

CdNnTe Semiconductor Radiation Detector Technology and Application

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HA, JANG HO Ph. D.

(Advanced Radiation Detection Instrument & Sensor Lab.)



Contents



- 1. Introduction**
- 2. CdZnTe Detector**
- 3. Wide band Gap Detector**
- 4. Silicon Detector**
- 5. Summary**

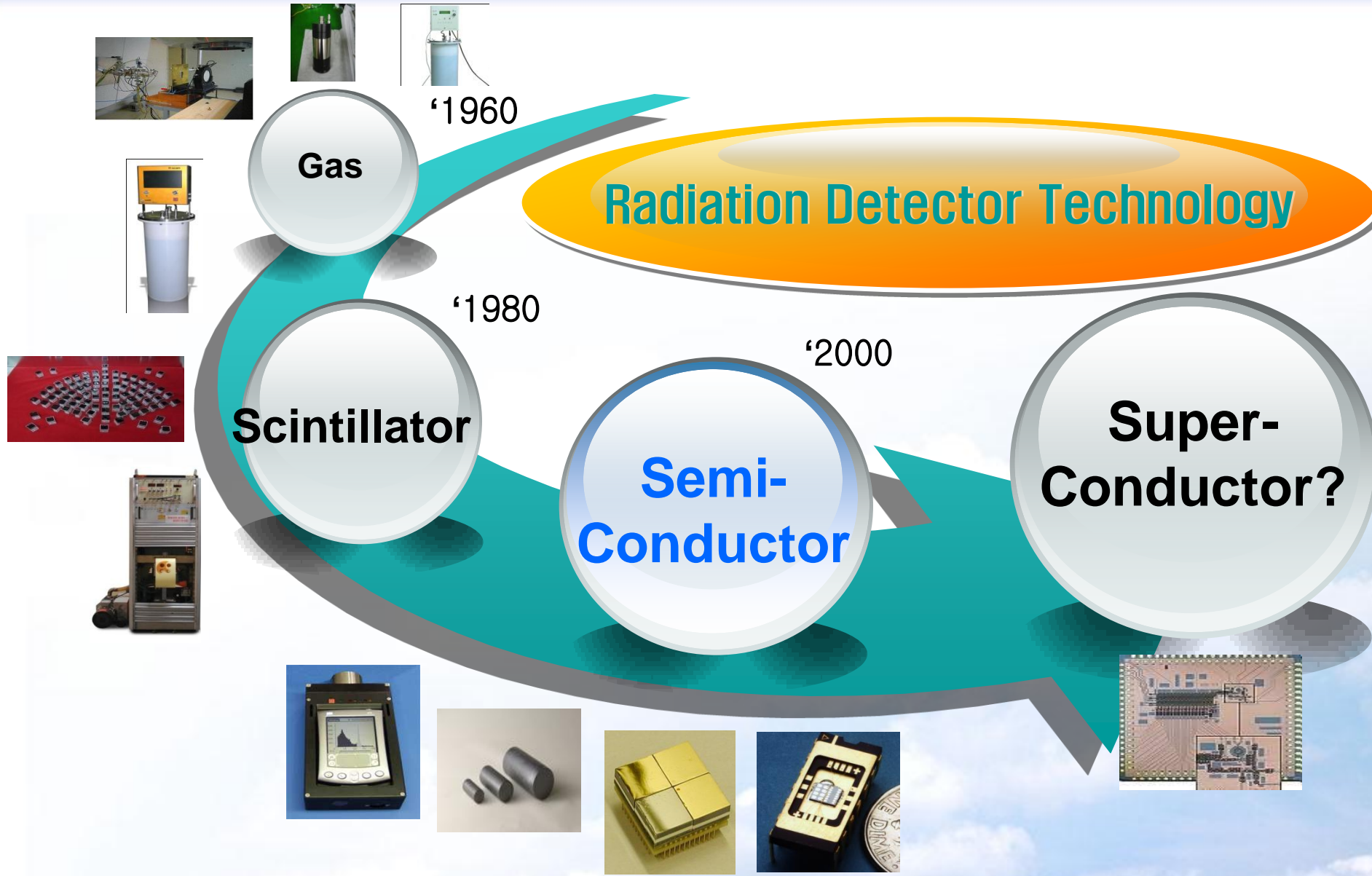


$E = mc^2$

1. Introduction



Radiation Detector Technical Trend



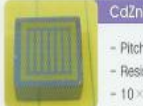
KAERI Research Fields(-2010)

Semiconductor Radiation Detectors



Compound Semiconductor Single Crystal

- Bridgman Method
- CdTe Single Crystal
- CdZnTe Single Crystal



CdZnTe Strip Detector

- Pitch : ~1mm
- Resistive Contact
- $10 \times 10 \times 5 \text{ mm}^3$



CdZnTe Radiation Detector

- Active Area : $5 \times 5 \times 2 \text{ mm}^3$
- BNC type
- Gamma Spectroscopy



SiC Radiation Detector

- Active Area : $\phi = 5 \text{ mm}$
- High Temperature and High Radiation Field Application



GaAs Radiation Detector

- BNC type
- Alpha and Beta Spectroscopy



Silicon Surface Barrier (SSB) Radiation Detector

- Active Area : $\phi = 3 \text{ cm}$
- Alpha and Beta Spectroscopy

Gas-Filled Radiation Detectors



Ionization Chambers

- Air-filled ion chamber
- High pressure Xe-chamber



Ionization Chamber for Thickness Measurements

- Xe-filled, 6 atm
- Beta Detection, Active Area : $\phi = 80 \text{ mm}$ (left)
- X-ray & Gamma Detection
- Active Area, $2 \times 6 \text{ cm}^2$ (Right)



Ionization Chamber for Environmental Radiation Monitoring

- Ar-filled, 25 atm,
- $\phi = 25.4 \text{ cm}$
- Monitoring Environmental Radiation



Ionization Chamber for Proton Beam Monitoring

- Ar-filled
- Active Area : 176 cm^2
- Monitoring Proton Beam



Gas Electron Multiplier (GEM)

- GEM type
- Active Area : $5 \times 5 \text{ cm}^2$
- Neutron & X-ray Detection



Air Equivalent Ionization Chamber

- Air-filled
- Active Volume : 14.4 cc
- Dosimetry for Medical application

Scintillator Radiation Detectors



CsI(Tl) Scintillator / PIN diode

- $10 \times 10 \times 20 \text{ mm}^3$
- X-ray & Gamma-ray detection
- Dosimetry for radon, Environment



Positron Radiation Detector

- Plastic & Inorganic Scintillators
- Coincidence Measurement (Charged Particles & Gamma-ray)



Inorganic Scintillator (GSO)

- $10 \times 10 \text{ mm}^2$
- Gamma & Beta Radiation Detection



Plastic Scintillator

- $\phi = 5 \text{ inch}$ (12.7cm)
- Beta Radiation Detection



ZnS Scintillator

- $10 \times 10 \times 1 \text{ mm}^3$
- Alpha, Beta & Low Energy X-ray Detection



ZnS(Ag) Scintillator

- $\phi = 4 \text{ inch}$ (10.16cm)
- Beta Radiation Detection

Commercial Products



Intelligent Radiation Monitoring System

- Measurement : X-ray, gamma-ray
- Dose Range : $10^{-3} \sim 10^4 \text{ mSv/h}$
- Interface : RS-232, Internet
- LCD display



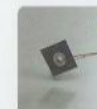
Ionization Chambers for Intelligent Radiation Monitoring System

- Air-filled, Active Volume : 11.8 L (Left)
- Xe-filled, Active Volume : 1 L (Right)
- Area Radiation Monitoring System



β-Thickness Gauge

- β-ray ion chamber Detector
- Measurement Range : $1 \sim 1000 \text{ g/m}^2$
- On-line textile weight monitoring



Cryogenic Semiconductor Detector

- InSb Schottky diode
- Operation temp : 10K



2D Array Detector

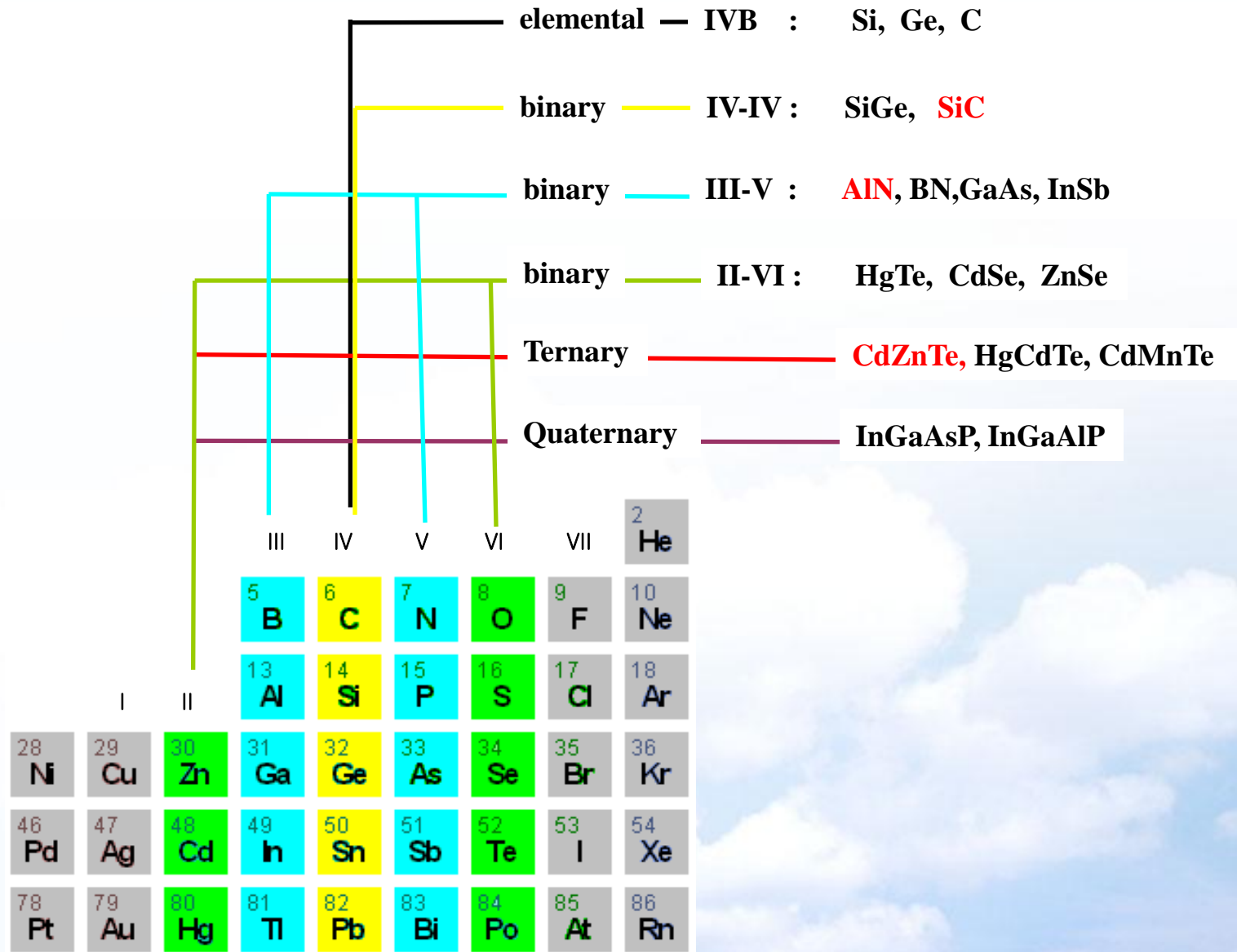
- 2D Array type
- Si, GaAs, SiC
- Radiation Imaging Sensor



