Experimental Evaluation of Longitudinal Momentum Deviation for Low Energy Heavy Ion Beam with Quasi-3D Profile Measurement on the Beam Line

準3次元ビームプロファイルモニターを用いた 低エネルギー重イオンビーム縦方向運動量分布の測定

Xingguang Liu, Takashi Yoshimoto

Department of Energy Sciences, Tokyo Institute of Technology
High Energy Accelerator Research Organization(KEK)

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Particle Accelerator Society of Japan

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Introduction

Particle motion:

$$x = x_b + D\frac{\Delta p}{p}$$

$$x_b = \sqrt{\varepsilon\beta}\cos(\varphi)$$

Betatron motion

Dispersion Effect induced excursion (equilibrium orbit)

Development of Quasi-3D profile monitor

⇩

Longitudinal dependent beam profile

⇩

$D\ is\ relatively\ large$

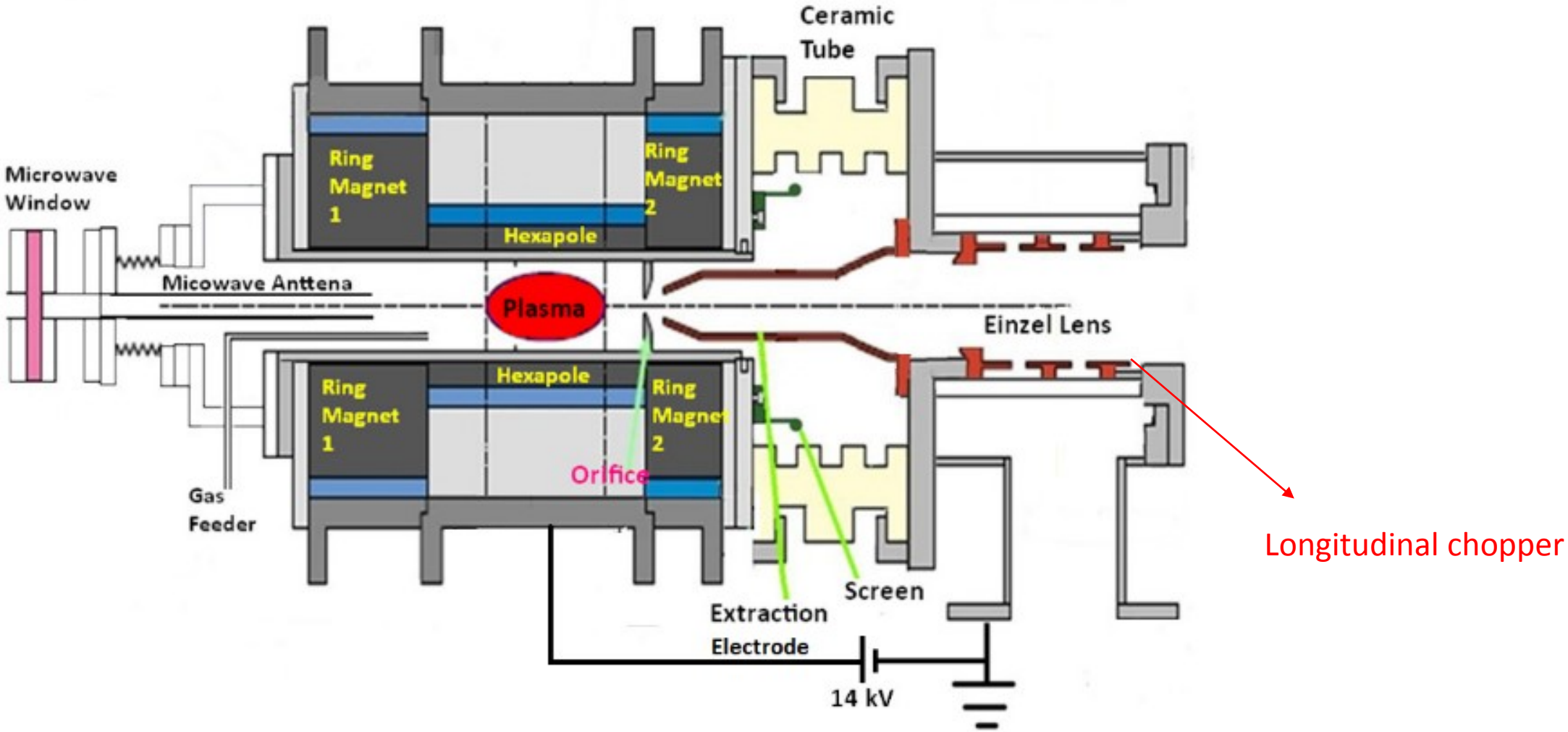
⇩

Excursion of beam center

⇩

Longitudinal momentum deviation

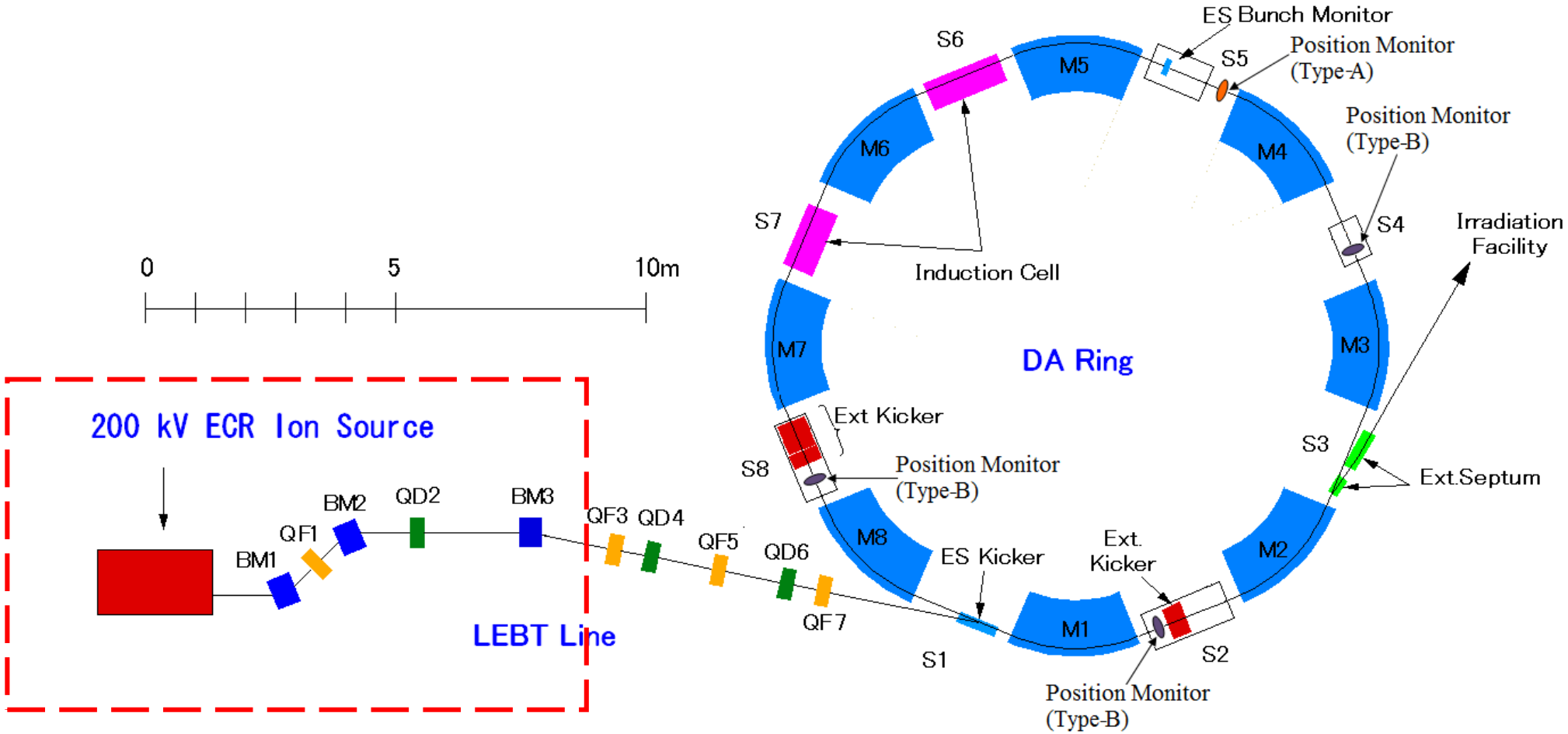
Electron Cyclotron Resonance Ion Source(ECRIS)



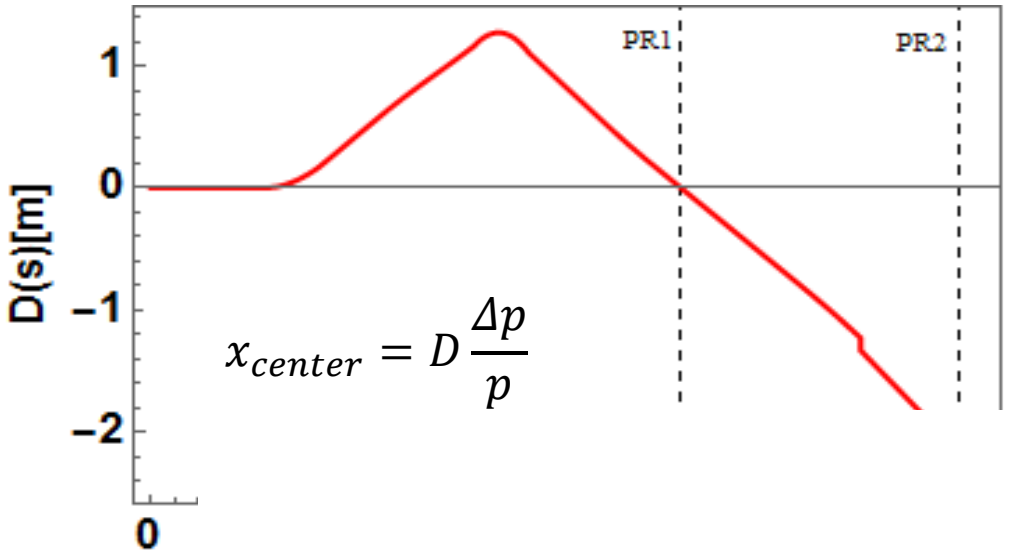
[1] H. Suzuki, K. Okazaki, N. Advanced, T. Co, “ECR Ion Source for the KEK All-Ion Accelerator”, Proc. EPAC08, Genoa, 2008

About KEK Digital Accelerator

[1] K.Takayama, and J.Kishiro, *Nucl. Inst. Meth. Phys. Res. A* 451, 304 (2000).
[2] T. Iwashita et al., *Phys. Rev. ST-AB* **14**, 071301 (2011).



