The beam diagnostics in the CSNS commissioning

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(on behalf of the beam diagnostics group)

CSNS
CHINESE ACADEMY OF SCIENCES

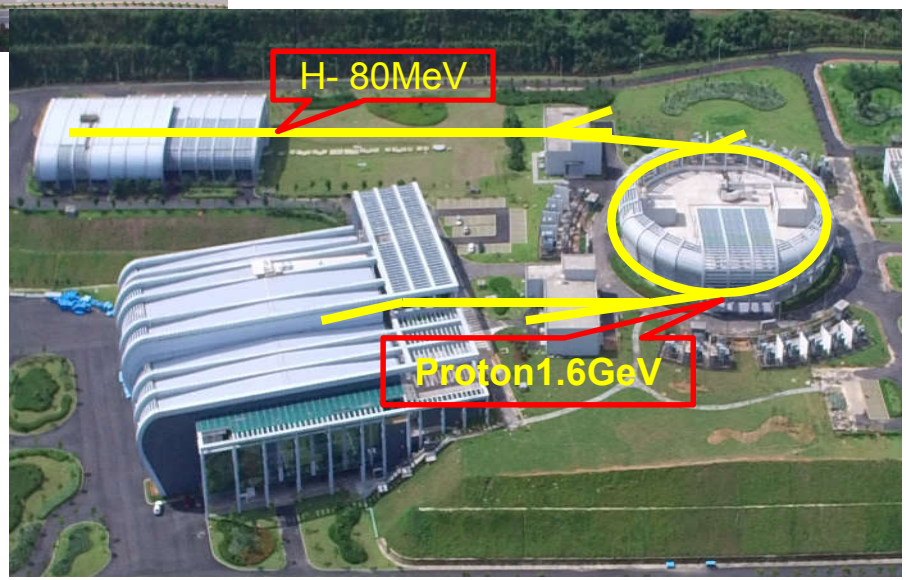
Content

The Highlight of CSNS

- The CSNS passed its national acceptance on August 23.
- It opens for users now.
- Till the end of the year, we plan supply 1000 hours for users.

Background-Accelerator

A bird view of CSNS campus

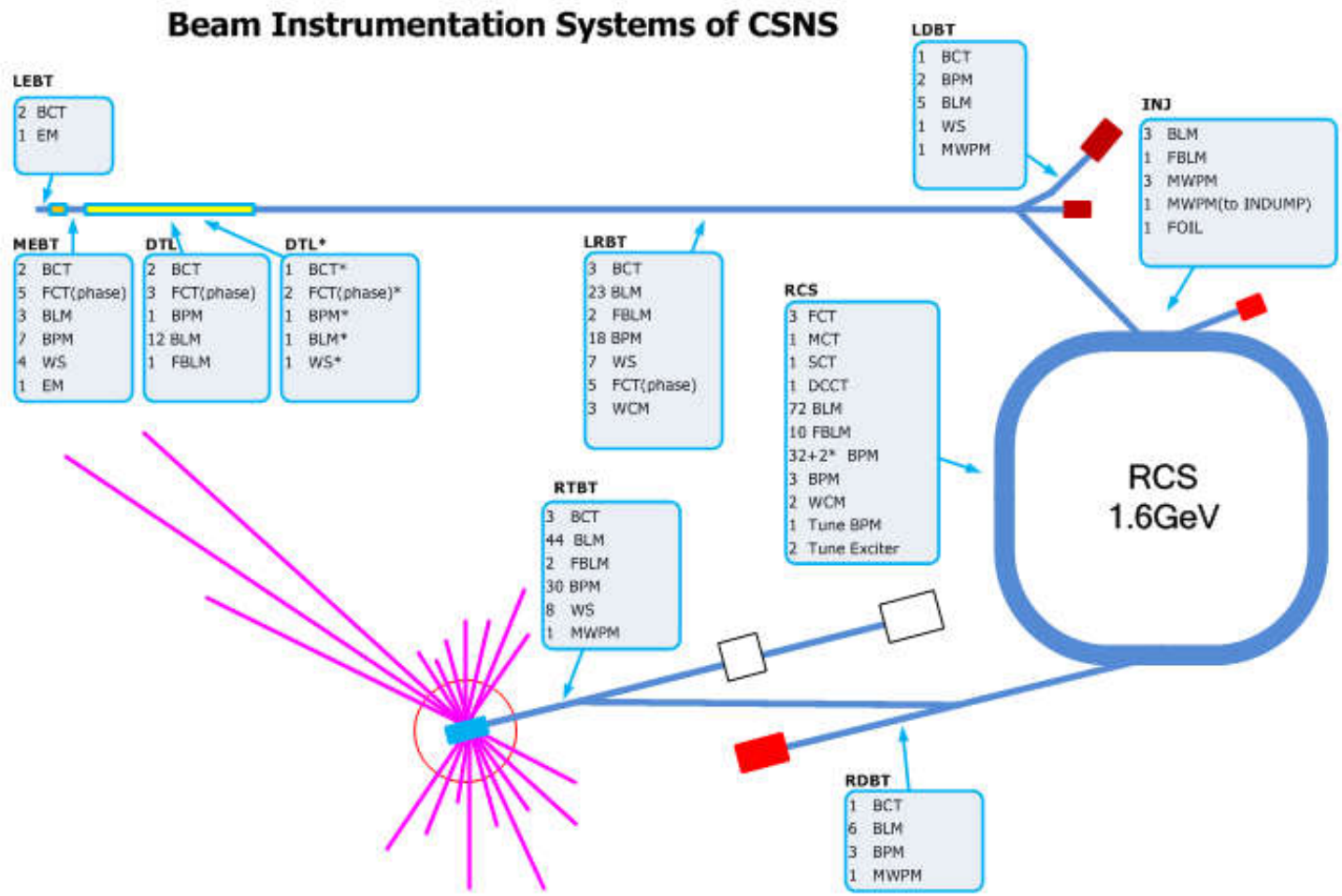


Background-beam parameters

Linac & LRBT	
Item	Design value/ operation value
Particle type	H-
Beam width(μs)	450/100
Repetition rate(Hz)	1~25
Pulse peak current(mA)	12/10-12
Chopped ratio(%)	30~70/50
Energy (MeV)	3,21,40, 60,80
RF frequcy (MHz)	324

RCS & RTBT	
	Design value/ operation value
Particle type	H+
Bunch number	2/1 or 2
Particle number(*10^12)	15.6/3
Energy(MeV)	80-1600
Bunch length(ns)	500-100
Circular frquency(MHz)	0.511-1.22

Background-BI layout

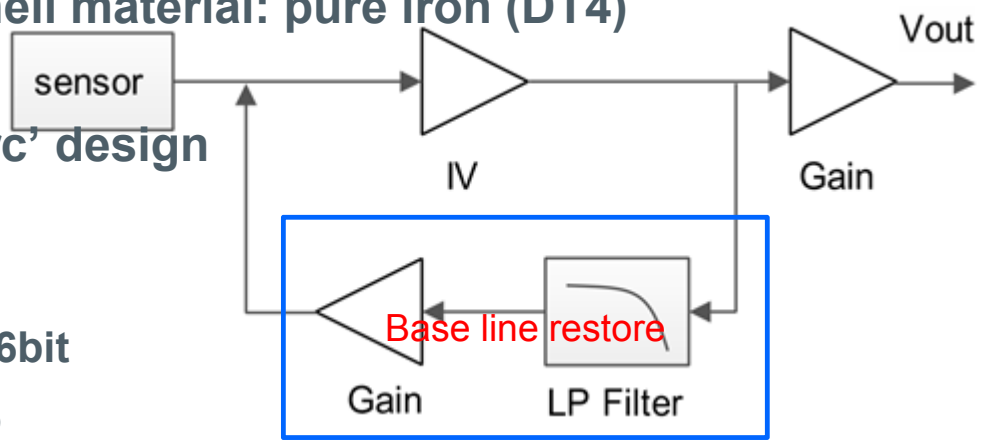


Beam devices-current

Beam current/ Charge number

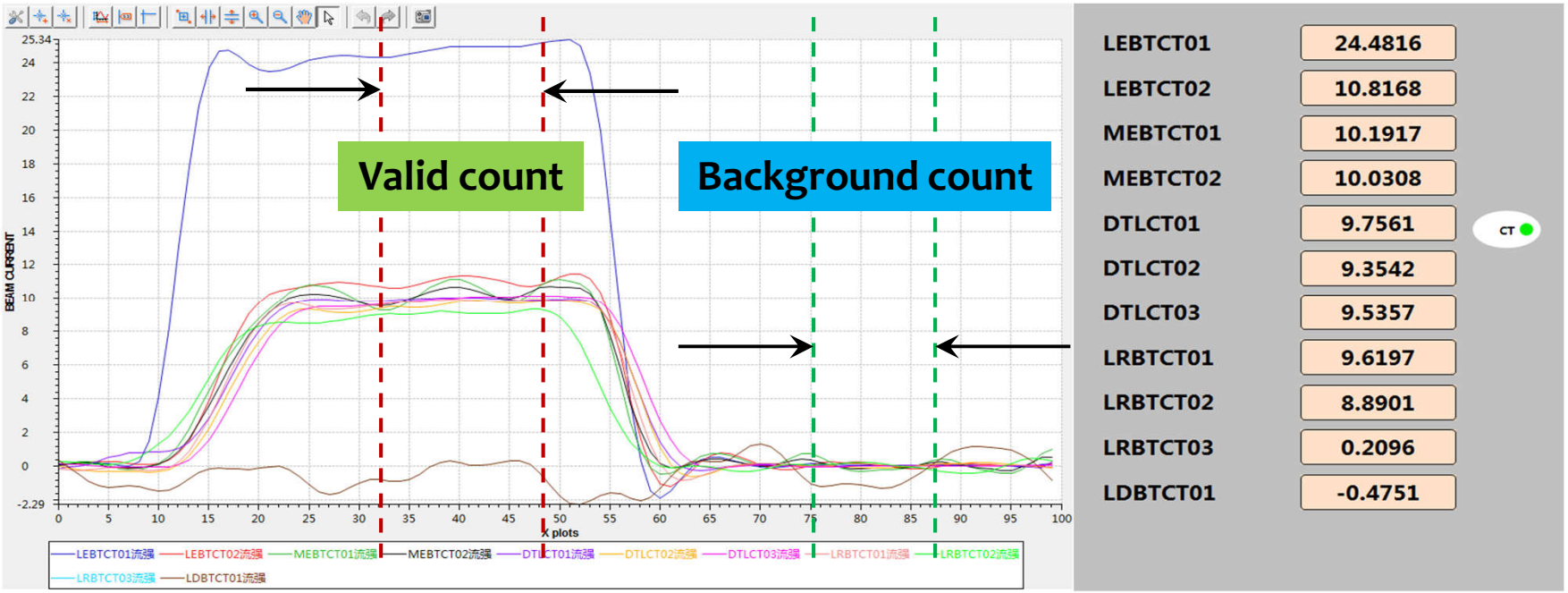
Linac BCT

- Sensor:
  - Current transformer；
  - Core material：Co based alloy;μr>20000;
  - Turn of the second coil:150
  - Turn of the calibration coil: 1
  - The shielding shell material: pure iron (DT4)
- Electronics
  - Refer from J-Parc' design
- Readout system
  - NI 6358
    - » 1.25MSa/s，16bit
- The accuracy: ~0.5%

