Beam Physics Challenges in RAON

HB2014 workshop

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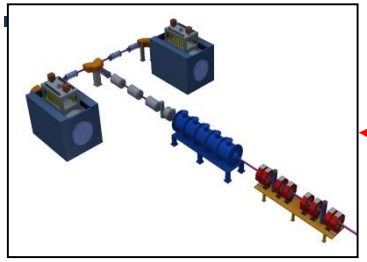
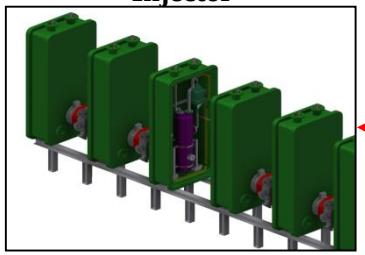
Hyung Jin Kim, ASD members (RISP/IBS)
Ji-Kwnag Hwang, Eun-San Kim (KNU)

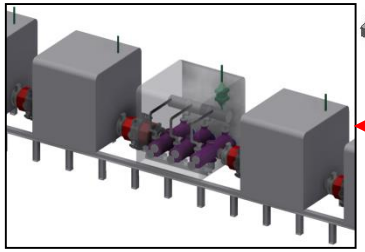
RAON Layout and Beam Parameters



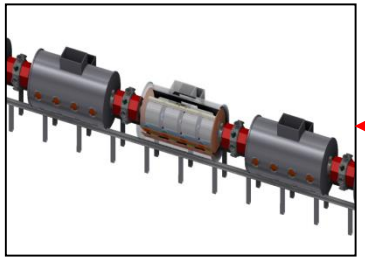
Injector



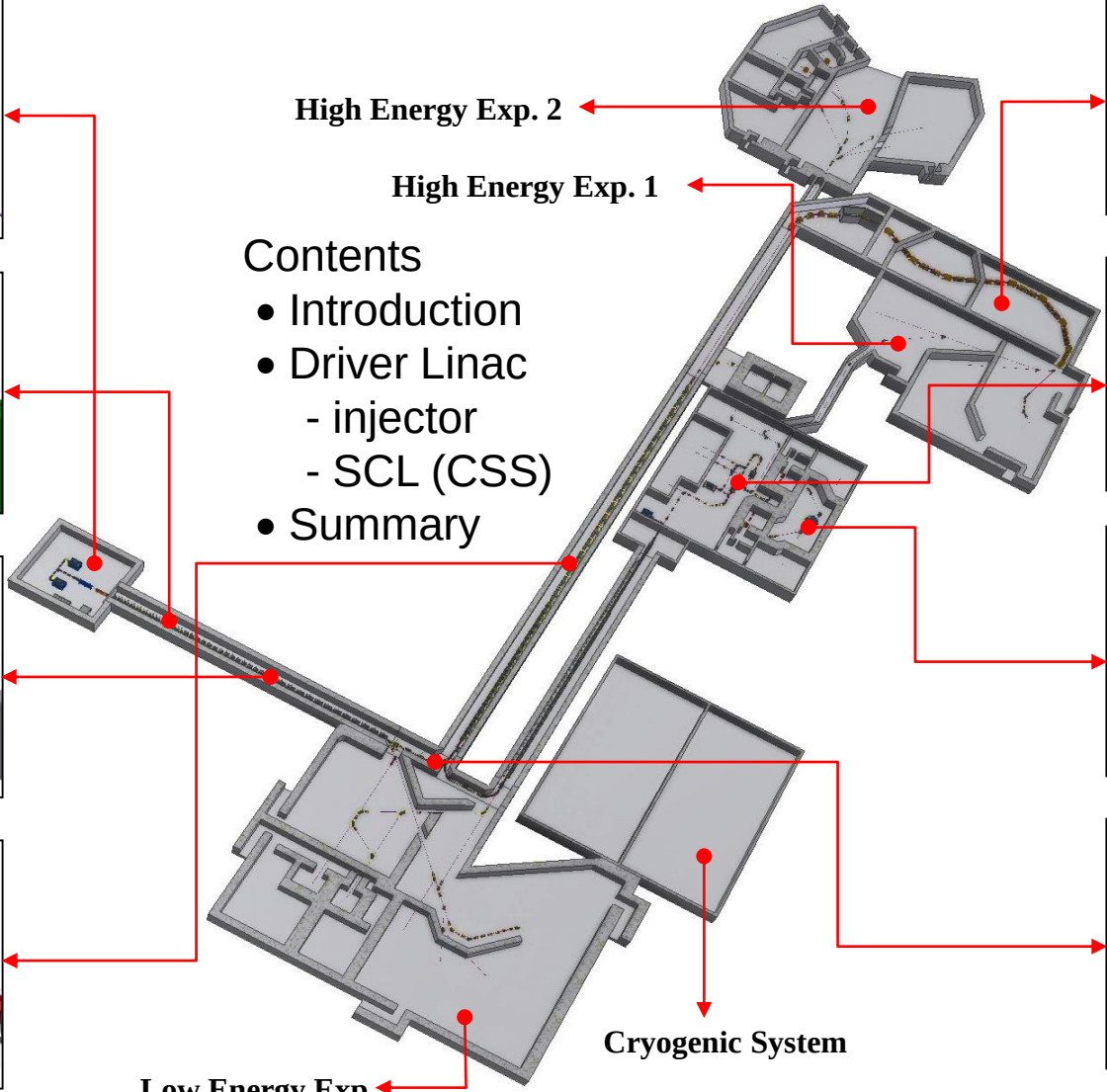
SCL1(QWR)



SCL1(HWR)

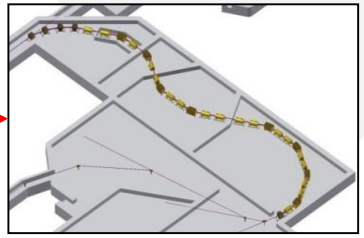


SCL2(SSR)

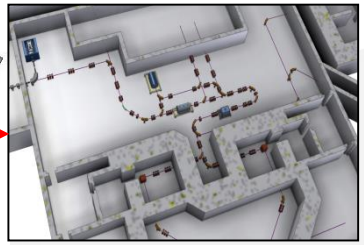


Contents

- Introduction
- Driver Linac
  - injector
  - SCL (CSS)
- Summary



IF SYSTEM



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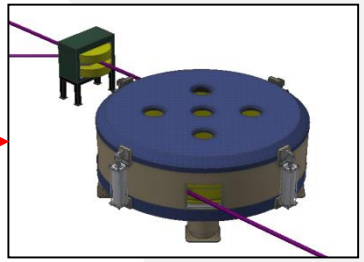
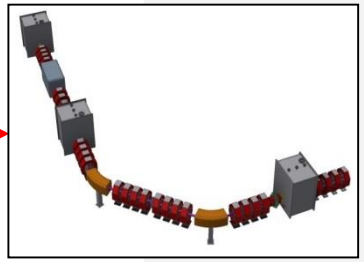


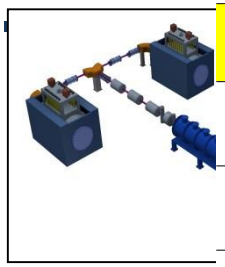
Cyclotron



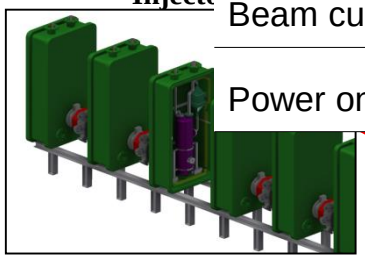
Charge Stripper

RAON Layout and Beam Parameters

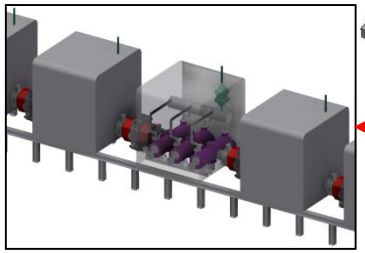
	Driver Linac				Post Acc.	Cyclotron
Particle	H^{+}	O^{+8}	Xe^{+54}	U^{+79}	RI beam	proton
Beam energy (MeV/u)	600	320	251	200	18.5	70
Beam current (pμA)	660	78	11	8.3	-	1000
Power on target (kW)	> 400	400	400	400	-	70



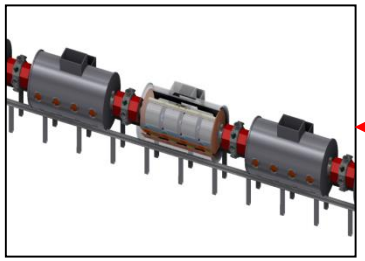
Injecto



SCL1(QWR)



