Simulation of a Photodisintegration of ^{3}H Experiment in Geant4

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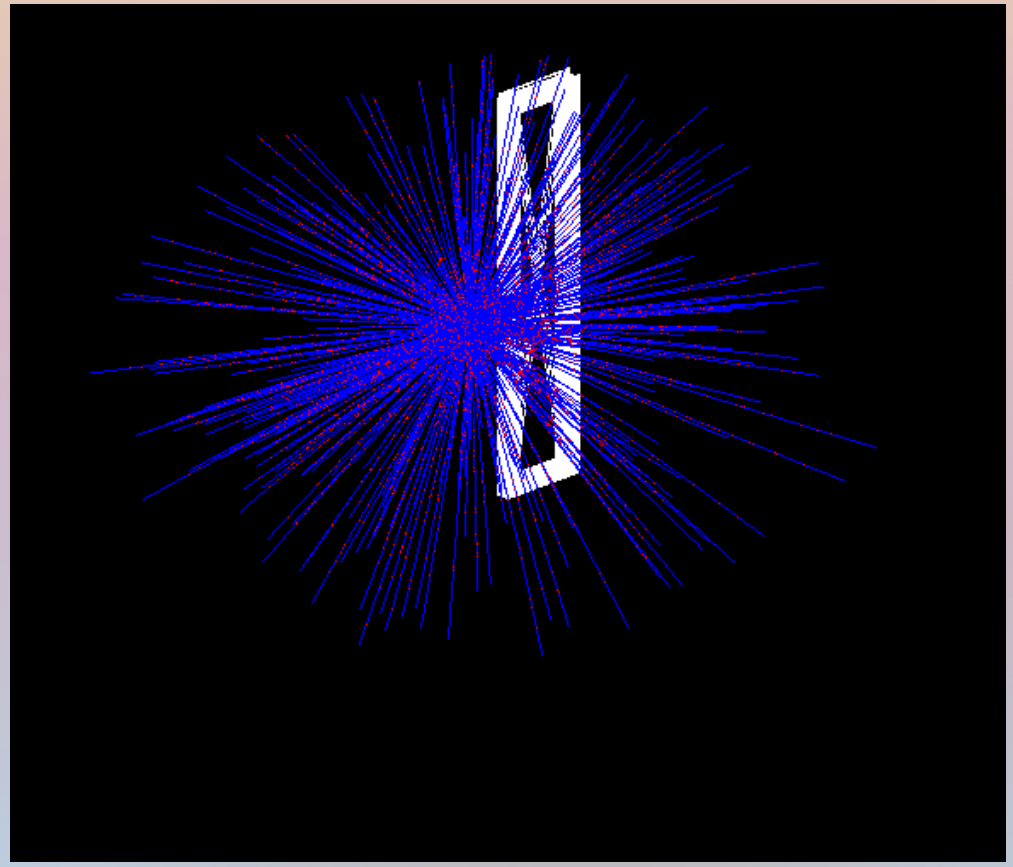


Introduction

- Photodisintegration of tritium allows us to explore pure NN interactions without complications of Coulomb interaction

- Two-body: $\gamma + {}^3H \rightarrow n + d$
- Three-body: $\gamma + {}^3H \rightarrow n + n + p$

- Interaction between any two nucleons can be characterized by a scattering length a_{nn} and an effective range r_{eff}

