Design study for Front-End System at Rare Isotope Science Project

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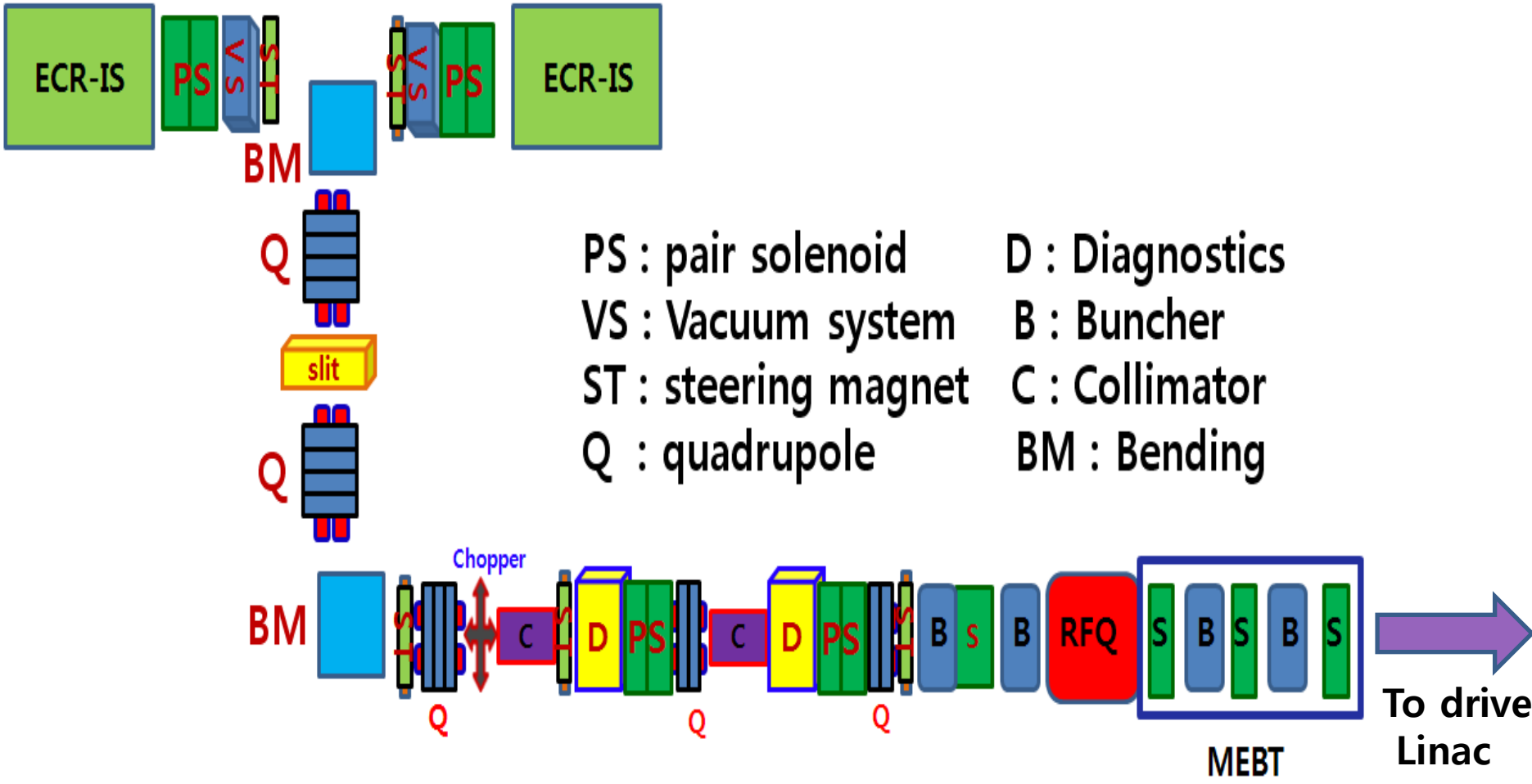
Front-End system for drive linac



Main parameters in Front-End

- ECR-IS
  - Nor. rms emittance : 0.1 π mm-mrad
  - Beam current : 400euA for $^{238}U^{33+}$ $^{238}U^{34+}$
  - Output beam energy : 10 keV/u
  - rf frequency : 28 GHz
- LEBT
  - Two bunchers : 40.625 MHz
  - Two Bends : 90 deg.
- RFQ
  - rf frequency : 81.25 MHz
  - Output beam energy : 300 keV/u
  - Vane voltage : 70 kV
  - Length : 4 m
- MEBT
  - Two re-bunchers : 81.25 MHz

Technical issues at Front-End

- **Generation of heavy-ions for 400 kW**
  - Two charge-states for heavier ions than Xe
- **Achievement of small longitudinal emittance**
  - Bunching in LEBT is optimized to match the beam longitudinally into RFQ
  - MEBT provides 6-D matching with driver linac.

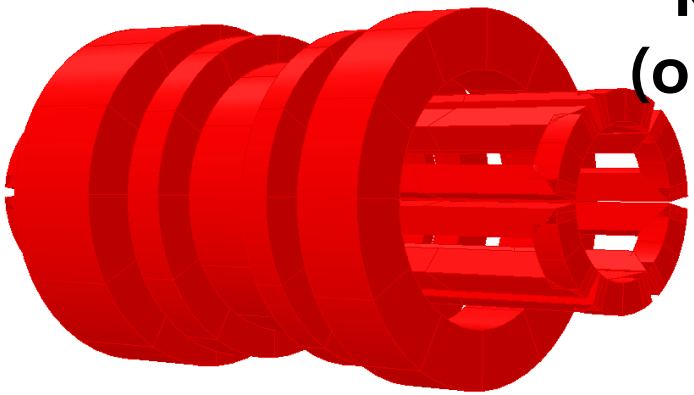
will show results on first Front-End simulations to optimize the beam and accelerator parameters.

ECR-IS

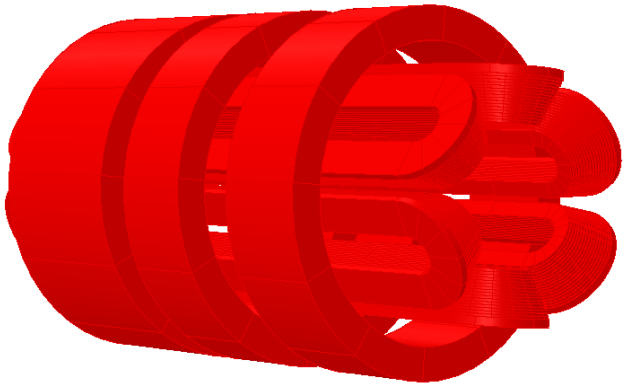
	KAERI Group	KBSI Group
Frequency [GHz]	28	28
RF Power [kW]	10	10
Plasma Chamber Diameter (mm)	150	150
Plasma Chamber Material	Al	Al
Mirror Length (mm)	500	500
V_{ext} [kV]	30	30
SC Wire	NbTi	NbTi
Number of Solenoid	5	3
B_{inj} [T]	> 4	3.5
B_r[T]	2.2	2
B_{ext} [T]	> 3	2
B_{min} [T]	0.3~0.8	0.4~0.8