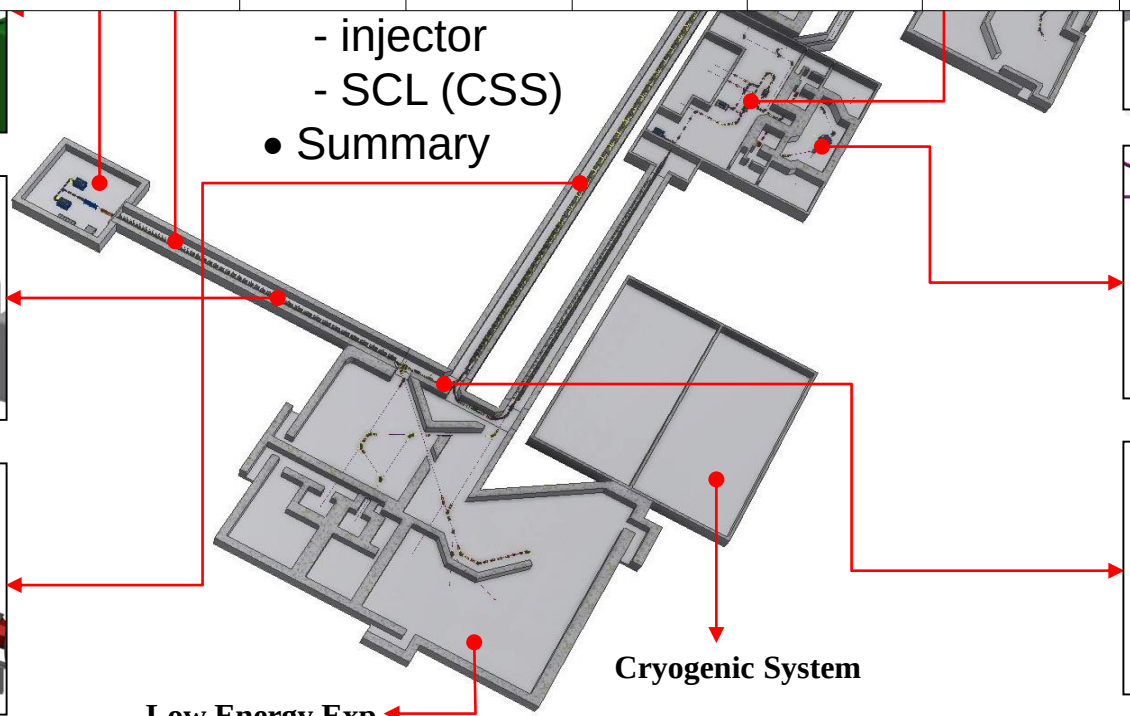
SCL1(HWR)



SCL2(SSR)

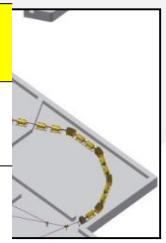
- injector
- SCL (CSS)

• Summary

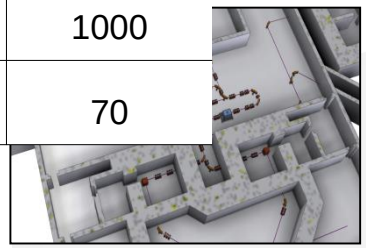


Low Energy Exp.

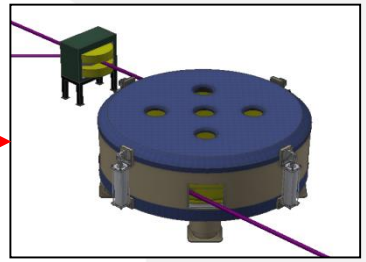
Cryogenic System



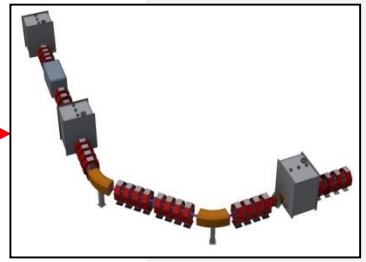
TEM



ISOL

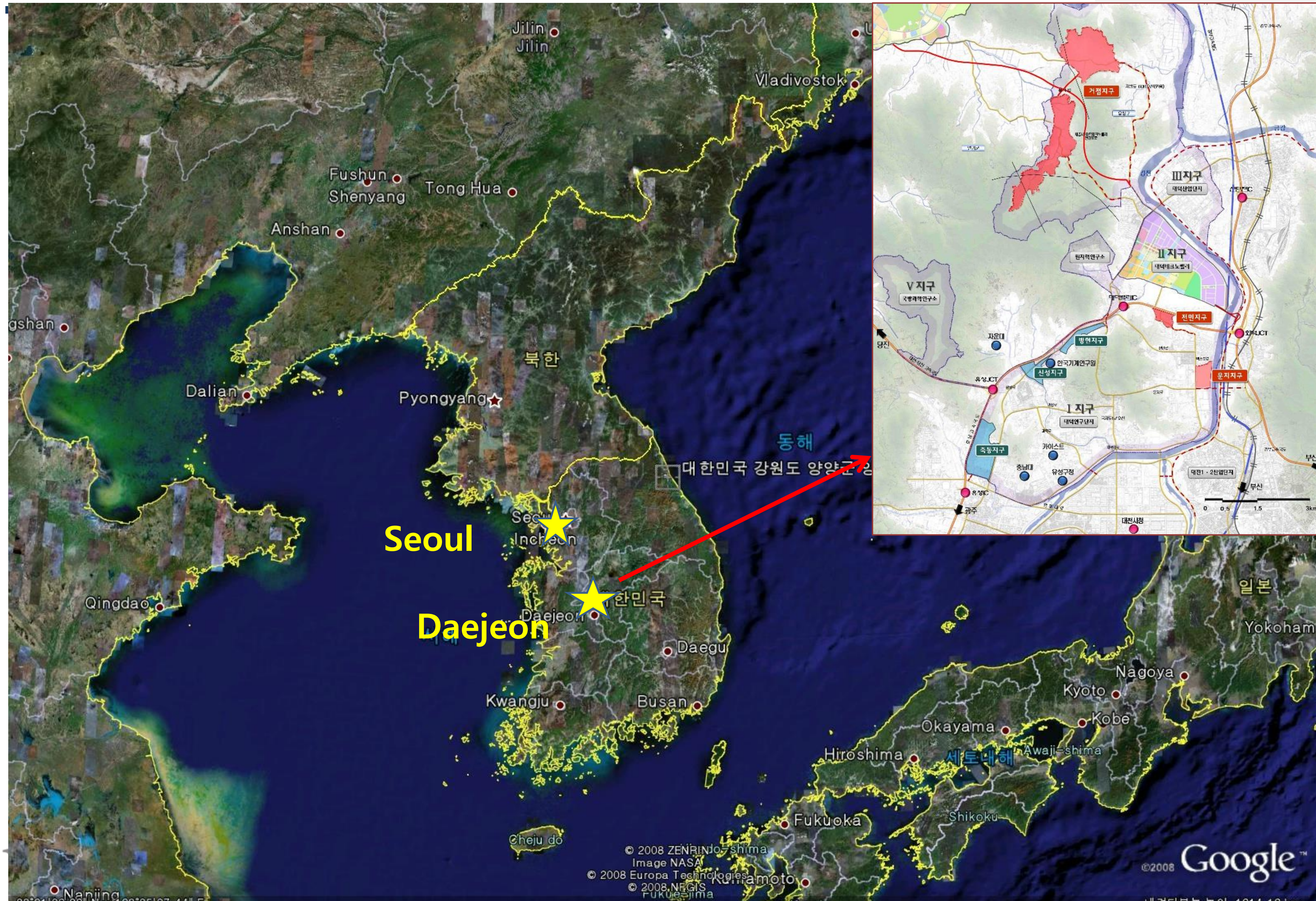


Cyclotron



Charge Stripper

RAON Site



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충남대
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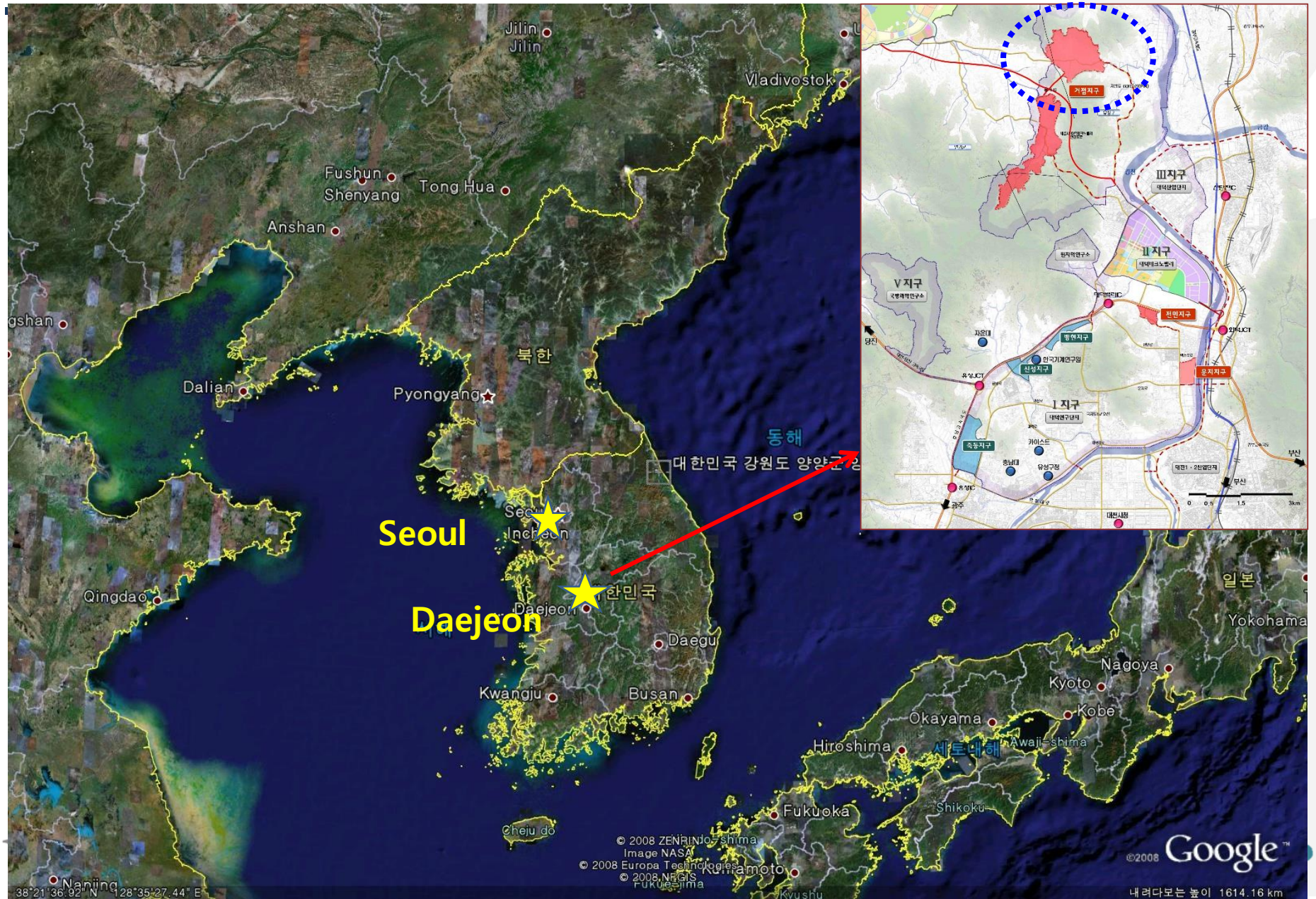
대전시청
유성JCT
회덕JCT
부산
광주
당진
0 0.5 1.5 3km

