Jet Substructure

Nick Amin

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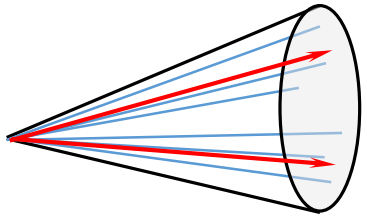
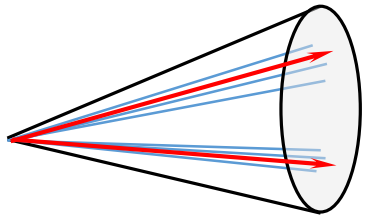
N-subjettiness

- Given *N* subjet axes in a fat jet, N-subjettiness, τ_N, is given by
  - $\tau_N = \frac{1}{d_0}\sum_k p_{T,k}\min\{\Delta R_{1,k}, \Delta R_{2,k}, \ldots, \Delta R_{N,k}\}$
    - $\Delta R_{N,k}$ is the angular separation between constituent *k* and candidate subjet *N*
    - d_0 is a normalization factor given by $d_0 = \sum_k p_{T,k} R_0$, so $0 \leq \tau_N \leq 1$
    - $R_0 = 0.8$ for AK8 clustering



High τ_2 (consitutents spread out)



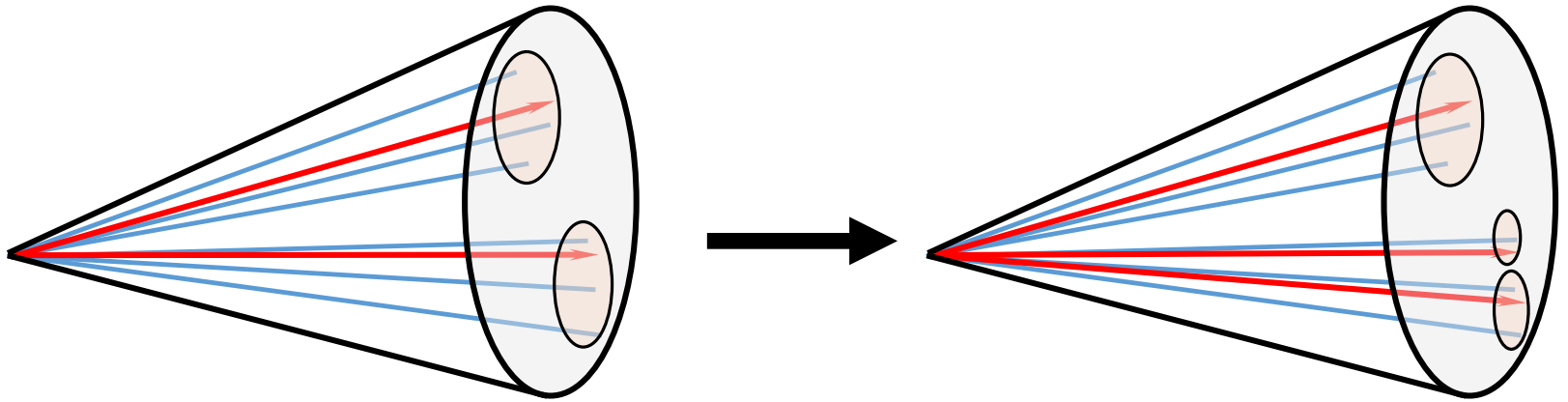
Low τ_2 (constituents close to subjet axes)

Clusters with exactly *N* subjets will have small τ_N

If $\tau_N \approx 1$, cluster most likely has more than *N* subjets

N-subjettiness

- When comparing N-subjetiness with (N+1)-subjettiness, adding extra candidate subjet allows minimum angular separation to decrease
- Thus, in most cases, $\tau_1 > \tau_2 > \tau_3$.
- Ratio $\tau_{NM} = \tau_N/\tau_M$, where *N=M+1*, is useful



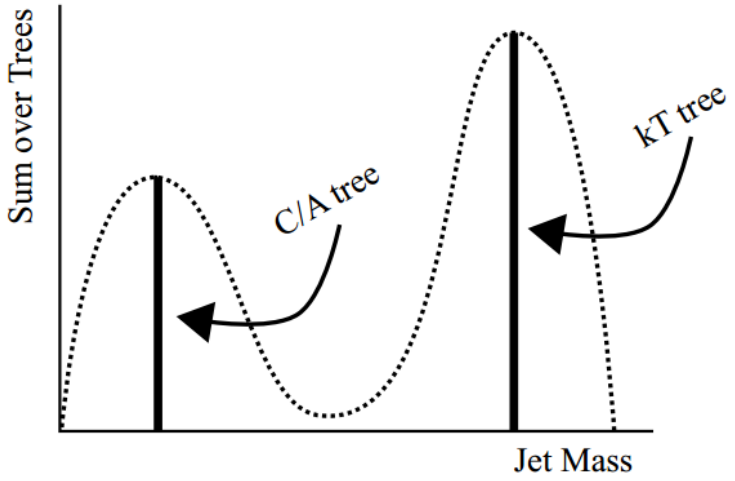
$\boldsymbol{\tau_2}$ $>$ $\boldsymbol{\tau_3}$

Clusters with small τ_{NM} most likely have *N* subjets.

