Enhancement of thermal photon production in event-by-event hydrodynamics

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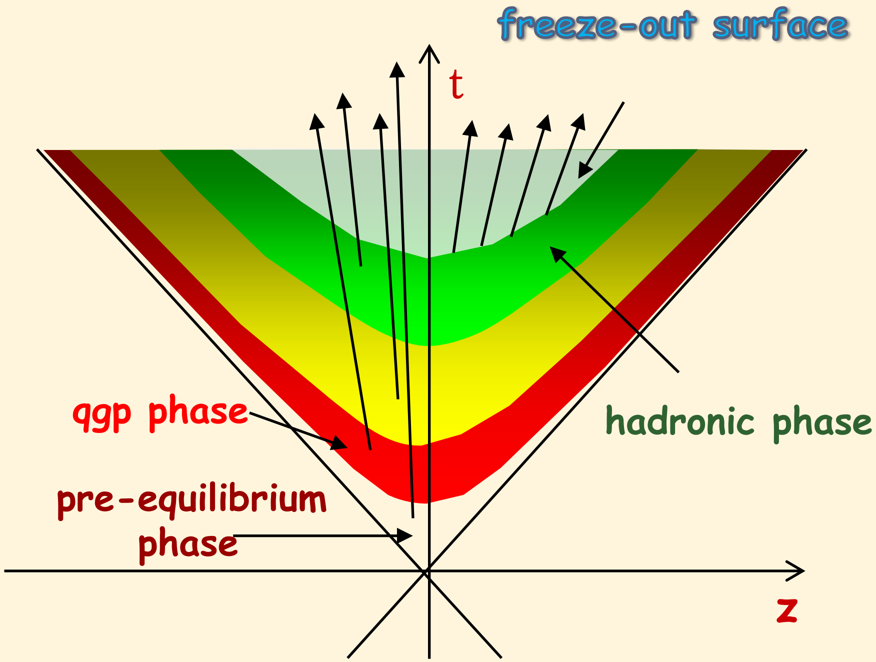
Plan of the talk:

- ♣ Thermal photons
- ♣ Event-by-event hydrodynamics
- ♣ Thermal photons from smooth and fluctuating initial conditions
- ♣ Time evolution and size parameter dependence
- ♣ Summary & conclusions.

Photons come out from every phase of the expanding system



- One of the most efficient and promising probes to characterize the initial state.

- suffer negligible final state interactions.

- carry undistorted information about the medium conditions at their production points.

- **Thermal photons:** from hot and dense plasma phase and the relatively cooler hadronic matter phase.

- emission is sensitive to the initial temperature.

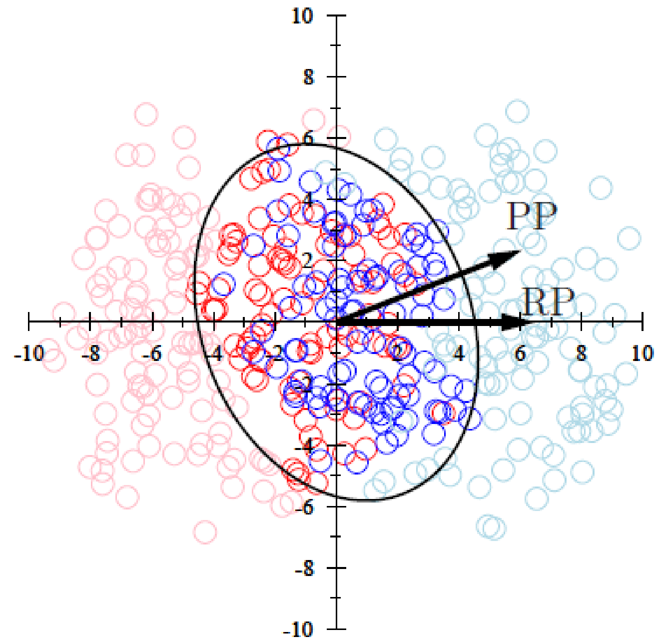
- especially suitable for probing fluctuations in the initial conditions.

Event-by-event hydrodynamics and initial density profile

- Event-by-event hydrodynamics from Hannu Holopainen et al., Phys. Rev. C 83, 034901 (2011). Talk by H. Holopainen on Friday.

- Monte Carlo Glauber Model: two nucleons i and j from different nuclei collide when

$$(x_i - x_j)^2 + (y_i - y_j)^2 \le \frac{\sigma_{NN}}{\pi}$$



- Entropy density s is distributed in the (x,y) plane around the wounded nucleons using a 2D Gaussian:

$$s(x,y) = \frac{K}{2\pi\sigma^2} \sum_{i=1}^{N_{WN}} \exp\left(- \frac{(x - x_i)^2 + (y - y_i)^2}{2\sigma^2} \right)$$

- σ is a free parameter determining the size of the fluctuation.

- Successfully reproduces both the measured centrality dependence and the p_T shape of charged particle elliptic flow upto p_T ~ 2GeV.

Initial parameters for 200A GeV Au+Au@RHIC

- Default value of σ = 0.4 fm,

(However σ is varied from 0.4 to 1.0 fm to check the sensitivity of the results).

- τ_0=0.17 fm/c => from EKRT minijet saturation model.

(Eskola et al. NPB570, 379 (2000).)

