

Quantifying and Correcting Background Distortion in the Lund Jet Plane

Lucas Weaver

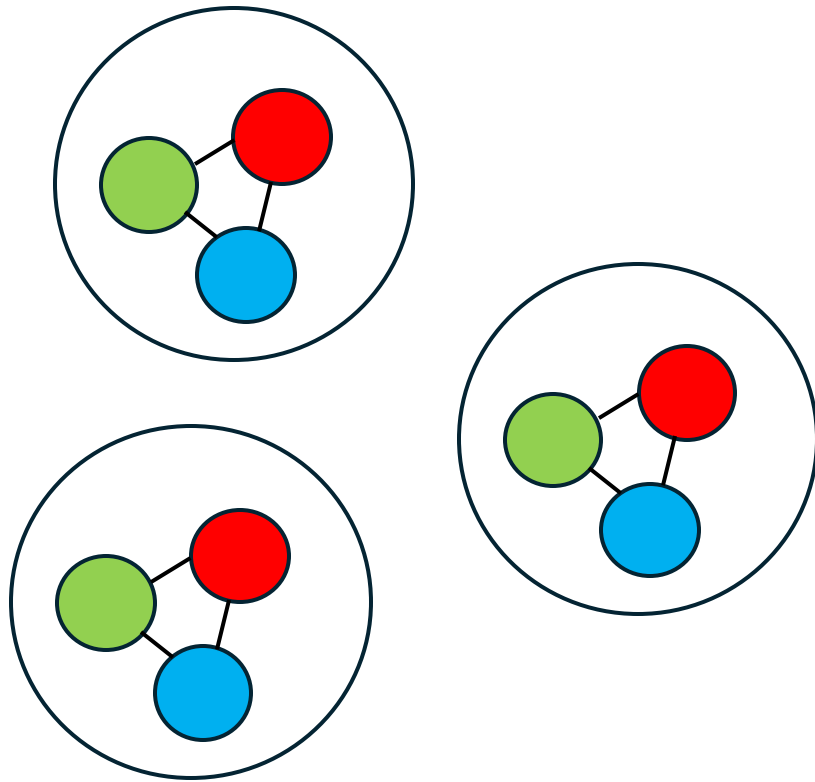
Relativistic Heavy Ion Group

Wright Lab

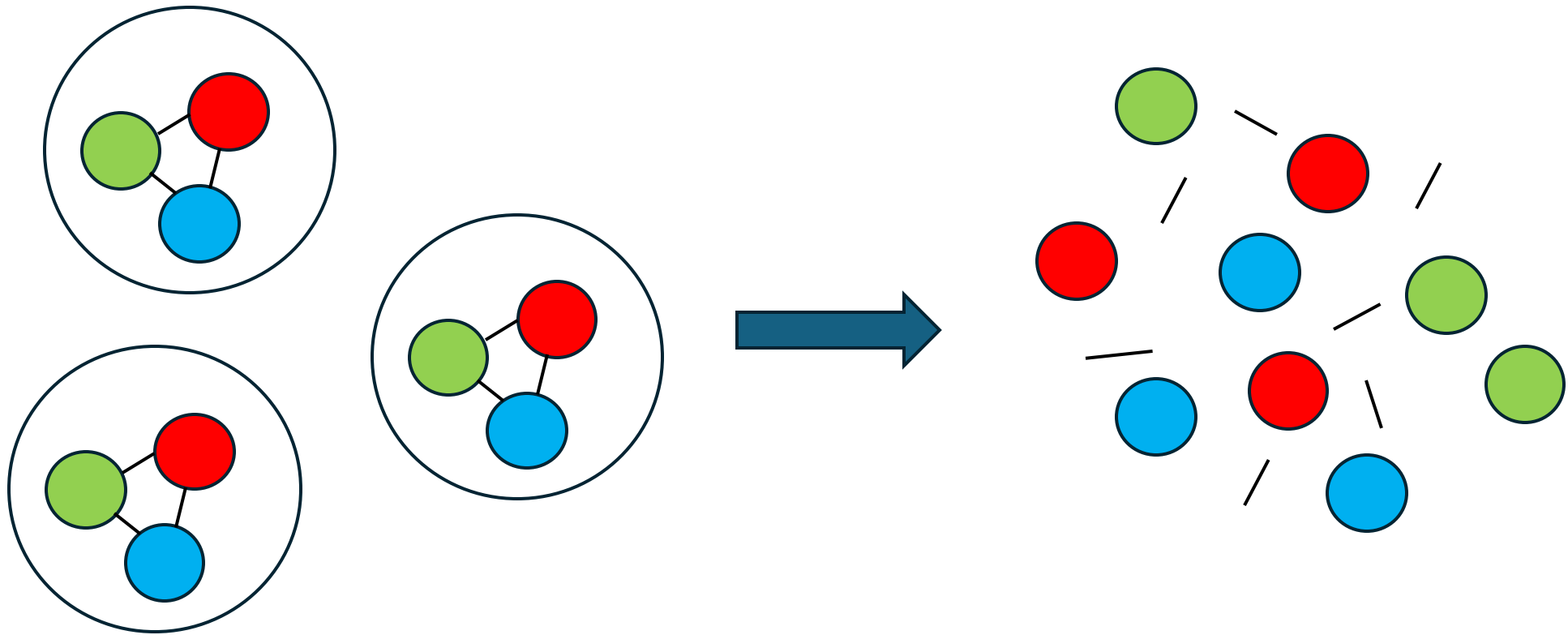
Yale University



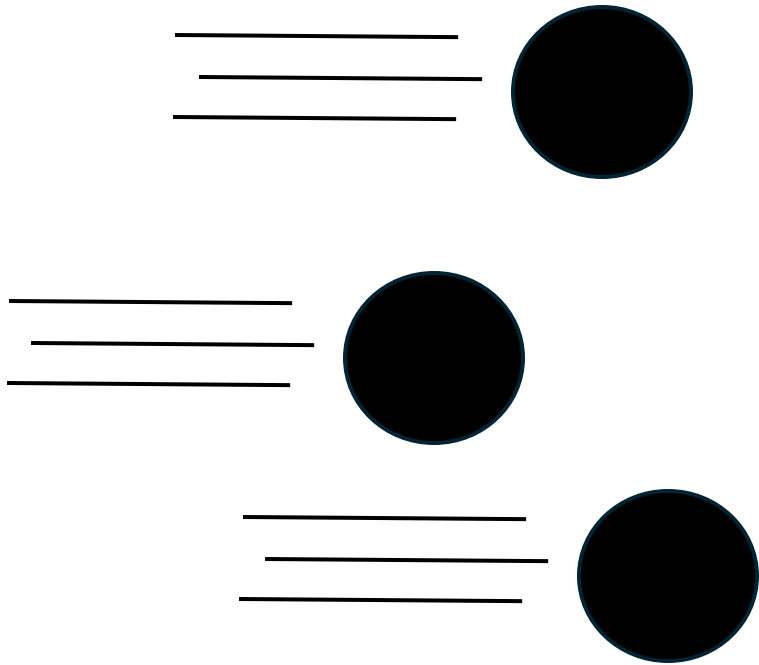
The Quark-Gluon Plasma



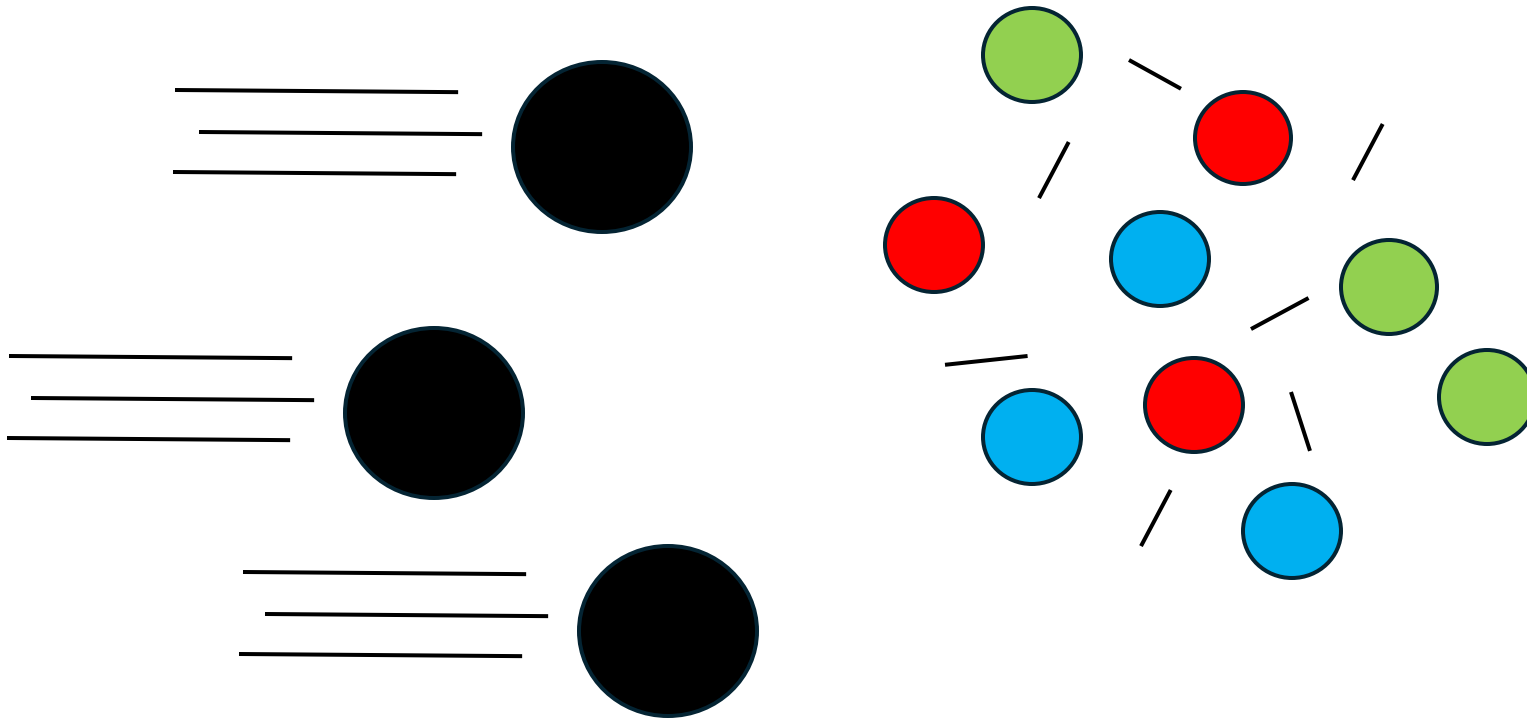
The Quark-Gluon Plasma



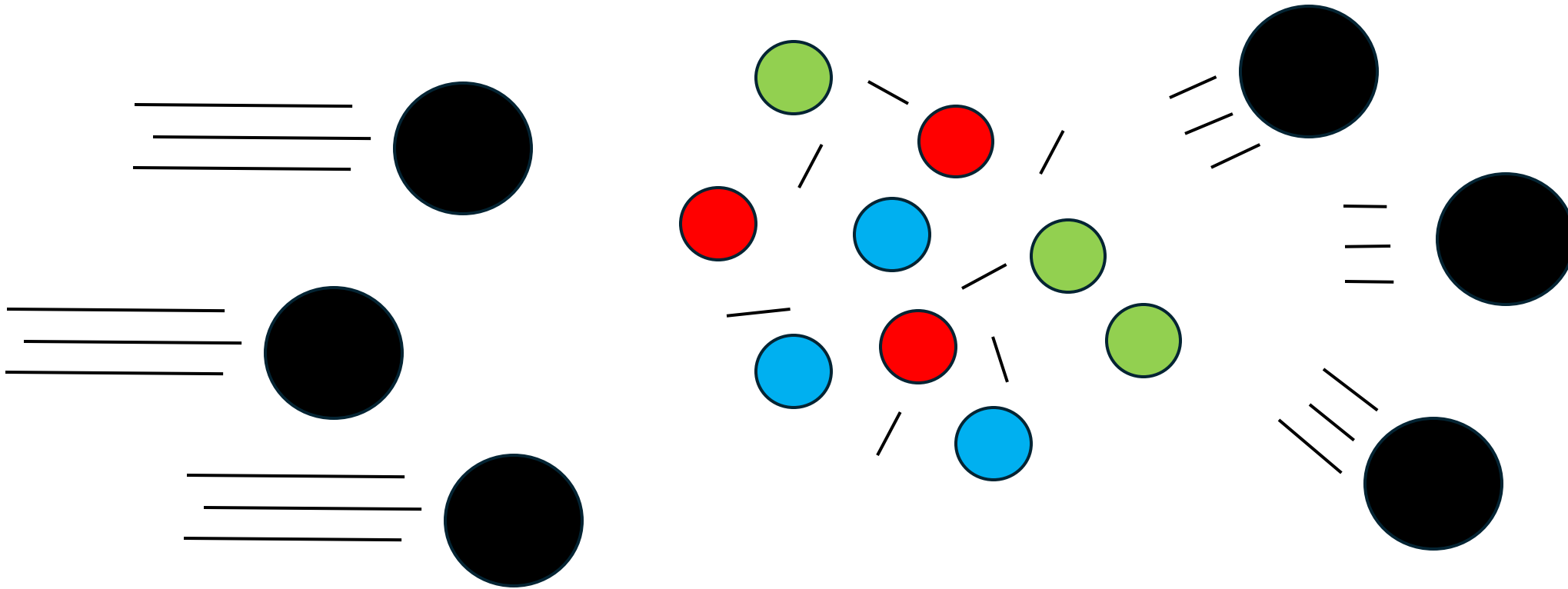
Studying the Quark-Gluon Plasma



Studying the Quark-Gluon Plasma



Studying the Quark-Gluon Plasma



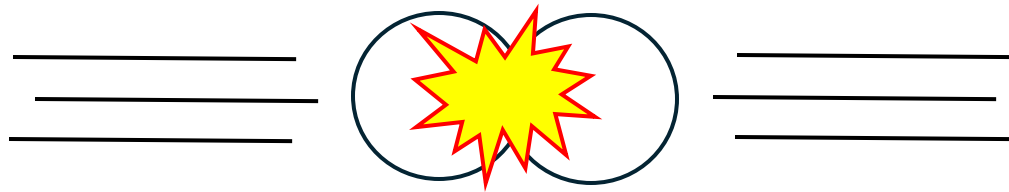
Studying the Quark-Gluon Plasma ... with Jets

- Jets: Collimated showers of single – origin particles



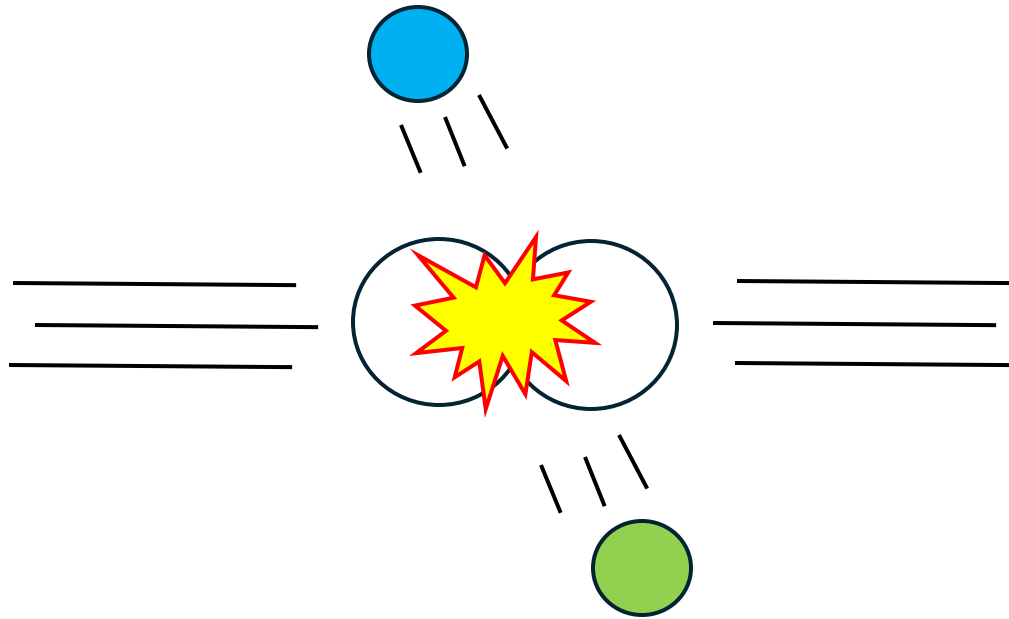
Studying the Quark-Gluon Plasma ... with Jets

- Jets: Collimated showers of single - origin particles



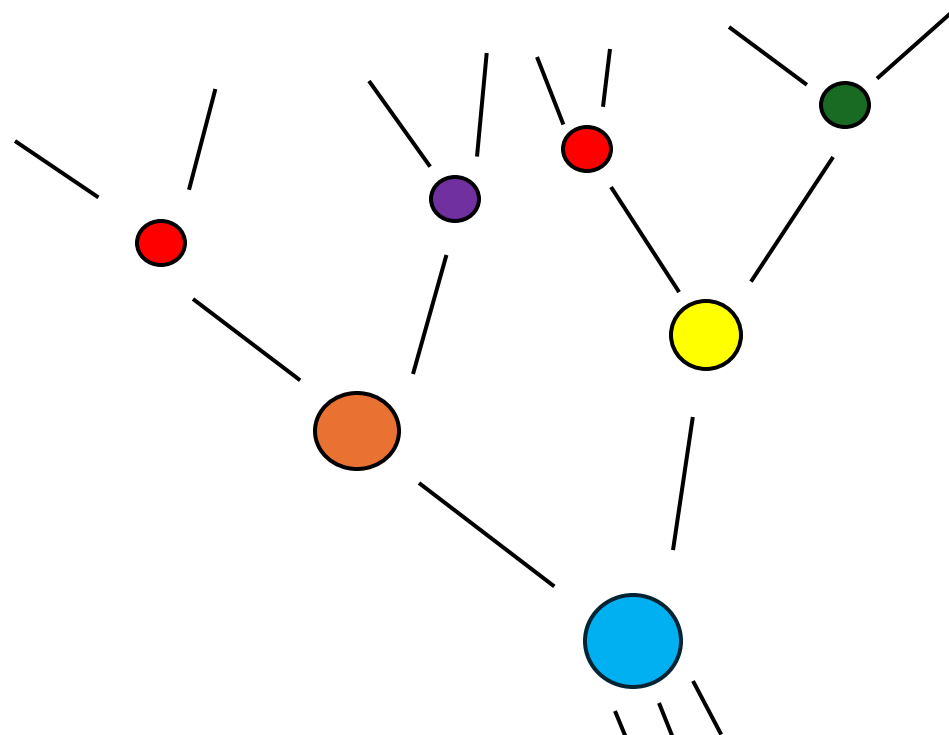
Studying the Quark-Gluon Plasma ... with Jets

- Jets: Collimated showers of single - origin particles

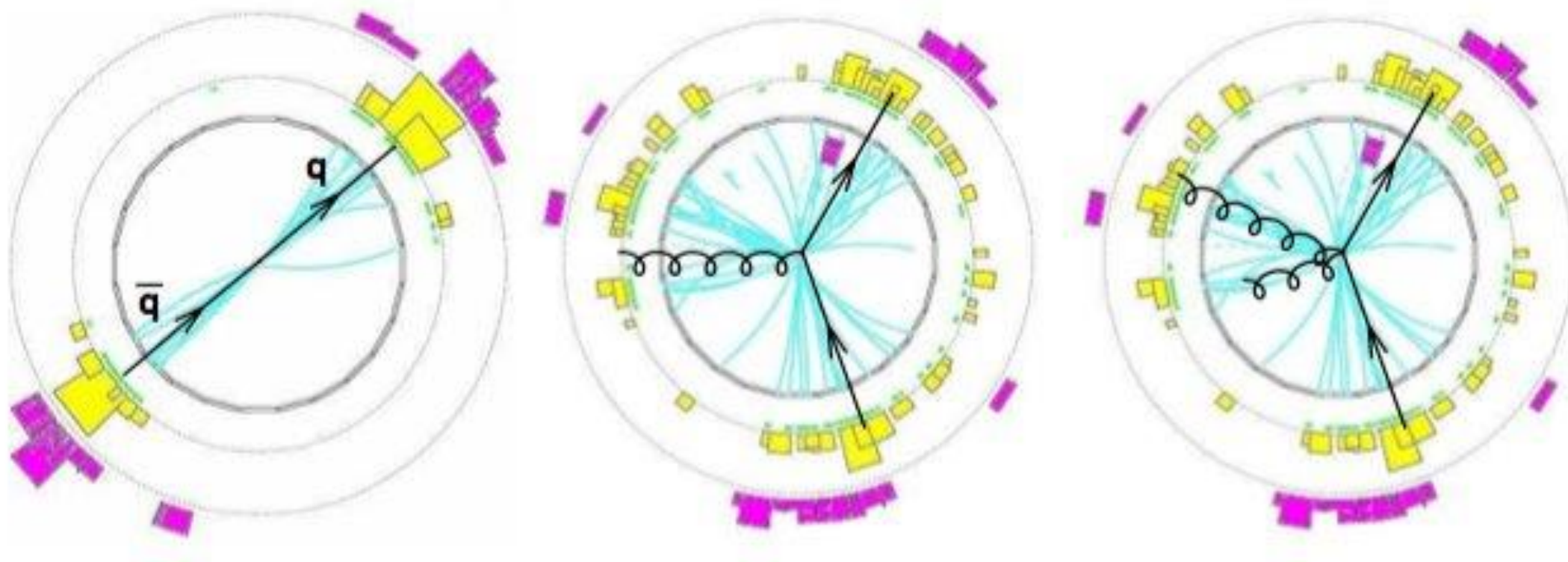


Studying the Quark-Gluon Plasma ... with Jets

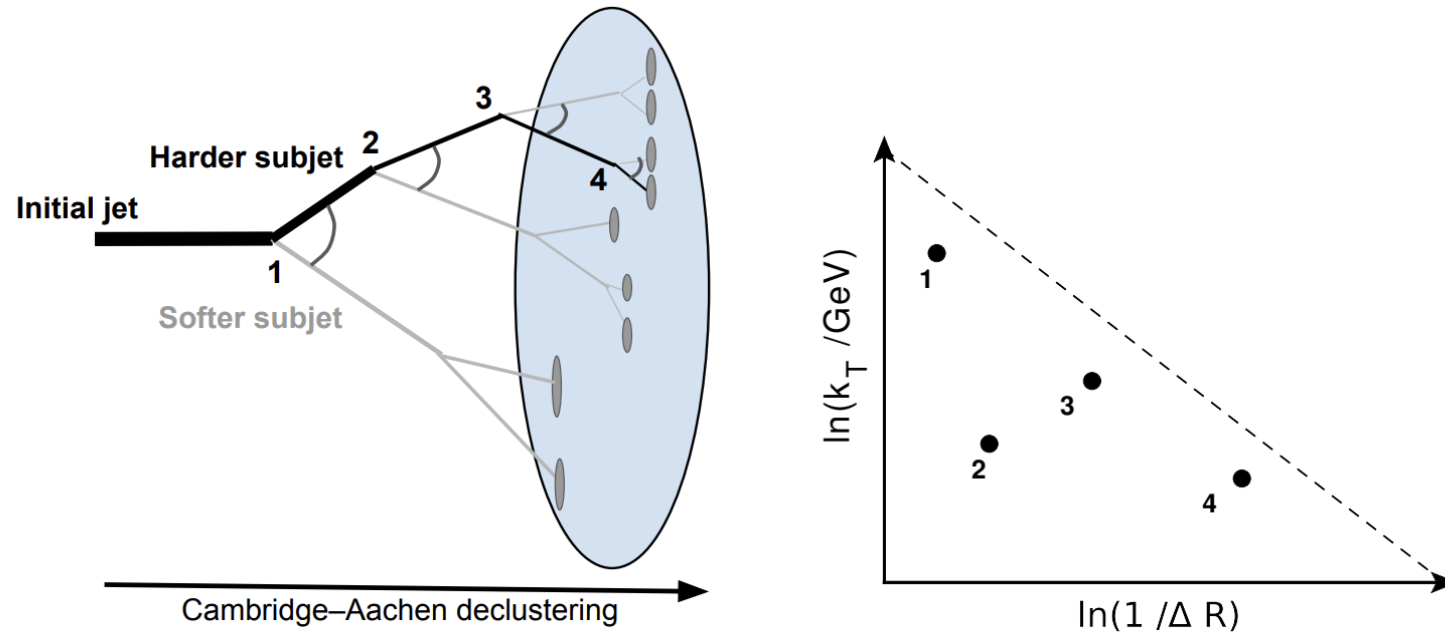
- Jets: Collimated showers of single - origin particles



