High-Intensity Beam simulation for IFMIF / like Accelerator

Seok Ho Moon & Moses Chung

2018. 06. 21 Thursday

Intense Beam and Accelerator Laboratory
Ulsan National Institute of Science and Technology

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- Introduction
- Low Energy Beam Transport (LEBT)
- Medium Energy Beam Transport (MEBT)
- Summary & Future plan

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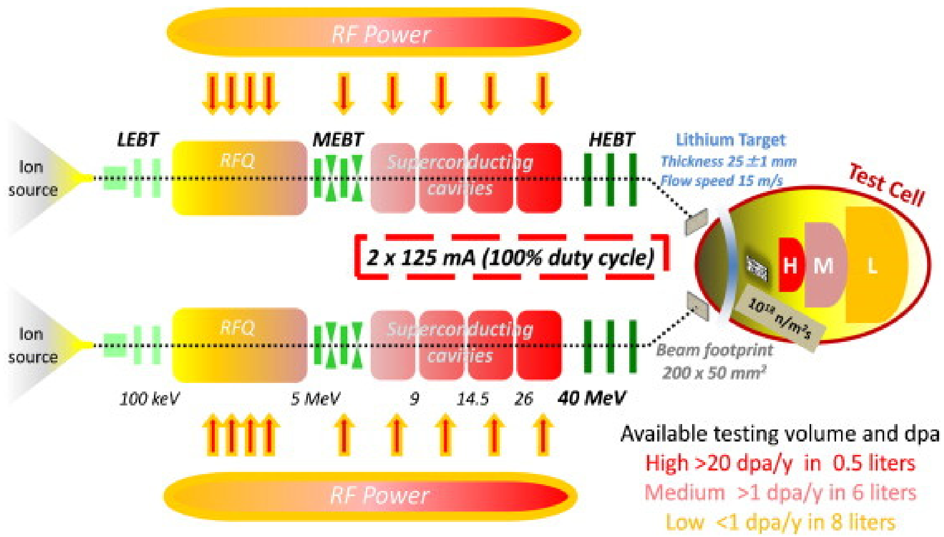
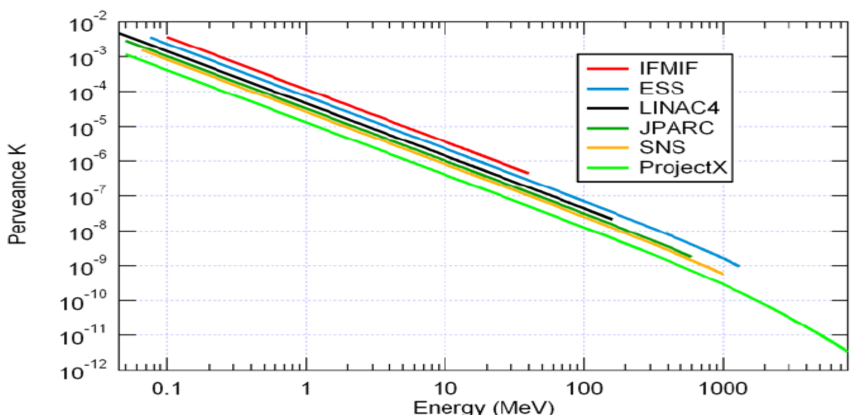
IFMIF



IFMIF/EVEDA, 2018, What is IFMIF, [http://www.ifmif.org/?page_id=6], Accessed May 24, 2018



Phu Anh Phi Nghiem et al, The IFMIF – EVEDA challenges in beam dynamics and their treatment (2011)

$$\begin{aligned} &Particle\ Type &&: D^{+} \\ &Beam\ Current &&: 125mA \\ &Operation\ Type &&: CW \end{aligned}$$

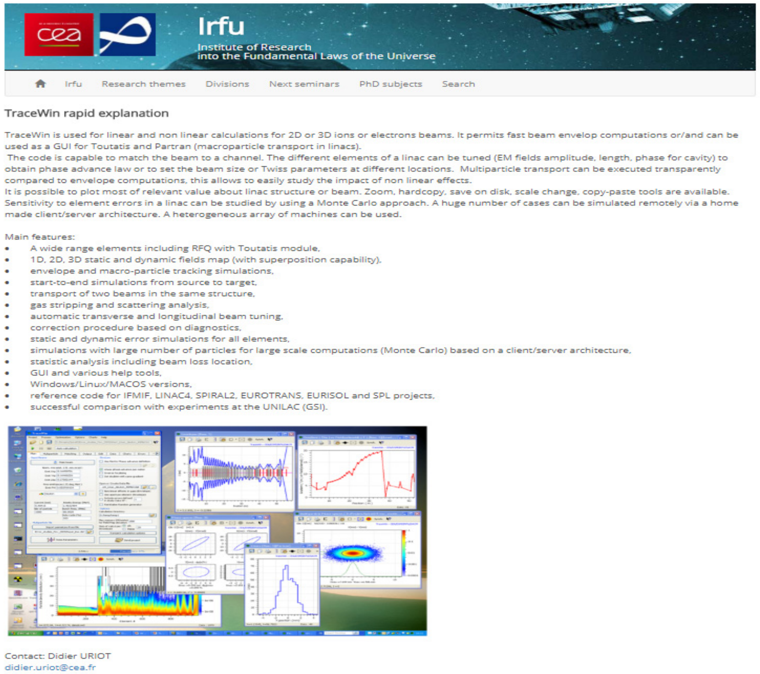
$$Perveance\ K = \frac{I}{I_0} \cdot \frac{2}{\beta^3 \gamma^3} \cdot (1 - \gamma^2 f_e)$$

