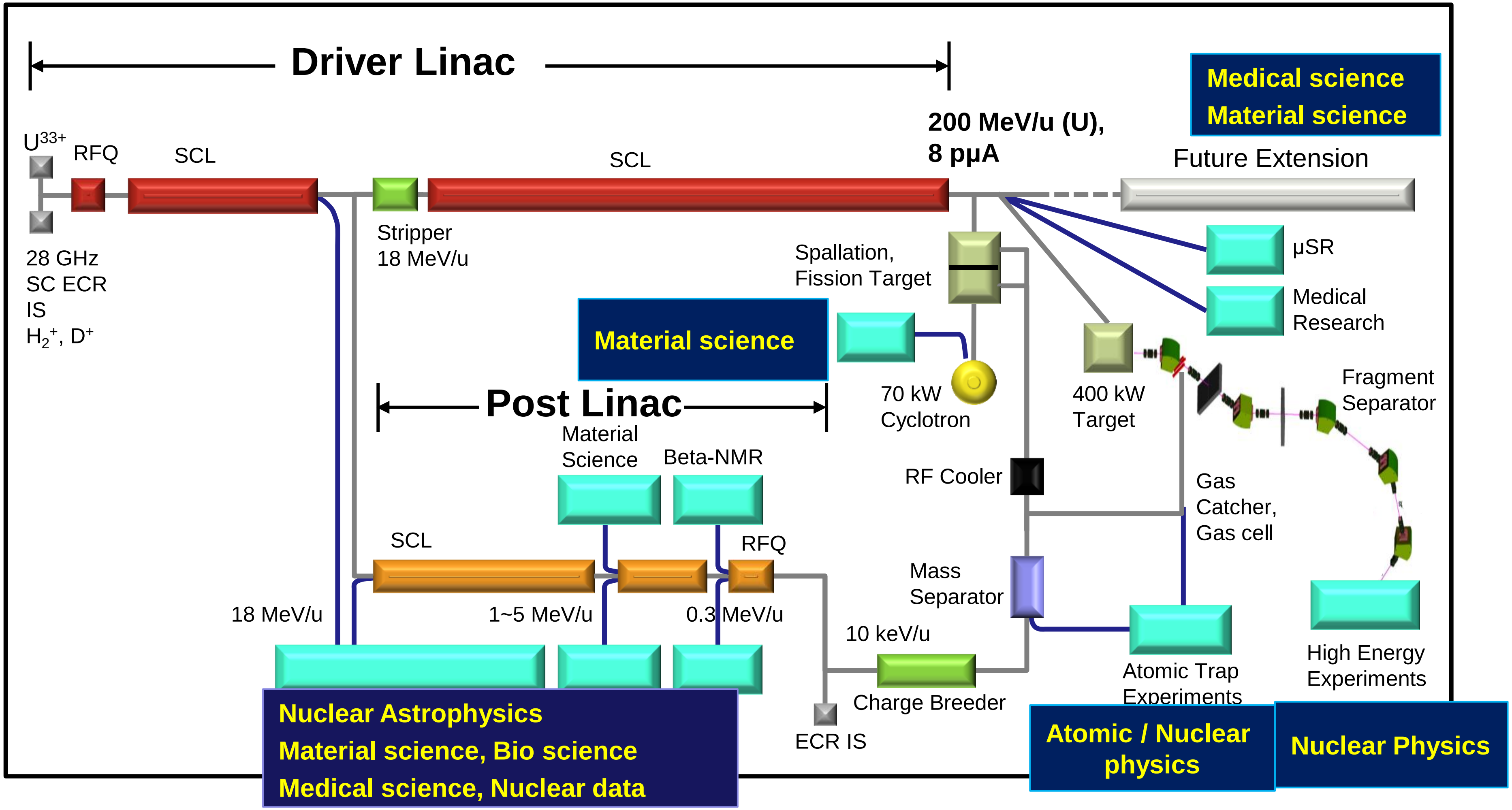
Overview of the RISP Superconducting Linac

