# A Plan for the Pulsed Neutron Source Based on the KOMAC 100-MeV Linac

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On behalf of the KOMAC Accelerator Team

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KOMAC, KAERI

KAERI

KOMAC
Korea Multi-purpose Accelerator Complex
양성자가속기연구센터

# Outline



- Introduction to KOMAC
- KOMAC 100-MeV linac operation
- Plan for secondary particle utilization
- Plan for pulse neutron source development
- Summary

# KOMAC - KOrea Multi-purpose Accelerator Complex

KOMAC

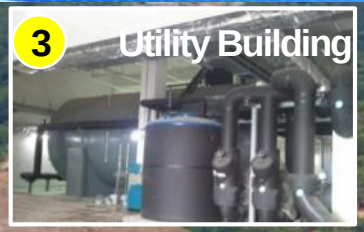
## ◆ Located on Miraero (road to the future), Gyeongju (a historic city)

- ✓ Developed via Proton Engineering Frontier Project (2002.7~2012.12, 10.5 Year)
- ✓ Budget investigated: ~300M $US (Gov: 180M, Gyeongju: 110M, Industry: 10M)

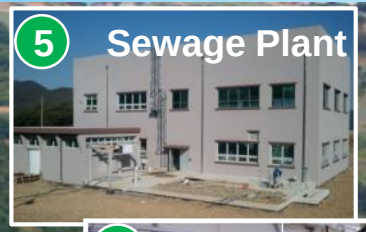
# KOMAC Close-up view













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Main Hall
(Under Const.)

9 Dormitory

8 Information

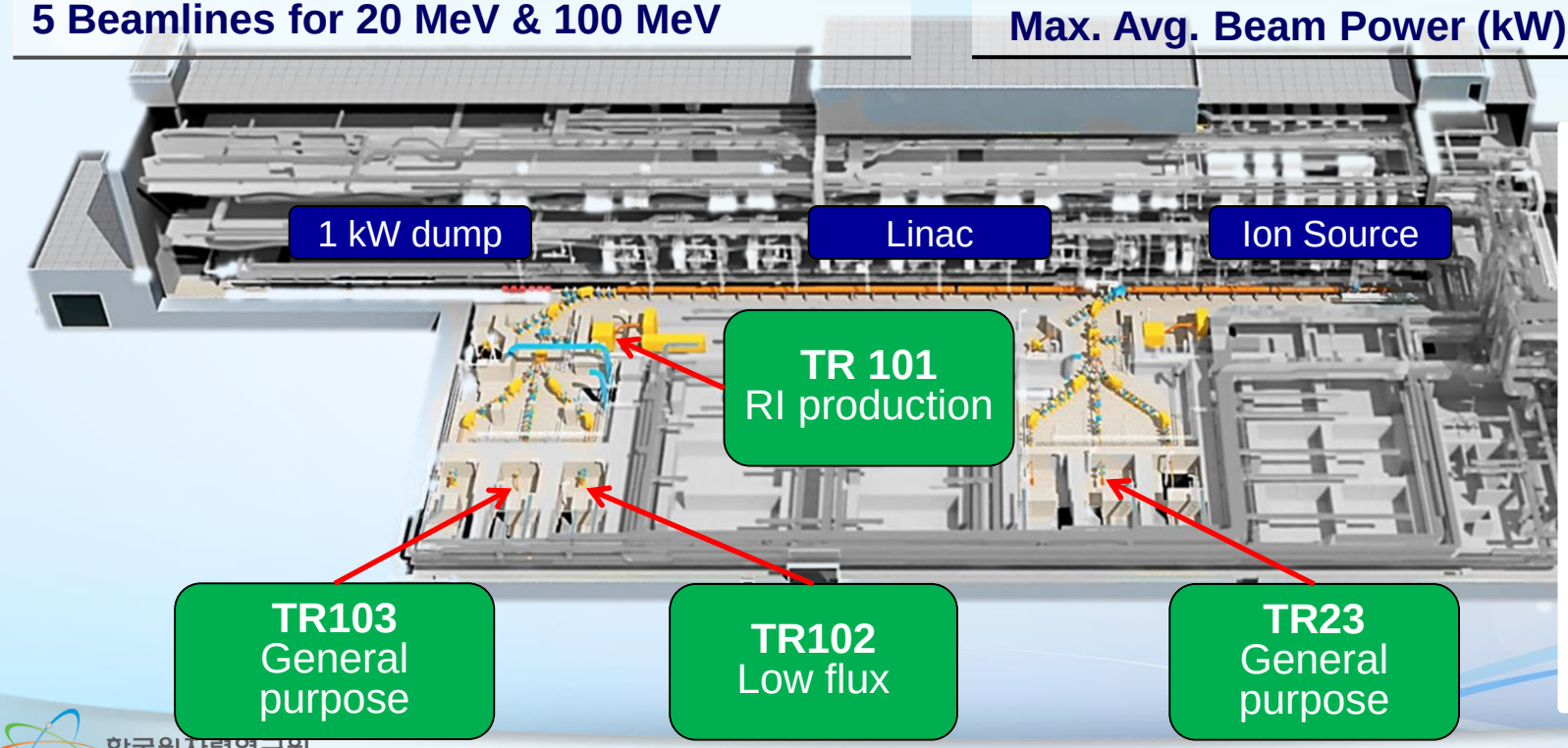
- Area: 180,000 m²
- Building: 27,322 m²
- Power: 154 kV, 20 MVA

# 100-MeV Linac and Beam Lines

KOMAC

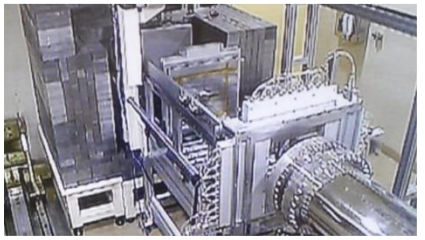
| Features of KOMAC 100-MeV linac |
|---|
| 50-keV Injector (Ion source + LEBT) |
| 3-MeV RFQ (4-vane type) |
| 20 & 100-MeV DTL |
| RF Frequency : 350 MHz |
| Beam Extractions at 20 or 100 MeV |
| 5 Beamlines for 20 MeV & 100 MeV |

