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AIDA Simulation for Proton Decay Using Geant4 Software and Monte Carlo

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Objective

Nuclear structure study is a key to understanding the world around us and the development of the universe. Exploring the nuclear existence at the proton drip line in the highly neutron deficient region between Z = 50 and 82 are the main subject of this study. Producing new nuclei in this region is very complicated and needs special system , such as AIDA used in this work, to be optemised before hand. Computer modelling of AIDA uses a Monte Carlo simulation approach would help plan experiments for new cases of proton radioactivity. Basically, the best silicon detector thickness to use for detecting proton emission will be testes, and whether a thickness of 1000 μm, might be appropriate rather than three thinner 300 μm detectors.

Introduction

Separating fragments of a 1GeV ^{238}U beam via FRS following implementation in AIDA, is one of the possible production means. So, the simulation for straightforward proton decay will be the first task. A single well-defined peak is expected and just this response need to be simulated. The main challenge will be the background which include the escaped protons that deposited part of its energy in the detector, β+ particles and beta delayed proton emission. This background has to be simulated to determine what the optimal detector thickness is, and assess how difficult these experiments are.

AIDA

AIDA (Advanced Implementation Detector Array) figure 1, which is a stack consisting of up to eight silicon detectors separated by 10mm distance, has been constructed figure 2. Each has dimensions of 8cm length (at x axis), 8cm width (at y axis), variable micrometer thickness (at z axis) is constructed and positioned in an air world. The blue one assumed to be the implementation detector (detector1) and chosen to generate the proton inside it. The other detectors are used as supporting tools for detecting the particles which were not stopped by detector1 as shown in figure 3.

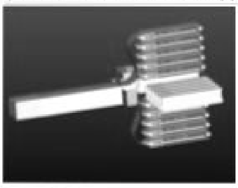

Figure1: AIDA

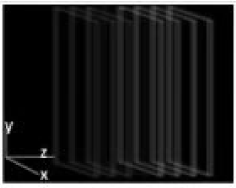

Figure2: A simulated AIDA model

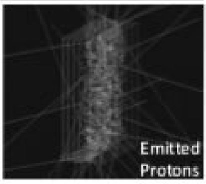

Figure3: The generated protons

Geant4 Software

- **Geant4**

The interaction of charged particles with materials can be simulated by the use of GEometry ANd Tracking (version4) (Geant4) software which applies the Monte Carlo approach. It is a toolkit software of Object-Oriented environment based on coding with C++ programming language.

- **Monte Carlo**

Monte Carlo algorithms method is the technique of repeating the same process (generating protons) but with randomised generated events or conditions (random directions).

Geant4 features allow users to fully control the following:

- Defining the geometry and materials of detectors and specifying components as sensitive detectors
- Identification of particles involved and specifying the processes to be considered
- Definition of any desired external experimental world such as air or vacuum
- Generation of primary events and tracking of both primary and secondary particles
- Identifying values of events and hits such as position, kinetic energy, energy deposit and time
- Producing output files and writing root files at the end of run

Results and Analysis

1. AIDA energy response

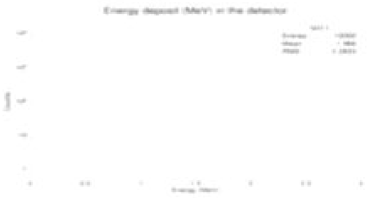

Figure 4: The energy spectrum of 2 MeV protons generated inside a silicon detector with 1000 μm thickness.

2. Analytical Calculation of AIDA Efficiency Against the Thickness

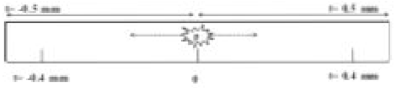

Figure 5: schematic drawing for 1mm silicon detector thick at the z direction where the thickness represented by the symbol t.

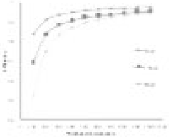

Figure 6: The efficiency dependency of the detector thickness for 1MeV, 1.5MeV and 2MeV protons.

Figure 7: The efficiency dependency of the deposited energy position for a 2MeV protons with a 100 μm range.

Effective efficiency	Geometric efficiency
fully deposited energy particles / total generated particles	Solid angle / 4π
94%	95%

3. Peak to Background Ratio

Figure 8: The normal energy distribution of the generated protons inside the silicon detector

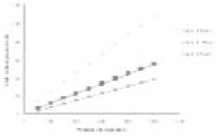

Figure9: The relation between the thickness of the silicon detector and the peak to background ratio.

4. AIDA Background Veto

Figure10: Comparison between the energy spectra of protons generated inside the silicon detector before and after the veto.

Conclusions

AIDA modelling outcomes for proton decay reveal significant indicators. First, the single well-defined peak reflects that the simulation of the detector response was completely successful. The plotted detector efficiency findings confirm that the thicker the detector is, the more efficient it will be. Therefore, it is perhaps not surprising that resulting peak to background ratio is enhanced as viewer protons escaped. This study has shown that 1mm silicon detector thickness is optimal for proton decay studies than the thinner one.

References 1.https://geant4.web.cern.ch/geant4/