Interferometry correlations in central p+Pb collisions

based on: https://doi.org/10.1140/epjc/s10052-017-5482-5 (with P. Bożek)

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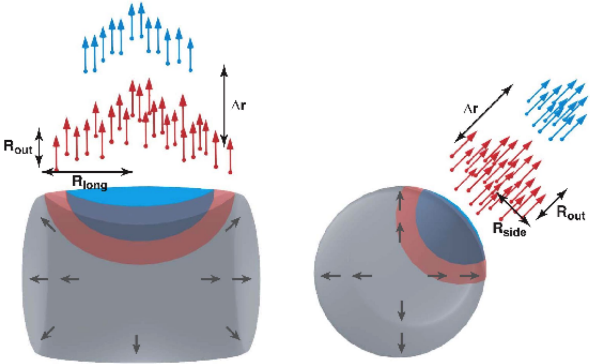
HBT radii and Bersch – Pratt coordinate system

M. A. Lisa and S. Pratt (2008), arXiv:0811.1352



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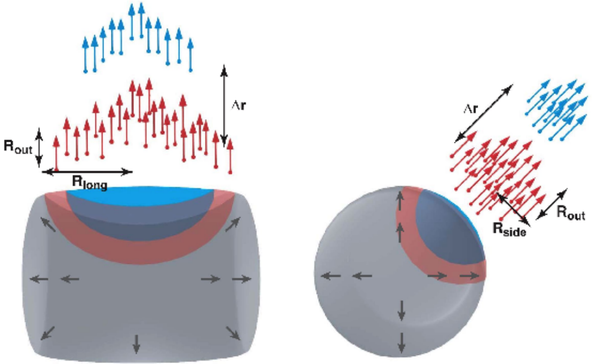


$$k_T = \frac{p_1 + p_2}{2} \qquad q = p_1 - p_2$$

$$C(q) = 1 + \lambda\, exp\,(\, -R_o^2 q_o^2 - R_s^2 q_s^2 - R_l^2 q_l^2\,)$$

Form of correlation function:

$$C(q,k) = \frac{\int d^4x_1 d^4x_2 S(x_1,p_1)S(x_2,p_2)|\Psi(q,x_1-x_2)|^2}{\int d^4x_1 S(x_1,p_1)\int d^4x_2 S(x_2,p_2)}$$

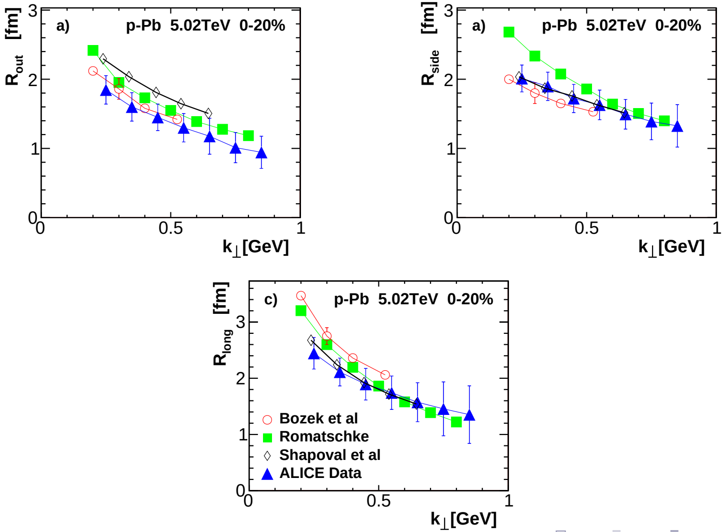
$$C(p^a,p^b) = \frac{\frac{dN^{ab}}{d^3p^a d^3p^b}}{(\frac{dN^a}{d^3p^a})(\frac{dN^b}{d^3p^b})}$$

$$C(q_a,k_b) = \frac{\frac{1}{N_{pairs,num}}\sum_{j=1}^{N_h}\sum_{l\neq m=1}^{N_e}\sum_{s=1}^{M_l}\sum_{f=1}^{M_m}\delta_{q_a}\delta_{k_b}\,|\Psi(q,x_1-x_2)|^2}{\frac{1}{N_{pairs,den}}\sum_{i\neq j=1}^{N_h}\sum_{l,m=1}^{N_e}\sum_{s=1}^{M_l}\sum_{f=1}^{M_m}\delta_{q_a}\delta_{k_b}}$$

numerator: pion pairs from events generated from **the same** hypersurface
denominator: pion pairs from events generated from **different** hypersurfaces ($i \neq j$) – combinatorical background

