IPAC'15

Overview of Beam Instrumentation for the CADS Injector I

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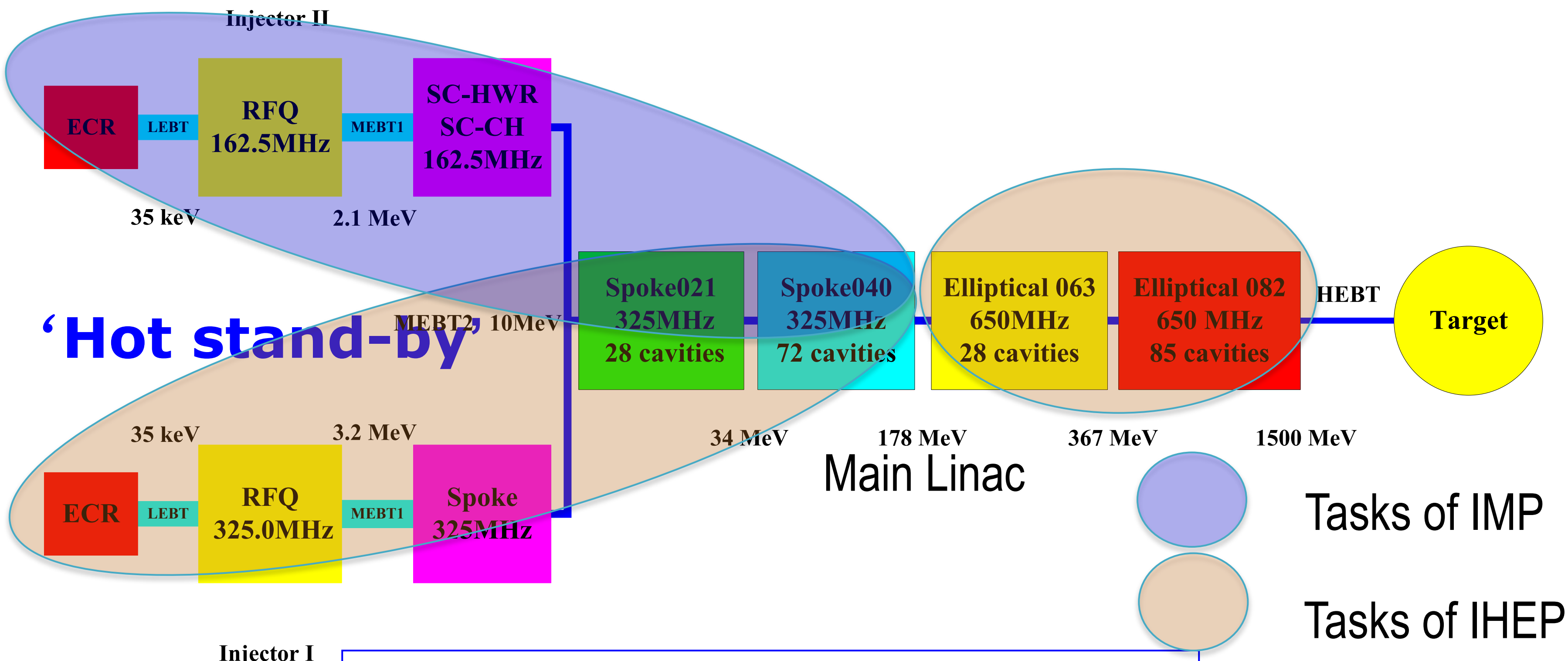
- Introduction of CADS
- Beam instrumentation of CADS injector I
- Commissioning tools for RFQ and TCM
- Conclusion

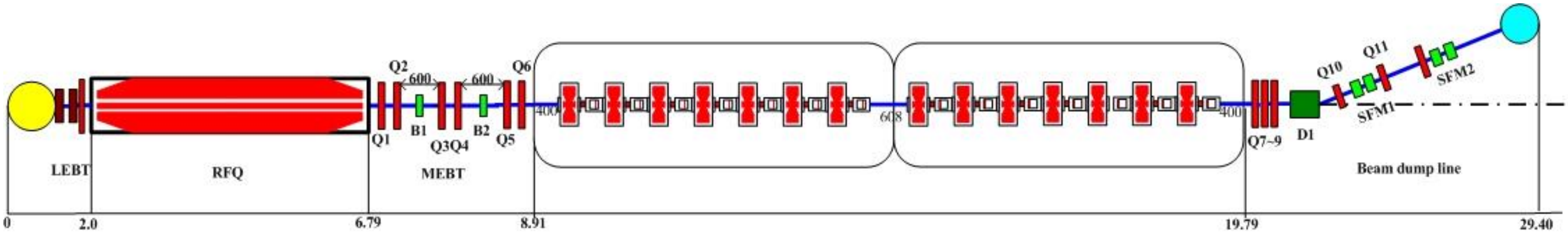
Introduction



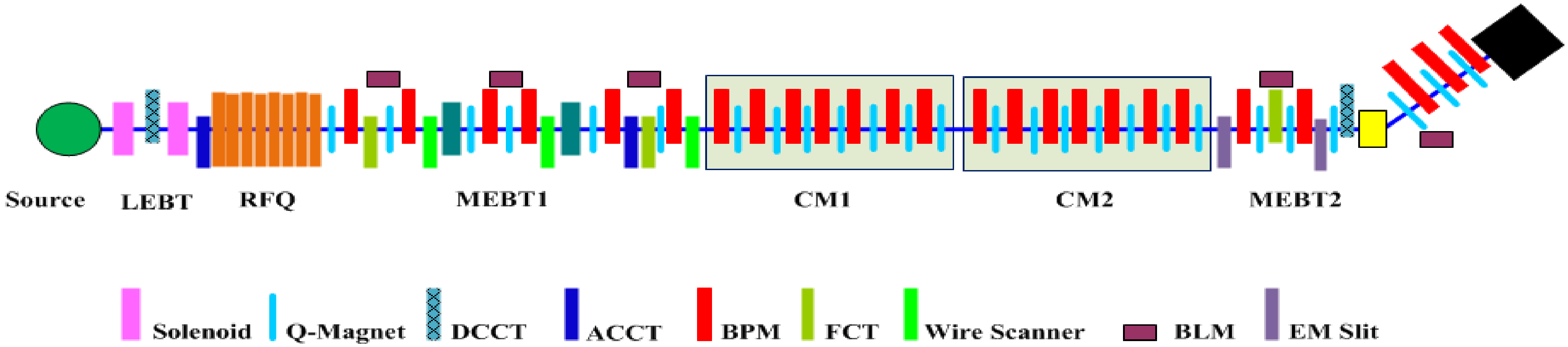
Two identical injectors on line, either with scheme injector I or with scheme injector II

Introduction

- Particle: proton
- RF frequency: 325 MHz
- Output energy: ~10 MeV
- Peak current: 10 mA
- Repetition rate: CW
- Beam power: 100 kW



