HB2012, Beijing, China

Status and Beam Commissioning Plan of PEFP 100-MeV Proton Linac

2012. 9. 20

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on behalf of the project team

PEFP, KAERI

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Proton Engineering Frontier Project

http://www.komac.re.kr

Contents

Introduction

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

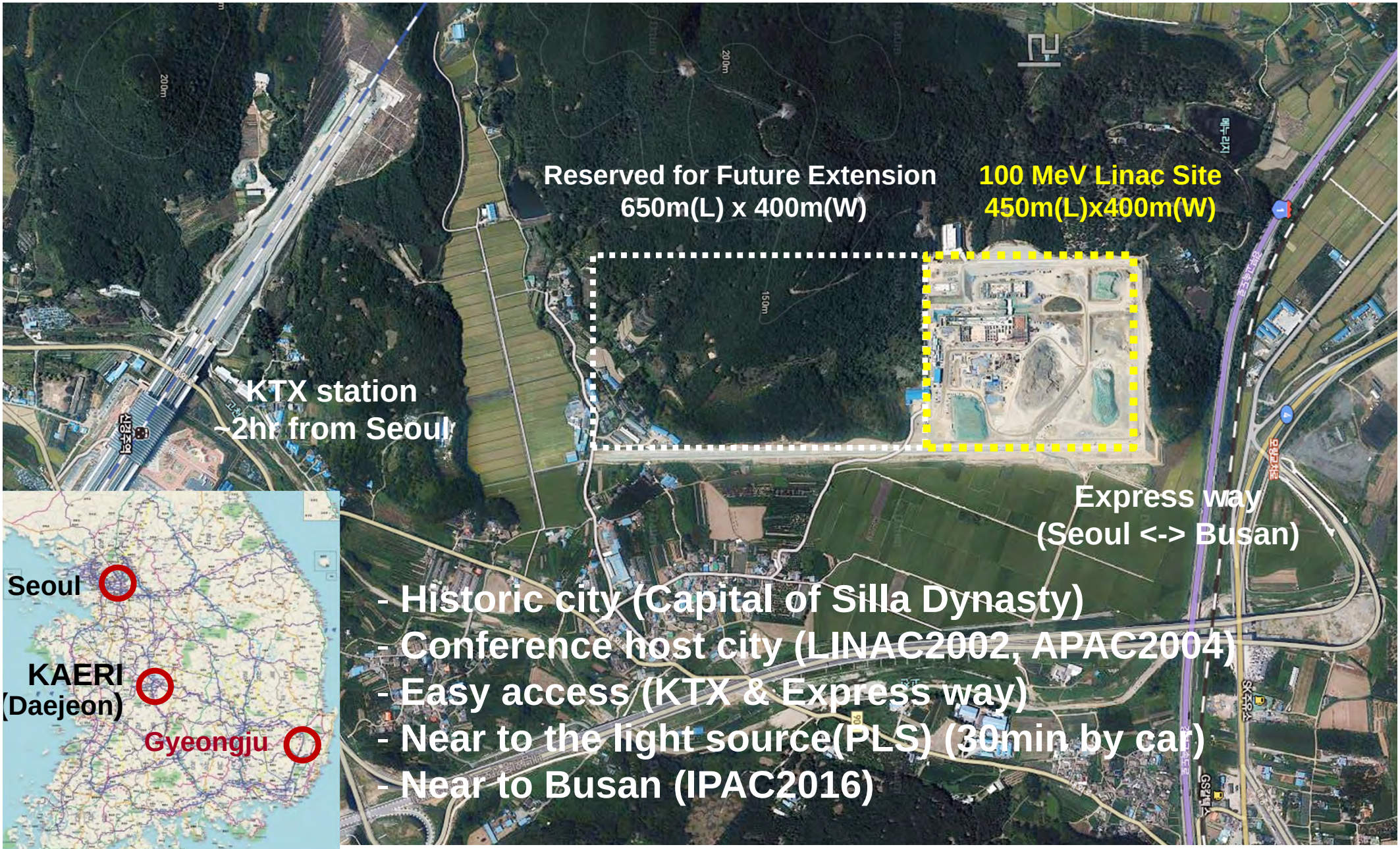
- **Objectives**
  - **To develop a High Power Proton Linac (100MeV, 20mA)**
  - **To develop Beam Utilization & Accelerator Application Technologies**
  - **To Industrialize Developed Technologies**

- **Period: July 2002 – December 2012**

- **Budget: 307.4 B KRW (~275.0 M US$)**
  - **Gov.: 176.3B(57.3%), Local Gov.: 118.2B(38.5%), Industry: 12.9B(4.2%)T**
  - **66B KRW to Accel. & Beamline (including R&D & personnel expenses)**

Project Site : Gyeongju

PEFP Proton Engineering Frontier Project



Site Plan

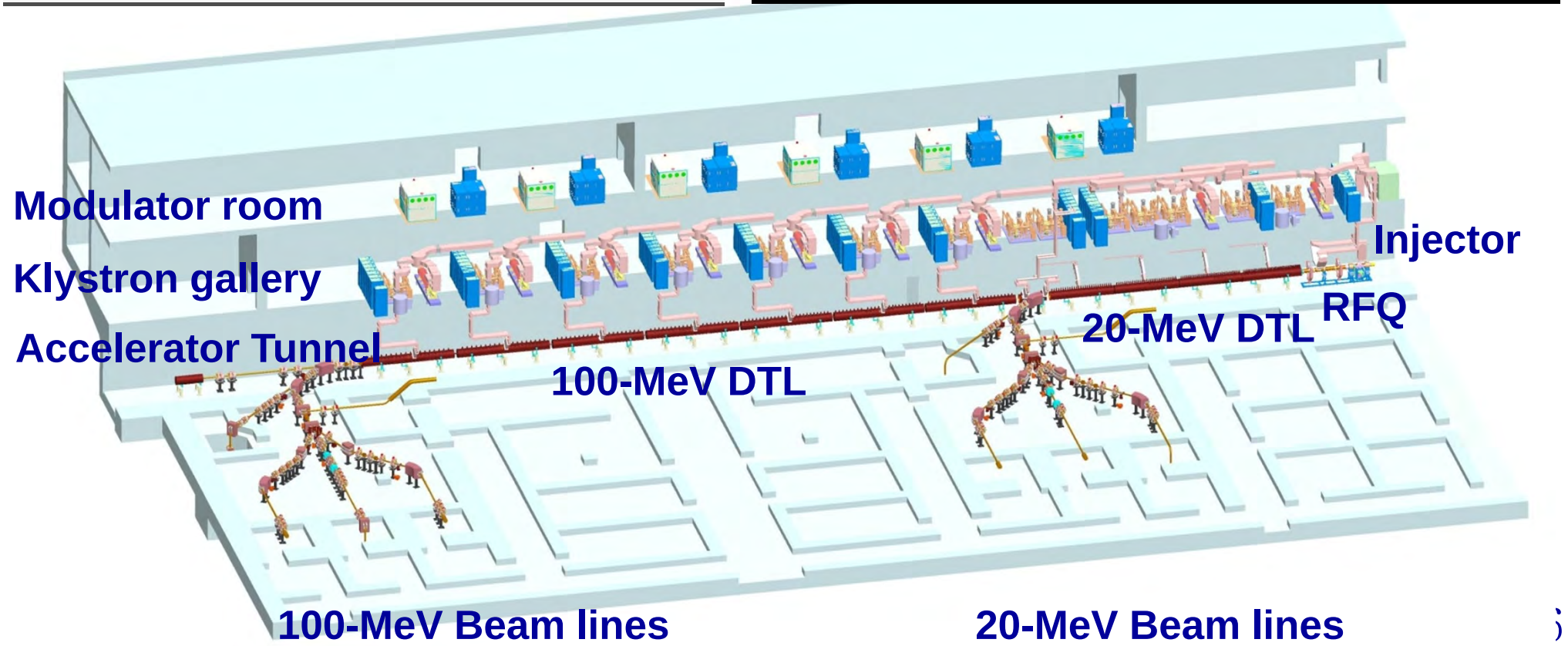
PEFP Proton Engineering Frontier Project

