1st ANPhA Symposium on Asian Nuclear Physics Facilities
J-PARC, Tokai, Jan 18-19, 2010

Proton Engineering Frontier Project*

Kui Young Kim
on behalf of the Proton Engineering Frontier Project
Korea Atomic Energy Research Institute

* Supported by the Ministry of Education, Science & Technology, Korea

❑ Contents

❑ Overview

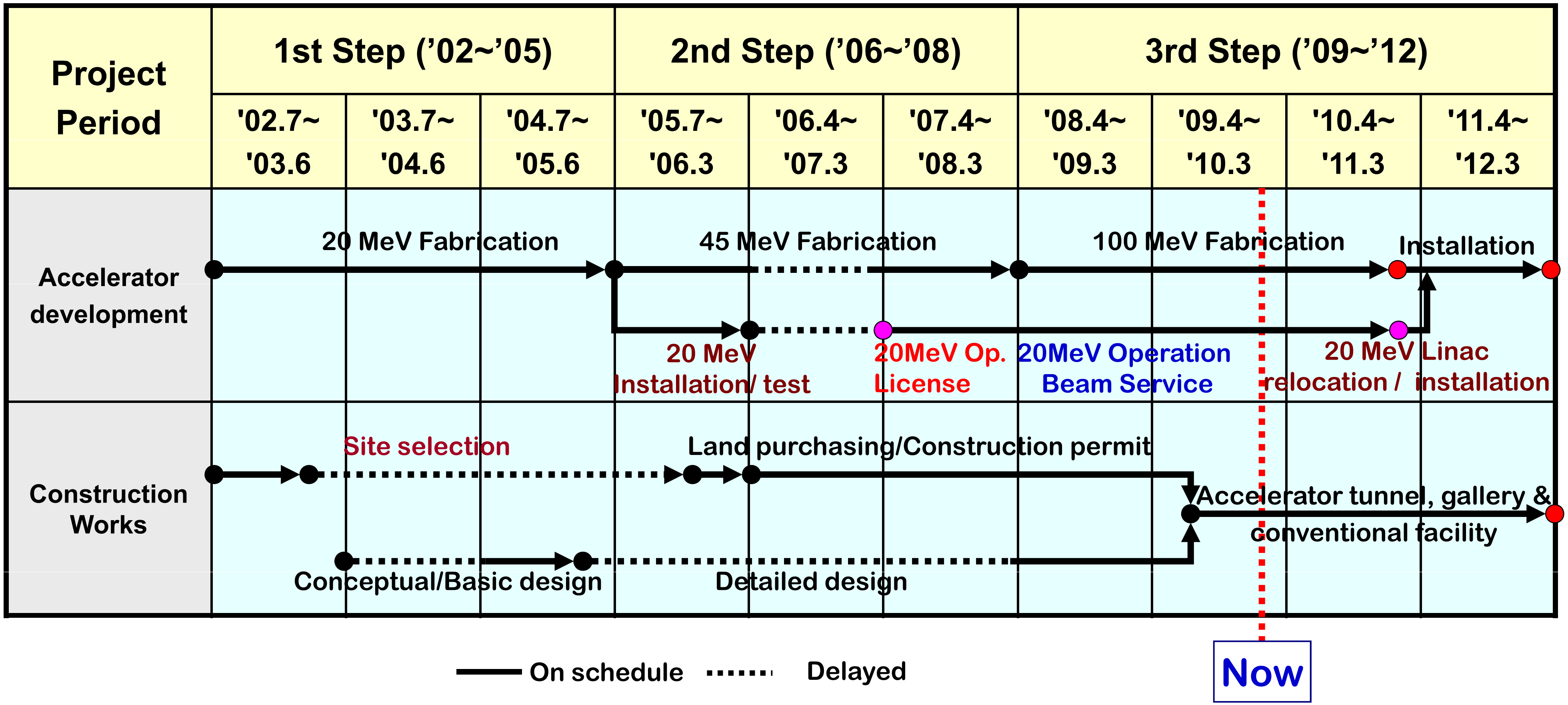
- **Project : Proton Engineering Frontier Project (PEFP)**
  21C Frontier R&D Program, MEST, Republic of Korea

- **Objectives :**
  - To develop a High Power Proton Linac (100MeV, 20mA)
  - To develop Beam Utilization & Accelerator Application Technologies
  - To Industrialize Developed Technologies

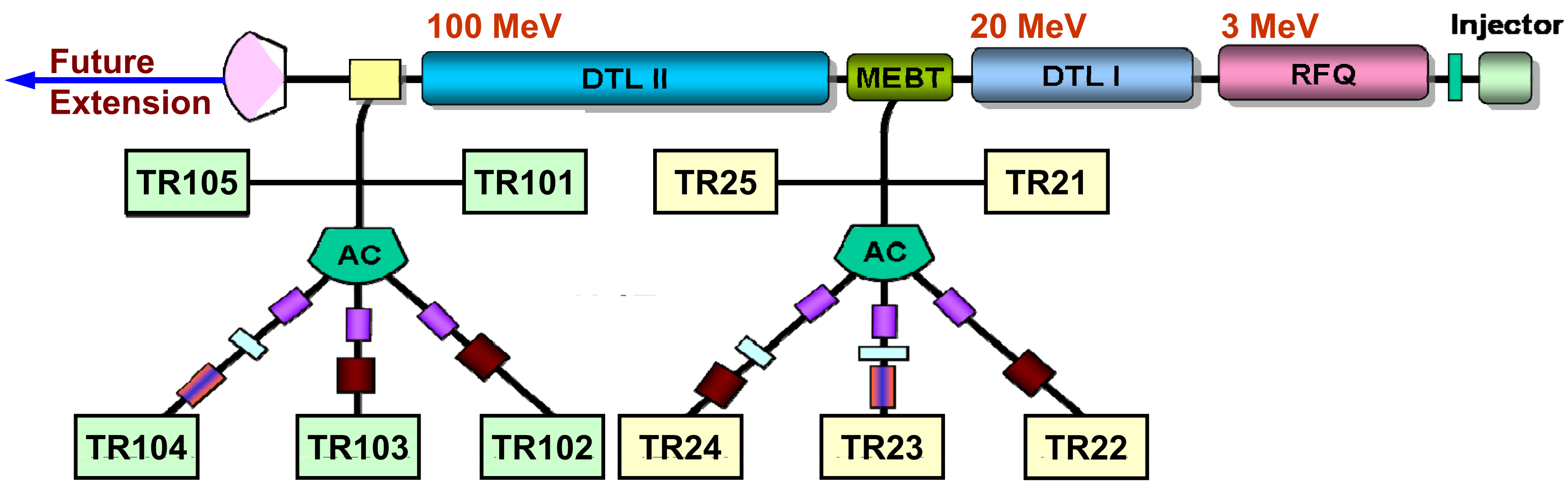
- **Period : July 2002 – March 2012 (10 years)**

- **Budget : 128.6 B KRW (Gov. 115.7 B, Private 12.9 B)**
  (Gyeongju City : Site, Buildings & Supporting Facilities)

❑ Schedule


Project Period
1st Step ('02~'05)
2nd Step ('06~'08)
3rd Step ('09~'12)
'02.7~ '03.6
'03.7~ '04.6
'04.7~ '05.6
'05.7~ '06.3
'06.4~ '07.3
'07.4~ '08.3
'08.4~ '09.3
'09.4~ '10.3
'10.4~ '11.3
'11.4~ '12.3
Accelerator development
20 MeV Fabrication
45 MeV Fabrication
100 MeV Fabrication
Installation
20 MeV Installation/ test
20MeV Op. License
20MeV Operation Beam Service
20 MeV Linac relocation / installation
Construction Works
Site selection
Land purchasing/Construction permit
Accelerator tunnel, gallery & conventional facility
Conceptual/Basic design
Detailed design
On schedule
Delayed
Now

