ABSORPTION OF HARD AND THERMAL PHOTONS IN A QUARK-GLUON PLASMA AND HADRON GAS

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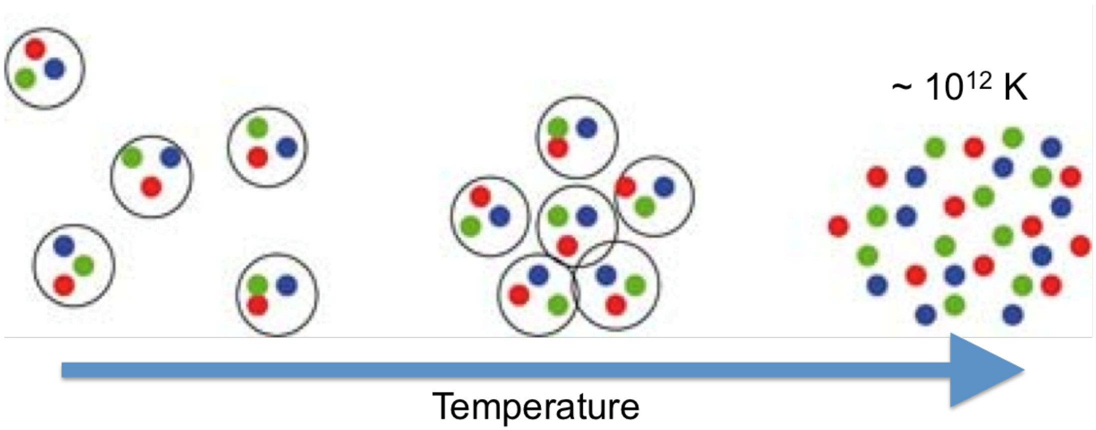
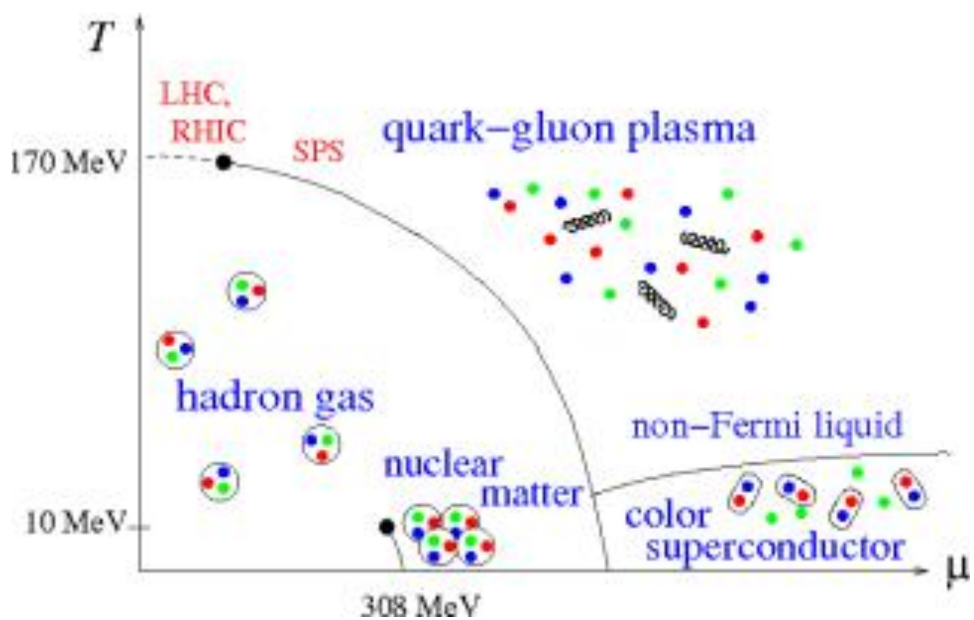
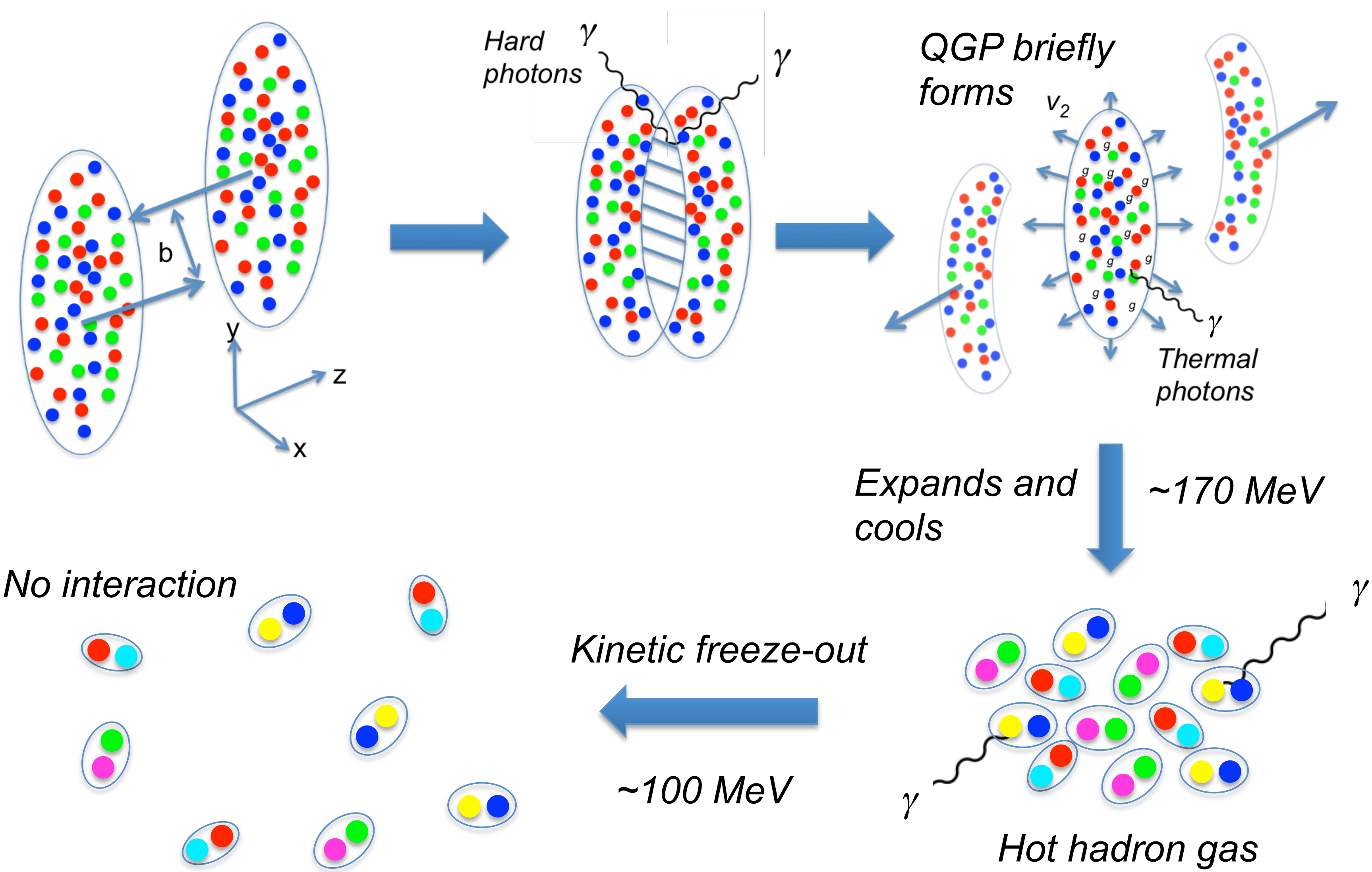
Quark-Gluon Plasma (QGP)



