Event Deconstruction: example with top quarks

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Introduction

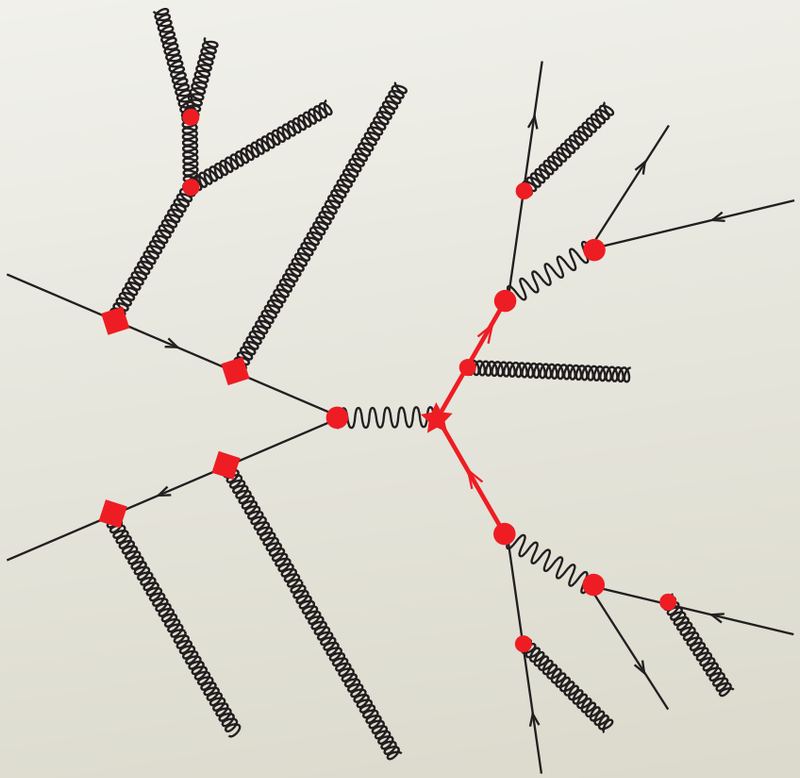
- One can examine the fine grained structure of events in order to dig out new physics signals.
- Michael Spannowsky and I proposed a general method for subjet analysis: “shower deconstruction.” (Phys. Rev. D84 (2011) 074002)
- An application is to find top quark jets. (Phys. Rev. D87 (2013) 054012)
- This works well in ATLAS: ``Performance of shower deconstruction in ATLAS,'' ATLAS-CONF-2014-003.

- We have extended this to “event deconstruction,” looking at the relevant features of whole events.
(arXiv:1402.1189 [hep-ph])

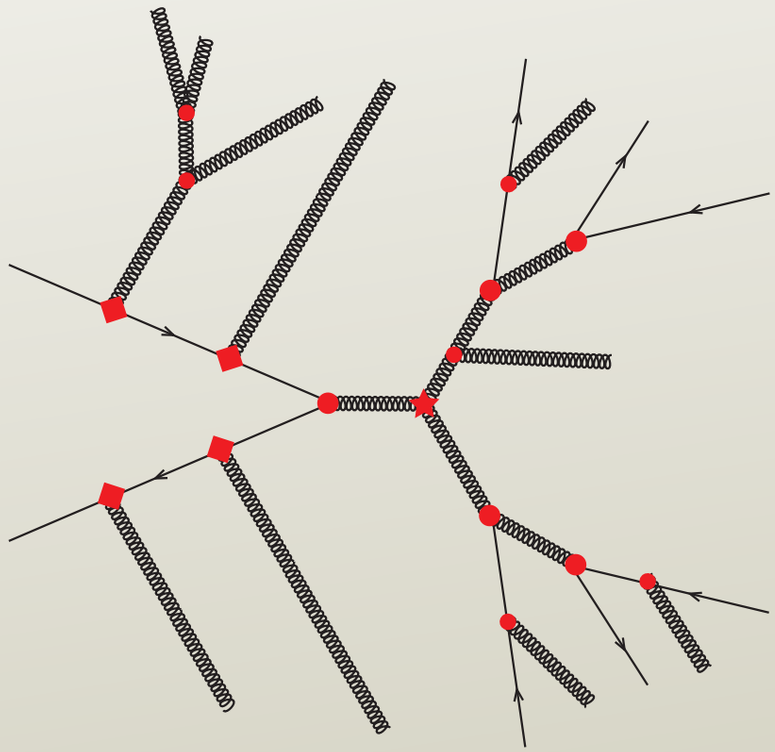
- Our example:

