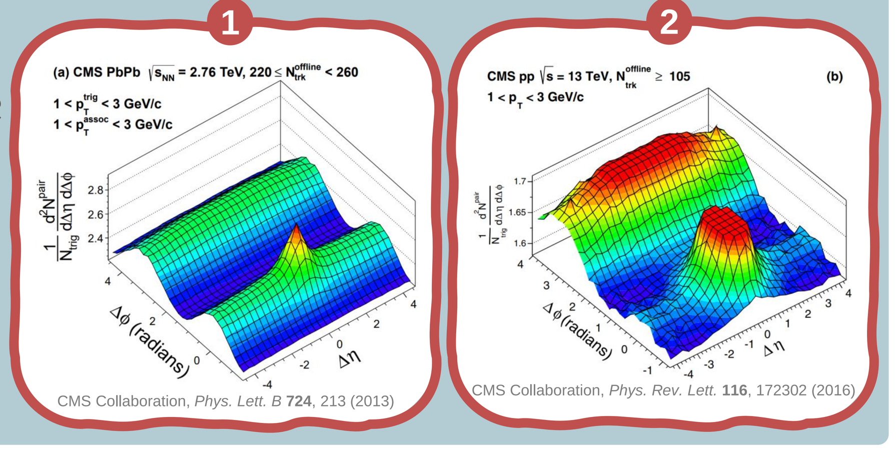
Applying the multiplicity-dependent Momentum Kick Model to the pp collisions at $\sqrt{s}$ = 13 TeV at the LHC

Jeongseok Yoon and Jin-Hee Yoon
Department of Physics, Inha University, Incheon, Republic of Korea

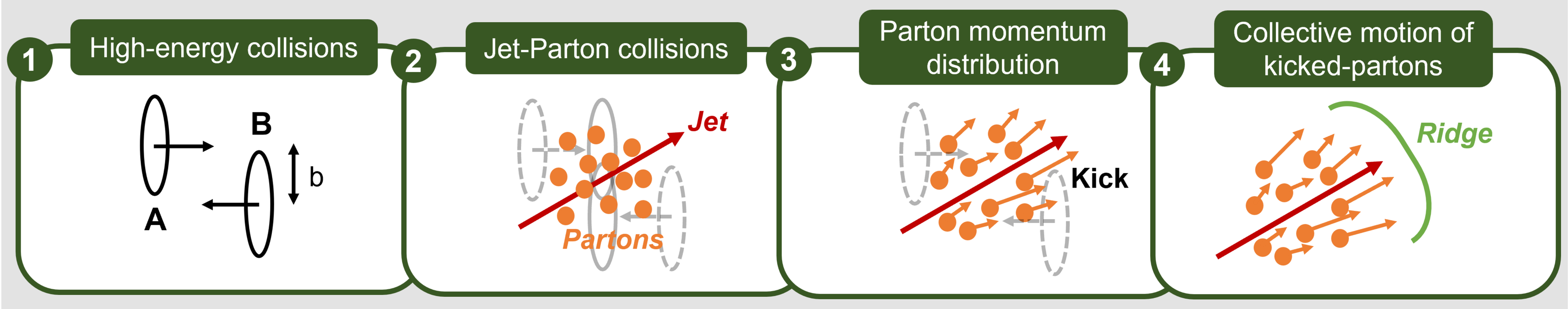
Motivation

- **Ridge structure** in long-range ($|\Delta\eta| > 2$) at near-side ($\Delta\phi \sim 0$)
  ① **Heavy-Ion collisions**
  ➢ Believed by the hydrodynamic flow effect of QGP
  ② **Small systems**
  ➢ Insufficient to generate QGP