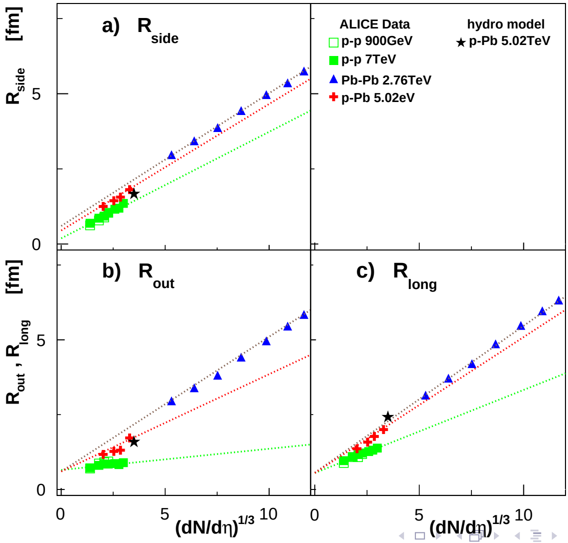
3 standard HBT radii in hydro

Hydro works in small systems



3 standard HBT radii in hydro – various systems

R_{out}, R_{side}, R_{long} are fairly well reproduced by hydro models.



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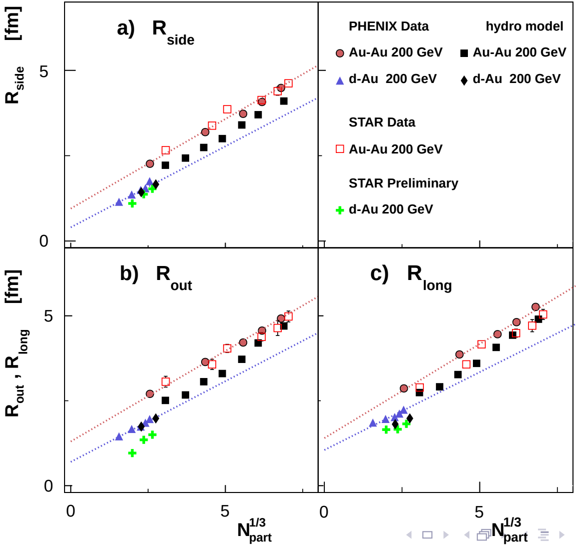
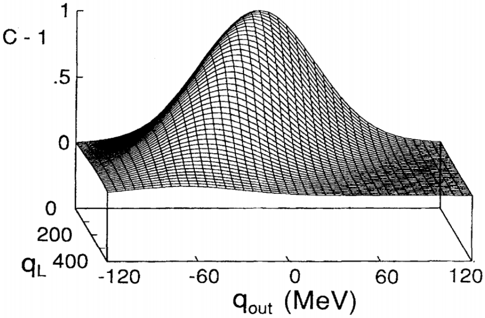


$R_{out-long}$ cross term

Proposed in *S. Chapman, et al, Phys. Rev. Lett. 74,4400 (1995).*



$$C(\mathbf{q}) = 1 + \lambda\, exp\,(-R_o^2 q_o^2 - R_s^2 q_s^2 - R_l^2 q_l^2 - \mathbf{2R_{ol}^2 q_o q_l})$$

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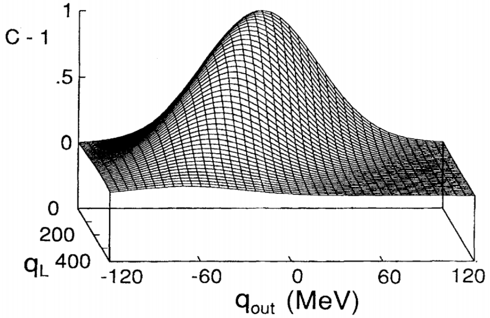

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In symmetric systems: $R_{ol} = 0$ in central rapidity.
$R_{ol} \neq 0$ in non–central rapidity.