❑ PEFP Accelerator & Beamline



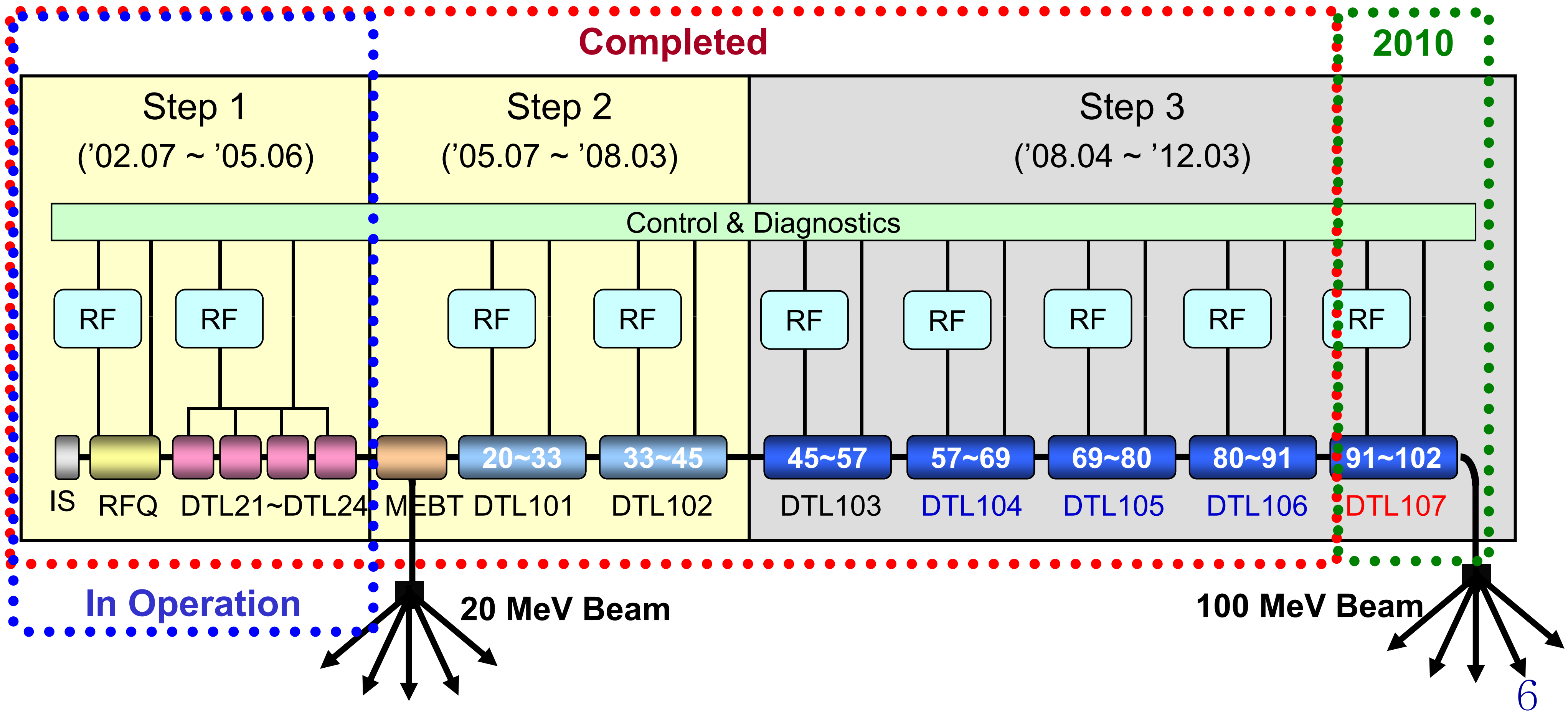
Features of the PEFP linac

- 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
  - Beam to be distributed to 3 BL via AC

Output Energy (MeV)	20	100
Peak Beam Current (mA)	20	20
Max. Beam Duty (%)	24	8
Avg. Beam Current (mA)	4.8	1.6
Pulse Length (ms)	2	1.33
Max. Repetition Rate (Hz)	120	60
Max. Avg. Beam Power (kW)	96	160

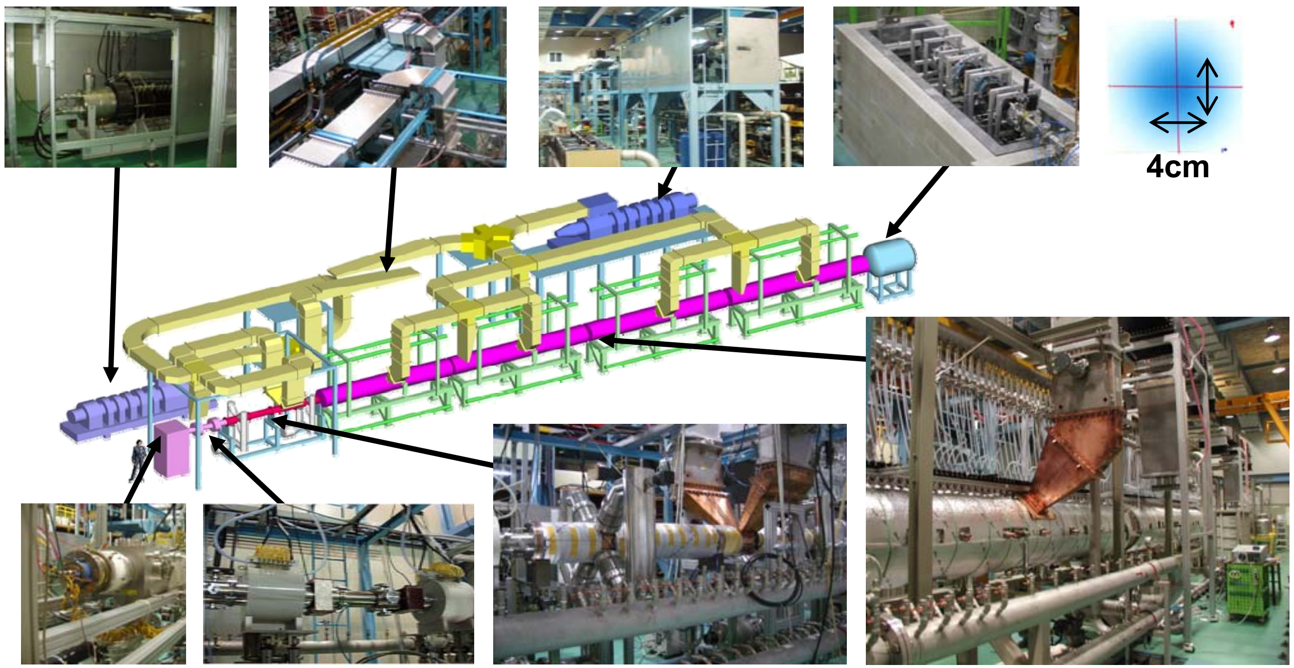
❑ Status of Accelerator Development

- ❖ Up to 20 MeV : Fully developed & installed and under routine operation
- ❖ Fabricated 20~91 MeV (6 DTL tanks)
- ❖ To the last DTL tank (91~100 MeV) in 2010

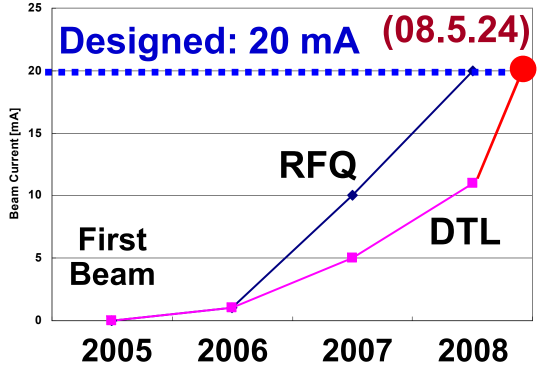


❑ Performance of PEFP 20 MeV Linac

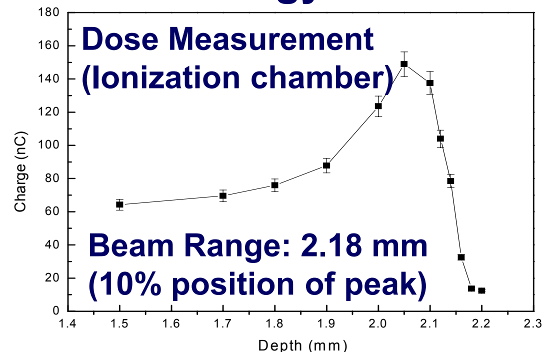
- **Extracted first beam (July 2005)**
- **Obtained operation license (June 2007)**
  - **Avg. current: 0.1 μA, Rep. Rate: 0.1 Hz, 4 hrs/week**
- **Started beam service (June 2007)**
- **Achieved designed performance (May 2008)**



