Overview of ISOL Facility at RISP

Sep. 25, 2014

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On behalf of ISOL Team
Rare Isotope Science Project (RISP), IBS

CATHI Final Review Meeting, Sep. 22-26, 2014

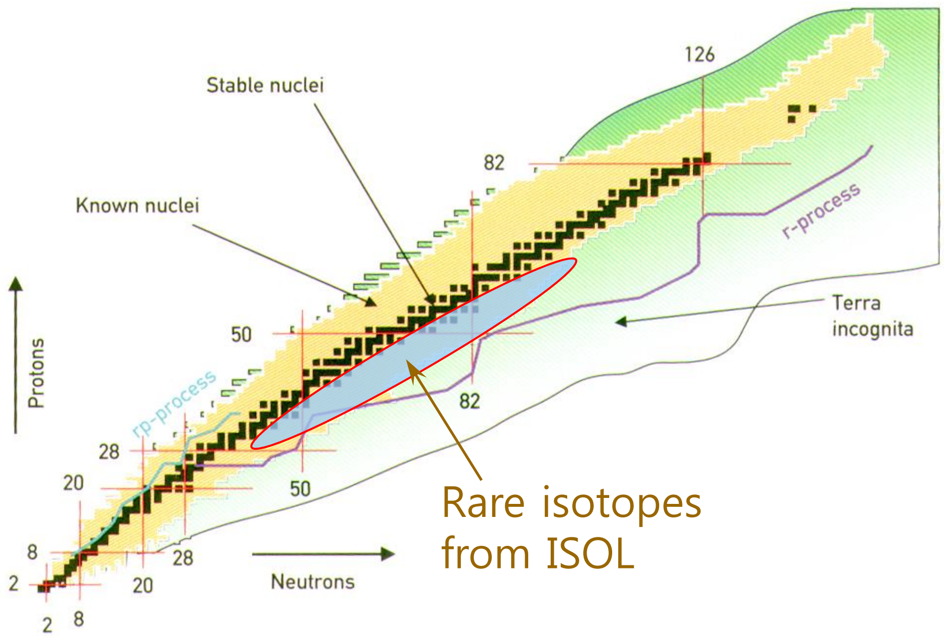
Outline

- Validity of ISOL @RISP
- Layout
- Schedule
- ISOL system
  - target & ion sources
  - Pre-separator / RF-cooler / HRMS
  - charge breeder / A/q separator
  - offline test facility / beam diagnostics
  - budget / manpower
- Strategy / collaboration
- Summary

Key Science Driver of RAON (ISOL)

- Highest priority research subjects
  - Nuclear reaction experiments important to nuclear-astrophysics : e.g. $^{15}O(\alpha,\gamma)^{19}Ne$, $^{45}V(p,\gamma)^{46}Cr$
  - Search for super-heavy elements: Z>119 (Z ~120)
  - Nuclear structure of n-rich RIs near 80<A<160
  - Nuclear symmetry energy at sub-saturation density
- Important scientific applications
  - Precision mass measurement & laser spectroscopy
  - Material science : β-NMR, μSR
  - Medical and bio-sciences
  - Nuclear data for next-generation NPP and nuclear waste transmutation

- User requirement :
  - high-quality (>90% purity),
  - intense n-rich RI Beam (highest priority)
- Method : RI beam from ISOL facility
  - ISOL with U fission target (max. 7×10^{13} fission/s)
  - 80<A<160
  - 10^6~10^9 pps on exp. target



Worldwide ISOL Facilities (2013/10)

Facility		Driver	Primary beam	Power on target	Fission rate (#/s)	^{132}Sn rate @lab. (pps)	State / 1st RIB
TRIAC, KEK		Tandem	30 MeV, 3 μA	0.09 kW	$\sim 10^{11}$	3×10^{5}	closed
HRIBF, ORNL		Cyclotron	40 MeV, 10 μA	0.4 kW	4×10^{11}	2×10^{5}	closed
ISOLDE, CERN	REX	Linac	1~1.4 GeV, 2 μA	2 kW	$\sim 10^{12}$	$\sim 10^{7}$	upgraded to HIE
	HIE		1~1.4 GeV	~10 kW	$\sim 10^{13}$	$\sim 10^{8}$	2014
ISAC, TRIUMF		Cyclotron	450 MeV, 70 μA	17 kW	5×10^{13}	?	in operation
SPIRAL2, GANIL (converter)		Linac	40 MeV (d), 5 mA	200 kW	$\sim 10^{14}$	$(0.3\sim 2) \times 10^{9}$	2015
SPES, INFN		Cyclotron	40 MeV, 200 μA	8 kW	$\sim 10^{13}$	3×10^{7}	2017
iThemba LABS	phase-1	Cyclotron	70 MeV, 0.115 mA	8 kW	$\sim 10^{13}$	$(0.2\sim 1) \times 10^{8}$	2020 (?)
	Phase-2		70 MeV, 0.5 mA	35 kW	5×10^{13}	$(0.8\sim 4) \times 10^{8}$	?
RISP, IBS	RISP	Cyclotron	70 MeV, 0.143 mA	10 kW	1.6×10^{13}	$(2\sim 4) \times 10^{7}$	2020
			70 MeV, 0.5 mA	35 kW	7×10^{13}	$(0.5\sim 1.2) \times 10^{8}$	?
	Post-RISP	Linac	660 MeV, 0.6 mA	400 kW			

Science program with beam schedule

Beam schedule	Science program	Exp. facility♯	Beam species on exp. target†		Beam Intensity on exp. (pps) (required/expected)
			Day-1	Extra 2 years	
2020.Q4 ~ from SCL1 (<18.5 MeV/u)	Nuclear structure SHE search, rp-process, Spin physics	RS	^{54}Cr	^{64}Ni ^{26m}Al (^{28}Si), ^{25}Al (^{28}Si), ^{44}Ti (^{42}Ca), ^{14,15}O (^{15}N)	^{15}N, ^{54}Cr ^{28}Si, ^{42}Ca, ^{50}Ti ^{25}Al, ^{26m}Al, ^{44}Ti, ^{14,15}O: (10^{5-6})
	Pigmy dipole resonance	LAS-L	^{58}Ni	^{40}Ca, ^{112}Sn	(10^{6-8} / <10^{9-10})
	Biological effects	BM	^{12}C		(<10^{12} / >10^{12})
	New materials, Polarized beam	β-NMR	^{8}Li by (d, n)(n,α) or (p,2p)		^{8}Li (10^{8} / 10^{9})
	Neutron cross section	NSF	n by (p,n) and (d,n)		n (< 10^{12} / 10^{12})
2021.Q1 ~ from **ISOL** (~5 keV/u)	Hyperfine structure, Mass measurement	Ion Trap LS	^{132}Sn	$^{130-135}$Sn	^{132}Sn (<10^{5} / 10^{7})‡, $^{130-135}$Sn (10^{3-6} / 10^{3-7})
2021.Q4 ~ **ISOL**-SCL3 (<18.5 MeV/u)	r-process	RS	^{132}Sn	$^{130-135}$Sn	^{132}Sn (10^{6} / 10^{7}), ^{65,66}Ni (10^{6-8} / 10^{6-7})
	Pigmy dipole resonance	LAS-L	^{132}Sn	$^{50+n}$Ca, $^{60+n}$Ni, $^{106+n}$Sn	
2021.Q4 ~ SCL1-SCL2 (~ hundreds MeV/u)	New materials	μSR	μ^{+} by (p, πx)		μ^{+} (10^{8} / 10^{9})
	Biological effects	BM	^{12}C		(<10^{12} / >10^{12})
	Baseline experiments, Spin physics	LAS-H	^{40}Ca	^{58}Ni, ^{112}Sn, ^{132}Xe	(10^{6-8} / <10^{9-11})
2022.Q2 ~ SCL1-SCL2-IF (~ hundreds MeV/u)	Nuclear structure	ZDS & HRS	$^{100+n}$Sn	$^{100+n}$Sn	^{128}Sn (10^{6-8} / 10^{7}) ^{132}Sn (10^{6-8}/10^{7})‡
	Symmetry energy	LAS-H	^{132}Sn	$^{44+n}$Ca, $^{60+n}$Ni, $^{106+n}$Sn, ^{144}Xe	
2022.Q4 ~ **ISOL**-SCL3-SCL2-IF(X) (~ hundreds MeV/u)	Nuclear structure	ZDS & HRS	^{132}Sn		^{132}Sn (10^{6-8} / 10^{7})‡ ^{144}Xe (10^{6-8} / 10^{6})
	Symmetry energy	LAS-H	$^{106+n}$Sn	$^{133+n}$Xe	
2023.Q2 ~ **ISOL**-SCL3-SCL2-IF (~ hundreds MeV/u)	Nuclear structure	ZDS & HRS			^{78}Ni (/ <2)

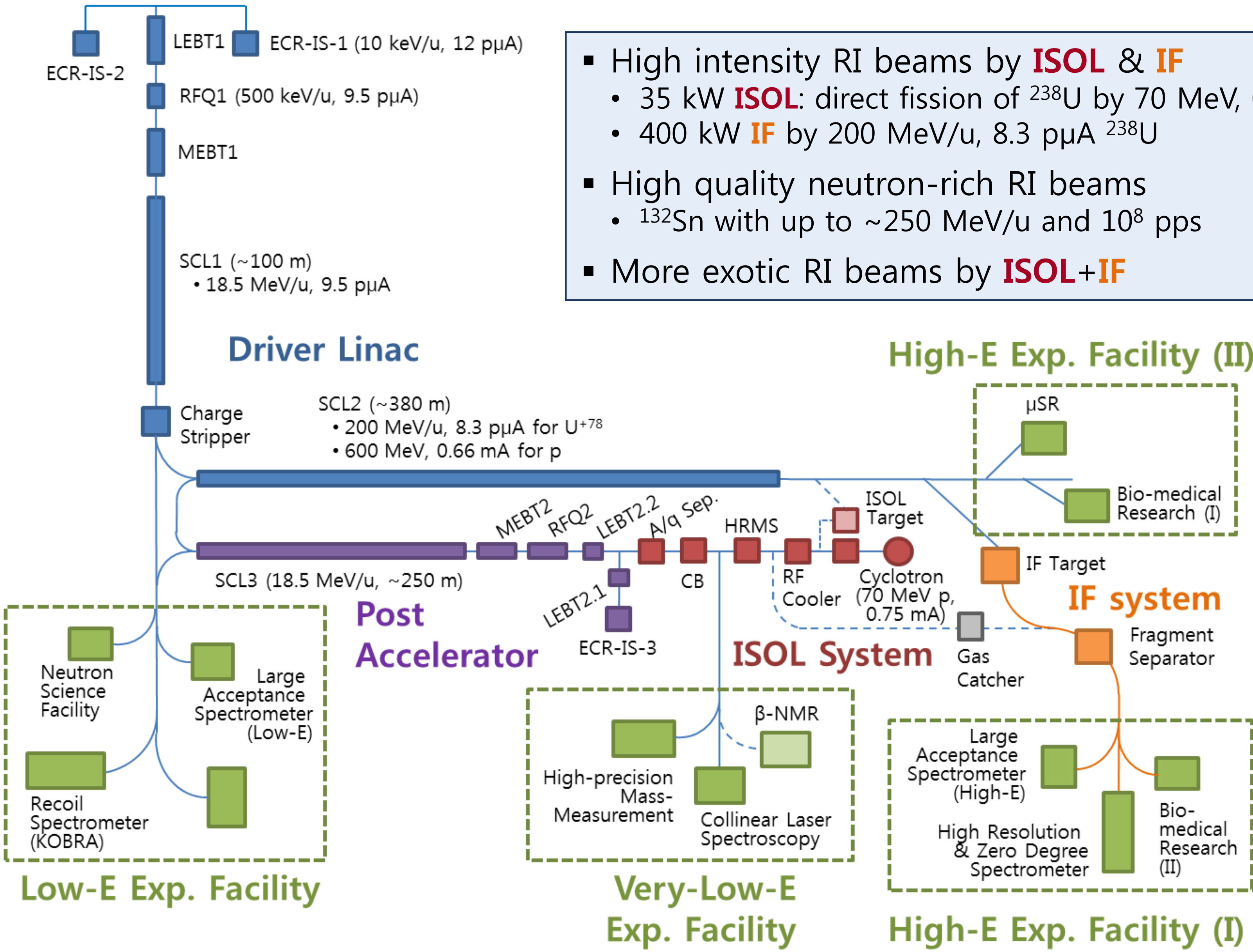
♯ **RS**: Recoil Spectrometer, **LAS**: Large Acceptance Spectrometer, **BM**: Bio & Medical, **LS**: Laser Spectrometer, **NSF**: Neutron Science Facility, **ZDS**: Zero Degree Spectrometer, **HRS**: High Resolution Spectrometer

