KOREA ATOMIC ENERGY RESEARCH INSTITUTE

Operational Status of the KOMAC 100 MeV Proton Linac and Pilot R&D for the 200 MeV Upgrade

2026. 8. 18.

Korea Atomic Energy Research Institute
Han-Sung Kim

KAERI Korea Atomic Energy Research Institute

A nuclear research institute
reshaping the future based on
peoples trust

KAERI

Korea Atomic Energy Research Institute

CONTENTS

Korea Atomic Energy Research Institute

KOREA ATOMIC ENERGY RESEARCH INSTITUTE

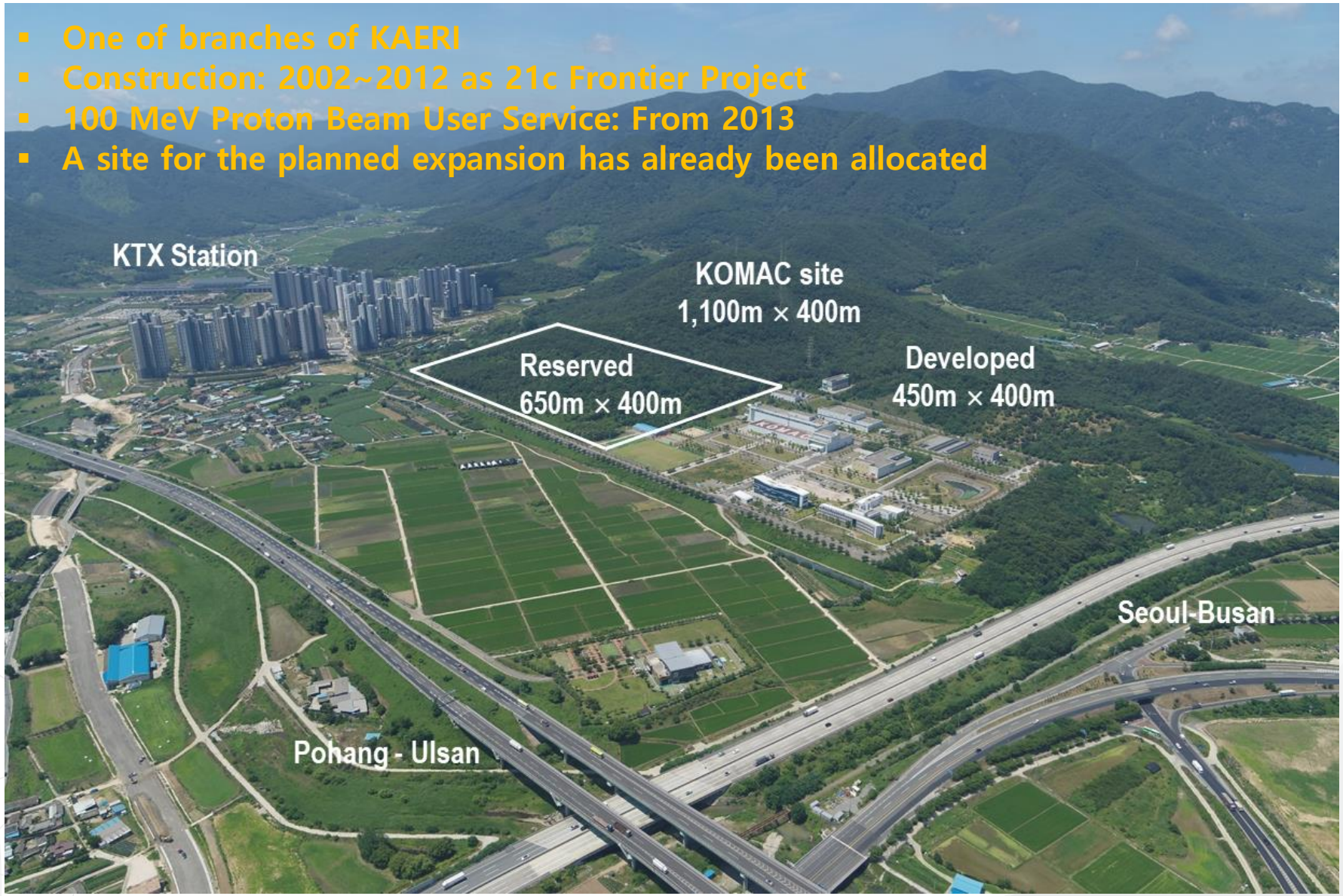
01

KOMAC Facility Introduction

Korea Atomic Energy Research Institute

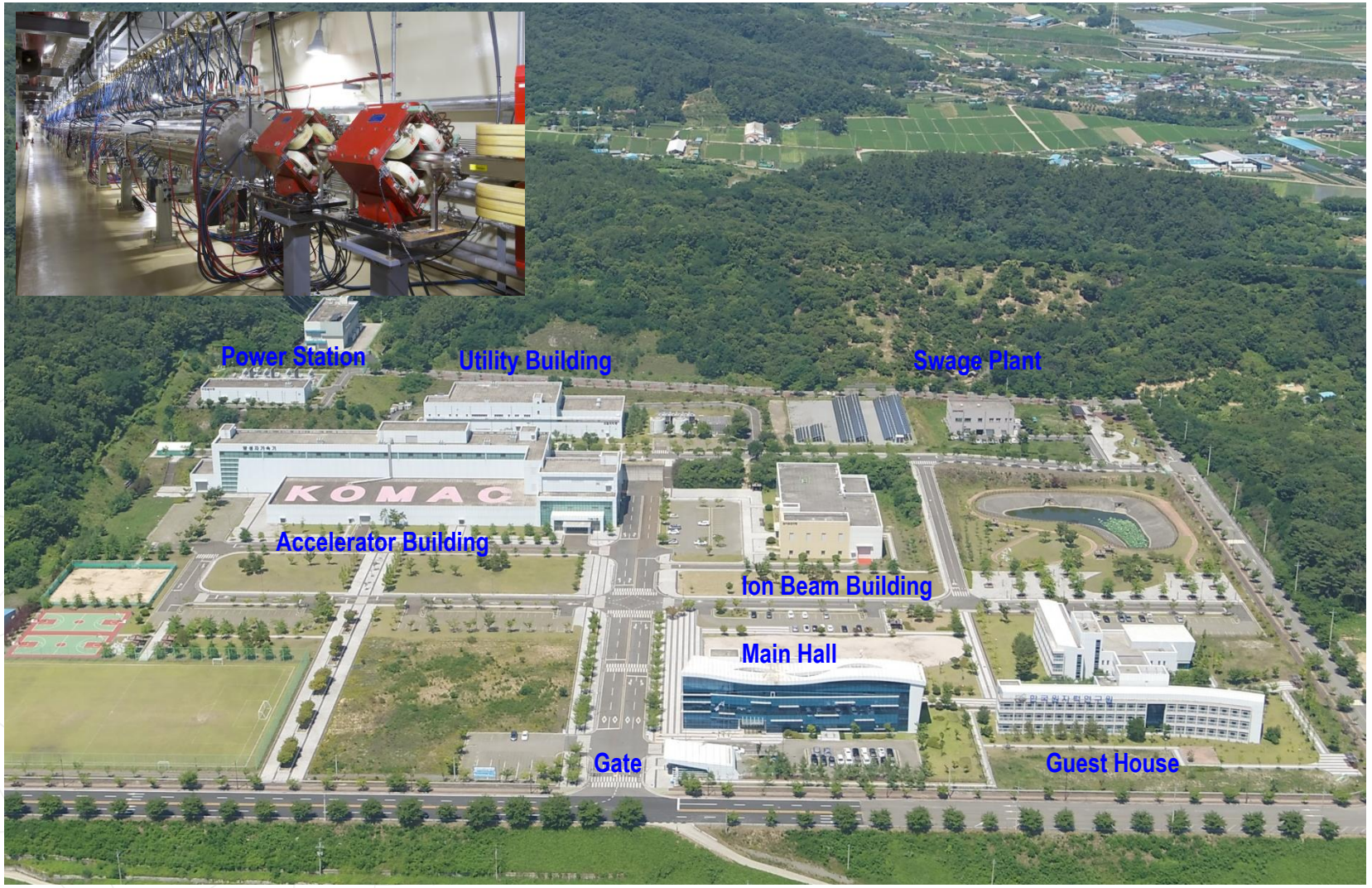
KOMAC: Korea Multi-purpose Accelerator Complex

- One of branches of KAERI
- Construction: 2002~2012 as 21c Frontier Project
- 100 MeV Proton Beam User Service: From 2013
- A site for the planned expansion has already been allocated



KOMAC Facilities

□ 100 MeV proton linear accelerator and several low energy ion accelerators



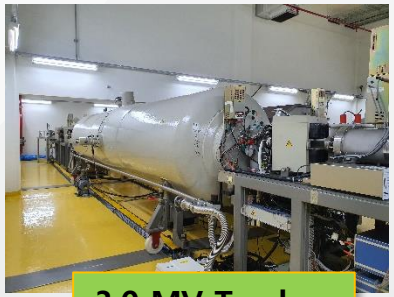

Gas ion beam


Metal ion beam


1.7 MV Tandem


1 MV single ended


1 MeV/n RFQ


3.0 MV Tandem

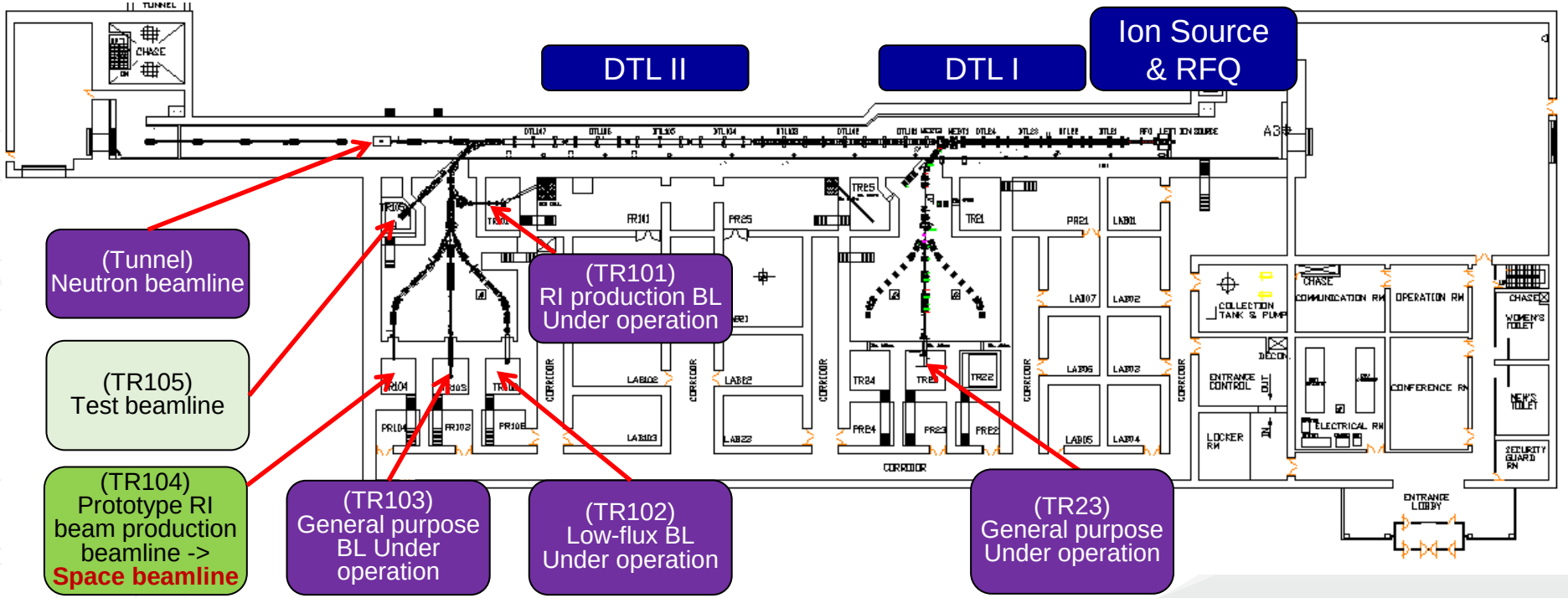
Korea Atomic Energy Research Institute

100 MeV Linac and Beamlines

- **Linac commissioning at 2013**
- **General purpose beamline and user service starts (2013~)**
- **RI production beamline (2016~)**
- **Low flux beamline (2017~)**
- **Accelerator test beamline (2017~)**
- **Prototype RI beam production beamline (2018~)**
- **Pilot operation of neutron beam test (2018~)**
- **Official operation of neutron beam service (2024 ~) / Total 4 proton beamlines and 1 neutron beamline are under user service in 2026**

