Commissioning of the Beam Instrumentation System of CSNS

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On behalf of BI group of CSNS, IHEP

AFAD 2021

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Outline

- CSNS Overview
- Performance of BI system during commissioning
- Summary

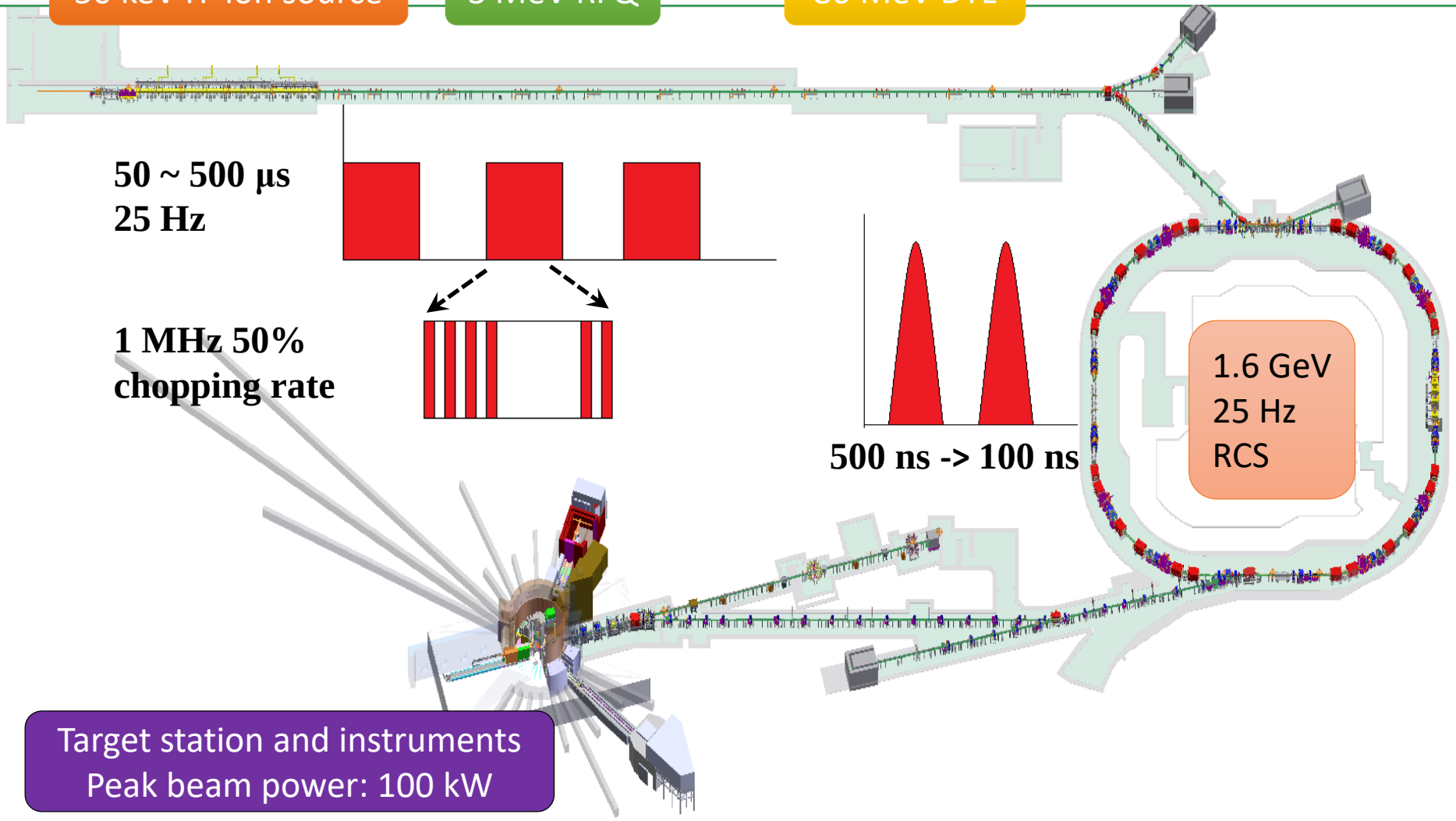
CSNS Overview

Layout of CSNS

50 keV H^- Ion source

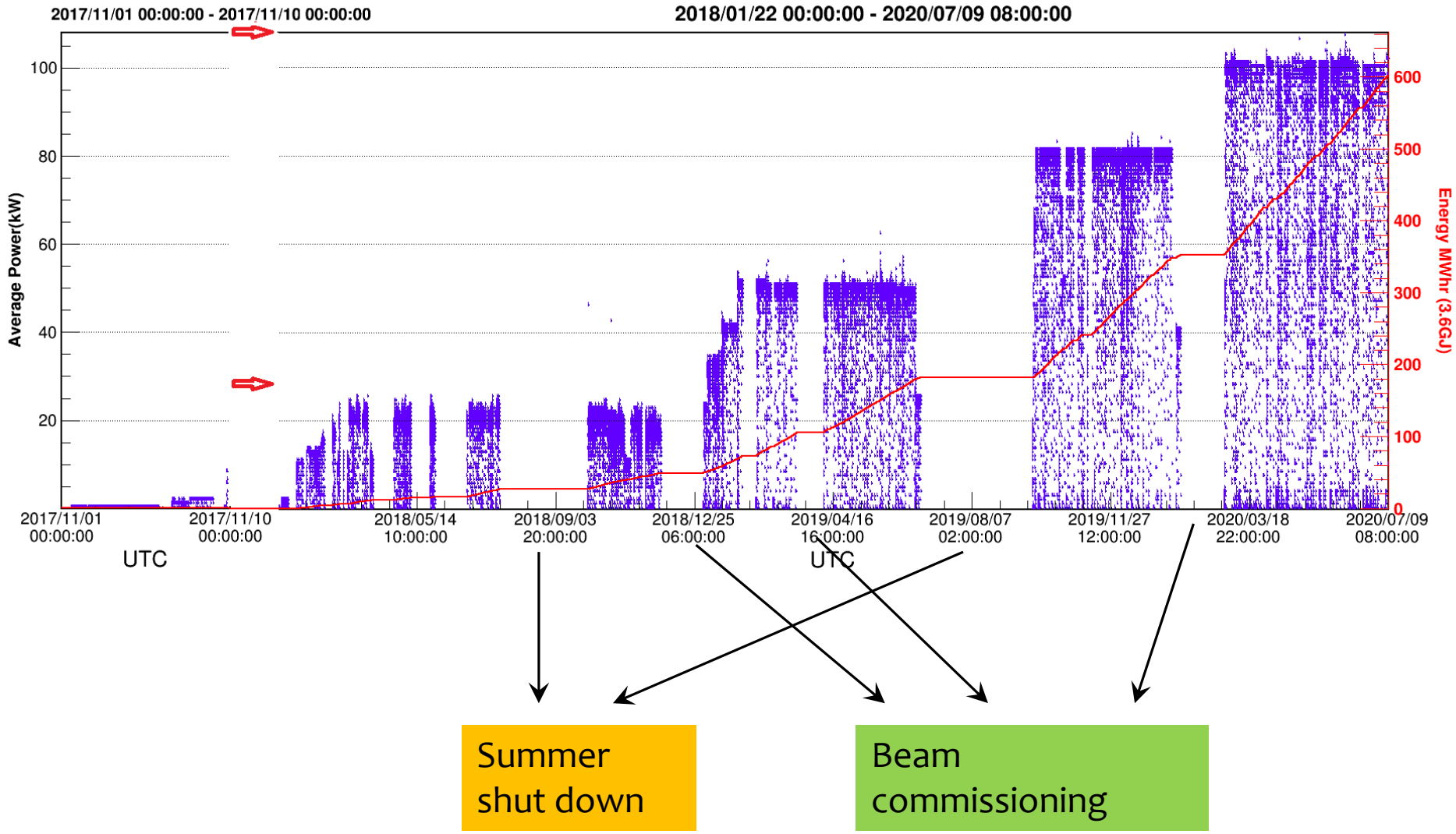
3 MeV RFQ

80 MeV DTL

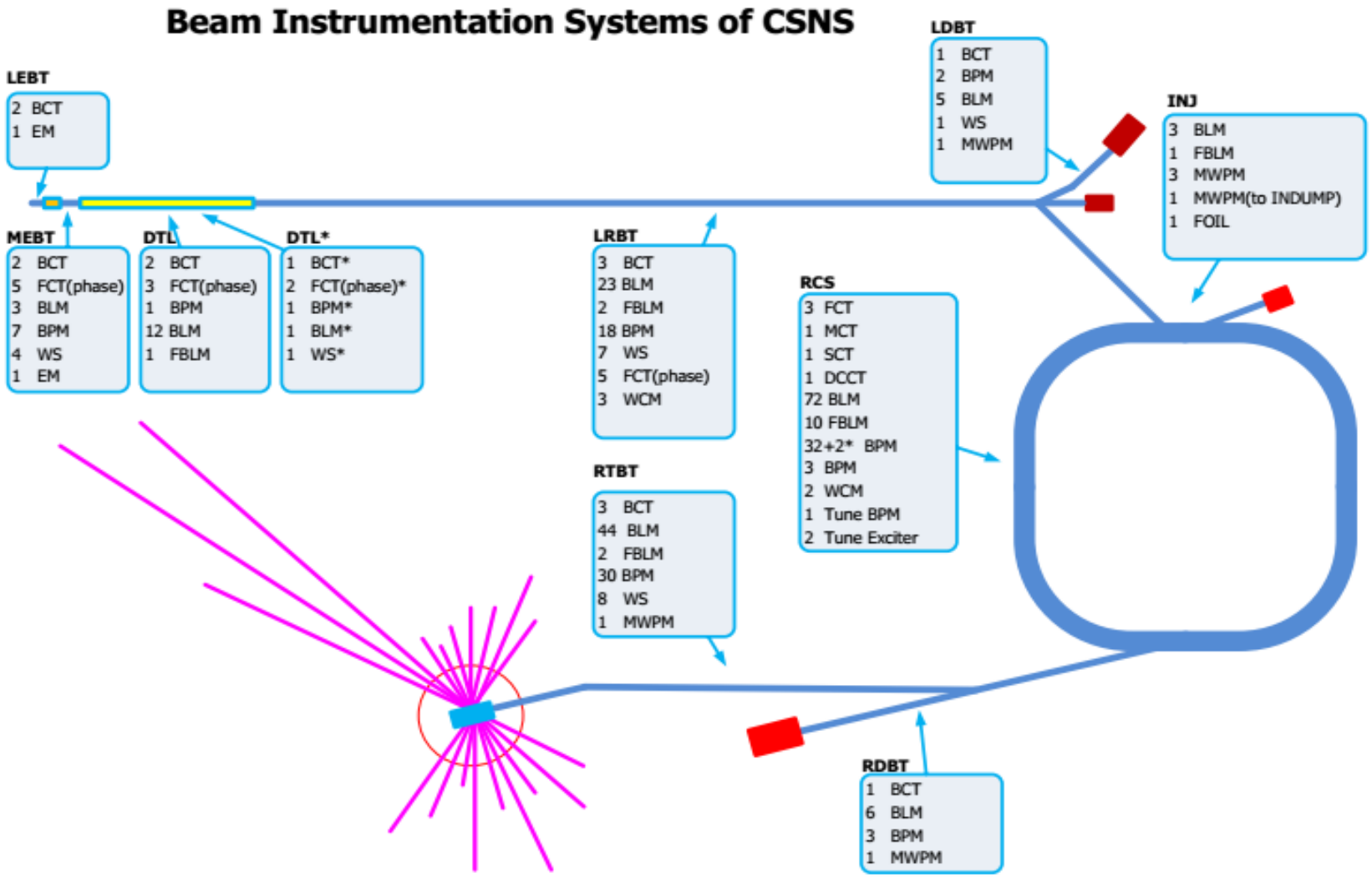


Target station and instruments
Peak beam power: 100 kW

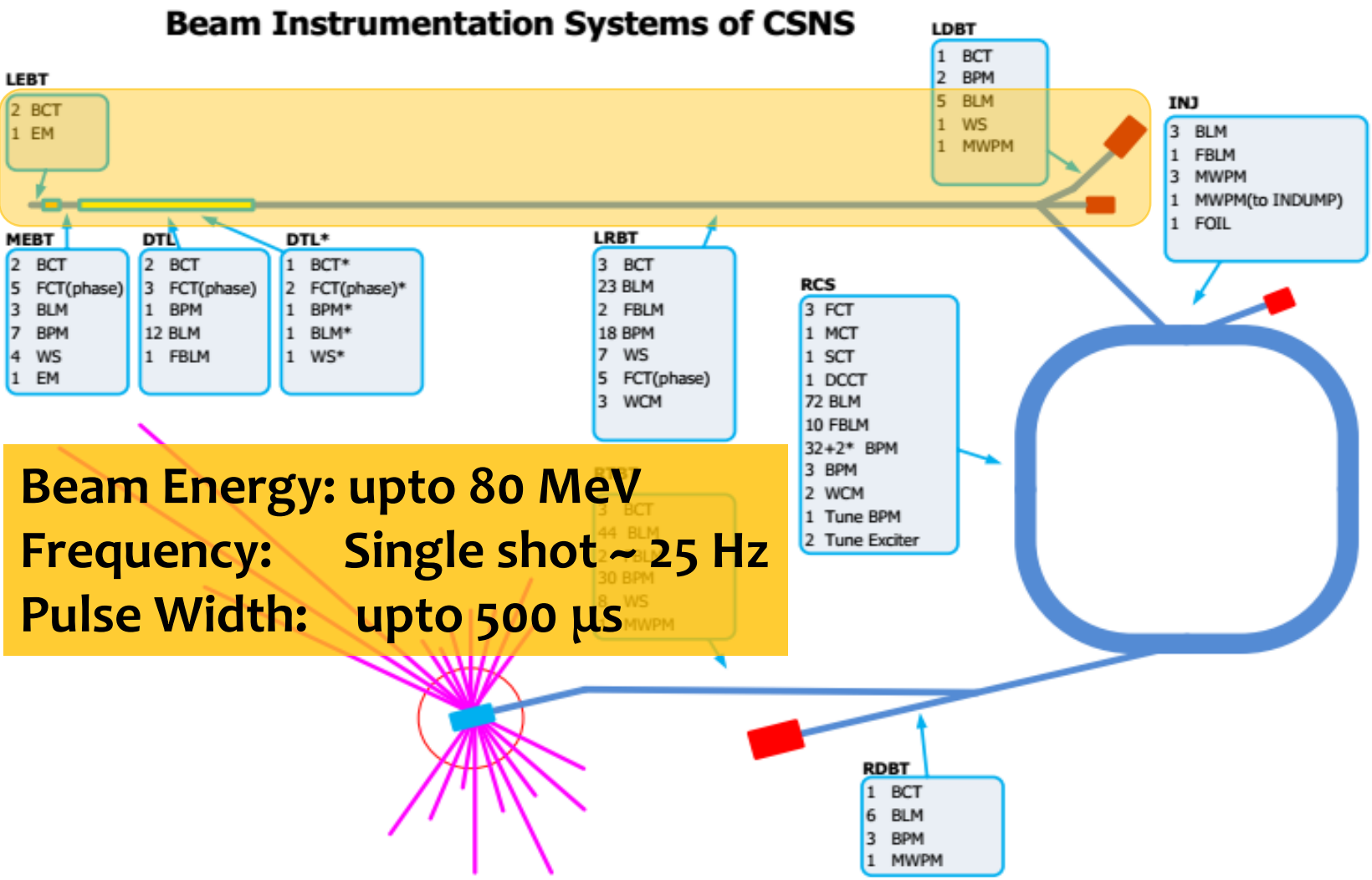
Beam Power History



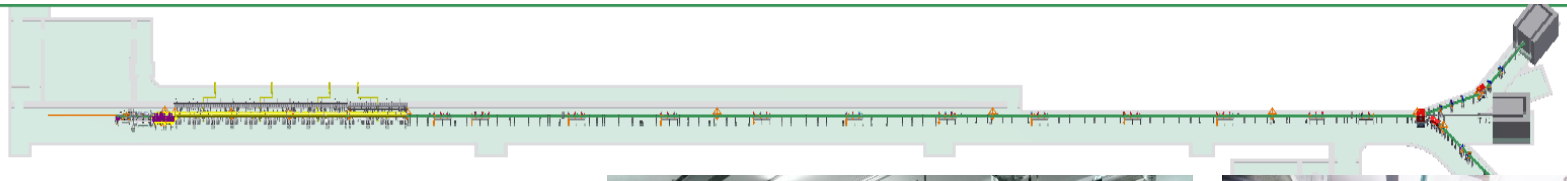
Beam instrumentation system