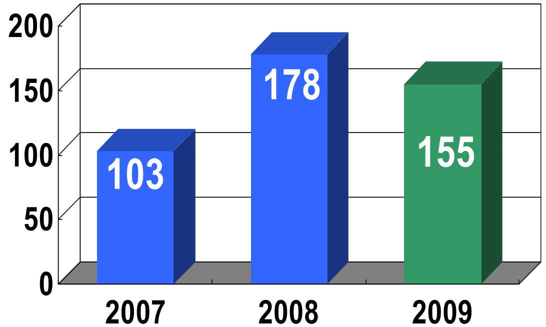
❖ **Beam Current** **20.2 mA**



❖ **Beam Energy: 20.33 MeV**

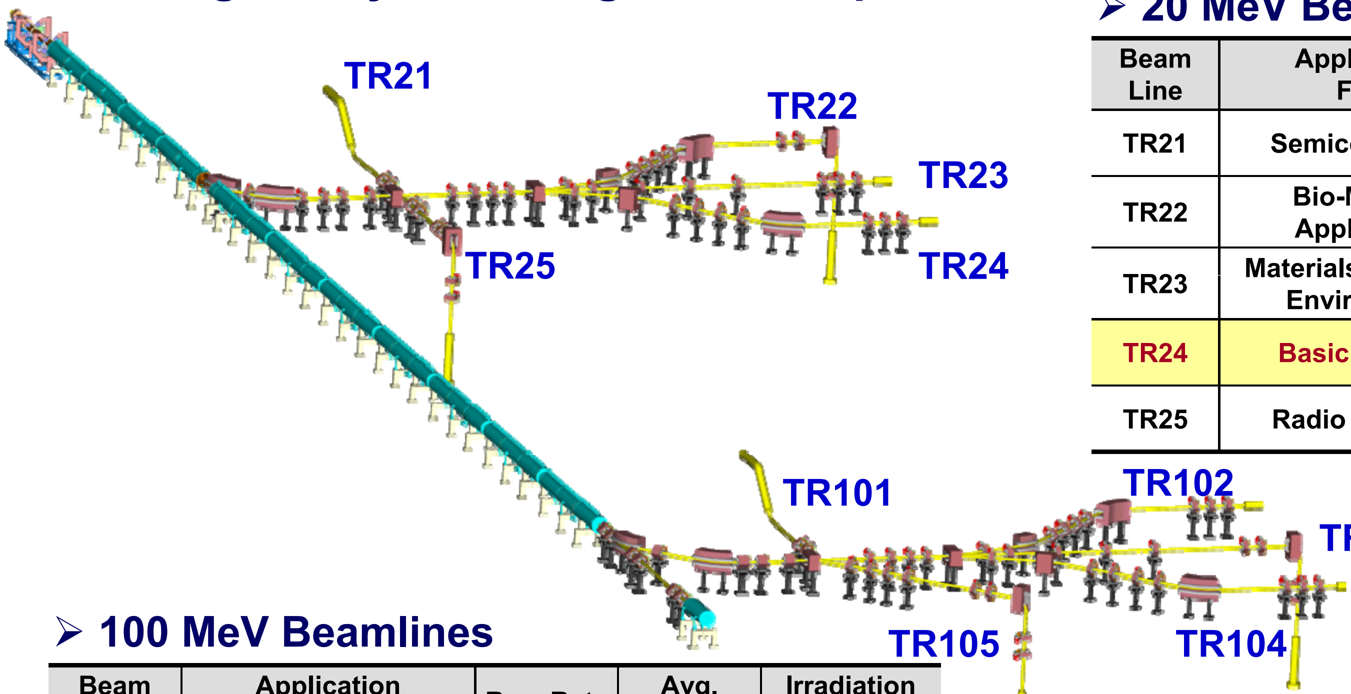


❖ **Irradiated Samples**



❑ Beamlines

❖ Designed by reflecting user's requirement



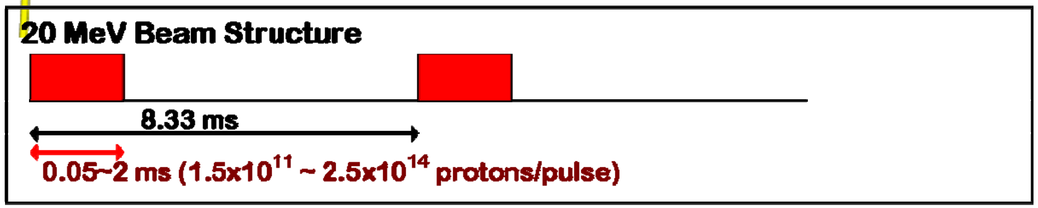
➢ 20 MeV Beamlines

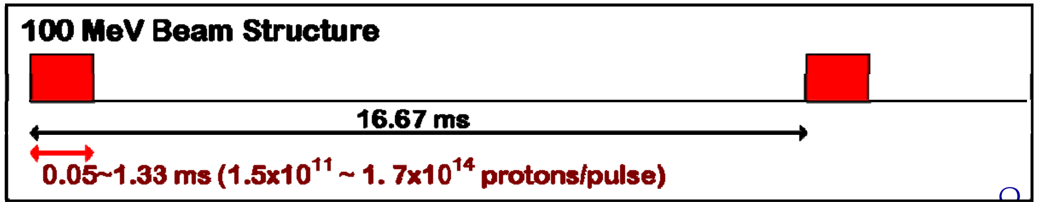
Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR21	Semiconductor	60 Hz	0.6 mA	Hor. Ext.
TR22	Bio-Medical Application	15 Hz	60 μA	Hor. Ext.
TR23	Materials, Energy & Environment	30 Hz	0.6 mA	Hor. Ext.
TR24	Basic Science	15 Hz	60 μA	Hor. Ext.
TR25	Radio Isotopes	60 Hz	1.2 mA	Hor. Vac.

➢ 100 MeV Beamlines

Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR101	Radio Isotopes	60 Hz	0.6 mA	Hor. Ext.
TR102	Medical Research (Proton therapy)	7.5 Hz	10 μA	Hor. Ext.
TR103	Materials, Energy & Environment	15 Hz	0.3 mA	Hor. Ext.
TR104	Basic Science Aero-Space tech.	7.5 Hz	10 μA	Hor. Ext.
TR105	Neutron Source Irradiation Test	60 Hz	1.6 mA	Hor. Vac.