$R_{out-long}$ cross term

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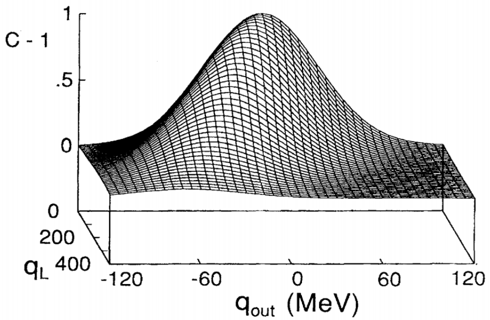


$$C(\mathbf{q}) = 1 + \lambda \, exp\left(-R_o^2 q_o^2 - R_s^2 q_s^2 - R_l^2 q_l^2 - \mathbf{2 R_{ol}^2 q_o q_l} \right)$$

$R_{ol} \neq 0$ also for asymmetric systems.

Cross terms

In azimuthally sensitive analyses (*arXiv:1408.1264*) :

$$R_{ol}^2 = H_1 + I_1 - G_0\beta_\perp + (I_1 + I_3 - H_1 + H_3)cos(2\Phi)$$

where, G_i, H_i, I_i:

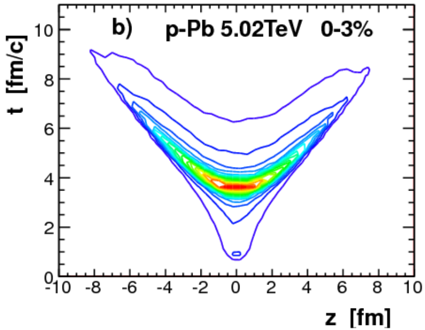
$$\langle tz\rangle - \langle t\rangle\langle z\rangle = \mathbf{G_0} + 2\sum_{n=2,4,\ldots} G_n\cos(n\Phi)$$

$$\langle xz\rangle - \langle x\rangle\langle z\rangle = 2\sum_{n=1,3,\ldots} H_n\cos(n\Phi)$$

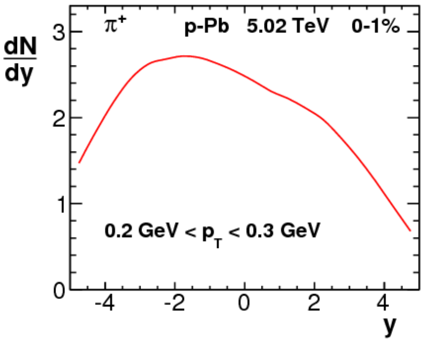
$$\langle yz\rangle - \langle y\rangle\langle z\rangle = 2\sum_{n=1,3,\ldots} I_n\sin(n\Phi)$$

Most significant among angle independent terms is G_0, appearing in Fourier expansion of time – beam-along moment of the emission function $S(x, k)$

$R_{out-long}$ – consequence of asymmetry in time evolution of source $\Rightarrow$ it results in not boost invariant y distribution



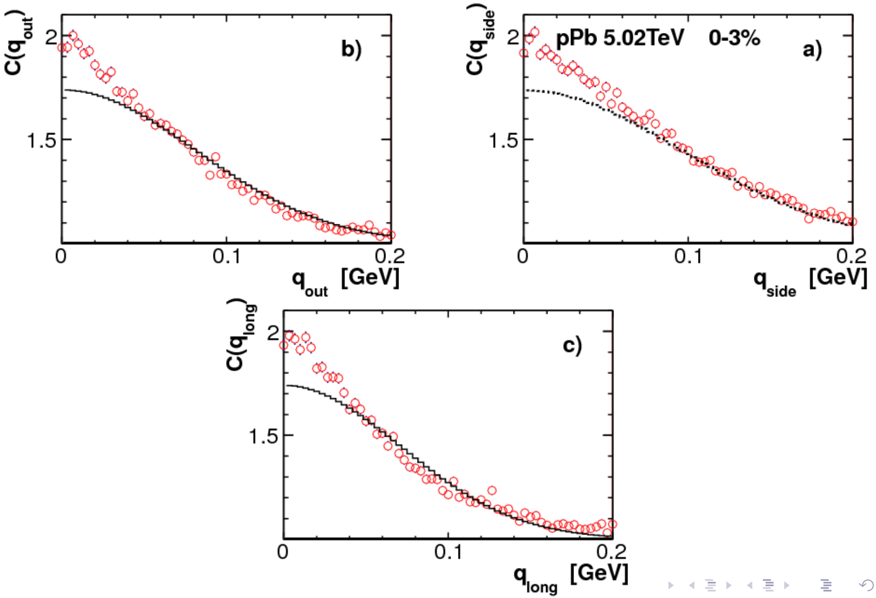
hydrodynamic emission source in asymmetric p+Pb collisions



$$\langle tz \rangle - \langle t \rangle \langle z \rangle \neq 0$$

Gaussian paramterization:

$$C(q,k) = 1 + \lambda\, exp\,(\, -R_o^2 q_o^2 - R_s^2 q_s^2 - R_l^2 q_l^2 - 2R_{ol}^2 q_o q_l\,)$$



