Status of RAON and LAMPS in Korea

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Location of RAON Complex

RAON: Rare isotope Accelerator complex for ON-line experiments

Current RISP Office ~ 11 km

September 4-7, 2017 NuSYM2017 @ GANIL
Basic design was finished in Dec. 2015.
A construction company was selected in Sept. 2016.
Site Preparation

- Construction and civil engineering for RAON has begun.
- The **ground breaking** for accelerators and experimental buildings was done on **Feb. 13th** this year.

Total area: 952,066 m²
Layout of RAON

- Scope: Accelerator Facility, Buildings & Utilities
- Budget: Total ~U$ 1.43 B
  - Accelerator and Expt. Facility: ~U$ 0.46 B
  - Building & Utility: ~U$ 0.97 B (including the land cost)
- Host: Ministry of Science, ICT and Future Planning (MSIP)
## Layout of RAON

### Table: Facility Parameters

<table>
<thead>
<tr>
<th></th>
<th>Driver Linac</th>
<th>Post Acc.</th>
<th>Cyclotron</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particle</strong></td>
<td>H⁺</td>
<td>O⁺⁸</td>
<td>Xe⁺⁵⁴</td>
</tr>
<tr>
<td><strong>Energy (MeV/u)</strong></td>
<td>600</td>
<td>320</td>
<td>251</td>
</tr>
<tr>
<td><strong>Current (pμA)</strong></td>
<td>660</td>
<td>78</td>
<td>11</td>
</tr>
<tr>
<td><strong>Power (kW)</strong></td>
<td>&gt; 400</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>

### Facilities
- **RISP 4.1**: Recoil Spectrometer (KOBRA)
- **RISP 4.2**: Large Acceptance Spectrometer
- **RISP 4.3**: High-precision Mass Measurement Facility
- **RISP 4.4**: Collinear Laser Spectroscopy
- **RISP 4.5**: µ-SR
- **RISP 4.6**: Neutron Science Facility
- **RISP 4.7**: Bio-medical Research Facility

### Driver Linac Parameters
- Energy (MeV/u): 600, 320, 251, 200, 18.5, 70
- Current (pμA): 660, 78, 11, 8.3, -
- Power (kW): >400, 400, 400, 400, -
RAON aims to provide an access to unexplored regions of nuclear chart.
Prototypes of Accelerator Components

28 GHz ECR Ion Source

QWR SC Cavity & its Cryomodule

HWR SC Cavity & its Cryomodule

SSR SC Cavity and its Cryomodule

HTS Q-magnet

RFQ
Experimental Systems

Neutron Facility


KOBRA

High Energy Expt. Bldg. (A)

μSR


Bio-medical facility

High Energy Expt. Bldg. (B)

CLS

HPMMS
Prototypes of Experimental Systems

- Gamma array
- Beam-tracking detector (PPAC)
- LASER for collinear laser spectroscopy
- ISOL target
- β-detection system for μSR
- Time Projection Chamber
- ISOL beam diagnostics

September 4-7, 2017
NuSYM2017 @ GANIL
Major Milestones

- **System**
  - Prototype development
  - Accelerator and Experimental System Installation and Commissioning
    - ECR Beam
    - ISOL SI Beam ('15.12)
    - SCL Demo Beam ('17.12)
    - Utility Supply ('18.9)
    - DAY-1 Expt. ('20.7)
    - ISOL RI Beam ('20.12)
    - IF RI Beam ('21.12)

- **Civil Construction**
  - Site Building
  - Basic Design
  - Detail Design
  - Tendering Process
  - Construction / Facility Inspection / Safety Management
  - Radiation Safety Approved by KINS

- **Milestones in 2017**
  - Cryomodule test for QWR and HWR → Mass production
  - Beam extraction from SCL demo (1 QWR)
  - Cavity test for SSR → Cryomodule test in early 2018
LAMPS:
Large-Acceptance MultiPurpose Spectrometer
Location of LAMPS

(RAON)

ECR

SCL1

SCL2

SCL3

ECR

Si-CsI

Neutron array

Solenoid Spectrometer

Dipole Spectrometer

Target Scintillation Counter

Si+CsI

Focal-plane detector

Neutron Detector Array
Location of LAMPS

Ion beams to IF target via SCL1+SCL2

RIB to IF target via ISOL+SCL3+SCL2
Time Projection Chamber

\[ \eta = -0.7 \ (127^\circ) \]
\[ \eta = 1.6 \ (24^\circ) \]

One central Au+Au event at 250 AMeV (IQMD)
Prototype TPC: Design

Half-dimension prototype TPC

Outer field cage

Triple GEM

Inner field cage

Bottom Al frame for PAD & GEM

Drift length: 570 mm

490 mm

150 mm
Prototype TPC: Components

[Readout Pads]
Tested pads with the two different dimensions
- $3 \times 10 \text{ mm}^2$: 357 Ch./Oct.
- $4 \times 15 \text{ mm}^2$: 175 Ch./Oct.
Multi-layer PCB board

[Readout Pads]
Tested pads with the two different dimensions
- $3 \times 10 \text{ mm}^2$: 357 Ch./Oct.
- $4 \times 15 \text{ mm}^2$: 175 Ch./Oct.
Multi-layer PCB board

[Field Cage]
- 35 $\mu$m thick and 2 mm wide Cu strips
- 500 $\mu$m gap between adjacent strips
- Mirror strips on the back
- 1 M$\Omega$ resistors with 0.1% var.
TPC body: G10 + Aramid honeycomb

