HB2018
61st ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams
Daejeon, Korea, 17-22 June, 2018

KOMAC operation and future plans

June 19, 2018

Yong-Sub Cho
on behalf of KOMAC

KOMAC / KAERI

KAERI

KOMAC
Korea Multi-purpose Accelerator Complex
양성자가속기연구센터

Contents

KAERI: Korea Atomic Energy Research Institute

KOMAC
Korea Multi-purpose Accelerator Complex
양성자가속기연구센터

- ❖ Established for Nuclear R&D (Power & Rad. Applications) in1959
- ❖ Located in 3 sites: Daejeon (HQ), Jungup (ARTI), Gyeongju (KOMAC)

KOMAC: Korea Multi-purpose Accelerator Complex

KOMAC
Korea Multi-purpose Accelerator Complex
양성자가속기연구센터

❖ Located in Gyeongju

- User facility to provide proton and ion beams for many applications

Main Facility

KOMAC
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TR103(100MeV) TR23 (20MeV)

- Area: 180,000 m²
- Building: 27,322 m²
- Power: 154kV, 20MVA

- **KOMAC Opening Ceremony: 5th April, 2018**

KOMAC 100-MeV Proton Linac

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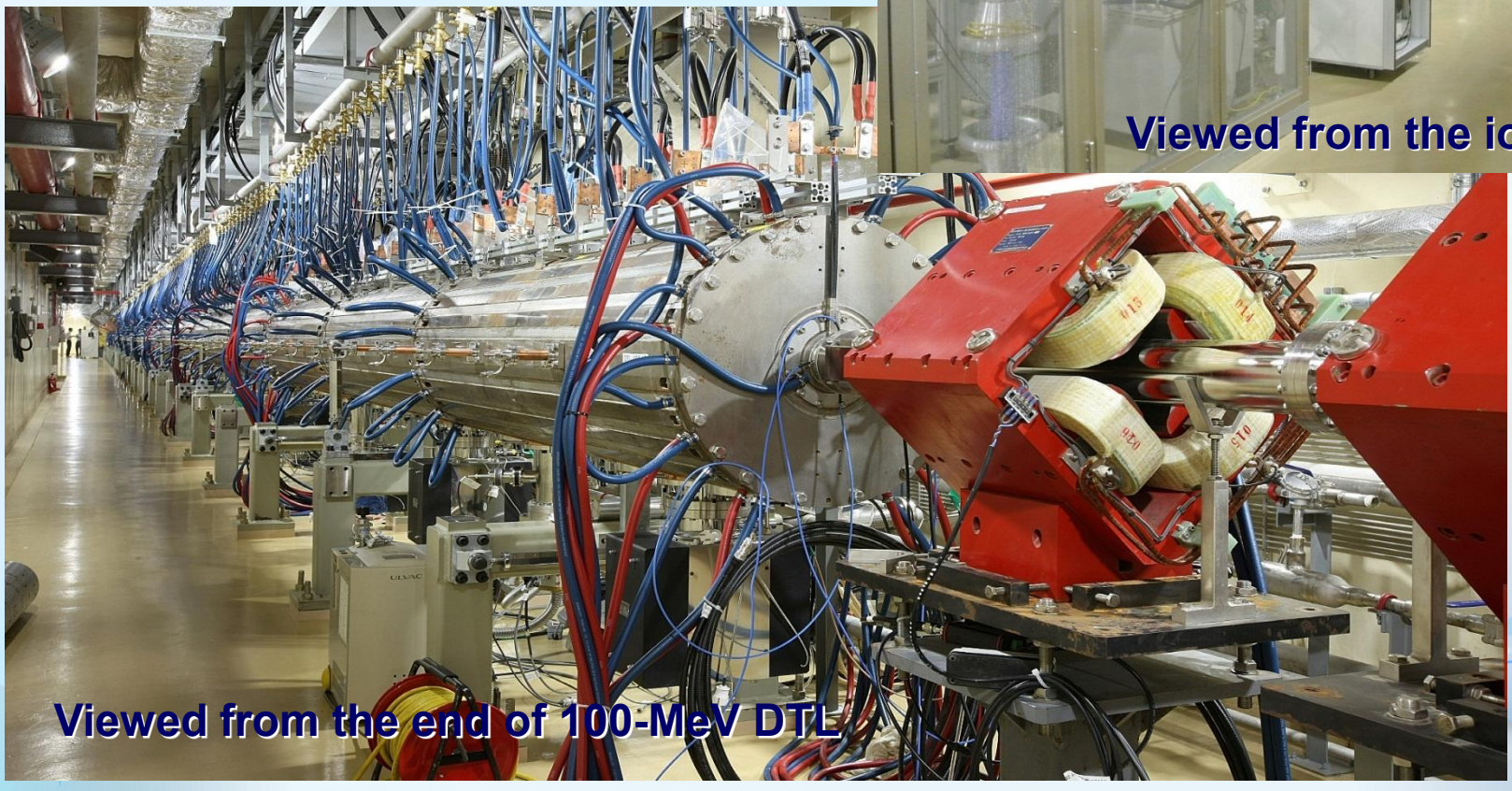
- Linac and beam lines : installed in 1st floor
- Tunnel : 100 m
- 100-MeV linac : 75 m
- HPRF and cooling system : installed in 2nd floor
- Commissioned & Started user service in July 2013

Viewed from the ion source



Viewed from the end of 100-MeV DTL

Operation Statistics (2013~2017)

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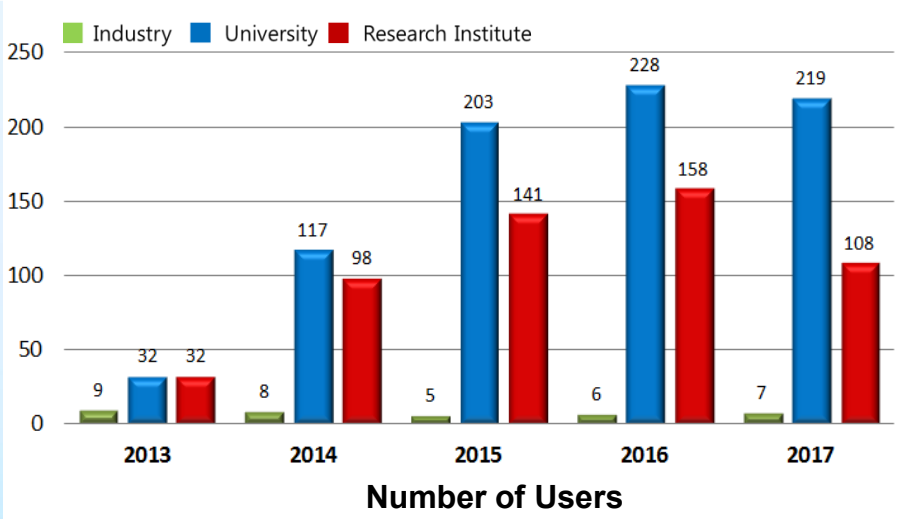
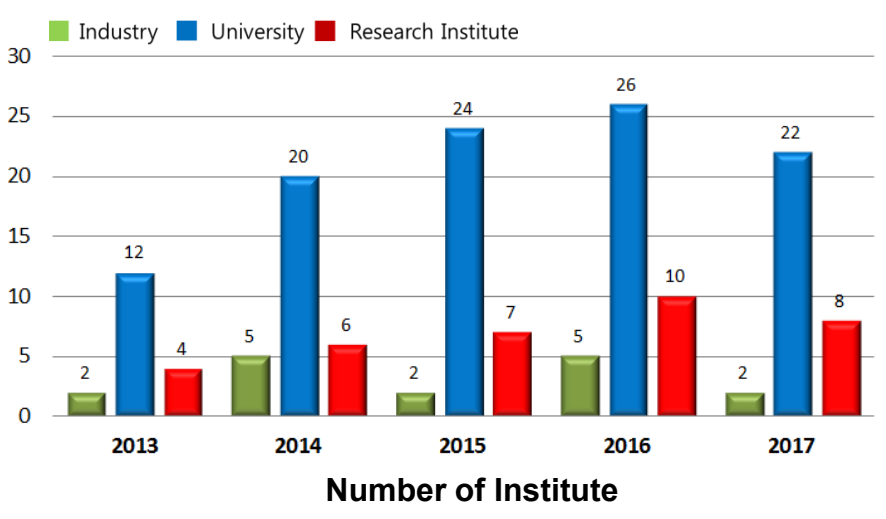
❖ Operated in weekly-based schedule through a yearly plan
- Beam service: Monday 13:00 ~ Friday 12:00