PEFP 100-MeV Linac

PEFP Proton Engineering Frontier Project

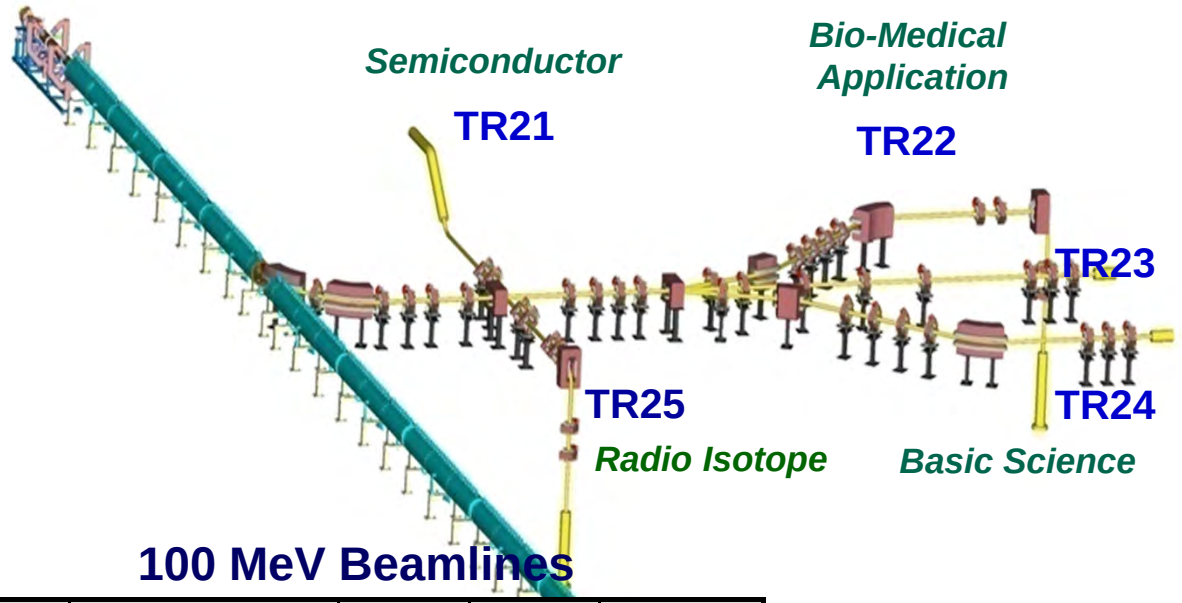
Features of the PEFP 100MeV linac
▪ 50 keV Injector (Ion source + LEBT)
▪ 3 MeV RFQ (4-vane type)
▪ 20 & 100 MeV DTL
▪ RF Frequency : 350 MHz
▪ Beam Extractions at 20 or 100 MeV
▪ 5 Beamlines for 20 MeV & 100 MeV

Output Energy (MeV)	20	100
Max. Peak Beam Current (mA)	1 ~ 20	1 ~ 20
Max. Beam Duty (%)	24	8
Avg. Beam Current (mA)	0.1 ~ 4.8	0.1 ~ 1.6
Pulse Length (ms)	0.1 ~ 2	0.1 ~ 1.33
Max. Repetition Rate (Hz)	120	60
Max. Avg. Beam Power (kW)	96	160



PEFP Beam Lines

- ❑ Designed by reflecting user's requirements (through User Program)
- ❑ Developed components: QM, ACM, DM & beam instruments, Beam window

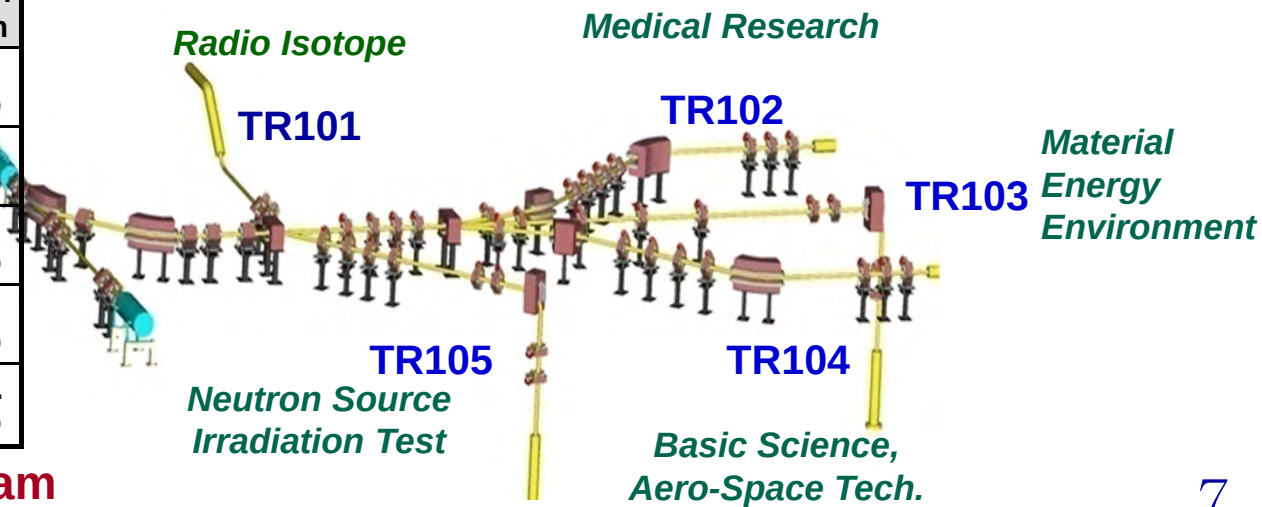


20 MeV Beamlines

Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR21	Semiconductor	60Hz	0.6mA	Hor. Ext. 300mmØ
TR22	Bio-Medical Application	15Hz	60μA	Hor. Ext. 300mmØ
TR23	Materials, Energy & Environment	30Hz	0.6mA	Hor. Ext. 300mmØ
TR24	Basic Science	15Hz	60μA	Hor. Ext. 100mmØ
TR25	Radio Isotopes	60Hz	1.2mA	Hor. Vac. 100mmØ

100 MeV Beamlines

Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR101	Radio Isotopes	60Hz	0.6mA	Hor. Ext. 100mmØ
TR102	Medical Research (Proton therapy)	7.5Hz	10μA	Hor. Ext. 300mmØ
TR103	Materials, Energy & Environment	15Hz	0.3mA	Hor. Ext. 300mmØ
TR104	Basic Science Aero-Space tech.	7.5Hz	10μA	Hor. Ext. 100mmØ
TR105	Neutron Source Irradiation Test	60Hz	1.6mA	Hor. Vac. 100mmØ

