**7th International Particle Accelerator Conference**
May 8-13, 2016, BEXCO, Busan Korea

**IPAC' 16**

# Collaboration with Industry in Korea for Medical Accelerators

**May 11, 2016**

**Sang Hoon Nam**

**KHIMA**
**Korea Institute of Radiological And Medical Sciences**

# Medical Accelerators in Korea

## ➢ Linear Accelerators:

- ✓ Total about 181 units are in operation (2012).
- ✓ All are imported.
- ✓ Some R&D activities in Korea are ongoing.

## ➢ Cyclotrons:

**The Operation Status of Cyclotrons for Radioisotope Production in Korea (2011)**

| Energy Range | 11~15 MeV | 16~20 MeV | 30 MeV~ | Total |
|---|---|---|---|---|
| Domestic | 9 | - | 1 | 10 |
| Imported | 13 | 12 | 1 | 26 |
| Total | 22 | 12 | 2 | 36 |

# Medical Accelerators in Korea Institute of Radiological & Medical Sciences

➢ **KIRAMS: Established in 1963 to promote the medical application of atomic energy. Played a leading role in radiation medicine as well as in the treatment and research of cancer in Korea.**

**Neutron Therapy (MC-50, the first & imported Cyclotron ['84]**

**Developed 13MeV Cyclotron for FDG Production ['02]**

**Developed 30MeV Cyclotron. Installed in Advanced Radiation Technology Institute in Jeongup-city, Korea ['07]**

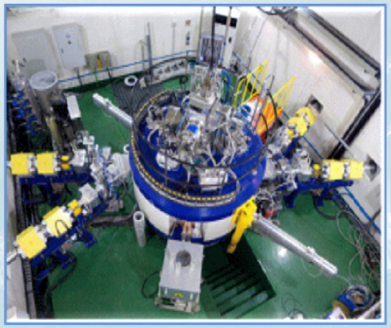
**Start Korea Heavy Ion Medical Accelerator Project , 430MeV/u ['10]**

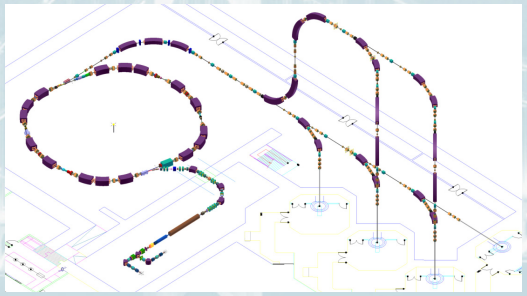
'84 '94 '02 '04 '06 '07 '08 '10 '15

Scantronix

The first cyclotron developed in Korea

- Provided to seven regional hospitals



# National Cancer Center, Ilsan, Korea
# Proton Therapy Facility

| | |
|---|---|
| 2005. 02. 15: | IBA Proteus 235 installation start |
| 2005. 10. 21: | First Beam Production |
| 2005. 09.~ 2007. 02.: | Beam Calibration, Acceptance test & GTR2 Commissioning |
| 2007. 03. 19: | First Proton treatment start at GTR2 |
| 2007. 07. 05: | GTR3 treatment start |
| 2009. 05. 15: | FBTR treatment start (Eye Cancer) |
| 2015. 09. 22: | PBS treatment start at GTR3 |



