LINAC12

Dan Panorama Hotel, Tel-Aviv, Israel

Status and Commissioning Plan of PEFP 100-MeV Linear Accelerator

2012. 9. 11

Hyeok-Jung Kwon

on behalf of the accelerator team

PEFP, KAERI

양성자기반공학기술개발사업단

Proton Engineering Frontier Project

http://www.komac.re.kr

Contents

PEFP Proton Engineering Frontier Project

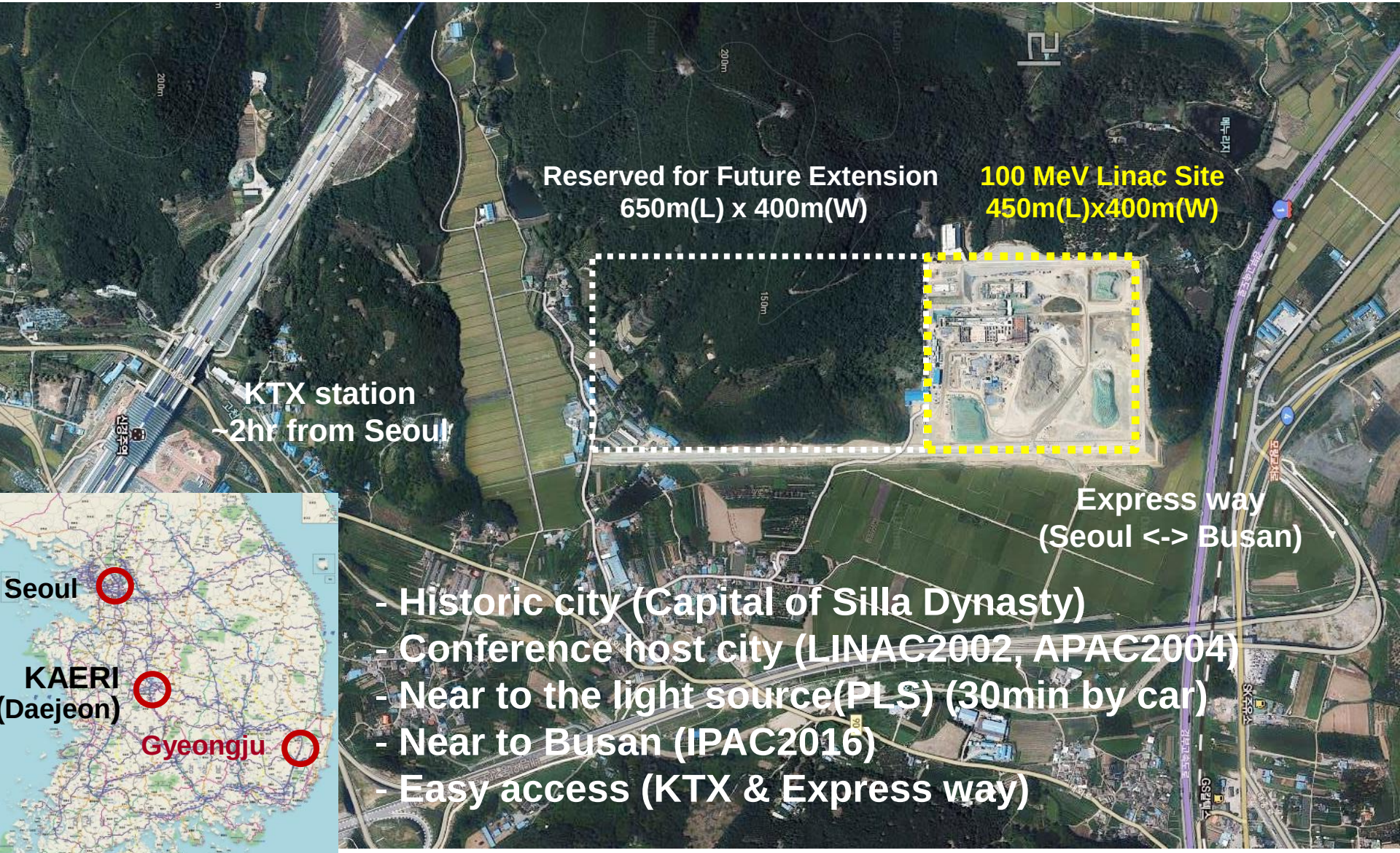
Overview of PEFP

PEFP Proton Engineering Frontier Project

- **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%)
  - 66B KRW to Accel. & Beamline (including R&D & personnel expenses)

Site : Gyeongju

PEFP Proton Engineering Frontier Project



Site Plan

PEFP Proton Engineering Frontier Project

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 Center
⑩ Dormitory
⑪ Information Center
⑫ Sewage Plant

