Design of Beam Diagnostics System for Heavy Ion Accelerator Facility, RAON

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on behalf of Beam Diagnostic Group, RISP, IBS

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RISP (Rare Isotope Science Project)

- Goal: To build a heavy ion accelerator complex, RAON, for rare isotope science researches
  * RAON - Rare Isotope Accelerator Complex for ON-line Experiments
- Total budget: ~1.43 B$ (Facilities ~0.46 B$, Bldgs & Utilities ~0.97 B$)

- **High intensity RI beams by ISOL & IF**
  - **ISOL**: direct fission of $^{238}$U by 70MeV-proton Cycl.
  - **IF**: 200MeV/u, 8.3μA of $^{238}$U (400kW SCL)

- **High quality neutron-rich RI beams**
  - $^{132}$Sn with up to ~250MeV/u, up to $10^8$ pps

- **More exotic RI beams combining by ISOL+IF**

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**Diagram:**
- ECR-IS (10keV/u, 12 μA)
- LEBT RFQ (500keV/u, 9.5 μA)
- MEBT
- SCL (18.5 MeV/u, 9.5 μA)
- Charge stripper
- Driver LINAC
- Post Accelerator
- ISOL system
- IF system
  - CB: Charge Breeder
  - HRMS: High Resolution Mass Separator
  - RF Cooler
  - Cyclotron (p, 70 MeV)
  - 1mA
  - ISOL Target
  - IF Target
  - μSR, Bio-medica
  - IF Separator
  - High Energy Experiments
  - Nuclear Structure/Symmetry Energy
RAON Site: Sindong in Daejeon

Map showing the location of Sindong in Daejeon, South Korea, with distances marked as approximately 11 km and 160 km from other locations.
RAON Layout

<Area 952,000 m²>

- Control Center
- ECR IS
- SCL1
- SCL2
- ISOL System
- HPMMS/CLS
- IF System
- BIS
- μSR
- Utility
- NDPS
- KOBRA
- HRS
- Cyclotron
- LAMPS

<RAON site (2018.5)>
RAON Layout: RI & Experimental System

- Neutron Facility
- Low Energy Exp. Bldg
- HPMMS
- CLS
- Ultra-low Exp. Bldg
- IF
- Bio-medical Facility
- High Energy Exp. Bldg
- KOBRA
- ISOL
- LAMPS
- μSR
Diagnostics devices (except for SCL1, ISOL, NSF & HEEF)  Number

- Beam Current (FC, ACCT, Plastic detector) 16, 11, 7
- Beam Position Monitor (BPM) 143
- Beam Loss Monitor (BLM) 127
- Beam Profile (Wire Scanner, Phosphor Screen) 43, 3
- Beam Shape Monitor (Beam Bunch Shape) 4
- Emittance Scanner 2

* SCL1 configuration is the same as the SCL3.
Beam Parameters & BD Functions

<table>
<thead>
<tr>
<th>Particle</th>
<th>Driver Linac</th>
<th>Post Acc.</th>
<th>Cyclotron</th>
</tr>
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<tbody>
<tr>
<td>H⁺</td>
<td>600  320  251 200</td>
<td>18.5</td>
<td>proton</td>
</tr>
<tr>
<td>O⁺⁸</td>
<td>320  251  200</td>
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</tr>
<tr>
<td>Xe⁺⁵⁴</td>
<td>251  200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U⁺⁷⁹</td>
<td>200  18.5</td>
<td></td>
<td></td>
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<tr>
<td>RI beam</td>
<td>18.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>proton</td>
<td>70  70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam energy (MeV/u)</td>
<td>600  320  251 200</td>
<td>18.5</td>
<td>proton</td>
</tr>
<tr>
<td>Beta (v/c)</td>
<td>0.79  0.67  0.62 0.57</td>
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<td>0.37</td>
</tr>
<tr>
<td>Particle current (pµA)</td>
<td>660  78  11 8.3</td>
<td>-</td>
<td>1000</td>
</tr>
<tr>
<td>Power on target (kW)</td>
<td>400  400  400 400</td>
<td>400</td>
<td>-</td>
</tr>
</tbody>
</table>

Functions of Beam Diagnostics

- **Initial commissioning & component tuning**
  - FC, WS, BV, CT, BPMs (position, phase, TOF), etc
  - commissioning beam : ex. Ar(9+), 30 eµA, 50 µs, 1 Hz, ...

- **During operation (on-line)**
  - monitoring beam transport and acceleration function
    - BPM : beam position and phase
    - BCM : beam current and transmission(RFQ, SCL3(1), P2DT, SCL2, etc.)
    - BLM : beam Loss and link to machine protection

- **Commissioning and during operation (on-demand)**
  - 1-D, 2-D beam profiles (WS, EM)
  - Bunch length (FFC)
Beam Position Monitor

- Measurements: beam position, phase & relative intensity

- Type of BPM: considering signal strength and space limitation, button-type BPMs were selected instead of stripline BPM.

- 4 sizes of BPM: BPM-40, 50, 60 & Large BPM at folding segment.

- Inspection of fabricated BPMs: vacuum, TDR and calibration (wire test).

* Please refer to the Poster (TUPC06) : ‘Beam Position Monitor for SCL3 of RAON’
Higher harmonic (≥2\textsuperscript{nd}) signals are dominant after SCL11 (SCL31).

