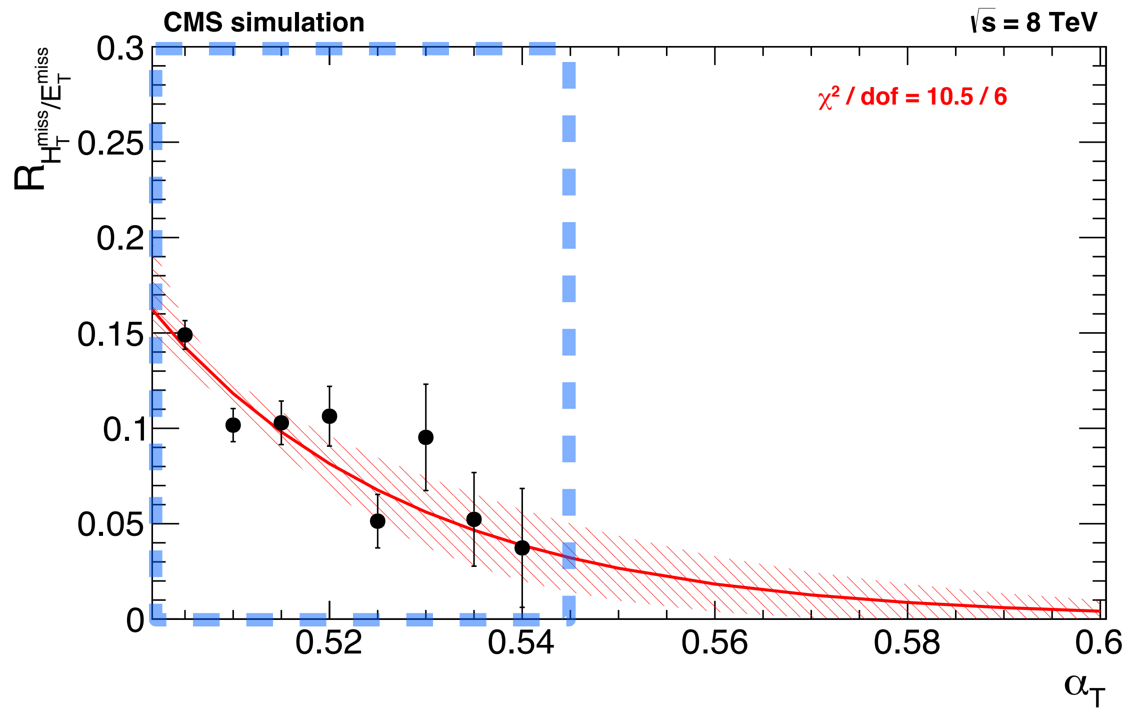




New method to estimate multijet background

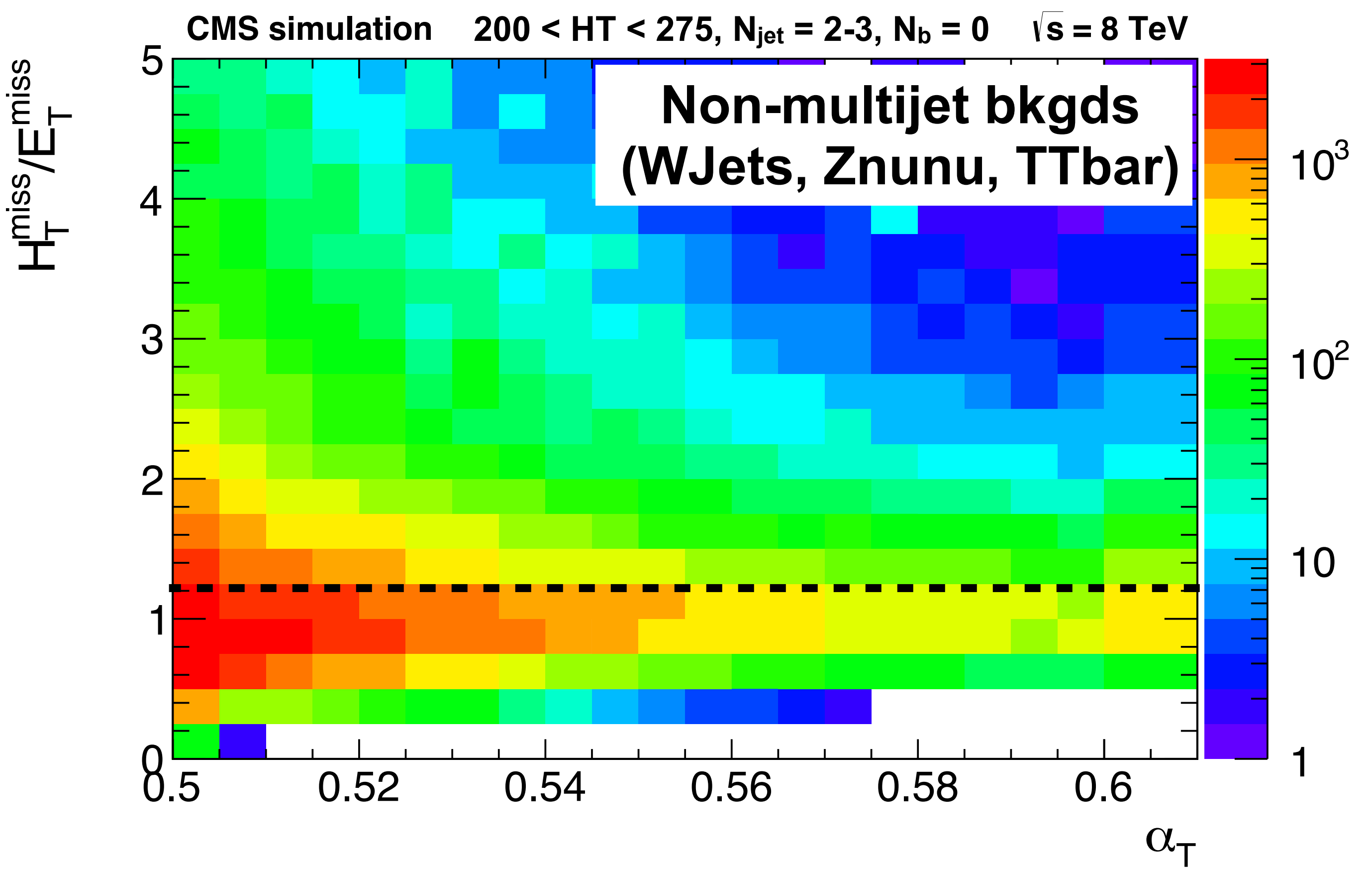
- Collect events with the HT (and HT_AlphaT) triggers
- Use multijet-enriched data sidebands (0.50 < AlphaT < 0.55, MHT/MET > 1.25)
- Use mu+jets data control sample to estimate non-multijet contribution
- Subtract NMJ contribution from data and assume remaining are multijet events
- Determine ratio of multijet events passing/failing MHT/MET cut as function of AlphaT
- Assume functional form (exponential) for $R_{MHT/MET}$ vs AlphaT and extrapolate
- Multiply $R_{MHT/MET}$ extrapolation with MHT/MET sideband yield to obtain MJ prediction
- MJ prediction obtained per signal region bin, propagated to likelihood function

