Пошук зникаючого світла: вирішення проблеми «Direct Photon Puzzle”

Search for the escaping light: solving “Direct Photon Puzzle” problem.

Поиск ускользающего света: решение проблемы “Direct Photon Puzzle”

Yuri Sinyukov
Bogolyubov Institute for Theoretical Physics
NAS Ukraine

For Professor Zinoviev,
co-author and leader,
in connection with his Jubilee

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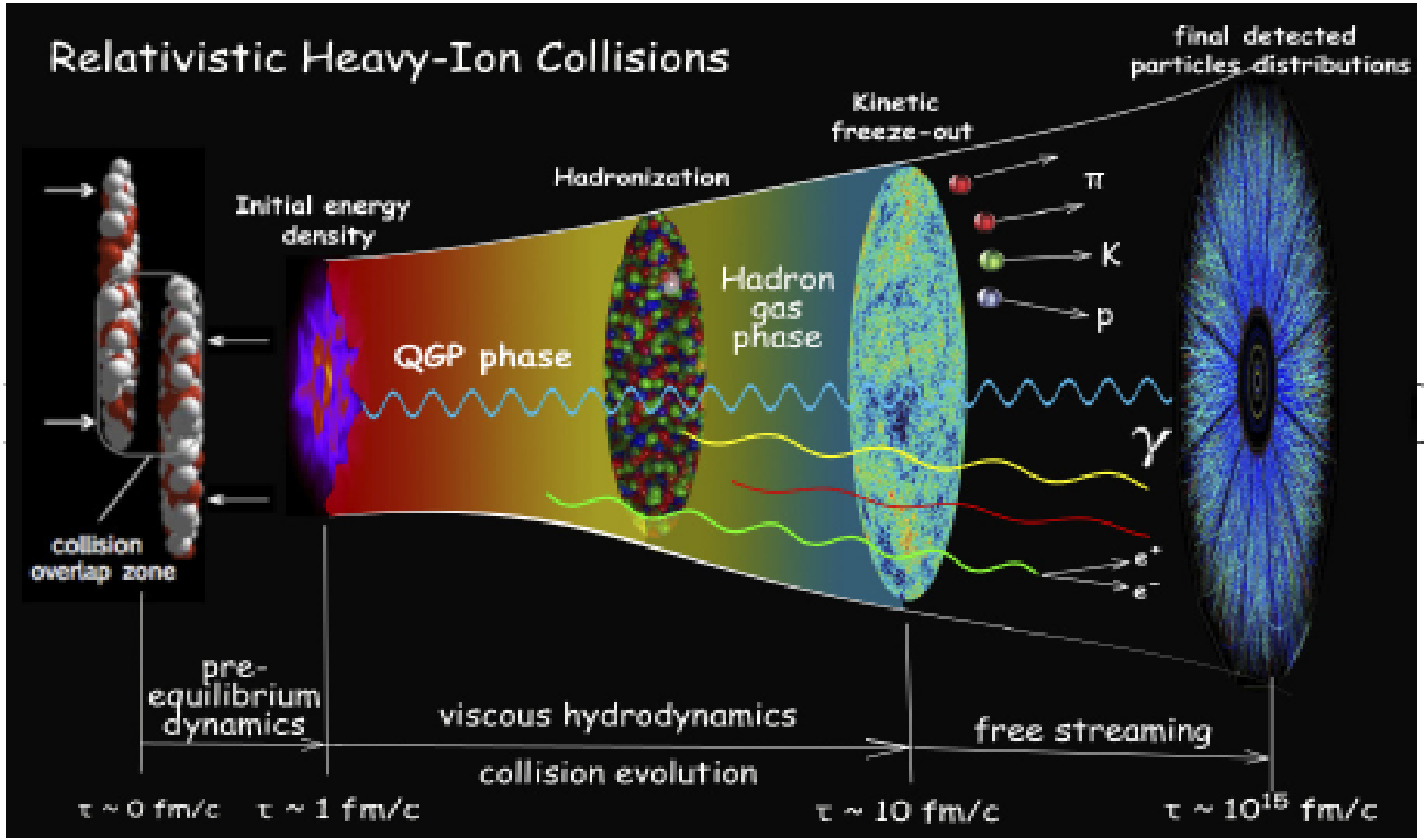
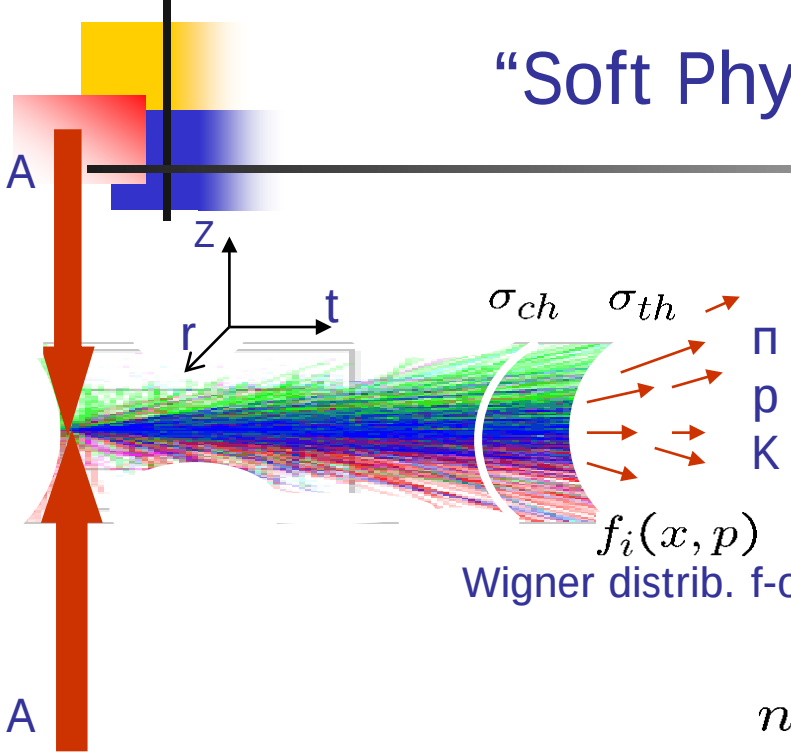
The stages of the matter evolution in A+A collisions

The initial huge kinetic energy of colliding nuclei converts into masses of the final observed particles (several tens of thousands) + the energy of collective flow



“Soft Physics” measurement



Wigner distrib. f-on

$$N_i = \int \frac{d^3p}{p^0} d\sigma_\mu p^\mu f_i(x,p)$$

$d^3x p^0$

$T_{f.o.}$

Ландау, 1953

$\sigma_{f.o.}$

$$n_i(p) \equiv p^0 \frac{d^3N_i}{d^3p} \sim e^{-\sqrt{m_i^2+p_T^2}/T_{eff,i}}$$

$p=(p_1+p_2)/2$

$q=p_1-p_2$

$$n_i(p_1,p_2) \equiv p_1^0 p_2^0 \frac{d^6N_i}{d^3p_1 d^3p_2} = C(p,q) n(p_1) n(p_2)$$

$\{\frac{N_i}{N_j}\}$ ⟹ T_{ch} and μ_{ch} parameters of chemical freeze-out.

$$\frac{d^3N}{dp_t\, dy\, d\varphi} = \frac{d^2N}{dp_t\, dy} \frac{1}{2\pi}(1 + 2v_1 \cos(\varphi) + 2v_2 \cos(2\varphi) + \ldots)$$

