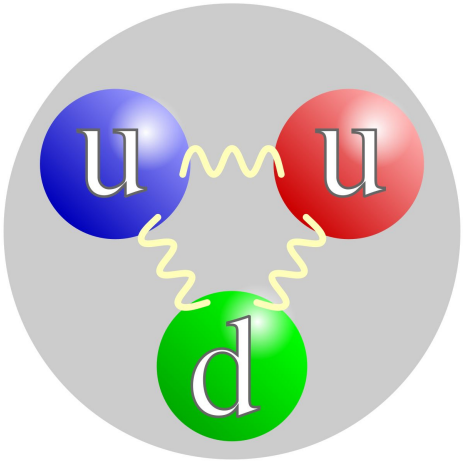
Thermal Toy Model for Jet Background Reduction

Lily Chatalbasheva
Summer ‘25
(Laura Havener)

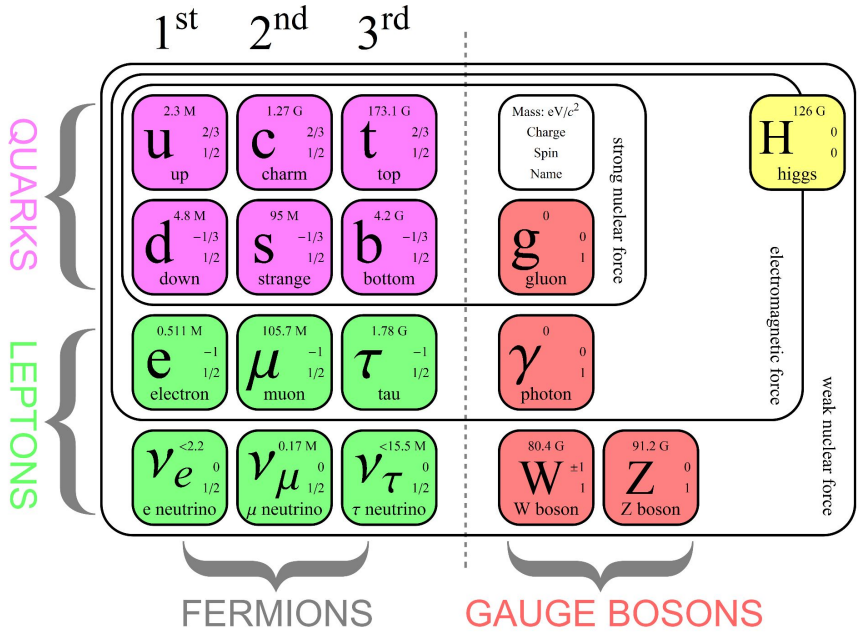
Overview

"Our research program focuses on understanding the strong interaction and the properties and evolution of the Quark-Gluon Plasma (QGP)"

The Standard Model

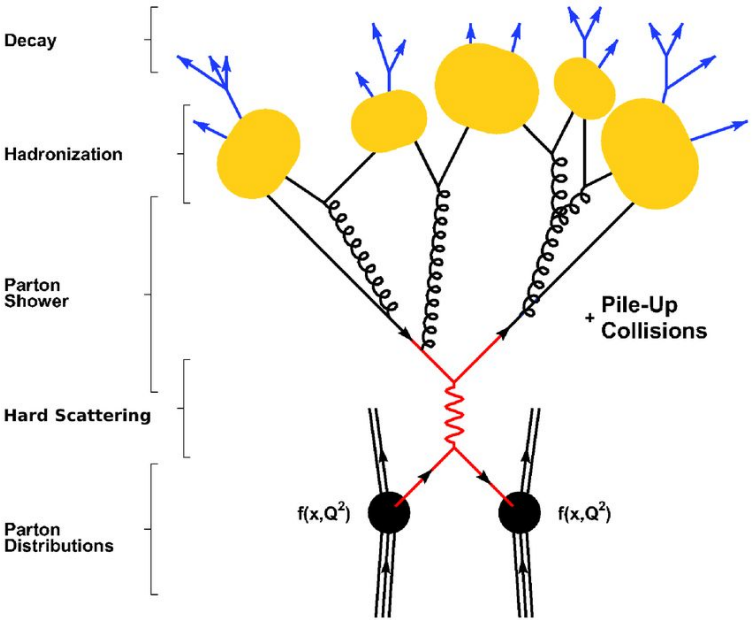


https://en.wikipedia.org/wiki/Quark



https://www-f9.ijs.si/~lubej/

Hadronic Shower



Link

"The incoming particles interact, producing multiple new particles with lesser energy; each of these then interacts, in the same way, a process that continues until many **thousands, millions, or even billions of low-energy particles are produced**."