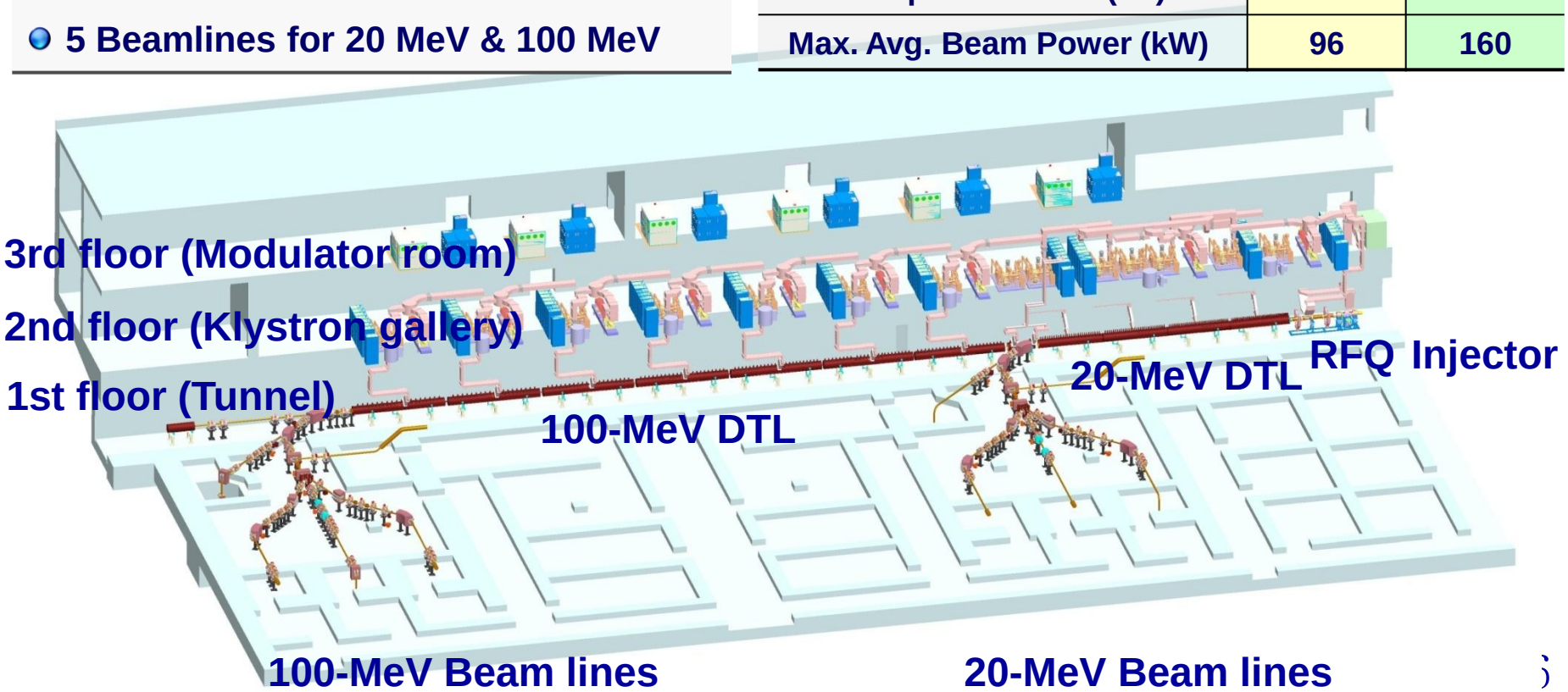
PEFP 100MeV Linac

PEFP Proton Engineering Frontier Project

Features of the PEFP 100MeV linac

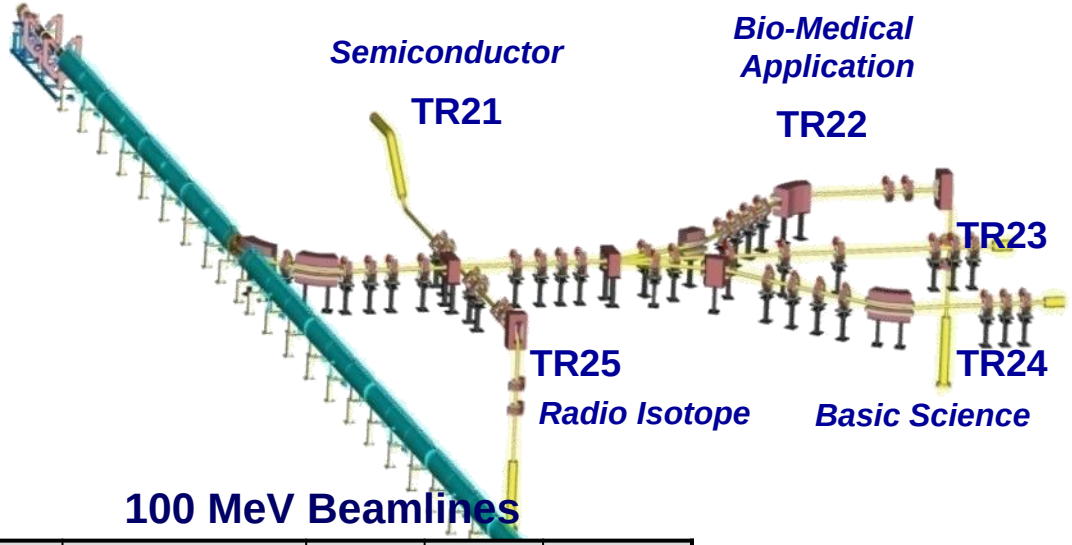
- 50 keV Injector (Ion source + LEBT)
- 3 MeV RFQ (4-vane type)
- 20 & 100 MeV DTL
- RF Frequency : 350 MHz
- Beam Extractions at 20 or 100 MeV
- 5 Beamlines for 20 MeV & 100 MeV

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



Beamlines

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

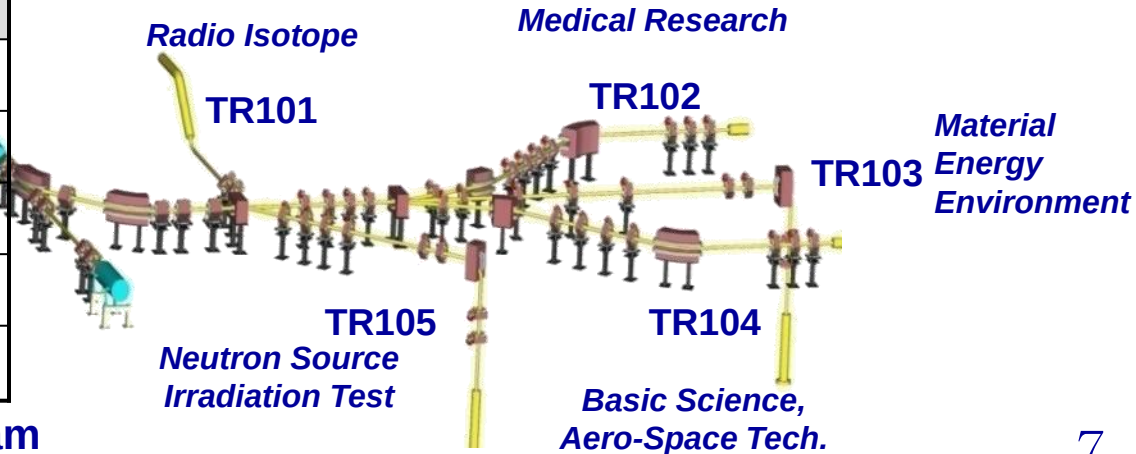


20 MeV Beamlines

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

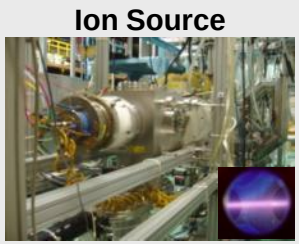


☞ 33, 45, 57, 69, 80, 91, 100 MeV beam

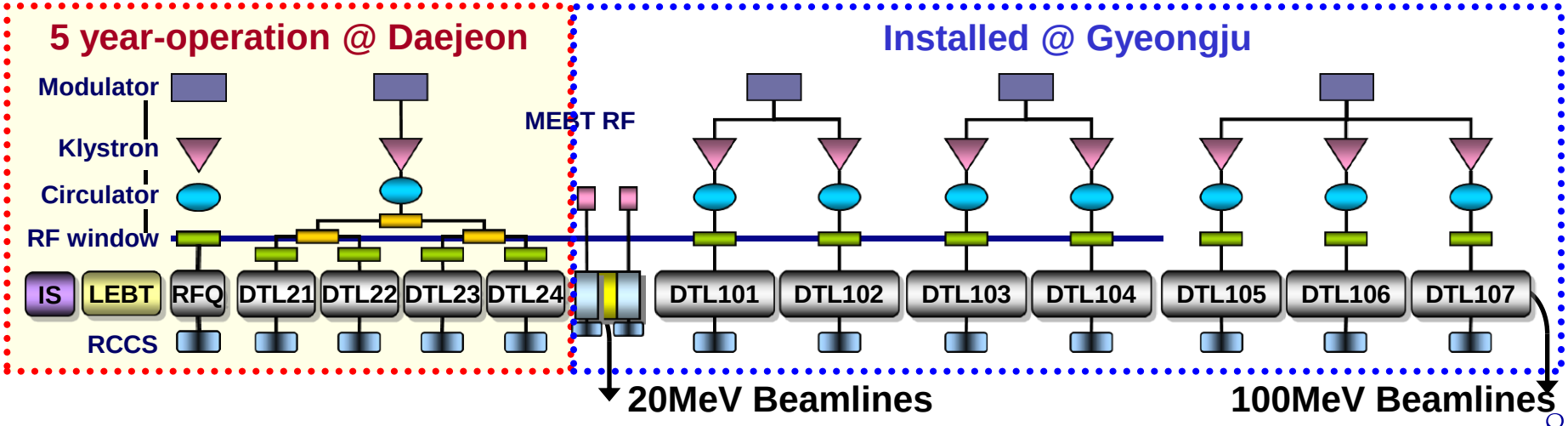
Accelerator & Beamline Development

PEFP Proton Engineering Frontier Project

- **Developed key components of proton linac and beam line**
  - Design (PEFP) → Fab. (17 Korean Industries) → Assembly, Test & Operation (PEFP)