† Beam species **: SI (black), RI (Blue)**

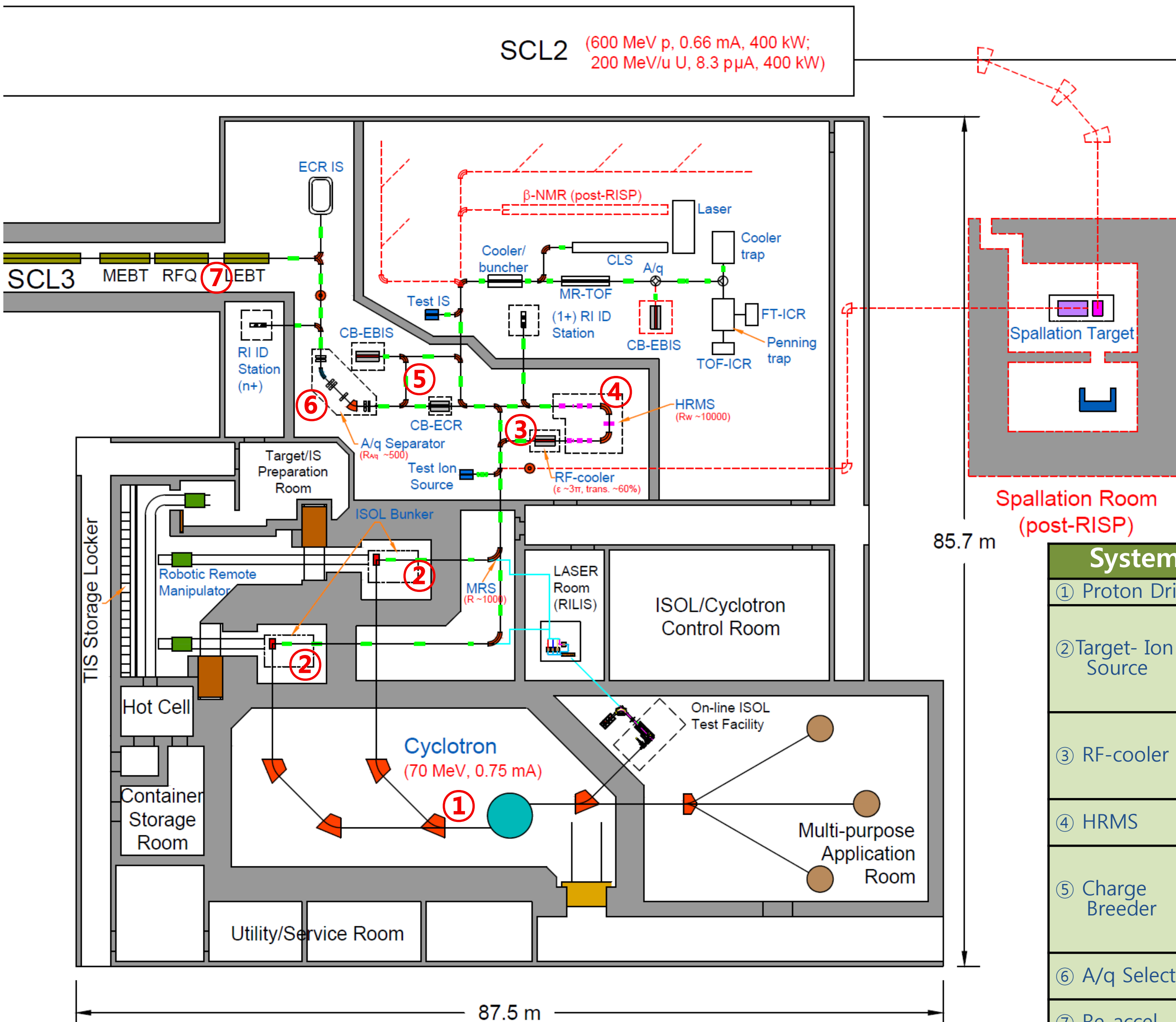
‡ Beam purity >90 % for ISOL, ~9% for IF

Layout of the RISP Accelerator Complex

- High intensity RI beams by **ISOL** & **IF**
  - 35 kW **ISOL**: direct fission of ^{238}U by 70 MeV, 0.5 mA P
  - 400 kW **IF** by 200 MeV/u, 8.3 pμA ^{238}U
- High quality neutron-rich RI beams
  - ^{132}Sn with up to ~250 MeV/u and 10^8 pps
- More exotic RI beams by **ISOL**+**IF**



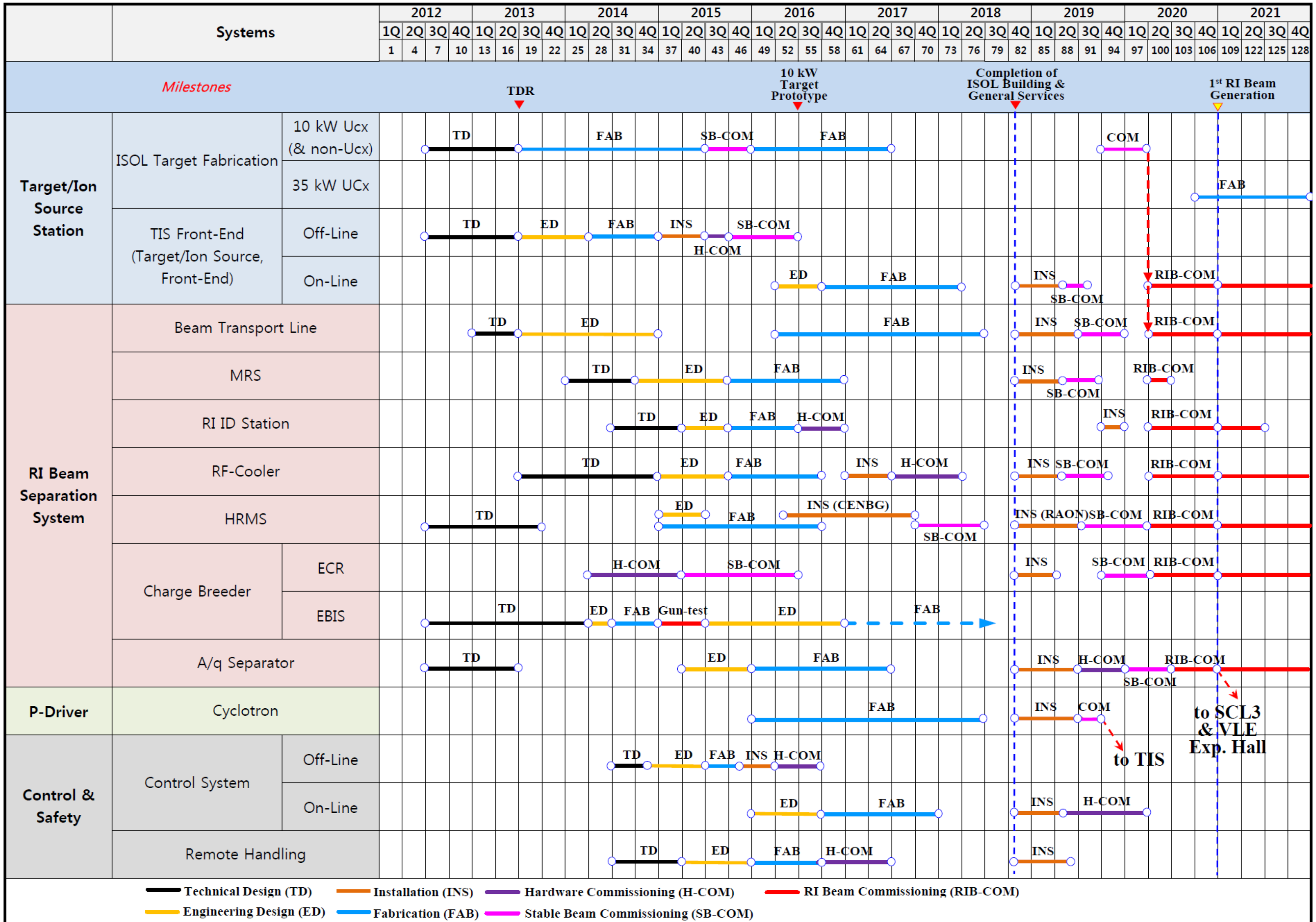
Layout of ISOL Facility



System	Development Goal
① Proton Driver	Cyclotron (70 MeV, 1 mA)
② Target- Ion Source	▪ Fission Target (10 kW & 35 kW) • 1.6×10^{13}~1.2×10^{14} f/s • 2.2×10^{9}~1.6×10^{10} ^{132}Sn/s ▪ Ion Sources • SIS, RILIS, FEBIAD
③ RF-cooler	▪ CW and Pulsed ▪ Beam current : up to 1 μA ▪ Emittance : ~ 3 π, $\Delta E/E$ < 5×10^{-5} ▪ $\varepsilon_{trans.}$ > 60 % (CW)
④ HRMS	▪ R_w~10,000 ▪ D > 34 cm/%
⑤ Charge Breeder	▪ EBIS (ECR) • efficiency : 4~30% (1~18%) • A/q : 2~4 (4~8) • E spread (eV/q) : ~50 (1~10) ▪ E/A : 5 keV/u
⑥ A/q Selector	▪ $R_{A/q}$ ~500 ▪ E+B combination
⑦ Re-accel	▪ Super-conducting LINAC (0.5~18.5A MeV)

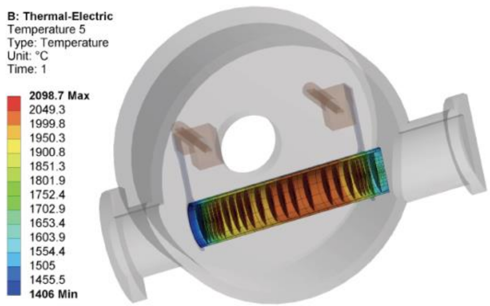
Planning for ISOL facility

ISOL Facility Schedule (updated, 2014. 9)

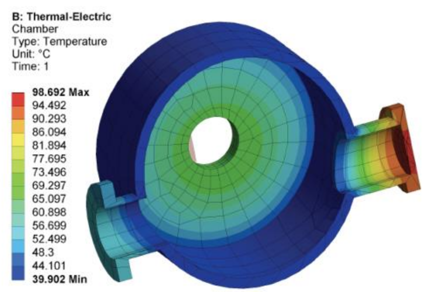


10 kW ISOL target

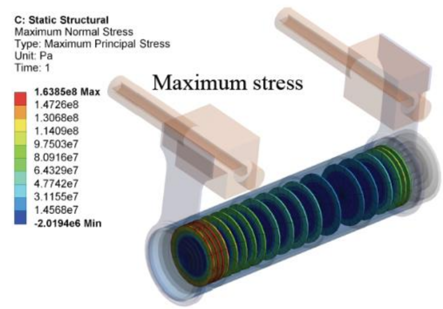
Temperature of the target



Temperature of the chamber



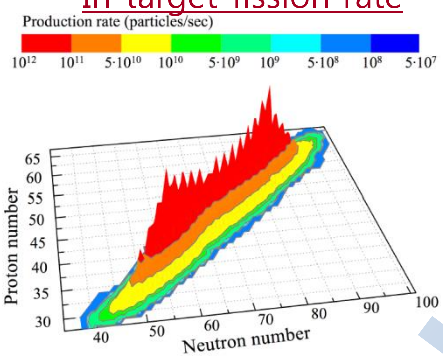
Thermal stress of the target



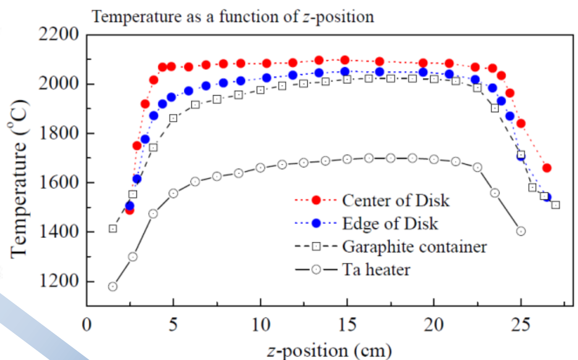
Proton Beam	
Energy	70 MeV
Power	10 kW
Beam size	45 mm

Target	
Material	UCx
Density	2.5 g/cm^3
U weight	101 g
# of disk	19
Disk thickness	1.3 mm
Disk diameter	50 mm
Total length	22 cm

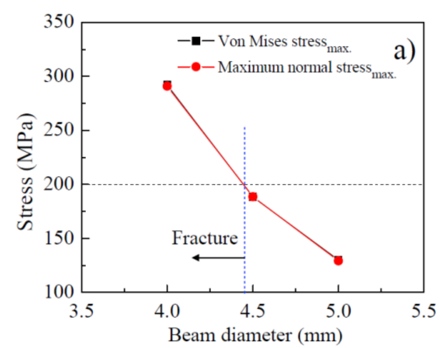
In-target fission rate



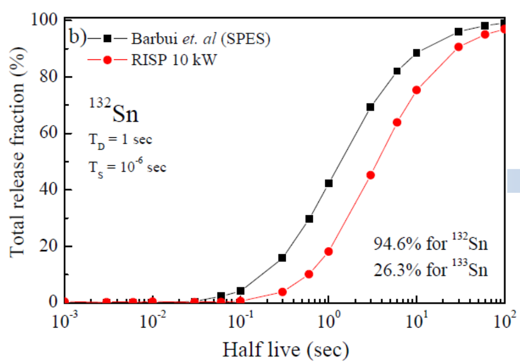
Temperature distribution



Maximum thermal stress



Release time of ^{132}Sn



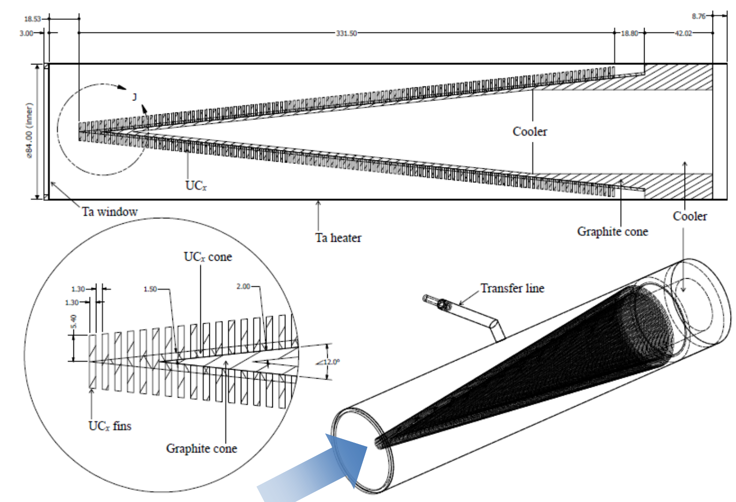
Calculation of the release rates for the n-rich Sn isotopes

Isotopes	Half live (s)	Production rate	Release rate
^{132}Sn	39.7	2.2×10^9 pps	**2.1×10^9 pps**
^{133}Sn	1.2	2.7×10^7 pps	**7.2×10^6 pps**
^{134}Sn	1.1	8.9×10^6 pps	**2.4×10^6 pps**
^{135}Sn	0.5		
^{136}Sn	0.3		
^{137}Sn	0.1		