https://en.wikipedia.org/wiki/Particle_shower

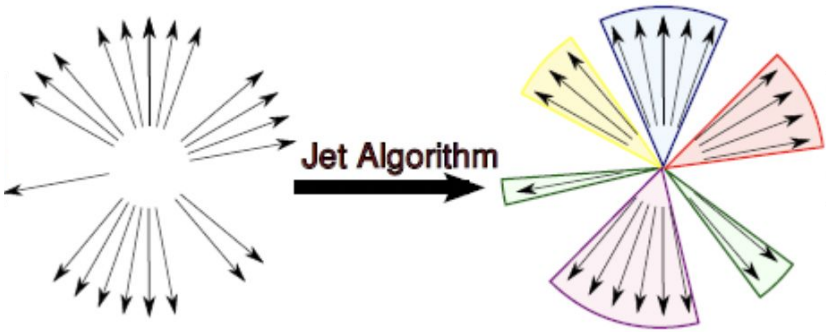
Jets

We use **clustering algorithms** to form well-defined **jets** based on the **sequential development** of particle shower, working our way **backwards** and repeatedly combining pairs of particles into a single one…

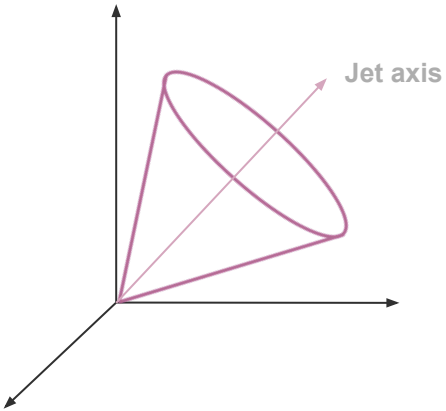
Anti-kt algorithm

$$d_{ij} = \min\left(p_{T,i}^{-2},\ p_{T,j}^{-2}\right) \cdot \frac{\Delta R_{ij}^2}{R^2}$$

$$\Delta R_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$$



https://www.kip.uni-heidelberg.de/atlas/seminars/SS2009_JC/jet_algorithms.pdf



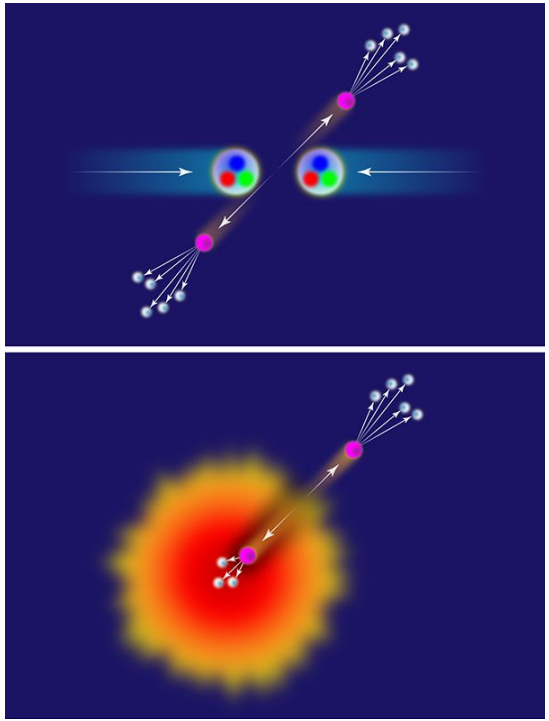
QGP and Jets

Quark-gluon plasma (QGP):

- Microseconds-old universe
- Deconfined state of partons
- Trillion-degree temperatures

Jet quenching: jets interact strongly with QGP, which allows us to study the medium, comparable to the conditions in the early universe via

