Discrimination of Materials according to Atomic Number Using Dual Energy

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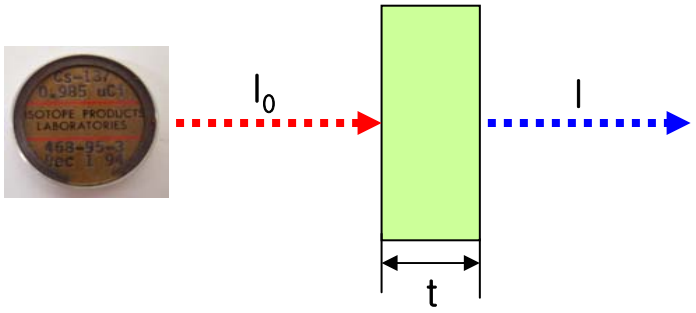
Abstract

본 연구에서는 Monochromatic X선- 및 감마선-빔에 대한 물질의 선별특성 및 선별능력을 향상시키기 위하여 single gamma-ray sources의 dual energy를 사용한 실험과 Monte-Carlo 시뮬레이션을 병행하여 수행하였다. 본 연구에서 도입한 에너지대가 다른 dual energy를 사용하면 기존의 입사빔 각도를 변화시키는 방법보다 간단하고 보다 더 물질의 선별력을 높일 수 있다는 것을 실험 및 컴퓨터 시뮬레이션으로 검증하였다. 시뮬레이션을 위해서는 MCNP4C 코드를 이용하였고, 에너지대가 다른 dual energy로서는 Cs-137의 0.662 MeV 및 Co-60의 1.25 MeV가 각각 사용되었다. 또한 위의 에너지영역에 있어서 감쇄계수인자를 구하기 위해 두께 2mm~100mm를 가지는 폴리에틸렌, 알루미늄, 철, 납등을 사용하였다.

Discrimination Method



$$I = I_0 e^{-\mu t}$$

$$\mu t = \ln (I_0 / I)$$

$$\mu t = \mu' t'$$

Discrimination is not possible !

t : thickness of material [cm]

μ : total linear attenuation coefficient [cm^{-1}]

$$\mu = \tau + \sigma + \kappa$$

τ : contribution of photoelectric effect

σ : contribution of compton effect

κ : contribution of pair production

Total Attenuation = $f (Z_m, \rho_m, t_m, E_{x\text{-}ray})$

I_0, I_0', I, I', t

$$I = I_0 e^{-\mu t}$$

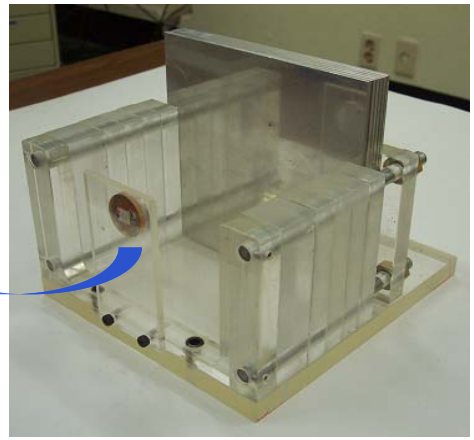
$$I' = I_0' e^{-\mu t}$$

$$\Rightarrow \frac{\mu}{\mu'} = \frac{\ln (I_0 / I)}{\ln (I_0'/I')} = R (E_1, E_2, t, Z)$$

Experimental Setup

Gamma-ray Source

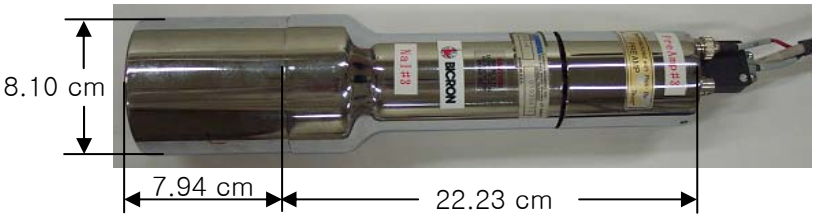
Nuclide	Activity	Photon energy(keV)
Cs-137	36.445 kBq (Dec.1.1994)	662 (85%)
Co-60	34.2 kBq (Dec.1.1997)	1173.2(99.9%) 1332.5(99.9%)

