Shower Deconstruction

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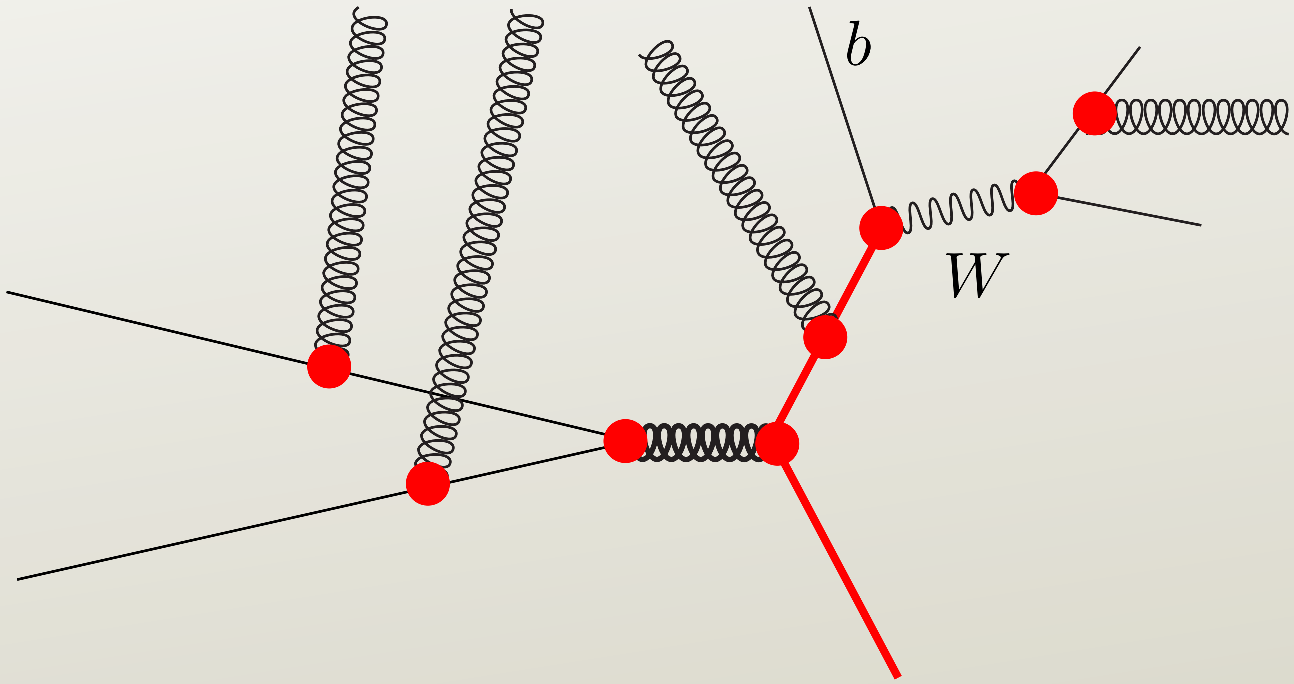
Introduction

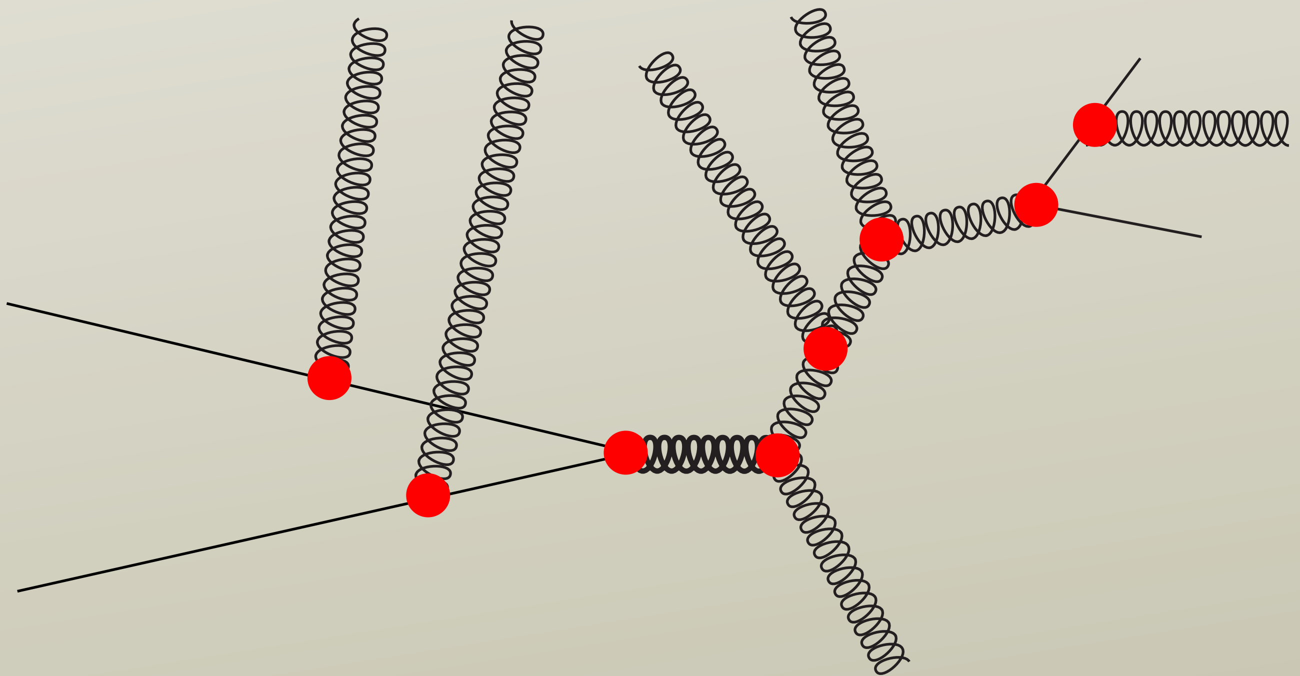
- One can examine the substructure of events in order to dig out new physics signals.
- Michael Spannowsky and I proposed a general method for subjet analysis: "shower deconstruction." (Phys. Rev. D84 (2011) 074002)
- The initial application was to a Higgs boson recoiling against a Z-boson and decaying to b quarks.
- A lot of the structure of this comes from the partitioned dipole shower algorithms by Zoltan Nagy and D. Soper.
- A new application is to find top quarks. (Phys. Rev. D87 (2013) 054012)

Our example

We want to find one of the tops in $t\bar{t}$ production.



In a background of QCD dijets.



Event selection

Signal is $t + \bar{t}$ from QCD simulated with Pythia 8.

Background is dijets simulated with Pythia 8.

