

Status of the Proton Accelerator Program in Korea - Focused on KOMAC Facility -

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KOMAC / KAERI



K O M A C
Korea Multi-purpose Accelerator Complex
양성자가속기연구센터

Overview: KAERI

- Nuclear R&D Institute (Power & Radiation Applications) established in 1959
- Located in 3 sites : HQ(Daejeon, 1980), ARTI(Jungup, 2005), **KOMAC(Gyeongju, 2013)**

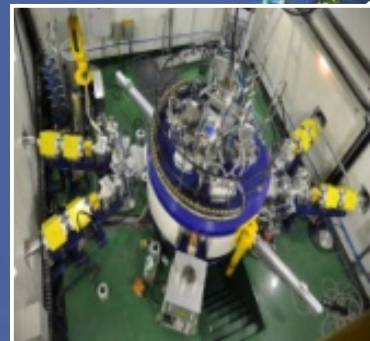
KAERI HQ (Daejeon)
▪ 20-MW RR Hanaro (1995~)



KAERI-KOMAC (Gyeongju)
▪ 100-MeV Proton Linac (2013~)



KAERI-ARTI (Jungup)
▪ 30-MeV Cyclotron (2014~)

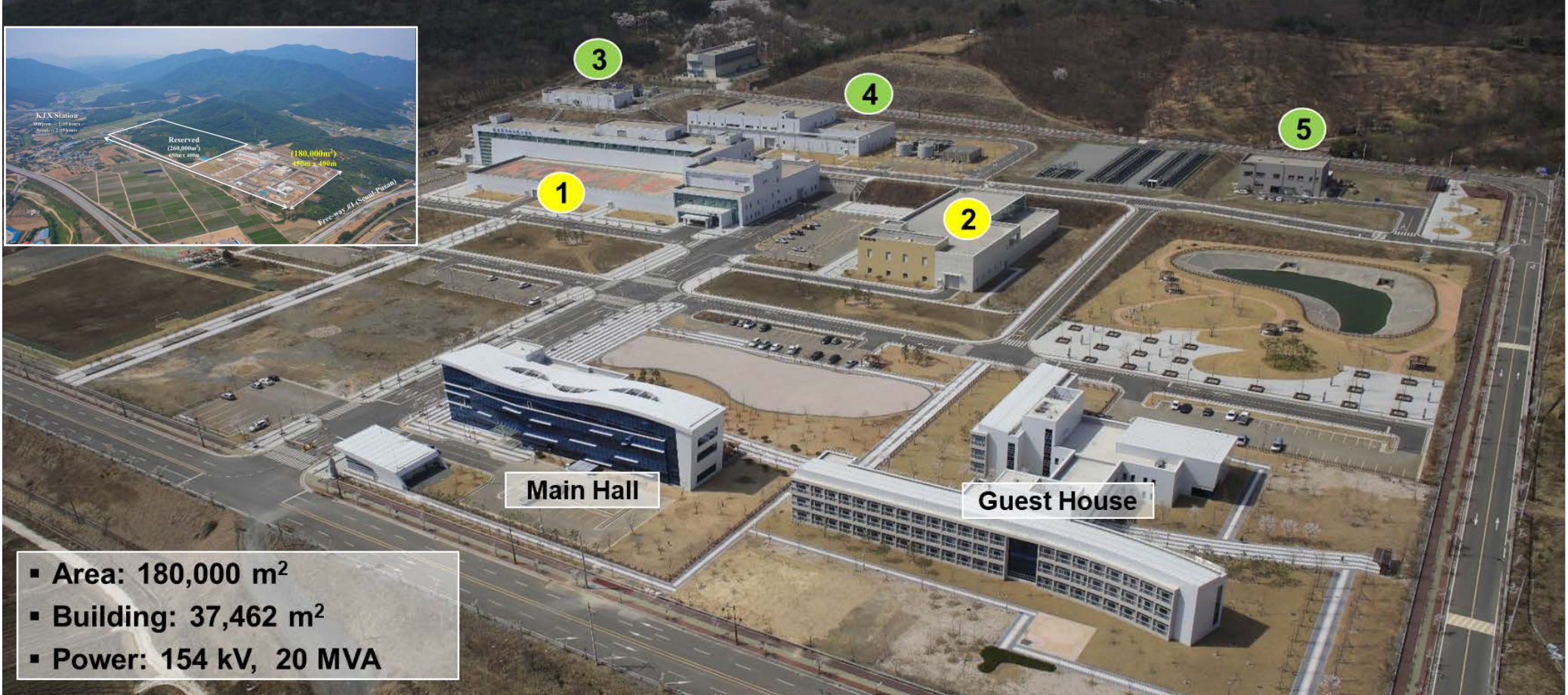


New RR (Busan)
▪ 20-MW RR (2019~)



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Image Landsat

❖ Located on Miraero (road to the future), Gyeongju (a historic city)



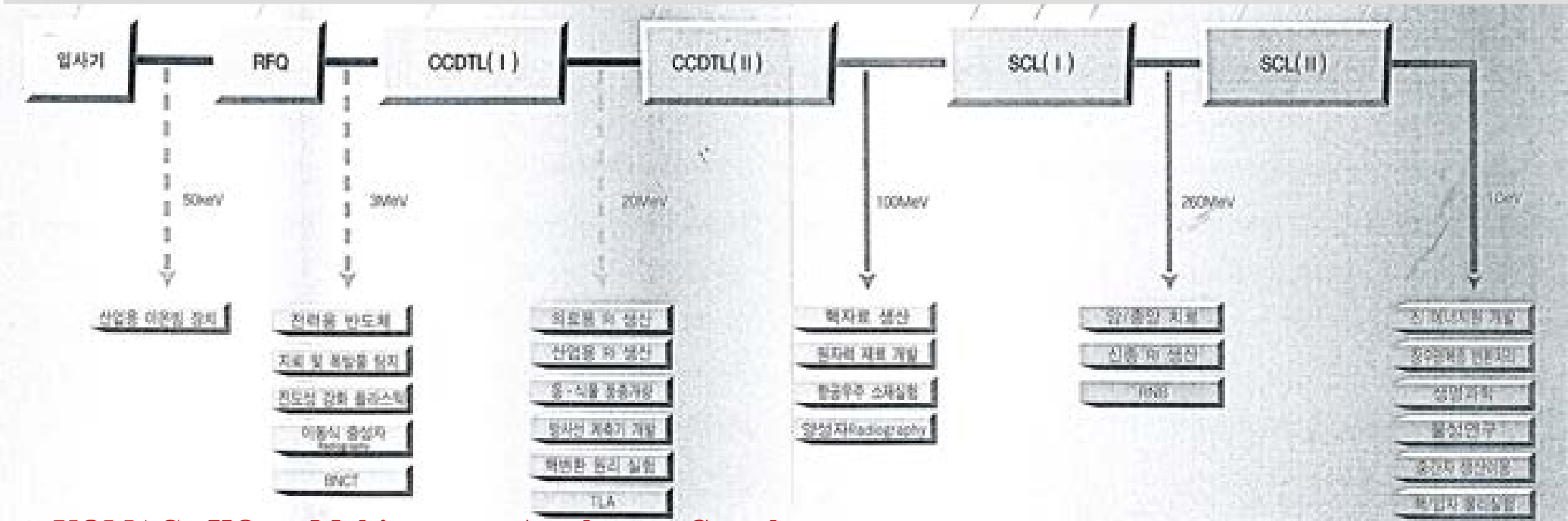
- Area: 180,000 m²
- Building: 37,462 m²
- Power: 154 kV, 20 MVA

❖ 1991 ~ 1999 : Dreaming to build a 1-GeV, MW-class Proton Accelerator - KOMAC

● Feasibility Studies & Proposals to have a Multi-purpose 1-GeV Proton Linac

- ADS : Accelerator Driven Subcritical System(Reactor) – an Energy Amplifier
- ATW : Accelerator Transmutation of Waste – a Spent Fuel Burner
- SNS : Spallation Neutron Source – a Neutron Science Facility
- ※ Project Cost : 1.2B \$US (R&D budget of ROK in 1999 : ~2.8B \$US)

