Theory of quenching in small systems

How do we know what to expect if we're not calculating energy-loss in an honestly small system?

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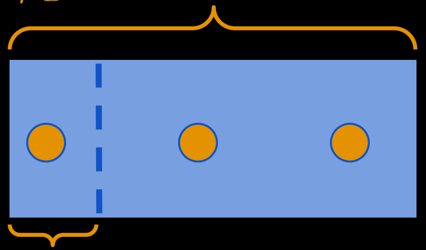
Relaxing large-L approximation

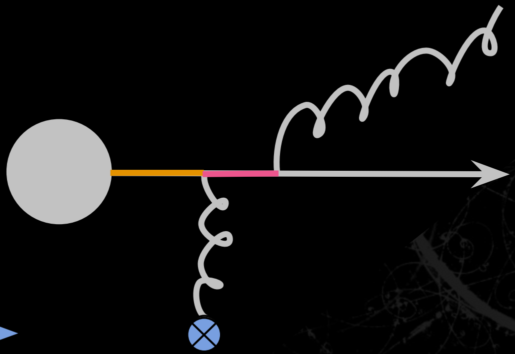
$$\frac{1}{\mu_D} \ll \Delta z \sim \lambda_{mfp} \ll L$$

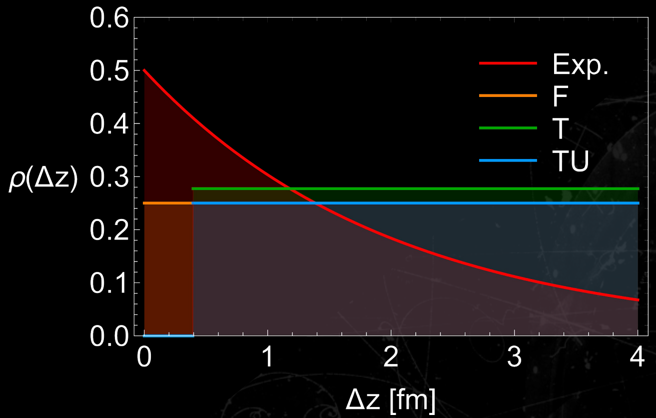


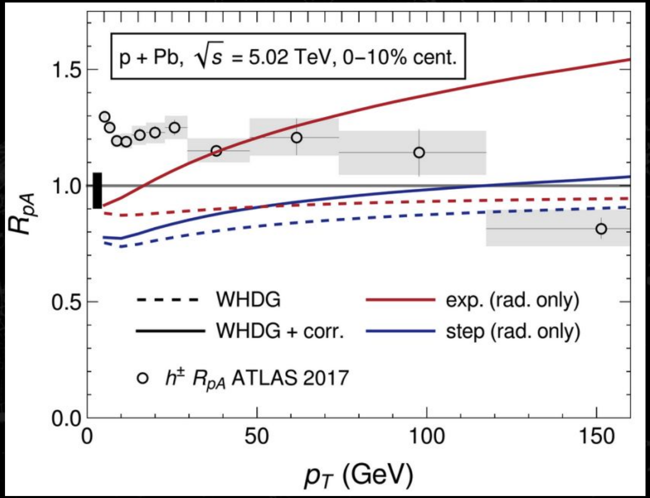
$$\frac{1}{\mu_D} \ll \lambda_{mfp}$$

DGLV poles

corr. pole







Many side-effects

L-dependence is not obviously L^2

$$\Delta E^{(1)}_{ind} = \frac{C_R \alpha_s L E}{\pi \lambda_g} \int dx \int \frac{d^2\mathbf{q}_1}{\pi} \frac{\mu^2}{(\mu^2+\mathbf{q}_1^2)^2} \frac{d^2\mathbf{k}}{\pi}$$
$$\times \int d\Delta z \bar{\rho}(\Delta z) \Bigg[-\frac{2(1-\cos\{(\omega_1+\tilde{\omega}_m)\Delta z\})}{(\mathbf{k}-\mathbf{q}_1)^2+M^2x^2+m_g^2}$$
$$\times \left(\frac{(\mathbf{k}-\mathbf{q}_1)\cdot\mathbf{k}}{\mathbf{k}^2+m_g^2+x^2M^2} - \frac{(\mathbf{k}-\mathbf{q}_1)^2}{(\mathbf{k}-\mathbf{q}_1)^2+M^2x^2+m_g^2} \right)$$