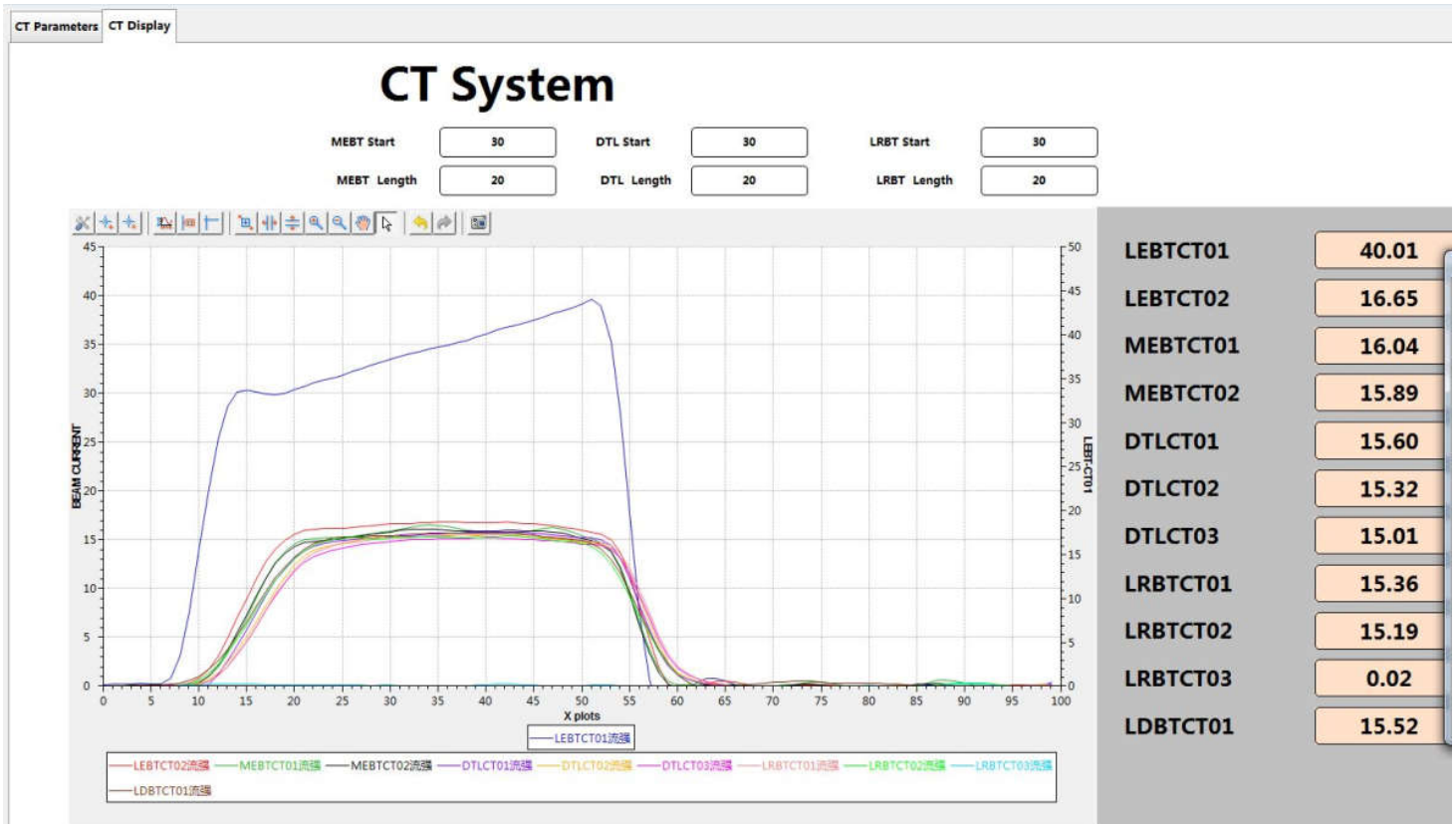


Beam devices-current

- Data processing
  - Current=Peak value-background value
  - To eliminate the DC drift



Beam devices-current

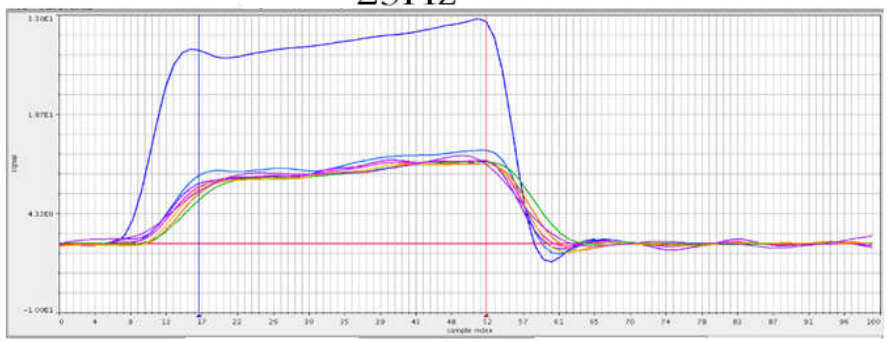


- **The best status of CSNS Linac**

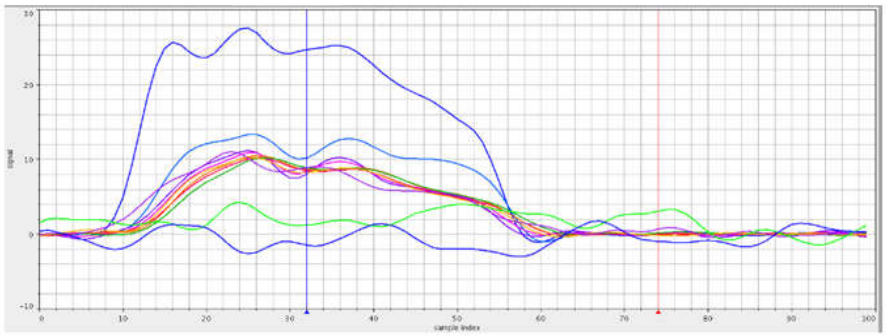
Beam devices-current

- During the commissioning: beam unstable; different delay time, chopped beam -> the accuracy of transmission rate was not so good.
- We plan to integrated all the signal to improve the transmission rate accuracy.

25Hz

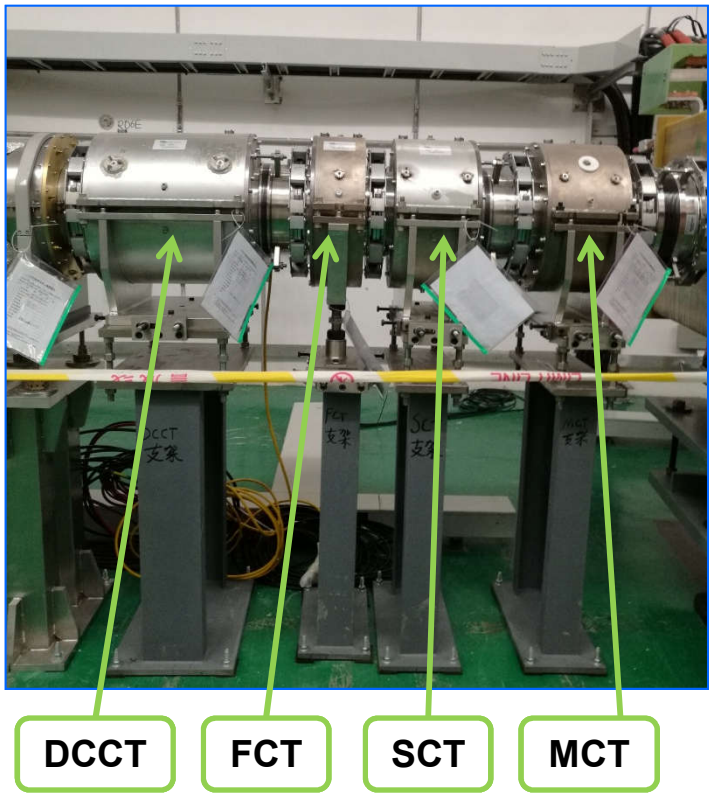


1Hz



Beam devices-current

- RCS section
  - DCCT
    - purchased from Bergoz company.
  - SCT
    - Hereward type; second coil:1000-turn; feedback coil:66-turn; calibration coil: 10-turn
    - self-made electronics
    - Droop<0.2%/20ms; Rising time: <50μs;
  - MCT
    - Whole system is similar with linac BCT.
    - The second coil: 1000-turn; calibration coil: 10-turn
    - Bandwidth:10Hz~1MHz
  - Readout system: NI ADC system;100kSa/s, 16bit

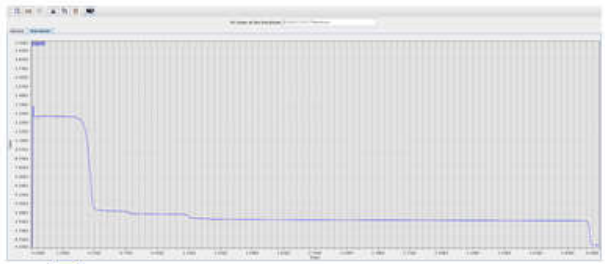


R2 arc section

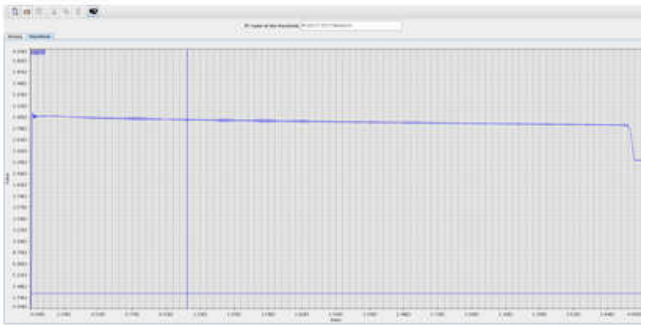
Beam devices-current

- During the RCS initial commissioning, DCCT gave more important information.

Optimization of the accumulation



1：Optimization of RF pattern
2：Optimization of the B field

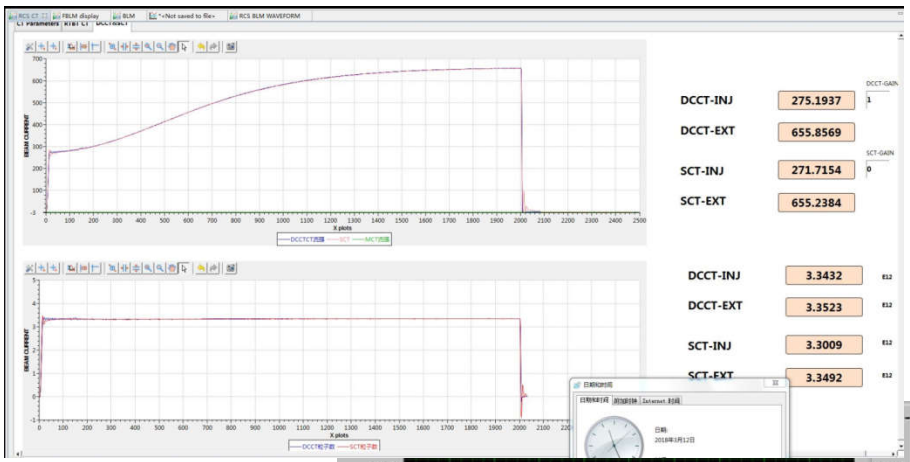


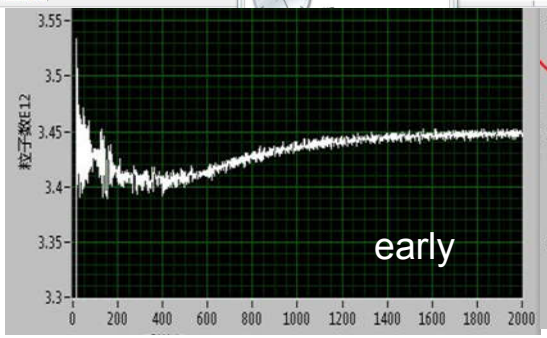
3：Height of Injection bump

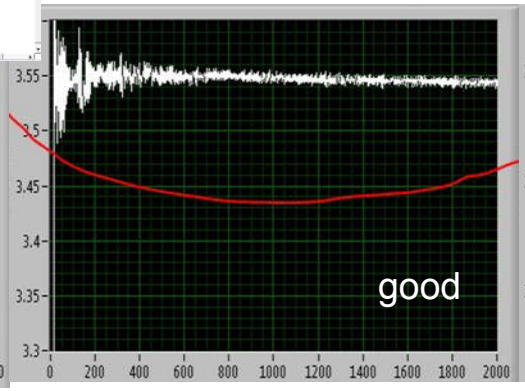
One day later, beam transmission was more than 98%