Require:

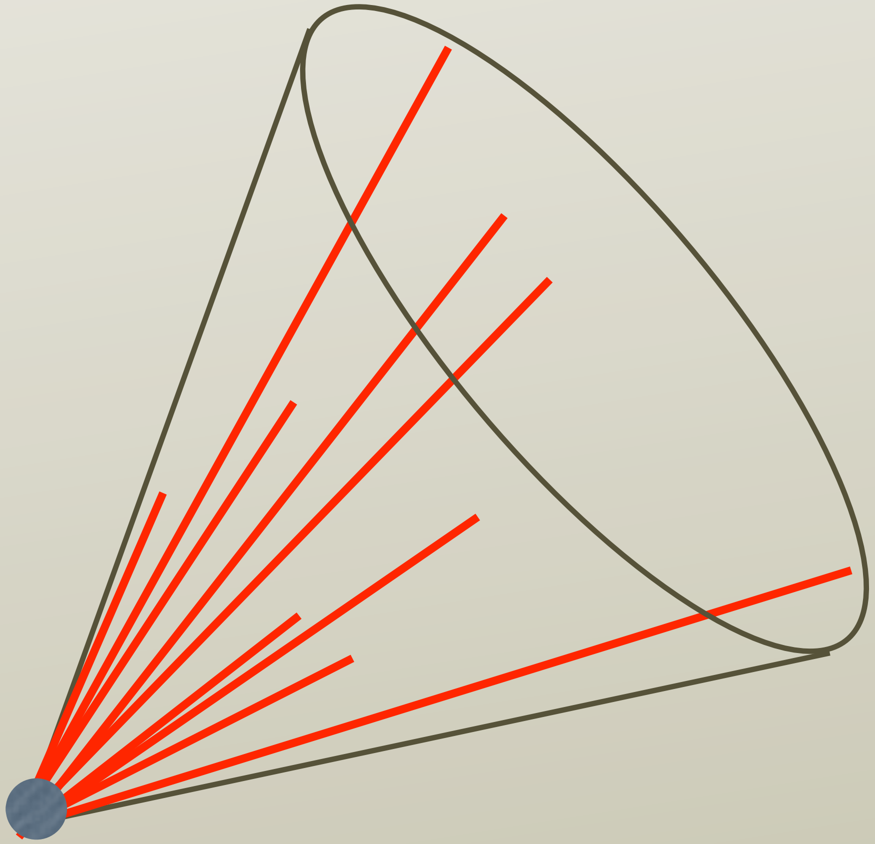
- Two fat jets with $P_T > 500$ GeV using CA algorithm with $R = 1.0$.

We look at just one of the fat jets.

Thus we are trying to identify just one top quark.

Microjets

- Base the analysis on "microjet" constituents of the fat jet.
- In data, microjets would be defined from the calorimeter.
- For theory, use the k_T algorithm with $R = 0.2$ to group the fat jet into microjets.
- Discard microjets with $P_T < 5$ GeV.
- If more than nine microjets, discard the softest.
- Microjets described by momenta $\{p\}_N = \{p_1, \ldots, p_N\}$.



What we would like

- Our data: momenta p for N microjets, $\{p\}_N$.

- Define probabilities for signal and background events to have $\{p\}_N$ according to a trusted Monte Carlo:

$$P_{\rm MC}(\{p\}_N|{\rm S}) = \frac{1}{\sigma_{\rm MC}({\rm S})}\,\frac{d\sigma_{\rm MC}({\rm S})}{d\{p\}_N}$$

$$P_{\rm MC}(\{p\}_N|{\rm B}) = \frac{1}{\sigma_{\rm MC}({\rm B})}\,\frac{d\sigma_{\rm MC}({\rm B})}{d\{p\}_N}$$

- We would like to separate signal an background using

$$\chi_{\rm MC}(\{p\}_N) = \frac{P_{\rm MC}(\{p\}_N|{\rm S})}{P_{\rm MC}(\{p\}_N|{\rm B})}$$

Why?

- Assuming that you believe your Monte Carlo, to get the most signal cross section for a given background cross section by making a cut, your cut should be along a contour line of

$$\chi_{\mathrm{MC}}(\{p\}_N) = \frac{P_{\mathrm{MC}}(\{p\}_N|\mathrm{S})}{P_{\mathrm{MC}}(\{p\}_N|\mathrm{B})}$$

What we do

- Calculate

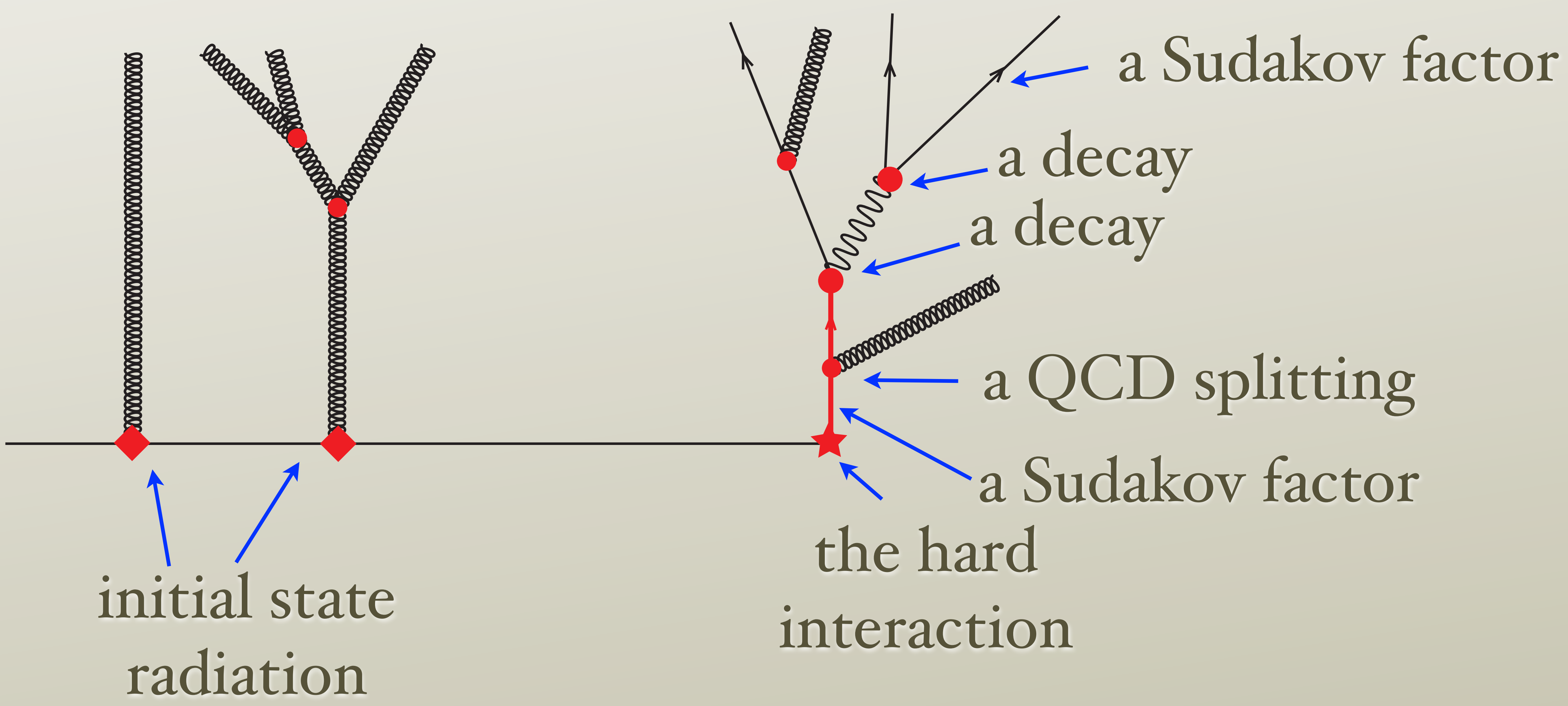
$$\chi(\{p\}_N) = \frac{P(\{p\}_N|\mathrm{S})}{P(\{p\}_N|\mathrm{B})}$$

according to a "simplified parton shower" algorithm.