In-target fission rate = 1.6×10^{13}/s

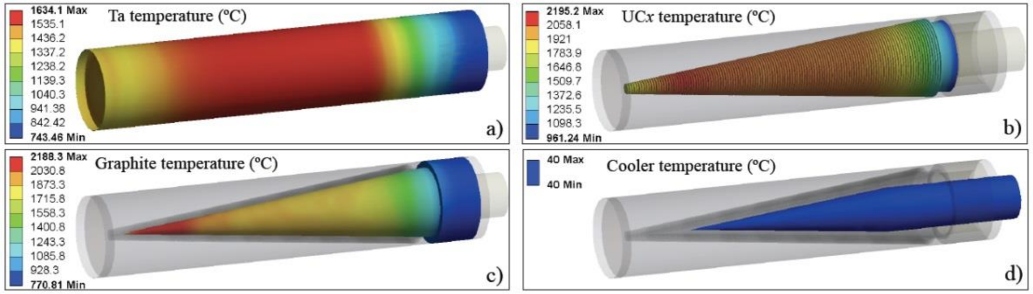
High power ISOL target

Technical drawing of the high power ISOL target

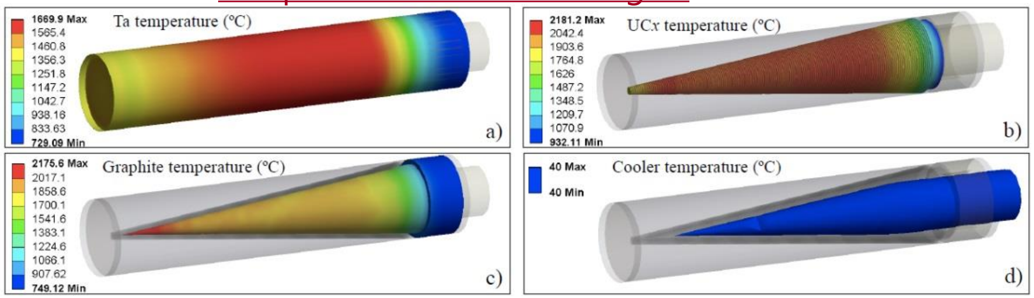


70 MeV proton beam

Temperature of 35 kW target



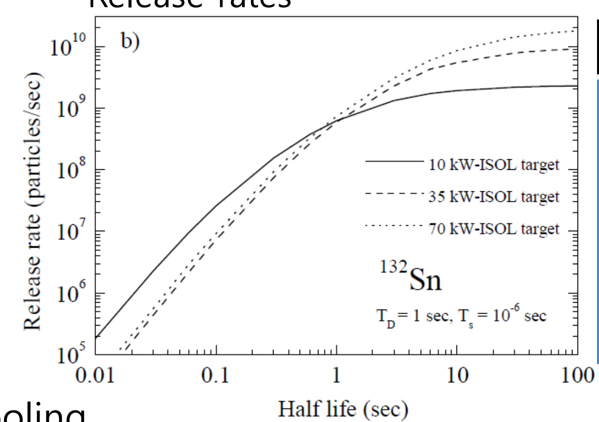
Temperature of 70 kW target



	10 kW	35 kW	70 kW
fission rate (s^{-1})	1.6×10^{13}	7.3×10^{13}	1.5×0^{14}
^{132}Sn production (s^{-1})	2.3×10^{9}	9.7×10^{9}	2.0×10^{10}
^{132}Sn release rate (s^{-1})	2.2×10^{9}	8.2×10^{9}	1.6×10^{10}
Yield @Exp. Hall (s^{-1})	1.1×10^{7}	3.9×10^{7}	7.5×10^{7}

*BERTINI-ORNL model
**assuming overall efficiency of ~0.5 %

Release rates



Size

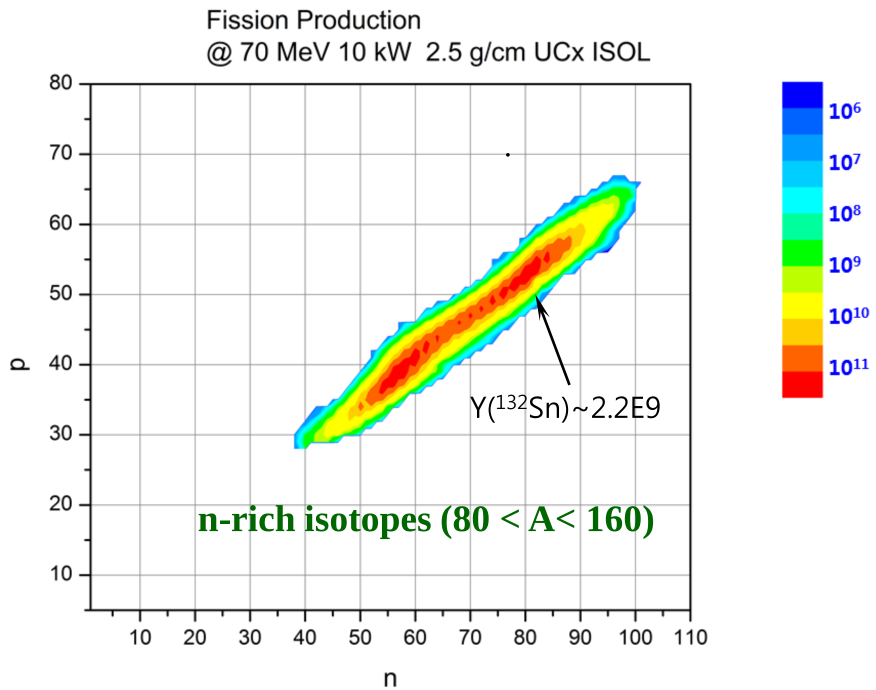
	35 kW	70 kW
Material	UCx	UCx
UCx density	2.5 g/cm^3	2.5 g/cm^3
Type	Cone	Cone
Diameter	84 mm	106 mm
Length	370 mm	540 mm

- Advantage: High fission rate and efficient cooling
- Disadvantage: Long release time

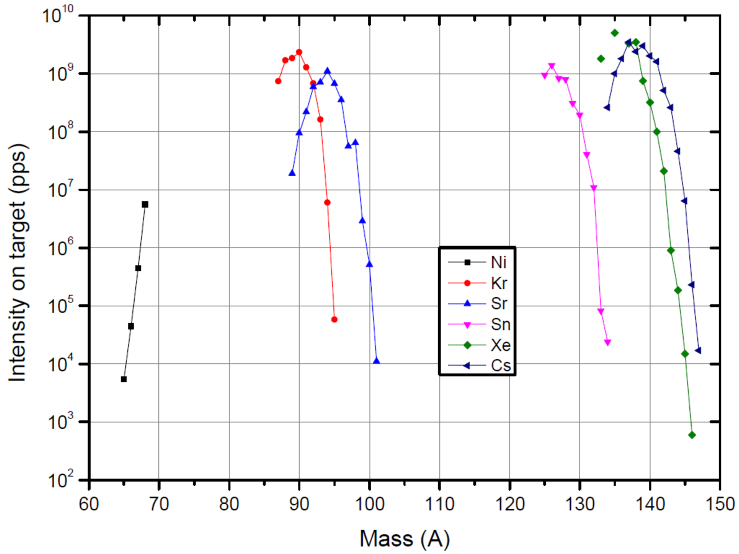
RI yield estimation

- p + UCx → n-rich isotopes (80 < A< 160) by fission reaction
- Fission rate (10 kW) : 1.6×10^{13} f/s

Production yield (10 kW ISOL target)



Expected lab. intensities (10 kW target)



Isotope	Half-life	Science	Lab. Yield (pps)
^{66}Ni	2.28 d	pigmy	4×10^5
^{68}Ni	21 s	symmetry	5×10^6
^{132}Sn	39.7 s	r-process, pigmy	1×10^7
$^{130-135}$Sn	0.5 s ~ 3.7 min	Fine structure, precision mass	$10^4 \sim 10^8$
^{140}Xe	13.6 s	Symmetry	3×10^8
^{144}Xe	0.4 s	Symmetry	1×10^5

ISOL target preparation (I)

Processing route for carbide production

Materials
- La_2O_3 (99.99% powders, Sigma Aldrich)
- Graphite (<45 μm, Sigma Aldrich)
- MWCNTs (~90 wt.%, Hanwha Nanotech)

Powder & disk preparation

Dry	Wet	Wet + Dry
• Planetary Ball Mill (La_2O_3, graphite & binder-phenolic resin) • Pressing	• Planetary Ball Mill (La_2O_3, graphite & binder in IPA) • Drying • Pressing	• Magnetic stirring (La_2O_3, graphite or MWCNTs & binder in IPA) • Drying • Planetary Ball Mill • Pressing

Two-step thermal treatment
1. Carbothermal reaction (2℃/min up to 1250℃, 24 h at 1250℃) under vacuum (10^{-7}~10^{-5} mbar)

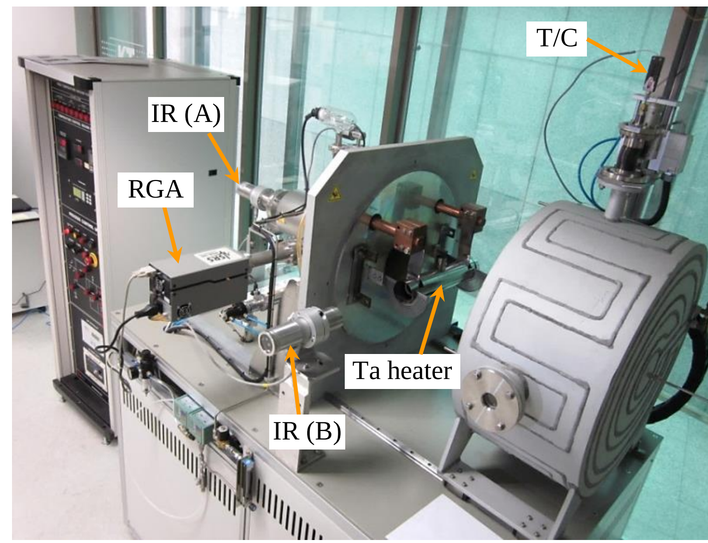
   *** $La_2O_3 + 11C \rightarrow 2LaC_2 + 4C + 3CO$**
2. Sintering the carburized powders (2℃/min up to 1600℃, 4 h at 1600℃)
3. Slow cooling at a rate of 2℃/min

Characterization
1. Grain size, density & open porosity, stoichiometry (SEM-EDX, XRD, He-pycnometer)
2. (high-temperature) emissivity & conductivity (dual-frequency pyrometer)

Planetary Ball Mill

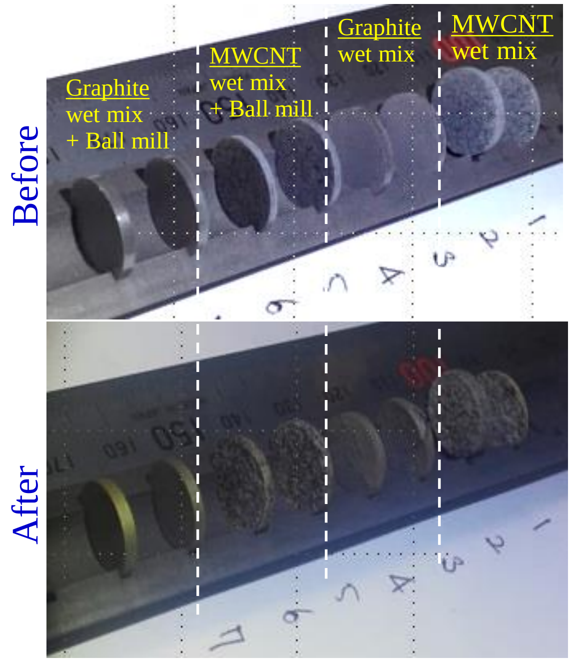
Glove Box

10 ton Press

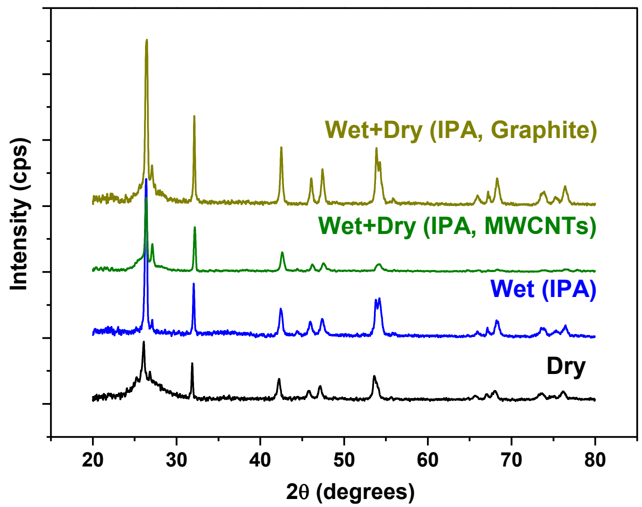


High-temp. (2100℃) Hgh-vacuum Furnace

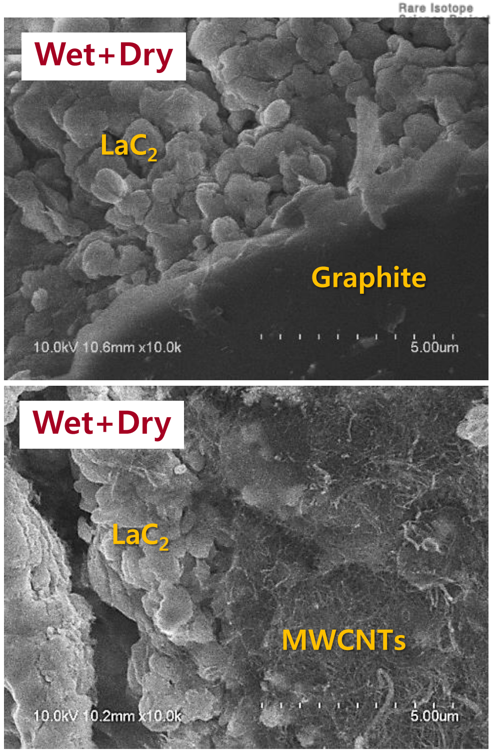
ISOL target preparation (II)



Target disks before & after thermal treatment



XRD spectra after thermal treatment



Target surface morphology by SEM

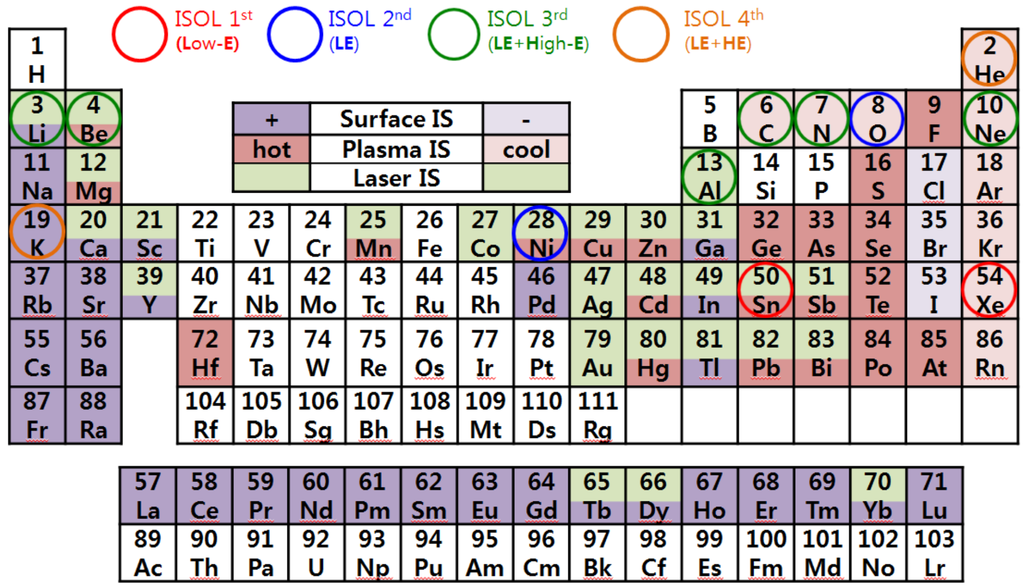
Summary of La carbide target preparation

