Effects of jet-medium interactions on angular correlations of jet-particle pairs at different energy scales

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Collaborators:

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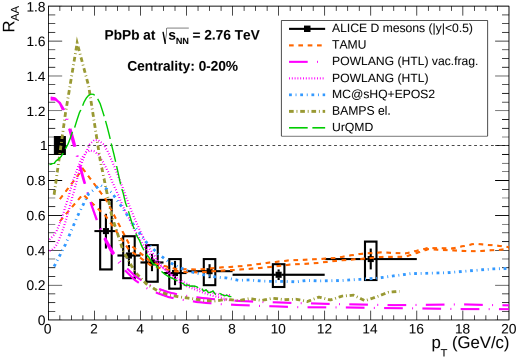
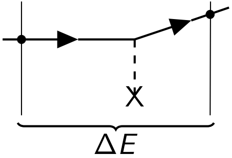
Nuclear modification factor R_{AA}

$$R_{AA}(p_T) := \frac{N_{AA}(p_T)}{\langle T_{AA}\rangle \sigma_{pp}(p_T)}\,.$$

Collisional Energy Loss:



[Eur. Phys. J. **C76** (2016) 1-151]



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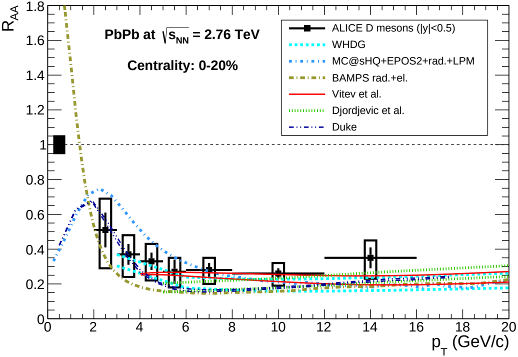
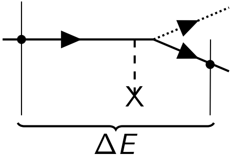
Collisional & Radiative Energy Loss:





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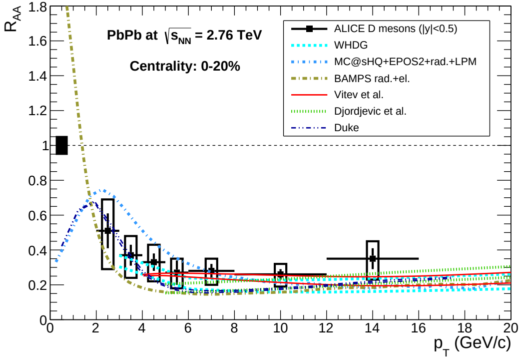

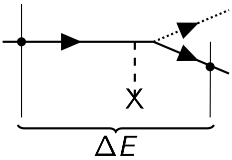

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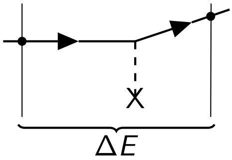
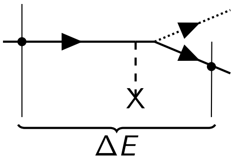
$\Rightarrow$ Need for more discriminative observables!

Collisional vs. Radiative Processes

collisional:



radiative:



$\Delta E \Rightarrow R_{\mathrm{AA}}$,

i.e.: Observables for sets of individual particles

Different Two-Particle Correlations!

Study pairs of correlated particles! $\Leftrightarrow$ Study Jets!

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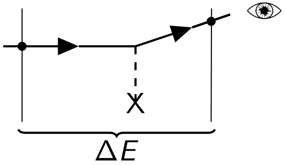
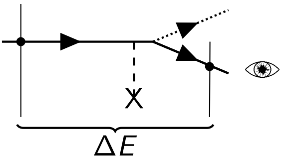


radiative:



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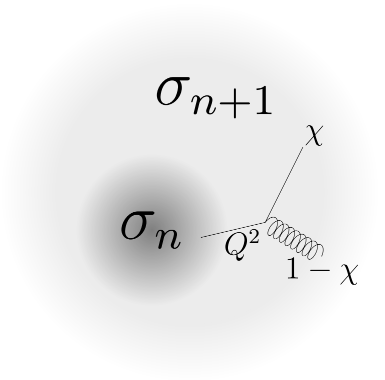
Descriptions of Jets in the Vacuum

Factorization and DGLAP evolution

Production of multiple partons:
soft and/or collinear emissions dominant! $\longrightarrow$ They factorize:



Number Distribution for particles:
$D(\chi, Q, m)$.