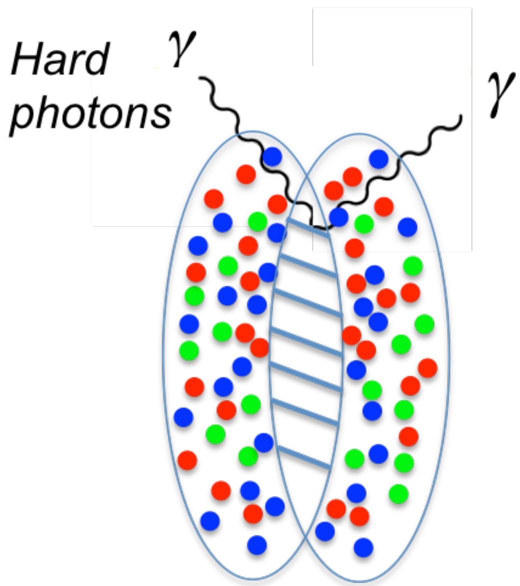


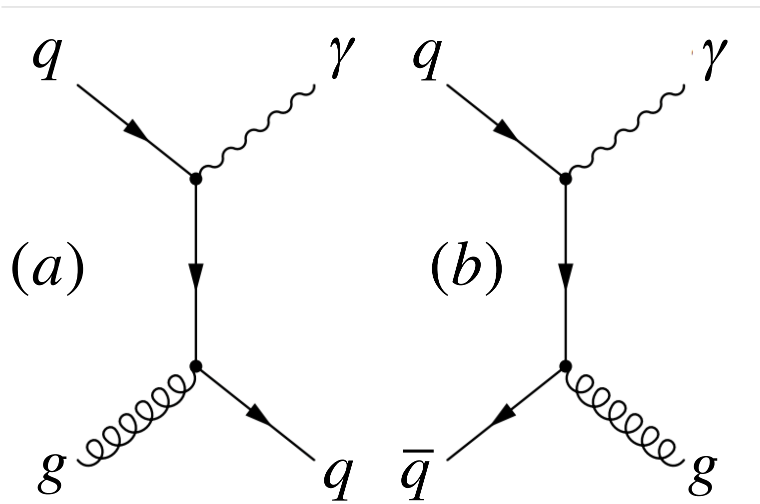
Direct Photons in Heavy Ion Collisions



Modeling Photon Production

- The initial momentum distribution of hard photons is calculated using leading-order (LO) pQCD [1]
- A Glauber model gives their initial spatial distribution
- AMY complete LO pQCD calculations give thermal production rates [2]
- State-of-the-art rates for HG [3]