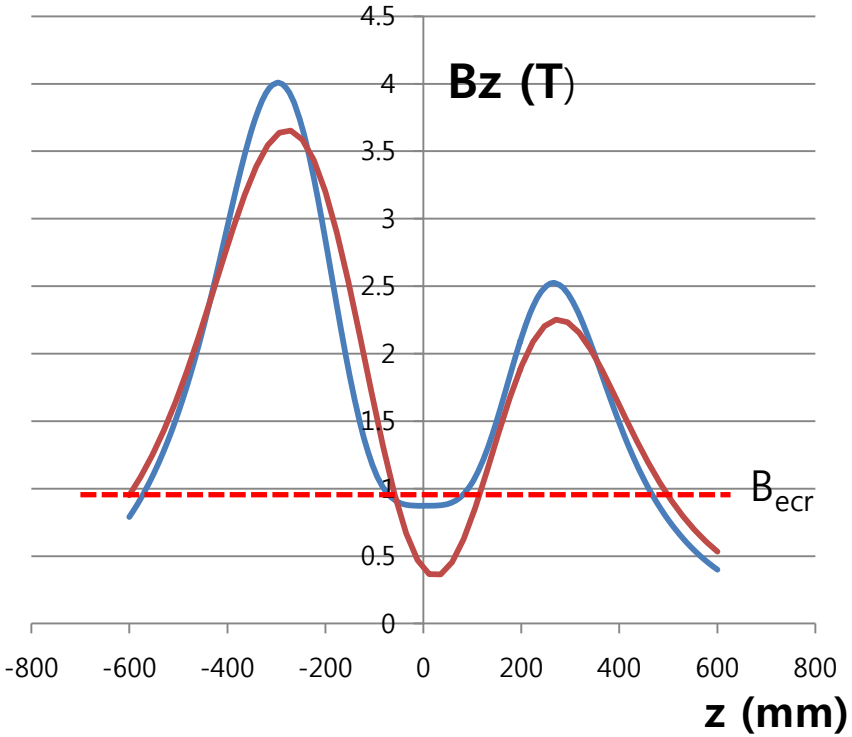
ECR-IS

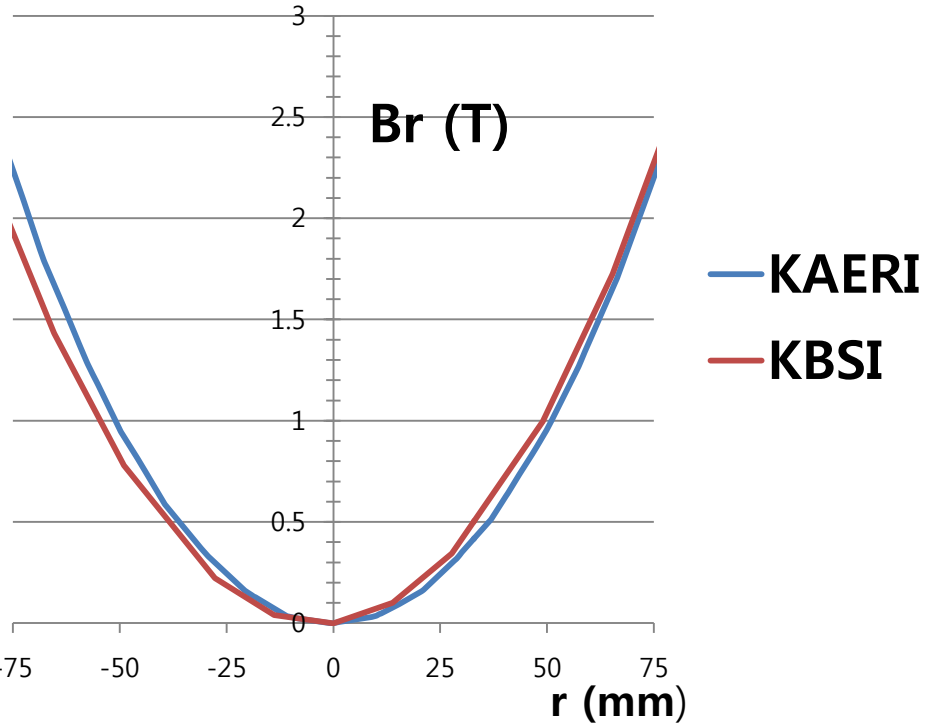
KAERI (on design)



KBSI (under testing)



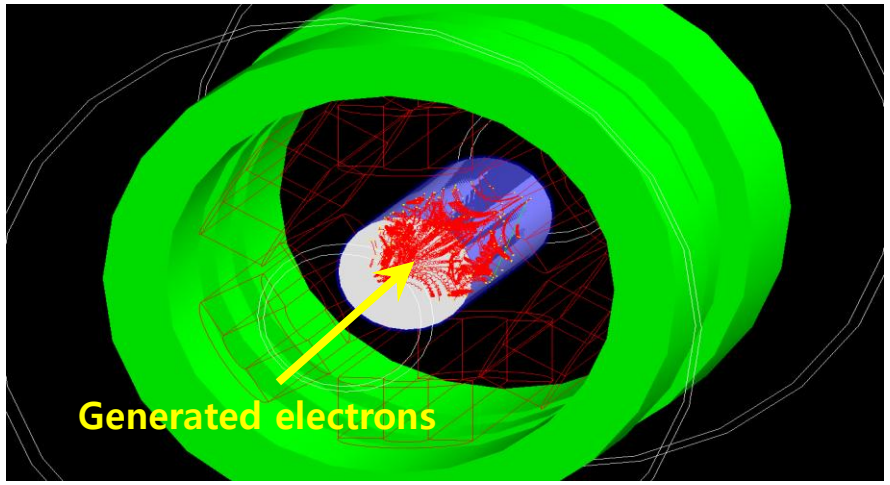


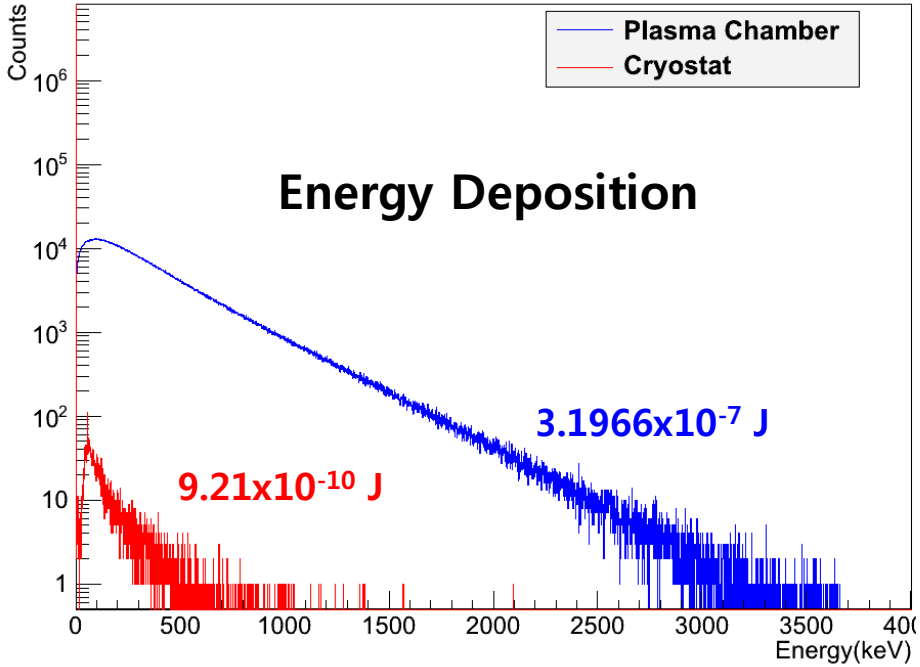


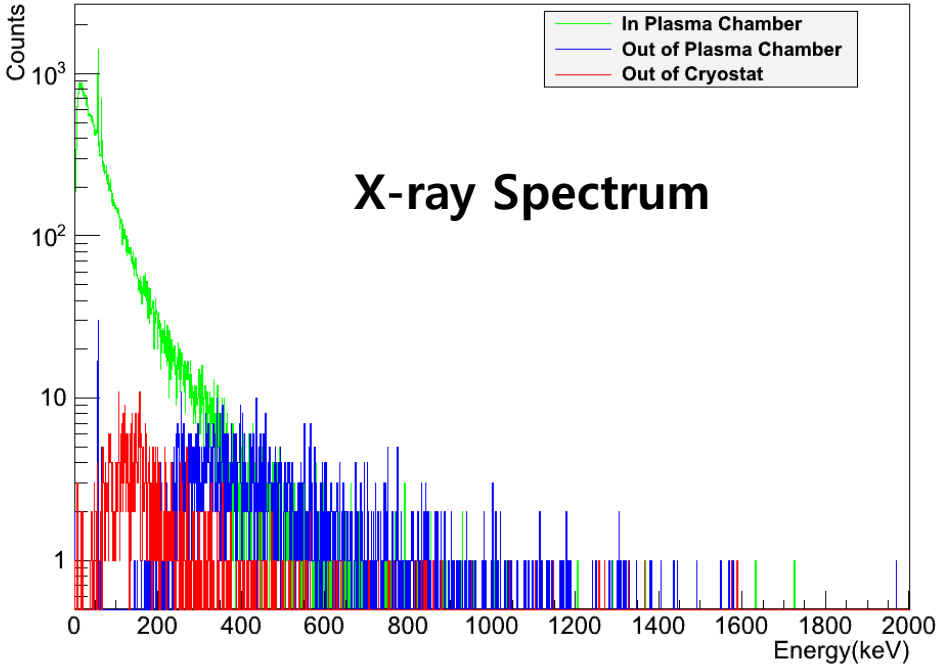
ECR-IS

(X-ray GEANT simulation)

- Electrons with $T_{\perp}$=300 keV, T_{II}=150 keV are generated by Maxwell-Boltzmann Energy Dist. (10^7 electrons)
- X-ray Shielding : 3mm Ta sheet







ECR-IS

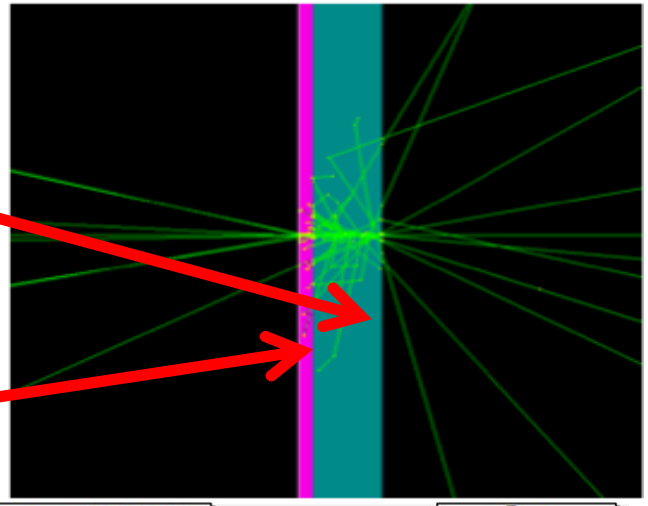
(X-ray GEANT simulation)