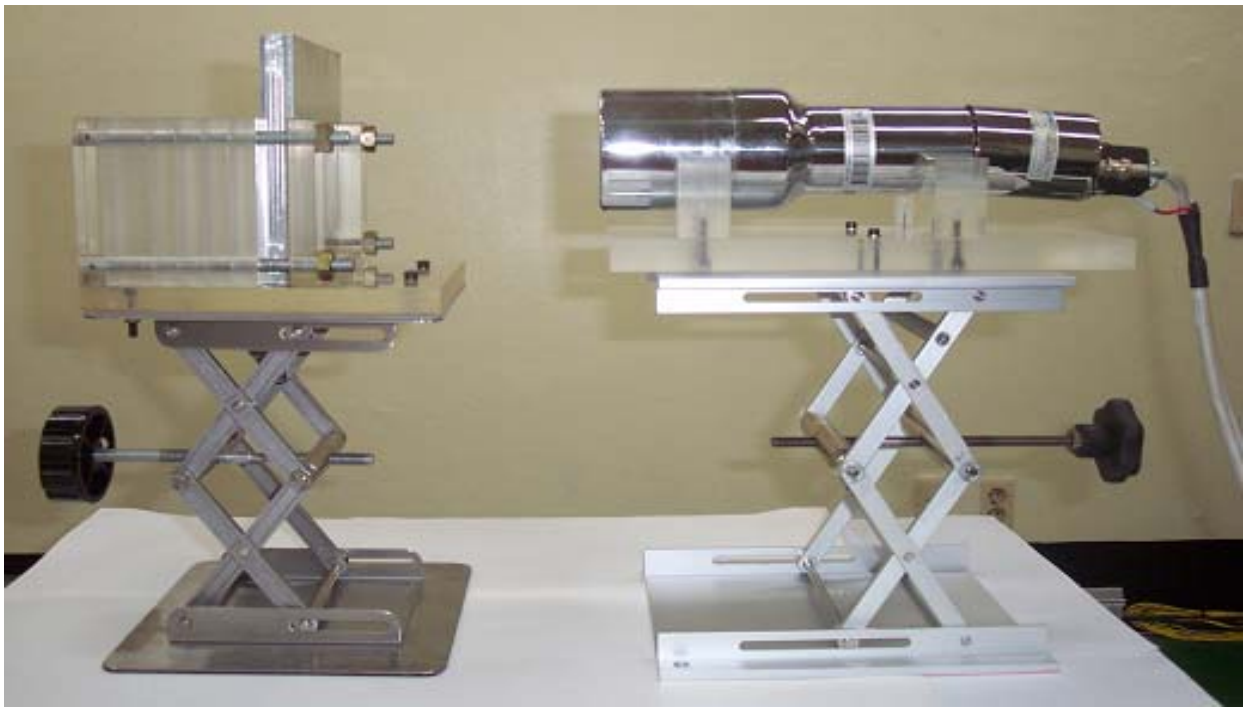


NaI(Tl) Scintillation Detector

Model	Crystal Size mm (in.)	Resolution*
802-3×3	76×76(3×3)	7.5%

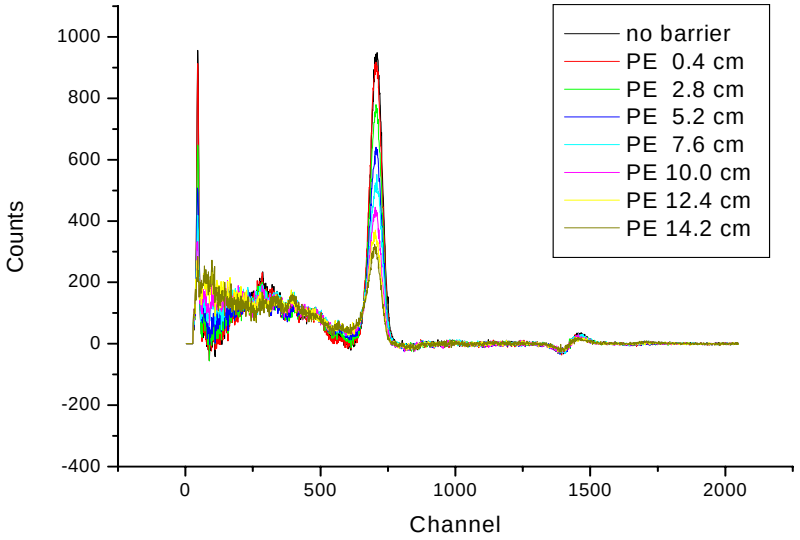
*Resolution is specified at the 662 keV peak of ^{137}Cs.