Dong-O Jeon

The Rare Isotope Science Project

Institute for Basic Science

Concept of the Accelerator Complex

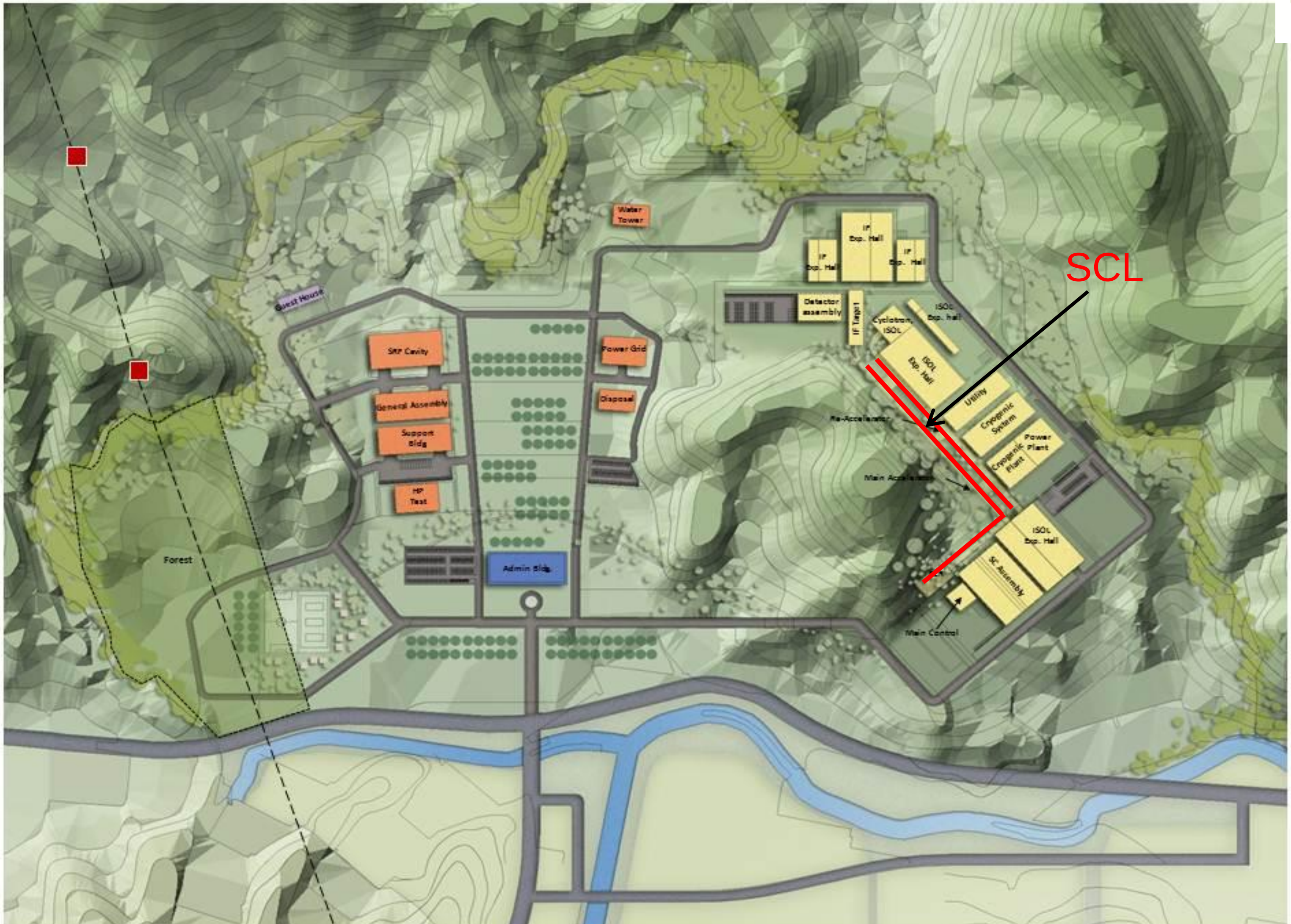


SC Linac 200MeV/u for ^{238}U, 600 MeV for p → IF driver, high power ISOL driver

Cyclotron 70 MeV, 1mA for p → ISOL driver

SC Linac ISOL post accelerator 18 MeV/u

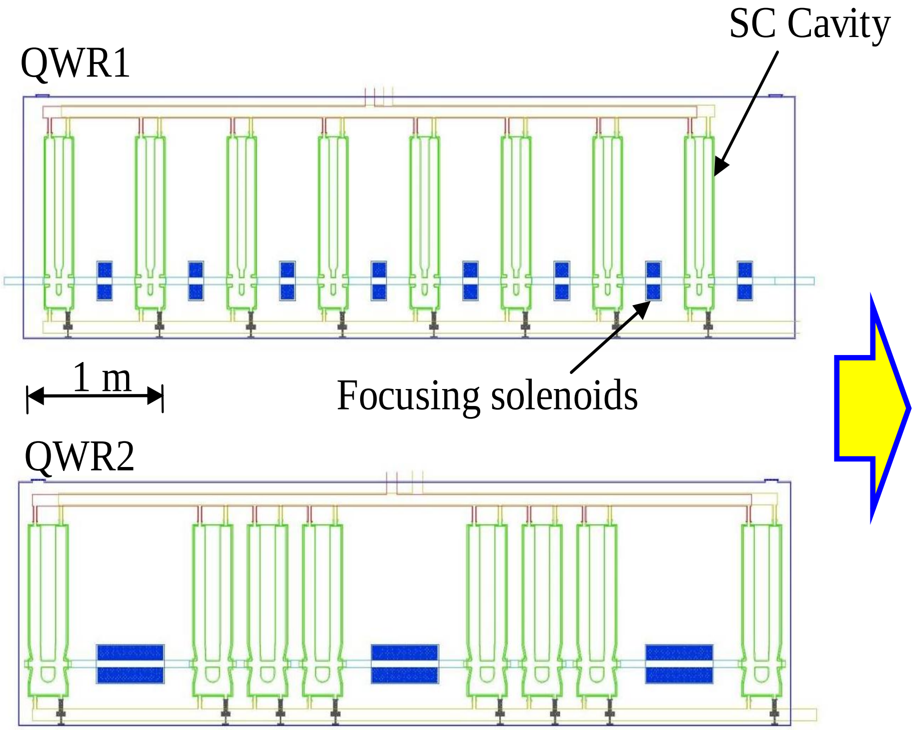
RISP Site Plan

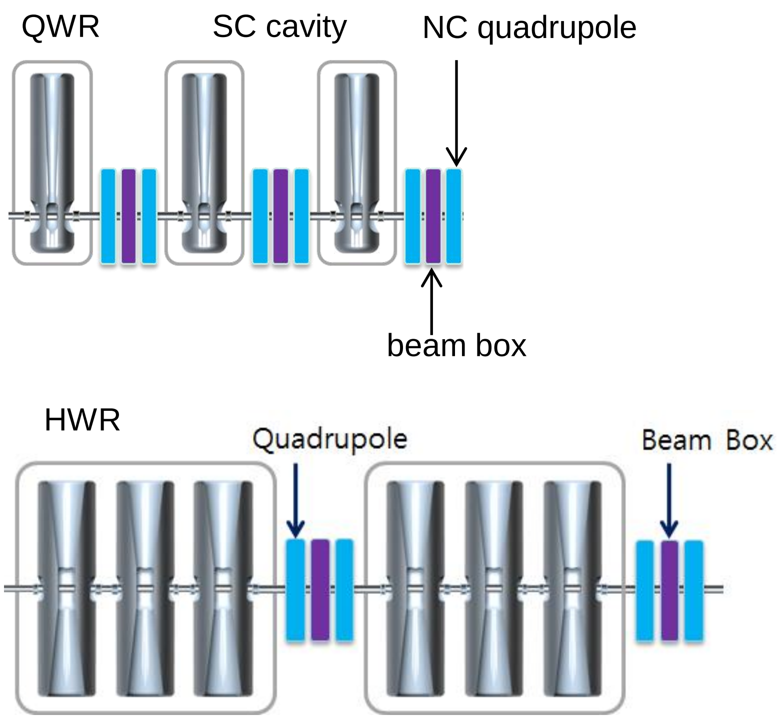


Bird's Eye View

Driver SC Linac Lattice Change

- Linac base frequency = 81.25 MHz
- Design to accelerate high intensity ion beams
- Flexile operation to meet the needs of various user groups

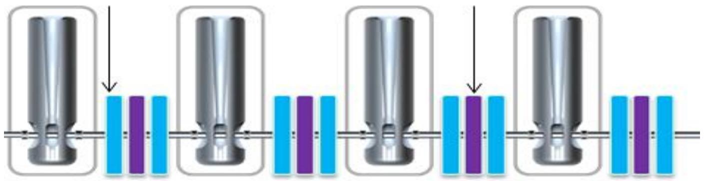




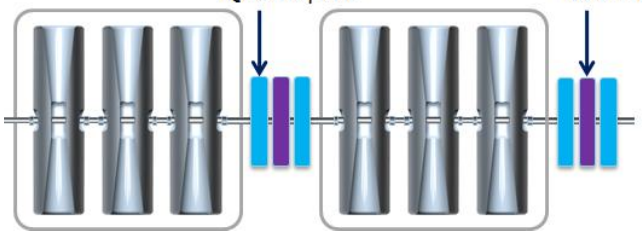
Previous Driver SCL Design
with SC solenoids

Driver SCL
with NC doublets

SCL Design

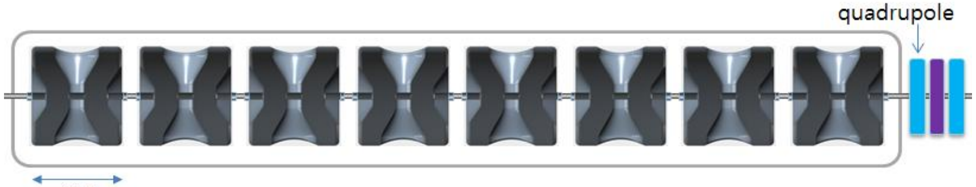


1 QWR + 1 QD

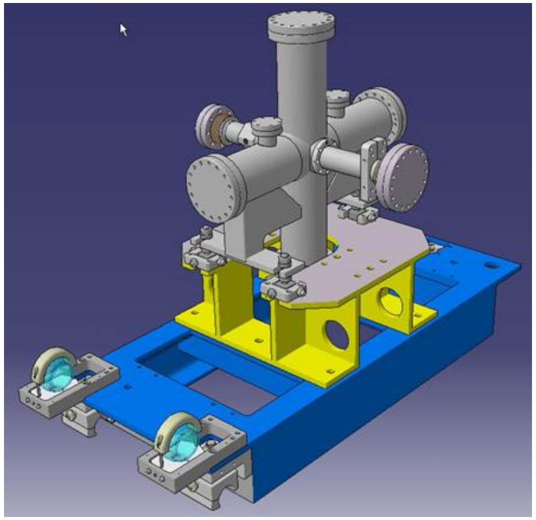


3 HWR + 1 QD
4 HWR + 1 QD

4 SSR + 1 QD



8 SSR + 1 QD



beam box example
(courtesy of SPIRAL2)

SCL	Cavity structure	Frequency	β_g	Number of cavities	Output energy
SCL1	QWR	81.25 MHz	0.047	24	2.7 MeV/u (U^{+33})
	HWR	162.5 MHz	0.12	131	18.6 MeV/u (U^{+33})
SCL2	SSR	325 MHz	0.3	90	66 MeV/u (U^{+79})
	SSR	325 MHz	0.53	160	200 MeV/u (U^{+79})

Driver SCL Lattice Change

NC quadrupole lattice option has the following merits:

1. Accurate alignment < 150 μm of NC quadrupoles is feasible.
2. Beam quality control is straightforward and design is more adequate for high power beam operation.
3. Advantages in beam diagnostics and collimation through beam boxes.
4. The linac cost seems to be in error range compared with the SC solenoid option. (← removal of costly SC solenoids)
5. Preliminary cryo-load comparison suggests that overall cryo-load difference is small compared with the dynamic load.
6. Linac length decrease : 97 m → 90 m for the SCL 1, compared with the previous design.

Beam Simulations in SCL1

$(\beta_1 + \beta_2)$

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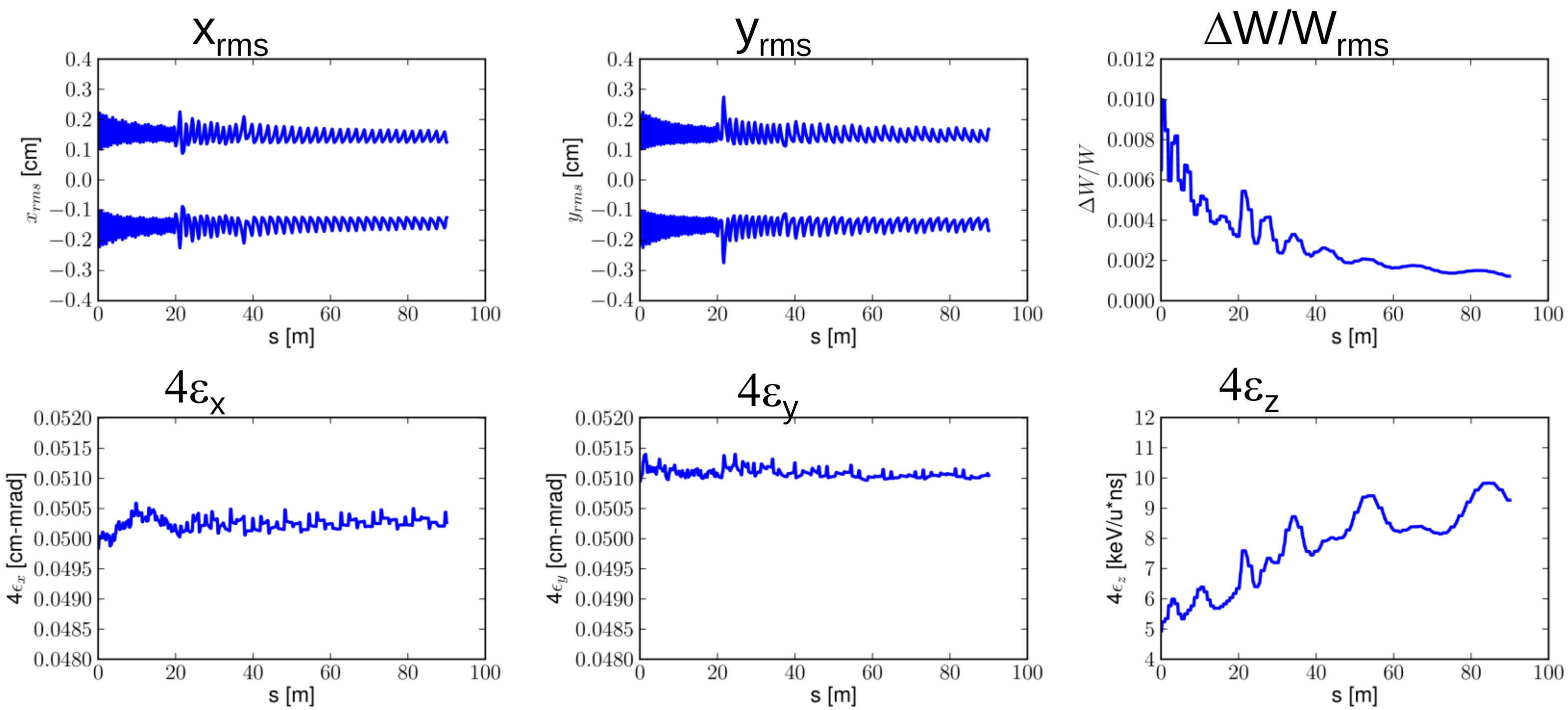