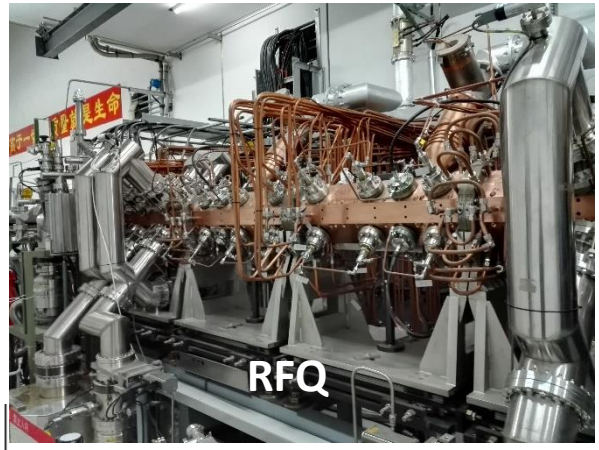
LINAC commissioning

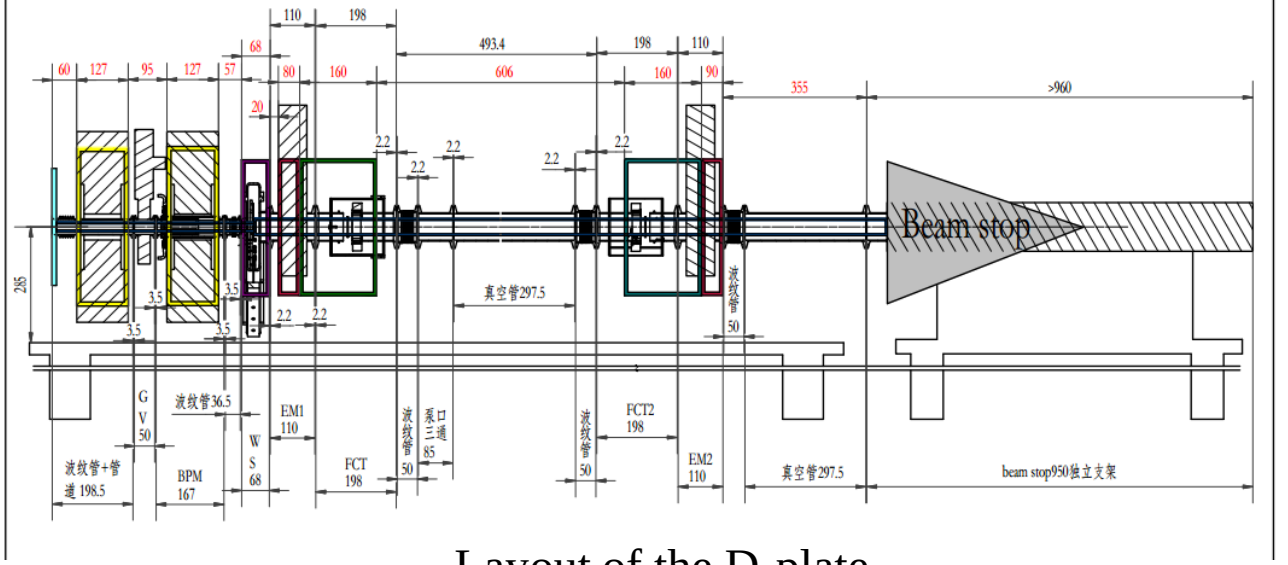


Commissioning and installation goes in parallel



- **Ion source, RFQ, MEBT and DTL1 was installed in beam tunnel in 2016.**
- **Beam parameters:**
  - 20 MeV
  - 1Hz, 10 mA max.
- **D-plate after DTL1**
  - 2 FCT
  - 1 CT
  - 1 Wire Scanner
  - 1 EM
  - Beam Dump



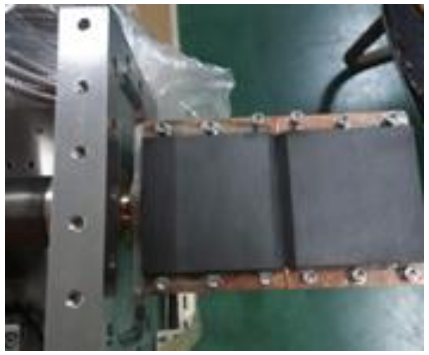


Layout of the D-plate

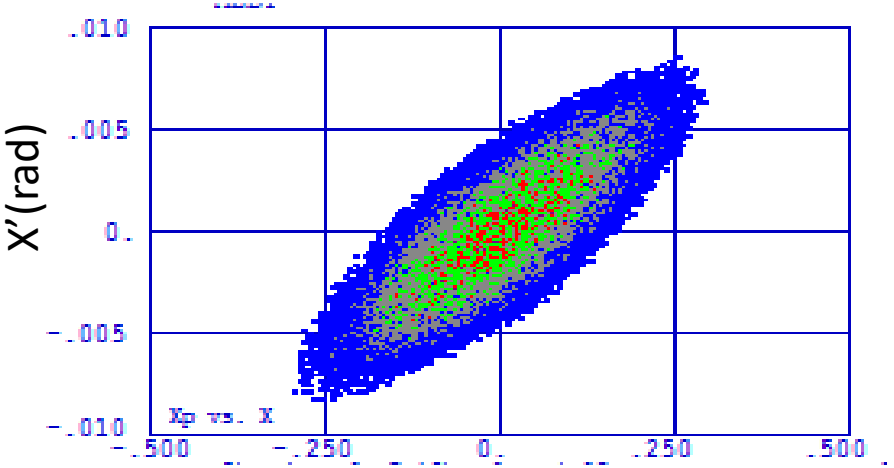
LINAC commissioning results

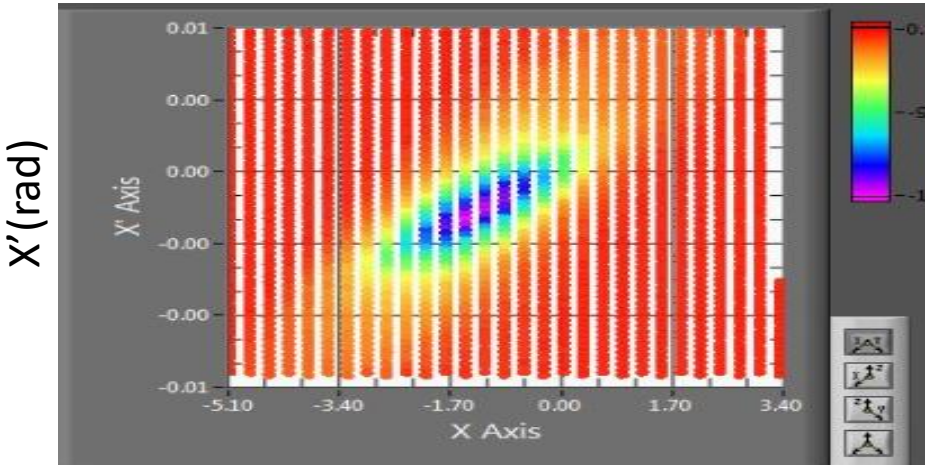
Emittance

- Double-slits + Faraday cup
- Run at 1 Hz, 50 μs



Graphite plate on the first slit to protect the cooper plate from the thermal deposition