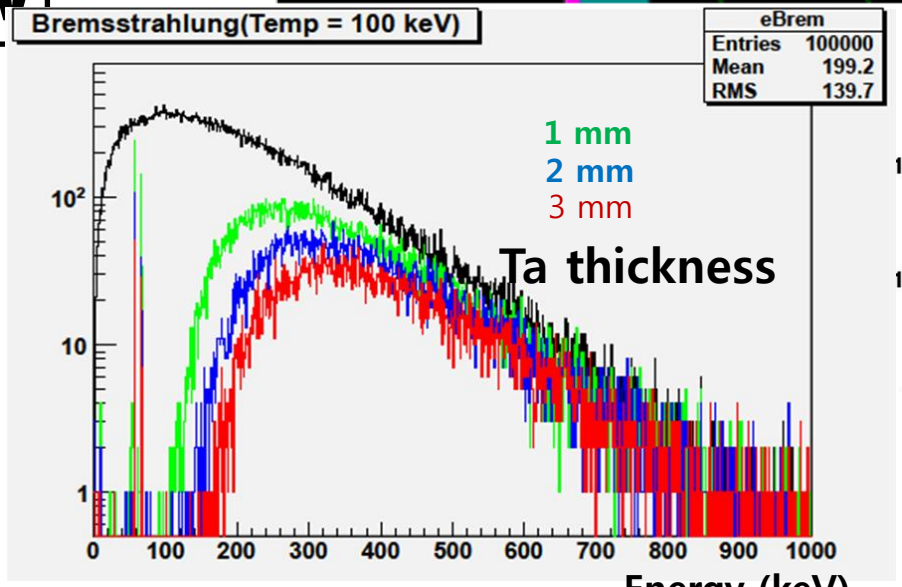
Effects of shielding thickness

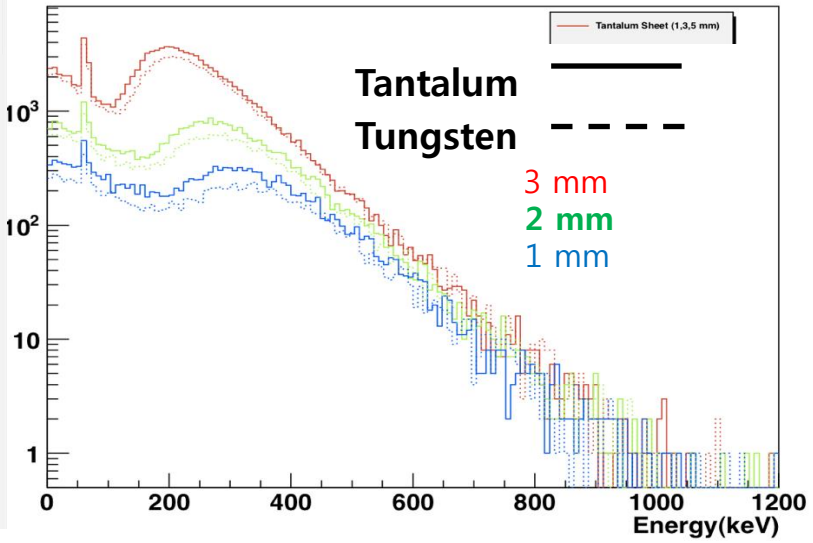
Plasma Chamber
SS316L (5 mm)

Ta

W







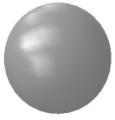
ECR-IS
(Beam extraction simulation)