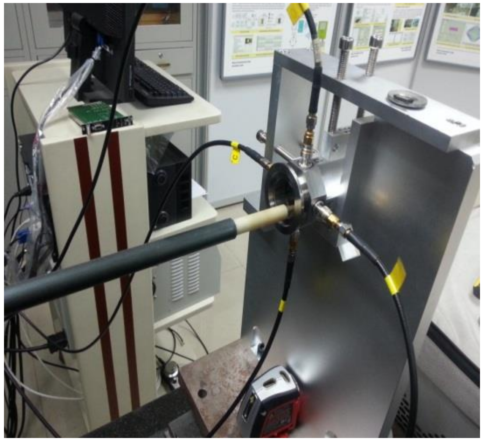
Beam instrumentation of CADS injector I

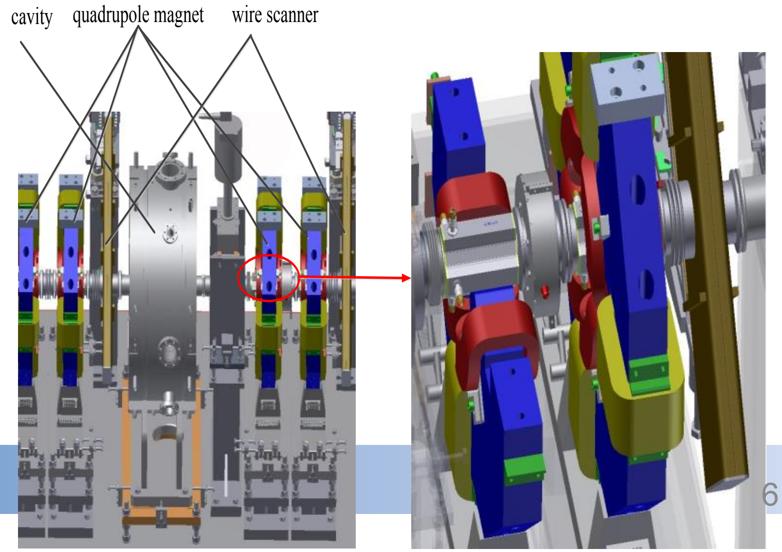


Device	Accuracy	Resolution	Quantity
Beam position monitor	±100um	30um	25
Wire scanner	±0.5mm	50um	4
Beam emittance unit	10%	-	2
Beam current monitor	1.5%	0.01mA	9
Beam loss monitor	1%	-	8
Beam energy monitor	±1deg	0.5deg	3
Ionization beam profile monitor	1mm	200um	1
Electron scanner	1mm	300um	1

Beam position monitor

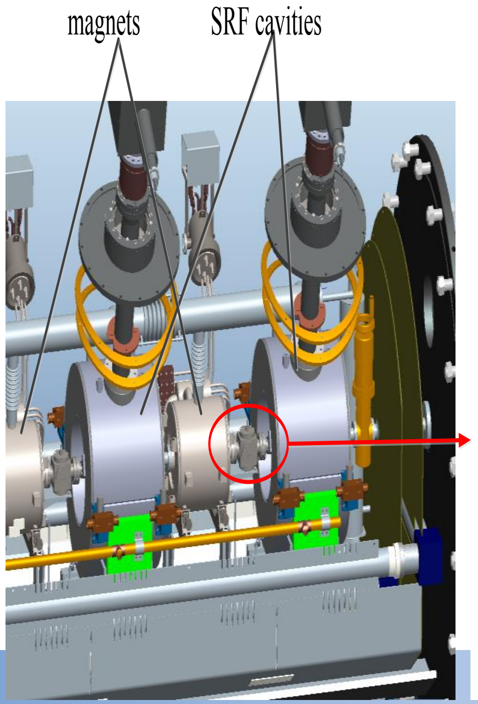
- Total of 25 BPMs will be installed along the Linac , including 14 Cold-BPM
- The warm BPM pickups are strip line
- The BPMs are installed in Q-magnets due to limited space

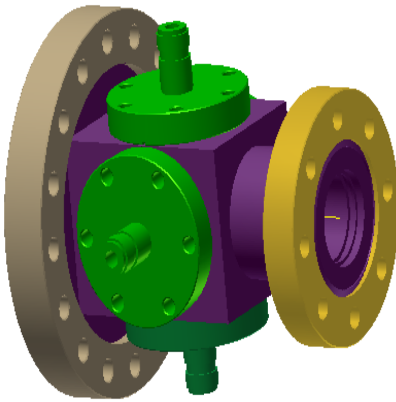




Beam position monitor

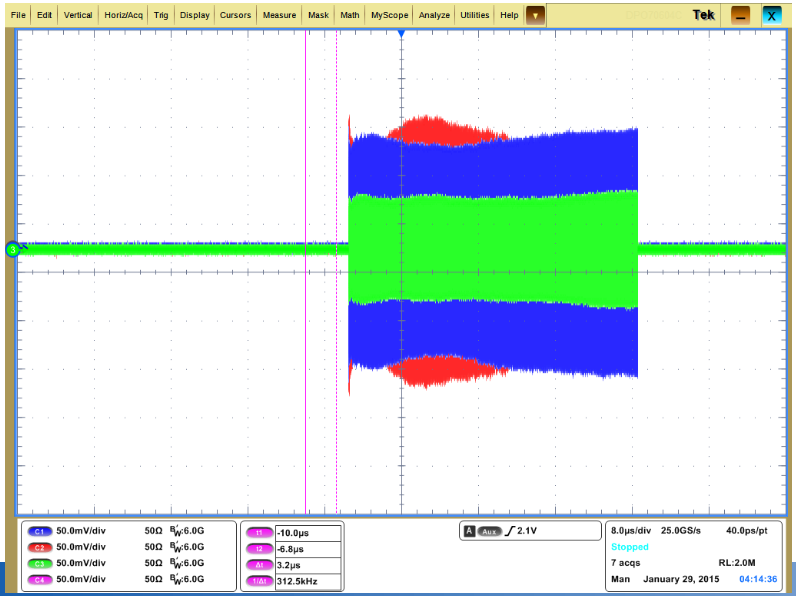
- Cold BPM pick-ups are buttons due space limitation
- Installed between SCQ magnet and SRF cavity
- Several times cold test with liquid nitrogen (300K-80K) before installed check feed through and bellows

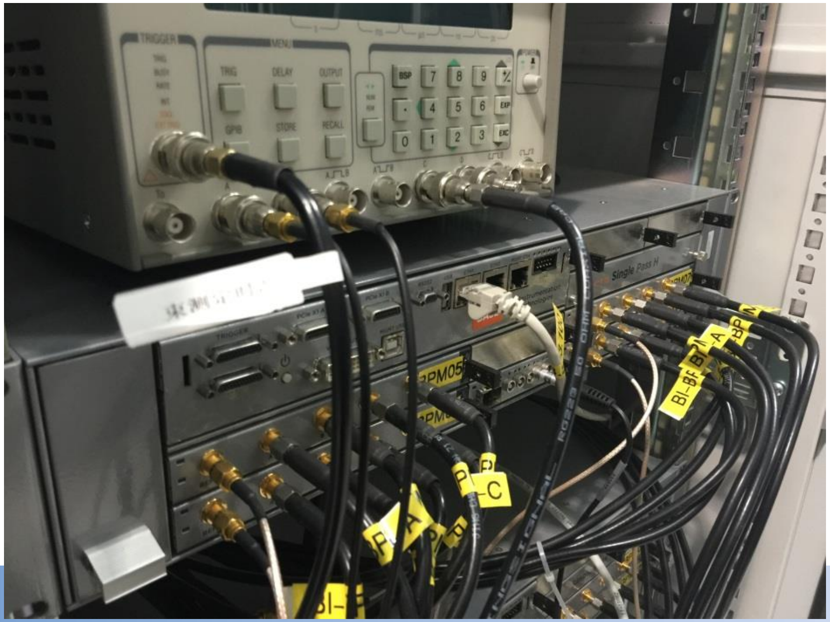




Beam position monitor

- Beam test
  - Effective signal Vp-p~150mV
- Electronics
  - Libera single pass –H
  - Also for machine protection



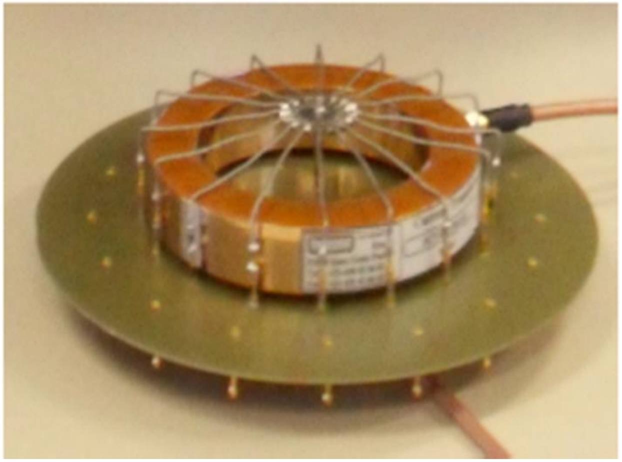


Beam current monitor

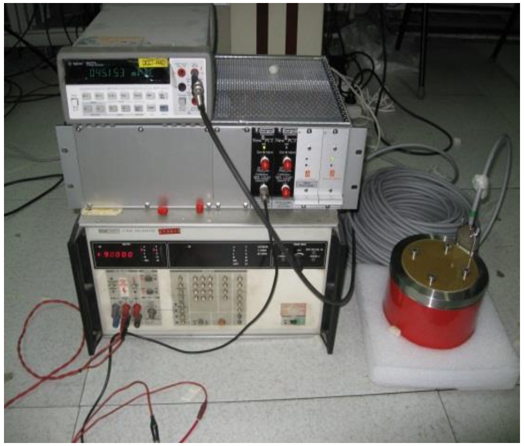
- Beam Current Monitors system is composed of AC Current Transformers (ACCT), Fast Current Transformers (FCT) and DC Current Transformers (NPCT).
- LEBT composed 1 NPCT monitoring the ion source; 1 ACCT at the entrance of RFQ measuring the beam transmission in the RFQ with another ACCT installed at the MEBT1
- MEBT1 including 2 FCT to measure the beam energy of the RFQ.

