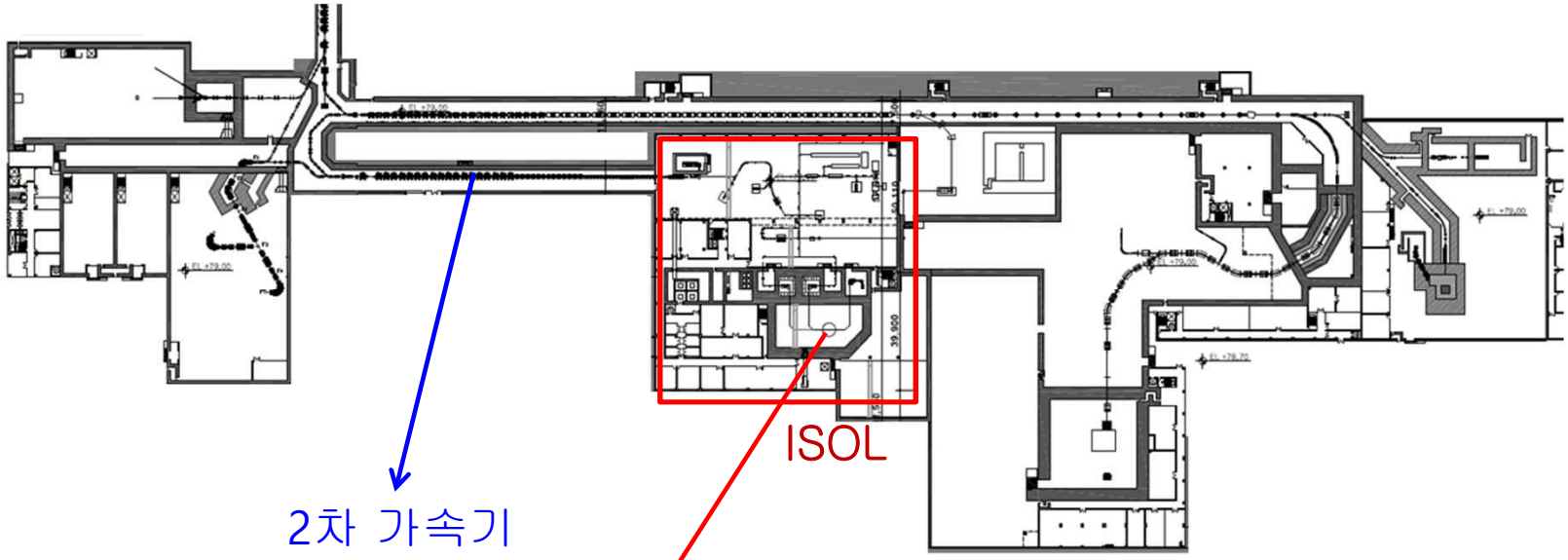
A use of 70 MeV proton cyclotron facility of RISP for CANS study

김종원
중이온가속기구축사업단, 기초과학연구원

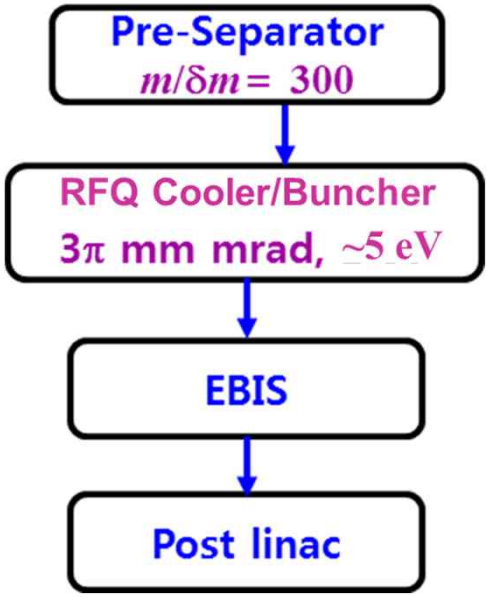
한국원자력학회 워크숍-소형 중성자원 개발과 이용-III
5월 12일, 2021년

사이클로트론 사용: ISOL driver+???



1차 가속기: 70 MeV 양성자 사이클로트론

	TIS	EBIS
Ion	$^{132}Sn^{1+}$	$^{132}Sn^{33+}$
E_{max}	60 keV	~10 keV/u



사이클로트론 설치 일정

2019

Jan.: Termination of a contract with Best Cyclotron Inc. (2017)

June: Contact with IBA

Aug.: Start the contract with first payment

2020

Jan.: Finalizing the beam line design for ISOL

Oct.: Field Mapping and shimming completed

CYCLONE®70

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 Cryo-pumps	6

2021

July~Aug.: Factory Acceptance Test and shipping

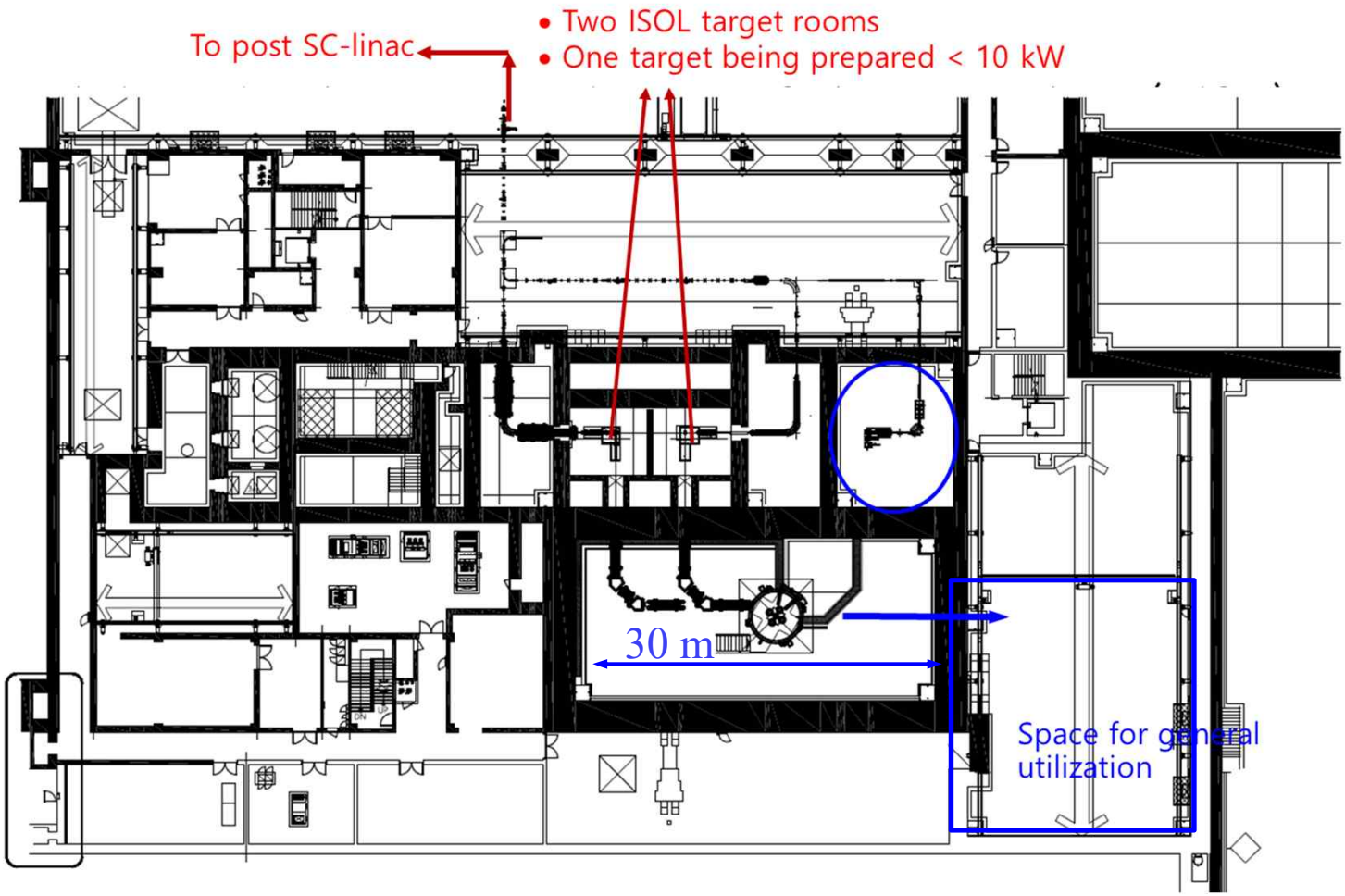
Oct.~Nov.: Cyclotron rigging and start installation

2022

Aug.: End of the contract

사이클로트론 건물(ISOL동) 평면도

- 사이클로트론 건물은 Best Cyclotron Inc.의 설치 요구 기준으로 설계됨.
- 건물 공사는 2019년 초 (IBA사와 계약 이전)에 이미 대부분 완료됨.

