Overview and Status of Beam Diagnostics Development for the CSNS Upgrade Project

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On behalf of CSNS Beam Instrumentation Group

03/09/2026

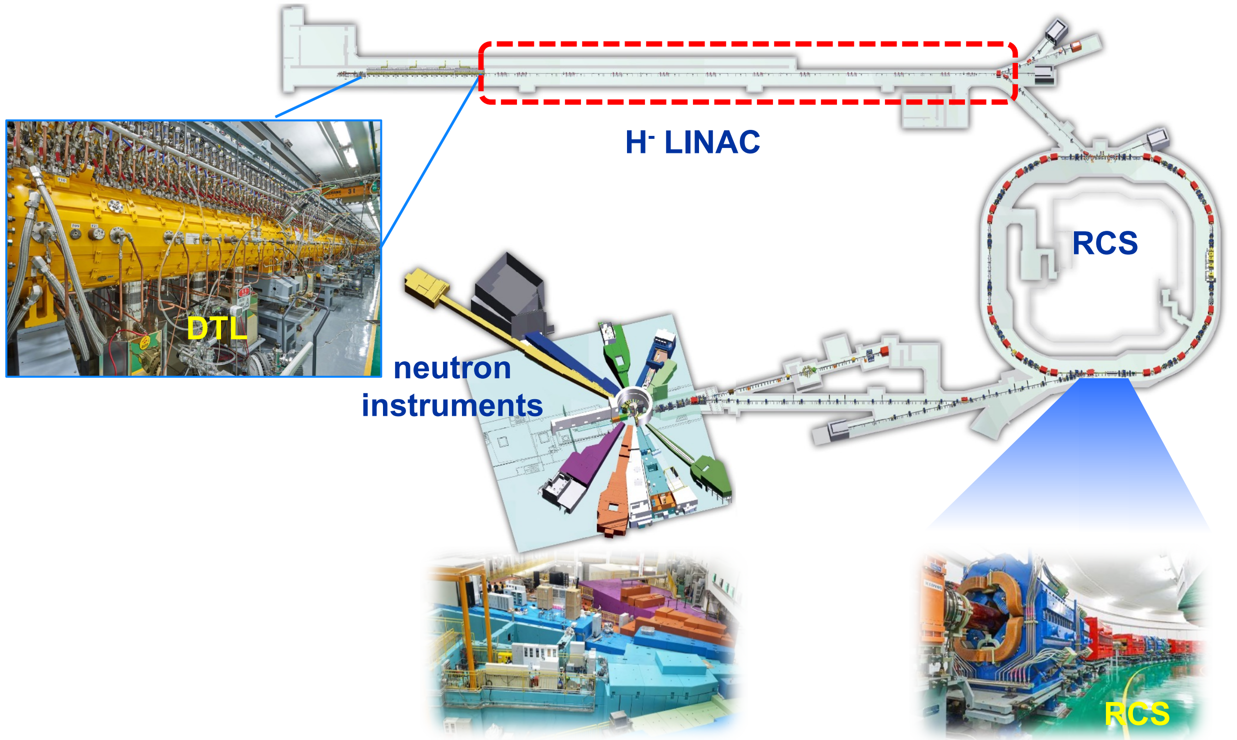
Whistler, Canada

China Spallation Neutron Source

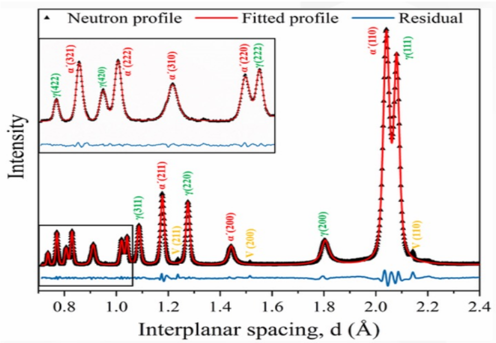
- The 4th pulsed neutron source in the world
  User program started since October 2018
- 3 initial instruments (GPPD, MR & SANS) +
  8 cooperative instruments
- CSNS-II (2024-2029): beam power ramp up to
  500 kW + 9 new neutron instruments + μ-source

Major machine parameters

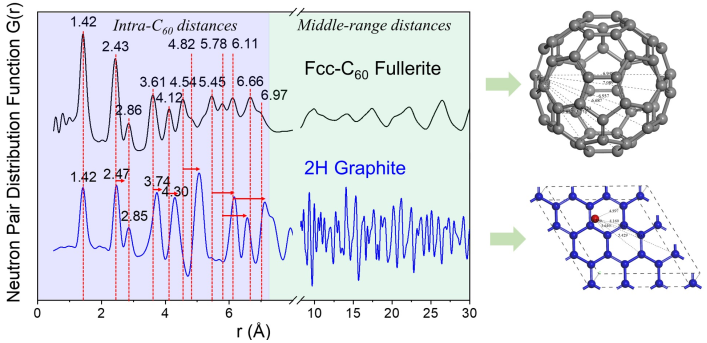
	CSNS	CSNS-II
Beam Power on target [kW]	185	500
Proton energy [GeV]	1.6	1.6
Average beam current [μA]	62.5	312.5
Pulse repetition rate [Hz]	25	25
Linac energy [MeV]	80	300
Macropulse avg. current [mA]	15	50
Linac bunch frequency [MHz]	324	324



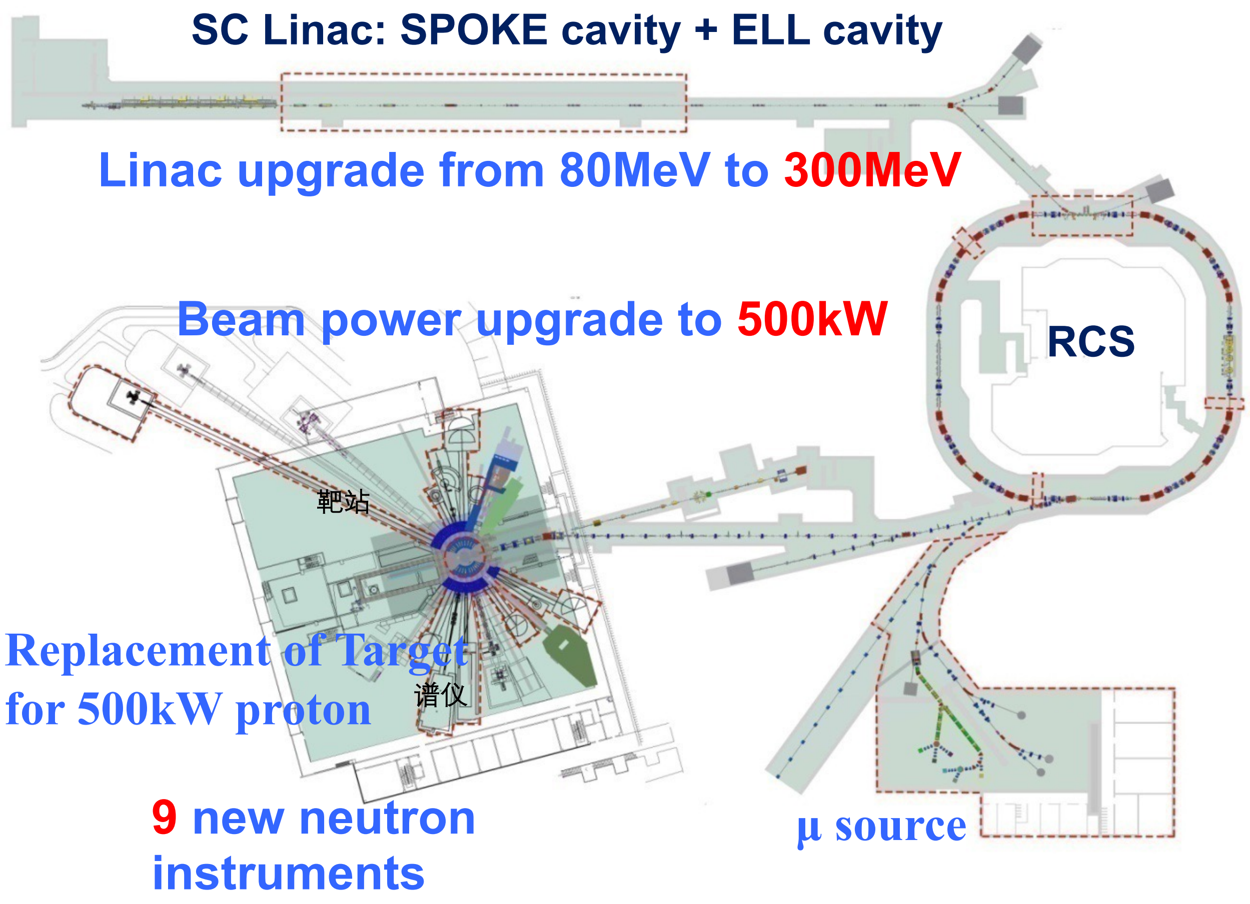
Liu et al., Science (2020)

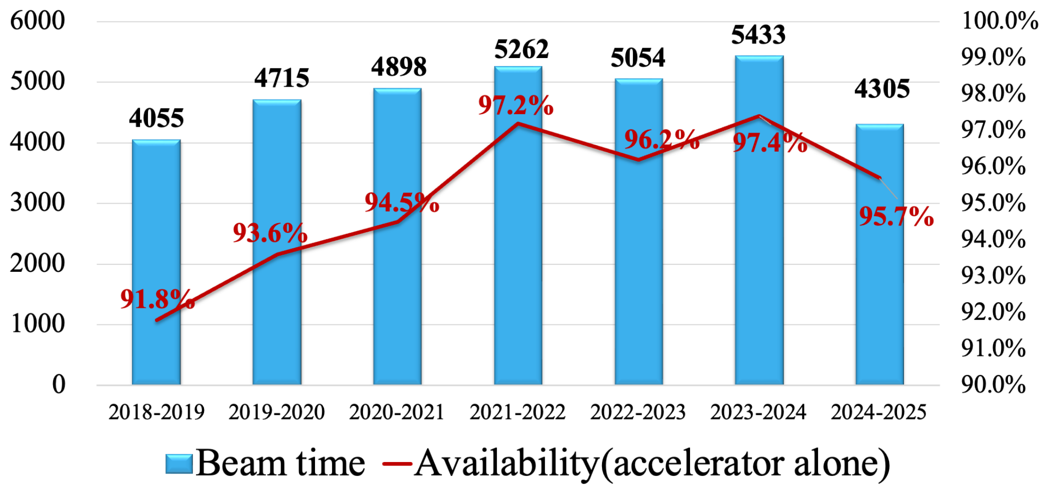


F. Pan et al., Nature (2023)



CSNS Upgrade Project (2024-2029)





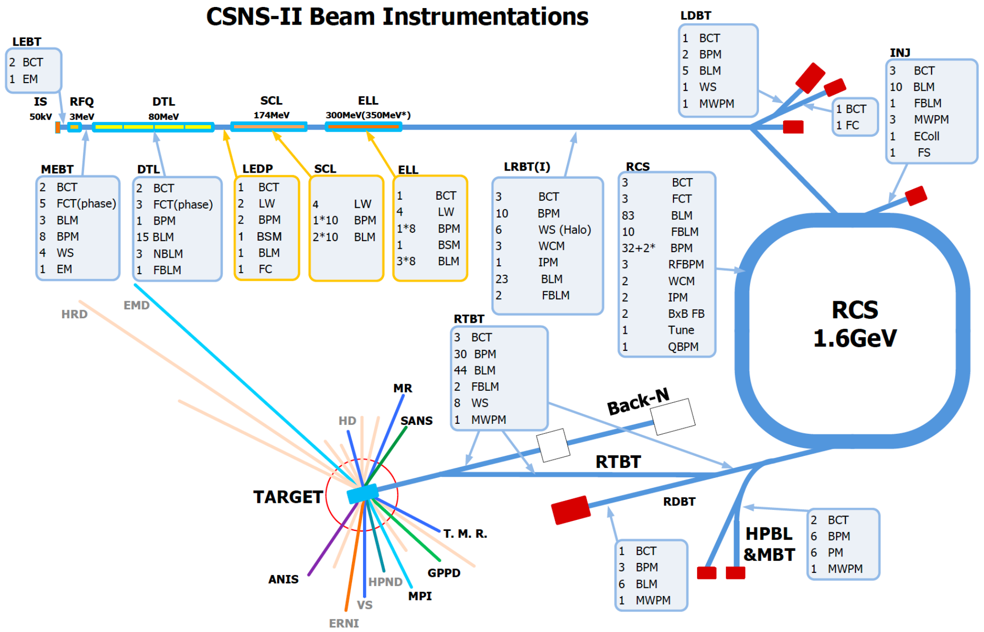
CSNS-II Accelerator upgrades

- Linac（80 MeV）+ RCS upgrade 150~200 kW
  - ✓ New dual harmonic RF system
  - ✓ AC trim quadrupoles, sextupoles and oct.
- Linac （300 MeV）+ upgraded RCS 500 kW
  - ✓ New injection system
  - ✓ SC Linac to 300 MeV

CSNS-II beam instrumentation

Work packages

- Essential updates aligning with the front-end and RCS injection upgrades (**2025-2026**)
- Diagnostics for the new superconducting LINAC and downstream transport beamlines (**2027-**)
- Tools for the RCS beam monitoring and instability control (**2027-**)
- Instrumentation for the two new proton beamlines (RABT, **2027-**)



About 200+ new instruments (~40 designs) will be developed, installed and commissioned

Highlights

- Renovate the RCS BPM electronics system
- Least-invasive 2D profile monitors (LW, IPM, ..)
- Transverse damper for the RCS instability
- Reinvent interceptive materials (CNTF wire, fluorescence wire, …)

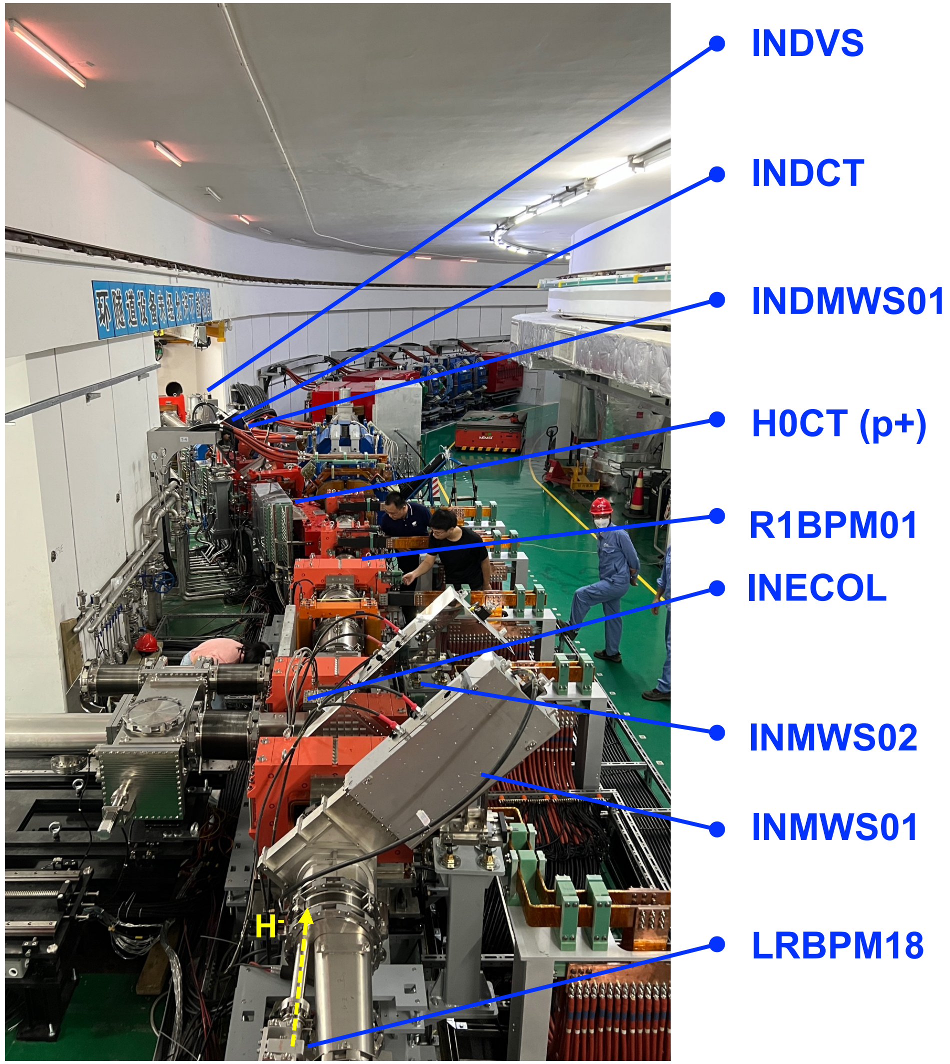
Diagnostics throughout CSNS-II Accelerator

