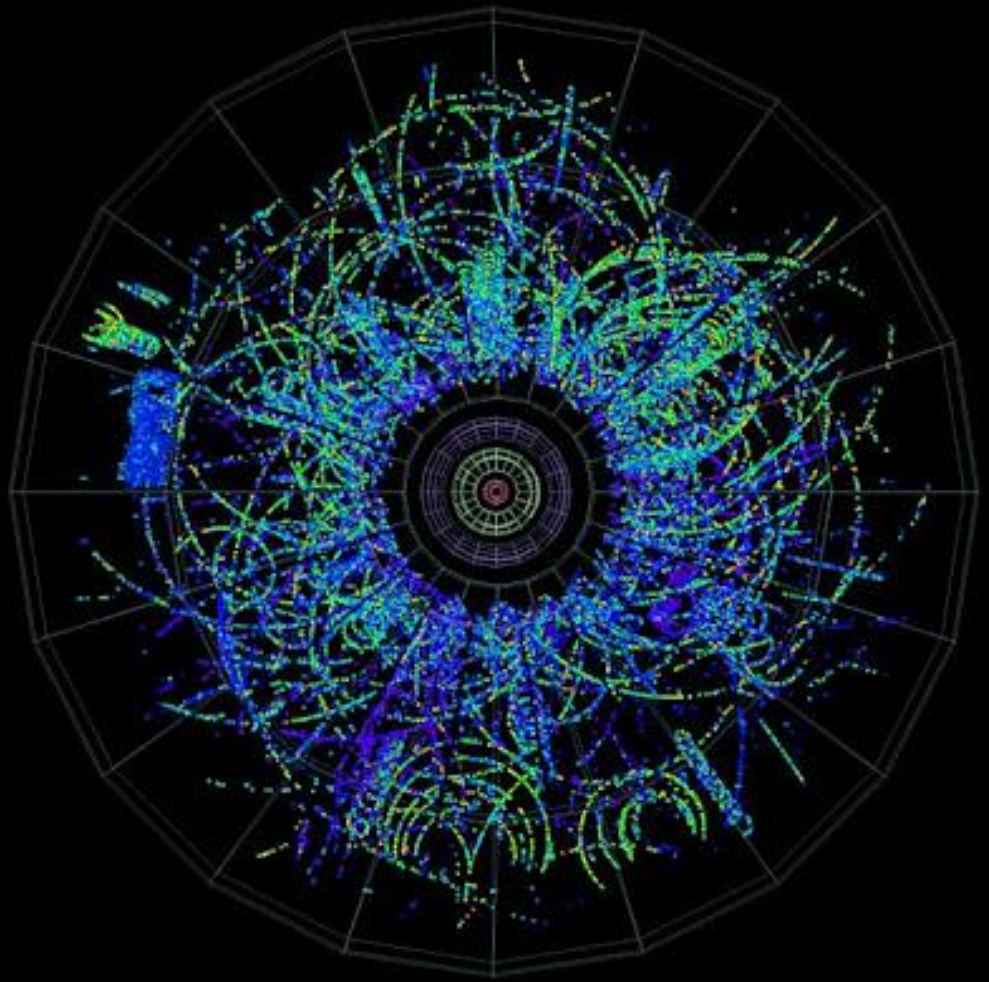

Novel jet algorithms to unveil the Quark-Gluon Plasma evolution

Alexandre Monforte
João Fernandes
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Supervisors:
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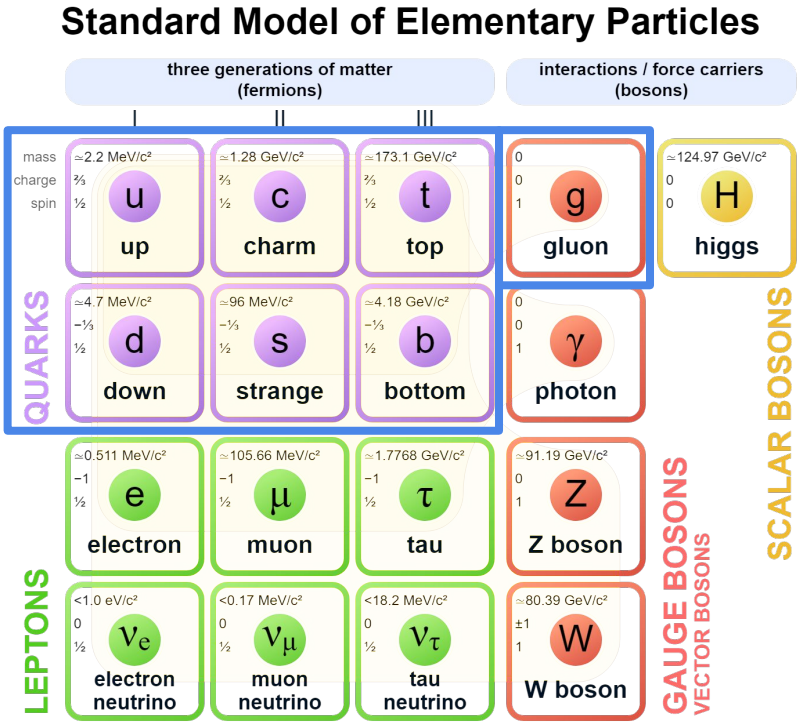
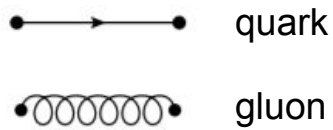
Introduction

