Towards Differentiable Jet Clustering

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Today’s Agenda

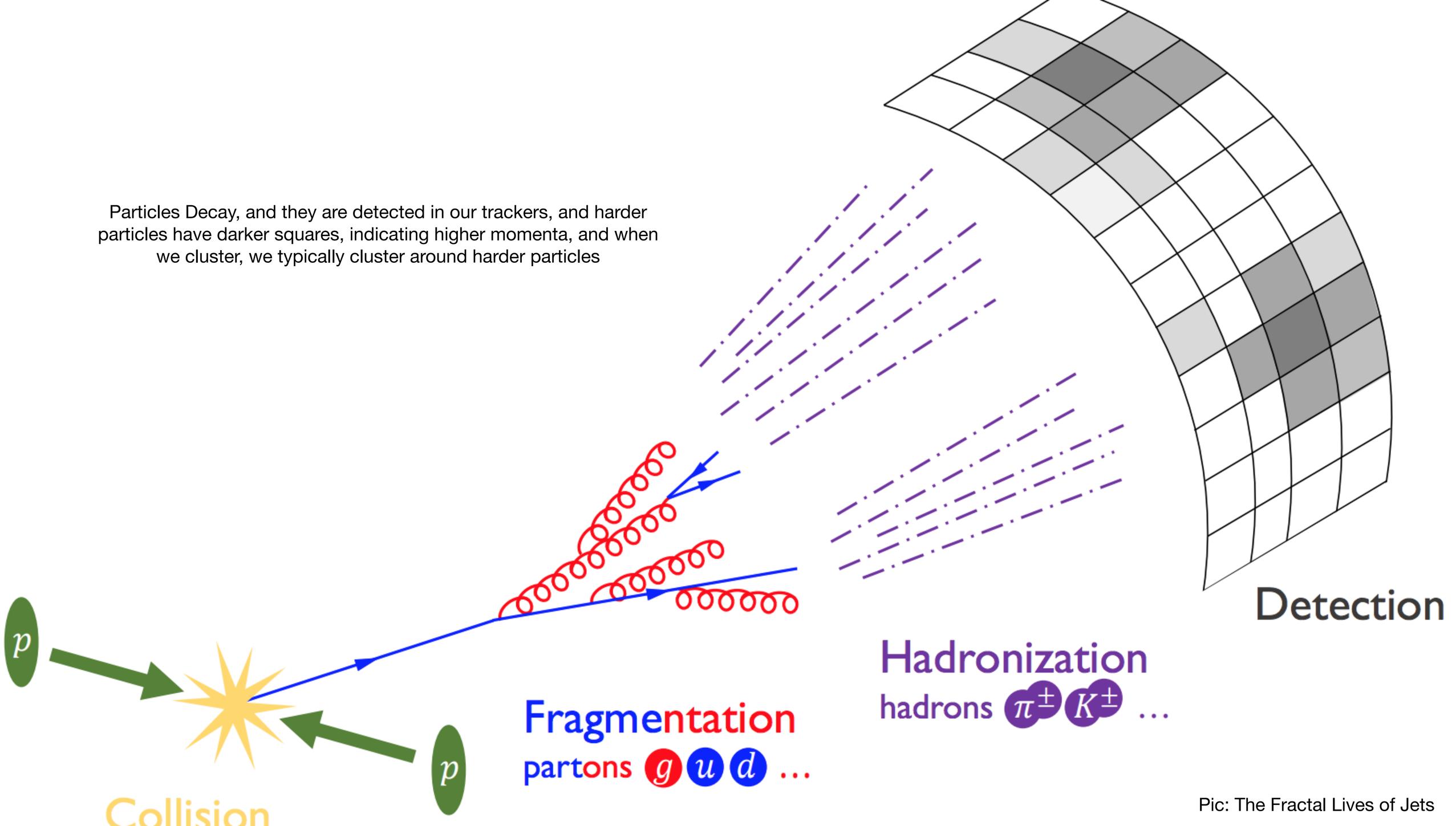
- What is Jet Clustering?
- What is the Problem with Jet Clustering?
- Optimization
- Looking Beyond the scope

Introduction

What is Jet Clustering?

