A new tool for jet definitions at high luminosity

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1. What will happen at 14 TeV?
2. Problems with the current plan
   - Jets formed out of noise
   - High minimum E_T cut → poor reconstruction of known physics objects
   - Examples of where this will be a problem

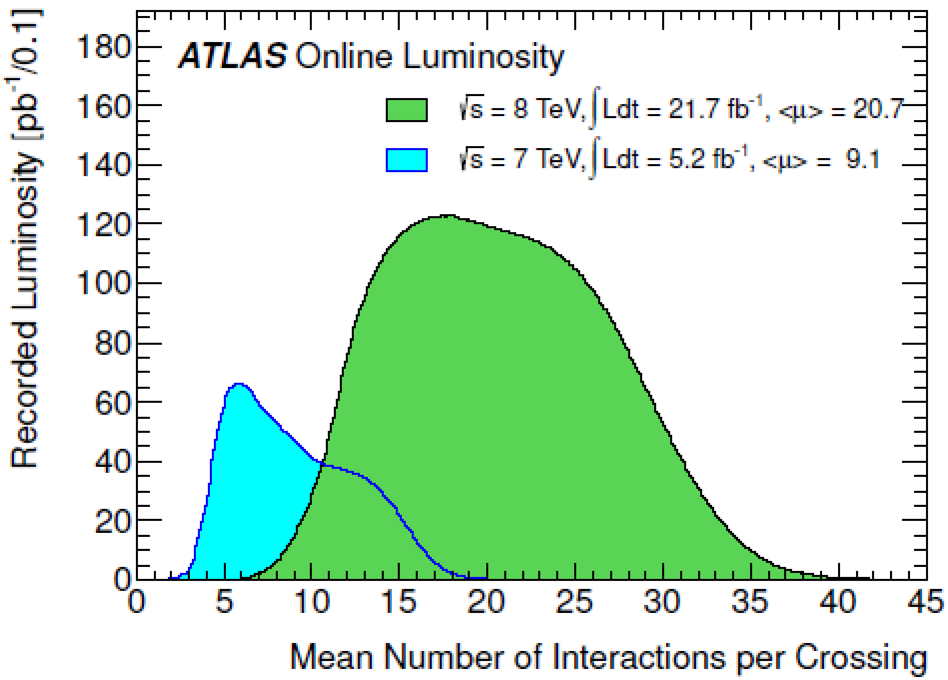
   (Many graphs taken from arXiv:1307.6908)
3. A new proposed solution
   - Theory: sculpting jets
   - Experiment: Simulation and strengths
   - Future Work

Introduction: What will happen (1)

- Increase in energy from each event
- More events per crossing (~20 -> ~50-140)
- Decrease in time between crossings

Worst case scenario: total whiteout in detector

Best case scenario: horrible noise contamination in all interesting physics events



arXiv:1307.6908

Introduction: What will happen (2)

Easiest Solutions:

Raise the jet energy threshold to avoid noise

-or-

Only look at charged tracks from a single vertex to form jets

Problems with the current plan (1)

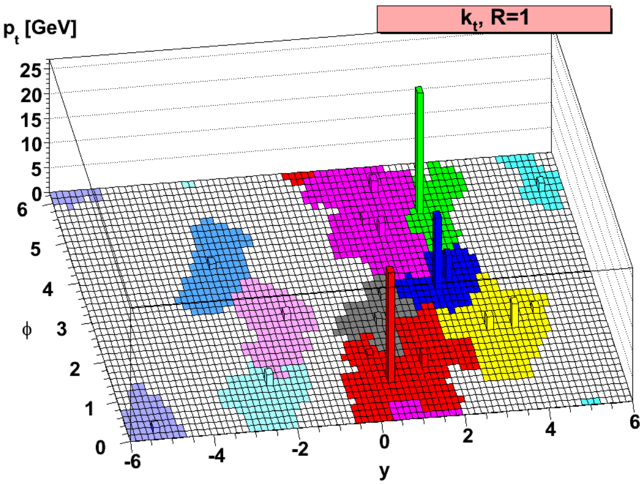
For any jet clustering algorithm:

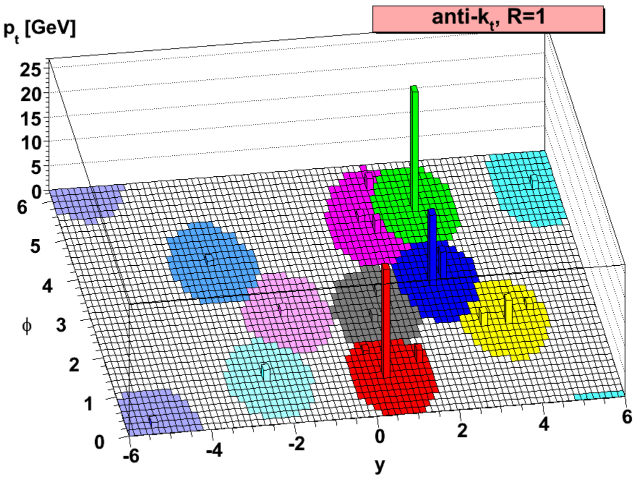
Because detector is flooded, any arbitrary cone drawn will pass limited cuts

Any jets that do exist will be bloated due to absorption of any and all nearby noise

- k_T will essentially suck up the entire detector into one jet

-anti-k_T will create a full detector of circle and circle-fragments, which don't necessarily correspond to the physical objects



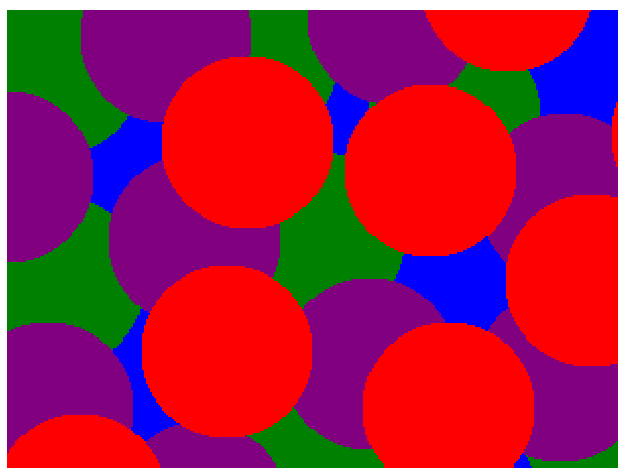


Problems with the current plan (2)

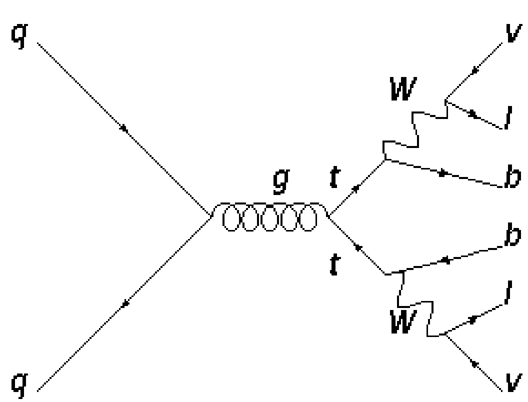
All known physics objects are less than 200 GeV, which tend to decay to objects under 100 GeV in energy

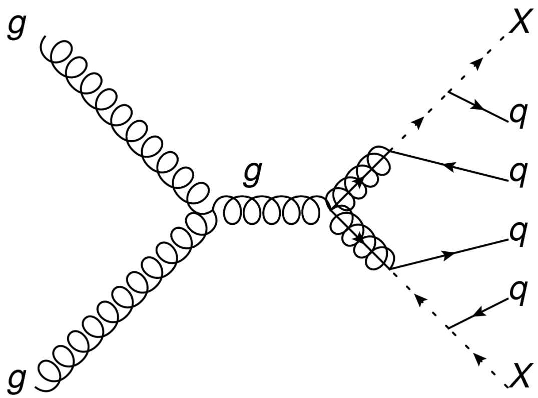
Many predicted particles will cascade to objects below 100 GeV.