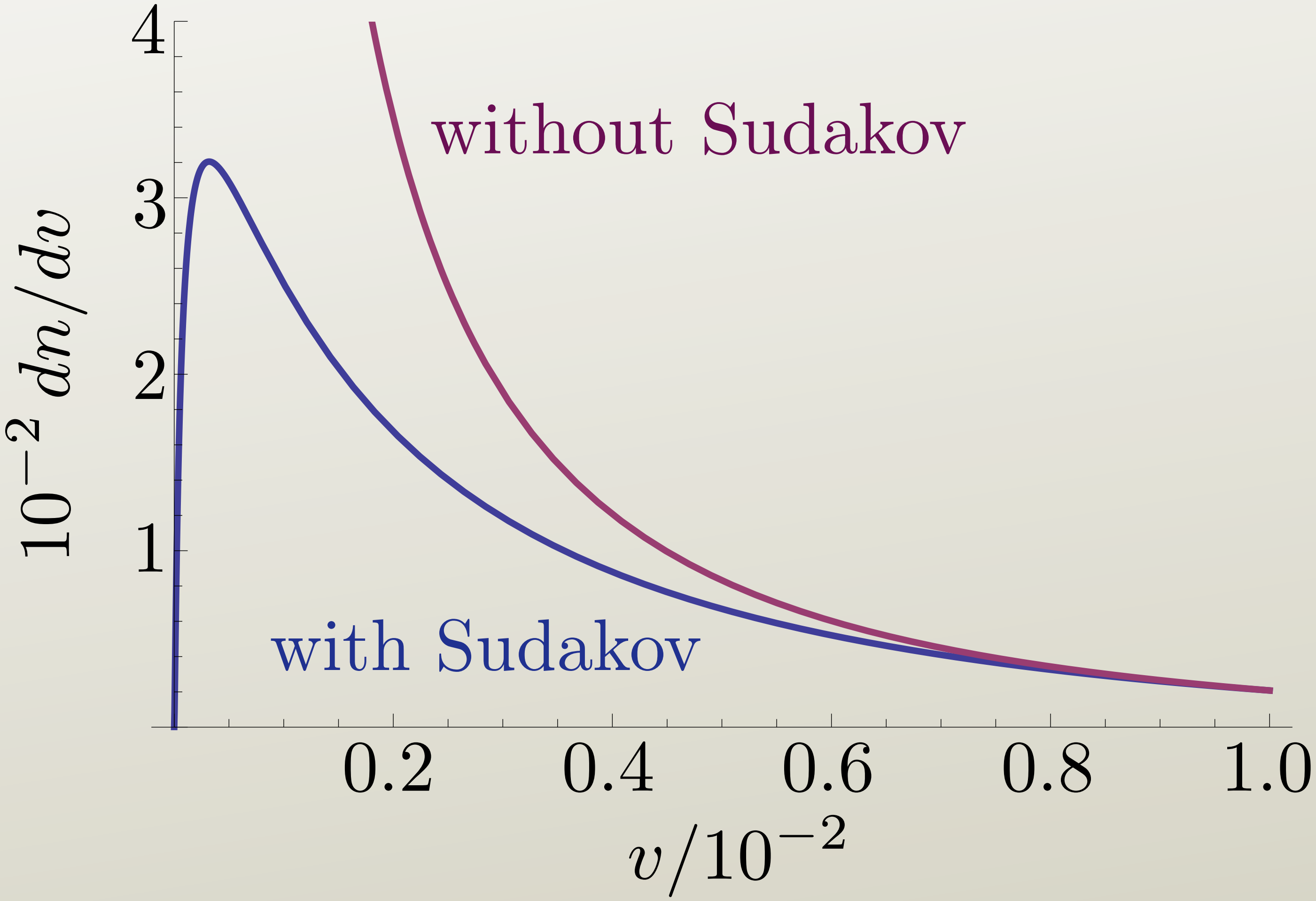
- The calculation is analytic.

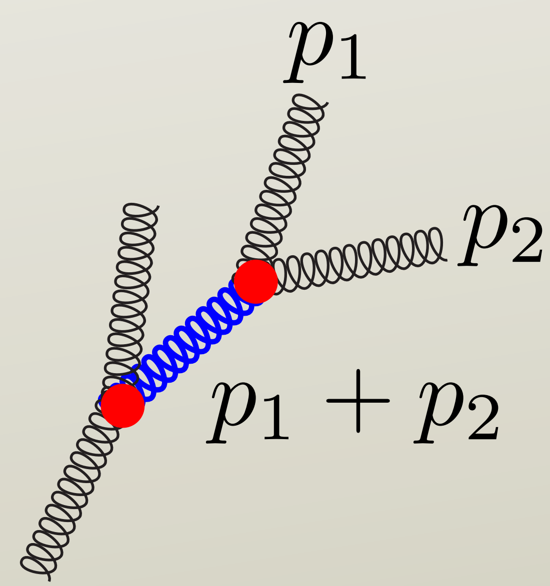
Event histories

- Each vertex and propagator corresponds to a shower algorithm factor.