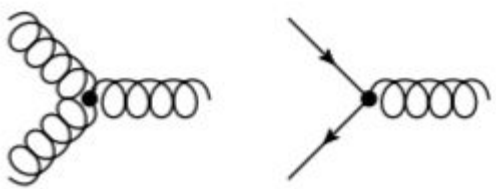
Quantum Chromodynamics



Diagrams

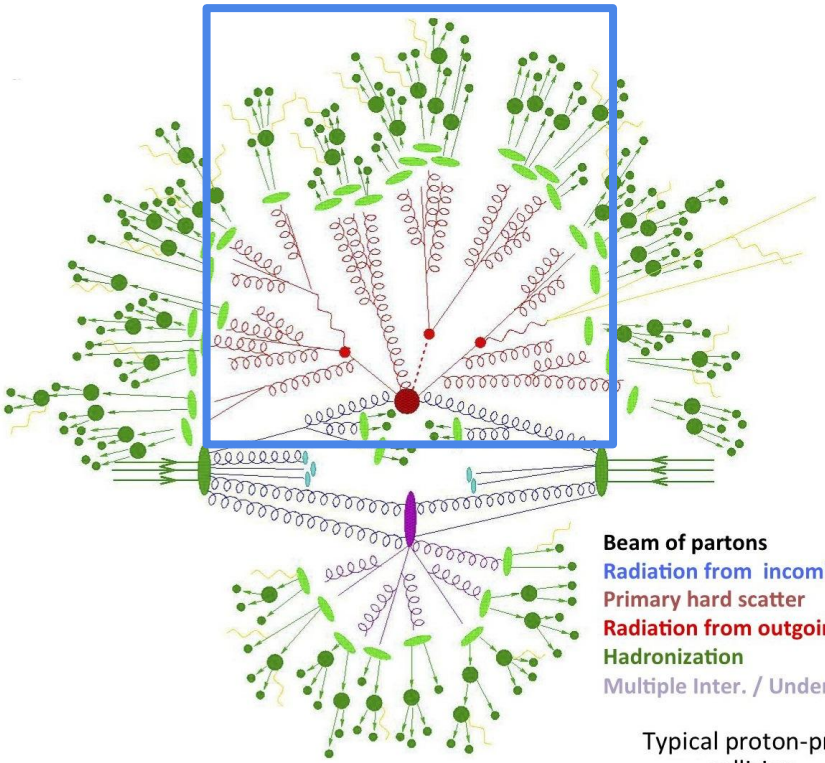


Basic Processes



Introduction

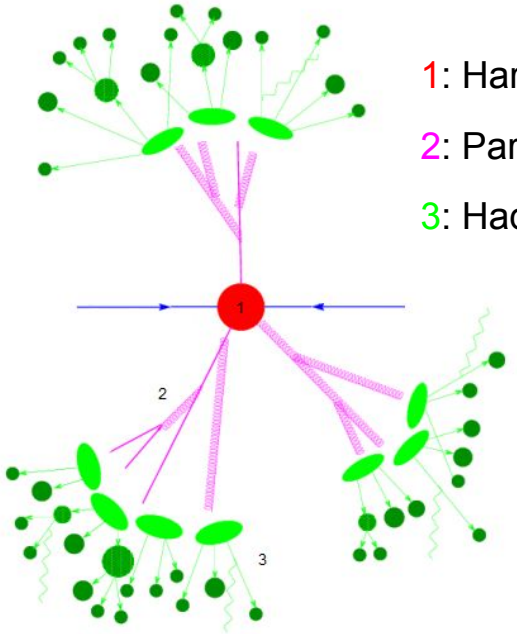
Parton Shower



Beam of partons
Radiation from incoming partons
Primary hard scatter
Radiation from outgoing partons
Hadronization
Multiple Inter. / Underlying event

Typical proton-proton collision

PIC 2011, R. Teuscher IPP/Toronto

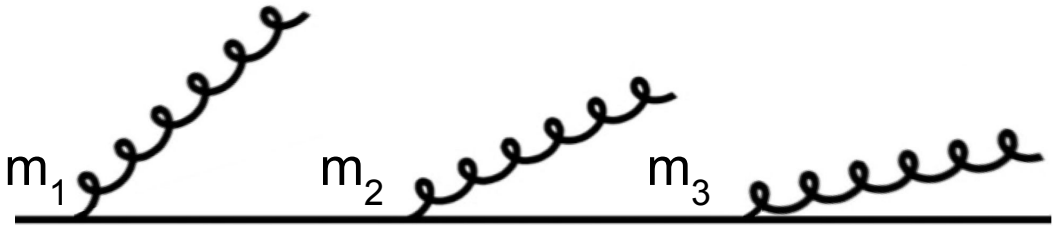


1: Hard Scattering

2: Parton Shower

3: Hadronization

Setup



10000 GeV

$m_1^2 > m_2^2 > m_3^2$

$k_{t\,1}^2 > k_{t\,2}^2 > k_{t\,3}^2$

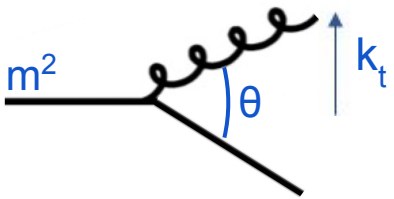
$\theta_1 > \theta_2 > \theta_3$

Sudakov factor

$$\Delta(t_1, t_2) = e^{-\frac{\alpha}{2\pi} C_R \left[ln^2\left(\frac{t_1}{t_{cut}}\right) - ln^2\left(\frac{t_2}{t_{cut}}\right)\right]}$$

probability of emitting in time t_2 if the last splitting was in time t_1

$$dP \propto \frac{dz}{z}\frac{d\theta}{\theta}$$



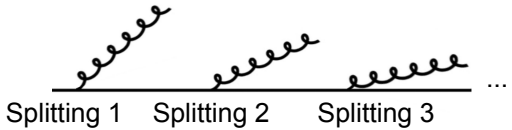
Equivalent scales:

- m^2 (mass)
- $z(1\text{-}z)\, m^2 \alpha\, k_T^2$ (transverse momentum)
- $\frac{m^2}{z(1\text{-}z)} \alpha\, E^2\, \theta^2$ (angle)

z: fraction of energy carried by the gluon

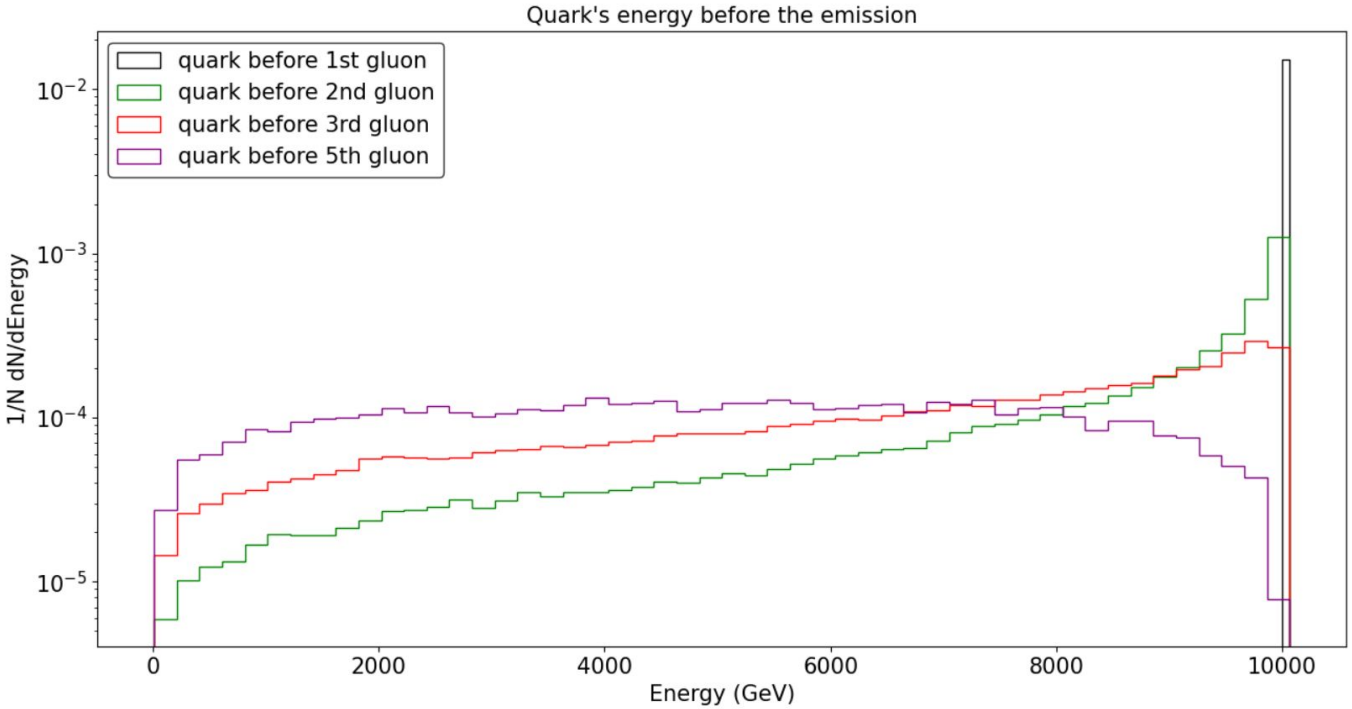
Results for Transverse Momentum (k_T^2) algorithm

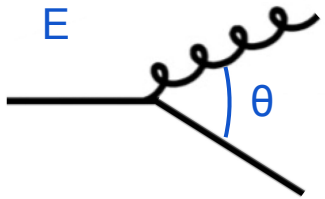
What is happening with my quark as it emits gluons?