Features of KOMAC 100MeV linac

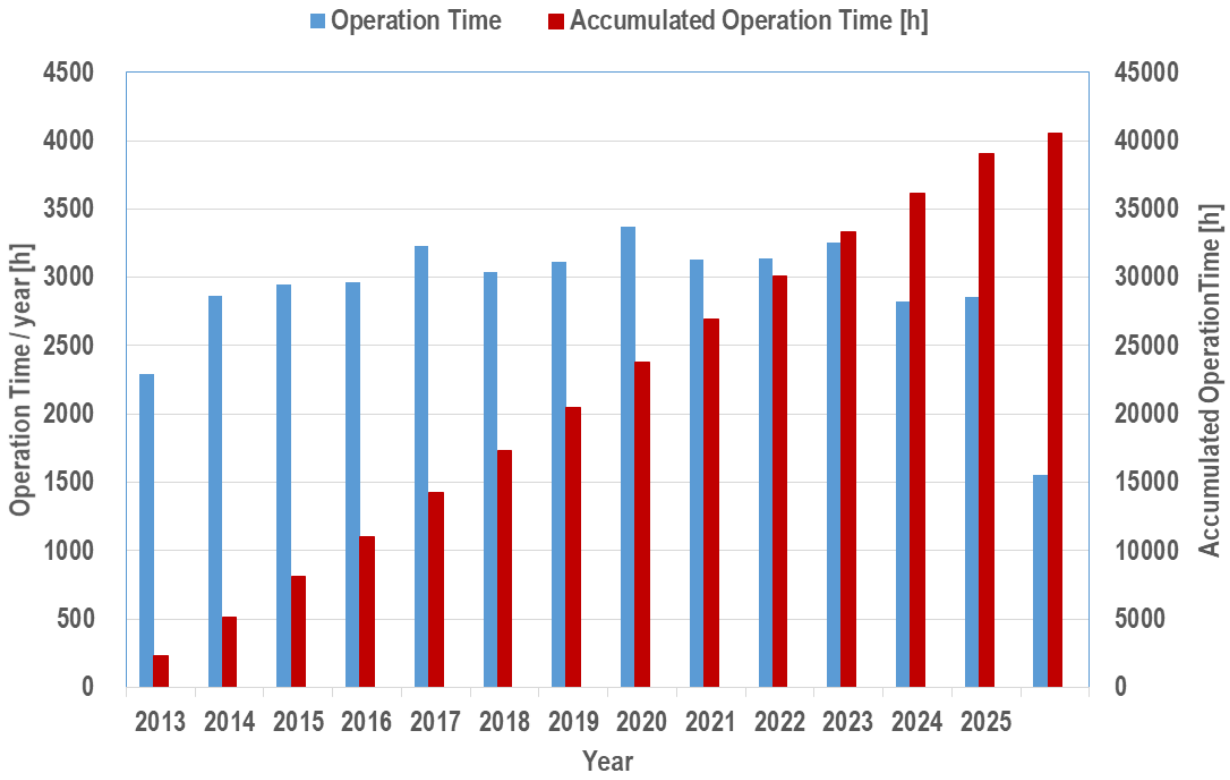
- 50-keV Injector (Ion source + LEBT)
- 3-MeV RFQ (4-vane type)
- 20 & 100-MeV DTL
- RF Frequency : 350 MHz
- Beam Extractions at 20 or 100 MeV
- 6 Beamlines for 20 MeV & 100 MeV



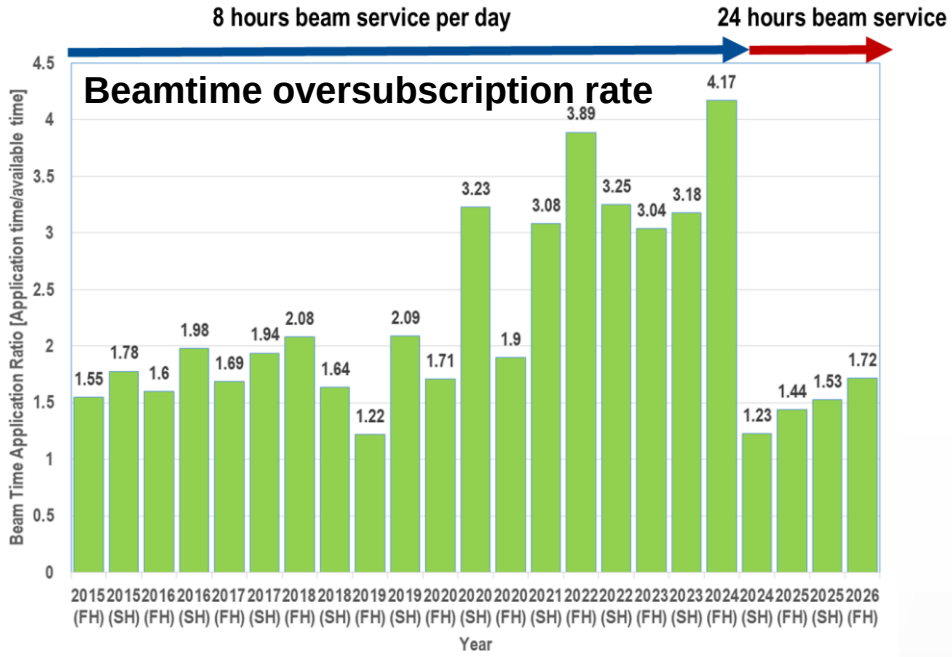
Korea Atomic Energy Research Institute

Operation Statistics

- Accumulated operation time exceeds 40,000 hours (2026.05)
- 24 hour beam service (2024.08~)

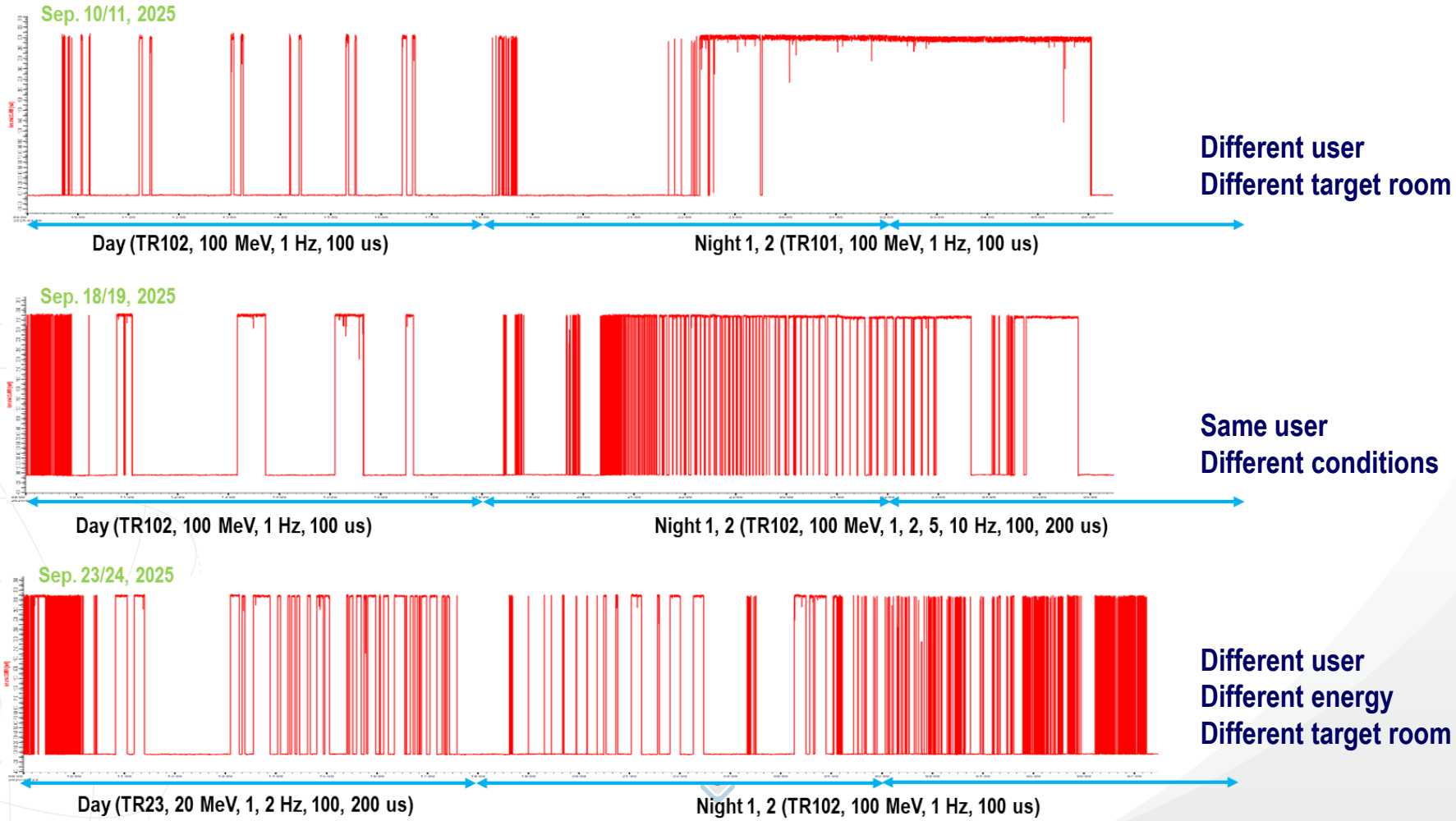


Annual and accumulated operation hours



Official 24-hour User Beam Service

- Change the beam service strategy: 1 slot per day -> 3 slots per day (to keep 8 hours per slot)
- Beam service characteristics: On / off proton beams with different energies, target rooms, operation conditions



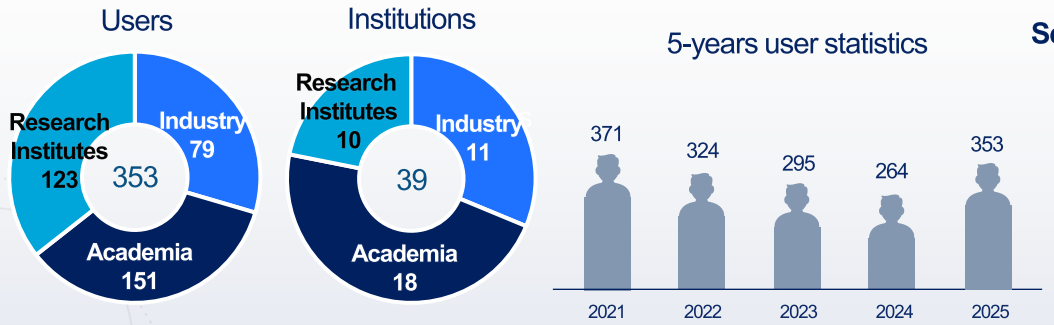
Korea Atomic Energy Research Institute

Beam User Statistics

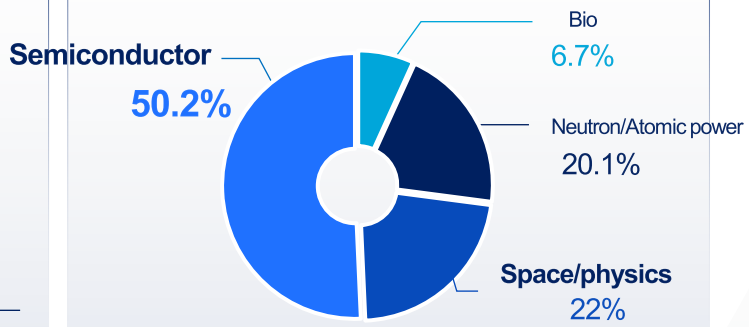
Utilization Overview

No. of Users	353
Operating days	210
Supported projects	112

User Statistics



Research Fields



(2013-2025) Cumulative 1,252 projects and 3,783 users

	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	'24	'25	Sum
Users	84	223	349	392	334	290	316	188	371	324	295	264	353	3,783
Projects	39	103	124	131	121	105	101	63	99	92	87	75	112	1,252
Days	64	195	176	162	146	123	139	94	142	139	150	141	210	1,881