Example of effect of Sudakov factor





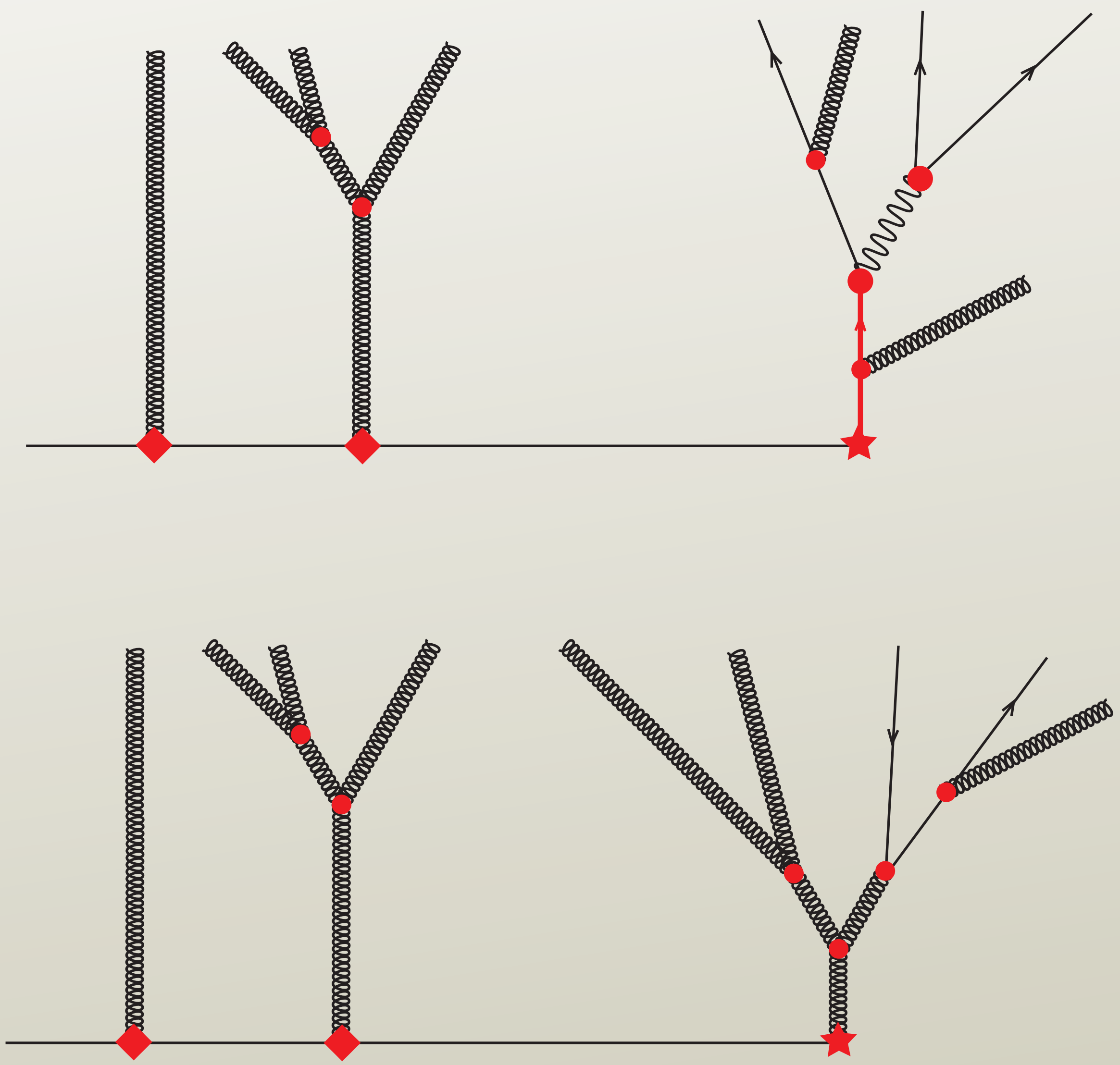
$v \propto$ virtuality in splitting

- "Without Sudakov" is just probability based on approximate $|\mathcal{M}|^2$.

Sum over event histories

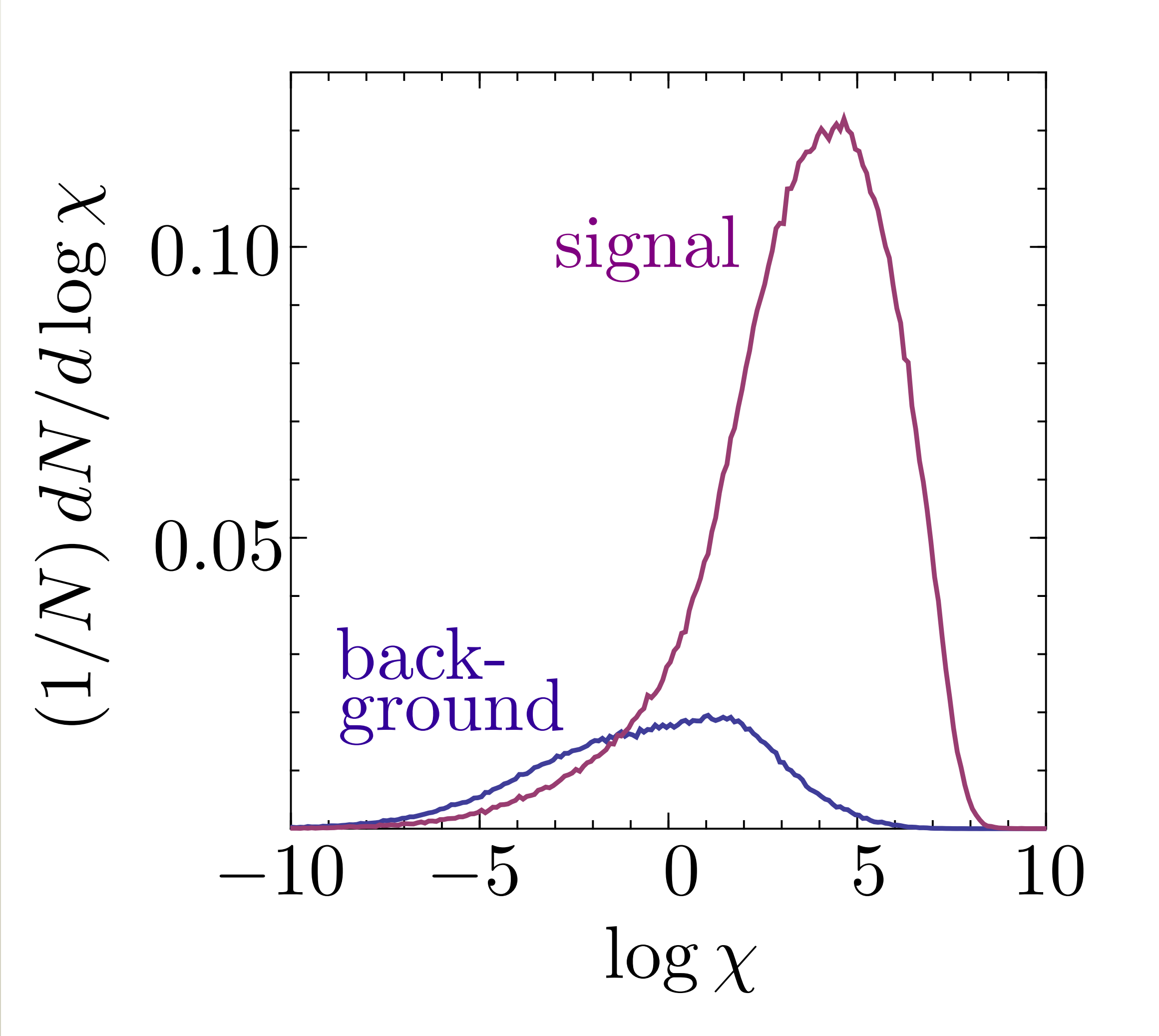
signal

background



χ distributions for signal and background

- Signal events have large χ.
- Background events have small χ.
- We can separate signal from background with a cut on χ.
- Events with $\chi = 0$ do not appear in the graph.