$$Z' \to t + \bar{t} + X \to \text{hadron jets} + X$$

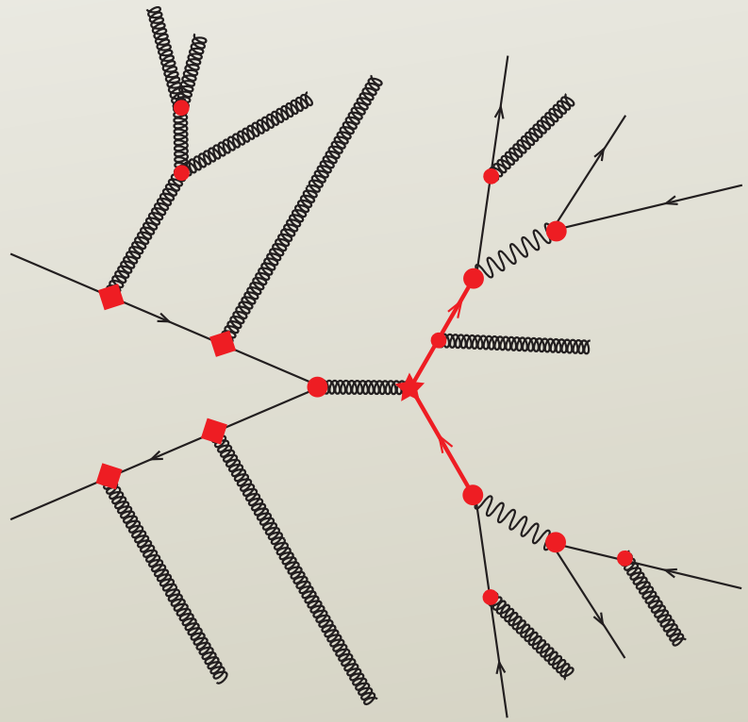
Our example



$Z' \to t + \bar{t} + X$
signal



QCD with no tops
background



QCD $\to t + \bar{t}$
background

Event sample

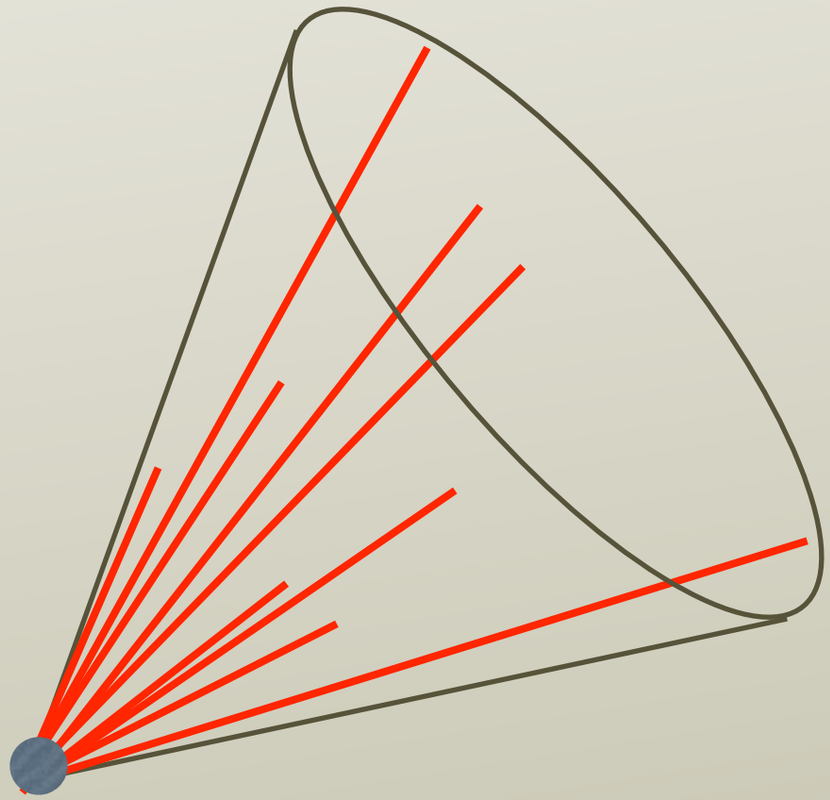
- Signal is $Z' \to t + \bar{t}$ simulated with Pythia 8 with $M(Z') = 1500$ GeV and $\Gamma(Z') = 65$ GeV.

