Forward Backward Multiplicity Correlations in pp collisions at LHC Energies

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Outline

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- Details of Data
- Forward Backward Correlations
- Results
- Conclusions

Introduction

- Forward-backward (FB) multiplicity correlations among the charged particles produced in different pseudorapidity, η, regions are regarded as a powerful tool for understanding the underlying mechanism of particle production in high energy h-h, h-A and A-A collisions.

- FB multiplicity correlations observed in the past decades have been interpreted using the concept of clustering, i.e. the particle production take place via the formation of some intermediate states, referred to as "clusters" which finally decay isotropically, in their center of mass frame, to real physical hadrons.

- By examining k-particle angular correlations, information regarding various properties of clusters, e.g., number of clusters produced on e-b-e basis, mean cluster multiplicity, size of clusters and the extent to phase space occupied by their decay products etc. may be extracted.

- The inclusive two-particle correlations have two components:
  Short Range Correlations (Confined to η ~ ±1)
  Long Range Correlations (extend over a relatively larger range >2 units of η)

- SRCs ⟶ Arise due to the tendency of the secondary particles to be grouped in clusters, which finally decay isotropically to real physical hadrons.

- LRCs ⟶ Arise due to e-by-e fluctuations of overall particle multiplicity at relatively higher incident energies.

- In the case of AA collisions, LRCs induced across a wide range in η are expected to reflect the earliest stages of the collisions, almost free from final state effects.

- In pp collisions by studying the dependence of FB correlations on particle pseudorapidity, collision energy and transverse momenta.

Details of Data

- Monte Carlo events samples (10^6 events) corresponding to LHC energies **$\sqrt{s}$ = 0.9, 2.76, 7.0** and **13.0 TeV** are simulated using codes AMPT-v1.21-v2.21 and HIJING-1.35.
- Events with $\mathbf{n_{ch} \geqslant 10}$ are selected for the analysis.
- Pseudorapidity cut used: $-1 \leqslant \eta_c \leq +1$
- p_T cut used: $0.3 < p_T < 1.5$ GeV/c

Forward Backward Correlations

The linear dependence of mean charged particle multiplicity in backward η region ($\langle n_B \rangle$), on the multiplicity of charged particles in the forward η- region (n_F) as,

$$\langle n_B \rangle = a + b_{corr} \cdot n_F \qquad (1)$$

For symmetric F-B regions, the correlation strength, b_{corr} is,

$$b_{corr} = \frac{\langle n_B n_F \rangle - \langle n_B \rangle \langle n_F \rangle}{\langle n_F^2 \rangle - \langle n_F \rangle^2} = \frac{D_{BF}^2}{D_{FF}^2} \qquad (2)$$

Where D_{BF} and D_{FF} respectively, denote the backward-forward and forward-forward dispersions.

[1] UA5 Collaboration, Z.Phys,C-Particles and Fields 37,191-213 (1988)
[2] A.Capella et al.,Phys.Rep. 236,225(1994)

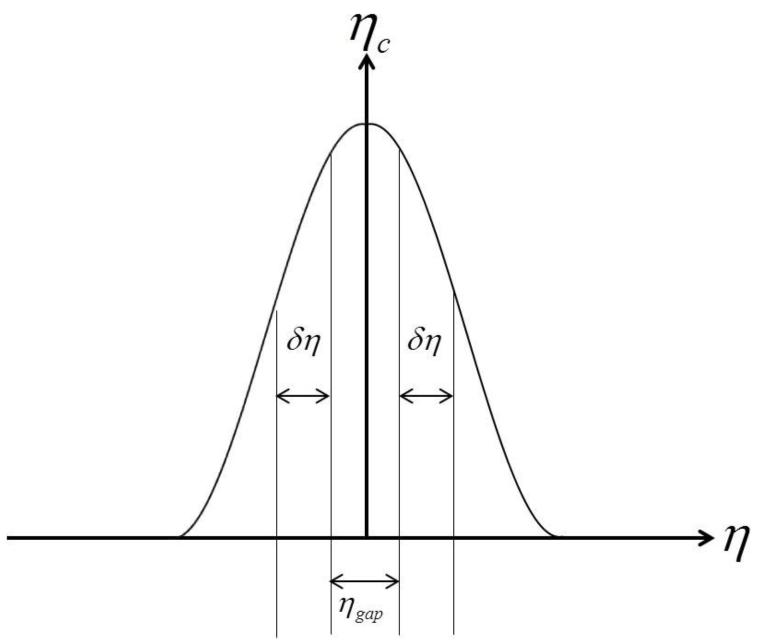
- Pseudorapidity, η distributions of charged particles is divided into two parts with respect to its centre of symmetry, η_c ($\eta = 0$).

- The region having values $\eta < \eta_c$ is referred to as the backward (B) region while the region having $\eta > \eta_c$ is termed as forward (F) region.

- Number of charged particles emitted in F and B regions, n_F and n_B on event-by-event (ebe) basis are counted.

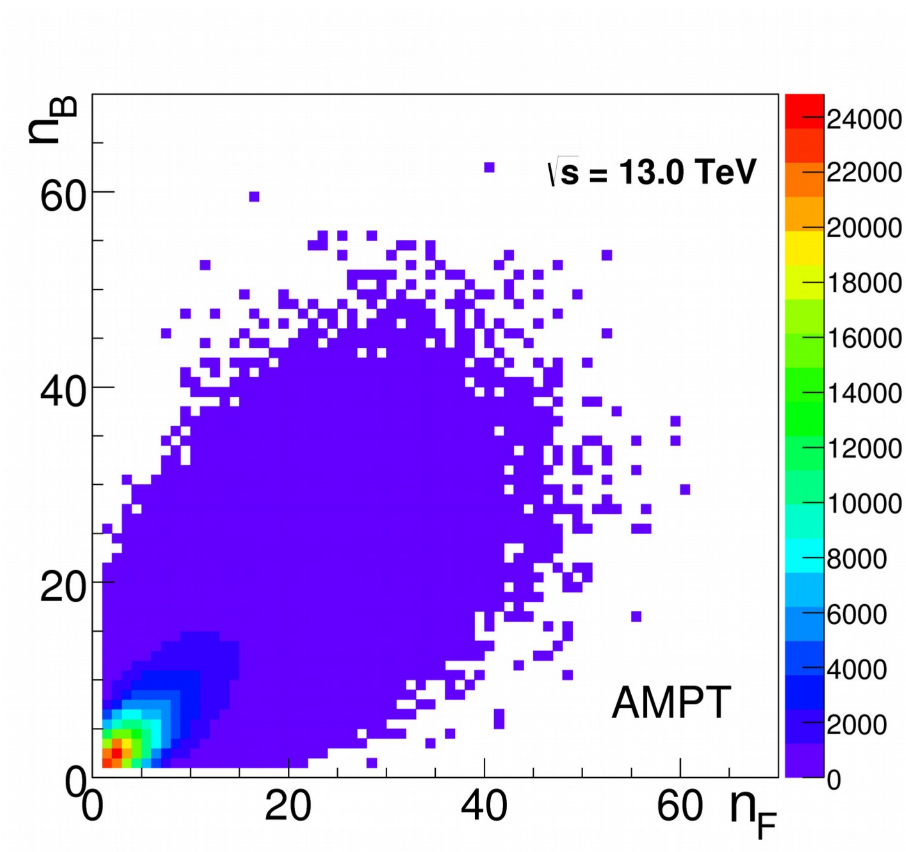
- The window width is then increased in steps of 0.2 till the region $\delta\eta = \eta_c \pm 0.8$ is covered.

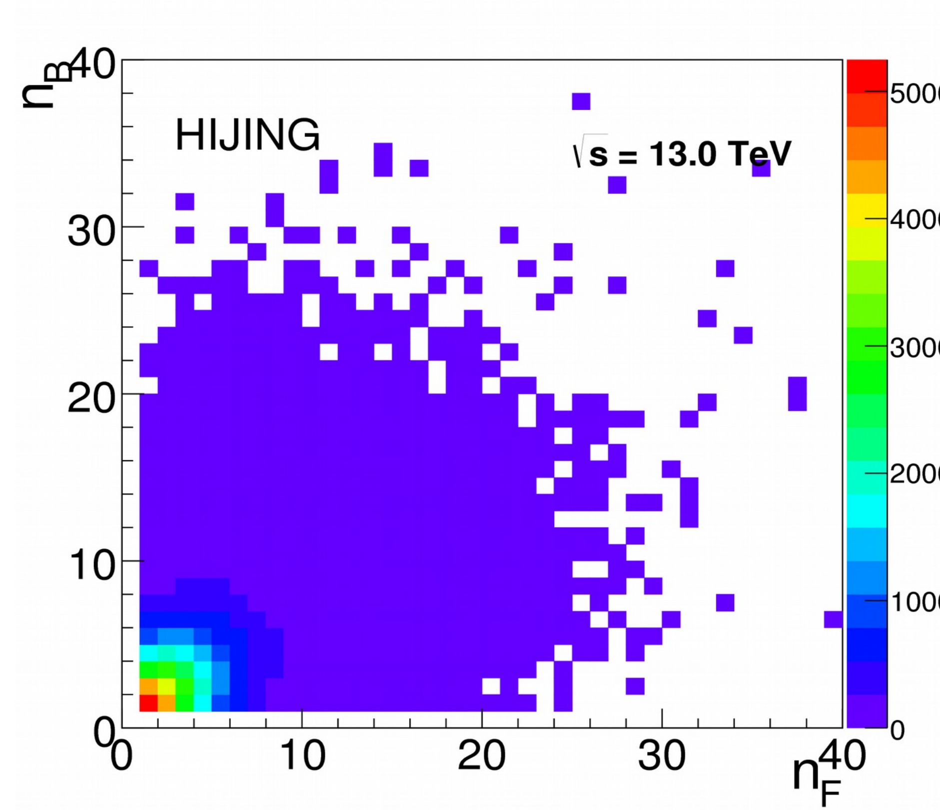
- For each η-window, values of n_F and n_B are calculated to study the dependence of correlation strength b_{corr} on η-bin width ($\delta\eta$) and as a function of the gap between the windows (η_{gap}).

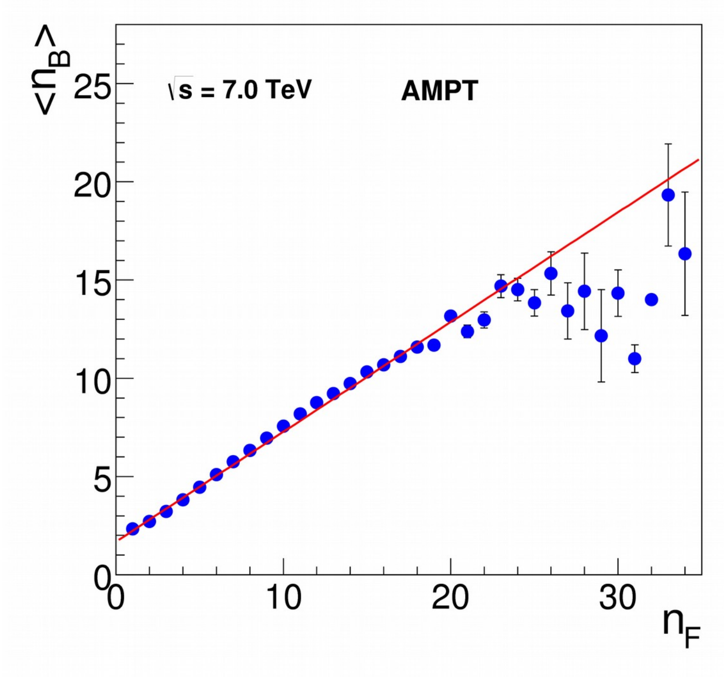


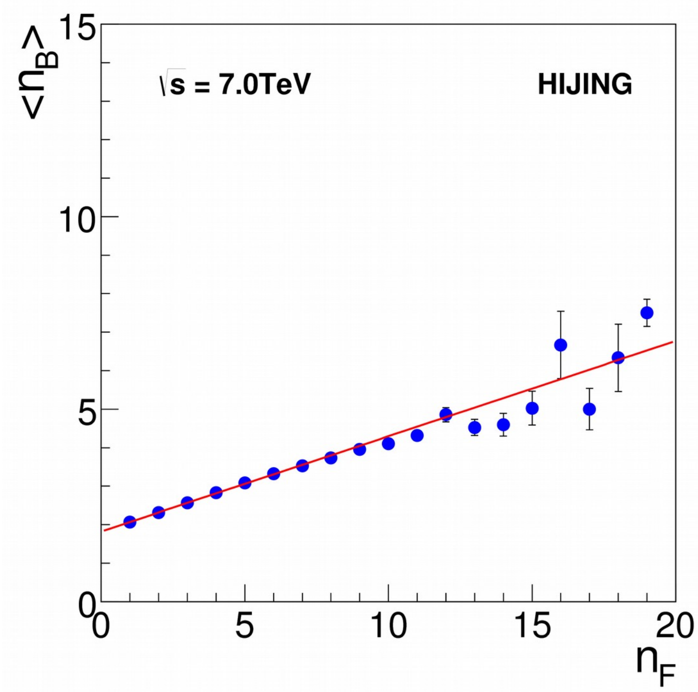
Results

Forward vs backward multiplicity distribution at √s = 13.0 TeV is shown for the AMPT (left) and HIJING (right) events.



