Transverse expansion in nuclear collisions at RHIC BES

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Introduction

- During the evolution of the QGP - collective expansion
- Azimuthal anisotropy of particle production - experimental signature of collective flow
- Fourier expansion

$$\frac{\mathrm{d}N}{\mathrm{d}\phi} \propto 1 + 2\sum_{n=1}^{\infty} v_n \cos[n(\phi - \Psi_{RP})]$$

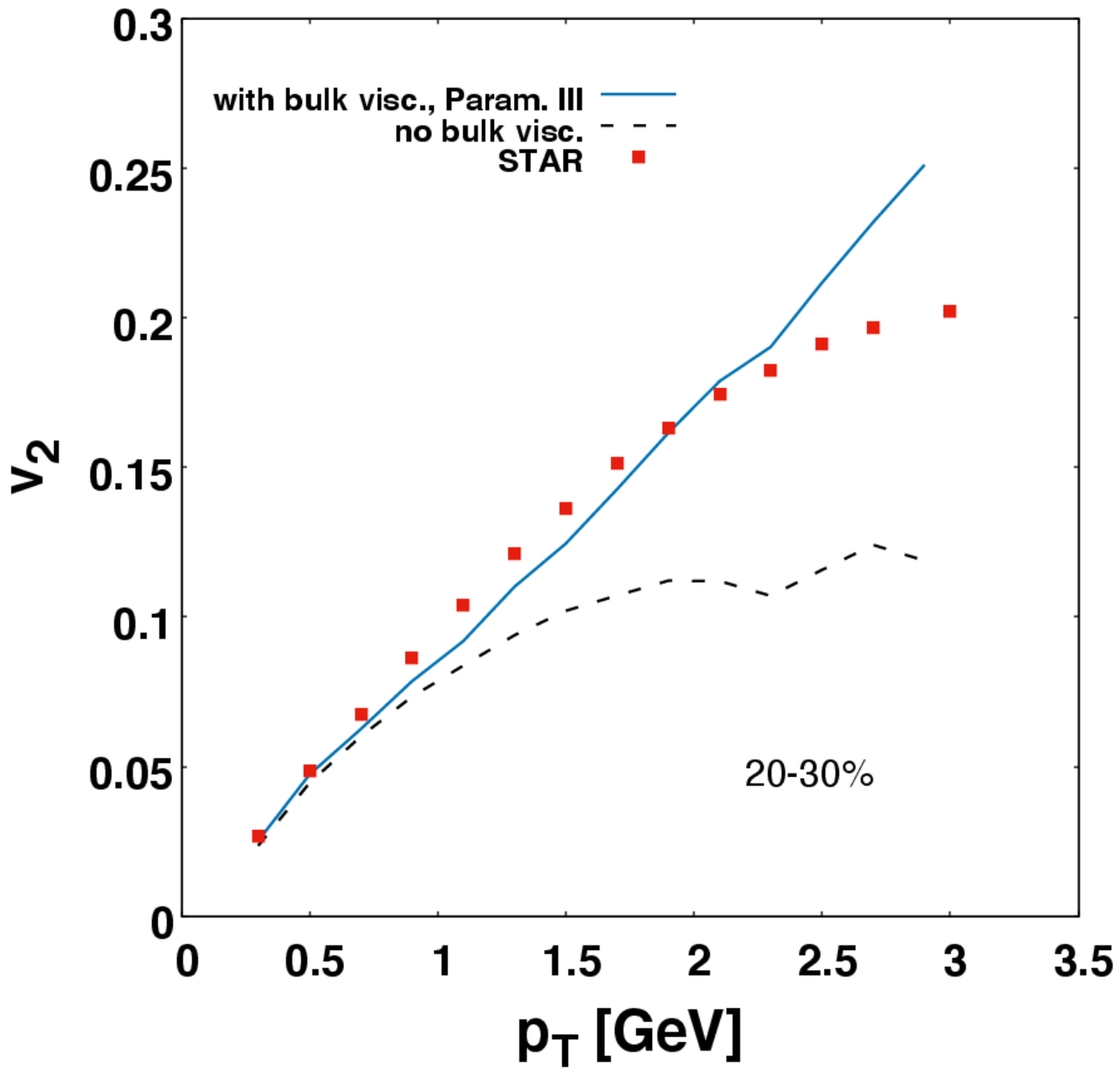
- Fourier coefficients - $v_n(p_T, y) = \langle \cos[n(\phi - \Psi_{RP})] \rangle$
- Second Fourier coefficient in Fourier series - elliptic flow - v_2
- Evolution of the fireball - hydrodynamic approach

vHLLE

- 3+1 dimensional hydrodynamic code
- Matter from initial state transformed into the initial fluid
- Fluid evolved by relativistic viscous hydrodynamic equations until freeze-out
- Important assumptions
    - Non-zero baryon density in the entire system
    - No boost-invariant longitudinal expansion
- Initial state - Glissando
- Final state - SMASH

Glissando+vHLLE+SMASH

- Au+Au at $\sqrt{s_{NN}} = 27$ GeV



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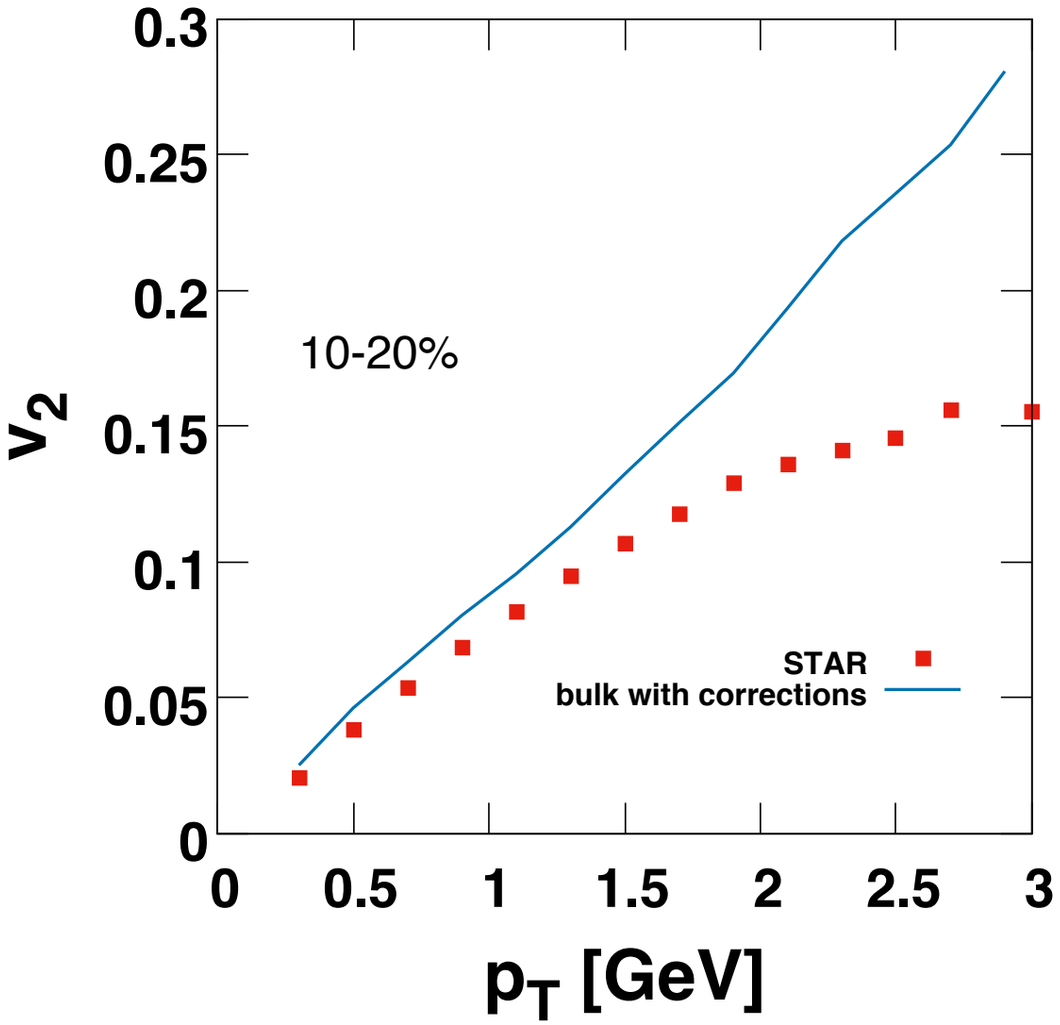
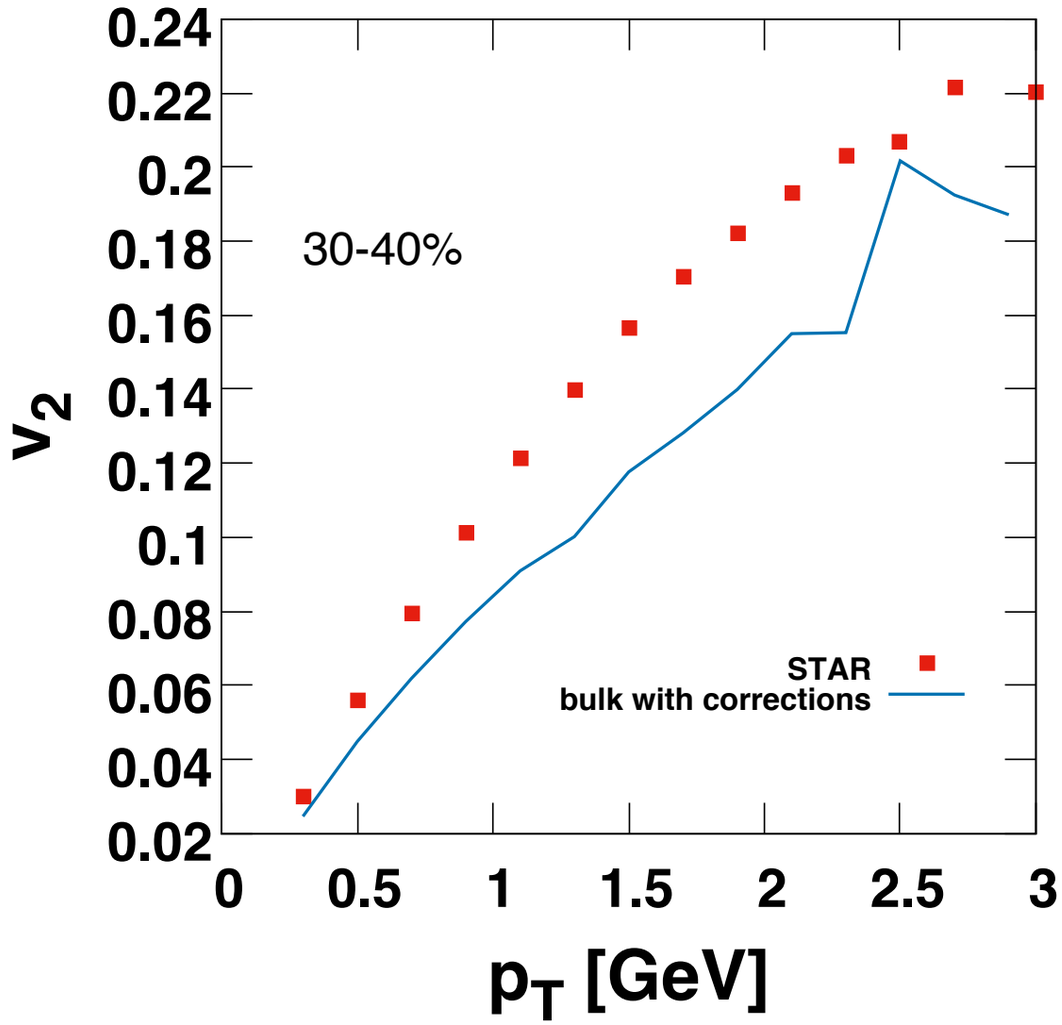




