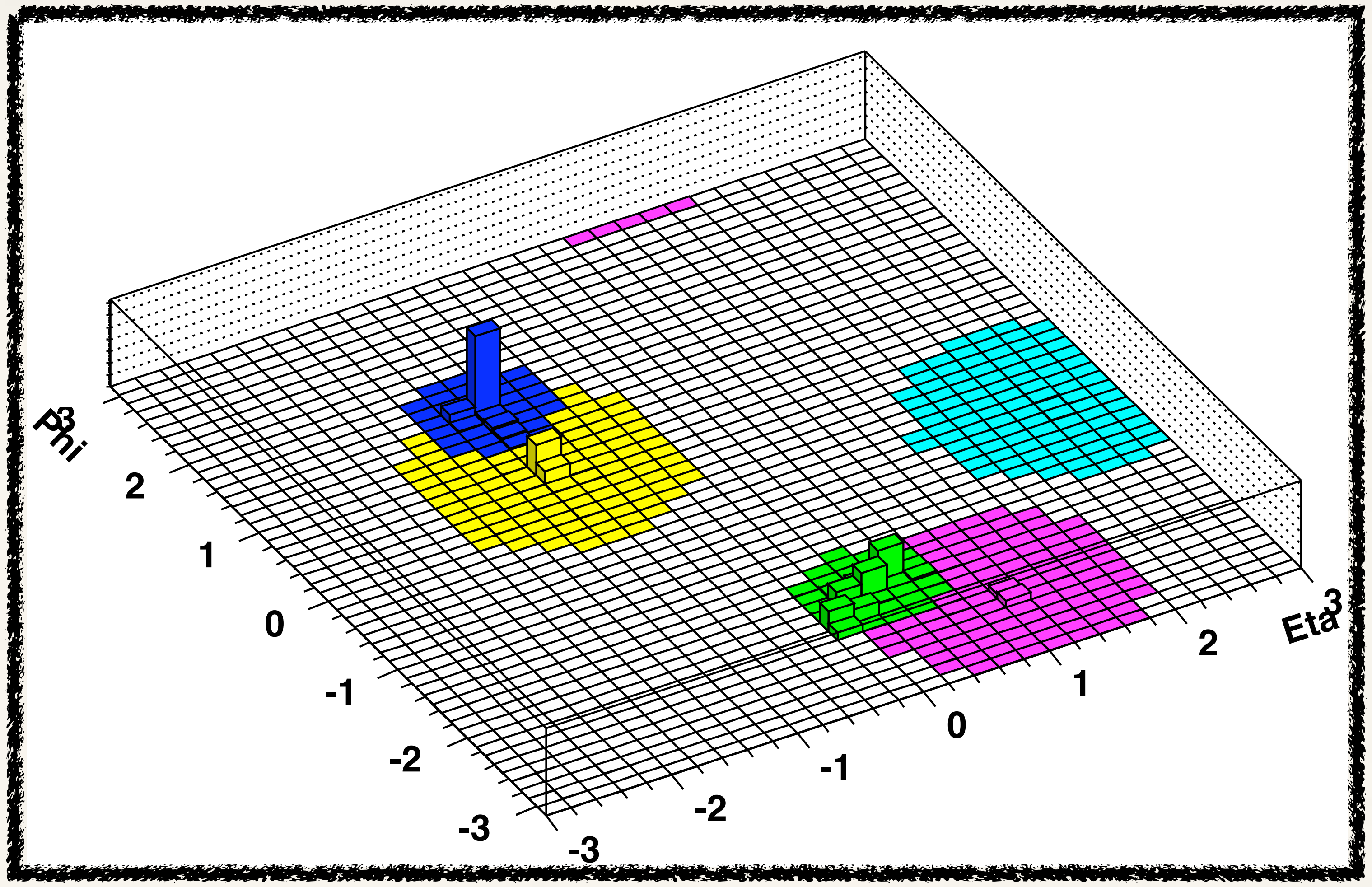


Jets with Variable R

David Krohn (Princeton)

