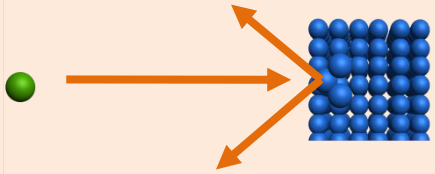
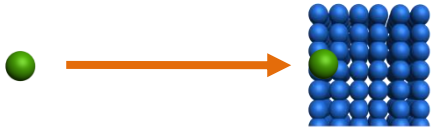
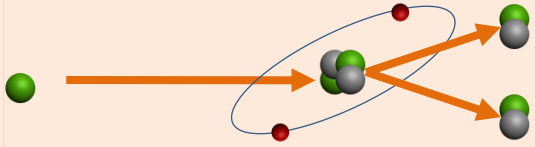
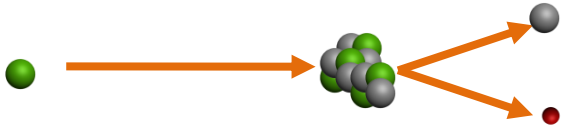
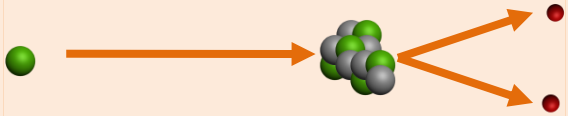
RFT
Road to Fine Tomorrow

RFT-30 사이클로트론 이용 연구개발

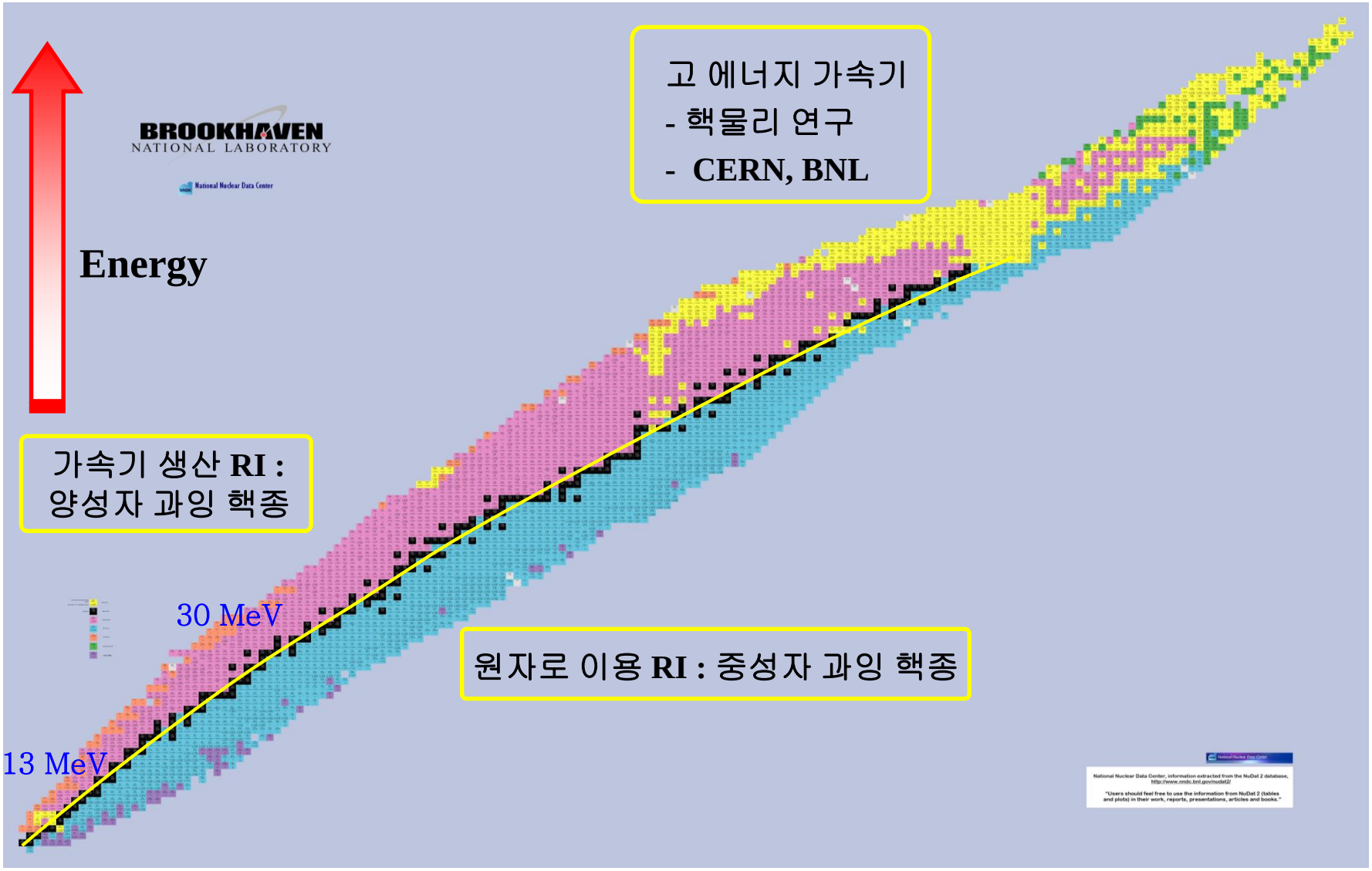
2015. 10. 28.