No.	Carbon Source	Binder (Solid)	Mixing & Grinding	Thermal Treatment	Porosity
D1	Graphite	phenolic resin (0.4 wt%)	**Dry**-Ball Mill, 12hr, 500rpm	1250℃, 10hr / 1600℃, 10hr	open 20% (total 28%)
W1	Graphite	phenolic resin (1 wt%)	**Wet, IPA**-Ball Mill, 3hr, 500rpm	1250℃, 10hr / 1600℃, 10hr	open 49% (total 61%)
WD1	MWCNT	phenolic resin (2 wt%)	**Wet, IPA**-Stirring, 2.5hr, 700 rpm **Dry**-Ball Mill, 2hr, 100rpm	1250℃, 10hr / 1600℃, 10hr	open 77% (total 80%)
WD2	Graphite	phenolic resin (2 wt%)	**Wet, IPA**-Stirrer, 2.5hr, 700rpm **Dry**-Ball Mill, 2hr, 100rpm	1250℃, 10hr / 1600℃, 10hr	open 48%, (total 55%)

He-Pycnometer

RI Ion Sources (ISOL)

- Standard requests:
  - rapidity: for isotopes with short half-life (high-temp. & short connection with target)
  - efficiency: limited amounts of radionuclides
  - selectivity: less isobaric contamination
  - high intensity: up to 10^{14} atoms/s
  - high brightness: for trap & charge breeder injection
  - simple, reliable & radiation resistant



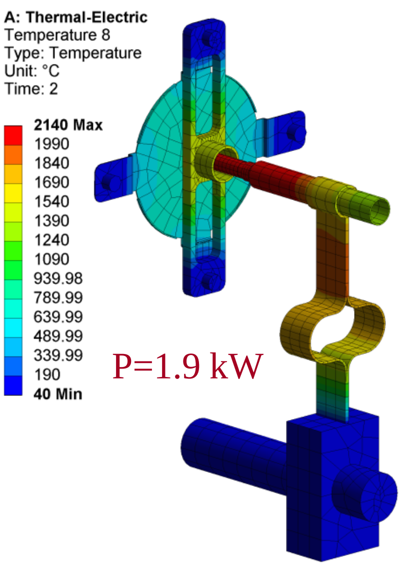
Periodic table for the elements (RISP)

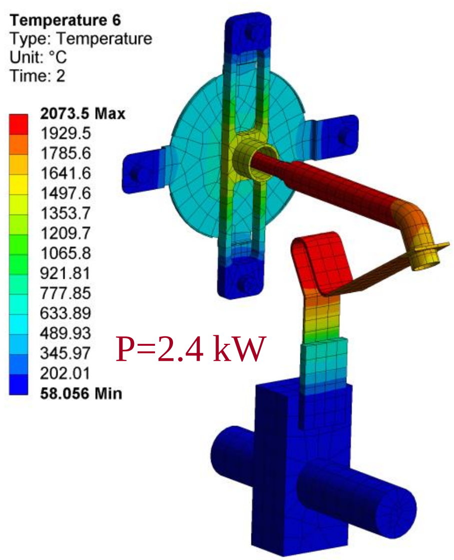
- No universal IS for on-line application
  - Alkali & alkaline earth metal : Surface Ionization Source (SIS)
  - Post-transition metal : Laser Ionization Source (LIS)
  - Gaseous element : FEBIAD
- Staged approach beginning with SIS which can be easily extended to LIS.
  - SIS ⇒ LIS ⇒ FEBIAD

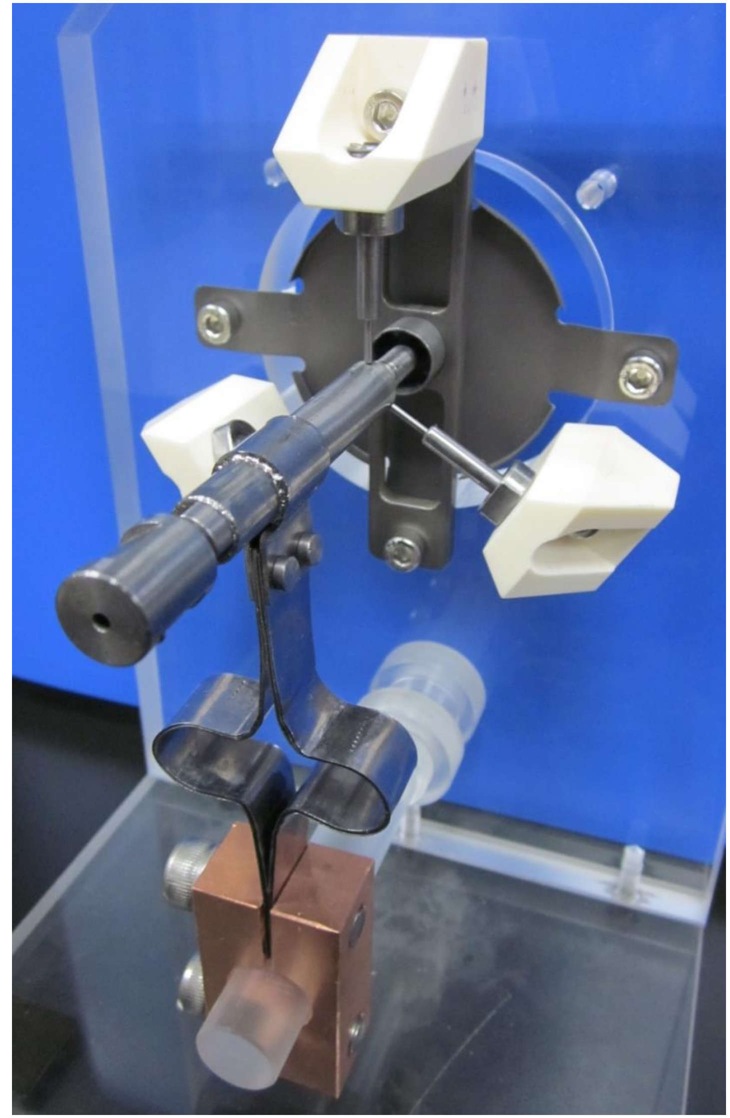
Surface Ionization Source

- Efficient ionization method for the elements with IP<7 eV (positive ions), mainly for the alkali and alkaline earth metals, and with EA>2 eV (negative ions).

Temperature	1200 - 2300°C
Cavity	L = 30 mm, ID = 3 mm
Cavity Material	Positive : Re (Ta, W) Negative : LaB_6, GdB_6
Heating	Ohmic heating, ~300 W
Plasma density	10^8-10^{10} /cm^3
E_e	~0.3 eV
Max. ion current	~1 μA/mm^2
Energy spread	<2 eV
$\varepsilon_{95\%}$@30kV	10-15 π mm mrad





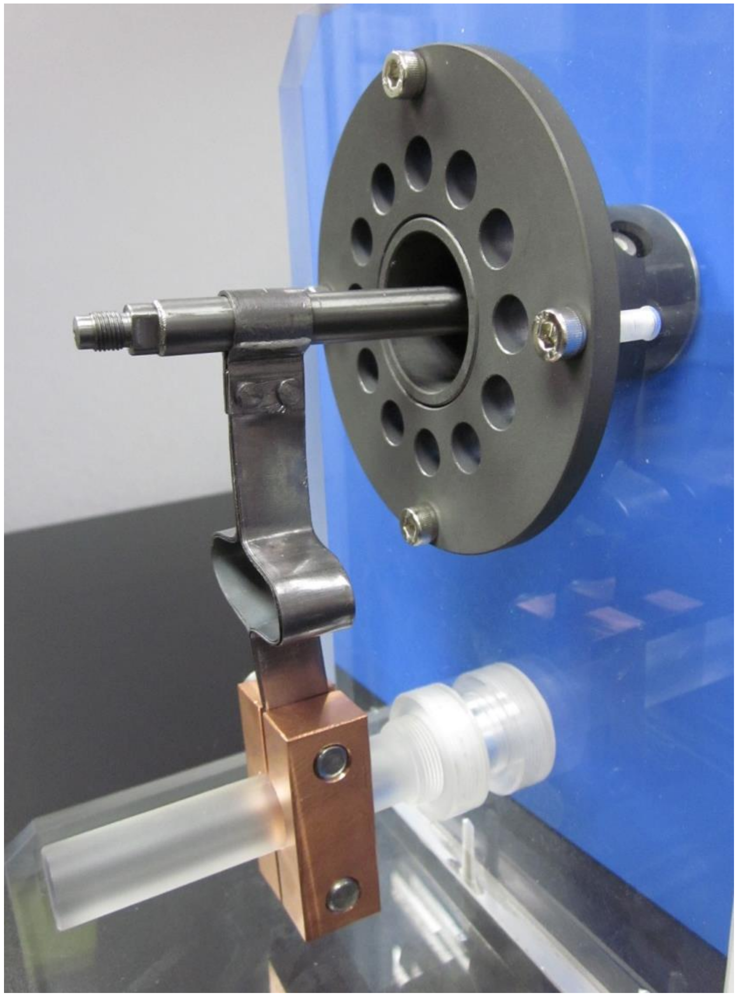


Surface Ion Source

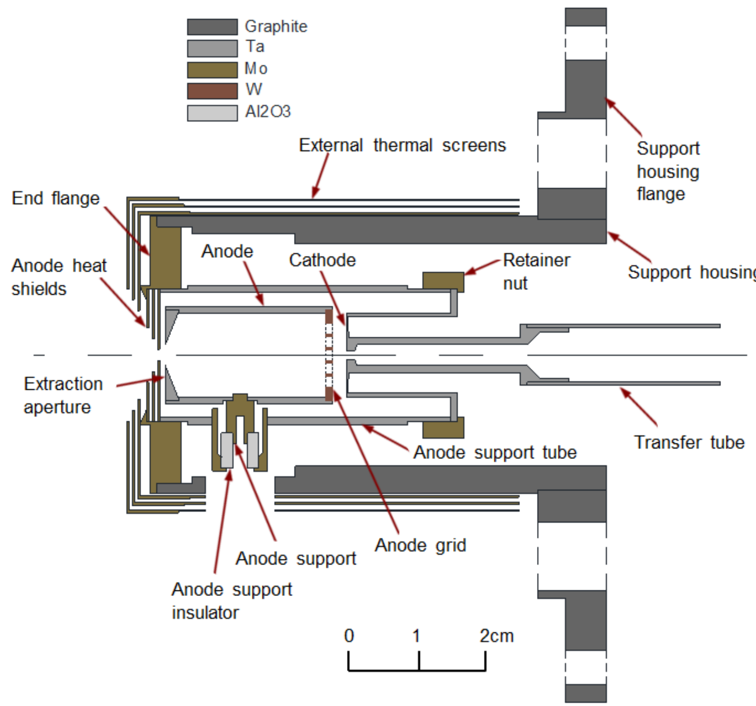
FEBIAD (plasma) Ion Source

- Purpose : production of gaseous n-rich RI beams
- Modeled in the ISOLDE MK5-type FEBIAD

Temperature	1500 - 2300°C
Cavity	L = 2-3 cm, Φ = 1-2 cm
Materials	C, Ta, Mo, W
Insulator	Al_2O_3 (BN, BeO)
Cathode heating	Ohmic heating, ~300 W
Operating pressure	10^{-5} ~ 10^{-4} mbar
Plasma density	10^8-10^{11} /cm^3
Plasma potential	70% of Anode Vtg (90-150 V)
E_e (E_{ion})	~10 eV (~0.2 eV)
Ionization efficiency (%)	Ar ~5%, Xe ~14%, Kr ~25%, Sn~45%
$\varepsilon_{95\%}$@30kV	15-25 π mm mrad
Extraction Potential	20~50 kV

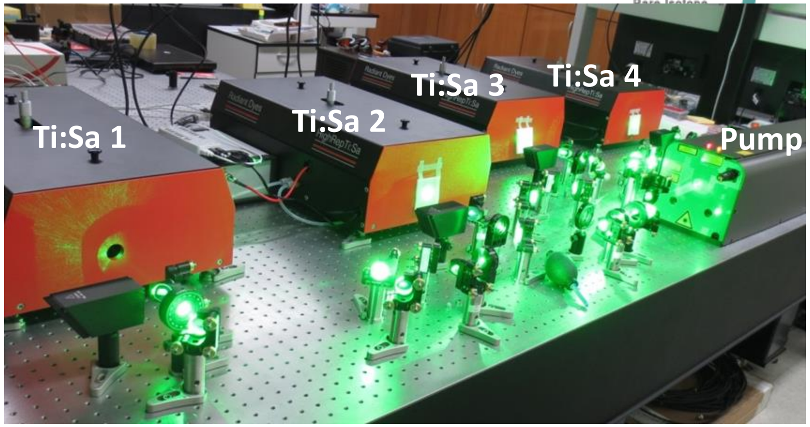


FEBIAD version-1 (RISP)

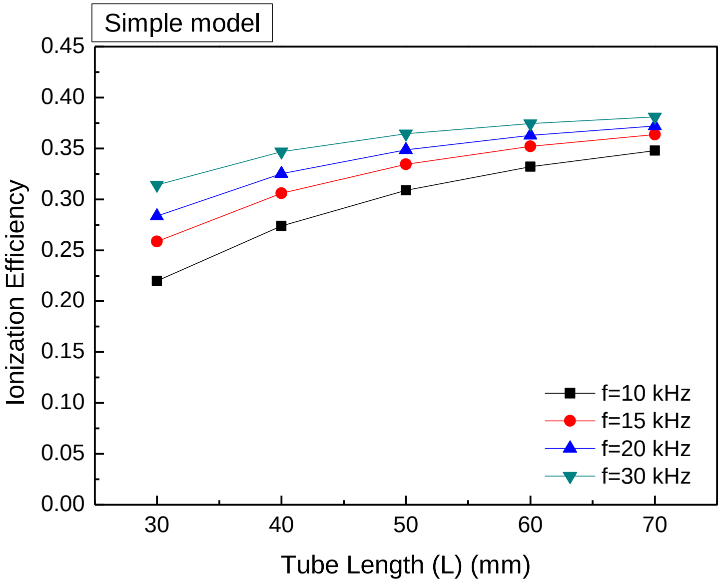


Resonance Ionization Laser Ion Source (RILIS)

