Transverse Momentum Spectra and Elliptic flow in ideal hydrodynamics and Geometric Scaling

Victor Roy

Variable energy Cyclotron Centre, Kolkata, India

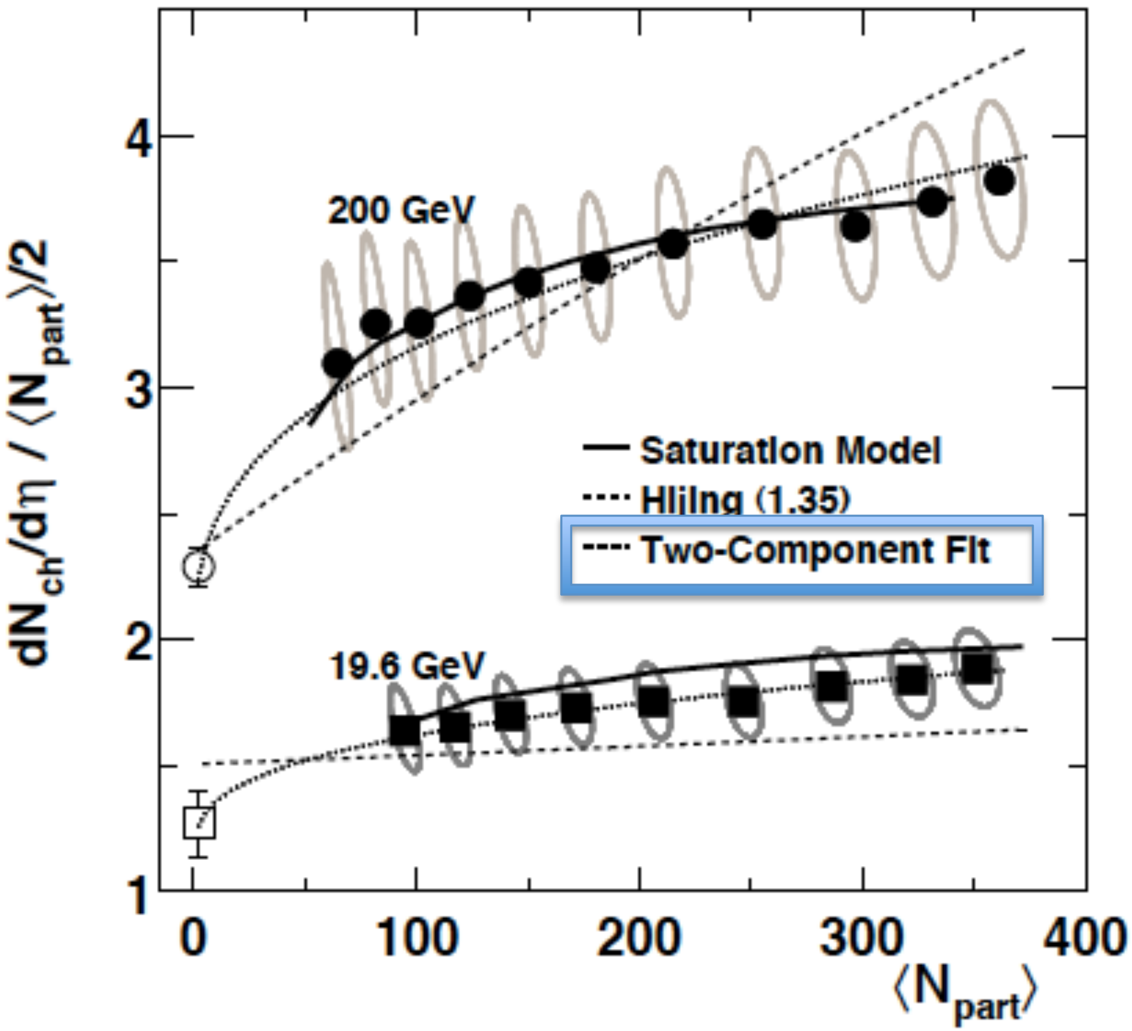
In collaboration with Dr. A.K.Chaudhuri

Plan of Talk

- Introduction
- Initial conditions
- hydrodynamics
- Result
- Summary and conclusion

