Understanding jet grooming through event shapes

Marat Freytsis

Harvard University

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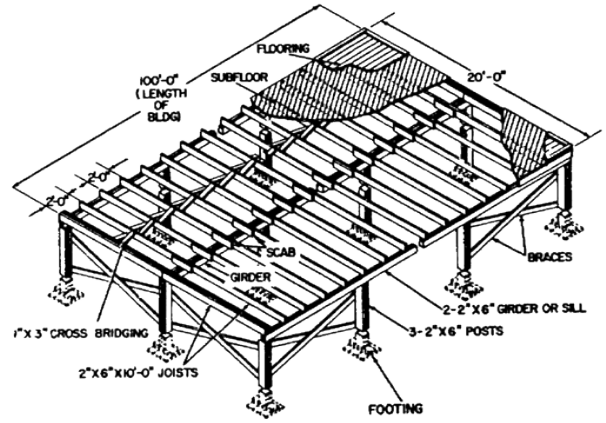


MF, Jesse Thaler
in preparation

Last Year at Flagstaff...

Jets without jets

$$N_{\text{jet}}(p_{T\,\text{cut}}, R) = \sum_{i \in \text{jets}} \Theta(p_{T\,i} - p_{T\,\text{cut}})$$

$$\Rightarrow \tilde{N}_{\text{jet}}(p_{T\,\text{cut}}, R) = \sum_{i \in \text{event}} \frac{p_{T\,i}}{p_{T\,i,R}} \Theta(p_{T\,i,R} - p_{T\,\text{cut}})$$

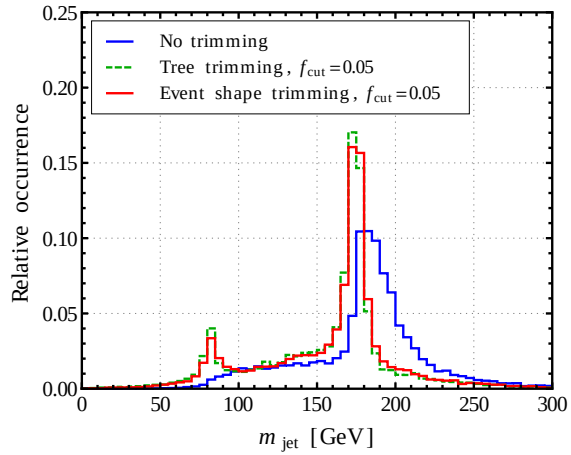
Other jet shapes analogously

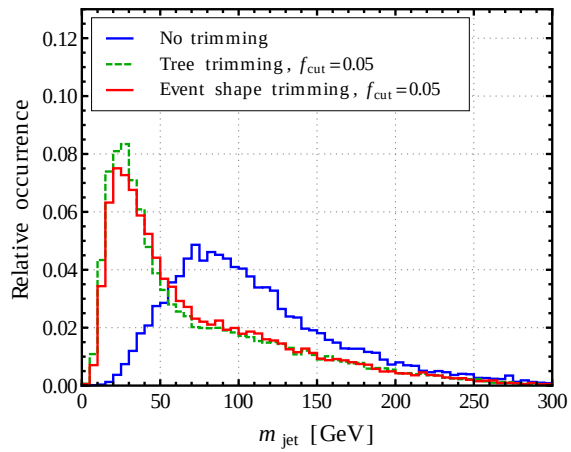
Trimming via local jet/subjet properties

[Krohn, Thaler, Wang 0912.1342]

$$p_i^\mu \Rightarrow w_i p_i^\mu$$

$$= \Theta\left(\frac{p_{T\,i,R_{\text{sub}}}}{p_{T\,i,R}} - f_{\text{cut}}\right) \Theta(p_{T\,i,R} - p_{T\,\text{cut}}) p_i^\mu$$



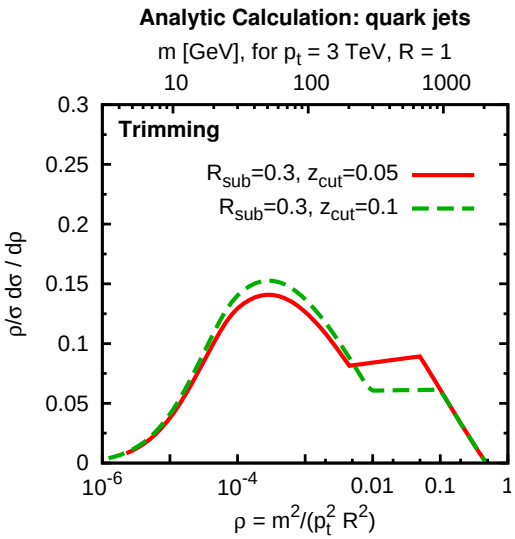


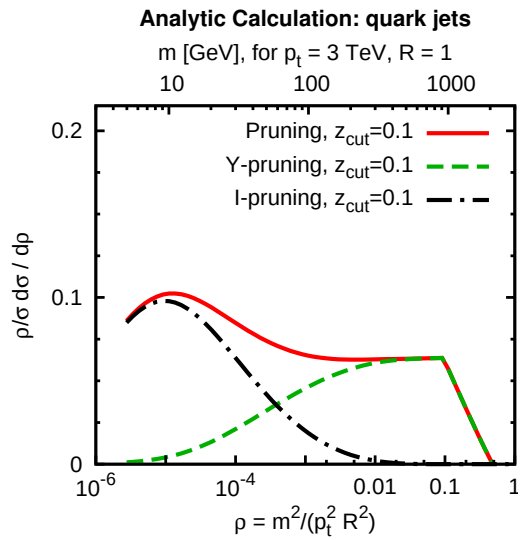
[Bertolini, Chan, Thaler, 1310.7584]

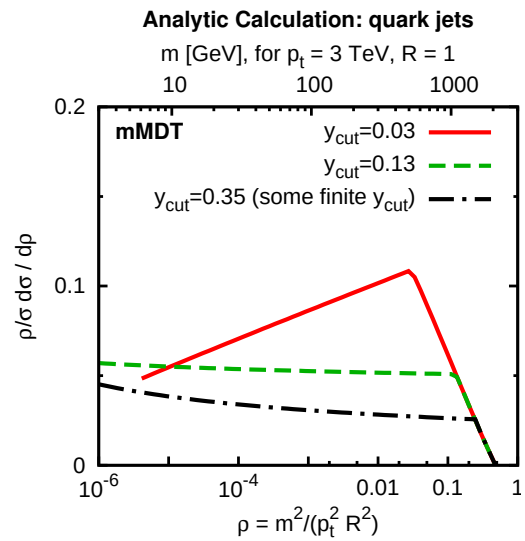
Last Year at Flagstaff…

Analytic calculations for jet grooming

[Dasgupta, Fregoso, Marzani, Salam, 1307.0007
Dasgupta, Fregoso, Marzani, Powling, 1307.0013]







More intricate resummation effects in pruning and mMDT than trimming
No Sudakov double logs for mMDT!