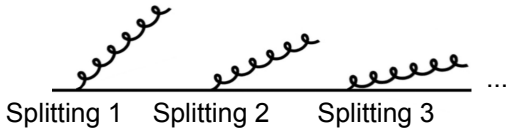
Results

Energy Decrease



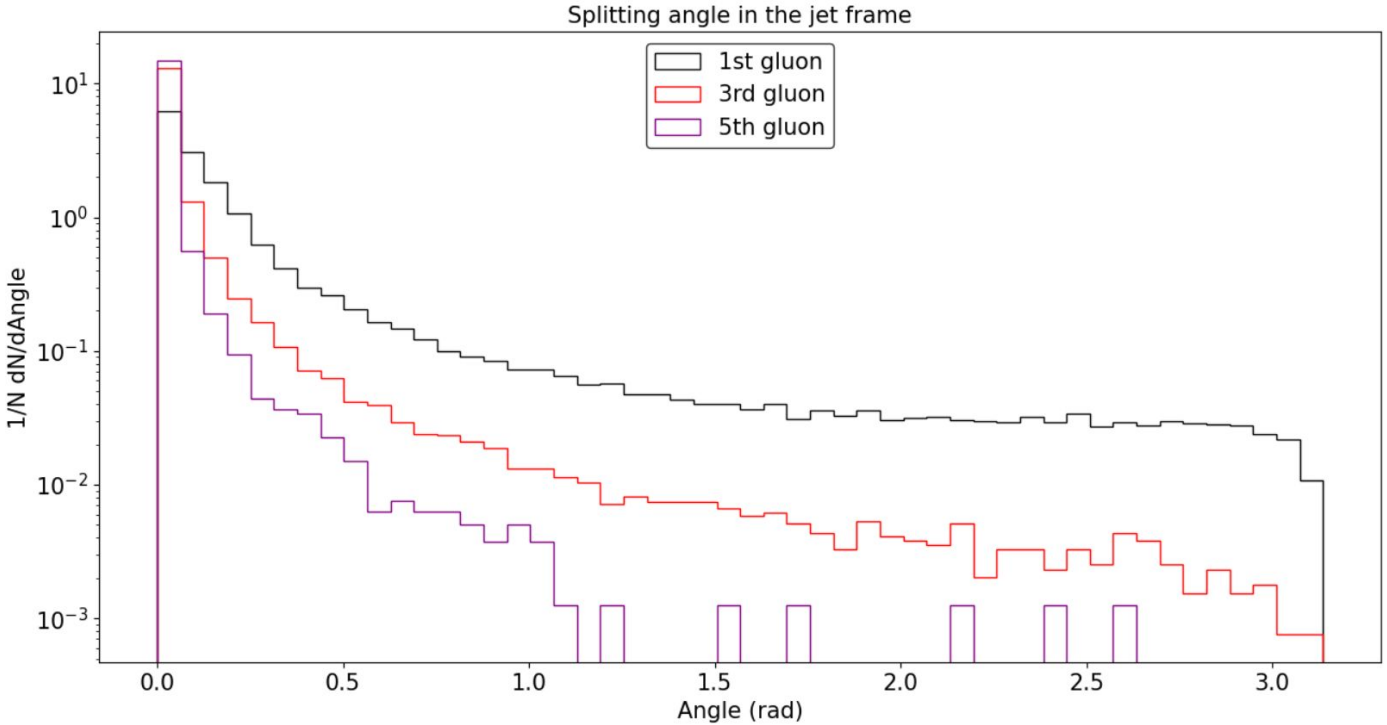


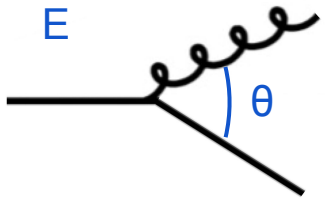
Kt^2 algorithm



Results

Angle distribution between gluon and quark mother





Kt² algorithm

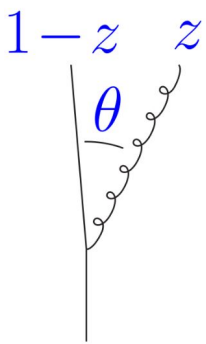
Let’s build a 2D visualization of the process…
Lund planes!

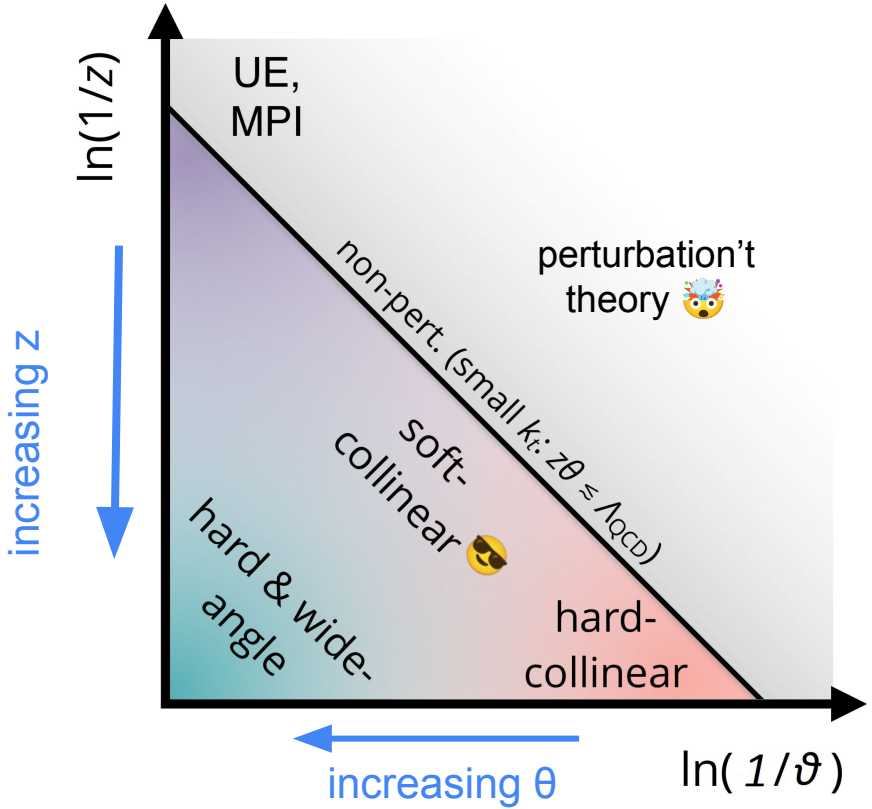
What is happening to my quark as it emits gluons?

Results

The Lund Plane

Our parton shower:
$1 \to 2$ splittings,
split by split



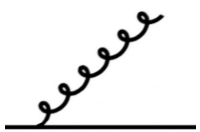


Soft & Collinear Limit:
(z << 1 & ϑ << 1)

$$\mathrm{d}P \propto \frac{\mathrm{d}z}{z}\frac{\mathrm{d}\theta}{\theta}$$

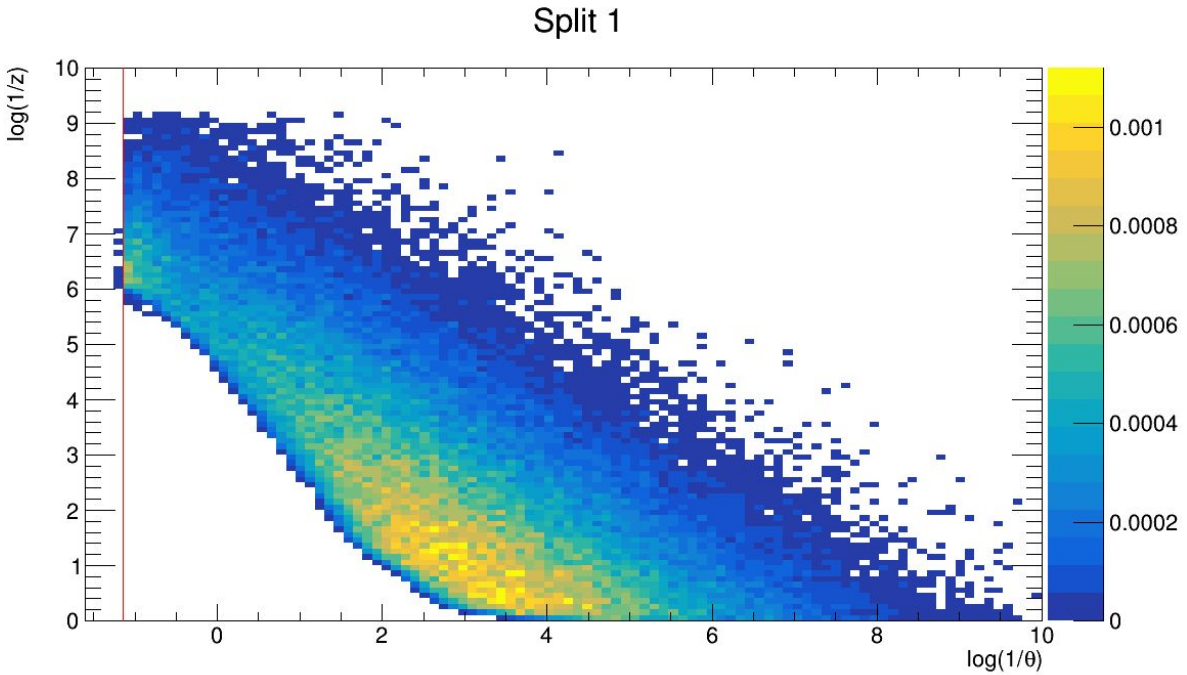
Our results:
strictly perturbative!