Phase advance in the SCL1

($\beta_1 + \beta_2$)

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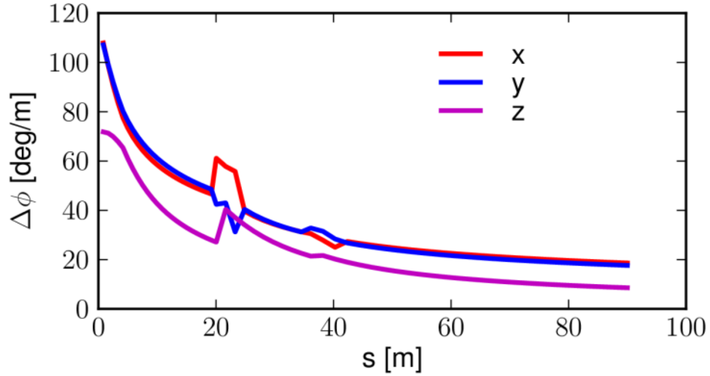
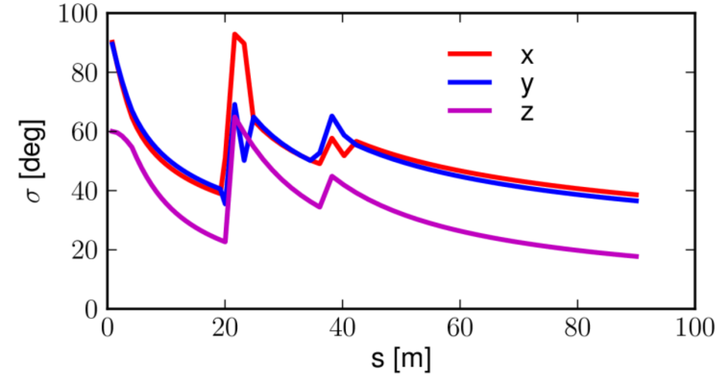
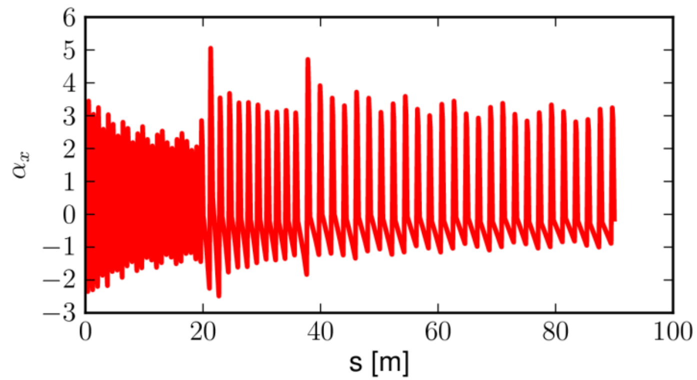
σ / m



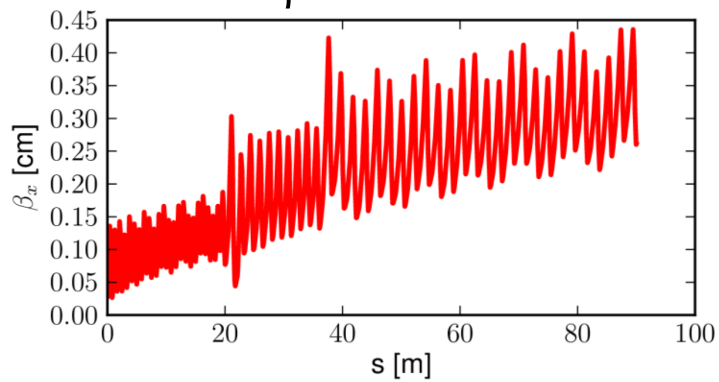
σ / period



α

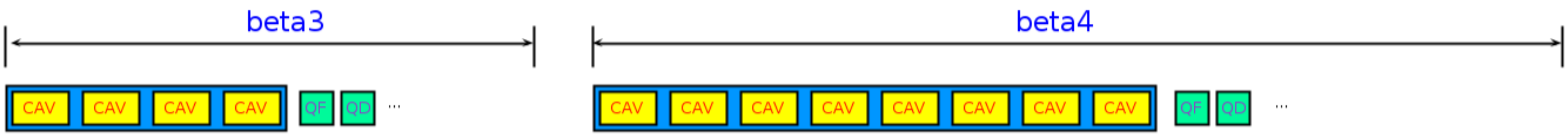


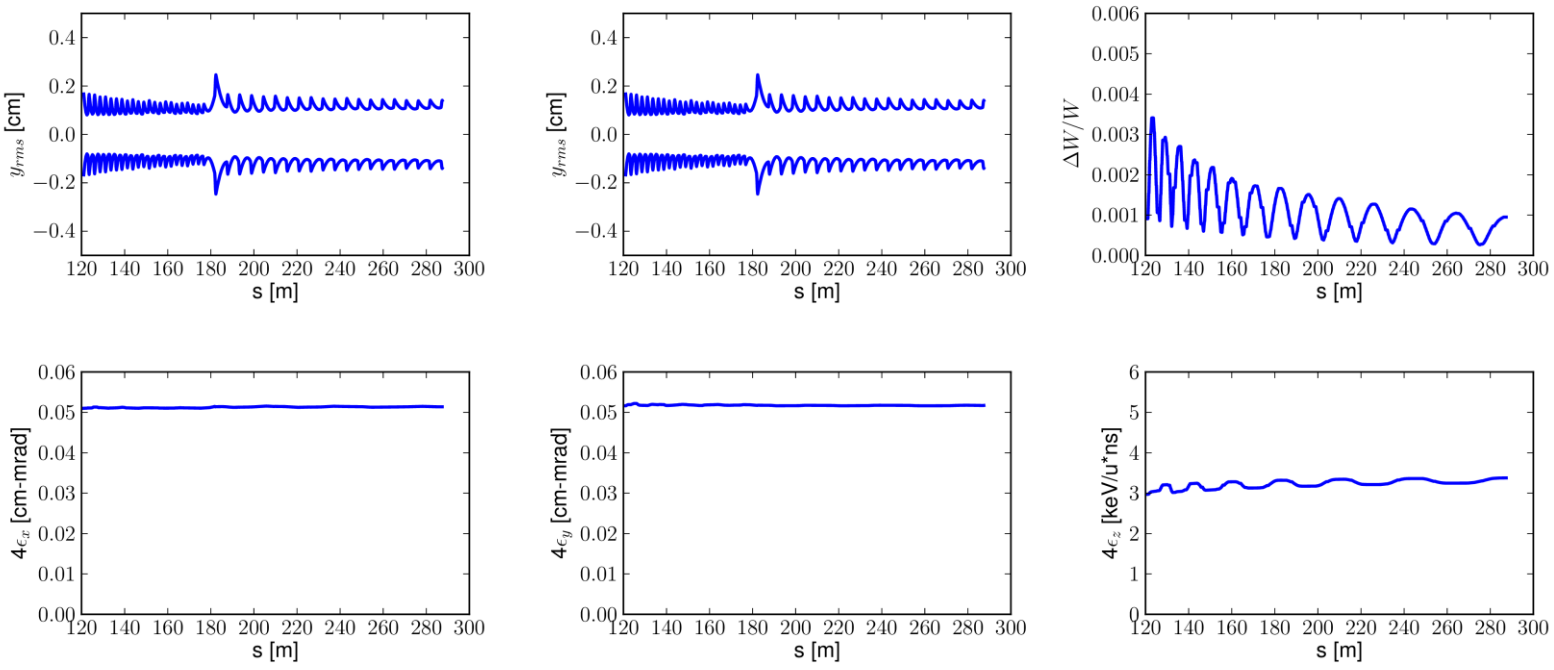
β



Beam Simulations in SCL2

(β_3 +β_4)