Probability density for splitting:
$P(\chi)$

DGLAP equations:

$$\frac{\partial D_i(x, Q, m)}{\partial \ln(Q^2)} \simeq \sum_j \int \frac{dz}{z} D_j(\frac{x}{z}, Q, m) P_{ij}(z) \,.$$

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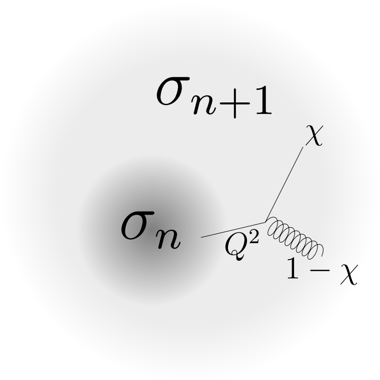

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$\rightarrow$ Monte-Carlo Simulation of DGLAP-equations for jets between scales: $Q_\uparrow$, $E_{\rm ini}$, and $Q_\downarrow$

Applications and Limitations

Applications:

- Parton cascades from:
  - $e^+ + e^-$ collisions,
  - pp-collisions (final state radiation),

  started by an initial parton.
- Allows to extract correlated parton pairs
  $\longrightarrow$ 2-particle correlations !

Limitations:

- $Q_\uparrow$, E_{ini} dependencies: No PDFs, no hard initial process, no initial state radiation,
- No multiple jet events,
- $Q_\downarrow$ dependence: No hadronization model.

Conclusion?$\longrightarrow$ need to fix $Q_\downarrow$! Use (IRC) stable observables!

Validation:

Event-shape observables (Thrust), Humped-Back plateau distribution, cf. Zapp [Eur.Phys.J. (2009) C60, 617-632].

Models of Jet-Medium Interaction

Radiative model A

Using a basic assumption of the YaJEM-model:
[Phys. Rev. **C78** (2008), 034908]

Virtuality Q increases in the medium over time t:

$$\frac{dQ^2}{dt} = \hat{q}_R(t)$$

Q increase $\Leftrightarrow$ More parton splittings:

Implementation (steps $t \mapsto t + \Delta t$):

$$Q \mapsto \sqrt{Q^2 + \hat{q}_R \Delta t}\,,$$
$$\vec{p} \mapsto \vec{p}\,,$$
$$\Rightarrow E \mapsto \sqrt{E^2 + \hat{q}_R \Delta t}\,.$$

...extra radiation!

Collisional model B

Transport coefficients: $\vec{A}(t) := -\frac{d}{dt}\langle \vec{p}_{\parallel} \rangle$, drag force deterministic

$\hat{q}_C(t) := \frac{d}{dt}\langle \vec{p}_{\perp} \rangle^2$. (squared) transverse momentum transfers stochastic

Thermalized medium: relation between $\vec{A}$ and $\hat{q}_C$

We use:

$$\frac{\hat{q}_C}{A} \approx 0.09 + 0.715 \frac{T}{T_C}$$

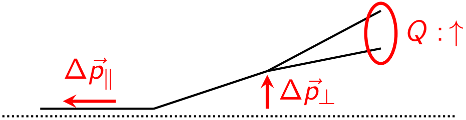
cf. Berrehrah et al. [Phys. Rev. **C90** (2014) 064906, arXiv:1405.3243[hep-ph]]

$\hat{q}_C \sim \frac{210}{1+53T} T^3$ ...cf. Jet-Collaboration
[Phys. Rev. **C90** (2014) 014909, arXiv:1312.5003]

Assumption: $\hat{q}_C = \hat{q}_R$ & Temperature profile $T(t)$ from EPOS2.