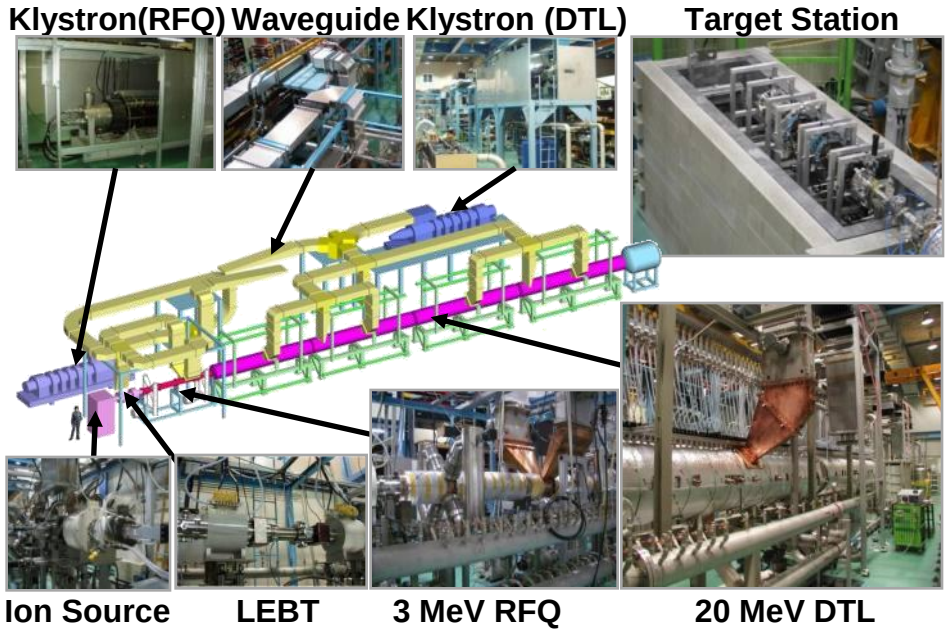


- **20 MeV: Operated for 5 years in Daejeon, now installed at Gyeongju**
- **20~100 MeV: Installed at Gyeongju**

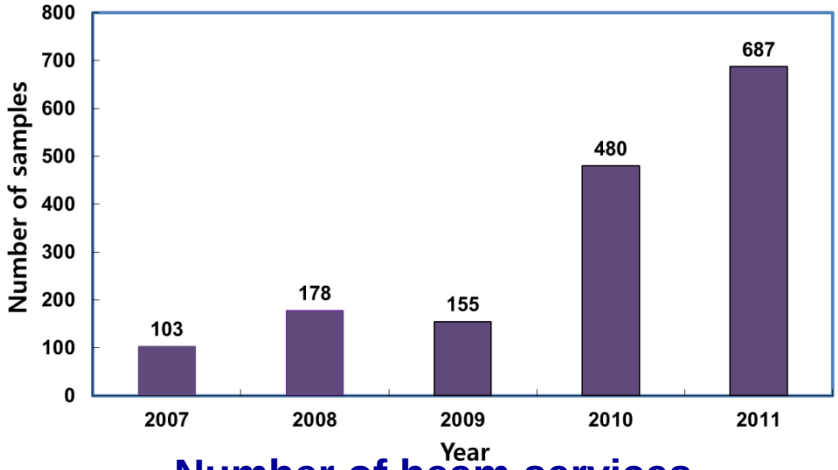


20MeV Linac

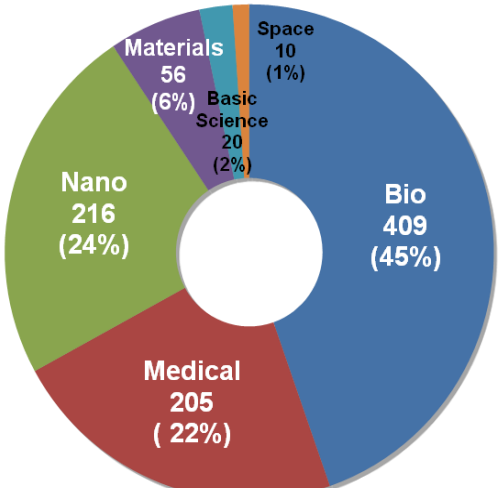
- Integrated (May 2005)
- First beam extraction (July 2005)
- Operation license (June 2007)
  - Avg. Current 1 μA, 4-hour/week
- User beam service (July 2007~)
- Operation finish (Nov. 2011)
- Installation at Gyeongju (Feb. 2012)



❑ Statistics for User Beam Services



Number of beam services depending on year

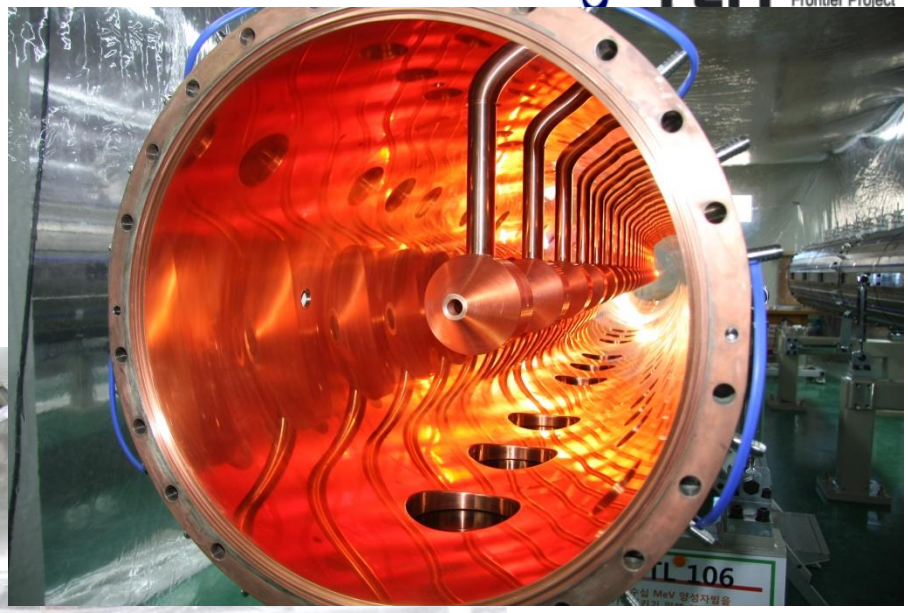


Beam service fields

20~100MeV DTL Development

PEFP Proton Engineering Frontier Project

- Total 7 DTL Tanks (20~100MeV)
- Development Complete (Dec, 2010)
- Installation at Gyeongju (Feb. 2012)

