Ridge correlation generated by CGC mechanism

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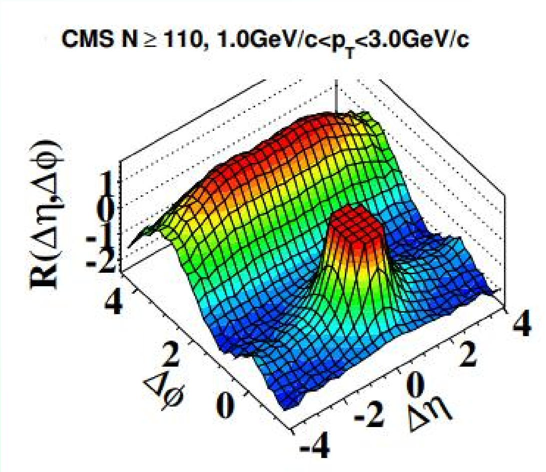
Reference:[1] Donghai Zhang, Yeyi Zhao, LuHua Qiu, Mingmei Xu, Yuanfang Wu, arXiv:2501.12099v2.
[2]Ridge correlations of O+O from CGC is in preparation.

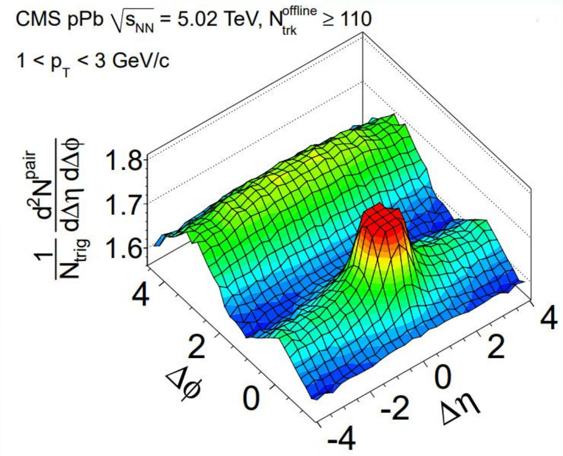
Nov 27, Wuhan

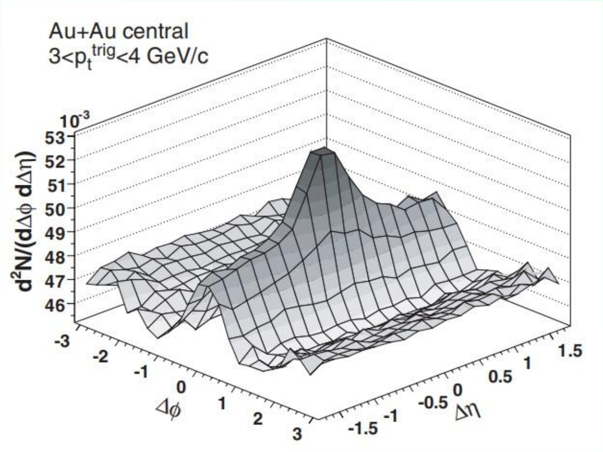
Introduction

☻ Near-side ridge discovered in high-multiplicity pp collisions and pPb.

(a) pp $\sqrt{s} = 7$ TeV (b) pPb $\sqrt{s} = 5.02$ TeV (c) AuAu $\sqrt{s} = 200$ GeV







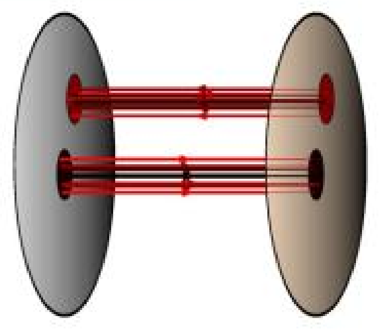
JHEP 09 (2010)091 PLB 718 (2013) 795 PRC 80 (2009) 064912

☻ What mechanism causes ridge in small systems?