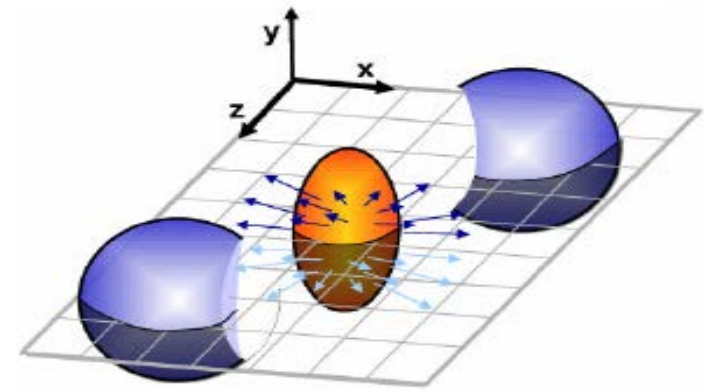
Directed flow

Elliptic flow

Radial flow

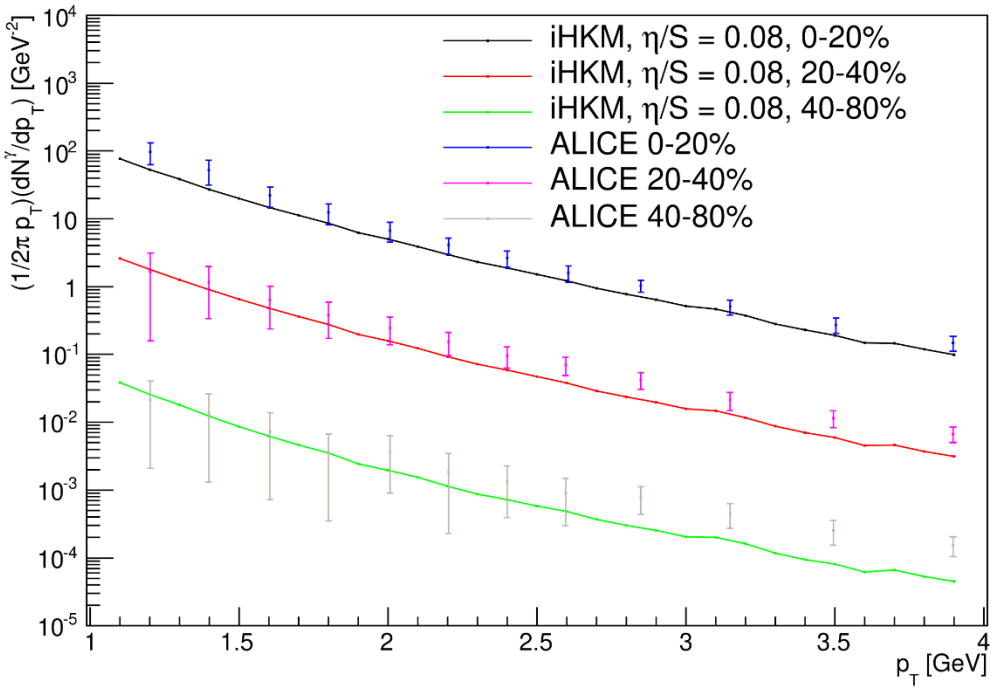
⟹ $T_{eff,i} \approx T_{f.o.} + m_i \frac{\langle v_T^2 \rangle}{2}$

Inverse of spectra slope

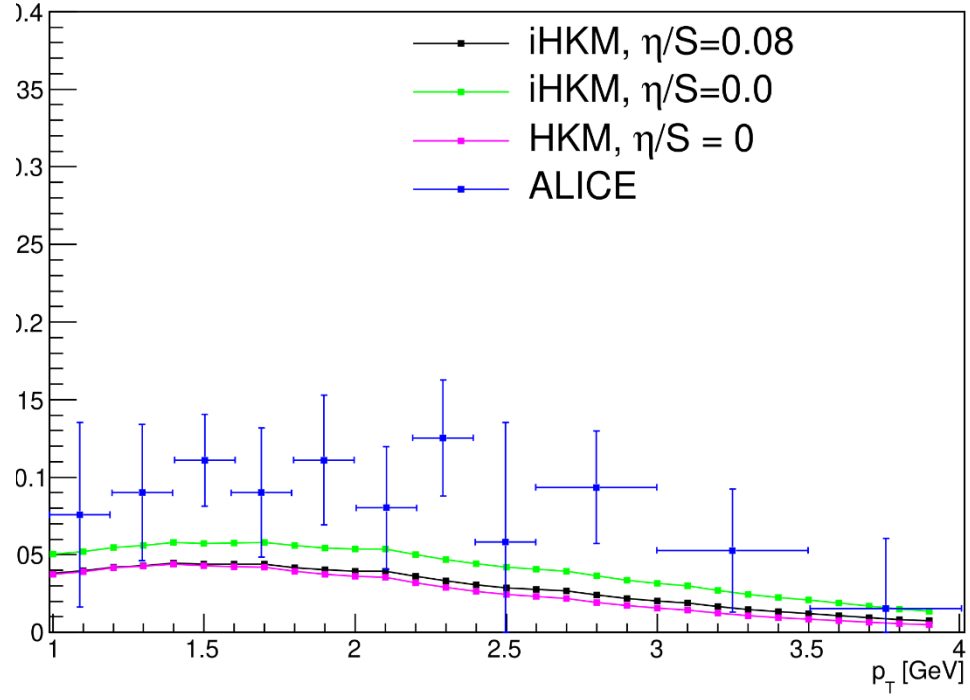


Direct Photon Puzzle

Direct photon spectra
at different centralities



Azimuthal spectra asymmetry:
v_2 - coefficients (elliptic flow)



Direct-photon spectrum and elliptic flow produced from Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV at the CERN Large Hadron Collider within an integrated hydrokinetic model

V. Yu. Naboka,[1] Yu. M. Sinyukov,[1] and G. M. Zinovjev[1]

[1]*Bogolyubov Institute for Theoretical Physics, 03680 Kiev, Ukraine*

(Received 22 October 2017; revised manuscript received 6 March 2018; published 16 May 2018)

The photon transverse momentum spectrum and its anisotropy from Pb+Pb collisions at the CERN Large Hadron Collider energy $\sqrt{s_{NN}} = 2.76$ TeV are investigated within the integrated hydrokinetic model (iHKM). Photon production is accumulated from the different processes at the various stages of relativistic heavy ion collisions: from the primary hard photons of very early stage of parton collisions to the thermal photons from equilibrated quark-gluon and hadron gas stages. Along the way a hadronic medium evolution is treated in two distinct, in a sense opposite, approaches: chemically equilibrated and chemically frozen system expansion. Studying the centrality dependence of the results obtained allows us to conclude that a relatively strong transverse momentum anisotropy of thermal radiation is suppressed by prompt photon emission which is an isotropic. We find out that this effect is getting stronger as centrality increases because of the simultaneous increase in the relative contribution of prompt photons in the soft part of the spectra. The substantial results obtained in iHKM with nonzero viscosity ($\eta/s = 0.08$) for photon spectra and v_2 coefficients are mostly within the error bars of experimental data, but there is some systematic underestimation of both observables for the near central events. We claim that a situation could be significantly improved if an additional photon radiation that accompanies the presence of a deconfined environment is included. Since a matter of a space-time layer where hadronization takes place is actively involved in anisotropic transverse flow, both positive contributions to the spectra and v_2 are considerable, albeit such an argument needs further research and elaboration.

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HADRONIZATION PHOTON EMISSION

Blow up the text

We claim that a situation could be significantly improved if an additional photon radiation that accompanies the presence of a deconfined environment is included. Since a matter of a space-time layer where hadronization takes place is actively involved in anisotropic transverse flow, both positive contributions to the spectra and v_2 are considerable, albeit such an argument needs further research and elaboration.

$$\frac{d^3N_\gamma}{d^3p} = \int dt d^3r G_{\rm hadr}(t,\mathbf{r},p) \;\lesssim\; p^0\frac{d^3N_\gamma}{d^3p} = \int_{\sigma_h} d^3\sigma_\mu(x)p^\mu F(pu(x),T_h)D_c(pu(x),T_h)$$

$$\gamma_{\rm hadr}^{d_c} \;\frac{1}{(2\pi)^3}\,\frac{g}{\exp\left[pu(x)/T_h\right]-1}$$

