Exploring the Quark-Gluon Plasma

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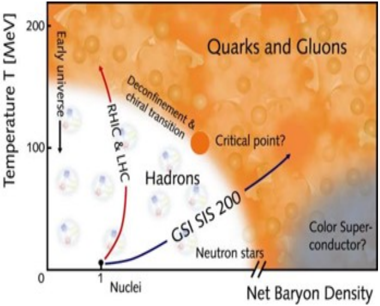
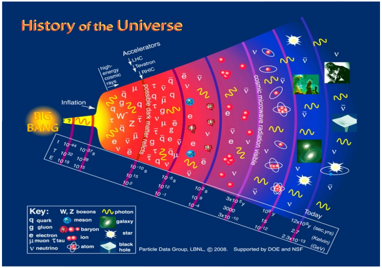
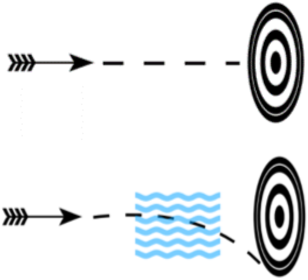
September 5, 2019

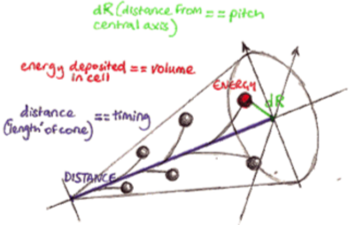
- Quark–gluon plasma (QGP): state of matter in QCD which exists at extremely high temperature and/or density.





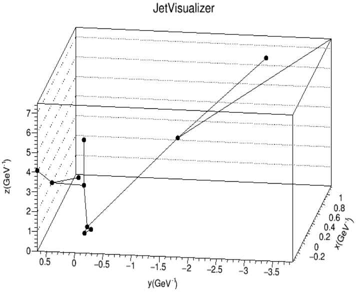
- Much like arrows, jets can be used to study the characteristics of the materials its particles have gone through

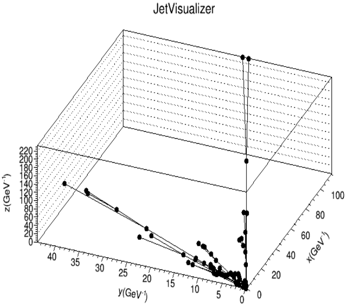




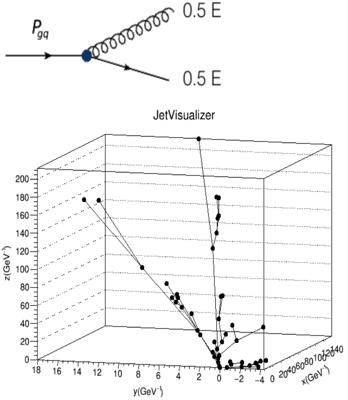
Jet Visualizer

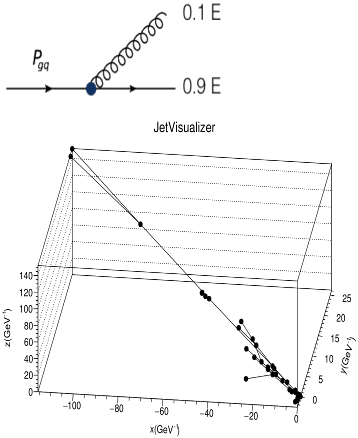
Fragmentation Patterns





- Quark initiated jet — low multiplicity
- Gluon initiated jet — high multiplicity