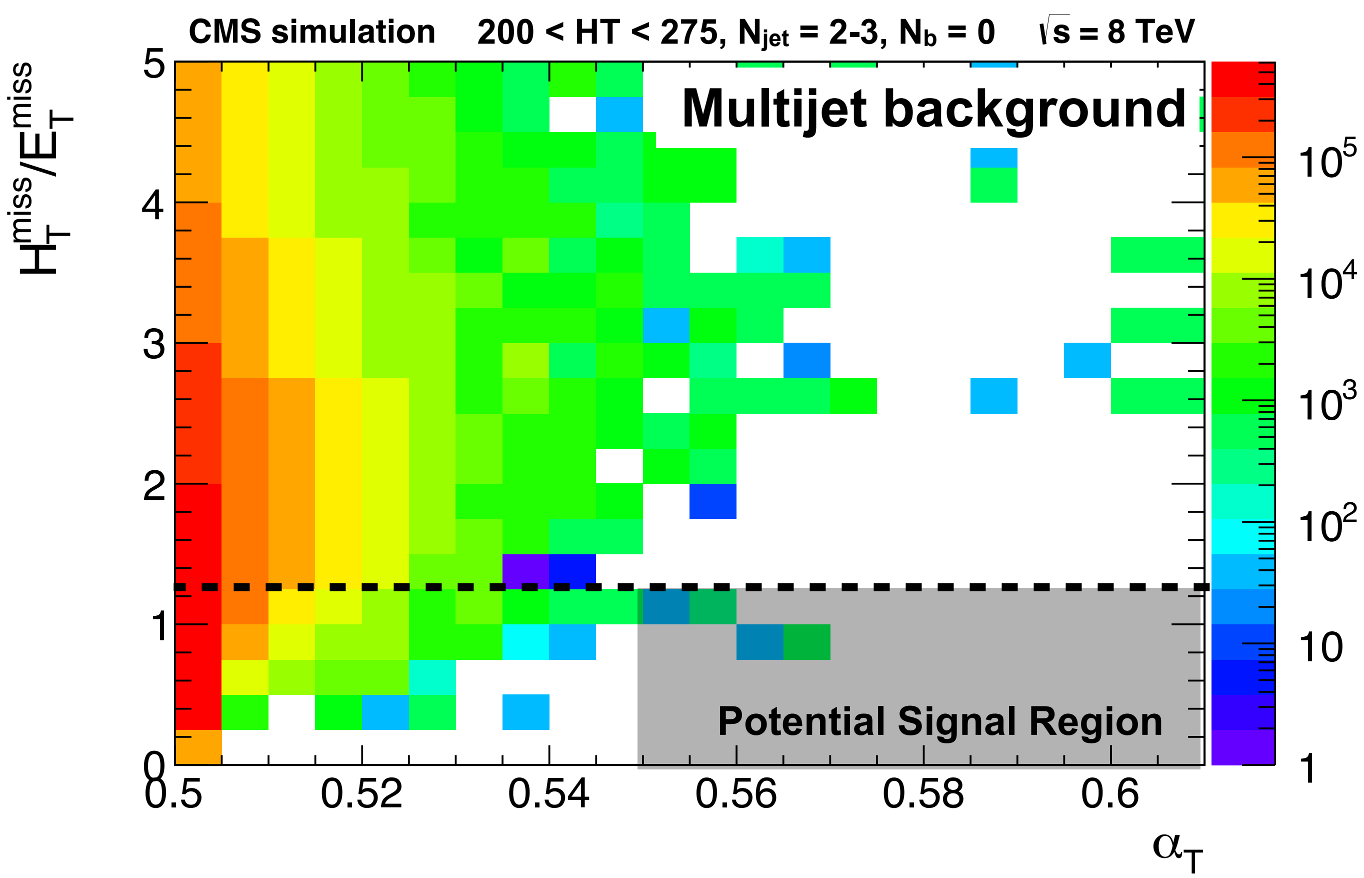


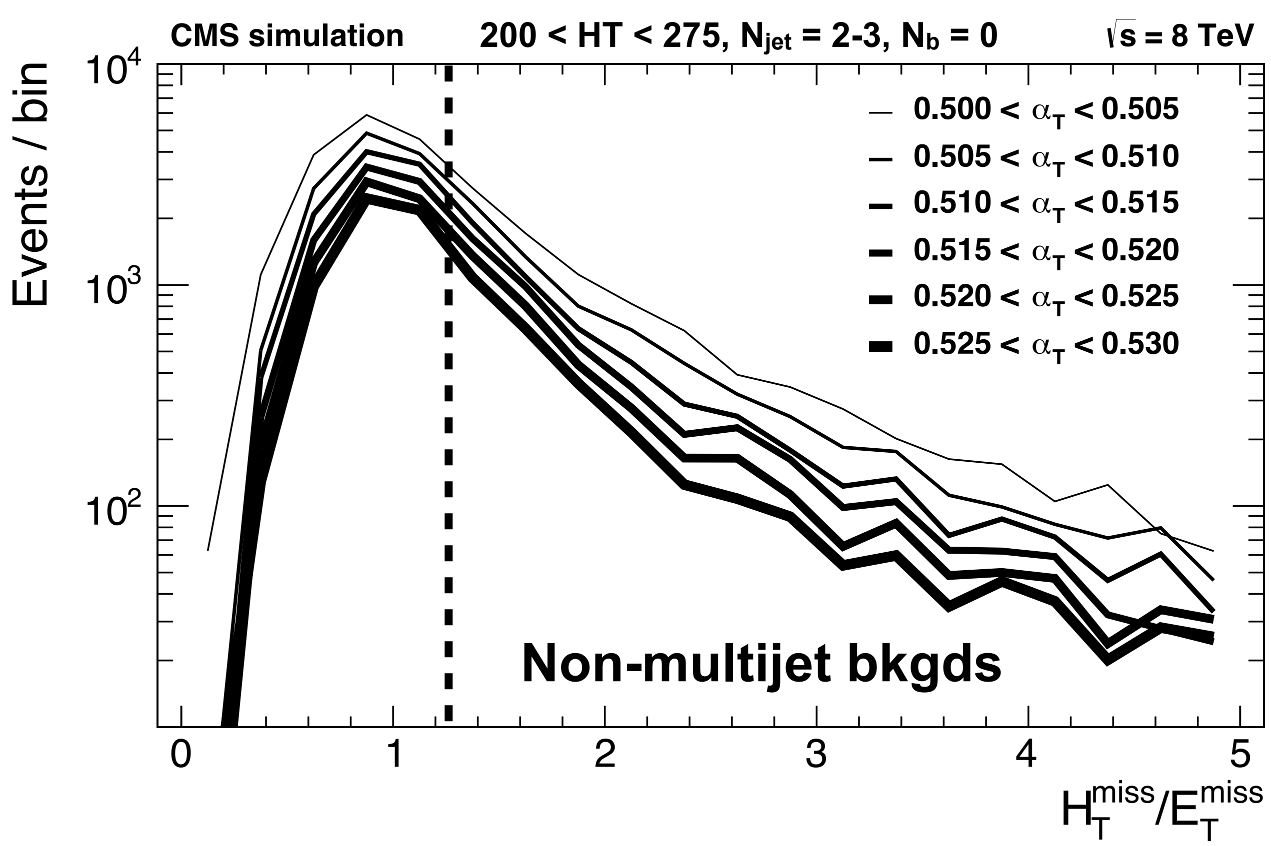


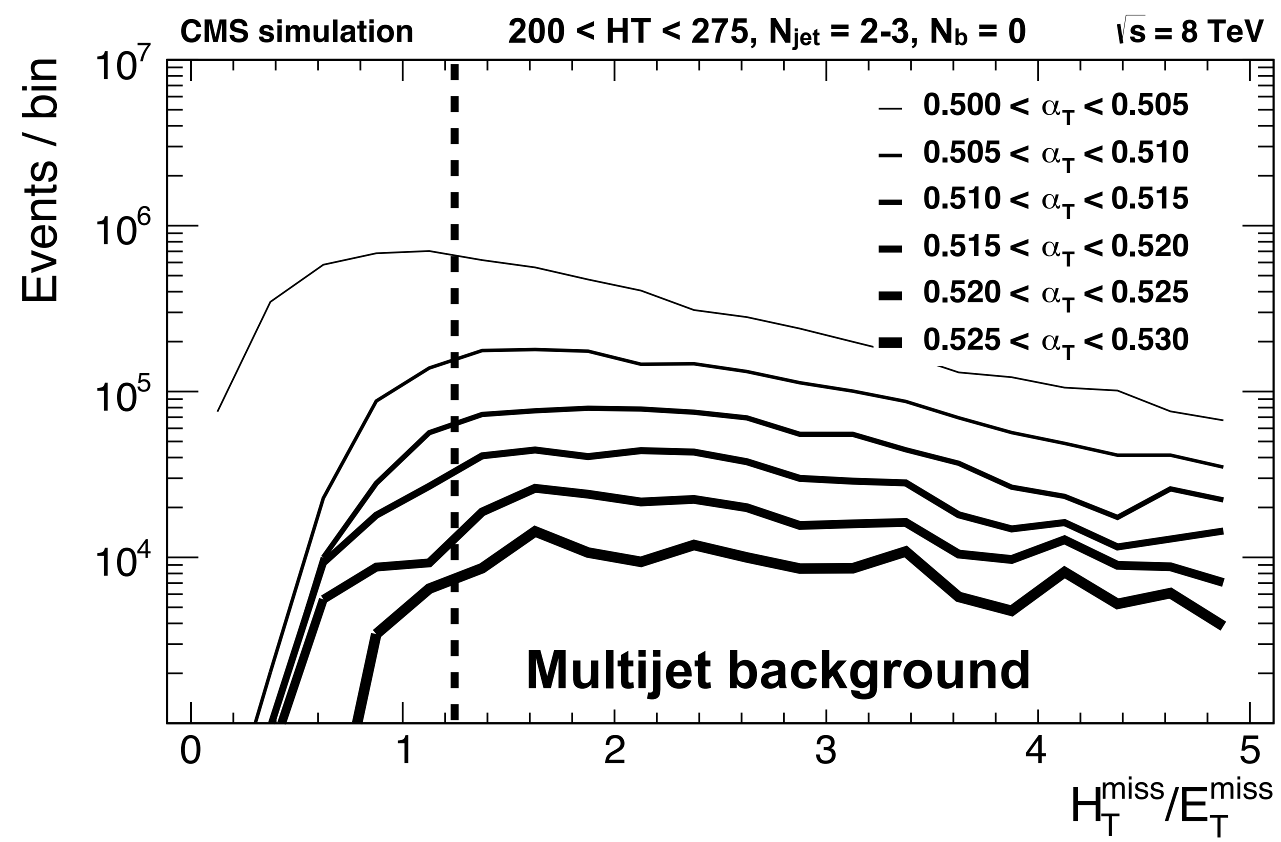
MJ and NJM in sidebands (simulation)

