



A New Gamma Emission Imaging Technique for Radiological Environments

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History of Gamma Emission Imaging

1877 1895 1900 1910 1950 1960 1970 1980 1990 2000

Vacuum Tube

Semiconductor

Digital network

Electromedicine

Radiological Diagnoses

Radiation Therapy

Audiology

Nuclear Medicine

Ultrasound

Computerized Tomography

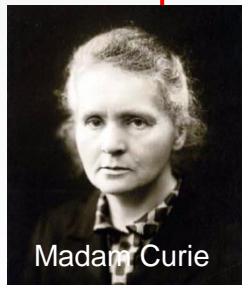
Magnetic Resonance

Networking (PACS)

Molecular Imaging
Personalized medicine



W. Röntgen

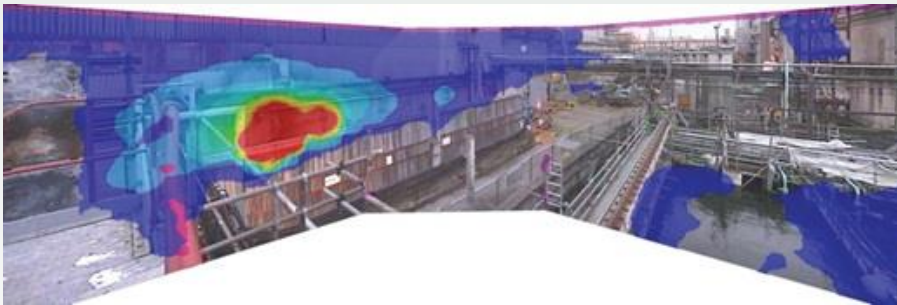


Madam Curie

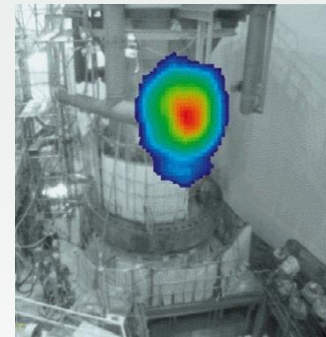


Applications: Radiological Environments

US, France, UK. started yr. 2000 \pm
Imaging of radiation distribution + fusion w/ CCD image



NPP survey



Reactor Monitoring



Baggage inspection



Nuclear waste mgmt.

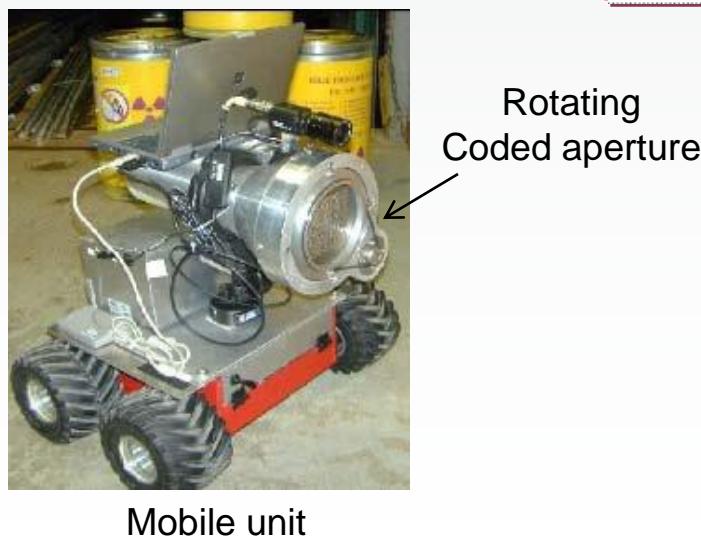
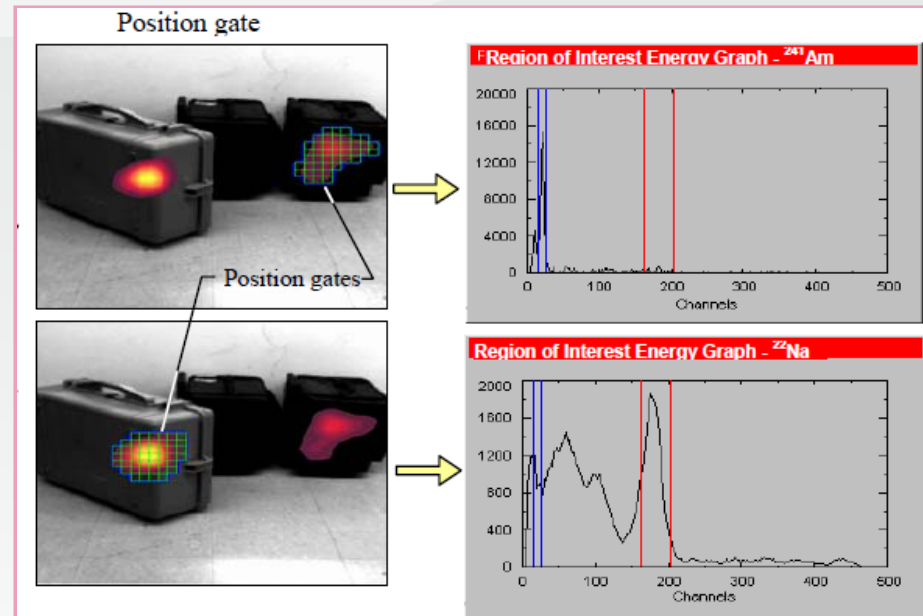
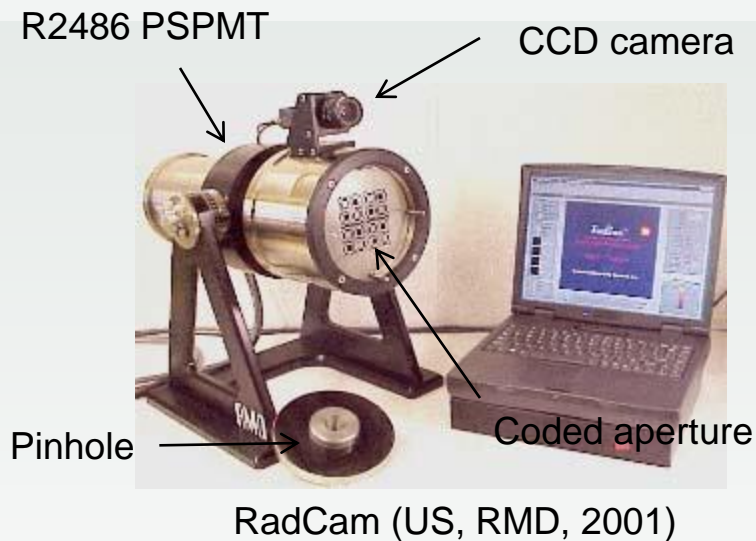