Low Energy Beam Transport(LEBT) Line



PR1: D(s)=0 m,
no beam center's excursion

PR2: D(s)=-2.17 m
beam center's excursion reflected by quasi-3D profile monitor

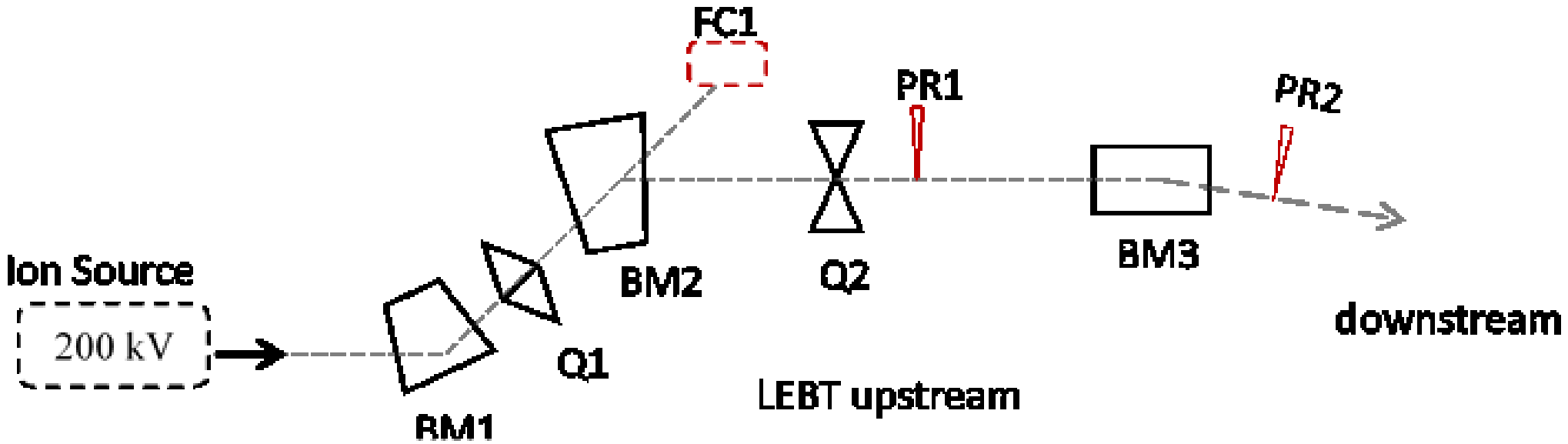
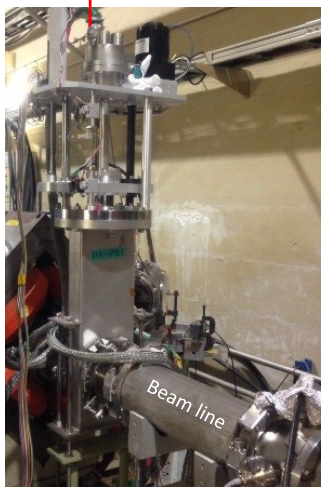
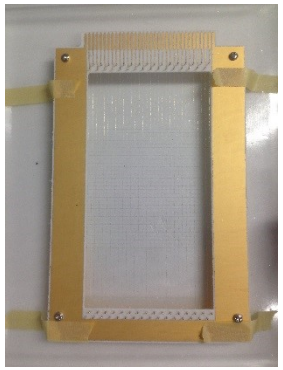
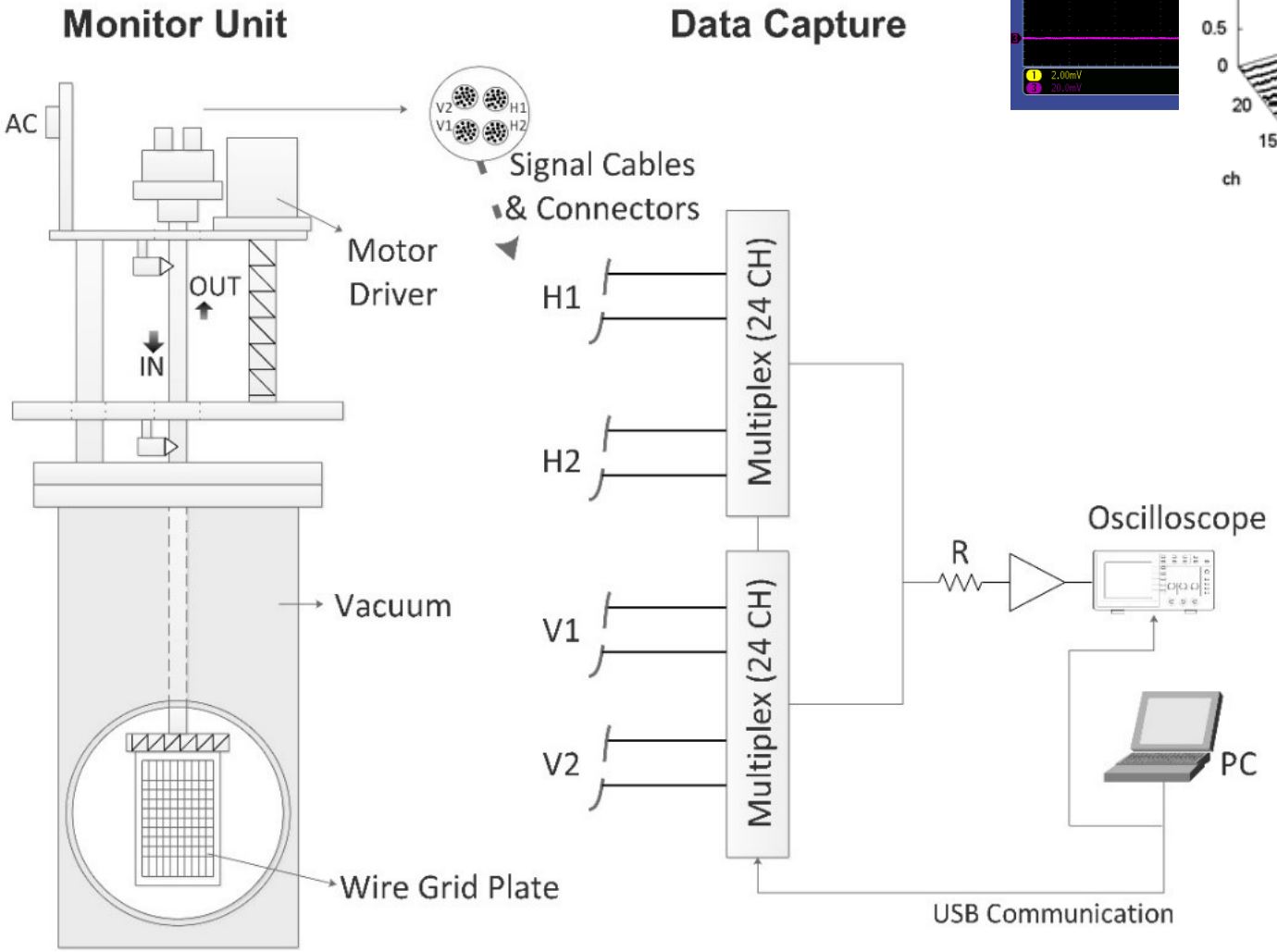


Figure 2: The upstream region of the LEBT line.