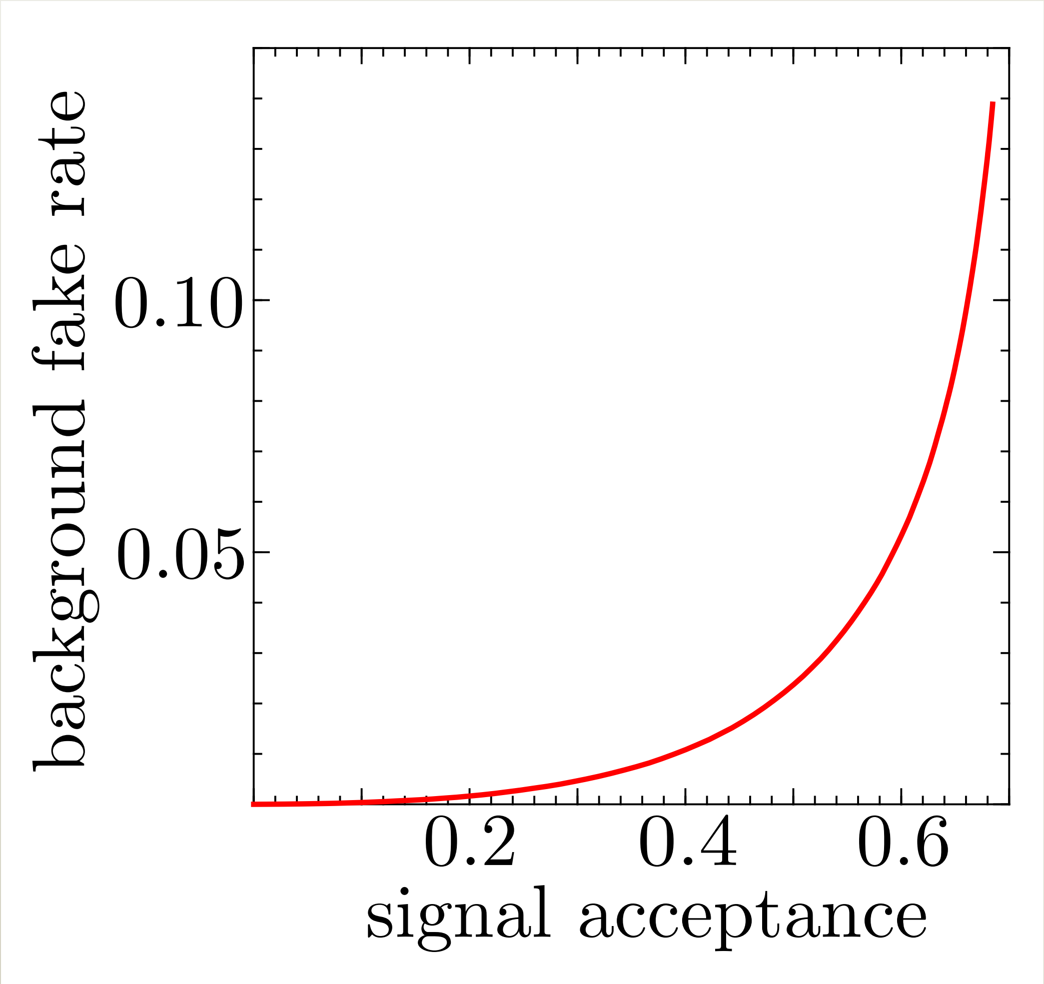


Tagging efficiency

- Select events with $\chi > \chi_{\rm cut}$.

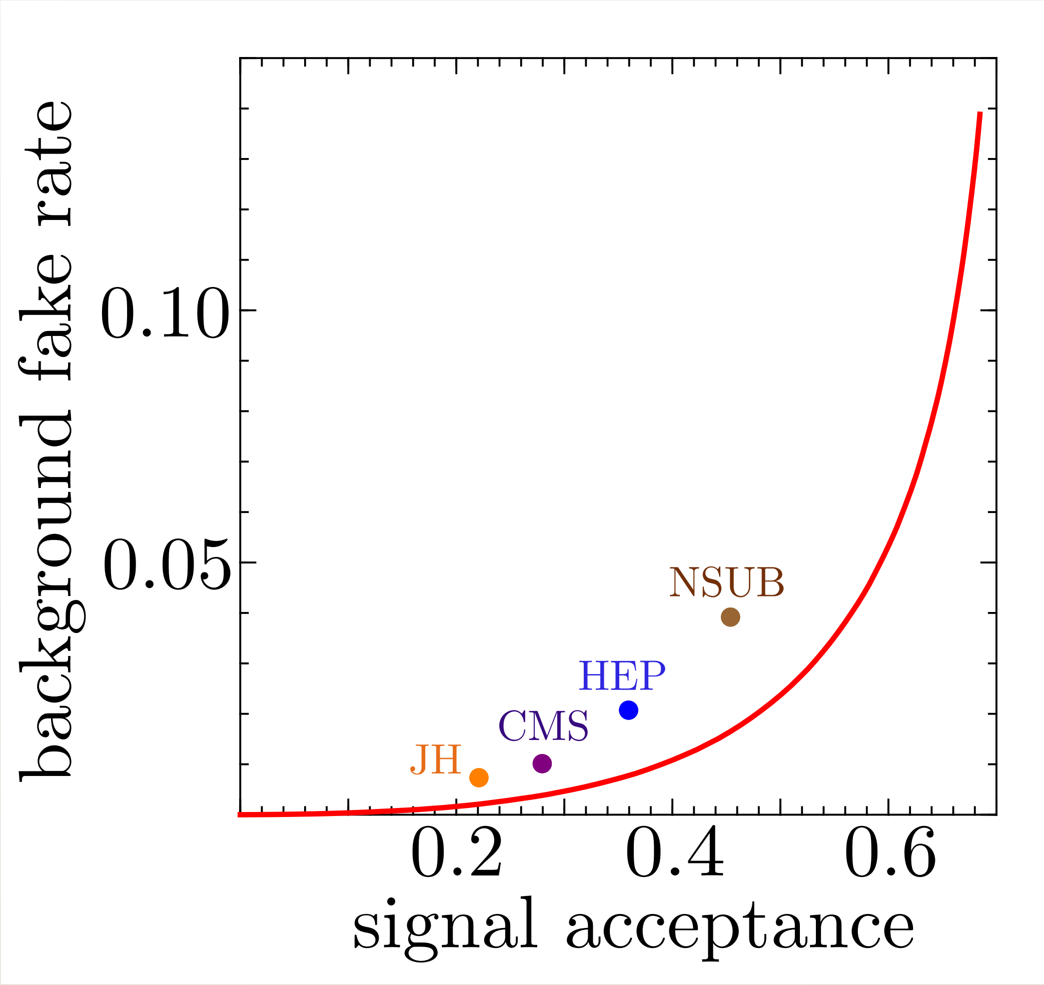
- Fraction of signal events accepted = "signal acceptance."

- Fraction of background events accepted = "background fake rate."