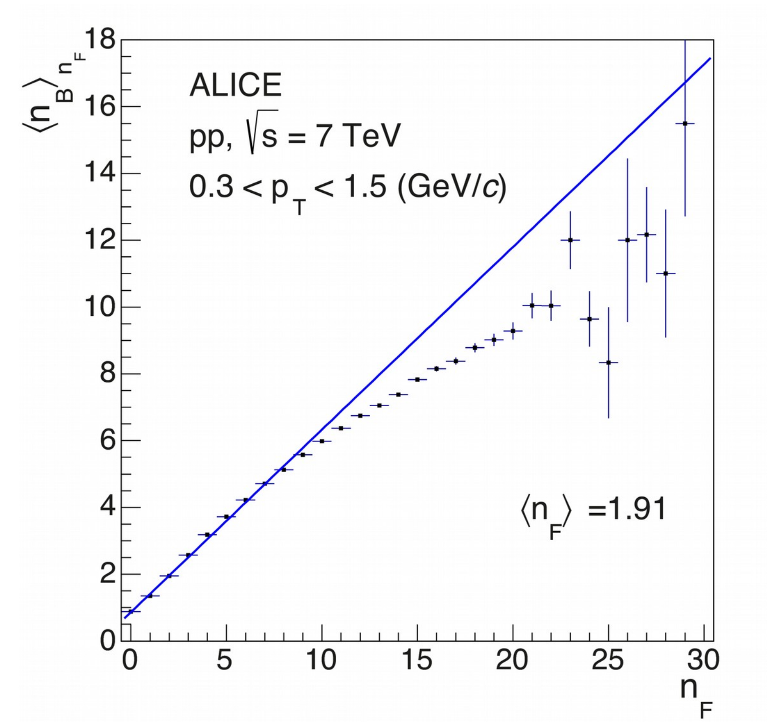


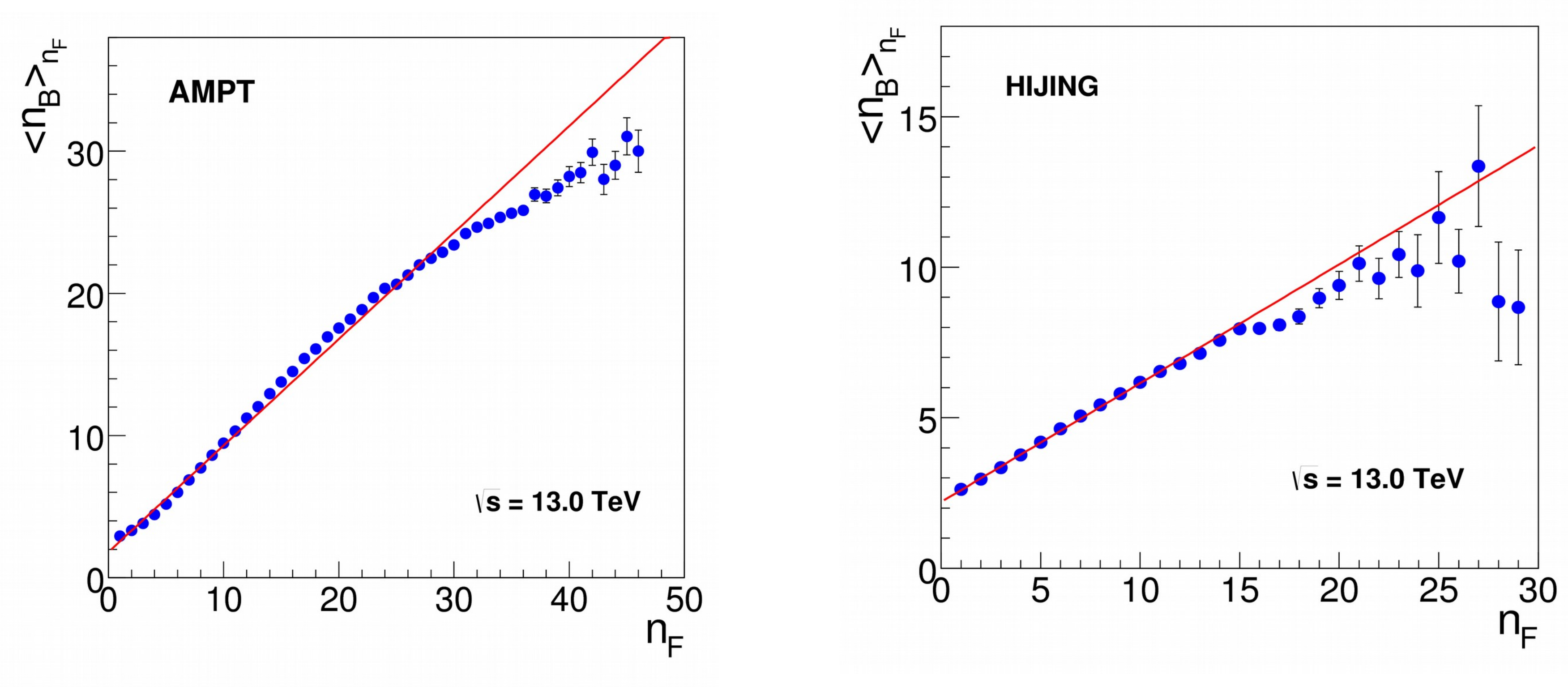




The straight lines in the figure represent the best fits to the data from Eq. 1.

Similar deviations were observed for pp data at √s = 7.0 TeV
[ALICE , J. of High En. Phys. 05 (2015) 097].





A deviation from the linearity for higher n_F values is observed for AMPT and HIJING events.

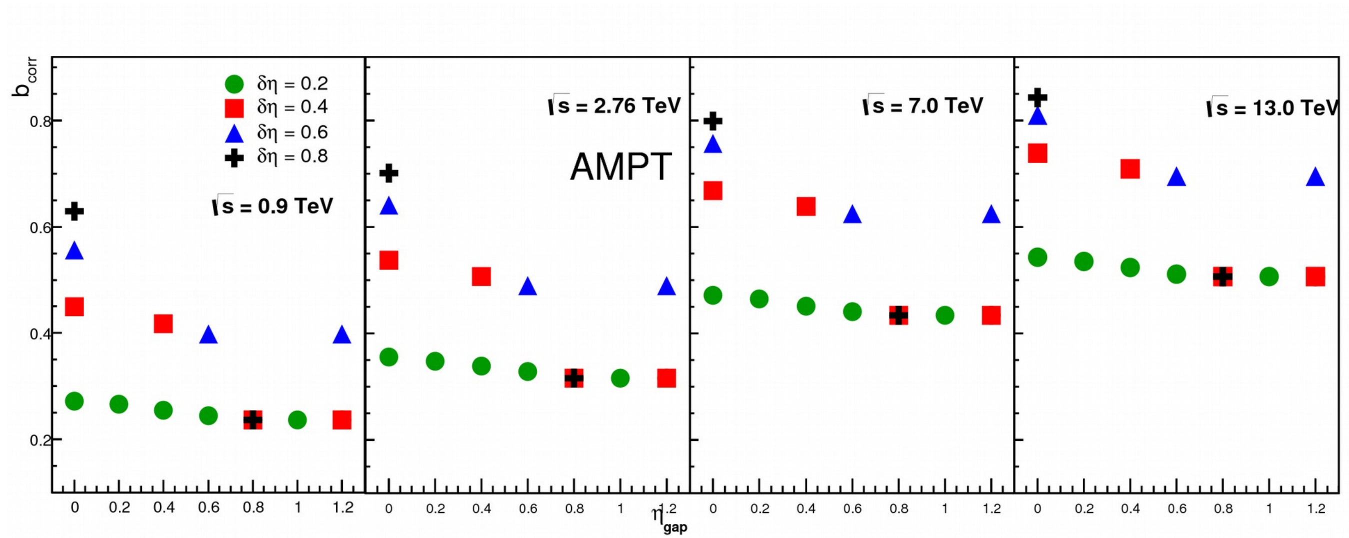
√s (TeV)	b_{corr} (linear fit)		$b_{corr} (= D^2_{BF}/D^2_{FF})$	
	AMPT	HIJING	AMPT	HIJING
0.9	0.349 ± 0.001	0.214 ± 0.001	0.350 ± 0.006	0.211 ± 0.006
2.76	0.447 ± 0.001	0.223 ± 0.001	0.448 ± 0.006	0.224 ± 0.005
7.0	0.558 ± 0.001	0.247 ± 0.001	0.567 ± 0.005	0.245 ± 0.005
13.0	0.643 ± 0.001	0.260 ± 0.001	0.650 ± 0.005	0.259 ± 0.005

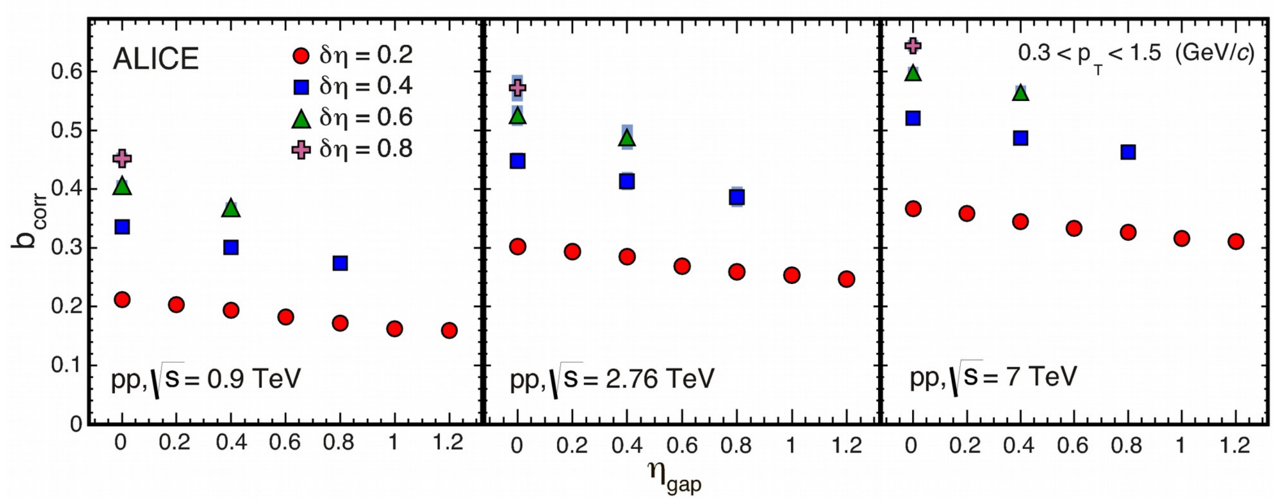
- The values of b_{corr}, from Eq. 1 and Eq. 2 are nearly the same and exhibit strong F-B correlation.
- Values of b_{corr} increases with increasing collision energy.
- HIJING gives somewhat smaller values of b_{corr} as compared to those predicted by AMPT.

Dependence of correlation strength on gap between the windows

Value of b_{corr} with η_{gap} for different windows widths $\delta\eta$ = 0.2, 0.4, 0.6 and 0.8 at different energies are plotted for AMPT data sets and compare the results with real data.

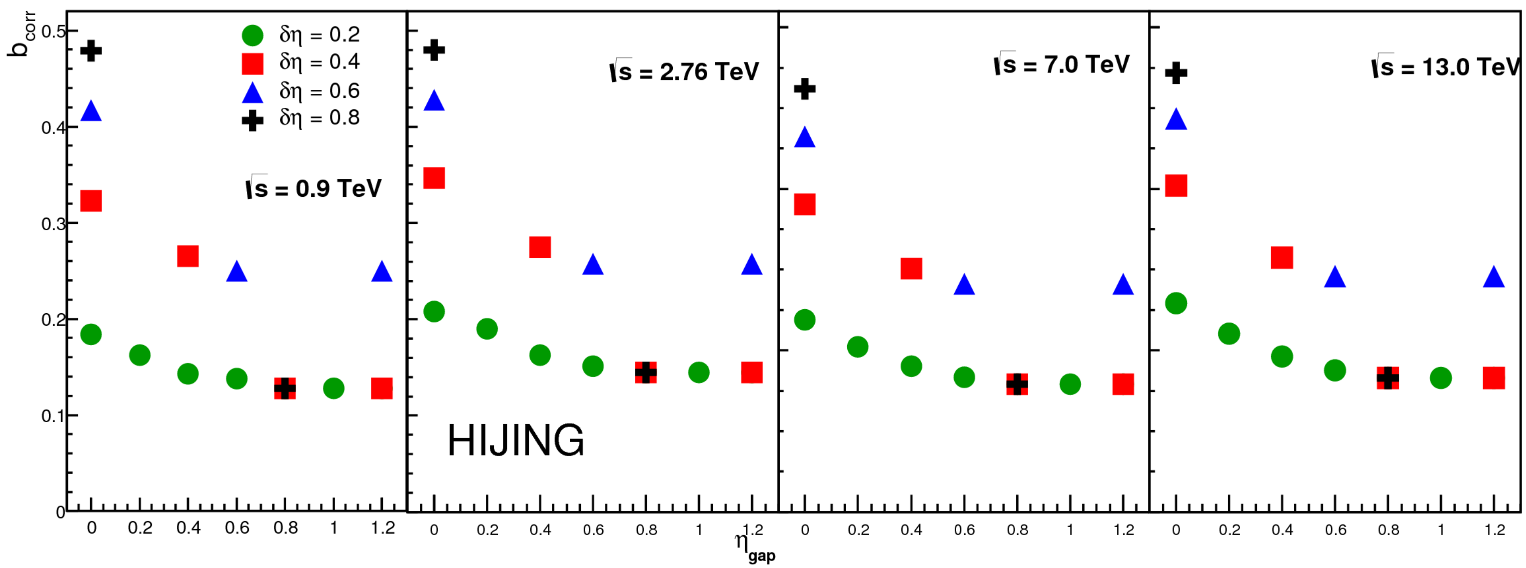
- For each √s, the FB correlation strength is decreasing slowly with increasing η_{gap}.
- The growth of the b_{corr} is observed with the increase of collisions energy from 0.9 to 13TeV.
- The slopes of b_{corr} does not affect. The contribution of the short-range correlations has a very weak √s dependence.
- LRCs plays a dominant role and its strength increases with the increase in collision energy .

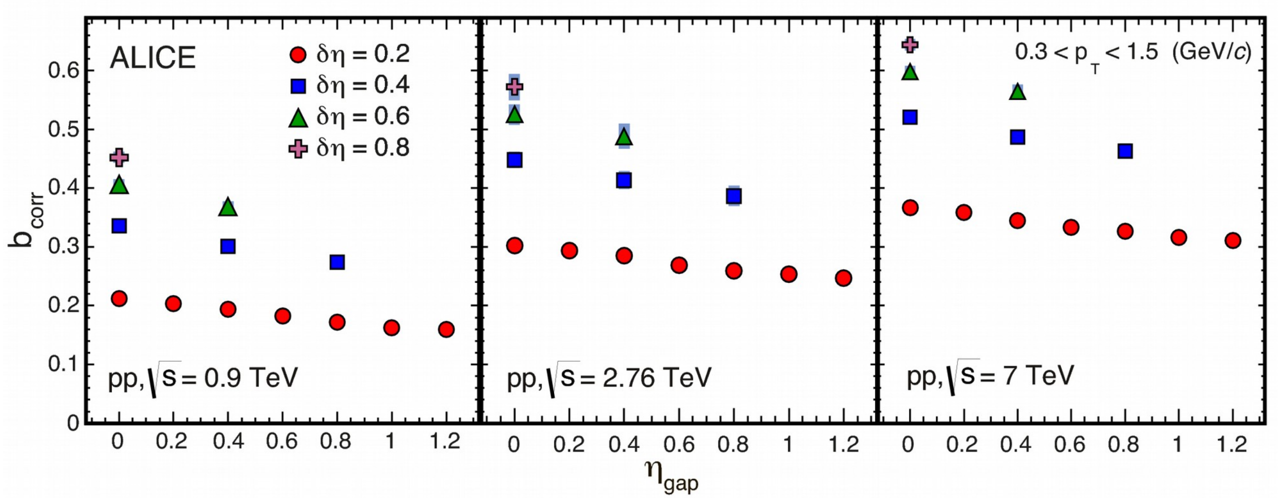




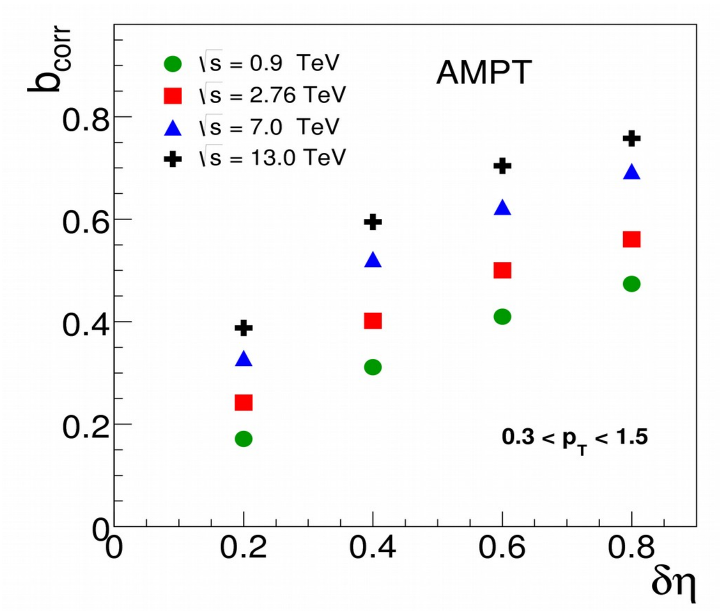
[ALICE, J. of High En. Phys. 05 (2015) 097]

Similar trends of variation is shown by HIJING events but somewhat smaller values of b_{corr} as compared to those predicted by AMPT.