- Very different behaviours for MJ and NMJ backgrounds in AlphaT and MHT/MET plane



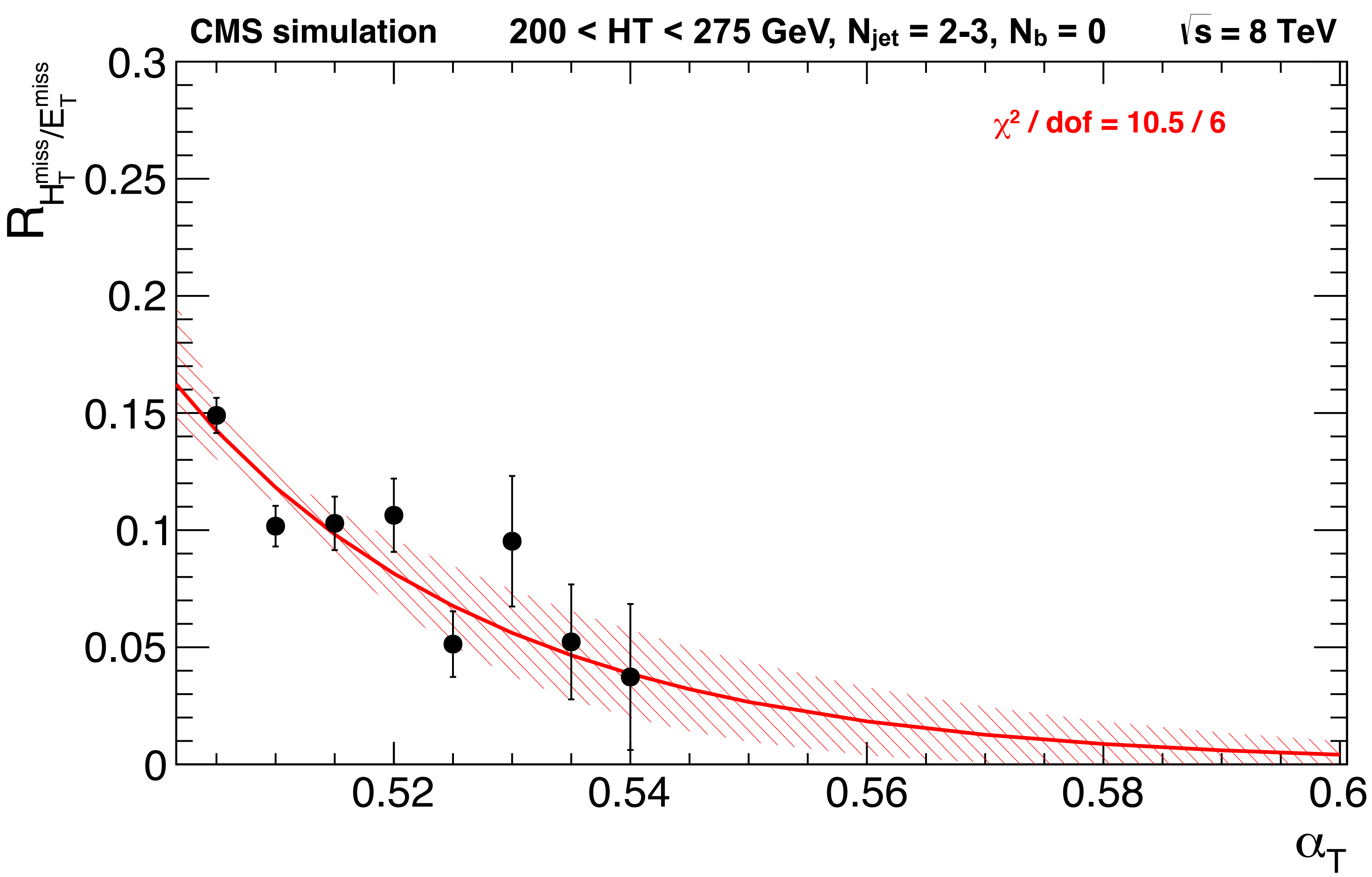


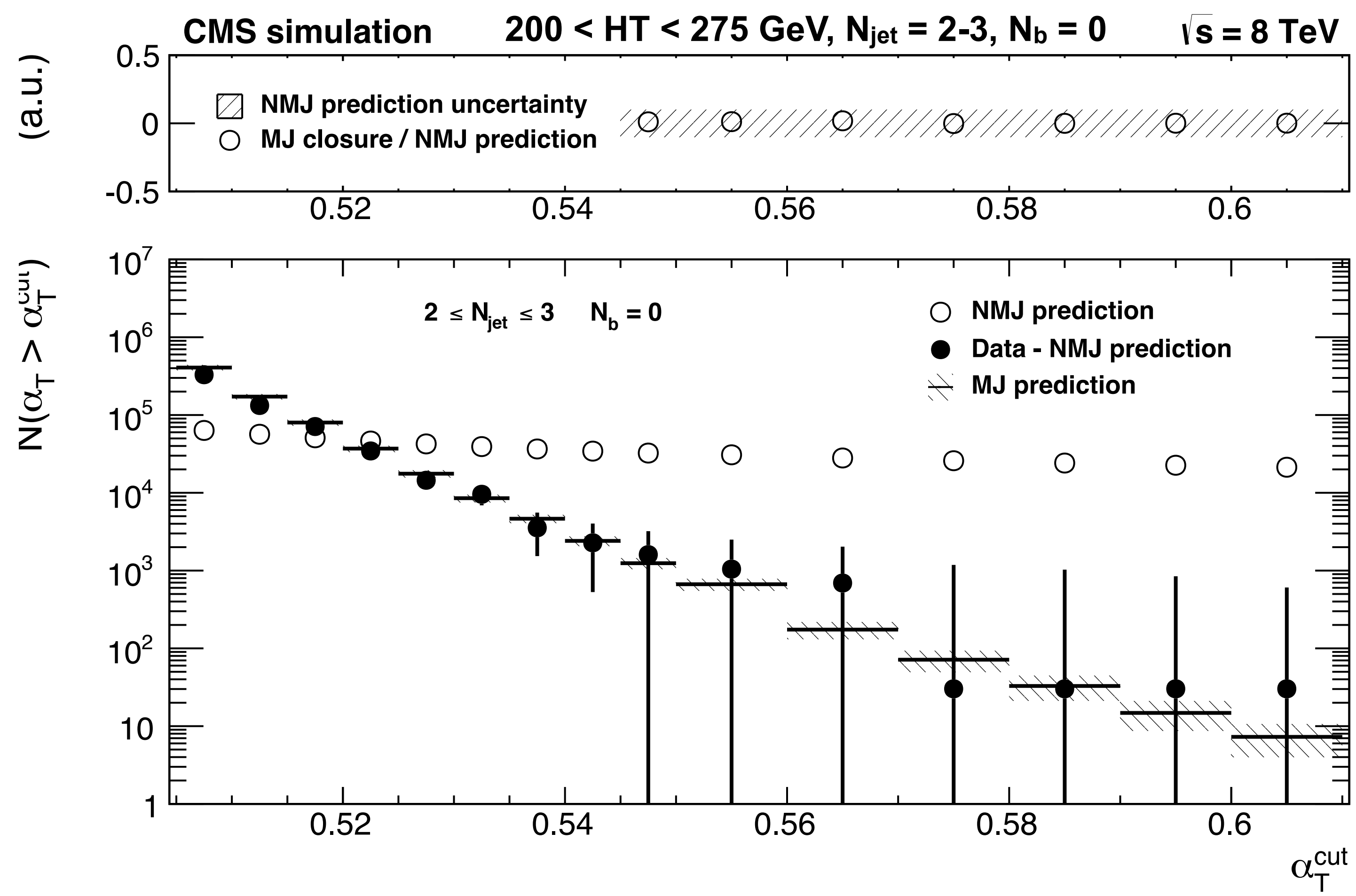




$R_{MHT/MET}$ (simulation)