| 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 |




20 MeV BL (TR23)

100 MeV BL (TR103)

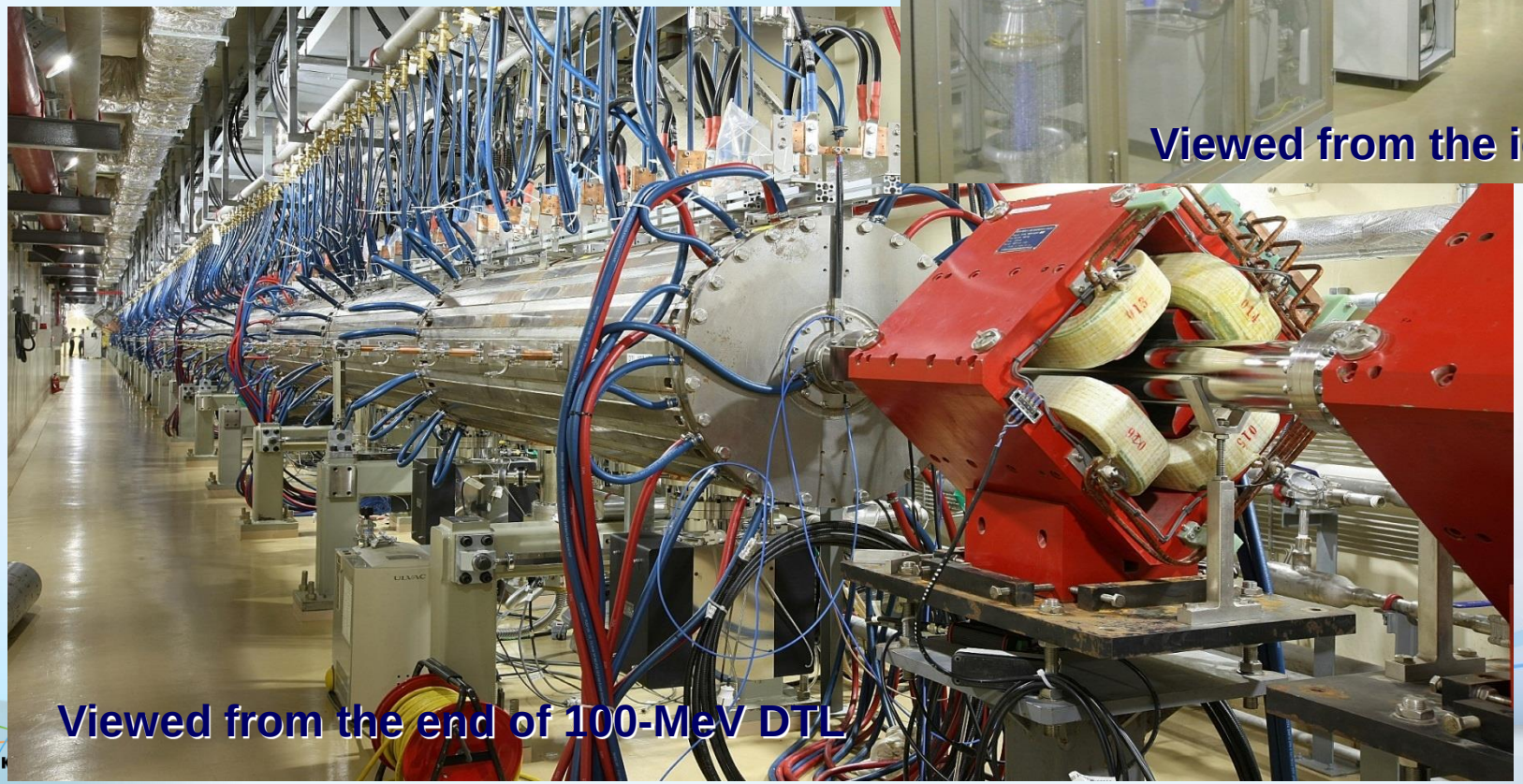


# KOMAC 100-MeV Proton Linac



- 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



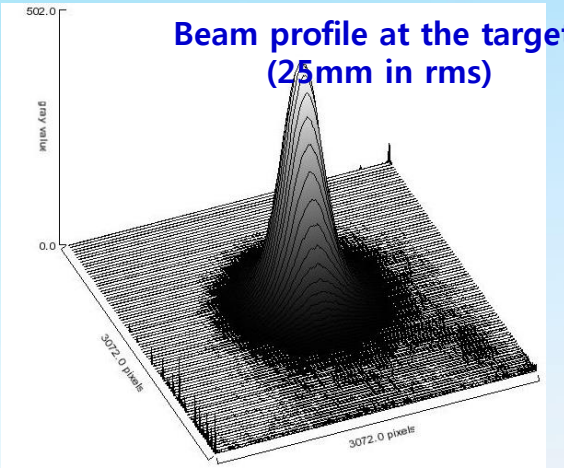
Viewed from the end of 100-MeV DTL

# Beamline (1)

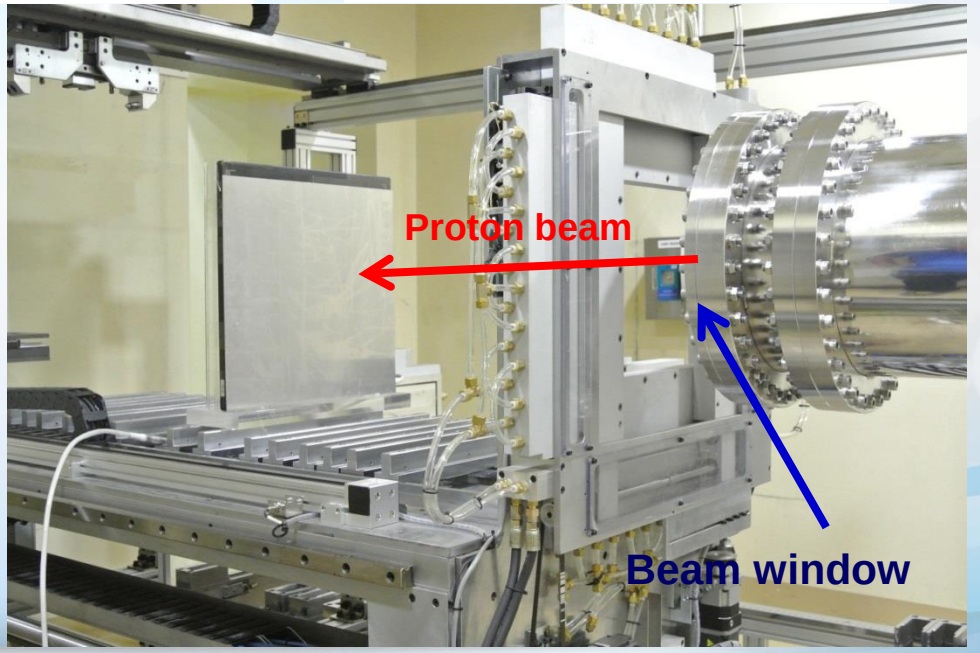
KOMAC

## ❖ 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~)




Hot cell for sample manipulation




Beam irradiation station

# Beamline (2)

KOMAC

## ❖ RI Production Beamline: 100-MeV Proton

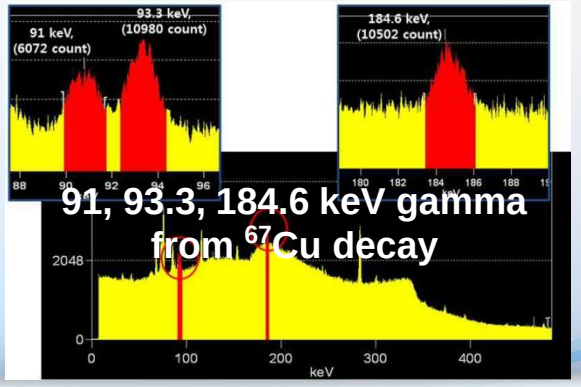
- **Application**
  - RI production: Cu-67, Sr-82, etc.
- **Proton beam**
  - Energy: 33 ~ 100 MeV
  - Beam power: 30 kW @ 100MeV
- **Status**
  - Completed installation: Dec. 2015
  - Status: Under operation (2016~)



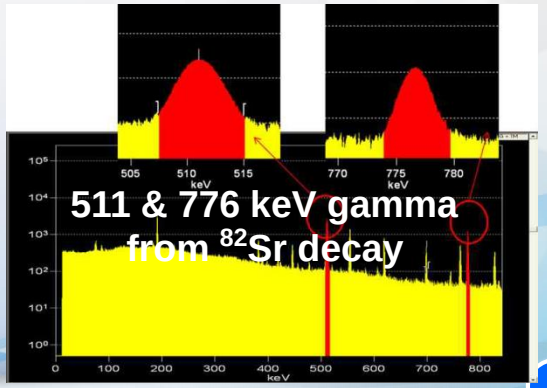


### Target Preparation


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




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



# Beamline (3)

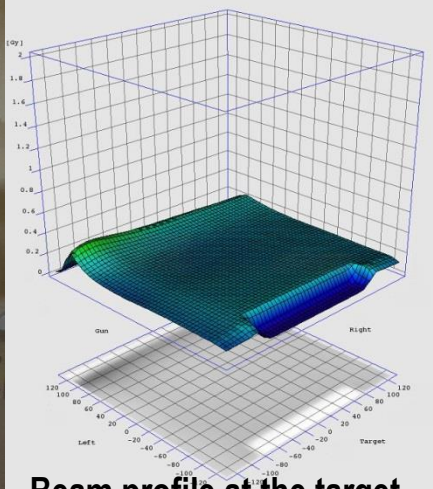
KOMAC

## ❖ Low-flux Beamline: 100-MeV Proton

- **Application :** Space radiation, Detector R&D, Bio etc.
- **Proton beam**
  - Energy: 20 ~ 100 MeV
  - Max. Avg. Current : 10 nA
  - Uniformity: < 10%, 100 mm X 100 mm
  - Flux: $1x10^5$ ~ $1x10^8/cm^2$
- **Status :** Under operation (2016~)