Introduction

PHOBOS: Charged particle multiplicity



$$\frac{dN}{d\eta} = n_{pp}\left[(1-x)\frac{N_{part}}{2} + xN_{coll}\right]$$

..............(1)

x ➔Fraction of hard scattering

Soft process ~ N_{part}

Hard process ~ N_{coll}

D. Kharzeev and M.Nardi

Phys. Lett. B, 507,121

Dependence of x on beam energy

Beam Energy (GeV)	X
*19.6	0.13 ± 0.01 ± 0.05
56	0.05±0.03
130	0.09 ± 0.03
*200	0.13 ± 0.01 ± 0.05

* PHOBOS

Application in hydrodynamic model

Geometric scaling of Au+Au collisions as in equation (1), has been widely Used in hydrodynamic model calculation

❖P. F. Kolb, U. W. Heinz, P. Huovinen, K. J. Eskola and K. Tuominen, Nucl. Phys. A 696, 197 (2001).

❖ T. Hirano and Y. Nara, Phys. Rev. C 79, 064904 (2009)

Glauber initial condition and ideal hydrodynamics

- Hydrodynamics model require initial energy density configuration.

$$\varepsilon(b,x,y) = \varepsilon_0\left[(1-x)N_{part}(b,x,y) + xN_{coll}(b,x,y)\right] \quad \text{...............(2)}$$

ε_0 is the central energy density in **b**=0 collision

➢ current status :

- hard scattering fraction x=0.25 explains a variety of experimental data, e.g. identified particle's multiplicity ,mean transverse momentum, elliptic flow etc.

P. F. Kolb and U. Heinz, in Quark-Gluon Plasma 3
edited by R. C. Hwa and X.-N. Wang (World Scientific,Singapore, 2004), p. 634

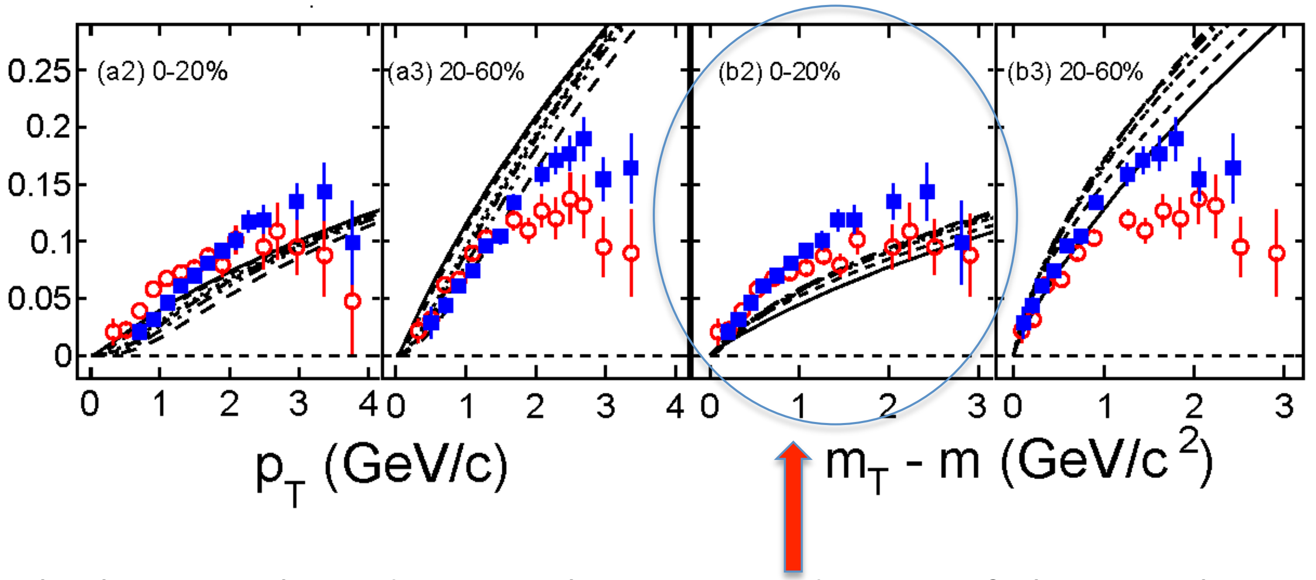
- With x=0.13, also gives reasonable description to the experimental data.