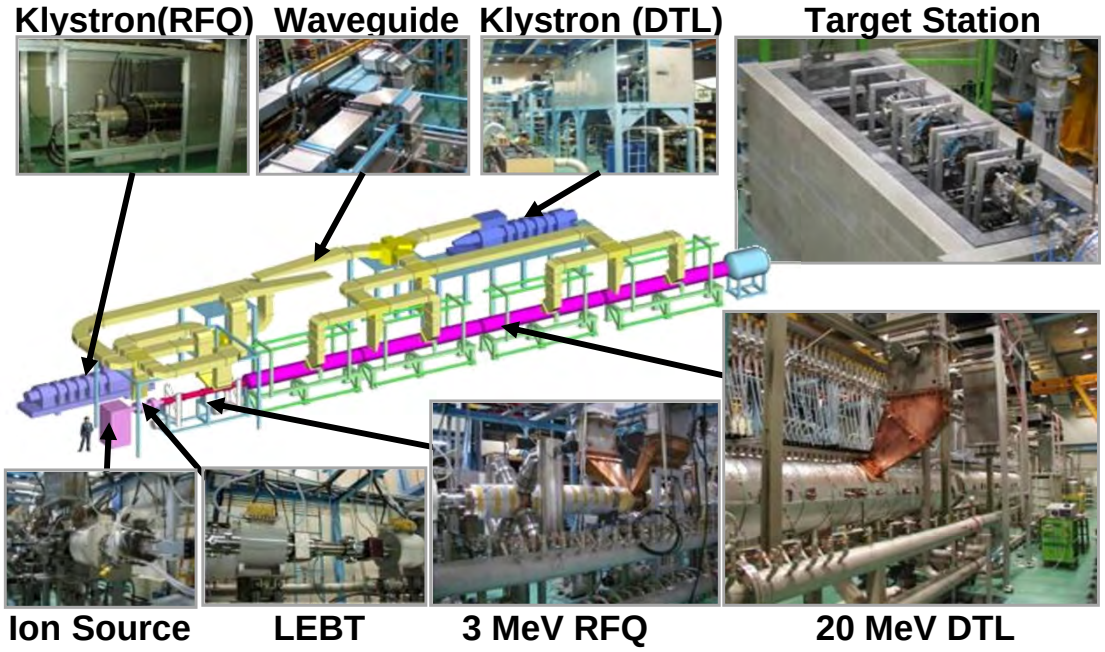


☞ 33, 45, 57, 69, 80, 91, 100 MeV beam

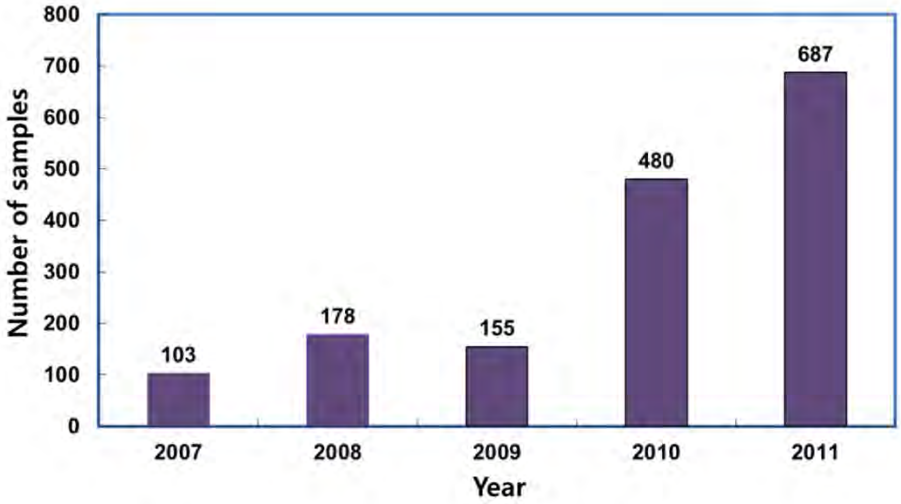
20 MeV Linac

PEFP Proton Engineering Frontier Project

- **Operation at KAERI in Daejeon : Linac test and Beam supply to users**
  - **RFQ, DTL : designed (PEFP), fabricated (domestic company)**
  - **Integrated (May 2005)**
  - **First beam extraction (July 2005)**
  - **Operation license (June 2007) : Avg. Current 1 μA, 4-hour/week**
  - **User beam service (from July 2007)**
  - **Operation finish (Nov. 2011)**
  - **Installation at project site in Gyeongju (Feb. 2012)**

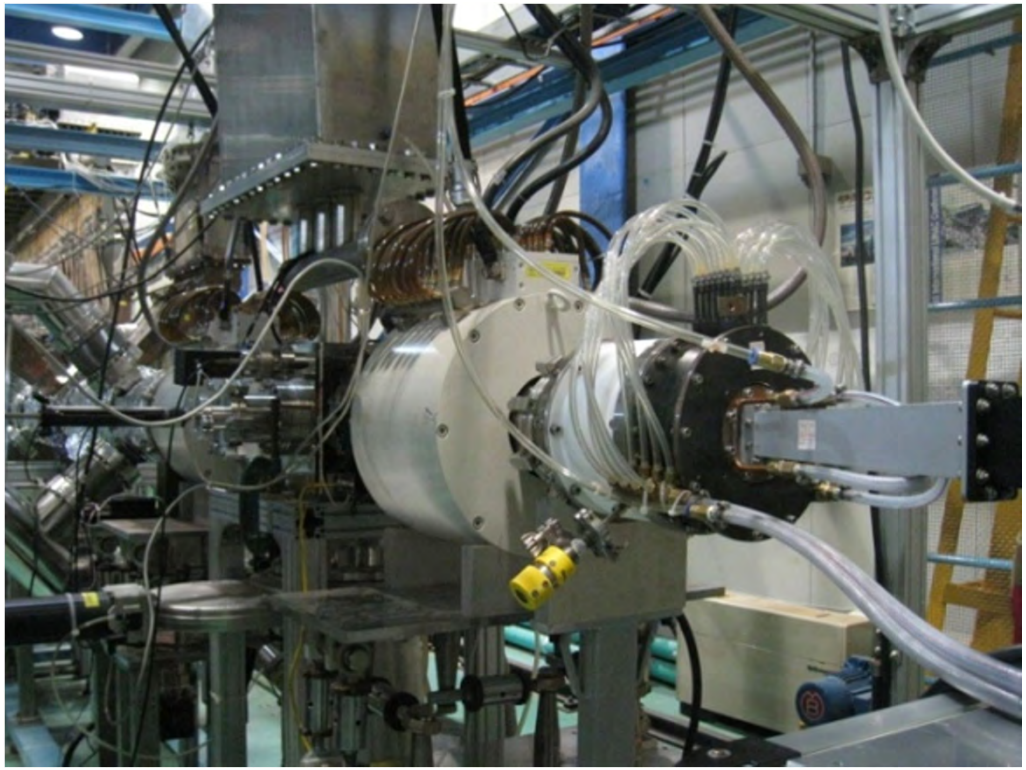


[Number of samples]

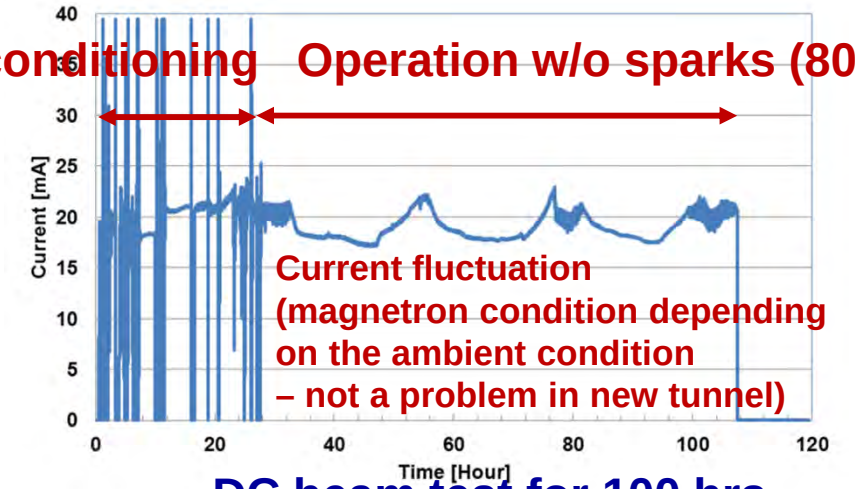


Microwave Ion Source

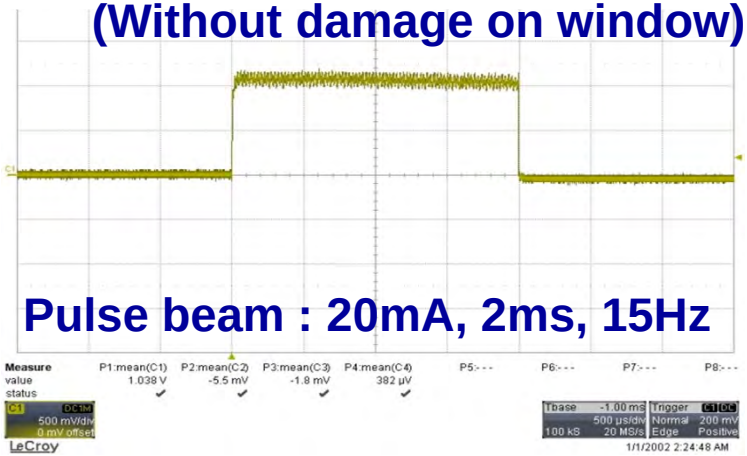
- Goal : 100 hrs operation without maintenance
- Proton beam with 50keV, 20mA
- DC or Pulse beam operation
- It was installed and successfully working at 20-MeV linac for 240 hrs without maintenance.



Microwave ion source installed in 20-MeV linac

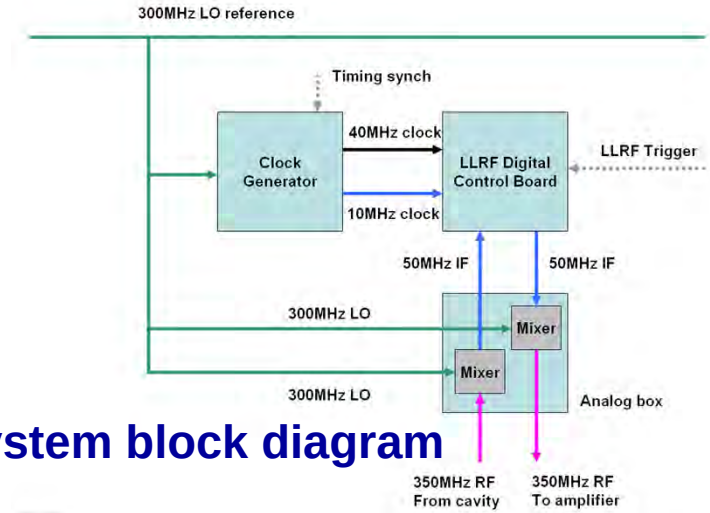


DC beam test for 100 hrs
(Without damage on window)