IMAGO

- Initial Momentum Anisotropy Glauber mOdel
- Allows transverse momentum deposition to the initial state
- Nucleon density - Woods-Saxon distribution

$$\rho = \frac{\rho_0}{1 + \exp\left(\frac{r - R}{a}\right)}$$

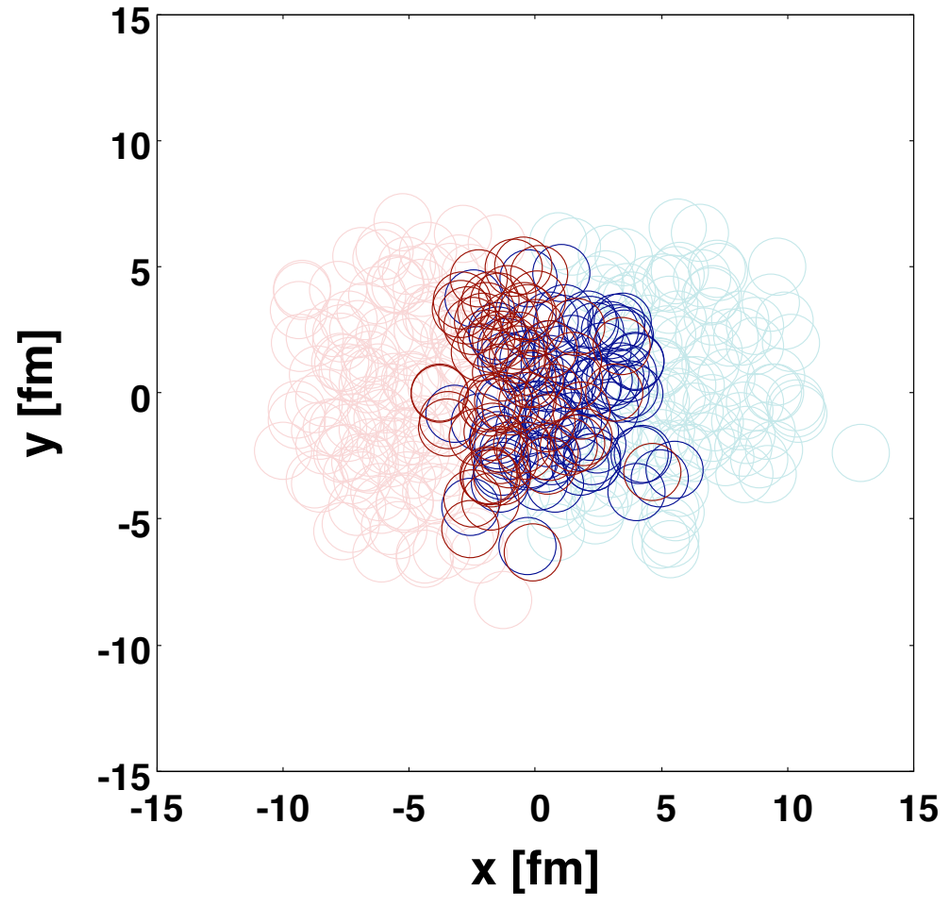
- Centers of nucleons generated with spacing between them

IMAGO

- Nucleon-nucleon collision occurs if

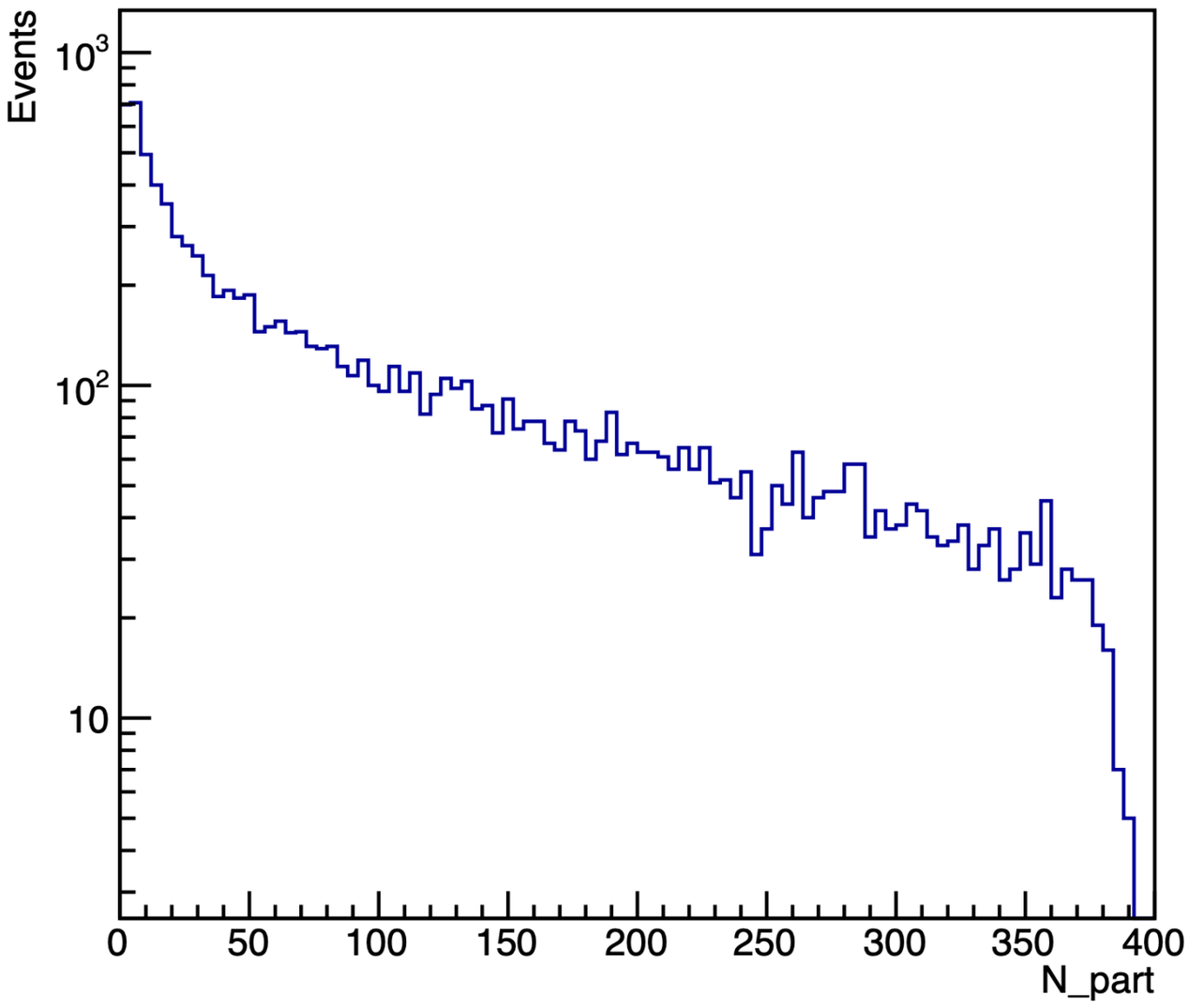
$$d \leq \sqrt{\frac{\sigma_{NN}}{\pi}}$$

