Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

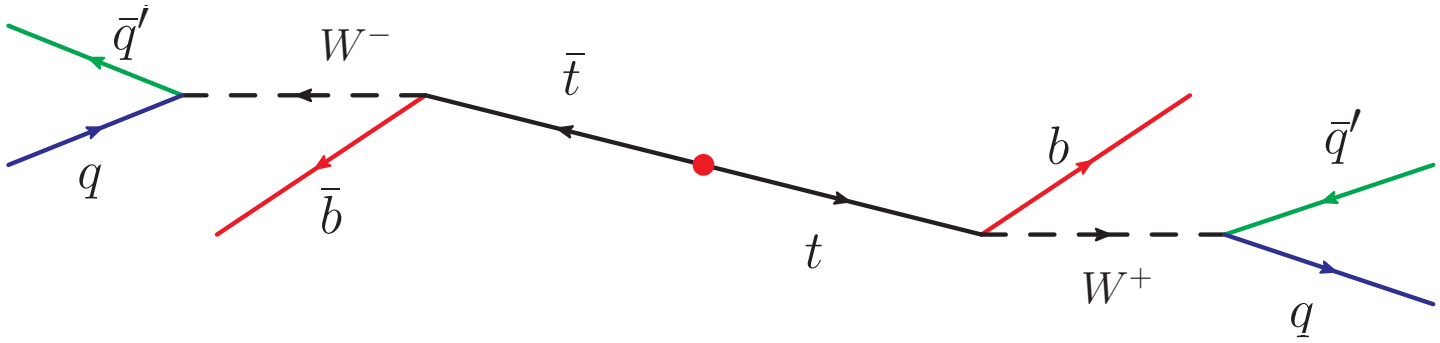
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Top-Quark Mass Measurement in All-Jets Final States (TOP-11-017)

Martijn Gosselink, Peter Schleper, Eike Schlieckau, Markus Seidel, Hartmut Stadie
- Universität Hamburg -

Benefits, Challenges and Analyses

- Benefits
  - Large branching ratio
  - No neutrino → no MET
  - Full kinematics available
- Challenges
  - Multi-jet background
  - Combinatorial background
  - Uncertainty from JES



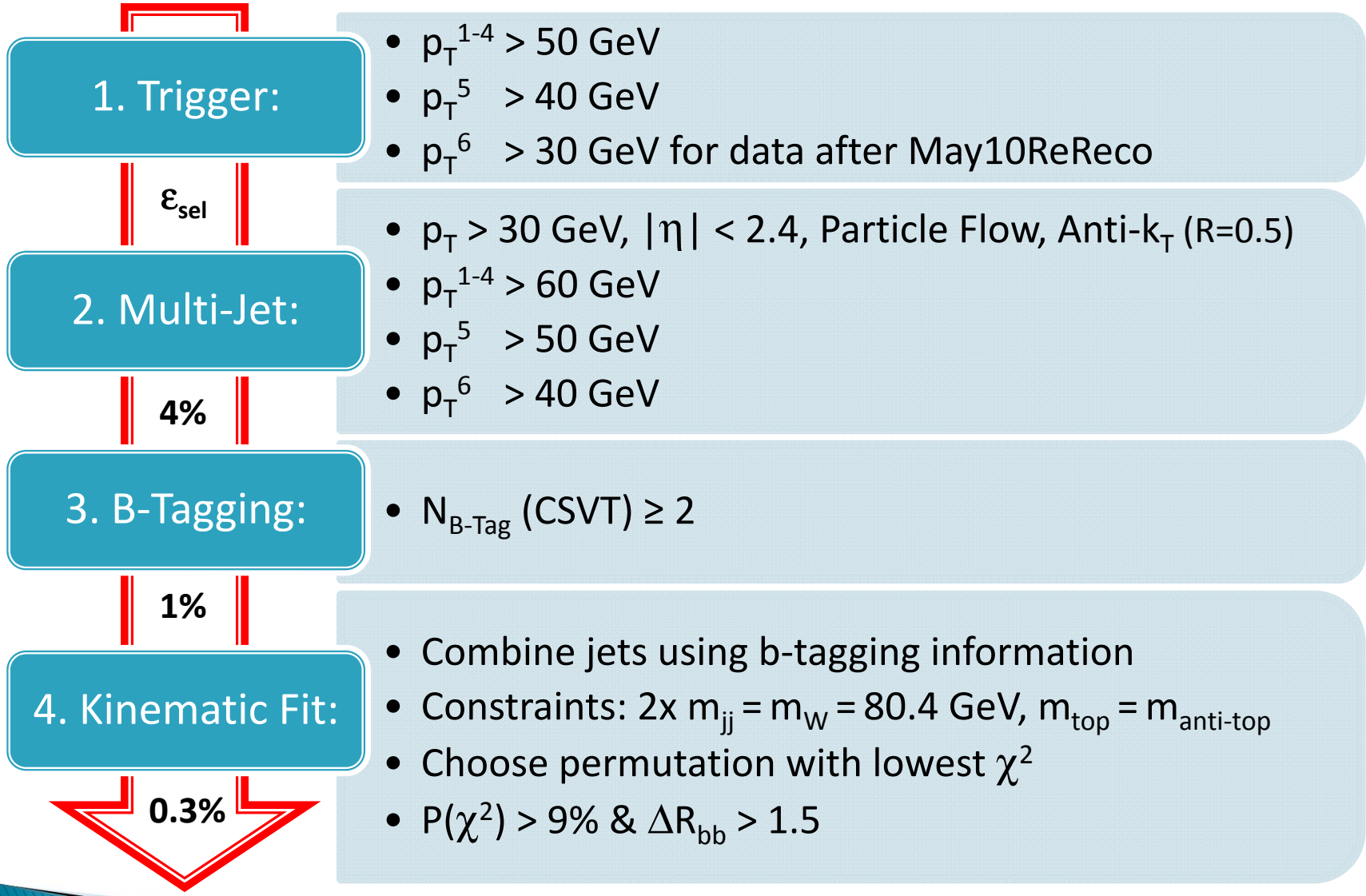
- Presented analysis:
  - TOP-11-017: Top-quark mass with all-jets final states

Data and Simulation

- Collision data
  - 3.54 fb^{-1} pp collisions @ $\sqrt{s}$ = 7 TeV (CMSSW 4.2)
  - Prescale corrected luminosity as prescaled triggers were necessary at the end of 2011 data taking

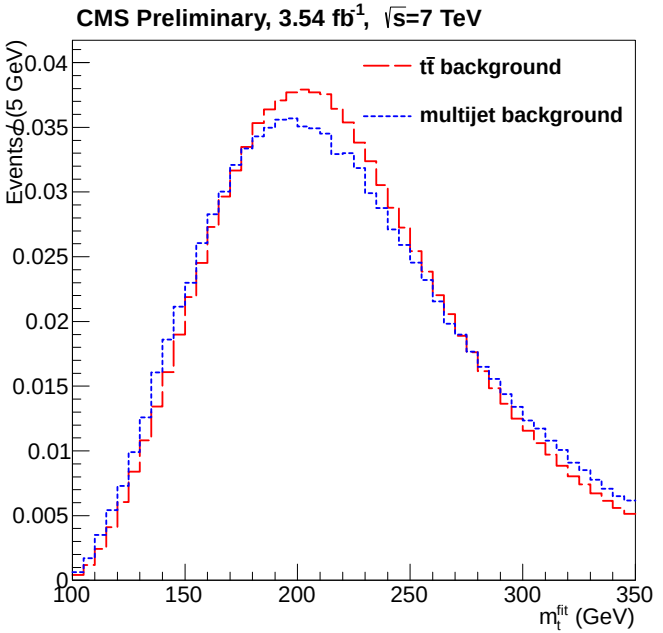
- Simulation
  - Madgraph $t\bar{t}$ sample with 9 masses and 3 JES (0.96,1.00,1.04)
  - Applied corrections to match data:
    - PU weighting
    - B-Tag scale factors
    - Jet energy resolution
    - Trigger efficiency scaling

