Development of a Teaching Laboratory for the Measurement of Prompt Neutrons from Californium 252 by Time-of-Flight Analysis

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Overview

- Background
- Why
- Detectors
- Time of Flight
- Road Blocks
- Conclusion
- Main Side Project
Californium 252 Fission Source

- High spontaneous fission branch $^1$ 3.09%
- 3.87 neutrons per fission $^4$
- 50 uCi 5/15/05 - ~42,000 neutrons/sec (July 2011)
Background

- Neutron was detected in 1932 by James Chadwick with proton recoil methods
- Neutrons are harder to detect than gammas
Why

- Neutrons are important constituents of matter
- Neutrons are vital for analysis of many nuclear reactions
- Nuclear security - radioactive material
- Nuclear reactors - clean energy
- Develop an advanced lab for physics majors
Detectors

- Plastic scintillator
- Optical couple (grease)
- Mu metal shield
- Photomultiplier tube
- High Voltage Base
Photomultiplier tubes

Converts photons to a fast current pulse

http://commons.wikimedia.org/wiki/File:Photomultipliertube.png
Time of Flight Method

n/γ Stop Detector

γ Start detector

Scintillator

Scintillator

Cf-252

Neutrons

γ-Rays
Time-of-Flight Spectrum using Cf-252
Path length 30 cm

- Prompt Gamma Peak
- Full Width at Half Maximum ~ 4 ns
- SF Neutron Continuum
Triggers and Thresholds

Single Channel Analyzer (SCA)

Constant Fraction Discriminator (CFD)

Fig. 3. Non-Timing SCA Output Triggering.

Fig. 6. Constant-Fraction SCA Output Triggering.
CFD Circuit

CFD - Constant Fraction Discriminator

TAC - Time to Pulse Height Converter

MCA - Multi Channel Analyzer

Start Detector → Cf-252 Source → 30 cm → Stop Detector

Fast Amp → CFD → Start

Fast Amp → CFD → Stop

Delay

TAC

0-5 V → MCA
No CFD Circuit

TAC - Time to Pulse Height Converter
MCA - Multi Channel Analyzer
The Apparatus

Stop detector

Start detector
Road Blocks

- Low Count Rate vs Separation
- Time Jitter
- Efficiency Correction
Time-of-Flight Spectrum

path length 60 cm

Over night Run
MCNP-Polimi
Detector Simulation Code

- **Timing Resolution of 4 ns**
- **Time Jitter**
  - Dependent on the detector geometry
  - Trigger dependent
Detection Efficiency Calculations

Threshold Value
- 100 KeVee
- 250 KeVee
- 350 KeVee
- 600 KeVee

Absolute Efficiency

Neutron Energy (MeV)
Neutron Energy Spectrum Deduced

Cf-252

- Data run 4
- $e^{-0.72E*\sqrt{0.93E}}$
- $e^{-0.88E*\sinh(\sqrt{2E})}$

14 hour run

Neutron Energy (MeV)

Corrected counts
Neutron Energy Spectrum Deduced

Cf-252

Non-CFD

- Data run 5
- \( e^{-.72E \times \text{Sqrt}(.93E)} \)
- \( e^{-.88E \times \text{Sinh(\text{Sqrt}(2E))}} \)

CFD

- Data run 2
- \( e^{-.72E \times \text{Sqrt}(.93E)} \)
- \( e^{-.88E \times \text{Sinh(\text{Sqrt}(2E))}} \)
Side Project

- Digitizer PSD work at the University of Notre Dame Accelerator Lab
Pulse Shape Discrimination

- N-Pulse
- γ-Pulse
- Short gate
- Long gate
- Slower Decay

Arbitrary Voltage vs. Time (ns)
PSD of Cf-252 using liquid scintillator

- Neutrons
- Gammas
Uncalibrated Neutron Energy Spectrum
Digitizer

Pros:
Can use 6-detector array
Post processing flexibility
High sample rate

Cons
Large data files
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Works Cited

3. O. I. Batenkov et al., INDC(NDS)-146, 1983.