Examination of in-medium heavy-quark energy-loss mechanisms via angular correlations between heavy and light mesons

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from SUBATECH, Nantes

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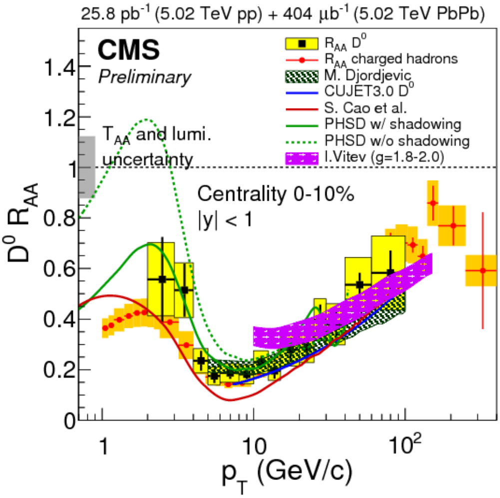
XVI Strangeness in Quark Matter, Berkeley

Some samples of R_{AA}



[CMS Collaboration, CMS-PAS-HIN-16-001.]

Overview

Approach in 2 directions:

Observables

Strategy of the analysis:

1. heavy-light-particle (angular) correlations:
   overall medium effects?
2. Search for origin of differences:
   specific shower processes + individual parton branchings.
3. Extract medium dependent quantities from global results.

Production of heavy-quark showers:

situation	vacuum	Inelastic	Elastic
Description	splitting functions	model A	model B
In-medium energy-loss		additional branchings	transfer shower$\longrightarrow$medium

Mechanisms

In-medium propagation: inelastic scattering

Model A:

[Th. Renk: Phys.Rev.C **78**, 034908 (2008)]

Virtuality increases/no changes in 3-momenta per small timesteps Δt:

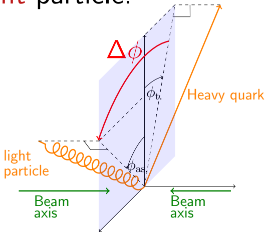
$$\begin{aligned} Q &\mapsto \sqrt{Q^2 + \hat{q}\Delta t}\,, \\ \vec{p} &\mapsto \vec{p}\,, \\ E &\mapsto \sqrt{E^2 + \hat{q}\Delta t}\,. \end{aligned} \tag{1}$$

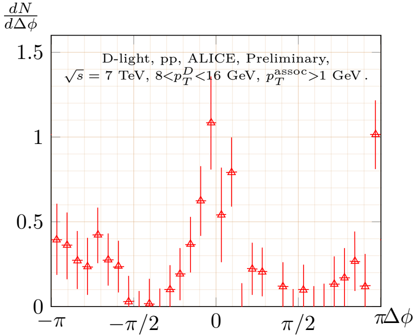
$\Rightarrow$ 3-momenta in shower only changed due to additional radiation!

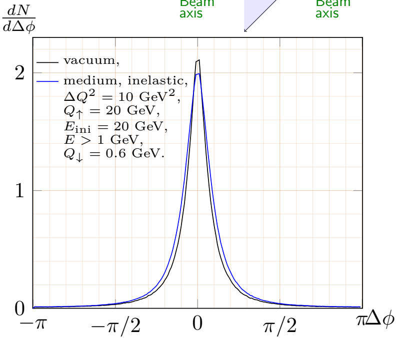
(Azimuthal) Angular correlations

Correlations of heavy quark & any light particle:

$$\cos(\Delta\phi) = \frac{\vec{p}_{h\perp} \cdot \vec{p}_{l\perp}}{\|\vec{p}_{h\perp}\| \|\vec{p}_{l\perp}\|} \ ,$$







[S. Bjelogrlić: J. Phys. Conf. Ser. **636**,012002 (2015)]

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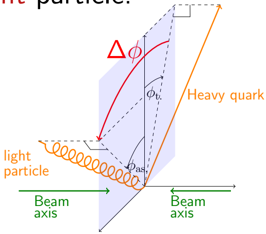
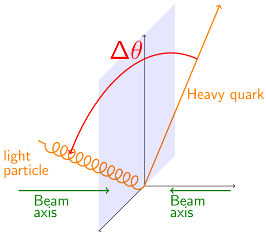
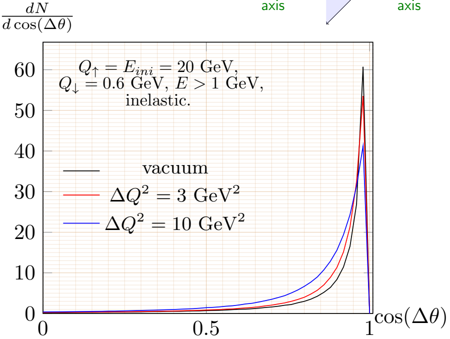
from physical viewpoint pretty equivalent to

$$\cos(\Delta\theta) = \frac{\vec{p}_{h}\cdot\vec{p}_{l}}{\|\vec{p}_{h}\|\|\vec{p}_{l}\|}\ .$$

