NERS 535
Detection Techniques for Nuclear Nonproliferation

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http://www-ners.engin.umich.edu/labs/dnng/

Requirements:
- **Personal laptop (can be shared if needed); MCNP5/MCNPX and MCNPX-PoliMi RSICC licenses (please request them ASAP at http://www-rsicc.ornl.gov/); MATLAB access**
- **Class attendance is mandatory**

Textbooks and study materials:
1. **G. F. Knoll, Radiation Detection and Measurement, 4th Ed.**
2. **U.S. NRC, Passive Nondestructive Assay of Nuclear Materials (PANDA; can be obtained at http://www.lanl.gov/orgs/n/n1/panda/index.shtml)**
3. **MCNP5/MCNPX and MCNPX-PoliMi manuals**
4. **Course handouts and notes**

Grading: **60% laboratory reports**
20% laboratory presentation
20% final exam (17-Dec-12, 16.00)

All laboratory reports are due at the start of class on the specified due date. Late reports will be penalized 10% for every day past the deadline.

NOTE: Lab reports are limited to 10 pages. Any content past page ten will not be read.

Honor Code:
Laboratory experimental work is collaborative. However, all data analysis and report writing is to be done individually. The laboratory presentation will be a collaborative assignment. The final exam will be completed individually.

Office Hours (GSIs):
Times: Tuesday, Thursday 1:00 – 2:00 p.m.
Room: ERBII 1213
E-mails: alexispr@umich.edu
kpolack@umich.edu

Format:
Weekly lectures, 2 hours per week on Mondays.
5 laboratories (4 measurement labs and 1 simulation lab). Laboratory meets during scheduled class period on Wednesdays.

Syllabus (Lectures are shown in bold)

Week 1

Nuclear nonproliferation; homeland security

Introduction to the physics of nuclear fission (Knoll Ch. 1)

- **Spontaneous/neutron induced fission**
- **Fission chain multiplication, Rossi alpha**
- **Neutron and gamma-ray sources (PANDA Ch. 11)**
- **Neutron and gamma-ray multiplicities**
- **Delayed neutrons and gamma rays**
- **Special nuclear material (plutonium and uranium)**

Weeks 2-3

Introduction to Monte Carlo simulations for nuclear nonproliferation applications

MCNP5/MCNPX, MCNP-PoliMi *(MCNP5 manual Vol. 1 Ch. 1)*

Passive detection of nuclear materials

- **Neutron measurement techniques**
- **Gamma-ray measurement techniques**

Laboratory 1: Introduction to Monte Carlo Simulation Techniques (3 weeks), due 10 October

1.1: Gamma Spectroscopy with MCNPX
1.2: Gamma Spectroscopy with GEANT4
1.3: Gamma Spectroscopy Validation Measurement

Weeks 4-11

Detectors and safeguards instruments (PANDA Ch. 14)

- **He-3 detectors, gamma-ray detectors (Knoll Ch. 14.III.B.6 and Ch. 12, PANDA Ch. 17)**
- **Liquid and plastic organic scintillation detectors – fast-neutron scattering (Knoll Ch. 8.1.A, 8.1.B and 15.III)**
- **Boron-loaded and lithium-glass scintillators – neutron collisions and capture mechanism (Knoll Ch. 14.II.F and 15.II.A.2)**
- **Pulse-shape discrimination between neutrons and gamma rays (Knoll Ch. 8.1.C, and 15.III.B.6)**
- **Cross-correlation and bi-correlation measurement techniques**

Laboratory 2: Gamma-Ray Enrichment Measurements (2 weeks), due 24 October

2.1: Uranium Enrichment Measurement
2.2: Enrichment Measurement Analysis using MCNPX (or GEANT4)

Laboratory 3: Organic Liquid Scintillator Measurements (2 weeks), due 14 November

3.1: Simulation of Neutron Pulse Height Distributions from Liquid Scintillators with MCNPX-PoliMi (or GEANT4)
3.2: Liquid Scintillator (EJ-309) Calibration and PSD Development
3.3: Measurement of Mixed Neutron/Gamma-ray Pulses using a Liquid Scintillator

Laboratory 4: Time-of-Flight Spectroscopy (3 weeks), due 28 November

4.1: Time-of-Flight Simulations with MCNPX-PoliMi (or GEANT4)
4.2: Time-of-Flight and Cross-Correlation Measurements with ^{252}Cf
4.3: Time-of-Flight Characterization of a D-D Source

Weeks 12-13

Active interrogation nuclear materials

- **Active interrogation with neutron sources**
- **Active interrogation with photon sources**
- **Photonuclear physics overview**

Laboratory 5:Active Interrogation with a Bremsstrahlung Source (2 weeks), due 11 December

5.1: Simulation of bremsstrahlung photon sources

5.2: Simulation of active photon interrogation of HEU

Week 13

Presentations and final exam preparation

Schedule:

Week 0	Wed, 05-Sep-2012	Course Introduction and Intro to MC + Dice Example
Week 1	Mon, 10-Sep-2012	Radiation Safety Training
	Wed, 12-Sep-2012	Lab 1.1 - Introduction to MCNP
Week 2	Mon, 17-Sep-2012	Random Walk/GEANT4
	Wed, 19-Sep-2012	Lab 1.2 - Introduction to GEANT4
Week 3	Mon, 24-Sep-2012	DNNG Measurement System Intro
	Wed, 26-Sep-2012	Lab 1.3 - Validation Measurement (NaI)
Week 4	Mon, 01-Oct-2012	Sources, Materials, and Gamma-Spec Enrichment Measurement
	Wed, 03-Oct-2012	Lab 2.1 - Enrichment Measurement (HPGe)
Week 5	Mon, 8-Oct-2012	Neutron PHDs and MCNPX-PoliMi Intro
	Wed, 10-Oct-2012	Lab 2.2 - Enrichment Measurement Analysis using MCNPX
Week 6	Mon, 15-Oct-2012	Fall Break
	Wed, 17-Oct-2012	Lab 3.1 - Neutron Pulse Height Distribution Simulation
Week 7	Mon, 22-Oct-2012	Organic Scintillators and PSD
	Wed, 24-Oct-2012	Lab 3.2 - Liquid Scintillator (EJ309) Calibration and Pulse Shape Discrimination
Week 8 (IEEE)	Mon, 29-Oct-2012	Organic Scintillators and PSD
	Wed, 31-Oct-2012	Lab 3.3 - EJ309 PSD/PHD Measurements
Week 9	Mon, 05-Nov-2012	Time-of-Flight and Cross Correlations
	Wed, 07-Nov-2012	Lab 4.1 - Time-of-Flight and Cross-Correlation Simulations
Week 10	Mon, 12-Nov-2012	Lab 4.2 - Time-of-Flight and Cross-Correlation Measurements
	Wed, 14-Nov-2012	Lab 4.3 – D-D Source Time-of-Flight Characterization
Week 11	Mon, 19-Nov-2012	Bremsstrahlung Sources, Lab 5.1 - Simulation of Bremsstrahlung Sources
	Wed, 21-Nov-2012	No meeting - Thanksgiving
Week 12	Mon, 26-Nov-2012	Active Photonuclear Interrogation
	Wed, 28-Nov-2012	Lab 5.2 - Active Photonuclear Interrogation with MCNPX
Week 13	Mon, 03-Dec-2012	Presentations
	Wed, 05-Dec-2012	Presentations
	Mon, 10-Dec-2012	Final Exam Preparation
	17-Dec-12	Final Exam 4 pm