Instructions:

1) Use the calibrated cable to calibrate the time-to-amplitude converter. You should derive from this exercise a parameter with units [ns/channel].

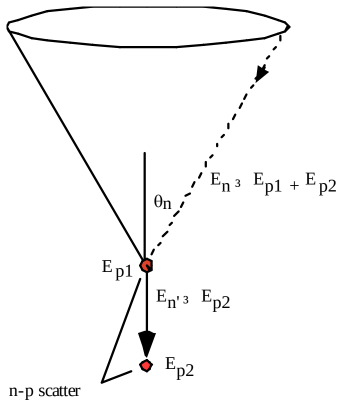
2) Determine the channel corresponding to zero time-of-flight, i.e., simultaneity.

3) What is the theoretical shortest ToF that should be measured from the Am-Be source? Neutrons from an Am-Be source have an average energy of about 4 MeV with a maximum (end point) of ~10 MeV.

4) What do you measure for this quantity?

You will need the kinematic expression for elastic scattering of neutrons off hydrogen, i.e.,

$$\sin^2 \theta = E_{p1}/E_n$$

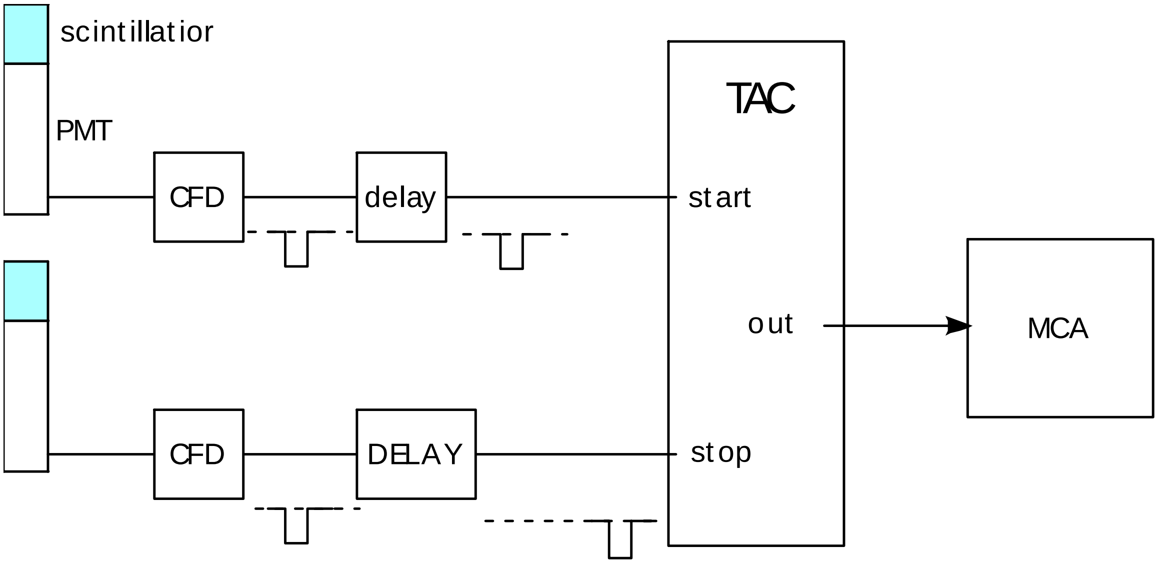


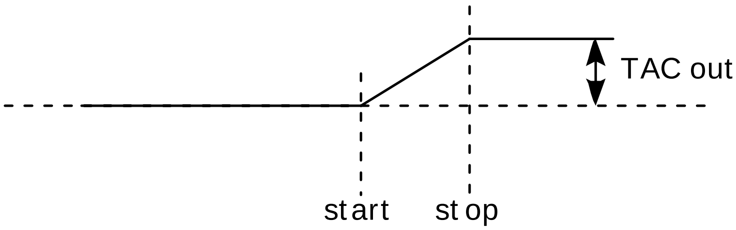
Double n-p Scatter Event

The mass of the neutron is 931.5 MeV. Use the expression for β given in the other half of the practicum.

5) What are factors contribute to the uncertainty in measuring the end point of the neutron spectrum?

