IBIC2023

12th INTERNATIONAL BEAM INSTRUMENTATION CONFERENCE
SASKATOON, CANADA
September 10-14, 2023
Canadian Light Source | Centre canadien de rayonnement synchrotron

Operation Performance Evaluation of Accelerator Based on Cluster Analysis of Bunch-by-bunch Diagnostic Data

YANG XING[1,3], LENG YONGBIN[2,*], ZHOU YIMEI[4]

1. Shanghai Institute of applied Physics, Chinese Academy of Sciences, Shanghai 201800, China

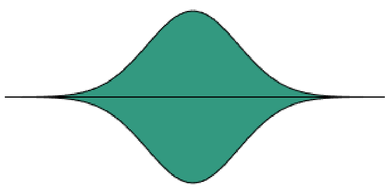
2. University of Science and Technology of China, Anhui 230026, China;

3. University of Chinese Academy of Sciences, Beijing 100049, China;

4.Shanghai Advanced Research Institue, Chinese Academy of Sciences, Shanghai 200120, China

Introduction

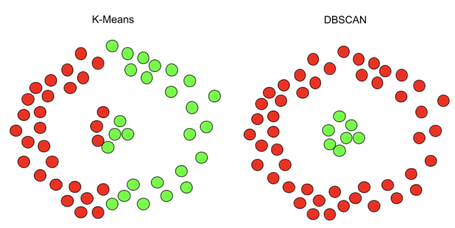
- In order to improve the operating performance of the particle accelerator, it is better to develop a toolkits to monitor and analyze the sub-health state of the facility in addition to ensuring the stability of basic parameters. such as
- The 3D bunch-by-bunch position measurement system combined with cluster analysis is a feasible solution for this requirement.



- beam current
- lifetime
- transverse size
- longitudinal length
- transverse postion
- longitudinal phase

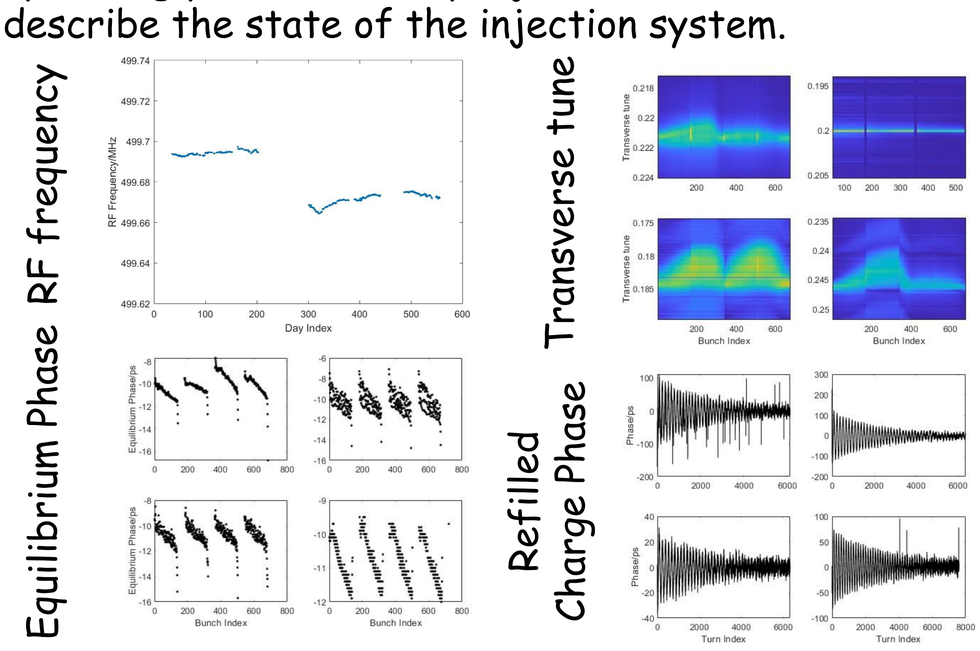
Algorithm

- Normalize the features of every sample into a vector space, compute the distances between them and then classify them based on their proximity is the fundamental principle of clustering analysis.
- Sample can be classified based on the distance between it and the center of the cluster, or they can be grouped into the same cluster if the distance between them is less than a certain threshold.
- This approach corresponds to the K-means and the DBSCAN algorithm respectively.