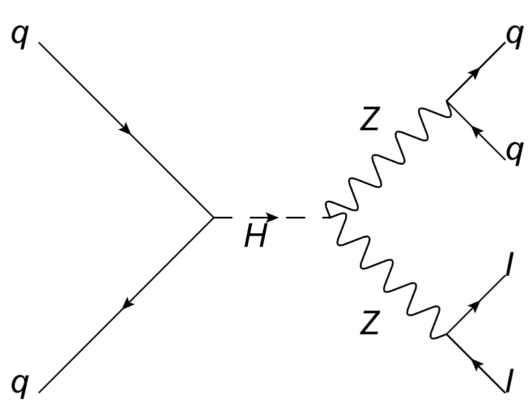
This situation is great when there is a minimum E_T cut of 20 GeV. If the E_T threshold is raised to 100 GeV, we cannot reconstruct known object production threshold, for anything that decays to jets.

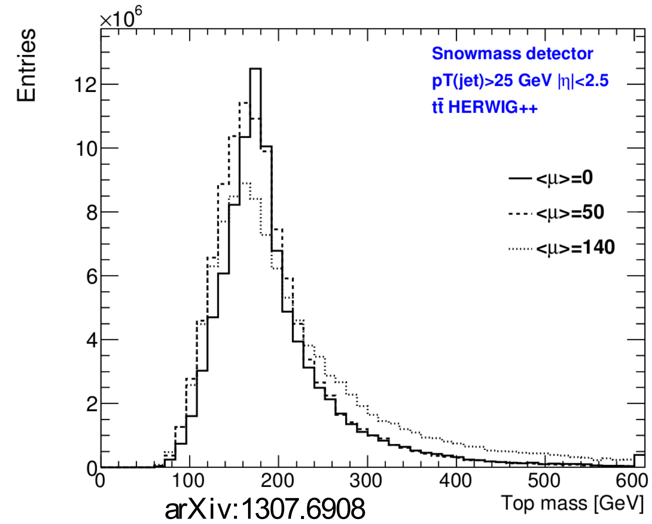


Examples

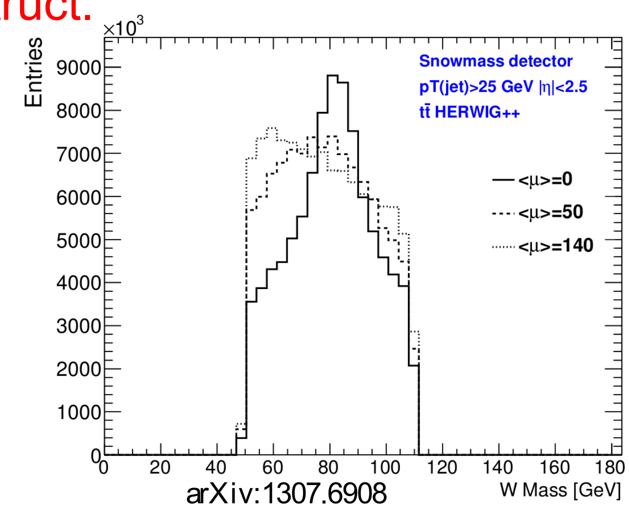








These are just a few examples where inability to accurately reconstruct low E_T jets will make formerly interesting events difficult, if not impossible, to reconstruct.



A Proposed Solution

Our solution: Create a new jet algorithm to craft jets. Our method uses the following assumptions:

- The shape of jets is somewhat understood

- The theory behind jet factorization is understood

Combine these into a jet algorithm to craft jets to the appropriate shape, and let a jet energy correction adjust for the addition of background noise

A Proposed Solution Theory (1)

Jet formation is most fundamentally seen in the difference between photon decay to qq and to qqg

In computation, the qqg cross-section has known singularities when the angle between two of the objects goes to 0 (collinear), or when the energy of any of the gluon goes to 0

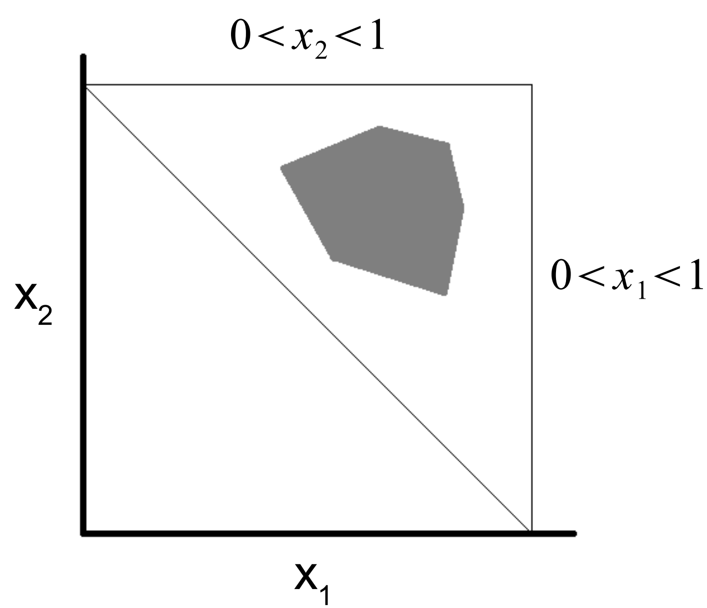
Jet algorithms alter the phase-space to avoid these singularities in the integral