PHENO - May 11, 2009

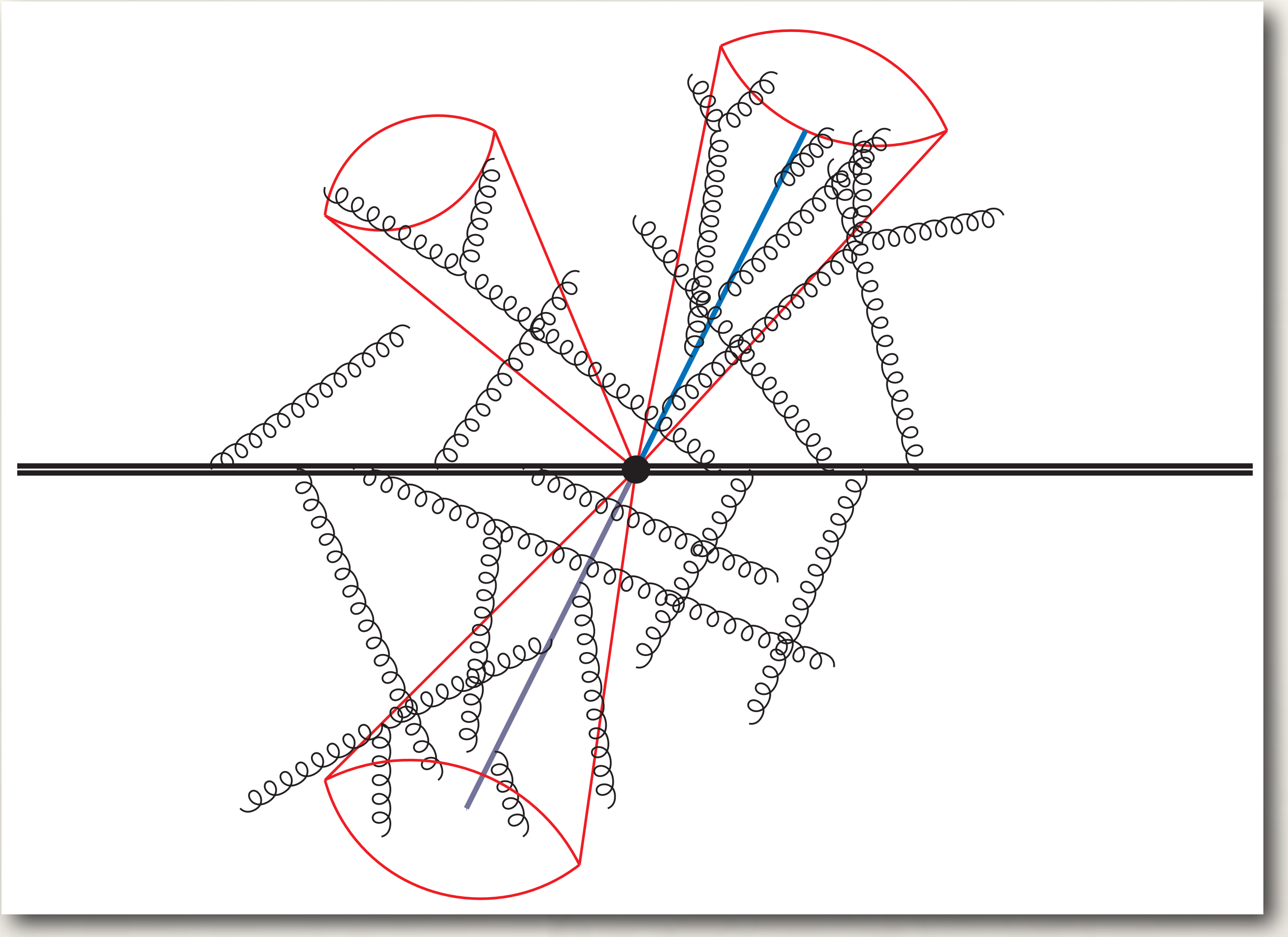
Based on "Jets with Variable R", arXiv:0903.0392, with Jesse Thaler and Lian-Tao Wang