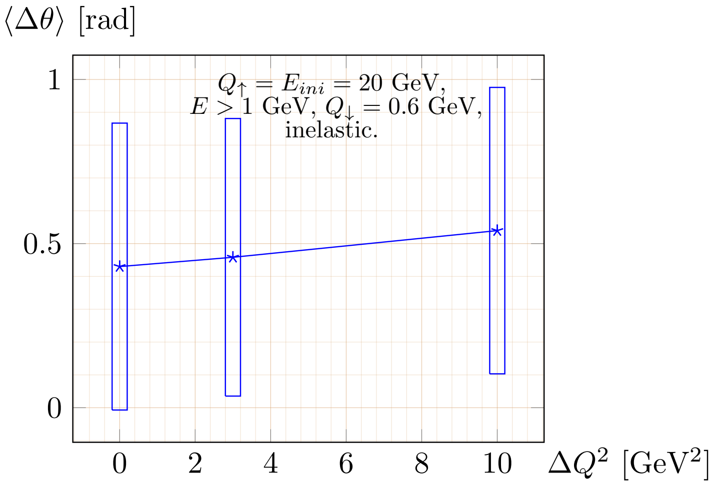






$$\Delta Q^2 = \int_{\tau_{ini}}^{\tau_{fin}} dt\,\hat{q}(t)$$

Angular Broadening

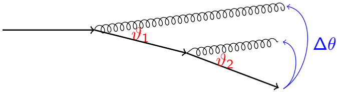


Boxes: half-width of $\frac{dN}{d\Delta\theta}$ distribution.

More sensitive observables?

Individual shower contributions to angular correlations

$\rightarrow$ Look at contributions from different topologies/processes with different numbers of emitted particles, e.g.:



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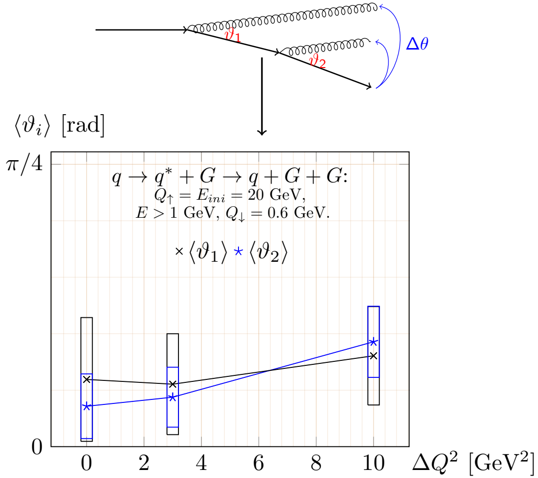

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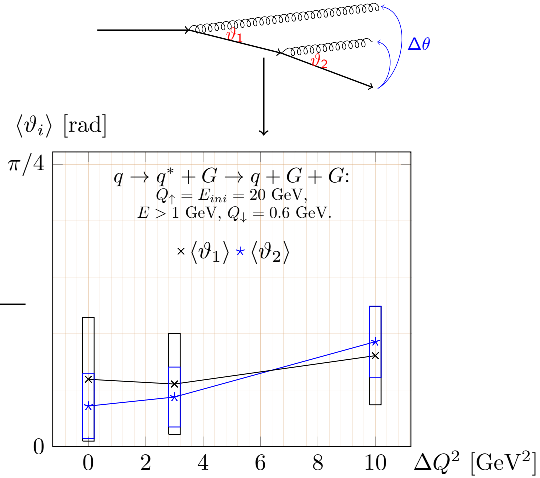

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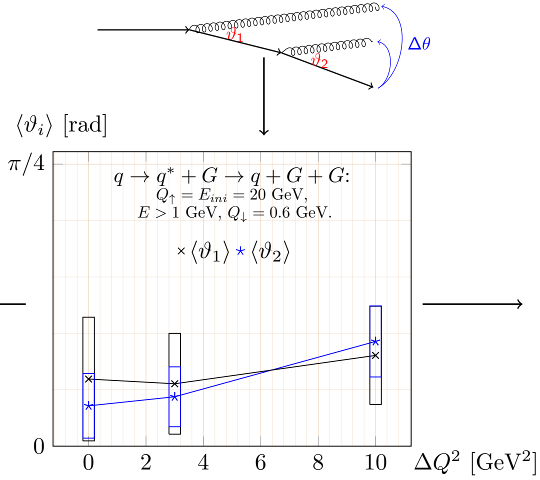

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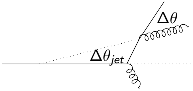
→ inversion of angular ordering in the medium

Which observable for a full shower?

