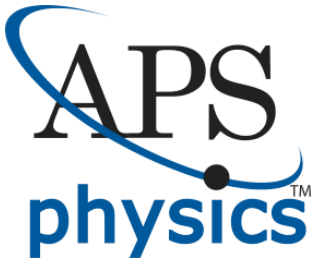


Two-particle correlations of identified hadrons in Au+Au collisions in the Beam Energy Scan program at RHIC

S. Jowzaee

for the STAR Collaboration

Wayne State University

APS April Meeting 2018, Columbus, OH

Introduction

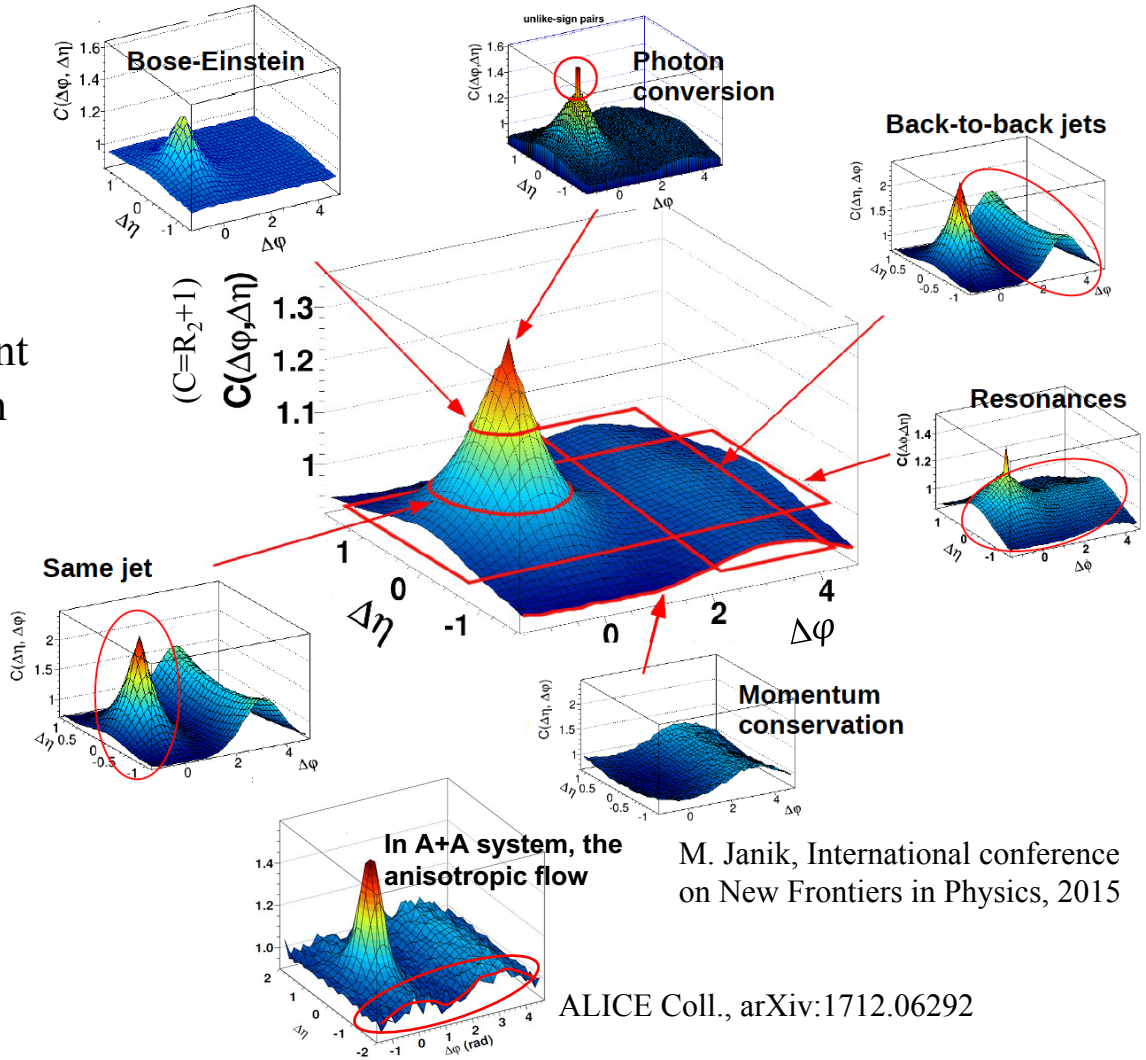
- Two-particle correlation function is a powerful tool to study the mechanisms involved in heavy-ion collisions

$$R_2(\Delta y, \Delta\varphi) = \frac{\rho_2(\Delta y, \Delta\varphi)}{\rho_1(y_1, \varphi_1) \otimes \rho_1(y_2, \varphi_2)} - 1$$

  - In the absence of any correlation R_2=0
  - For correlated particles R_2>0
  - For anti-correlated particles R_2<0

- Different physical phenomena are reflected as different structures like ridge or peak in $R_2(\Delta y,\Delta\phi)$ distribution
  - ➢ Short-range correlations (resonance decays, jet fragmentation, Bose-Einstein correlations)
  - ➢ Long-range correlations
  - ➢ QCD Critical Point

- **Goal: Systematic exploration of hadron correlations in the Beam Energy Scan I data measured by STAR at RHIC**



M. Janik, International conference on New Frontiers in Physics, 2015

ALICE Coll., arXiv:1712.06292

Dataset and Analysis Details

- BES-I dataset: Au+Au at eight different energies
  - ➢ $\sqrt{s_{NN}}$: 7.7, 11.5, 14.5, 19.6, 27, 39, 62.4 & 200 GeV
- Particles of interest: $\pi^{\pm}$, $K^{\pm}$ & $p\bar{p}$
- Two charge combinations of like-sign & unlike-sign
- Nine different centrality bins from most central 0-5% to peripheral 70-80%
- Transverse momentum
  - ➢ $0.2<p_T<2.0(1.6)$ GeV/c for $\pi^{\pm}$ ($K^{\pm}$) and $0.4<p_T<2.0$ GeV/c for $p\bar{p}$