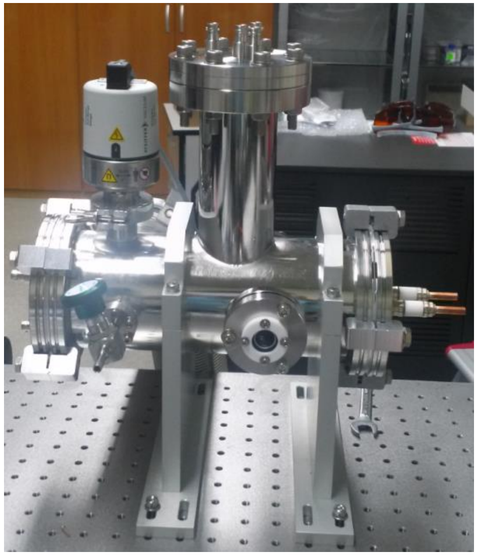
Temperature		1500 - 2200°C
Cavity (Ta)		L = 3 cm, ID = 3 mmΦ
Heating		ohmic heating, ~300 W
Ion current density		100 nA/mm^2 @20-60 kV
Ionization efficiency		Sn 22%, Al 13%, Ni 3%, Be 3%
$\varepsilon_{95\%}$@30kV		10-15 π mm mrad
Laser	Ti:Sa Laser (4 ea)	• wavelength 700-1000 nm (5 W) • rep. rate 10 kHz (pulse width 40-70 ns) • Radiant Dyes Laser (Germany)
	Nd:YAG (1 ea)	• wavelength 532 nm (100 W) • rep. rate 10 kHz (pulse width 100 ns) • Lee Laser, LDP-200MQG-HP (USA)



Laser System installed at RISP



Ionization efficiency of Sn as a function of laser frequency & tube length



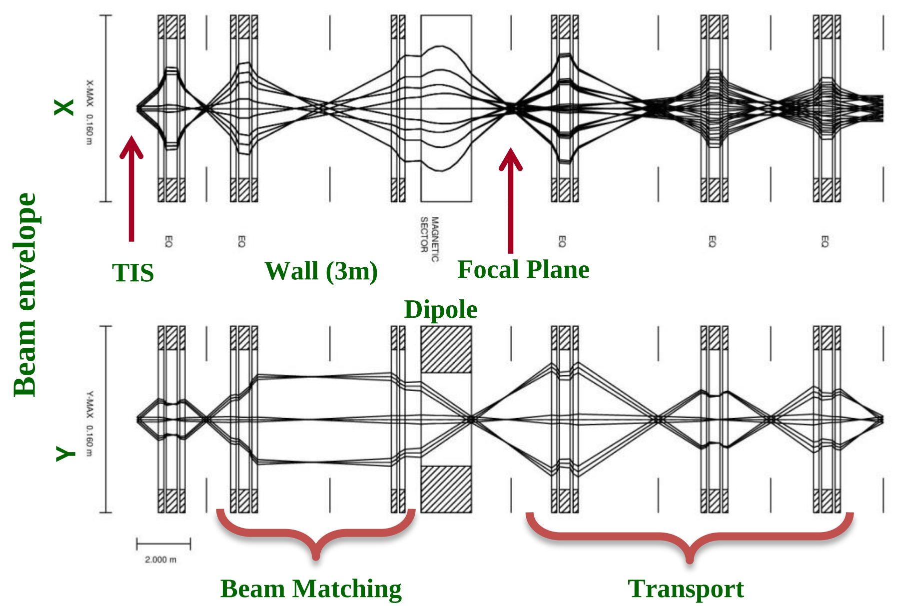
Reference cell for the off-line ionization test

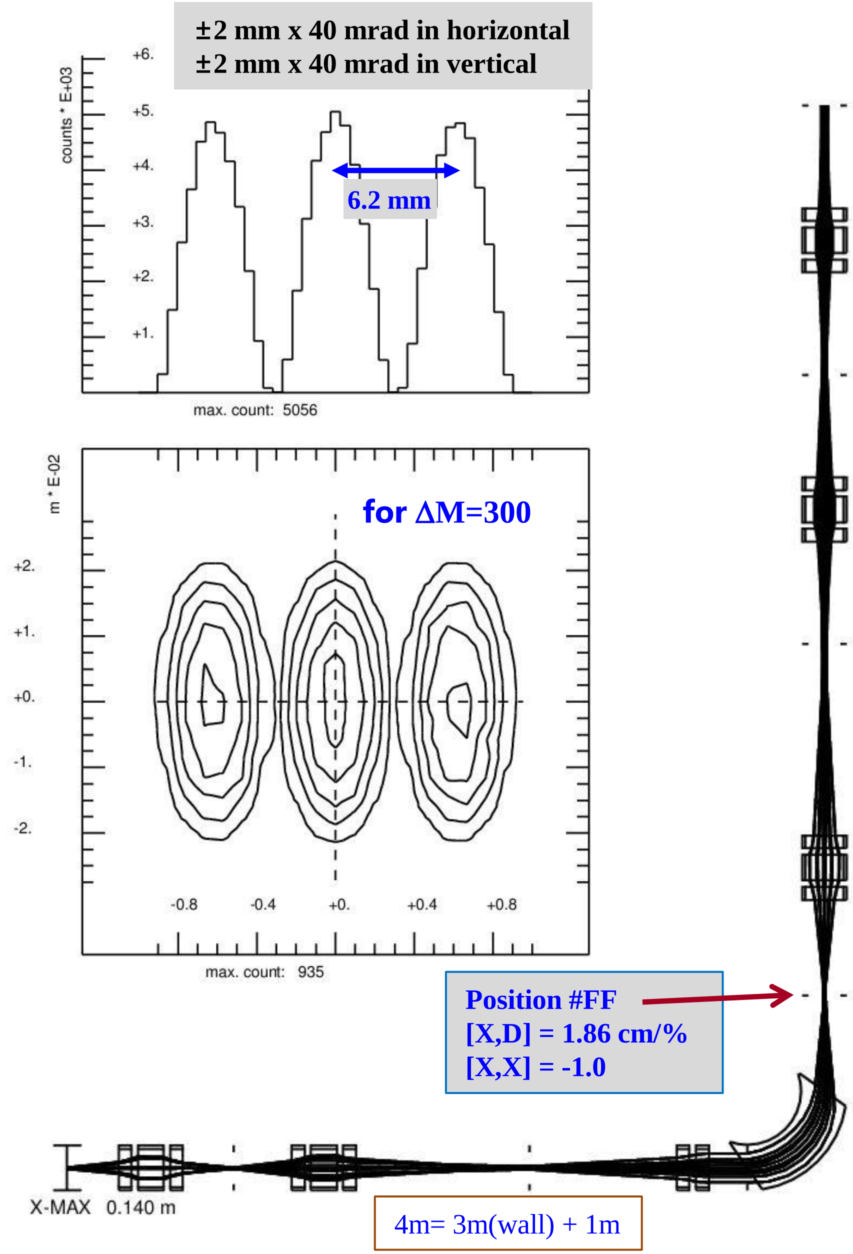
- **Current Status**
  - **The Laser system** for RILIS was installed.
  - **The reference cell** was fabricated in collaboration with Mainz Univ. (Prof. Wendt)
  - **The ionization scheme for tin** will be tested using the reference cell in time.

Design of Pre-separator

Extraction Voltage		Max 50 kV, 1+ charge state
Bρ		0.37 Tm
Beam size		±2 mm
Angular acceptance		±15 mrad
Dipole	Bending angle	90º
	Bending radius	1.2 m
	Gap	8 cm
	Pole face angle: entrance, exit	35º
Electro Static Quadrupole		Φ120 mm, Length 20-40-20 cm Gap 10 cm
Mass Dispersion		1.86 cm/%
Slit Position after Dipole		1.5 m
Slit Width		±3 mm for reject mass diff. 300

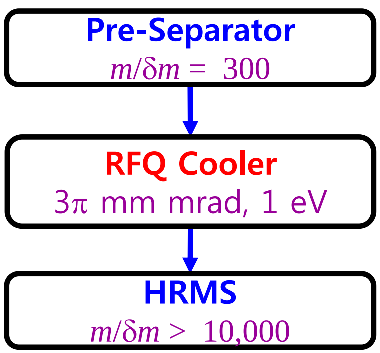
* All components are electrostatic module except for dipole

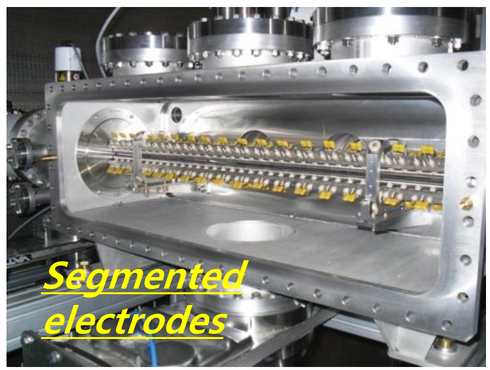




RFQ-Cooler

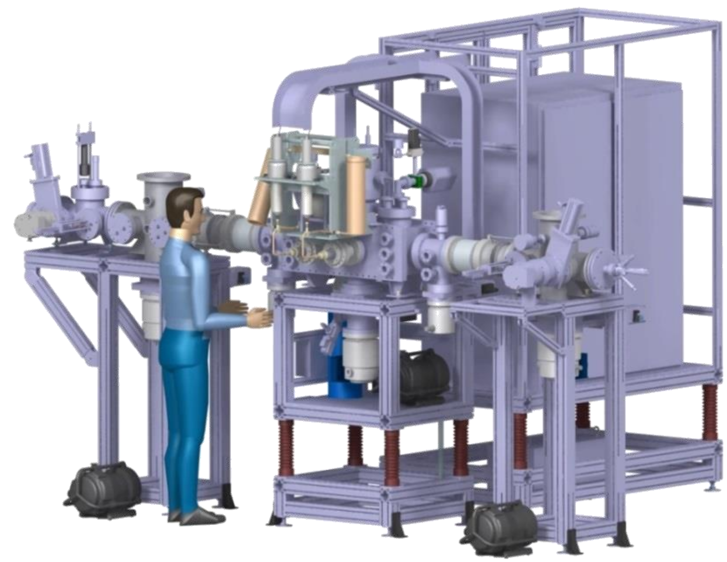
- **Objective**: Securing the resolution of HRMS by enhancing the beam quality
- **Method**: international collaboration between LPC-CAEN and RISP
- **Acceptibility**
  - beam current: up to 1 μA
  - transverse emittance: > 30 π mm mrad @ 20 keV
  - energy spread: > 10 eV





	Requirements	Results	Fulfillment
Transmission	20 % for m ≈ 12 u 40 % for m ≈ 40 u 60 % for m ≥ 90 u	**?** **T > 70%** **T > 70%**	**OK**
Energy spread	≤ 1eV (FWHM)	**1.65 eV @ 50nA**	
Emittance	≤ 3 π.mm.mrad	**< 3 π.mm.mrad**	**OK**

Test with ^{39}K and ^{133}Cs

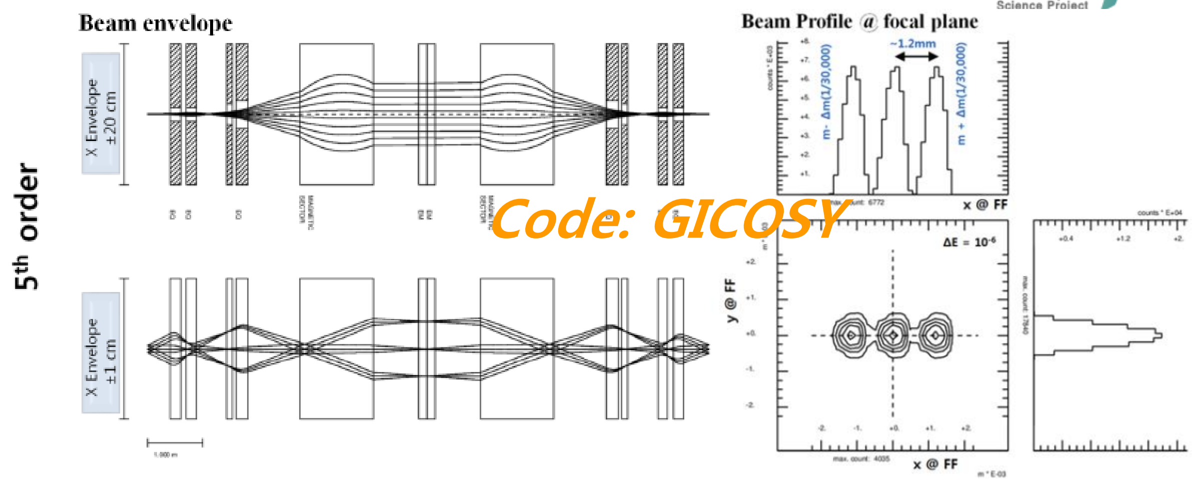


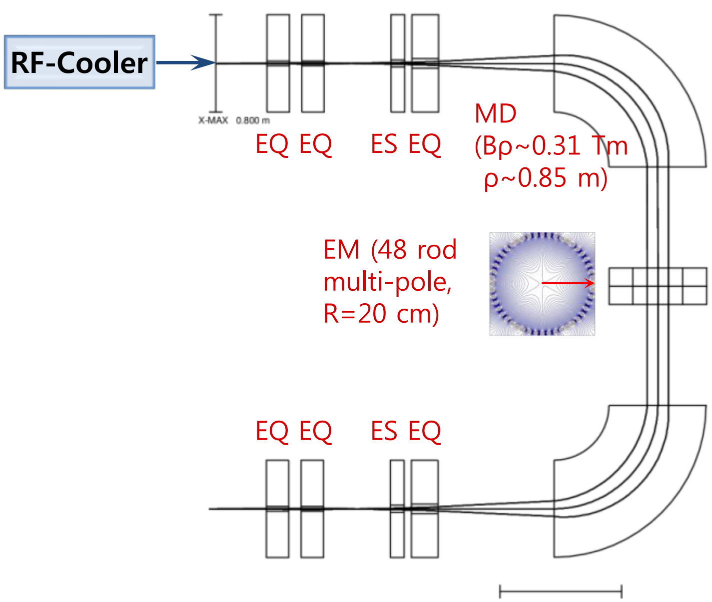
RFQ-cooler for SPIRAL-2

HRMS (High-Resolution Mass Separator)