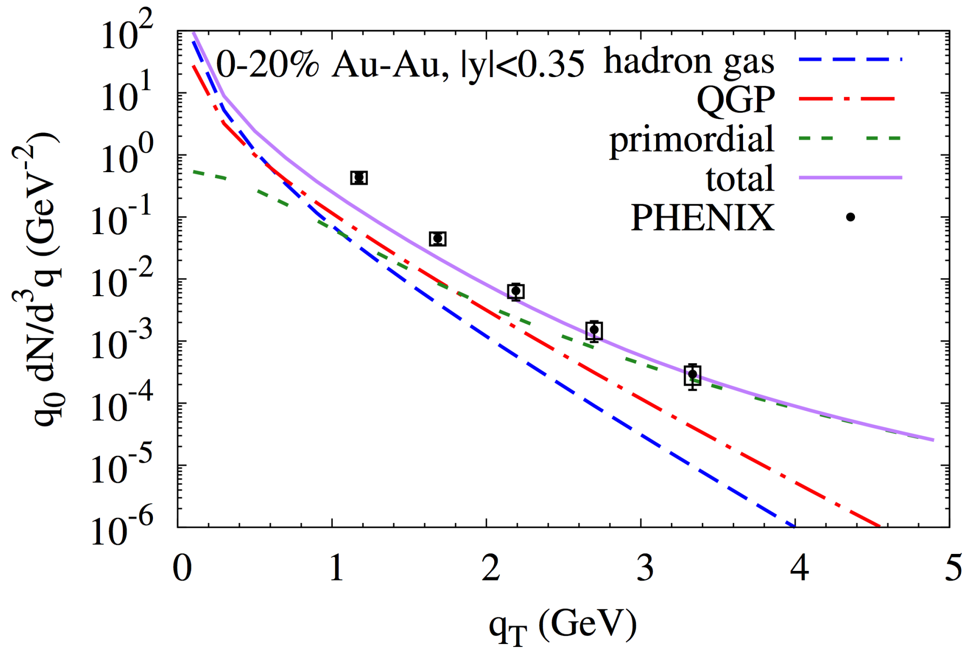


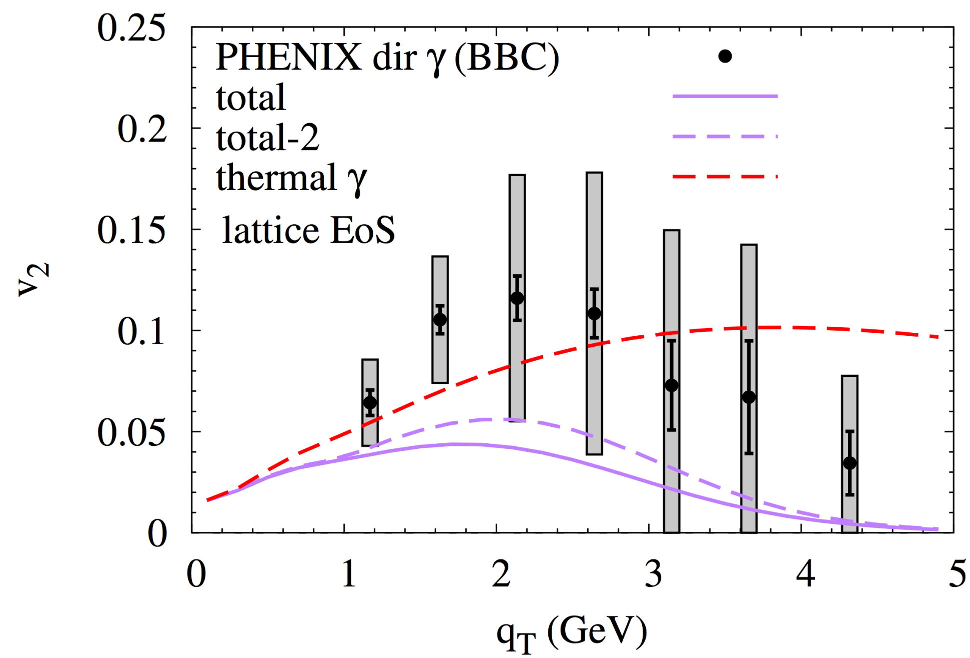


(a) Compton scattering
(b) Quark annihilation

Discrepancies with Data

- Tension fitting photon spectrum and elliptic flow (v_2) simultaneously
- Recent calculations from He *et al.* are an example [3]

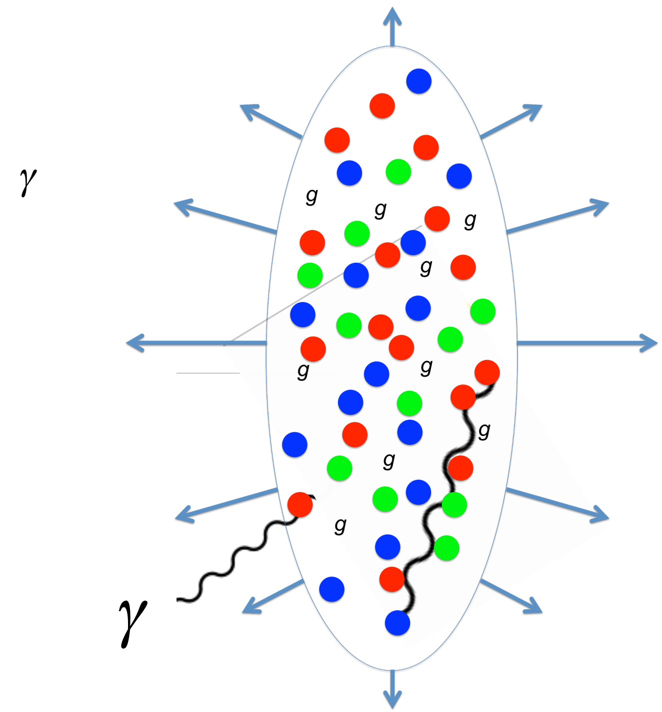




[3]

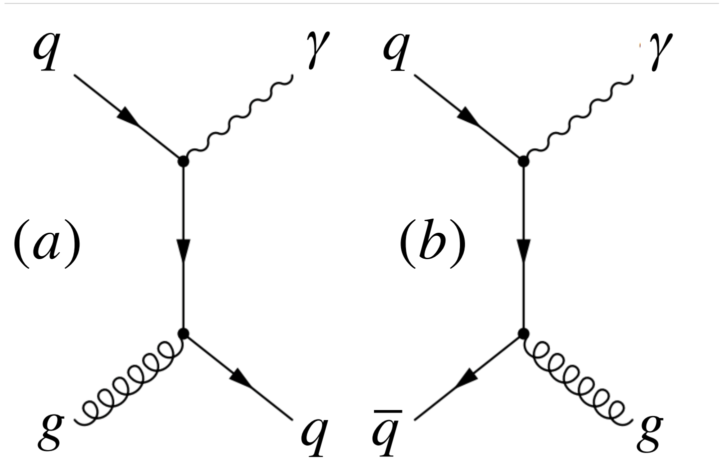
Motivation

- Photons are a major probe of QGP as they do not interact strongly
- They are assumed to have mean free paths of ~400 fm, significantly longer than the spatial dimensions of the QGP (~15 fm). [4]
- We explore the possibility that some of these photons are reabsorbed in the hopes of better fitting experimental data