- 0-20% Au+Au @RHIC, N_{part} fluctuates from 391 to 197.

Corresponding average impact parameter ~ 4.4 fm.

- EOS from Laine and Schroder, PRD 73, 085009 (2006).

- Temperature at Freeze-out 160 MeV.

- Photons from QGP: Arnold, Moore, and Yaffe, JHEP 0112, 009 (2001).
- Photons from hadronic matter: Turbide, Rapp, and Gale, Phys. Rev. C 69, 014903 (2004).

The thermal photon emission from the QGP and the hadronic phases are obtained by integrating the emission rates R (=E dN/d^3pd^4x) over the space time history of the fireball as

$$E\, dN_\gamma/d^3p = \int d^4x\, R(E^*(x), T(x))$$

Where, $E^*(x) = p^\mu . u_\mu(x)$

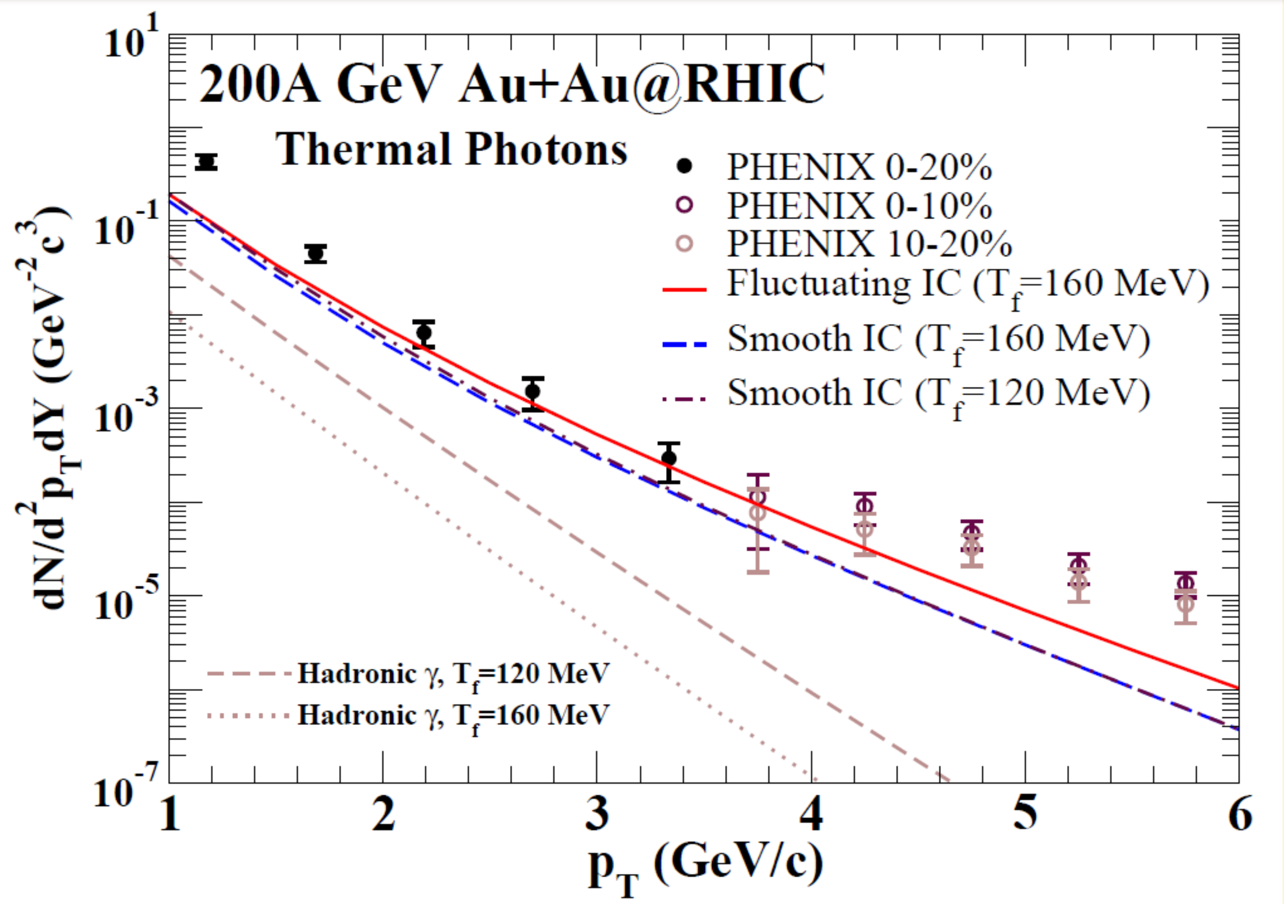
p^μ =>4-momentum of the photons

u_μ=>4 velocity of the flow field

d^4x =>4-volume element.