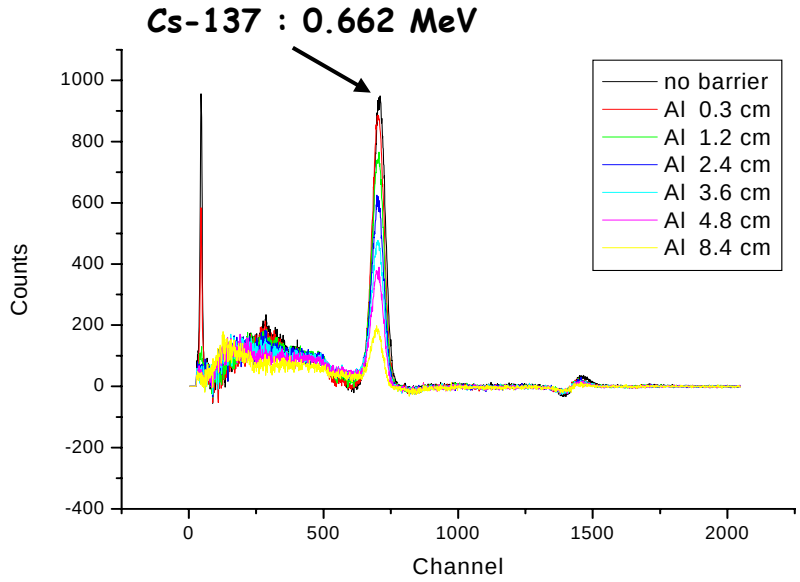


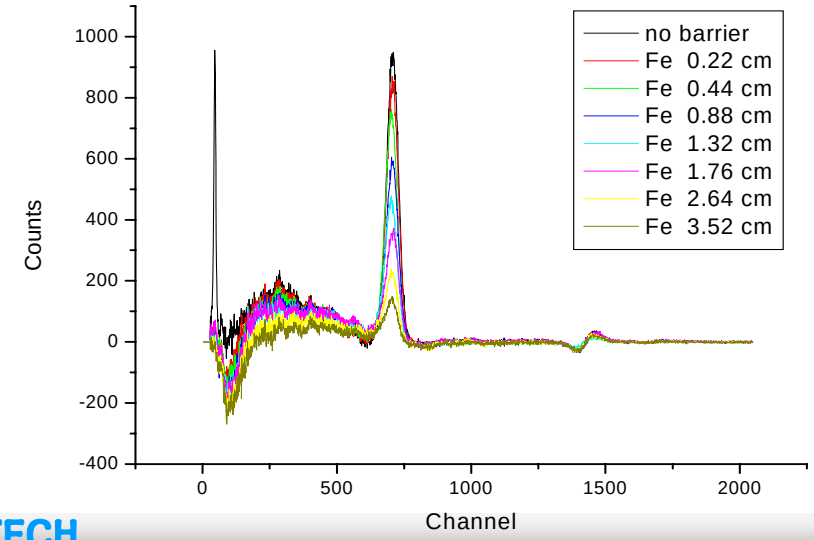


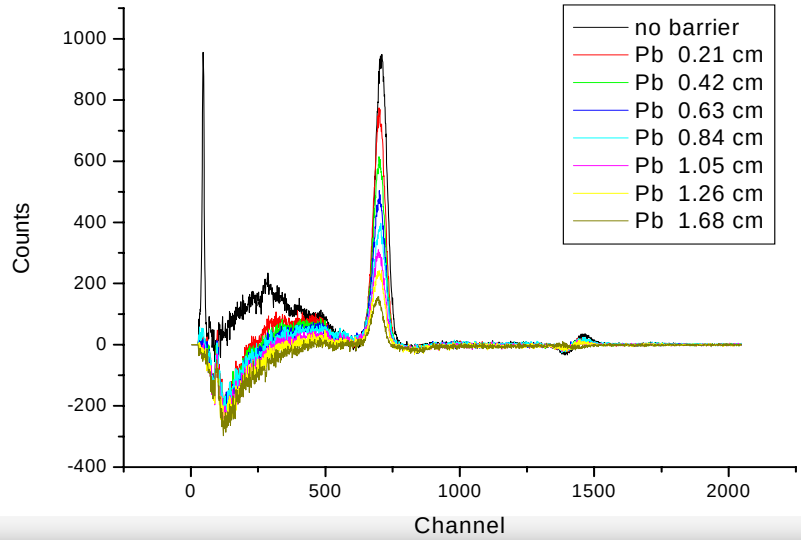
Spectrums of Only One Source(Cs-137)