Si MOS Detector

- MOS structure
- Gamma-ray, neutron
- Military, medical

Semiconductor Family

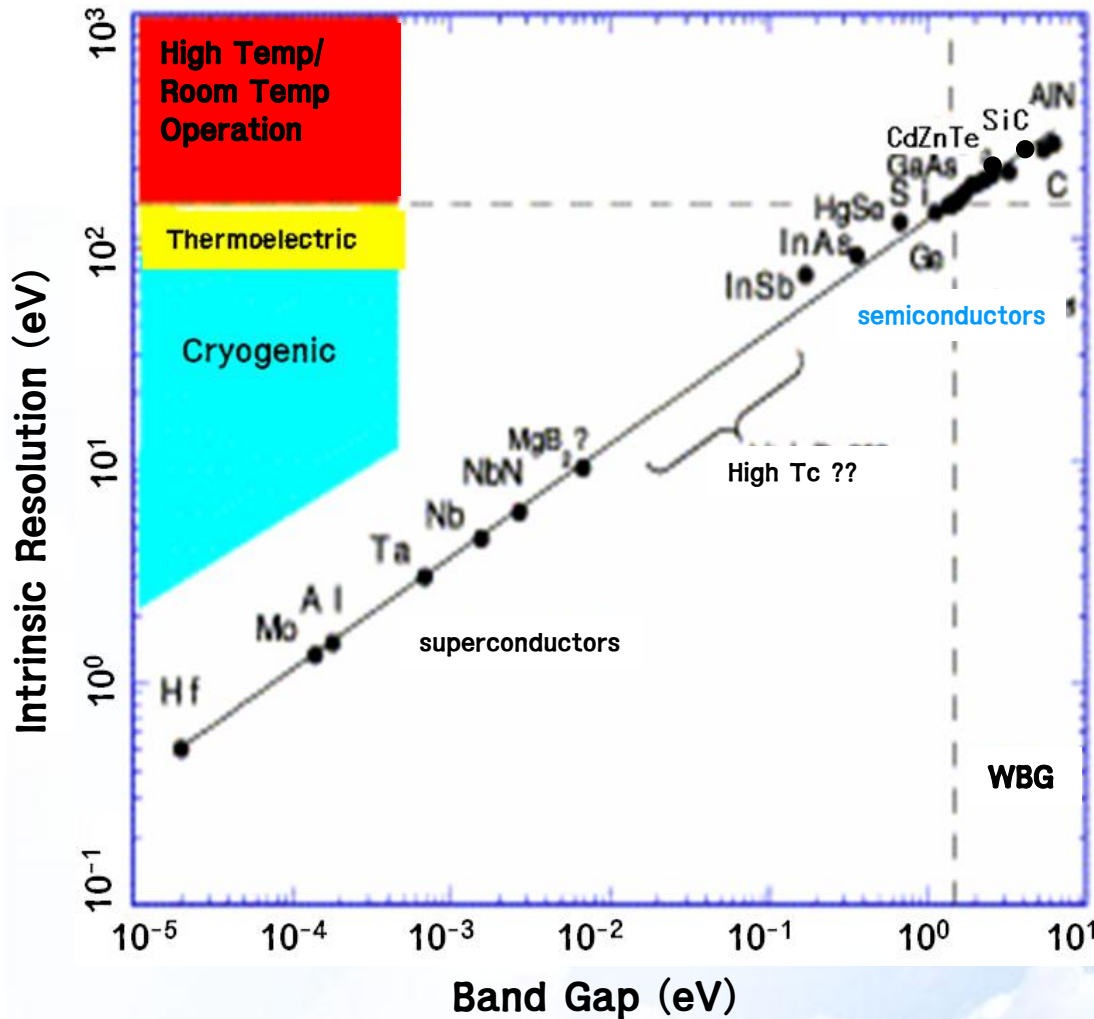


Semiconductor Properties



Material	Atomic number	Relative density	E_g (eV)	Pair creation energy, W (eV)	Resistivity(Ω cm)	Thickness to stop 90% of 50keV
Si	14	2.33	1.12	3.62	Adjustable	2.3cm
a-Si:H	14	2.3	~1.7	4	10^{12}	2.3cm
Ge	32	5.32	0.7	2.97	Adjustable	1.3mm
GaAs	31-33	5.32	1.42	1.43	Adjustable	1.3mm
a-Se	34	4.3	2.3	40	10^{12}	1.4mm
CdTe	48-52	6.2	1.44	4.42	10^9	66 μ m
TlBr	81-35	7.6	2.68	6.5	$10^9 \sim 10^{12}$	52 μ m
HgI ₂	80-53	6.4	2.13	4.15	10^{13}	65 μ m
PbO	82-16	9.53	1.9	14.8		71 μ m
PbI ₂	82-53	6.2	2.32	4.9	10^{12}	64 μ m
BiI ₃	83-53	5.8	1.7		10^{12}	63 μ m

Intrinsic Energy Resolution Relation



$$\Delta E \sim 2.355 (F \cdot \epsilon \cdot E_0)^{1/2}$$

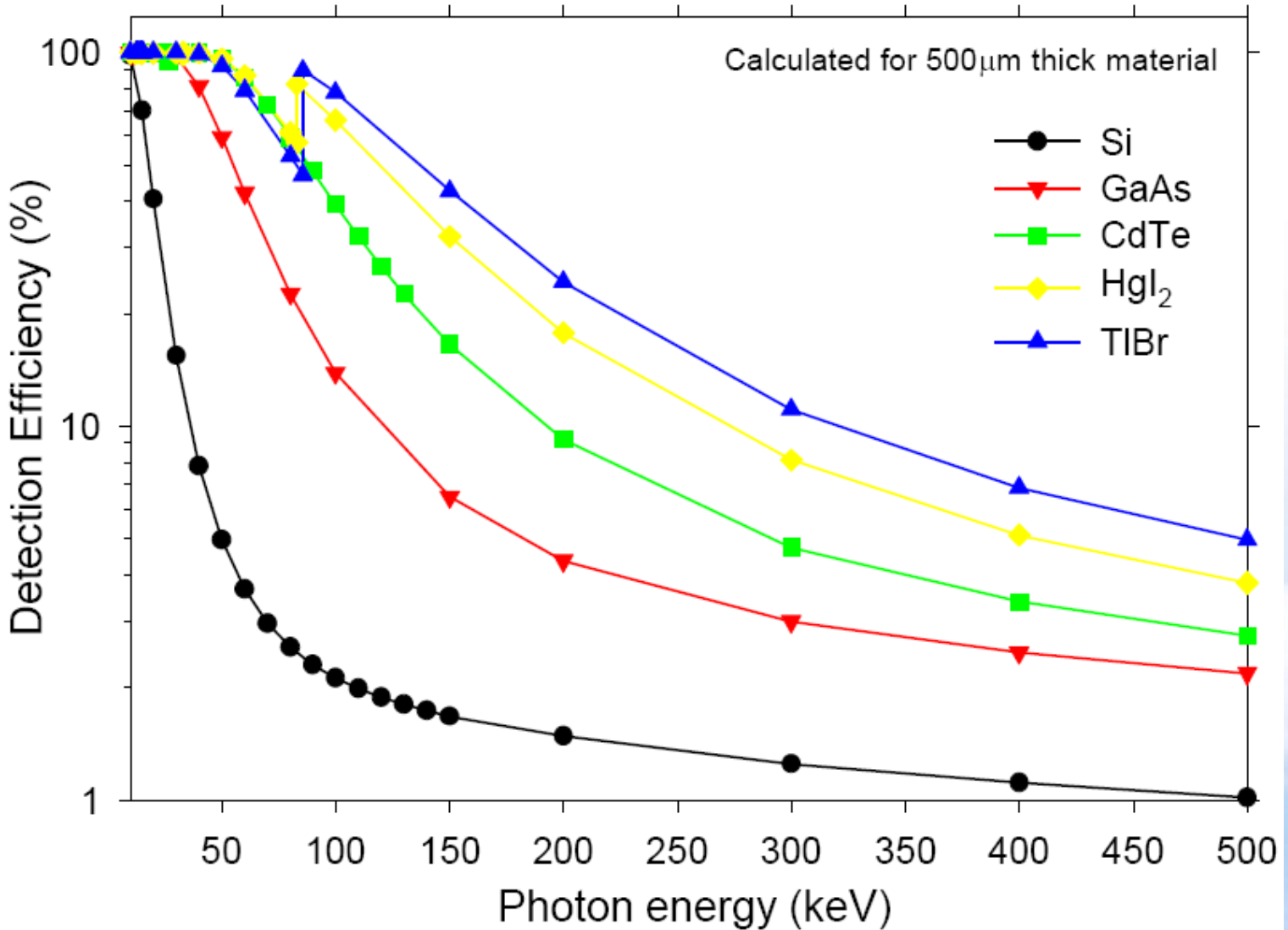
ϵ : e-h pair creation energy
 F: Fano factor
 E₀: deposited energy



$E = mc^2$

2. CdZnTe Detector

Gamma-ray Detection Efficiency

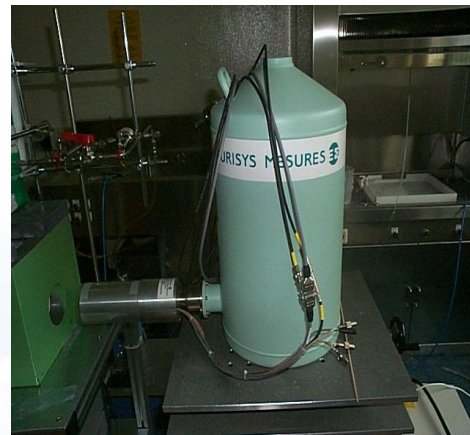


Semiconductor Radiation Detectors

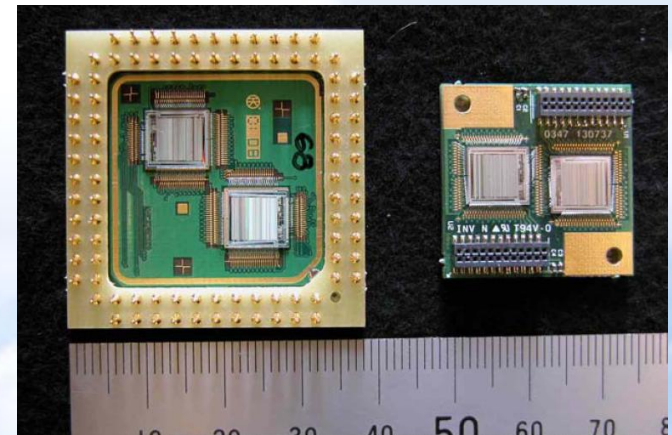
Detector Type	Scintillator	Si, Ge Semiconductor	CZT Semiconductor
Energy Resolution	30keV	2keV@-70°C	~10keV
Detection Method	Indirect	Direct	Direct
Efficiency	Low	Low	High
Compactness	X	X	O
Spatial Resolution	Normal	High	High



< Scintillator >

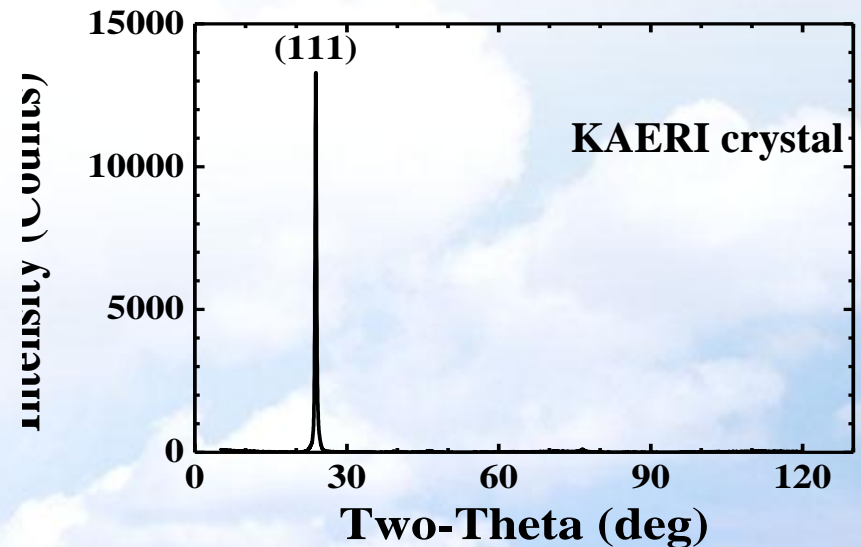
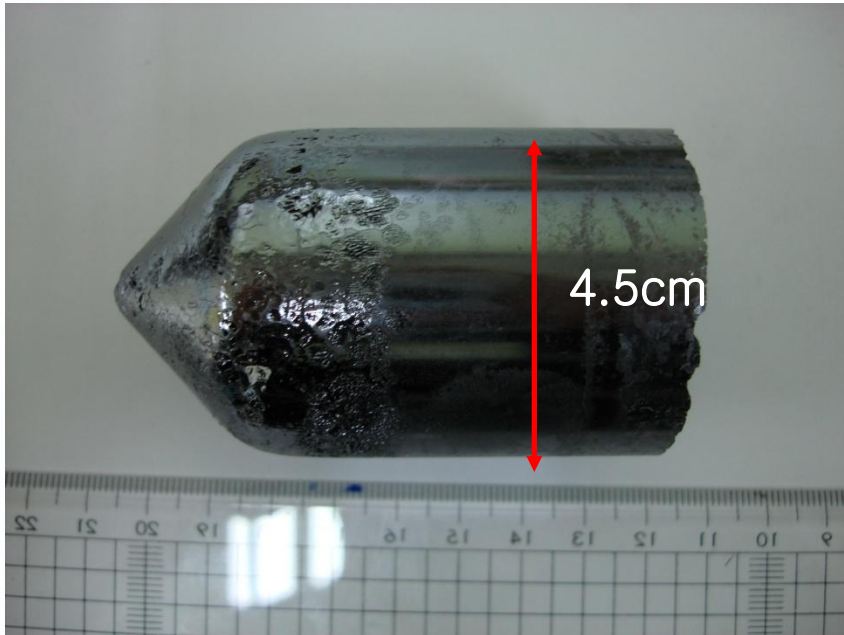
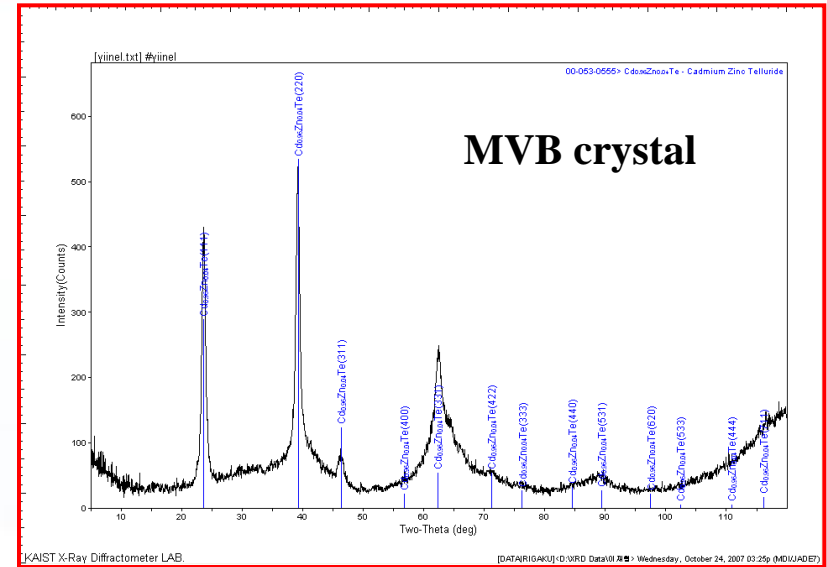
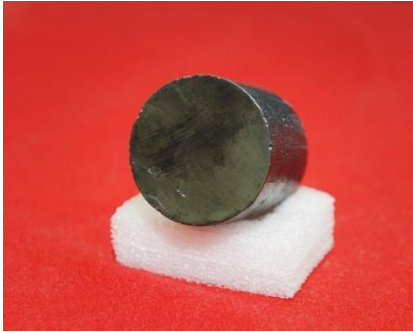