Parameters

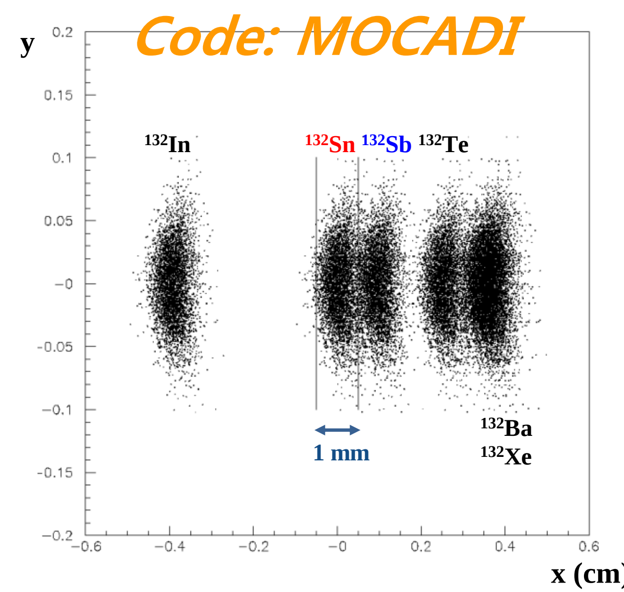
- acceptable mass range: 6<A<240
- KE < 50 keV (ΔE ~1 eV)
- acceptance : 3π mm mrad
- QQSQ-DMD-QSQQ symmetry (modelled on HRS@SPIRAL2)
- dispersion D_m ~ 34 cm/%
- R_W (R_S) ~10,000 (34,000)
- transmission: >90% for ^{132}Sn



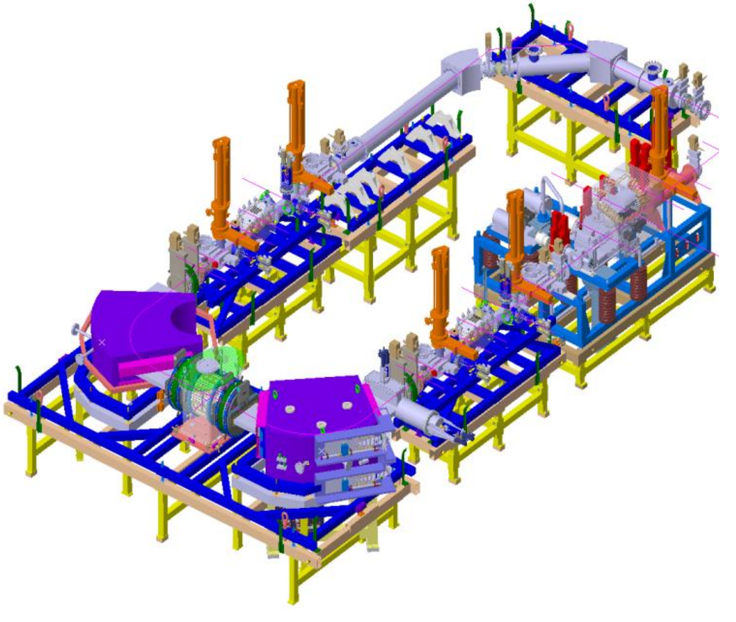


Isobar separation

- Slit width : ±0.5 mm
  - transmission ~93 % for ^{132}Sn
  - contamination of ^{132}Sb ~ 4 % (assuming same intensity)
- systematic instability not considered

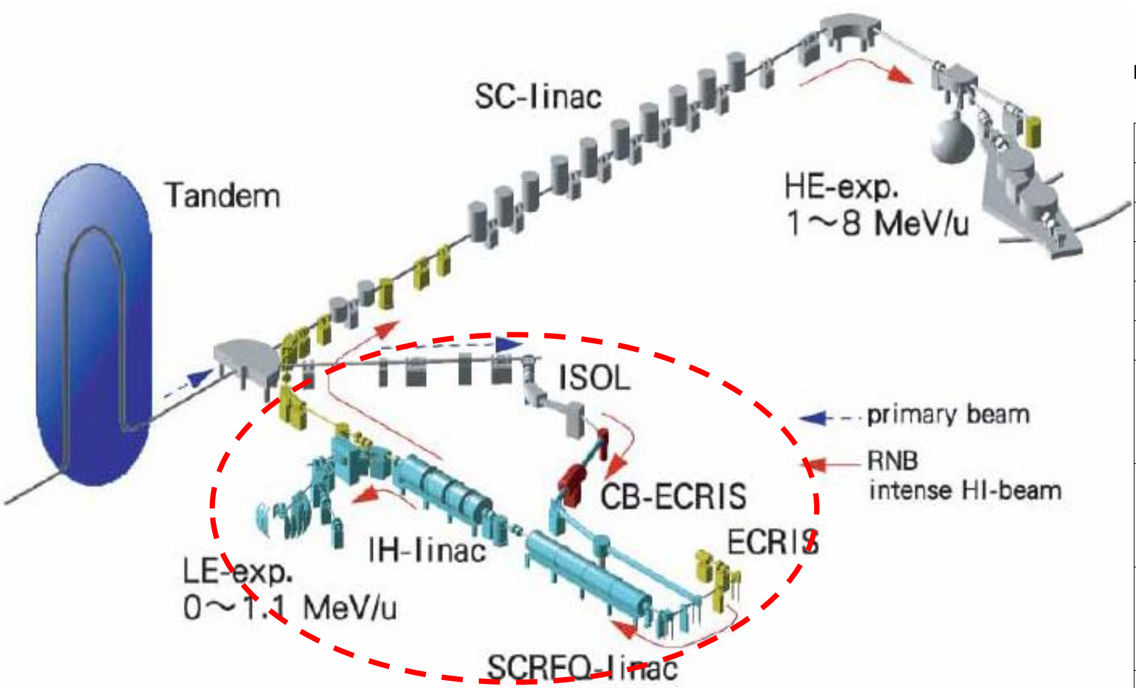


- Collaboration with CENBG for RISP HRMS (duplication of HRS@SPIRAL2)
- Main differences between the HRMS and HRS (due to the level of activity)
  - not modular system : no quick connection and disconnection systems modules
  - support frames may be different
  - diagnostics may be different...
    - slit system
    - no double valve on diagnostics
- A completion of the Research Agreement is in the final stage.
  - about 2M€ is allocated for HRMS
  - development schedule
    - 9/2014 ~ 6/2015 : technical & engineering design
    - 1/2015 ~ 9/2016 : fabrication
    - 4/2016 ~ 9/2017 : installation at CENBG
    - 10/2017 ~ 6/2018 : commissioning with stable beam
    - 7/2018 ~ 6/2019 : transfer & integration to/at RISP
    - 7/2019 ~ : commissioning with stable & RI beams



Charge Breeder

- Purpose : charge state increase ($1^+ \rightarrow n^+$) of ions for efficient acceleration at post-accelerator
- Strategy for charge breeder R&D
  - upgrade & introduction of ECR-CB at DIAC/KAERI (old TRIAC/KEK)
  - development of EBIS-type CB (in Accelerator Division)

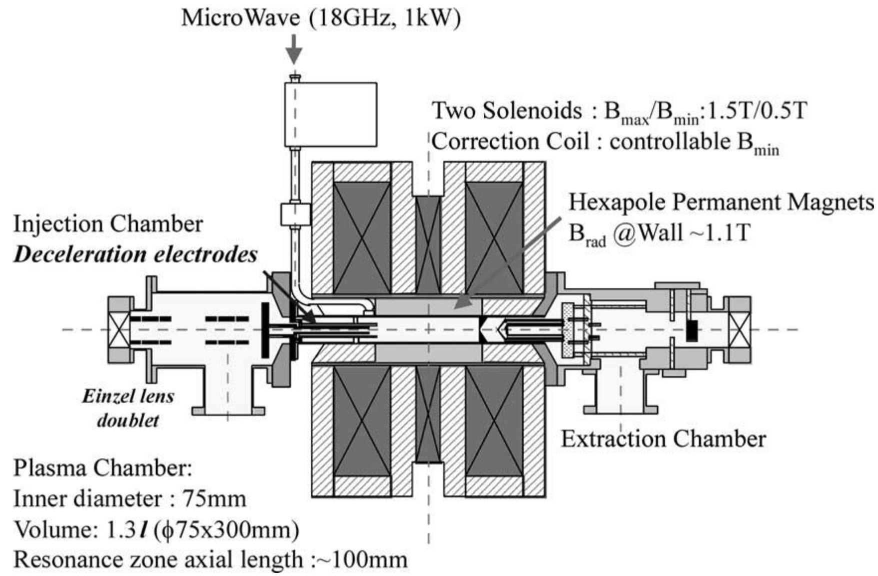


Old TRIAC layout at KEK

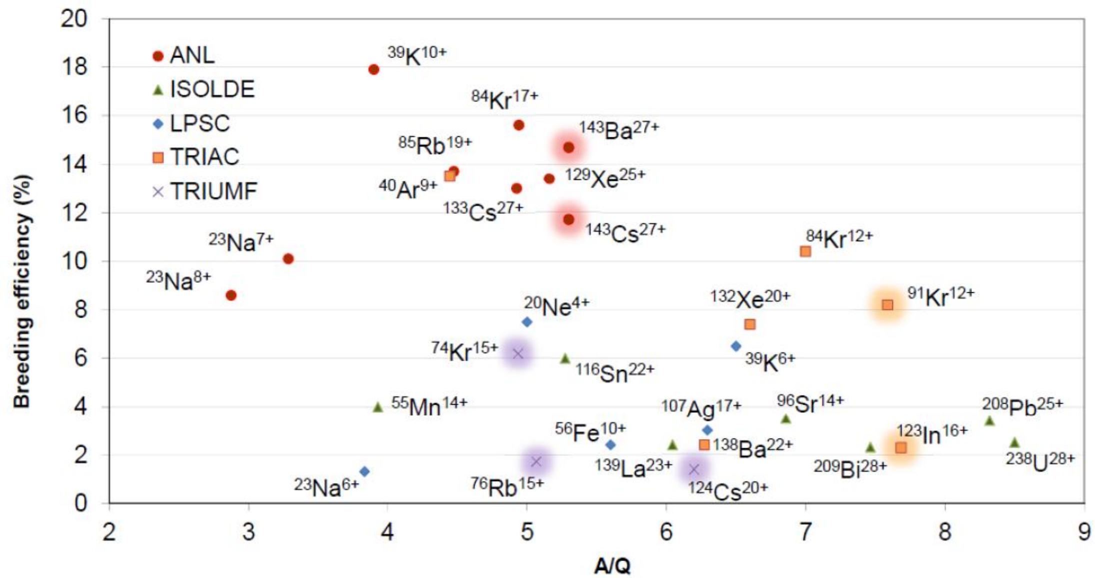
- Charge Breeder

Parameter	Value
RF Frequency	18 GHz / 1 kW
B_{max}	1.5 T
B_{min}	0.5 T
Correction coil	Controllable B_{min}
Mirror ratio	R_{axial} = 2.3, R_{radial} = 1.7
Hexapole Permanent Magnets	Length = 300 mm Inner diameter = 85 mm B_{rad} = 1.1 T @ wall
Plasma chamber	Inner diameter = 75 mm Volume = 1.3 L (Ø75 × 300 mm) ECR zone ~ Ø100 × 100 mm
Deceleration system	Two cylindrical electrode Movable axial direction Outer/Inner diameter = 40/20 mm
Extraction voltage	30 kV

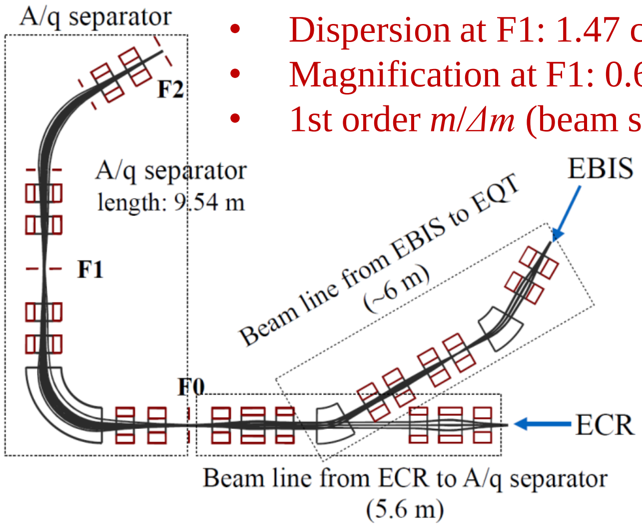
DIAC (old-TRIAC) layout at KAERI site



Cross-sectional view and specifications of the 18 GHz ECR-CB.
(TRIAC/KEK → DIAC/KAERI)



A/q separator combined with beam lines of ECR and EBIS CBs



- Dispersion at F1: 1.47 cm/%
- Magnification at F1: 0.63
- 1st order *m/Δm* (beam size: ±1 mm): **1170**

Magnetic dipole:
beading angle = 90°,
radius = 1.0 m,
full gap: 8 cm

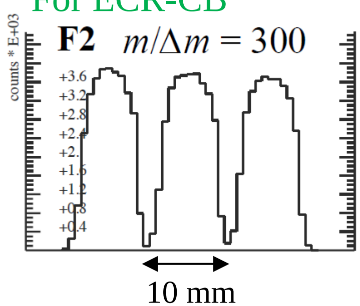
Electrostatic bender:
beading angle = 60°,
radius = 1.5 m,
full gap: 15 cm

Incident beam conditions

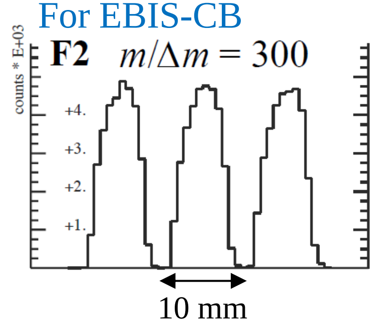
- ECR-CB: **60** and **100** π mm mrad at ***x*** and ***y***
- EBIS-CB: **25** π mm mrad at both *x* and *y*

Position distributions at F2 (5th order calculations)

