Collision centrality and τ_0 dependence of the emission of thermal photons from fluctuating initial conditions

(arXiv: 1204.2249)

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Work done with:

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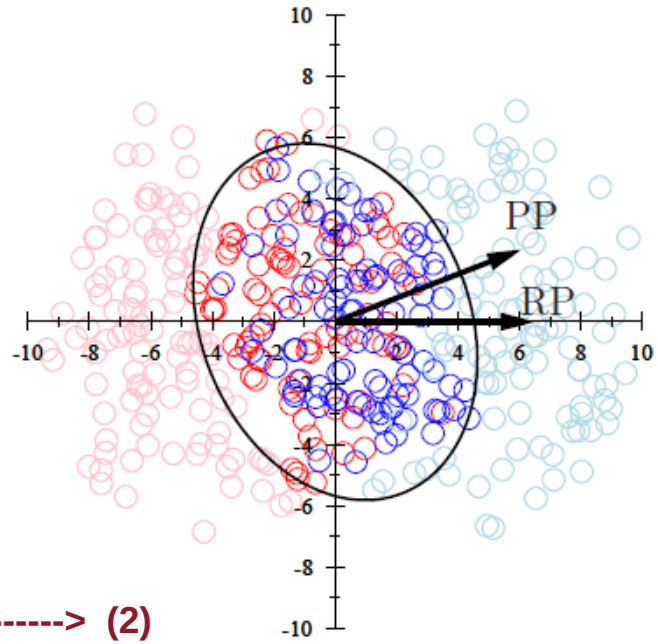
Event-by-event hydrodynamics and initial density profile

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

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

$$(x_i - x_j)^2 + (y_i - y_j)^2 \leq \frac{\sigma_{NN}}{\pi} \quad \text{-------> (1)}$$



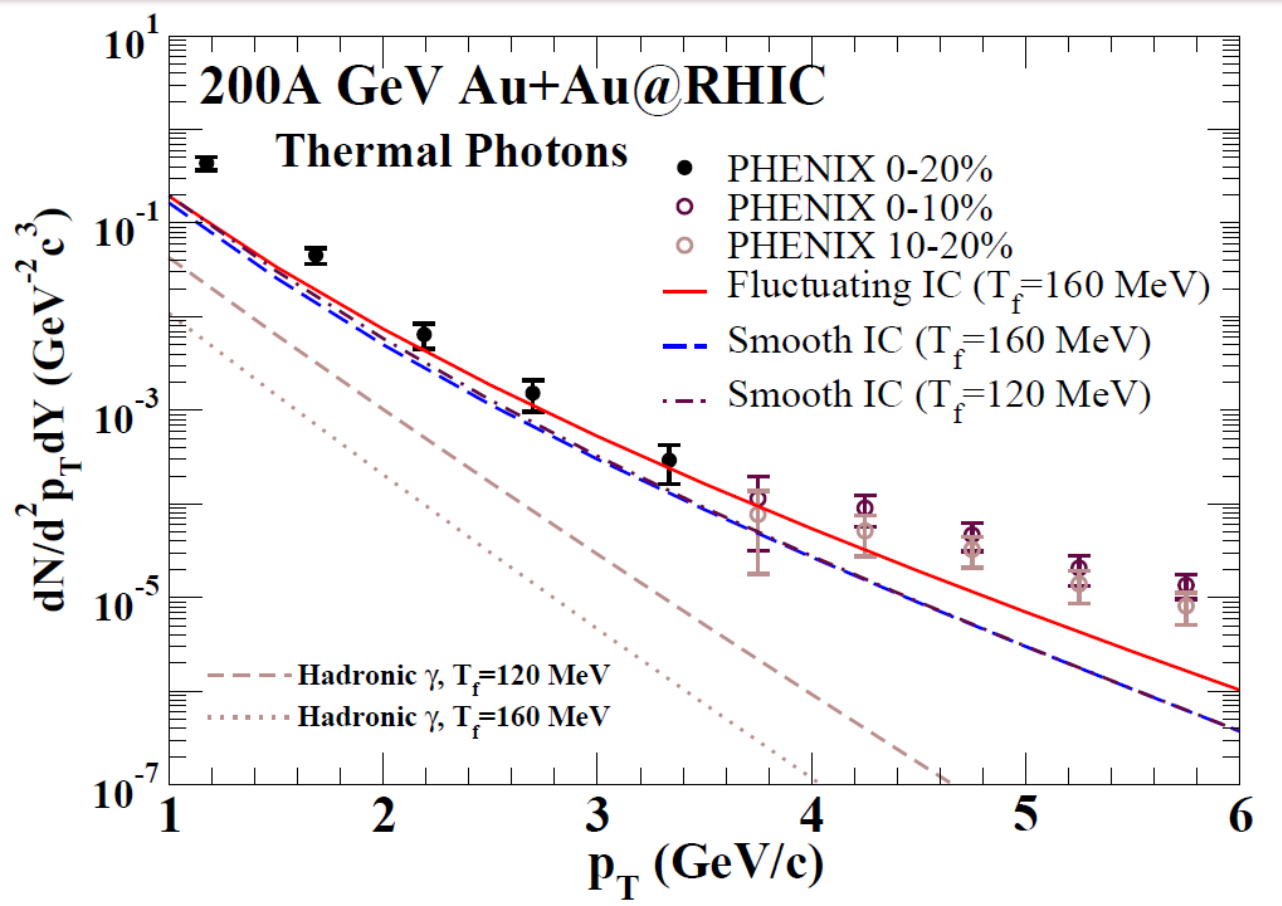
- Entropy density s is distributed in the (x,y) plane around the wounded nucleons using a 2D Gaussian:

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

- 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 $p_T \sim 2$ GeV.