Test Setup, TAC principle

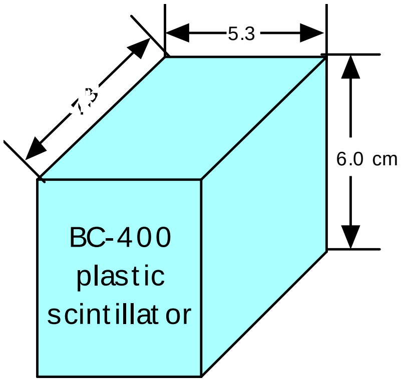




PMT: photomultiplier
TAC: time to amplitude converter
CFD: constant fraction discriminator
MCA: multi-channel analyzer, a.k.a. pulse height analyzer (PHA)

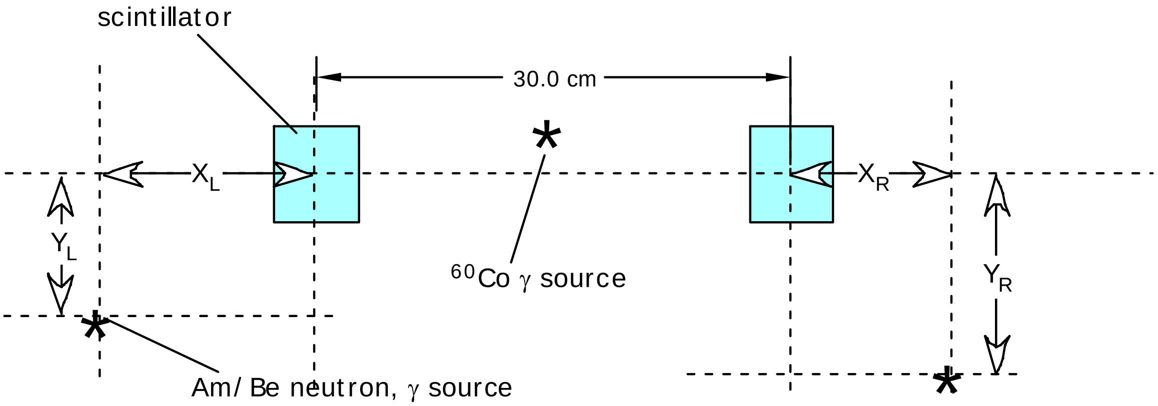
Detector thresholds, as set with the CFDs: ~250 keV electron equivalent (γ)
Neutron threshold energy (proton equivalent): ~1 MeV

Plastic scintillator detectors (2)

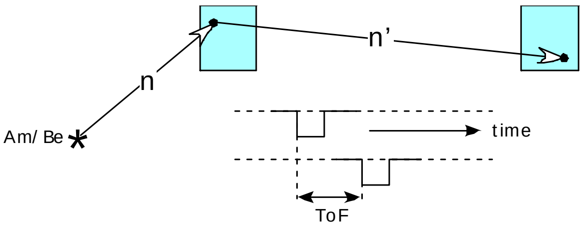


Measurement geometry

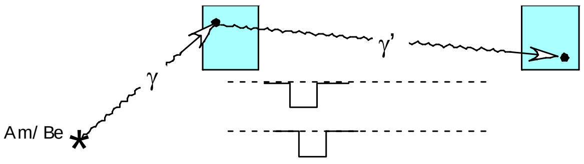
Lead absorbers (2 mm thick) to stop the 60 keV photos from the Am/Be source are not shown.
Dimensions ±0.5 cm



Time-of-Flight (ToF)