For ECR-CB

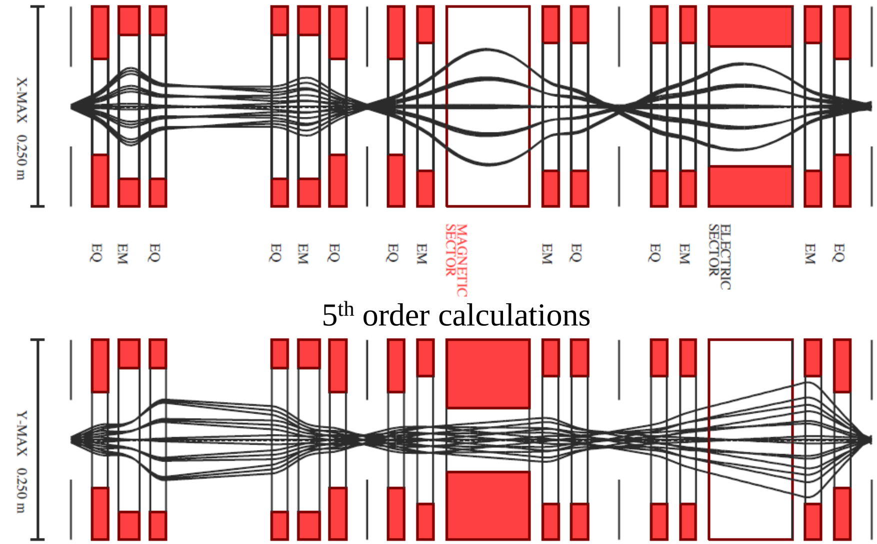


For EBIS-CB

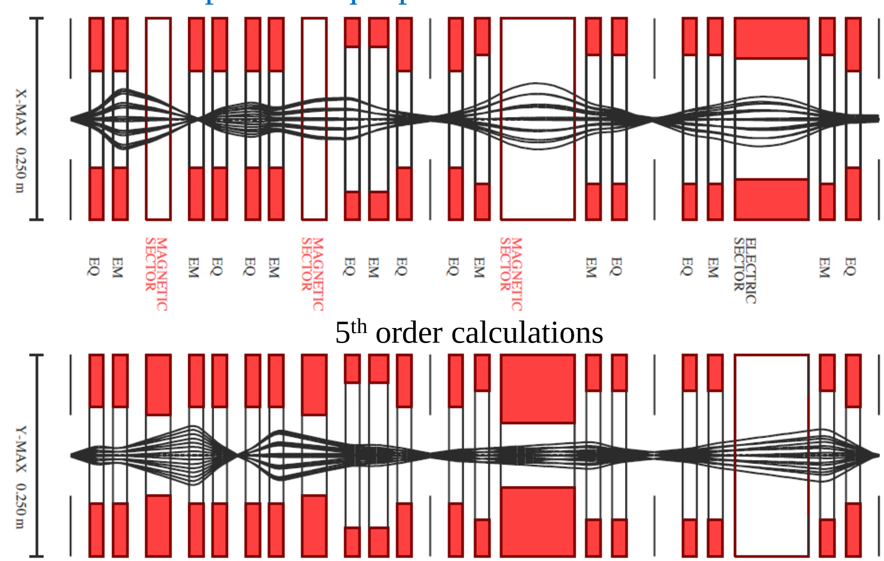


- Clear mass separation of *m/Δm* = 300 with small tail of the position distribution.
- Clear elimination of the high order aberrations, taking into account the aberrations of the CB beam lines

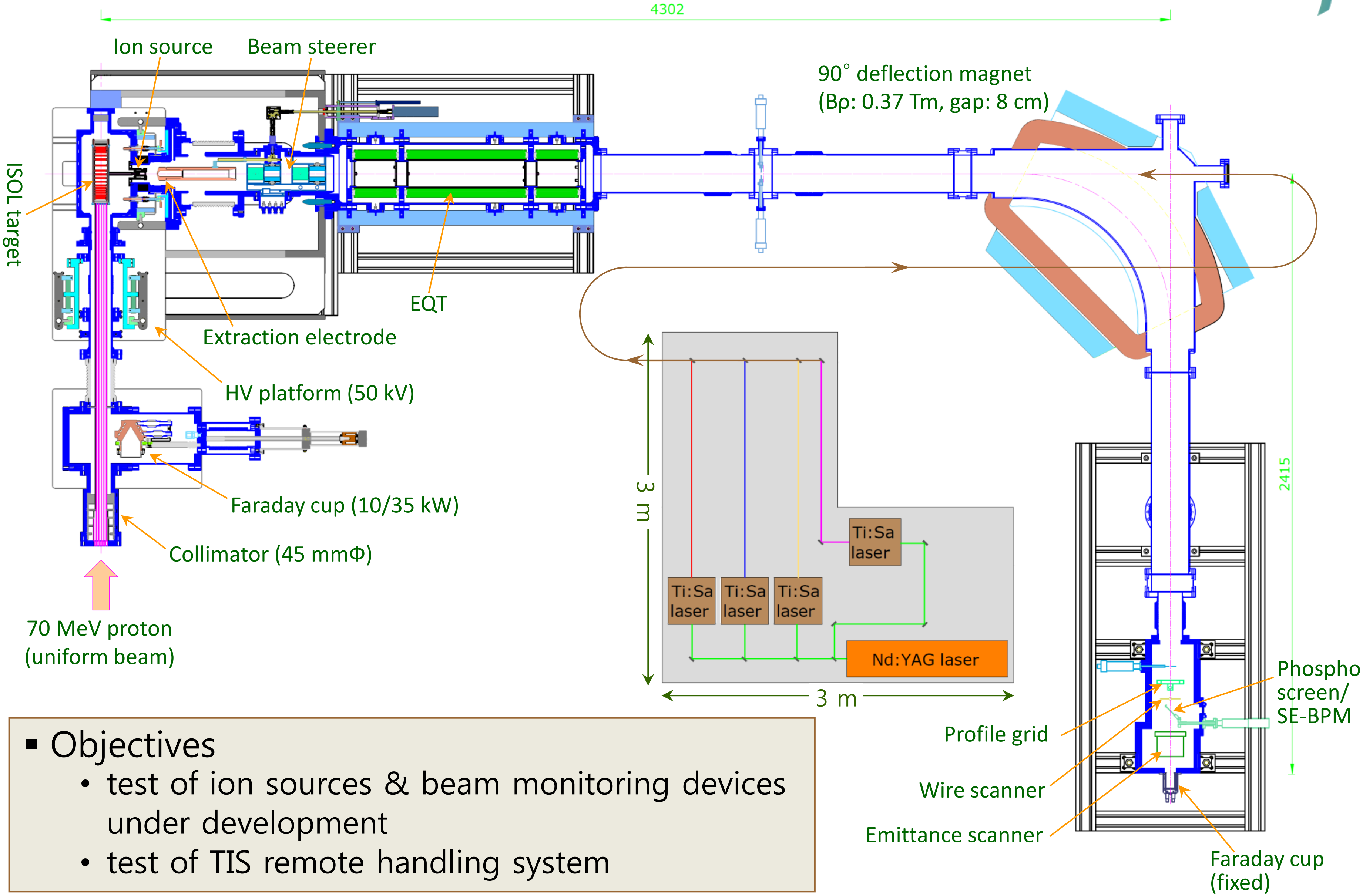
Beam envelopes of A/q separator **with ECR-CB beam line**



Beam envelopes of A/q separator **with EBIS-CB beam line**

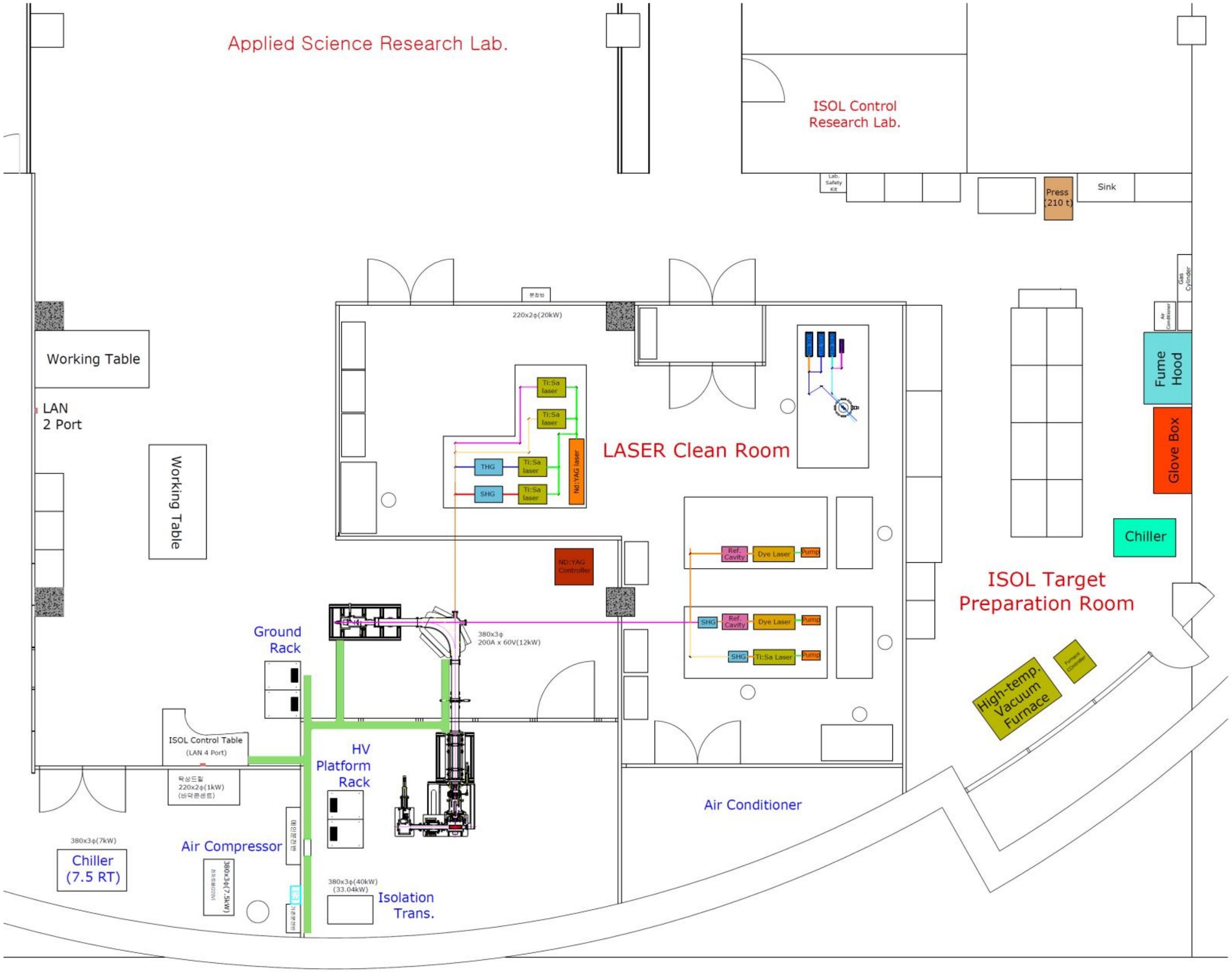


ISOL test facility (off-line)



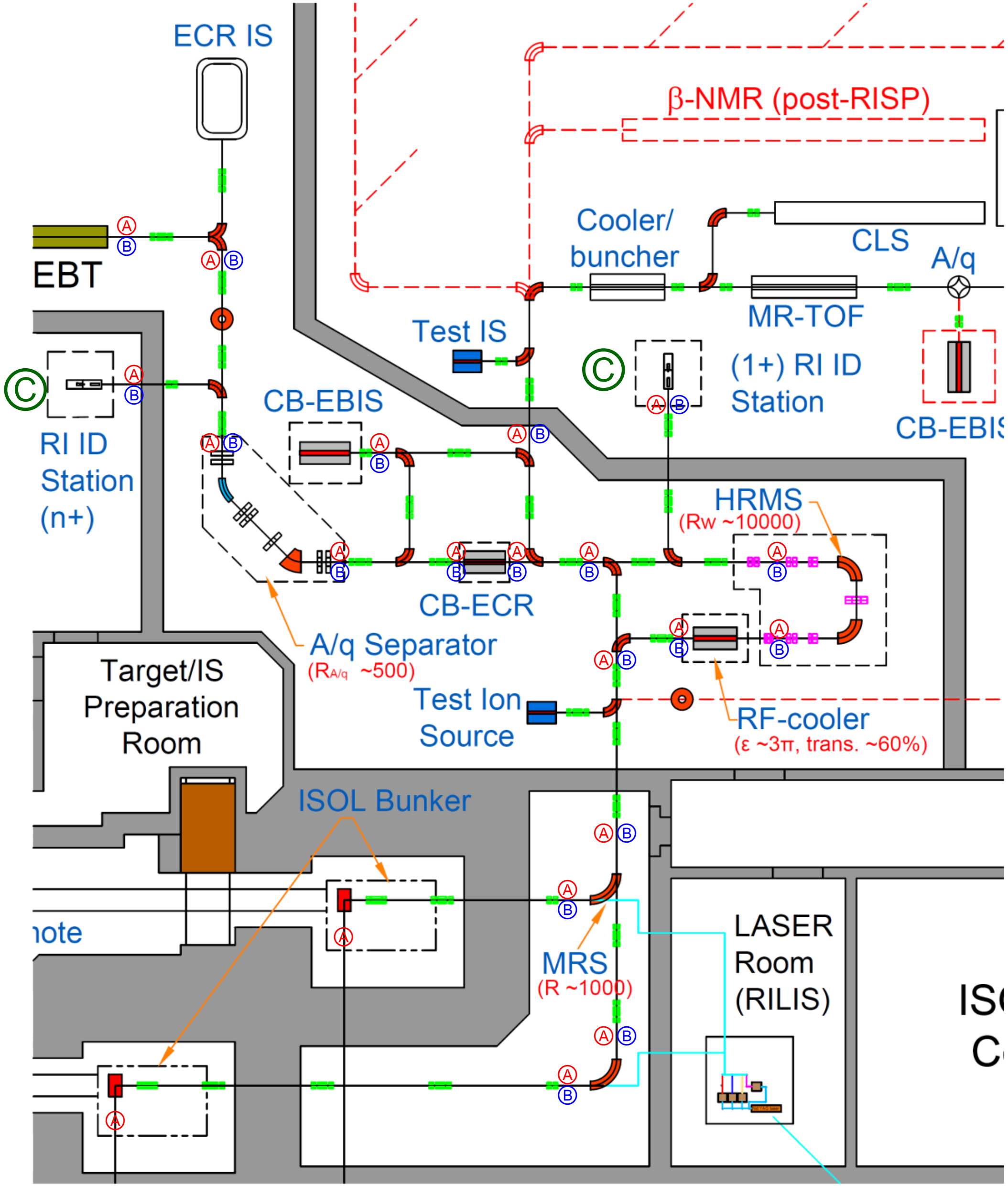
- Objectives
  - test of ion sources & beam monitoring devices under development
  - test of TIS remote handling system

ISOL Laboratory (for Test Facility)



Lab. Layout of Experimental Systems Div.