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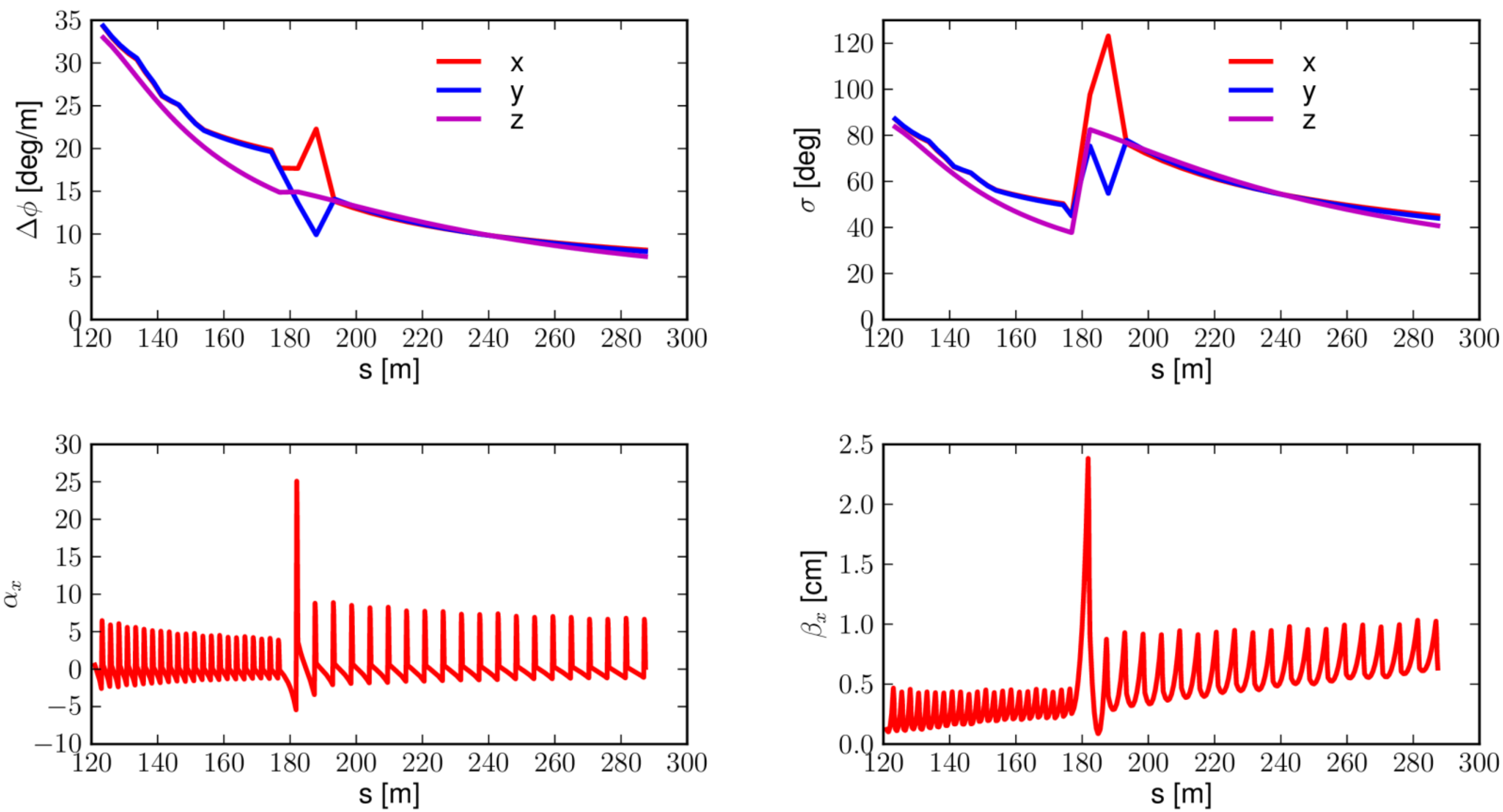
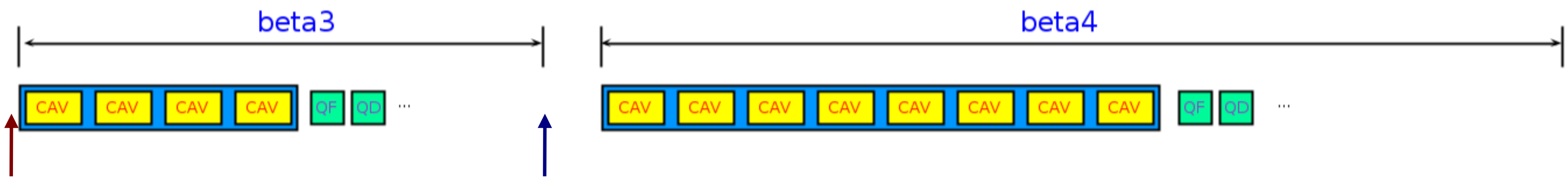
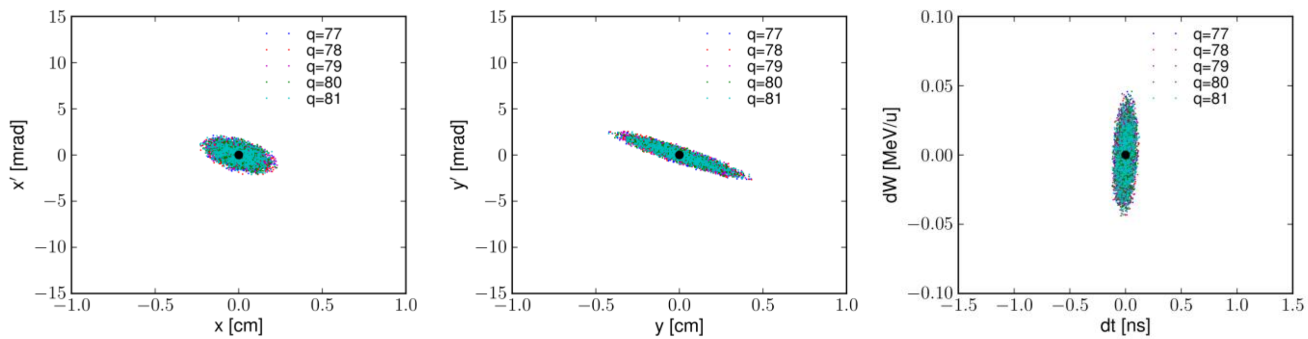
Phase Advance in SCL2
(β_3 +β_4)



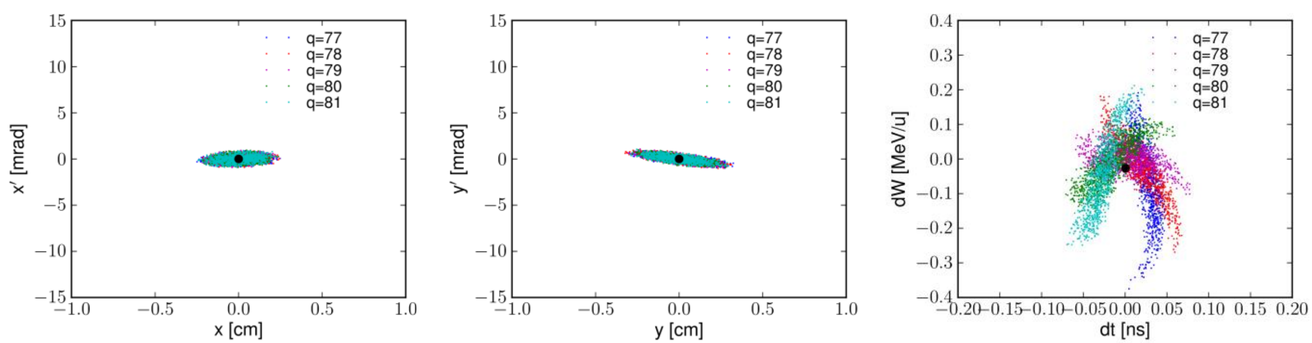
Beam Simulations in SCL2
(β_3 +β_4)



β3 section entrance
- 18.5 MeV/u
- five charge States (77,78,79, 80,81)

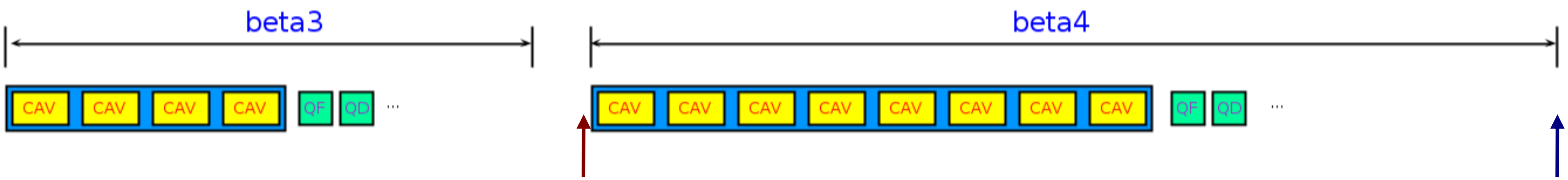


β3 section exit
- 66 MeV/u
- five charge states (77,78,79,80,81)
- matched to β4



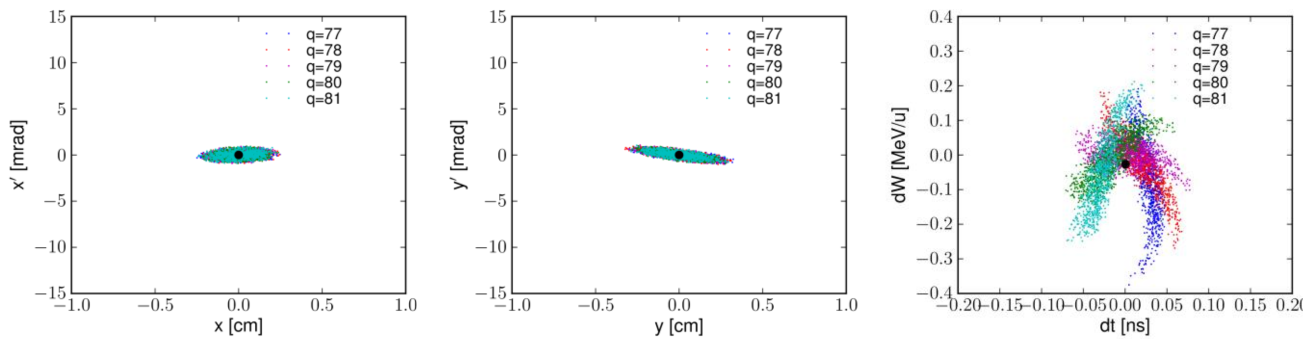
Beam Simulations in SCL2

(β_3 +β_4)