$$f_e : neutralization\ factor$$

TRACEWIN & WARP

< TRACEWIN >

Developer: Researchers of CEA

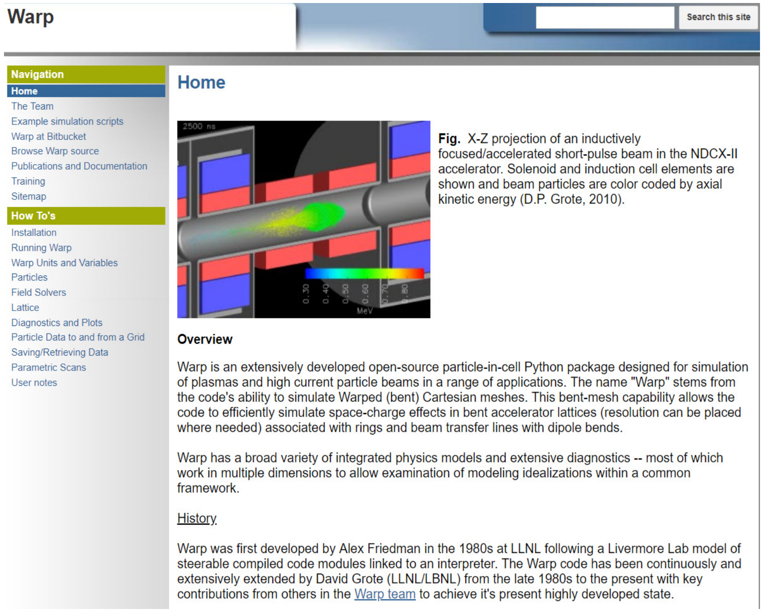


http://irfu.cea.fr/dacm/en/logiciels/index.php

Second order momentum / Macroparticle

< WARP >

Developer: D.Grote, J.L.Vay, A.Friedman, S.Lund

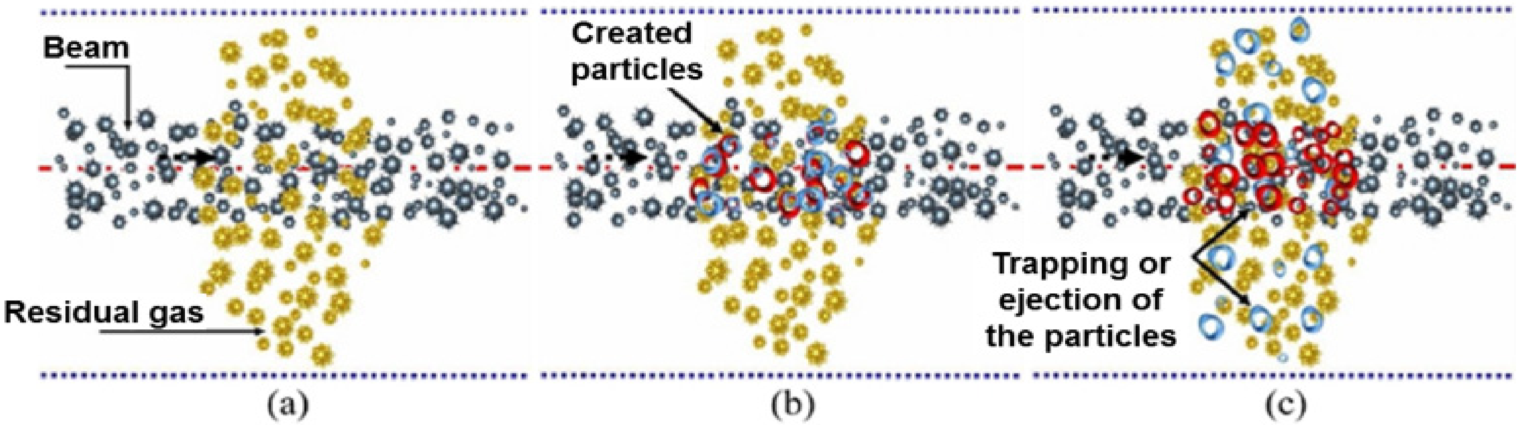


http://warp.lbl.gov/home

Full PIC

Contents

SCC(Space Charge Compensation)



Nicolas, Chauvin. Space-Charge effect.(2014):12

Neutralization time: $\tau_n = \frac{1}{n_g \sigma_i v_b}$

Atomic Processes

1. Ionization by beam

$$D^+ + Kr \rightarrow D^+ + Kr^+ + e^-$$

2. Ionization by electron

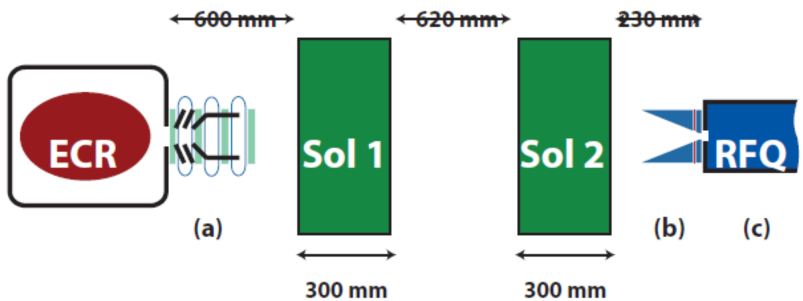
$$e^- + Kr \rightarrow e^- + Kr^+ + e^-$$

3. Recombination

$$Kr^+ + e^- \rightarrow Kr$$

Schematic of LEBT & Parameter

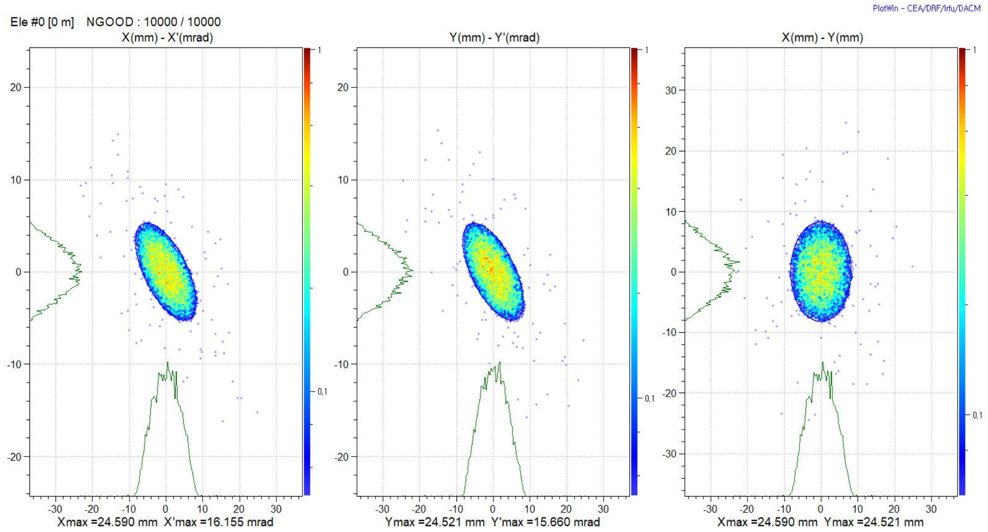
Schematic of IFMIF LEBT



Nicolas, Chauvin et al. Final Design of the IFMIF-EVEDA Low Energy Beam Transport Line. PAC (2009): 1-2

Lattice parameter	Value
Beam Pipe Radius	80mm
Cone Radius	35mm,12mm
B-field of Solenoid	Sol1:0.37T Sol2:0.47T

