Charm balance function in relativistic heavy-ion collisions

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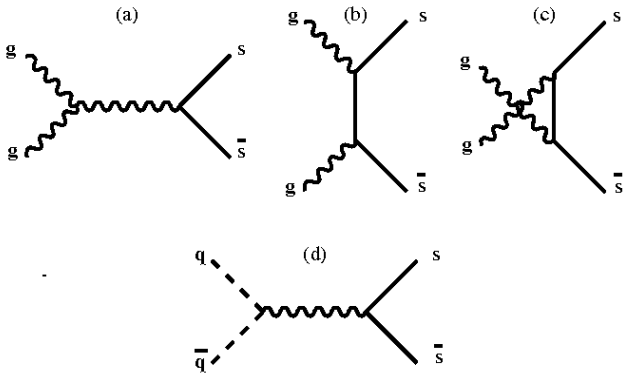
Tribhuban Parida, P. B., Sandeep Chatterjee, PRC 2024

Pair creaction in medium

- charges are created in pairs $+-$, $s\bar{s}$, $B\bar{B}$, ...



- charges evolve in medium until hadronization
- interactions with medium and flow change the charge-anticharge distributions

Charge Balance function

$$B(p_1|p_2) = \frac{1}{2}\left[\frac{N^{c\bar{c}}(p_1,p_2)}{N^{\bar{c}}(p_2)} - \frac{N^{\bar{c}\bar{c}}(p_1,p_2)}{N^{\bar{c}}(p_2)} + \frac{N^{\bar{c}c}(p_1,p_2)}{N^{c}(p_2)} - \frac{N^{cc}(p_1,p_2)}{N^{c}(p_2)}\right]$$

Conditional probability of finding $\pm$ at p_1 when $\mp$ is observed at p_2

S. Bass, P. Danielewicz, S. Pratt, PRL 2000

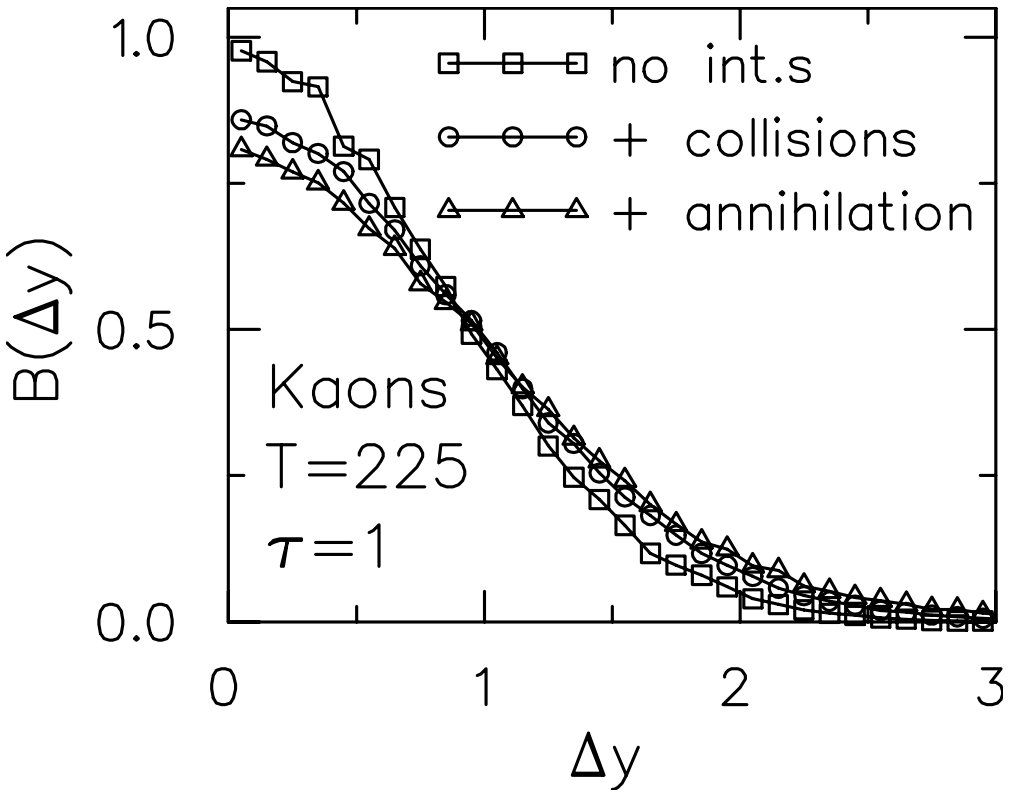
balance function in relative rapidity

$$B(\Delta y) = \int_A dp_1 \int_A dp_2 B(p_1|p_2)\delta\left(\Delta y - y_1 + y_2\right)$$