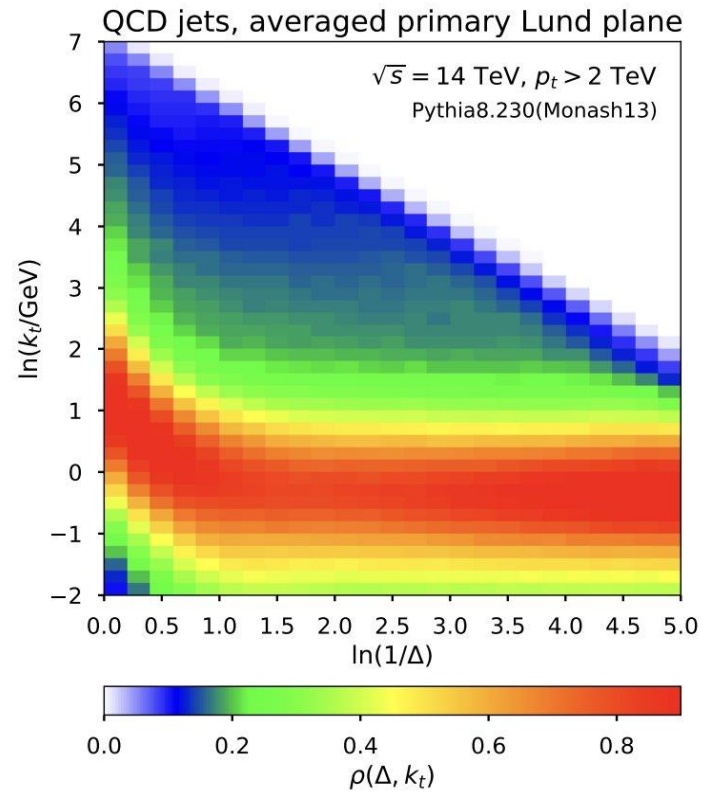
Jet Classification



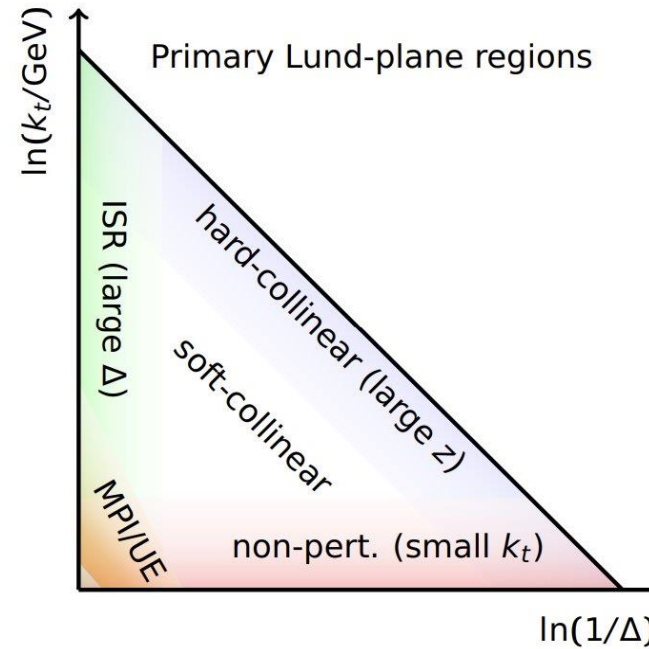
Jet Analysis – The Lund Plane



Jet Substructure – The Lund Plane

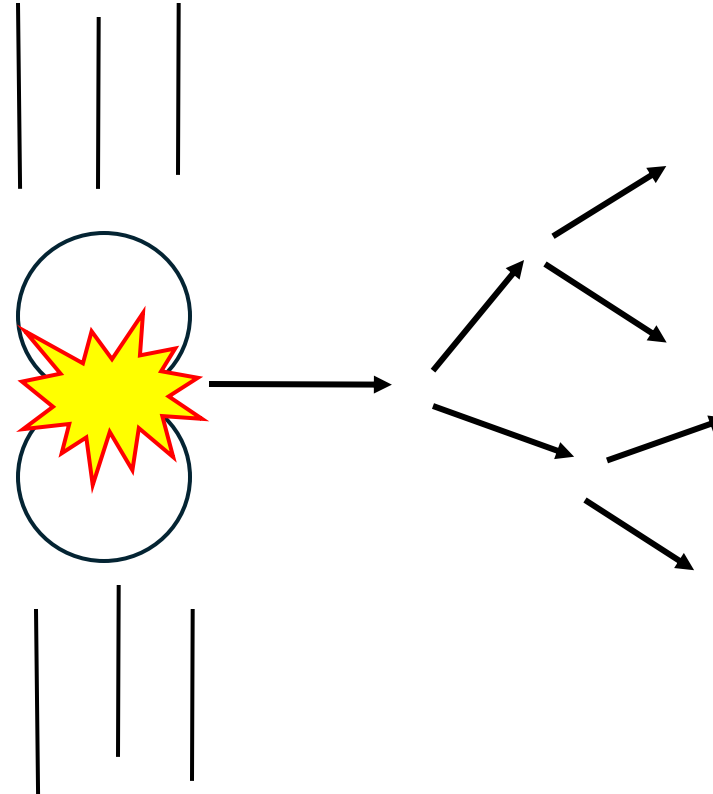


(a)

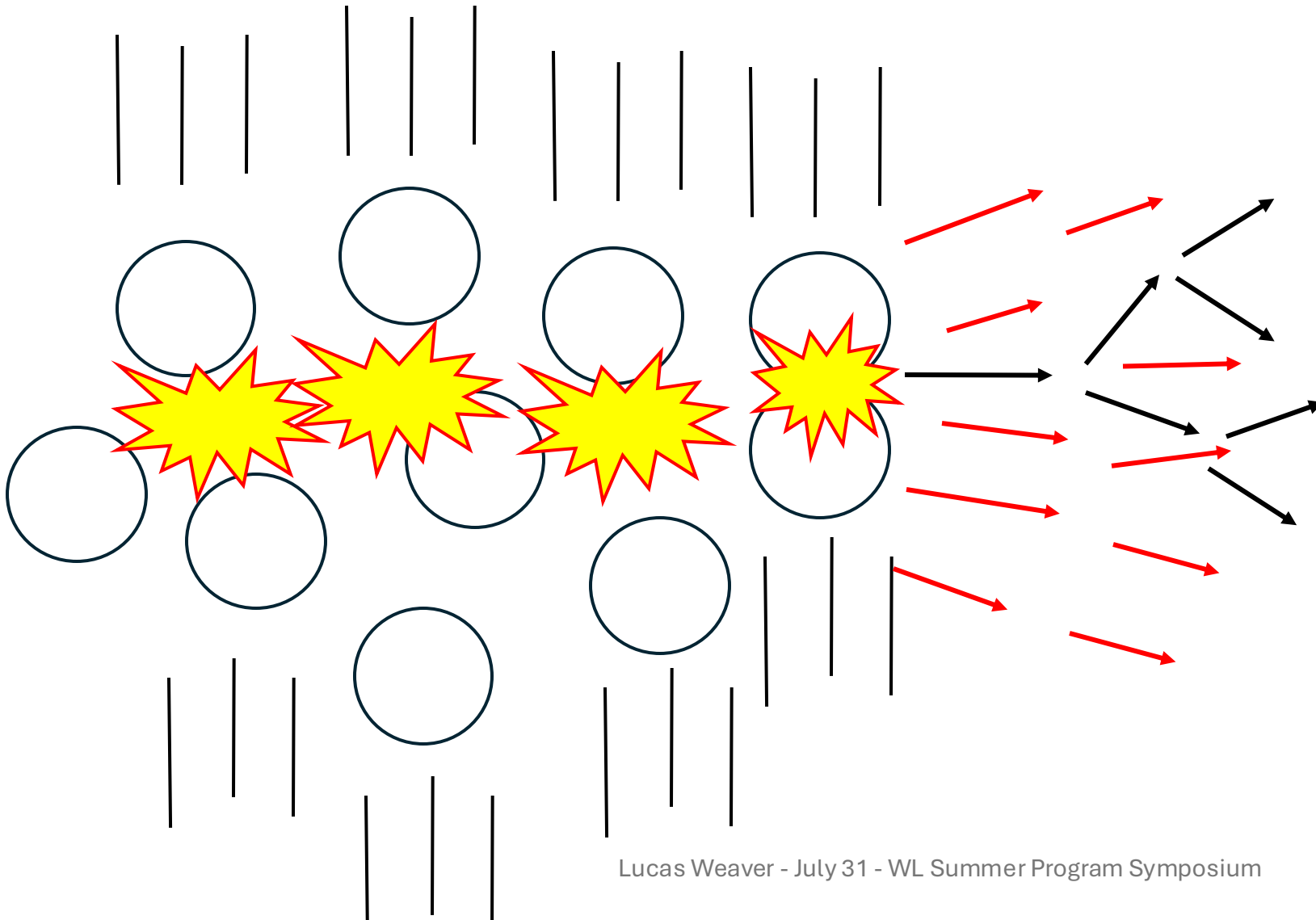


(b)

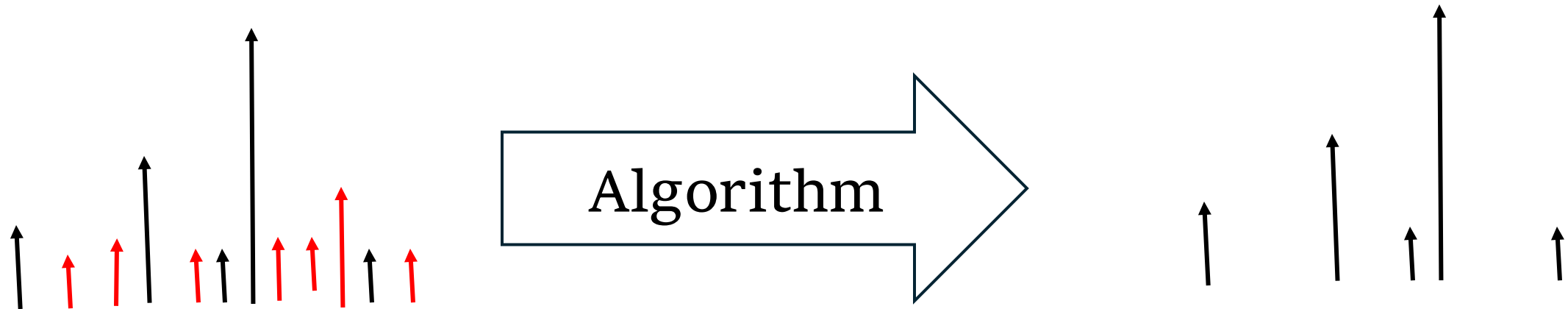
The Problem: Underlying Event Background



The Problem: Underlying Event Background



Background Removal



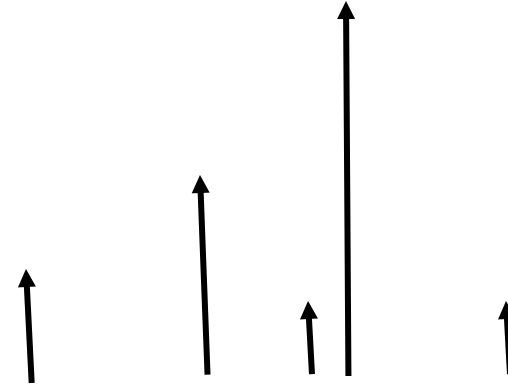
Can we recover the true Lund jet plane from underneath the heavy-ion thermal background?

Methods

- Generate events - Pythia8

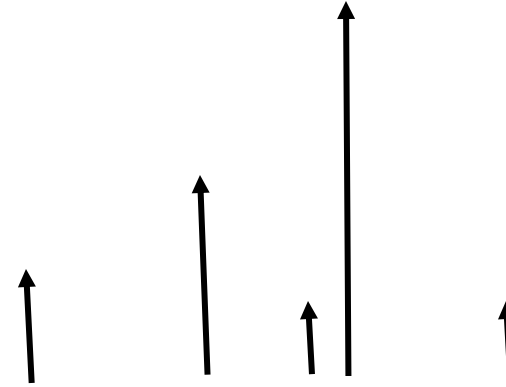
Methods

- Generate events - Pythia8

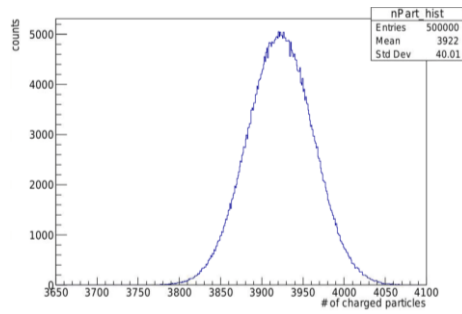


Methods

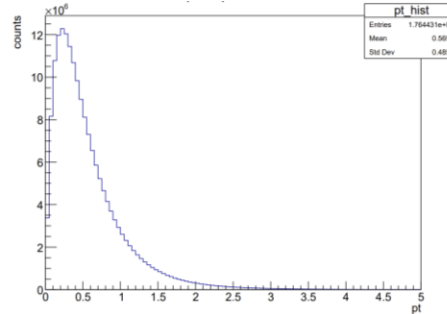
- Generate events
- Generate backgrounds



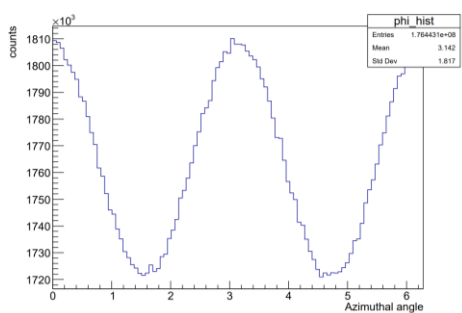
Particle Multiplicity



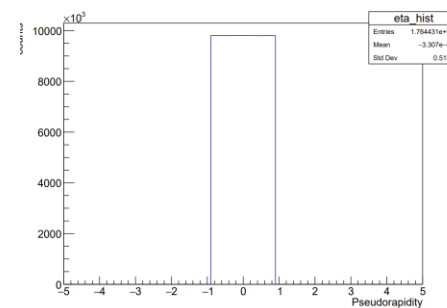
Particle Momentum



Particle Azimuthal Angle

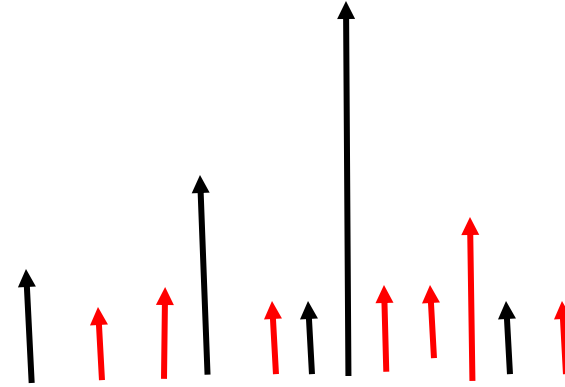


Particle Pseudorapidity

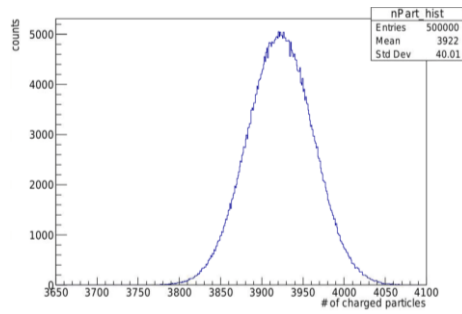


Methods

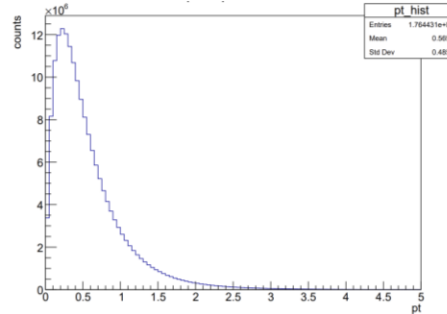
- Generate events
- Generate backgrounds



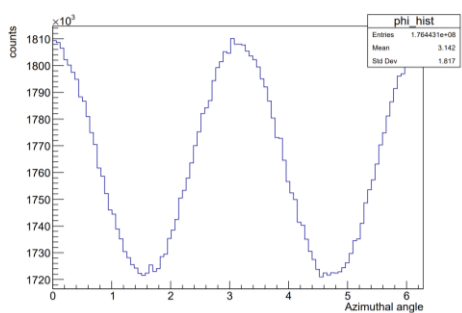
Particle Multiplicity



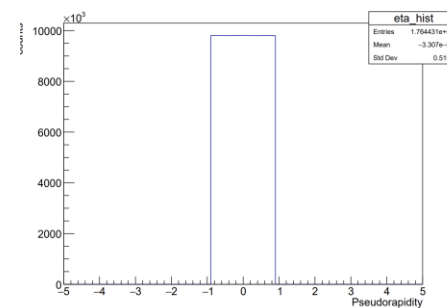
Particle Momentum



Particle Azimuthal Angle

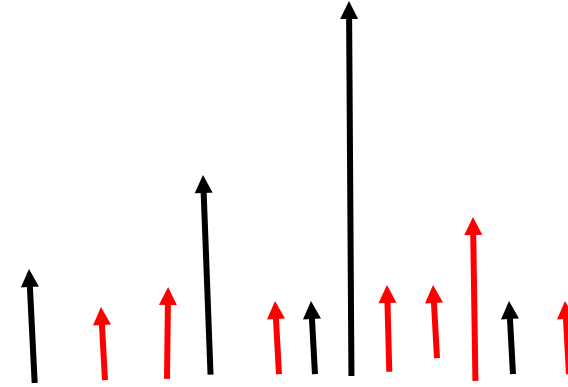


Particle Pseudorapidity



Methods

- Generate events
- Generate backgrounds
- Apply Subtraction techniques



Constituent
Subtraction

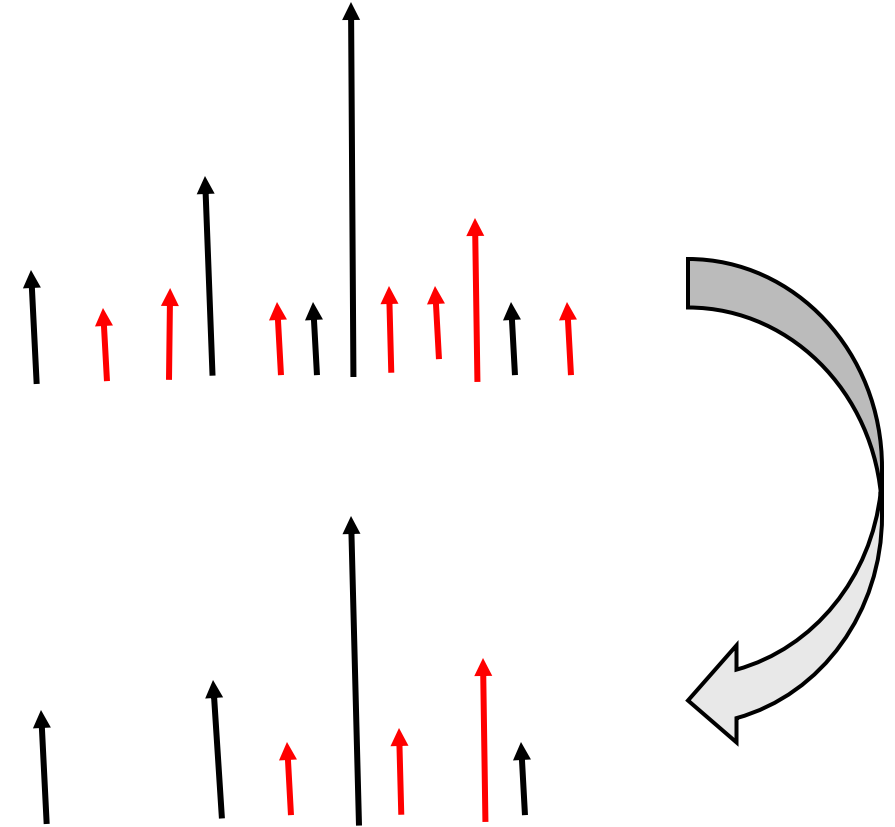
Recursive
SoftDrop

SoftKiller

Perpendicular
Cone

Methods

- Generate events
- Generate backgrounds
- Apply Subtraction techniques



Constituent
Subtraction

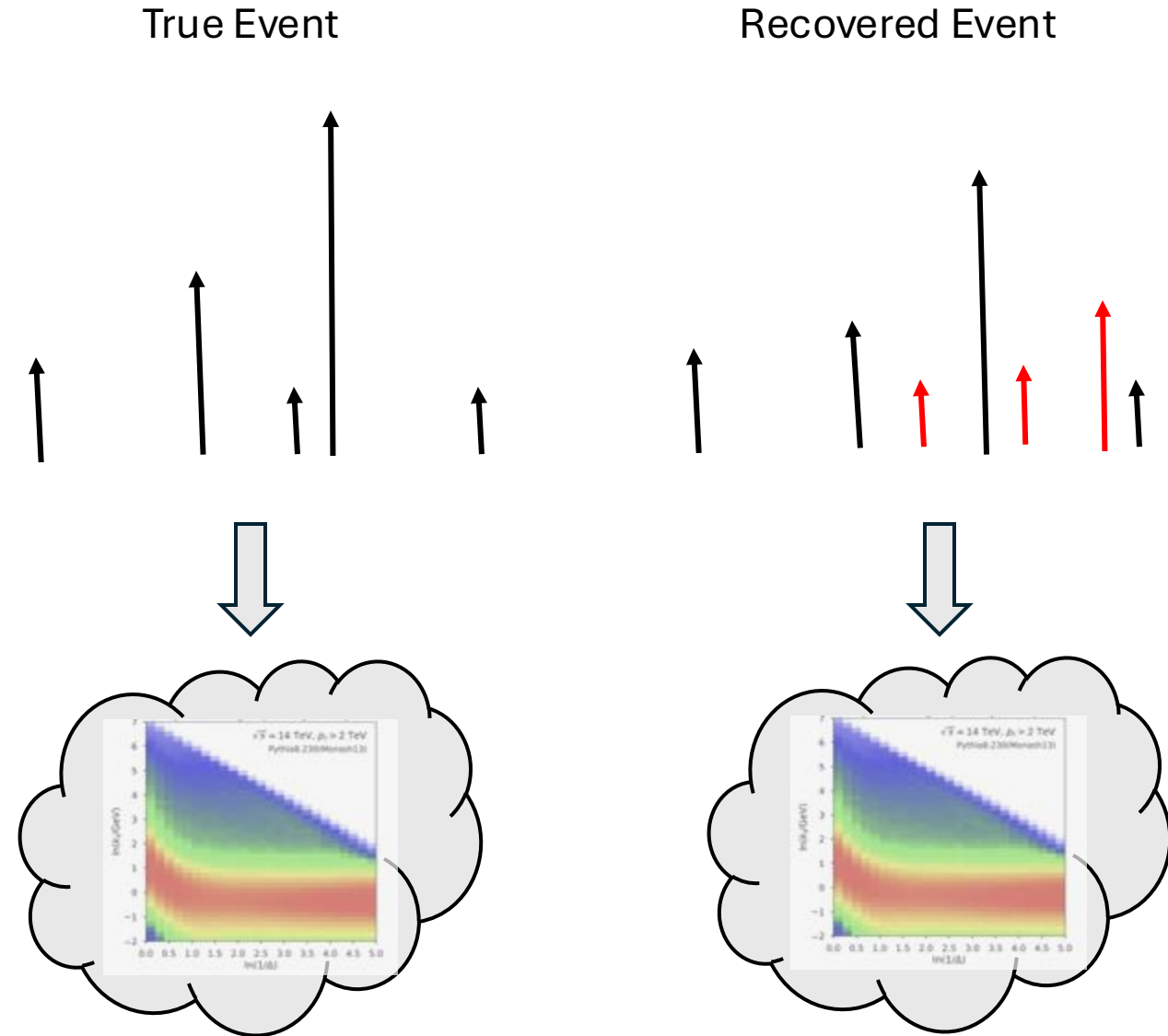
Recursive
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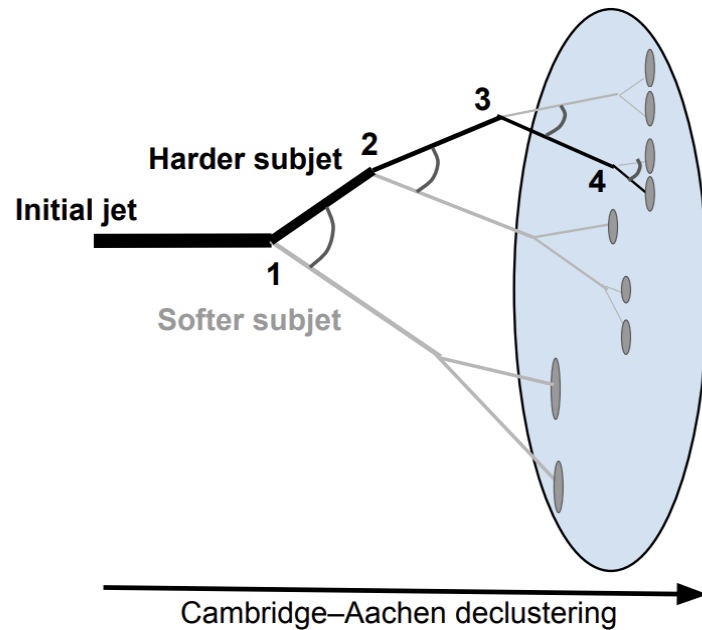
Methods