$$p^\mu . u_\mu = \gamma_T [\, p_T \cosh(Y - \eta) - p_x v_x - p_y v_y]$$

Thermal photons from smooth and fluctuating initial density profiles



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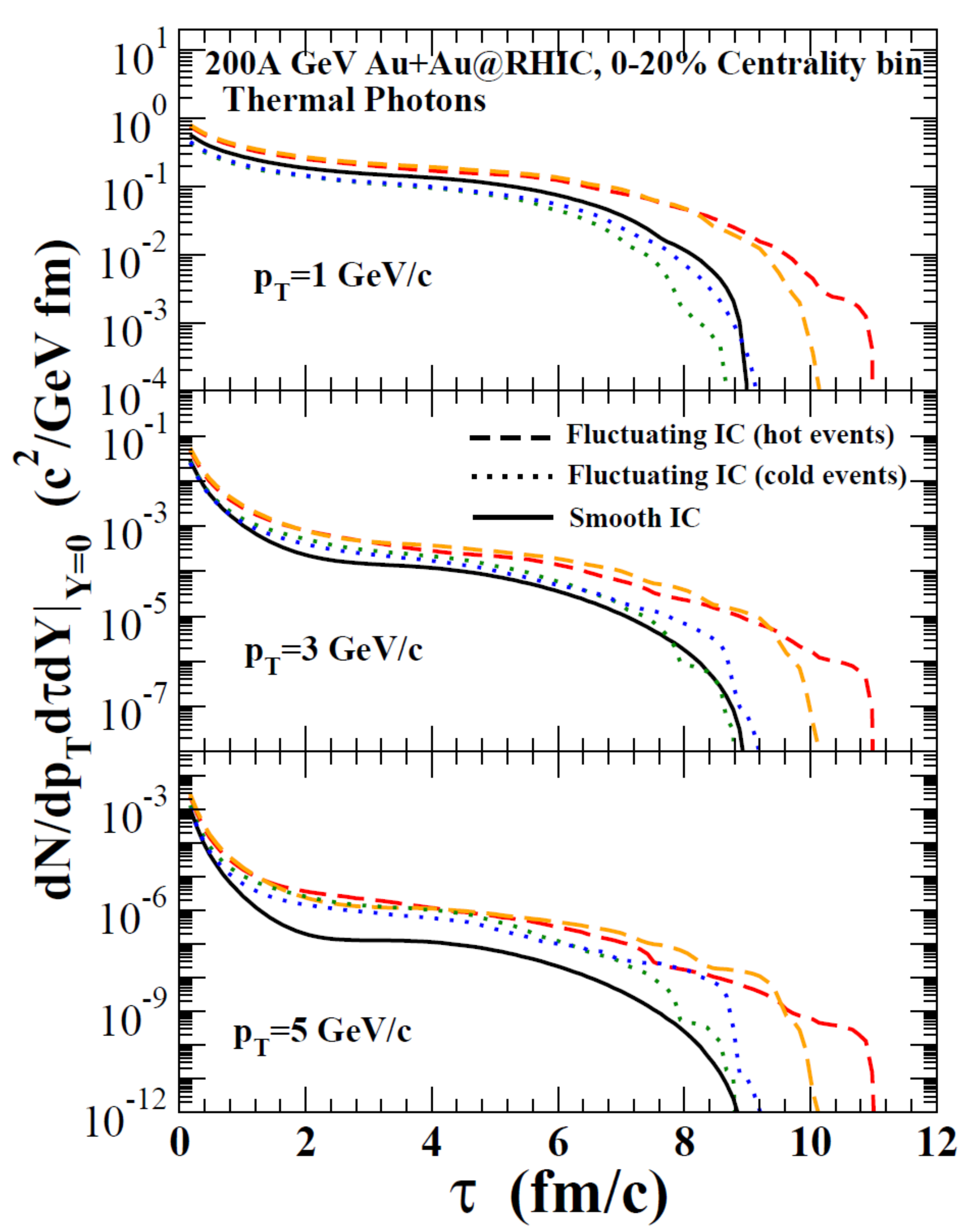
- The hotspots in the fluctuating events produce more high p_T photons compared to the smooth profile.

- Note: Hardening of hadron spectra from fluctuating IC is due to different reason.

Time evolution



- Results from smooth and fluctuating initial conditions.

- Two very hot events and two relatively cold events are chosen for the fluctuating IC.

Hot events: entropy larger than average entropy.
Cold events: entropy smaller than average entropy.

- The cold events produce more photons compared to the smooth IC for $p_T \geq 3$ GeV/c due to the presence of hotspots.