- Background is QCD with no tops and QCD $t + t$ simulated with Pythia 8.

- Require two fat jets (using CA with $R = 1.5$) with $|y| < 2.5$ and $p_T > 400$ GeV.

Microjets

- Base the analysis on "microjet" constituents of each fat jet.
- In data, microjets would be defined from the calorimeter.
- For theory, use the CA algorithm with $R = 0.2$ to group the fat jet into microjets.
- Discard microjets with $P_T < 10$ GeV.
- If more than nine microjets in a fat jet, discard the softest.
- Microjets in both jets together 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:

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

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

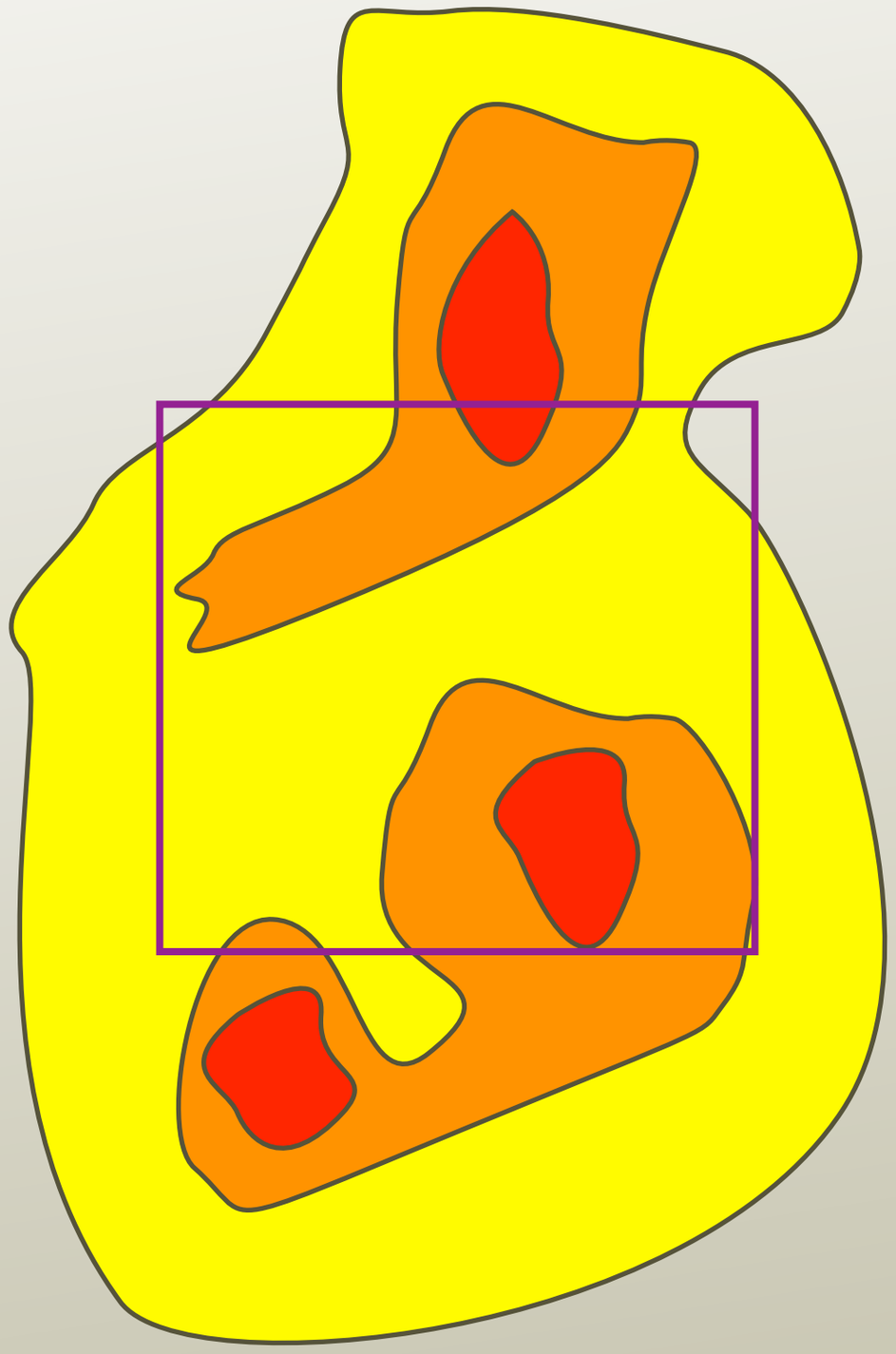
- We would like to separate signal an background using