Beam current monitor

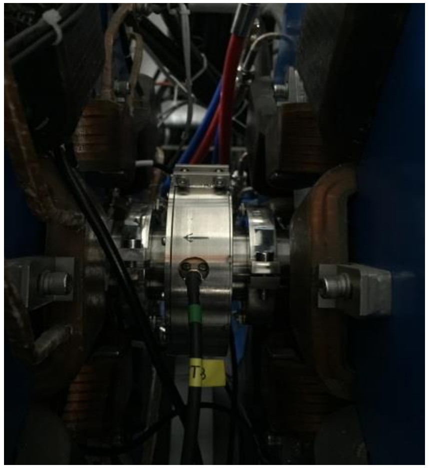
- 2 FCTs in MEBT2 to measure the beam energy of TCM (CM1 and CM2) ,1 NPCT for beam DC current monitor
- All CTs are standard products and calibrated before installation



Test bench of FCT and ACCT



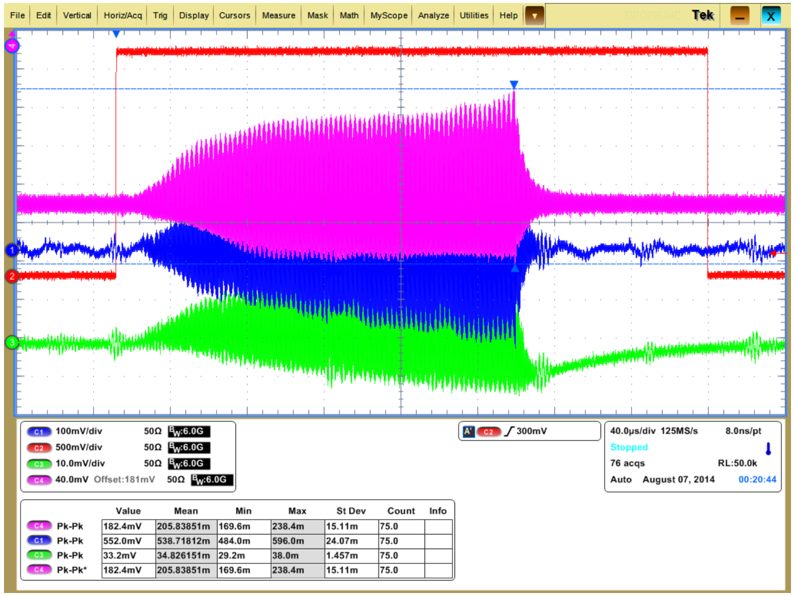
Calibration of DCCT

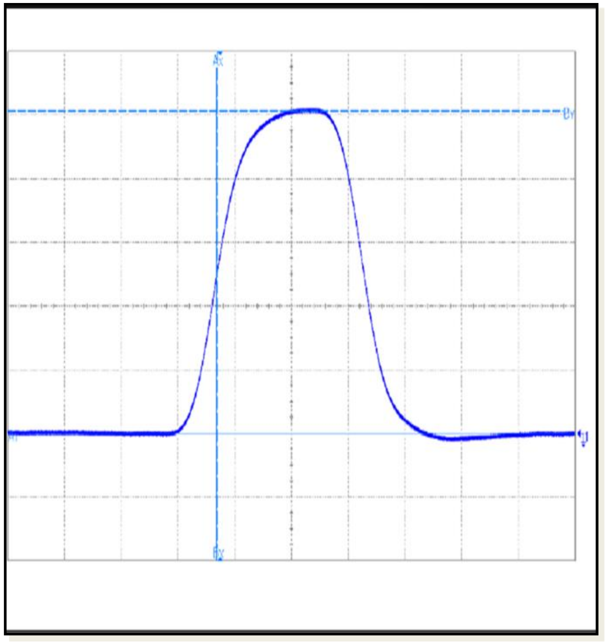


FCT between Q-magnet

Beam current monitor

- Beam test

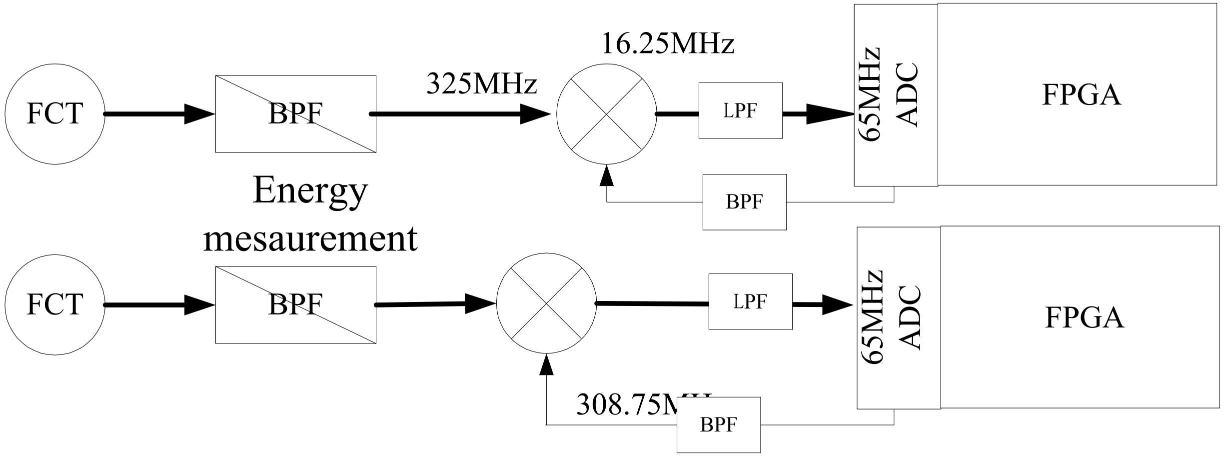




- Readout system
  - NPCT Based on PCI-4070+LABView+EPICS
  - ACCT Based on PCI-6120+LABView+EPICS

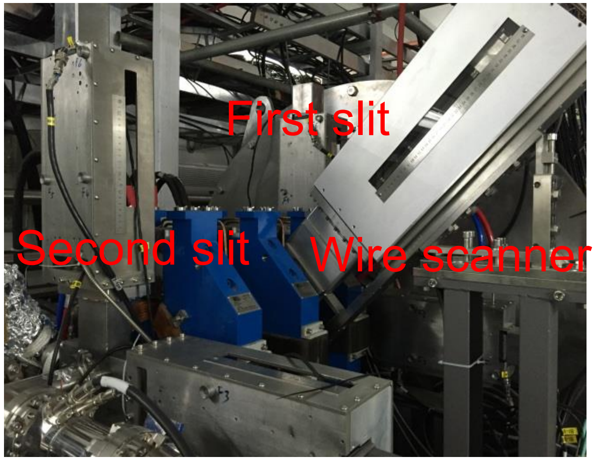
Beam current monitor

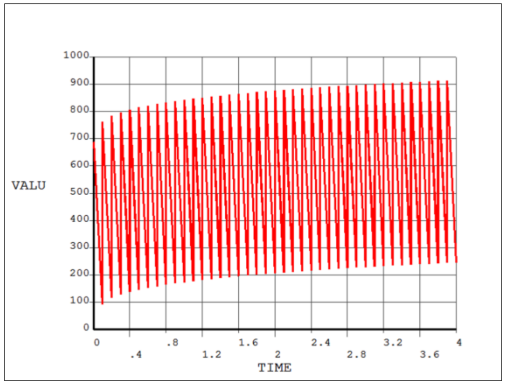
- Beam energy measurement
  – Beam energy is measured with the aid of FCT based on the TOF (Time-OF-Flight) method

