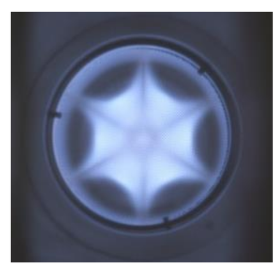
Downsizing Study of SMASHI LEBT for Higher Beam Transmission



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Abstract

Performance of ECRIS SMASHI (Superconducting Multi-application Source of Highly-charged Ions) has been steadily improved since 2015. As one approach of the improvement we investigated the ion beam transport in the LEBT (Low Energy Beam Transport) beamline. In the last commissioning experiment we found that the extracted beam loss is quite high (>50 %) in the LEBT, especially in the inlet of the dipole magnet [1]. Here, we tried to analyze the causes of the beam loss by way of systematic beam profile measurements and beam envelope analyses. With various extractions and beamline condition such as extraction-Einzel lens field, slit size, and the beamline length before the dipole magnet, the changes of the beam profiles have been intensively investigated. Based on the analysis, we also suggest a newly upgraded LEBT layout improved in its size and beam transmission efficiency.

[1] H. J. You, S. O. Jang, and W. I. Choo, Proc. of the 4th Int. Beam Instrumentation Conferrence, 113 (MOPB035), 2015, Melbourne, Australia

Downsizing of the SMASHI LEBT

» Features of SMASHI

(1) 2.1 T (B_{inj}), 1.5 T (B_{ext}), 0.4-0.6 T (B_{min})→"Liquid He-free" SC magnet & its flexible tuning, (2) 1.3 T of high radial field (permanent magnet hexapole), (3) 18 GHz & Two frequency heating (18, 18±Δ GHz) Max. TWT power=1250 W, (4) High power-capable S.S. or Al plasma chamber (Ø82×410 mm=2.2 liter), (5) Extraction voltage(V_{ext})=10-30 kV, Max. Einzel lens voltage=-(10-30) kV

» LEBT

The present LEBT is composed of 5 sections: Einzel lens, beam diagnostics 1(BD-1), double focusing dipole magnet (DM), beam diagnostics 2, and 3 (BD-2, -3). In the LEBT, extracted ion beams are diagnosed by a Faraday cup (FC) and/or BPM1:WS then specific mass and charge state of beam is selected by the DM. After the DM, the species-analyzed beam can be profile-monitored by a BPM2:slit-FC system and a BPM3:BPG in BD-2 and BD-3, respectively. The Einzel lens 1, located just after the extraction system, helps to focus the diverged beam, so that it could go parallel or slightly diverge to the DM and then be focused at slit 2(SL2). In BD-1, a high power FC are installed for measuring the total ion beam current from the source. The DM is a 90◦ double focusing analysing magnet of which bending radius, pole gap, magnetic rigidity, and mass resolution are 400 mm, 60 mm, 0.36 Tm, and 150, respectively. The inlet and the outlet dimensions of the DM vacuum chamber are both 135 wide and 52 mm high. BD-2 just after the DM also consists of a beam slits (horizontal and vertical) and a FC. A horizontal(x) and a vertical(y) slit can operate to limit the beam divergence and envelope, and they also play a role of analyzing slits in the slit-FC system for beam profile measurement. Thereafter, Einzel lens 2 is installed between BD-2 and BD-3 to re-focus the beam. Steering magnets (ST 1 and ST 2) can be used before and after the DM in case beam paths need to be adjusted. In the end of the present LEBT a pepper pot emittance meter are installed.

