Azimuthally sensitive femtoscopy and v_2

Boris Tomášik

The Niels Bohr Institute

and NPI ASCR Řež

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1 Motivation

• v_2: caused by spatial and/or flow anisotropy
⇒ correlation between spatial and flow anisotropy

• ϕ dependence of HBT: caused by spatial and/or flow anisotropy
⇒ some other correlation between spatial and flow anisotropy

Can we determine spatial and flow anisotropy from both v_2 and asHBT?
(recall measuring T and v_T from p_T-spectra and HBT radii)

Statements in literature:

• not possible to conclude on spatial anisotropy from v_2 but HBT will do [STAR, PRL **87** (2001) 182301]

• different final states of hydro simulations distinguished by HBT [U Heinz, P F Kolb, PLB **542** (2002) 216]

Motivation: questions asked here

- What is the correlation between spatial and flow anisotropy in determining v_2?

- What is the correlation between spatial and flow anisotropy in determining the azimuthal dependence of HBT radii?

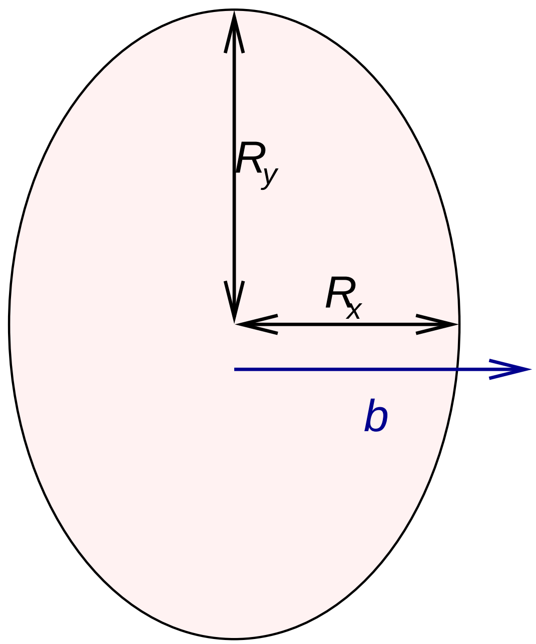
- Can we unambiguously get both anisotropies from data?

$\rightarrow$ Study these questions by exploring a large class of models expressed via the blast-wave parametrisation.

2 The azimuthally anisotropic blast-wave model

- thermalised, temperature T
- longitudinally boost-invariant expansion
- ellipsoidal transverse profile

$$S(x,p) \propto \Theta(1-\tilde{r})\,, \qquad \tilde{r} = \sqrt{\frac{x^2}{R_x^2} + \frac{y^2}{R_y^2}}$$



spatial anisotropy parameter a:

$$R_x = a\,R\,, \qquad R_y = \frac{R}{a}$$

out-of-plane source: $R_x < R_y\,, \quad a < 1$

in-plane source: $R_x > R_y\,, \quad a > 1$

The . . . model: transverse flow

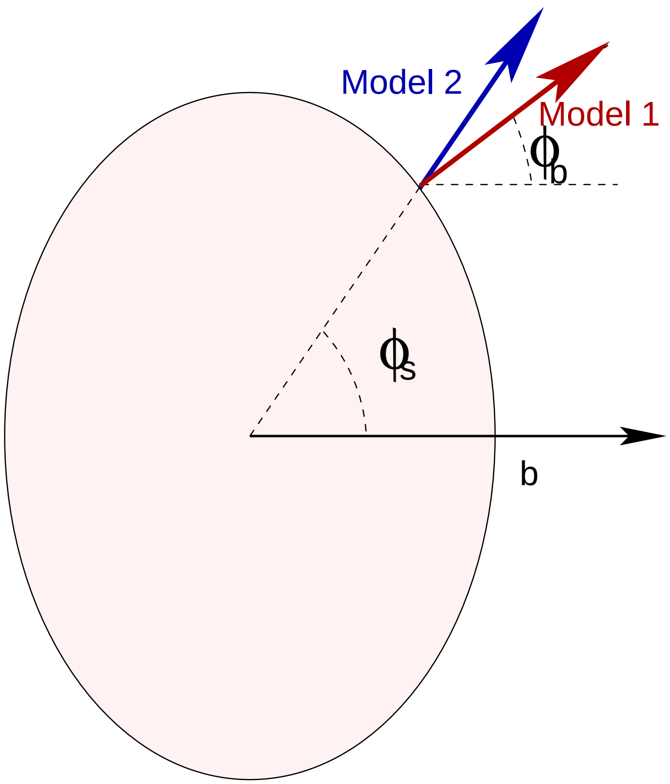
- two models differ in the azimuthal variation of flow velocity