- Generate events
- Generate backgrounds
- Apply Subtraction techniques
- Compare Lund Planes



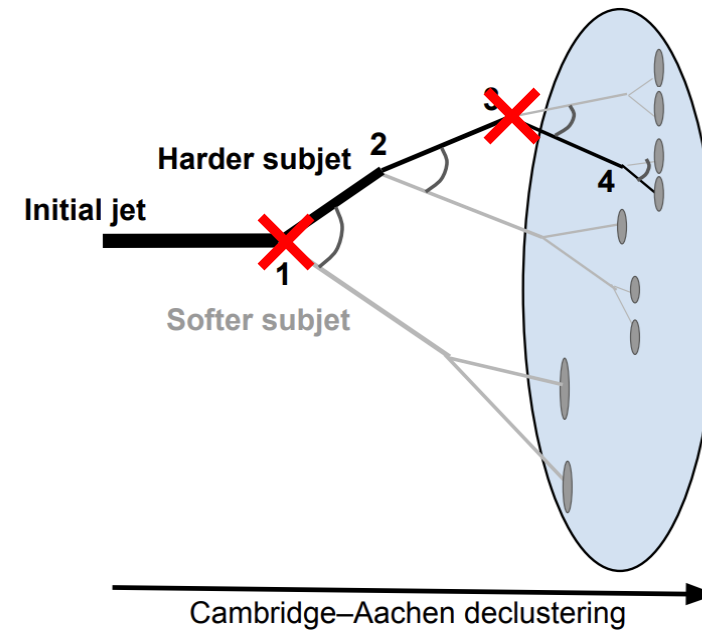
Methods: Comparing Lund planes

Full Lund Plane



Groomed Lund Plane

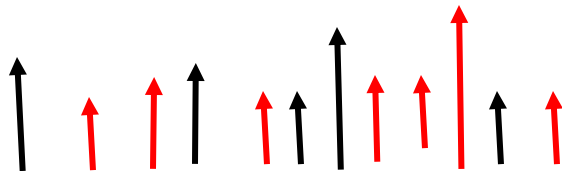
SoftDrop Condition



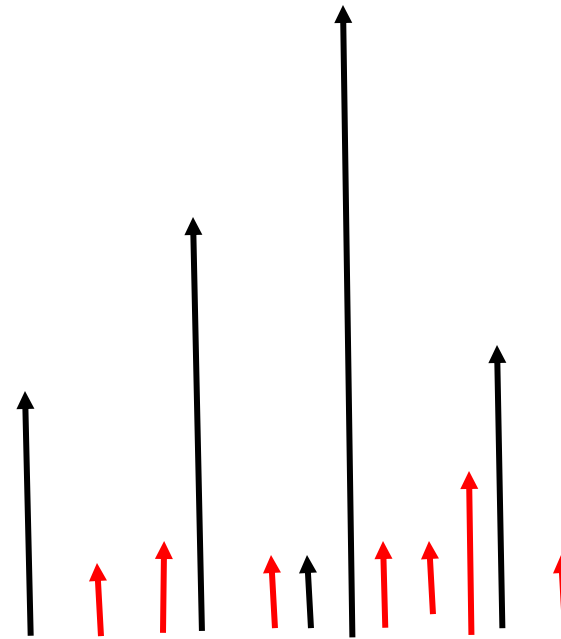
Methods: Comparing Lund planes

Jet pT cuts

Low pT jet:

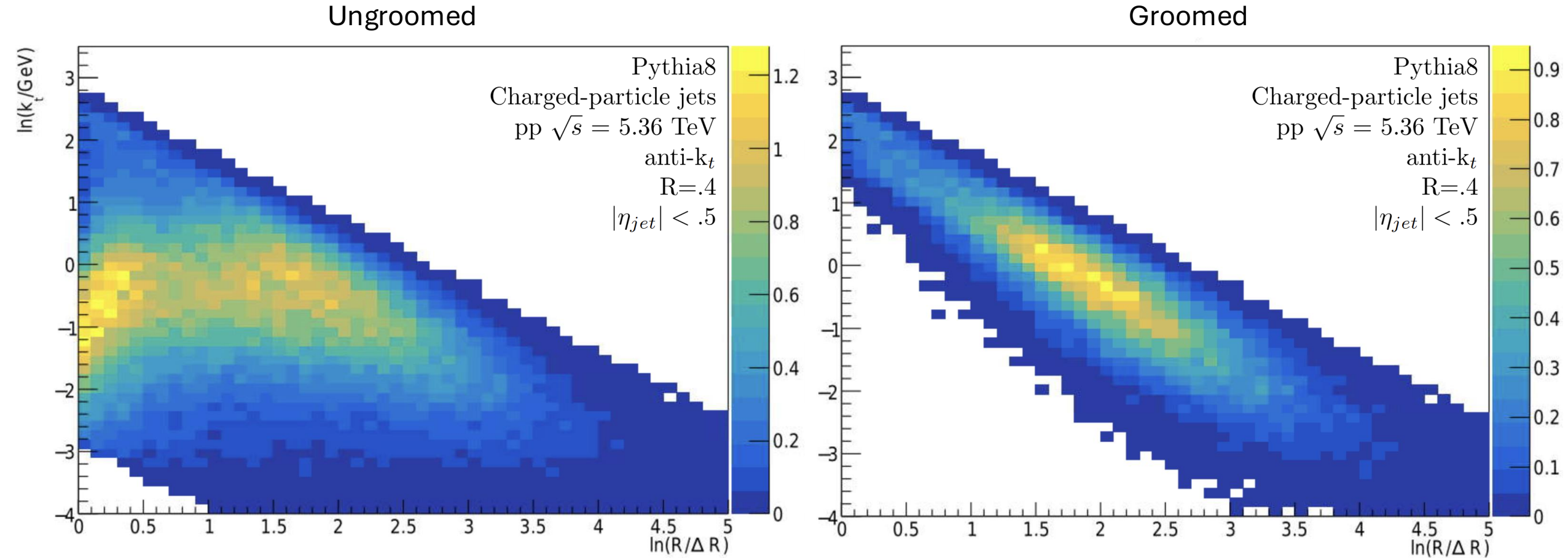


High pT jet:

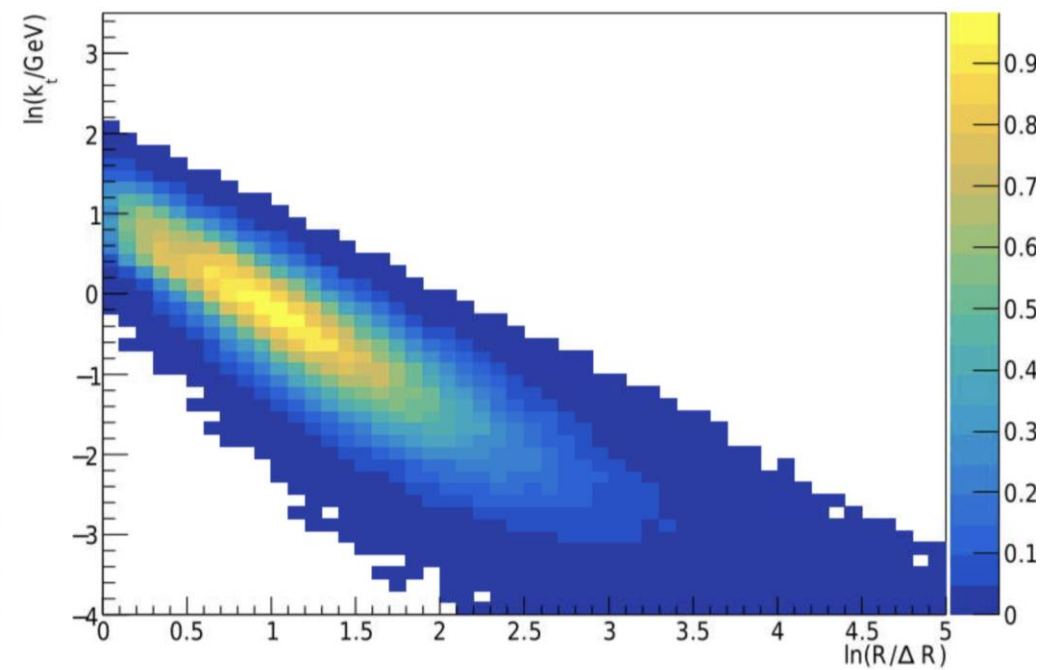
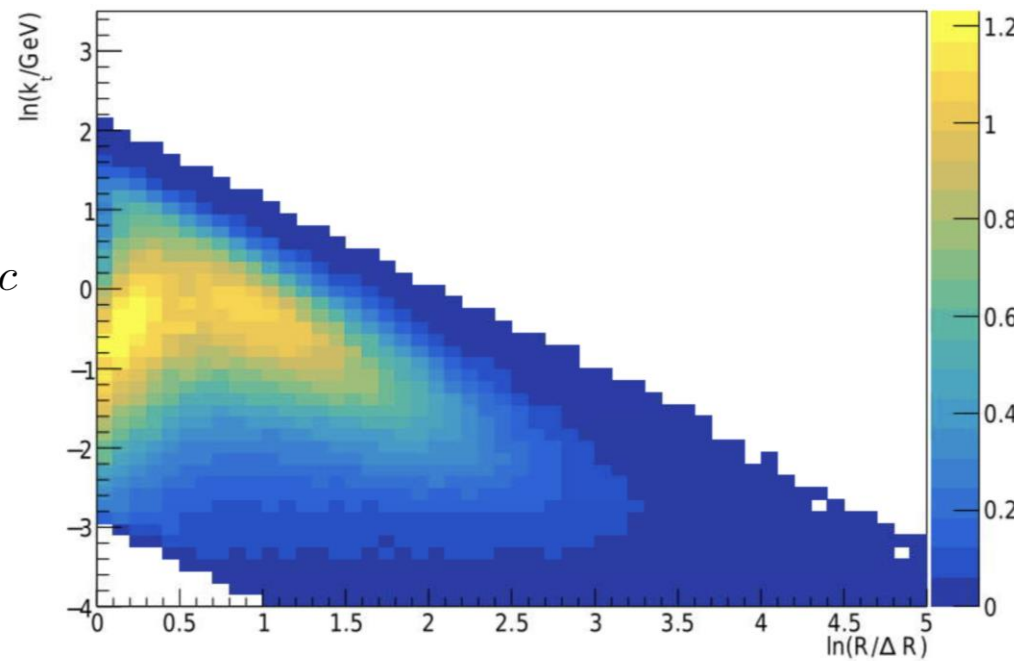


Results

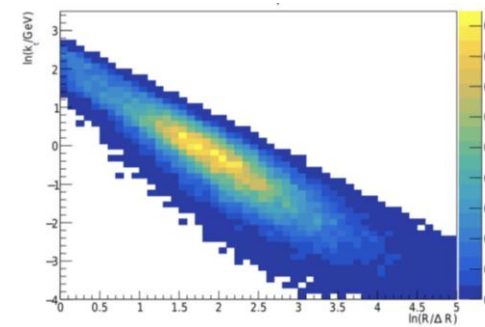
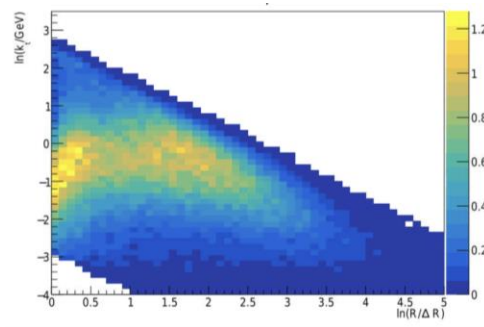
Results: Truth-level Event



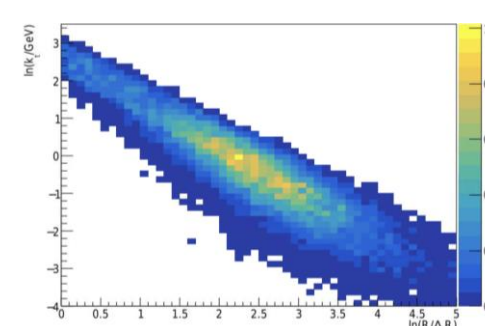
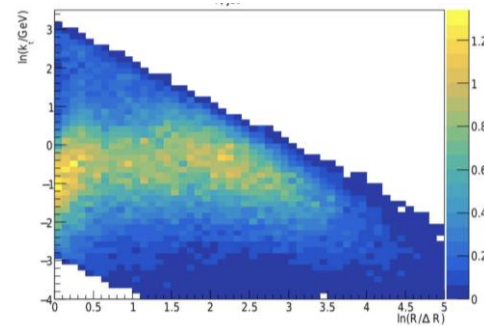
$20 < p_{T,jet} < 40 \text{ GeV}/c$



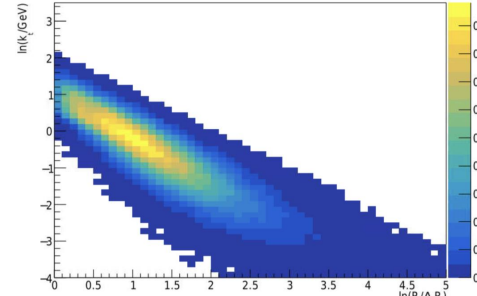
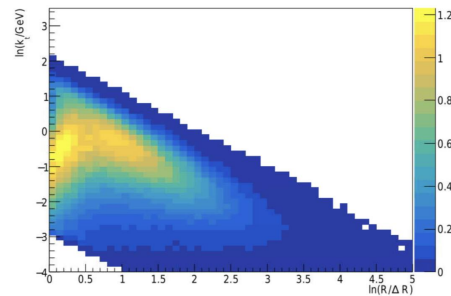
$60 < p_{T,jet} < 80 \text{ GeV}/c$



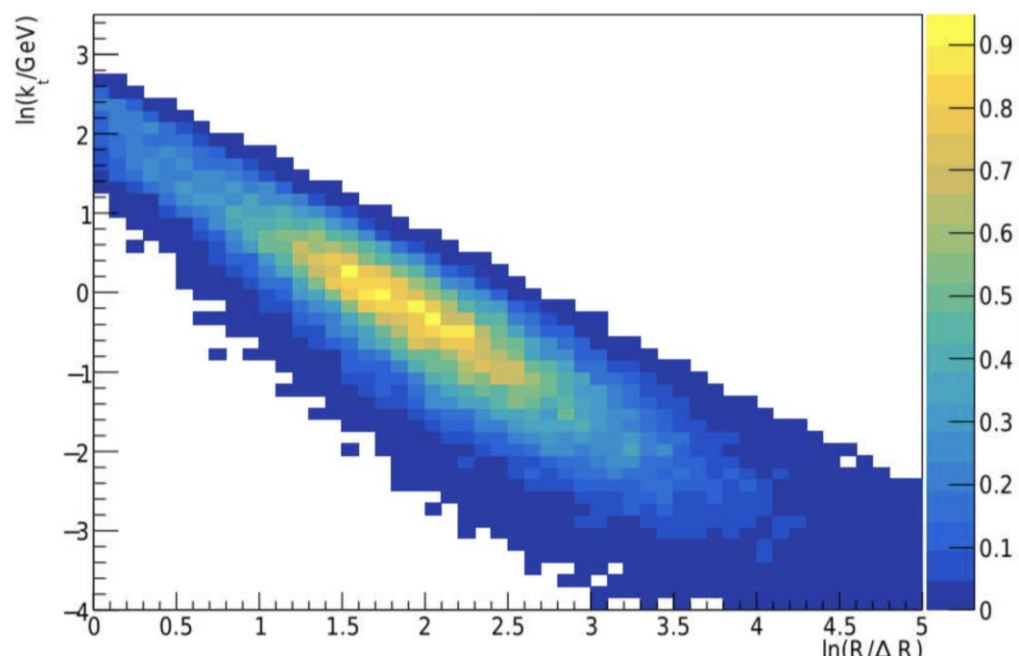
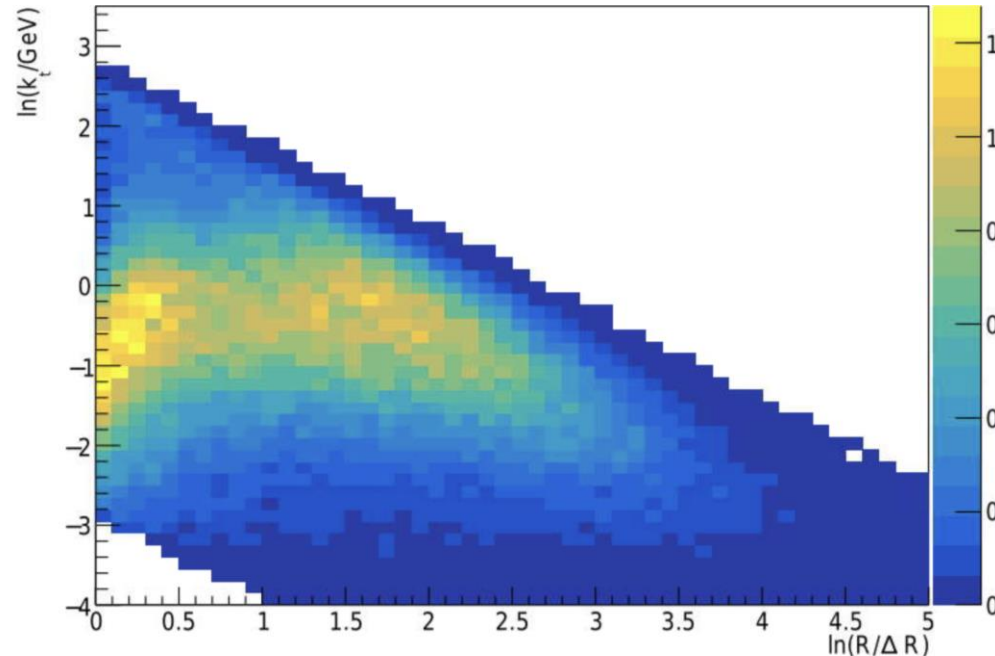
$100 < p_{T,jet} < 120 \text{ GeV}/c$



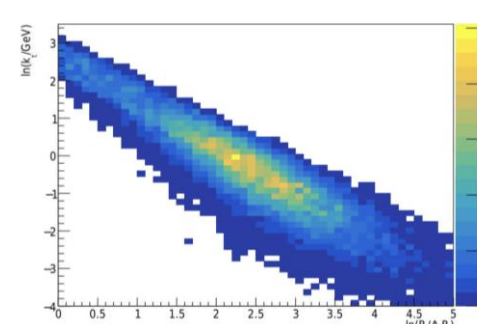
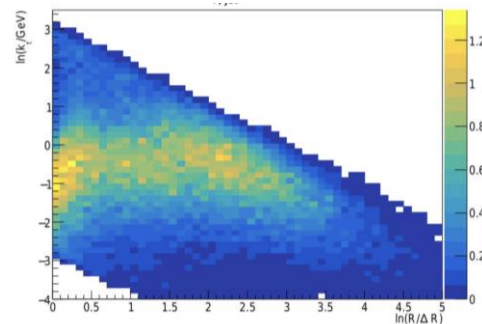
$20 < p_{T,jet} < 40 \text{ GeV}/c$



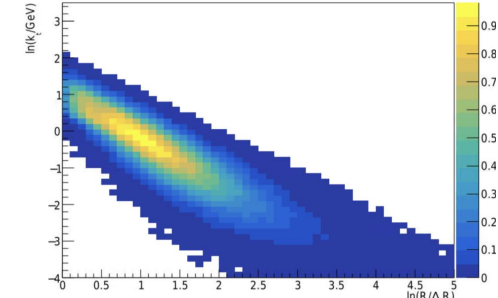
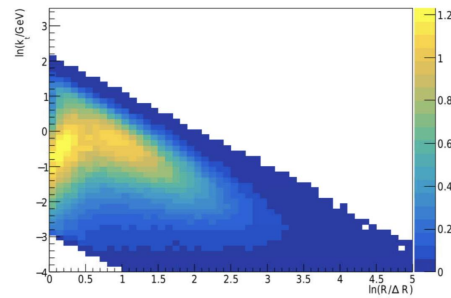
$60 < p_{T,jet} < 80 \text{ GeV}/c$



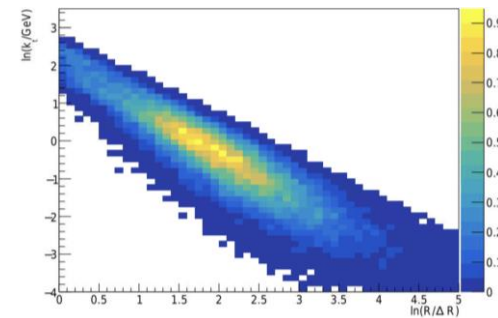
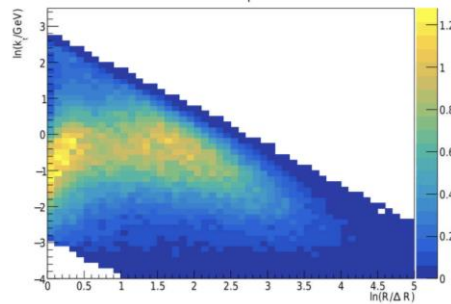
$100 < p_{T,jet} < 120 \text{ GeV}/c$