RAON Site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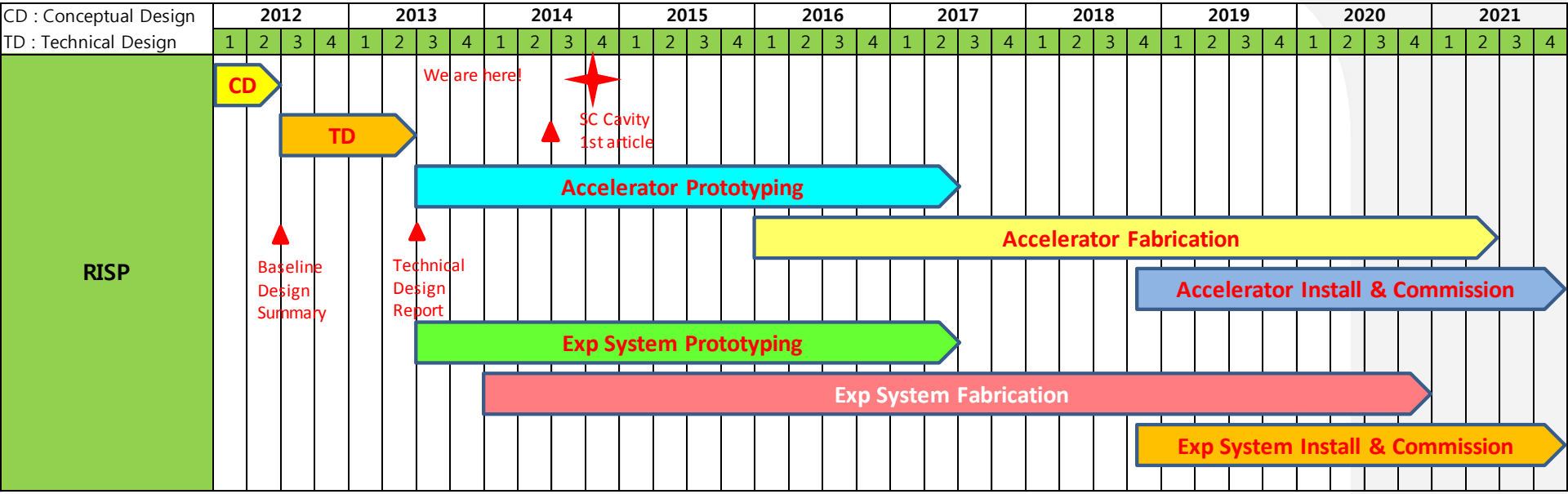
Ⅴ지구
전인지구
Ⅰ지구
신성지구
부산

Budget and Schedule

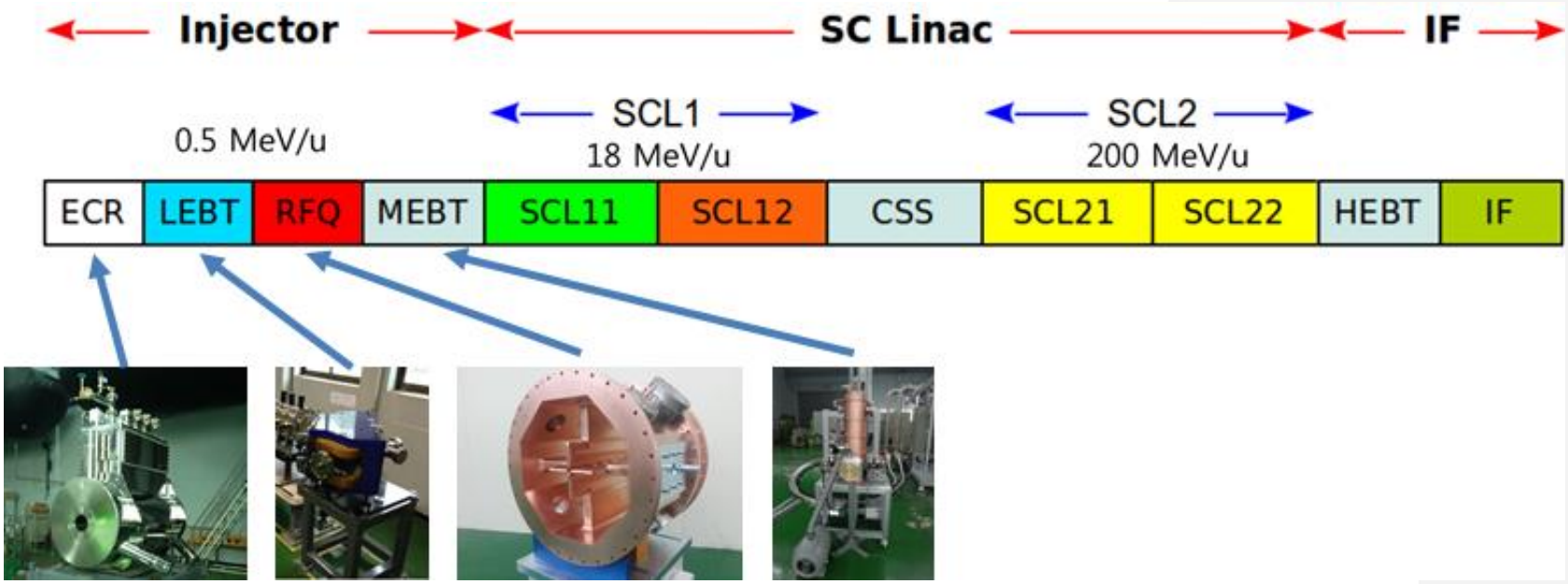
- The RAON Project Cost
  Accelerator and Experimental Systems : $420M (46.02B KRW)
  Conventional Facility : $568M (62.43B KRW)
  Site Cost : $327M (36.00B KRW)

- Conventional facility budget was finalized 2014.05.
- Construction to be completed by 2021.12.



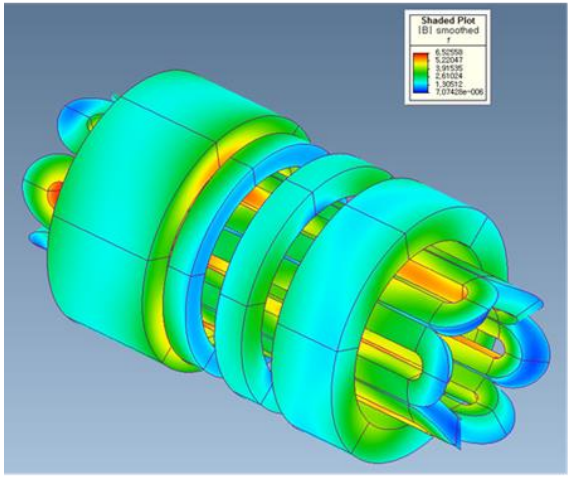
RAON Injector

- Injector consists of ECR IS, LEBT, RFQ and MEBT
- Two charge states (33, 34) of Uranium beams
- Fabrication of prototype components finished and their tests are in progress.