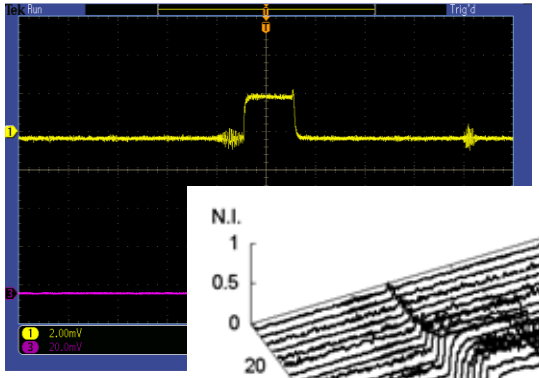
Quasi-3D Profile Monitor



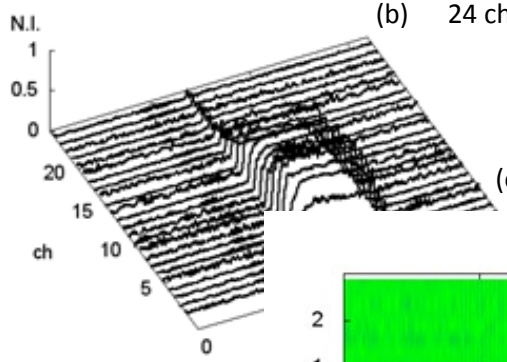




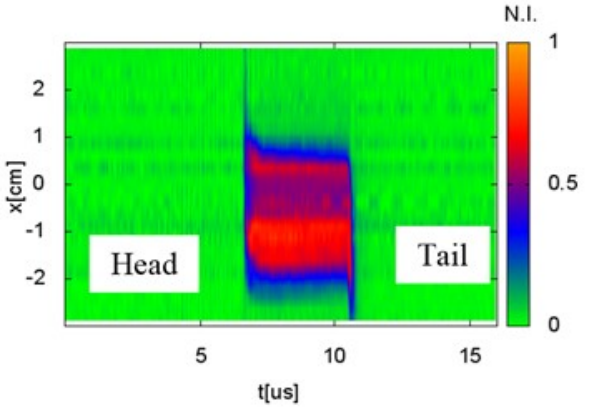
(a) Single wire signal



(b) 24 channel in sequence



(c) x-t profile of short beam



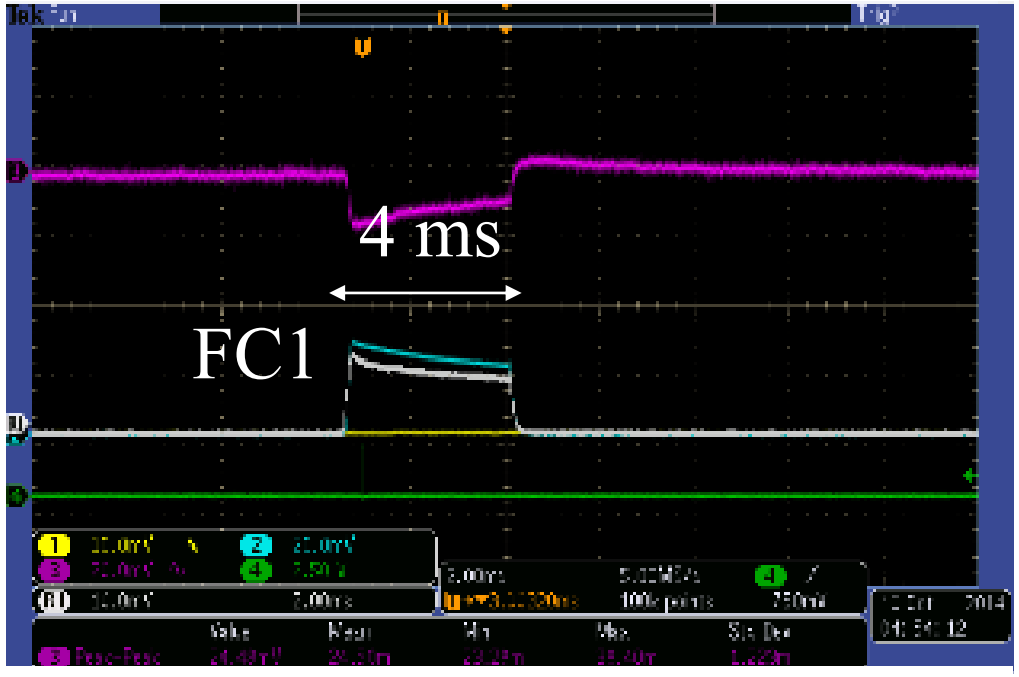
Diameter of wires	30 μm
Wire spacing	2.5 mm
Number of wires	32 wires for X/Y
Measureable range	(-4 to 4 cm) for X/Y
Material	Au-plated W
Frame insulation	Ceramic

Tested Beam

	Long beam	Short beam
Beam length	4ms	4μs
Energy	200 keV	
A/Q	4	
Intensity	~130 μA	
β	0.01	

Long beam (4 ms)

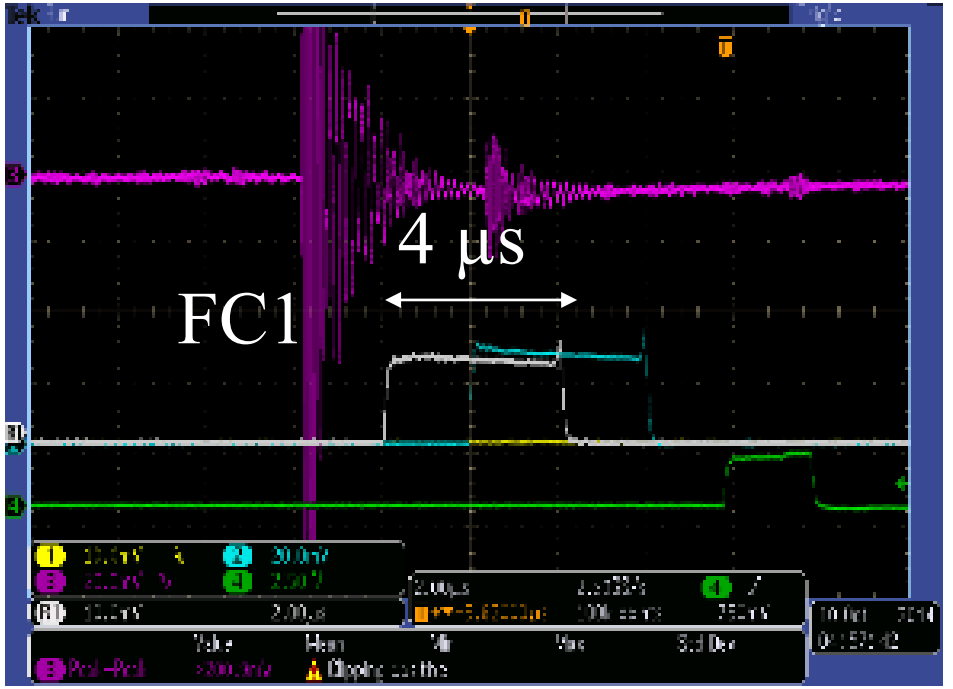
(Microwave in pulse in pulse mode)



(a)long beam, 4 ms

Short beam (4 μs)

(chopped from the 4 ms beam)

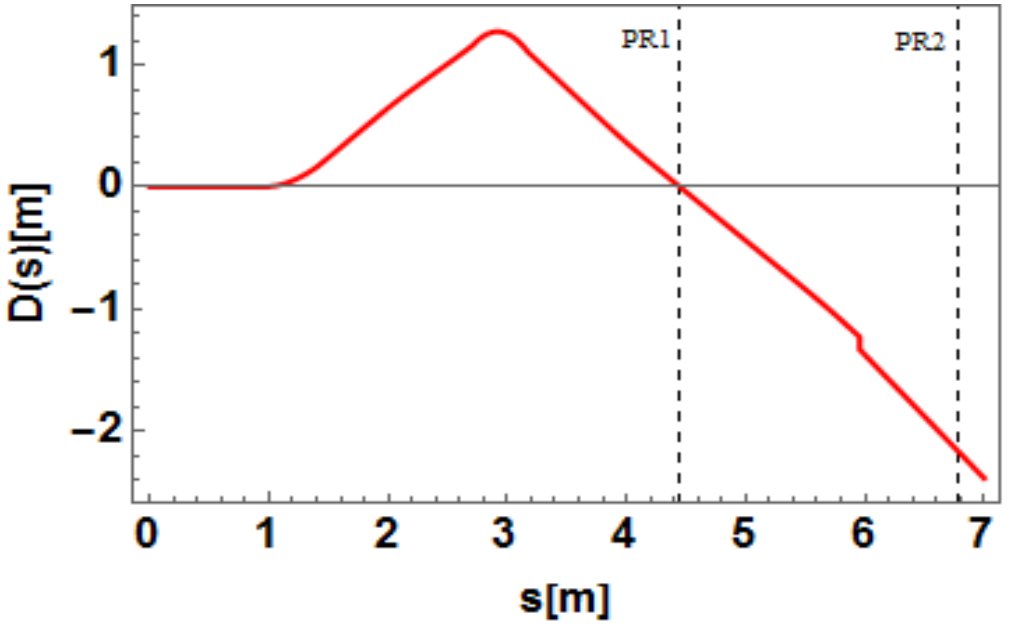


(b) short beam, 4 μs

Beam profile
Long beam

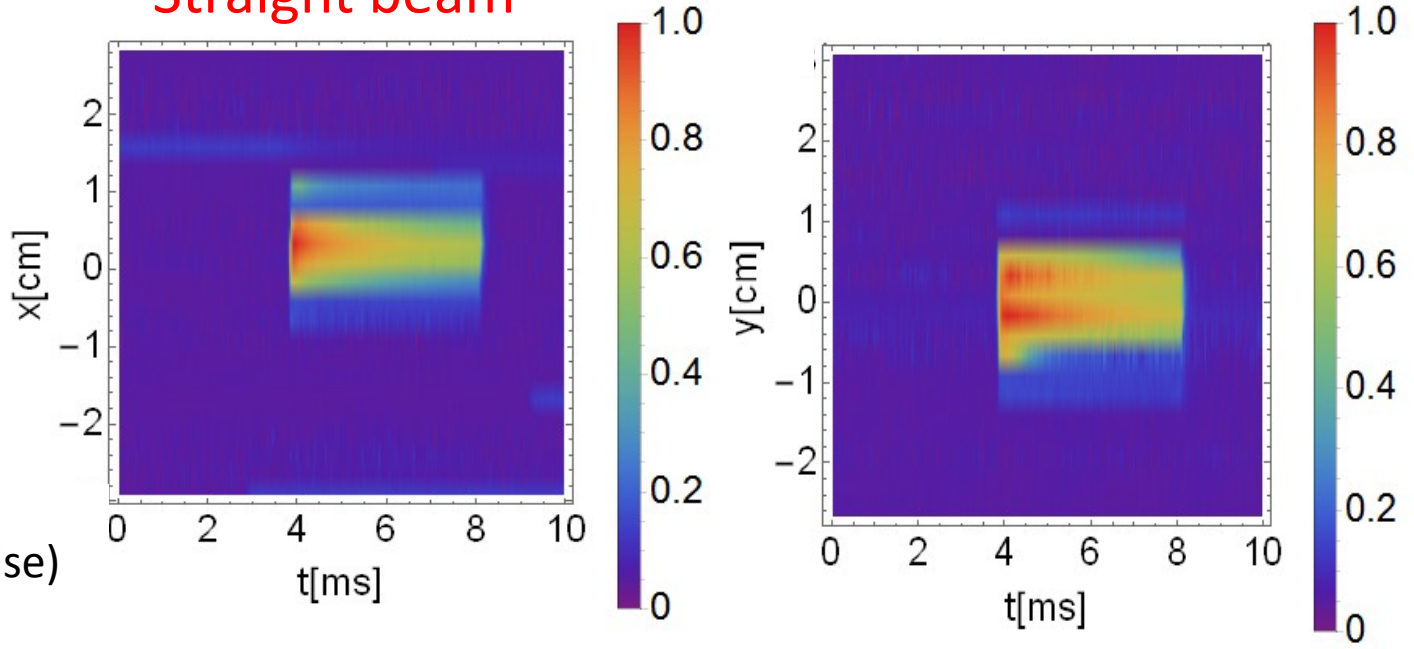
$$x_{center} = D\frac{\Delta p}{p}$$

(a large momentum deviation varies along the beam pulse)