Event Selection

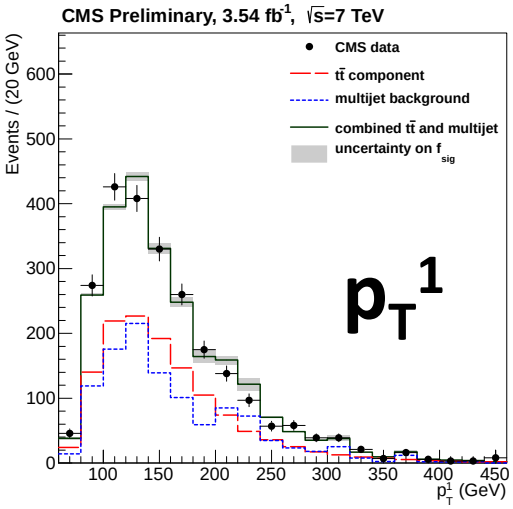


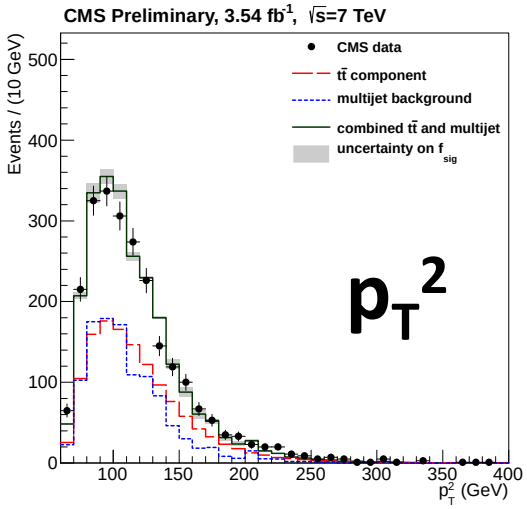
Background Modeling

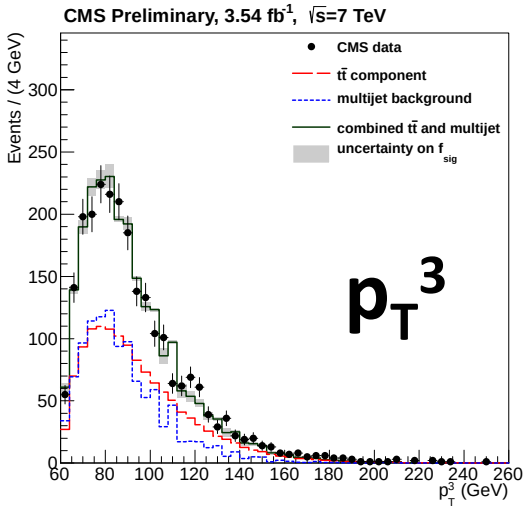
- Background for mass estimated using event mixing
  - Using all events after b-tagging requirement
    - Expected $t\bar{t}$ contamination: 20%
  - All jets in mixed events originate from different events
  - Uncertainty for modeling:
    - Compare to events mixed from $t\bar{t}$ simulation only

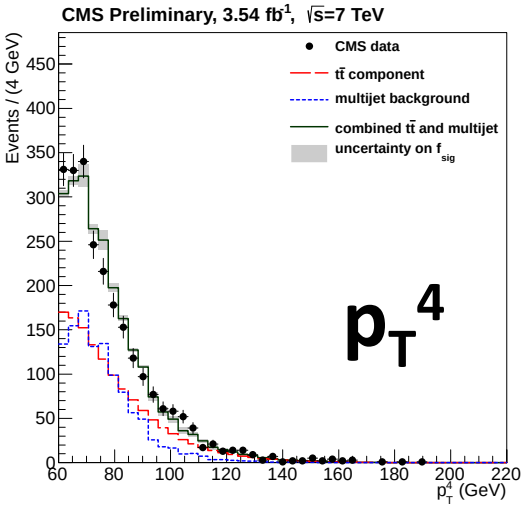


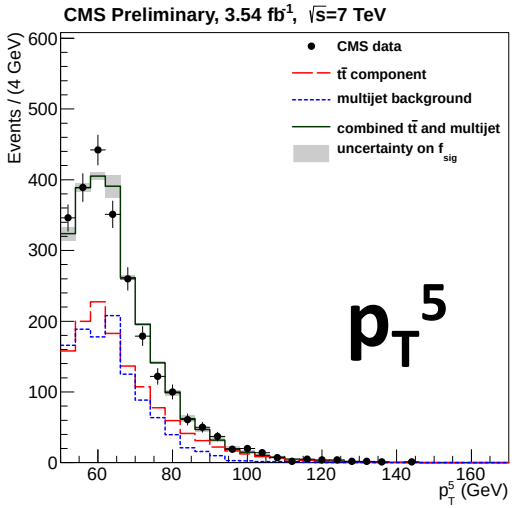
Validation Plots

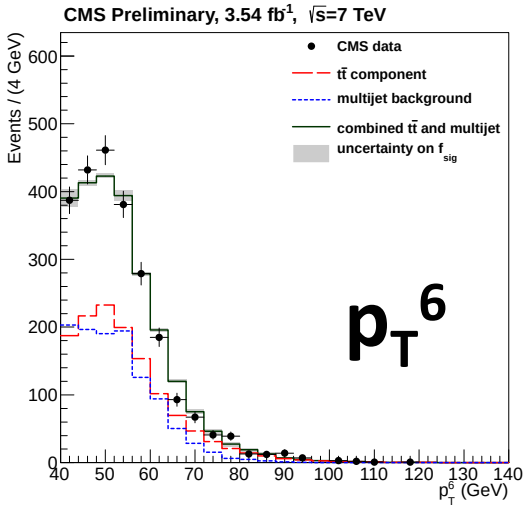




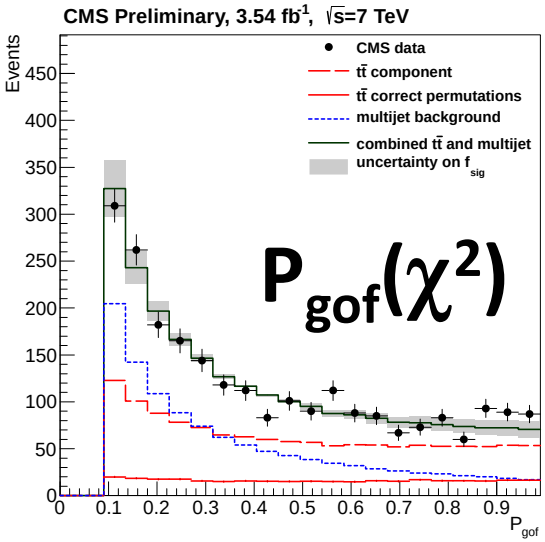


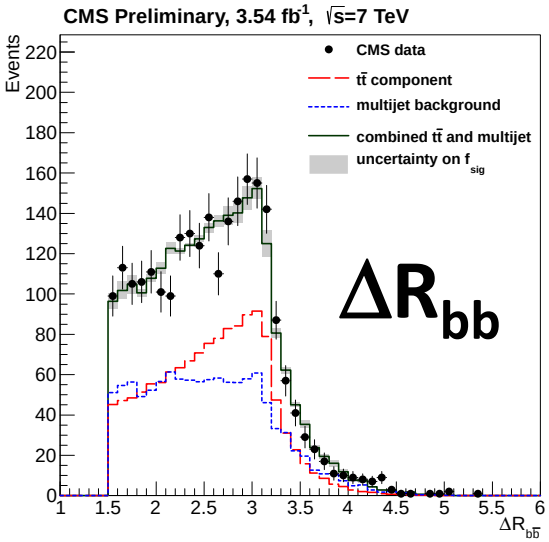


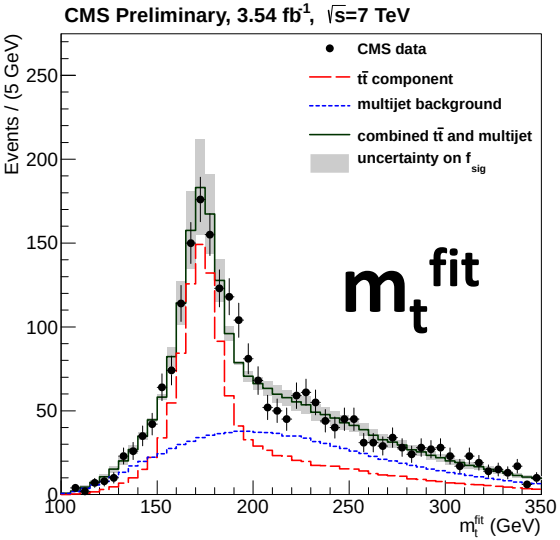


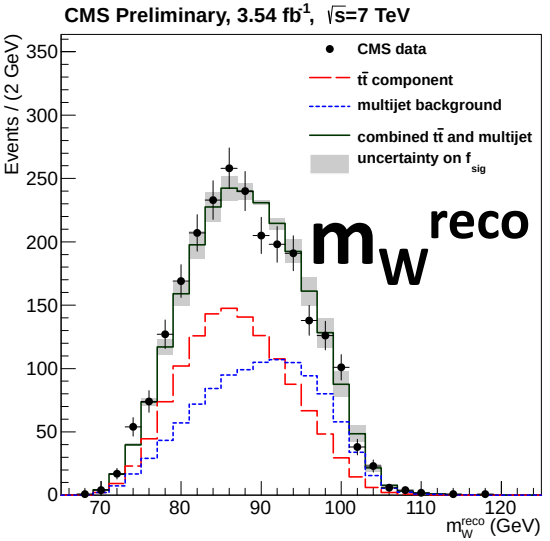


Plots


CMS Preliminary, 3.54 fb-1, √s=7 TeV
CMS data
tt̄ component
tt̄ correct permutations
multijet background
combined tt̄ and multijet
uncertainty on f sig
Events
P gof
P gof(χ2)