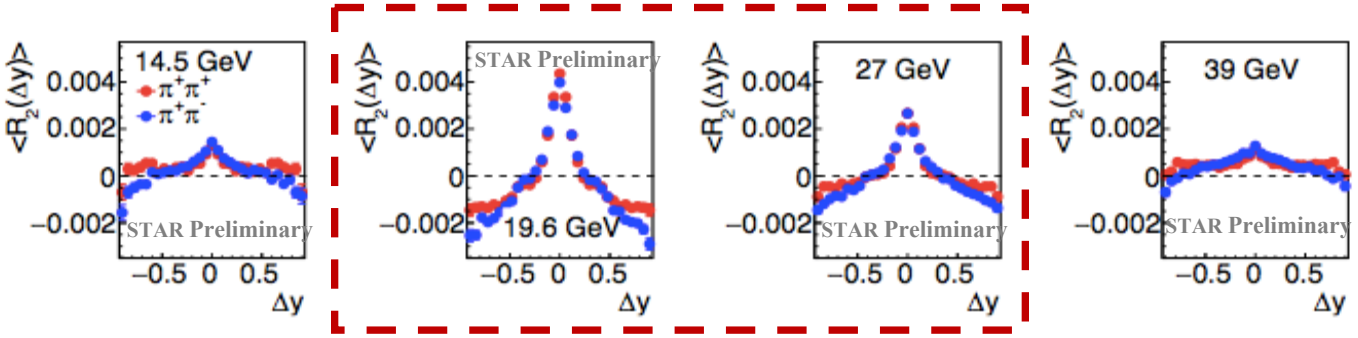
$\sqrt{s_{NN}}$ (GeV)	Good events recorded (M events)	Year	μ_B (MeV) [0-5%]
7.7	4	2010	422
11.5	12	2010	316
14.5	20	2014	264
19.6	36	2011	206
27	70	2011	156
39	130	2010	112
62.4	67	2010	73
200	350	2010	24

- Using more efficient PID approach compared to QM2017 to correct the observed detector effect in pions at 19.6 and 27 GeV

  https://indico.cern.ch/event/433345/contributions/2358266/attachments/1408121/2154119/QM17-Jowzaee.pdf
  - PID based on TPC and TOF in all p (if TOF is available) && TPC only in $0.2<p<0.6(0.9)$ GeV/c for π, K(p) (if TOF is not available)
- Pseudo-correlations from Z-vertex smearing and track merging and crossing were corrected
- Systematic uncertainties from track selection cuts included in the results
- Same analysis with UrQMD simulation events

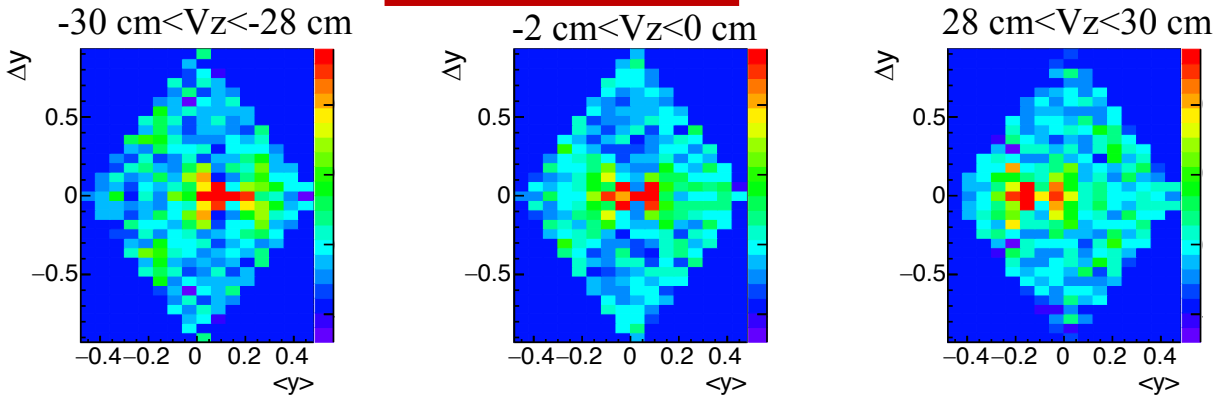
Observed Δφ ridge in pions

QM/CPOD 2017 results based on PID: TPC+TOF in all p range



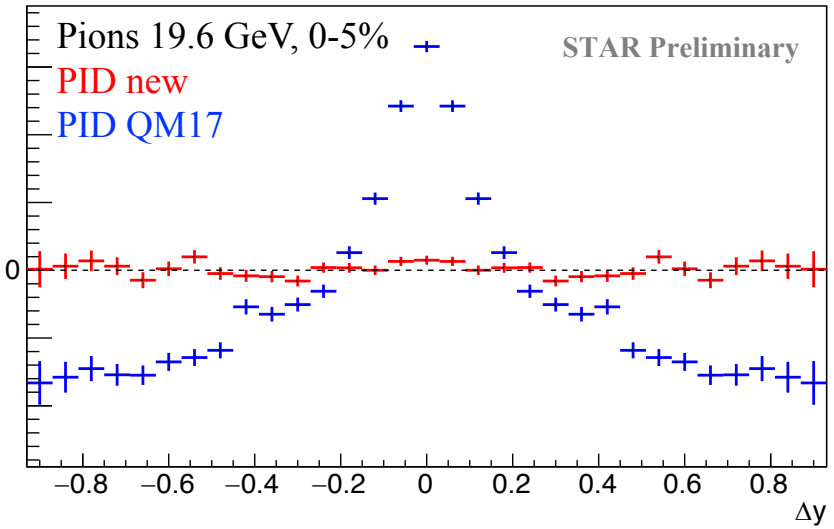
- A lot of detail checks was done to understand the effect
  - Transverse projection of $R_2(<y>,\Delta y)$ shows the pion effect is localized in <y> and moving by Vz