charge conservation

$$\int d(\Delta y) B(\delta Y) = 1$$

Charge-Anticharge Diffusion



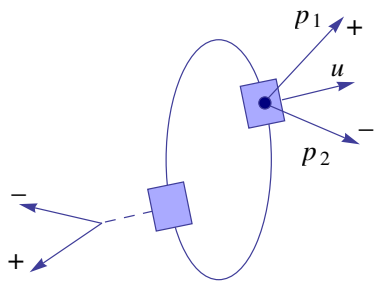
S. Bass, P. Danielewicz, S. Pratt, PRL 2000

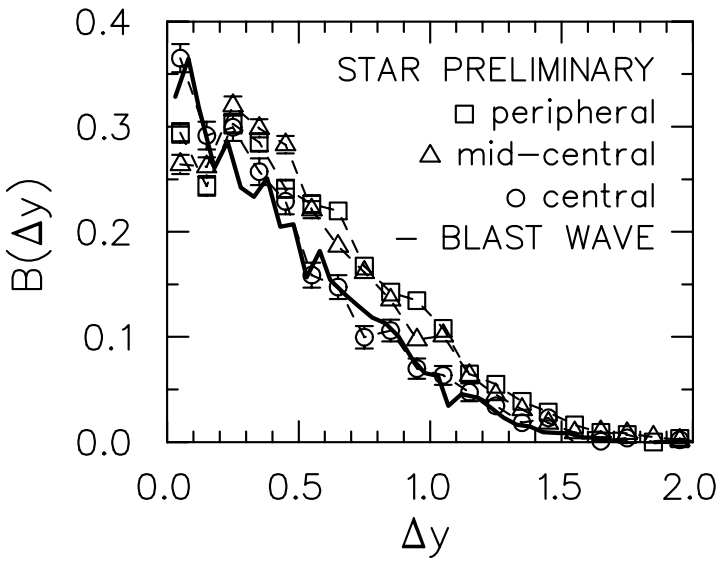
Diffusion increases the relative rapidity between charge-anticharge.

Measure of diffusion time/rate

Charge correlations at hadronization

Electric charge (pions) balance functions - correlations at hadronization
(+-) pairs at freeze-out + thermal spread





pairs from fluid element
resonance decays

PB, W. Broniowski, PRL 2012

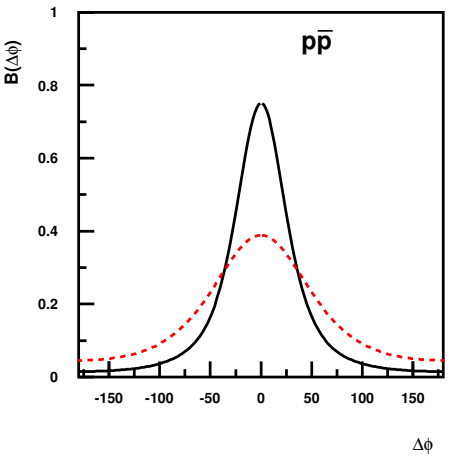
S. Cheng, S. Petriconi, S. Pratt, S. Coby, C. Gale,

PRC 2004

- resonance decays
- pair anihilation/creation in the dynamics
- hadrons : charge, strangness, baryon number correlations