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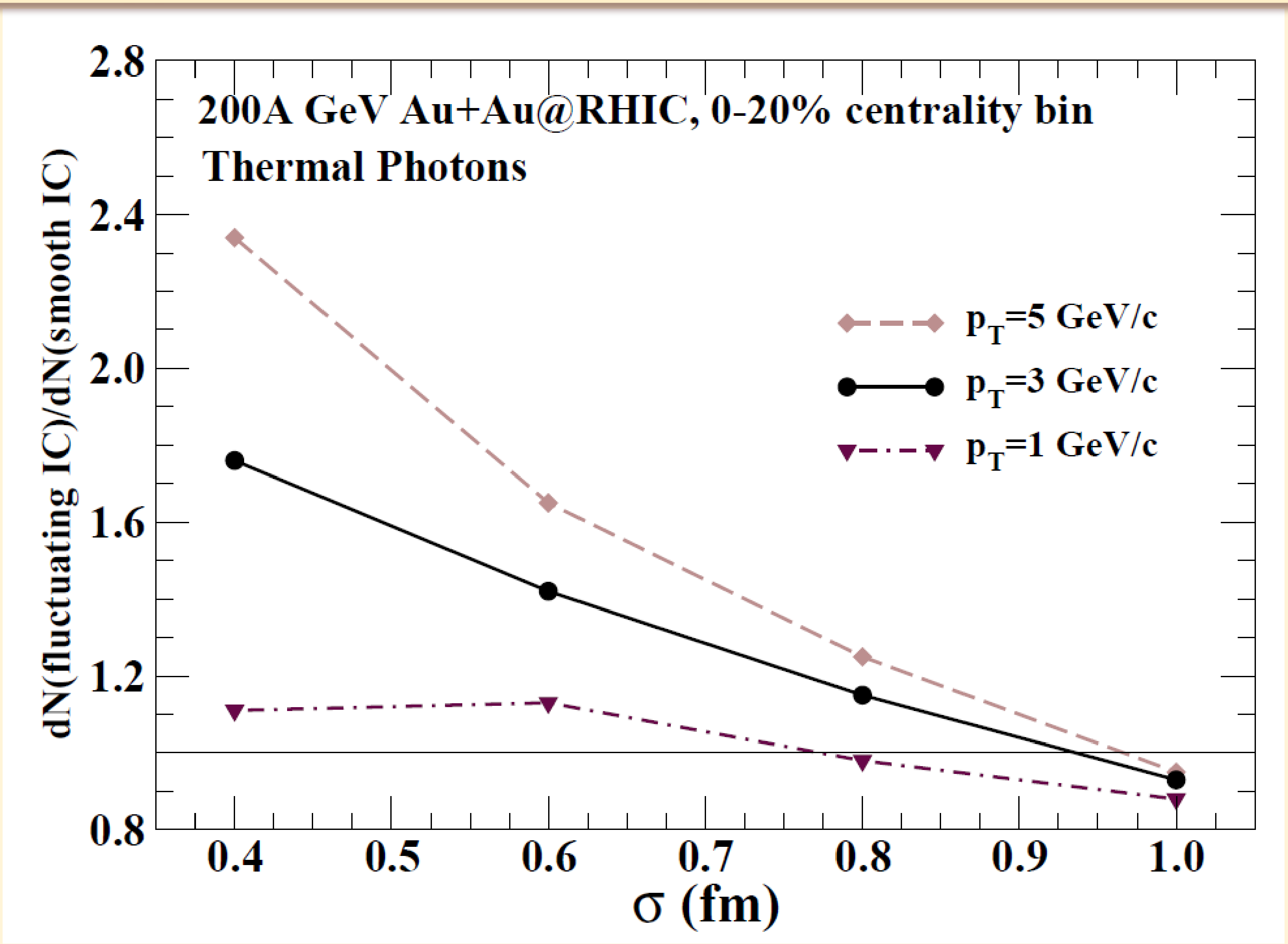
Ratio of photon production from fluctuating and smooth IC at different p_T as a function of the size parameter σ.