Introduction

☻ Hydrodynomics: random distribution of flux tube → asymmetric initial energy density → drive fluid expansion

☻ CGC: color flux tube → fracture generates particles (collimated)



NPA 810 (2008) 91-108

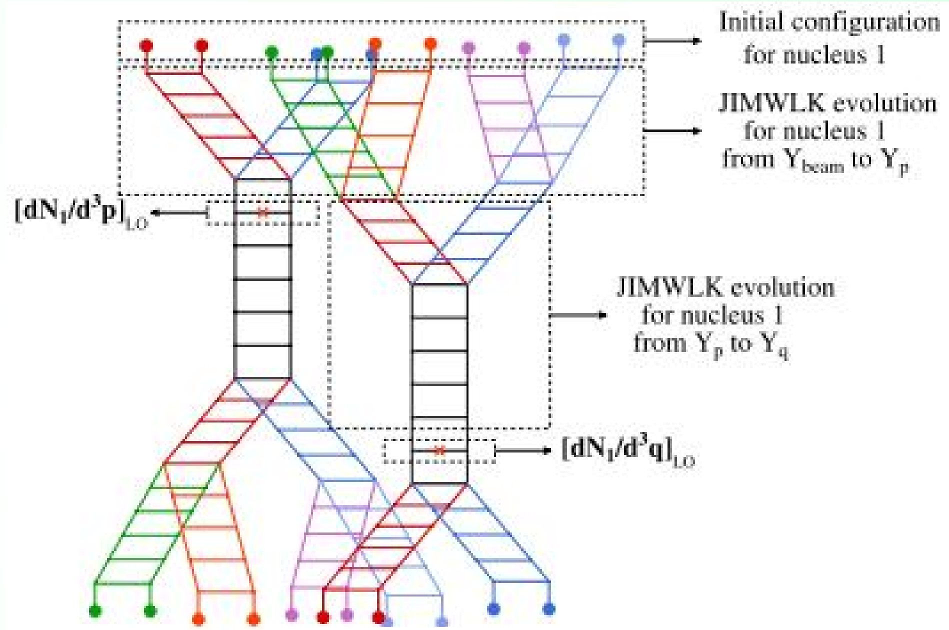
color flux tube: boost invariant in rapidity

theory	hydrodynomics	CGC
v_n	√	/
$c_2\{4\}$	×	√
the v_2 of heavy flavor:	×	√
the mass ordering of v_2	/	√

Theoretical framework

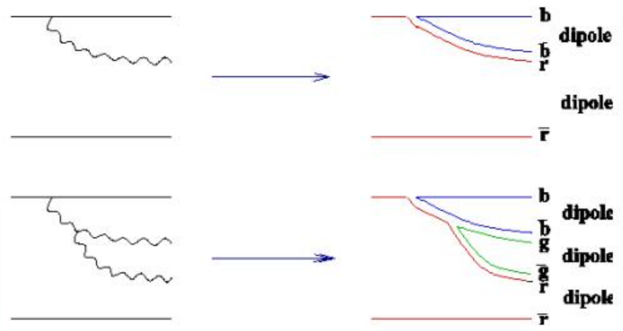
☻ JIMWLK renormalization group equations: describe the evolution of gluons with energy.

NPA 836 (2010) 159-182



☻BK equation: in large Nc limit,

gluons → dipole



$$\frac{\partial \mathcal{N}(r_\perp, x)}{\partial \ln(x_0/x)} = \int d^2 r_{\perp 1} K^{run}(r_\perp, r_{\perp 1}, r_{\perp 2})$$

$$\times [\mathcal{N}(r_{\perp 1}, x) + \mathcal{N}(r_{\perp 2}, x) - \mathcal{N}(r_\perp, x) - \mathcal{N}(r_{\perp 1}, x)\mathcal{N}(r_{\perp 2}, x)]$$

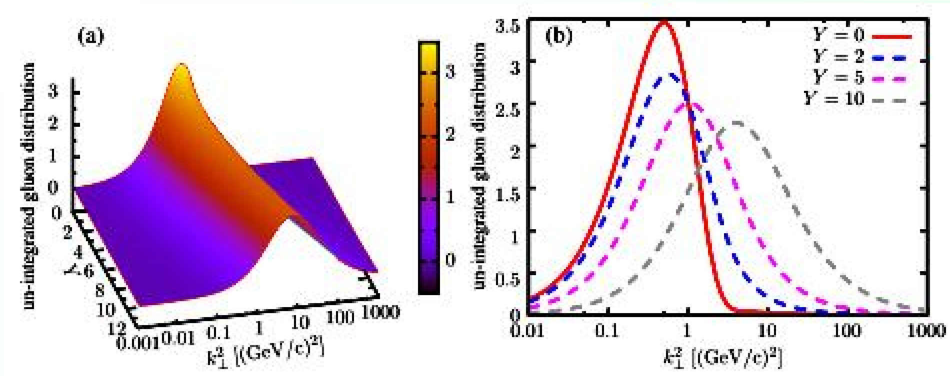
Unitegrated gluon distribution (ugd)