- Choose exponential function to parameterise behaviour of $R_{MHT/MET}$ versus AlphaT
  - Arbitrary choice, validated by closure tests with both simulation and data
  - Fit to ratios in sideband region defined by 0.505 < AlphaT < 0.54
- Predicted number of MJ events with AlphaT > cut is consistent with MC yields
- Level of closure is better than (or compatible with) uncertainties on NMJ predictions
- Closure also for higher HT bins (within statistical uncertainties)



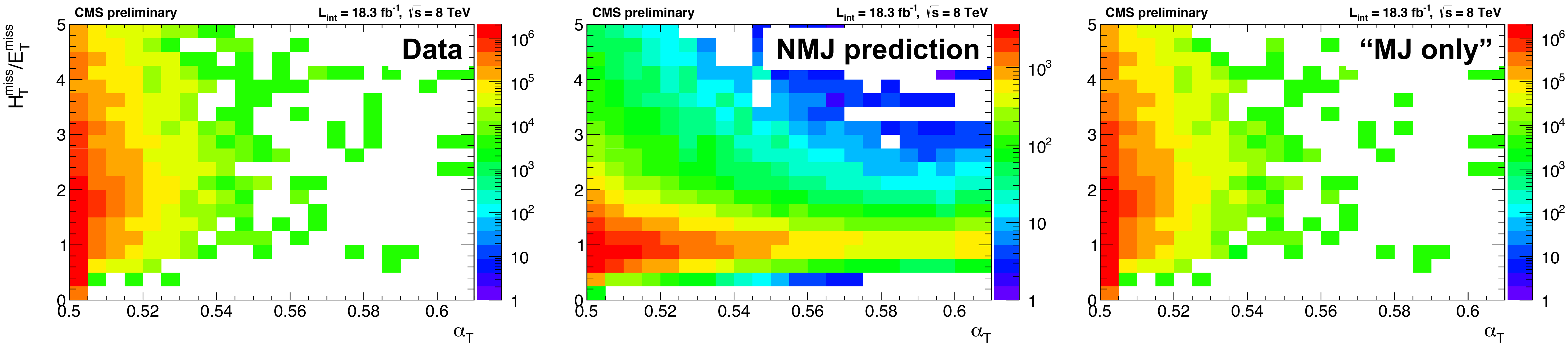


MJ and NJM in sidebands (data)

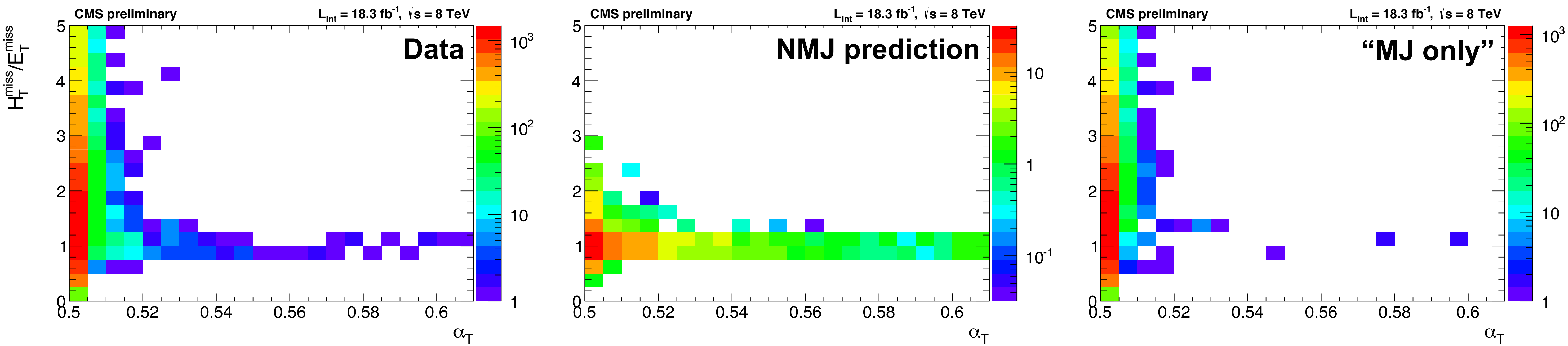
Imperial College London

- First step: subtract NMJ prediction from data yields to obtain “MJ only”
  - Note different colour scales and different trigger prescales

200 < HT < 275 GeV (HT200 trigger, prescale = 4800)



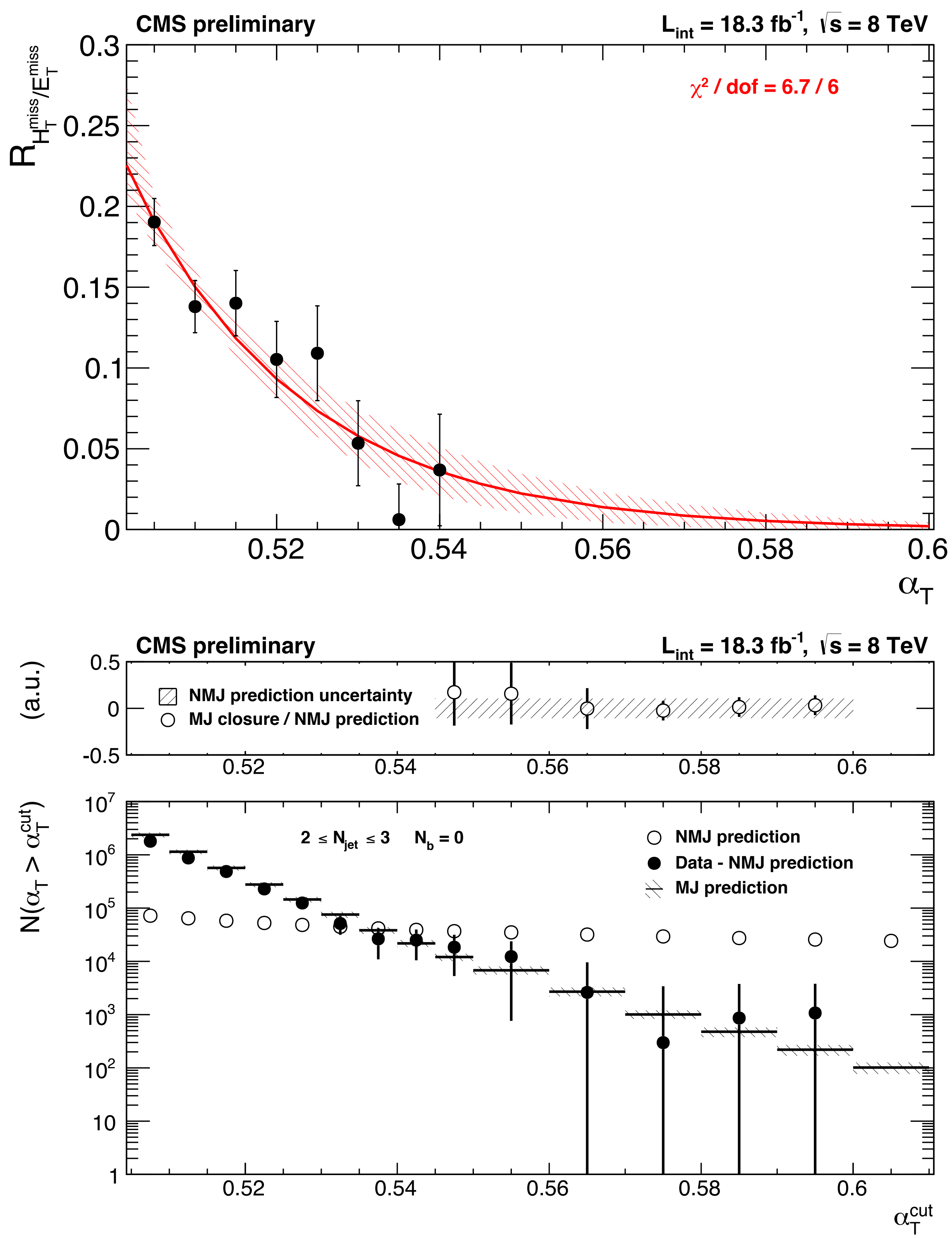
775 < HT < 875 GeV (HT750 trigger, prescale = 1)



