Basic Physics Processes in a Sodium Iodide (NaI) Calorimeter

NaI is a "scintillator". As a charged particle traversing the NaI it loses energy. The energy is absorbed by the molecules and puts the NaI molecules into an excited state. NaI gives off light ("scintillates") when it de-excites back to the ground state.

The amount of light given off by NaI is proportional to the amount energy absorbed.

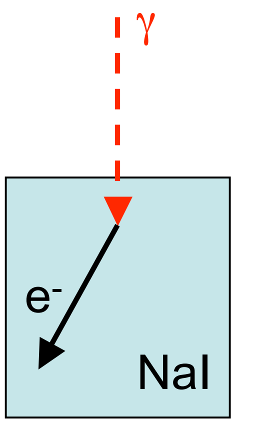
The light yield is ~ 1 photon produced per 100 eV deposited in NaI (1 MeV = 10^4 γ's).

However, not all γ's are collected as the efficiency of the photocathode is ~ 20%.

Photoelectric Effect

γ absorbed by material

electron ejected

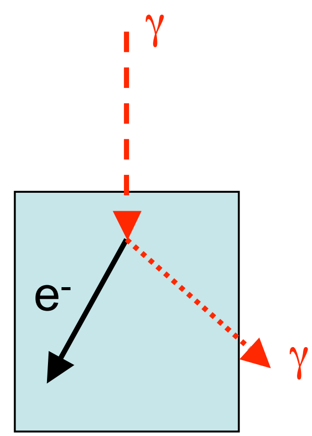


hv < 0.05 MeV

Compton Scattering

$\gamma e^- \rightarrow \gamma e^-$

"elastic scattering"

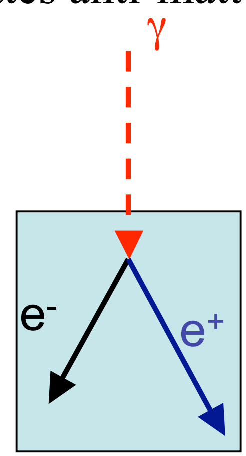


0.05 < hv < 10 MeV

Pair Production

$\gamma \rightarrow e^+ e^-$

creates anti-matter

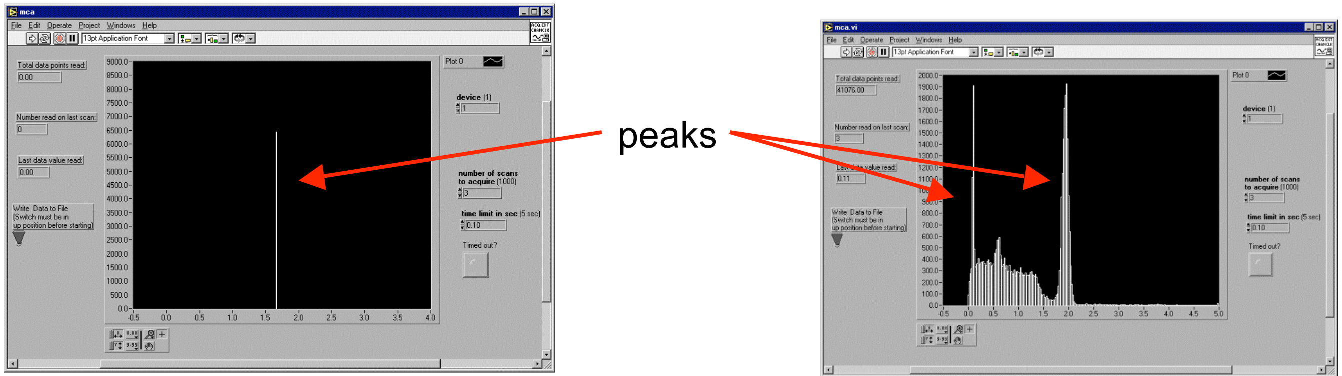


hv > 10 MeV

γ-ray must have E > $2m_e$

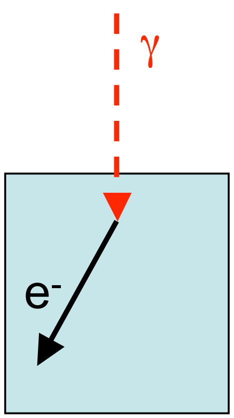
How do we get a PEAK in the energy spectrum?

A peak in the energy spectrum corresponds to the case when all of the γ-ray's energy is absorbed in the NaI calorimeter.