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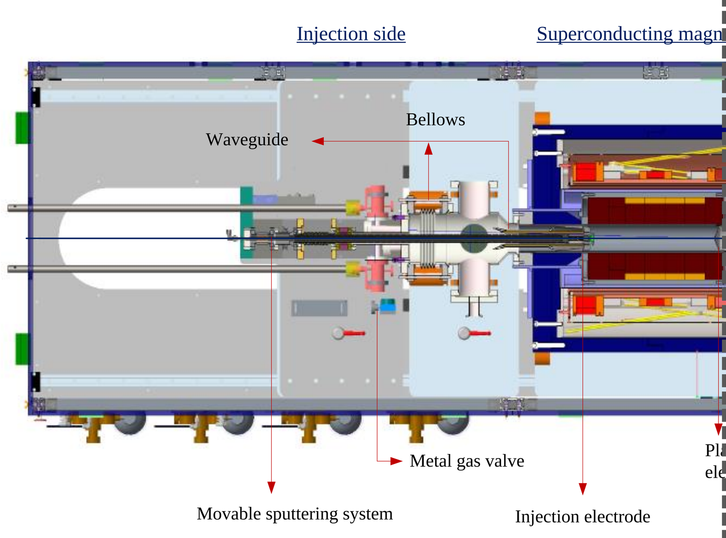
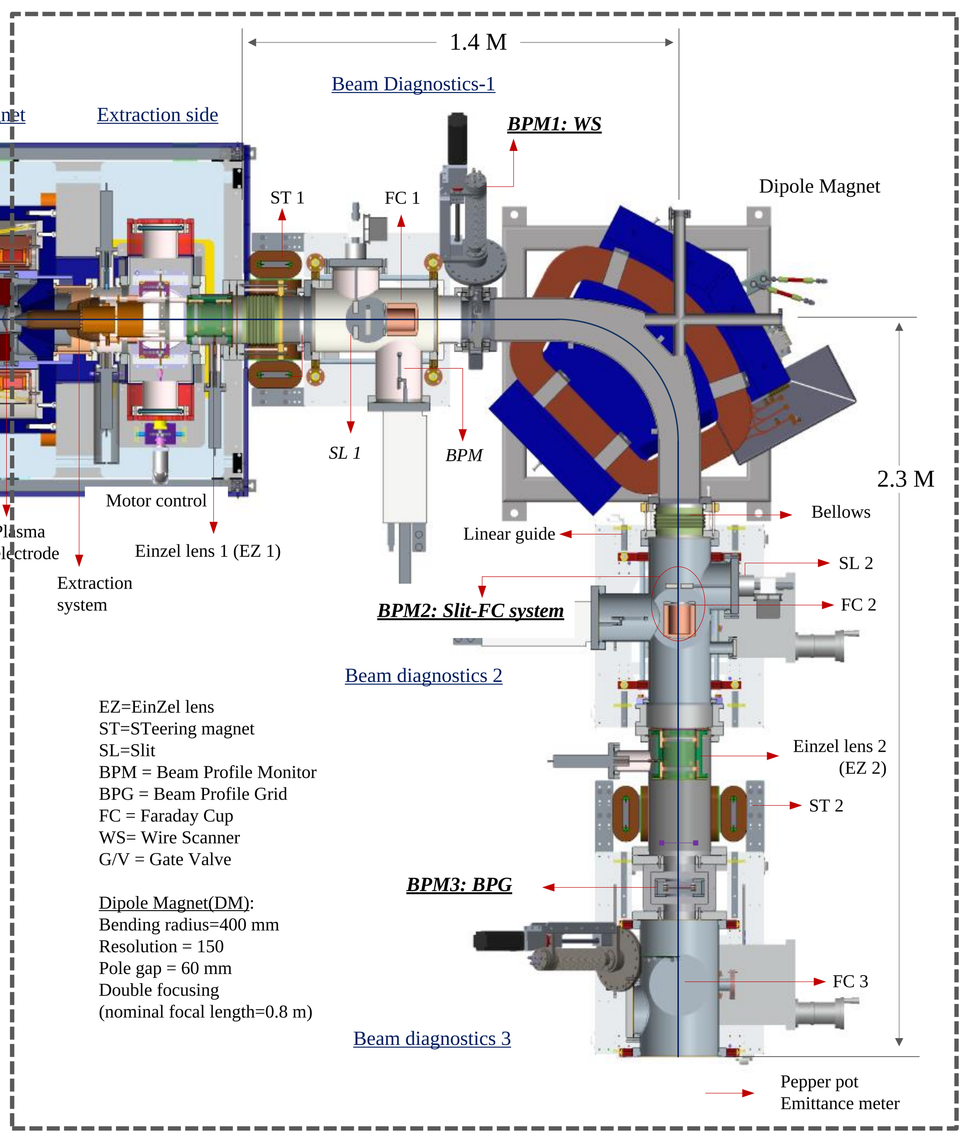