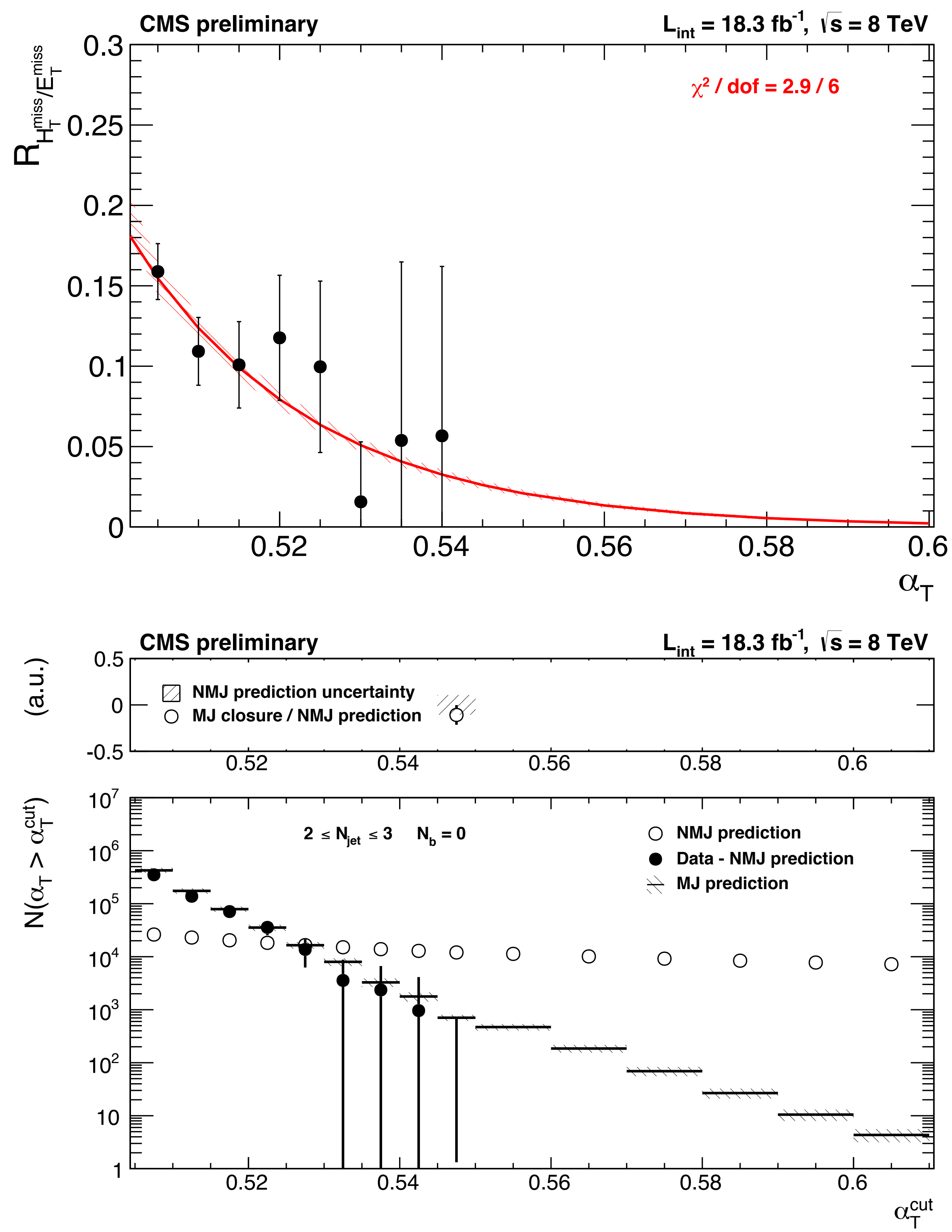
RMHT/MET (data)

- Level of closure is better than (or compatible with) uncertainties on NMJ predictions

200 < HT < 275 GeV, N_{jet} = 2-3, N_b = 0



275 < HT < 325 GeV, N_{jet} = 2-3, N_b = 0



MJ predictions

- MJ predictions << EWK prediction uncertainties, hence can claim to be “QCD free”
  - –Predictions propagated to likelihood function

- Will investigate the use of mistag rate for ≥1b categories (and use fit only as a cross check)

Table 1: Predicted yields for the multijet (MJ) and, for reference, non-multijet (NMJ) backgrounds as determined in data for various H_T bins and the requirements $\alpha_T > \alpha_T^{cut}$, $2 \leq N_{jet} \leq 3$, and $N_b = 0$.

H_T	200–275		275–325		325–375		375–475	
α_T^{cut}	MJ	NMJ	MJ	NMJ	MJ	NMJ	MJ	NMJ
0.505	$(2.4 \pm 0.2) \times 10^6$	$(7.8 \pm 0.5) \times 10^4$	$(4.3 \pm 0.4) \times 10^5$	$(2.8 \pm 0.2) \times 10^4$	$(5.0 \pm 0.8) \times 10^4$	$(1.2 \pm 0.1) \times 10^4$	$(1.2 \pm 0.4) \times 10^4$	$(9.1 \pm 0.6) \times 10^3$
0.510	$(1.1 \pm 0.1) \times 10^6$	$(7.0 \pm 0.4) \times 10^4$	$(1.7 \pm 0.2) \times 10^5$	$(2.5 \pm 0.2) \times 10^4$	$(1.8 \pm 0.3) \times 10^4$	$(1.1 \pm 0.1) \times 10^4$	$(2.2 \pm 0.6) \times 10^3$	$(7.9 \pm 0.5) \times 10^3$
0.515	$(5.7 \pm 0.7) \times 10^5$	$(6.3 \pm 0.4) \times 10^4$	$(7.8 \pm 0.8) \times 10^4$	$(2.2 \pm 0.1) \times 10^4$	$(6.9 \pm 1.3) \times 10^3$	$(9.5 \pm 0.6) \times 10^3$	$(3.8 \pm 1.2) \times 10^2$	$(6.9 \pm 0.4) \times 10^3$
0.520	$(2.8 \pm 0.5) \times 10^5$	$(5.7 \pm 0.3) \times 10^4$	$(3.5 \pm 0.4) \times 10^4$	$(2.0 \pm 0.1) \times 10^4$	$(2.8 \pm 0.6) \times 10^3$	$(8.5 \pm 0.5) \times 10^3$	$(1.1 \pm 0.4) \times 10^2$	$(6.1 \pm 0.4) \times 10^3$
0.525	$(1.4 \pm 0.3) \times 10^5$	$(5.2 \pm 0.3) \times 10^4$	$(1.6 \pm 0.2) \times 10^4$	$(1.8 \pm 0.1) \times 10^4$	$(1.0 \pm 0.2) \times 10^3$	$(7.7 \pm 0.5) \times 10^3$	26 ± 10	$(5.5 \pm 0.3) \times 10^3$
0.530	$(7.5 \pm 2.2) \times 10^4$	$(4.8 \pm 0.3) \times 10^4$	$(7.8 \pm 1.1) \times 10^3$	$(1.6 \pm 0.1) \times 10^4$	$(5.3 \pm 1.4) \times 10^2$	$(7.0 \pm 0.4) \times 10^3$	7.1 ± 3.0	$(5.0 \pm 0.3) \times 10^3$
0.535	$(3.8 \pm 1.4) \times 10^4$	$(4.5 \pm 0.3) \times 10^4$	$(3.2 \pm 0.5) \times 10^3$	$(1.5 \pm 0.1) \times 10^4$	$(2.4 \pm 0.7) \times 10^2$	$(6.5 \pm 0.4) \times 10^3$	1.5 ± 0.7	$(4.6 \pm 0.3) \times 10^3$
0.540	$(2.1 \pm 0.9) \times 10^4$	$(4.2 \pm 0.3) \times 10^4$	$(1.7 \pm 0.3) \times 10^3$	$(1.4 \pm 0.1) \times 10^4$	$(1.1 \pm 0.3) \times 10^2$	$(6.0 \pm 0.4) \times 10^3$	0.37 ± 0.19	$(4.3 \pm 0.3) \times 10^3$
0.545	$(1.2 \pm 0.6) \times 10^4$	$(4.0 \pm 0.2) \times 10^4$	$(6.8 \pm 0.7) \times 10^2$	$(1.3 \pm 0.1) \times 10^4$	56 ± 14	$(5.6 \pm 0.3) \times 10^3$	0.13 ± 0.06	$(4.0 \pm 0.2) \times 10^3$
0.550	$(6.7 \pm 3.8) \times 10^3$	$(3.8 \pm 0.2) \times 10^4$	$(4.5 \pm 0.5) \times 10^2$	$(1.2 \pm 0.1) \times 10^4$	28 ± 7	$(5.3 \pm 0.3) \times 10^3$	0.039 ± 0.019	$(3.7 \pm 0.2) \times 10^3$
0.560	$(2.6 \pm 1.9) \times 10^3$	$(3.4 \pm 0.2) \times 10^4$	$(1.8 \pm 0.2) \times 10^2$	$(1.1 \pm 0.1) \times 10^4$	7.3 ± 2.3	$(4.7 \pm 0.3) \times 10^3$	0.0036 ± 0.0020	$(3.3 \pm 0.2) \times 10^3$
0.570	$(9.8 \pm 8.2) \times 10^2$	$(3.2 \pm 0.2) \times 10^4$	65 ± 9	$(9.9 \pm 0.6) \times 10^3$	2.2 ± 0.8	$(4.2 \pm 0.3) \times 10^3$	0.00041 ± 0.00027	$(2.9 \pm 0.2) \times 10^3$
0.580	$(4.6 \pm 4.5) \times 10^2$	$(3.0 \pm 0.2) \times 10^4$	25 ± 4	$(9.1 \pm 0.6) \times 10^3$	0.67 ± 0.27	$(3.8 \pm 0.2) \times 10^3$	$(5.6 \pm 4.1) \times 10^{-5}$	$(2.7 \pm 0.2) \times 10^3$
0.590	$(2.1 \pm 2.3) \times 10^2$	$(2.8 \pm 0.2) \times 10^4$	9.5 ± 1.8	$(8.4 \pm 0.5) \times 10^3$	0.21 ± 0.10	$(3.5 \pm 0.2) \times 10^3$	$(7.6 \pm 6.4) \times 10^{-6}$	$(2.5 \pm 0.1) \times 10^3$
0.600	$(1.0 \pm 1.2) \times 10^2$	$(2.6 \pm 0.2) \times 10^4$	3.8 ± 0.8	$(7.8 \pm 0.5) \times 10^3$	0.083 ± 0.043	$(3.3 \pm 0.2) \times 10^3$	$(1.3 \pm 1.2) \times 10^{-6}$	$(2.3 \pm 0.1) \times 10^3$