● Schematics of KOMAC 1-GeV Proton Linac



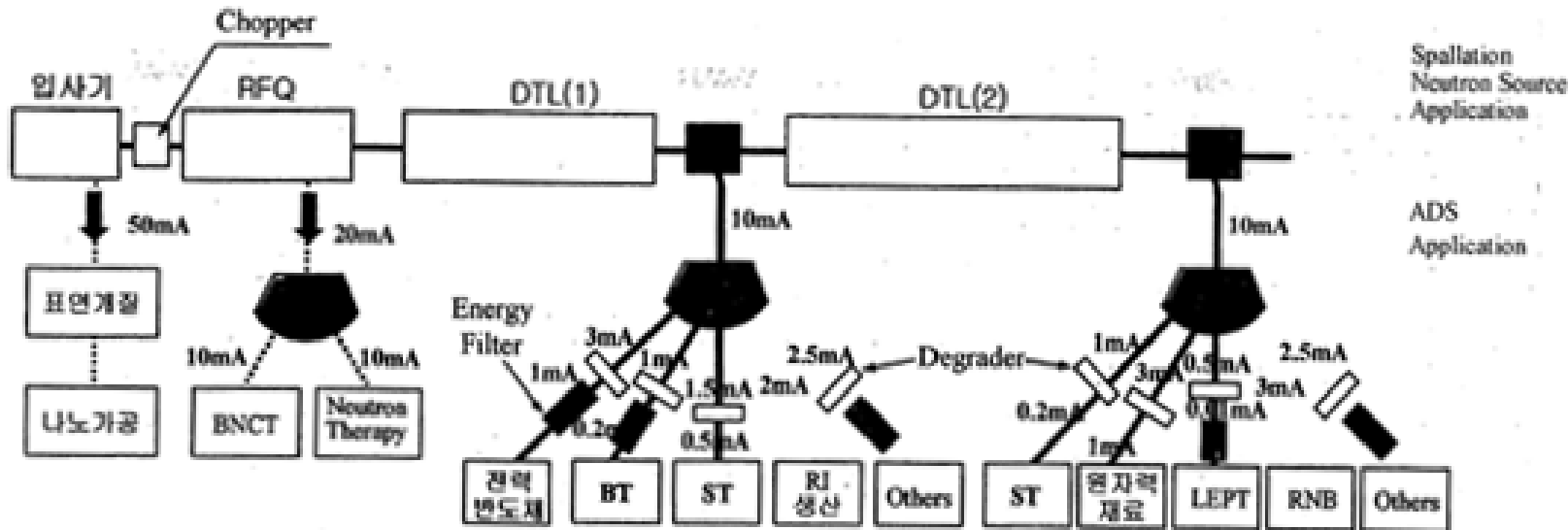
※ **KOMAC : KOrea Multi-purpose Accelerator Complex**

History (2)

❖ 2000 ~ 2002 : Launching a project to build a 100-MeV proton linac - PEFP

- Nominated as a candidate of Korean 21C Frontier Projects (2000)
 - 250-MeV Proton Linac: Proton & Neutron Sources
- Approved as a 21C Frontier Project (2002) : Proton Engineering Frontier Project
 - Goal: 100-MeV, 20-mA Proton Linac - Proton & Neutron Sources, RI production, etc.
 - Budget: ~300M \$US (Gov. 180M, Gyeongju 120M)

PEFP 100-MeV, 20-mA Proton Linac



- LEPT (Low Energy Proton Therapy)
- RNB (Radio Nuclear Beam)

KOMAC 100-MeV Proton Linac [1]

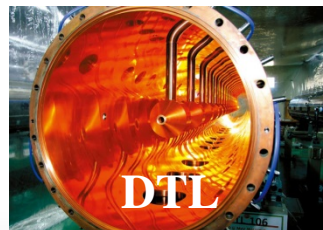
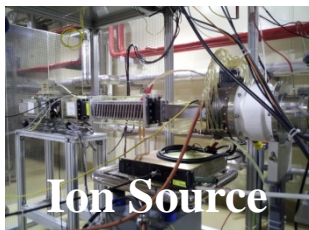
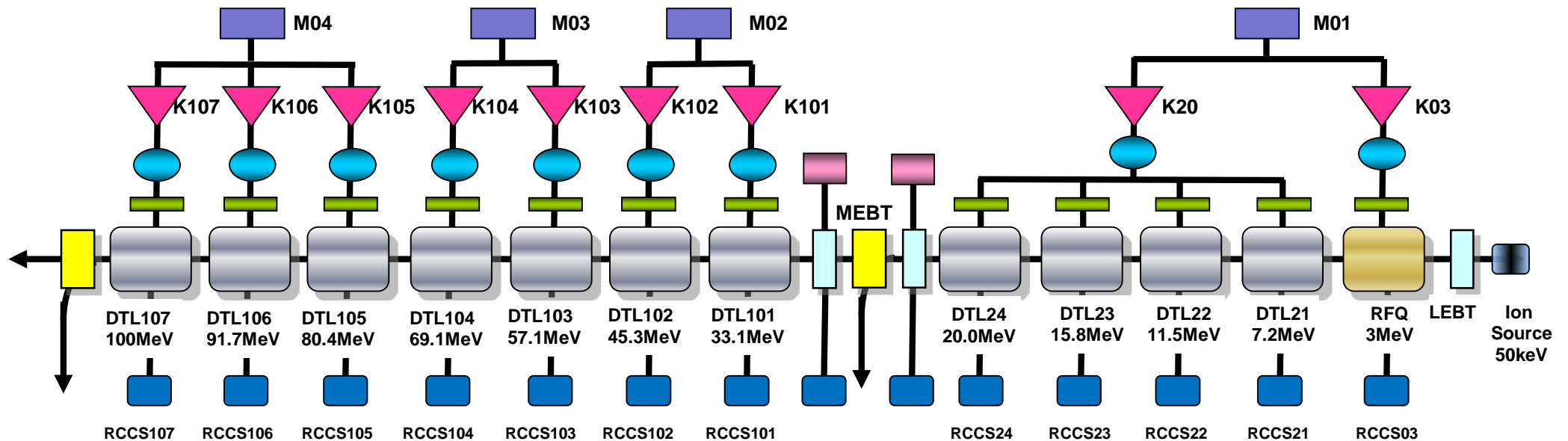
❖ 2002~2012: Building the KOMAC 100-MeV Linac

● Accelerator Body

- IS: 2.45 GHz Magnetron, 50 keV, 20 mA, 2 ms
- RFQ: 4-vane, 50keV ~ 3MeV, 20 mA, 350 MHz
- DTL: 3~100 MeV, 20mA, 24%/8% , 350 MHz