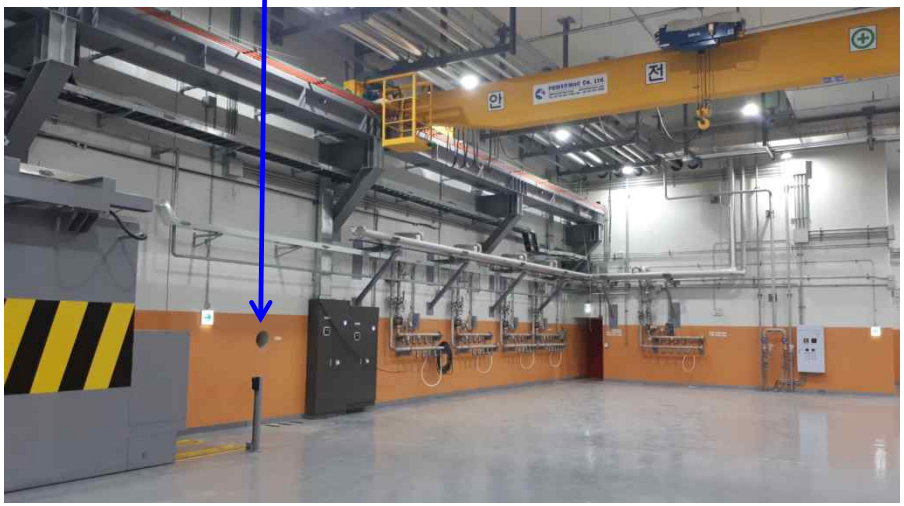


사이클로트론 및 다용도실 사진 (2020년, 10월)

사이클로트론실

빔 라인
관통부

다용도실



건물 및 ISOL벙커 사진

ISOL bunker for ISOL target modules designed for remote handling

추가 공사 (2021년 1월)

Steel plates for cyclotron support

3 ton jib crane

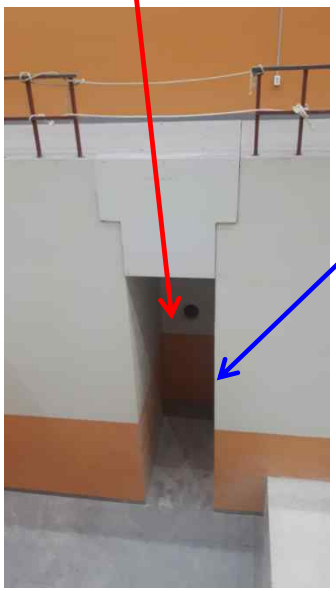
Additional penetration holes for HV of ion source

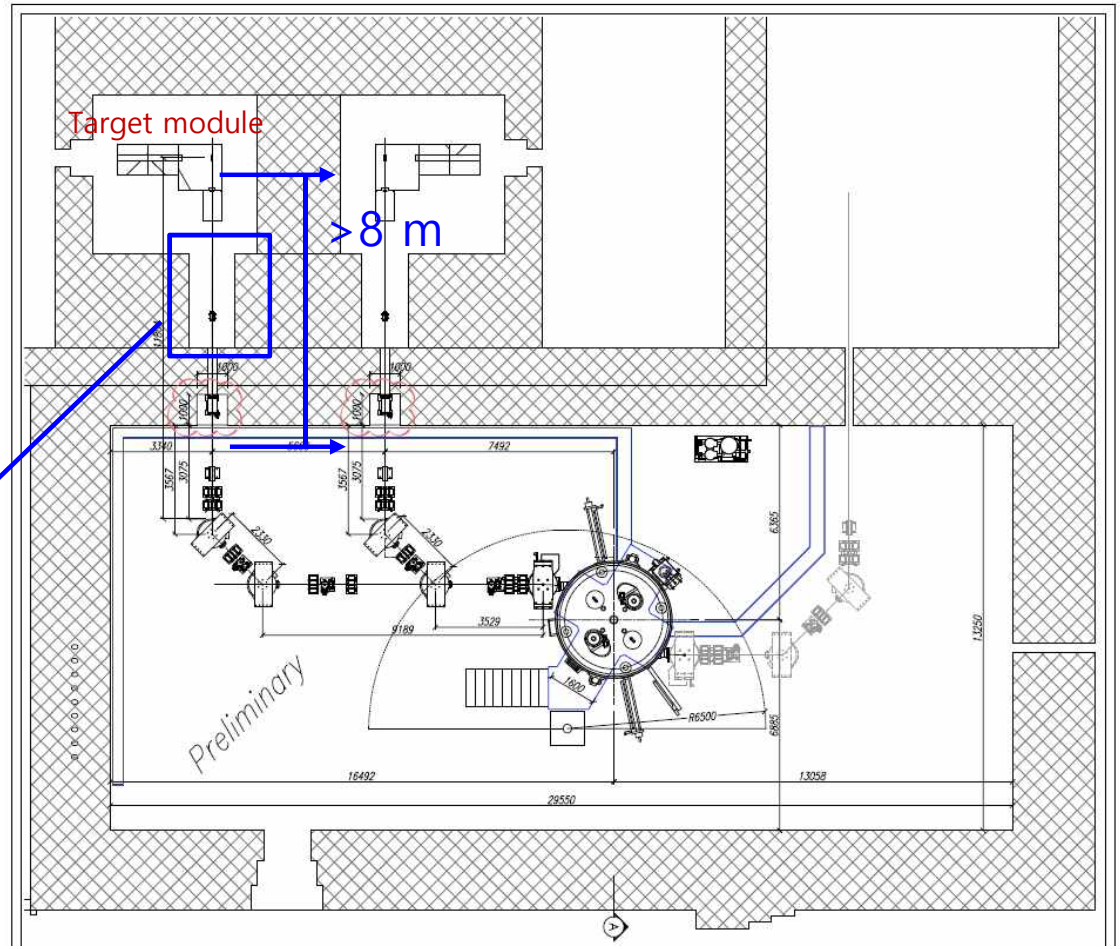
빔 라인 설계 확정 (2020년 1월)

주요 고려 사항:

- A long distance (>8m) from last quadrupole doublet to the ISOL target if the doublet is located in the cyclotron room.
- Uniform beam distribution is formed by a wobbler to a size of ϕ2-5 cm keeping minimum beam losses.