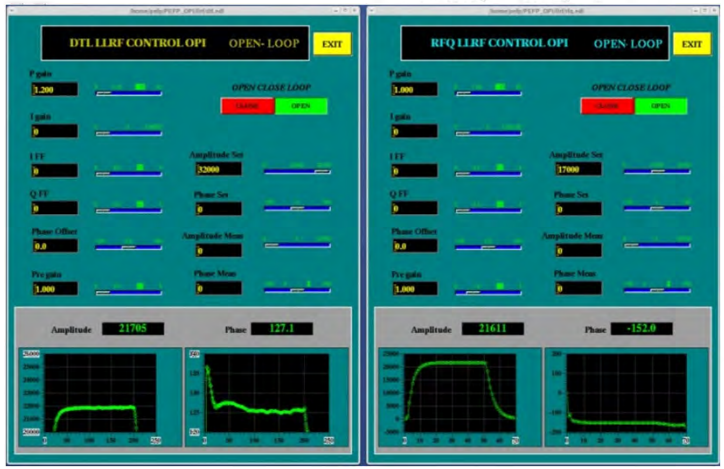


Digital LLRF

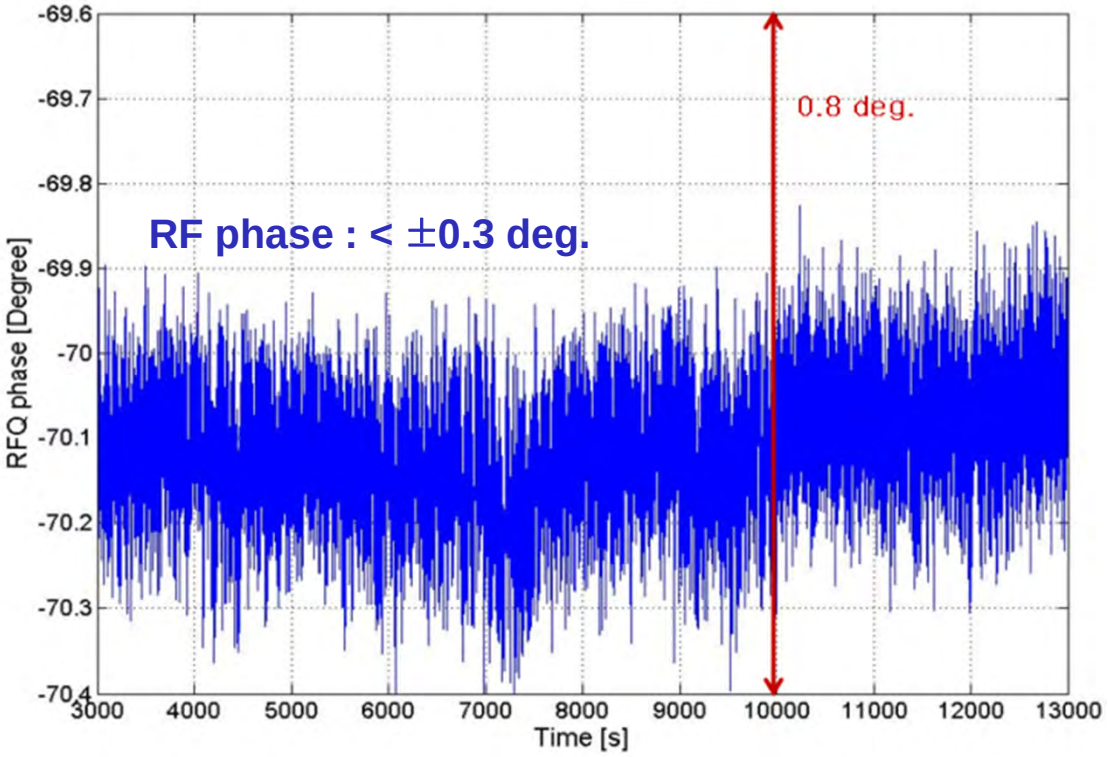
- Goal : 1% in amplitude, 1 degree in phase
- Control hardware : Commercially available control board
- Control software : PI implemented in FPGA and EPICS OPI by PEFP
- Digital LLRF was tested at the 20-MeV linac (2010)