Detector effect and not physics



No physics effect is expected in the transverse region

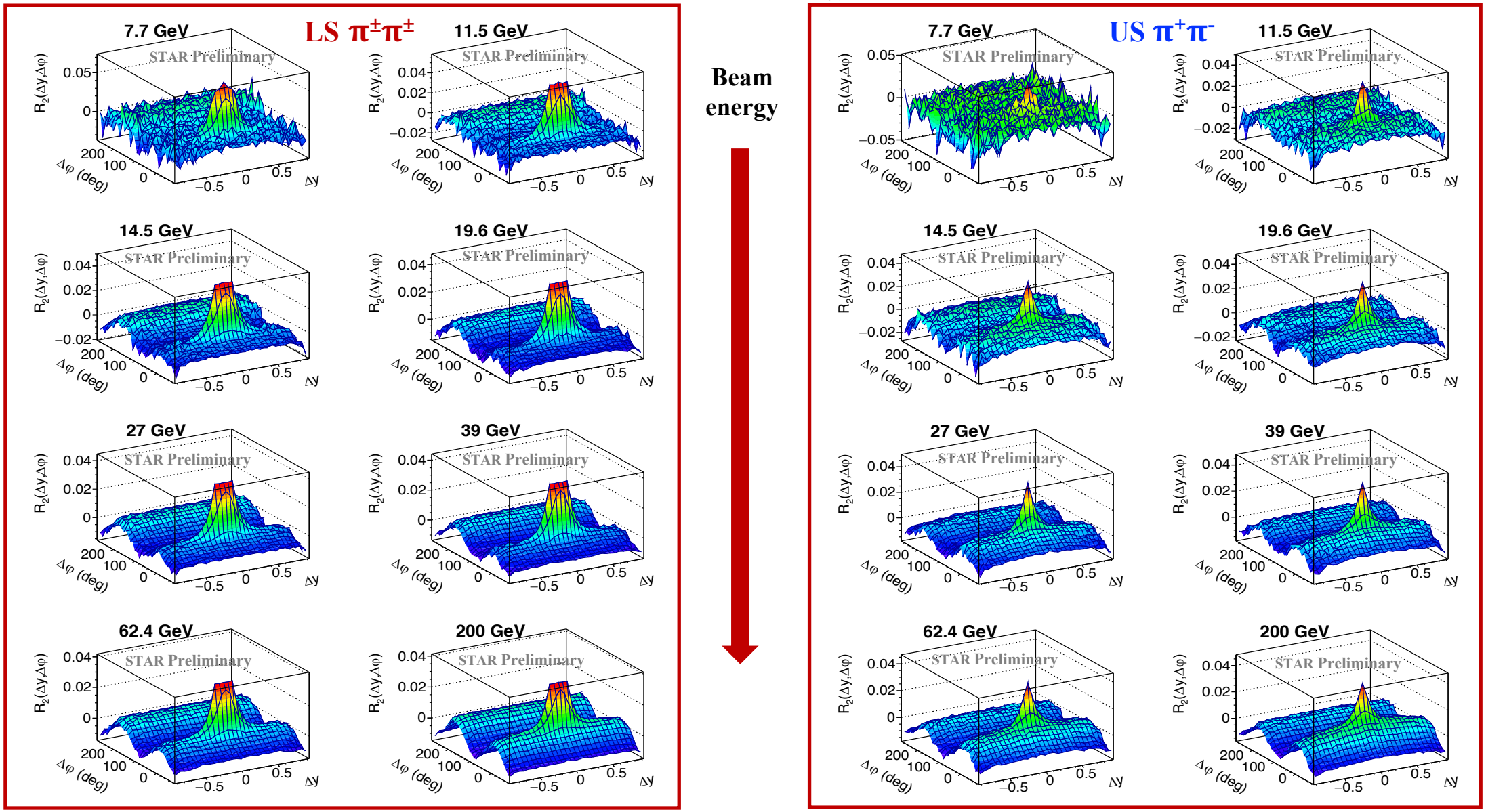
Transverse projection: 30°<Δφ<150° & 210°<Δφ<330°



- The experimental effect of pions is removed using more efficient PID and/or rapidity cut
  - Transverse projection $<R_2(\Delta y)>$ shows the pion effect is removed using new PID