$$+ \frac{1}{2} e^{-\mu_1 \Delta z} \Bigg\{ \left(\frac{\mathbf{k}}{\mathbf{k}^2+m_g^2+x^2M^2} \right)^2$$
$$\times \left(1-\frac{2C_R}{C_A}\right)\left(1-\cos\{(\omega_0-\tilde{\omega}_m)\Delta z\}\right)$$
$$+ \frac{\mathbf{k}\cdot(\mathbf{k}-\mathbf{q}_1)}{(\mathbf{k}^2+m_g^2+x^2M^2)((\mathbf{k}-\mathbf{q}_1)^2+M^2x^2+m_g^2)}$$
$$\times \left(\cos\{(\omega_0-\tilde{\omega}_m)\Delta z\} - \cos\{(\omega_0-\omega_1)\Delta z\} \right) \Bigg\} \Bigg]$$

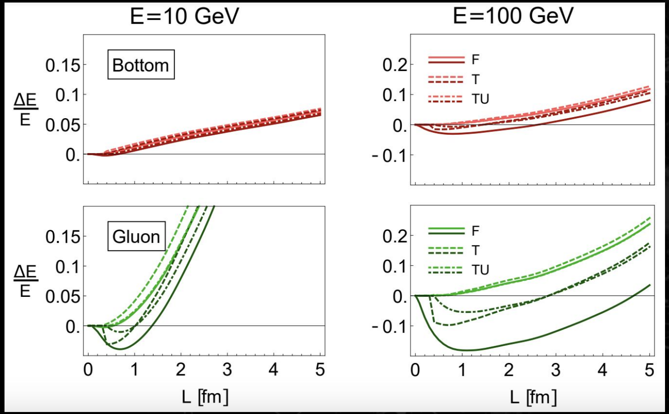
DGLV

$\approx$

$$\Delta E^{(1)}_{LO} = \frac{C_R \alpha_s}{4} \frac{L^2 \mu^2}{\lambda_g} \log \frac{E}{\mu}$$

All-pathlength correction

$$\Delta E^{(1)}_{NLO} = \frac{E C_R \alpha}{\pi \lambda_g} \left(-\frac{2C_R}{C_A} \right) \frac{L}{2+L\mu} \times$$
$$\times \left(\log\left\{ \frac{2EL}{(2+L\mu)} \right\} - 1 \right)$$



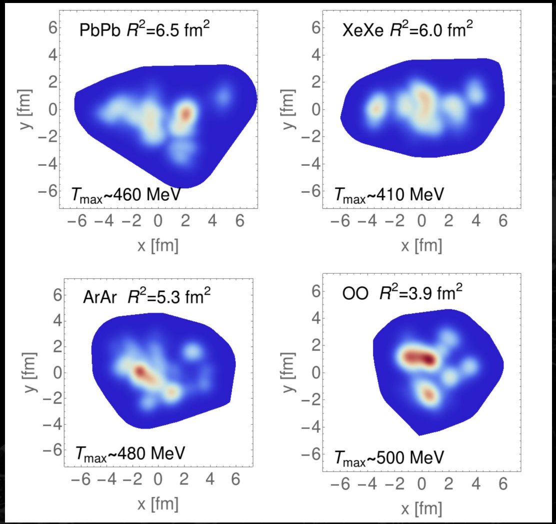
Formation time of gluon becomes critically important

This is GLV, are multiple interactions important?

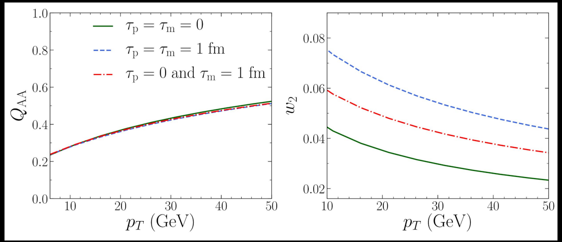
What about interference with other diagrams?

