Probing Anisotropic and Radial Flow with Di-hadron Correlations in the BES

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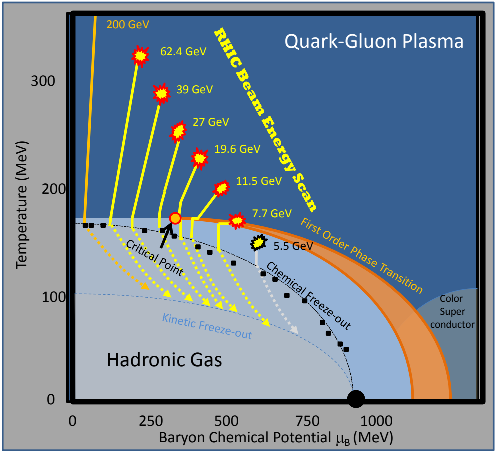
June 10th, 2015

About the BES program

In 2010 and 2011 RHIC completed phase I of the BES program with data sets at 7.7, 11.5, 19.6, 27 and 39 GeV,and in 2014, 14.5 GeV.

Goals of the BES program:

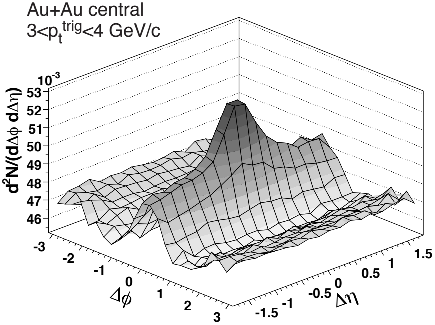
- Determine the energy at which key QGP signatures turn off.
- Search for the critical point.
- Search for the first order phase transition.



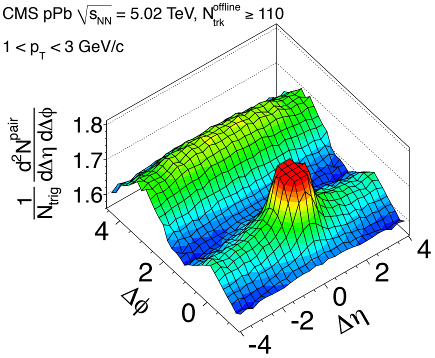
The QCD phase diagram

Di-hadron correlations from RHIC and LHC

Di-hadron correlations are a key observable in probing the collectivity of the system. How does the collectivity evolve in the BES?



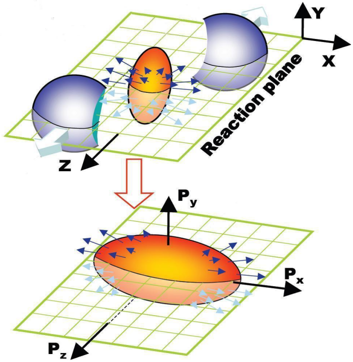
STAR ridge (Phys. Rev. C80 (2009) 064912)

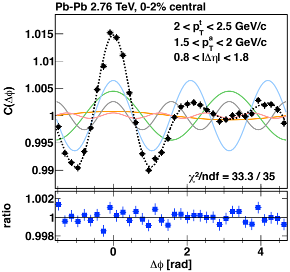


p+Pb di-hadron correlations (Phys. Lett. B 718 (2013) 795)

Anisotropic flow

Long range correlations (i.e. the ridge) are dominated by the anisotropic flow. So the following analysis will mostly concentrate on long range correlations ($1 < |\Delta\eta| < 2$) in an anisotropic flow study.



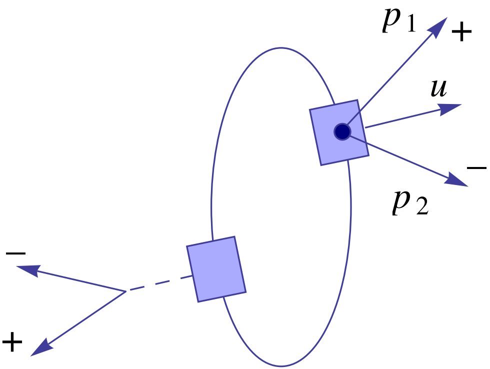


$C(\Delta\phi)$for particle pairs at $|\Delta\eta| > 0.8$.The Fourier harmonics for $V_{1\Delta}$to $V_{5\Delta}$ are superimposed in color. (arXiv:1109.2501v1)

$$\frac{dN}{d\Delta\phi} \propto 1 + 2\sum_{n=1}^{\infty} v_n^2 cos(n\Delta\phi)$$

Radial flow

Short range correlations (i.e., the near-side peak) will be influenced by radial flow. Pairs produced via charge conservation will be narrowed by radial flow.