- Model 1

[Retière & Lisa, PRC **70** (2004) 044907]

$$\rho(r,\phi) = \tilde{r}\,\rho_0\,(1+\rho_2\,\cos(2\phi_b))$$

early expansion pattern: $\vec{v} \parallel \vec{a} \parallel \nabla p$



- Model 2

$$\rho(r,\phi) = \tilde{r}\,\rho_0\,(1+\rho_2\,\cos(2\phi_s))$$

possibly later expansion pattern

3 The elliptic flow, v_2

- second Fourier coefficient of azimuthal dependence of the spectrum

$$P_1(p_T,\phi) = \frac{1}{2\pi} \left.\frac{d^2N}{p_T\,dp_T\,dy}\right|_{y=0} (1 + 2v_2(p_T)\cos(2\phi) + \dots)$$

the two used models give

$$v_2 = \frac{\int_0^1 d\tilde{r}\,\tilde{r}\int_0^{2\pi} d\phi\,\cos(2\phi)\,J(\phi)\,K_1(\cdots)\,I_2(\cdots)}{\int_0^1 d\tilde{r}\,\tilde{r}\int_0^{2\pi} d\phi\,J(\phi)\,K_1(\cdots)\,I_0(\cdots)}$$

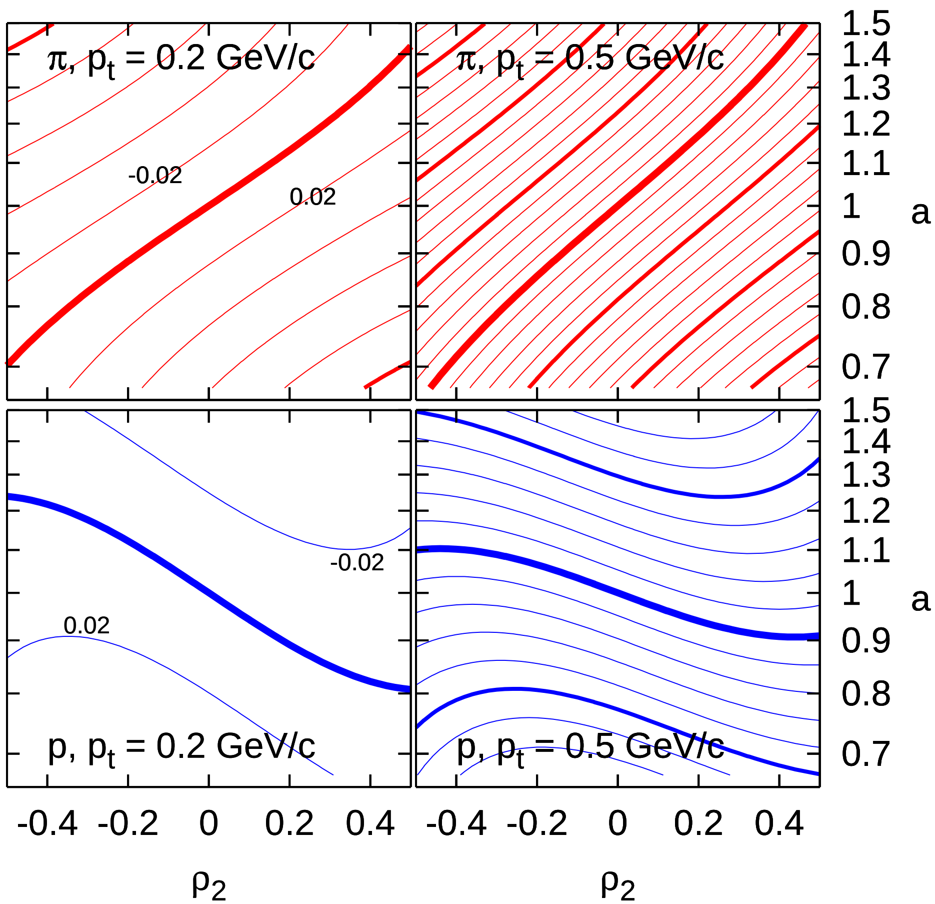
the results for different Models differ only in $J(\phi)$