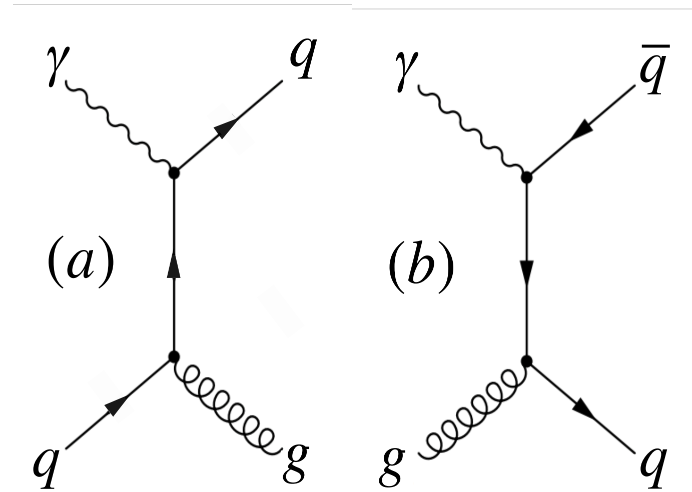
Photon Production and Absorption

Production processes



(a) Compton scattering
(b) Quark annihilation

Absorption processes



(a) Compton scattering
(b) Quark pair-production

Production Rate:

$$\Gamma_{prod} \equiv \frac{EdN}{d^3p\, d^4x}$$

Time reversal symmetry

Absorption Rate:

$$\Gamma_{abs} = \frac{(2\pi)^3}{2p} e^{\frac{p}{T}} \Gamma_{prod}$$

[4]

Methodology

- Thermal and spatial evolution of fireball modeled with ideal hydrodynamics (AZHYDRO) [5][6]
- 170 MeV phase transition
- 100 MeV kinetic freeze out
- Calculate production rates using complete LO pQCD rates for the hard photons [1], AMY rates [2] for QGP and state-of-the-art rates[3] for hadron gas
- Calculate absorption rates
- PPM applies the production and absorption rates to hard and thermal photons and propagates them through the fireball [7]
- Note: Production/absorption of photons prior to thermalization is neglected

Observables

- Spectrum: Boost invariant measure of number of photons with a given momentum:

$$\frac{EdN}{d^3p}$$

- Suppression factor:

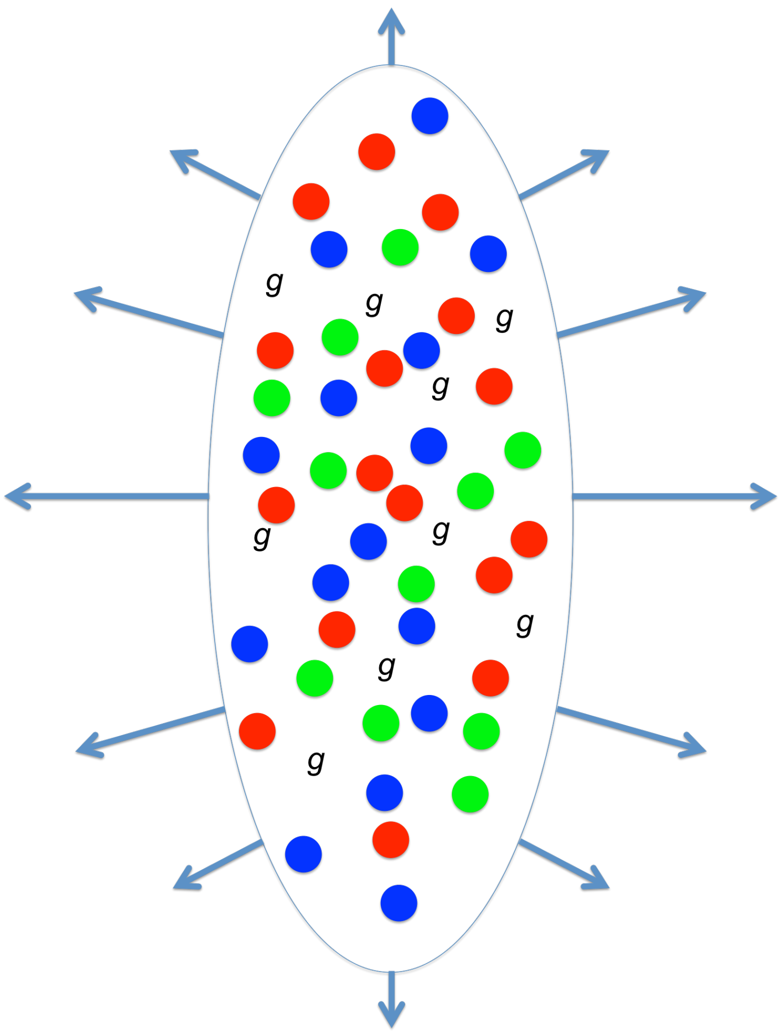
$$S_{AA} = \frac{(dN^{AA} / d^2 p_t)}{(dN^{AA} / d^2 p_t)} \quad \begin{matrix} \text{(w/ absorption)} \\ \text{(w/o absorption)} \end{matrix}$$