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[GEM Foil]
- Trapezoidal shape
- Thickness: 75 $\mu$m
- Area: $166 \times 118 \text{ mm}^2$
- Triple layers for each plane

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Prototype TPC: Assembly

Inner Field Cage installed
Outer Field Cage installed
Prototype TPC assembled
Prototype TPC: back
Prototype TPC: Test at ELPH

- ELPH: Research Center for Electron Photon Science at Tohoku University, Japan
- Dates: November 1-2, 2016
- Beams: $e^+$ beams at 500 MeV
- Gas: Ar(90%)+CH$_4$(10%) (P10)  
  Ar(90%)+CO$_2$(10%) (ArCO$_2$)
- Purpose: To study the detailed characteristics, such as $v_{drift}$, diffusion and $\sigma_x$, of LAMPS TPC
Prototype TPC: Event Displays
Prototype TPC: Drift Velocity

\[ \nu_{drift} \leq 5.3 \text{ cm/\(\mu\)s} \text{ for P10:} \]

Maximum distance: 512 timing bins \(\times 0.04 \text{ \(\mu\)s/bin} \times 5 \text{ cm/\(\mu\)s} \approx 100 \text{ cm} \)

Tested P20 with cosmic muons: \(\nu_{drift} > 6 \text{ cm/\(\mu\)s} \) that will be suitable for LAMPS TPC if read out from only one endcap side.
Prototype TPC: Diffusion

\[ \sigma_{track}^2 = D^2 z + \sigma_0^2 \]

where

- \( z \): drift length
- \( \sigma_{track} \): width of hit distributions w.r.t. the fitted track
- \( D \): diffusion coefficient
- \( \sigma_0 \): coefficient depending on the amplification system
Prototype TPC: Position Resolution

\[ \sigma = 0.72 \text{ mm} \]

\[ \sigma = 0.20 \text{ mm} \]

Preliminary
Neutron Detector Array

Dimensions of each scintillation bar: $10 \times 10 \times 200 \text{ cm}^3$

- Construction of the real-size prototype detectors and test of their performances using
  - Radiation-source test: $^{60}\text{Co}$ and $^{252}\text{Cf}$
  - Neutron-beam test at RCNP, Japan
Watt spectrum: \( dN/dE \propto e^{-aE} \sinh \sqrt{bE} \)
- \( a=0.88 \text{ MeV}^{-1} \) and \( b=2.0 \text{ MeV}^{-1} \)
- B. Watt, Physical Review 87, 1037 (1952)
E479 approved in B-PAC in March 2016

Date: May 29, 2016 (Visited RCNP for May 22 – June 2)

Beam specifications
- Protons on Li production target (p+^7Li \rightarrow n + ^7Be)
- Neutron energies: 65 and 392 MeV in N0 beamline
- 10 nA flux × 1/9 chopping
- Background neutron above 3MeV is less than 1% [NIMA629, 43 (2011)]
Distance from target to the detector: 15 m
Gap between stations: 60 cm
Dim. of each S1 detector: $10 \times 10 \times 100 \text{ cm}^3$
Dim. of each S2 detector: $10 \times 10 \times 200 \text{ cm}^3$
Beam size at S1: $25 \times 30 \text{ cm}^2$
NDA: Energy Resolution for Neutrons

- **Time resolution:**
  \[
  \Delta t = \sqrt{(\Delta \tau)^2 + (\Delta x/\nu)^2} = 0.66 \text{ ns}
  \]
  where
  \[
  \Delta \tau = \text{FWHM of } \gamma \text{ peak} = 0.60 \text{ ns}
  \]
  \[
  \Delta x = \text{effective thickness of the detector}
  \]
  \[
  = (\text{Total thinness of Li target, veto, and neutron detector})/2 = 6.0 \text{ cm}
  \]
  \[
  \nu = \text{neutron velocity} = 21.3 \text{ cm/ns}
  \]

- **Neutron energy resolution:**
  \[
  \frac{\Delta E}{E} = \gamma (\gamma + 1) \frac{\Delta t}{t} = 3.2\%
  \]
  where
  \[
  \gamma = 1 + E/mc^2 = 1.42
  \]
  \[
  t = 70.4 \text{ ns}
  \]

- **Energy resolution (FWHM/E) = 3.3%**
NDA: Position Resolution for Neutrons & Cosmics

- Hit position difference between $D1$ and $D2$ for neutrons:
  \[ \Delta x_{S1} \equiv x_{D1} - x_{D2} \]
  for 10 MeV threshold and $\delta t < 3$ ns

- Relative position resolution for neutrons for one bar:
  \[ \sigma_n = \frac{\sigma(\Delta x_{S1})}{\sqrt{2}} = 3.1 \text{ cm} \]

- Position difference between the projected hit position and the hit position for $D3$ for cosmic muons:
  \[ \Delta x_{S2} \equiv x_{D3,proj} - x_{D3,\text{hit}} \]

- Relative position resolution for cosmic muons for one bar:
  \[ \sigma_\mu = \frac{\sigma(\Delta x_{S2})}{1.87} = 3.1 \text{ cm} \]
Summary

- Rare Isotope Science Project (RISP) at IBS, Korea is moving forward.
- The construction and civil engineering for RAON has begun: The ground breaking for accelerators and experimental buildings was done on Feb. 13th this year.
- LAMPS is a dedicated spectrometer for nuclear symmetry energy at RAON.
- Performance tests of the prototype TPC and the neutron-detector-array modules with accelerator beams were done, and we are analyzing the data.