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

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

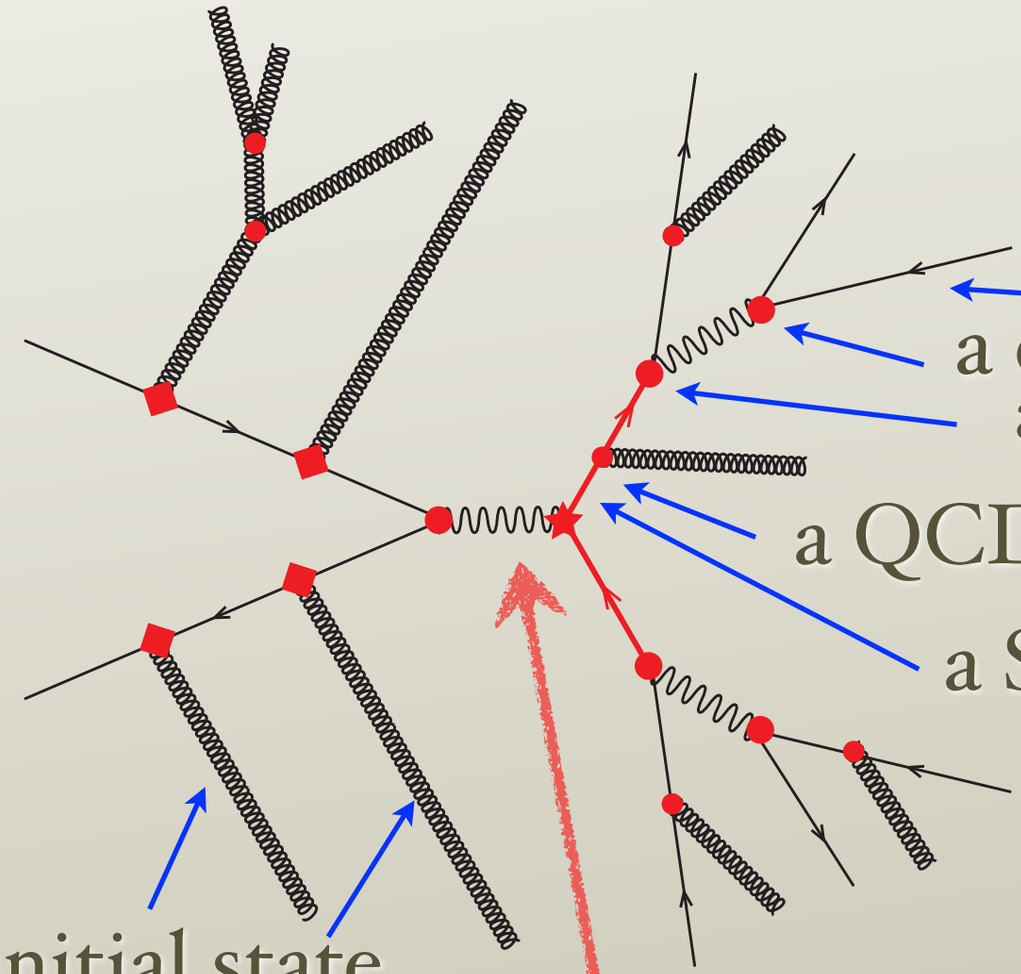
$$\chi(\{p\}_N) = \frac{P(\{p\}_N|\mathrm{S})}{P(\{p\}_N|\mathrm{B})}$$

according to a hard matrix element, parton distribution functions, and a simplified parton shower algorithm