Thermal photons from smooth and fluctuating initial density profiles



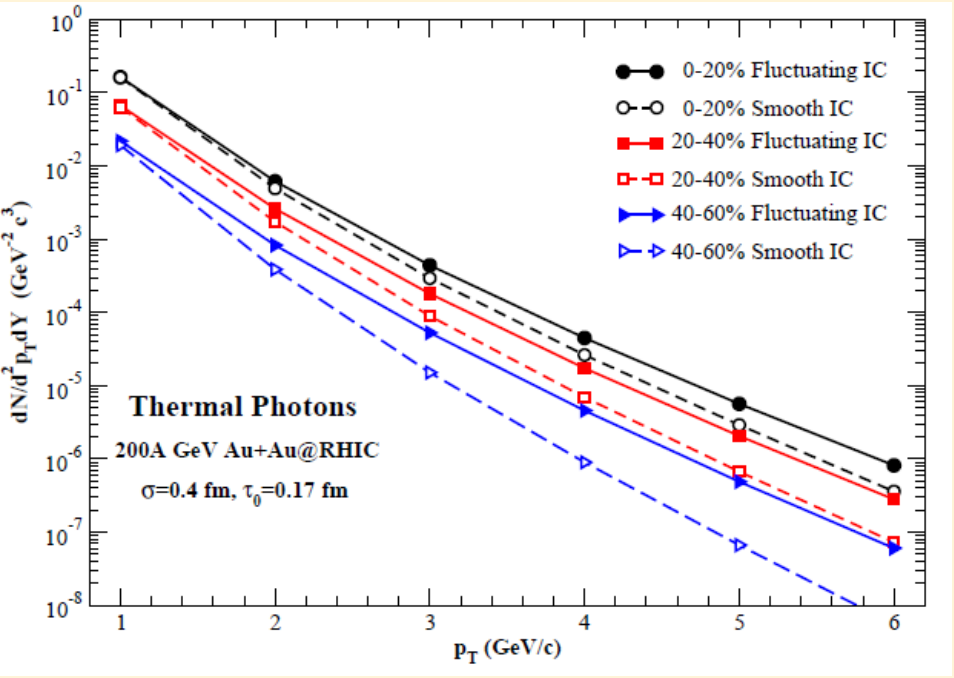
τ_0=0.17 fm/c
σ=0.4 fm

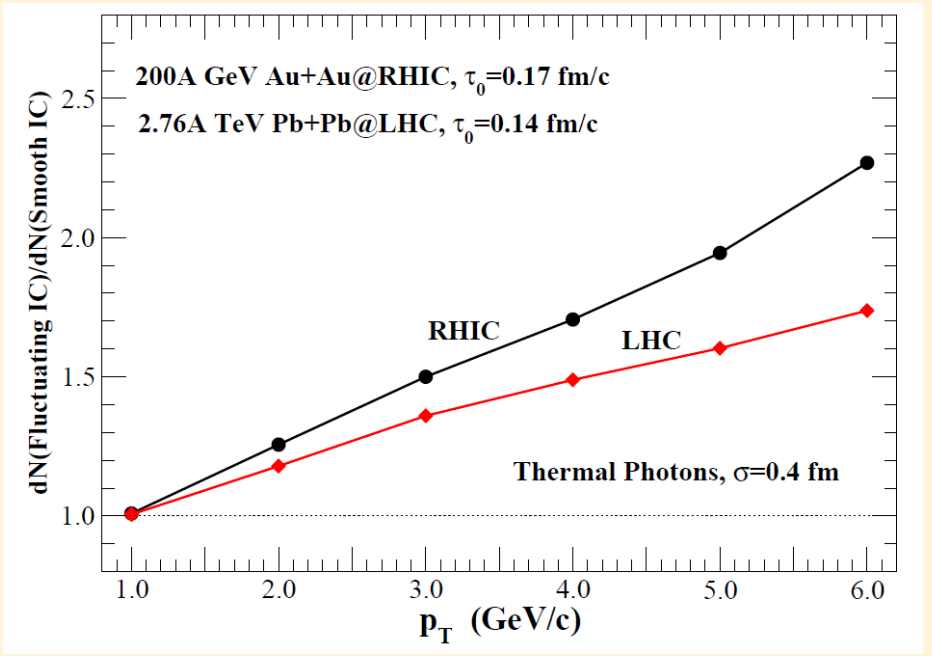
RC, Holopainen, Renk, Eskola
Phys. Rev. C 83, 054908 (2011)

- 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.

Thermal photons from smooth and fluctuating initial conditions: collision centrality and beam energy dependence





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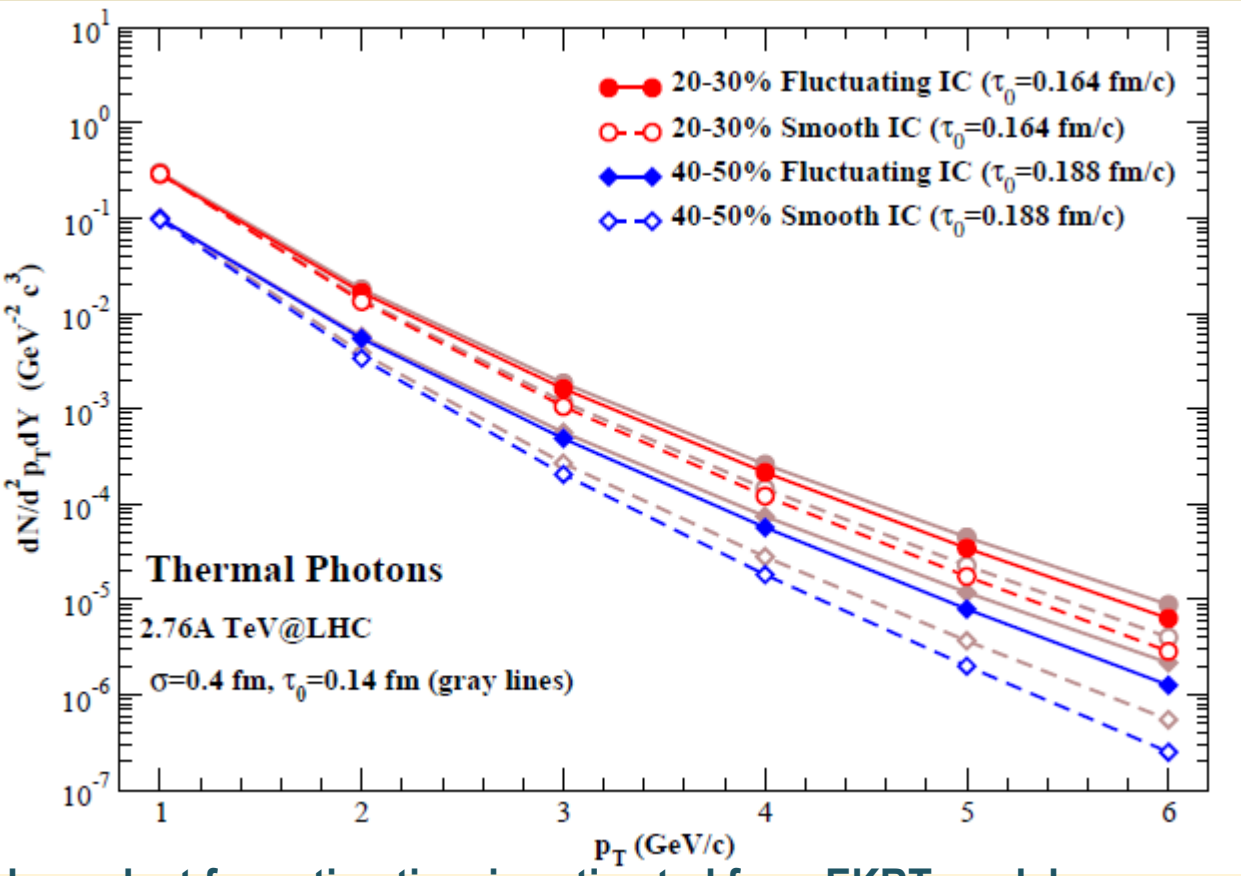
The effect of fluctuations in the IC is more pronounced for peripheral collisions and for lower beam energies.

