RFT
Road to Fine Tomorrow

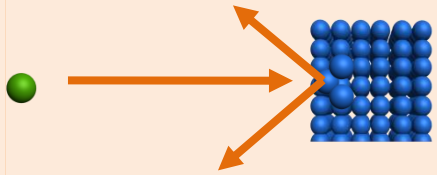
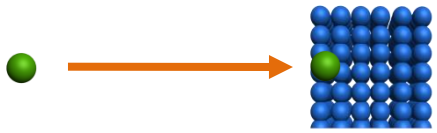
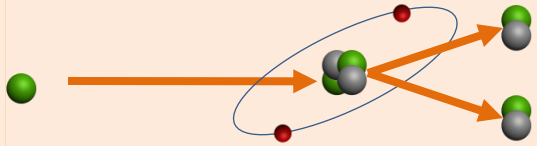
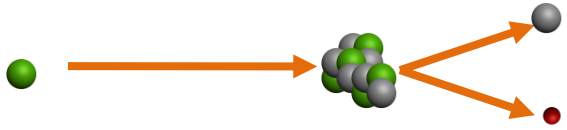
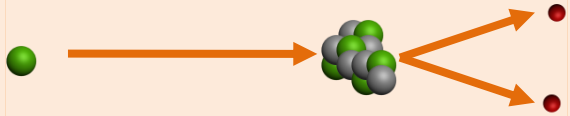
RFT-30 사이클로트론 이용연구 개발현황

2015. 10. 28.

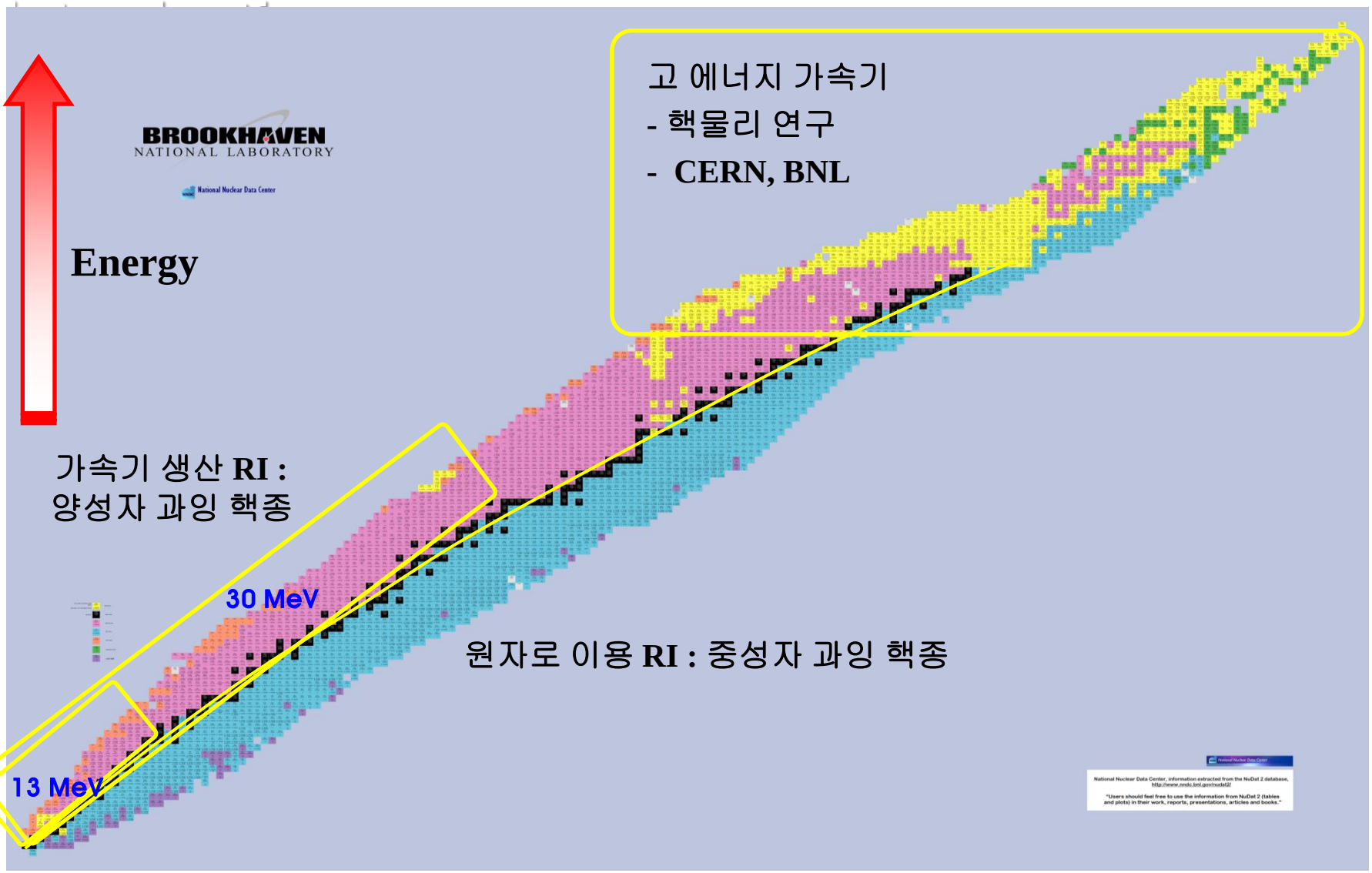
박 정 훈
한국원자력연구원

발표순서 (Contents)