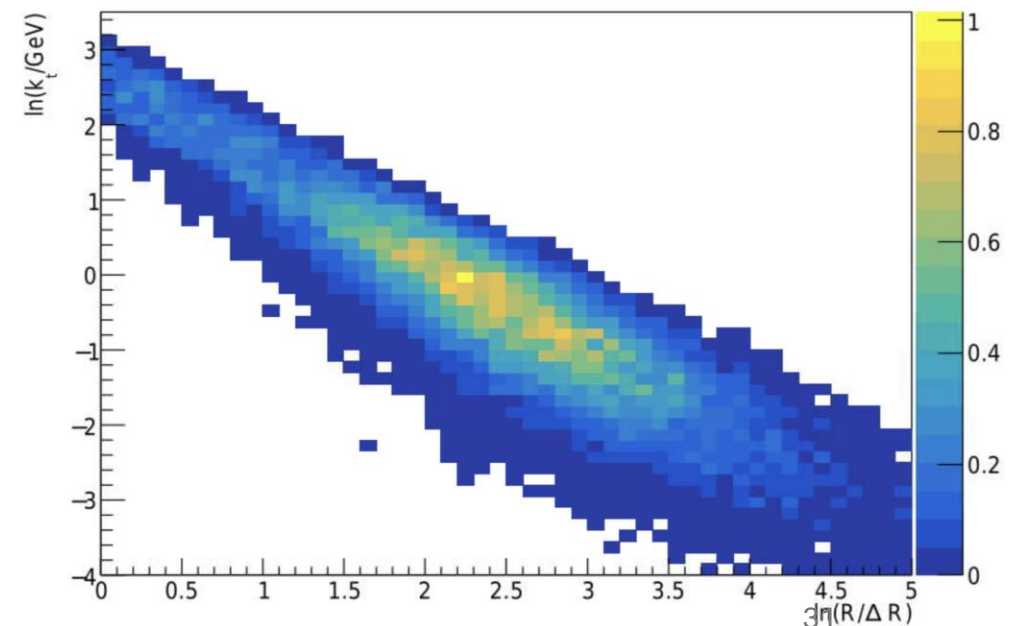
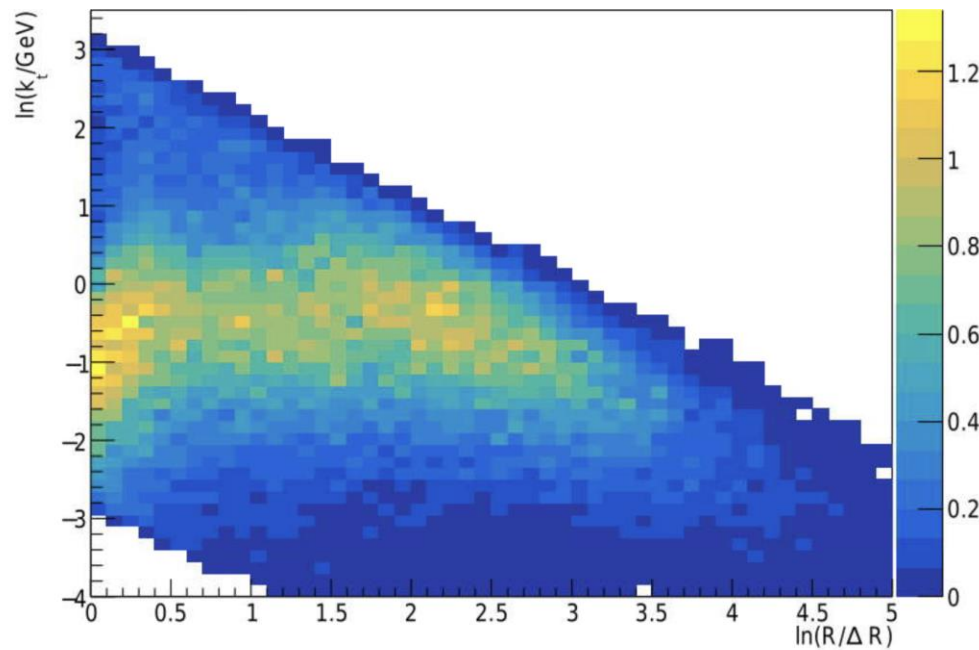
$$20 < p_{T,jet} < 40 \text{ GeV}/c$$



$$60 < p_{T,jet} < 80 \text{ GeV}/c$$

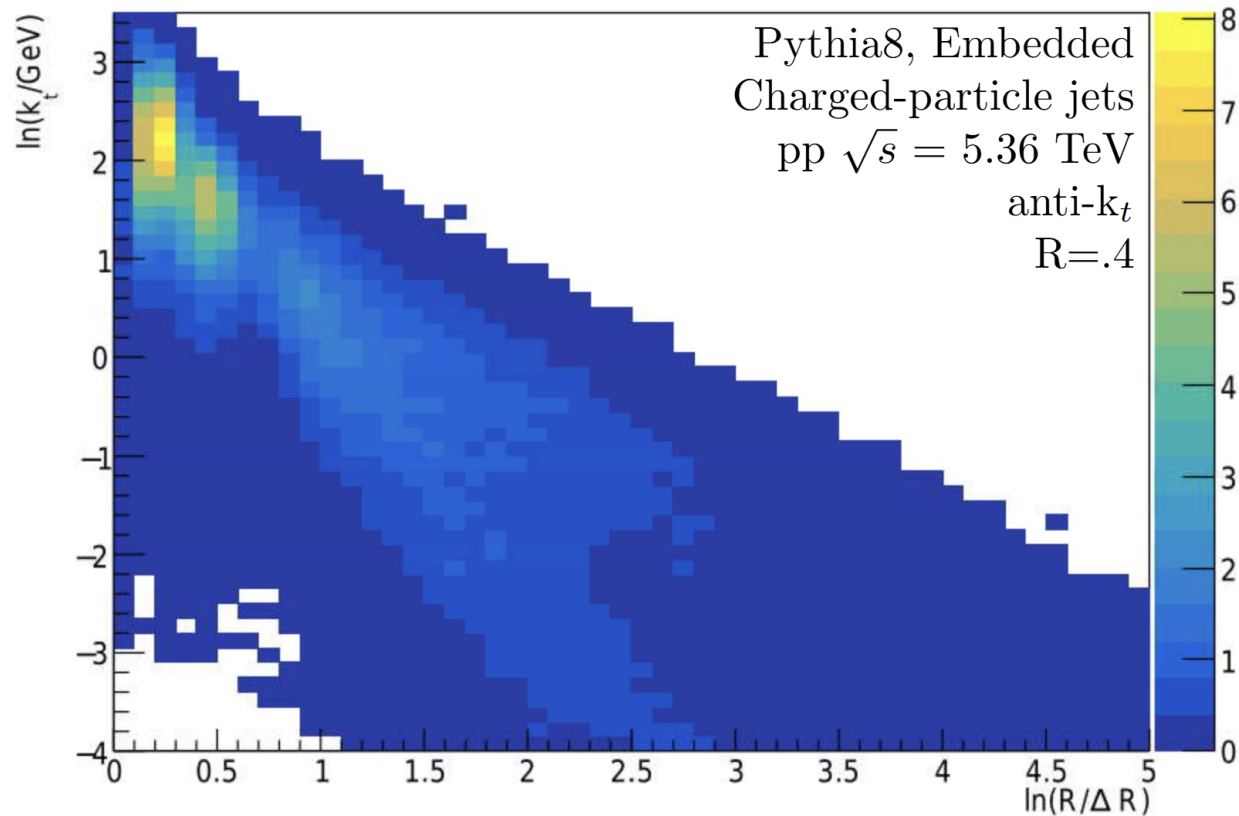


$$100 < p_{T,jet} < 120 \text{ GeV}/c$$

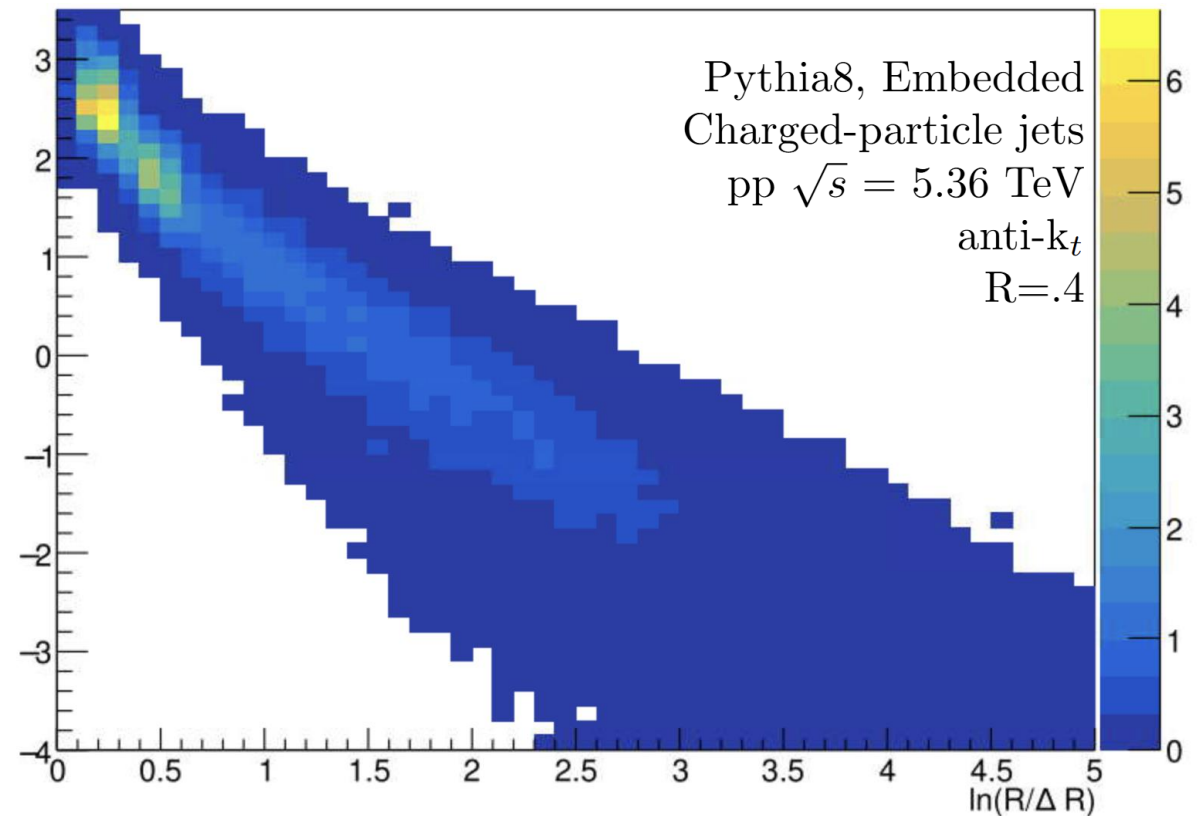


Results: Embedded Event

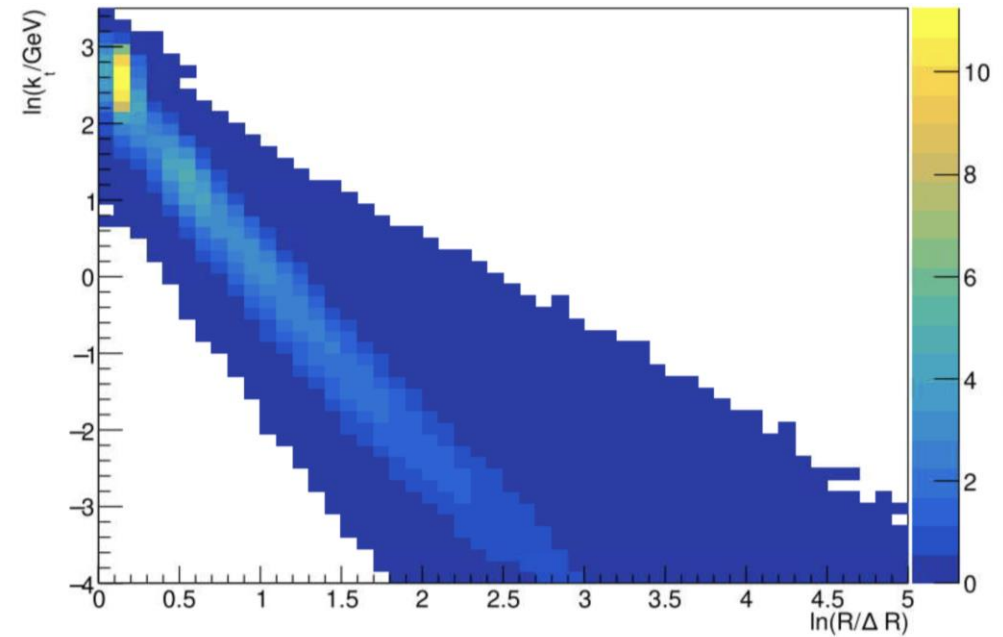
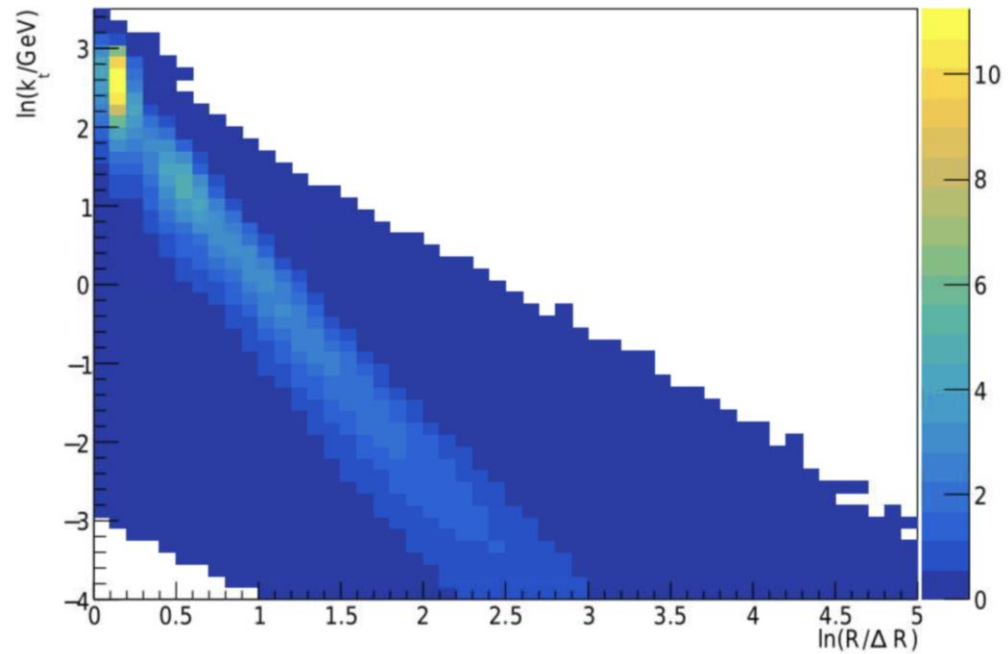
Ungroomed



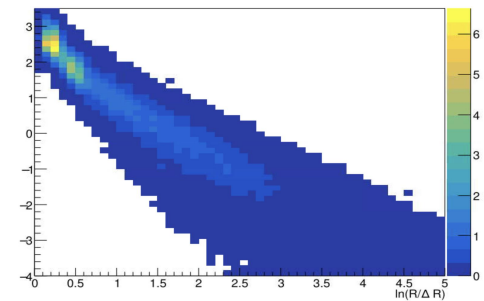
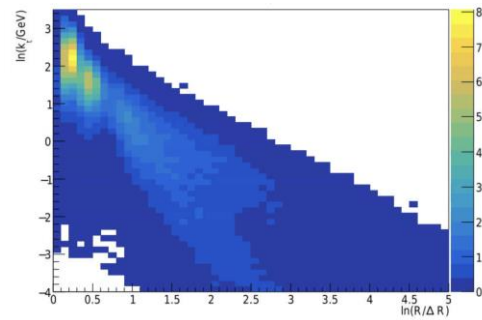
Groomed



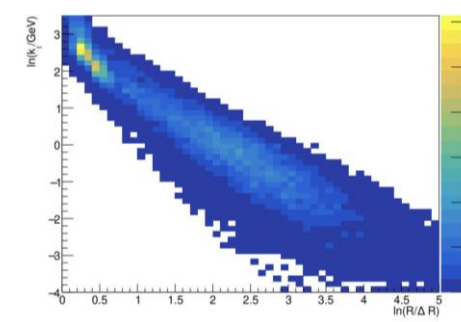
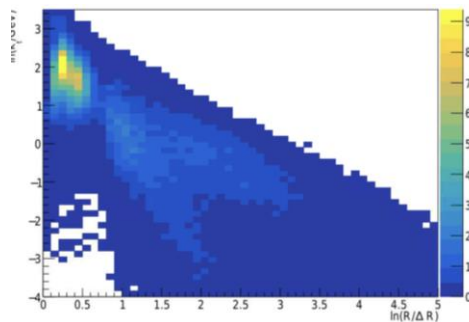
$20 < p_{T,jet} < 40 \text{ GeV}/c$



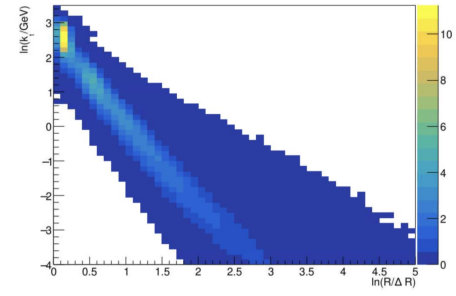
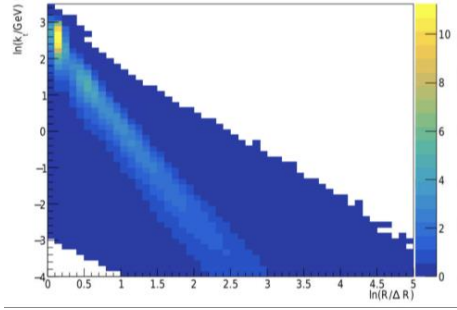
$60 < p_{T,jet} < 80 \text{ GeV}/c$



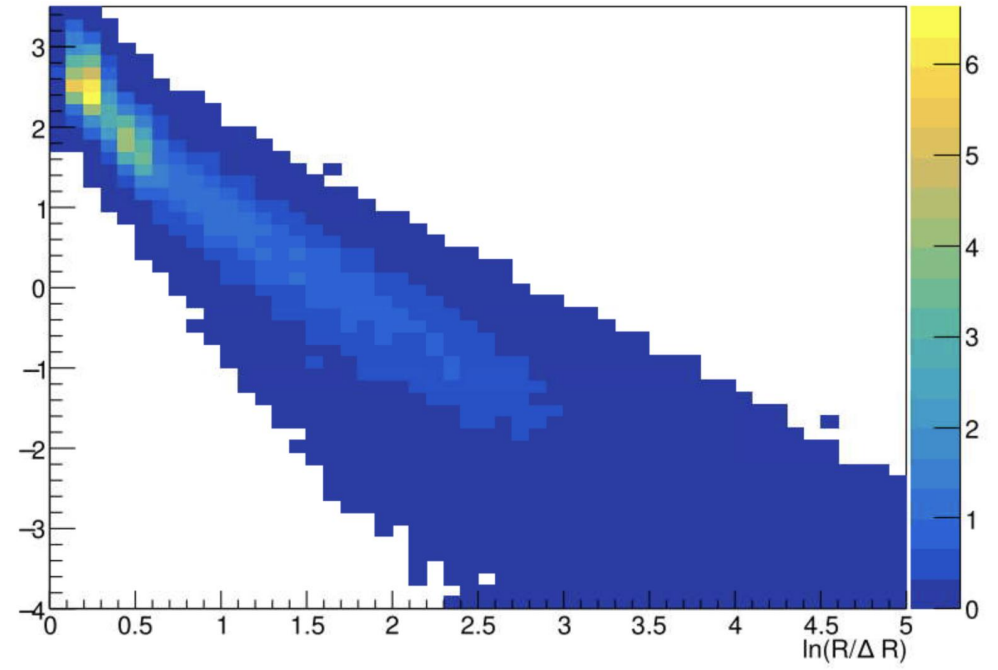
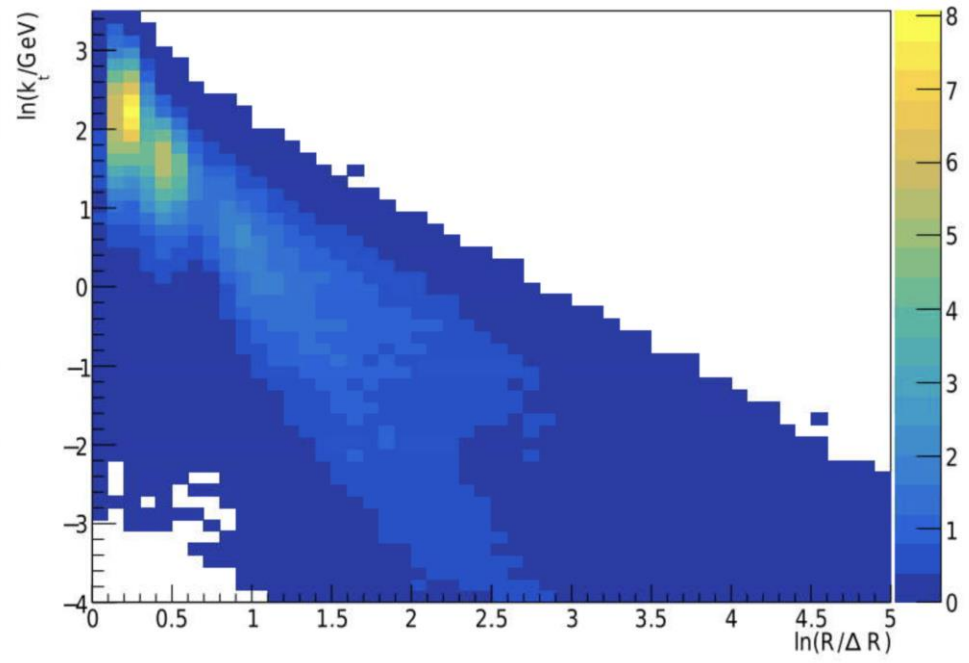
$100 < p_{T,jet} < 120 \text{ GeV}/c$



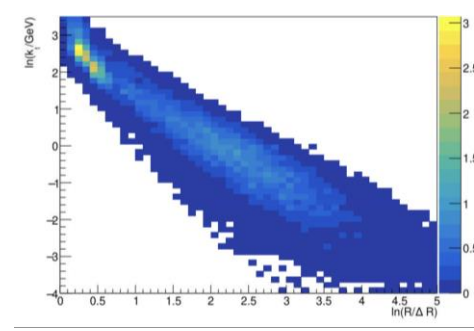
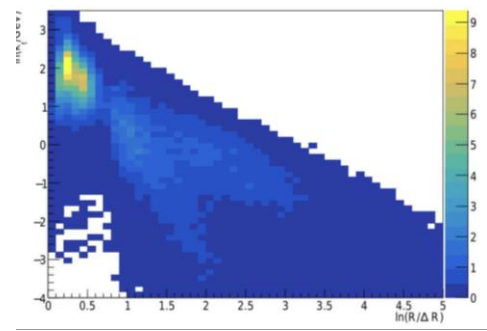
$20 < p_{T,jet} < 40 \text{ GeV}/c$



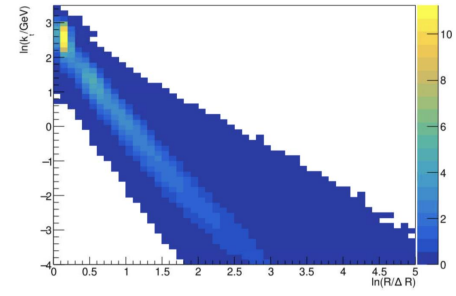
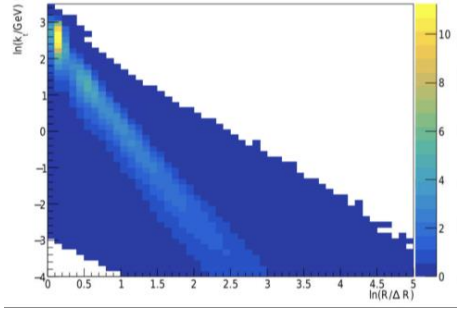
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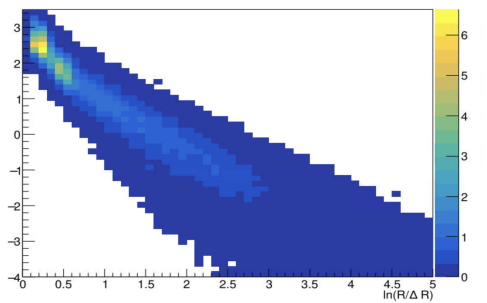
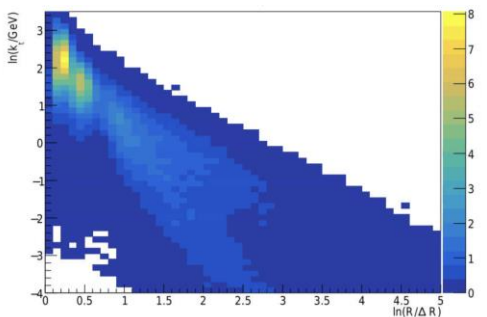
$100 < p_{T,jet} < 120 \text{ GeV}/c$