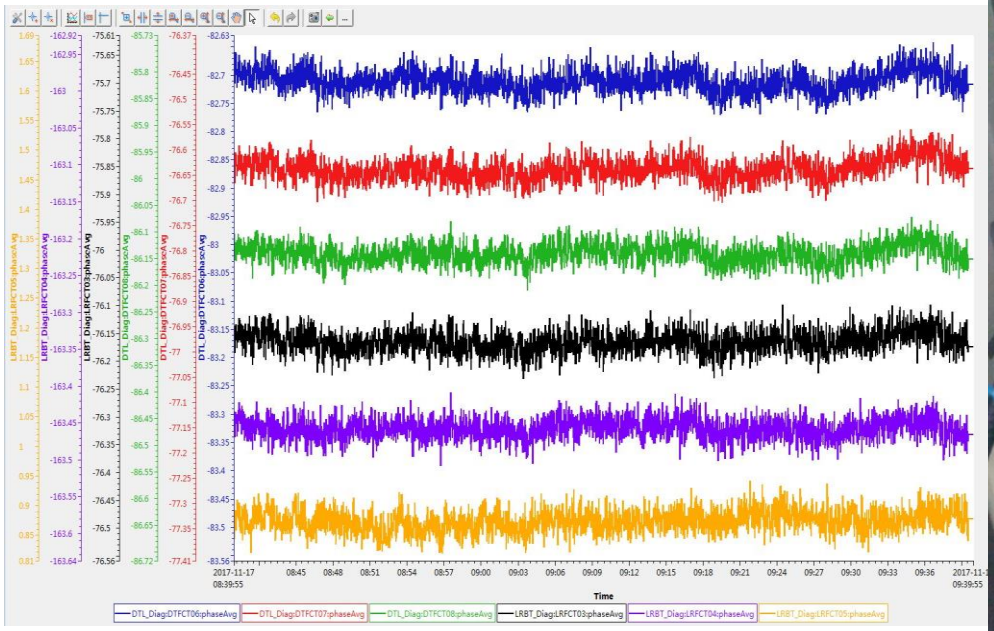


MEBT PARMILA simulation result:
ε_x= 0.152 π mm mrad

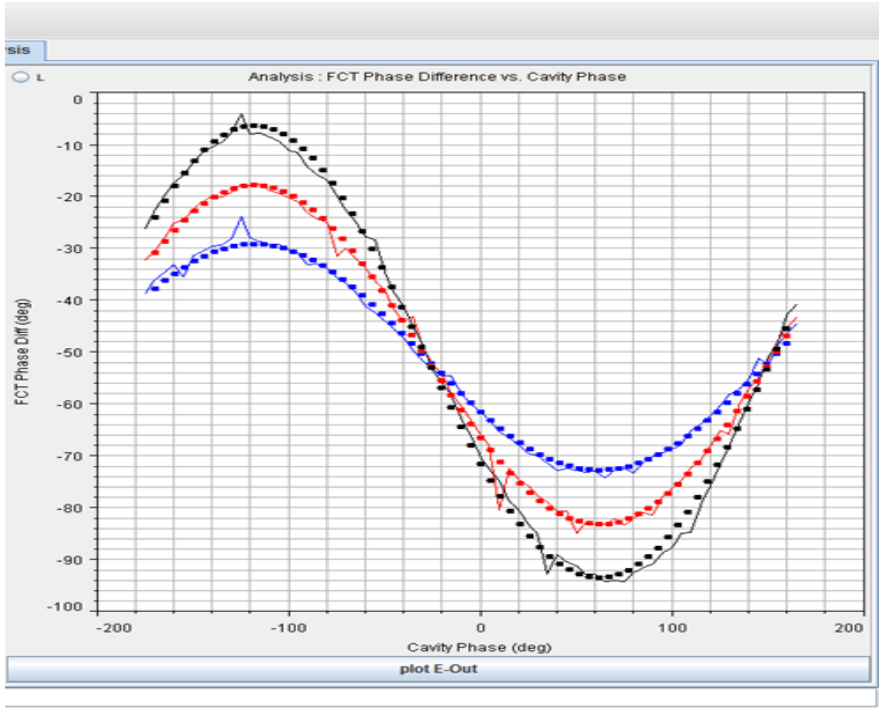
MEBT measurement result:
ε_x= 0.16 π mm mrad

Beam phase

- Bergoz FCT
- Domestic customized electronics for phase measurement.
- Stability within ±0.5 °



DTL1 Phase Scan



Beam energy measurement by two methods

- **Phase scan**
- **ToF**

	Design [MeV]	Phase scan [MeV]	ToF [MeV]
RFQ	3.026	3.029	3.027 ±0.01
DTL1	21.669	21.802	21.685±0.01
DTL2	41.415	41.52	41.566±0.14
DTL3	61.072	60.917	61.09±0.34

Energy deviation < 1%

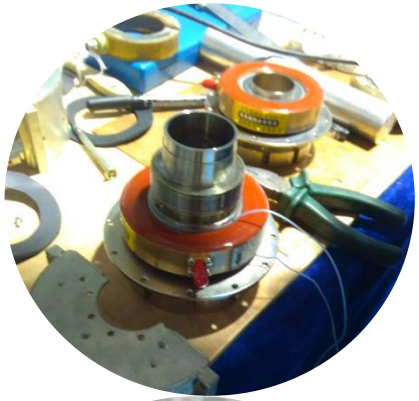
Current monitor

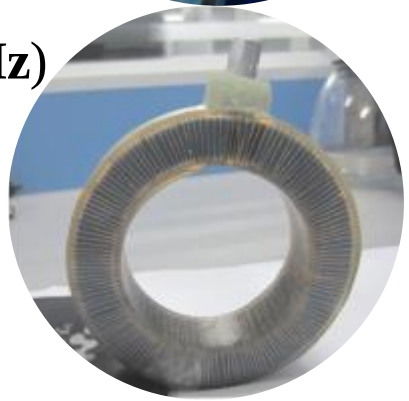
Beam Current Monitor @LINAC

- Magnetic ring from Bergoz
- Magnetic ring from domestic company

  (**Cobalt-base alloys, $\mu_r \approx$ 20,000~25,000 @25Hz**)

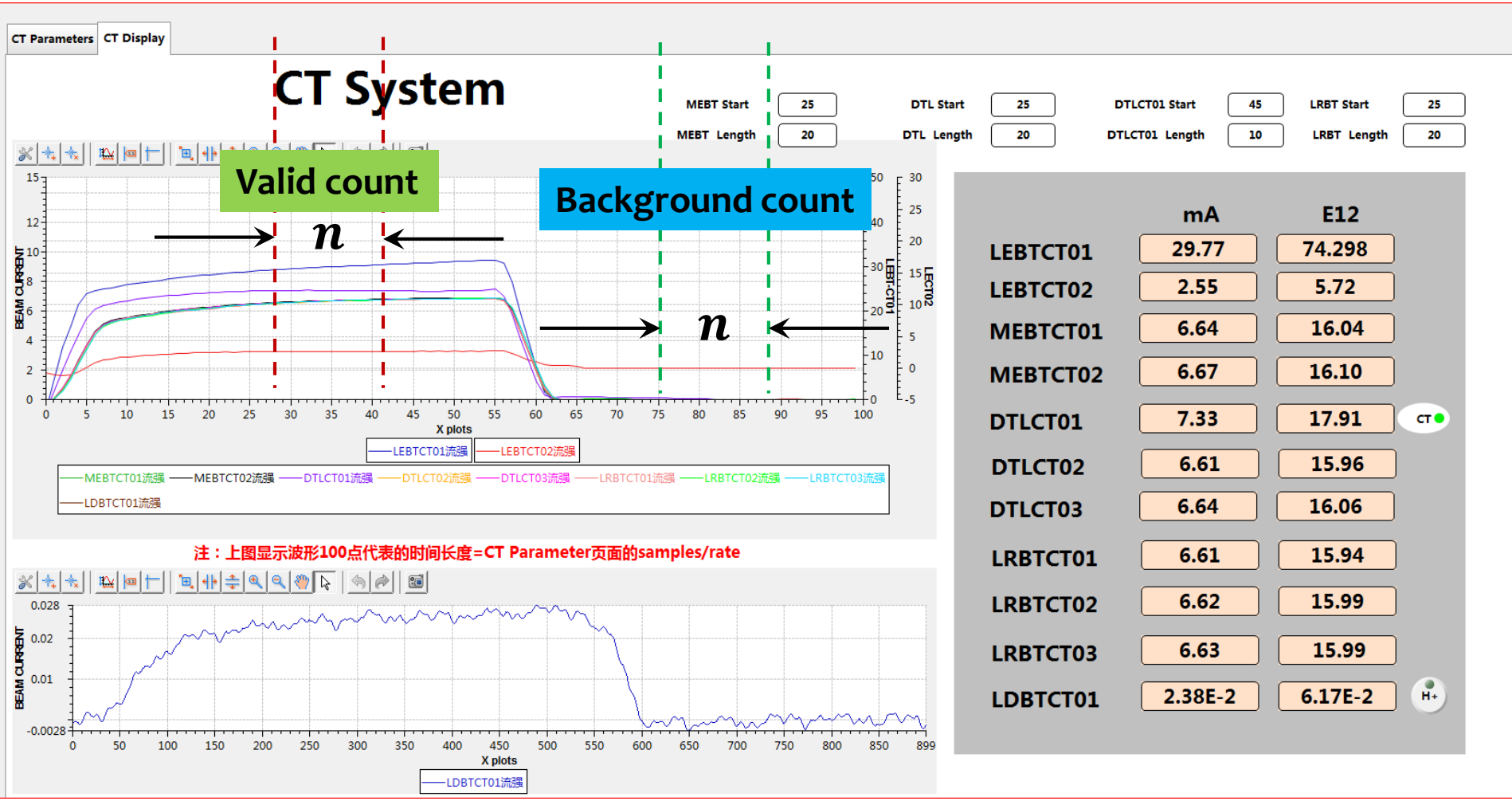
  - Coil number: 150
  - Amplitude droop < 1%
  - Rising time < 1 μs