Non – gaussian parametrization used by ATLAS

- First measurements including out-long coupling
- First time radii as a function of rapidity

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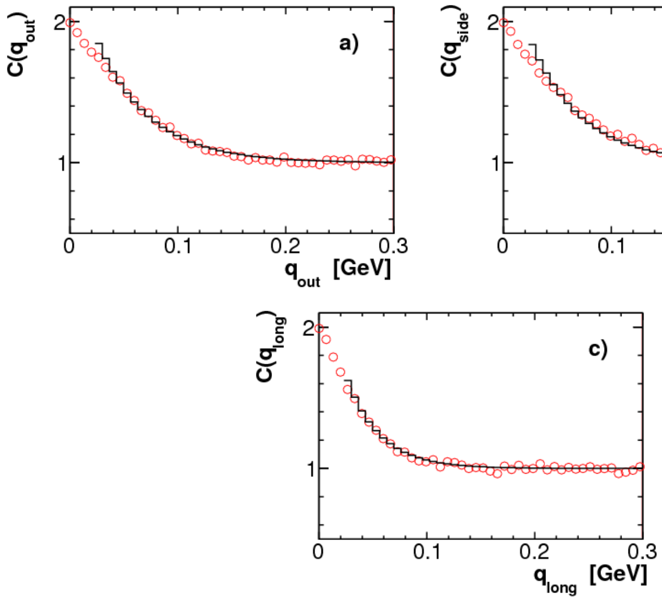
$$C(\mathbf{q}) = 1 + \lambda exp(-\|R\,\mathbf{q}\|)$$

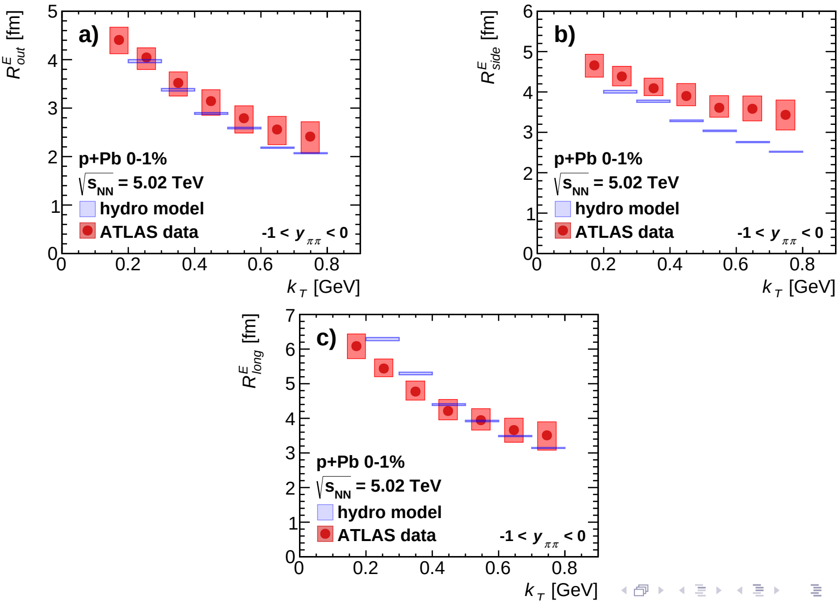
$$\|R\mathbf{q}\| = \Big[\left(R^E_{out} q_{out} + R^E_{mix} q_{long} \right)^2 + (R^E_{side} q_{side})^2 + \left(R^E_{long} q_{long} + R^E_{mix} q_{out} \right)^2 \Big]^{1/2}$$

$$\|R\mathbf{q}\| = \Big[\left({R^E_{out}}^2 + {R^E_{mix}}^2 \right) q^2_{out} + {R^E_{side}}^2 q^2_{side} + \left({R^E_{long}}^2 + {R^E_{mix}}^2 \right) q^2_{long} + 2 \left(R^E_{out} + R^E_{long} \right) R^E_{mix} q_{out} q_{long} \Big]^{1/2}$$

