Commissioning of 70 MeV cyclotron system of IBS and Consideration for the use as neutron source

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2022년 10월 19일, 창원컨밴션센터

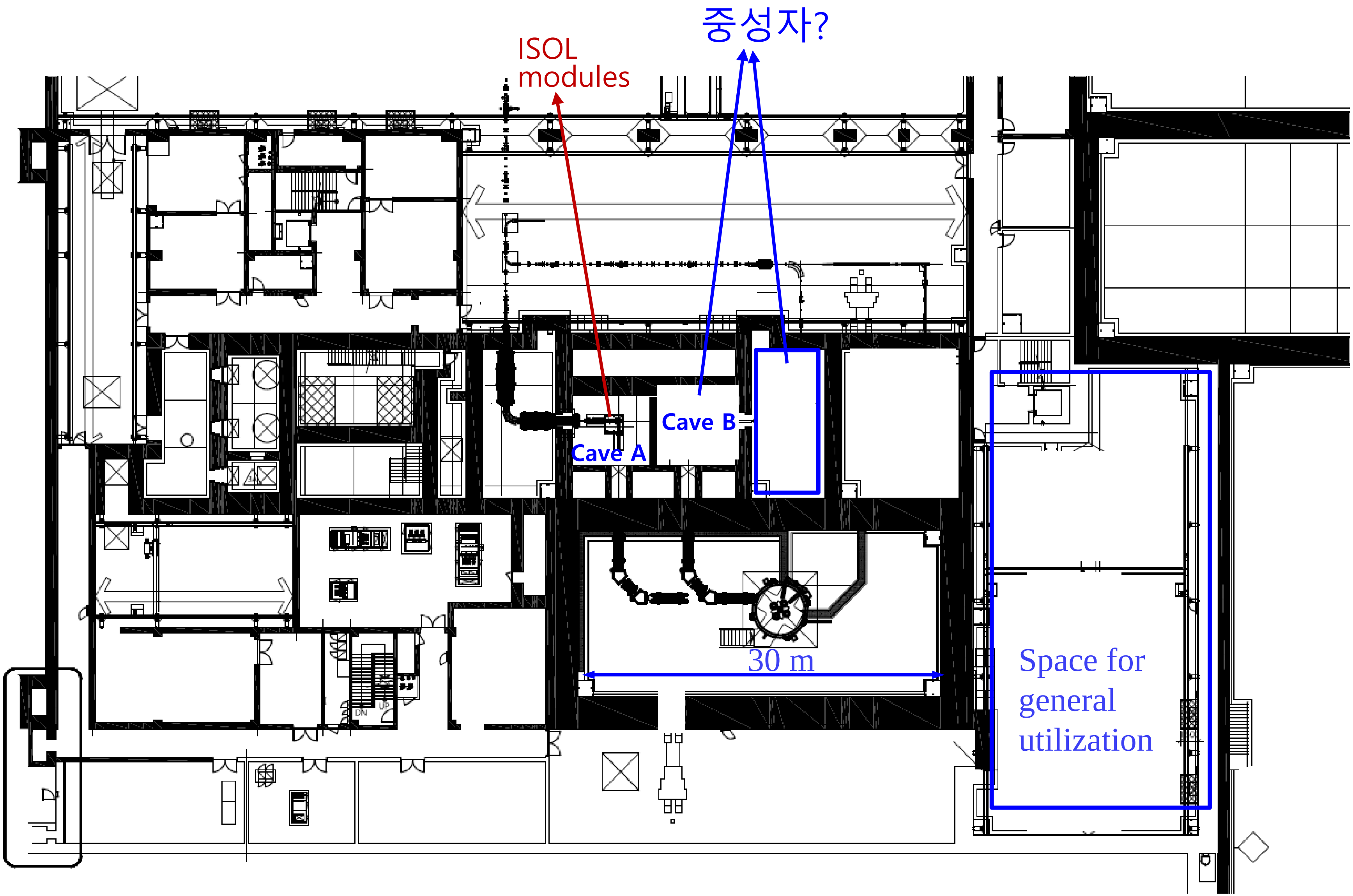
주요 내용

1. 기초과학연구원 (IBS) 70 MeV 양성자 사이클로트론 시설 구축 및 빔 시운전 현황 소개

2. IBS 사이클로트론의 중성자원 사용에 대한 고려

3. High Brilliance Neutron Source of Jülich (70 MeV proton) and 70 MeV cyclotron of INFN for neutron production

사이클로트론 시스템 지역 단면도 (B1)



사이클로트론 시스템 설치, 시운전 주요 일정

2019 8월: IBA사(벨기에)와 계약

2020 1월: 빔 라인 설계 확정
10월: 사이클로트론 자기장 측정 및 Shimming

2021
7월: Factory Acceptance Test 완료
11월 사이클로트론 시스템 건물 반입/설치

2022
6월: 사이클로트론 내부 빔 가속, 방사선 지역 출입제한
7월: 빔 인출 및 빔 특성 측정 시작 (40-70 MeV)
9월: 현장 검수 시작
10-11월: 현장 검수 완료 및 계약종료