Effect of centrality dependent formation time and fluctuating IC



RC, Holopainen, Renk, Eskola arXiv: 1204.2249

Centrality dependent formation time is estimated from EKRT model.

Centrality bin (%)	p_0 (GeV)	A_{eff}	τ_0 (fm)
0 – 5	1.3945	193	0.140
20 – 30	1.2070	90	0.164
40 – 50	1.0507	40	0.188

Table from R. Paatelainen

The p_T spectra alone are found to be insufficient to quantify the fluctuations in the IC due to uncertainties in the initial conditions.

A suitably normalized ratio of central to peripheral yield of thermal photons (R^{γ}_{cp}) can be a useful measure of the fluctuation size scale by reducing the uncertainties in the model calculation.

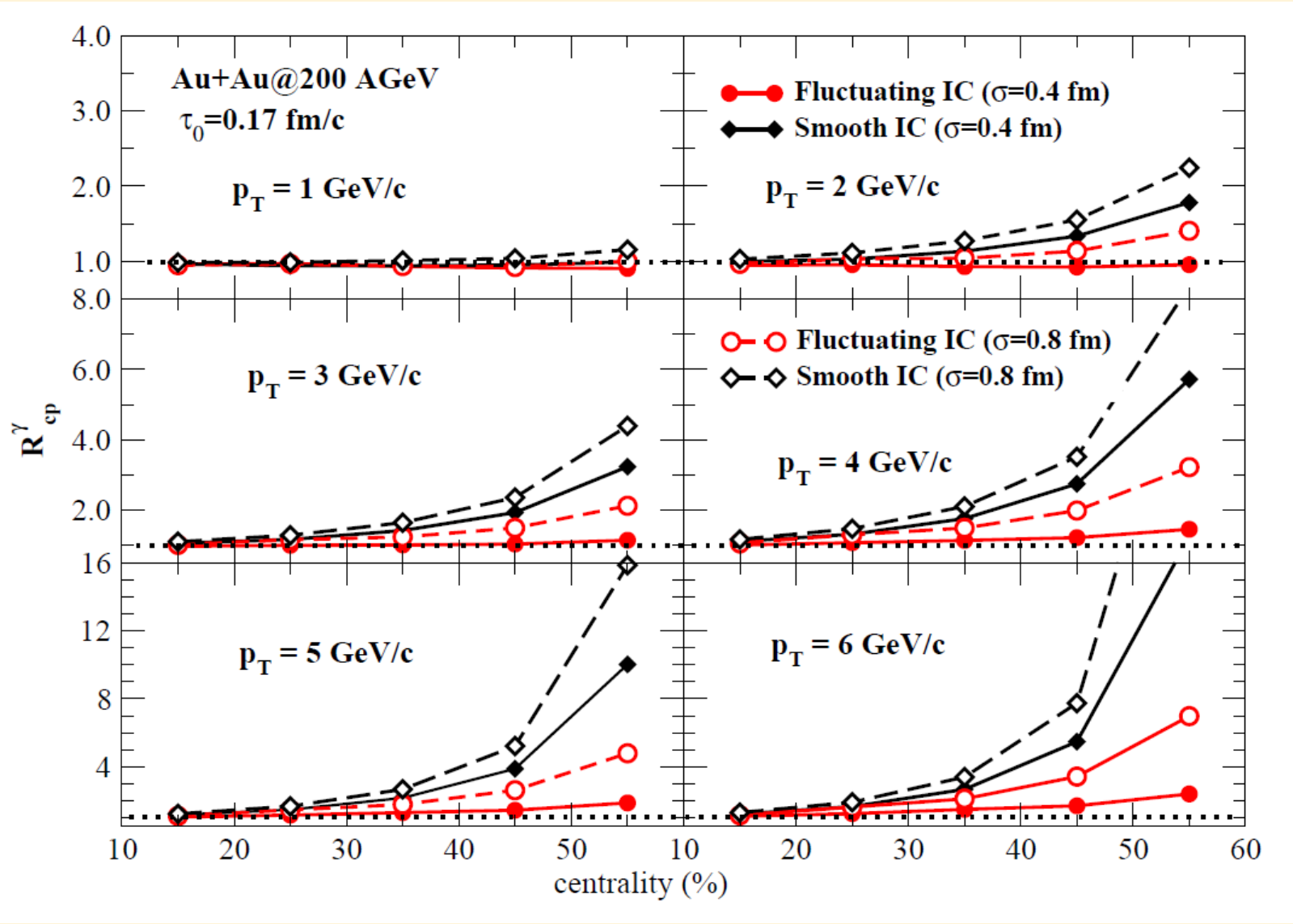
R^{γ}_{cp}, is defined as:

$$R^{\gamma}_{cp}|_i = \frac{dN/d^2p_T dY|_{0-10\%}}{dN/d^2p_T dY|_{i-j\%}} \times \frac{N_{bin}|_{i-j\%}}{N_{bin}|_{0-10\%}},$$

where the value of i is changed from 10 to 70 in steps of 10 and j=i+10. R^{γ}_{cp} is calculated as a function of collision centrality for different values of p_T and σ.

We choose a different definition of R^{γ}_{cp} rather than the conventional definition where the result from the most peripheral collision is kept fixed as a denominator and the numerator is changed for different centrality bins.

Thermal photons R^{γ}_{cp} at RHIC for σ values 0.4 & 0.8 fm



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Summary and conclusions

- Fluctuations in the initial QCD matter density distribution lead to a significant enhancement in the production of thermal photons compared to a smooth initial state averaged profile.

- The enhancement is found to be more pronounced for peripheral collisions than for central collisions. The relative enhancement is found to be comparatively less at LHC than at RHIC for the same centrality bin.

- The p_T spectra at RHIC and LHC are found to be quite sensitive to the value of the initial formation time which may also vary with collision centralities.

- The p_T spectra alone are found to be insufficient to quantify the fluctuations in the initial density distribution due to the uncertainties in the initial conditions.

- A suitably normalized ratio of central-to-peripheral yield as a function of collision centrality and p_T can be a useful measure of the fluctuation size scale.

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).)