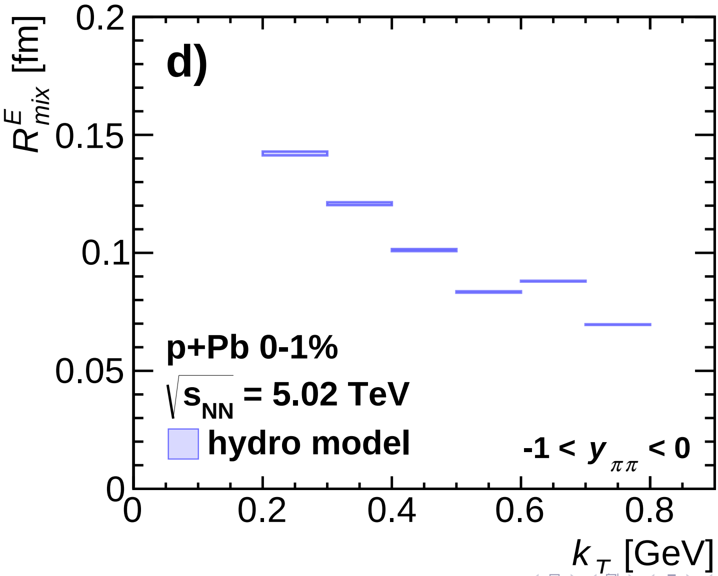
Non – gaussian parametrization used by ATLAS