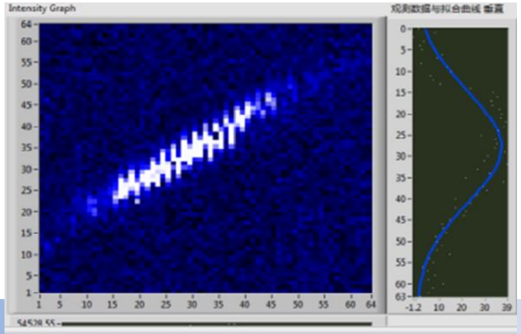


Beam emittance measurement

- Double-slit meter was chosen for its adaption to different beam conditions and the robustness
- The first slit is 0.2mm, the tungsten plated on stainless steel with cool water
- The heat load is simulated with the duty factor 0.1%
- The distance between two slit is about 300mm
- The second slit is 0.1mm, and a faraday cup at the downstream



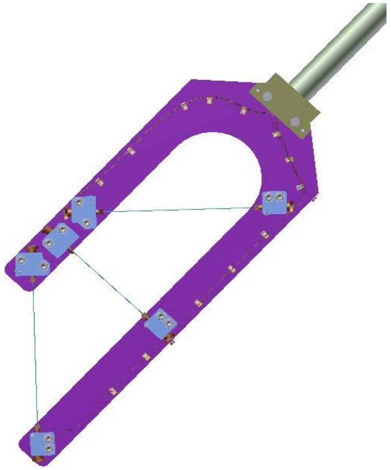


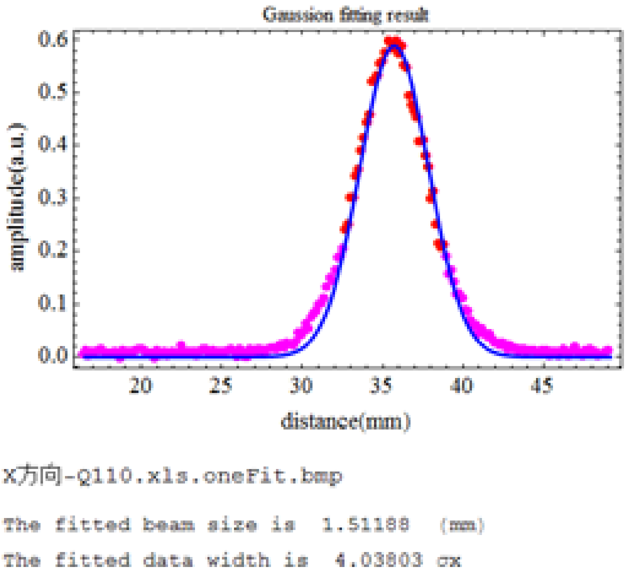


Example of beam emittance

Beam profile monitor

- The wire scanner with three tungsten wires (H,V,U) mounted on fork is used
- Beam pulse frequency is reduced to 10Hz and the beam pulse length reduced to 100us or less to ensure the wire safe.
- The motion control and DAQ based on PXI





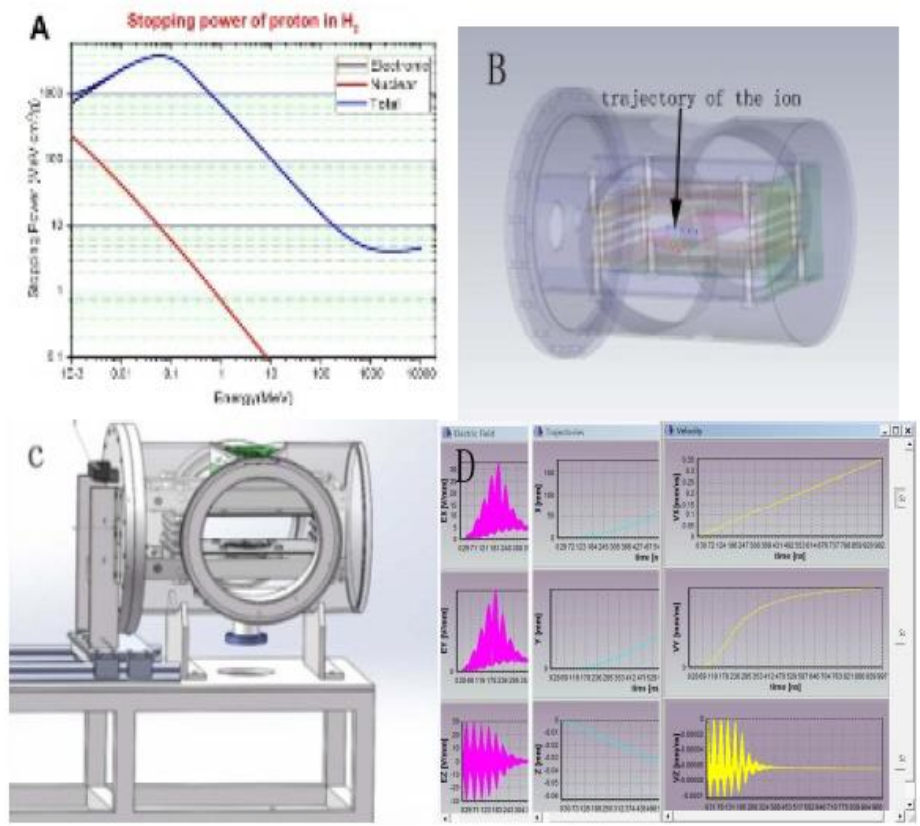
Example of Transverse Profile

Beam profile monitor

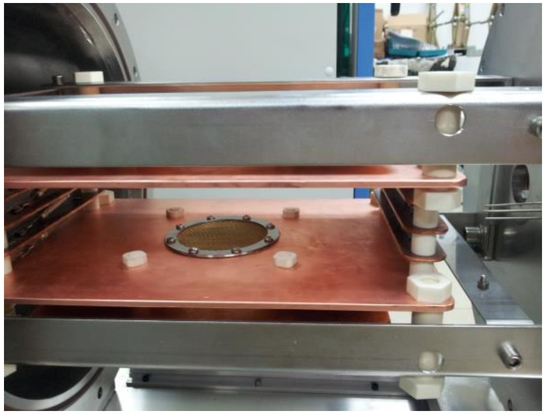
- Two non-invasive beam profile measurement methods were developed for the CADS Injector I Proton Linac. IPM and electron scanner.
- IPM detect the ionized products from a collision of the beam particle with residual gas atoms or molecules present in the vacuum pipe

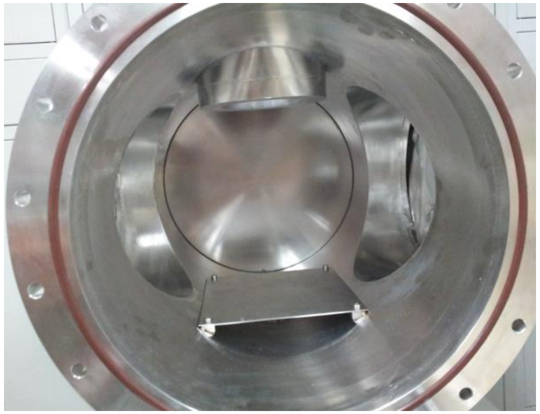
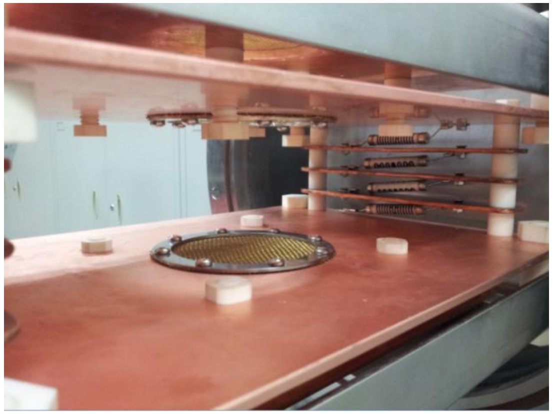
non-invasive beam profile (IPM)