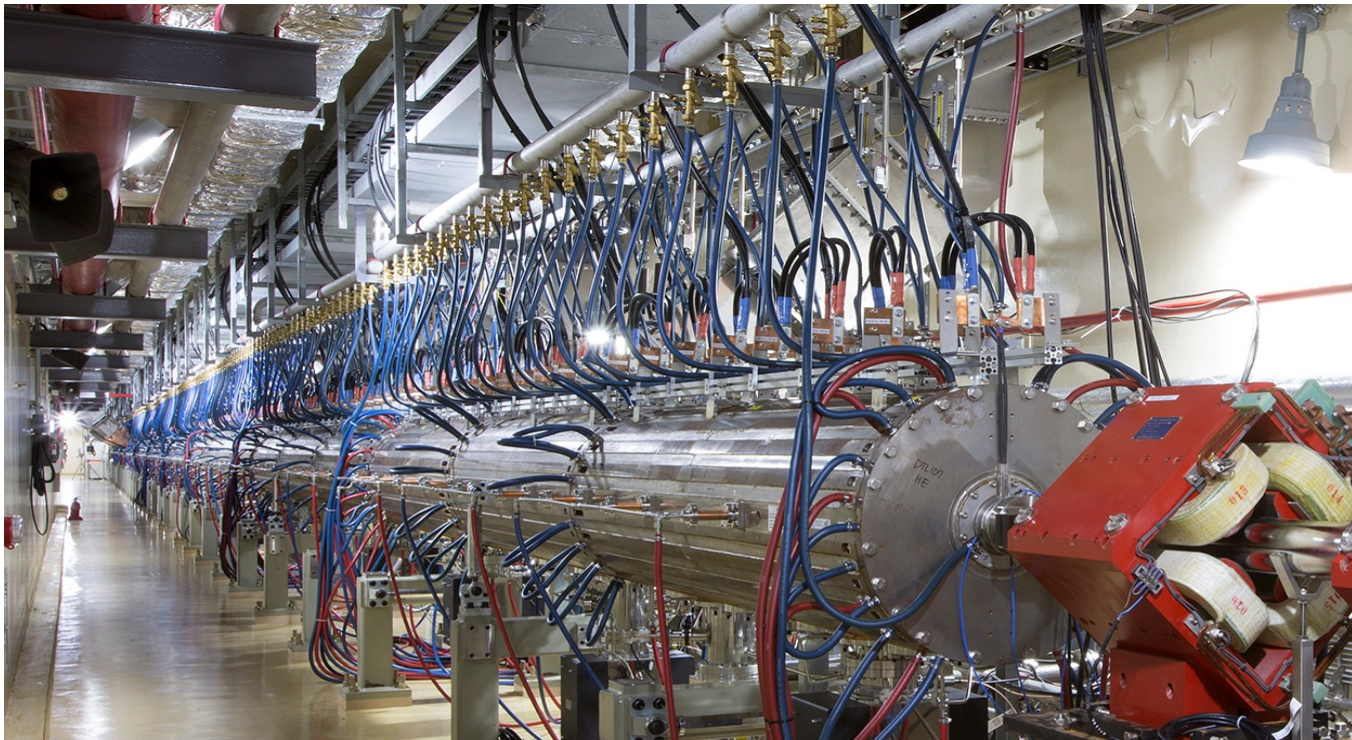
● RF System

- Modulators: -105kV, 50A, 5.8 MW, 10%
- Klystrons: 350 MHz, 1.6 MW, 9%
- RCCS, Circulators, RF windows, RF power couplers

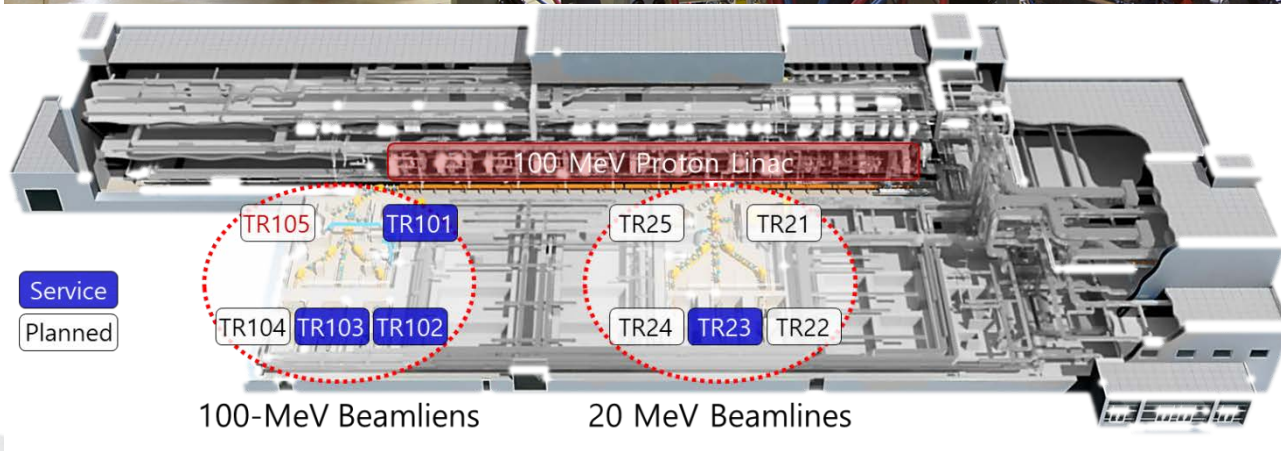
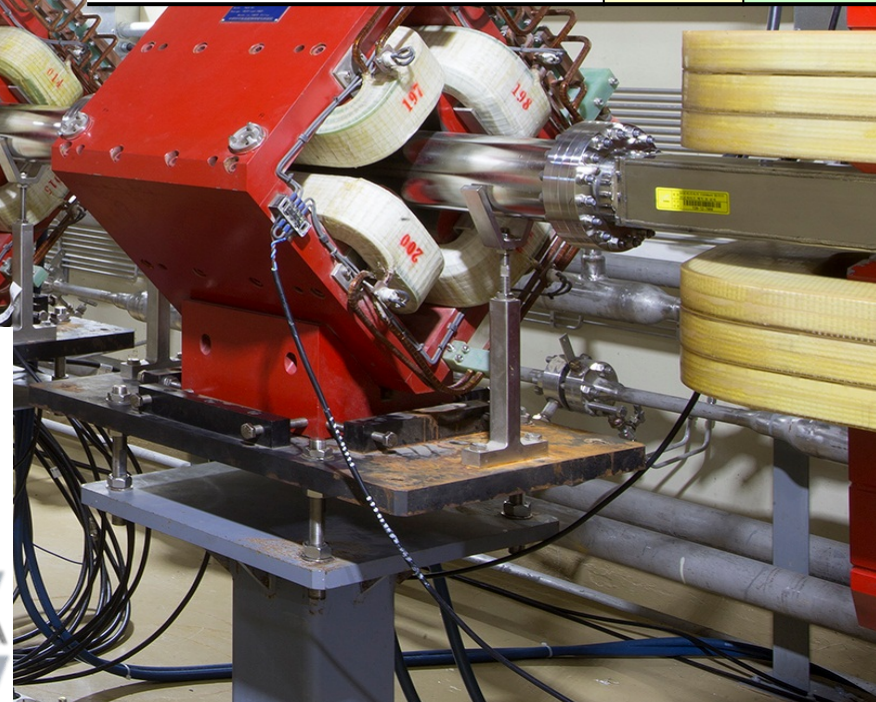


KOMAC 100-MeV Proton Linac [2]

❖ Commissioned and Started User Service in July 2013



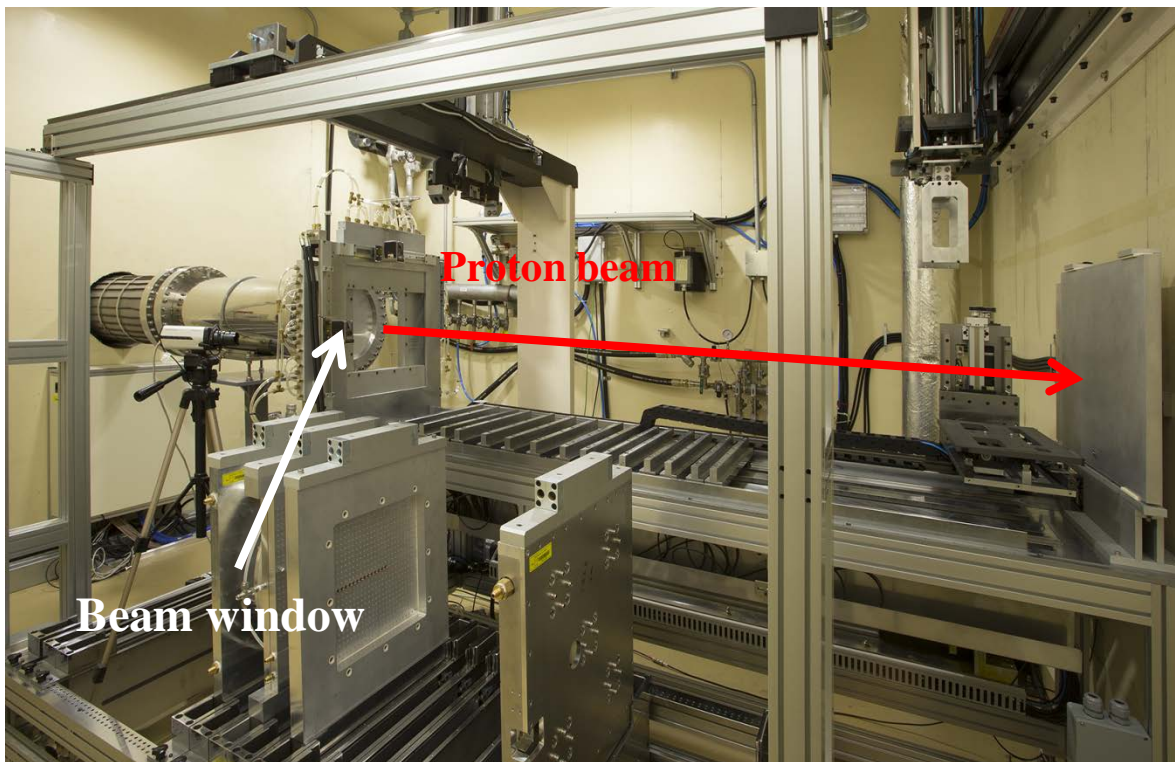
Extraction Energy (MeV)	20	100
Peak Beam Current (mA)	20	
Max. Beam Duty (%)	24	8
Avg. Beam Current (mA)	4.8	1.6
Pulse Length (ms)	2.0	1.33
Max. Repetition Rate (Hz)	120	60
Max. Avg. Beam Power (kW)	96	160



