

Integrals and RMS of Balance Functions



- Integral and RMS of balance functions (B_2) for all centralities and particle pairs (π , K , p) for 62.4 GeV and 200 GeV.
- Explore the energy dependence of B_2 at 200 GeV, 62.4 GeV and 39 GeV

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Balance Function Workshop
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Analysis Details

- Analysis in $|\eta| < 0.5$, centrality from primary multiplicity inside $0.5 < |\eta| < 1.0$ (refmult2).
- Track crossing correction implemented.
Note: Correction incomplete in 0-5% pions at 200 GeV
- Denominator in correlation function (R_2) obtained by **mixing 40** events (convolution also being used).

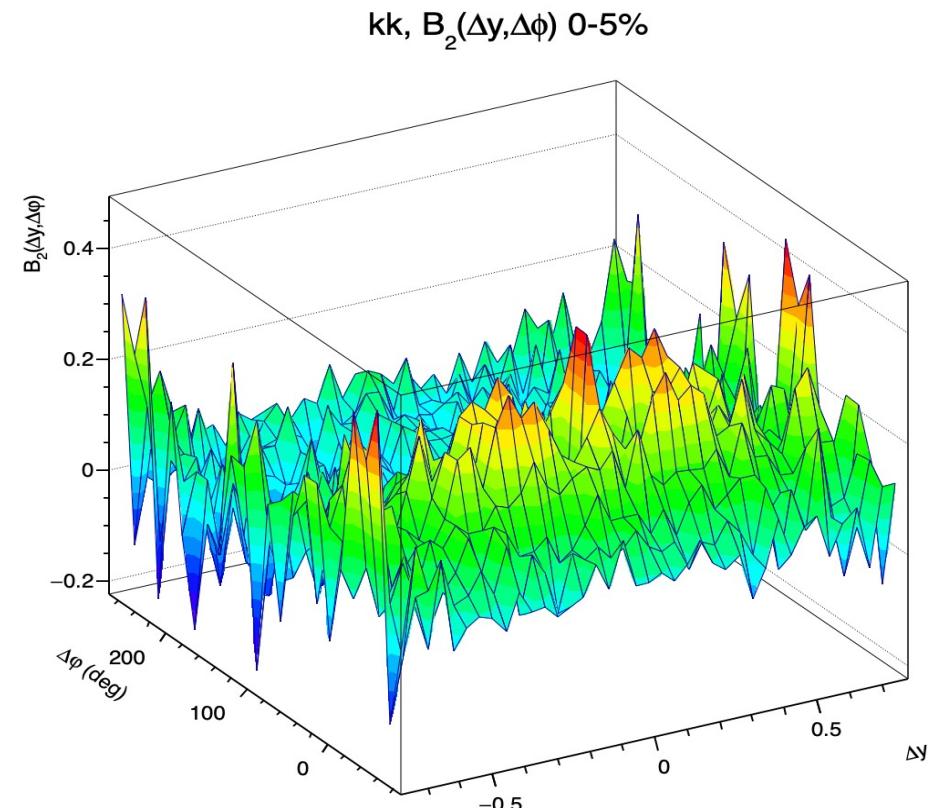
$$R_2(dy, d\phi) = \frac{\rho_2}{\rho_1 \rho_1} - 1$$

- Balance function (B_2) defined as:

$$B^{a+b}(\Delta y, \Delta\phi) = \langle N^{b^-} \rangle R_2^{a+b^-}(\Delta y, \Delta\phi) - \langle N^{b^+} \rangle R_2^{a+b^+}(\Delta y, \Delta\phi)$$

$$B^{a-b}(\Delta y, \Delta\phi) = \langle N^{b^+} \rangle R_2^{a-b^+}(\Delta y, \Delta\phi) - \langle N^{b^-} \rangle R_2^{a-b^-}(\Delta y, \Delta\phi)$$

$$B^{ab}(\Delta y, \Delta\phi) = \frac{1}{2} [B^{a+b} + B^{a-b}]$$



Example: kk B_2 for 0-5% centrality of Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

- The prefactors $\langle N^{b^+} \rangle$ and $\langle N^{b^-} \rangle$ taken from the STAR publication: **PRC 79, 034909 (2009)**.
- Systematic uncertainties not yet calculated.

Integrals of B_2 vs. Centrality at 200 GeV

Integral of B_2 from $B_2(dy, d\phi)$

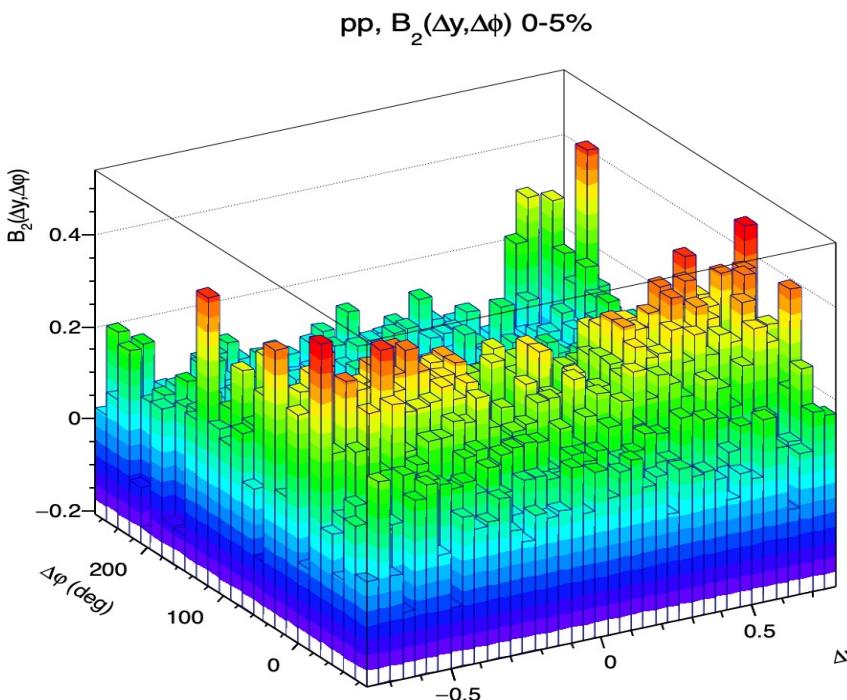
Integrals of B_2 evaluated from the 2-D distribution i.e. $B_2(dy, d\phi)$ using the “width” option.

$$\text{Integral defined as: } I = \iint B_2(dy, d\phi) d(dy) d(d\phi)$$

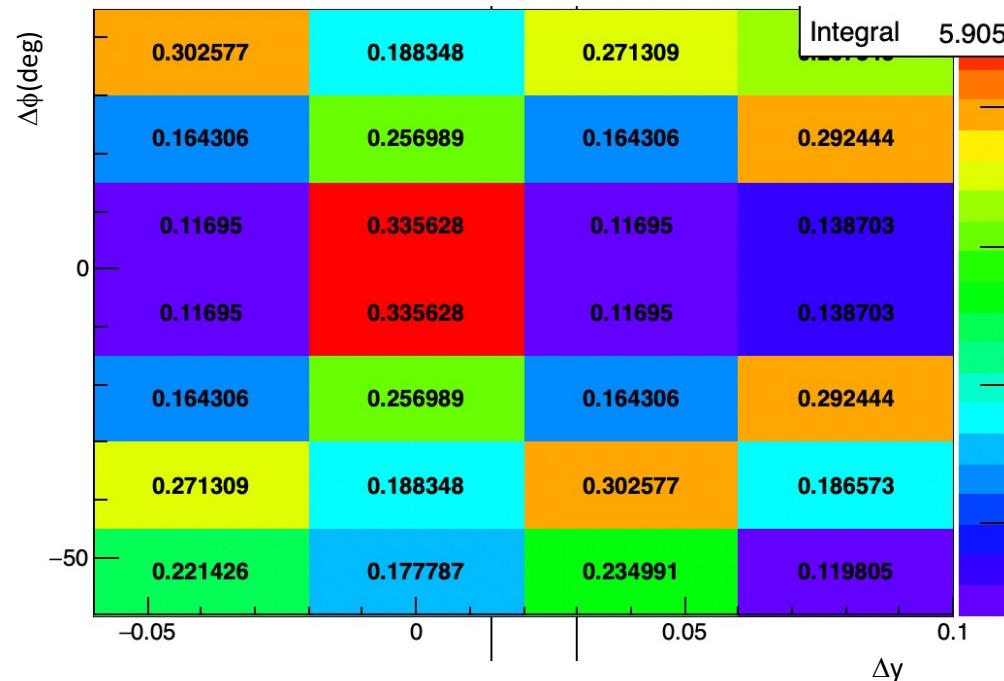
For discrete bins the $(i,j)^{\text{th}}$ bin with content B_{ij} and bin-widths w_i and w_j for the x and y components:

$$I = \sum_{j=1}^{N_y} \sum_{i=1}^{N_x} B_{ij} \cdot w_i \cdot w_j$$

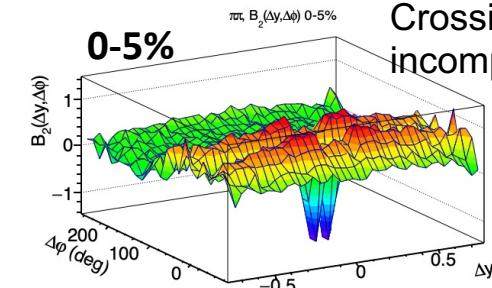
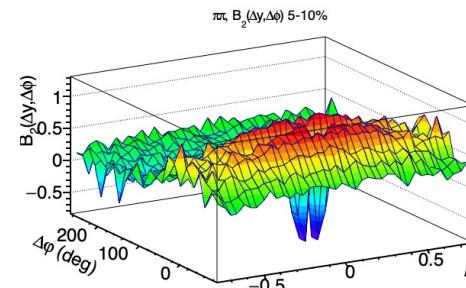
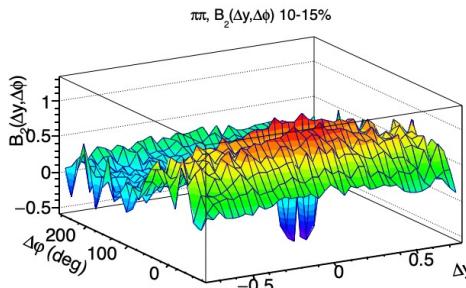
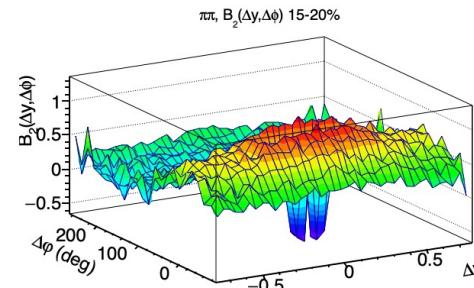
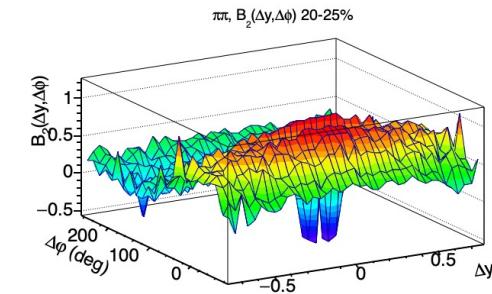
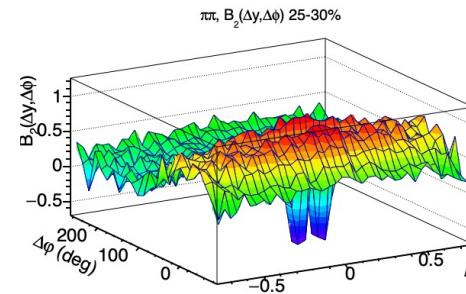
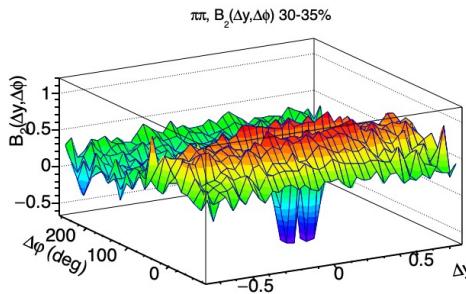
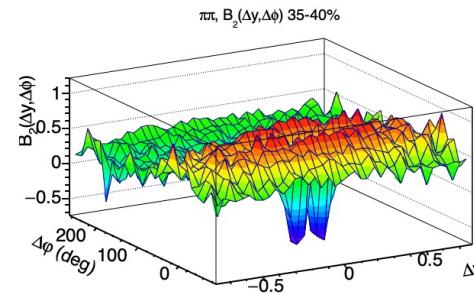
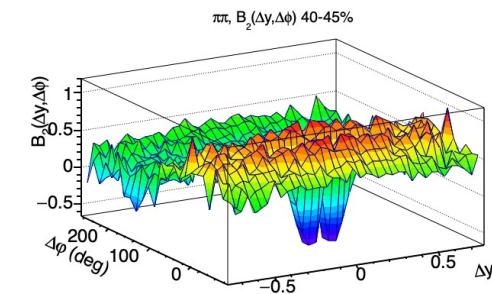
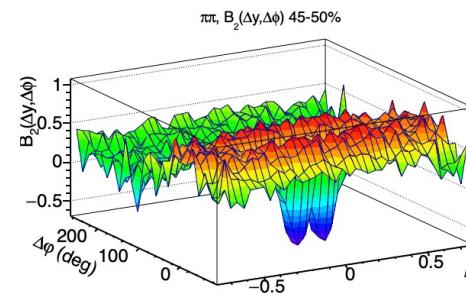
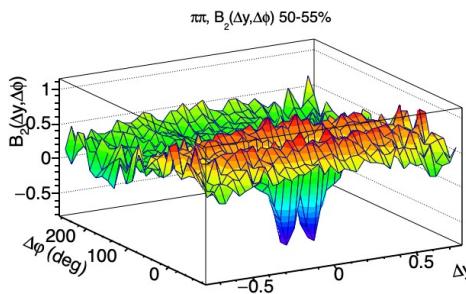
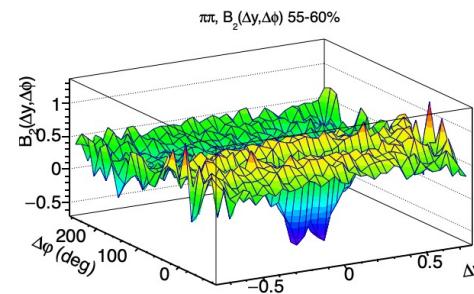
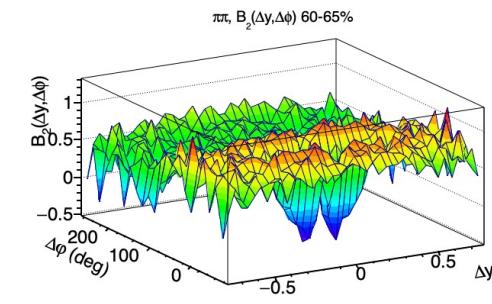
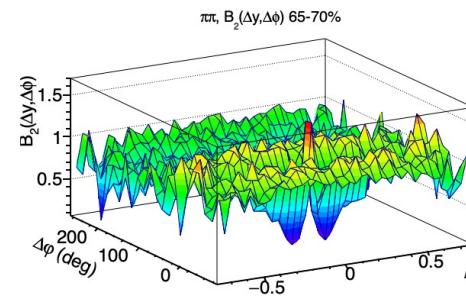
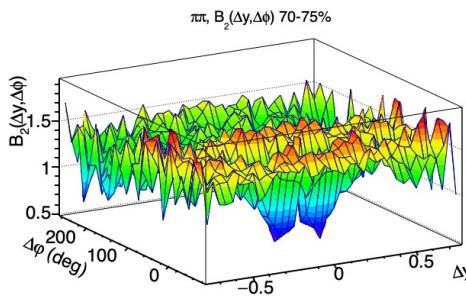
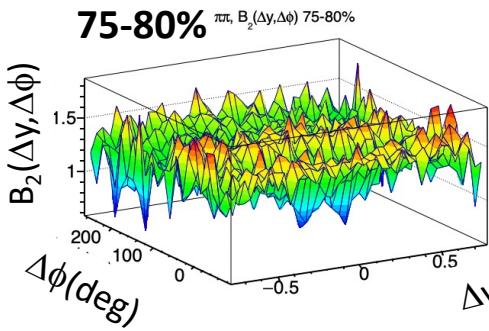
N_x and N_y and total number of x and y bins.