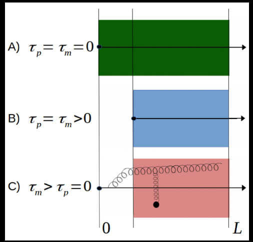
Temperature is also important

$$\lambda_{mfp} \sim \frac{1}{\rho\sigma} \sim \frac{1}{g^2 T} \qquad \mu_D \sim gT$$

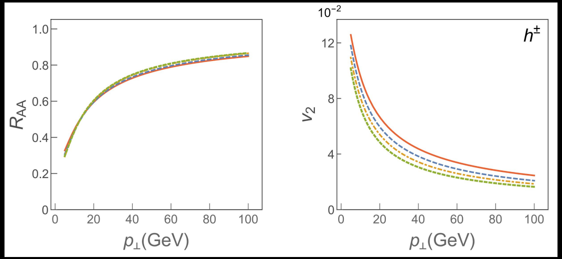


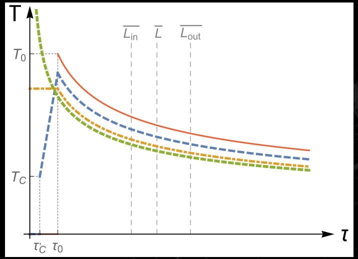
Also important for v_2 and R_{AA}





Sensitivity to the nature of radiation in the early stages





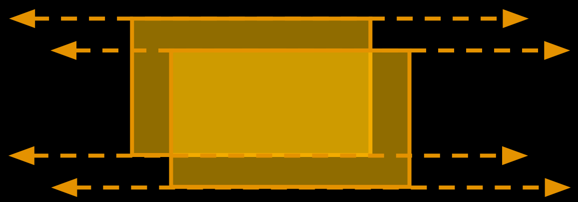
Or sensitivity to late-time temperature profile?

How can we be faithful to rapidly evolving temperature profile in a pQCD calculation?

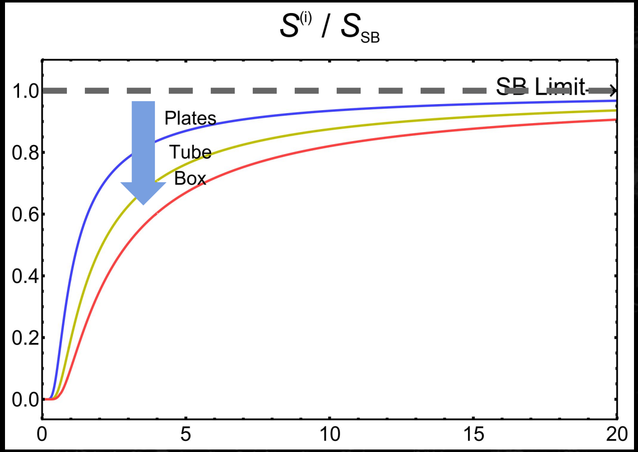
What does the temperature profile have to be to get R_pPb~1 but v_2 >0?

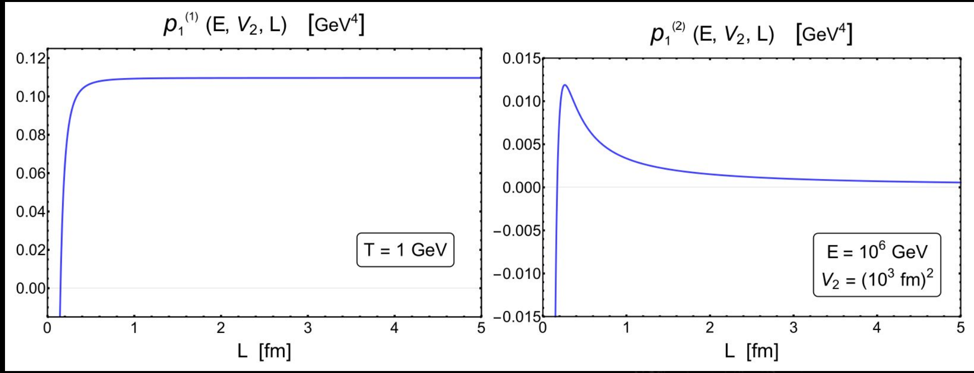
Thermodynamics in small systems

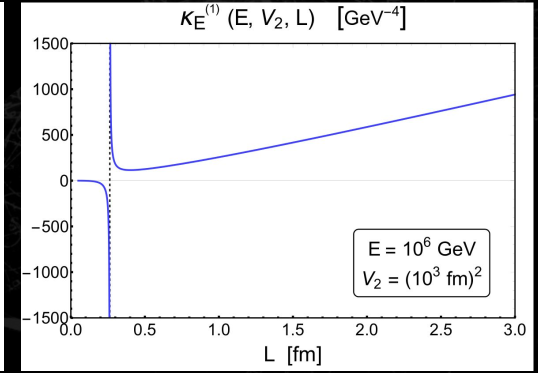
What effect do finite system boundaries have on the fundamental properties of the medium?