$$\sigma_{q\bar{q}g} = \sigma_{q\bar{q}} \int \frac{x_1^2 + x_2^2}{(1 - x_1)(1 - x_2)}$$

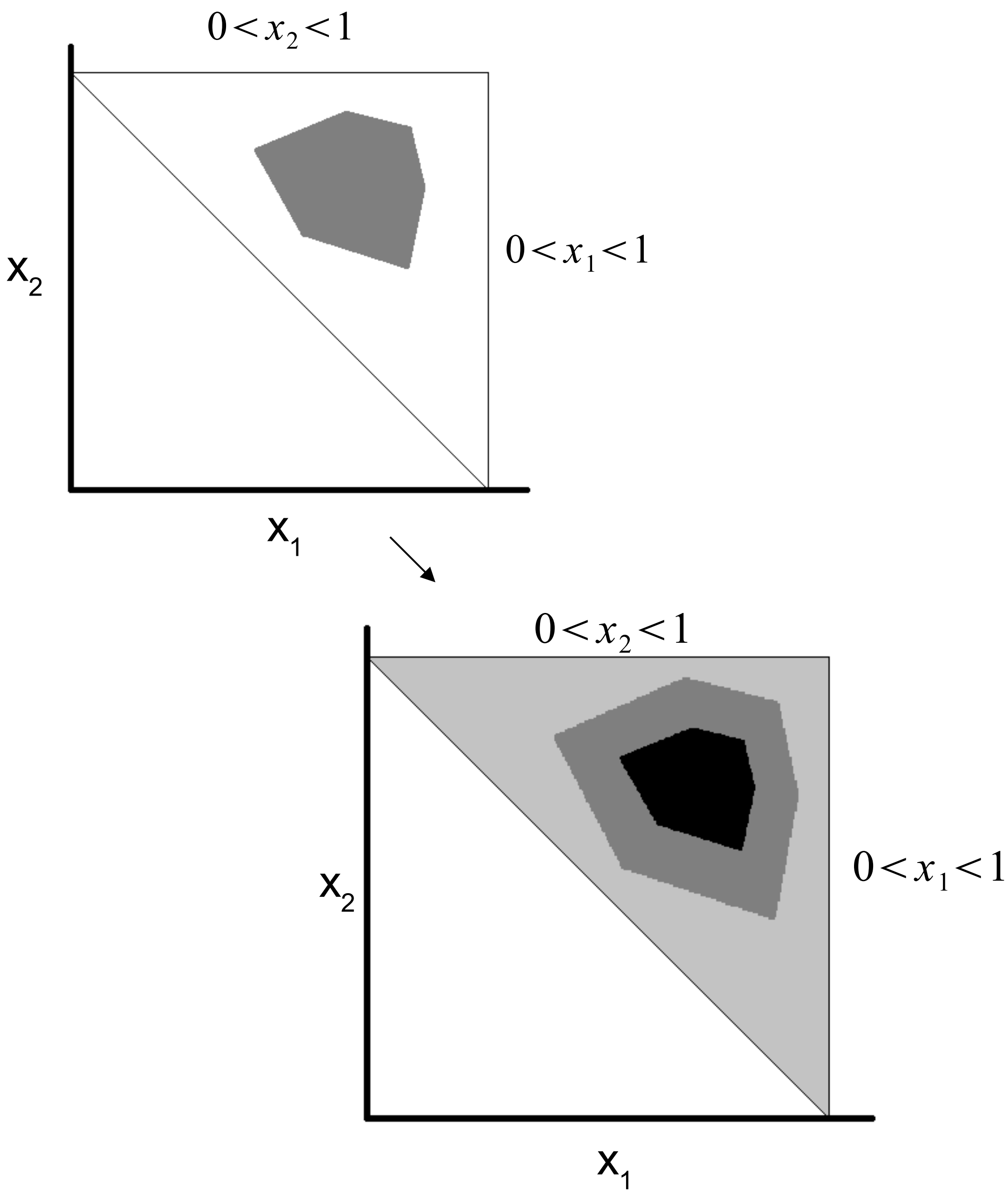
$$x_1 = \frac{2E_q}{\sqrt{s}} \quad x_2 = \frac{2E_{\bar{q}}}{\sqrt{s}} \quad x_3 = \frac{2E_g}{\sqrt{s}}$$

