Development of an Active Deuteron Target for Dibaryon Studies

Jake Watson

Supervisors: Mikhail Bashkanov & Nicholas Zachariou

Contents

Introduction

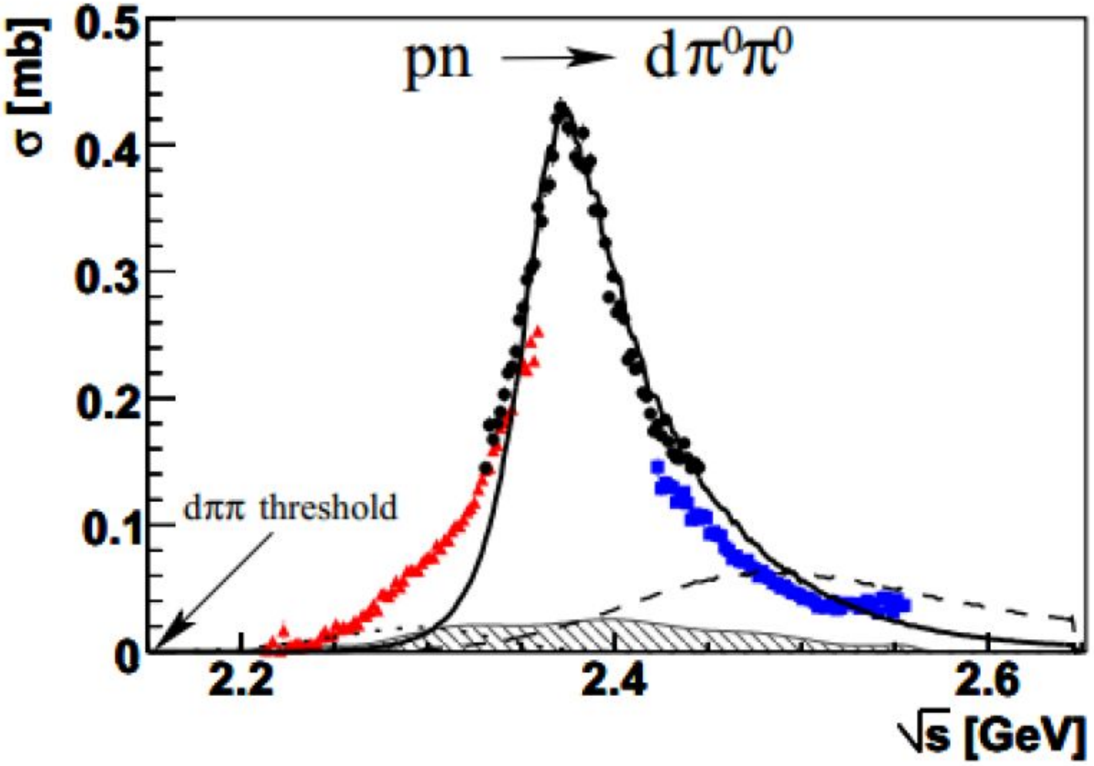
- The d*(2380) dibaryon discovered at WASA-COSY, 2011
- Study of new resonance ongoing at MAMI Crystal Ball collaboration
- Project aims to use simulations and physical experiment to produce a prototype target for MAMI

Hunt for Dibaryons

- First stable two-baryon system – deuterium – found 1931
- Except for deuterium (1p, 1n), no other stable di-nucleon state
- Dibaryon search started in 1976 – "Perhaps a stable dihyperon"
- Along with the search for glueballs, quark-gluon hybrids, tetraquarks, pentaquarks
- Apart from deuteron, no stable dibaryonic particle yet found