Contamination EDR



Nuclear facility

Conventional technology I



^{57}Co (~10 mCi) 2min, 40m

Conventional technology II

CCD, Pinhole or CA type



CARTOGAM (Fr, 2001)

CsI+CCD
CsI: 2-4mm, 4cm
Pinhole: 30-50



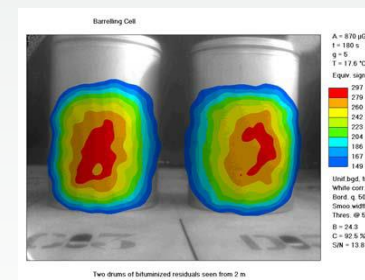
RadScan (UK, BIL)

CsI+CCD (-40F)
Coded A: 30-50

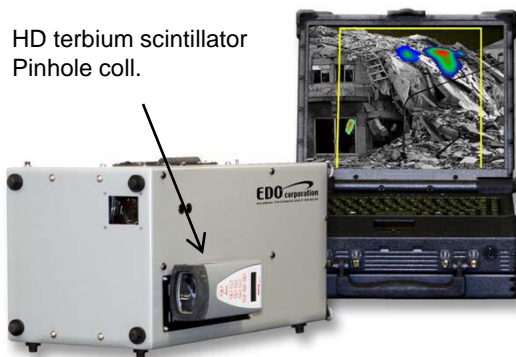
NaI-PMT
2,3,4 degree
aperture



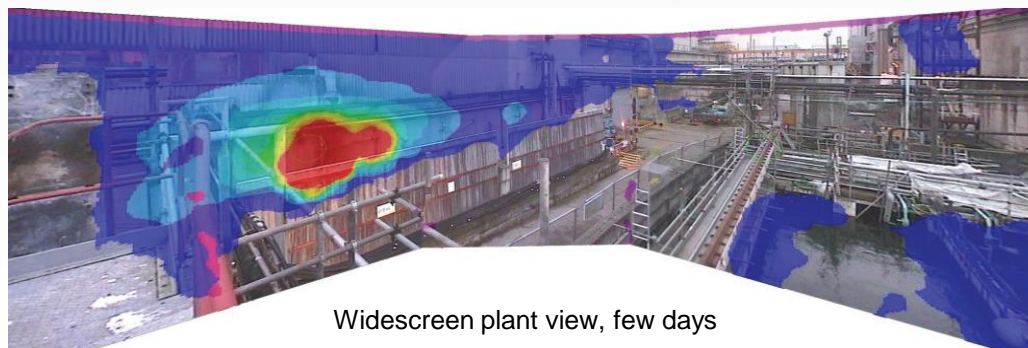
GammaCam (US,DOE, 1998)



HD terbium scintillator
Pinhole coll.