< Ge, Si Type >



< CZT Type >

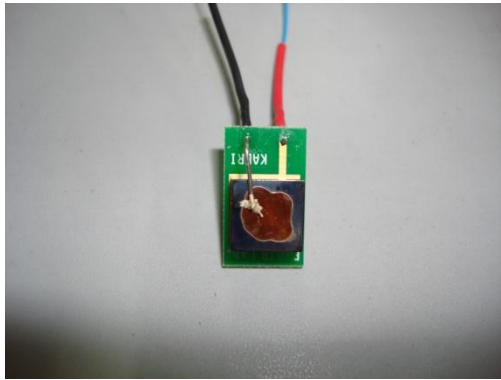
Single Crystal Growth (CdZnTe)



Metal/Semiconductor Contact

(eV-products crystal)

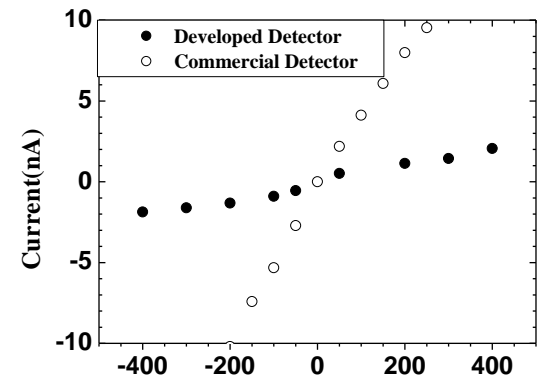
CZT Ohmic-Ohmic



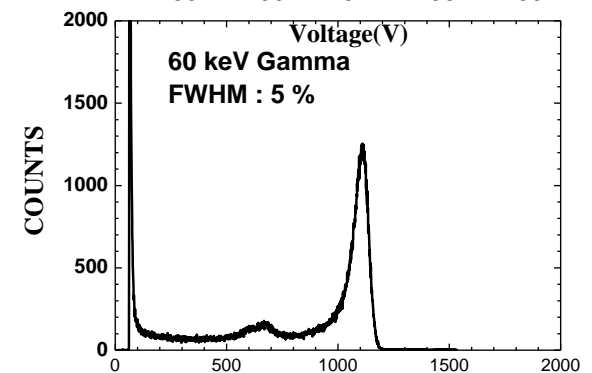
CZT Schottky



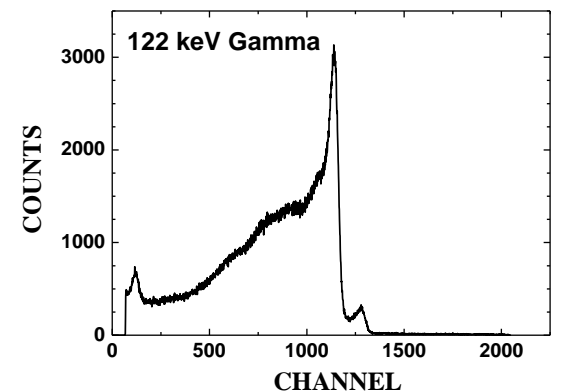
i) Ohmic I-V



ii) Ohmic



iii) Schottky



CdZnTe Pocket Spectrometer



Dozimetr - 연영각원

연영각원 | 연영각원 | 연영각원 | 연영각원

Connect | Disconnect | Data S.I.B. | Trend | Setup

통신 설정
Com Port: COM1 | Baud Rate: 19200 | 연결

알림 정보

Index	Title	Type	Exp. person
1	일반 측정	Normal	홍준표
2	측정	Normal	홍준표
3	연영	Extend	홍준표

알림 목록 | 알림 취소 | 알림 설정 | 알림 설정 | 알림 설정

측정 정보

ID	Serial	Date	Dose
0	1	2007-03-19 15:43:25	401.00uV
1	2	2007-03-19 15:43:25	3.00mV
2	3	2007-03-19 16:11:31	20.00mV

1 - 일반 측정 Built-in Test | 보류 시간 | 보류 조건

알림 시작 시간: 2007-03-19 15:43:25 | 종료 시간: 2007-03-19 16:11:31

Color	색상 ID	색상 Serial	가중치	측정값	설정값
Red	0	1	0	0	0
Yellow	1	2	0	0	0
Green	2	3	0	0	0

F-N Dose: 0.00uCy | F-N Total Dose: 0.00uCy | F-N Base V1: 0Voff

T-N Dose: 0.00uCy | T-N Total Dose: 0.00uCy | T-N Base V1: 0Voff

Gamma: 0.00uCy | Gamma Total Dose: 0.00uCy | Gamma Base V1: 0Voff

NUM

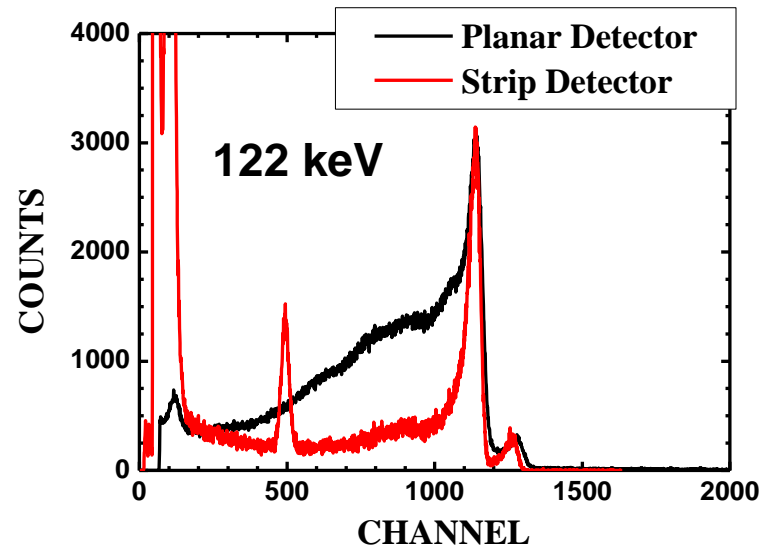
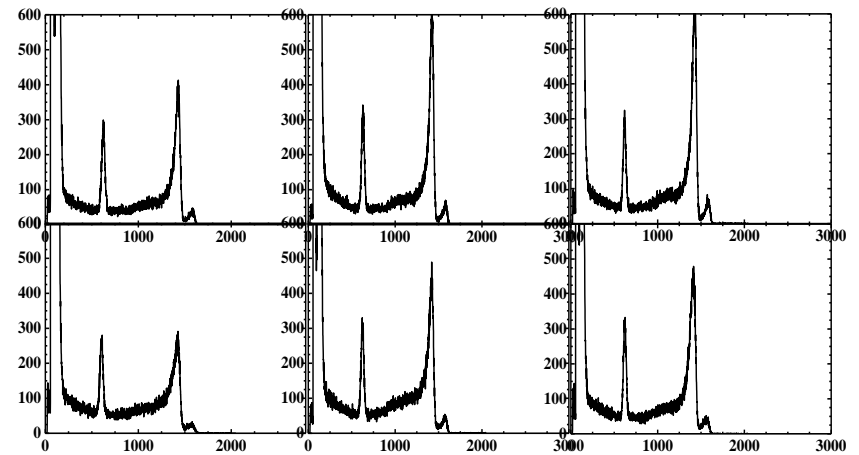
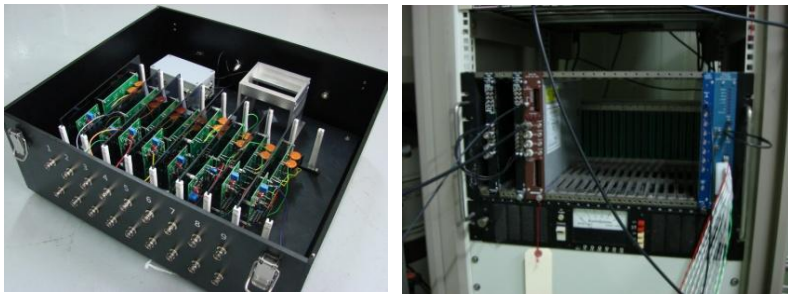
1-D CZT Strip Detector

$$E = mc^2$$

CZT Strip Detector

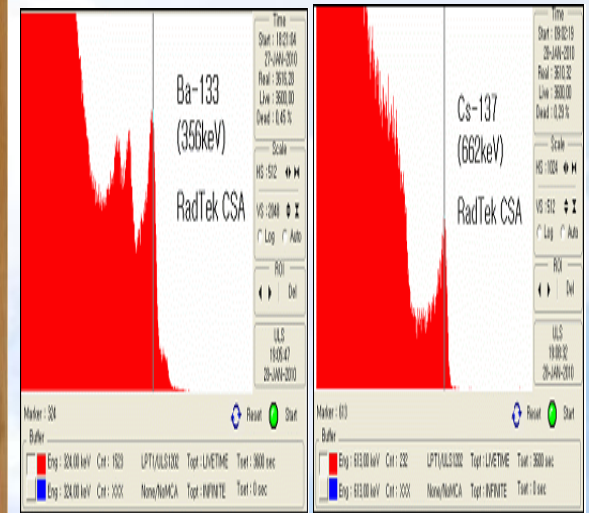
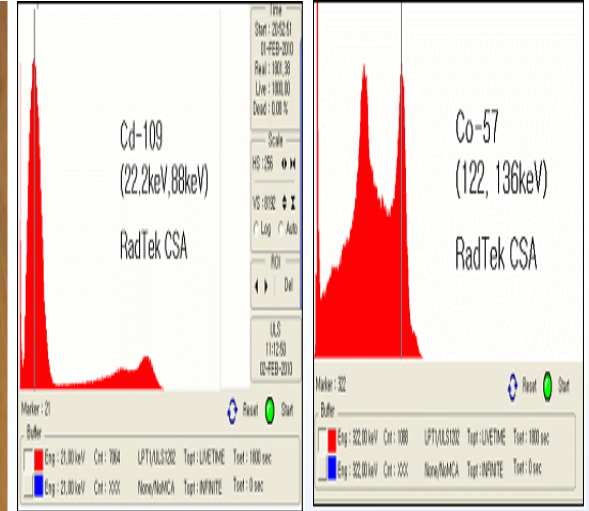
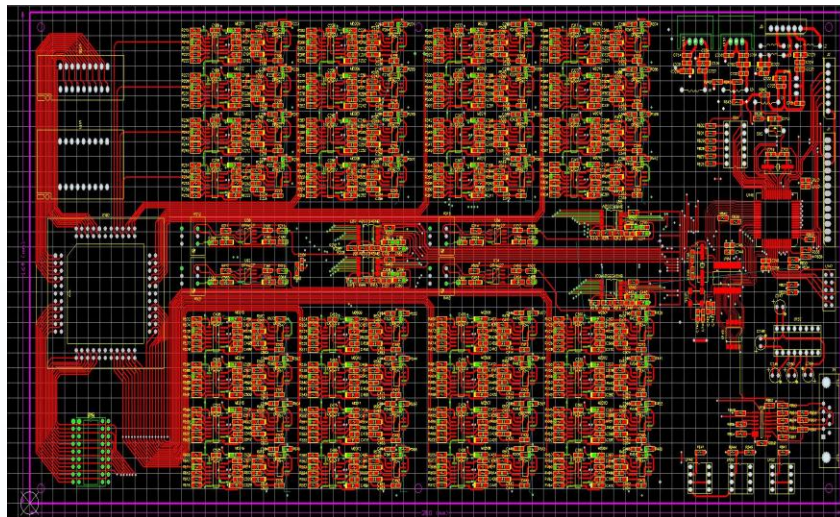
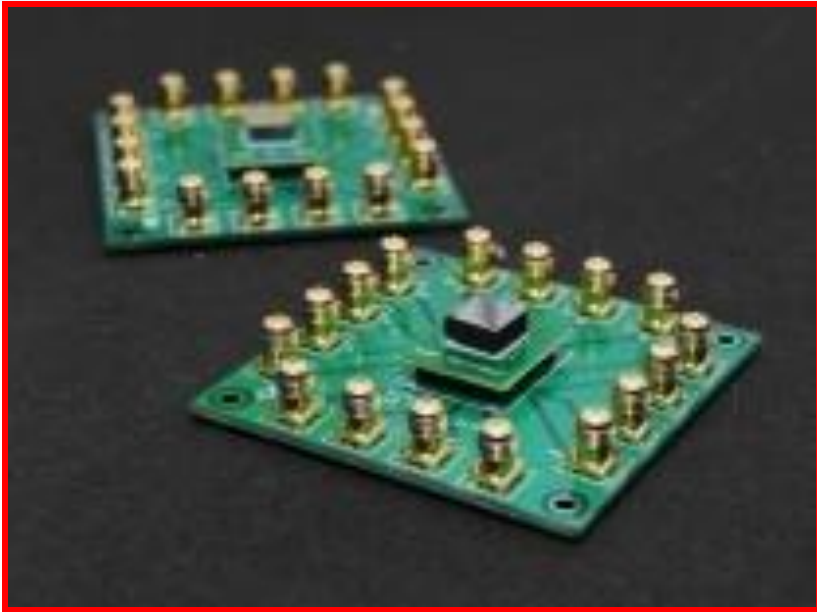


Electronics & DAQ(CAMAC)