박 정 훈
한국원자력연구원

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)



방사성동위원소의 이용

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

Global Market

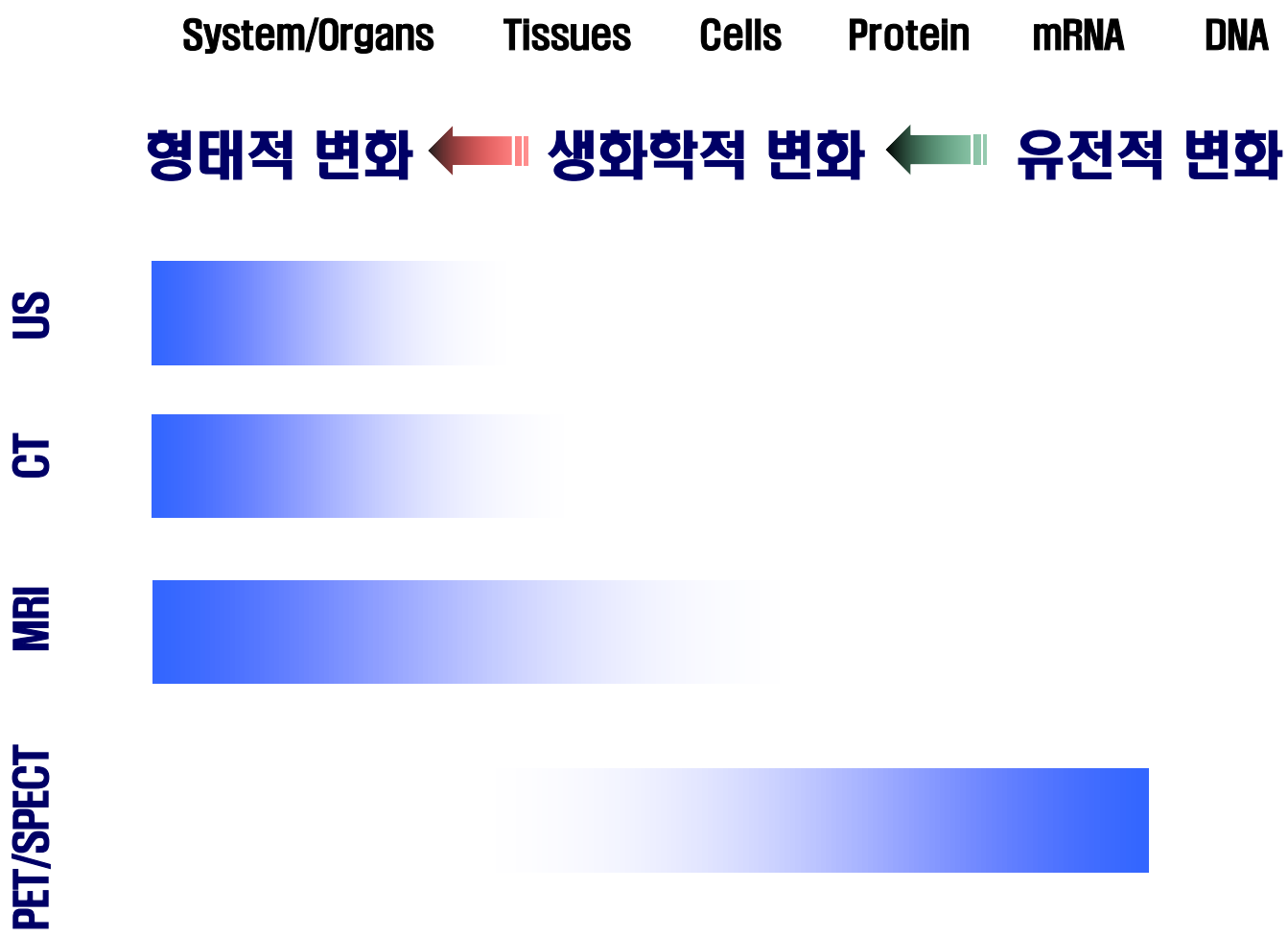
RADIOPHARMACEUTICALS MARKET REVENUE, BY RADIOISOTOPE, 2008 – 2015 ($THOUSAND)