Balance function in azimuthal angle

collimation from transverse flow

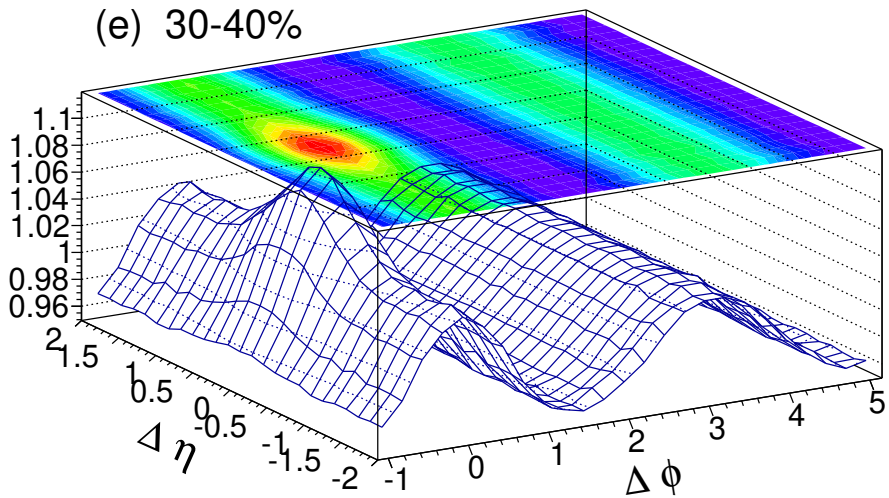


narrower - higher β, lower T

PB, PLB 2005

fall of the ridge

$B(\Delta Y, \Delta\phi)$



PB, W. Broniowski, PRL 2012

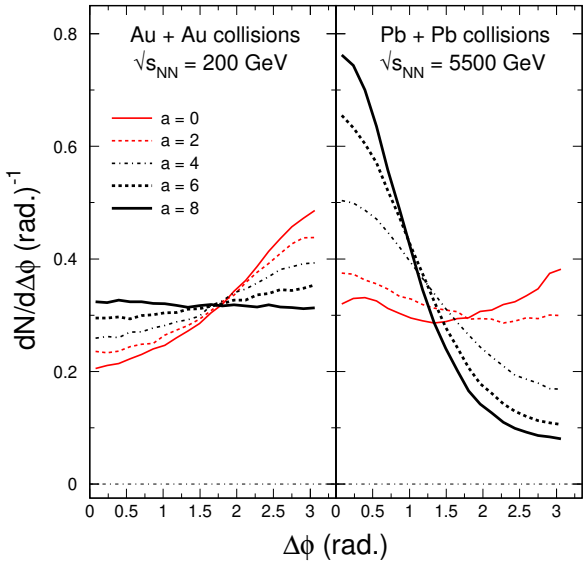
important as CME background

What about CHARM BALANCE FUNCTION ?

charm balance function by bing AI

$D\bar{D}$ correlations

azimuthal angle correlation



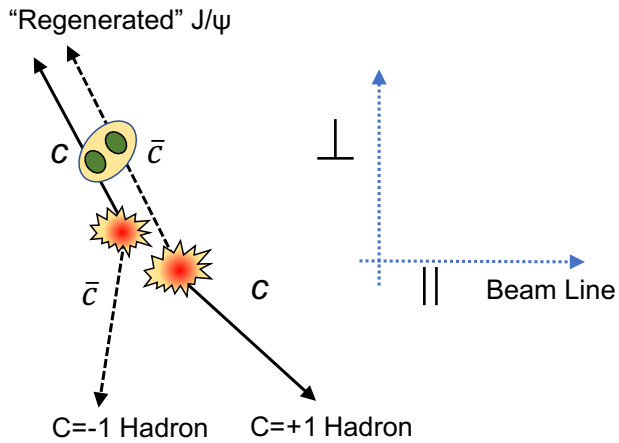
X. Zhu, N. Xu, P. Zhuang, PRL 2008

- $c\bar{c}$ pair follows the whole evolution
- transverse flow ("parton wind") collimation

Z. Zhu, M. Bleicher, S. Huang, H. Stocker, PLB 2007; G. Tsiledakis, H. Appelshauser, K. Schweda, J. Stachel, NPA 2011; M. Younus, D. Srivastava, JPhysG 1013; M. Adare, M. McCumber, J. Nagle, P. Romatschke PRC 2014, ...