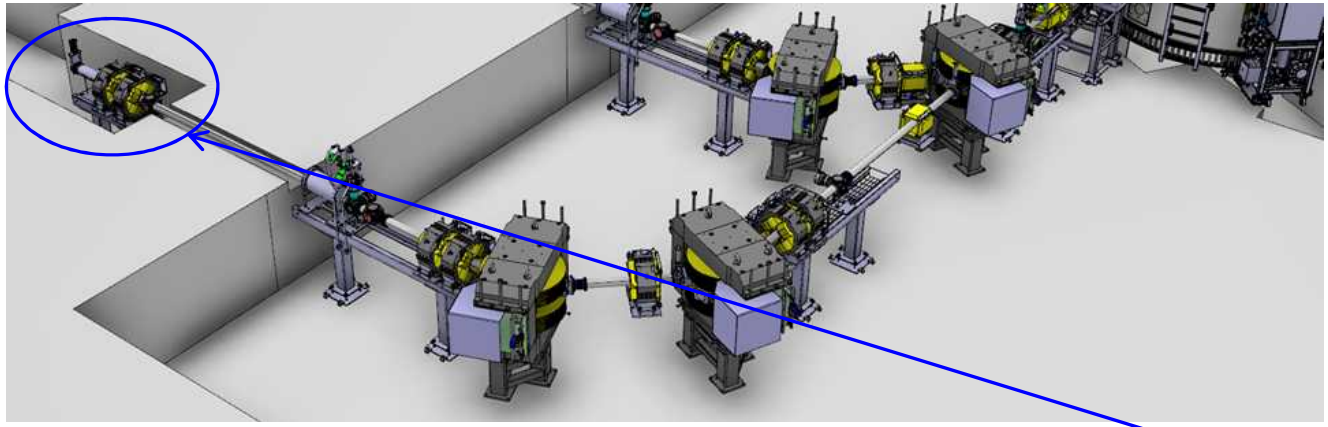
ISOL tunnel





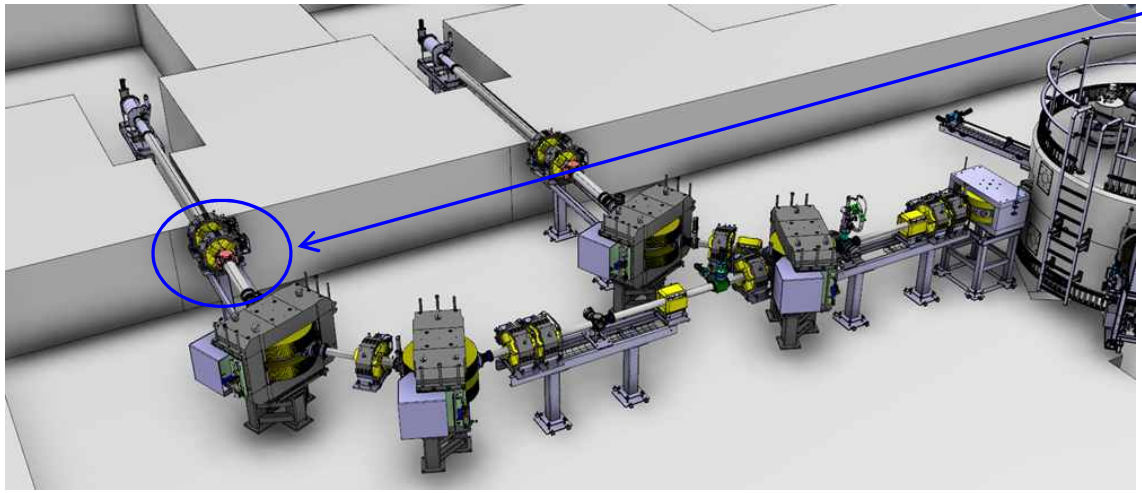
Two configurations considered in optimizing beam optics

Configure 1: Quadrupole doublet in ISOL tunnel (**chosen**)



Quadrupole doublet

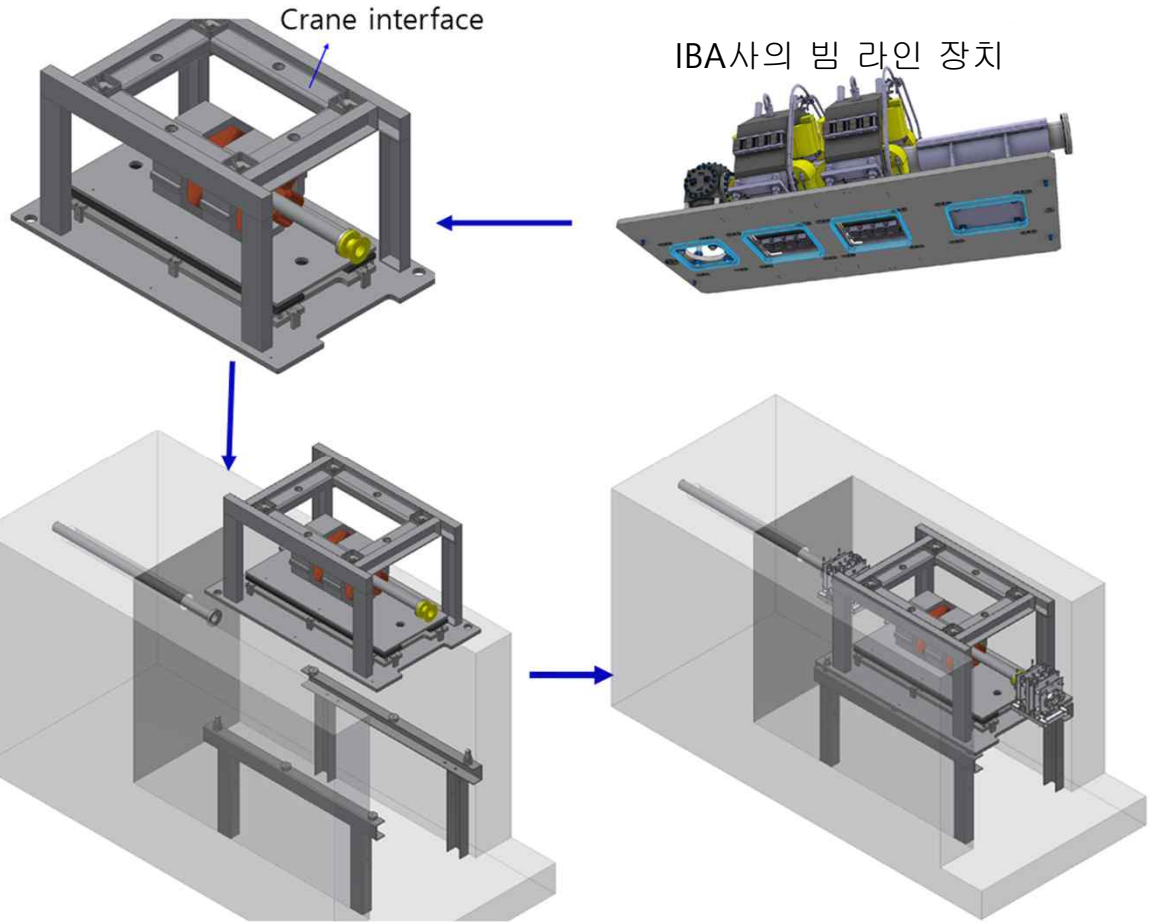
Configure 2: No quadrupole magnets in ISOL tunnel



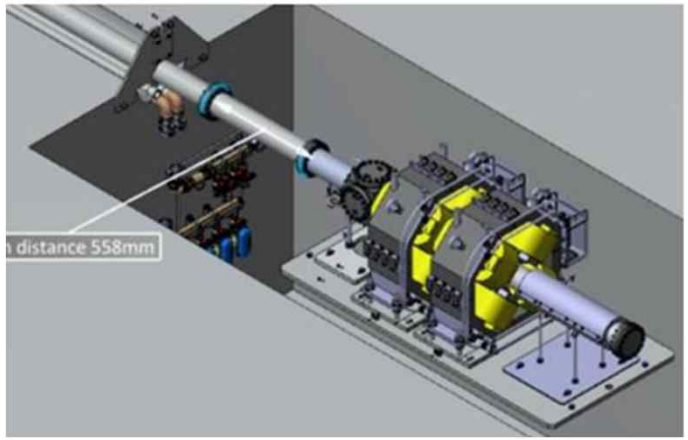
원격조작 빔 라인 지지대 (ISOL터널 내부)

원격조작 크레인 (ISOL 벙커)