GammaCam (US, DOE)



Widescreen plant view, few days

Recent technology

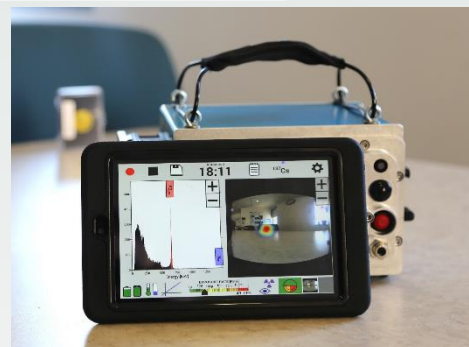
Compton Camera



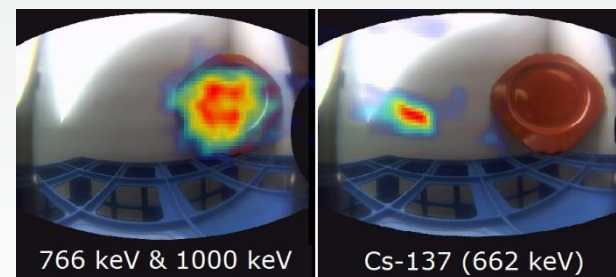
Coded aperture

Canberra, iPIX

- CZT solid state
- Portable



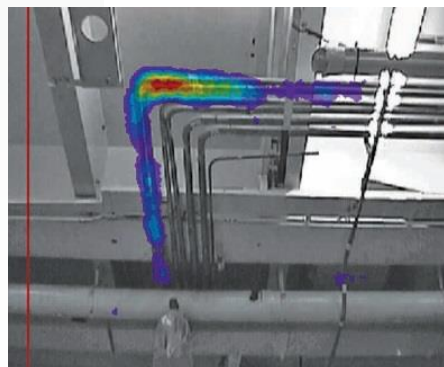
H3D, Polalis



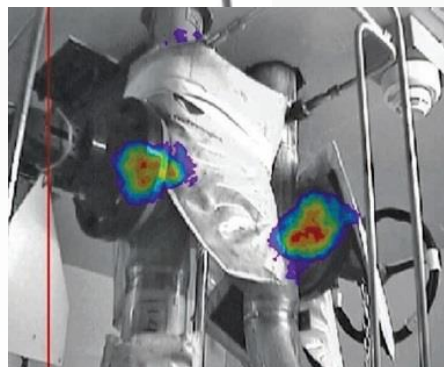
766 keV & 1000 keV

Cs-137 (662 keV)