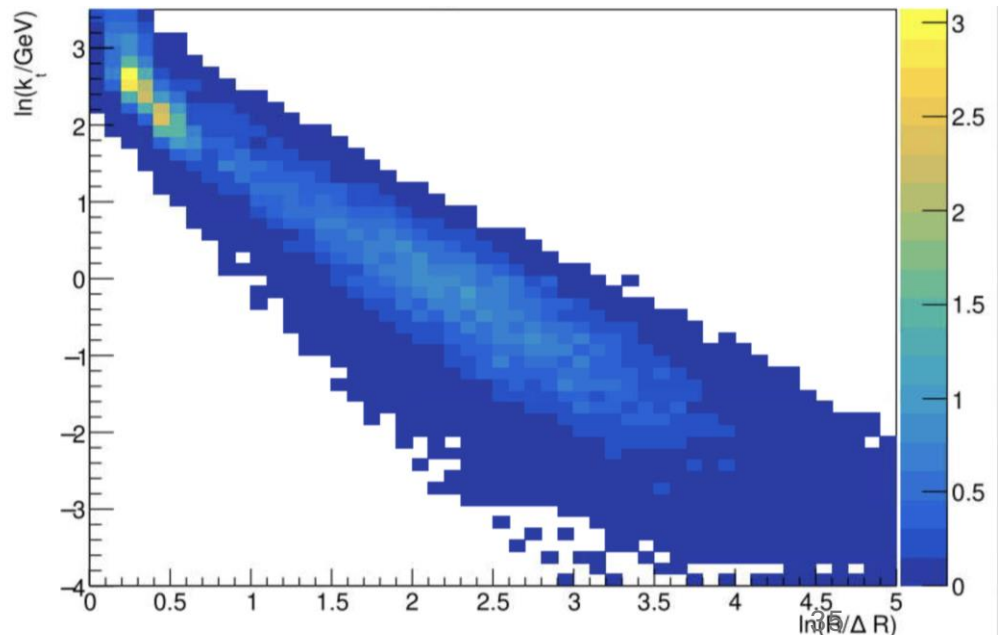
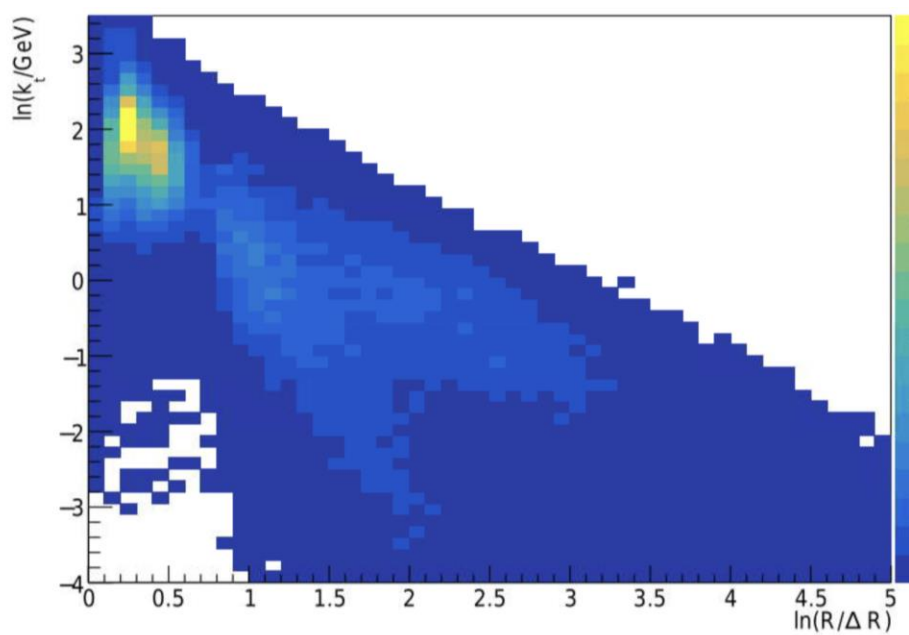
$20 < p_{T,jet} < 40 \text{ GeV}/c$