Elliptic Flow

- Second Fourier coefficient, $v_{2,}$ of the azimuthal asymmetry of spectrum

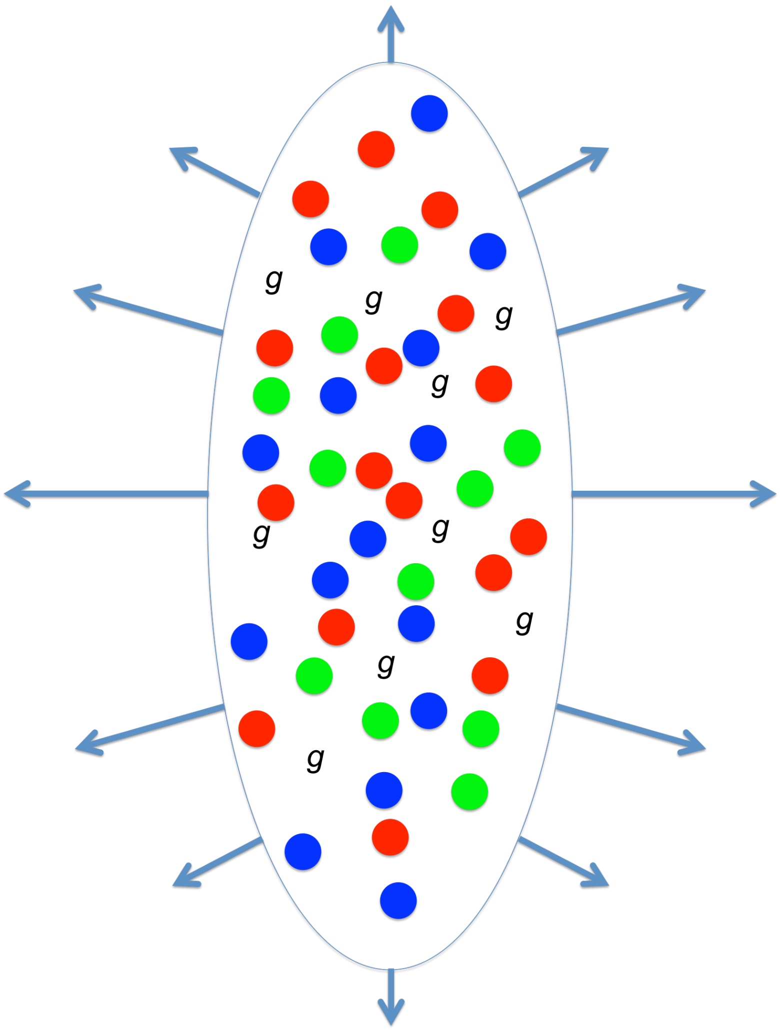
$$\frac{EdN}{d^3p} = \frac{1}{2\pi}\frac{dN}{p_t\,dp_t\,dy}\left(1+\sum_n v_n\cos(n\psi)\right)$$

$$v_2 = \frac{\int_\psi (dN/d^2p_t)\cos(2\psi)d\psi}{\int_\psi (dN/d^2p_t)d\psi}$$