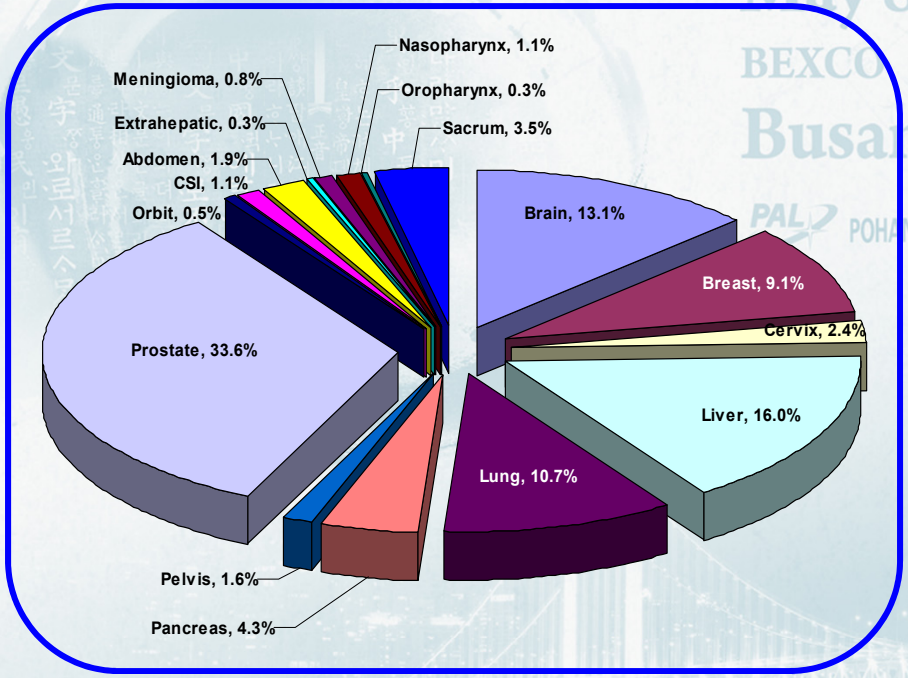

▪ Courtesy of Dr. Se Byeong Lee of NCC

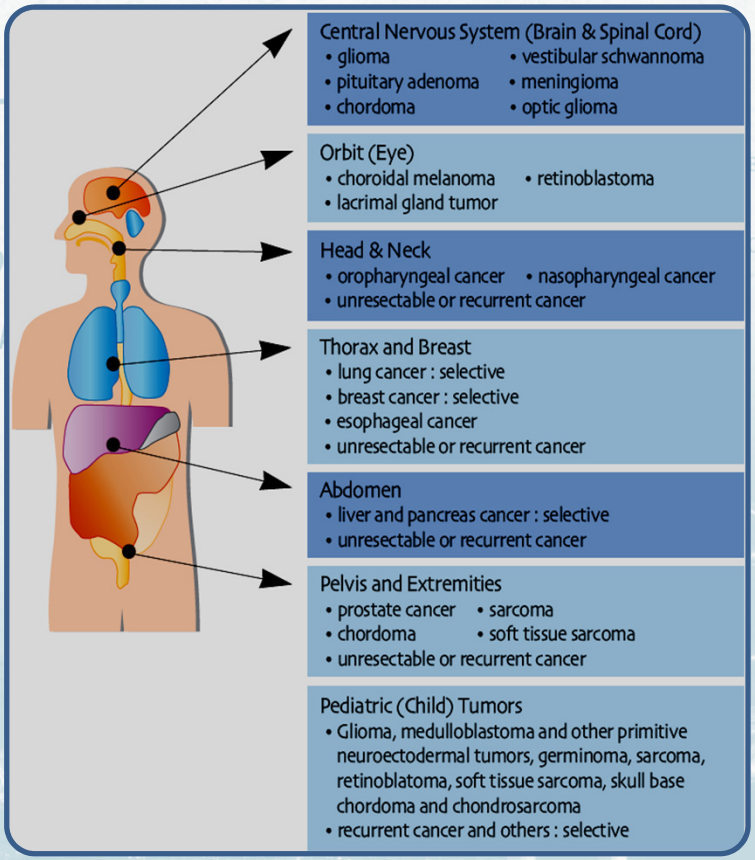
# NCC Proton therapy Facility


*2 Gantry, 1 Horizontal Fixed, 1 Experimental Rooms*

▪ Courtesy of Dr. Se Byeong Lee of NCC

# Treatment Experience at NCC




**1041 patients Treated during Mar. 2007- Dec. 2012**

▪ Courtesy of Dr. Se Byeong Lee of NCC

# Samsung Medical Center, Seoul, Korea
# Proton Therapy Facility Time Line

**2007, 04** — **Project Launch**

**Product Review:**

**2010, 10** — **Forward L.O.I to Sumitomo Heavy Industry**

**2011, 04** — **Purchasing Contract with Sumitomo signed**

**2011, 10** — **Ground Breaking**

**KINS Approval Process**

**2013, 05** — **Start of Machine Installation**

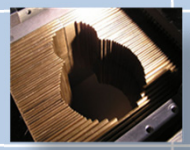