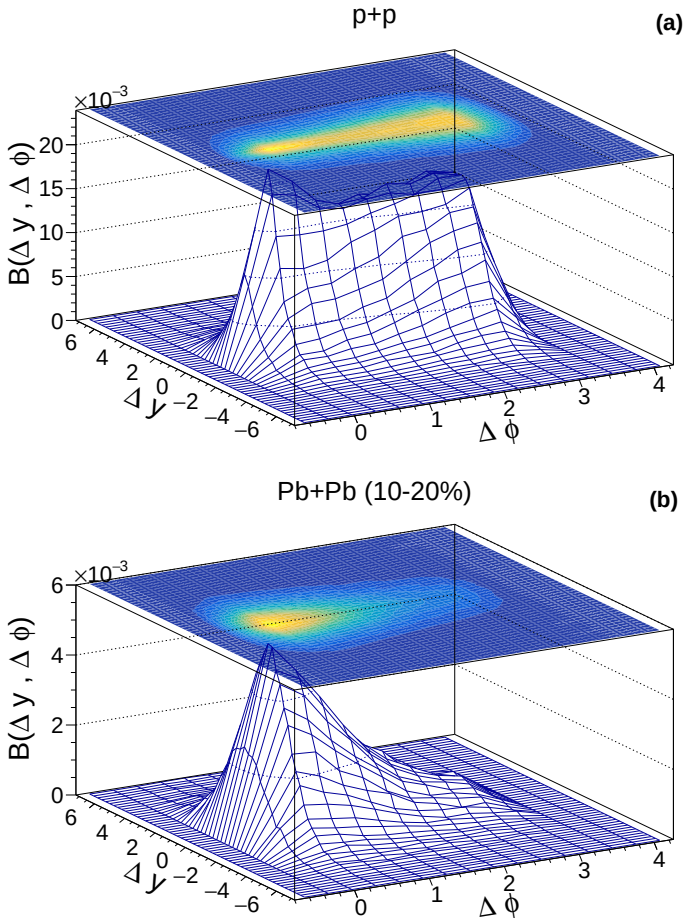
correlation between
formed J/Ψ and D mesons

S. Basu, P. Christiansen, A. Ohlson, D. Silvermyr, EPJC 2021



$c\bar{c}$ balance function

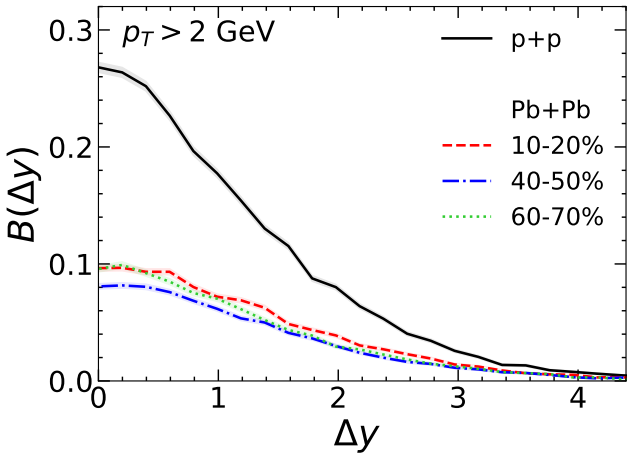
- $c\bar{c}$ from PYTHIA
- MUSIC 3+1D hydro evolution in PbPb
- Langevin eq. diffusion