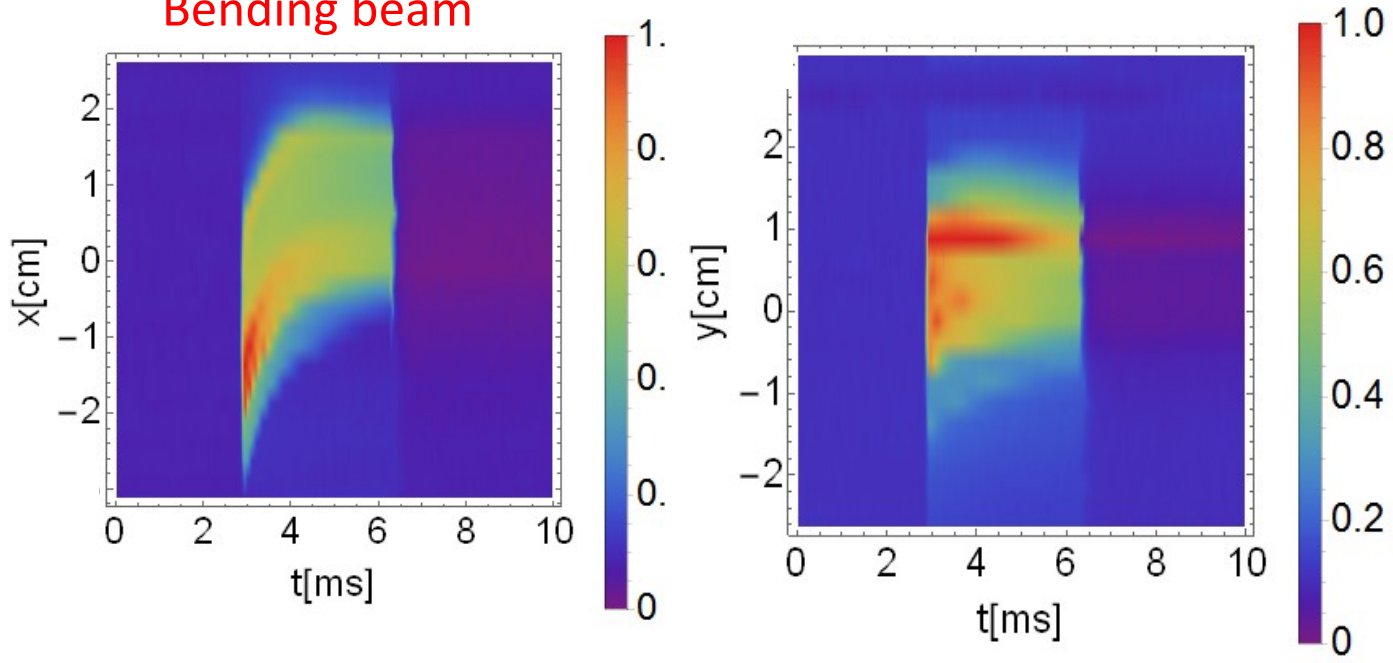
Straight beam

PR1



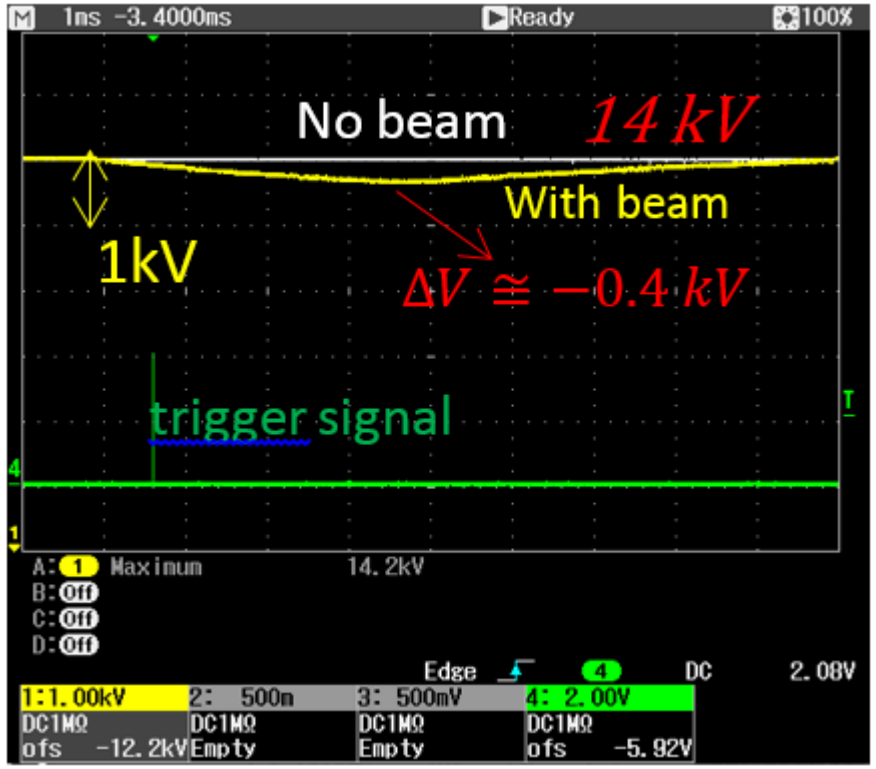
Bending beam

PR2

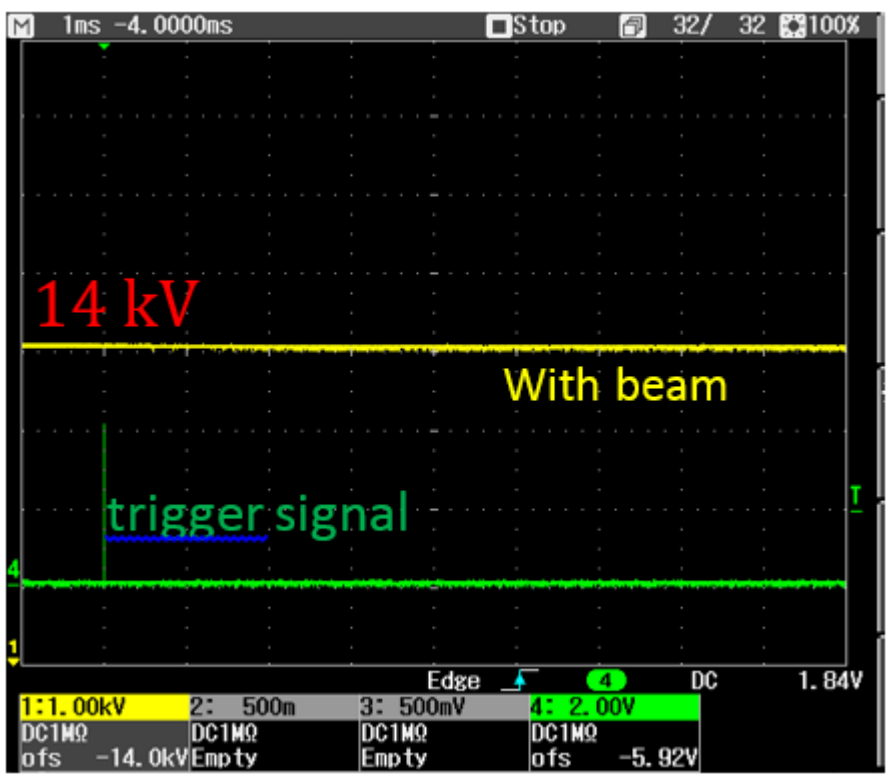


Beam loading effect on the ECRIS extraction voltage

Without stabilizer

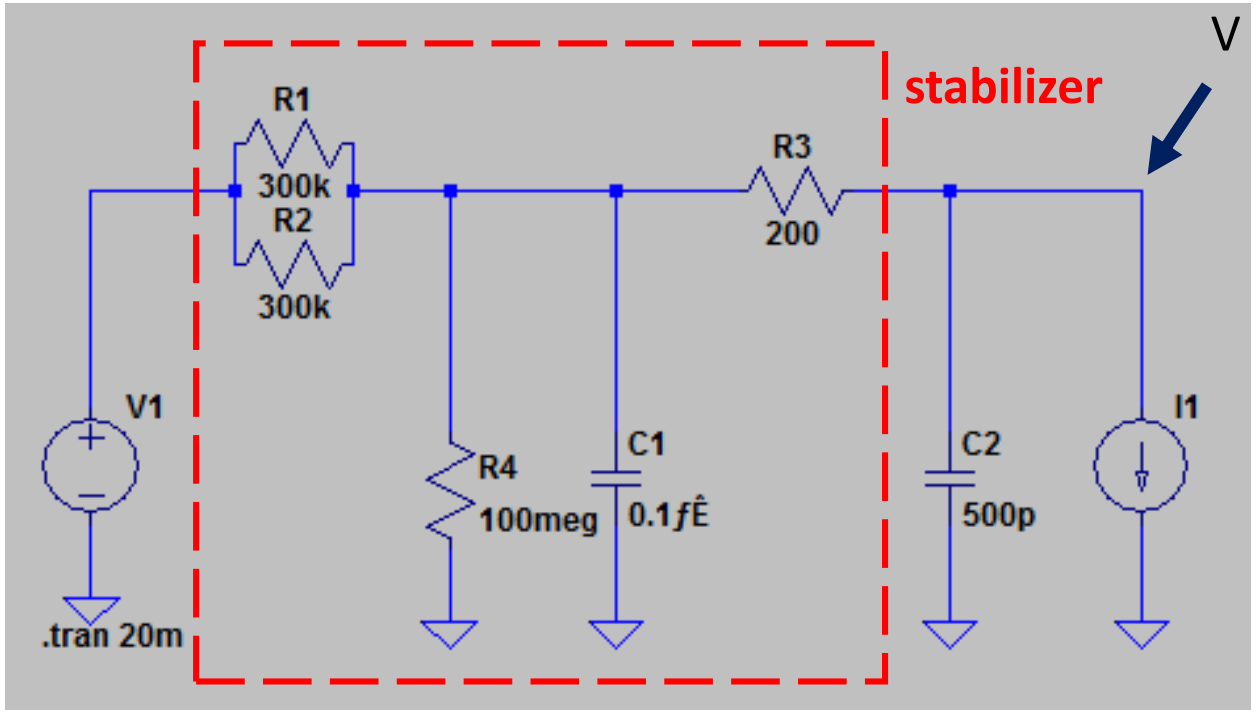


With stabilizer

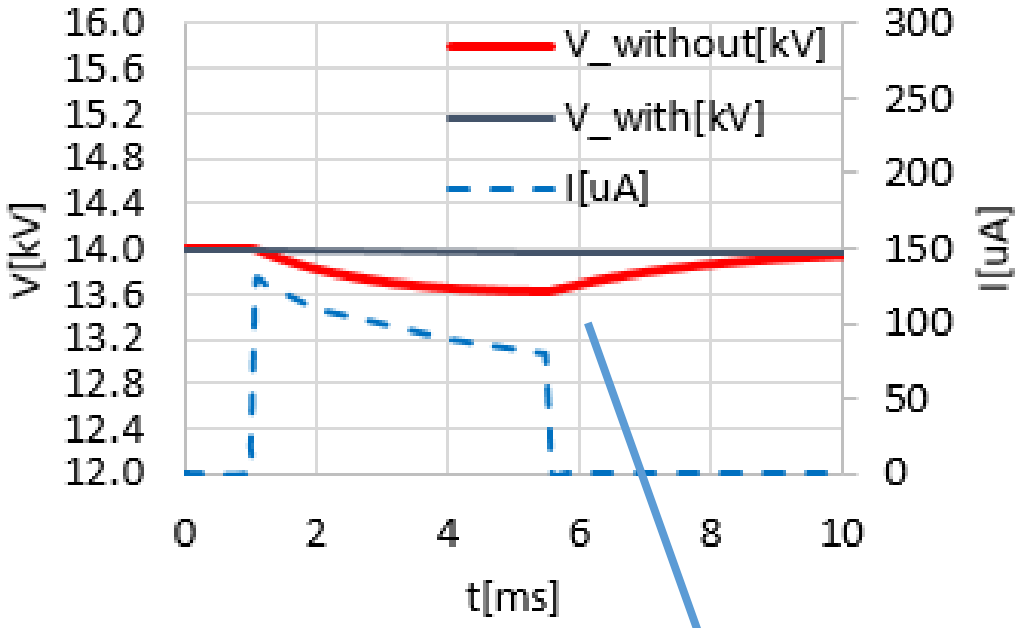