CSNS-II accelerator will be equipped with ~480 instruments, incorporating 200+ new/restored detectors

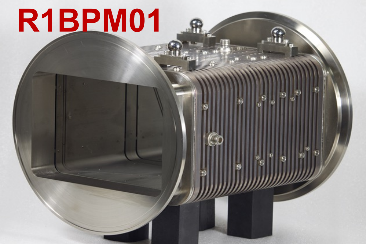
	BCT	FCT	BPM	BLM	WS	LW	MWS	IPM	VS	EM	FFC/ BSM	WCM	FC	Feed back	Tune
Front-end	3		8	3	2					2	1		1		
DTL	3	3	1	18											
SC-LINAC	3		20	63	0	8					2		1		
LRBT	3	2	19	25	5	1				1					
LDBT	2		2	5	1		1						1		
I-Dump	2			4			1		1						
RCS	3	3	35	98			2	2				2		2	2
RTBT		3	30	44	4		1								
RDBT		1	3	6	4		1								
RABT		2	6	8	0		1		1						
Total	19	14	124	274	16	9	7	2	2	3	3	2	3	2	2

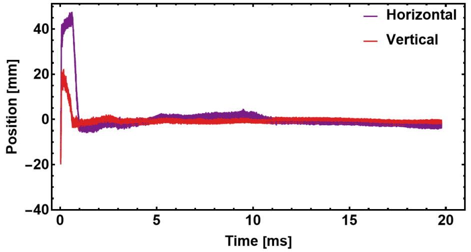
- Upgrade of instruments in RCS injection region (in operation)
- Upgrade of beam instrumentation in the MEBT (installation in 2026)
- Design and prototype of beam instrumentation for Superconducting LINAC
- Design and prototype of beam instrumentation for RCS and extraction lines

Injection beam instrumentation upgrade

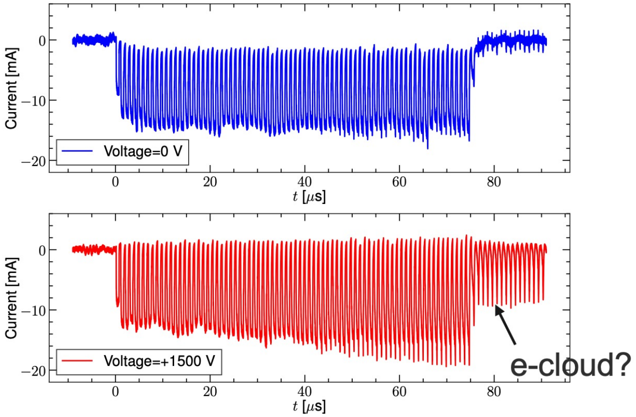


- Nine new detectors are installed in 2025 summer
  - LRBPM18: shorted stripline BPM (diam.=50 mm)
  - INMWS01-02, INMWS03: SEM grids (136 ch.)
  - INECOL: stripped electron catcher
  - R1BPM01: rectangular BPM (260 mmx180 mm)
  - H0CT, INDCT: current transformers (10 μA-50 mA)
  - INDVS: screen monitor (Chromox6)
- All detectors worked from Day 1, as soon as beam reached the injection area

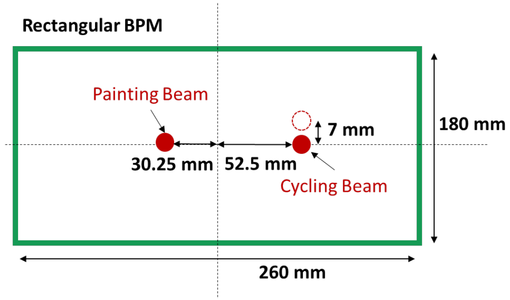


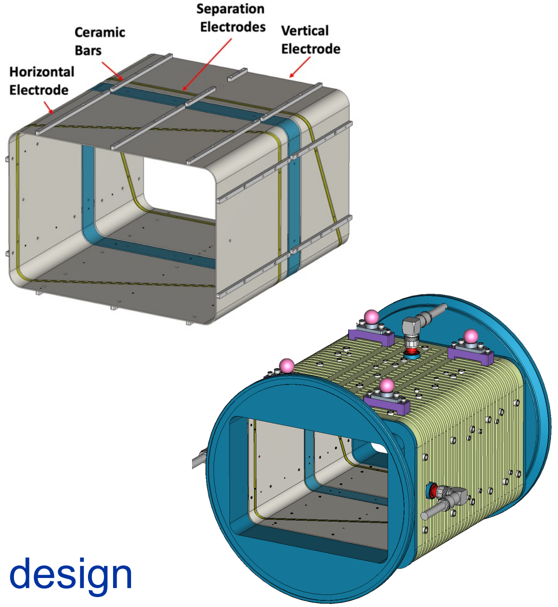


Signal of the stripped e-

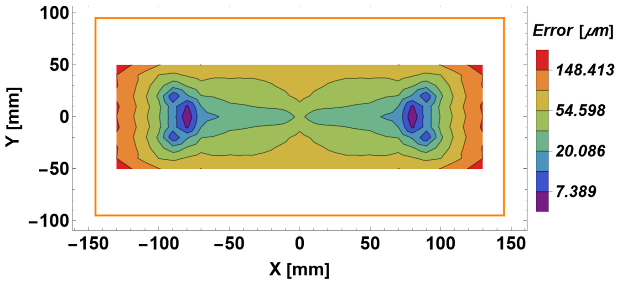


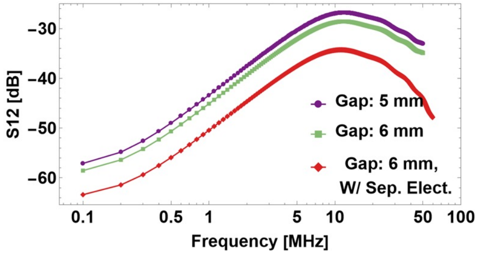
New BPMs in the RCS injection area





- A rectangular shoebox BPM is required near the stripping foil to detect the painting & cycling p+ beam
- Design specifications
  - Position resolution <0.1 mm (simulation)
  - Electrode separation (6 mm)=> -42 dB@1-10MHz
  - More than 80% linearity over full aperture
  - Vacuum duct used as the guard rings

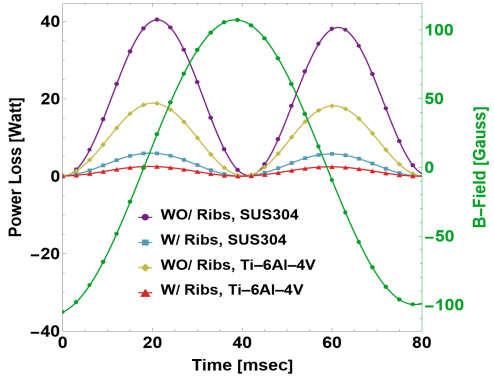




Requirements for BPM design

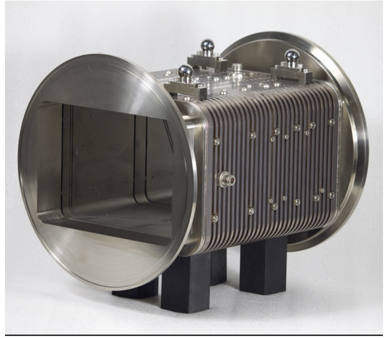
Parameter	CSNS-I/II
Beam energy	80 MeV-1.6 GeV
Intensity	1.5 to 7.8×10^{13} (ppb)
Freq. range	1.022– 2.44 MHz
BPM aperture	260 mm*180 mm
Position Accuracy	1 mm
Position Resolution	100 μm
Linearity Hor.	±70 mm

Parameters	Power Loss [W]
SS. w/o ribs	40.4
SS. w/ ribs	18.8
Ti-alloy w/o ribs (Ti-6Al-4V)	5.9
Ti-alloy w/ ribs (Ti-6Al-4V)	2.5



New BPMs in the RCS injection area

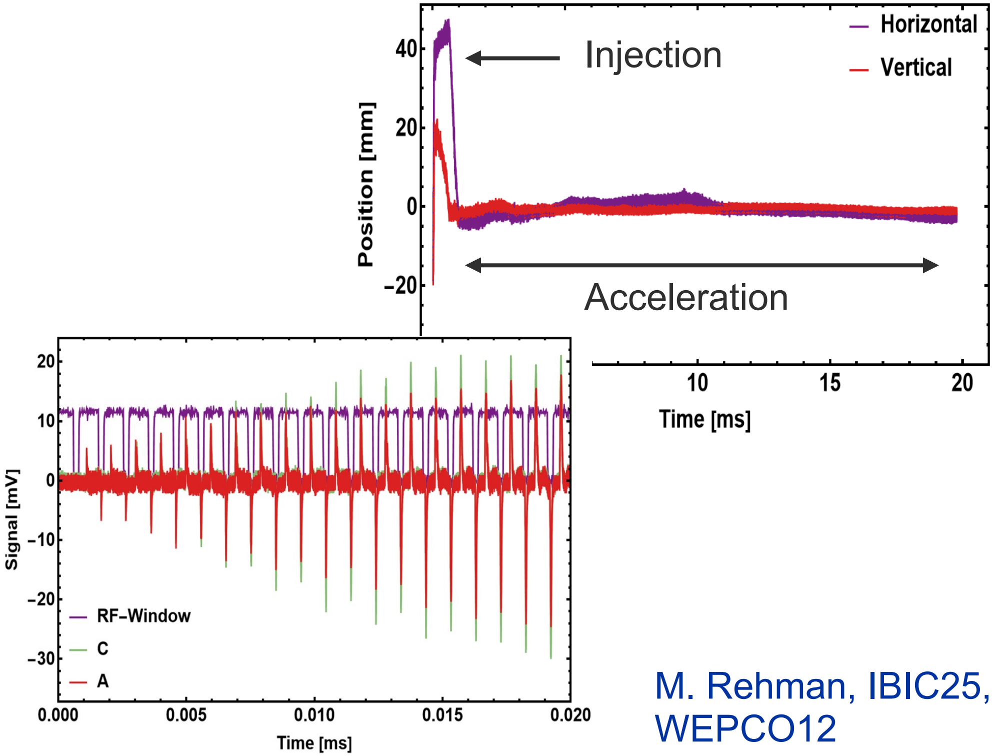
- Technical difficulties
  - Brazing of Ti-alloy (94 brazing points)
  - Manufacturing precision (1 mm thickness)
- Satisfactory manufacturing & assembling precision (size, flatness, roughness, parallelism) after 2-3 failed attempts



Manufacture specifications

	Design	Achieved
Electrode size (Inner/Outer)	180×260 mm^2/ 182×262 mm^2	179.99×259.99 mm^2/ 181.99×262.01 mm^2
Electrode flatness	≤0.05 mm	0.01-0.05 mm
Electrode roughness	≤Ra 1.6	≤Ra 0.6
Electrode parallelism	≤0.1 mm	0.18 mm
Chamber inner surface parallelism	≤0.05 mm	0.01-0.05 mm

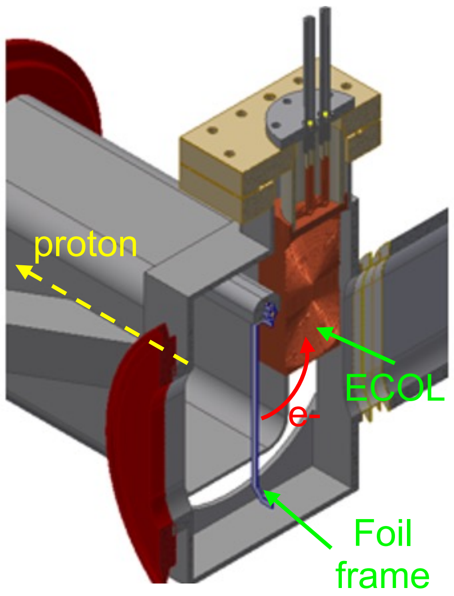
- Mapping in lab. shows an offset of <2.5 mm between the mechanical and electrical center
- Isolation of <-35 dB (0-50 MHz)
- Painting beam signal at first turn of injection, and clear picture of painting & accelerating beam orbit



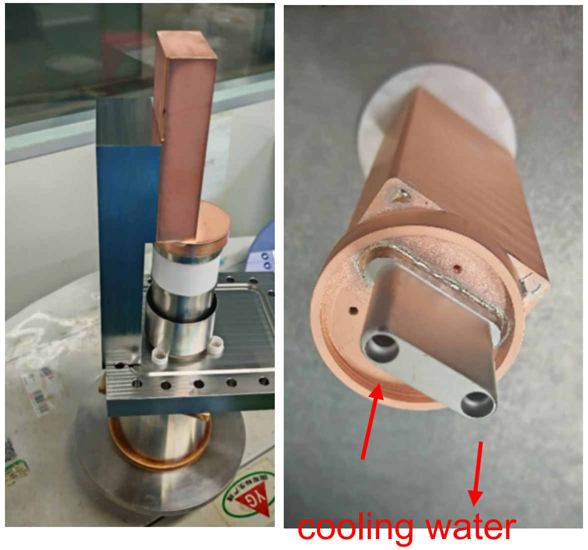
M. Rehman, IBIC25, WEPCO12

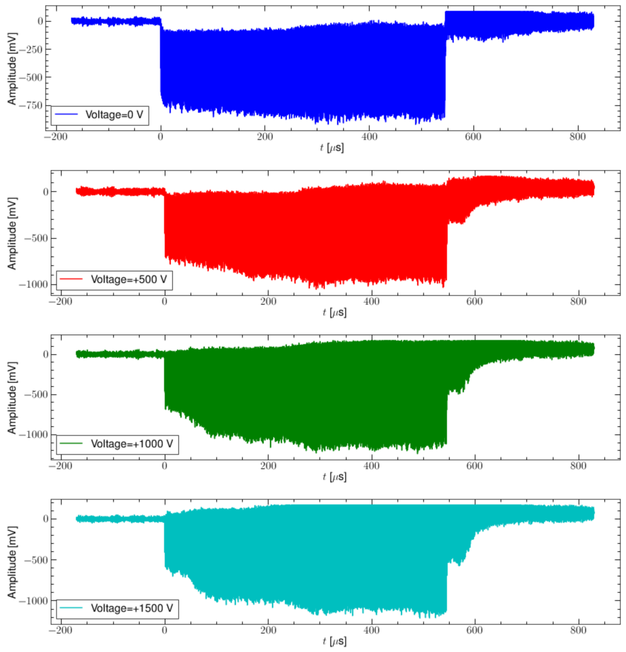
Stripped Electron Catcher

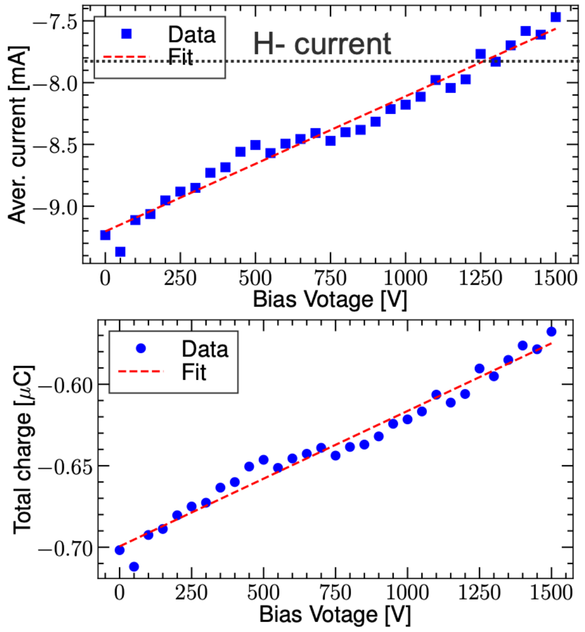
- An electron collector (ECOL) has been designed and installed near the primary stripping foil
- Dimension: 60x130 mm^2, dispersion-strengthened copper; peak power~8 kW => max. temp. 340 K (ANSYS)
- Intermediate pulse time structure (@1.02 MHz) => DC bias voltage ~1 kV appears important
  Extra tails after injection due to stray e-?
- Correlation between ECOL output and DC bias voltage remains to be understood



Test in lab.