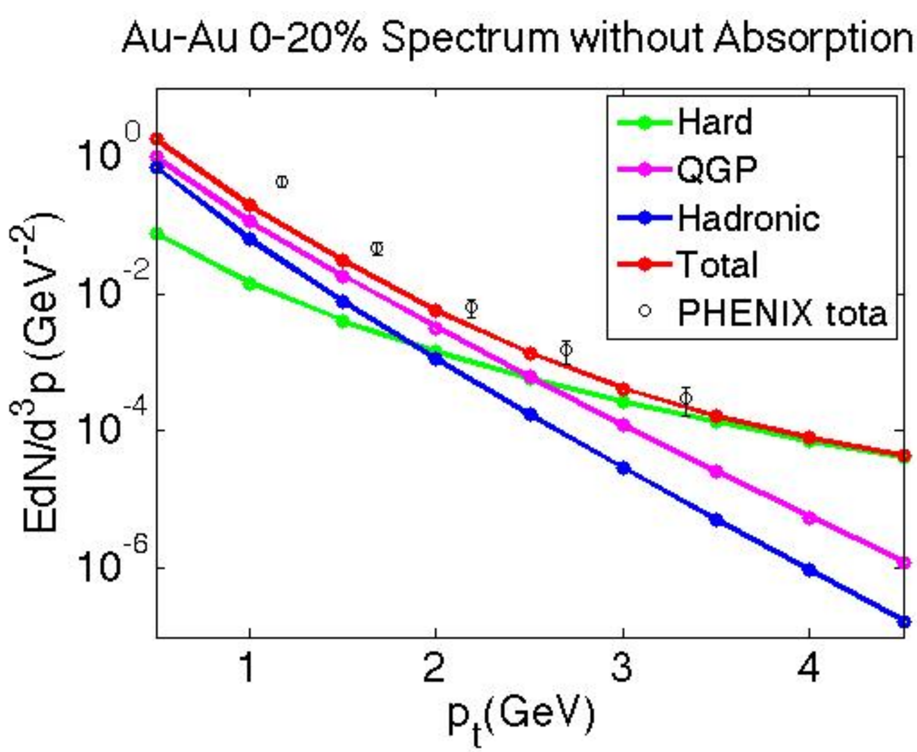


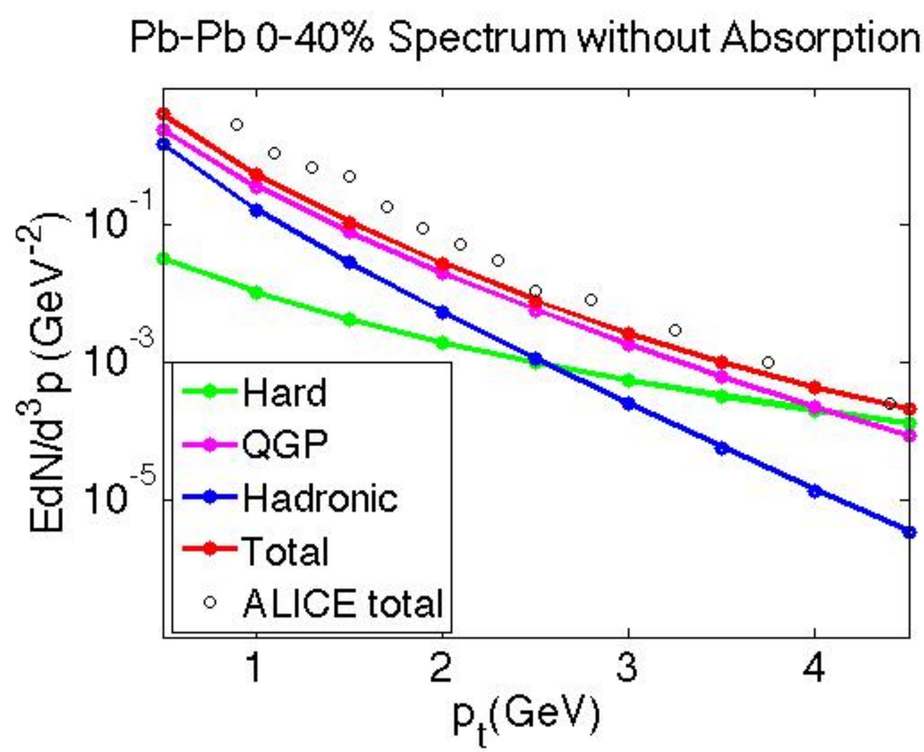
Elliptic Flow: Competing Effects

- Early anisotropy → shorter x distance traveled → increased v_2
- Late anisotropy → longer x distance traveled → decreased v_2
- Flow: faster expansion along x → lower momentum in medium's rest frame
→ more absorption along x→ decreased v_2