Country	2008	2009	2010	2015
U.S	1,386,801	1,369,781	1,409,264	2,078,226
CANADA	101,088	96,069	106,621	155,275
EUROPE	665,916	653,590	677,623	974,172
APAC	480,167	467,956	494,964	770,971
JAPAN	401,192	393,579	398,412	563,790

※ APAC : Asia nations excluding Japan

Ref. MarketsandMarkets

질병수준에 따른 영상기기의 측정범위



방사성의약품을 이용한 영상진단기기

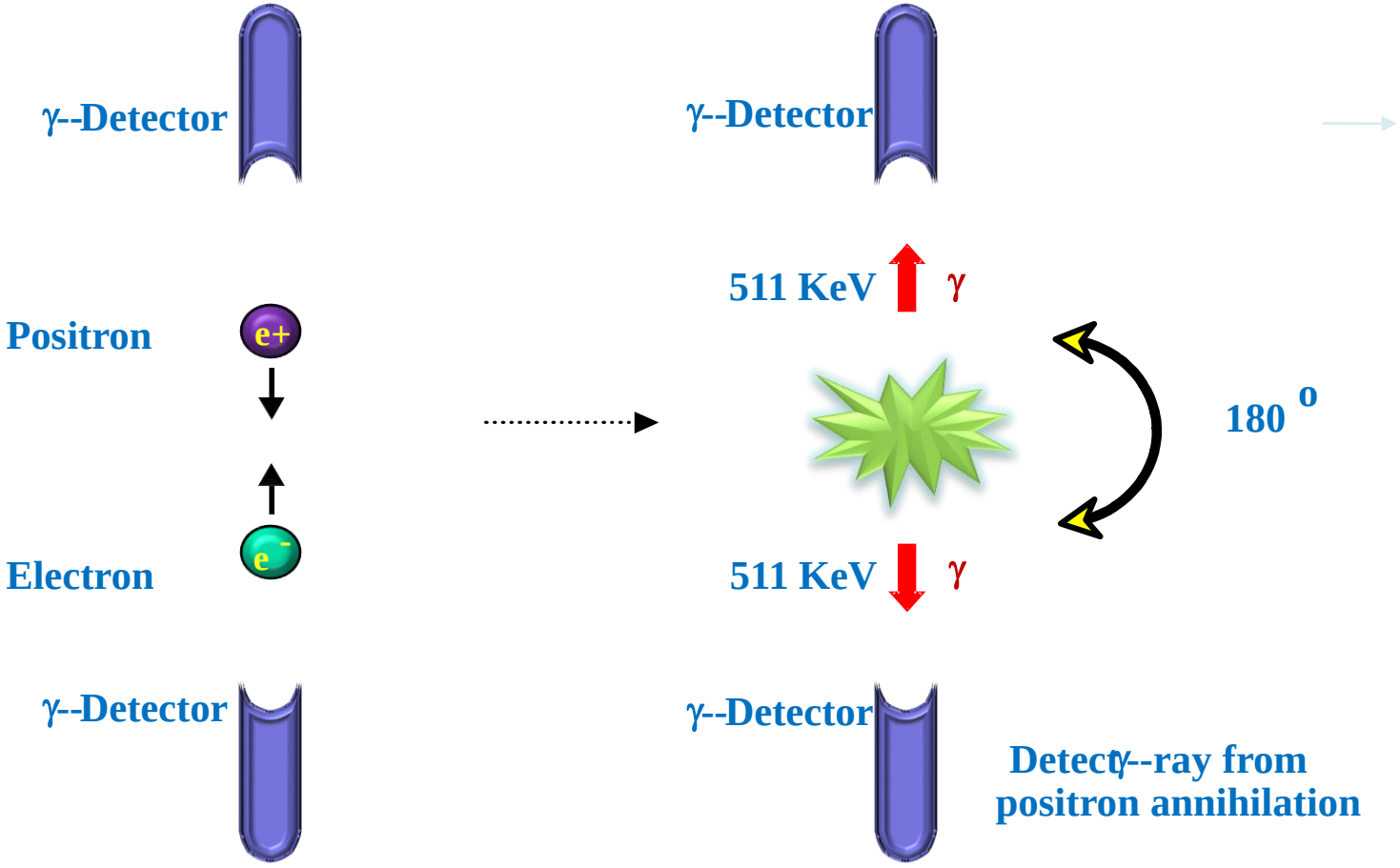
양전자방출 촬영장치 (PET)

Positron Emission
Tomography

단일광전자 방출 촬영장치 (SPECT)

Single-Photon Emission
Computed Tomography

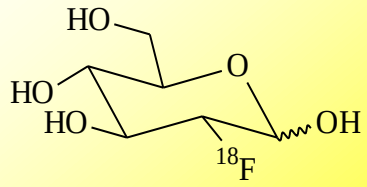
PET의 원리 (Principle of PET)