...energy transfer to the medium!

Effective Models of Jet-Medium Interaction



$\Rightarrow$ family of models:

model	Q	$\vec{p}_{\parallel}$	$\vec{p}_{\perp}$	E
A (radiative/YaJEM-like)	$\uparrow$	$=$	$=$	$\uparrow$
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C (hybrid)	$\uparrow$	$\downarrow$	$\uparrow$	$\boldsymbol{\downarrow}\uparrow$

Disadvantages: Simplifying assumptions; lack of microscopic interactions.

Advantage: Consistent framework for studying collisional and radiative mechanisms.

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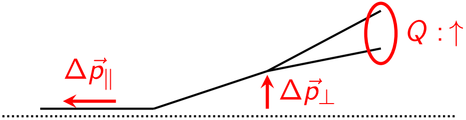

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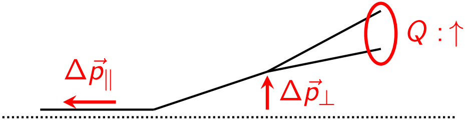

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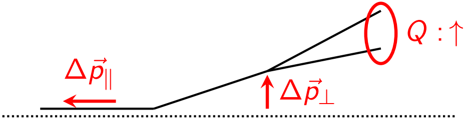

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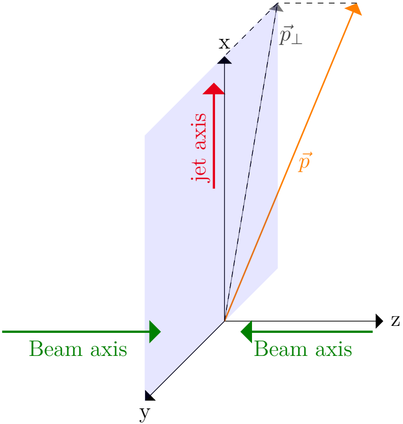
Jet shapes: $\rho(r)$

$$\rho(r) := \frac{1}{\delta r}\frac{1}{N_{\mathrm{jet}}}\sum_{\mathrm{jet}}\frac{\sum_{\mathrm{trk}\in[\mathrm{r_a},\mathrm{r_b}]} p_\perp^{\mathrm{trk}}}{p_\perp^{\mathrm{jet}}}\,, \qquad r = \sqrt{\Delta\phi^2 + \Delta\eta^2}\,.$$



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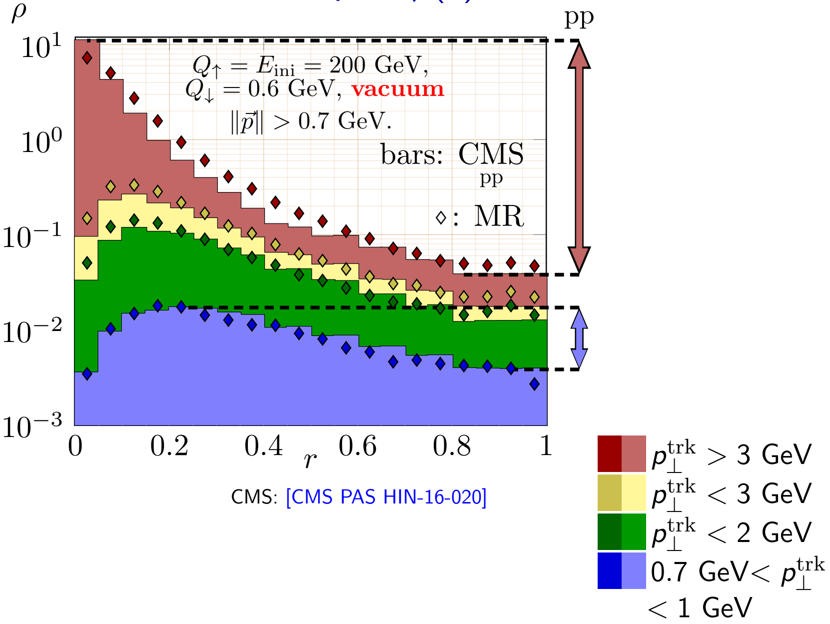