T. Hirano and Y. Nara, Phys. Rev. C 79, 064904 (2009)

This work extends this investigation

Ideal hydro and elliptic flow

STAR 1001.5052, Cu+Cu 200 GeV



◆Glauber initial condition with x=0.13 and x=0.25 fails to explain central collision.

◆Elliptic flow is a key observable to established the existence of partonic medium and address the issue of thermalization in Au+Au collision

◆***Important to understand why Glauber model initial condition underestimate Elliptic flow in very central collision***

◆Inclusion of dissipative effect will not improve the situation as it will only reduce v_2

Hydrodynamic simulation with Glauber model initialization

Current Study :

$$\partial_\mu T^{\mu\nu} = 0 \qquad \text{.......................(3)}$$

- We have simulated 200 GeV Au+Au collisions
- with Glauber model initial condition at two extreme limit of the hard scattering fraction

x=0 ~ soft process

x=1 ~ hard process

$$\varepsilon(b,x,y) = \varepsilon_0\left[(1-x)N_{part}(b,x,y) + xN_{coll}(b,x,y)\right]$$

- We assume that in Au+Au collisions, a 'baryonless', 'ideal' QGP fluid is produced.

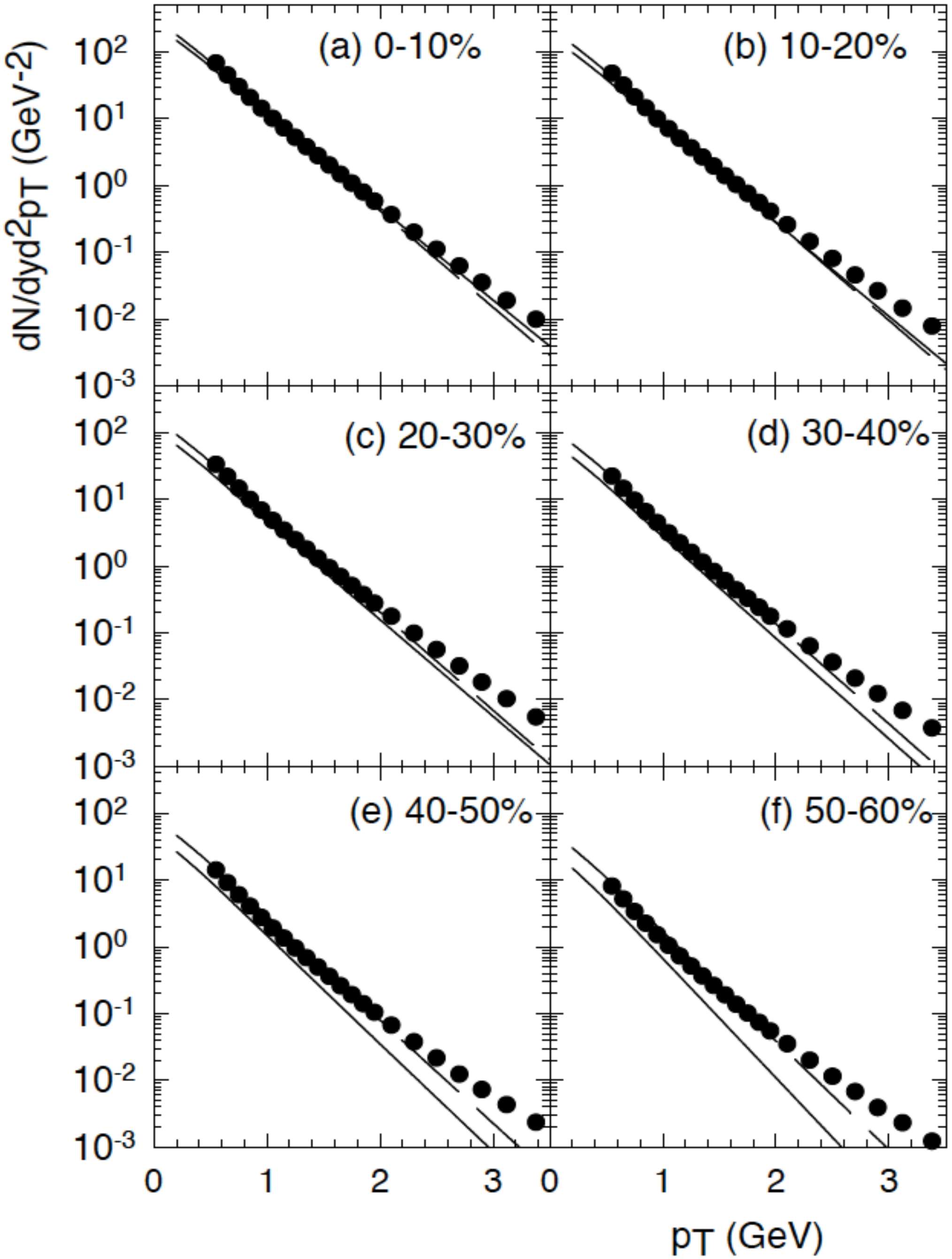
Assumptions and initial conditions

- Coordinate system : $\tau = \sqrt{t^2 - z^2}$,x ,y, $\eta = \frac{1}{2}\ln\frac{t+z}{t-z}$
- Longitudinal boost invariant : η symmetry
- EOS : lattice+HRG EOS ,T_{co}=196 MeV
  lattice-(2+1)
  Hadron gas (mass ≤ 2.5 GeV)
  M. Cheng *et al.*, Phys. Rev. D **77**, 014511
- Initial time : $\tau_i = 0.6\, fm$
- Initial fluid velocity : $v_x(x,y) = v_y(x,y) = 0$
- Freeze-out temperature : T_F=150 MeV.
- Initial central energy density :

ε_0 =36.1 GeV/fm^3 , x=0

ε_0 =48 GeV/fm^3 ,x=1

Charged Hadron p_T spectra,200GeV,Au+Au (PHENIX)