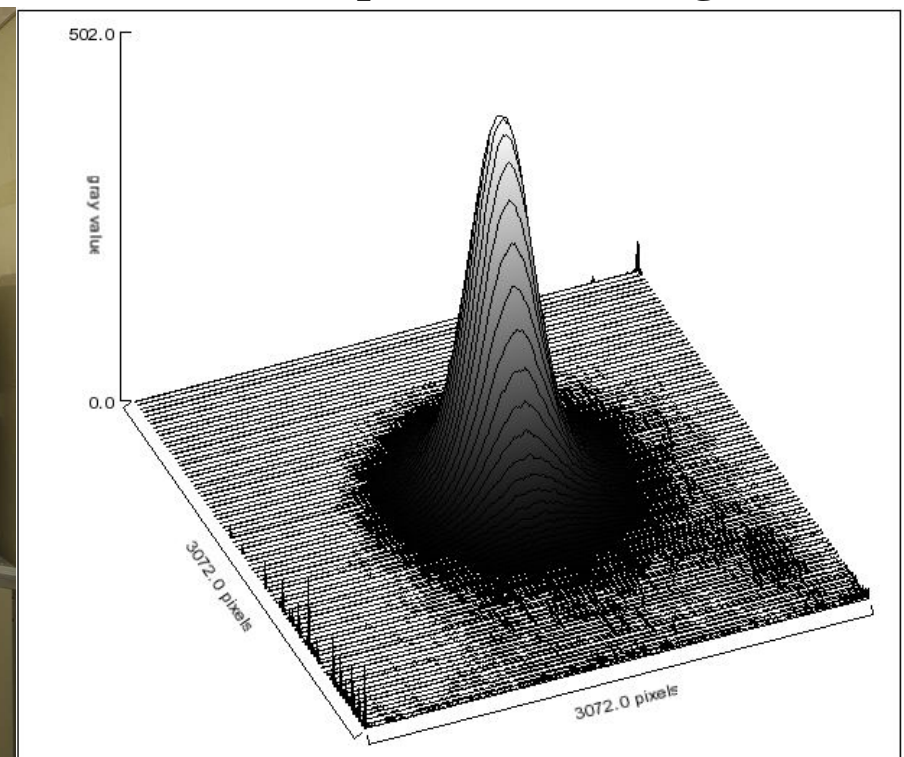
❖ General-purpose Beamlines - TR23 & TR103 : In Service (2013~)

- Applications : Materials, Nano-device, Semiconductor, etc.
- Beam characteristics
 - Energy: 20 MeV, 33~100 MeV, Beam power : 10 kW @ 100 MeV ($\sim 10^{14}$ pps)

Beam Irradiation Chamber



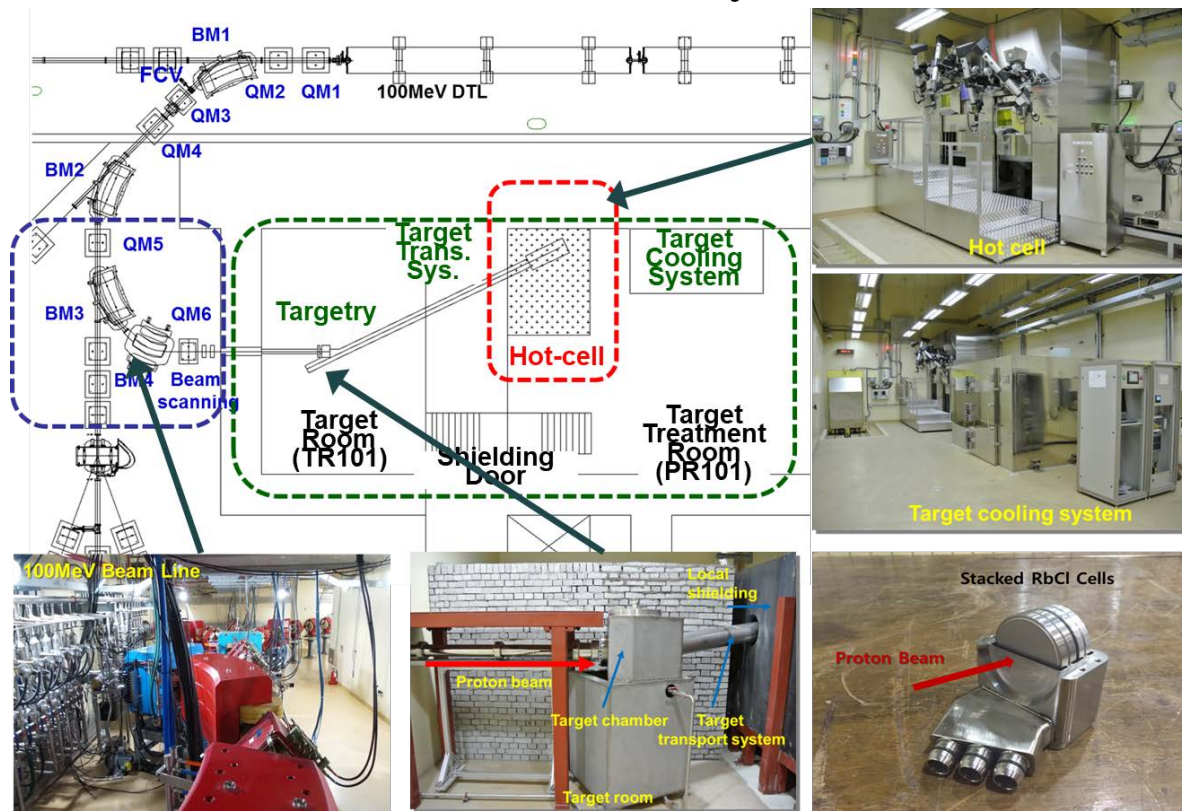
Beam profile at the target



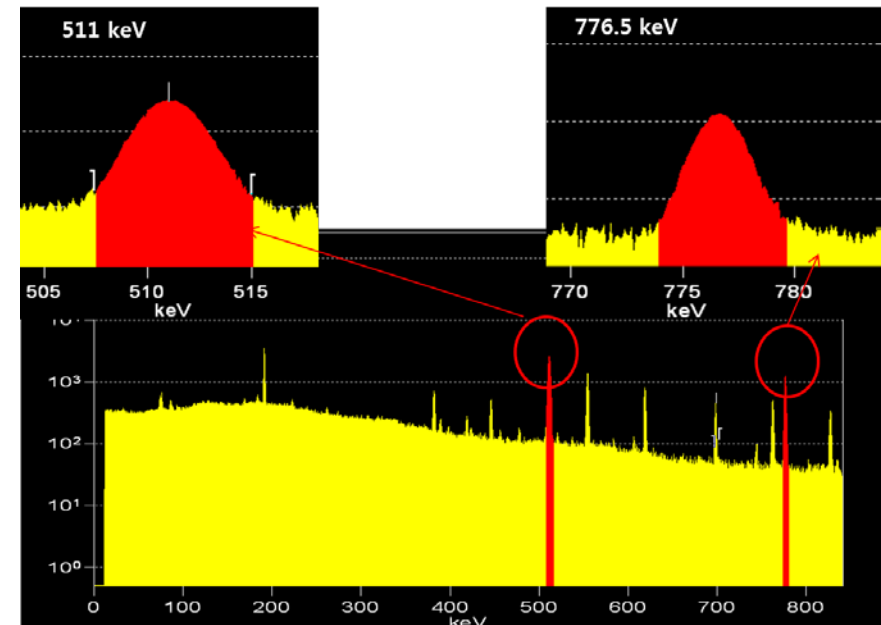
❖ RI Production Beamline - TR101 : In Operation (2016~)

- Applications : Medical Radioisotope production – Cu-67, Ge-68, Sr-82, Ac-225, etc.
- Beam characteristics
 - Energy: 33~100 MeV, Beam power : 30 kW @ 100 MeV (~10¹⁴ pps)

RI Production Facility



(511 keV, 776 keV gamma from ⁸²Sr Decay)