Simulation and Compensation circuit

Equivalent circuit

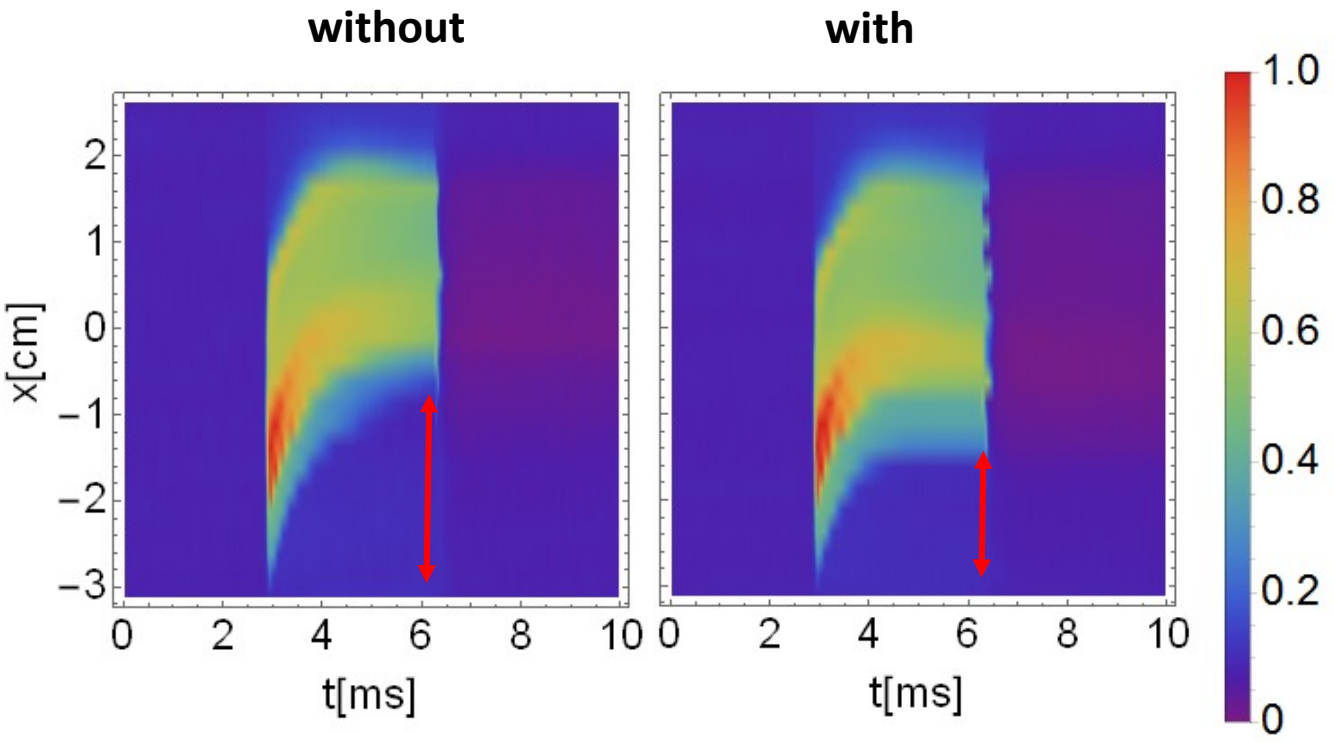


Simulation result

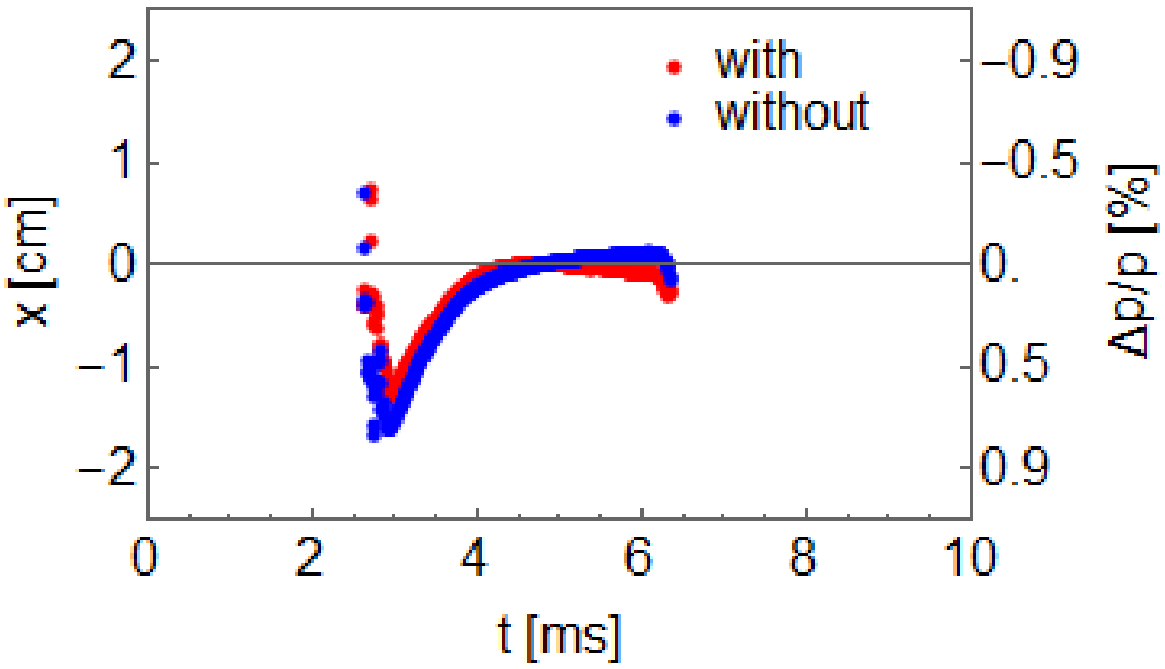


Voltage drop: 0.4 kV

After Compensation: PR2

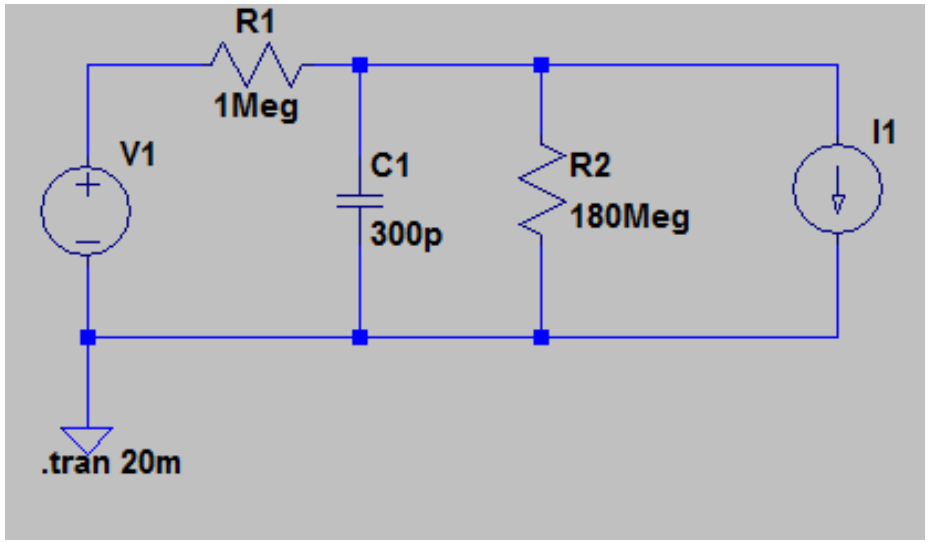


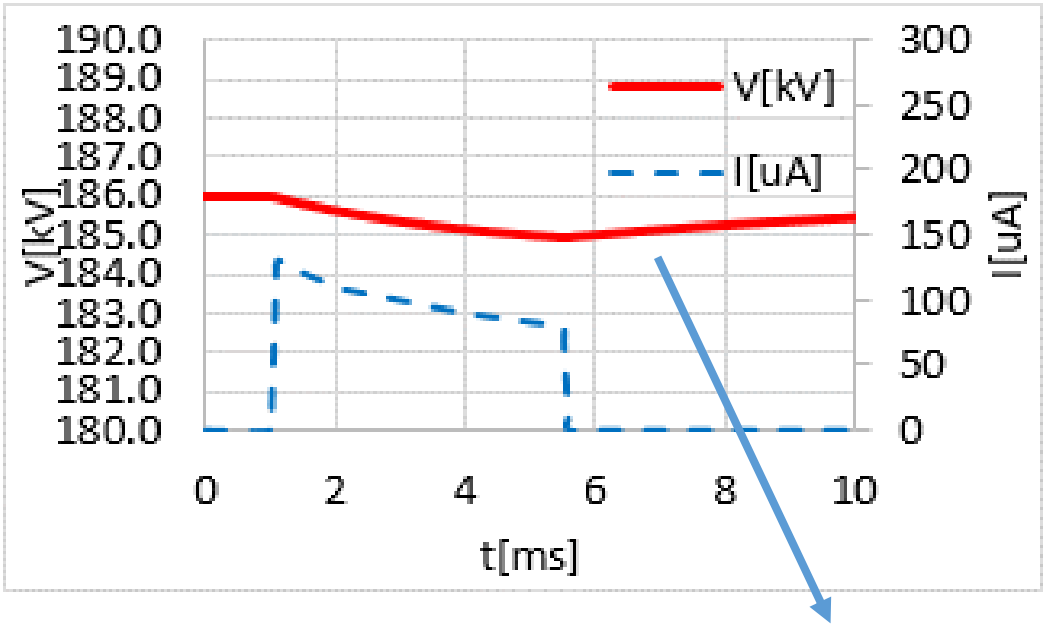
Longitudinal center of the beam and dp/p