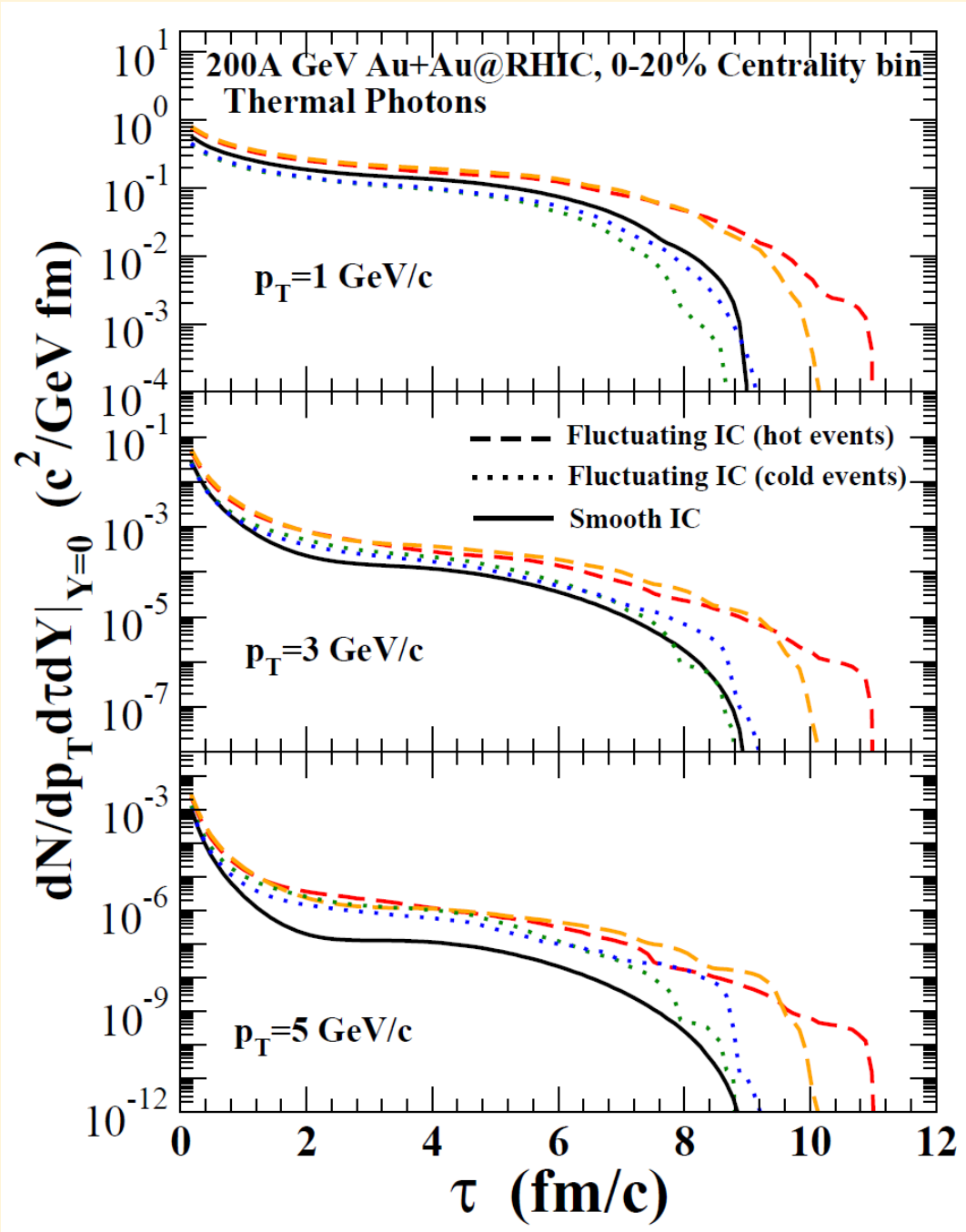
- 0-20% Au+Au @RHIC, N_{part} fluctuates from 391 to 197.

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).



Time evolution

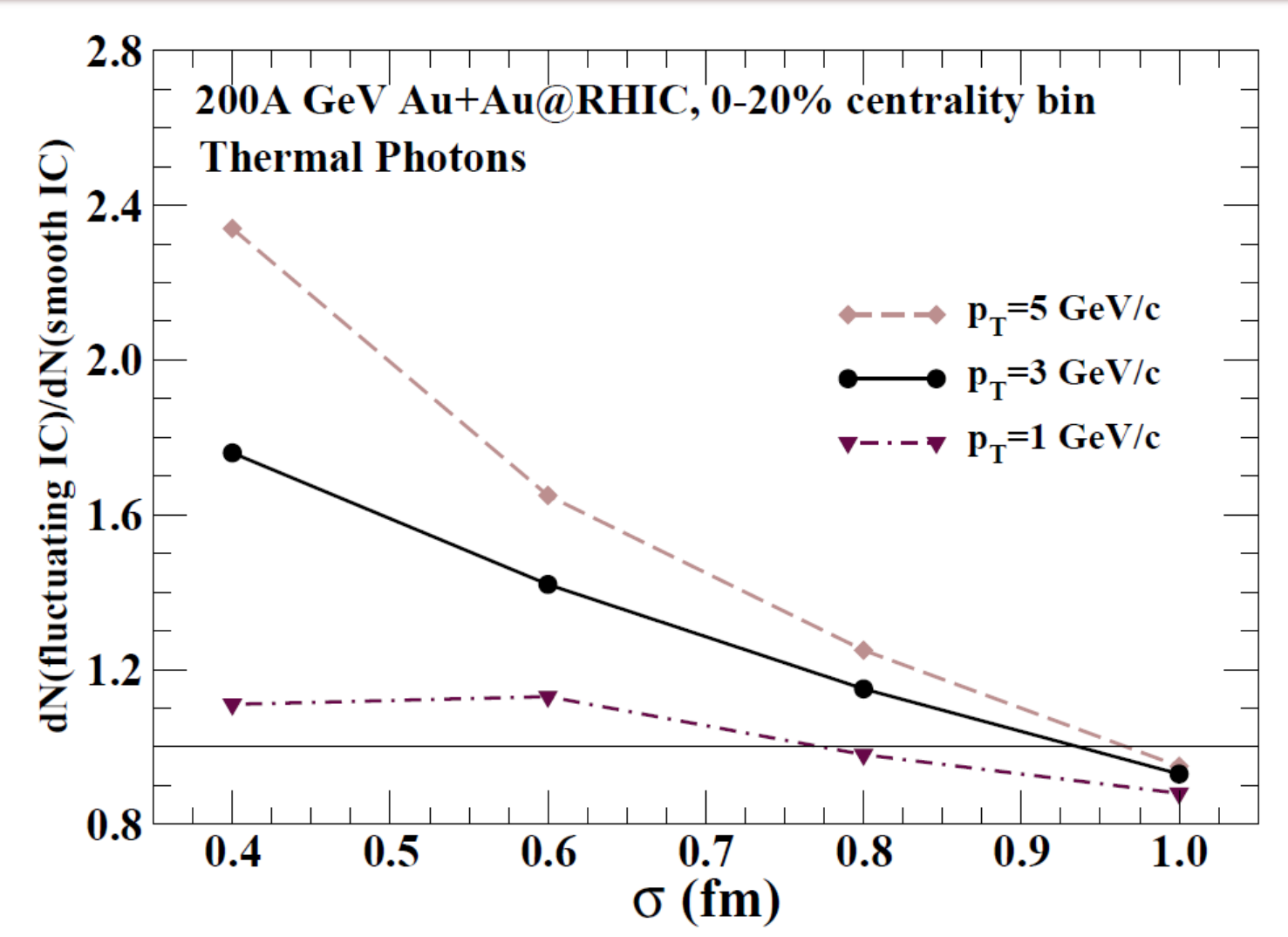
- Results from smooth and fluctuating initial conditions.
- Two very hot events and two relatively cold events are chosen for the fluctuating IC.