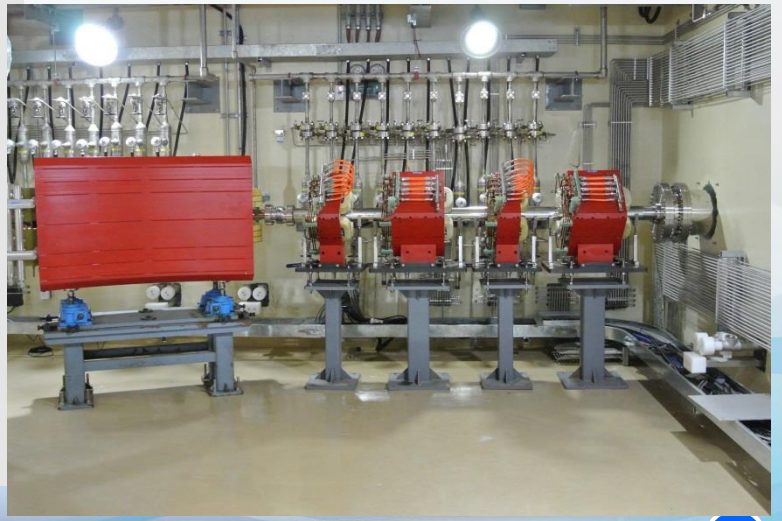
Beamline with collimator

Target room



Beam profile at the target

5.7% @ 100 mm X 100 mm

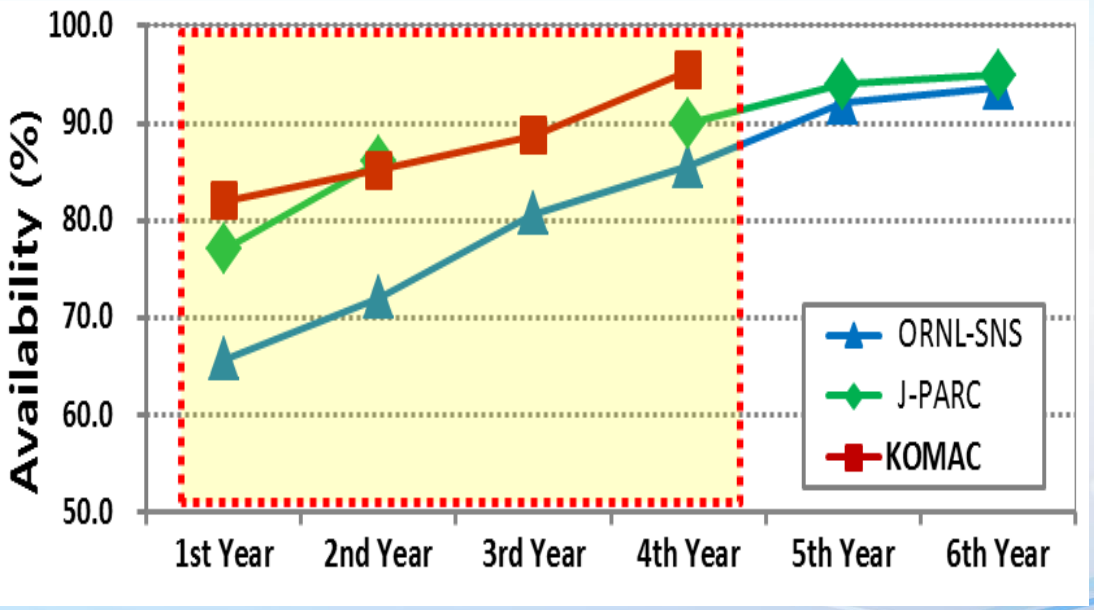


Beamline with Octupole

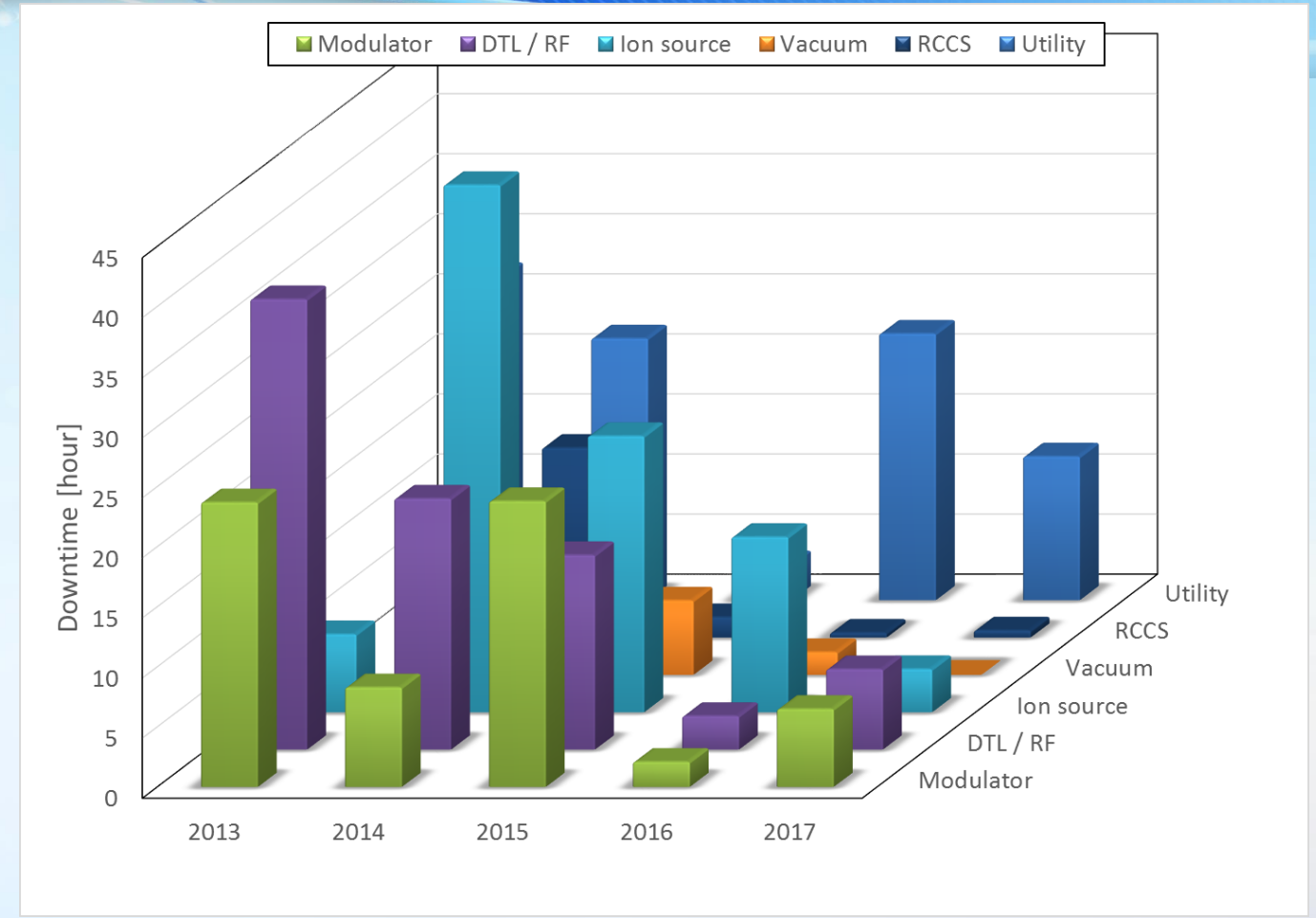
# Operation Statistics

◆ Operated in weekly-based schedule through a yearly plan

| | 2013 | 2014 | 2015 | 2016 | 2017 | Sum |
|---|---|---|---|---|---|---|
| Operation hours | 2,290 | 2,863 | 2,948 | 2,961 | 3,232 | 14,294 |
| Availability | 82.0% | 86.3 % | 90.5% | 94.9% | 94.9% | 91.3% |



# Downtime Analysis




- Downtime continuously decreases.
- In 2017, 40 % of downtime was due to shielding door fault (not accelerator).

# Beam Service Statistics

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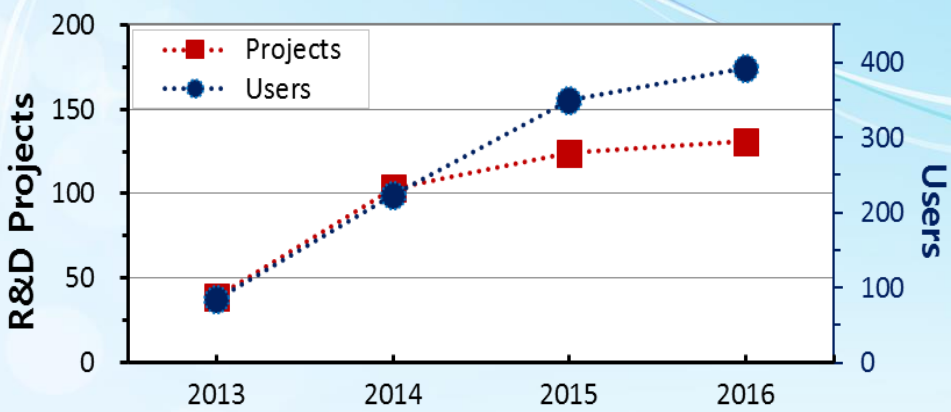
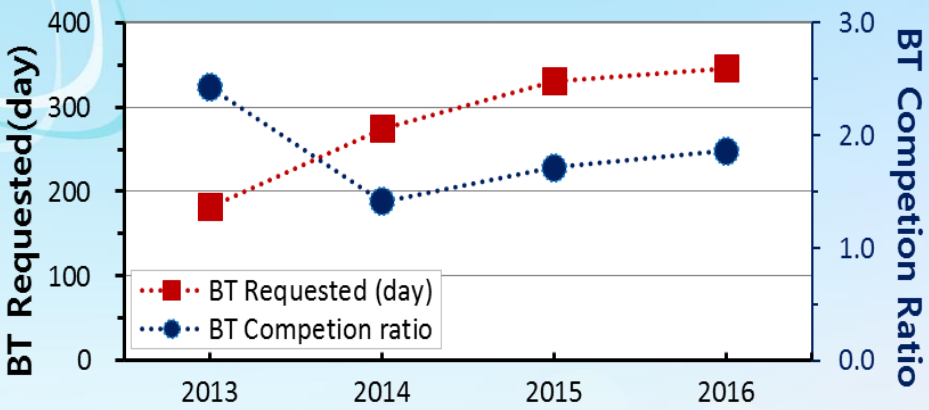
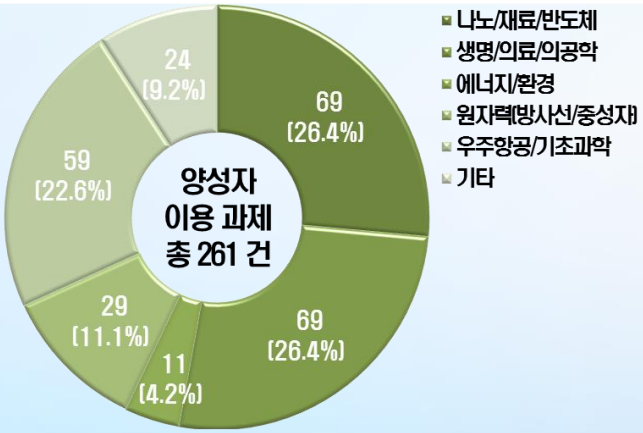
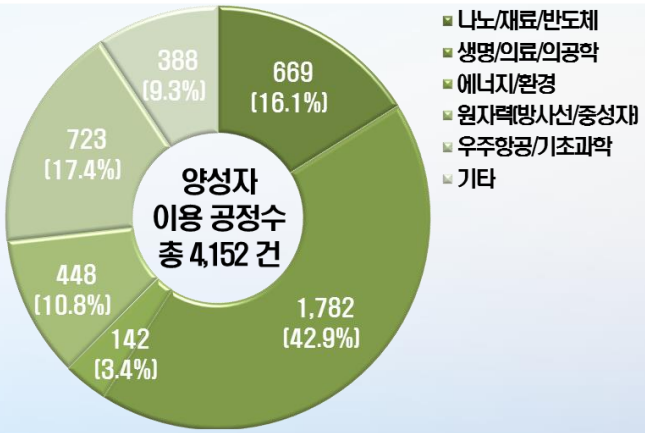
## ◆ Proton Accelerator Utilization