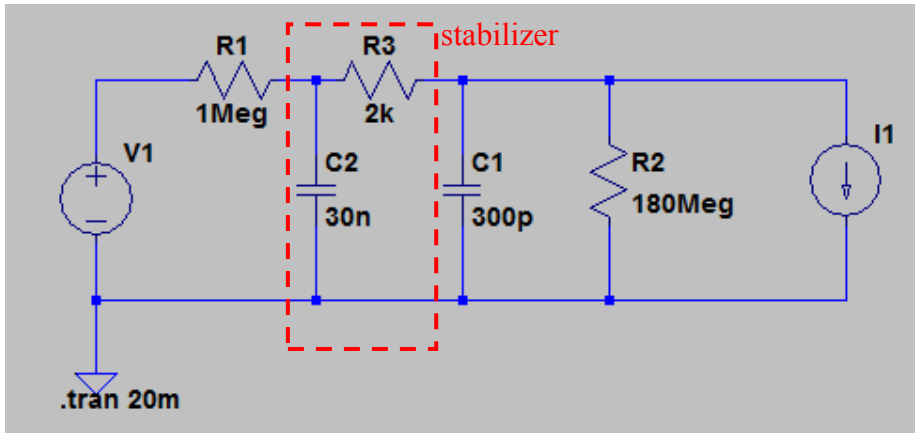
0.4 kV voltage difference

Beam Loading Effect on the Post-acceleration Column HV





Voltage drop: **1.0 kV**



reduce the voltage drop to less than 20 V

Comparison between Theory and Experiment

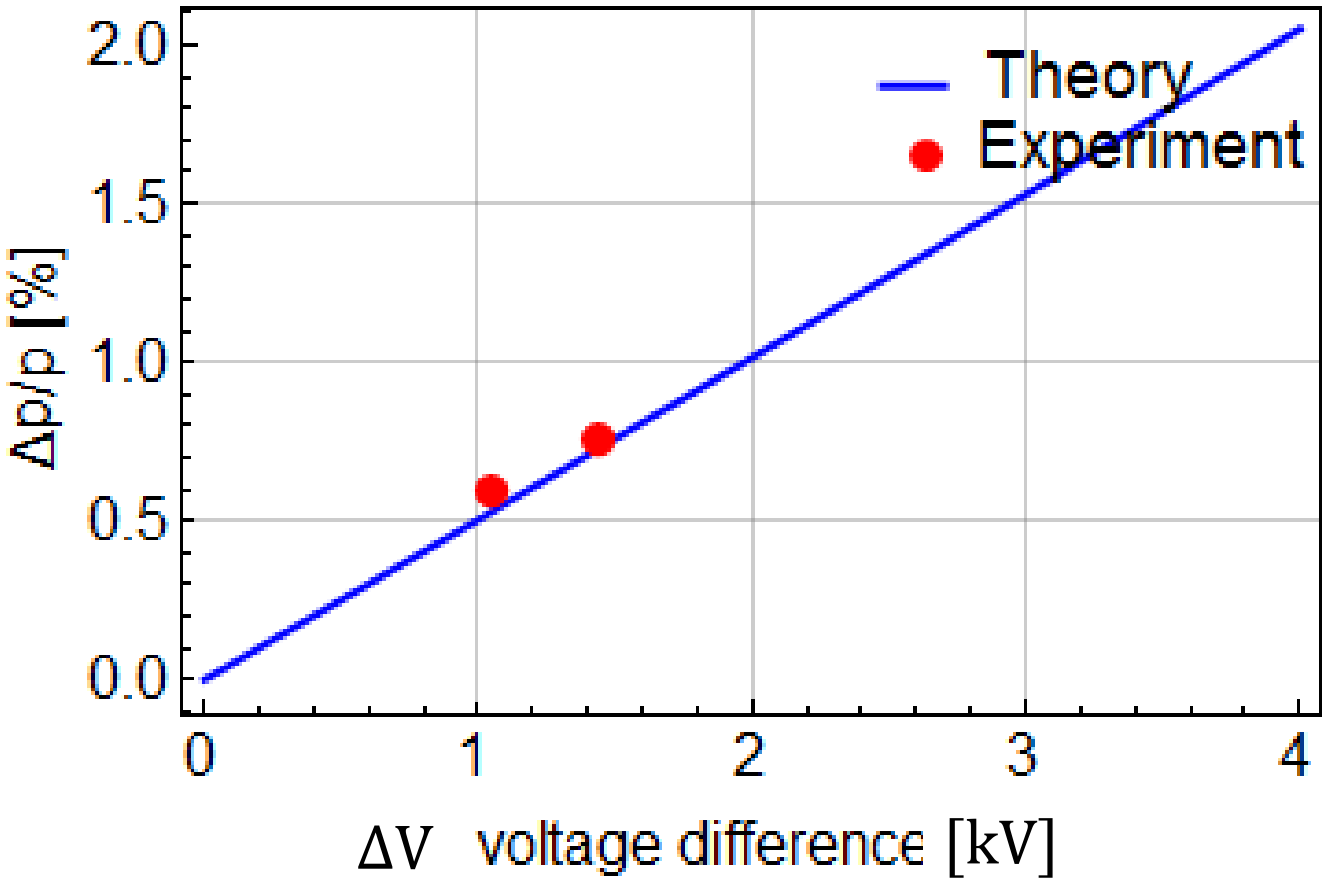
Theory：

$$\frac{\Delta V}{V} \xrightarrow{A,Q,\ m} \frac{\Delta p}{p}$$

Experimental：

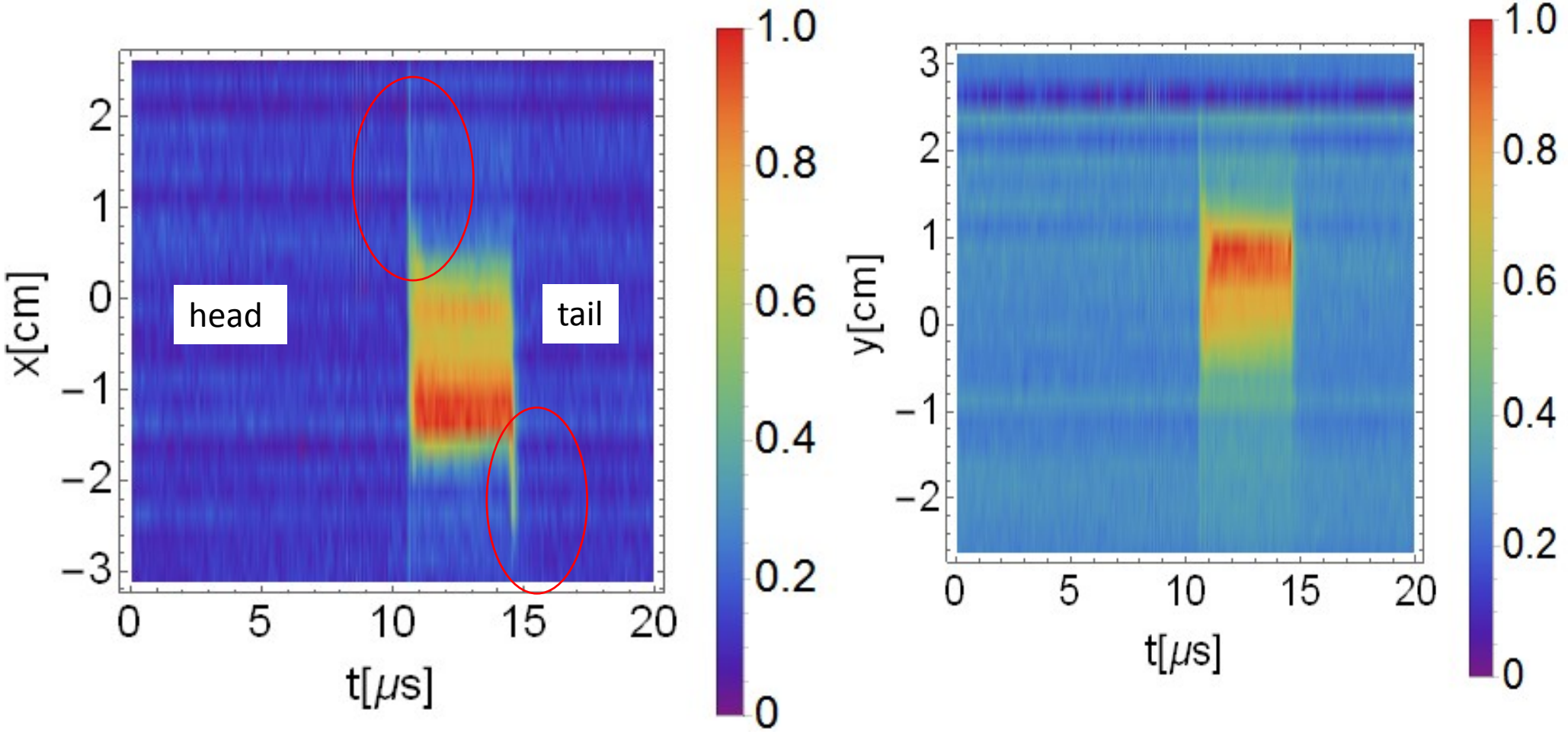
ΔV: Experimental/simulation

$\frac{\Delta p}{p}$: profile monitor evaluation