Dibaryon Discovery

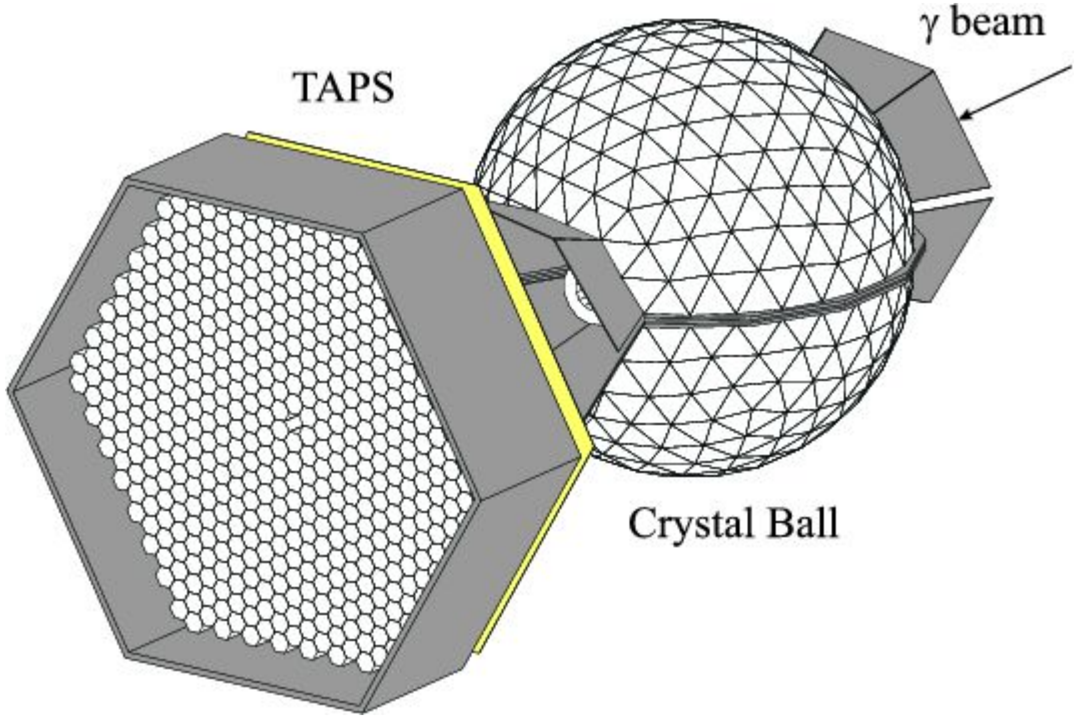
- Discovered in the WASA detector at the COSY collaboration, 2011
- Nucleon beams on a deuteron target
- Shows a resonance structure with a mass of 2380 MeV and a width of 80 MeV



Internal Structure

- There are two possibilities for the internal structure of the dibaryon
  - Bound state of two Δ baryons, known as Deltaron
  - Genuine six-quark dibaryon, all six quarks in single bag
- Studies ongoing at MAMI Crystal Ball using photoexcitation:

$$\gamma d \rightarrow d^{*} \rightarrow X$$



Crystal Ball Experiment

- The MAMI Crystal Ball Detector will measure the reaction:

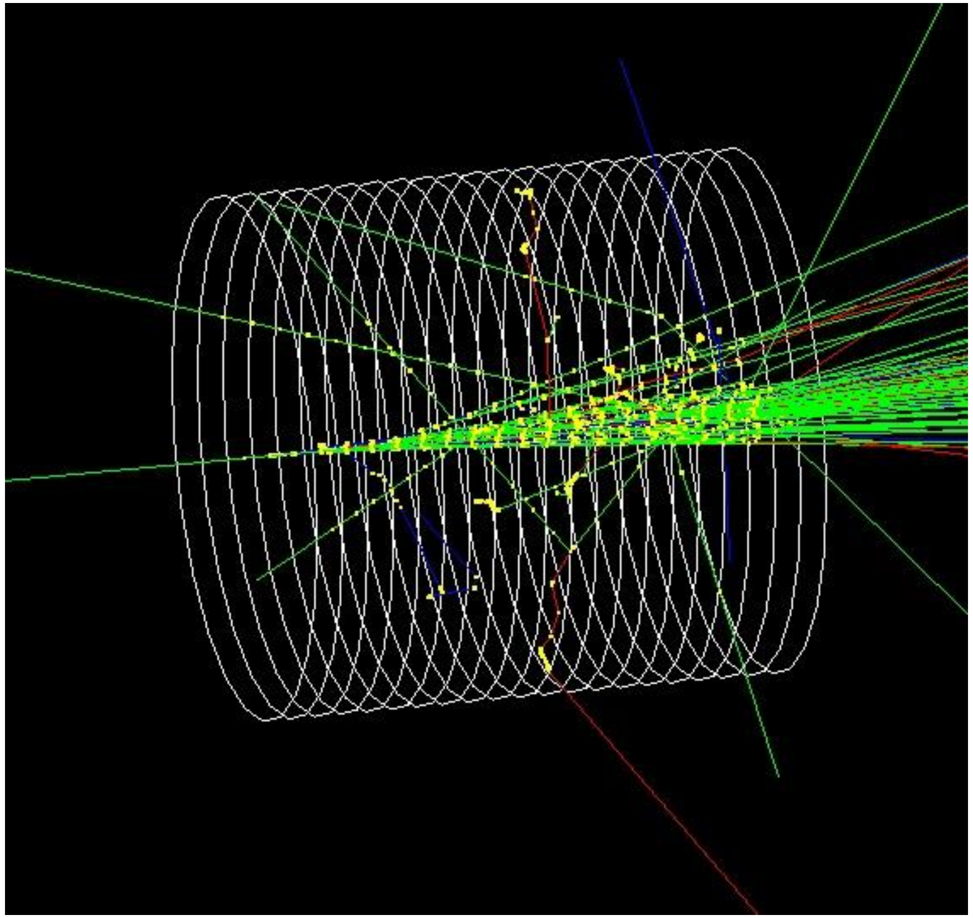
$$\gamma + d \rightarrow d^* \rightarrow \pi^0 + \pi^0 + d \rightarrow d + 4\gamma,$$

- This will be studied using an active deuteron target, composed of alternating deuterated plastic and plastic scintillator layers.
  - Active Target – reaction products from d* decay are very low energy, so scintillators used in target design to increase chance of measurement

Background Reactions

- Two reaction channels that produce background in the measured energy range:
  - $\gamma + d \rightarrow d + \pi^0 + \pi^0 \rightarrow d + 4\gamma$
  - $\gamma + p \rightarrow p + \pi^0 + \pi^0 \rightarrow p + 4\gamma$

- Additional Photon Shower Background – bombardment with high energy photons creates showers of particles in the target



Project Task

- Design an active deuteron target to study the d* dibaryon
- The design must force reaction products from main background channels to be separate in energy
- If the reaction products can not be disentangled from one another, then no data can be extracted.