After penetrating barriers : Polyethylene, Al, Fe, and Pb



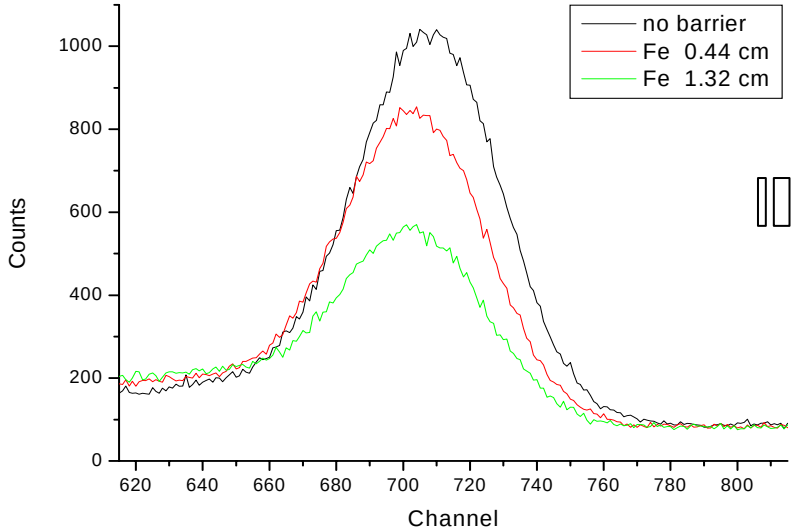






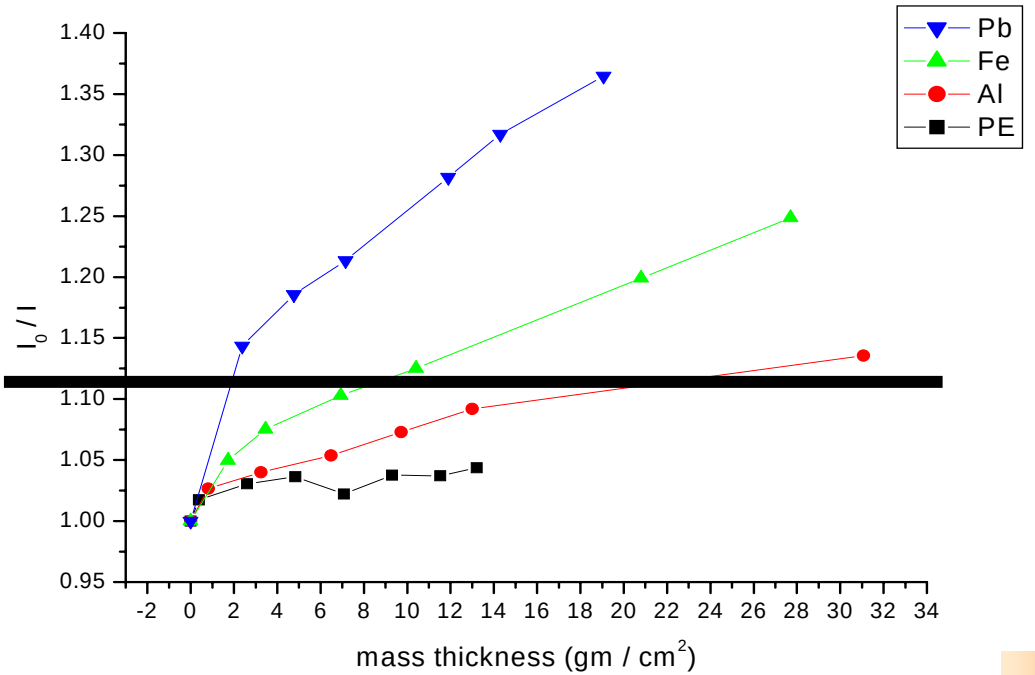
Ratio of Intensities of Only One Source(Cs-137)