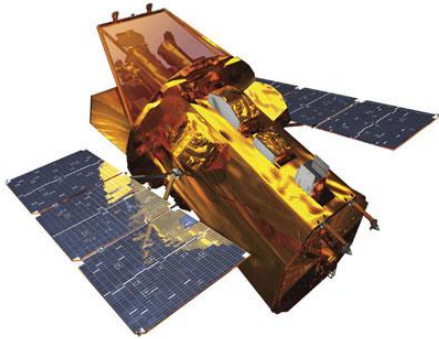


<CZT Strip Detector Energy Spectrum, $E_\gamma = 122$ keV>

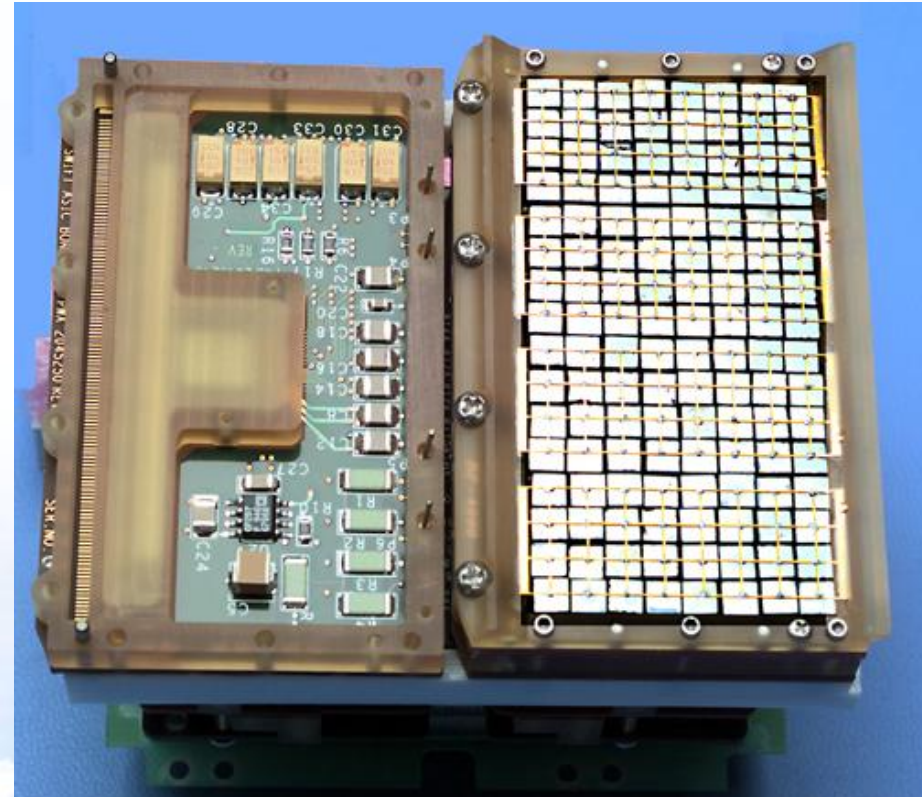
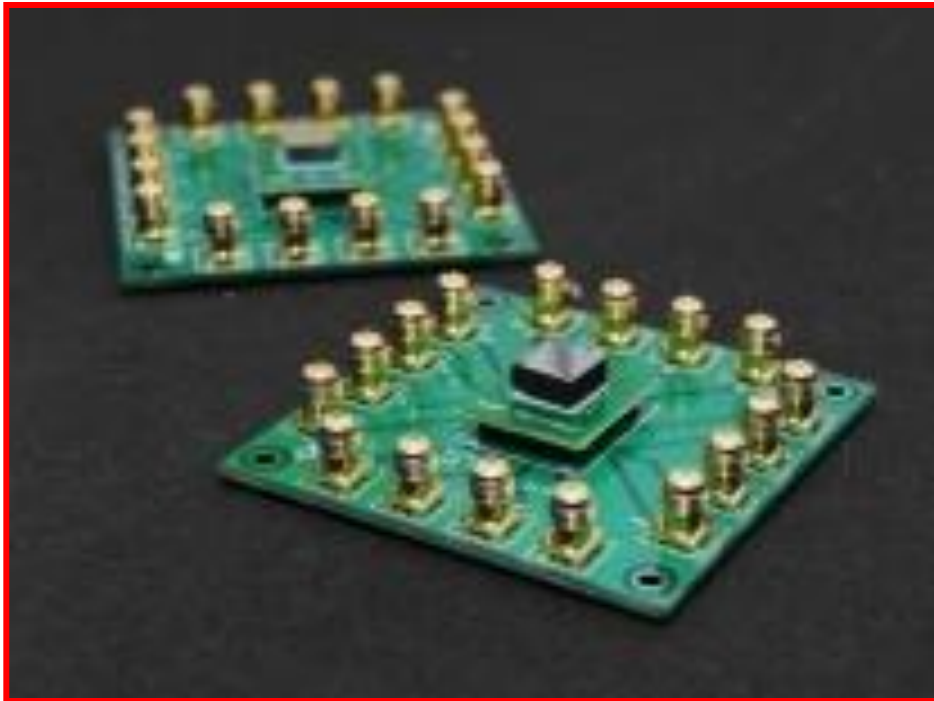
CdZnTe 2-D Spectrometer



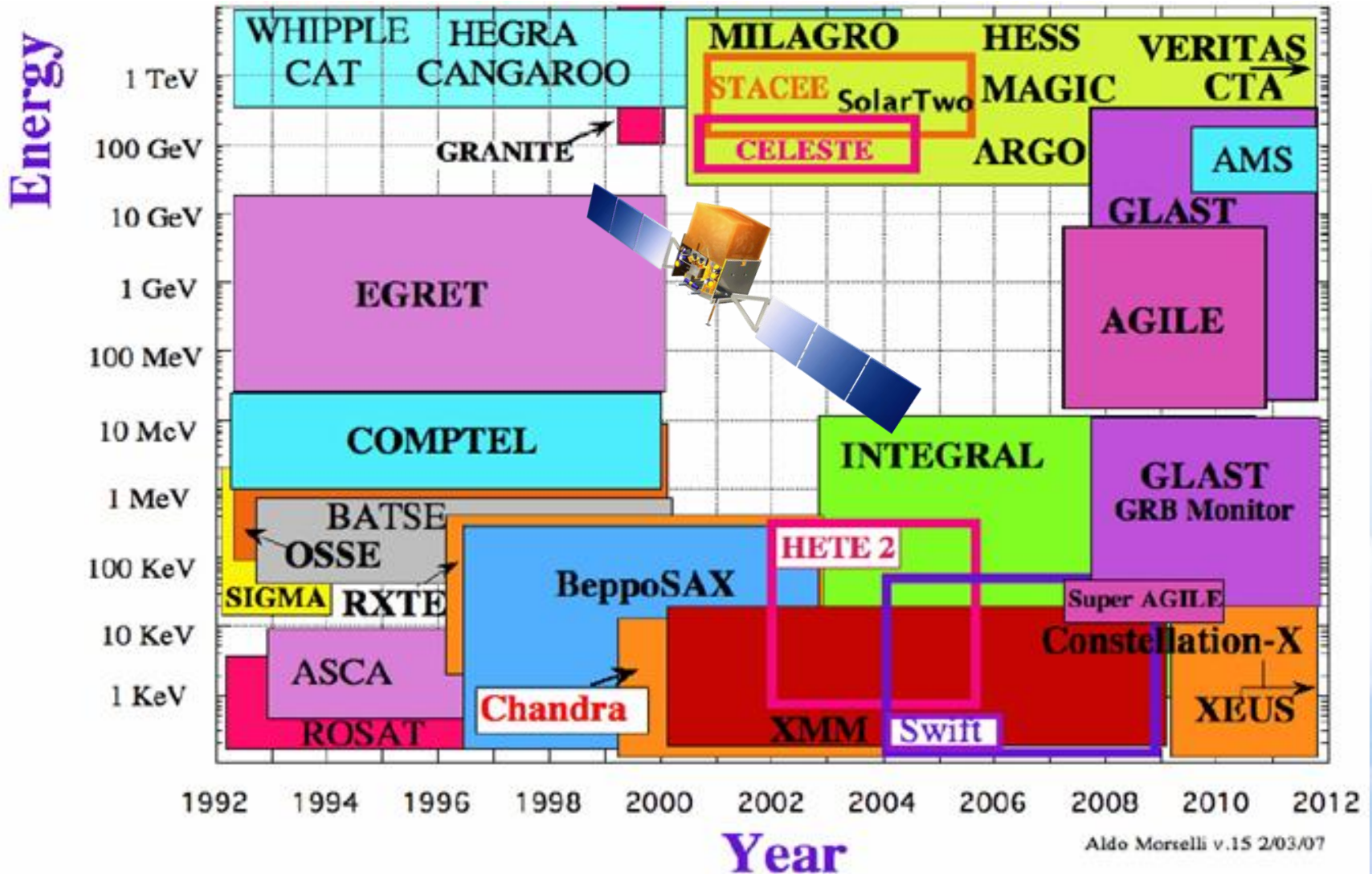
CdZnTe gamma-ray imager(plan)



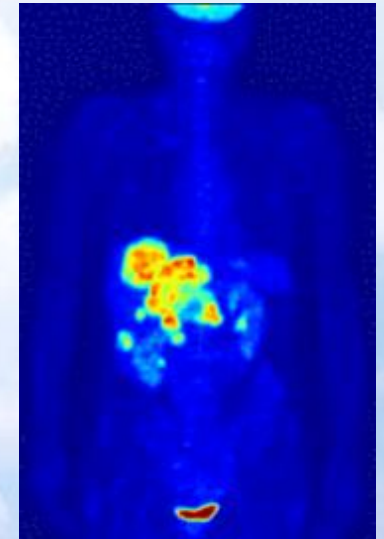
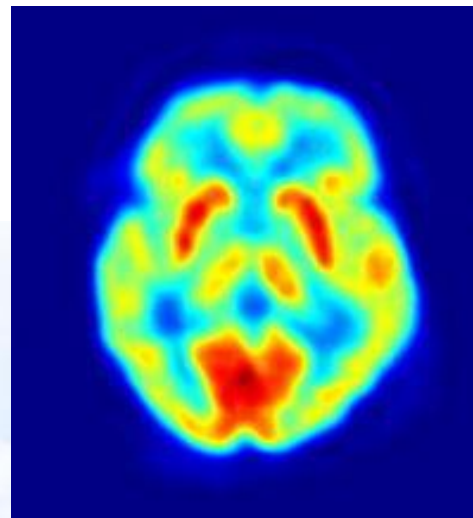
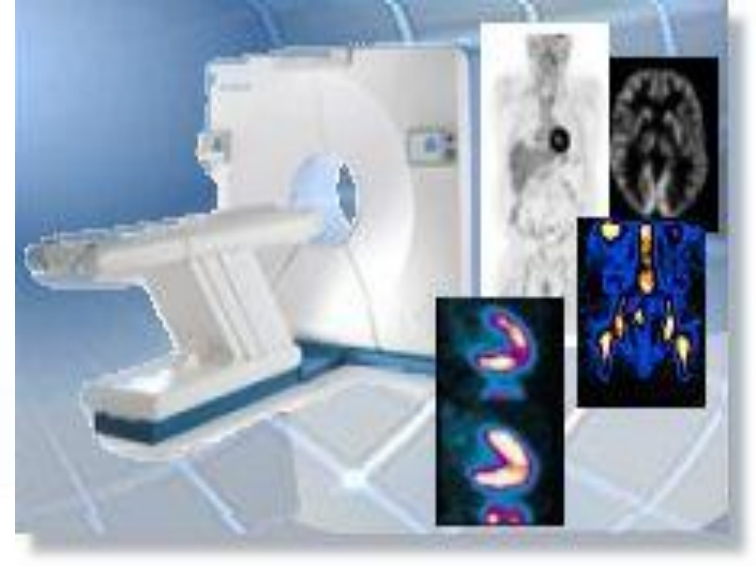
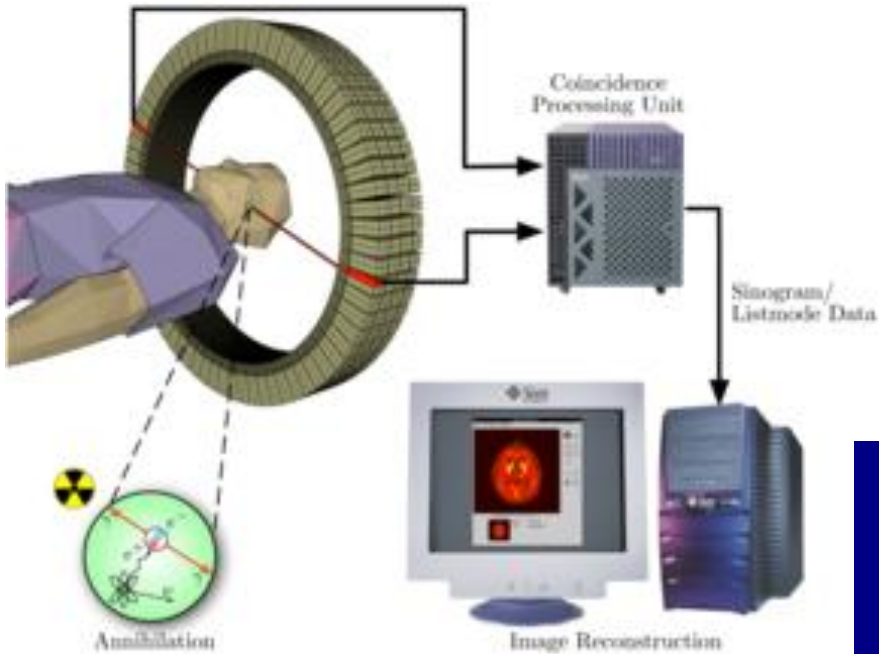
- Swift's GRB :
 - The Burst Alert Telescope (BAT)
-
- 32,768 pieces of 4 x 4 x 2 mm CZT