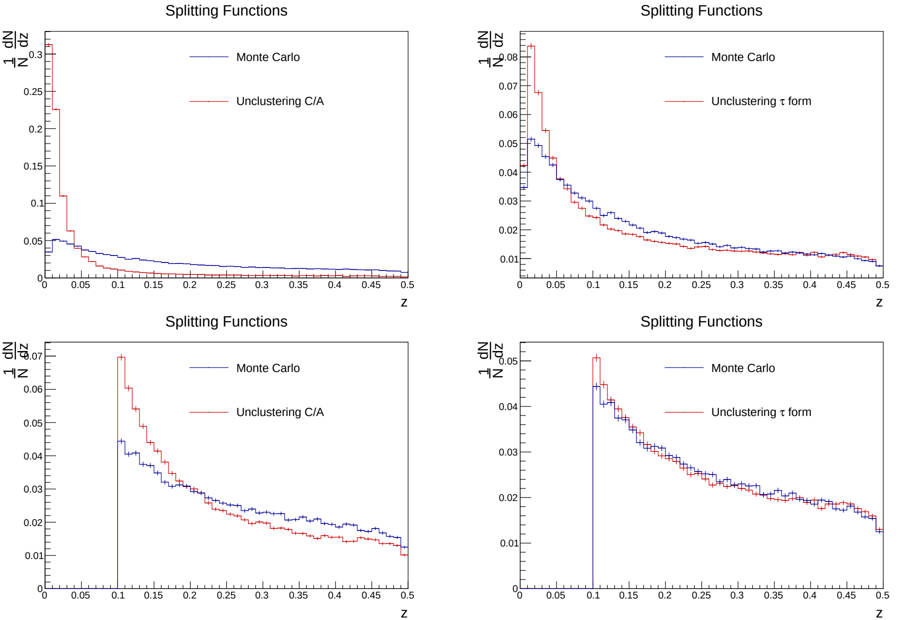
- Symmetric splitting function — two main branches
- Asymmetric splitting function — one main branch

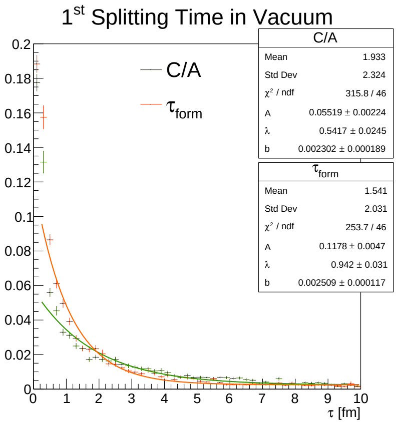
Jet Reconstruction Algorithms

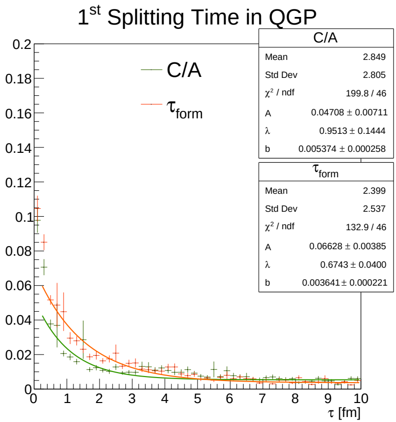
Generalized kt-family of jet clustering algorithms

- **Smallest distance:**
  - $d_{ij} = min\{p_{ti}^{2p}, p_{tj}^{2p}\}\frac{\Delta R_{ij}^2}{R^2}$
- **Algorithms and their differences:**
  - **Anti-kt** $\Rightarrow p = -1 \longrightarrow$ Signal identification (di-jets)
  - **Cambridge-Aachen (C/A)** $\Rightarrow p = 0.0 \longrightarrow$ Jet reclustering based on angular ordering
  - **Formation Time (τ_{form})** $\Rightarrow p = 0.5 \longrightarrow$ jet reclustering based on angular and transverse momenta: formation time ordering
- **Energy Cut**
  - $z = \frac{E_{child2}}{E_{child1} + E_{child2}}$
  - **0.0** or **0.1** $\Rightarrow$ First Splitting selection by energy forced exclusion

Splitting Functions: Cambridge-Aachen (C/A) *vs* τ_{form}

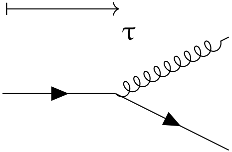




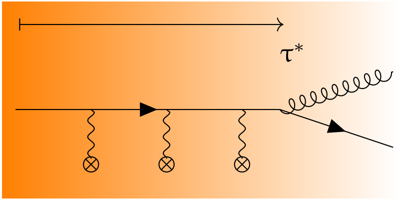


- Jet formed in QGP $\longrightarrow$ delayed jet formation.
- Why does this happen?