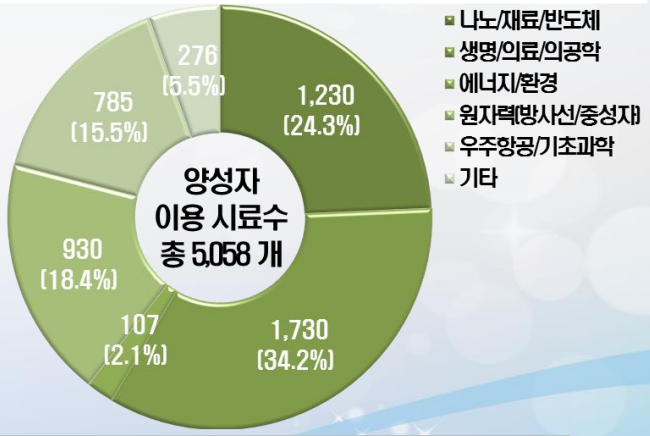



**R&D Fields: Bio/medical(26.4%), Materials(26.4%), SpaceRad./Basic Sci.(22.6%) etc.**



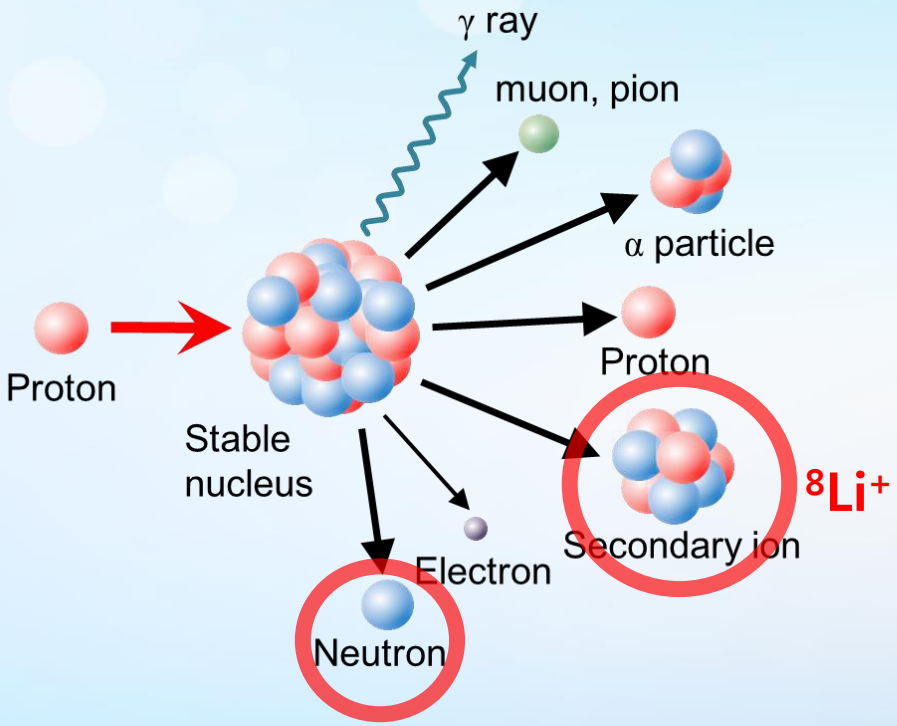



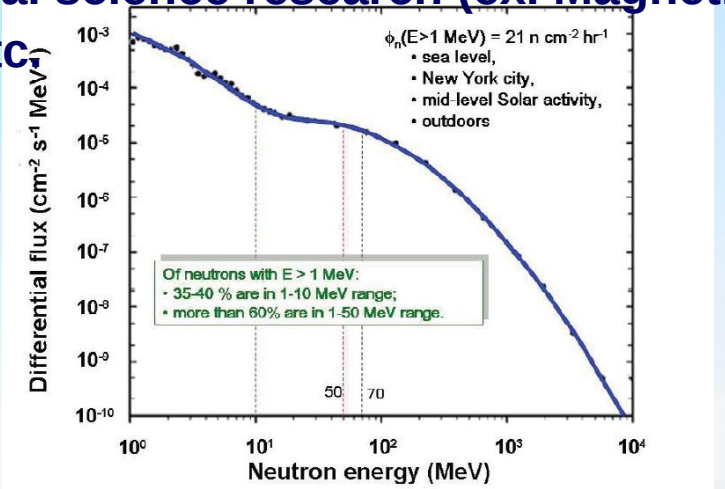

**KOPUA: Korea Proton Beam User Association (Self-organized user network)**

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

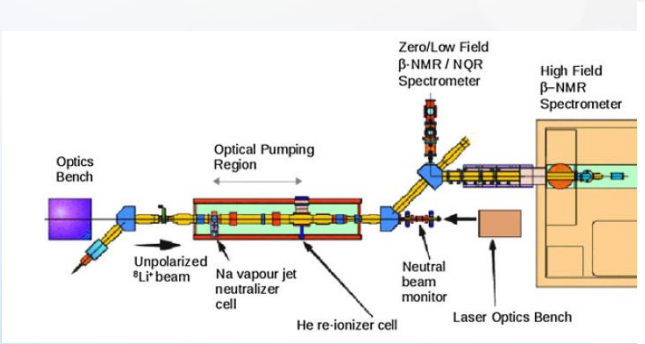
# Secondary Particle

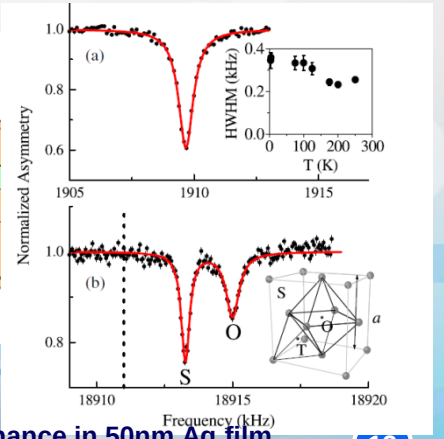
- KOMAC prepares programs to improve proton linac and to supply secondary particle.
  - Neutron: Semiconductor, Neutron imaging, Nuclear data, Detector, etc.
  - RI beam: β-NMR($^{8}$Li, $^{11}$Be, $^{31}$Mg, etc.) for material science research (ex. Magnetic property of thin film and nano scale sample), etc.