사이클로트론 주요 사양

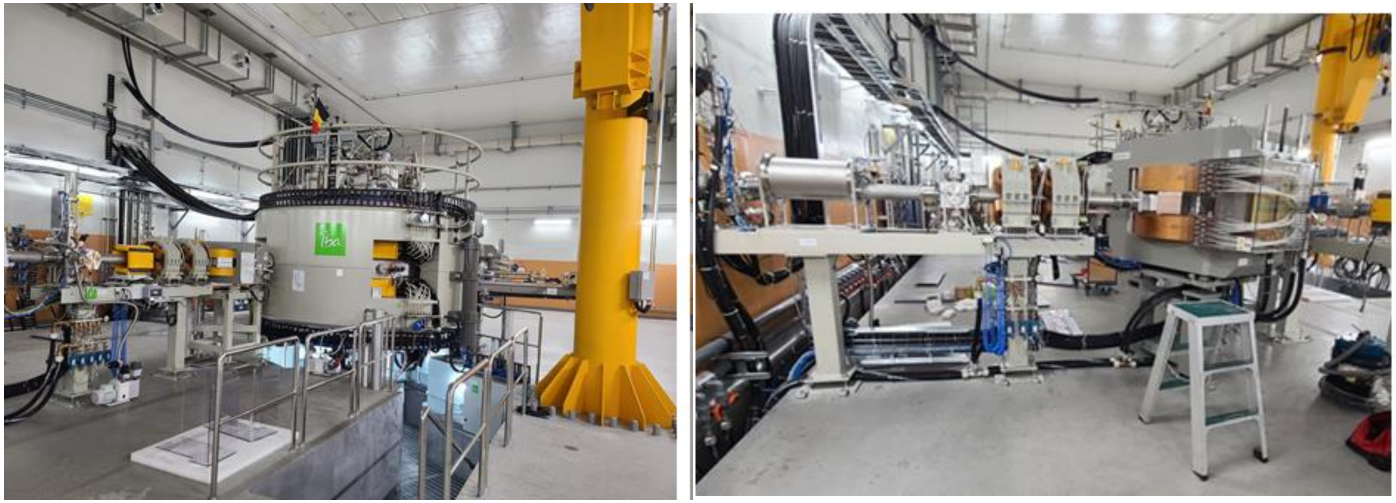
Energy	30-70 MeV
Maximum proton intensity	750 μA
Simultaneous extracted beams	2
Number of sectors	4
Hill field	1.6 Tesla
Harmonic mode	4
Frequency (fixed)	62MHz
Injected H-current	10 mA (H-)
Total weight	140 tons
Cyclotron dia.	3.8 m

Cyclotron System Rigging (2021년 11월)

1200톤
크레인

Installation of all components and utilities (2022년 4월)

Cyclotron vault

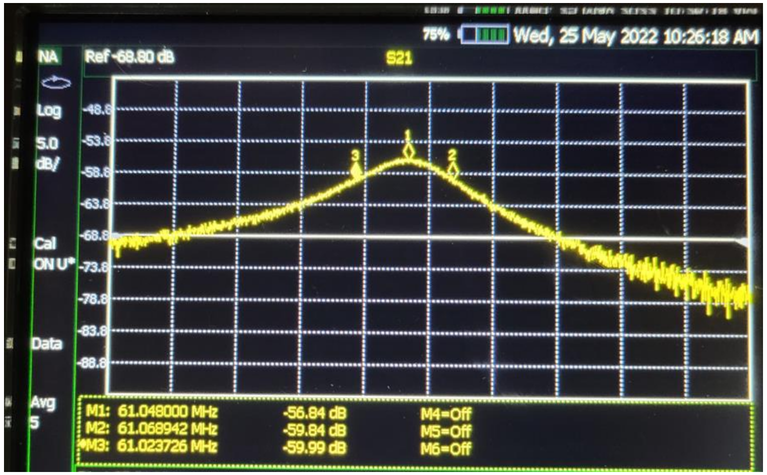


Cyclotron cooling room

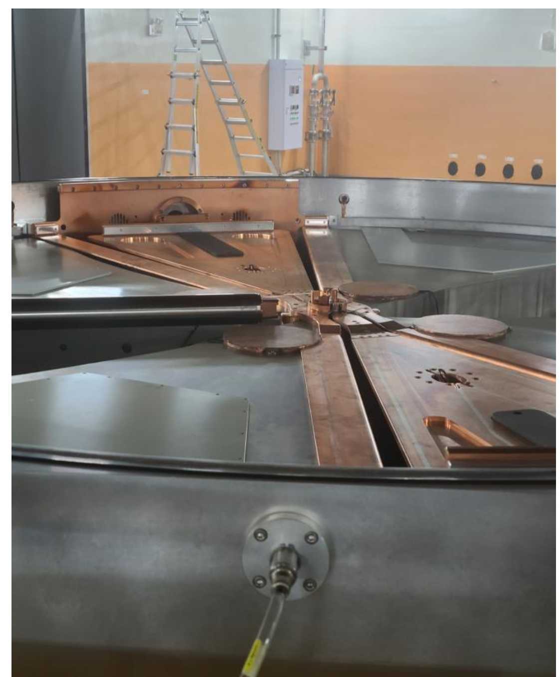
Power Supply & Control room

Final focusing & wobbler module in ISOL bunker (X2)

RF system test (2022년 5-6월)

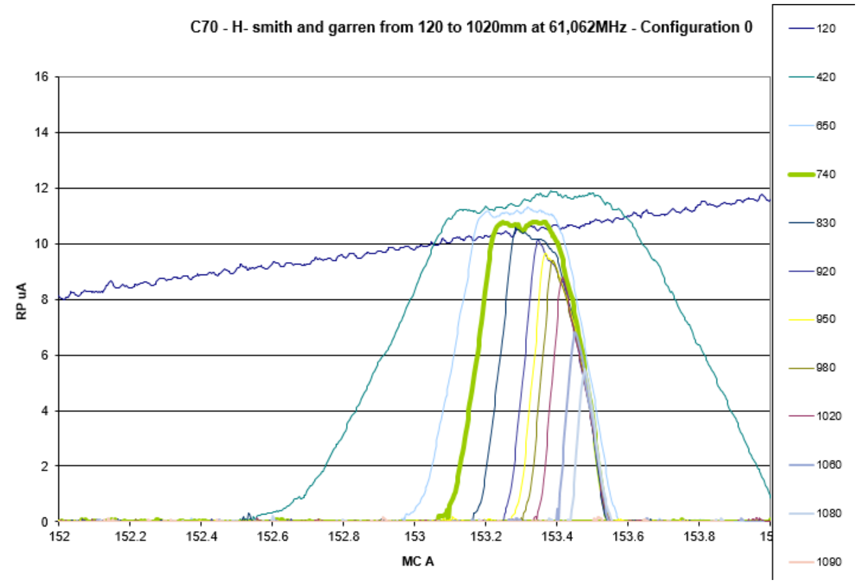


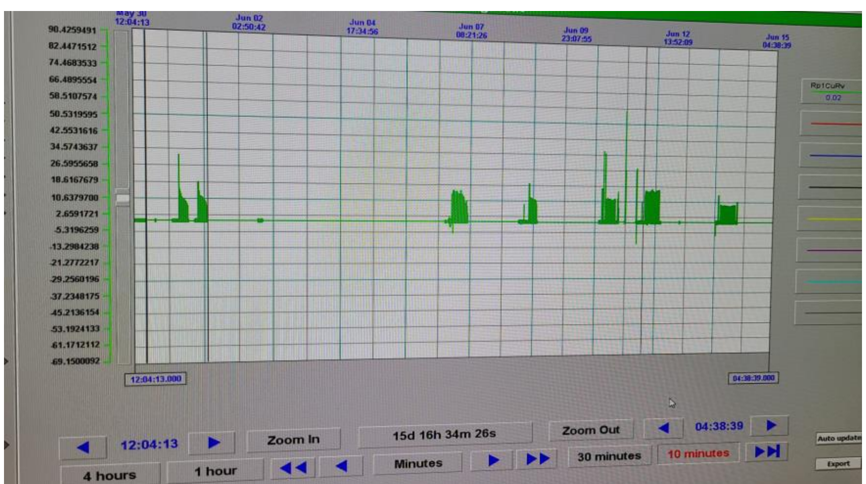
LLRF → Solid State Amp. (5 kW) → Final Power Amp. (100 kW)