- Medium-induced gluon radiation
- Energy loss



https://physics.aps.org/articles/v7/97

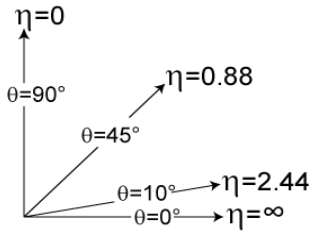
Ingredients

Pythia Particles + Thermal Particles + FastJet =
1000 Lines of Code + 40 Histograms + 7 Memes

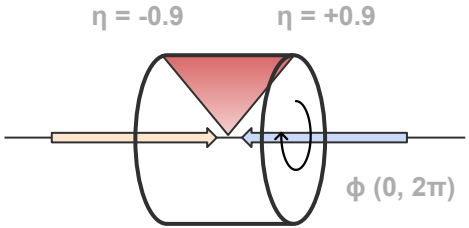
Phi-Eta Detector Space

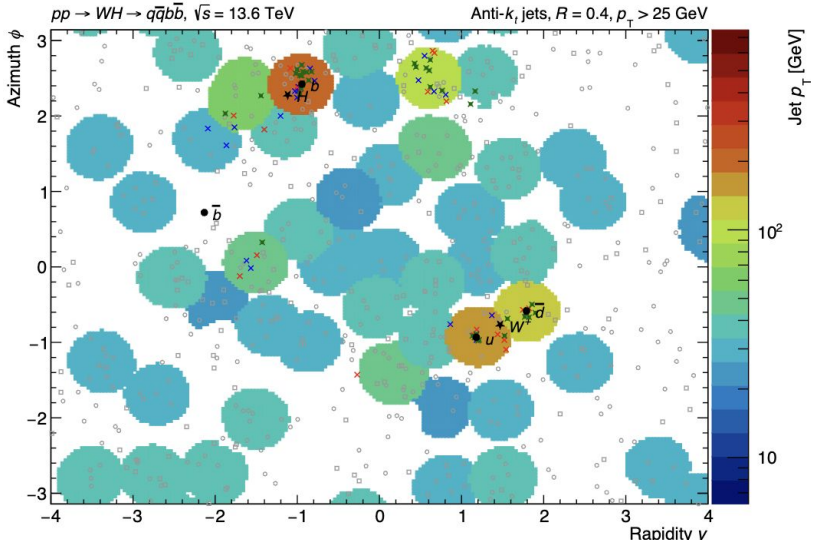
$$\eta \equiv -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

Pseudorapidity: spatial coordinate describing the angle of a particle relative to the beam axis



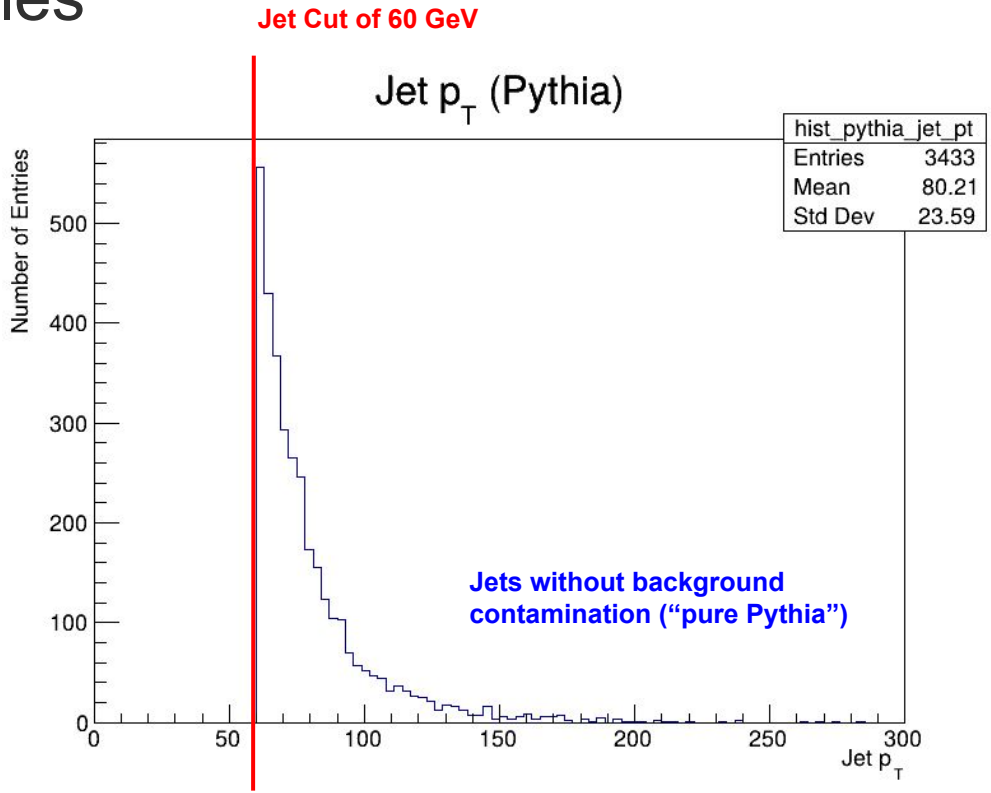
https://en.wikipedia.org/wiki/Pseudorapidity