Features

- SA or FA data indicates the long-term operation status of the equipment.
- Evaluating the short-term or even transient operating status of a device requires turn-by-turn or even bunch-by-bunch variation data.
- We abstract the bunch-by-bunch data provided by HOTCAP into a feature that describes the short-term state of the device.
- We abstract the transient changes in the lateral operating point caused by injection into features that describe the state of the injection system.



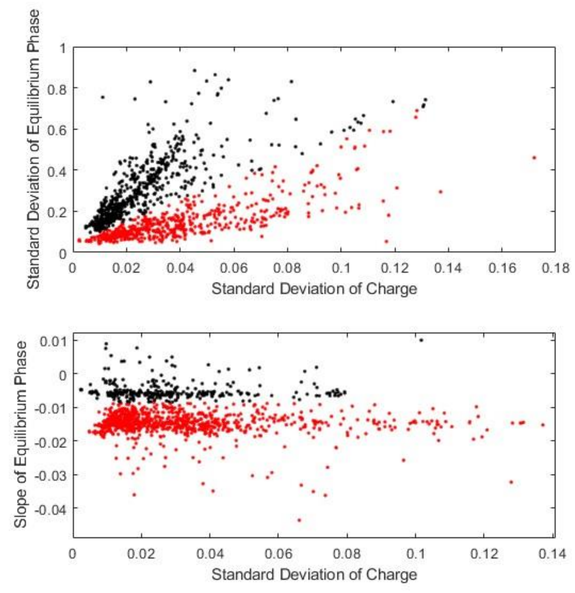
HOTCAP

- A software package to be used in high-speed oscilloscope-based three-dimensional bunch-by-bunch charge and position measurement is presented.
- It offers many additional features such as injection analysis, bunch response function reconstruction, and turn-by-turn beam analysis.
- The software package has an easy-to-understand graphical user interface and convenient interactive operation, which has been verified on the Windows 10 system.

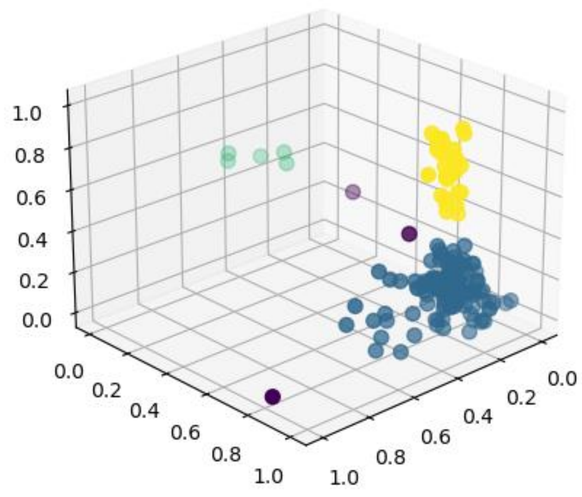
Analysis

Collect steady-state operation data on different days, extract the equilibrium phase and perform cluster analysis along with the feature of fill pattern.

- X is the feature of fill pattern, which represents the uniformity of charge filling between bunches.
- Y in up represents the dispersion of equilibrium phases. Y in bottom represents the slope of equilibrium phases.



- Collect injection data on different days.
- The longitudinal motion of refilled charge can be abstracted as three features: vibration amplitude, vibration frequency, and decay time.



Conclusion

- Cluster analysis can be used to evaluate the operation performance using the bunch-by-bunch diagnostic data.
- In SSRF storage ring, the relationship between the equilibrium phase and the filling pattern can be clustered in two different states.
- There are three different states in which the injection system is matched to the storage ring.

References
[1] https://scikit-learn.org/1.2/
[2] Xu X Y, Leng Y B, Gao B, et al. HOTCAP: a new software package for high-speed oscilloscope-based three-dimensional bunch charge and position measurement[J]. Nuclear Science and Techniques, 2021, 32: 1-11.

Contact Email: lengyb@ustc.edu.cn