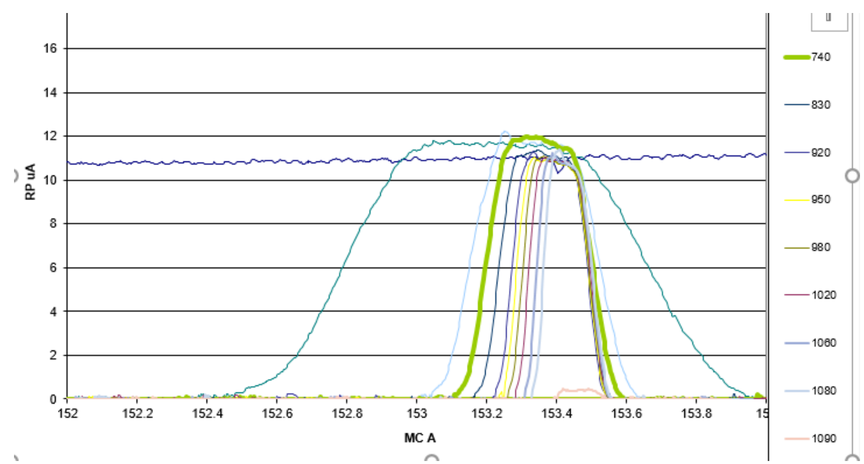
Optimization of magnet field using Smith-Garren method

Before Smith-Garren



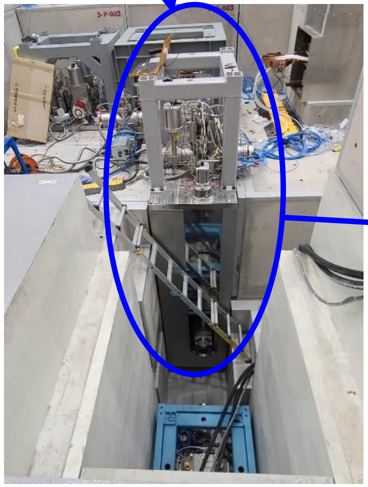


After a few iterations



현장 검수를 위한 빔 라인 준비 (2022년 8월)

ISOL 모듈



Cave A (beam line for SAT)

Cave B (radiation shielding for SAT)

Cave A 빔 시운전 시작

50 kW 빔 덤프 (ISOL 타겟 위치)

IBA Beam Profile Monitor

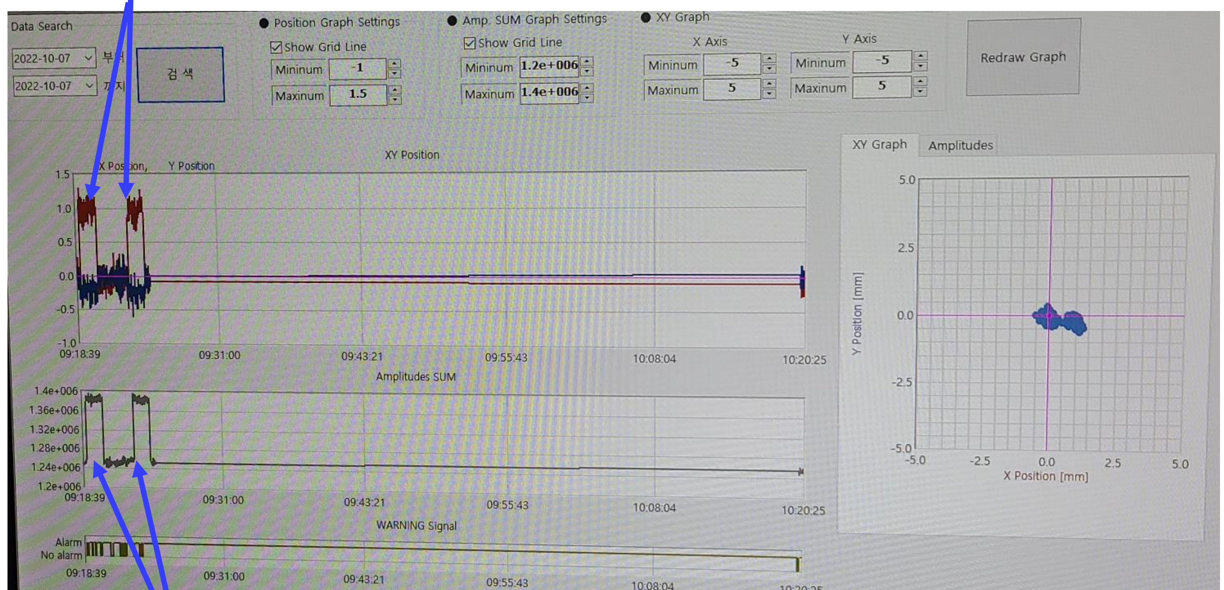
Cave A

Beam off-center 측정

ΔX: ~1 mm

ΔY: <0.5 mm

IBS Beam Position Monitor (BPM)