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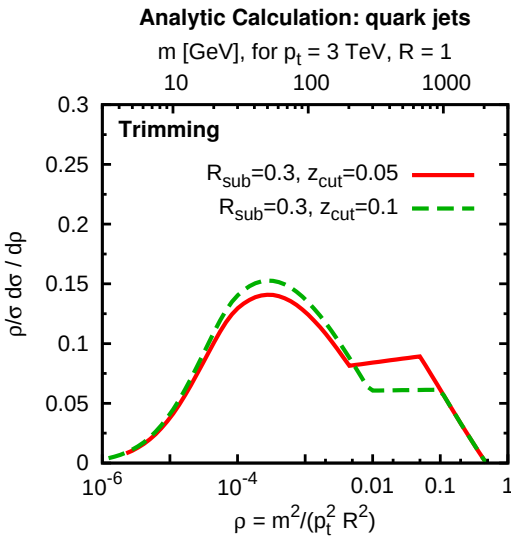

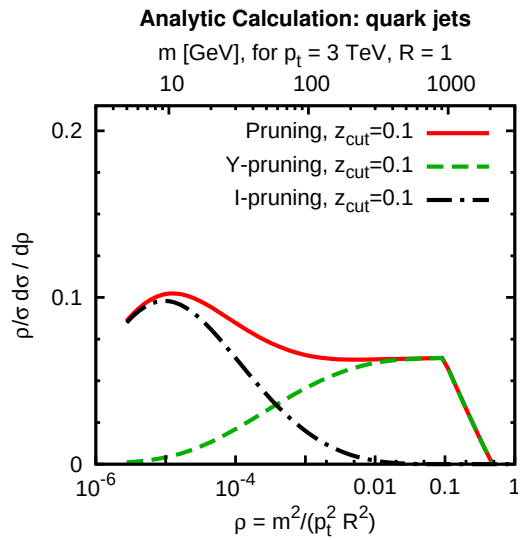

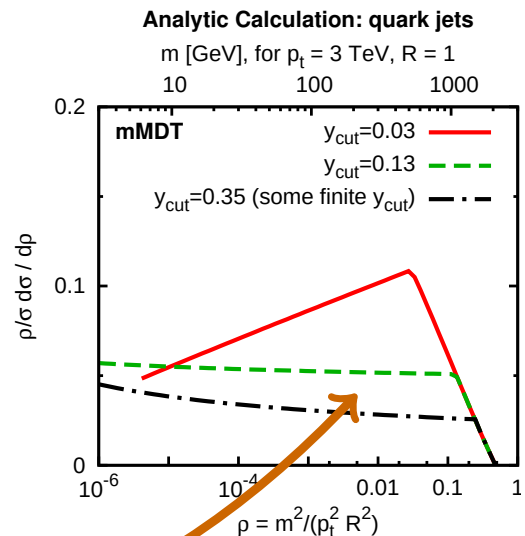

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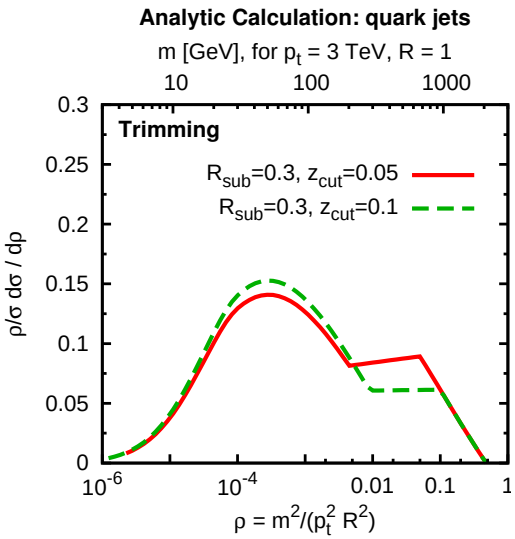

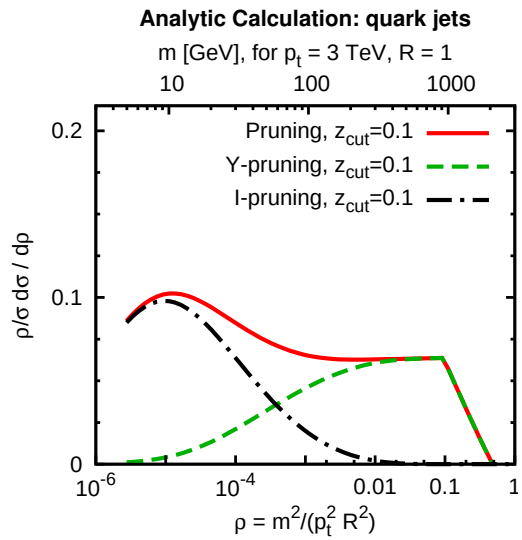

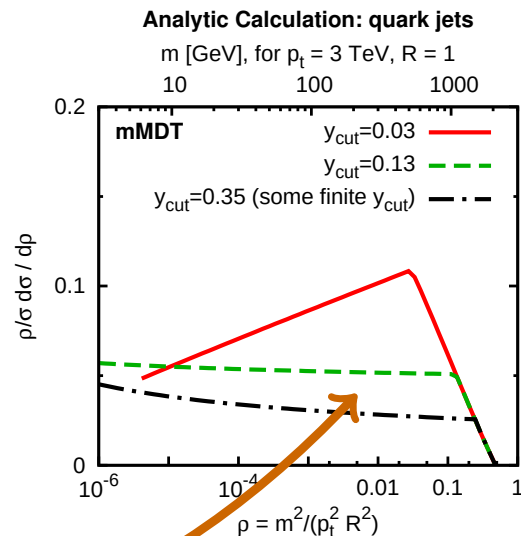

More intricate resummation effects in pruning and mMDT than trimming
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Can any of this structure be replicated in jet shapes?

Outline

Event shapes for modified clustering algorithms?