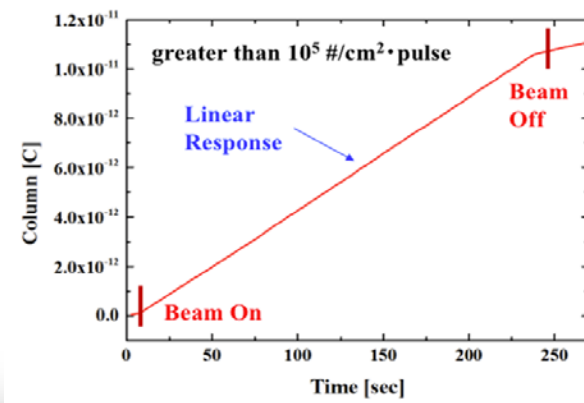
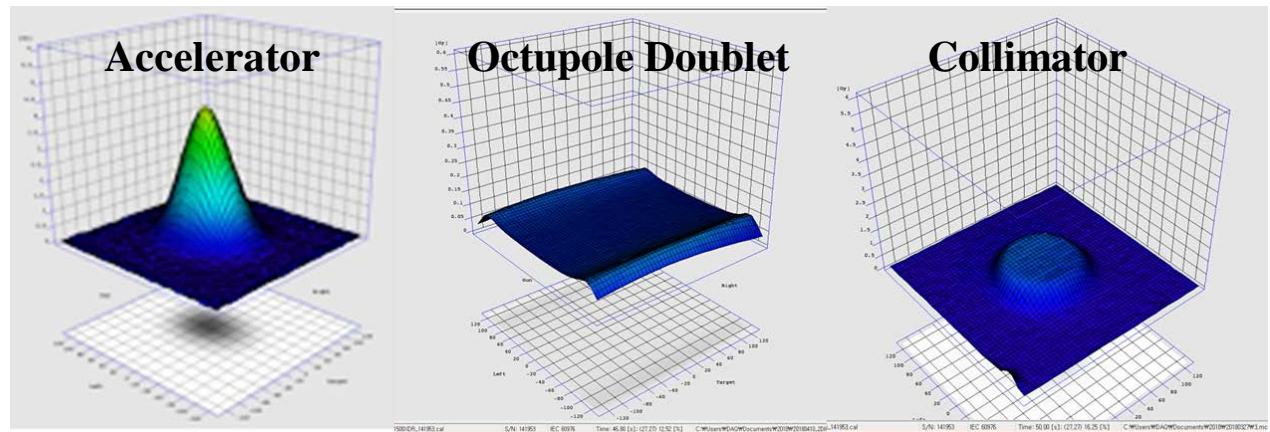
❖ Low-flux Beamline - TR102 : In Service (2018~)

- Applications: Space/Natural radiation effects, Biological effects, Detector R&D, etc.
- Beam characteristics
 - Energy: 33~100 MeV, Flux: $1 \times 10^5 \sim 1 \times 10^8 / \text{cm}^2 \cdot \text{pulse}$, Uniformity < 5% over 100 mm ϕ

Beam Irradiation Target Room



Beam profile at the target

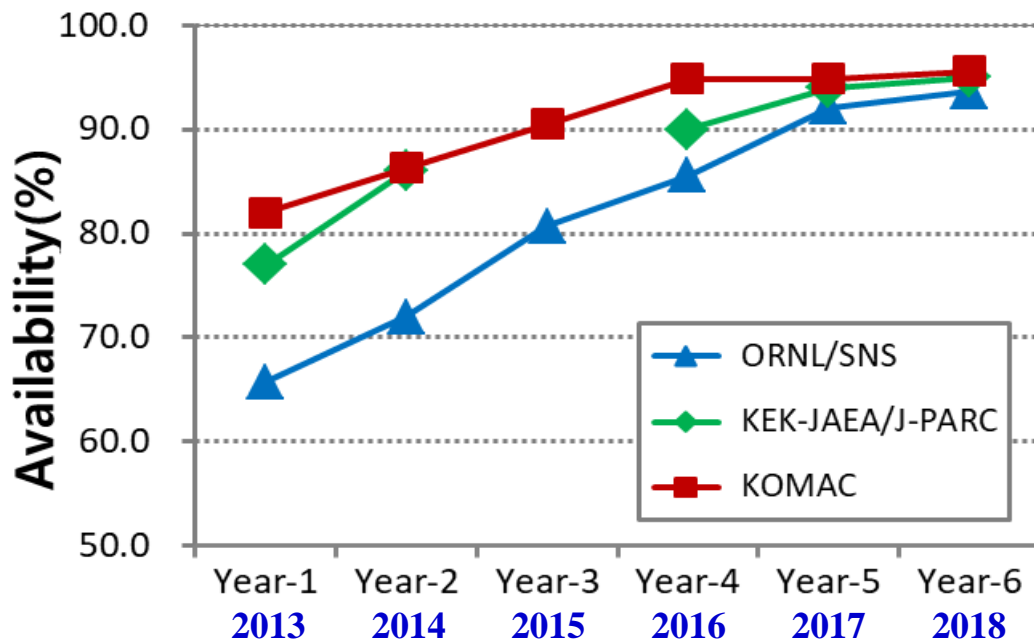


Operation Stat. of 100-MeV Proton Linac (1)

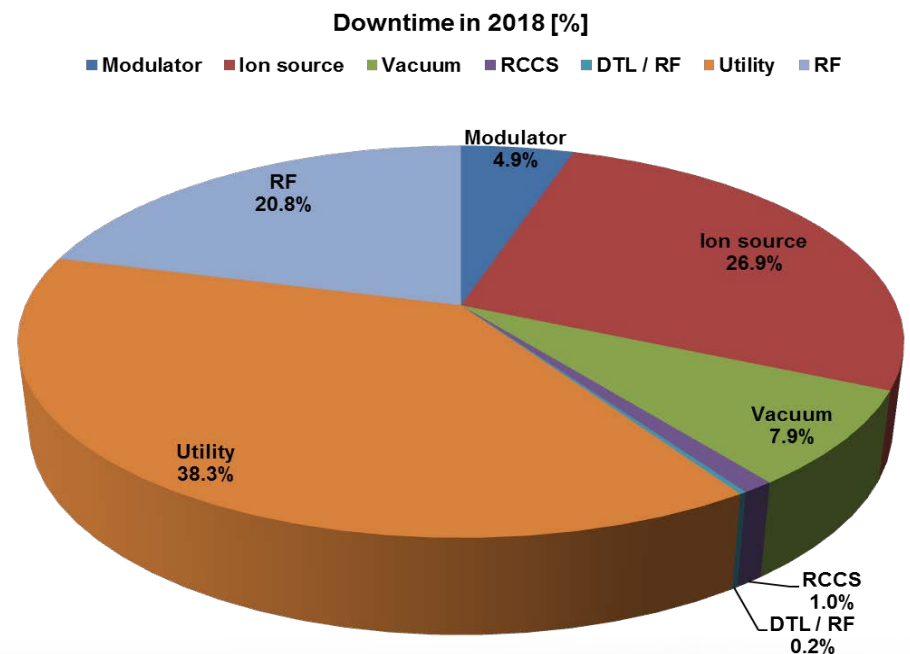
❖ Operation Statistics (2013~2018)

Year	2013	2014	2015	2016	2017	2018	Sum
Operation hours	2,290	2,863	2,948	2,961	3,231	3,038	17,331
Unplanned Downtime	412	392	280	151	164	134	1,534
Machine Availability	82.0%	86.3 %	90.5%	94.9%	94.9%	95.6%	91.1%