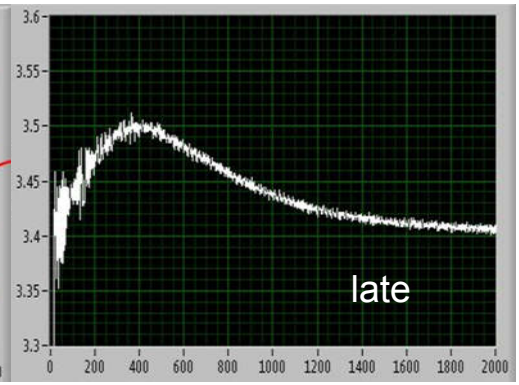
Beam devices-current

- Compare with DCCT, SCT has same accuracy.
- Particle number= DCCT/SCT curve/frequency curve
  - The two curve should be carefully aligned.



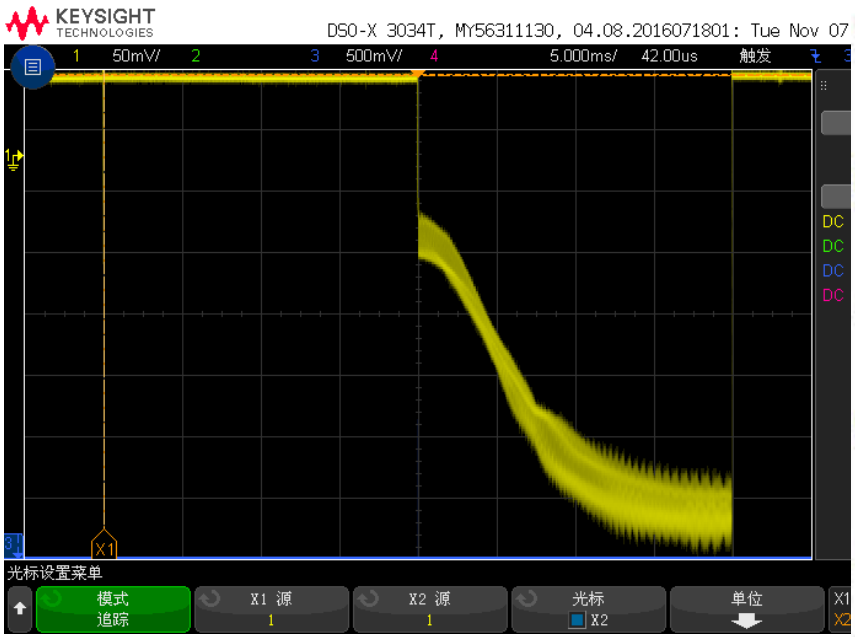


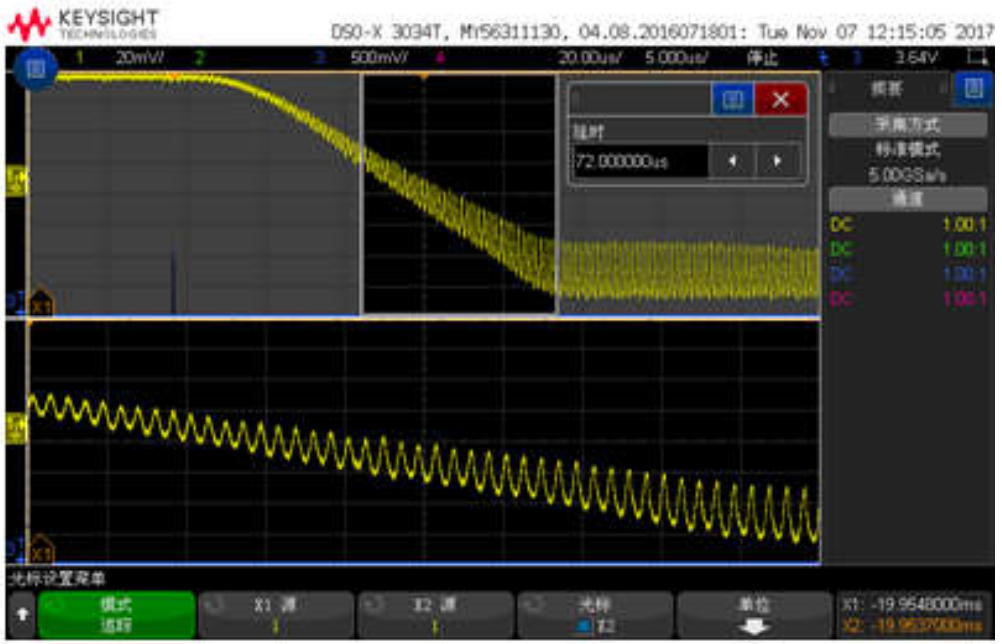




Beam devices-current

- MCT
  - It can observe the injection current changes.
  - The function should be clear.

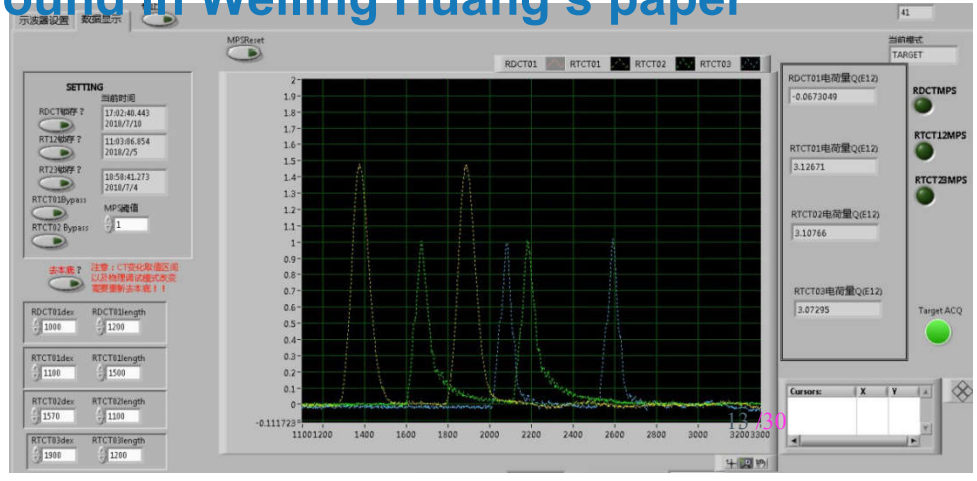




Beam devices-current

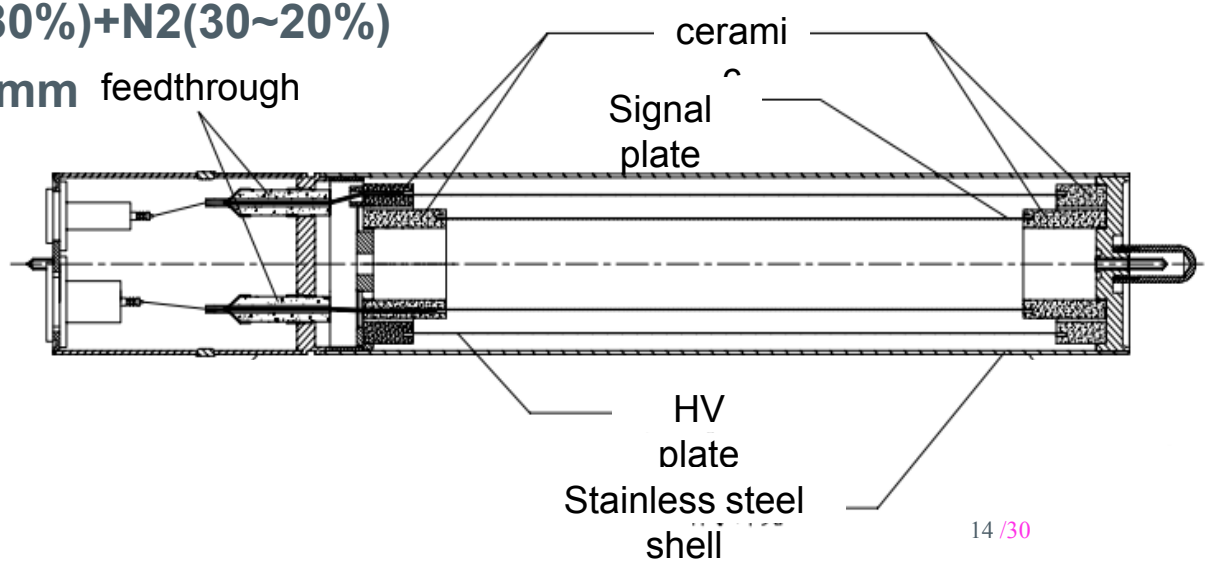
- RTBT section
  - ICT +3* FCT
    - Purchased from Bergoz
  - Electronics
    - Method 1: Bergoz BCM+SRS SR 250*3
    - Method 2: NI PXIe-5160 oscilloscope digitizer, 10bit, 1.25GSa/s
  - Although we calibrated the whole system carefully, the measurement data has a little different with DCCT value.
  - We try to find the reason !

- About this, the detail can be found in Weiling Huang's paper MOPC04 in this conference.