https://pythia.org/latest-manual/SampleMainPrograms.html#section7

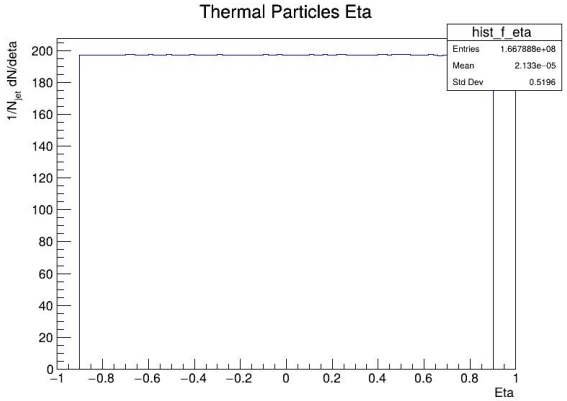
Pythia Particles

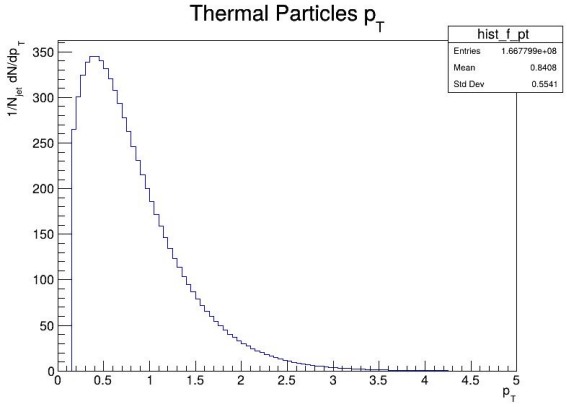


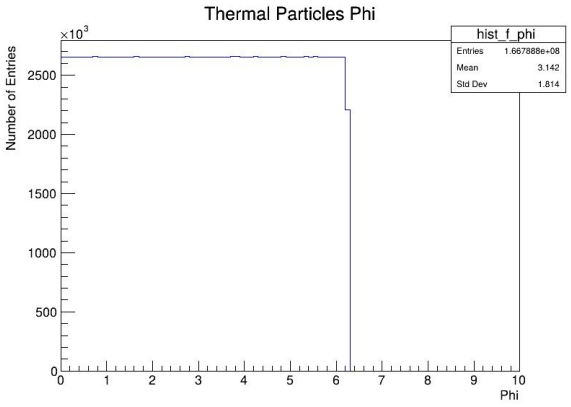
Thermal Particles

1. Number of thermal particles per event
2. Properties of each thermal particle

- We sample randomly from:
  - Gaussian (3922, 40)
    - ALICE experimental data for most central Lead-lead collisions
  - Eta [-0.9, 0.9]
  - Phi [0, 2π]
  - p_T x*exp(-x/0.4)