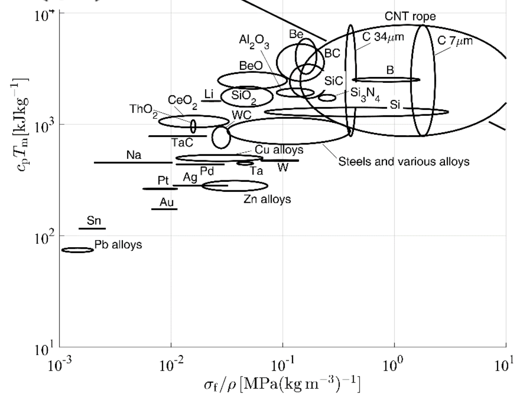




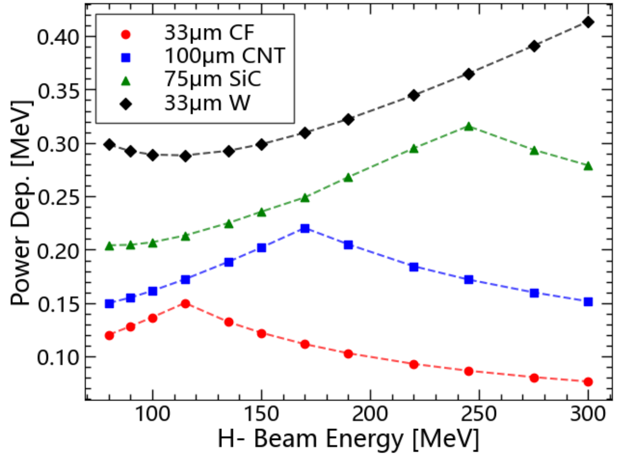
SEM grids in the RCS injection area

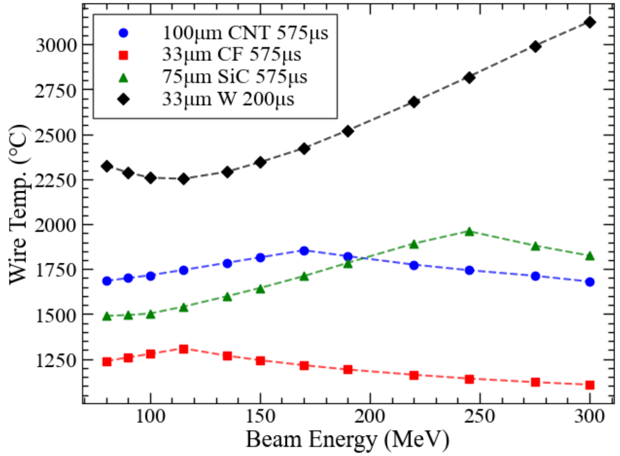
- Three SEM grids are required for the RCS injection tuning (H^- beam, 80-300 MeV, 30 mA, 575 μs, σ_{xy}~2.0 mm, 1 Hz)
- The thermal analysis in ANSYS based on G4 simulations suggests that the commonly used tungsten and SiC wires might melt/sublimate, while the peak temperature of the CF (33 μm) is only 1310 °C
- For the CF, the SEY is <5%*I_{H-}@>115 MeV, and the mechanical stress & deflection might be serious issues for massive implementation!

$$M = c_p T_{max} \left(\frac{\sigma_f}{\rho} \right)^{\frac{1}{2}}$$



Material	CNT	CF	W	SiC
Diameter (um)	100	33	33	75
Density(g/cm^3)	1.08	1.8	19.35	2.89
Thermal conductivity (W/mK)	350	24	173	340
Tensile Strength(GPa)	1.79	3	1	5.9
Work Temperature (℃)	<2000	<2000	<2000	≥1250
Expected max. temperature (℃)	1855	1310	>3000	1962





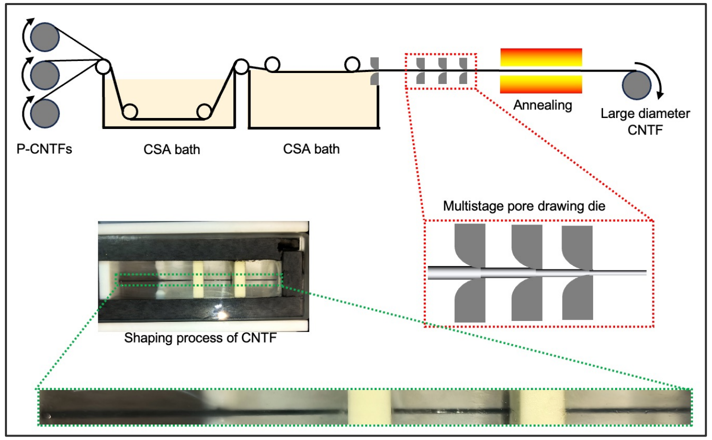
[1] H. Bigland et al., Advanced Engineering Materials (2020)
[2] https://www.specmaterials.com/

Novel CNTF fabrication & characterization

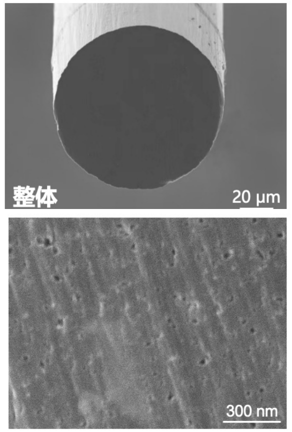
C. Xie, MORT05, IBIC26

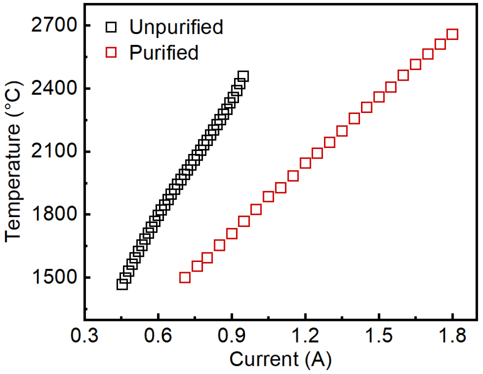
- Large-diameter CNT wire fused by ~30 CNT fibers prepared through FCCVD method
- Ferrocene ($Fe(C_5H_5)_2$) purified through heating up to 1600-1800 ^oC in vacuum (10^{-5} Pa)

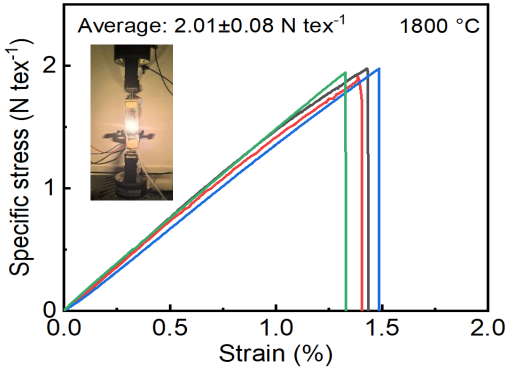
Manufacture of CNT wire



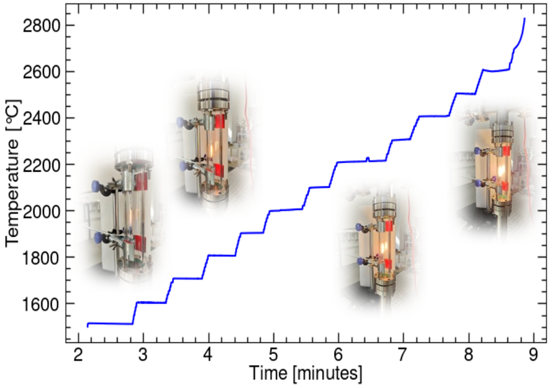
uniformity~3%

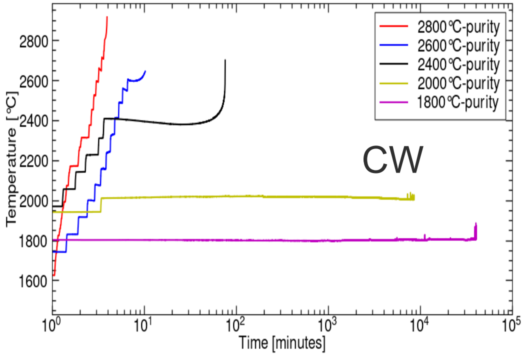


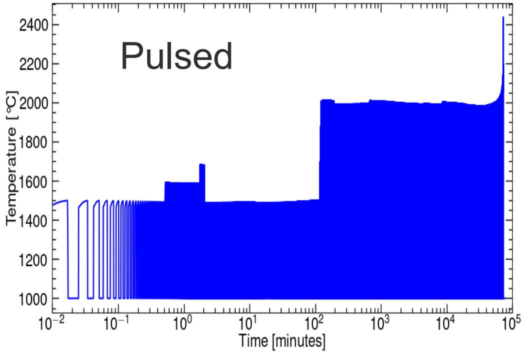




- Thermal heating experiments in lab. show: a max. temperature ~2800 ^oC; endurance at 2070 K for ~700 h (continuous) & >1000 h (1 Hz, duty~0.5)



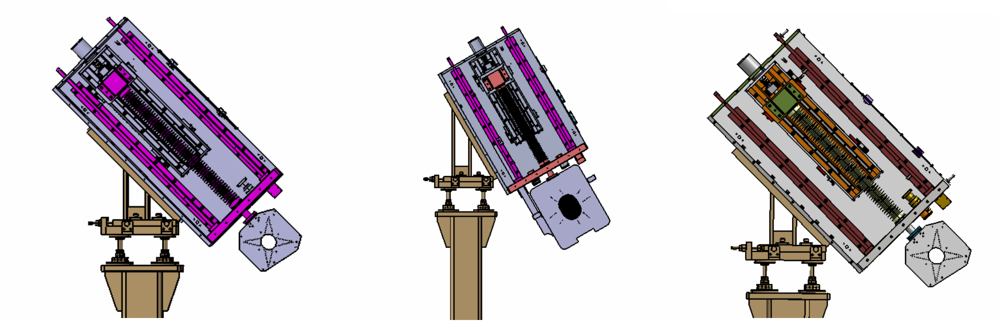


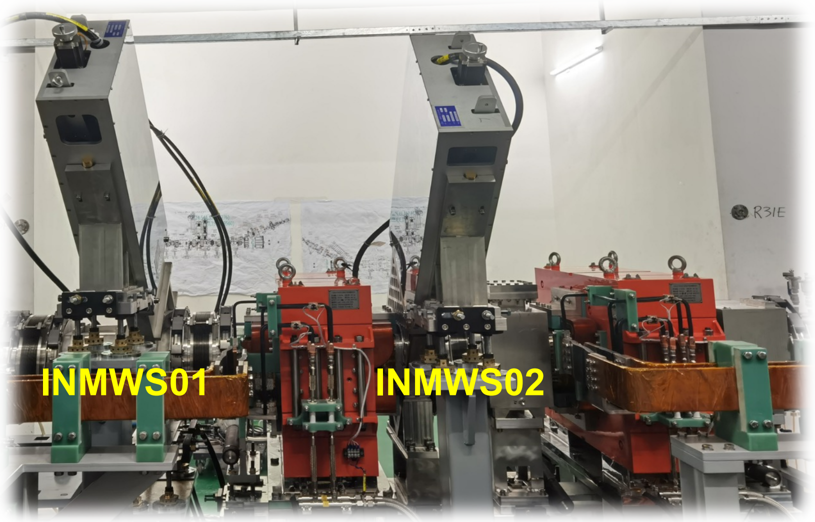


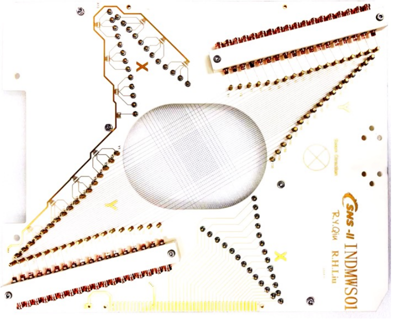
CNTF SEM grids in the RCS injection area

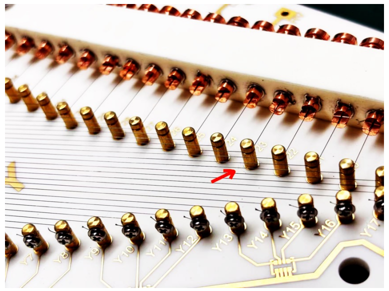
- Three SEM grids with 136 signal CNT wires, a min. wire space of 1.5 mm on a ceramic frame
- Φ2 mm coil springs form 0.5 N steady tension
- Individually biased wires on the other frame (+100V)
- DAQ: Linux + NI PXIe digitizer+ EPICS IOC

INMWS01 **INMWS02** **INDMWS01**

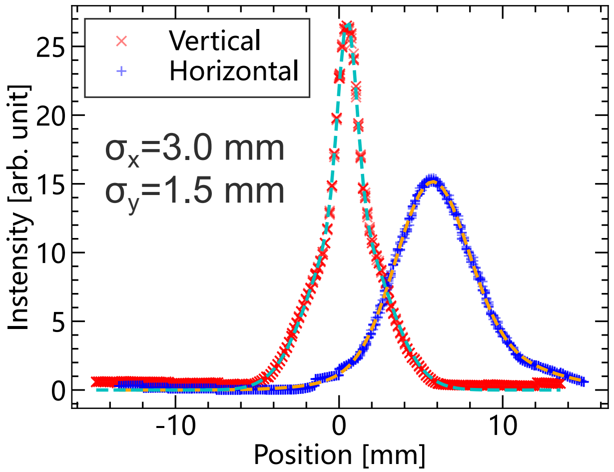








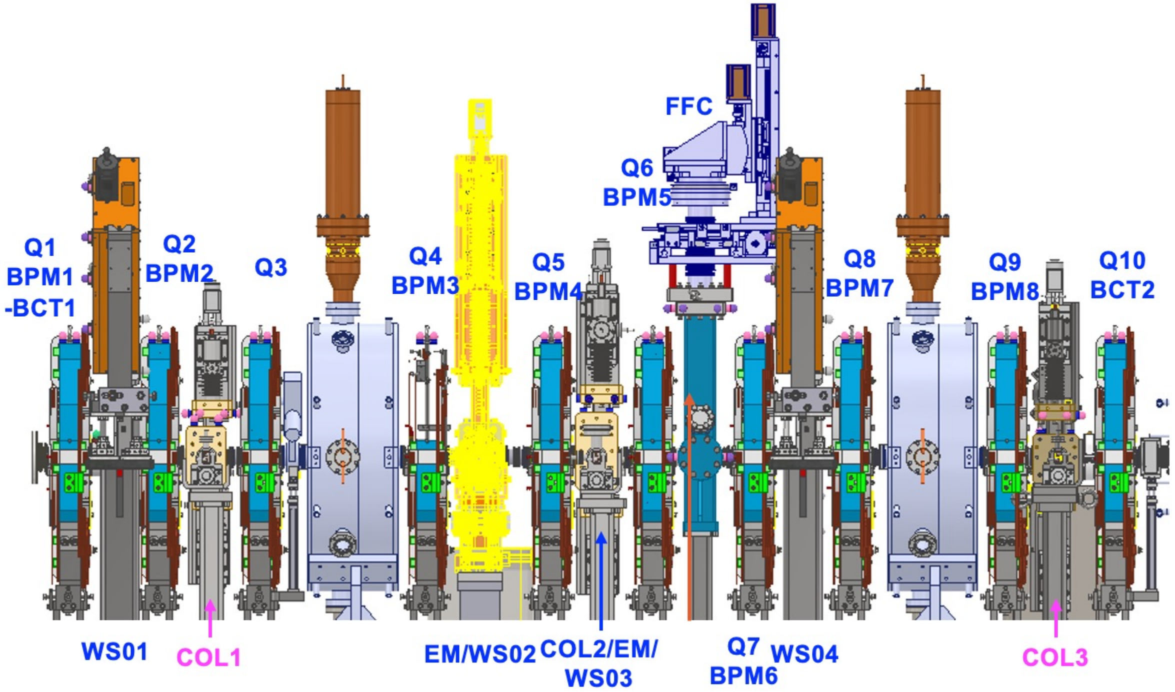
Resolution further improved by scan function (0.15 mm)



- Upgrade of instruments in RCS injection region (in operation)
- Upgrade of beam instrumentation in the MEBT (installation in 2026)
- Design and prototype of beam instrumentation for Superconducting LINAC
- Design and prototype of beam instrumentation for RCS and extraction lines

