Monte Carlo Simulation Study of Bremsstrahlung Produced by 9 MeV-Electron Linear Accelerator

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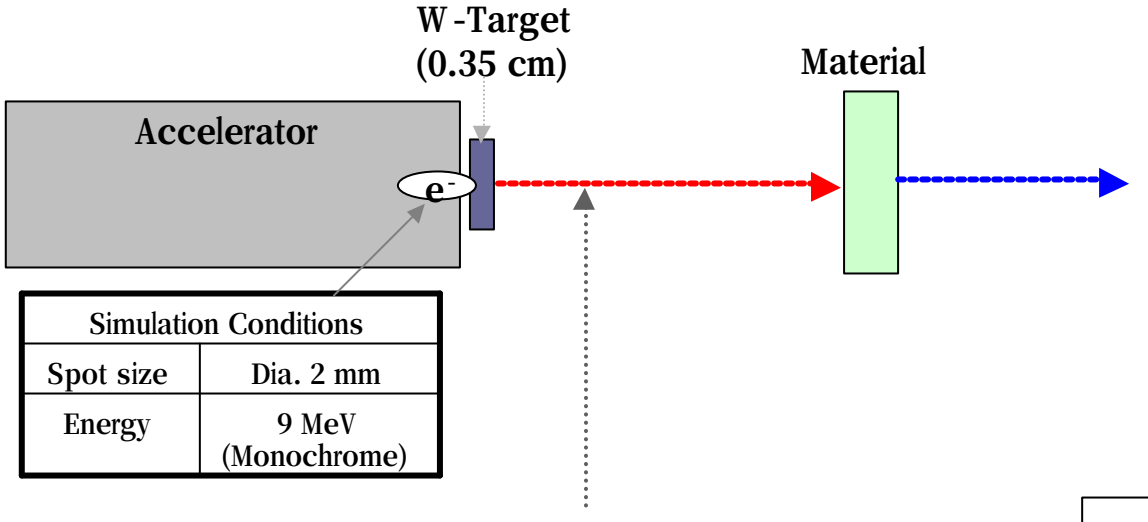
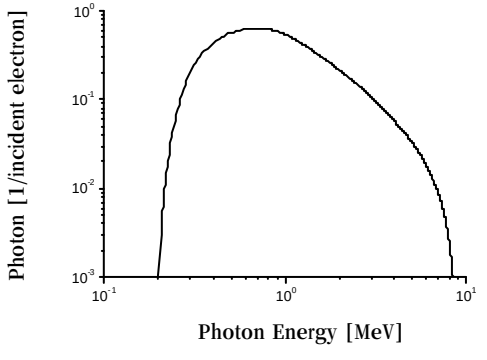
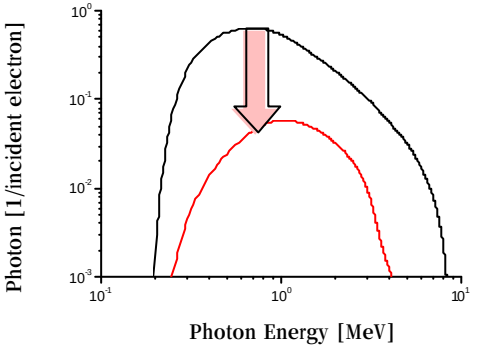
Introduction



Simulation Conditions	
Spot size	Dia. 2 mm
Energy	9 MeV (Monochrome)

Result of ***MCNP simulation*** of Bremsstrahlung spectrum after 9 MeV-electron beam passes through target

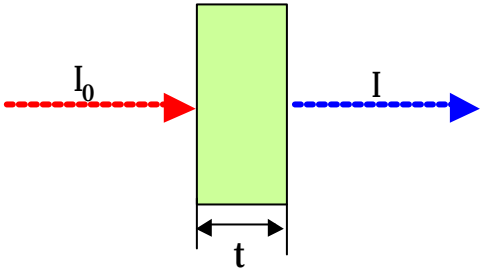




Spectrum analysis of Bremsstrahlung according to material, and their thickness

Helpful to perform shielding calculation for electron linear accelerator

Attenuation for Monochromatic X-ray Beam



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

$$\mu = \frac{1}{t} \ln (I_0 / I)$$

t : thickness of material [cm]