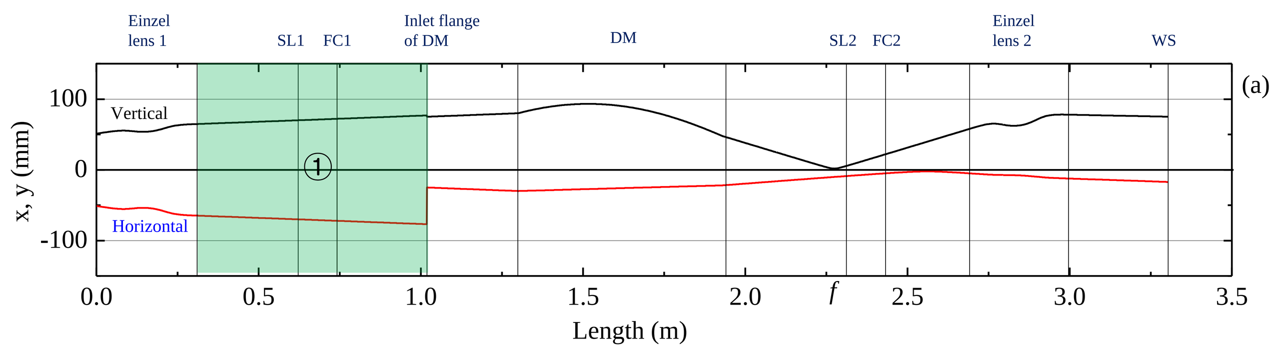
» Source Operation Conditions

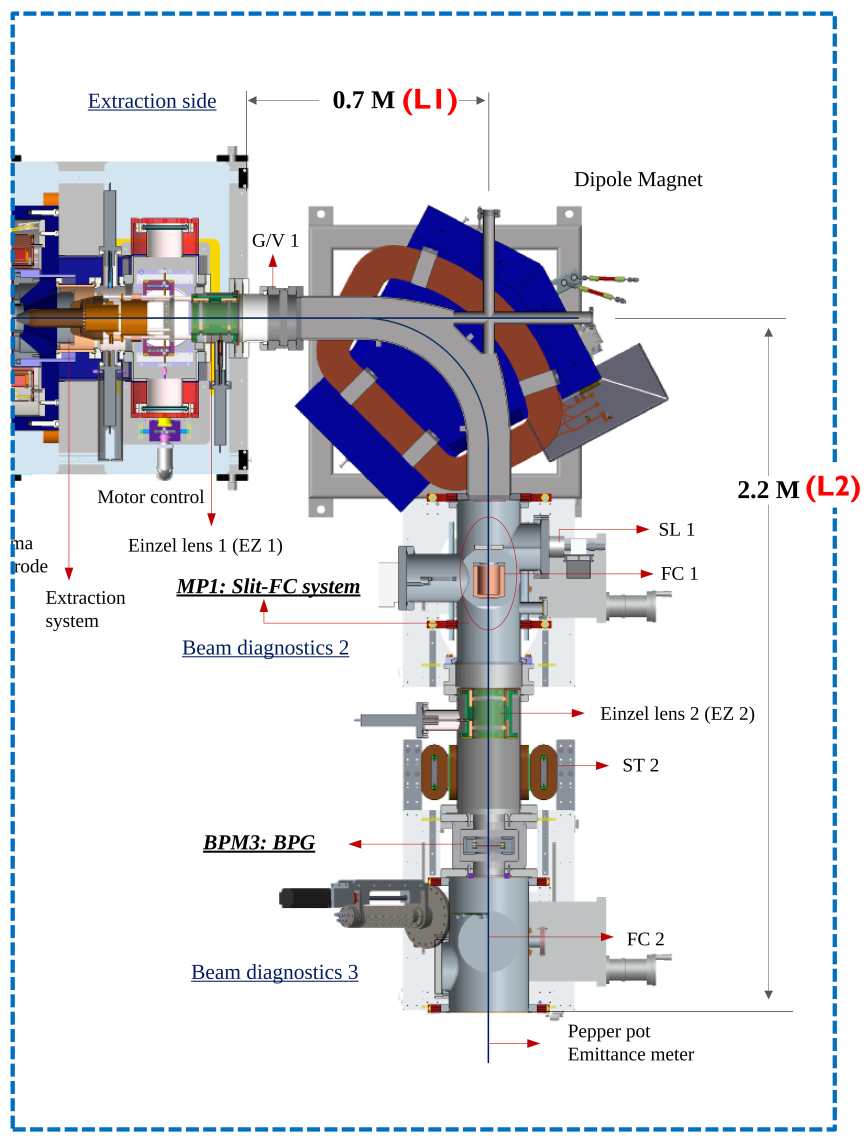
- TWT Power = 320 W
- *Argon gas* (inj/extr)=1.3 x 10^{-7}/1.3 x 10^{-7} Torr
- B_{inj}=1.7 T (80 %), B_{ext}=1.3 T, B_{min}=0.5 T
- Extraction voltage = 15 kV, Ø8 mm aperture
- Biased disk voltage = -480 V
- EZ1(Einzel lens 1) voltage = -5~-25 kV
- SL1 (slit 1) opening=5-35 mm