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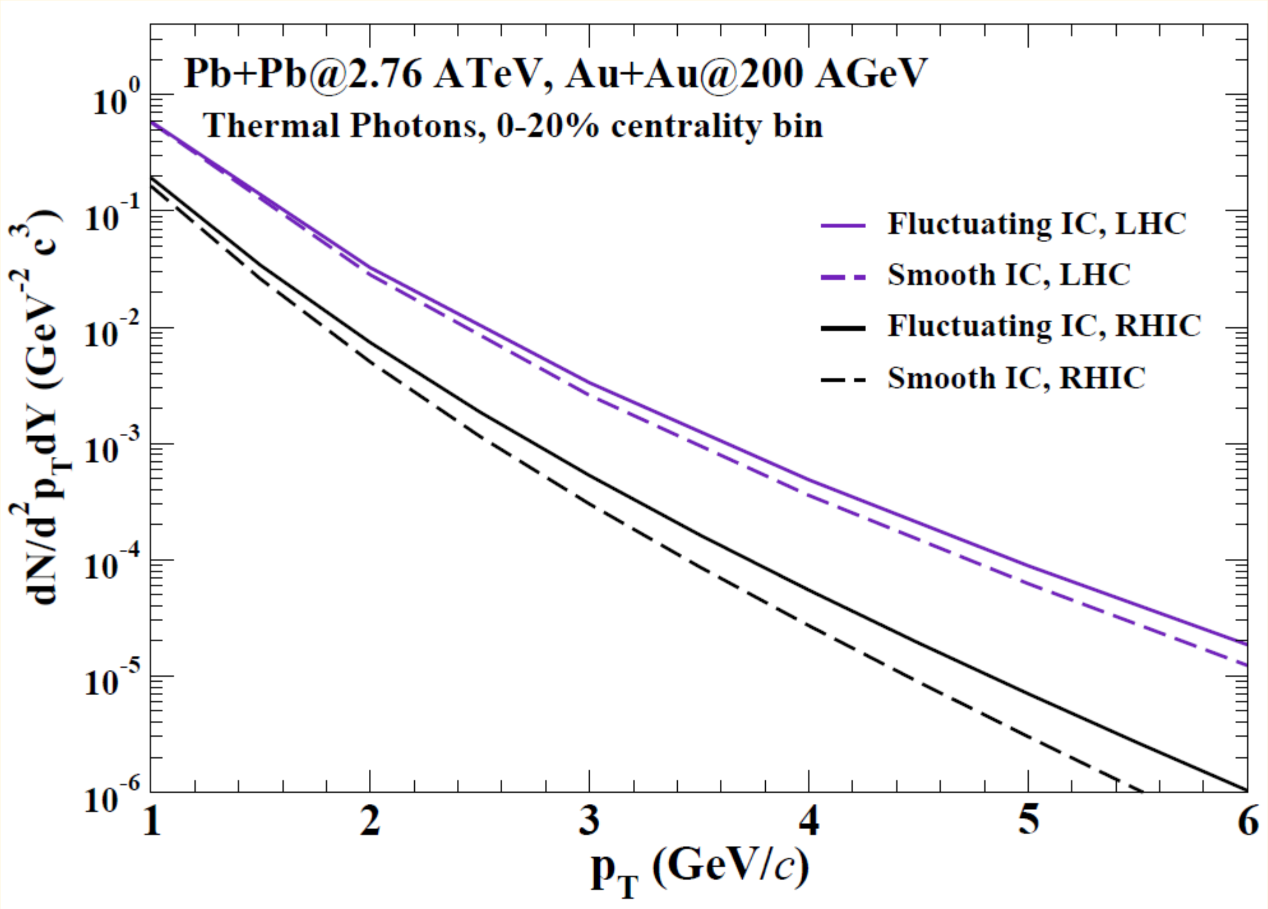
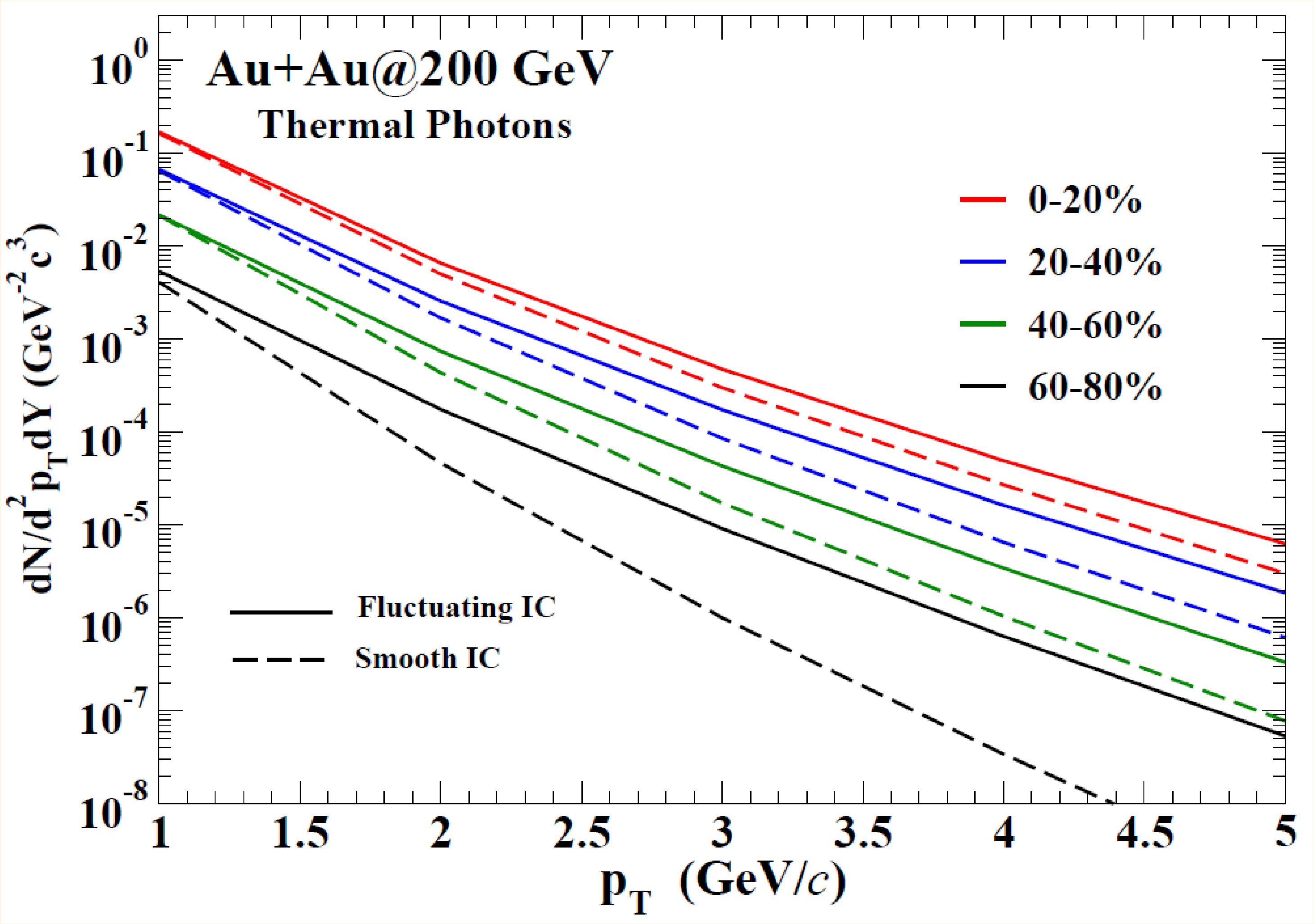
Thermal photons from smooth and fluctuating IC, RHIC and LHC



τ_0 at LHC=0.12 fm/c

in preparation, RC, H. Holopainen, T. Renk, and K. Eskola

Thermal photons from fluctuating IC; centrality dependence



in preparation, RC, H. Holopainen, T. Renk, and K. Eskola

Summary and Conclusions

- Fluctuations in the initial density distribution enhance the production of thermal photons compared to a smooth initial state averaged profile in the ideal hydrodynamic calculation.