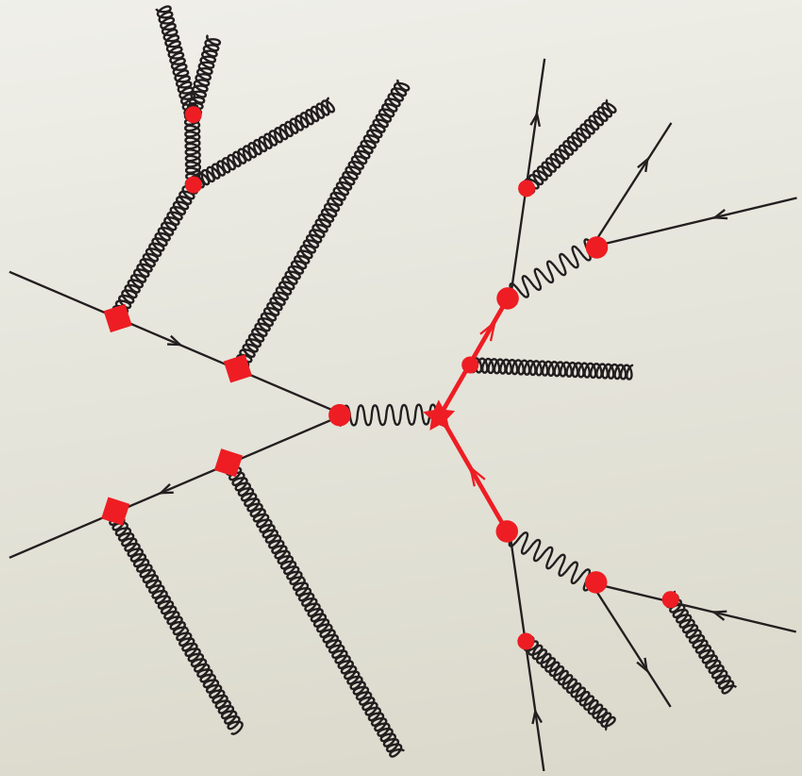
- The calculation is analytic.

Event histories

- Each part of the diagram corresponds to a factor in an event generator.