Example: Bin widths, $w_{\Delta y} = 0.04$ and $w_{\Delta\phi} = 15^\circ$
 Integral in the plot shown below is sum of contents of all
 bins i.e. $\sum_{j=1}^{N_y} \sum_{i=1}^{N_x} B_{ij} = 5.905$
 Thus, $I(\text{"width"}) = 5.905 * 0.04 * 15 = 3.54$

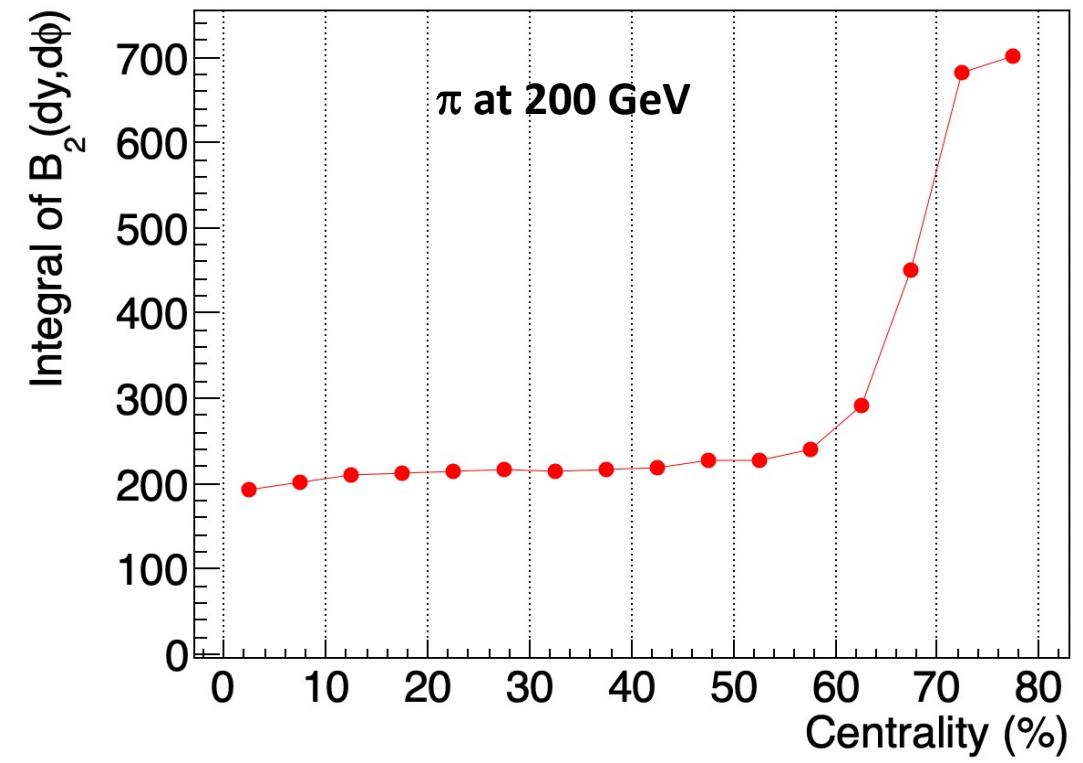
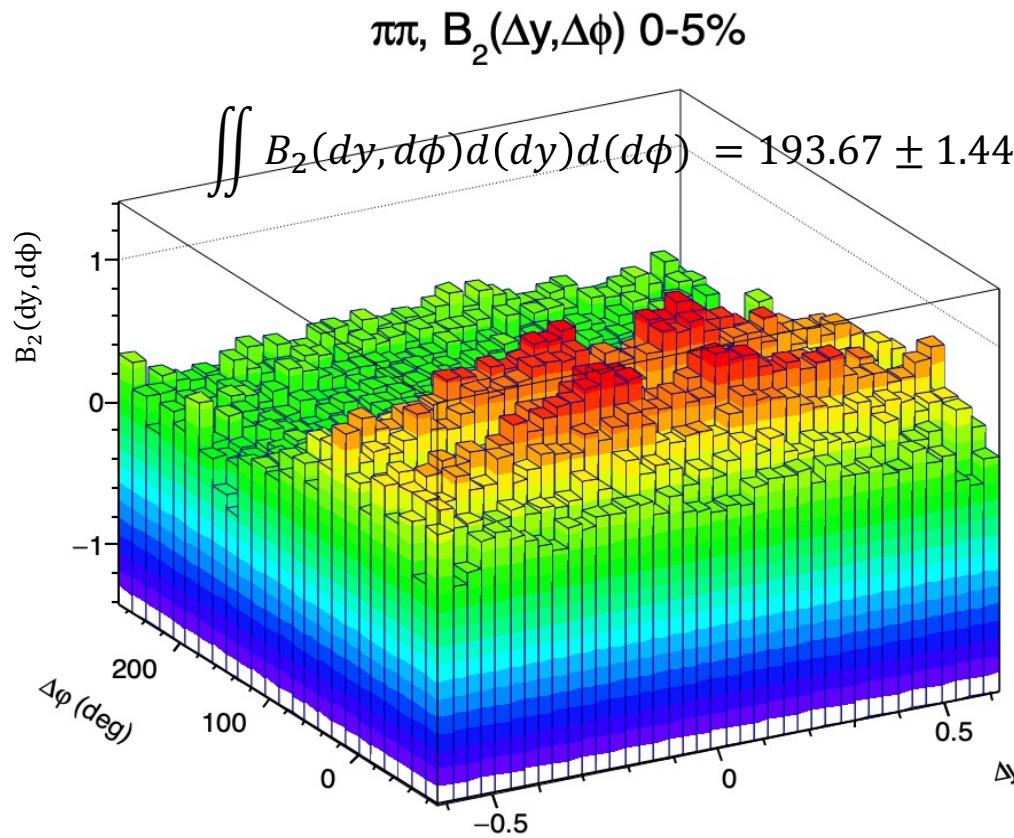


$B_2(\Delta y, \Delta\phi)$ of π at 200 GeV for centralities

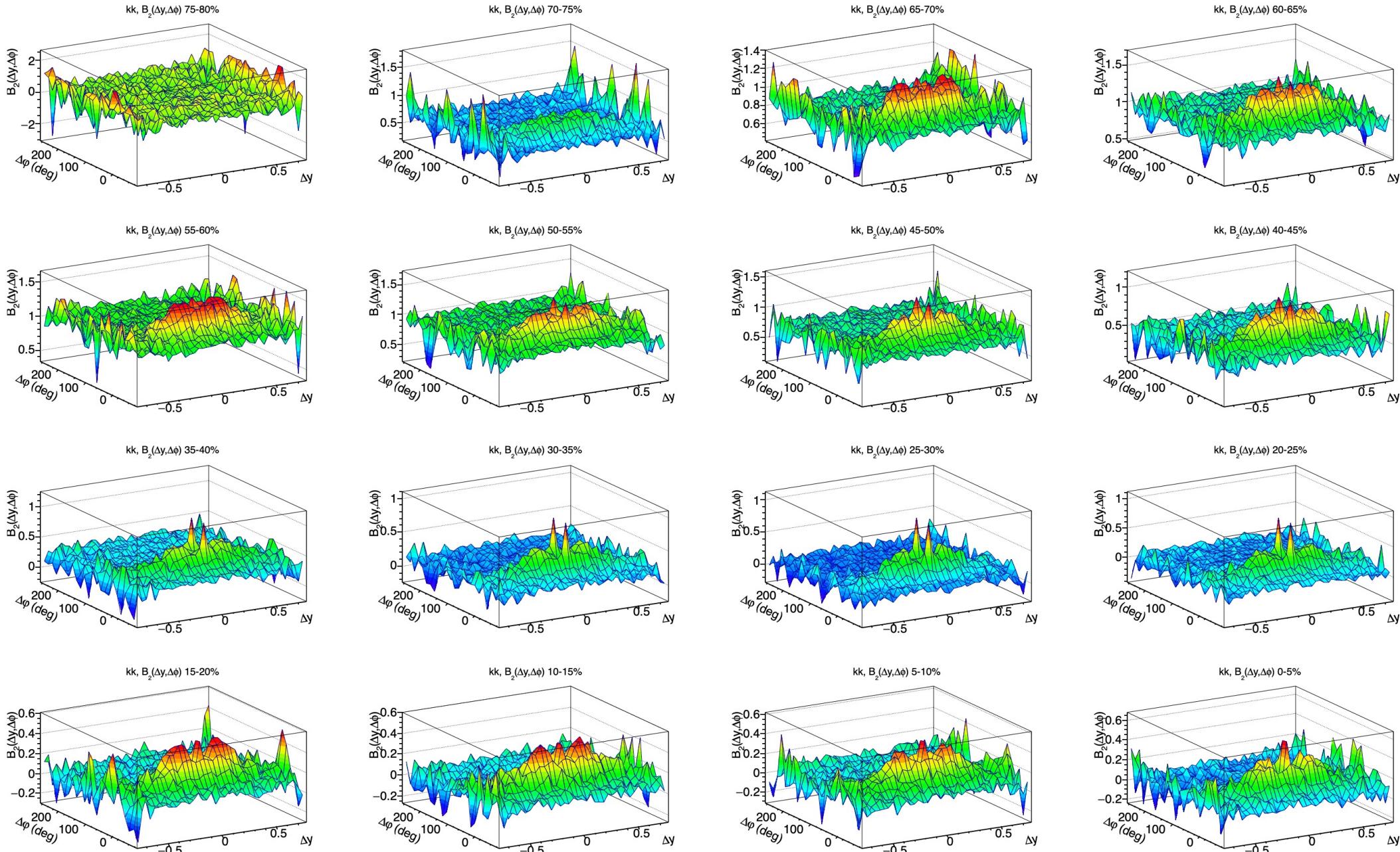


Integral from $B_2(dy, d\phi)$ of π at 200 GeV

Integral of B_2 decreases for more central collisions in case of pions.

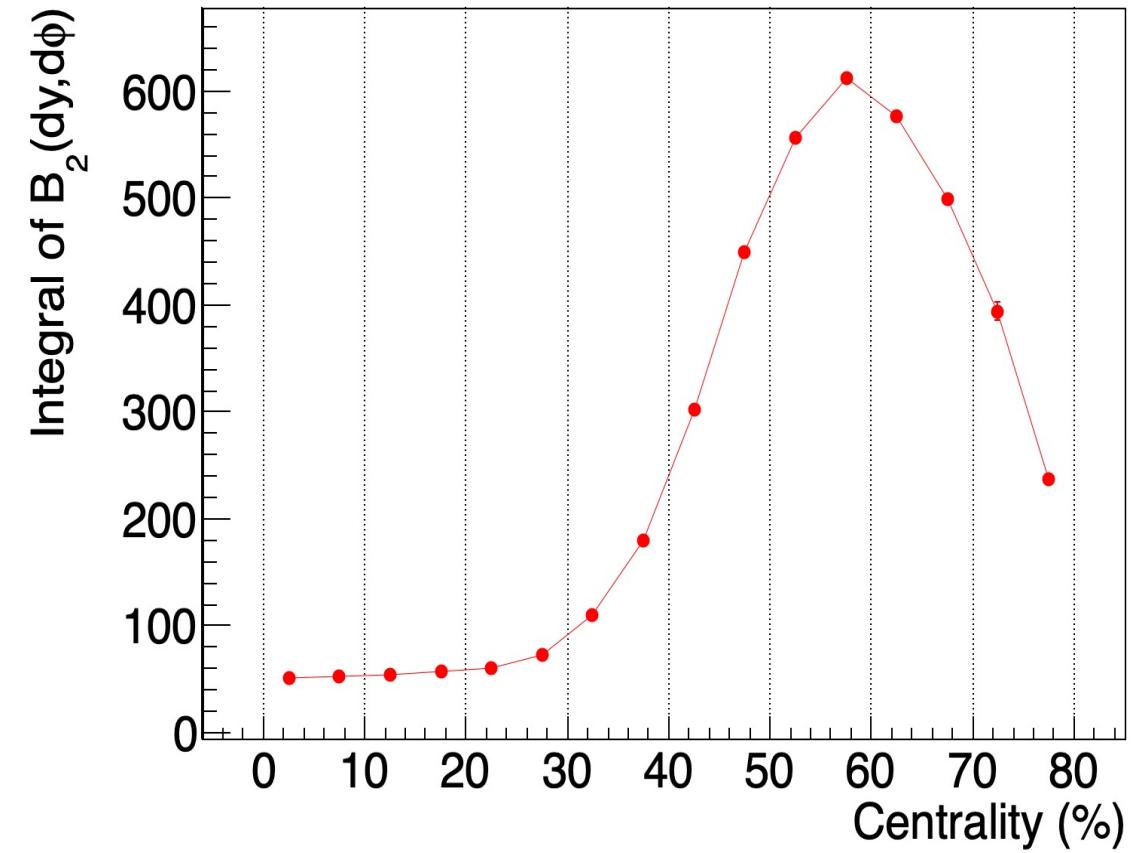
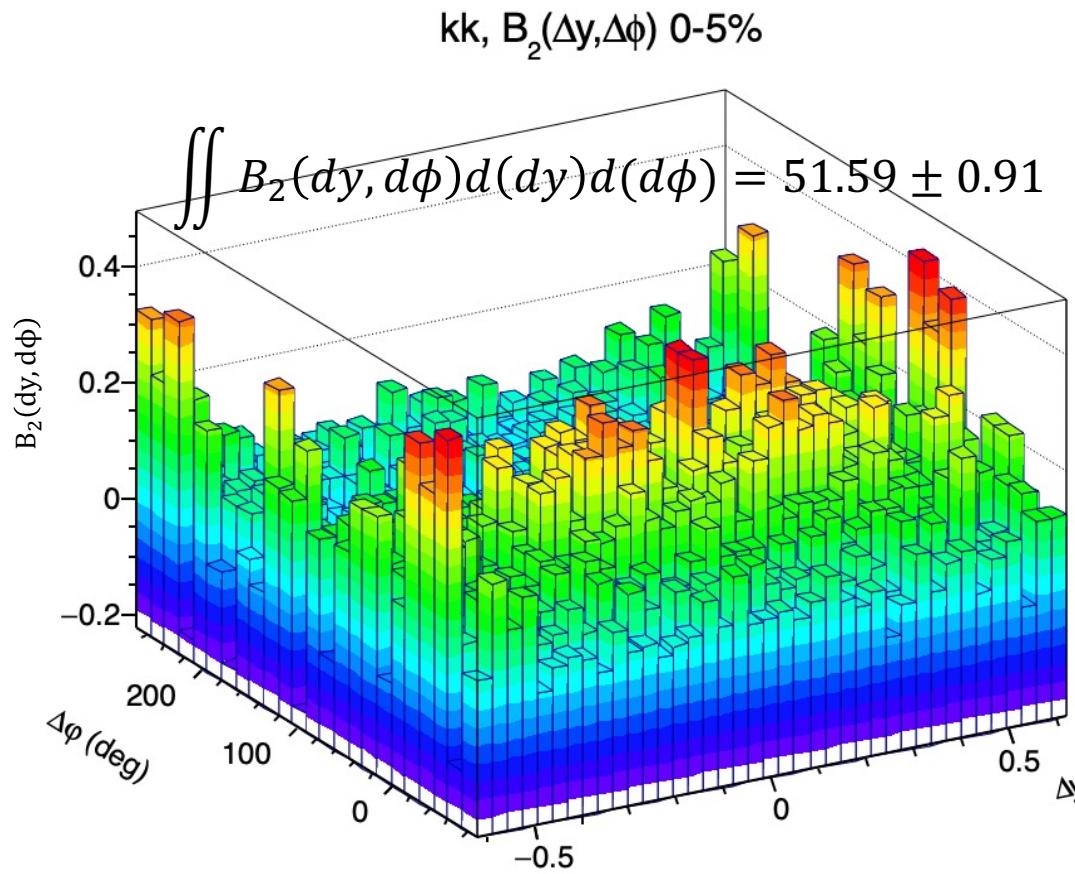