Split 1

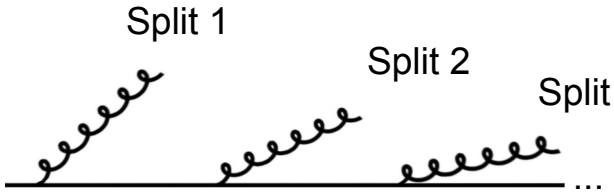


Results

The Lund Plane

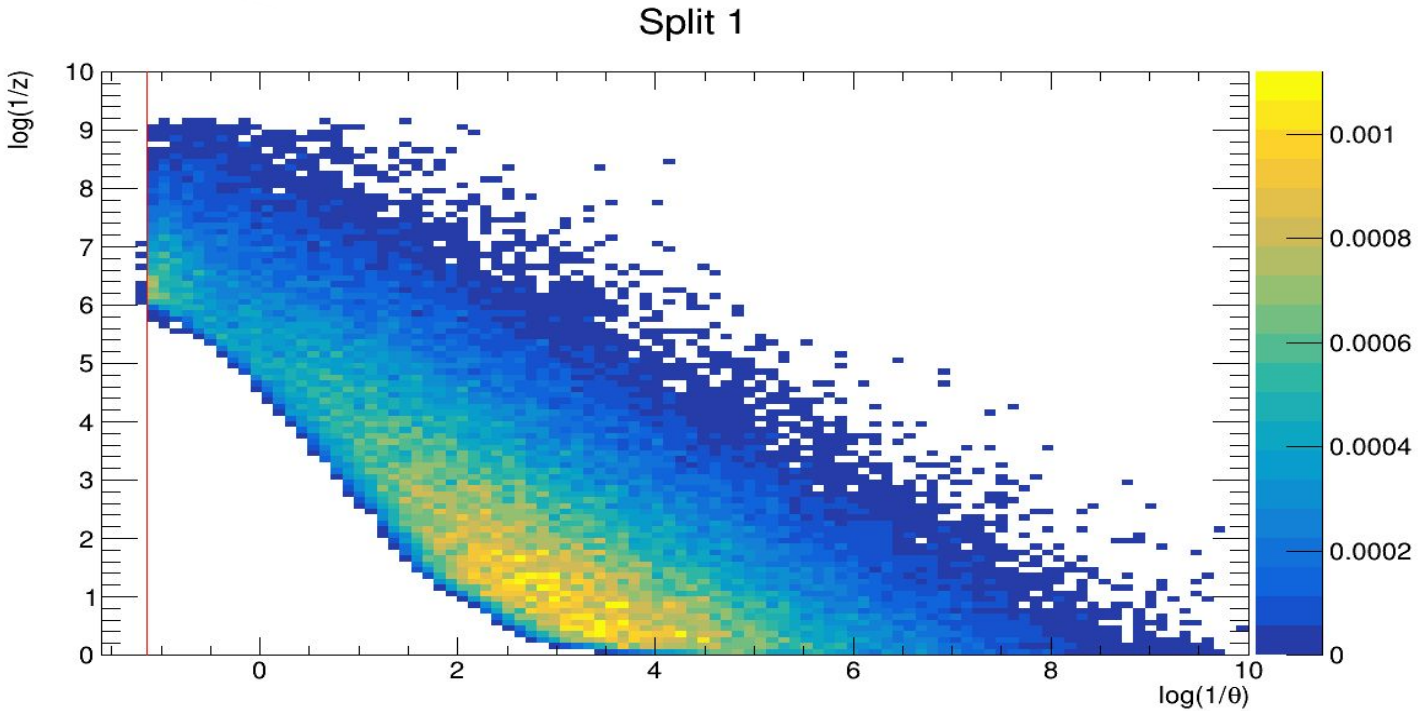


k_T^2 ordering

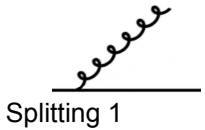


Results

The Lund Plane

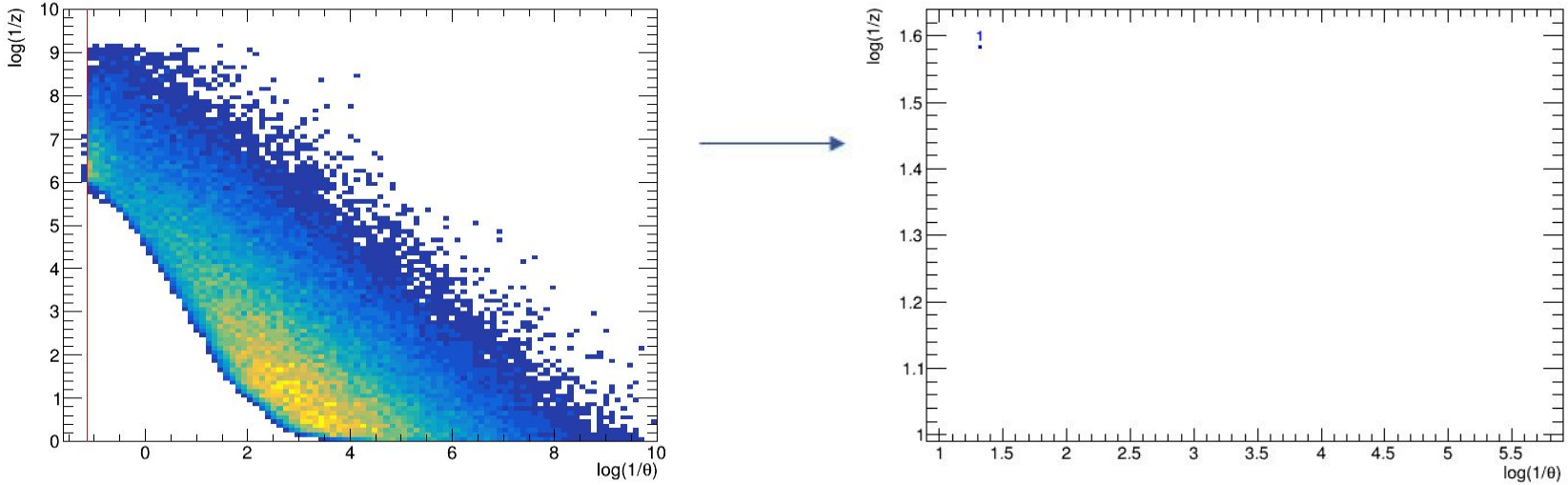


k_T^2 ordering

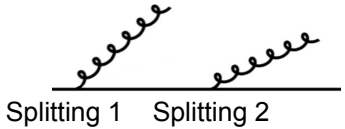


Results

Trajectories in Lund's Plane