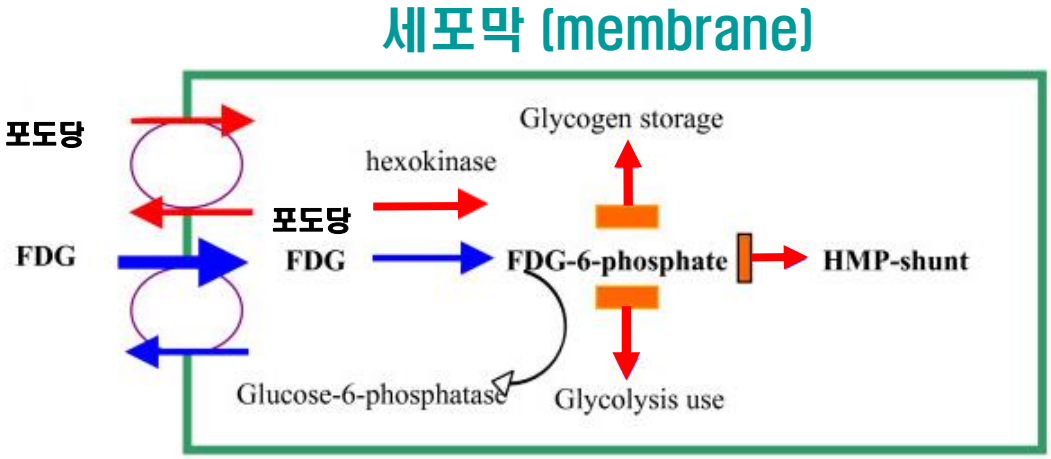
PET Imaging Agent

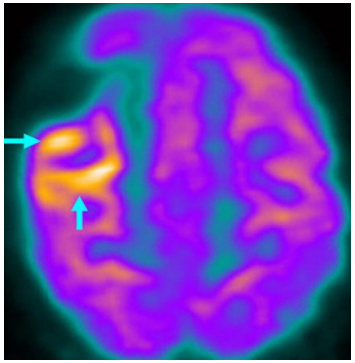
- [^{18}F]FDG (2-[^{18}F]fluoro-2-deoxy-glucose)