Single, massless, non-interacting, scalar field in a finite box





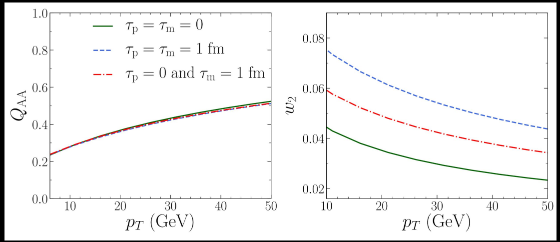


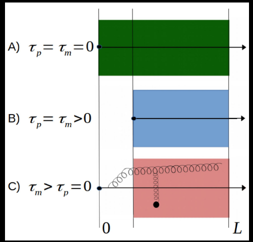
Speculation on a system-size scan

- Can we get to the space-time structure of medium-induced modification with a system-size scan?
- What would we have to compute?
    - Eg. Korinna's suggestion of color-coherence and formation time. Maybe these provide a scale?
    - Are there observables that predict an experimentally measurable modification in OO but predict a too-small modification in pPb?
- Can one isolate the effect of the pre-hydrodynamic phase in small systems and see it become sub-dominant in larger systems?

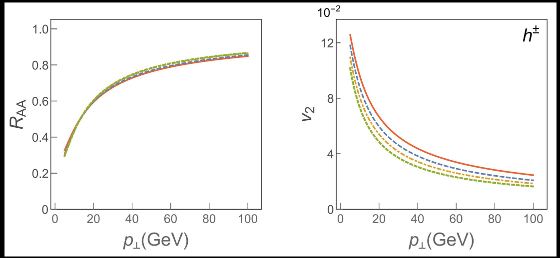
Backups

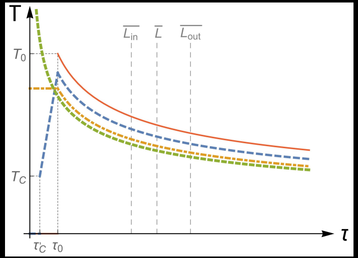
Description of R_{AA} and v_2 is non-trivial in AA



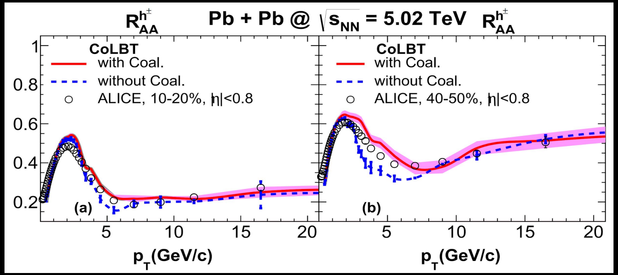


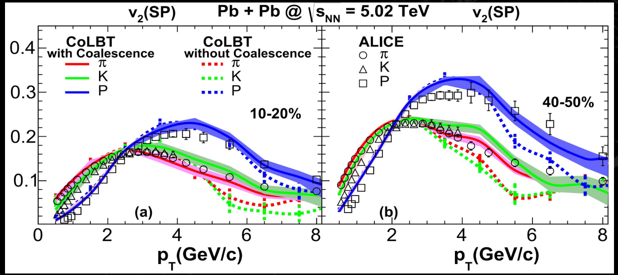
Sensitivity to the nature of radiation in the early stages





Or sensitivity to late-time temperature profile?



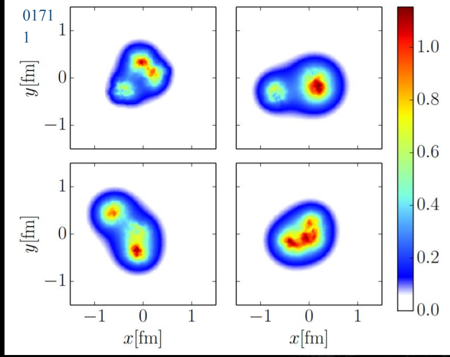


Or do you need comprehensive hadronization picture?