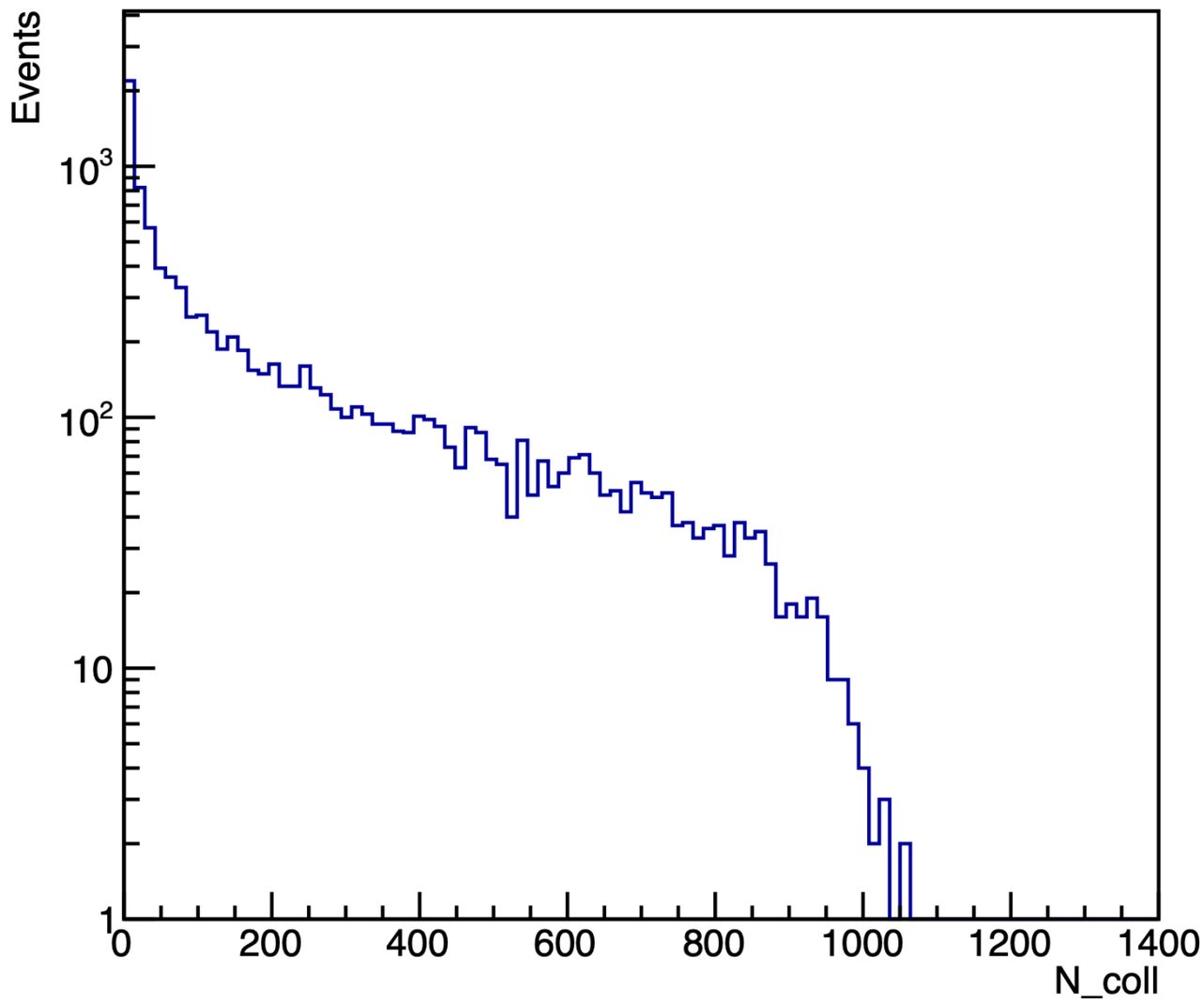
- For $\sqrt{s_{NN}} = 27$ GeV -> $\sigma_{NN} = 33.1$ mb



IMAGO

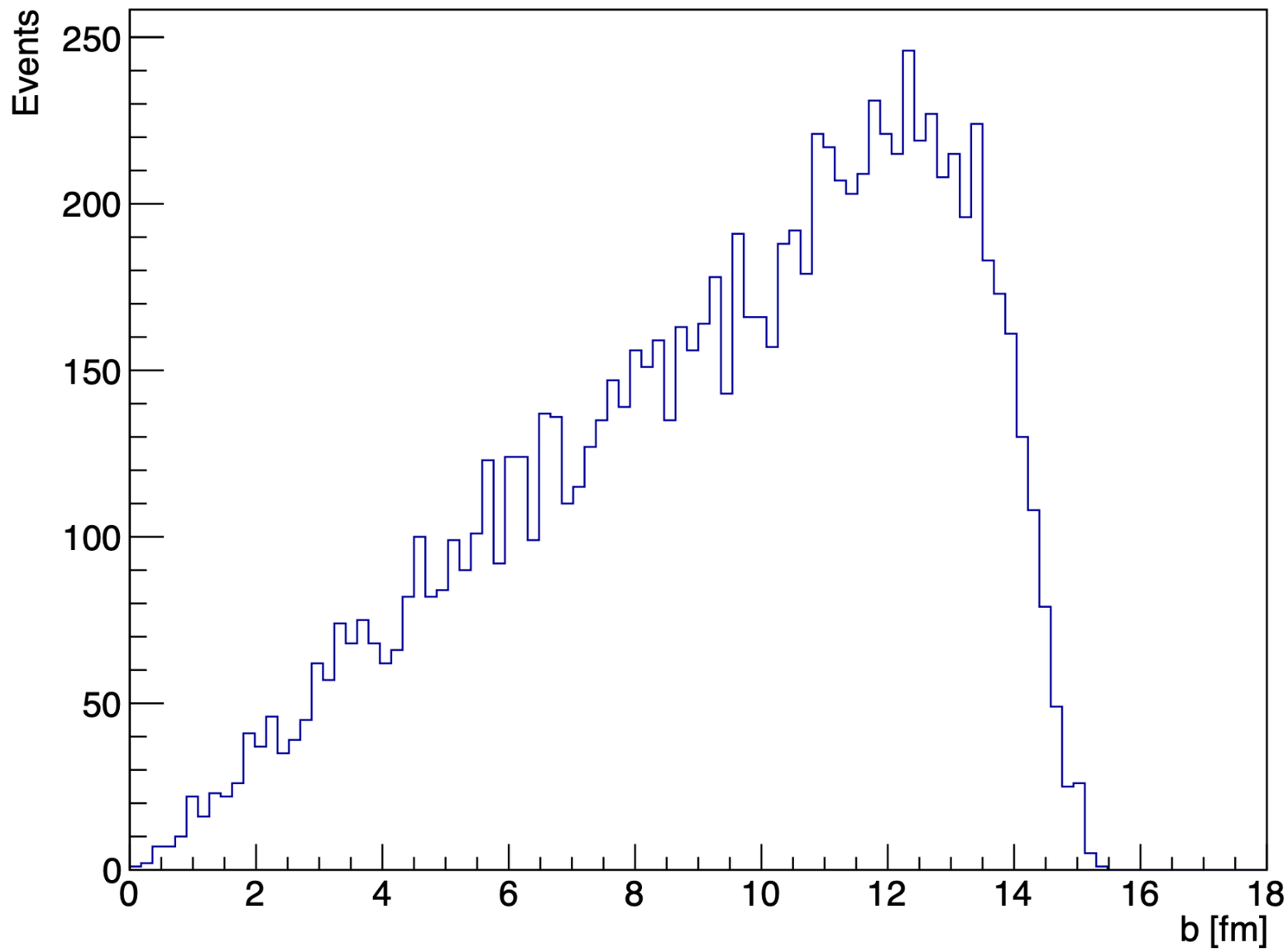
- Number of participants N_{part} and number of binary collisions N_{coll}