$B_2(\Delta y, \Delta\phi)$ of k at 200 GeV for centralities

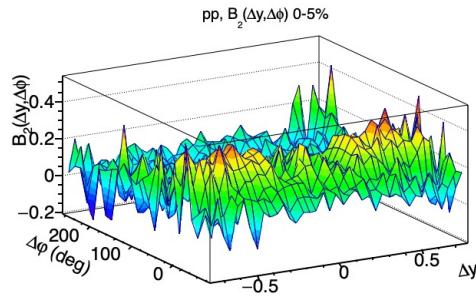
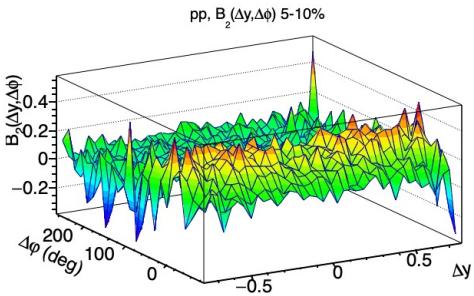
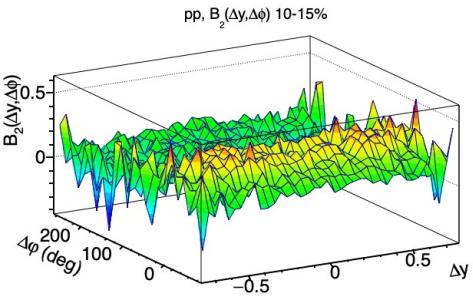
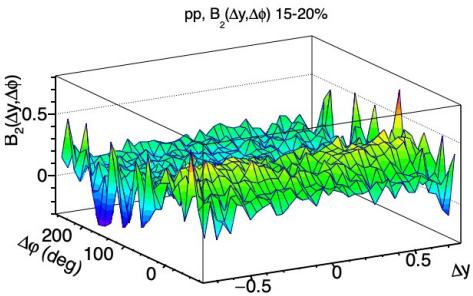
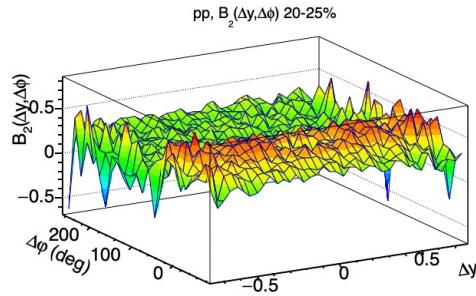
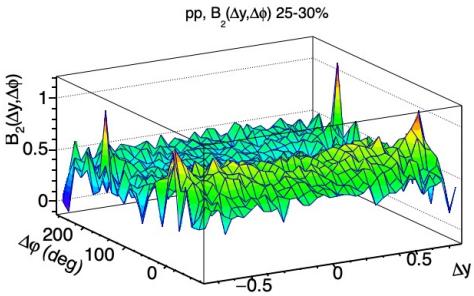
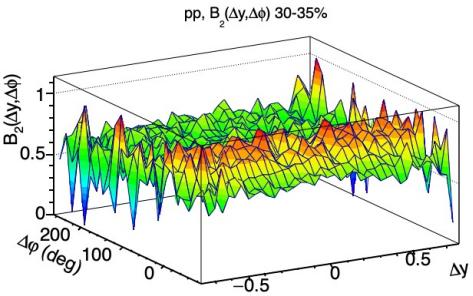
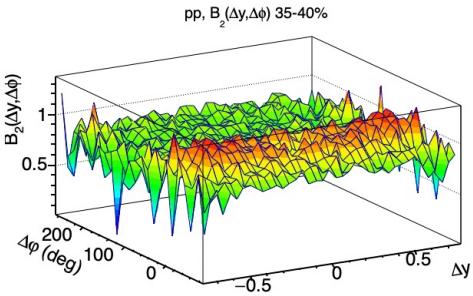
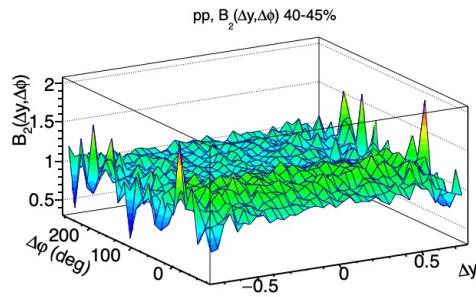
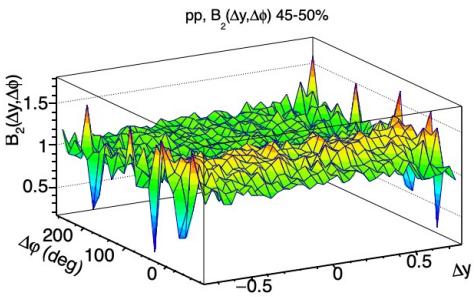
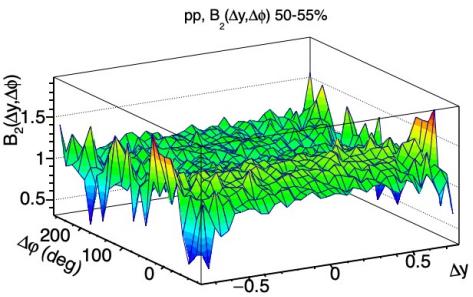
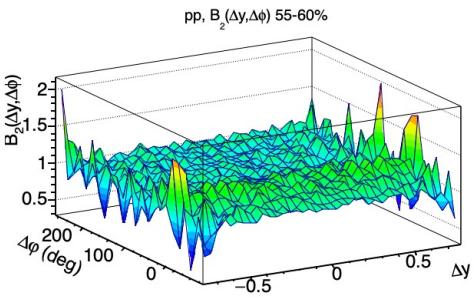
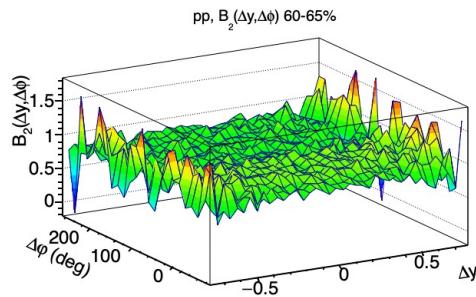
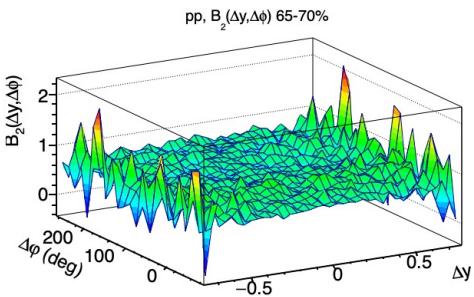
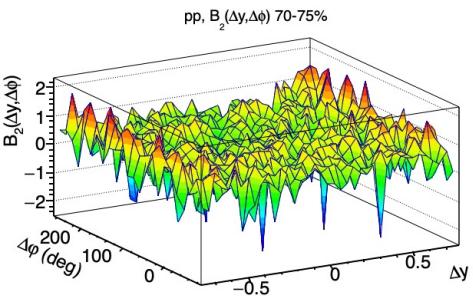
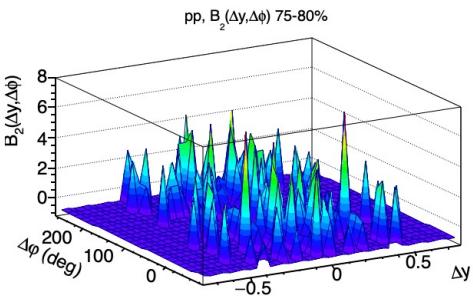


Integral from $B_2(dy, d\phi)$ of k at 200 GeV

Integral of B_2 decreases for more central collisions in the range of 0-5% to 55-60% centrality in case of kaons.

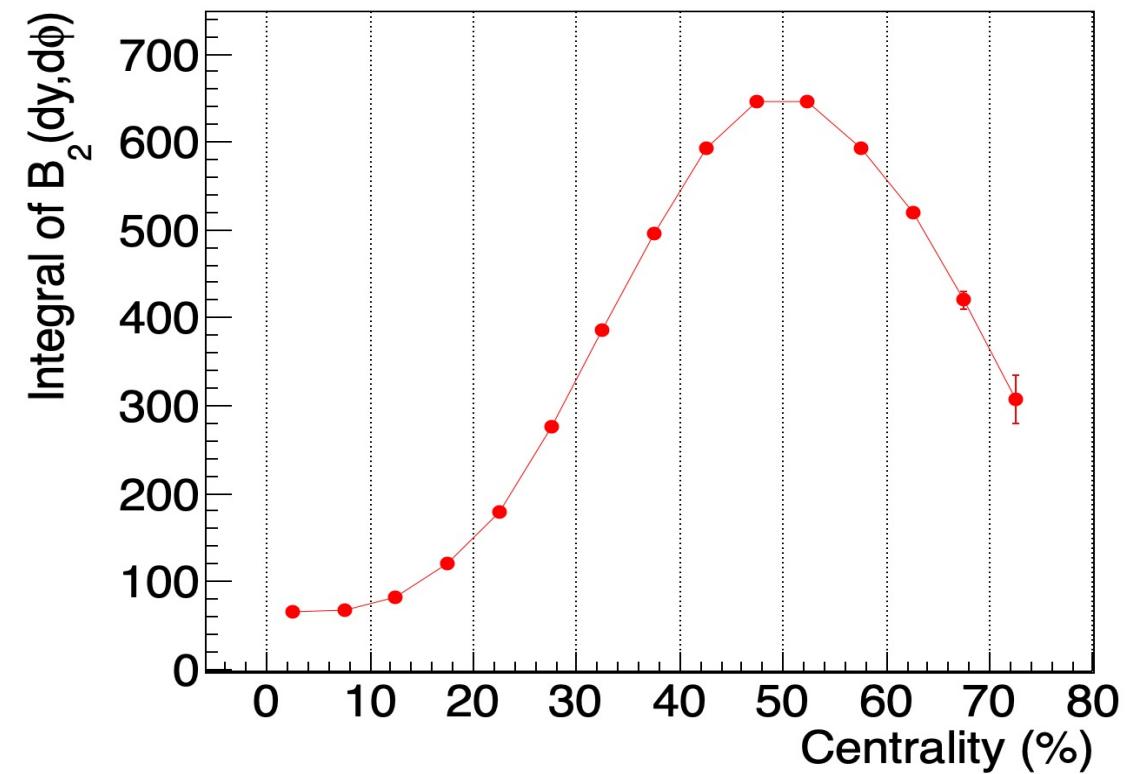
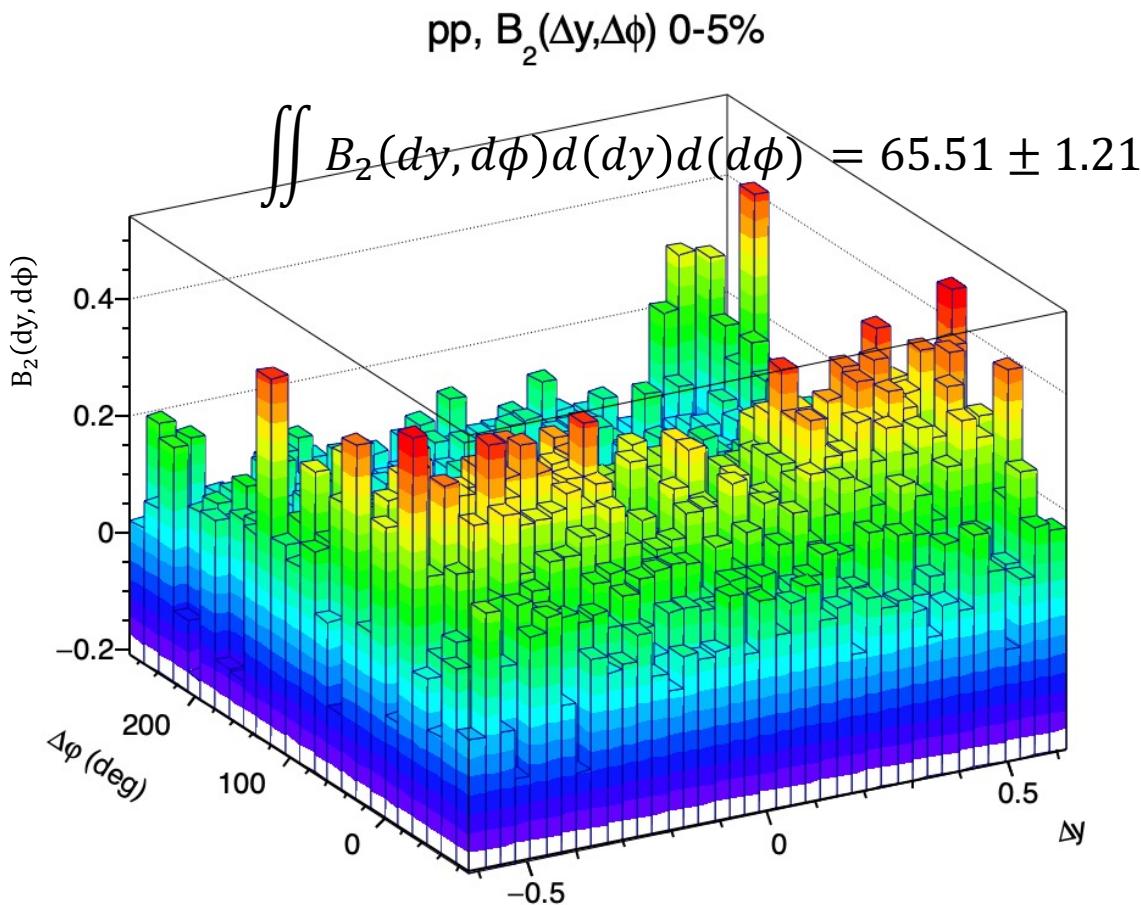


