The development of beam trip diagnostic system for BEPCII storagering

J.S. Cao Q.Y. Deng J.H. Yue

Institute of High Energy Physics, CHINA

Outline

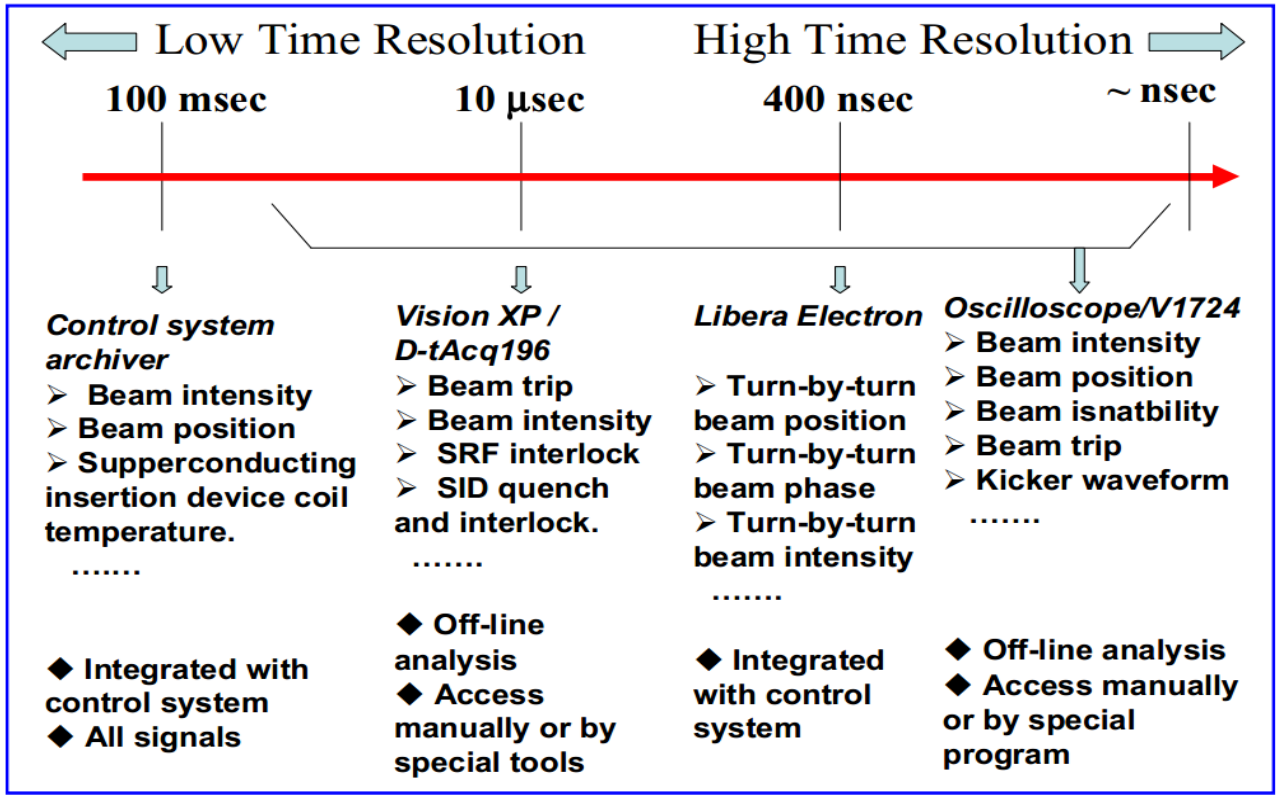
- Introduction
  - Examples
  - BEPCII storage rings
- Bunch-by-bunch system
- Analysis results
  - RF trip
  - Magnet power instabilities
  - Beam instabilities
- summary

Examples of beam trip diagnosis

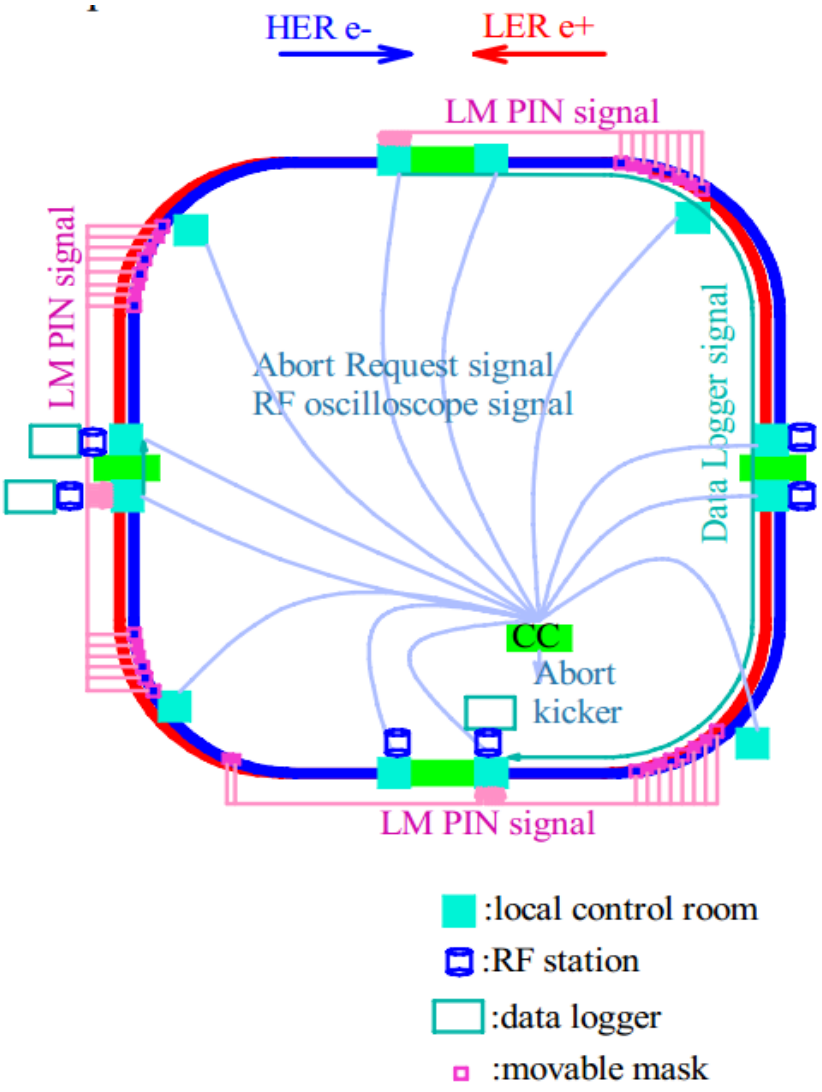
The beam trip is an important problem for accelerator operation. It is the hot spot in research for knowing which system caused the beam trip. Because the accelerator system is very complicated, involves many subsystems, and various conditions are mixed together, so, it is difficult to get to the real cause for beam trip. At present, many accelerator all over the world has established a powerful beam trip diagnostic system, such as LHC, PEP-II, RHIC, TLS and so on.

Examples of beam trip diagnosis

Based on a variety of measurement tools, the Taiwan light source has developed a beam trip diagnostic system, it Includes a high speed data recorder, oscilloscope, BPM electronics (post mortem data) and the bunch by bunch feedback system.



Examples of beam trip diagnosis



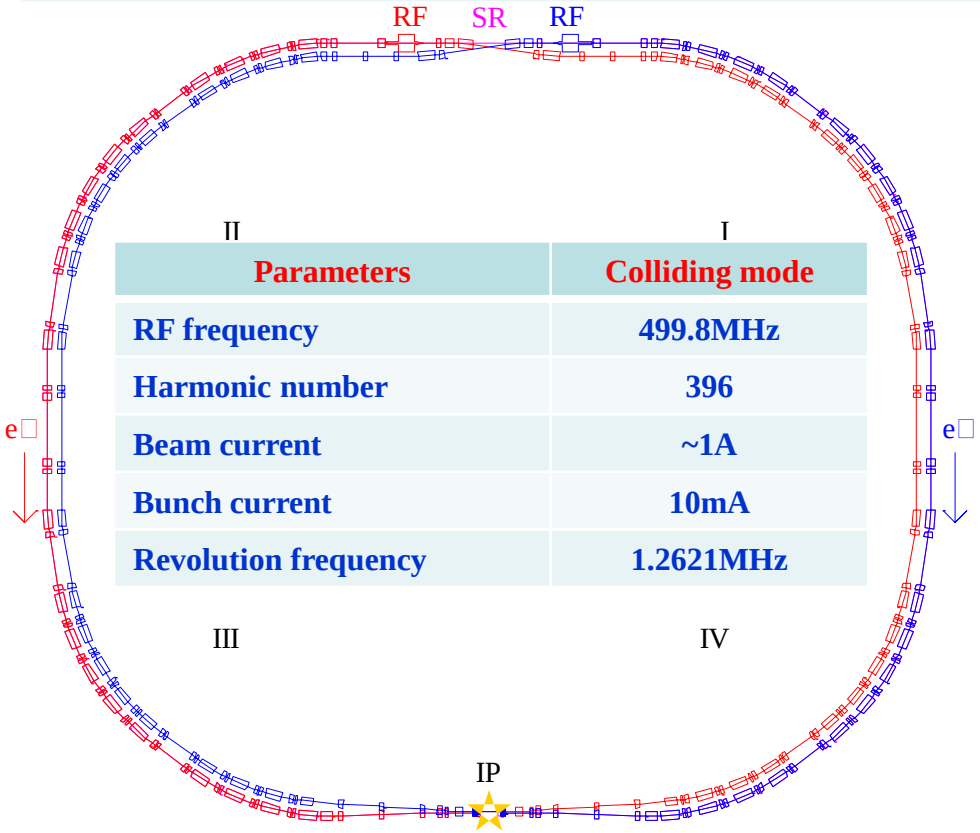
KEKB beam trip diagnostic system can record a lot of beam information, including the beam intensity, beam loss detectors signal, RF signal, beam phase signal and signal of injection trigger.