We can use this quantity for cuts.

Q-jets Volatility

- Associate clustering history (“tree”) with jets
  - Depending on the route (AK8-like, CA8-like, etc.) taken to get a jet, the mass can change, so you get a mass **distribution** for a jet when considering the space of possible trees
- For a pruned jet mass distribution, define **volatility** as $V = \frac{\sqrt{\langle m^2 \rangle - \langle m \rangle^2}}{\langle m \rangle}$
  - Physically, dependence of jet mass on clustering method governs volatility (large mass fluctuations over different algorithms/routes means the jet is **volatile**/fuzzy)



A. Hornig

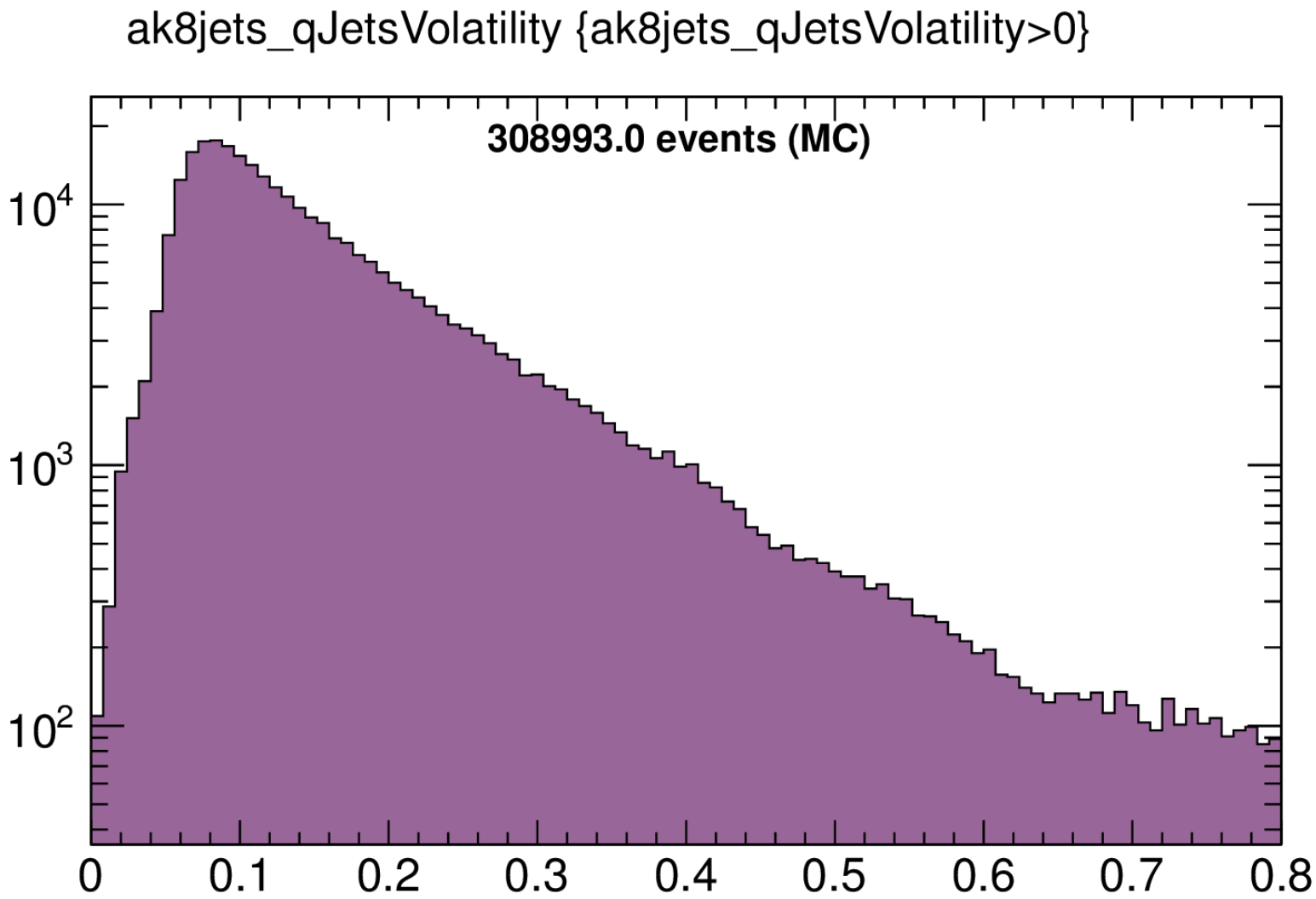
Jet Toolbox

- Jet toolbox available at https://twiki.cern.ch/twiki/bin/viewauth/CMS/JetToolbox