Model 1: $J(\phi) = (a^2\cos^2\phi + a^{-2}\sin^2\phi)^{-1}$

Model 2: $J(\phi) = (a^{-2}\cos^2\phi + a^2\sin^2\phi)^{-1}$

$\Rightarrow$ same v_2 can be obtained from one in-plane ($a < 1$) and other out-of-plane ($a > 1$) source!

The correlation between a and ρ_2



- v_2 calculated with Model 1 for pions and protons
- $T = 100\,\text{MeV}$, $\rho_0 = 0.88$

- get results for Model 2 by $a \to a^{-1}$

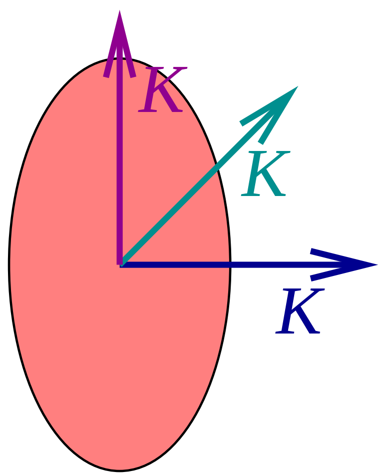
$\Rightarrow$ for given Model can disentangle dependence on a and ρ_2 by looking at different species

$\Rightarrow$ If the Model is known obtain T and ρ_0 from fit to azimuthally integrated spectrum, and ρ_2 and a from fit to v_2

4 Azimuthally sensitive HBT

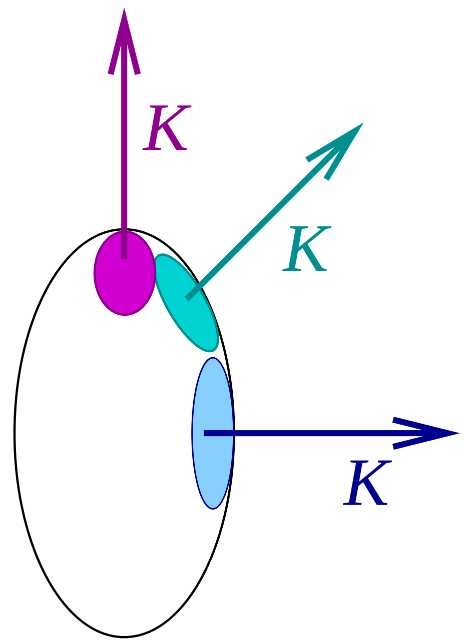
explicit ϕ–dependence:

sensitive to spatial anisotropy (a)



implicit ϕ–dependence:

generated by transverse flow and its anisotropy (ρ_2)