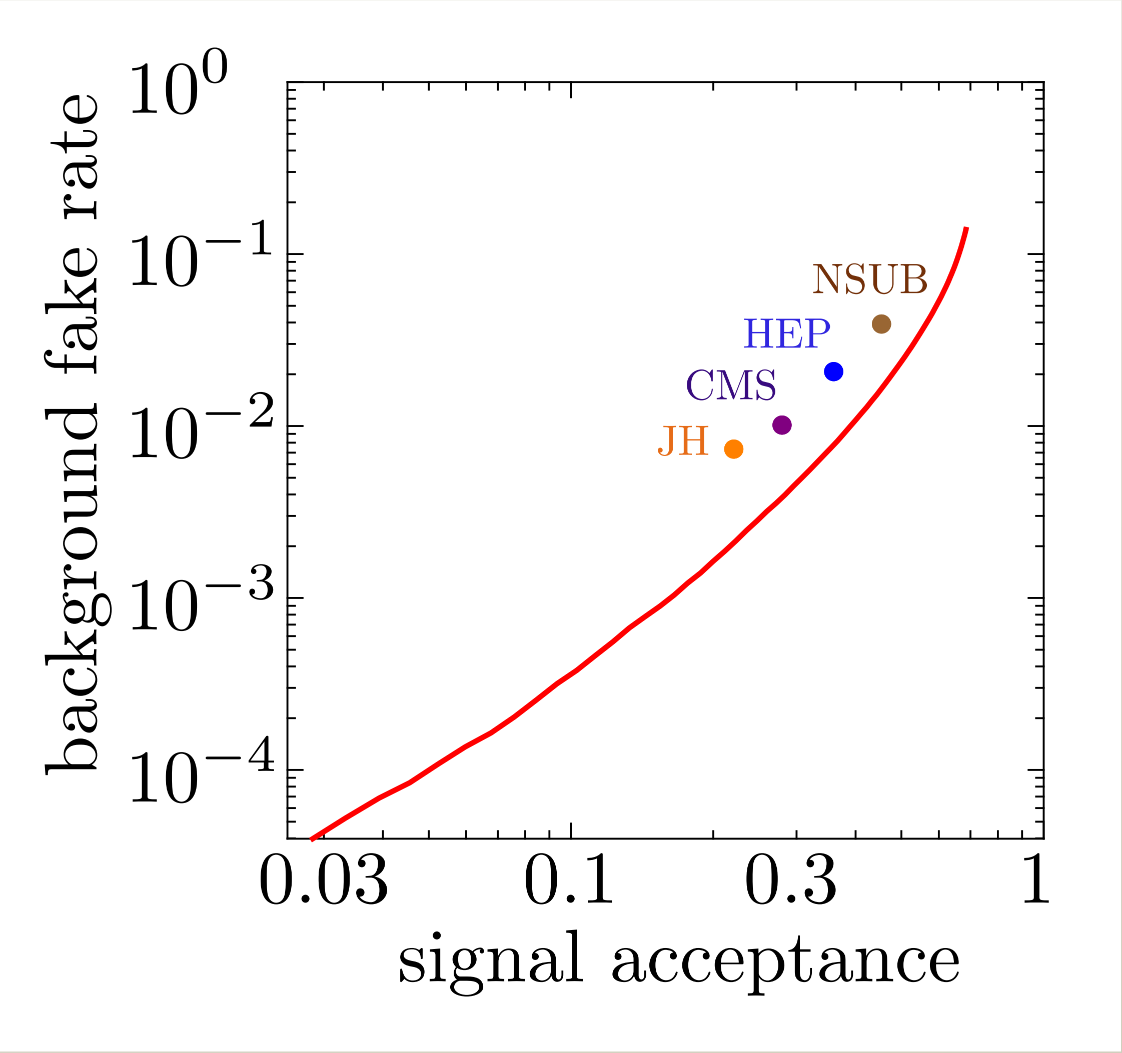


Comparison to other top tagging methods

- Johns Hopkins top tagger
- HEP top tagger
- CMS top tagger
- N-subjettiness as a top tagger