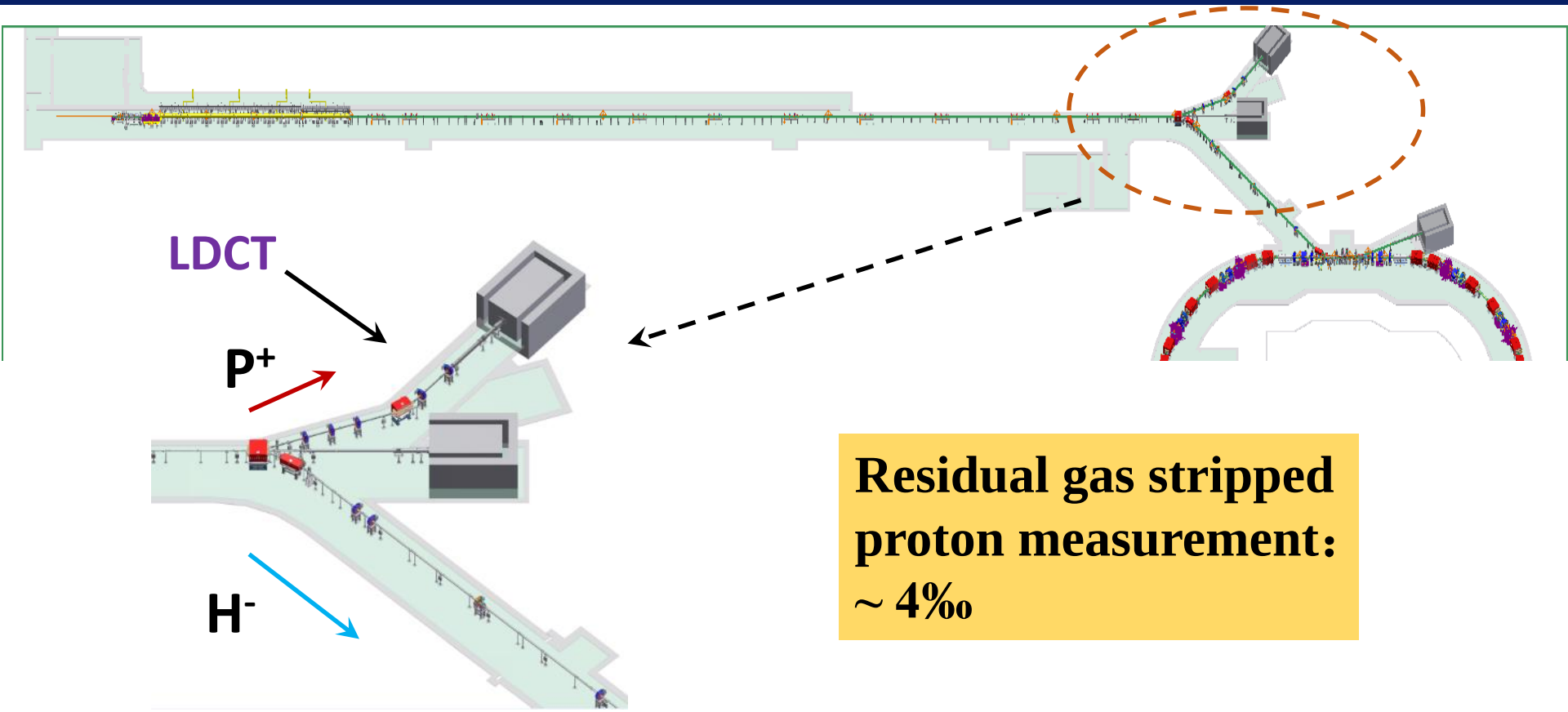
Current monitor

- Beam Current = [Sum(Valid) – Sum(Background)] / n

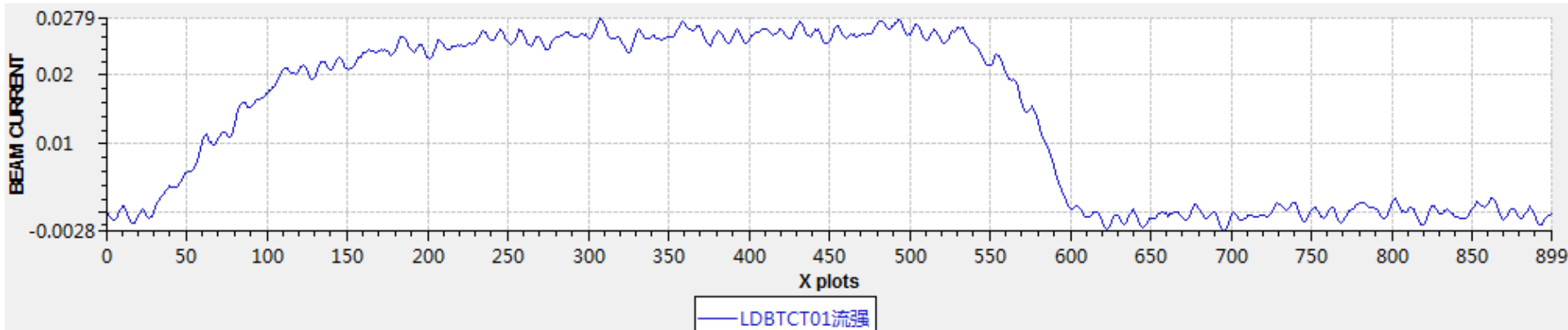


- Integrated waveform value for the particle number calculation

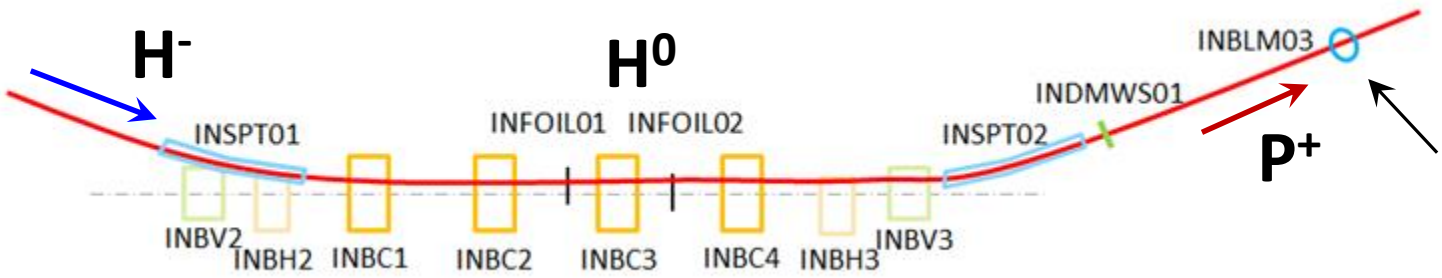
Two special beam current monitor

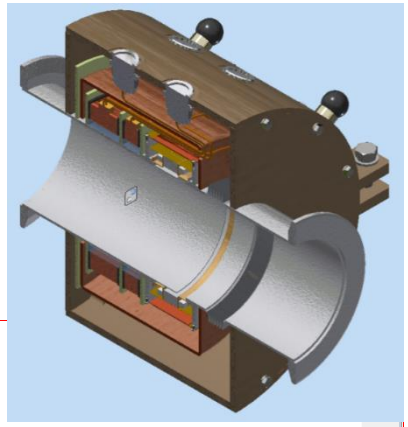


Residual gas stripped proton measurement: ~ 4‰



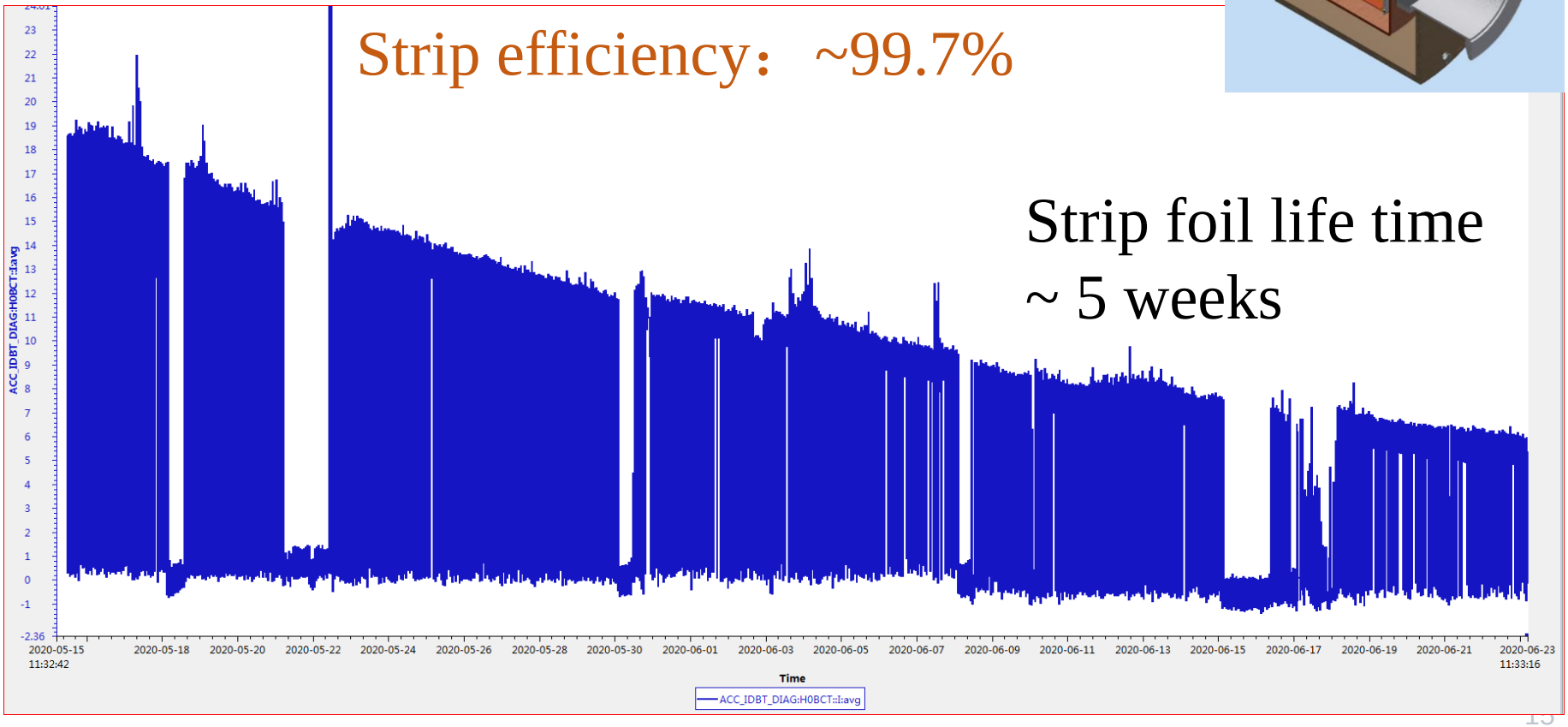
Strip foil efficiency





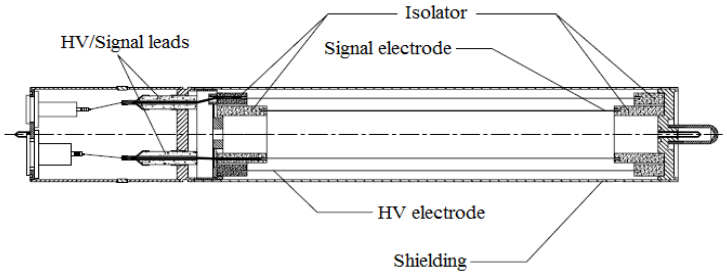
Strip efficiency： ~99.7%

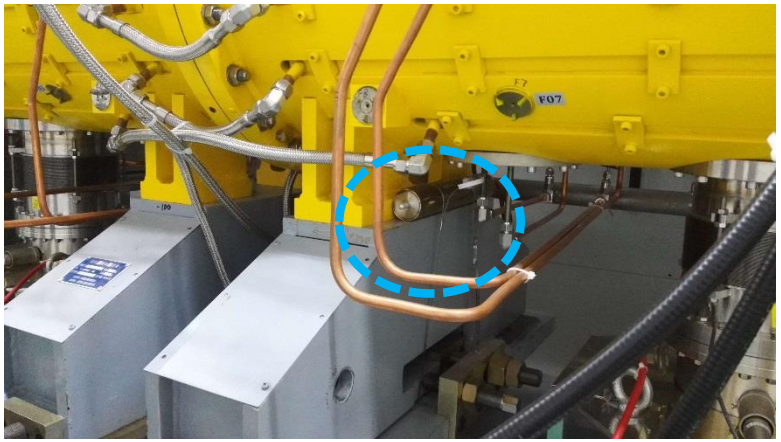
Strip foil life time
~ 5 weeks



BLM

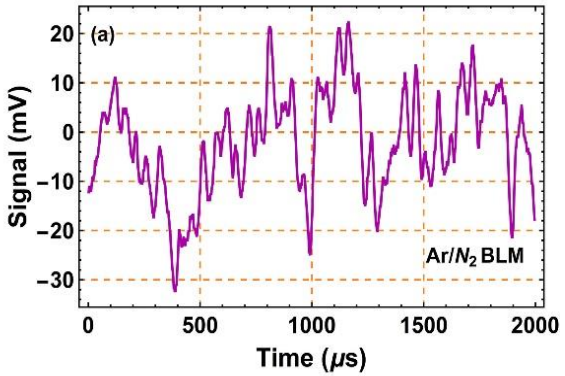
- **Ion chamber: Ar+N_2, BF_3**
- **Electronics outputs integrated into the MPS**
  - Direct output for instant beam loss protection: rise time ~ 7 μs
  - Integrated output for continuous low beam loss (one period) protection
- **Backgrounds subtracted in software level**

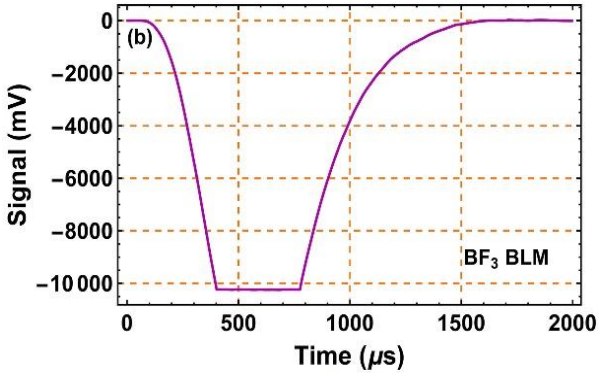




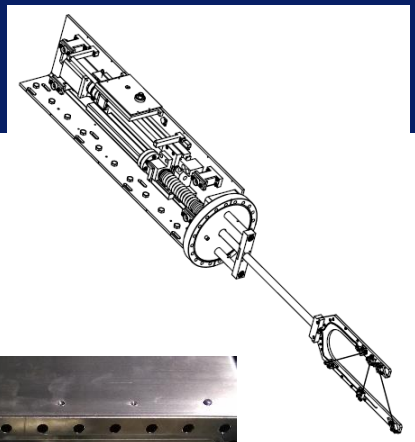
DTL		DTL	
BLM01	-15.6	BLM01	-22.8
BLM02	-11.6	BLM02	-47.3
BLM03	-38.2	BLM03	-586.1
BLM04	-33.3	BLM04	-139.9