$B_2(dy, d\phi)$ of p at 200 GeV for centralities



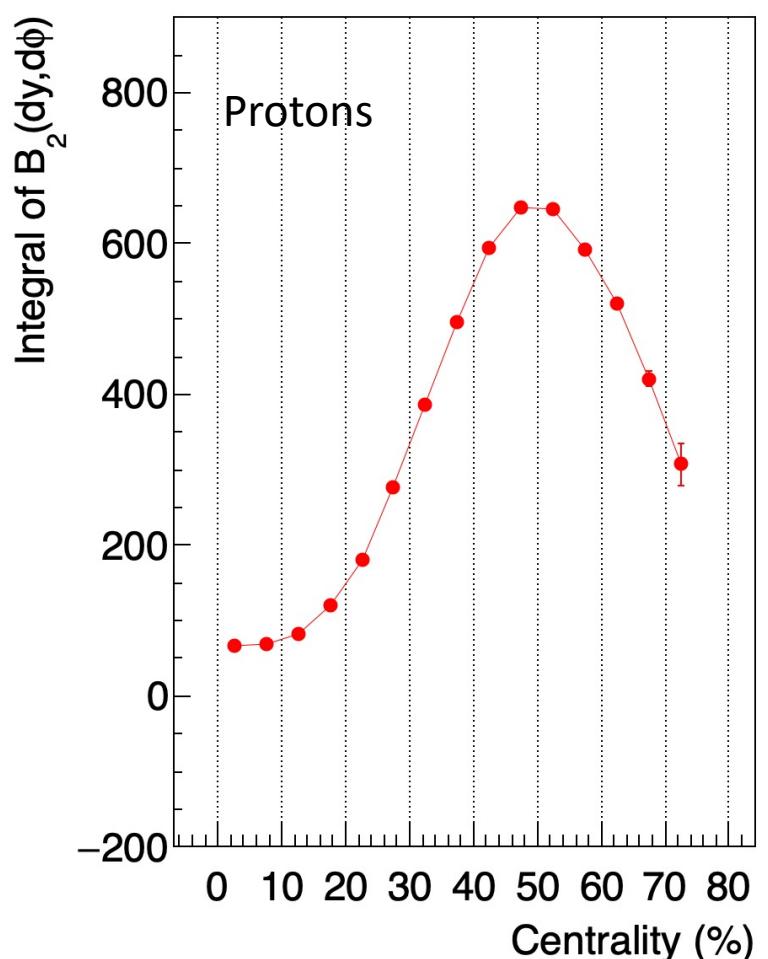
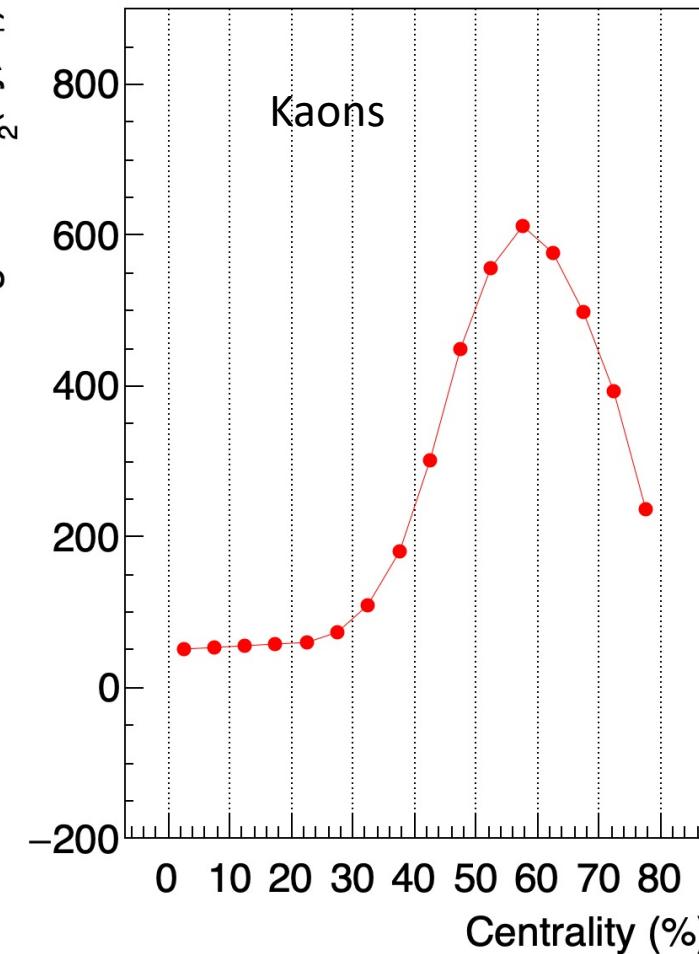
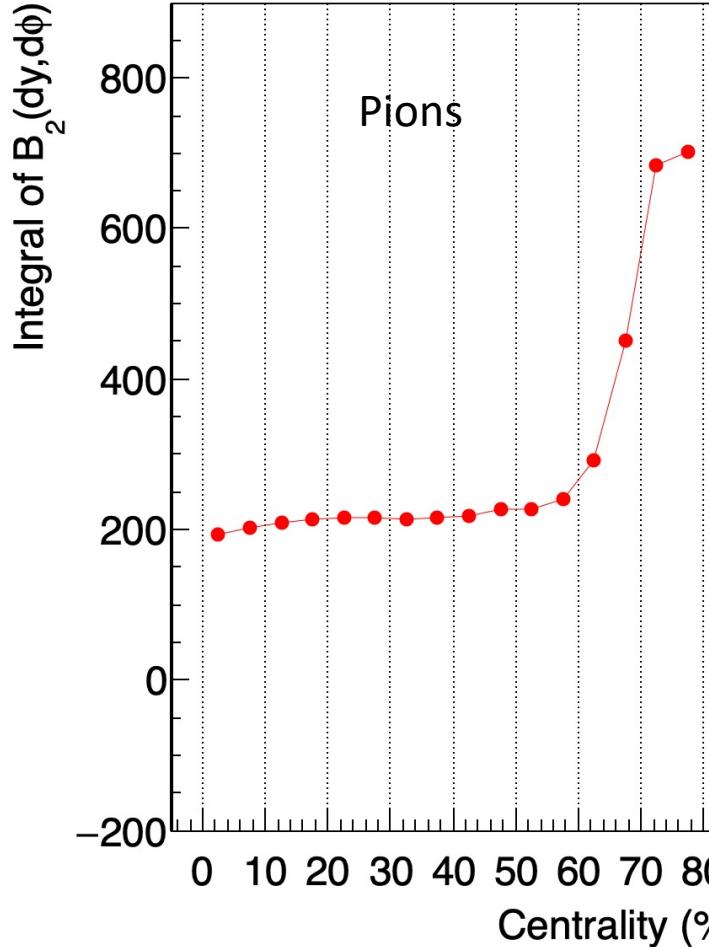
Integral from $B_2(dy, d\phi)$ of p at 200 GeV

Integral of B_2 decreases for more central collisions in the range of 0-5% to 50-55% centrality in case of protons.



Comparison of Integrals of $B_2(dy,d\phi)$ vs. centrality for all particles

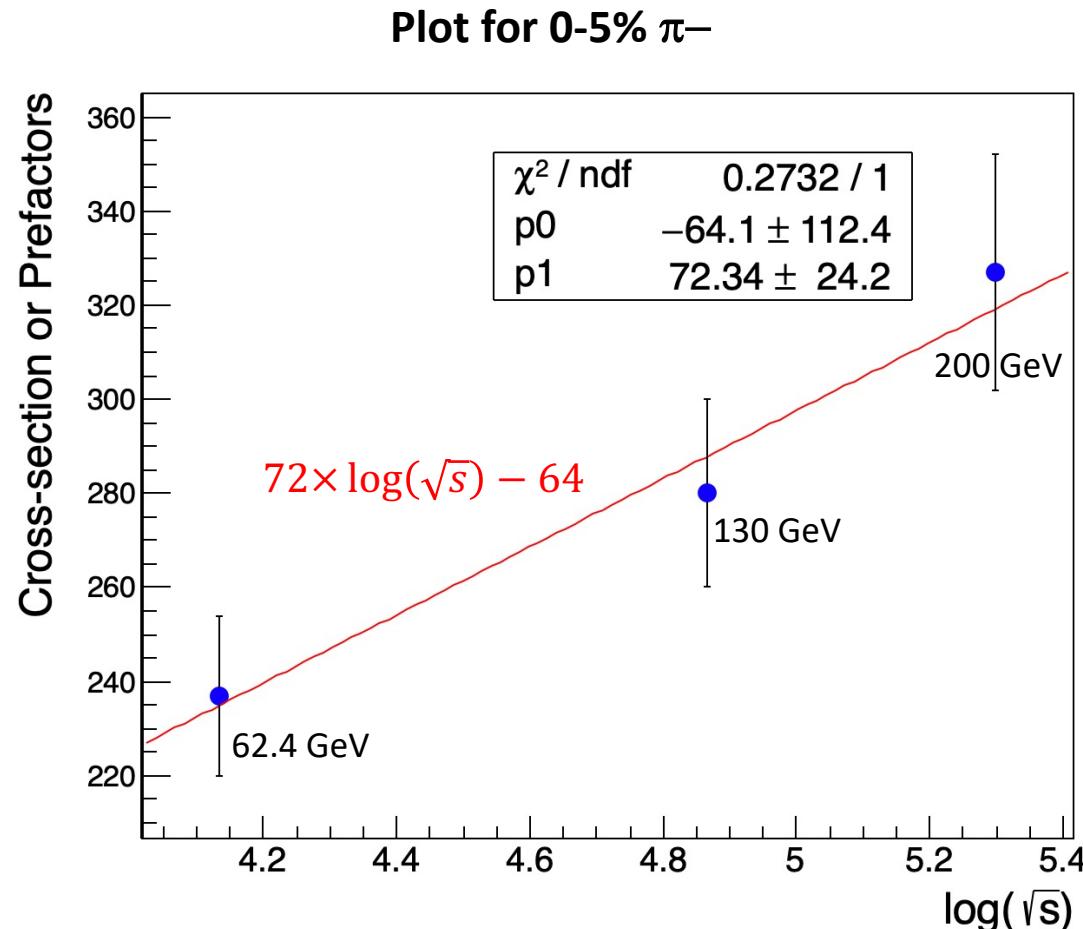
A summary of comparisons of integrals of B_2 vs. centrality for all particles.



Extracting prefactors for other energies.

System	Centrality	π^-
Au + Au 200 GeV	40–50%	58.9 ± 4.5
	30–40%	89.6 ± 6.8
	20–30%	136 ± 10
	10–20%	196 ± 15
	5–10%	261 ± 20
	0–5%	327 ± 25
Au + Au 130 GeV	58–85%	16.0 ± 2.1
	45–58%	42.4 ± 3.5
	34–45%	70.9 ± 4.9
	26–34%	104 ± 8
	18–26%	140 ± 11
	11–18%	187 ± 16
	6–11%	228 ± 16
	0–6%	280 ± 20
	30–40%	67.4 ± 5.2
	20–30%	101 ± 7
Au + Au 62.4 GeV	10–20%	146 ± 11
	5–10%	192 ± 13
	0–5%	237 ± 17

Example of the procedure for π^- for 0–5%



Graph from publication **PRC 79, 034909 (2009)**

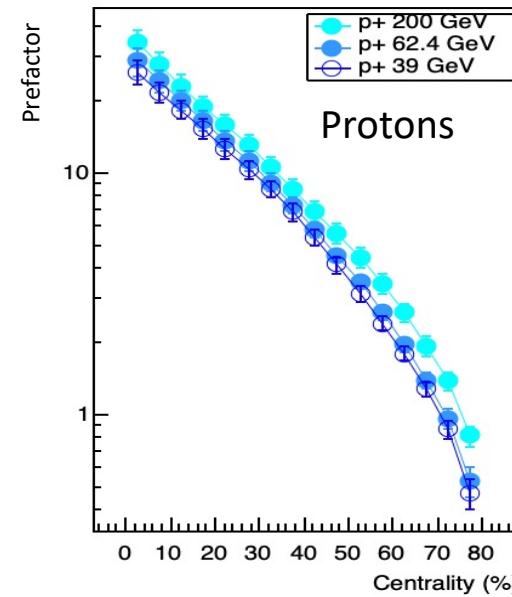
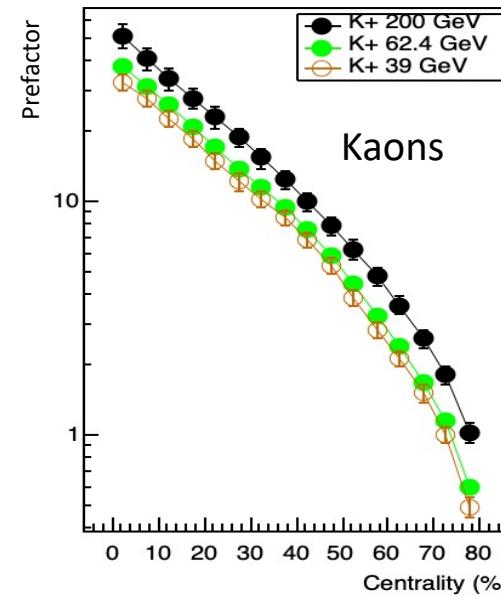
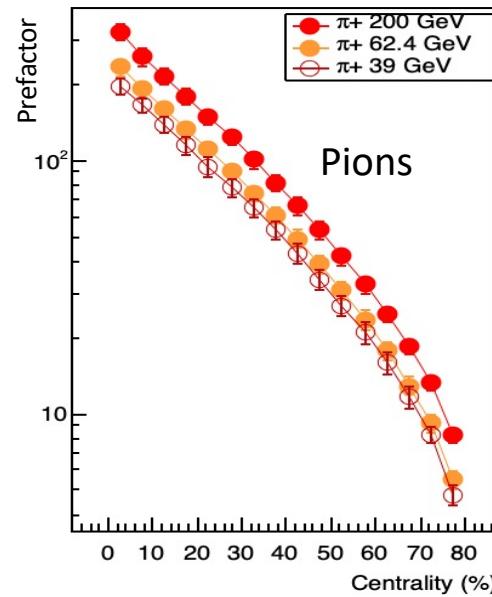
Table below uses a linear fit function to extract prefactors for 39 GeV.

Energy (GeV)	Prefactor
39	200.92
62.4	234.92
200	319.17

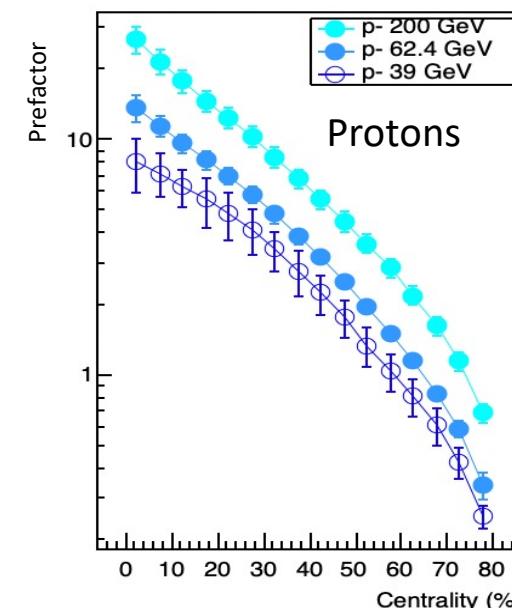
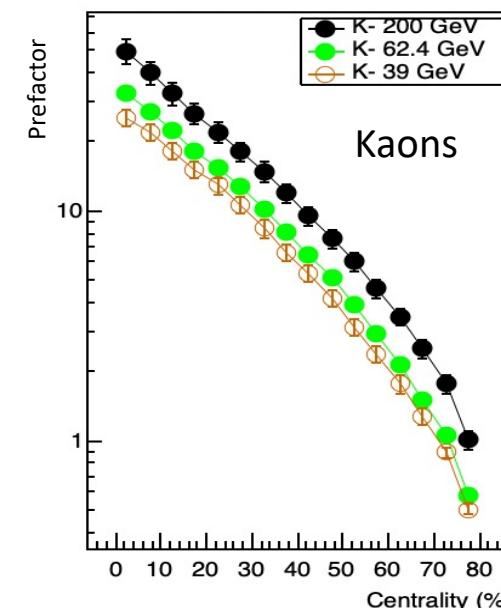
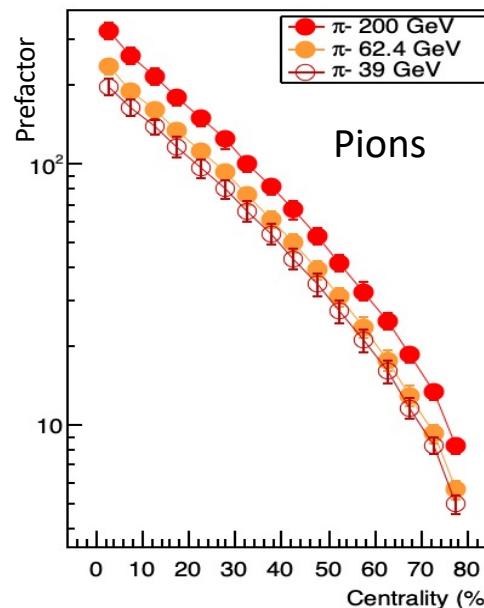
200 GeV and 62.4 GeV prefactors agree within the error bars of published results.

Prefactors – extrapolated values of 39 GeV

Prefactor for 39 GeV is extrapolated (open circles) from published results of 200 GeV and 62.4 GeV (closed circles).