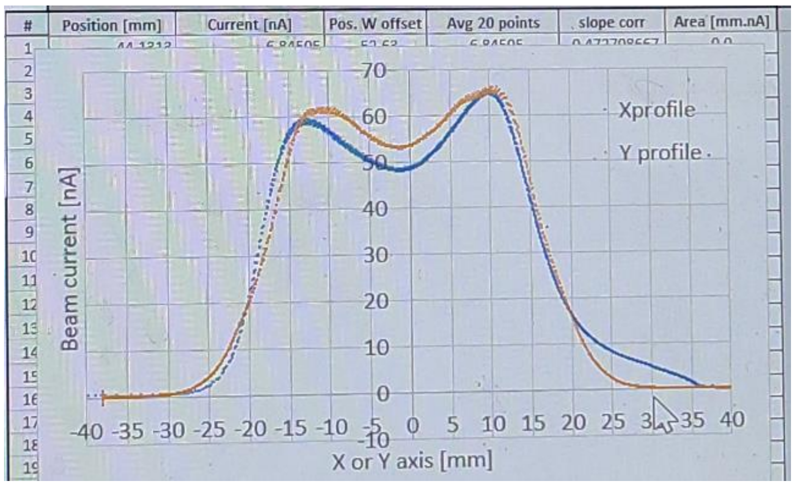


양성자 빔 전류 (~10 μA)

2022년 10월 7일

현장 검수 빔 시운전

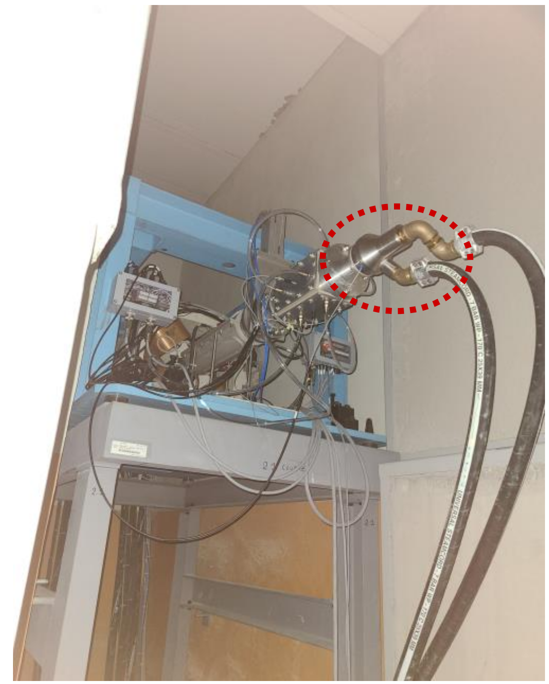
Cave A



Beam wobbling (Oct. 12, 2022)

Wobbler (AC magnet, 60 Hz)

Cave B

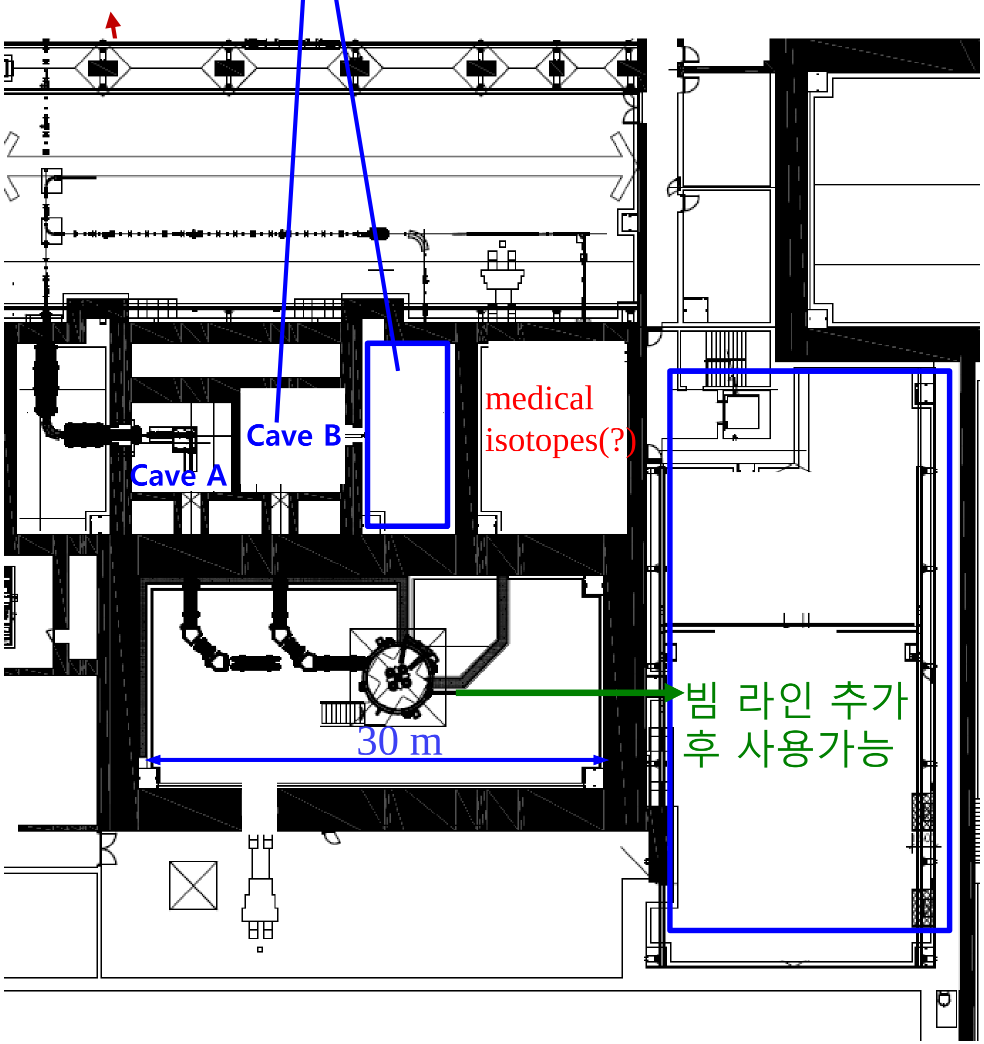


50 kW (70 MeV, 0.7 mA) 빔 시험 예정

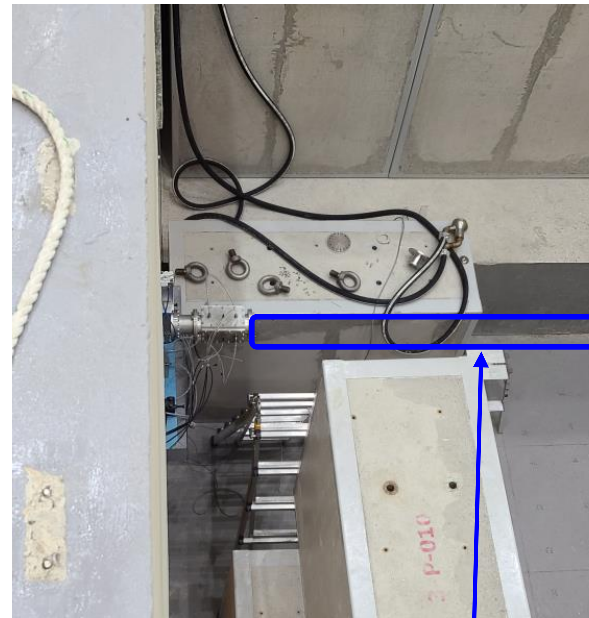
→ Fine tuning of beam line is required.