Dependence of correlation strength on window width



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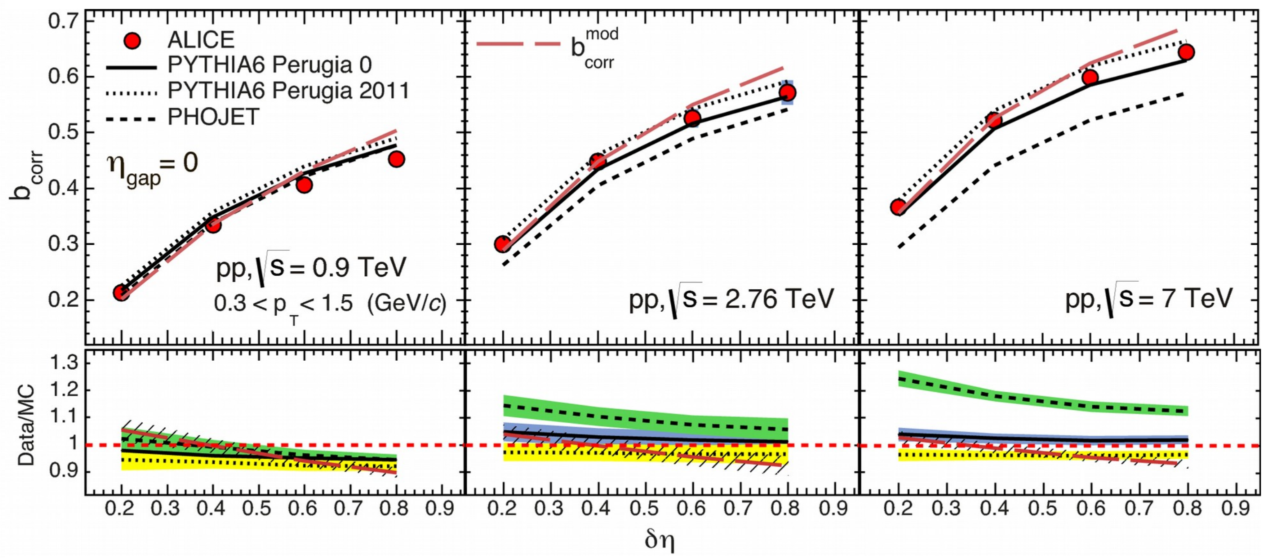
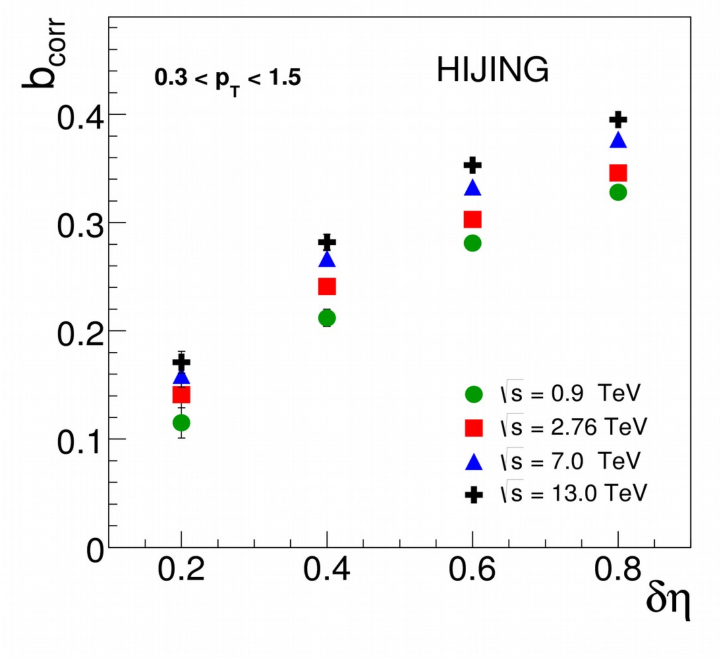


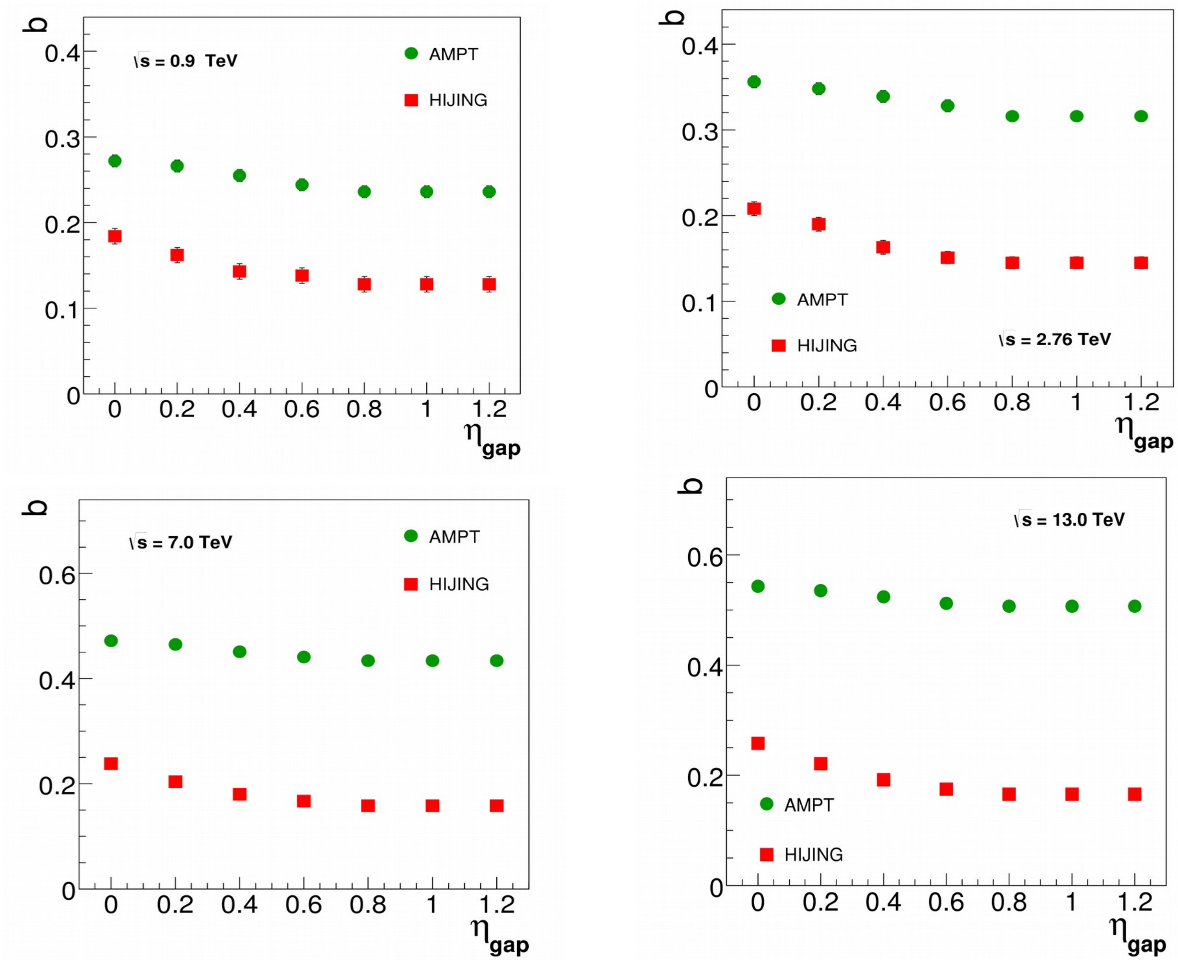


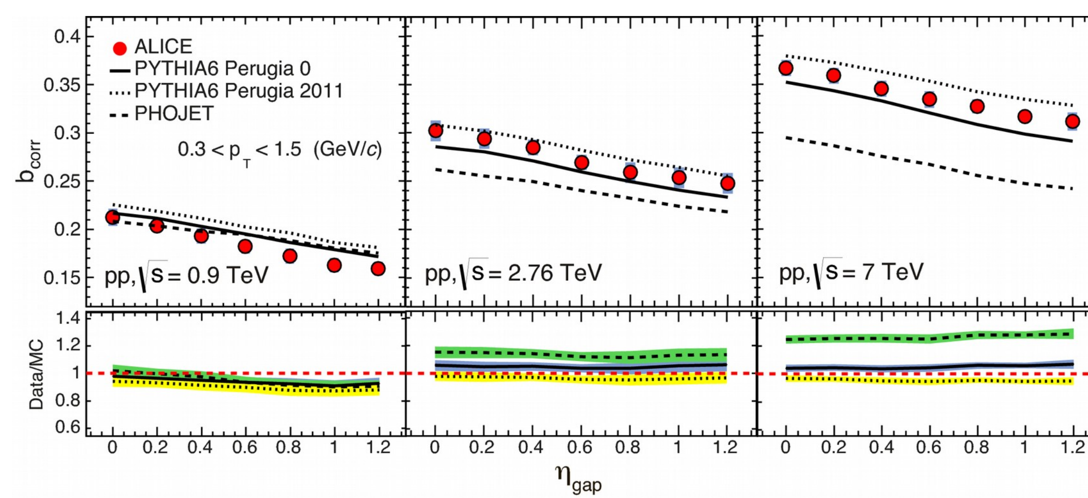
The correlation strength b_{corr}, increases non-linearly with increase in the window width δη, for all collision energies.

The trend is quite well described by the AMPT and HIJING data sets but HIJING gives somewhat smaller values as compare to the AMPT.

Dependence of correlation strength on the collision energy

- The comparison of b_{corr} as a function of η_{gap} for $\delta\eta$ = 0.2 at $\sqrt{s}$ = 0.9, 2.76, 7.0 and 13.0 TeV with the results obtained from AMPT and HIJING.
- The values of b_{corr} increases with $\sqrt{s}$.
- AMPT shows higher values as compare to HIJING but the trend of variations are same.
- The values of b_{corr} at $\sqrt{s}$ = 0.9 TeV shows smaller variations while the large discrepancies are observed at higher collision energies.





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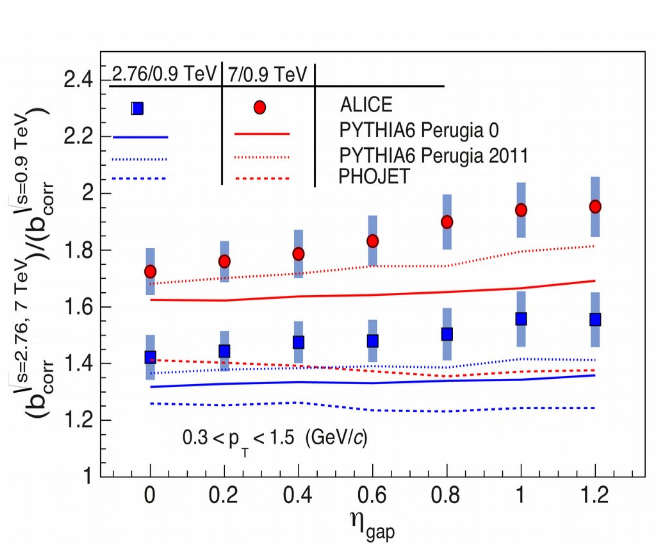
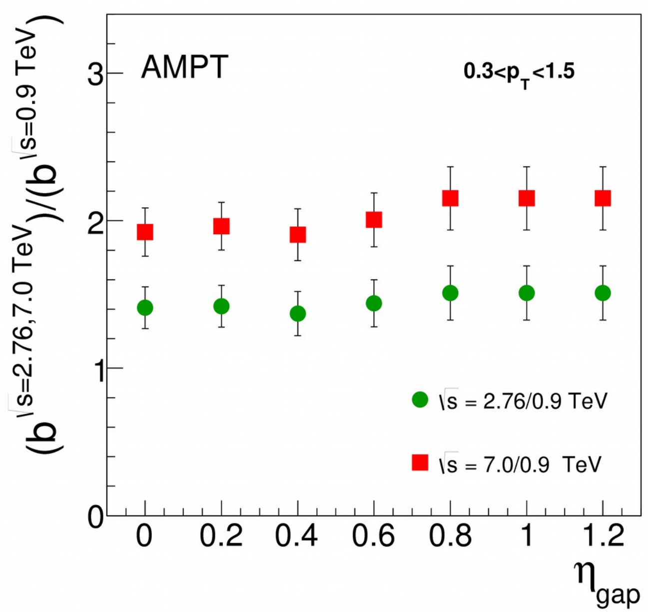
Correlation strength b_{corr} with $<n_F>$ and the corresponding values of $\delta\eta$ in pp collisions at 0.9, 2.76, 7.0 and 13.0 TeV for the HIJING and AMPT data sets.

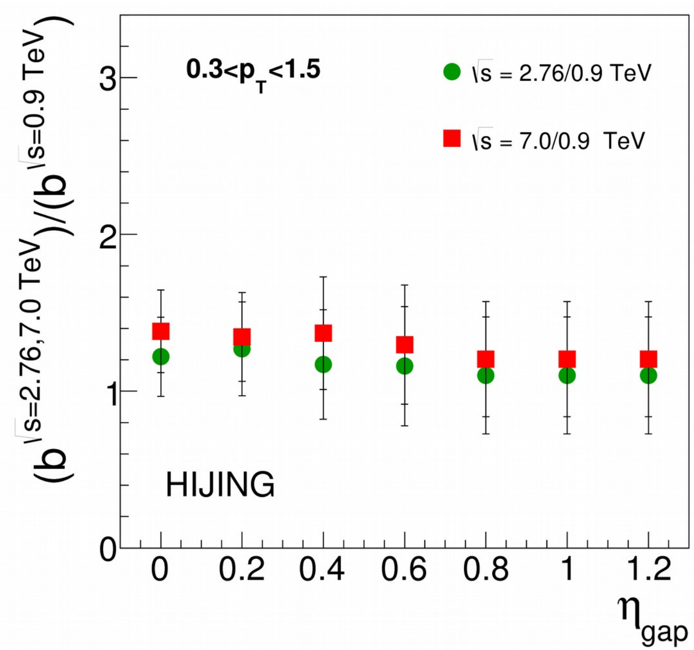
	HIJING			AMPT		
$\sqrt{s}$ (TeV)	$\delta\eta$	$<n_F>$	b_{corr}	$\delta\eta$	$<n_F>$	b_{corr}
0.9	0.565	2.07	0.271 ± 0.007	0.405	2.07	0.313 ± 0.007
2.76	0.525	2.07	0.283 ± 0.006	0.317	2.07	0.324 ± 0.007
7.0	0.445	2.07	0.285 ± 0.006	0.207	2.07	0.338 ± 0.007
13.0	0.41	2.07	0.287 ± 0.007	0.155	2.07	0.344 ± 0.007

- The ratio of b_{corr} at 2.76 and 7.0 TeV with respect to 0.9 TeV vs. η_{gap} for AMPT simulated events in $0.3 < p_T < 1.5$ (GeV/c) is shown.
- The multiplicity correlation strength b_{corr}, shows linear increase with η_{gap} for the AMPT data sets.
- Similar deviations were observed for pp data at 7.0 TeV
  [ALICE, J. of High En. Phys. 05 (2015) 097]
- b_{corr} shows almost constant values with η_{gap} for the HIJING events.