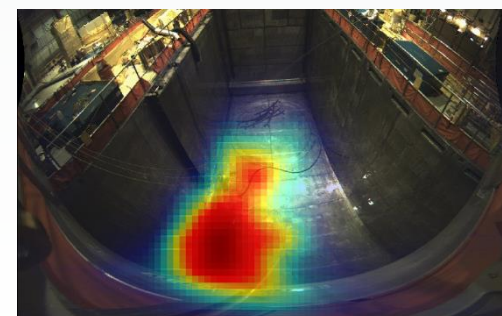
Decommissioning



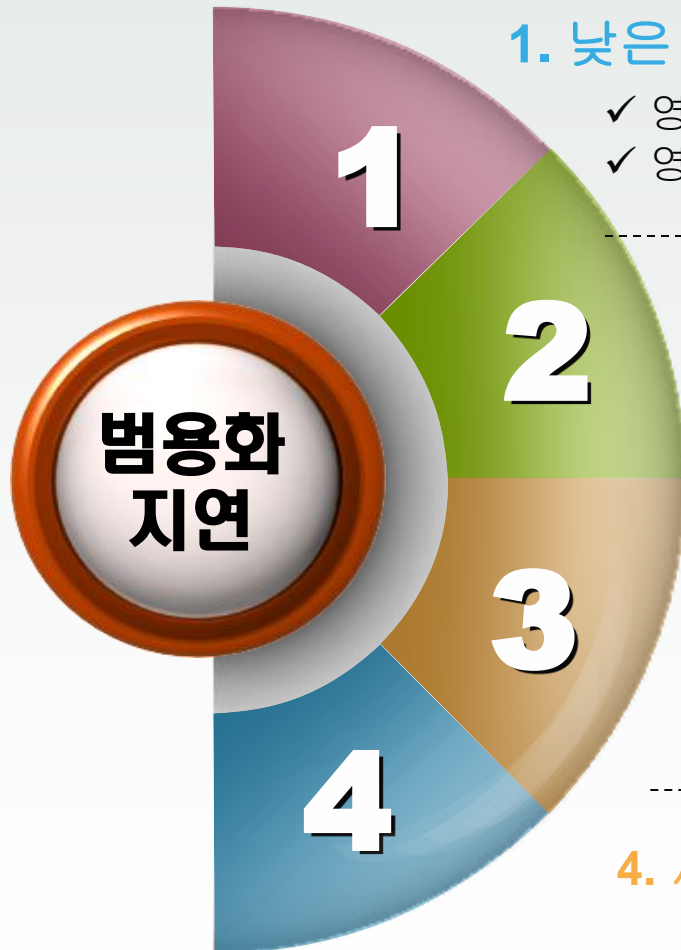
Surveying pipe



Test shielding effect



선행기술의 문제점



1. 낮은 민감도

- ✓ 영상수집의 구조적 한계: 소형 검출기 → 광역/원거리 영상
- ✓ 영상을 위한 섬광체 & 콜리메이터에 의한 제약

2. 낮은 공간 분해능 (해상도)

- ✓ 원거리 영상에 따른 해상도 저하
- ✓ 고에너지 영상화에 따른 penetration 증가

3. 3차원 영상구현의 문제점

- ✓ 3차원 영상을 위한 다각도 촬영의 한계
- ✓ 기기의 이동 및 피폭증가 문제점

4. 시스템 운용상의 문제점

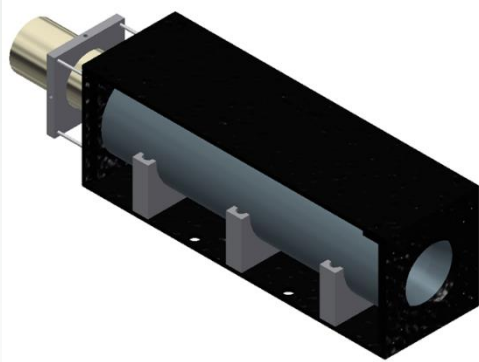
- ✓ 고비용 기기(로봇, 고가검출기, 제한적 시장)
- ✓ 설치 및 운용/이동성 제약



Proposed Method

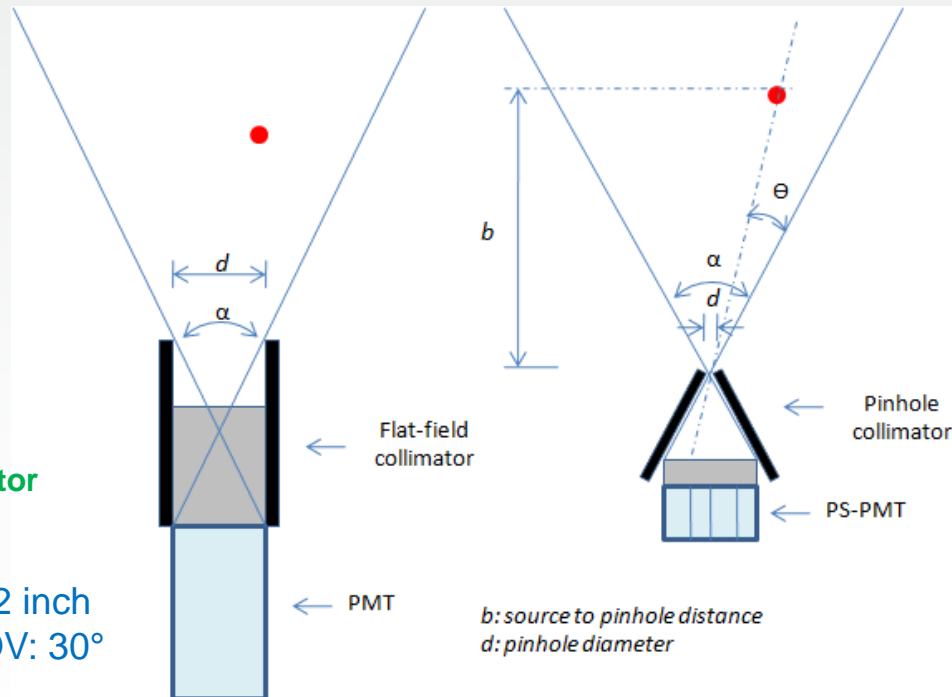
High Sensitivity Design (HW) ➡ Resolution Recovery (SW)