Korea Atomic Energy Research Institute

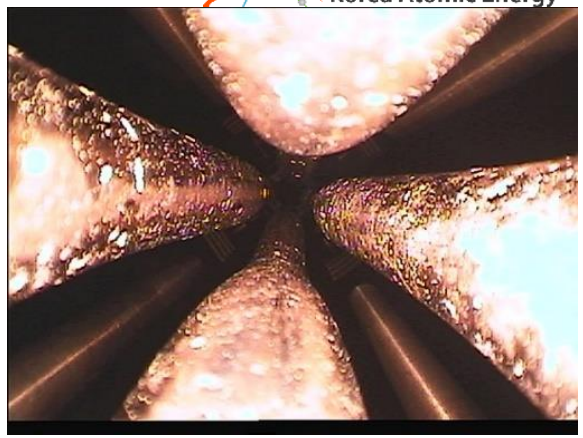
KOREA ATOMIC ENERGY RESEARCH INSTITUTE

02

Recent Research Activities

Aging Control: 3-MeV RFQ

- Operation since 2005 (First RFQ developed in Korea)
  - Low transmission rate
  - Field flatness check – dipole field tilting – retuning
  - Vane erosion check
- Spare RFQ is necessary (SNS, J-PARC, LINAC4 RFQ case)
  - KOMAC Strategy: Use until it fails, but we should prepare a spare RFQ ASAP
- Spare RFQ development
  - New design, Gentle buncher energy range 86.5 keV / 550 keV -> 54.0 keV / 580 keV (RFQ length : 3.2 m -> 3.5 m)
  - Field stabilization by dipole stabilization rods only (remove the coupling plate)
  - 4 sections -> 3 sections (in house brazing furnace)
  - New brazing technique (with modified filler groove, longer temperature ramping time)
  - Spare RFQ is under construction, completed in 2026



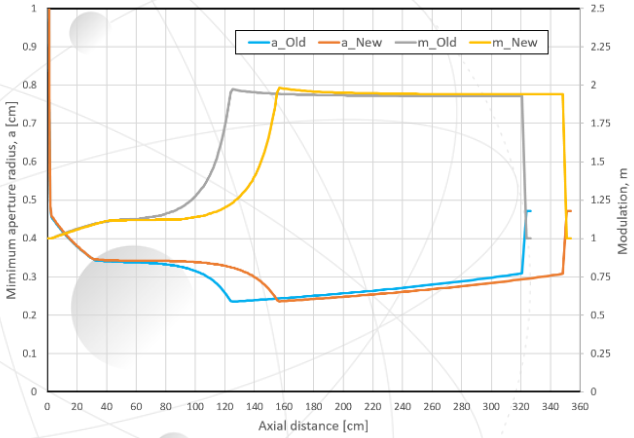
Vane erosion observed using endoscope

PHYSICAL REVIEW ACCELERATORS AND BEAMS 28, 104501 (2025)
Editors' Suggestion

Investigation of sputtering and erosion phenomena in radio-frequency quadrupoles

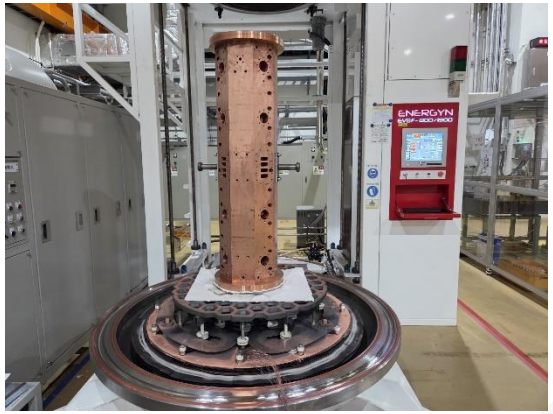
Emmanouil Trachanas,[1,2,*] Luca Bellan,[3] Gyula Nagy,[4] Antonio Palmieri,[3] Andrea Bignami,[1] Richard Arthur Wilhelm,[4] Francesco Grespan,[3] and Nikolaos Gazis[1]
[1]European Spallation Source, Lund, Sweden
[2]National Technical University of Athens, Athens, Greece
[3]National Institute for Nuclear Physics (INFN), Legnaro National Laboratories (LNL), Legnaro, Italy
[4]TU Wien, Institute of Applied Physics, Vienna, Austria

(Received 3 July 2025; accepted 8 October 2025; published 27 October 2025)

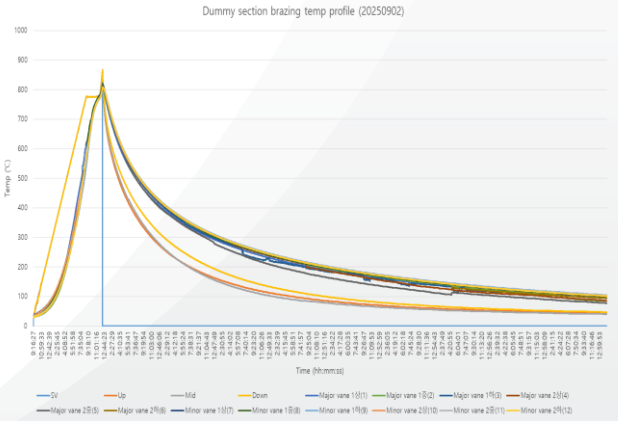


Vane modulation profile and vane radius (original and new one)

Major vane machining



In-house section brazing setup

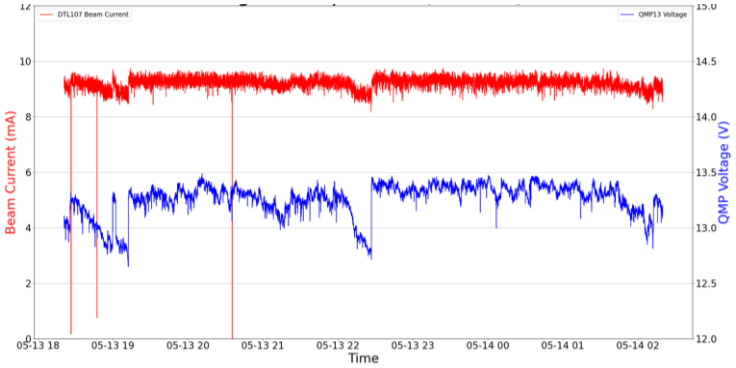


Temperature profile during section brazing

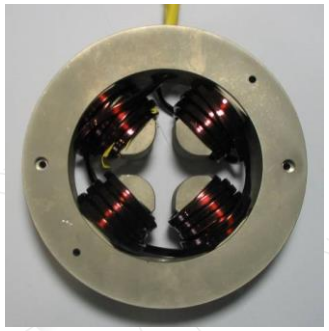
Korea Atomic Energy Research Institute

Aging Control: 20-MeV DTL

- Operation since 2005 (First DTL developed in Korea)
  - Used pool type electromagnet inside drift tube (cf. for DTL-II, hallow conductor EMQs are used)
  - Damaged insulation and corrosion of the yoke: electromagnet fault
  - Changed the fault drift tube with new one: 1~3 drift tubes per year
- Considering change of all DTQ from pool-type electromagnet to permanent magnet
  - 16 segments trapezoidal Halbach geometry with Sm_2Co_{17} (neutron-induced degradation, temperature effect)
- 1 (spare) DTL tank is under fabrication based on the PMQ, completed in 2026

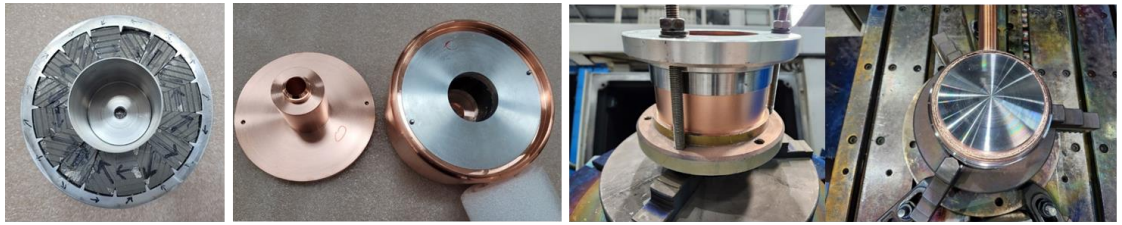


Beam current fluctuation depending on DTQ PS voltage

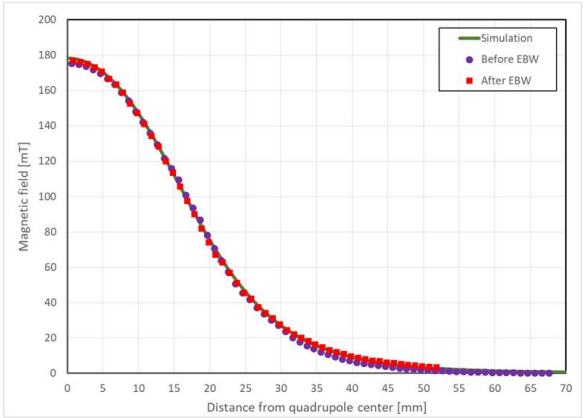


Pool type electromagnet (20 MeV DTL)

Cutting view of the drift tube
Poor insulation between windings and yoke



Array assembly → Installation → Magnetic shield

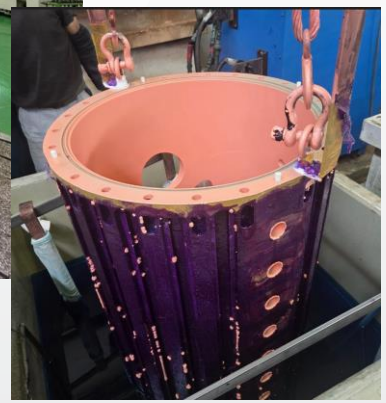


Magnet measurement (Before and after the welding)

E beam welding

Vacuum test

Fabrication process of the prototype PMQ

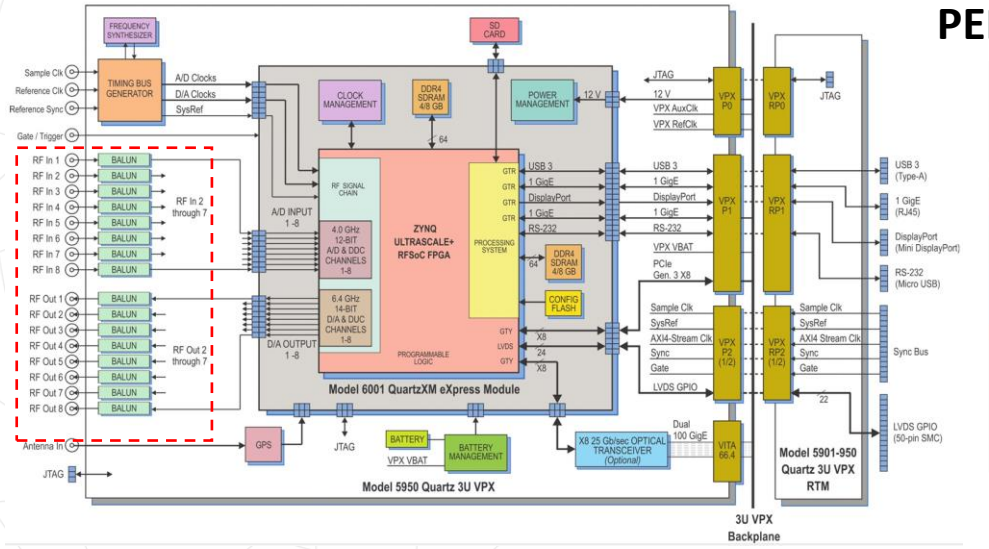


DTL tank fabrication (machining and Cu-plating)

Legacy Control Hardware Upgrade

- **Legacy VME-based hardware will be replaced with modern RFSoC and Micro TCA platform to improve performance, reliability, maintainability, and long-term sustainability of the accelerator control system**
- **Legacy LLRF & Diagnostics & Timing System Modernization**

Legacy System	Upgraded System	Key Benefits
VME-based LLRF Controller	UltraScale+RFSoC for LLRF and BPM	Integrated RFSoC architecture (ADC,DAC,FPGA) Higher-performance real-time digital signal processing
MRF EVG-230/EVR-230 (VME)	EVM-300/EVR-300 (MicroTCA)	Long-term maintainability Scalability for future accelerator upgrades