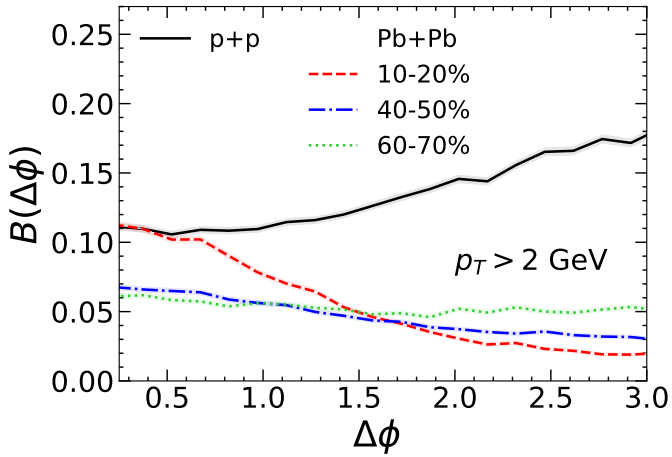


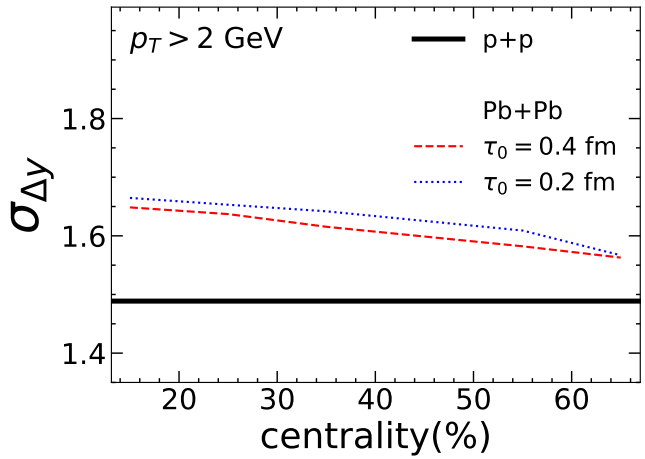
- collimation in $\Delta\phi$
- widening in ΔY