Examples of beam trip diagnosis

- **BESSY II: based on iGp electronics, The beam trip diagnosis is made.**
- **PEP II: based on the data of turn by turn BPM, and through the method of combining time domain and frequency domain, to analyze the beam trip.**
- **PETRA III: has established a perfect machine protection system, the system contains many subsystems, such as beam current measurement system, vacuum system, a temperature detection system, the beam position measurement system and orbit feedback system,RF system, power supply system, PPS and so on.**

Beam trip in BEPCII storage ring

High beam current can cause the beam instability and make devices unstable, thus easily lead to the beam trip. Beam trip seriously affects the efficiency of the machine, also may cause damage to the hardware system. So, it is necessary for BEPCII to develop a diagnostic system for studying the beam trip.



Parameters	Colliding mode
RF frequency	499.8MHz
Harmonic number	396
Beam current	~1A
Bunch current	10mA
Revolution frequency	1.2621MHz

BEPCII double rings layout

Cause of beam trip

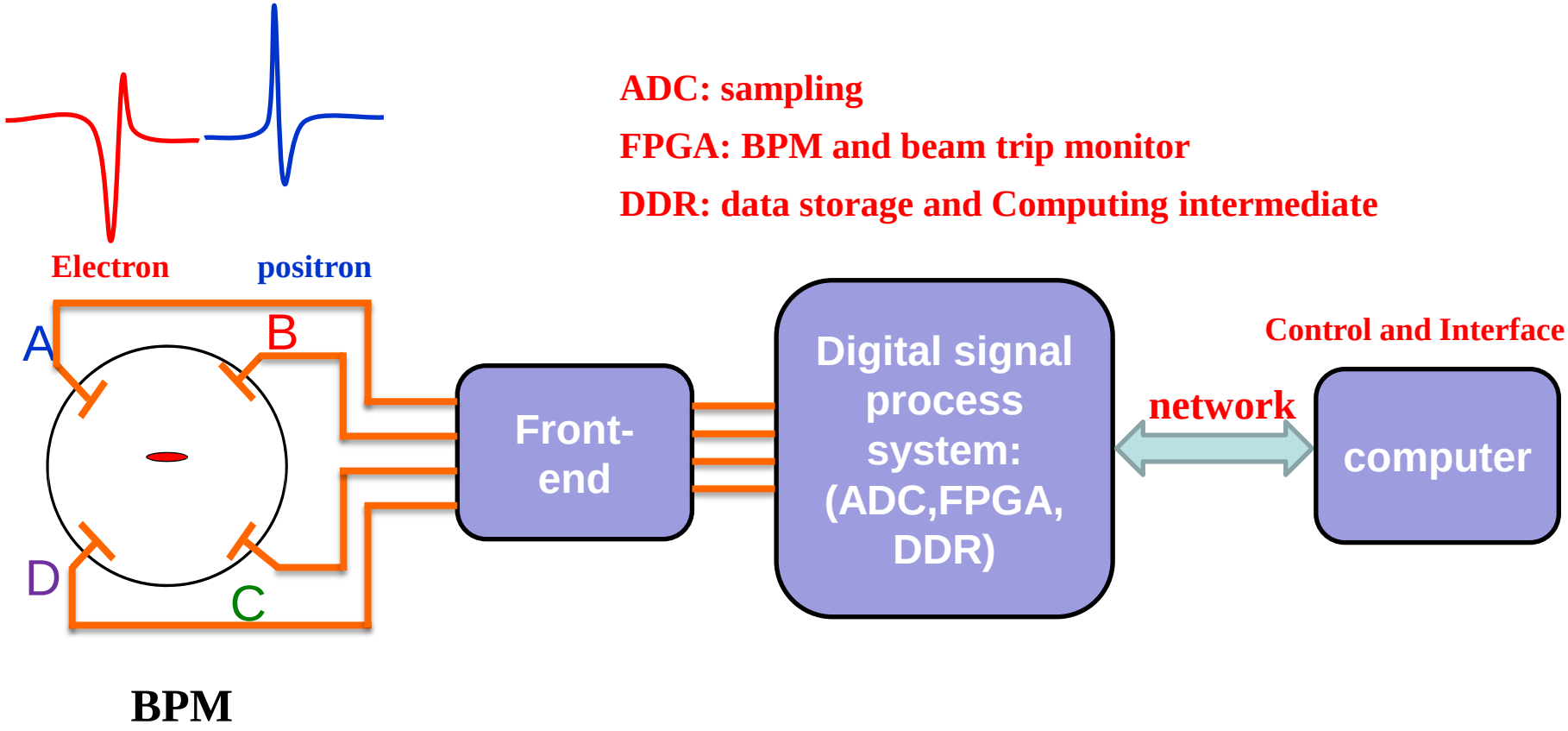
- Subsystem failure
- RF (trip, LLRF)
- Beam instabilities
- …

Result of beam trip

- Degrade the operating efficiency
- Troubleshoot time cost
- Others subsystem trip
- …

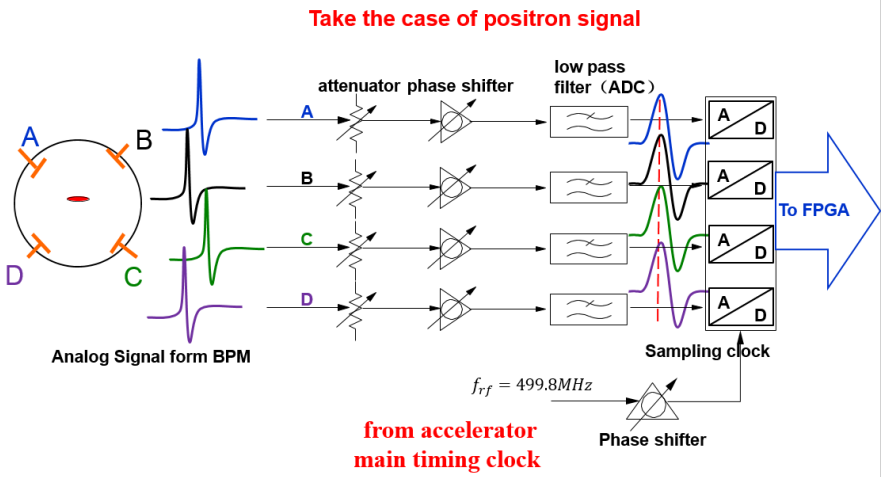
Bunch-by-bunch system overview

- **Bunch-by-bunch position measurement prototype for BEPCII**



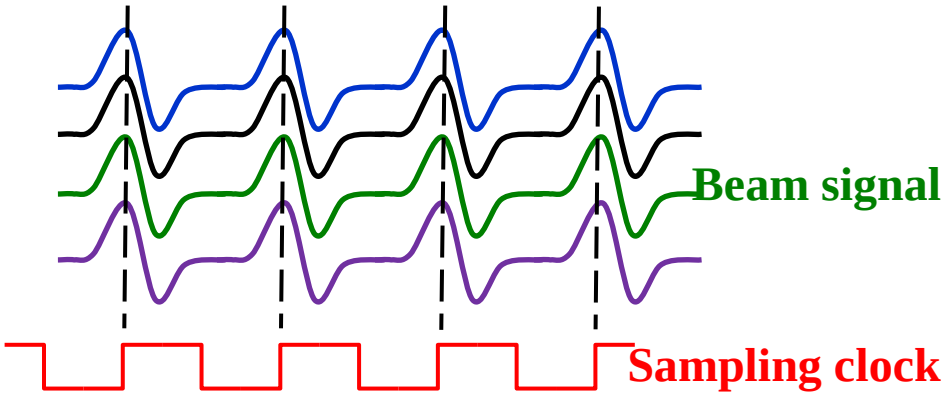
Front end and sampling

- Sampling rate : RF frequency (~500MHz).
- large analogue bandwidth
- Achieve high isolation