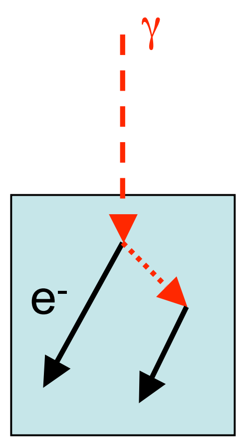


perfect energy resolution
all γ energy totally absorbed

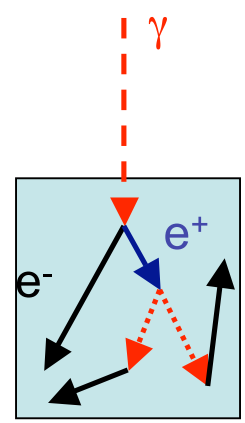
actual energy resolution
not all γ energy totally absorbed



Photoelectric effect and electron stops in NaI.

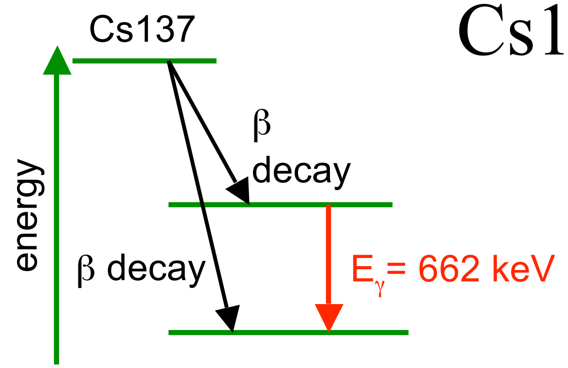


Compton scatter followed by photoelectric effect



Pair production
e^- is absorbed in NaI
e^+ annihilates into 2 γ's
γ's undergo photoelectric effect