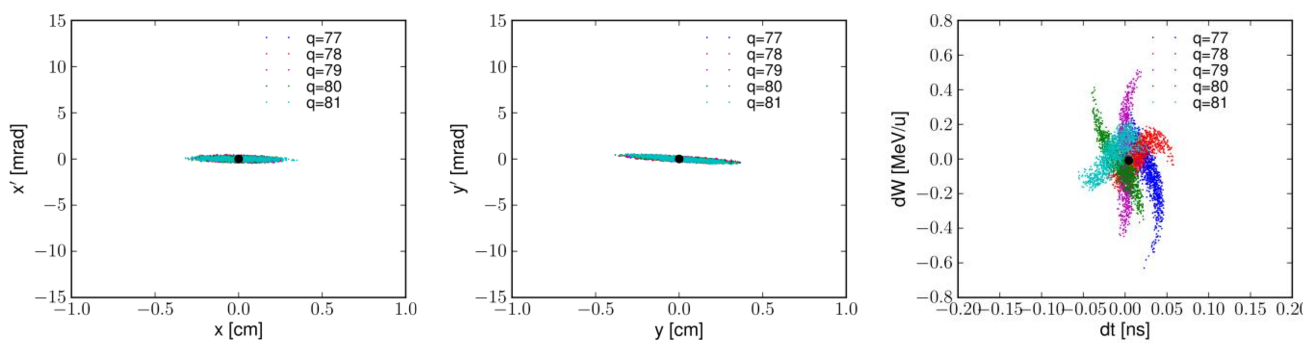
β4 section entrance

- 66 MeV/u
- five charge states (77,78,79,80,81)



β4 section exit

- 200 MeV/u
- five charge states (77,78,79,80,81)



Machine Imperfections

Hyung Jin Kim

Parameters	SCRF Cavity	Warm Quadrupole	SC Solenoid	Distribution
Displacement (mm)	±1	±0.15	±0.5	Uniform
Rotation (mrad)	-	±5	-	Uniform
Phase (deg)	±1	-	-	3σ Gaussian
Amplitude (%)	±1	-	-	3σ Gaussian

- For actual accelerators, certain imperfections are unavoidable due to engineering/alignment imperfections.

Machine imperfection simulations in β_1 section (baseline vs solenoid option)

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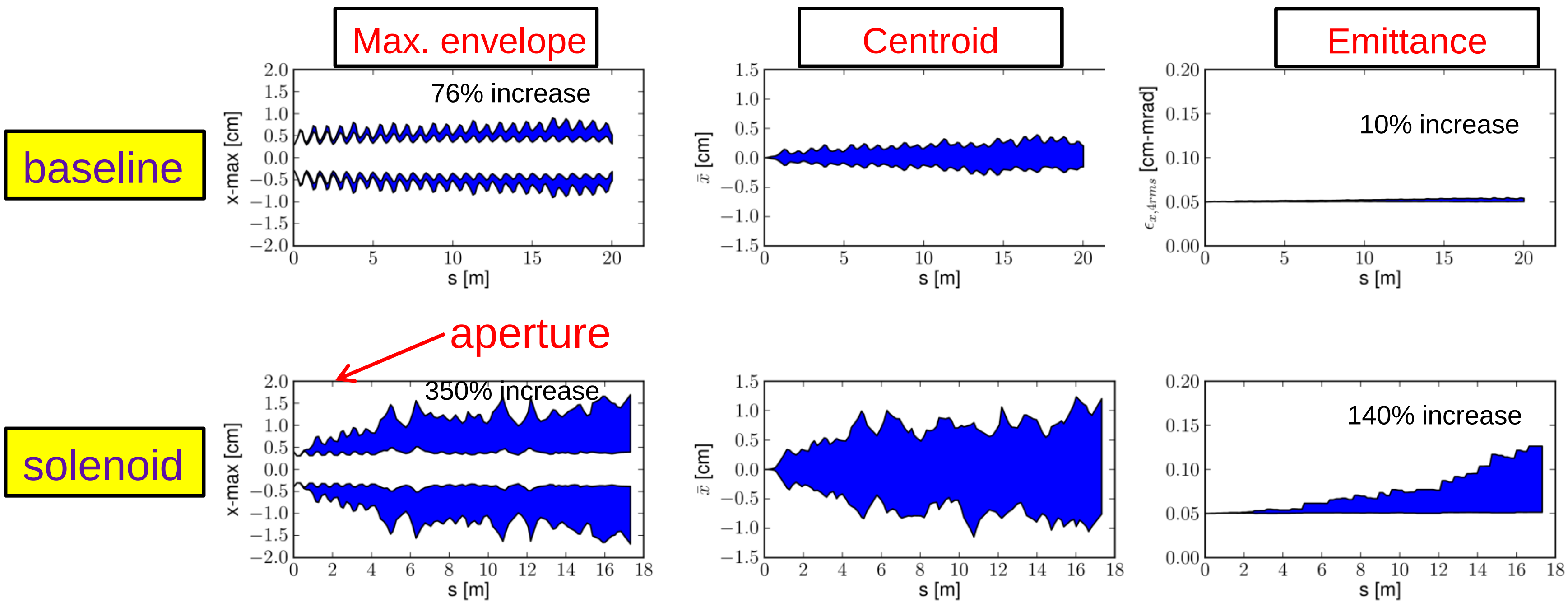
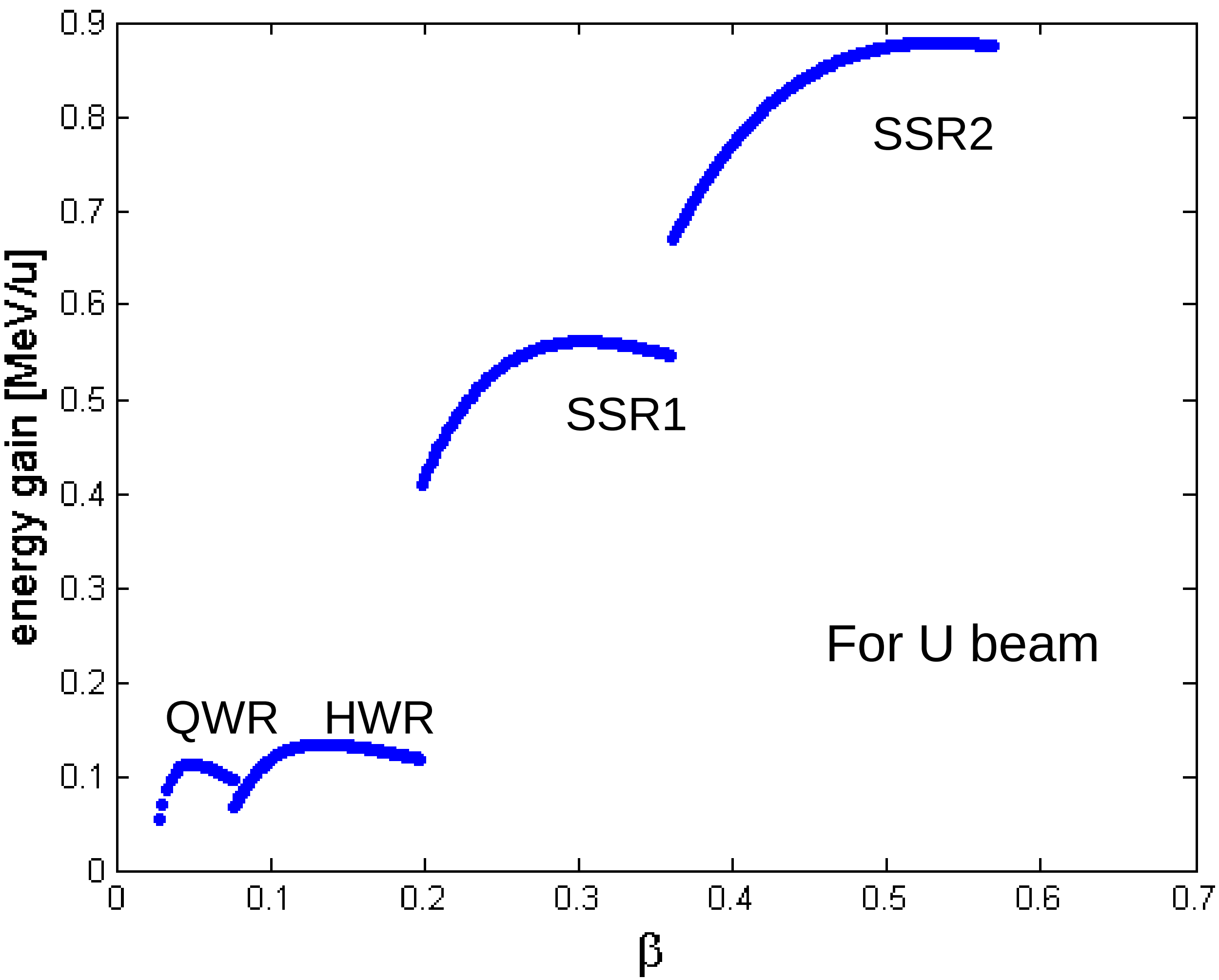


- The shade region represents the bounds of envelope, centroid and e mittance due to misalignment and field errors.
- Simulation shows that proposed baseline design improves beam quali ty significantly.