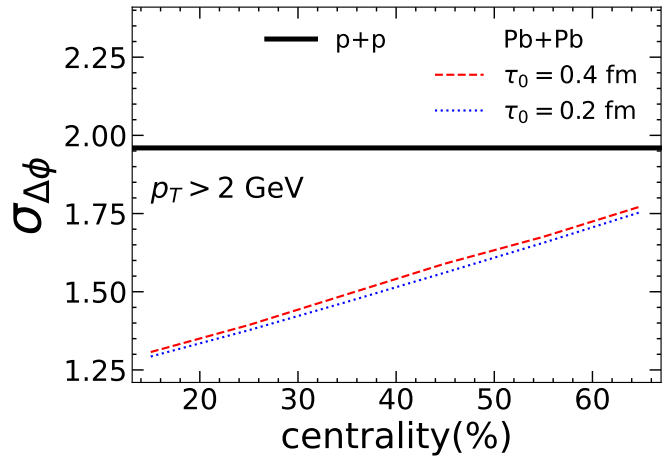
T. Parida, PB, S. Chatterjee, PRC 2024

1D $c\bar{c}$ balance functions





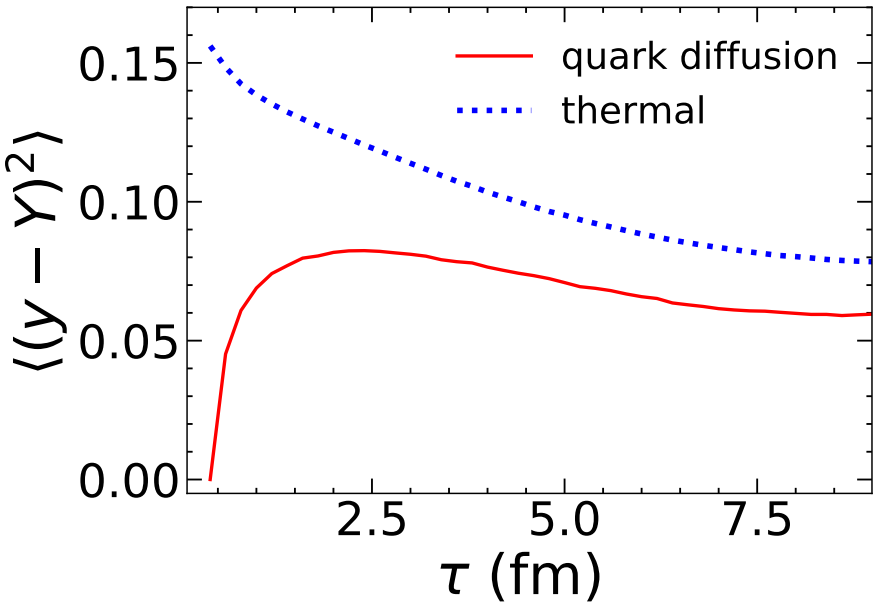




strong centrality dependence
small sensitivty to early phase

small centrality dependence
strong sensitivty to early phase

Thermal spread



quark evolution in a fluid cell

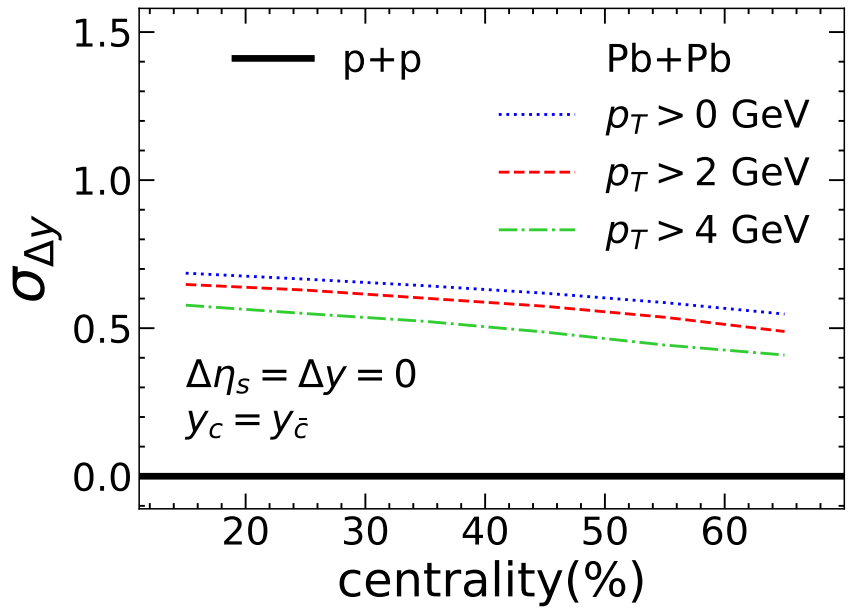
thermal

$$f_{th}(y-Y) = \sqrt{\frac{(1+\sinh(y-Y)^2)}{2\pi E_T T}} \exp\left(-\frac{\sinh(y-Y)^2 E_T}{2T}\right)$$

- cooling of the fluid
- energy loss
- "pressure asymmetry" effect

Diffusion in rapidity

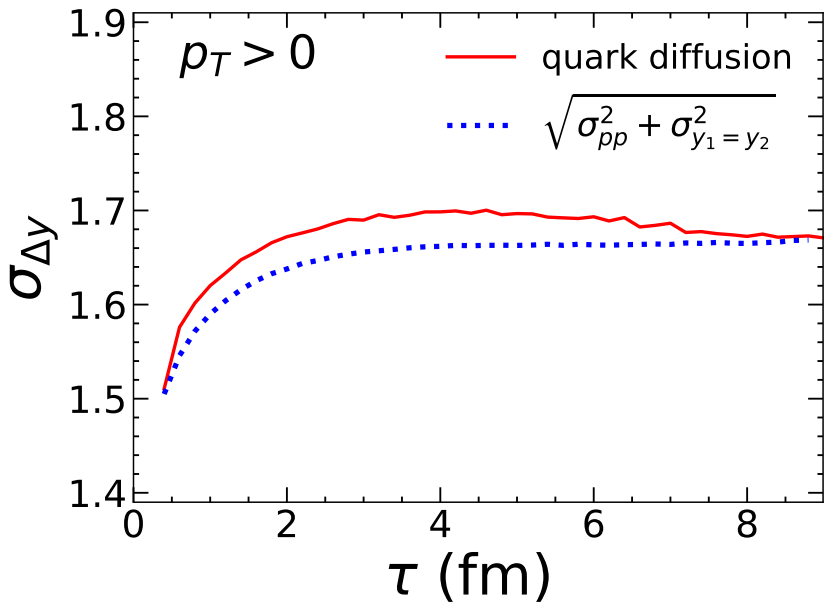
$c\bar{c}$ initially in the same fluid cell