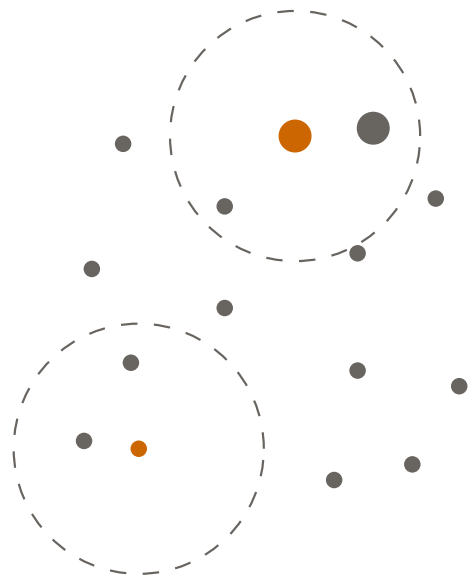
- Event Shape Pruning
  and modified clustering
- Event Shape Trimming Redux
  and pileup sensitivity
- Event Shape Mass/Soft Drop
  and soft-collinear logs

From shape trimming to shape pruning

Pruning:

1. Compute $R_{\rm pr} = 2D_{\rm fact}\frac{m_J}{p_T}$.
2. Recluster. Discard softer constituent if $R_{ab} > R_{\rm pr}$ and $\frac{\min(p_{Ta},p_{Tb})}{p_{Tab}} < z_{\rm cut}$ at each step.

[Ellis, Vermilion, Walsh 0912.0033]



Per 1307.0007, for up to two IR emissions, phase space of pruning and trimming with variable $R_{\rm sub} = R_{\rm pr}$ identical.

Suggests:

$$p_i^\mu \Rightarrow w_i p_i^\mu = \Theta\left(\frac{p_{T\,i,R_{{\rm pr},i}}}{p_{T\,i,R}} - z_{\rm cut}\right)\Theta(p_{T\,i,R} - p_{T\,\rm cut})p_i^\mu,$$

with $R_{{\rm pr},i} = 2D_{\rm fact}\frac{m_{i,R}}{p_{T\,i,R}}$.

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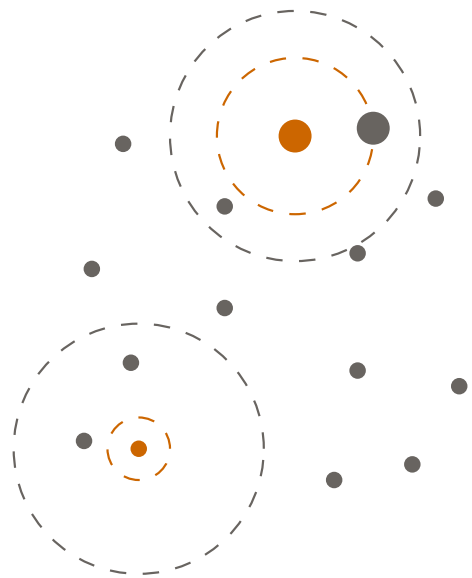

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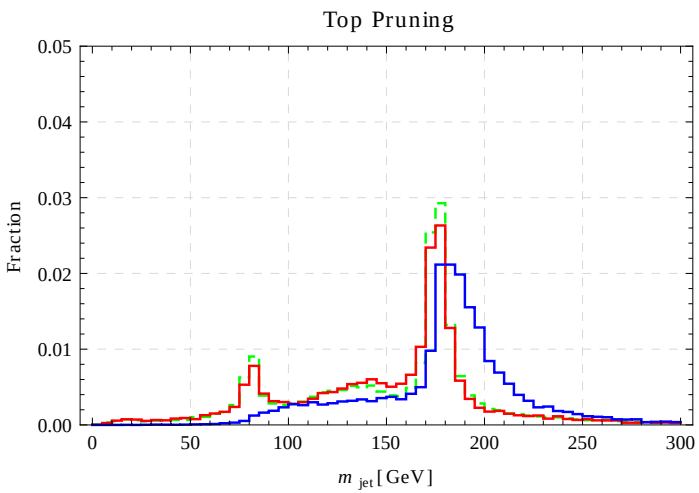
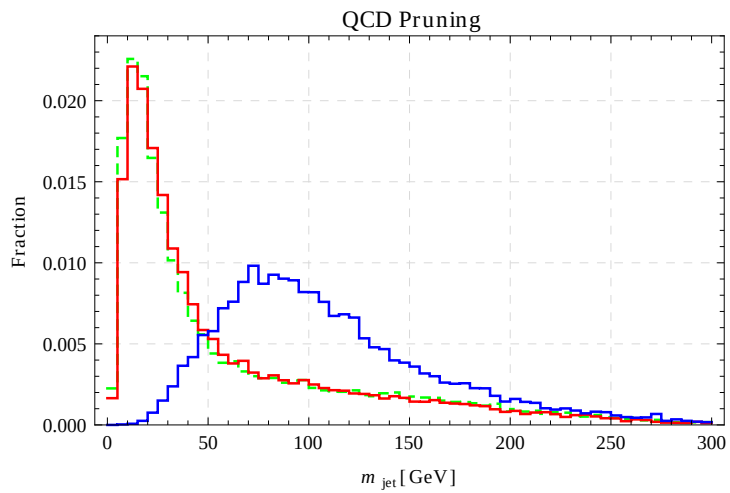
Event shapes confront trees

Pruning

Compare ungroomed, tree pruned, and event shape pruned QCD and $t\bar{t}$ events...





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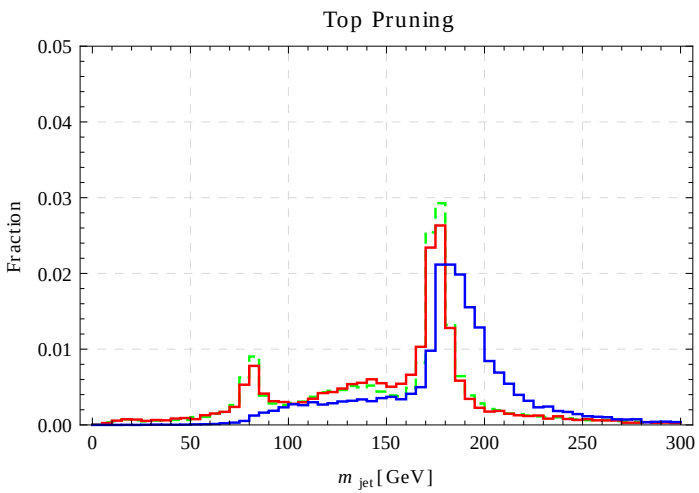