Prefactors from STAR Publication
PRC 79, 034909 (2009)

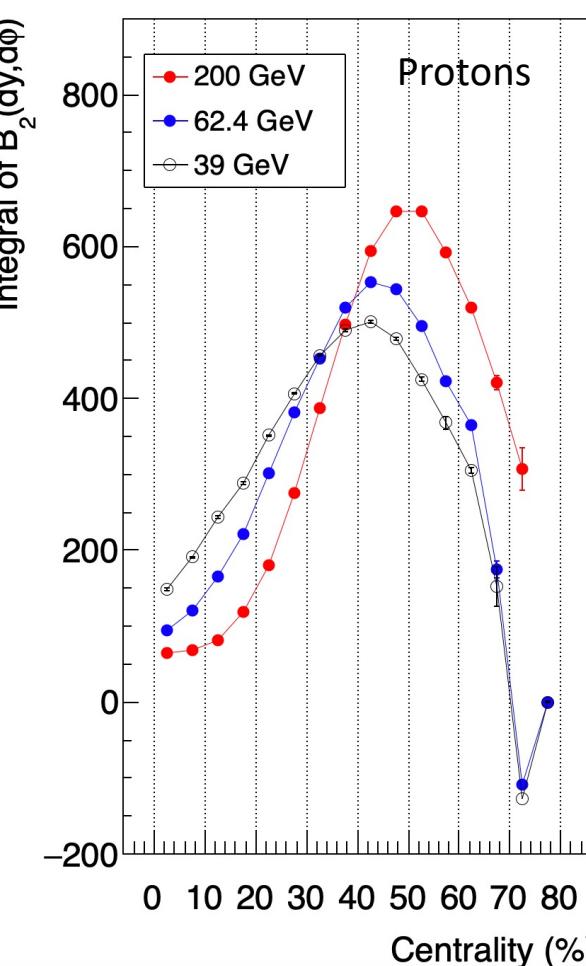
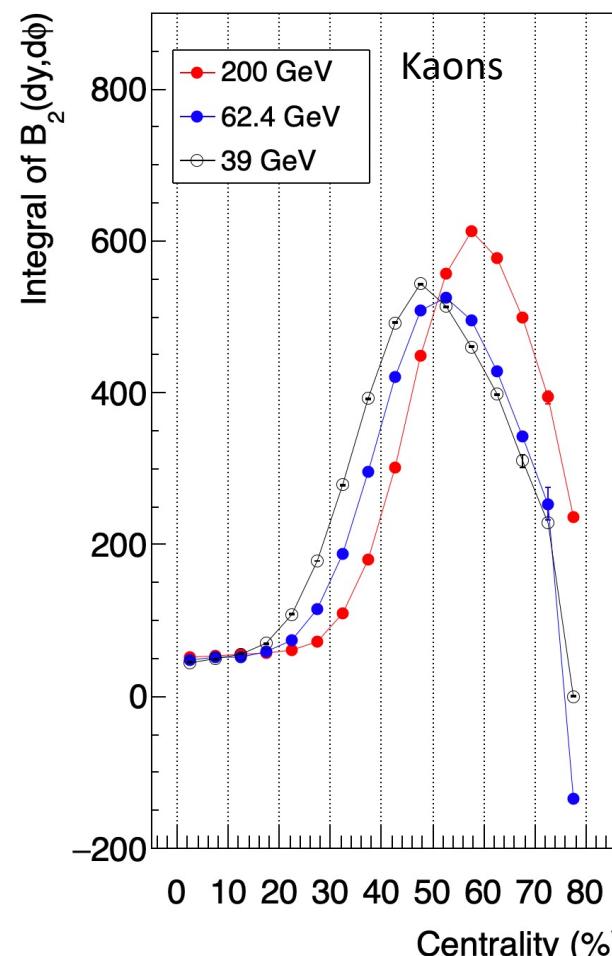
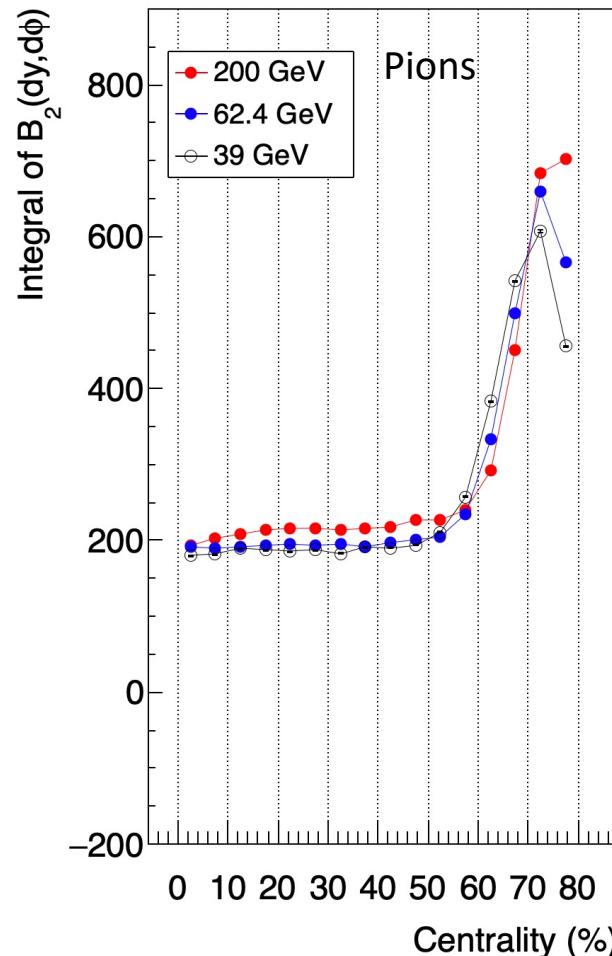


Comparison of Integrals of $B_2(dy,d\phi)$ vs. centrality

A comparisons of integrals of B_2 vs. centrality for 200 GeV, 62.4 GeV and 39 GeV.

Prefactors for 200 GeV and 62.4 GeV are taken from STAR publication: **PRC 79, 034909 (2009)**.

Prefactors for 39 GeV are extrapolated from the known values at 200 GeV, 130 GeV and 62.4 GeV.

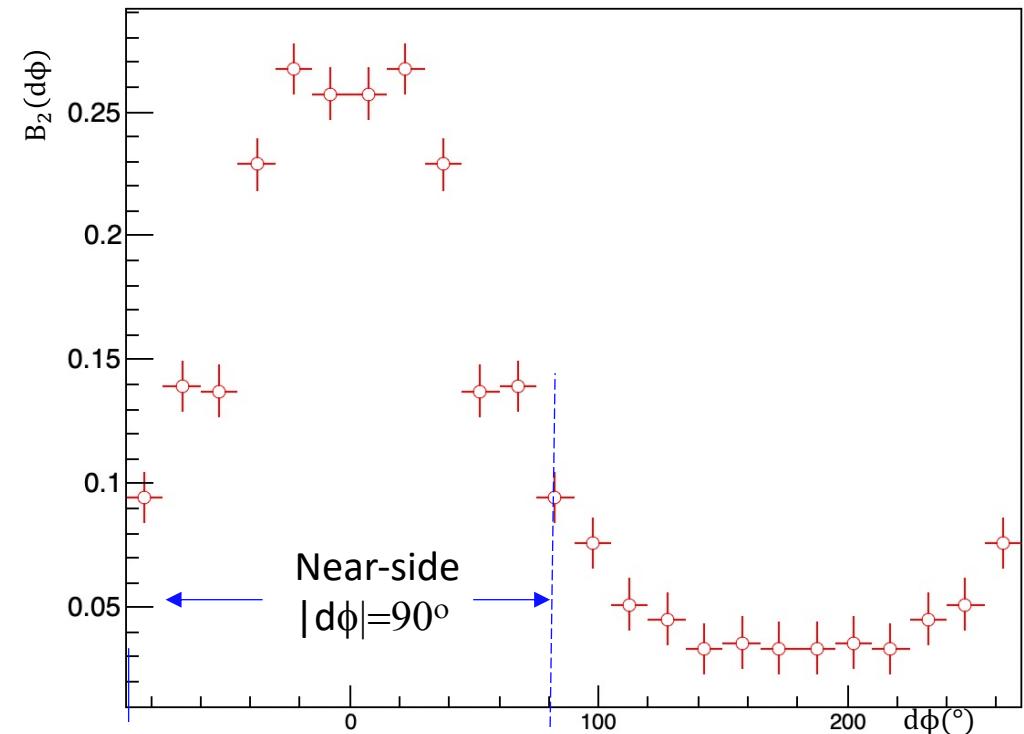


RMS of B_2 vs. Centrality at 200 GeV

Comparison of RMS of B_2 vs. Centrality – 200 GeV

The RMS was found from the 2-D distribution of $B_2(dy, d\phi)$.

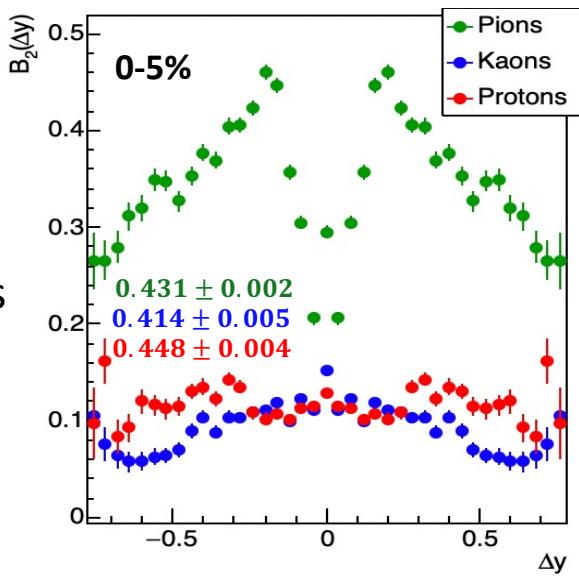
Evaluated the RMS of $B_2(dy)$ for both the near-side and entire $d\phi$ space. RMS of $B_2(d\phi)$ is evaluated only for the near-side in $d\phi$.



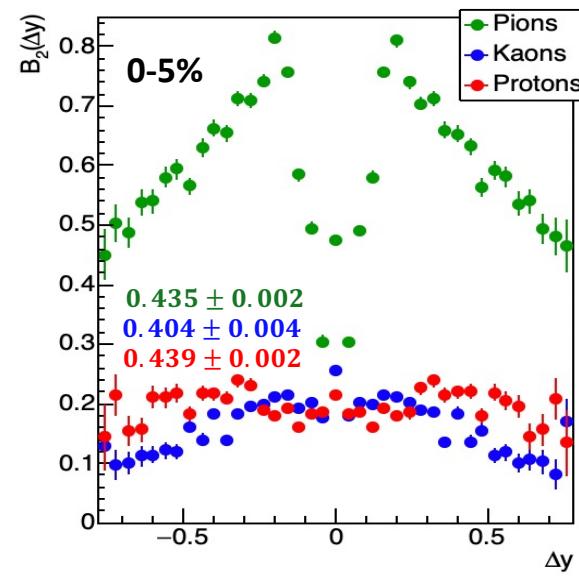
Examples of RMS of B_2 – 200 GeV

Projections of B_2 with the corresponding RMS for all pairs and centralities 0-5% (top row) and 35-40% (bottom row).

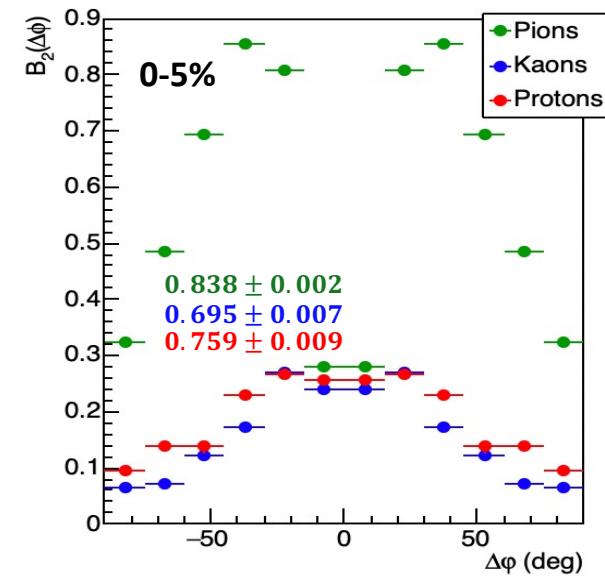
RMS $B_2(dy)$ Entire $d\phi$ space



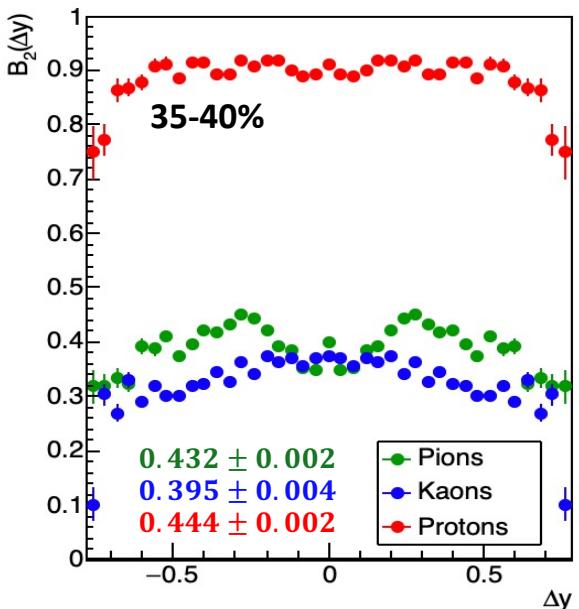
RMS $B_2(dy)$ – Near Side



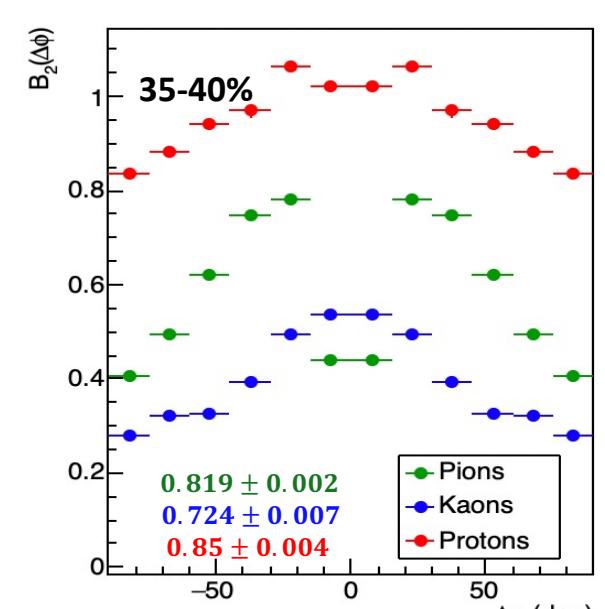
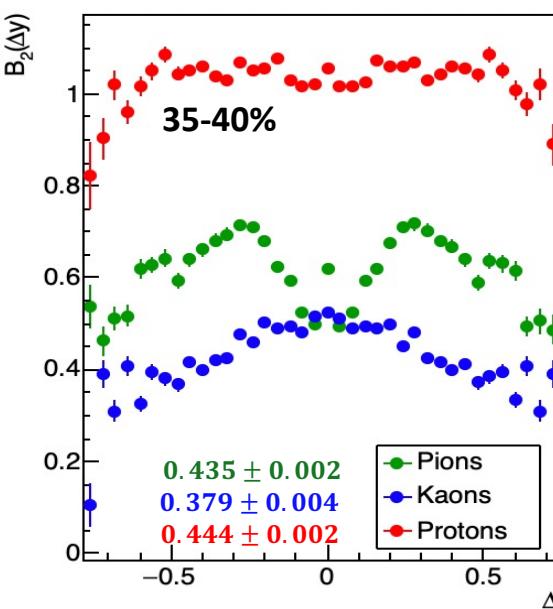
RMS $B_2(d\phi)$ – Near Side