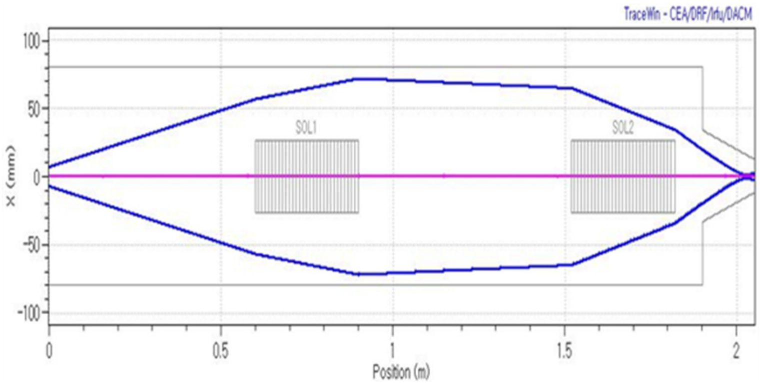
Initial Beam Parameter

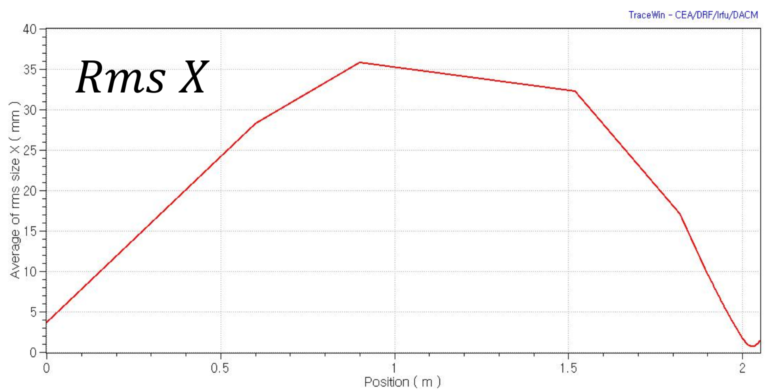


Beam Parameter	Initial Value
Particle Type	D^+
Beam Current	125mA
Initial Energy	100keV
Emittance	$0.064\ \pi.mm.mrad$
Twiss Parameter	$\alpha = 0.8, \beta = 2.0$

Without SCC

TRACEWIN

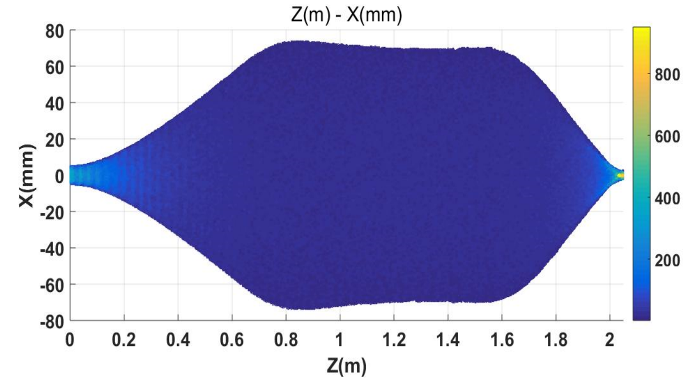


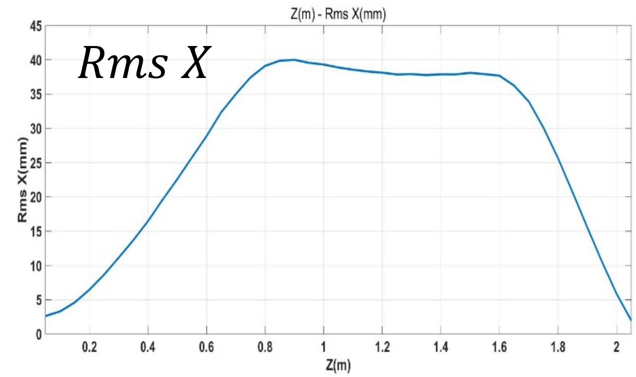


At exit

$$\varepsilon_{n,rms\ x} = 0.2796\pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.2794\pi.mm.mrad$$

WARP





At exit

$$\varepsilon_{n,rms\ x} = 0.3697\ \pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.3778\pi.mm.mrad$$

Target value: $\varepsilon_{n,rms} = 0.233\pi.mm.mrad$

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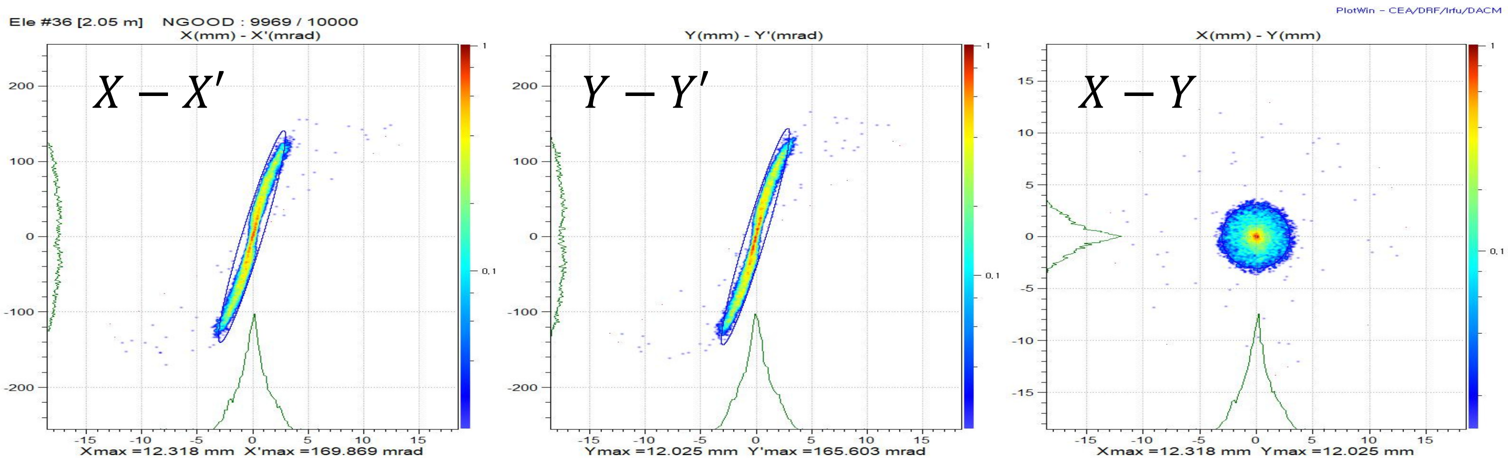
Without SCC