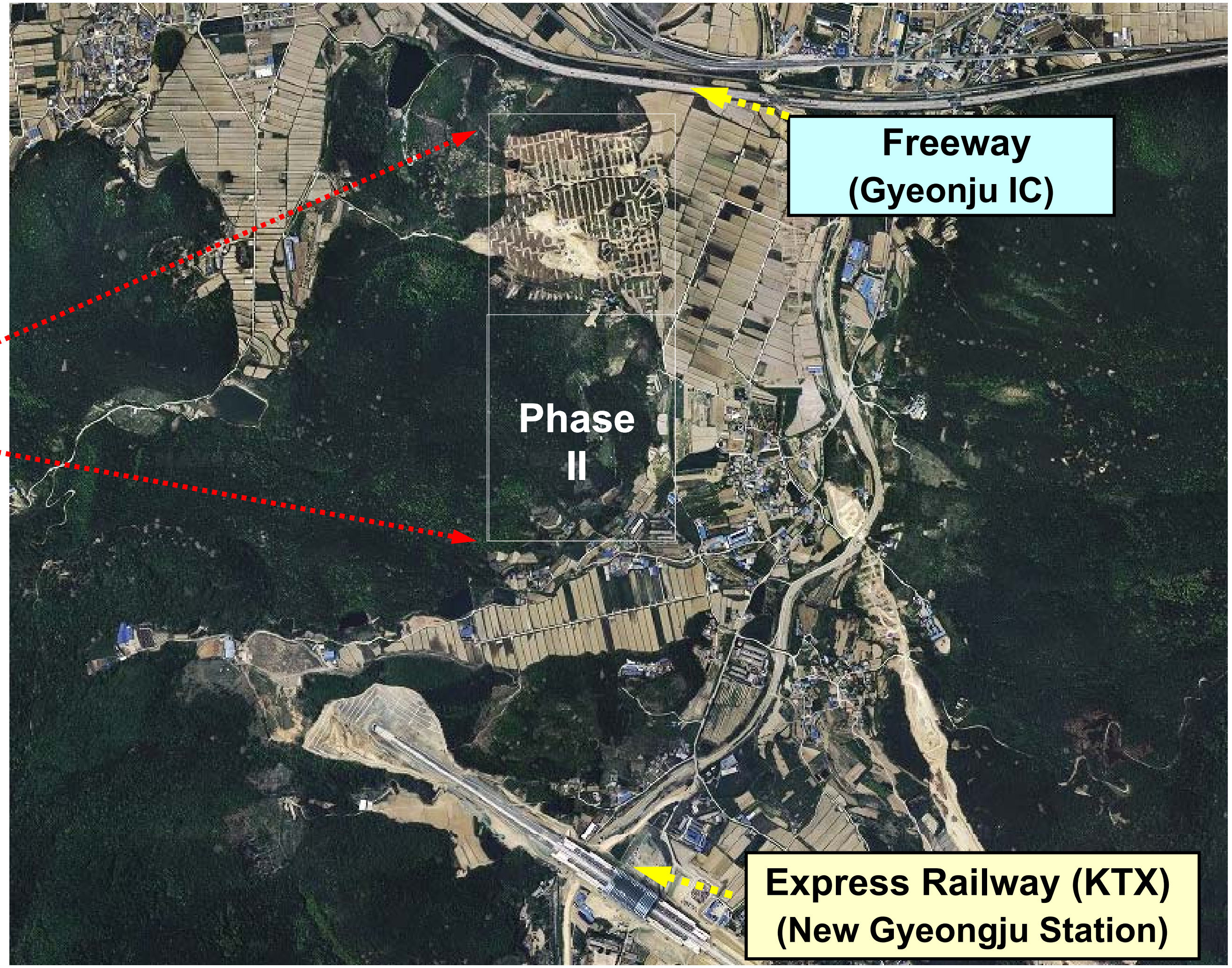
☞ 33, 45, 57, 69, 80, 91, 100 MeV p beam





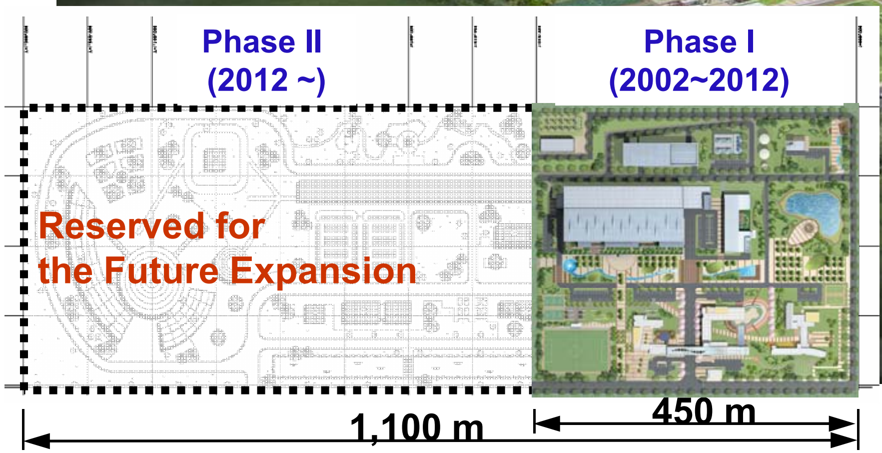
❑ The Project Site

❖ The Project Site (Area: 440,000 m^2) is located at Gyoengju.
(The capital of Shilla dynasty for 992 years, from BC 57 to AD 935.)



❑ Site Plan

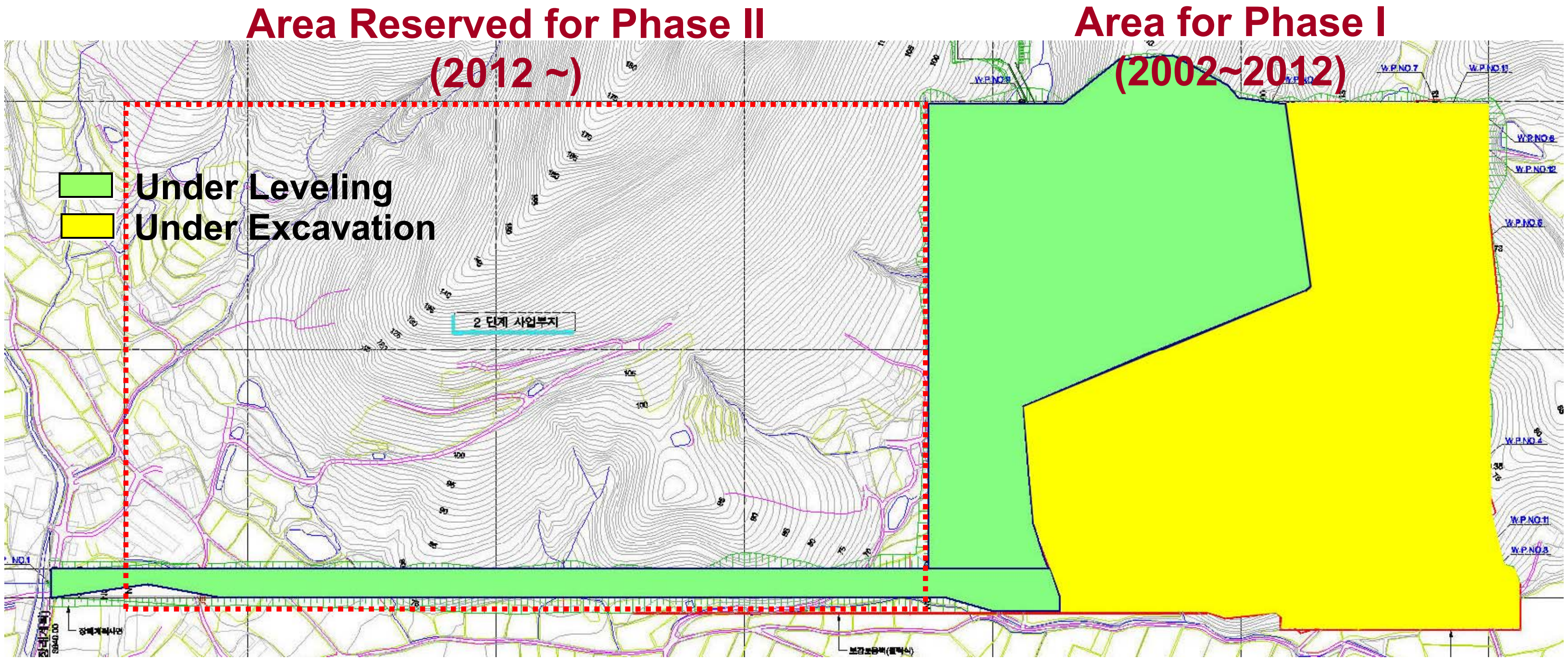

Proton Accelerator Research Center
① Accelerator Tunnel
② Experimental Hall
③ Ion Beam Facility
④ Utility Building
⑤ Substation
⑥ Cooling Tower
⑦ Water Storages
⑧ Main Office Building
⑨ Regional Cooperation Cente
⑩ Dormitory
⑪ Information Center
⑫ Sewage Plant
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫


Phase II
(2012 ~)
Phase I
(2002~2012)
Reserved for
the Future Expansion
400 m
1,100 m
450 m


Express Railway
(Under construction)
Phase - II
Phase - I
Gyeong-bu
Freeway

❑ Excavation and Site Preparation

- ❖ **Gyeongju; purchased the land**
- ❖ **Excavating Phase1 site (Feb, 2009)**
- ❖ **Started Site Preparation (May 27, 2009)**
  ⇒ Site leveling and access road construction



❑ Construction Schedule (08FY ~ 12FY)