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

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

τ : contribution of photoelectric effect

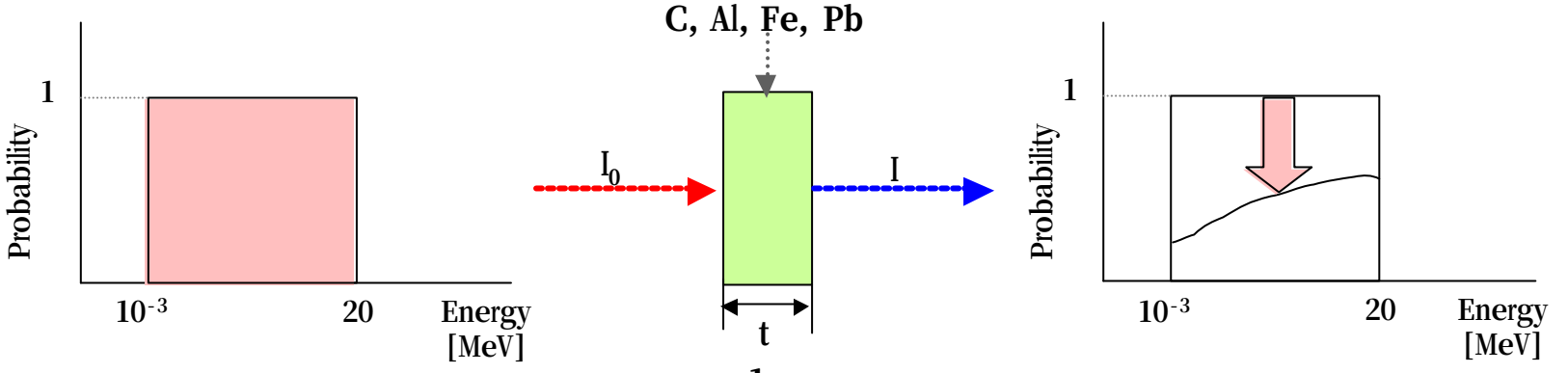
σ : contribution of compton effect

κ : contribution of pair production

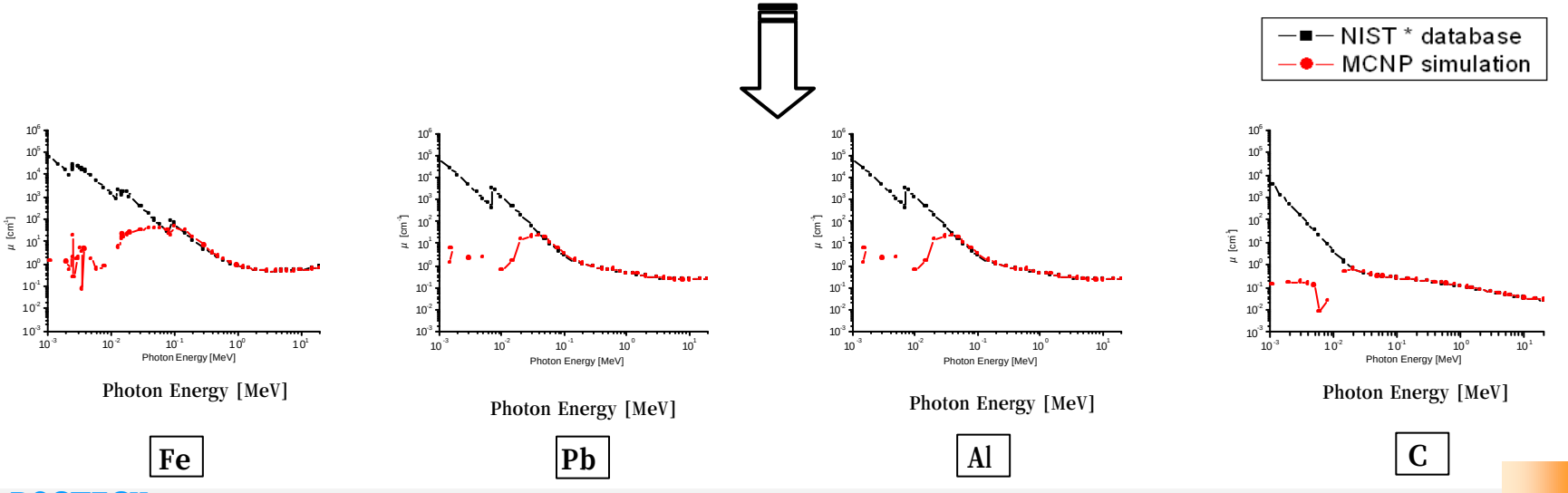
Total Attenuation = $f(Z_m, \rho_m, t_m, E_{x\text{-}ray})$

Interaction type	Energy dependence	Energy range [MeV]	Atomic number dependence	Application
Photoelectric effect	$E^{-3.5}$	~ 0.5	Z^5	Medical diagnosis
Compton effect	E^{-1}	0.5 ~ 5, 1 Max	Z/A	Cargo inspection
Pair production	E -1.02	1.02~	$Z^2/A \sim Z$	Medical treatment