  - Takes miniAOD (or AODSIM) and adds various substructure branches
  - ~0.1 Hz for miniAOD→miniAOD+substructure
- For AK8, it includes:
  - Q-jets Volatility
  - N-subjettiness (τ_1, τ_2, τ_3)
  - Masses of pruned, trimmed, filtered jets
  - Top-tagged jet mass
    - If an ungroomed jet is matched to top-tagged jet, this branch is filled with the jet mass

Current Setup

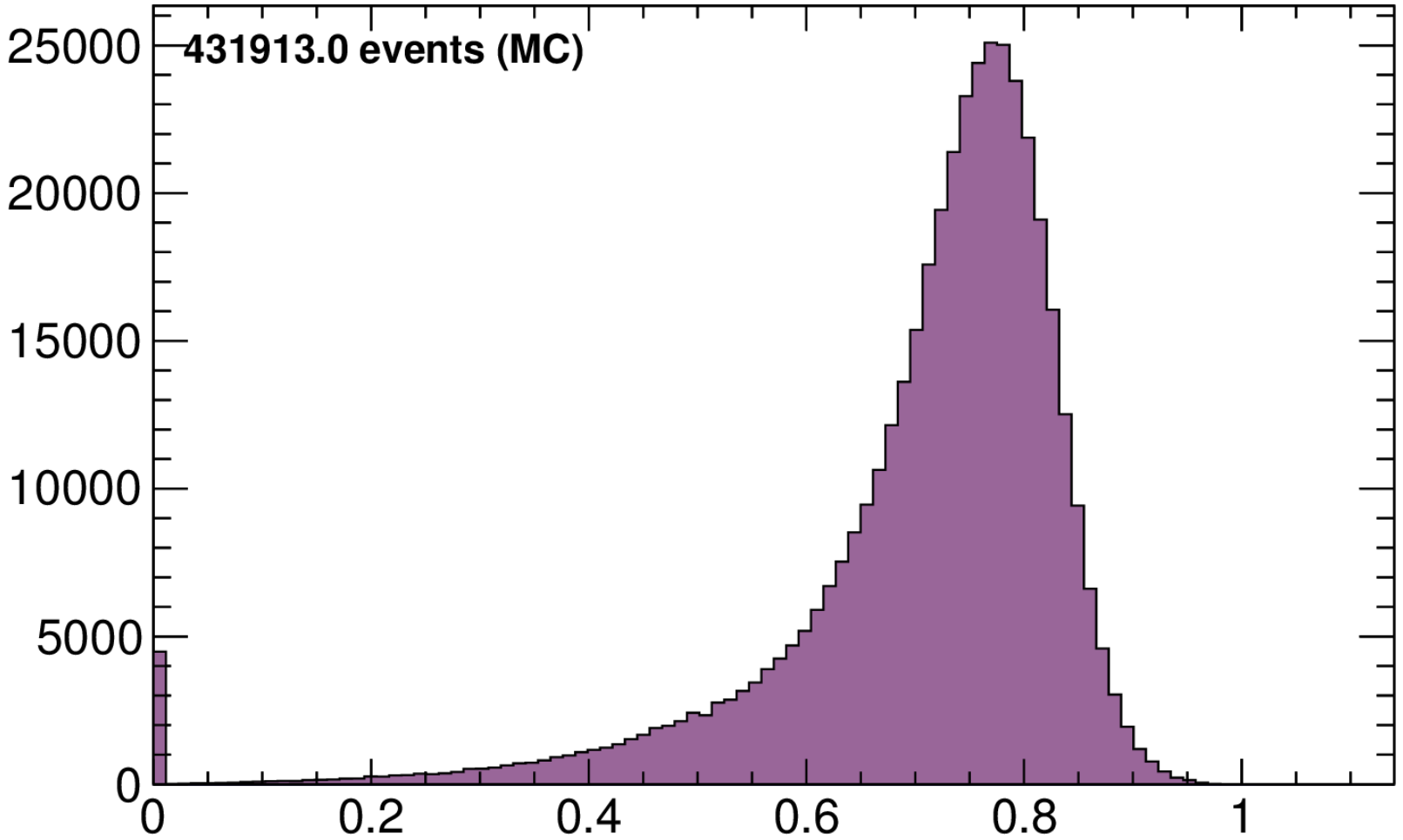
- Have 10k-event T2tt sample from Alex (m_{stop} = 850, m_{LSP} = 100)
- Added “SubJetMaker” to CMS3 makers, which adds substructure variables from toolboxed miniAOD
- Preliminary distributions of substructure variables follow
  - Working on meaningful distributions in my previous framework, along with same plots with AK8 instead of AK5