가속입자의 에너지에 따른 물질의 기본반응

입자에너지	그림 설명	기본반응	활용 분야
~ 1KeV		Sputtering 물질표면의 원자를 낱개로 분리	박막가공 나노가공
~ 10KeV		Implantation 물질 속에 투여하여 물질구조와 성질변화	표면 개질 나노결정 반도체 도핑
~ 100MeV		Nuclear Reaction 물질의 원자핵과 반응 새로운 원소 생성	**신종 유전자원** **RI 생산** **방사선 치료기기**
~ 10GeV		Spallation 무거운 원자핵을 쪼개서 가벼운 원자 또는 중성자생성	중성자원 신종 RI 생산
~ 100GeV		소립자 연구 원자핵 속의 양성자 중성자를 쪼개 소립자 생성	신종 소립자 탐색 핵 및 고에너지 물리

핵종종류 (Nuclide Chart)



사이클로트론 (Cyclotron)

Ernest Lawrence
(1901 –1958, USA)

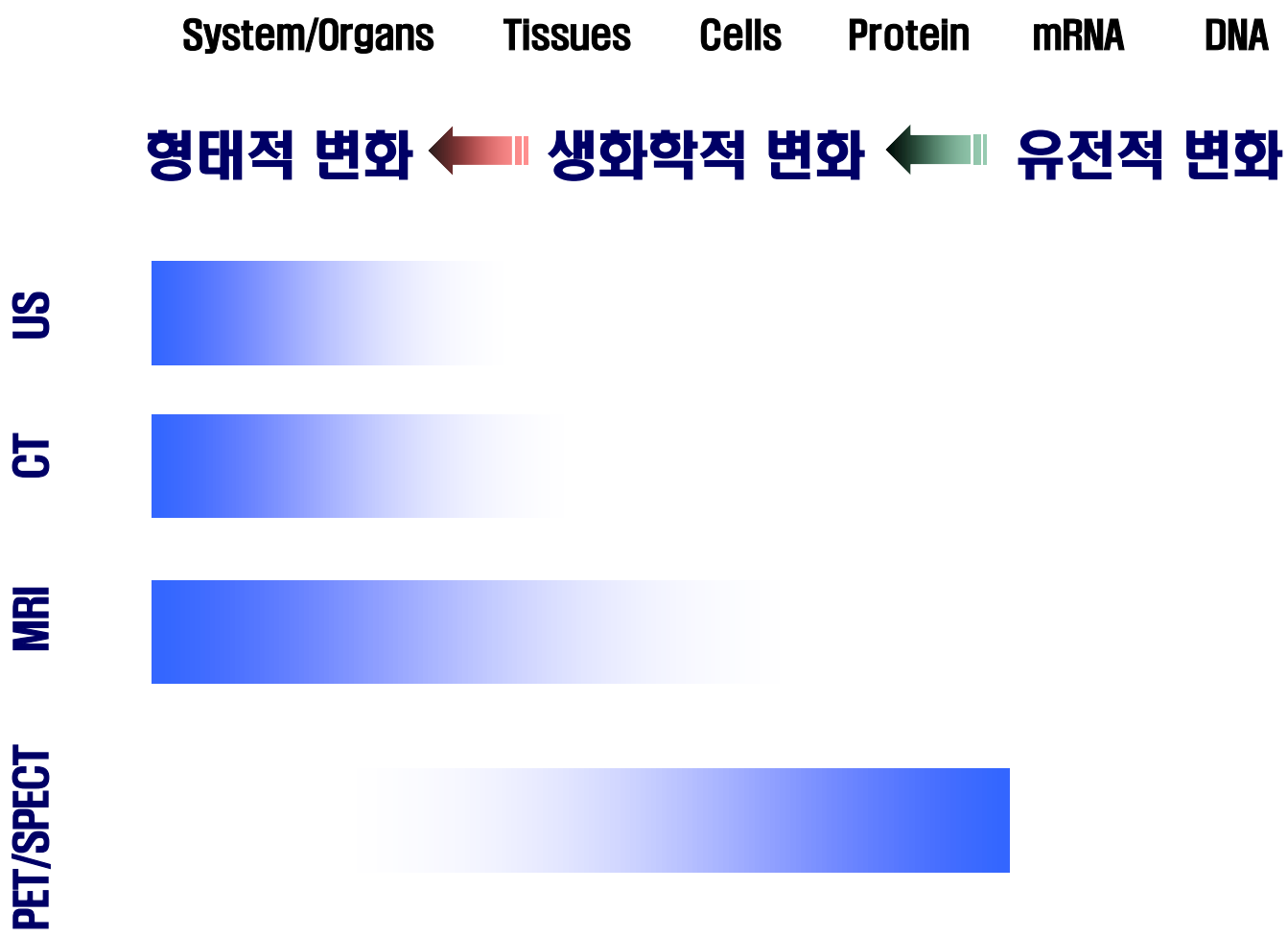
A pioneering American nuclear scientist, winner of the Nobel Prize for Physics in 1939 for his invention of the cyclotron. He is also known for his work on uranium–isotope separation for the Manhattan Project, and for founding the Lawrence Berkeley Laboratory and the Lawrence Livermore Laboratory.

"The First Cyclotron, Built by Ernest O. Lawrence in 1931, UC Berkeley, March 1967," *UC Berkeley Library* he produced a 4.5–inch instrument of brass and wax in which can energy of 80,000 electron volts was achieved with protons.