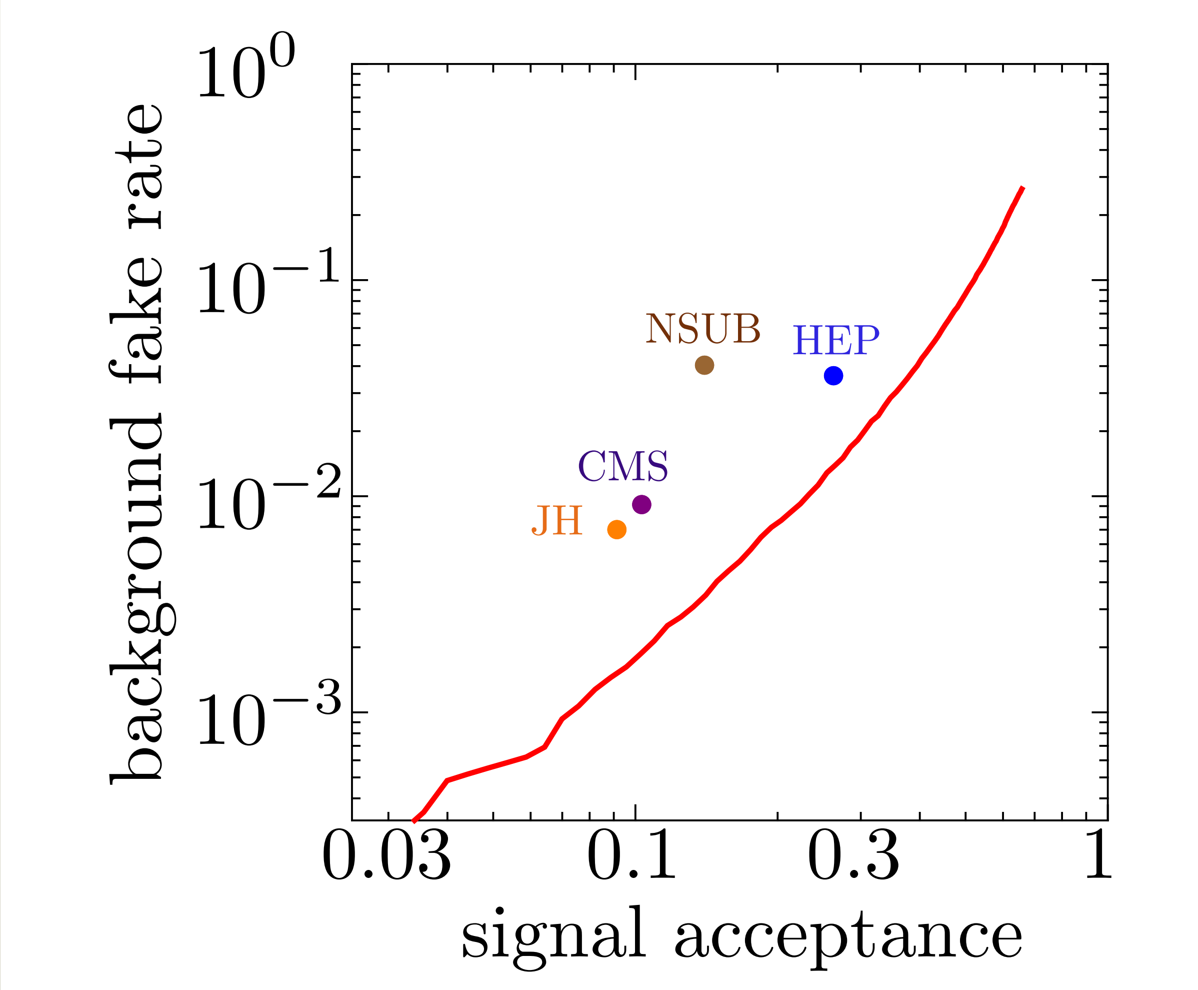
Comparisons with a log scale



“Highly boosted” is not so important

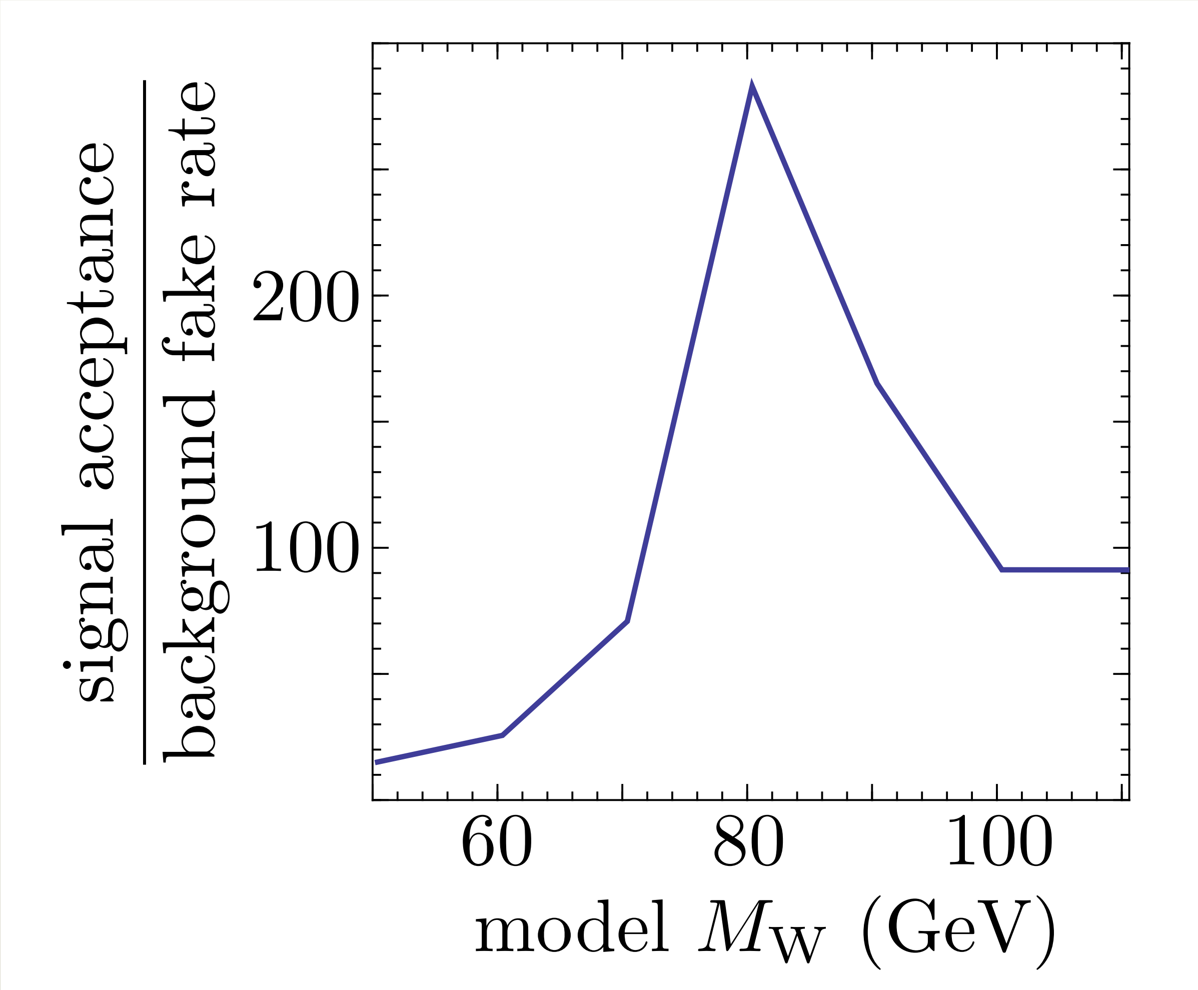
- Examine jets with $P_T > 200$ GeV using fatter jets with $R = 1.5$.

- Shower deconstruction still works.



Finding unknown parameters

- Pretend that we didn't know the W mass.