❖ Operation statistics

	2013	2014	2015	2016	2017	Sum
Operation hours	2,290	2,863	2,948	2,961	3,231	14,293
Availability	82.0%	86.3 %	90.5%	94.9%	94.9%	89.7%

❖ User statistics





● R&D Fields: Materials(36%), Bio/Medical(26%), Space Rad./Basic Sci.(21%) etc.

Proton Beamline (1)

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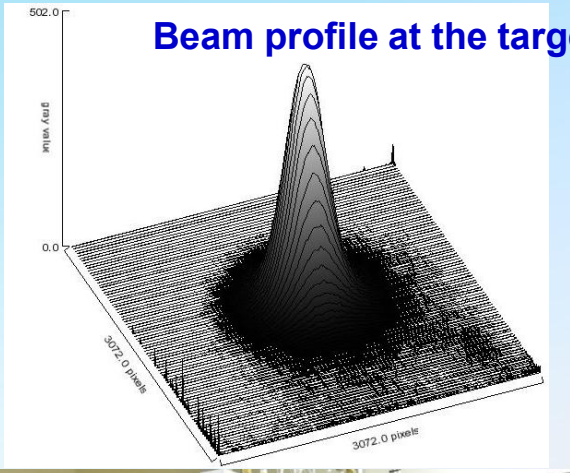
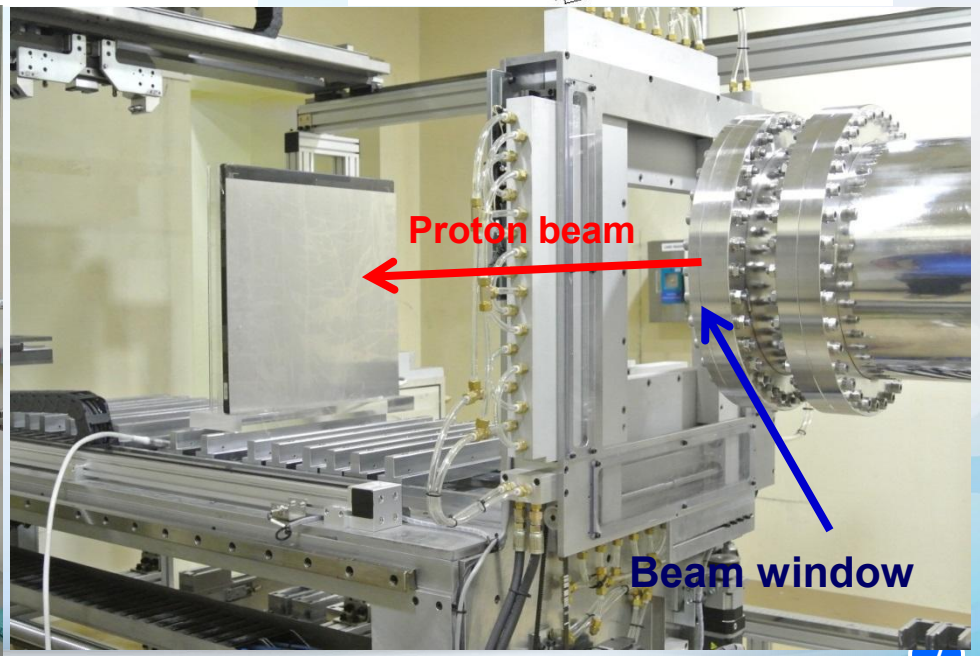
❖ General Purpose Beamline: 20-MeV / 100-MeV Proton

- **Application :** Proton beam irradiation for general purpose (material / nano-science, semiconductor etc.)
- **Proton beam**
  - Energy: 20 MeV / 33 ~ 100 MeV
  - Beam power: 10 kW @ 100 MeV
- **Status :** Under operation (2013~)

Beam profile at the target



Hot cell for sample manipulation



Beam irradiation station

Proton Beamline (2)

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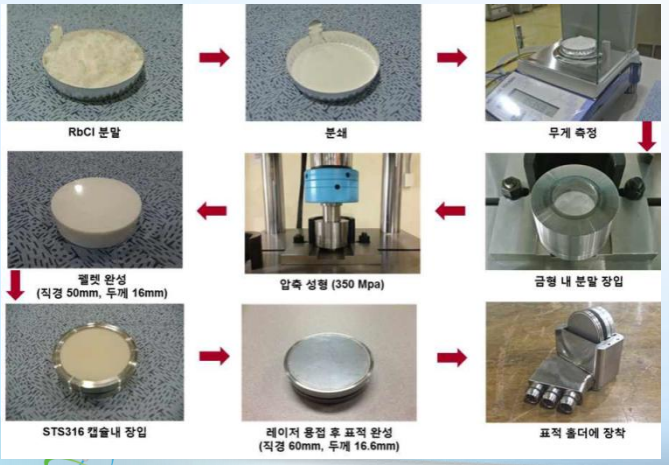
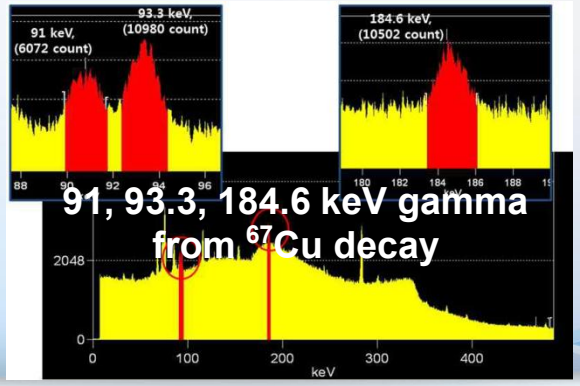
❖ RI Production Beamline: 100-MeV Proton

- **Application**
  - RI production: Cu-67, Sr-82, etc.
- **Proton beam**
  - Energy: 33 ~ 100 MeV
  - Beam power: 30 kW @ 100MeV
- **Status**
  - Completed installation: Dec. 2015
  - Status: under operation (2016~)