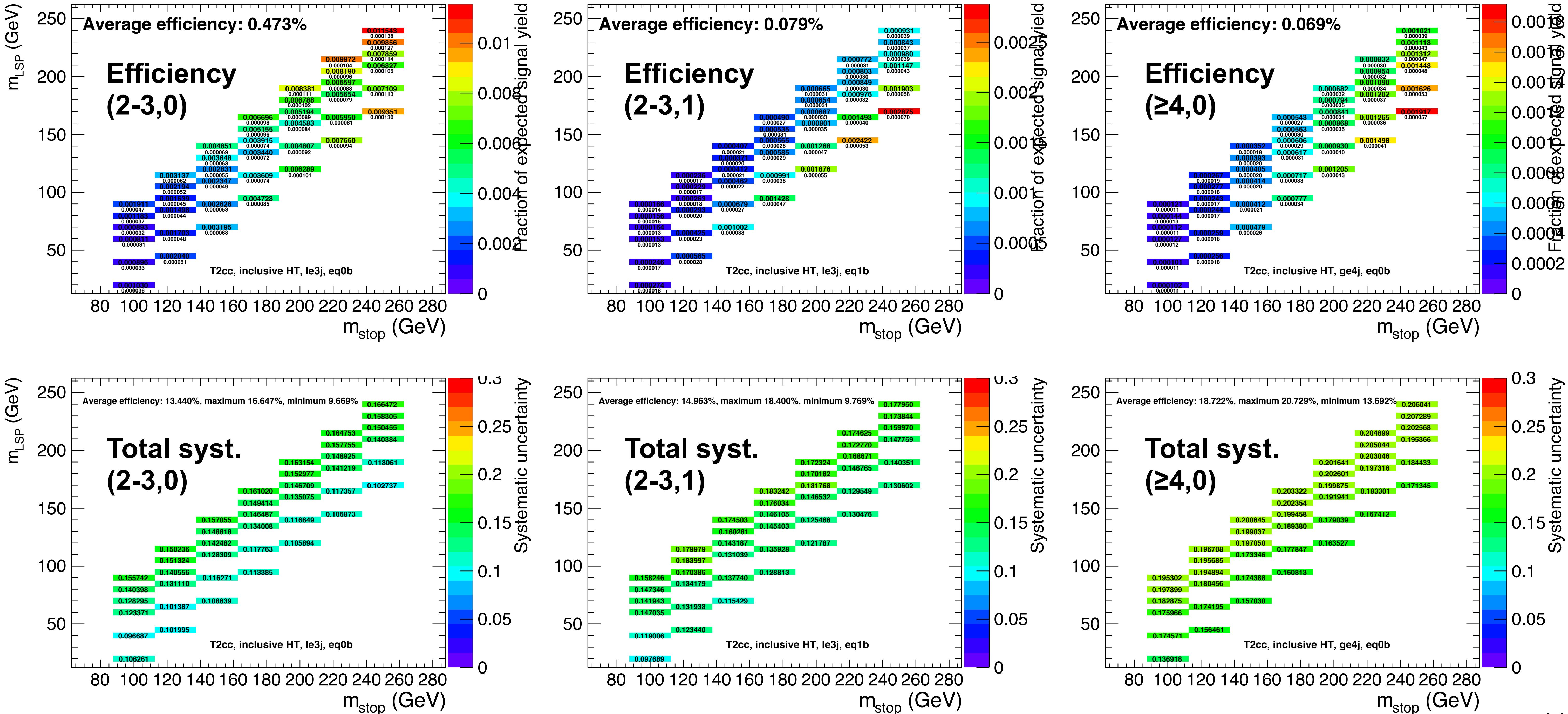
Table 2: Summary of predicted yields for the multijet (MJ) backgrounds as determined in data for various H_T bins and requirements on α_T^{cut}, n_{jet}, and n_b.

		H_T (α_T^{cut})			
n_{jet}	n_b	200–275 (0.600)	275–325 (0.550)	325–375 (0.550)	375–475 (0.550)
2–3	0	$(1.0 \pm 1.2) \times 10^2$	$(4.5 \pm 0.5) \times 10^2$	28 ± 7	0.039 ± 0.019
2–3	≥ 1	21 ± 9	1.0 ± 0.1	15 ± 4	47 ± 27
≥ 4	0	23 ± 42	$(6.2 \pm 5.4) \times 10^2$	4.3 ± 6.9	0.0070 ± 0.0013
≥ 4	≥ 1	7.3 ± 4.5	2.5 ± 0.6	1.4 ± 0.5	0.015 ± 0.004

T2cc efficiencies and systematics

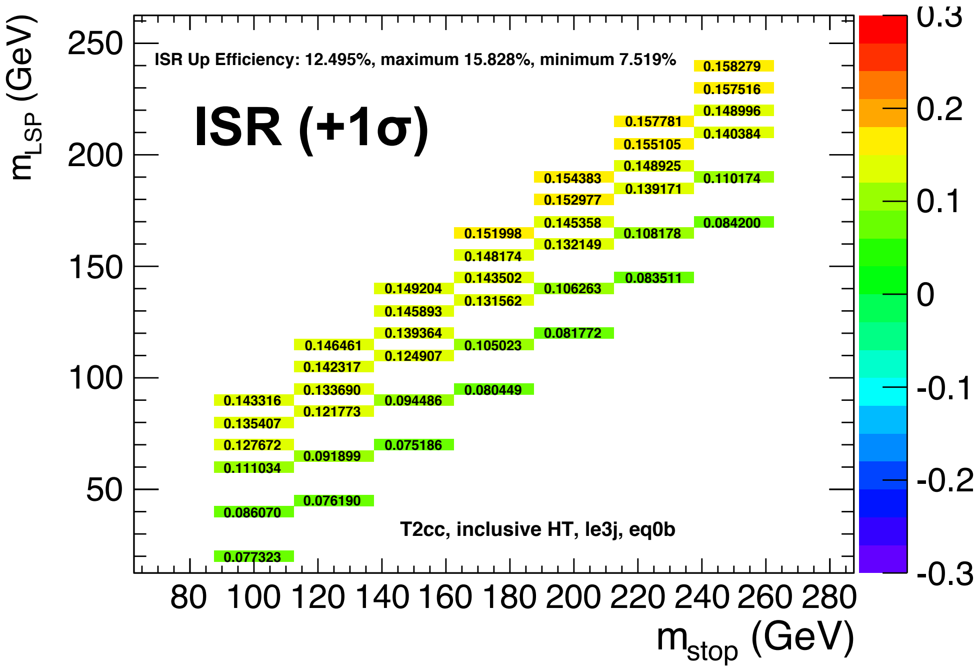
T2cc signal efficiencies and uncertainties