Beam instrumentation for MEBT

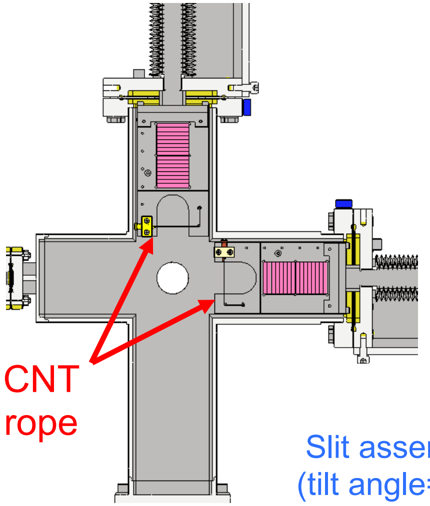
- In accordance with the revision of the MEBT optics and structure, beam instrumentation is being upgraded
- 6 individual BPMs, 2 BCM-BPMs, 2 individual WSs, 3 FBLMs, 1 EM/WS2-COL2/EM/WS03 assembly plus an extra space reserved for the longitudinal diagnostics (FFC vs. BSM)
  - Reuse the current BPM & CT sensor designs and electronics (commercial, Bergoz & Libera)
  - Reduce the transverse dimension of the WS (<0.77 m in hor.), use CNTF wires (SNR X10)

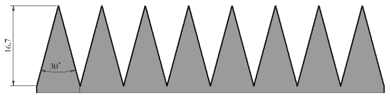


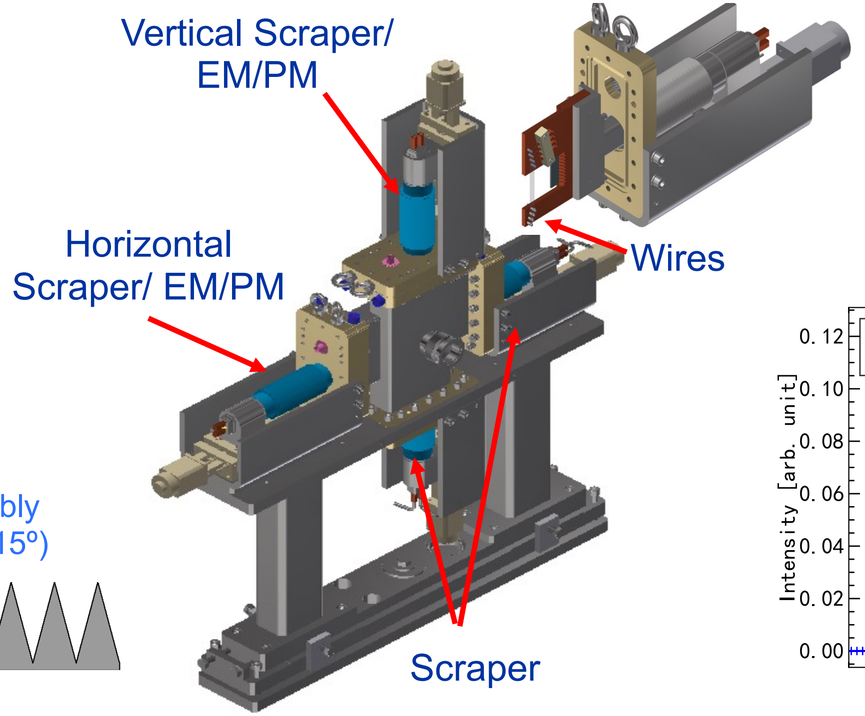
	No.	Requirements	Features
BPM	8	Position resolution <0.2%*R phase resolution 0.2°@324 MHz	BPM embedded in quad. poles (8 new BPM+1 LIBERA electronics)
BCT	2	Range: 1-50 mA Linearity: ±0.5% Risetime: ≤10 μs	BPM-BCT welded together
EM	1	Max. beam power: 50 mA*20 μs Accuracy: ~10%	Slit-wire configuration, integrated with collimator (COL2) and WS02, WS03, 4 wires for beamlet (4X faster)
WS	4	Scan range: ±R Resolution: ≤0.2 mm Positioning repeatability: ≤0.5 mm	Φ100 μm CNT wire, x & y (WS01/WS04)

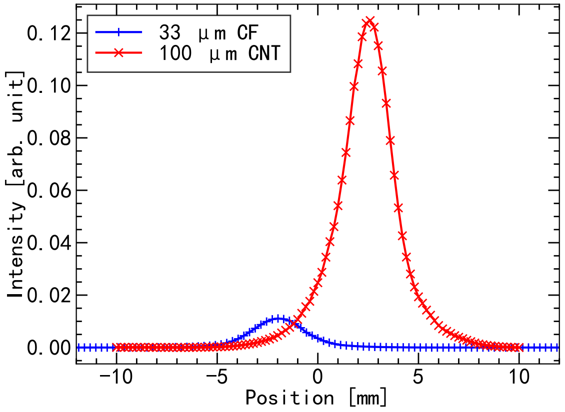
MEBT emittance meter (EM)

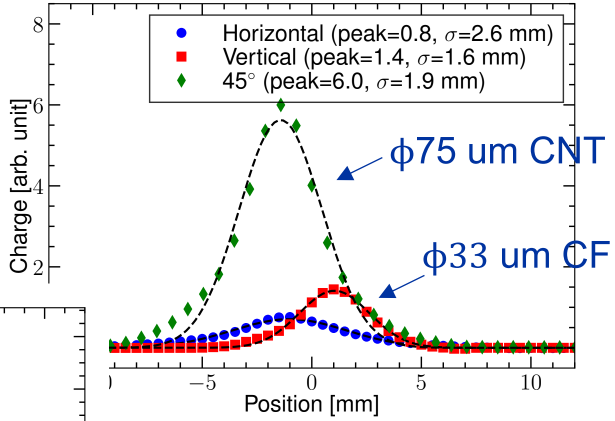
- A combination of emittance meter, collimator and wire scanners driven by the compact layout design
  - Single-wire + slit (hor. and ver. separately), slit width=0.2 mm, d100 μm CNT wire
  - Slit arm: segment the slit in several blades made of tungsten
  - Multi-wire + scraper (hor. and ver. separately), pitch width=2 mm, 5 CNT wires in each direction, double-ended
  - ***ϕ*100 um CNTF** rope's signal shows a 10X enhancement compared with the ϕ33um CF




Slit assembly (tilt angle=15º)







Longitudinal diagnostics at MEBT

- The new CSNS-II MEBT design leaves ~141 mm space (z-direction) for the longitudinal bunch shape diagnostics while the space required by Feschenko-BSM is around ~200 mm
- At several accelerators, the Feschenko-BSM operates NOT often, and the adjacent quads are powered off during operation (re-match optics); BSM operation by experienced experts
- Alternative solution: coaxial FFC+EOM

MEBT major beam parameters

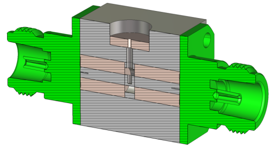
Parameter	Value
Beam energy	3 MeV
Beta	0.08
Beam current	1-50 mA
Bunch freq.	324 MHz
Avg. beam size	2-3 mm
Bunch length	**50-250 ps**

low-β bunch shape diagnostic

GHz sensor

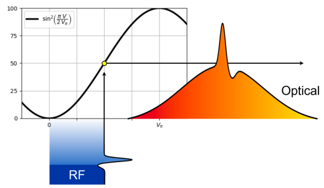
RF signal distortion

FFC (FNAL idea)



- Round 50 Ω coaxial line
- BW>10 GHz
- Bias voltage (secondary e-)

EO modulation



- Mach-Zehnder EO modulator
- C-band CW laser + SMF
- BW~40 GHz (1550 nm laser)
- Atten.: 0.2 dB/km @1550 nm

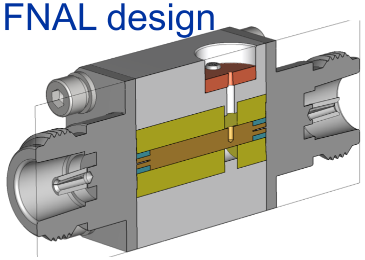
[1] A. Carneiro et al.,Int. J. of Mod. Phys. A, 2019
[2] T. Suwada et al, Scientific Reports (2022); A. Schlogelhofer et al., IBIC2024

Longitudinal diagnostics at MEBT (cont.)

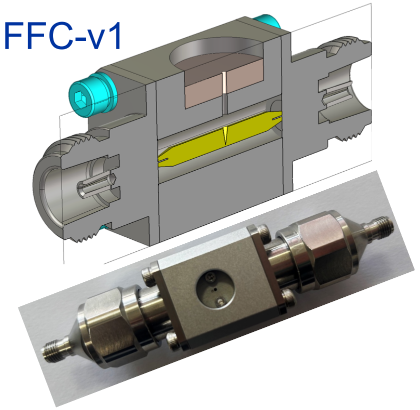
- Two versions of the coaxial FFC were prepared, and a bandwidth of >20 GHz has been realized
- Simulations in CST (MPE=7.5 eV) suggest that a DC bias of >50 V (TMI BT-GA01) is needed to suppress the tail induced by the secondary emission
- A 5-axis mover manipulator to adjust the position/tilt of the FFC sensor; 40 GHz feedthru, in-vacuum coaxial cable and bias-tee connected (BW limited by the coaxial FFC)

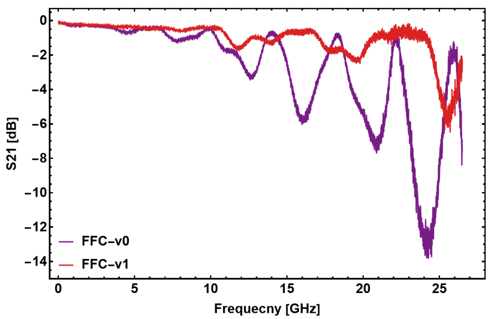
<u>Beam test in 09/2026</u>

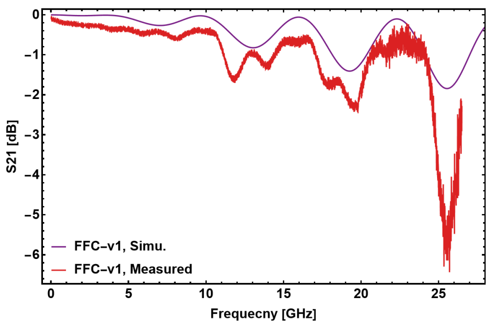
FFC-v0
FNAL design

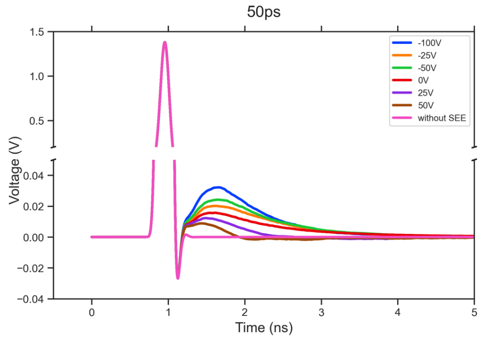


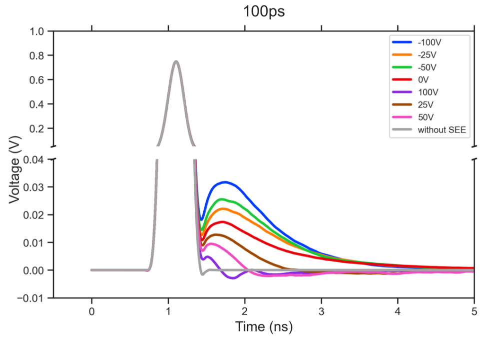
FFC-v1

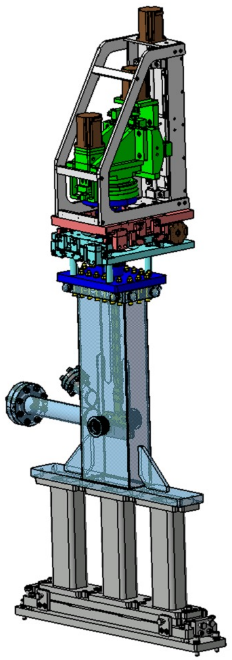


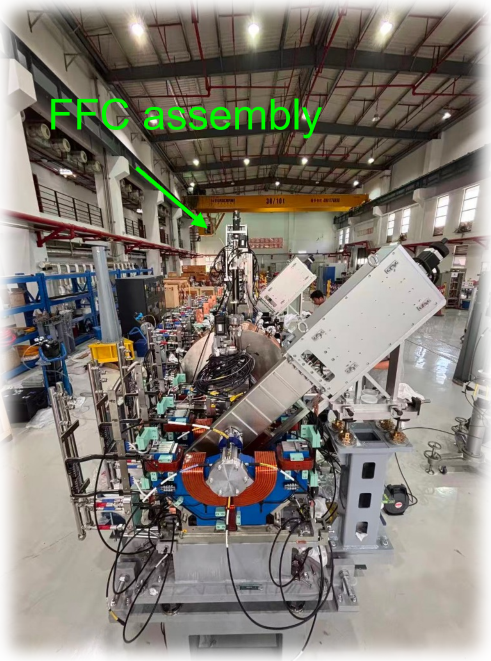










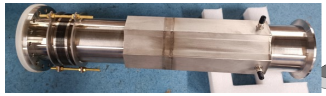


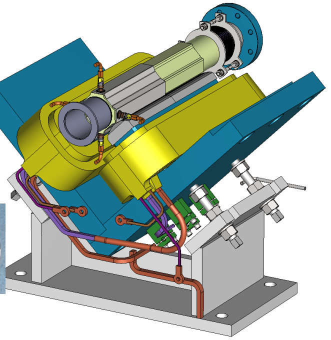
- Upgrade of instruments in RCS injection region (in operation)
- Upgrade of beam instrumentation in the MEBT (installation in 2026)
- Design and prototype of beam instrumentation for superconducting LINAC
- Design and prototype of beam instrumentation for RCS and extraction lines

BPMs in SC LINAC and LRBT

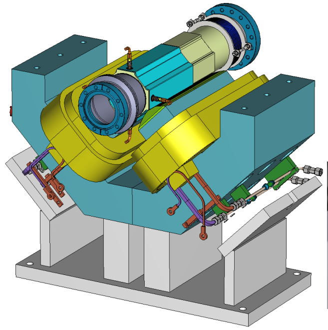
- 11 BPMs in spoke-cavity section, 8 BPMs in elliptical-cavity section, and 11 BPMs in the LRBT will be installed in 2027
  - The shorted stripline BPM has been employed at CSNS LINAC (resolution <50 μm)
  - BPM in SPOKE section was designed, prototyped, tested with H$^-$ beam
  - Specifications: position resolution <0.1 mm @ +/-R/2 (R=26 & 50 mm), phase resolution <0.2^o
  - Massive production since 2026
- Reuse the current Libera Single-pass & Spark electronics w/ necessary updates
  - The intra-pulse position deviation was observed along the macro-pulse (500 μs)
    => BxB bunch position or intermediate-pulse position (1.02 MHz)?

BPM in Quad. (SPOKE)





BPM in Quad. (ELL.)