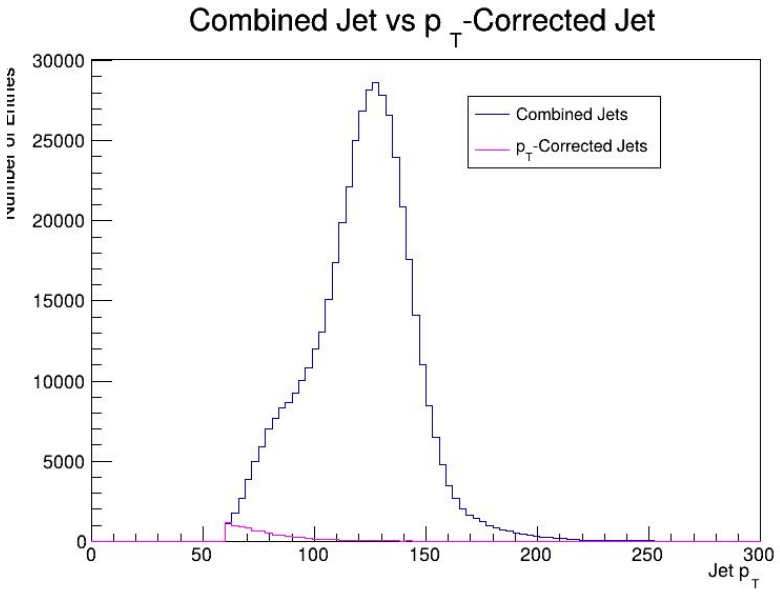






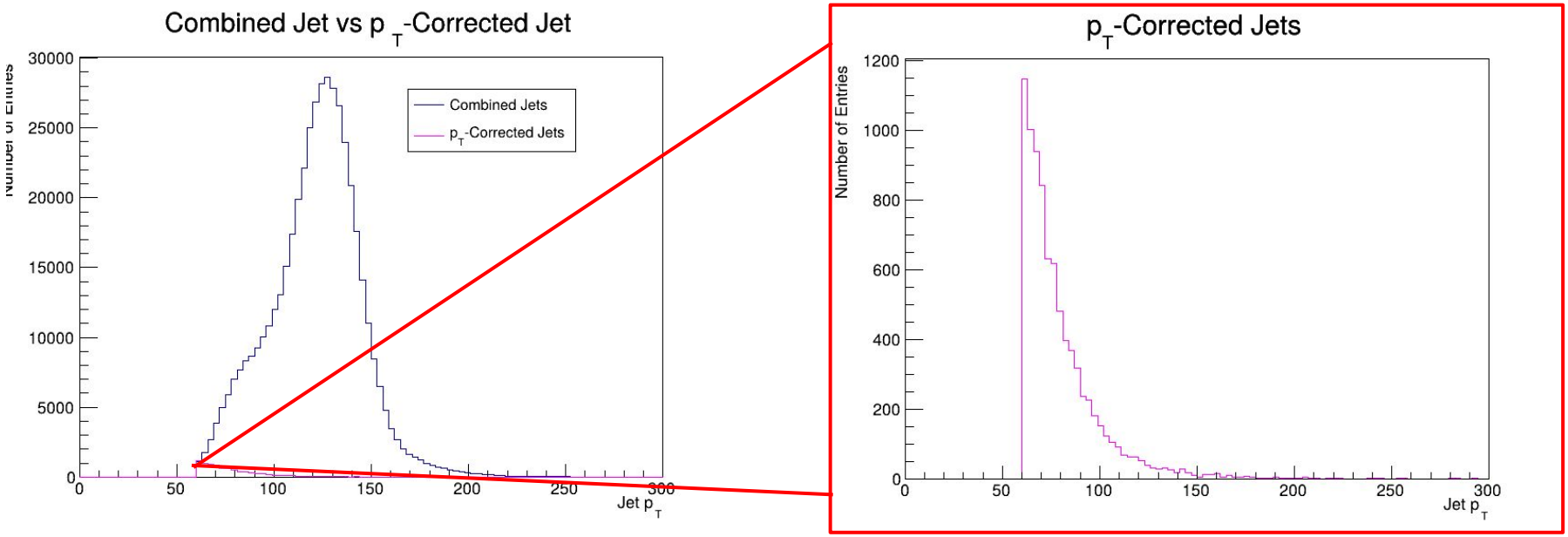
Combined Jets and p_T-correction

We obtain the median background per jet from FastJet and subtract it



Combined Jets and p_T-correction

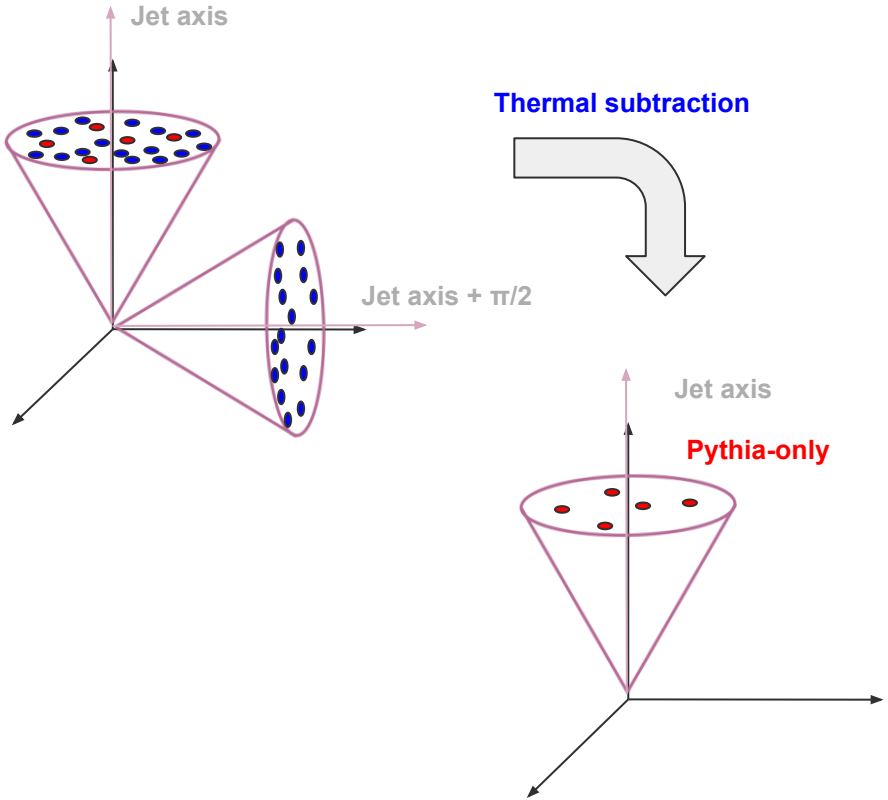
We obtain the median background per jet from FastJet and subtract it



Perpendicular Cones

Question we are trying to answer:

“Are perpendicular cones a good estimate of the background we would expect?”