transverse momentum (k_t^2) ordering



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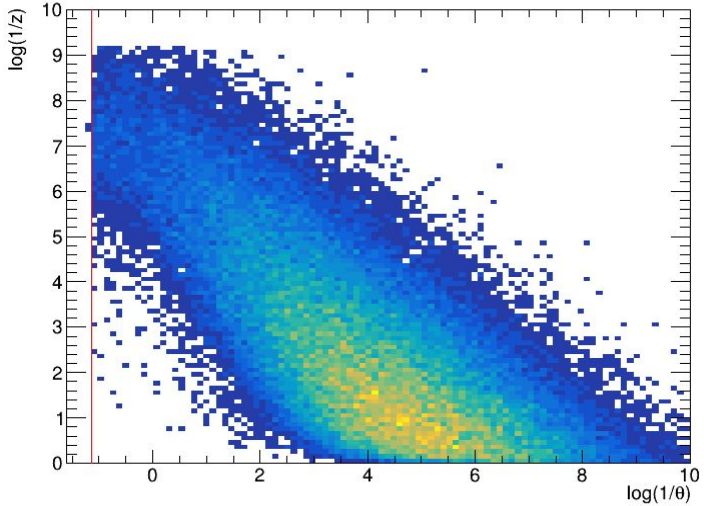

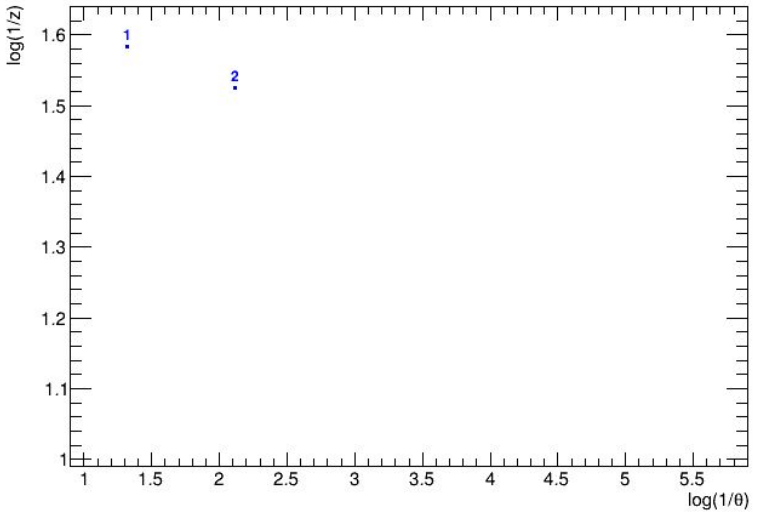

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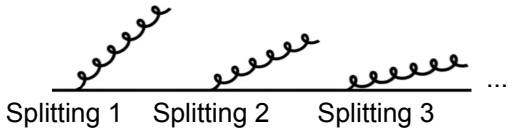

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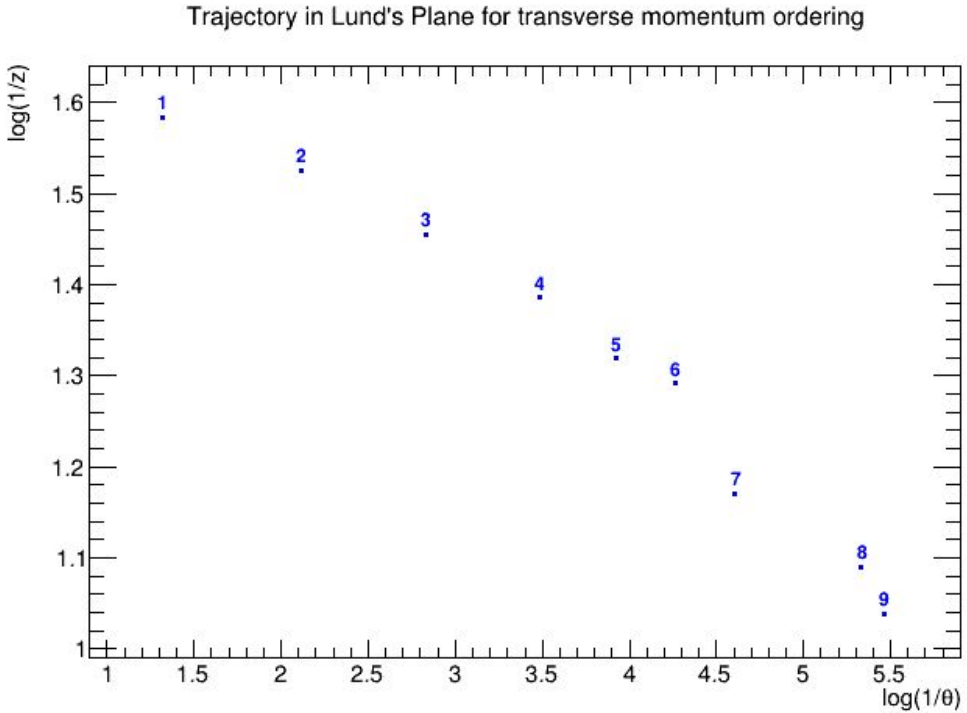