CMS: [CMS PAS HIN-16-020]

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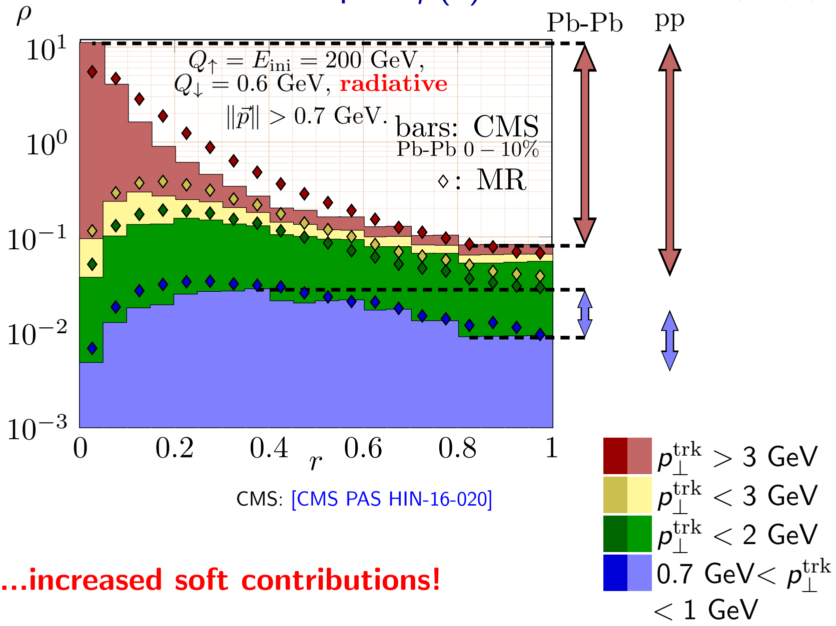

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...increased soft contributions!

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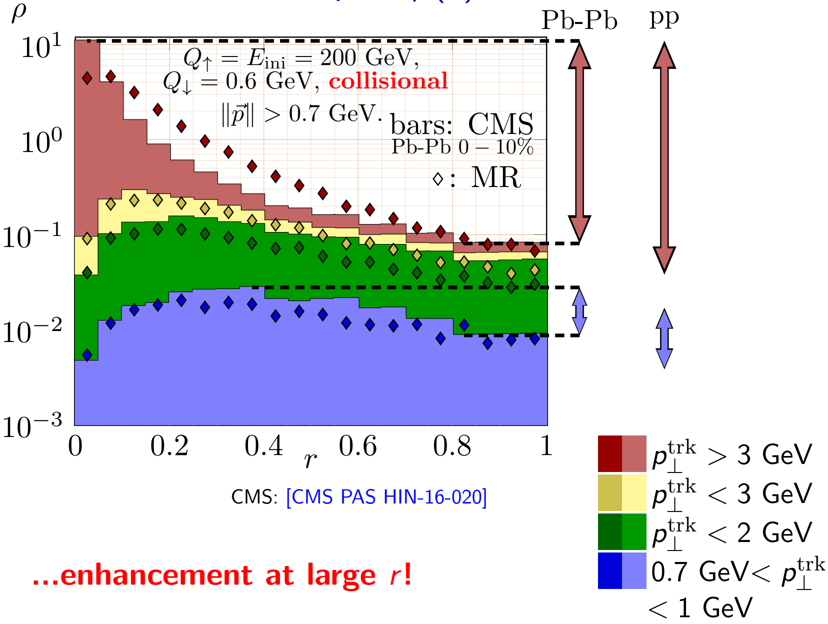

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...enhancement at large r!