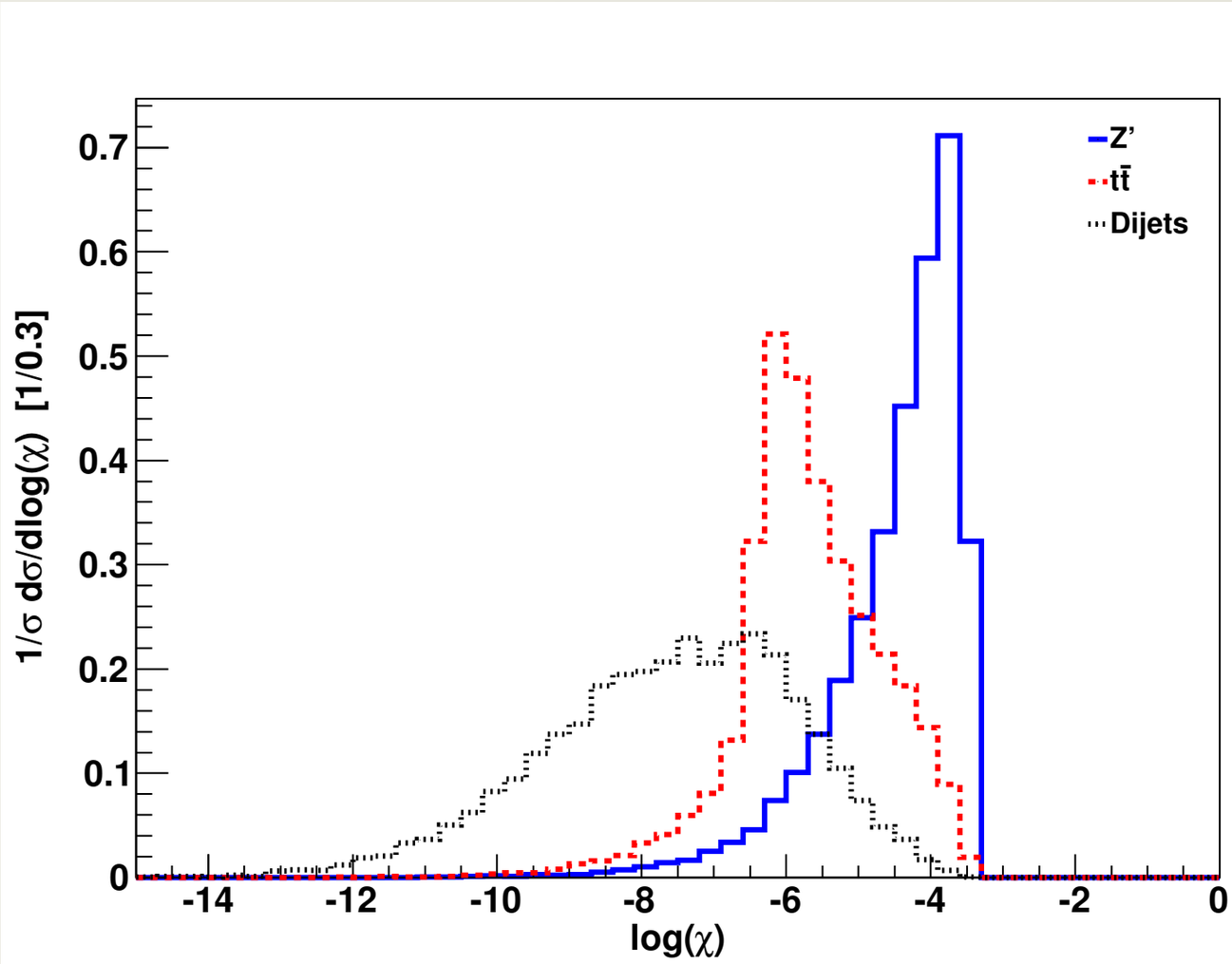
Sum over event histories



with some simiplifications to make the two fat jets effectively independent.

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.