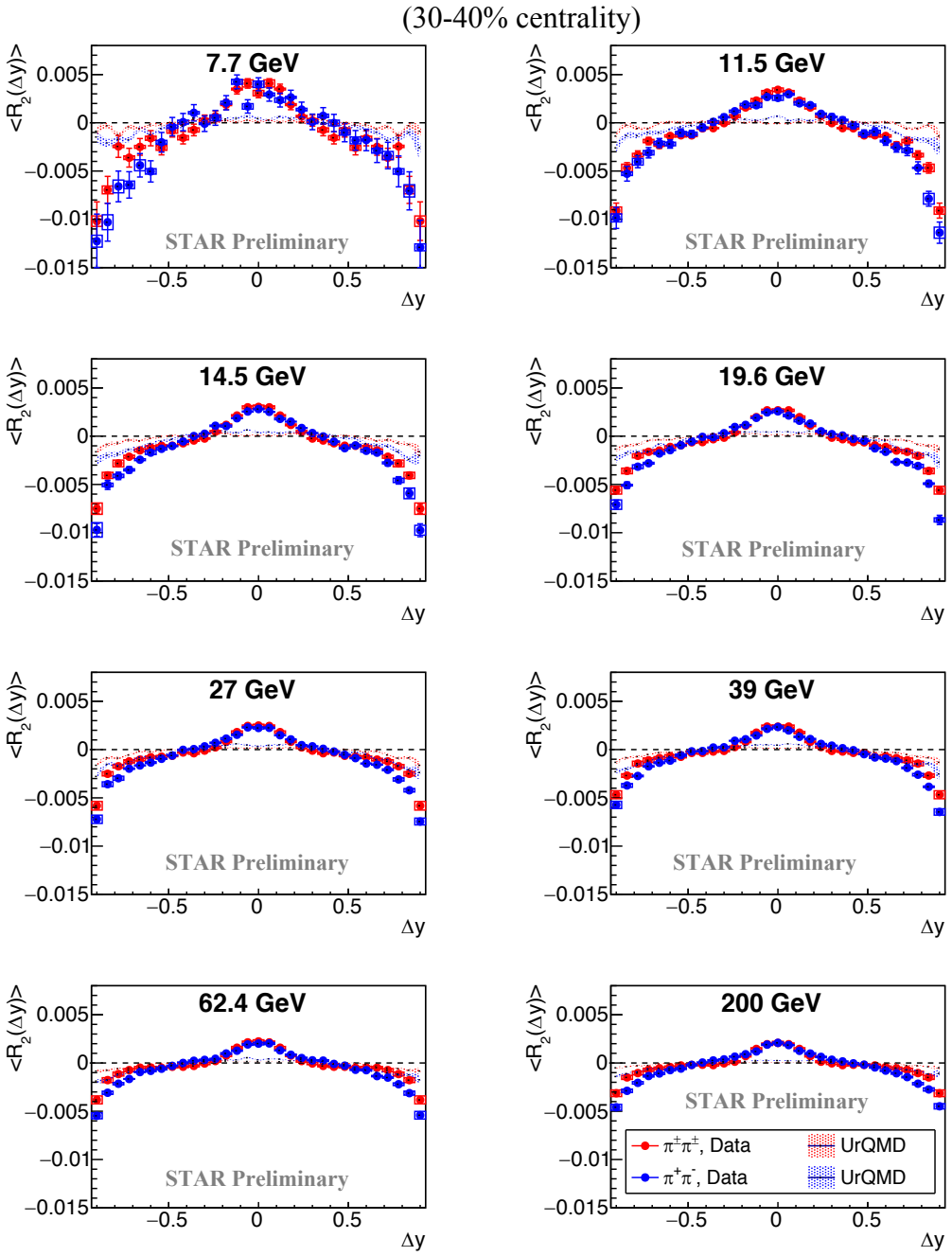
Correlations of ππ

(30-40% centrality)



