# Shower Deconstruction

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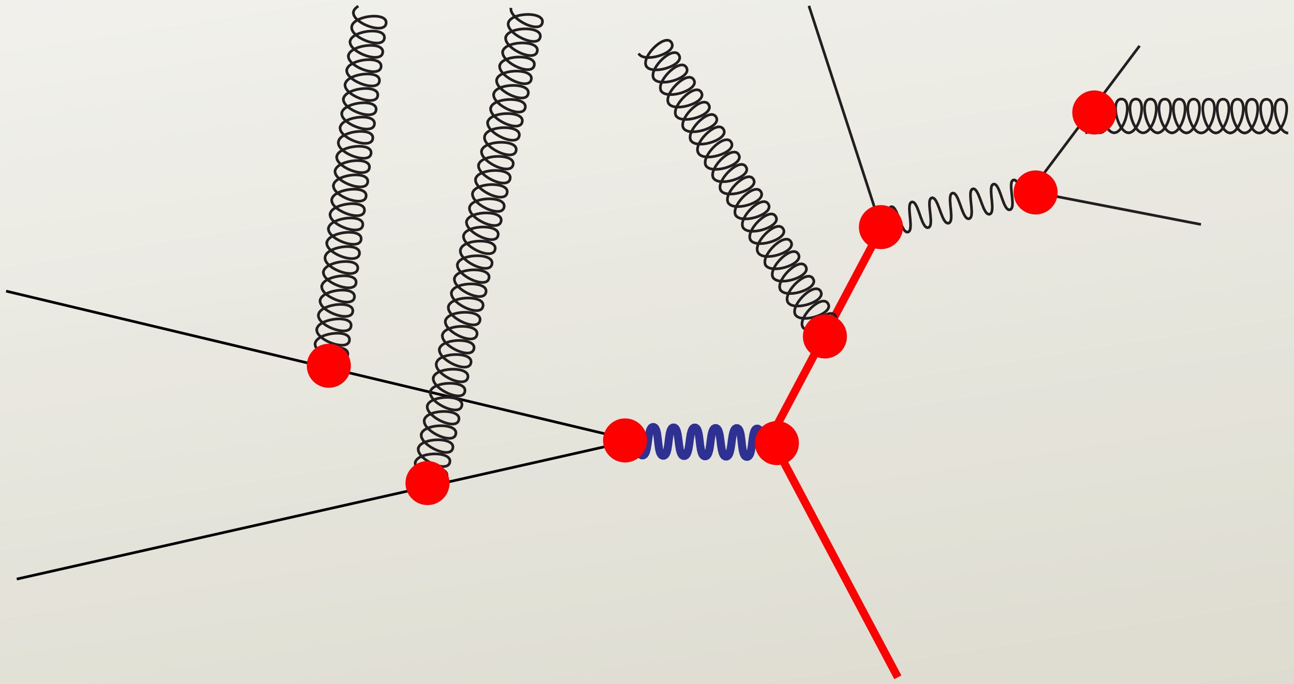
# Introduction

- One can examine the substructure of events with showers in order to dig out new physics signals.
- One uses especially jets that may contain highly boosted heavy objects.
- Methods include “mass drop + filtering,” “trimming,” and “pruning.”
- There has been a lot of activity in this field.