Sensitivity gain: $\sim 10^4$



Nucare Design
Single detector **w/o collimator**

2x2 inch
FOV: 30°



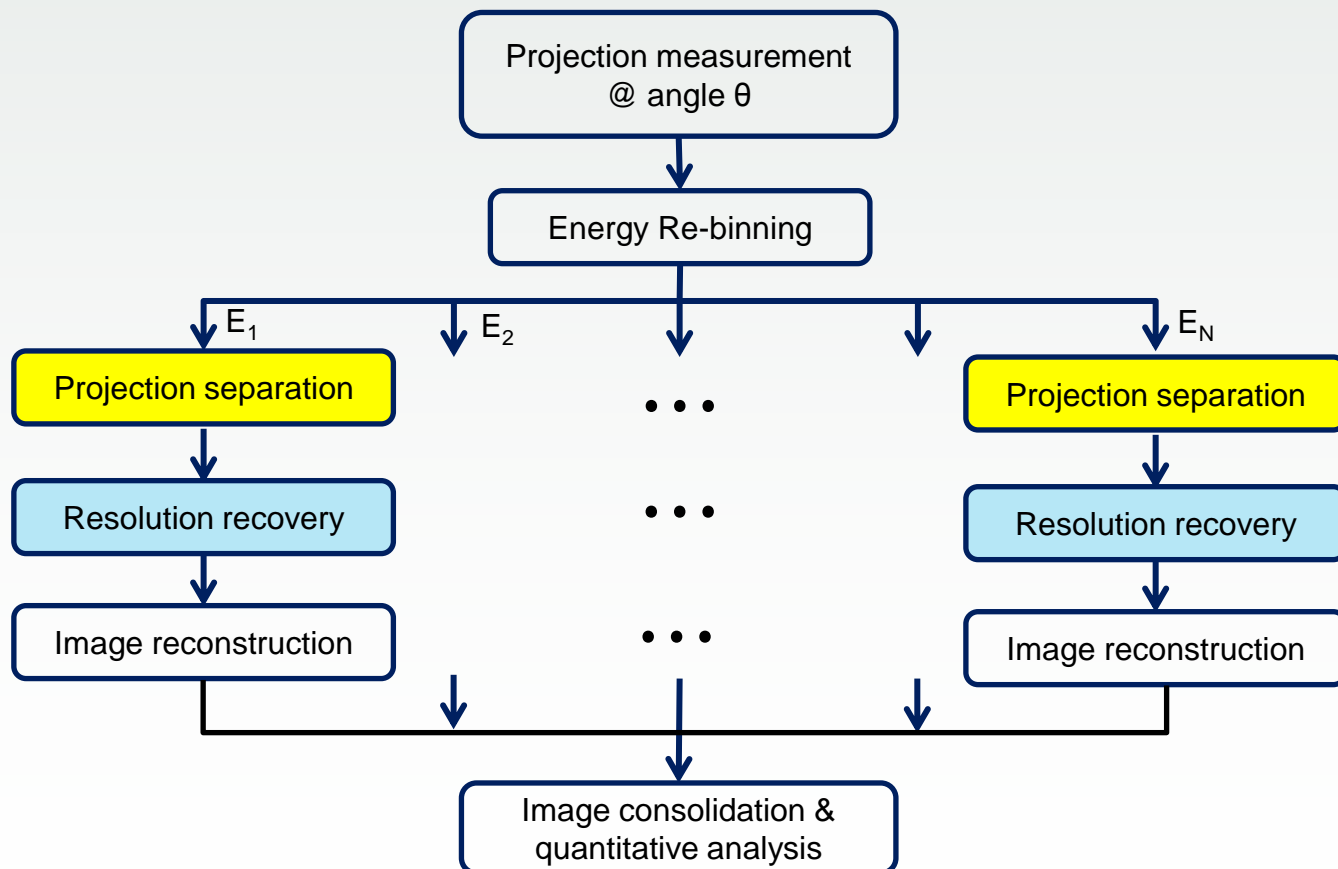
4mm ϕ



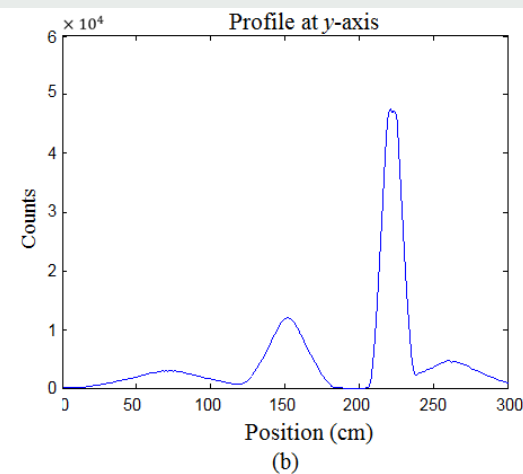
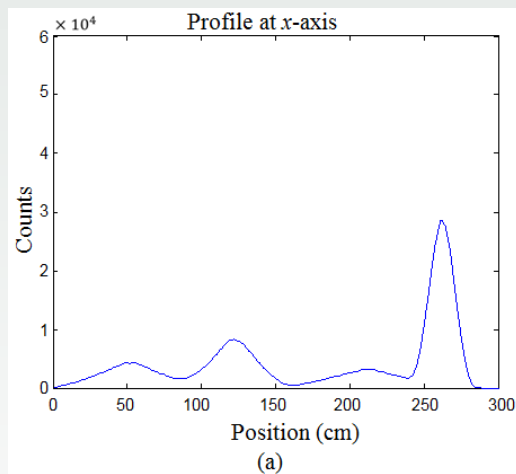
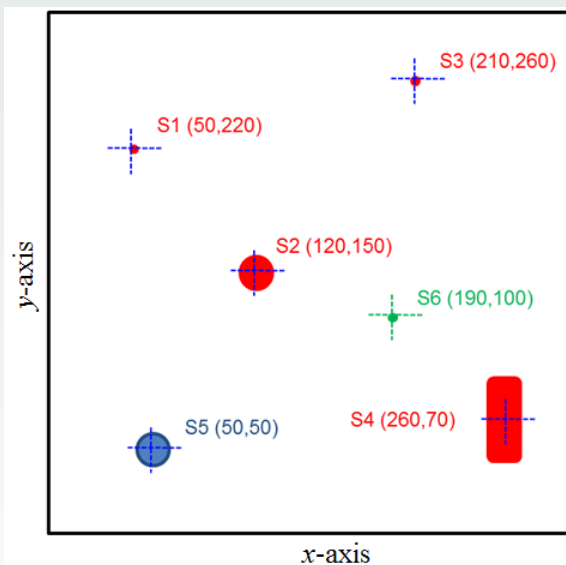
CZT imaging module