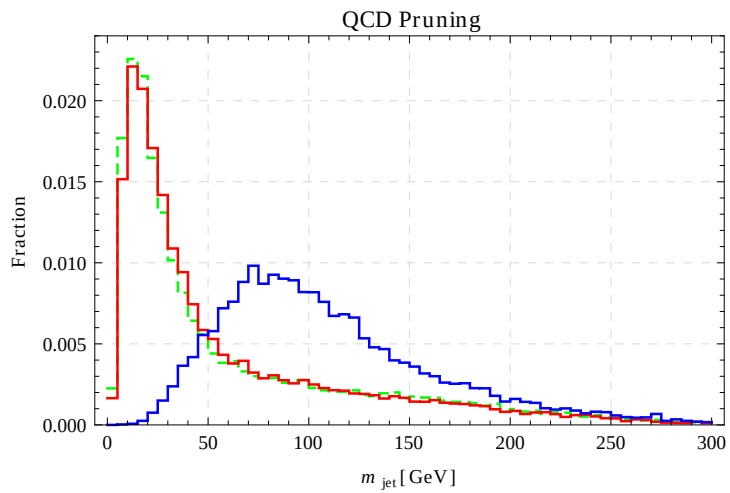

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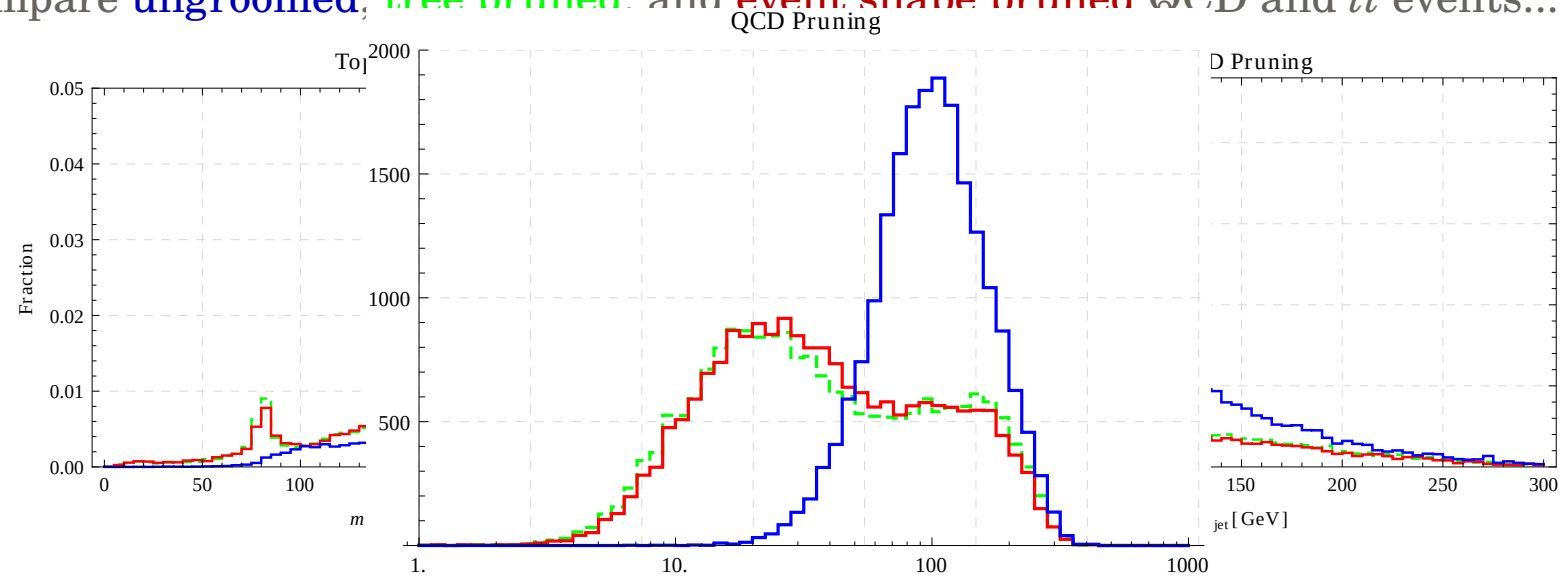

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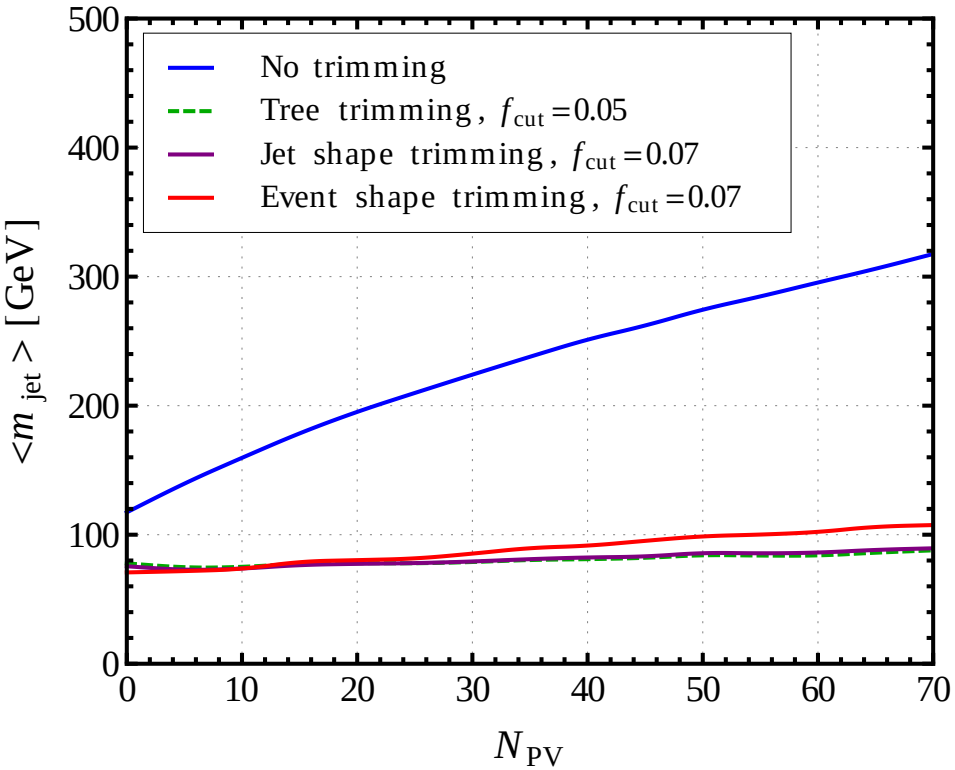
Shape trimming meets pileup



Jet-by-jet, event and tree trimming are similarly effectivve. Event-wide shape trimming shows a noticable drop in performance. Why?