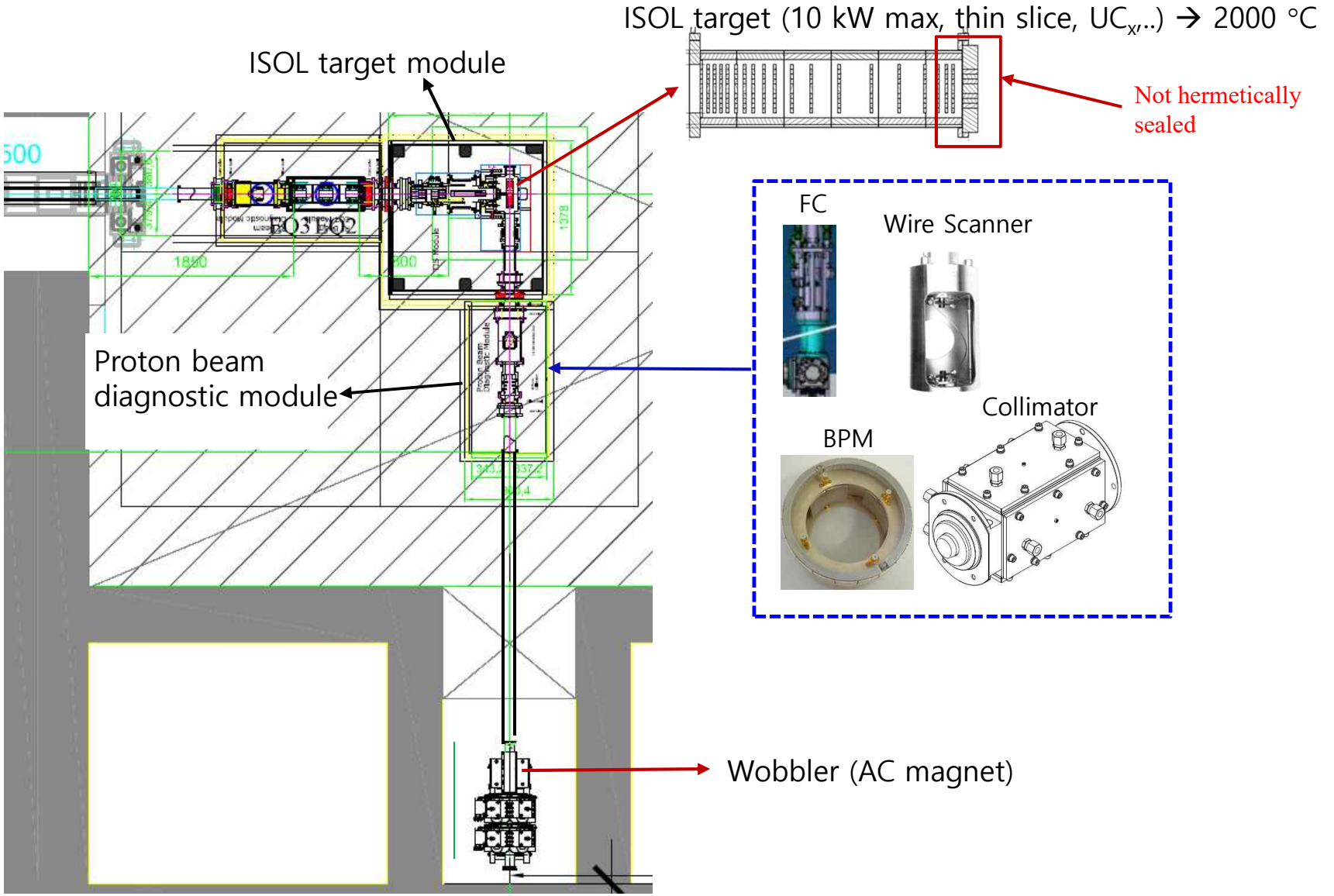
빔 라인 장치 조립 및 설치



ISOL 터널내 최종 설치도

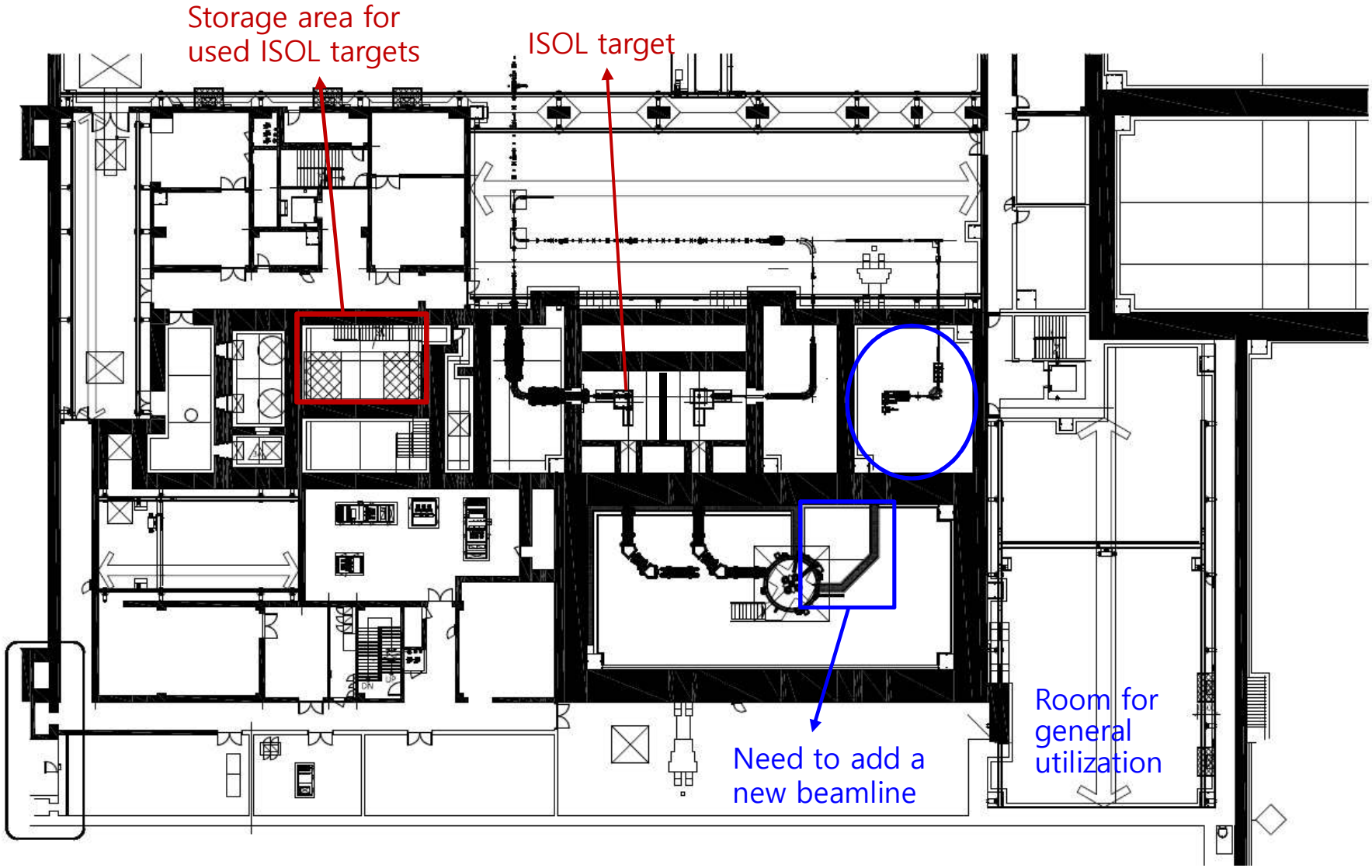


ISOL 타겟 빔 라인


ISOL target (10 kW max, thin slice, UC_x..) → 2000 °C
ISOL target module
Not hermetically sealed
FC
Wire Scanner
Collimator
BPM
Proton beam diagnostic module
Wobbler (AC magnet)

의학용 동위원소 생산?

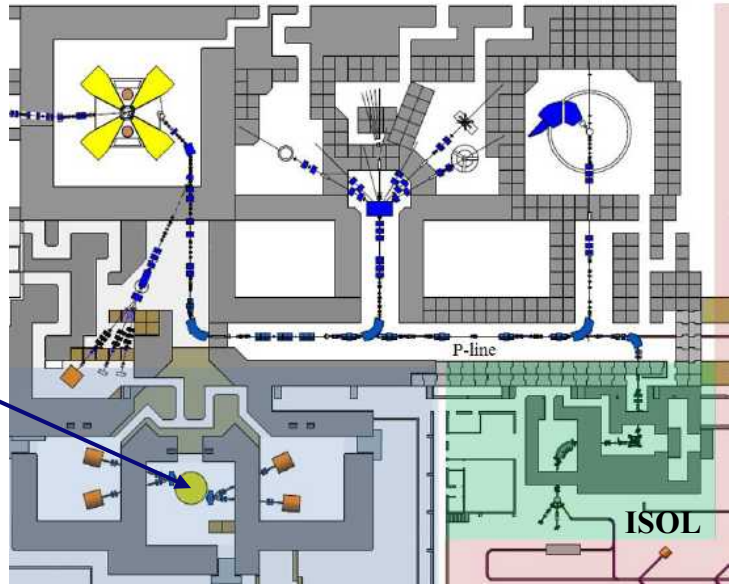
- ISOL target's lifetime is ~2 weeks and it will take 1-2 weeks for replacement.
- Simultaneous two beam extraction is possible for C70.