Outline

- Review of Jet Algorithms
- Letting the Jet Radius Vary
- The *VR* Algorithms
- Results
- Future Directions

Jets

- Scattering events at hadron colliders produce colored particles that radiate and shower.
- To understand the hard process we must use jets as an approximation to the short distance kinematics.



Jet Algorithms

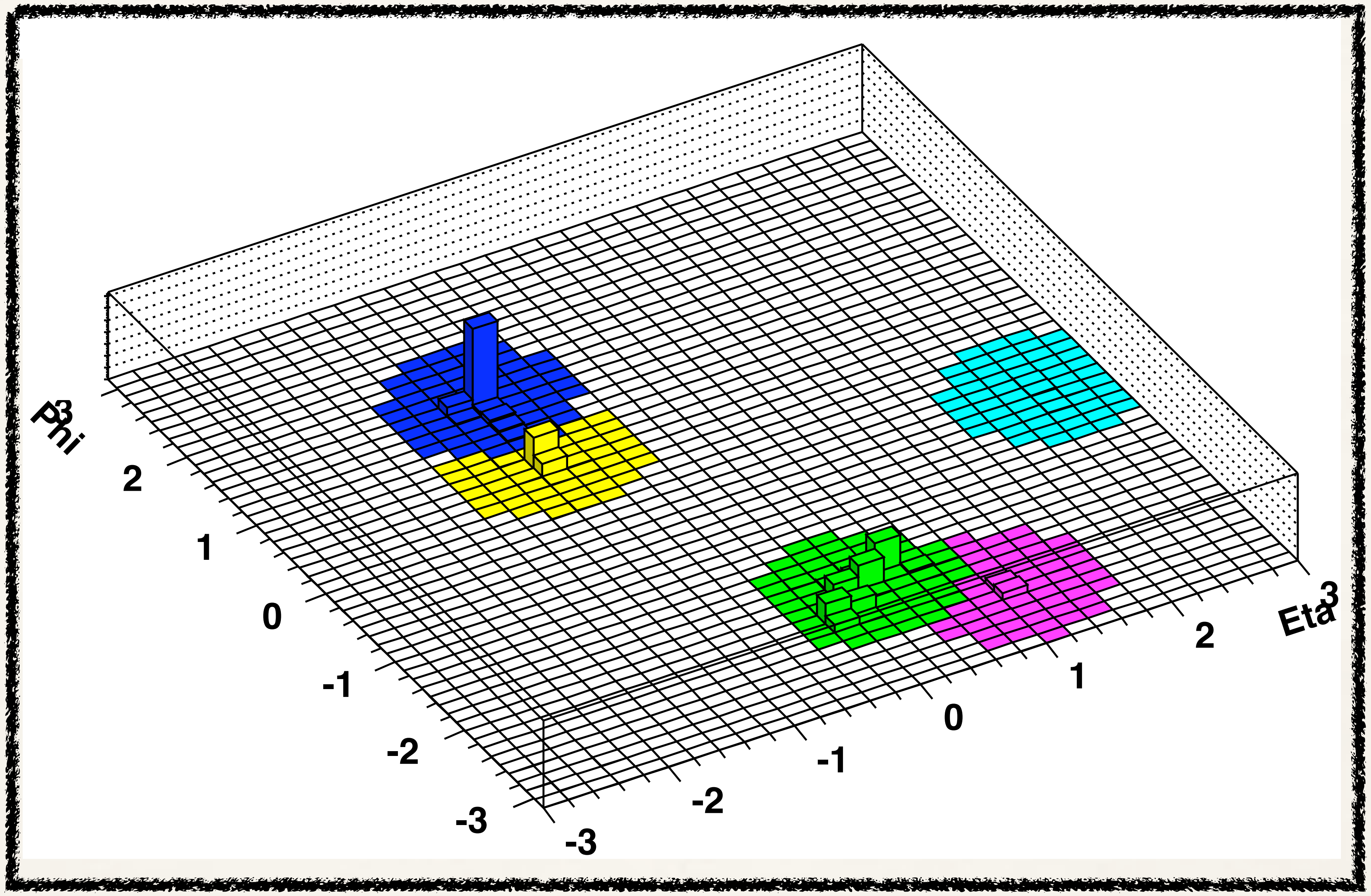
- Jet algorithms provide a prescription for clustering all the calorimeter cells of an event into a few four-vectors (the jets).
- Many such algorithms exist (too many to name), but they can be distinguished by a few traits:
  - How do they cluster: Cones? Sequential recombination?
  - How are things combined: By angle? Hard -> Soft? Soft ->Hard?