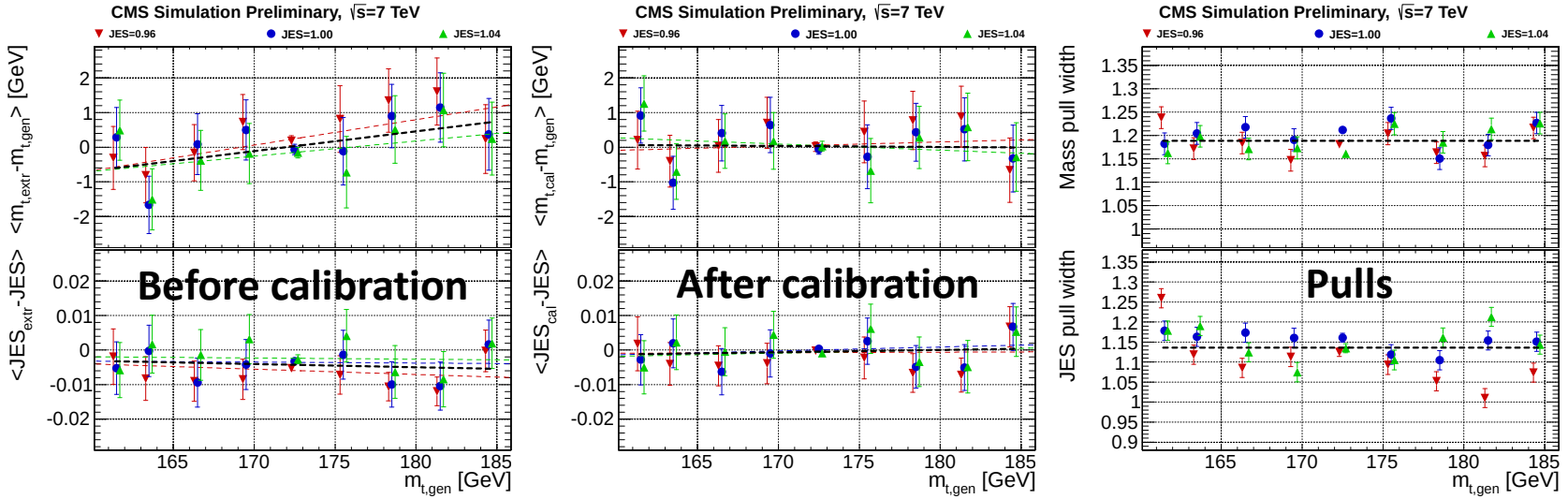

CMS Preliminary, 3.54 fb-1, √s=7 TeV
CMS data
tt̄ component
multijet background
combined tt̄ and multijet
uncertainty on f sig
Events
ΔR bb̄
ΔRbb


CMS Preliminary, 3.54 fb-1, √s=7 TeV
CMS data
tt̄ component
multijet background
combined tt̄ and multijet
uncertainty on f sig
Events / (5 GeV)
m t fit (GeV)
m t fit


CMS Preliminary, 3.54 fb-1, √s=7 TeV
CMS data
tt̄ component
multijet background
combined tt̄ and multijet
uncertainty on f sig
Events / (2 GeV)
m W reco (GeV)
m W reco

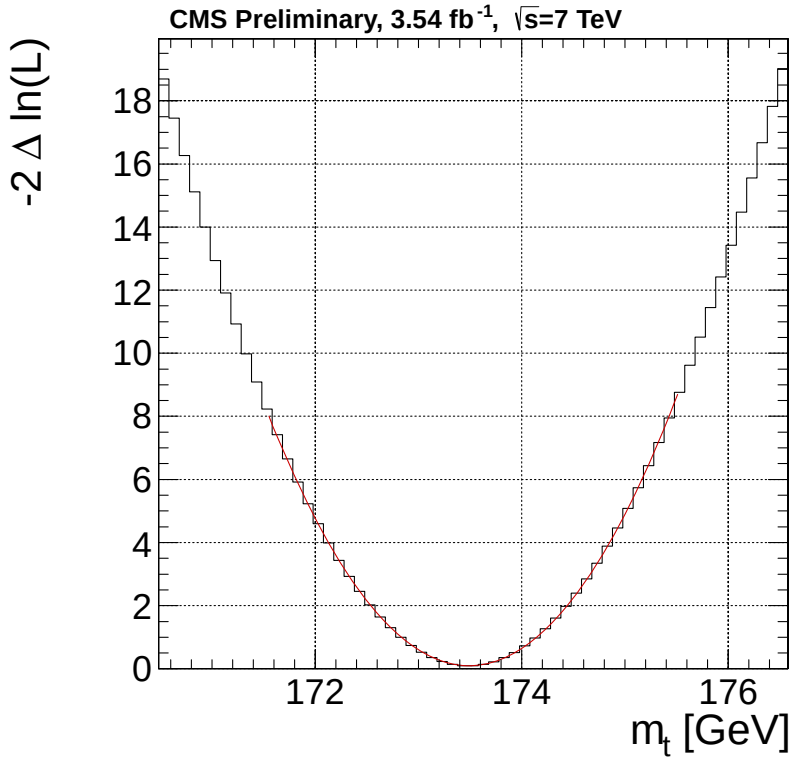
Ideogram Method

- Probability for a single event (only best permutation)
  - $\mathcal{L}(\text{event}|m_t, \text{JES}) = P\left(m_t{}^{fit}, m_W{}^{reco}\middle|m_t, \text{JES}\right) =$
    $f_{\text{sig}} \cdot \Sigma_j f_j P_j\left(m_t{}^{fit}\middle|m_t, \text{JES}\right) \cdot P_j(m_W{}^{reco}|m_t, \text{JES})$
    $+(1-f_{\text{sig}}) \cdot P_{\text{bkg}}\left(m_t{}^{fit}\right) \cdot P_{\text{bkg}}(m_W{}^{reco}),$
- Most likely m_t and JES
  - $\mathcal{L}(m_t, \text{JES}|\text{sample}) \sim \Pi_{\text{events}} \mathcal{L}(\text{event}|m_t, \text{JES})^{w_{event}}$

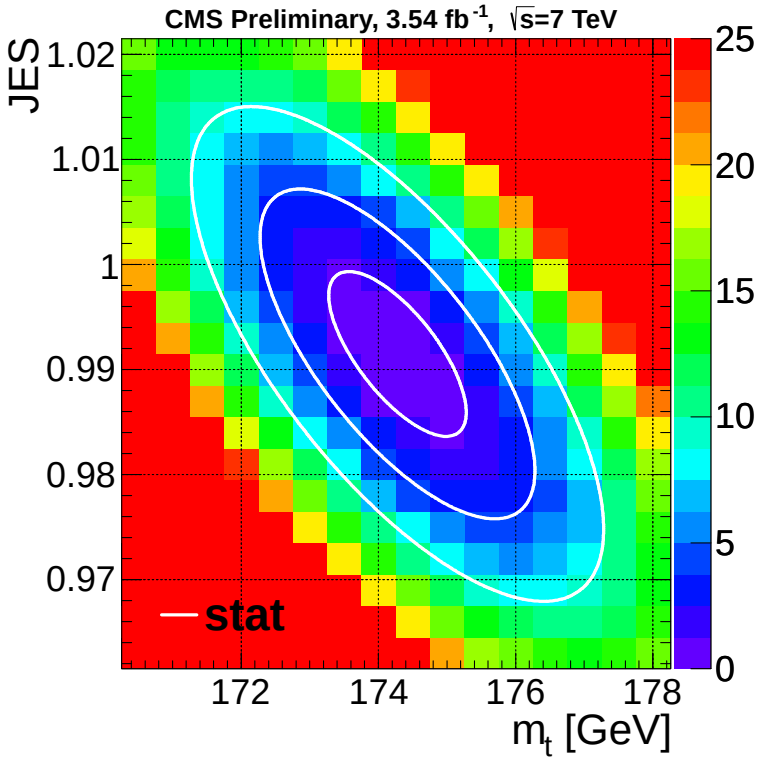


Likelihoods on data

1D: $\mathcal{L}(m_t, JES=1|sample)$



2D: $\mathcal{L}(m_t, JES|sample)$



Uncertainties

- $\delta = \max(\delta^{up}, \delta^{down}, \sigma_\delta)$

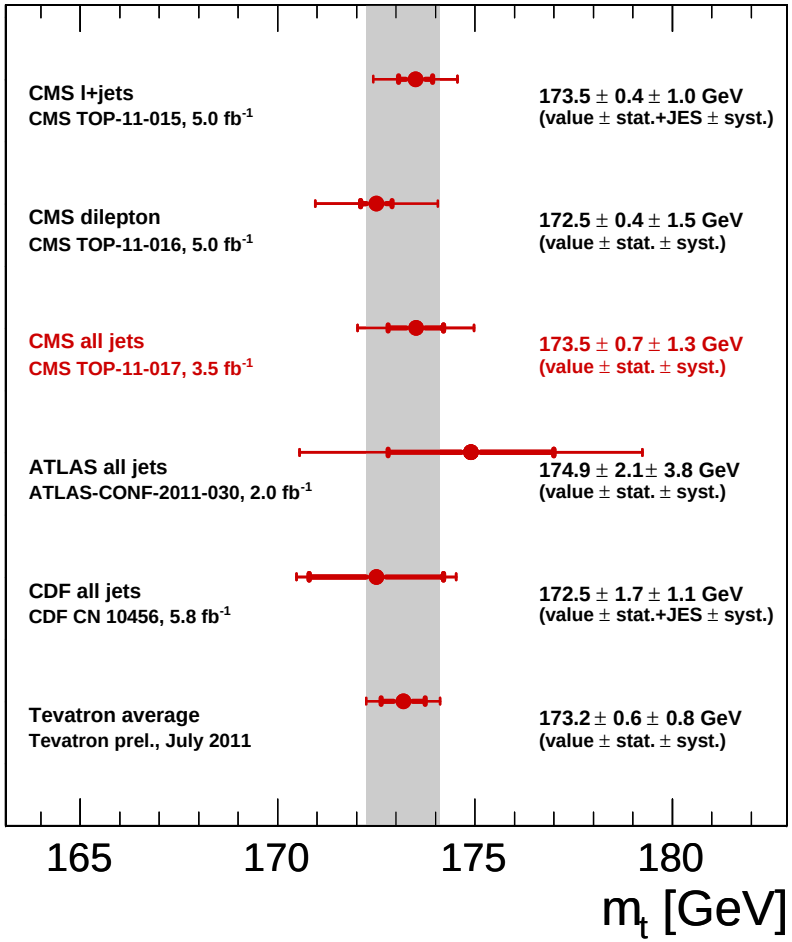
	1-D analysis	2-D analysis	
	δ_{m_t} (GeV)	δ_{m_t} (GeV)	δ_{JES}
Fit calibration	**0.13**	**0.14**	**0.001**
Jet energy scale	**0.97** $\pm$ 0.06	0.09 $\pm$ **0.10**	**0.002** $\pm$ 0.001
b-JES	**0.49** $\pm$ 0.06	**0.52** $\pm$ 0.10	**0.001** $\pm$ 0.001
Jet energy resolution	**0.15** $\pm$ 0.06	**0.13** $\pm$ 0.10	**0.003** $\pm$ 0.001
b tagging	0.05 $\pm$ **0.06**	0.04 $\pm$ **0.10**	**0.001** $\pm$ 0.001
Trigger	**0.24** $\pm$ 0.06	**0.26** $\pm$ 0.10	**0.006** $\pm$ 0.001
Pileup	0.05 $\pm$ **0.06**	0.09 $\pm$ **0.10**	**0.001** $\pm$ 0.001
Parton distribution functions	0.03 $\pm$ **0.06**	0.07 $\pm$ **0.10**	**0.001** $\pm$ 0.001
Q^2 scale	0.08 $\pm$ **0.22**	0.31 $\pm$ **0.34**	**0.005** $\pm$ 0.003
ME-PS matching threshold	**0.24** $\pm$ 0.22	0.29 $\pm$ **0.34**	0.001 $\pm$ **0.003**
Underlying event	**0.32** $\pm$ 0.15	**0.88** $\pm$ 0.26	**0.007** $\pm$ 0.002
Color reconnection effects	0.04 $\pm$ **0.15**	**0.58** $\pm$ 0.25	**0.006** $\pm$ 0.002
Non-$t\bar{t}$ background	**0.20** $\pm$ 0.06	**0.62** $\pm$ 0.10	**0.008** $\pm$ 0.001
Total	1.25	1.46	0.015