[Bertolini, Chan, Thaler, 1310.7584]

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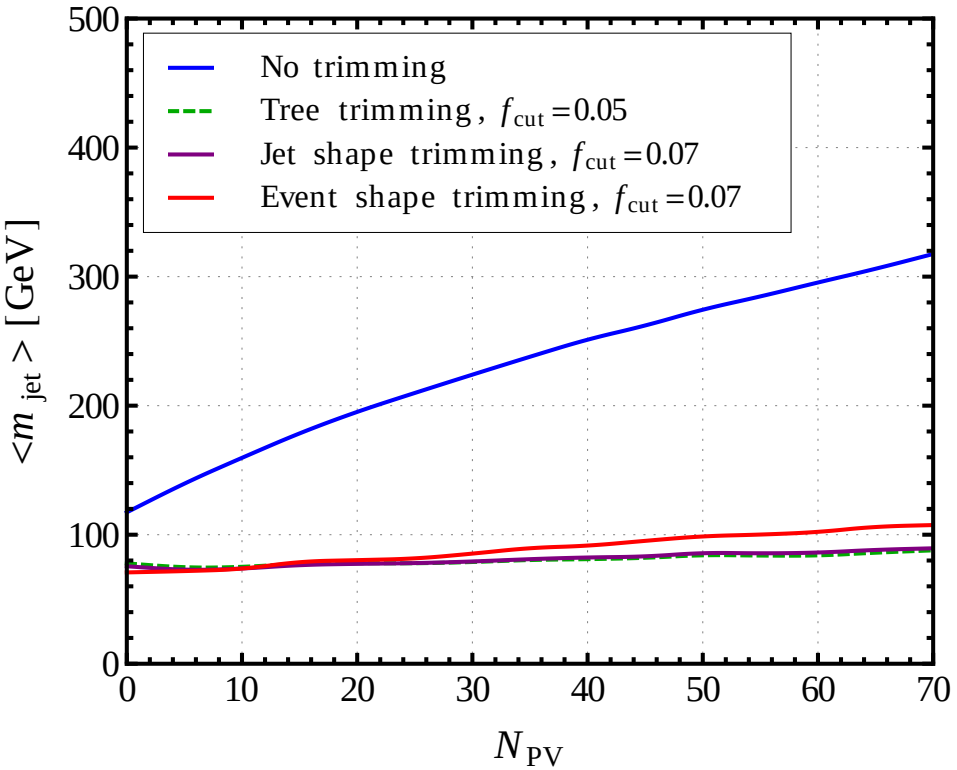

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Issue traced to soft cut degradation at edges of jets. Would like constituent to "know" when it is near a jet core. How?

[Bertolini, Chan, Thaler, 1310.7584]

Crowned variables

Local "jet finding" without recursion

An IRC-safe way to find properties of putative local jets

$$\overset{\curlywedge}{\mathcal{O}}_{i,R} = \sum_{R_{ij}<R} \frac{p_{Tj}}{p_{Ti,R}} \mathcal{O}_{(i)j} = \sum_{R_{ij}<R} w_i \mathcal{O}_{(i)j}$$

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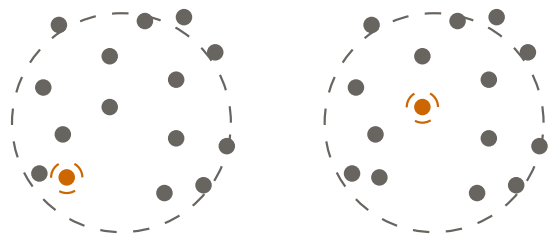
More concrete examples

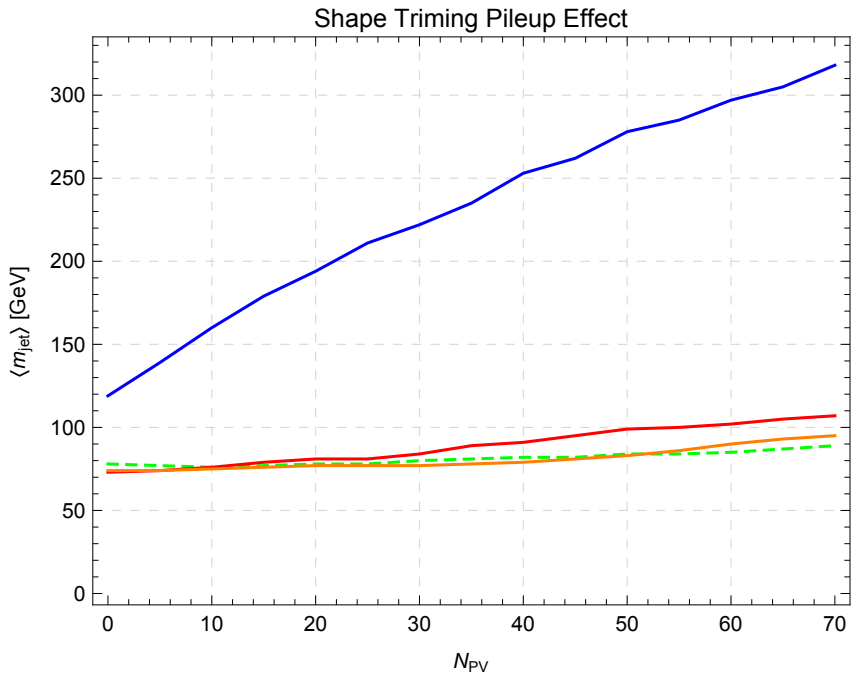
$$\overset{\wedge\wedge}{p}_{Ti,R} = \sum_{R_{ij}<R} \frac{p_{Tj}}{p_{Ti,R}} p_{Tj,R}$$

$$\overset{\wedge\wedge}{R}_{\mathrm{rp},i} = \sum_{R_{ij}<R} \frac{p_{Tj}}{p_{Ti,R}} 2D_{\mathrm{fact}} \frac{m_{j,R}}{p_{Tj,R}}$$