방사성동위원소의 이용

- ❖ Biology, Medicine, and Pharmaceuticals
- ❖ Physical Sciences and Engineering
- ❖ National Security and Other Applications

질병수준에 따른 영상기기의 측정범위



방사성의약품을 이용한 영상진단기기

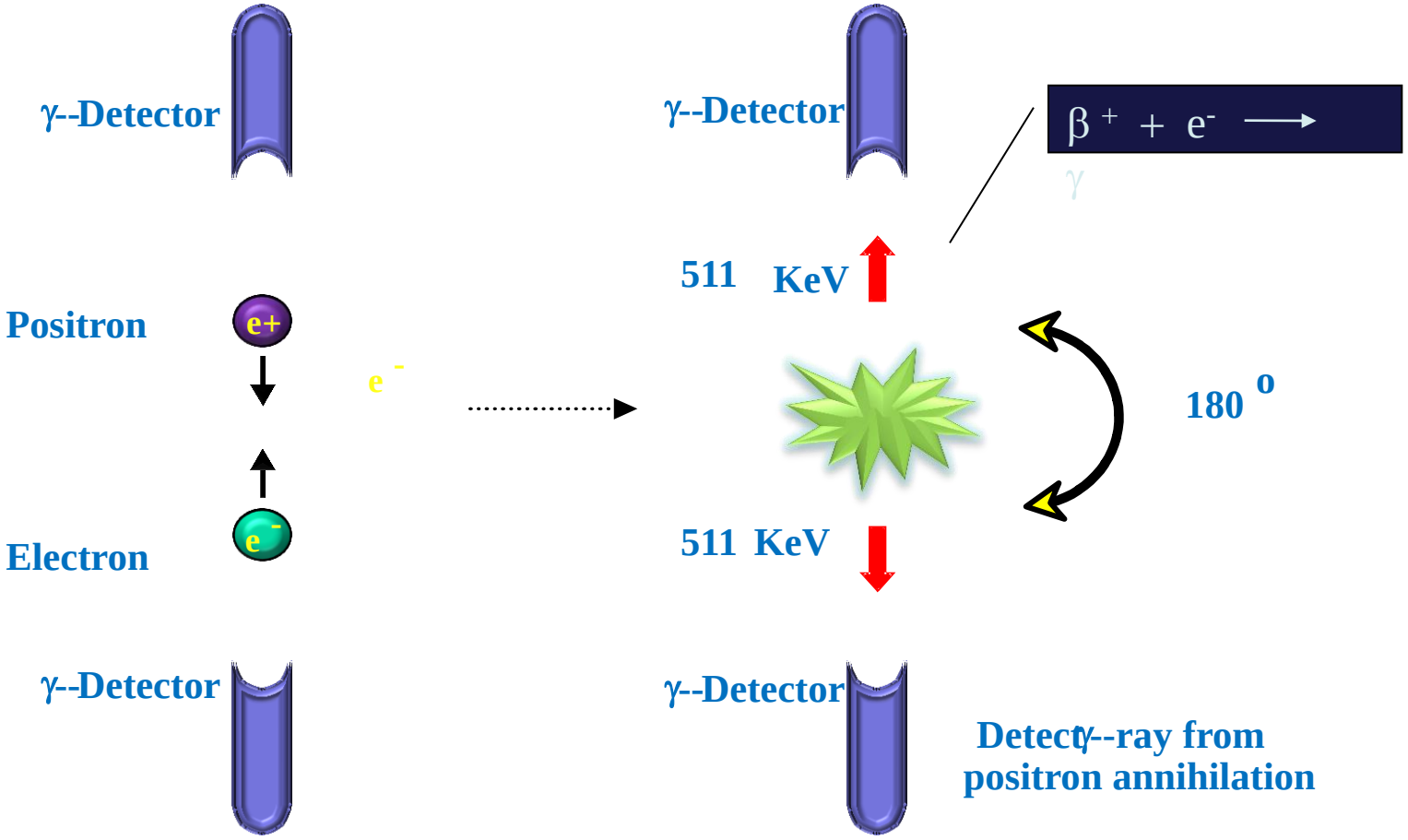
양전자방출 촬영장치 (PET)

Positron Emission
Tomography

단일광전자 방출 촬영장치 (SPECT)

Single-Photon Emission
Computed Tomography

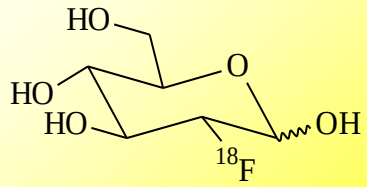
PET의 원리 (Principle of PET)



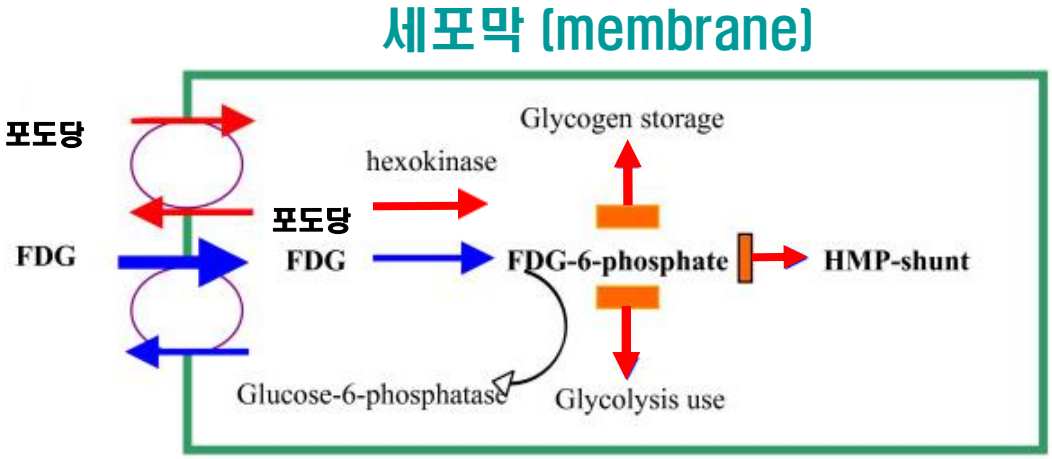
PET Imaging Agent

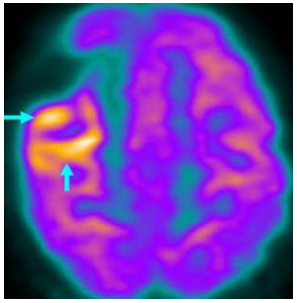
- [^{18}F]FDG (2-[^{18}F]fluoro-2-deoxy-glucose)