TRACEWIN



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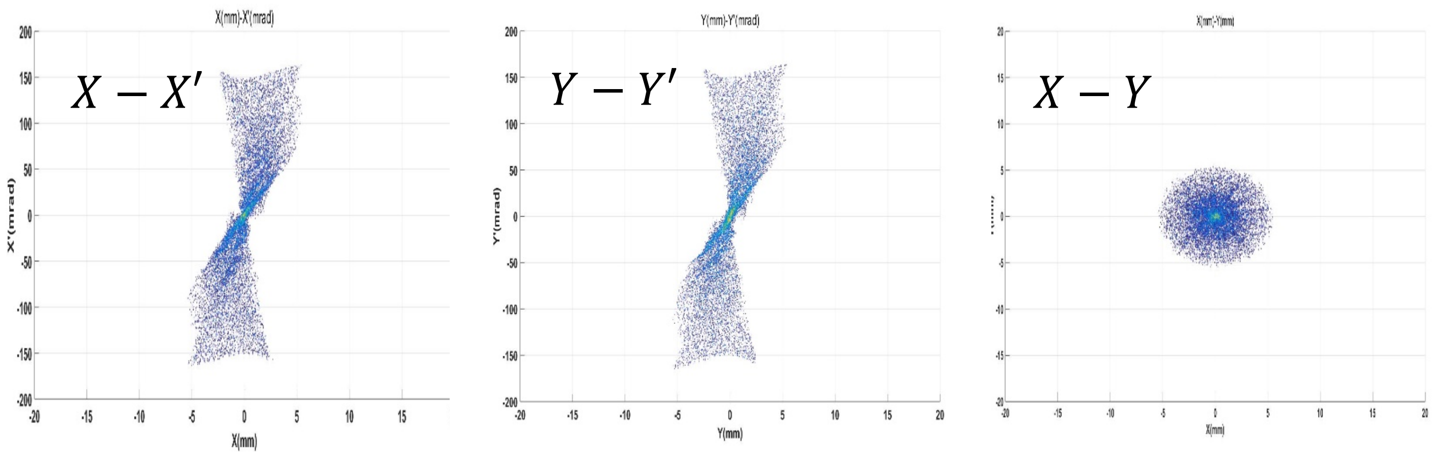
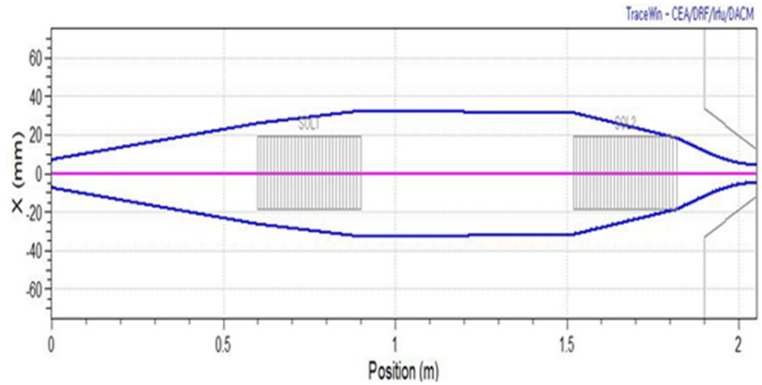
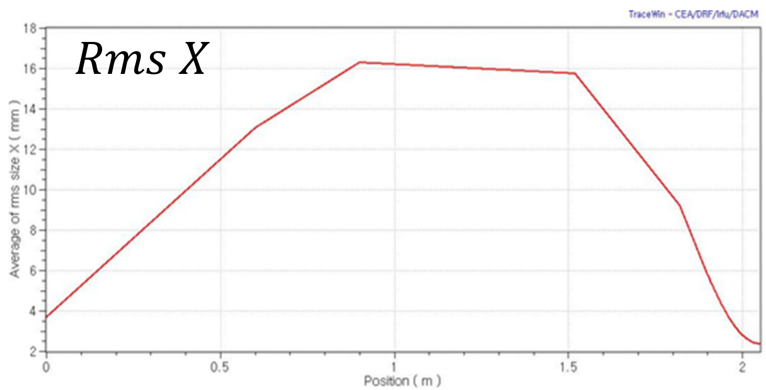


With SCC

TRACEWIN

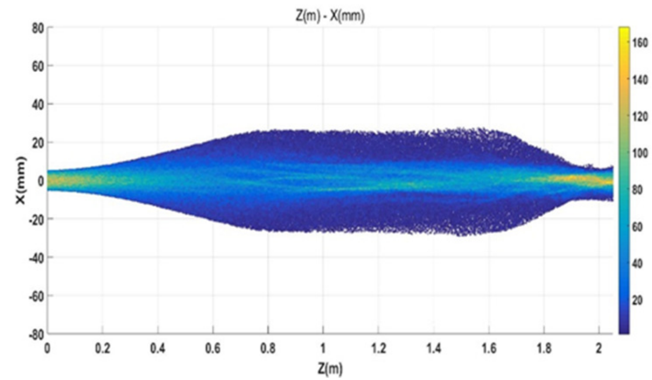


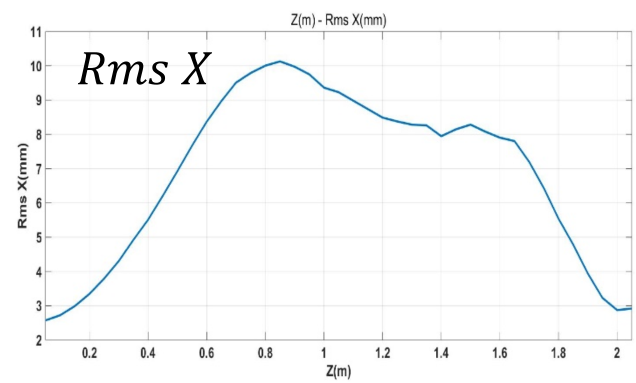


At exit

$$\varepsilon_{n,rms\ x} = 0.1228\pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.1189\pi.mm.mrad$$

WARP





At exit

$$\varepsilon_{n,rms\ x} = 0.1763\pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.1957\pi.mm.mrad$$

Target value: $\varepsilon_{n,rms} = 0.233\pi.mm.mrad$

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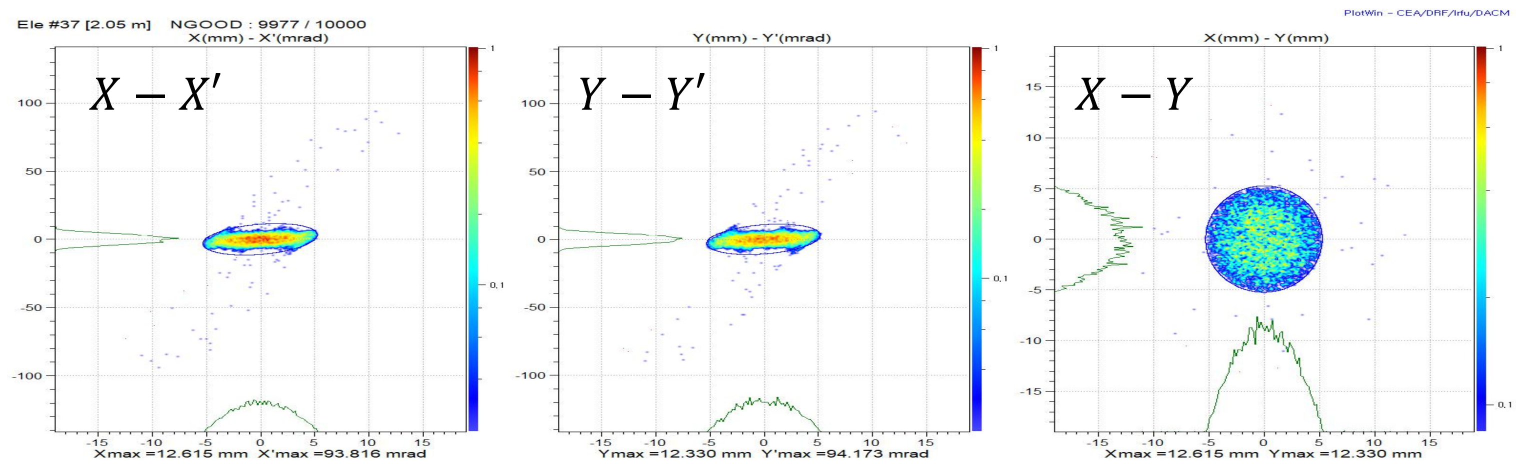
With SCC