Higher beam transmission

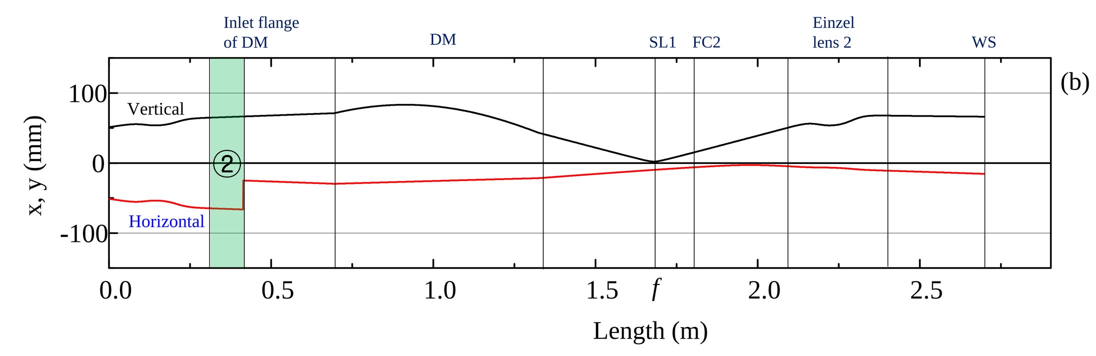
with

- Decreased diverging space(L1)
- *Higher focusing before DM with EZ1*
- Optimized focusing with L2 at BPM2 (SL1 at right)





<The present LEBT analyzed>

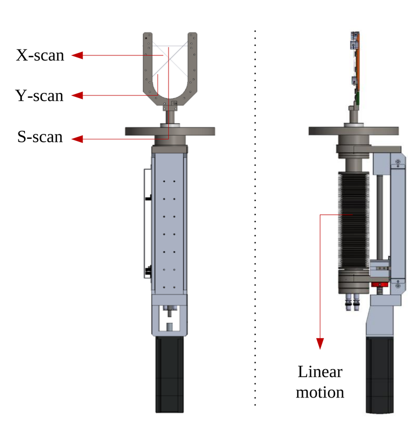


<Newly upgraded LEBT>

Validation of the Above LEBT Downsizing and/or Optimization by Beam Profile Measurements

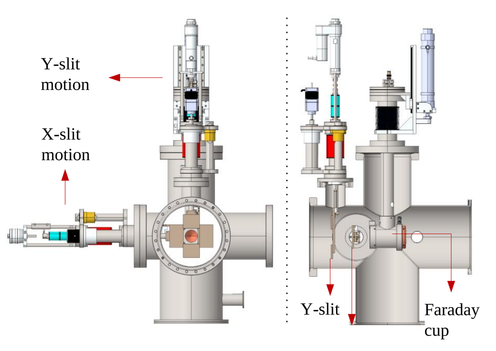
» Beam Instrumentation for Beam Profile Measurement