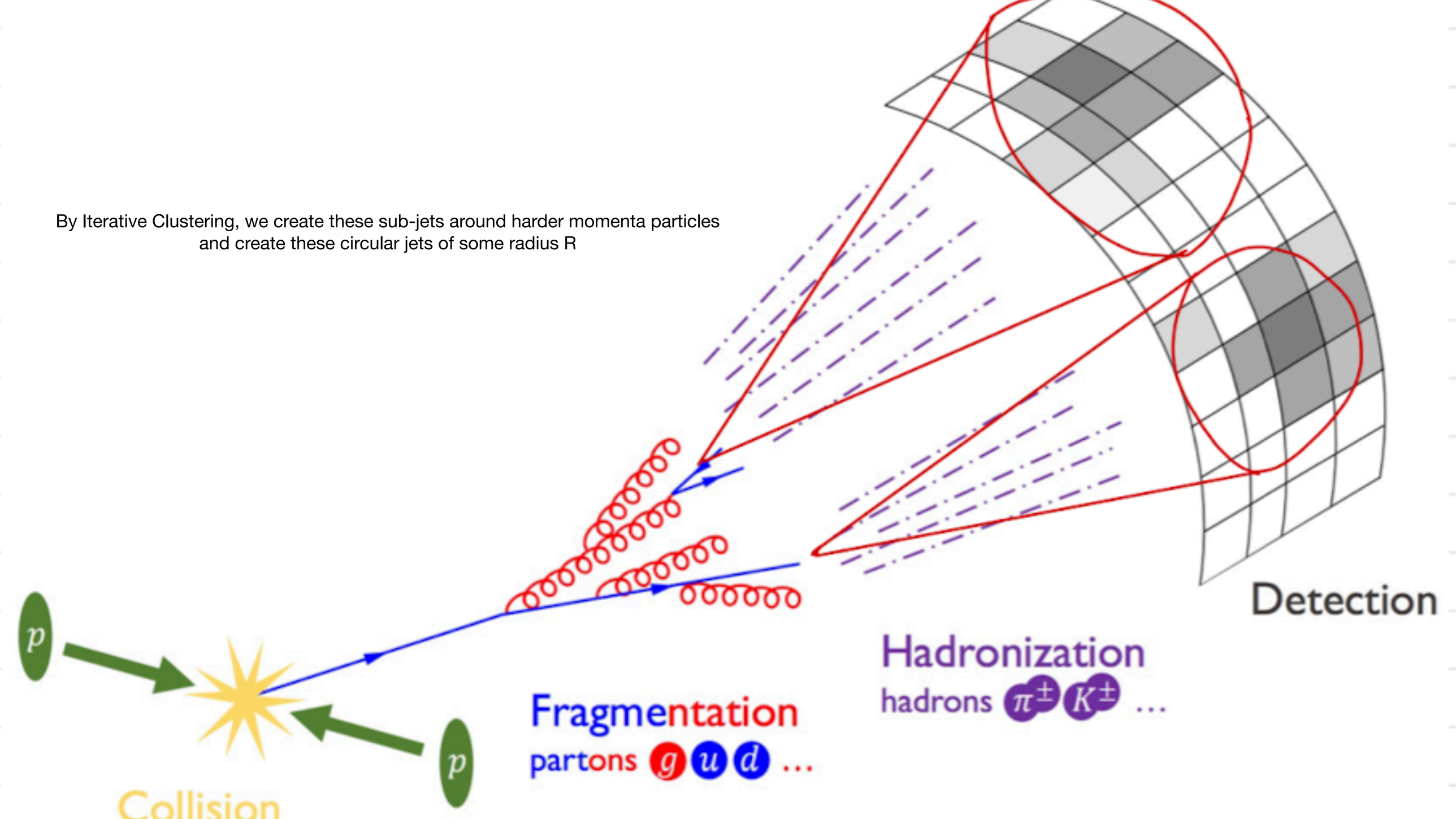
- Jets: Collimated sprays of particles created via hadronization (cascade of decays)
- We only detect stable particles
- Iterative Jet Clustering using parameters: distance, momenta, angular ordering, etc.
- Outcome: A Jet!!
- Jet can tell you the invariant mass of the original particle

Particles Decay, and they are detected in our trackers, and harder particles have darker squares, indicating higher momenta, and when we cluster, we typically cluster around harder particles