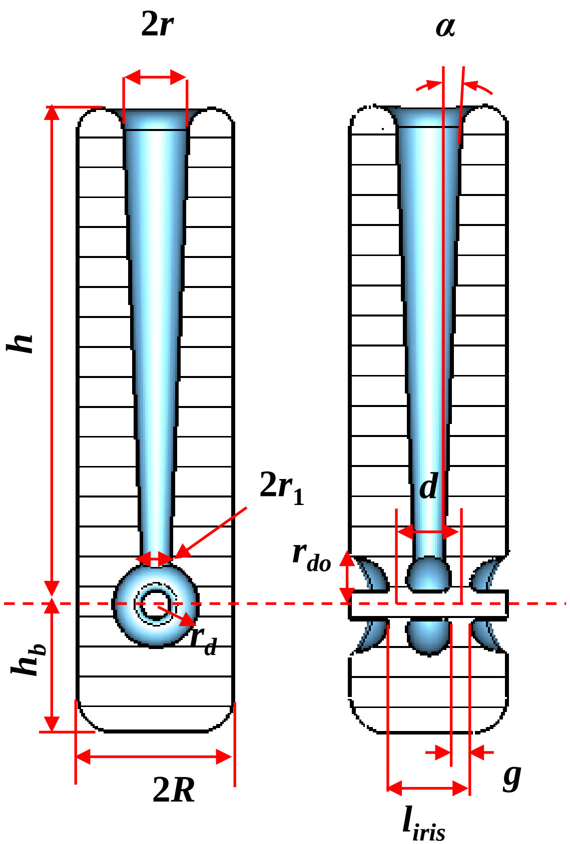
Cavity type and optimization



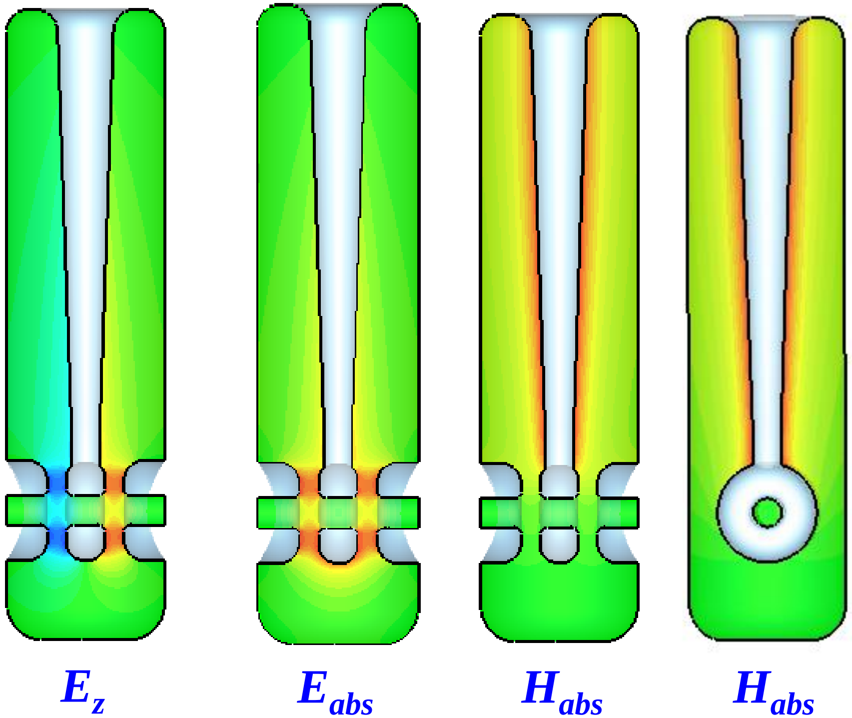
before		**after**
QWR 0.041	→	QWR 0.047
QWR 0.085	→	HWR 0.120
HWR 0.285	→	SSR 0.300
HWR 0.530	→	SSR 0.530

Cavity types are changed for high intensity, high power beam operation.
Cavity geometry is optimized for all four types of the SC cavities.

Cavity Geometry Optimization
(dimensions are in cm)

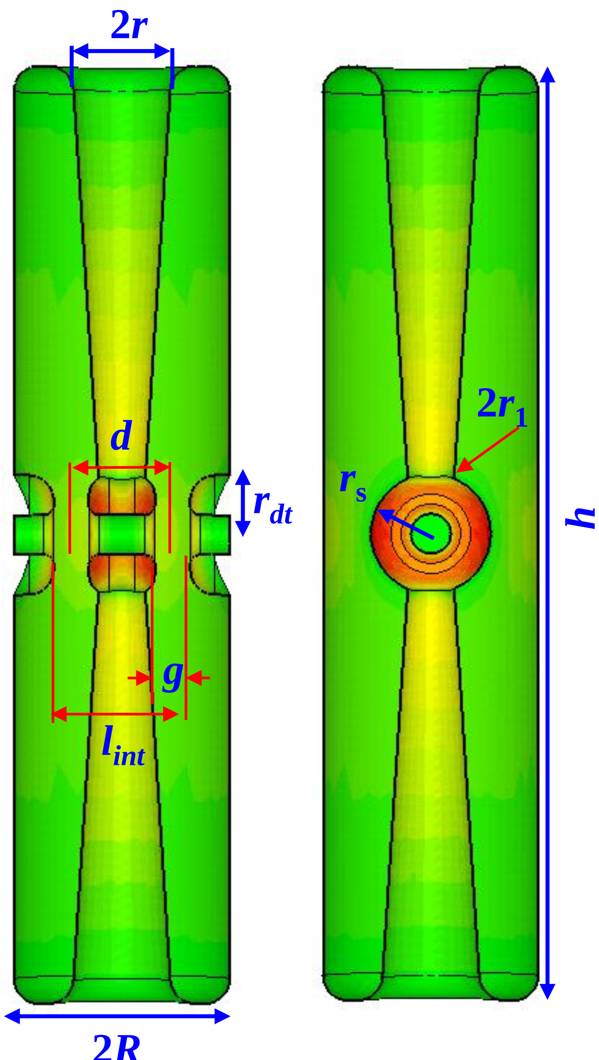


Parameter	value
h	69.6
r	4
R	11
h_b	18
r_1	2
r_{do}	7
r_d	7
l_{iris}	10.48
g	2.54
d	7.94

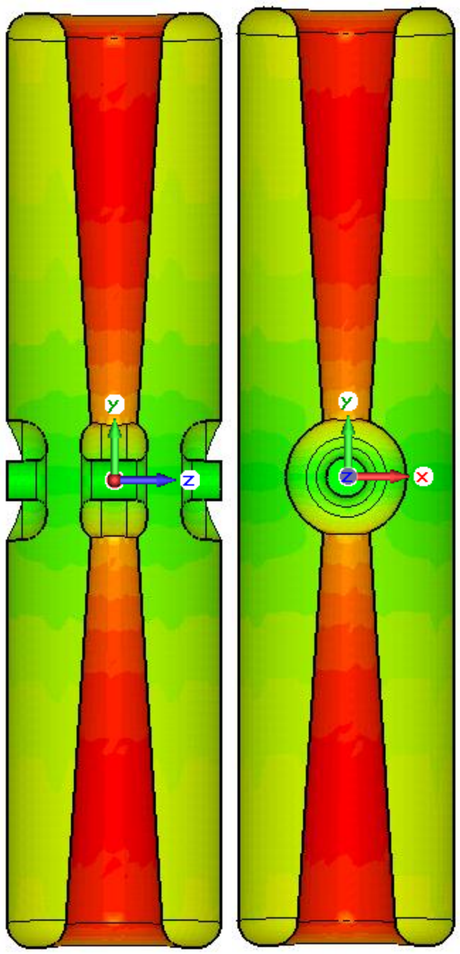


- The geometry of the quarter wave resonator is optimized.