$60 < p_{T,jet} < 80 \text{ GeV}/c$



$100 < p_{T,jet} < 120 \text{ GeV}/c$



Analysis: Background Removal Techniques

Constituent
Subtraction

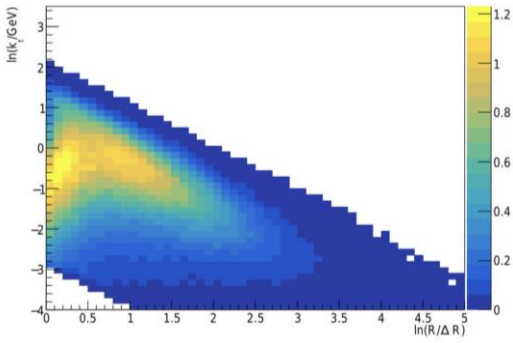
Recursive
SoftDrop

SoftKiller

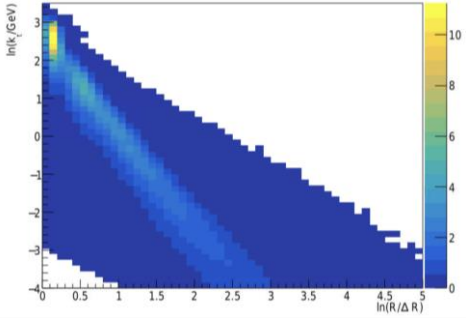
Perpendicular
Cone

$$20 < p_{T,jet} < 40 \text{ GeV}/c$$

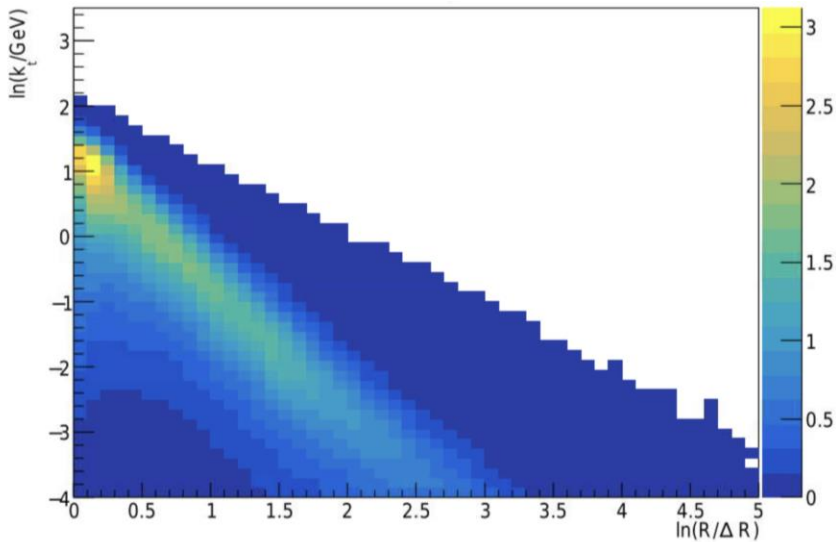
True Event



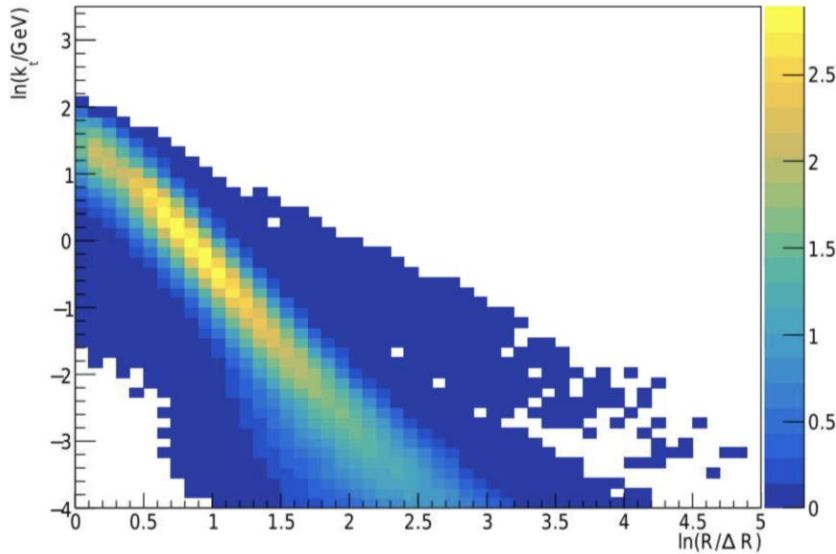
Embedded Event



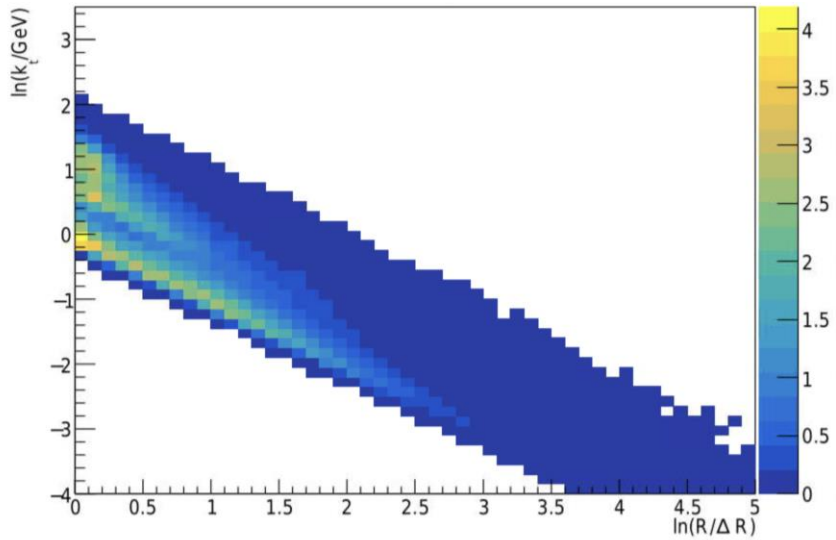
Constituent Subtraction



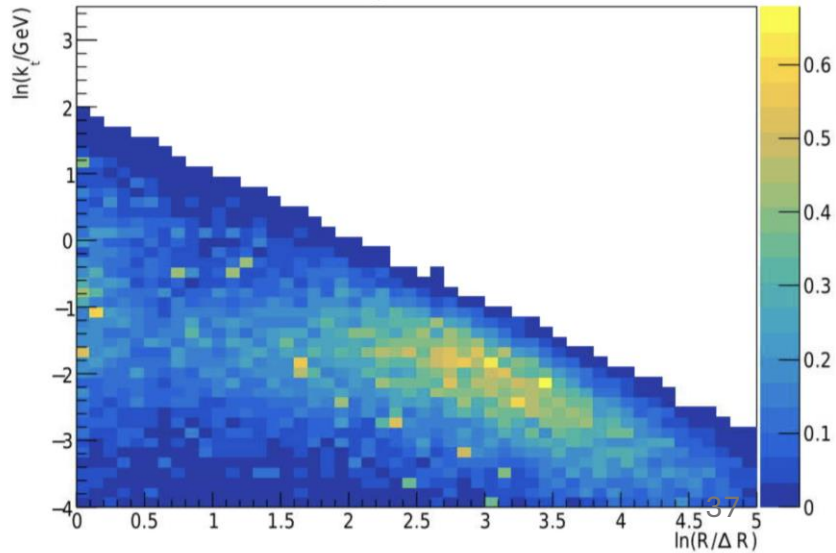
Recursive SoftDrop



SoftKiller

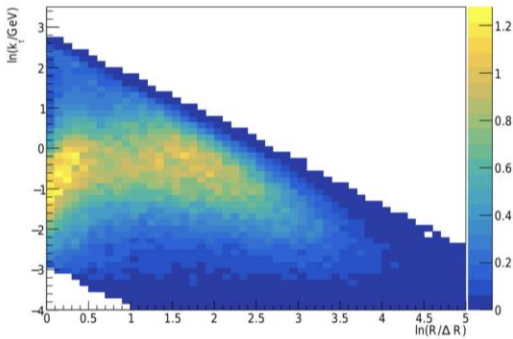


Perpendicular Cone

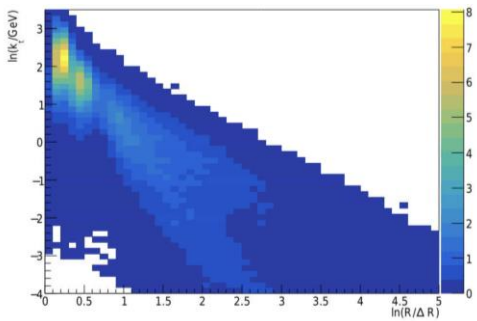


$60 < p_{T,jet} < 80 \text{ GeV}/c$

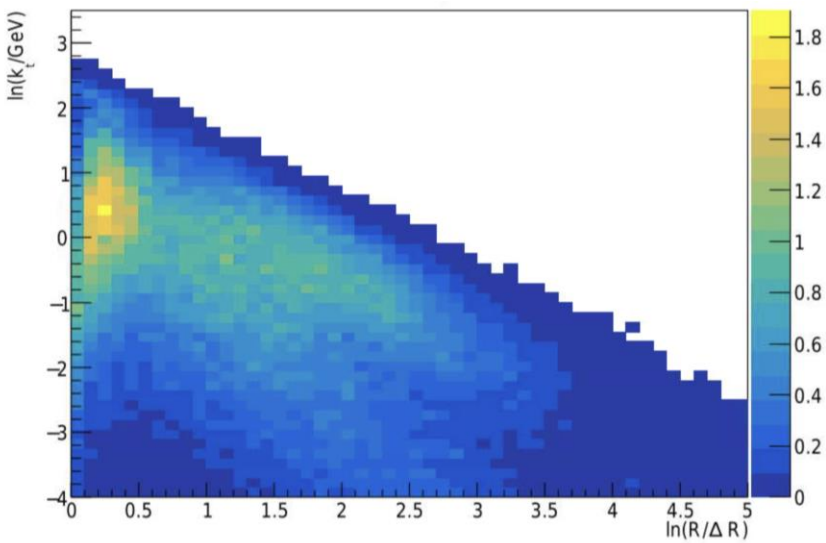
True Event



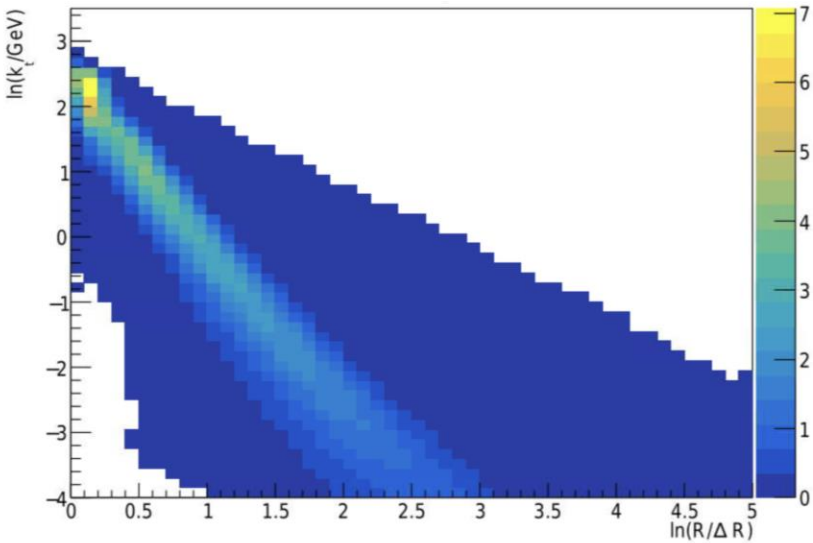
Embedded Event



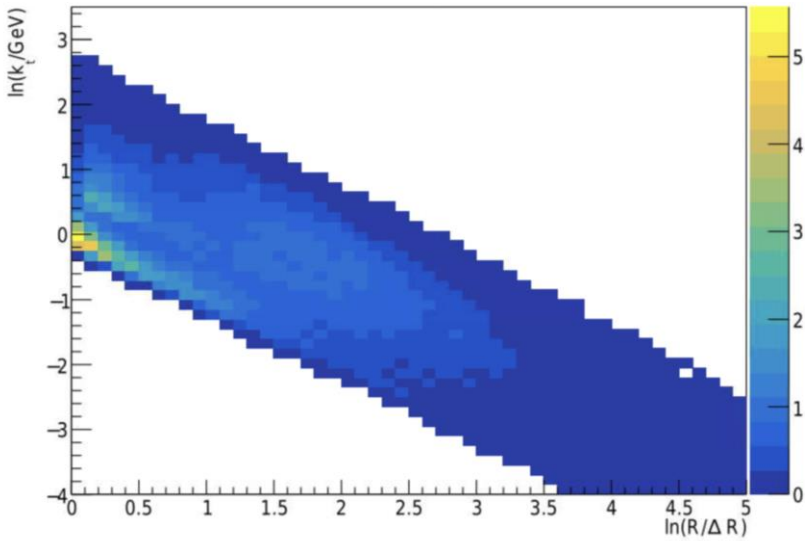
Constituent Subtraction



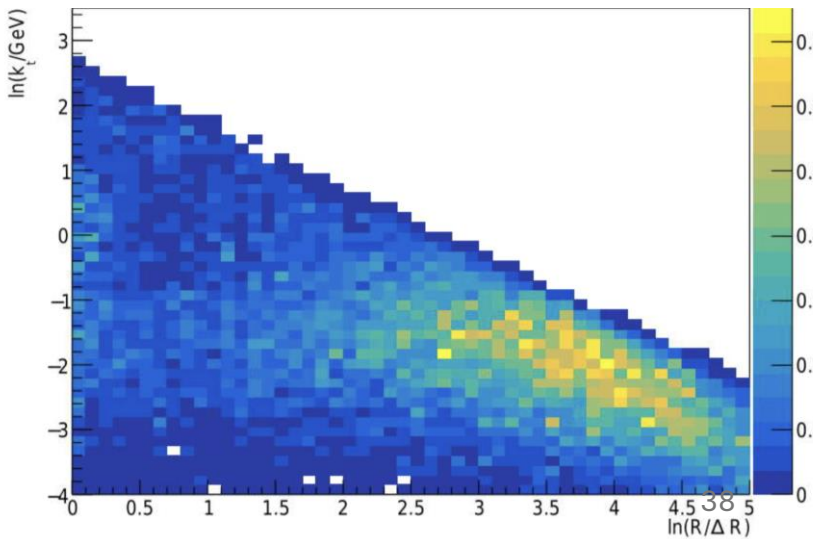
Recursive SoftDrop



SoftKiller

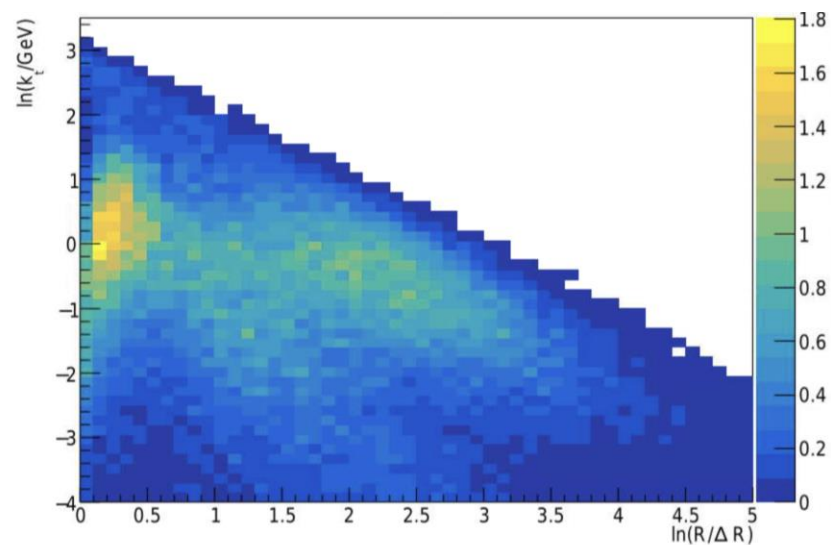


Perpendicular Cone

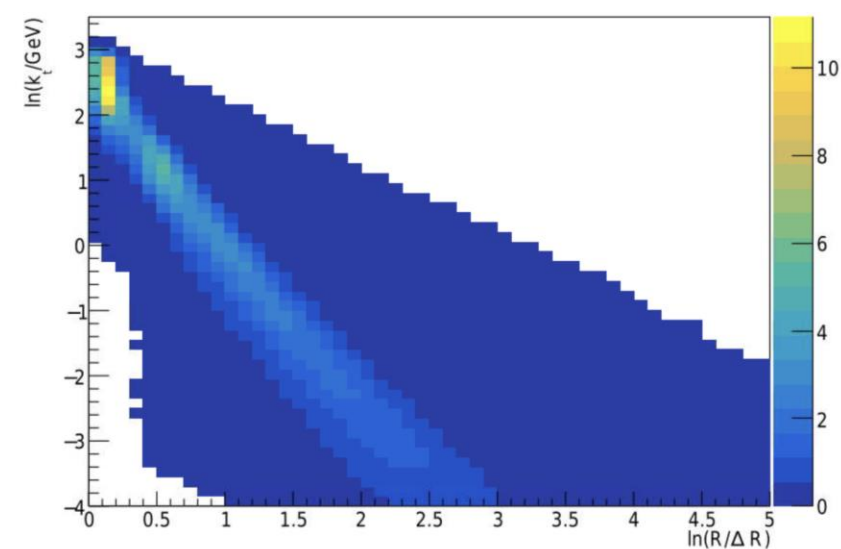


$$100 < p_{T,jet} < 120 \text{ GeV}/c$$

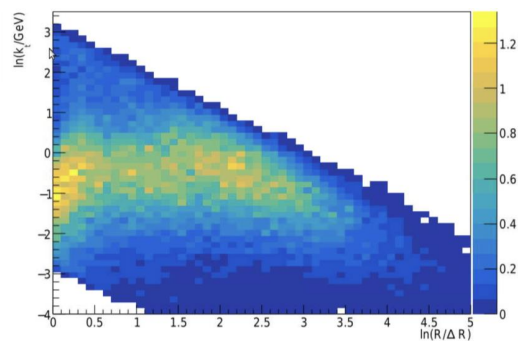
Constituent Subtraction



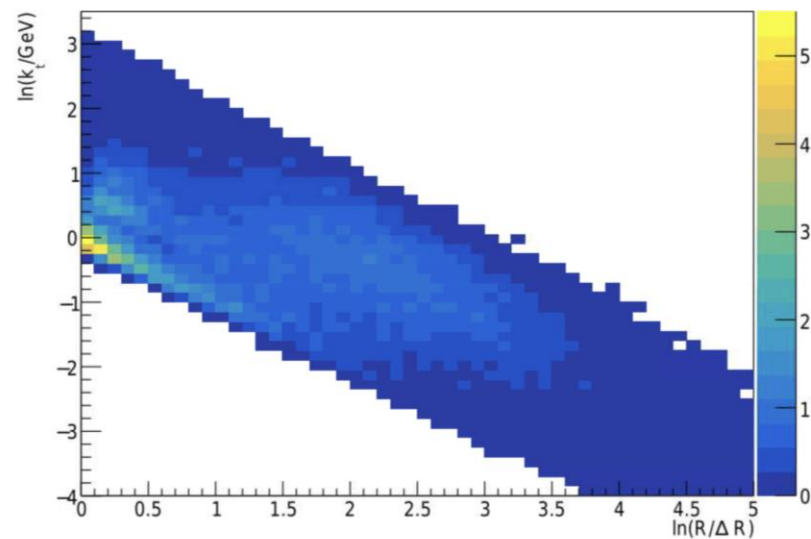
Recursive SoftDrop



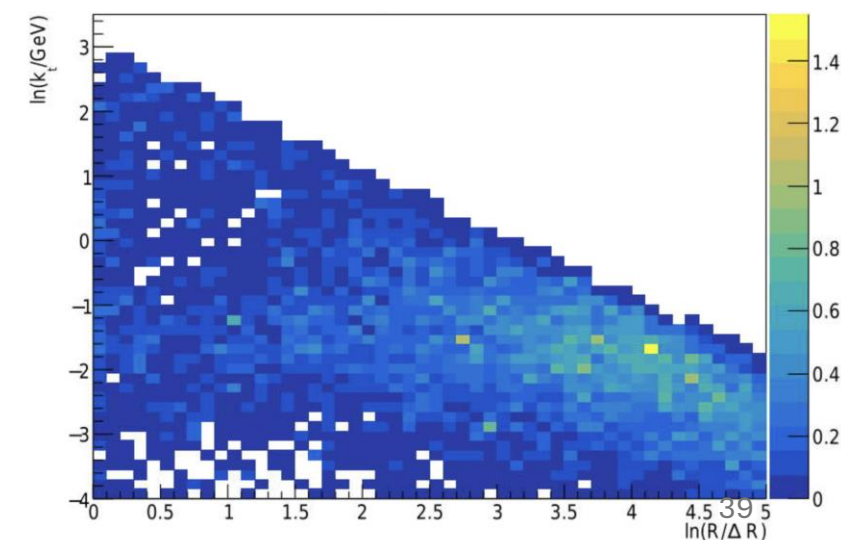
True Event



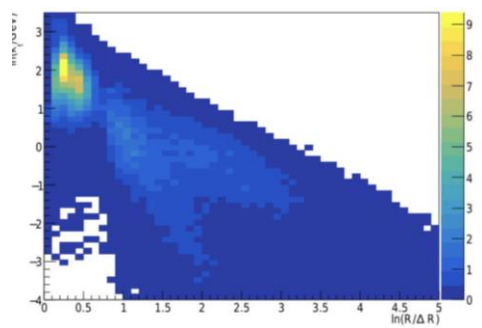
SoftKiller



Perpendicular Cone



Embedded Event

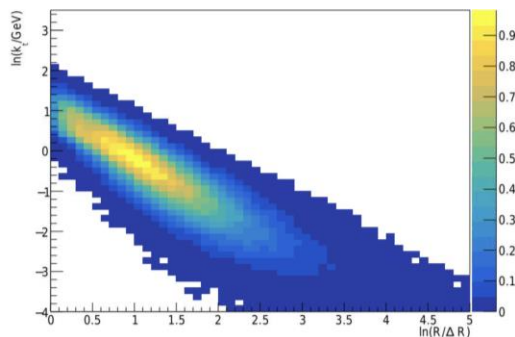


Analysis: The Groomed Lund Plane

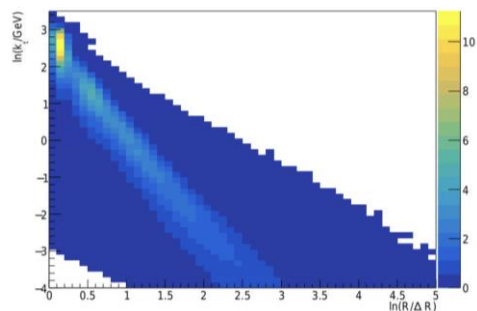
Groomed

$$20 < p_{T,jet} < 40 \text{ GeV}/c$$

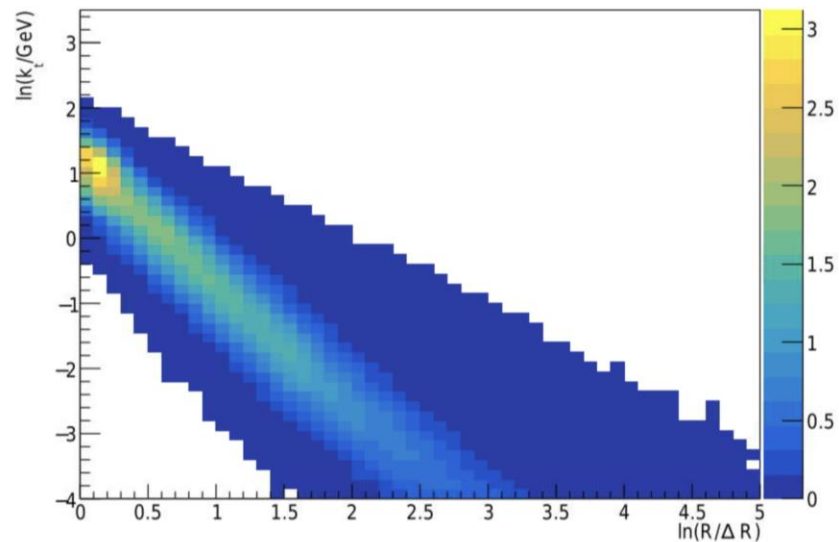
True Event