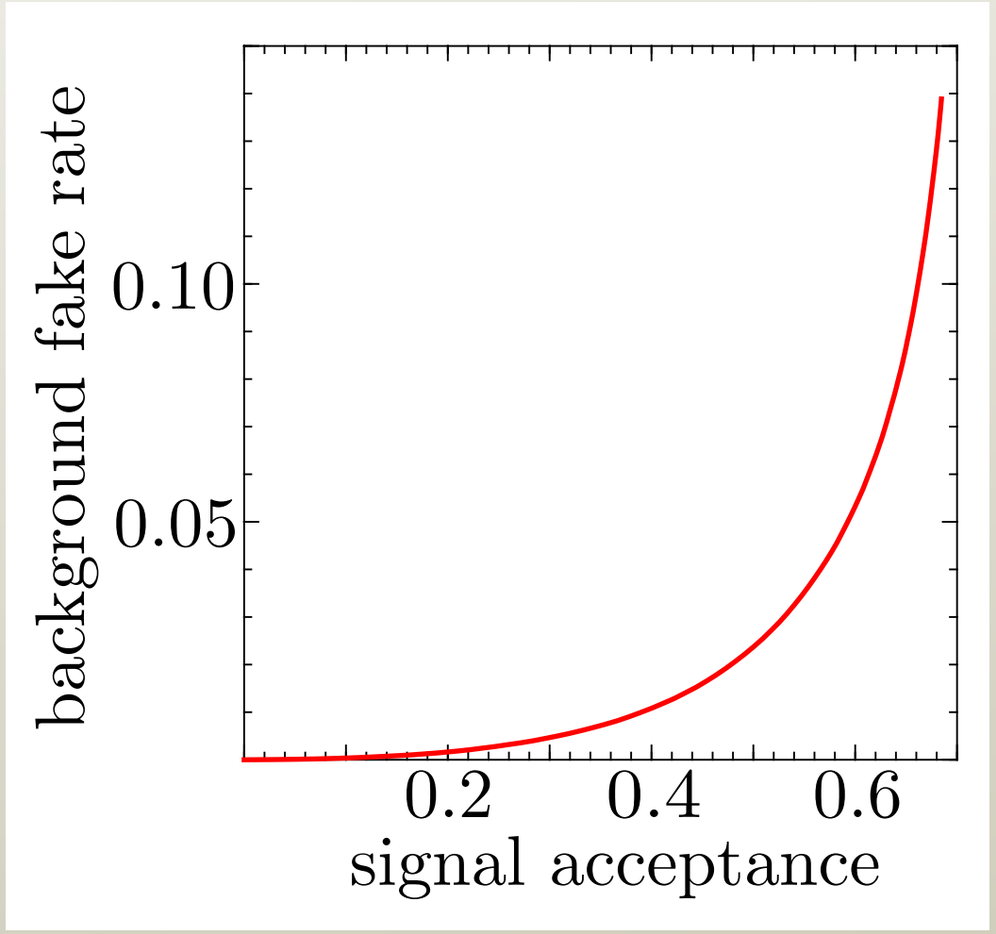


Tagging efficiency

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

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

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

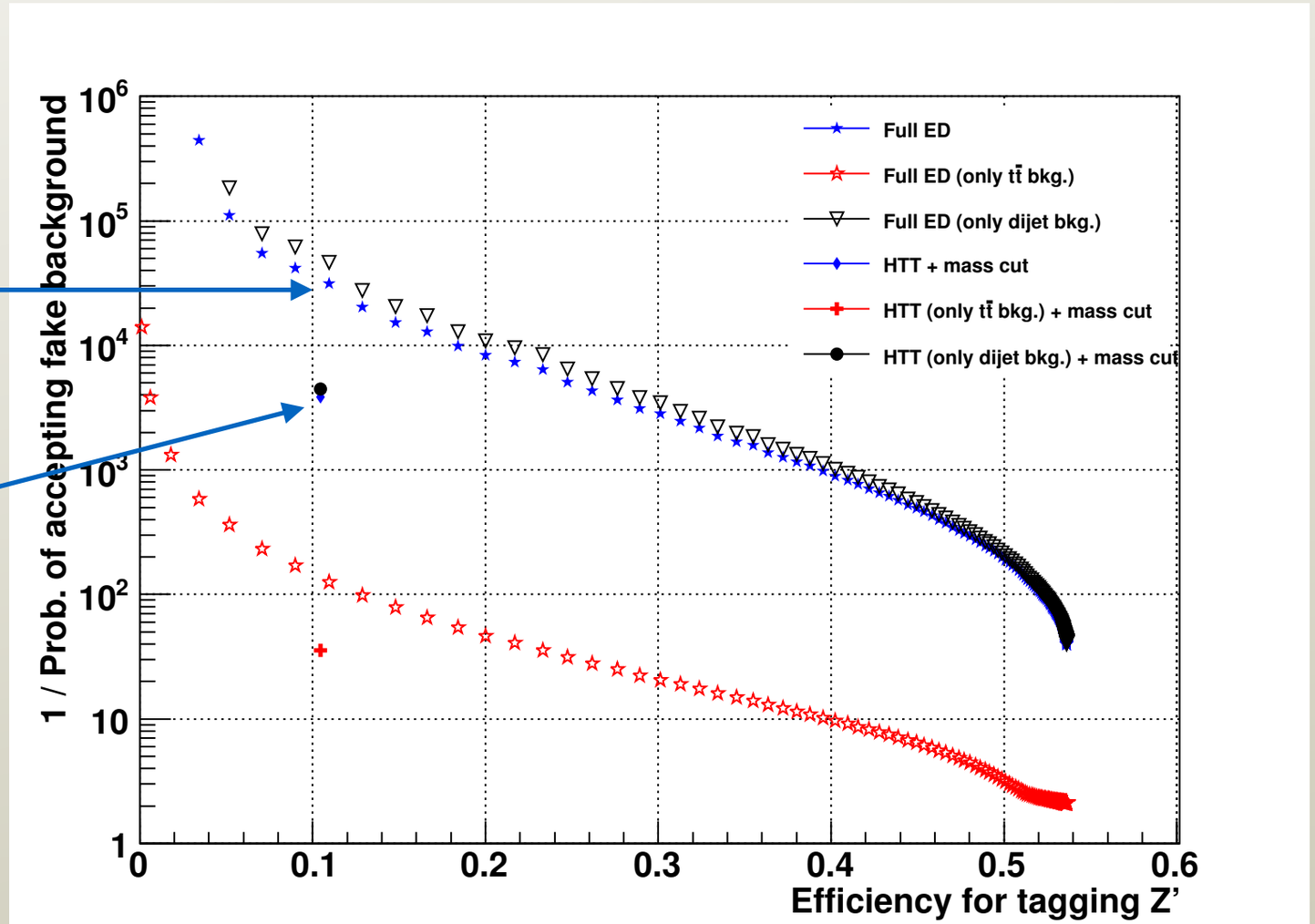


- On next page, we will plot 1/"background fake rate" on the vertical axis.

Comparison to HEP top tagger

Event deconstruction

HEP top tagger and mass cut



Conclusions

- Event deconstruction seems to work well.
- For tagging single jets, shower deconstruction also works nicely with Monte Carlo events.
- ATLAS finds that shower deconstruction works well for finding top quark jets in experiment.
- The general method could be helped by contributions from other theorists.