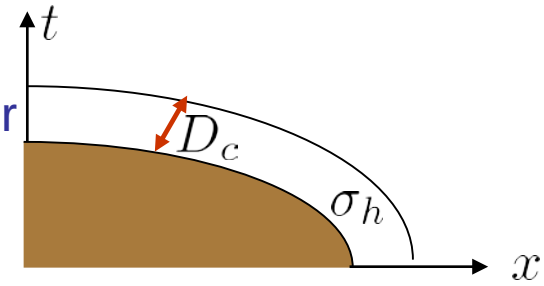
α

where

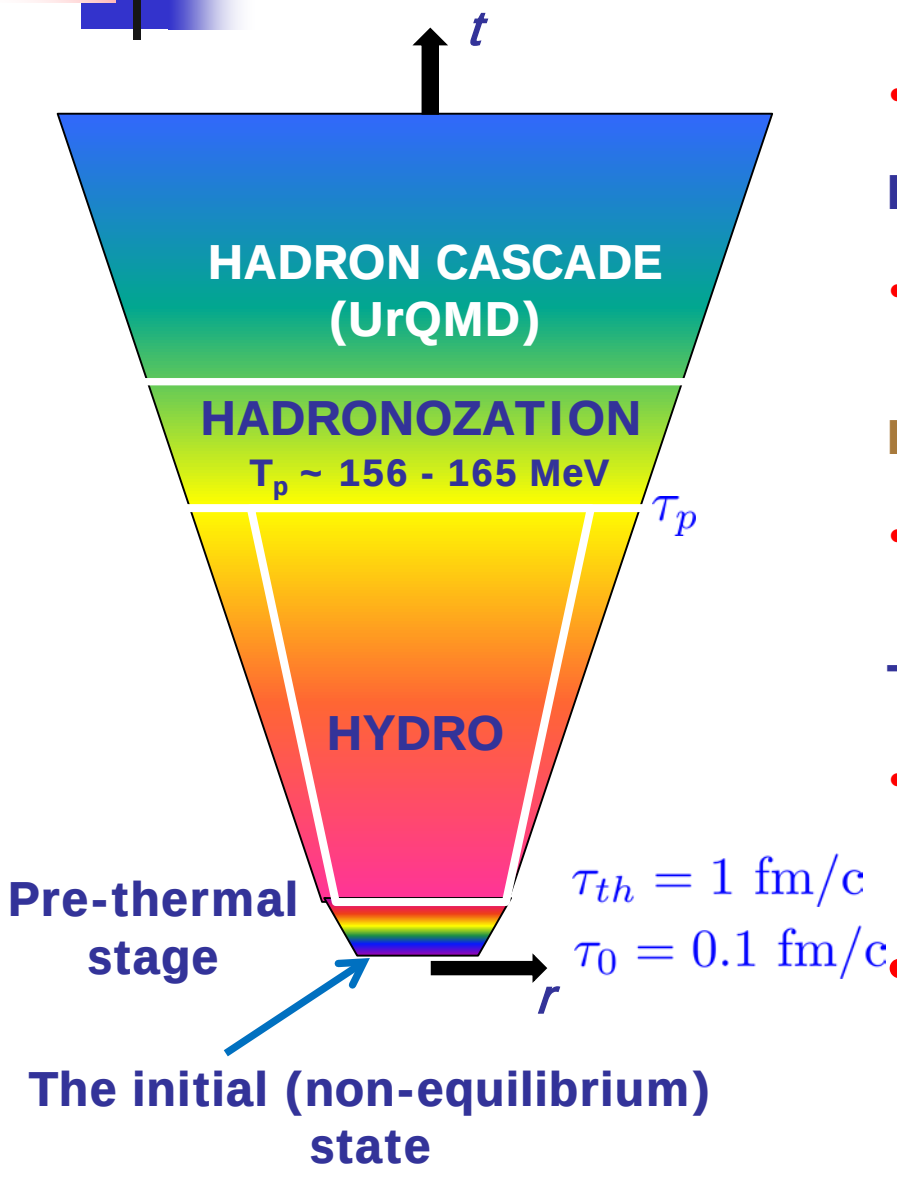
$pu \equiv p^\mu u_\mu$, $g = 2$, and $T_h = 165$ MeV

$\alpha = 0.04$

Hadronization layer



Photon radiation in **iHKM**



- **generation of the initial states: (MC Glaub & CGC)**

PROMPT PHOTONS

- **thermalization of initially non-thermal matter;**

PRE-THERMAL PHOTONS

- **viscous chemically equilibrated hydrodynamic expansion;**

THERMAL PHOTONS FROM QGP

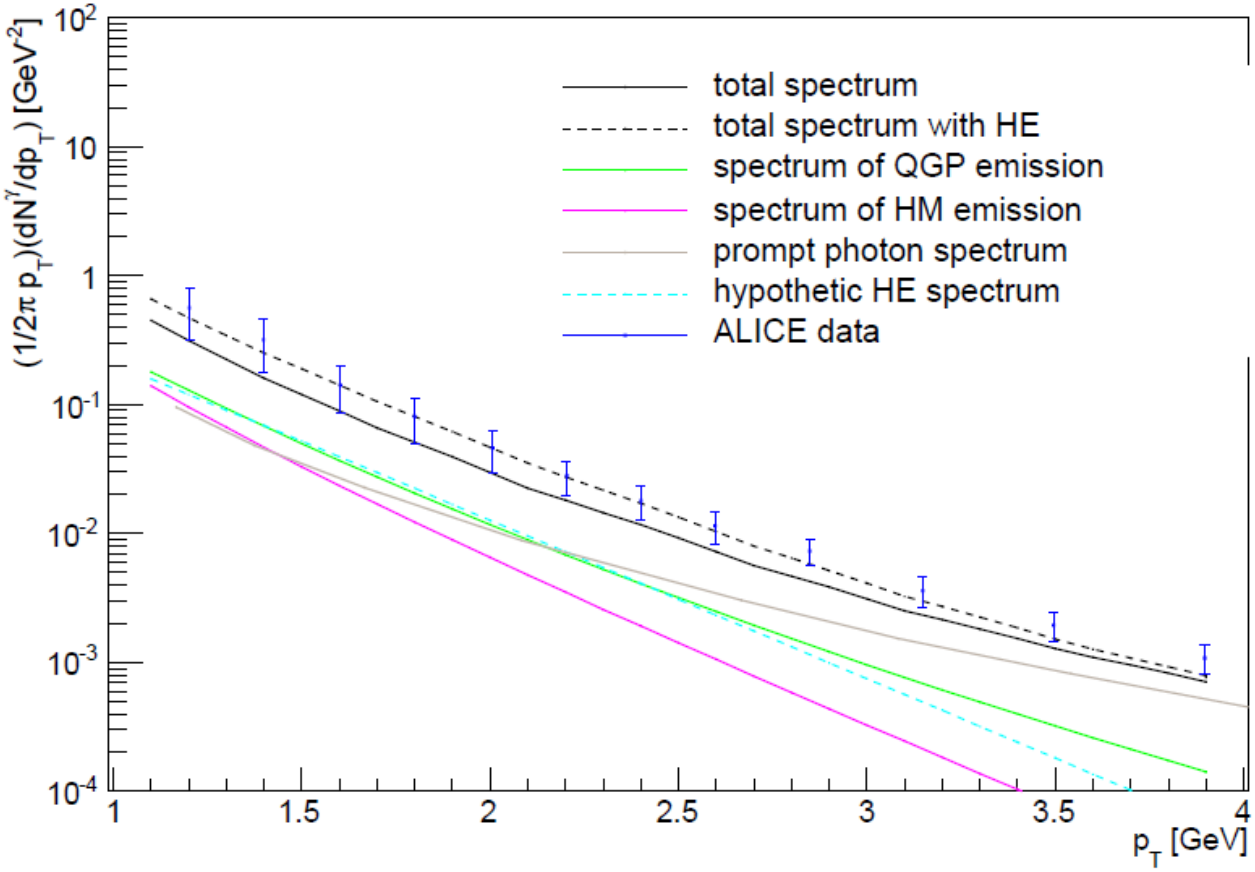
- **hadronization of expanding medium**

HADRONIZATION EMISSION

- **hadron matter expansion**

THERMAL PHOTONS FROM HADRONIC STAGE

Direct photons. Transverse Spectra



We claim that a description of photon spectra and its anisotropy could be significantly improved if an additional photon radiation, that accompanies the presence of deconfined environment, is included.

FIG. 1. Total direct photon spectra in iHKM: thermal QGP + thermal HM + prompt + hadronization emission (HE). Centrality is 0-40%. Experimental results are taken from [7].

Photon puzzle:
Anisotropy of spectra, large v2 coefficients.