LLRF system block diagram



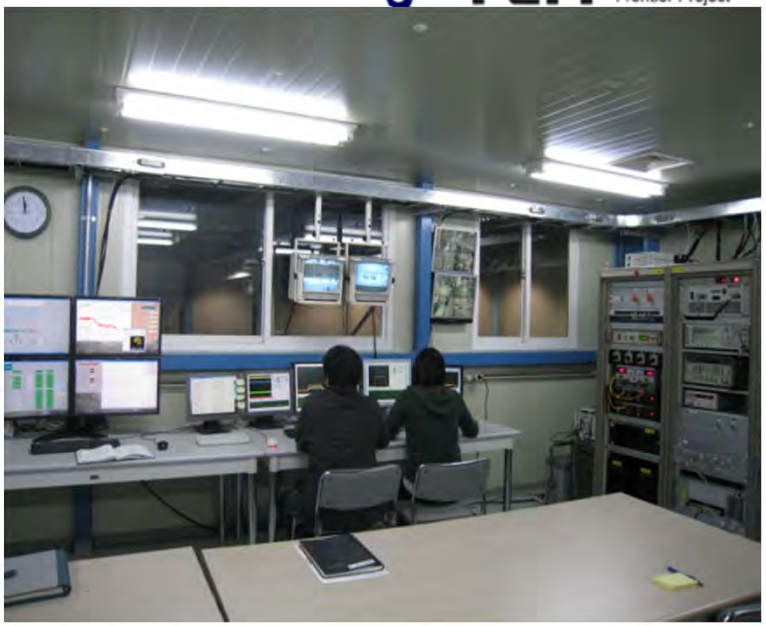
LLRF OPI based on EPICS



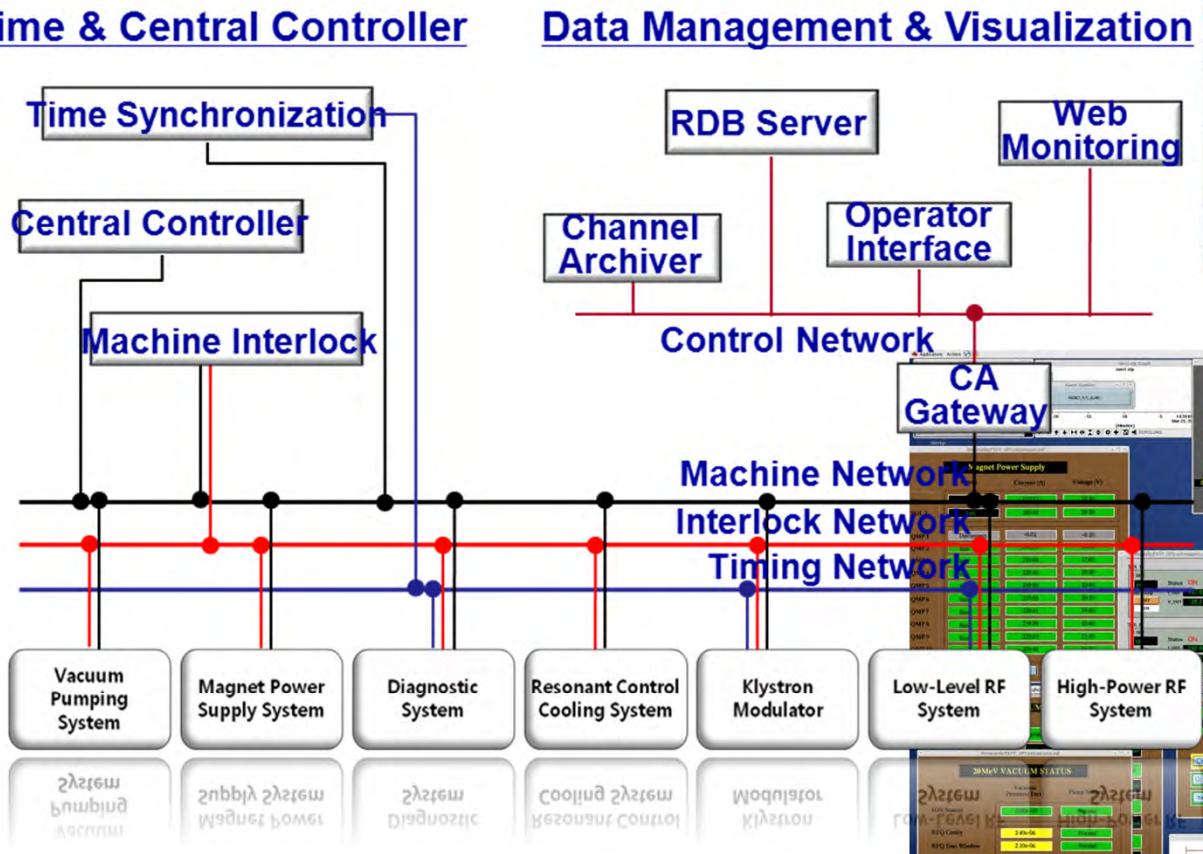
Phase variation during HPRF operation

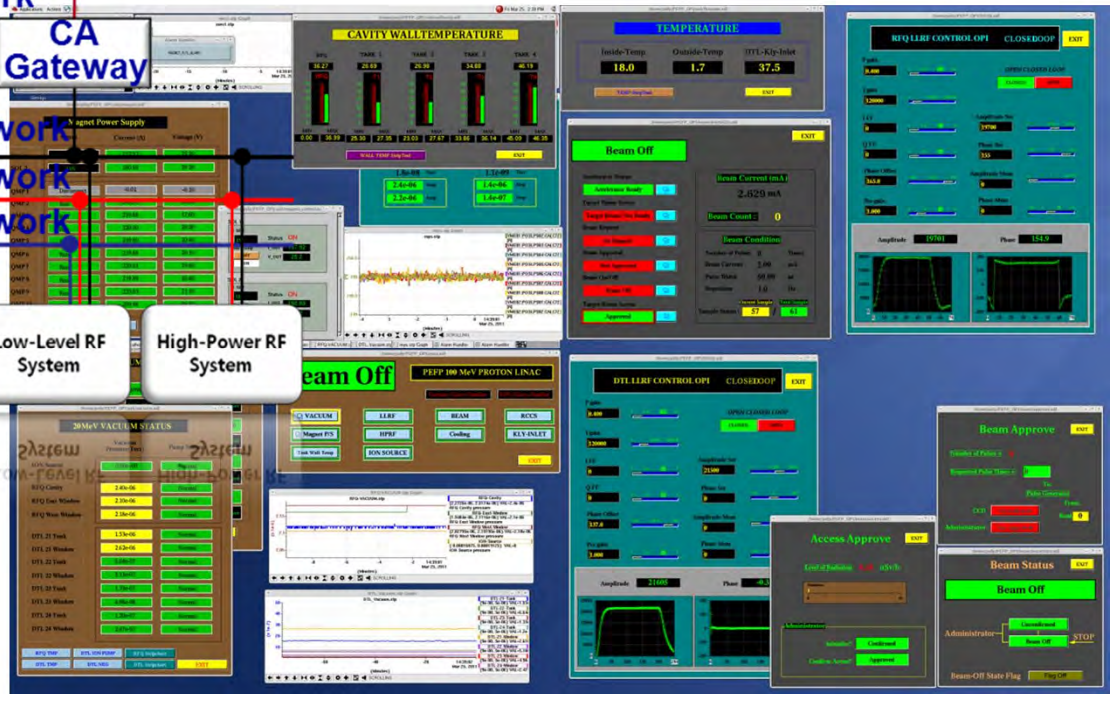
Control System

- EPCIS based system
- Timing based on the event system
- Test and operation at the 20-MeV linac



20MeV control room at Daejeon

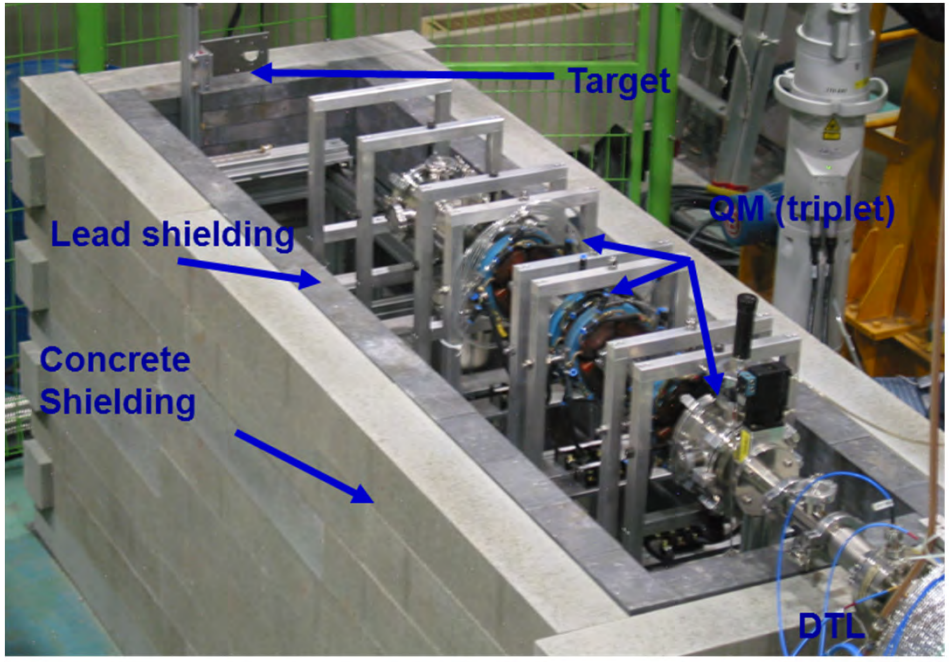




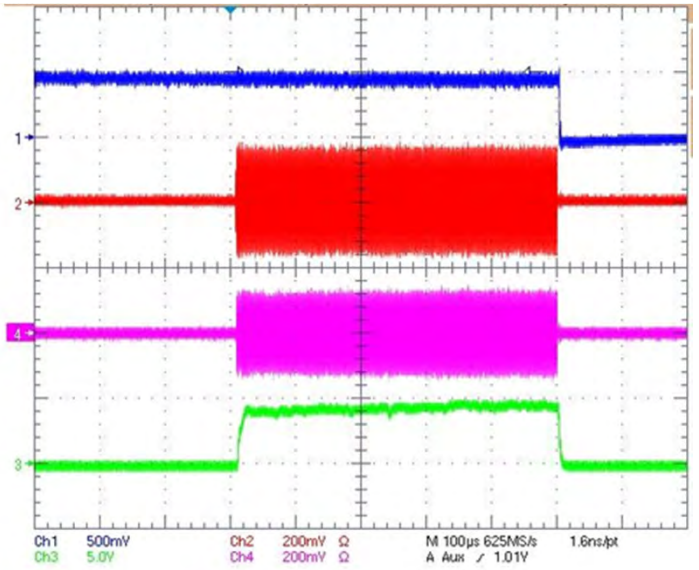
EPICS based OPI

Linac Integrated Test : 20-MeV

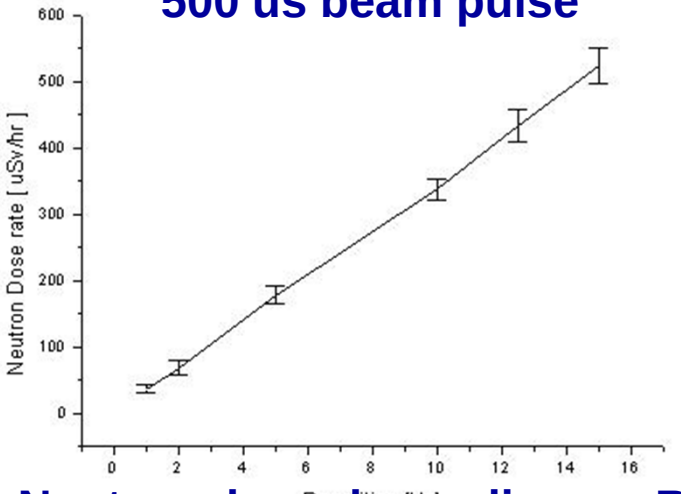
- Ion Source, HPRF, LLRF control, overall control system performance check
- 500 us pulse operation, 15Hz repetition rate operation
- Test limited by the radiation shielding at Daejeon
- Beam service : typically 20-MeV, 5mA, 1Hz



20-MeV beam target room
during installation at Daejeon



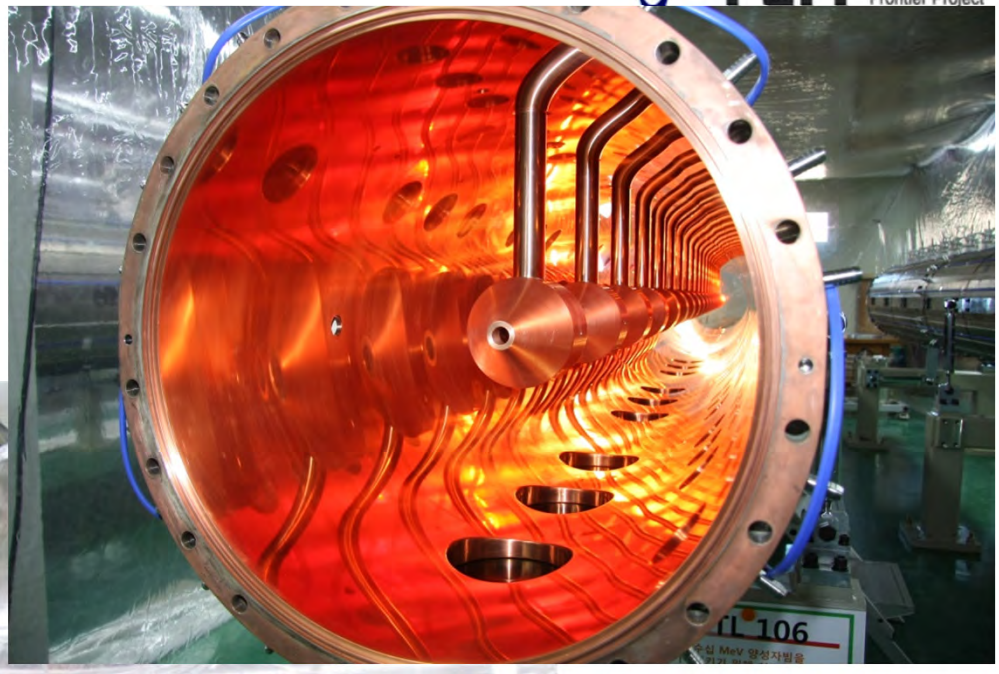
500 us beam pulse



Neutron dose depending on RR

20~100MeV DTL Development

- Total 7 DTL Tanks (20~100MeV)
- Development Complete (Dec, 2010)
- DT aligned (< 50 μm)
- Installed in tunnel (Feb. 2012)