Neutron differential flux of atmospheric neutron at sea level
Dario Bisello, et all, Physics Procedia 26 (2012) 284-293

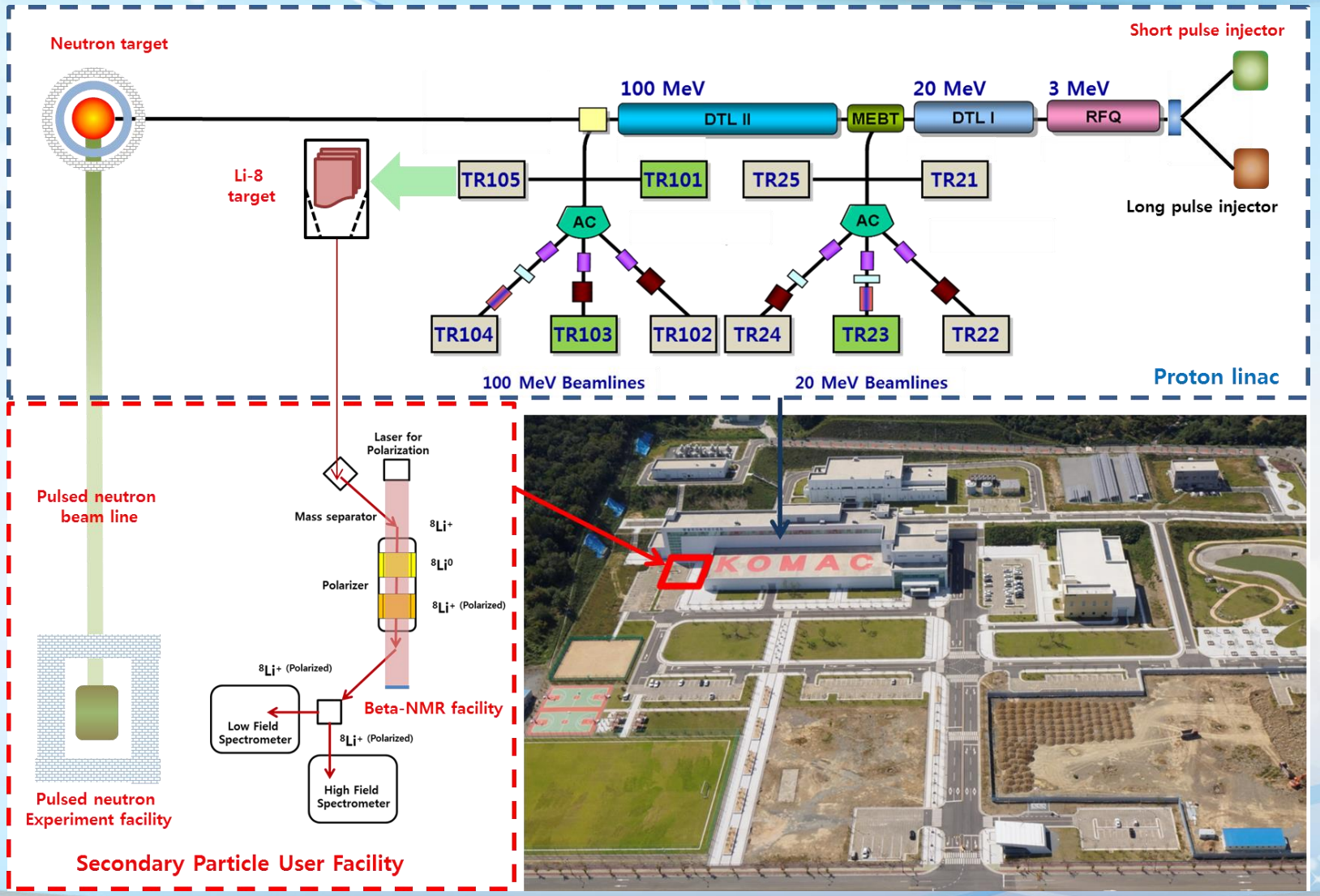



Beta NMR at TRIUMF and resonance in 50nm Ag film
Gerald D. Morris, Hyperfine Interact (2014) 225: 173-182

# Plan for the Secondary Particle Facility

KOMAC

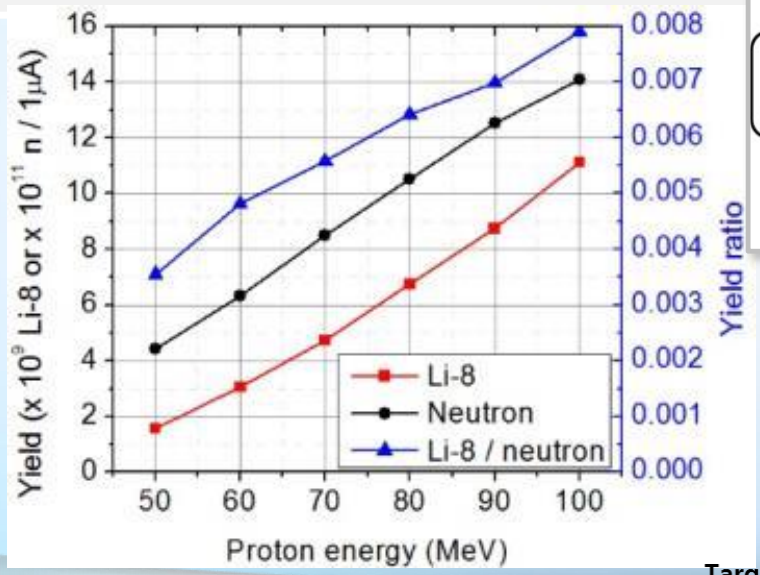


# Beamline (4)

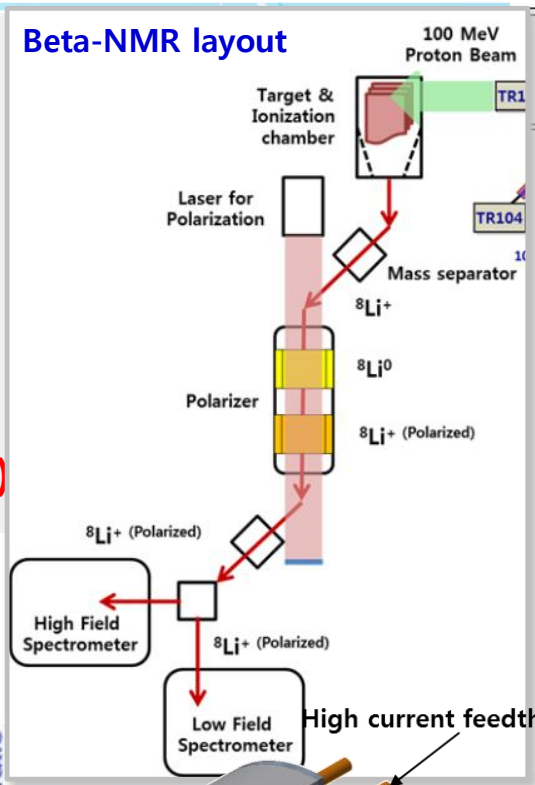
KOMAC

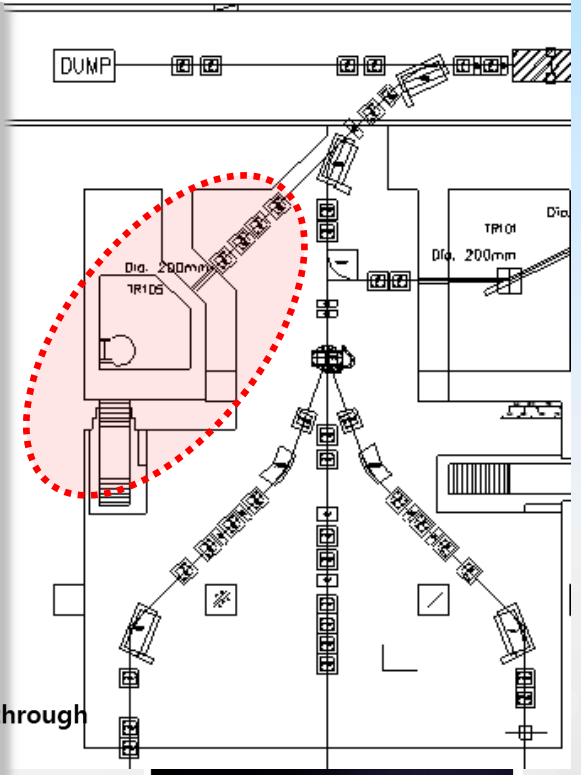
## ❖ RI Beam Production (Test) Beamline: 100-MeV Proton

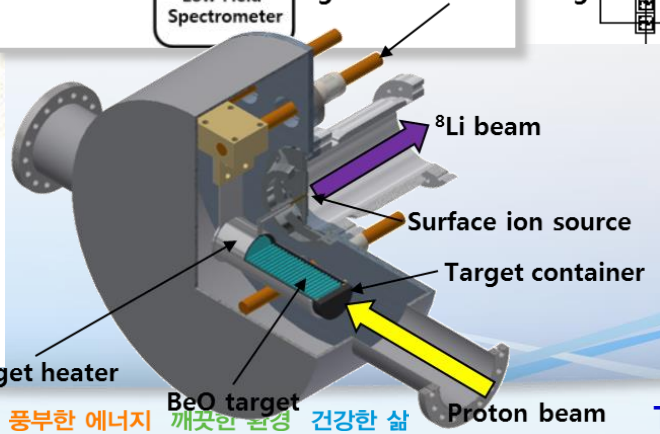
- **Application : Beta NMR**
- **Proton beam**
  - Energy: 100 MeV
  - Beam Power: 1 kW @ 100 MeV
  - Li-8 Ion Production: 1x10$^{8}$ pps
  - Target Target: BeO
- **Status : Under development (2017~)**