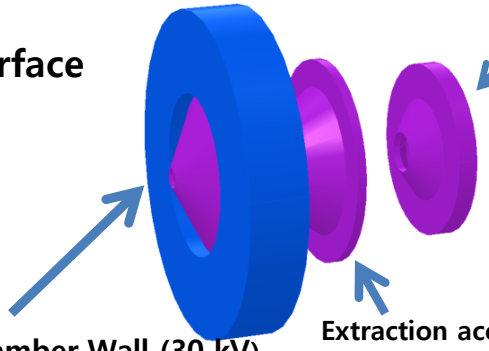
Opera-3D SCALA

KBSI 28 GHz structure

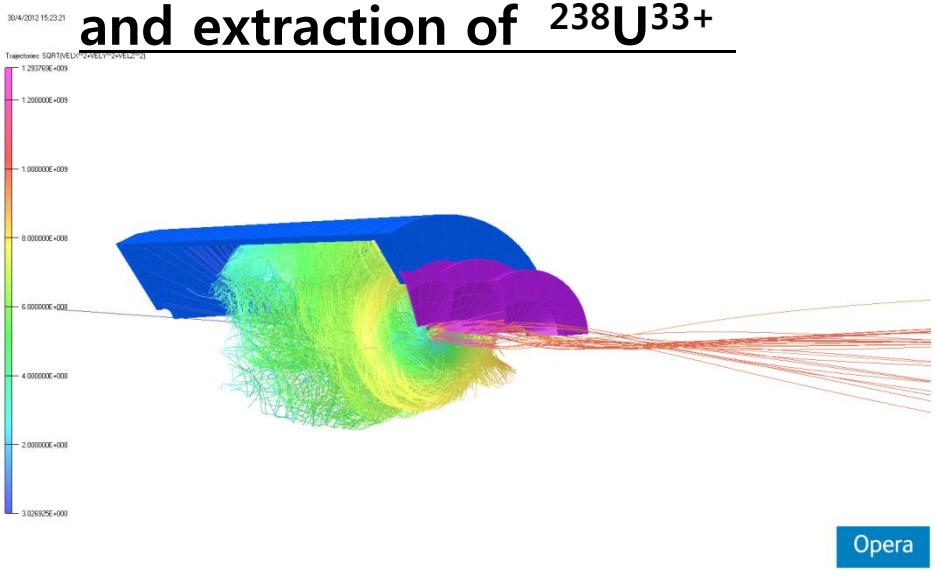
(Assumed 30 kV) plasma surface

$^{238}U^{33+}$ ions

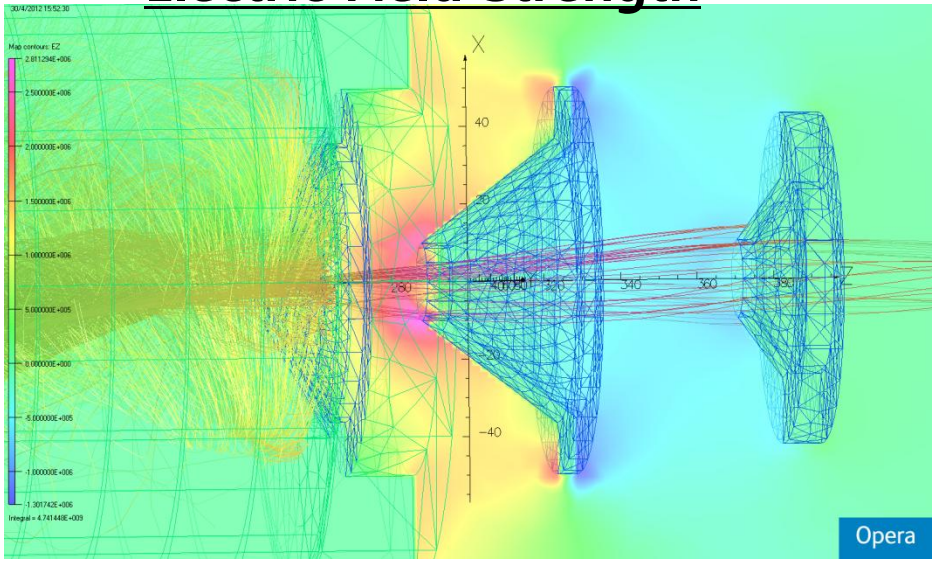




Tracking in inner chamber and extraction of $^{238}U^{33+}$



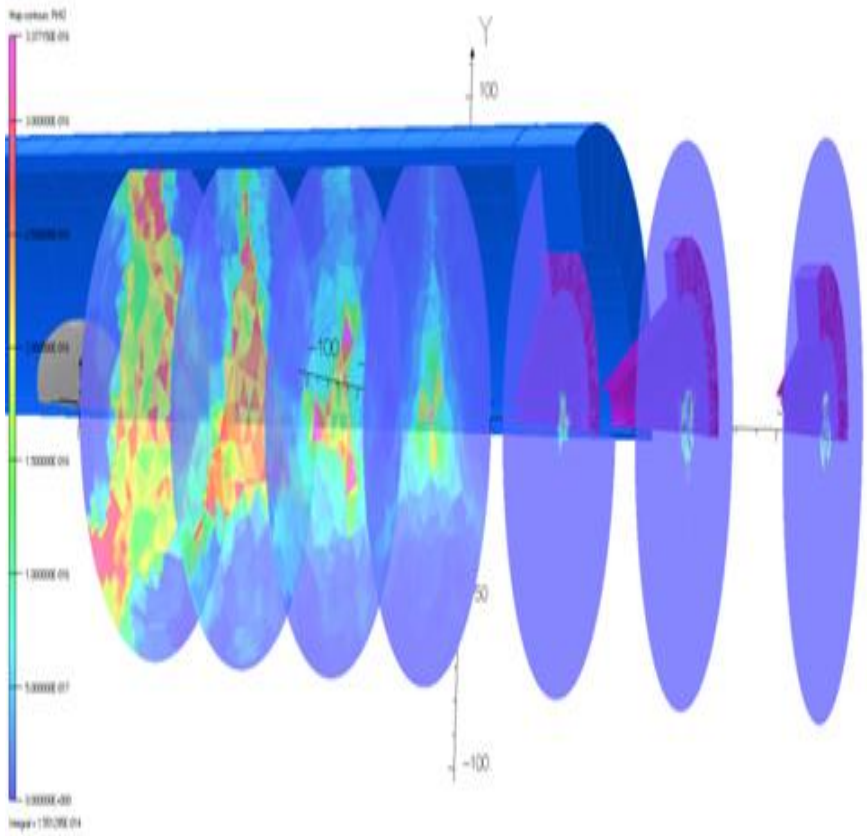
Electric Field Strength

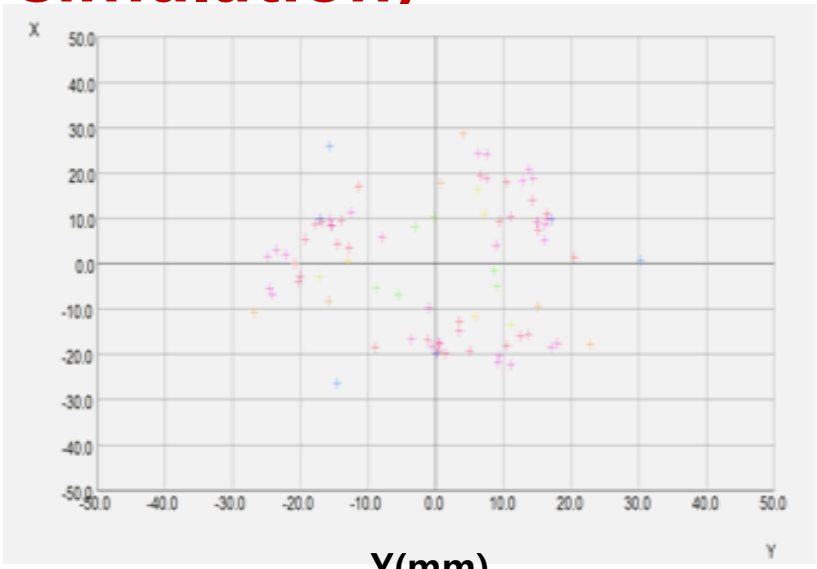


ECR-IS

(Beam extraction simulation)

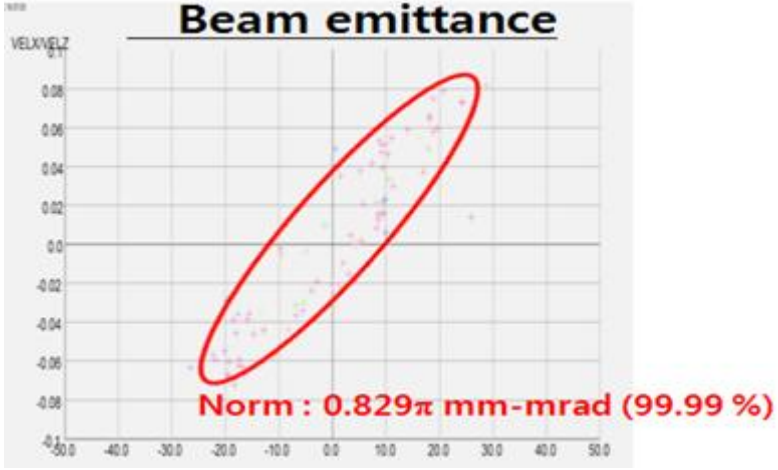
Charge density





Y(mm)

Beam distribution @extraction



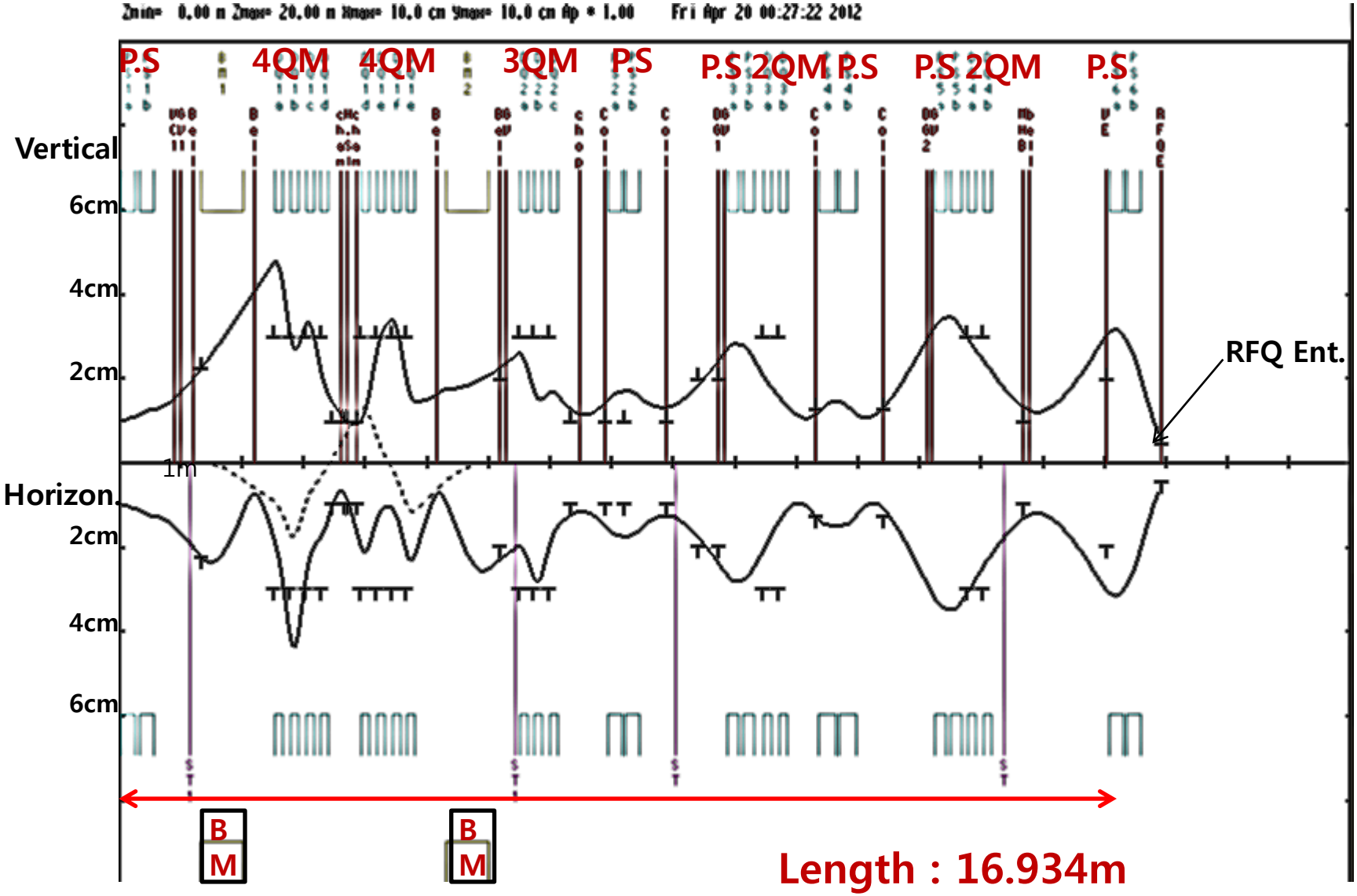
X′

X(mm)

LEBT

- Achromatic optical system
  : two 90 deg. bends
- Solenoids for beam focusing and matching with ECR-IS and RFQ
- Quadrupoles for beam focusing
- Collimation systems
- 2 bunchers with 40.625 MHz
- Beam diagnostics and steering magnets