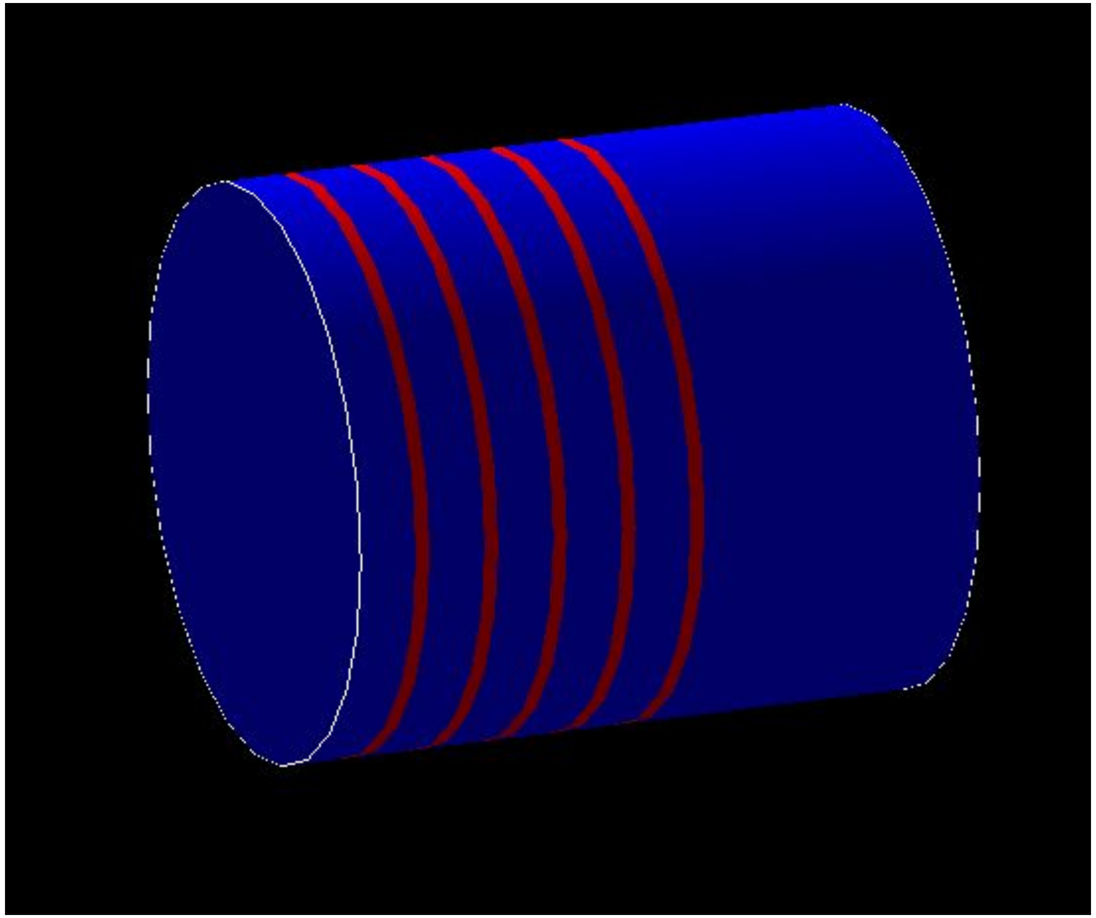
Methodology

- Build a GEANT 4 simulation of the target
  - GEANT 4 is the gold-standard in HEP
- Use the simulation to find the optimum dimensions for the prototype target
  - Time and expense saving
- Build and test the prototype in laboratory