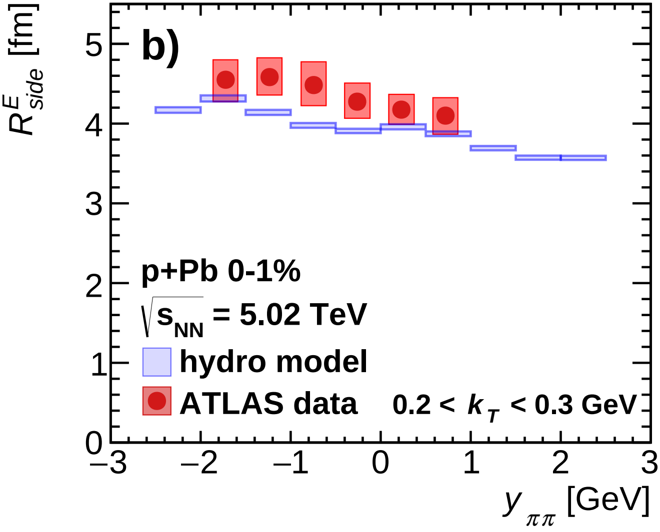
Results – $R^E_{o,s,l}(k_T)$



Results – $R^E_{mix}(k_T)$

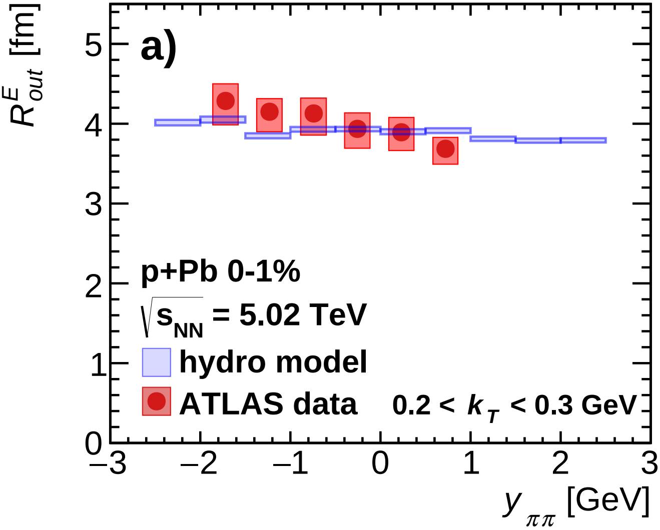


first measurement of y-dependent HBT radii



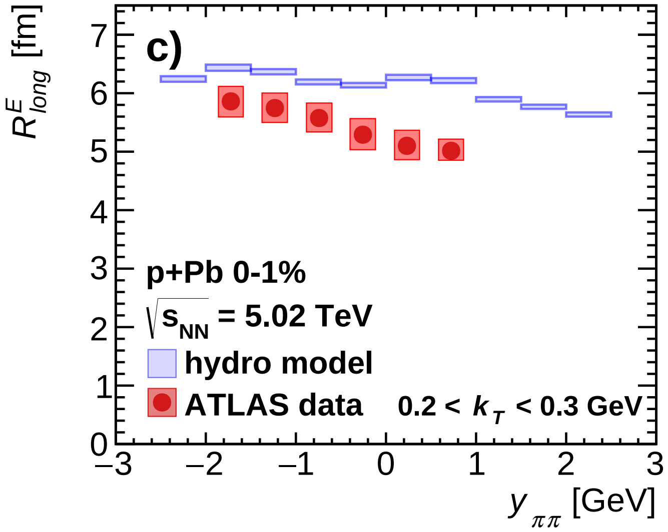
Results – $R^E_{out}(y)$

first measurement of y-dependent HBT radii

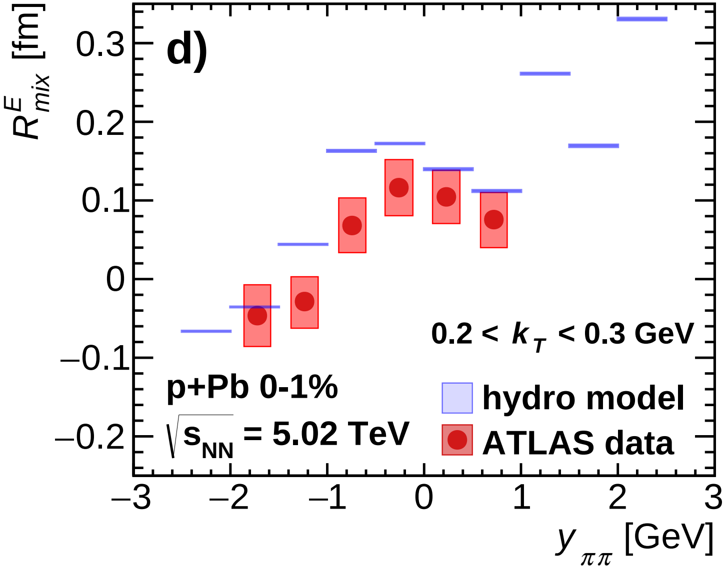


Results – $R^E_{long}(y)$:

first measurement of y-dependent HBT radii



Results – $R^E_{mix}(y)$



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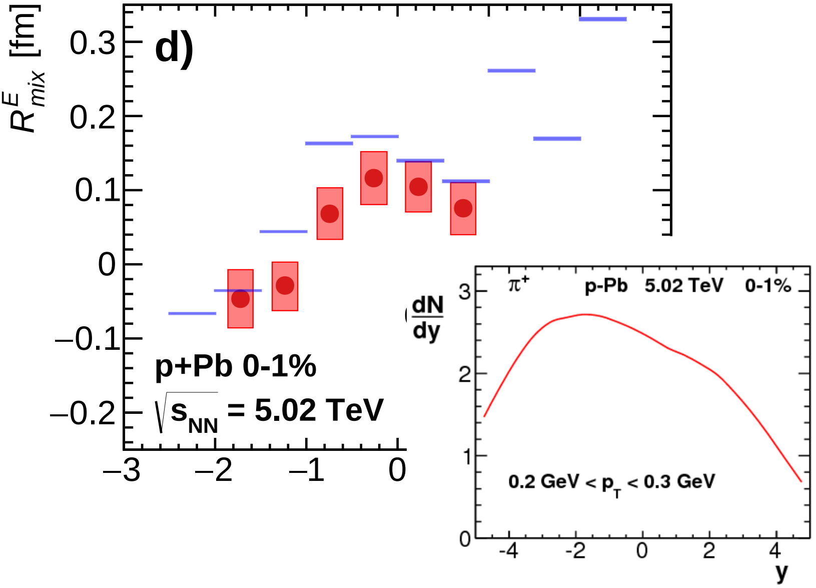

Conclusions

- hydrodynamic models can describe (semi-)quantitatively HBT radii dependence on k_T in pPb collisions – both in gaussian and exponential parametrization
- rapidity dependance of HBT radii can be reproduced partly-qualitatively in simulations
- hydro models can explain out-long cross term in asymmetric collisions