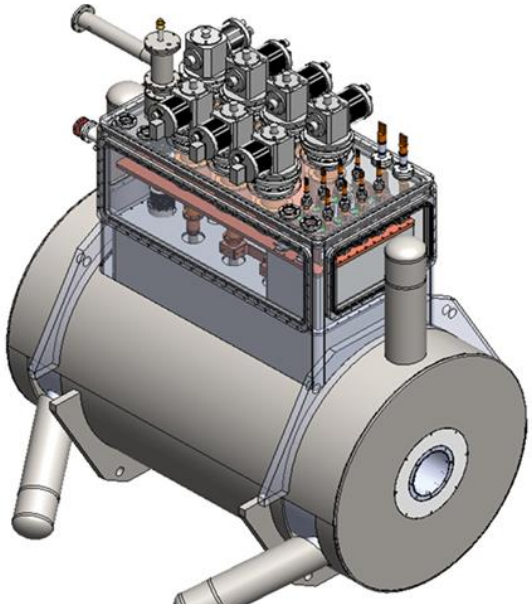


28 GHz ECR Ion Source

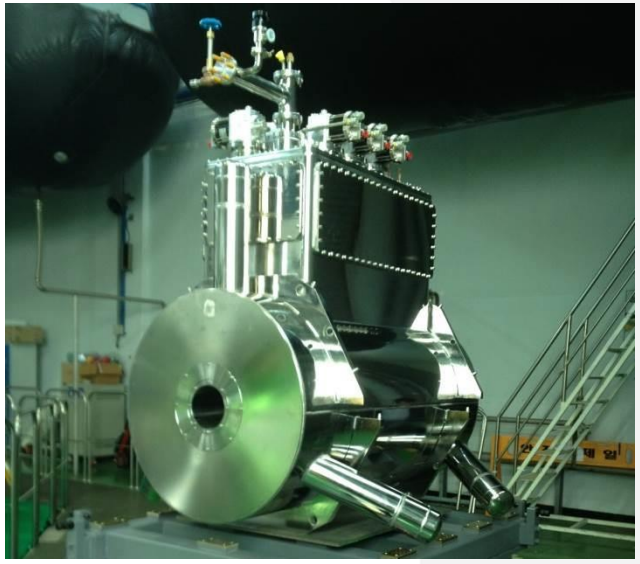
- Superconducting sextupole and solenoid prototypes were tested and achieved > 30% margin.
- Superconducting magnet assembly (sextupole + 4 solenoids) was completed.
- Cryostat fabrication was completed and test will be performed.
- Preparing for beam test in late 2014.



B_{inj}= 3.5 T, B_{ext}= 2.2 T,
B_r= 2 B_{ecr} , B_{min}= 0.7 T



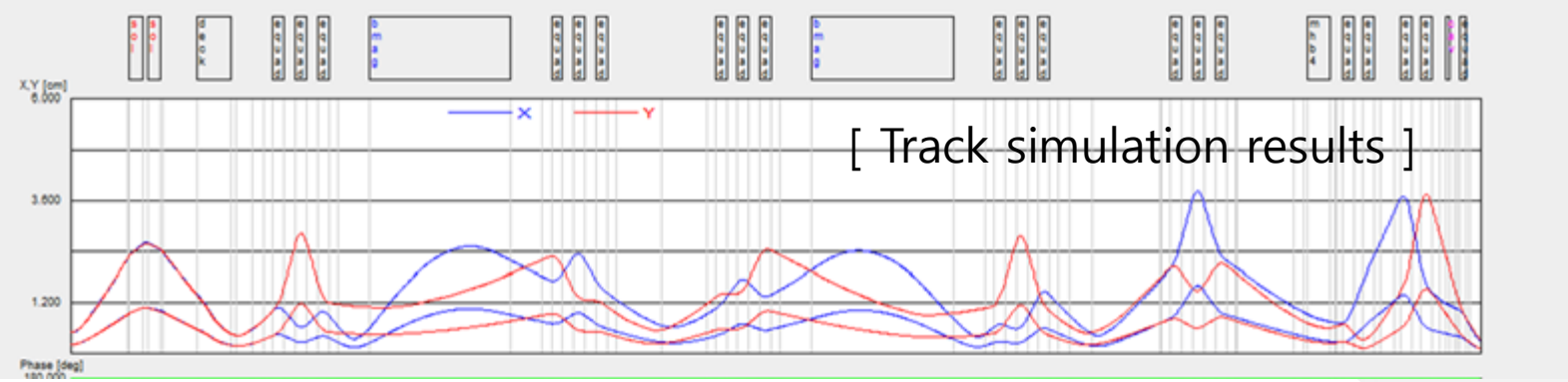
Six 4K cryocoolers,
One single stage cryocooler

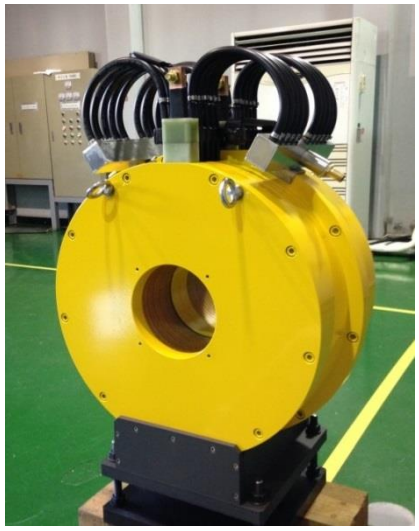


Cryostat fabrication

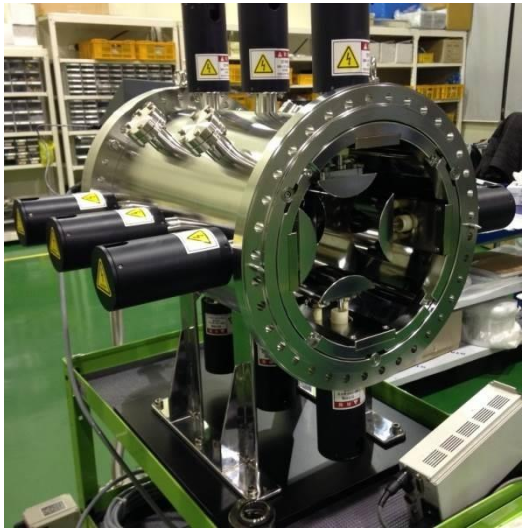
LEBT

- Electrostatic quadrupoles: two charge states for uranium beams (33,34)
- MHB and VE: reducing rms beam emittance of RFQ output beams.

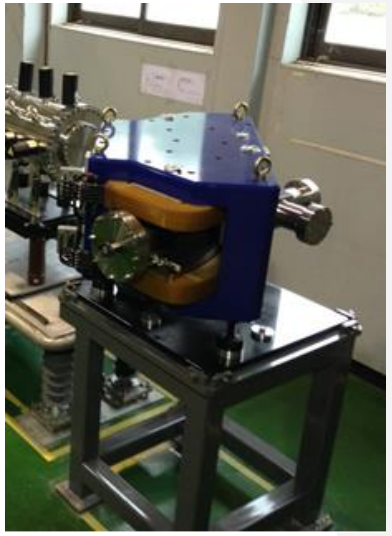




[Solenoids]



[ESQ triplet]

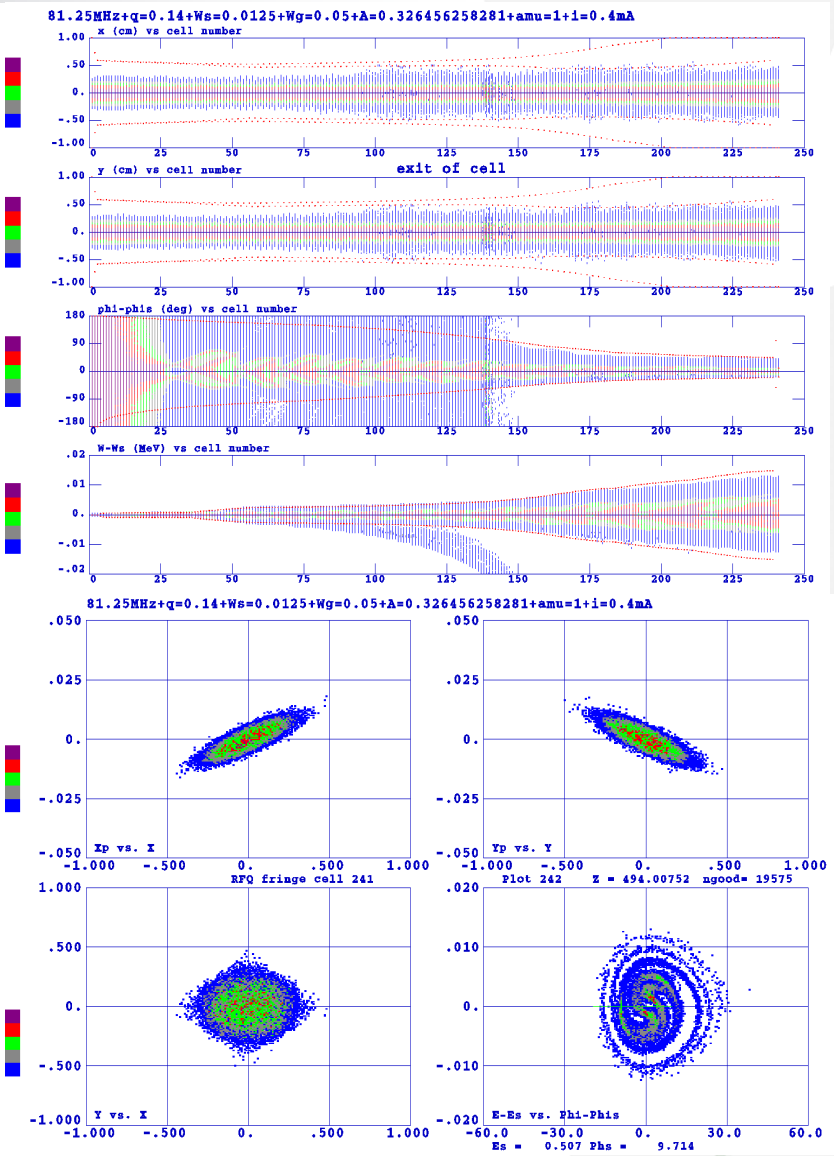


[Bending Magnet]