BLM05	-60.5	BLM05	-88.6
BLM06	-39.4	BLM06	-862.7
BLM07	-23.5	BLM07	-873.1
BLM08	-18.2	BLM08	-2101.8
BLM09	-7.3	BLM09	-2908.4
BLM10	-28.4	BLM10	-50.6
BLM11	-24.9	BLM11	-11.8
BLM12	-15.8	BLM12	-19.3

- **Experiment on low energy beam loss detection**
  - Fast neutrons can be moderated to thermal neutrons by polyethylene (PE), and detected by BF_3.
  - BF_3 type BLM covered by 7.5 cm thick PE located under DTL1 (beam energy ~15 MeV)
  - BF_3 signal is ~1757 times higher than $Ar+N_2$, agrees well with theoretical calculation （~1600）





Profile monitor

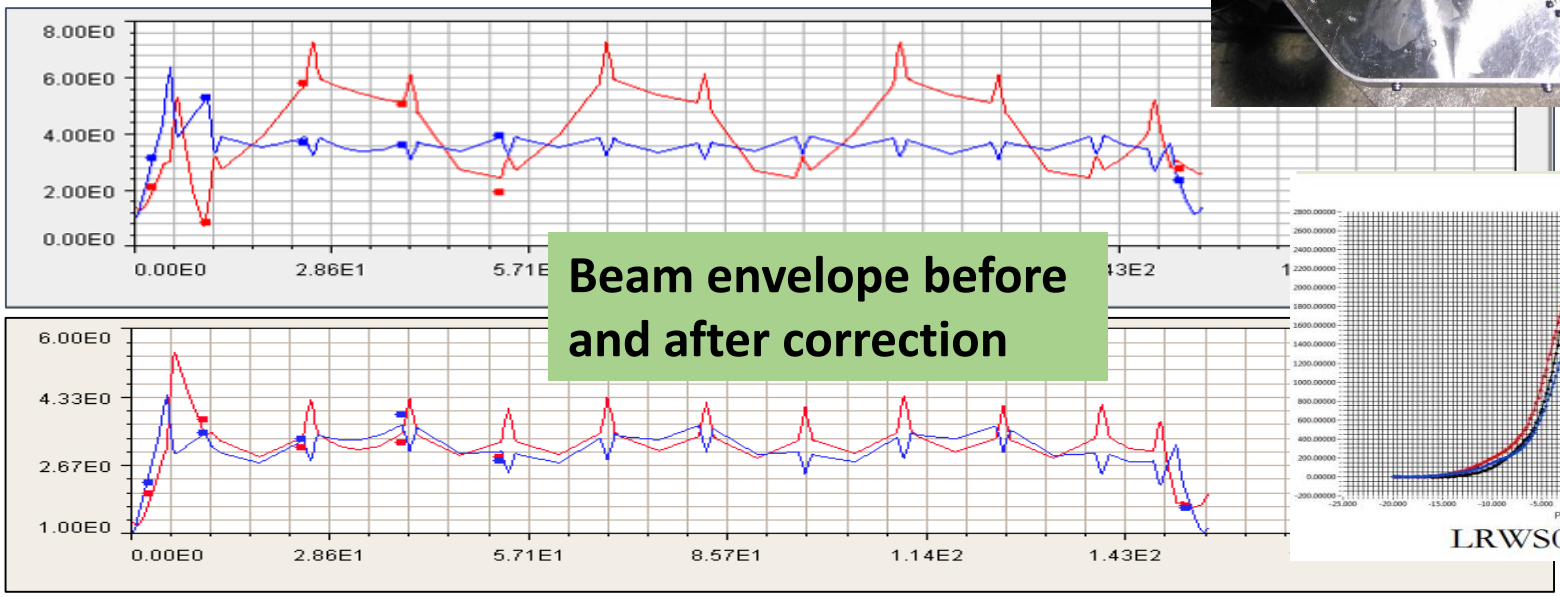


Wire scanner

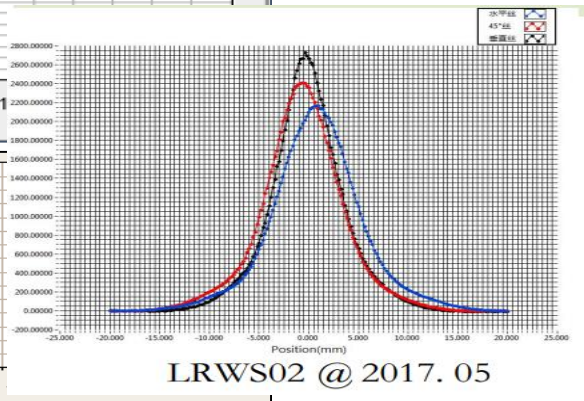
- MEBT (3 MeV): Carbon wire, 30 μm
- LRBT (80 MeV): Tungsten wire, 50 μm

Multi-wire

- In front of beam-dump
- Injection area

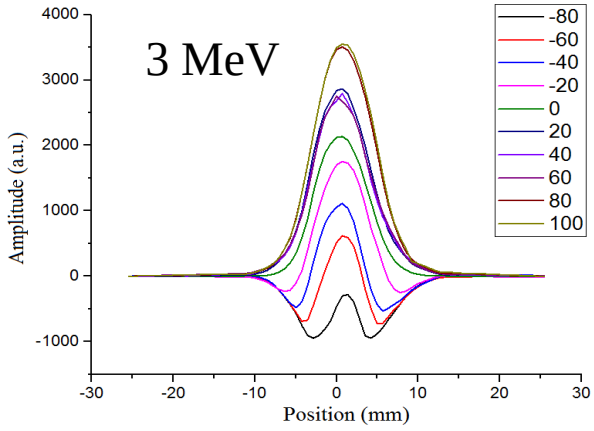


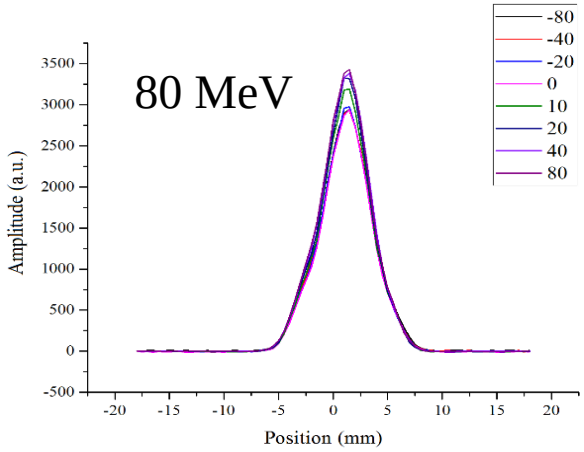
Beam envelope before and after correction



Bias voltage experiment

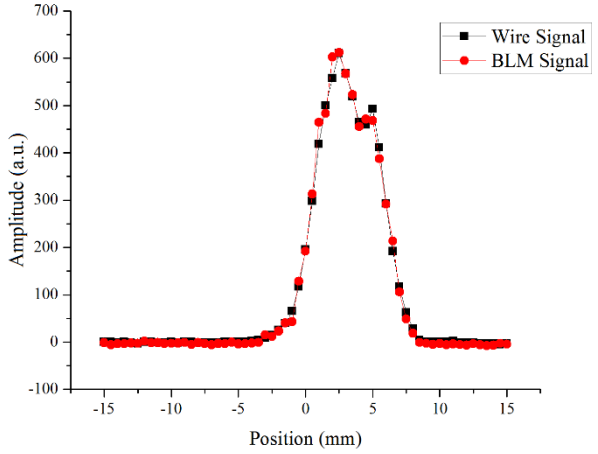
- Positive bias applied for H- measurement to enhance the S/N ratio
- A 20 V bias should be satisfy the profile measurement