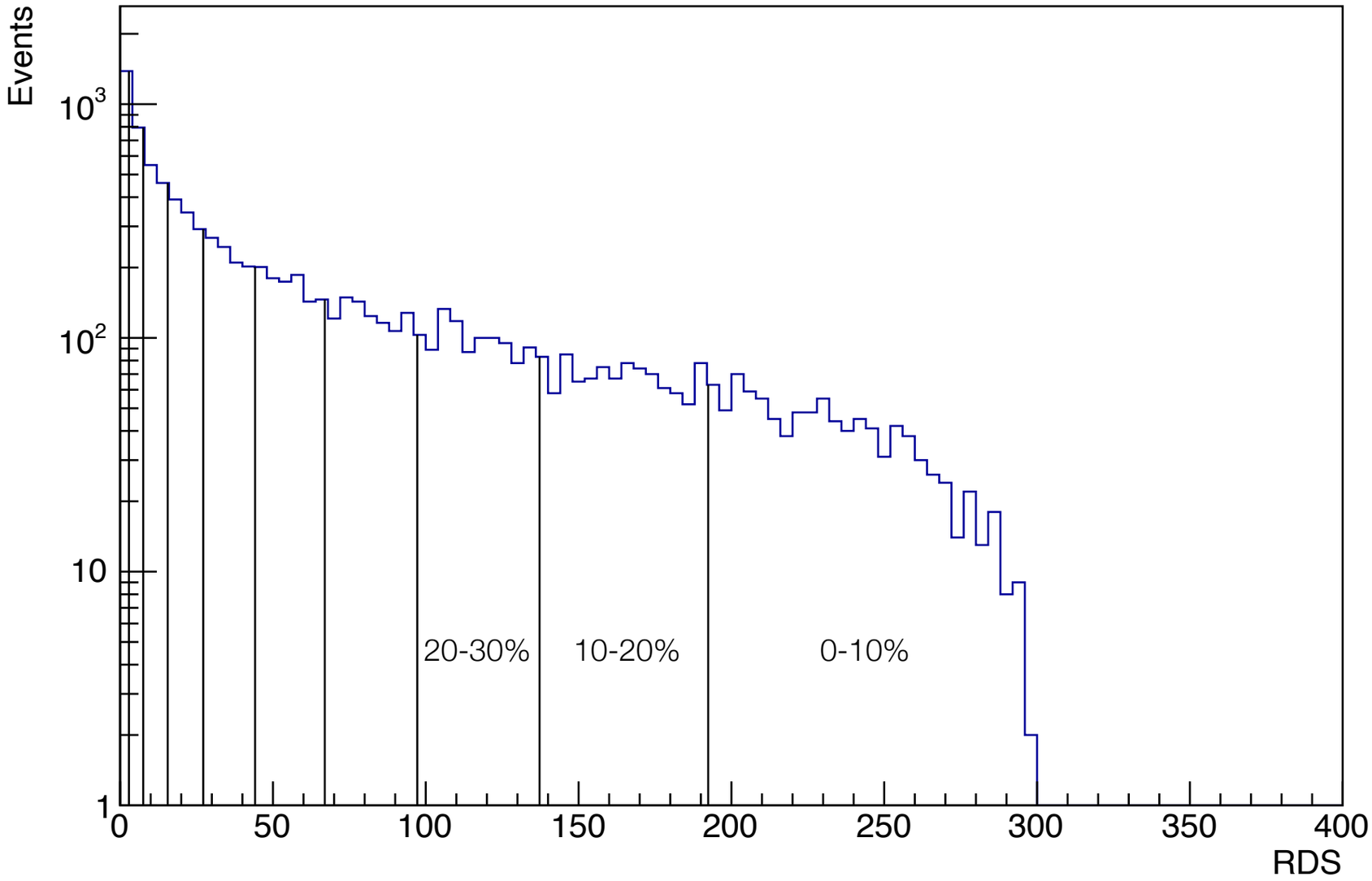
IMAGO

- Linear distribution of the impact parameter $\rho(b) = 2\frac{b}{b_{max}^2}$



IMAGO

- Centrality definition - relative deposited strength - $RDS = \frac{(1-\alpha)}{2} N_{part} + \alpha N_{coll}$



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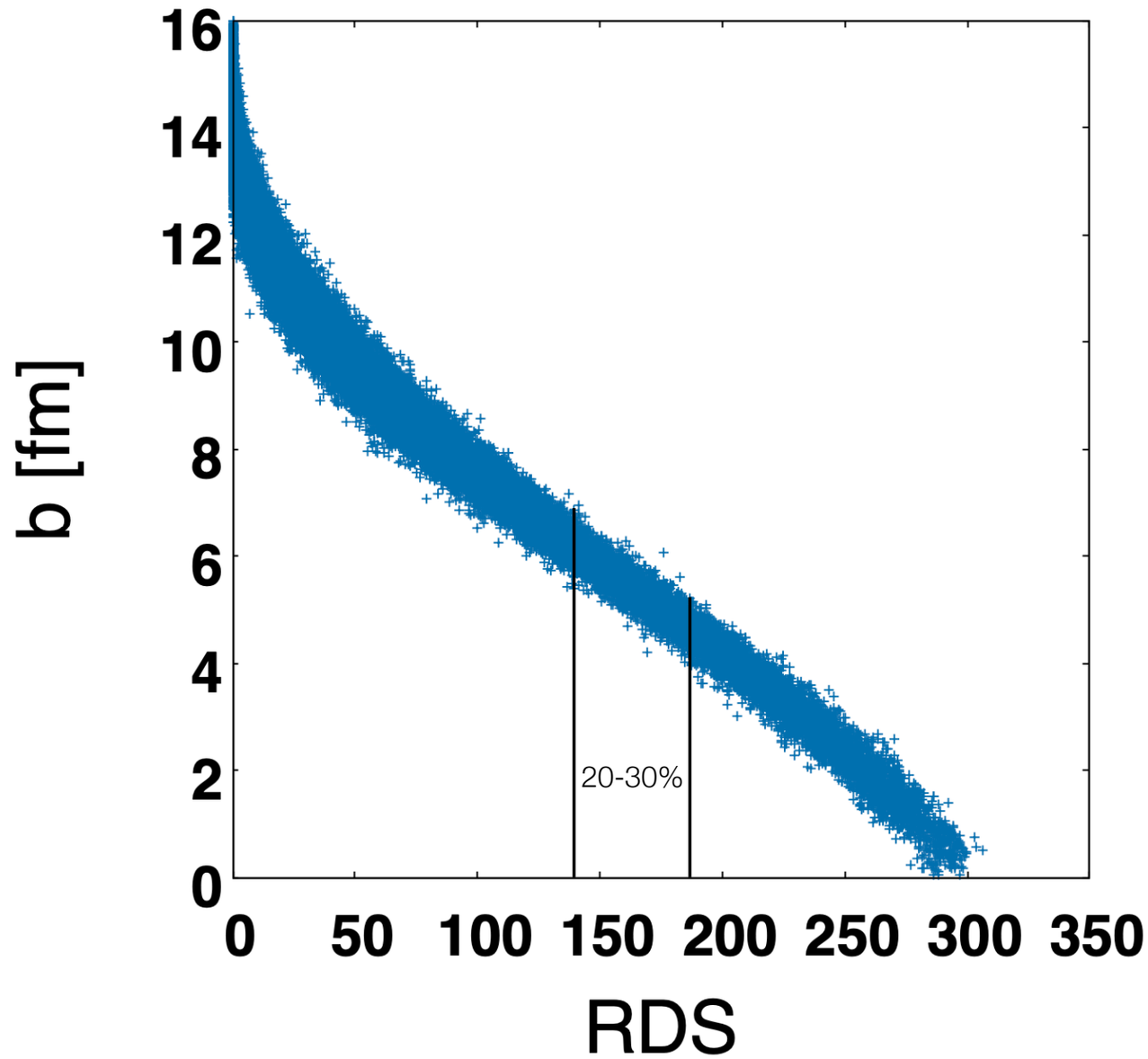
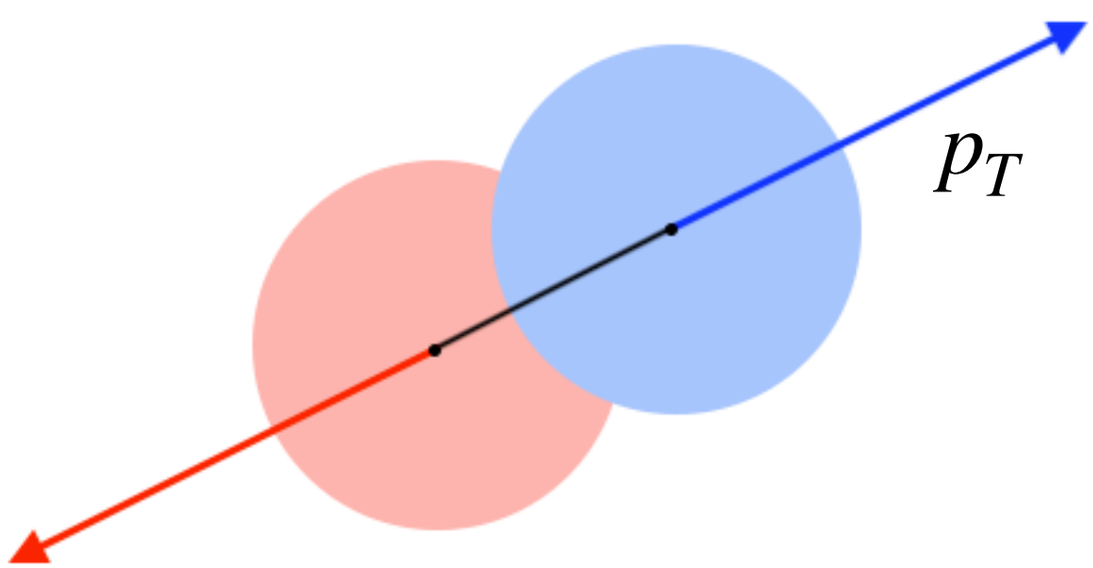