Tank inside after DT alignment

Completion of the last DTL tank (22th, Dec. 2010)

Building Construction

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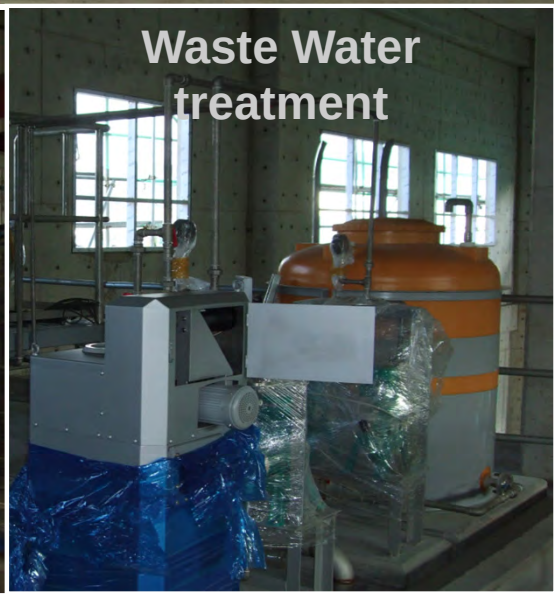


20-MeV Linac Disassembly and Movement

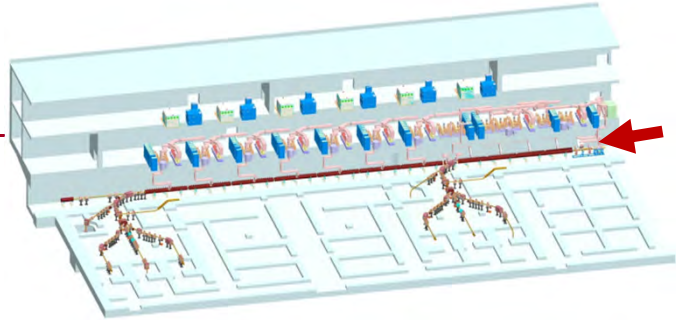
PEFP Proton Engineering Frontier Project

- Disassembly of the 20-MeV linac from Dec. 2011
- Movement from Daejeon to Gyeongju (~200km apart)
- DTL and klystron was trasported by using the vibration free truck through express way.
- No notable field distortions in DTL before and after (~ 3%)
- Special supporter with oil jack and caster was used in the tunnel.