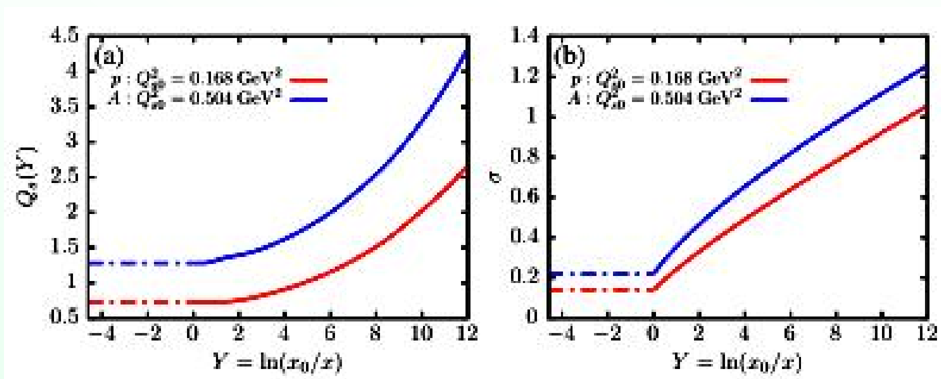
- ugd: gluon density at a unit transverse area per rapidity of proton, or nucleus A, or B.

$$\Phi_{A(B)}(x, k_\perp) = \frac{\pi N_c k_\perp^2}{2\alpha_s} \int dr_\perp r_\perp J_0(k_\perp r_\perp)[1 - \mathcal{N}(r_\perp, Y)]^2$$

- The transverse momentum corresponding to the peak of ugd is the saturated momentum Q_s.
- Q_s: $Q_{sA} > Q_{sp}$.
- σ: $\sigma_A > \sigma_p$.

NPA 955 (2016) 88-100





The single- and two-gluons distirbutions

- In leading logarithmic accuracy in x, the signle gluon distribution is:

$$\frac{dN_1}{d^2p_\perp dy_p} = \frac{\alpha_s(p_\perp)N_c S_\perp}{\pi^4(N_c^2-1)}\frac{1}{p_\perp^2}\int\frac{dk_\perp^2}{(2\pi)^2}\Phi_A(y_p,k_\perp)\Phi_p(y_p,p_\perp-k_\perp)$$

- the two gluons distribution

$$\frac{dN_2^{corr}}{d^2p_\perp dy_p d^2q_\perp dy_q}$$

$$= \frac{C_2}{p_\perp^2 q_\perp^2}[\int\frac{dk_\perp^2}{(2\pi)^2}(D_1+D_2)+\sum_{j=\pm}[D_3(p_\perp,jq_\perp)+\frac{1}{2}D_4(p_\perp,jq_\perp)]]$$

$$\frac{d^2N_{Assoc}}{d\Delta\phi d\Delta y} = \int_{y^{min}}^{y^{max}}dy_p\int_{y^{min}}^{y^{max}}dy_q\,\delta(y_q-y_p-\Delta y)\int_0^{2\pi}d\phi_p\int_0^{2\pi}d\phi_q$$

$$\times\,\delta(\phi_q-\phi_p-\Delta\phi)\int_{p_\perp^{min}}^{p_\perp^{max}}\frac{dp_\perp^2}{2}\int_{q_\perp^{min}}^{q_\perp^{max}}\frac{dq_\perp^2}{2}\frac{dN_2^{corr}}{d^2p_\perp dy_p d^2q_\perp dy_q}$$