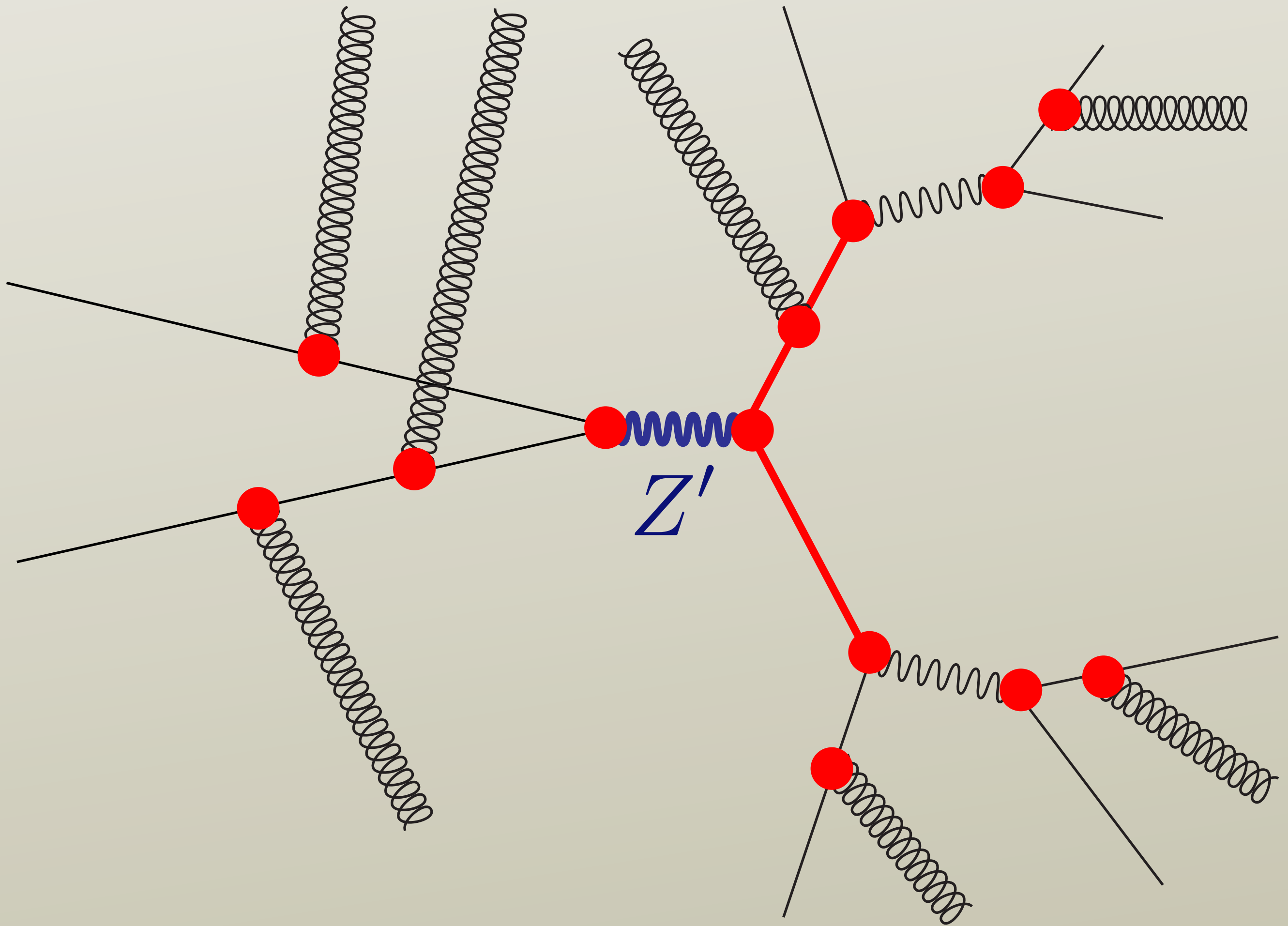
- Plot (signal acceptance)/(background fake rate) for $\chi_{\mathrm{cut}} = 384$ as a function of M_W in the signal model.
- If M_W doesn't match nature, we get a bad "signal" acceptance.

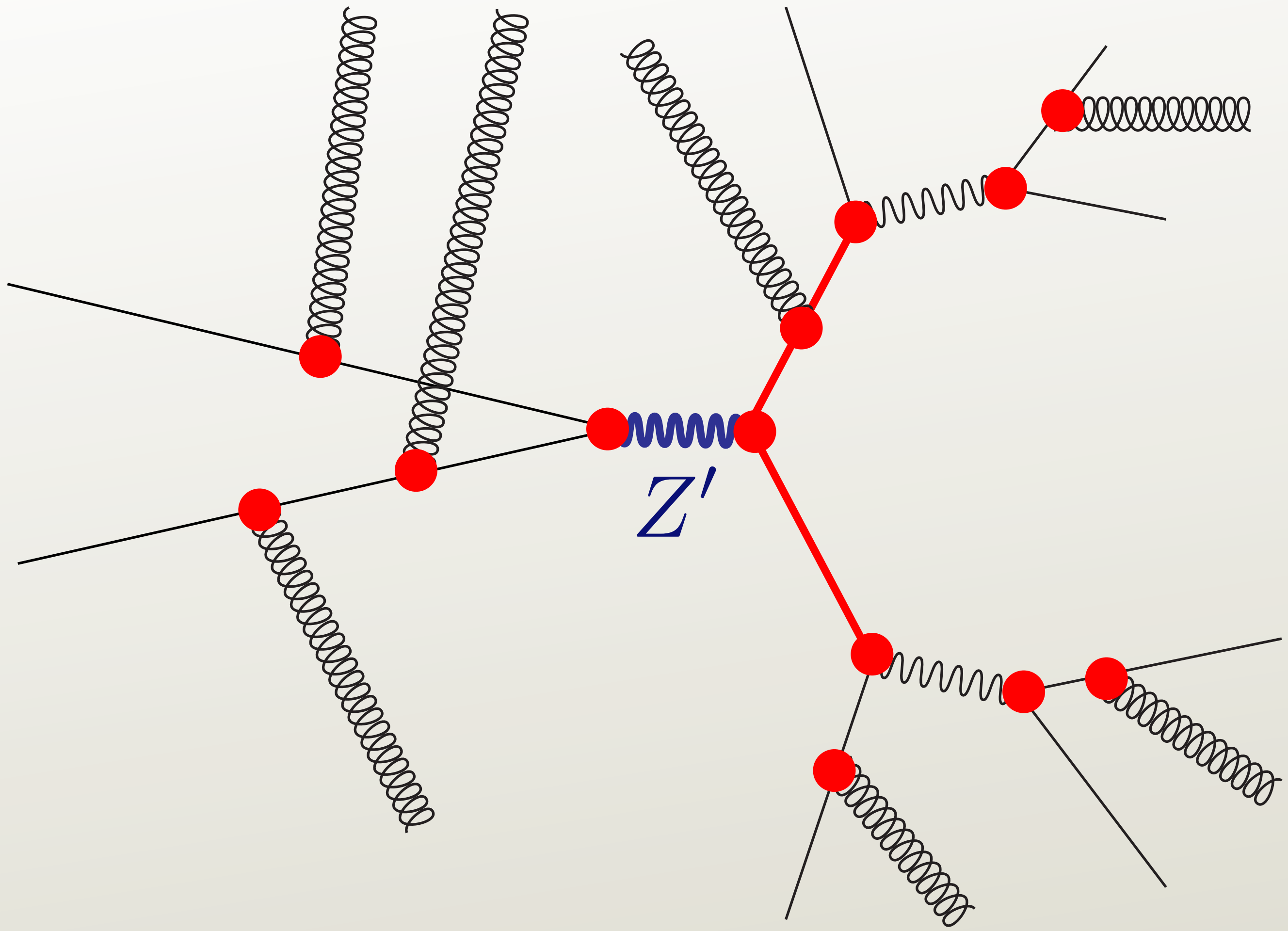
Results to date

- Shower deconstruction tries to optimally use very detailed information on jet substructure.
- There are, necessarily, approximations.
- For the studied scenarios, it finds top quarks more efficiently than current top taggers.
- It also worked well for finding boosted Higgs bosons.
- We are working with the Glasgow Atlas group on the experimental realization.

Event deconstruction

- So far we have tried to tag (fat) jets.
- Why not look at whole events?
  (Or at least big chunks of whole events.)
- *Eg.* $Z' \to t + \bar{t}$.





- Use $|\mathcal{M}|^2 \times pdf \times pdf$ for $Z' \to t + \bar{t}$.
- Look inside two fat jets.
- Scan over Z' mass values and other model parameters.
- Possibly other enhancements on our wish list.
- Add other processes.
- Aim for a versatile public tool.

Conclusions

- Shower deconstruction seems to work well.
- We eagerly await news about how well it works in an experimental environment.
- Event deconstruction can work too.
- The general method could be helped by contributions from other theorists.