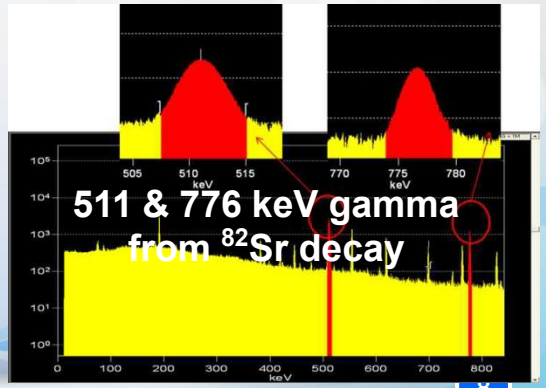
Target Preparation



$^{68}Zn(p,2p)^{67}Cu$



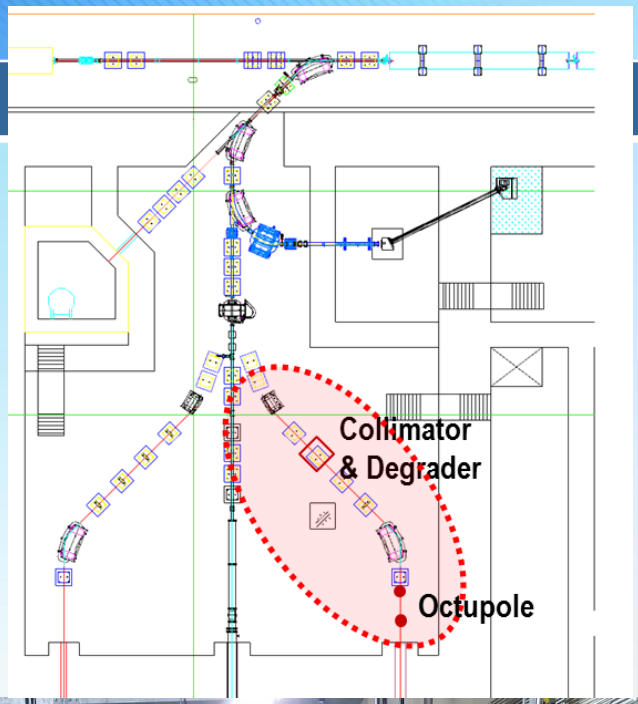
$^{nat}Rb(p,x)^{82}Sr$



Proton Beamline (3)

❖ Low-flux Beamline: 100-MeV Proton

- **Application :** Space radiation, Detector R&D, Bio etc.
- **Proton beam**
  - Energy: max. 100 MeV
  - Avg. Current : max. 10 nA
  - Uniformity: < 10%, 100 mm X 100 mm
  - Flux: $1x10^5 \sim 1x10^8/cm^2$ / pulse
- **Status :** Under operation (2017~)



Collimator

Octupole magnet

Proton Beamline (3)

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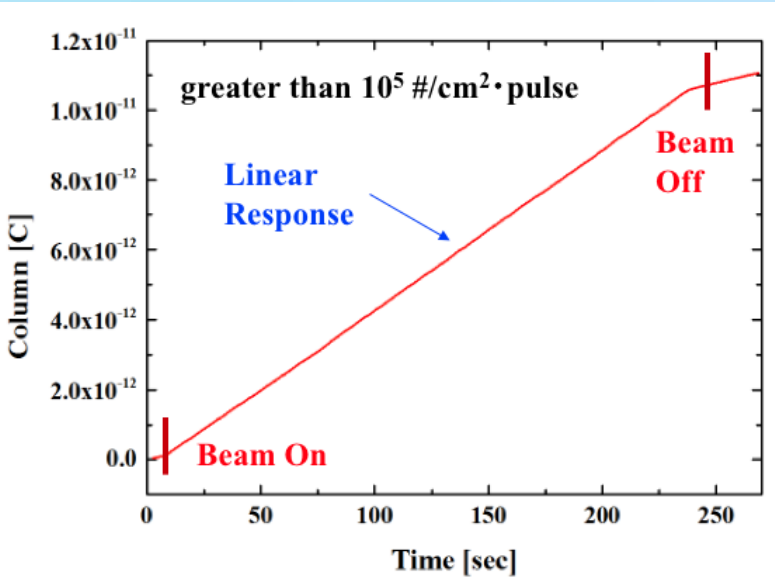
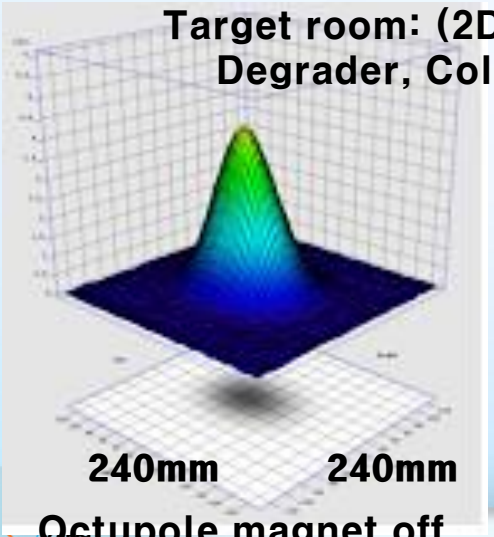
❖ Low-flux Beamline: 100-MeV Proton

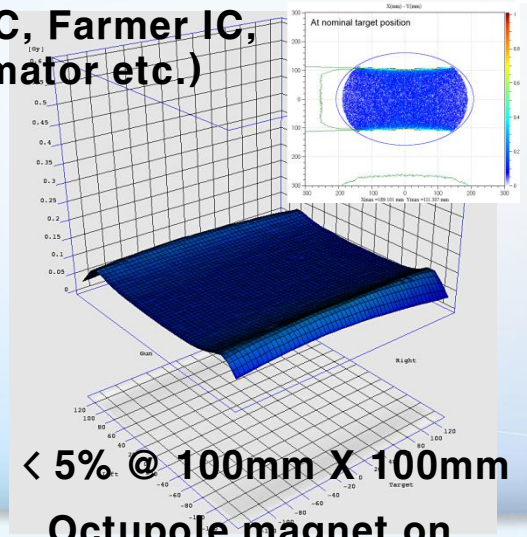


Target room: (2D IC, Farmer IC, Degrader, Collimator etc.)



240mm 240mm

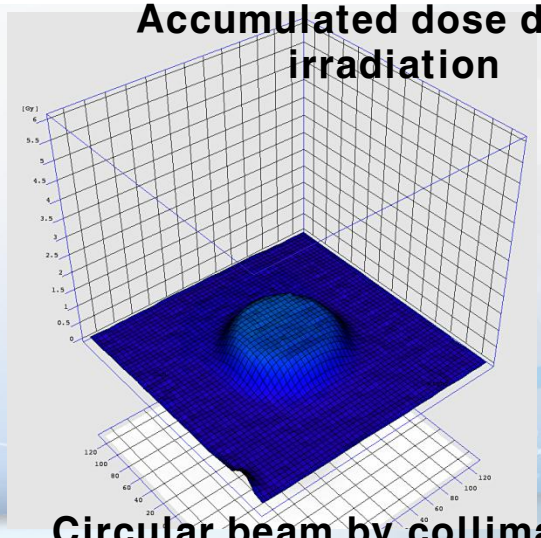
Octupole magnet off



< 5% @ 100mm X 100mm

Octupole magnet on

Accumulated dose during irradiation



Circular beam by collimator

Proton Beamline (4)