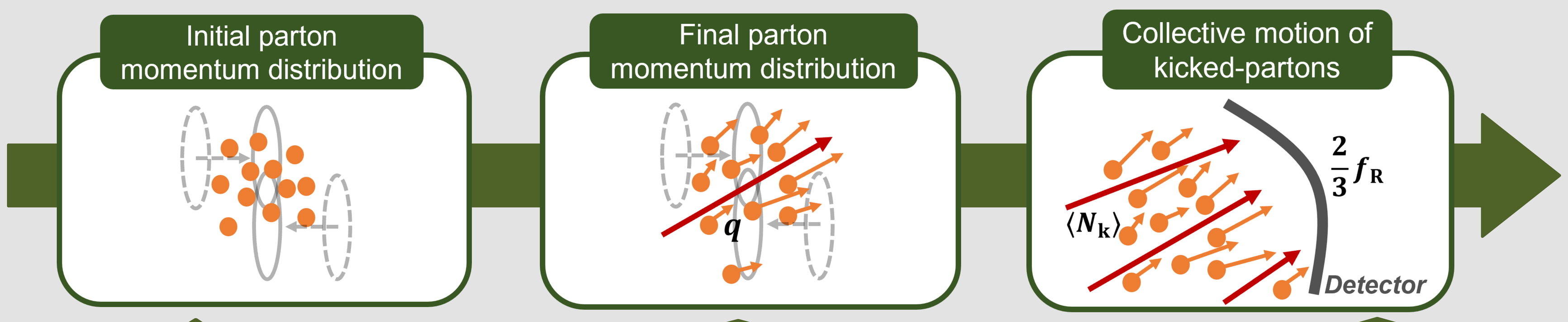


Momentum Kick Model (MKM)

- **Kinematic process** explains the ridge structure



- **Formalism**



$P_i(p_{T_i}, \Delta y_i, \Delta\phi_i)$ → parameterize

$P_f(p_{T_f}, \Delta\eta_f, \Delta\phi_f) = [P_i(p_{T_i}, \Delta y_i, \Delta\phi_i) \times L]_{p_i = p_f - q} \times J(\Delta y \to \Delta\eta)$

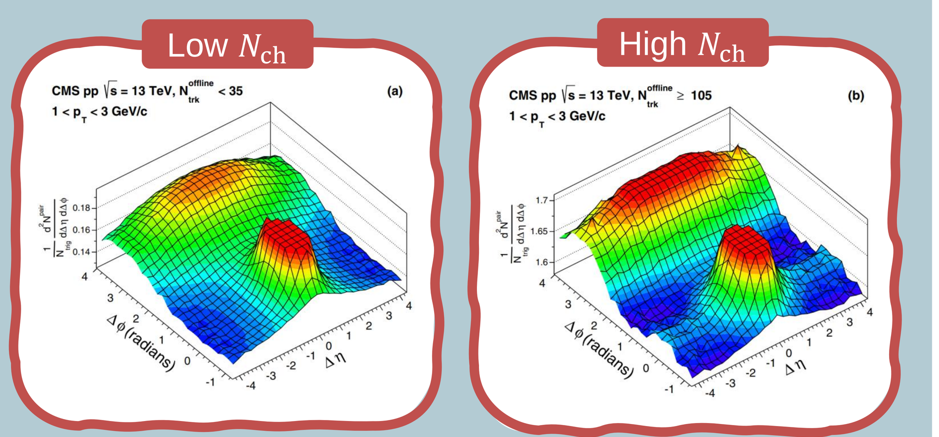
L: Lorentz invariant ensuring factor
q: Average momentum transfer
J: Jacobian

$Y_{assoc}(p_{T_f}, \Delta\eta_f, \Delta\phi_f) = \frac{2}{3} \times f_R \times \langle N_k\rangle \times P_f(p_{T_f}, \Delta\eta_f, \Delta\phi_f)$

f_R: Survival factor reaching the detector
$\langle N_k\rangle$: The average number of kicked-partons