Resolution Recovery Algorithm

- **Hypotheses: Hot-spot-like imaging**
- **Gaussian Separation + Deconvolution**



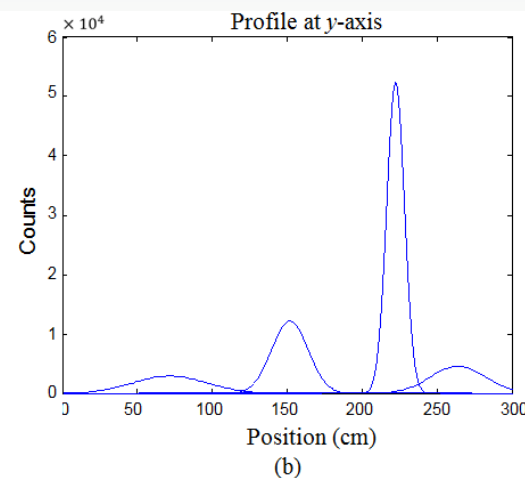
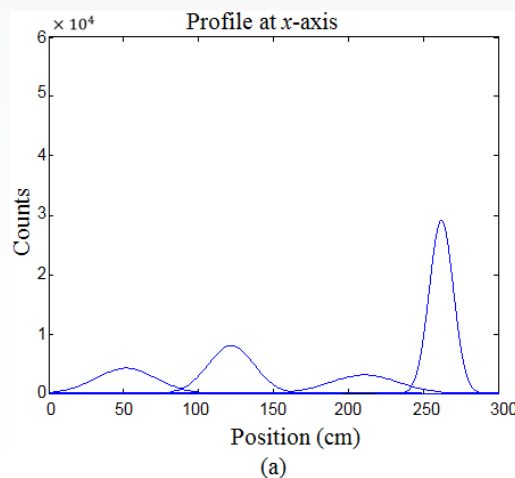
Projection Separation



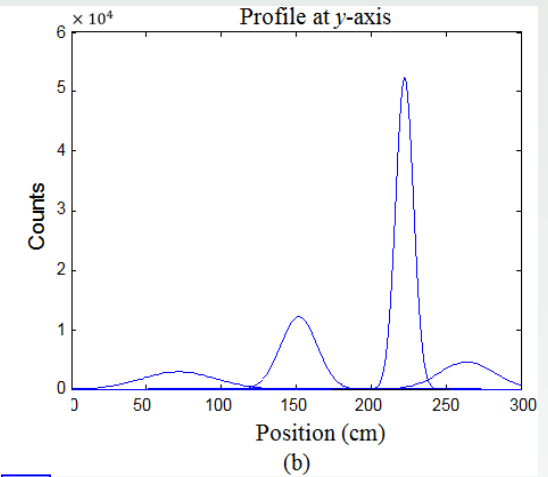
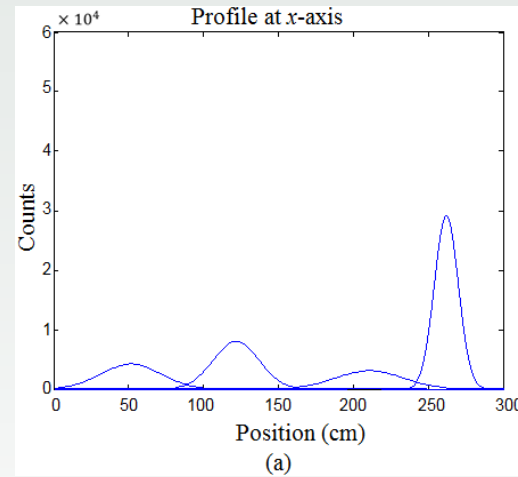
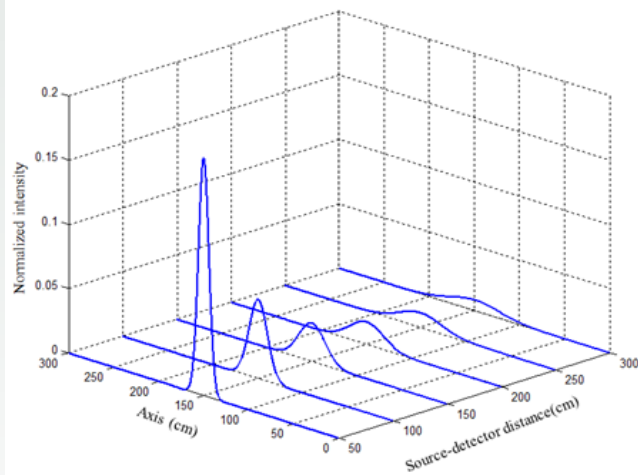
Gaussian Separation