Top-Quark Mass

- Measured top-quark mass in all-jets final states:
  - 1D measurement:

$173.49 \pm 0.69 \pm 1.25$ GeV
(m_t ± stat. ± syst.)
$\delta m_t = 1.43$ (total) GeV

  - 2D measurement incl. JES fit:
    - $174.28 \pm 1.00 \pm 1.46$ GeV
      (m_t ± stat.+JES ± syst.)
      $0.991 \pm 0.008 \pm 0.015$
      (JES ± stat. ± syst.)

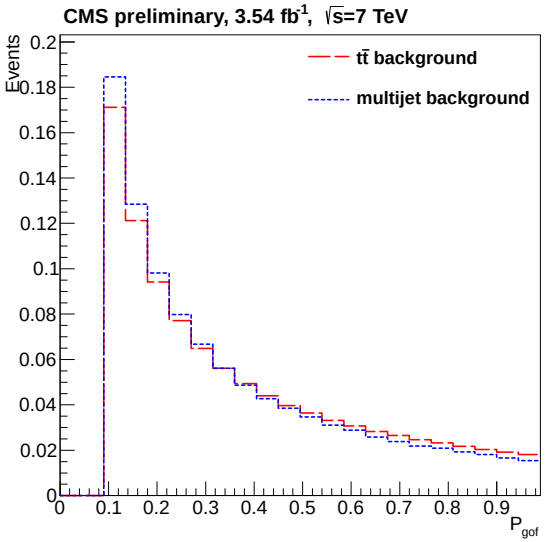


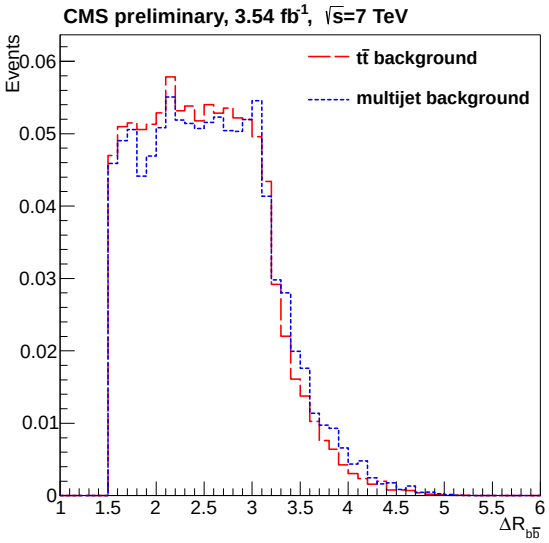
Back Up

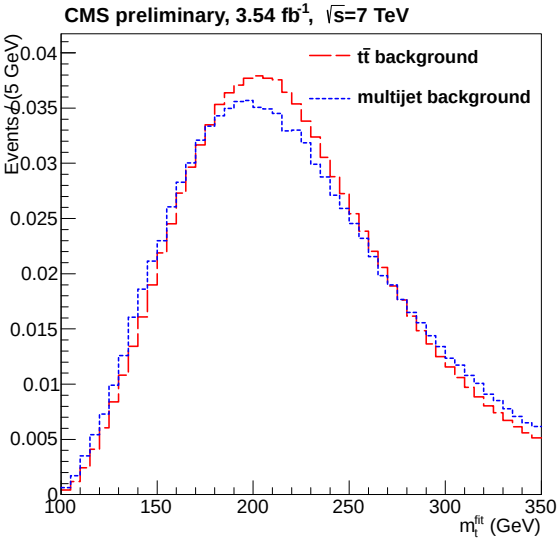
Uncertainty Sources

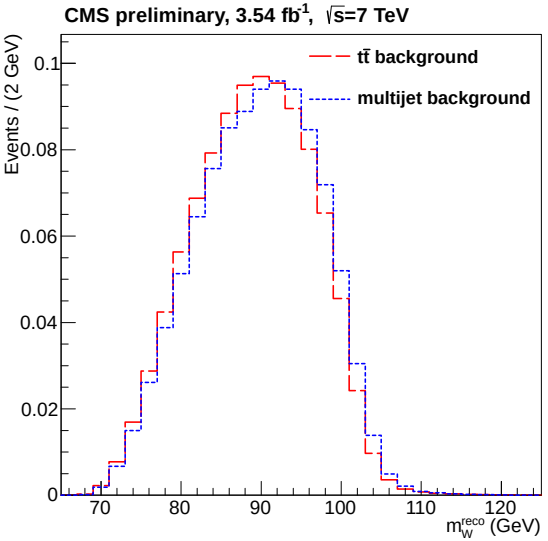
- Fit calibration:
  - Statistical uncertainty on calibration fit
- Jet energy scale:
  - Scale jet energies $\pm 1\sigma_{\text{overall}}$
- b-JES:
  - Scale b-jet energies $\pm 1\sigma_{\text{flavor}}$
- JER:
  - Scale jet energy resolution $\pm 1\sigma$
- b-tagging:
  - Vary CSVT working point so that efficiency changes by ± 3%
- Trigger:
  - Vary 4^{th}, 5^{th} and 6^{th} p_t threshold up by 2 GeV
- Pileup:
  - Shift average number of PU events ±5%
- Parton distribution functions:
  - Uncertainty on CTEQ 6.5 PDF
- Q^2 scale, ME-PS matching threshold:
  - Dedicated MC samples, varied by factors 0.5 and 2
- Underlying event, color reconnection effects:
  - Dedicated MC samples (P11-FastSim vs. P11TeV-FastSim & P11mpiHi-FastSim, P11 vs. P11noCR)
- Non-$t\bar{t}$ background:
  - Vary signal fraction from 44% to 64%
  - Vary background model from data (20% $t\bar{t}$ contamination) to $t\bar{t}$ MC (100% $t\bar{t}$ contamination)

Comparison


CMS preliminary, 3.54 fb-1, √s=7 TeV
tt̄ background
multijet background
Events
Pgof

