Experimental Activities in Korea

Young-Sik Cho
Korea Atomic Energy Research Institute

on behalf of

T.-Y. Song (NDC@KAERI),
PAL, KIGAM, KIRAMS, PEFP and IBS
Facilities for Nuclear Data Measurements

- Existing facilities

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• \((n,\gamma)\) by neutron activation method  
• Isomeric yield ratio  
• Photo fission |
| Tandem (KIGAM)            | • 1.7 MV  
• Neutron production \((p+Li, p+T, d+D)\) | • Total cross section |
| Cyclotron (KIRAMS)        | • \(p\) : 20-50 MeV / 40 \(\mu\)A  
• \(d\) : 10-25 MeV / 20 \(\mu\)A  
• \(\alpha\) : 20-50 MeV / 1 \(\mu\)A | • Activation cross section |

- Planned facilities

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| Heavy-ion accelerator (IBS) | • Cyclotron (70 MeV proton)  
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# Activities at PAL

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Electron Linear Accelerator (PAL)

Pohang Accelerator Laboratory

100-MeV e-linac

2.5 GeV e-linac

WPEC Meeting, 24-25 May 2012
Pohang Neutron Facility (PNF)

- Electron energy = 50 ~ 70 MeV
- Repetition rate = Below 30Hz
- Pulse width = 1 ~ 2 μs
- Peak beam current = 30 ~ 60 mA
- TOF flight length = 11.5~12m
- Target + water moderator : Ta plates + cooling
- Vertical TOF beam line

Generated Neutron Spectrum

Neutron Arrival Time (μs)

Ta target
PAL Gamma Facility

- Gamma production by 100 MeV linac: 0.1 mm thick W target

- Gamma production by 2.5 GeV linac: 0.2 mm thick W target
Measurements at PAL Facility (1)

- Research groups: KNU (Kyungpook National University), Dong-A University, POSTECH (Pohang University of Science and Technology), KAERI
- Total cross sections: Nb, Er, Mo etc.

(n, γ) cross sections by neutron activation method: W, Ho, Au etc.
Isomeric yield ratio:

- $^{44m,g}_{\text{Sc}}$, $^{52m,g}_{\text{Mn}}$, $^{196m,g}_{\text{Au}}$, $^{89m,g}_{\text{Nb}}$, $^{117m,g}_{\text{In}}$ etc.

- Photo fission: Pb, Bi etc.
# Activities at KIGAM

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**Tandem Facility (KIGAM)**

- Tandem at KIGAM (Korea Institute of Geoscience and Mineral resources)
  - Terminal voltage = 1.7 MV
  - Current = 6 $\mu$A (3.4 MeV H$^+$)
  - Repetition rate = 8 MHz
    (Beam bunching system for TOF)
  - Pulse width = 1 ~ 2 ns
  - TOF flight length = 4.2~4.3m
  - Neutron production
    1) p+Li
    2) p+T
    3) d+D

---

Experimental Room

Bunching System

WPEC Meeting, 24-25 May 2012
Measurements at KIGAM Facility

- Research groups: KIGAM, Hanyang University, Nambu University, KAERI
- Total cross sections: Ti, Fe, Cu, Co, Nb, Y, Ta, Au, Bi, Si, SiO₂, Al, W etc.

[Graphs showing neutron total cross sections for Au, Cu, Bi, and more]
Activities at KIRAMS

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Cyclotron Facility (KIRAMS)

- Cyclotron at KIRAMS (Korea Institute of Radiological & Medical Sciences)

<table>
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<tr>
<th>Beam</th>
<th>Energy (MeV)</th>
<th>Current (µA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>20-50</td>
<td>40</td>
</tr>
<tr>
<td>d</td>
<td>10-25</td>
<td>30</td>
</tr>
<tr>
<td>α</td>
<td>20-50</td>
<td>1</td>
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MC-50 cyclotron

RI target irradiation

Low intensity irradiation

Nuclear interaction etc.