RFQ Beam Dynamics Design

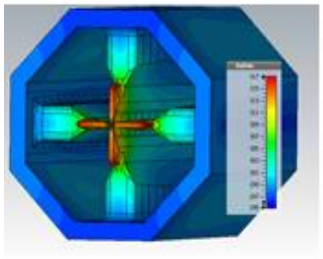
[RFQ parameters]

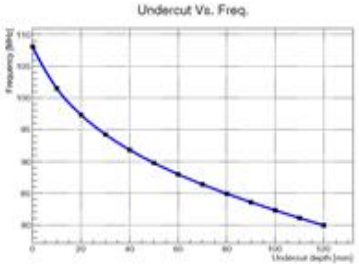
Parameters	Values
Particles	Proton ~ $^{238}U^{33+,34+}$
Frequency	81.25 MHz
Input/Output Energy	10keV/u, 500 keV/u
Peak Surface Field	1.7 Kilpartic
Type	Four Vane
Operation Mode	CW
Transmission	98%
Length	4.94 m

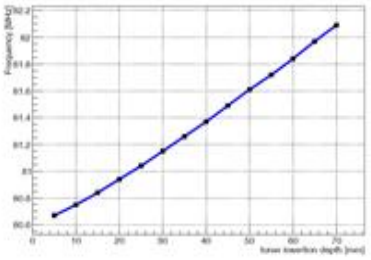


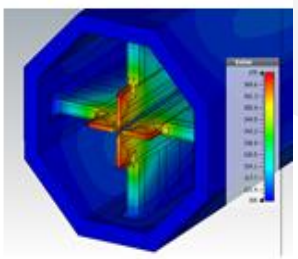
[PARMTEQ simulation]

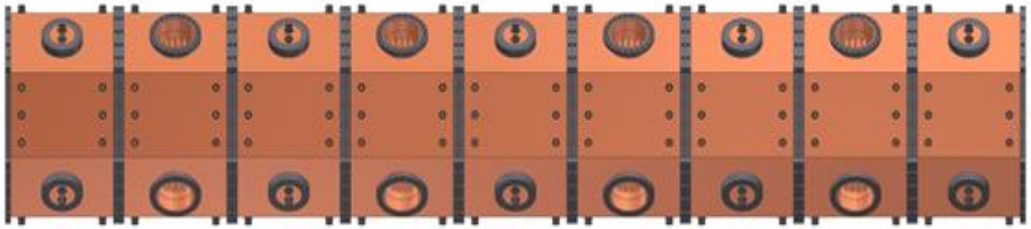
RFQ Engineering Design



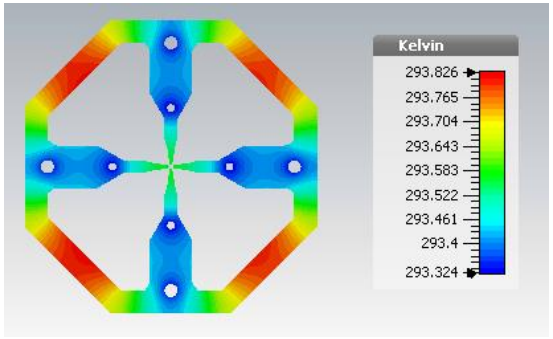




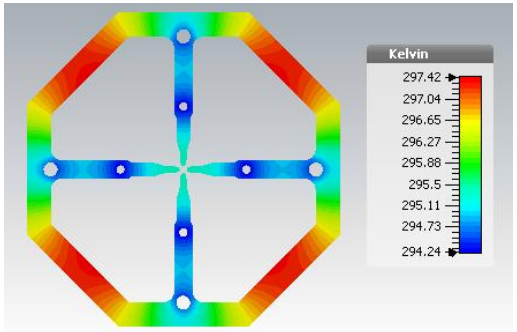




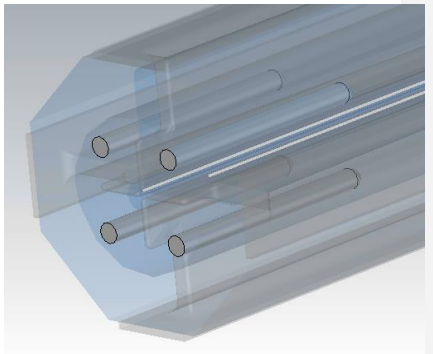
LE End



HE End



Mode separation 1.84 MHz

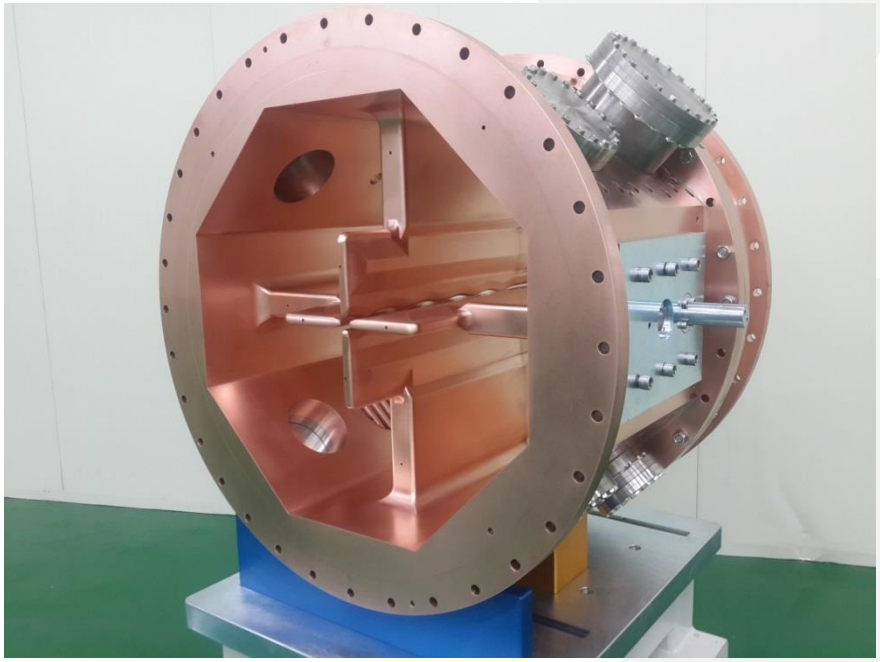


Technical design was completed (August 2013) and reviewed November 2013.

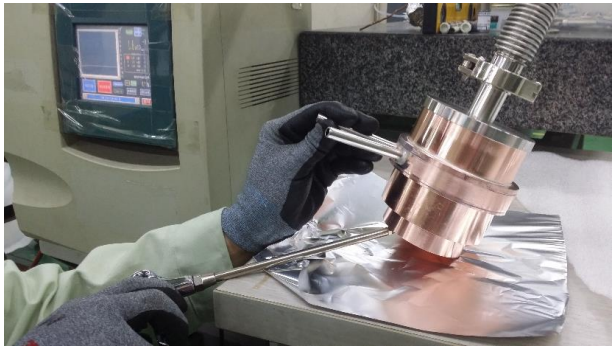
RFQ Prototype

- RFQ Prototype
  - vane machining and 3D measurement
  - The 1st brazing failed (2014.04)
  - Brazing procedure modified (2014.05)
  - Confirmed brazing procedure (2014.06)
  - **RFQ prototype completed successfully through domestic vendor (2014.10)**

- RFQ Prototype test
  - 15kW SSA, coupler, RCCS are ready



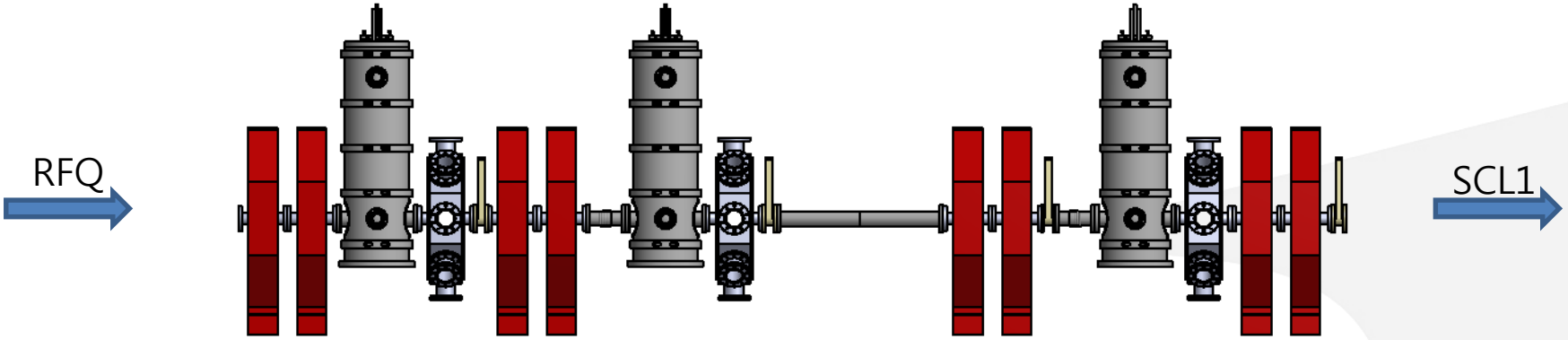
[prototype RFQ]