Front end and ADC schematic

$$I_{bunch} = k\sum(a+b+c+d)$$



Ideal Sampling schematic

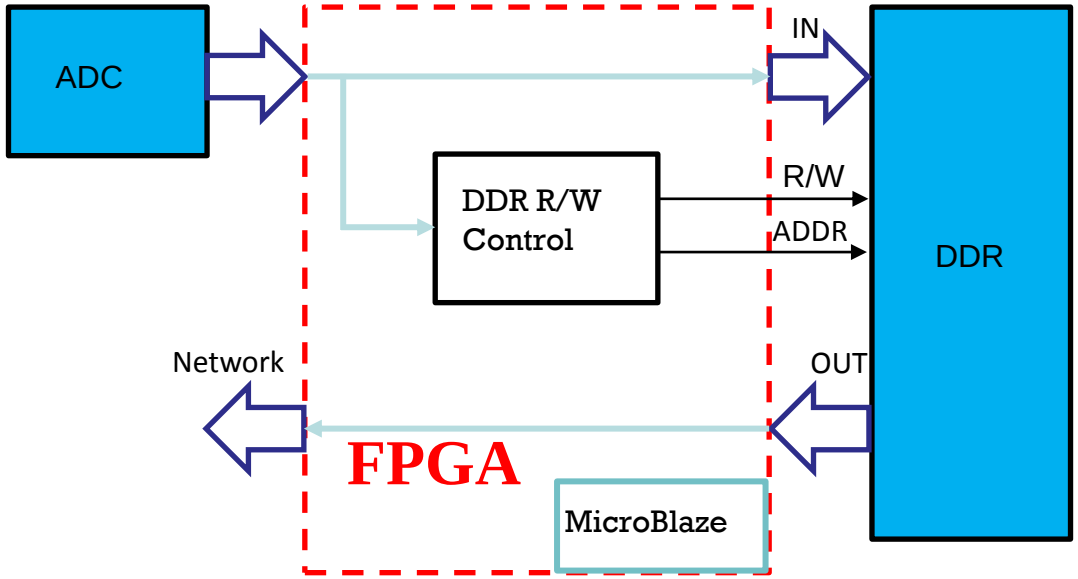
Digital signal process

- 4GB DDR3 memory (2 second data)
- Write all sampling data to DDR
- Judge logic for beam trip in FPGA(Regardless of the oscillation):

$$I_{beem} = k\sum_{t_i}^{t_i+t_{rev}}(a+b+c+d)$$

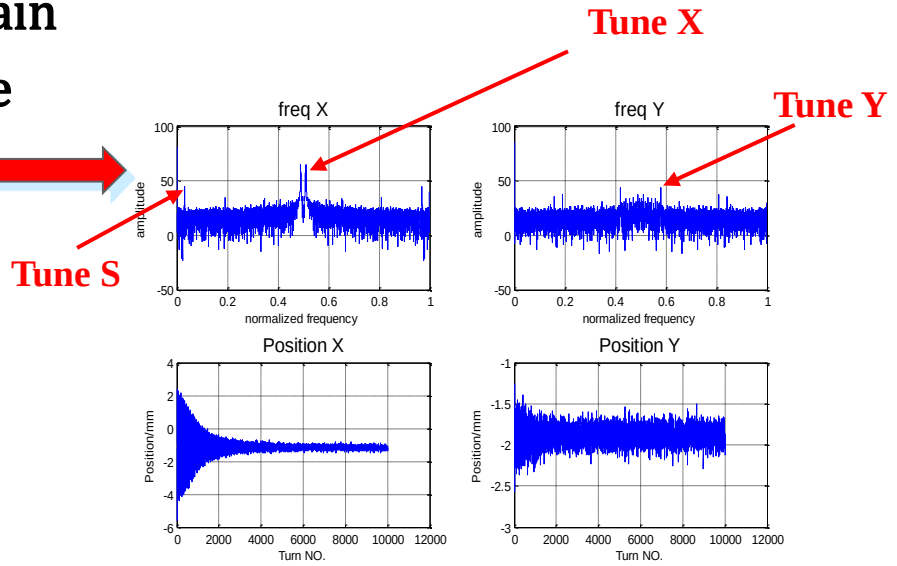
system doesn’ t need any trigger signal input

- lock the DDR data after beam trip then Transport the DDR data to computer

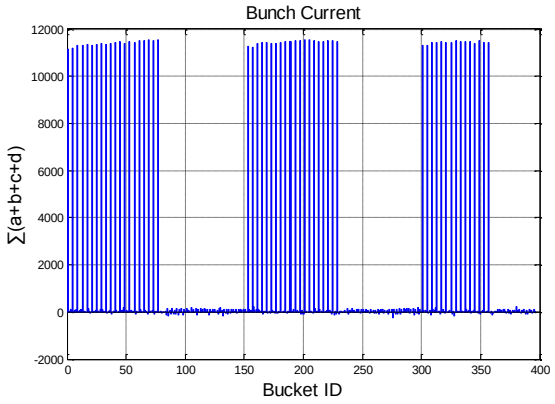


Beam trip research in BEPCII

- Beam trip events
  - more than 300 beam trip events had been collected and analysis
  - Many contrast experiment
- Beam trip analysis by bunch-by-bunch system
  - Time domain and frequency domain
  - Bunch-by-bunch and turn-by-tune
  - Tune in three dimensions
- Some trip events become clear
  - RF trip
  - Magnet power instabilities
  - Beam instabilities
  - ...

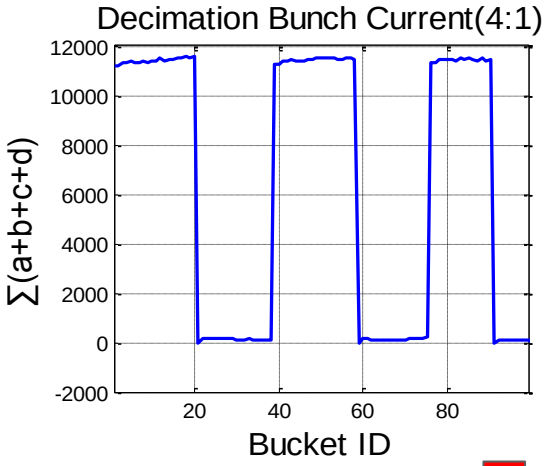


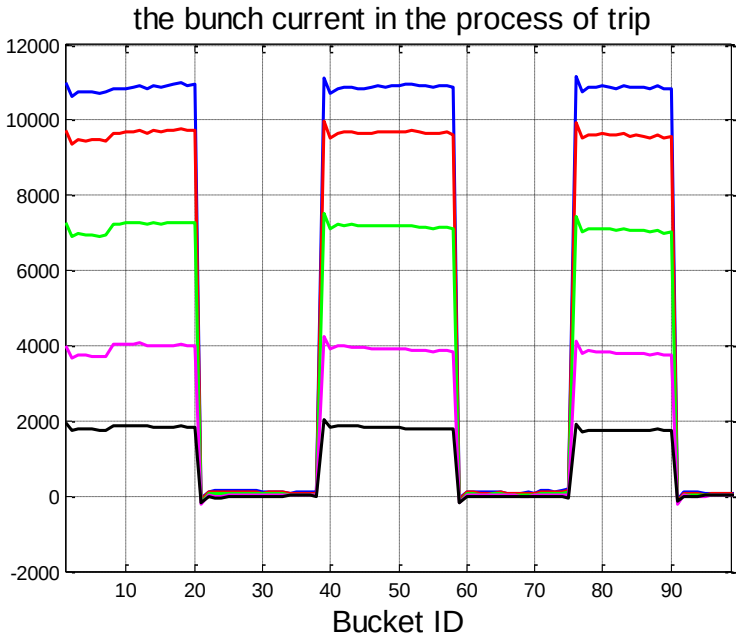
RF trip



Filling pattern: three bunch train
bunch spacing (8ns)