Cs137 γ-ray Spectrum

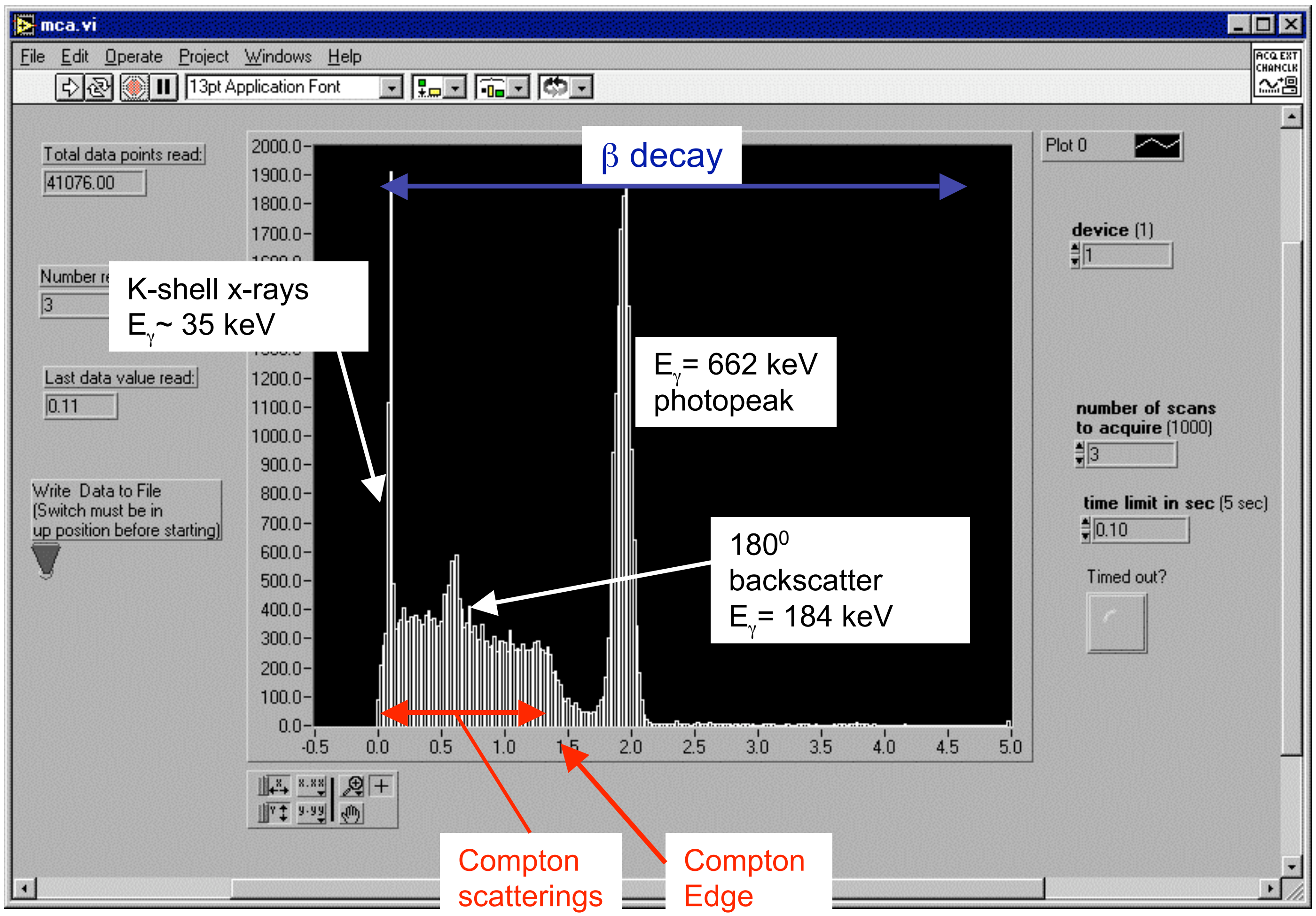


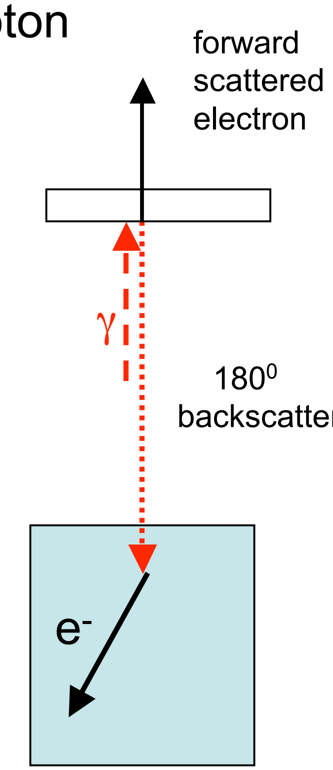
β decay gives off electrons with a range of energies

Emax = 514 keV, 1170 keV

γ decay gives off a monchromatic photon

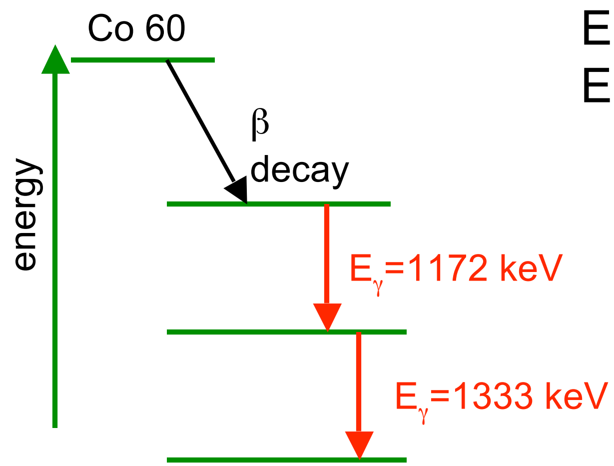
E = 662 keV





Co60 and Na22

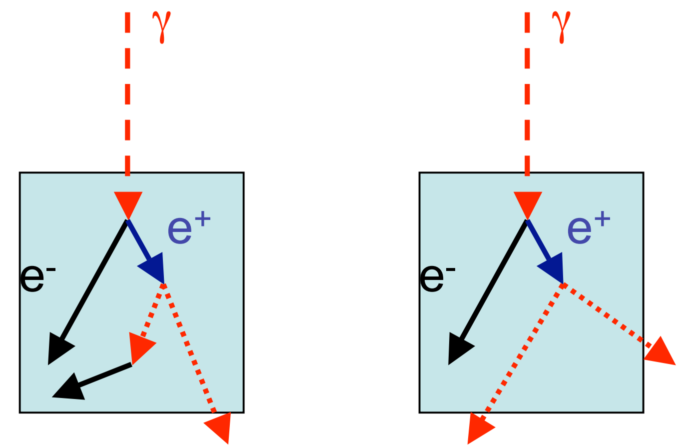
Both Co60 and Na22 have complicated spectra since their γ's have enough energy to undergo pair production.

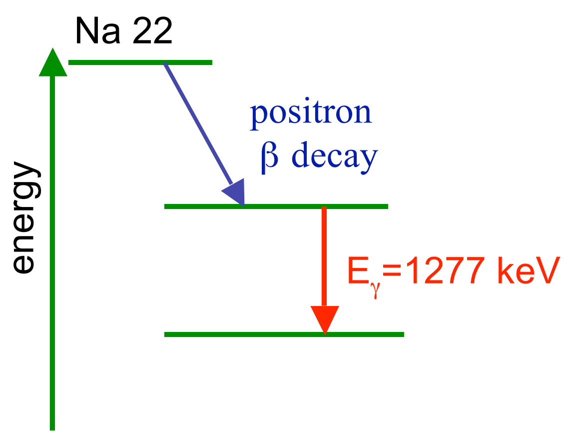


Will have "escape" peaks from positron annihilation

$E = E_\gamma$ - (rest energy of electron)

$E = E_\gamma$ - 2x(rest energy of electron)





Na22 gives off a positron which will annihilate and produce 2 γ's. But only one γ will be detected!