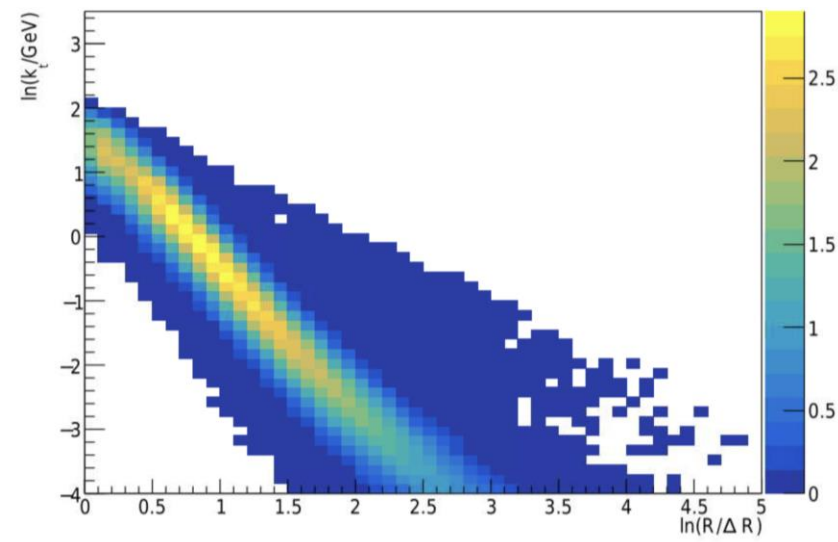
Embedded Event



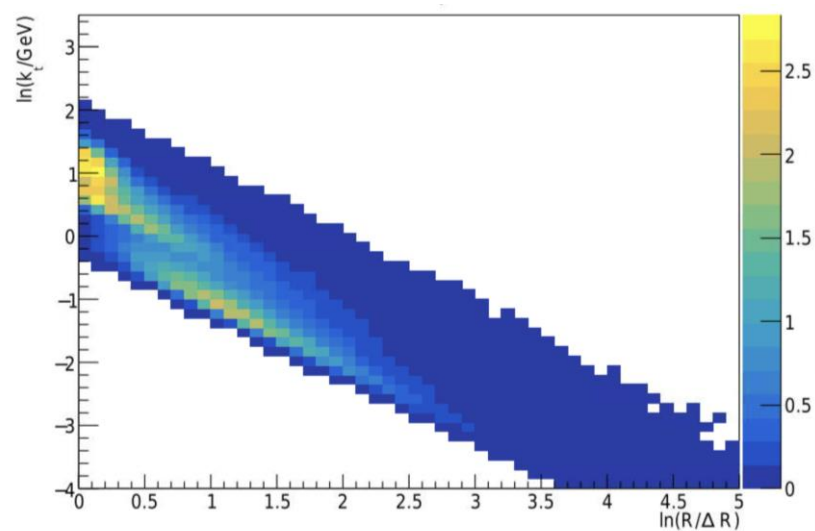
Constituent Subtraction



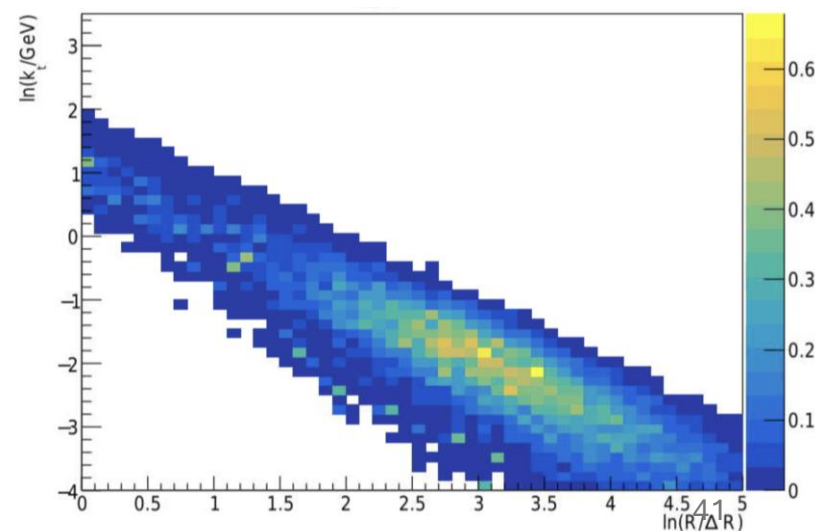
Recursive SoftDrop



SoftKiller



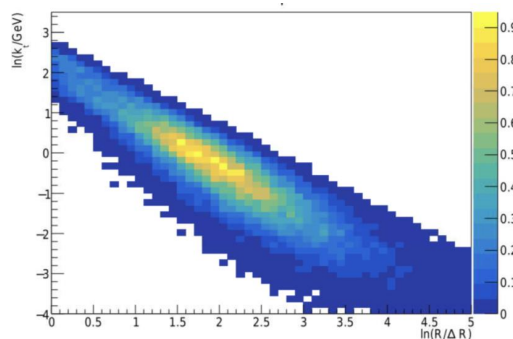
Perpendicular Cone



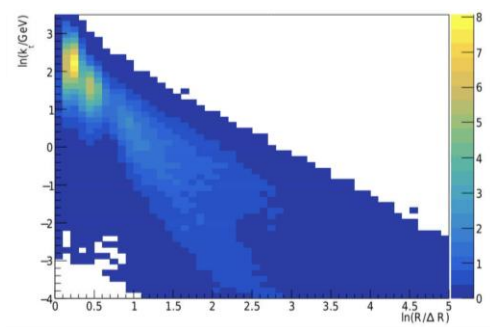
Groomed

$$60 < p_{T,jet} < 80 \text{ GeV}/c$$

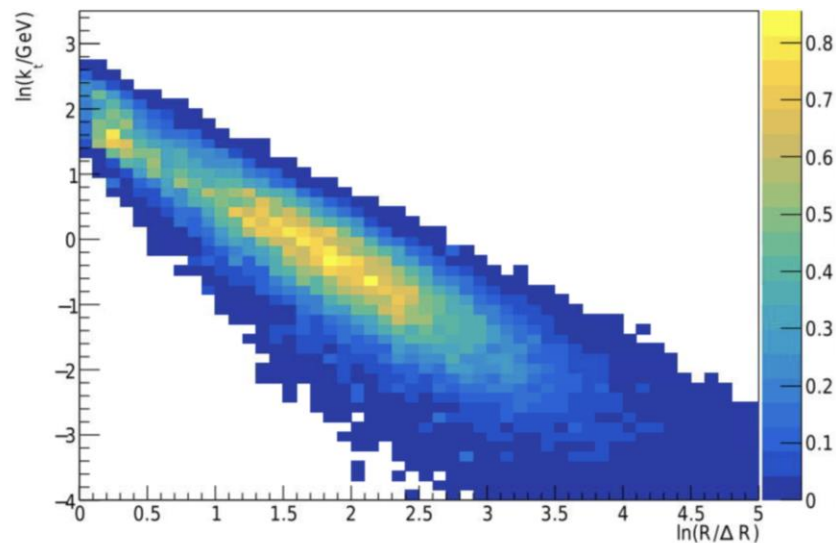
True Event



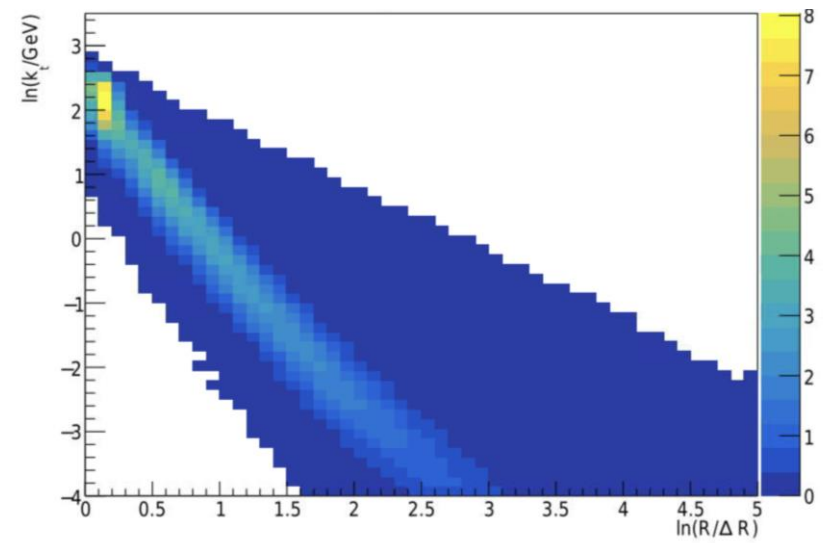
Embedded Event



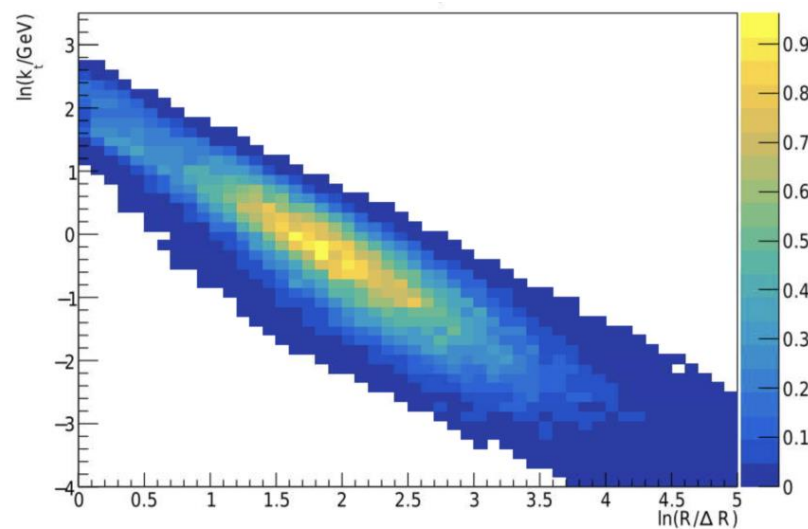
Constituent Subtraction



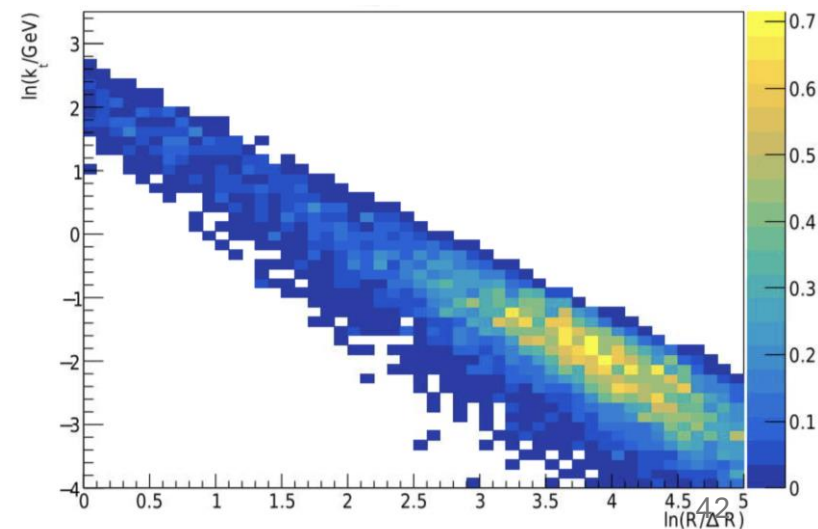
Recursive SoftDrop



SoftKiller



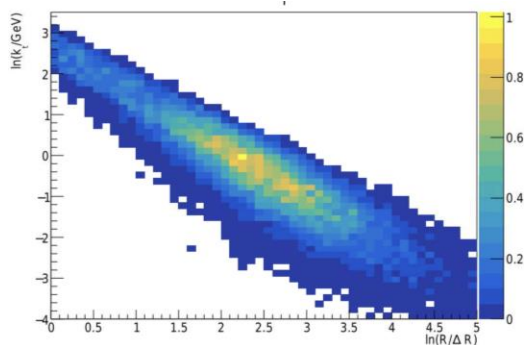
Perpendicular Cone



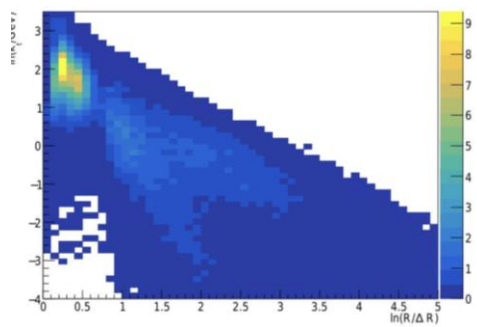
Groomed

$$100 < p_{T,jet} < 120 \text{ GeV}/c$$

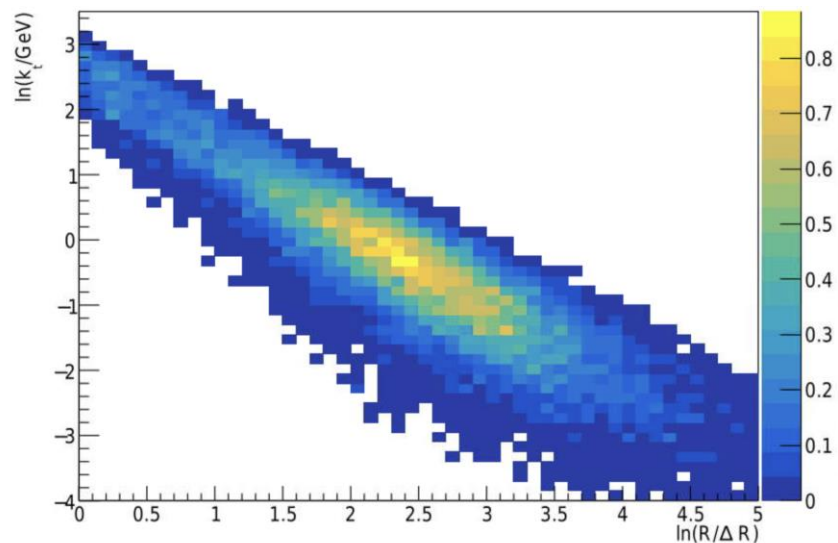
True Event



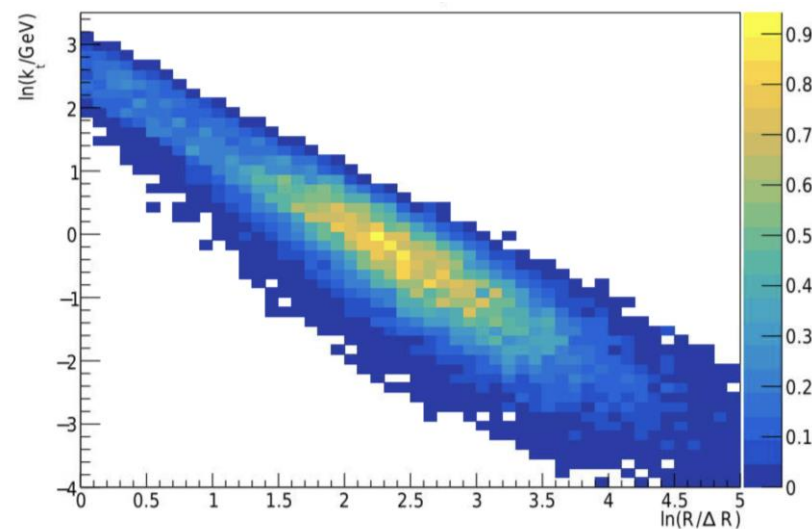
Embedded Event



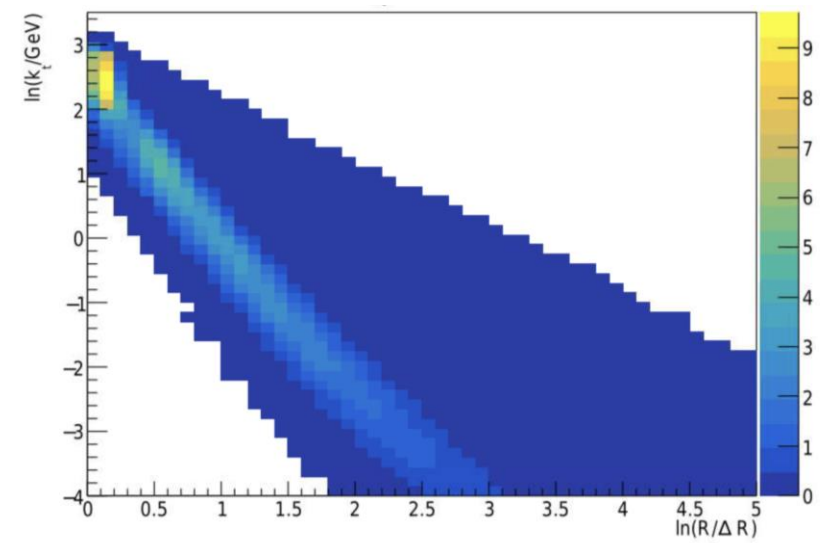
Constituent Subtraction



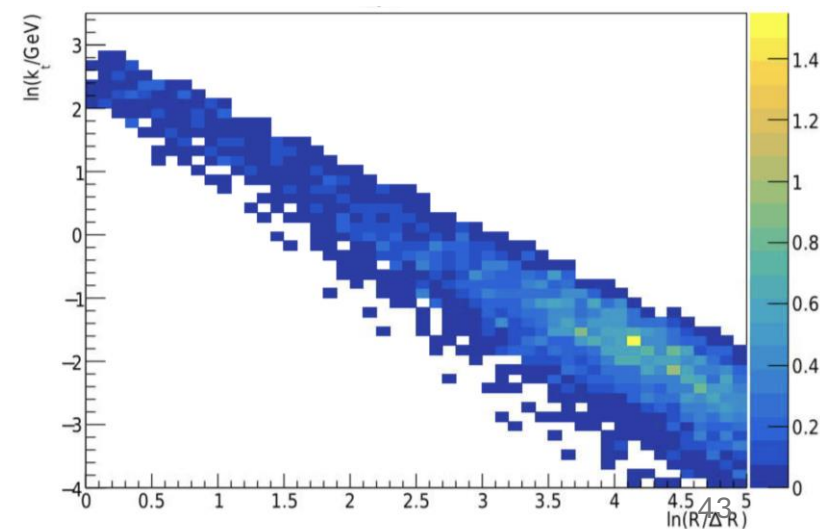
SoftKiller



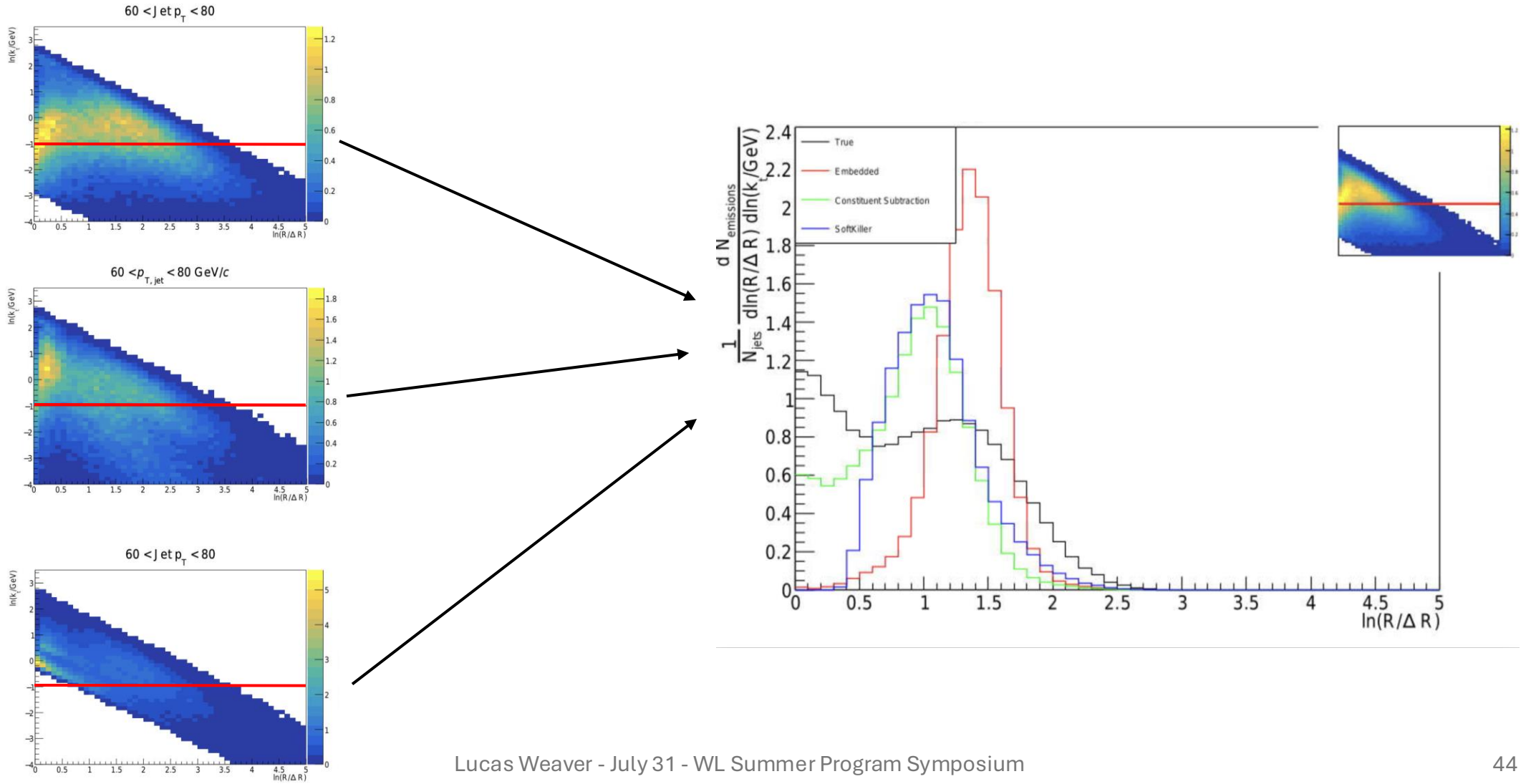
Recursive SoftDrop



Perpendicular Cone



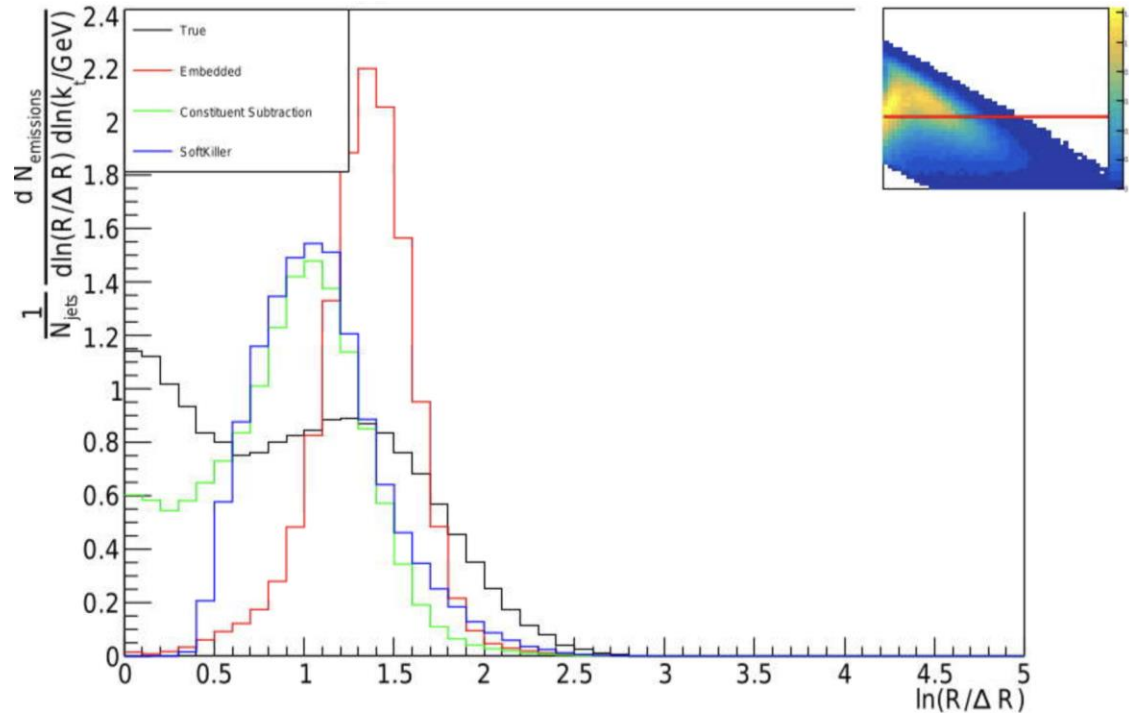
Analysis: Lund Plane cuts



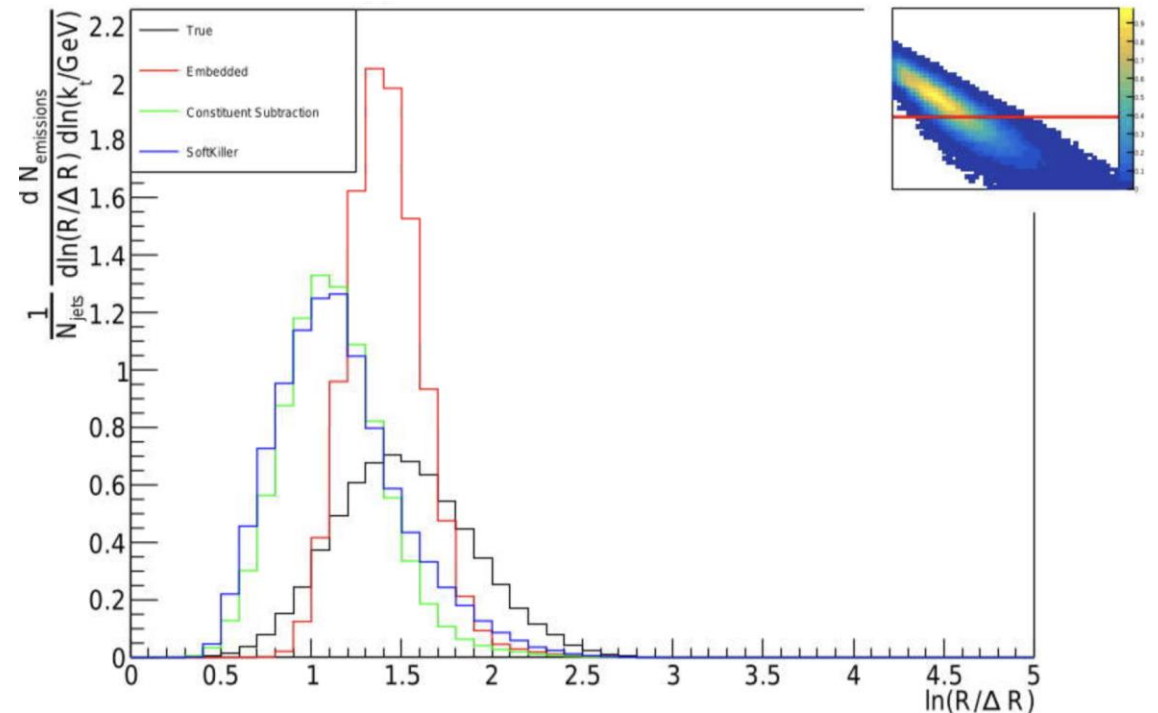
$$\ln(k_T) = -1$$

$$20 < p_{T,jet} < 40 \text{ GeV}/c$$

Ungroomed



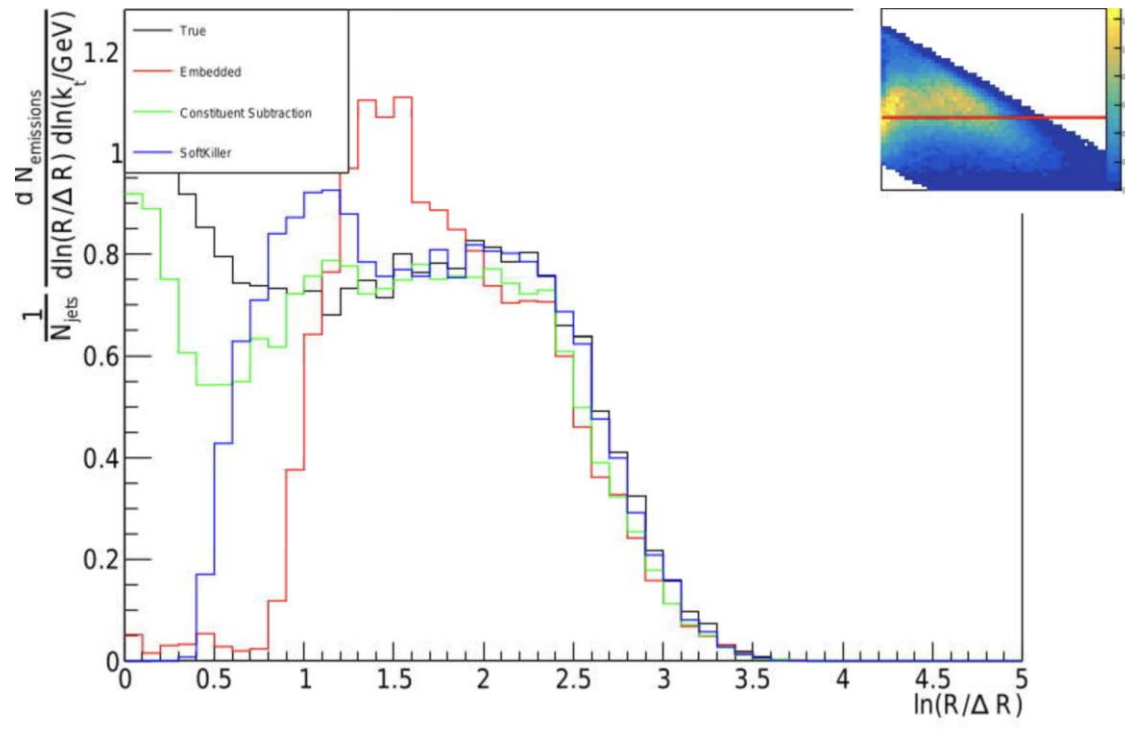
Groomed



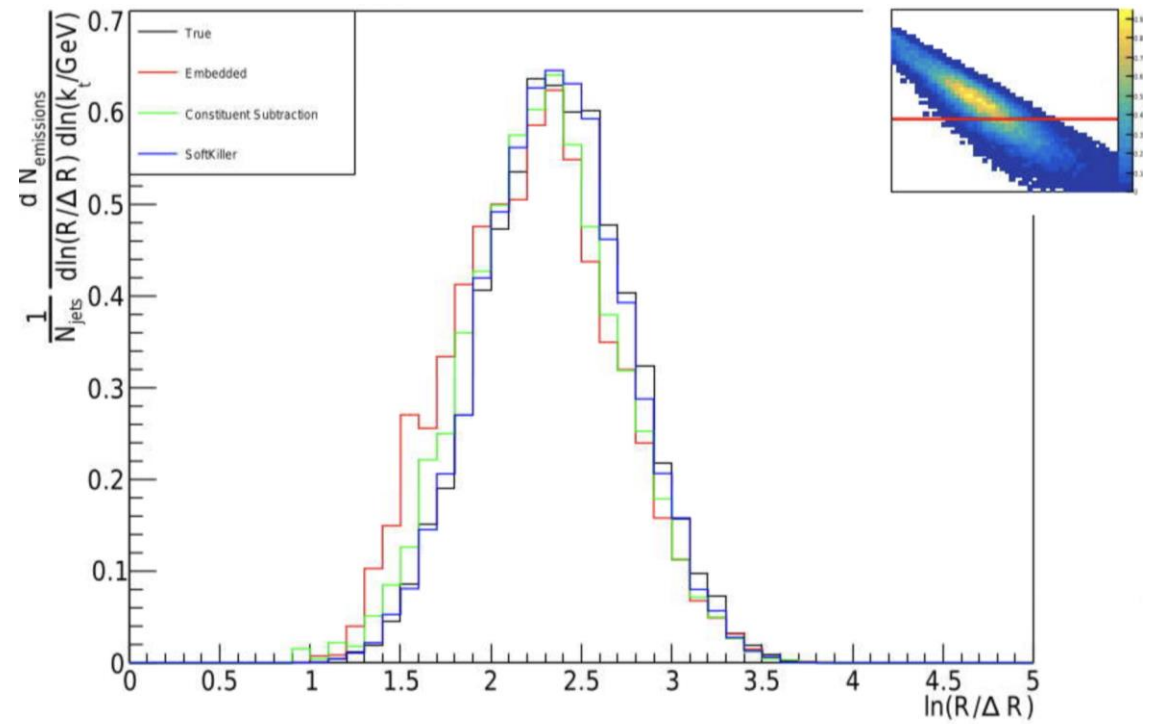
$$\ln(k_T) = -1$$

$$60 < p_{T,jet} < 80 \text{ GeV}/c$$

Ungroomed



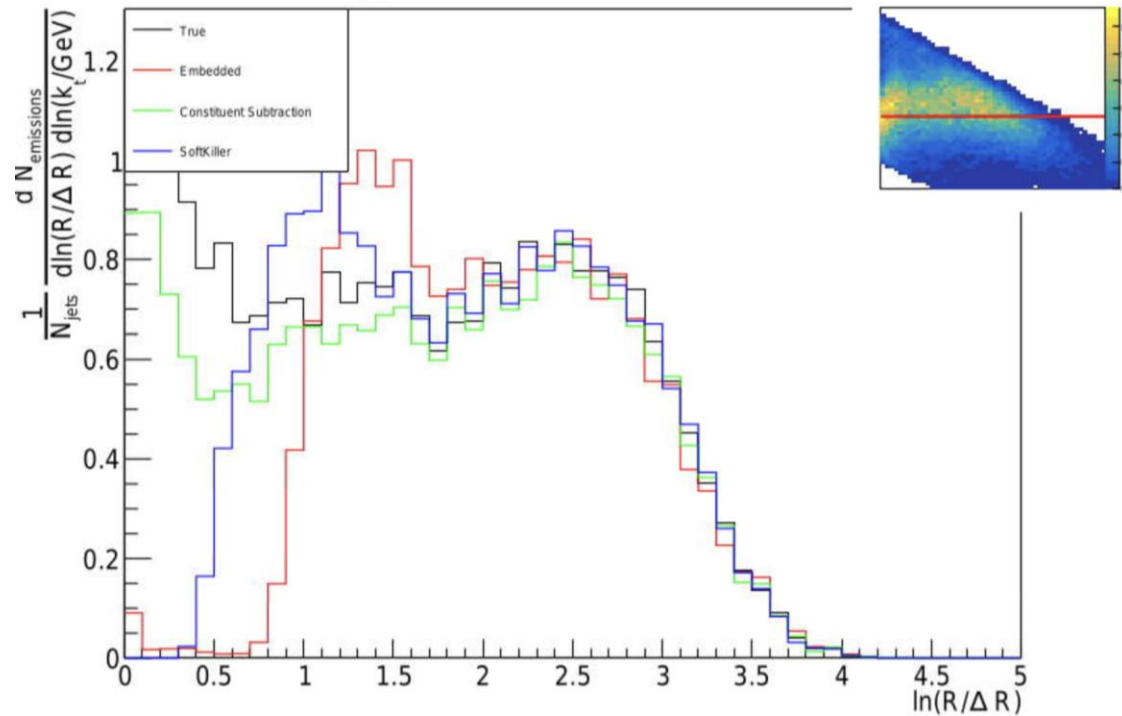
Groomed



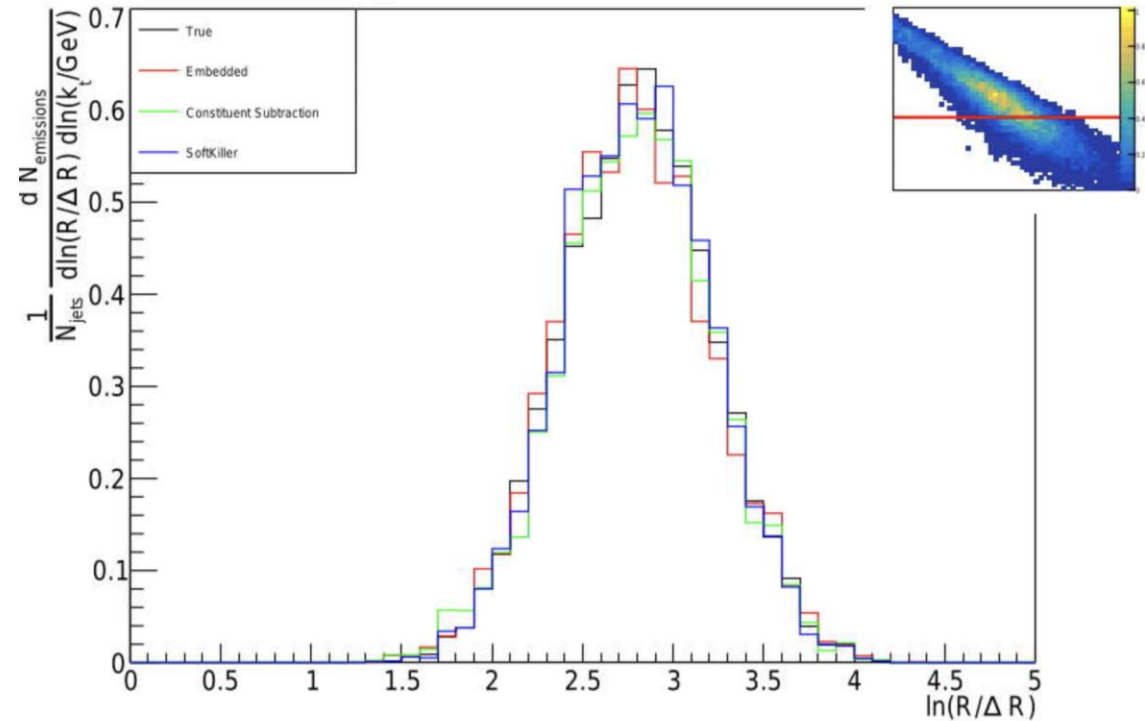
$$\ln(k_T) = -1$$

$$100 < p_{T,jet} < 120 \text{ GeV}/c$$

Ungroomed



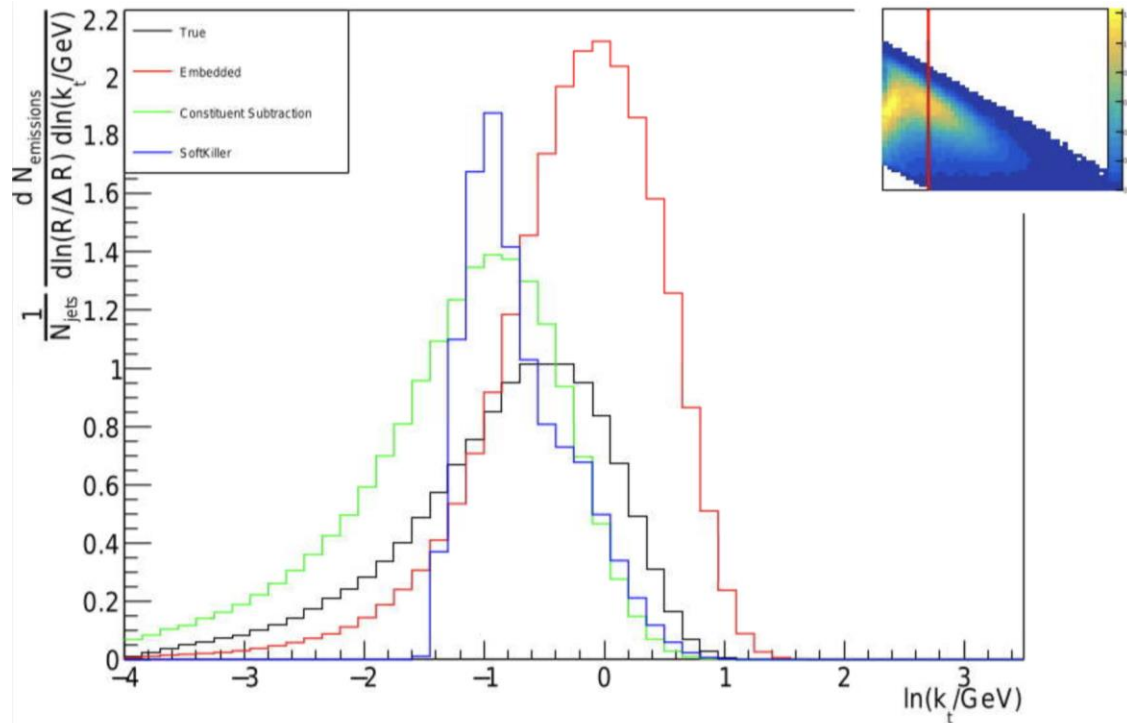