Angular Ordering?

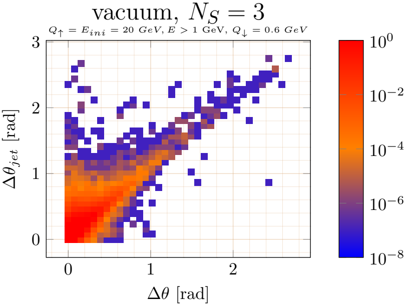
Compare angles between momenta of a light particle and:

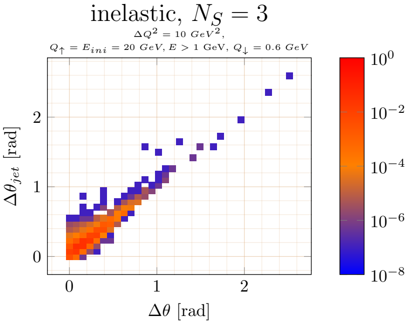
the heavy particle... $\Delta\theta$ ⟶ contain heavy quark branchings
the entire jet... $\Delta\theta_{\text{jet}}$ ⟶ "history" of previous branchings



$$\longrightarrow \frac{d^2N}{d\Delta\theta d\Delta\theta_{\text{jet}}}$$

contributions from 3 splittings:





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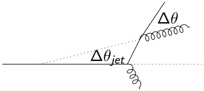
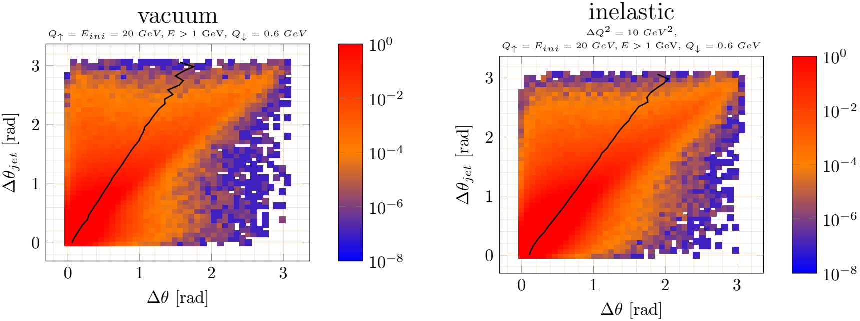


$$\rightarrow \frac{d^2N}{d\Delta\theta d\Delta\theta_{\mathrm{jet}}}$$

results for arbitrary N_S:



→ indication for weakened angular ordering

black curves: $\langle\Delta\theta(\Delta\theta_{jet})\rangle$

Conclusions for observables from model A

Observables

- angular broadening verified.
- refined analysis of broadening
  $\longrightarrow$ small angles affected most strongly.
- indications for angular ordering violations.

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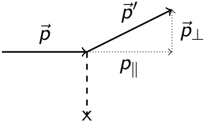
model A → model B

In-medium propagation: elastic scattering

Model B:

Forces transverse and parallel to incident 3-momenta $\vec{p}$ + changes in particle energy; Q=constant:



$$\vec{p} = (\vec{0}, p) \mapsto \vec{p}' = (\vec{p}_\perp, p_\parallel)\,,$$

$$p_\perp = \sqrt{\hat{q}\Delta t}\,, \qquad p_\parallel = p - A\Delta t\,. \quad (2)$$

$\hat{q}$ → transverse momentum transfer

A → (longitudinal) drag force

$$A = \frac{\hat{q}}{\kappa T}\,, \qquad \begin{array}{l} A \ldots \text{drag force}\,, \\ T \ldots \text{Temperature (medium)}\,, \\ \kappa \ldots \text{proportionality constant}\,. \end{array} \quad (3)$$

[H. Berrehrah, P. B. Gossiaux, J. Aichelin, W. Cassing, E. Bratkovskaya: Phys. Rev. C**90**, 064906 (2014)]

⇒ 3-momenta changed via stochastic force from medium, but no additional radiation!

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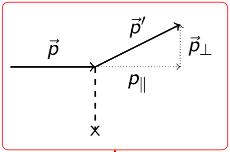

Energy→Medium

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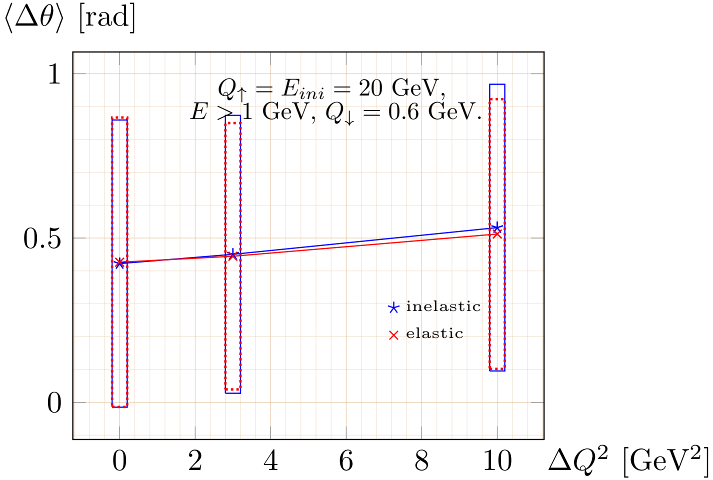

Angular Broadening: different energy dependencies for model A and B?