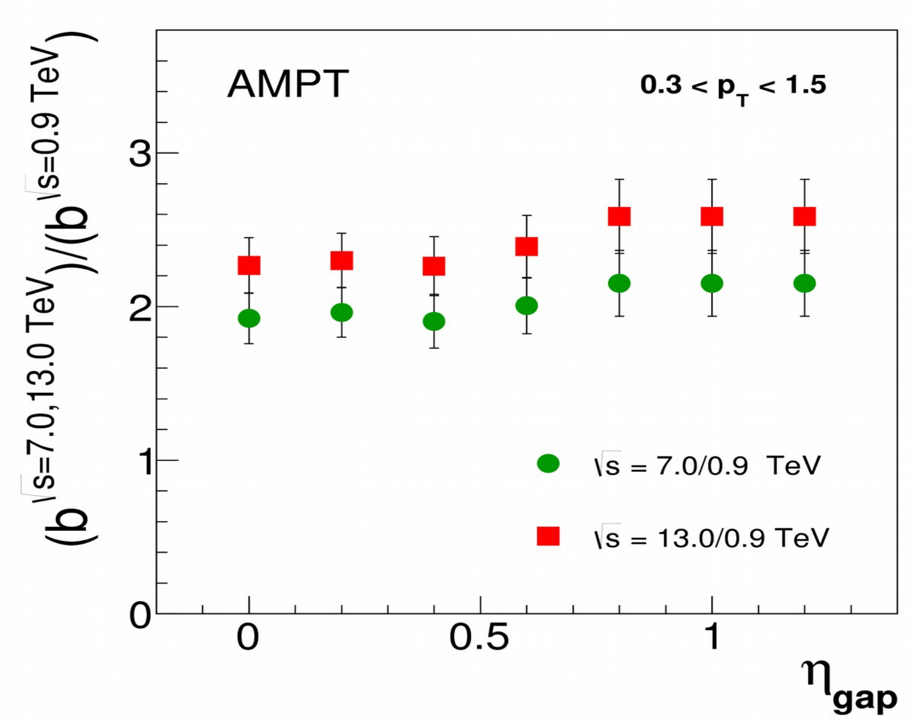
(δη bin-width = 0.2)

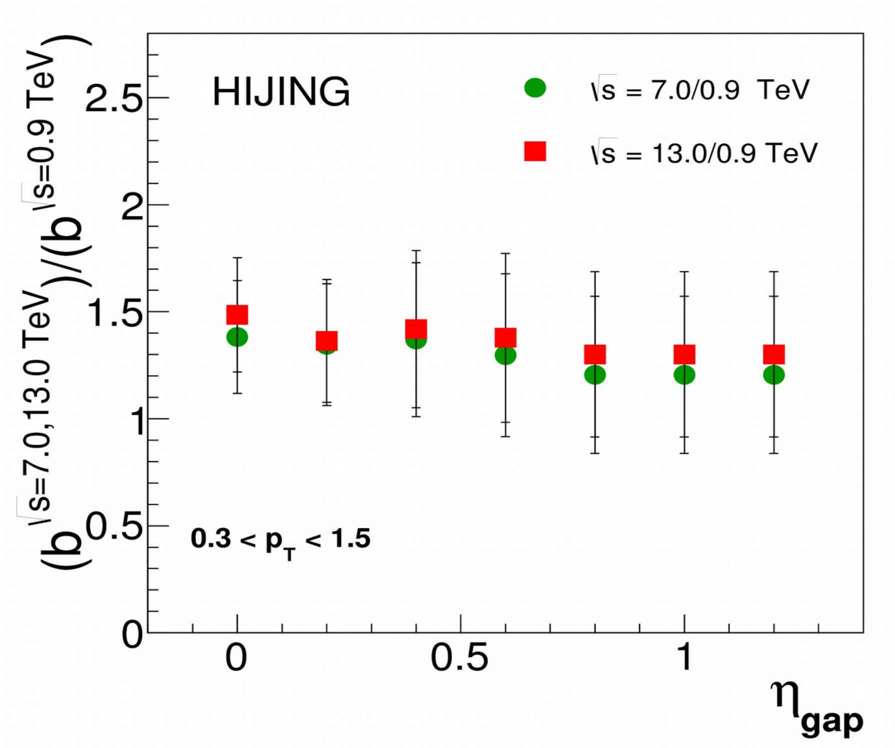






Red Points = Ratio between values of b_{corr} at 7 TeV and 0.9 TeV
Green Points = Ratio between values of b_{corr} at 2.76 TeV and 0.9 TeV



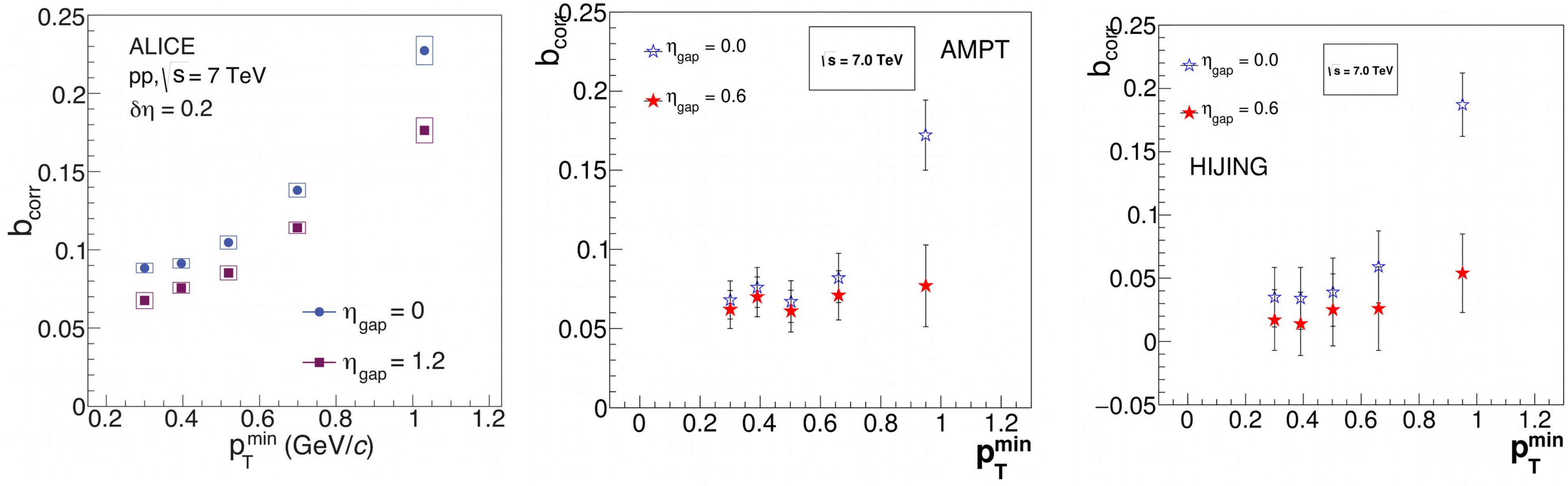


Red Points = Ratio between values of b_{corr} at 13 TeV and 0.9 TeV

Green Points = Ratio between values of b_{corr} at 7 TeV and 0.9 TeV

Dependence of correlation strength on p_T intervals

- Strong non-linear dependence of b_{corr} on the size of pseudorapidity windows and on the mean multiplicity in the window.
- In order to check the p_T^{min} dependence on b_{corr}, we use five p_T intervals with the same $<n_{ch}>$.
- p_T intervals within $0.3 < p_T < 6$ GeV/c for window width $\delta\eta = 0.2$ are: 0.3 – 0.39, 0.39 – 0.502, 0.502 – 0.66, 0.66 – 0.95, 0.95 – 6.0 (GeV/c).
- ALICE collaboration, which reported a increase in the multiplicity correlation strength with p_T^{min}.



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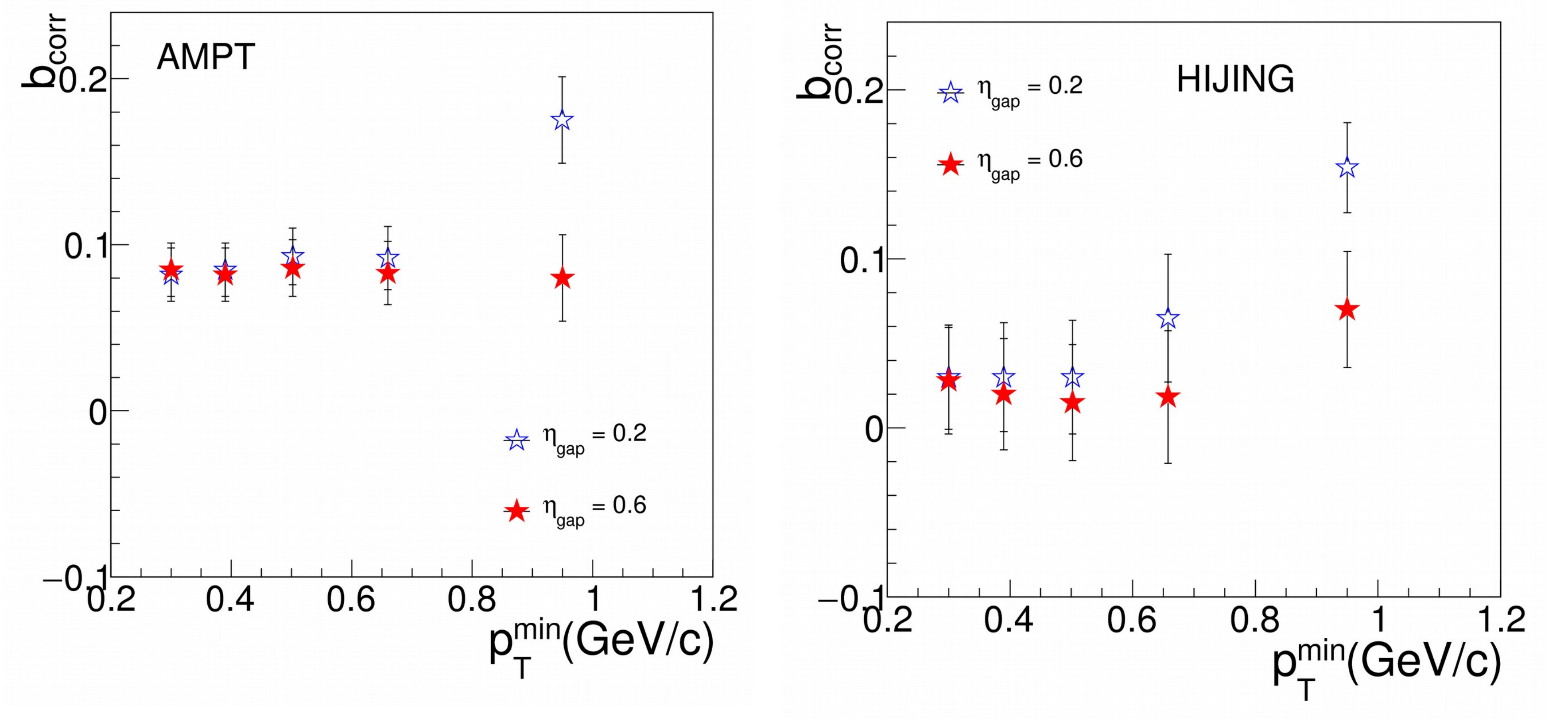
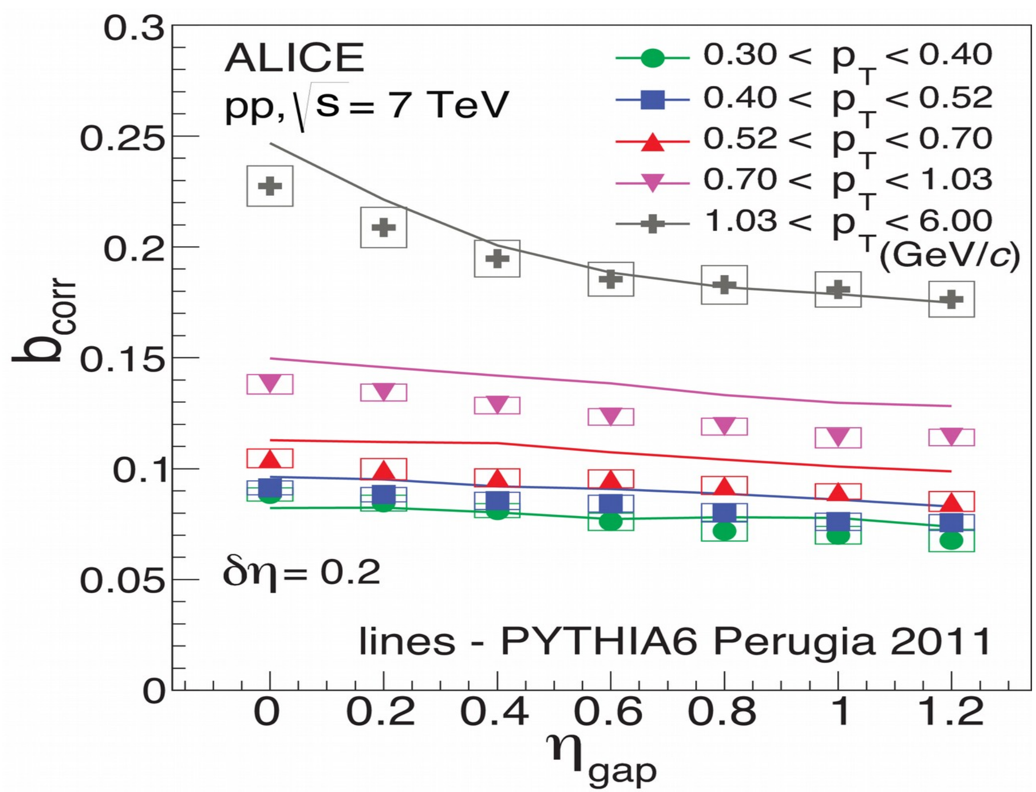


FB correlation strength increases with the transverse momentum if p_T intervals with the same mean multiplicity are chosen.

Dependence of b_{corr} as a function of η_{gap} for different p_T intervals at 7.0 TeV for pseudorapidity window of width $\delta\eta = 0.2$ for the AMPT and HIJING data.

The values of b_{corr} increases with higher p_T^{min} for $\eta_{gap} = 0$.