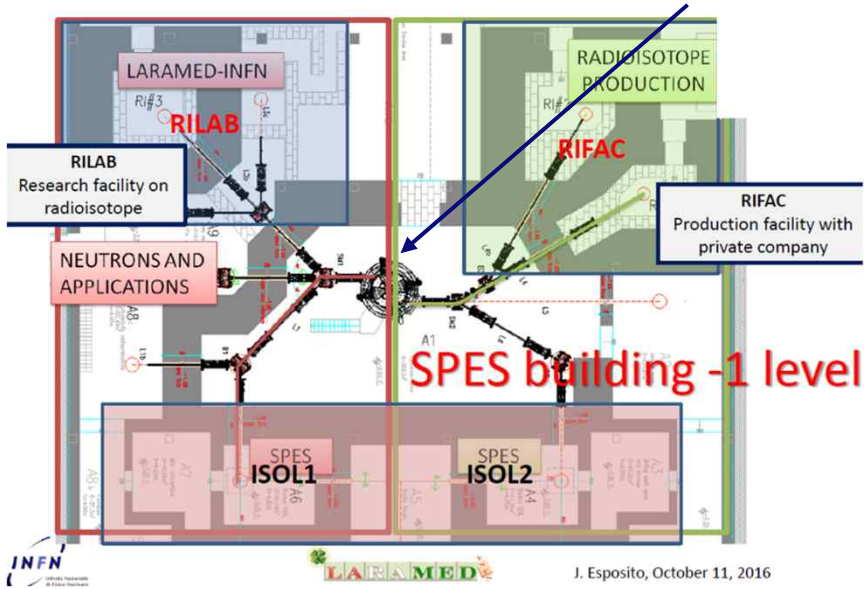
국외의 70 MeV 사용 의료동위원소 생산 예

Similar cases: 1) **iThemba LABS of South Africa**, 2) LARAMED (LAboratory of RAdionuclides for MEDicine) project at **INFN Legnaro**.

C70 of IBA



70 MeV p cyclotron of Best Cyclotron Inc.

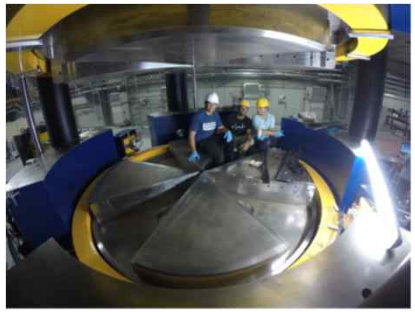


Major medical isotopes by 70 MeV protons

^{67}Cu (therapy+diagnostic applications) ^{82}Sr/**^{82}Rb** (heart function) and **^{68}Ga**/^{68}Ge generator systems

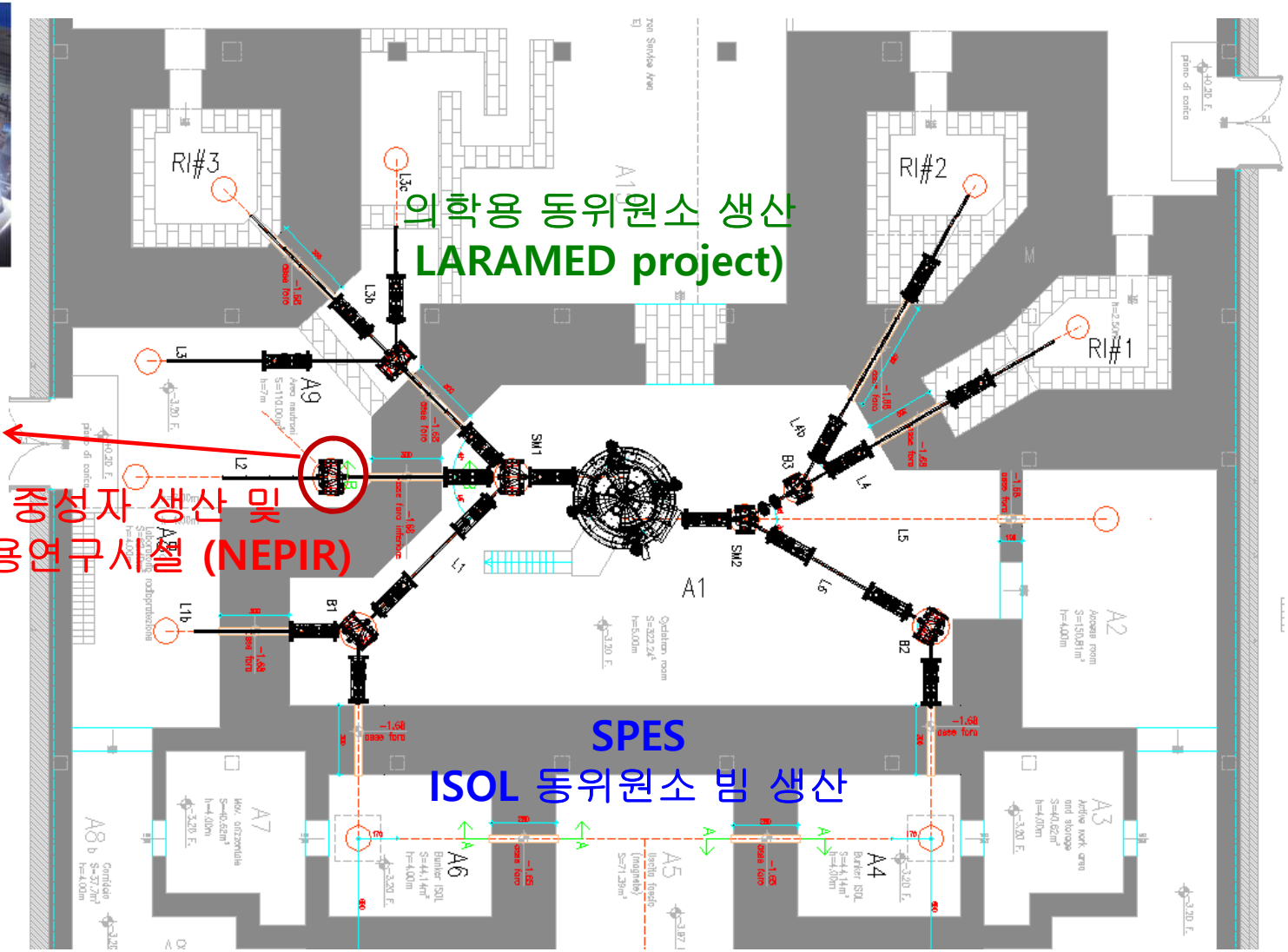
중성자 생산시설 예: INFN 70 MeV 사이클로트론

Cyclotron of BEST Inc.