Multiplicity dependence

- Motivation
  - Ridge yield in small systems: **Low N_{ch} vs. high N_{ch}**



CMS Collaboration, Phys. Rev. Lett. 116, 172302 (2016)
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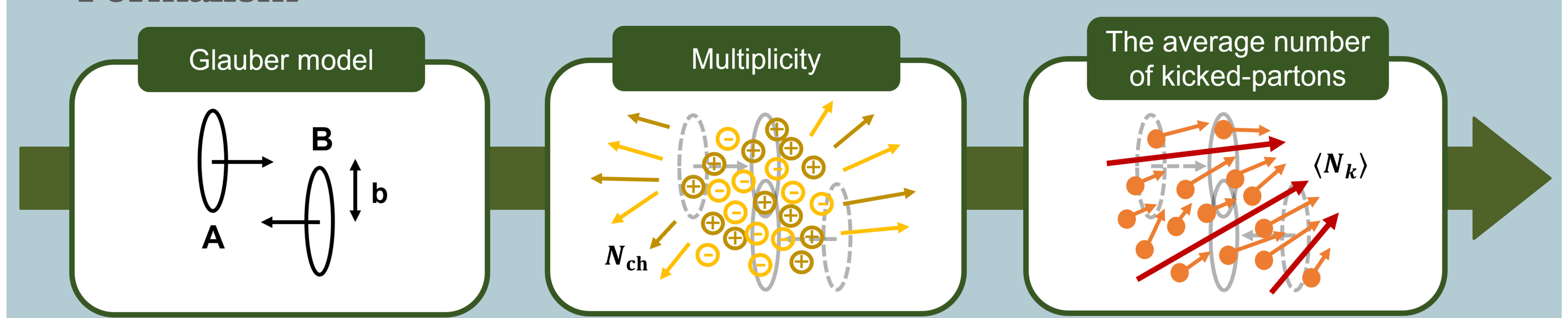
- Formalism



$\frac{dN_{particp}}{db'} = T_A(\mathbf{b}_A) + T_B(\mathbf{b}_B)$

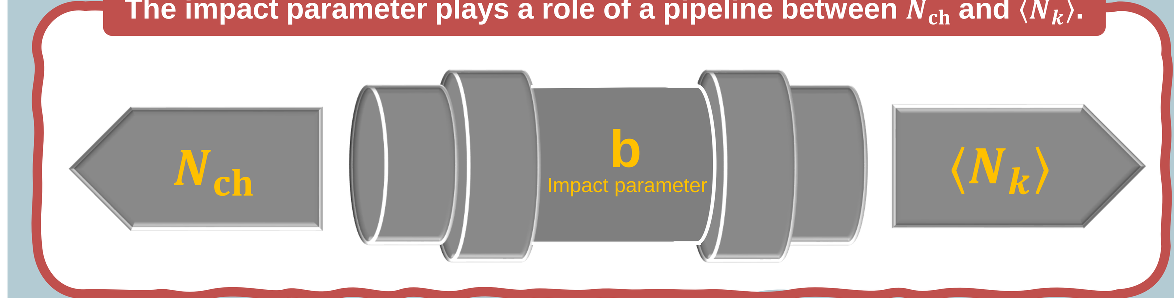
$T(x)$: Thickness function

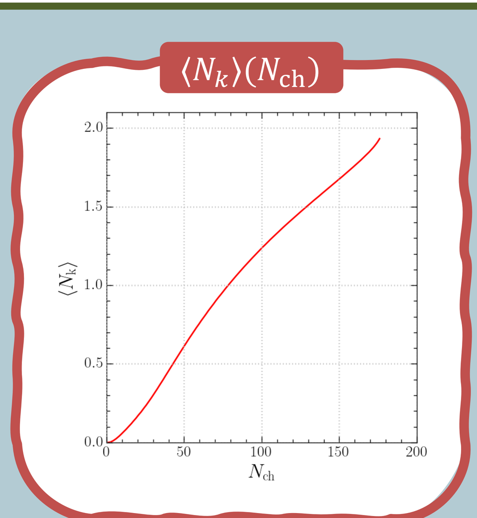
$N_{ch}(\mathbf{b}) = \frac{2}{3} \times \frac{\langle N_{MP}\rangle}{\langle N_{particp}\rangle} \times \int db' \frac{dN_{particp}}{db'}$

$\langle N_k\rangle(\mathbf{b}) = \int db' \frac{dN_{particp}}{db'} \times P_{jet} \times f_{att} \times \sigma_{MP}\Big|_{mean}$

P_{jet}: Jet production probability
f_{att}: Jet attenuation factor
σ_{MP}: Jet-Parton cross-section

The impact parameter plays a role of a pipeline between N_{ch} and $\langle N_k\rangle$.