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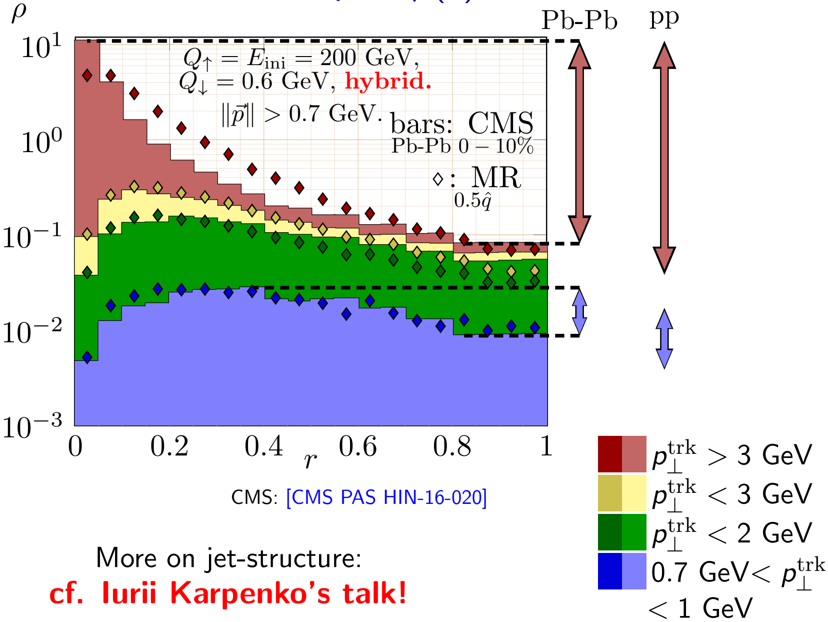

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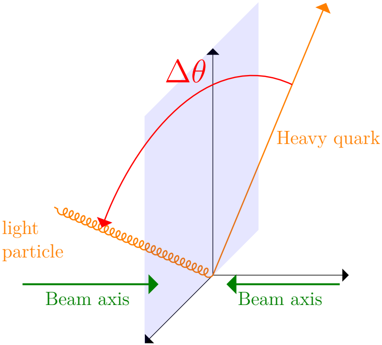
More on jet-structure:

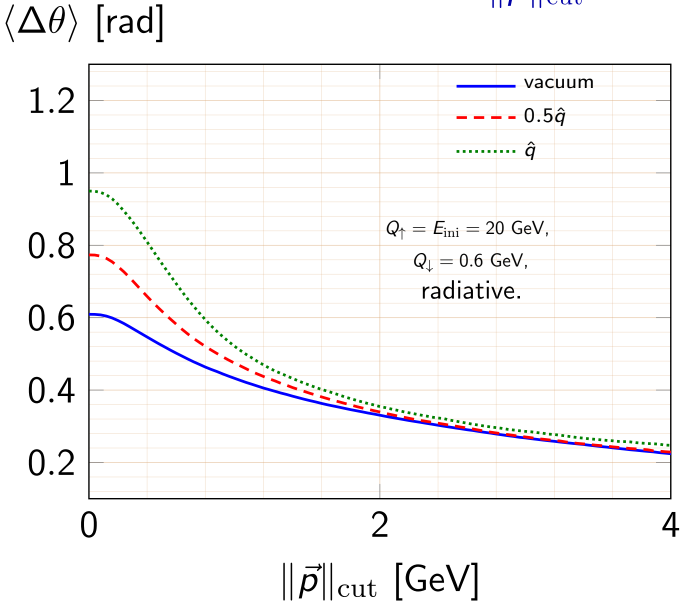
cf. Iurii Karpenko's talk!