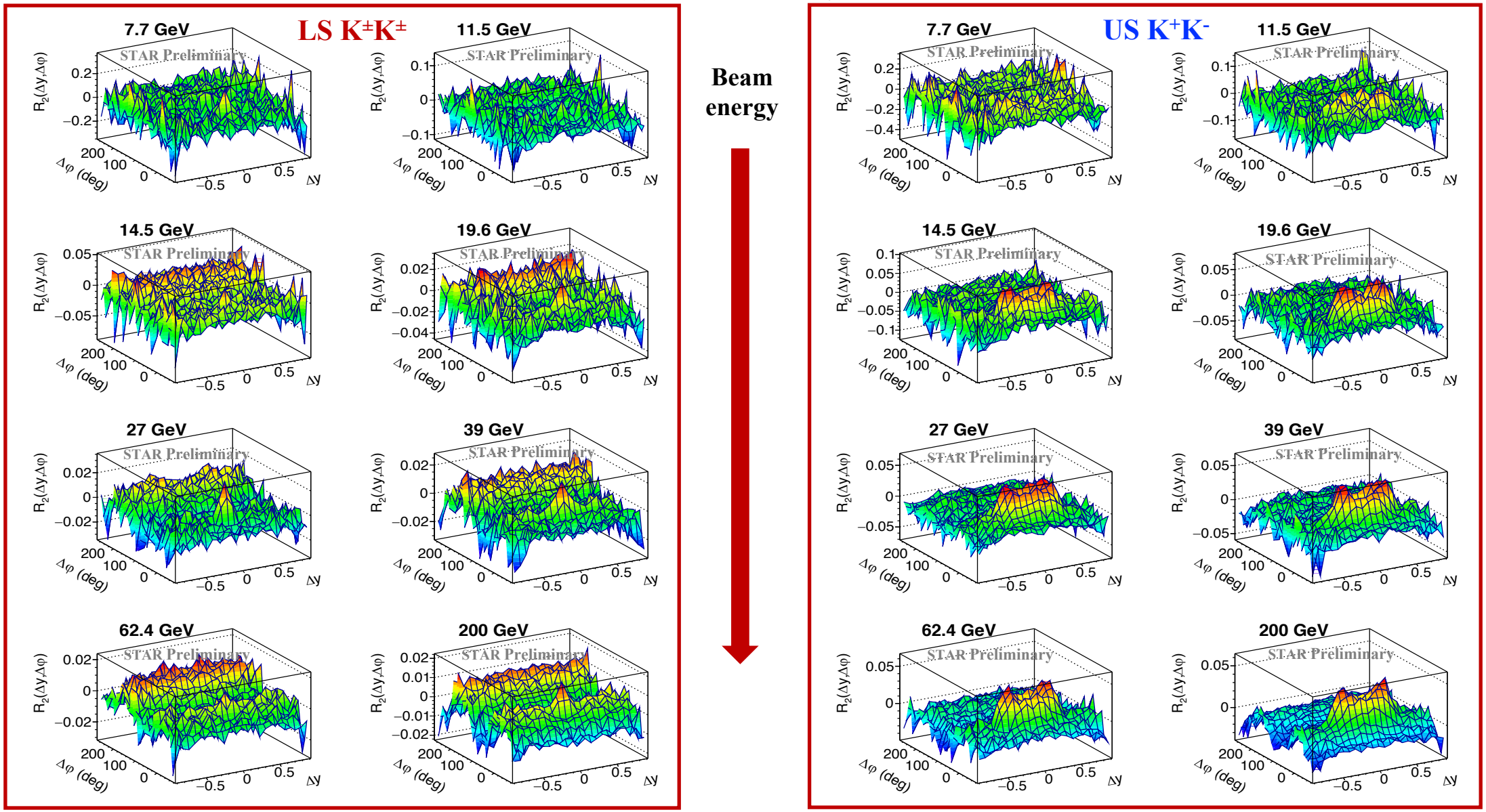
Correlations of ππ

- A near-side strong enhancement is observed in $\pi^{\pm}\pi^{\pm}$ and $\pi^{+}\pi^{-}$
  - ➢ Expected structure from short-range mechanisms like jet fragmentation and resonance decays
- No difference observed in like-sign and unlike-sign charge combinations
- Correlations slightly decrease by increasing the incident energy
- UrQMD simulation does not reproduce the observed correlations in pions
  - ➢ UrQMD model does not include jet fragmentation mechanism



Correlations of KK

(30-40% centrality)

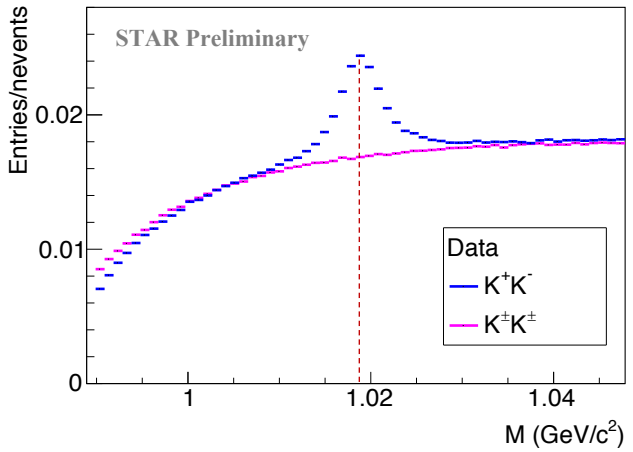


Correlations of KK

- A near-side enhancement is observed in K^+K^- which is wider in Δy than short-range structure
  - ➢ Structure corresponds to the $\phi(1020)$ resonance decay
  - ➢ $\phi(1020) \rightarrow K^+K^-$ (48.9 ±0.5)%

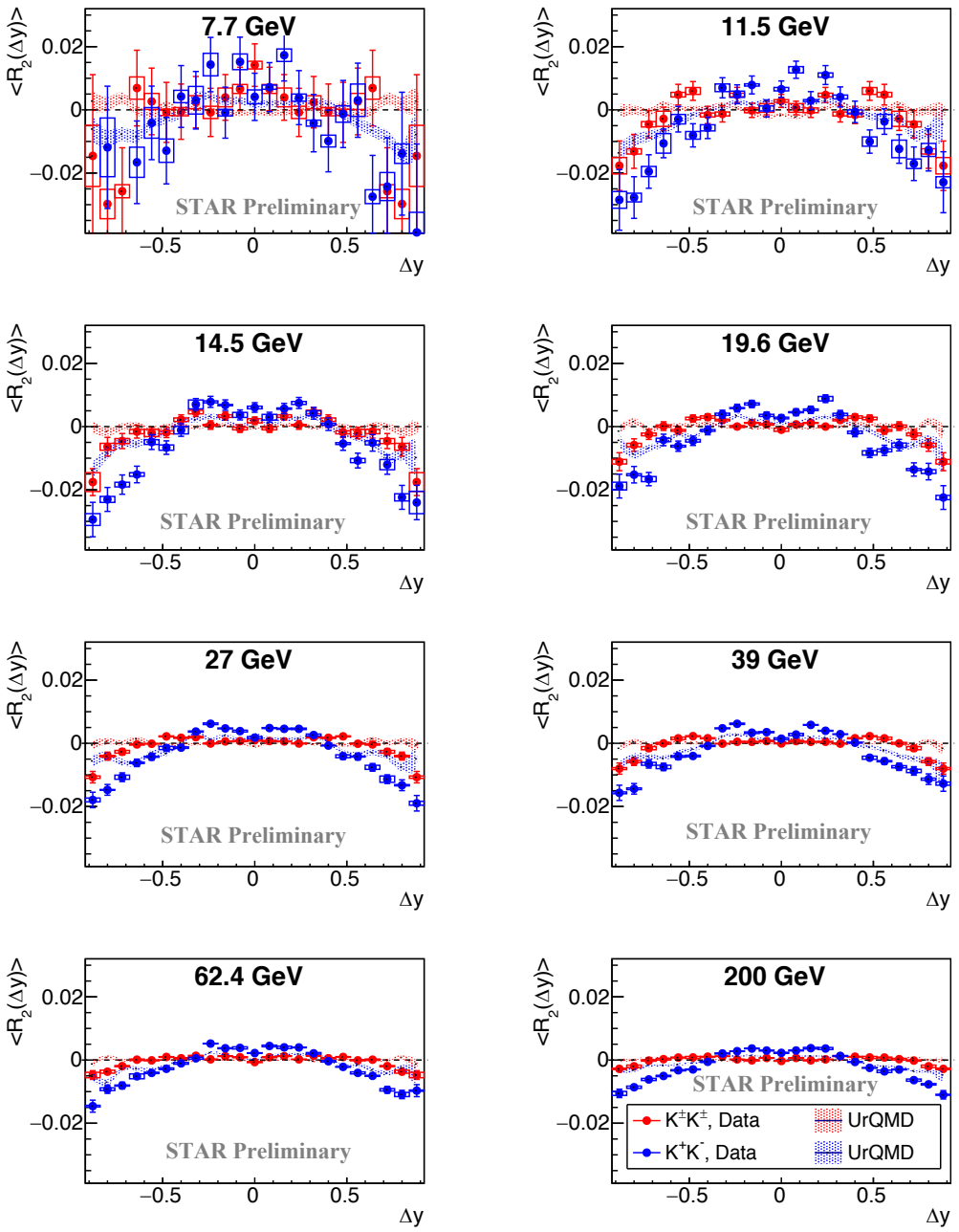
C. Patrignani et al. (Particle Data Group), Chin. Phys. C, 40, 100001 (2016) and 2017 update