✓Dashed lines

x=0

$\varepsilon_0 = 36.1\, GeV / fm^3$

✓Solid line

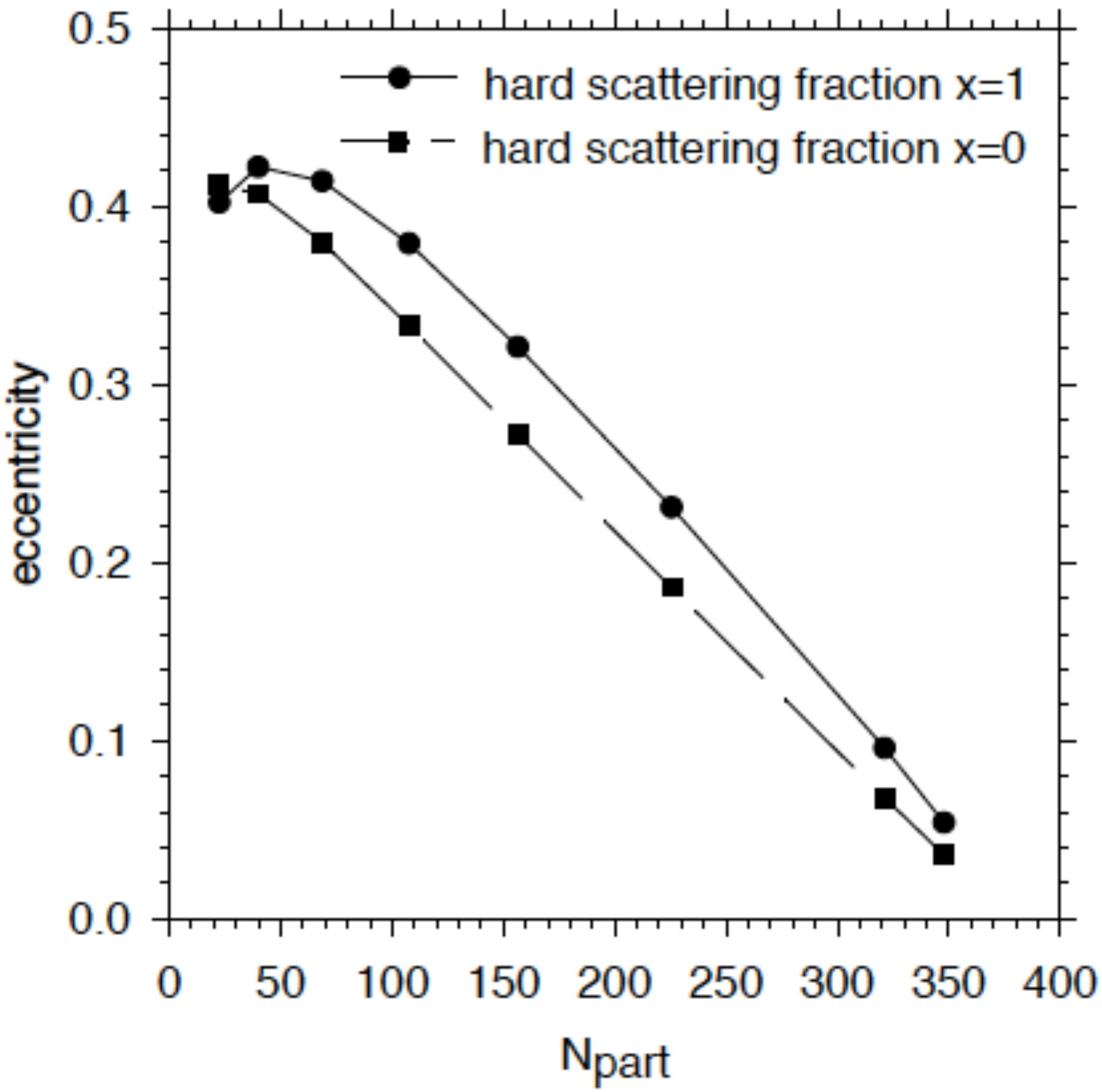
x=1

$\varepsilon_0 = 48\, GeV / fm^3$

- 0-10% reasonable fit in both scenario
- Different behavior in peripheral collision

*S. S. Adler et al. [PHENIX Collaboration], Phys. Rev. C 69, 034910 (2004)

Elliptic flow and Initial Spatial Eccentricity



Ideal hydrodynamics:

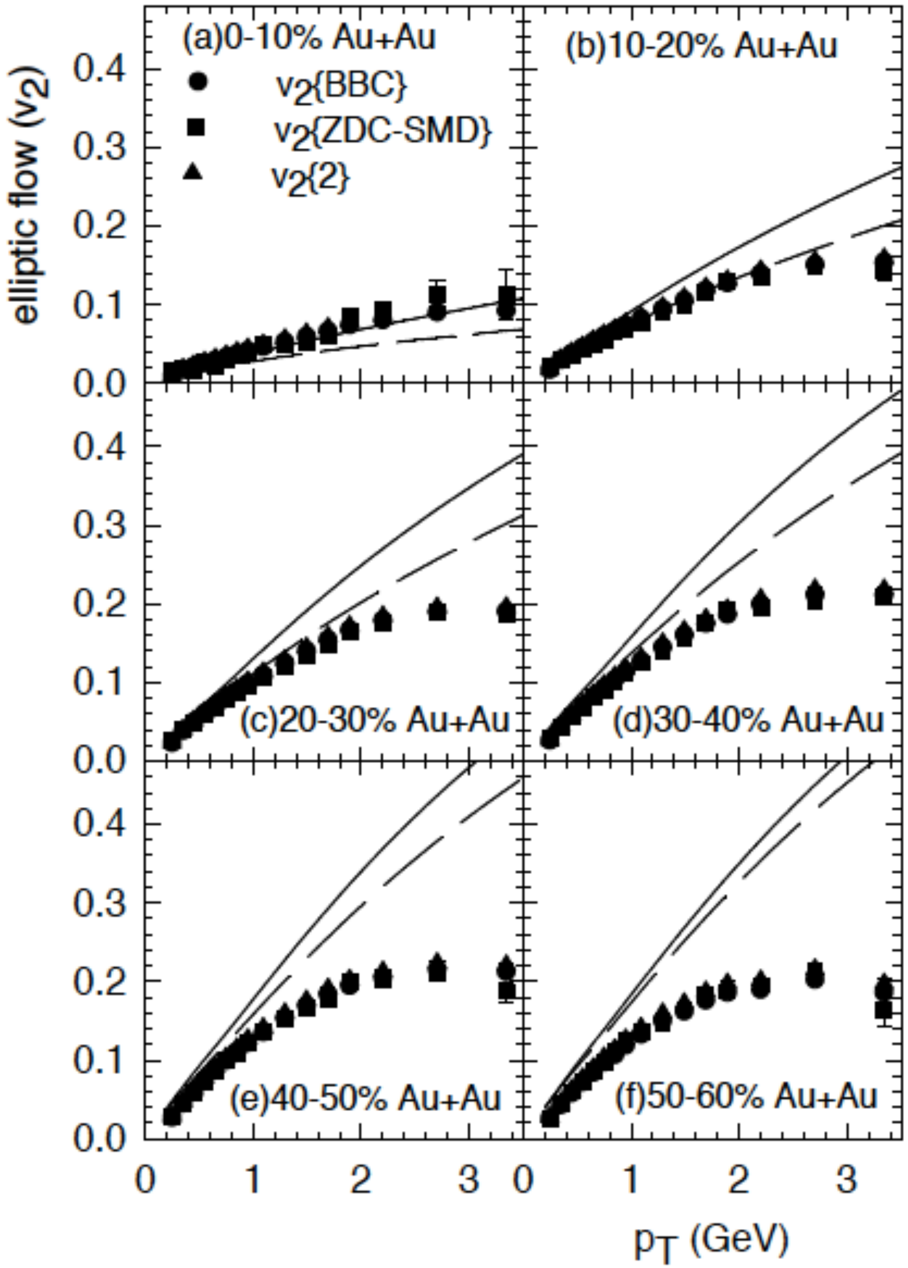
$$v_2 \propto \varepsilon_x$$

$$\varepsilon_x = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle}$$

$\langle \ldots \rangle$ Denotes energy density weighted averaging

Initial eccentricity are different for two scenario

Charged particle v_2, 200 GeV, Au+Au (PHENIX)



❖The solid line ➔ $x = 1$

❖The dashed line ➔ $x = 0$

❖Other conditions same as for charged hadron p_T spectra

$x = 1$ -- data is over predicted for higher centrality .

10-20% ,P_T=1.5 GeV ~20% higher
50-60% at P_T=1.5 GeV ~60% higher

$x = 0$ --data under predicted
0-10% -- P_T=1.5 GeV ~ 35%

*S. Afanasiev et al. [PHENIX Collaboration], Phys. Rev.C 80, 024909 (2009).

- Present analysis indicate that in 0-10% Au+Au collisions, simultaneous description of the p_T spectra and elliptic flow require hard scattering fraction $x = 1$ in the Glauber model initial condition.
- However less central collision, $x = 0$,better describe v_2 and p_T
- Geometric scaling of Au+Au collisions changes with collision centrality. Arguably, transition from binary collision number scaling to participant scaling can not be as sharp as conjectured here.

and

More detailed analysis is required to find the width and exact location of the transition.

Few comments

- In the present analysis we have not included eccentricity fluctuation.
- Hirano and Nara* have studied the effect of eccentricity fluctuation on elliptic flow. They found Glauber model initialization (13% hard scattering fraction), even with eccentricity fluctuation, under predict experimental (integrated) elliptic flow.

*T. Hirano and Y. Nara, Phys. Rev. C 79, 064904 (2009).

- We have estimated the effect of eccentricity fluctuations on differential elliptic flow . With participant scaling($x = 0$),in 0-10% collision, in the p_T range 1-2 GeV, elliptic flow increases only by ≈ 10%. Experimental flow are still under predicted.
- Other models of initials condition like CGC, Quark participant .

Summary and conclusion

- Two extreme scenario with Glauber model initialization in ideal hydrodynamic are considered

$$\varepsilon(b,X,Y) = \varepsilon_0\left[(1-x)N_{part}(b,X,Y) + xN_{coll}(b,X,Y)\right]$$

$x = 1$ → Hard processes

$x = 0$ → Soft processes

- Both scenario explains 0-10% Au+Au 200 GeV data on charged hadron p_T spectra.