PENTEK Model 5950

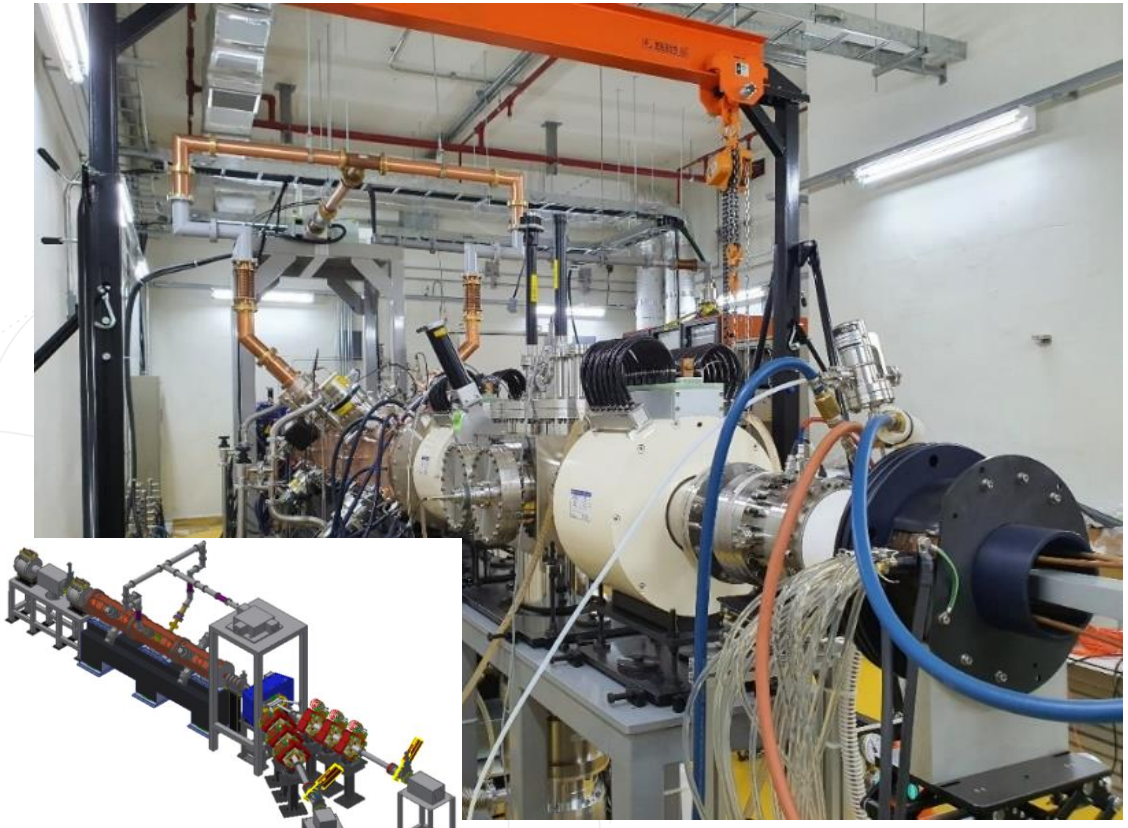
mTCA EVM-300

mTCA EVR-300

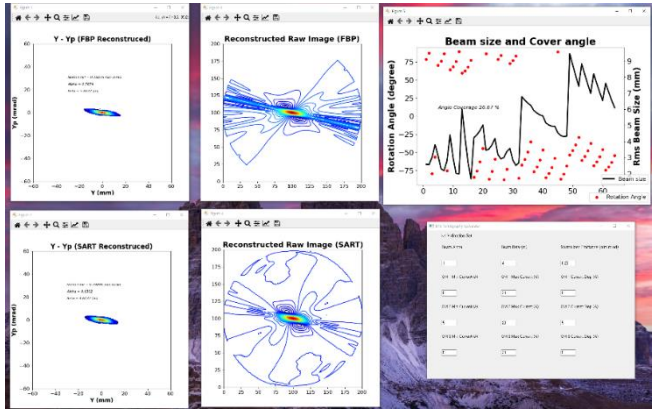
KAERI Korea Atomic Energy Research Institute

BTS: Beam Test Stand based on 1 MeV/n RFQ

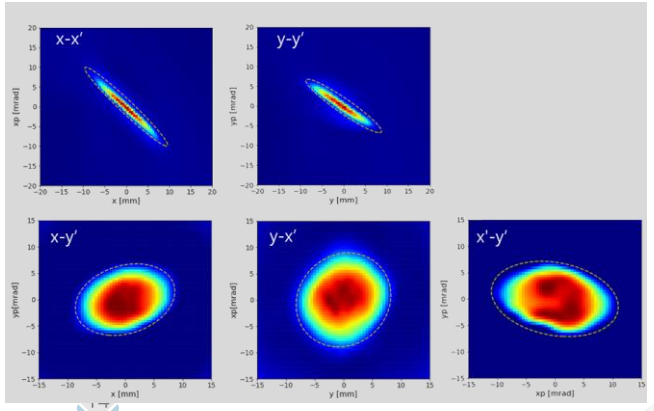
- BTS operation (2022~)
- Ion source characterization (Gas neutralization, time evolution of the beam)
- LLRF control algorithm development (Adaptive FF based on iterative learning)
- Beam diagnostics (Allison scanner, gas profile measurement, 4D measurement, CT, VPP)
- Optimization based on machine learning



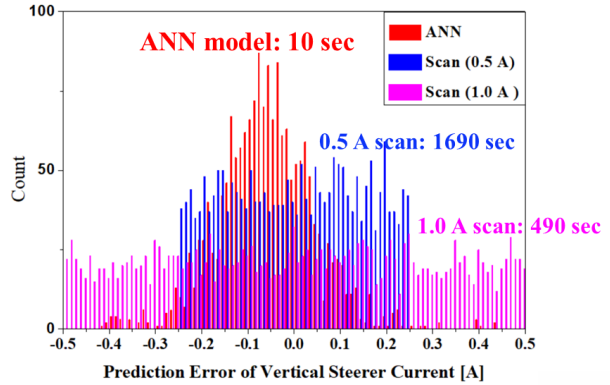
Beam Test Stand



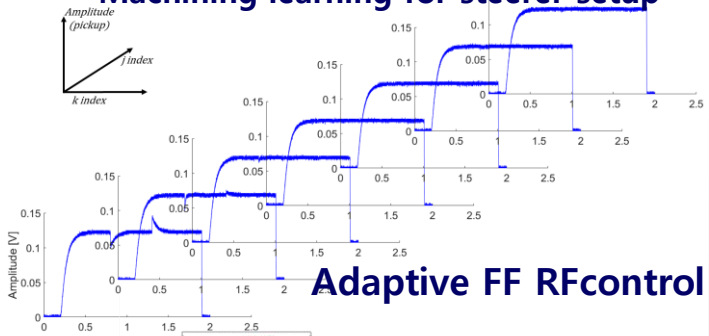
CT based beam measurement



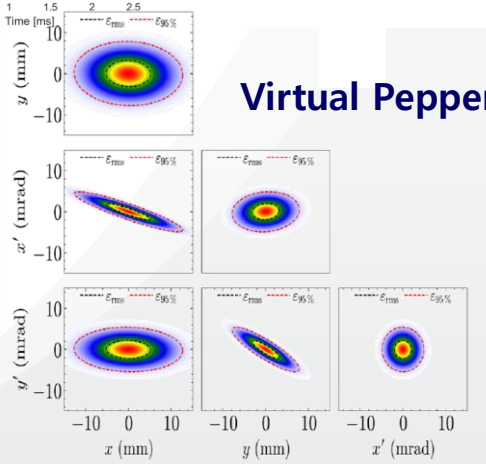
4D phase space measurement



Machining learning for steerer setup



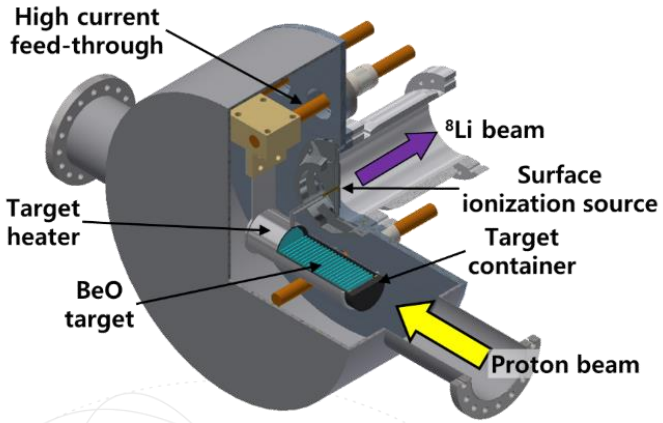
Adaptive FF RFcontrol

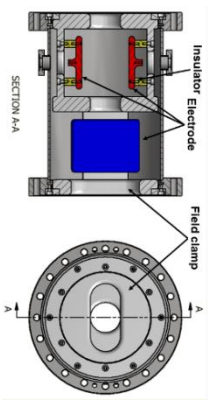


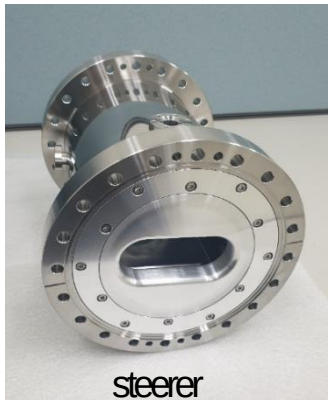
Virtual Pepper-pot

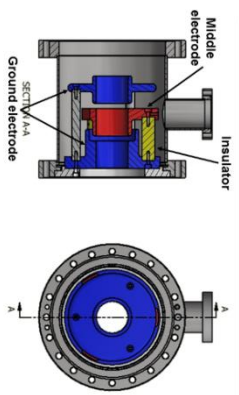
RI Beam Production

- Radio-active Isotope beam generation (Li8+, 30 keV) by using 100 MeV proton beam on target ion source
- Basis of beta-NMR spectroscopy for advanced surface analysis

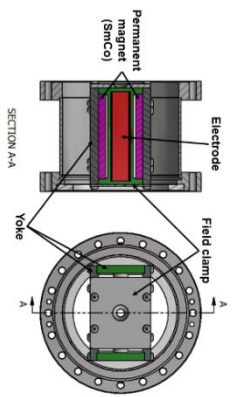


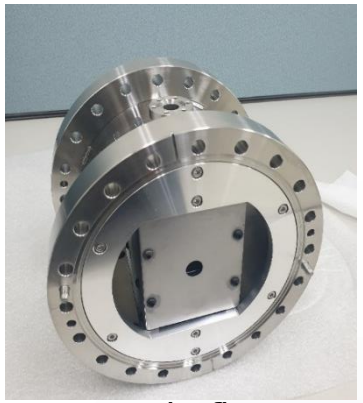


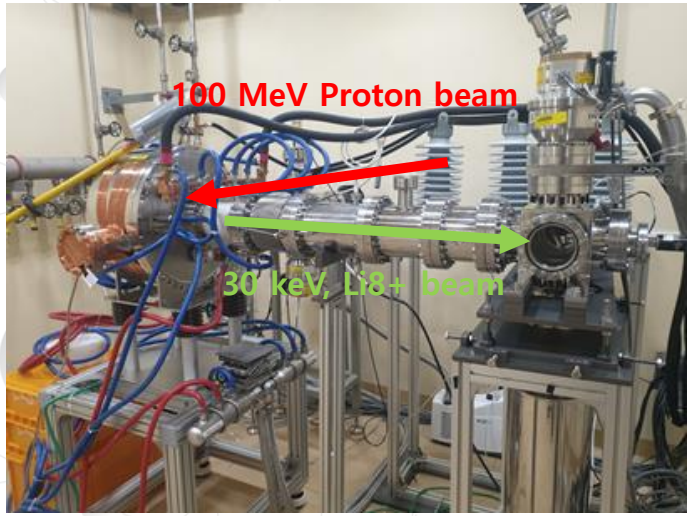

steerer



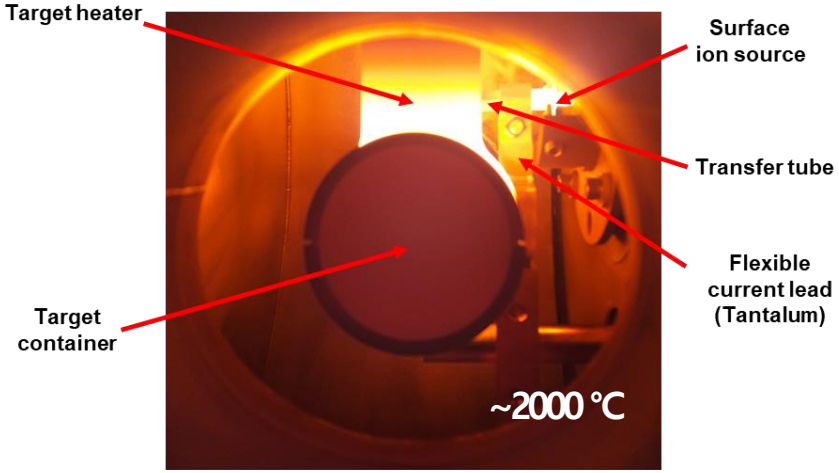

Einzel lens



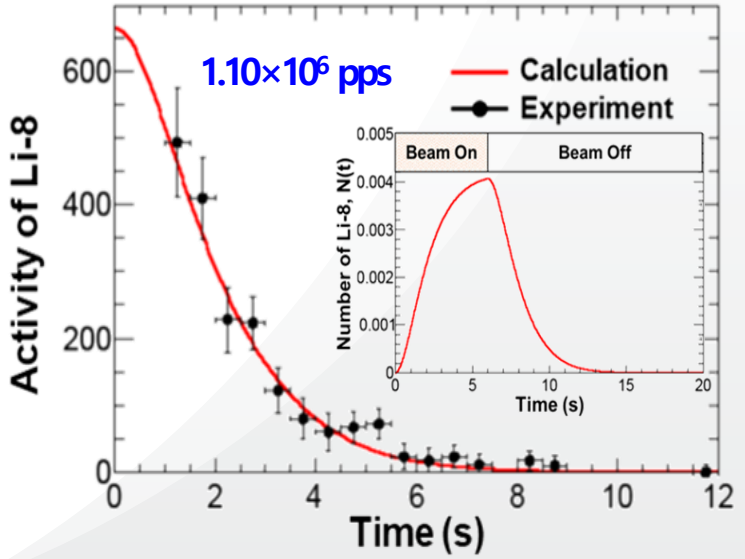

Wien filter



Target Ion Source (TIS)