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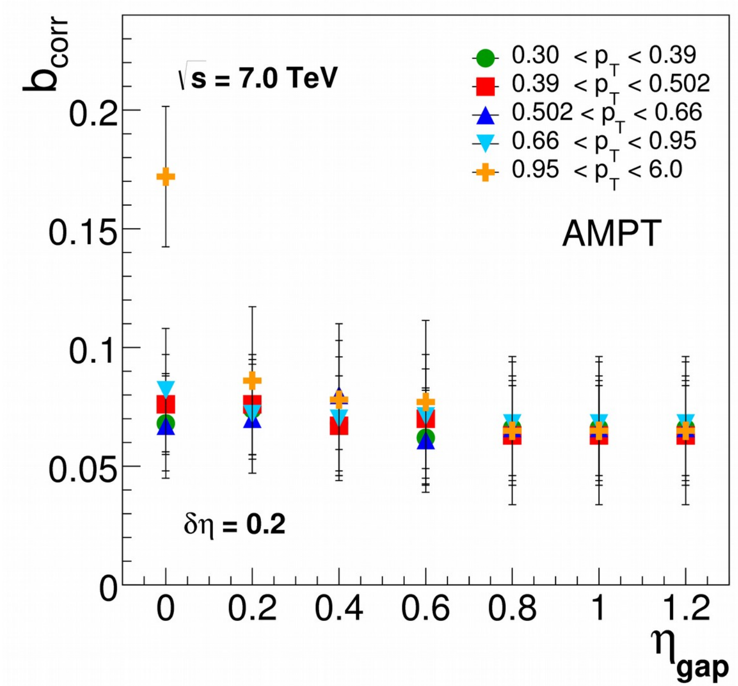
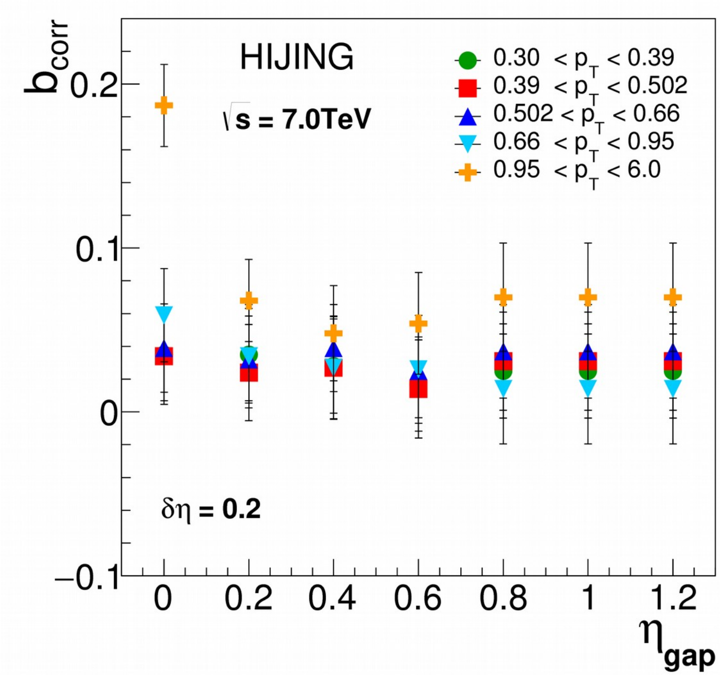
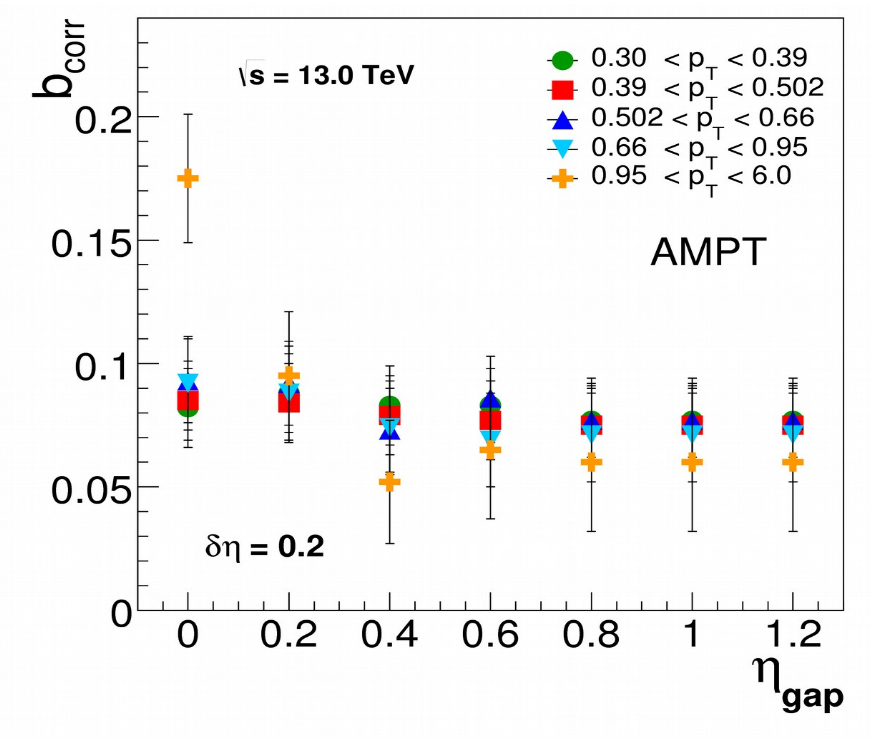
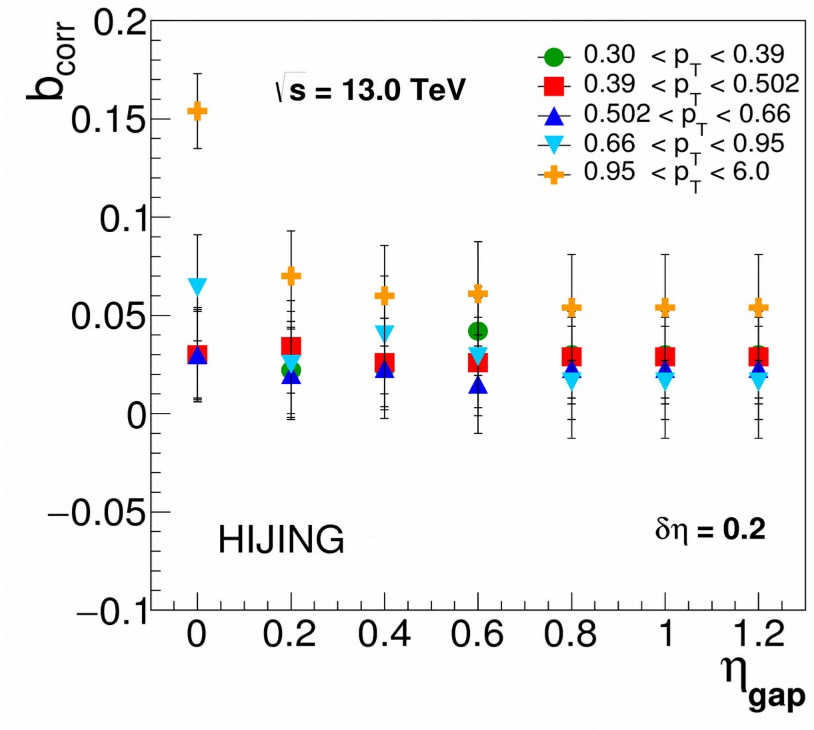






b_corr
√s = 13.0 TeV
0.30 < p_T < 0.39
0.39 < p_T < 0.502
0.502 < p_T < 0.66
0.66 < p_T < 0.95
0.95 < p_T < 6.0
AMPT
δη = 0.2
η_gap



b_corr
√s = 13.0 TeV
0.30 < p_T < 0.39
0.39 < p_T < 0.502
0.502 < p_T < 0.66
0.66 < p_T < 0.95
0.95 < p_T < 6.0
HIJING
δη = 0.2
η_gap

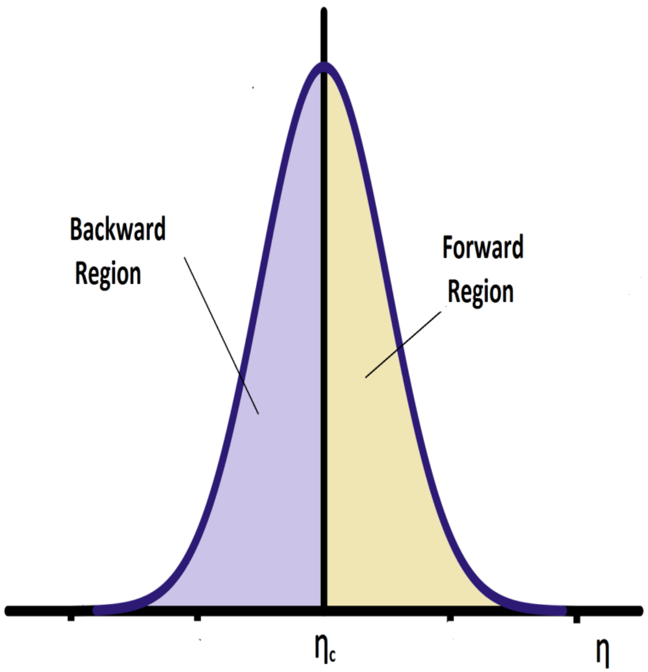
Conclusions

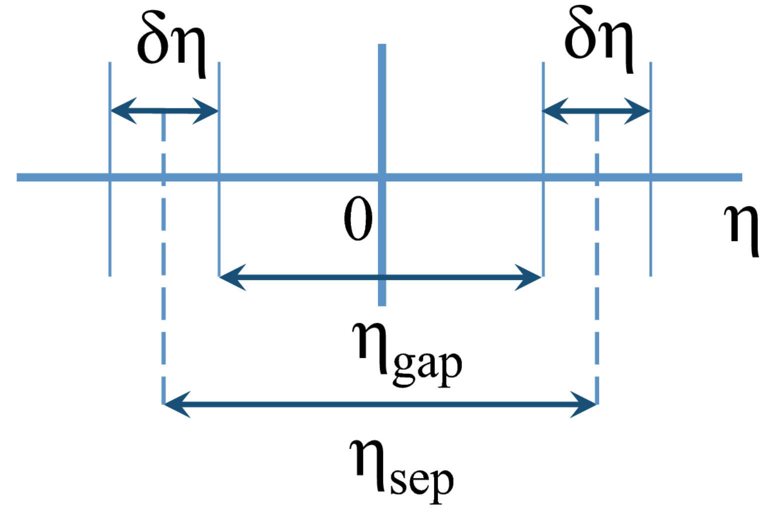
- FB correlation strength increases with the increase in collision energy.
- Strong non-linear dependence of the Forward-Backward multiplicity correlation coefficient value on the width of the pseudorapidity windows is observed.
- The observed FB correlation strength increases with the transverse momenta.
- The MC event generators AMPT and HIJING are able to describe the general trends of b_{corr} as a function of $\delta\eta$, η_{gap} and its dependence on the collision energy.
- In p_T-dependent analysis of b_{corr}, AMPT describes data reasonably well, while HIJING shows smaller values.

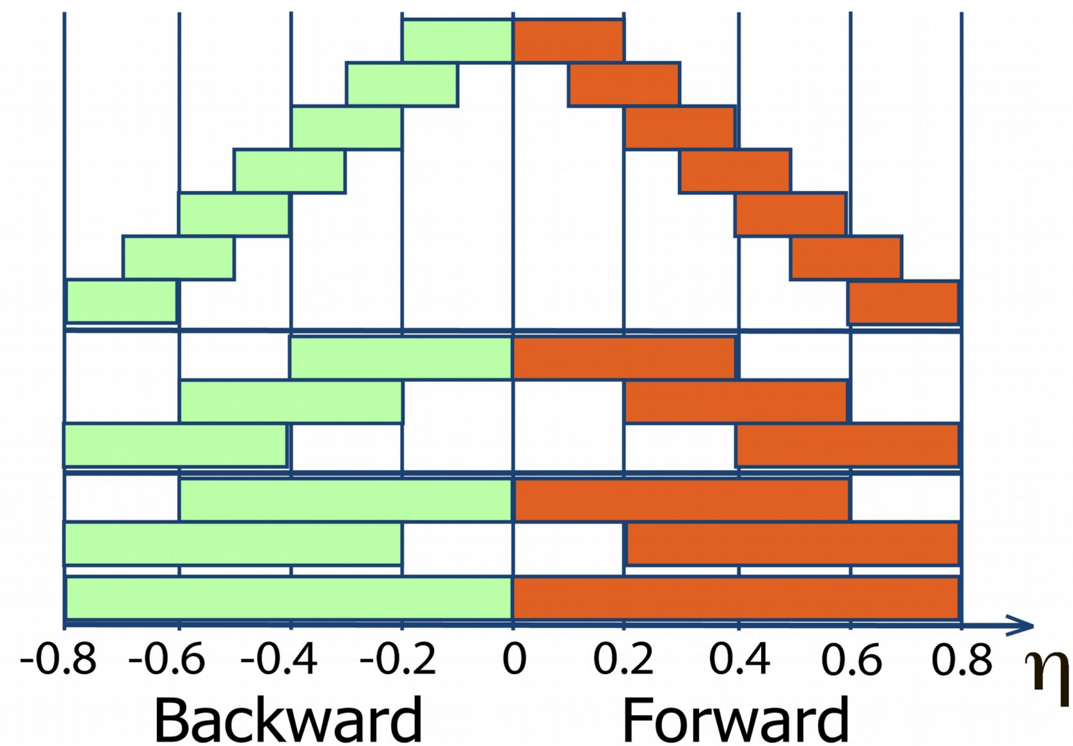
Work is in progress...........