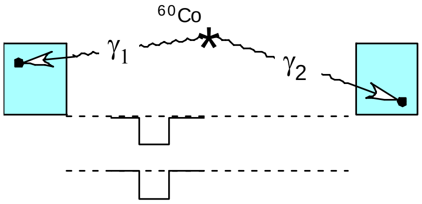
Neutron ToF



Gamma ToF

Calibration

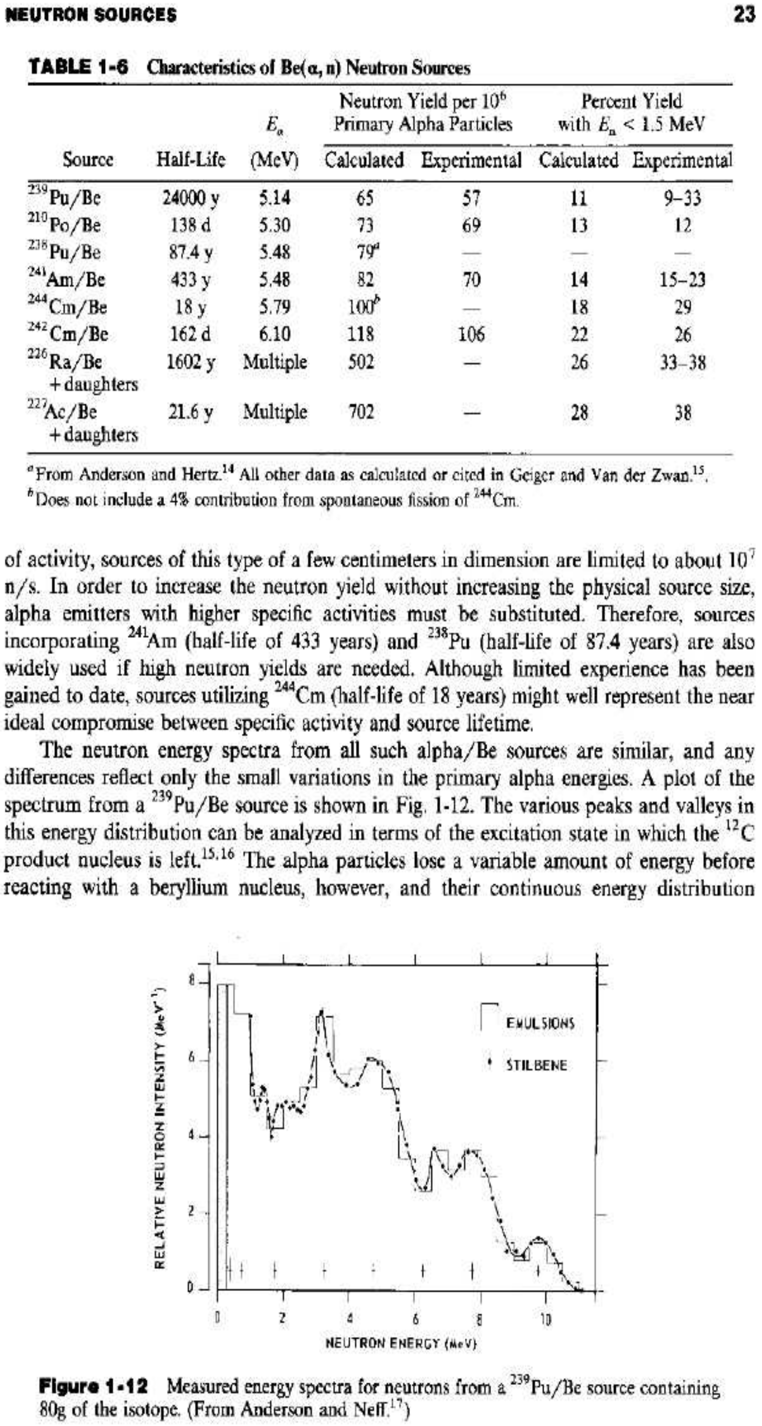
The ^{60}Co source (1.2 μCi) emits two photons (1.17 MeV and 1.33 MeV), essentially simultaneously. Place this source at the midpoint between the scintillation detectors to find the ToF zero.



Delay the start or the stop signal to the time to amplitude converter (TAC) by a known amount (9.4 ns) to calibrate the time scale of the measurement system (ns/channel).

The Am/Be neutron source (10 mCi) emits both neutrons and gamma-ray photons, including a 4.4 MeV photon.

Reference: Knoll, Radiation Detection and Measurement



NEUTRON SOURCES **23**

TABLE 1-6 Characteristics of Be(α, n) Neutron Sources

		E_α	Neutron Yield per 10^6 Primary Alpha Particles		Percent Yield with E_n < 1.5 MeV	
Source	Half-Life	(MeV)	Calculated	Experimental	Calculated	Experimental
^{239}Pu/Be	24000 y	5.14	65	57	11	9–33
^{210}Po/Be	138 d	5.30	73	69	13	12
^{238}Pu/Be	87.4 y	5.48	79[a]	—	—	—
^{241}Am/Be	433 y	5.48	82	70	14	15–23
^{244}Cm/Be	18 y	5.79	100[b]	—	18	29
^{242}Cm/Be	162 d	6.10	118	106	22	26
^{226}Ra/Be + daughters	1602 y	Multiple	502	—	26	33–38
^{227}Ac/Be + daughters	21.6 y	Multiple	702	—	28	38

[a] From Anderson and Hertz.[14] All other data as calculated or cited in Geiger and Van der Zwan.[15].