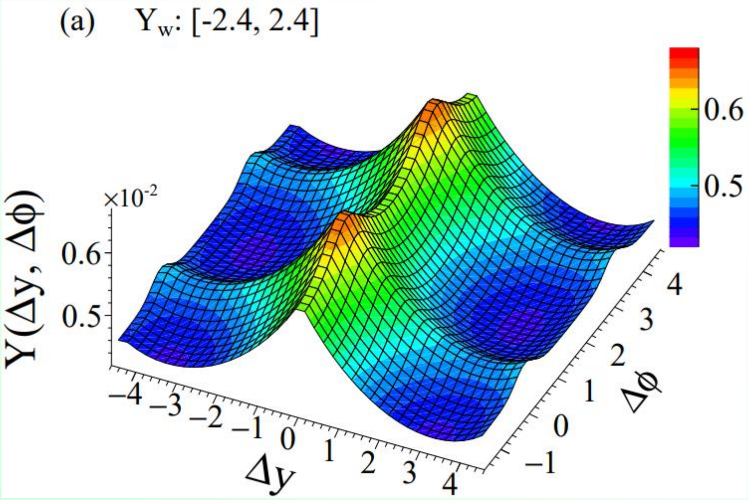
The per-trigger yield

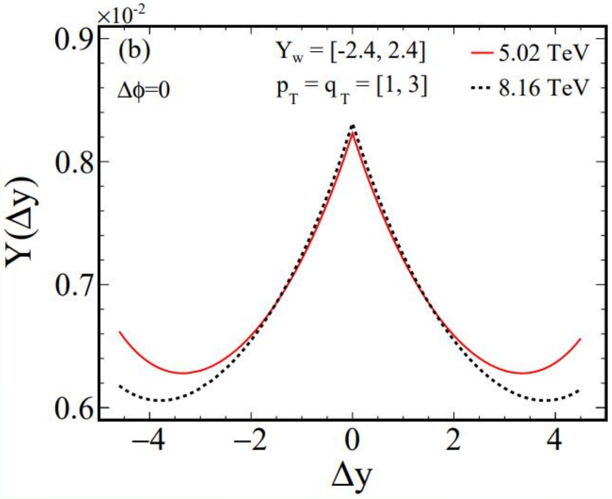
- The per-trigger yield:

$$Y(\Delta y, \Delta\phi) = \frac{1}{N_{Trig}} \frac{d^2 N^{Assoc}}{d\Delta y d\Delta\phi} = B(0,0) \frac{S(\Delta y, \Delta\phi)}{B(\Delta y, \Delta\phi)}$$

- Higher energy → the rebound of large-rapidity ridge correlations shifts to larger rapidity gap.