Beam diagnostics (I)



Ⓐ Beam Current Monitor (BCM)

- location
  - before & after main components
  - after bending
- type
  - Faraday cup
  - ???

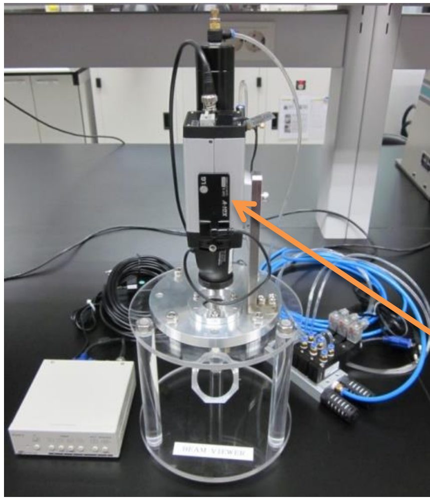
Ⓑ Beam Profile Monitor (BPM)

- location
  - before & after main components & benders
- type
  - Profile grid (at high-rad area)
  - Wire scanner
  - SE-BPM (for low-intensity beam)

Ⓒ RI ID Station

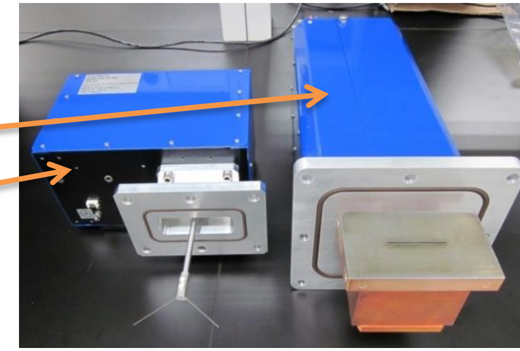
- two stations for (1+) & (n+) RI beams
- used to :
  - control the production of target via the 1+ source and the separator
  - control the good behaviour of the charge breeder
  - control the identity of the ions injected into SCL3

Beam diagnostics (II)



Beam viewer

Beam diagnostics chamber at the off-line ISOL facility



Oscillating wire scanner & Allison-type Emittance scanner (D-Pace)

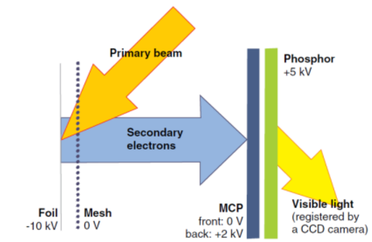
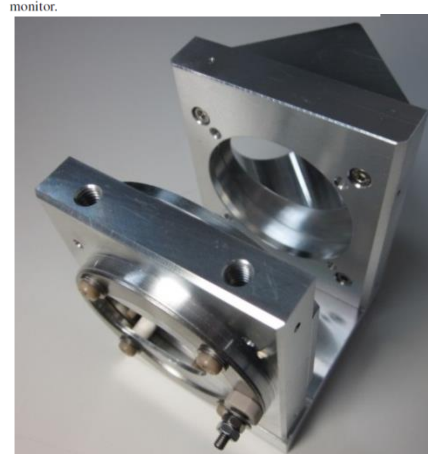


FIG. 3. Operation principle of a foil-based secondary emission monitor.

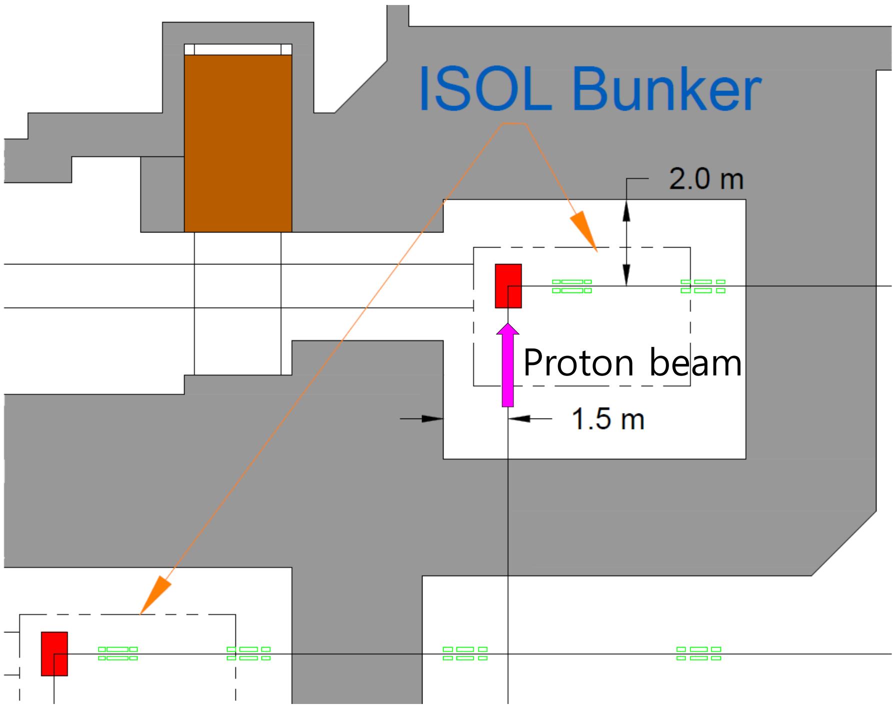
Wire grid (NTG) at high-rad area



SE-BPM

ISOL Target Room Shielding (35 kW)

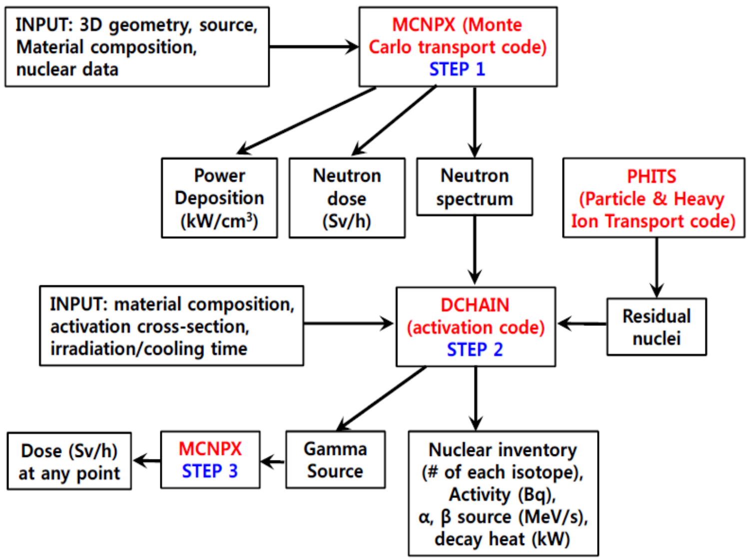
- **Dose limits**
  - public area : 0.25 μSv/h
  - control area : 5 μSv/h
- **Concrete composition (weight fraction, %)**
  - H 0.55, O 49.9, Na 1.72, Mg 0.24, Al 4.6, Si 31.51, K 1.92, Ca 8.32, Fe 1.24)
  - ρ~ 2.3 g/cm^3
- **Flux to dose conversion:**
  - ICRP-74 (1996) ambient dose equivalent



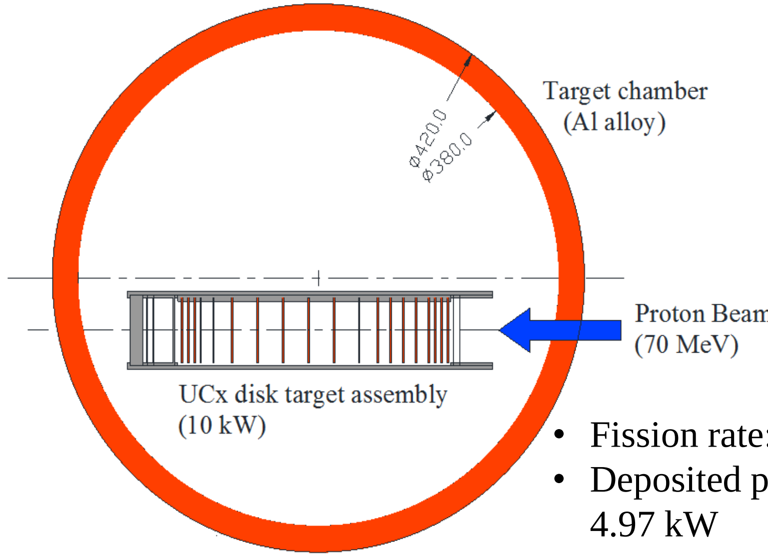
	Forward	Side		Backward	Roof	Bottom (soil/water)
		Left	Right			
Shield (cm)	405	300	345	270	325	345
Dose (μSv/h)	4.43	3.36	3.77	2.68	4.02	4.53

ISOL target activation (10 kW)

Block diagram for target activation simulation



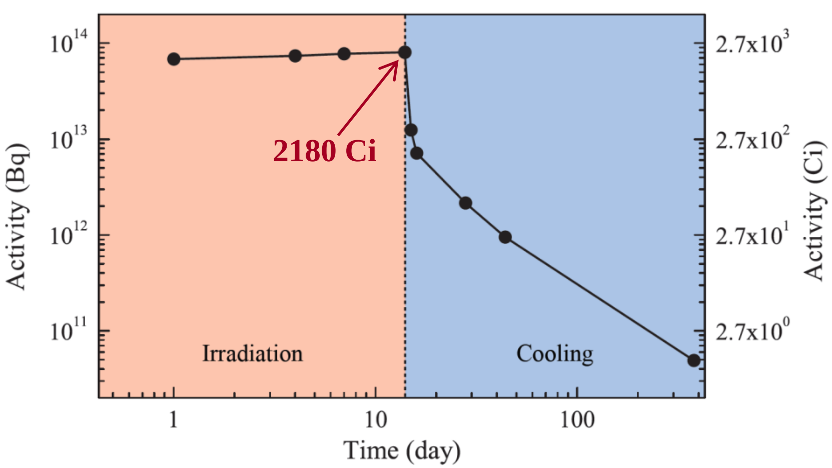
Reference target configuration for the calculation



- Fission rate: 1.6×10^{13} s^{-1}
- Deposited power in the disks: 4.97 kW

- 70 MeV p, 0.143 mA (10 kW), uniform beam 45 mmΦ
- UCx disk : 50 mmΦ, 1.3 mmt, total 121.3 g
- Graphite box (2.65 mmt), Ta container (0.2 mmt)

Activity of UCx target



- Dose rate at 2 m
  - without shield : ~24 mSv/h
  - with shield (2cm Lead) : ~2.4 mSv/h.
- aborbed dose in case of manual operation by radiation worker
  - 0.2 mSv for 5 min operation << 20 mSv(/y)

Cost breakdown/budget profile & manpower

Item	2012	2013	2014	2015	2016	2017	2018	2019	kUS$
Target/IS/FE/Pre-separator	160	540	1180	1650	1870	1100	900	700	8100
TIS/FE test facility (off-line)	30	200	830	410	220	160	150	-	2000
RF-cooler & HRMS	50	250	1240	1300	610	350	300	300	4400
Beam transport & diagnostics	30	180	1030	1150	630	370	260	250	3900
Charge breeder & A/q separator	20	120	660	840	550	200	160	150	2700
TIS remote handling system & hot cell	-	90	300	660	510	480	260	100	2400
ISOL control & radiation safety	20	130	480	720	1000	600	420	330	3700
sub-total	310	1510	5720	6730	5390	3260	2450	1830	**27 200**
Personnel	5	5	8 (6)	11	13	15	15	16	
	Welcome foreign experts with open arms!								

Manpower/collaborations

Function		affiliation		
		ISOL team	other team	other institutes
Target/Ion Source Station	• ISOL target development	• Hwang, Jeong		• CERN (ISOLDE)
	• Ion source development	• Woo, P-1	• Yun (0.5)	
RI Beam Separation System	• Pre-separator	• Kang		
	• RF-cooler		• Park (0.5)	• LPC-CAEN/GANIL
	• HRMS	• Kang		• CENBG
	• CB-ECR	• Seo		• **KAERI (FRC)**
	• CB-EBIS		• Hahn (0.3)	
	• A/q separator	• Tshoo		
	• RI beam transport line	• Kang, P-2		• **KAERI (KOMAC)**/TRIUMF
	• RI ID station	• Kang, C-1		• LPC-CAEN/GANIL
	• Beam diagnostics	• Woo		• CERN/GANIL
Control & Safety System	• ISOL control system	• Lee, C-1		• INFN (SPES)
	• TIS remote handling system	• Lee, C-1		• CERN/INFN
	• Safety & utility	• Lee, C-2		• GANIL/CERN
ISOL Test Facility	• Off-line test facility	• Seo		
	• Test of ion sources & beam monitoring devices	• Woo, C-3		
Cyclotron	• Procurement of Cylotron (70 MeV, 0.75 mA)		• Kim (1.0)	
		• total 7 (+10)		

Summary

- ISOL project at RISP is a challenging project in this field, and as a newcomer partly we are entering the engineering design stage.
- The R&D of ISOL target chemistry is practically ongoing, and the off-line ISOL test facility with newly developed ion sources will be in operation from the early months of next year.
- The beam dynamics design of ISOL beam transport line is ongoing with high-order simulations of some critical components.
- In order to get first exotic beam from ISOL system in late 2020,
  - (well-experienced) manpower should be reinforced especially in the fields of ion beam physics/engineering and control/safety system.
  - extensive & active collaboration with advanced (foreign) institutes seems to be essential, in particular, for the successful development of RF-cooler, HRMS, charge breeder and A/q separator.
  - completion of ISOL building and general services should be on schedule (not later than 3rd quarter of 2018).

- Acknowledgements
  - B.H. Kang, C.S. Seo, J.H. Lee, K. Tshoo, W. Hwang, J.W. Jeong
  - Y.-H. Park, J.W. Yoon, D.Y. Jang, G.D. Kim, Y.K. Kim

Thank you for Your attention !