LEBT

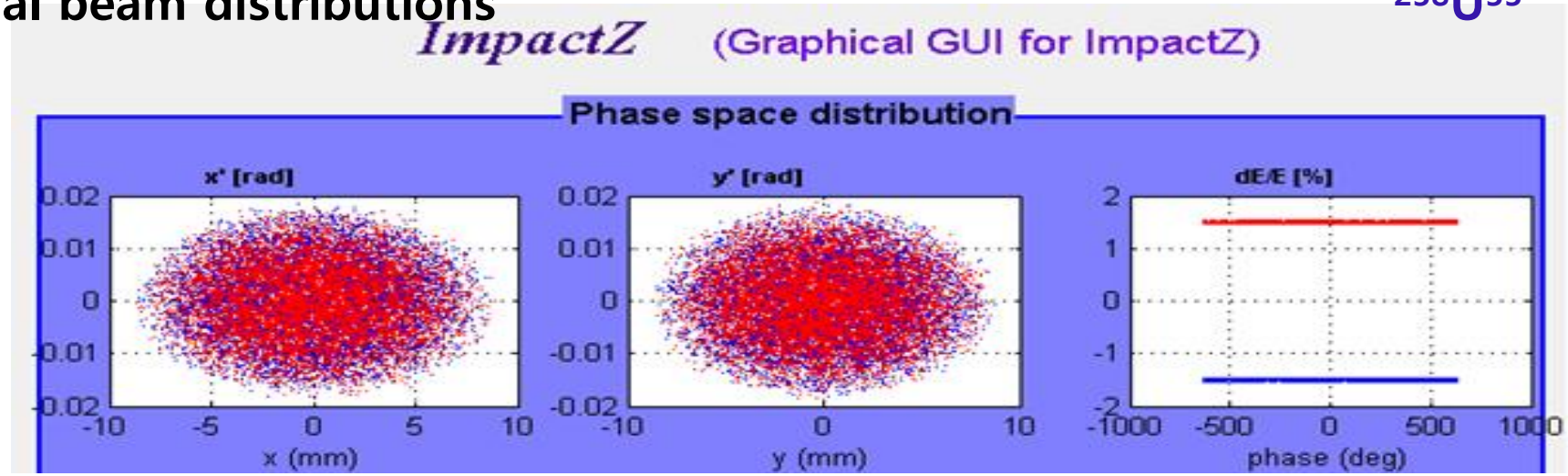

P.S
4QM
4QM
3QM
P.S
P.S
2QM
P.S
P.S
2QM
P.S
Vertical
6cm
4cm
2cm
RFQ Ent.
1m
Horizon.
2cm
4cm
6cm
B
M
B
M
Length : 16.934m