$M_{\phi(1020)} = 1.01945 \pm 0.020$ (GeV/c^2)



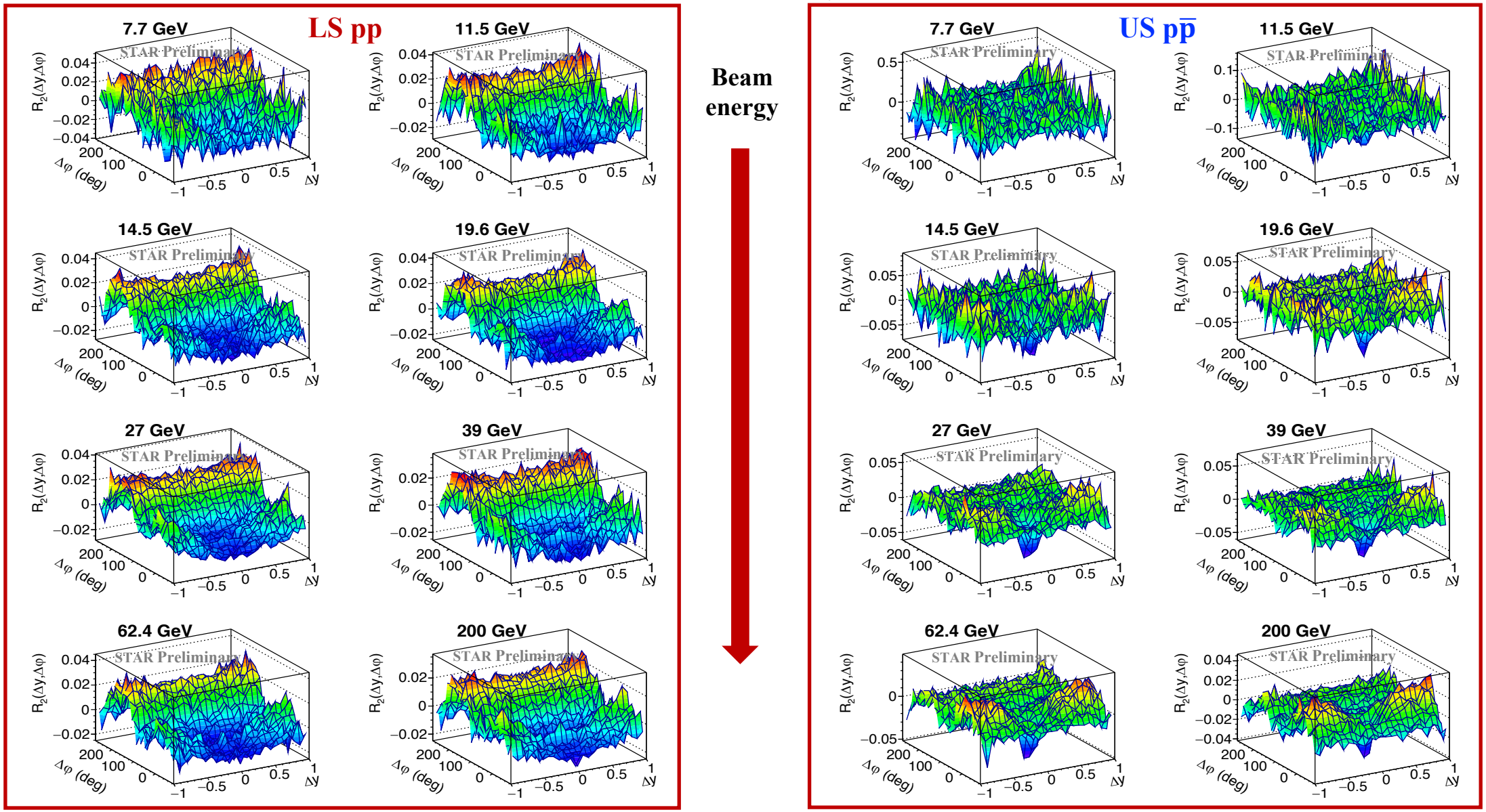
- ϕ-meson decay structure also seen in UrQMD simulation but with smaller magnitude

(30-40% centrality)



