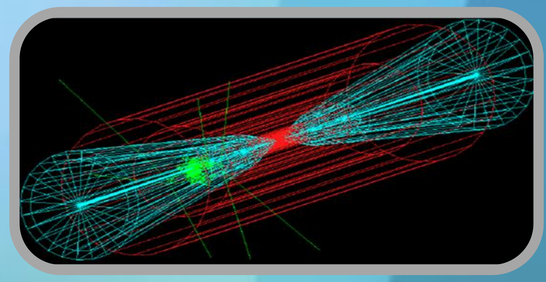
Simulations of Neutron Interactions with Various Materials for Particle Detector Shielding

Elizabeth De Waard and Dr. Joseph Kozminski
Lewis University Physics Department

Abstract

In order to study subatomic particles produced in particle collider, the particle background that interfere with the desired signal must be reduced. Detector shielding is essential in accomplishing this goal and can be optimized prior to implementation through computer simulation. In this work, G4Beamline was used to simulate neutron interactions with cylindrical targets of various materials. The results of these studies can be applied to the beam stop of the Mu2e Experiment at Fermilab and shielding for a future Muon Collider. This study examines the neutron absorption rate and corresponding photon and electron production rates in various beam stop materials.



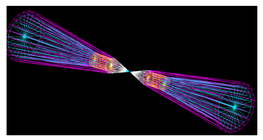
Introduction

Background

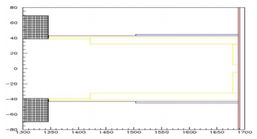
Muon beam backgrounds arise primarily from particle decay processes. The background particles can damage the detector or result in poor detector resolution, making the signal of interest difficult to resolve. Industry standards for shielding include tungsten for electrons and borated polyethylene for neutrons.

Applications

Shielding studies are necessary in designing a Muon Collider or the more imminent Mu2e Experiment at Fermilab and in nuclear and medical physics fields .



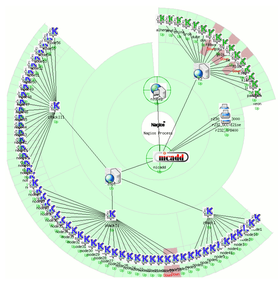
MC W shielding horns



Mu2e Beam Stop

Computer Simulation

Simulations can be used to develop and optimize shielding . G4Beamline is ideal for use in these studies and is run on the NICADD cluster (figure below) at NIU.



- Monte Carlo simulations
- Front-end to Geant4
- User-friendly
- Built in elements
- Includes interactions with matter

G4 Beamline is freely available at http://g4beamline.muonsinc.com

Current Work

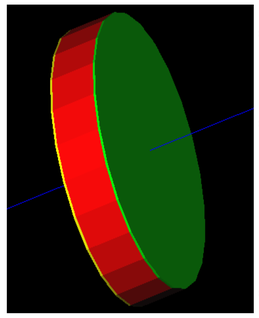
Validation studies have been previously conducted by comparing simulation results of various materials with known absorption cross sections from the National Nuclear Data Center and with MARS, another simulation program.

Research Methods

- Create a text file with exact beam and target design
- Run simulation using G4Beamline
- Run ROOT macro to analyze G4Beamline data

Experimental Parameters

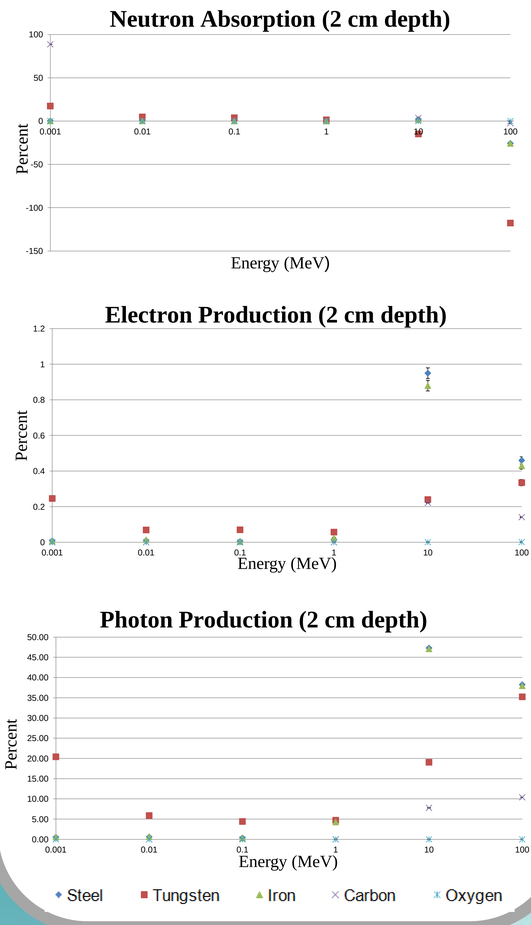
The current series of studies investigates neutron absorption in materials present in the Mu2e experimental design. These materials include: Boron and Lithium doped Polyethylene, pure Polyethylene, Tungsten, Iron, Carbon and Oxygen.



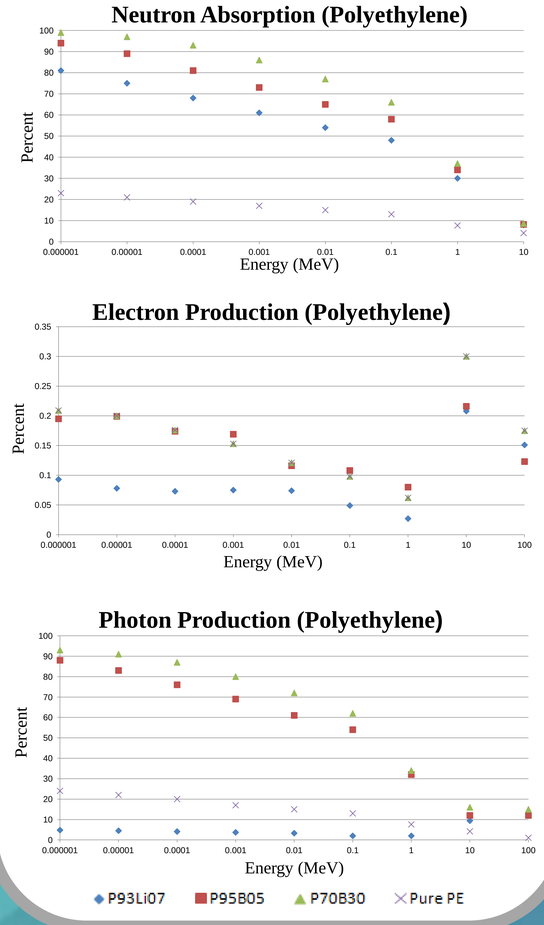
- Neutron beam
  - 1 keV to 100 MeV
- Cylindrical target
  - 15 cm radius
  - 2 and 5cm target depths
- 3 virtual detectors

Target performance was examined based on the rates of neutron absorption as well as electron and photon production.

Results



Results



Conclusions

These studies revealed that Lithium-doped polyethylene may perform better than the standard Boron-doped polyethylene. The differences in neutron absorption rates are insignificant at the highest energy ranges, and lithiated polyethylene has considerably lower photon production.

Acknowledgements

Much of this work was done in collaboration with Muons, Inc., Northern Illinois University, and the Mu2e project at Fermilab.