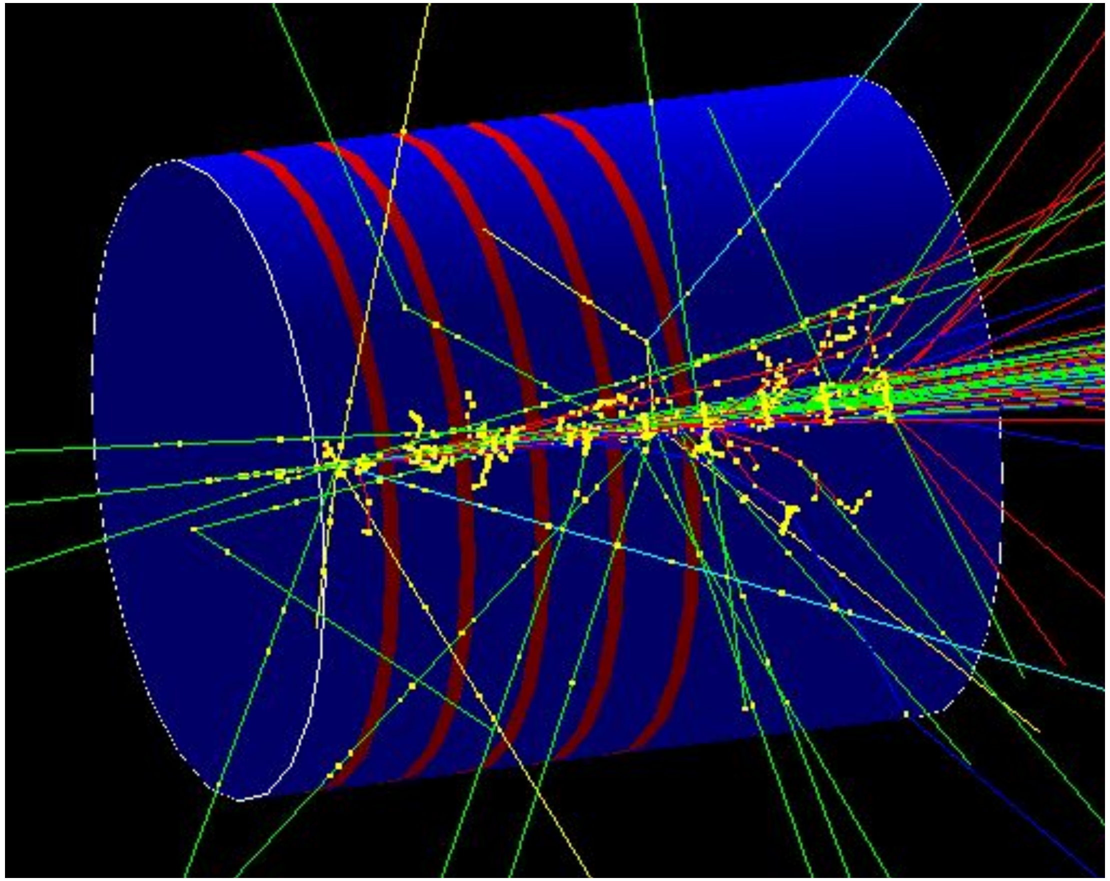
GEANT4 Simulation

- Simulation written in C++, composed of 6 classes
- Simulated target composed of CD2 deuterated plastic and Vinyltoluene plastic scintillator
- Three different input particles:
  - 570 MeV gamma-rays
  - Variable energy deuterons
  - Variable energy protons
- Outputs data to a ROOT file for easy analysis

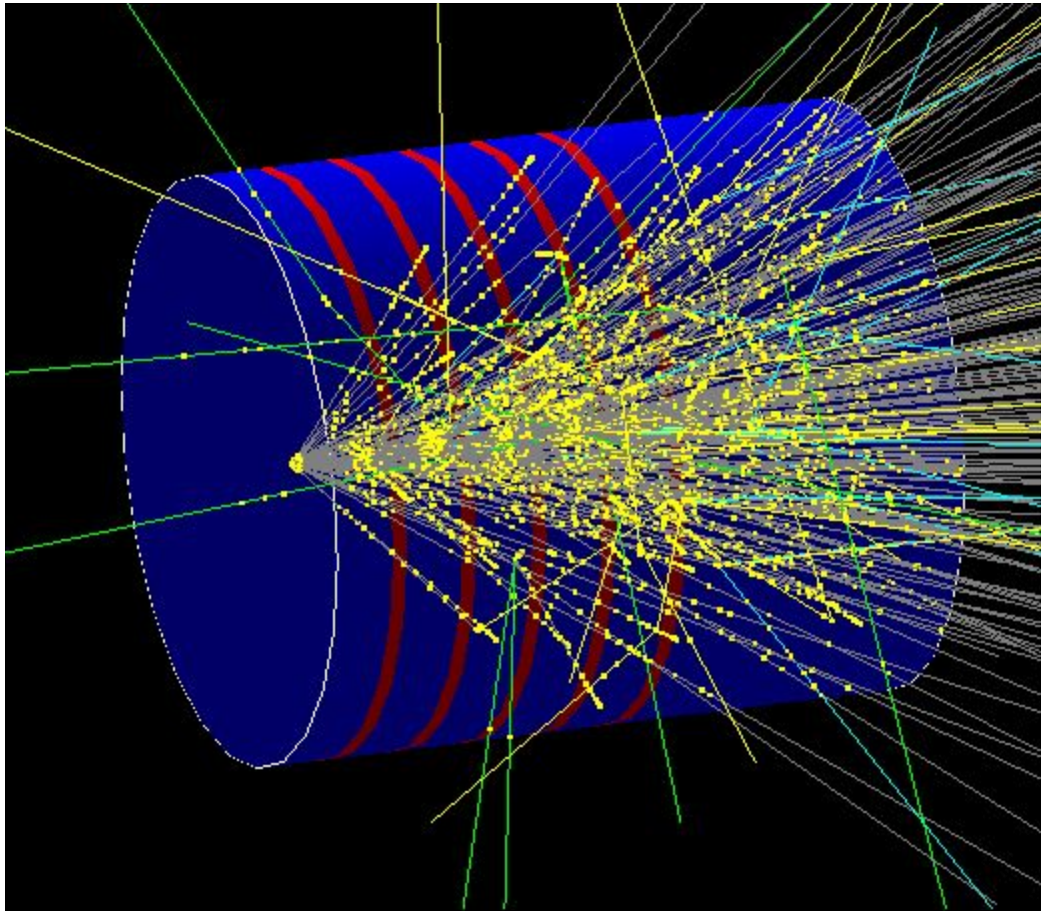
- Visualisation was done using built-in GEANT4 OpenGL
- Image shows the geometry of the target:
  - 5 composite deuterated(red) + scintillator (blue)
  - 1 layer of scintillator at front
  - 4 layers of scintillator at back
  - scintillator width 4mm
  - Deuterated plastic width 1mm
- As well as input particle type, the thickness of the scintillator layers was varied between 1mm and 4mm