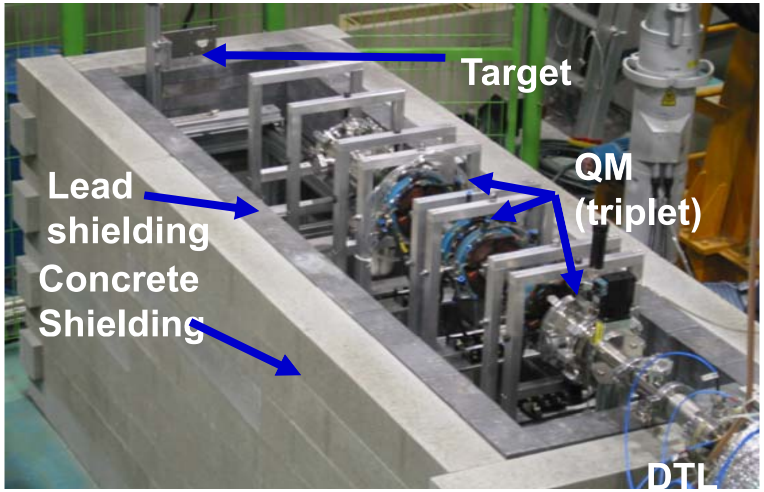
Date	Major Activities
2008. 9	Obtained the construction permit
2009. 5	Started construction (ground breaking)
2010. 4	To start foundation work (accelerator & beam utilization building)
2011. 3	To complete accelerator, ion beam & utility facility building
2011. 6	To supply 154 kV power & water
2011. 12	To complete mechanical, electrical, I&C system
2012. 3	To complete of buildings & yard facilities
2012. 3	To complete the project

❑ User Program Development

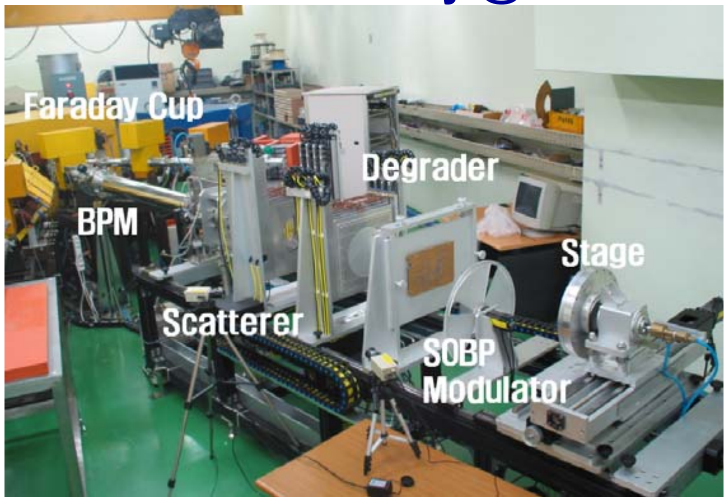
❑ User Program Development (2003~)

Research Fields	Sub-categories
Nano Technology	Ion-cutting, Nano-particle fabrication, Carbon nano-tube, Nano-machining
Information Technology	High power semiconductor, Semiconductor manufacturing R&D, etc.
Space Technology	Radiation hard electronic device, Radiation effect on materials
Bio-Technology	Mutations of plants & micro-organisms, Extraction of natural product
Medical research	Low energy proton therapy study, Biological radiation effects, RI production, etc.
Materials Science	Proton irradiation effects with various materials, Gemstone coloration
Energy & Environment	New μ-organism (bio fuel), New materials for fuel cell, nano catalyst, organic solar cell
Nuclear & Particle Physics	Detector R&D, Nuclear data, TLA (Thin Layer Activation)

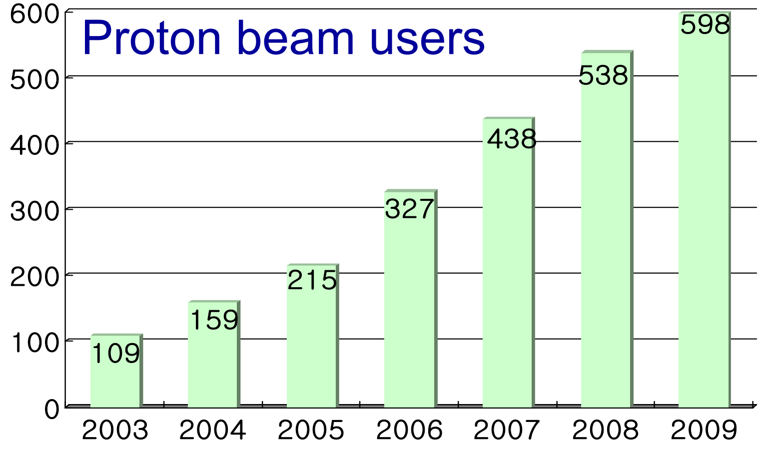
❖ 20 MeV Beam Facility @ KAERI



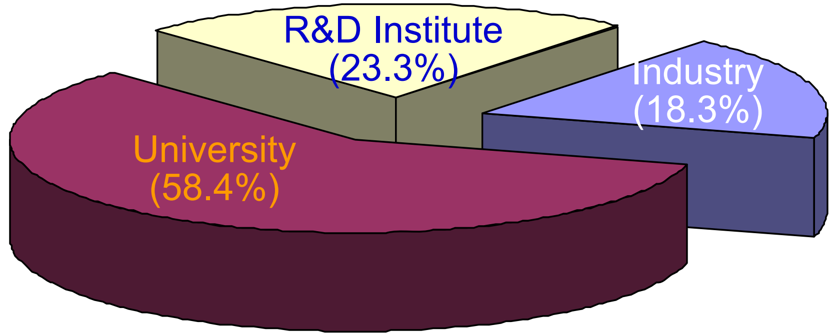
❖ 45 MeV beam facility @ KIRAMS*



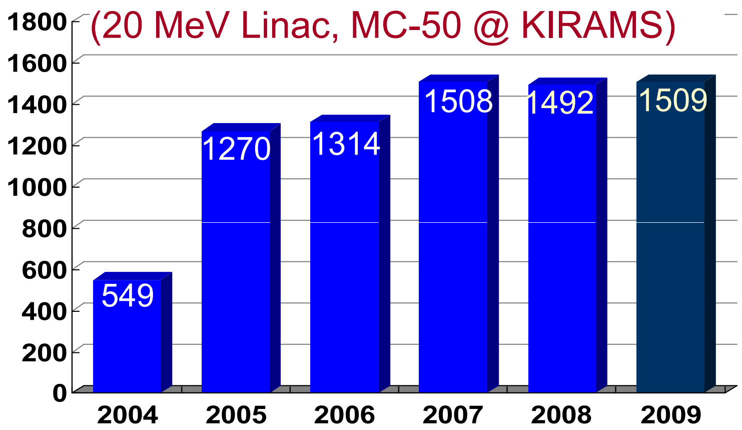
❑ Status of PEFP User Program



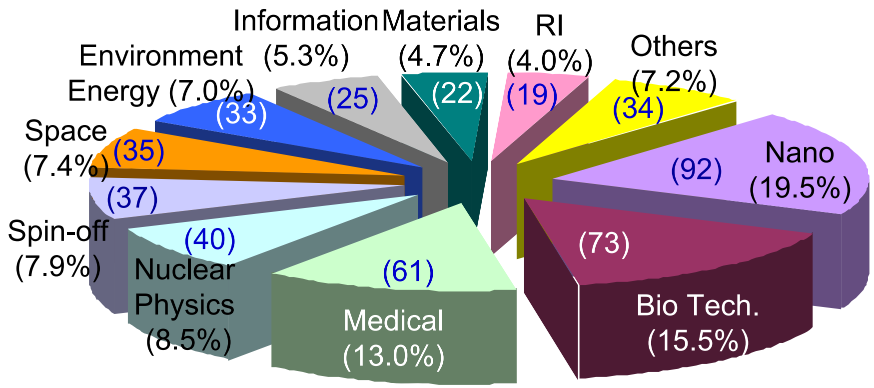
❖ User Distribution (99 Institutions)



Irradiated Samples



❖ User Distribution (R&D Fields)



❑ R&D Highlights (I)