포도당 대사 영상

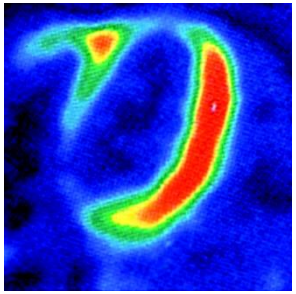


[^{18}F]FDG





Brain



heart

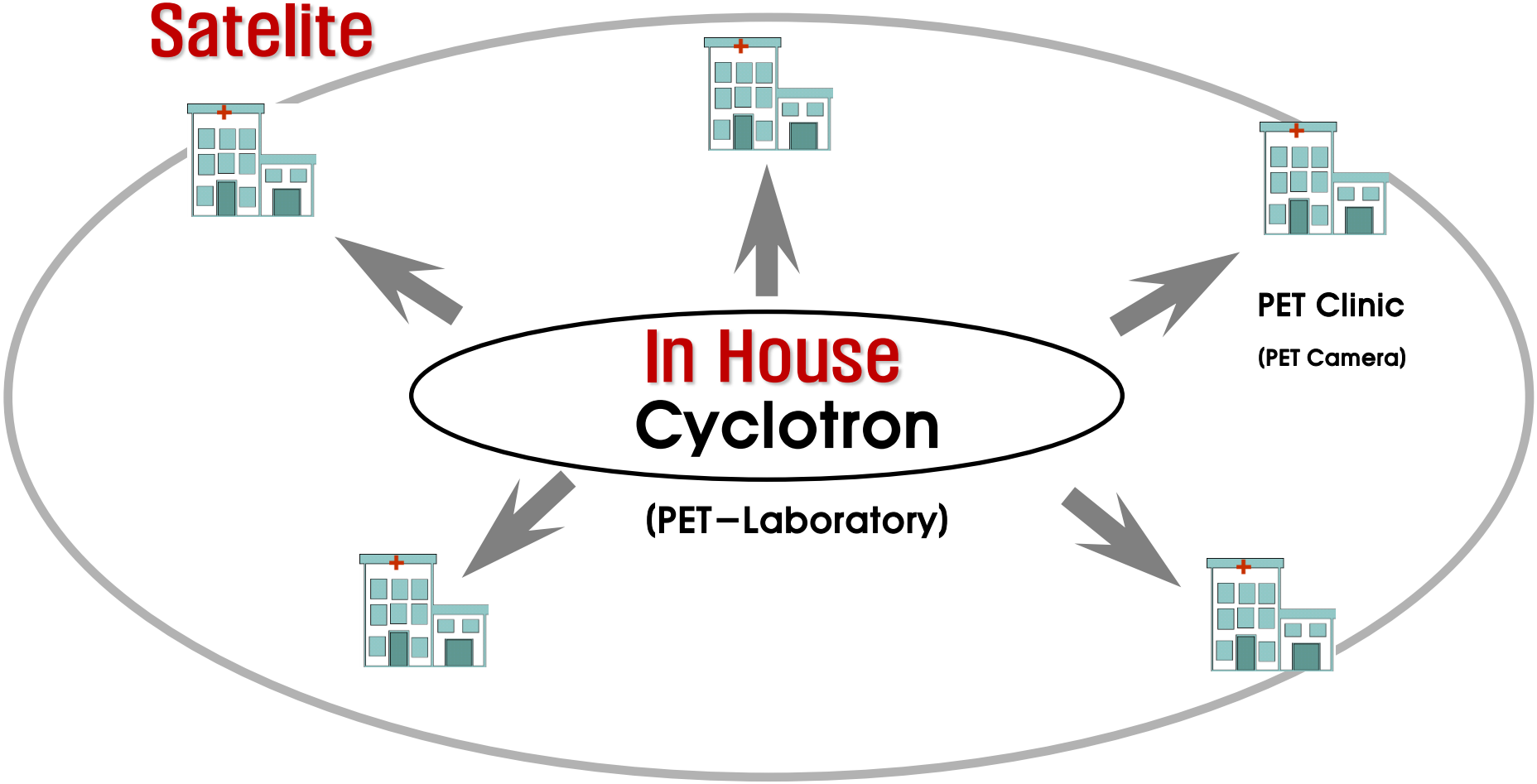
Isotopes production in Korea

Isotope	Half-Life	Device	Used for
C-11	20.4m	Medical Cyclotron (Hospital)	PET
N-13	9.96m		PET
F-18	1.83h		PET
I-123	13.2h	30MeV Cyclotron (KIRAMS, KAERI)	SPECT
I-124	4.18d		PET
Tl-201	3.04 d		SPECT
Ga-67	3.26d		SPECT
Cu-64	12.7 h		PET
Ge-68	271 d		Generator
Ti-44	47 y		Generator

Conventional Positron Emitters

$^{14}N(P, \alpha)^{11}C$	$t_{1/2}$ = 20.3 min
$^{16}O(P, \alpha)^{13}N$	$t_{1/2}$ = 9.97 min
$^{14}N(d, n)^{15}O$	$t_{1/2}$ = 2.0 min
$^{18}O(p, n)^{18}F$	$t_{1/2}$ = 109.7 min