Q-jets Volatility

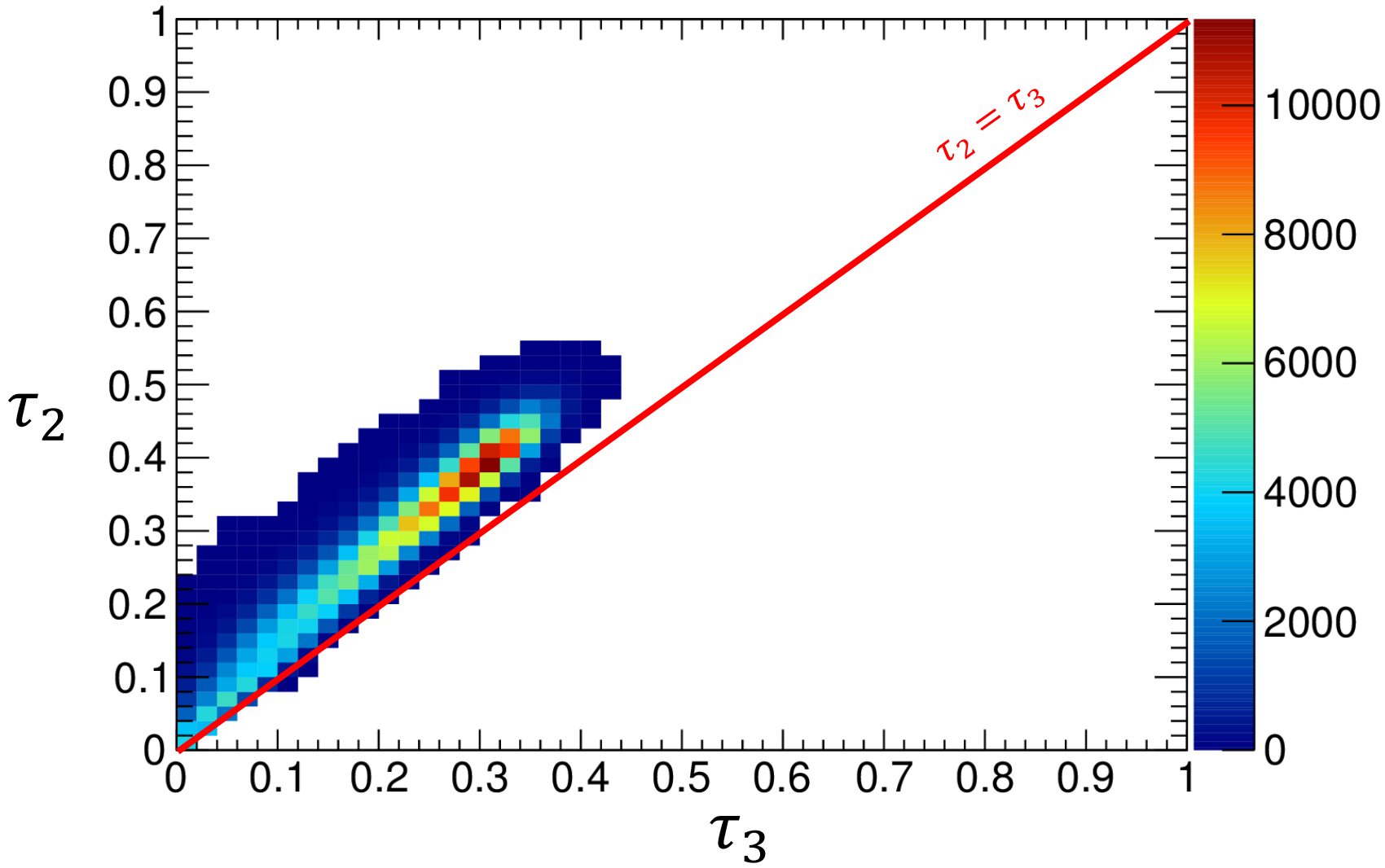


N-subjettiness

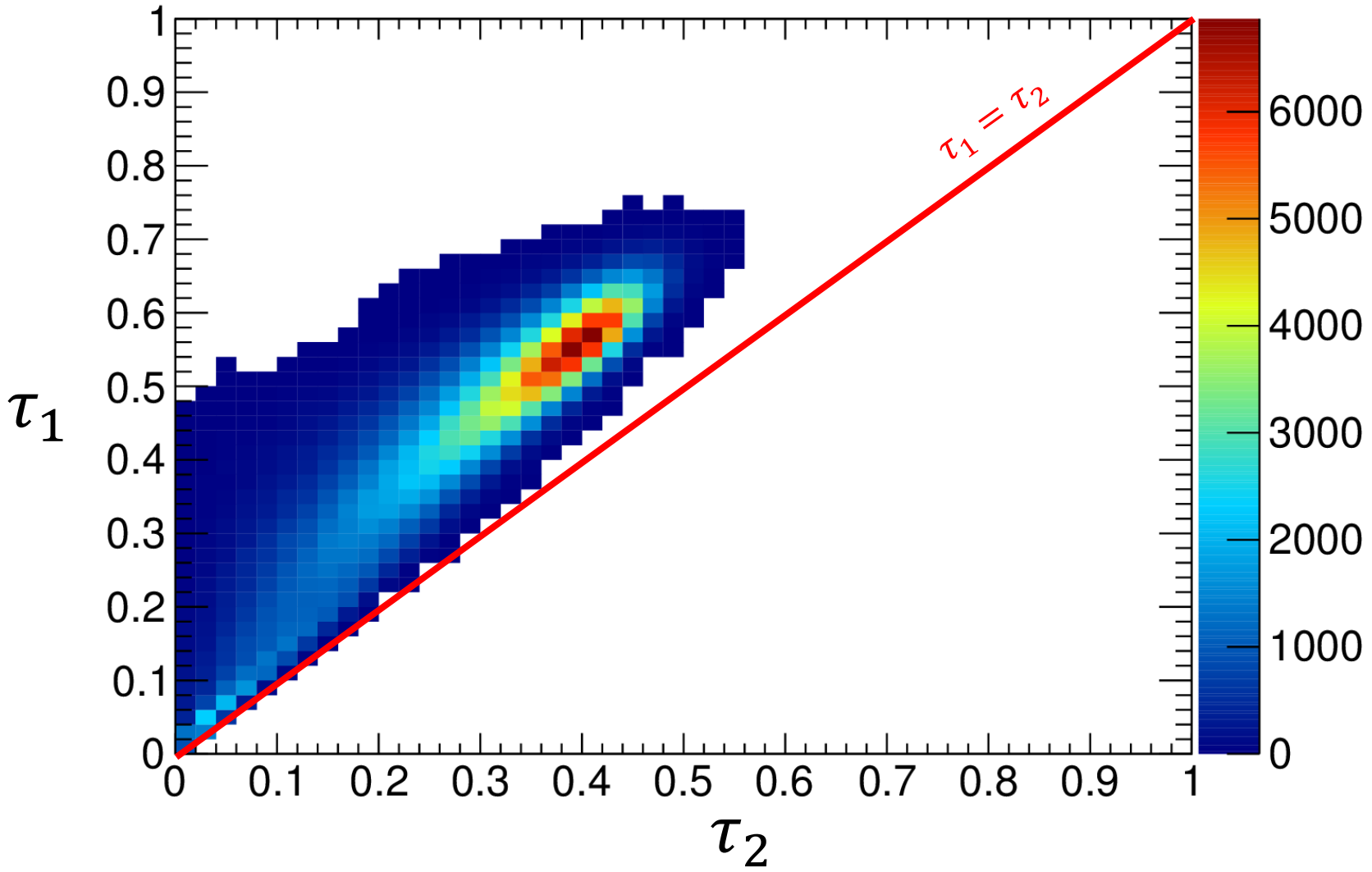
τ_3/τ_2



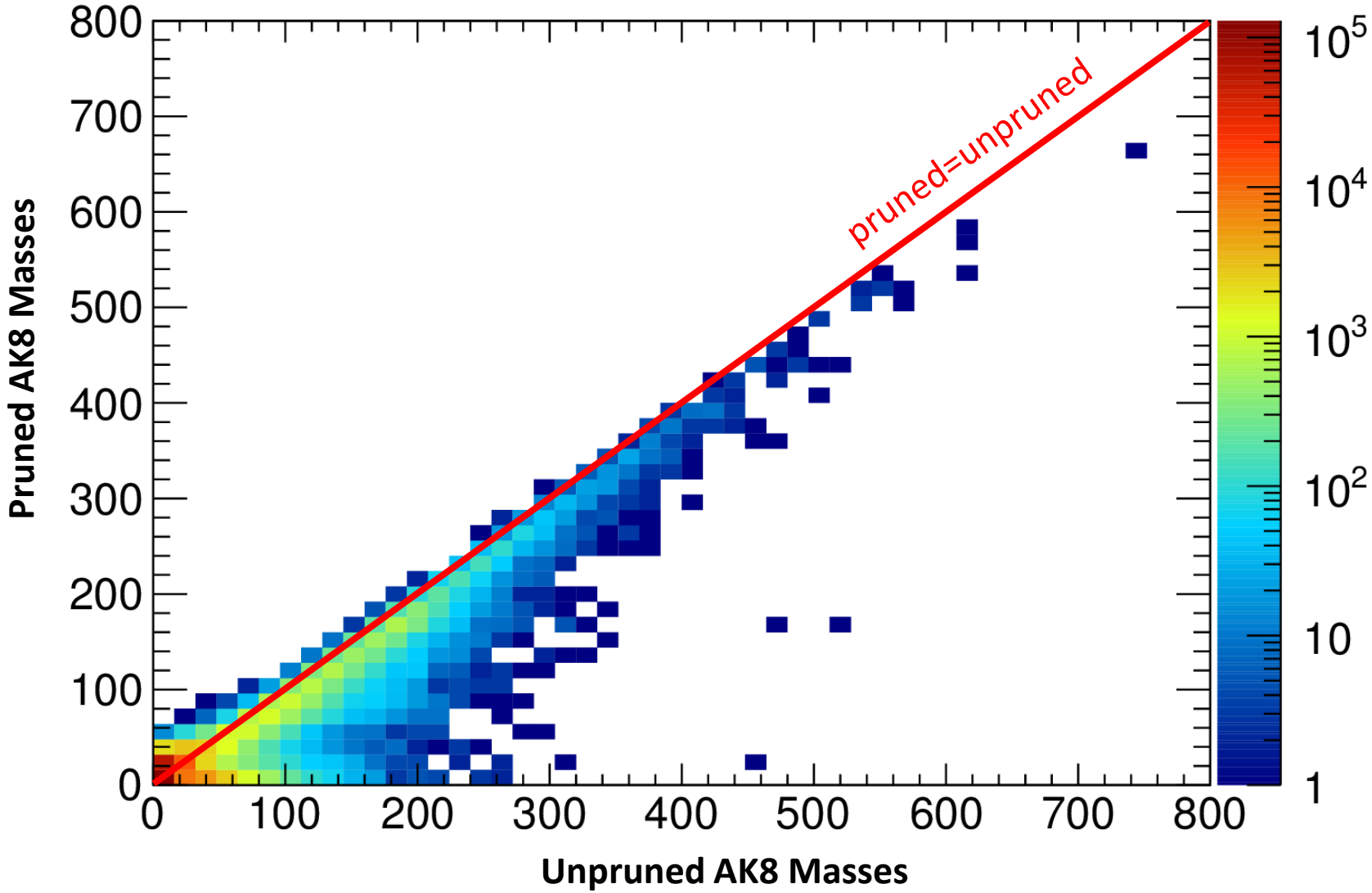