PU resistant event shapes

Crowned event trimming



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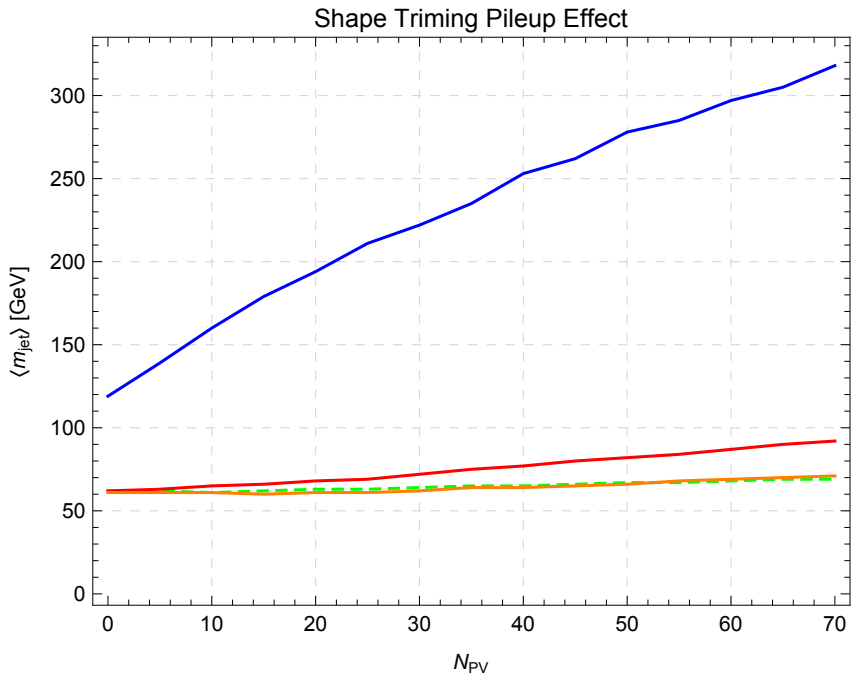
PU resistant event shapes

Crowned event pruning

Similar problem – similar solution.



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Declustering and event shapes

Soft Drop:

1. Undo the last stage of clustering, $j \to j_a j_b$
2. Drop softer jet if $\frac{\min(p_{Ta}, p_{Tb})}{p_{Tab}} < z_{\text{cut}} \left(\frac{R_{ab}}{R_0}\right)^{\beta}$, otherwise stop.
3. Iterate until declustering is impossible. Either remove ("tagging mode") or keep ("grooming mode") the last constituent.

[Dasgupta, Fregoso, Marzani, Salam 1307.0007; Larkoski, Marzani, Soyez, Thaler 1307.0007]

Unlike pruning, already need to know clustering history for 3 constituents.

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Unlike pruning, already need to know clustering history for 3 constituents.

Need to know about 2 subjet-like configurations? Extend crowning procedure to all pairwise configurations!

Shape Soft Drop

The soft drop weighting function is

$$p_i^\mu \Rightarrow \Theta(t_i)\Theta(p_{T\,i,R} - p_{T\,\mathrm{cut}})p_i^\mu$$

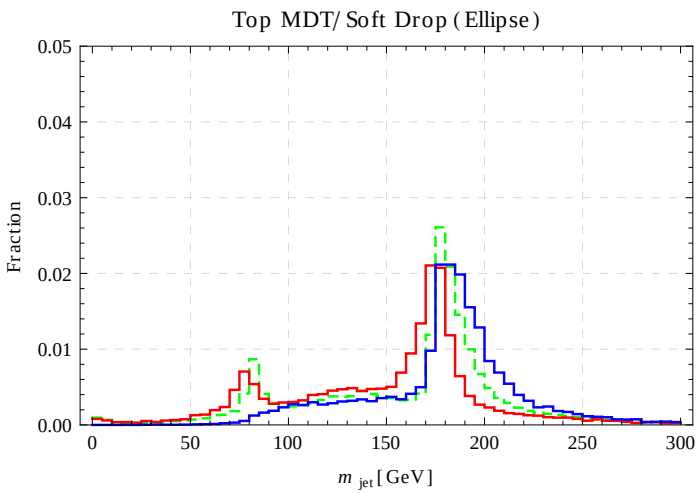
with

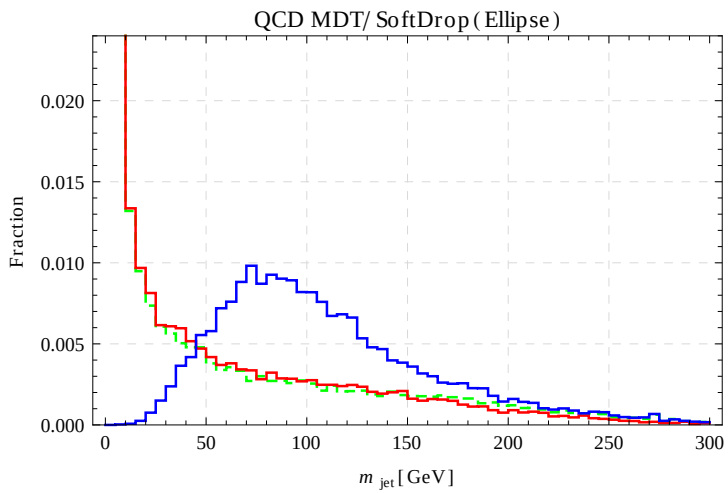
$$t_i = \sum_{\substack{R_{ij}<R \\ R_{ik}<R \\ R_{ij}+R_{ik}<2R_{jk}}} \frac{p_{T\,j}}{p_{T\,i,R}} \frac{p_{T\,k}}{p_{T\,i,R}} \left(\frac{\min(p_{T\,j\triangleleft}, p_{T\,k\,\triangleright})}{p_{T\,\bigcirc}} - z_{\mathrm{cut}} \left(\frac{R_{ab}}{R_0} \right)^\beta \right)$$

Event shapes confront declustered trees

Shape mMDT / soft drop

Compare ungroomed, tree pruned, and event shape pruned QCD and $t\bar{t}$ events...