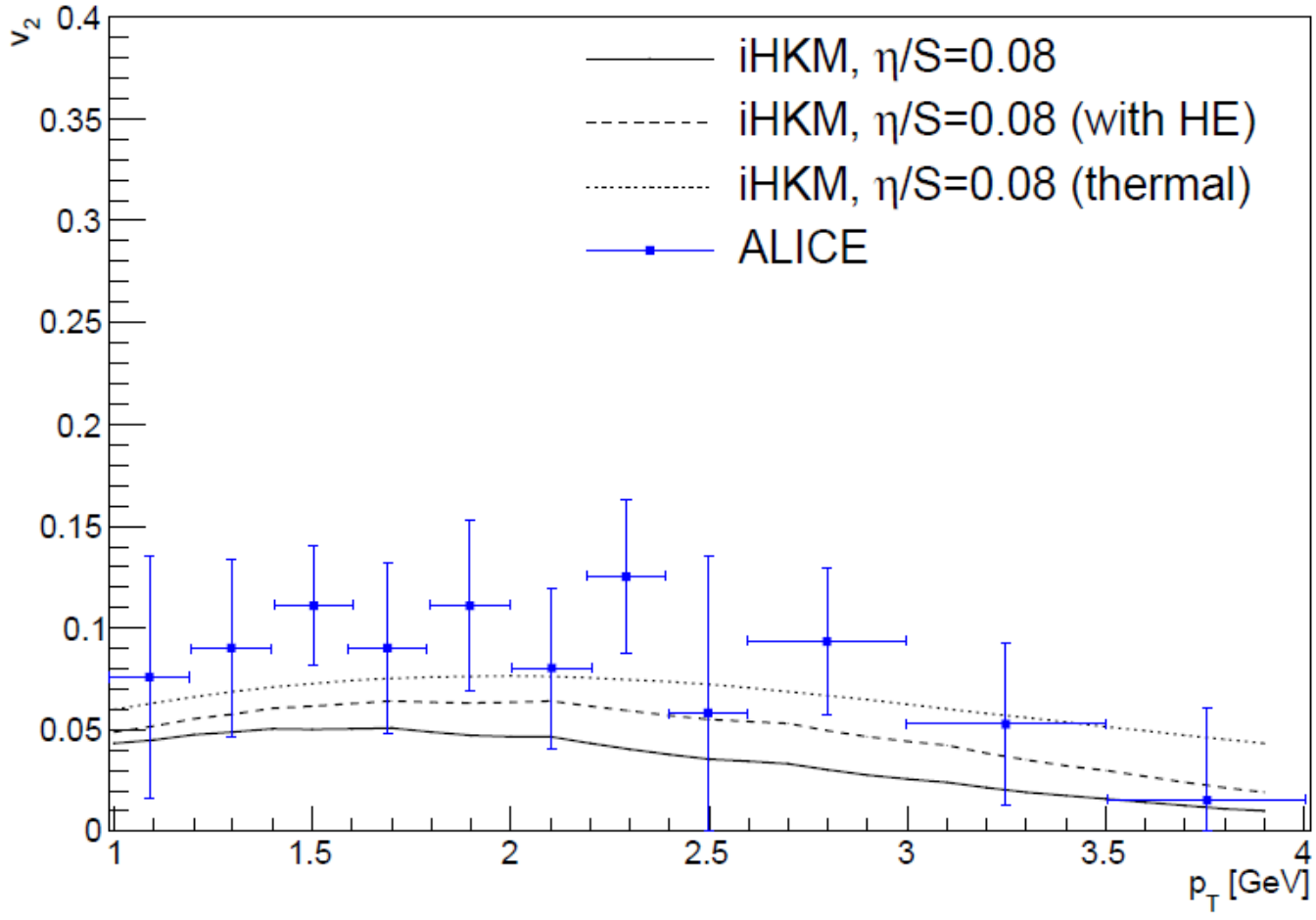


FIG. 2. Photon momentum anisotropy v_2-coefficient for 0-40% centrality. The results including the synchrotron radiation (HE) and results for prompt photons only (without HE) are also presented.

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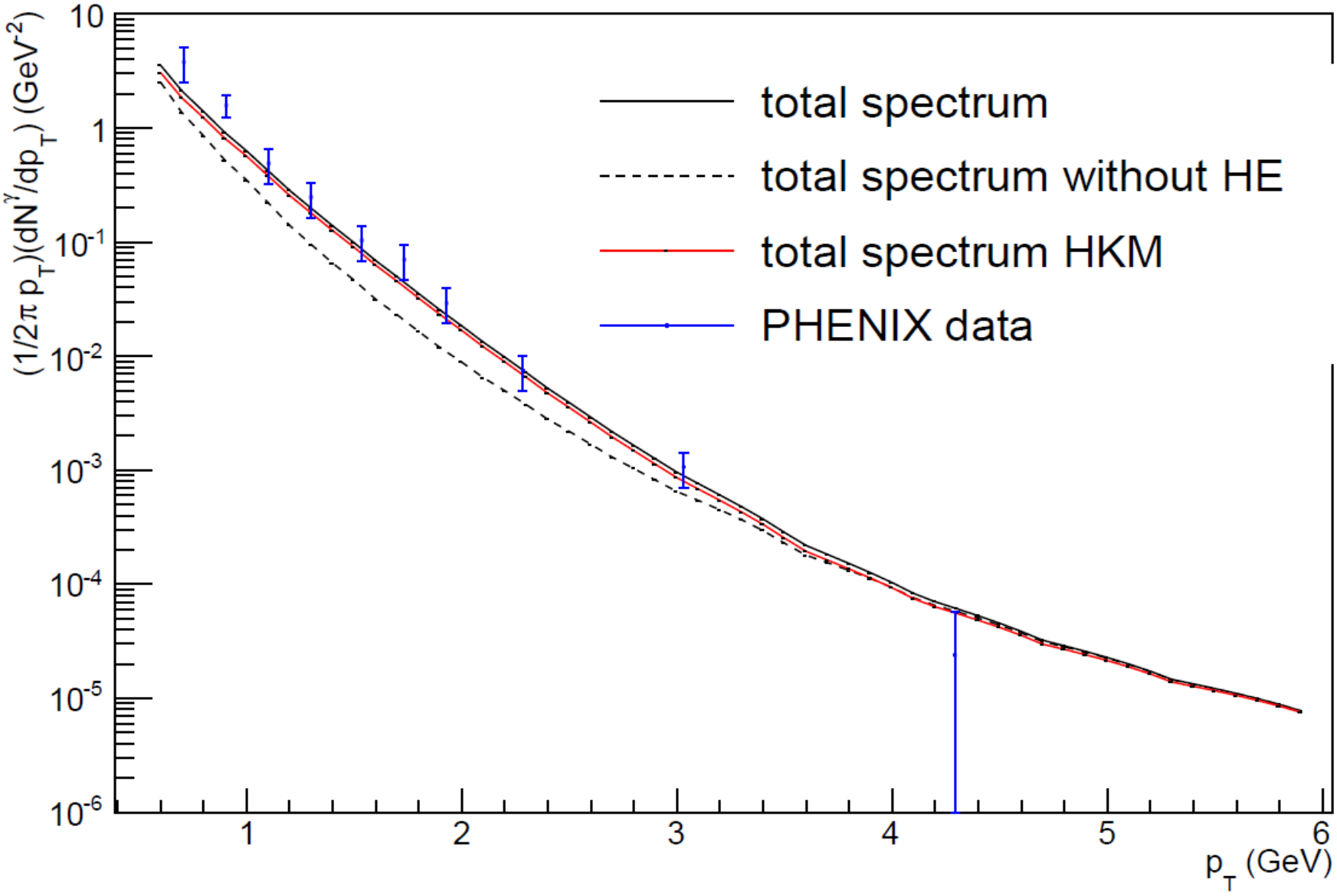
Photon spectra and anisotropic flow in heavy ion collisions at the top RHIC energy within the integrated hydrokinetic model with photon hadronization emission

V.Yu. Naboka [a], Yu.M. Sinyukov [a,*], G.M. Zinovjev [a]

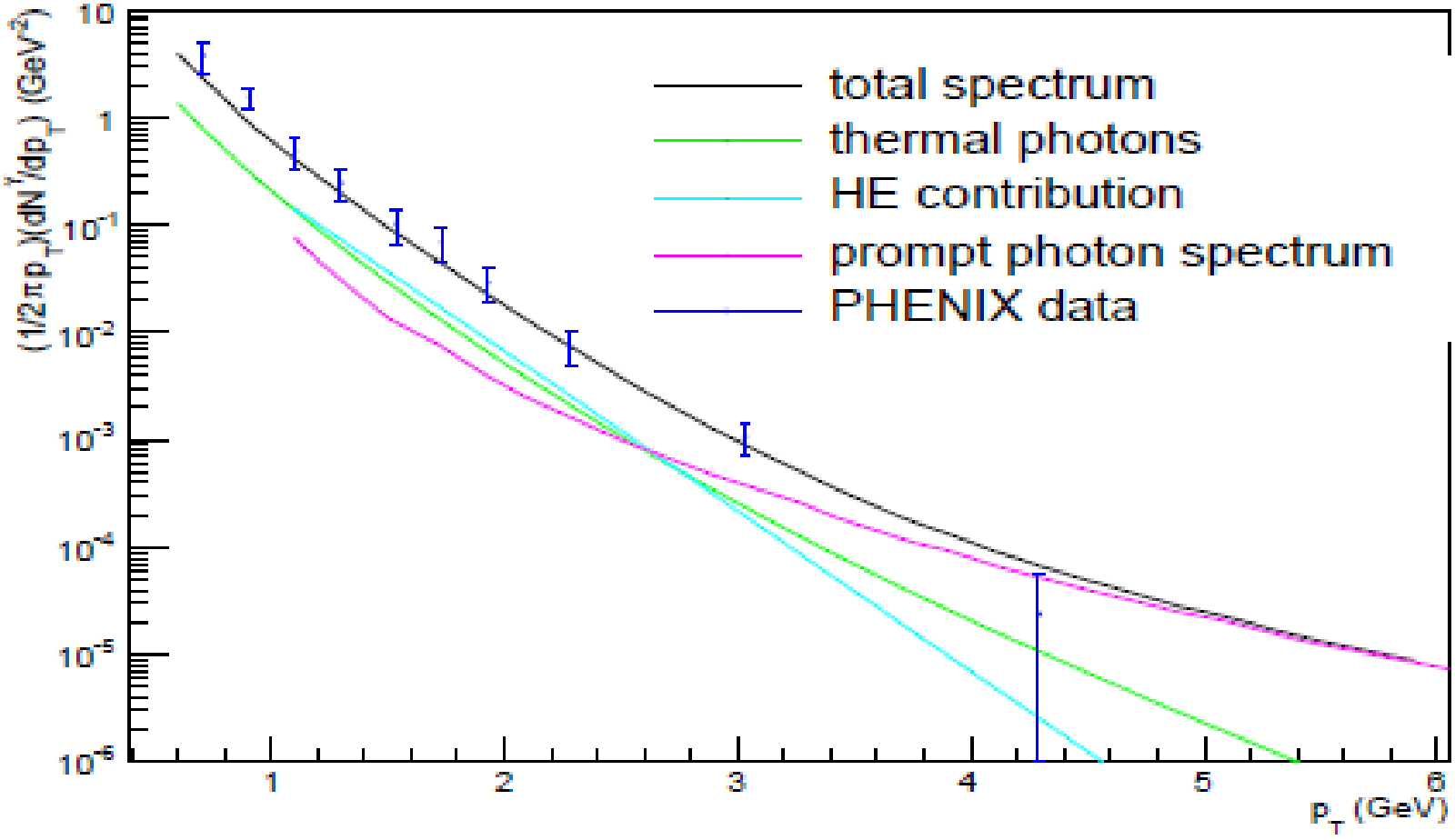
[a] *Bogolyubov Institute for Theoretical Physics, 03680 Kiev, Ukraine*