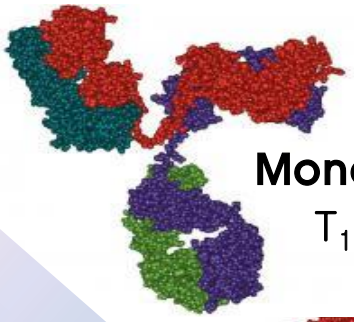
Isotopes delivery system



Radiometals

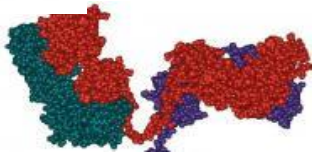
- Large variety of decay properties ($t_{1/2}$, mode, energy)
- Well known coordination chemistry
- Available through various production methods
- Serve to scrutinize biological processes in the order of minutes to days
- Seamless integration of isotope pairs for theragnostic applications ($^{86}Y/^{90}Y$, $^{67}Ga/^{68}Ga$, $^{44}Sc/^{47}Sc$)
- Radiometals have an special place in PET imaging as alternative to ^{18}F, ^{11}C and ^{15}N)

Half life choose



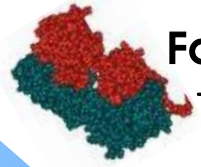
Monoclonal antibody

$T_{1/2}$: 1 – 10 days



F(ab')$_2$ fragment

$T_{1/2}$: 10 – 20 hours



Fab fragment

$T_{1/2}$: 1 – 5 hours

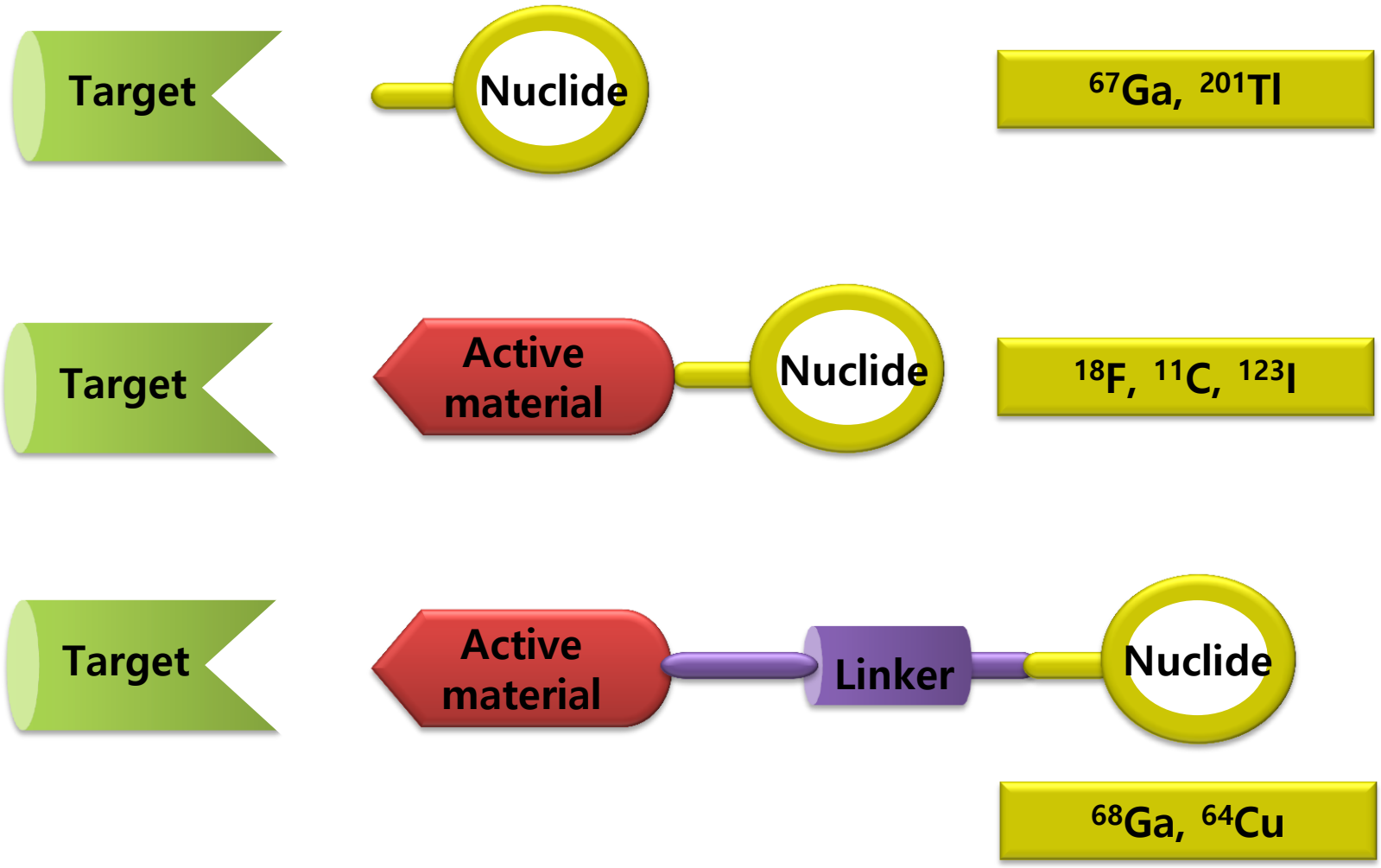
ScFv

$T_{1/2}$: 0.5 – 2 hours

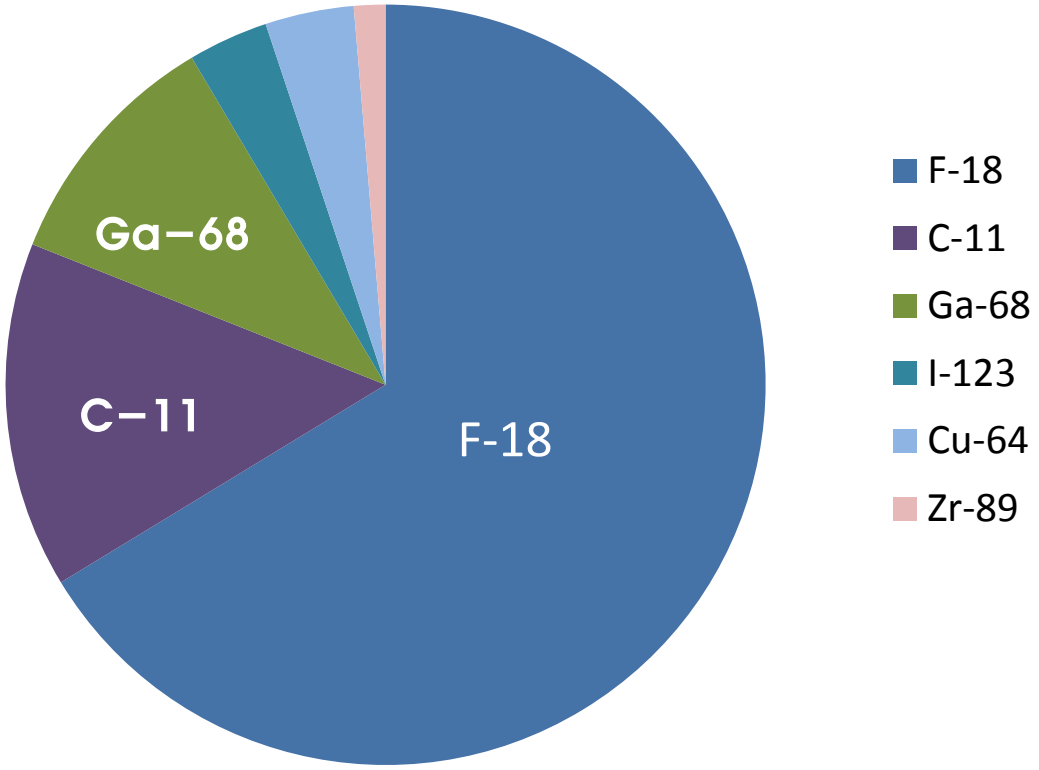
Peptide

$T_{1/2}$: 0.5 – 2 hours

Targeted Molecular Labeling System



Papers on Positron Emitters (2011–2014)



- Nuclear Medicine and Biology
- Journal of Nuclear medicine
- European Journal of Nuclear medicine & Molecular Imaging