BOOST2010 sample events, p_T 500-600 GeV

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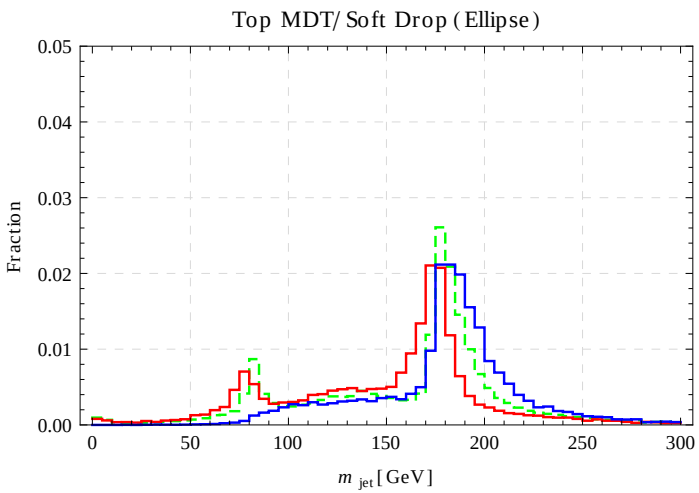

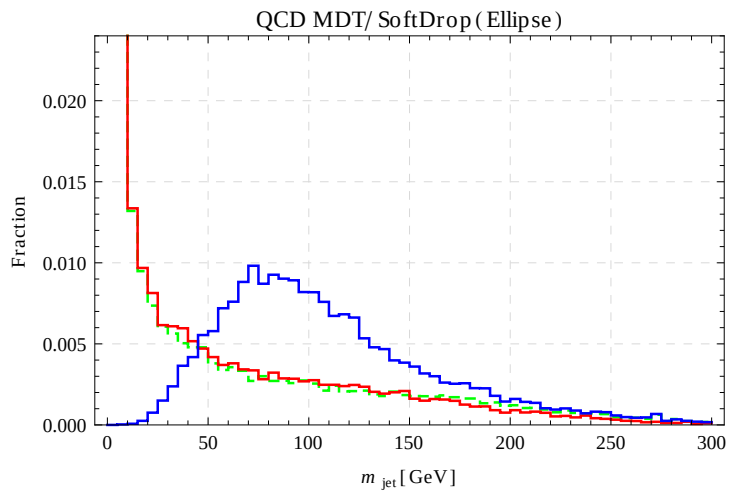

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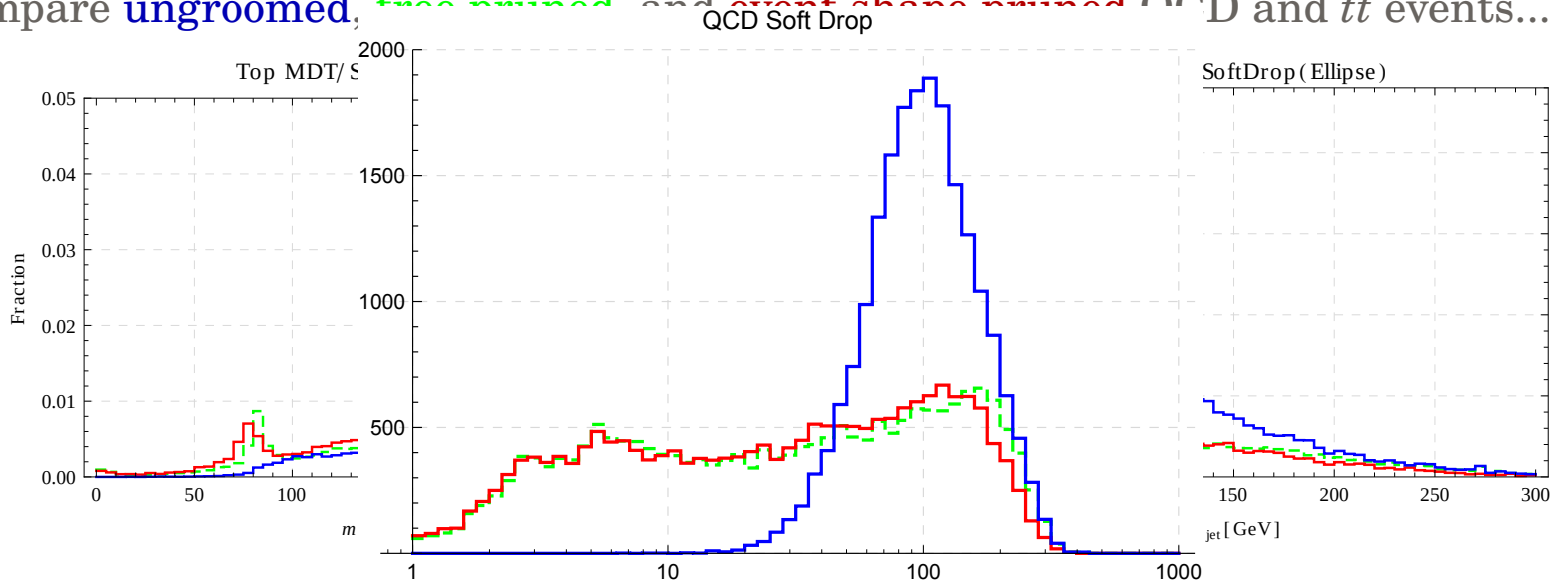

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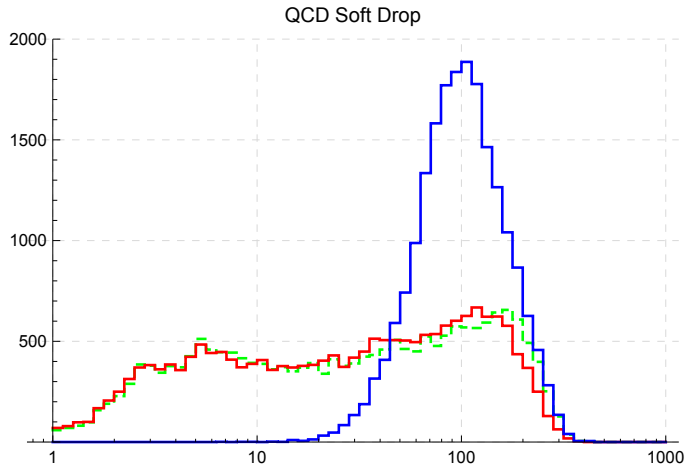
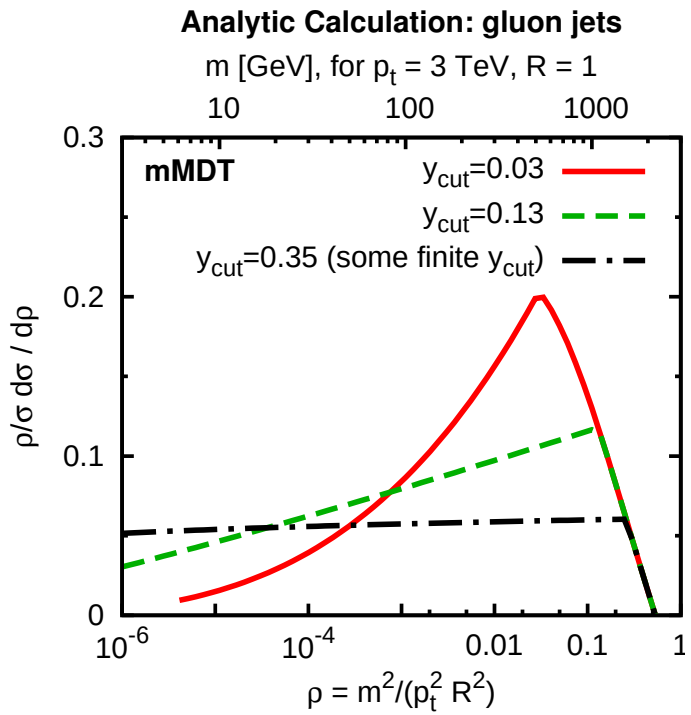
IR structure of soft drop shape

