Quantifying the performance of jet definitions for kinematic reconstruction at the LHC

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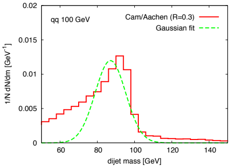
Aim

- There exist many jet definitions and reconstruction algorithms.
- What is the **best jet definition** for kinematic reconstructions?
- Example: search for a narrow resonance from a new boson.
- The distribution of the reconstructed mass after parton shower is often non-Gaussian:



- Use physical parameters rather than unphysical Monte Carlo partons to find a quantitive measure of jet performance.

Analysis

The basic idea

- Parton pairs produce ficticious bosons with a **narrow resonance** width of $1\,\mathrm{GeV}$
- The boson decays, producing quarks or gluons, which hadronize
- The hadrons are modelled as jets
- The mass of the boson is reconstructed

- Z' bosons are associated with jets from quarks: $q\bar{q} \to Z' \to q\bar{q}$
- H bosons are associated with jets from gluons: $gg \to H \to gg$
- We scan the masses of the ficitious bosons Z', H in mass range $100\,\mathrm{GeV} - 2\,\mathrm{TeV}$. We show only a few examples.

Jet Definition (1)

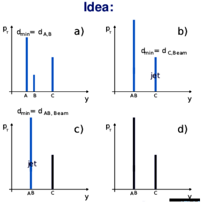
For k_t algorithm we define:

$$d_{ij} = \min\left(p_{ti}^2, p_{tj}^2\right)\frac{\Delta R_{ij}}{R}; \quad d_{iB} = p_{ti}^2 \tag{1}$$

d_{ij} - distance between the jets
p_{ti}, p_{tj} - jet transverse momenta
$\Delta R_{ij}^2 = (\phi_i - \phi_j)^2 + (y_i - y_j)^2$ - jet distance in azimuthal-rapidity plane between the 2 jets
R - the minimum jet separation we impose ("focus parameter")

Then the algorithm proceeds;

1. Evaluate d_{ij} for every couple of particles;
2. Find smallest of d_{ij};
3. If $d_{ij} > d_{iB}$, stop clustering. Otherwise recombine i and j;
4. Repeat from step 1;



Jet definition (2)

For *anti* $- k_t$ algorithm we define:

$$d_{ij} = \min\left(\frac{1}{(p_{ti})^2}, \frac{1}{(p_{tj})^2}\right)\frac{\Delta R_{ij}}{R}; \quad d_{iB} = \frac{1}{(p_{ti})^2} \qquad (2)$$

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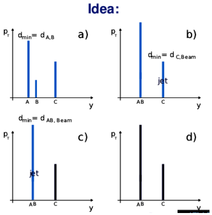

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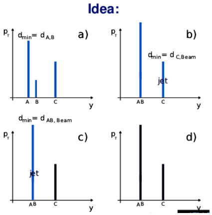
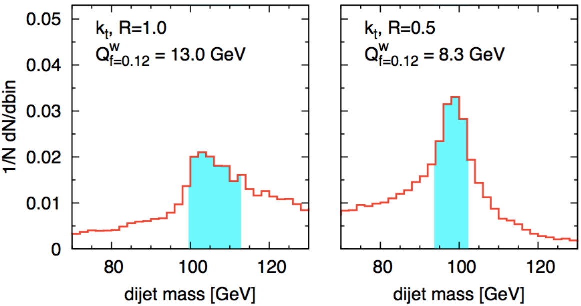


K_t algorithm starts recombining the clusters from the smallest jets. $Anti - K_t$ algorithm starts recombining the clusters from the biggest jets.

Figure of merit

$Q^{\mathrm{w}}_{\mathrm{f}=z}$: a measure of the performance of jet definitions

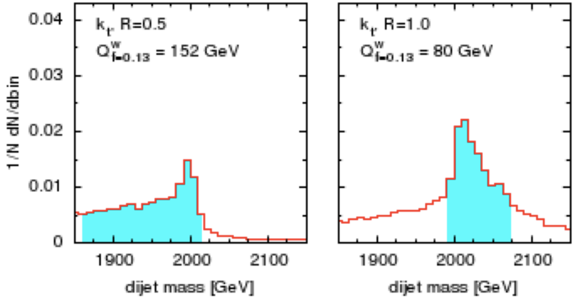
- If two peaks have similar numbers of events, the **narrower** one **is better**.
- $Q^{\mathrm{w}}_{\mathrm{f}=z}$: the width of the smallest **reconstructed mass window** that contains a fraction f of the generated massive objects
- $Q^{\mathrm{w}}_{\mathrm{f}=z}$ has a dependence on R
- Low value of $Q^{\mathrm{w}}_{\mathrm{f}=z}$ = narrower peak = better jet definition



$Z' \to q\bar{q}$, 100 GeV

Sharper peak for small R

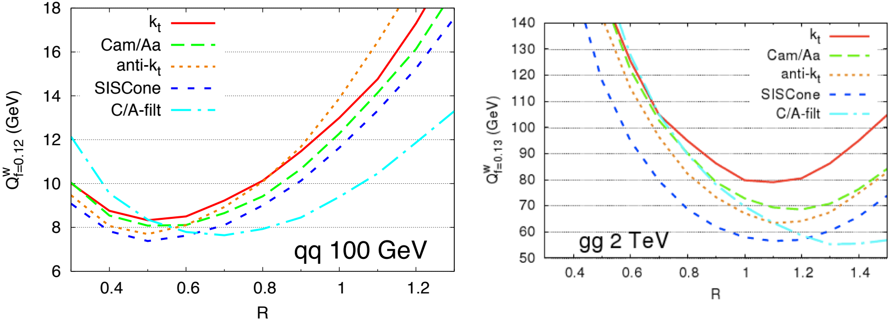
Results 1



$H \to gg,\ 2\,\mathrm{TeV}$

Sharper peak for big R

Results 2



- For low-energetic quark jets ($\sim 100\,\mathrm{GeV}$), small values of R (~ 0.5) are preferred
- For high-energetic gluon jets ($\sim 2\,\mathrm{TeV}$), larger values of R (~ 1.2) are preferred
- Production of **secondary gluons** highest for high-energetic gluon pairs - larger R required

Conclusions

- Definition of a **data-driven physical quantitative** measure $Q^{\mathrm{w}}_{\mathrm{f}=z}$ characterizing the sharpness of a peak
- Use $Q^{\mathrm{w}}_{\mathrm{f}=z}$ to describe the performance of a jet definition
- Well adapted for non-Gaussian reconstructed masses
- **Sharpness** of the peak is related to the **sensitivity** of a measurement
- An optimal choice of R can increase the discovery potential of new particles