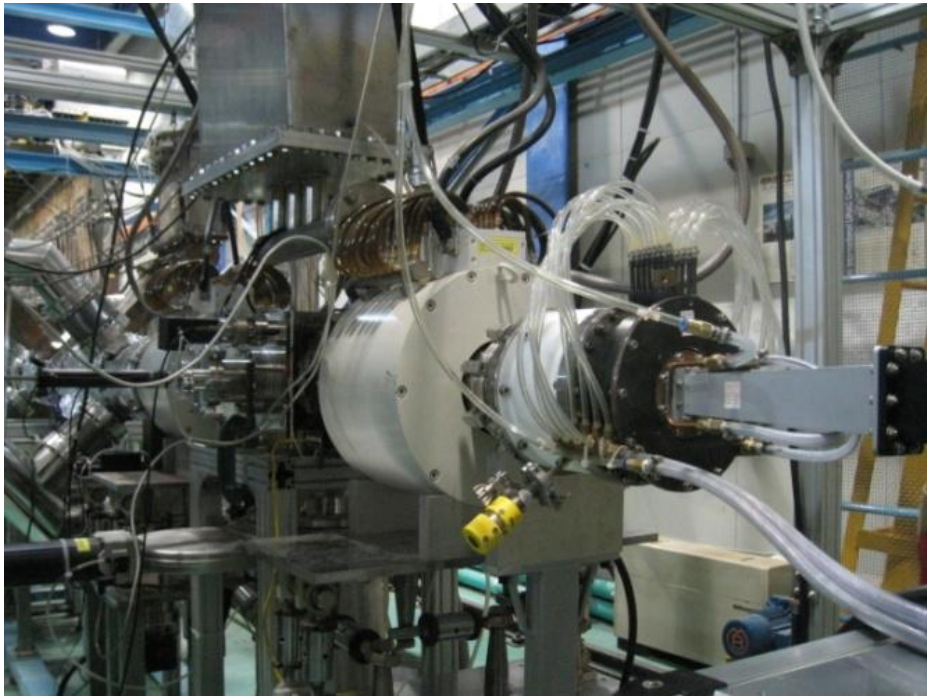


Tank inside after DT alignment

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

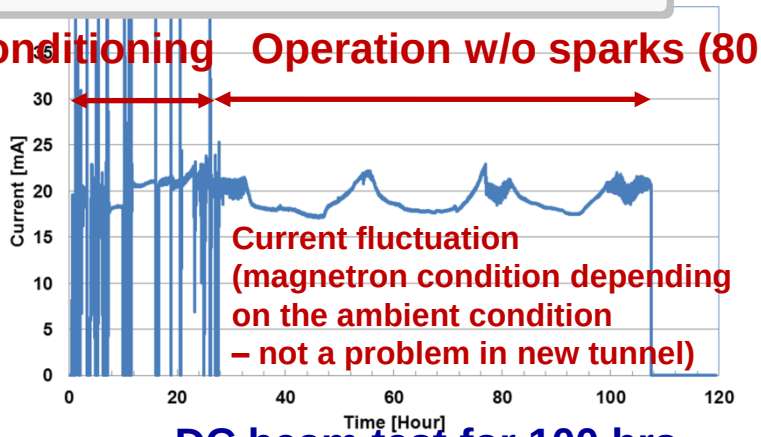
Microwave Ion Source

- Goal : 100 hrs operation without maintenance
- Proton beam with 50keV, 20mA
- Compact with one solenoid
- DC or Pulse beam operation
- 240 hrs accumulated operation time without maintenance at the 20-MeV linac

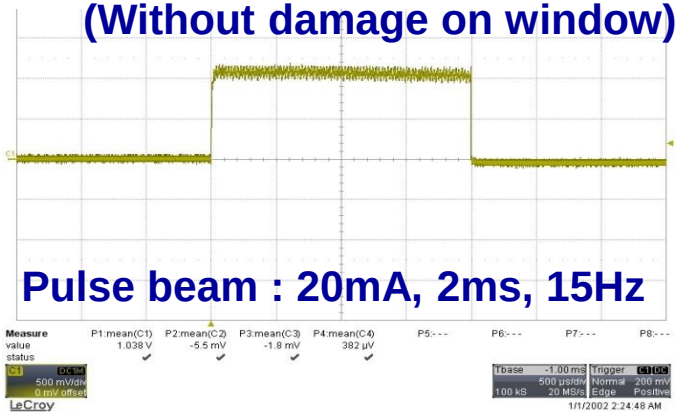


Microwave ion source installed in 20-MeV linac

Initial conditioning Operation w/o sparks (80hrs)

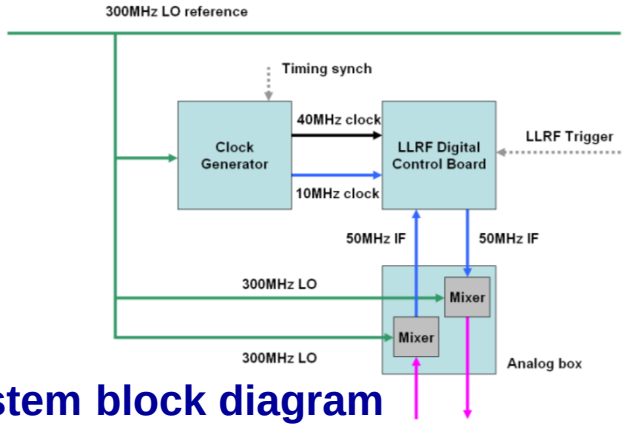


DC beam test for 100 hrs
(Without damage on window)

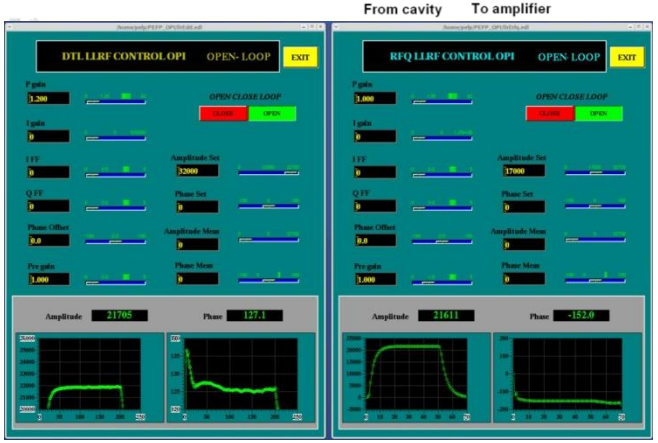


Digital LLRF

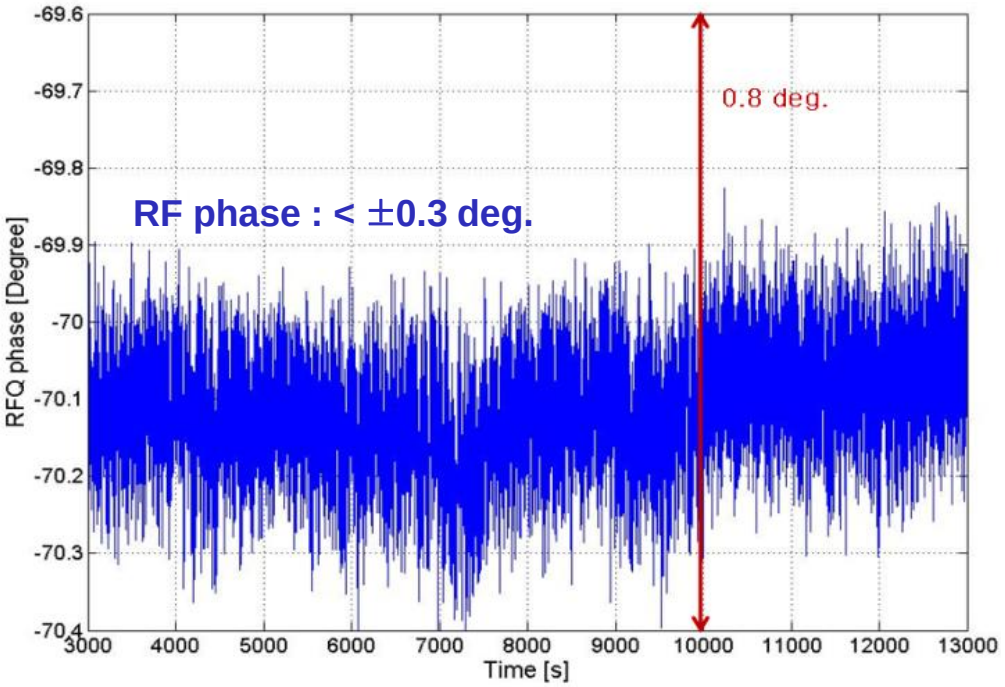
- Goal : 1% in amplitude, 1 degree in phase, resonance frequency error
- Control hardware : Commercially available control board
- Control software : PI implemented in FPGA and EPICS OPI by PEFP
- 5 years operation with upgrade at 2010 at the 20-MeV linac