Verification of the BLM sensitivity

- Current intercepted by the wire can be calculated theoretically
- BLM sensitivity to the beam is better than 100 nA

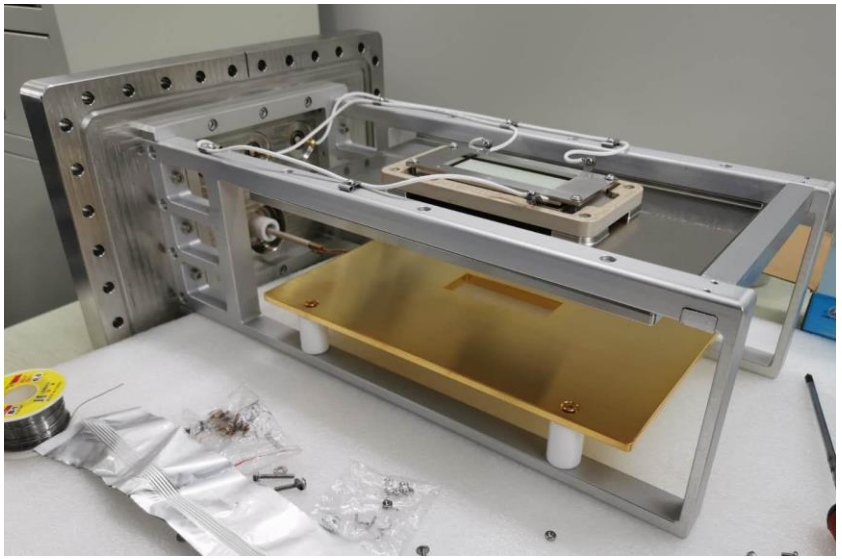


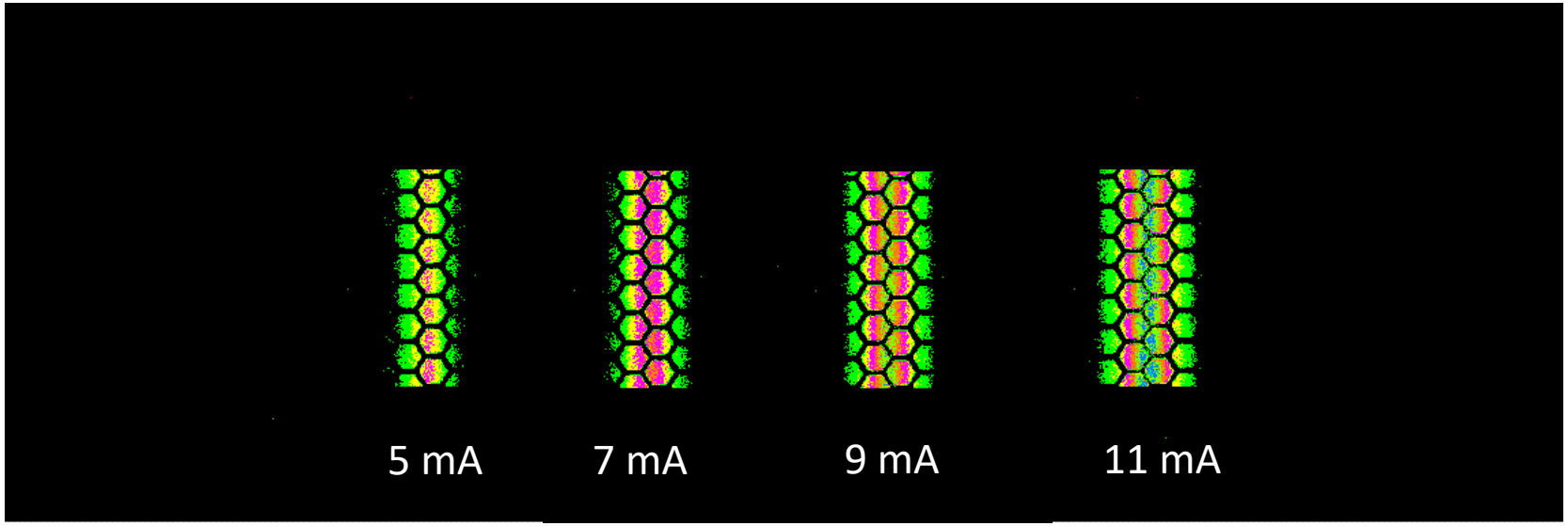
Beam profile plotted by wire signal and downstream BLM signal.

LINAC-IPM

Image acquisition type IPM

- Need carefully study
- Image profile size varying with the beam current, while beam repetition rate, pulse width and camera configuration keep remain