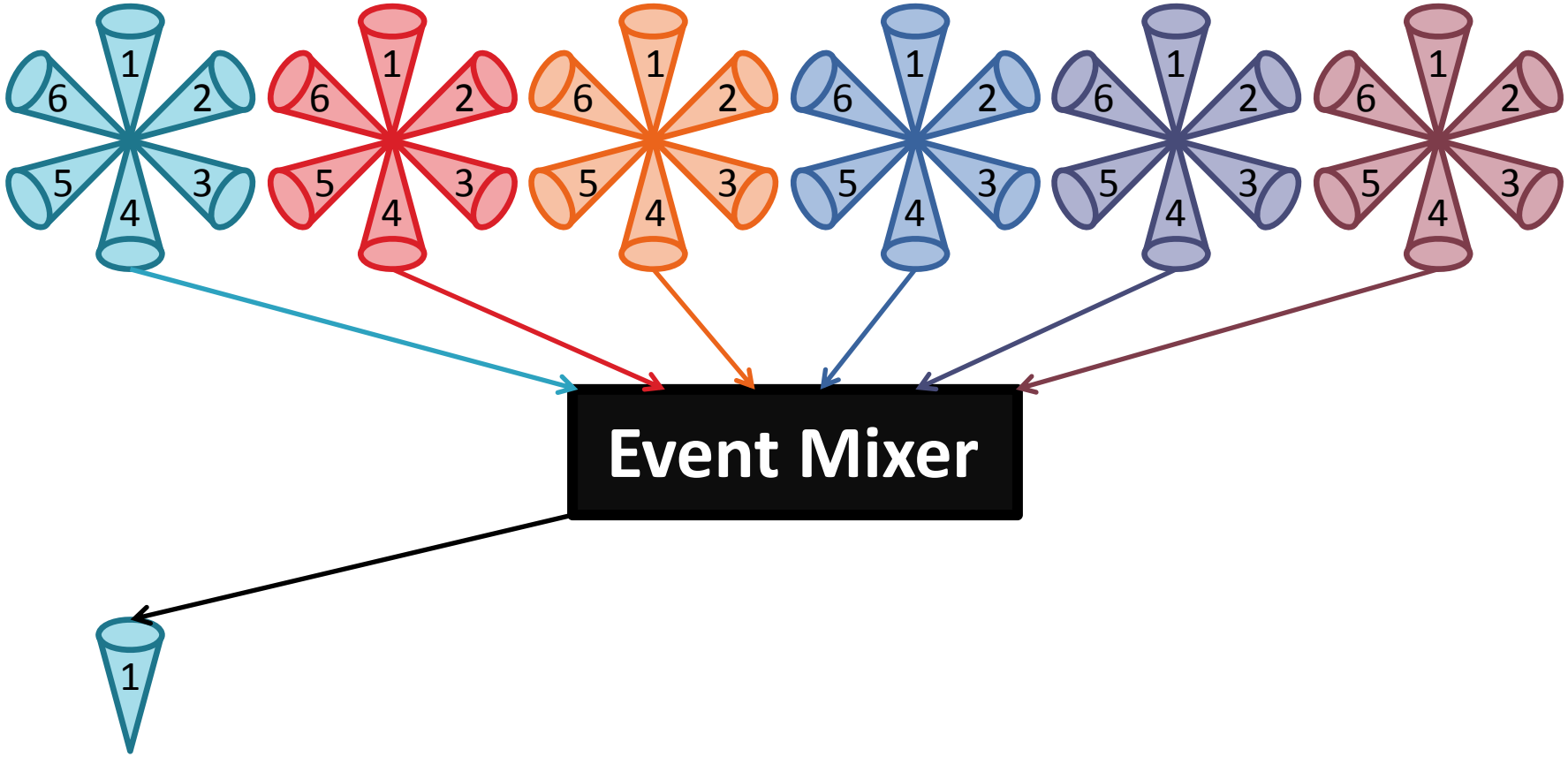

CMS preliminary, 3.54 fb-1, √s=7 TeV
tt̄ background
multijet background
Events
ΔRbb̄


CMS preliminary, 3.54 fb-1, √s=7 TeV
tt̄ background
multijet background
Events/(5 GeV)
mtfit (GeV)

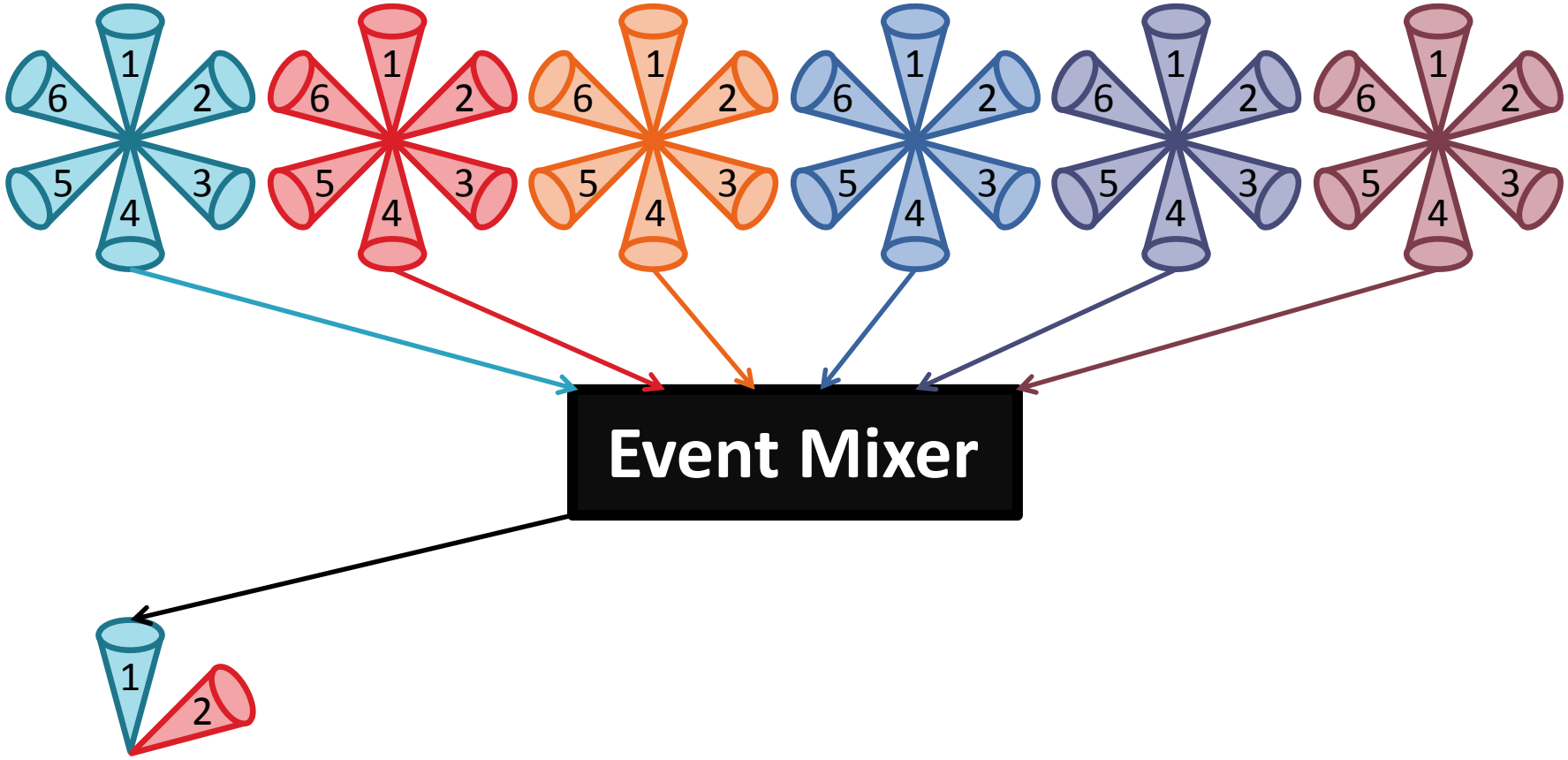

CMS preliminary, 3.54 fb-1, √s=7 TeV
tt̄ background
multijet background
Events / (2 GeV)
mWreco (GeV)