$$P(x) = \sum_{n=1}^N \pi_n N(x|\mu_n, \Sigma_n),$$

$$N(x|\mu_n, \Sigma_n) = \frac{1}{(2\pi|\Sigma_n|)^{1/2}} e^{-\frac{1}{2}(x-\mu_n)^T \Sigma_n^{-1} (x-\mu_n)}$$



Resolution Recovery

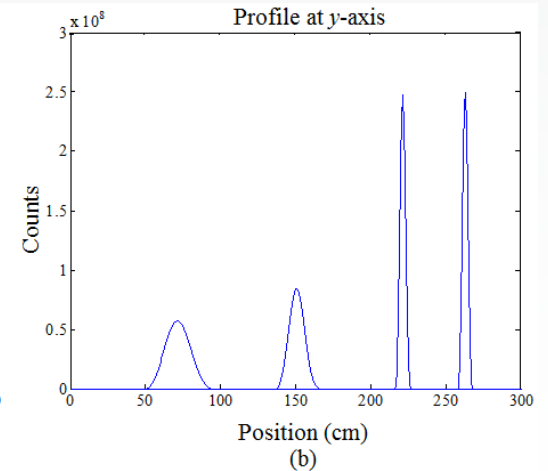
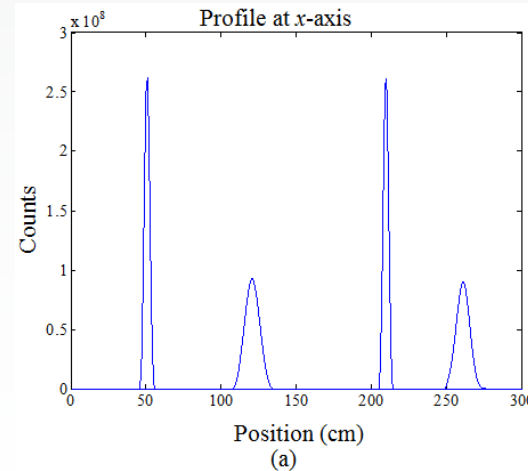


Deconvolution Process

$$psf = f\{distance, energy, attenuation\}$$

$$P_n(x) = T_n(x) * psf_n(x),$$

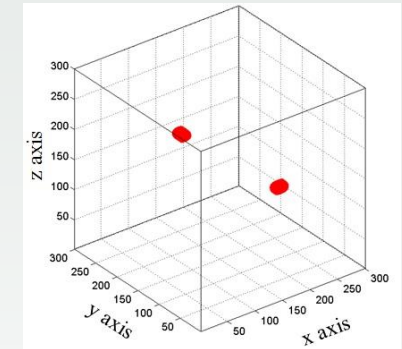
$$T(x) = \sum_{n=1}^N \{decon(P_n(x), psf_n(x))\}$$



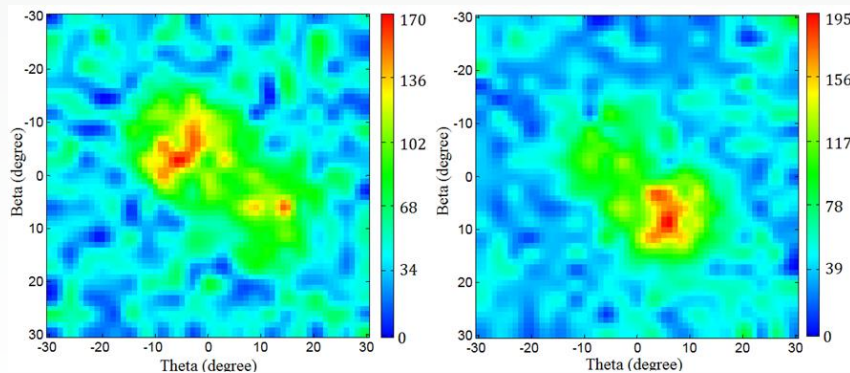
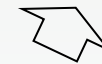
제안기술의 혁신성/차별성 개요