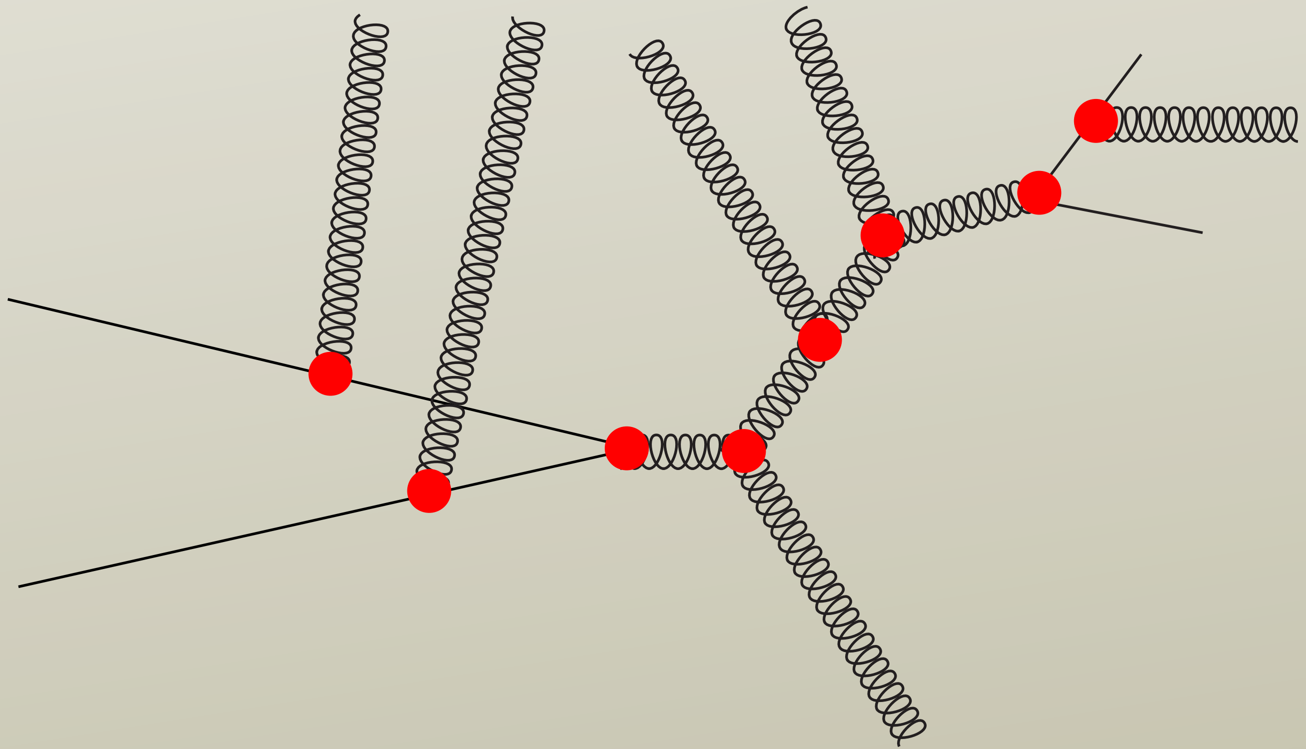
- Michael Spannowsky and I proposed a general method for subjet analysis: “shower deconstruction.” (Phys. Rev. D84 (2011) 074002)
- The initial application was to production of a Higgs boson recoiling against a Z-boson and decaying to b quarks.
- A lot of the structure of this comes from the partitioned dipole shower algorithms by Zoltan Nagy and D. Soper.
- A new application (with Spannowsky and Nagy) is to find top quarks.

# Our example

We want to find one of the tops in $Z' \to t + \bar{t}$.



In a background of QCD dijets.



# Event selection

Signal is $Z' \to t + \bar{t}$ with $Z'$ mass 1.5 TeV, simulated with Pythia 8.

Background is dijets simulated with Pythia 8.

Require:

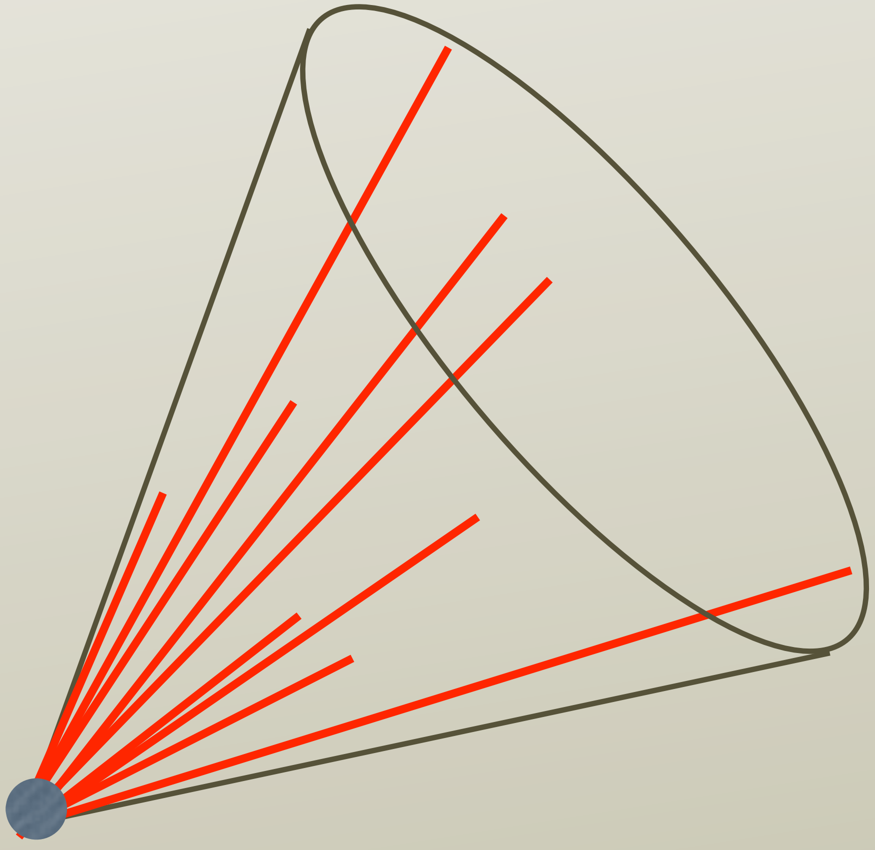
- Two fat jets with $P_T > 500$ GeV using CA algorithm with $R = 1.0$.
- For signal, check using MC truth that top is in fat jet.

We look at just one of the fat jets.

Thus we are trying to identify just one top quark.

# Define the microjet constituents

- Use the $k_T$ algorithm with $R = 0.15$ to group the fat jet into microjets.
- Discard microjets with $P_T < 3$ 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