Correlations of pp

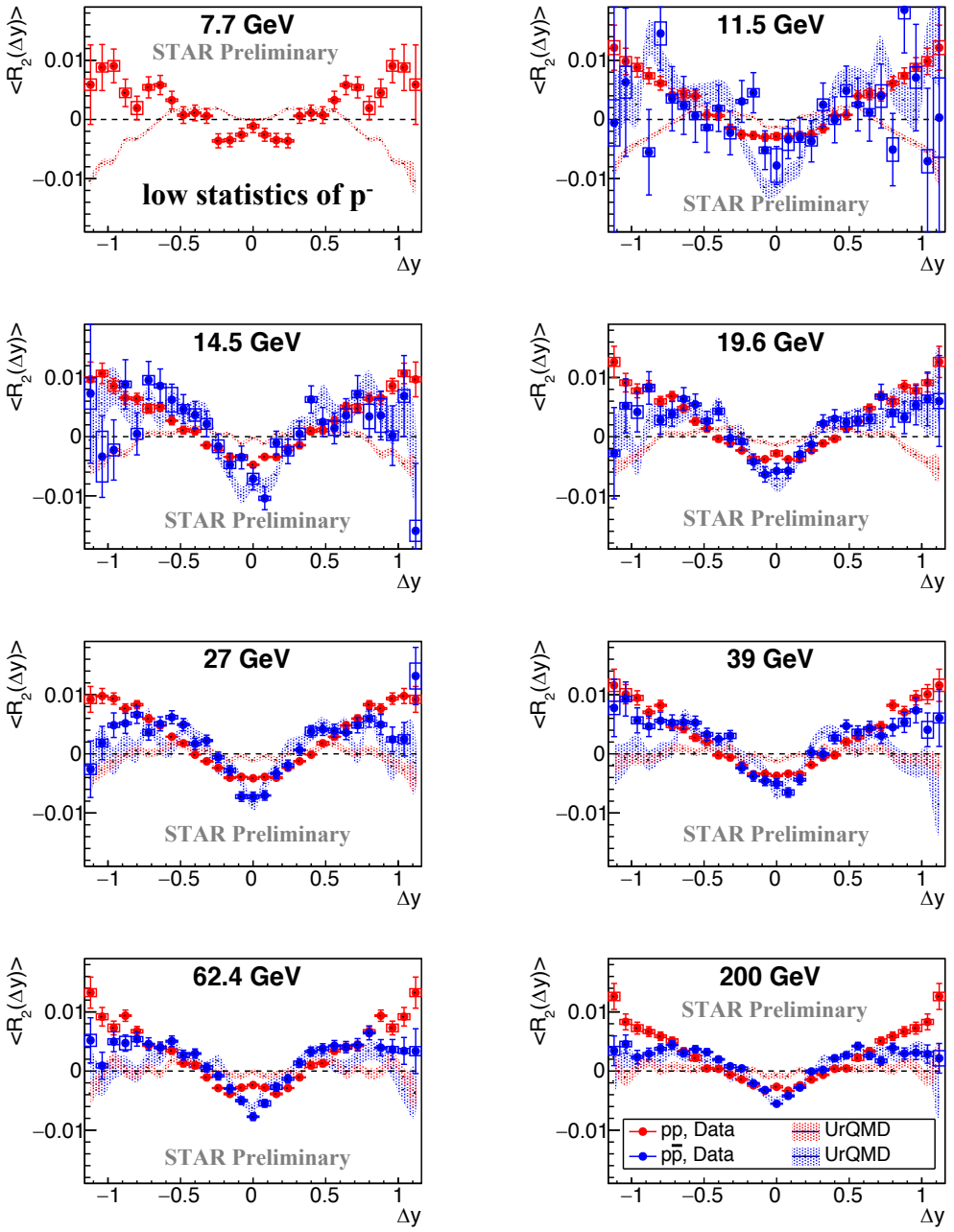
(30-40% centrality)



Correlations of pp

- A near-side strong anti-correlation is observed in proton correlations instead of a peak
  - ➢ Protons behave differently than mesons (π and K)
- Observed for the first time in A+A system
  - ➢ Anti-correlation in like-sign baryons was reported for small systems
    - ➢ e^+e^- annihilation at 29 GeV by TPC/Two-Gamma Collaboration (PEP, SLAC)
      H. Aihara et al. Phys. Rev. Lett. 57(1986) 3140
    - ➢ p+p at $\sqrt{s_{NN}}$=7 TeV by ALICE
      ALICE Coll., Eur. Phys. J. C (2017) 77:569
- The anti-correlation is observed in both like-sign and unlike-sign charge combinations
  - ➢ It is narrower in Δy for $p\bar{p}$ compared to pp
- UrQMD simulation reproduced the observed anti-correlation in unlike-sign pairs

(30-40% centrality)