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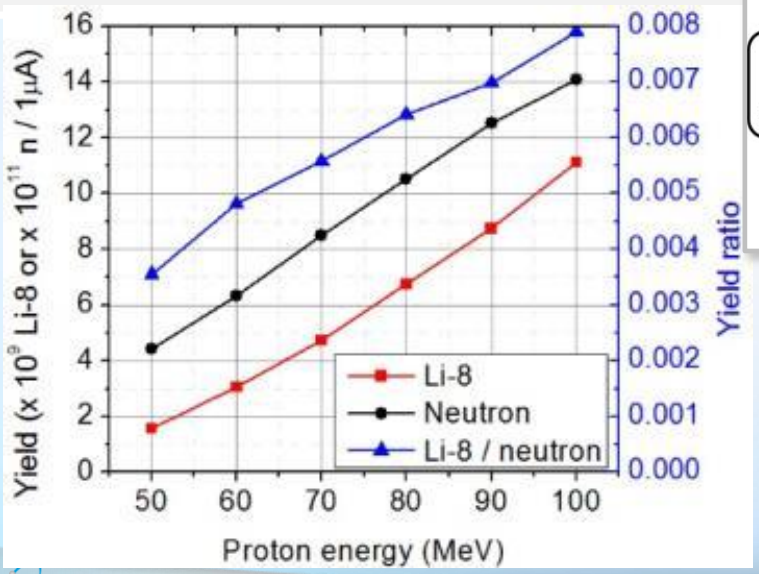
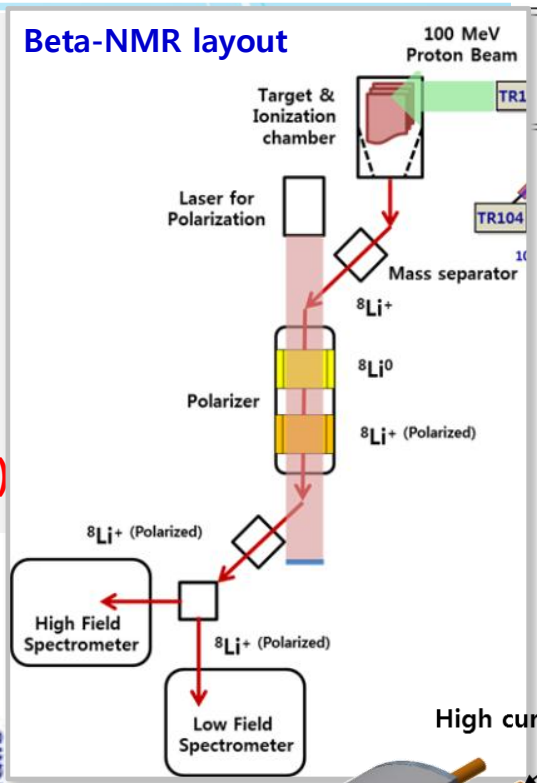
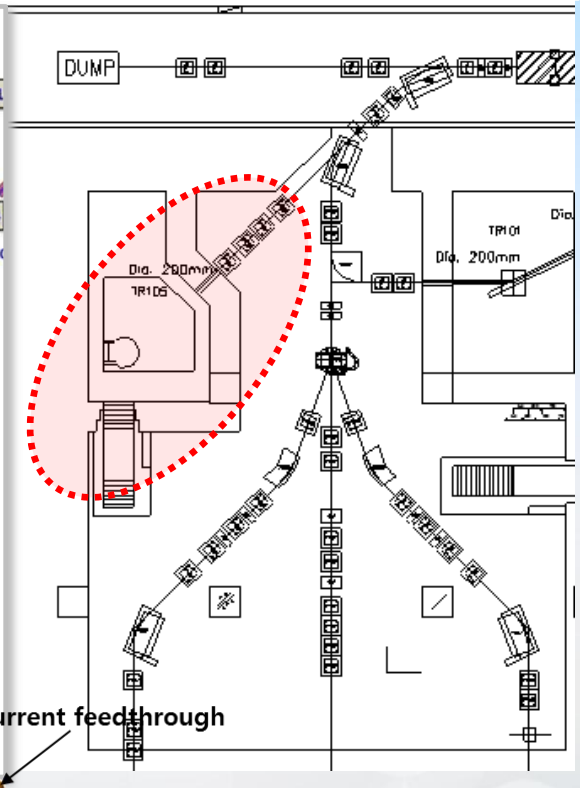
❖ Li-8 Production Beamline: 100-MeV Proton

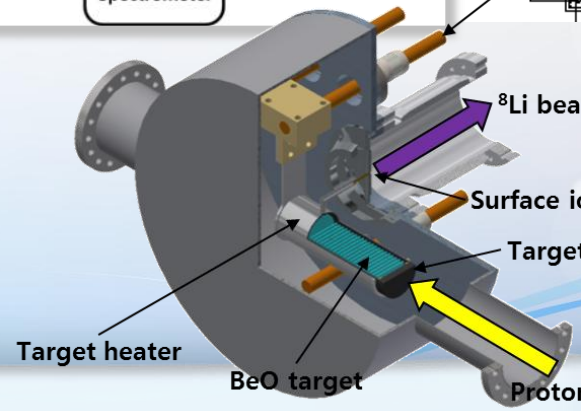
- **Application : Beta NMR**
- **Proton beam**
  - Energy: 100 MeV
  - Beam Power: 1 kW @ 100 MeV
  - Li-8 Ion Production: 1×10^8 pps
  - Target: BeO
- **Status : Under development (2017~)**



^{8}Li production rate calculated by FLUKA







Target Ion Source
under development

Proton Beamline (5)

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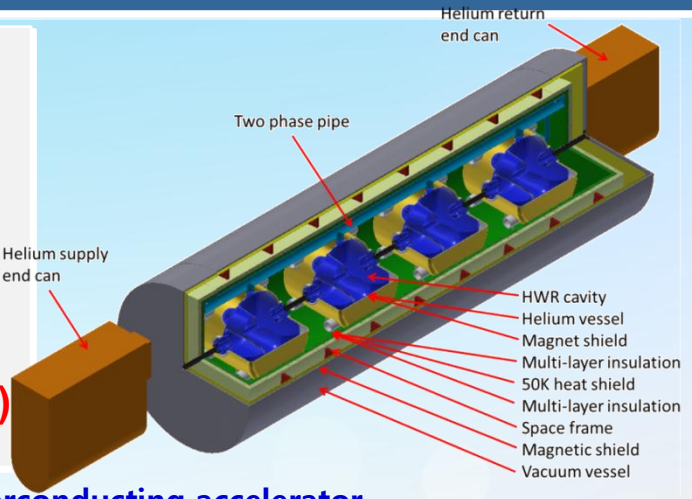
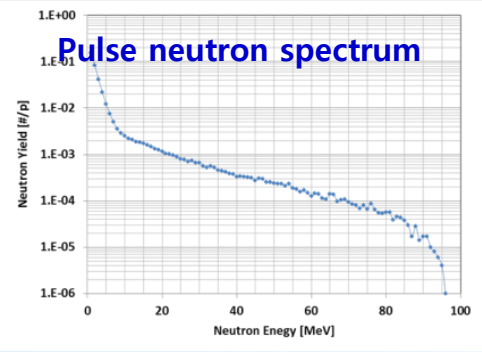
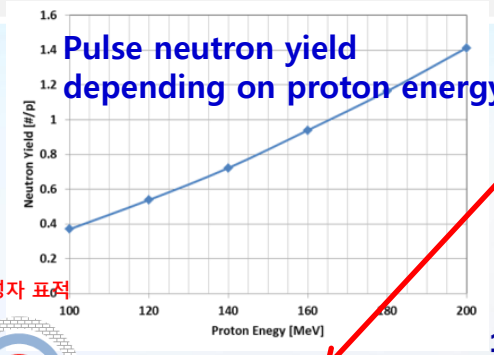
❖ Pulse Neutron Production Beamline: 100-MeV Proton