PEFP Proton Engineering Frontier Project

• Condensed Matter

Identification of ferromagnetism of proton-irradiated graphite

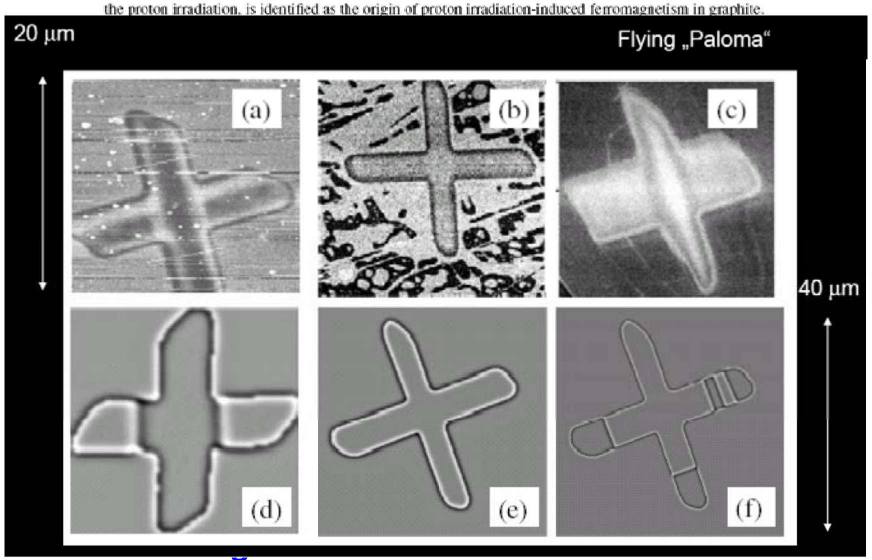
APS physics Physical Review Letters
AMERICAN PHYSICAL SOCIETY

PRL 97, 137206 (2006) PHYSICAL REVIEW LETTERS week ending 29 SEPTEMBER 2006

Electron Spin Resonance of Proton-Irradiated Graphite

Kyu Won Lee and Cheol Eui Lee*
Department of Physics and Institute for Nano Science, Korea University, Seoul 136-713, Korea
(Received 31 May 2005; revised manuscript received 13 June 2006; published 28 September 2006)

In the case of colossal magnetoresistance in the perovskite manganites, "double exchange" mediated by the itinerant spins is believed to play a key role in the ferromagnetism. In contrast, the conventional "Heisenberg" interaction, i.e., direct (unmediated) interaction between the localized spins produced by the proton irradiation, is identified as the origin of proton irradiation-induced ferromagnetism in graphite.



• Materials Science

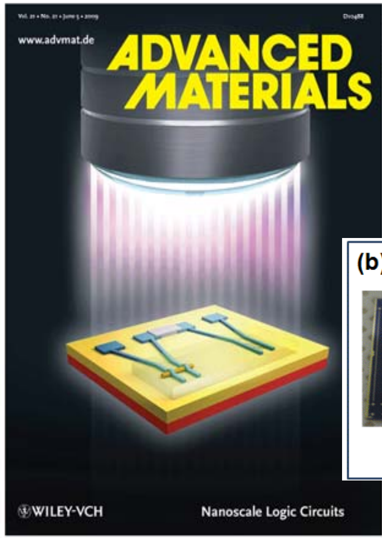
- Hybrid nano-logic circuits
  n-type nanowire + p-type nanotube

WILEY-VCH Nanoscale Logic Circuits

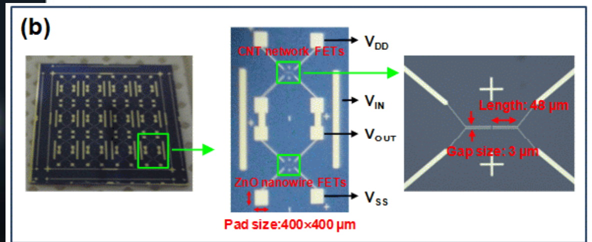
ADVANCED MATERIALS www.advmat.de
COMMUNICATION

Hybrid Complementary Logic Circuits of One-Dimensional Nanomaterials with Adjustment of Operation Voltage

By *Gunho Jo, Woong-Ki Hong, Jung Inn Sohn, Minseok Jo, Jiyong Shin, Mark E. Welland, Hyunsang Hwang, Kurt E. Geckeler, and Takhee Lee**



additional compensation circuits. To this end, the precise modulation and matching of the current and operating voltage in transistors have been achieved electrostatically by adjusting the population of proton radiation-generated charges in the dielectric layer, providing an alternative to chemical doping. Recently, we have demonstrated that SWNT FETs show a high tolerance against proton radiation,[21] while the electrical characteristics of

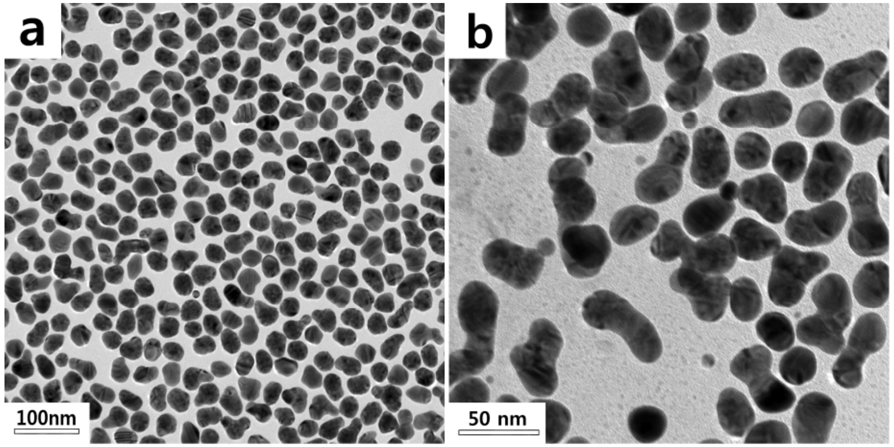


❑ R&D Highlights (II)

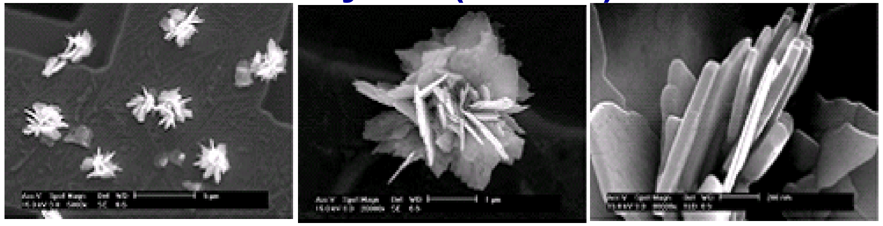
• Nano-Tech

❖ Fabrication of metallic nano-particles
- Gold, Platinum, Silver

❖ **Silver nano particle (SEM Images)**

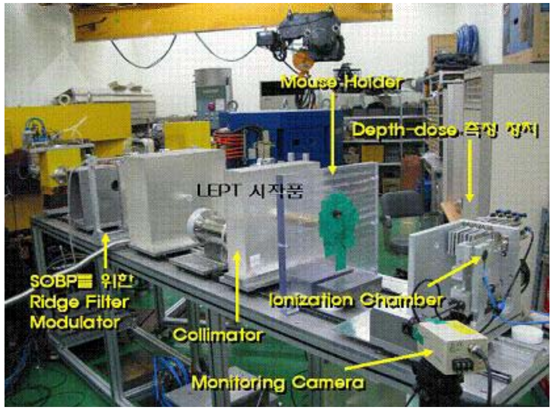


❖ **Silver nano crystal (Flower) formation**

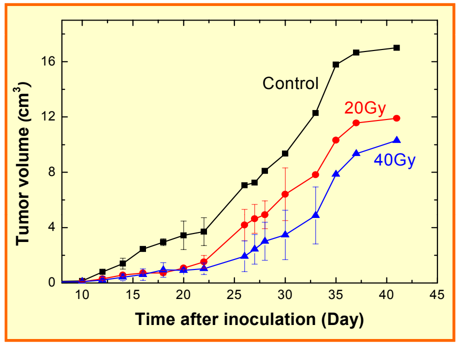


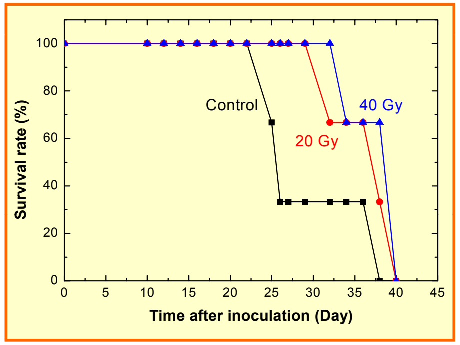
• Bio-Medical Science

❖ In-vivo proton beam experiments
- LLC (Lewis Lung Carcinoma)



Proto-type LEPT Beam line for proton therapy study





❑ R&D Highlights (III)

• Nuclear Physics

Expecting for your contributions.