Calculating μ with *MCNP simulation*

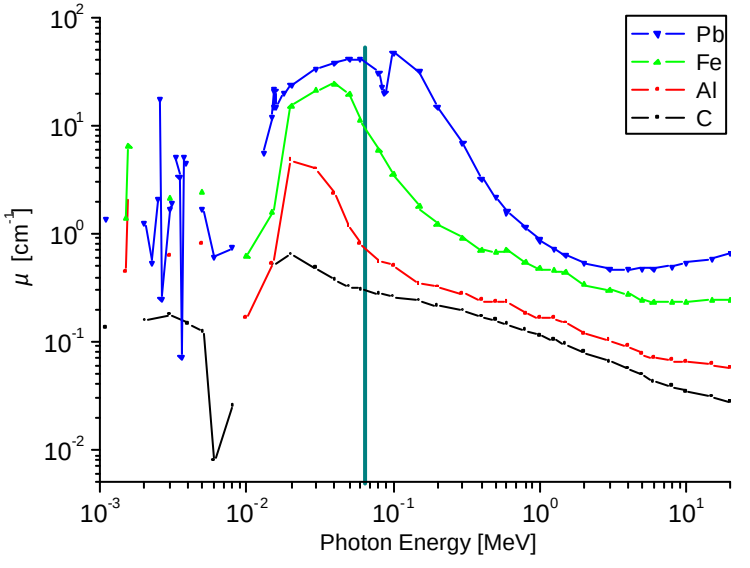


$$\mu = \frac{1}{t} \ln (I_0 / I)$$



* NIST : National Institute of Standards and Technology

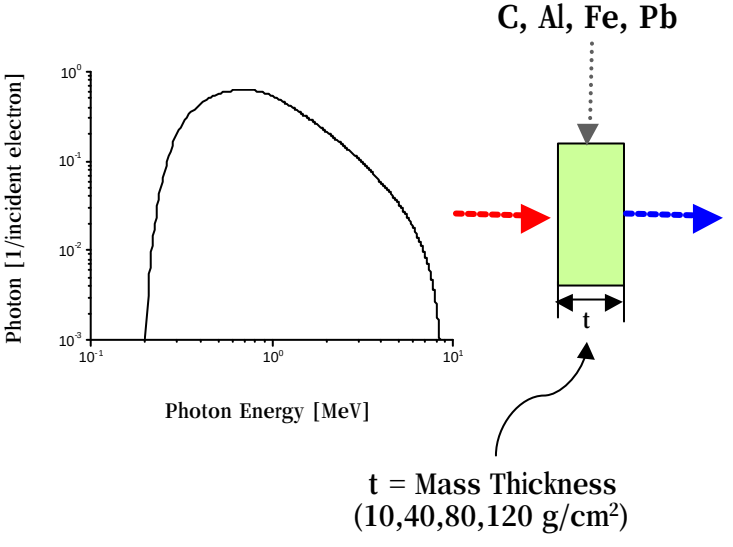
X-ray Linear Attenuation Coefficient

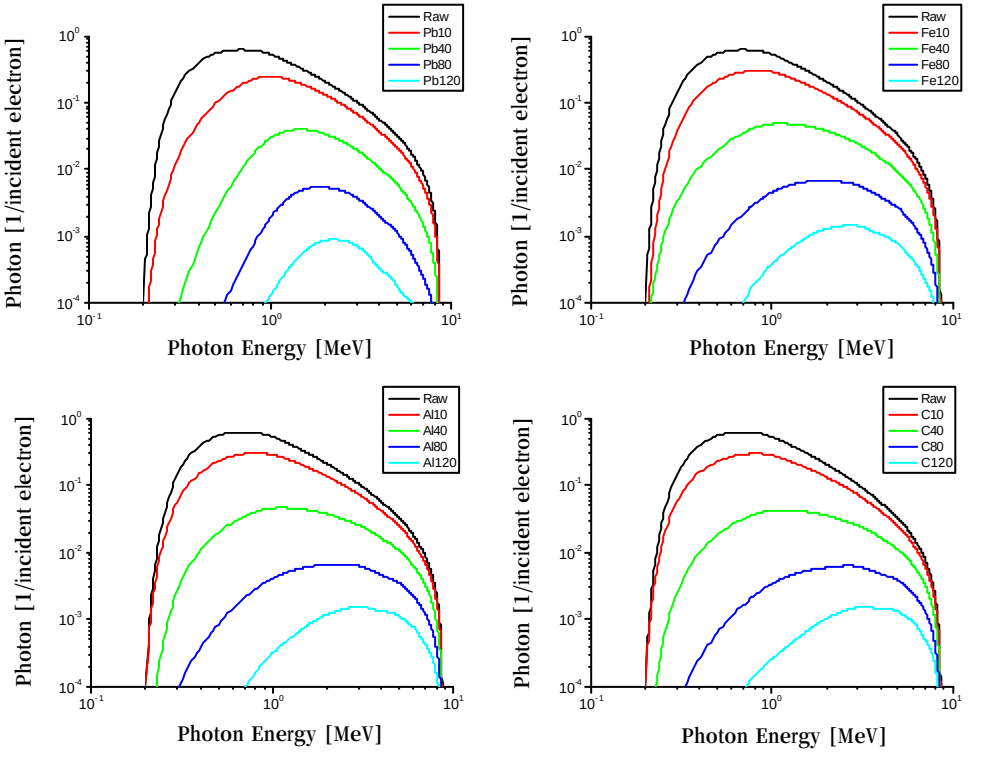


Results of ***MCNP simulation*** of calculating μ for Pb, Fe, Al and C

Result of ***MCNP simulation*** is correspond to data of NIST above 60 keV.
But till now, we assumed monochromatic gamma beam.
In real case, broad bremsstrahlung spectrum must be considered.

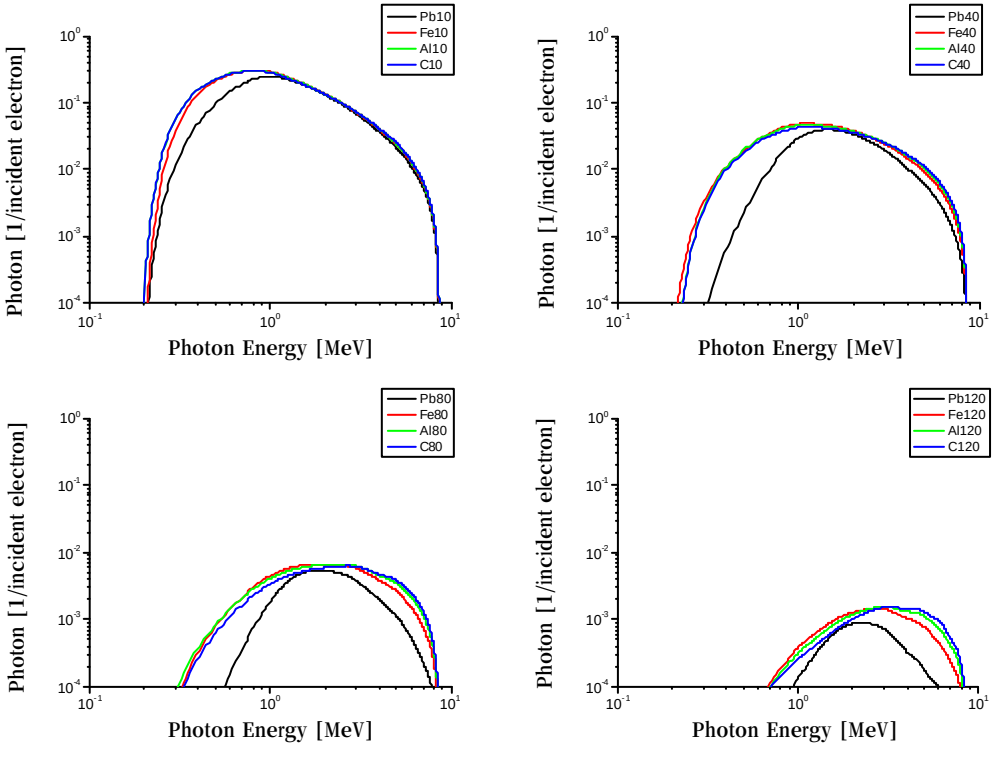
Attenuation for Broad Bremsstrahlung Spectrum





'Raw' is Spectrum before passing material. Curves are spectral attenuations of broad bremsstrahlung for 10, 40, 80, 120 g/cm². 4 pictures correspond to the following materials : Pb, Fe, Al, and C.

Attenuation for Several Material
(Same Mass Thickness)



'Raw' is Spectrum before passing material. Curves are spectral attenuations of broad bremsstrahlung of the following materials : Pb, Fe, Al, and C. Each pictures correspond to the same mass thickness.

X-ray attenuation is sensitive to the mass thickness of material. This phenomenon is achieved by the hardening of x-ray spectrum during its penetration through a barrier.

Especially, the attenuation of thick lead is dominant in high energy range as well as low energy.

This characteristics can be used to filter the soft part of the bremsstrahlung spectrum and to shield high energy x-ray produced the electron linac.

Conclusion

The data of x-ray attenuation according to material and their thickness can be used to shield x-ray produced by the electron linear accelerator.

For the appropriate shielding calculation, the accurate calculation of μ with MCNP simulation is required in the broad bremsstrahlung spectrum as well as in the monochromatic beam.