● Machine Availability: Stabilized to ~95%

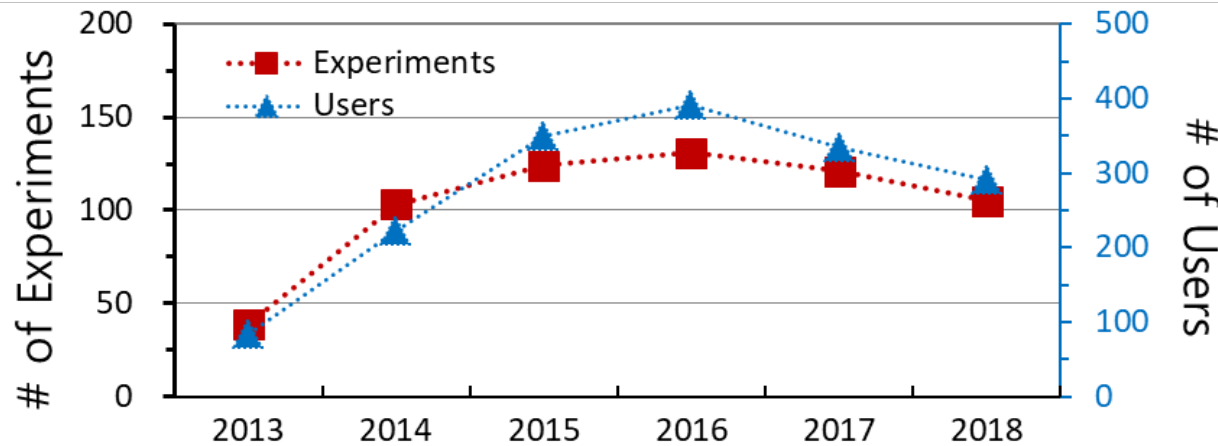


● Downtime: Utility, IS, RF, Vacuum fails

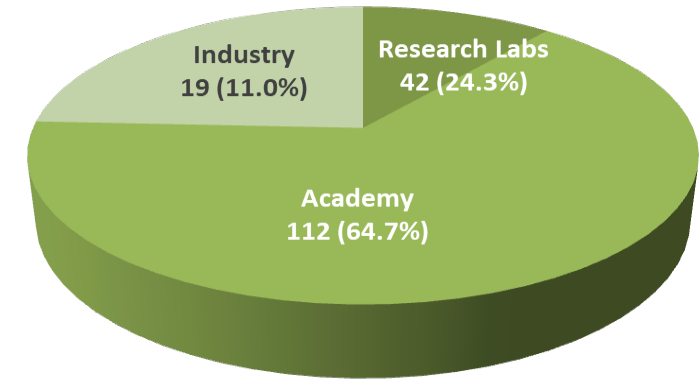


Operation Stat. of 100-MeV Proton Linac (2)

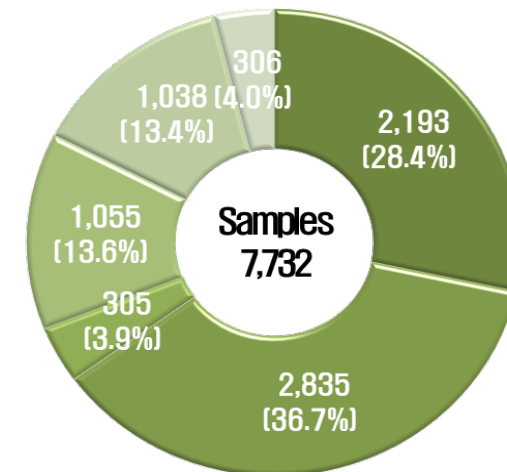
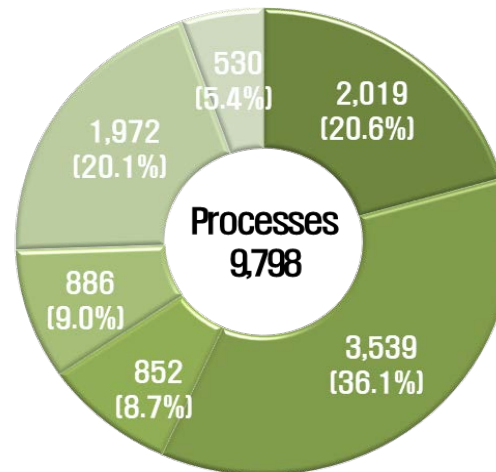
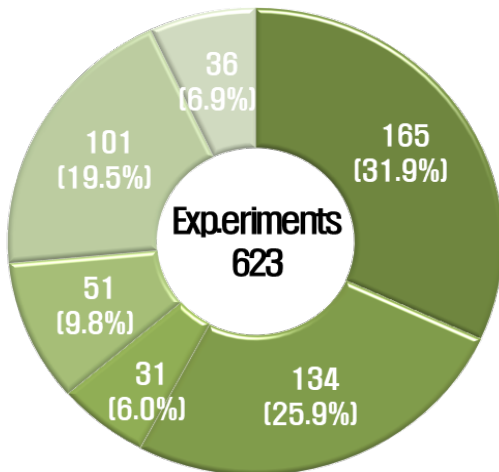
❖ User Services (2013~2018)



● User's Institution



● Utilization Fields: Materials(31.9%), Bio-Life(25.9%), Space/Basic(19.5%) etc.



- Materials/Nano
- Bio-Life
- Energy/Env.
- Nuclear
- Space/Basic Sci
- Etc.

● KOPUA: Korea Proton Beam User Association (Self-organized user network)

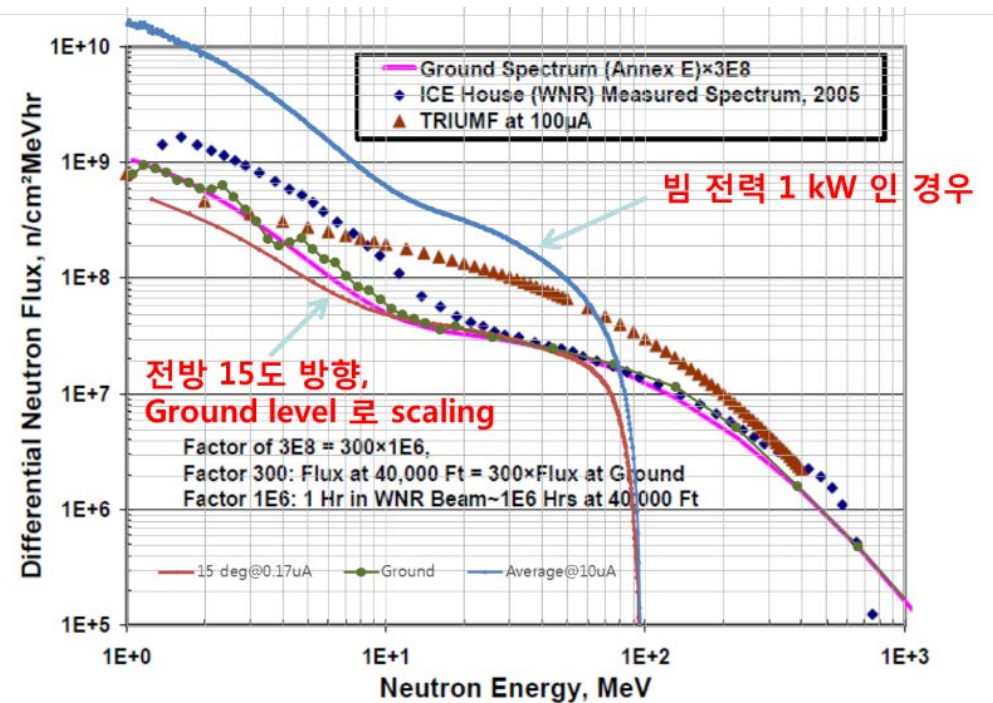
- PAC(Program Advisory Committee): Review proposals & Allocate beamtime

❖ Pulsed Neutron Source (1) : Temporary PNS in the Acc. tunnel

- Applications : Space/Natural radiation effects, Materials Science
- Beam characteristics
 - Proton : Energy 100 MeV, Beam power 1 kW @ 100 MeV
 - Neutron : $\sim 10^{13}$ pps, W Target \rightarrow To Reproduce Terrestrial Neutron Spectrum