We find the description of direct photon spectra, elliptic and triangular flow are significantly improved, similar to that found in iHKM for the LHC energies, if an additional portion of photon radiation associated with the confinement processes, the "hadronization photons", is included into consideration.

Spectra: Photons at RHIC, c. 10-20 %

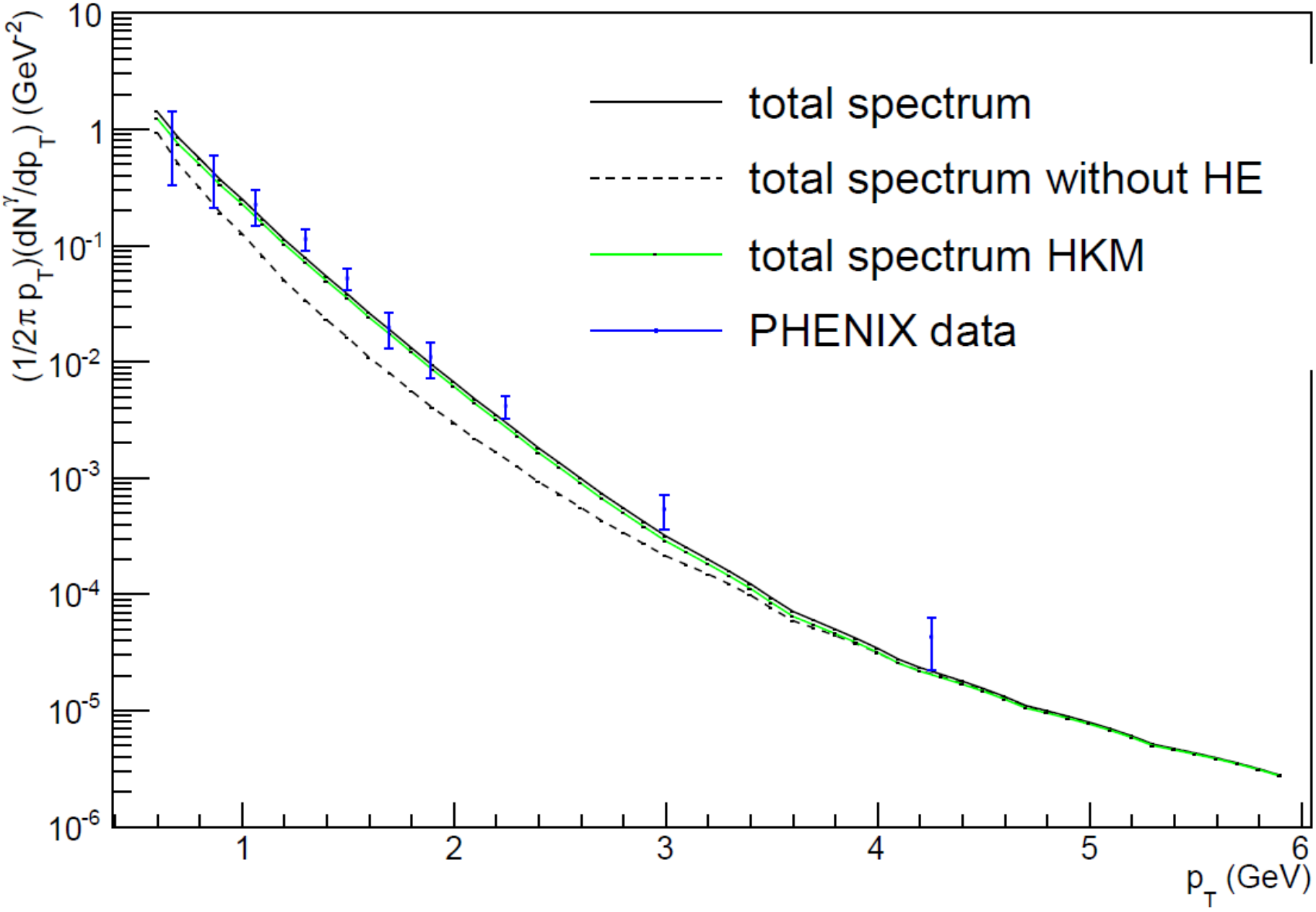


Contributions to photon spectra, c. 0-20%

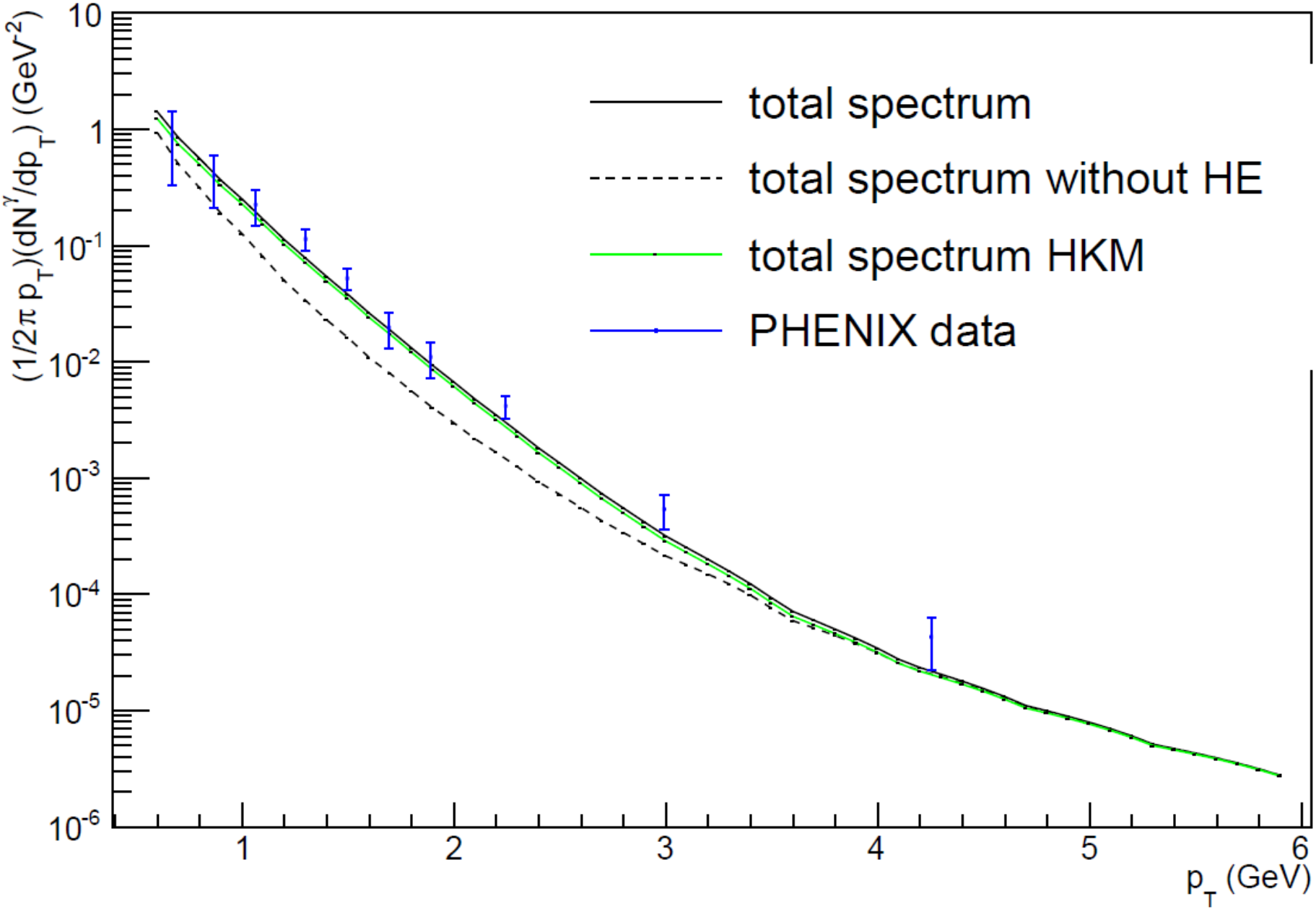


!. Total photon spectra calculated within chemically equilibrated iHKM for 0-20% centrality along with its constituents: thermal (including prethermal) photons, prompt photons, and hadronization emission (HE) contribution. Experimental results are taken from [51].