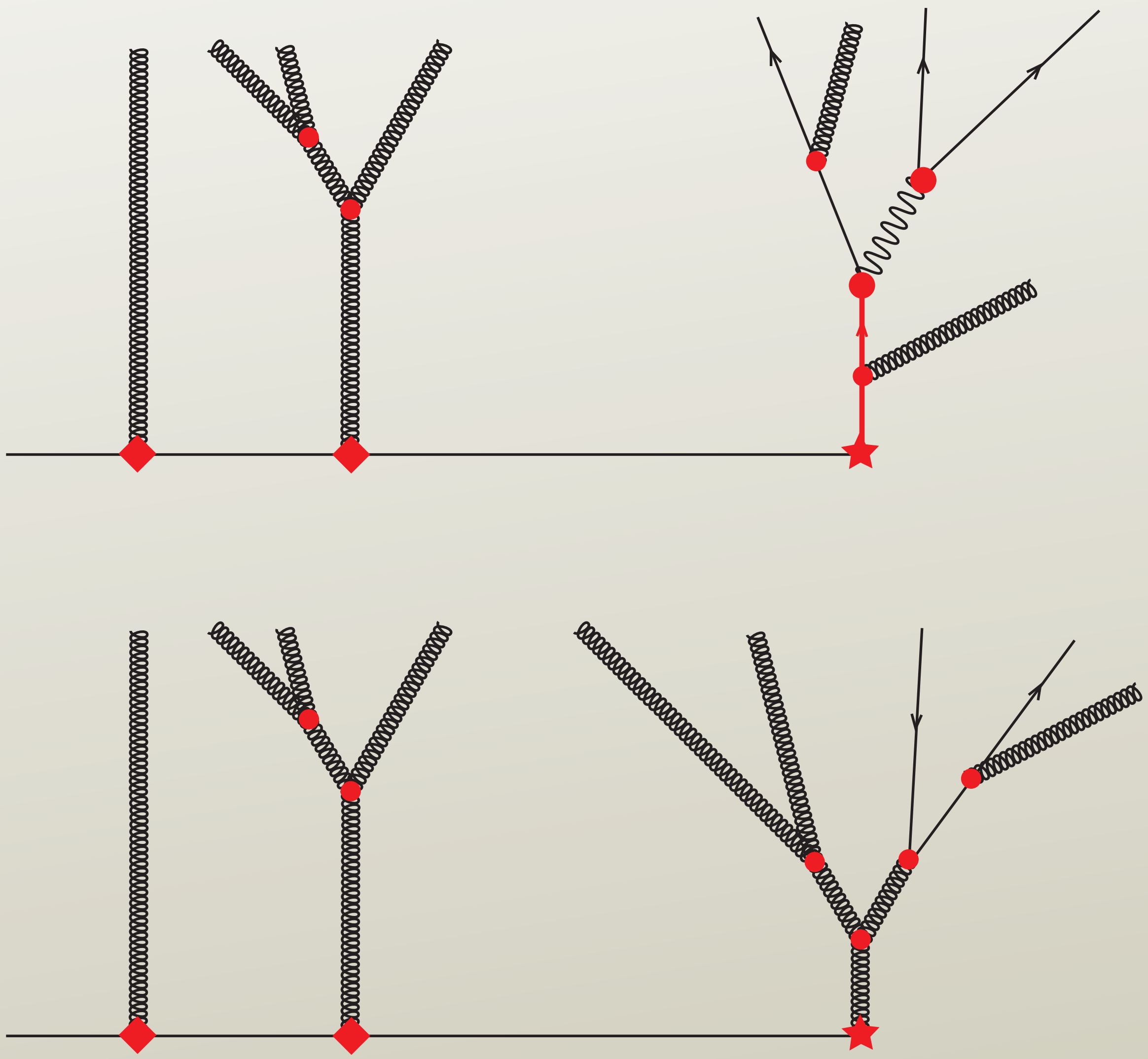
- Calculate

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