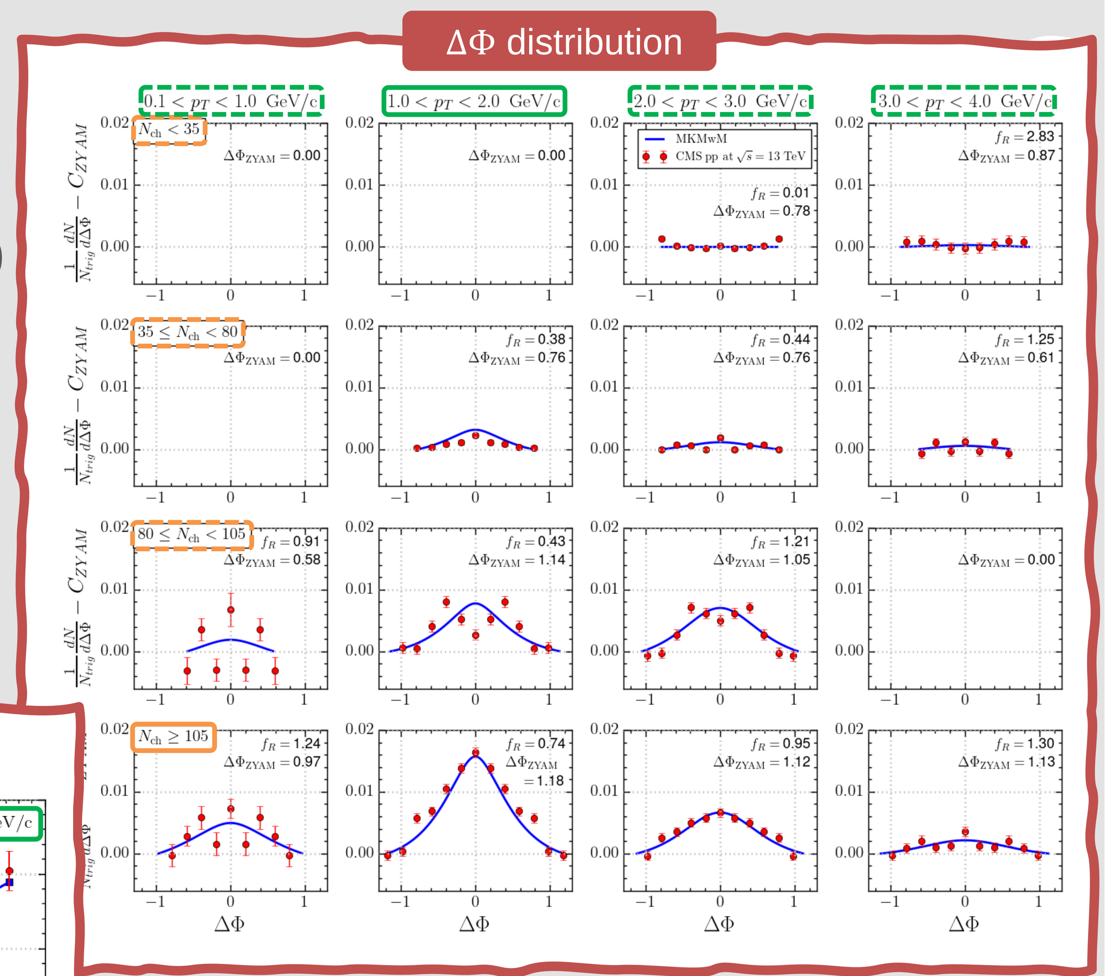


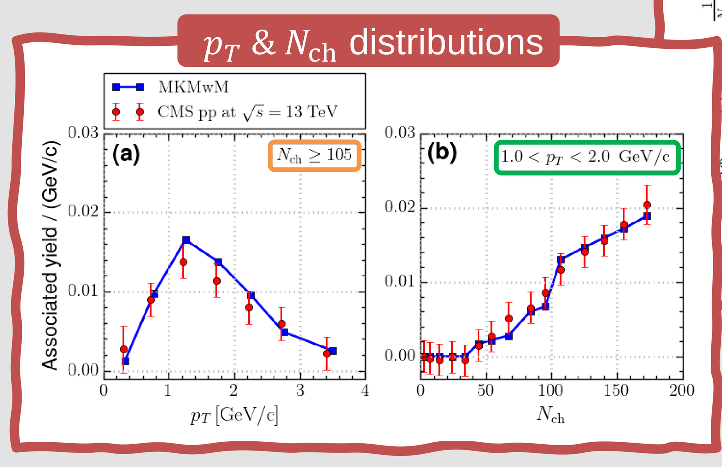


Application

- Averaged over $2 < |\Delta\eta| < 4$
- ZYAM procedure (zero-yield-at-minimum)

✓ Least square fitting method
① $q = 1.2$ GeV/c
② f_R increases with p_T





➢ Integrated over $|\Delta\Phi| < \Delta\Phi_{ZYAM}$

❖ **Questions** raised by CMS Collaboration

1. Ridge yield reaches a maximum around $p_T \approx 1$ GeV/c
   ➢ **MKMwM**: The q is active at $p_T = 1.2$ GeV/c
2. Ridge yield shows a linear increase with N_{ch}
   ➢ **MKMwM**: This linearity is attributed to $\langle N_k\rangle$