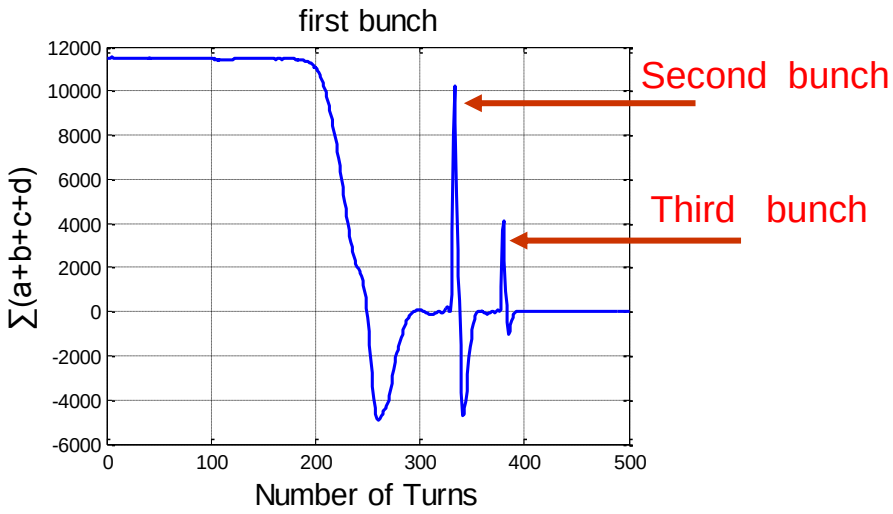
extraction

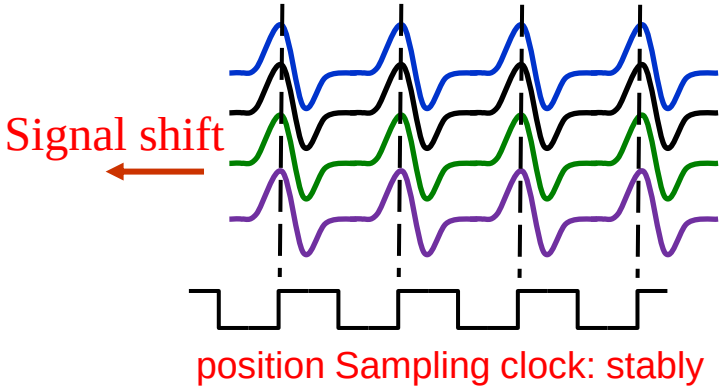


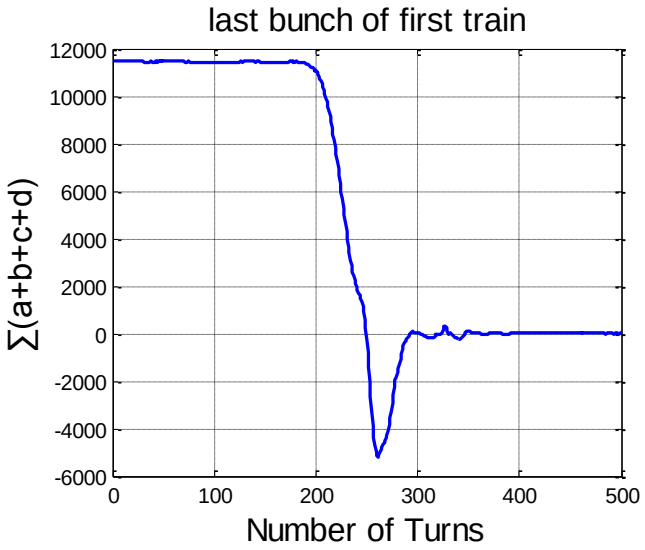


The bunch current is uniform in the process of trip

RF trip





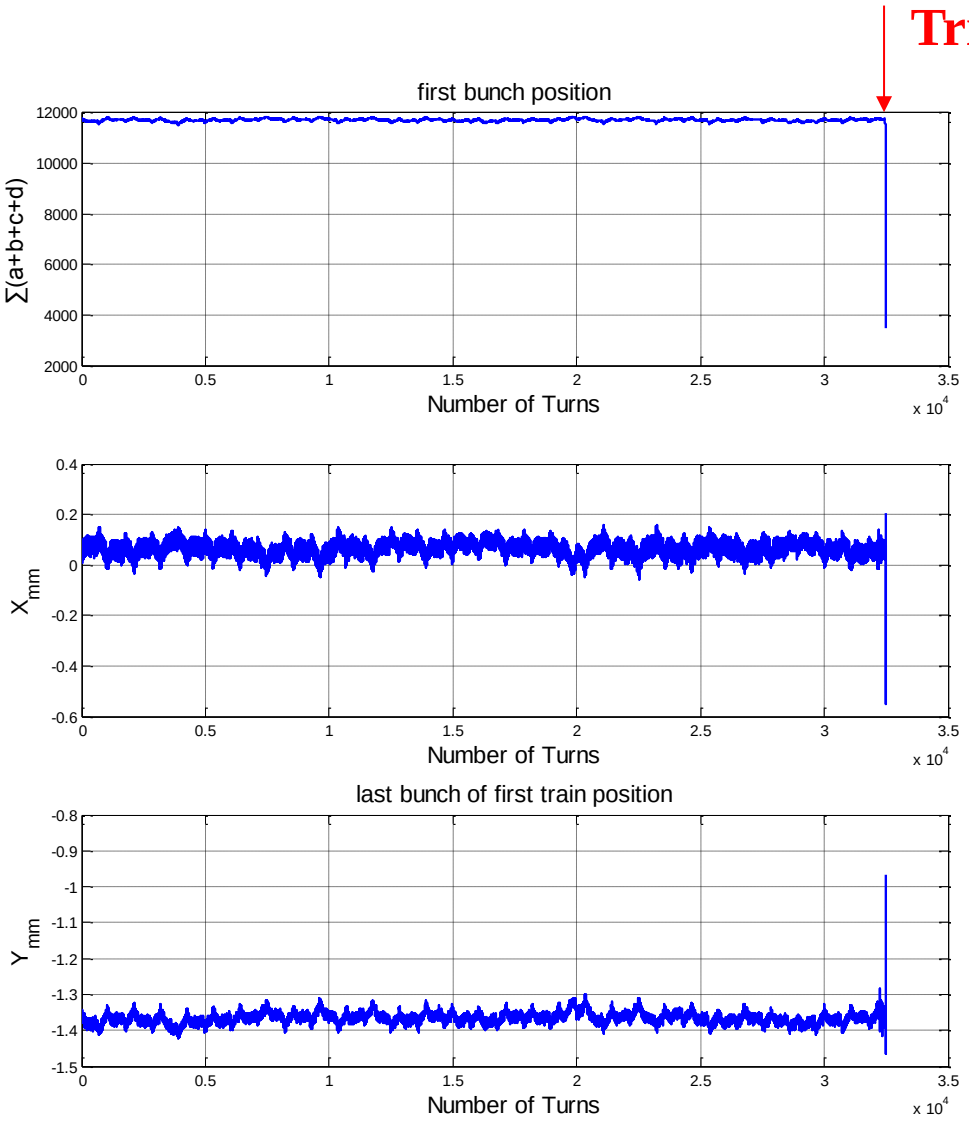


→Sum Signal change
→beam longitudinal phase changed violently
→ beam energy has changed

fast process ~200us (0.8us per turn)

The sum signal in the process of beam trip

RF trip



No position change

No obvious Instability oscillation

RF trip

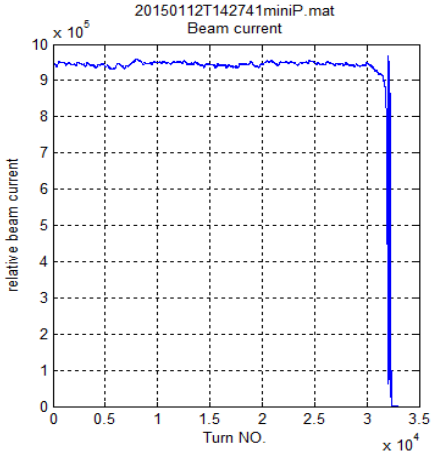
- **Conclusion**
  - The bunch current is uniform in the process of trip
  - No obvious Instability oscillation
  - No position change
  - longitudinal phase changed →Beam energy change

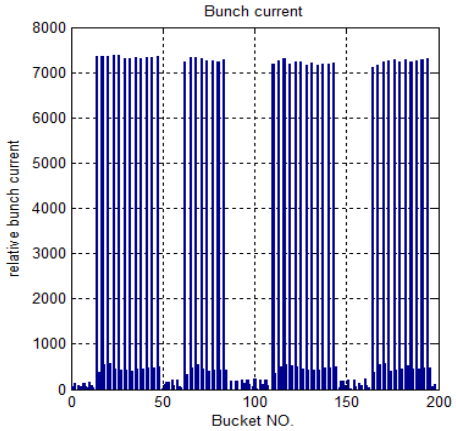
  →RF trip!

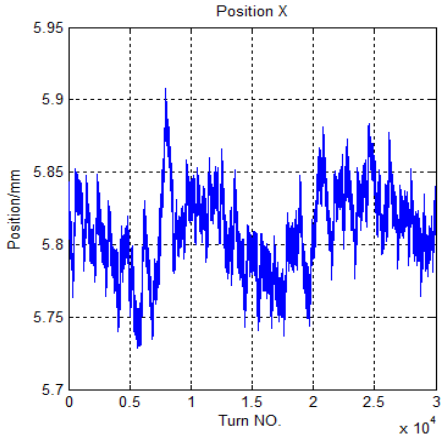
- confirmation experiments
  - turn off the RF system manually

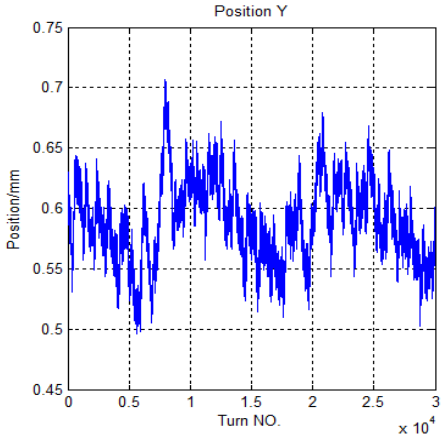
Almost all the beam trip events in BEPCII storage rings are accompanied with RF trip, or may say that will cause RF trip .