the quark diffuse to other fluid cells

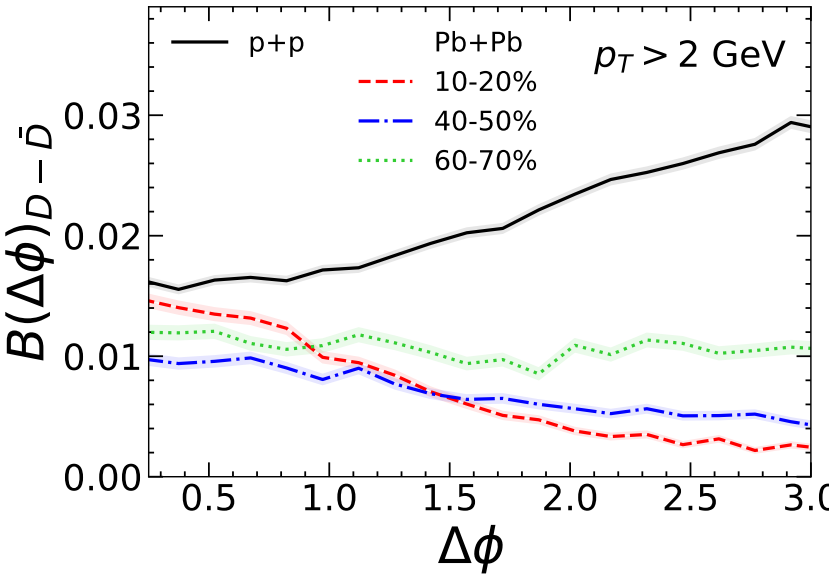
$c\bar{c}$ relative diffusion

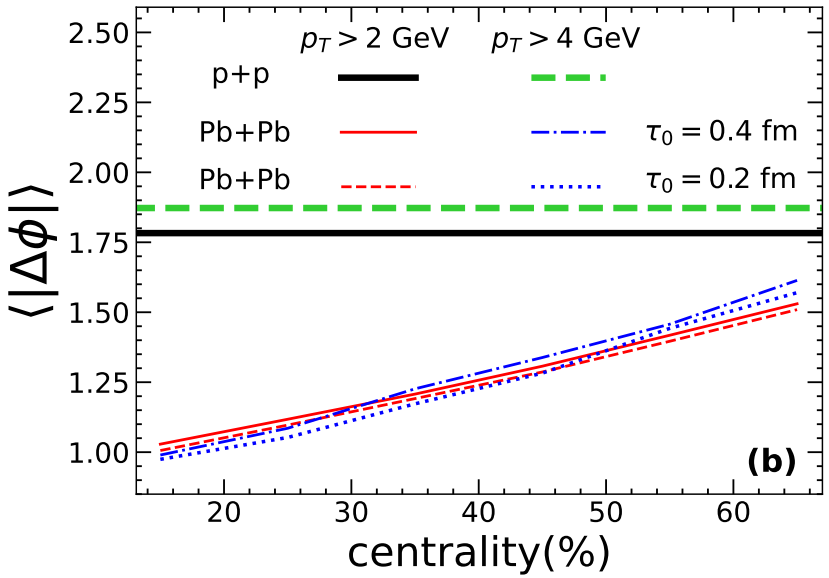
time evolution of the $c\bar{c}$ spread



collisional diffusion + flow acceleration

$D\bar{D}$ balance function - angle

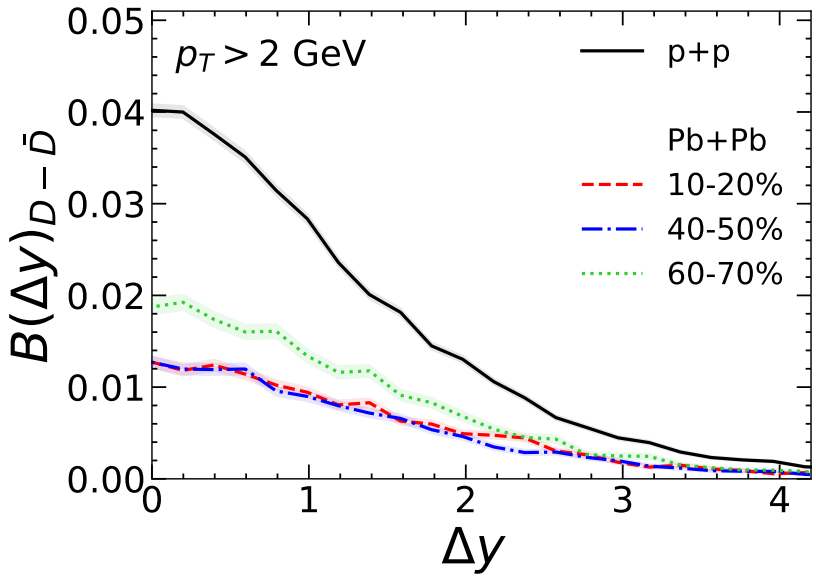


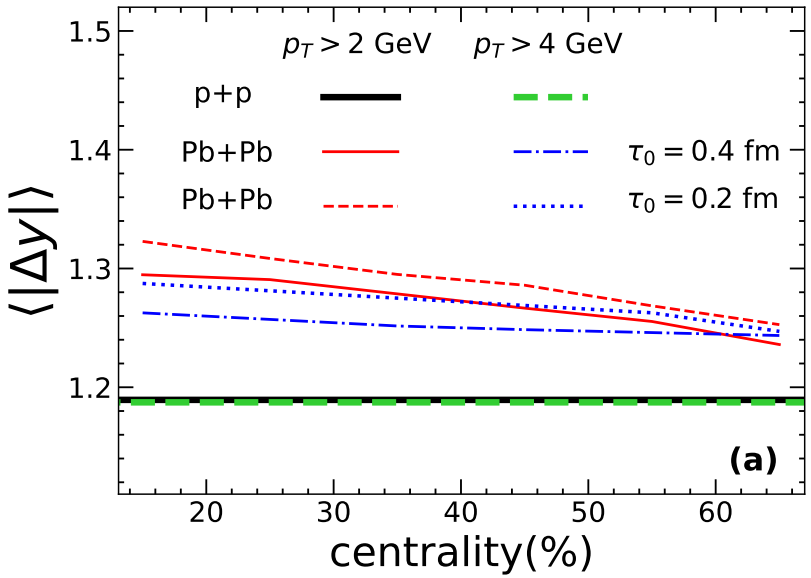


strong centrality dependence
small sensitivty to early phase

qualitatively similar to $c\bar{c}$

$D\bar{D}$ balance function - rapidity





small centrality dependence
strong sensitivty to early phase

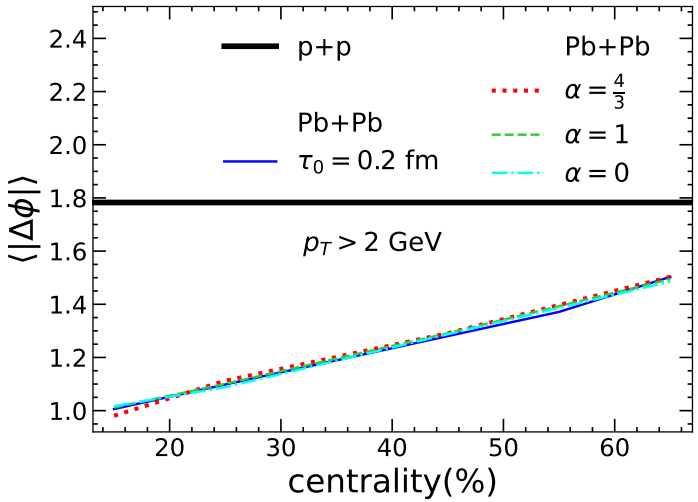