according to a "simplified parton shower" algorithm.

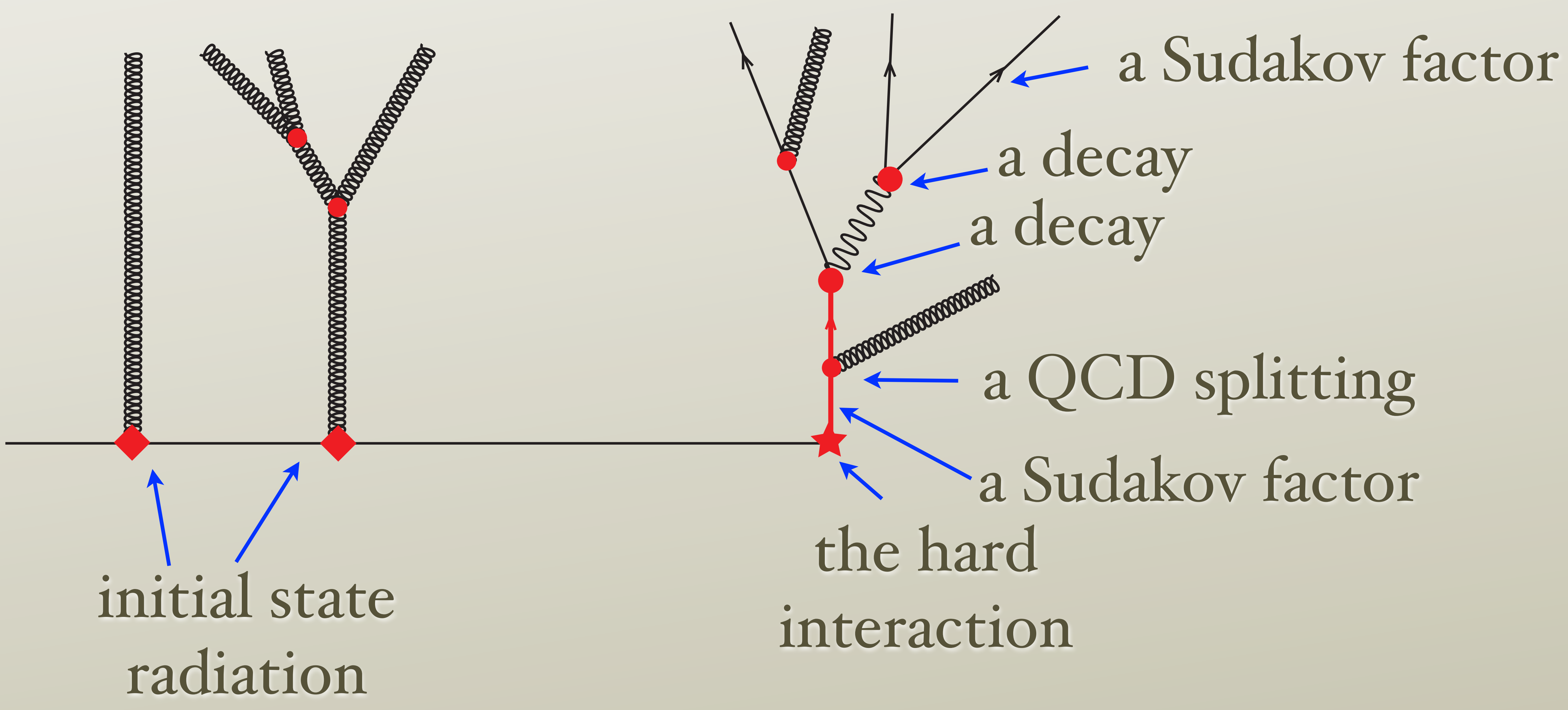
# How does it work?