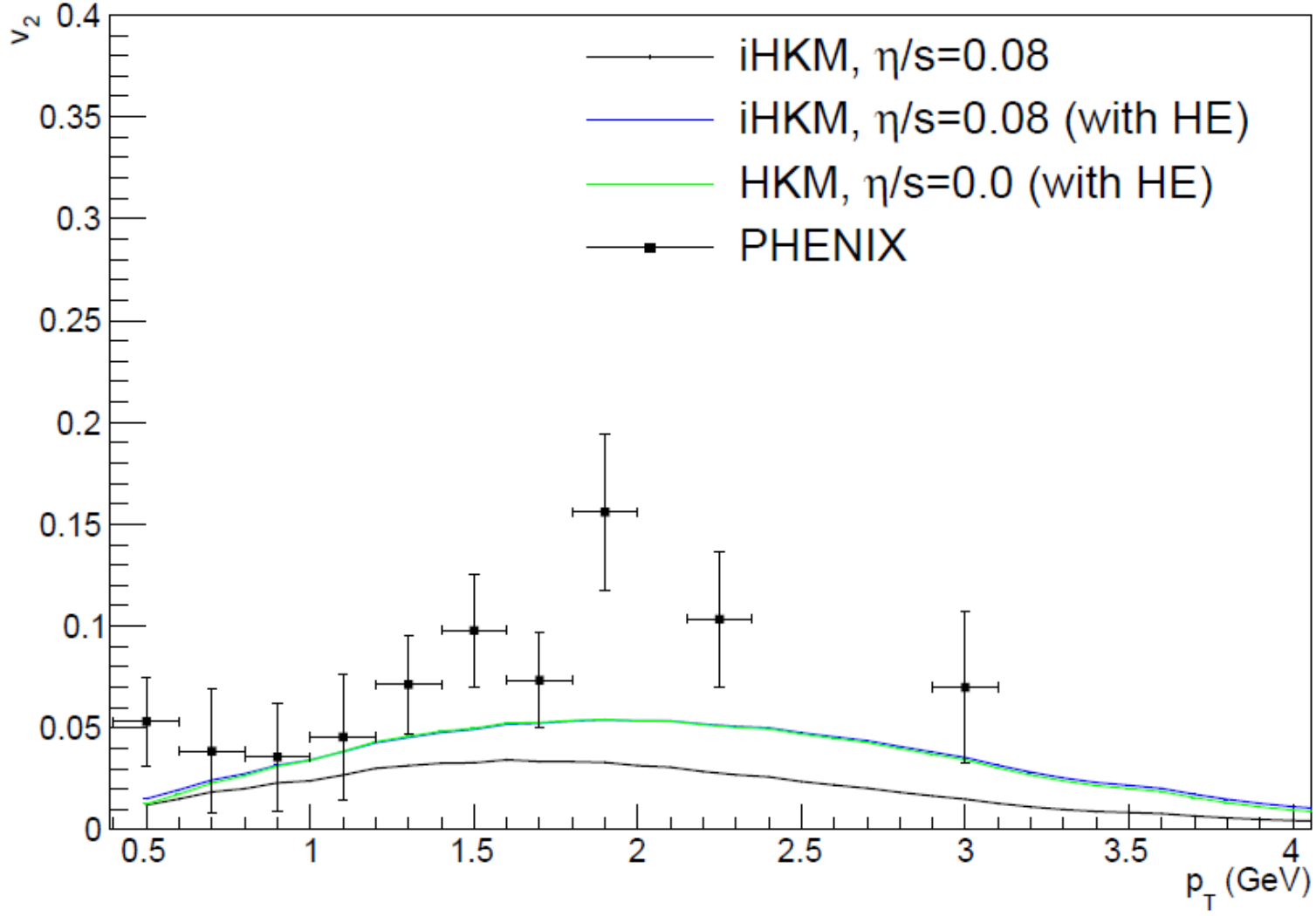
Spectra: Photons at RHIC, c. 20-40 %



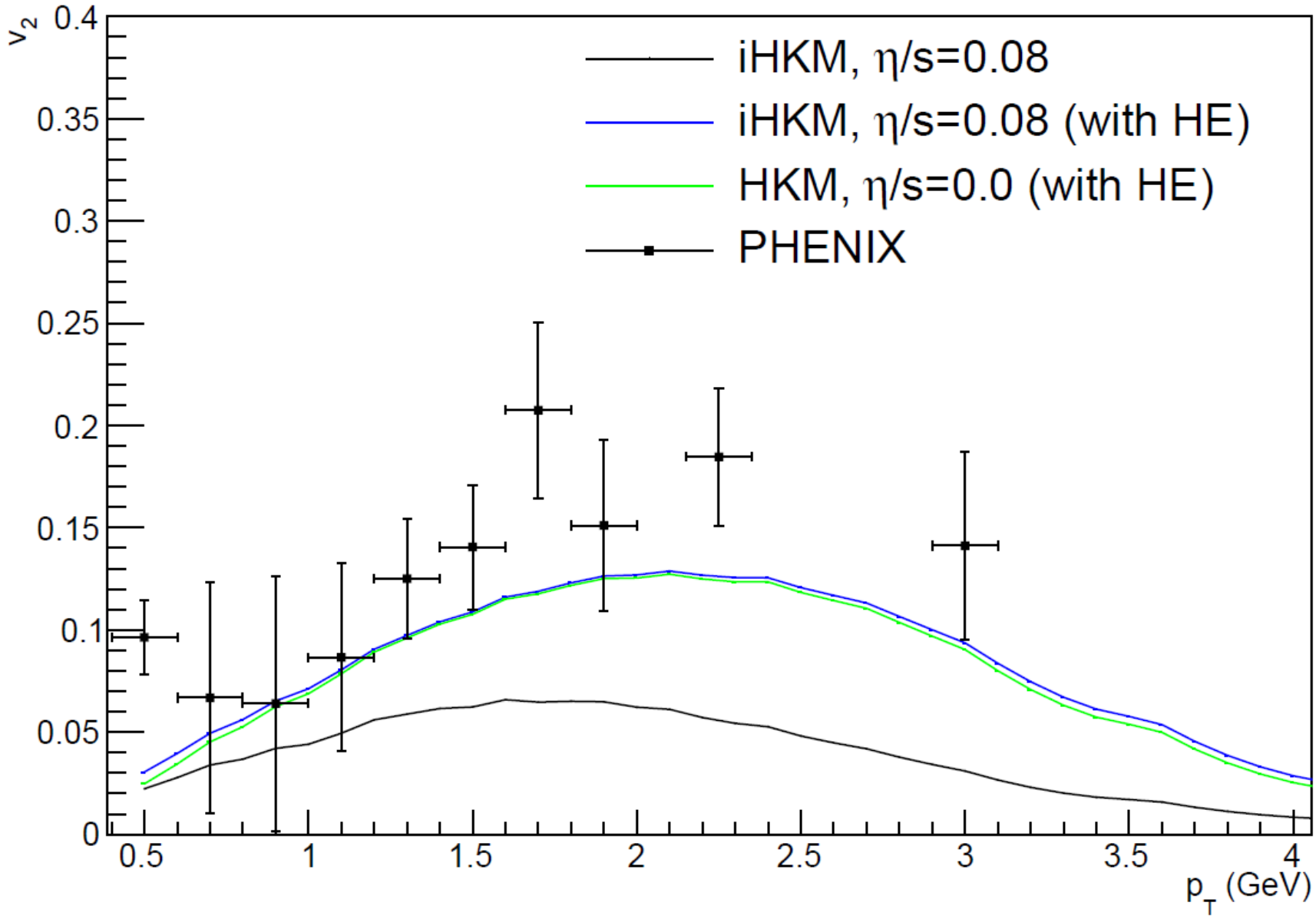
Spectra: Photons at RHIC, c. 40-60 %



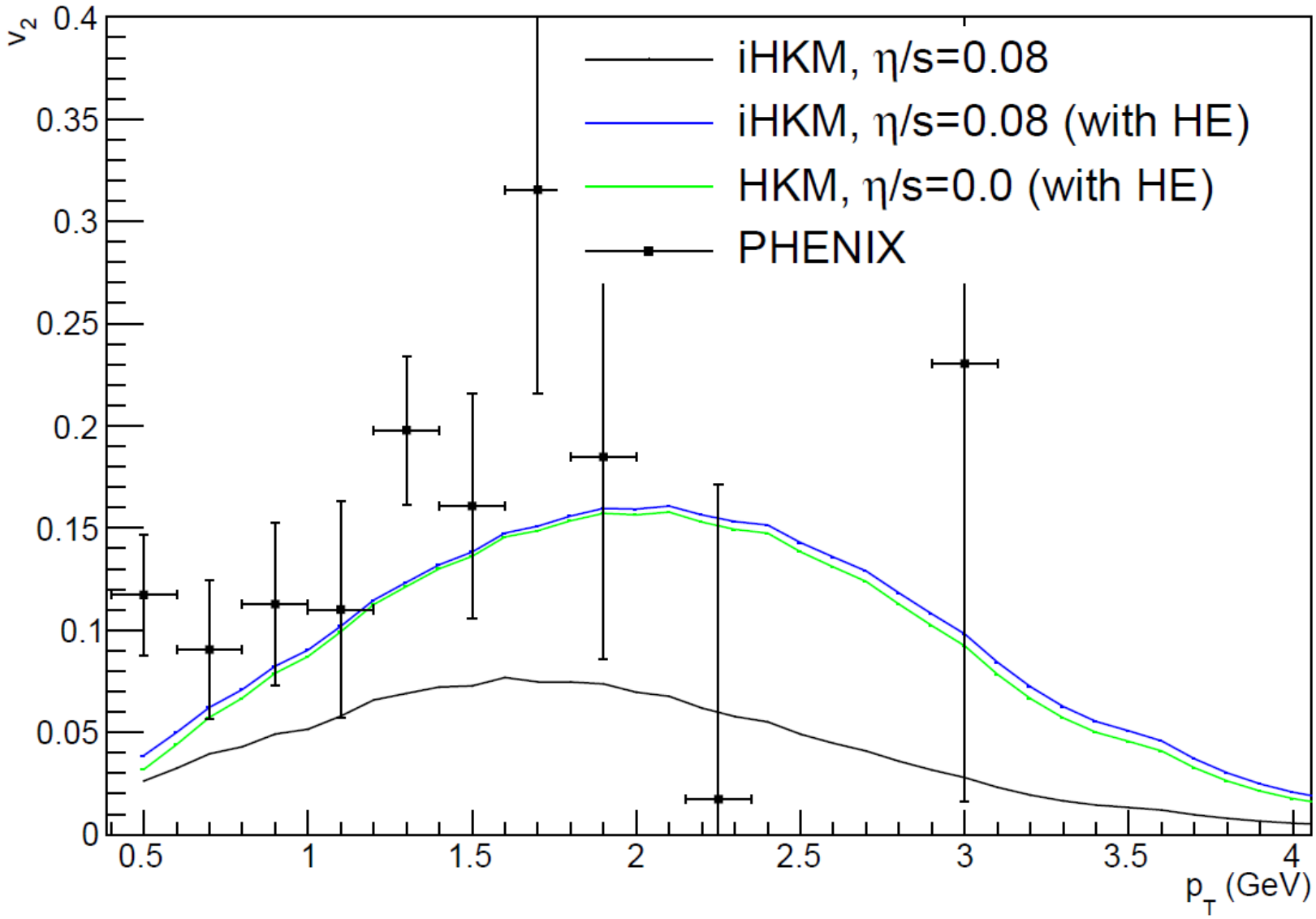
Photons at RHIC, v2 , c. 10 – 20 %



Photons at RHIC, v2 , c. 20 – 40 %



Photons at RHIC, v2 , c. 40 – 60 %



Triangular flow, v_3 coefficients, c. 0-20%

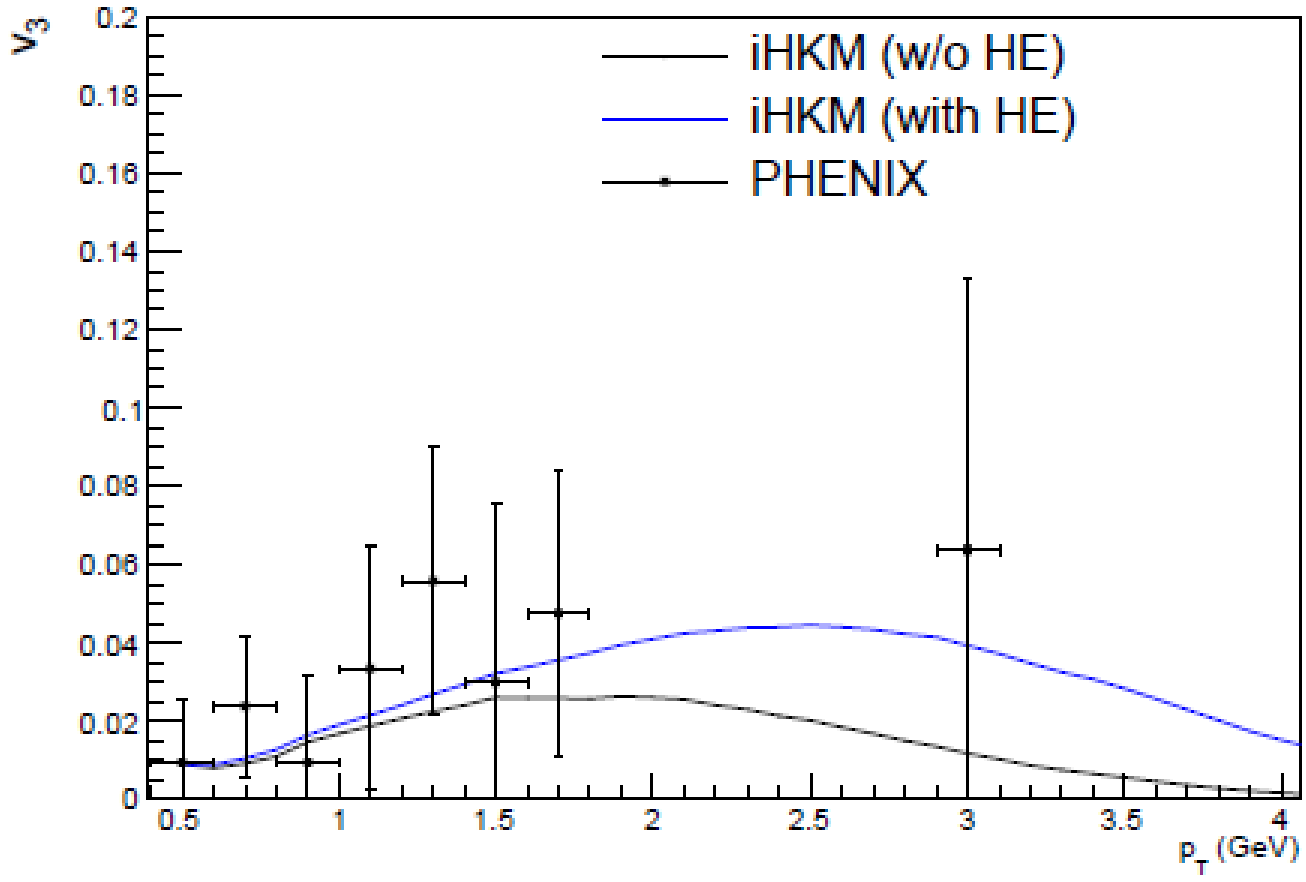
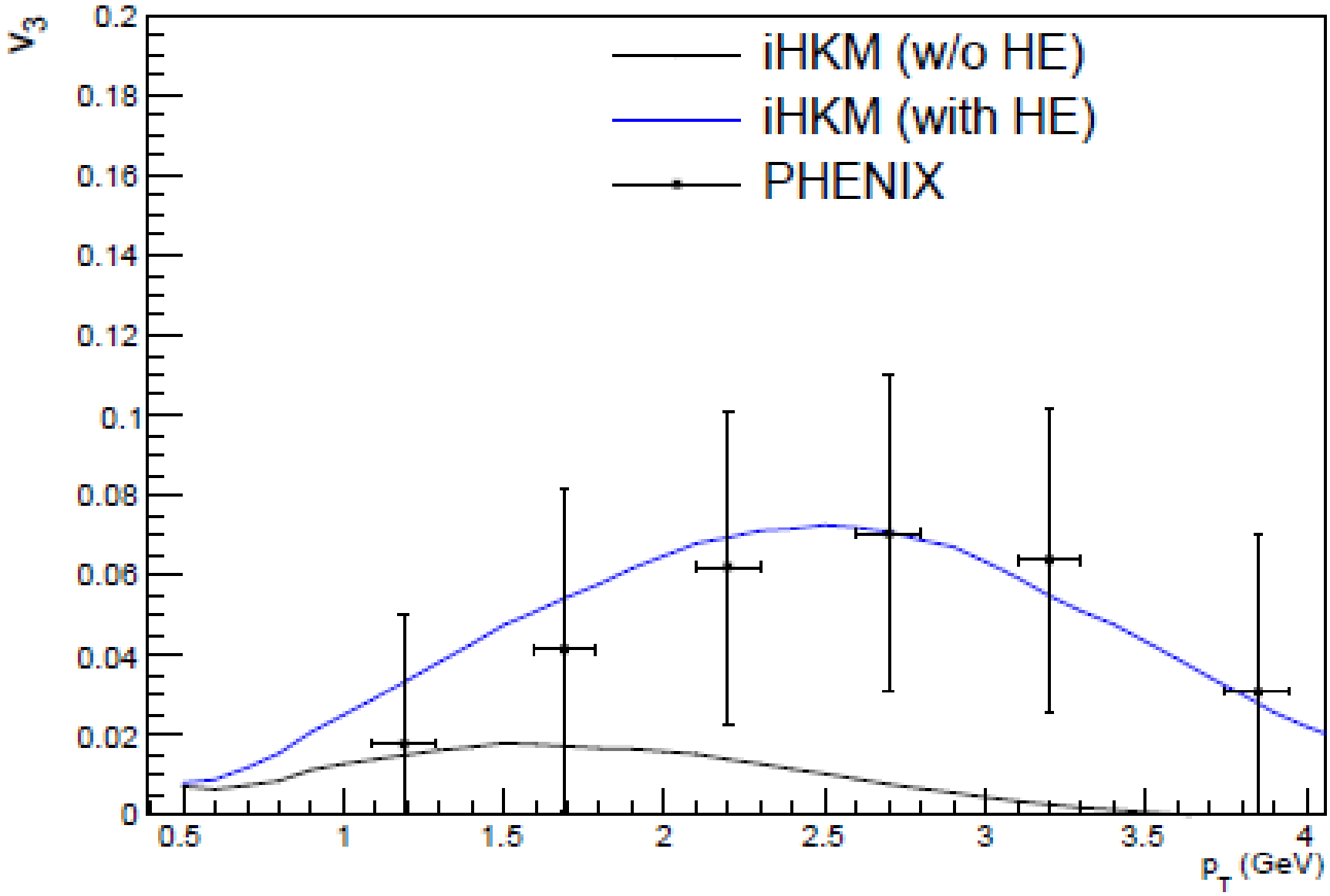
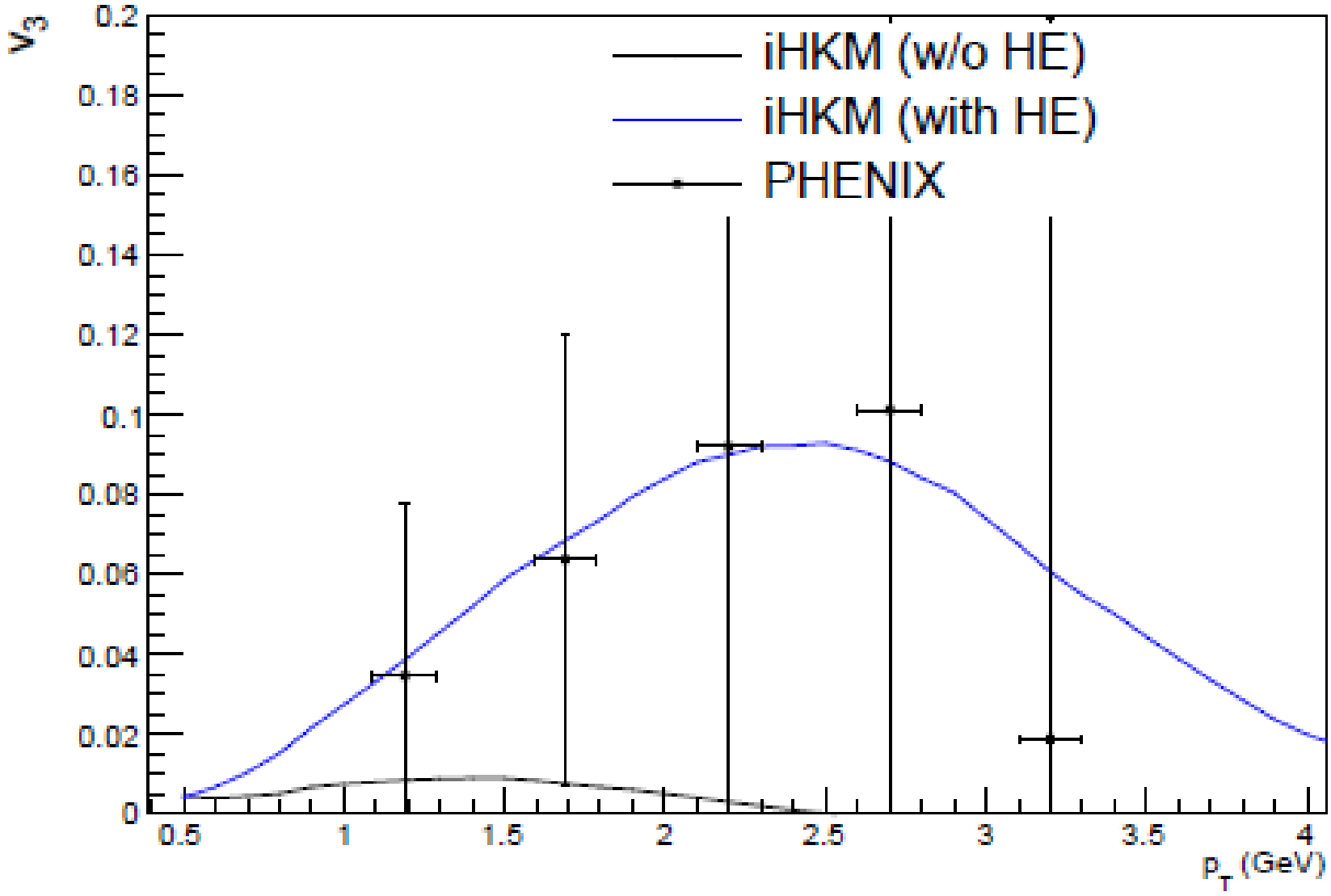


FIG. 6. Triangular flow for 0-20% centrality for the different models: iHKM chemically equilibrated without hadronization emission (thermal and prompt photons only) contribution and iHKM chemically equilibrated with HE contribution. Experimental results are taken from [52].

Triangular flow, v_3 coefficients, c. 20-40%