포도당 대사 영상

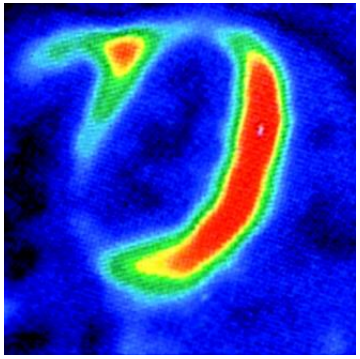


[^{18}F]FDG





Brain



heart

FDG 국내시장 규모

2013년 기준 약 1200억원

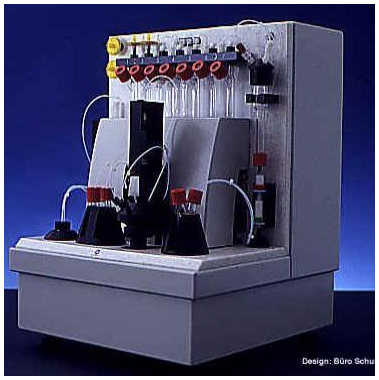
- 출처 : 대한핵의학회 -

양전자방출 단층촬영 (PET) 시스템

A. 사이클로트론 (cyclotron)

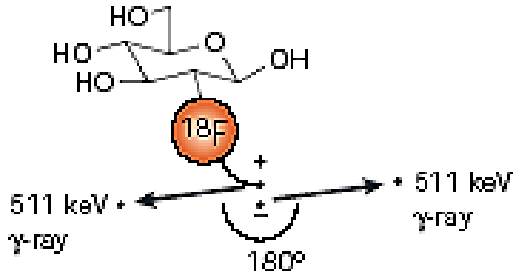
C-11, F-18, I-124 생산

B. 합성장치



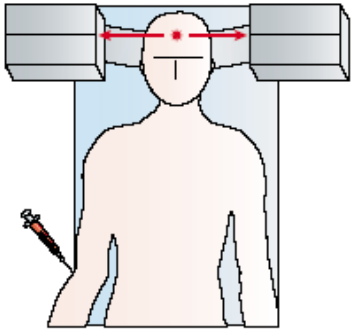
방사성 의약품 합성

C. PET용 방사성 의약품



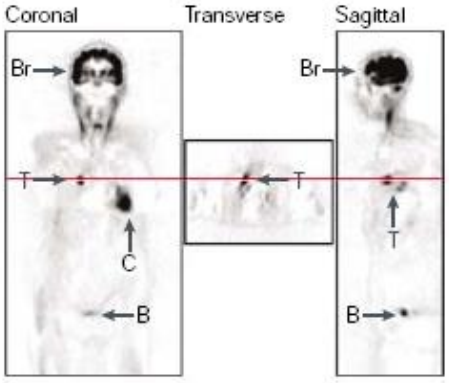
[18F]FDG

D. PET scanner



정맥주사 후 scanning

E. PET images



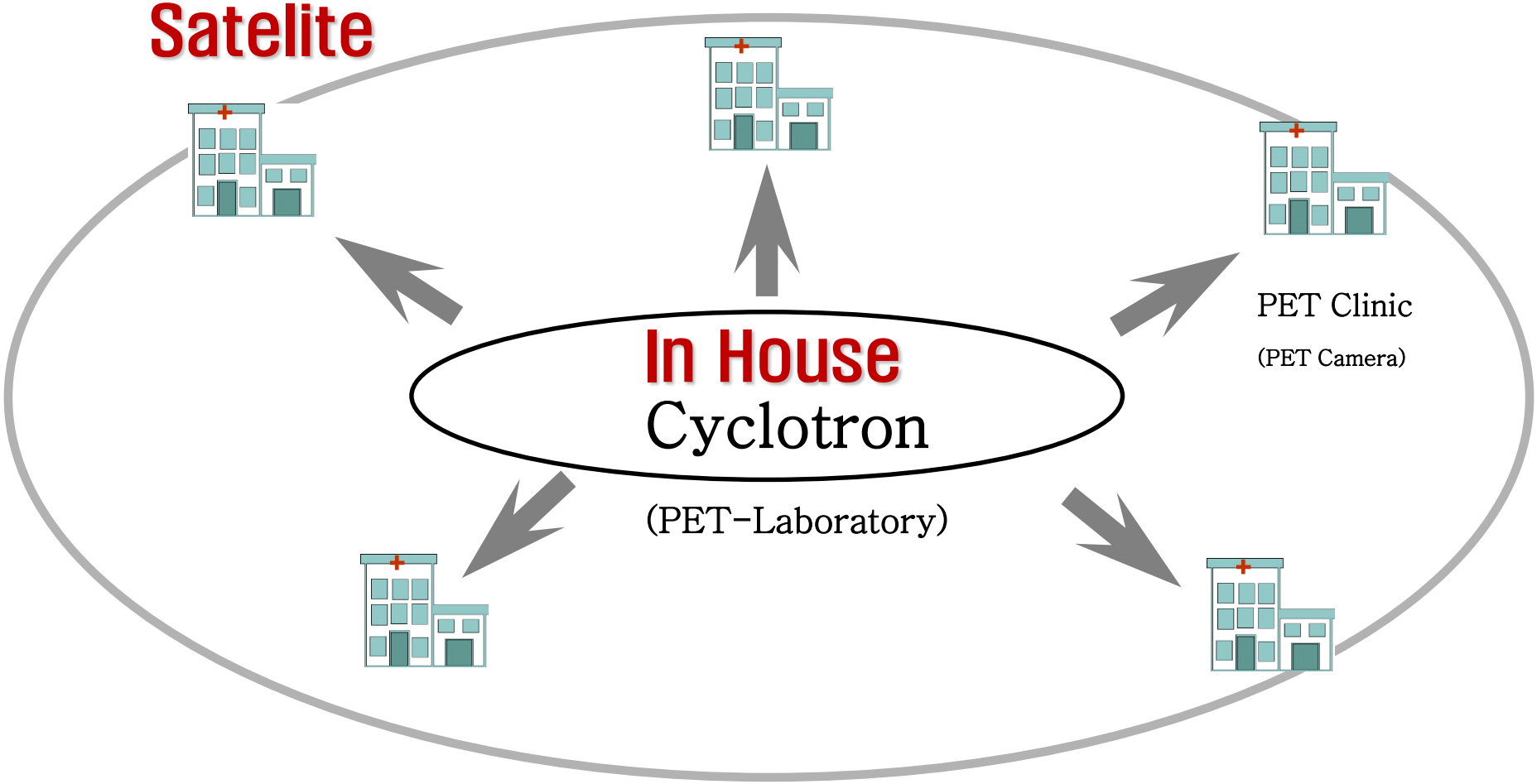
Isotopes production with cyclotron

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 (KAERI, KIRAMS)	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 PET radioisotopes

$^{14}N(P, \alpha)^{11}C$	$t_{1/2}$ = 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