DTL tanks inside vibration free truck

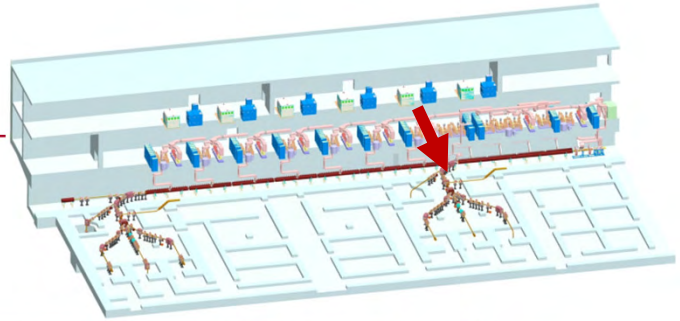
Special supporter inside tunnel

Accelerator Installation

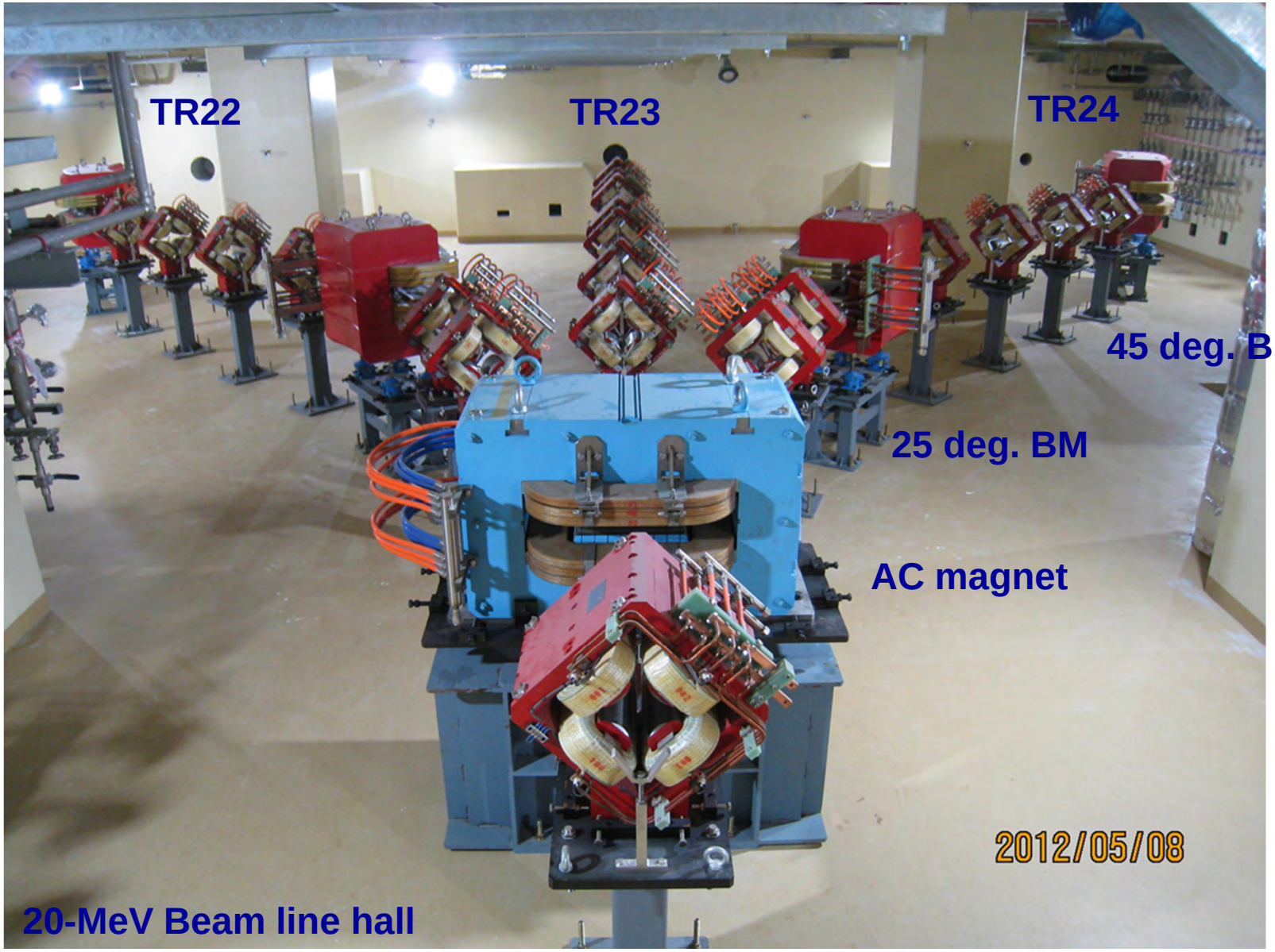


- Installed inside tunnel at March, 2012

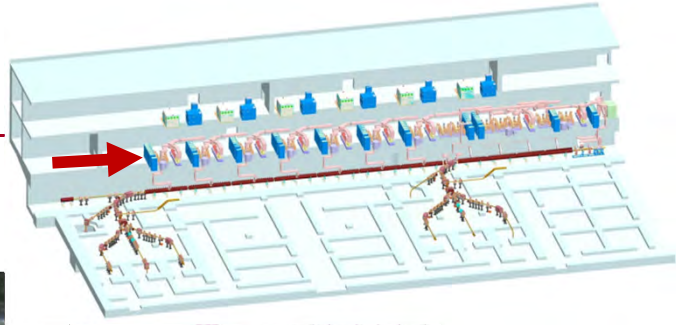
Beam Line Installation



- Magnet Installed inside experimental hall at May, 2012

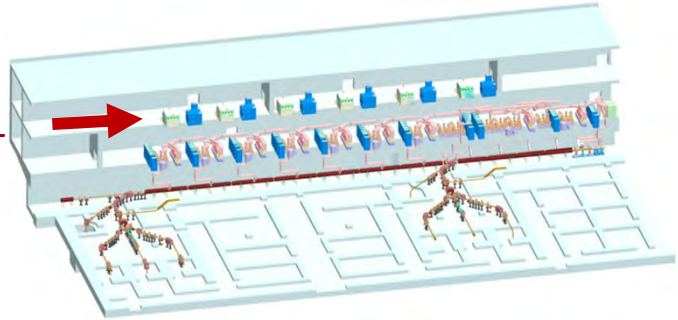


Klystron Gallery: 2nd Floor



- Installation starts at September, 2012

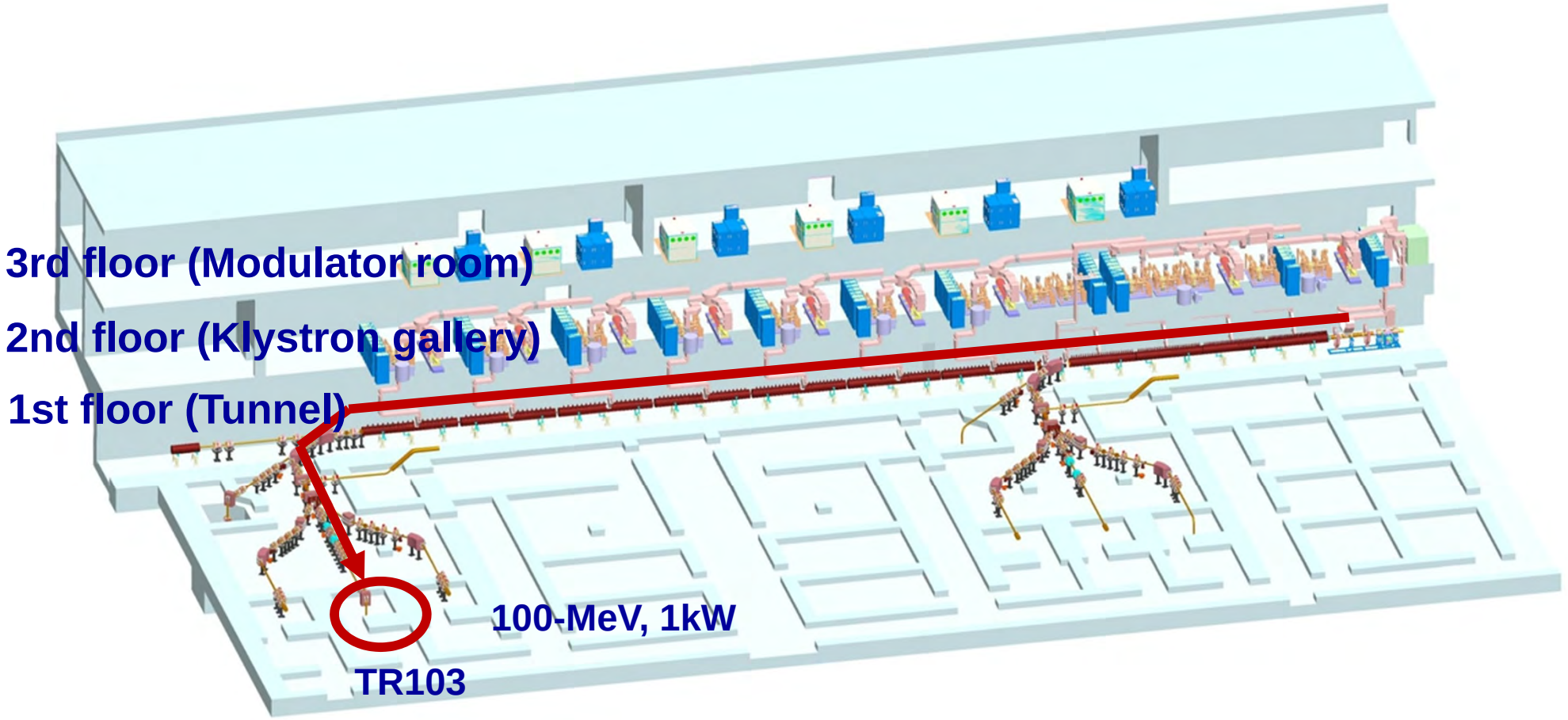
Modulator Installation: 3rd Floor



- Installation starts at September, 2012

Commissioning Plan

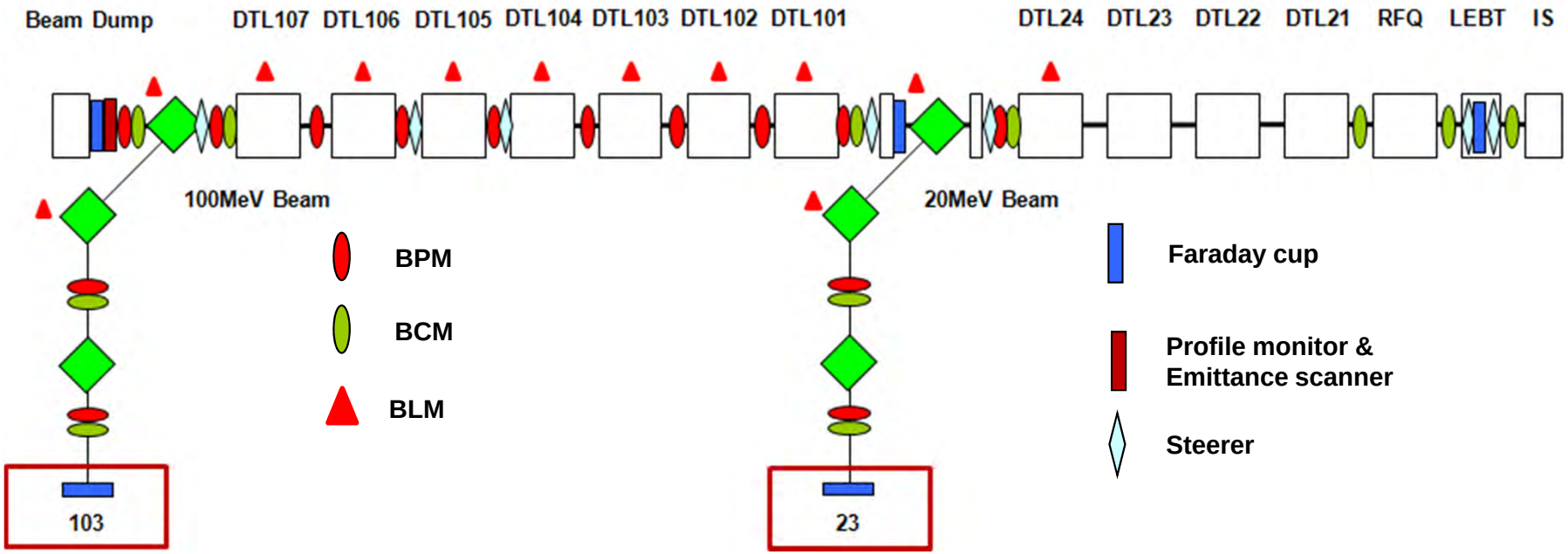
- Goal : 100-MeV, 1kW proton beam at 103 target room beam dump
- Both on-line conditioning and commissioning
- High power conditioning sequence : 3rd floor -> 2nd floor -> Tunnel (1st floor)
- 20-MeV experience is helpful for 100-MeV commissioning
- Accelerator commissioning starts in this winter
- Power increase in parallel with beam service after commissioning



Beam Commissioning

PEFP Proton Engineering Frontier Project

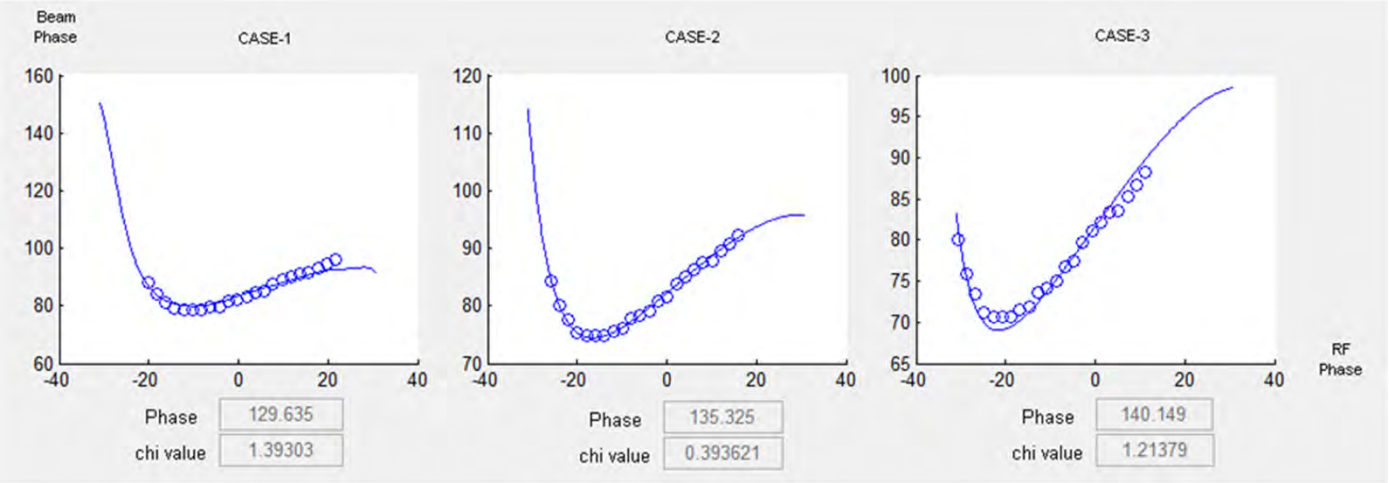
- **Beam commissioning plan**
  - **Beam energy:** 100 MeV
  - **Peak beam current:** 20 mA
  - **Average Beam power:** 1 kW
  - **Commissioning steps:** 20 MeV acceleration (experienced)
    100 MeV acceleration (1 kW beam dump)
    Delivery to a 100-MeV target room
  - **RF set point:** Phase scan method (BPM)
  - **Diagnostics:**