Low energy therapy research

PEFP experiment line

Horizontal beam

Vertical beam

Neutron and High Intensity Irradiation

WPEC Meeting, 24-25 May 2012
Measurements at KIRAMS Facility

- Research groups: KNU (Kyungpook National University), KAERI
- Activation cross sections by proton and α irradiation
  - Stacked foil technique
  - Target samples: Mo, Zn, Zr, W, Cd, Ni, Sn, Ag, Ti, Pd, Y, Fe etc.

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**Diagram:**
- Proton beam
- Monitor foil
- Target sample
- Irradiated sample
- Pb bricks
- MCA
- HV (-3.5kV)
- AMP.

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**Graphs:**
- Cross-section vs. Proton Energy
- Cross-section vs. Alpha Energy
## Activities at KAERI

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• Planning for data measurements                                                            |
Electron Linear Accelerator (KAERI)

- Beam applications
  - Development of materials
  - Environment
  - Irradiation test

- Accelerator specifications

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>Energy</td>
<td>17 MeV</td>
</tr>
<tr>
<td>RF Power</td>
<td>Max. 100 kW</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>~ 20 ps</td>
</tr>
<tr>
<td>Pulse Current</td>
<td>~ 20 A</td>
</tr>
<tr>
<td>Pulse Frequency</td>
<td>Max. 2 MHz</td>
</tr>
<tr>
<td>Beam Power</td>
<td>Max. 14 kW</td>
</tr>
<tr>
<td>Average Current</td>
<td>Max. 0.8 mA</td>
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For neutron TOF, high frequency is needed to utilize high beam power of SC e-linac. Fast neutron TOF facility is appropriate with high beam repetition rate.

Small pulse width gives good neutron TOF energy resolution at short distance. Need to make a small volume target and appropriate detection system. Adopting HZDR liquid Pb target system.

Beam Irradiation Area

<table>
<thead>
<tr>
<th>Target</th>
<th>Cross-section</th>
</tr>
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<tbody>
<tr>
<td>Mo</td>
<td>-</td>
</tr>
<tr>
<td>Pb</td>
<td>-</td>
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Velocity 1 m/s

Temperature (K)

Target Cross-section
KAERI Electron Accelerator TOF Facility (2)

- **1st Stage**
  - Energy: 17 MeV
  - Pulse Frequency: ~ 200 kHz
  - Beam Power: ~ 1.4 kW
  - Neutron Yield: $3.5 \times 10^{11} \text{ s}^{-1}$
  - Flight Length: ~ 10 m
  - Energy Resolution: ~ 1% (at 1 MeV)

- **2nd Stage**
  - Increased beam energy and current
  - Construction of a target room
  - Collimator located between the target room and the experimental room

WPEC Meeting, 24-25 May 2012
Activities at KAERI/PEFP

● Existing facilities

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Proton Linear Accelerator Facility (PEFP)

Features of the PEFP 100MeV linac

- 50 keV Injector (Ion source + LEBT)
- 3 MeV RFQ (4-vane type)
- 20 & 100 MeV DTL
- RF Frequency : 350 MHz
- Beam Extractions at 20 or 100 MeV
- 5 Beamlines for 20 MeV & 100 MeV

<table>
<thead>
<tr>
<th>Output Energy (MeV)</th>
<th>20</th>
<th>100</th>
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<tbody>
<tr>
<td>Max. Peak Beam Current (mA)</td>
<td>1 ~ 20</td>
<td>1 ~ 20</td>
</tr>
<tr>
<td>Max. Beam Duty (%)</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Avg. Beam Current (mA)</td>
<td>0.1 ~ 4.8</td>
<td>0.1 ~ 1.6</td>
</tr>
<tr>
<td>Pulse Length (ms)</td>
<td>0.1 ~ 2</td>
<td>0.1 ~ 1.33</td>
</tr>
<tr>
<td>Max. Repetition Rate (Hz)</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Max. Avg. Beam Power (kW)</td>
<td>96</td>
<td>160</td>
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Characteristics & Application Fields

- Characteristics of PEFP Linac
  - Feasible for industrial applications
  - High duty & High current
  - Suitable for various application fields
  - Controllable Energy & Current
  - Multi-users support

- Application Fields
  - Nano : MNP synthesis, etc.
  - Semiconductor : Power switch, etc.
  - Medical : RI, BNCT, Proton therapy, Radiation effects, etc.
  - Bio : Mutations of plants & microorganisms, etc.
  - Space : Space radiation simulation, Electronics & materials, etc.