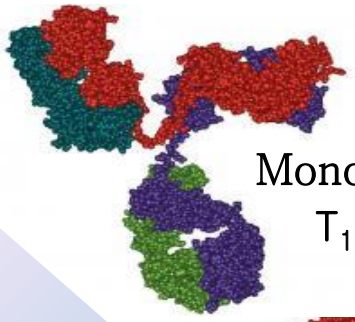
Isotopes delivery system



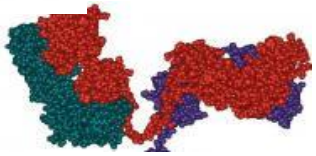
Radiometals

- 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)

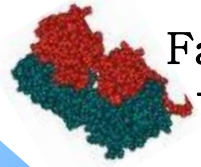
Half life choose



Monoclonal antibody
$T_{1/2}$: 1 – 10 days



F(ab')$_2$ fragment
$T_{1/2}$: 10 – 20 hours

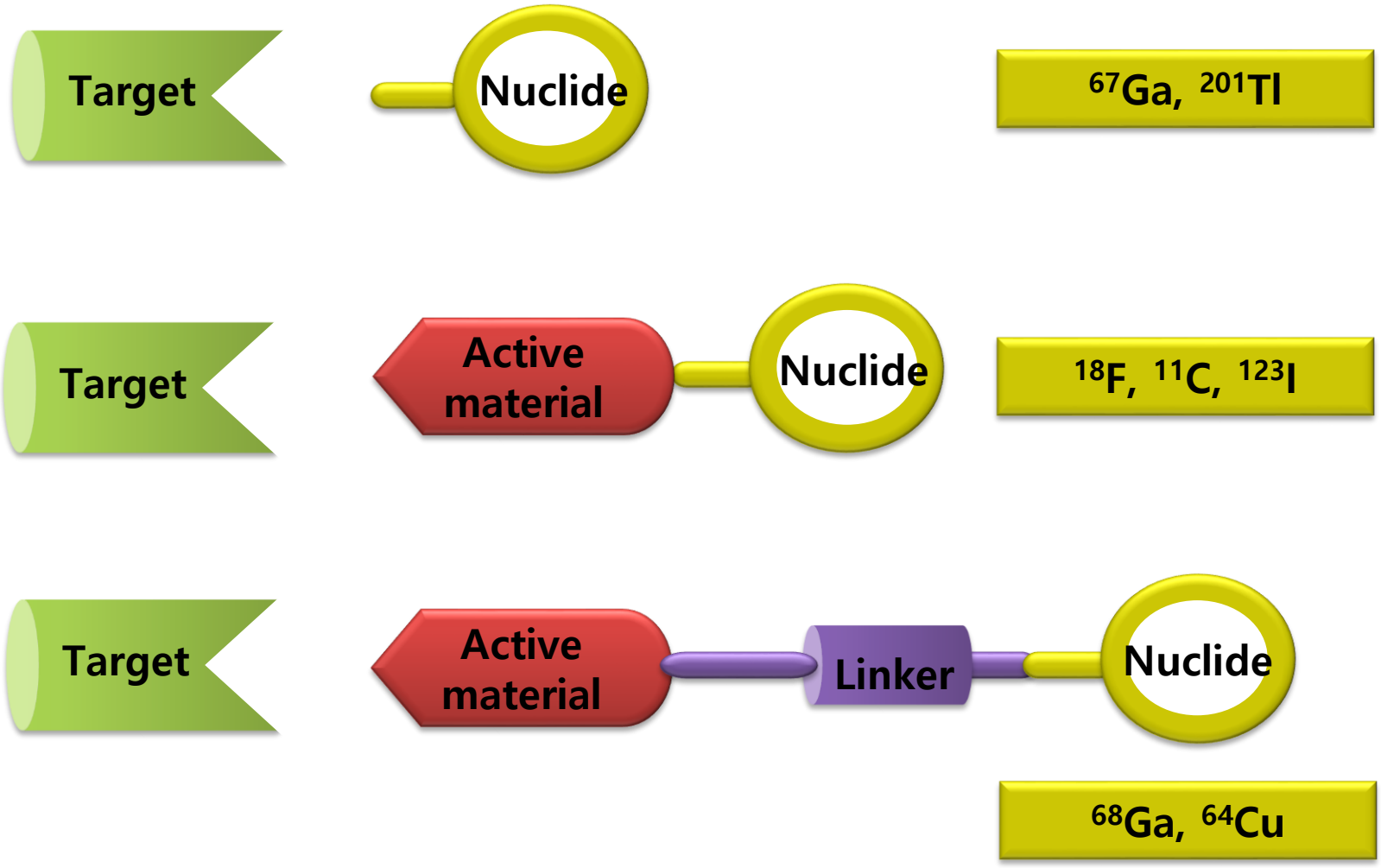


Fab fragment
$T_{1/2}$: 1 – 5 hours

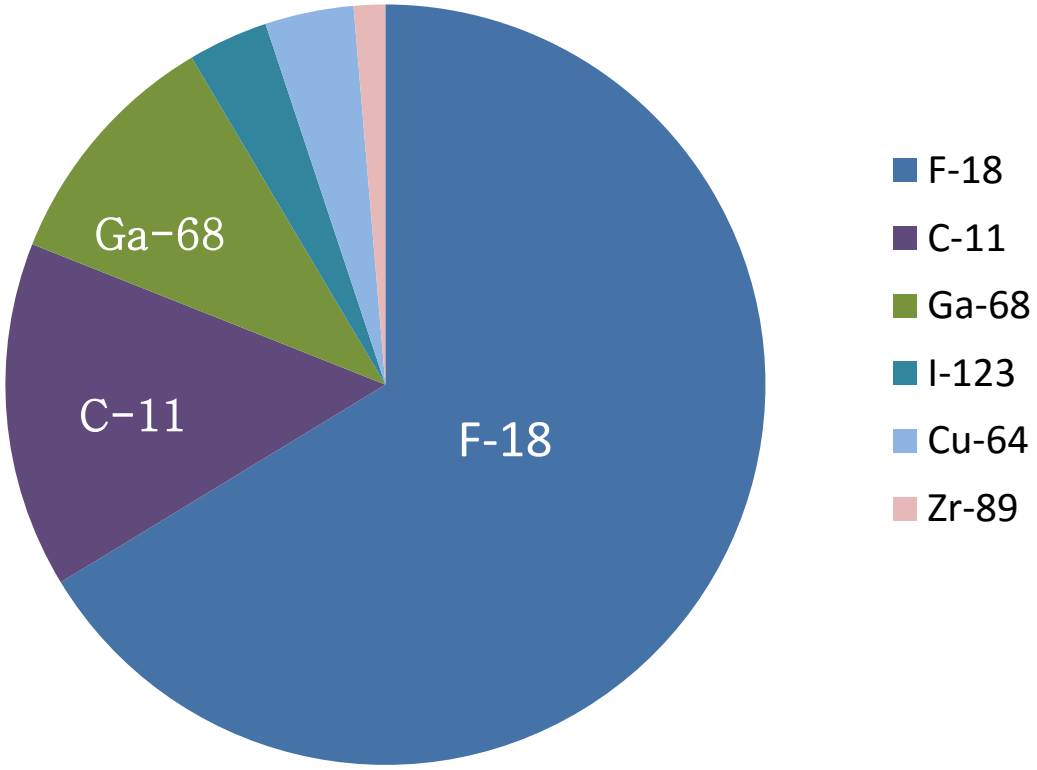
ScFv
$T_{1/2}$: 0.5 – 2 hours