LEBT

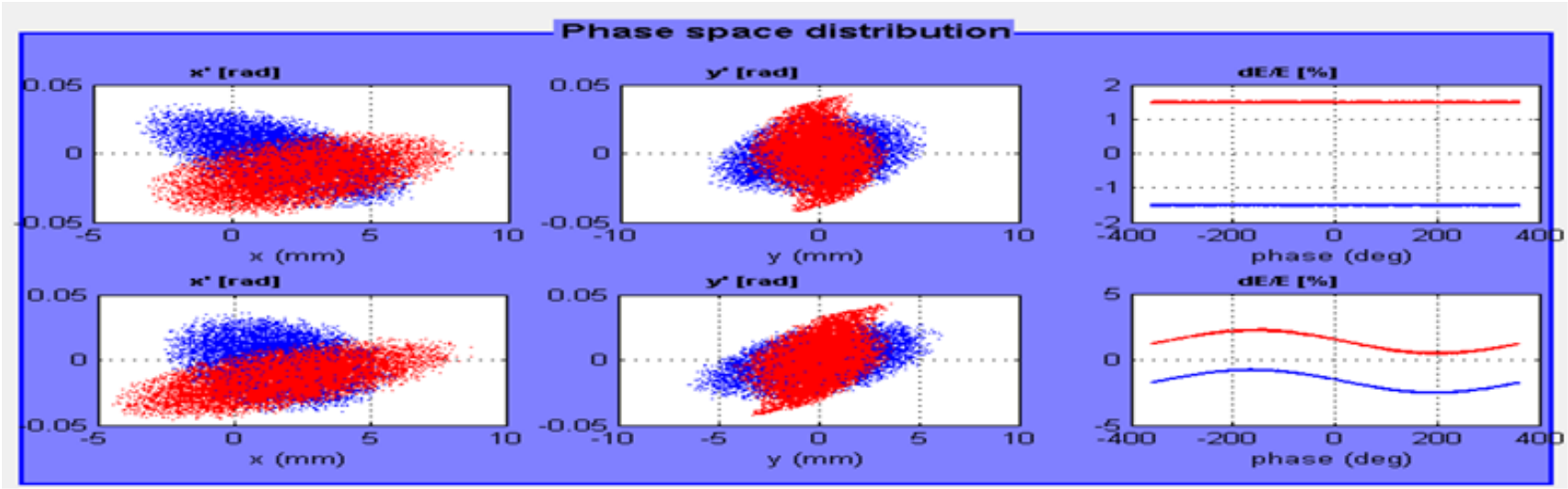
$^{238}U^{34}$

$^{238}U^{33}$

Initial beam distributions



Beam distributions before and after 1st buncher

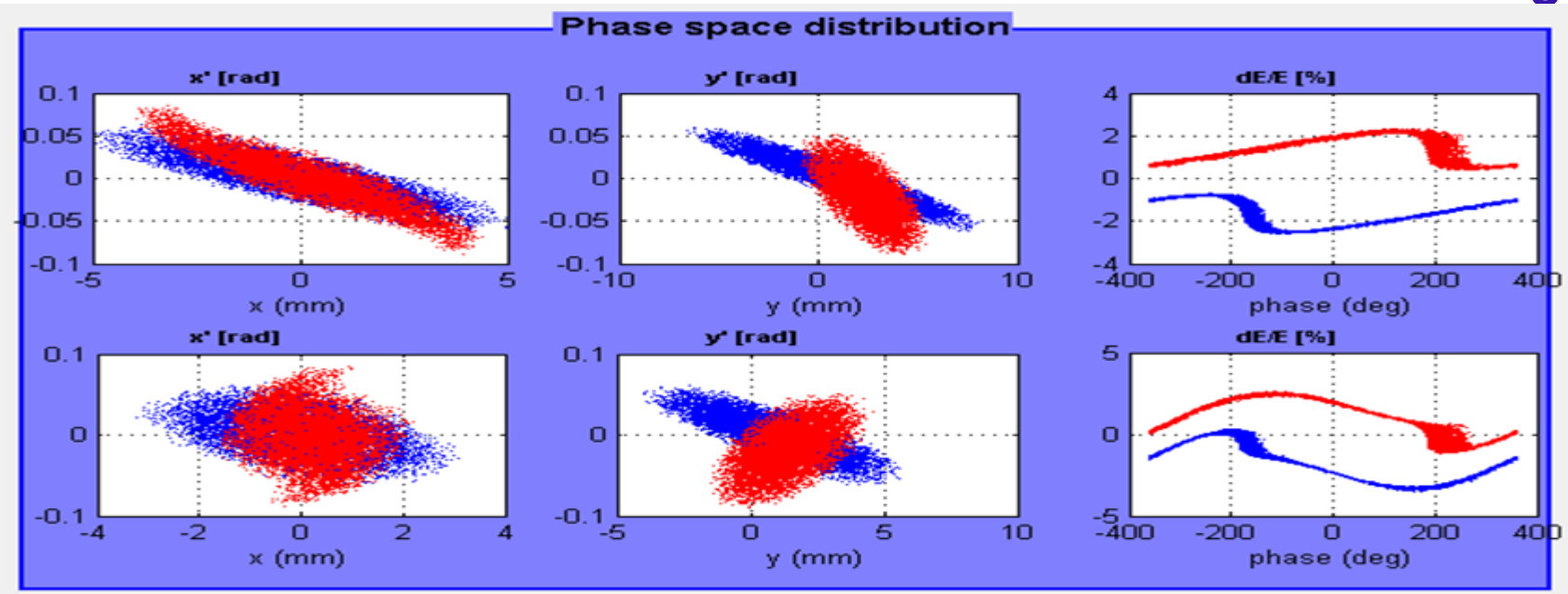


LEBT

Beam distributions before and after 2nd buncher

$^{238}U^{34}$

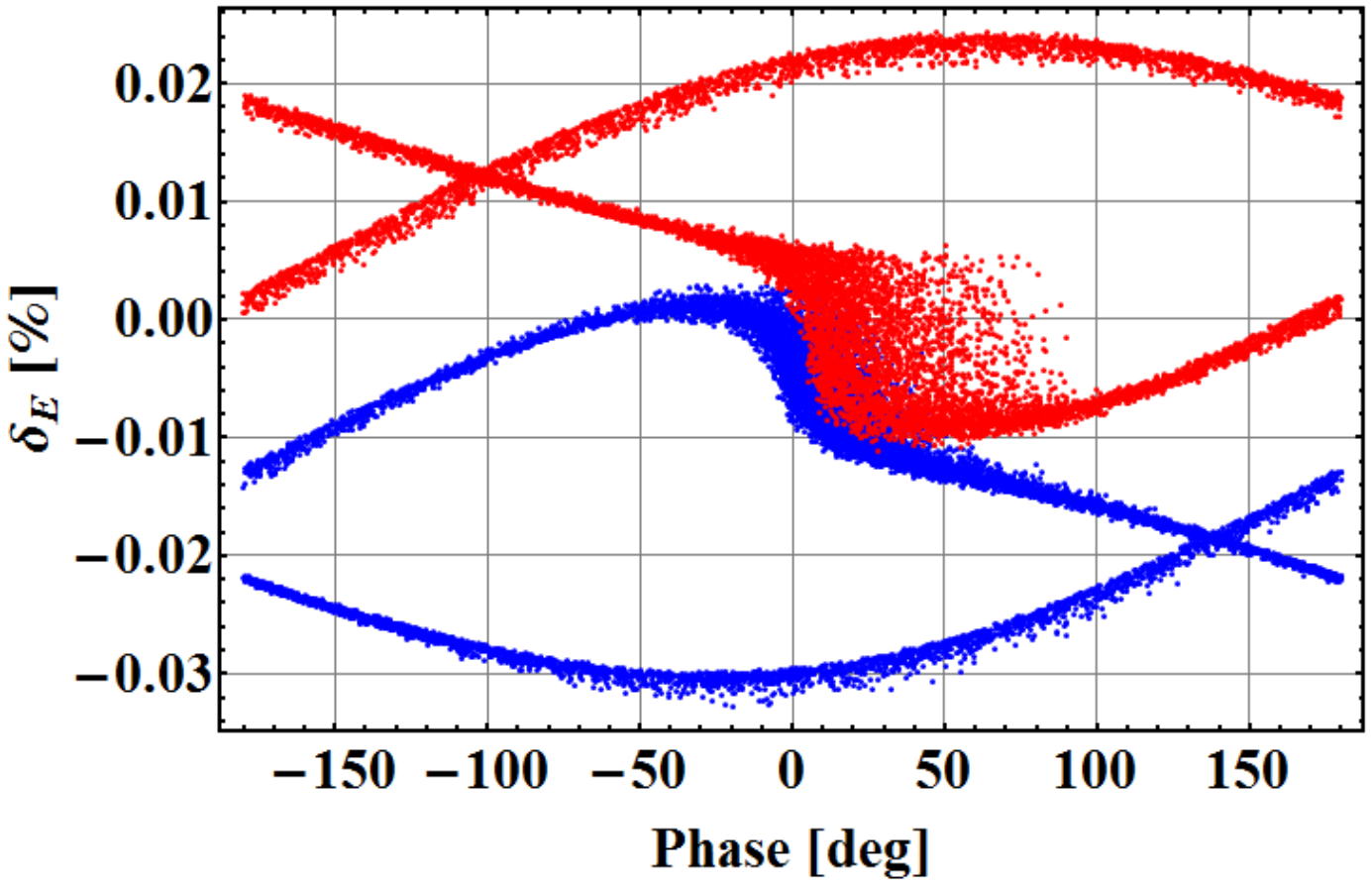
$^{238}U^{33}$



- Two charge-state beam due to 1st buncher is bunched as well as longitudinally separated from each other due to velocity difference.
- 2nd buncher provides each of two-charge state beams with the same energy at RFQ entrance.

(HV platform may be used to adjust drift time duration.)

LEBT



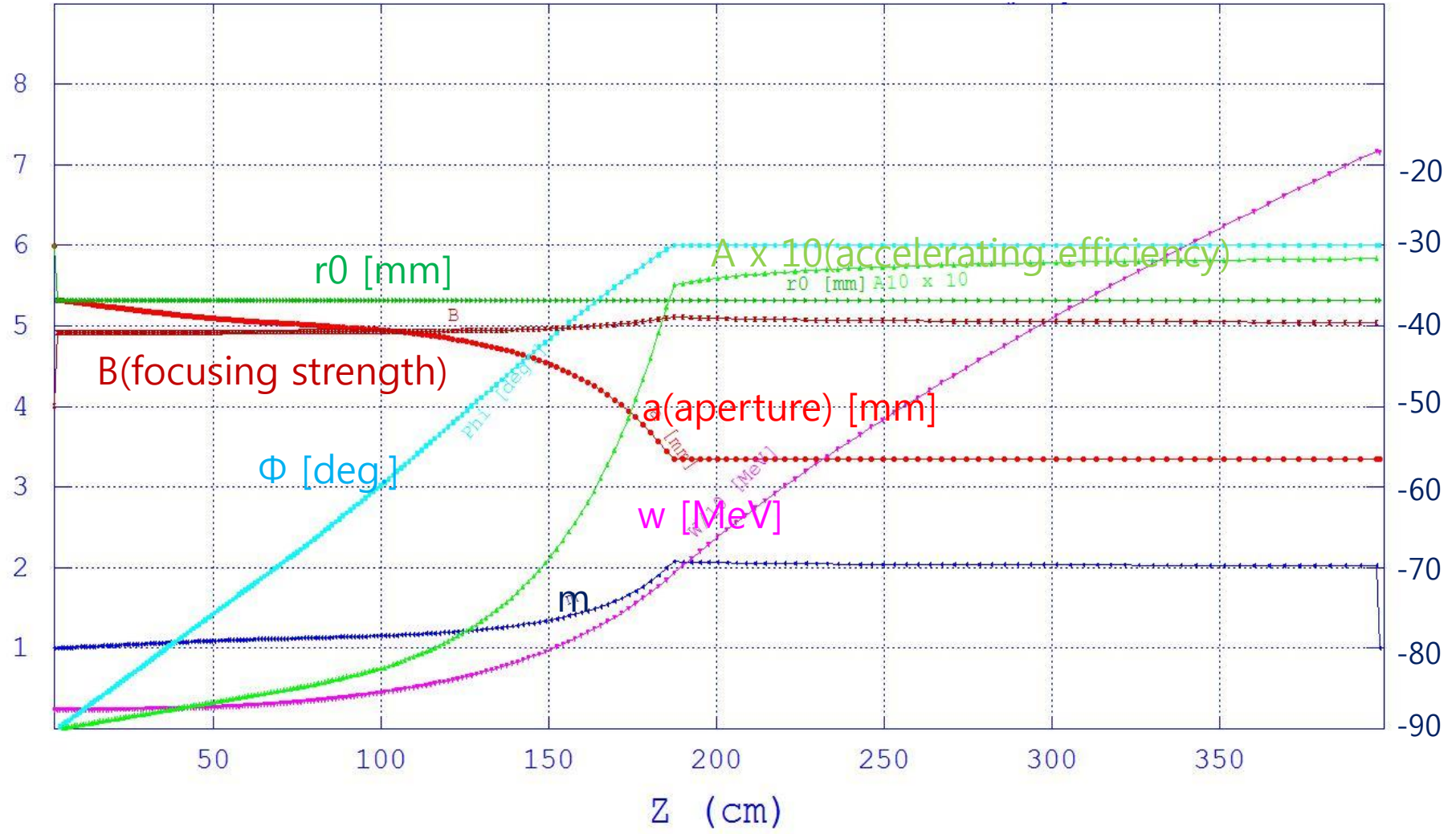
Longitudinal beam distribution at the entrance of RFQ.

RFQ

Frequency	81.25 MHz
Input Energy	10 keV/u
Output Energy	300 keV/u
Current	12 pμA
Wg	19 MeV
Mass[amu]	238
Charge	33.5(33 , 34)
Vane voltage	70 kV
M(modulation)	1 ~ 2
Phase	-90 → -30 deg
B(focusing strength)	5.08
A(accelerating efficiency)	0.55
Peak field($E_{kilpatrick}$)	1.68

	Length [cm]	Cell
Radial matching	3.42	4
Shaper	75.64	84
Gentle buncher	105.97	72
Accelerating section	212.76	59
Total	397.79	219

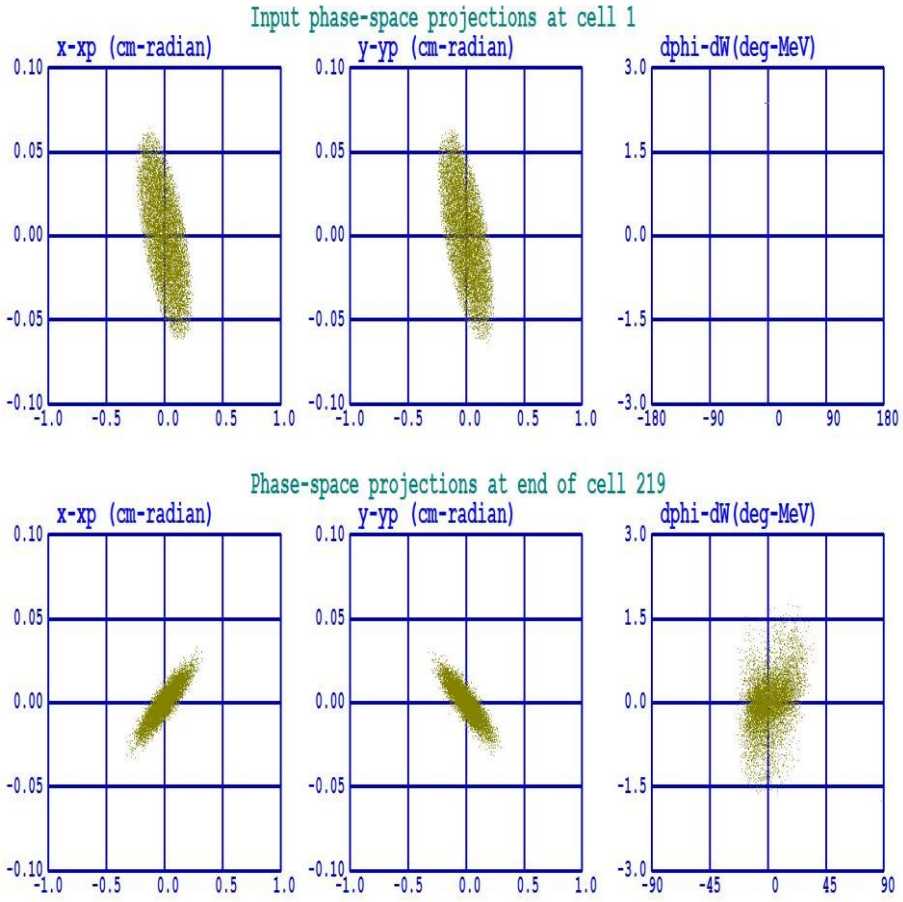
RFQ
(PARMTEQ simulation)