SAT 이후 Cave B 지역 사용 고려

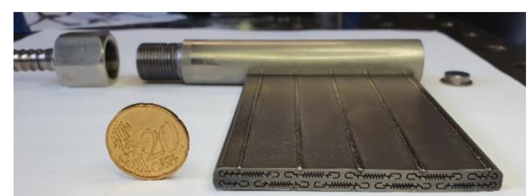
중성자 발생 (지역)용으로
사용 가능해 보임



Cave B before shielding



빔 라인 및 중성자 생산 타겟 등 추가?



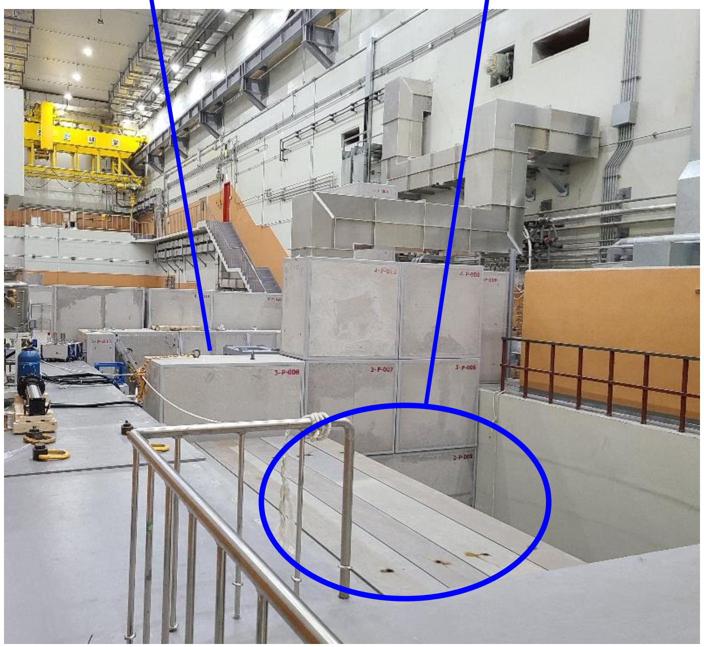
70 MeV 양성자 빔 용 Ta 타겟 (Julich)

Cave A & B 지역 방사선 차폐

ISOL 벙커 상부

Cave A

Cave B



Cave A 차폐 체 추가
(~200 μA)

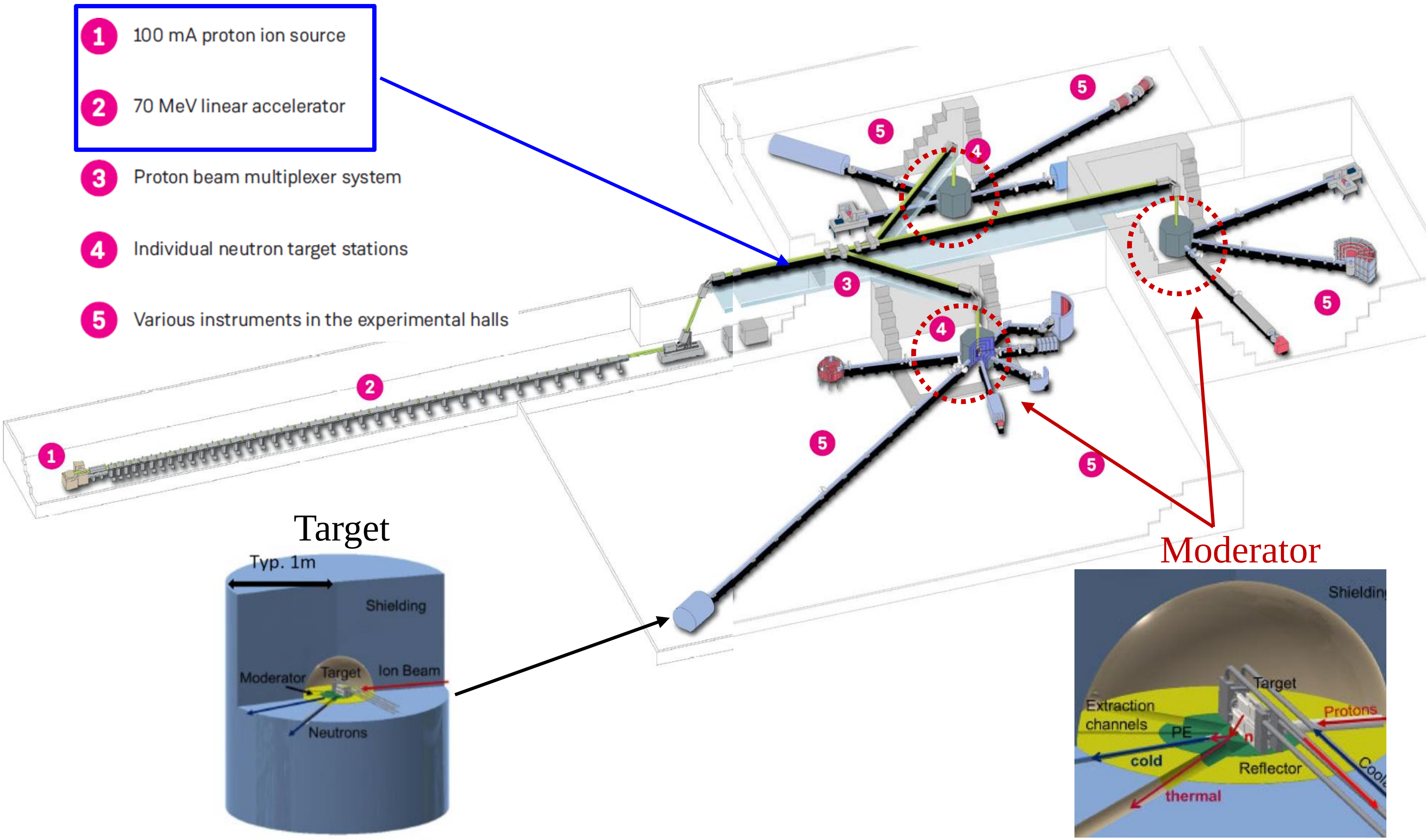
Cave B
(~700 μA)