- First background to simulate was the showers of secondary particles produced by the photon beam
- Reactions of interest - $\gamma + p$ and $\gamma + d$ - have very low cross-sections compared to reactions with other target materials
- Number of proton and deuteron



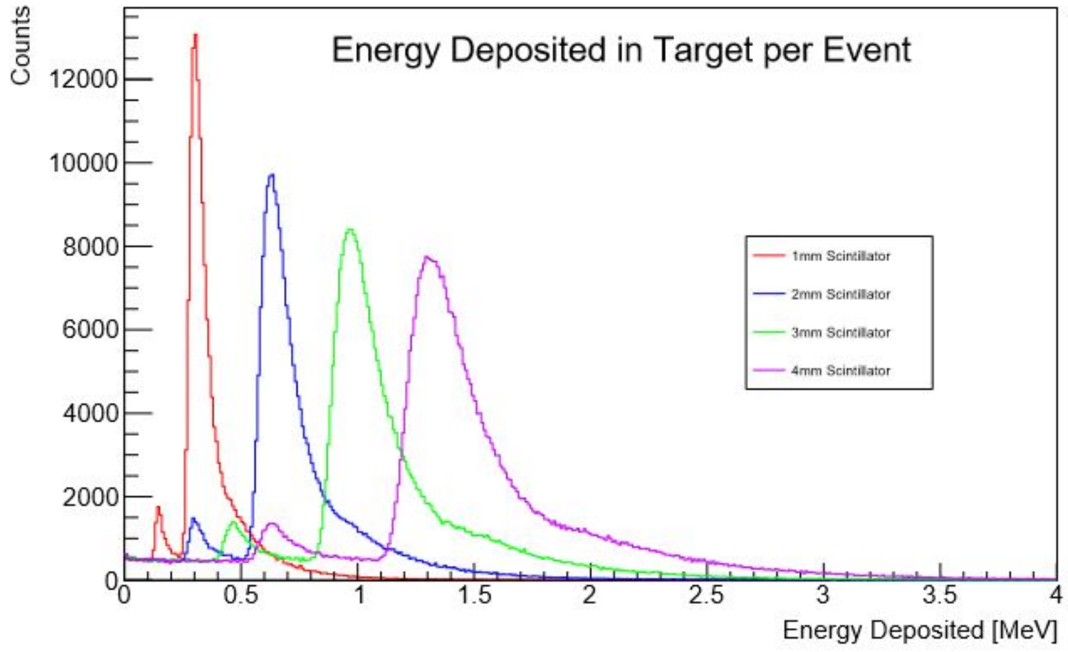
- Image shows simulation with deuteron input – deuterons created randomly in any of the 5 layers of deuterated plastic
- Allows for direct study of the deuteron background
- Proton input simulation is not yet complete