Event Mixing

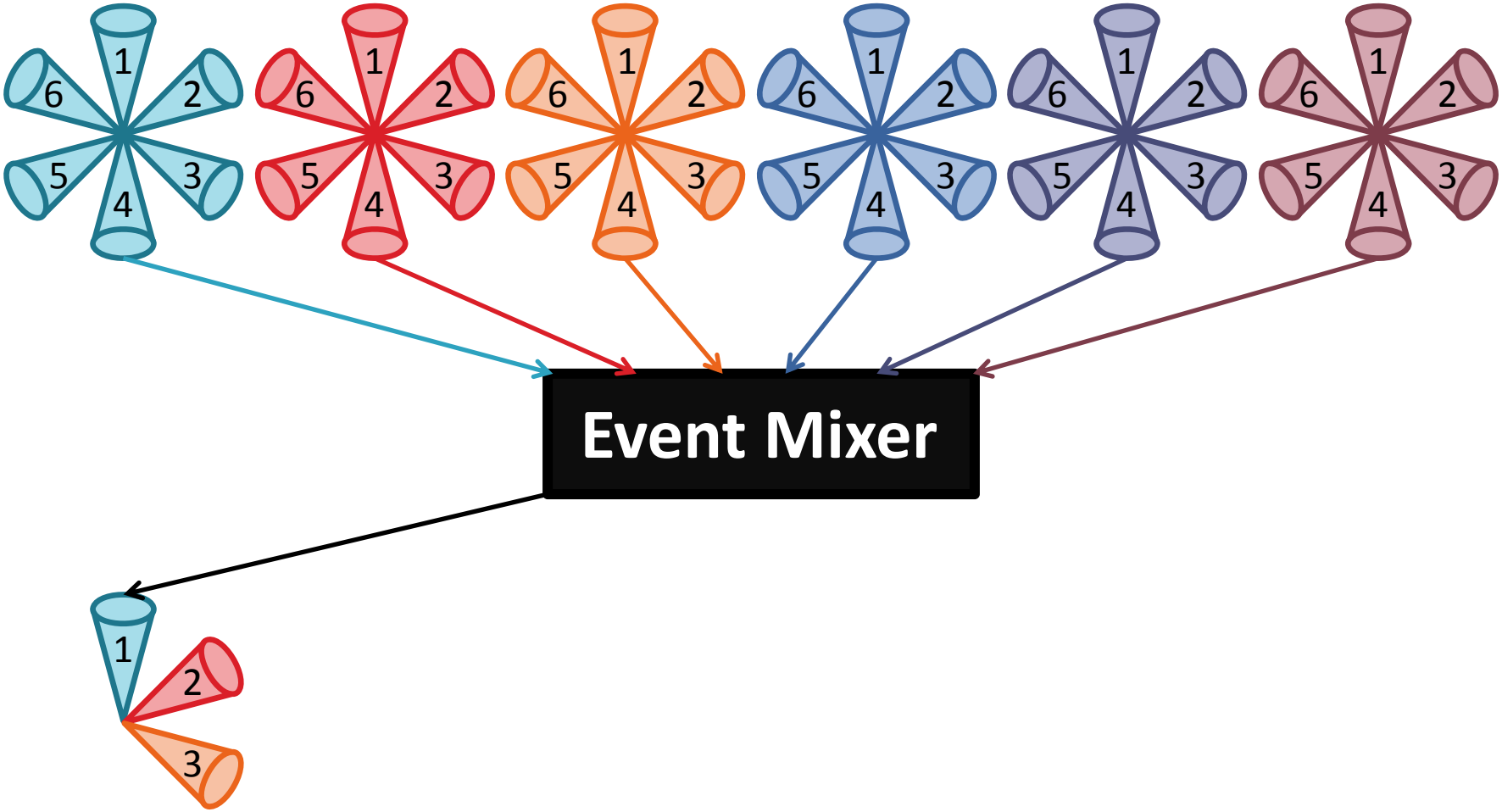
Event Mixing



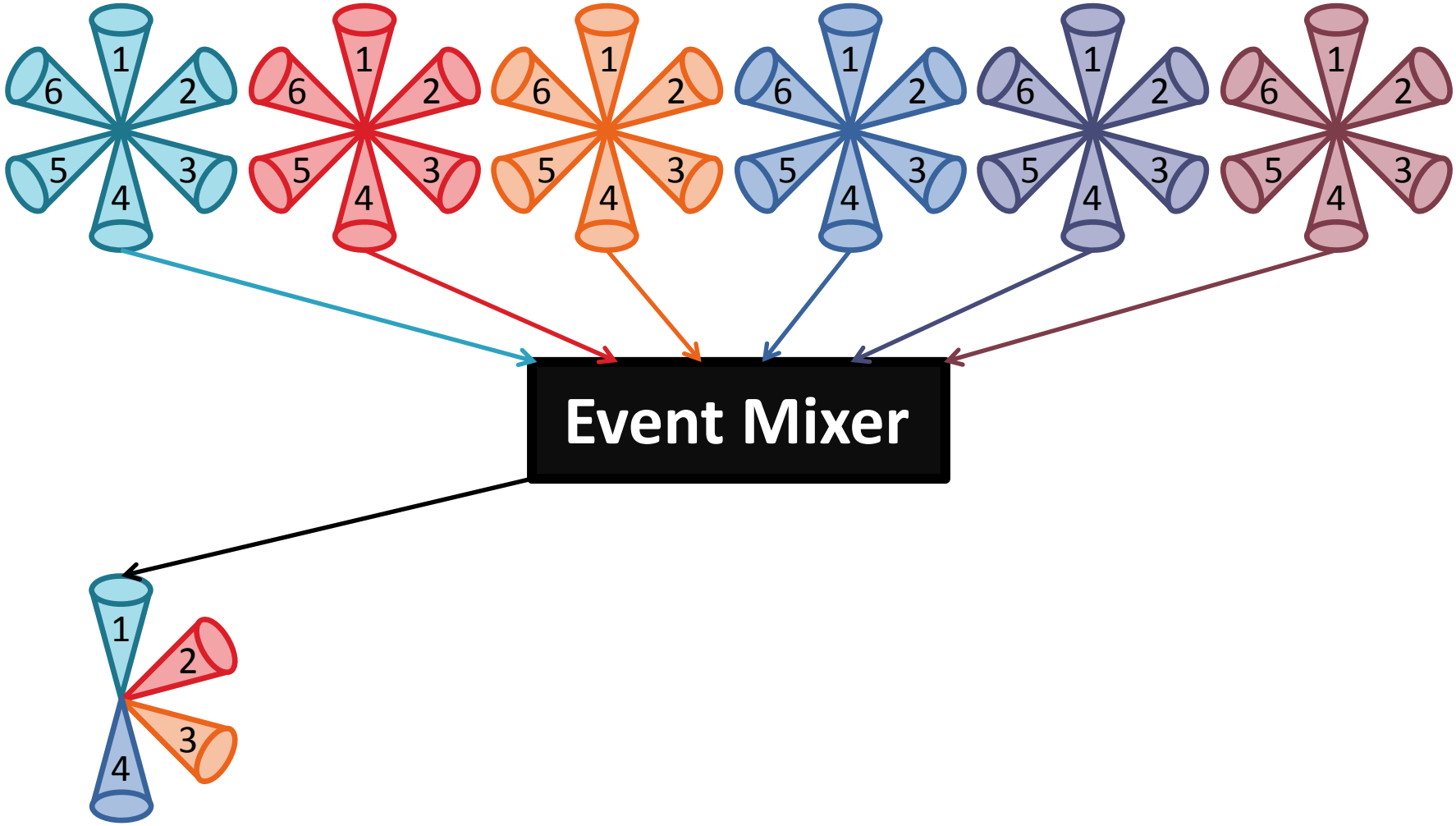
Event Mixing



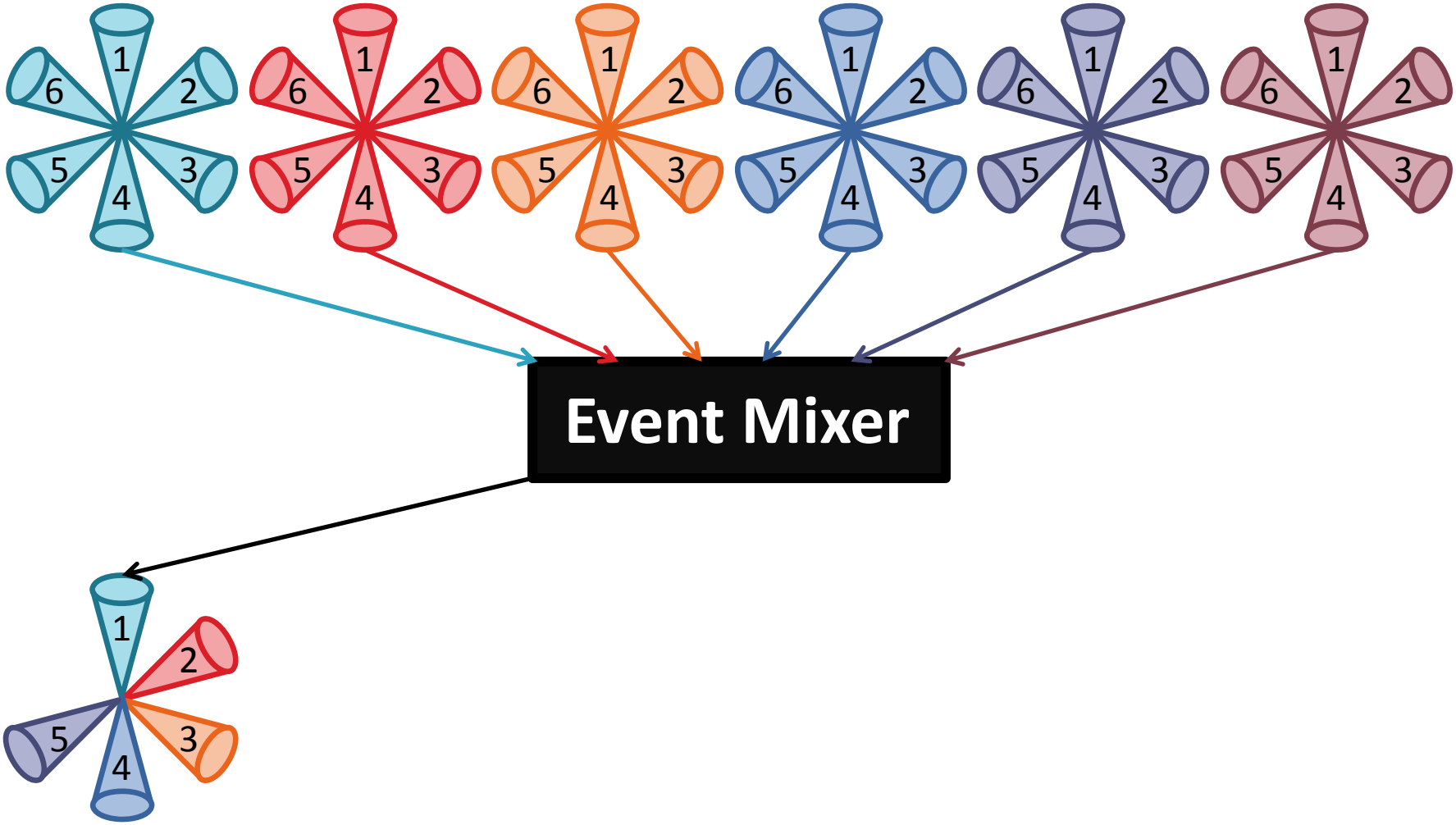
Event Mixing



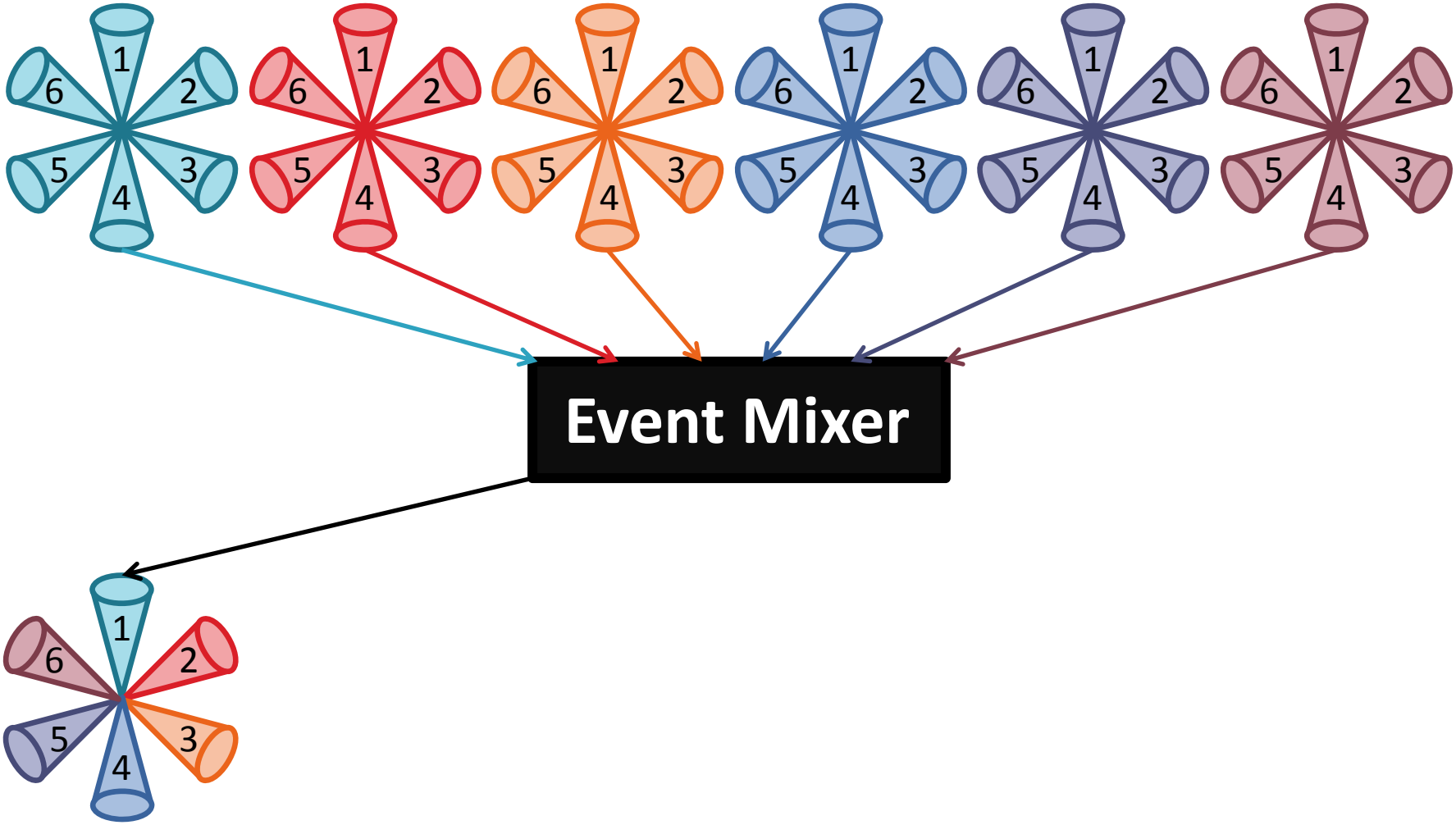
Event Mixing



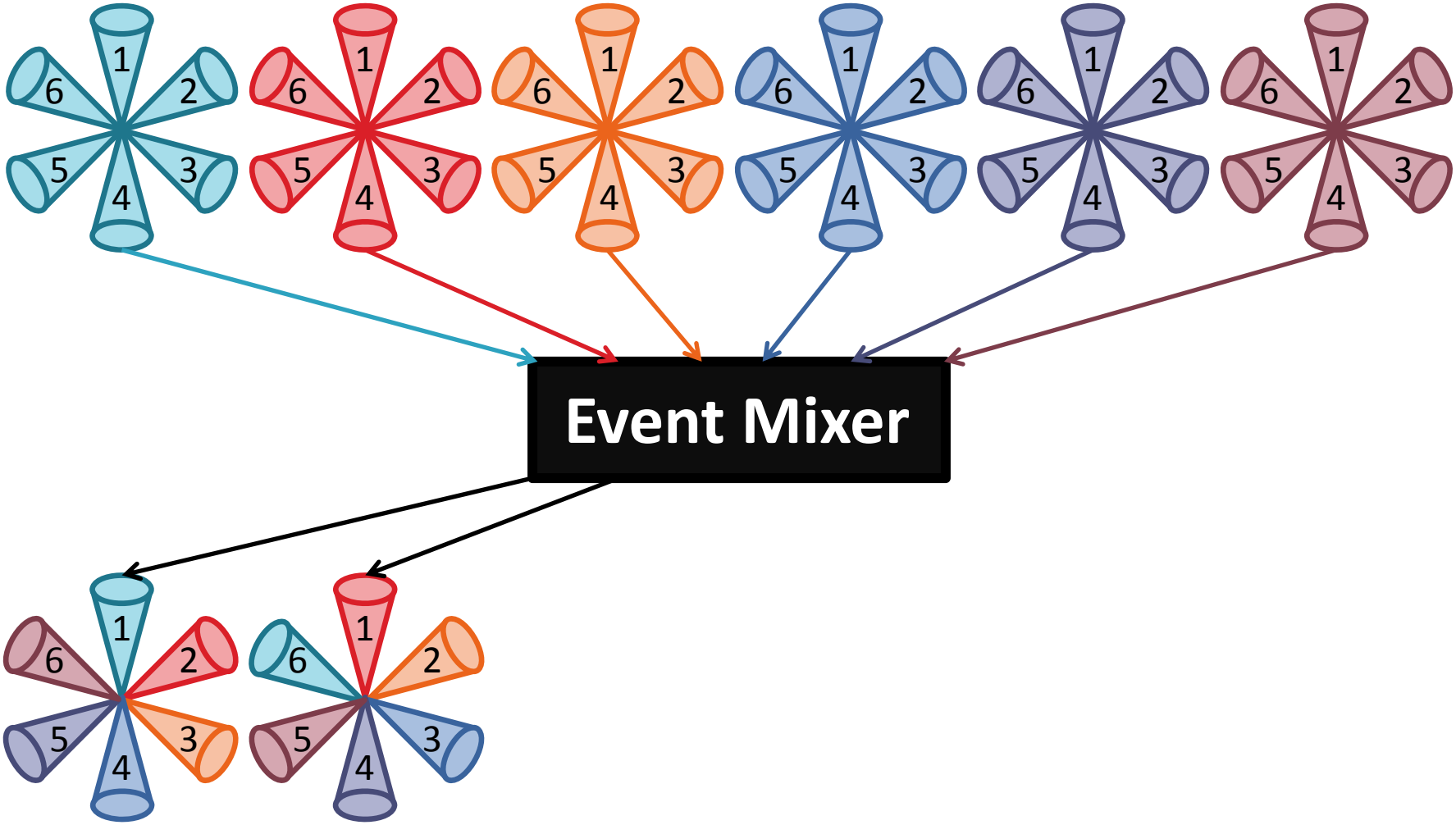
Event Mixing



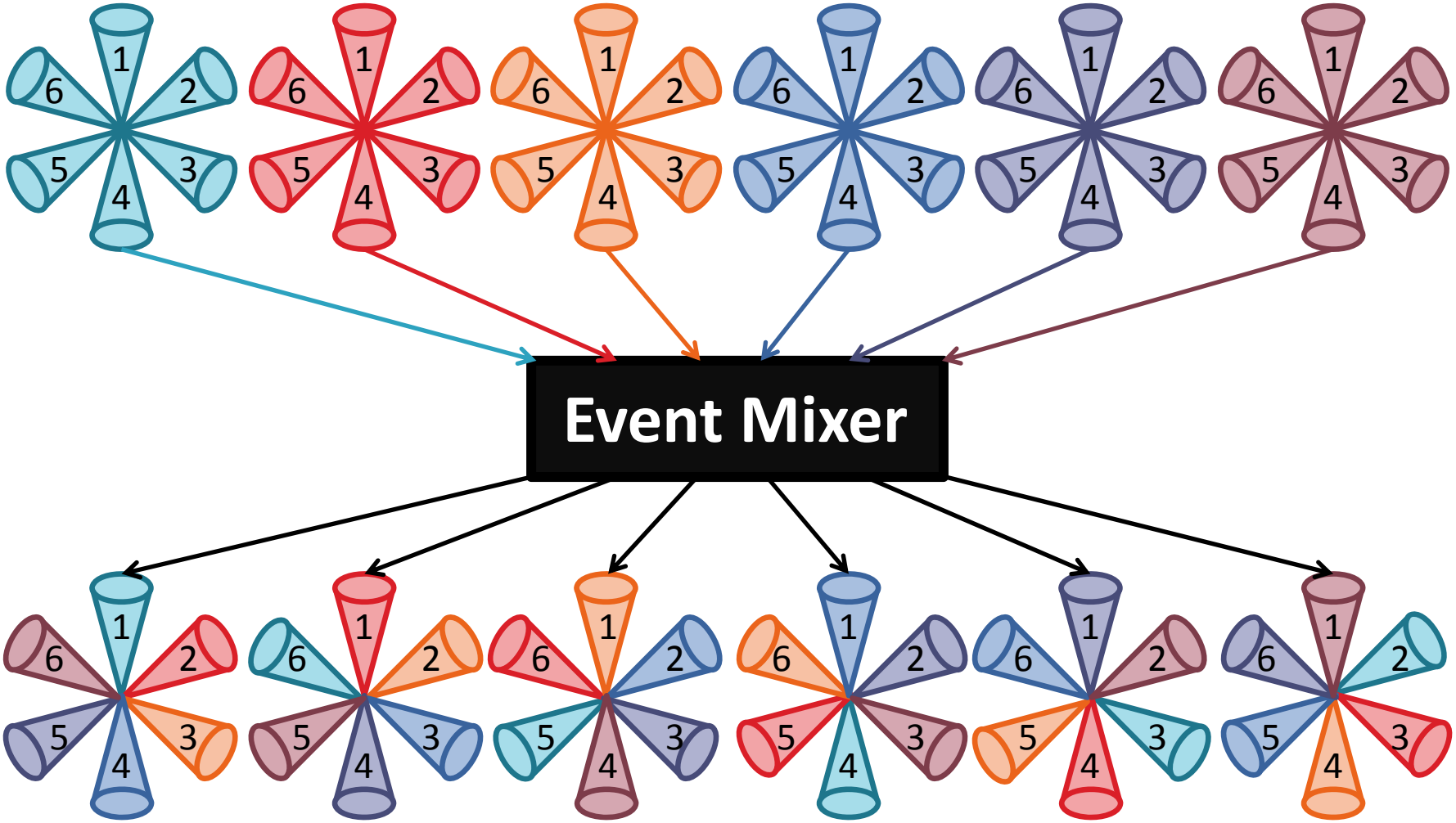
Event Mixing



Event Mixing