Jet Size

- All of these algorithms cluster in a boost invariant manner by using rapidity, azimuth, and pt.
- The angular distance measure becomes:

$$\Delta R = \sqrt{(\Delta y)^2 + (\Delta \phi)^2}$$

- The resulting jets from these algorithms all have a constant angular size (all the circles below have the same radius).



Sample event clustered with the anti-kt algorithm

Letting R Vary

- In *Jets with Variable R* we ask what happens when we let the characteristic size of a jet vary.
- The paper contains guidelines for writing sequential recombination algorithms with non-constant R that are theoretically robust (IR/ collinear safe). Go out and try your own ideas!
- For the rest of the talk, I'll discuss a particular implementation of these algorithms which we call *VR*.

VR Jets

- Using rapidity and azimuth to describe an event can be a little unnatural.
- The figure to the right shows why: circles of constant R are projected onto the theta/phi sphere. They are large in the central region, but small in the forward areas.

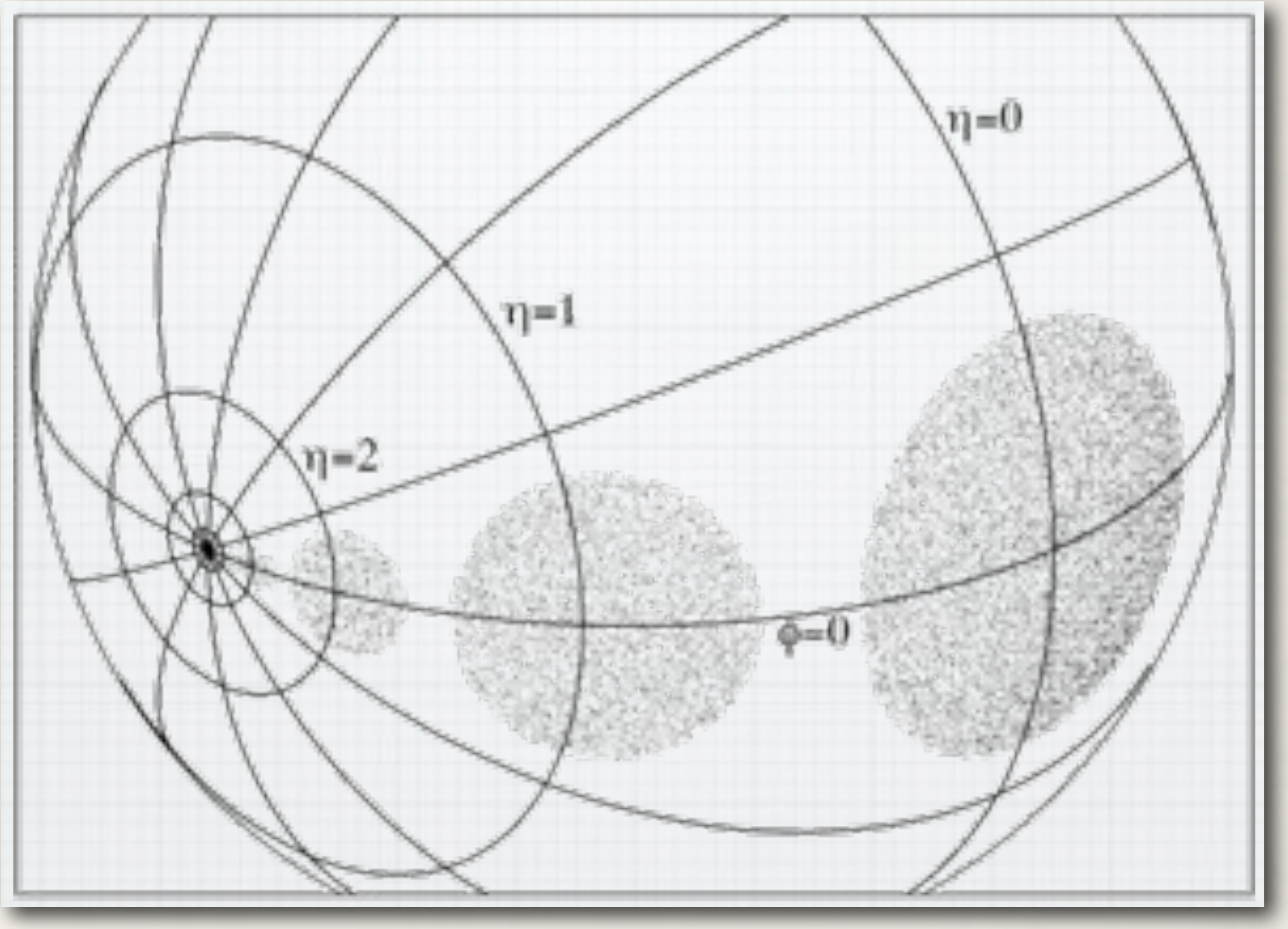


Figure stolen from John Conway's PGS talk: http://online.itp.ucsb.edu/online/lhco_c06/conway/

- Imagine producing a resonance and decaying it to two jets. To lowest order, the radiation from these should look the same regardless of their orientation.

- If we try to analyze such an event with a fixed R algorithm we have a Goldilocks problem: the resulting jets will inevitably be too small in the forward regions and too large in the central region.

- To resolve this problem, imagine starting with a jet of constant energy (E) and opening angle in theta/phi (S). If we rotate it, E & S will stay the same while pt and R will change.