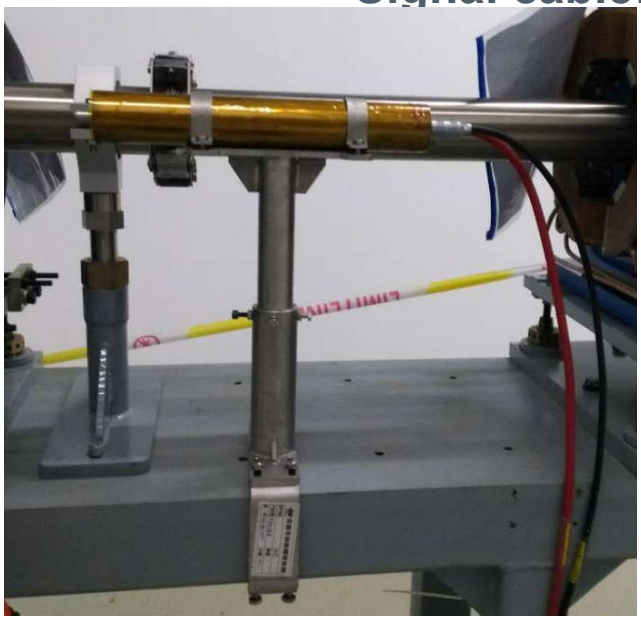
Beam devices-beam loss monitor

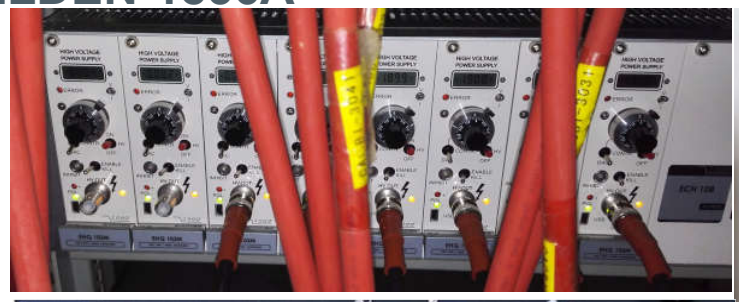
- Two types of BLM
  - Ion chamber + self-made electronics + NI 6358
  - Plastic scintillator +PMT+
    - Type 1： self-made electronics +NI 6358
    - Type 2：Libera BLM signal acquisition electronics – named as FBLM
- Ion chamber
  - 1atm Ar(70~80%)+N2(30~20%)
  - Diameter: 50mm

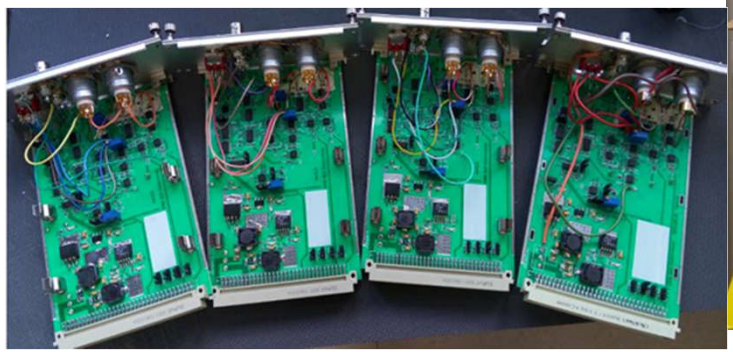


Beam devices-beam loss monitor

- Ion chamber electronics
  - Trans-impedance circuit + *5 amplifier
  - Trans-impedance: 100M, 1M,100k,10k
  - 100M: independent input channel; guard ring technology
- Cable
  - Signal cable: BELDEN-1856A

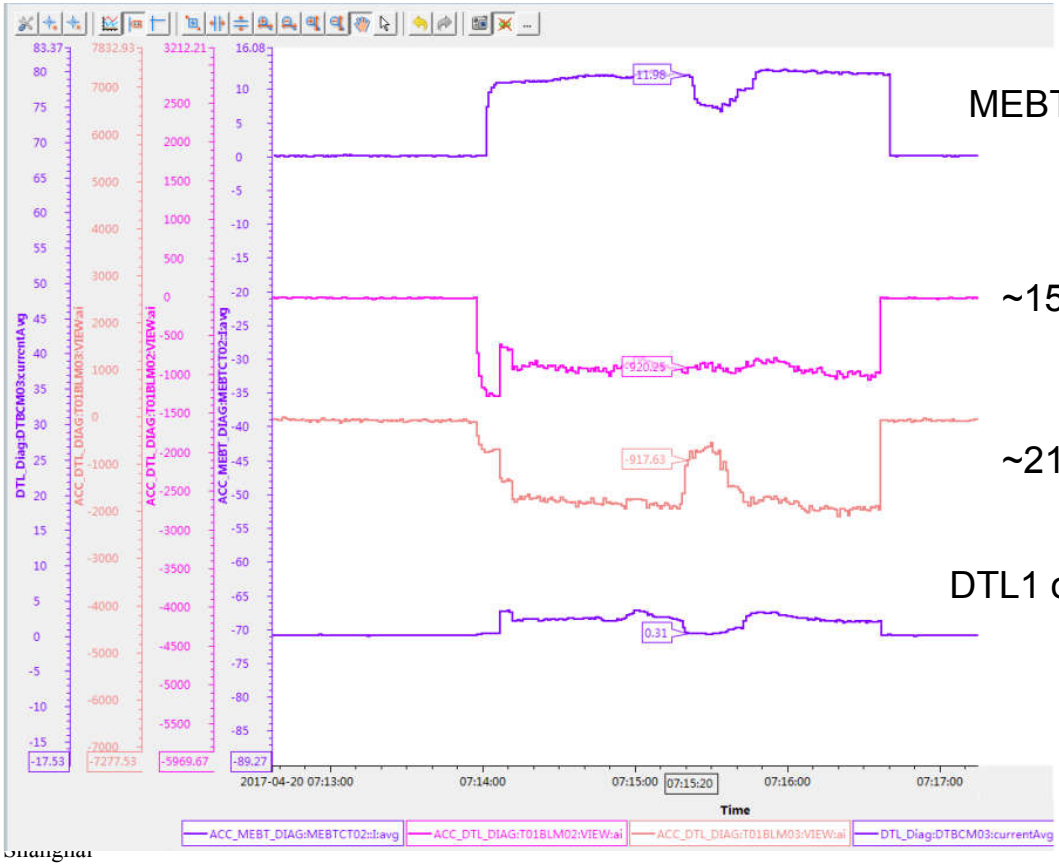






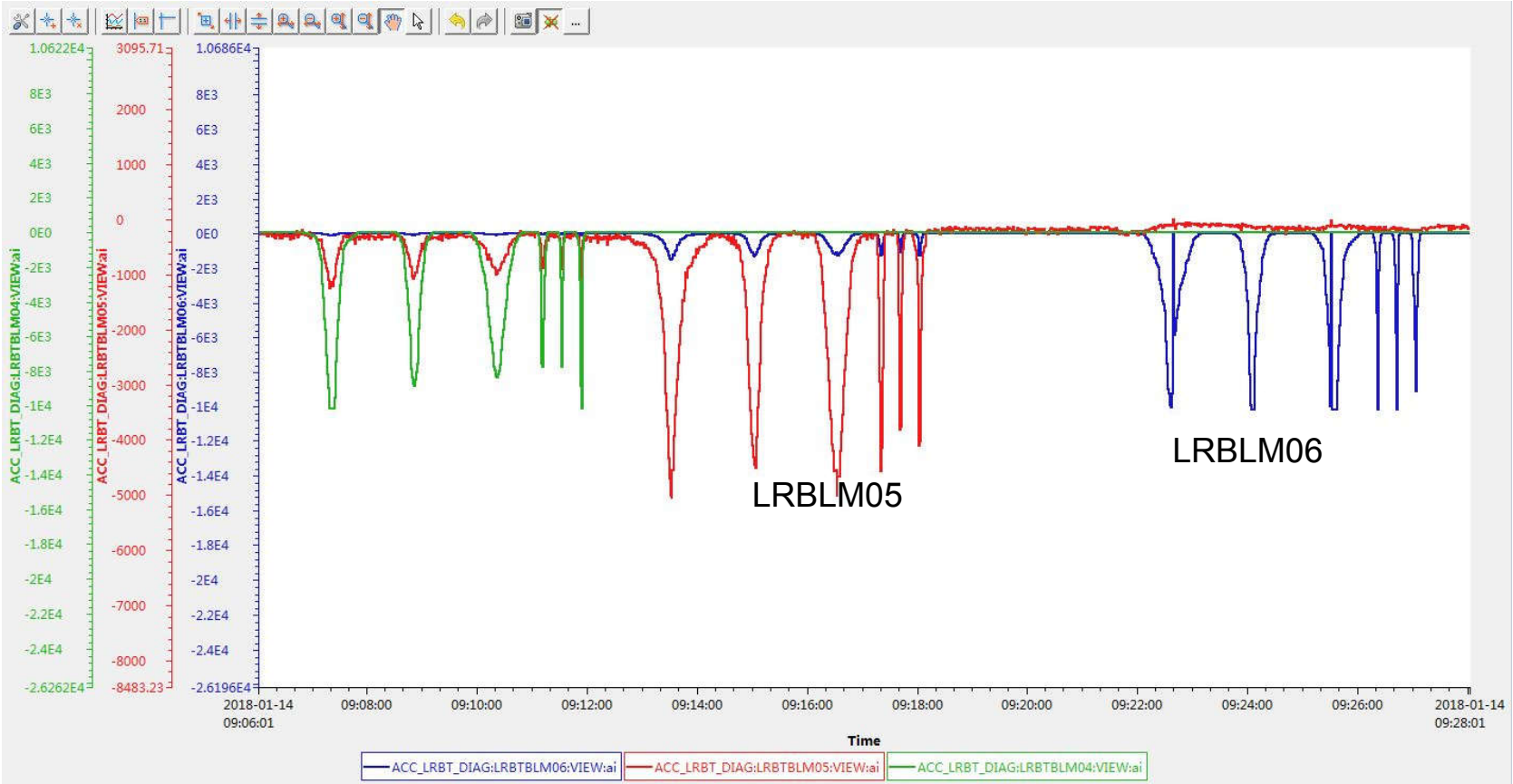
Beam devices-beam loss monitor

- During the commissioning, the ion chamber system supplied more useful information.
  - ~20MeV beam loss can be observed @7mA total beam loss.



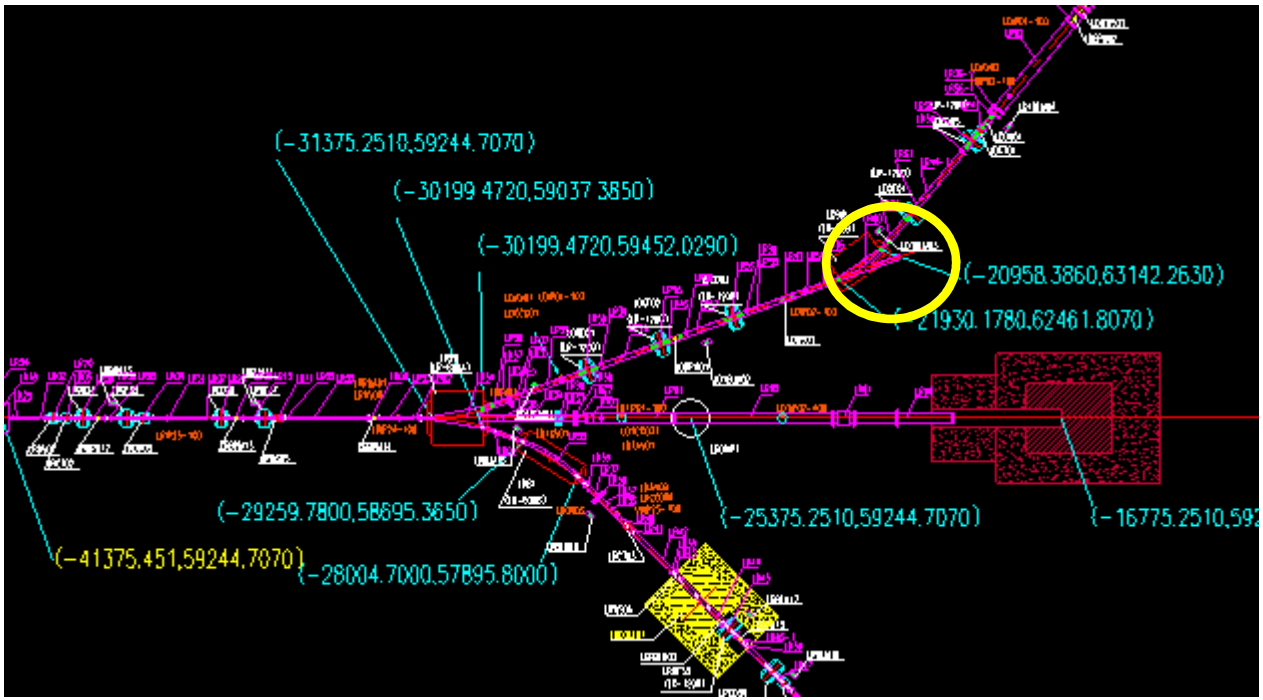
Beam devices-beam loss monitor

- 80MeV, wire scanner LRWS03 working, 2.5 meters downstream LRBLM05,15 meters downstream LRBLM06 had effective signal.