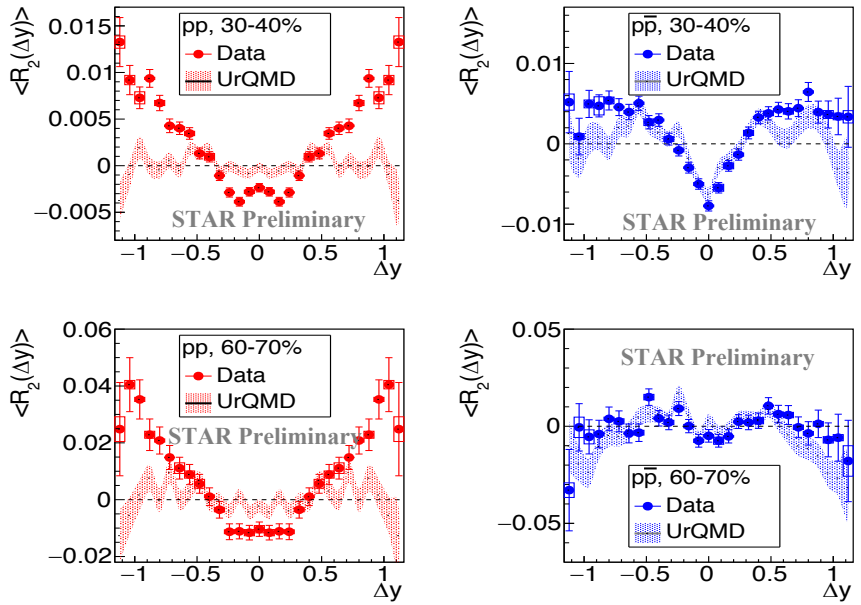


Centrality dependence of correlations

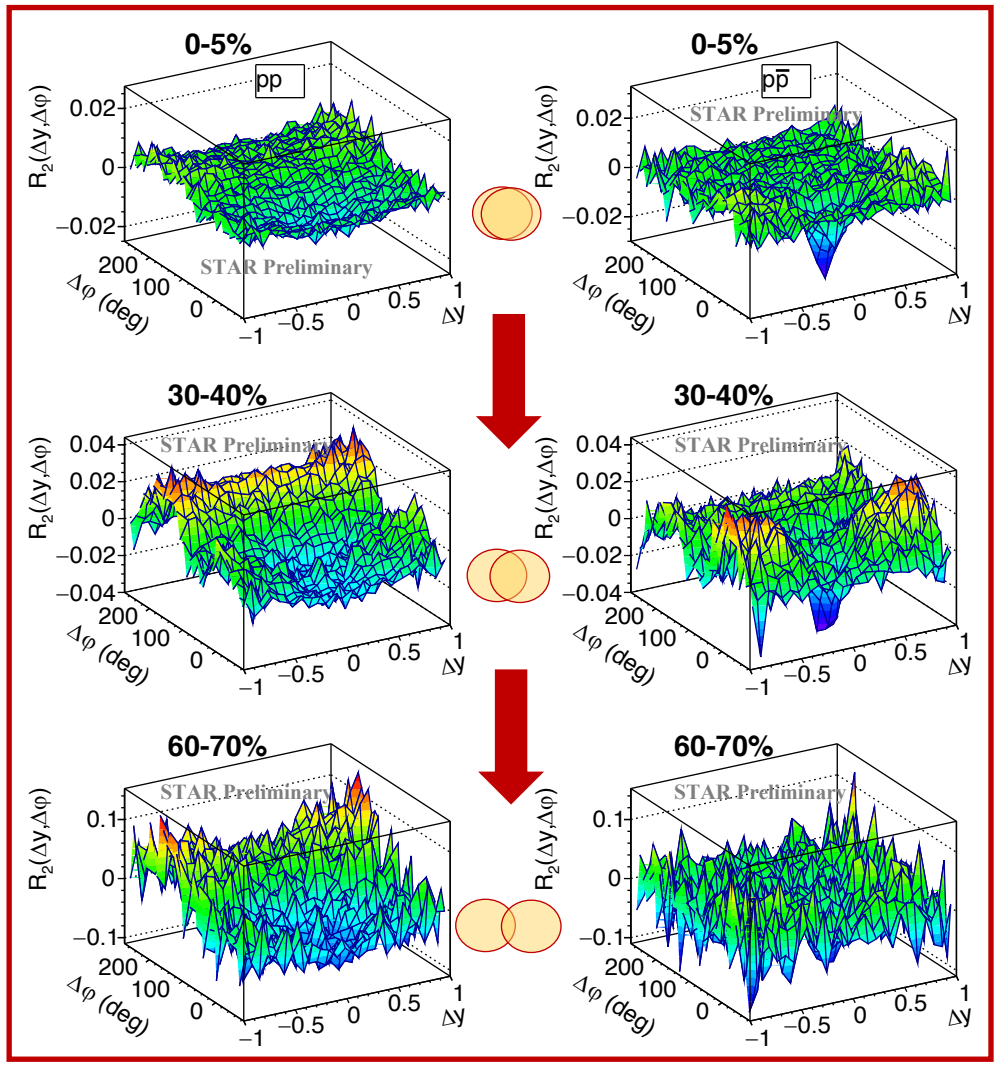
- Correlations of particles increase with centrality change from most central to peripheral collisions
  - For protons, the near-side anti-correlation increases significantly by centrality from most central to peripheral

- For all centralities, the anti-correlation observed in unlike-sign proton pairs $p\bar{p}$ is narrower in Δy compared to the like-sign pairs pp

- UrQMD simulation well reproduces the anti-correlation for unlike-sign proton pairs in different centralities



62.4 GeV, proton correlations



Summary

- Two-particle correlations of identified pions, kaons and protons have been studied in BES-I at RHIC for Au+Au collisions from 7.7 to 200 GeV
- No non-monotonic behavior was observed in two-particle correlations as a function of beam energy
- A previously observed $\Delta\varphi$ ridge for pions in 19.6 and 27 GeV at 0-5% was found as a detector effect
- The correlations of mesons (pions and kaons) show an expected near-side peak corresponding to the short-range mechanisms like jet fragmentation and resonance decays, and decreases with increasing beam energy
- The correlations between baryons (protons) exhibit a strong anti-correlations in the near-side region and this is observed for the first time in a A+A collisions
- The proton-proton anti-correlations is p_T independent and decrease with increasing beam energy and increase with the centrality changes from the most central to peripheral events

Back-up

p_T dependence of correlations

- Low p_T range: $0.2<p_T<0.6$ GeV/c for $\pi^{\pm}$, $K^{\pm}$ and $0.4<p_T<0.8$ GeV/c for $p^{\pm}$
- High p_T range: $0.6<p_T<2.0(1.6)$ GeV/c for $\pi^{\pm}$ ($K^{\pm}$) and $0.8<p_T<2.0$ GeV/c for $p^{\pm}$
- Correlations of pions and like-sign kaons do not show any significant p_T dependence
- The ϕ-meson decay structure in unlike-sign kaons gets narrower in Δy by increasing the transverse momentum of kaons
  - ➢ This is explained by the kinematics of $\phi(1020)$ decay to K^+K^-
- The near-side anti-correlation in both like-sign and unlike-sign proton pairs does not show any p_T dependence