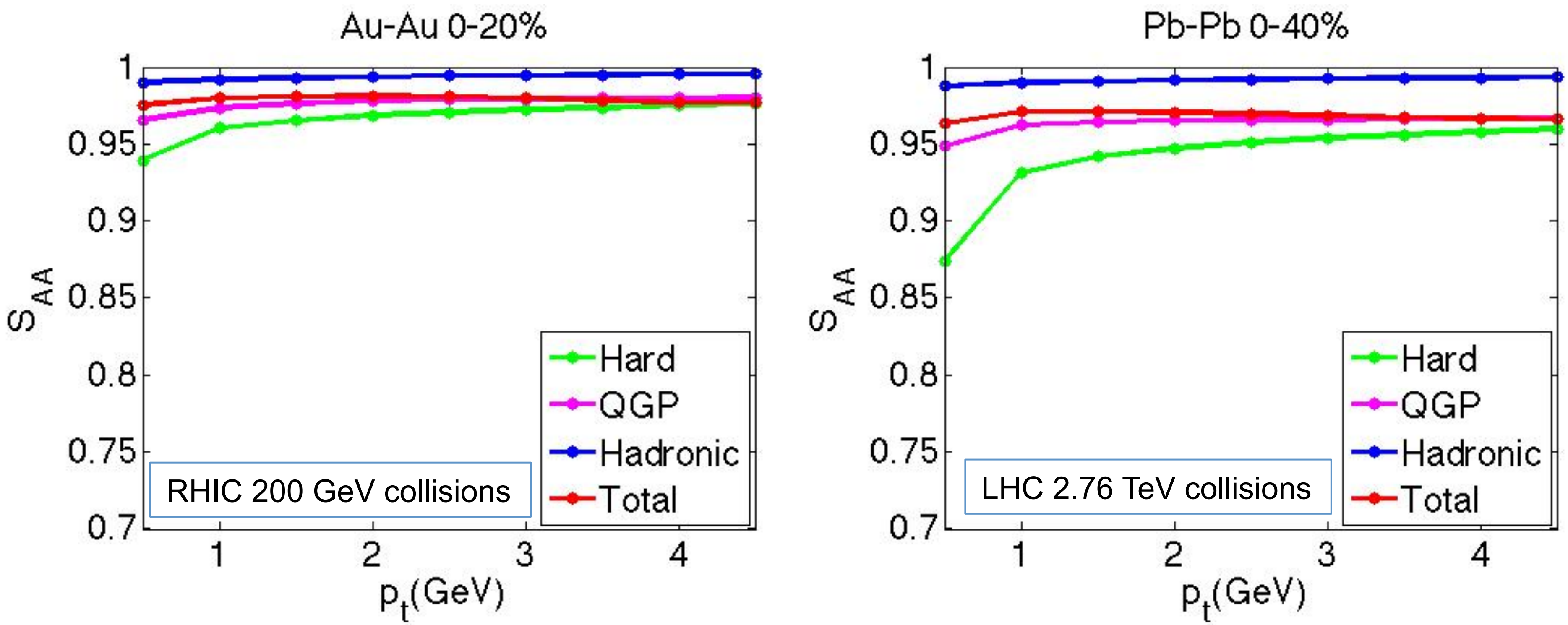


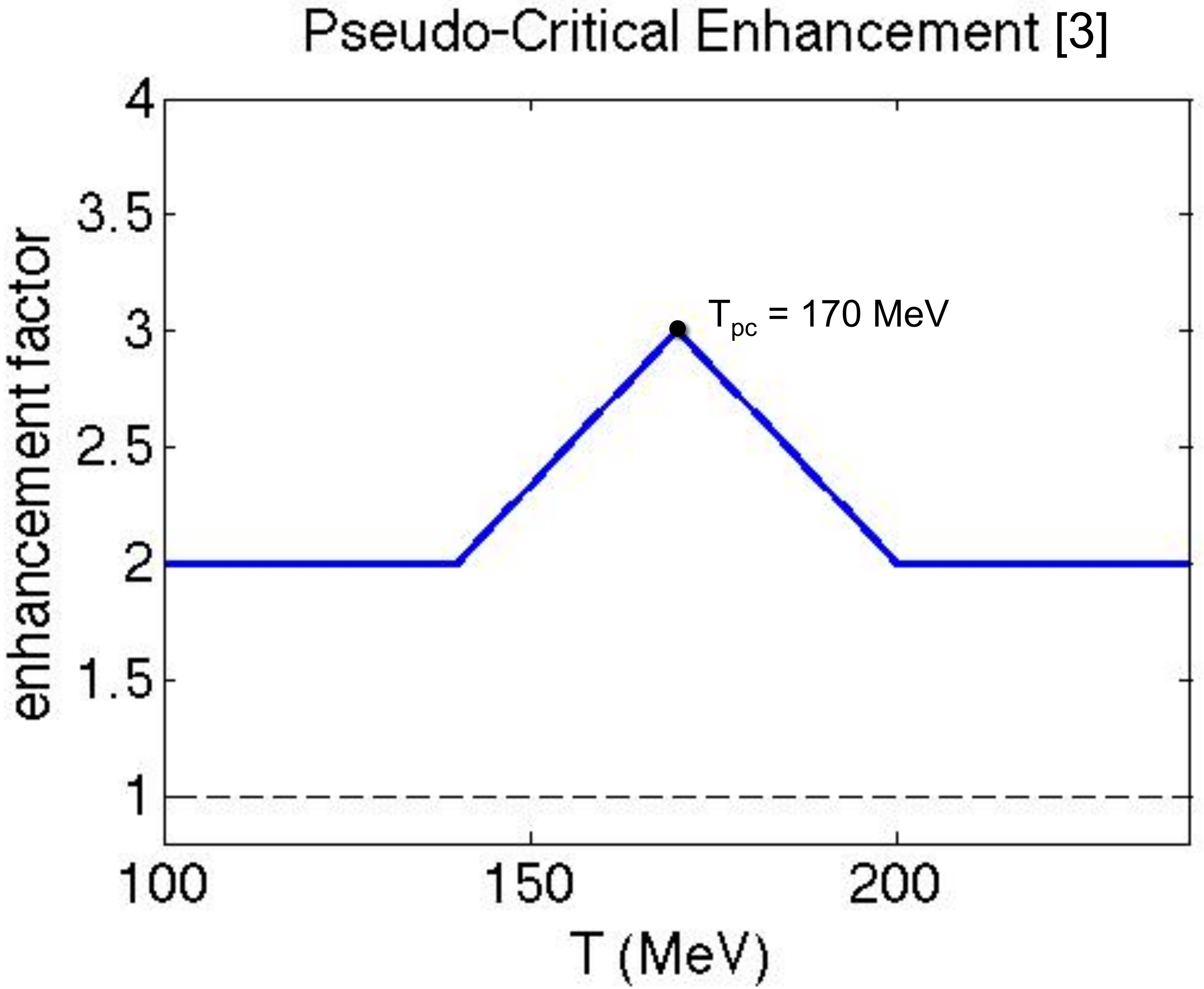
Photon Spectra for Au-Au and Pb-Pb Collisions