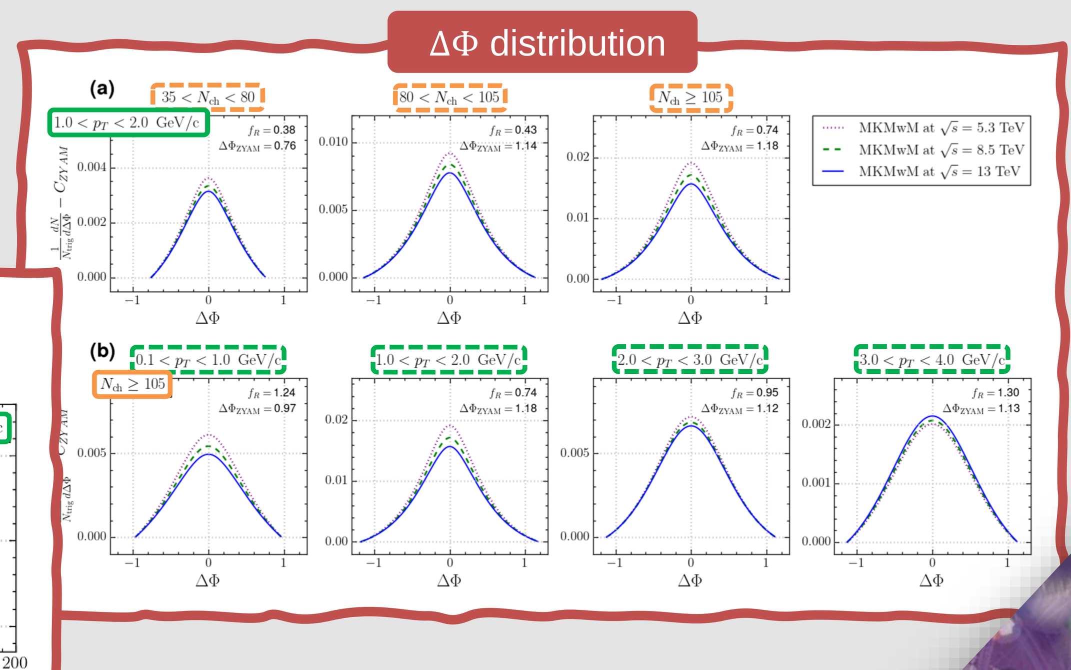
Parameters

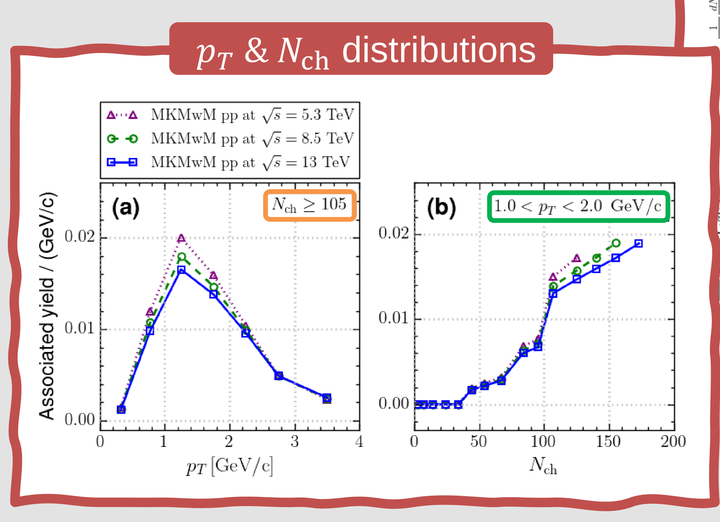
		Physical parameters	STAR[a] & PHENIX[b]	CMS	
			AuAu at $\sqrt{s}$ = 0.2 TeV	pp at $\sqrt{s}$ = 7 TeV[c]	pp at $\sqrt{s}$ = 13 TeV
MKM	q	average momentum transfer	1.0 & 0.8 GeV/c	2.0 GeV/c	**1.2 GeV/c**
	f_R	survival factor	-	1.00	**0.38 ~ 1.30**
	T	medium temperature	0.50 GeV	0.70 GeV	**0.77 GeV**
	m_d	mass parameter	1.0 GeV		**1.0 GeV**
	a	fall-off parameter	0.5		**0.5**
Multiplicity dependence	R	proton radius	-	0.80 fm	**0.74 fm**
	t_0	initial time	0.60 fm/c	0.43 fm/c	**0.39 fm/c**
	κ'	$\frac{\langle N_{MP}\rangle}{\langle N_{particp}\rangle}$	21	367	**134**
	σ_{MP}	cross-section btw jet & parton	1.4 mb		**1.4 mb**
	ζ	empirical attenuation coefficient	0.2		**0.2**

(a): C. Y. Wong, Phys. Rev. C 78, 064905 (2008)
(b): C. Y. Wong, Phys. Rev. C 80, 034908 (2009)
(c): C. Y. Wong, Phys. Rev. C 84, 024901 (2011)

Prediction

- **Motivation**
  - CMS compared the yield at $\sqrt{s}$ = 13 TeV with 7 TeV for pp collisions
    ➢ **CMS**: $\Delta Y \approx$ same → no clear $\sqrt{s}$ dependence
    ➢ **MKMwM**: Prediction by fixing $q = 1.2$ GeV/c from $\sqrt{s}$ = 13 TeV plus, confirmed $q = 1.1$ GeV/c at $\sqrt{s}$ = 7 TeV
- **Results**
  - Upcoming LHC Run 3
  - Using the same f_R & $\Delta\Phi_{ZYAM}$





➢ Integrated over $|\Delta\Phi| < \Delta\Phi_{ZYAM}$

Conclusions & Discussions

- MKMwM at $\sqrt{s}$ = 13 TeV successfully explains the long-range near-side ridge structure through recent data-driven parameters.
- Prediction using the same f_R & $\Delta\Phi_{ZYAM}$ values from $\sqrt{s}$ = 13 TeV may result in some uncertainties.
- Feasibility of the MKMwM in heavy-ion collisions needs to be further investigated.

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