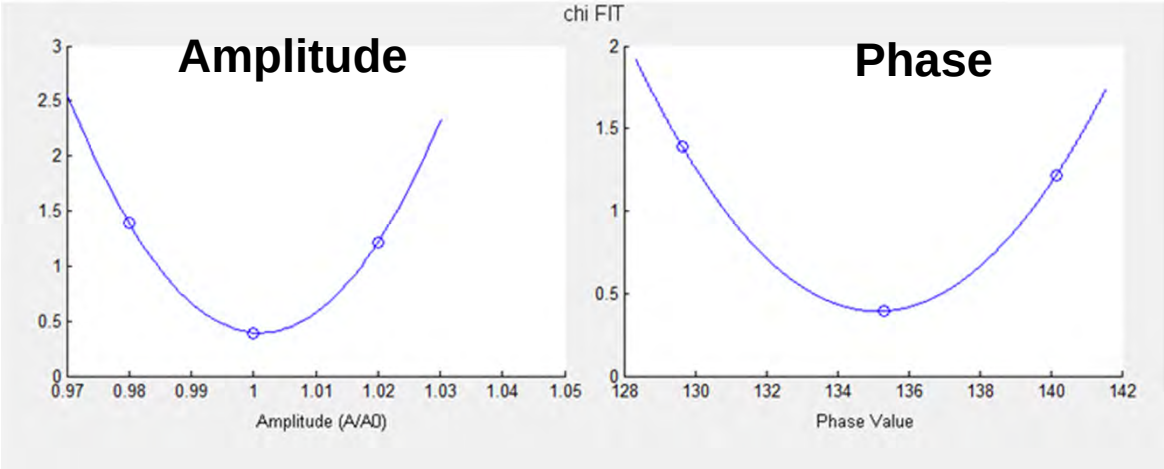
RF set point of DTL tank

- We plan to use the phase scan method to determine the RF operation point.
  - A RF set-point program was tested by using artificial experimental data.
  - χ-values were calculated for different relative amplitude A/A_0

$A/A_0 = 0.98$ $A/A_0 = 1.00$ $A/A_0 = 1.02$



- RF set-point can be determined at the minimum points in quadratic fitting of χ-values

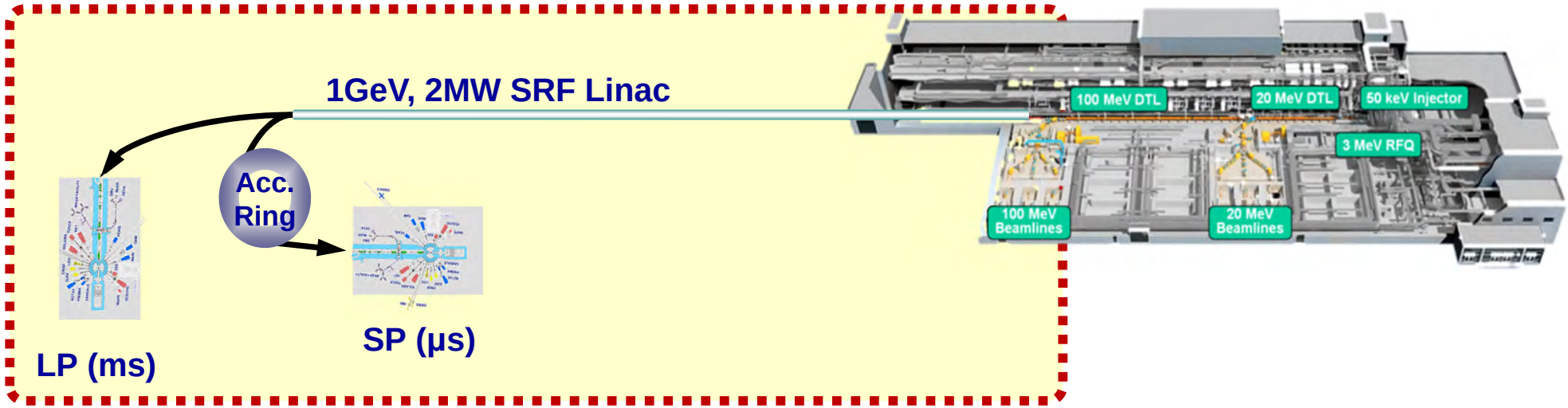


	Artificial Exp.	Program
Amplitude	1.0	1.001
Phase	135.4	135.2

Artificial Experimental data includes gaussian error of $\sigma = 0.5°$ in beam phase.

Future Plan

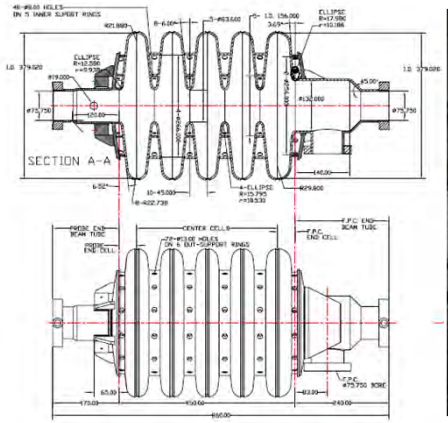
- GeV, MW-class Accelerator suggested by planning studies
  - Long-term Planning for PEFP (STEPI, 2009)
  - Efficient Management and Development Scheme for PAR (MEST, 2010)
- 1GeV, 2MW SRF Proton Linac + Spallation Sources (LP + SP)
  - Included in National Large Research Facility Road Map (2010)



Started SRF R&D from the beginning of the PEFP

SRF R&D

- Prototyping of the 700MHz, 5cell elliptical cavity with domestic company
- Design, fabrication and test experience



Design

Forming

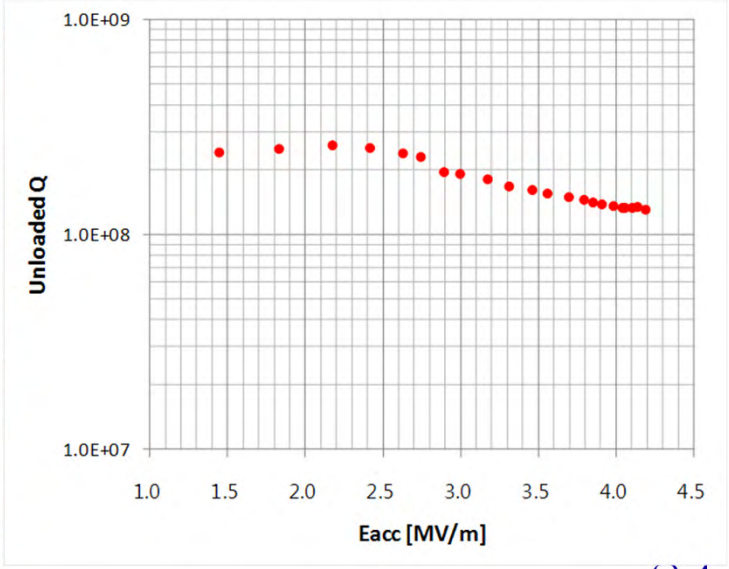
E-beam welding

Tuning

Cleaning

Test preparation

Test



First result

Summary

PEFP Proton Engineering Frontier Project

- **PEFP Linac and beam lines**
  - **Injector, 3 MeV RFQ, 100 MeV DTL, 10 beam lines**
  - **Developed the linac technologies through this project.**

- **20 MeV linac**
  - **5 year operation gives us experience on installation, commissioning, and operation of the proton linac.**
  - **Test beam line: supplying proton beams to users**

- **Linac and beam line magnet installation: completed**
  - **20 MeV part: disintegrated, moved and installed at project site in Gyeongju**
  - **20 ~ 100 MeV part, beam line magnet: fabrication, tested and installed**

- **Commissioning**
  - **HPRF installation started in September 2012**
  - **Commissioning will start in this winter**
  - **Beam service will start in spring 2013**

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Thank you for your attention