N-subjettiness



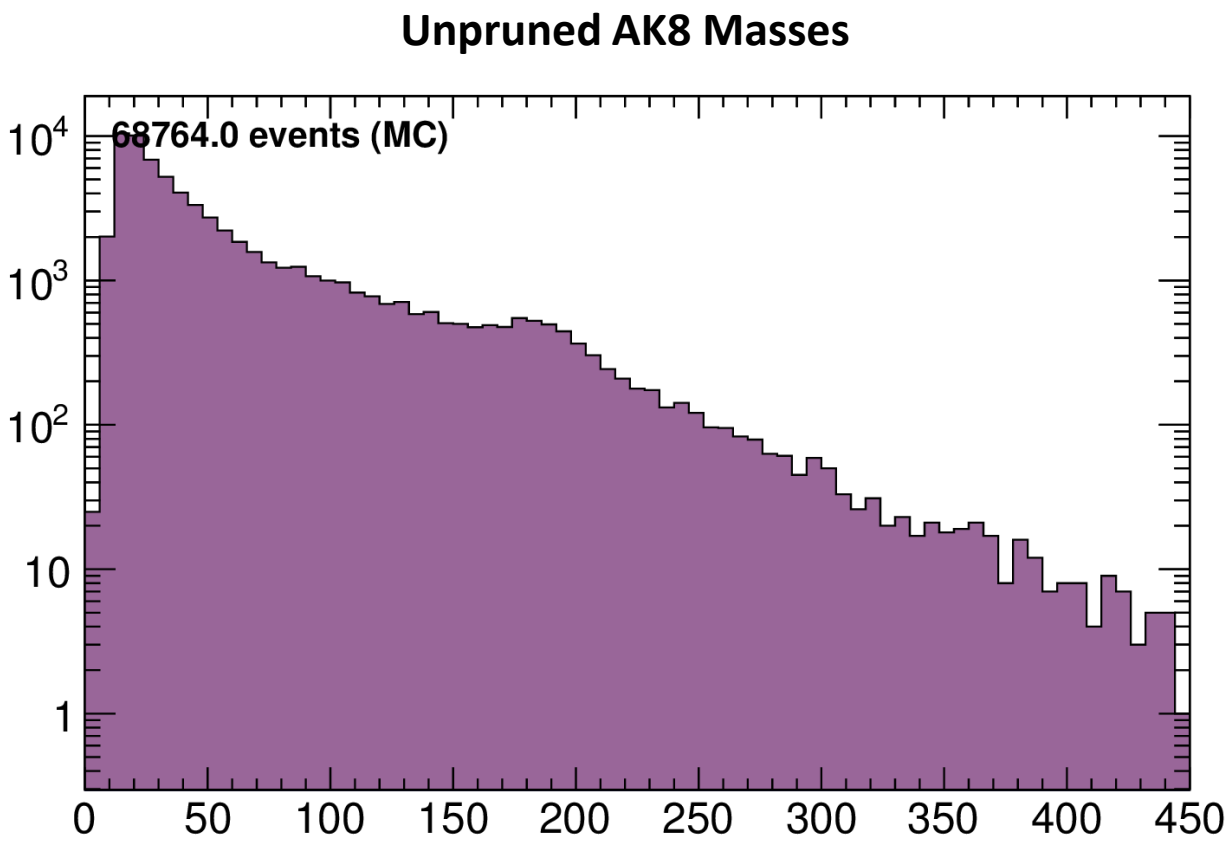
N-subjettiness

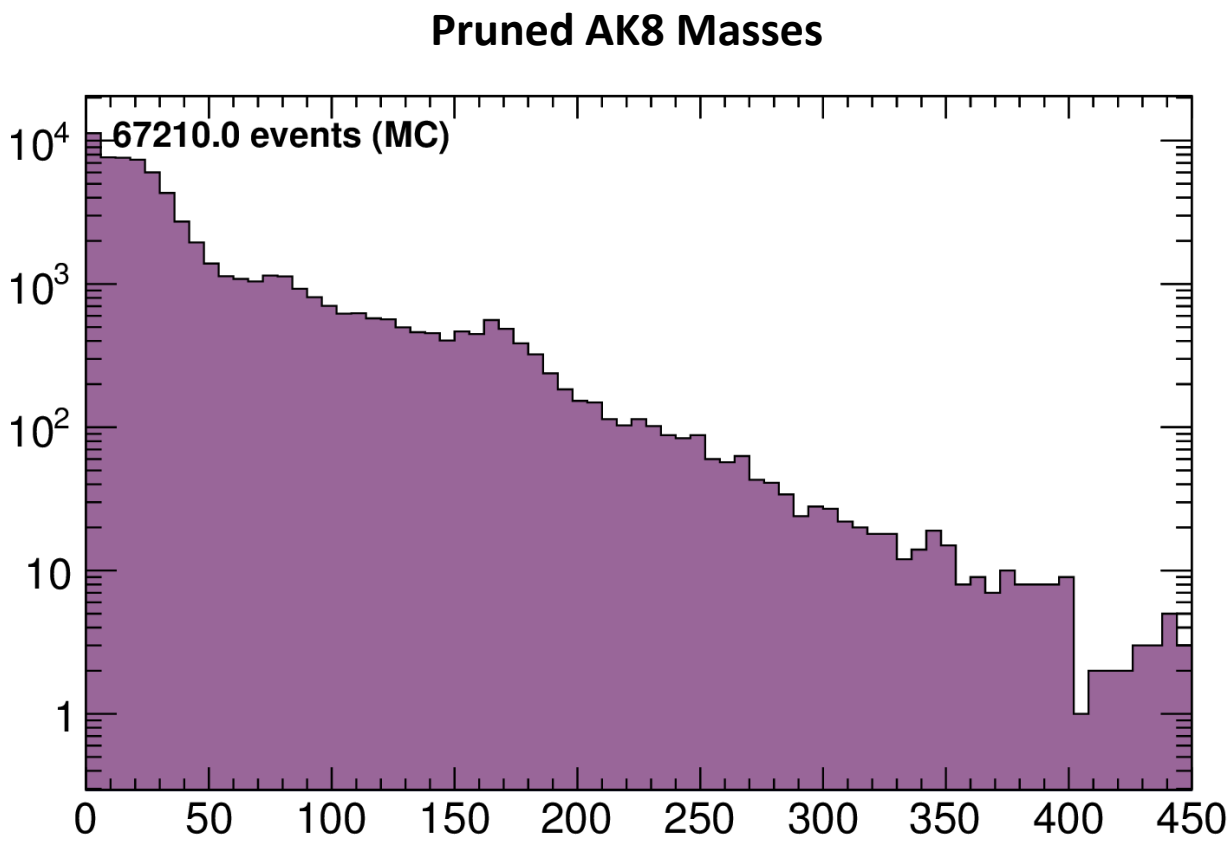


Pruning

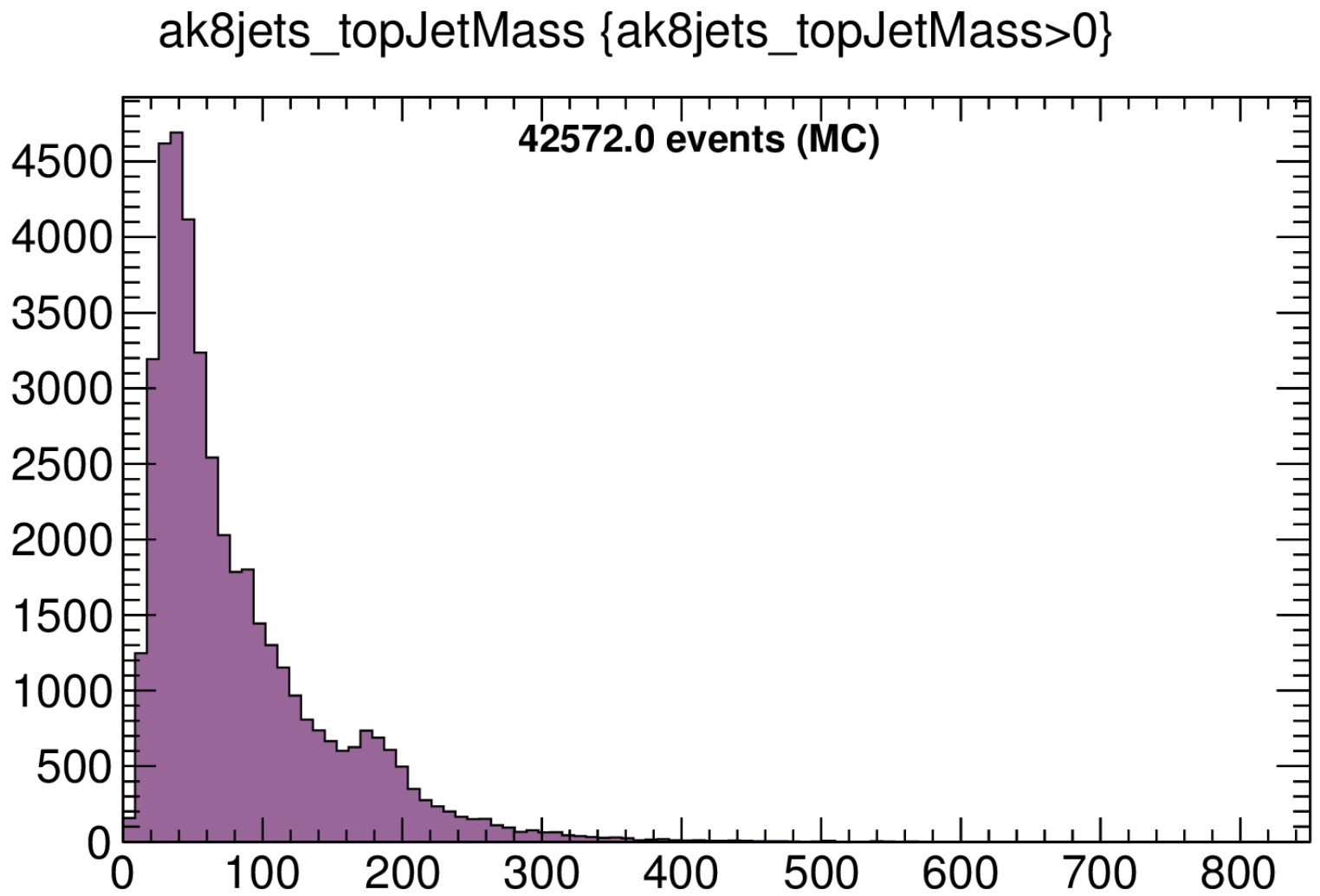

Pruned AK8 Masses
Unpruned AK8 Masses
pruned=unpruned
0
100
200
300
400
500
600
700
800
1
10
10^2
10^3
10^4
10^5

Pruning


Unpruned AK8 Masses
68764.0 events (MC)
10^4
10^3
10^2
10
1
0
50
100
150
200
250
300
350
400
450


Pruned AK8 Masses
67210.0 events (MC)
10^4
10^3
10^2
10
1
0
50
100
150
200
250
300
350
400
450

Top-tagged Jet Mass



Links

- A. Hornig: https://indico.cern.ch/event/179612/session/2/contribution/39/material/slides/0.pdf
- H. K. Lou: http://indico.cern.ch/event/215704/session/2/contribution/31/material/slides/0.pdf