A schematic view of the charge balancing mechanism, producing pairs of particles with opposite charges. The rectangles indicate fluid elements moving outward with a collective velocity u. The dot indicates the space-time location of the emission of the pair of opposite-charge particles of momenta p_1 and p_2. The dashed line represents a neutral resonance, decaying into a pair particles (Phys. Rev. Lett. 109, 062301 (2012))

Data sets and event/track selections

Au+Au collisions by center of mass energy $\sqrt{s_{NN}} = 7.7 \sim 39$ GeV

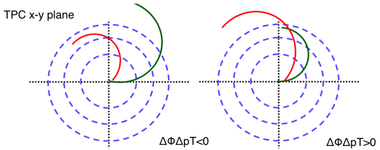
Energy (GeV)	pvz cut (cm)	Number of events
7.7	±70	4.7M
11.5	±50	12M
19.6	±40	21M
27	±40	38M
39	±40	117M

track cuts:

- $|\eta| < 1.0$
- $0.2 < p_T < 2$GeV/c
- number of TPC hits> 15
- fitted hits/Maximum possible hits > 0.52
- DCA < 2cm

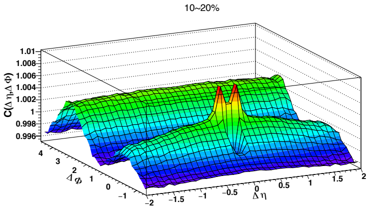
Pair loss corrections for the correlation function

In STAR BES enegies, track crossing is the dominant factor for pair loss.



From Michael Daugherity's thesis

Take Au+Au $\sqrt{s_{NN}}$ =19.6 GeV as an example:



For example,in the positive B field ,the two tracks may cross if:

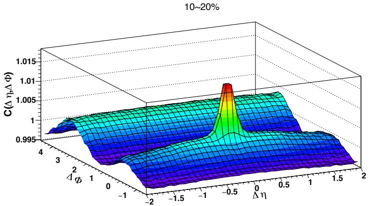
$++$:$\Delta\phi\Delta p_T < 0$

$--$:$\Delta\phi\Delta p_T > 0$

$+-$:$\Delta\phi > 0$

$-+$:$\Delta\phi < 0$

reversely in negative B field.



Correlation function

Mixed events are used to determine the uncorrelated yield and to correct for non-uniform acceptance.

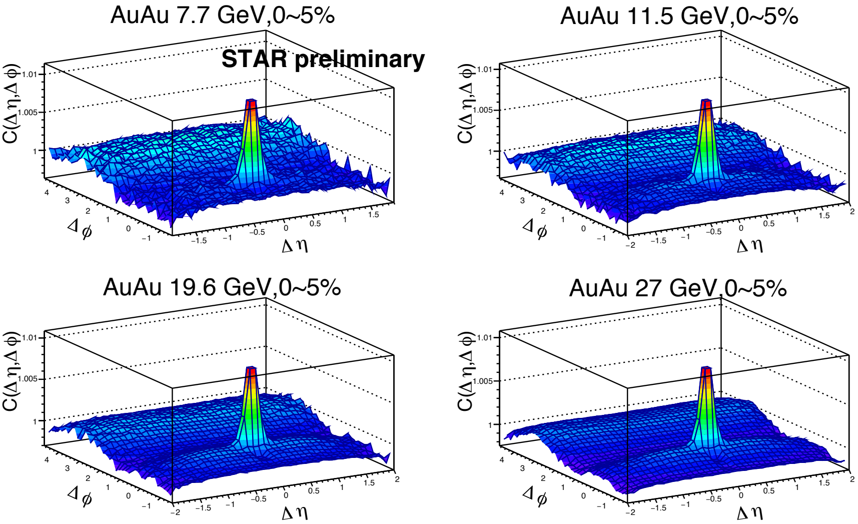
The correlation function we extract is:

$$C(\Delta\phi, \Delta\eta) = \frac{N_{mixed}}{N_{same}} \times \frac{N_{same}(\Delta\phi, \Delta\eta)}{N_{mixed}(\Delta\phi, \Delta\eta)}$$

two-particle Fourier coefficients:

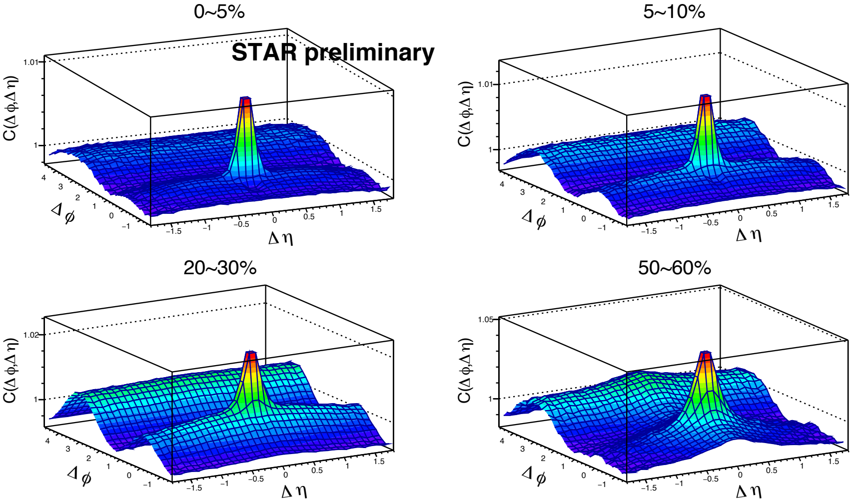
$$v_n\{2\}^2 = \sum_i C_i cos(n\Delta\phi_i) / \sum_i C_i$$

Di-hadron correlations in BES energies

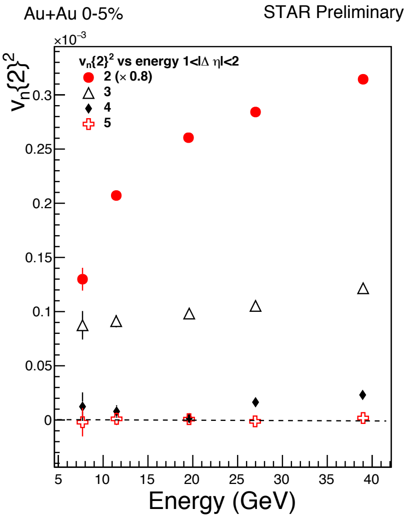


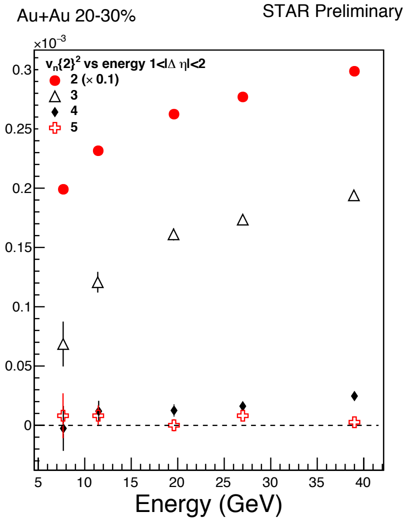
Centrality evolution of di-hadron correlations

Take AuAu $\sqrt{s_{NN}} = 19.6$ GeV as an example to illustrate the centrality evolution of the di-hadron correlations:

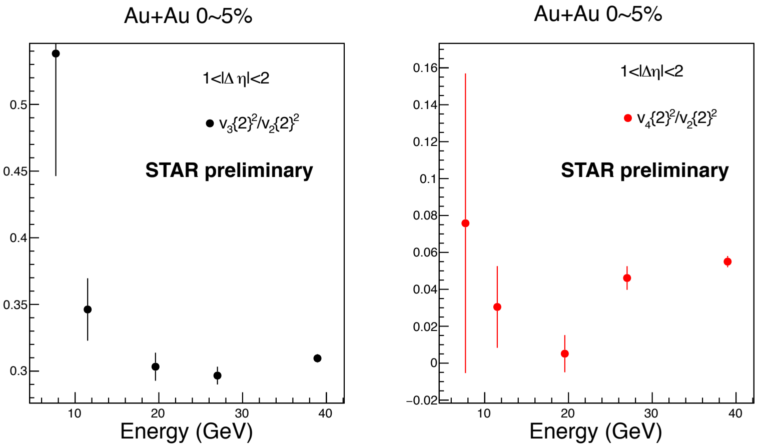


$v_n\{2\}^2$ vs energy





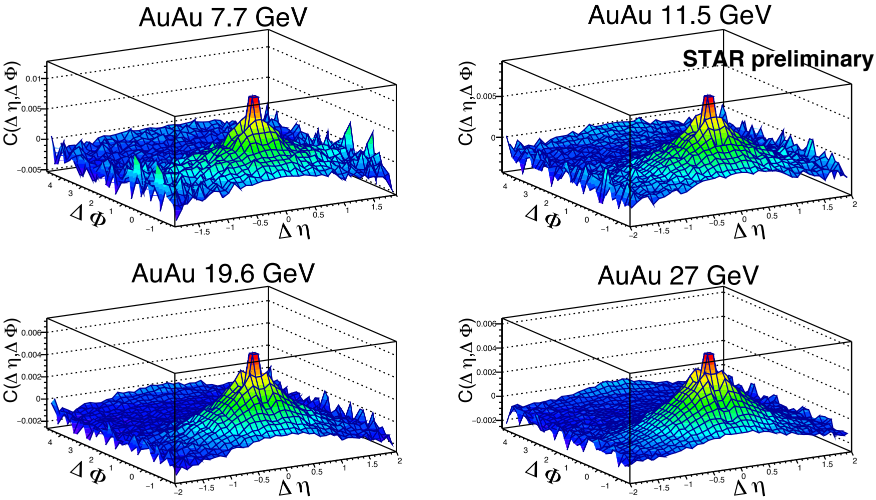
$v_n\{2\}^2/v_2\{2\}^2$ vs energy



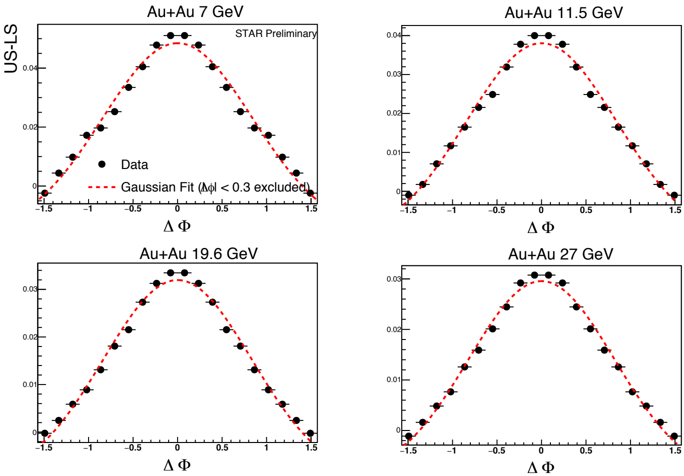
As higher harmonics are damped more by finite viscosities, the ratios have an inverse relationship to viscosity. (D. Teaney, L. Yan, Phys. Rev. C 83 (2011) 064904, G. Y. Qin, H. Petersen, S. A. Bass, B. Muller, Phys. Rev. C82, 064903 (2010))

Charge-dependent correlations

By subtracting like-sign correlations from unlike-sign correlations($C(+-,-+) - C(++,--)$), contributions from anisotropic flow are eliminated, isolating the radial flow.

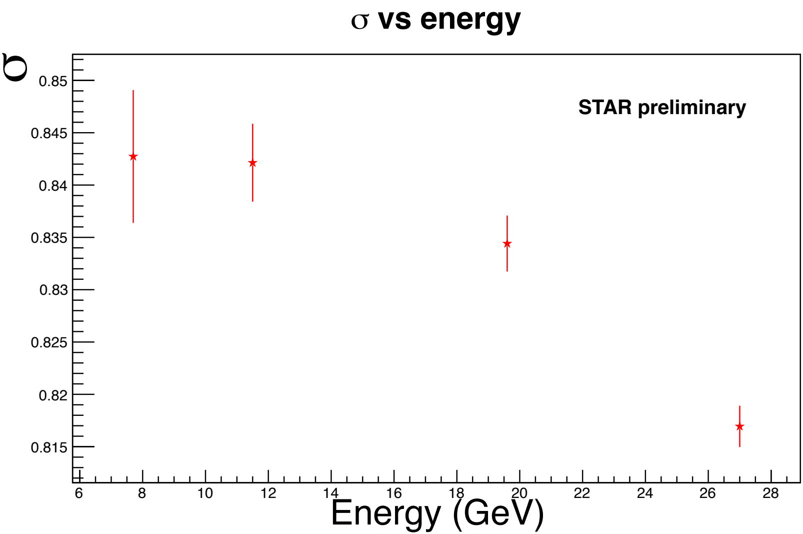


Fit to the projection in $\Delta\phi$



We fit those data points with Gaussian functions $Ae^{-\frac{1}{2}(\frac{x}{\sigma})^2} + B$ in the $|\Delta\phi| > 0.3$ region excluding e^+e^- pairs.(B. Abelev et al (STAR Collaboration), arXiv:0806.0513)

σ vs energy



σ decreases with energy, which implies increasing radial flow.

Summary

- Di-hadron correlations evolve with energy in the BES region.
- Ridge v_n coefficients generally increase with energy.
- US-LS near-side peak narrows with increasing energy.