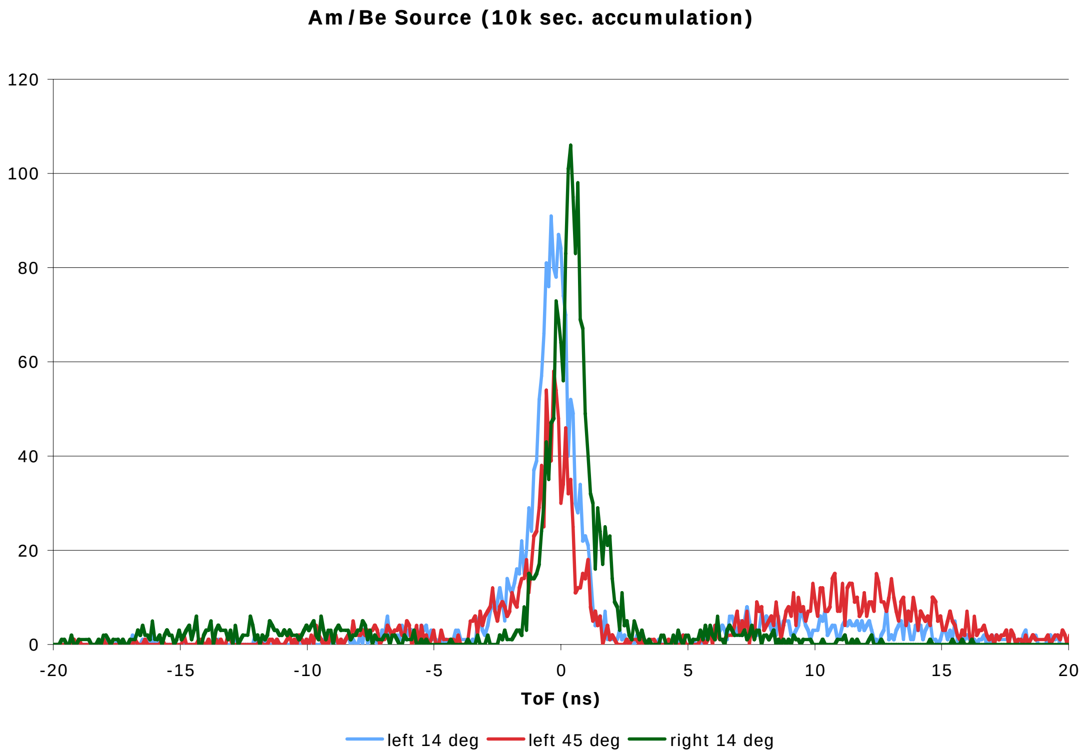
[b] Does not include a 4% contribution from spontaneous fission of ^{244}Cm.

of activity, sources of this type of a few centimeters in dimension are limited to about 10^7 n/s. In order to increase the neutron yield without increasing the physical source size, alpha emitters with higher specific activities must be substituted. Therefore, sources incorporating ^{241}Am (half-life of 433 years) and ^{238}Pu (half-life of 87.4 years) are also widely used if high neutron yields are needed. Although limited experience has been gained to date, sources utilizing ^{244}Cm (half-life of 18 years) might well represent the near ideal compromise between specific activity and source lifetime.

The neutron energy spectra from all such alpha/Be sources are similar, and any differences reflect only the small variations in the primary alpha energies. A plot of the spectrum from a ^{239}Pu/Be source is shown in Fig. 1-12. The various peaks and valleys in this energy distribution can be analyzed in terms of the excitation state in which the ^{12}C product nucleus is left.[15,16] The alpha particles lose a variable amount of energy before reacting with a beryllium nucleus, however, and their continuous energy distribution

Figure 1-12 Measured energy spectra for neutrons from a ^{239}Pu/Be source containing 80g of the isotope. (From Anderson and Neff.[17])

ToF Spectra


Am / Be Source (10k sec. accumulation)
120
100
80
60
40
20
0
-20
-15
-10
-5
0
5
10
15
20
ToF (ns)
left 14 deg
left 45 deg
right 14 deg