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.

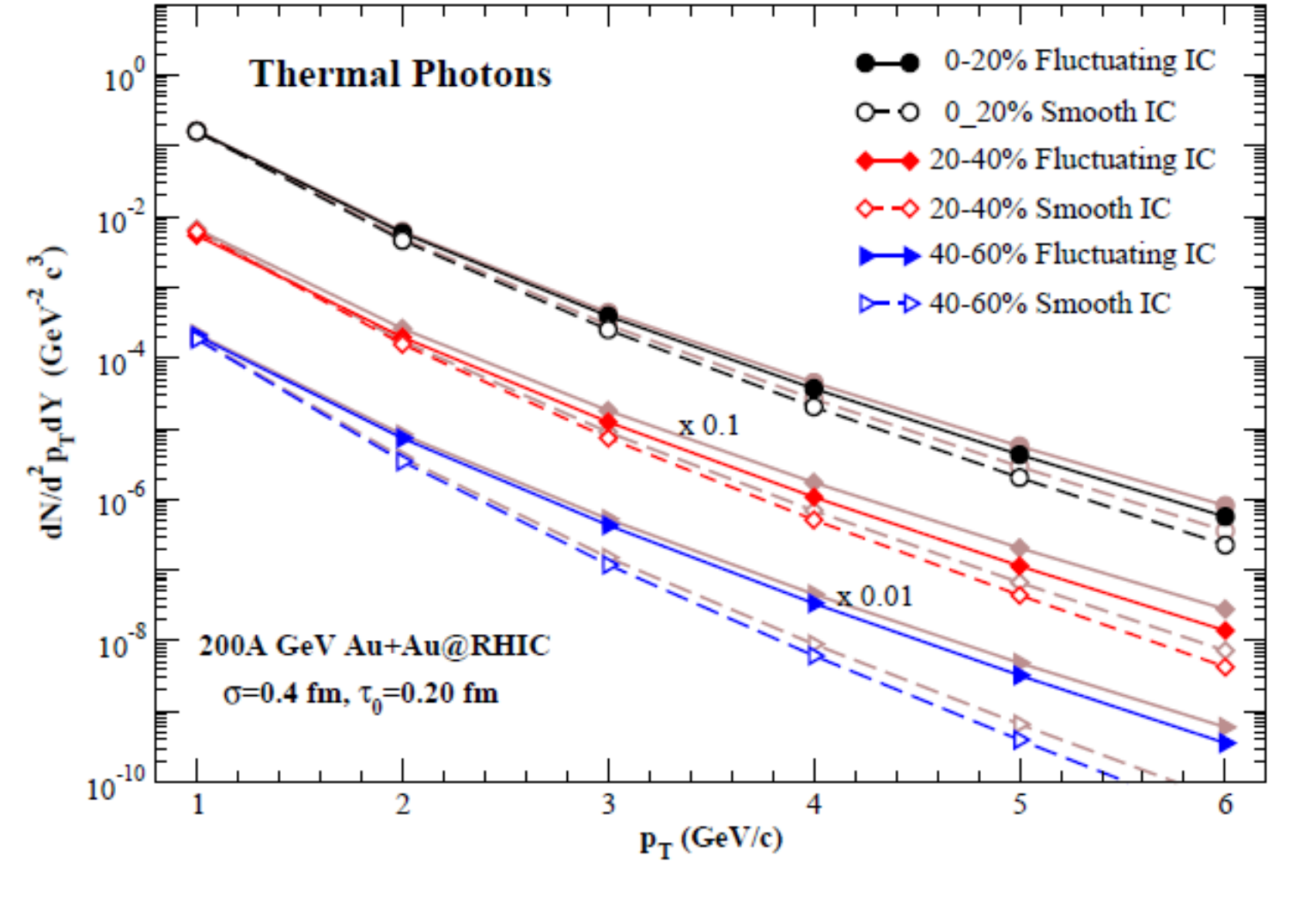
Phys. Rev. C 83, 054908 (2011)