- **Application : Pulse Neutron Production**
- **Proton beam**
  - **Energy: 100 MeV**
  - **Beam Power: 1 kW @ 100 MeV (upgrade 160 MeV)**
  - **Target: Tungsten**
- **Status : Neutron utilization, accelerator upgrade (2017~)**

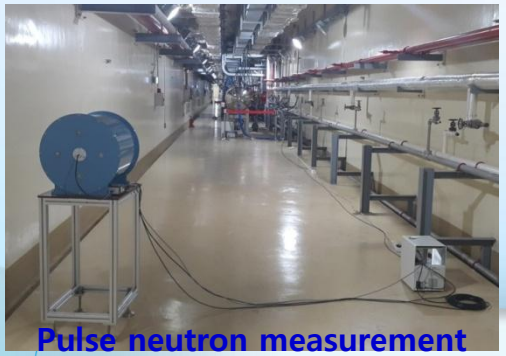


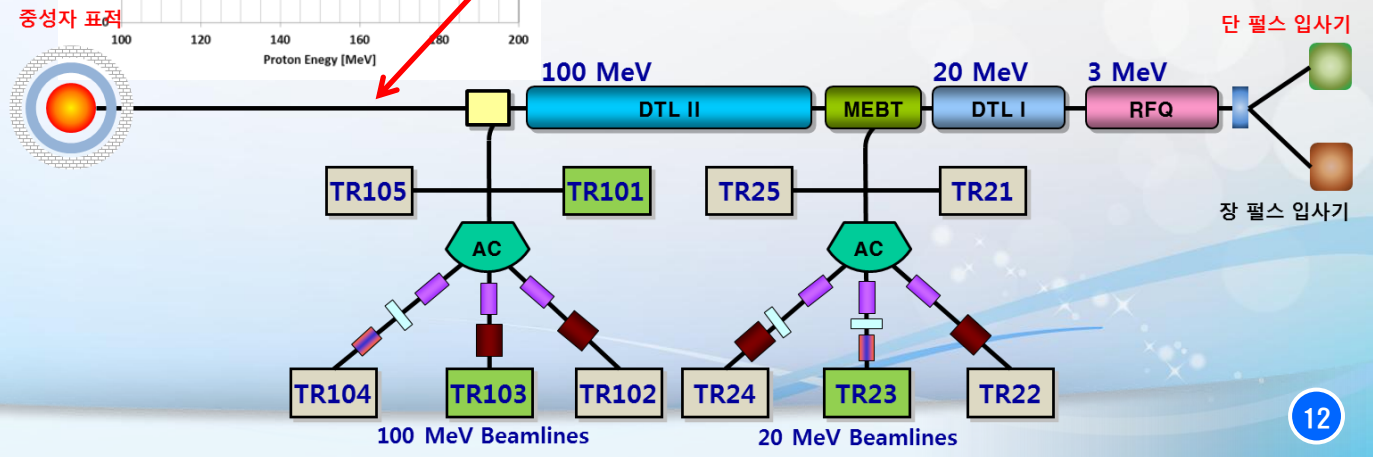




Superconducting accelerator

- Energy: 100 MeV ~ 160 MeV
- Type: HWR (Half-Wave Resonator)
- Cryomodule: Cylindrical
- Operating temperature: 2K
- Focusing: External normal conducting QM





6 T EBIS

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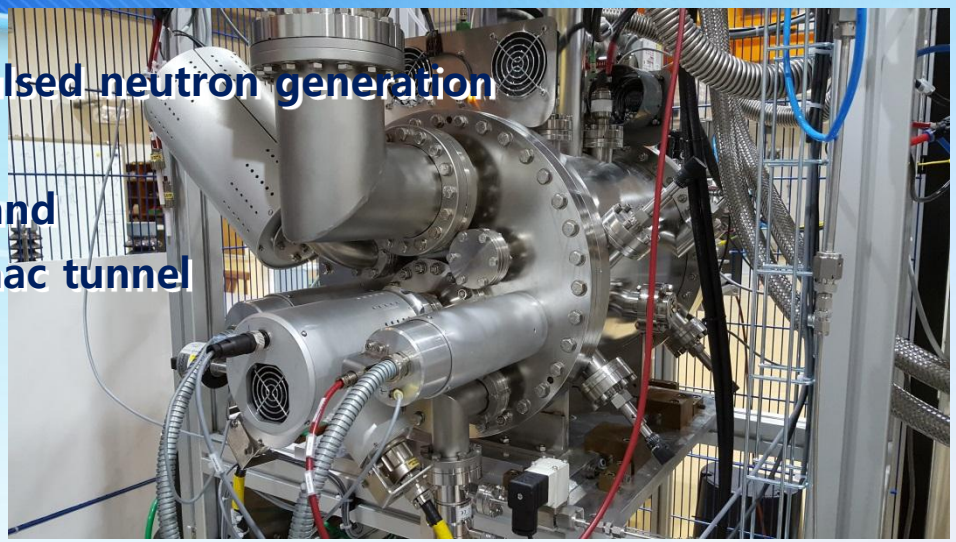
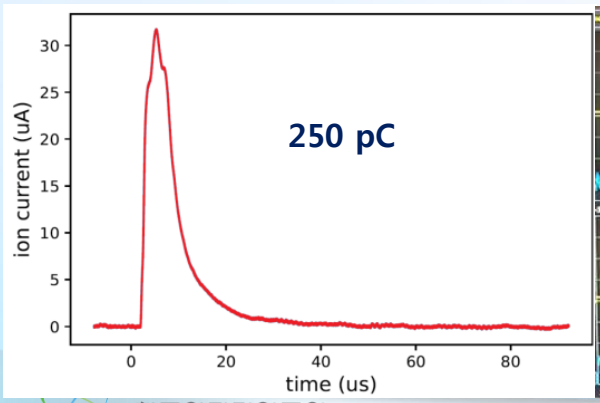
- Short pulse (10 ns) proton injector for pulsed neutron generation
- Status
  - Short pulse extraction test at test stand
  - Planed to be installed in 100 MeV linac tunnel
- Specification

Max. electron current	300 mA
Max. electron energy	20 keV
Max. ion energy	60 keV (for proton)
Magnetic field	6 T
Magnet bore dia.	50 mm
Drift tube length	200 mm

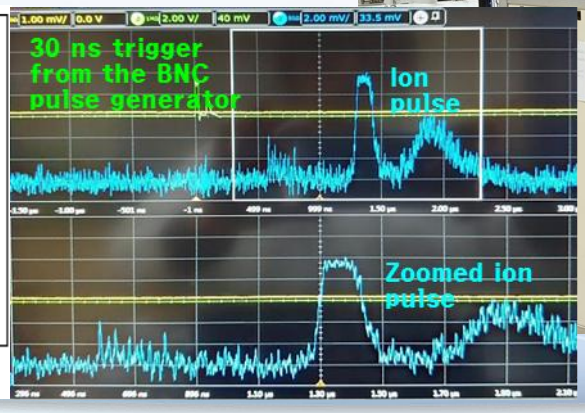


6T EBIS

6T EBIS test stand



Charge in single pulse



Single pulse extraction (present: 150 ns)