Potential vs distance

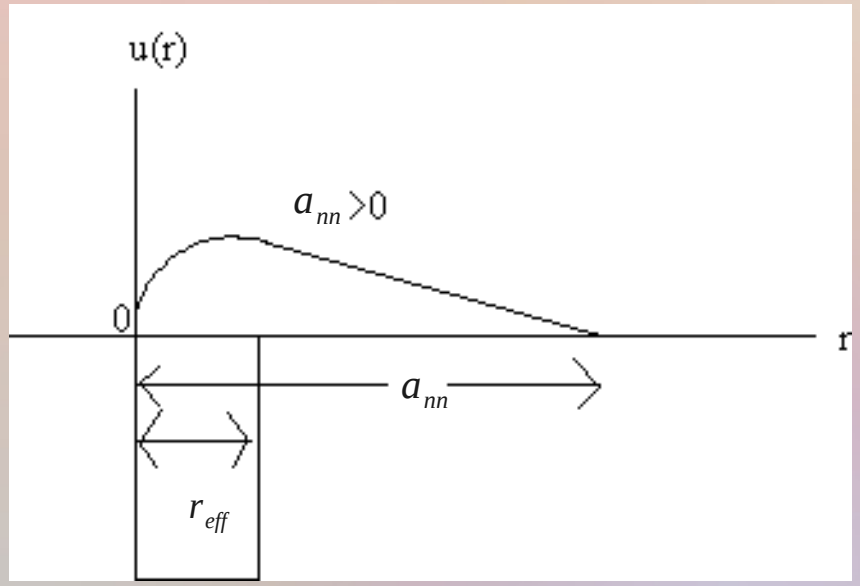


Image credit: http://electron6.phys.utk.edu/qm2/modules/m7/resonances.htm

Problems with Theory

- Quasi-free scattering: one particle is at rest in lab frame
- np QFS agrees with theory, but nn QFS is significantly underpredicted by theory

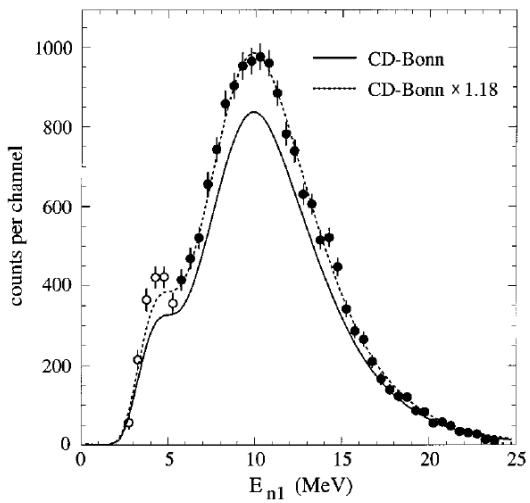


Figure Credit: [2]

- Increasing strength of nn interaction corrects cross-sections, but predicts a bound dineutron state

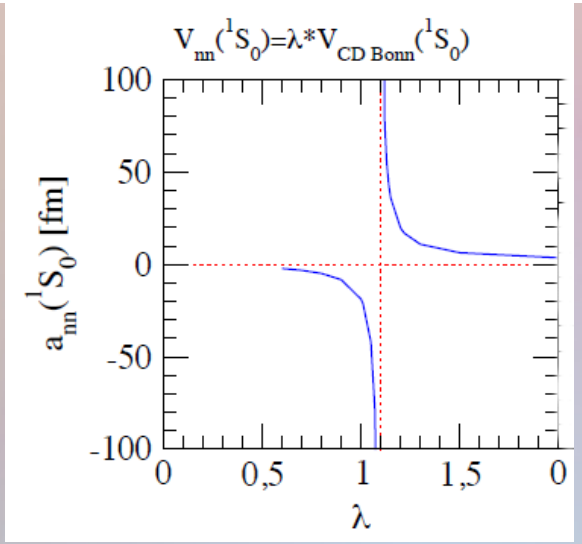


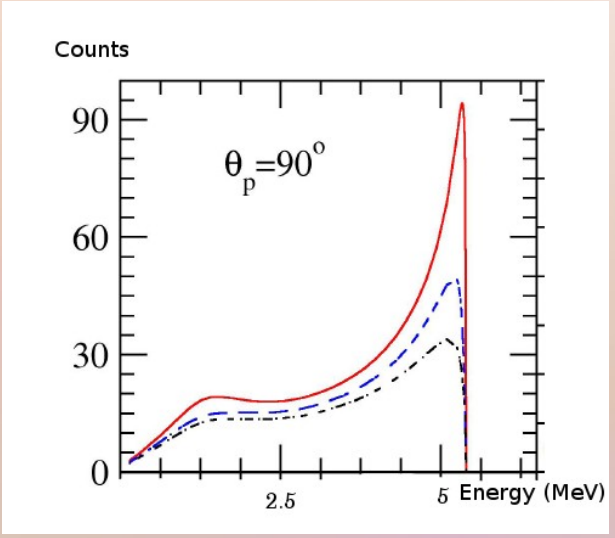
Figure Credit: [1]