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

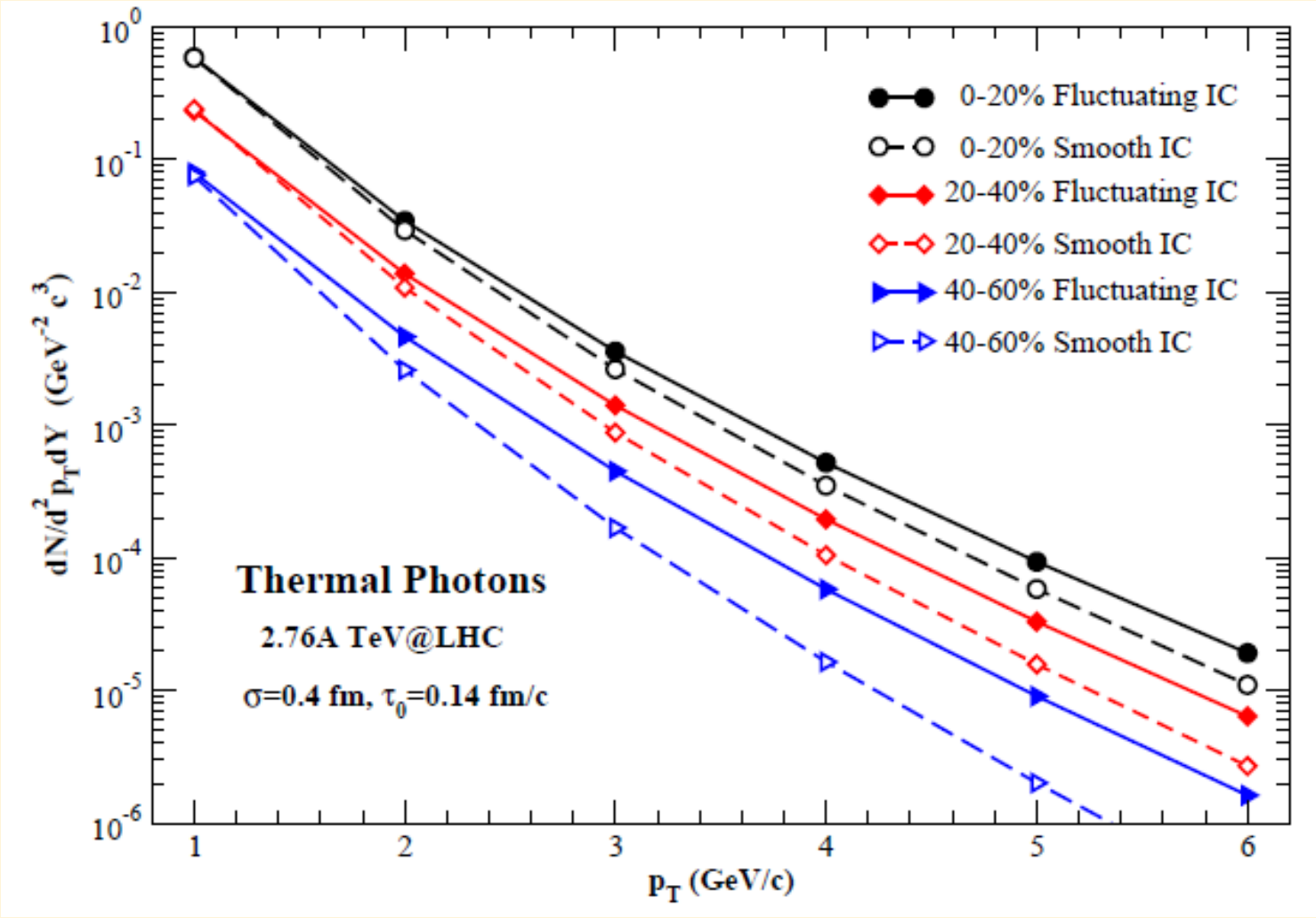


Phys. Rev. C 83, 054908 (2011)

Thermal photons from smooth and fluctuating IC at RHIC comparison between results from τ_0= 0.17 and 0.20 fm/c



Thermal photons from fluctuating IC; centrality dependence @LHC



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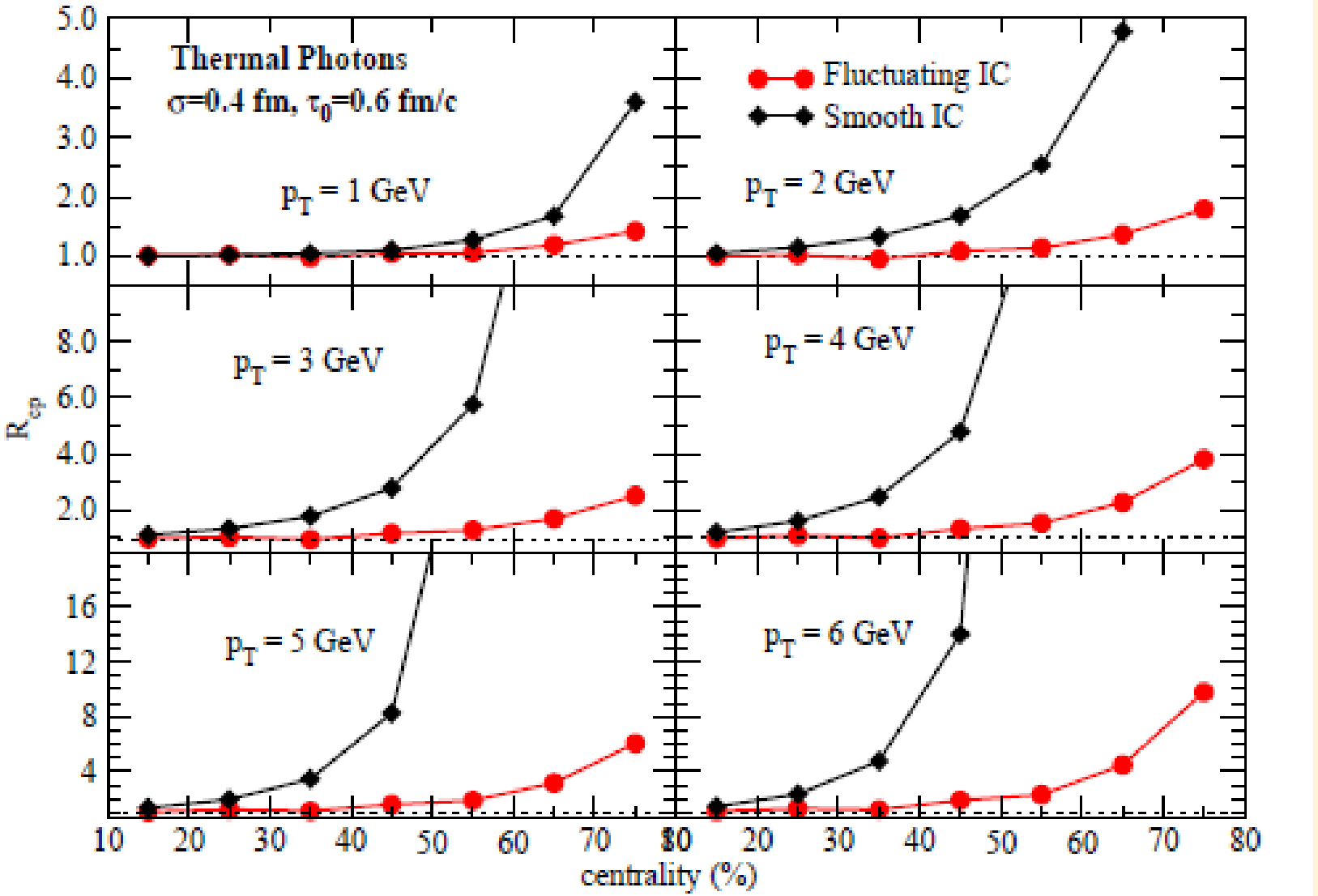
R^{γ}_{cp} for thermal photons at RHIC, size parameter 0.4 fm and τ_o=0.6 fm/c



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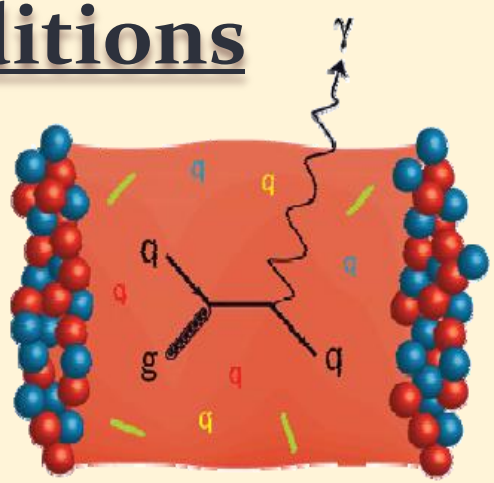
Photons are especially suitable for probing fluctations in the initial conditions