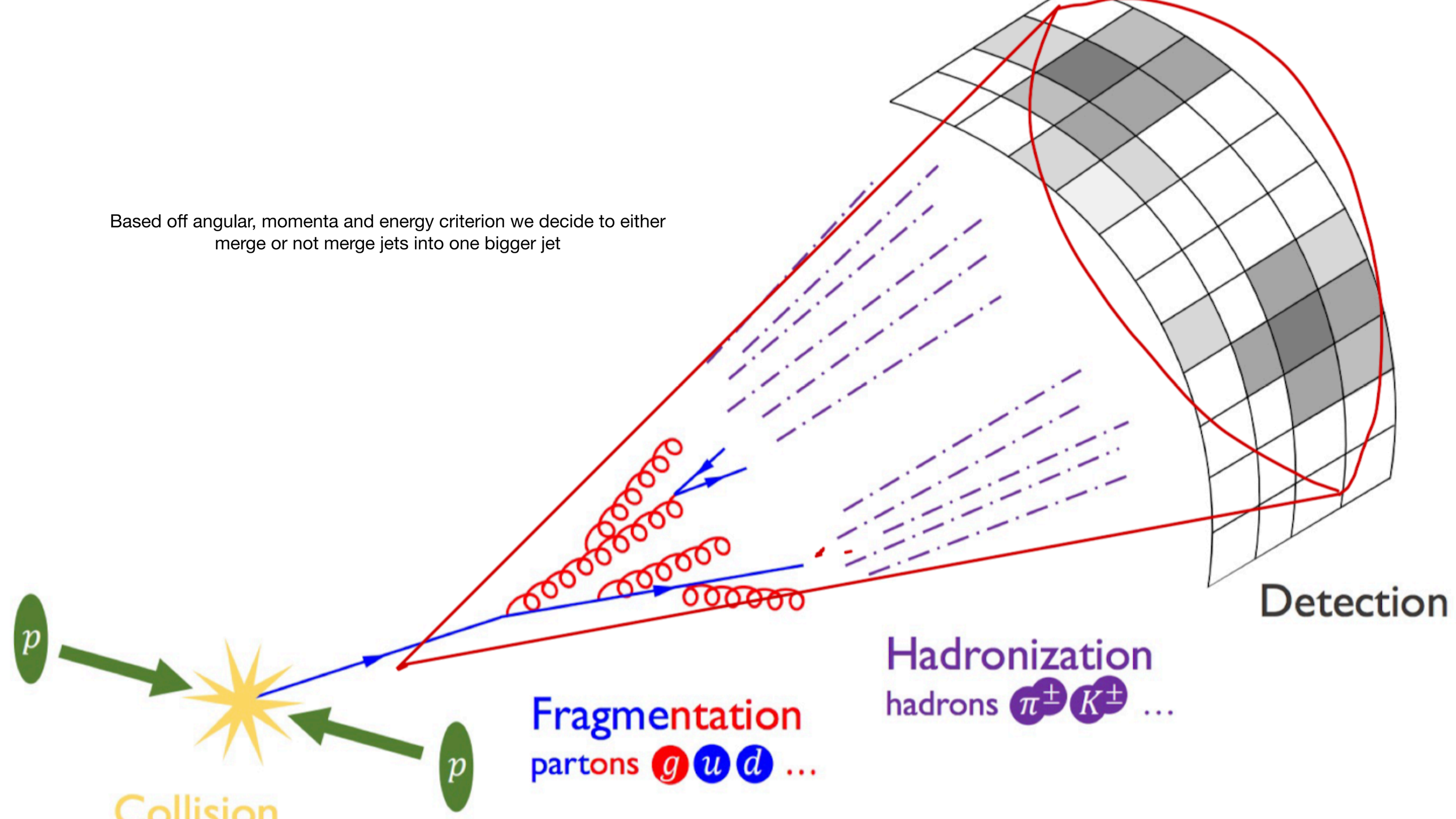


Pic: The Fractal Lives of Jets

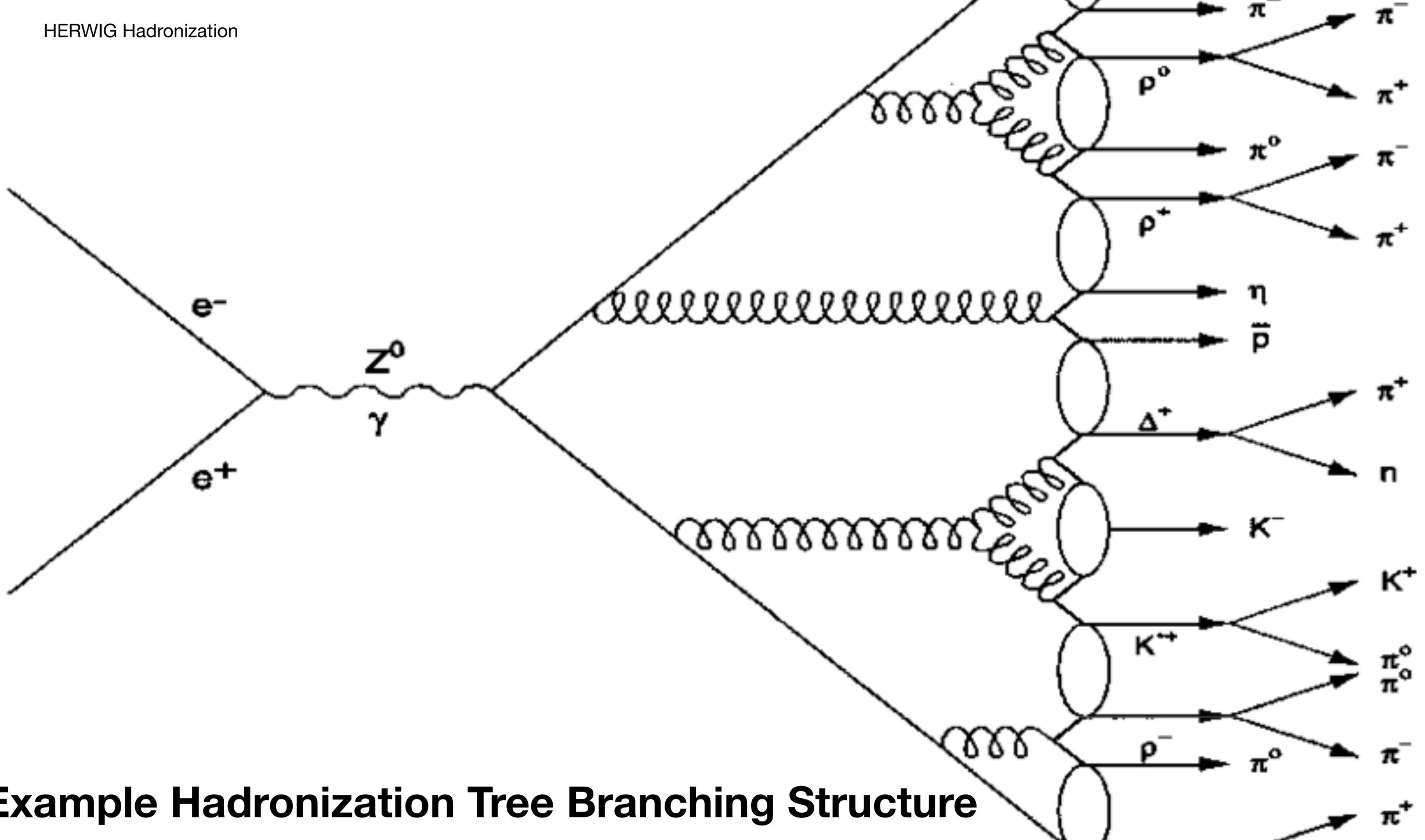
By Iterative Clustering, we create these sub-jets around harder momenta particles and create these circular jets of some radius R