**2015, 11** — **Takeover by SMC**

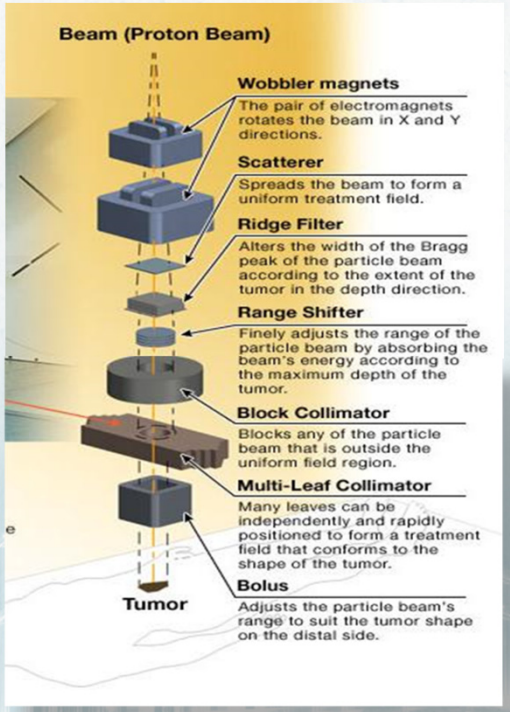
**2015, 12** — **beginning of Wobbling Treatment**

**2016, 03** — **beginning of Scanning Treatment**

▪ Courtesy of Prof. Youngyih Han of SMC

# SMC Proton Center Project: Equipment

| | Room 1 | Room 2 |
|---|---|---|
| Gantry | Rotating Gantry ( w rolling floor) | Rotating Gantry (w rolling floor) |
| Patient Positioning System | Robotic Couch | Robotic Couch |
| Nozzle | Conventional + Scanning | Scanning Dedicated (patient aperture can be used) |
| MLC | Yes  | No |
| Setup Verification System | - 2 Orthogonal X-rays<br>- CBCT<br>- Fluoroscopy | -2 Orthogonal X-rays<br>- CBCT<br>- Fluoroscopy |
| Gating | Yes | Yes |