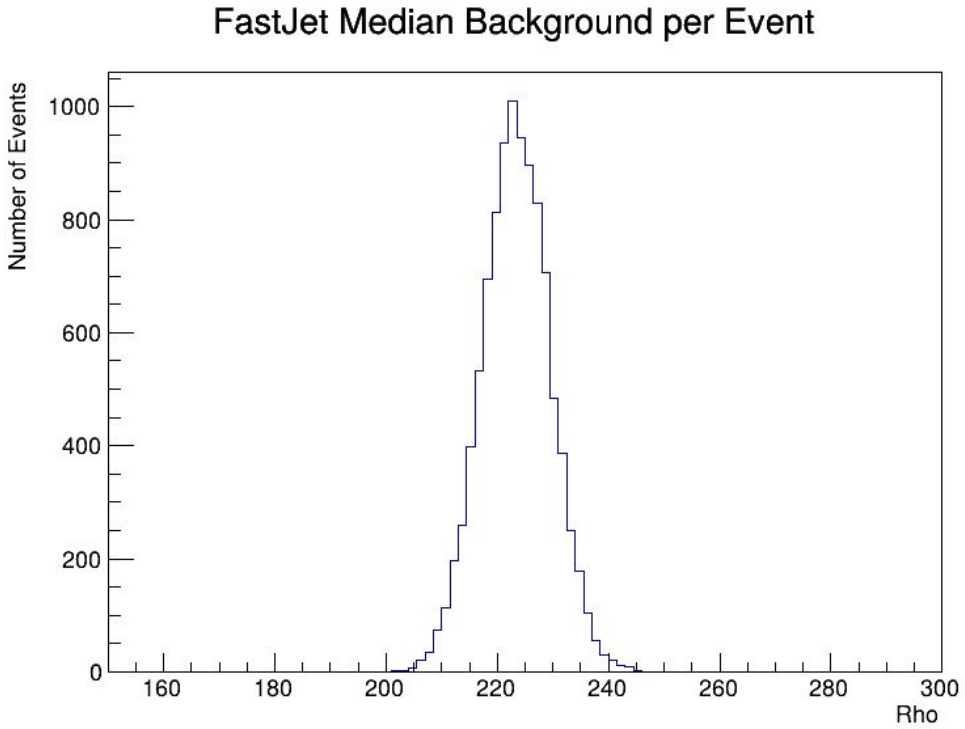
Steps

1. Generate a bunch of **Pythia and thermal particles**
2. Form **combined jets** of Pythia and thermal particles
3. Use FastJet to get the overall **median background per event** and subtract it to get your **p_T-corrected** combined jets
4. Get a **perpendicular cone** by rotating the jet axis in phi 90-degrees