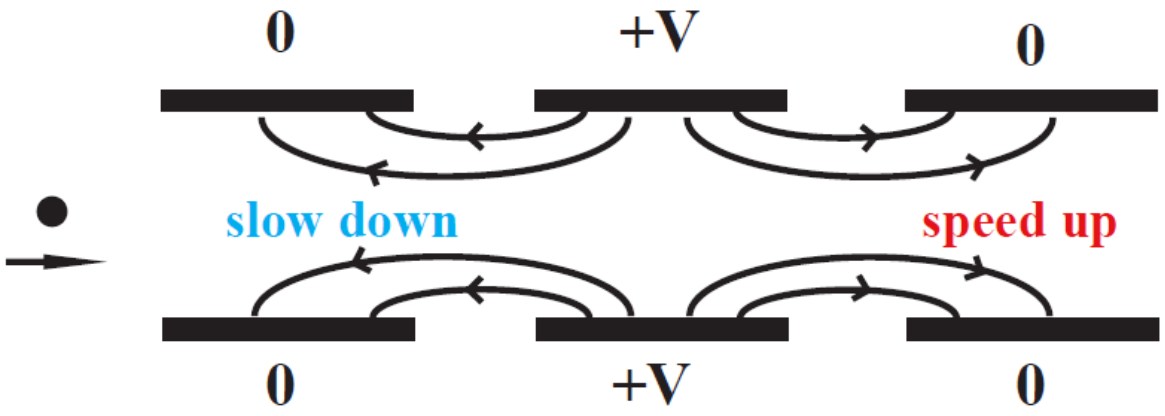
Beam profile (PR2): Short beam

Peaks on the beam head and beam tail

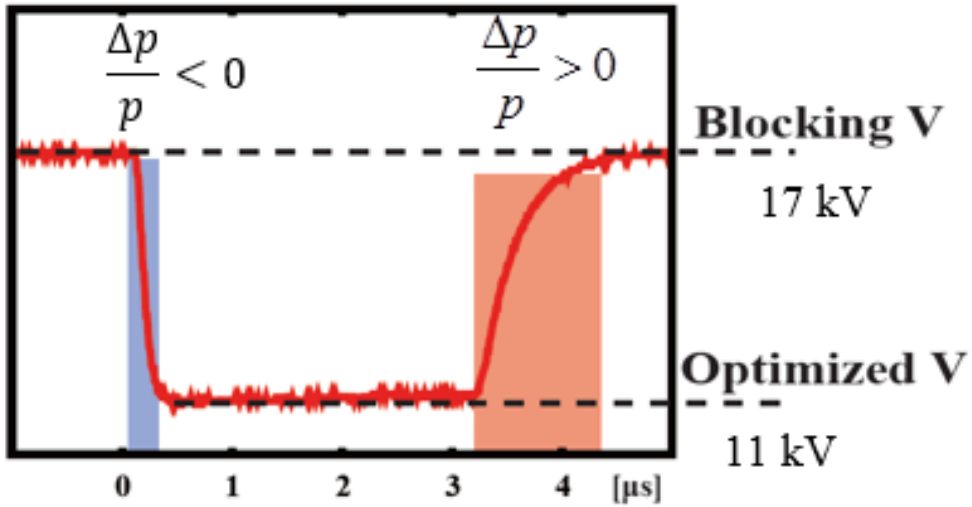


Einzel Lens Chopper: momentum deviaton

Schematic view



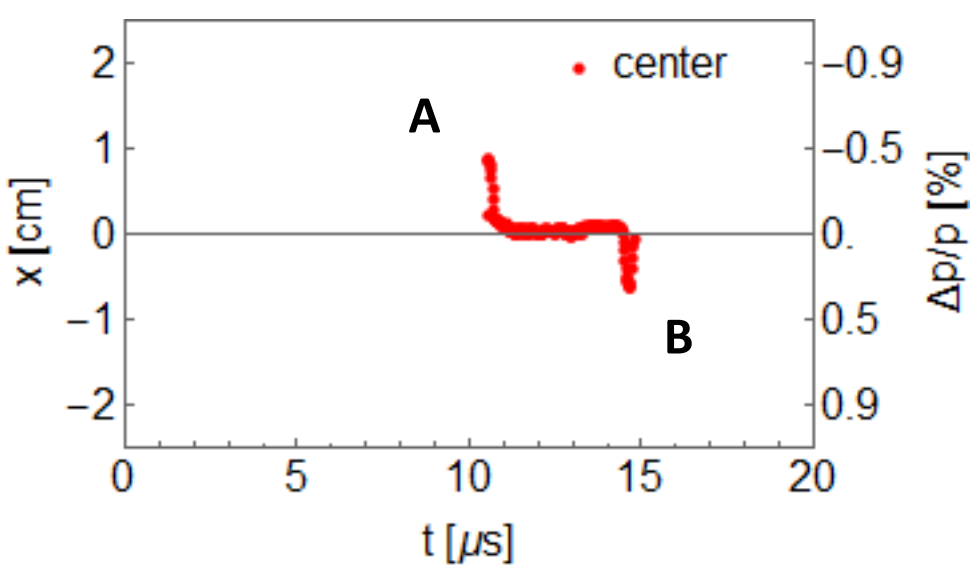
Pulse voltage (longitudinal chopper)
On the middle electrode



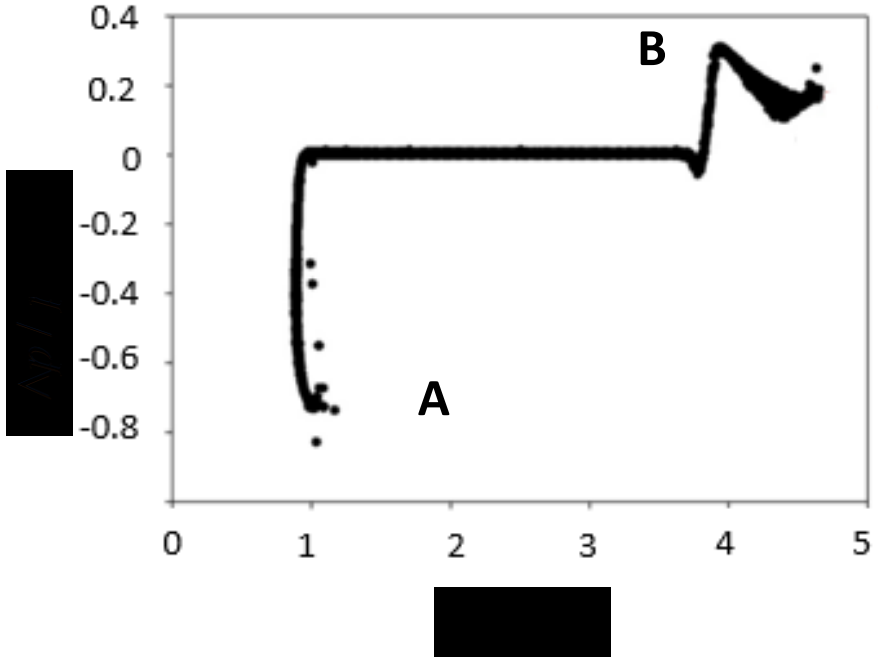
[2] T. Adachi, T. Arai, K. Takayama, L.K. Wah, "Solid-State Marx Generator Driven Einzel Lens Chopper", Rev. Sci. Instrum. 82 (2011) 1233–1235