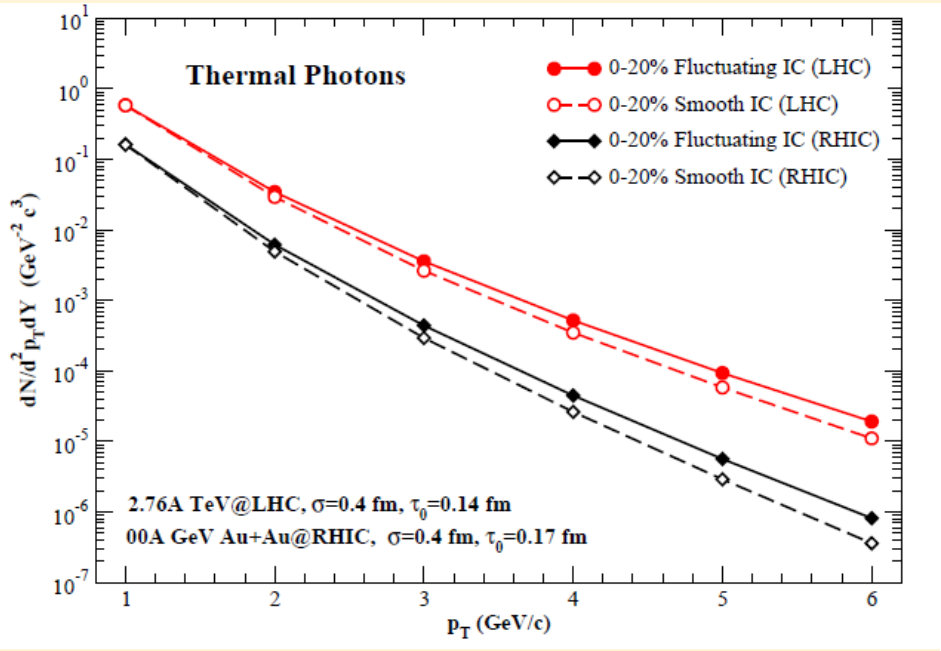
Direct photons are penetrating probes; provide direct information about the earliest hot and dense stage of the system.

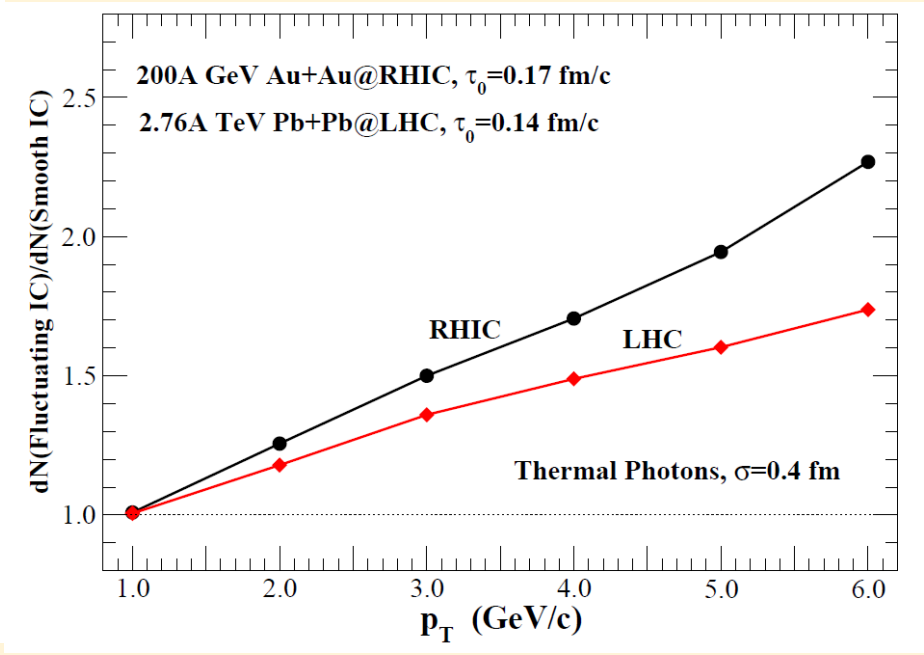
Thermal photons

- emitted from hot and dense QGP and hot hadronic matter phases.
- predicted to be the dominant source of direct photons in the range $1 \leq p_T \leq 3$ GeV/c.
- with $p_T > 1$ GeV/c are specially suitable for probing fluctuations in the initial conditions .

QGP rates: Arnold, Moore, and Yaffe, JHEP 0112, 009 (2001).
Hadronic rates: Turbide, Rapp, and Gale, Phys. Rev. C 69, 014903 (2004).