Triangular flow, v_3 coefficients, c. 40-60%



Summary for photons

. The iHKM contains all the stages of the nucleus collision process, has natural zero initial transverse velocity and continuous freeze-out. Being applied here to the photon business, it needs the only additional parameter to describe photon spectra, elliptic and triangular flow at three centralities classes at RHIC. This parameter for the photon rate $\beta = 0.04$ is related to the specific processes of photon radiation that is connected to confining interactions at the hadronization transition. It could probably include photons from additional reaction channels for hadrons with modified properties that just created in hadronizating medium.

В награду за хорошие статьи

А ТЕПЕРЬ – НАРОДНОЕ ГУЛЯНЬЕ ПО тому же поводу

ПРОДОЛЖЕНИЕ НАРОДНОГО ГУЛЯНЬЯ

ШУТКИ ПАНОРАМНОЙ СЪЕМКИ: Г.М. – на дальнем плане

The time when we all were young. It was 1986...

О разложении непростых чисел

Стихотворение

Посвящается 80-летнему Юбилею
Геннадия Михайловича Зиновьева

Восемь десяток, четыре двадцаток, иль две сороков?!
Кто ж Вы, Учитель, на деле таков?

Равен ль восьми озорным мальчуганам,
Иль четверым молодым дон жуанам,
Может, двоим очень крупным талантам,
Тем, кто творят нам новые старты?..

Нету ответа?..
Так *я* пожелаю! -
Быть Вам живым без конца и без края:

Быть завсегда озорным мальчуганом,
И четверым молодым Дон Жуанам,
Мыслить, как два очень зрелых таланта,
Счастья желаю и творческих стартов!

18.04.2021 Юрий Синюков

Acknowledgement

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