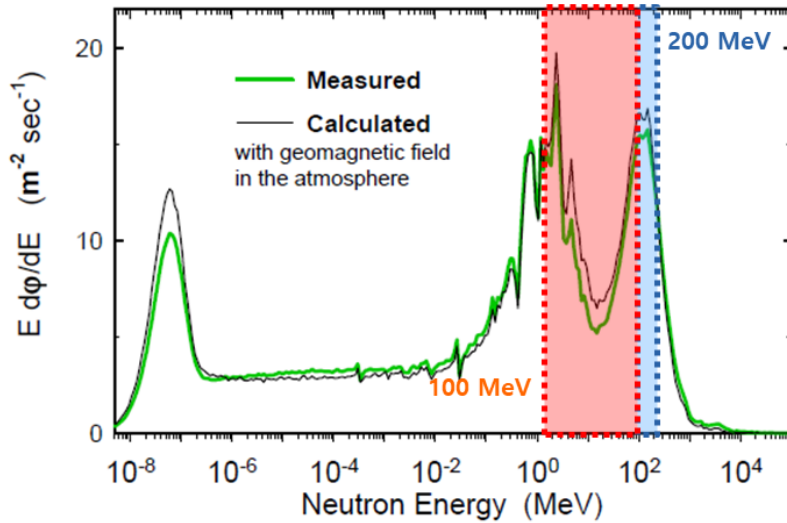
Pulse neutron measurement



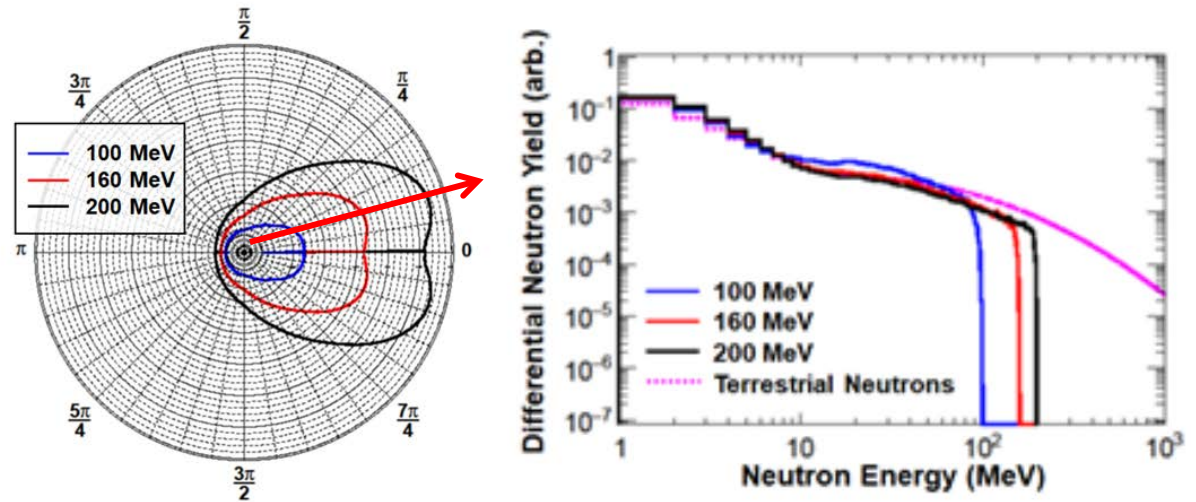
❖ Pulsed Neutron Source (2) : Energy Upgrade to 160 or 200 MeV

- To meet the user demands with more realistic neutron spectra & increased acceleration factors

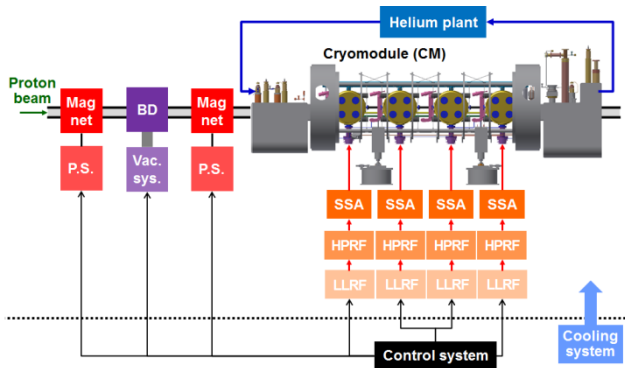
Terrestrial Neutron Spectrum



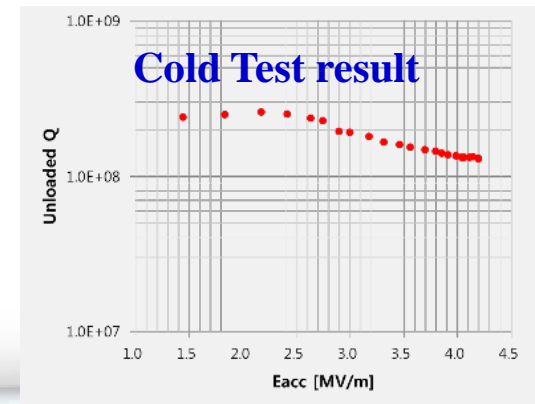
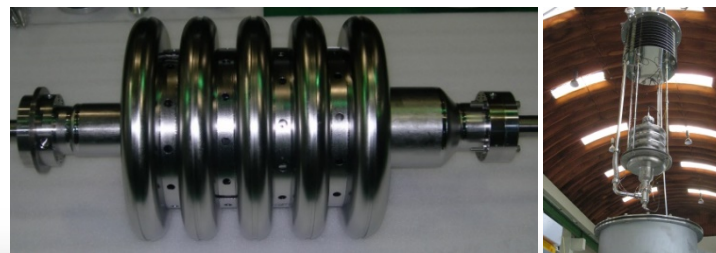
Pulse Neutron Spectra with Diff. Proton Energy



● R&D activities for energy upgrade: SFR cavities

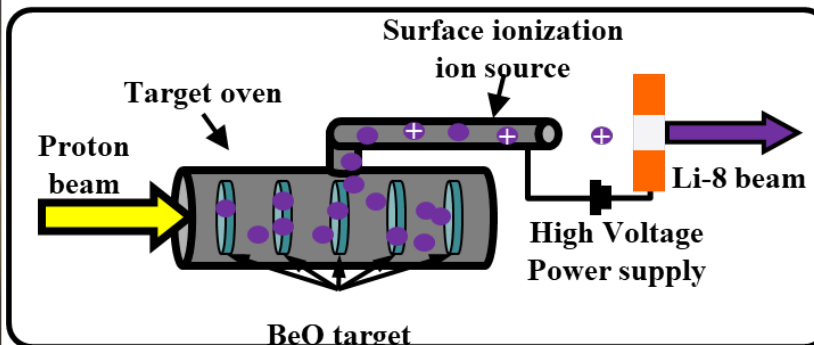
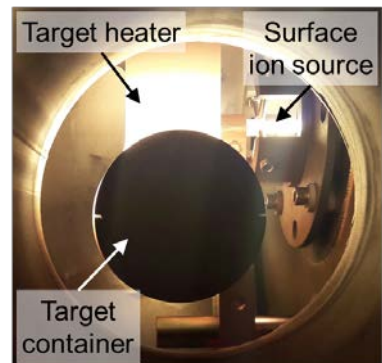
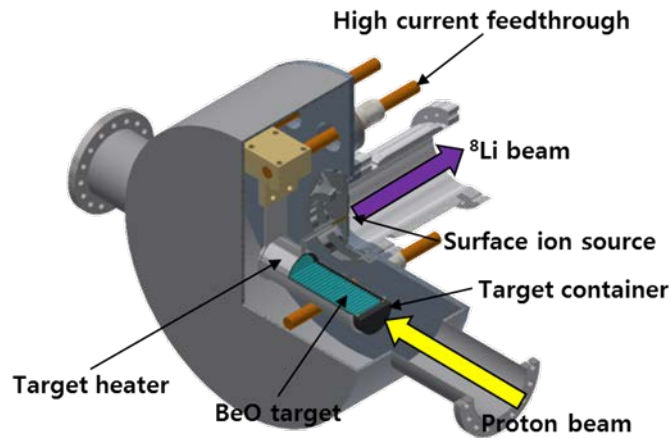


$\beta=0.42$, 700 MHz Elliptical Cavity

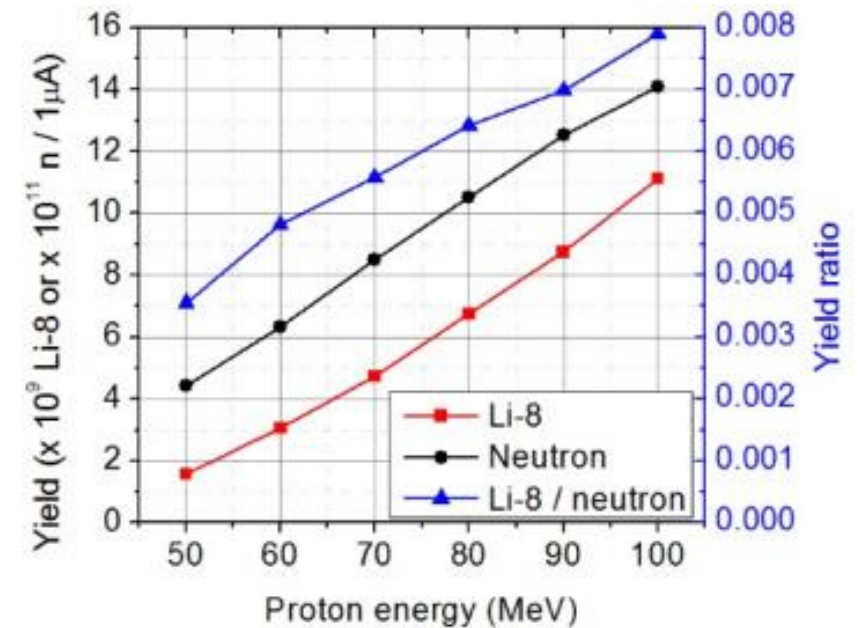


❖ Li-8 β -NMR Spectrometer

- Applications : Materials Science
- Beam characteristics
 - Proton : Energy 100 MeV, Beam power 1 kW @ 100 MeV
 - Li-8 : 1×10^8 pps, BeO Target (small ISOL target)