5. **Subtract the p_T spectra of thermal particles** in the perpendicular cone from your original p_T-corrected combined jet constituent spectra
6. Normalize histograms per jet
7. Compare to the constituents of **Pythia-only jets**

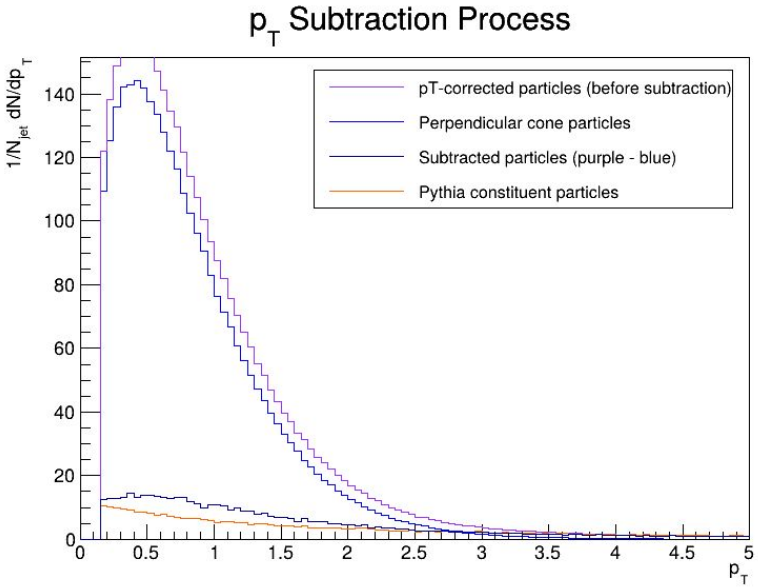
Results

Background Subtraction

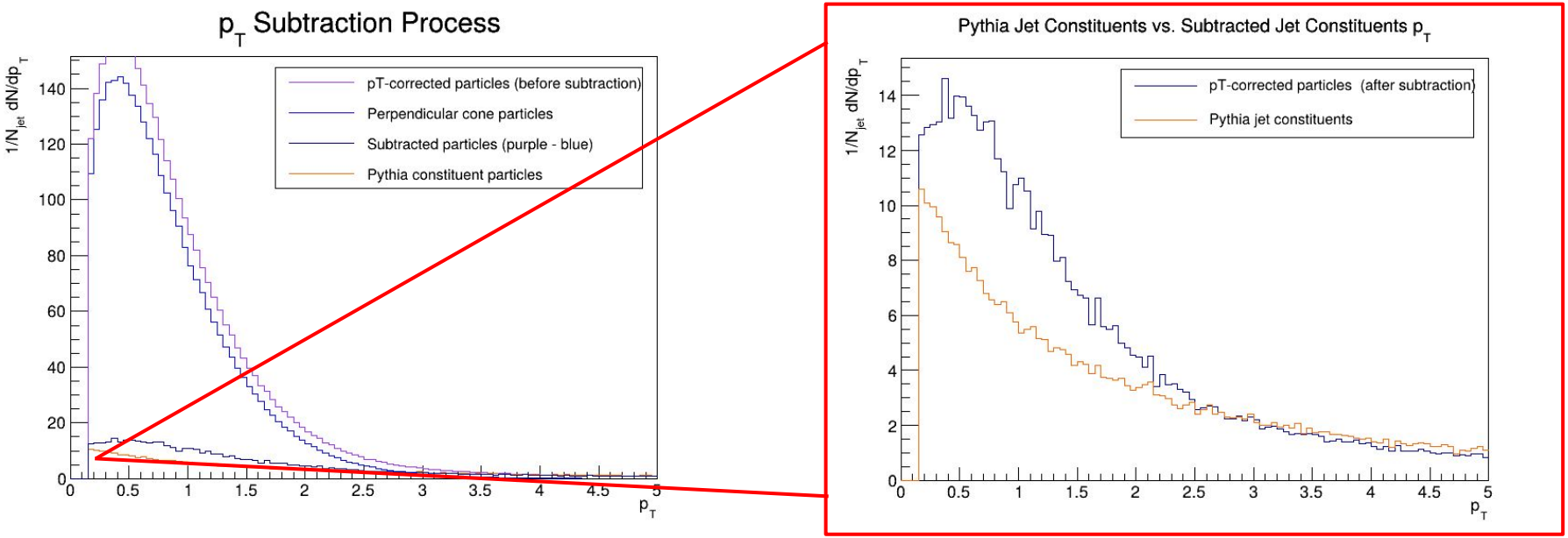
Results Pt. 1 (Rho)