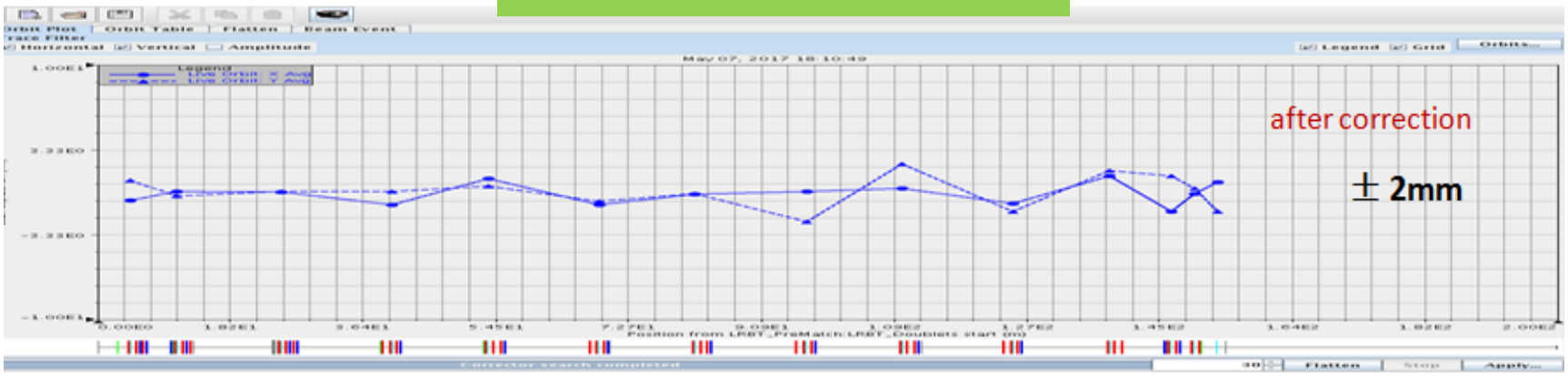




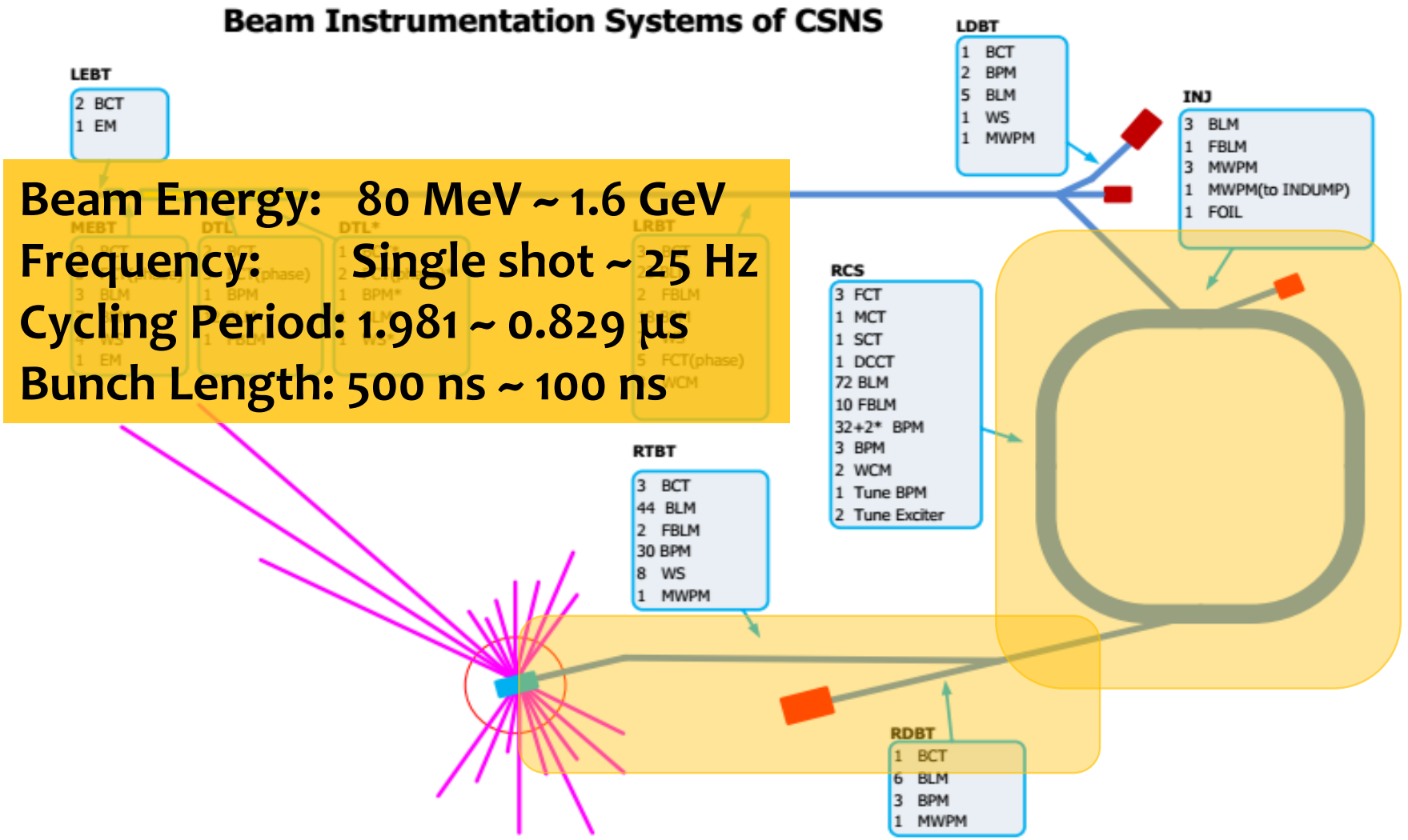
BPM

- Strip line
  - Libera → EPICS Released
  - Bergoz → NI ADC → LabVIEW

LRBT orbit correction



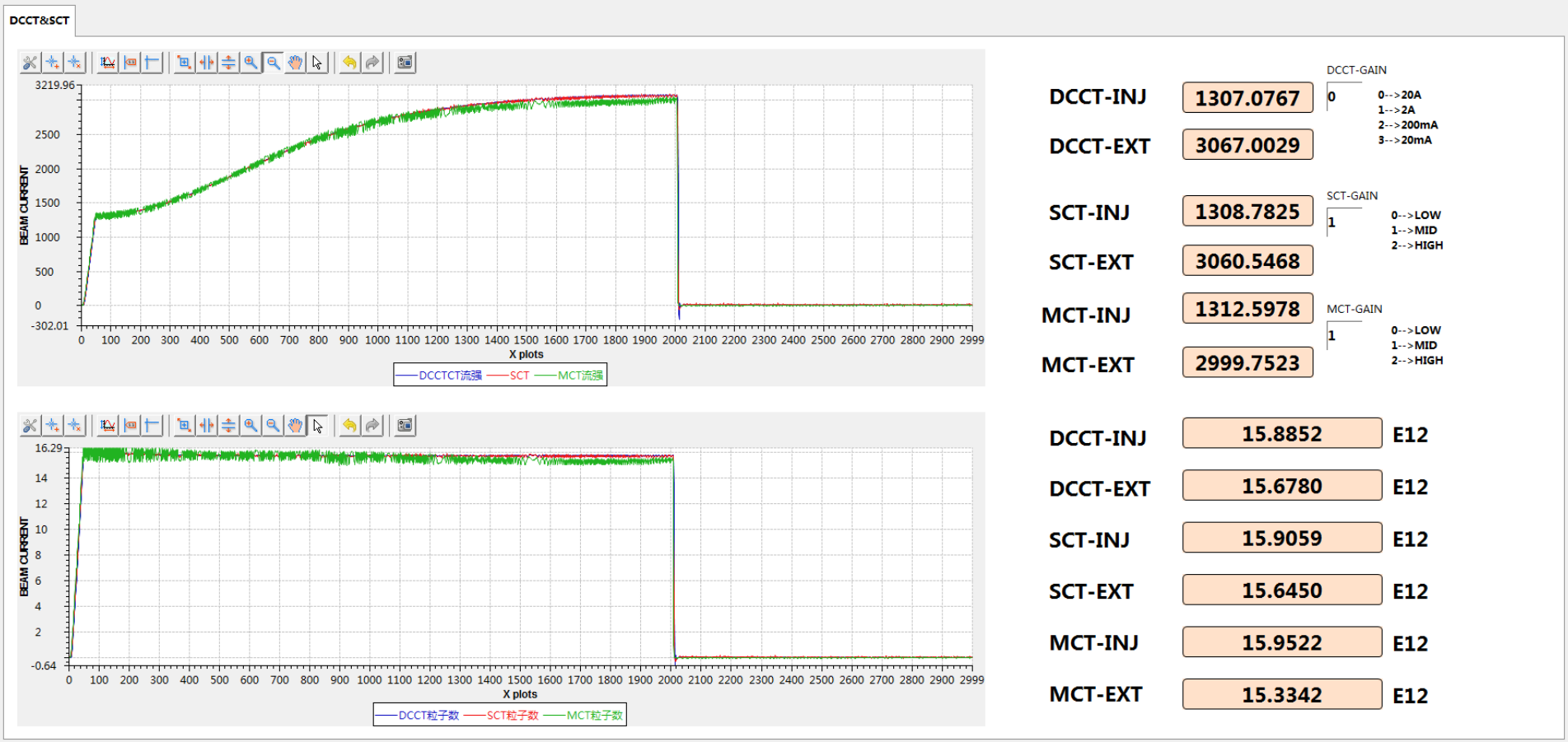
RCS&RTBT Commissioning



Beam Energy: 80 MeV ~ 1.6 GeV
Frequency: Single shot ~ 25 Hz
Cycling Period: 1.981 ~ 0.829 μs
Bunch Length: 500 ns ~ 100 ns

RCS – DCCT / SCT

- DCCT: Commercial product from Bergoz
- SCT: Self developed sensor and electronics



BPM

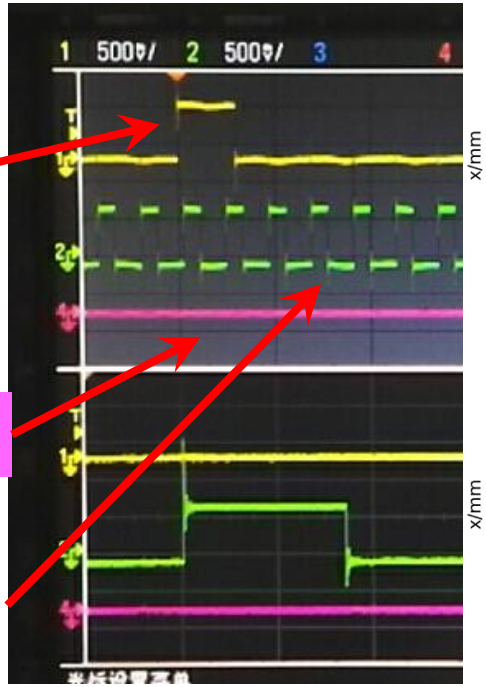
RCS & RTBT

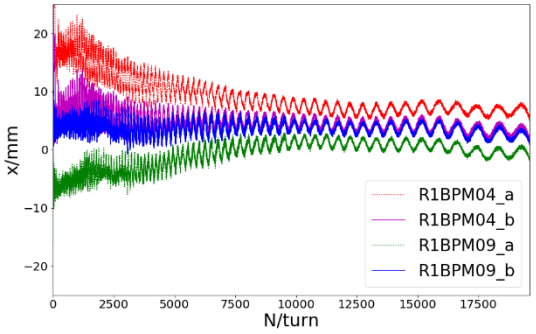
- Cylindrical shoebox type
- Self-developed electronics, TBT or COD mode
- RTBT: commercial electronics from Libera Spark

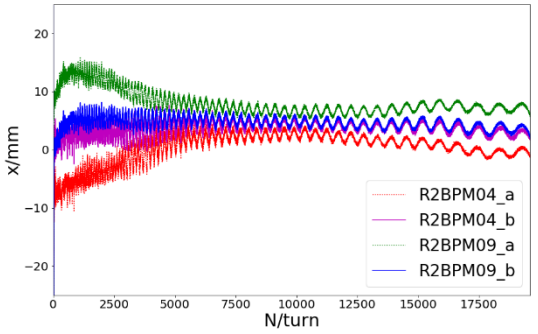
To from control system

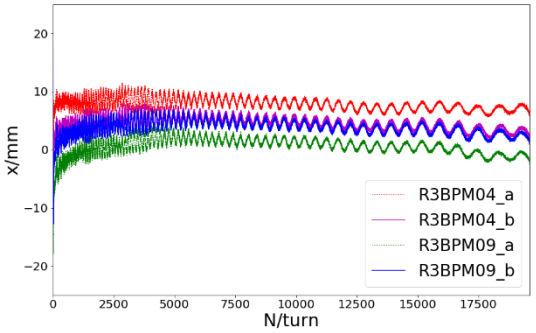
Beam Signal

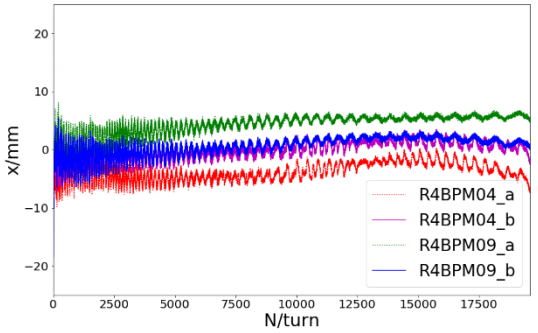
RF Trigger

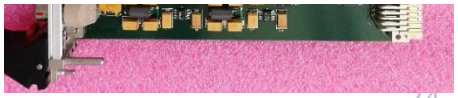






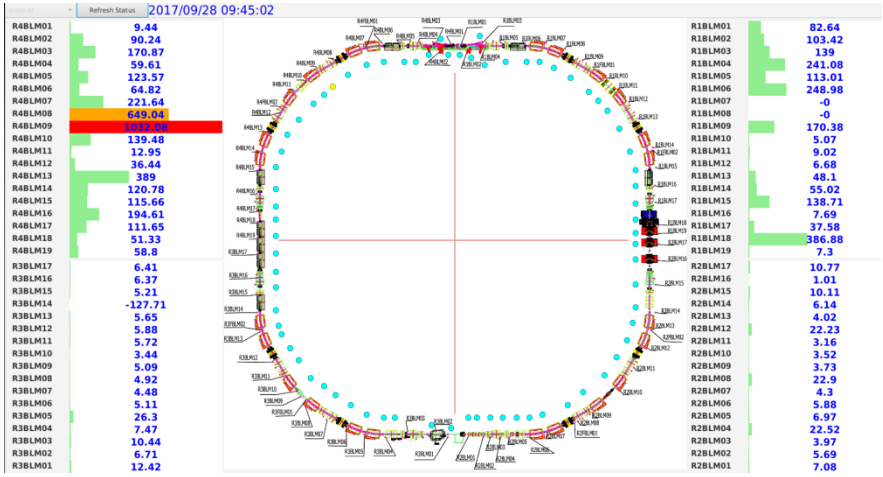


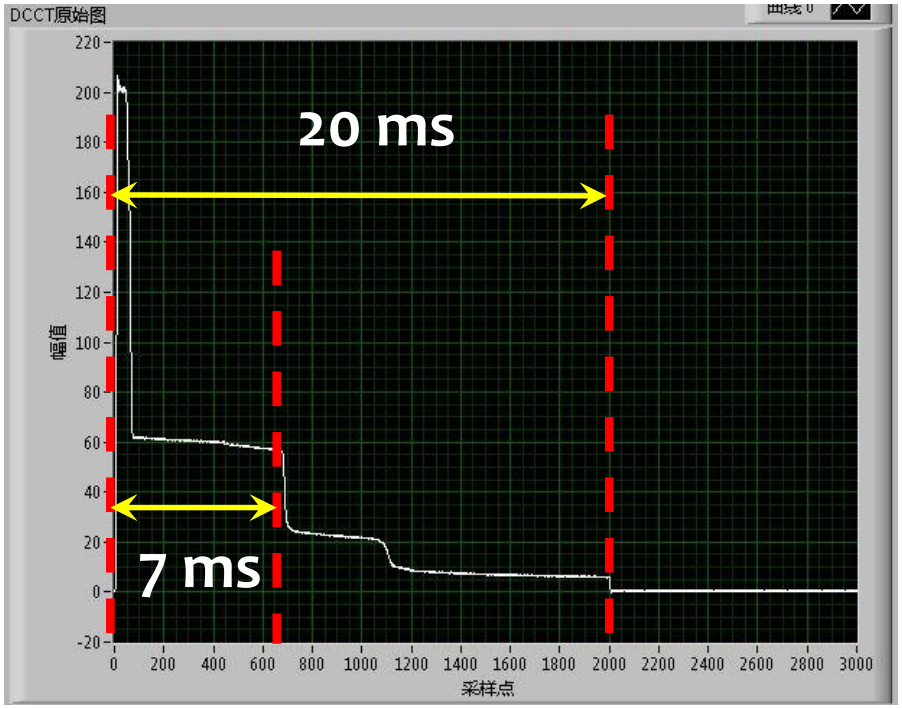


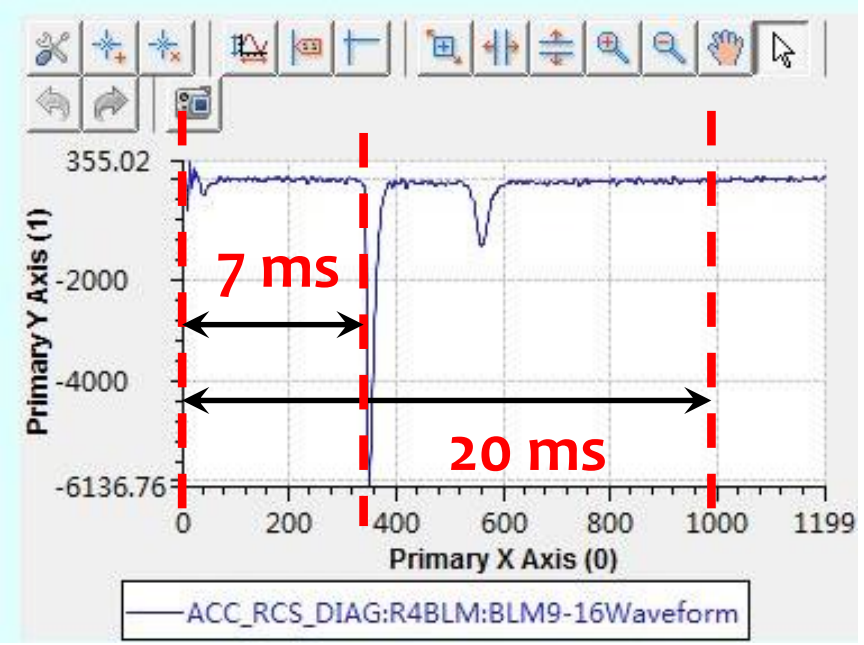


RCS – BLM

- 75 ion chamber
- 12 more ion chamber mounted at injection and collimation area
- 10 Plastic scintillator + photomultiplier