^8Li production rate calculated by FLUKA



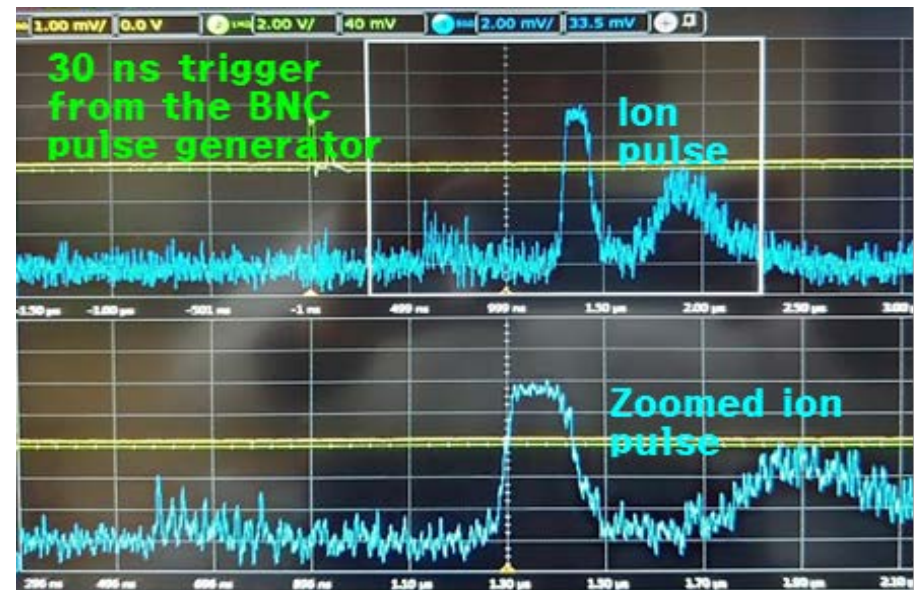
❖ Short-Pulse Injector : 7T SC EBIS – to be installed this year

- 2nd Ion Source of KOMAC 100-MeV linac to drive a short pulsed neutron source

EBIS-SC Test Stand



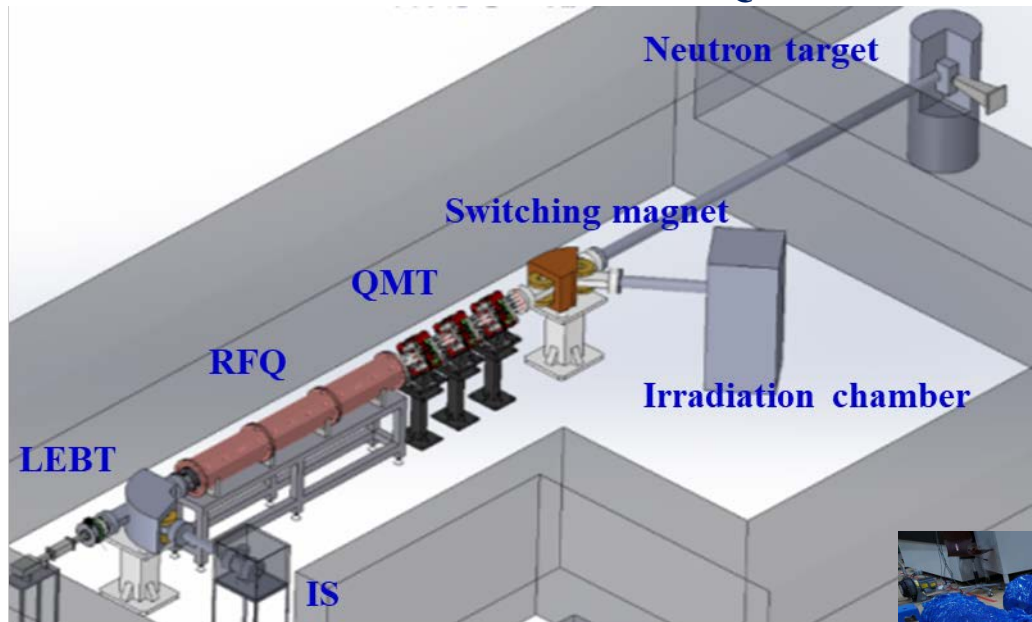
Single pulse extraction (present: 150 ns)



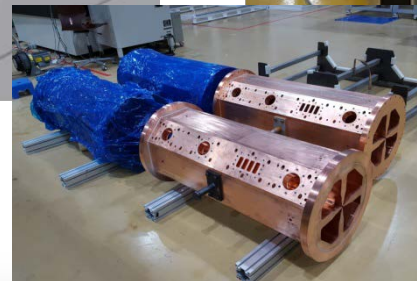
❖ Development of a 1 MeV/n RFQ

- Applications: Heavy ion irradiations, neutron source, etc.
- Specifications
 - Ions: D, He, ... Xe, Beam Energy: 1 MeV/n, Beam current: 1 mA
 - RF: 200 MHz, SSA

Schematics of 1-MeV/n RFQ



Under installation

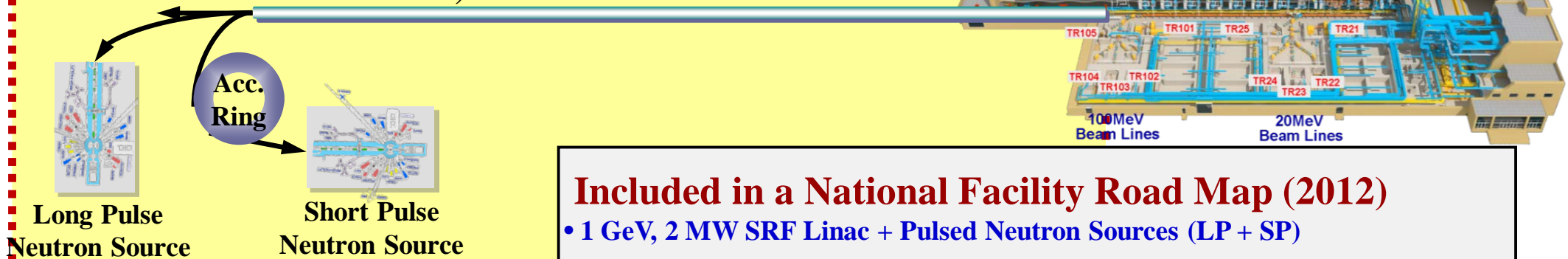


Dream to have a GeV-class Facility

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

Upgrade Plan

1 GeV, 2 MW SRF Linac



Included in a National Facility Road Map (2012)

- 1 GeV, 2 MW SRF Linac + Pulsed Neutron Sources (LP + SP)

- **Neutron Source:** Materials, Bio-life, Energy, Environment, etc.
 - **Long Pulse (1.3 ms):** Spatial resolution: $\mu\text{m}\sim\text{nm}$, Temporal resolution: $\mu\text{s}\sim\text{ns}$
 - SANS, Holography, Phase shift interferometry, Static & Dynamic tomography, Spin echo, etc.
 - **Short Pulse ($\sim\mu\text{s}$):** 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, High Energy Physics, Nuclear engineering, etc.
- **Neutrino Source:** High Energy Physics

❖ International Partners around the World



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- **Operation of 100-MeV proton linac**
 - **Machine availability : ~95%**
 - **User service : with 3 beamlines**

- **Near/Mid-term plan**
 - **Pulsed-neutron source (with energy upgrade to 200 MeV)**
 - **^8Li -based β -NMR spectrometer**
 - **Short pulse injector**
 - **1 MeV/n RFQ**

- **Dream to have 1-GeV linac**
 - **R&D on SFR, MW target, etc.**

Thank you.