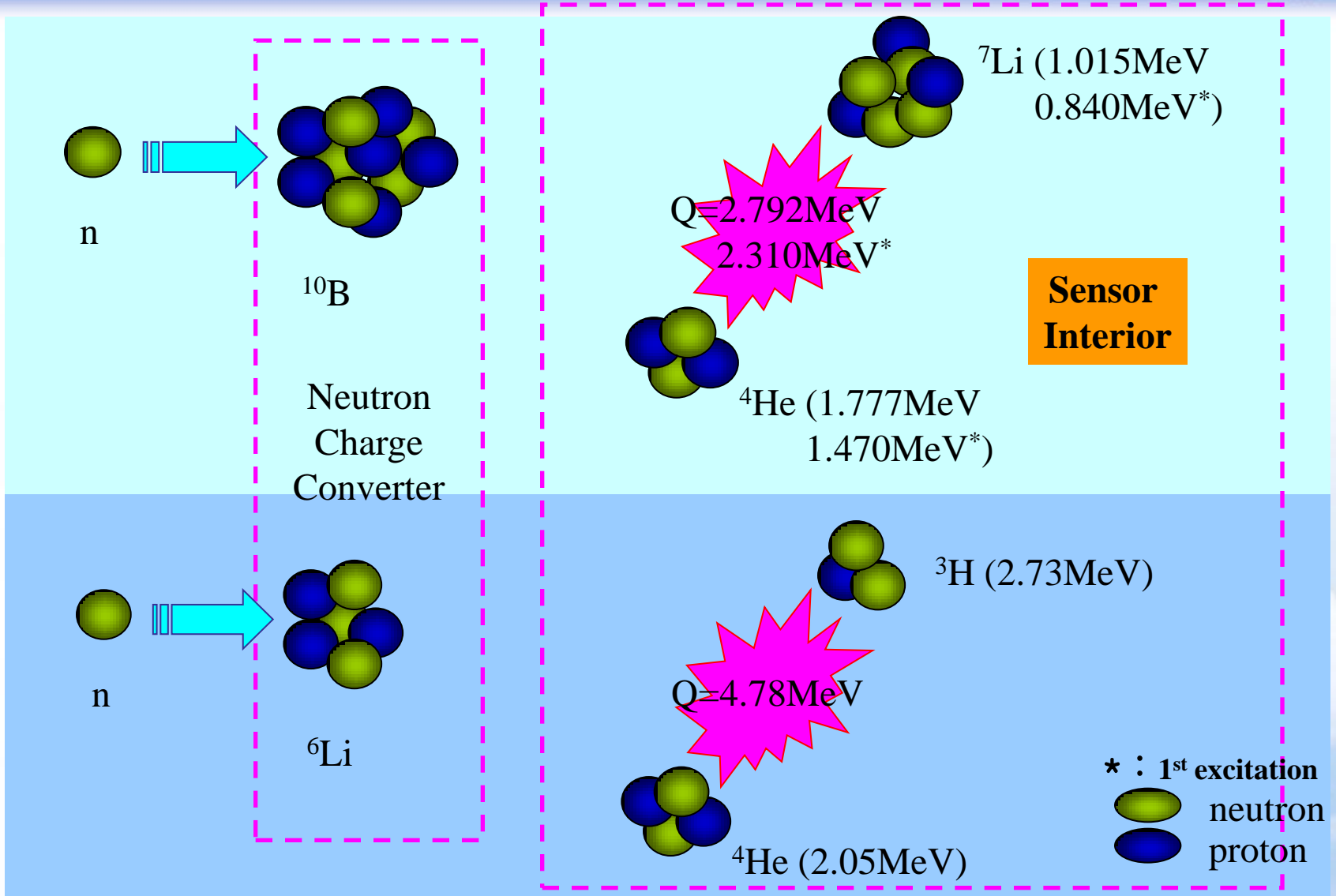
High Energy Space Telescopes



Positron Emission Tomography (PET)



Neutron flux Detection Principle



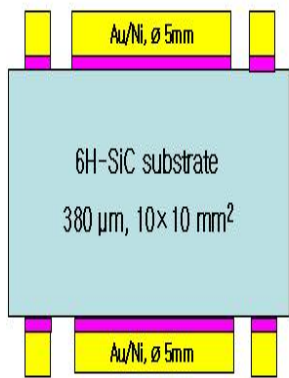


$E = mc^2$

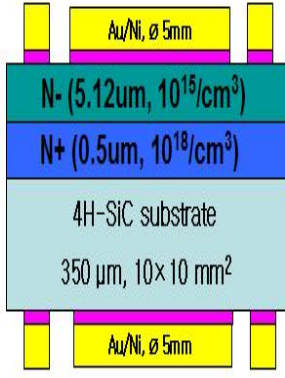
3. Wide Band gap Detectors



SiC High Temp. Neutron Detector



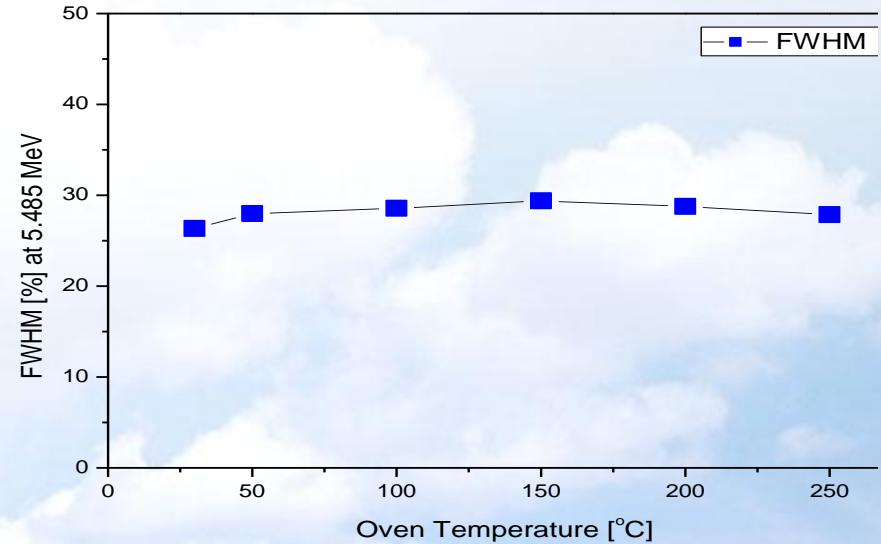
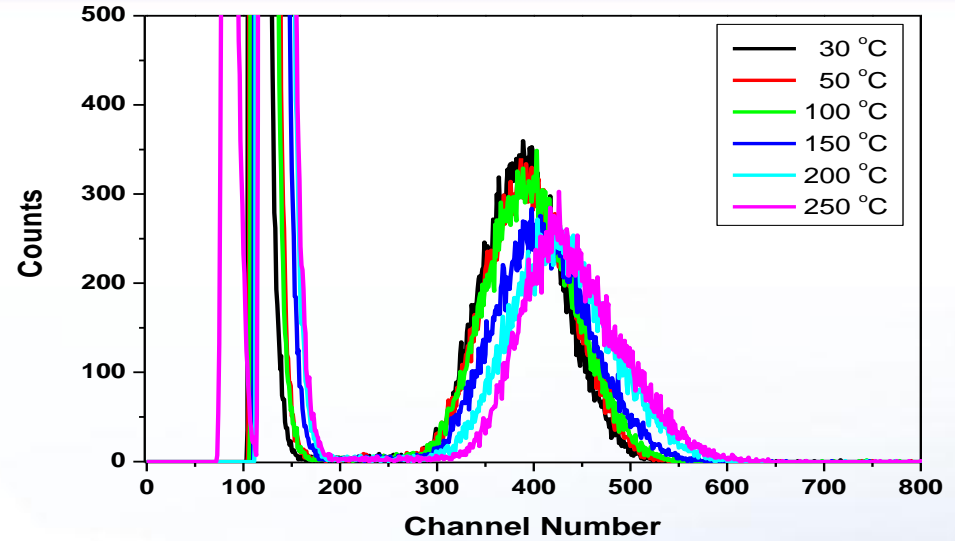
6H-SiC Schottky 다이오드



4H-SiC nn+ 다이오드

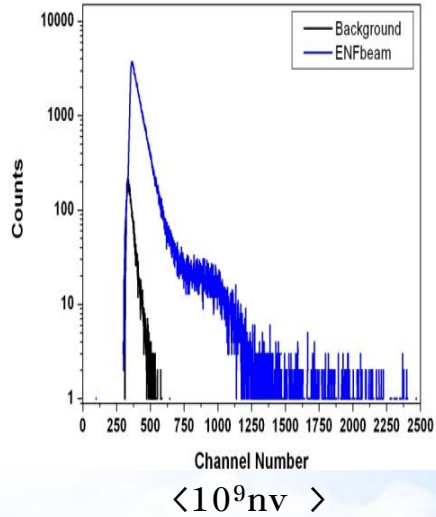
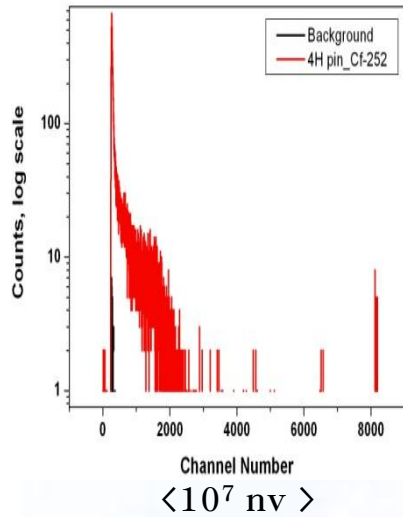


4H-SiC PIN 다이오드



SiC Neutron Detectors

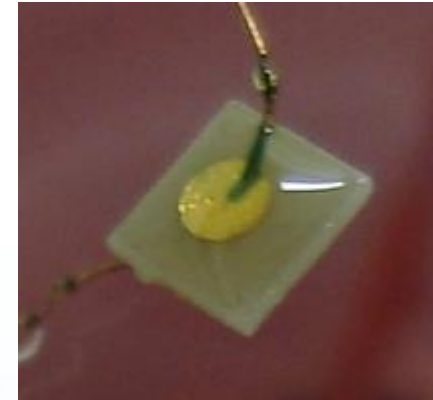
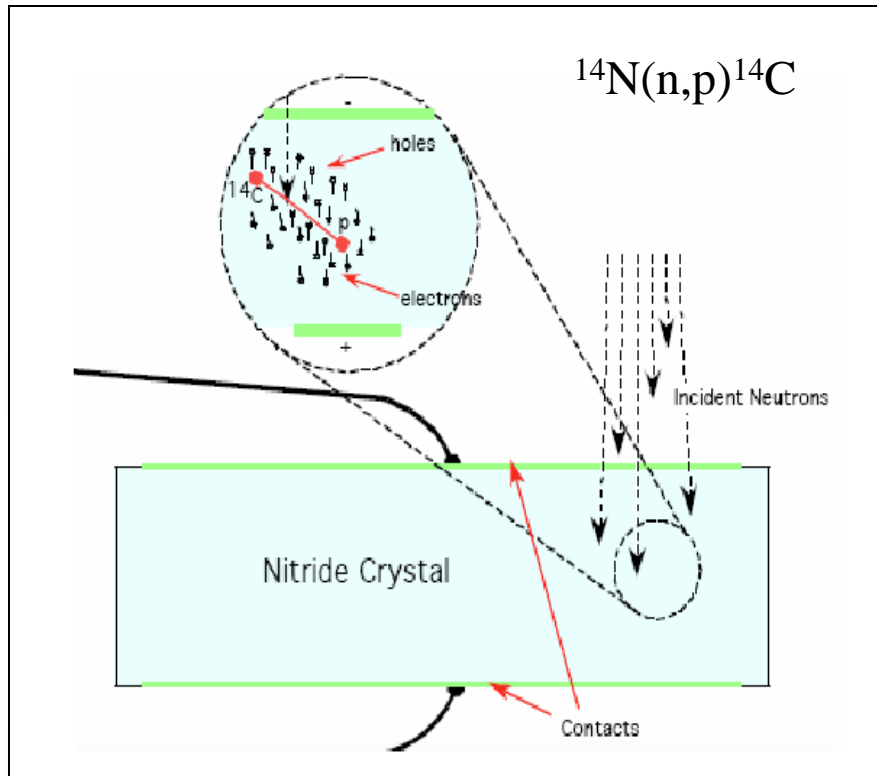
$$E = mc^2$$



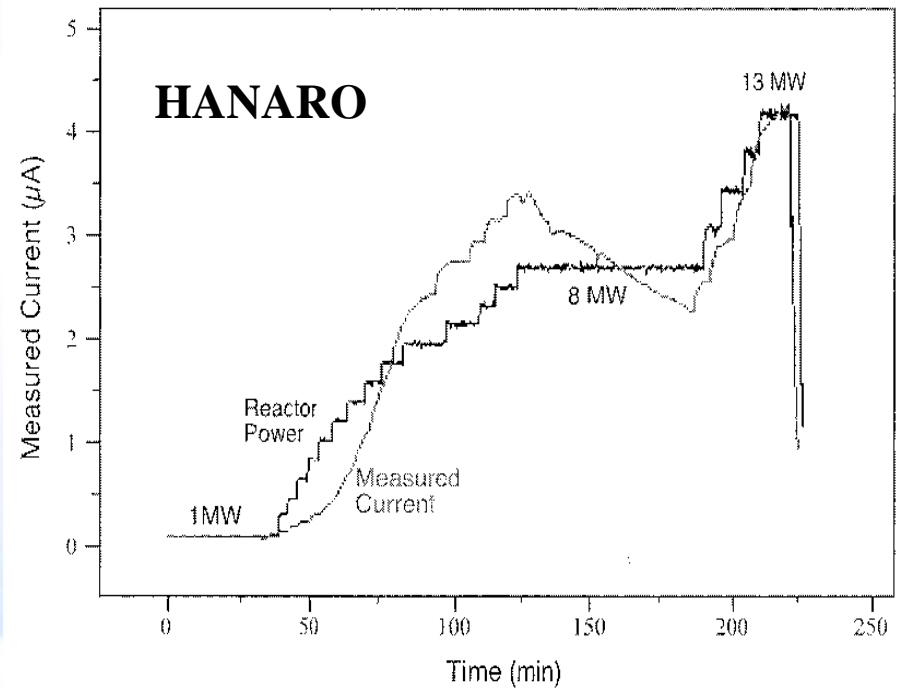
AlN Neutron Flux Detector



KAERI-ORNL(2003)