LLRF system block diagram



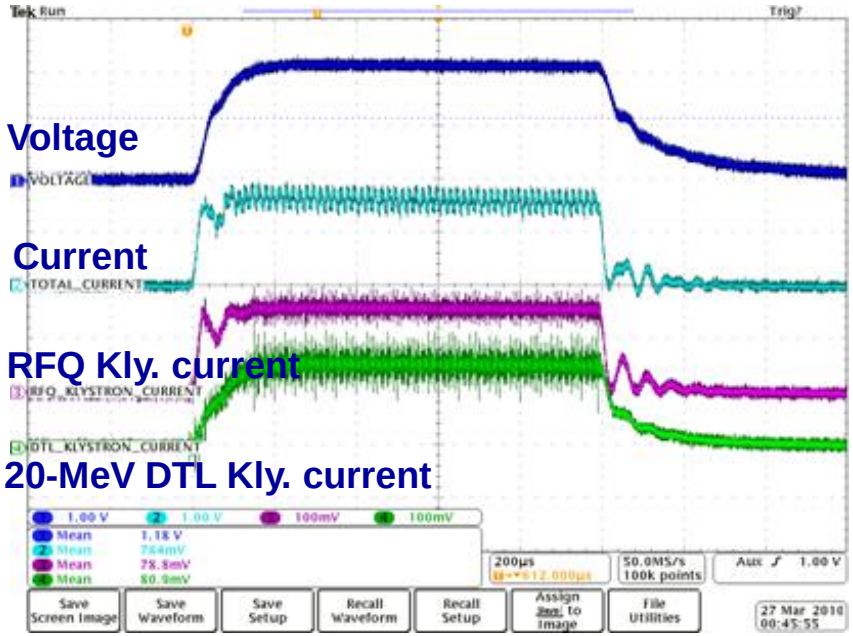
LLRF OPI based on EPICS



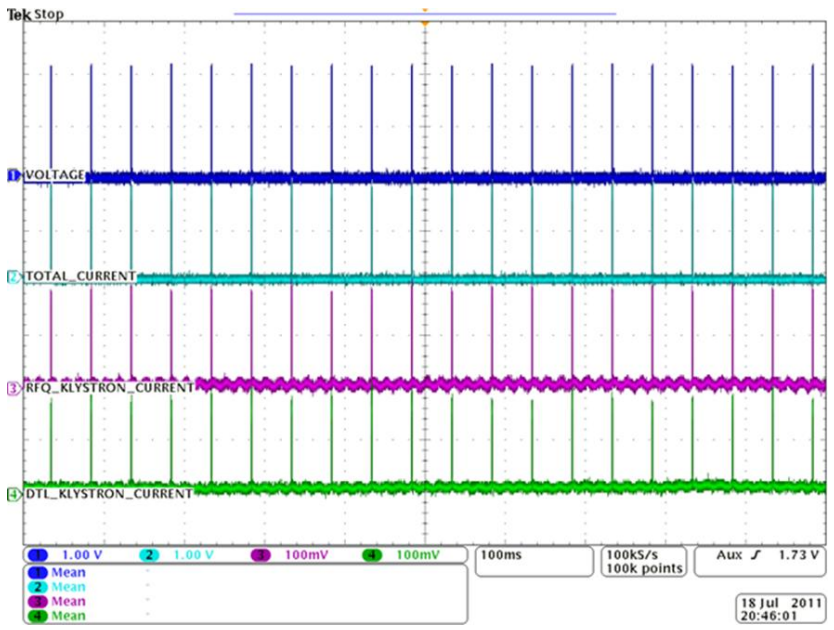
Phase variation during HPRF operation

Klystron & Modulator

- 350MHz, 1.6MW peak, 9% duty
- Klystron : Modified from the 352MHz, 1MW CW klystron
- Modulator : High voltage converter modulator, voltage droop < 1%
- Two klystrons per modulator
- Test and operation at the 20-MeV linac



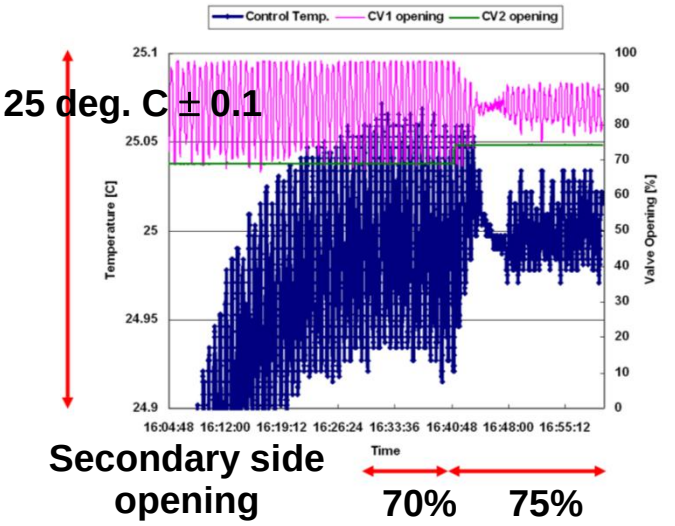
Modulator pulse shape (1ms)

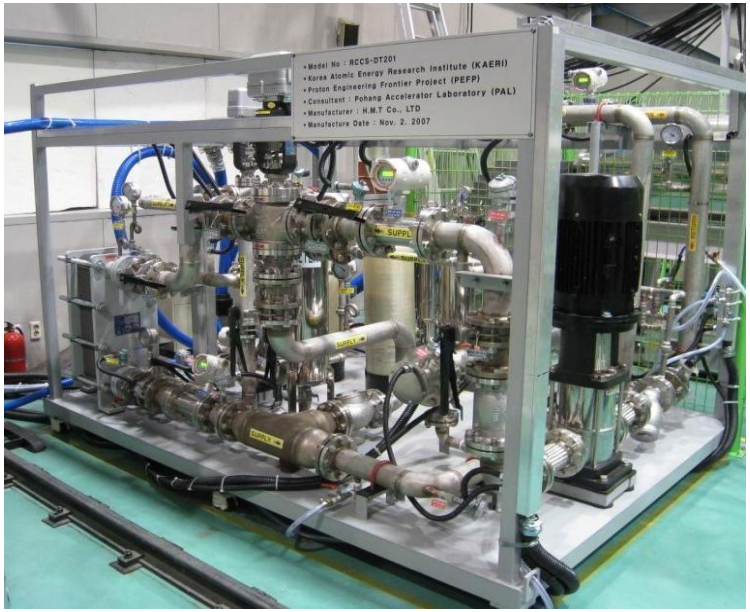


20Hz, 1% duty operation

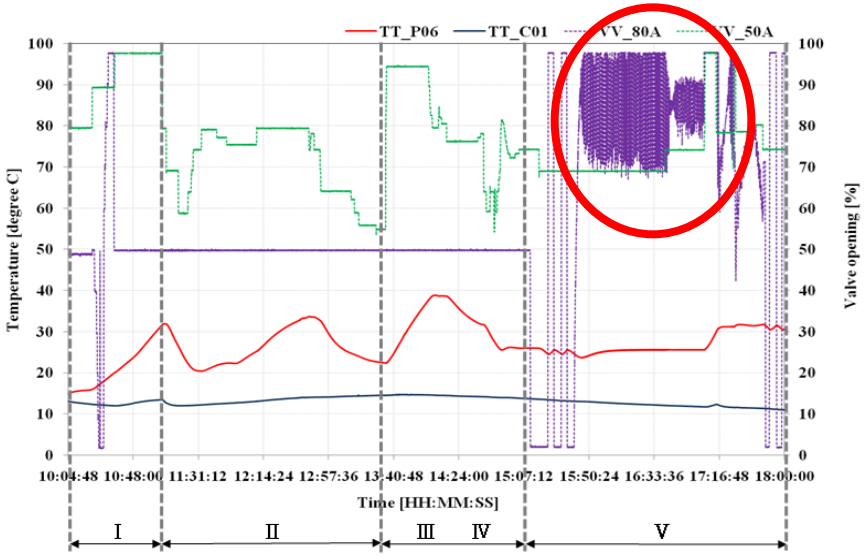
RCCS

- Maximum heat load 94kW, 21~33°C, ±0.1 °C
- Developed in cooperation with PAL
- Two control valves at primary and secondary side
- Incorporated with the digital LLRF control system
- One RCCS per DTL tank
- Test and operation at the 20-MeV linac