Ion Beam Facility (1)

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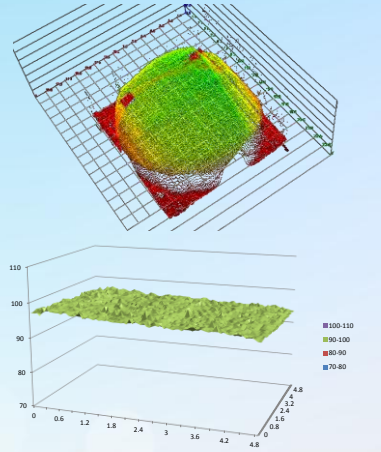
❖ Ion Beam Implanters

- **Application : Surface Modification**
- **Beam specification**
  - **Ion species: N, Ar, O etc. (Gas)/Cr, Fe, Co etc. (Metal)**
  - **Beam energy: 200 keV (Gas) /150 keV (Metal)**
  - **Beam current: 4mA (N) / 1 mA (Metal)**
- **Status : Under beam service (2013~)**



Metal ion implanter

Gas ion implanter

ion beam machine based on MEVVA ion source

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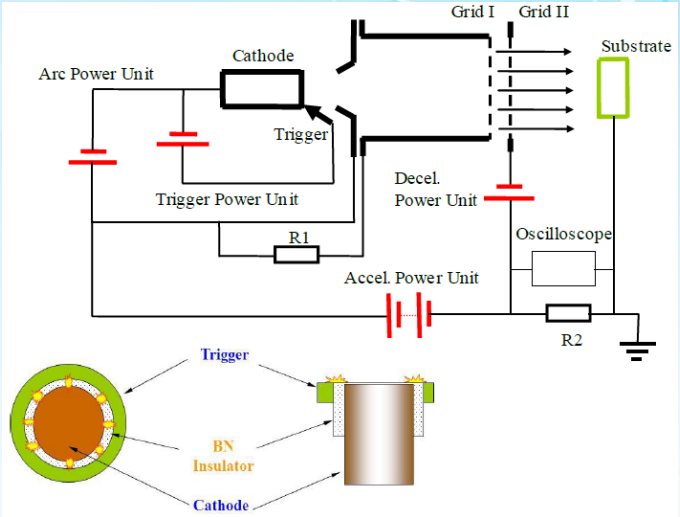
MEVVA ion source



MEVVA based machine

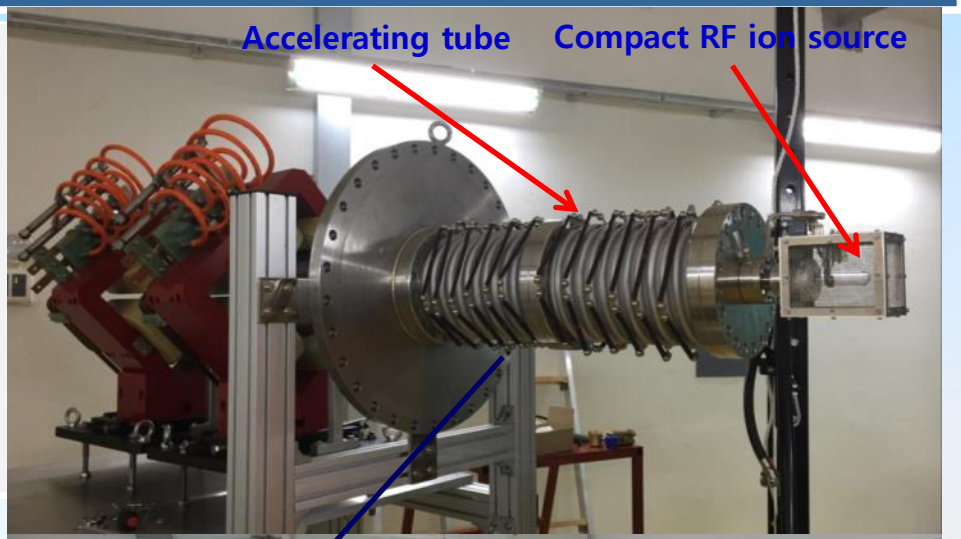
- Species : all metal
- Pulse width : 1ms
- Rep. rated : 0-20Hz
- Acc. voltage : 30kV - 80kV
- Avg. beam current : 0~5mA

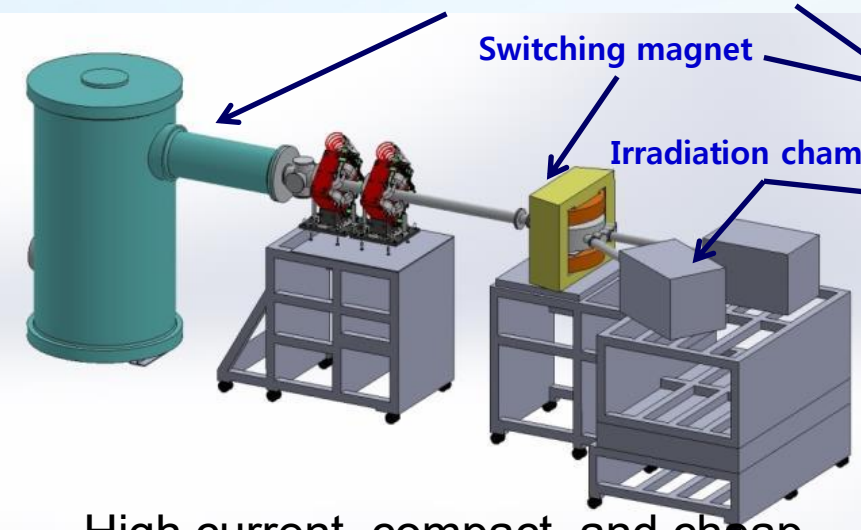
Under construction

Ion Beam Facility [2]

❖ 1 MV High Current Accelerator

- **Application : Silicon On Insulator (SOI)**
- **Beam specification**
  - **Ion species: H, N**
  - **Max. voltage: 1 MV**
  - **Beam current: > 1mA**
- **Status : Under development**
  (Beam service 2018~)