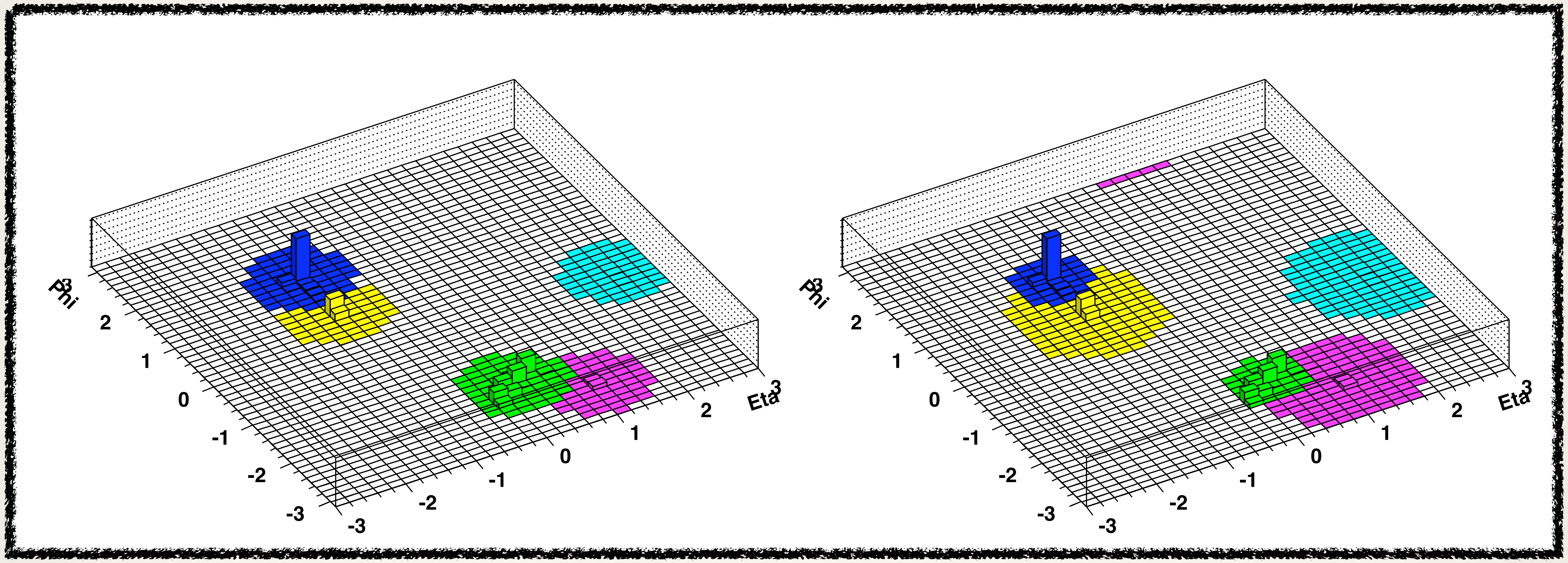
- Now, for small angles and masses:

$$E\Delta S \approx p_T \Delta R$$

- So if we let the radius of a jet (R) scale as

$$R \propto \frac{1}{p_T}$$

- Then as we vary the orientation of the jet the opening angle (in theta/phi) will stay the same!