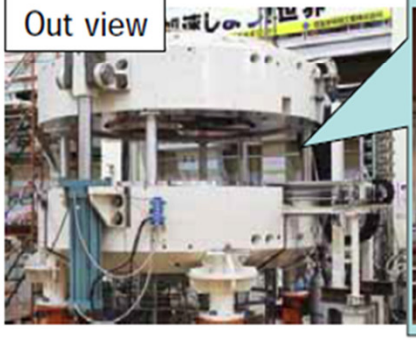

▪ Courtesy of Prof. Youngyih Han of SMC

# SMC Proton Center Project: Equipment

## P235 cyclotron

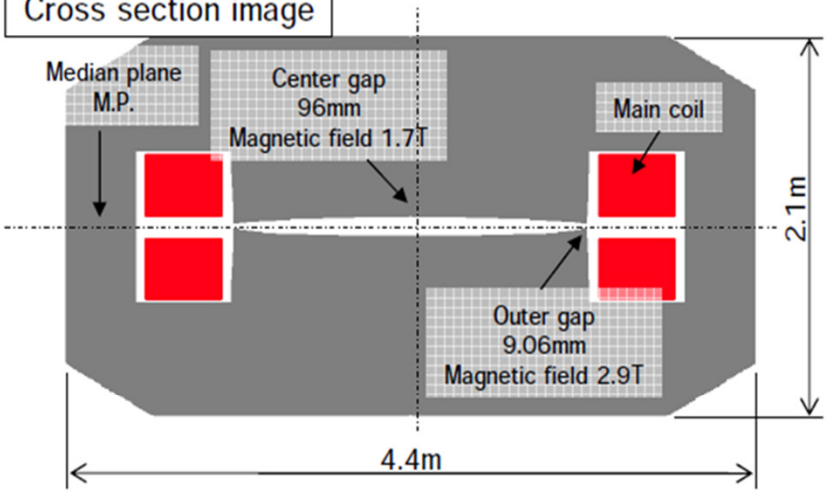
Sumitomo Heavy Industries

Out view



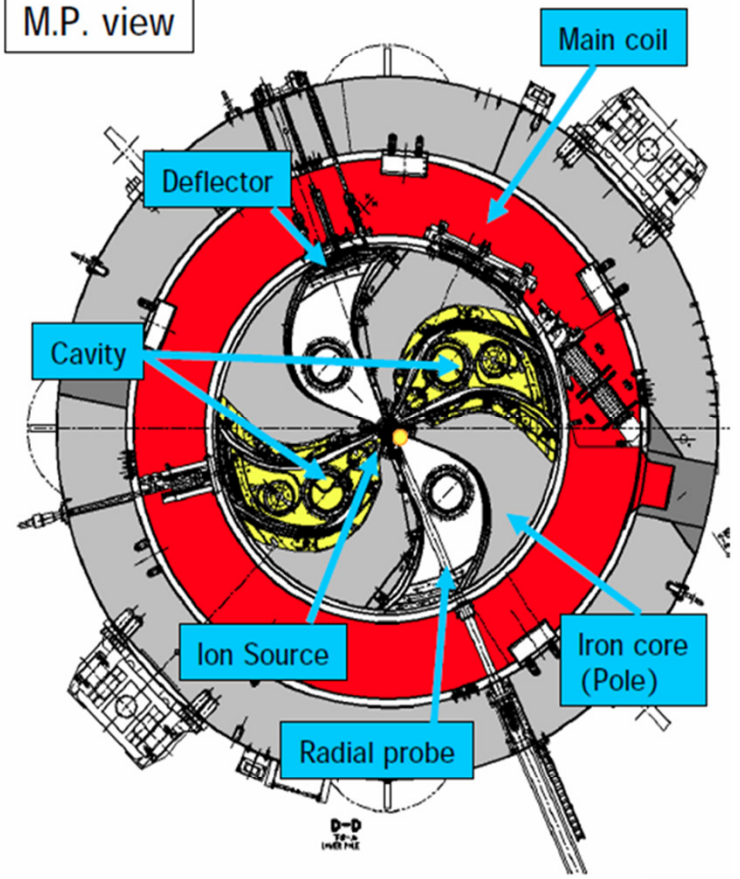
Inner view

Cross section image




Spiral sector type AVF cyclotron
Particle / Energy: Proton / 230MeV
Weight: 220ton
Magnetic field: Max 2.9Tesla

M.P. view




From Ion Source to Deflector ~10usec

P235 cyclotron can be compact by ellipse shape pole gap

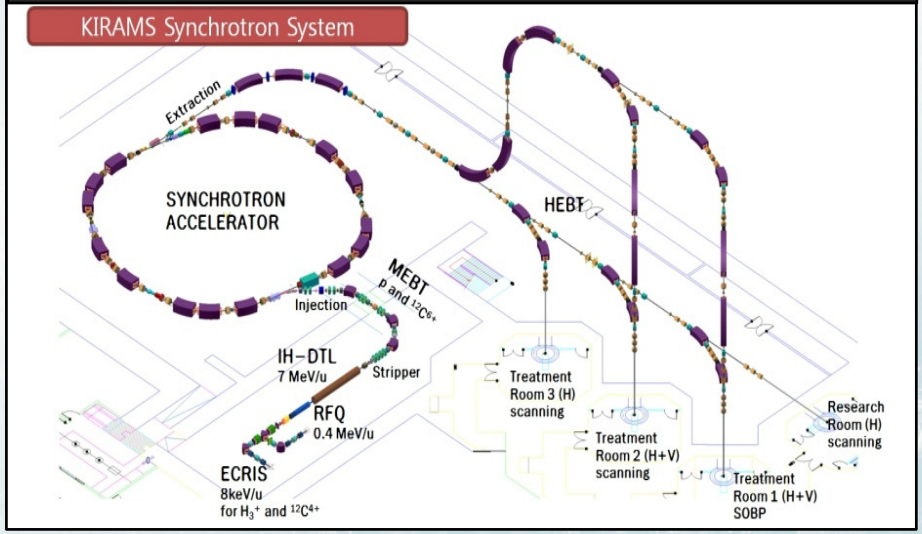
- Courtesy of Prof. Youngyih Han of SMC

# Korea Heavy Ion Medical Accelerator (KHIMA) Project

- *Leading Organization*: **KIRAMS (Korea Institute of Radiological And Medical Sciences)**
- *Location*: **Gijang County, Busan Metropolitan City**
- *Project Period*: **2010 ~ 2017 (Planned 2019)**
- *Project Budget*: **about 195 million USD(195 billion KRW)**