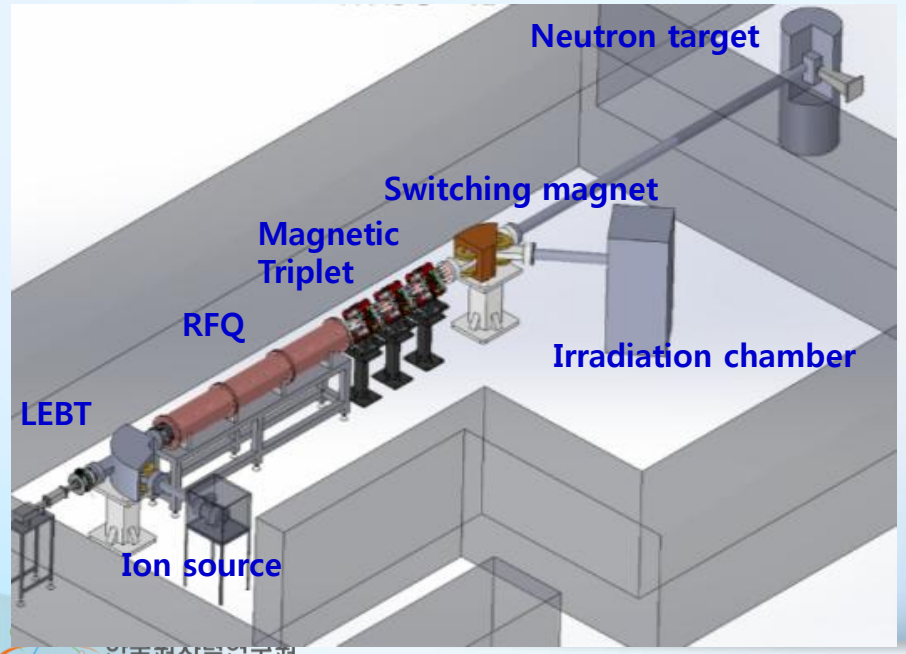


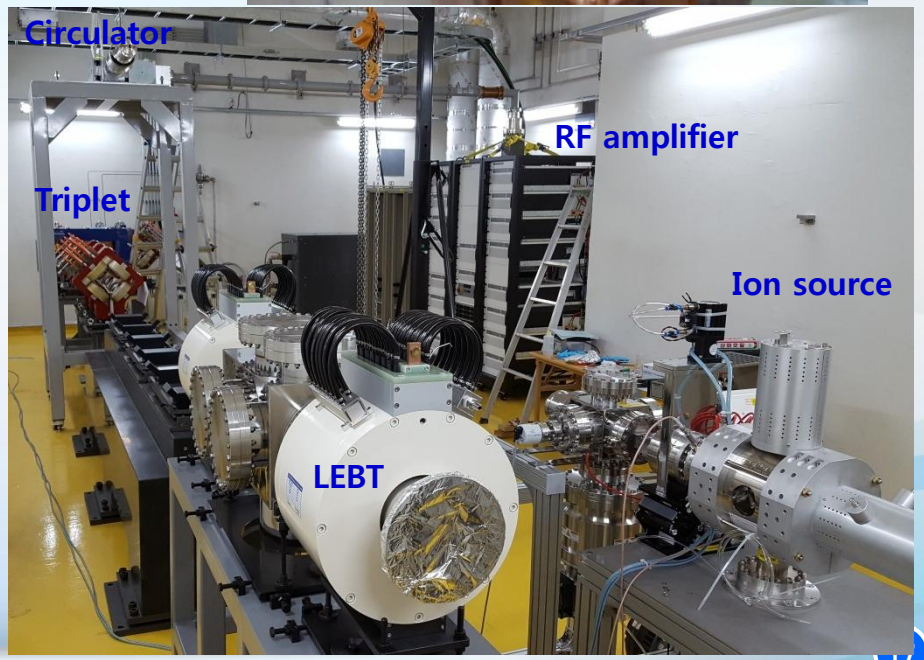
High current, compact, and cheap

Ion Beam Facility [3]

❖ Radio Frequency Quadrupole (RFQ) based accelerator

- Application : Irradiation, neutron production
- Beam specification
  - Ion species: D, highly charged heavy ion up to Xe
  - Beam energy: 1 MeV/n
  - Beam current: 1 mA
- Status : Under development





7 T EBIS

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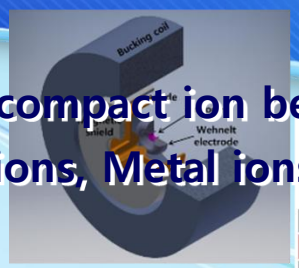
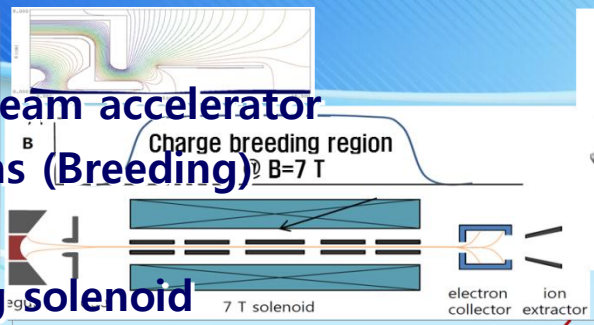
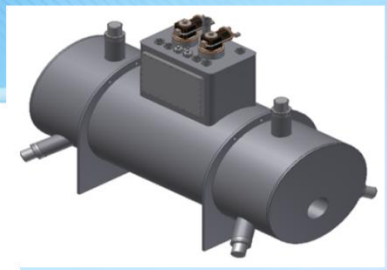
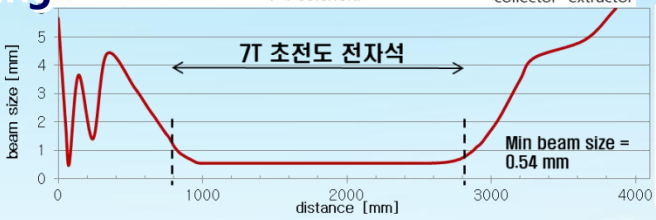
- Ion Source for RFQ based compact ion beam accelerator
  - Multiply charged gas ions, Metal ions (Breeding)
- Status
  - Development of 7T Superconducting solenoid
  - Development of electron gun
  - Development of DT and collector
- Specification



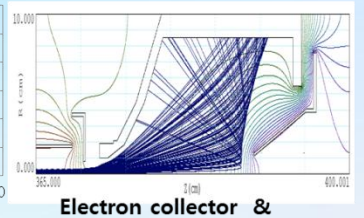
전자총




7 T 초전도전자석

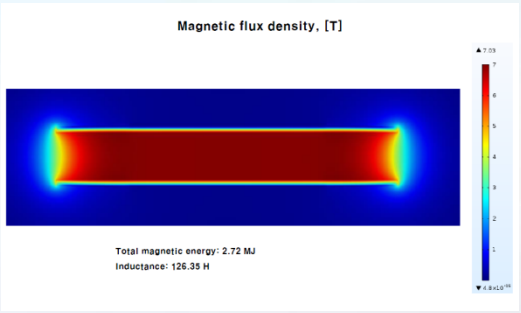


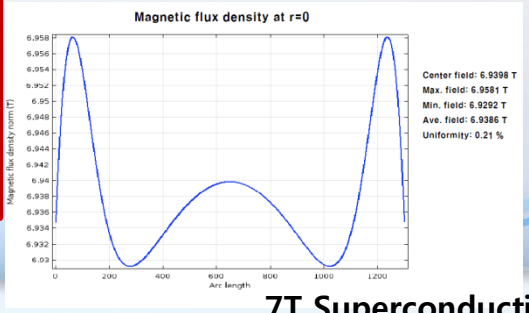
전자빔 반경


Electron collector & ion extractor

7T EBIS Design

EBIS Specifications	BNL	ANL	KOMAC (Design)
e⁻ beam current (A)	10	2	10
e⁻ beam energy (keV)	20	20	20
e⁻ beam density (A/cm2)	575	385	660
e⁻ gun diameter (mm)	9.2	4.2	9.2
DT length (mm)	1500	500	1500
DT diameter (mm)	42.2	20	42.2
Ion trap capacity (charges)	11×10^{11}	1.4×10^{11}	11×10^{11}
Max. magnetic field at DT (T)	6	6	7
Solenoid length (mm)	2000	1000	2000






7T Superconducting solenoid magnet

Ion Beam Facility [4]