Summary of optimized HWR

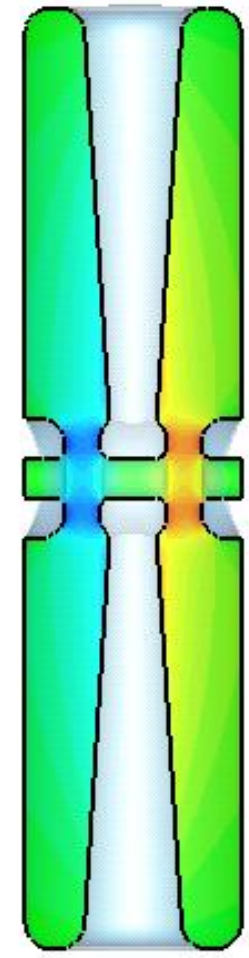


E_{abs}



H_{abs}

parameter	value
r, mm	48.5
R, mm	120
d, mm	107.8
l_{int}, mm	136
g, mm	35
r_{dt} , mm	60
r_s , mm	60
r_1 , mm	20
h, mm	910.38

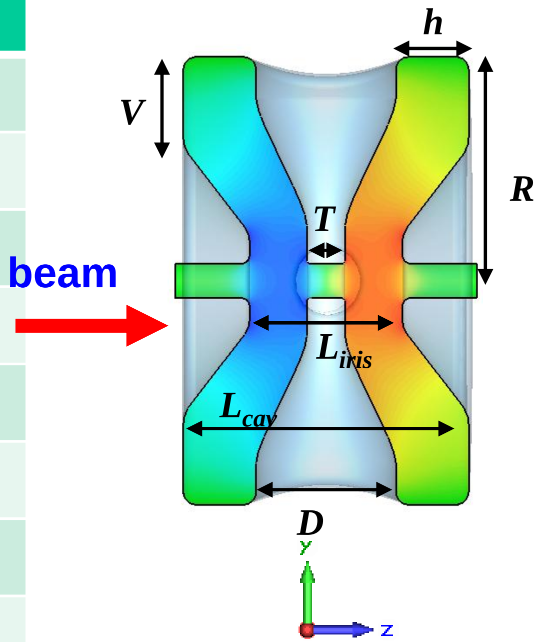


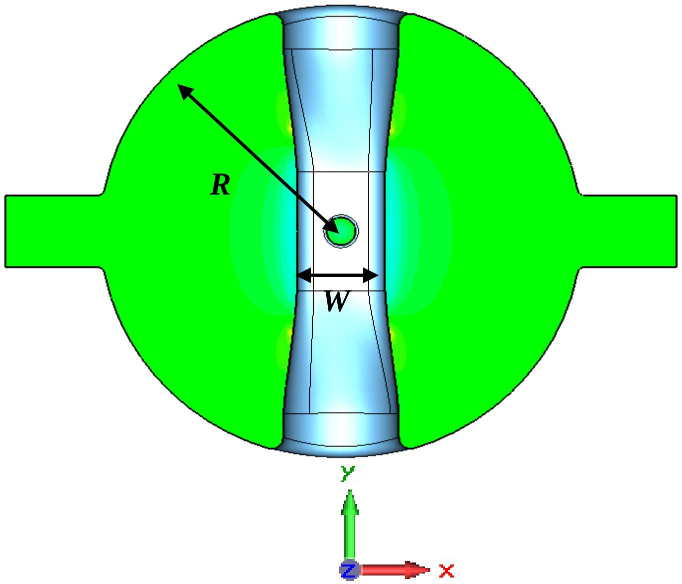
E_z

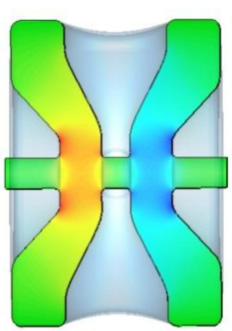
- The geometry of the half wave resonator is optimized.

Summary of optimized SSR's

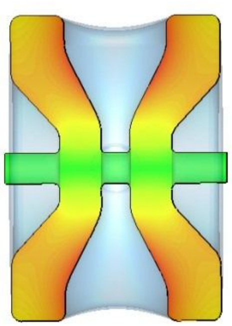
parameter	SSR1	SSR2
h, mm	85	120
L_iris, mm	190	330
T, mm	55	115
L_cav, mm	339	510
D, mm	169	238
V, mm	93	95
w, mm	100	180
R, mm	250	265



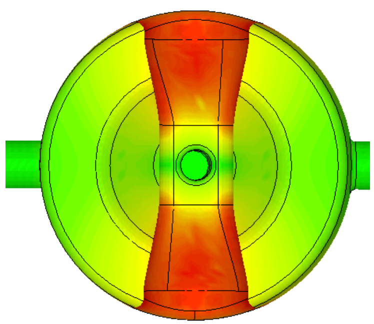




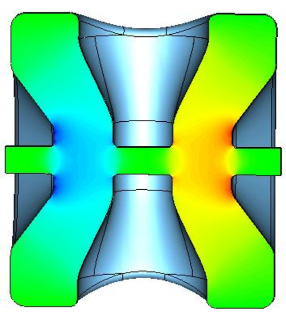
E_z



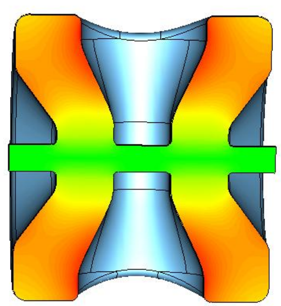
H_{abs}



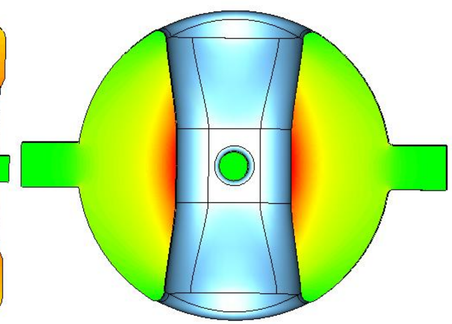
H_{abs}



E_z



H_{abs}



E_z

Cavity Parameters

Driver SCL load = 2.1 kW, ISOL SCL load = 0.33 kW

Parameters	Unit	QWR	HWR	SSR 1	SSR 2
β_g	-	0.047	0.12	0.30	0.53
Resonant frequency	MHz	81.25	162.5	325	325
No of cavities	-	24	131	90	160
Aperture diameter	mm	40	40	50	50
QR_s	Ohm	17.5	41.2	86.1	104.7
R/Q	Ohm	472.3	264.8	237.0	298.0
V_{acc}	MV	1.02	1.07	2.04	3.53
E_{peak}	MV/m	30	30	30	30
B_{peak}	mT	54.1	40.8	52.2	62.3
E_{peak}/E_{acc}		5.08	6.2	4.06	4.15
B_{peak}/E_{acc}		9.16	8.4	7.07	8.6
$Q_{calc}/10^9$	-	1.8	4.0	8.1	9.1
Operating temperature	K	2	2	2	2
P_0	W	2.7	2.0	4.8	8.4
P_{beam} / emA (proton)	W	854	925	1440	2770
P_{beam} / emA (Uranium)	W	113	134	524	926
Beam current (Uranium)	pμA	9.5	9.5	8	8
Average charge state (U)	-	33.5	33.5	79	79

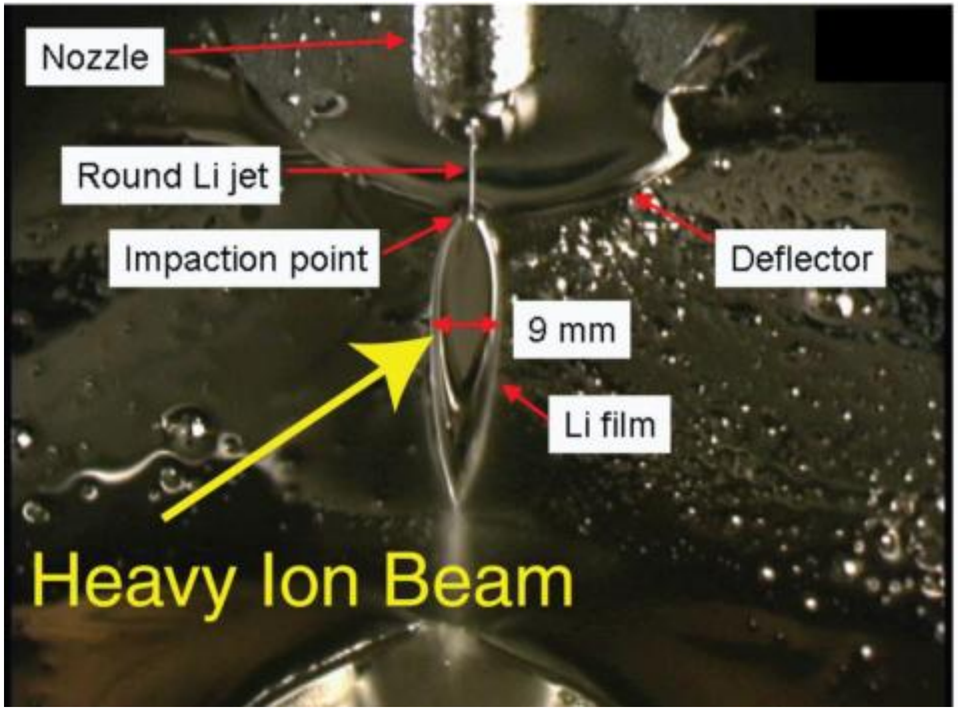
$$E_{acc} = V_{acc} / (\beta\lambda)$$

ISOL post-accelerator

- For the ISOL SCL lattice, we are planning to share the same doublet lattice as the driver SCL to reduce cost and required R&D efforts.
- EBIS is considered rather than ECR IS, generating higher charge state beams.
- Design optimized for $A/q \leq 8$.