Two-Particle Correlations

Angular Heavy-Light Particle Correlations



Discrimination via $\|\vec{p}\|_{\mathrm{cut}}$



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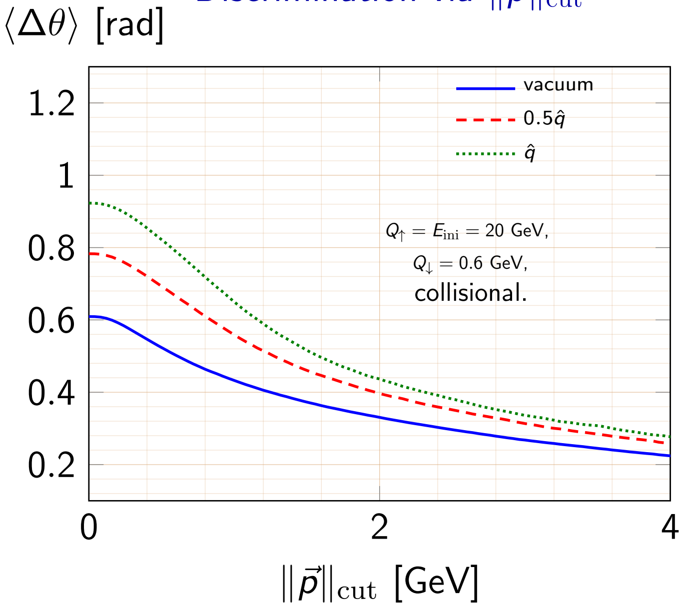

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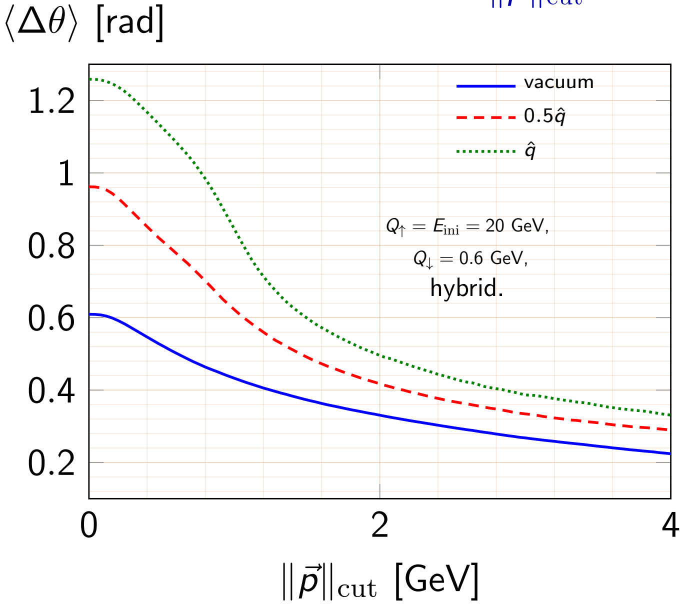

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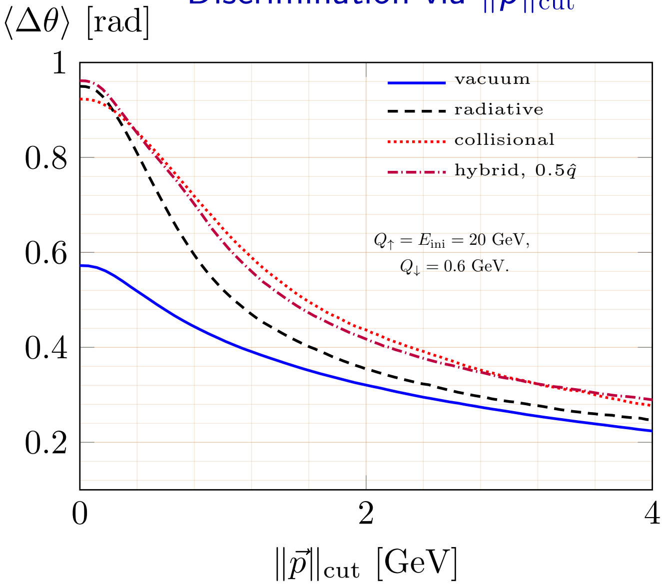

Summary

Key-Result:

Induced Radiation: Broadening at small energies.
Transverse forces: Broadening at all energies.

Main Conclusion:

Angular Heavy-Light particle correlations allow to distinguish different mechanisms of in-medium parton-energy loss!

To Do:

Hadronization$\leftrightarrow$jet-algorithms, heavy quark masses (cf. Dead-Cone effect), PDF's, initial state radiation, hard initial collisions,...

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