- We sum over event histories.



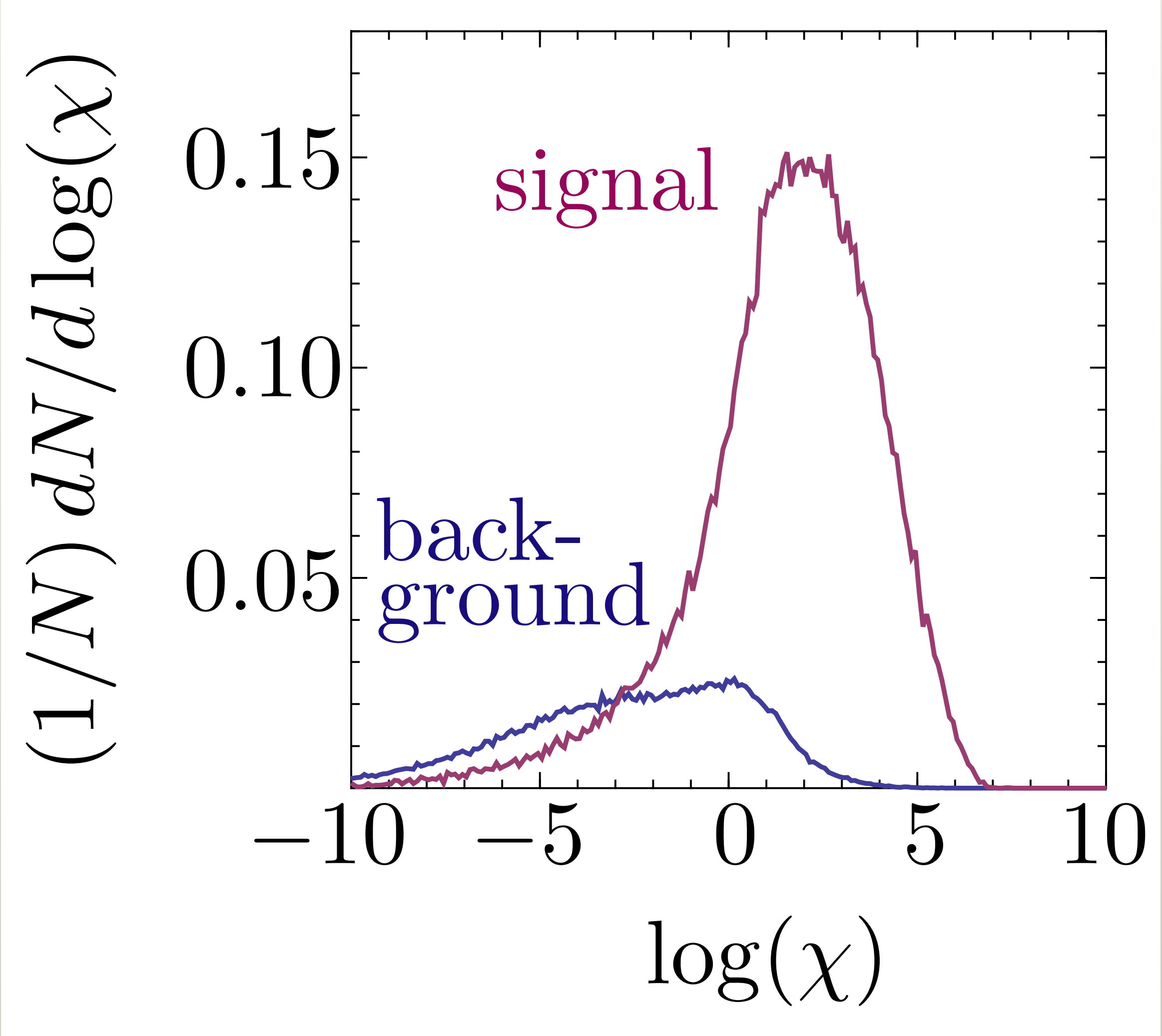
# About histories

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



# $\chi$ distributions for signal and background

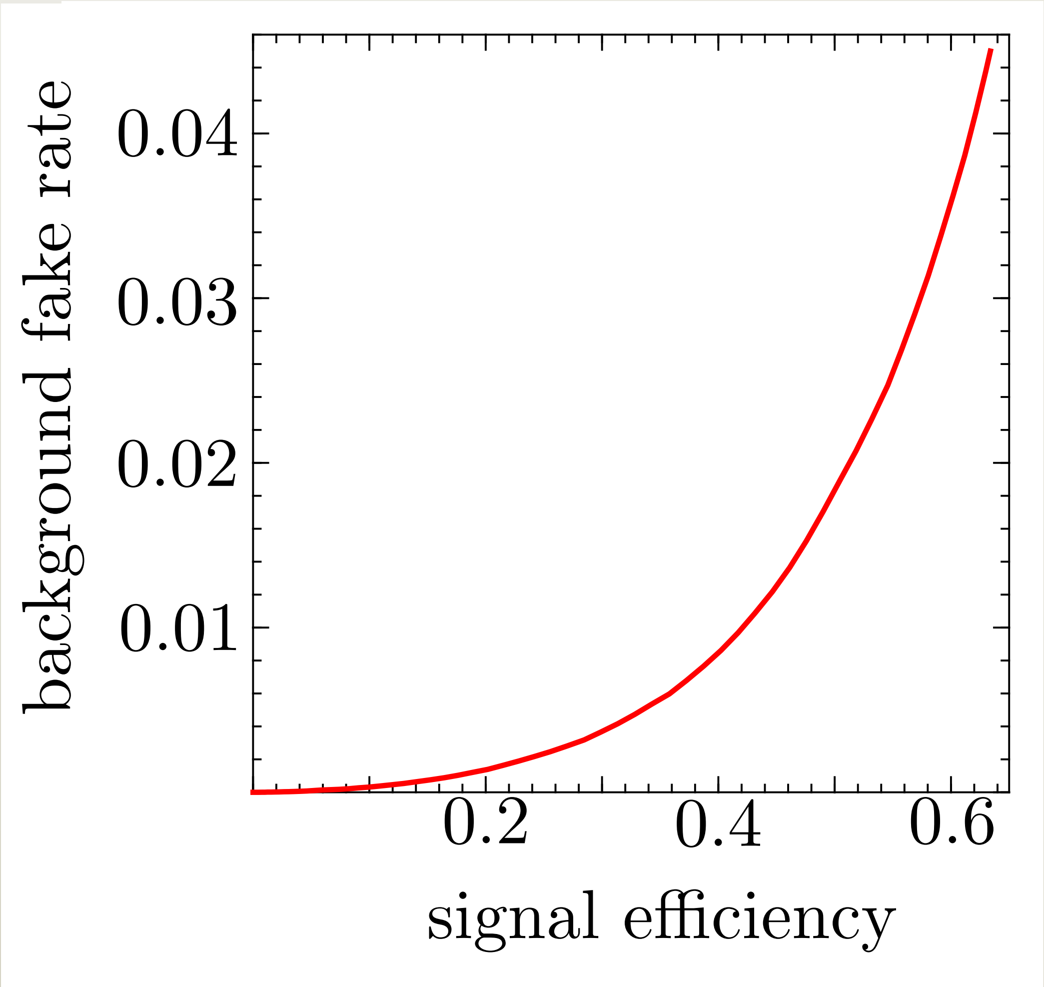
- Signal events have large $\chi$.
- Background events have small $\chi$.
- We can separate signal from background with a cut on $\chi$.
- Events with $\chi = 0$ do not appear in the graph.