pPb $\sqrt{s} = 7$ TeV

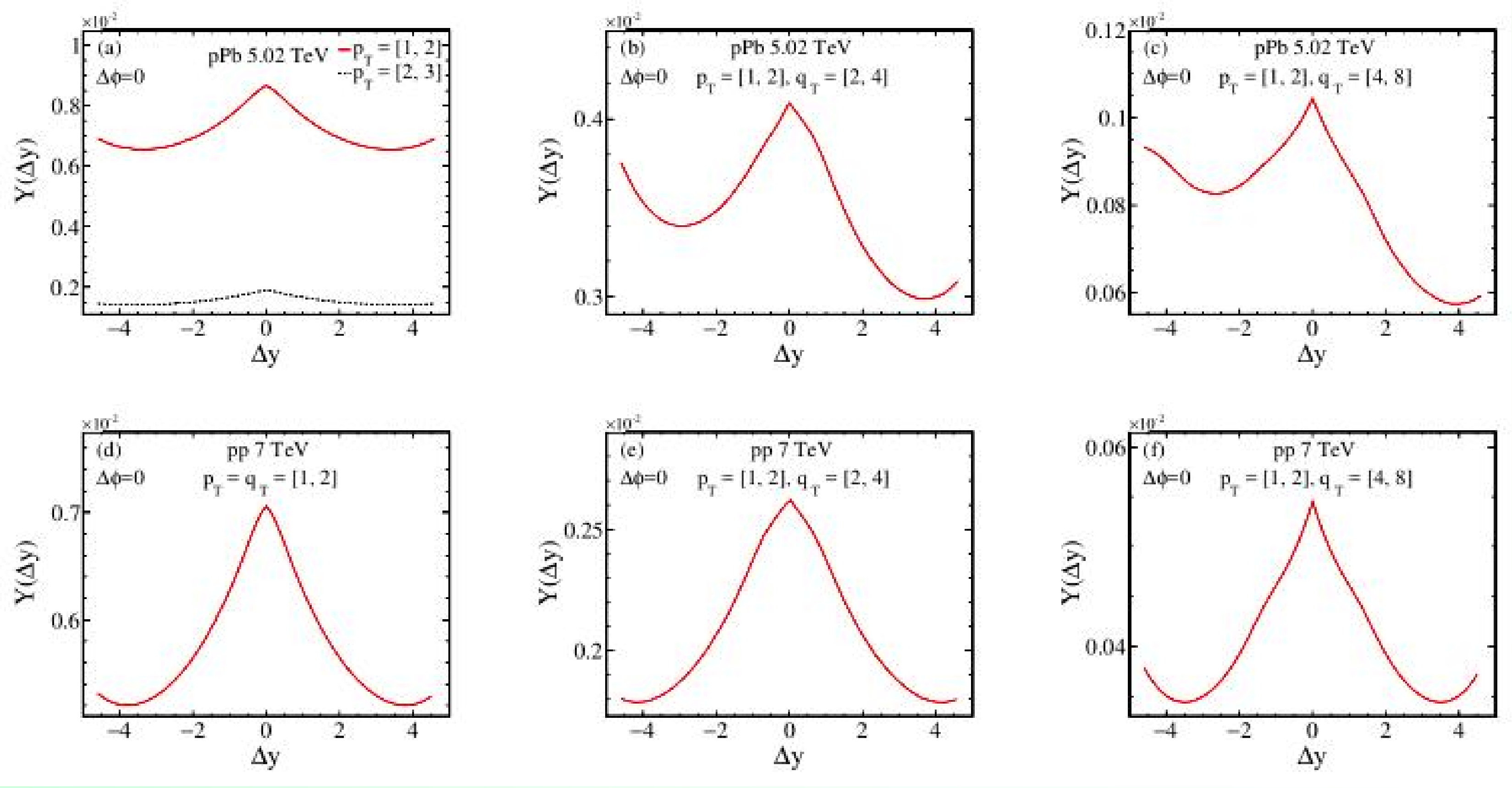




Transverse momentum dependence of long-range rapidity correlations

- ☻ Large-rapidity ridge correlations exhibit a strong $p_\perp$-dependent asymmetry in pPb collisions.

Reversible: when the $p_\perp$ and $q_\perp$ intervals are swapped



Transverse momentum dependence of long-range rapidity correlations

- Asymmetric collision system: There is a deviation between laboratory and center-of-mass frames.

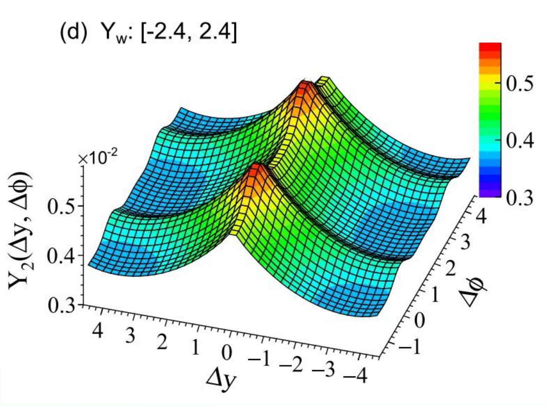
Acceptance (Lab)	$Y_W = [-2.4, 2.4]$			
Collision system	pp		pPb	
Acceptance (COM)	$Y_W = [-2.4, 2.4]$		$Y_W = [-2.865, 1.935]$	
Rapidity gap	$\Delta y = -3.5$	$\Delta y = 3.5$	$\Delta y = -3.5$	$\Delta y = 3.5$
x-values	$x_q = \frac{q_T}{\sqrt{s}} e^{2.0}$ $x_p = \frac{p_T}{\sqrt{s}} e^{1.5}$	$x_q = \frac{q_T}{\sqrt{s}} e^{2.0}$ $x_p = \frac{p_T}{\sqrt{s}} e^{1.5}$	$x_q = \frac{q_T}{\sqrt{s}} e^{2.4}$ $x_p = \frac{p_T}{\sqrt{s}} e^{0.9}$	$x_q = \frac{q_T}{\sqrt{s}} e^{0.9}$ $x_p = \frac{p_T}{\sqrt{s}} e^{2.4}$
$\|x_q - x_p\|$	alway identical at same $\|\Delta y\|$		only $p_\perp = q_\perp$ is identical at smae $\|\Delta y\|$	