- Not available single crystal
- Long lifetime for high burn-up



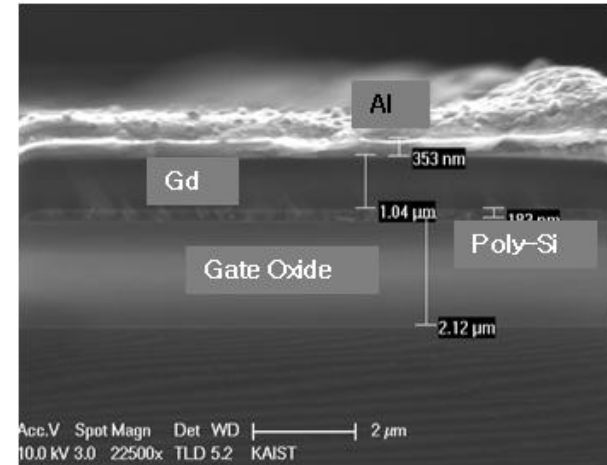
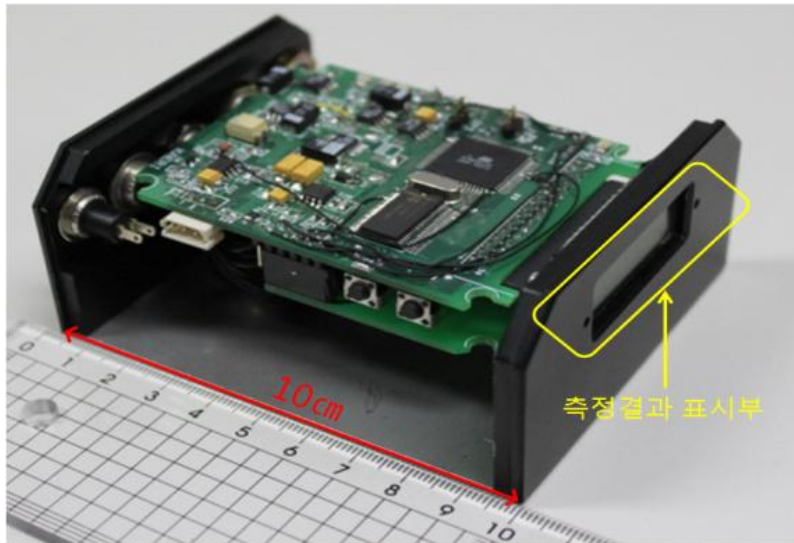


$E = mc^2$

4. Silicon Detectors

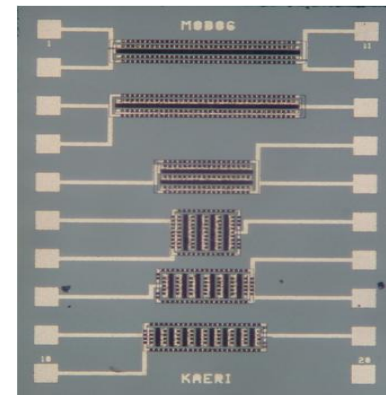
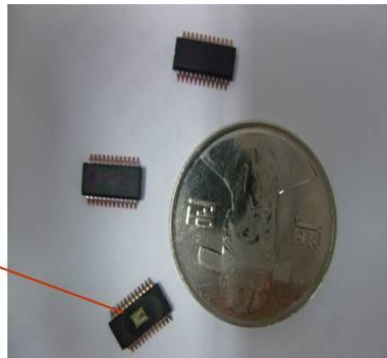
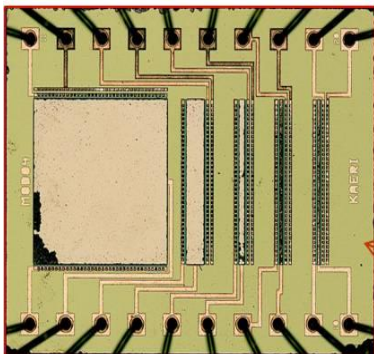


MOSFET Radiation Detector



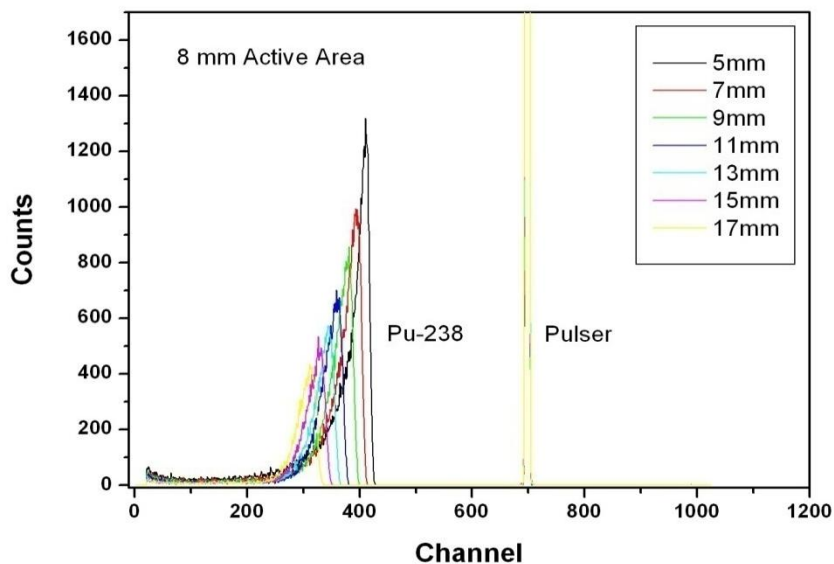
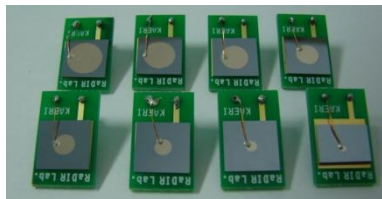
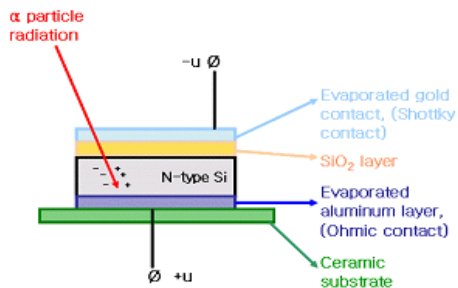
< pMOSFET Gate Topology >

($T_{OX} \doteq 1\mu m$, $T_{GD} \doteq 2\mu m$)



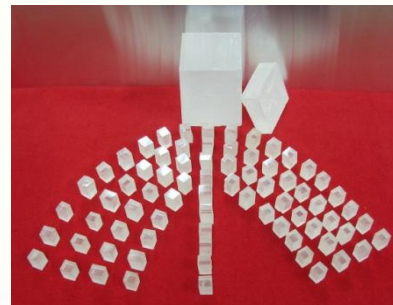
CsI/Si-PIN Detector for α & γ -rays

* Silicon Surface Barrier for alpha

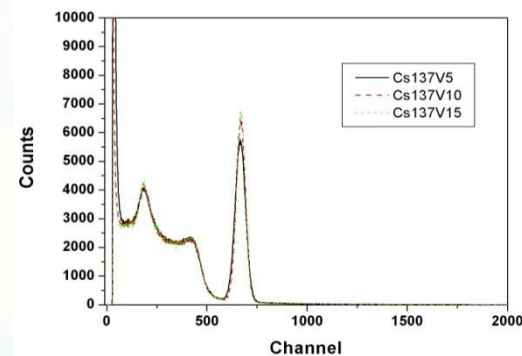


Alpha-ray in 1 atm pressure
(R = 3% @ Vacuum)

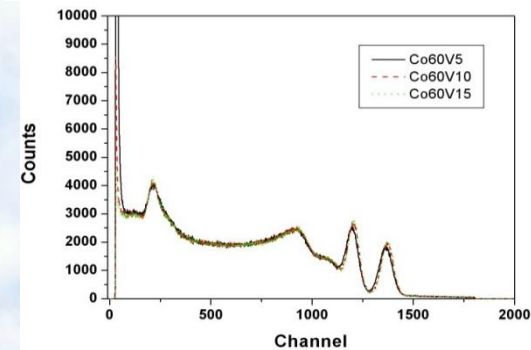
* CsI(Tl) + PIN diode Detector



Cs-137
(662 keV)
R= 8%



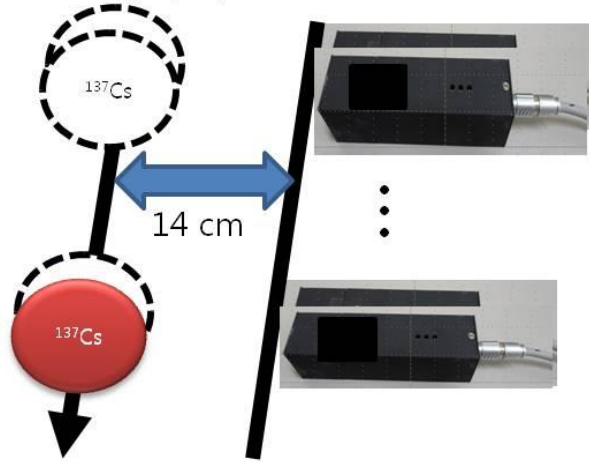
Co-60
(1173 keV)
(1332 keV)
R= 5%



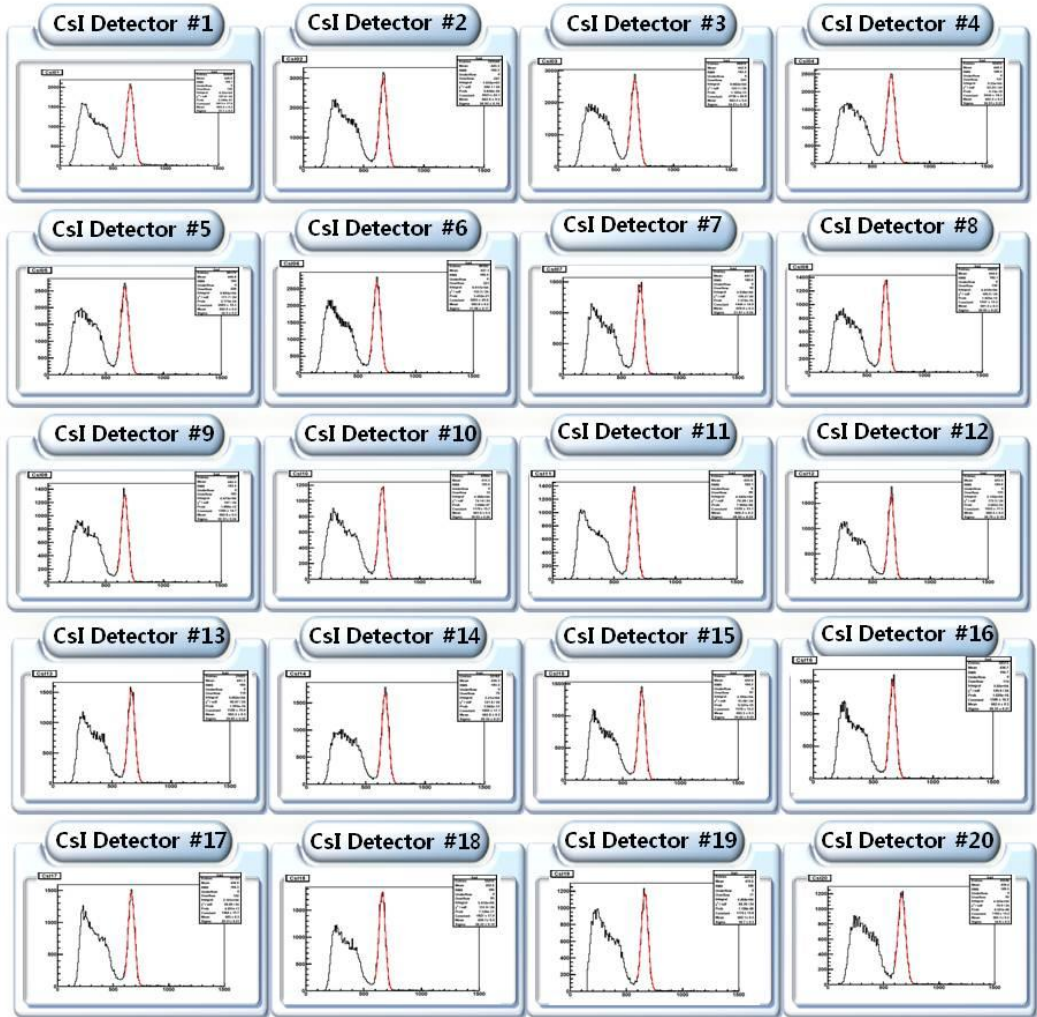
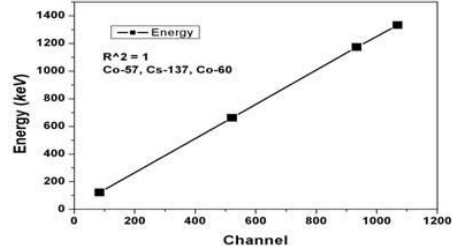
CsI/PIN Detectors



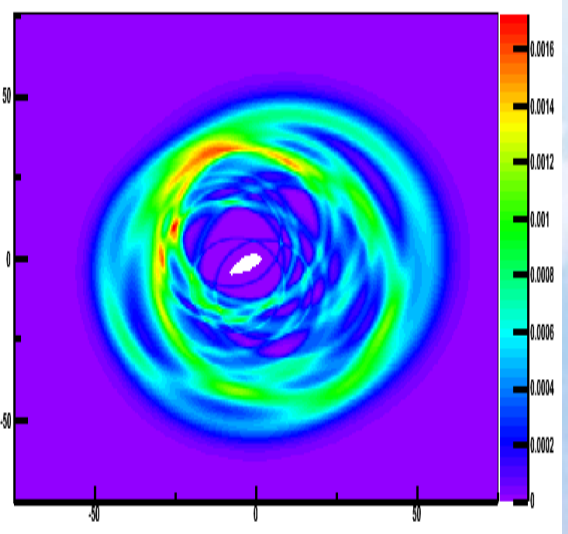
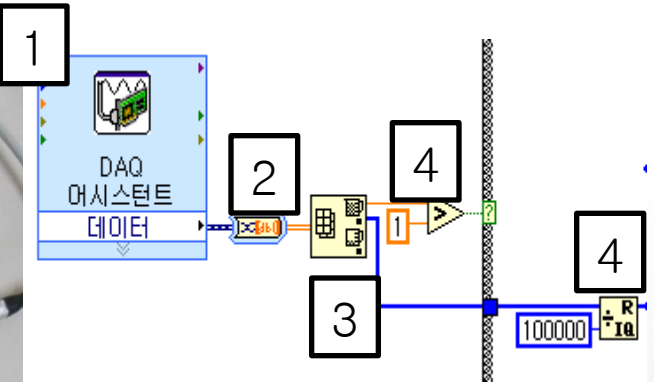
선원 위치이동