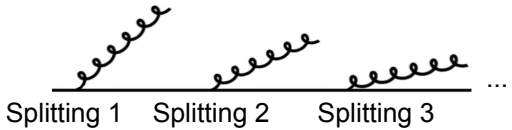

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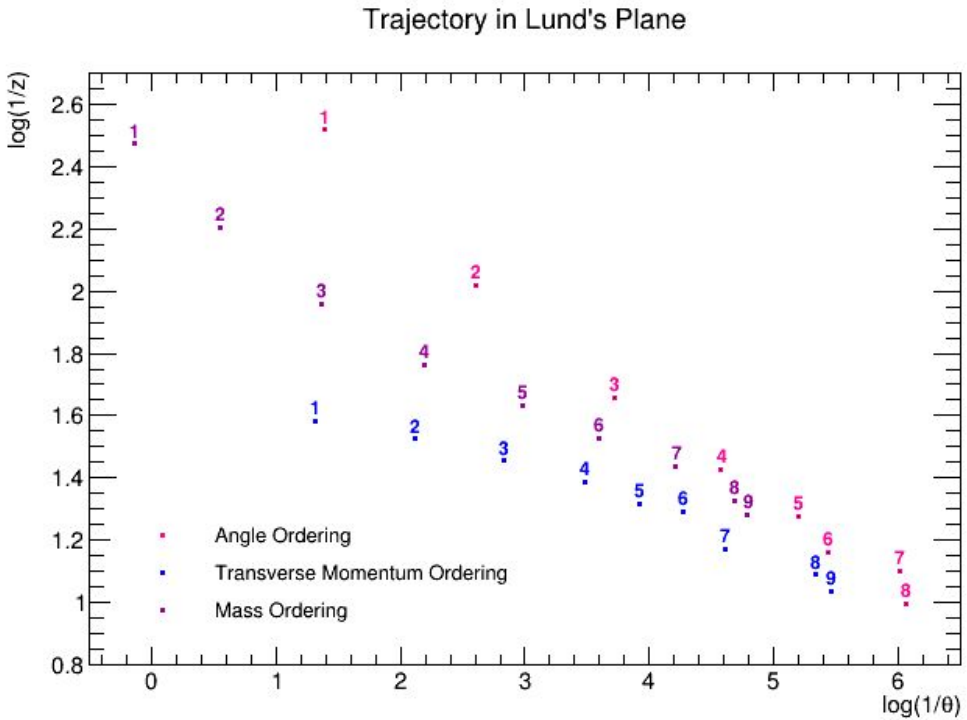

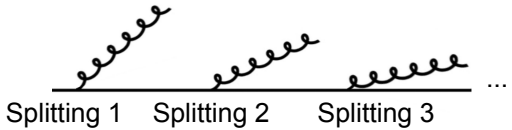

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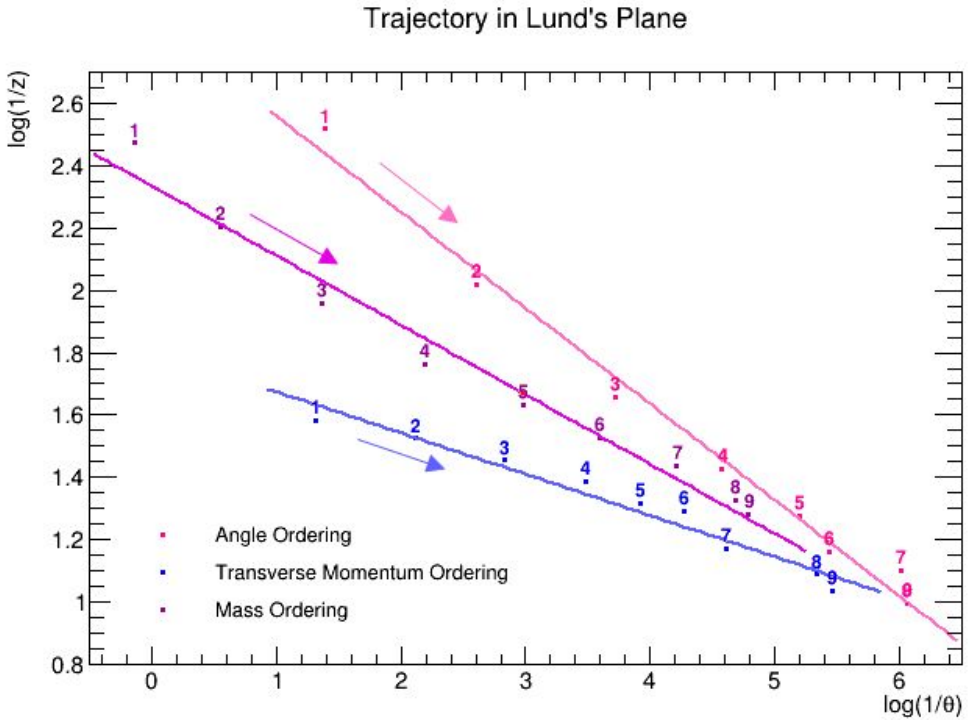