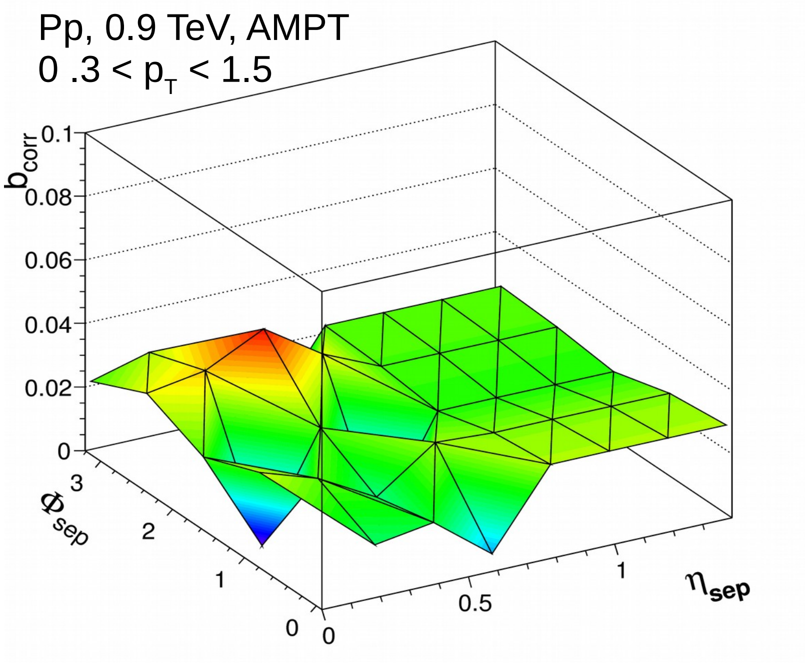
THANK YOU

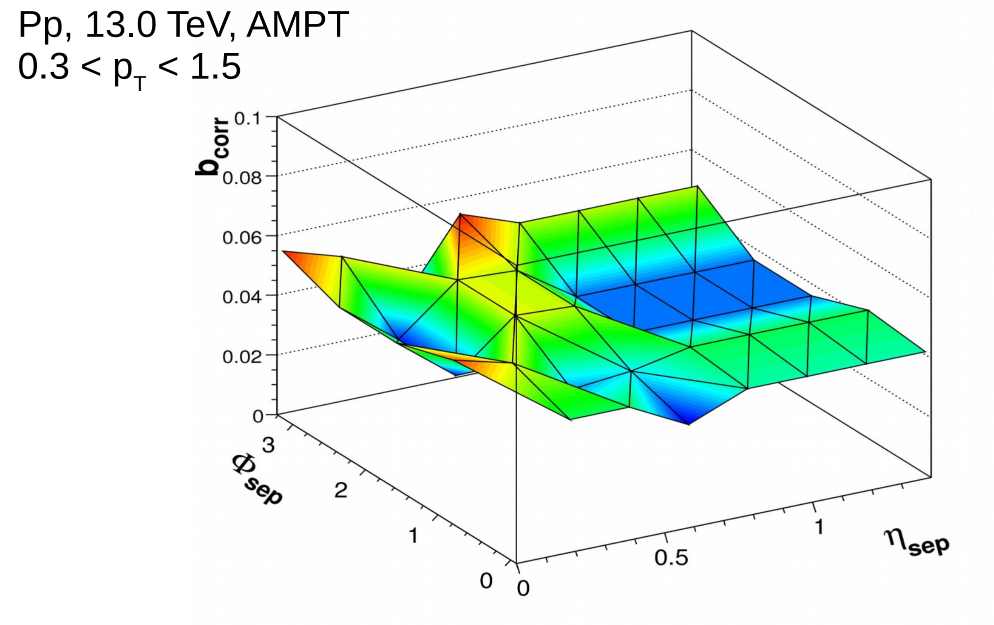
BACK UP SLIDES


Backward
Region
Forward
Region
ηc
η


δη
δη
0
η
ηgap
ηsep


-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
η
Backward
Forward


Pp, 0.9 TeV, AMPT
0 .3 < p_T < 1.5
b_corr
0.1
0.08
0.06
0.04
0.02
0
Φ_sep
3
2
1
0
η_sep
0
0.5
1


Pp, 13.0 TeV, AMPT
0.3 < p_T < 1.5
b_corr
0.1
0.08
0.06
0.04
0.02
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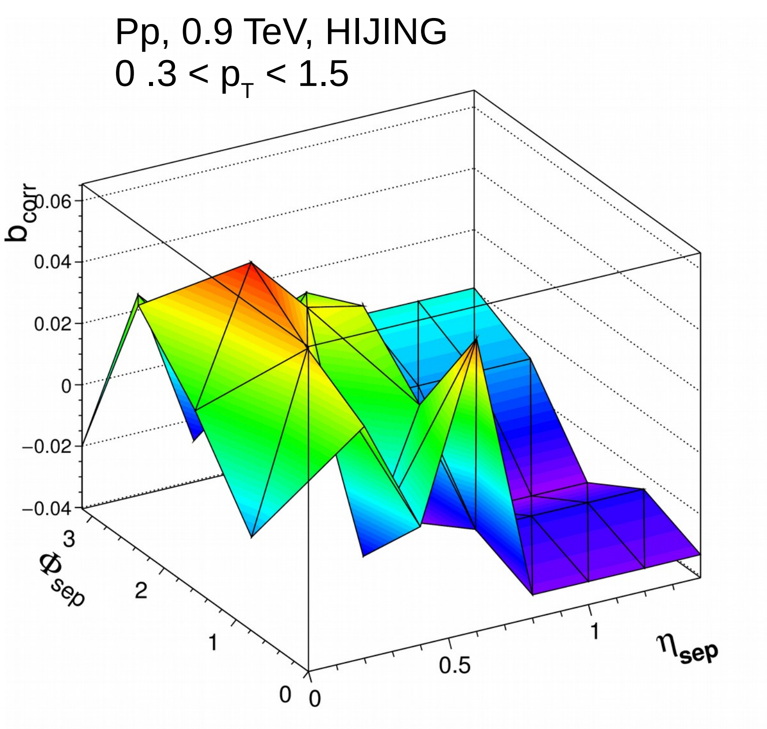
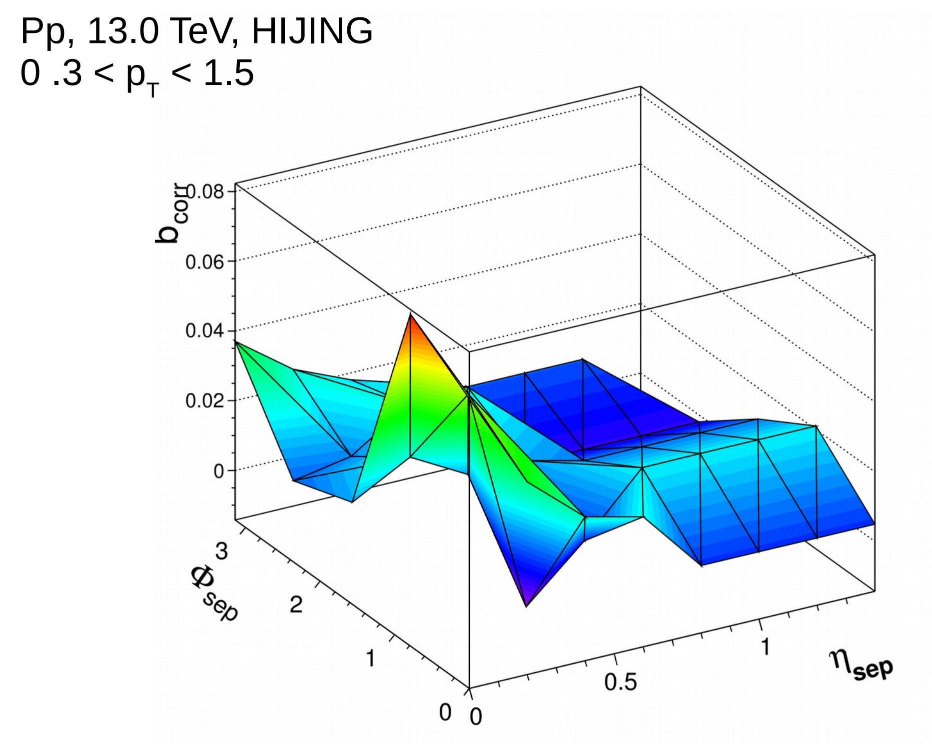
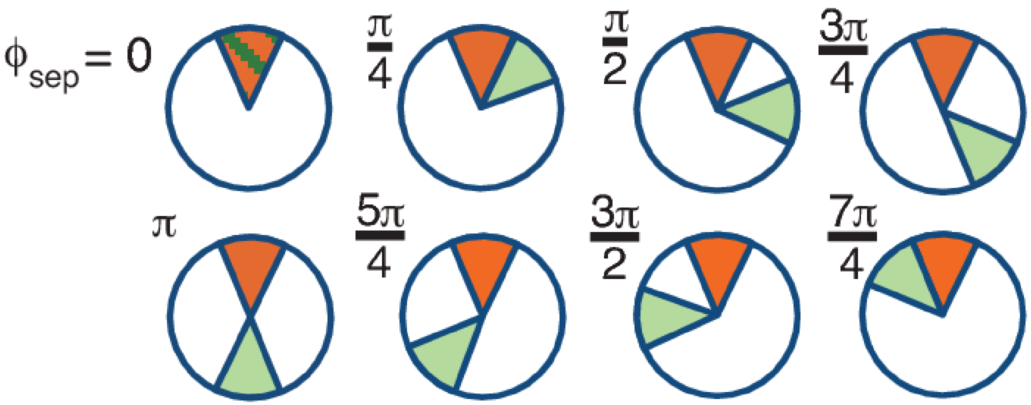
Φ_sep
3
2
1
0
η_sep
0
0.5
1


Pp, 0.9 TeV, HIJING
0 .3 < p_T < 1.5
b_corr
0.06
0.04
0.02
0
−0.02
−0.04
Φ_sep
3
2
1
0
η_sep
0
0.5
1

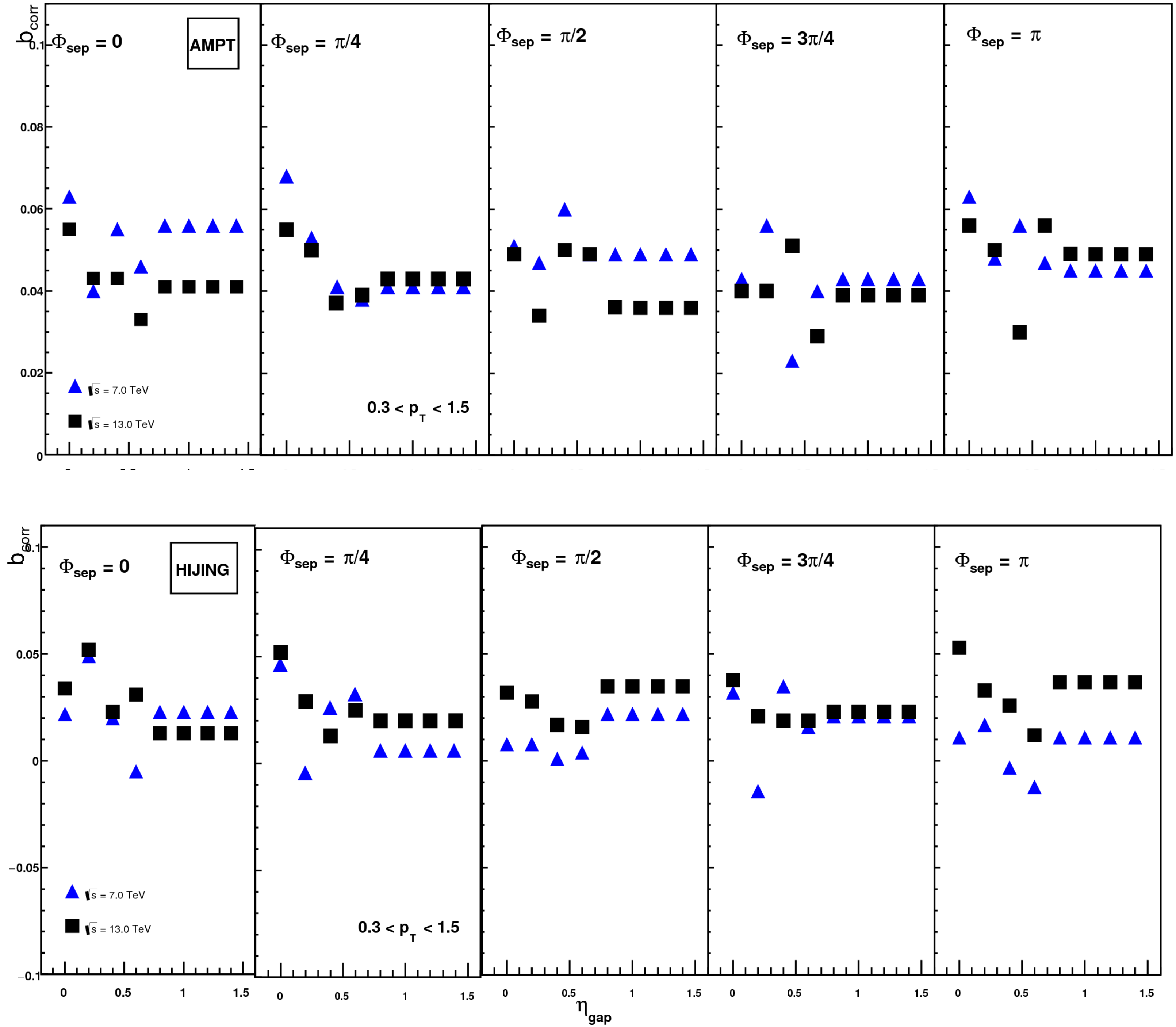

Pp, 13.0 TeV, HIJING
0 .3 < p_T < 1.5
b_corr
0.08
0.06
0.04
0.02
0
Φ_sep
3
2
1
0
η_sep
0
0.5
1

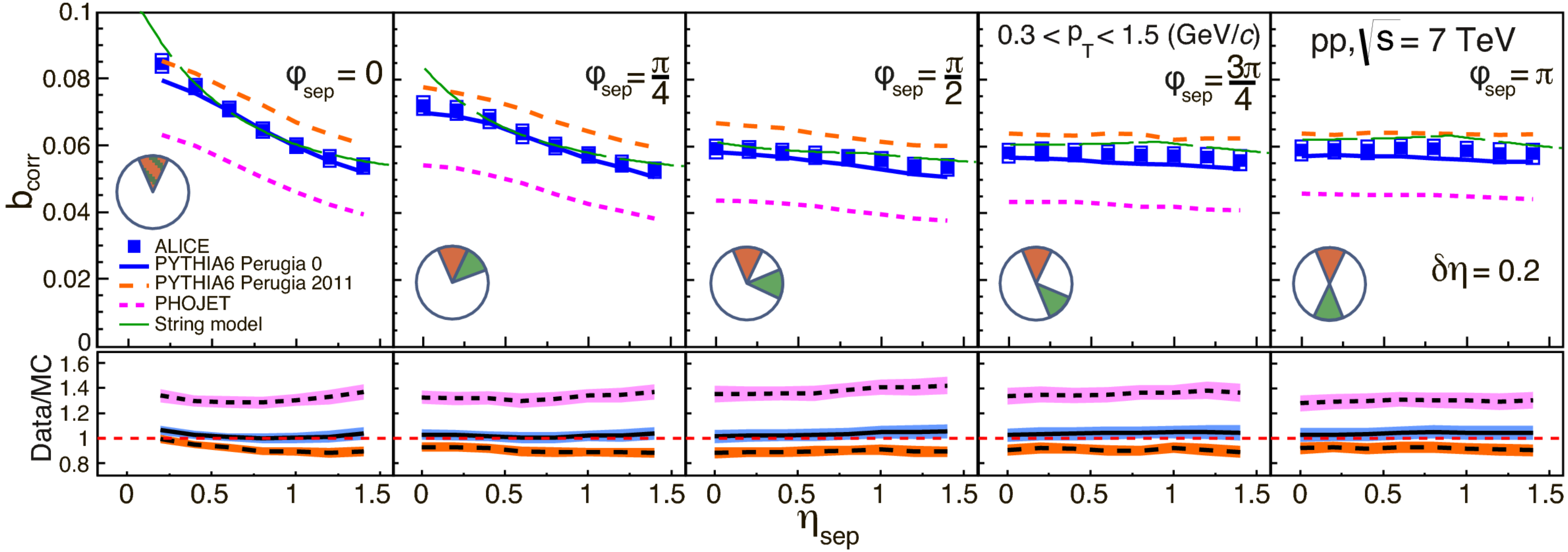
- Furthermore, the strength of correlation is estimated in various configurations of azimuthal sectors selected within the symmetric η-windows.