**Funding from Korean government(70), Local governments(Busan & Kijang; 50) and *KIRAMS (75)***

*KHIMA Accelerator System*




*Bird's-eye View of* Treatment Center

# Clinical Requirements and Beam Specifications



| | Clinical Requirements | | | items | Beam Specifications for KIRAMS |
|---|---|---|---|---|---|
| 1 | **Beam particle species** | proton, carbon-12 | | **Type of ion** | **$^{1}H_{3}^{+}$ proton and $^{12}C^{4+}$ for carbon @ ECRIS** |
| 2 | **Beam Range** | 3.0 to 27.0 in body | g/㎠ | Energy range | **60~230** MeV for proton<br>**110-430** MeV/u for carbon<br>(with the consideration of 3-5 ㎝ scatterer) |
| 3 | Bragg peak modulation steps | 0.1~0.2 | g/㎠ | Energy steps | >250 steps |
| 4 | **Range adjustment** | 0.1 | g/㎠ | Energy adjustment | **1.101~0.416** MeV for proton<br>**2.030~0.878** MeV/u for carbon |
| 5 | Adjustment/modulation accuracy | ≤± 0.025 | g/㎠ | **Energy adjustment accuracy** | ≤± **0.274~0.104** MeV for proton<br>≤± **0.505~0.219** MeV/u for carbon |
| 6 | **Distal dose fall-off (80%-20%)**<br>(in addition to the intrinsic DFO) | < 2 | ㎜ | **Energy spread**<br>[1σ in Gaussian dist.] | < **0.12** % at 230 MeV for proton<br>< **0.12** % at 430MeV/u for carbon |
| 7 | Average dose rate<br>(for treatment volume of 1000 ㎤) | 2 | Gy/min | Beam intensity | Min./Max. No. of particles per spill<br>**$1x10^{8}$ / $1x10^{10}$ for proton**<br>**$4x10^{6}$ / $4x10^{8}$ for carbon**<br>Nominal number of spills : 60 spills in 2~3 min |
| 8 | **Beam size (FWHM)** | 4 to 10 | ㎜ | Beam size (FWHM) | 4 to 10 ㎜ |
| 9 | Beam size step | 1 | ㎜ | Beam size step | 1 ㎜ |
| 10 | Beam size accuracy | ≤± 0.2 | ㎜ | Beam size accuracy | ≤± 0.2 ㎜ |
| 11 | Beam axis height (above floor) | 120 | ㎝ | Beam axis height | 120 ㎝ |
| 12 | Irradiation Room | 1 H (scanning)<br>1 H+V (scanning)<br>1 H+V (SOBP)<br>1 H (scanning, Research) | | Irradiation Room | 1 H (scanning)<br>1 H+V (scanning)<br>1 H+V (SOBP)<br>1 H (scanning, Research) |

Beam energy
Beam Intensity
Beam Size and Position

| | |
|---|---|
| **Scan Speed** | **> 20 [mm/ms]** |
| **Field Size** | **20 cm X 20 cm** |

# KHIMA Construction Site View (May 2016)

- Nov. 2010 Geological and Cultural Property Survey
- May 2012 Groundwork
- Jan. 2014 Groundbreaking
- Nov. 2014 Assembly and Test Bldg. Contract
- Jan. 2015 Assembly and Test Bldg. Ready
- May 2016 Treatment Center Completion(Treatment Facility only)