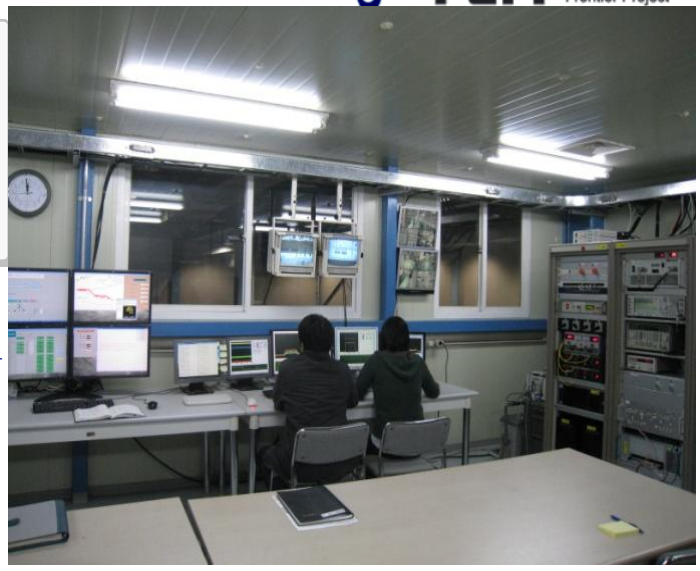
RCCS test for 20-MeV operation



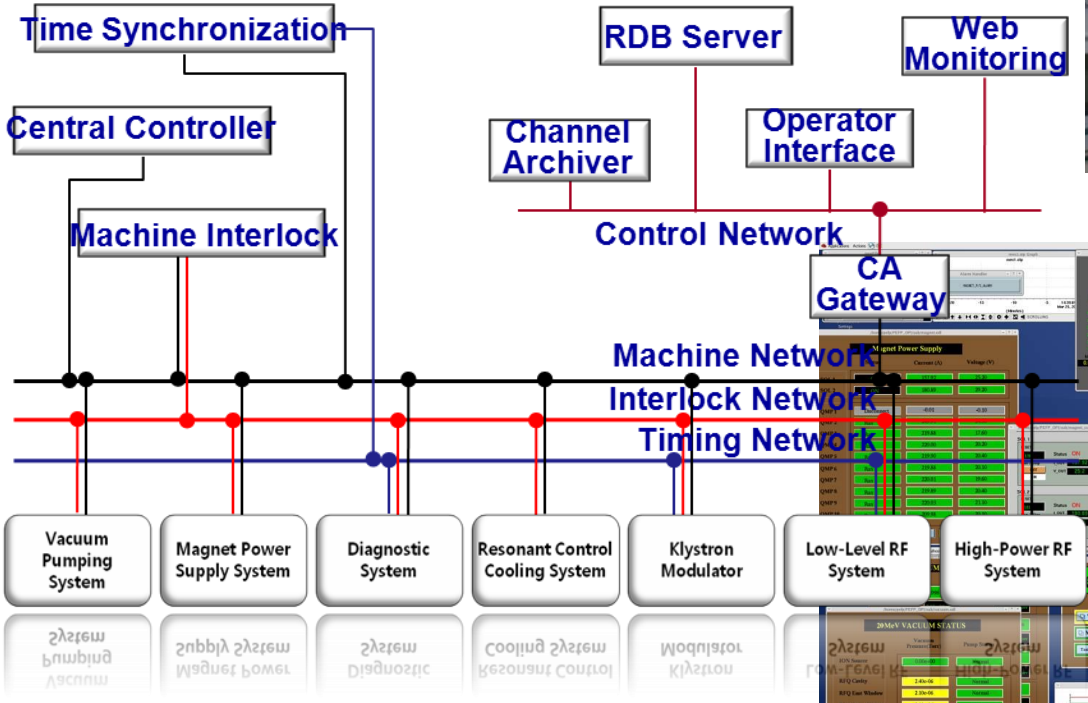
RCCS Test (with 53kW heat load)

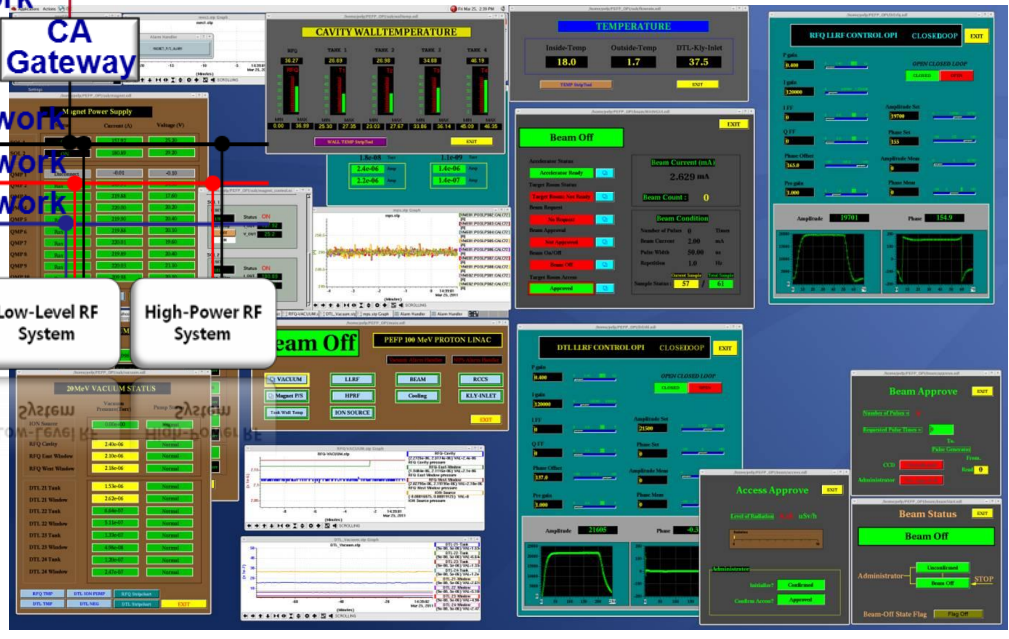
Control System

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



20MeV control room at Daejeon





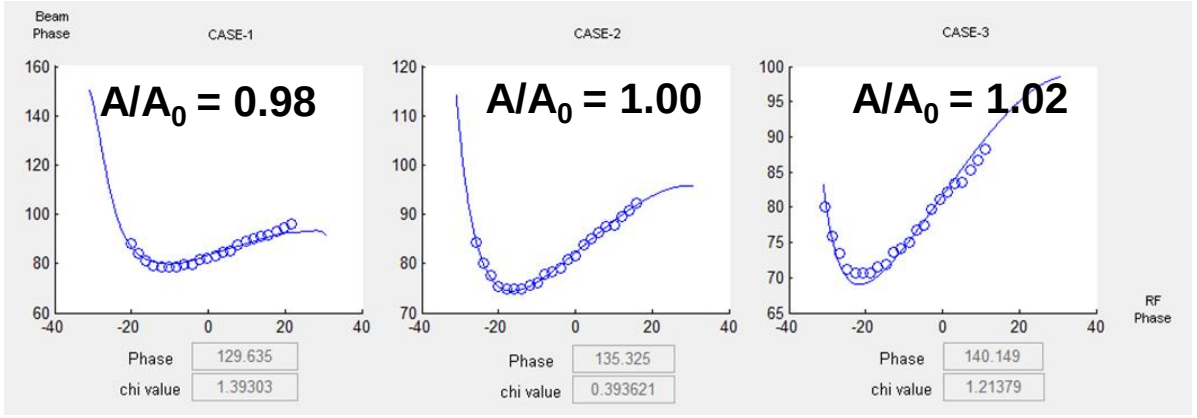
EPICS based OPI

Phase Scan Test for Commissioning

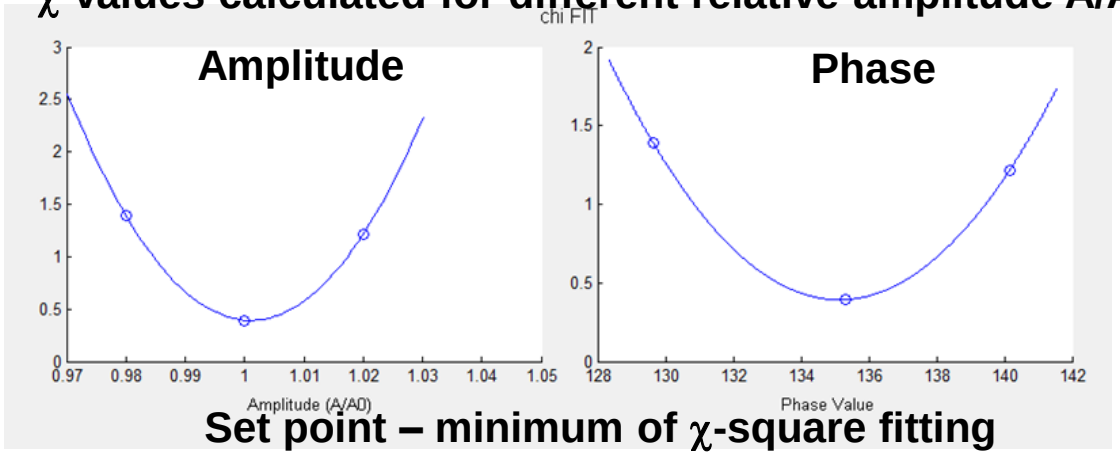
PEFP Proton Engineering Frontier Project