Parameter	Value
electric field intensity(V/m)	1e5
Distance of two big plate (cm)	8
Size of MCP (mm)	Φ 75
Size of EGA (mm)	Φ 70
Detectors	Screen
Work mode	Ions
magnetic field	0



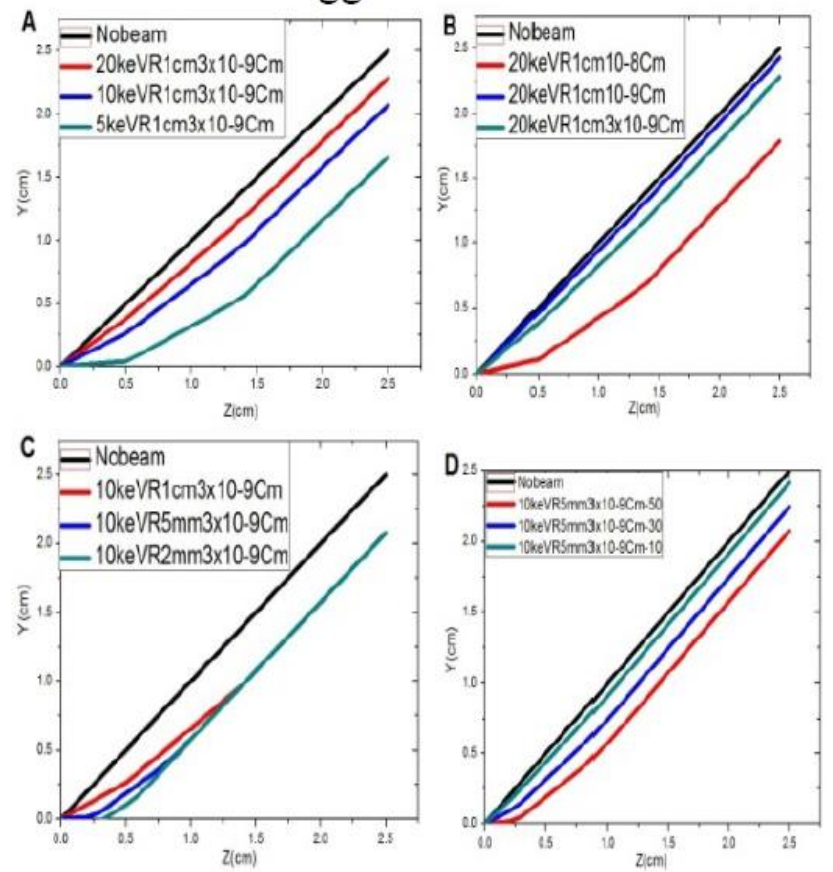
non-invasive beam profile (IPM)

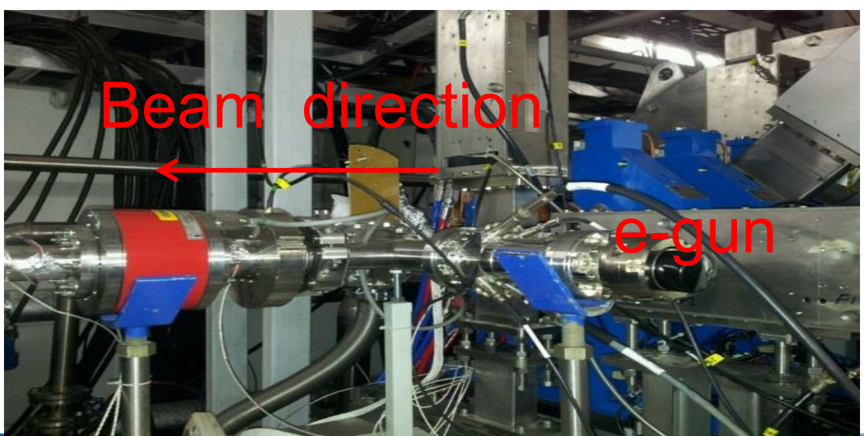



non-invasive beam profile (electron scan)

- Using a low energy electron beam instead of a metal wire to sweep through the beam. The deflection of electron beam by the collective field of the high intensity beam is measured
- Gun- A Kimball Physics electron gun, model EMG-4212, 20kV, 10uA
- Commissioning in next month