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 % β^+	2 $<E_{\beta^+}>$	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	√ 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

True Theranostic Radionuclide Pairs

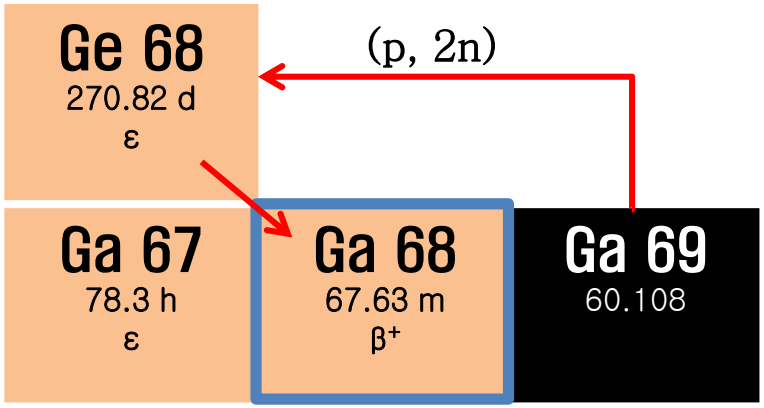
Nuclide pair PET/therapy	Half-lives	E_{β^+}avg (MeV)	I_{β^+} (%)	E_γ (MeV)	I_γ (%)	E_{β^-}avg (MeV)	I_{β^-} (%)	E_γ (MeV)	I_γ (%)
$^{44}Sc/^{47}Sc$	4.0 h/3.4 d	0.63	94.3	1157.0	99.9	0.162	100.0	159.4	68.3
$^{64}Cu/^{67}Cu$	12.7 h/2.6 d	0.28	17.6	1345.8	0.5	0.141	100.0	184.6	48.7
$^{68}Ga/^{67}Ga$	67.6 m/3.3d	0.83	88.9	1077.3	3.2	Augar	229.0	93.3	38.8