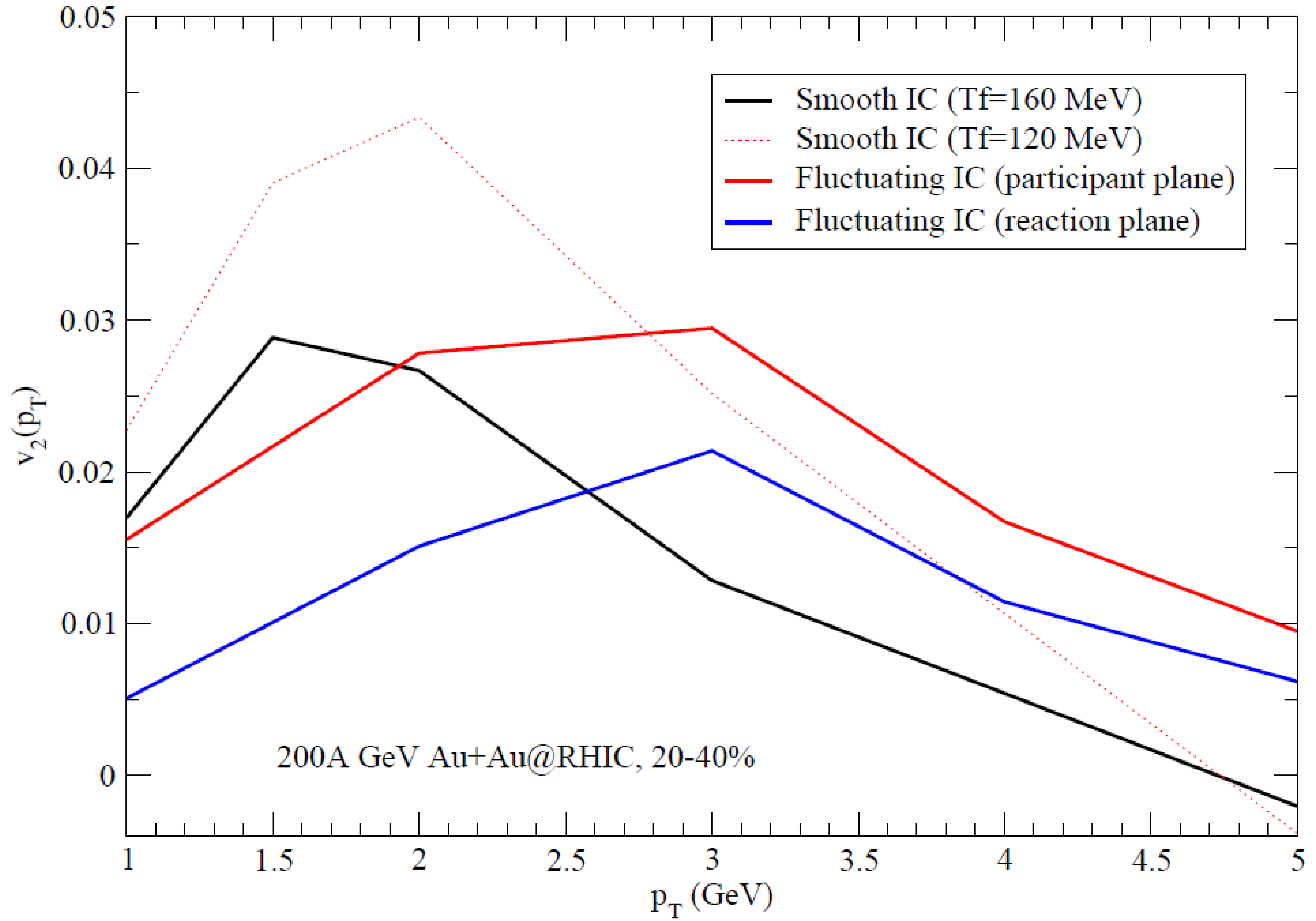
- The enhancement is a result of the strong temperature dependence of the thermal photon emission rates which specifically probe the hotspots in the profile.

- The difference between the fluctuating and the smooth IC is an early time effect when the radial flow is still very small.