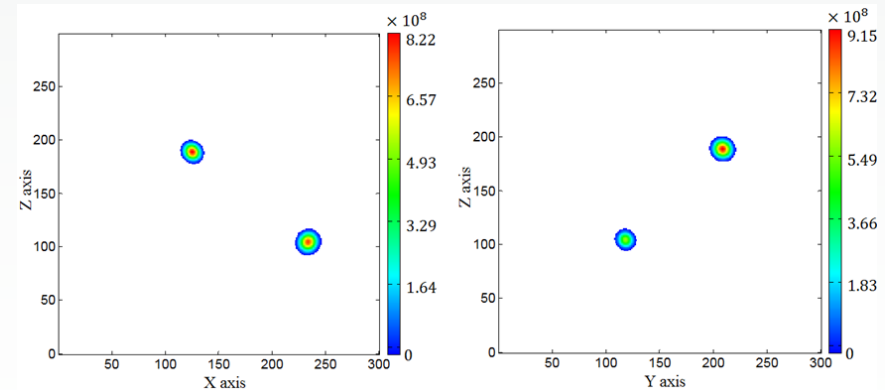
Pseudo 3D



3x3x3 m³



민감도 향상에 따른 해상도 저하



해상도 복원 알고리즘 적용후



Preliminary Results

110 min/projection



True locations versus measured locations.

Radioactive source	True location (x,y,z) cm	Measured location (x,y,z) cm	Averaged Error (%)
Ba-133	(229,129,97)	(233,118,106)	6.51
Cs-137	(112,223,190)	(125,208,190)	6.11

Activity concentration estimates of the reconstructed sources.

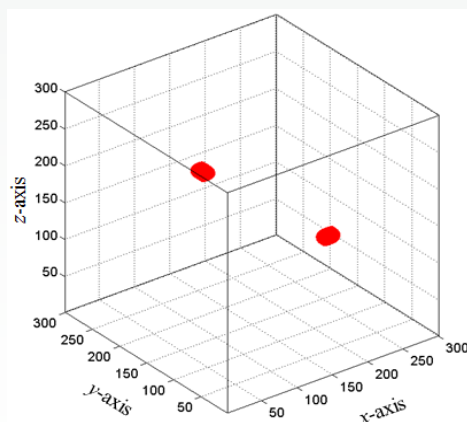
Radioactive source	True activity (μCi)	Measured activity (μCi)	Error (%)
Ba-133	15.35	17.39	13.28
Cs-137	17.39	17.19	1.15



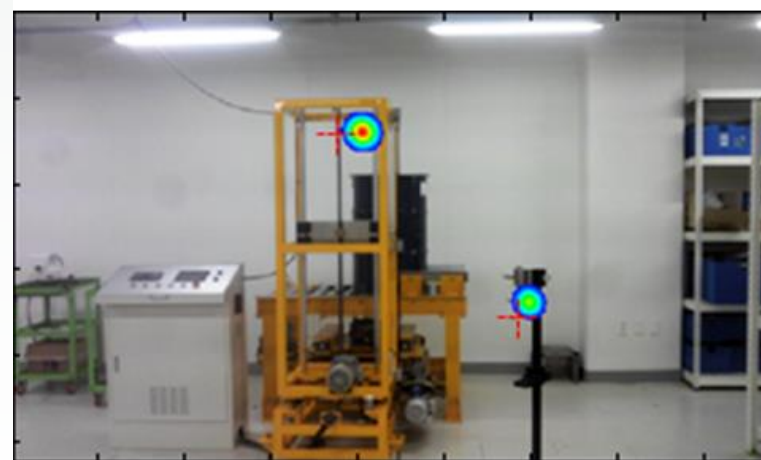
(a)



POC system



Pseudo 3D



(b)



Future works

- Non-Gaussian and/or **non-hot-spot like object** imaging
- Studies for various **attenuation conditions**
- Extension of **2D array detector** module
- **Other applications**: waste drum, container truck imaging
- NPP on-site experiment (KHNP?)

Reference

- [1] “Radiation imaging method and system.” U.S. Patent Application 14/861,384.
- [2] “방사선 영상화 방법 ” 한국 특허출원 10-2015-0108889
- [3] “Investigation of Innovative Radiation Imaging Method and System for Radiological Environments” **NIM Vol. 847, PP. 15-28, Mar. 2017**