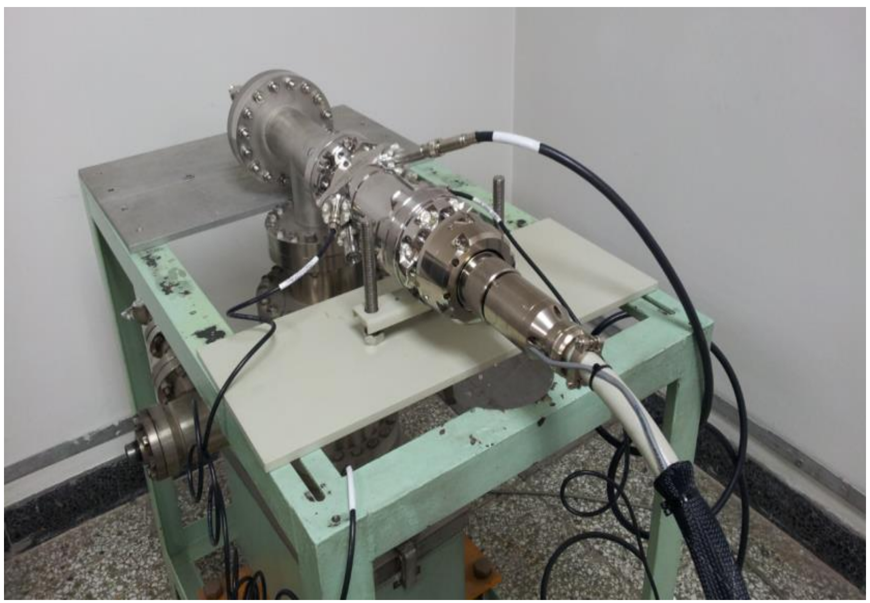


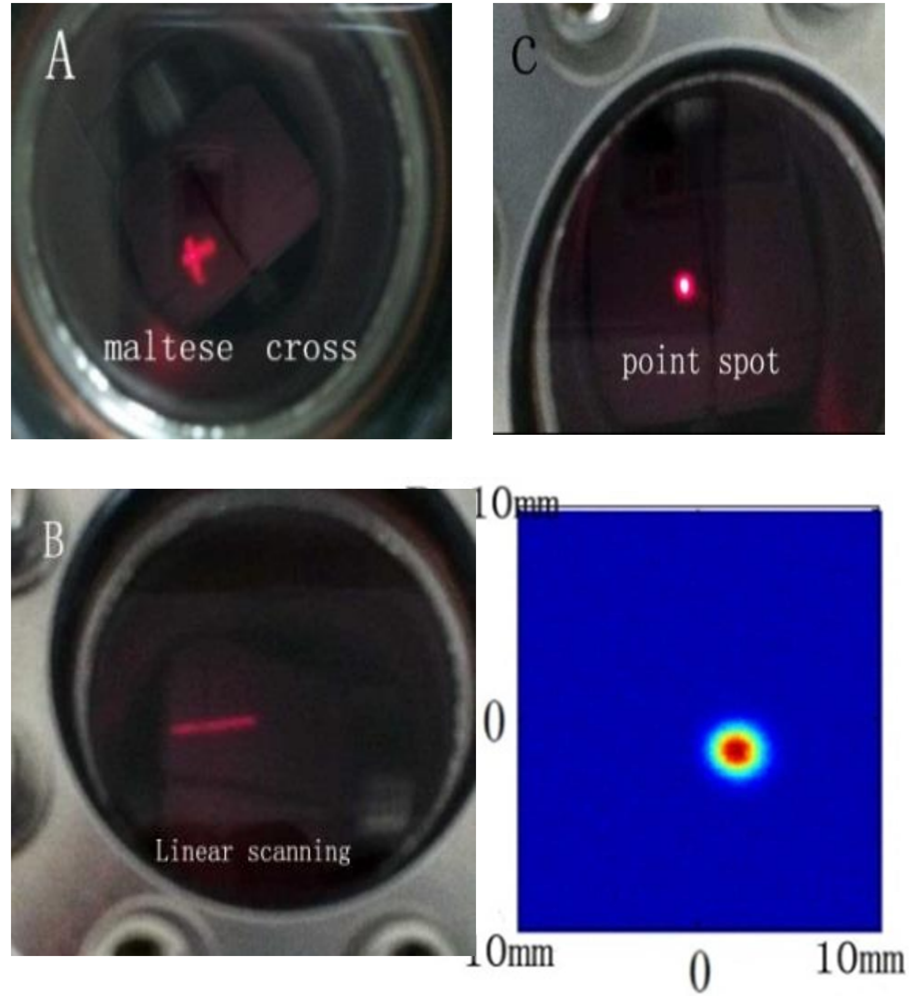


calculated deflection as a function of the probe electron energy, linear density of proton , distance between the detector and the centre of the proton beam

non-invasive beam profile (electron scan)

- Electron gun was test in the stand
- Different beam spot on the screen



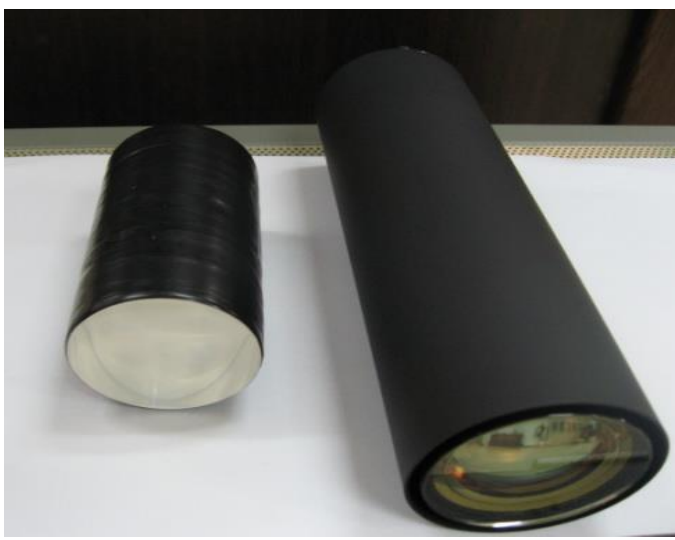


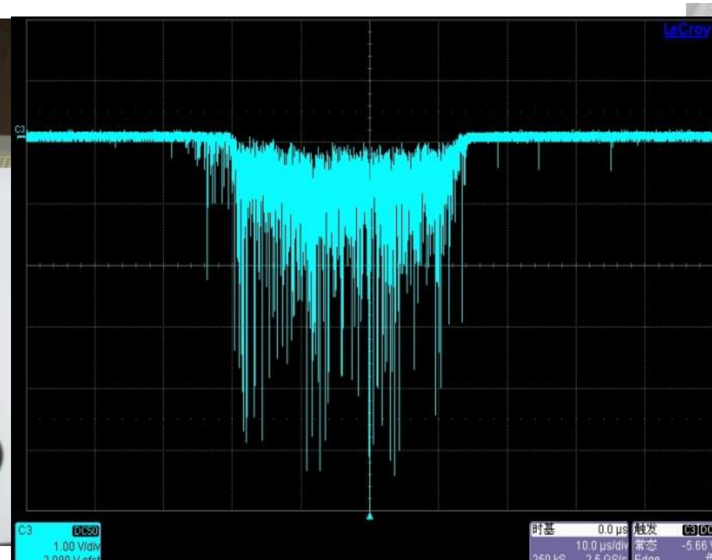
Beam loss monitor

- The purpose of the beam loss monitor is to avoid the accelerator damage and excessive machine activation by beam loss.
- Ionization chambers will be the main beam loss detector. But at low energies(<10MeV), ionization chambers are not effective to detect beam loss due to the shielding.
- The differential current measurement between two beam position monitor will be the primary input to the fast machine interlock system.

Beam loss monitor

- For the high energy, plastic scintillator + PMT will be the fast beam loss monitor for machine protection





The commissioning of RFQ

- The beam parameters measurement
  - The transmission of RFQ
  - The energy of RFQ
  - The beam emittance
  - The duty factor of RFQ

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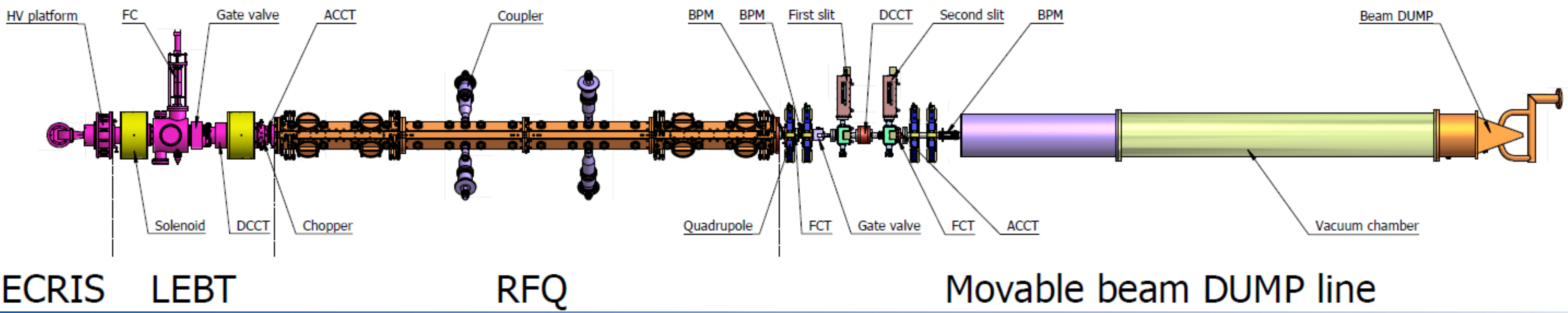
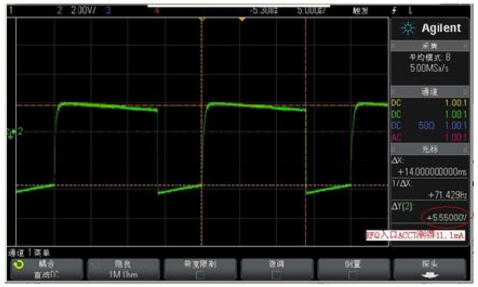
BEAM COMMISSIONING OF C-ADS INJECTOR-I RFQ ACCELERATOR

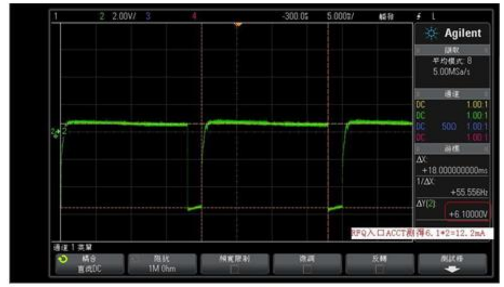
ADS injector I RFQ commissioning setup



The transmission of RFQ



(a)



(c)