# World Carbon HIRT Facilities

Apr. 2014

| Status | Country / Local Area | | Institution | Accelerator | Open | People Treated |
|---|---|---|---|---|---|---|
| ***in Operation*** (8+1 facilities) | Japan | Chiba | HIMAC | synchrotron | 1994 | 8,158 |
| | | Hyogo | HIBMC | synchrotron | 2002 | 1,523 |
| | | Gunma | GHMC | synchrotron | 2010 | 968 |
| | | Tosu | SAGA HIMAT | synchrotron | 2013 | 62 |
| | Germany | Heidelberg | HIT | synchrotron | 2009 | 1,368 |
| | | Darmstadt | GSI* | synchrotron | 1997-2009 | 440 |
| | China | Lanzhou | IMP-CAS | synchrotron | 2006 | 213 |
| | Italy | Pavia | CNAO | synchrotron | 2012 | 105 |
| | China | Shanghai | Fudan University Shanghai | synchrotron | 2014 | |
| ***in Construction*** (5 facilities) | China | Lanzhou | HITFiL | synchrotron | 2014 | |
| | | Wuwei | HITWiL | synchrotron | 2014 | - |
| | Japan | Kanagawa | I-ROCK | synchrotron | 2015 | - |
| | Germany | Marburg | Marburg | synchrotron | 2014 | - |
| | Austria | Wiener Neustadt | Med-Austron | synchrotron | 2015 | - |
| | **Korea** | **Busan** | **KIRAMS** | synchrotron | **2017** | - |
| ***Planning*** (6 facilities) | USA | Rochester | Mayo | synchrotron | - | - |
| | Saudi Arabia | Riyadh | KACST | synchrotron | - | - |
| | Malaysia | Penang | USM | synchrotron | - | - |
| | Taiwan | Taipei | Chang Yung-Fa Foundation | synchrotron | - | - |
| | Russia | Moscow | ITEP | synchrotron | - | - |
| | Australia | Clayton | ANSTO | Synchrotron | - | - |

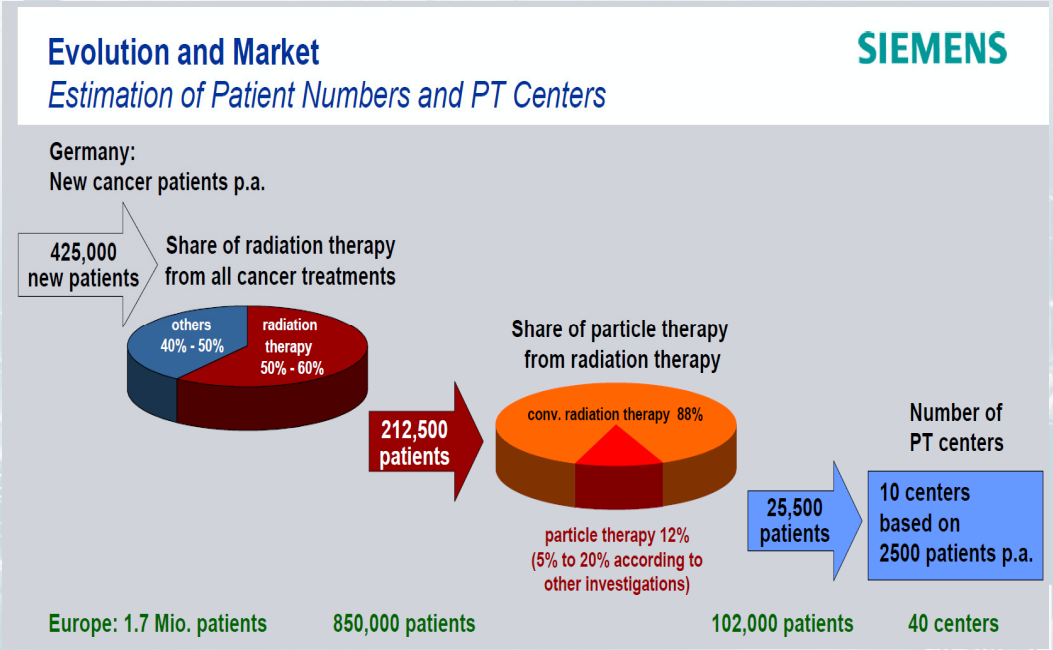
total 12,837

* Closed operation

# Needs of Carbon HIRT Facilities



| | facilities | note |
|---|---|---|
| **Current Status** | • 8 facilities(4 countries) in operation<br>• 13 facilities in construction *or* planning | • people treated: 12,837 (Apr. 2014) |
| **Needs in Europe** | 40 facilities | • 1 facility per 20 millions ( Ugo Amaldi, 2003) |
| **Needs in Korea** | ~ 4 facilities | • 1 facility per 20 millions |



# C-Ion RT Patient Number Estimation in Korea

- The need of carbon ion radiotherapy (C-ion RT) in Korea was estimated based on the Korean cancer survey system conducted by KIRAMS in 2010.