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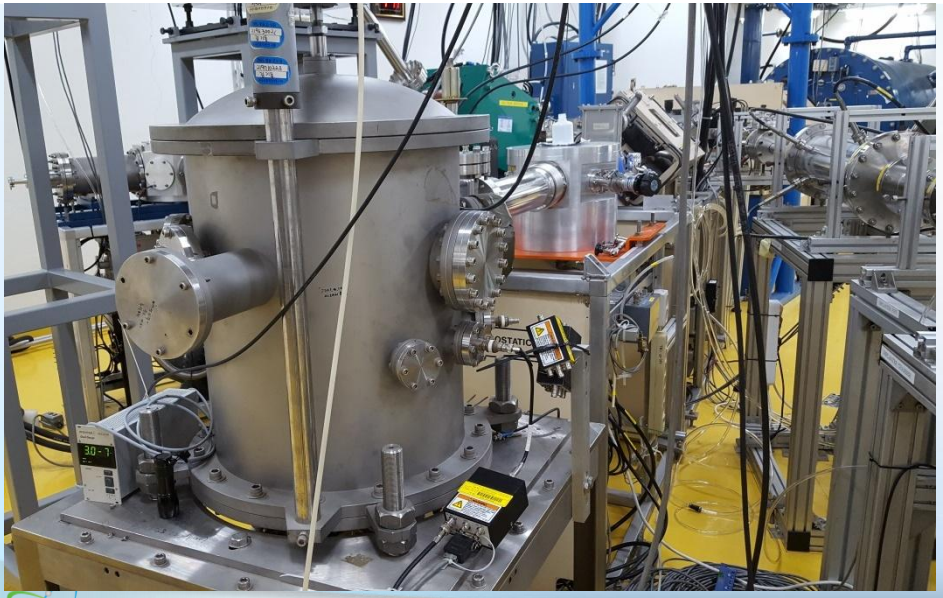
❖ 1.7 MV Tandem Accelerator

- **Application** : Surface analysis, ion implantation, standard neutron
- **Beam specification**
  - Ion species: H, He, Cl etc.
  - Voltage: max. 1.7 MV
  - Beam current: 10 uA (H+)
  - Beam line: PIXE, RBS/ERD, Implantation, standard neutron source
- **Status** : Under operation (2016~)

Tandem accelerator



RBS beam line (Surface barrier detector)

PIXE beam line (Si(Li) detector)

3 MV Tandem Accelerator

- **Application : AMS, Material damage test by ion beam**
- **Beam specification**
  - **Ion species: C, He, Fe etc.**
  - **Voltage: max. 3.0 MV**
  - **Beamline: AMS, irradiation, PIGE**
- **Status : Under installation (Beam service 2018~)**

AMS pretreatment facility
(Carbon dating)

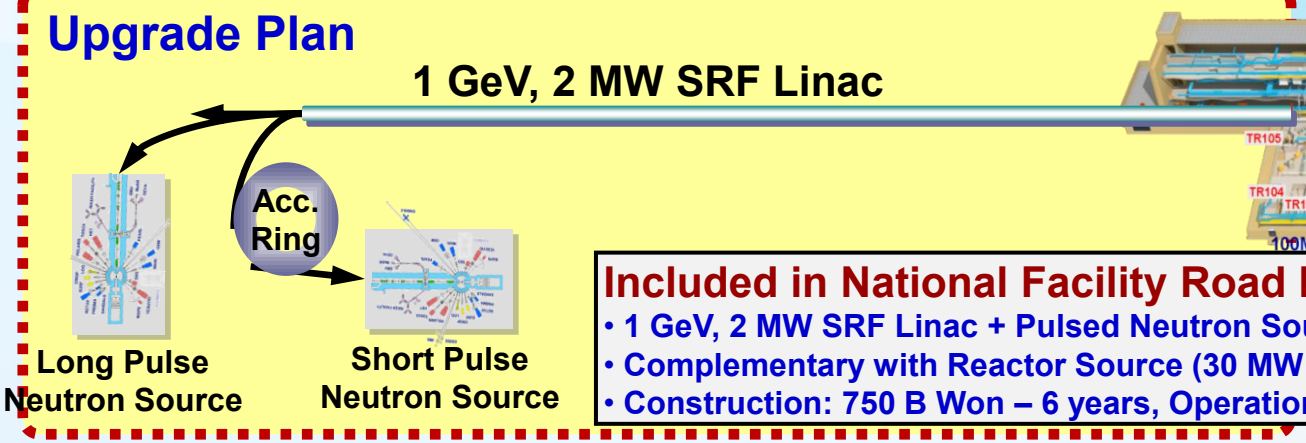
3 MV Tandem under installation

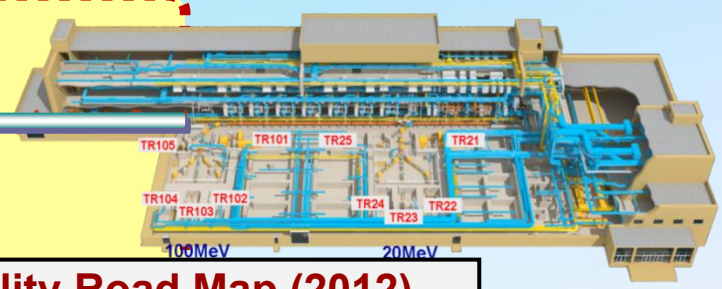
Upgrade to a GeV-class Facility

KOMAC
Korea Multi-purpose Accelerator Complex
양성자가속기연구센터

❖ **Upgrade to 1GeV, 2MW proton linac, two pulsed neutron sources**
- **Reflected in National Large Research Facility Road Map (2010 & 2012)**

Upgrade Plan





Included in National Facility Road Map (2012)
- 1 GeV, 2 MW SRF Linac + Pulsed Neutron Sources (LP + SP)
- Complementary with Reactor Source (30 MW Hanaro)
- Construction: 750 B Won – 6 years, Operation: 60 B Won/year

- **Neutron Sources:** Materials, Bio-life, Energy, Environment, etc.
  - **Long Pulse (1.3 ms):** Spatial resolution: μm~nm, Temporal resolution: μs~ns
    - SANS, Holography, Phase shift interferometry, Static & Dynamic tomography, Spin echo, etc.
  - **Short Pulse (~μs):** Spatial resolution: 0.01~10 nm, Temporal resolution: ns~fs
    - Elastic scattering, Diffraction, PGAA, Neutron resonance transmission, Neutron resonance capture analysis, Neutron spectroscopy, Neutron stimulated emission CT, etc.
- **Muon Source**: Materials, HEP, Nuclear engineering, etc.
- **Neutrino Source**: HEP

Summary

- 100-MeV linac operation
  - Commissioned the 100-MeV linac with 1 kW in 2013
  - Availability > 90% since 2015
  - Stable for beam service
- Proton beam service
  - Many Users with complicated requirements
  - New beam lines for RI production in 2016 and for low-flux in 2017
  - Preparing beam lines one by one according to user demand
    Next beam lines will be neutron and beta-NMR.
- Pulsed neutron
  - Under user service with 100-MeV linac
  - Accelerator upgrade plan up to 200 MeV and 1GeV for future
- Ion Beams
  - Ion beam is a very useful radiation for industrial applications
  - KOMAC is operating & developing several ion beam machines
  - More R&D for ion beam machines is required.

Thank you