IMAGO

- Transverse momentum deposited in the opposite direction of relative position of the nucleons
- $|p_T|$ is parameter of the model
- Random walk



Initial fluid

- Point-like “sources” in the traverse profile - smearing

$$g_i(x,y) = \frac{1}{2\pi\sigma_\perp^2}\exp\left(-\frac{(x-x_i)^2+(y-y_i)^2}{2\sigma_\perp^2}\right)$$

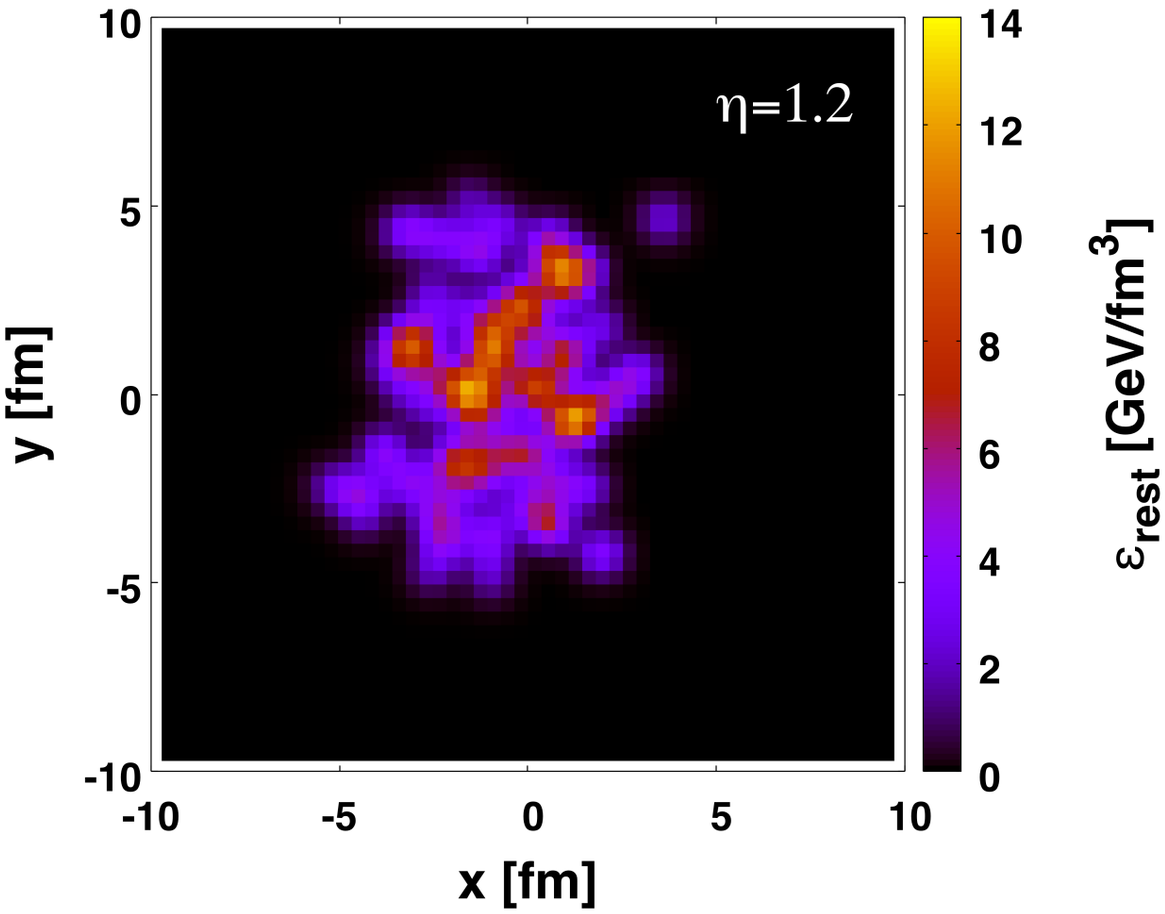
- Extension into the rapidity

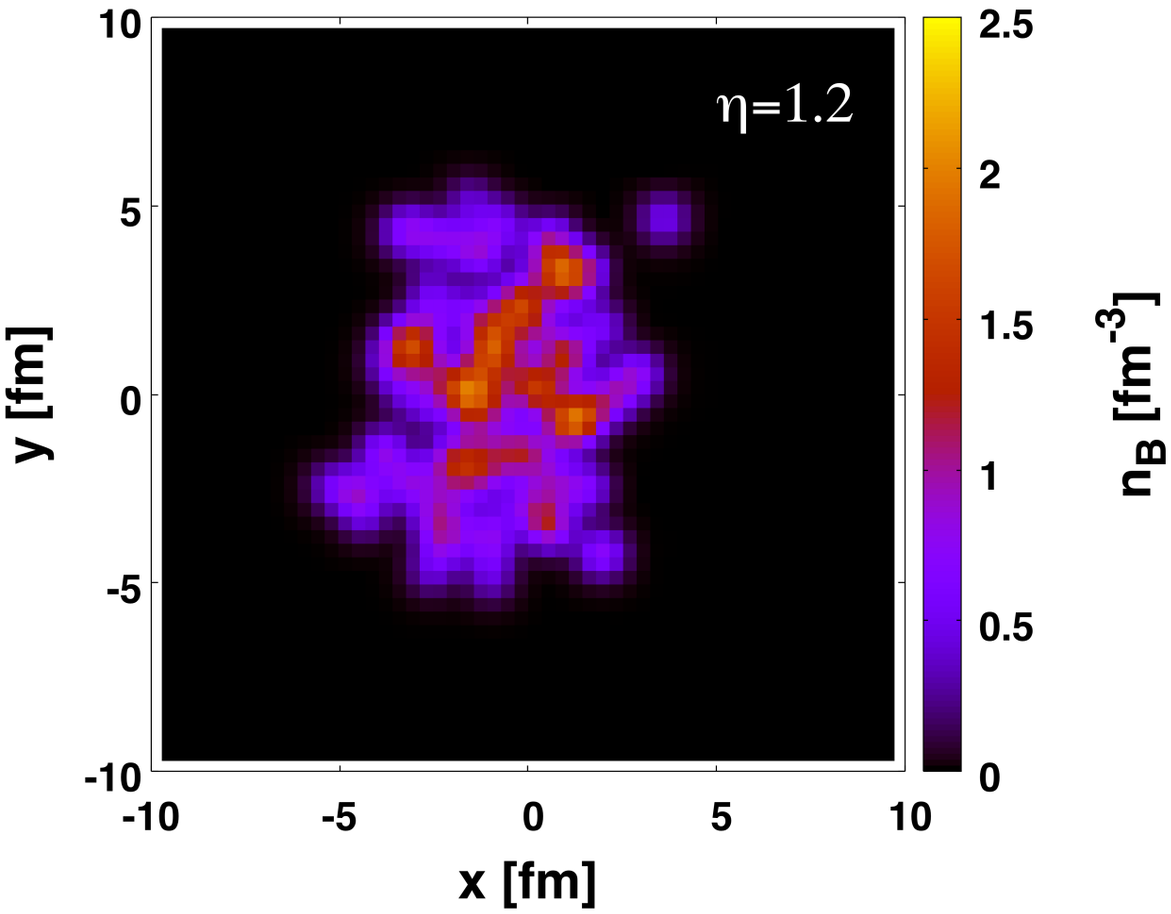
$$f(\eta_\parallel) = \exp\left(-\frac{(\eta_\parallel-\eta_0)^2}{2\sigma_\eta}\Theta(|\eta_\parallel-\eta_0|)\right)$$