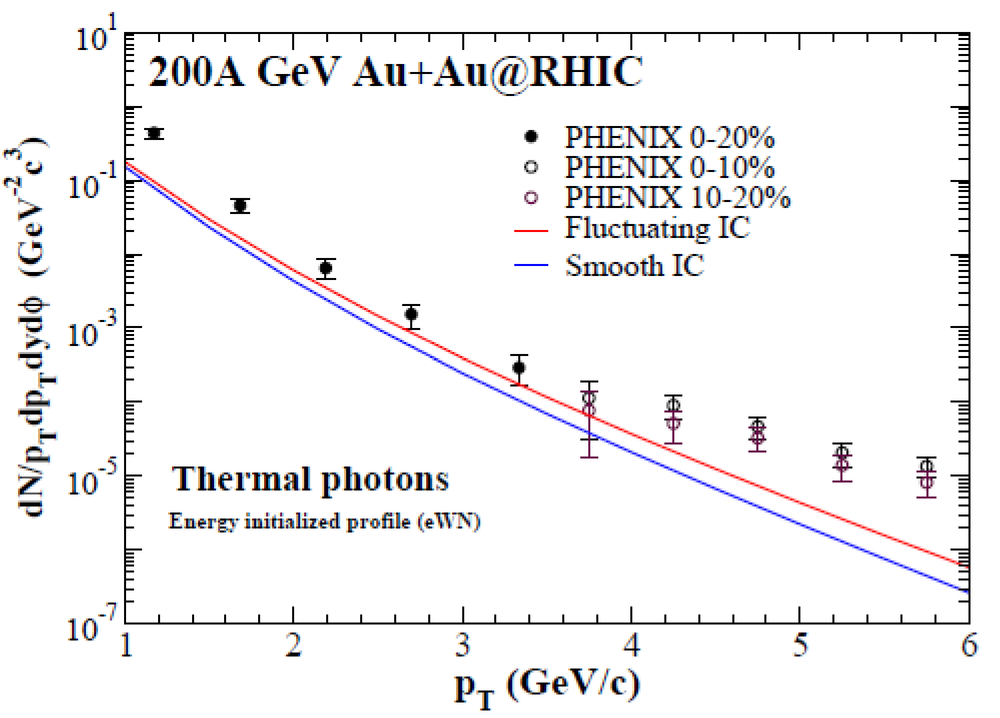
- The enhancement strongly depends on the value of the size parameter σ.

- The difference between the smooth and fluctuating profiles is expected to increase towards peripheral collisions and for lower beam energies.

- Photon elliptic flow results from event-by-event hydrodynamics would be very interesting.



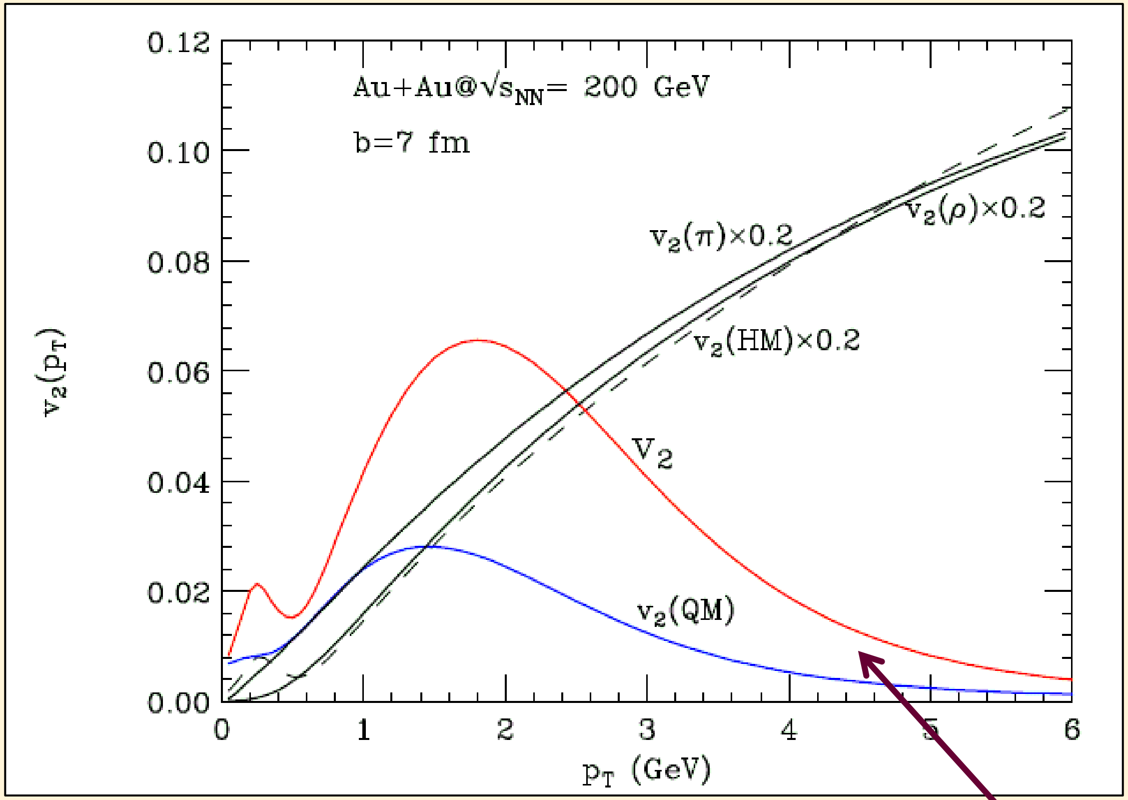
Smooth IC (Tf=160 MeV)
Smooth IC (Tf=120 MeV)
Fluctuating IC (participant plane)
Fluctuating IC (reaction plane)
200A GeV Au+Au@RHIC, 20-40%
v2(pT)
pT (GeV)
0.05
0.04
0.03
0.02
0.01
0
1
1.5
2
2.5
3
3.5
4
4.5
5



200A GeV Au+Au@RHIC
PHENIX 0-20%
PHENIX 0-10%
PHENIX 10-20%
Fluctuating IC
Smooth IC
Thermal photons
Energy initialized profile (eWN)
$dN/p_T dp_T dy d\phi$ $(GeV^{-2}c^{3})$
p_T (GeV/c)
10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{-7}
1
2
3
4
5
6

First prediction of thermal photon elliptic flow at Relativistic Heavy Ion Collider (RHIC)

Elliptic flow of thermal photons as function of transverse momentum p_T shows interesting nature . . . .



v_2 is not simple addition of $v_2(QM)$ and $v_2(HM)$.