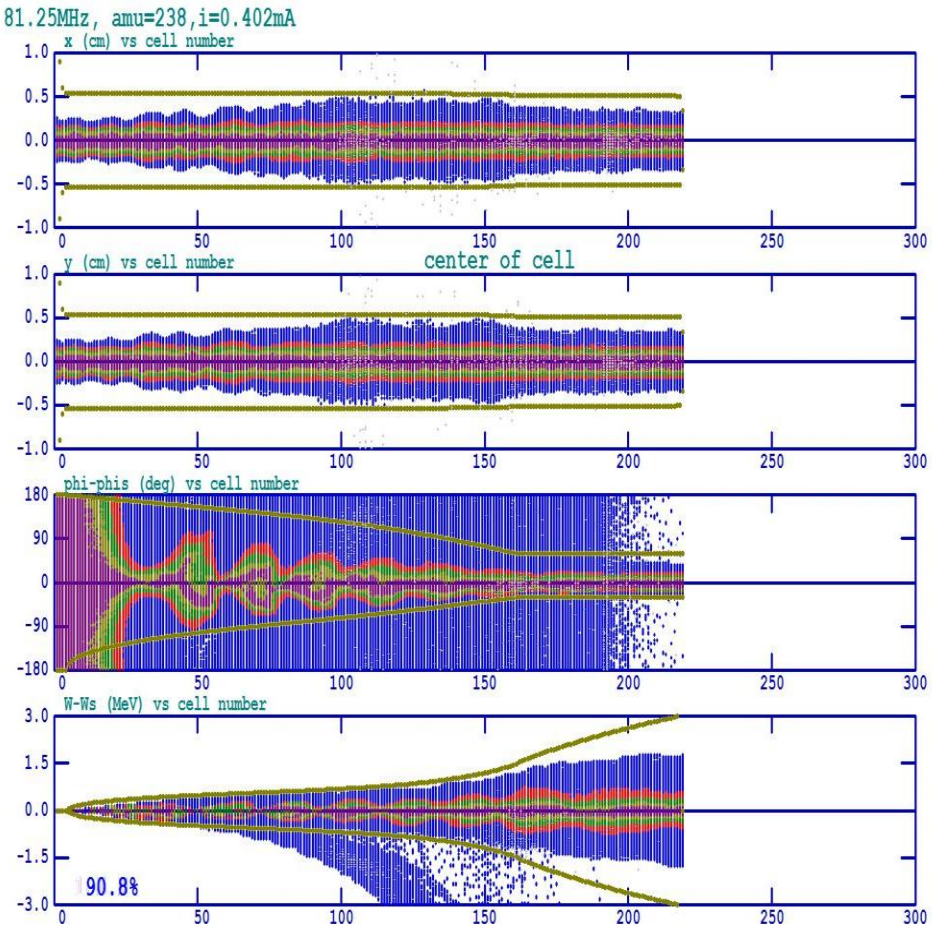


Transmission : 90%

RFQ

(PARMTEQ simulation)