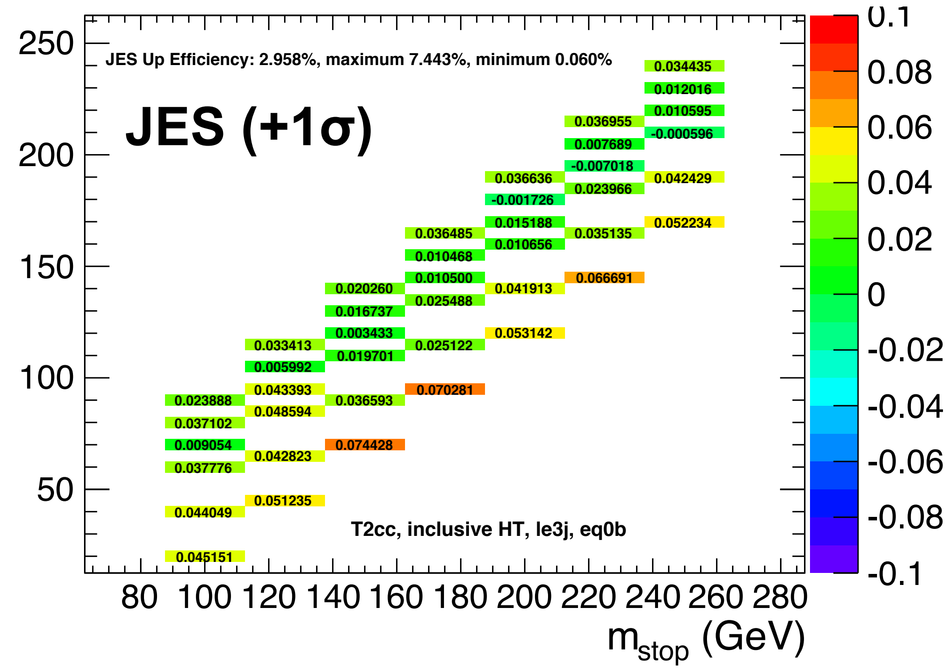
- Three event categories used for the T2cc limit: (N_{jet},N_b) = (2-3,0), (2-3,1), (≥4,0)
  - (2-3,0) drives the limit on the diagonal, (2-3,1) and (≥4,0) help for the larger mass splittings
- Systematics factorised according to acceptance and shape (former dominates)
  - Uncertainty on signal acceptance (HT > 200 GeV) dominated by ISR (currently using flat 20%)

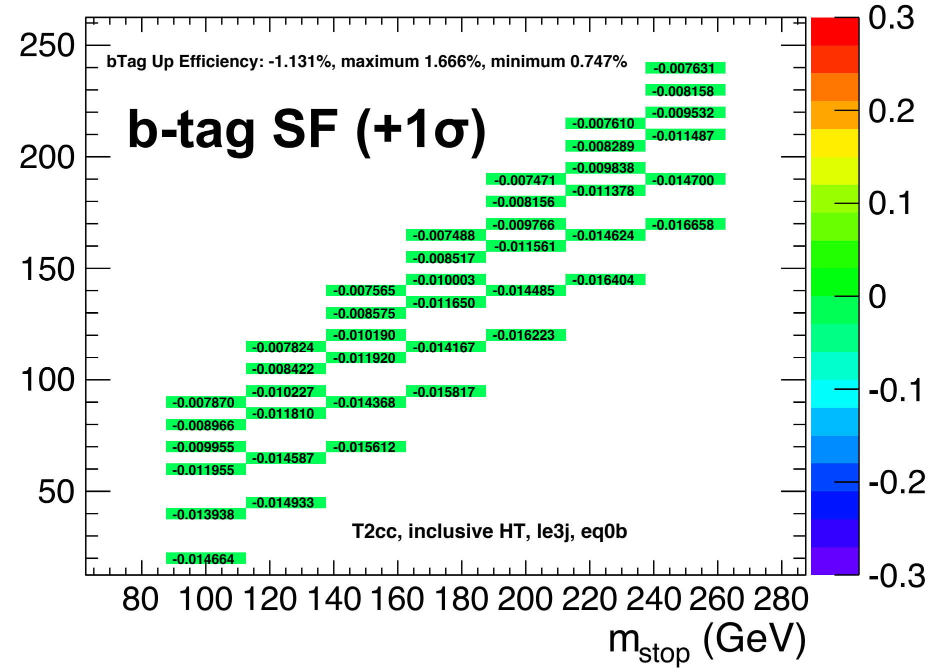


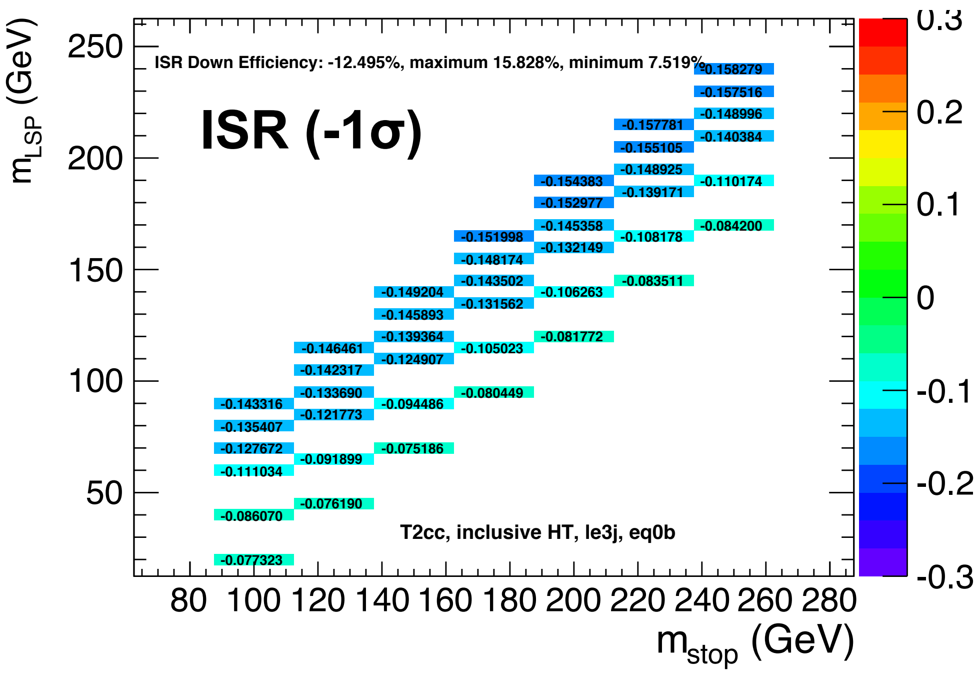
Dominant T2cc systematics for (N_{jet}=2-3,N_b=0)

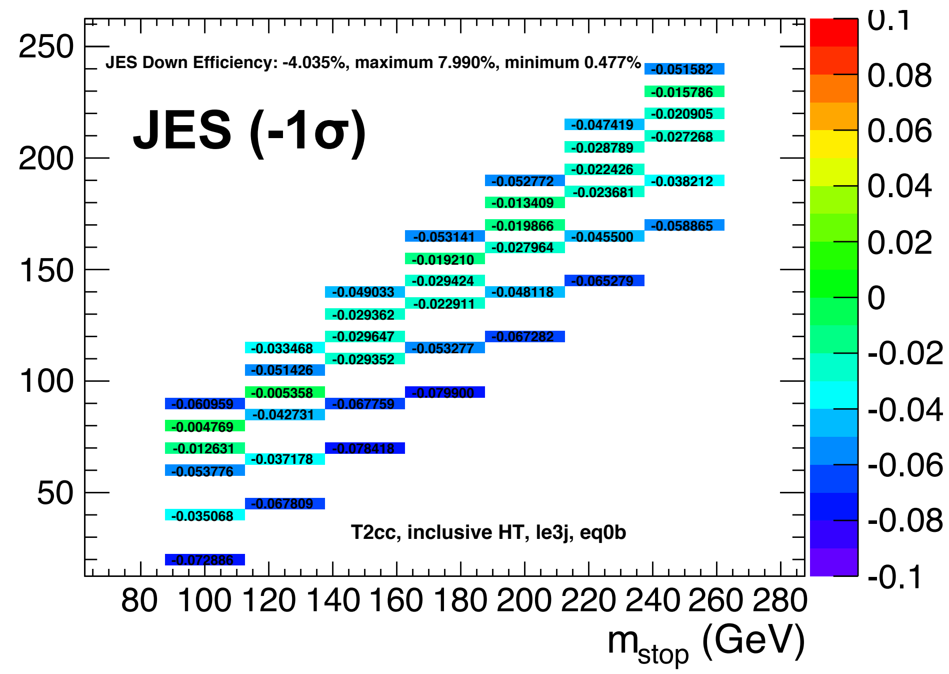
- Total acceptance systematic is dominated by uncertainties on ISR, JES, and PDF
  - Systematic due to b-tag SF is sub-dominant for T2cc
  - Other (sub-dominant) systematics to be included (luminosity, lepton vetoes, MHT/MET,...)