- However $x = 1$ explains better elliptic flow(v_2) in 0-10% centrality.

- Geometric scaling of Au+Au collisions changes with collision centrality

- Central collision~ energy density scales with binary collision (hard processes)

- Less central ~ number of participant (soft processes)

THANK YOU

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And

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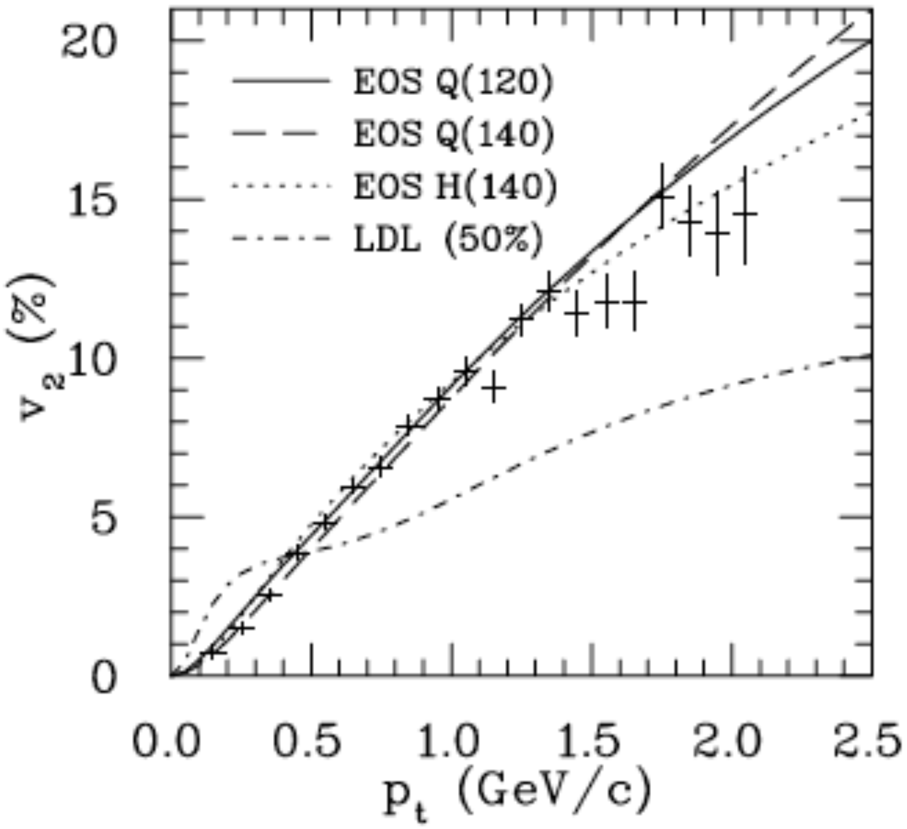
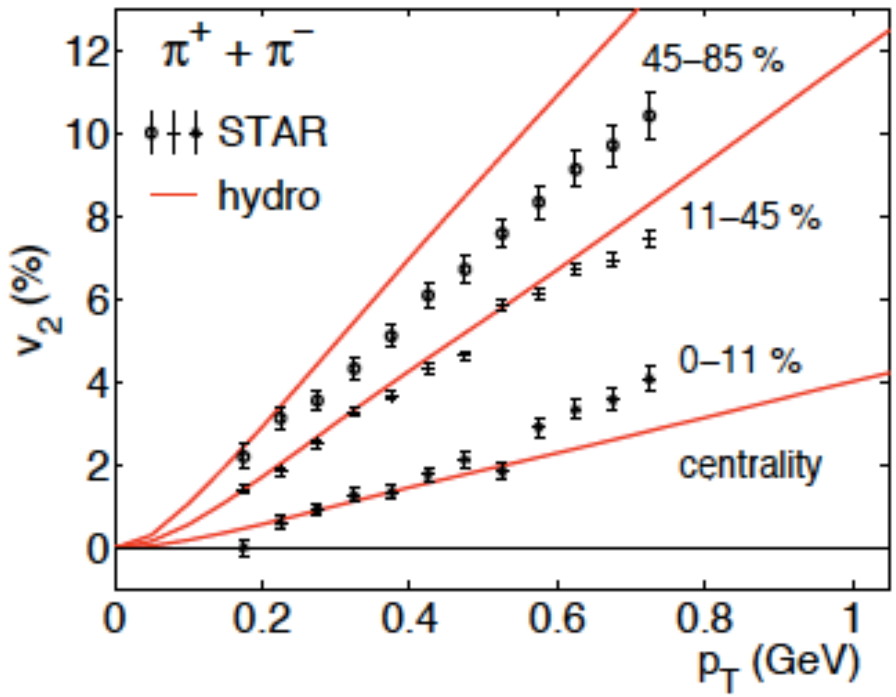
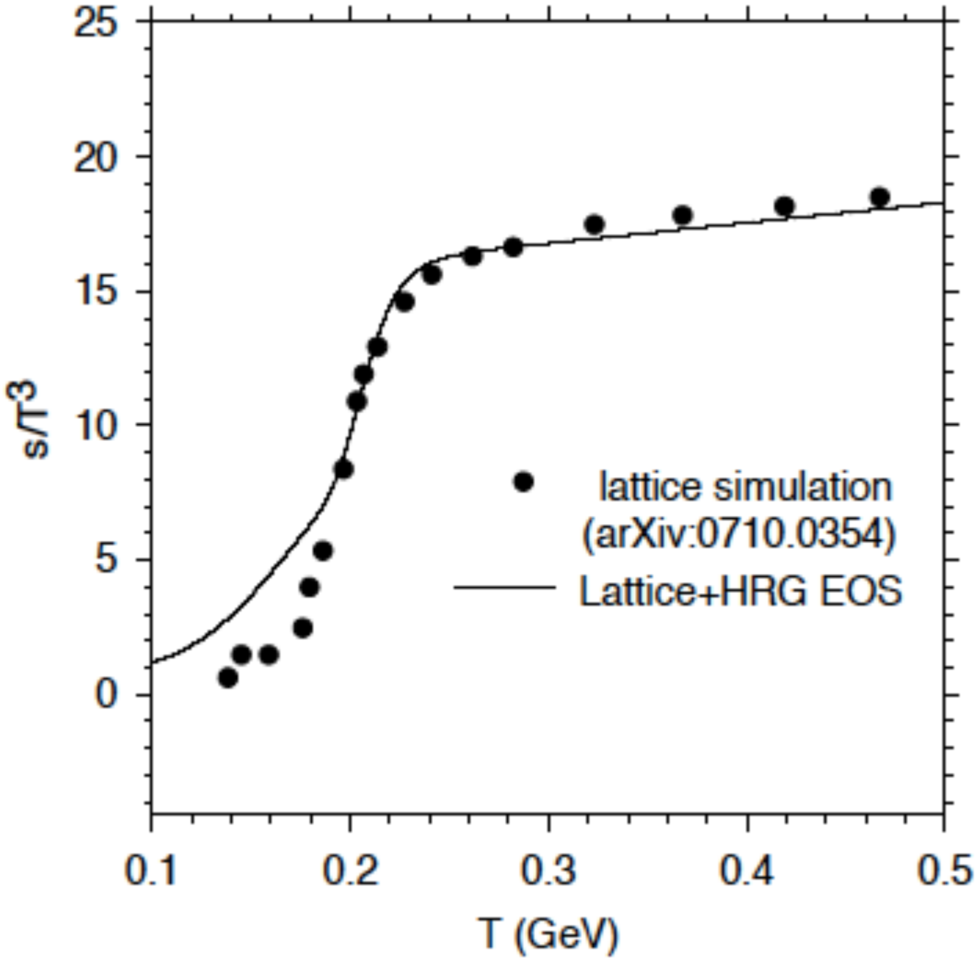
Back up

Charged Hadron AuAu 130 STAR, heinz





Combined EOS



$$\frac{s}{T^3} = \alpha + [\beta + \gamma T][1 + tanh\frac{T - T_c}{\Delta T}],$$

$$\begin{aligned} p(T) &= \int_0^T s(T')dT' \\ \varepsilon(T) &= Ts - p. \end{aligned}$$