- Journal of Labelled Compounds & Radiopharmaceuticals

Selection criteria for suitable PET nuclides

	Criterion	Rationale
1	High positron branching	Radiation dose to patient and personnel
2	Low positron energy, –ies	Image resolution, radiation dose
3	Suitable half–life	(De–)centralized production in GMP cerified radiopharmalcles
4	Ease and scalability of production	Cost of individual dose
5	Established labelling chemistry & radiopharmaceuticals	Decrease time to market introduction
6	Theragnostic or pseudo–theragnostic pair?	Enable personalized dosimetry of radionuclide therapy

A. Tuerler (PSI, Switzerland) in EANM 2014

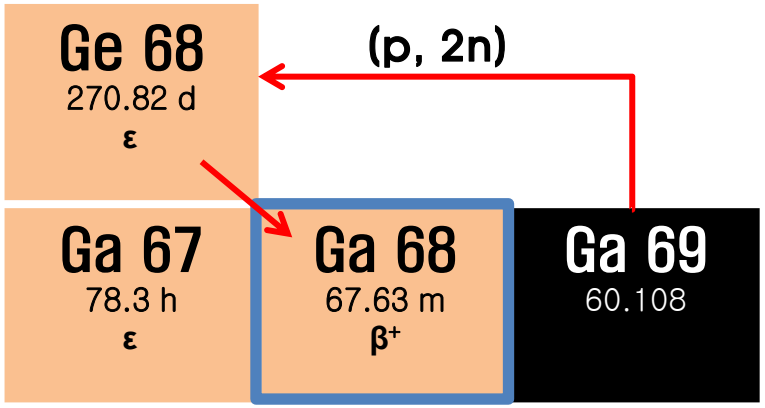
Selection criteria for suitable PET nuclides

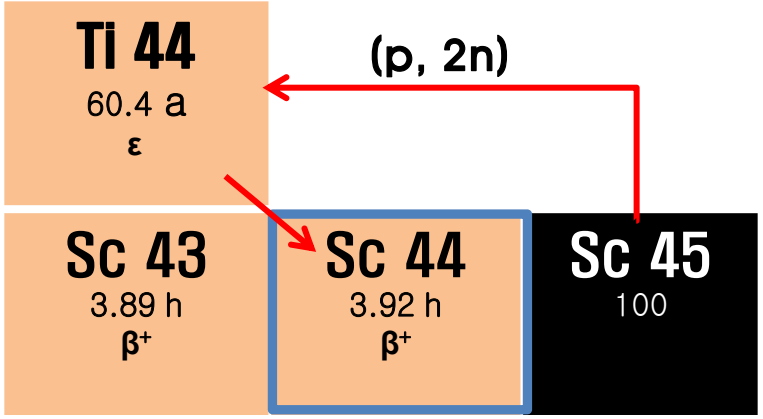
PET Nuclide	1 % ß+	2 <$E_{ß^+}$>	3 $T_{1/2}$	4 Prod.	5 Pharm.	6 Pair?
^{18}F	√ 96.7 %	√ 249.8 keV	√ 1.83 h	√	√	X
^{64}Cu	X 17.6 %	√ 278.2 keV	√ 12.7 h	X	√	√ ^{67}Cu
^{68}Ga	√ 88.9 %	√ 829.5 keV	X 68 m	√	√	√ ^{67}Ga
^{44}Sc	√ 94.3 %	√ 632.0 keV	√ 3.97 h	√	√*	√ ^{47}Sc
^{89}Zr	X 22.7 %	√ 396.0 keV	√ 78.4 h	√	√	X
^{86}Y	X 31.9 %	√ 660.0 keV	√ 14.7 h	√	√	√ ^{90}Y