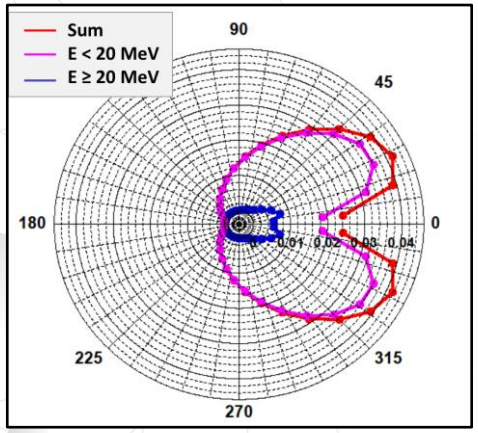
Target & ion source heating



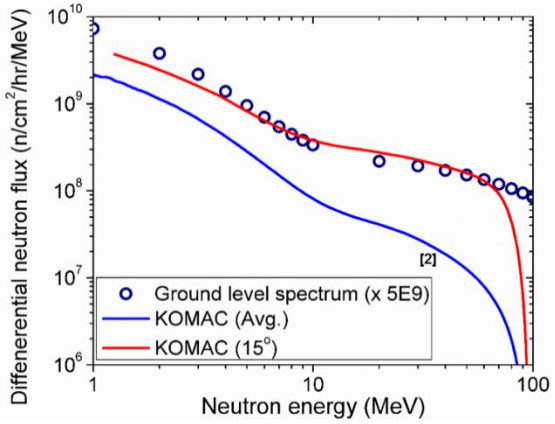
Neutron Beam Service

- Using by-product neutron at the beam dump
- Official user service from 2025

Beam dump (neutron generation target)



Angular distribution



Energy spectrum

Terrestrial radiation test facility

User control room

Beam Trigger-Synchronized Data Acquisition

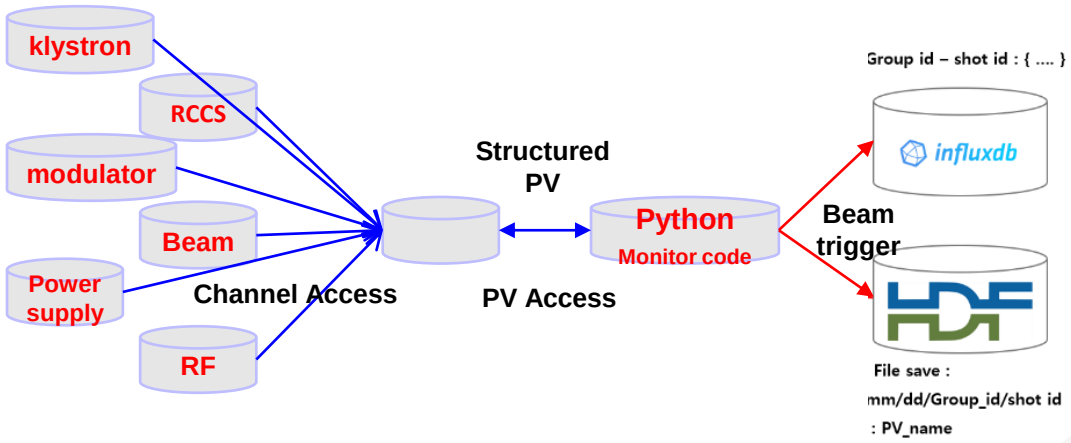
- **Objective**
  - **Diversify the data storage architecture**
  - **Collect synchronized Beam-RF time-series data**
  - **Generate AI-ready features for inference and prediction**

→ Data Acquisition
- Synchronize Beam Trigger, RF, and Timing data
- Store synchronized data in InfluxDB

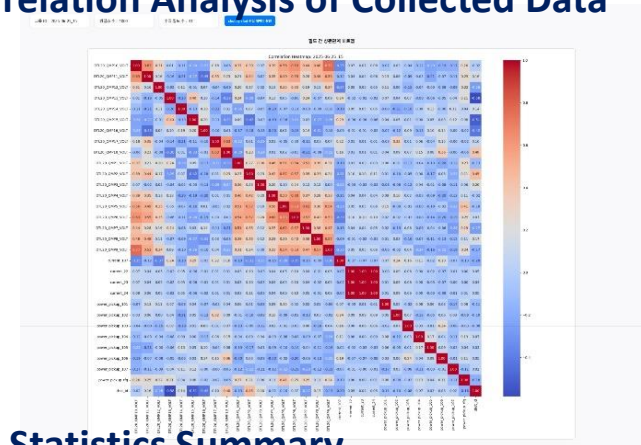
→ Feature Extraction
- Shot-based statistical features

→ AI Analytics:
- Anomaly Detection,
- Trip Prediction,
- Beam Quality Prediction

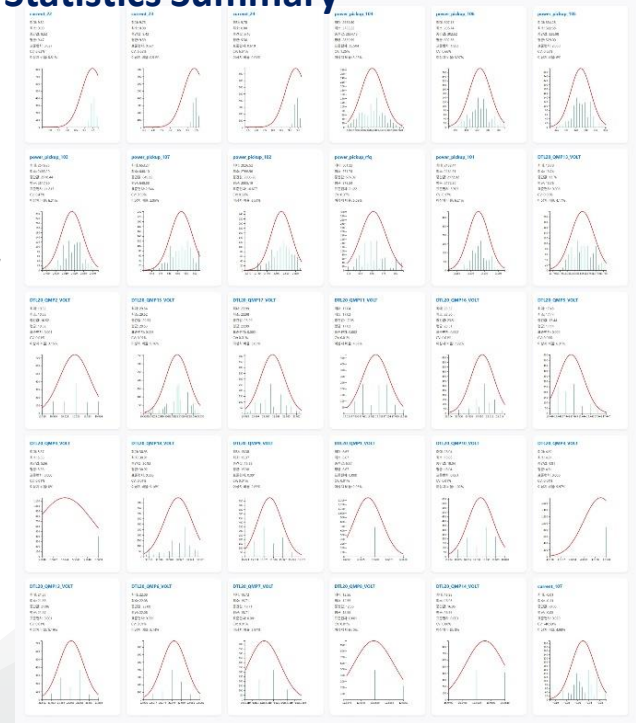
→ ***Towards Smart Operation***
- Predictive Maintenance
- Higher Reliability
- Digital Twin & Autonomous Operation



Correlation Analysis of Collected Data



PV Statistics Summary



Korea Atomic Energy Research Institute

KOREA ATOMIC ENERGY RESEARCH INSTITUTE

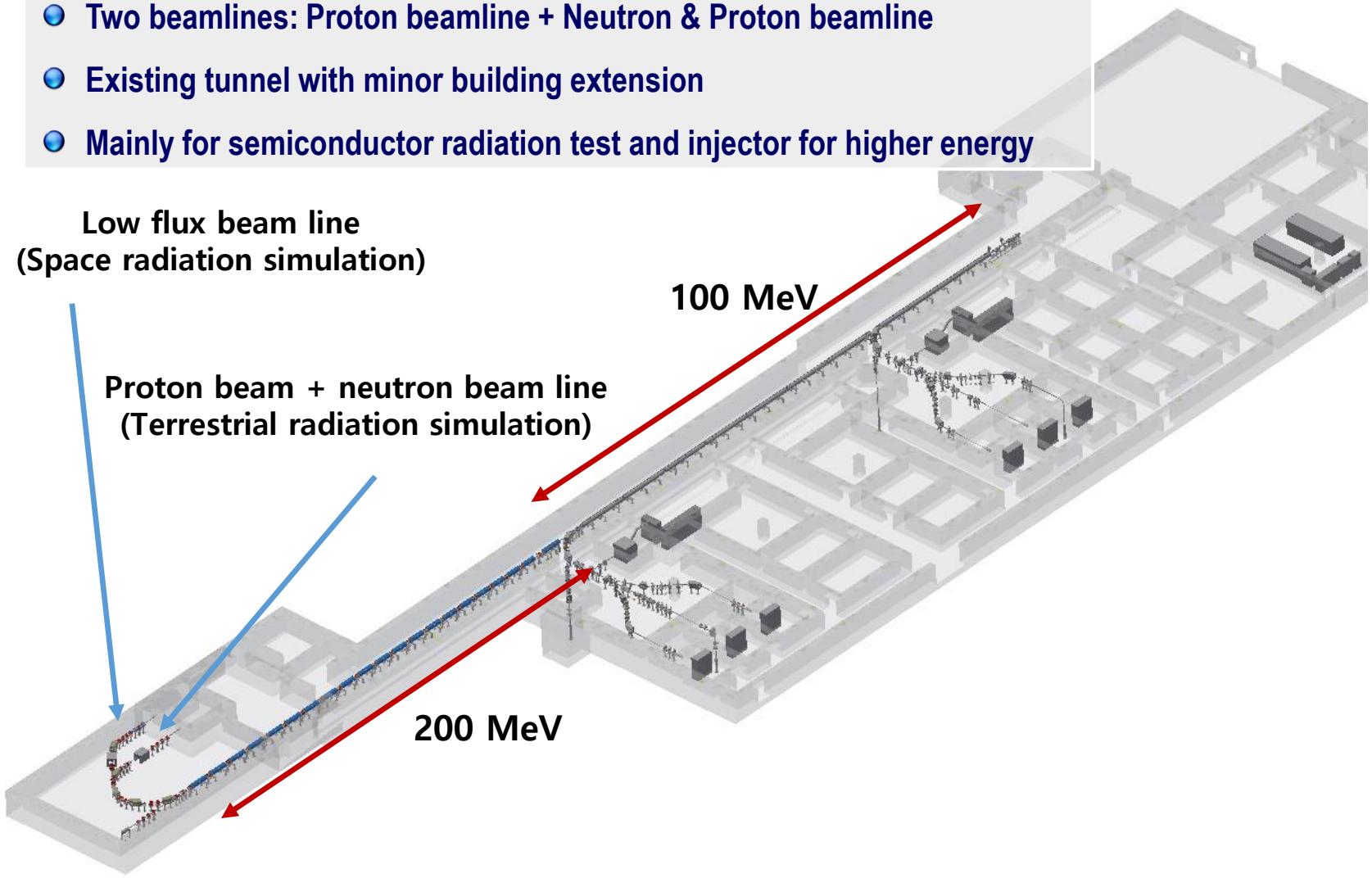
03

Upgrade Plan

Korea Atomic Energy Research Institute

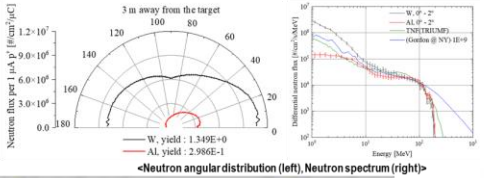
KOMAC Phase2: 200 MeV Linac Upgrade

- Energy upgrade up to 200 MeV by using SDTL
- Two beamlines: Proton beamline + Neutron & Proton beamline
- Existing tunnel with minor building extension
- Mainly for semiconductor radiation test and injector for higher energy