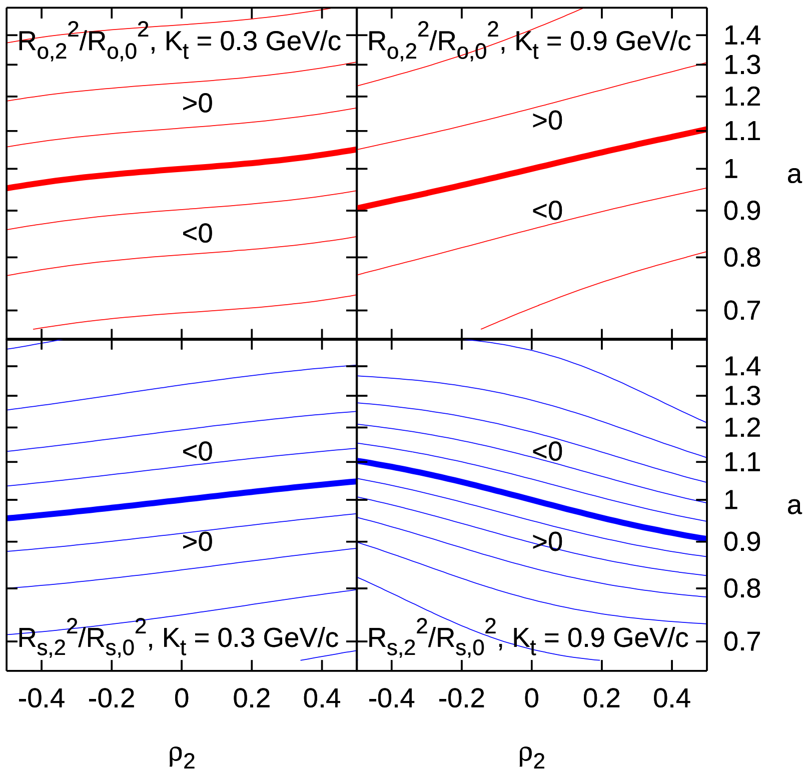


Fourier expansion of the radii at midrapidity

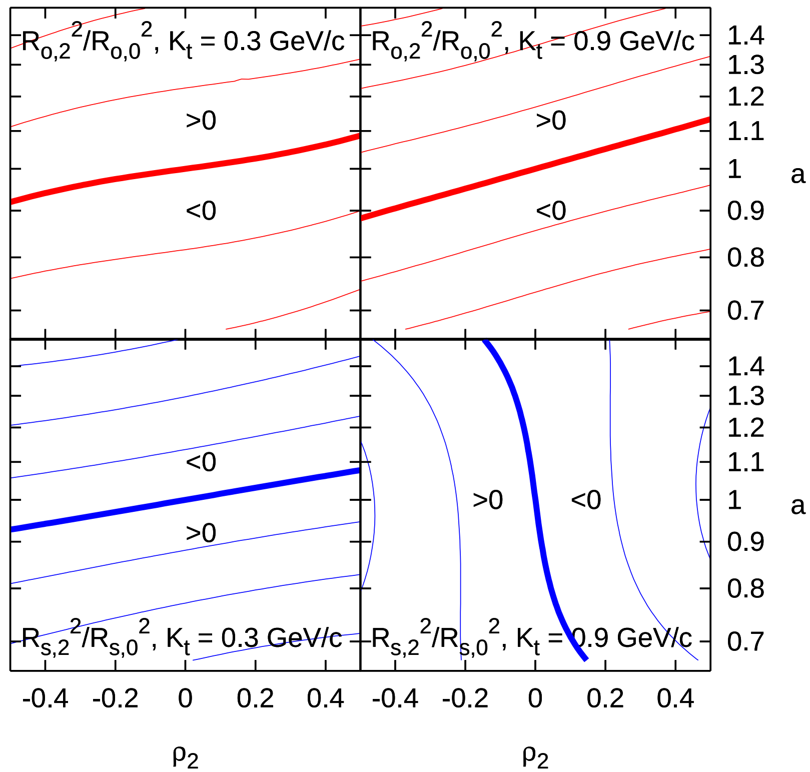
$$
\begin{aligned}
R_o^2(\phi) &= R_{o,0}^2 + 2R_{o,2}^2 \cos 2\phi + \dots \\
R_s^2(\phi) &= R_{s,0}^2 + 2R_{s,2}^2 \cos 2\phi + \dots \\
R_{os}^2(\phi) &= 2R_{os,2}^2 \sin 2\phi + \dots \\
R_l^2(\phi) &= R_{l,0}^2 + 2R_{l,2}^2 \cos 2\phi + \dots .
\end{aligned}
$$