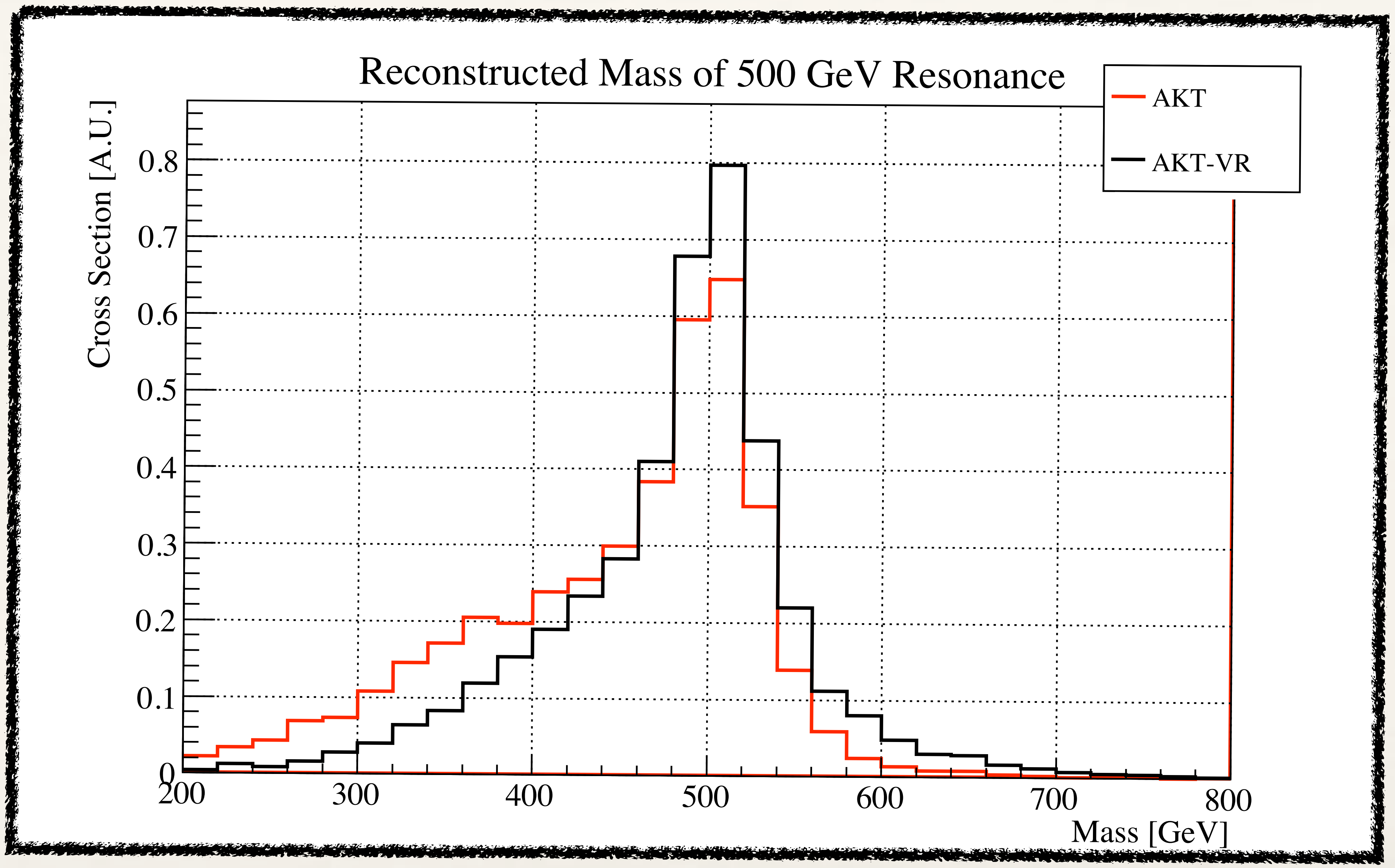


The same event clustered with fixed R (left) and VR (right)

Results

- In our paper we test the VR algorithms in a number of scenarios
    - Single resonance reconstruction (with and without background)
    - Multiple resonance reconstruction (pp >X >YY > 4J)
    - Gluino endpoint reconstruction
- In general, we see a 10-20% improvement in signal efficiency over the anti-kt and Cambridge-Aachen algorithms. Moreover, we have not fully optimized the algorithm so additional improvement might be expected.

Reconstruction of a 500 GeV Resonance



- We have two implementations of VR available as plugins for Fastjet (tested with versions 2.3.4 and 2.4.0).
- You can download them from http://jthaler.net/VR

Future Directions

- New applications of VR jets
  - Top jet reconstruction
  - Combining VR/fixed cone into one algorithm
- New jet algorithms
  - Removal of ISR (dynamic pruning)
  - Reconstructing boosted objects
  - Better split/merge

Conclusions

- All current jet algorithms have a fixed R size.
- It's possible to write IR/collinear safe algorithms where R varies. There are many possibilities and we encourage you to come up with new ideas.
- We have demonstrated this by writing a boost invariant algorithm where R scales as the inverse of p_T for better treatment of resonances/symmetric events.
- Initial results with VR show improvement over anti-kt and C/A.

Appendix: Sequential Recombination Implementation

- To cluster jets with a non-constant R in a sequential recombination algorithm you can define the jet distance measures, for n<=0, to be:

$$d_{ij} = \min(p_{Ti}^{2n}, p_{Tj}^{2n}) R_{ij}^2, \;\; d_{iB} = p_{Ti}^{2n} R_{\mathrm{e}} \;\; (p_{Ti})^2$$

where R_{eff} regulates the jet radius scaling behavior.

- For more information on how sequential algorithms work see our paper, or look at Gavin Salam's CTEQ summer school lectures available from

http://www.lpthe.jussieu.fr/~salam/repository/talks/2008-cteq-mcnet.pdf