TRACEWIN



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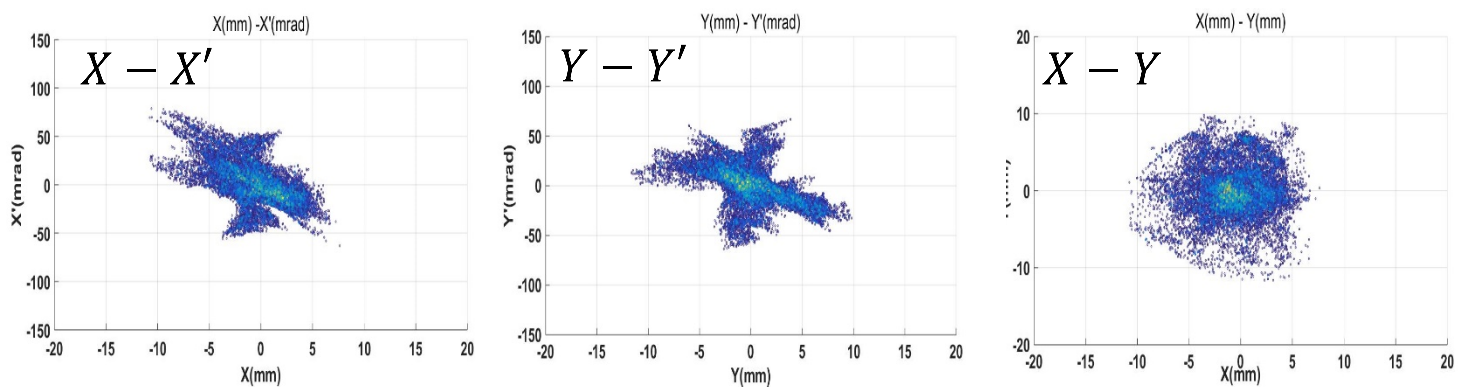
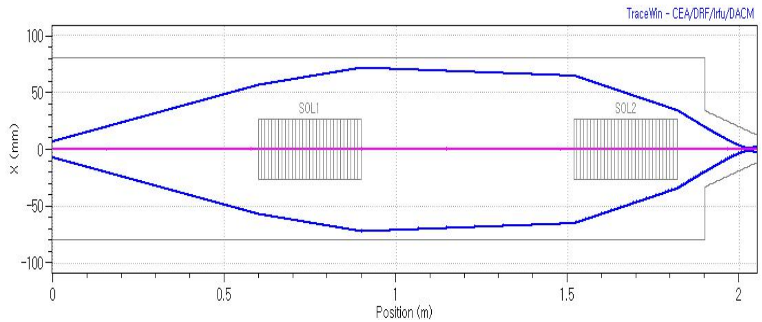
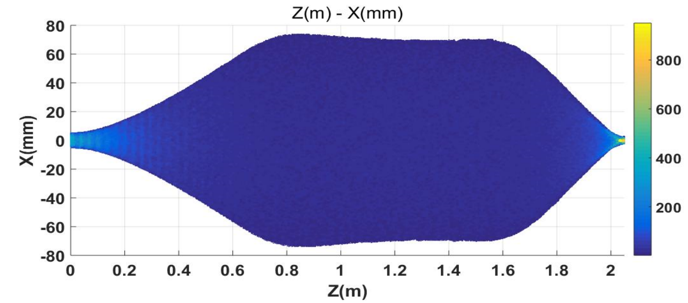


Result Comparison

Without SCC

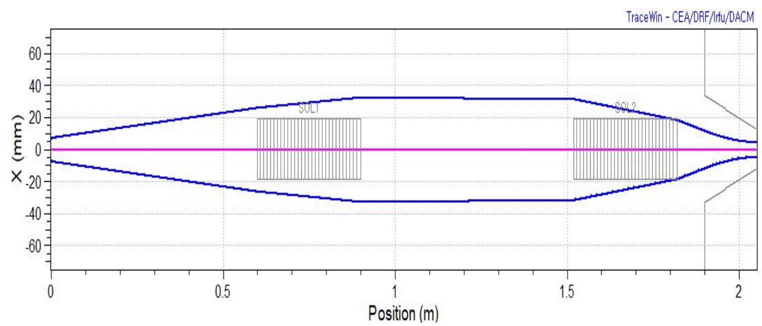


$$\varepsilon_{n,rms\ x} = 0.2796\pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.2794\pi.mm.mrad$$

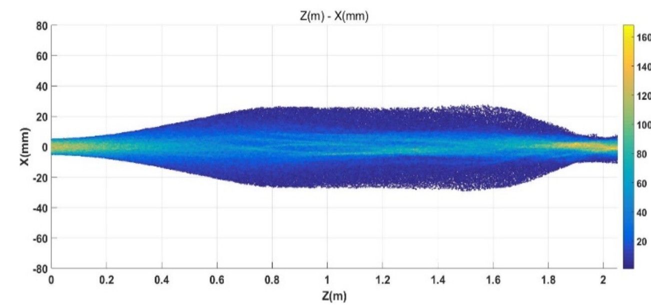


$$\varepsilon_{n,rms\ x} = 0.3697\ \pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.3778\pi.mm.mrad$$

With SCC



$$\varepsilon_{n,rms\ x} = 0.1228\pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.1189\pi.mm.mrad$$



$$\varepsilon_{n,rms\ x} = 0.1763\pi.mm.mrad$$
$$\varepsilon_{n,rms\ y} = 0.1957\pi.mm.mrad$$