BPM1: Wire Scanner



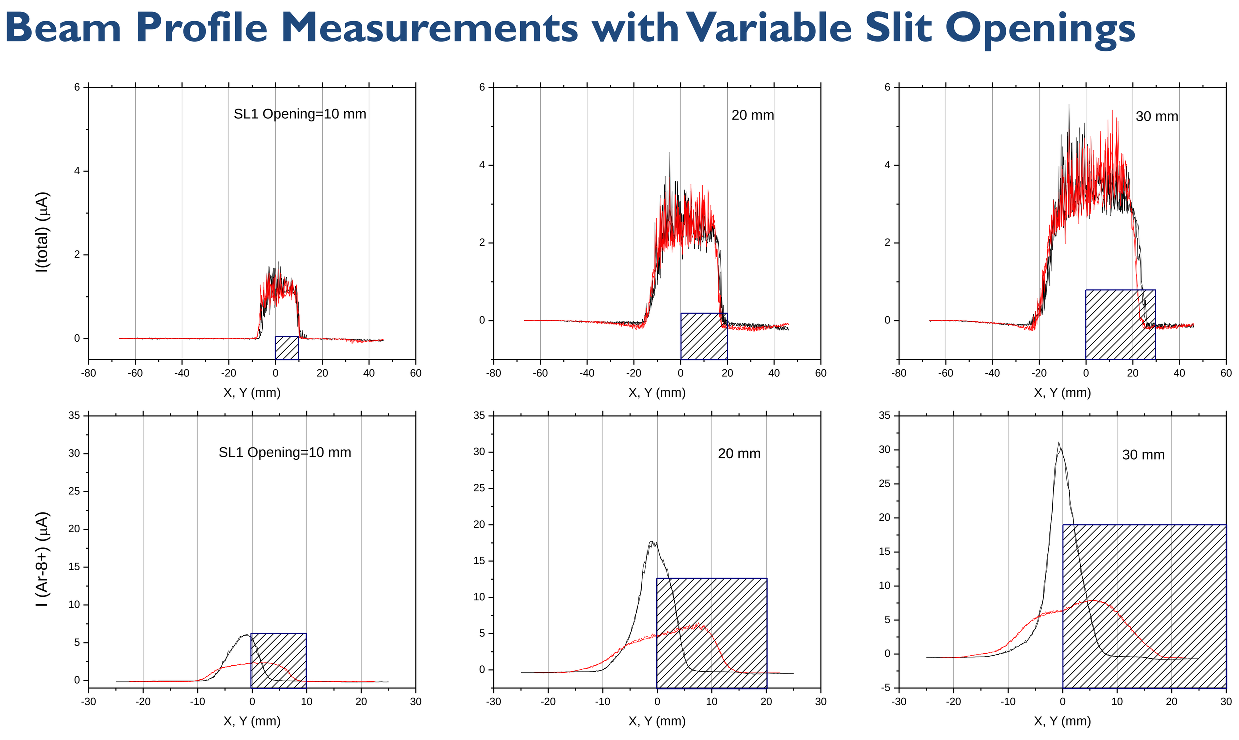
The BPM 1: Wire scanner (WS) is installed at the beamline close to the inlet flange of dipole magnet by an angle of 45 degree., so that the beam profile there can be monitored. The WS is composed of three wires mounted in horizontal(x), vertical(y), and diagonal(s) directions, so that three directions of profiles can be simultaneously measured by one passage. The scanning length of the WS was designed to be 165 mm; The measurement ranges of x, y, and s direction become 50(-25 to 25 mm), 50(-25 to 25 mm), 95 mm(-42.5 to 42.5 mm), respectively.