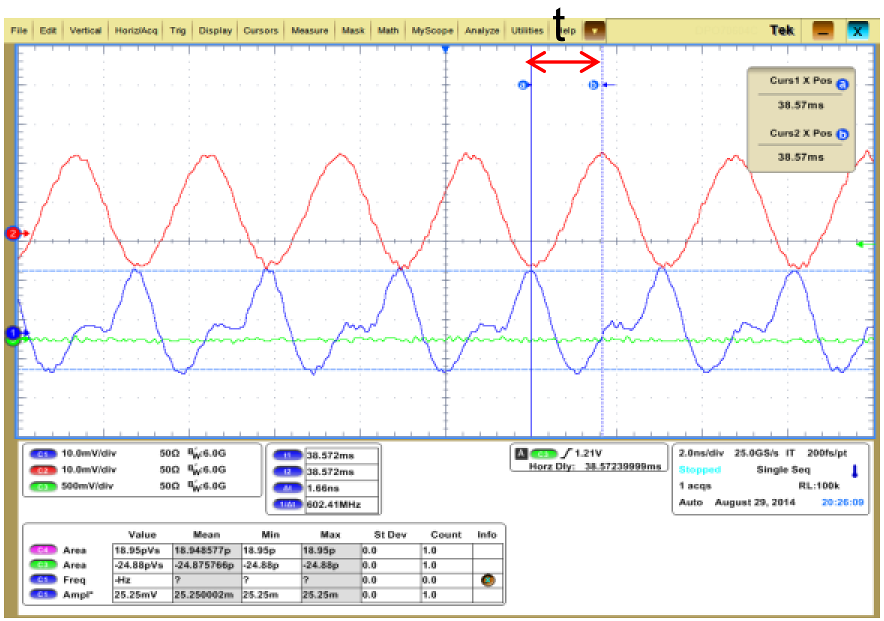
(b)

(d)

- 70% duty factor, 95% beam transmission efficiency
- 90% duty factor,11 mA,31 kW proton beam with 90% beam transmission efficiency

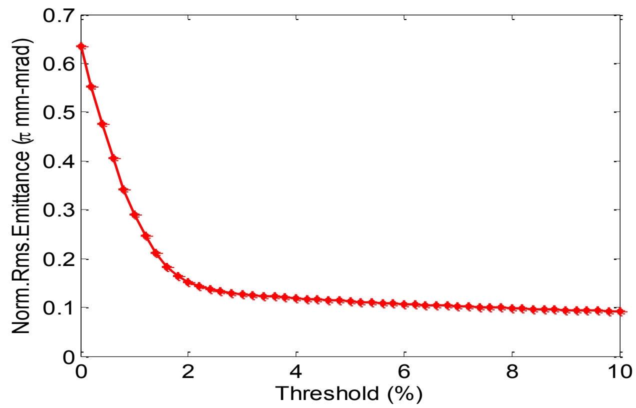
The energy of RFQ

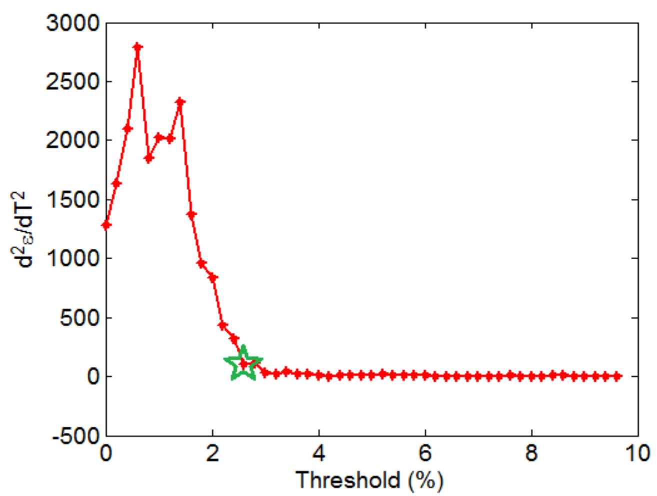
- Two FCTs for beam energy measurement
  - Carefully alignment
  - Using scope measuring the phase between two FCTs signals
  - T=nT0+t
  - Beam energy 3.199MeV

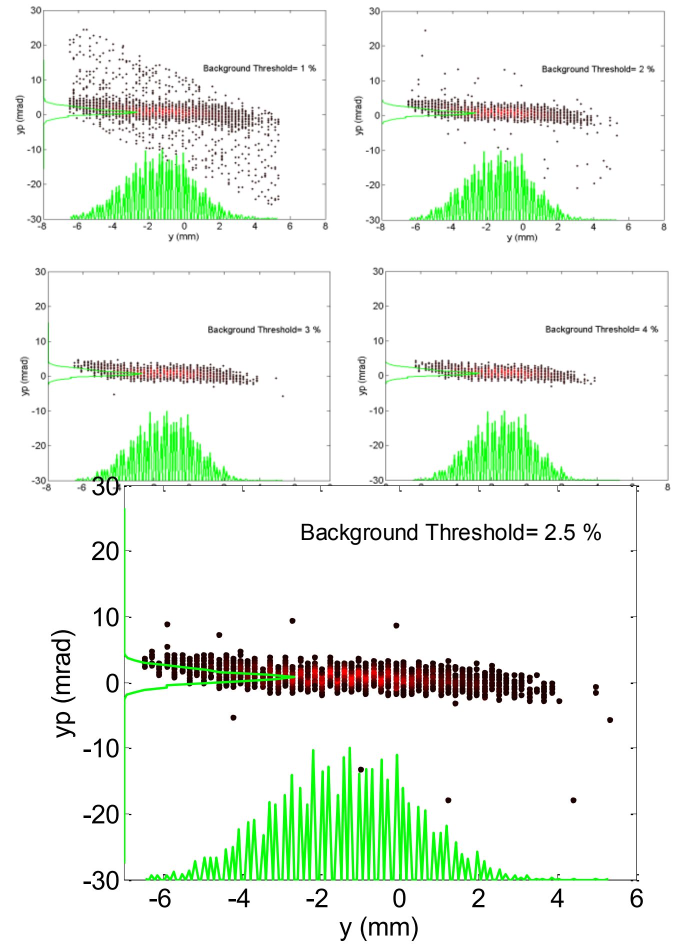


The beam emittance of RFQ

- Using the double slits emittance measurement



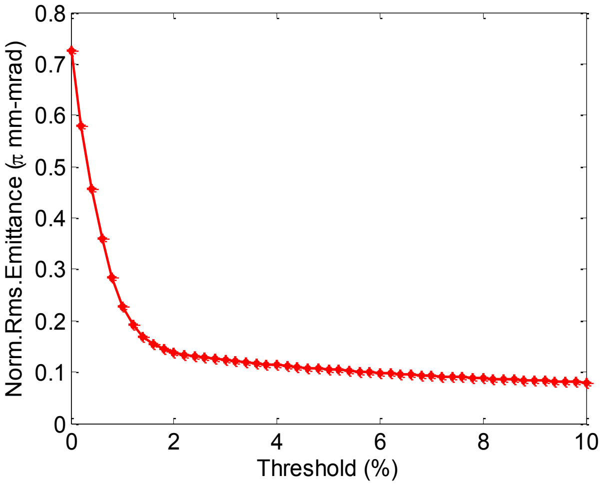


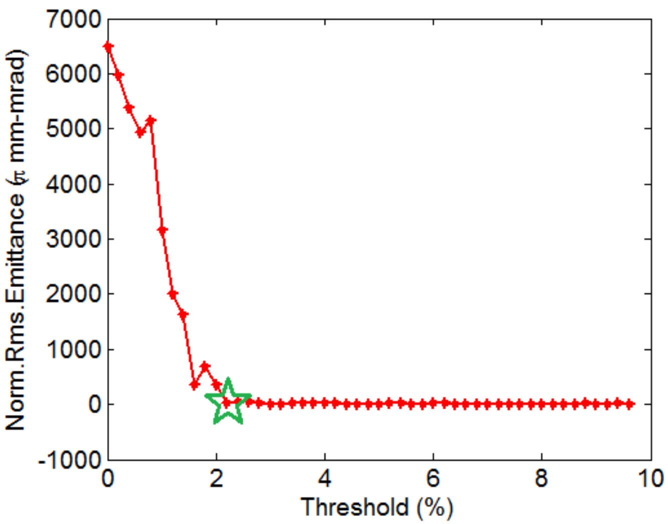


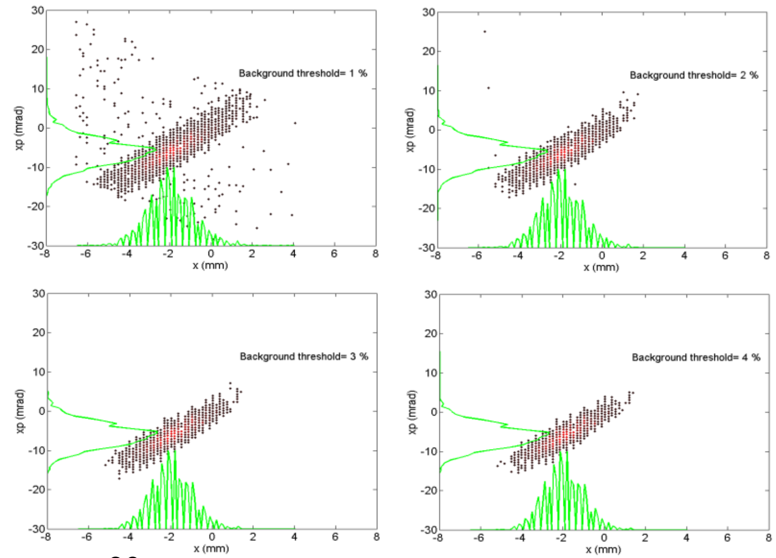
$\varepsilon_{n,rms}=0.1347\ \pi mm.mard$