Based off angular, momenta and energy criterion we decide to either merge or not merge jets into one bigger jet



HERWIG Hadronization

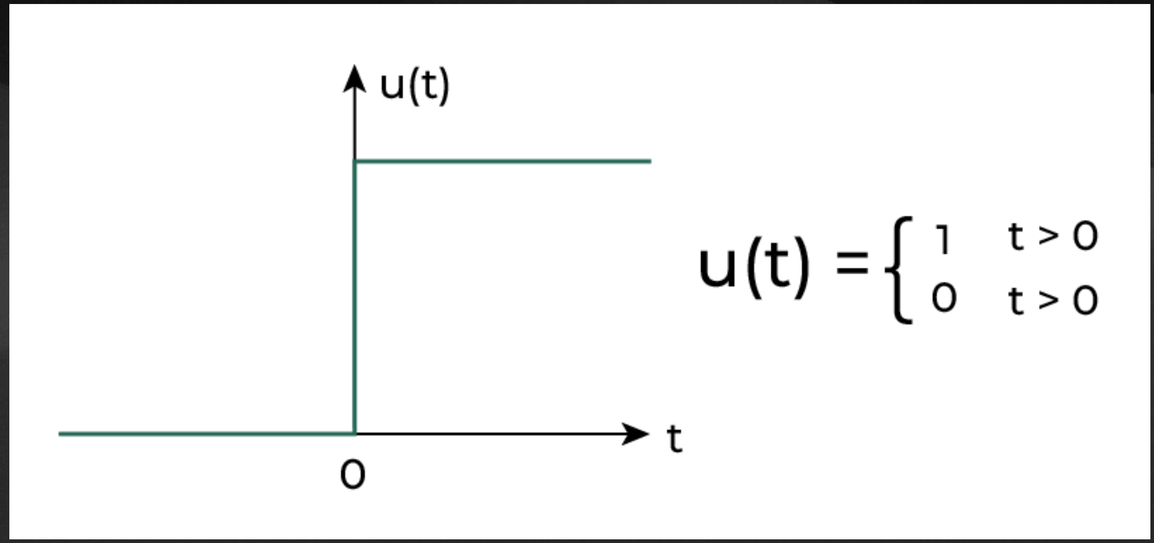


Example Hadronization Tree Branching Structure

Motivations

What is the Problem with Jet Clustering?