미로 구조

Julich High Brilliance neutron Source (HBS) project

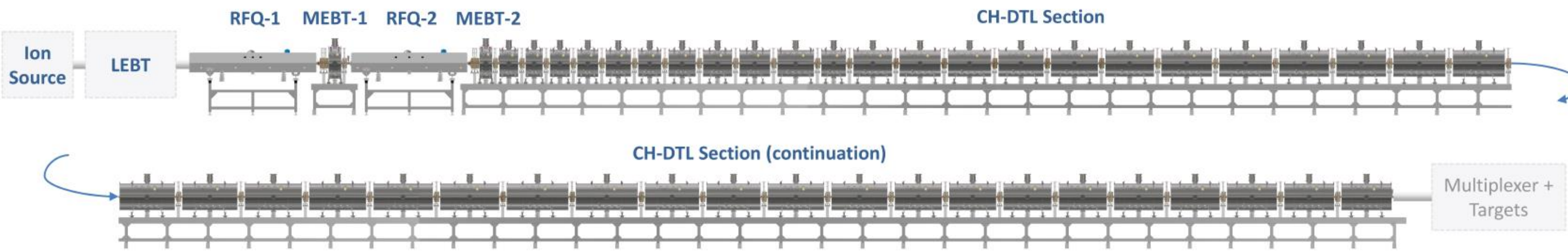
improving access to neutrons!

a peak brilliance of 2×10^{13} n s^{-1} cm^{-2} Å^{-1} sr^{-1}



HBS 선형가속기 설계

- High Brilliance Neutron Source belongs to Compact Accelerator Based Neutron Sources(CANS) class.
- The term "compact" must be seen here in comparison with spallation sources, which typically require an order of magnitude higher beam energy.

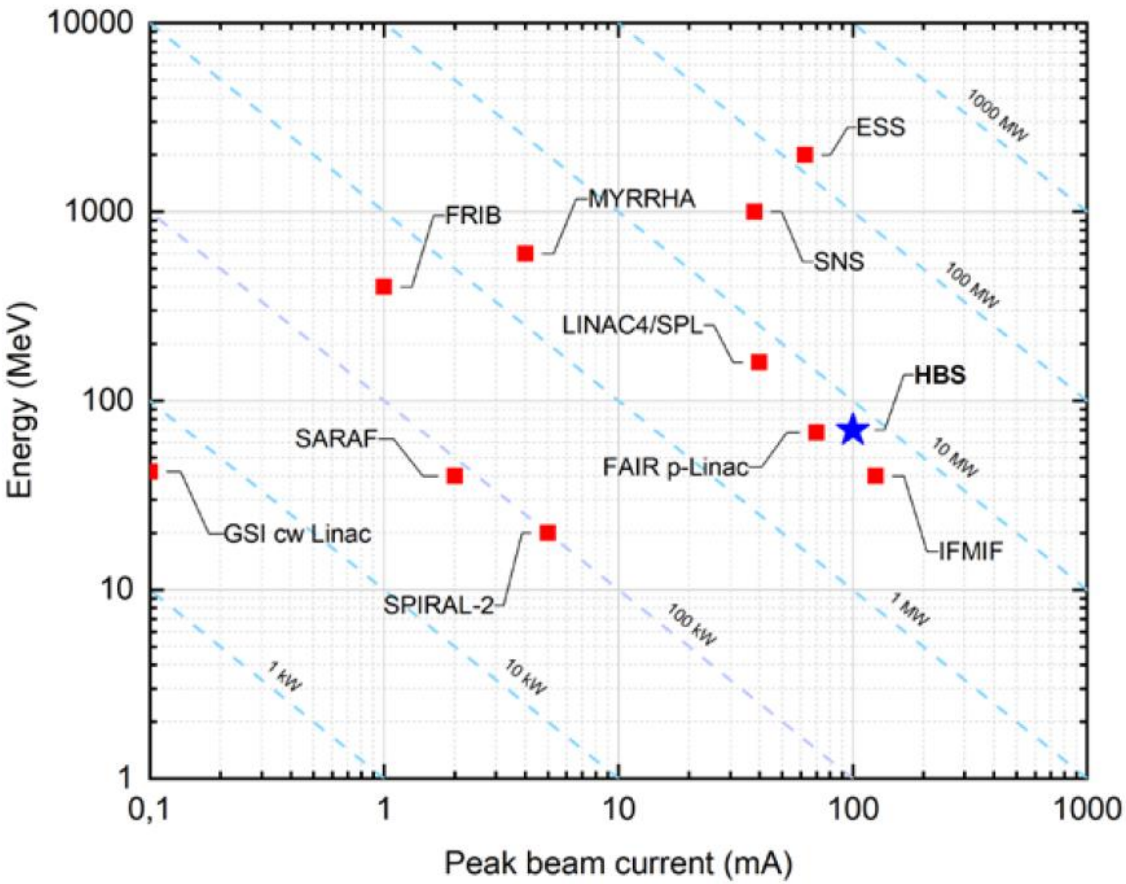


Based on MYRRHA injector (176.1 MHz)