단일 센서 선형성 평가



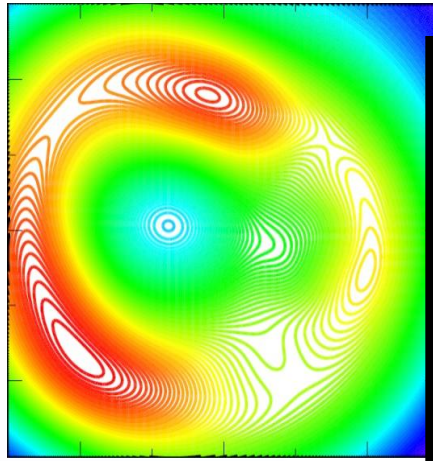
Gamma-CT Prototype



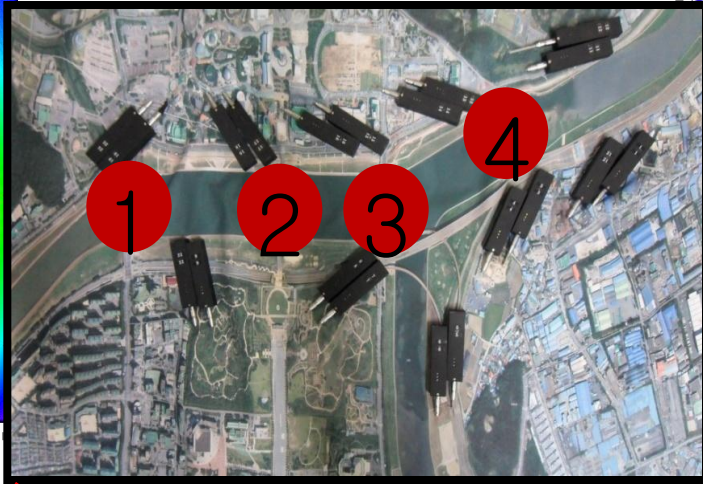
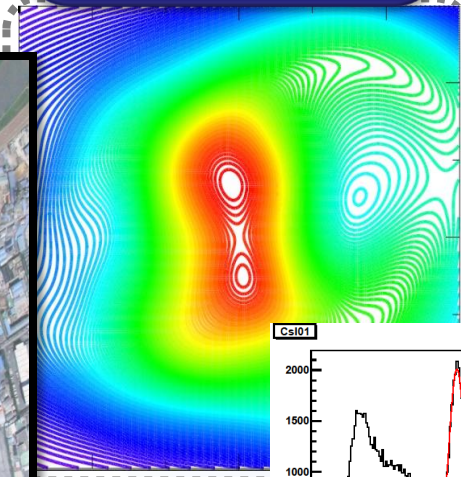
Water RI Contamination Monitoring System prototype



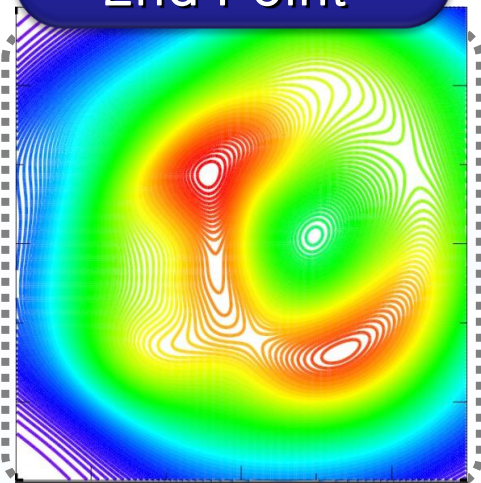
1st Point



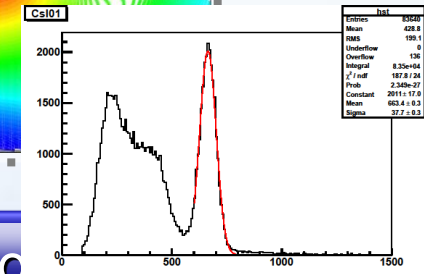
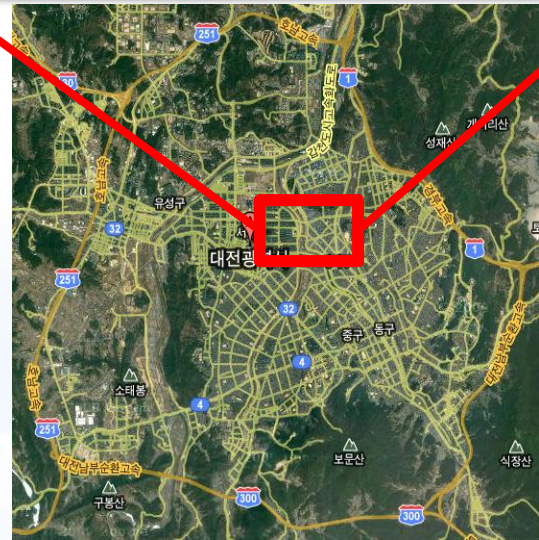
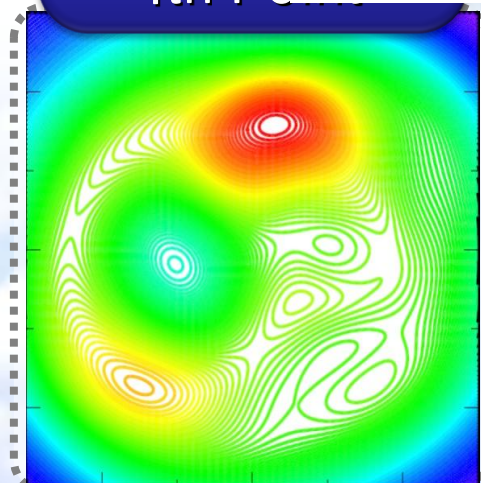
3rd Point



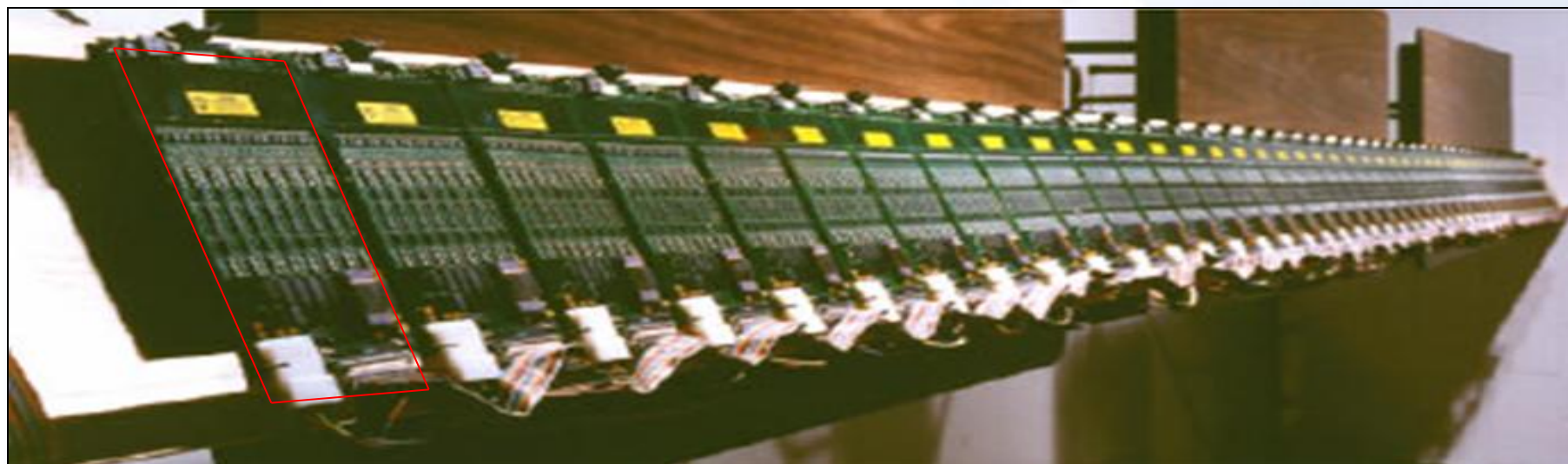
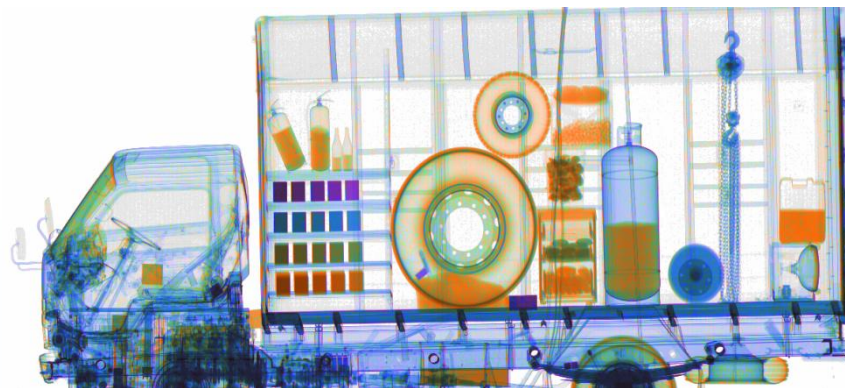
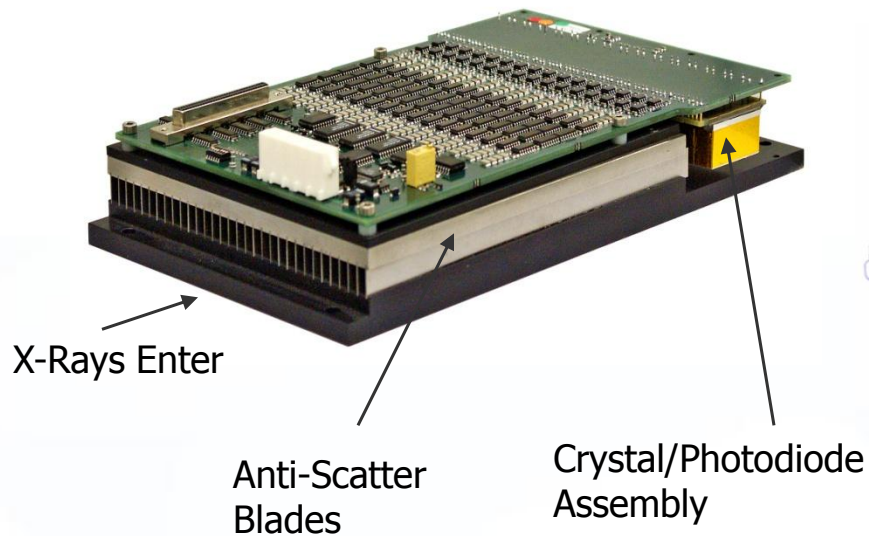
2nd Point



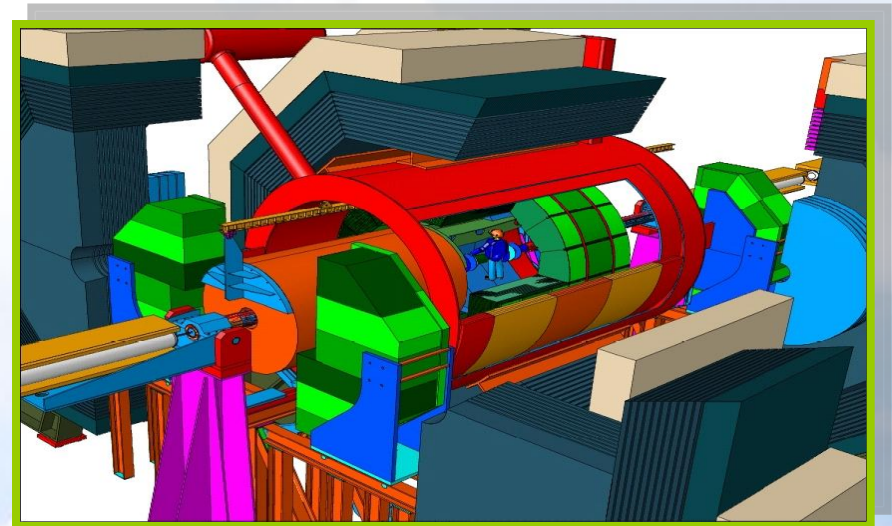
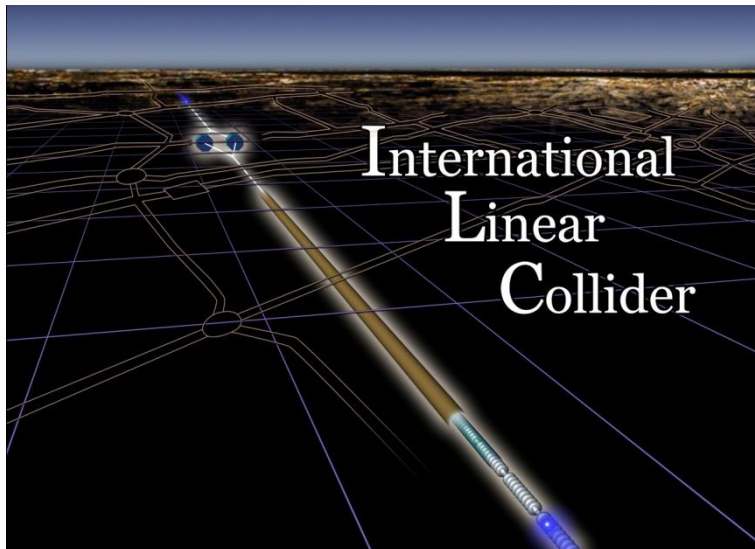
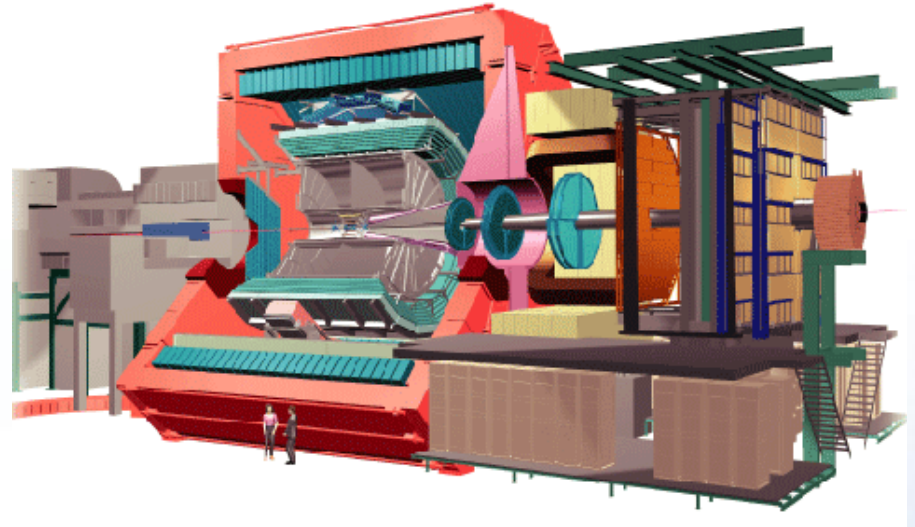
4th Po