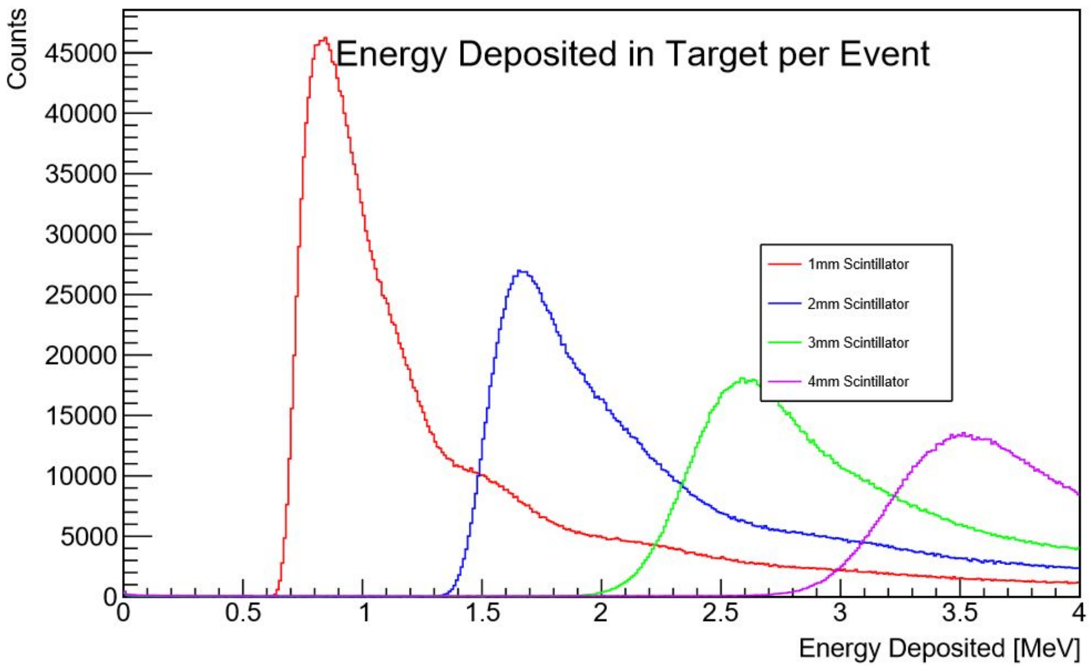
Data Analysis

- Raw data produced by the simulation as a ROOT file
- A ROOT script was produced to create plots of several types
- These plots have so far been analysed by eye
- Further plots will be analysed quantitatively