After penetrating barriers : Polyethylene, Al, Fe, and Pb



I_0 : Area of channel 615~815 of "no barrier"

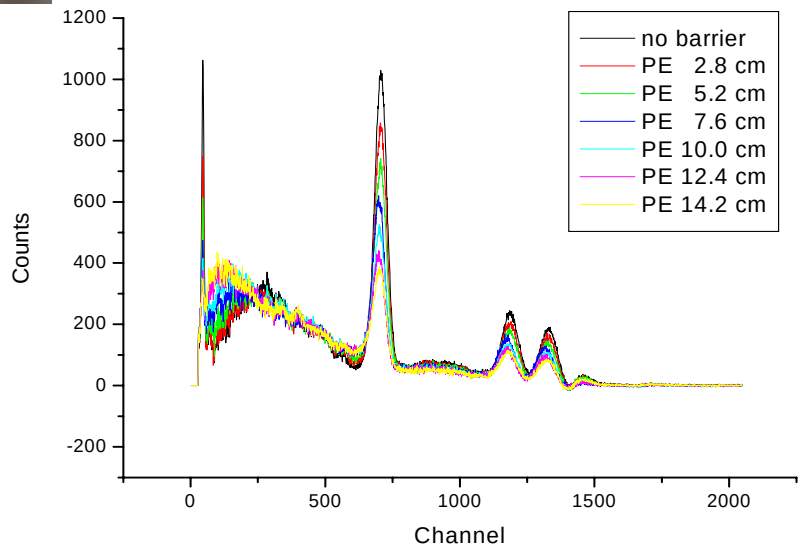
I : Area of channel 615~815 of each barrier

