



Contribution ID: 82

Type: Oral

## Principal Component Analysis of collective flow in Heavy-Ion collisions

Tuesday, 25 June 2019 18:20 (20 minutes)

Principal Component Analysis (PCA) is a mathematical tool that can capture the most important information in data. As one of the unsupervised algorithms of machine learning, PCA is good at discovering modes or hidden patterns in huge amount of data. It has seen successful applications of PCA in computer vision, data science and physics. Compared with deep learning algorithms, the advantage of PCA lies in its simple and elegant mathematical formulation, which is understandable and traceable. In this talk, we implement PCA to analyze collective flow in Relativistic Heavy-Ion Collisions.

In the first part [1], we demonstrate the ability of PCA to automatically discover flow without any guidance from human beings. PCA is applied to particle yields distribution as a function of transverse plane angle  $\varphi$  in the reaction plane. The eigenmodes decomposed by PCA are similar to, but not identical with traditional Fourier bases. Furthermore, we define new flow harmonics with PCA modes and the new ones serve as better linear predictors for initial eccentricities than traditional ones. Specifically, correlations between same and different harmonics of initial and final states increase and decrease respectively, showing smaller mode-mixing effects.

In the second part [2], as another application of PCA, we study factorization breaking in two-particle correlation  $V_{n\Delta}(p_{T1}, p_{T2})$  with respect to transverse momentum  $p_T$  [3]. In particular, we focus on the sub-leading flow, which hopefully sheds light on different sources in initial geometries [4]. However, the stability and interpretation of PCA results have to be re-examined. We design different tests to explore the limitations of PCA, arguing that improper choice of  $p_T$  range and weight matrix might lead to confusing and inconsistent results. As a consequence, these mentioned technical issues should be addressed before we could come to any conclusions or truly understand physics from PCA results.

[1] Z. Liu, W. Zhao and H. Song, in preparation.

[2] Z. Liu, A. Behera, H. Song and J. Jia, in preparation.

[3] CMS Collaboration, Phys.Rev. C.96.064902

[4] A. Mazeliauskas and D. Teaney, Phys.Rev. C91 (2015) no.4, 044902

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**Session Classification:** Parallel: Initial conditions for hydrodynamics & transport coefficients

**Track Classification:** Initial conditions for hydrodynamics & transport coefficients