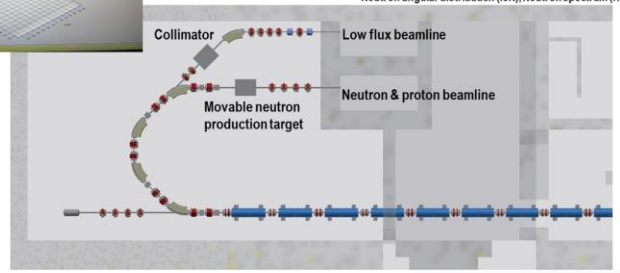


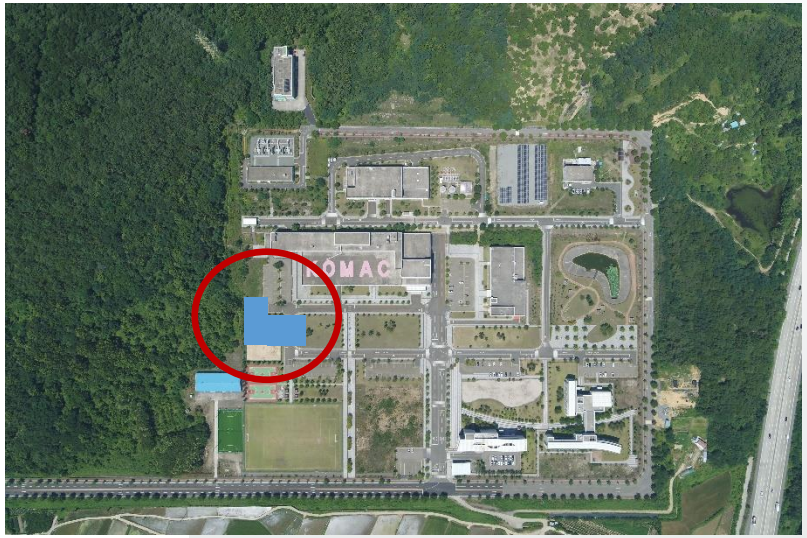
Low flux beamline (Space radiation test)
- Beam species: Proton
- Maximum energy: 200 MeV
- Beam size: 100 mm X 100 mm
- Uniformity: < 10%
- Flux range: 10^6 ~ 10^8 p/cm² s

Proton & neutron beamline (Terrestrial radiation test)
- Beam species: Neutron, proton
- Neutron maximum energy: 200 MeV
- Neutron flux: > 10^6 n/cm² s (> 10 MeV)
- Proton maximum energy: 200 MeV



<Neutron angular distribution (left), Neutron spectrum (right)>



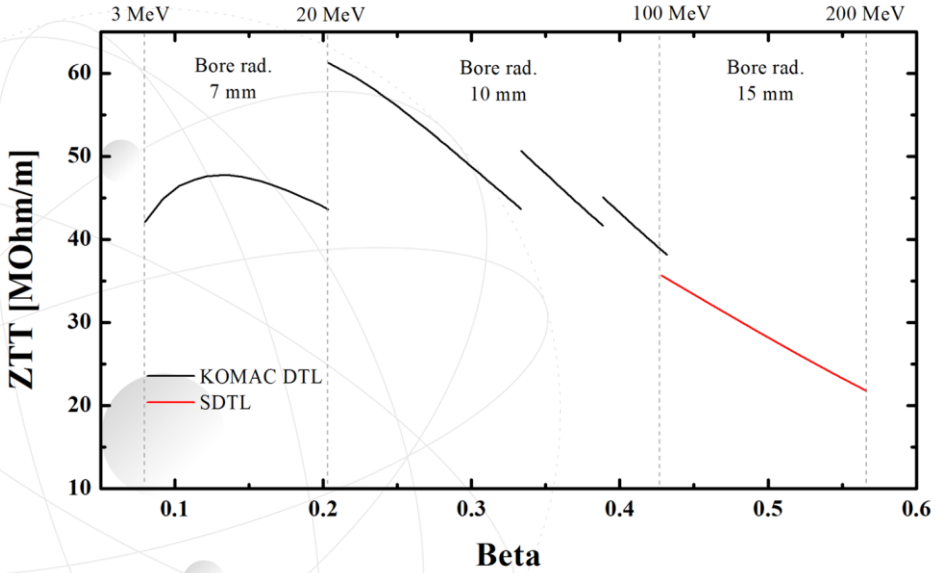


Korea Atomic Energy Research Institute

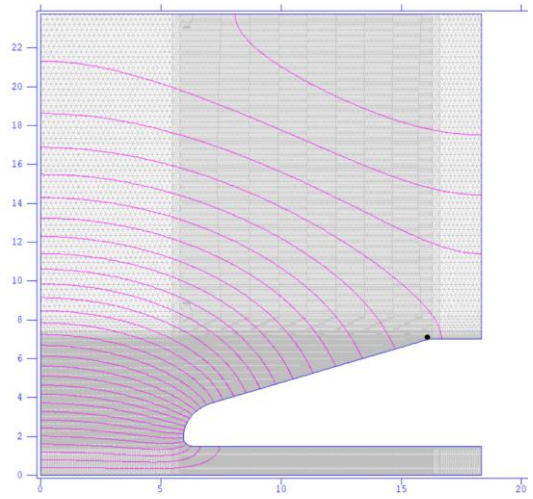
KOMAC Phase2: 200 MeV Linac Upgrade

SDTL drift tube design

- DT geometry optimization
- Structure : 6 cell per a tank containing 5 DTs
- Proton energy : ~ 200 MeV when E0 = 3.8 MV/m , phase = -28 ° (16 SDTL tanks required)
- Tank length : 225 ~289 cm (entire SDTL section length : 55.3 m)
- RF power required : 820 ~ 1110 kW for 20 mA



ZTT for 3 ~ 200 MeV



Optimized DT geometry

Optimized cell parameters

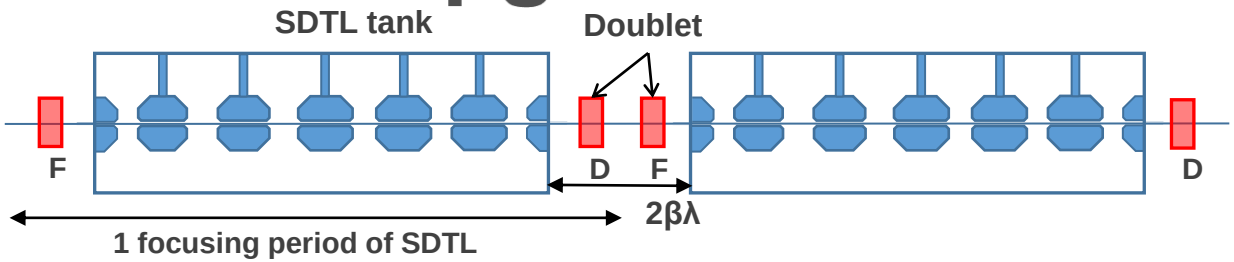
RF frequency	350 MHz
Reference temperature	27 °
Energy range	100~ 200 MeV
E0	3.8 MV/m
Max. Kilpatrick	1.4
Tank diameter	475 mm
Drift tube diameter	14 mm
Bore radius	15 mm
Drift tube face angle	70 °
Drift tube flat length	1 mm
Corner radius	1 mm
Inner nose radius	4.5 mm
Outer nose radius	18 mm
Stem diameter	36 mm

Korea Atomic Energy Research Institute

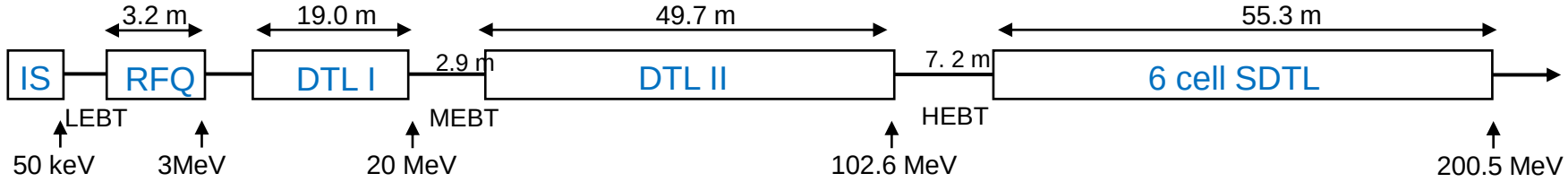
KOMAC Phase2: 200 MeV Linac Upgrade

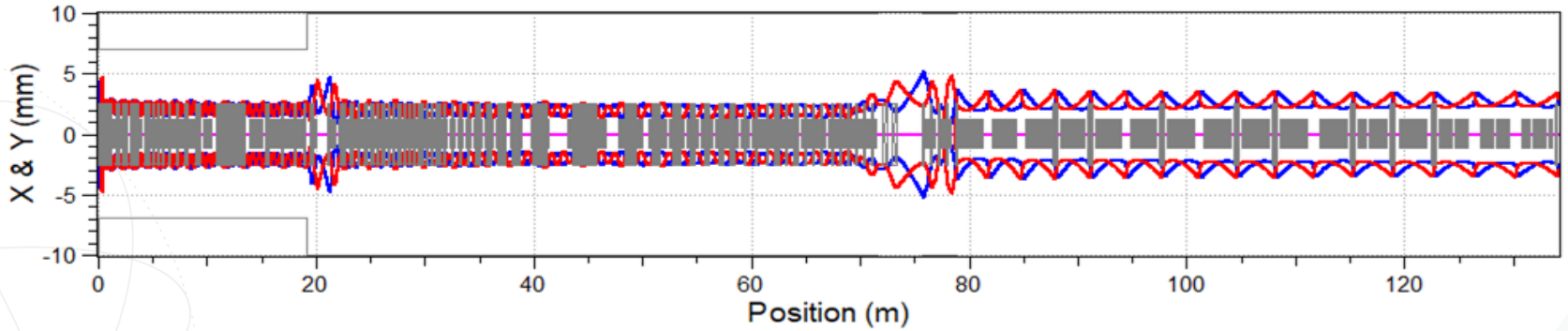
SDTL Lattice

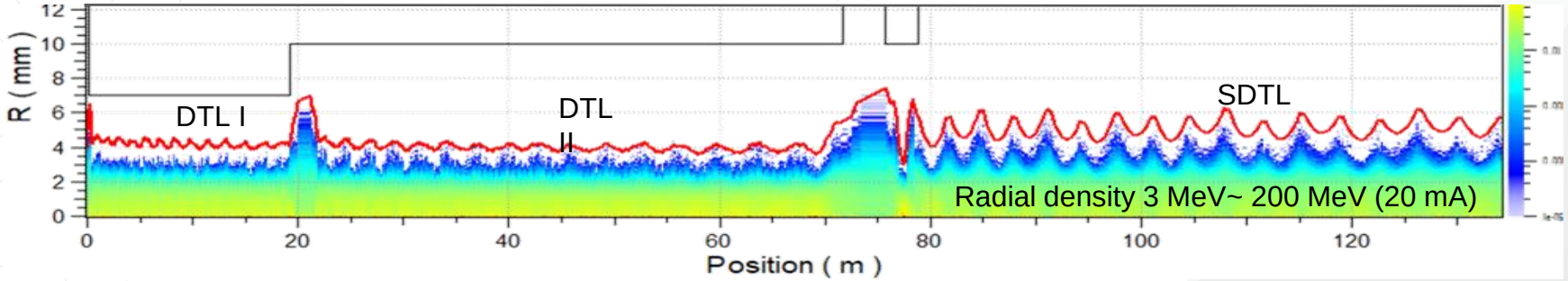
- **Doublet focusing structure**
- **Lattice period : Doublet center to next doublet center**