Target value: $\varepsilon_{n,rms} = 0.233\pi.mm.mrad$

Instability Issue

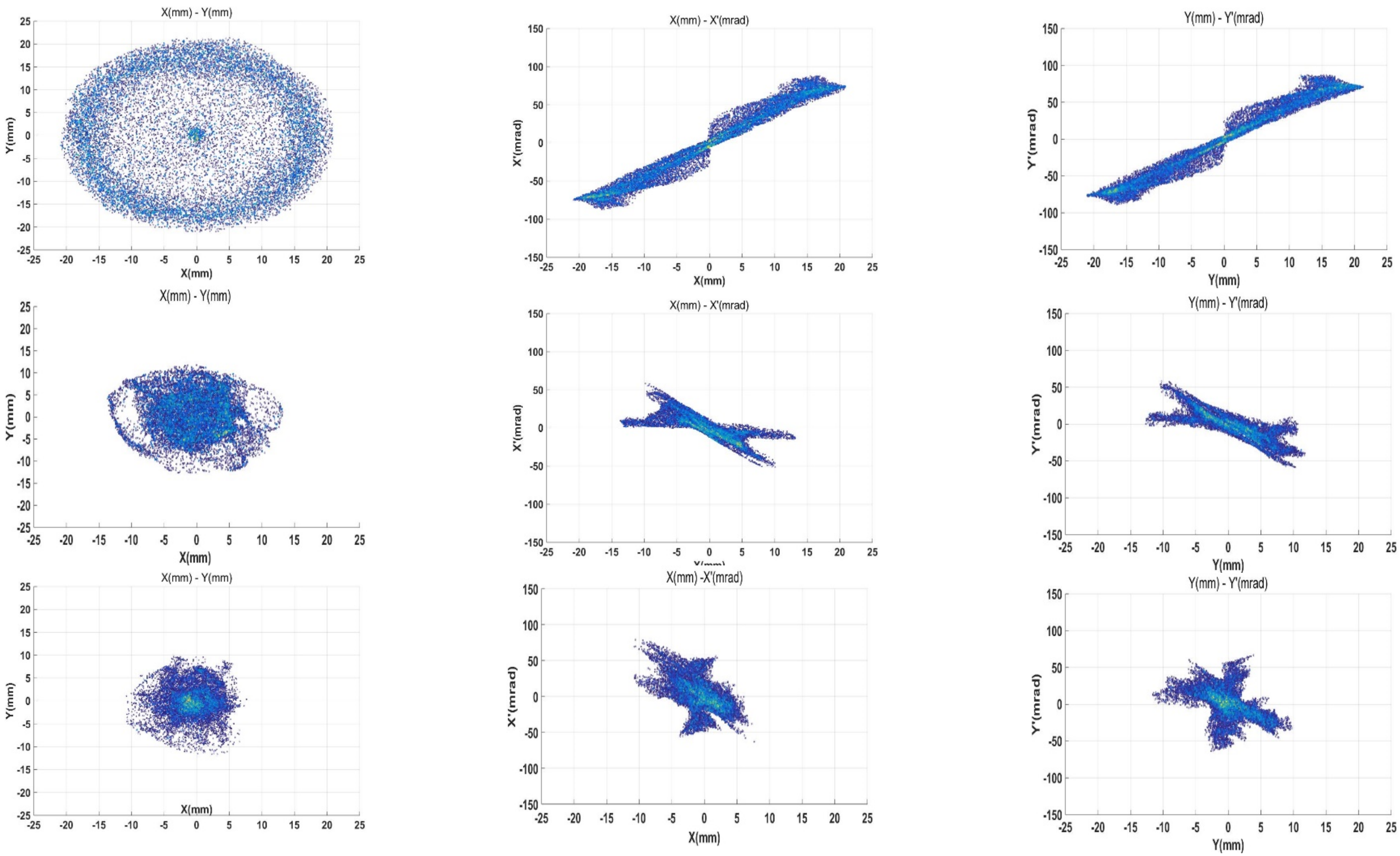
Two stream instability: $F(k,\omega) = \frac{\omega_{pe}^2}{\omega^2} + \frac{\omega_{pi}^2}{(\omega - k v_0)^2}$ $(unstable\ when\ F(k,\omega) > 1)$

$X - Y$ | $X - X'$ | $Y - Y'$

$2\mu s$

$4\mu s$

$6\mu s$



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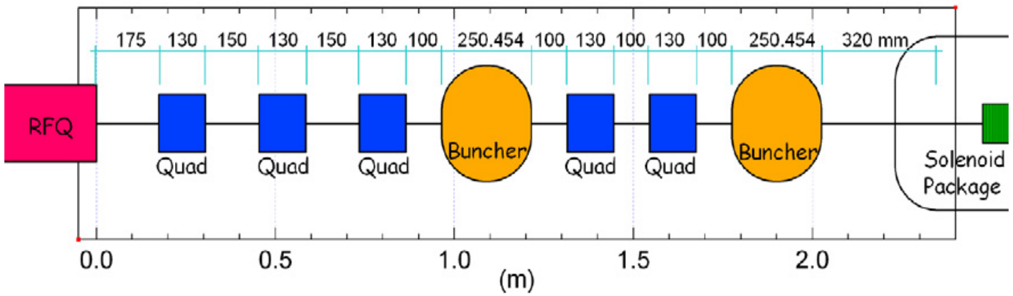
Schematic of MEBT & Parameter

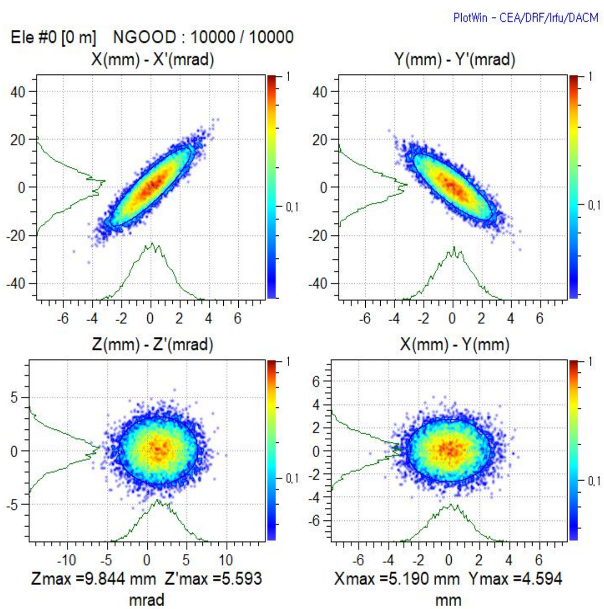
Schematic of IFMIF MEBT



I. Podadera et al. The Medium Energy Beam Transport Line(MEBT) of IFMIF/EVEDA Lipac. IPAC (2011): 1-2

Lattice Parameter	Value
Gradient of Quadrupole	Quad1,2,3:25T/m Quad4: 20.5T/m Quad5: 20T/m
Buncher Frequency	175MHz
Maximum E_0LT	350kV

Initial Beam Parameter



Beam Parameter	Initial Value
Particle Type	D^+
Beam Peak Current	125mA
Initial Energy	4.98MeV
Longitudinal Emittance	0.3 π. $mm.mrad$
Twiss Parameter	$\alpha_x = -1.95, \beta_x = 0.37$ $\alpha_y = 1.5, \beta_y = 0.355$