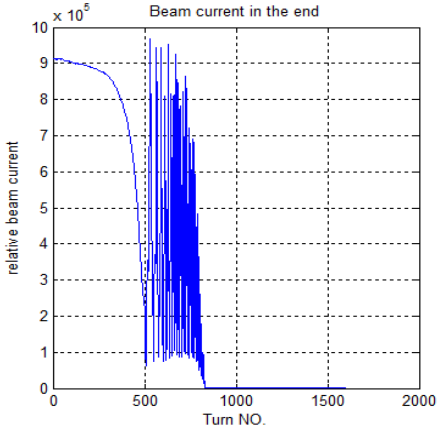
The online measurement results of beam trip—caused by RF trip

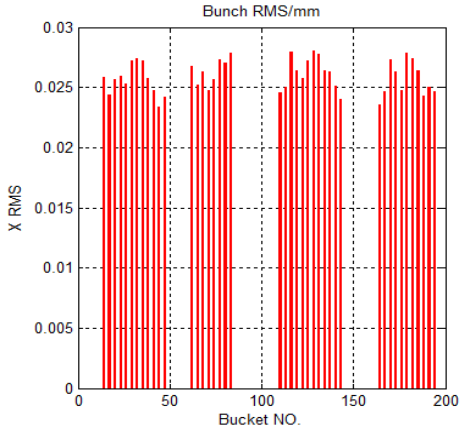


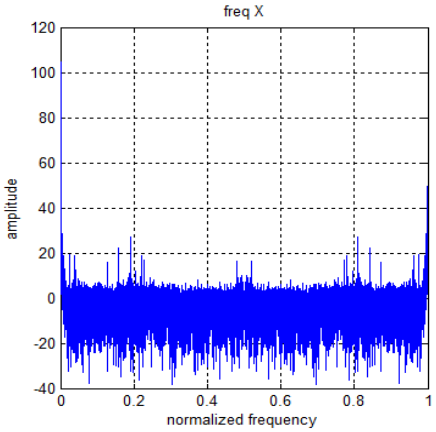


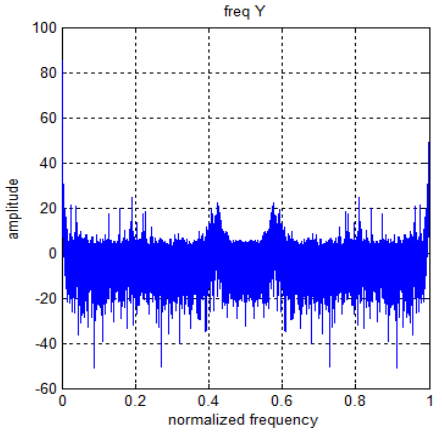






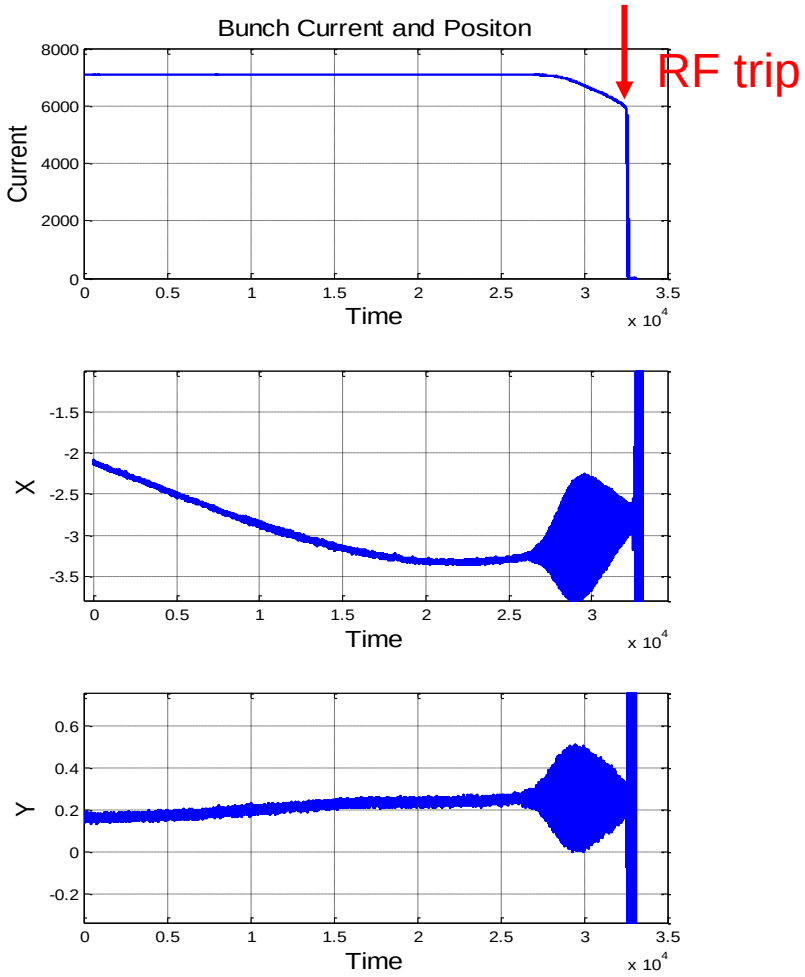




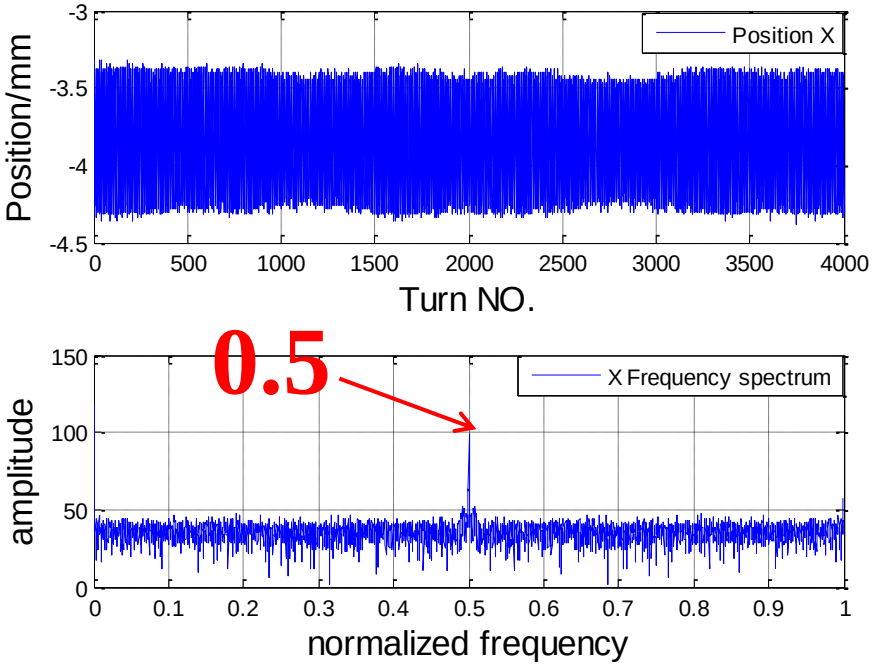


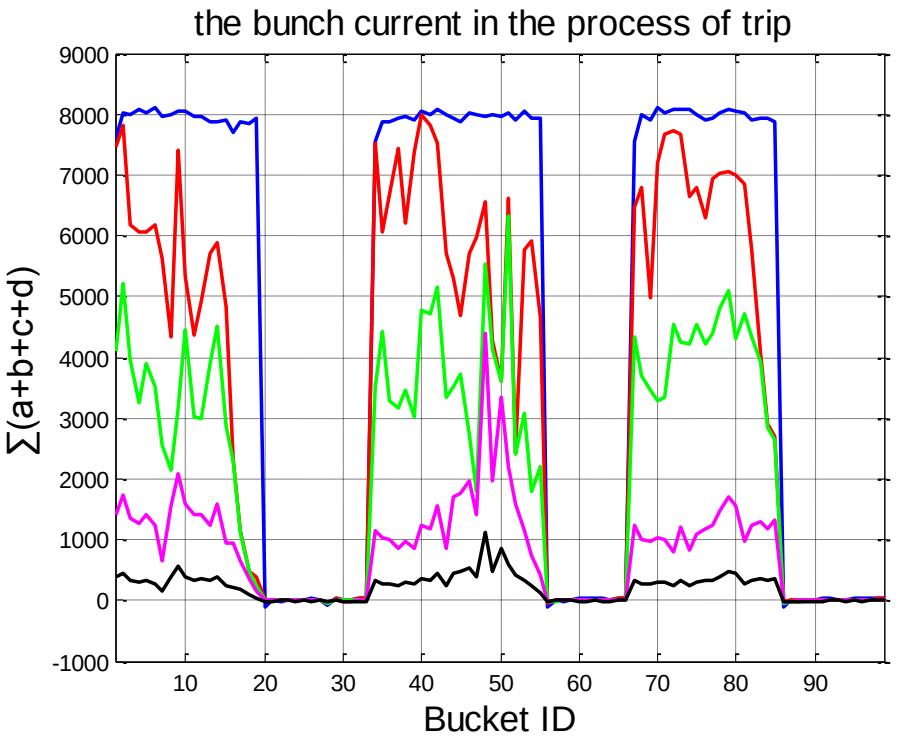
Magnet power instability

- There is no fast monitoring system for magnet power.
- Magnet power failure
- Analysis the beam trip by Magnet power instability . Needed!