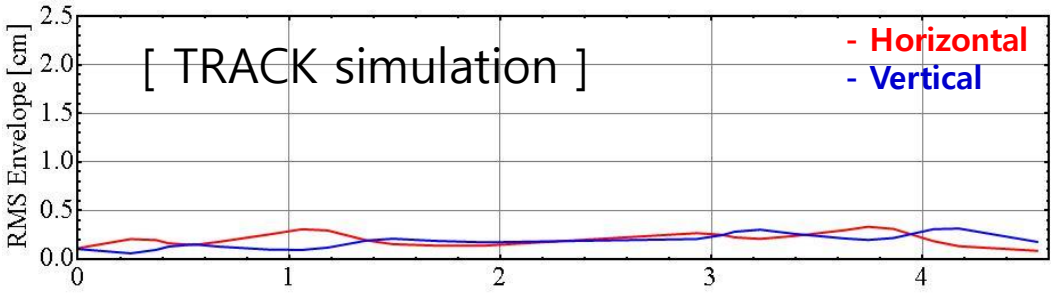


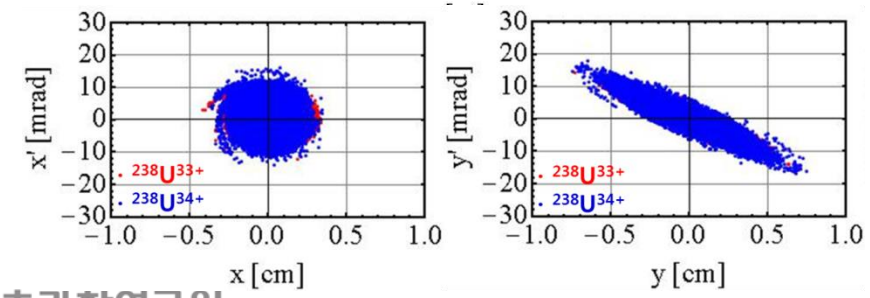
[RFQ coupler leak test]

MEBT

- MEBT: 8 quadrupole magnets, 3 rebuncher cavities
- MHB and VE: reducing rms beam emittance of RFQ output beams.





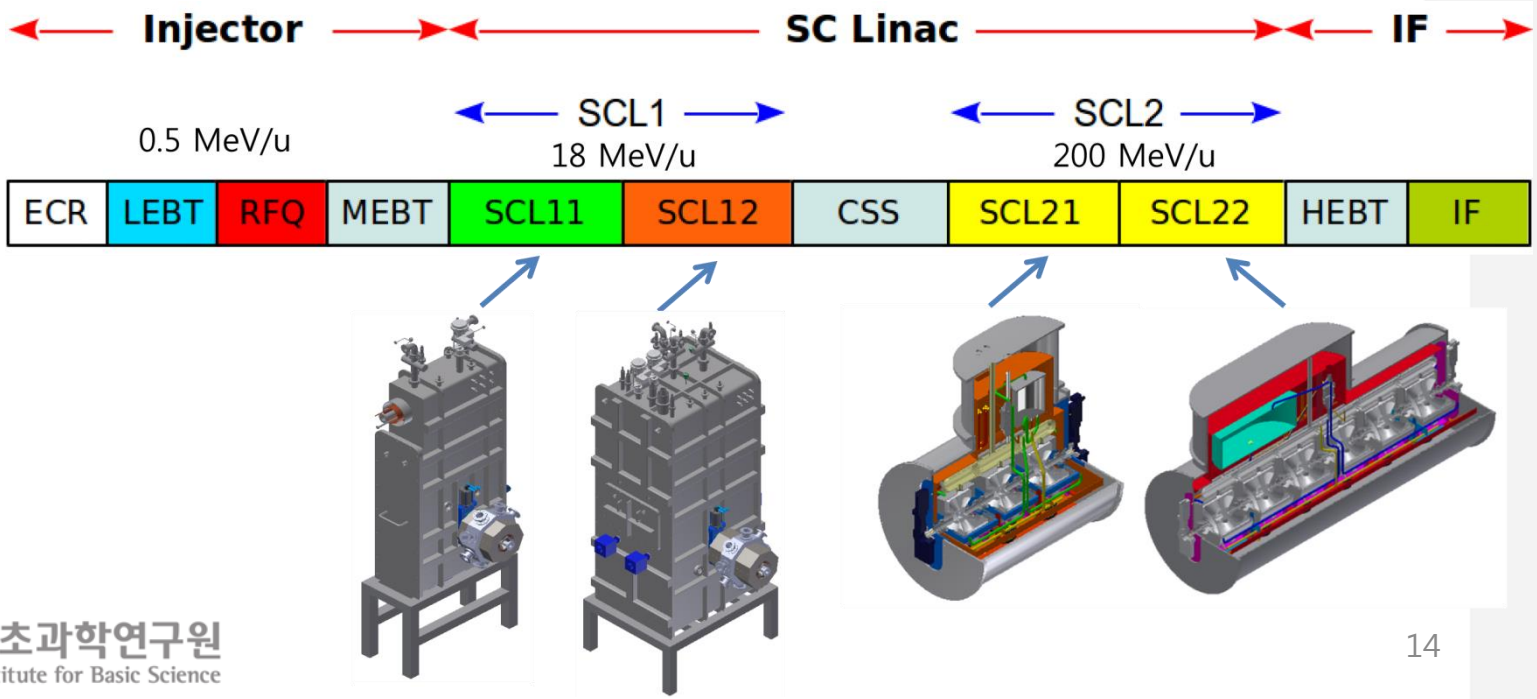


[Particle distribution at exit of MEBT]

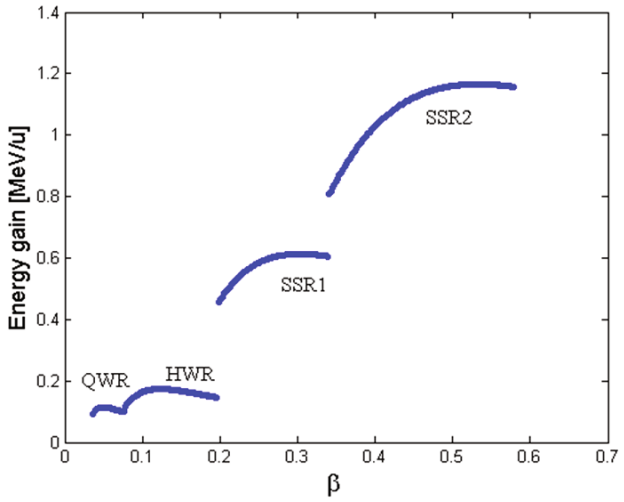
[Rebuncher cavity]

RAON Superconducting Linac

- RAON SCL is designed to accelerate high intensity beams.
- Focusing by NC quad doublets rather than SC solenoids.
- Optimized geometric beta of SC cavities (0.047, 0.12, 0.30, 0.51).
- Employs larger aperture to reduce beam loss (40 / 50 mm aperture).
- Prototyping of SC cavities and cryomodules is under way and preparing for test.



Superconducting cavity



[Energy gain]

[Design Parameters]

Parameters	Unit	QWR	HWR	SSR1	SSR2
b_g	-	0.047	0.12	0.30	0.51
F	MHz	81.25	162.5	325	325
Aperture	mm	40	40	50	50
QR_s	Ohm	22	42	94	112
R/Q	Ohm	468	310	246	296
V_{acc}	MV	1.1	1.5	2.4	4.1
E_{peak}	MV/m	35	35	35	35
B_{peak}	mT	57	55	58	64
$Q_{calc}/10^9$	-	2.1	4.2	9.0	10.5
Temp.	K	4.5	2	2	2

[QWR]

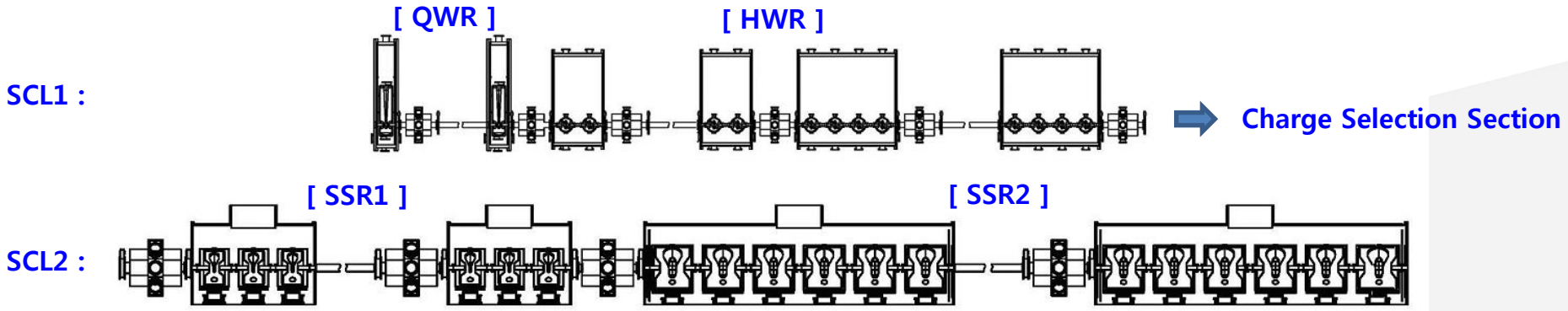
[HWR]

[SSR1]