Charge Stripper

- Previously carbon foil was considered as the charge stripper.
- We are designing the charge stripper section to accommodate liquid Li or He gas charge stripper.



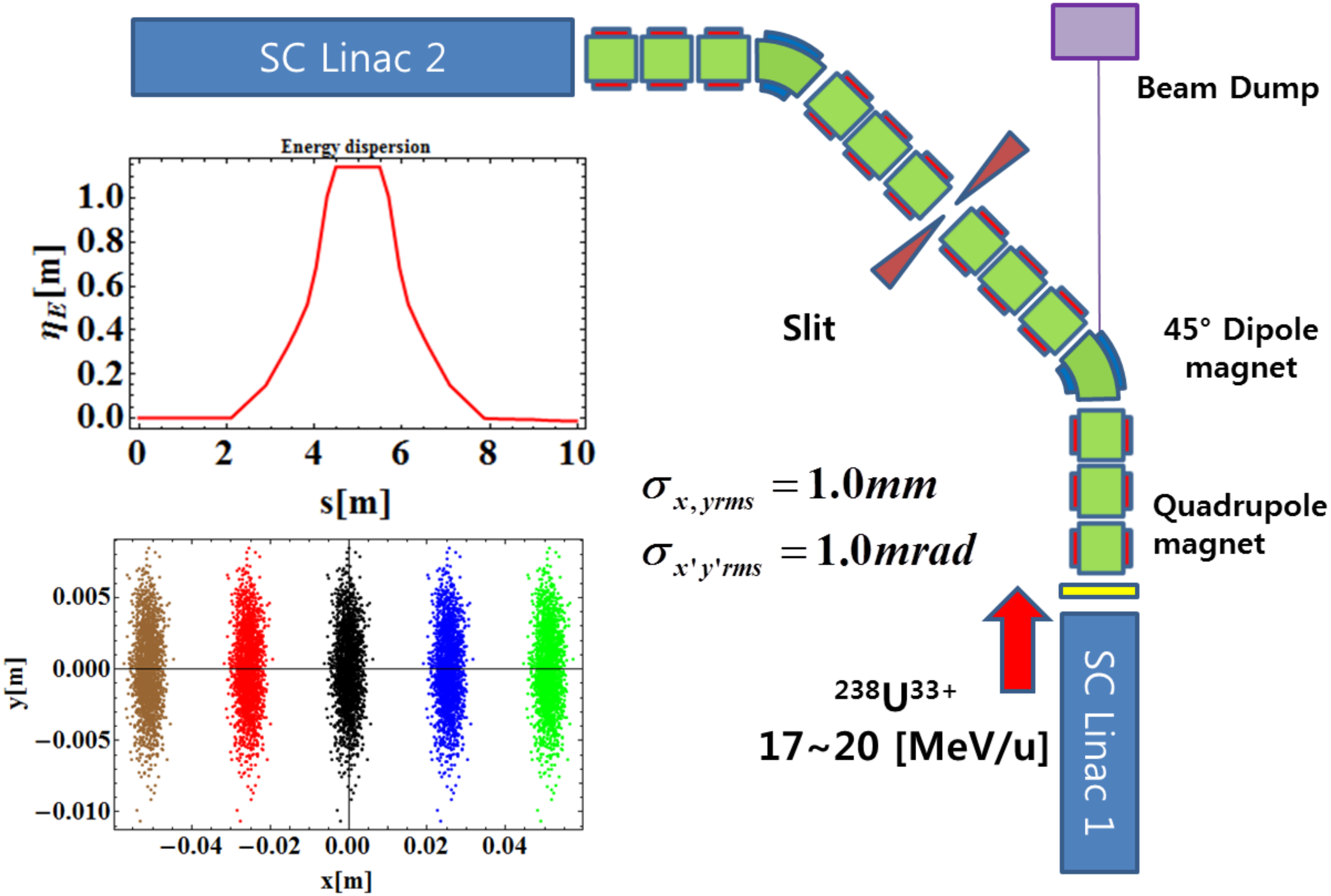
Courtesy of FRIB

Stripping Station Conceptual Design

- Change from 180º chicane to 90º bend.
- Conforms better to the topography of the site.
- Shorter in length → better control in longitudinal plane.
- Better in radiation activation control for the downstream section.
- Various Charge Strippers are under study.

Present Charge Stripping Section 90° bend

Hye-Jin Kim

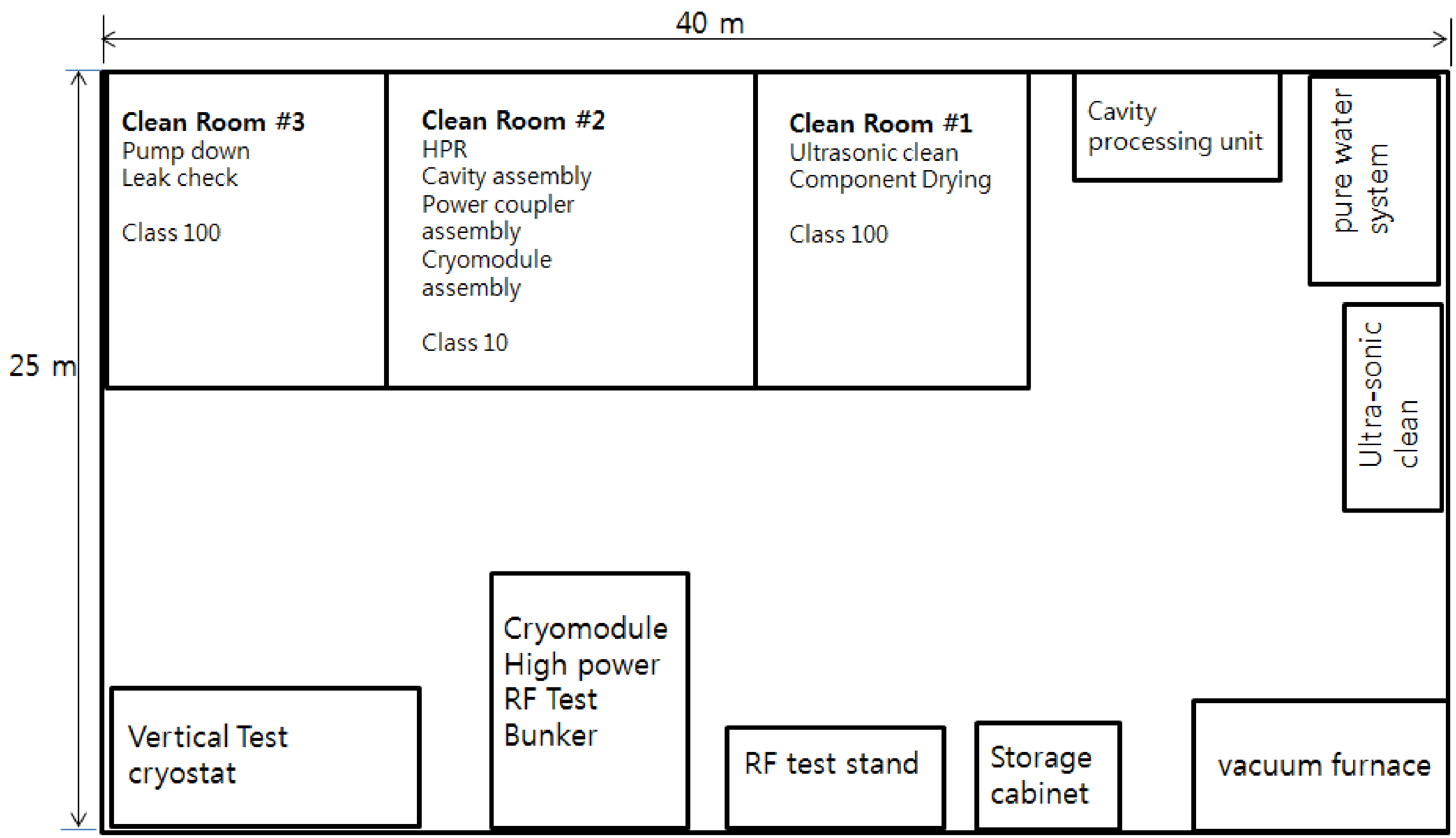


$$\sigma_{x,yrms} = 1.0mm$$

$$\sigma_{x'y'rms} = 1.0mrad$$

Temp SRF Test Facility

- A contingency plan for the temporary Superconducting RF and Magnet Test Facility is being developed, considering a possible delay in procuring the site.
- Plan and cost estimation are developed.
- Cost is 2856 M KRW (= $2.4 M) for SRF Facility and 1200 M KRW for Magnet Test Facility (20m x 20m)



Summary

- Base frequency of the SCL is determined.
- For the SCL, NC quadrupole lattice is adopted rather than the SC solenoid:
  - Better beam quality control
  - Beam diagnostics and collimation advantages
- Same design for the ISOL post-linac.
- Cavity types and geometric betas are determined.
- Cavity geometry is being optimized.

Summary

- Construction of the Superconducting RF Test Facility is under way.
- International Collaboration is an essential part for the success of the project.

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Thanks for your attention!