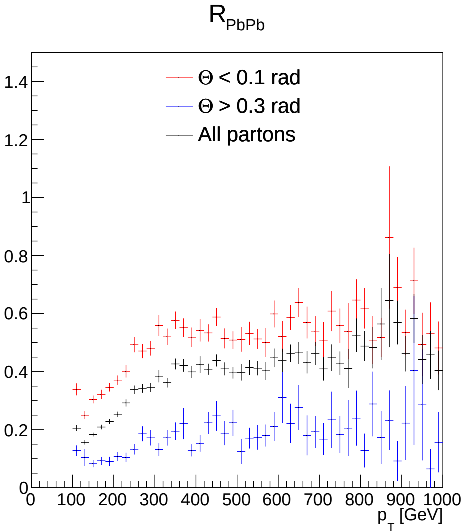
- Heisenberg uncertainty in rest frame:
  - $\Delta t \propto \frac{1}{\Delta E} \Rightarrow \tau \propto \frac{1}{m}$

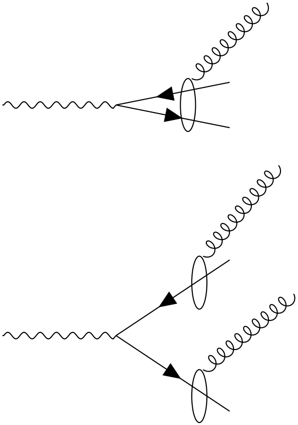


- Lorentz boost:
  - $\tau \propto \frac{\gamma}{m}$
- Parton interaction with medium → lower effective mass:
  - $m^* < m \Leftrightarrow \tau^* > \tau$