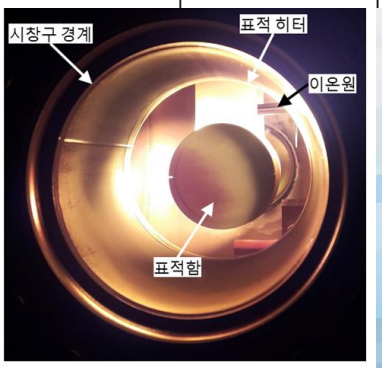



$^{8}$Li production rate calculated by FLUKA



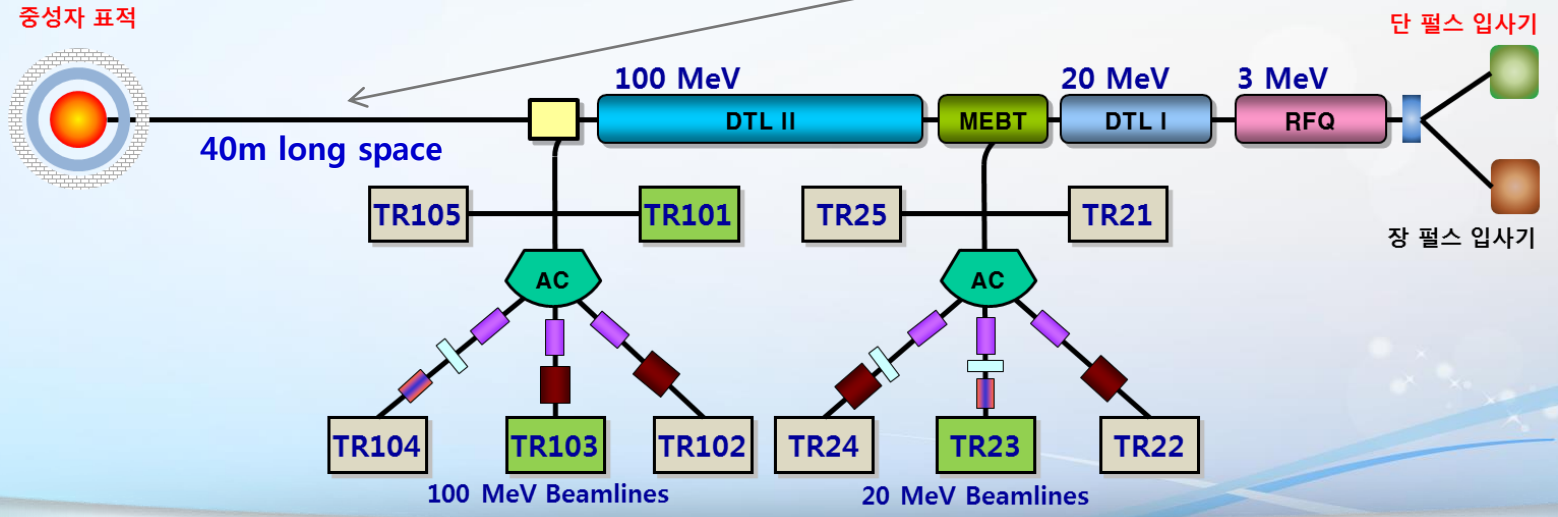

TIS under development

# Beamline (5)

## ❖ Pulsed Neutron Production Beamline: 100 MeV Proton

- **Application : Pulse Neutron Production for semiconductor, imaging and so on**
- **Proton beam**
  - **Energy: 100 MeV**
  - **Beam Power: 1 kW @ 100 MeV (upgrade 160 MeV)**
  - **Target: Tungsten**
- **Status : Neutron measurement, Target design**