Magnet power instability: resonance



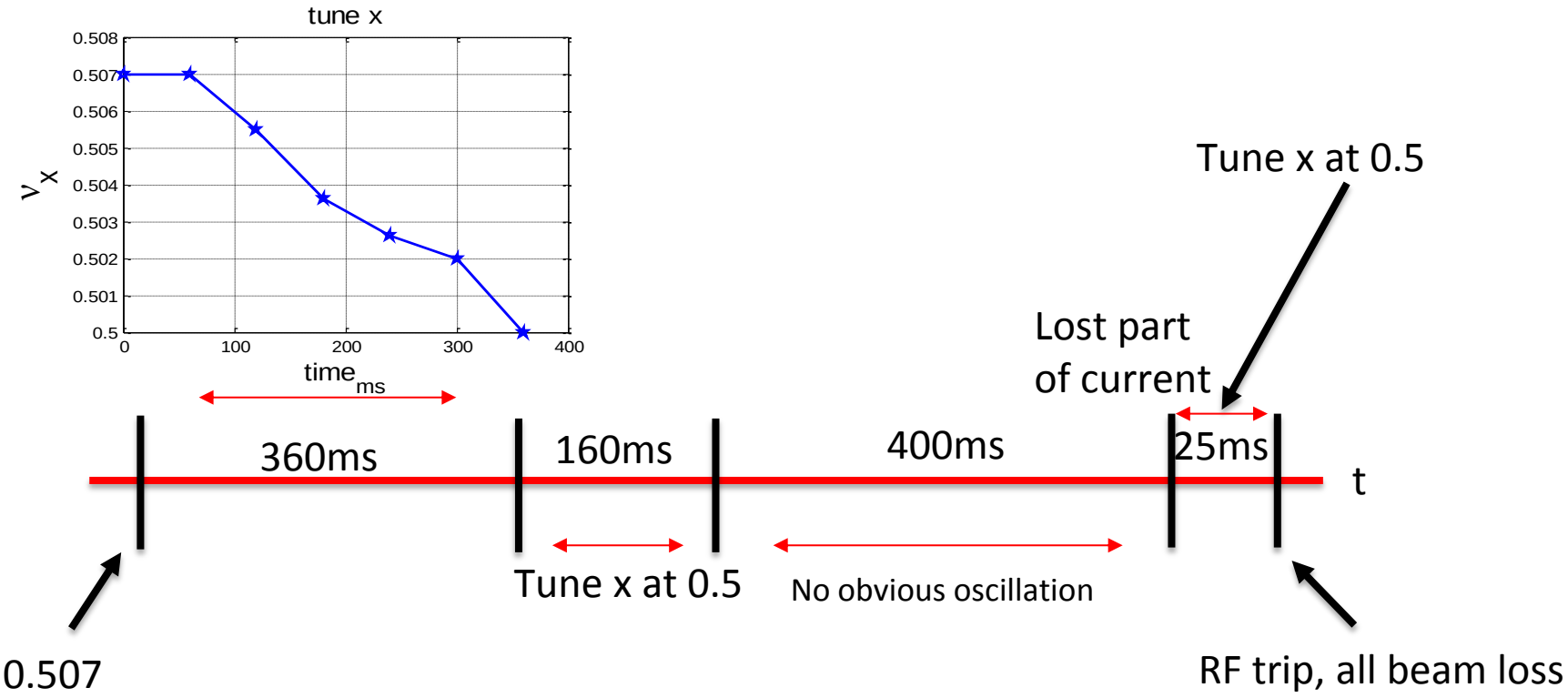


- **The amplitude at 0.5 is very large**
- **The bunch current nonuniform in the process of beam trip**

Whole process analysis

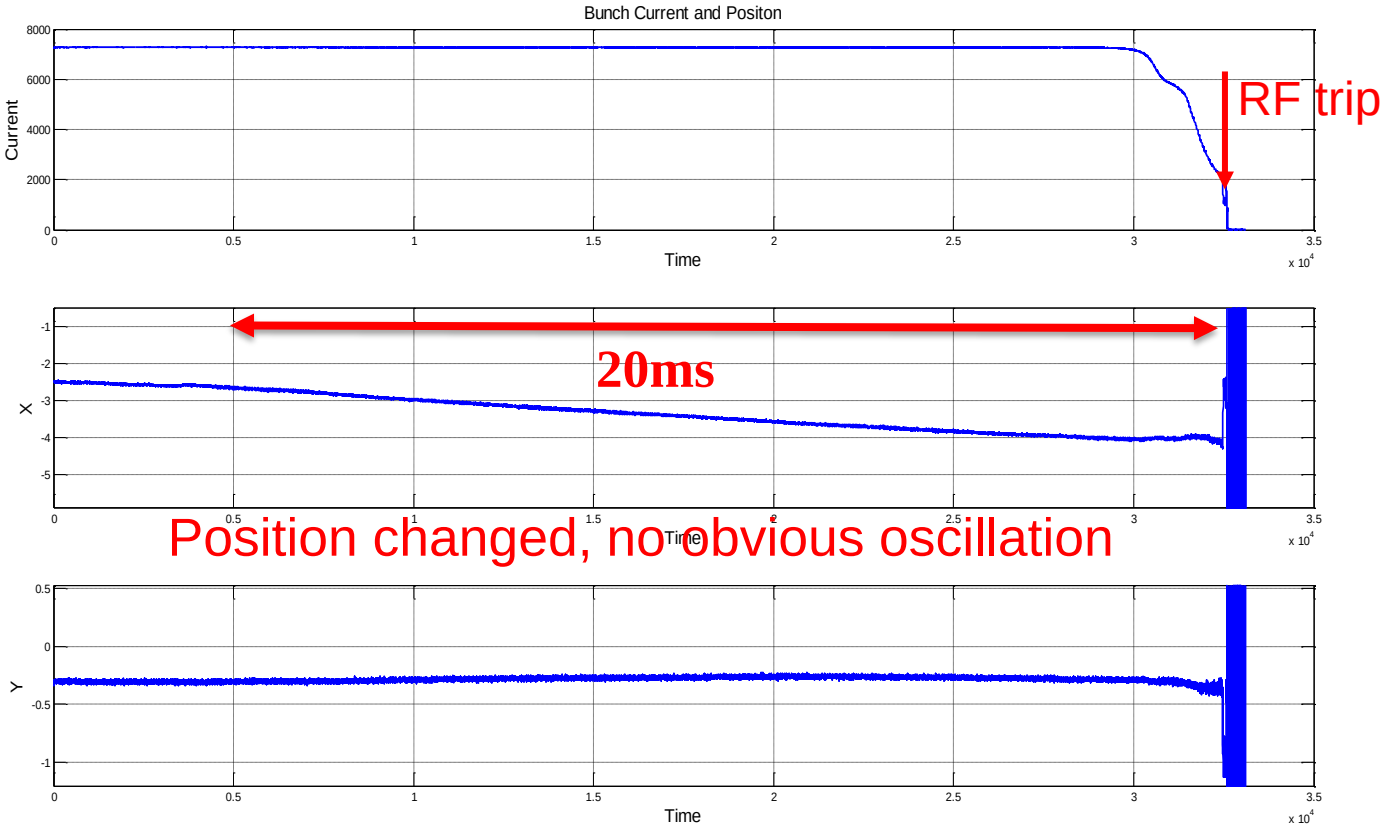
Magnet power instabilities:

→Tune shift to half integer →Resonance, partial beam loss →RF trip, all beam loss

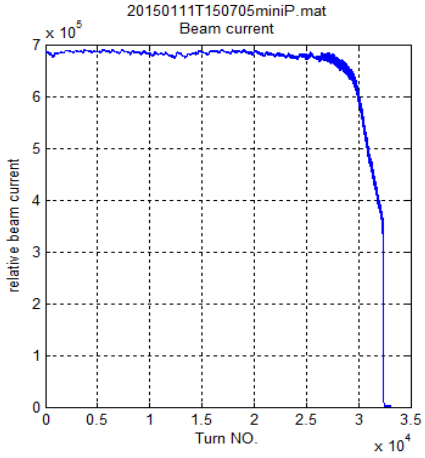


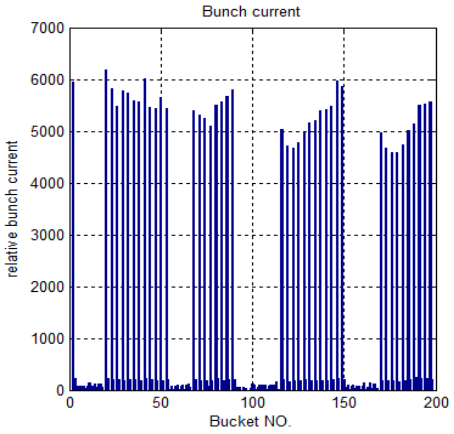
Magnet power instability

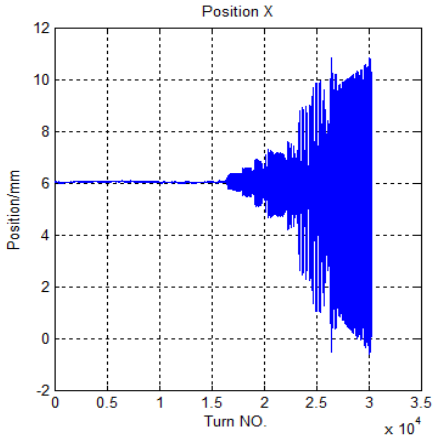
- **Position change**
- **Partial beam loss**
- **RF trip, all beam loss**