❑ Options for the Future

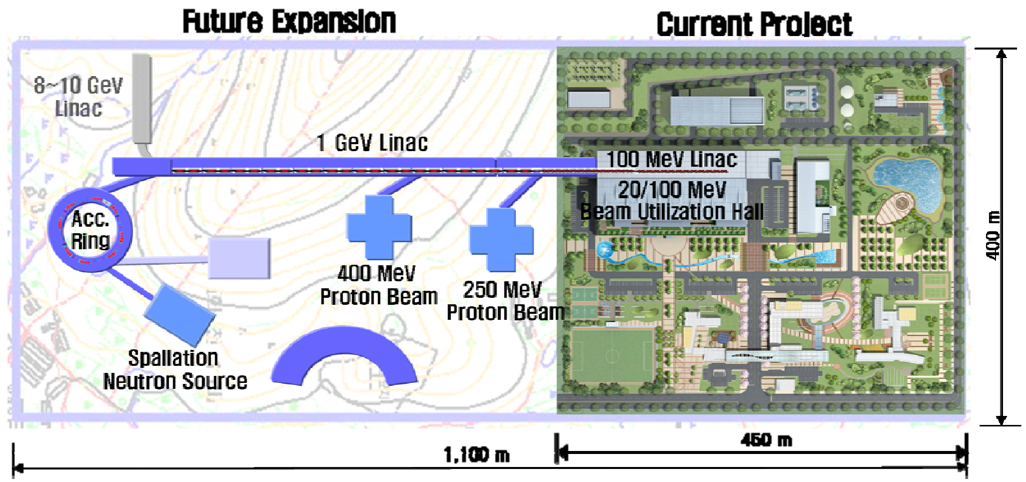
PEFP Proton Engineering Frontier Project

❑ Two Options Proposed by Science & TEchnology Policy Institute (Feb, 2009)

"*Long-term Planning for Proton Engineering Frontier Project*"

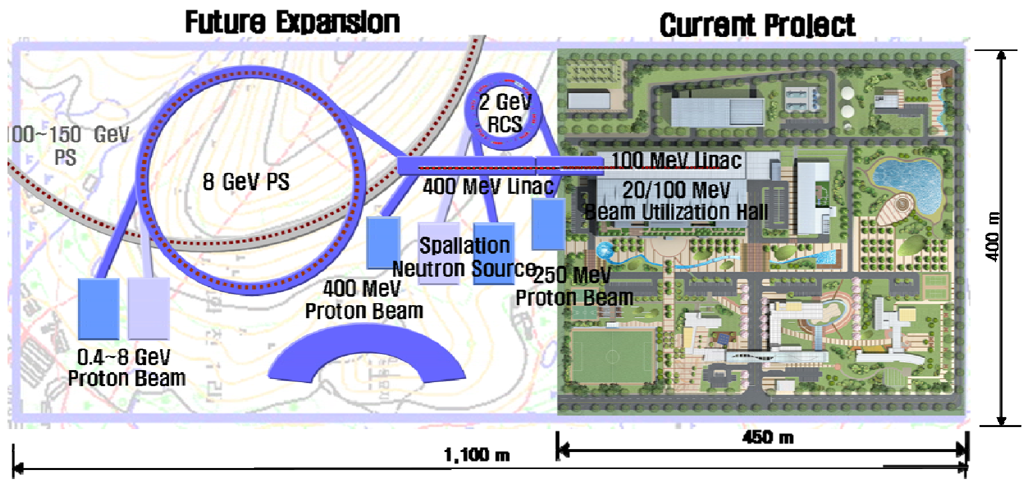
❖ Option 1

- 1 GeV Linac + Accumulation Ring
  - ⇒ 2 MW Spallation Neutron Source
  - ⇒ 250, 400, 1000 MeV Proton Beam



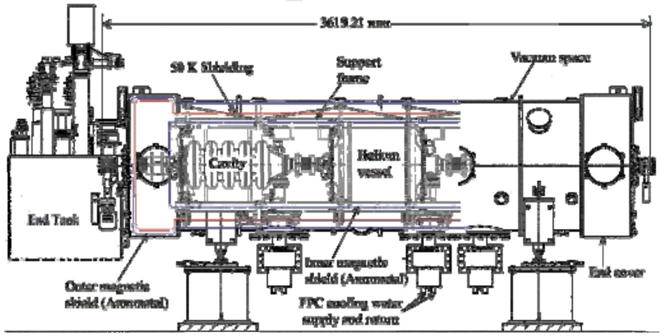
❖ Option 2

- 200 MeV Linac + 2 GeV RCS
  - ⇒ 0.5 MW Spallation Neutron Source
  - ⇒ 250 MeV Proton Beam
- 400 MeV Linac + 8 GeV PS
  - ⇒ 8 GeV Proton Beam

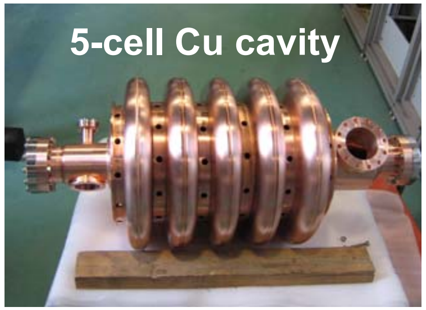


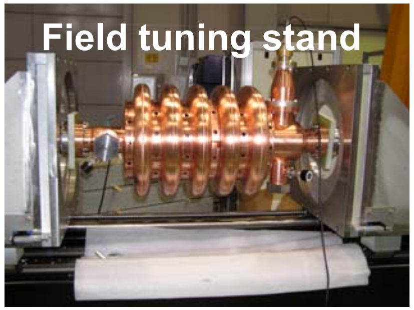
❑ SRF (Superconducting Linac)

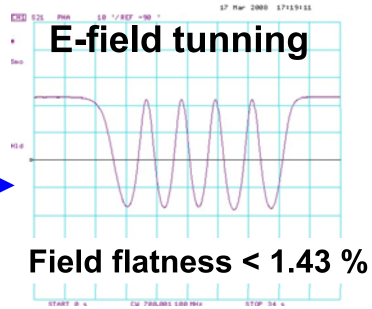
- β=0.42, RF: 700 MHz
- SC Cavity, RF coupler, Tuner, Vacuum Vessel, etc.
- Fabricated & tested a warm module (Cu Cavity)
- Fabricated and tested a 2-cell cold module (Nb Cavity)