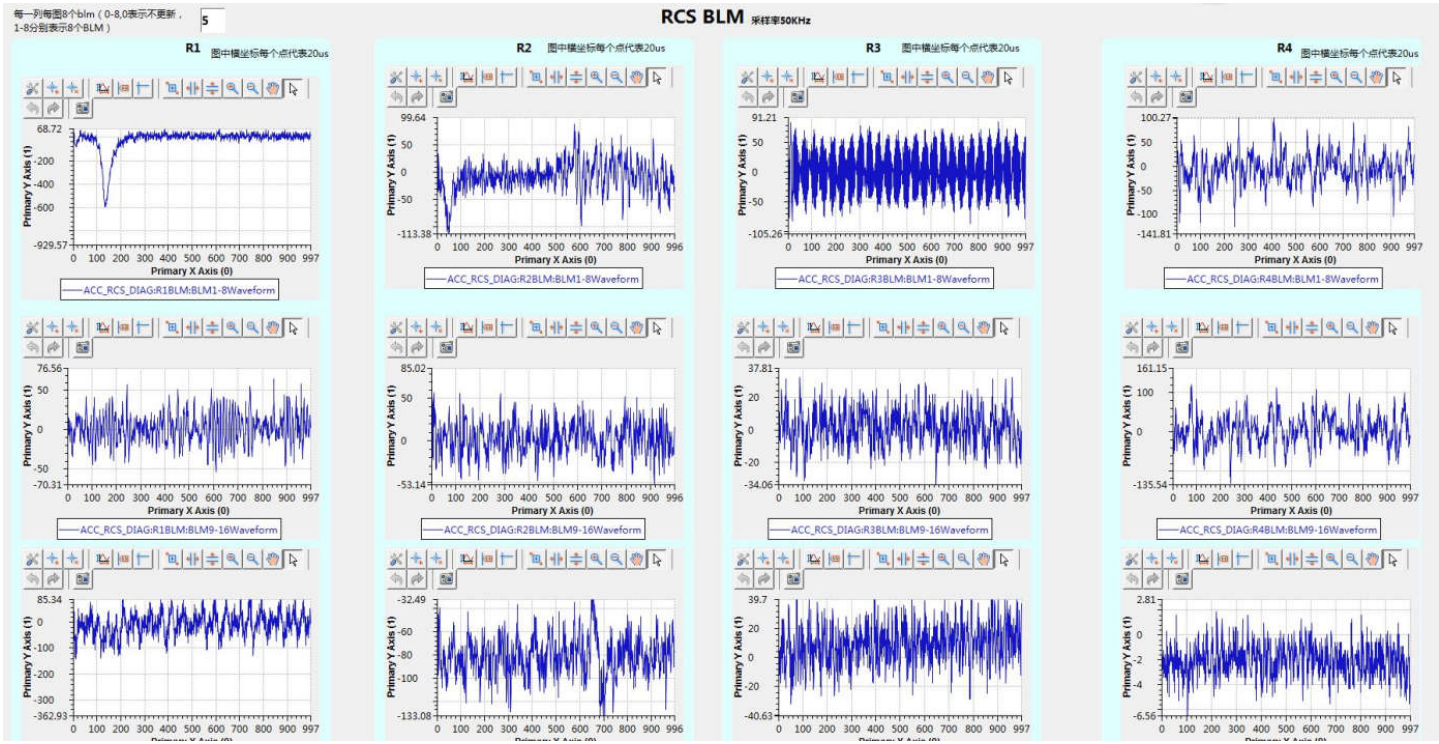
Beam devices-beam loss monitor

- 80MeV proton beam loss was found.



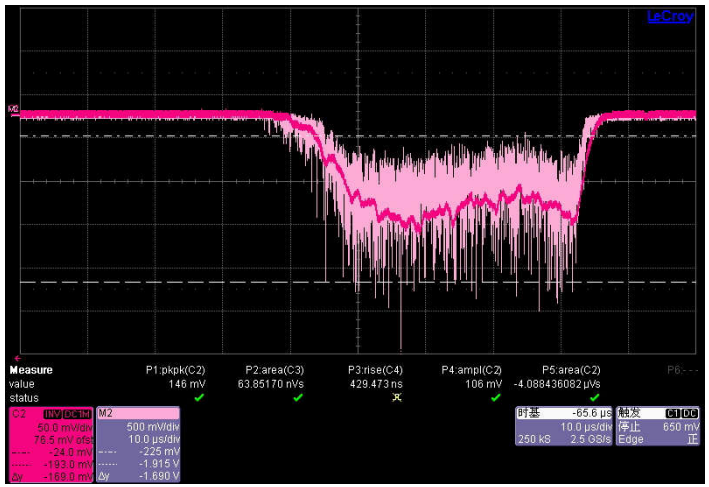
Beam devices-beam loss monitor

- In RCS commissioning, when the beam transmission rate was not changed (from DCCT result), a little BLM on RCS can found beam loss.



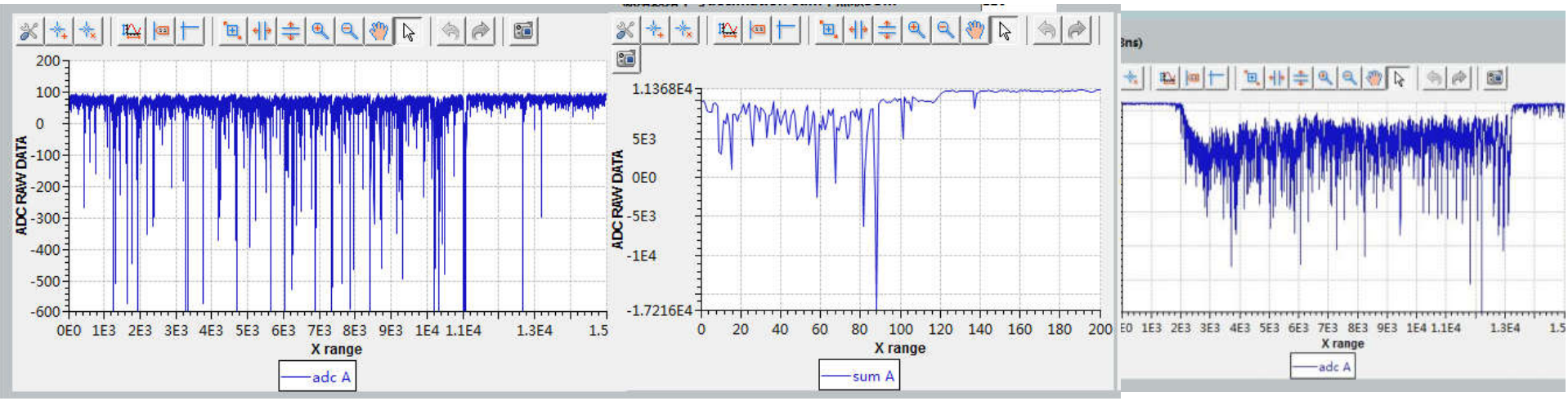
Beam devices-beam loss monitor

- In MEBT，
  - Plastic scintillator +PMT+ self-made electronics +NI 6358
  - self-made electronics
    - Filter and signal conditioning
  - The system can observe the beam loss.
  - we get the support from NSFC(11575219) to research the property change of Plastic scintillator and PMT in low energy section of the accelerator.



Beam devices-beam loss monitor

- FBLM
  - Plastic scintillator +PMT + Libera BLM signal acquisition electronics



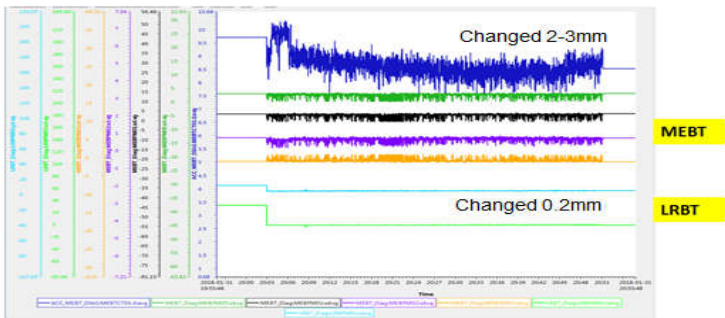
- Now, BLM system is the most sensitive device in CSNS beam devices.

Beam devices-beam position monitor

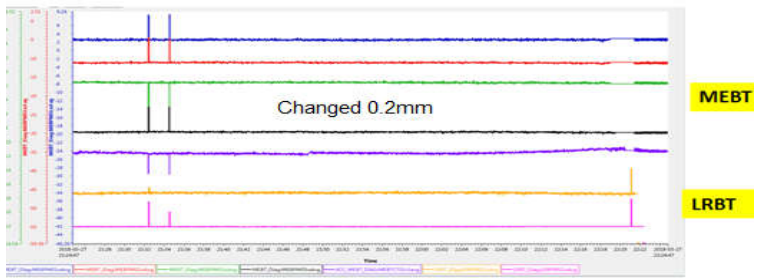
Linac section:

- Sensors：Downstream end shorted stripline BPM
- Electronics:
  - Bergoz LR-BPM/ Libera Spark HL
  - Libera Single Pass H *3 focus on phase measurement function
- During the commissioning:
  - different beam mode, different results.
  - How to determine the BPM data validity
    - LRBPM01: y:10mm
    - In this summer maintenance, before this BPM, a steering magnet was added.

BPM, 1Hz,100μs



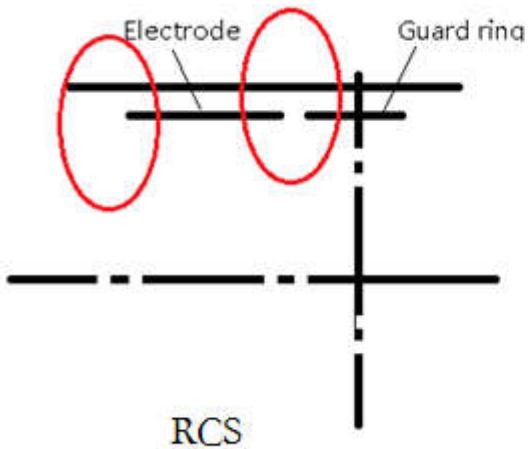
BPM, 25Hz,100μs

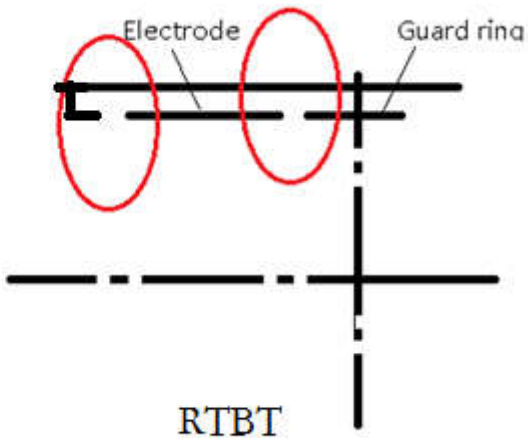


Beam devices- beam position monitor

RCS & RTBT section

- Sensors： shoe box type BPM
  - Stray capacitance question was met.