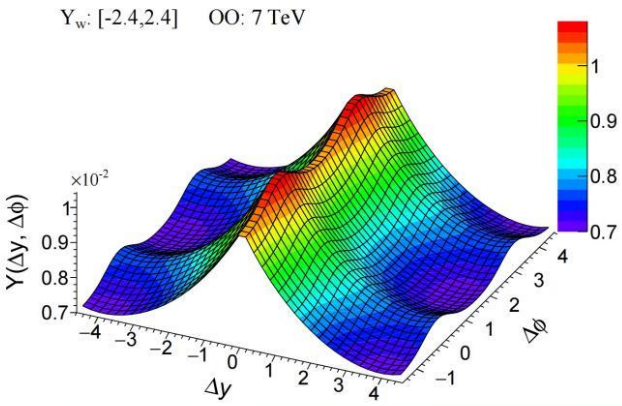
The per-trigger yield of OO collisions

☻ The yield of OO collision is significantly higher than that of pp collision.

pp $\sqrt{s} = 7$ TeV

OO $\sqrt{s} = 7$ TeV





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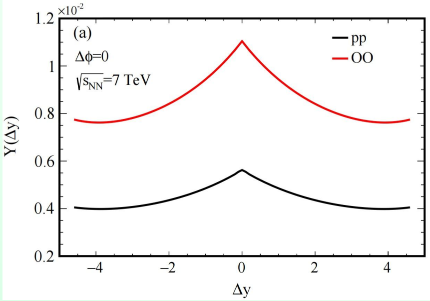
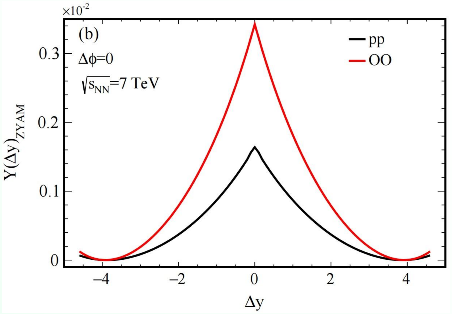
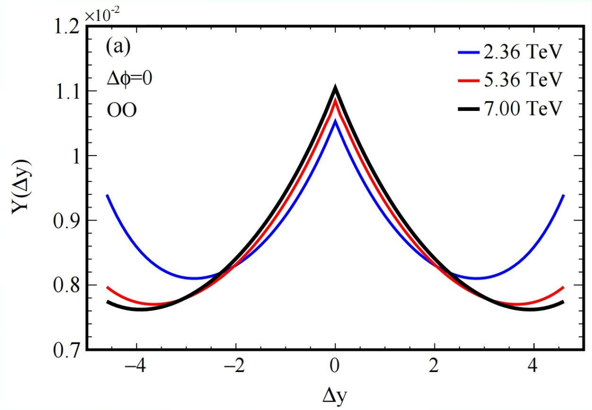
☻ OO collision does not change the Δy correspoinding to the start point of the rebound.