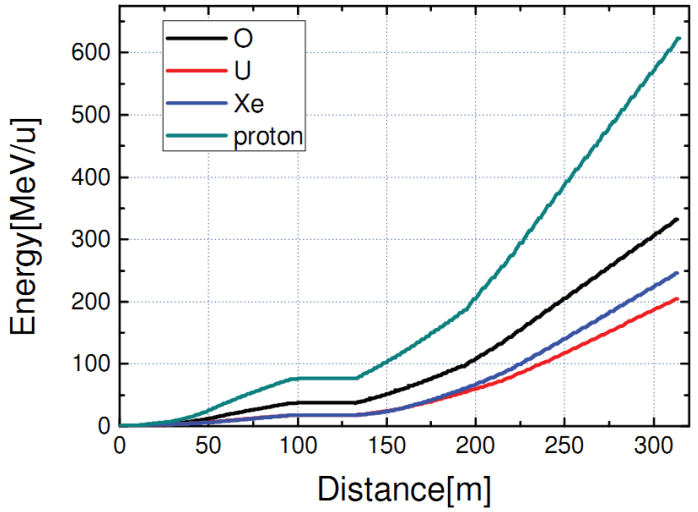
[SSR2]

Beam Dynamics in Linac (1/2)

- Lattice: Doublet with normal conducting quadrupole magnets
- $^{238}U^{33+,34+}$ in SCL1, $^{238}U^{77+\sim81+}$ in SCL2 after CSS

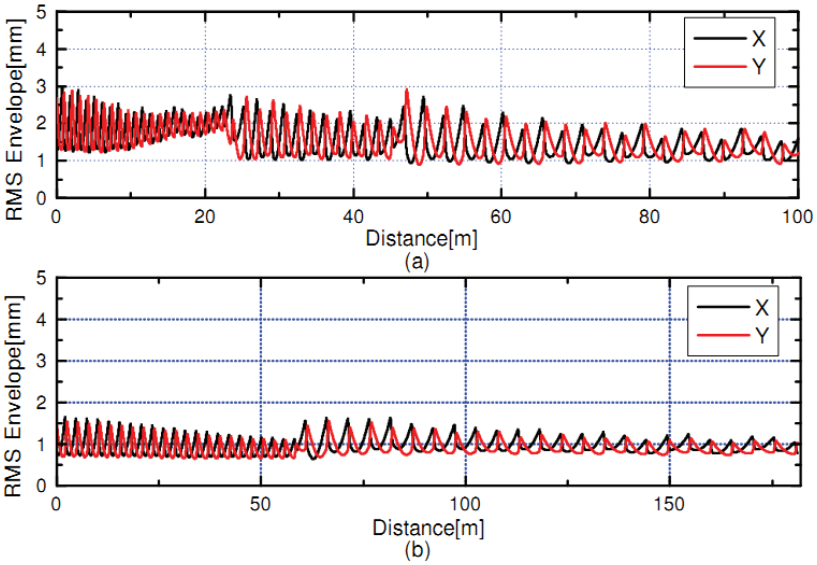


	SCL11	SCL12		SCL21	SCL22
CM#	22	13	19	23	23
Cav. # / CM	1	2	4	3	6
Cav. Type	QWR	HWR	HWR	SSR1	SSR2

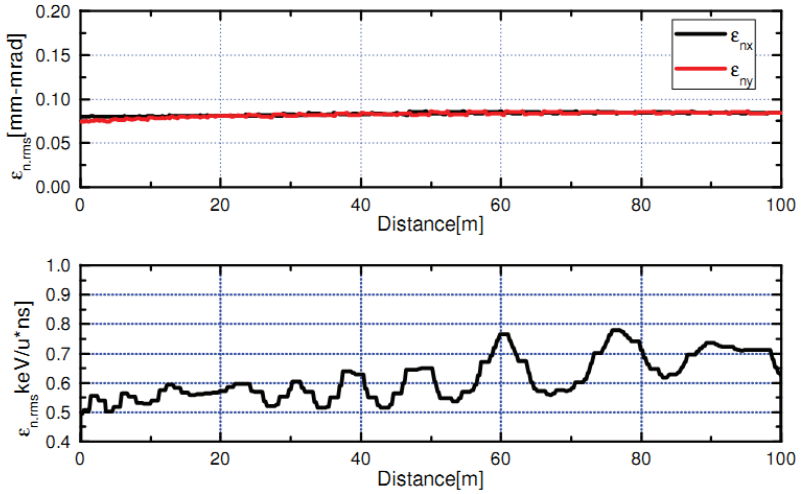


[Final Energy]

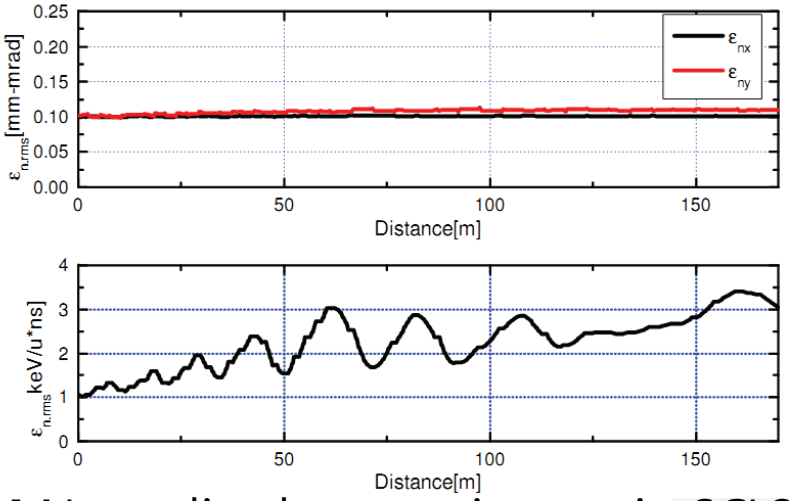
Beam Dynamics in Linac (2/2)



[Beam Envelope (rms)]



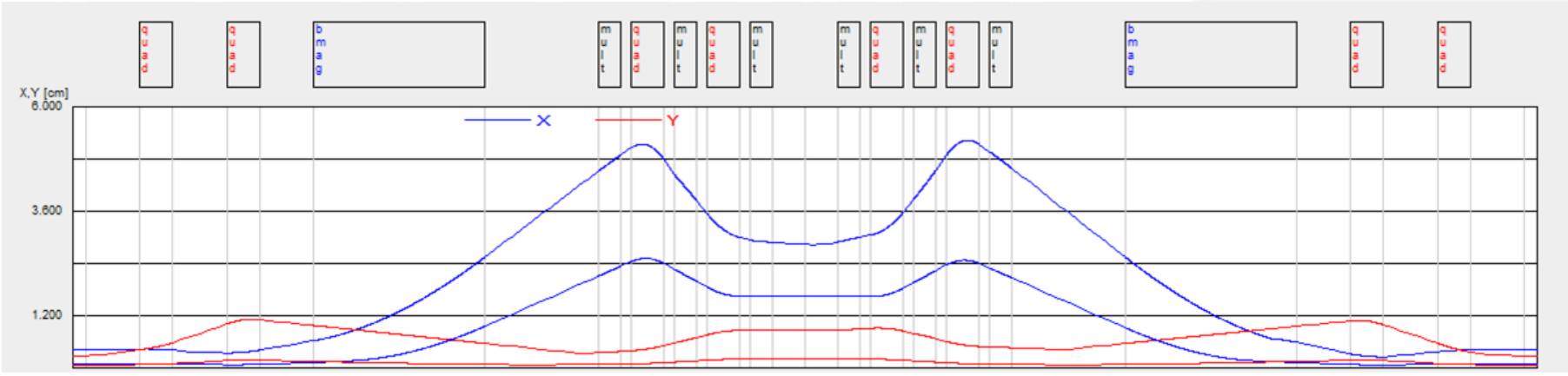
[Normalized rms emittance in SCL1]



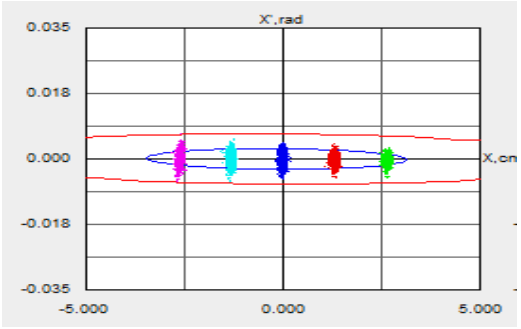
[Normalized rms emittance in SCL2]

Charge Selection Section

- 90-degree bending section: using mirror symmetry
- 2nd order achromat : 6 sextupole magnet to minimize T_{126}, T_{266}, T_{436}
- Emittance growth: $\Delta\varepsilon_x$ = 1.8%, $\Delta\varepsilon_y$ = 1.5%,
  (first order achromat: $\Delta\varepsilon_x$ = 23.6%)



[TRACK simulation results]



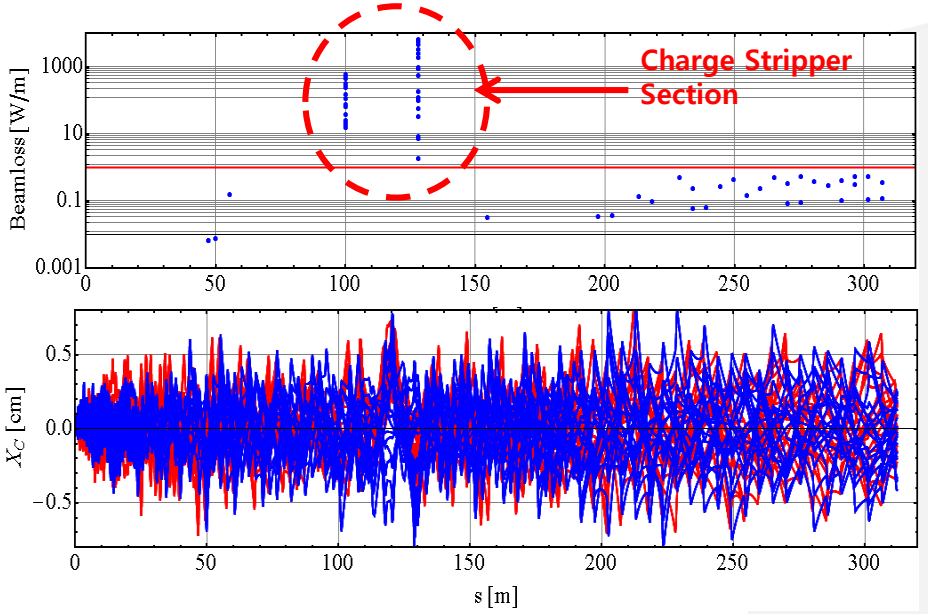
[Particle distribution at center of CSS]

Machine Imperfection Effects

- Beam loss requirement (1W/m) is met even without orbit correction.
- It is expected that beam loss will reduce with orbit correction.