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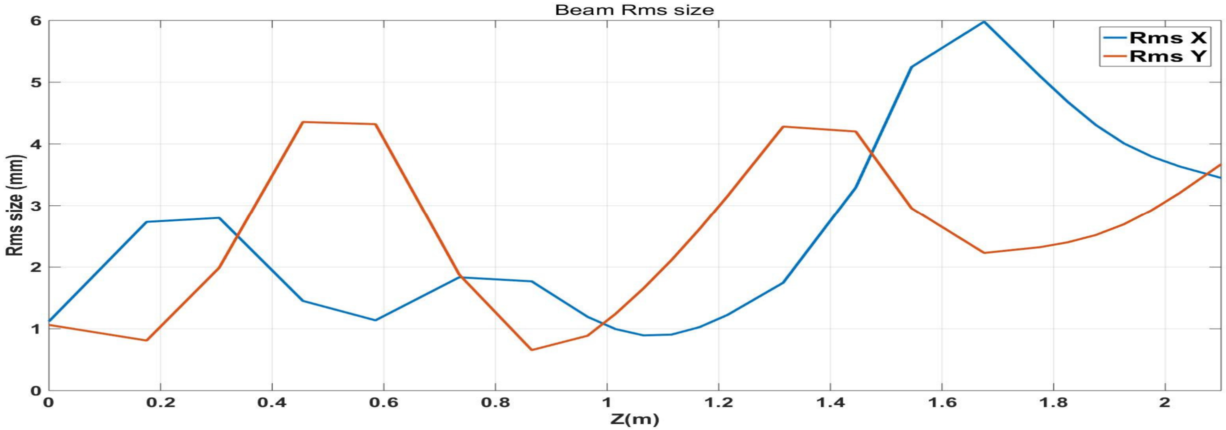
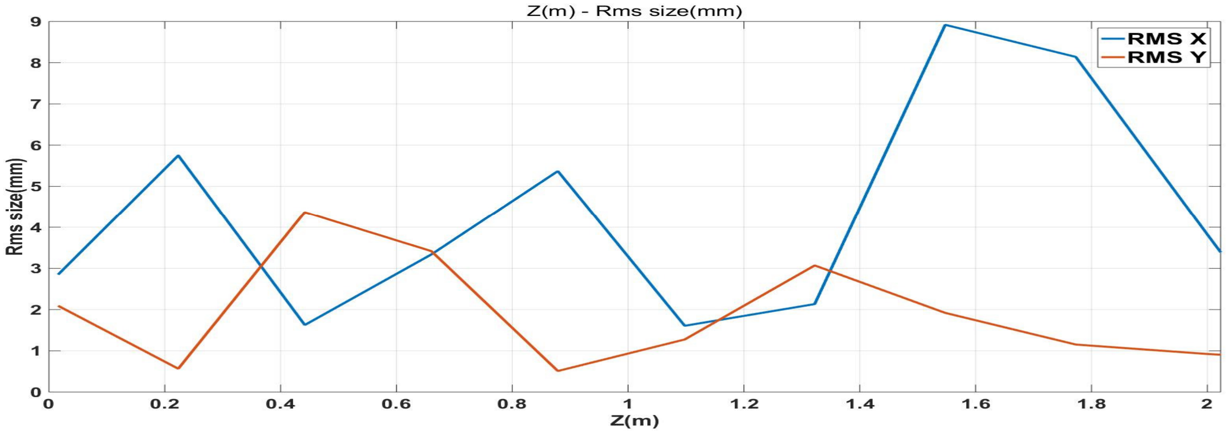
Simulation Result