1. QMN (Quasi Mono-energetic) source

2. ANEM:
전자장비 방사선 손상 연구: 비행 고도 및 해수면 대기 중의 중성자 및 **solar proton**



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

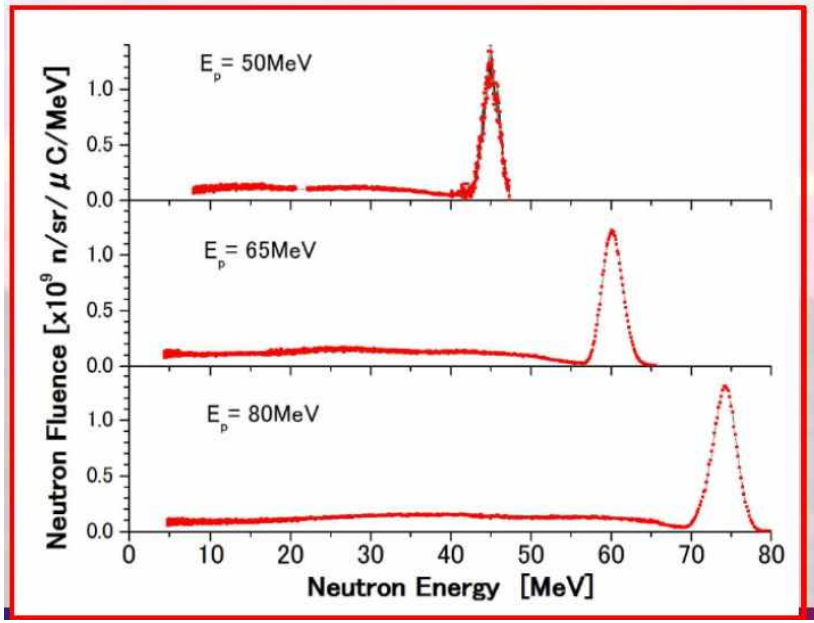
70 MeV 양성자 사이클로트론 기반 중성자원 특성

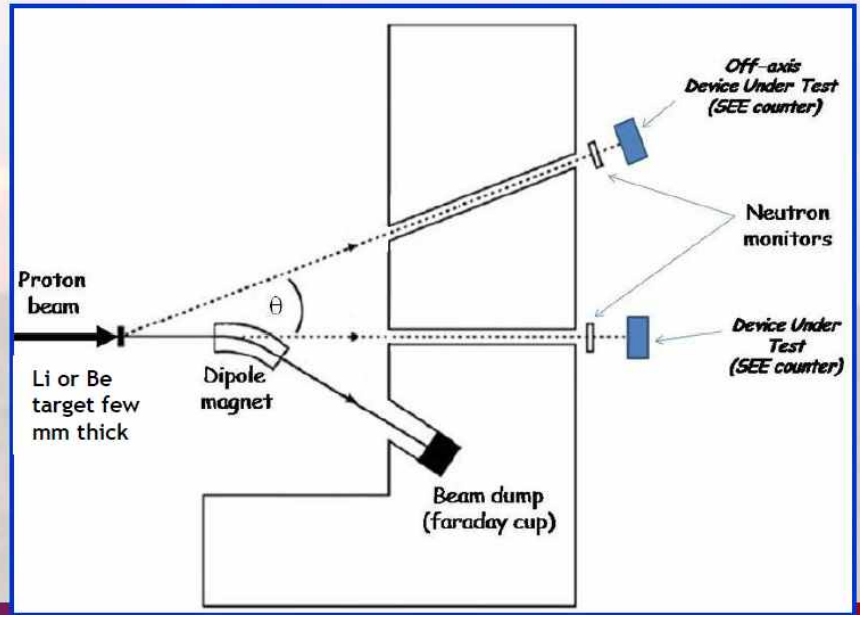
1. QMN: a source of **quasi mono-energetic neutrons** (QMN) with a controllable energy peak in the (20)35-70 MeV energy range.

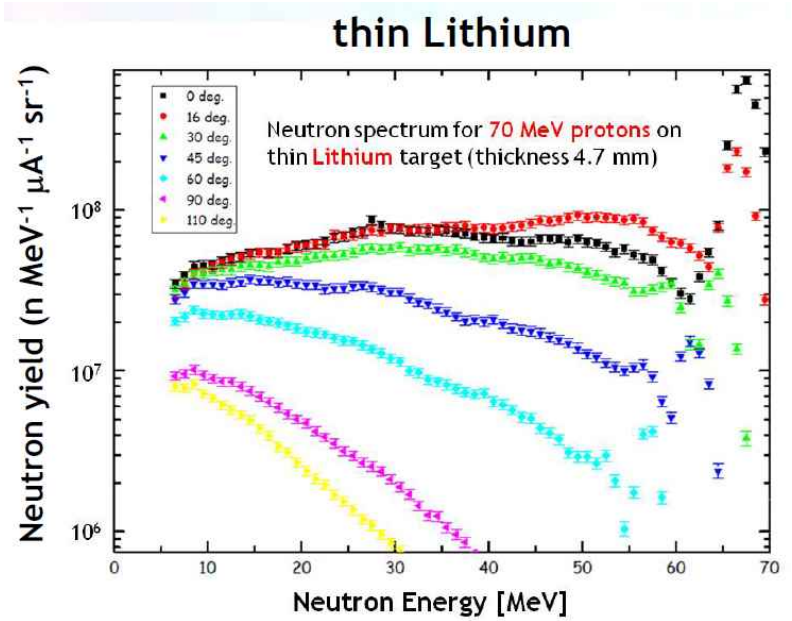
2. ANEM: (*Atmospheric Neutron Emulator*) an intense source of ***fast* neutrons (E > 1 MeV)** with a continuous energy distribution similar to that of atmospheric neutrons found at flight-altitudes and at sea-level in the 1-65 MeV energy range.

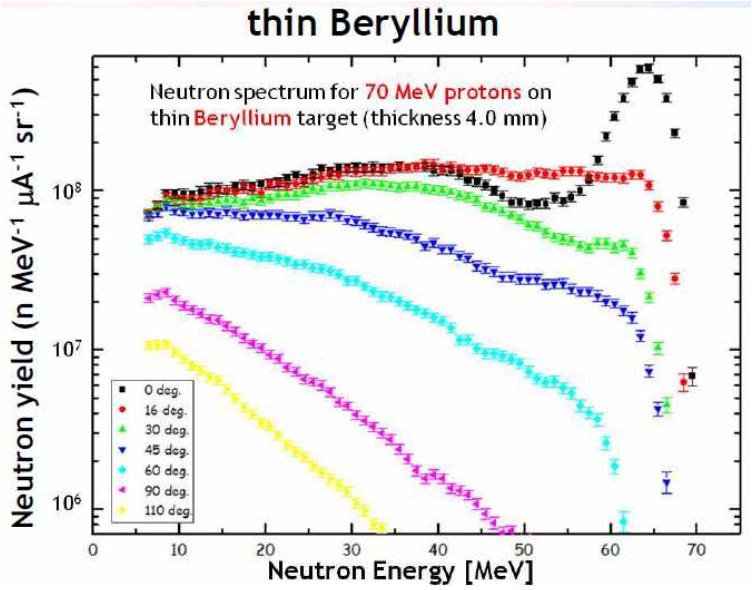
Neutrons for electronics				
QMN discrete	Energy range 20-70 MeV 😐	Essential to study energy dependencies (cross-section vs energy curves) ☺	Neutron flux at test point is user controlled, up to 10^5 n cm^{-2} s^{-1} ☺	Angle correction ☺!
ANEM continuous	Energy cut-off 70 MeV ☹	Before full energy tests at very high-energy facilities like Chip-IR (ISIS), it is useful to make flexible studies/checks for unexpected sensitivity to lower energy neutrons 😐 → ☺	Neutron flux at test point is user controlled, flux E_n > 1 MeV at test point up to ϕ ~ 10^7 n cm^{-2} s^{-1} ☺	