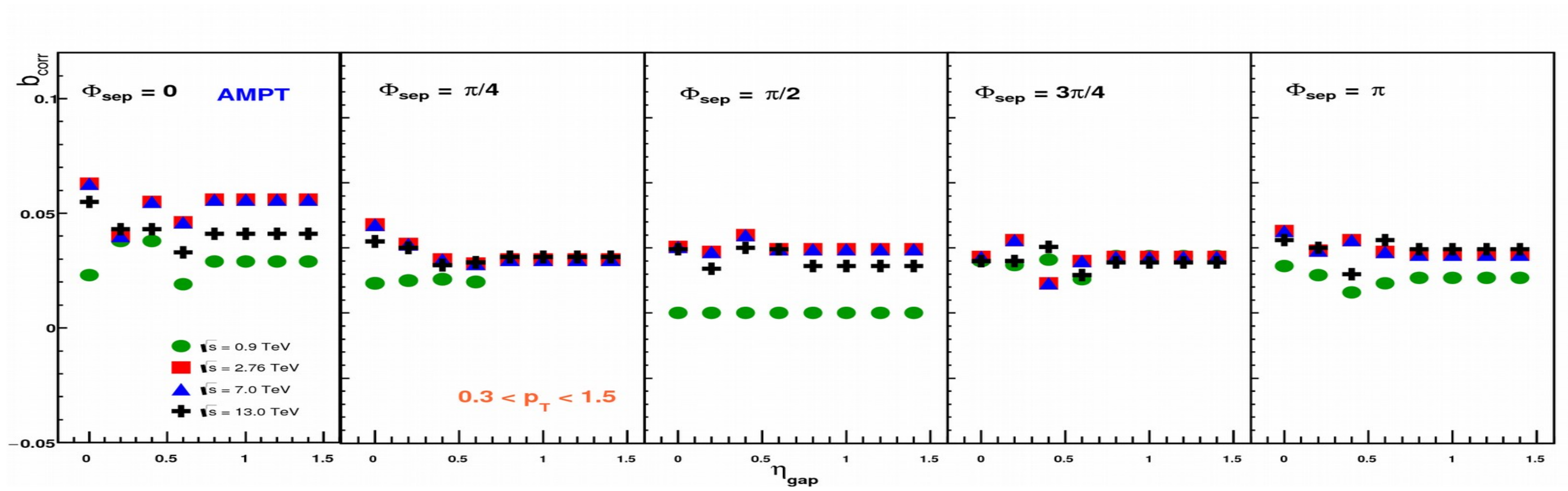
- The Φ-angle sectors are chosen in separated forward and backward pseudorapidity windows of width $\delta\eta = 0.2$ and $\delta\Phi = \pi/4$ as shown.

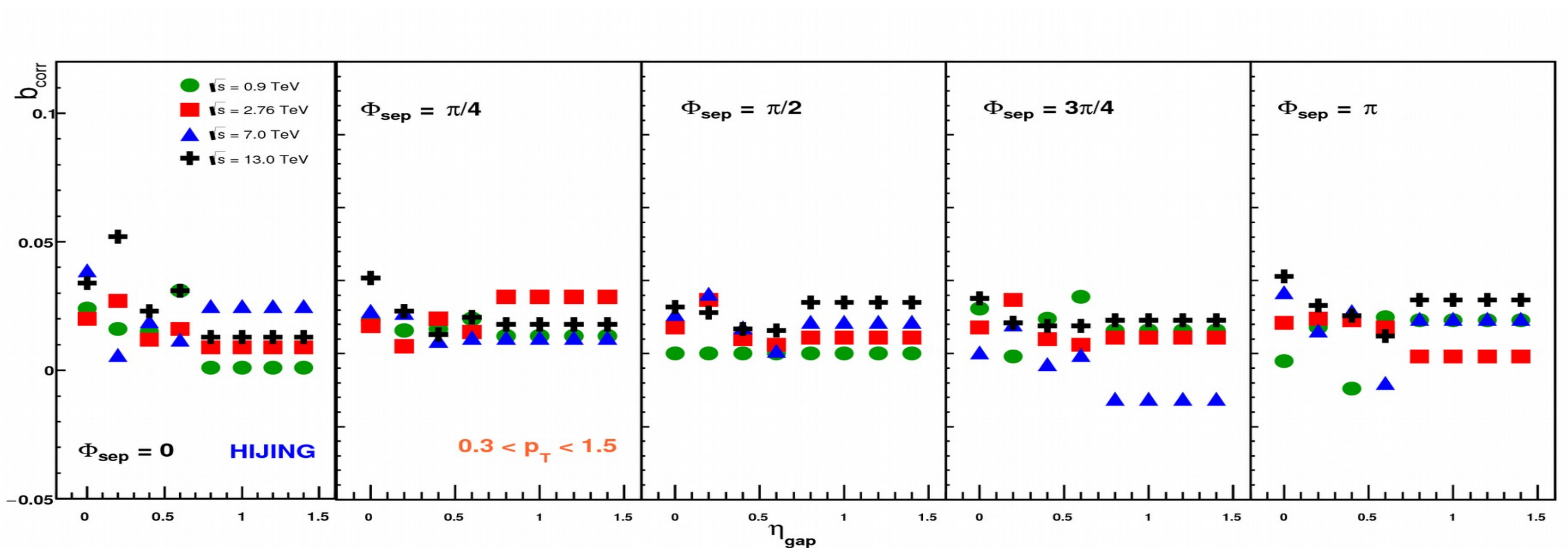


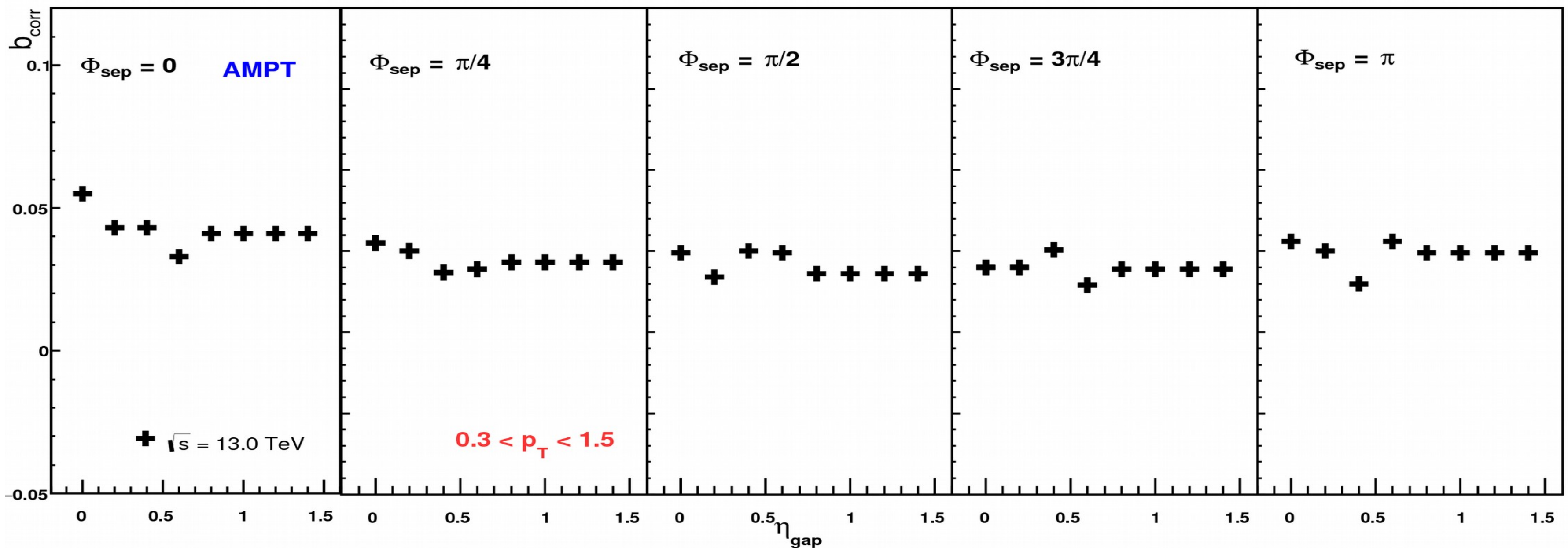
[ALICE , J. of High En. Phys. 05 (2015) 097]

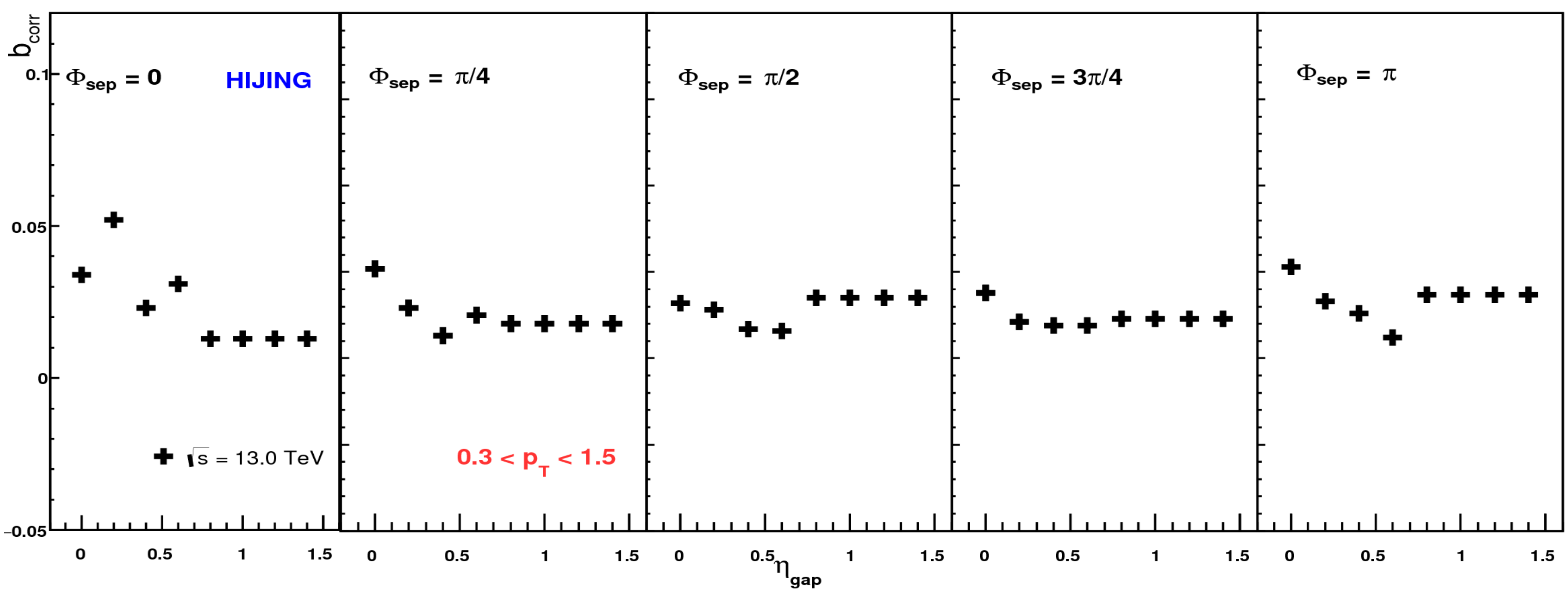

AMPT
HIJING
b_{corr}
$\Phi_{sep} = 0$
$\Phi_{sep} = \pi/4$
$\Phi_{sep} = \pi/2$
$\Phi_{sep} = 3\pi/4$
$\Phi_{sep} = \pi$
$\sqrt{s}$ = 7.0 TeV
$\sqrt{s}$ = 13.0 TeV
$0.3 < p_T < 1.5$
η_{gap}

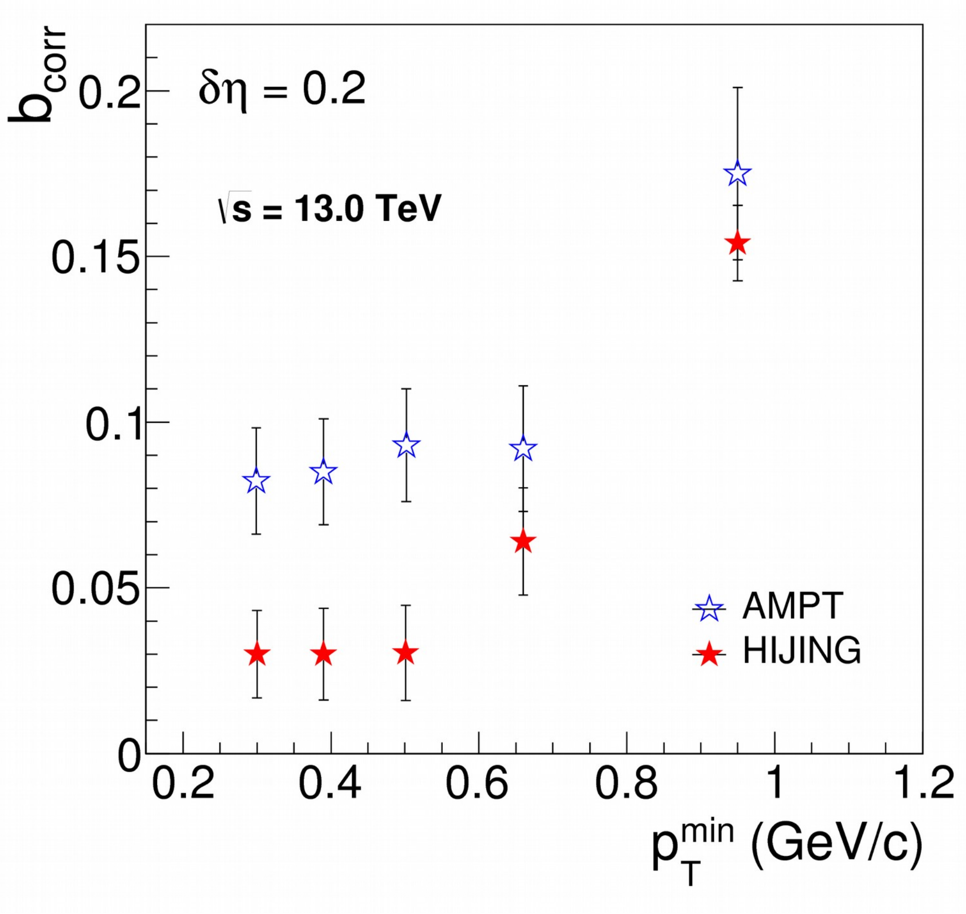

0.3 < p$_T$ < 1.5 (GeV/c)
pp, $\sqrt{s}$ = 7 TeV
$\varphi_{sep} = 0$
$\varphi_{sep} = \frac{\pi}{4}$
$\varphi_{sep} = \frac{\pi}{2}$
$\varphi_{sep} = \frac{3\pi}{4}$
$\varphi_{sep} = \pi$
$\delta\eta = 0.2$
ALICE
PYTHIA6 Perugia 0
PYTHIA6 Perugia 2011
PHOJET
String model
b_{corr}
Data/MC
η_{sep}


b_{corr}
Φ_{sep} = 0
AMPT
Φ_{sep} = π/4
Φ_{sep} = π/2
Φ_{sep} = 3π/4
Φ_{sep} = π
$\sqrt{s}$ = 0.9 TeV
$\sqrt{s}$ = 2.76 TeV
$\sqrt{s}$ = 7.0 TeV
$\sqrt{s}$ = 13.0 TeV
0.3 < p_T < 1.5
η_{gap}