35-40%

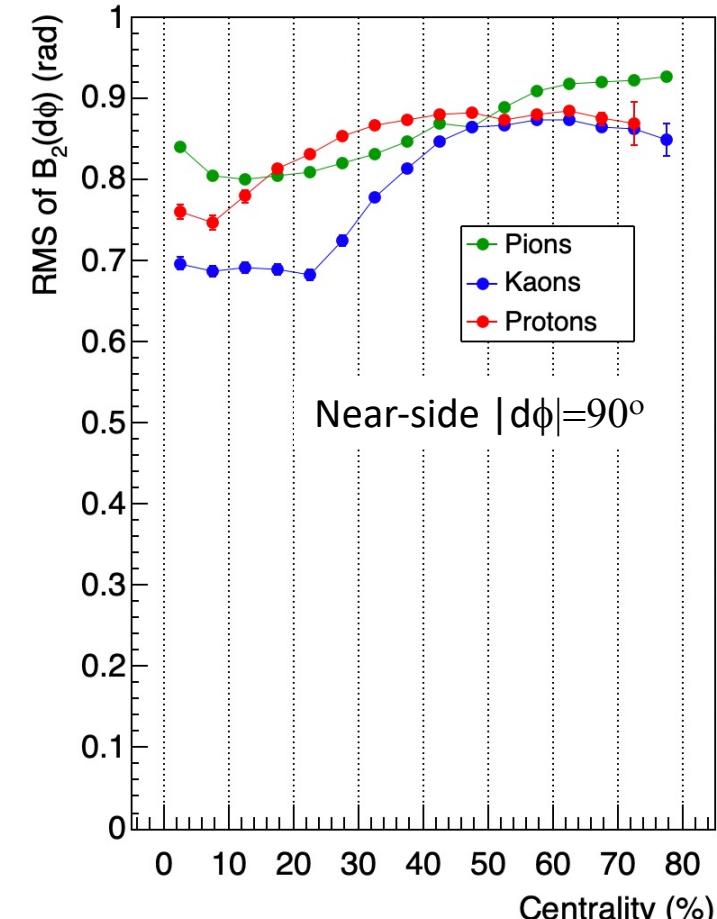
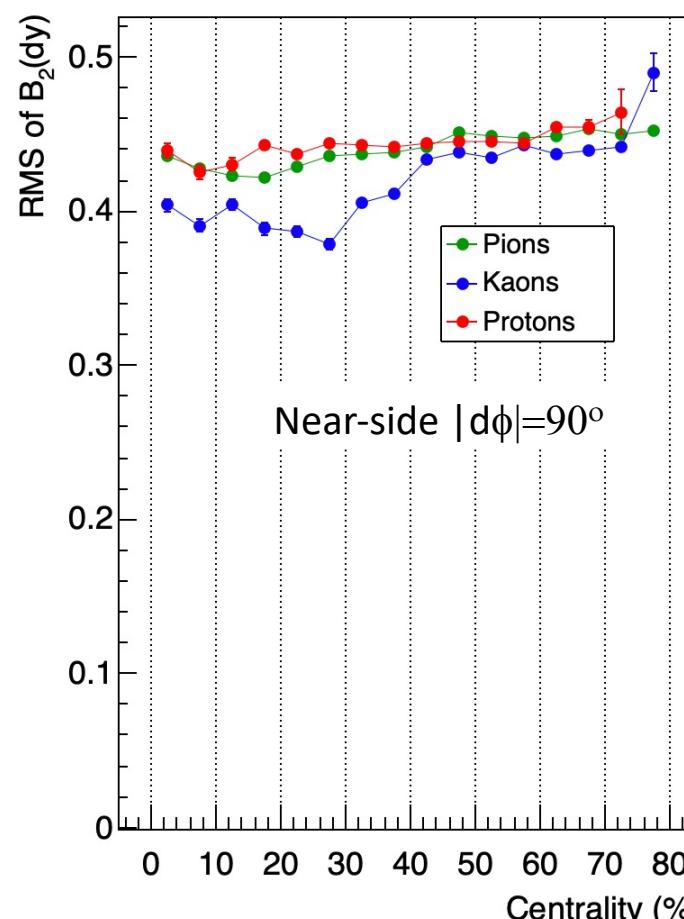
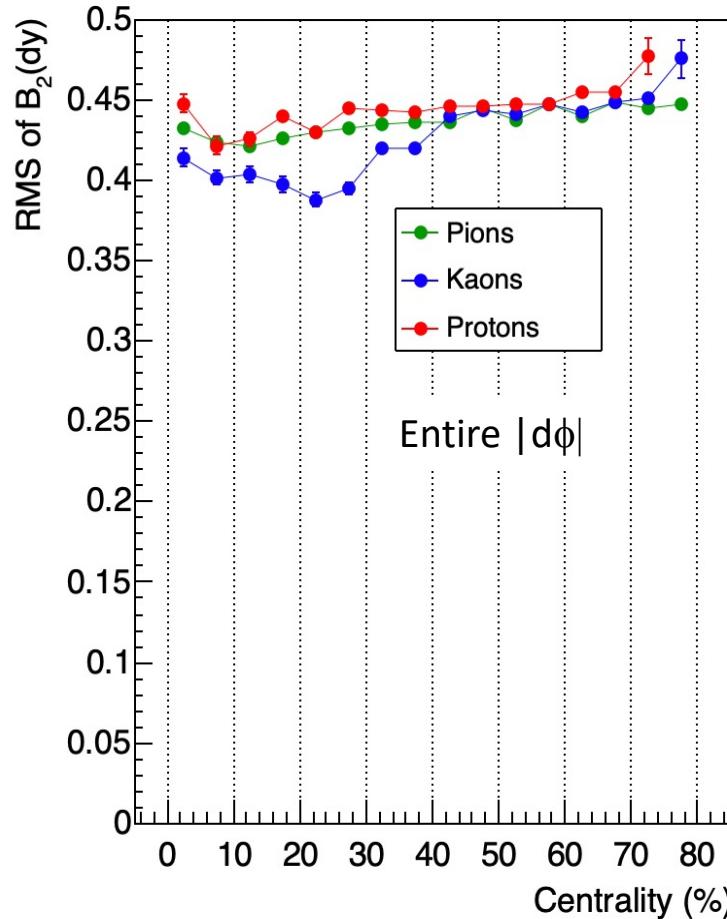


35-40%



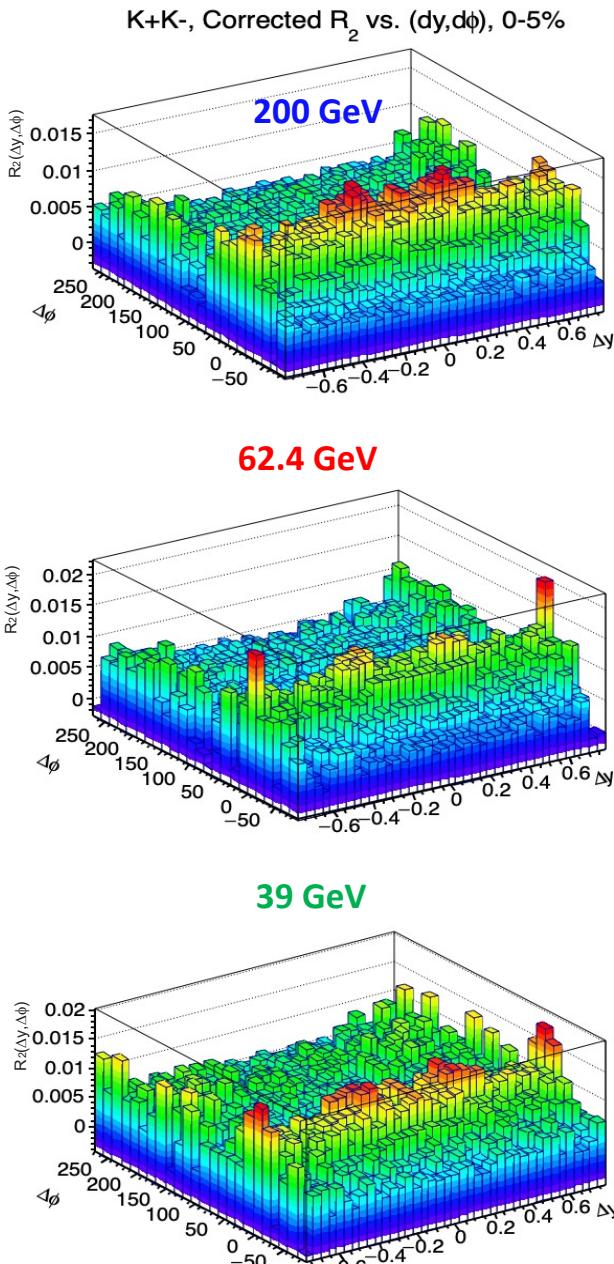
Comparison of RMS of B_2 vs. Centrality – 200 GeV

- The RMS of $B_2(dy)$ and $B_2(d\phi)$ decreases as the collisions become more central.
- In case of kaons and protons all widths seem to "saturate" to asymptotes as the collisions become more peripheral (inferred from near-side plot).

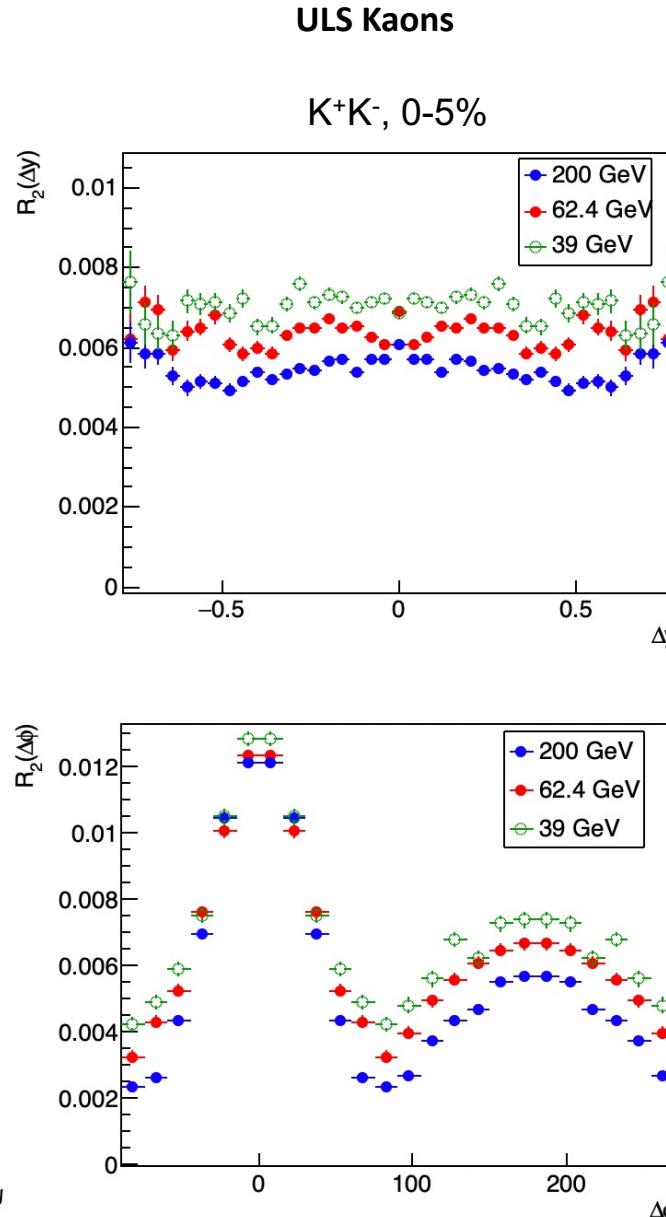


Comparison of RMS of B_2 for 200, 62.4 and 39 GeV

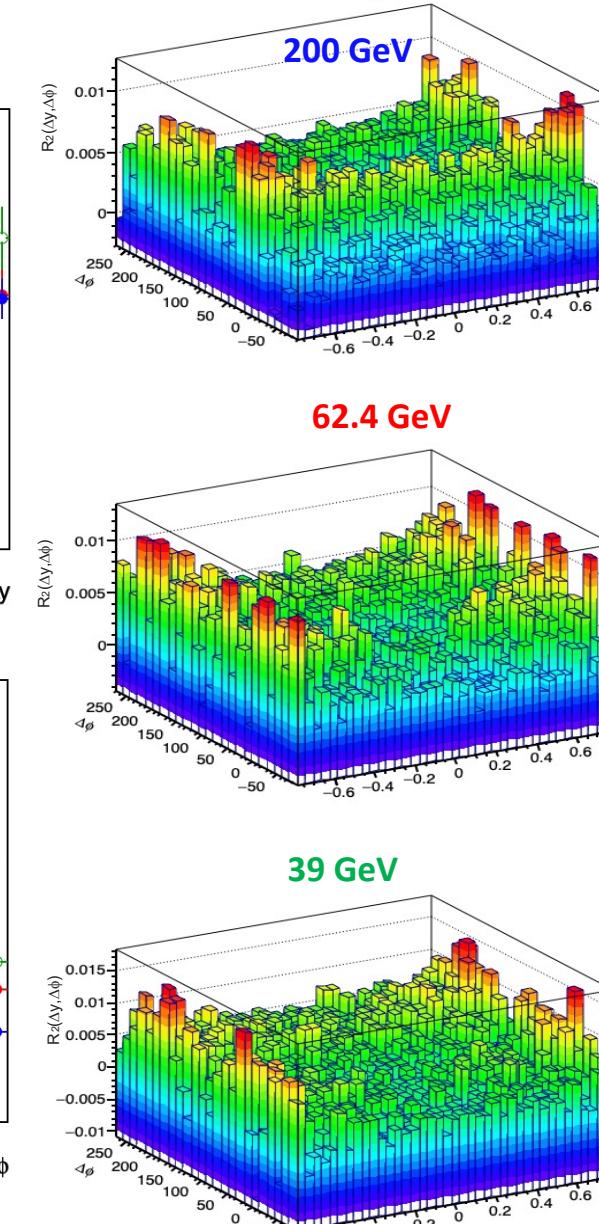
Comparison of R_2 for Kaons for 200 GeV, 62.4 GeV and 39 GeV