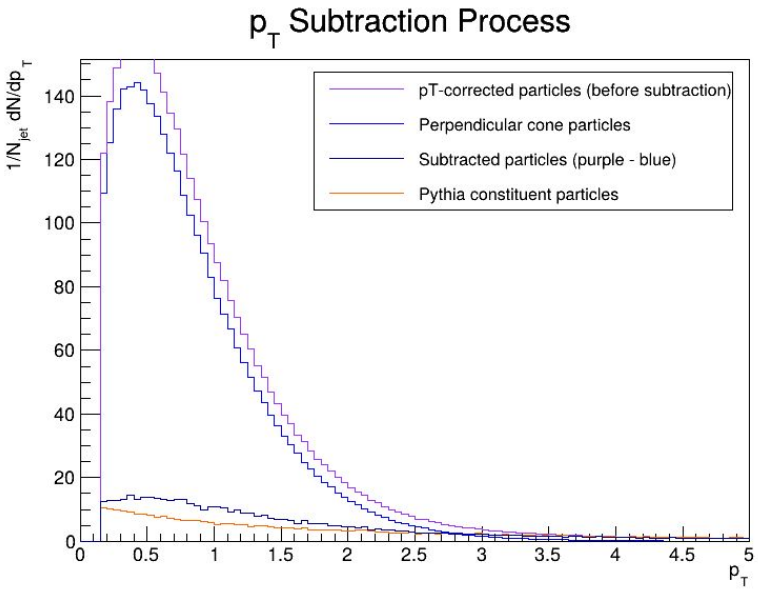
Results Pt. 2 (Constituents Spectra)



Results Pt. 2 (Constituents Spectra)



Results Pt. 2 (Constituents Spectra)

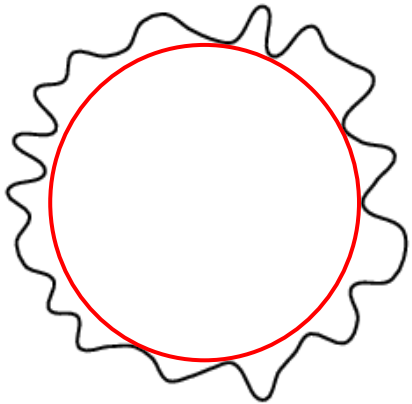


Question we are trying to answer:

"Are perpendicular cones a good estimate of the background we would expect?"

- We successfully simulated a collision with a background that, while not perfect, is **fairly realistic**.
- We tested the **perpendicular cone method** and found that it performs reasonably well in subtracting background, although it does not remove all of it.
- This method requires further improvement, and our next step will be to introduce a **multiplicative correction factor** to account for the remaining background.

Next Steps



- Fine tune the generation of thermal particles to experimental data
  - Distributions in reality:
    - Number of thermal particles in an event is not Gaussian
    - Phi distribution is not uniform (flow)
    - p_T distribution can be better obtained from experimentally measured p_T spectra
- Use leading jets, instead of all jets
- Manually obtain the median background estimate (instead of the mean) and compare to FastJet's rho
- Introduce multiplicative factor in perpendicular cone method

Acknowledgements

Wright Lab
Summer Experience Award
PI: Laura Havener