Particle Accelerators in Korea

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Outlines

• Brief Facts about Korea
  - Government Organization for R&D and Budget Trend

• Large-scale Science Programs
  - Accelerator, Nuclear, Fusion, Space Programs

• Accelerators:
  - PLS and PLS-II at POSTECH
  - Proton Linac at KAERI
  - Plasma Wakefield Acceleration at GIST
  - Medical Accelerators
  - Heavy Ion Accelerator

• R&D Collaboration with Industrial Companies
## Brief Facts about Korea

### People & Language:
Korean (~4,500 yrs in the area)

### Area (South):
~100,000 km² (~38,000 sq. mi.)

### Population (South):
48.5 million

### Recent History:
- 1945: Divided into North and South
- 1950~1953: Korean Conflict
- 1960~1970: Modernization (Migration to cities)
- 1970~1980: Industrialization (Heavy Industries)
- 1990~2008: High-tech oriented

### Leading Industries:
- Electronics, Steel, Ship-building, Automobile,
- Chemicals, Construction, Textiles

### Economy:
GDP = 929 B$, 19 k$/capita in 2008

### Religion:
Christian (~30%), Buddhism (~30%)

### Education:
> 80% high-school seniors go to college
Korean Government Reorganization

- The new administration combined Ministry of Education and Ministry of Science and Technology in March 2008.

- A bureau for large-scale science programs is established

- There are growing demands for promoting basic sciences and multi-disciplinary users’ facilities
Science and Technology Budget in Korea
## Large-scale Science Programs in Korea

### On-going programs:

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<th>Program</th>
<th>Duration</th>
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<tr>
<td>PLS - Light Source</td>
<td>1988 - 1994</td>
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<td>Hanaro - Research Reactor</td>
<td>1988 - 1994</td>
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<td>KSTAR - Fusion Tokamak</td>
<td>1996 - 2008</td>
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<td>PEFR - Proton Linac</td>
<td>2002 - 2012</td>
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<td>ITER-Korea – ITER member</td>
<td>2006 – 2016</td>
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<td>PLS-II – Light Source Upgrade</td>
<td>2009 – 2011</td>
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<td>Scientific Satellite</td>
<td>2009</td>
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### Proposals:

- X-ray FEL (PAL)
- Heavy Ion accelerator
Hanaro Overview

• Research Nuclear Reactor
  - 30-MW open-tank-in-pool type, and 20% $U_3Si-Al$ Fuel

• National users’ facility
  - Intense neutron source for neutron science
  - Medical & industrial application of Radioisotopes

  - First Criticality Achieved: Feb. 1995

• Construction & Operation by Korea Atomic Energy Research Institute (KAERI)

⇒ 20 reactors are in operation (30 ~ 40 %) and 6-units are under construction with the Korea Standard Type
Hanaro Reactor

Horizontal Experimental Tubes
- ST1: Polarized Neutron Spectrometer
- ST2: High Resolution Powder Diffractometer / Four Circle Diffractometer
- ST3: Neutron Reflectometer / Medium Resolution Powder Diffractometer
- ST4: Triple Axis Spectrometer
- CN: Small Angle Neutron Spectrometer
- IR: Boron Neutron Capture Therapy Facility
- NR: Neutron Radiography Facility

Vertical Experimental Holes
- IR, CT: Capsule Irradiation Facility
- LH: Fuel Test Loop
- OR: Capsule Irradiation / RI Production
- IP: RI Production
- HTS: Hydraulic Transfer System for RI Production
- PTS: Pneumatic Transfer System for Neutron Activation Analysis
- NTD: Neutron Transmutation Doping of Silicon
- CNS: Cold Neutron Research Facility
Hanaro Reactor
KSTAR Overview

• Fusion Research Tokamak
  - All Super-conducting magnets
  - Steady-state capable tokamak with a major radius of 1.8 m

• National users’ facility
  - Long-pulse tokamak plasma research
  - Heating and current drive for steady-state operation

• Project Period: Jan. 1996 - June 2008

• First Plasma: June 2008

• Construction & Operation by National Fusion Research Institute (NFRI)
KSTAR Experimental Buildings
**KSTAR Construction Progress**

- **Basic R&D, Conceptual Design (95.12 – 98.8)**
- **Engineering Design (98.9 - 02.5)**
- **Machine Construction (02.6 - 07.8)**
- **Commissioning & 1st Plasma (07.9 – 08.6)**
- **Operation (09.4 ~ )**

G. S. Lee, NFRI
Installation of Cryostat Cylinder
**2nd Harmonic ECH Start-up**

- **Shot no. 794**  
  Conventional mode  
  Perpendicular launch  
  EC beam target:  
  $Z=0\text{m}, R=\sim1.8\text{ m}$

- **Shot no. 977**  
  Dipole-like mode  
  Perpendicular launch  
  EC beam target:  
  $Z=\sim-0.1\text{m}, R=\sim1.7\text{ m}$

- **Shot no. 1057**  
  Dipole-like mode  
  Oblique launch (tor. angle=-10°)  
  EC beam target:  
  $Z=\sim-0.1\text{m}, R=\sim1.7\text{ m}$

- Using ECH, successful plasma discharge at low Ohmic voltage!