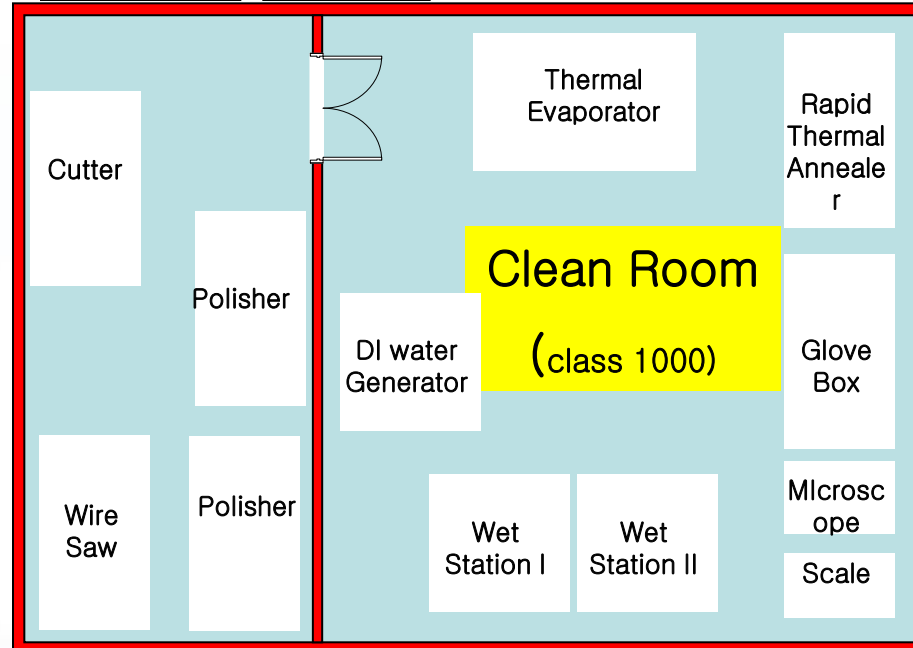
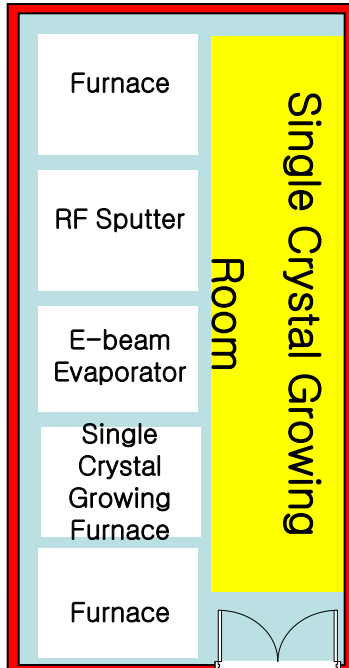
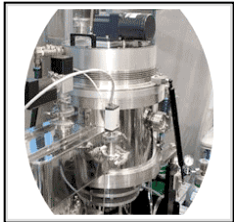
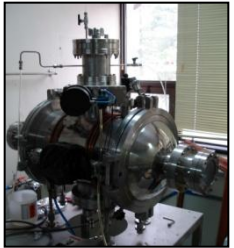
Container Imaging System (Plan)



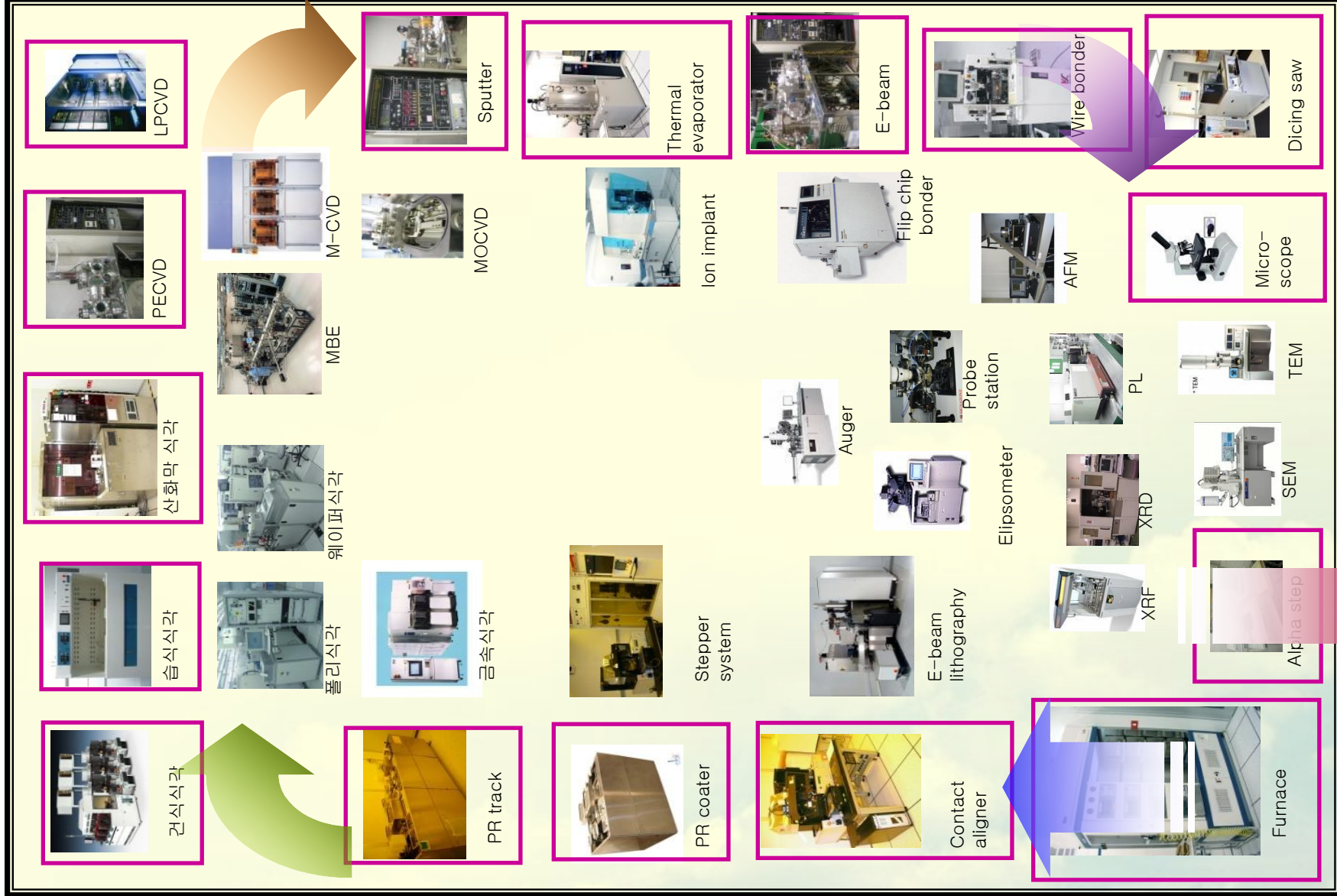
High Energy Particle Detection System



Semiconductor Detector Fab.(KAERI)



Radiation Detector Fab. (2011- 2014)



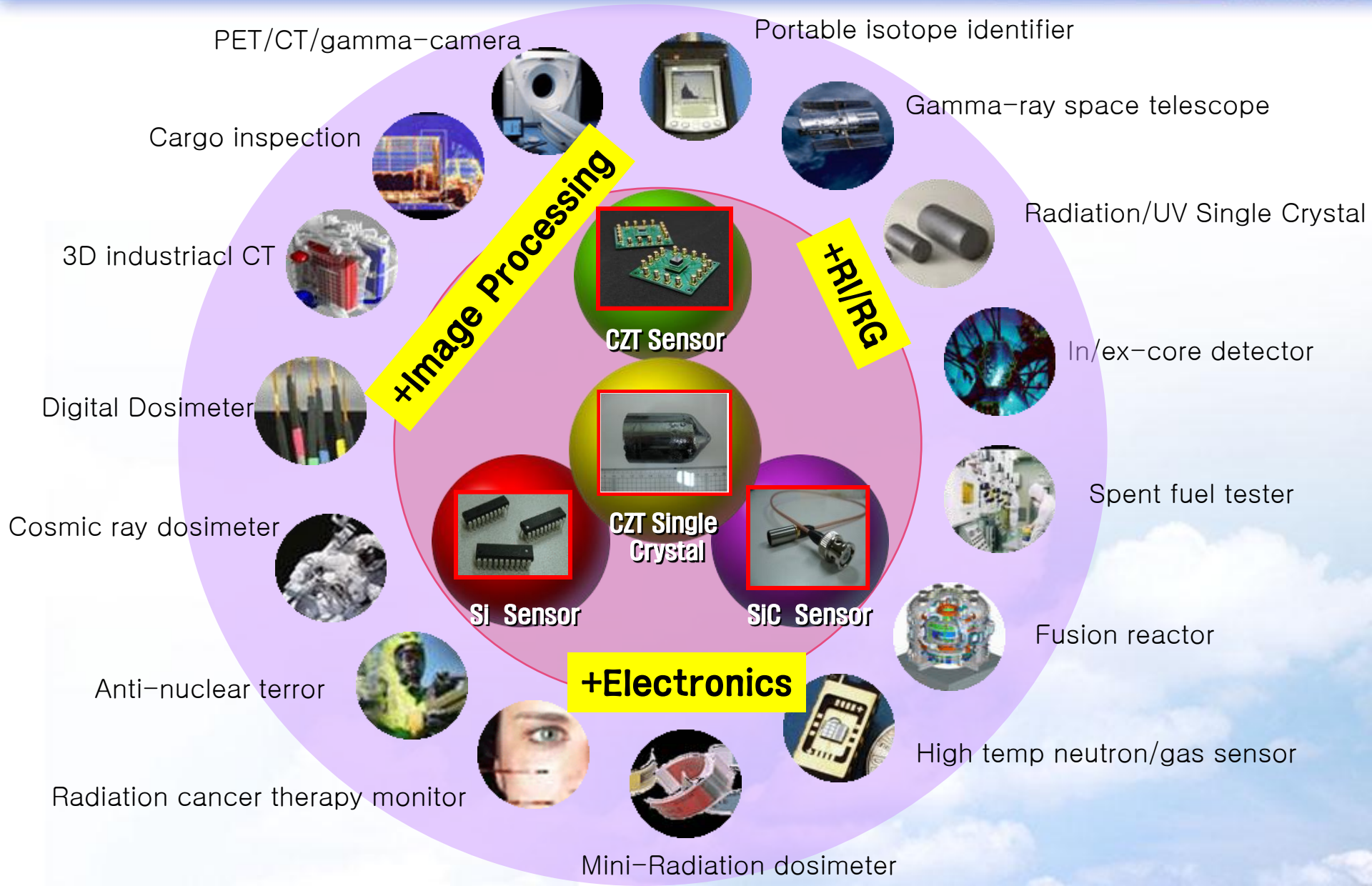


$E = mc^2$

4. Summary



Application of Radiation Detectors



A glowing, translucent flower with a bright center, set against a dark background. The flower is rendered in a semi-transparent, wireframe-like style, with its petals and stem appearing as thin, glowing lines. The center of the flower is a bright, circular glow. The background is a solid dark color, making the glowing flower stand out prominently.

*Radiation Detector is a fusion
technology with material, process,
electronics and system integration.*

“It is a open frontier for you!”



국가 미래 에너지를 책임지는 연구원

JHHA@KAERI.RE.KR

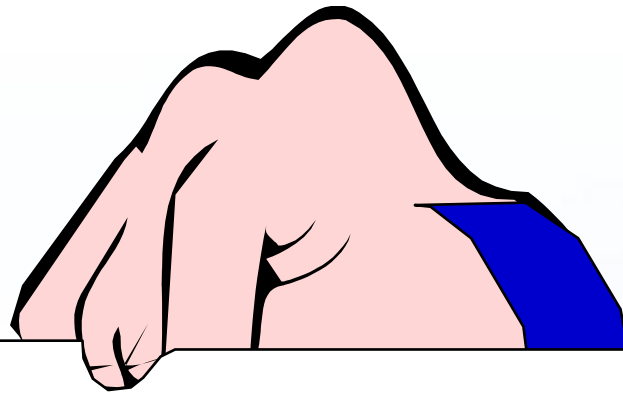


한국원자력연구원
Korea Atomic Energy Research Institute

$$E = mc^2$$



Contact us :



Korea Atomic Energy Research Institute

Jang Ho HA Ph. D.

Tel : +82-42-868-2038

Fax : +82-42-868-4738

C.P. : +82-17-276-8433

E-mail: jhha@kaeri.re.kr