qualitatively similar to $c\bar{c}$

- charm balance function - excellent probe of medium density and diffusion
- balance function in rapidity - early phase
- balance function in angle sensitive to late transverse flow
  consitency check with spectra, v_2

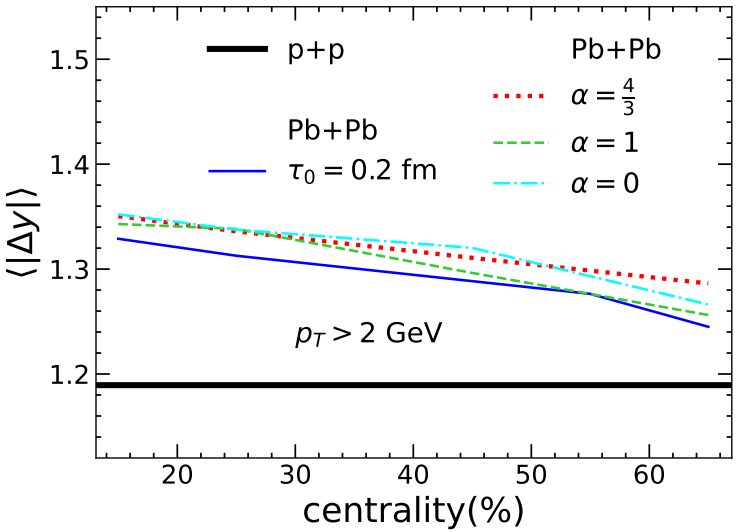
It would very interesting to have experiemental data on $c\bar{c}$ correlations in rapidity!

width in rapidity (AA vs pp, centrality dependence)

Sensitivity to very early phase



$$\epsilon(\tau) \propto \tau^{-\alpha}$$



negligible effect of early phase on azimuthal correlations

no transverse flow

other dynamics than Langevin diffusion?