- Total energy normalized to $\frac{N_{part}}{2}\sqrt{s_{NN}}$

Density profiles from IMAGO

- Centrality 20-30%, $|p_T| = 200$ MeV





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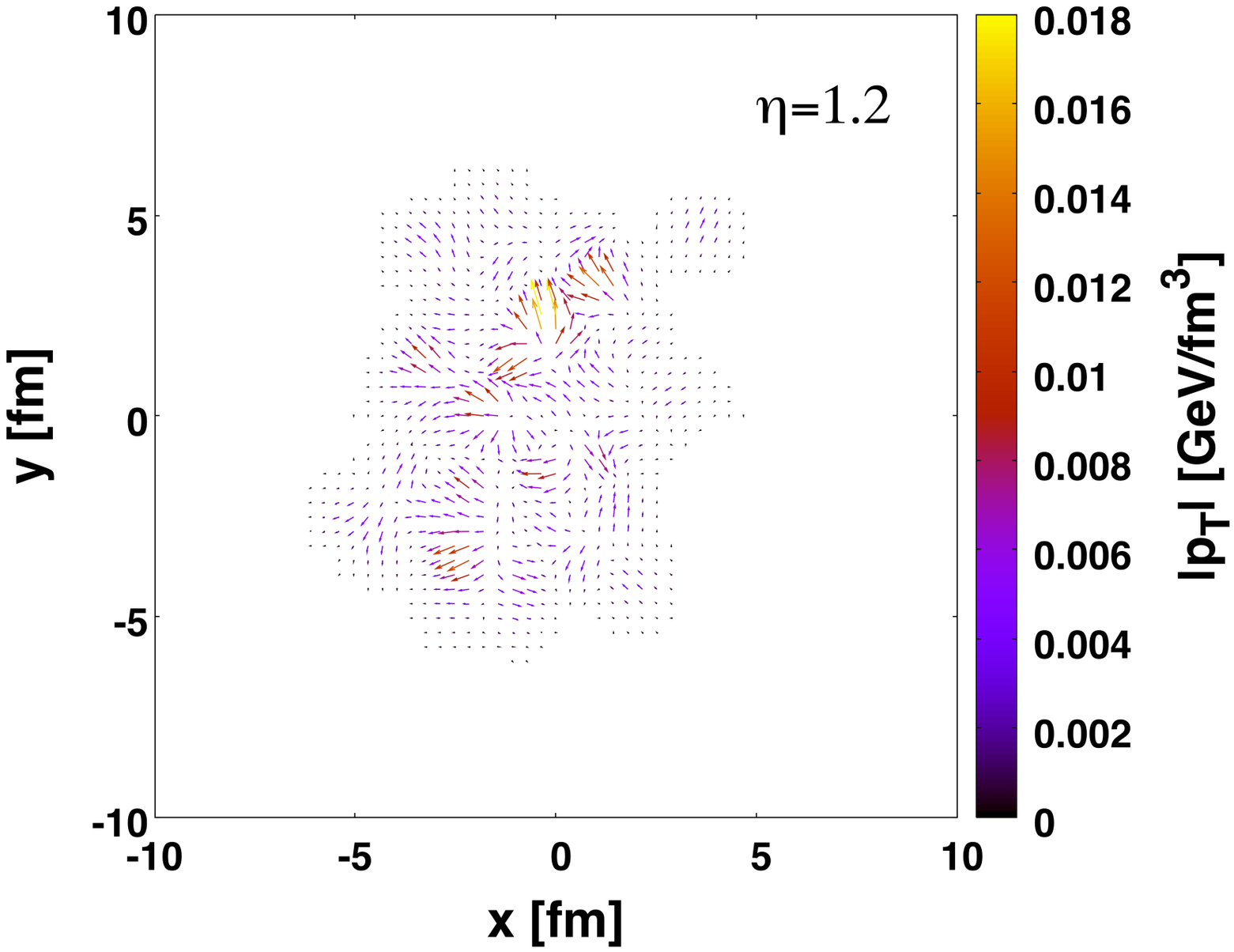
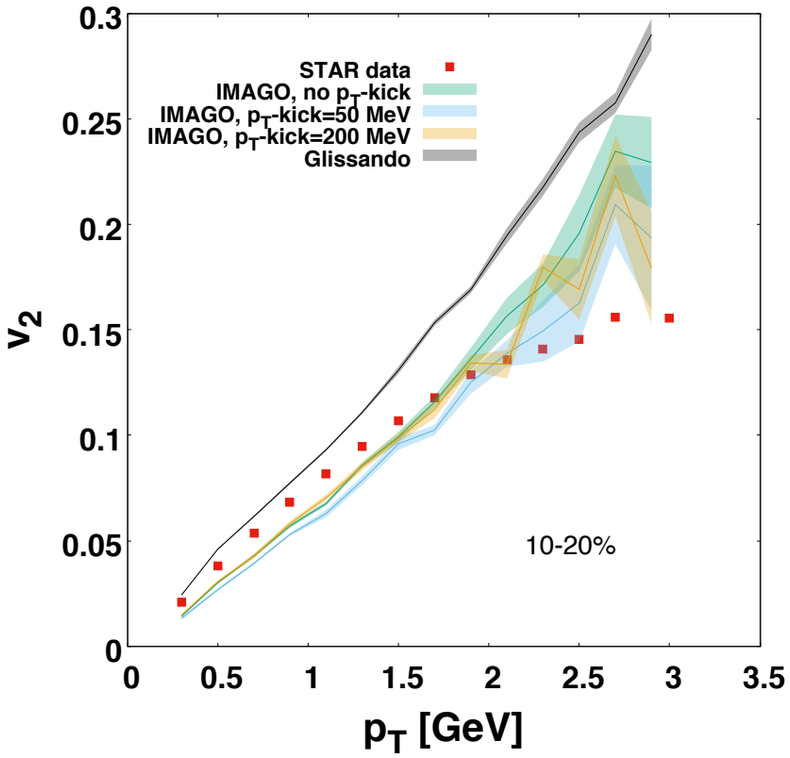
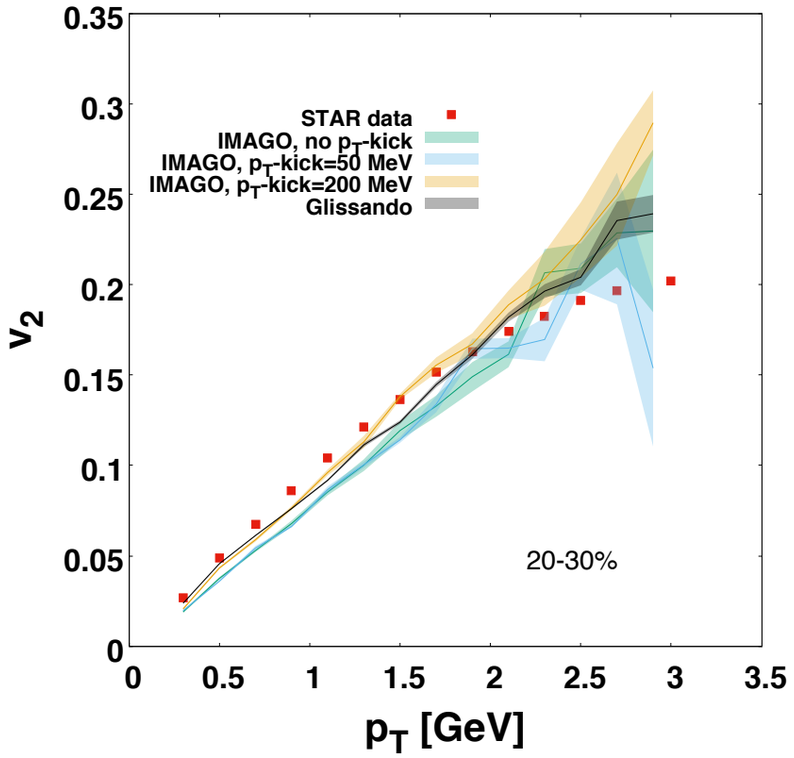
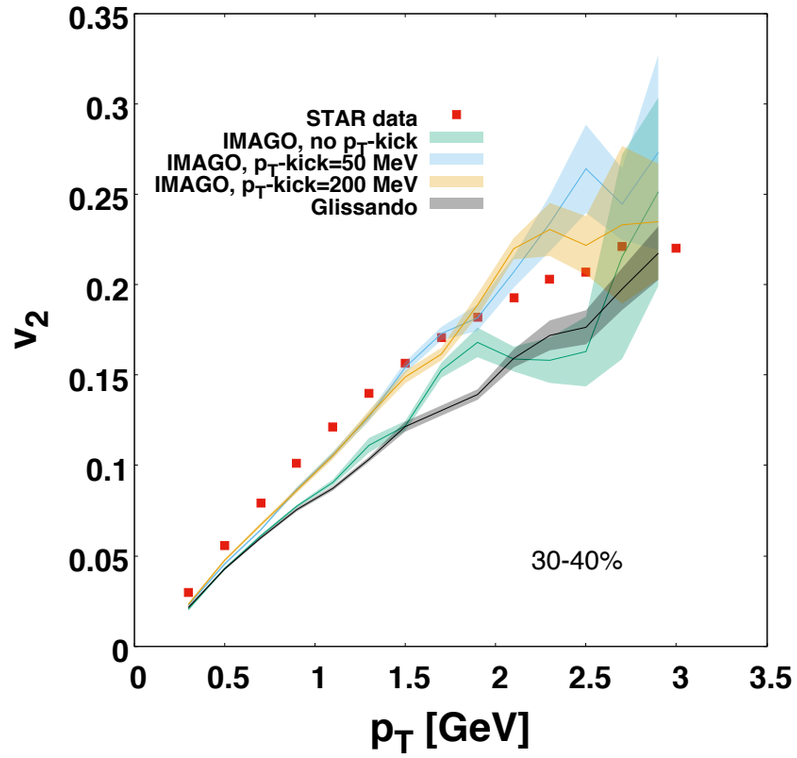