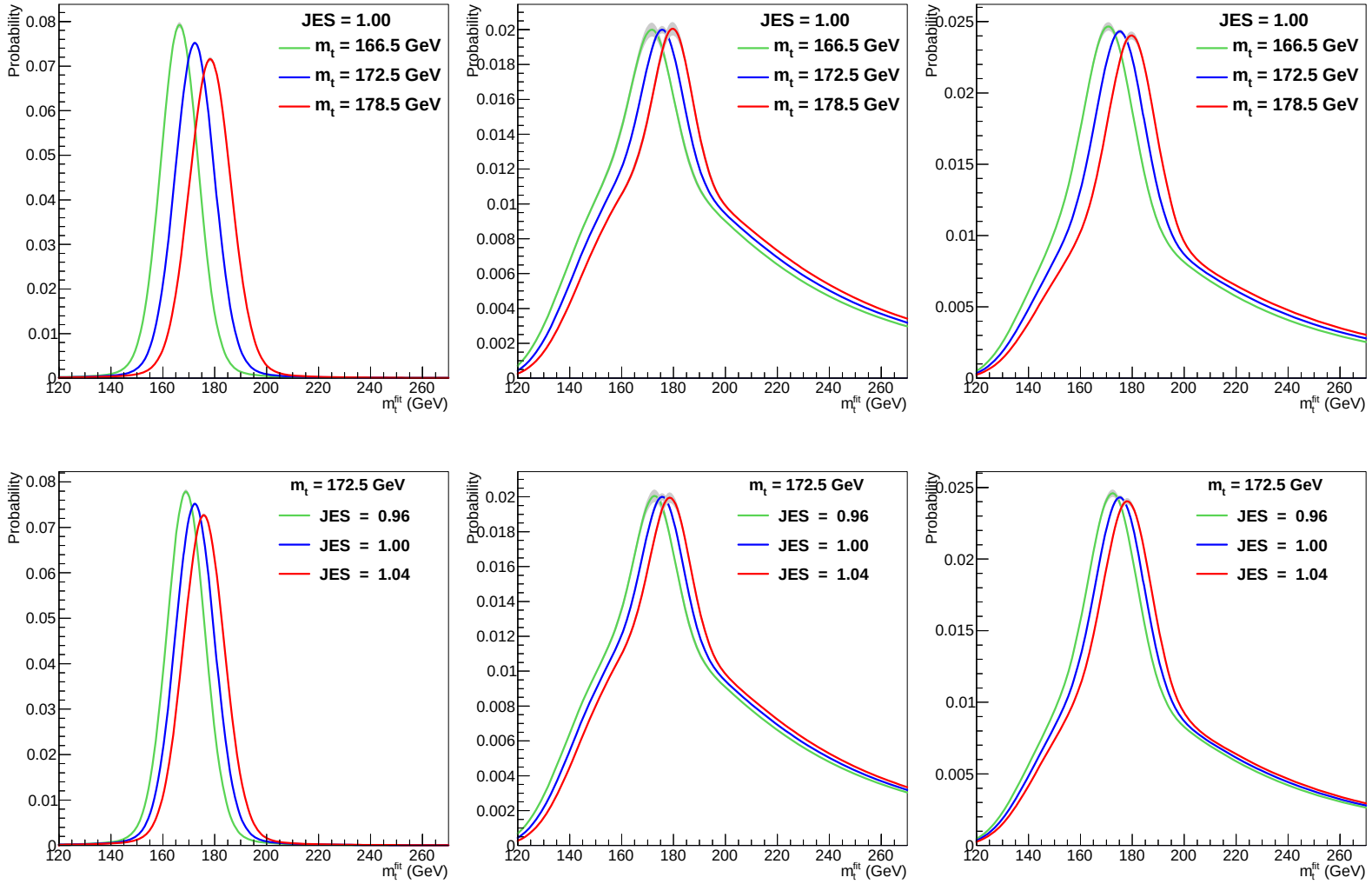
Event Mixing



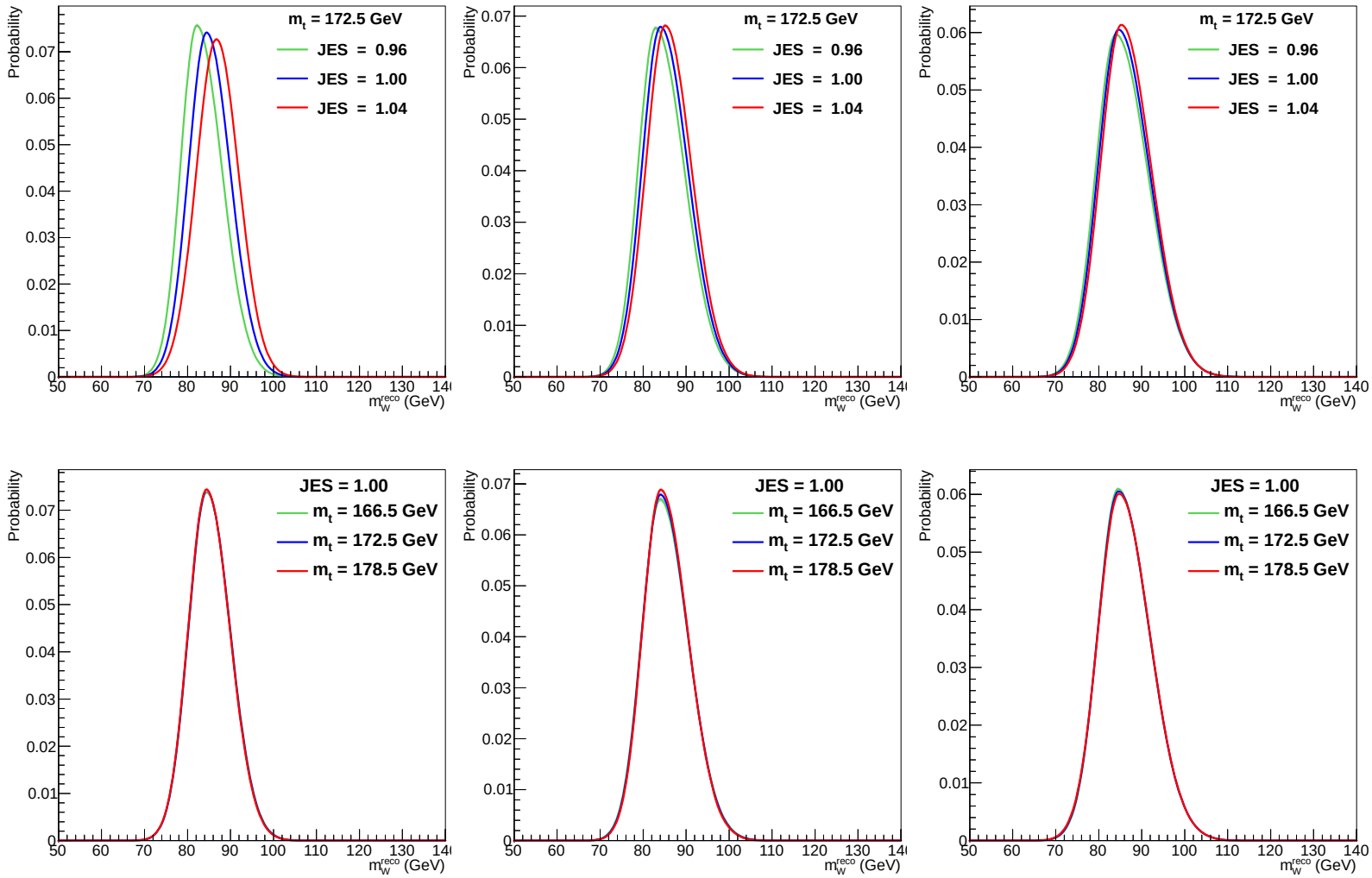
Templates I

- Distinguish 3 different types of permutations (found via jet-parton matching on MC)
  - Correct: 27.9%
  - Wrong: 22.6% (mainly missing a jet)
  - Unmatched: 49.4% (using unambiguousOnly algorithm)
- Weight events by $P(\chi^2)$ to increase significance
  - Correct: 30.1%
  - Wrong: 24.5%
  - Unmatched: 45.4%
- Functions used:
  - Voigtian for m_t correct permutations
  - Landau+Gaussian (with common mean) for remaining m_t
  - Asymmetric Gaussian for mean m_W

Templates II



Templates III



Templates IV

- Parameterization of background:
  - Gamma + Landau for m_t
  - Asymmetric Gaussian for mean m_W