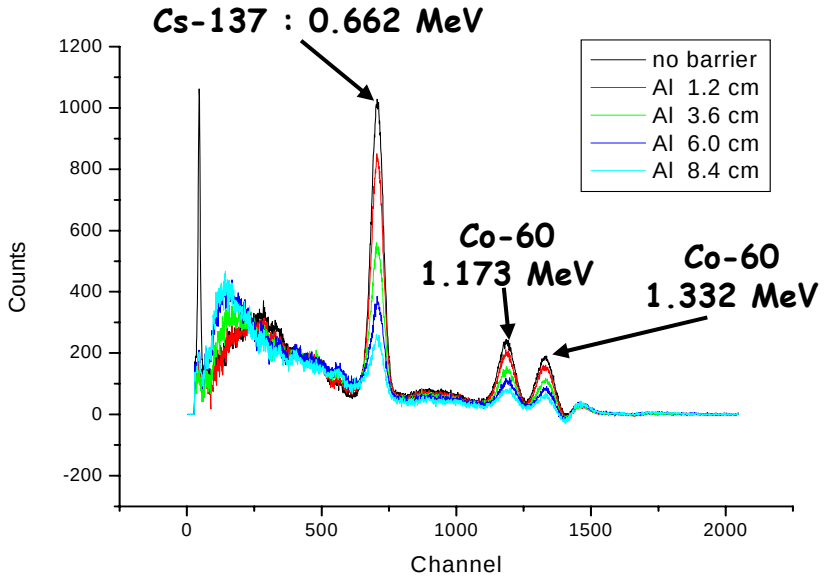


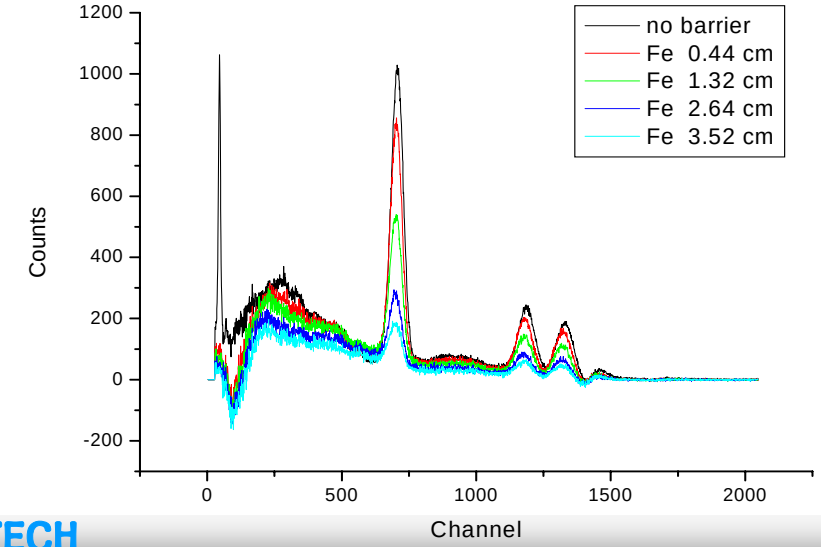
If there are the equal values of I_0 /I in the different materials, discrimination is not possible!

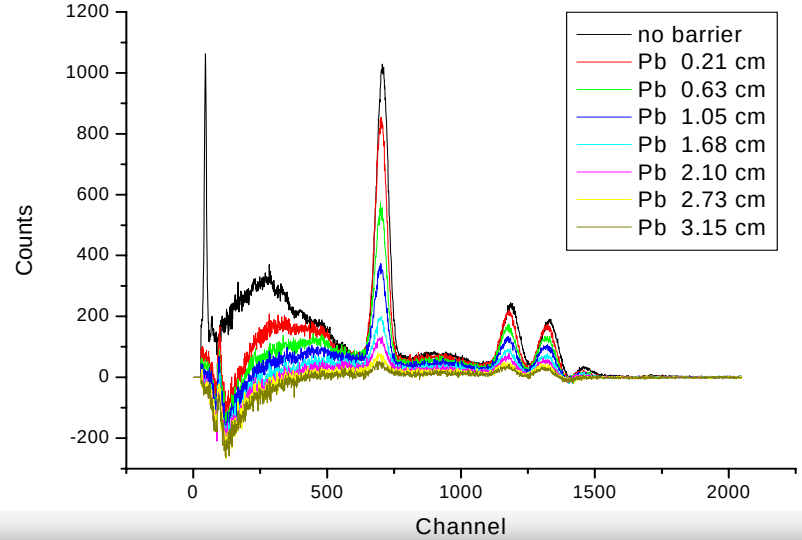
Spectrums of Dual Source(Cs-137, Co-60)