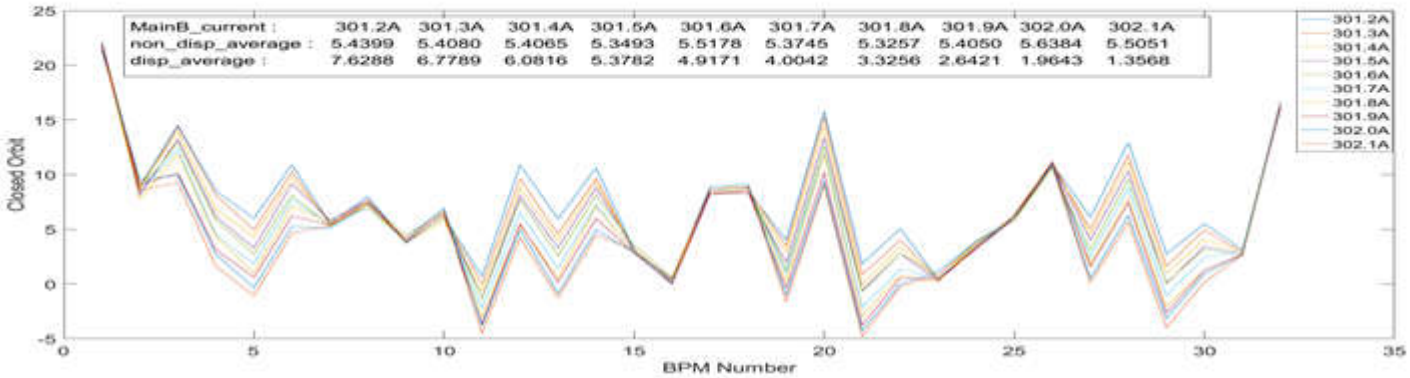
X=9.839866+100.799478*U-100.416398*V
Y=0.867384+100.935847*U+99.881786*V

X=-1.698753+137.496222*U-0.432827*V
Y=-1.248943+0.044904*U+139.356222*V

Beam devices-beam position monitor

- Different vacuum tube size affected the BPM results.
  - Using same size tube, measure the BPM response again.

Matching between beam energy and B field



- When the average orbit in dispersion region closed to that of dispersion-free region, it is regarded as matching.
- The average orbit in the dispersion-free region is about 5.5mm, BPM offset?

Beam devices-beam position monitor

- The electronics for shoe box type BPM
  - RCS section:
    - developed by our colleague.
      - » Gain: ×16, × 6, × 1, ÷6, ÷ 16
      - » Identify the beam with a RF window

Fig.4: The PCB board

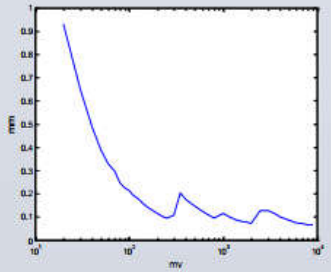


Fig.8: Bunch-by-bunch position resolution

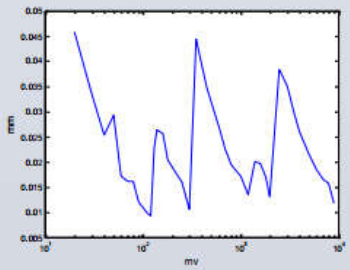


Fig.9: Closed Orbit position resolution

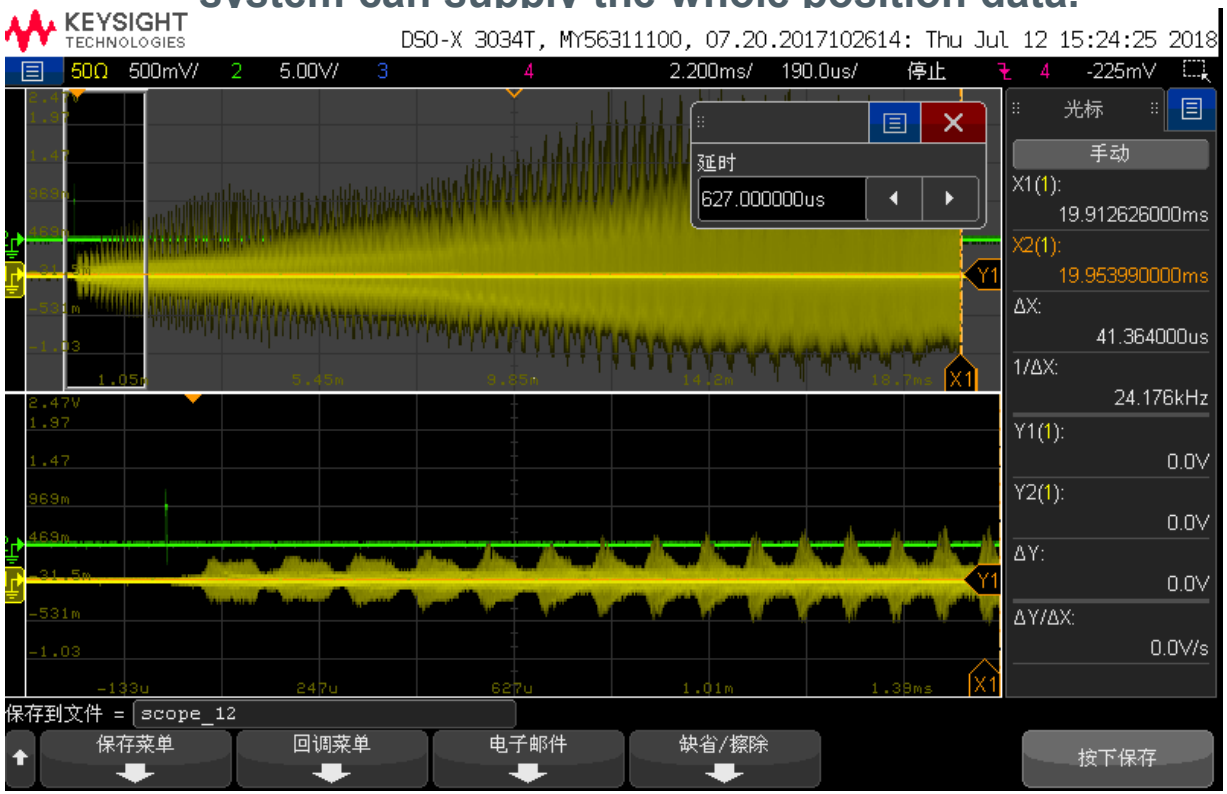
Bunch-by-bunch position resolution: 0.9mm@10mV

Closed Orbit position resolution: 50um@10mV

Primary test @ laboratory

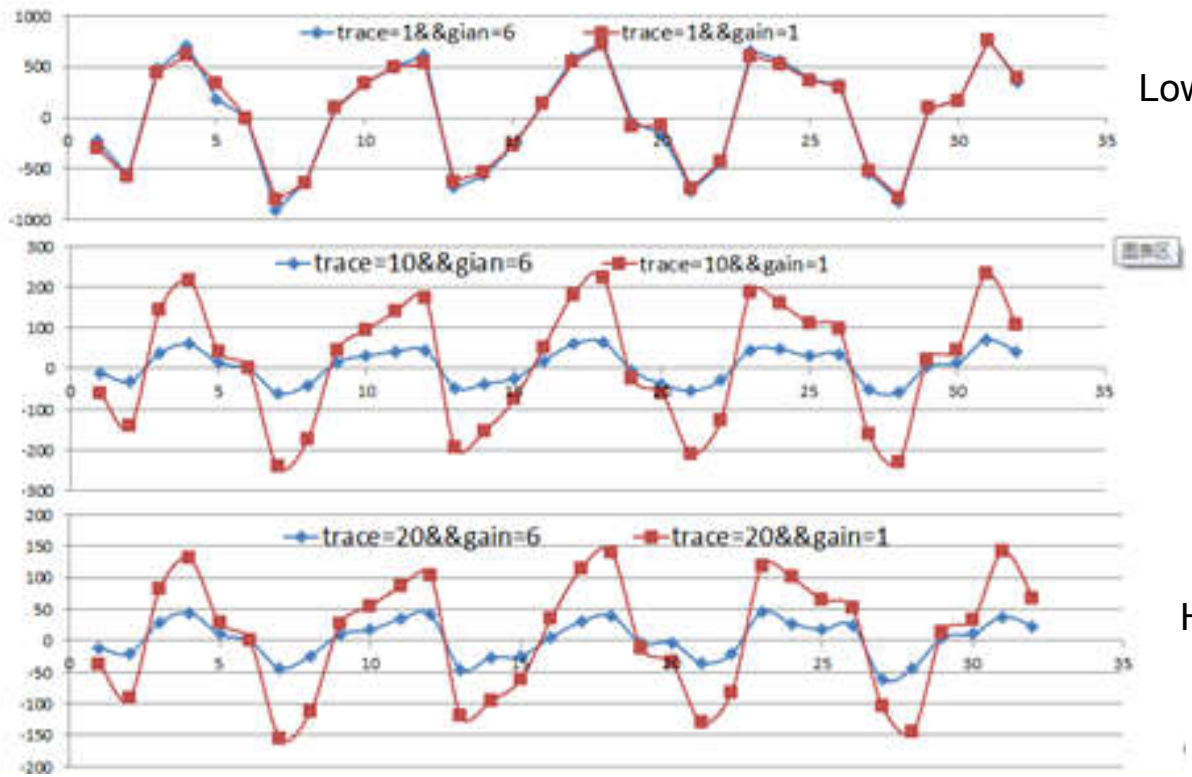
Beam devices-beam position monitor

- Tested the Libera Hadron
  - During the commissioning, “threshold” method is not reliable.
  - Cooperated with I-Tech, using external trig method, the system can supply the whole position data.



Beam devices-beam position monitor

- For RCS BPM electronics
  - Should be noticed that saturation phenomenon
  - We hope the system can output a saturation warning message .