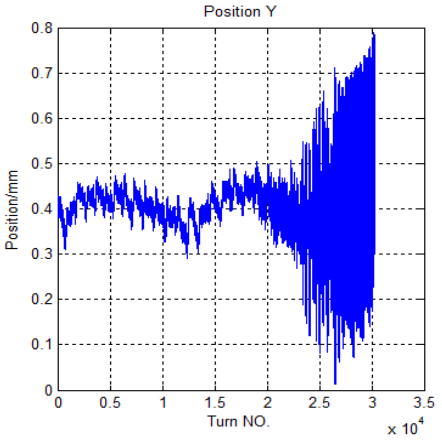


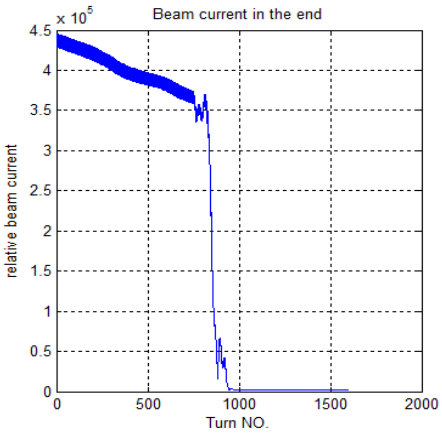
The online measurement results of beam trip—caused by magnet power instability

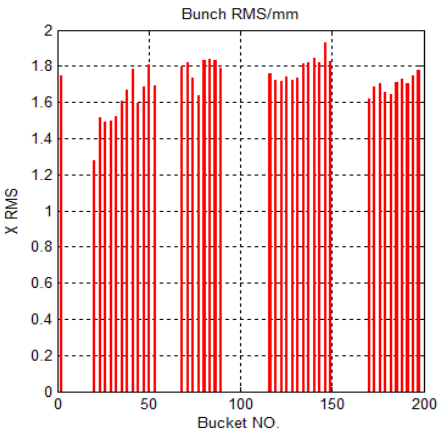


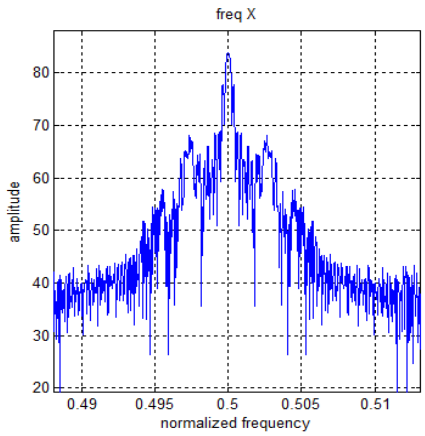


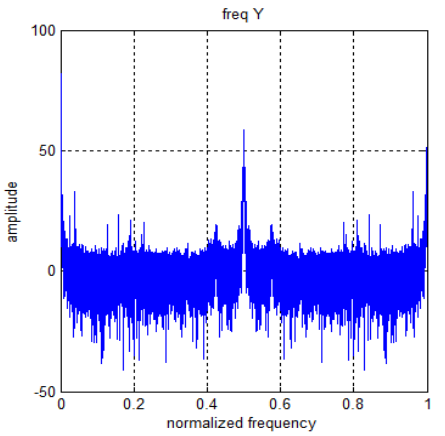






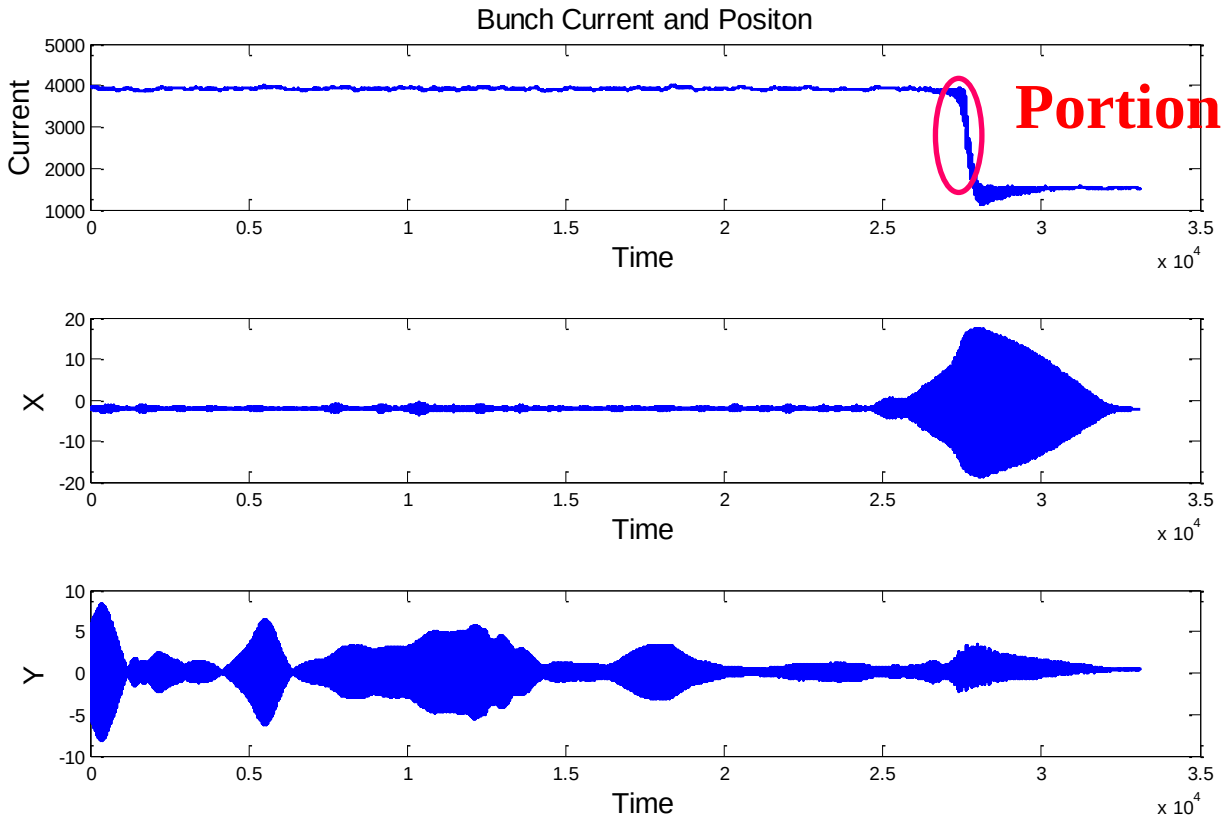






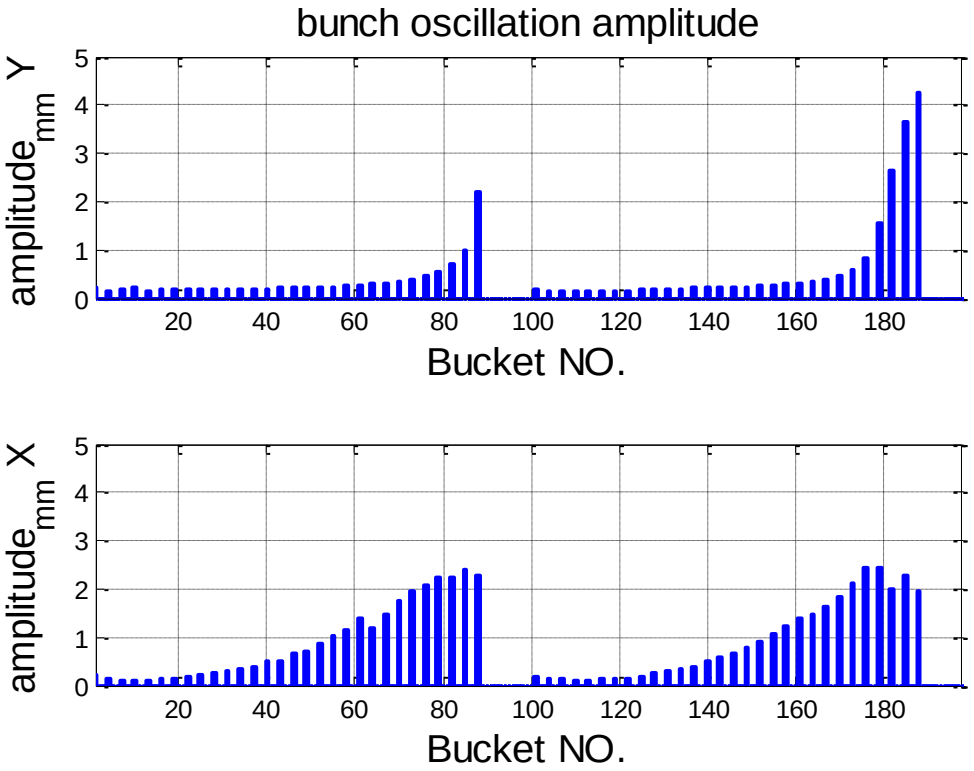
Beam instabilities

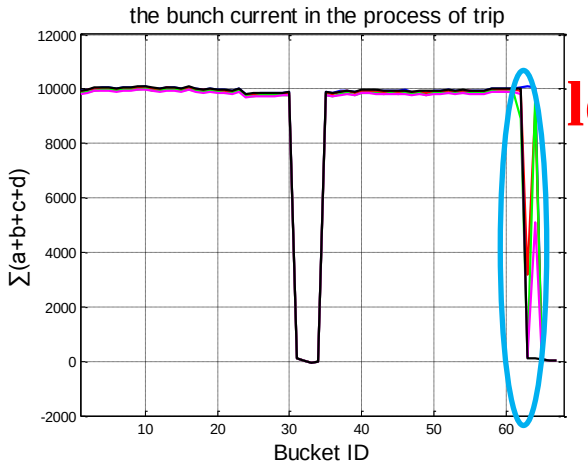
- At high beam current condition
- Beam instabilities feedback system may work at critical state