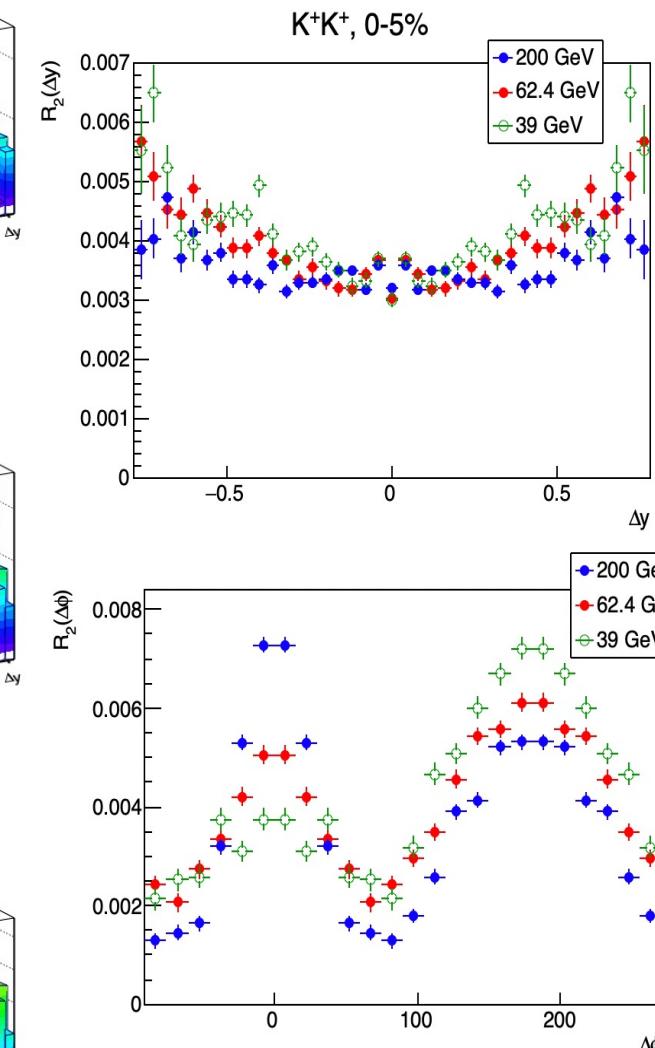
ULS Kaons



K+K+, Corrected R_2 vs. $(dy, d\phi)$, 0-5%

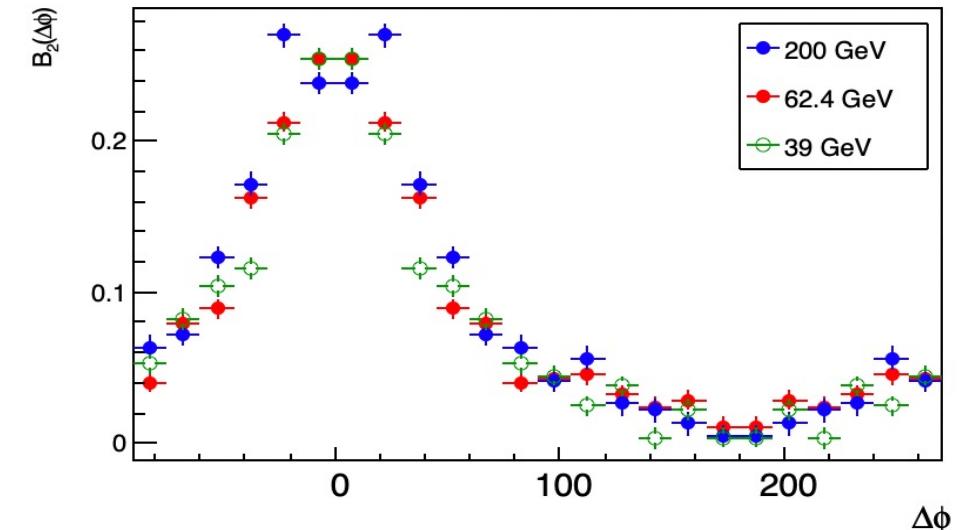
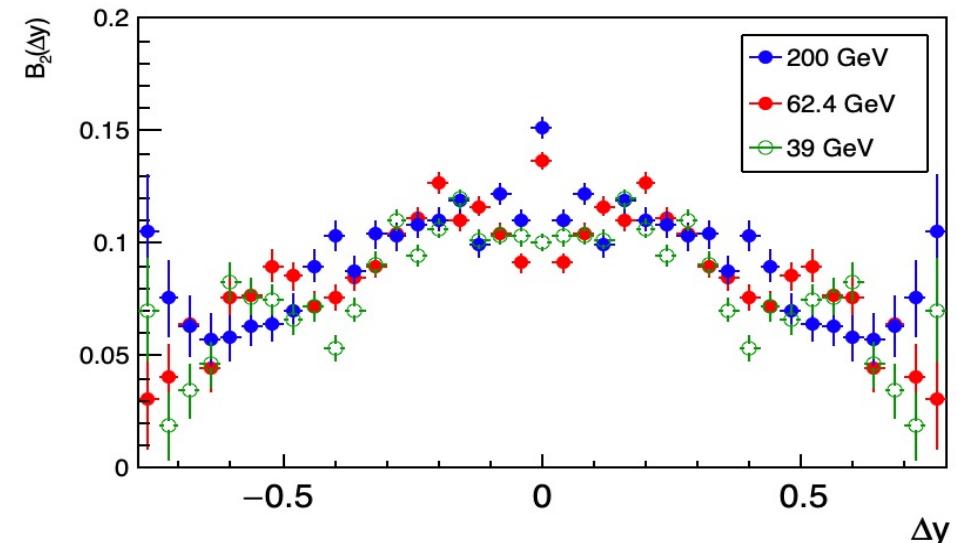
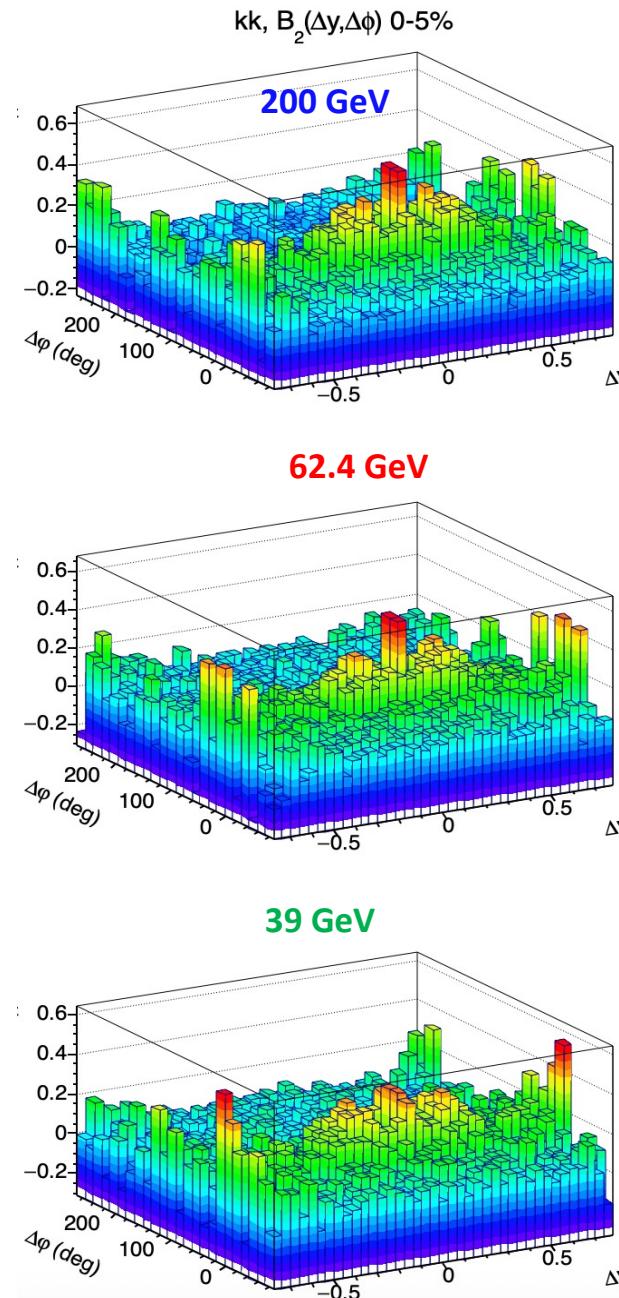


LS Kaons

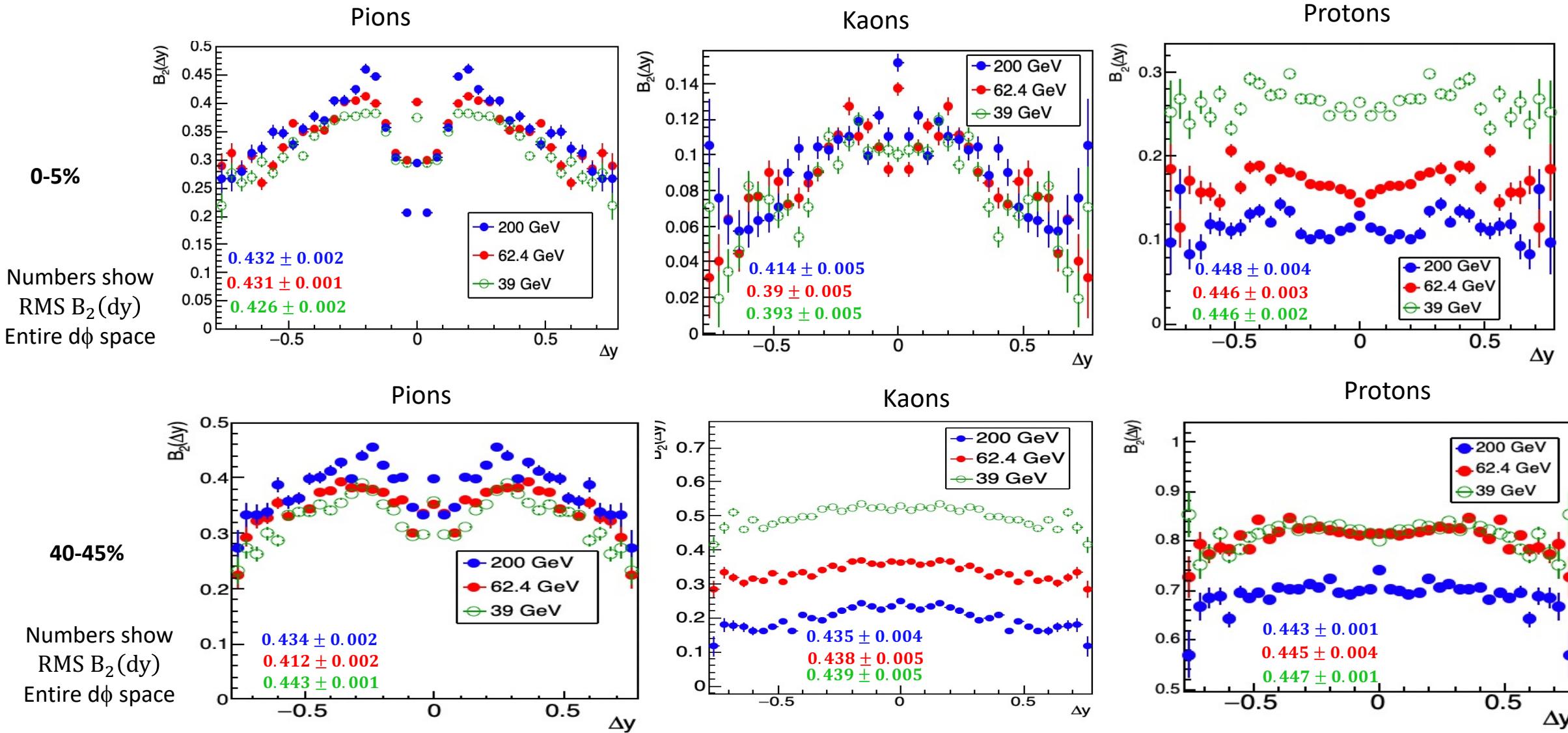


Comparison of B_2 for Kaons for different energies.

Comparisons of average projections B_2 for all three energies for most central kaons. The prefactor for 39 GeV is extrapolated.



Examples of RMS of $B_2(\Delta y)$ – all energies

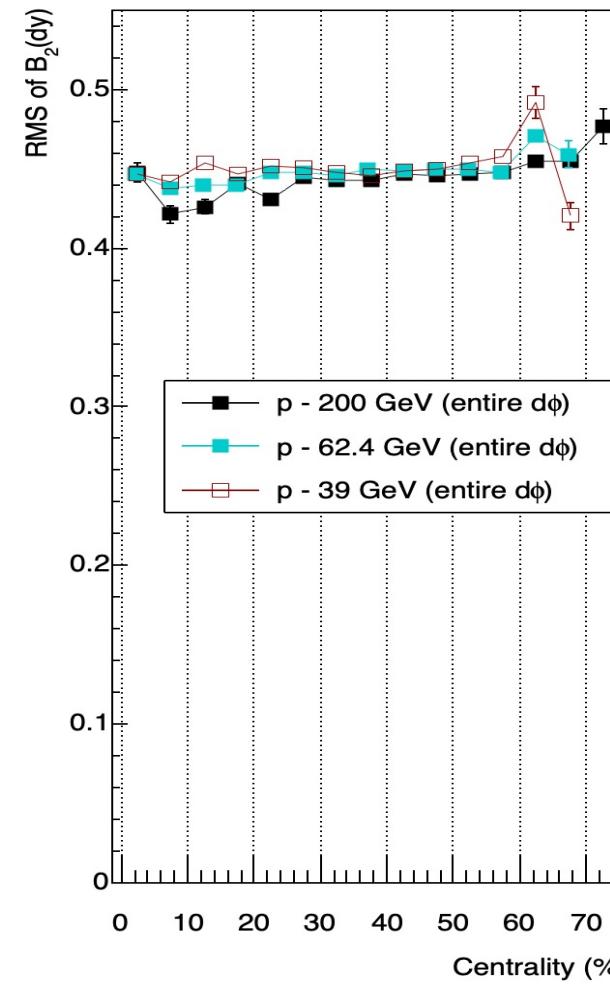
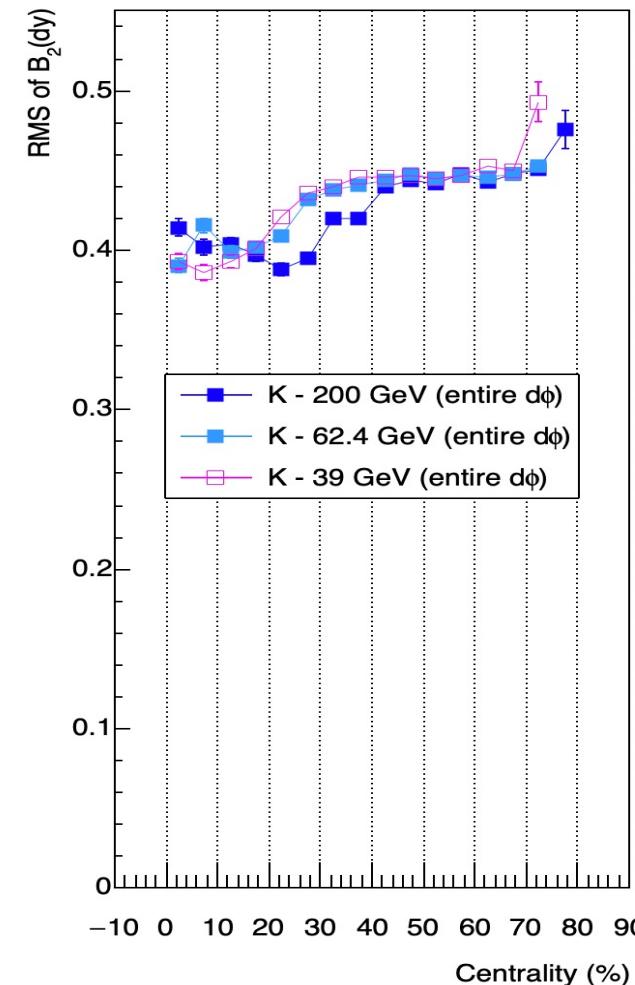
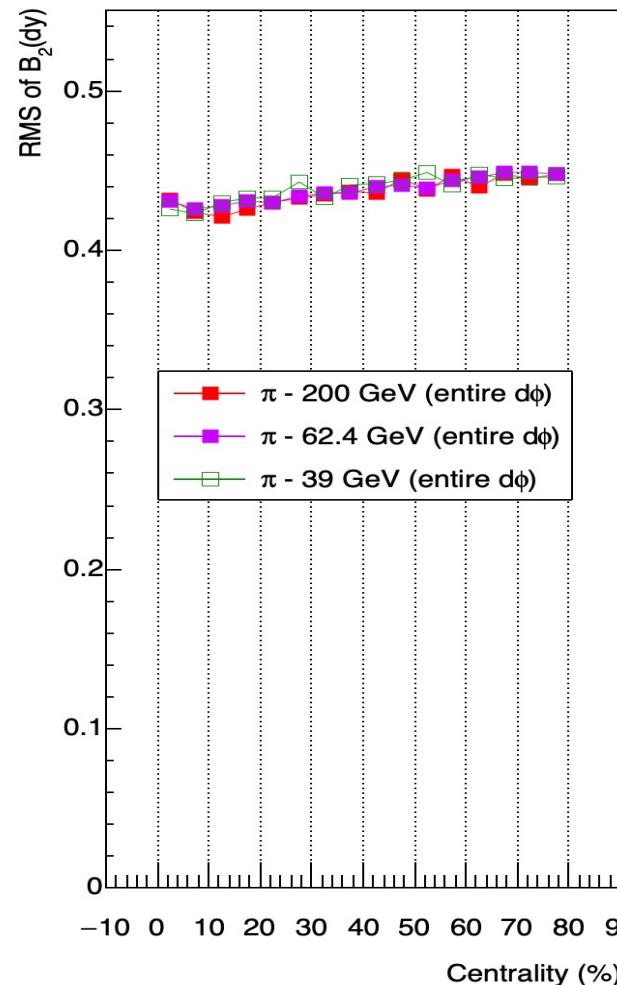