Results – Energy Deposited in Target per Event

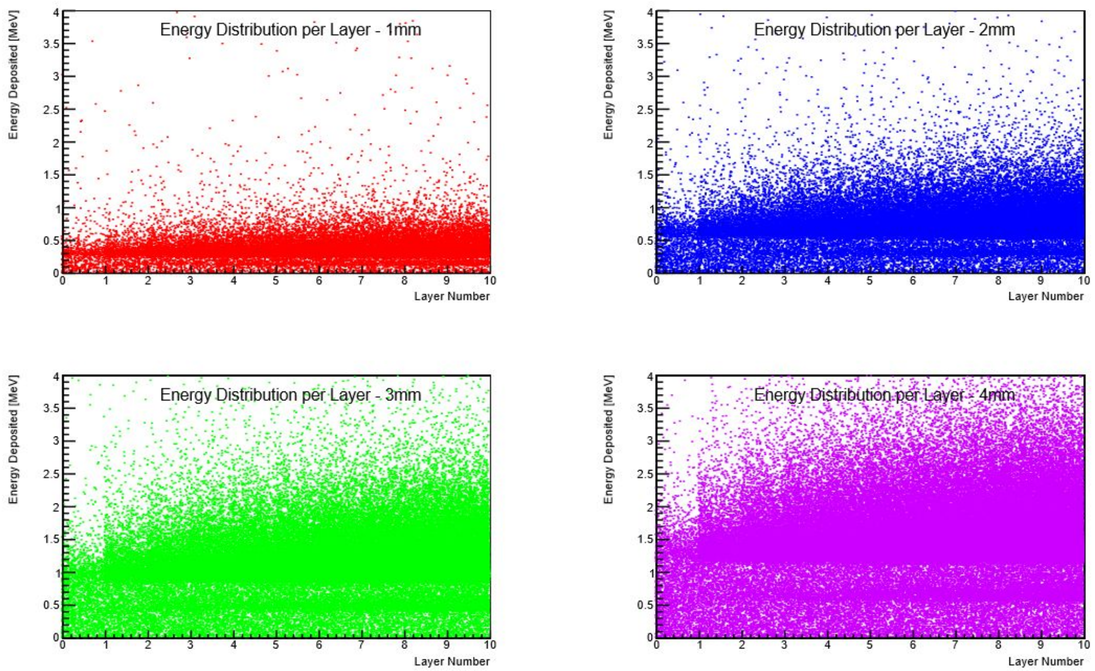


Photon Showers Simulation

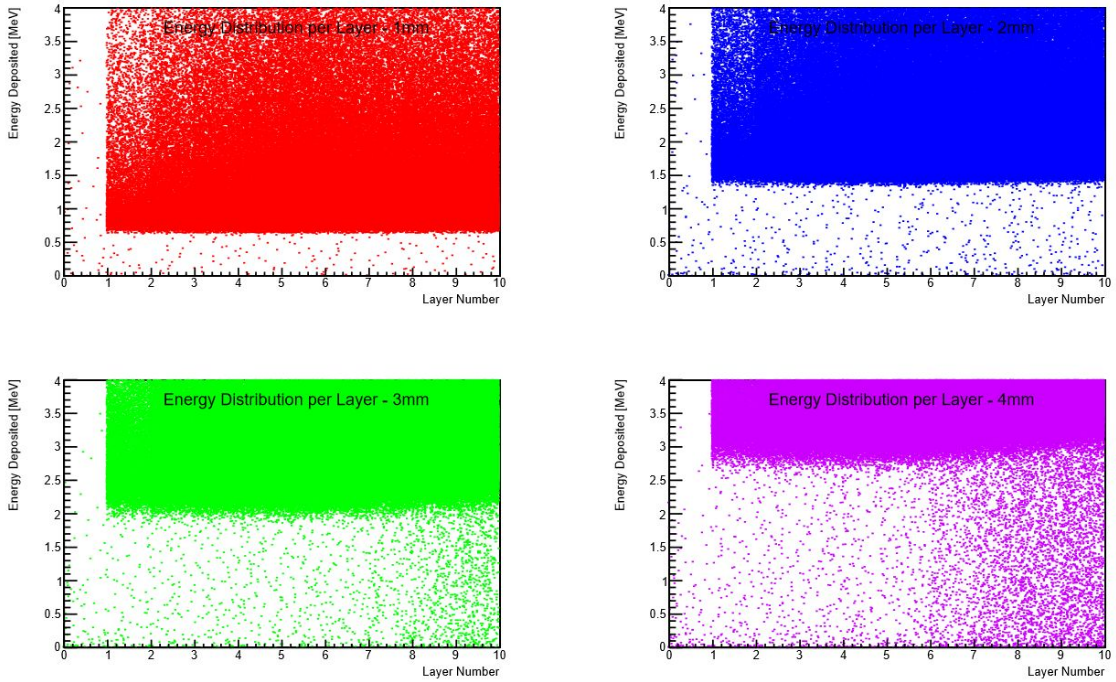


Deuteron Simulation

Results – Energy Distribution per Layer



Photon Showers Simulation



Deuteron Simulation

Results Summary

- Energy deposited per layer increases with scintillator thickness
- Energy deposited by photon showers in each layer is significantly lower than for deuterons
- Suggests the background from photons and deuterons can be separated and identified based on energy
- 4mm scintillator thickness appears the most promising
- Further simulation of proton input and improved analysis may confirm separability

Questions