BPM2: Slit-FC System



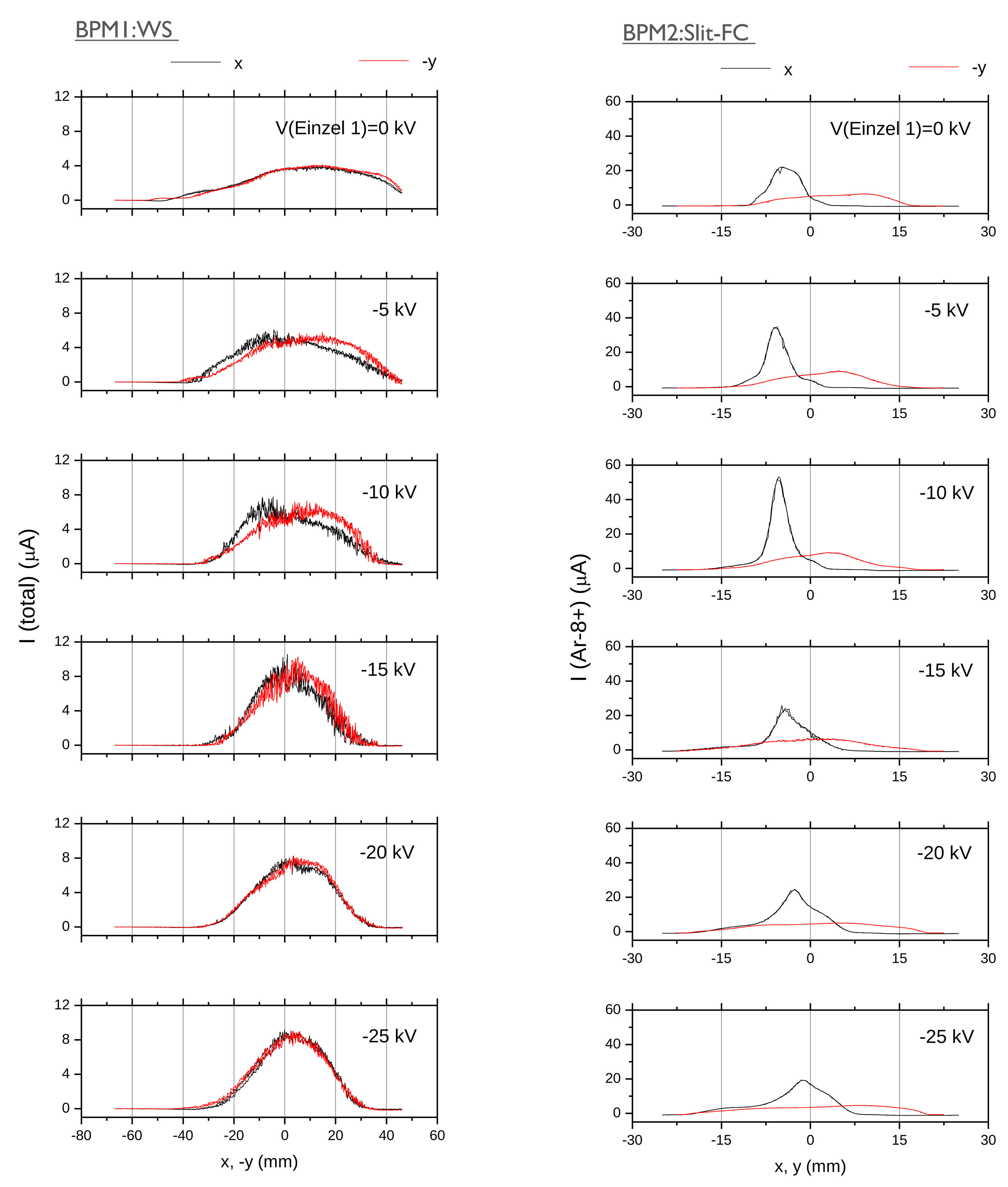
BPM 2: Slit-FC system is operated for measuring beam profiles at the position of charge/mass selection slit (SL2), where the x and y slit in the slit-FC system are designed to be independently moving from -25 to 25 mm. Also the gap widths(d's) of the slits are remotely controllable from 0 to 50 mm. When the slit-FC system works for BPM, the gap width of a moving slit is normally set to 2.0 mm, and the other one is set to 50 mm. The FC is comprise of an isolated metal cup and a high voltage suppression ring close to the entrance of the cup. The cup is Ø50 mm in diameter and 80 mm in length, and the suppression ring can be biased up to -1 kV.

» Beam Profile Measurements with Variable Slit Openings



With variable slit openings horizontal (x) and vertical (y) beam profiles measured at BPM1 & BPM2 positions. Eizel lens 1 potential (V_{einzel}) was fixed to a optimum potential(i.e. -10 kV). It is noted that beam divergence is relatively decreased with slit openings.

» Beam Profile Measurements without Slit (SL1)



Measured Horizontal (x) and vertical (y) beam profiles at BPM1 & BPM2 positions in the absence of SL1(slit). The measurements BPM1 & BPM2 were done by wire scanner and slit-FC system, respectively.
The beam profiles at BPM1 and BPM2 are strongly dependent on Einzel lens 1 potential (V_{einzel}); There is a optimum V_{einzel} for the higher beam transmission to FC2. In this case the optimum V_{einzel} is -10 kV. It can be found that higher negative V_{einzel} gives higher beam transmission at BPM1, but those beam has wider beam profiles at BPM2.

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