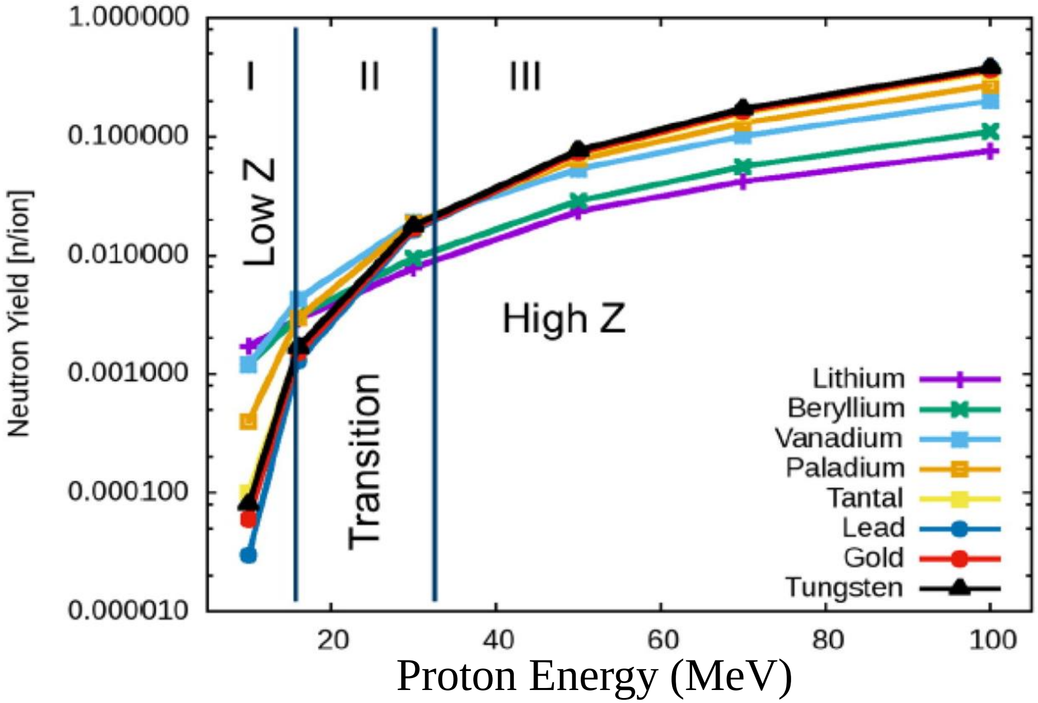
Parameter	Specifications
Particle type	Protons
Peak beam current	100 mA
Final energy	70 MeV
Duty cycle (beam/RF)	13.6/15.3 %
Beam pulse length	208/833/2000 μs
Repetition rate	96/24/48 Hz
Peak beam power	7 MW
Average beam power	952 kW

HBS

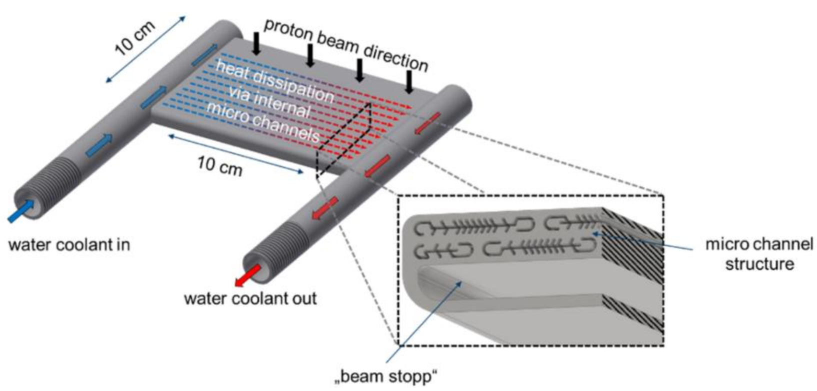
- An efficient and cost effective alternative to the current low- and medium-flux reactor and spallation sources with the potential to offer science and industry access to neutrons.
- There are however currently no high brilliance CANS in routine operation across the world. The operation of a relatively high-power target (50kW) even at a low proton energy has still to be demonstrated.

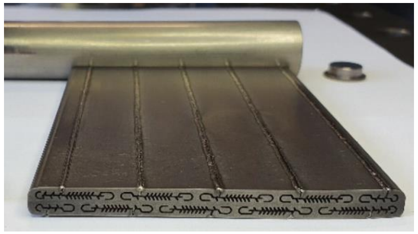


Neutron yields by low-energy protons for different targets



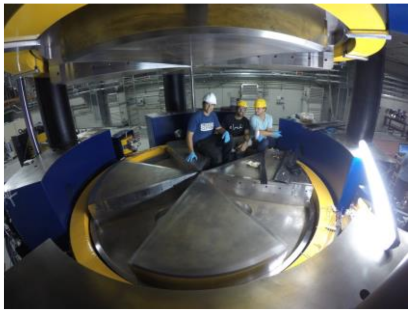
HBS tantalum target with fin-like μ-channel structure