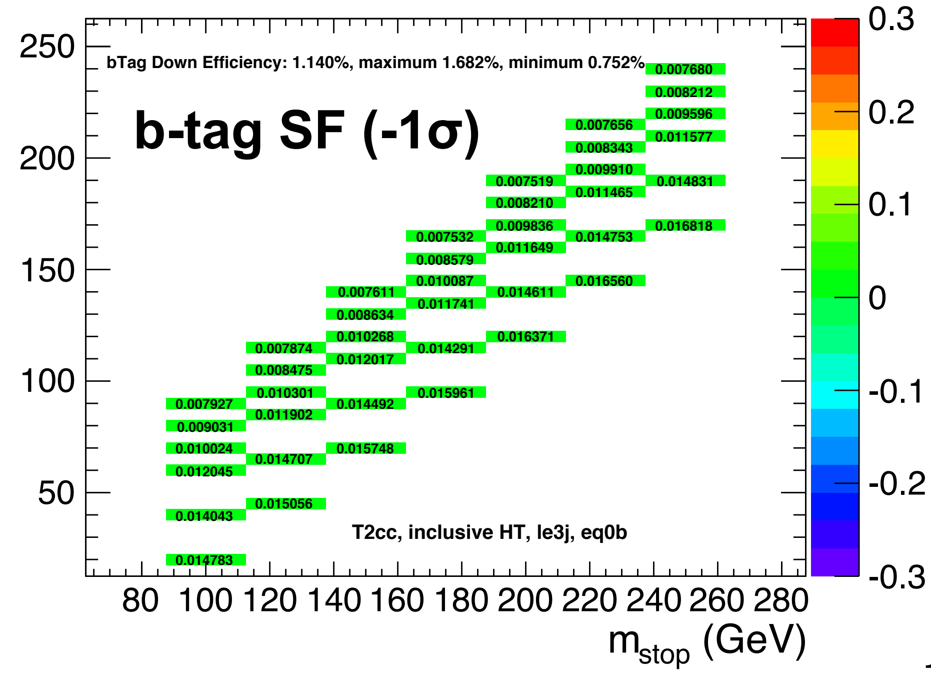












Trigger plans for 2015

Status and plans for 2015

- A suite of HT_AlphaT cross triggers have been used throughout Run 1
  - Challenging but successful program of hadronic triggers
- High performance: sharp turn ons, high efficiencies, low rate
  - Combinatoric logic to ensure high efficiencies regardless of offline jet pT thresholds
  - eg, ~10-20% inefficiency (L1) for lowest HT bins, 100% for all other bins, rate ≲ 10 Hz
- Successful addition of parked trigger: extended phase space coverage
  - Currently being used in the analysis of the full 2012 dataset (important for small Δm)
- Equally important: successful program of ancillary triggers
  - SingleMu, SinglePhoton, HT (prescaled), reference triggers for eff. measurements
- Challenges for the future:
  - Efficient L1 seeds will be crucial (present signal trigger inefficiencies are due to L1)
  - Maintaining acceptance for signal and control triggers, at a reasonable rate
- We request that the AlphaT suite of triggers are part of 2015 trigger menu
  - We have ideas on how to improve on Run 1 performance (acceptance, efficiencies)

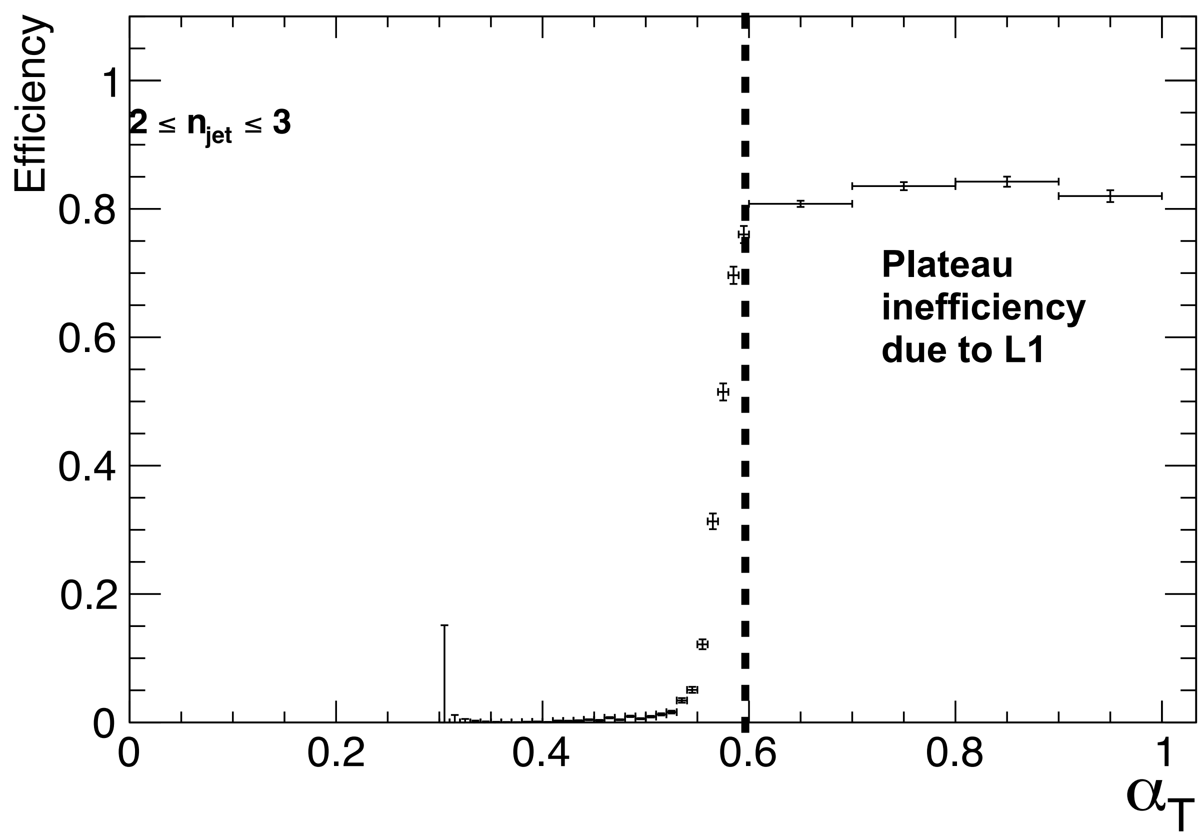
Trigger efficiencies

- For more information, see here, here, and here

Signal trigger efficiencies

Trigger	H_T (Gev)	α_T	Efficiency (%) $2 \leq n_{jet} \leq 3$	Efficiency (%) $n_{jet} \geq 4$
HLT_HT200_AlphaT0p57_v*	200–275	> 0.60	81.6 ± 0.4	66.5 ± 3.3
HLT_HT250_AlphaT0p55_v*	275–325	> 0.55	90.1 ± 0.4	66.6 ± 1.3
HLT_HT300_AlphaT0p53_v*	325–375	> 0.55	98.8 ± 0.2	97.1 ± 0.8
HLT_HT350_AlphaT0p52_v*	375–475	> 0.55	99.4 ± 0.2	98.8 ± 0.6
HLT_HT400_AlphaT0p51_v*	> 475	> 0.55	100.0 ± 0.2	100.0 ± 0.5

Parked trigger (HT200_AlphaT0p57)



HT trigger efficiencies (Hadronic control sample)

Trigger	H_T (GeV)	Efficiency (%) $2 \leq n_{jet} \leq 3$	Efficiency (%) $n_{jet} \geq 4$
HLT_HT200_v*	200–275	66.3 ± 10.8	81.7 ± 81.7
HLT_HT250_v*	275–325	79.3 ± 15.9	50.2 ± 29.1
HLT_HT300_v*	325–375	106.9 ± 19.0	117.3 ± 48.0
HLT_HT350_v*	375–475	106.7 ± 15.0	67.7 ± 27.8
HLT_HT450_v*	475–575	104.1 ± 12.8	96.2 ± 20.6
HLT_HT550_v*	575–675	83.9 ± 11.7	107.0 ± 19.8
HLT_HT650_v*	675–775	105.7 ± 13.8	99.5 ± 18.2
HLT_HT750_v*	775–875	96.9 ± 5.2	95.0 ± 7.0
HLT_HT750_v*	875–975	100.0 ± 7.2	100.0 ± 10.5
HLT_HT750_v*	975–1075	100.0 ± 9.6	100.0 ± 13.5
HLT_HT750_v*	> 1075	100.0 ± 13.5	100.0 ± 19.4

Summary

Multijet background estimation

- New multijet background estimation based on multijet-enriched data sidebands
- Method indicates all bins are “multijet free” (relative to EWK prediction uncertainties)
- HT200 bin is “multijet free” for AlphaT > 0.6 (threshold also motivated by trigger)

T2cc signal efficiencies and systematics

- Three event categories contribute (significantly) to acceptance
- Total systematic is ~20%, dominated by ISR

Trigger status and plans for 2015

- Very successful trigger campaign in Run 1
- We request that our triggers be considered for the 2015 menu