TRACEWIN

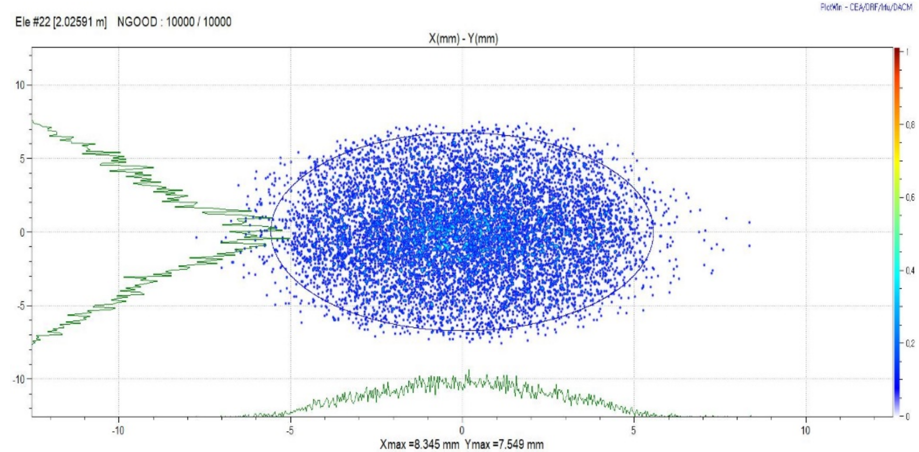


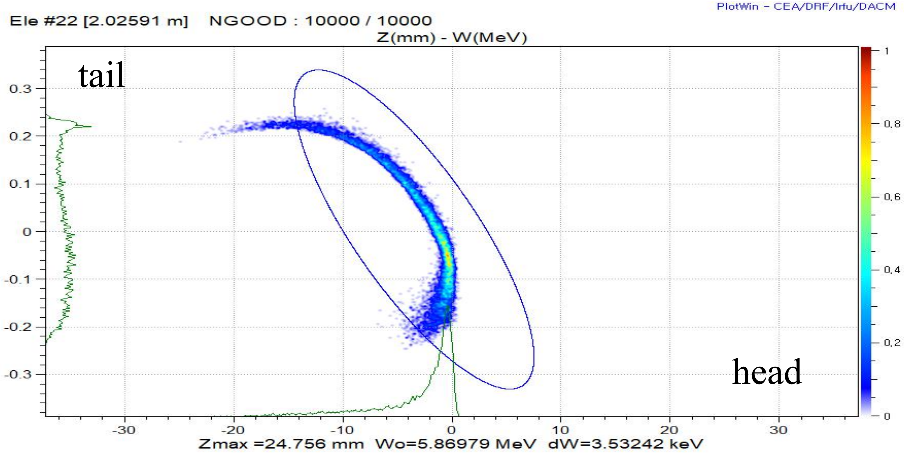
WARP



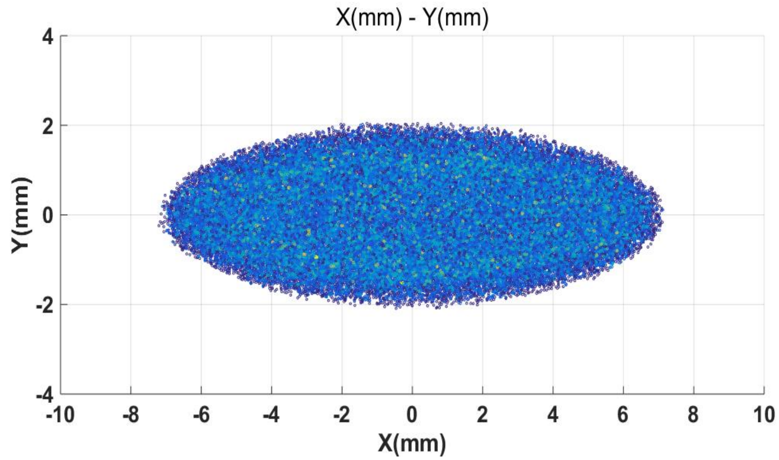
Simulation Result

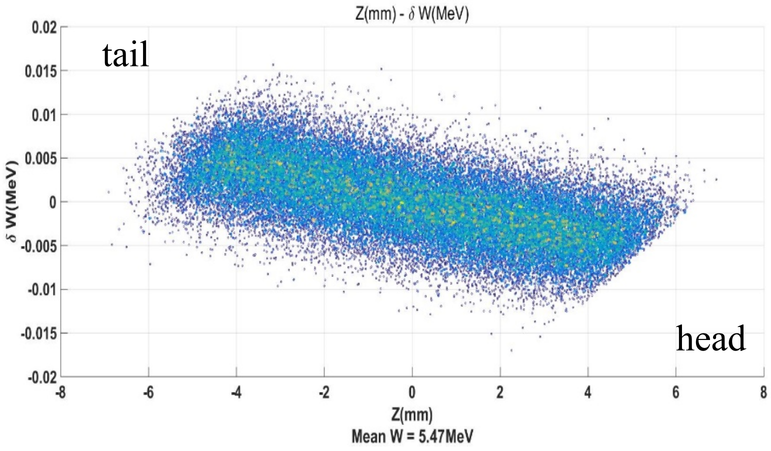
TRACEWIN





WARP



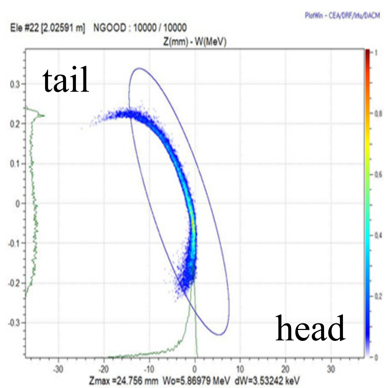


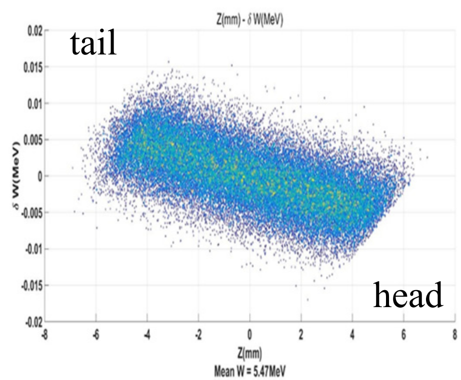
Peak Current Issue

Longitudinal space charge: $F_z = -\frac{q^2 g}{4\pi\varepsilon_0\gamma^2}\frac{d\lambda}{dz}$ $\left(\gamma{:}\ kinematic\ factor, g{:}\ 1+\ln\left(\frac{b}{a}\right)\right)$

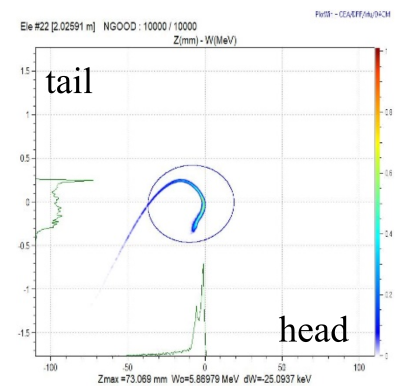
Left: TRACEWIN, Right: WARP

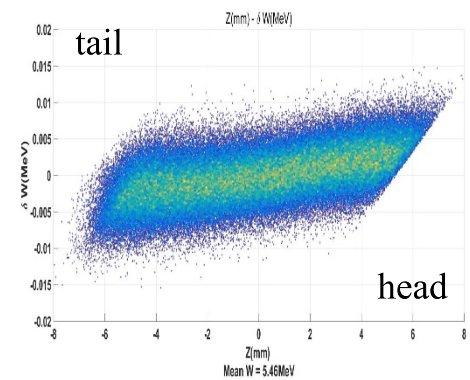
125mA



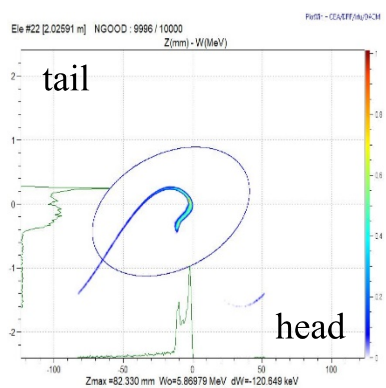


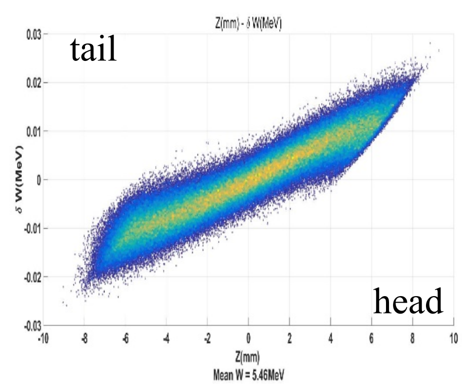
375mA



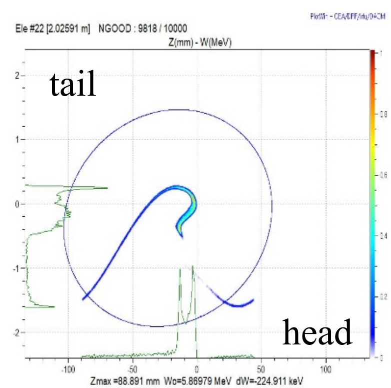


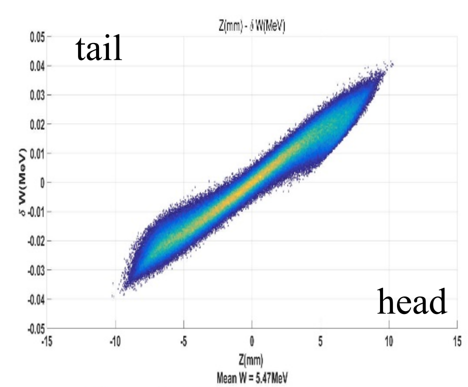
625mA





875mA





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Future Plan & Summary

- SCC (Space – Charge – Compensation) is essential for achieving required emittance.

- Instability in LEBT, WARP simulation for MEBT will be optimized.

- RFQ,HWR(SRF) simulation can't be done in warp simulation. Therefore RFQ,HWR(SRF) simulation will be done by TRACEWIN, IMPACT – Z. Results from those two simulation codes will be cross checked.

Thank you!

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