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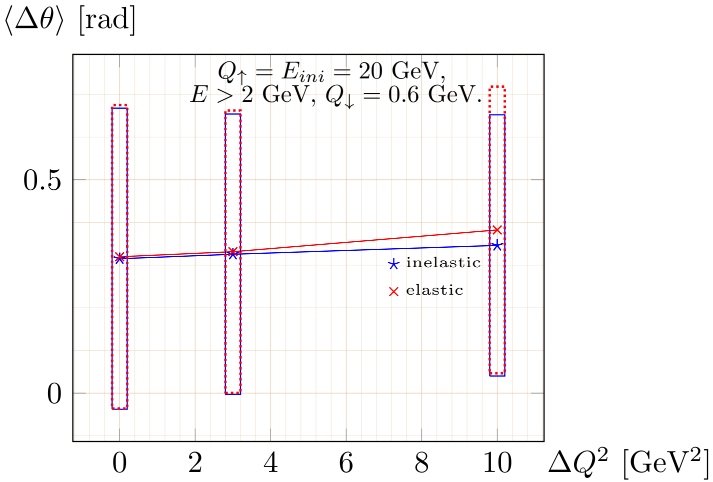


Angular Broadening: different energy dependencies for model A and B?

Summary

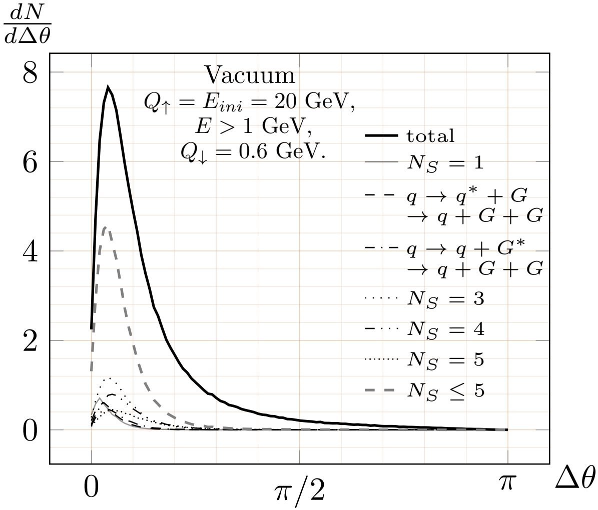
- Angular correlations as possible way to study medium effects!
- 2 mechanisms of energy loss simulated:
  inelastic (model A) and elastic scattering (model B).
- Angular broadening reflected in results!
- ...allows to distinguish hot and dense medium from vacuum...
- ...and maybe different energy-loss mechanisms from one another (further, ongoing studies)!

Thank you for your attention!

Backup

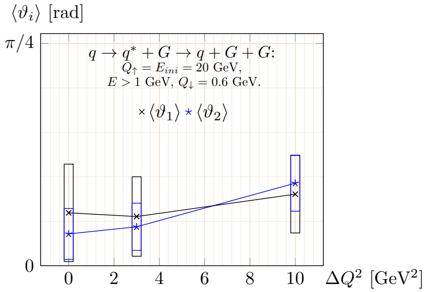
Contributions from different processes

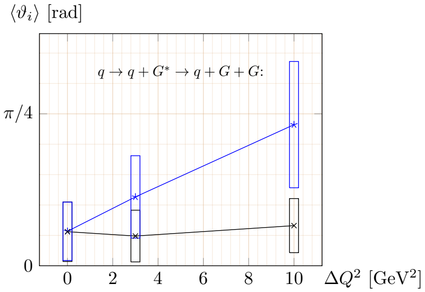
Dominant: Small number of branchings N_S!

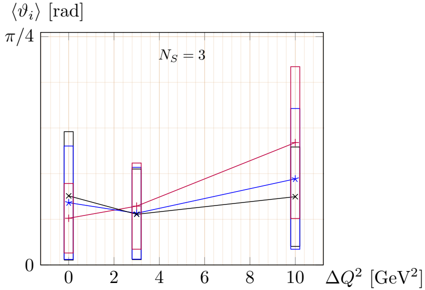


Processes of 1 quark $\longrightarrow$ 2 gluons: $\approx 10\%$

Branching angles







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