$$x_1 + x_2 + x_3 = 2 \quad 0 < x_i < 1$$

$$(1 - x_1) = x_2 x_3 \sin(\theta_{13})$$



A Proposed Solution Theory (2)



Rather than restrict phase space, it is possible to weight the inclusion of nearby energy to the jet, so that at the singularity, the infinity is zeroed out.

This is the fundamental difference in this proposed algorithm.

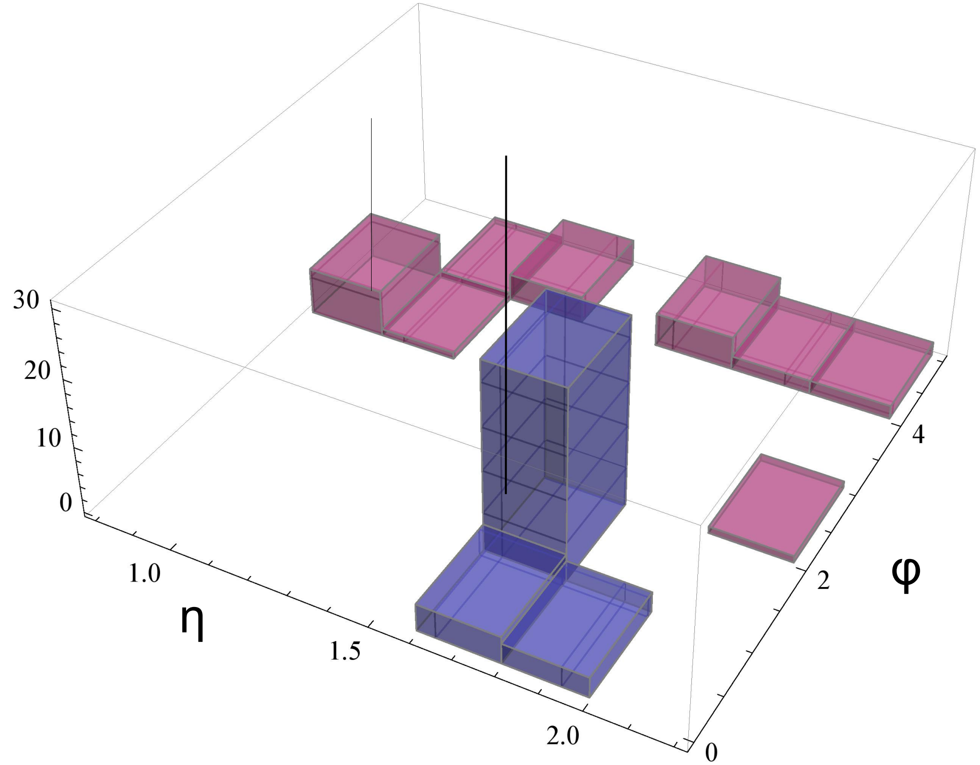
The explicit choice of weighting is still very much undefined, and a work in progress.

A Proposed Solution Simulation (1)

The first stage in the algorithm is nearing completion.

We are able to reconstruct the quarks from a MadEvent output from the 4-momenta outputted from Pythia.

The energies are not a perfect match, but that will be corrected in the future by use of a jet energy correction algorithm.