Portion current loss

Beam instabilities

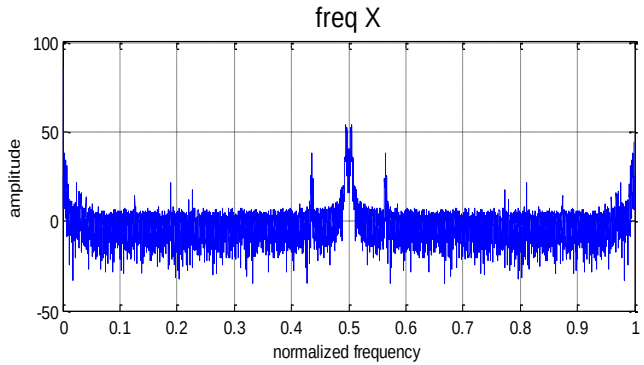


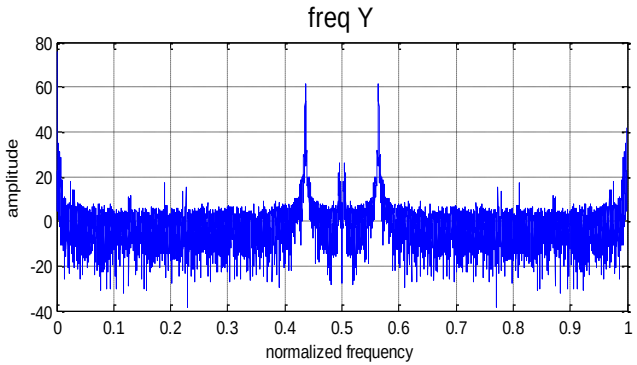


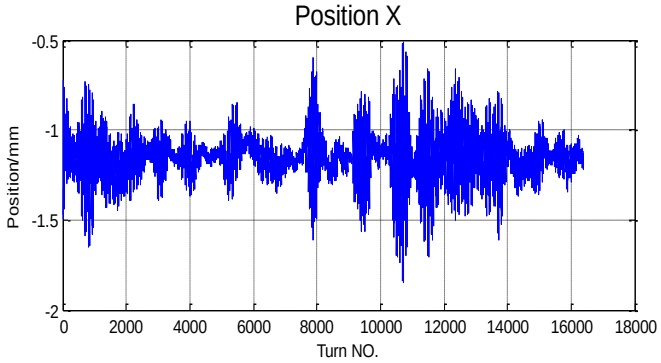
lost

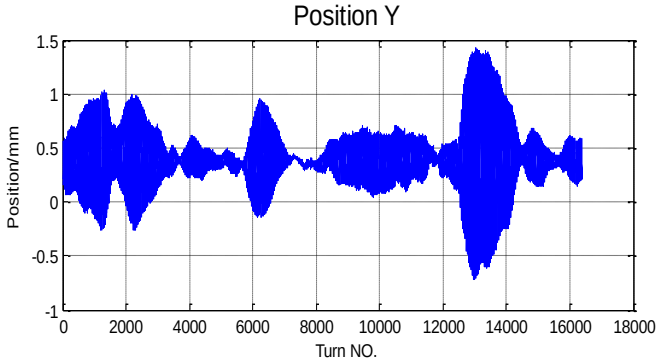
- Instabilities increase along bunch trains
- Tail bunches loss
- RF trip.

Beam instabilities





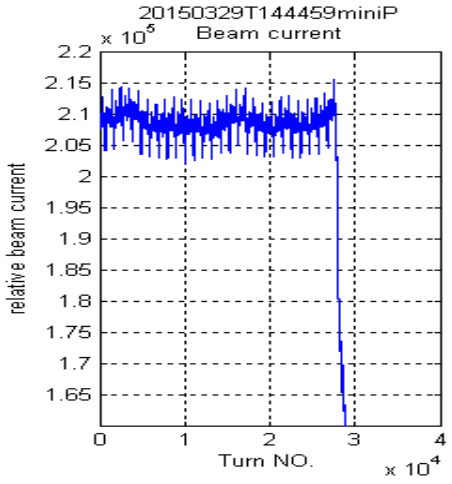


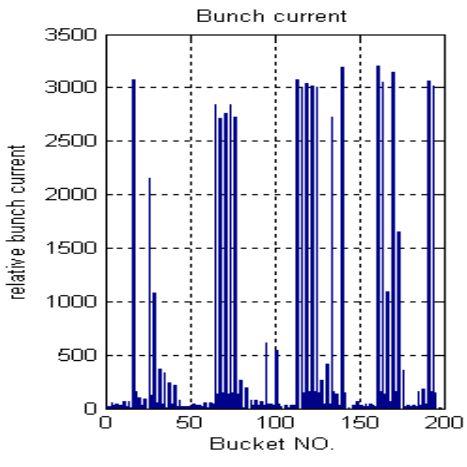


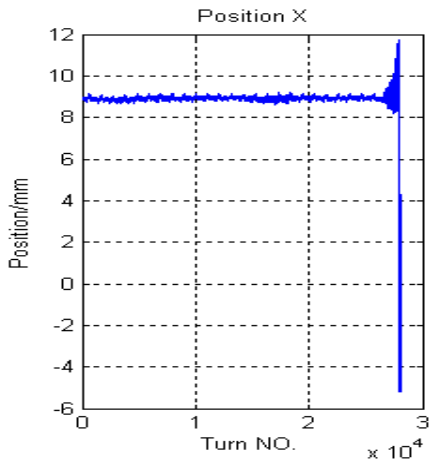
Compare to the data of 2 second before:

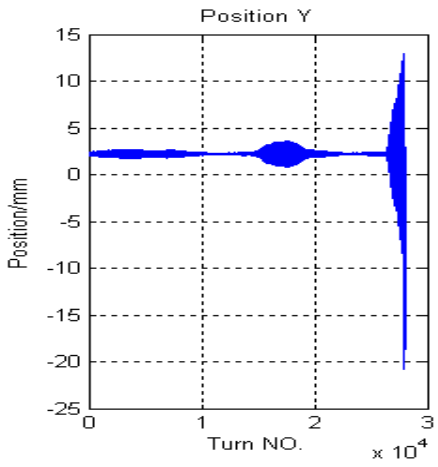
- **Position no change**
- **Bunch tune(normal)**

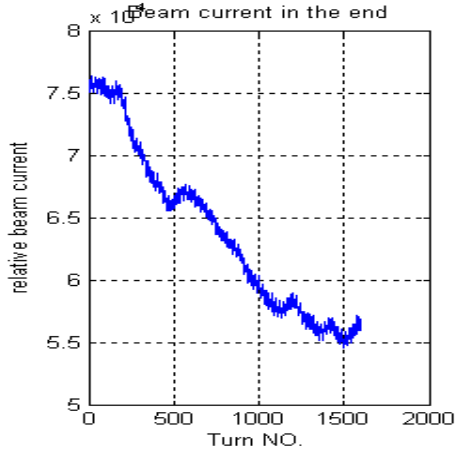
The online measurement results of beam trip—caused by beam instability

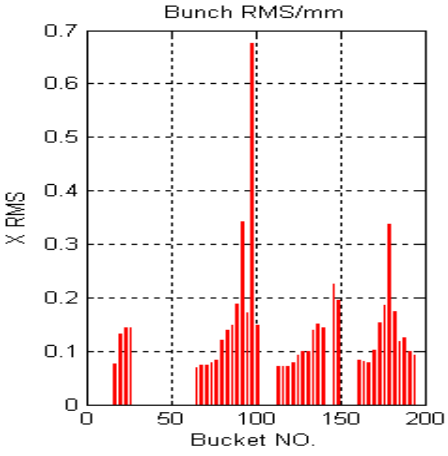


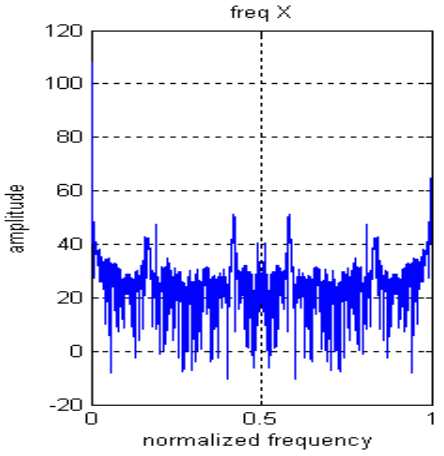


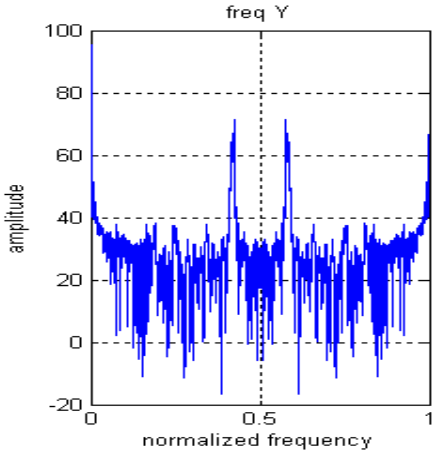












summary

- Advantage
  - simple and stand alone.
  - directly and accurately .
  - RF trip and multi-bunch instabilities
- Many aspects remains to be improved
  - degree of automation
  - perfect application functions
  - …

Thank you !

- **Thank you for your attention !**