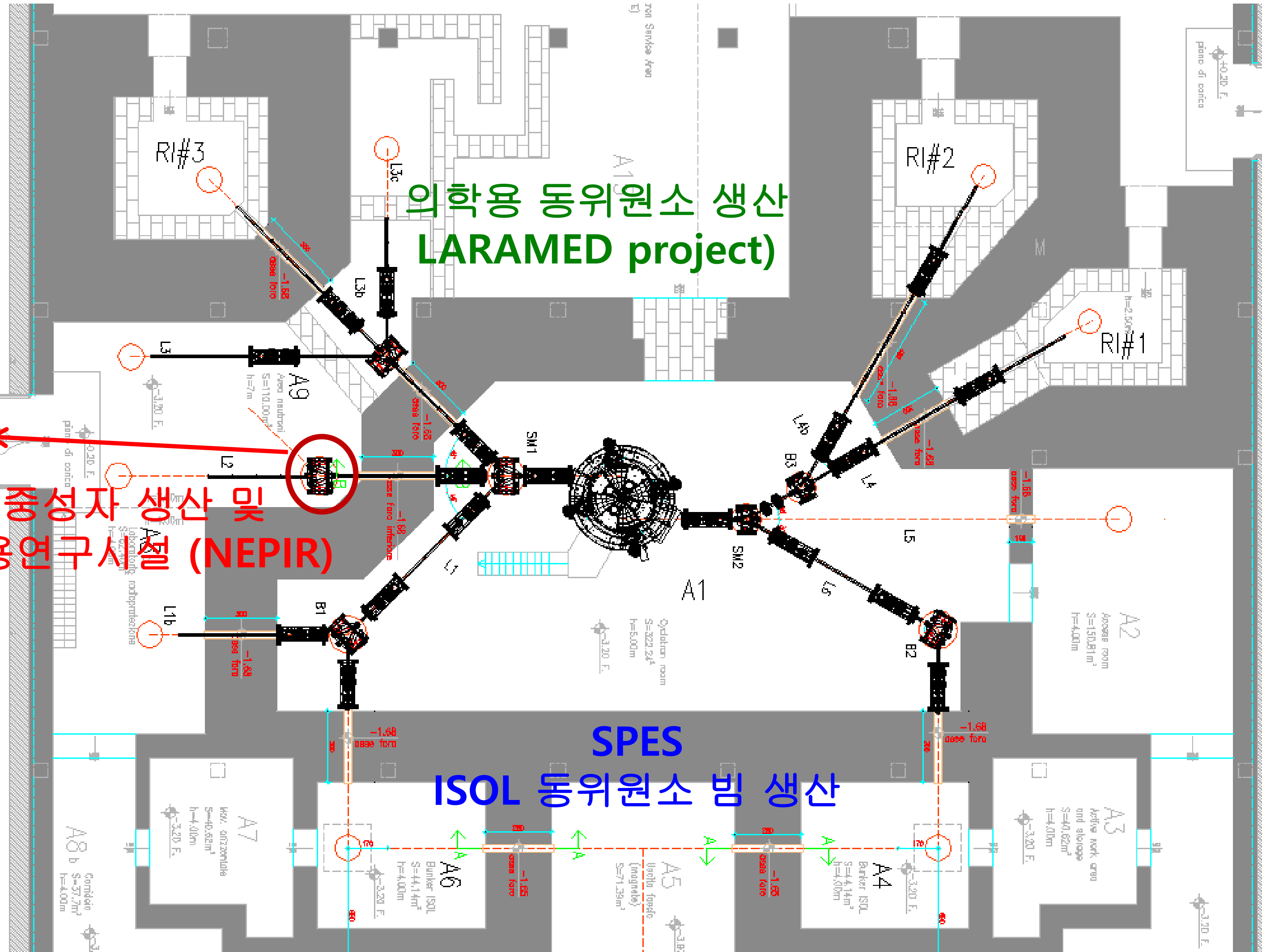




INFN 70 MeV 사이클로트론 활용

Cyclotron of BEST Inc.



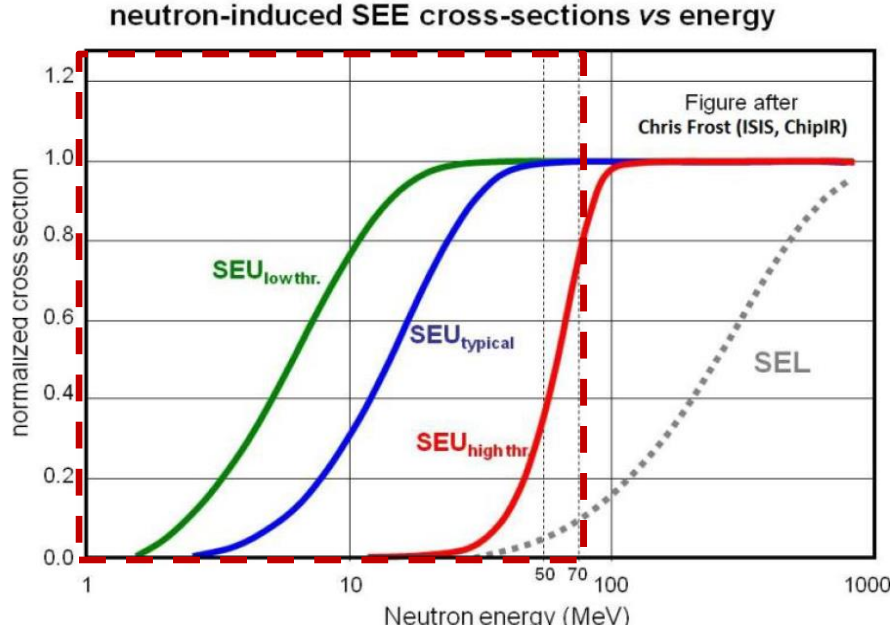


1. QMN: Quasi Mono-energetic source with peak energy control

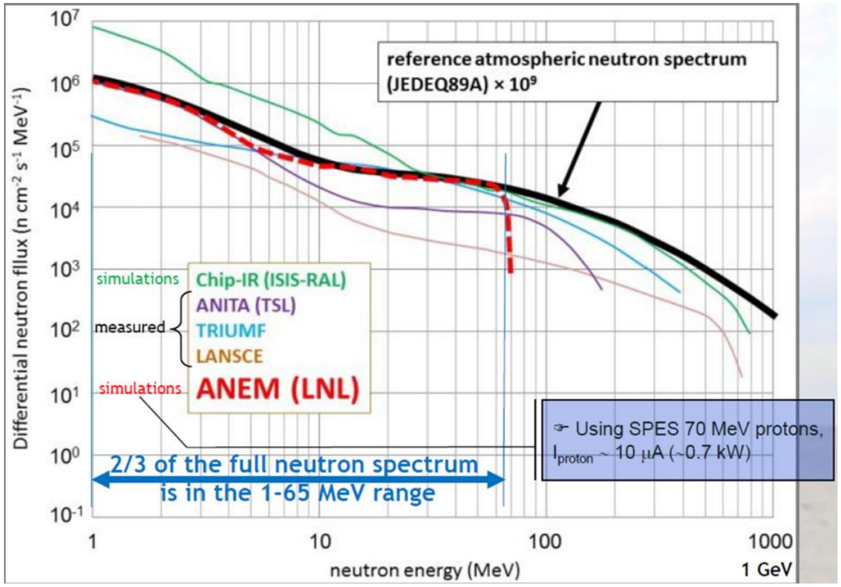
2. ANEM (Atmospheric Neutron Emulator): 전자장비 방사선 손상 연구, 비행 고도 및 해수면 대기 중의 중성자 등

L. Silvestrin, 40th European Cyclotron Progress Meeting, 2017

Continuous energy neutron source: ANEM (*Atmospheric Neutron Emulator*)



Comparison of white neutron spectrum



결론

- IBS 사이클로트론 빔 현장 검수 후 **Cave A**에 ISOL 가동을 위한 빔 라인 연결 및 저출력 (<1 kW) 초기 빔 시험 진행 예정

- **Cave B**에 중성자 생산을 위한 빔 라인/Target/Modulator 설치 및 시험 가능 예상

- CANS로 ~70 MeV 양성자 가속기 사용에 대한 국제적인 시도가 진행되는 것으로 판단됨