Results

- Au+Au at $\sqrt{s_{NN}} = 27$ GeV







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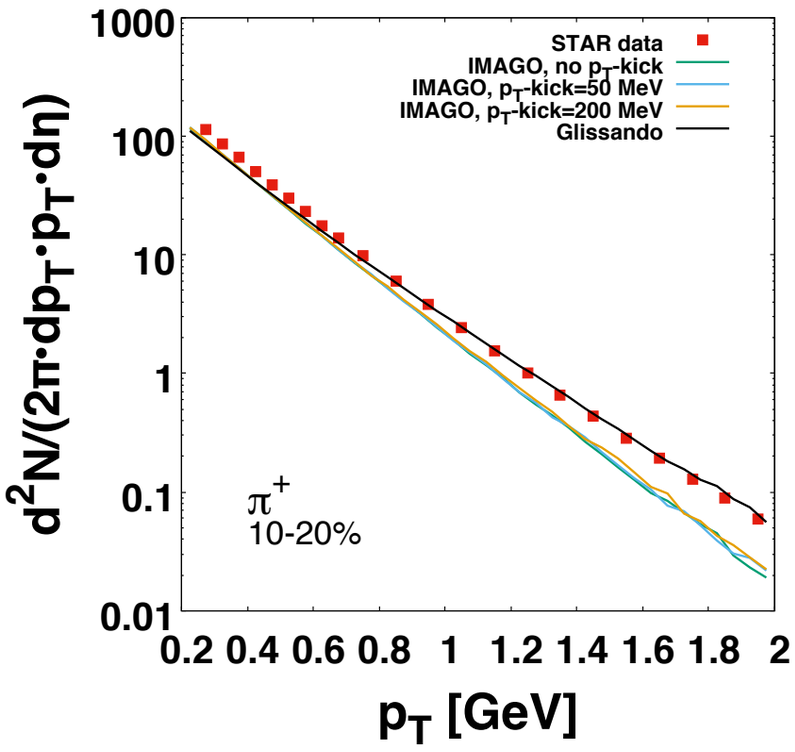
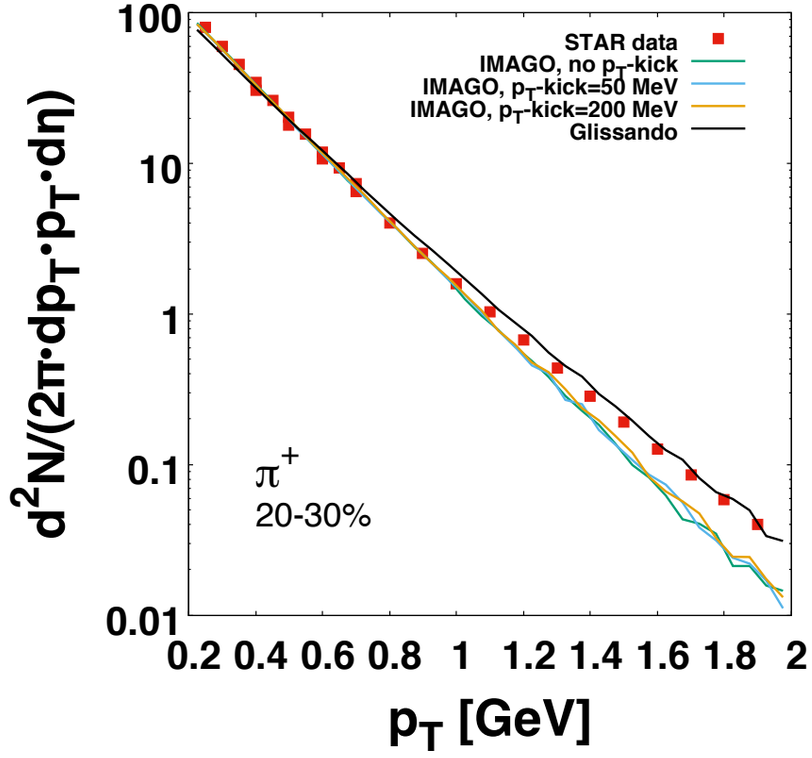
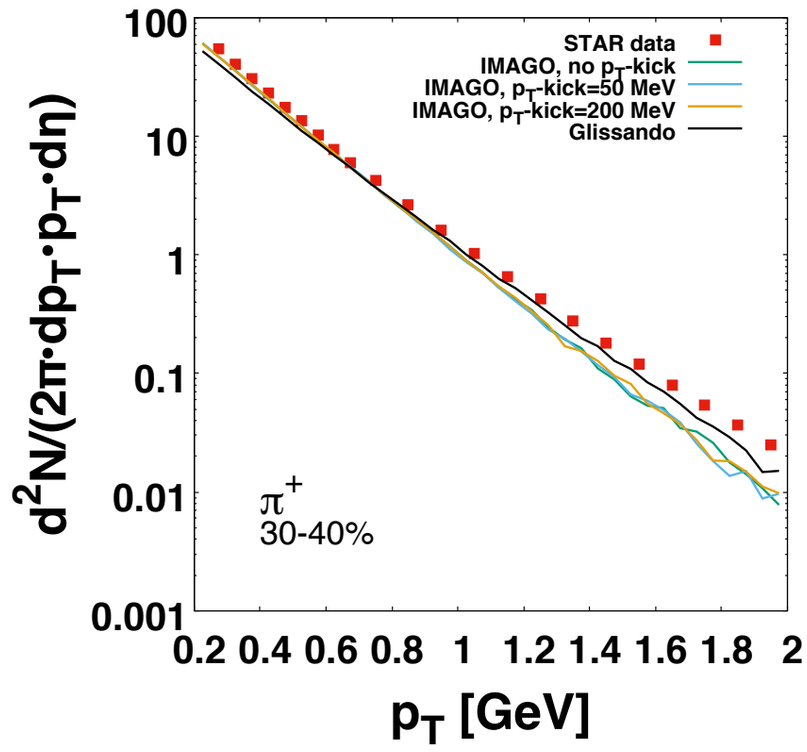