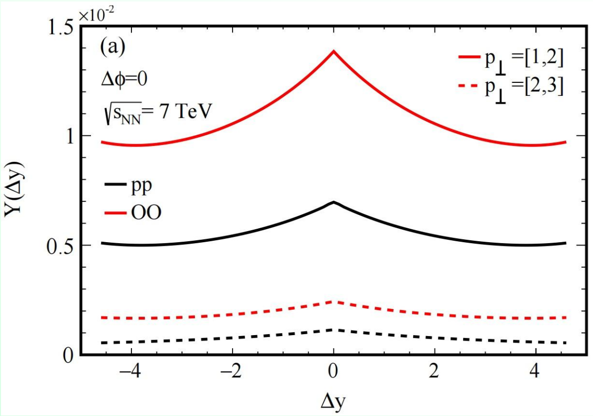


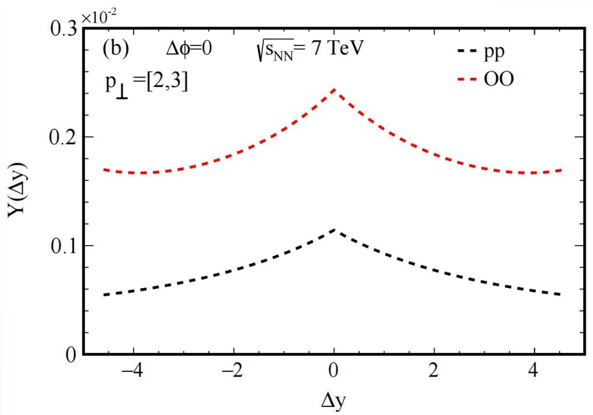
The rebound of OO collision

☻ Rebound more significantly at low energy.



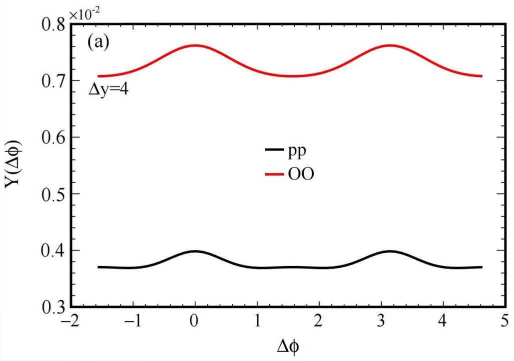
☻ Throughout the entre transverse momentum interval [1,3] GeV/c, the rebound of OO collision still exists..

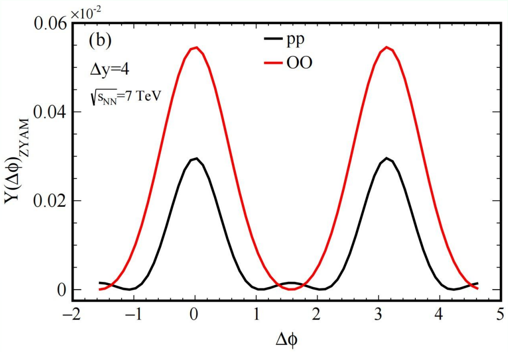




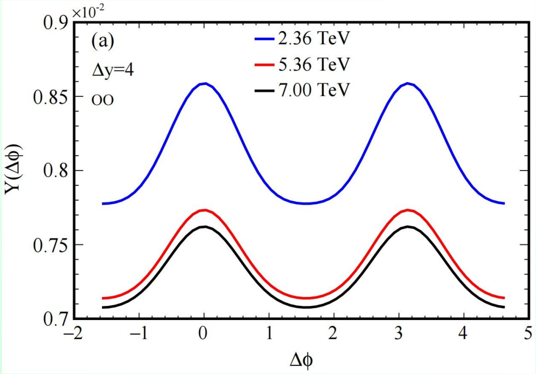
The long-range $\Delta\phi$ distribution

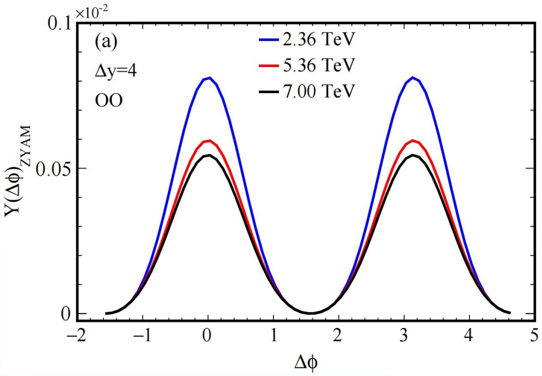
- The yield and net yeild of OO collisions are both higher.
- pp collision exists a Fourier coefficient $\cos(4\Delta\phi)$, while OO collision does not.





- The rebound of OO collision is more significantly at low energy.





Summary

☻ The rebound of the ridge correlation structure at large rapidity after it bottomed out was reproduced in both pPb and OO collisions.

☻ The near-side rapidity correlations demonstrate the $p_{\perp}$-dependent asymmetry in p-Pb collisions.

☻ OO collision does not change the Δy correspoinding to the start point of the rebound.

☻ Predict that it is eaiser to oberve the rebound of OO collision at low energy.

☻ OO collision have a rebound in larger transverse momentum interval.