*Sc can be exchanged to Ga, due to very similar chemistry

A. Tuerler (PSI, Switzerland) in EANM 2014

Generators for Positron Emitter





Commercial Ge-68/Ga-68 generator

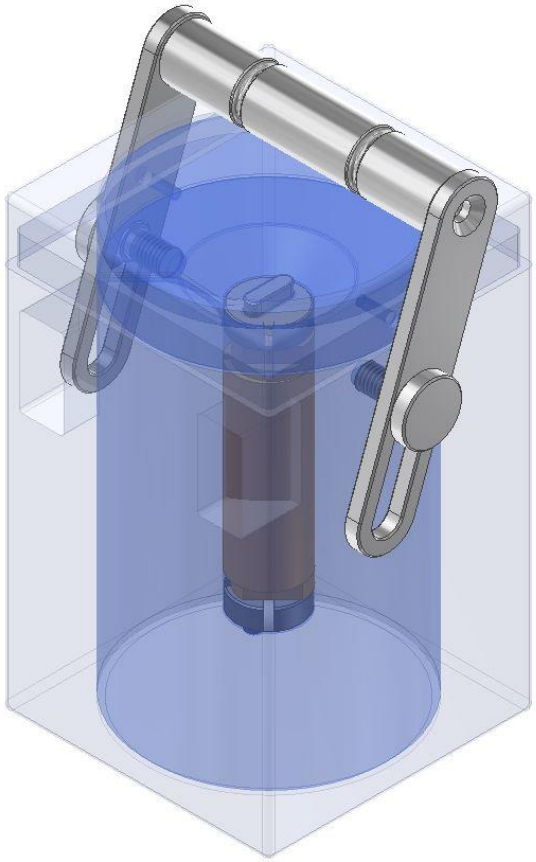
(Obninsk, Russia)

(IGG 100, Germany)

(iThemba LABS, SAF)
IDB (Holland)

(itG, Germany)

Generator shield case



Parts	Material
Shield	Tungsten
Case	Al (Hard Anodize)
Column body	PEEK

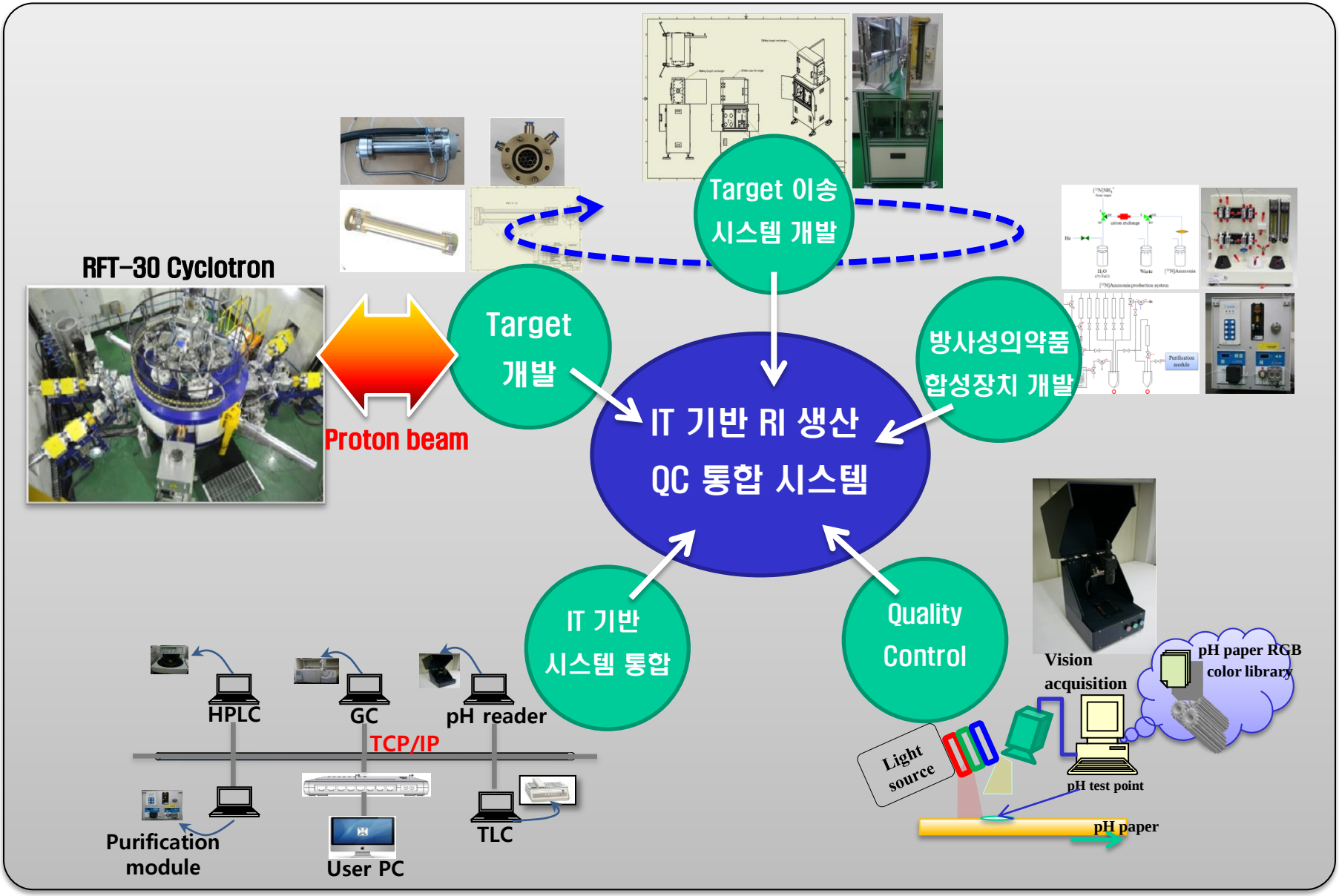
	Specification
Shield thickness	Tungsten 30 mm
Case	90 x 90 x 155
Max. Activity	50 mCi