Comparison of RMS of $B_2(dy)$ vs. centralities for different energies

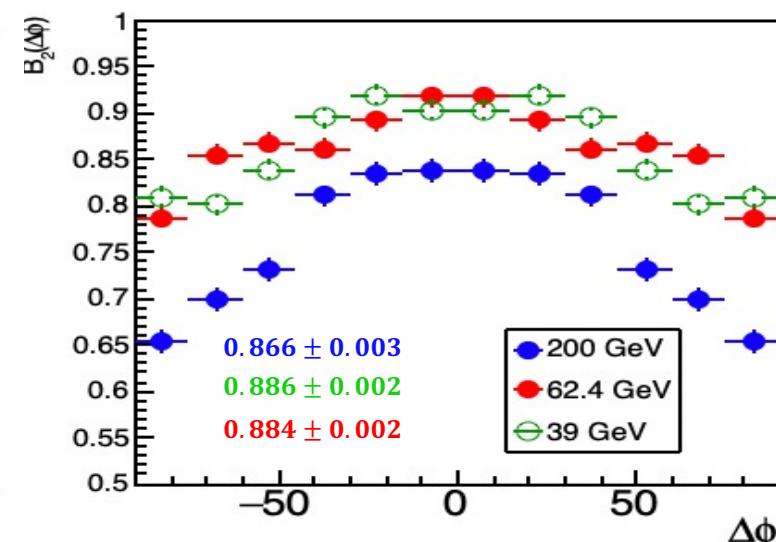
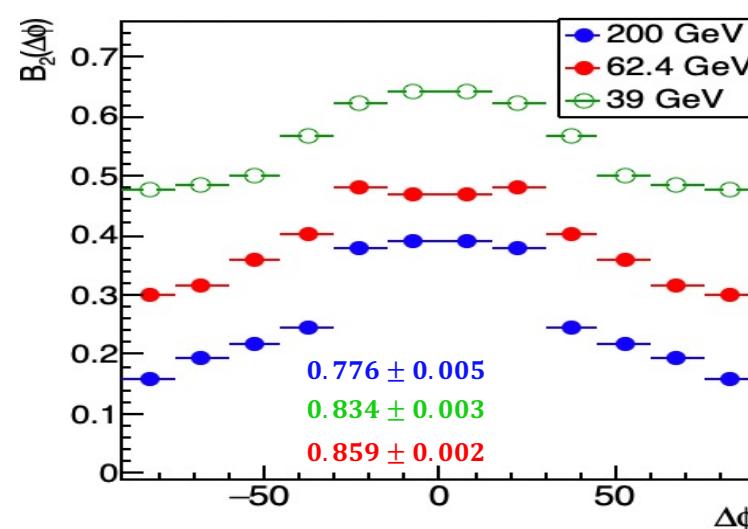
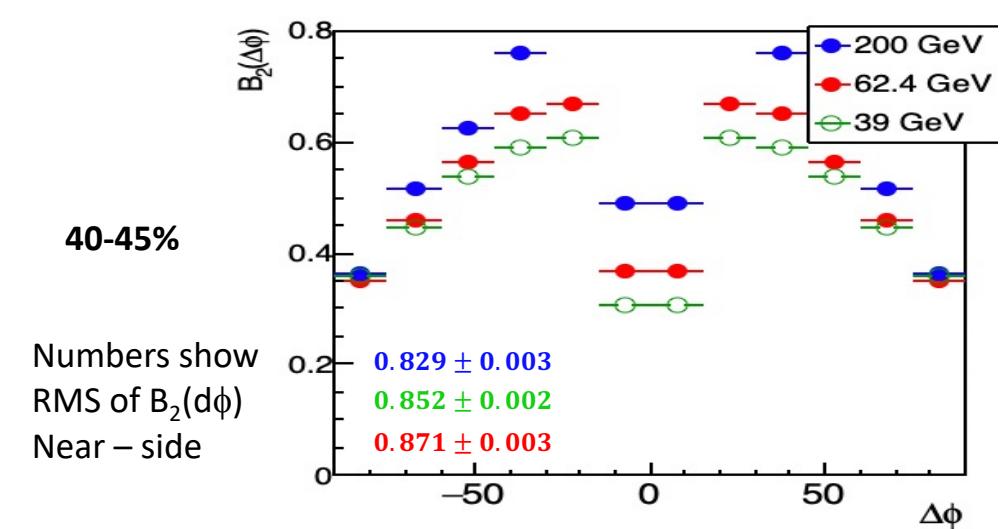
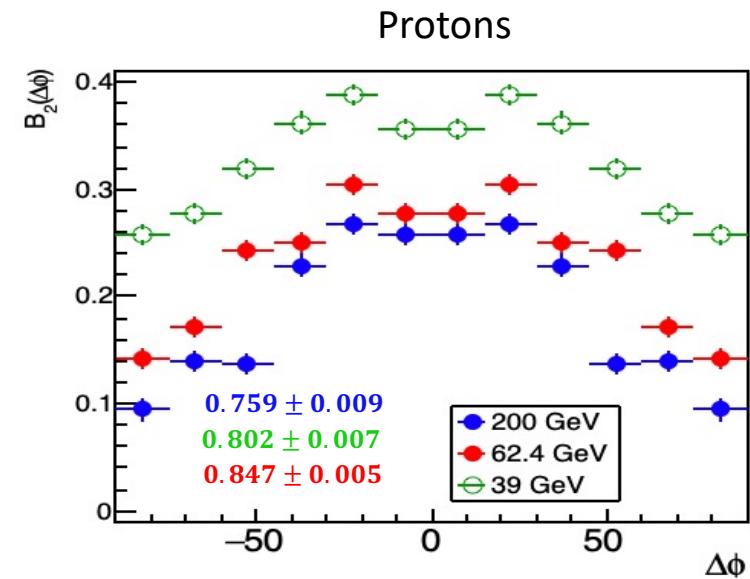
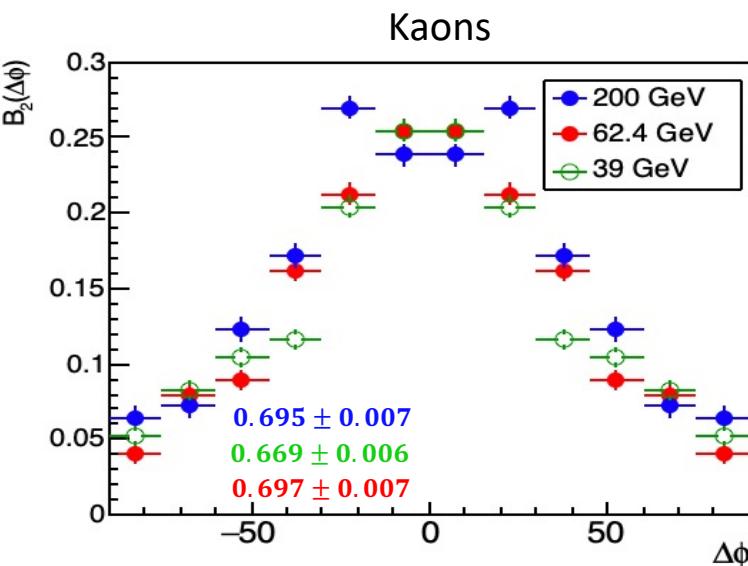
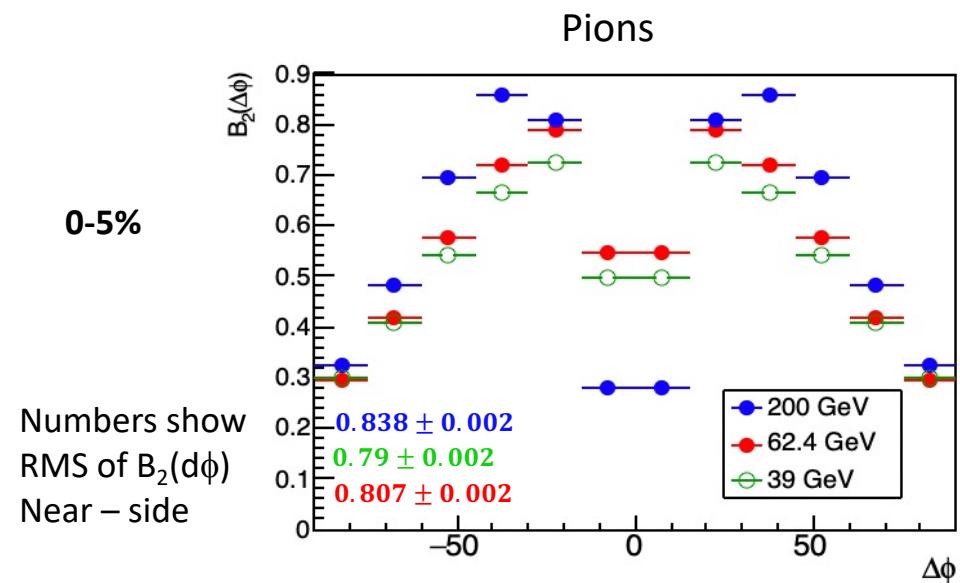
Comparing RMS of $B_2(dy)$ all particles for **entire $d\phi$** .

General narrowing of B_2 observed with centrality for pions and kaons. Almost constant width for protons.

Open squares – 39 GeV (extrapolated data)
 Full squares – 200 and 62.4 GeV

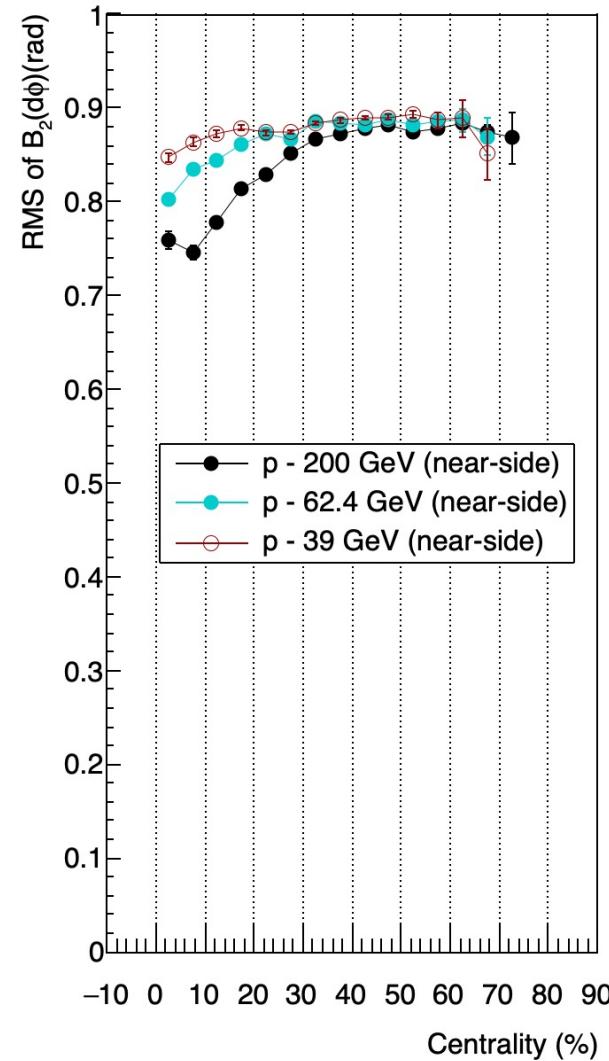
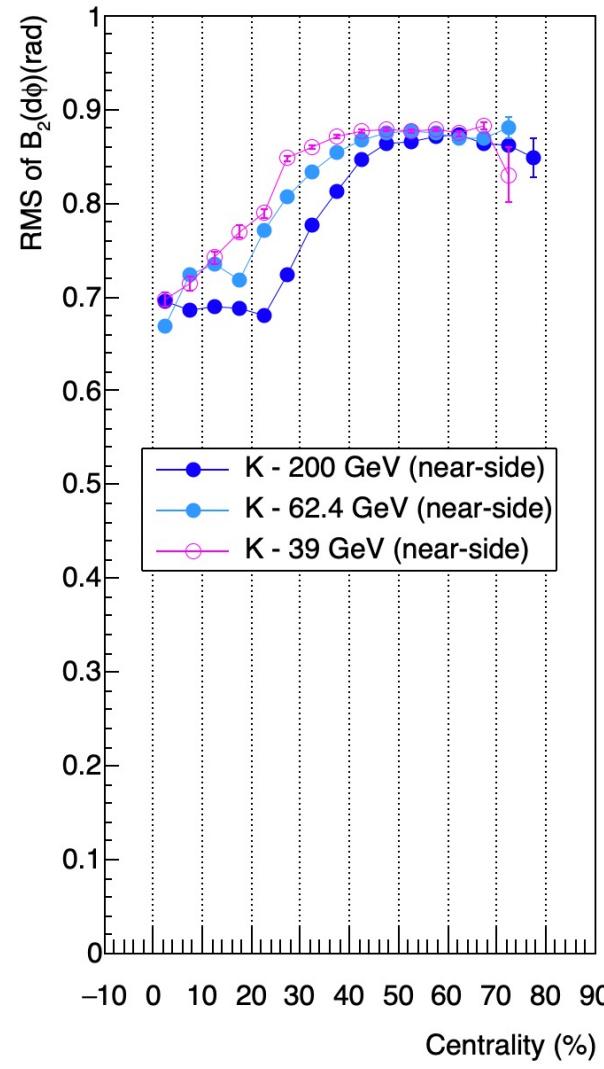
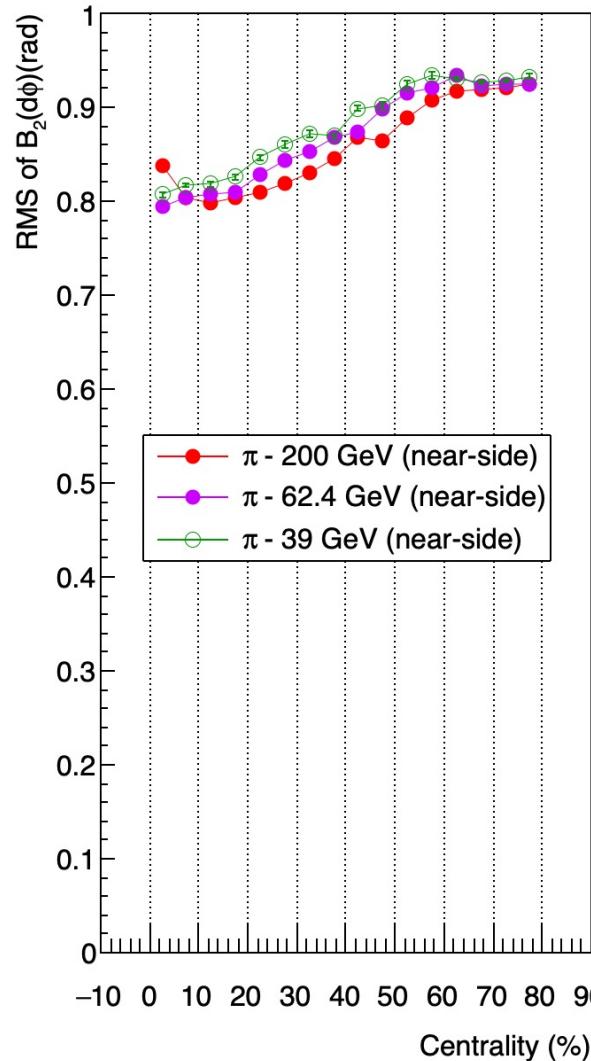


Examples of RMS of $B_2(\Delta\phi)$ – Near – Side all energies



Comparison of RMS of $B_2(d\phi)$ vs. centralities for different energies – near side.

Narrowing of RMS B_2 with centrality appears to saturate for kaons and protons (kaons at ~45-50% and protons at ~30-35%)



Summary and future work

- The integral B_2 decreases for more central collisions for all energies in case of pions.
- Integral of B_2 decreases for more central collisions in the range of 0-5% to 50-55% centrality in case of kaons and protons.
- RMS (or width) of B_2 decreases for more central collisions for pions for all energies we studied.
- In case of kaons and protons all widths seem to "saturate" to asymptotes as the collisions become more peripheral (kaons at ~45-50% and protons at ~30-35%)
- Studied B_2 for all centralities at 62.4 GeV and 200 GeV. Results at 39 GeV obtained using extrapolated prefactors.
- Use Ayeh's published approach for improving crossing in 200 GeV pions.
- Calculate systematic uncertainties.