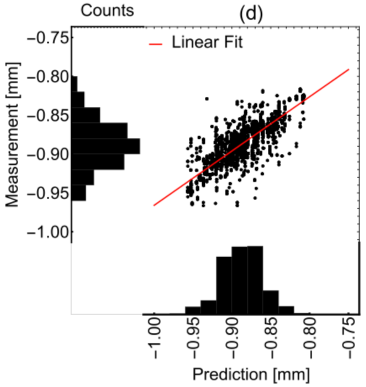


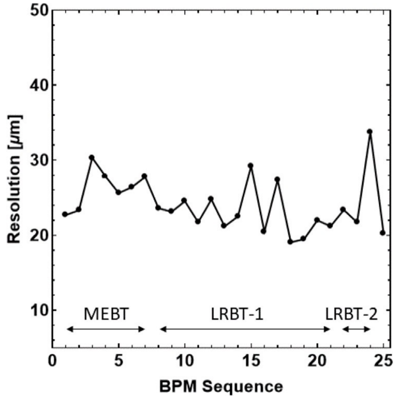
BPM parameters

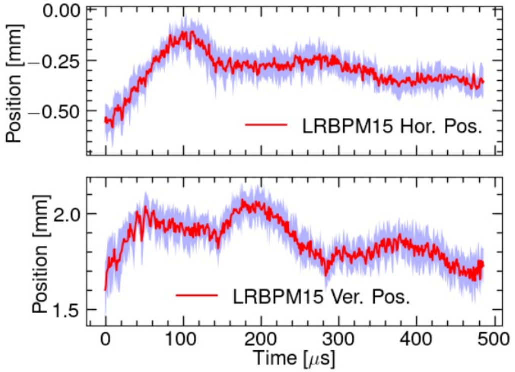
Location	SPOKE	ELL.	LRBT
Stripline Opening Angle	36.12°	25.3°	40 °
Stripline Width (mm)	15.5	21.0	34.2
Stripline Length (mm)	146.0	172.0	182.3
Vertical Gap to Duct (mm)	6.1	7.0	3
Horizontal Gap to Duct (mm)	4.08	8.35	8.8
Stripline width (mm)	2.0	2.0	1.5
Inner Diameter (mm)	50.0	96.0	100.0

[1] M. Rehman et al., NIMA 1080:170671 (2025)

Resolution of current LINAC BPMs

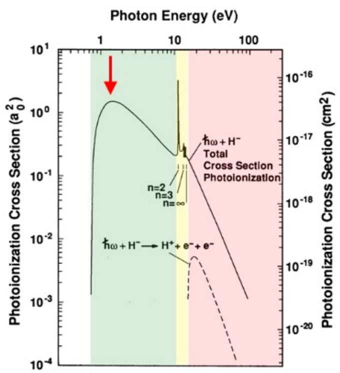


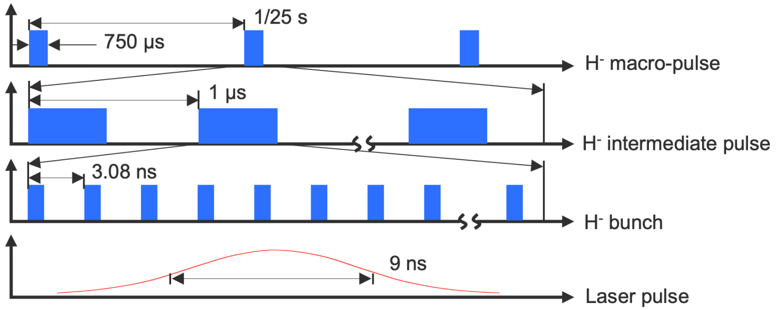


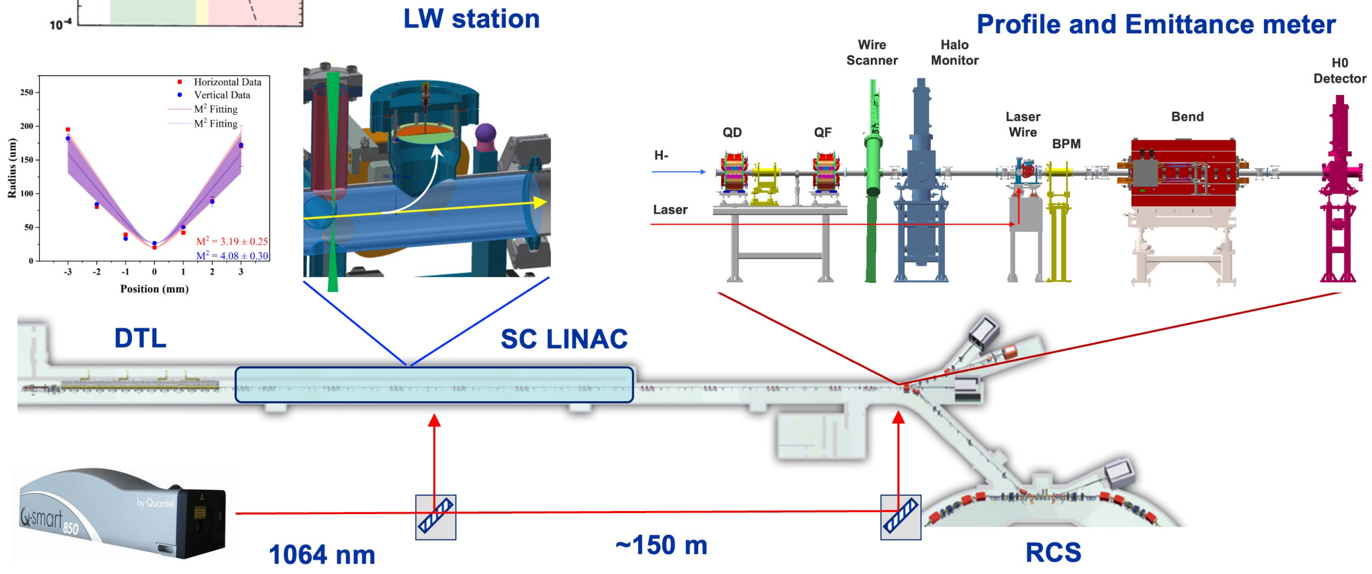


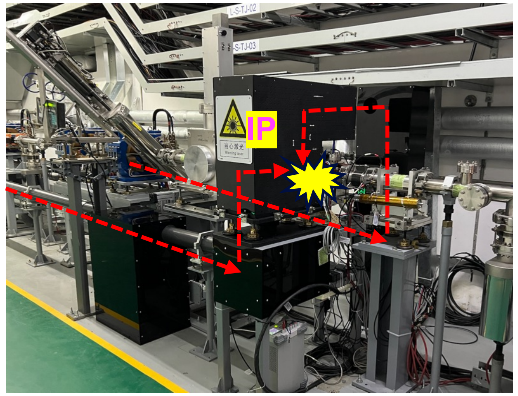
Laser-wire profile monitor

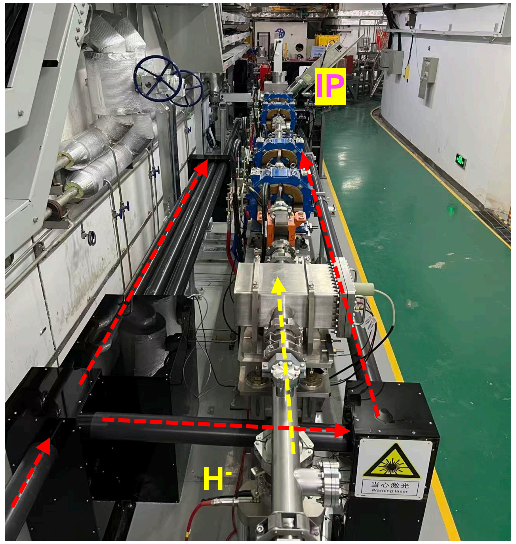
- LW profile monitor: a Swiss-army-knife-style diagnostic tool for superconducting LINAC (8 stations)
- A prototype of the LW profile monitor/emittance meter was established at the LRBT





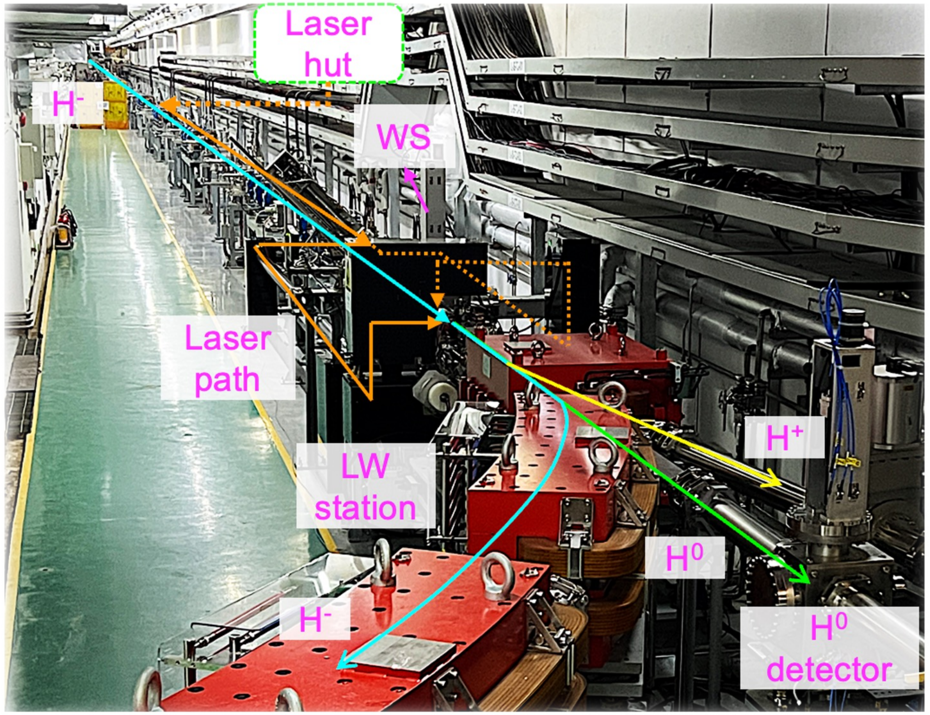


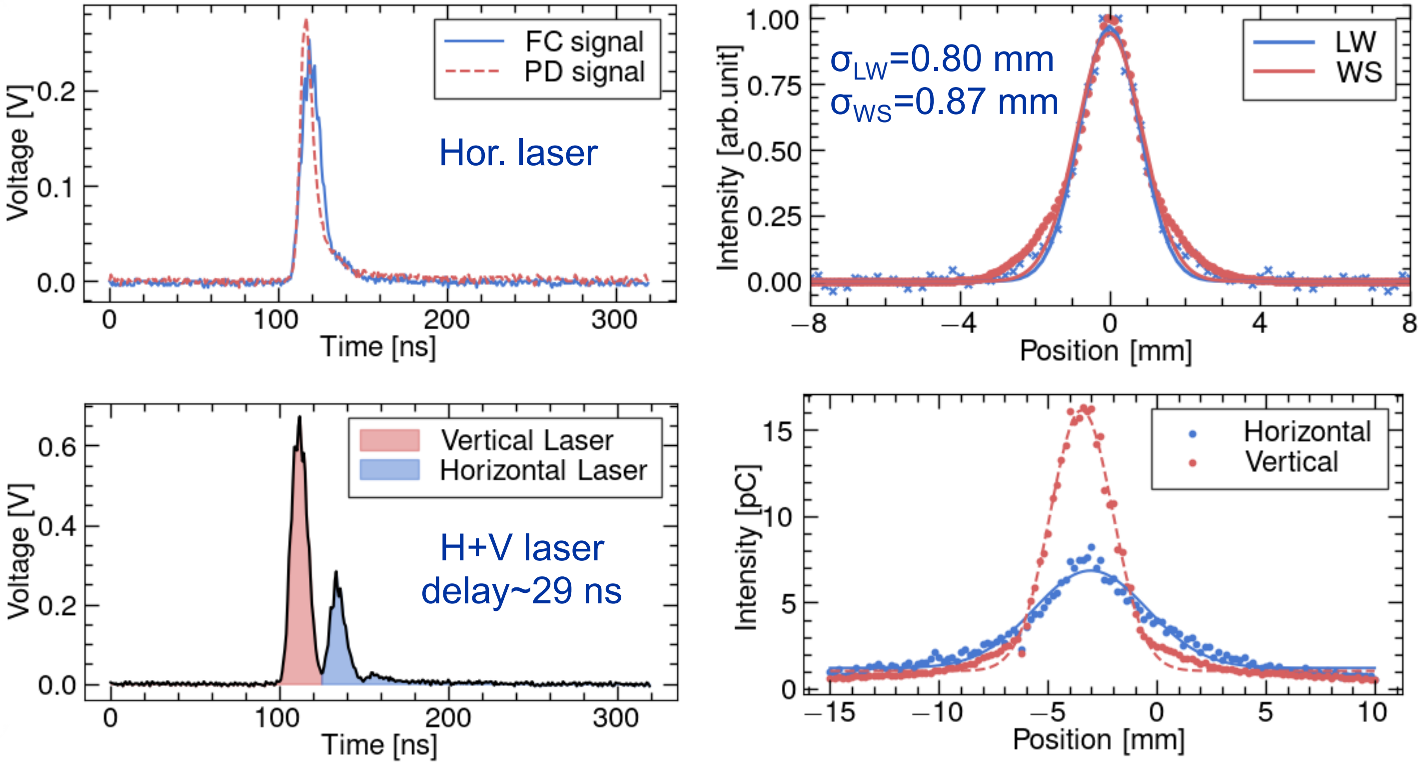




LW prototype at CSNS LINAC

- A 1064 nm Nd:YAG laser (900 mJ/pulse, 7.2±1.2 ns pulse width, 1-10 Hz); 80 m transport line (>80%, M^2~4)
- Stripped electron captured by a FC (Φ60 mm), and then amplified by a 20 dB current amplifier in tunnel
- Calibration with an adjacent WS: σ_{LW}=0.80 mm vs. σ_{WS}=0.87 mm => intra-pulse bunch position displacement



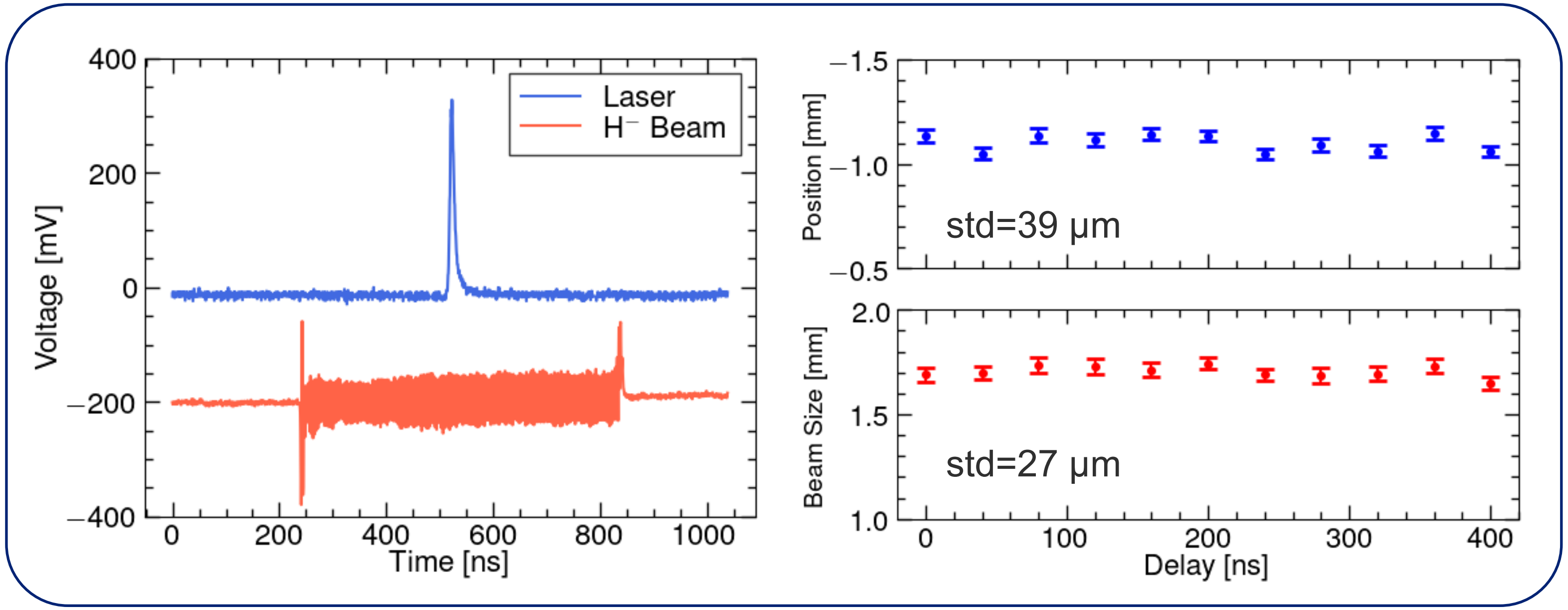


[1] B. Zhang et al., NIMA 1087:171429 (2026)

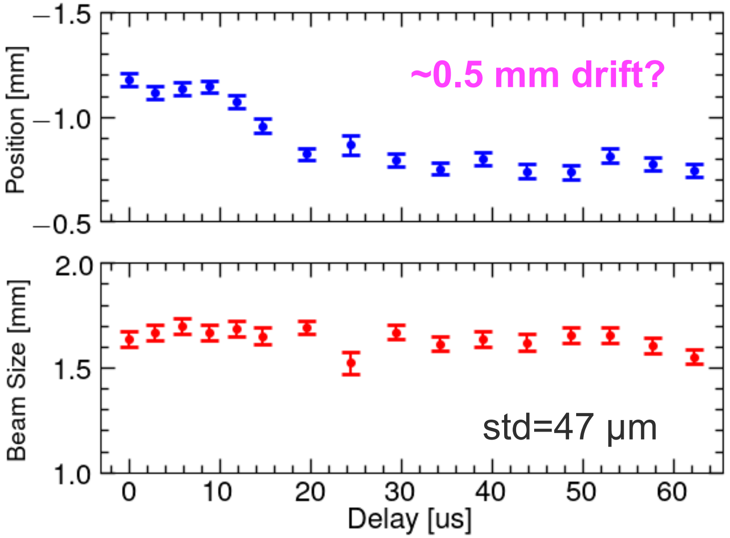
Time-resolved beam profiles (scan)