Jets with 600 GeV $< p_T <$ 700 GeV

# Tagging efficiency

- Select events with $\chi > \chi_{\text{cut}}$.
- Fraction of signal events accepted = "signal efficiency."
- Fraction of background events accepted = "background fake rate."

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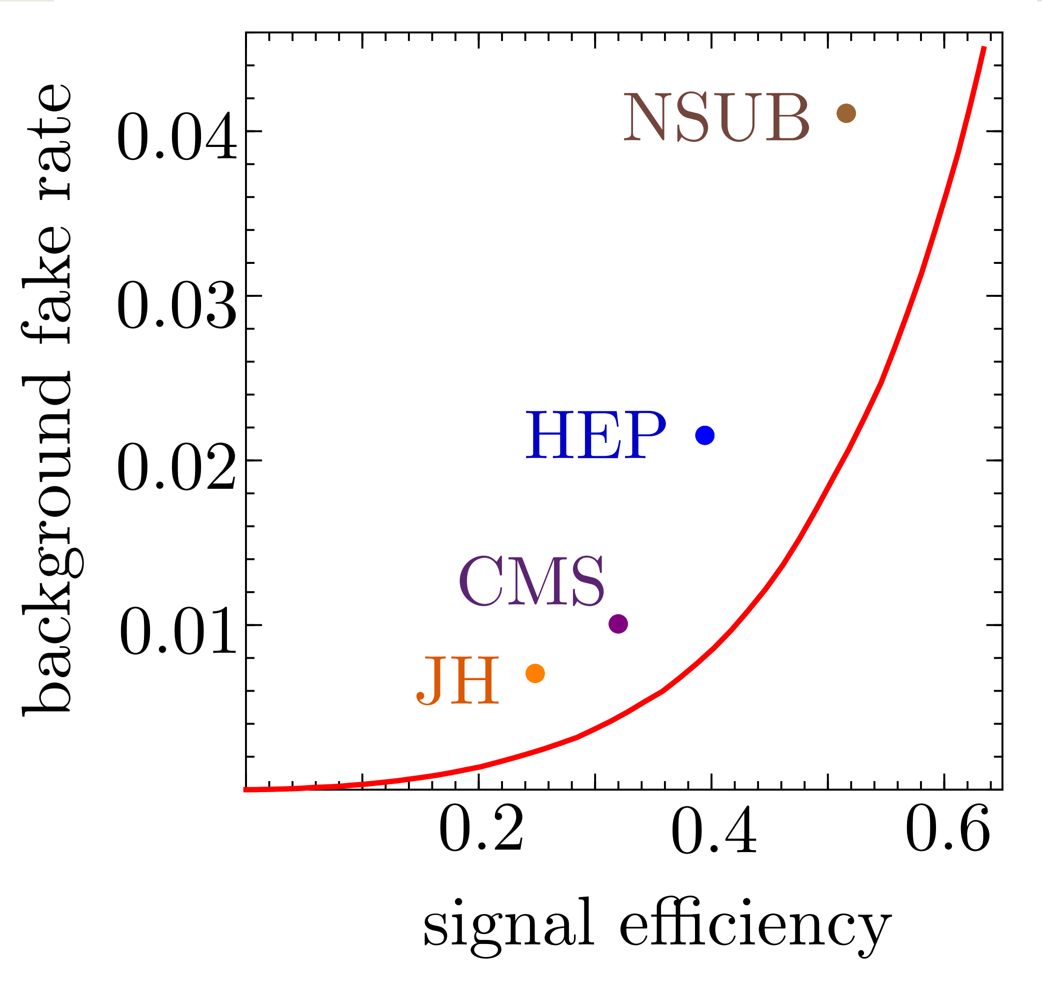
# Comparison to other top tagging methods