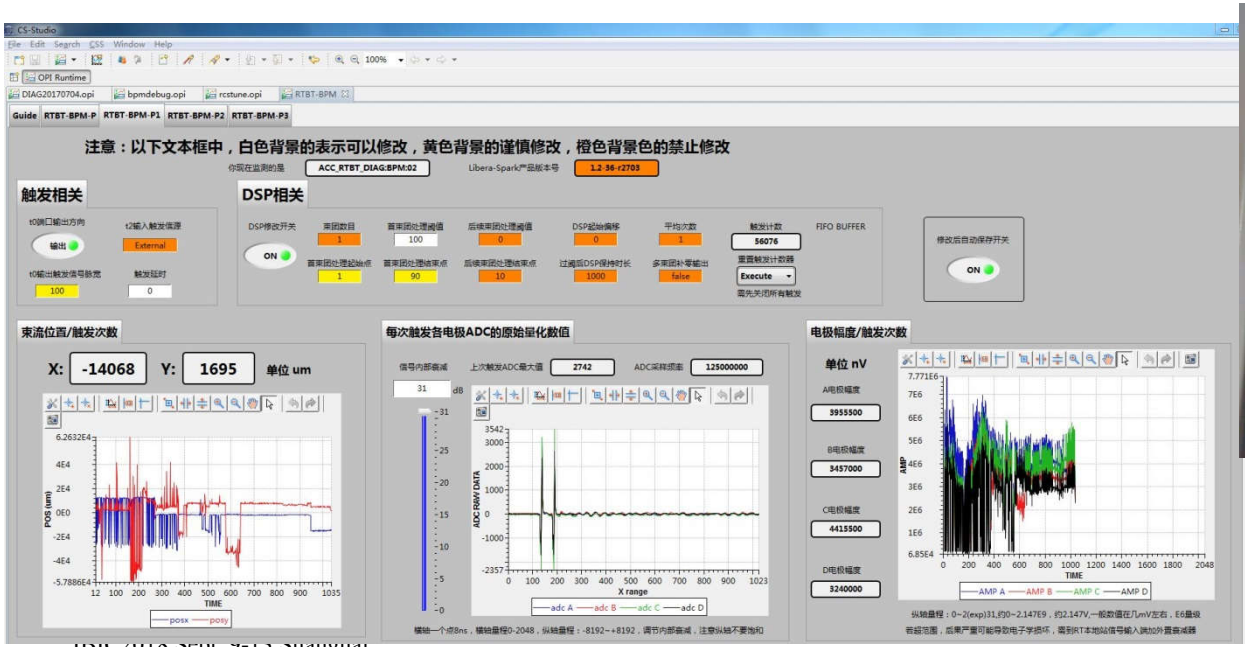


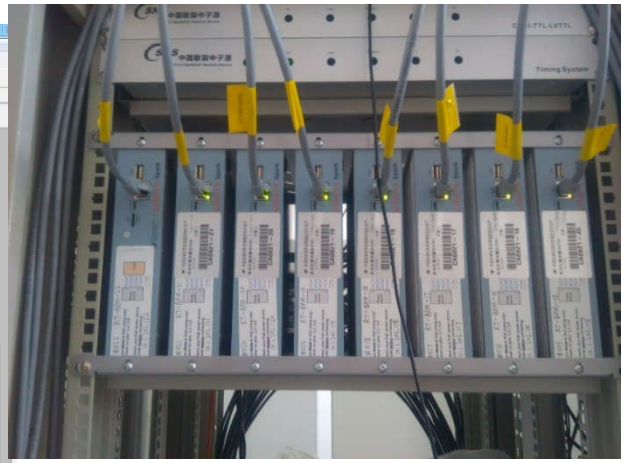
Low energy

High energy

Beam devices-beam position monitor

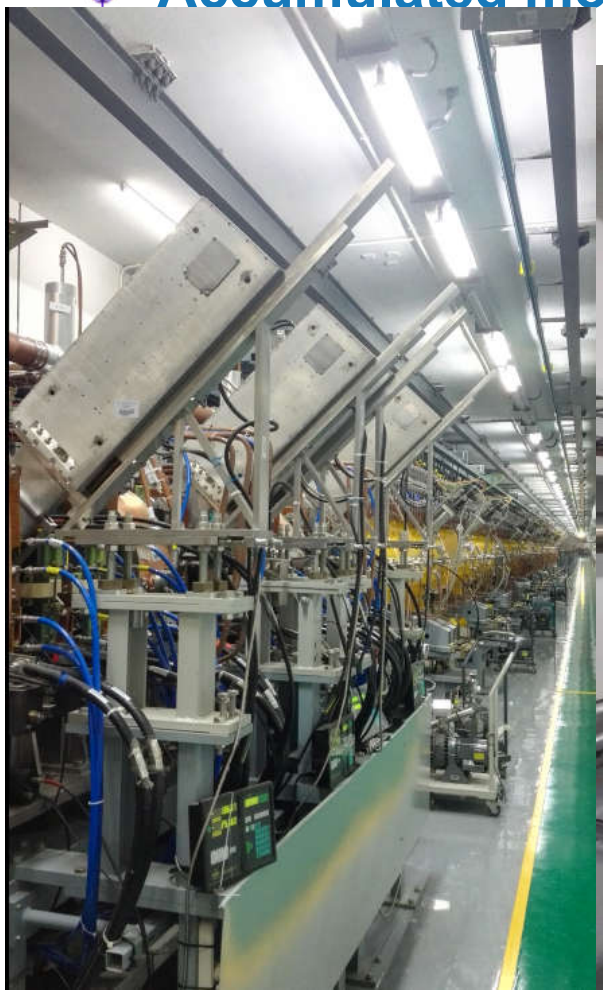
- RTBT section
  - Libera Spark HL: 33sets
  - It can give each bunch position.
  - Using this mode, we found that the y position of the two bunch was different.
  - The extraction system should be tuned.



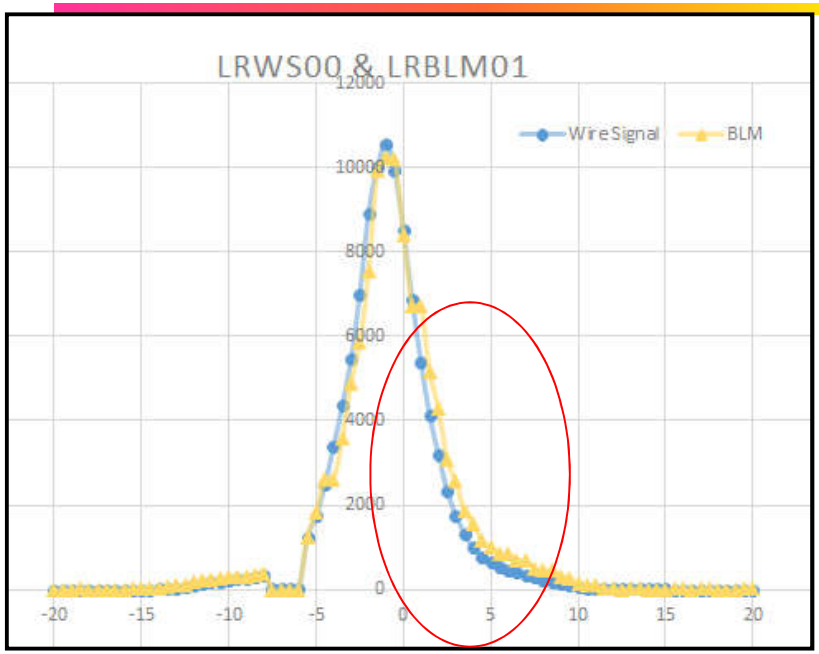


Beam devices-WS

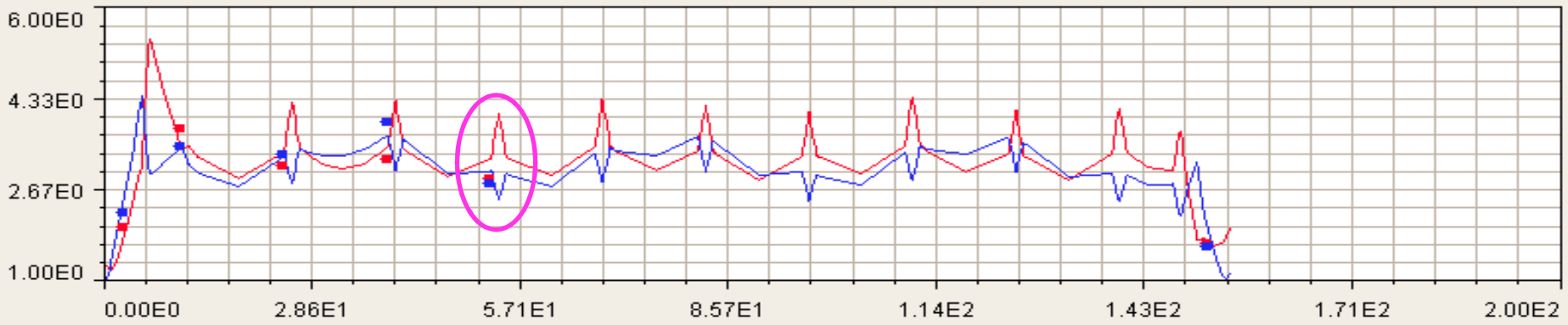
- Accumulated more data to cross check both methods.



Beam devices-WS

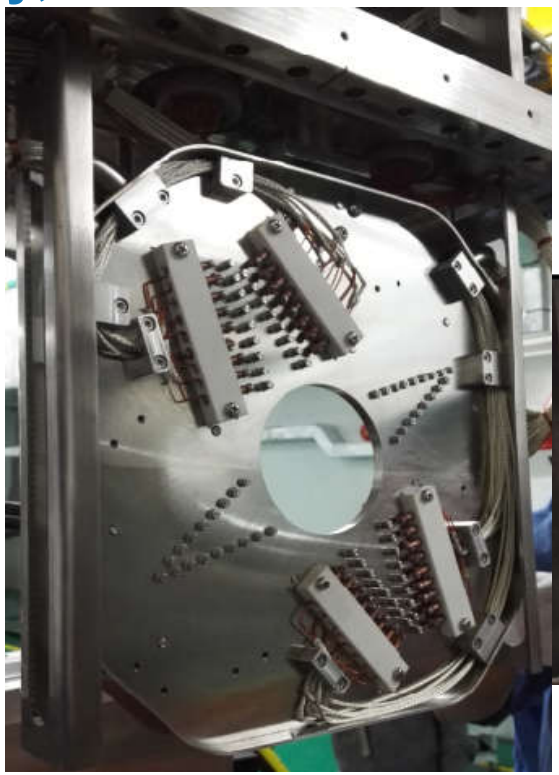


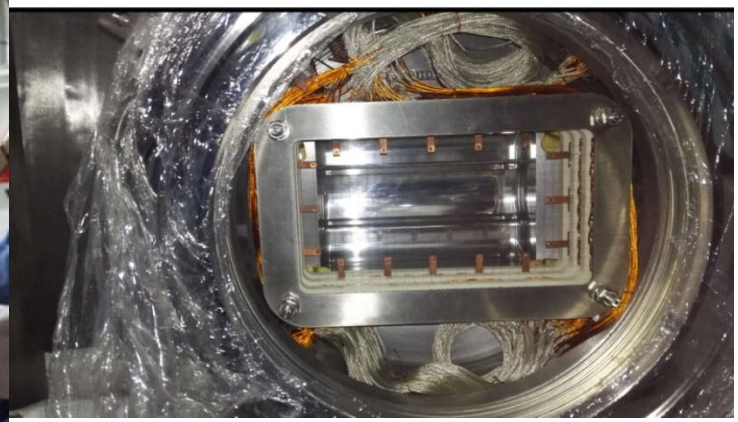
- Two method beam profile results compare
- LRWS04 result was not matched the physical result.



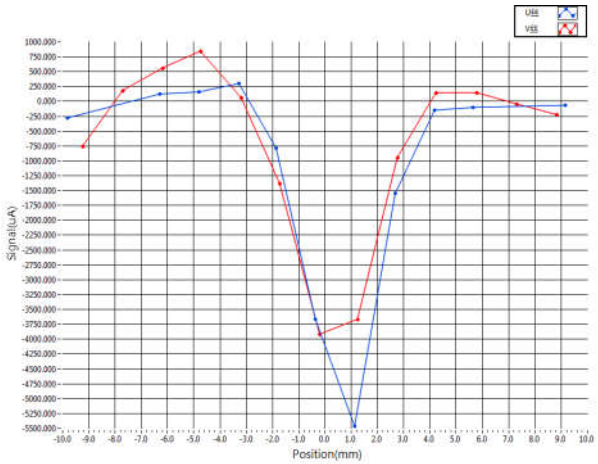
Beam devices-MWPM

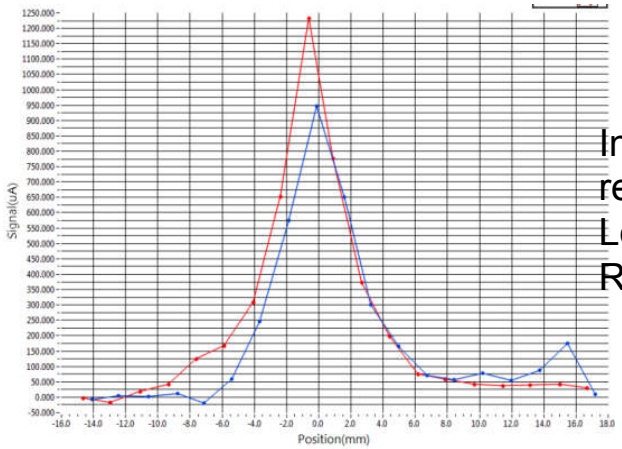
- During the “single shot” mode, the system was used as BPM.
- For accuracy, the scan method of the MWPM should be added.