- First time-resolved beam profile measurements at CSNS in 04/2025
- Resolved inner-intermediate-pulse profiles (≤40 ns); stable beam position and size within one intermediate pulse (400 ns); **~0.5 mm position variation along the macro-pulse** (~60 μs, under investigation)
- Recent efforts: 1064 nm => 532 nm; active pointing stabilization; H0 detection (wire + screen, ~5 m)

Vertical beam position & size inside one intermediate pulse (~400 ns)



Beam position and size variations along macro-pulse (60 μs)



[1] C. Xie et al., IPAC26 MOP6631 (2026)

Concept of a fluorescence wire scanner

- Wishlist for a large-dynamic-range beam halo monitor for a high-intensity p+ accelerator
  - Least perturbation to the beam and high tolerance to beam damage: WS, non-invasive methods
  - High sensitivity, low background noise: optical methods (fluorescence material, ~10^4 ph/MeV)
  - Radiation hard
  - Simple and cheap (use commercial devices)

- Great DNR and sensitivity, but incomplete 2D image; beam loss after inserting screens

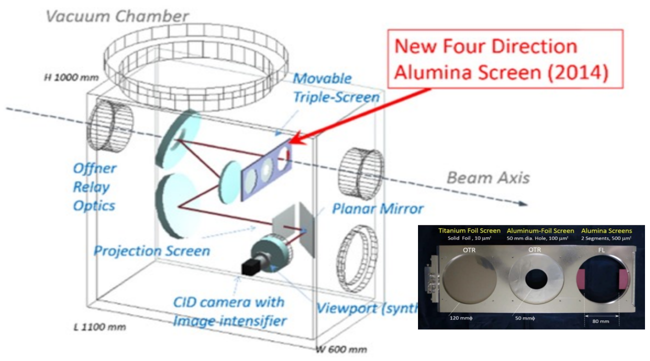
➢ **Thin strip/wire**

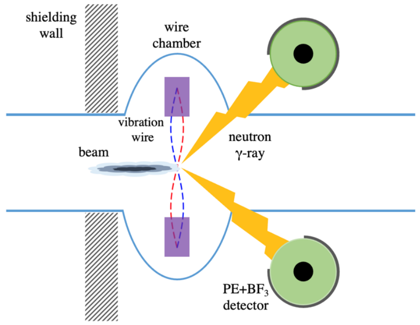
- Small perturbations to beam (∝ wire diam.), simple, rad. hard
- A fair DNR limited by background neutron&γ-ray noise

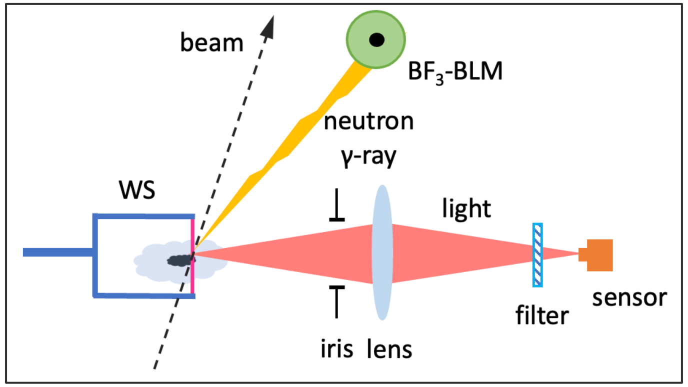
➢ **Combining optical method**

Fluorescence wire scanner (FWS)

- Core & tail: WS-nBLM scheme
- Halo: fluorescence light collection (2D image not necessary, light flux ∝ wire thickness)
- **no diffraction light from beam core**



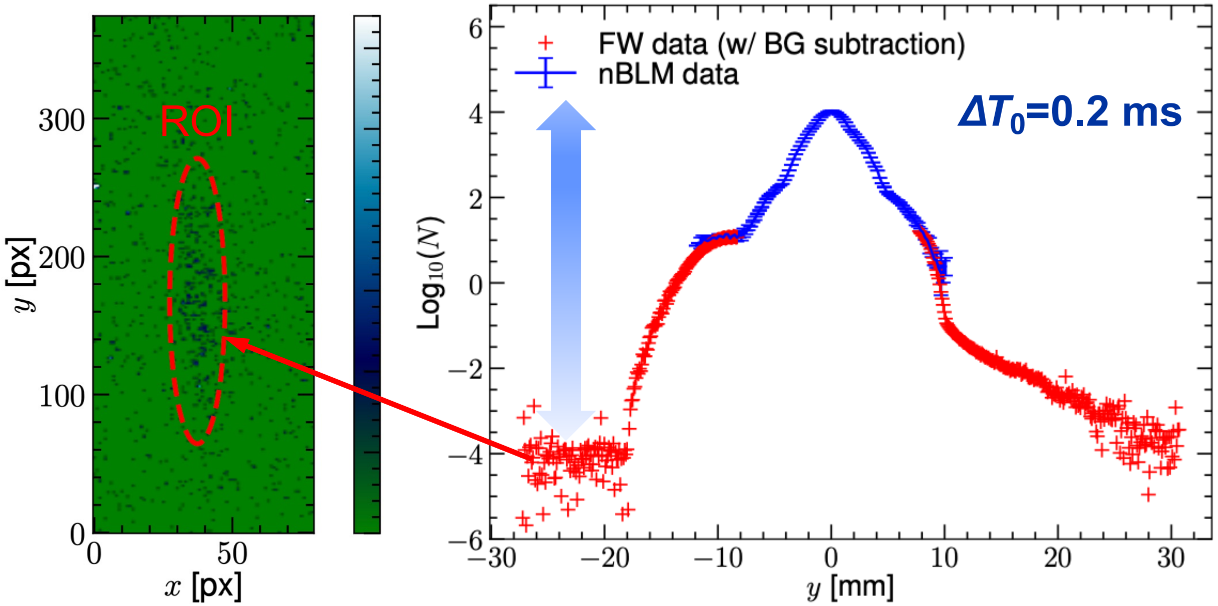




Commissioning results

- A dynamic range of >10^8 has been obtained with 8-bit depth, hor./ver. binning=2/4 !!
- **After optimizing the T0 trigger timing to ~0.2 ms behind the H^- beam, a dynamic range of ~1.7×10^8 has been successfully established at 12-bit depth!**
  - Determine the background level (DN/pixel) over ROI when the fluorescence wire is near home position
  - Combination (rescaling) of the nBLM and camera data wrt. the observed signal in the overlapping regions

12-bit, DNR~1.7×10^8

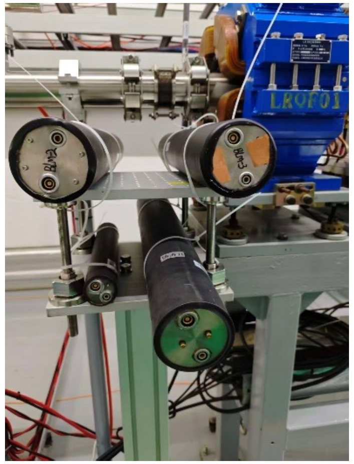


[1] R. Yang et al., IBIC24, WEBI1; R. Yang et al., IPAC26, THO6T03

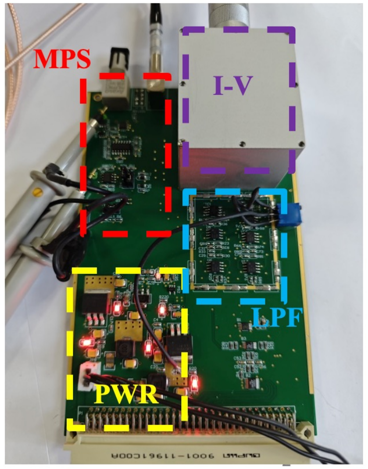
Beam loss monitors for the SC-LINAC

- Two types of BLMs are required to localize the loss position and MPS (**damage and quench prevention**)
- Parallel-plate ionization chamber (IC) filled with Xe (1.1 atm) and Xe (1.05 atm)+N2 (0.05 atm)
  sensitivity >200 μC/rad; response times of 2 μs and 0.3 μs (e- drift time)
  - One parallel-plate IC per SC cavity throughout the SC LINAC (abort threshold ~800 nA for >0.01 W/m loss)
  - Electronics shift from I-F converter (CFC) to I-V converter; transimpedance amplifier (1 & 100 MΩ, 0.02-20 μA & 0.2-20 nA) + 1 MSPS ADC (>20 bit) + FPGA (counter, encoder …)
- New IC and analogue electronics satisfy the design requirements => CFC electronics for higher dynamic range
- Plastic scintillator-PMT as Fast BLM

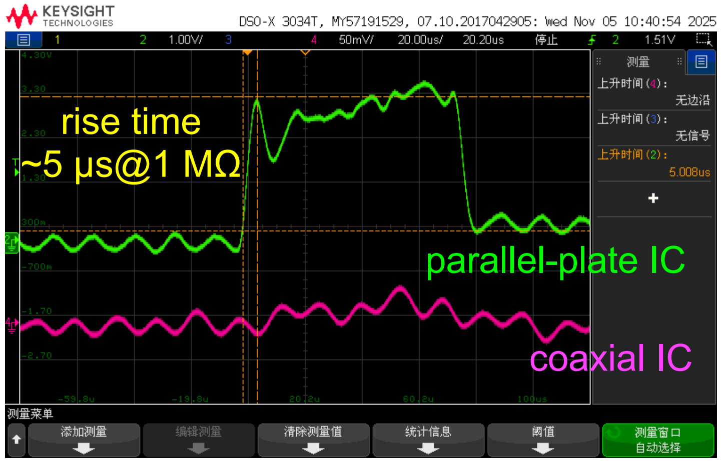
Test at LRBT



FMC board (v1)



Test at LRBT

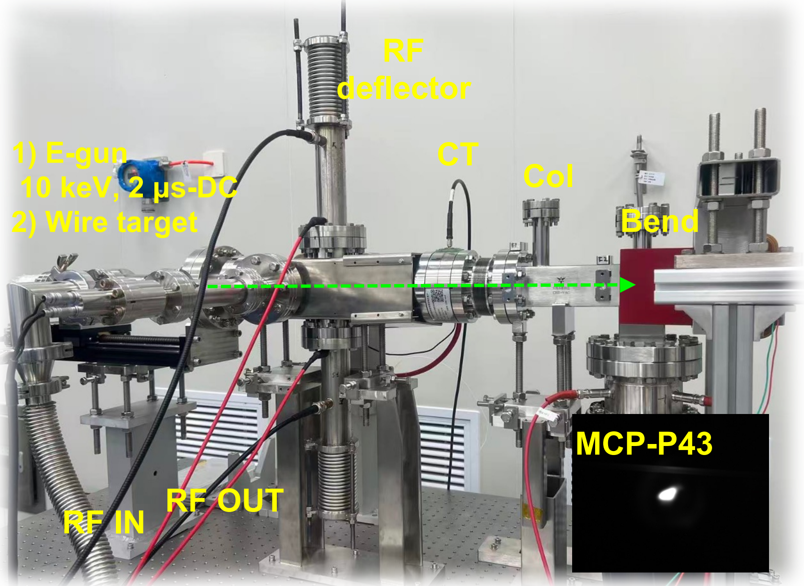


IC leak current: 8 pA

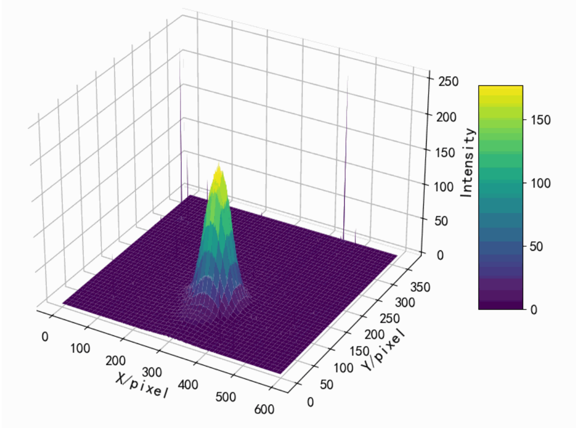
Transimpe d-ance	Noise level (Vpp, max)
1 MΩ	15.9 mV
100 MΩ	8.4 mV
1 GΩ	8 mV

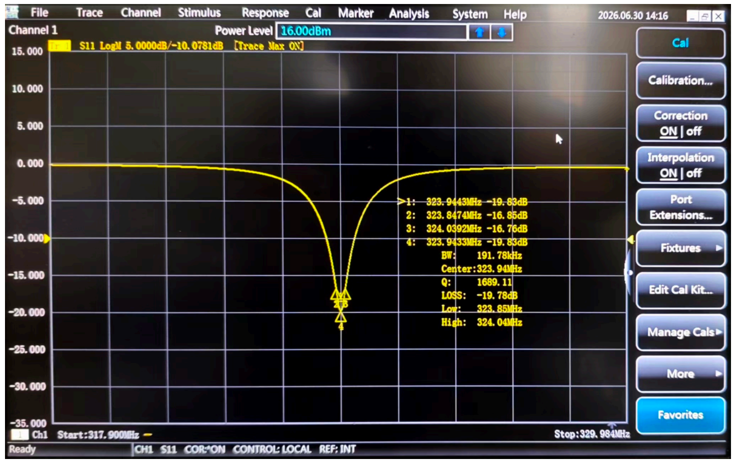
Feschenko-type BSM

- Feschenko-type BSMs at the entrance & exit of the SC-LINAC are required for the longitudinal phase-space matching and optimization
- Direct detection techniques have to resolve the low-β stretch, high-bandwidth detection & signal transmission => a Feschenko-type BSM with a 324 MHz λ/2 RF deflector (phase resolution <1°@324 MHz)
- A testbench based upon e-source was constructed in lab., and the prototype will be installed this week



- Evolutions of electron optics (position, profile) were demonstrated w/ an e-gun, or thermal emission of wire
- New RFD w/ a design Q~3000, measured Q_{load}>1500, S_{11}=-35 dB





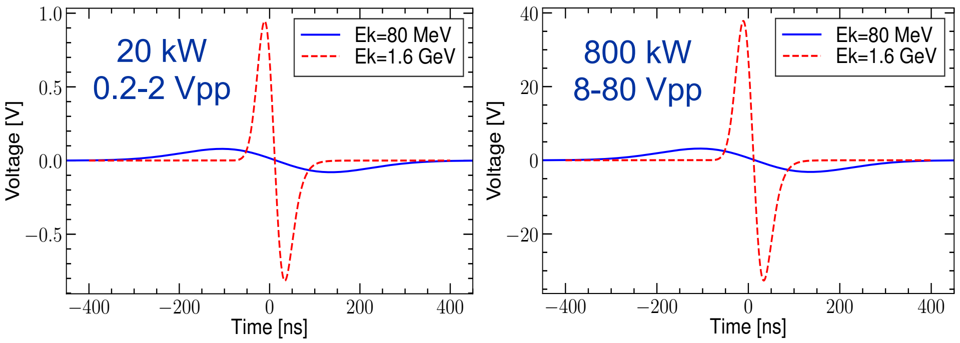
Acknowledgement to P. Forck (GSI) & Y. Zhang (IMP)

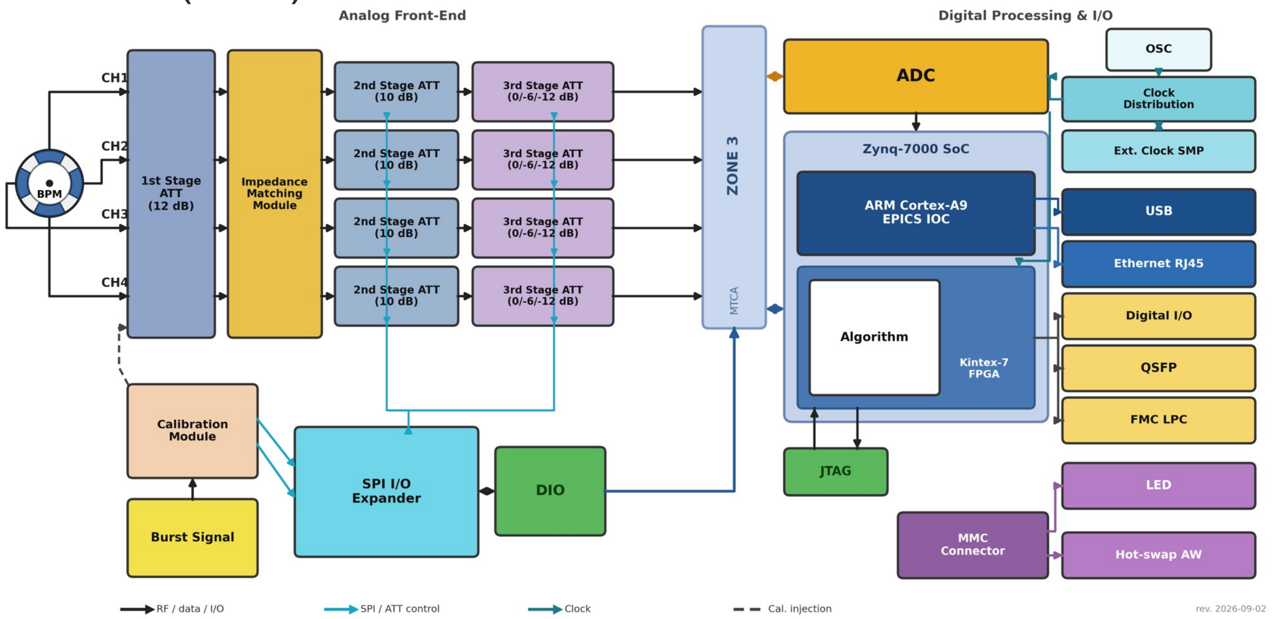
- Upgrade of instruments in RCS injection region (in operation)
- Upgrade of beam instrumentation in the MEBT (installation in 2026)
- Design and prototype of beam instrumentation for Superconducting LINAC
- Design and prototype of beam instrumentation for RCS and extraction lines