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

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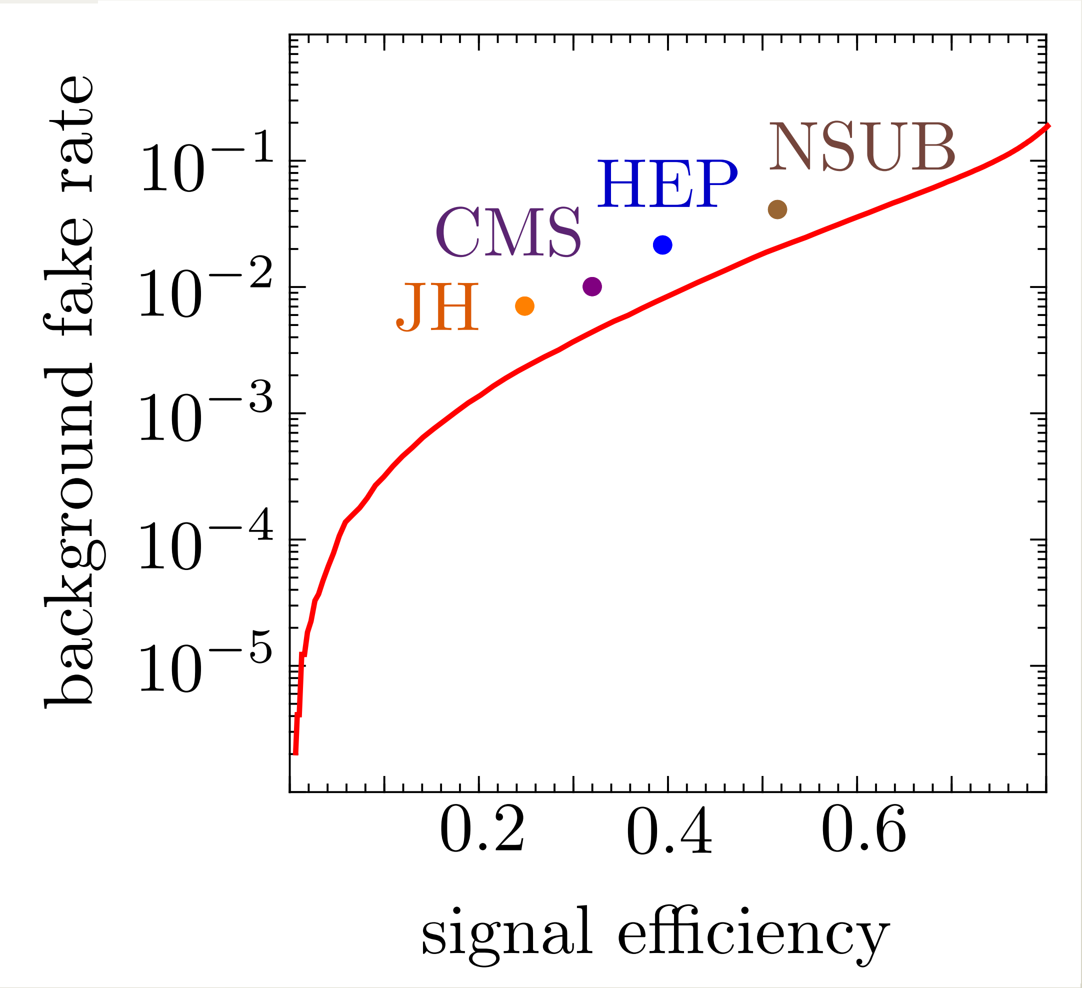
The same comparison on a log scale.

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# Conclusions

- 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.

# The future

- We are working with the Glasgow Atlas group on the experimental realization.
- Shower deconstruction is modular and the parts can be improved.
- It may be possible to improve the computer speed.
- We want to expand the range of applications.
- New ideas are needed to incorporate multiple neutrinos or other invisible particles.