- MW upgrade
  - Spallation Source, RNB, ADS, etc.
# Activities at IBS

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| (PEFP)                        |                                                                                |                                                          |
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• Planning for data measurements |
| (IBS)                         |                                                                                |                                                          |
Heavy-ion Accelerator Facility (IBS)

Heavy-ion accelerator facility at IBS (Institute for Basic Science)
Research Areas Using IBS Facility

- To complete the chart of nuclei
- To understand the properties of isotopes near neutron-rich drip line

- To understand the role of unstable nuclei in the nucleosynthesis
- To understand the life cycle of a star and origin of elements

- To understand symmetry energy, EOS of hot and dense nuclear matter and property of hadron at dense neutron region

- To understand origin of matter to describe the history of the Universe
- To understand the matter by describing nuclear structure and reaction

- Development of new cancer therapy using heavy ion beam
- To understand biological effect of tissue and DNA by RI beam

- Development and utilization of new material
- To understand property of material by RI

- Nuclear data construction to develop future nuclear power technology
- Research for the radioactive waste transmutation

- To understand basic property of atom and nuclei
- Study of structure and characteristics of element and nuclei
Nuclear Data Measurements Using IBS Facility

**Top ic 1**
- p, d
- Li, Be, ...
- Fast neutrons
- Fast neutron data & fusion applications

**Top ic 2**
- p
- W, Ta, Pb, U
- Spallation neutrons
- Neutron data for GEN-VI & future system

- In-flight, ISOL
- Short-lived Rare Isotopes
- Neutron data for waste transmutation

**Top ic 3**
- W, Ta, Pb, U
- p, d
- Inverse kinematics
- Improve nuclear reaction models

- d, t, He, ...
- U, Pu, Np, Cm
- Surrogate reactions
- Neutron data for ultra short-lived isotopes
Contributions to EXFOR

1969~1989
- Yonsei Univ.(1)
- Seoul Univ.(3)
- KAERI (1)

1990~1999
- KRISS (1)
- Seoul Univ. (4)
- RIKEN (1)
- KIGAM (1)
- Kyoto Univ. (1)

2000~2005
- Kyungpook Univ. (8)
- Pohang Univ. (1)
- Dong-A Univ. (2)
- Seoul Univ. (1)
- Pusan Univ. (1)
- Chung-Ang Univ. (2)
- KRISS (1)
- TRIUMF (1)
- Kyoto Univ. (4)

2006~2011
- Kyungpook Univ. (30)
- Dong-A Univ. (5)
- Seoul Univ. (1)
- Chung-Ang Univ. (1)
- Sejong Univ. (1)
- KIGAM (2)
- KIRAMS (1)

- Cockcroft-Walton Accel.
- SNU/VDG
- RIKEN
- KIGAM/VDGT
- Kyoto/LINAC

- SNU/VDG
- RIKEN
- KIGAM/VDGT
- Kyoto/LINAC

- KIRAMS
- PNF
- KAERI/PGAA
- Kyoto/LINAC
- Tokyo/VDGT
- KEK
- RIKEN
- USA/VDGT

- KIRAMS
- PNF
- KIGAM/VDGT
- KAERI/HANARO
- Kyoto/LINAC
- Tokyo/VDGT
- RIKEN

- NDC@KAERI also has compiled and submitted the experimental data to EXFOR since 2009.
- NDC@KAERI recently created the experimental group to participate in the measurements.
Thank you for your attention!