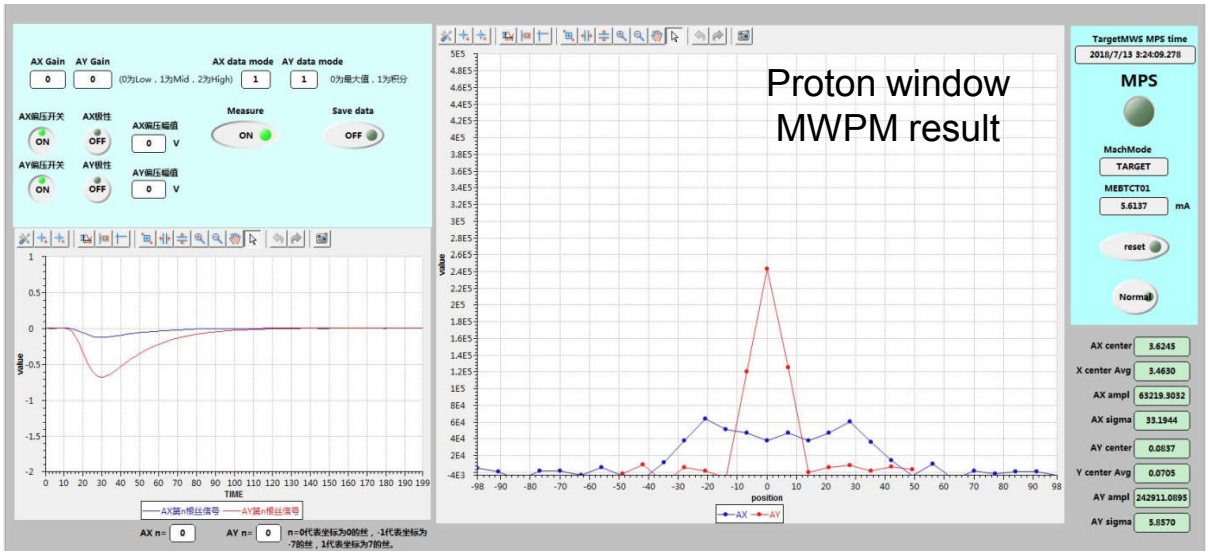


Beam devices-MWPM





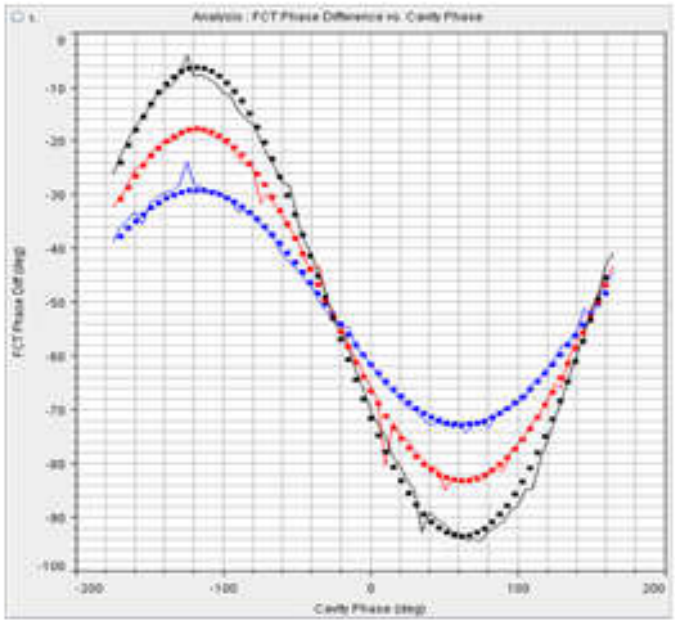
Injection section MWPM results
Left: before stripping foil
Right: after the foil



Beam devices-Phase

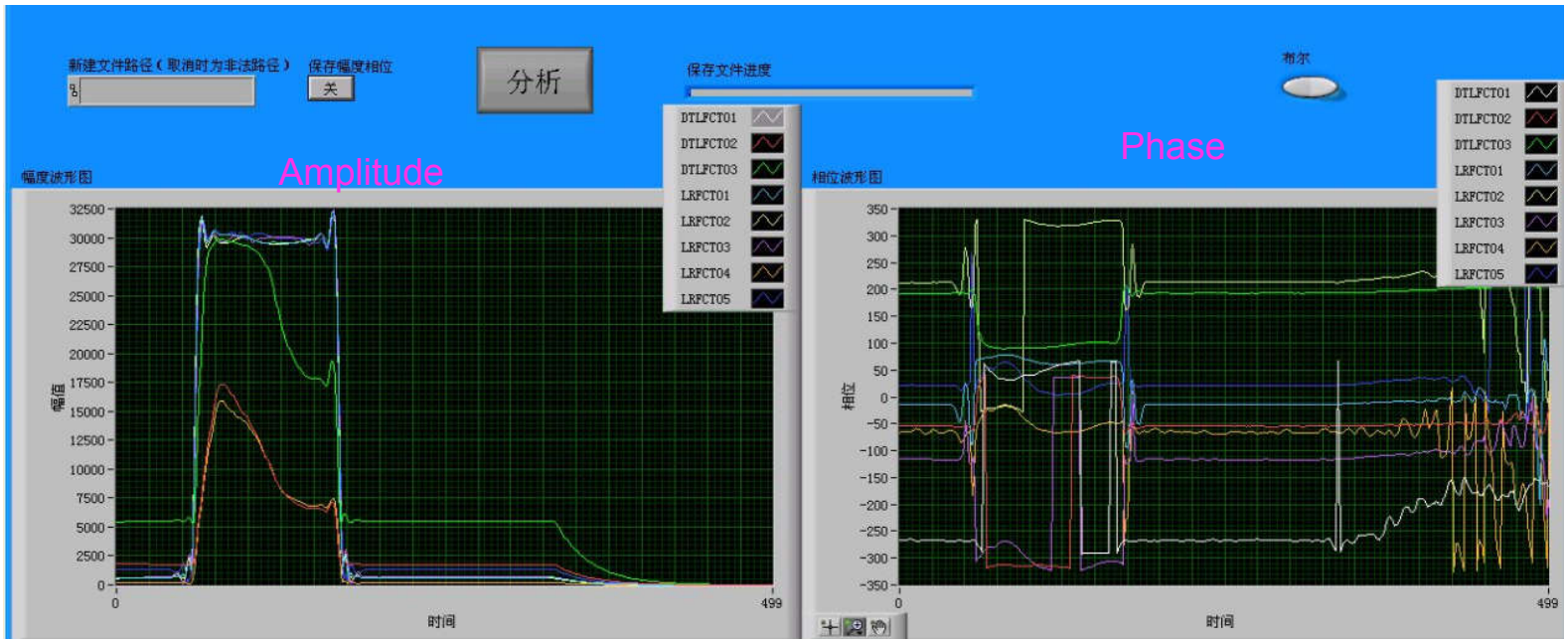
- The RF cavity tuning was finished by using RF system and phase measurement.
- During the commissioning early stage, beam was unstable, we can not got this result.

Buncher02 Phase Scan



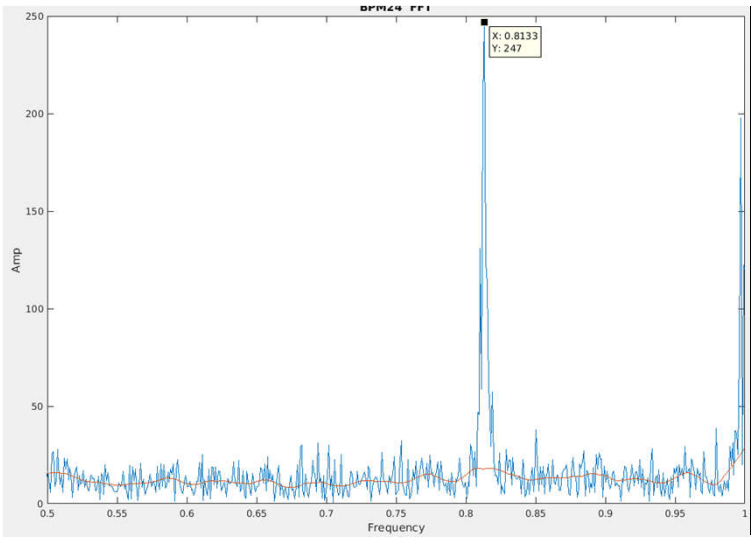
Beam devices-Phase

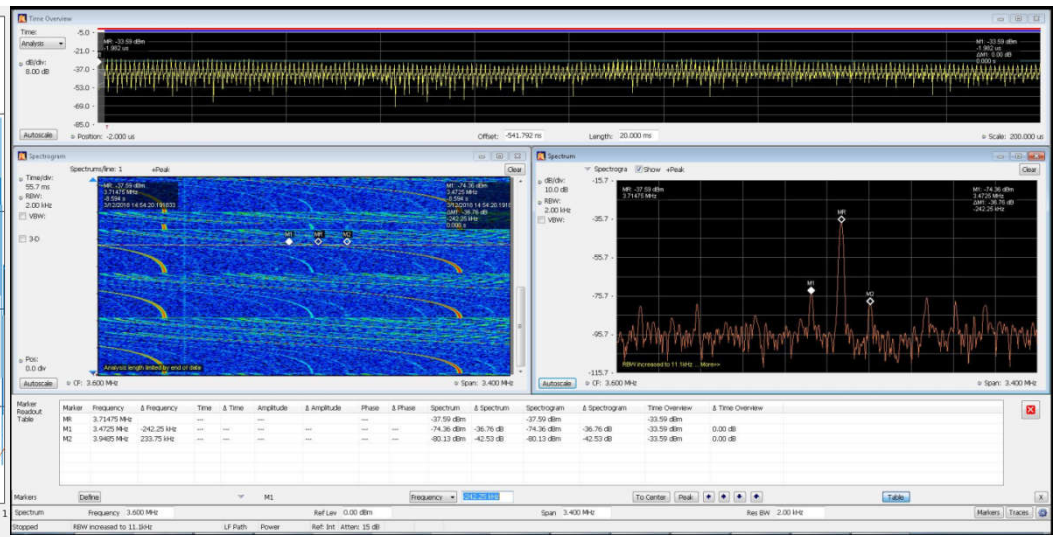
- The phase result sometimes appears “360 jump”, we should resolve it.
- About this, the detail can be found in Peng Li’s paper WEPA07 in this conference.



Beam devices-Tune

- **Beam exciter**
  - Keysight 33500 signal generator + 2KW amplifier + kicker
- **Two methods to get tune**
  - BPM TBT data-FFT
  - ΔBPM-Tektronix RSA5103B Real-time signal analyzer





Conclusion

- All the beam devices works normally during the beam commissioning.
- Many questions are found, and should be resolve in the future.
- We need notice the new technology to improve our system.

Thanks for your attention!

Thanks J-Parc persons give us more detail help!
Thanks SNS BI group documents sharing!

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