- RF set point – phase scan to prepare 100-MeV commissioning
- Software development for phase scan
- Strip-line BPM development for phase measurement
- Test at the 20-MeV linac
- Chance to check and revise the scheme during J-PARC linac re-commissioning

Strip line type BPM for linac



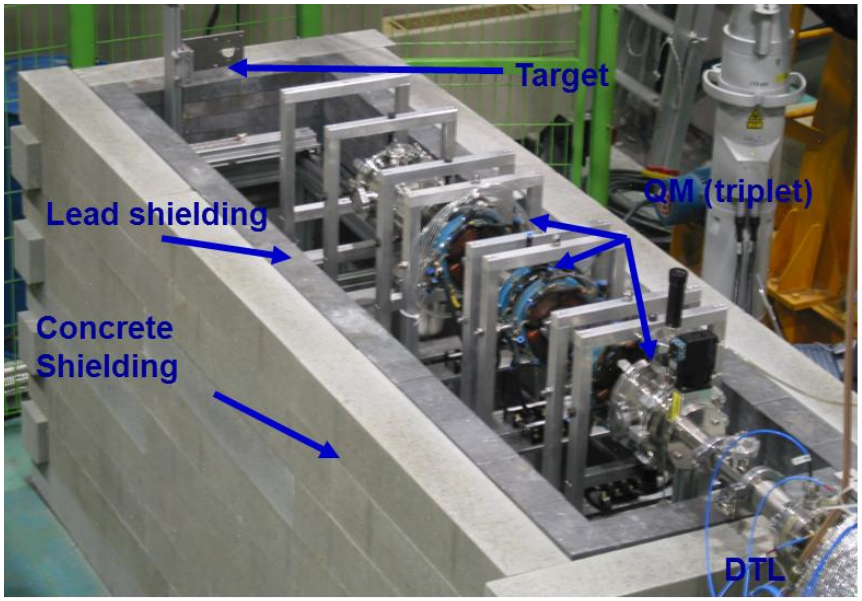
χ-values calculated for different relative amplitude A/A_0



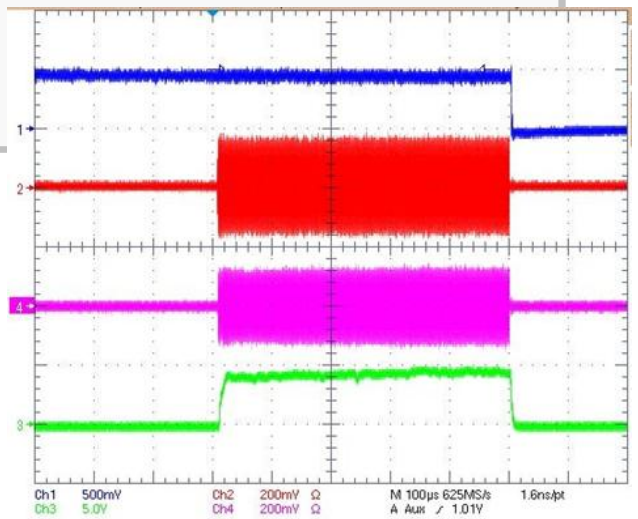
Set point – minimum of χ-square fitting

Linac Integrated Test : 20-MeV

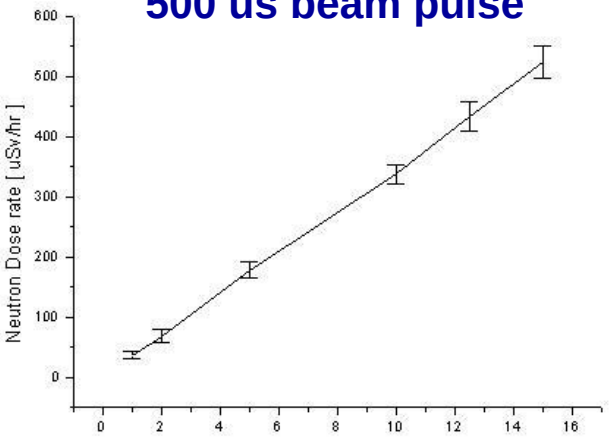
- 500 us pulse operation
- 15Hz repetition rate operation
- Ion Source, HPRF, LLRF control, overall control system performance check
- Test limited by the radiation shielding at Daejeon
- Beam service : typically 20-MeV, 5mA, 1Hz



20-MeV beam target room
during installation at Daejeon



500 us beam pulse



Neutron dose depending on RR

20-MeV Linac Disassembly and Transport

PEFP Proton Engineering Frontier Project

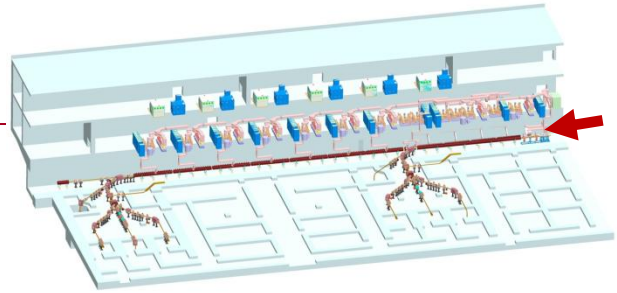
- Disassembly of the 20-MeV linac from Dec. 2011
- Transport from Daejeon to Gyeongju (~200km apart)
- DTL and klystron move by using the vibration free truck
- Most ways are express way
- No notable distortions in DTL before and after
- Special supporter with oil jack and caster