Signal Processing with,
- 1\textsuperscript{st}, 2\textsuperscript{nd} harmonics for MEBT & SCL11 (SCL31)
- 1\textsuperscript{st}, 3\textsuperscript{rd} harmonics for SCL12(SCL32)

60 BPM modules in fabrication by a domestic company (Mobiis).

- CST Particle Studio
  Repetition: 81.25 MHz, ~ 12.3 ns
Beam Position Monitor

BPM-50

BPM-60

BPM(FS)

174 mm

90 mm

180 mm
Wire Test Bench

Precision @±5 mm : <50 μm
Injector Beamline
Fast Faraday Cup (FFC)

- Coaxial Fast Faraday Cup (for SCL demo-facility)

- Stripline Fast Faraday Cup (SFFC)
**SCL QWR Section**

- Nb-plating at FC head
- Nb wire at WS

![Diagram of SCL QWR Section](image-url)
• BPM inside of Magnetic Quadrupole
• Installation (& align) procedure of BDC/BPM/Beam Pipe assembly (with pure N\textsubscript{2} purging) in between two cryo-modules was prepared.
Beam Loss Monitor (BLM)

- Monitor regular (slow) and irregular (fast) losses
- Radiation Sources
  - Radiation: neutron, proton, gamma, electron, ion for $>~7 \text{ MeV/u}$
  - gamma, electron $<~7 \text{ MeV/u}$
  - outside of Vacuum Chamber (secondary): gamma, neutron
  - at low energy region (SCL31/SCL11): very low radiation level expected
  - X-rays from SC Cavity & RF source is background source to BLM
- Source term simulation (MCNPX) has been done throughout Linac Tunnel
- MPS (Machine Protection System) requirements are checked
  - DBCM (Differential Beam Current Monitor) with ACCT networks is considered for primary fast loss detection.
  - CT networks: ACCT1 – RFQ – ACCT2 – MEBT – ACCT3 – SCL3 – ACCT4 ...
- Beam Loss Collector, Plastic Scintillator and Proportional Counter are considered as BLM sensors.

**Please refer to the Poster (TUPA11): 'Design Study of the Beam Loss and Halo Monitoring for the RAON Heavy Ion Accelerator'**
MCNPX simulation

Dose map

Slow loss (continuous, 1 W/m)

Fast loss (point Loss, 1 W)

Energy spectrum

Photon energy spectrum from Uranium beam

Neutron energy spectrum from Uranium beam
BLM Layout (preliminary)

- Superconducting Linac: 1 BLM/warm section
- Bending Section (P2DT): Beam Loss Points (charge selector, collimator, etc.)
- DBCM (ACCT networks): Primary MPS input for fast loss

### Section | BLM
--- | ---
SCL31 (QWR) | DBCM, BLC | -
SCL32 (HWR-A) | DBCM, BLC | -
SCL32 (HWR-B) | DBCM, BLC | PD
P2DT | DBCM, PD | PC
SCL21 (SSR1) | DBCM, PD | BLC
SCL22 (SSR2) | DBCM, PD | BLC

*DBCM: Differential Beam Current Monitor
BLC: Beam Loss Collector
PD: Plastic Detector
PC: Proportional Counter
DAQ System

- **BPM – standalone (with timing, trigger, interlock, etc.)**
  - Libera Single Pass H has been used at SCL demo-facility.
  - 60 modules (domestic) in fabrication (delivery in Jan. 2019).

- **Others (WS, FC, CT, BLM, etc.) with µTCA system**
  - CAENels AMC-pico: 8ch 20bit Pico-ammeter
  - Vadatech DAQ523: 12ch 16bit volt-meter (for ACCT only)
  - System design and test finished
Summary & Plan (I)

- **SCL-demo system**
  - Beam Diagnostic Chamber (BDC)-1 with RBS, Phosphor Screen, two Phase Probes, FFC was used for RFQ commissioning in November 2016.
  - BDC-2 with WS & FC, two BPM-50 and SFFC was used for QWR commissioning in October 2017.

- **Injector beamline**
  - BDC (LEBT) with 2D-ES, WS, FC and beam viewer was fabricated this year.
  - Beam Diagnostic System (for LEBT & MEBT) will be prepared this year.

- **SCL3 warm-section**
  - 60 Button-type BPMs were fabricated and tested, and 60 modules are under fabrication.
  - 15 BDCs in SCL3 warm section is under fabrication.

- **P2DT/KOBRA beamline**
  - Design of Beam Diagnostic System was finished, and ready to order.
  - Three Large BPMs (for P2DT) were fabricated and tested.
**BCM (ACCT)**
- was tested at SCL Demo and showed good sensitivity to measure ~ few μA.
- 6 Bergoz ACCT are ready for installation

**BLM (Beam Loss Monitor)**
- Plastic Scintillator, Proportional Counter, BLC are under consideration.
- 3 PCs (Toshiba BLM) are under test.
- DBCM (ACCT networks) will be used for primary MPS.

**DAQ System**
- Readout and control systems with μTCA are being designed and tested.

**Schedule**
- 2018~2020: Fabrication (Injector→SCL3→P2DT→SCL2→SCL1 in the order)
- 2019~2021: Installation & commissioning

**Some difficult subjects**
- Optimization of BLM system
- Design of BD system for low-intensity rare isotope beams from ISOL system.
• Acknowledgements
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Thank you for your attention!