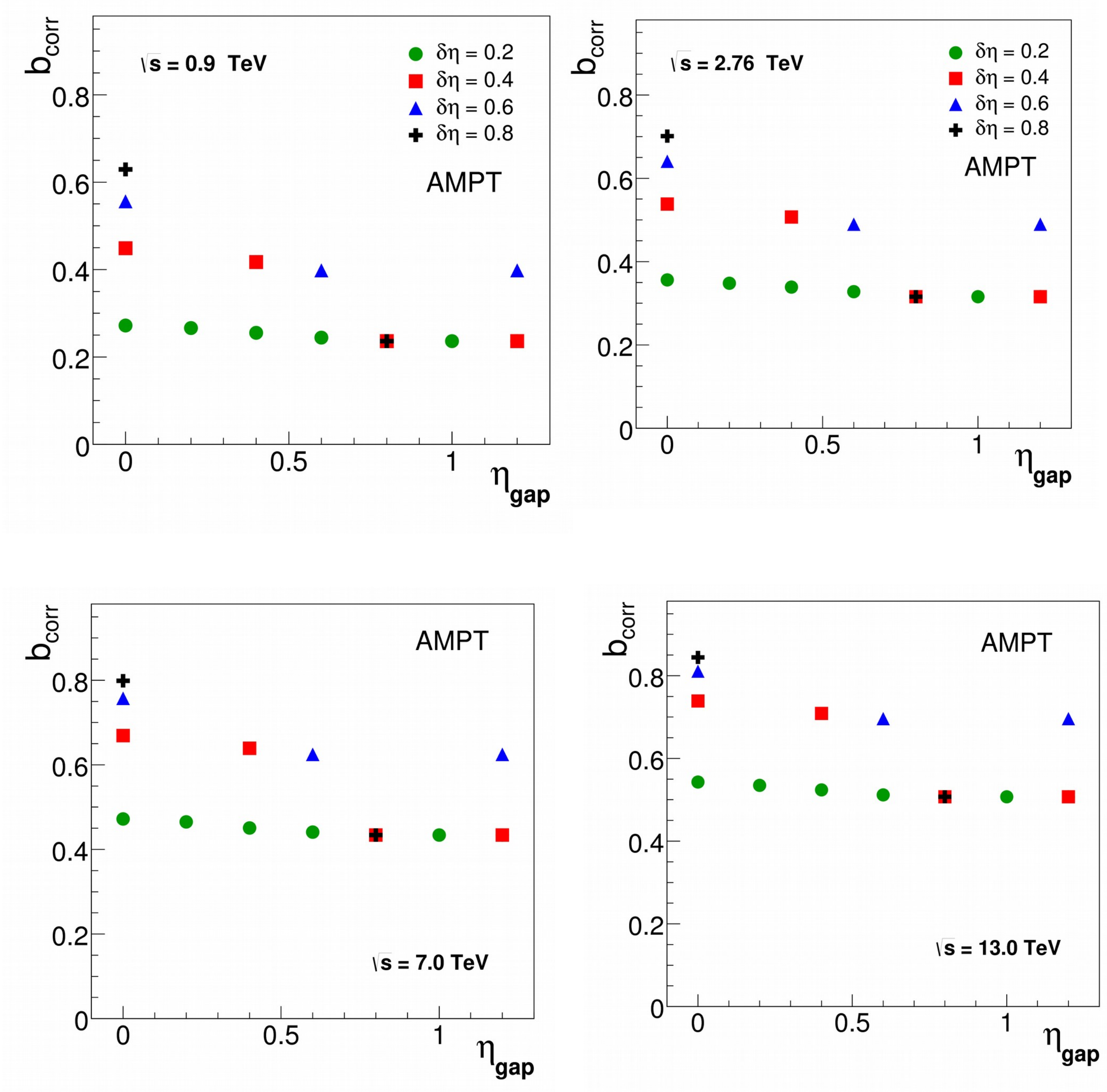

b_{corr}
$\sqrt{s}$ = 0.9 TeV
$\sqrt{s}$ = 2.76 TeV
$\sqrt{s}$ = 7.0 TeV
$\sqrt{s}$ = 13.0 TeV
Φ_{sep} = π/4
Φ_{sep} = π/2
Φ_{sep} = 3π/4
Φ_{sep} = π
Φ_{sep} = 0
HIJING
0.3 < p_T < 1.5
η_{gap}


b_corr
0.1
0.05
0
−0.05
Φsep = 0
AMPT
Φsep = π/4
Φsep = π/2
Φsep = 3π/4
Φsep = π
√s = 13.0 TeV
0.3 < pT < 1.5
0
0.5
1
1.5
η_gap


b_corr
0.1
0.05
0
−0.05
Φsep = 0
HIJING
Φsep = π/4
Φsep = π/2
Φsep = 3π/4
Φsep = π
√s = 13.0 TeV
0.3 < pT < 1.5
0
0.5
1
1.5
η_gap

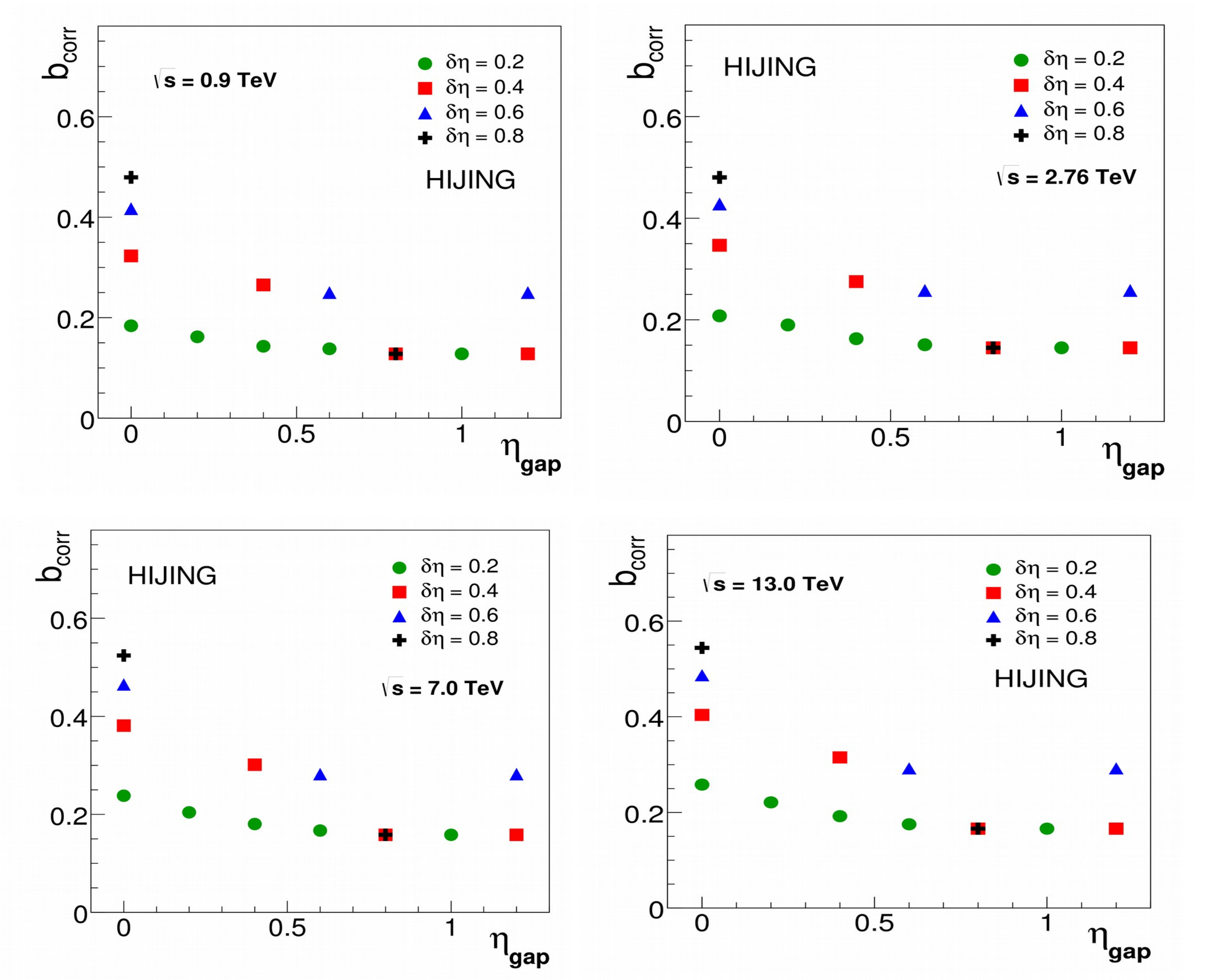


b_{corr}
$\delta\eta = 0.2$
$\sqrt{s}$ = 13.0 TeV
AMPT
HIJING
0
0.05
0.1
0.15
0.2
0.2
0.4
0.6
0.8
1
1.2
p_T^{min} (GeV/c)



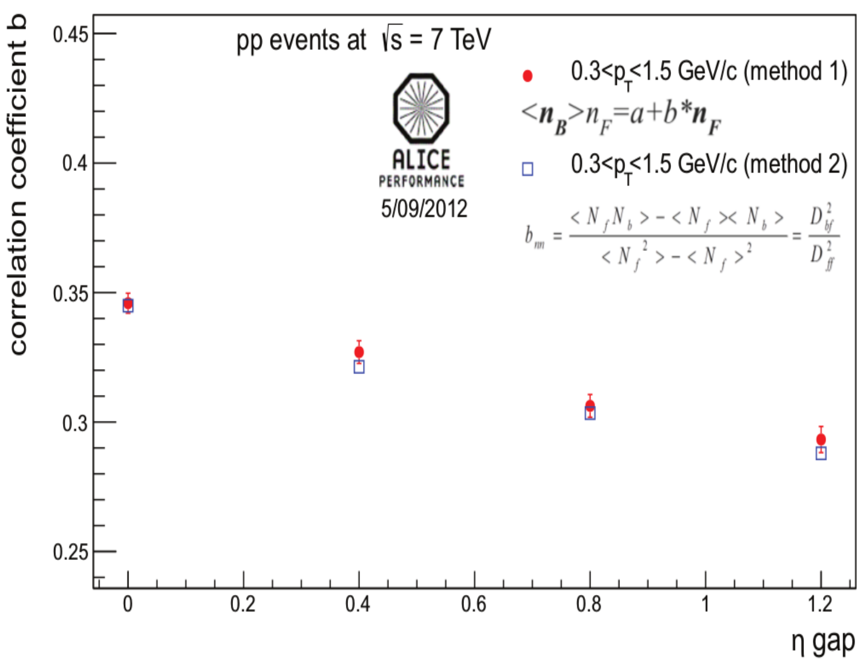
b_corr
√s = 0.9 TeV
δη = 0.2
δη = 0.4
δη = 0.6
δη = 0.8
AMPT
η_gap
√s = 2.76 TeV
√s = 7.0 TeV
√s = 13.0 TeV
0
0.2
0.4
0.6
0.8
0.5
1

Similar trends of variation is shown by HIJING events but somewhat smaller values of b_{corr} as compared to those predicted by AMPT.



Correlation strength b_{corr} calculated from Eq. 1 and 2 is plotted against η_{gap} at 7.0 TeV.

- The values of b_{corr}, from Eq. 1 and Eq. 2 are nearly the same and exhibit strong F-B correlation in both AMPT and HIJING data samples.
- The values of b_{corr} decreases with increasing η_{gap}.



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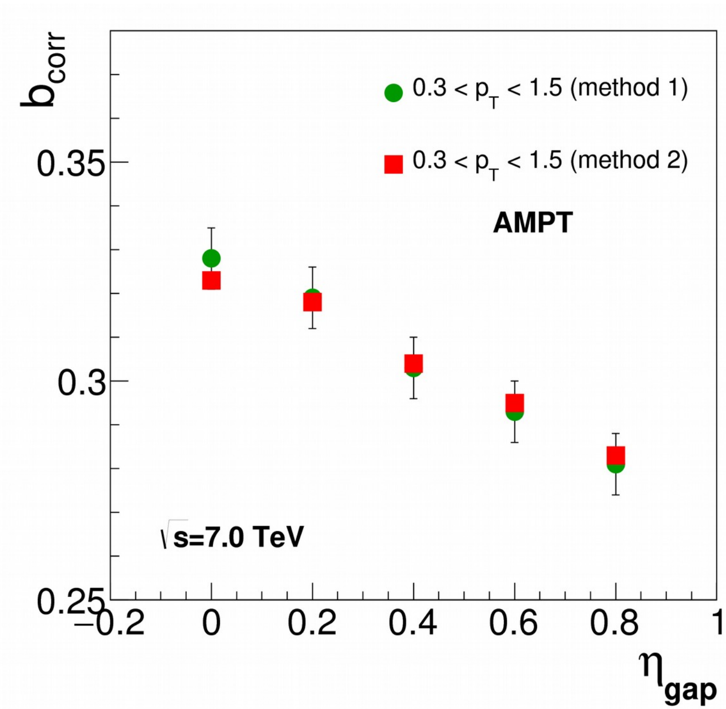

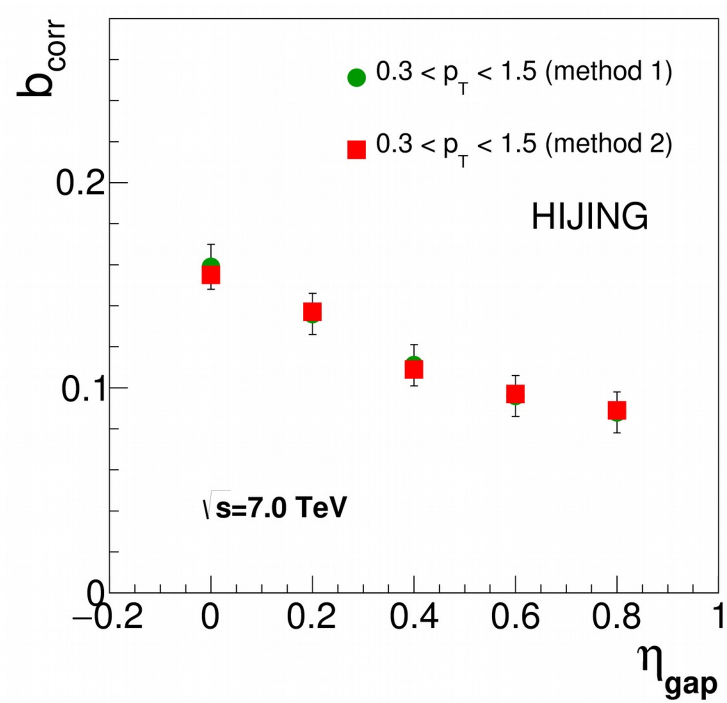

Correlation strength b_{corr} calculated from Eq. 1 and 2 is plotted against η_{gap} at 13.0 TeV.