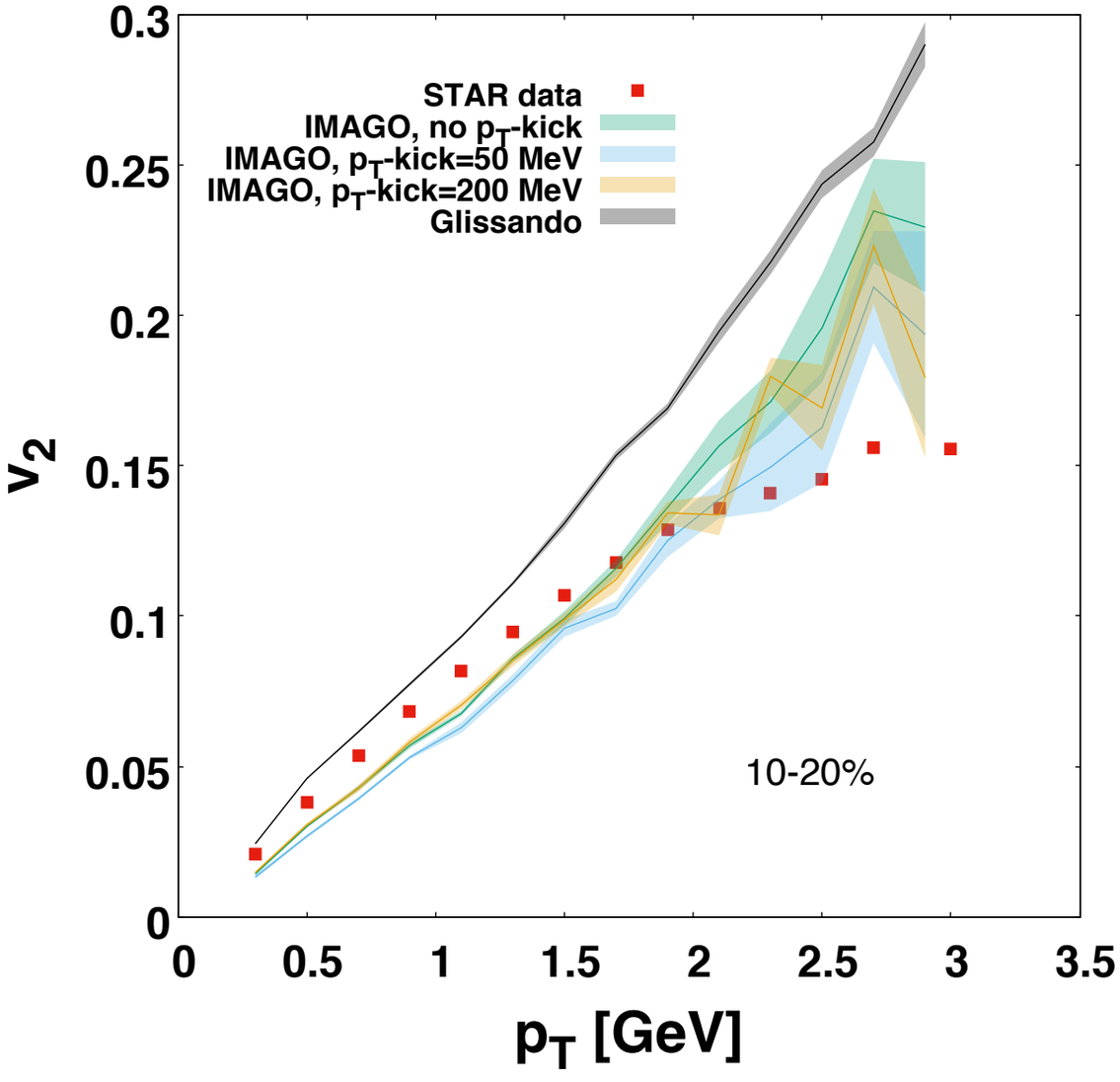


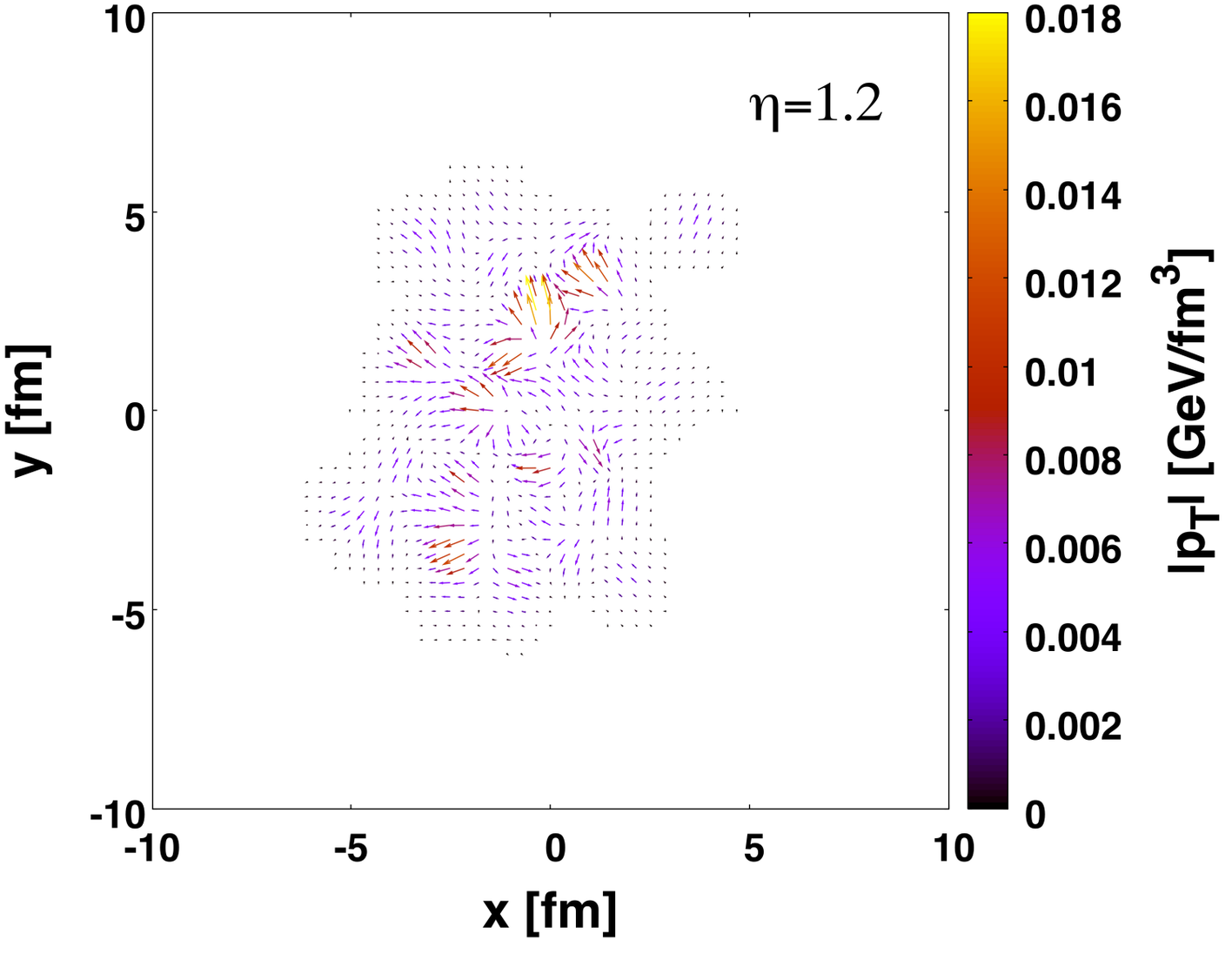


Summary

- Using hybrid vHLLE package with Glissando as i. c., the v_2 values do not match data from RHIC BES
- New Glauber model which allows transverse momentum deposition into the initial state is created
- Results from the new model are improved in comparison to the simulations using Glissando

Backup


STAR data
IMAGO, no p_T-kick
IMAGO, p_T-kick=50 MeV
IMAGO, p_T-kick=200 MeV
Glissando
10-20%
v_2
p_T [GeV]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.5
1
1.5
2
2.5
3
3.5


η=1.2
y [fm]
x [fm]
$|p_T|$ [GeV/fm^3]
10
5
0
-5
-10
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0