* Achieved Loop voltage: less than 0.3 V/m, ~ 2.0 V
Joining in ITER

G. S. Lee (1995), NFRI
ITER-Korea Procurement Items

1. TF Conductor
   Total Value (kIUA) : 215.0
   KO : 20%
   KO Value (kIUA) : 43.0

2. Vacuum Vessel
   Total Value (kIUA) : 124.2
   KO : 20%
   KO Value (kIUA) : 24.84

3. Vacuum Vessel Ports
   Total Value (kIUA) : 78.5
   KO : 76%
   KO Value (kIUA) : 59.66

4. Blanket First Wall *
   Total Value (kIUA) : 87.0
   KO : 10%
   KO Value (kIUA) : 8.7

5. Blanket Shield Block
   Total Value (kIUA) : 58.0
   KO : 10%
   KO Value (kIUA) : 5.8

6. Assembly Tooling
   Total Value (kIUA) : 22.0
   KO : 100%
   KO Value (kIUA) : 22.0

7. Thermal Shield
   Total Value (kIUA) : 28.8
   KO : 100%
   KO Value (kIUA) : 28.8

8. Tritium SDS *
   Total Value (kIUA) : 14.5
   KO : 88%
   KO Value (kIUA) : 12.76

9. AC/DC Converters
   Total Value (kIUA) : 82.2
   KO : 38%
   KO Value (kIUA) : 31.24

10. Diagnostics
    Total Value (kIUA) : 137.5
    KO : 3.3%
    KO Value (kIUA) : 4.54

Total KO Value 241.34 kIUA ( 342.7 M€)
Space Program

- 6 communication satellites built in the past 20 years
- First Korean astronaut in 2008
- Launching site has been built
- First launch of scientific satellite (~100 kg) is expected in 2009
Pohang University of Science and Technology (POSTECH)

• Established by POSCO, a steel company, in 1986

• One of the leading S&T Universities in Korea along with SNU in Seoul and KAIST in Daejeon

• 11 Academic Departments in Science and Engineering

• Students: Undergraduate: 1,200
  Graduate: 1,500

• Faculty members: ~ 250
POSTECH Campus and PAL
PLS Overview

• In 1987, POSTECH, a newly established university, proposed to construct a synchrotron light source on its campus.

• PLS is a 3rd generation synchrotron radiation source:
  - 2 GeV injector linac and storage ring with upgrade option to 2.5-GeV.

• Construction Project: April 1988 ~ December 1994
  - Funded by POSCO (60%) & Government (40%)

• Operation: funded by Government (80%) & POSCO (20%)
Pohang Light Source (PLS) at PAL
Examples of Research at PLS: Academic and Industry
Statistics for Experiments and Users at PAL

'08 data is tentative
• **PLS –II is the upgrade program of PLS after 15-yr’s:**
  - 3.0 GeV injector linac and storage ring with DBA lattice and lower emittance (20 straight sections for users)

• **Project period: January 2009 ~ December 2011**
  - Funded by Government (100%)

• **This afternoon, 17:00 at TH4PBC03 “PLS-II at PAL,”**
  by S. Nam.
Proton Engineering Frontier Project

• High-Power Proton Accelerator: Staged construction of 1.0 GeV, 20 mA proton linac
  - 100 MeV: New Frontier Program (2002-2012)
  - 1.0 GeV: Under R&D Study

• Government decided the construction site in Gyeongju
  - Near the KTX station (March 2006)

• National Users’ Facility: Intense neutron source for basic and applied science research

• Lead Lab.: Korea Atomic Energy Research Institute (KAERI)
PEFP 20 MeV Linear Accelerator
Site Plan for the PEFP

Proton Accelerator Research Center

Accelerator Tunnel
Experimental Hall
Ion Beam Facility
Utility Building
Substation
Cooling Tower

Water Storages
Main Office Building
Regional Cooperation Center
Dormitory
Information Center
Sewage Plant
Laser-Plasma Wakefield Acceleration at GIST

- Peak power : 100 TW
- Pulse duration : 30 fs
- Wavelength : 800 nm (Ti:sapphire)
- Energy stability ~1.4% rms
**Experimental Results**