After penetrating barriers : Polyethylene, Al, Fe, and Pb



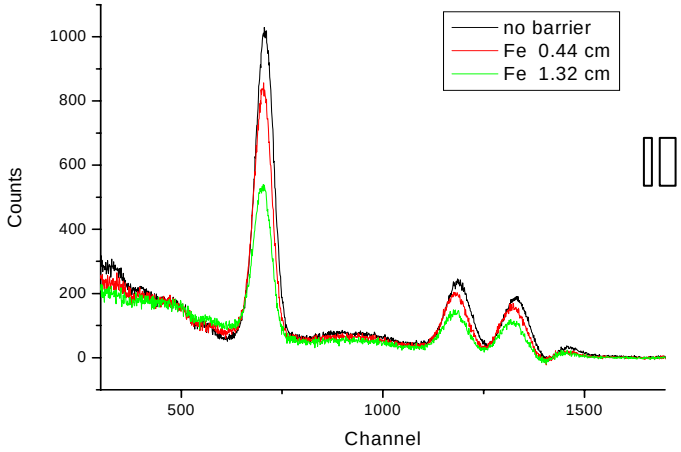






Ratio of Attenuation Coefficient, $\frac{\mu_{Cs-137}}{\mu_{Co-60}}$

for barriers : Polyethylene, Al, Fe, and Pb

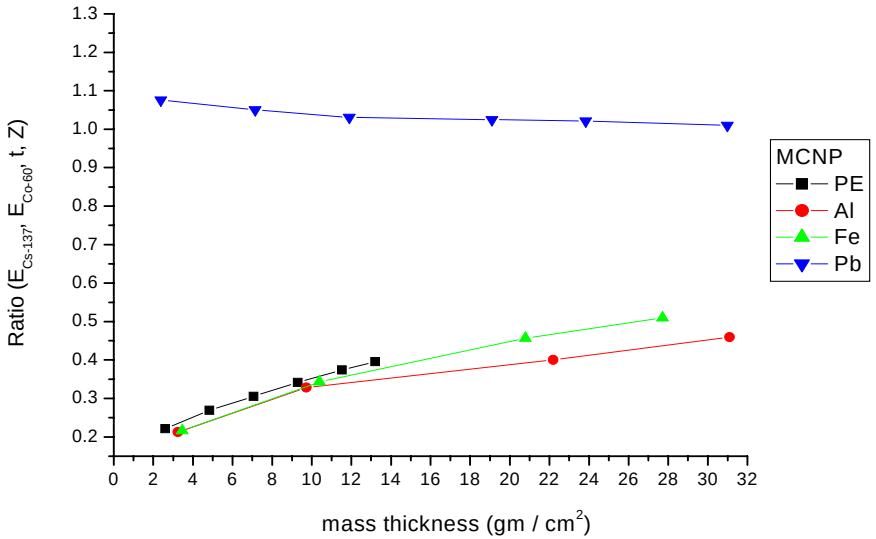


I_0 : Area of channel 501~1000 of "no barrier"

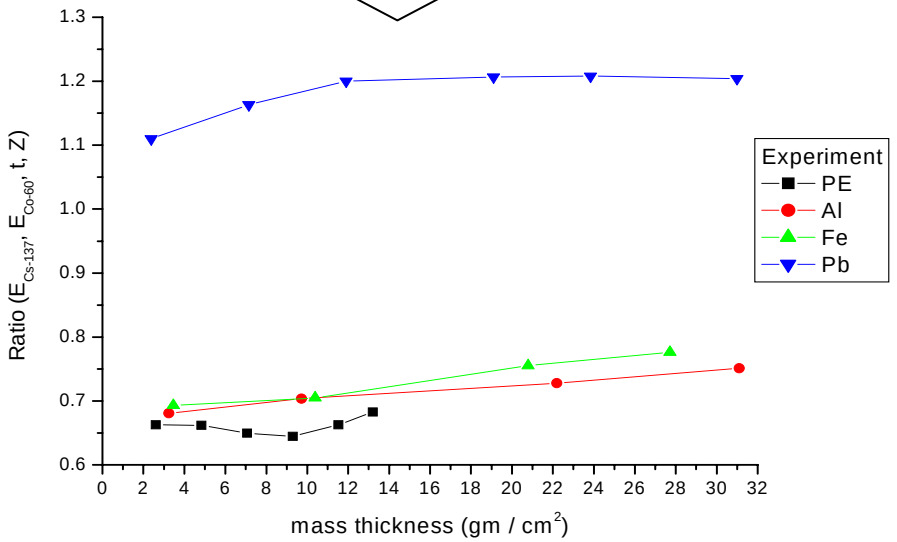
I : Area of channel 501~1000 of each barrier