원자력기반구축사업

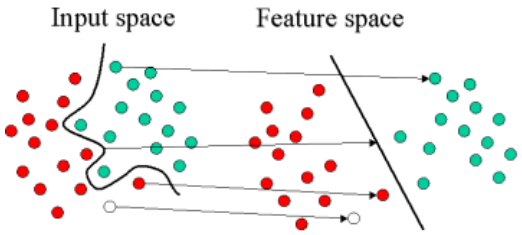
❖ 대형연구시설이용사업

- 사이클로트론 이용자 지원사업
- 성균관대, 연세대, 전남대 등 11개 연구지원

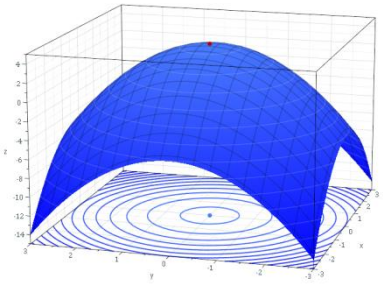
IT 기반 RI 생산 및 QC 통합 시스템



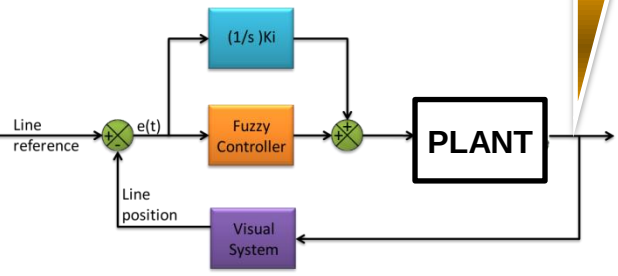
사이클로트론 기반 지능형 제어 시스템 개발



Pattern classification



Optimization

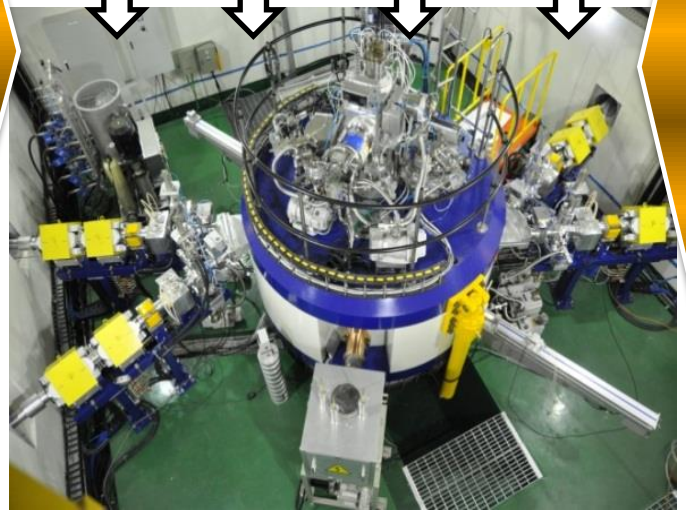


Feedback Control

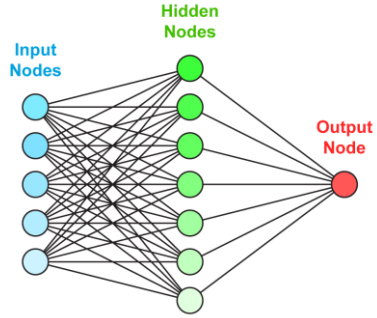
Intelligent Accelerator System

Power supply | Control PC | Current meter | LLRF system

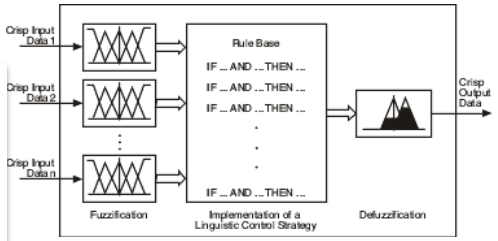
RF PA | CPF | CPF



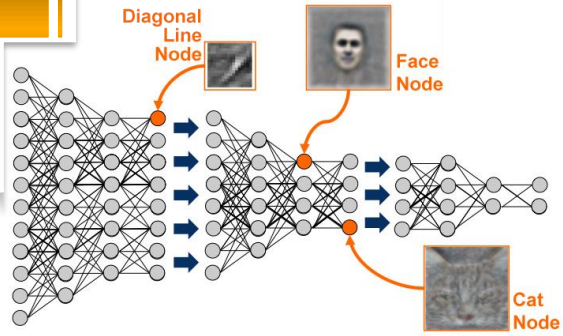
Accelerator



Neural network



Fuzzy logic



Deep learning

RFT

Road to Fine Tomorrow

방사선융합기술은

밝은 미래로 가는 길입니다

감사합니다