No Sudakov double logs, same as algorithm:

Event shape with no double log sensitivity





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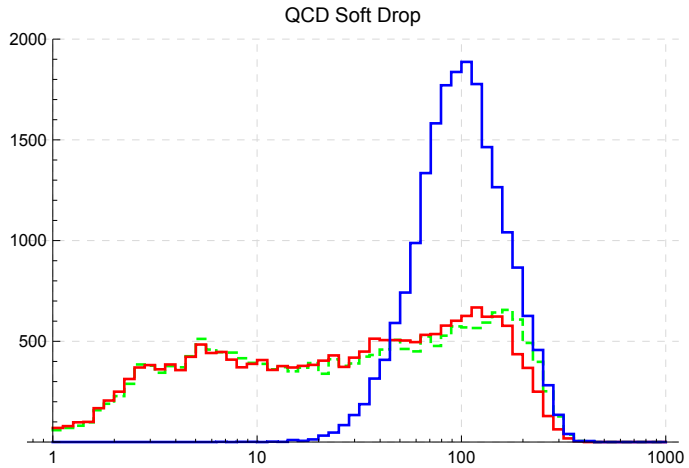
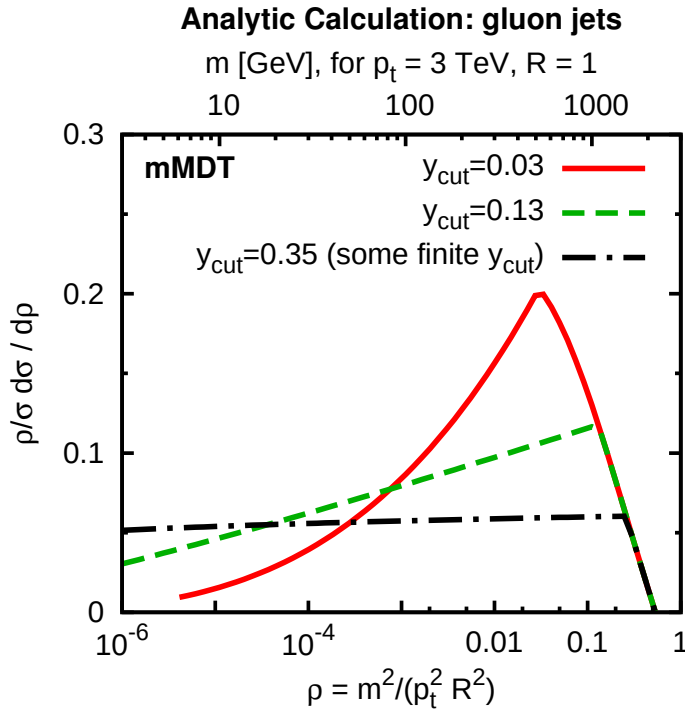
Not particularly pretty, but proof of principle

Can we write down something simpler? (Calculable?)





Summary

General story, so far:

Clustering modification? Change local weighting function

Declustering modification? Weight all local configurations

- Event Shape Pruning
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- Event Shape Trimming Redux
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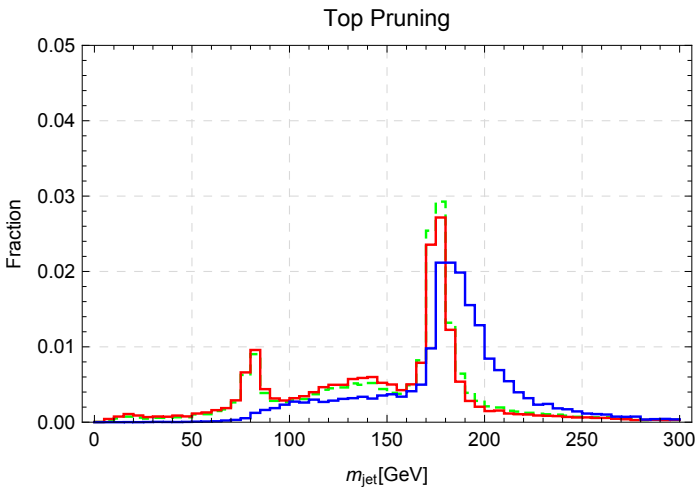
Future directions

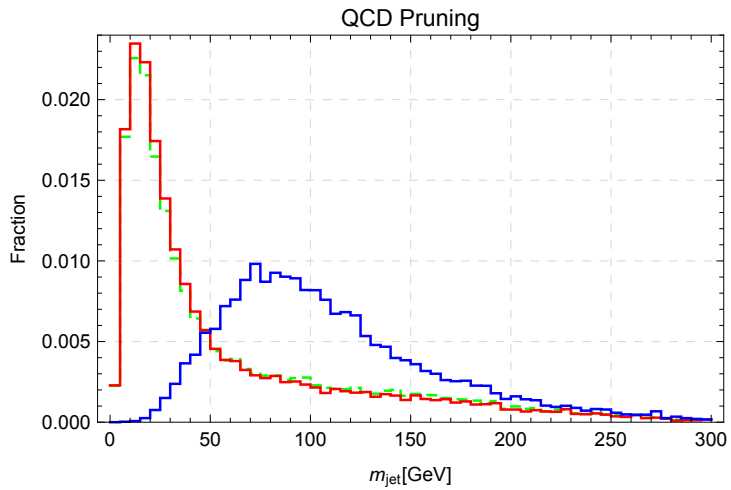
- Add to jets without jets `fastjet-contrib`
- Closed for expressions – systematically improvable resummation?
- Simpler event shapes with single IR logs?
- Weighted expressions as means of distributions – can we learn something about Qjets?

Backup

Pruned Trimming

Result for shape pruning implies that subjet reclustering with $R_{\text{sub}} = R_{\text{pr}}$ should behave almost like pruning.





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