A Proposed Solution Simulation (2)

Advantages:

- More realistic than some algorithms (lower energy jets are wider, high energy jets are more narrow)

- Avoids including all but the closest “noise” in the detector

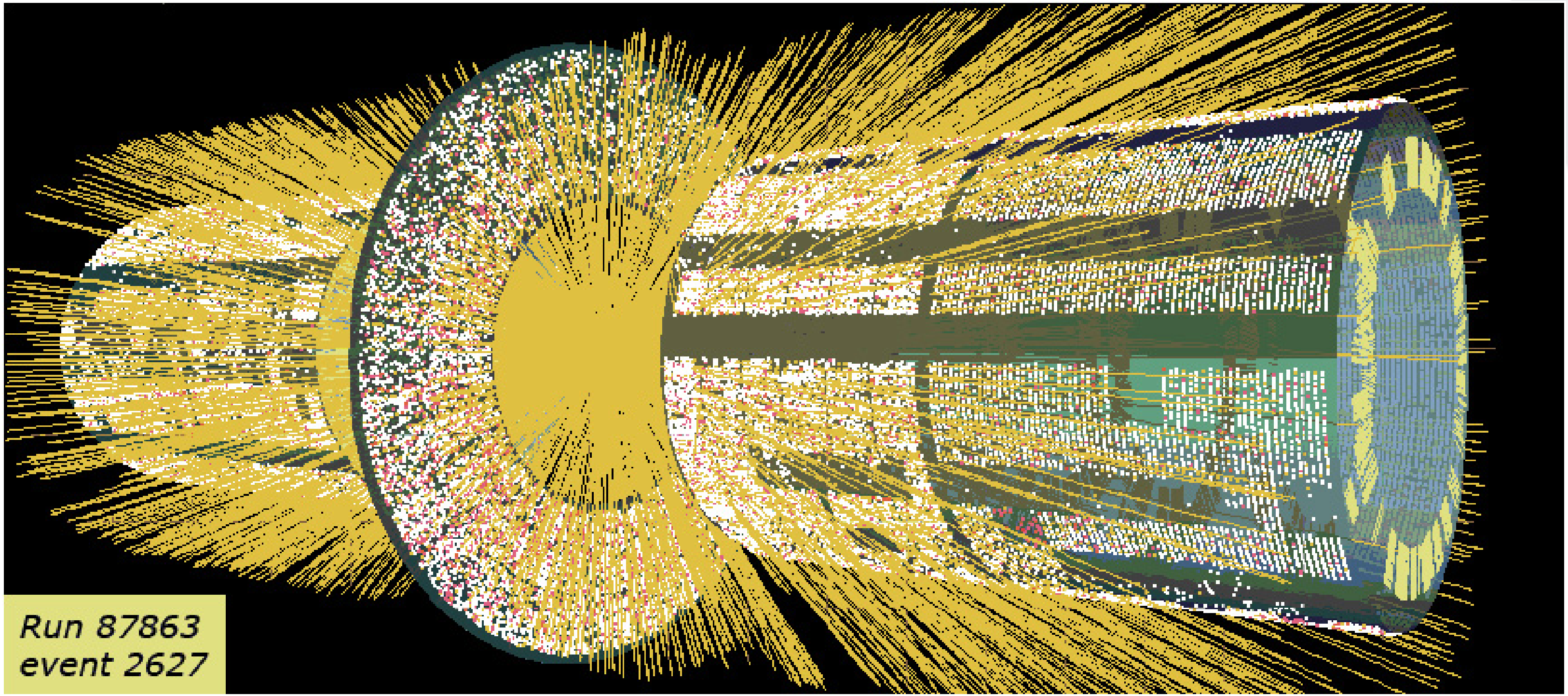
Challenges:

- Still have difficulty consistently locating jets (This can be corrected with a better choice of distance function)

- Before optimization, algorithm is very slow (Order N^3 now, can probably be reduced significantly after some tricks)

A Proposed Solution: Future Work

1. Study how choice in distance function affects the reconstruction of jets
2. Study jet energy calibration
3. Test jet reconstruction in a high multiplicity environment, and reproduce known physics results
4. Test on actual data from LHC experiments (if possible)



Conclusions

- When the LHC turns back on, pileup will alter our ability to see physics
  - If not dealt with in some fashion, the only well-resolved hadronic signatures will be high energy jets
- Our proposed solution is a new jet algorithm in the calorimeter
  - Sculpt the jets into understood shapes
  - Avoid low-energy noise, but not significant energy
  - Adjust energies in a post-detector correction

Expect more on this over the coming year

Thank You

Questions?