Compared to the Particle Tracking Simulation

Experiment



Particle tracking simulation*

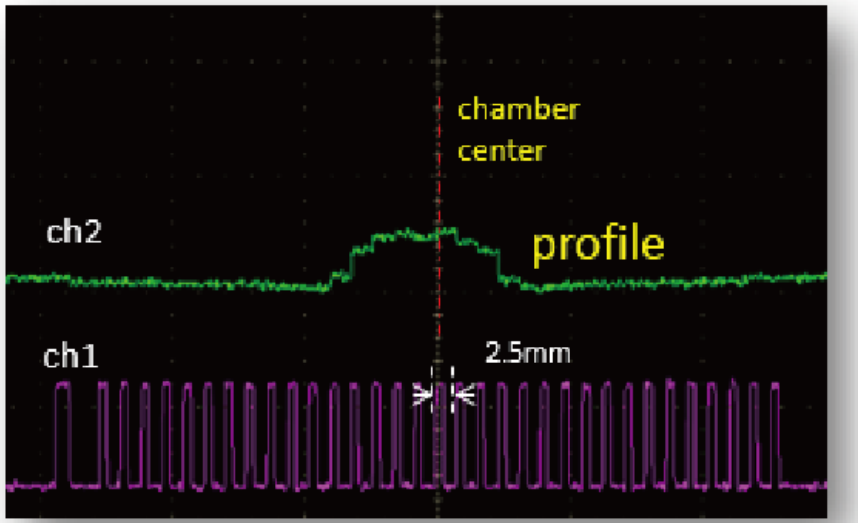


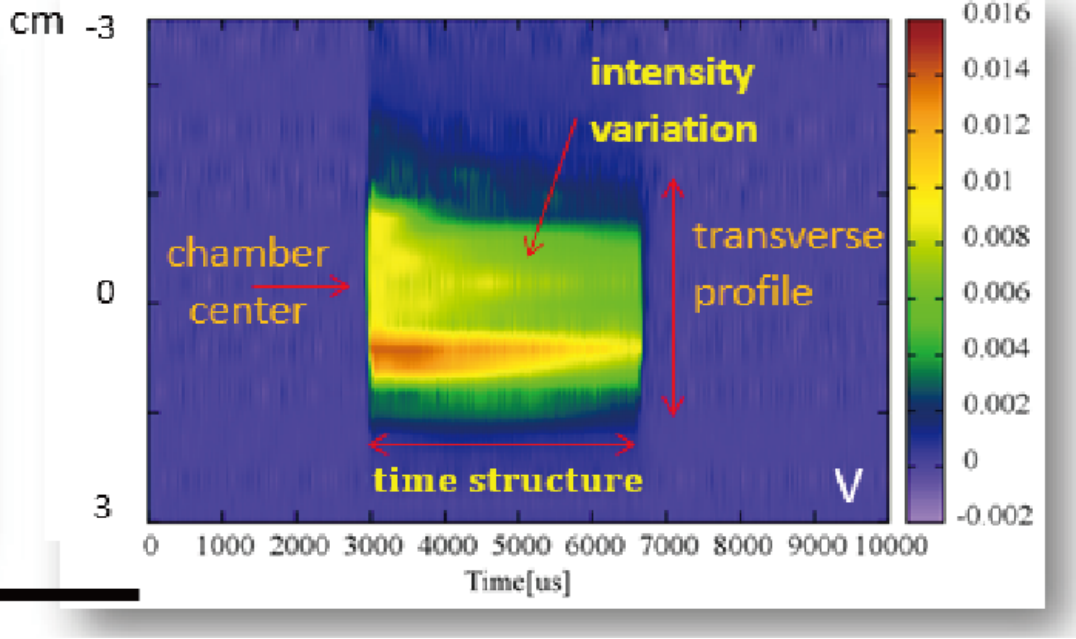
[3] K. Leo, T. Adachi, T. Arai, K. Takayama, “Einzel Lens Chopper and Behavior of The Chopped Beam in the KEK Digital Accelerator”, Phys. Rev. Spec. Top. - Accel. Beams. 16 (2013) 043502

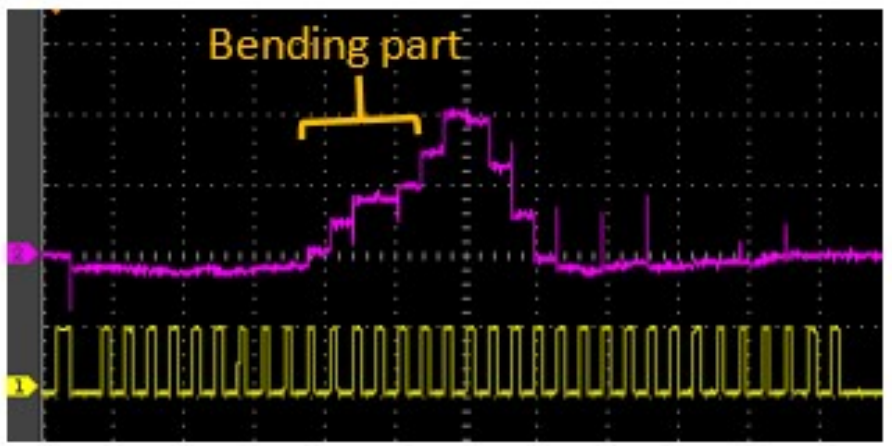
SUMMARY

- Quasi-3D profile monitor has been developed which can provide the information of the transverse beam profile on the LEBT in the longitudinal direction.
- With the profile monitor installed at the location where the dispersion function is relatively large, the longitudinal momentum deviation has been successfully evaluated for ms-long or μs-long beam
- The longitudinal energy modulation induced due to beam loading effects and the transient effect of Einzel Lens Chopper have been clearly identified and the exiting simulation result has been experimentally verified.

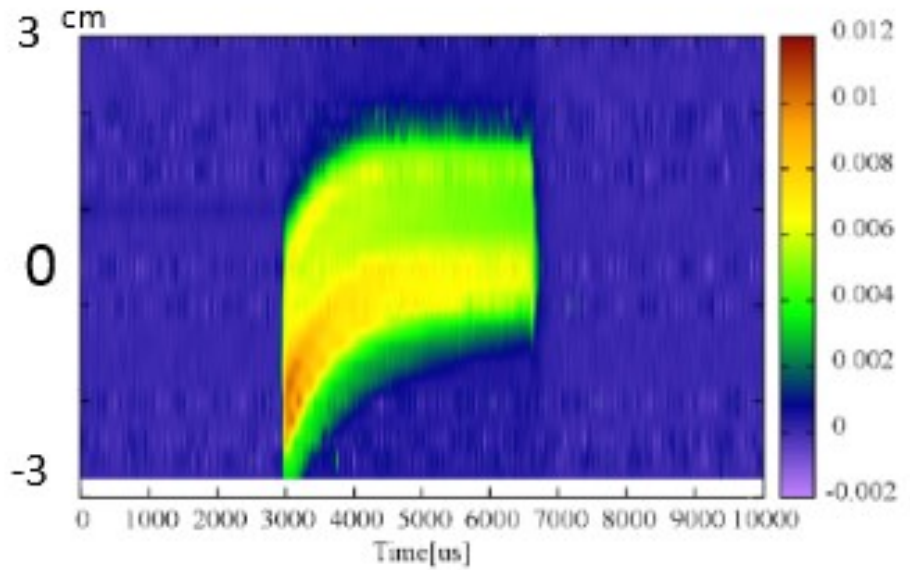
Comparison





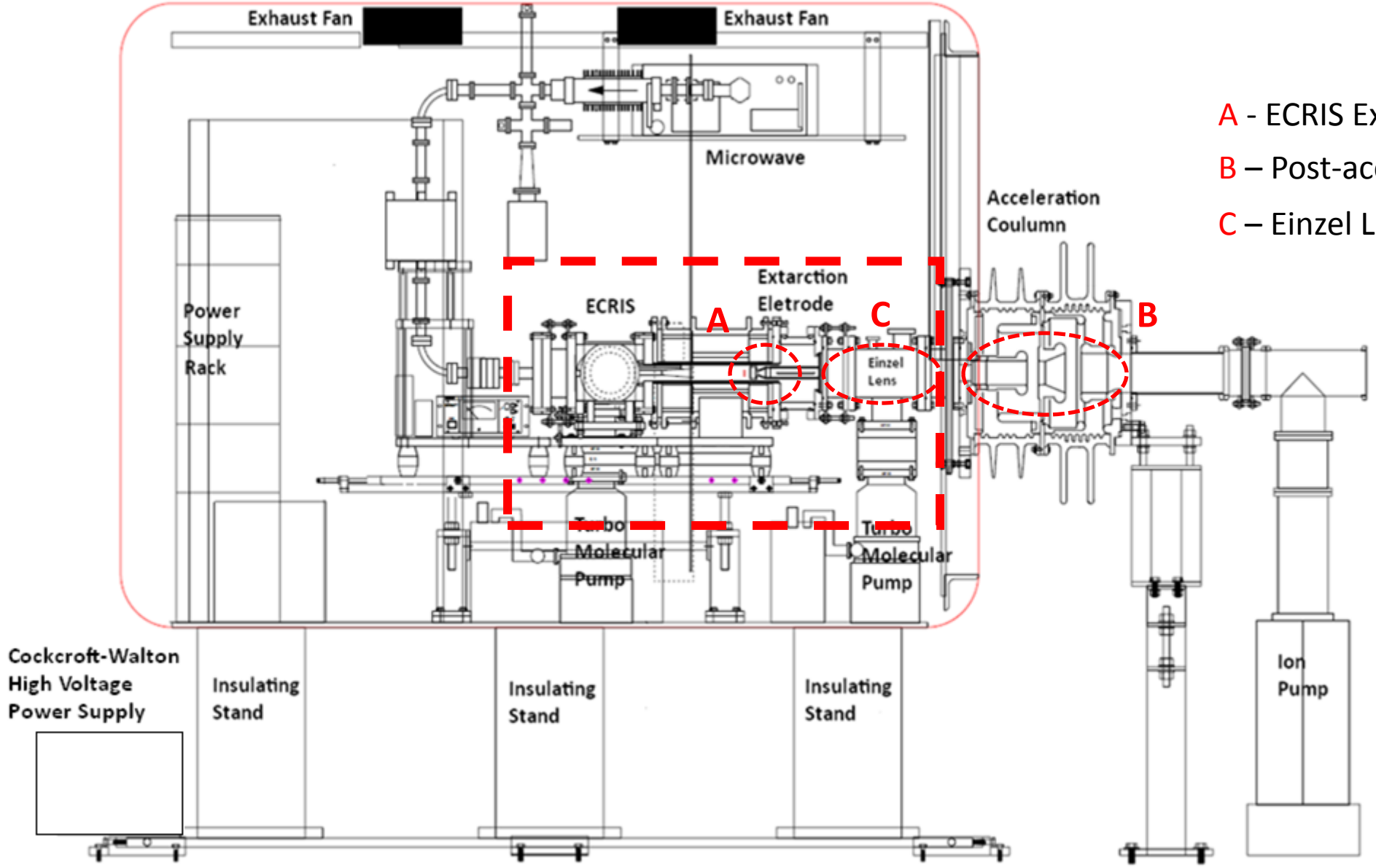


(A) conventional



(B) Quasi-3D

High Voltage Platform



A - ECRIS Extraction Gap

B – Post-acceleration column

C – Einzel Lens Chopper