Item	Quantity	Error
Cavity	Misalignment	1mm
	Tilt	5 mrad
	Voltage, phase	1%, 1°
Quadrupole	Misalignment	0.15mm
	Tilt	5 mrad
	Magnetic field	1%

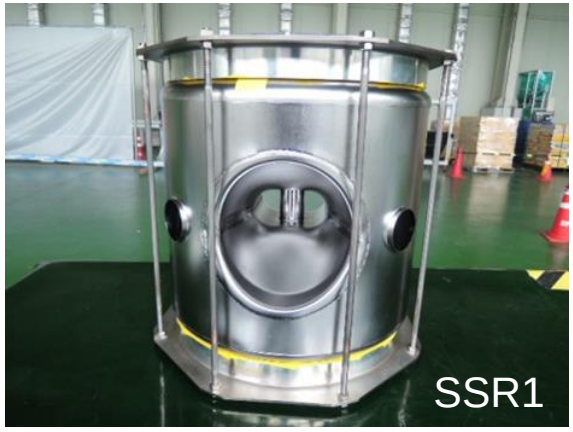
[Error Limit]



[Beam Loss Result]

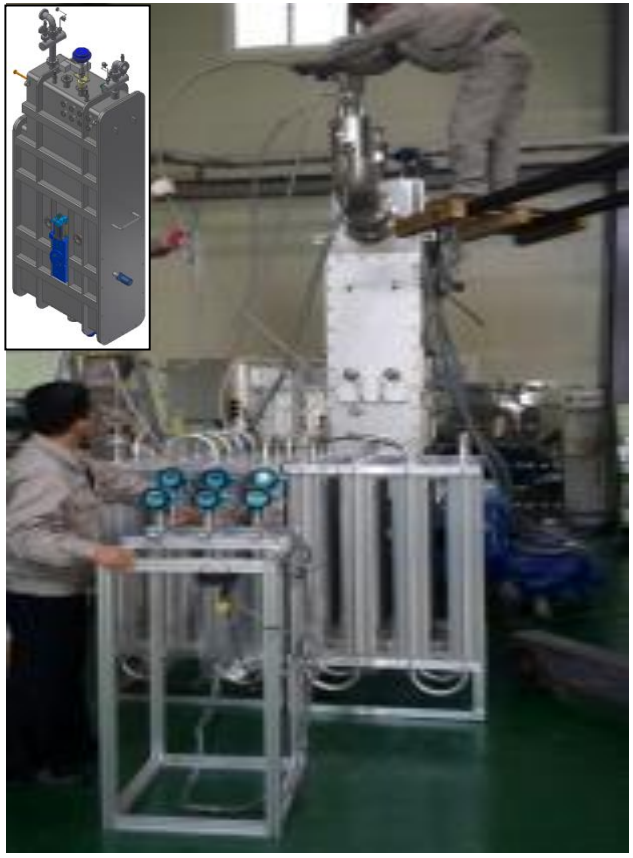
SC Cavity Prototyping

- Prototype superconducting cavities are fabricated through domestic venders.



Cryomodule Prototyping

- Fabrication of QWR and HWR cryomodule prototypes is completed.
- LN_2 test is performed from Oct/22/2014.
- LHe test will be performed afterward.



[QWR cryomodule]

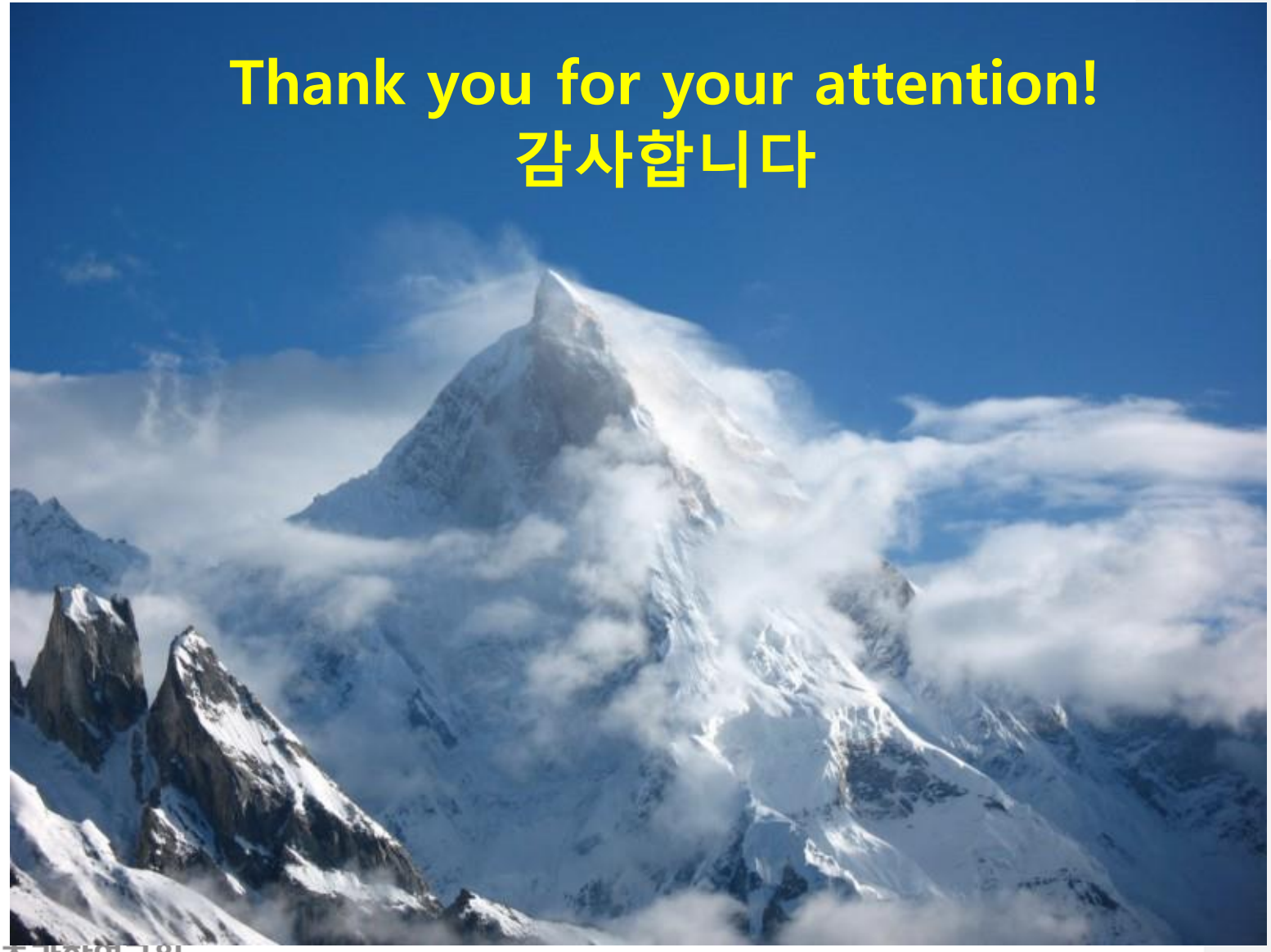
[HWR cryomodule]

Summary (1/2)

- Integration of independent ISOL & IF systems is one of the distinct feature of the RAON.
- Technical Design Report was completed in 2013.09 meeting the project milestone.
- Optimization in beam dynamics is in progress.
- Prototyping of major accelerator parts has been in progress since 2013 through domestic vendors.
  - ECR ion source cryostat was fabricated (2014.09)
  - RFQ prototype fabricated successfully (2014.10)
  - SC cavity prototypes were delivered for test (since 2014.05)
  - Cryomodule prototypes to be delivered from 2014.12
- Some prototypes are in testing stage.
  - ECR ion source, RFQ, MEBT buncher
  - Superconducting cavities (QWR, HWR)

Summary (1/2)

- Experimental systems are being developed in parallel.
  - KOBRA is the first experimental system at RAON, which is a recoil spectrometer for nuclear structure and nuclear astrophysics studies.
  - MR-TOF system will be developed as a high precision mass measurement system by 2018.
- The conventional facility budget for the RAON was finalized in 2014.05.
- Conventional facility preliminary design contract is to be signed by Nov/28/2014.


Thank you for your attention!
감사합니다