- look at R_o^2 and R_s^2

- study $R_{i,2}^2/R_{i,0}^2$: sensitive to a and ρ_2 but less sensitive to R and ρ_0



Model 1

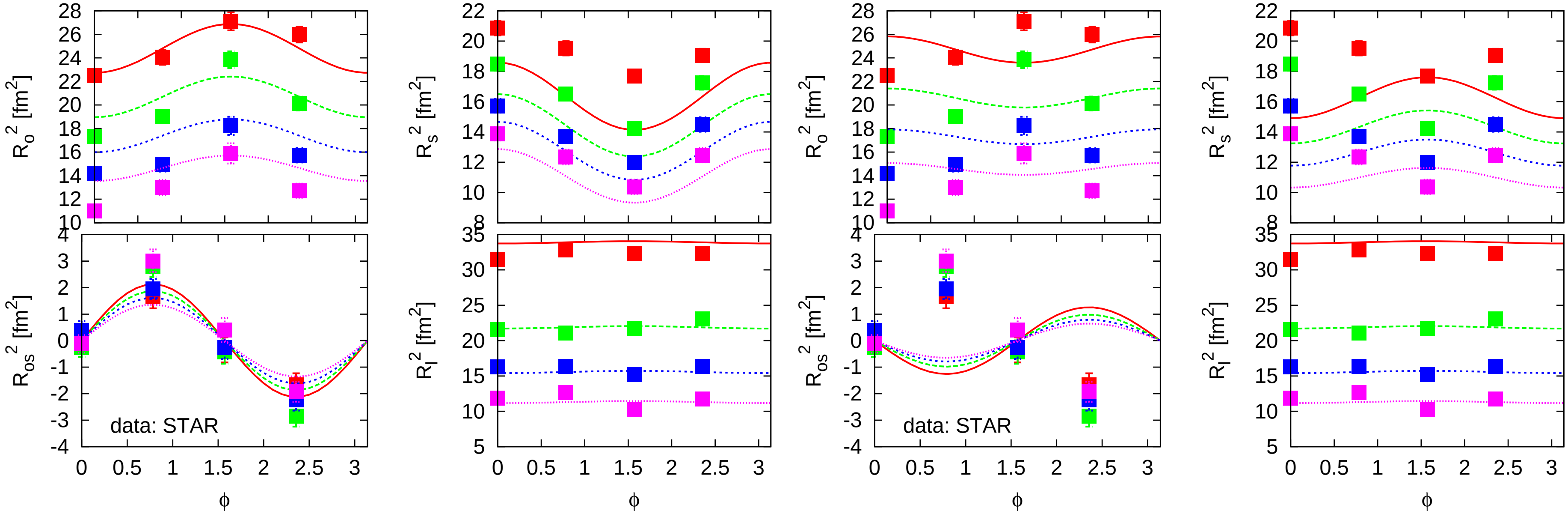


Model 2

- at low p_T similar results at given a (unlike v_2)
- Model 2: at high p_T flow-dominated behaviour; not in Model 1
- HBT sensitive mainly to spatial anisotropy

Which model fits the STAR data?

- both models fit v_2 for π and p (related by $a \to a^{-1}$)



Model 1 Model 2

- Model 1 fits qualitatively well, Model 2 does not

- flow pattern at LHC might possibly lead to Model 2

5 Conclusions

shown analytically and/or in numerical analysis of parameter space:

- from v_2 solely cannot determine spatial and flow anisotropy

- in-plane and out-of-plane can be distinguished from asHBT

- if the type of Model is known: disentangle spatial and flow anisotropy from v_2 for different species

[BT, Acta Physica Polonica B **36** (2005) 2087 (nucl-th/0409074)]