Goals of the Experiment

$$\gamma + {}^{3}H \rightarrow n + n + p$$

- 3-body cross-section is very sensitive to strength of $^1S_0$ nn interaction

Red: $\lambda = 1.0$
Blue: $\lambda = 1.16$
Black: $\lambda = 1.22$



- Aim to provide best measurements of 2 and 3-body photodisintegration to date

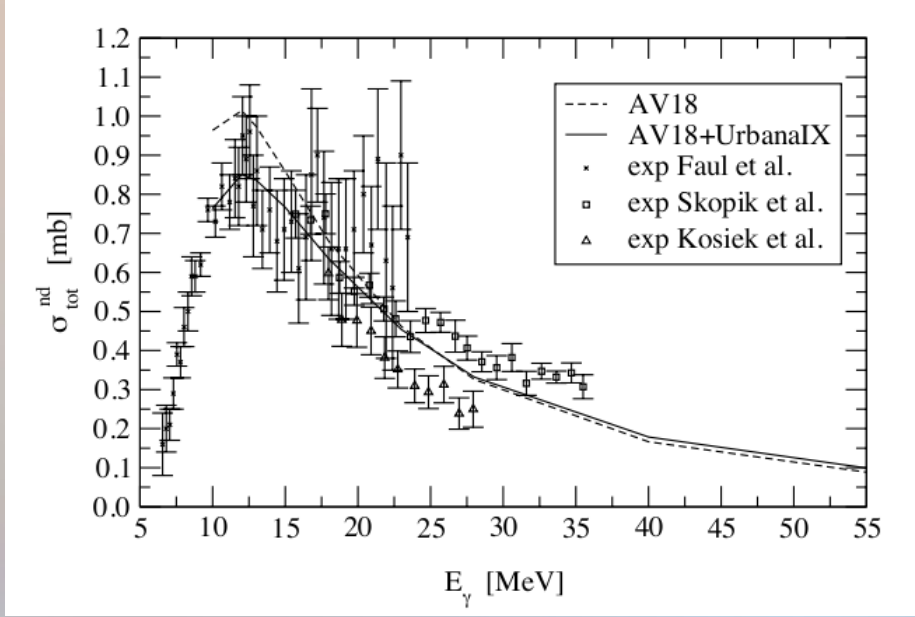
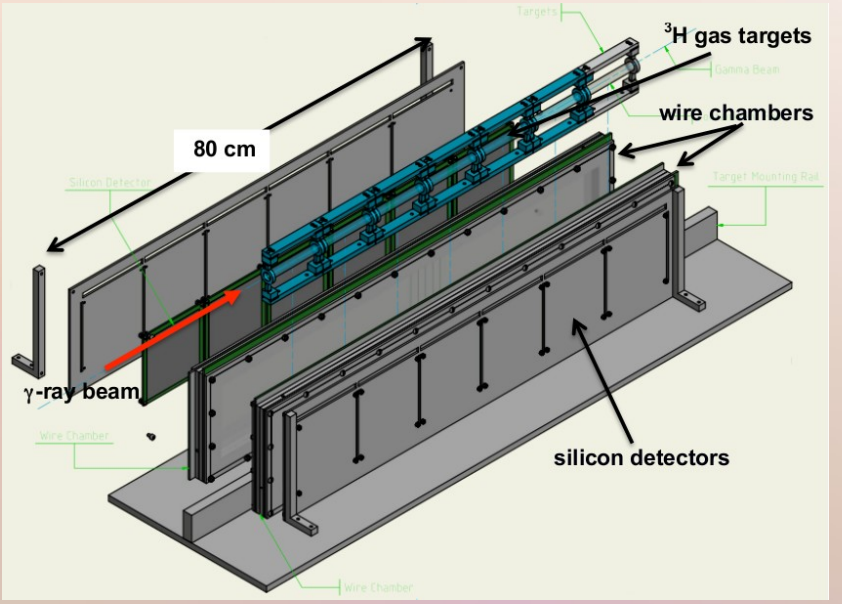