Groomed



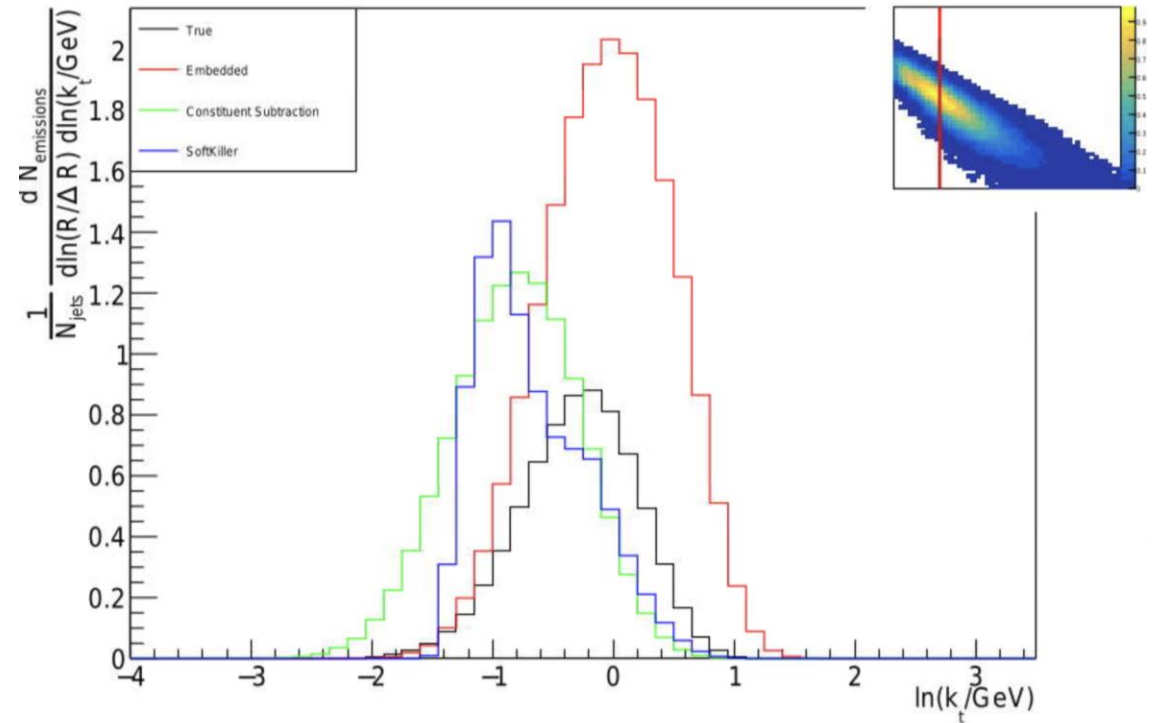
$$\ln(R/\Delta R) = 1$$

$$20 < p_{T,jet} < 40 \text{ GeV}/c$$

Ungroomed



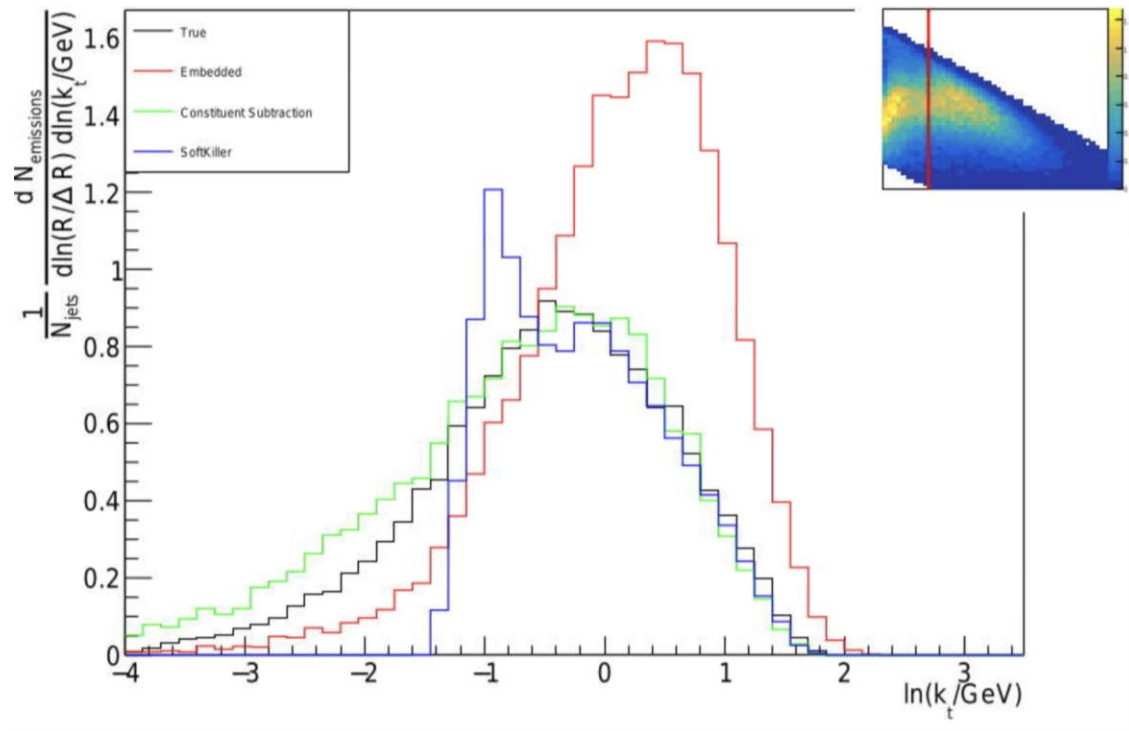
Groomed



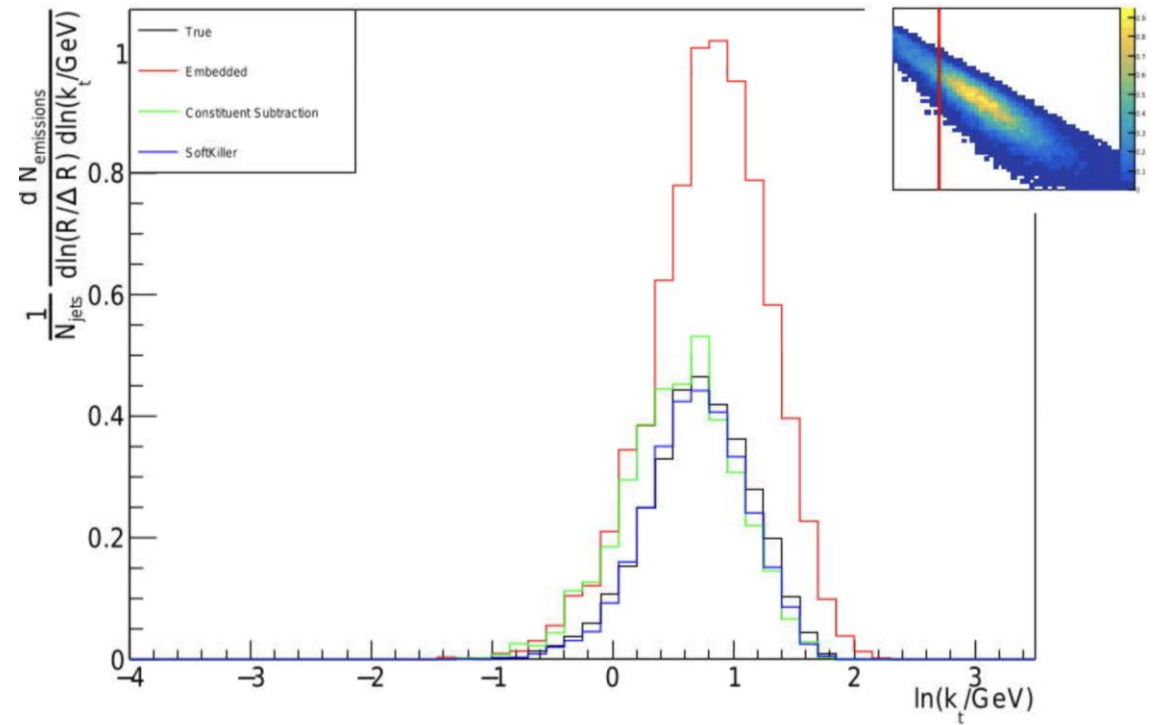
$$\ln(R/\Delta R) = 1$$

$$60 < p_{T,jet} < 80 \text{ GeV}/c$$

Ungroomed



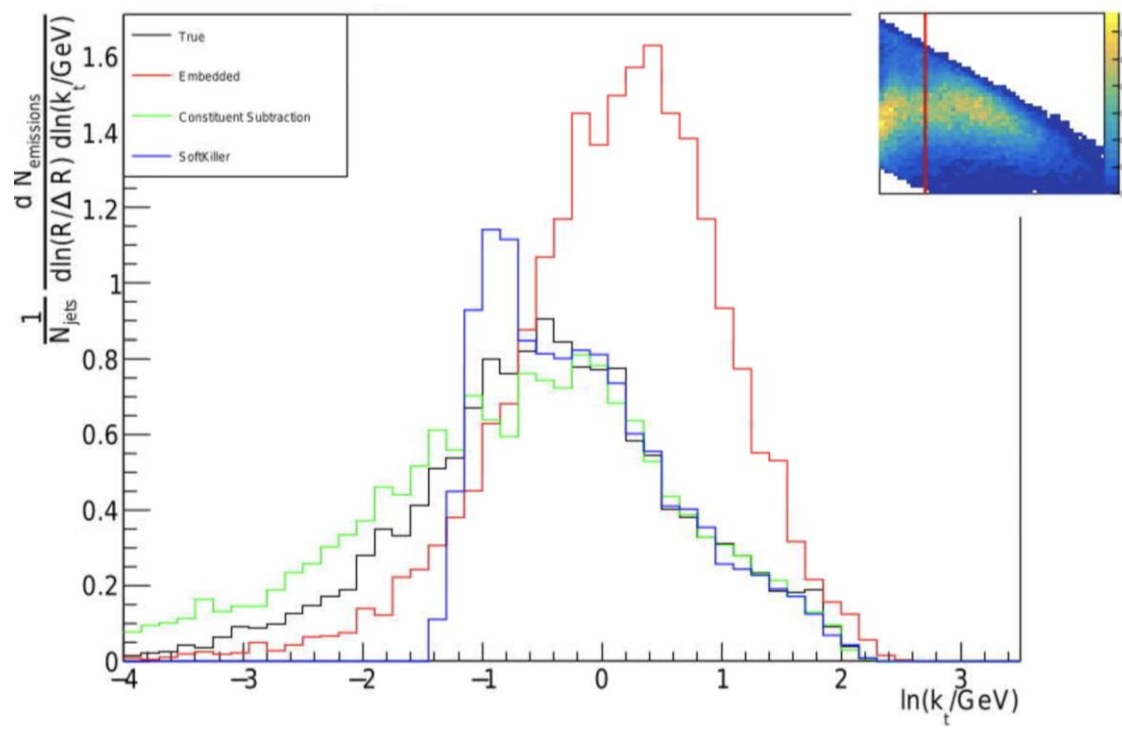
Groomed



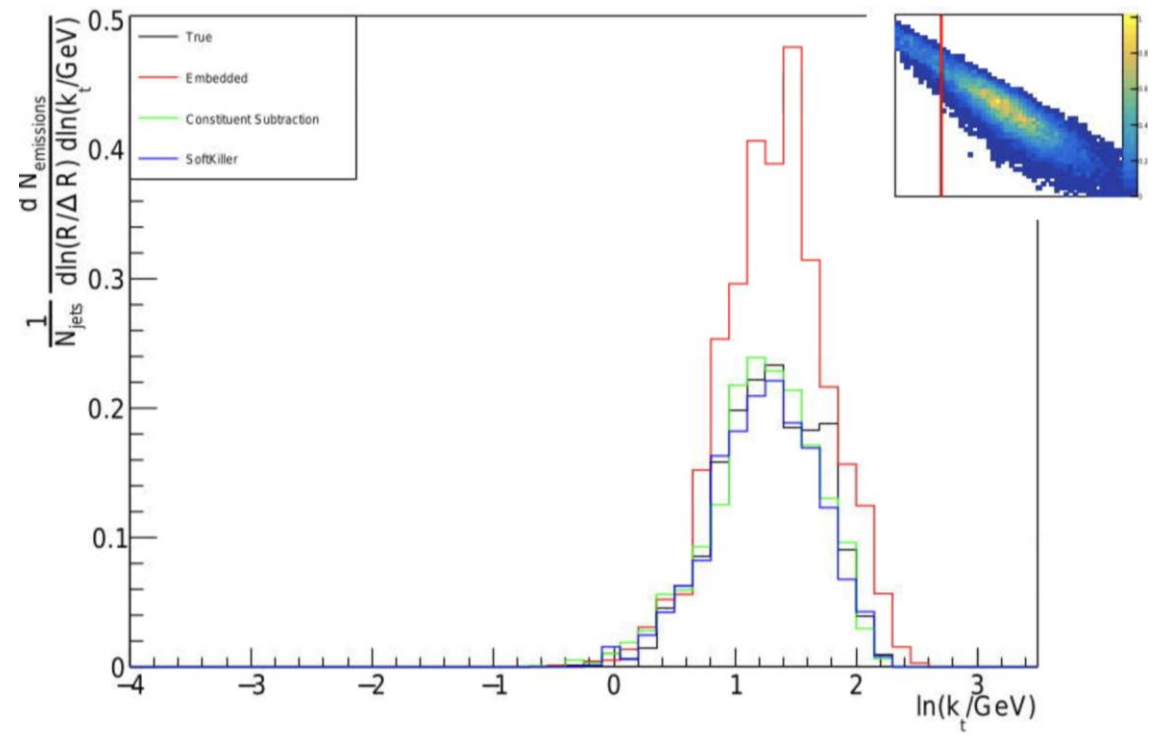
$$\ln(R/\Delta R) = 1$$

$$100 < p_{T,jet} < 120 \text{ GeV}/c$$

Ungroomed

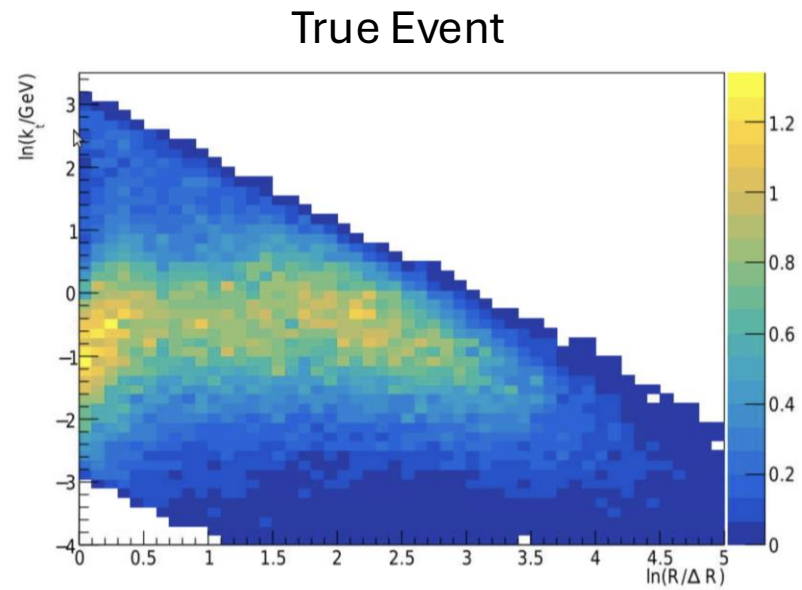


Groomed



Conclusion

Ungroomed / Full Lund Plane



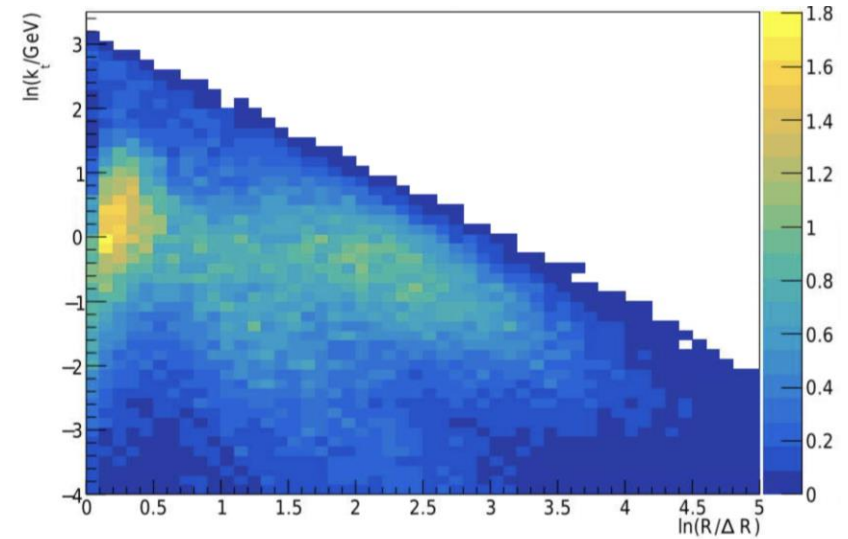
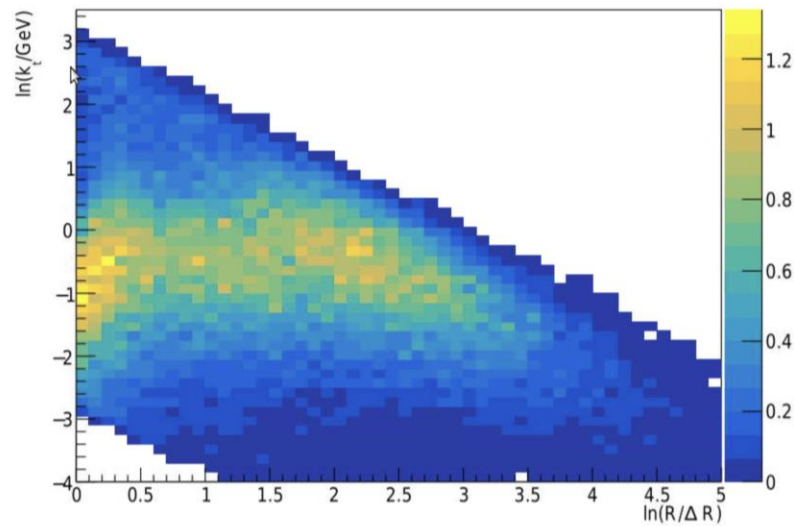
Ungroomed / Full Lund Plane



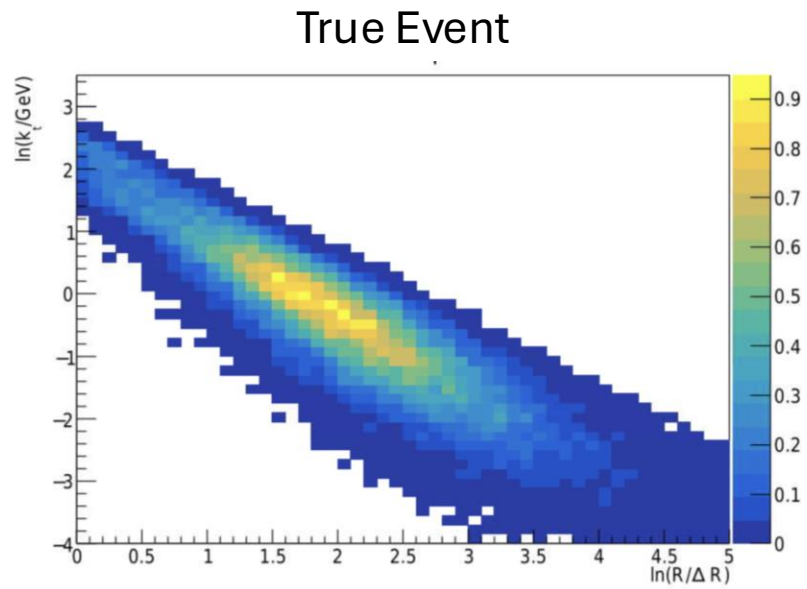
Constituent Subtraction

$$100 \text{ GeV}/c < p_{T,jet}$$

True Event



Groomed Lund Plane



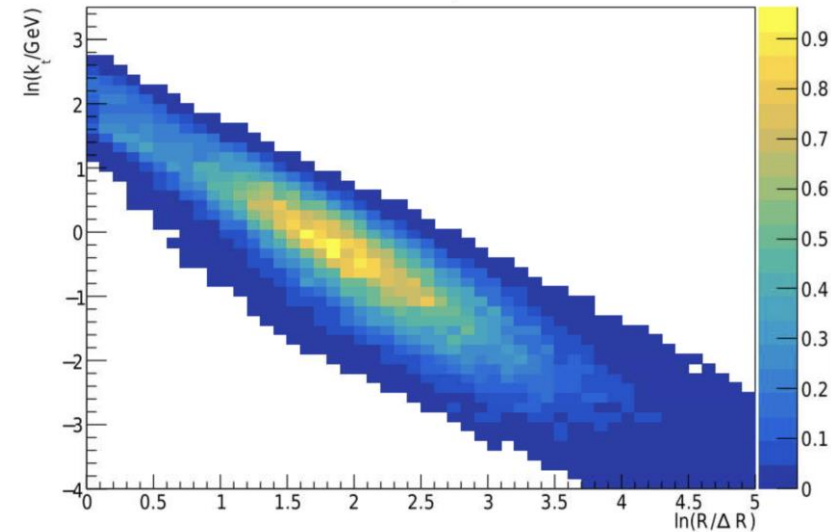
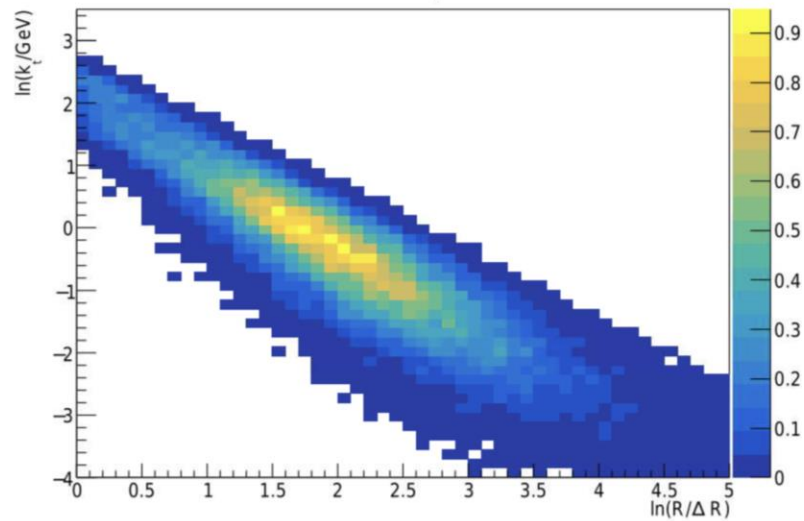
Groomed Lund Plane



SoftKiller

$$60 \text{ GeV}/c < p_{T,jet}$$

True Event



Groomed Lund Plane



SoftKiller



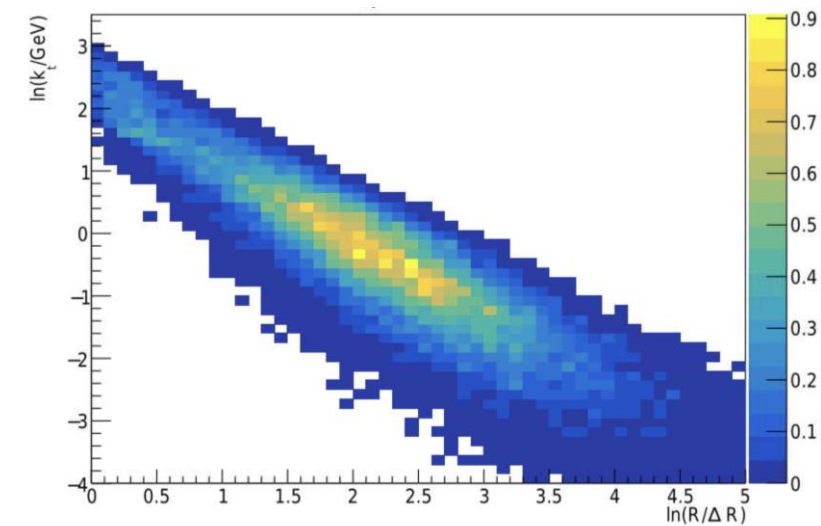
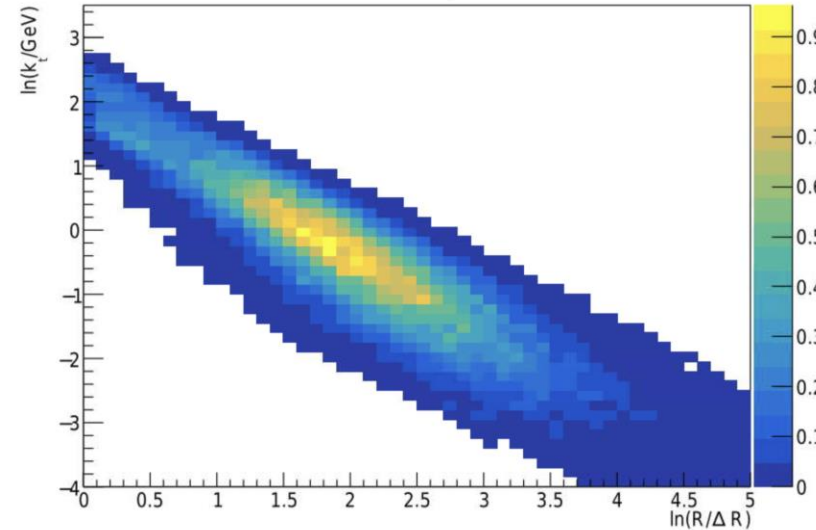
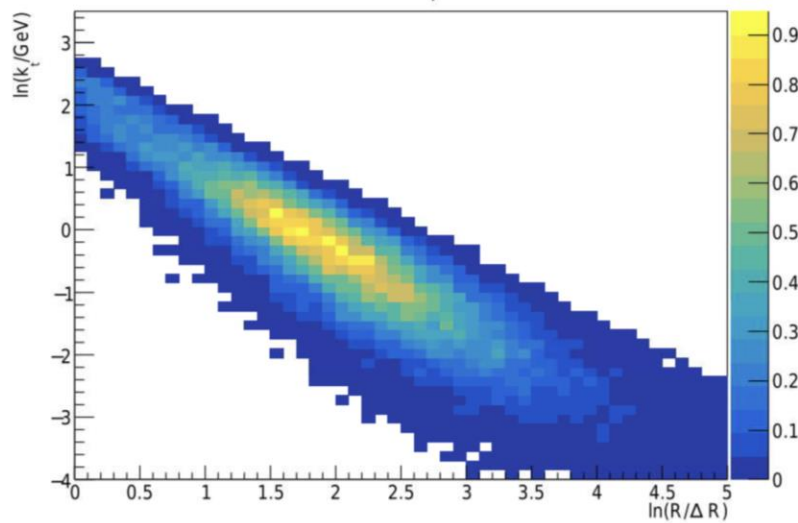
Constituent Subtraction



$$60 \text{ GeV}/c < p_{T,jet}$$

$$80 \text{ GeV}/c < p_{T,jet}$$

True Event



Looking Forward

- Can we ever recover the full Lund jet plane?
 - Might the distribution of proton-proton underlying event particles...
 - Depend on the angle from the primary jet axis?
 - Be influenced by neighboring jets?
 - Be organized in predictable patterns within the jets

A neural network trained on simulation data might pick up on metrics that aren't obvious to us