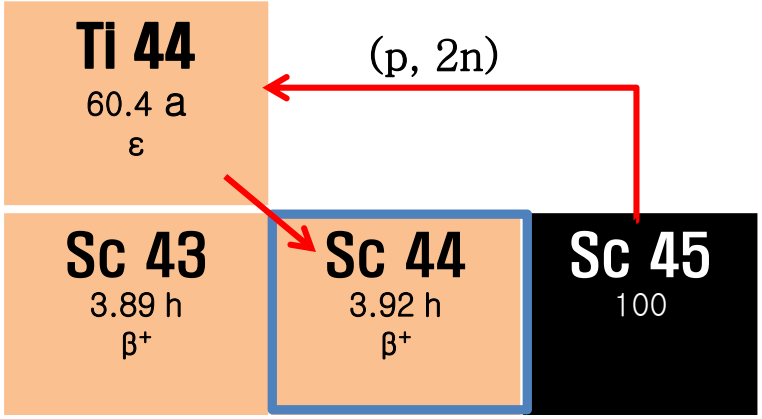
IAEA : Coordinated Research Project (CRP) for ^{67}Cu, ^{186}Re, ^{47}Sc

- their theranostic potential and their dual production routes from cyclotrons and reactors

A. Tuerler (PSI, Switzerland) in EANM 2014

Production of nuclei of generators from Cyclotron





Ge-68/Ga-68 Generator

Main Tech

1. Production of ^{68}Ge
2. Coloumn material
3. Shielding & Aseembly

Commercial Ge-68/Ga-68 generator

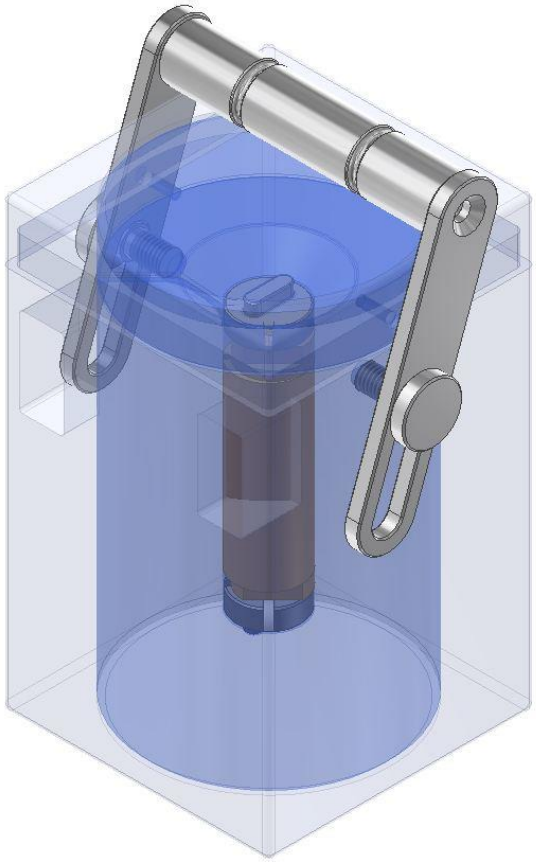
(Obninsk, Russia)

(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

❖ 대형연구시설 공동이용활성화

□ 사업목적

- 대형 원자력연구시설의 산· 학· 연 연구의 효율적 활용 지원
- 활용과제 지원을 통한 원자력 관련 전문연구그룹 육성

□ 세부사업 (대형연구시설별)

- 하나로 이용 연구 : 다목적 연구로
- 전자빔 이용 연구 : 전자빔 발생장치
- 사이클로트론 이용 연구 : 이온빔 발생장치
- 양성자 가속기 이용 연구 : 양성자빔 발생장치

원자력기반구축사업

❖ 대형연구시설 공동이용활성화

□ 2015~16 사이클로트론 이용 과제 (21개 선정)

- 생명/의학/방사성동위원소 : 14건
- 물리/나노/재료 : 4건
- 전기/전자 : 3건

□ 사이클로트론 이용자 사업 참여기관

성균관대, 연세대, 동국대, 건국대, 서울시립대, 인하대, 가천대,
충남대, 경북대, DGIST, 전북대, 전남대, GIST, 순천대 등

방사성동위원소 이용 연구시설

SPECT용 핵종 전용

PET용 핵종 전용

Chromatography
(LC/GC/IC)

형광분석장비

방사성동위원소 이용 연구시설

동물부검실

사육캐비넷

세포배양실

PET/X-ray

서남권 사이클로트론 이용 연구 클러스터

- 금속방사성동위원소 공급

  전북대 핵의학과, 전남대 핵의학과
- 사이클로트론 이용 연구개발

  조선대 사이클로트론센터
- 방사성의약제 연구개발

  순천대 약대, (목포대 약대)
- 양성자빔 이용연구개발

  한국과학기술연구원 (KIST)

  광주과학기술원 (GIST)

RFT

Radiation Fusion Technology
Road to Fine Tomorrow

방사선융합기술은

밝은 미래로 가는 길입니다

감사합니다!