I_0' : Area of channel 1001~1500 of "no barrier"

I' : Area of channel 1001~1500 of each barrier



compare



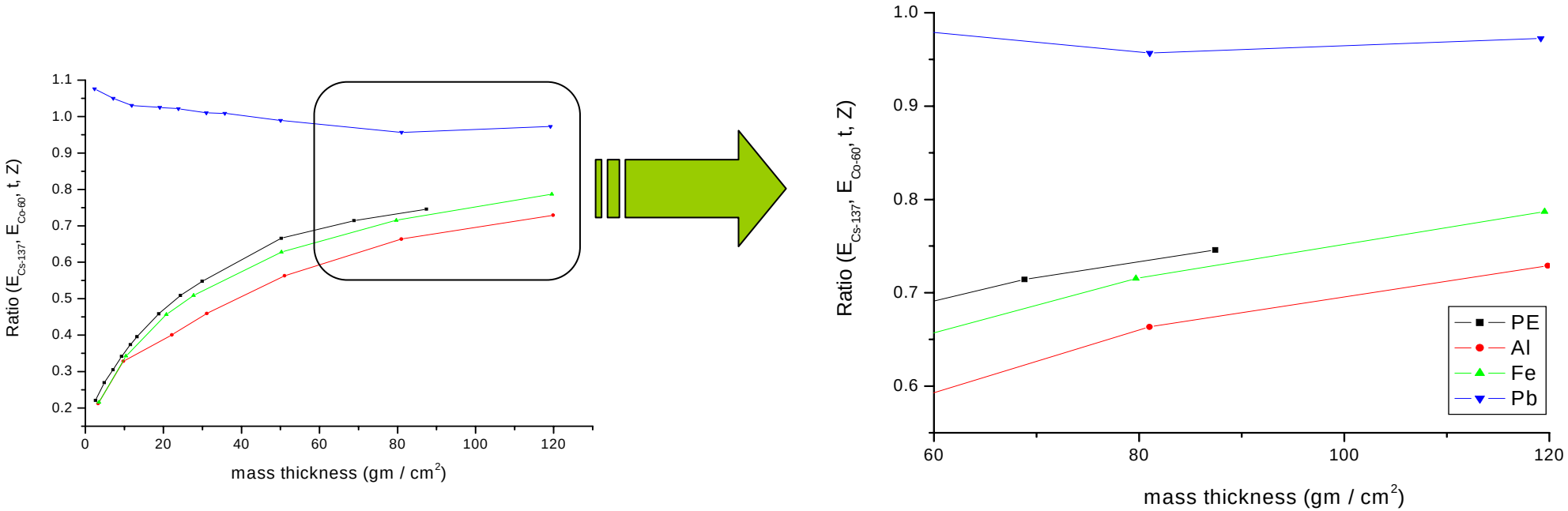
MCNP simulation for monochromatic beam geometry

Experimental data using dual source

Ratio of Attenuation Coefficient, $\frac{\mu_{Cs\text{-}137}}{\mu_{Co\text{-}60}}$

for barriers : Polyethylene, Al, Fe, and Pb

Expension of thickness in *MCNP simulation*



The 60~120 gm/cm^2 mass thickness range is optimal for material recognition!

Conclusion

- We have measured with the dual sources(Cs-137 : 0.662 MeV, Co-60 : 1.173, 1.332 MeV) to estimate the ratio of attenuation coefficients.

- The measured data in this study are good in agreement with the MCNP simulation.

- The dual energy technique is more effective for the discrimination of materials according to their atomic number compared to the single energy technique.