DTL tanks inside vibration free truck

Special supporter inside tunnel

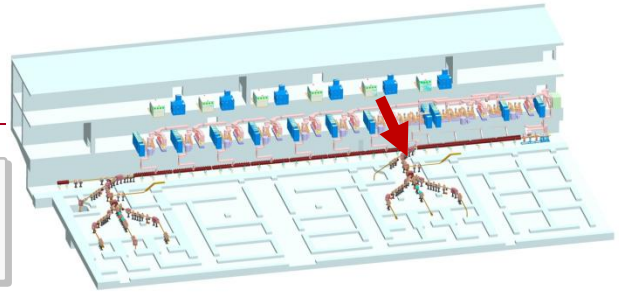
Building Construction

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

Klystron Gallery: 2nd Floor

- Installation starts at September, 2012

Klystron Gallery: 2nd Floor

- Installation starts at September, 2012

Modulator Installation: 3rd Floor

- Installation starts at September, 2012

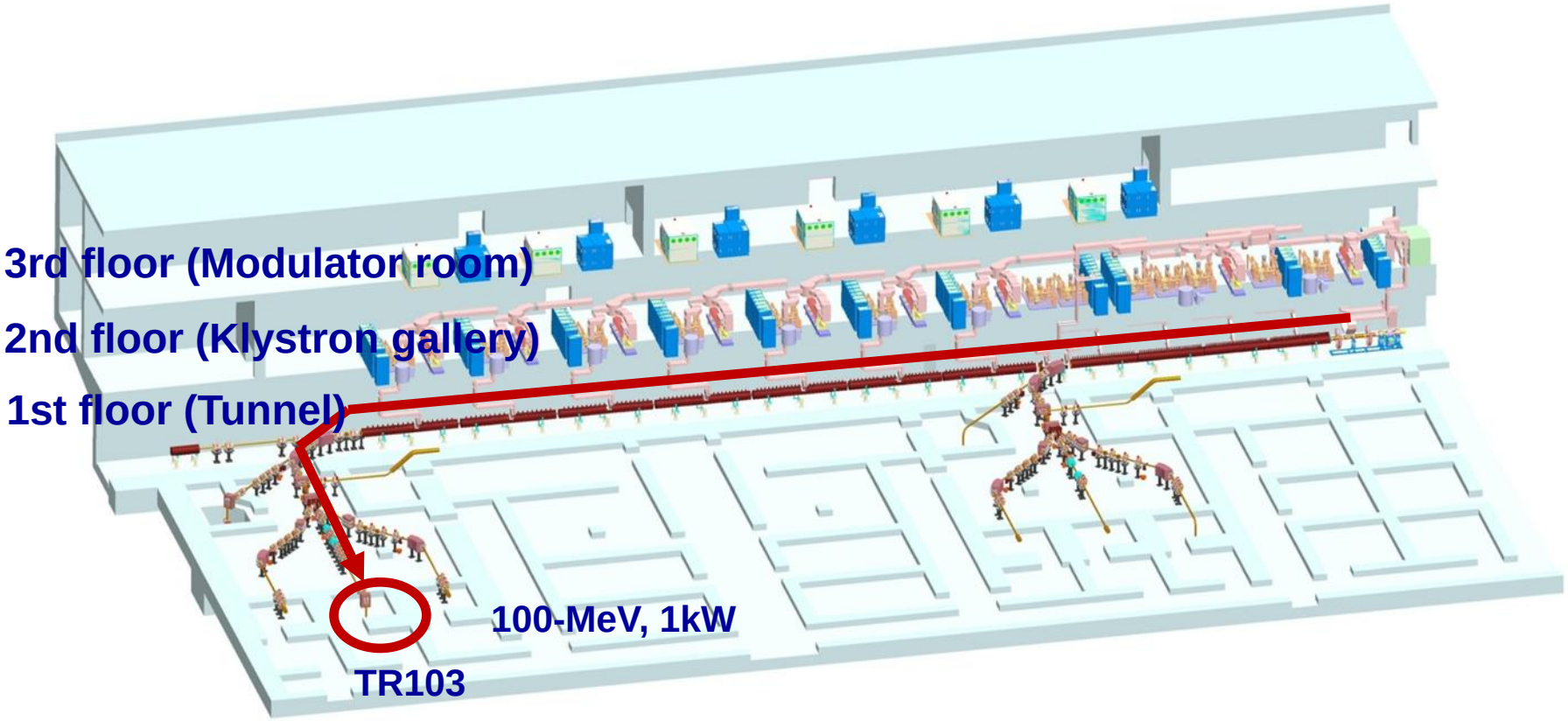
Modulator Installation: 3rd Floor

- Installation starts at September, 2012

Commissioning Plan

PEFP Proton Engineering Frontier Project

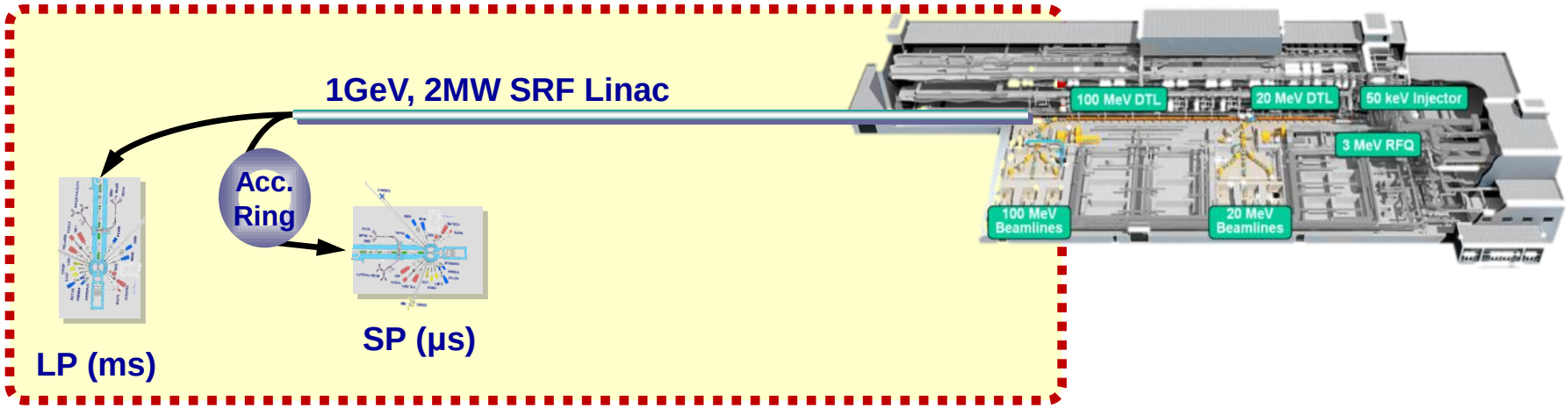
- Goal : 100-MeV, 1kW proton beam to TR 103 beam dump
- Both on-line conditioning and commissioning
- High power conditioning sequence : 3rd floor -> 2nd floor -> Tunnel (1st floor)
- 20-MeV experience is helpful for 100-MeV commissioning
- Accelerator commissioning starts in this winter
- Power increase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



Future Plan

PEFP Proton Engineering Frontier Project

- 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)

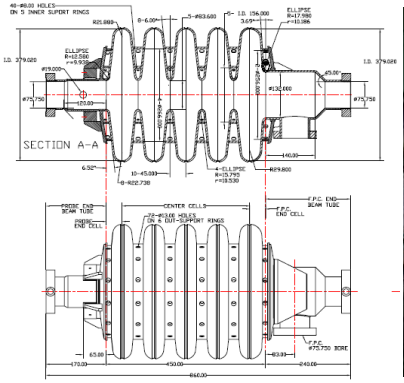


Started SRF R&D from the beginning of the PEFP

Future Plan : SRF R&D

PEFP Proton Engineering Frontier Project

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



Design

Forming

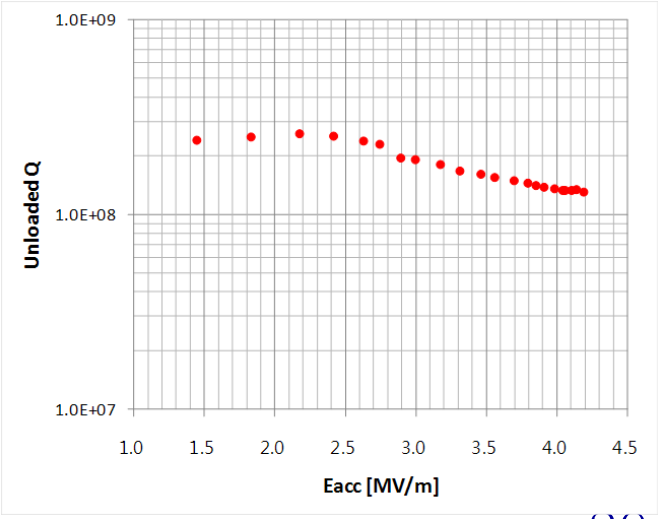
E-beam welding

Tuning

Cleaning

Test preparation

Test



First result

Summary

PEFP Proton Engineering Frontier Project

- **Proton Linac Technologies has been developed**
  - **ion source, RFQ, DTL, RF, etc**
- **20 MeV Linac : 5 year operation**
  - **accumulated valuable experiences to install, commission, and operate 100MeV linac**
  - **disintegrated, moved and installed at new site**
- **20~100 MeV Part : completed fabrication, tested and installed**
- **Commissioning Plan**
  - **to start Installation of HPRF in September 2012**
  - **to start the commissioning in this winter**
  - **to start Beam Service in spring 2013**
- **Future Plan**
  - **GeV grade high power proton linac : SRF R&D**

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Thank you.