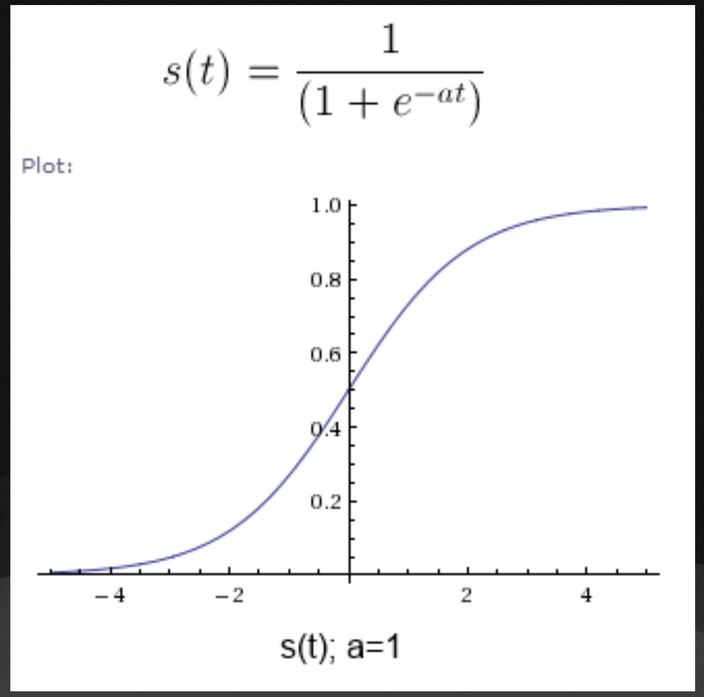
- Jet Clustering has free parameters
  - Radius is optimized once (R = 0.7) then kept constant
  - Is the radius always going to be a constant for all jets? Highly unlikely
- Clustering is probabilistically a binary decision
  - Given multiple sub-jets, the decision to merge these is either: merge, or don’t merge which can be modeled as 1 or 0 which is non-differentiable



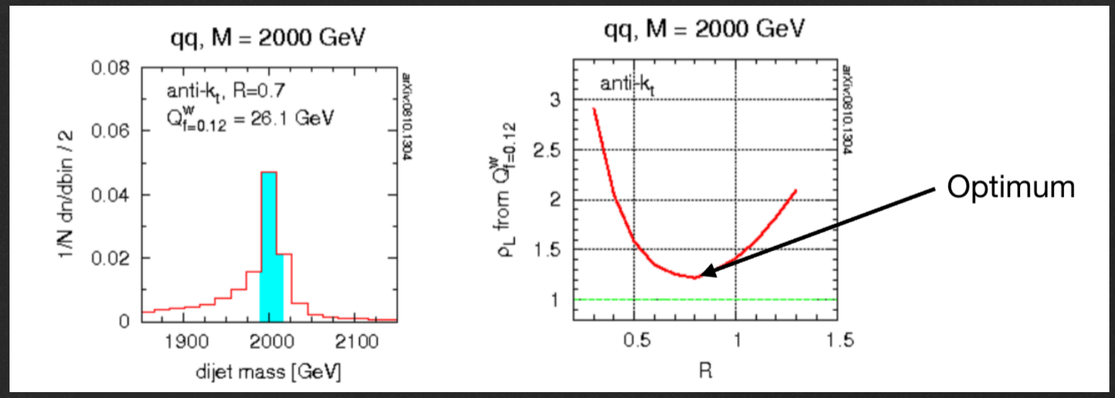
Pic: GeekForGeeks

Methods
Optimization

- Solution: Make the Step Function continuous → Sigmoid
  - This gives you a smooth probability distribution that is also differentiable
- Use this for Jet Radii calculations, specifically if we look at the di-jet invariant mass reconstruction
  - Resonance width varies with radius
  - Can find this optimal width with derivatives



Pic: Neural Network



Pic: FastJet

Applications

Looking beyond the Scope

- One of the core issues with using ML for jet clustering is that jet merge decision themselves are non-differentiable
  - If Jets were differentiable we would be able to do back propagation within the context of NNs
  - Use NNs to optimize Jet/sub-Jet Clustering and lump sum Jet Tagging as well (Jet Clustering creates jets without extracting information, Jet Tagging takes jet information and tells you what particle these decay products all originated from so like b-jets, c-jets etc.)