New RCS BPM electronics

- Diagonal cut-plane BPM was chosen for a large linear range, 32 BPMs for COD + several RFBPM
- Updated design based upon μTCA.4 system (max. dynamic range~100 dB)
  - Custom RTM board enables cascaded signal attenuation and transparent gain switch (J-PARC MR experience)
    - Slow & fast switches: <1 ms & ~600 ns adapting to commissioning at low and high beam power (20-500 kW), and injection to extraction (0 dB => -34 dB)
  - Digital AMC board: 125 MSPS/16 bit ADC, Zynq-7000; EPICS IOC
- Beam position calculation algorithm: standard deviation (STD)[1]

Expected PU signal



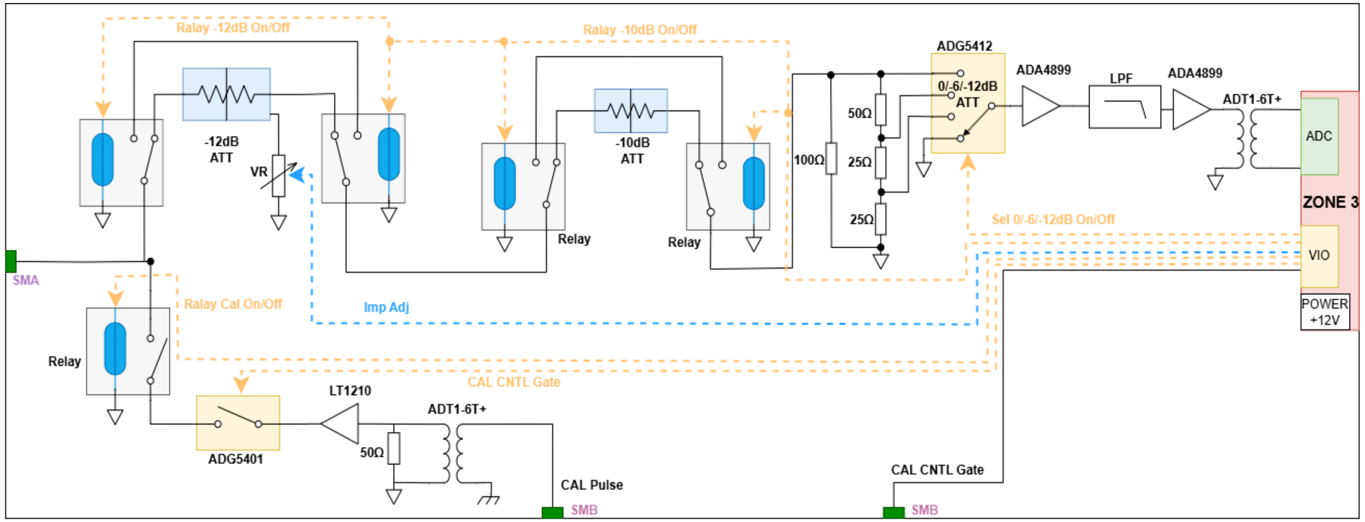


[1] A. Reiter and R. Singh, NIMA 890:18-27 (2018)
Acknowledgement: K. Satou, T. Toyama, R. Singh, P. Forck

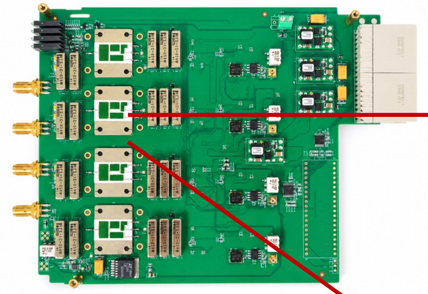
New RCS BPM electronics: analogue board

- For all possible beam powers (double-bunch), and the respective signal amplitude ranges from 0.1 V to 50 V for the accelerating beams while the ADC linear range is ±1 V
  - Tantalum Nitride (TaN) thin-film RF divider (-12 dB atten. + impedance matching, BW=0.03-30 MHz)
  - Three-stage attenuation modules (-12 dB, -10 dB, 0/-6/-12 dB)
  - Measured specifications: non-linearity <0.6%; crosstalk <-70 dB@0.03-50MHz; gain difference <0.6%; switch time 325 μs (relay switch)/620 ns; zero-input noise 4.14 nV/ √Hz

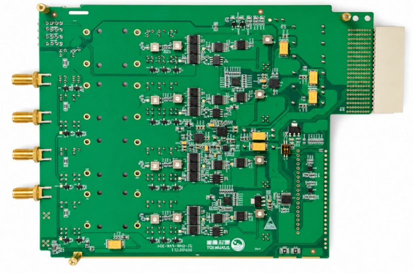
Schematic block diagram



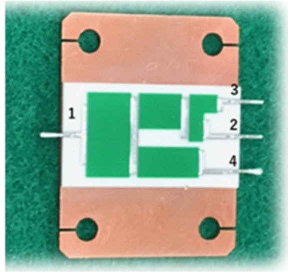
Front side



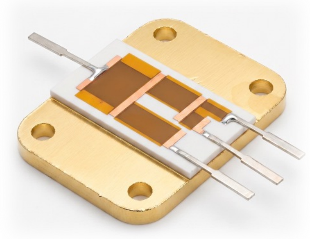
Back side



Hirak RF-20033 (J-PARC design)

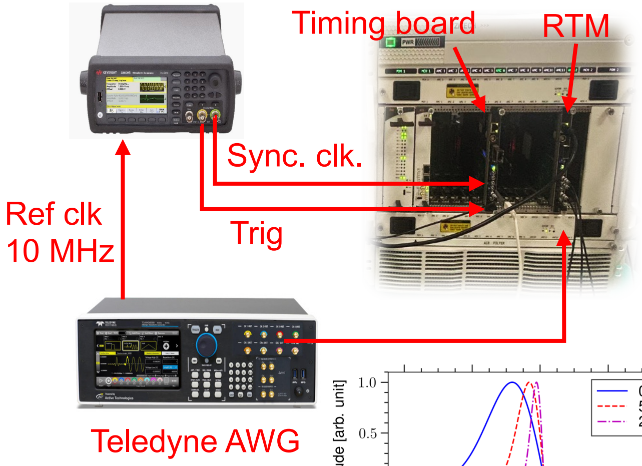


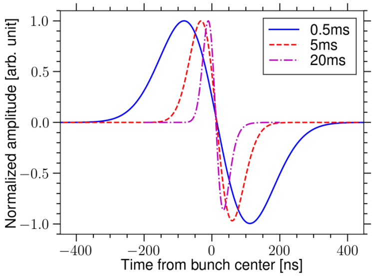
TaN attenuator by IHEP

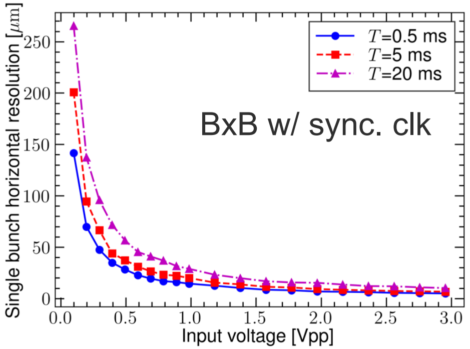


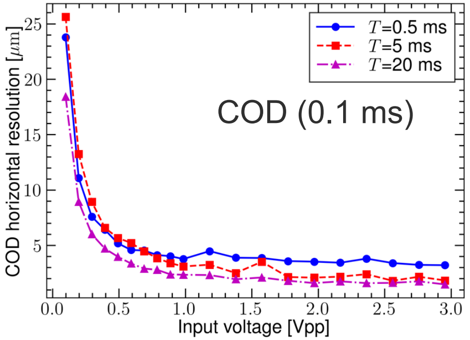
Resolution determinations

- An arb. waveform generator (16 bits, 12.32 GS/s, 5 Vpp) generates the expected PU output signal (injection → extraction) with varying amplitudes
- COD and BxB positions calculated by STD algorithm
- BxB position resolution: <50 μm@Vpp>0.6 V (0.05% R)
  COD resolution: <5 μm@Vpp>0.5 V



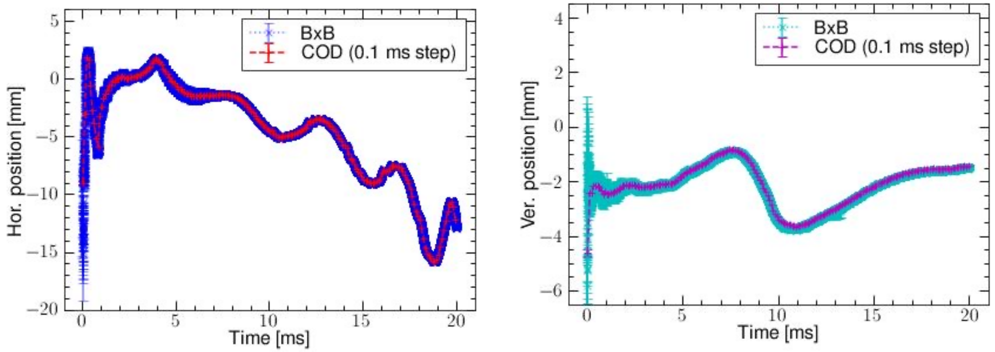




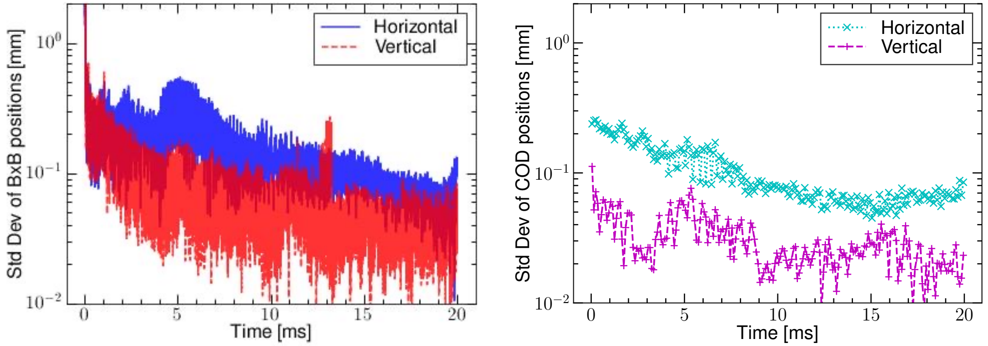


- Beam test w/ E_k=80 MeV-1.6 GeV, ~1e13 ppb @CSNS
- Position resolutions
  - BxB: <0.2 mm (h) and <0.1 mm (v) @Vpp>0.2 V
  - COD: <0.1 mm (h) and < 0.05 mm (v) @Vpp>0.2 V

COD (0.1 ms, **w/o** sync. clk)