Quasi mono-energetic neutron production with Li and Be targets









Worldwide facilities of Quasi Mono-energetic Neutron source

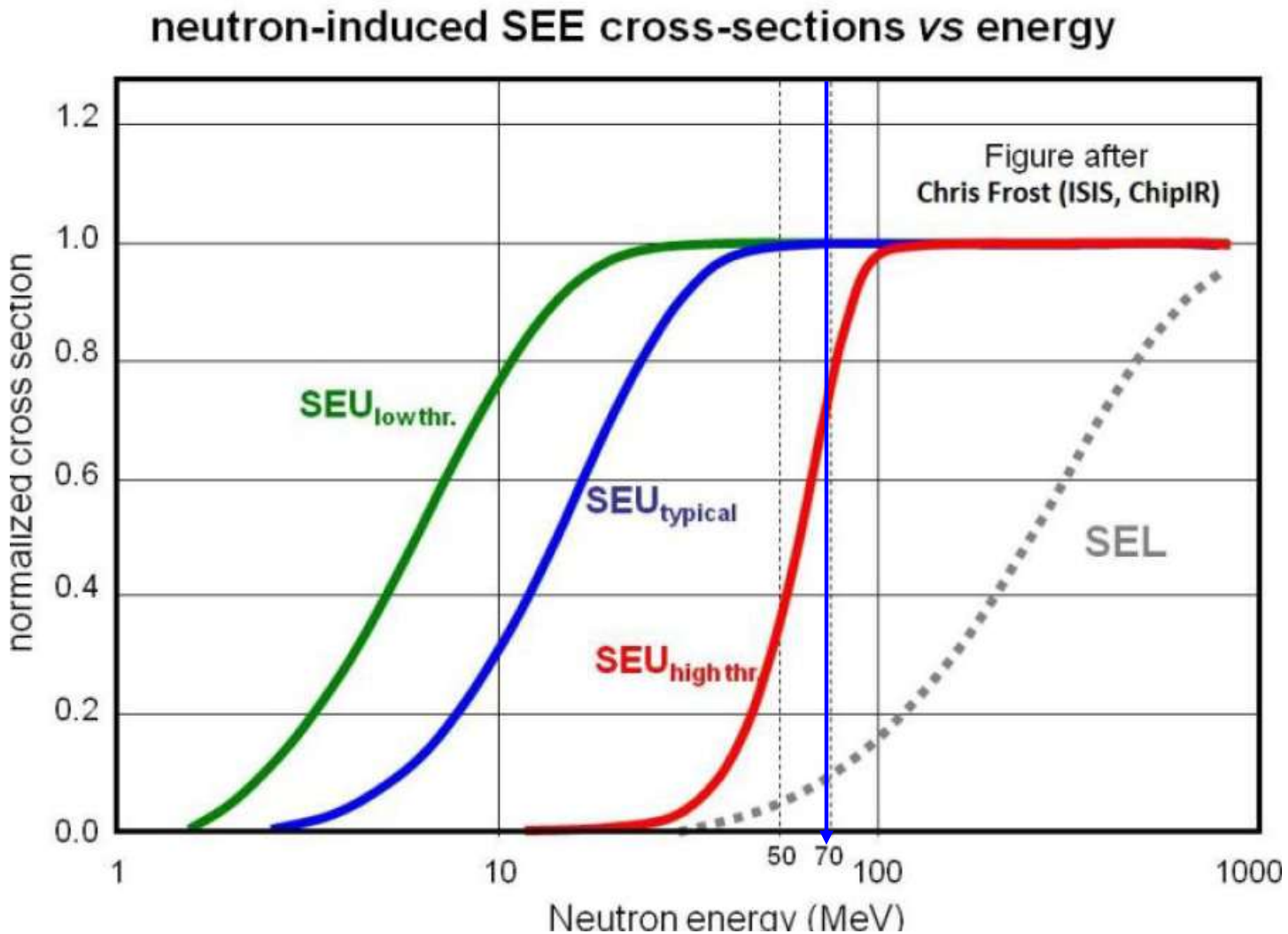
LAB	Energy of the protons (MeV)	Distance (m) of target to the test point	Mono-energetic neutron (peak) flux at the test point
TIARA (Japan)	40-90	12.9	~3.5-5 $\times 10^3$ n cm^{-2} s^{-1} for max 1-3 μA
CRYIC (Japan)	14-80	1.2	10^6 n cm^{-2} for 3 μA
RCNP (Japan)	100-400	10	10^4 n cm^{-2} s^{-1} for 1 μA
iTHEMBA (South Africa)	25-200	8	1-1.5 $\times$ 10^4 n cm^{-2} s^{-1} for typical 3 μA
ANITA (Sweden)	25-200	3.73	~ 3×10^5 n cm^{-2} s^{-1} for max 5-10 μA
NFS (France) UNDER CONSTR.	1-30	5	~ $1,2\times10^5$ n cm^{-2} s^{-1} for 30 μA, 30 MeV (calc.)
NEPIR Li target, 4.7 mm thick	30-70	3	~ 5×10^4 n cm^{-2} s^{-1} for 1 μA, 70 MeV
NEPIR Be target, 4.0 mm thick	30-70	3	~ 4.5×10^4 n cm^{-2} s^{-1} for 1 μA, 70 MeV

Target current for LNL QMN to be comparable with ANITA (TSL, Sweden): 10 μA
Foreseen flux: ~ 5×10^5 n cm^{-2} s^{-1} for 70 MeV protons, using a Li target 4.7 mm

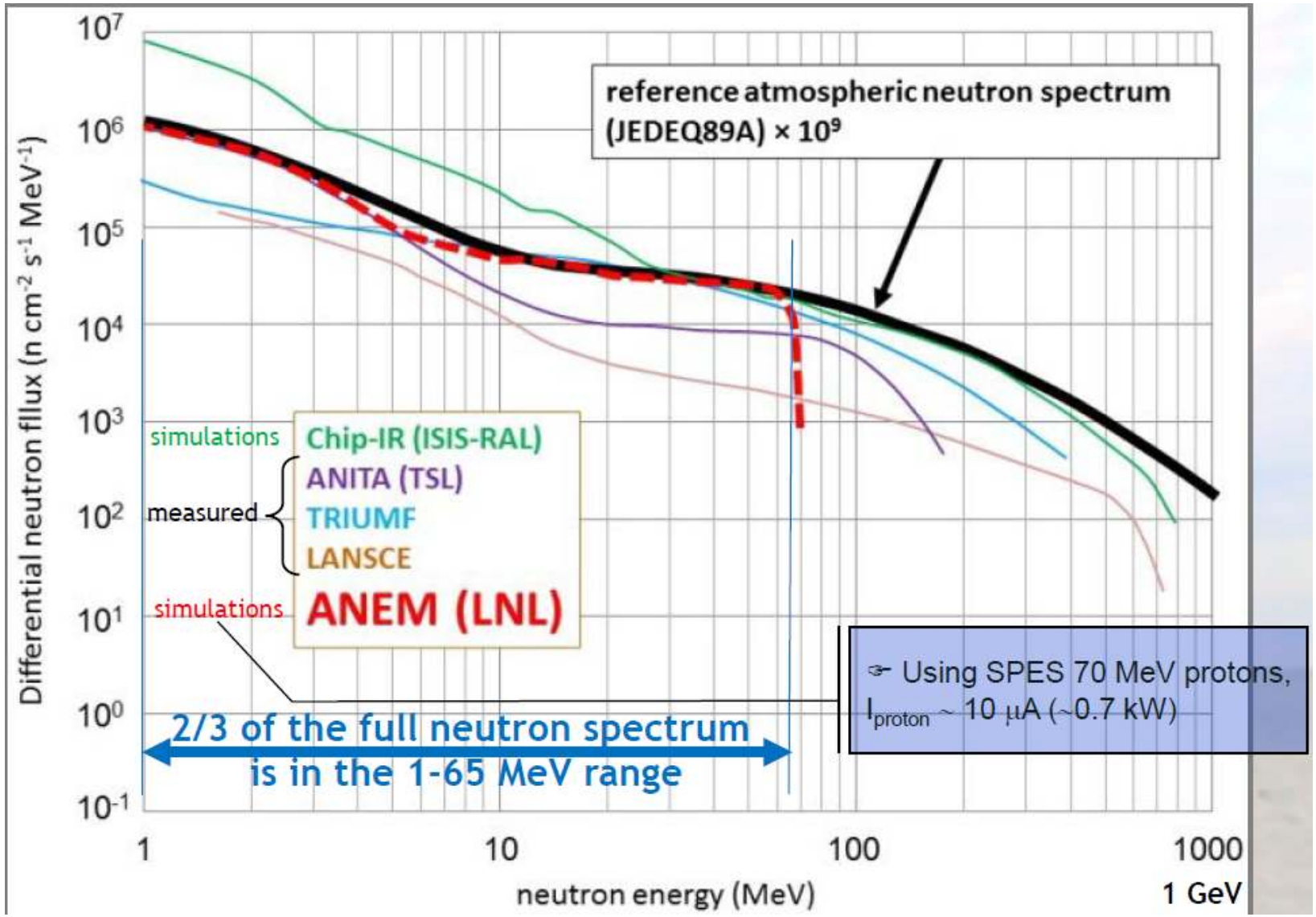
INFN 계획: 20-70 MeV QMN in NEPIR
70-230 MeV QMN in Trento proton-therapy center