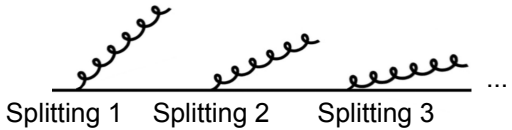

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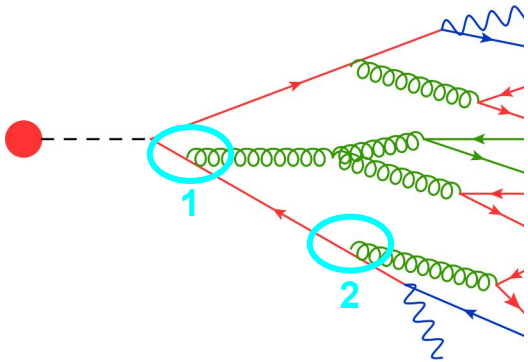
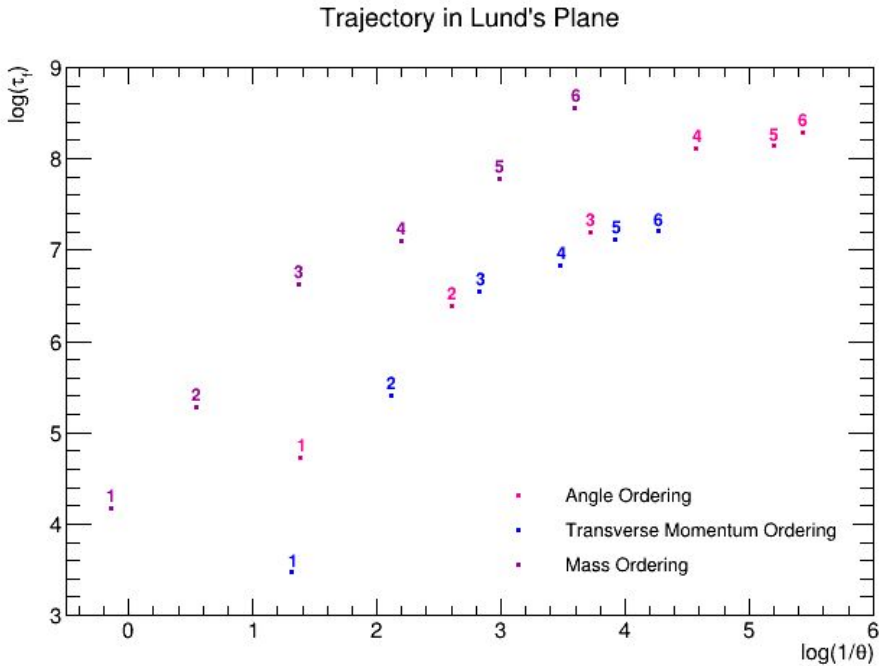
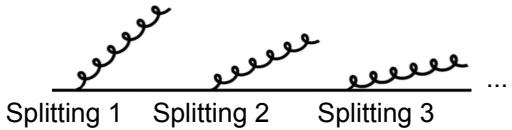


formation time

$$\tau_f = \frac{1}{2\,E\,z\,(1-z)(1-\cos\theta)}$$





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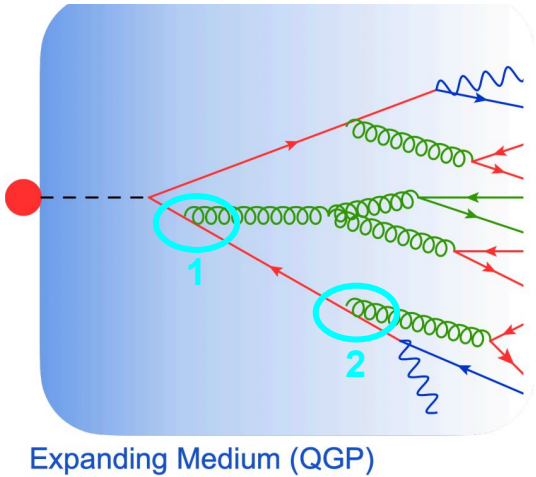

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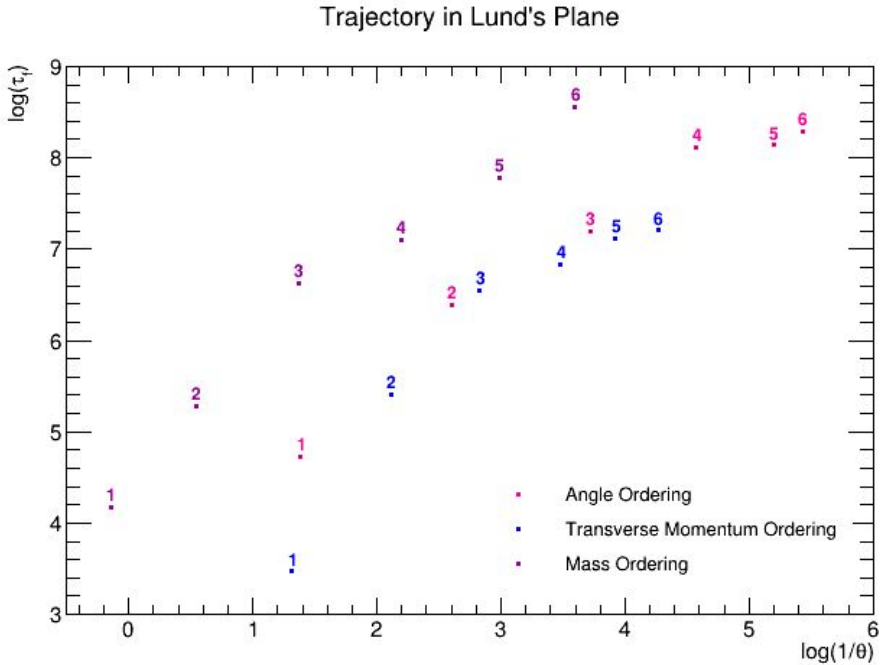

Conclusion

- Goal: understand QCD parton showers and how to use them in heavy-ion collisions
- Results:
  - Studied algorithms (m^2, angle, k_t^2) have equivalent final distributions (as expected), but exact ordering is different
  - In pp collisions, these differences cannot be measured…
  - In heavy-ion collisions, different emissions will take place at a different QGP density (not shown)
    - Exploration avenue to better understand QCD parton showers!