GIST-APRI 100TW 30fs laser

Some sub-GeV electron beams from 1cm gas jet

Laser: 27 TW, 35 fs  Plasma: $7 \times 10^{18}$cm$^{-3}$

E = 225 MeV  $\Delta E/E = 17\%$
Divergence ~a few mrad
Charge ~100pC

Laser: 50 TW, 35 fs  Plasma: $3.4 \times 10^{18}$cm$^{-3}$

$E_1=540$ MeV, $\Delta E/E = 11\%$
$E_2=330$ MeV, $\Delta E/E = 33\%$
$Q_1=20pC$, $Q_2=200pC$

N. M. Hafz et al., Nature Photonics (2008)
Laser system upgrade to 500 TW is now underway in the new research building and it will be finished by 2010.
KIRAMS-13 installed at Kyungpook National University Hospital
Regional Cyclotron Center in KOREA

KIRAMS-13 supplies its Cycle 5 through the government-oriented regional cyclotron center project.

- KIRAMS.
- Kangwon National Univ.
- Kyungpook National Univ.
- Chosun National Univ.
- Pusan National Univ.
- Seoul National Univ. Bundang Hospital
- Jeju National Univ.
Proton therapy facility, National Cancer Center

- **2002 July:** Contract with IBA
- **2003 Jan:** Complete the building design
  June: Start the building construction
- **2005 Jan:** Site survey
  Feb: Starting the installation
  Oct: Beam test begin
- **2006 Dec:** Acceptance of 1st gantry room + 2nd gantry room + fixed beam room
- **2007 Mar 19:** Treatment of the first patient (prostates)
  July: 2nd gantry room is used to treat patient
  Aug-Oct: Fixed beam treatment room to be used
  Dec: End of one year operation by IBA
- **2008 Dec:** Total treatment of 370 patients
KoRIA: Korea Rare Isotope Accelerator

- Multipurpose HI accelerator for RIB:
  - Nuclear and Astro-nuclear Physics
  - Nuclear Data Production for Applications
  - Materials Science using RIB
  - Bio and Medical Science with RIB and HI

- Planning: 2009 ~ 2012:
  - CDR started in 2009

- Construction: Planned in 2012 ~ 2016
Leading industrial companies in Korea built-up their own R&D capability for global competitiveness, for examples,

- Electronics
- Iron & Steel
- Shipbuilding
- Automobile
- Communications
POSCO Plants in Pohang & Gwangyang

- Established: 1968
- Employees: 17,300
- Steel Production: ~ 30.0 M tons
- Revenue: 30.6 B$
- Net Profit: 4.4 B$

Gwangyang Plant

Pohang Plant

Map showing locations of Pohang and Gwangyang plants with major cities marked:
- Seoul
- Daejeon
- Pohang
- Ulsan
- Busan
- Gwangyang
### R&D Collaboration with Industrial Companies

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<th>Samsung</th>
<th>POSCO</th>
<th>Hyundai Heavy</th>
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<tr>
<td></td>
<td>Electronics</td>
<td>Steel</td>
<td>Ship building</td>
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<tr>
<td></td>
<td>Revenue</td>
<td>Revenue</td>
<td>Revenue</td>
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<tr>
<td></td>
<td>Profits Net / Business</td>
<td>Profits Net / Business</td>
<td>Profits Net / Business</td>
</tr>
<tr>
<td>2006</td>
<td>59.0</td>
<td>20.0</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td>7.9 / 6.9</td>
<td>3.2 / 3.9</td>
<td>0.7 / 0.9</td>
</tr>
<tr>
<td>2007</td>
<td>63.0</td>
<td>22.0</td>
<td>16.0</td>
</tr>
<tr>
<td></td>
<td>7.4 / 5.9</td>
<td>3.7 / 4.3</td>
<td>1.7 / 1.8</td>
</tr>
<tr>
<td>2008</td>
<td>73.0</td>
<td>30.6</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>5.5 / 4.1</td>
<td>4.4 / 6.5</td>
<td>2.3 / 2.2</td>
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<tr>
<th>University</th>
<th>SKK University</th>
<th>POSTECH</th>
<th>Ulsan University</th>
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<td>Scientific Area</td>
<td>KSTAR SC Coil R&amp;D</td>
<td>PLS Accelerator</td>
<td>KSTAR Vacuum Chamber</td>
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</tbody>
</table>
Korea has successfully improved her economic condition through industrialization. The underline driving force is considered as, not only the government planning but also trained man-power available through individual education.

With the success of light source, research reactor and tokamak, there are growing demands for more multi-user facilities, such as light sources, heavy ion accelerator, and others.

Government now established a bureau for large-scale science programs including space science and fusion research.

For the large-scale science projects, we need consensus among scientists in this economy-oriented society.