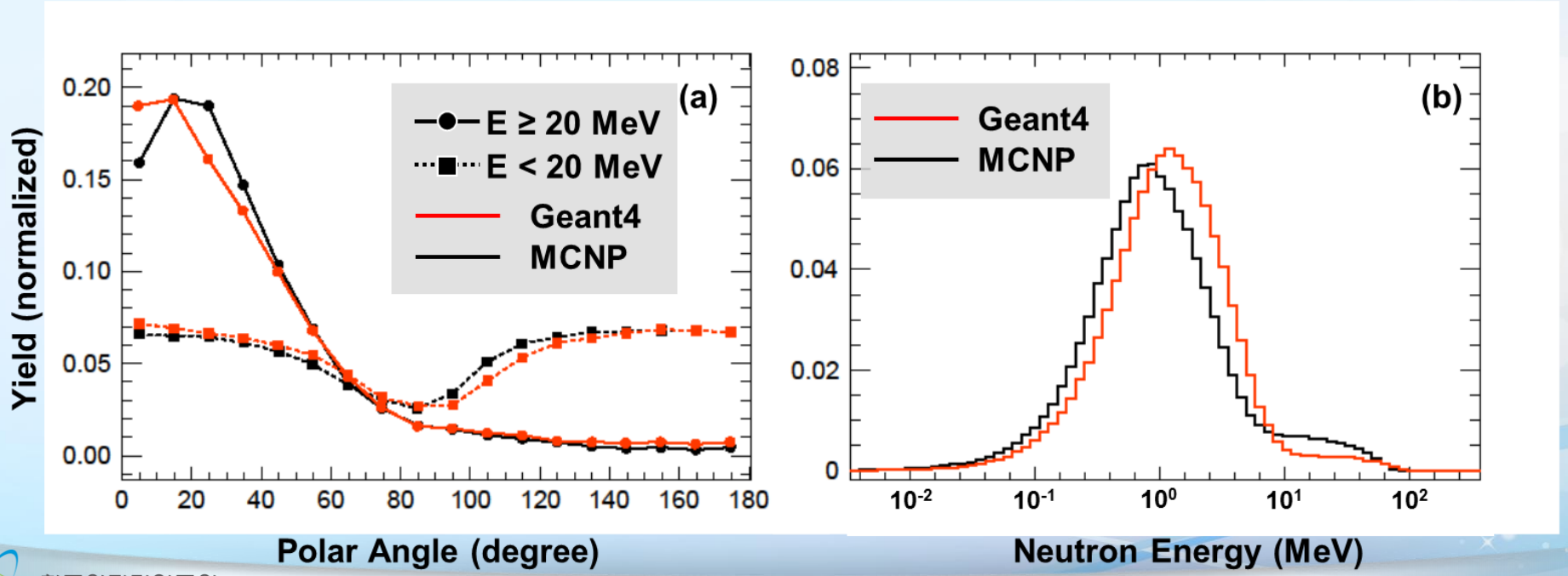
Pulse neutron measurement



# Neutron Generation Based on 100 MeV Beam

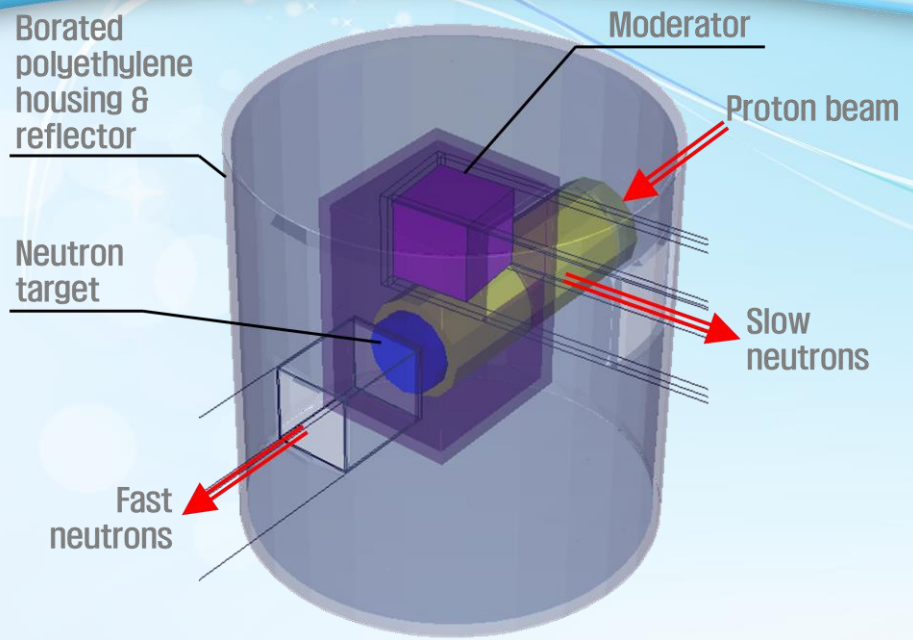
KOMAC

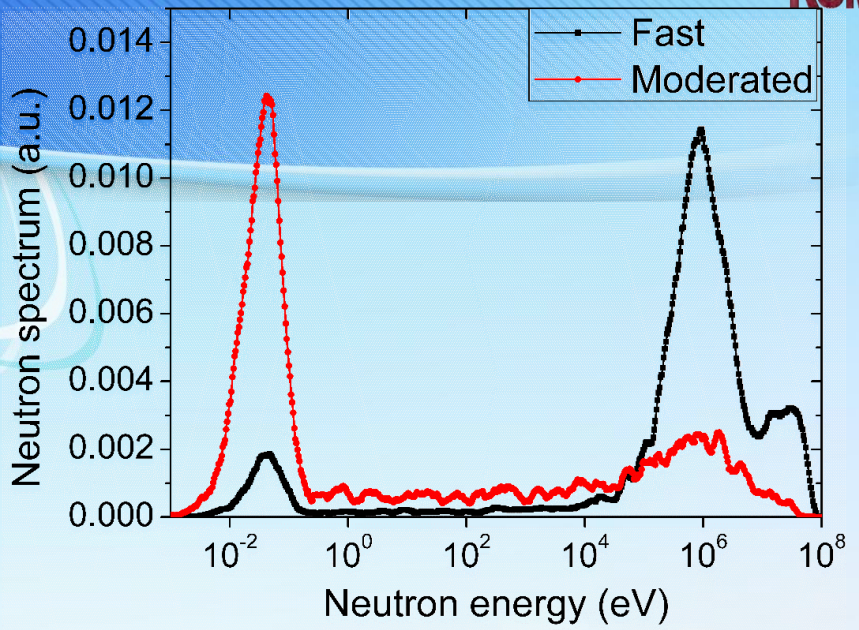
- Neutron yield : 0.2 n/p (Cu target), 0.37 n/p (W target)
- Neutron generation by Cu target irradiated by 100 MeV and 1 kW proton beam
  - $I_{avg.}$ = 10 μA (= 6.25 x$10^{13}$ protons/s)
  - Neutron yield = 2.3 x$10^{13}$ neutrons/s (time averaged)
  - Neutron flux at 1 m away from target
    : 1.03 x$10^{8}$ n/cm$^2$ s (time average), 1.03 x$10^{11}$ n/cm$^2$ s (peak, 0.1% duty)

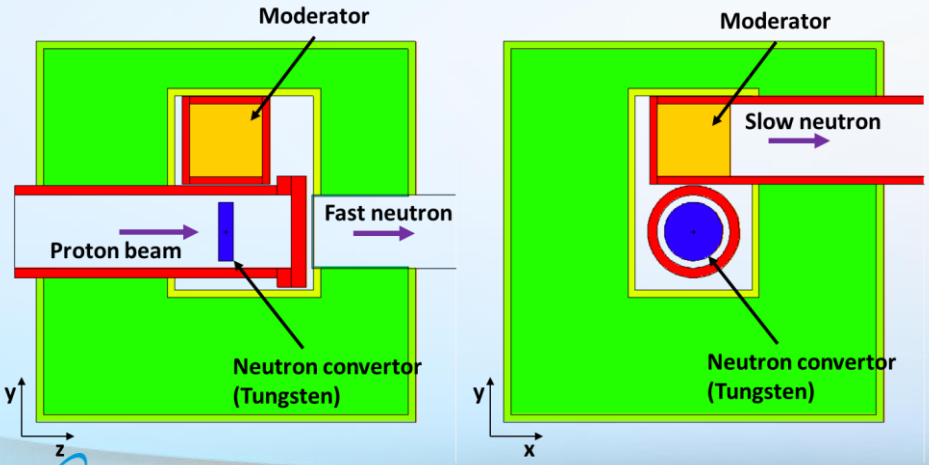


# Neutron Target System



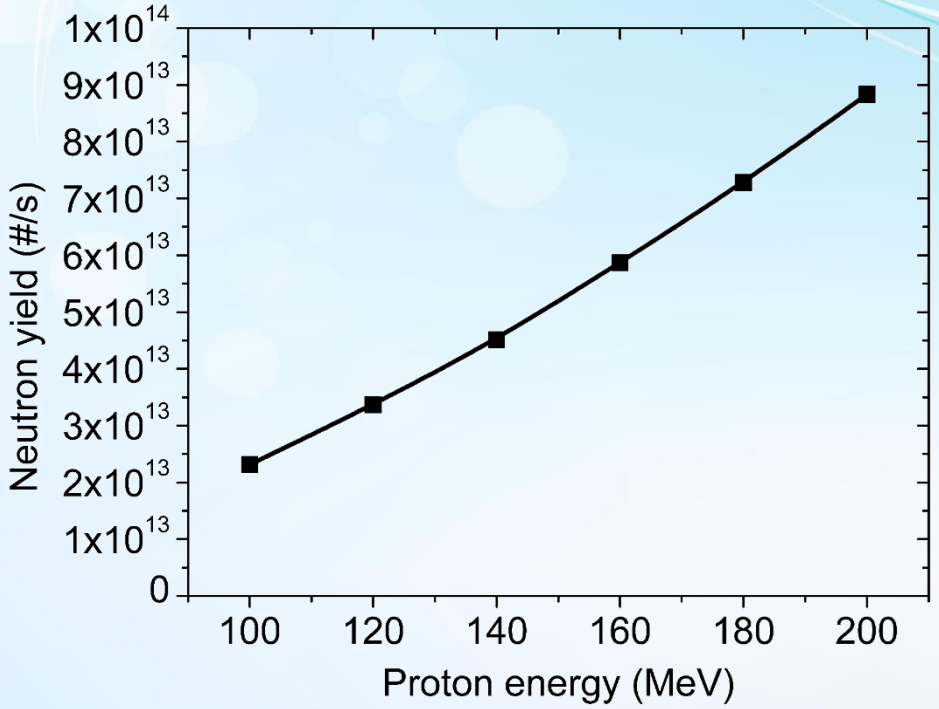


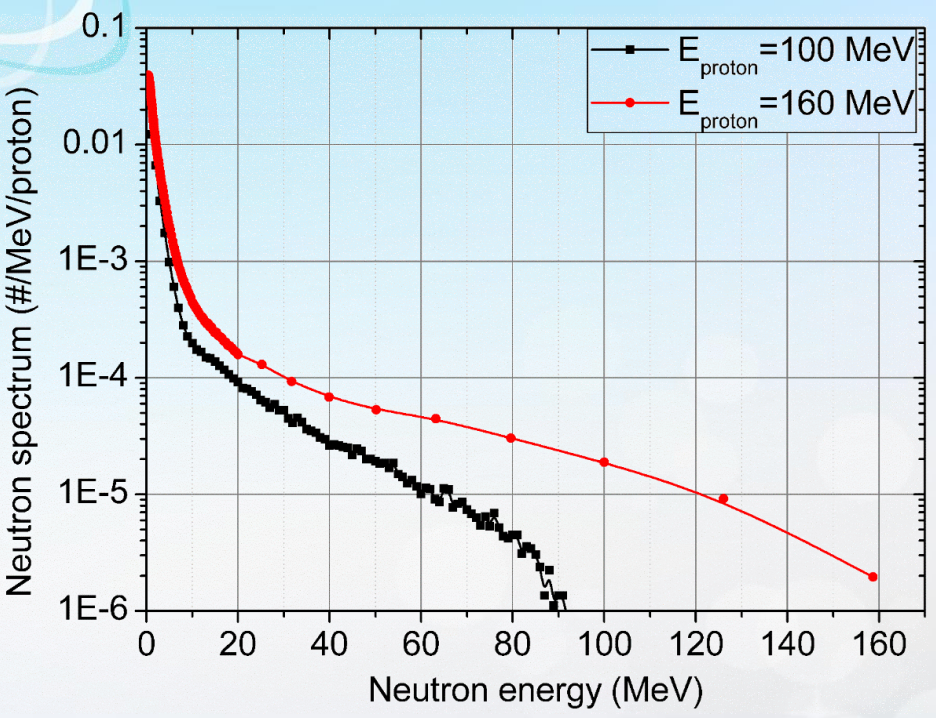




| | |
|---|---|
| Target | Tungsten (Disk type, 18 mm-thick) |
| Moderator | Non-borated polyethylene |
| Reflector | Water |
| Neutron Yield at Target (@ 100-MeV, 1 kW) | $2.3\times10^{13}$ n/s |
| Extraction Angle | Zero degree (Fast), 96 degrees (Thermal) |