Thermal photons from smooth and fluctuating IC, RHIC and LHC





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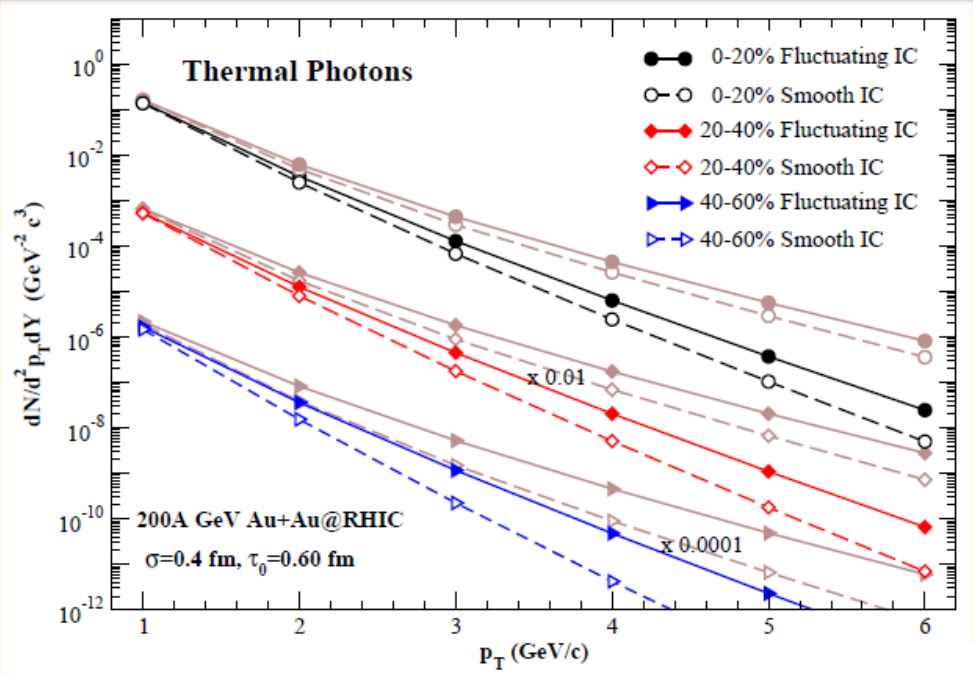
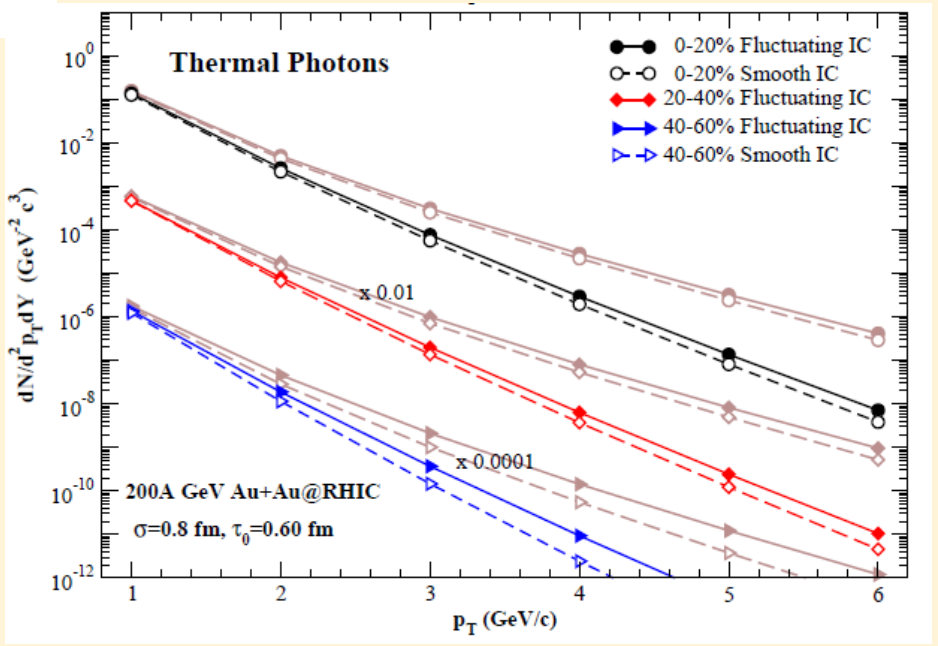
The effect of fluctuations in the IC is less pronounced at LHC than at RHIC.

Results are sensitive to the initial formation time and size parameter



Thermal photons from smooth and fluctuating IC at RHIC, comparison between results from τ_0= 0.17 and 0.60 fm/c.
Size parameter σ=0.4 fm.

Thermal photons from smooth and fluctuating IC at RHIC, comparison between results from τ_0= 0.17 and 0.60 fm/c.
Size parameter σ=0.8 fm.



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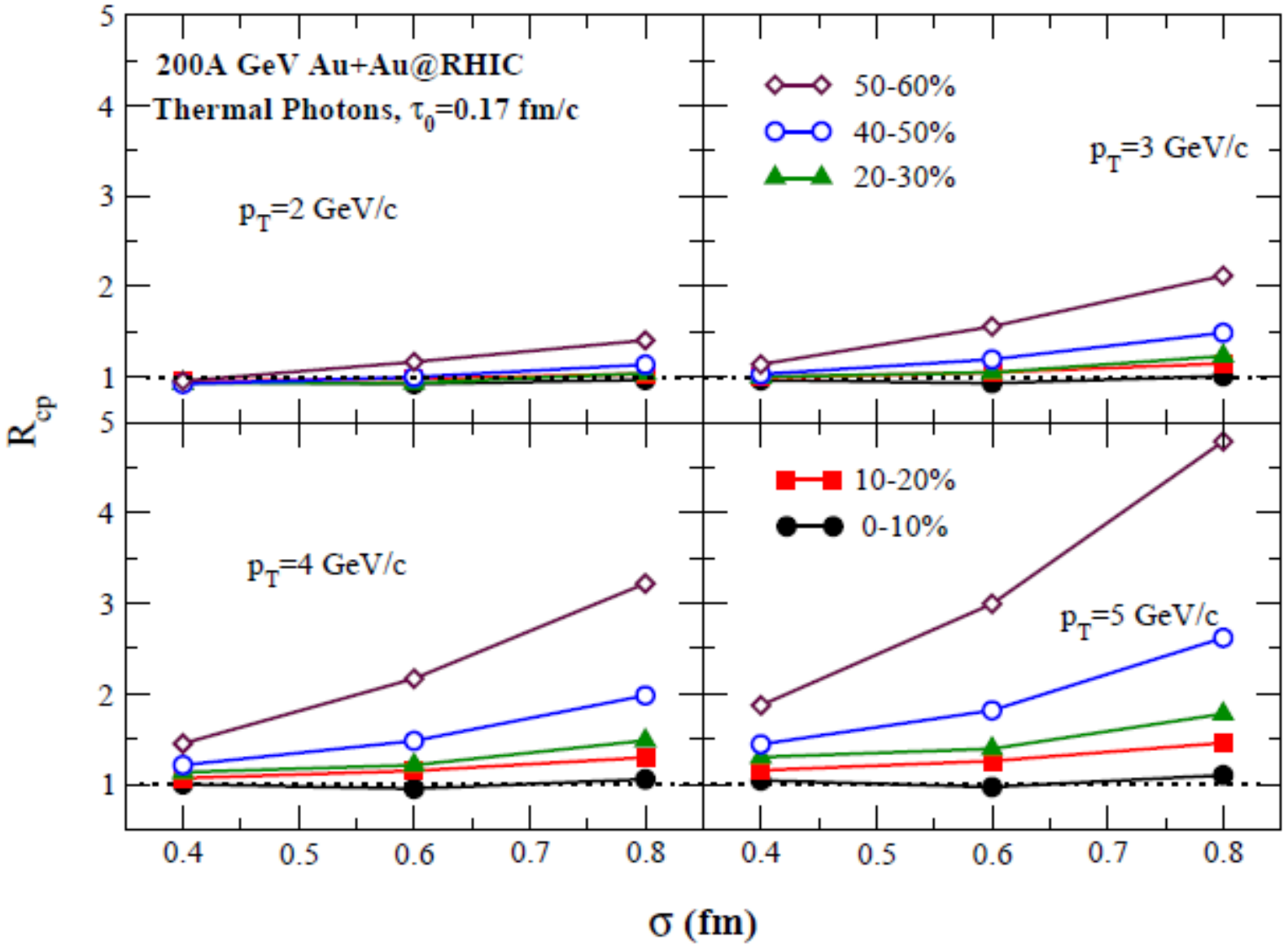
R^{γ}_{cp} as a function of σ for different p_T



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