Doublet focusing structure







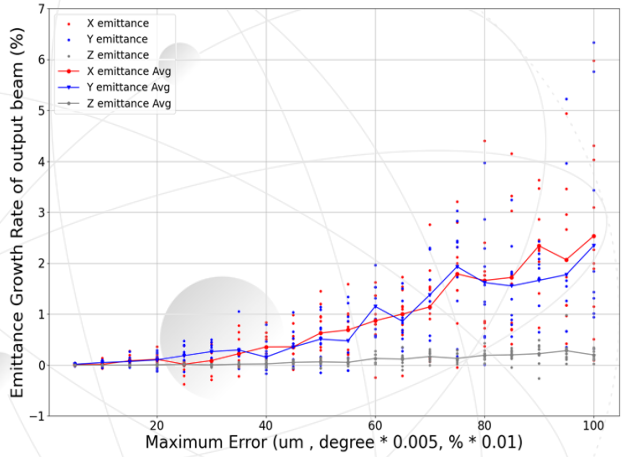
KOMAC Phase2: 200 MeV Linac Upgrade

Error studies

- **Error distribution type: Uniform distribution**
- **Input Beam Current : 20 mA**
- **Error statistical set up: 10 lattice per 1 step**
- **# of Error lattice: 200 (10 lattice * 20 step)**
- **Result : max. 2 % emittance growth for quad magnet errors,**
- **significant impact on emittance growth for input beam centroid & angle**

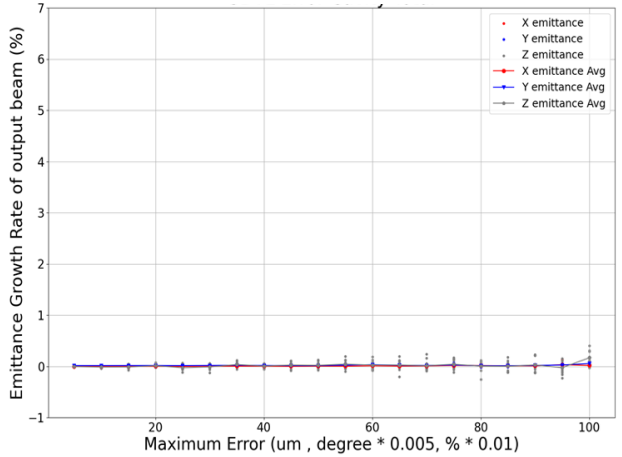
Error Type	Value
Quad magnet displacement (dx, dy)	$\pm 100\ um$
Quad magnet rotation (ϕ_x, ϕ_y, ϕ_z)	$\pm 0.5°, 0.5°, 0.25°$
Quad magnet gradient	$\pm 1\%$
Cavity displacement (dx, dy)	$\pm 100\ um$
Cavity rotation (ϕ_x, ϕ_y)	$\pm 0.5°$
Cavity Acc. Voltage	$\pm 1\%$
Cavity Phase (ϕ_{sync})	$\pm 1°$

SDTL Error Quad Total



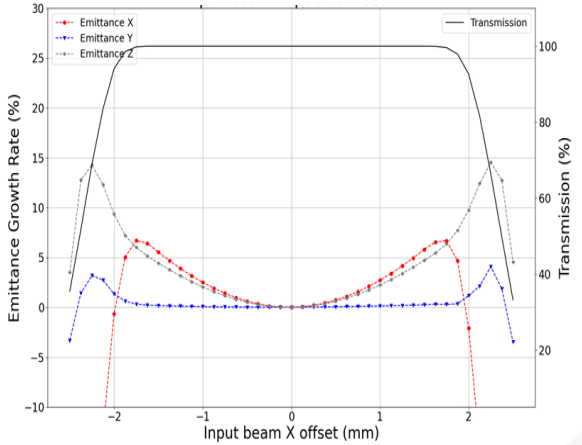
max emittance growth : ~ 2 %

SDTL Error Cavity Total

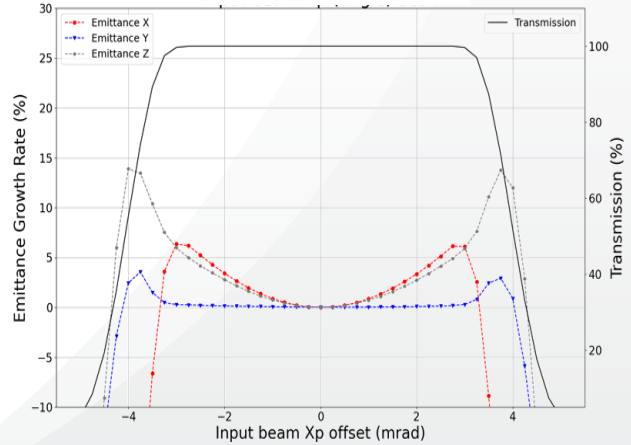


no Emittance growth

Centroid Shift



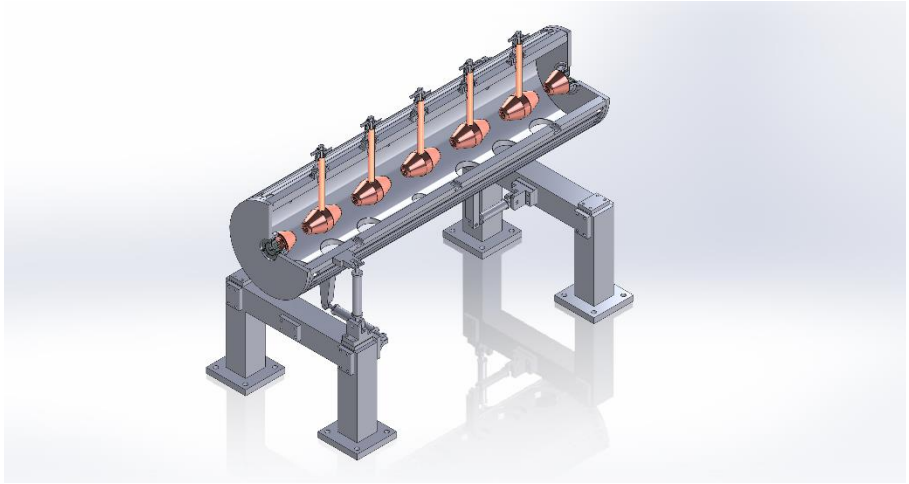
Angle



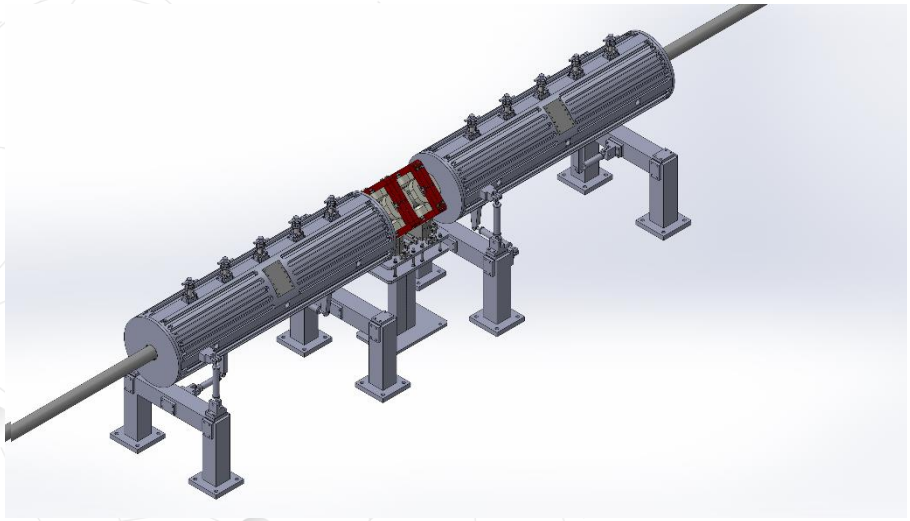
significant emittance growth

Korea Atomic Energy Research Institute

KOMAC Phase2: 200 MeV Linac Upgrade



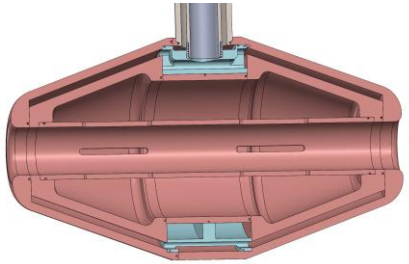
6-cell SDTL tank

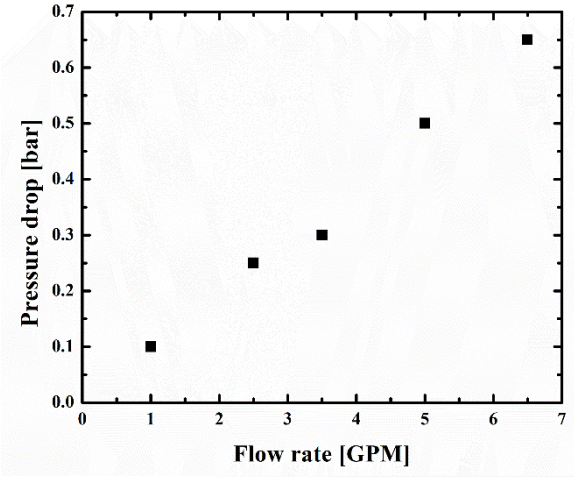


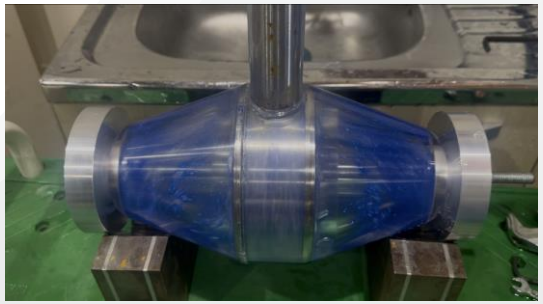
SDTL tank with doublet magnet

Prototyping of the drift tube for SDTL

- **Separate cooling channels for central and peripheral region**
- **In addition to the copper prototype, acrylic prototype was fabricated to visualize coolant flow**