# Effect of Proton Energy on Neutron Source



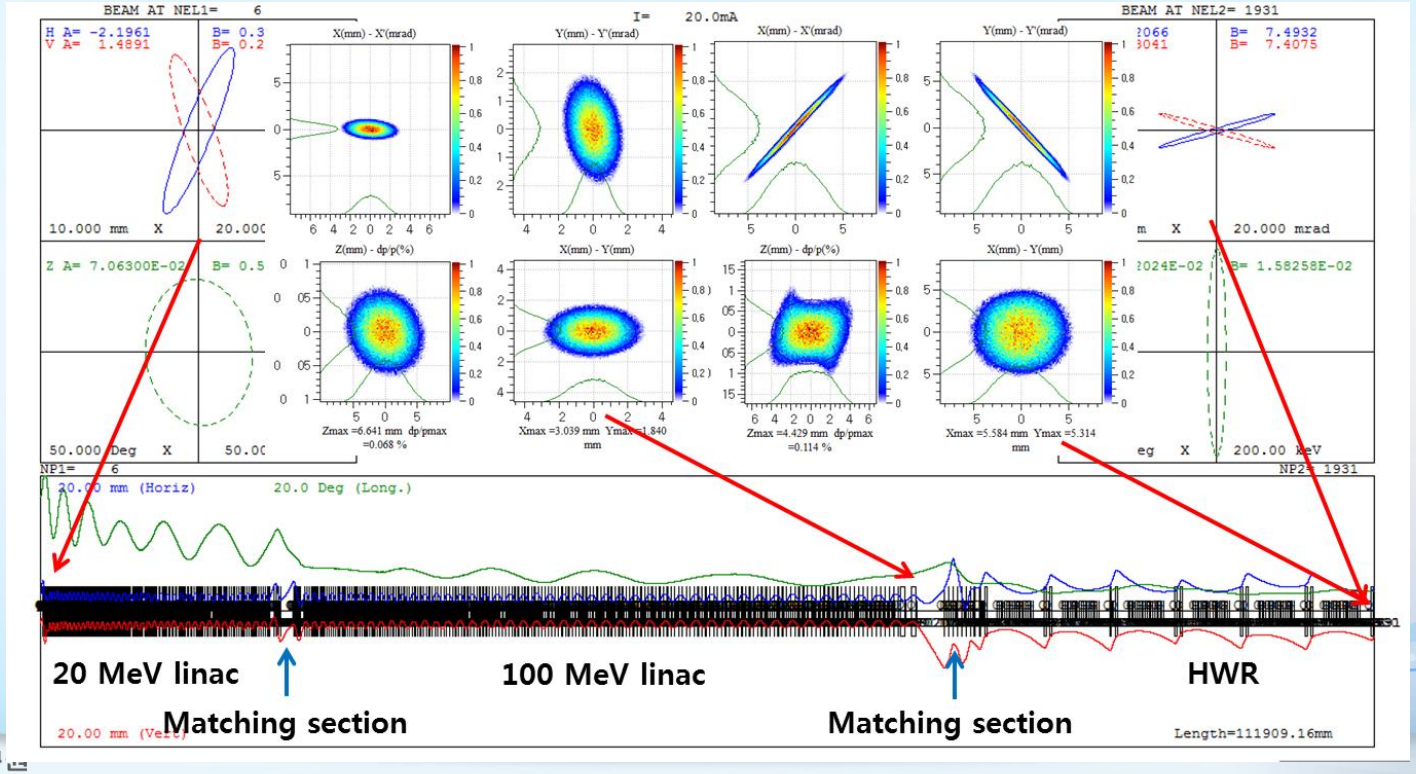




**To increase neutron yield and neutron energy,**
**higher energy proton beam is required.**

# Baseline Design Concept for Higher Energy

KOMAC

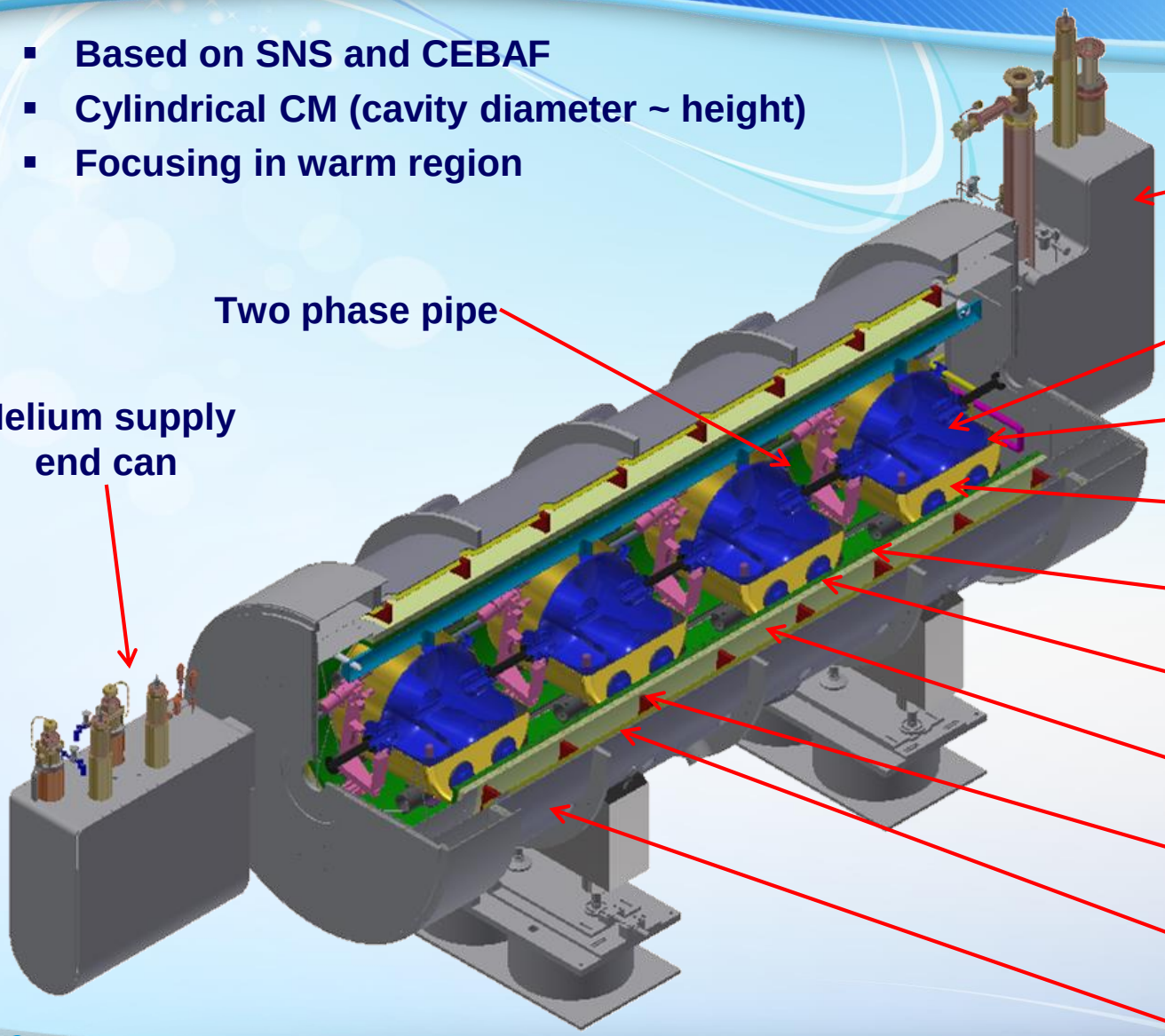
- Superconducting HWRs at 40m space inside the existing tunnel
- 4 cavities / cryomodule
- External normal conducting quadrupole magnet for focusing
- Lattice: doublet
- Operation temperature: 2 K
- Cavity geometry: height ~ 0.5 * λ, diameter ~ $\beta_g$* λ, cylindrical cryo-module
- Use well proven technologies (tuner, coupler, cryo-module, etc) except HWR cavity



# Cryomodule Design

KOMAC

- Based on SNS and CEBAF
- Cylindrical CM (cavity diameter ~ height)
- Focusing in warm region



Helium return end can

Two phase pipe

HWR cavity

Helium supply end can

He vessel

Magnetic shield (inner)

Multi layer insulation

50 K thermal shield

Multi layer insulation

Space frame

Magnetic shield (outer)

Vacuum vessel

# Summary

- 100-MeV proton linac operation at KOMAC since 2013
  - 4 beamlines are under operation
    :20MeV/100MeV General purpose, 100MeV RI production, 100MeV low flux
  - Increasing users and availability

- KOMAC prepares secondary particle production to expand application fields of 100-MeV linac
  - Pulsed neutron for neutron-related science and technology
  - RI beam (Li-8) for beta-NMR (advanced surface analysis)

- R&D Status for Neutron Source
  - Test of pulse neutron generation and measurement based on existing system
  - Development of Target-Moderator-Reflector (TMR) system
  - Development of superconducting linac for higher proton energy


Thank you
안내동