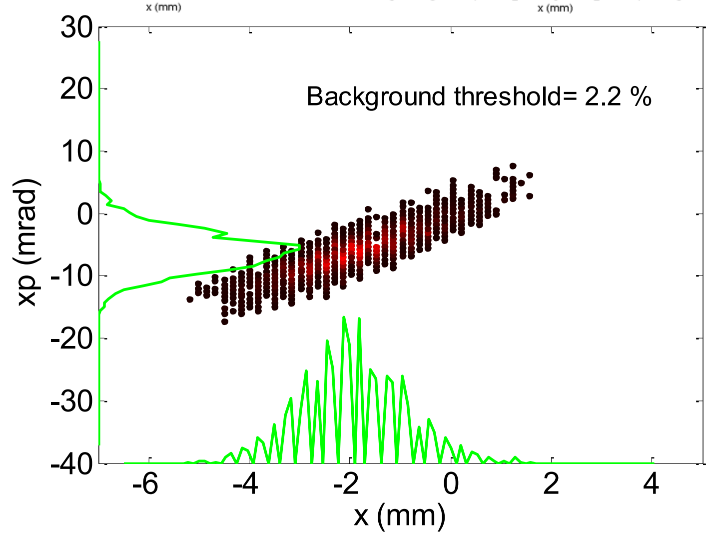
$\alpha=0.4578,\ \beta=1.91\ mm/mard$

The beam emittance of RFQ





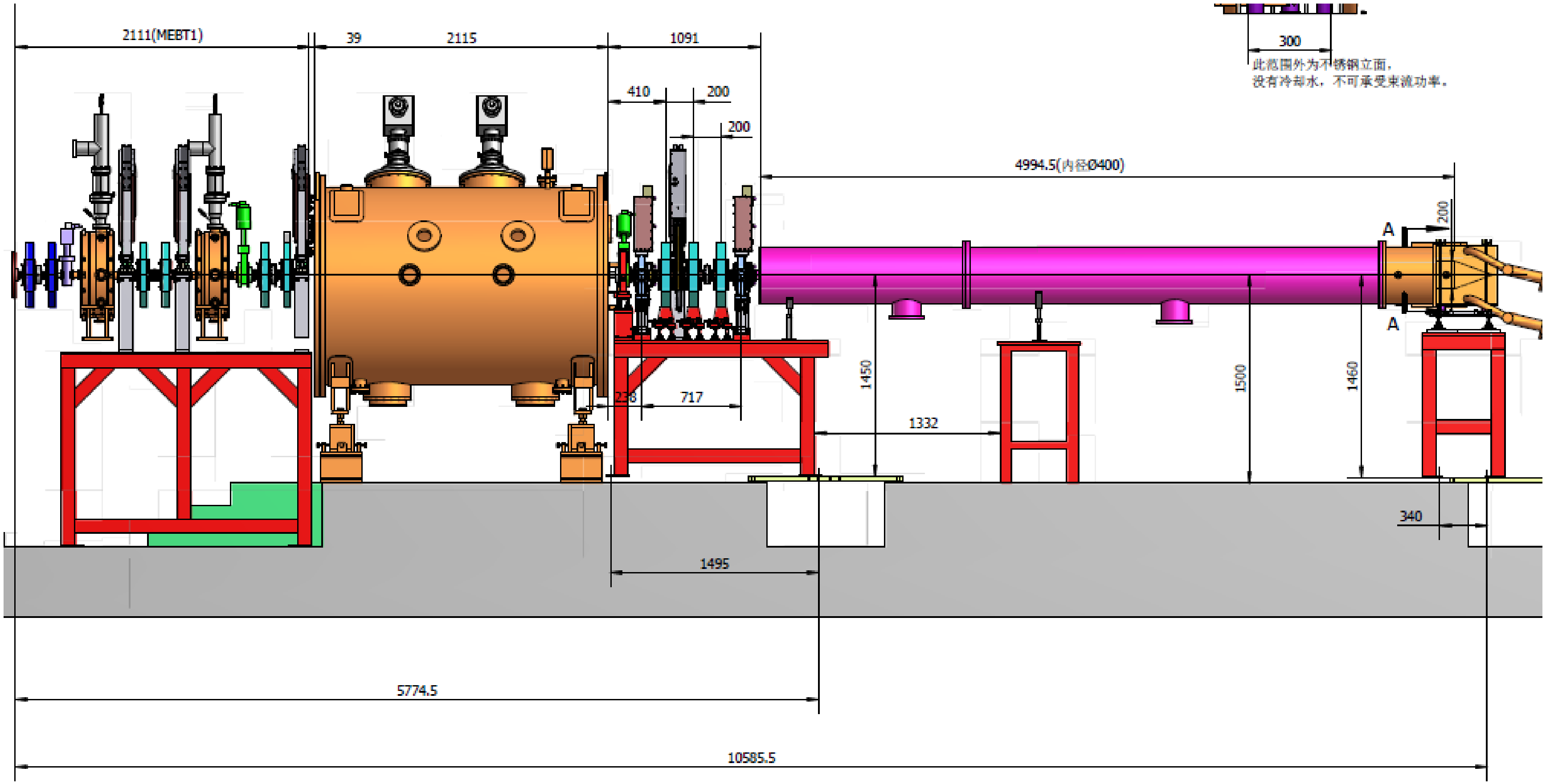




$$\varepsilon_{n,rms} = 0.1345\ \pi mm.mard$$

$$\alpha = -1.82, \beta = 0.66\ mm/mard$$

The primary commissioning of TCM



- TCM(Test Cryomodule) including 2 spoke cavities, 2 SCQ magnets and 2 cold BPMs.

The primary commissioning of TCM

	SRF1 (status/ Ecc)	SRF1 (status/ Ecc)	beam energy of MEBT1	Beam energy after TCM	Beam energy from SRF1	Beam energy from SRF1	Total energy
	MV/m		MeV				
Detuning	off/0	off/0	3.19	3.12			
Tuning	off/0	on/0	3.19	3.04			
	on/3.51	off/0		3.23	0.19		0.19
	on/3.51	on/5.06		3.59	0.19	0.36	0.55

THPF055

STATUS OF THE SUPERCONDUCTING CAVITY DEVELOPMENT AT IHEP FOR THE CADS LINAC

Conclusion

- The beam instrumentation system works well and the characteristic of beam is measured.
- The RFQ and test cryomodule (TCM) tuning are finished.
- To establish more stable and safety operation, more improvement should be done to the interlock system.
- To measure the longitudinal bunch profile in high power beam and tune the longitudinal matching, some longitudinal diagnostic should be developed such as non-intercepting bunch shape monitor based on the IPM principle and so on.

Acknowledgement

- Thank accelerator physicists for their advice and discussion
- Thank all members of CADS accelerator team for injector I commissioning
- Thanks are also given to the members who give help on system design and manufacture
- Thanks also give people who shares pictures of this talk.

Thank you

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