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

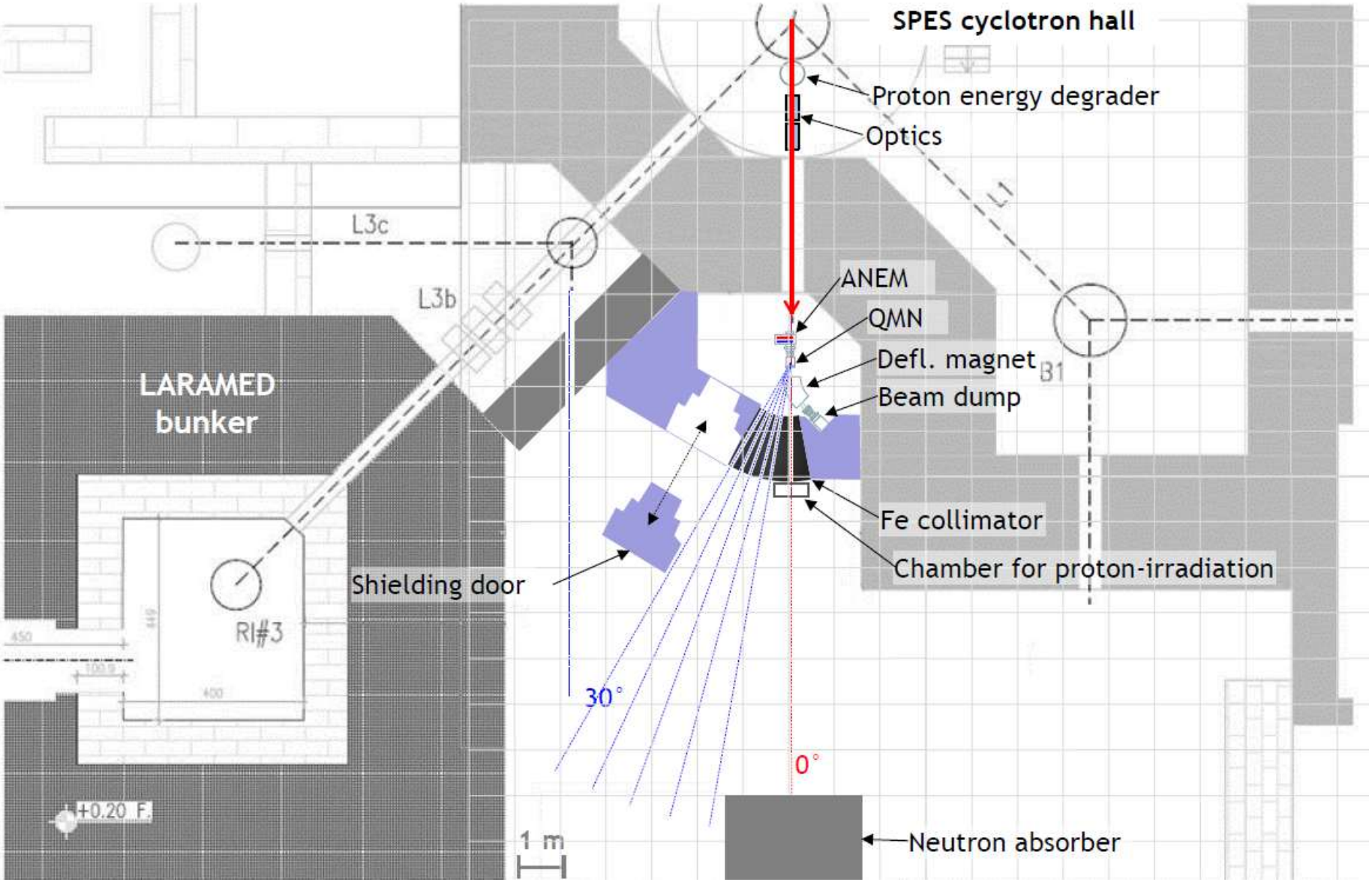
Continuous energy neutron source: ANEM (*Atmospheric Neutron Emulator*)



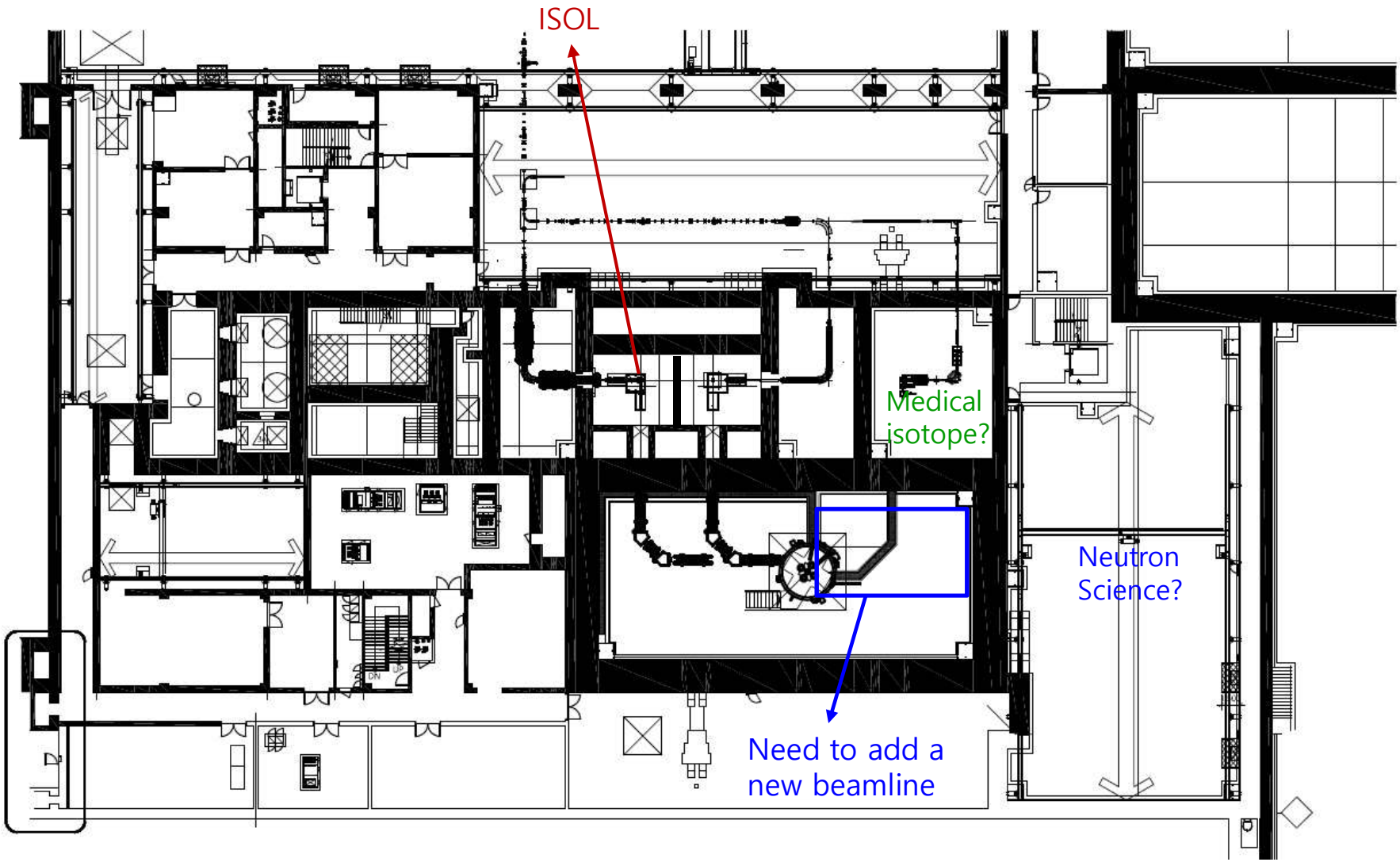
Comparison of white neutron spectrum



NEPIR (중성자 생산 및 응용연구시설) 배치도



사이클로트론 활용


ISOL
Medical isotope?
Neutron Science?
Need to add a new beamline