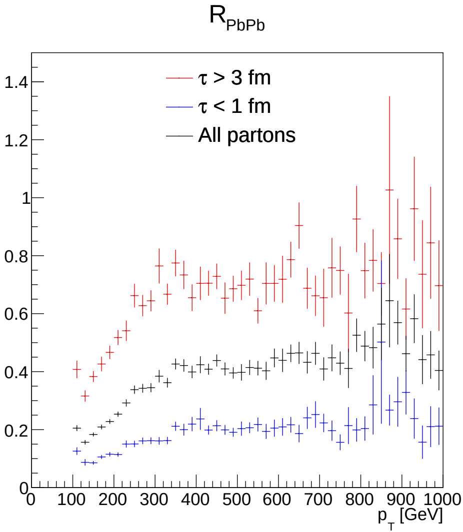
Splitting Angle as a Selection Variable

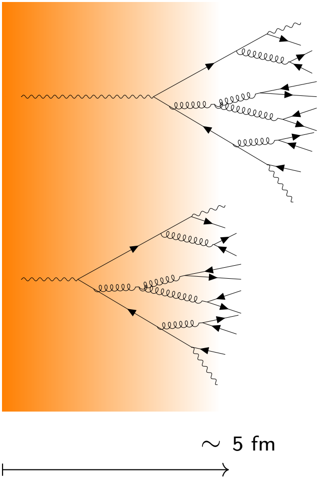




- Small angle ⟶ Coherent radiation ⟶ Less suppression

Formation Time as a Selection Variable





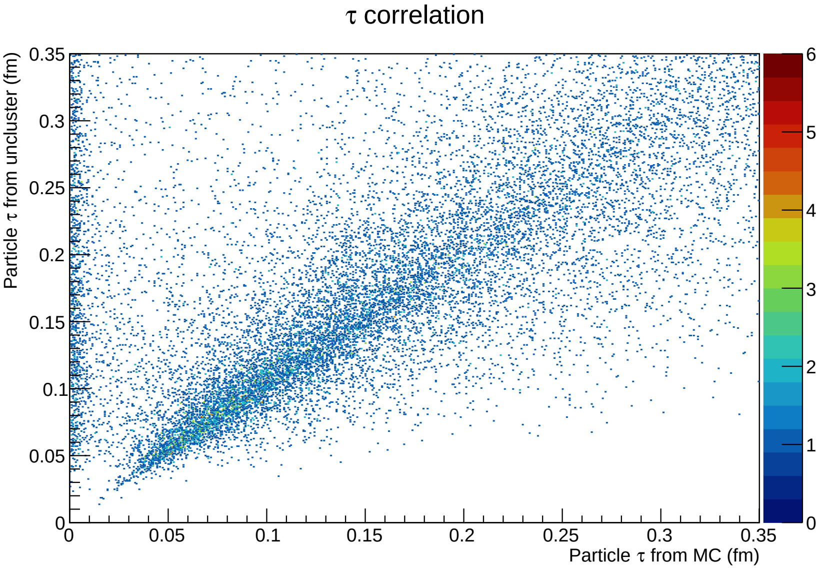
- Delayed jet formation ⟶ Vacuum-like evolution ⟶ Less suppression

Conclusions

- Jet visualization tool:
  - Able to show different fragmentation patterns.
- Recovery of the Monte-Carlo splitting function possible with $Z_{cut} = 0.1$
  - τ_{form} seems slightly better.
- For medium-modified jets τ seems to be a better binning variable than Θ (the natural variable for vacuum-like jets).
  - Selection of different τ allows differences in medium path length (different energy loss).

Backup Slides

τ **Correlation:** Pythia Monte Carlo *vs* Unclestering alg.



- Formation time correlation between *Pythia Monte Carlo* and τ_{form} algorithm.

First Splitting Correlation Factor

τ_{form} *vs* Cambridge-Aachen (C/A)

- **C/A**
  - Correlation factor: $Z_{cut} = 0.0 \longrightarrow 49.3\%$
  - Correlation factor: $Z_{cut} = 0.1$:
    - **With outliers:** $\longrightarrow 61.0\%$
    - **Without outliers:** $\longrightarrow 71.6\%$

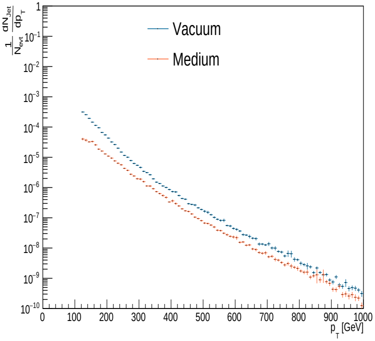
- τ_{form}
  - Correlation factor: $Z_{cut} = 0.0 \longrightarrow 46.4\%$
  - Correlation factor: $Z_{cut} = 0.1$:
    - **With outliers:** $\longrightarrow 61.0\%$
    - **Without outliers:** Without outliers $\longrightarrow 72.1\%$

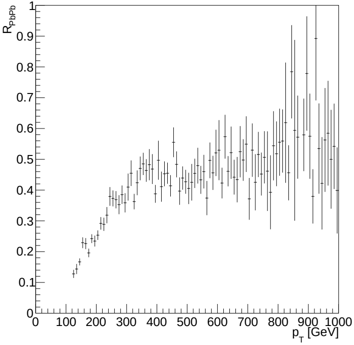
Nuclear Modification Factor: R_{AA}

Quantifying Bulk Behaviour

$$R_{AA}(p_t) = \frac{1/N_{evt}^{AA}\ dN_{jet}^{AA}/dp_t}{1/N_{evt}^{pp}\ dN_{jet}^{pp}/dp_t}$$

- Trigger on dijets (representative of whole spectrum);
- Ratio quantifies jets that survive QGP.





Formation Time & Splitting Angle Spectra