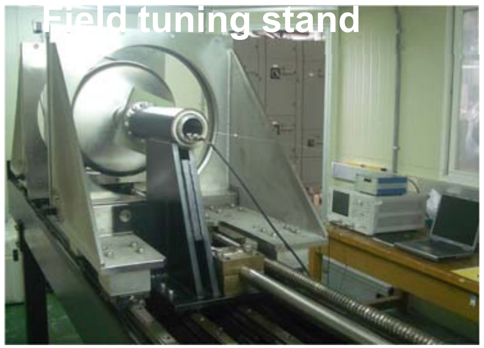
< Designed SRF module >

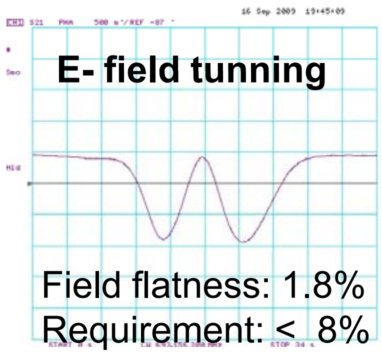






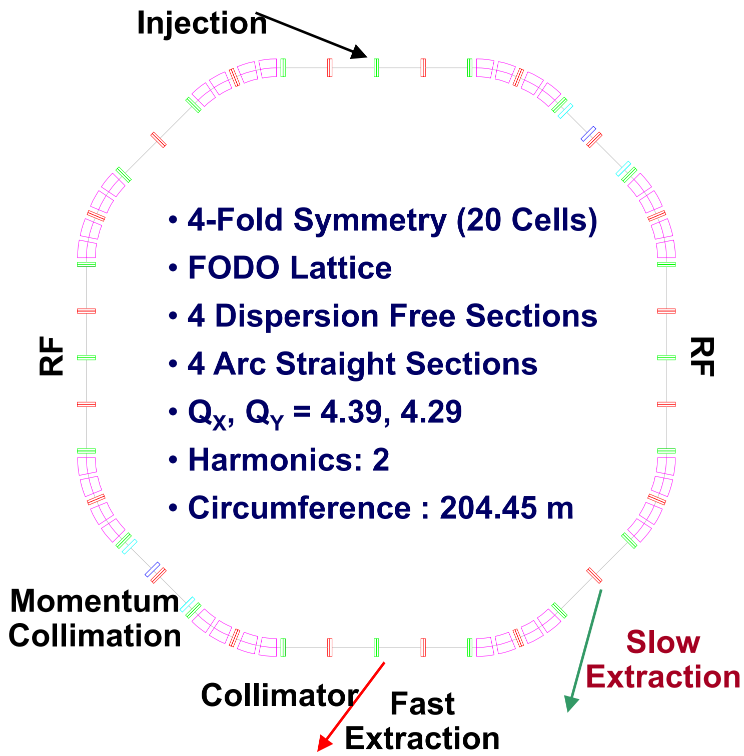
- Developed digital LLRF test system (H/W+S/W)
- Performed LLRF closed-loop test with Cu Cavity
- Achieved amplitude, ±1 %, phase, ±1°.





- Cryostat & Vertical tests to be performed. (in cooperation with PAL)

❑ RCS (Rapid Cycling Synchrotron)



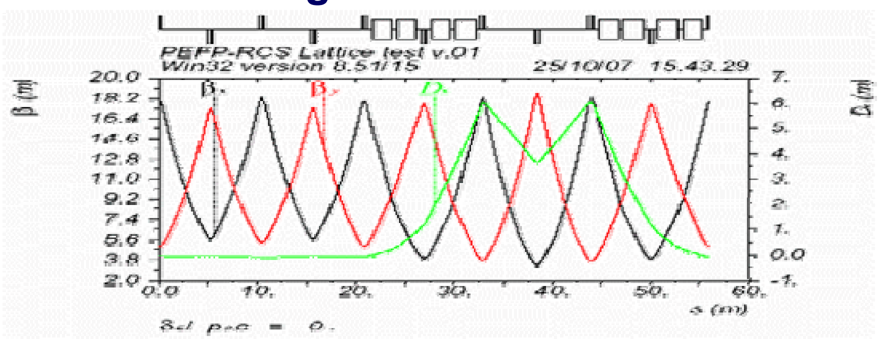
- 4-Fold Symmetry (20 Cells)
- FODO Lattice
- 4 Dispersion Free Sections
- 4 Arc Straight Sections
- Q_X, Q_Y = 4.39, 4.29
- Harmonics: 2
- Circumference : 204.45 m

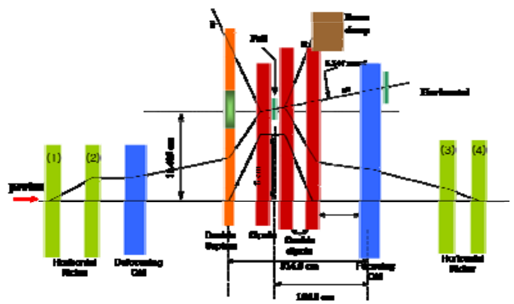
- Injection Energy: 100 (200) MeV
- Extraction Energy: 1 (2) GeV
- Injection : Charge Exchange
- Fast Extraction : Spallation neutron source
- Slow Extraction (~450 MeV): Medical application
- with great help from Dr. Y.Y. Lee @ BNL

❖ Upgrade Path

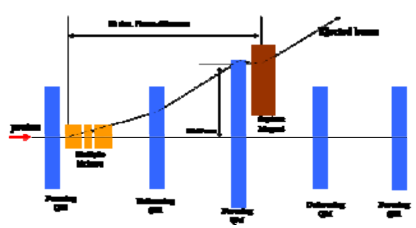
	Injection [GeV]	Extraction [GeV]	Repetition [Hz]	RF [KV]	Power [KW]
Initial	0.1	1.0	15	80	60
Upgrade #1	0.1	1.0	30	140	120
Upgrade #2	0.1	2.0	30	260	250
Upgrade #3	0.2	2.0	30	250	500

❖ Lattice Design





[Injection system]

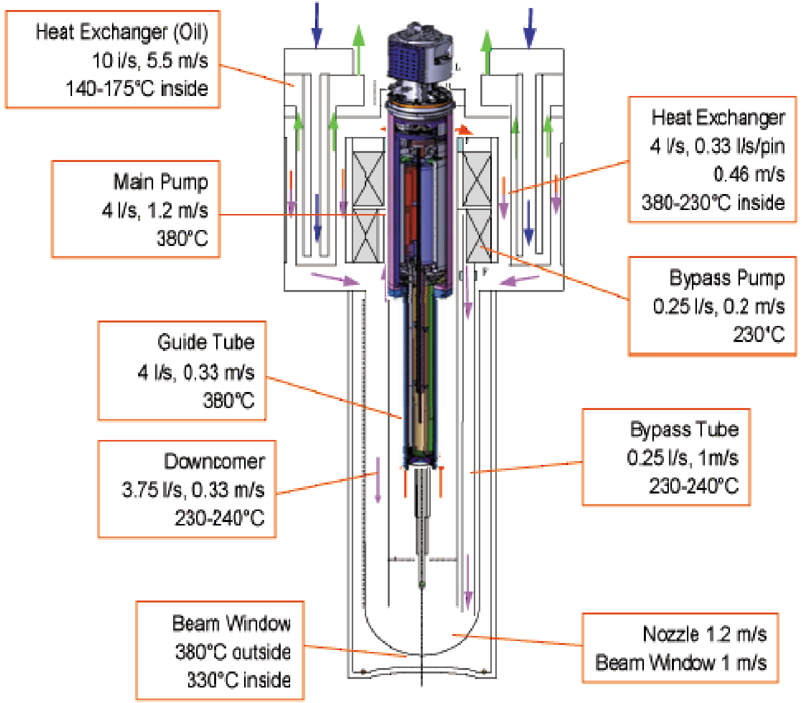


[Extraction system]

❑ Target (Spallation Neutron)

❖ MEGAPI (MEGAwatt Pilot Experiment)

Collaborating Institutes: PSI, CEA, CNRS, FZK, ENEA, SCK-CEN, JAEA, LANL, KAERI-PEFP



- '01.12 Joined MEGAPI collaboration
- '06.2 : Irradiated Pb-Bi target by SINQ at PSI
- '06.12 : Disintegrated the target system & analyzed the experiment
- '08. 8-11 : To perform the final cold test
- '09. 9 : Dismantled target & moved to Hotlab
- '10: To distribute PIE Sample
- '11.12.: To complete the MEGAPIE-I

Summary

100 MeV, 20 mA Proton Linac & Beamlines

- 20 MeV Linac :
  - Completed & In beam service
  - Achieved designed beam energy & current
- Higher energy part:
  - 20~91 MeV (6 DTL tanks): fabricated and tested
  - 91-100 MeV (1 DTL tank): to be fabricated in 2010
- To relocate the 20 MeV linac to the site from April 2011
- To complete the 100 MeV linac & beamlines by March 2012

Construction Work

- Under leveling the site along with excavation
- To start foundation work in April 2010, accelerator & experimental hall to be completed by March 2011

Beam Utilization & Applications

- Cultivated and fostered user programs in the wide range of research fields
- Produced promising outcomes including some industrialized

Activities for the Future (a Spallation Neutron Source)

- R&D in SCL, RCS, RF Power Source, Spallation Neutron Target


Thank you very much
&
Welcome to the PEFP's Home