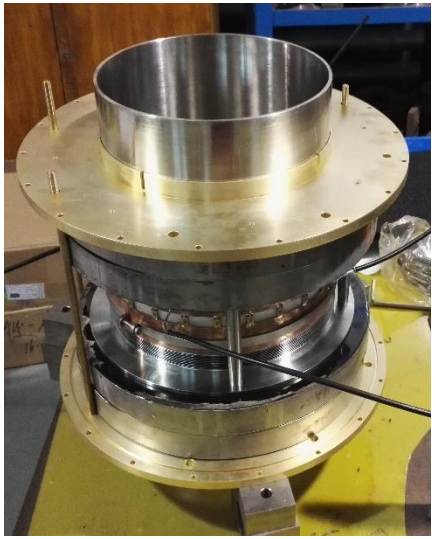


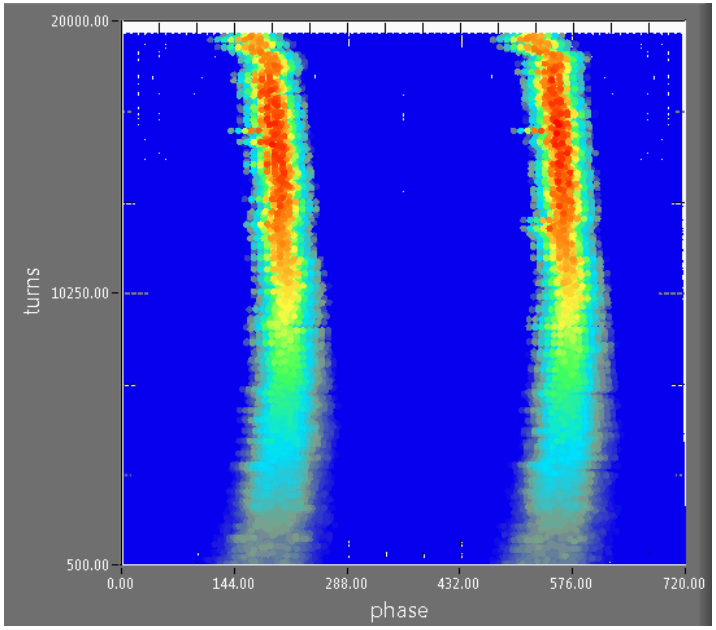




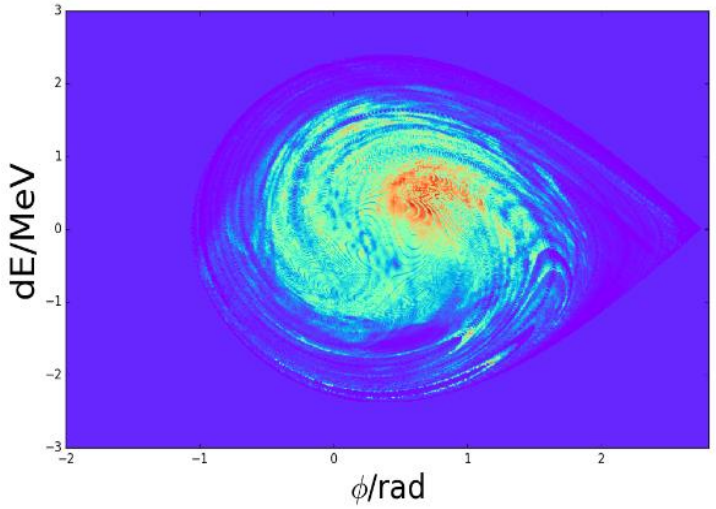
RCS-Wall current monitor

- Band width > 100 MHz
- NI PXI-5124 Oscilloscope + LabVIEW GUI





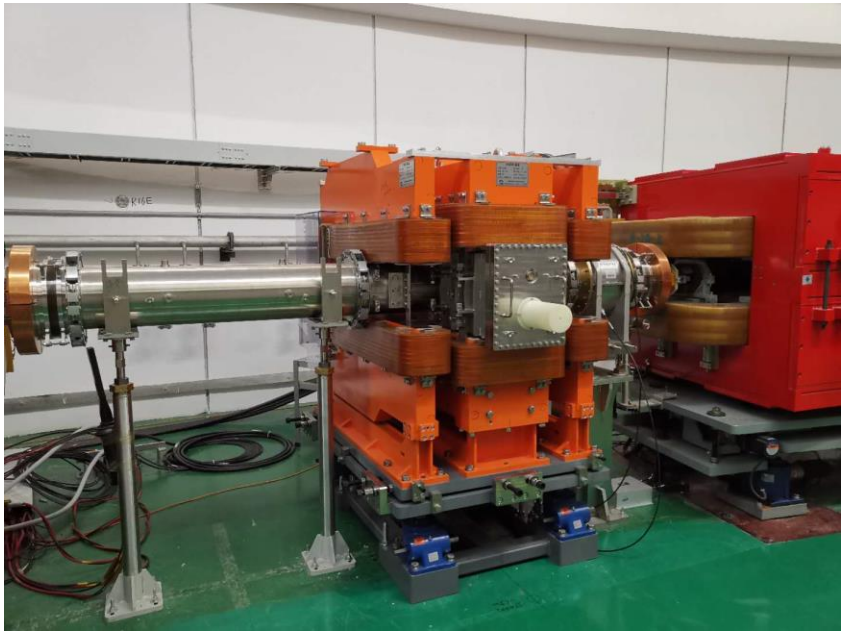
Bunch phase with respect to RF signal



Longitudinal phase space tomography

RCS-IPM

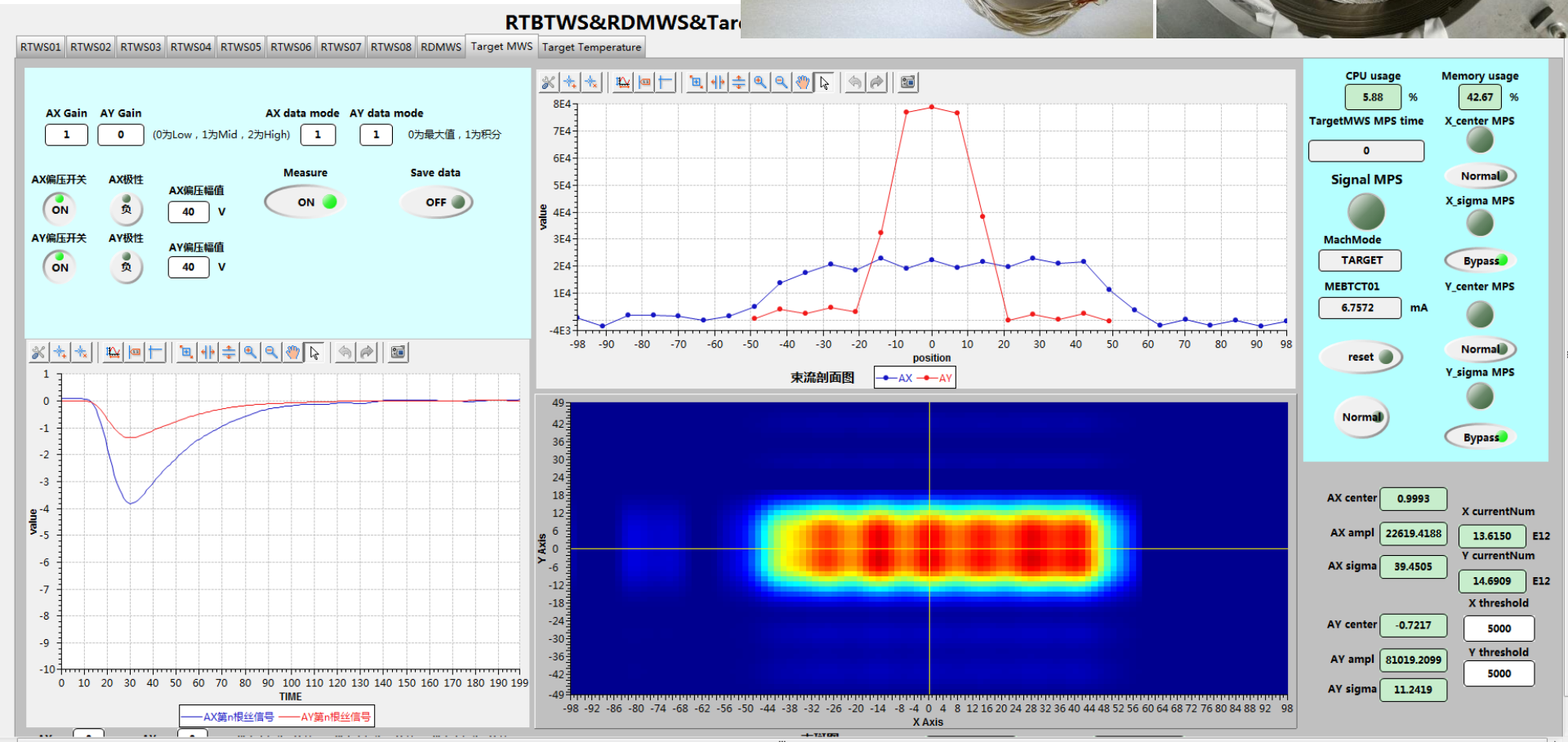
- An Ionization Profile Monitor (IPM) has been developed and mounted in beam tunnel.
- Electron collection, HV up to -50 keV
- Magnetic field up to 0.2 T



Many thanks to Dr. Kenichirou Satou from J-PARC for his generous help.

Profile Monitor @PWB

- Multi-wire profile monitor



Summary

- CSNS has achieved its design goal of 100 kW, Feb. 2020, 18 months ahead of schedule, and running @100 kW stably since then.
- For beam instrumentation, all subsystems perform well, we are keep developing, improving and updating.
- CSNS-II is now on the agenda, the beam power will be increased to 500 kW.

Thanks for your attention!