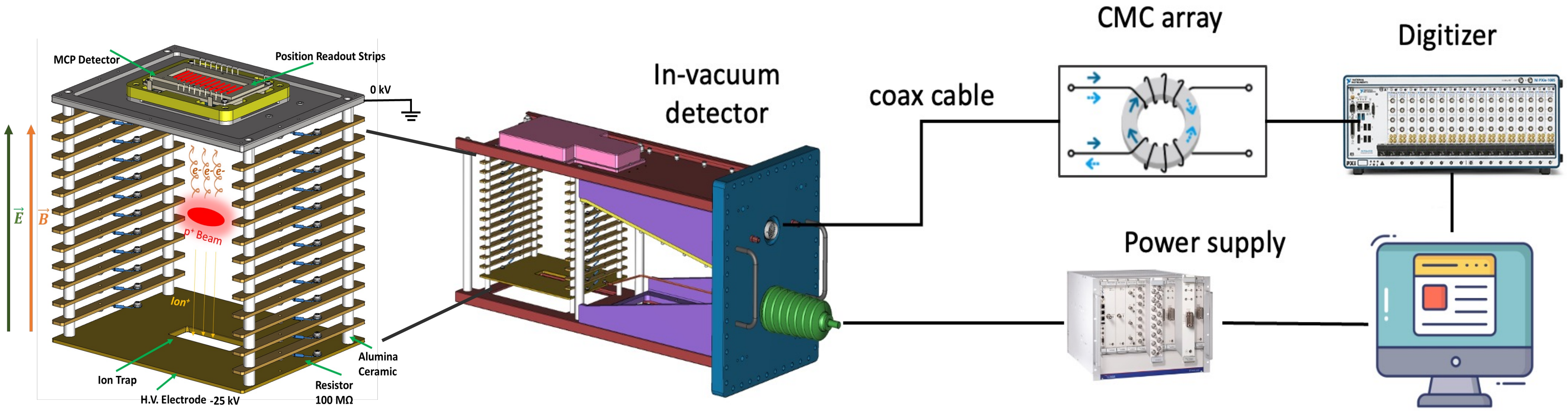


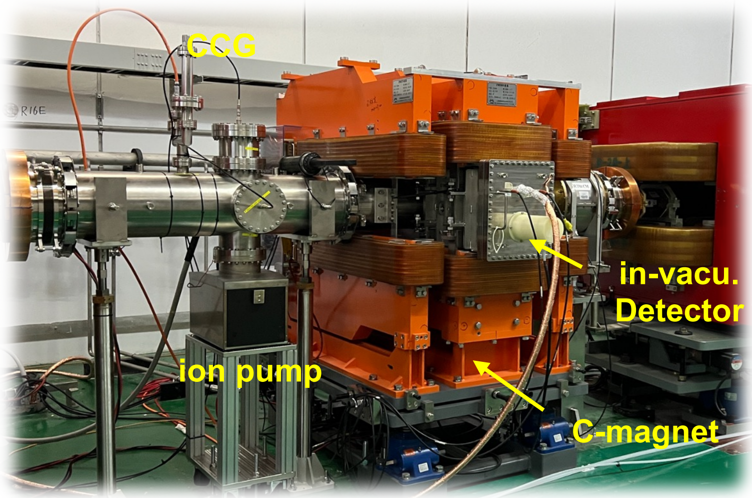
BxB w/ sync. clk



Ionization Profile Monitors

First prototype: 2019-2024



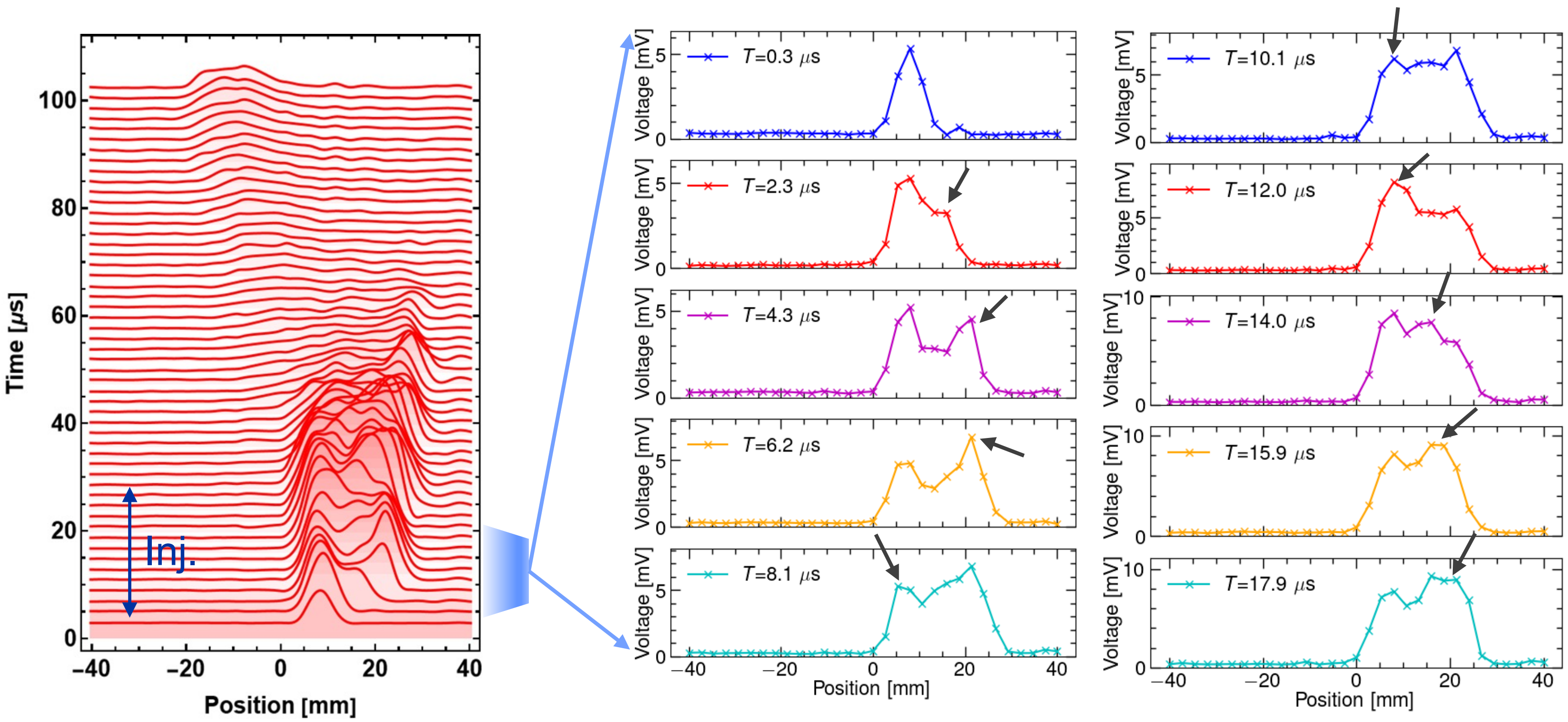


- IPM for BxB beam profile observation
  - In-vacuum Faraday Cage → -42 dB
  - Good field cage → field uniformity ~0.6 %
  - Ion trap prevents SE→ efficiency ~70%
  - 32-ch MCP (R_b=20 MΩ, gain>10^6, pitch width=2.5 mm)
  - CMC to suppress the common-mode noise
  - 40-ch digitizer acquires raw signal w/ 125 MSa/s, 16 bits
  - An extra synchronization clk. signal or peak finding to determine the beam passage

First observations of the RCS injection beam

- The initial commissioning of the IPM detector focuses on the ion-mode (w/o B-field)
- The primary beam intensity is limited to <10^{12} ppb => image the early injection proton beam

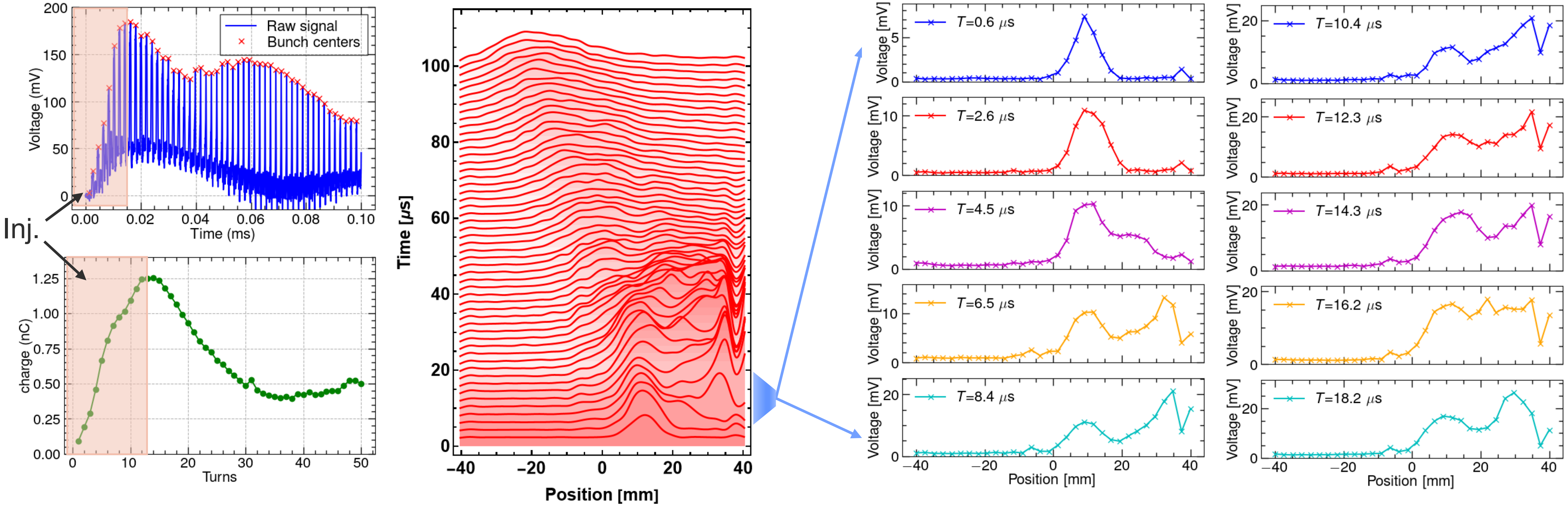
Horizontal injection painting scheme: direct observations



* M. Rehman et al., NIMA 1092: 171809 (2026)

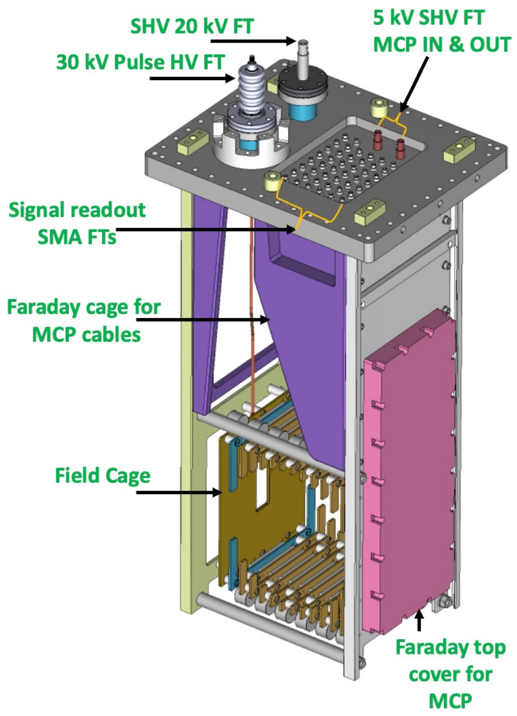
Experimental observations in the e-mode

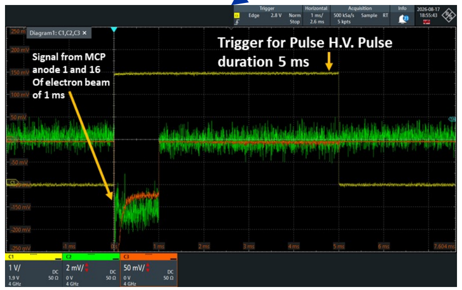
- Measurement in e-mode is expected to be less sensitive to the space-charge force of the p+ beam
- Detector parameters: E-field~100 kV/m, B_y>200 Gs, MCP gain~10^6, ADC@100 MSa/s, 14 bits
- Compared to the ion-mode data, the observed bunch distributions are significantly off-center and diluted
  Space-charge force of irregular p+ shape? a tilted B-field?



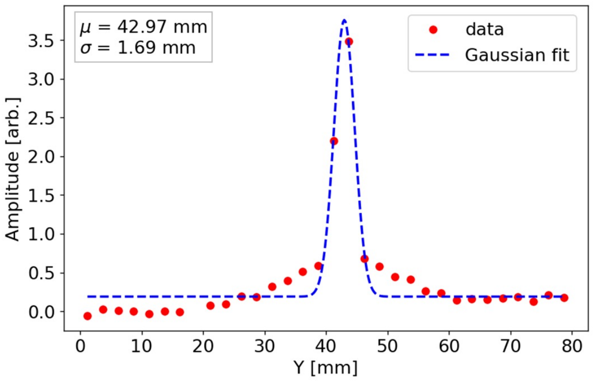
A new gated IPM

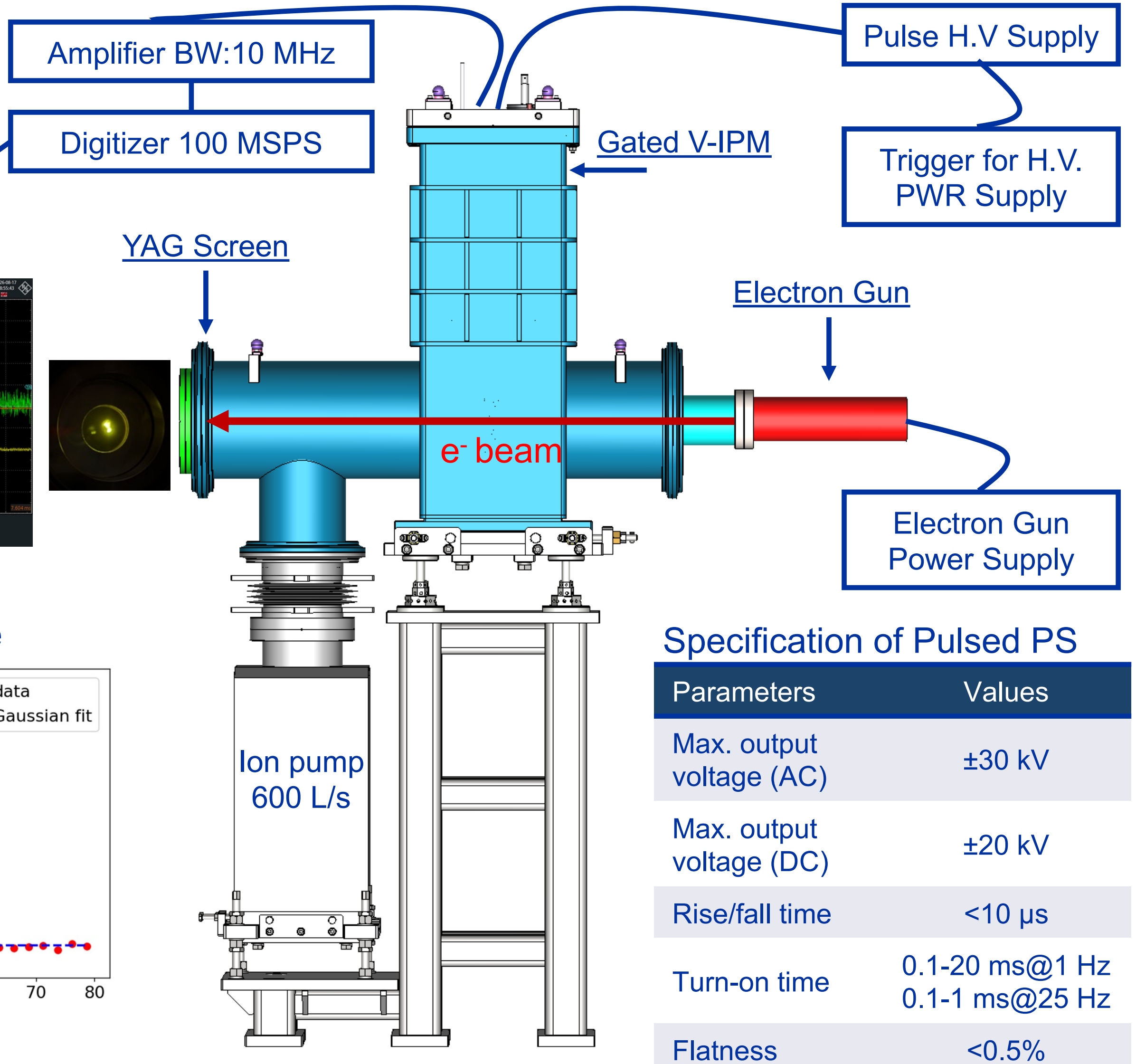
- Customized 30 kV pulsed & DC power supply
- Faraday cage for MCP assembly (SE~-44 dB)
- Test in lab with e-gun and IPM cage biased at 3-15 kV@5 ms width => clear 1d profile of e- beam





e- beam profile





Specification of Pulsed PS

Parameters	Values
Max. output voltage (AC)	±30 kV
Max. output voltage (DC)	±20 kV
Rise/fall time	<10 μs
Turn-on time	0.1-20 ms@1 Hz 0.1-1 ms@25 Hz
Flatness	<0.5%

Acknowledgement: K. Satou, P. Forck

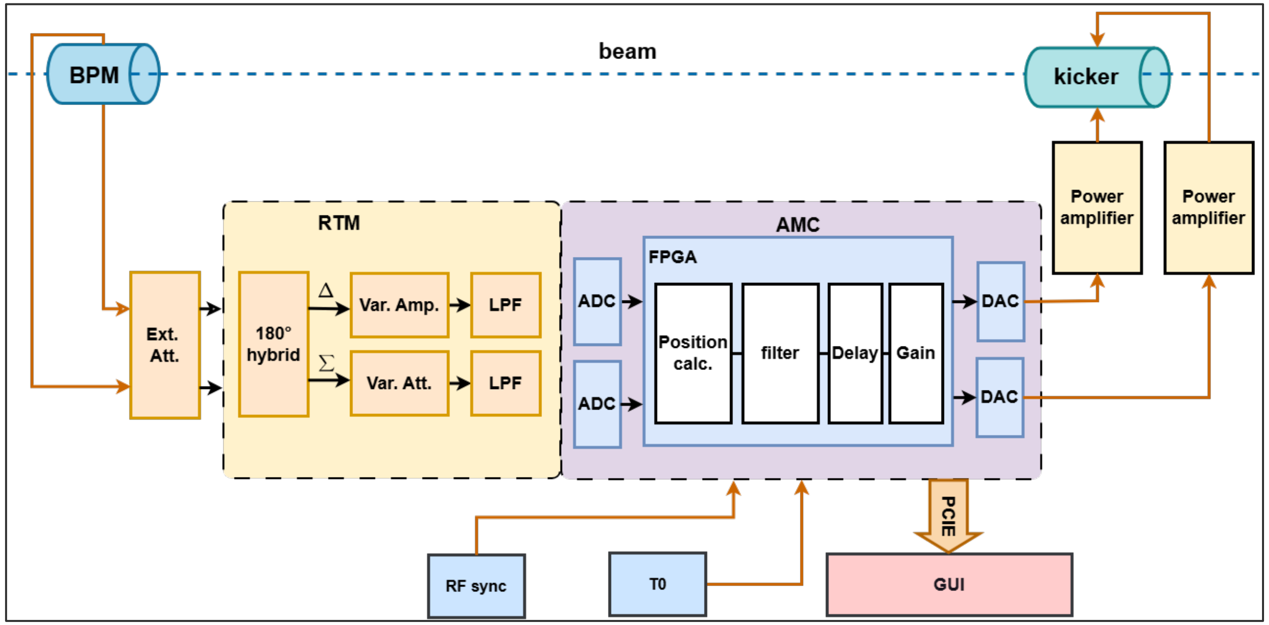
BxB Feedback System

- A BxB feedback system based on μTCA.4 and the existing PU and stripline kicker
- DSP electronics update (wide dynamic range, high PU signal power)
  - Analogue part: attenuator (max. 50 V, >10 W input) – hybrid (0.3-25 MHz) – LPF - amplification (diff.) / attenuation (sum)
    Finalizing the RTM board design after the lab. test of the key analogue modules
  - Digital part (SIS 8300): debugging the integrated FPGA program, DAC function (cos., white noise waveform) demonstrated

Design specifications

Parameter	Value
Work freq.	$2*f_{RF}$
Bandwidth	10 kHz~10 MHz
Damping time	0.5 ms
Amp. Power	2 kW*2
Time delay	5-20 turns
Processor	ADC@125 MSa/s 32-tap FIR
Phase linearity	±10 º
Gain stability	±1 dB
Timing accuracy	<10 ns

BxB feedback architecture



Summary

- Much progress has been made in the development, beam test and production across all tasks
  - Successful instrumentation development for the RCS injection upgrade
  - Beam monitors in the MEBT section are to be commissioned (09/2026 -)
  - Design/prototyping of the BPM electronics, LW, IPM, and BxB feedback are promising
- We acknowledge the internal, domestic and overseas collaborations (SINANO, USTC, PKU, CERN, GSI, KEK, etc.)

Thank you!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