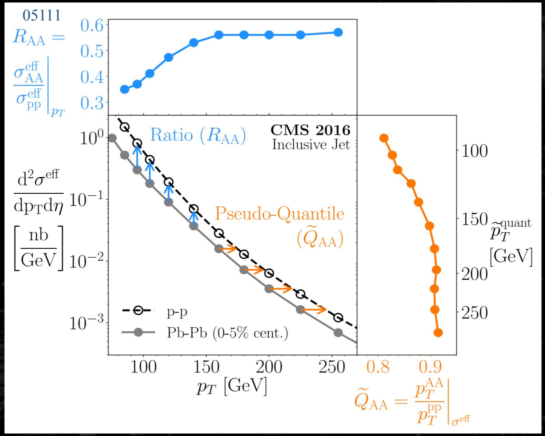
RAA and v2 are not useful at high-pT in small systems

- Reliance on a reference system
- Steeply falling production spectrum
  - Sensitive only to large ΔE
  - Sensitive to PDFs and nPDFs
  - Species-dependent
- Sensitive to initial condition
  - Geometry
  - Momentum anisotropy
- Sensitive to jet fragmentation
- Supposed to quantify ΔE, but
  - $\Delta E \leftarrow L \leftarrow N_{coll}$: uncontrolled
  - $\Delta E = \Delta E(T)$: T is uncontrolled

1607.01711



1812.05111



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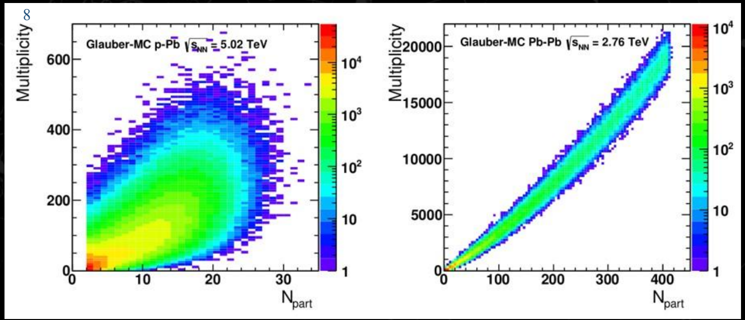
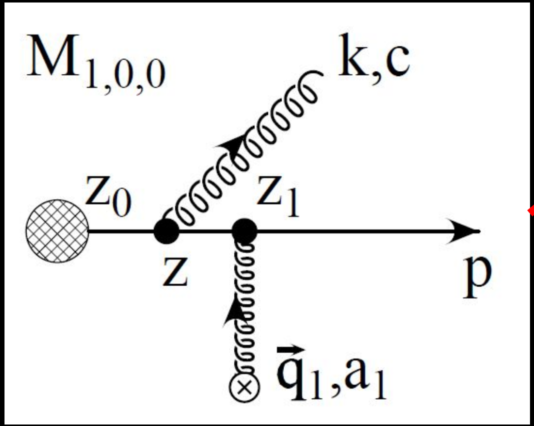


All-pathlength energy loss - Details



$$
\begin{aligned}
M_{1,0,0} &= \int \frac{d^4 q_1}{(2\pi)^4}\, iJ(p+k-q_1)\, e^{i(p+k-q_1)x_0}\, (ig_s)\epsilon_\alpha(2p-2q_1+k)^\alpha \times \\
&\quad \times i\Delta_M(p-q_1+k)\, i\Delta_M(p-q_1)(2p-q_1)^0 V(q_1)\, e^{iq_1 x_1} T_{a_1 a_1 c} \\
&\approx J(p+k)\, e^{i(p+k)x_0}(-ig_s a_1 c T_{a_1}) 2E \int \frac{d^2 \mathbf{q}_1}{(2\pi)^2} e^{-i\mathbf{q}_1 \mathbf{b}_1} I_2,
\end{aligned}
$$

$$-i\mu$$

$$I_2(p,k,\mathbf{q}_1,z_1-z_0) = \int \frac{dq_{z1}}{2\pi} \frac{\epsilon_\alpha(2p-2q_1+k)^\alpha}{(p-q_1+k)^2 - M^2 + i\epsilon} \frac{1}{(p-q_1)^2 - M^2 + i\epsilon}\, v(\vec{\mathbf{q}}_1)\, e^{-iq_{1z}(z_1-z_0)}.$$