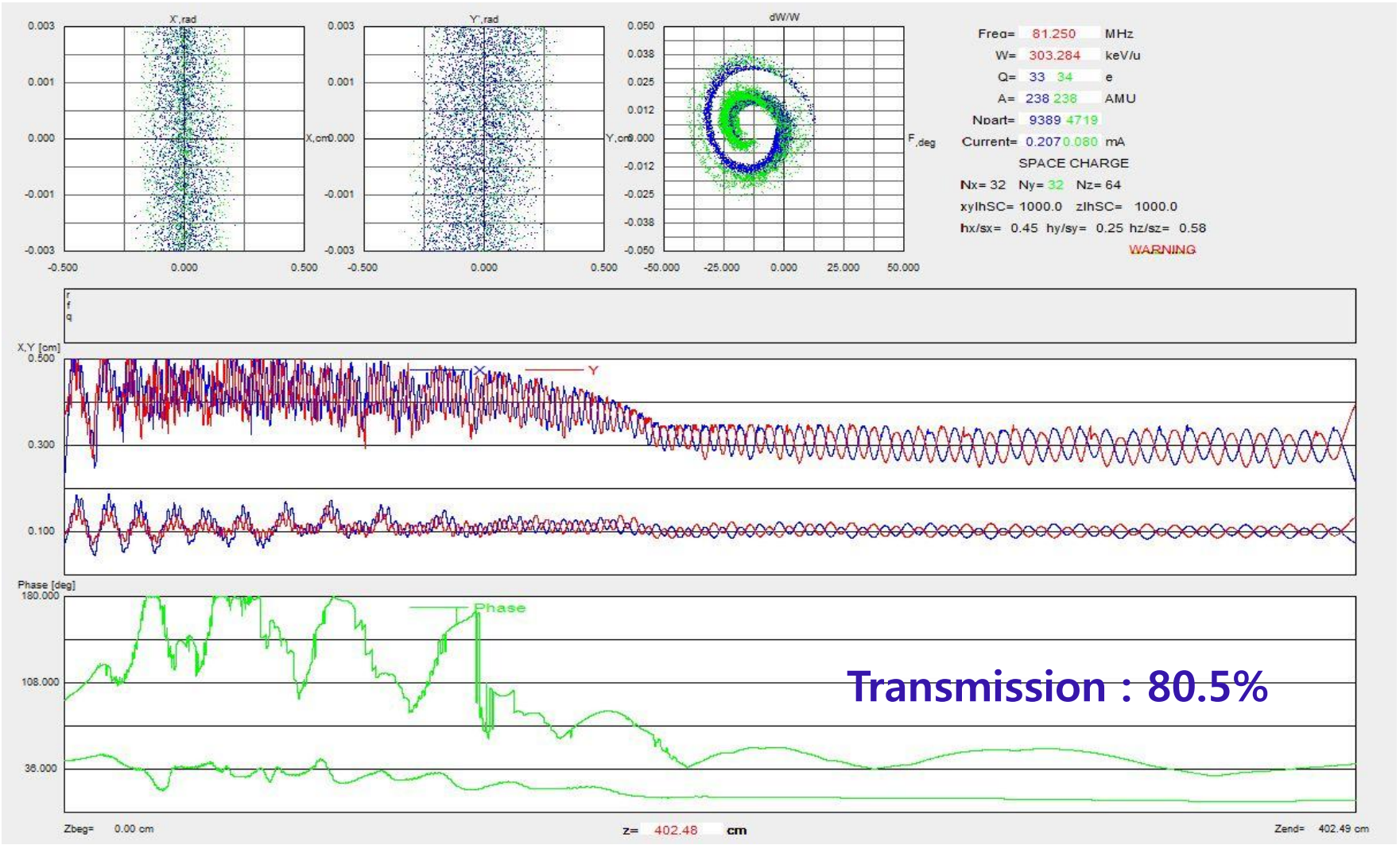
rms

ε_x=0.10 mm-mrad, ε_y=0.10 mm-mrad @ entrance of RFQ

ε_x=0.12 mm-mrad, ε_y=0.12 mm-mrad, ε_z=6.6 MeV-deg @ exit of RFQ

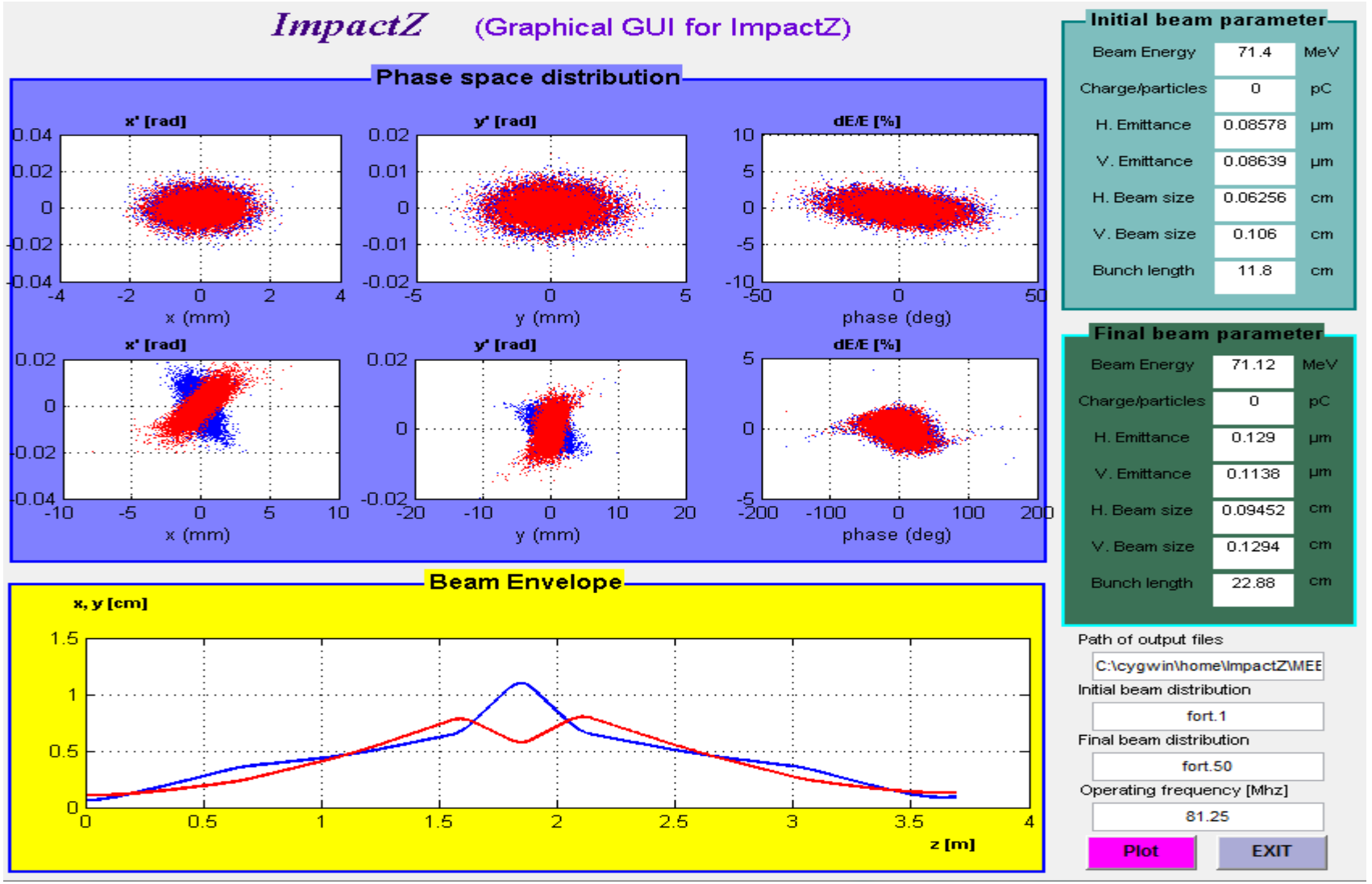
RFQ

By using a beam from LEBT with bunchers (TRACK)



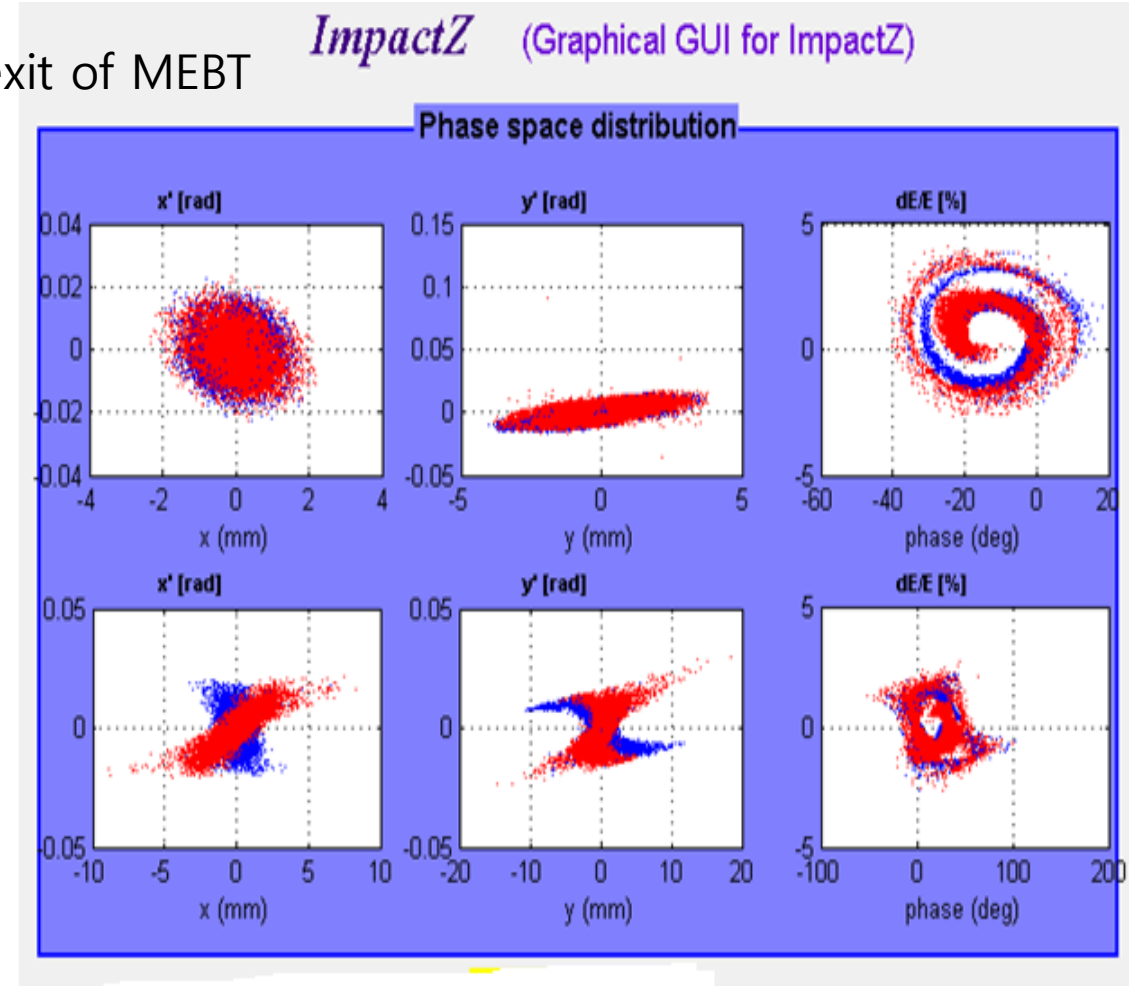
ε_x=0.12 mm-mrad, ε_y=0.18 mm-mrad, ε_z=8.2 MeV-deg @ exit of RFQ

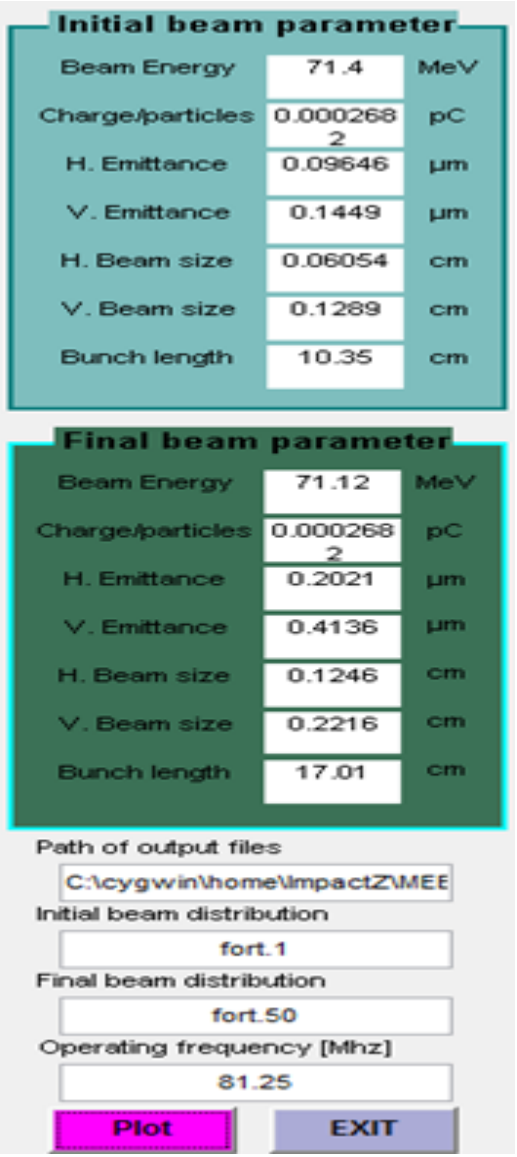
MEBT
(5 Quads + 2 Re-bunchers)



Front-End Simulations (LEBT-RFQ-MEBT)

at the exit of MEBT





$\varepsilon_x/\varepsilon_y$=0.19/0.14 mm-mrad, ε_z=9.3 MeV-deg

@ the exit of MEBT

Beam parameters from Front-End simulations

With Bunchers	Number of Particle	Transm. (%)	Current[mA] 33+, 34+	Nor.rms_x [mmmrad]	Nor. rms _y [mmmrad]	Nor. rms _z [deg-MeV]
Initial	20000	100	0.22, 0.17	0.100	0.100	3.66
LEBT	19253	96.27	0.22, 0.16	0.109	0.174	3.15
RFQ	16093	80.47	0.19, 0.13	0.122	0.183	8.27
MEBT	15790	78.95	0.19, 0.12	0.194	0.140	9.3

Used simulation codes

ECR-IS	LEBT	RFQ	MEBT
Opera3D WARP(plan)	TRANSPORT IMPACT TRACE3D	PARMTEQ TRACK	TRACE3D IMPACT

Summary and Plans

- First beam simulations for FRONT-END were performed to optimize the beam and accelerator parameters for two-charge state beam.
- Beam diagnostics will be designed and proto-type of RFQ will be fabricated.
- Multi-harmonic buncher in LEBT will be considered and beam from ECR-IS will be used for the front-end simulations.

Summary and Plans

- Front-End with charge-breeder for re-accelerator will be designed and optimized.