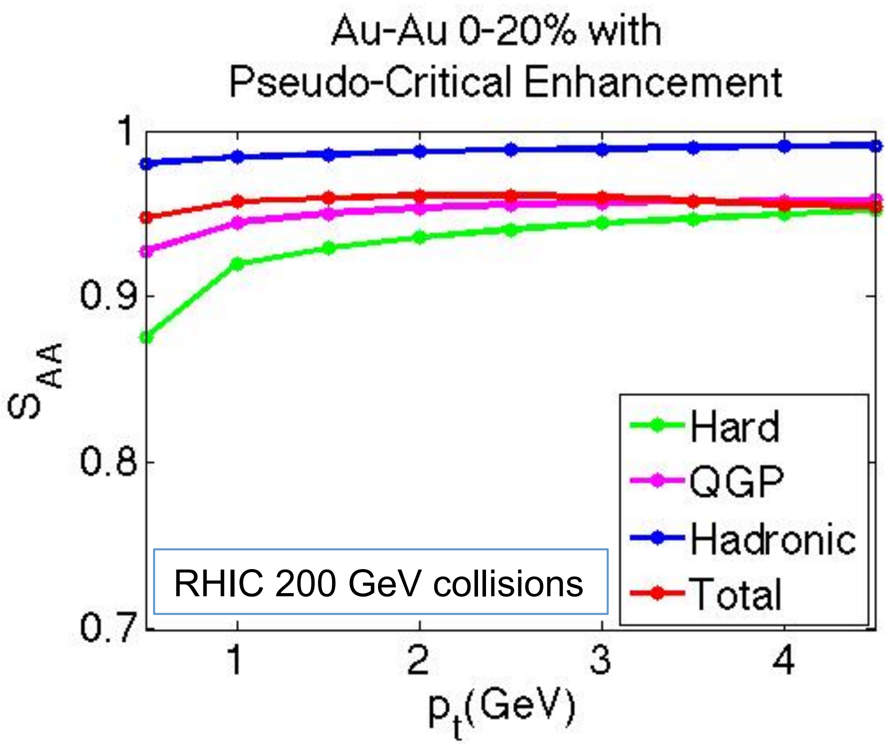
S_{AA} for Au-Au and Pb-Pb Collisions

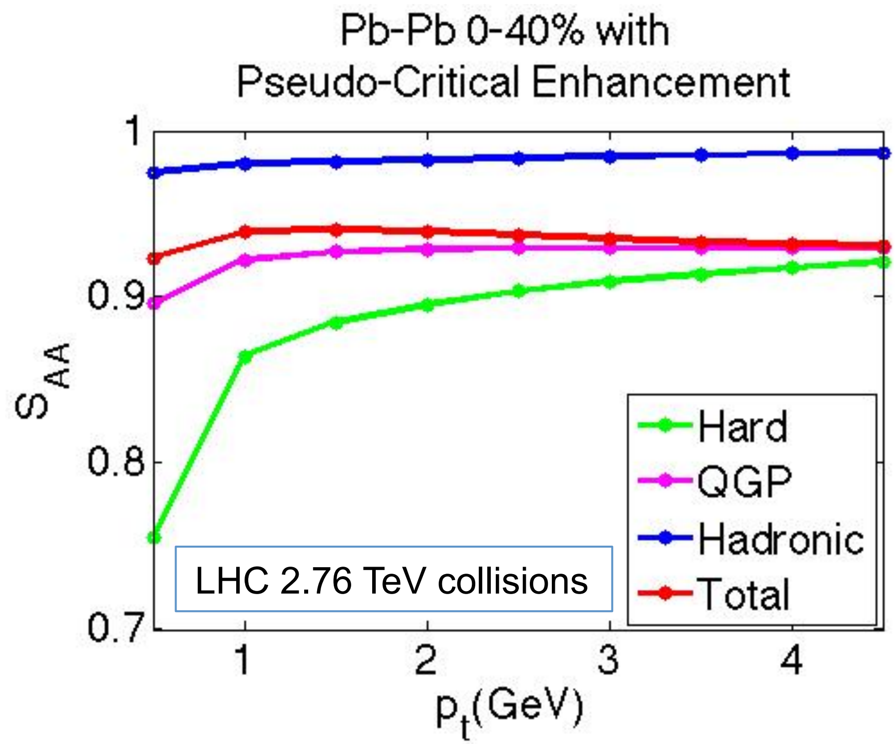




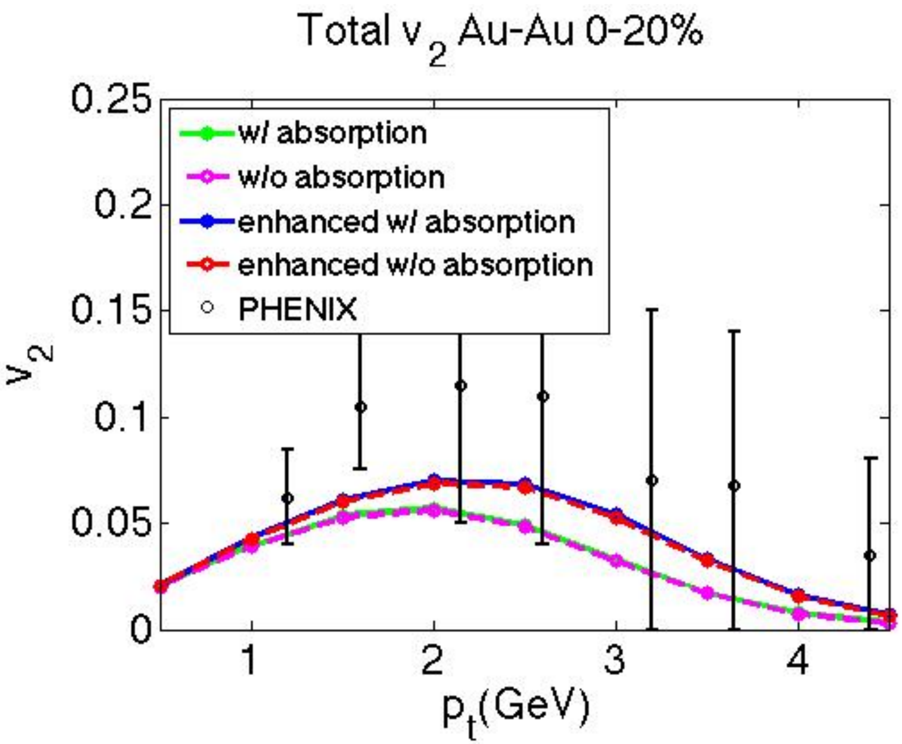
Pseudo-Critical Enhancement [3]
enhancement factor
T (MeV)
T_pc = 170 MeV
4
3.5
3
2.5
2
1.5
1
100
150
200

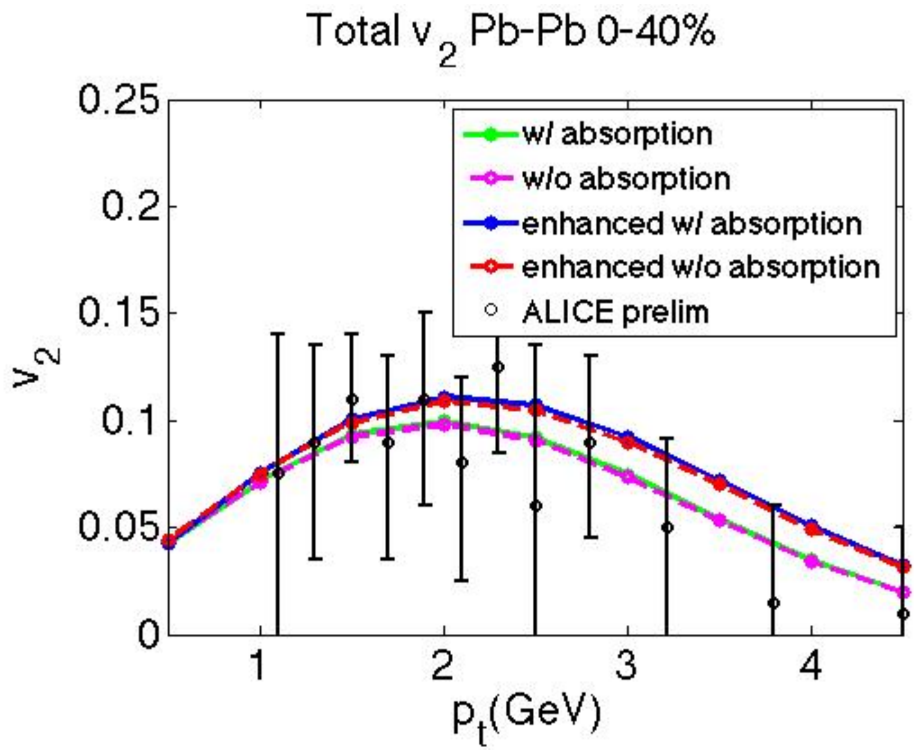
S_{AA} for Au-Au and Pb-Pb Collisions with a Pseudo-Critical Enhancement





v_2 for Au-Au and Pb-Pb Collisions with and without Absorption





Conclusions

- Hard photons show significant suppression (up to 13%) and even more so with a pseudo-critical enhancement (up to 24%).
- Thermal photons originating from the QGP also show some suppression, while those from the HG show little to no suppression.
- Mean free path is shortest for soft photons, about 30 fm for p = 0.5 GeV photons in T = 400 MeV QGP and 70 fm at T = 170 MeV. These number go to 15 and 23 fm when the pseudo-critical enhancement is applied.
- Absorption slightly increases v_2 hard and thermal photons

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