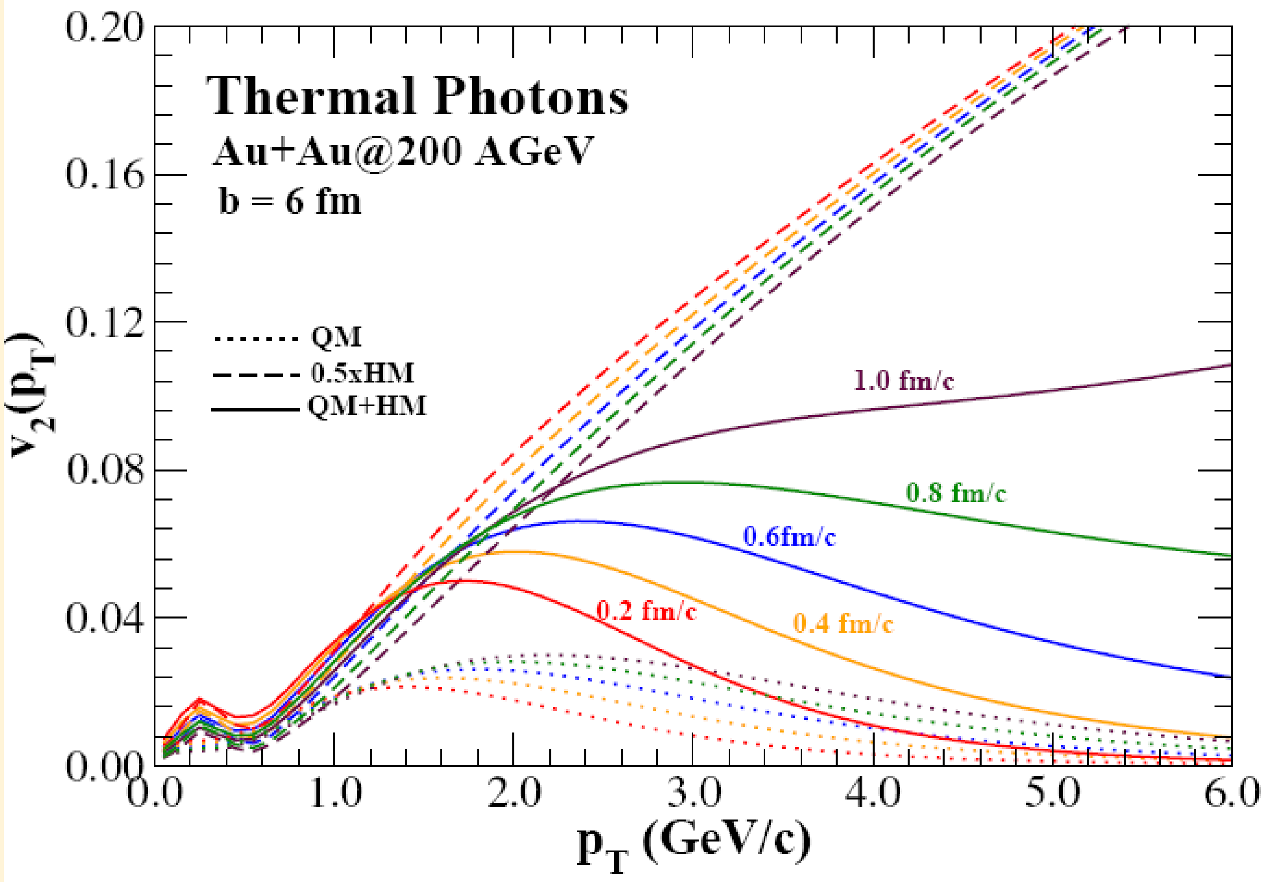
$$v_2 = \frac{v_2(QM) * dN(QM) + v_2(HM) * dN(HM)}{dN(QM) + dN(HM)}$$

- Sum v_2 tracks $v_2(QM)$ at high p_T.
- Interesting structure at p_T ~ 0.4 GeV/c, should sustain in the experimental data.

R. Chatterjee, E. Frodermann, U. Heinz, D. K. Srivastava, Phys. Rev. Lett. 96, 202302 (2006).

- Elliptic flow of thermal photon shows a completely different nature compared to the elliptic flow of hadrons at large values of transverse momentum and reflects the momentum anisotropies of initial partonic phase.

Formation time of the plasma from thermal photon elliptic flow



- v_2 for thermal photons reveals a large sensitivity to the initial time τ_0 for p_T greater than about 1.5 GeV/c.

- With smaller $\tau_{0,}$ QM contribution increases, however v_2(QM) decreases. v_2(HM) increases with smaller τ_0 and the overall v_2 decreases.

Rupa Chatterjee & D. K. Srivastava, Phys. Rev. C (Rapid Com.) 79, 021901(R) (2009).