- RT Patient : 42,000 (21.1 % out of total incidence) in 2008
- Estimation of Particle therapy : Roughly 5 % → 2,100

- Carbon ion RT patient : 1,800 patients (corresponding to 4.3% and 1% of patients treated with RT and the newly diagnosed cancer patients in Korea, respectively)

- Needs more than 2 particle therapy centers in Korea!

# Major Accelerator Activities in Korea


: Locations of major accelerator centers in Korea.

- **Pohang: PAL (PLS:1994 & PLS-II:2011, PAL XFEL:2015)**
  - ✓ Synchroton Radiation Source
- **GyeongJu: PEFP:2014**
  - ✓ High Power Proron Linac (100 MeV, 20 mA with 1 GeV Upgrade Option)
- **Sejong: RISP:2021**
  - ✓ Rear Isotope Science Project
  - ✓ 200 MeV/u Uranium, 8pμA
  - ✓ Basic Science

- **Busan: KHIMA:2019**
  - ✓ Heavy Ion Beam Treatment
  - ✓ 430 MeV/u Carbon
  - ✓ Medical Accelerator

- **Proton Therapy Centers in Korea**
  - National Cancer Center in Ilsan (near Seoul)
  - Samsung Medical Center in Seoul

# Collaboration with Industry in Korea for Accelerators

- The accelerator related business in Korea has flourished since 1994 when the Pohang Light Source (PLS) was constructed.
- During the process in research and development of accelerators, about 400 large and small industries have been involved in the accelerator business.
- These industries have formed an industrial ecosystem with about sixteen major companies (Korea Association of Fusion and Accelerator Technologies (KAFAT) Survey).
- There exist no companies that could manage overall accelerator systems, either for basic R&D or for medical purposes. *(EB-Tech is a company that could handle manufacturing industrial accelerator systems for beam irradiation, but not yet involved in medical area.)*

# Related Technologies in the Industrial Ecosystem of Accelerator and Fusion Tech. in Korea

- Ultra-high vacuum
- Cryogenics & Superconducting
- Large scale high level control system
- Special materials
- Precision machining
- Diagnostics and instruments
- High stability cooling systems
- High precision magnet power supplies
- High and low power RF and low lever RF controls
- Survey and alignment
- High precision magnets
- Mechanical components such as girders and stages, etc.

# Industrial Ecosystem of Accelerator and Fusion Tech. in Korea (KAFAT Survey)

| No | Company | Specialty |
|---|---|---|
| 1 | Dowonsys | Power Conversion |
| 2 | VITZROTech | RF Cavities, |
| 3 | Motion Hightech | |
| 4 | Genesis | |
| 5 | Seongwoo Instruments Inc. | Cryogenics |
| 6 | HMT | High & Low Level Control |
| 7 | VMT | Vacuum pump |
| 8 | SFA | Automation Equipment, Precision Machining |
| 9 | POSCO ICT | control, power conversion |
| 10 | Kumgang | |
| 11 | Halla EBTech | e-beam welding |
| 12 | CVE Co., Ltd. | cryogenics, vacuum, superconducting |
| 13 | KUMKANG TECH | Fine machining, welding, vacuum chamber |
| 14 | Dongwoo Optron | Optics, Gas Detection and Measurement |
| 15 | PLASPO | Power Conversion |
| 16 | Alpha-plus | Vacuum System and components |

▪ Courtesy of KAFAT

# Collaboration with Industry in Korea for Medical Accelerators

- Most of the current accelerator related industries are maintaining their accelerator business by collaborating with national R&D institutions and applying their experience and specialty in national large scale projects, such as KHIMA.
- In 2015, Dawonsys established a subsidiary company that pursues a business specialized in medical accelerator development and manufacturing. This subsidiary company of Dawonsys becomes effectively the first formal medical accelerator business in Korea.
- More are expected to come in near future.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