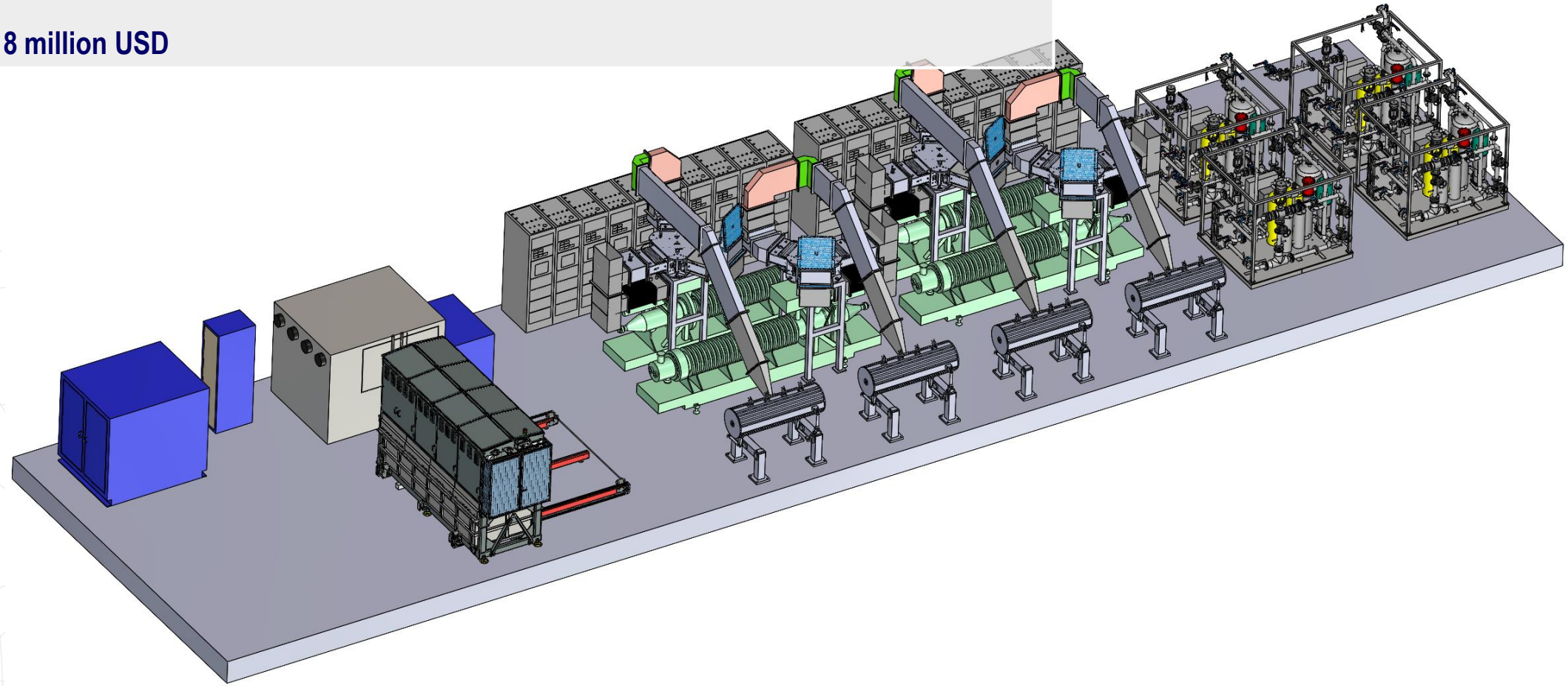


Korea Atomic Energy Research Institute

KOMAC Phase2: 200 MeV Linac Upgrade

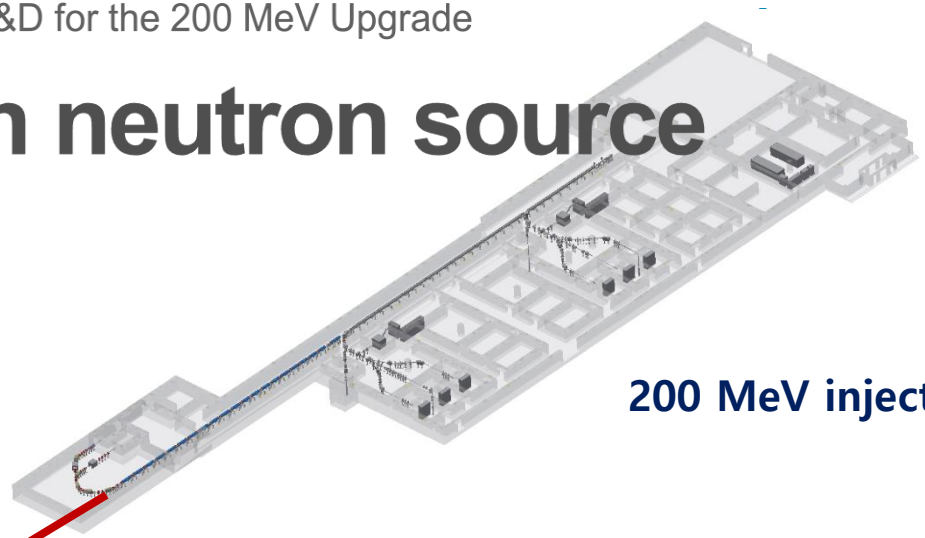
Pilot R&D for 200 MeV Upgrade

- Scope: First 4 SDTL tanks with RF system including LLRF, klystron, HV modulator and utilities
- Period: 2026.4.1.~2028.12.31.
- Budget: ~18 million USD

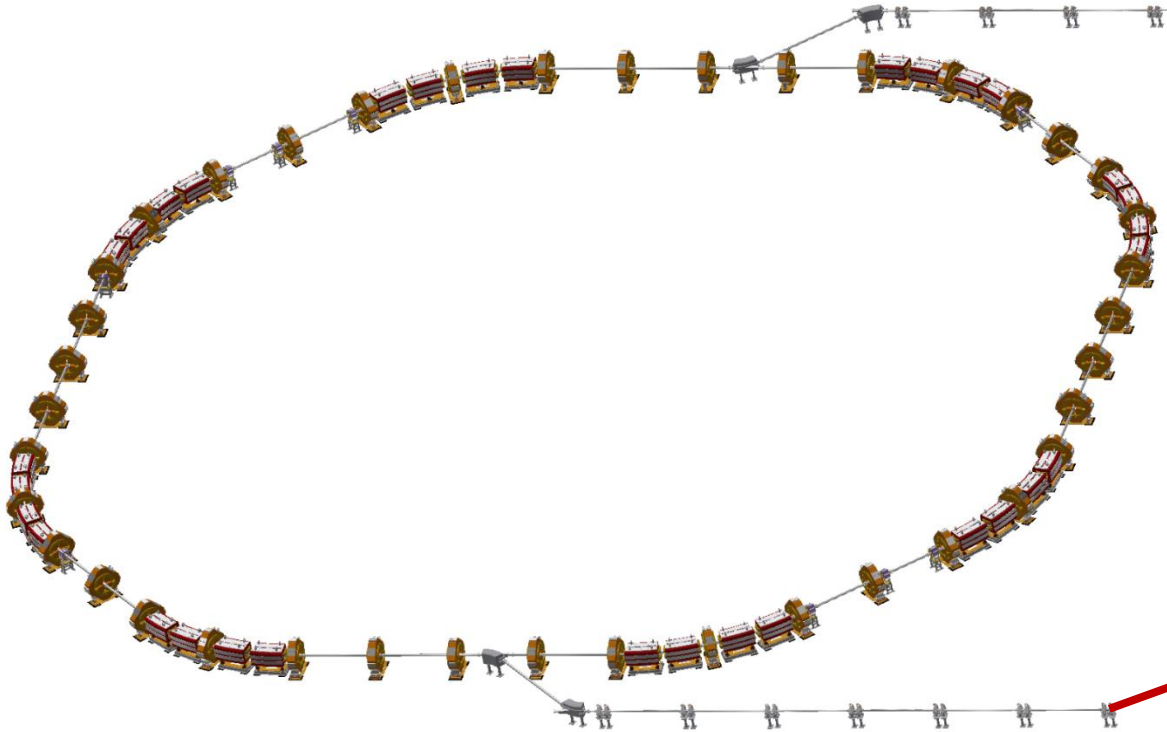


KOMAC Phase3: Spallation neutron source

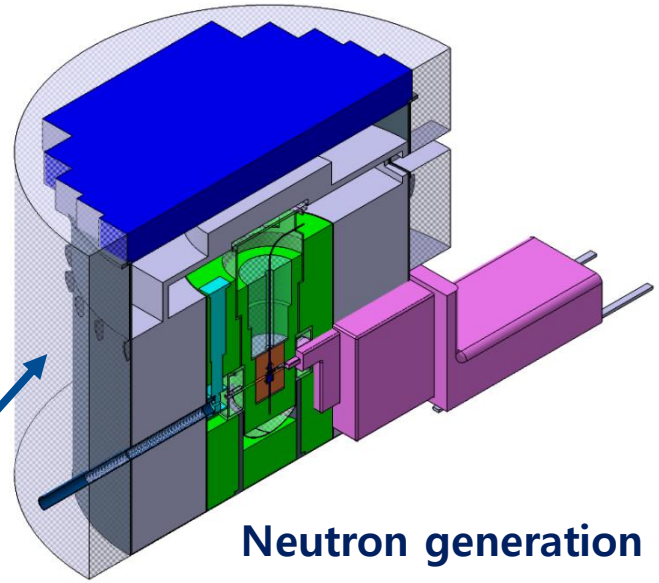
- GeV-grade accelerator
- Neutron generation target
- Utilization instruments
- Dedicated building and utilities



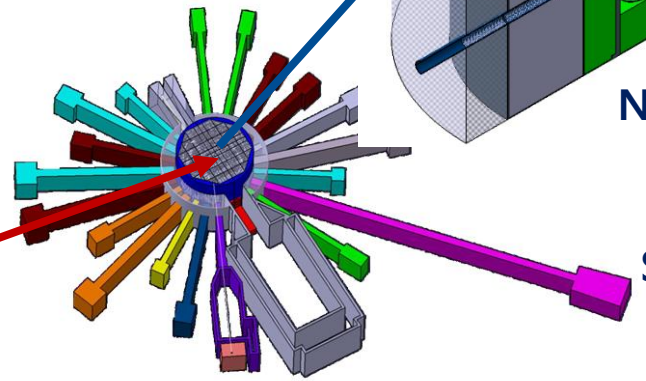
200 MeV injector



GeV-grade RCS



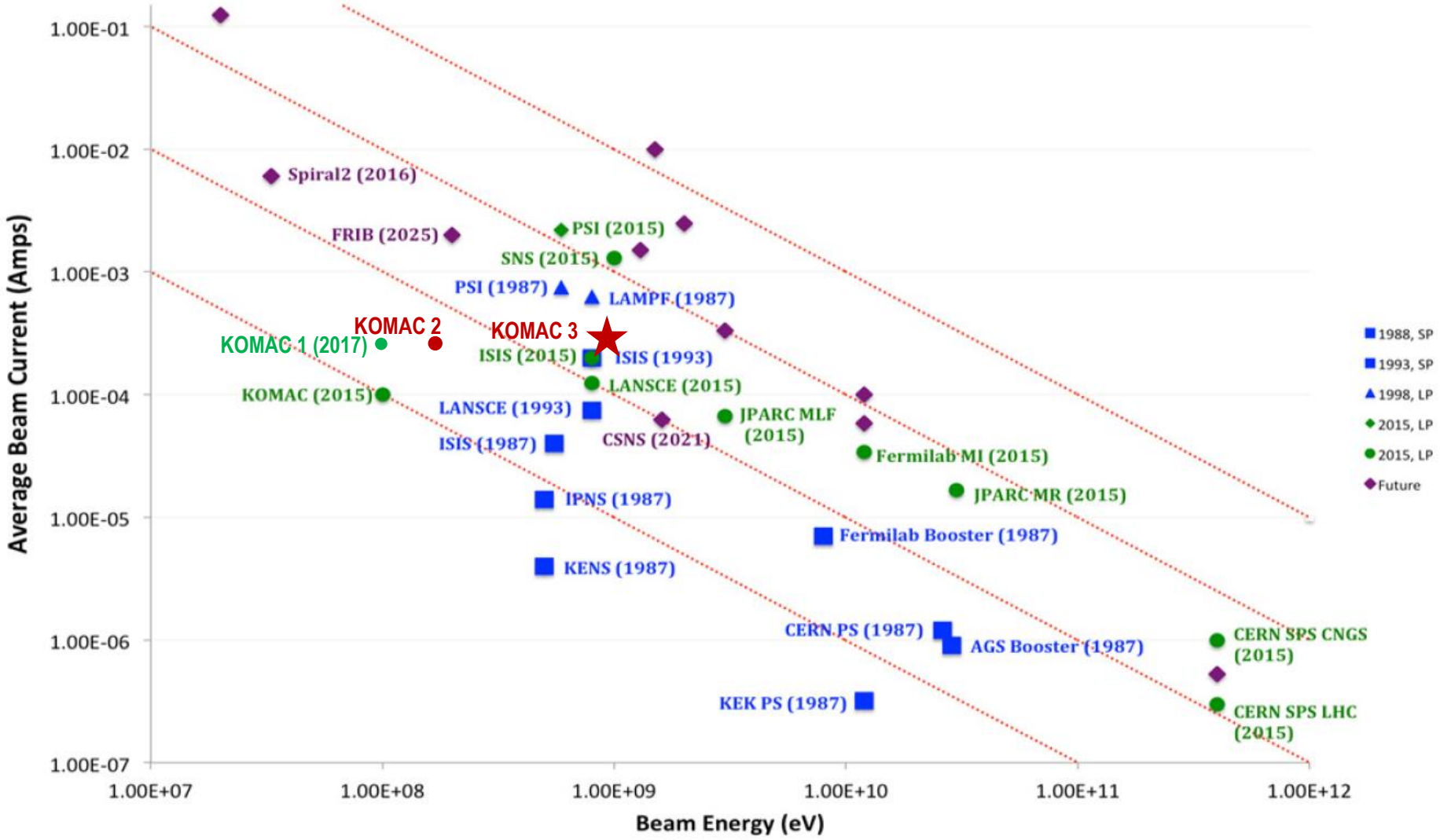
Neutron generation target



Spallation neutron source
And instruments

Korea Atomic Energy Research Institute

High Power Proton Accelerators



Modifed based on S. Cousineau, High power proton facilities: Operational experience, challenges and the future, Proceedings of 6th International Particle Accelerator Conference, Richardmond, VA, USA, 2015)

Korea Atomic Energy Research Institute

KOREA ATOMIC ENERGY RESEARCH INSTITUTE

04

Summary

Summary

Operational Status

- Commissioned in 2013 and surpassed 40,000 operating hours in 2026.
- Increasing competition for beam time, leading to the provision of 24-hour beam services.
- Radiation effects testing of semiconductors and space components for both space and terrestrial radiation environments.
- User programs supporting high-energy physics, nuclear physics, and advanced life science research.

Current Accelerator R&D Activities

- Aging management through the development of spare RFQ and DTL systems.
- Upgrade of legacy accelerator control hardware.
- Accelerator research based on Beam Test Stand (BTS) facilities.
- Development of radioactive isotope (RI) beam generation technologies.
- Expansion of neutron beam services.
- Development of a beam-synchronized data acquisition system.

Energy Upgrade Plan

- Development of a 200 MeV proton accelerator (KOMAC Phase II).
- Long-term plan for a spallation neutron source facility (KOMAC Phase III)

Korea Atomic Energy Research Institute

Thank you