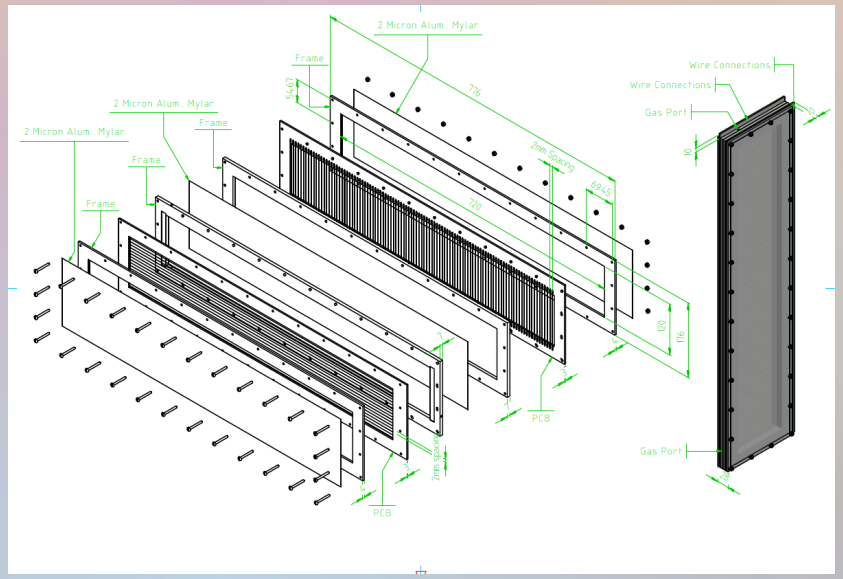
Figure Credit: (1)

Experimental Apparatus

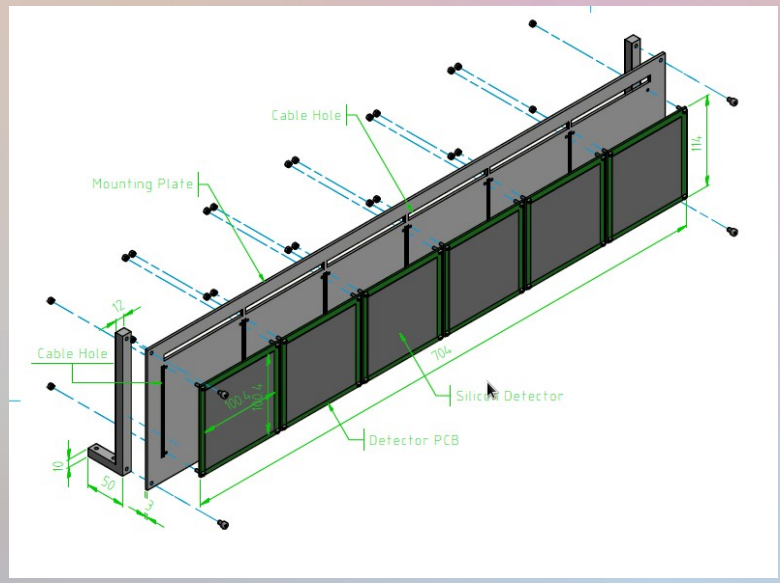
- Seven target chambers filled with a total of 23 mg of tritium
- Wire chambers on either side, followed by silicon detectors
- Detectors will record position, energy deposited, particle type, and time of flight



Wire Chamber



Silicon Detector

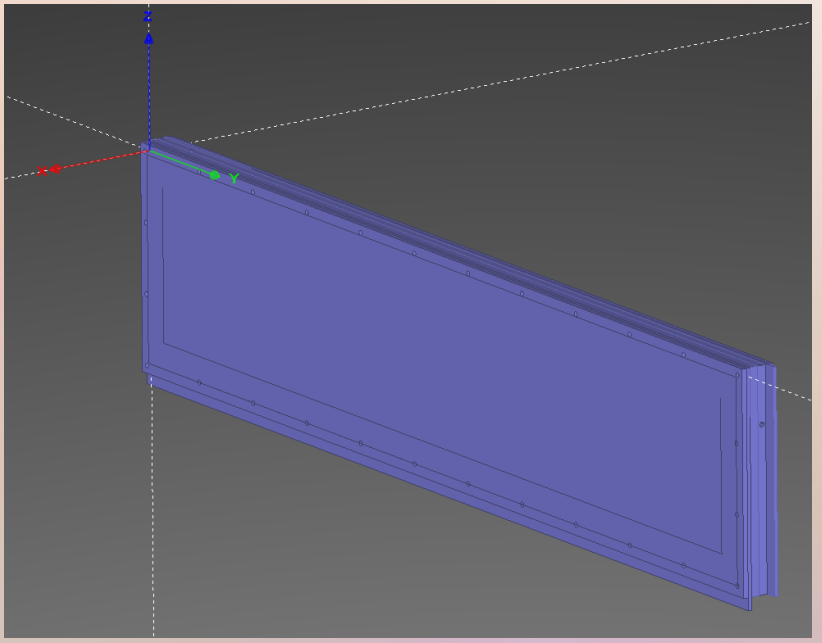


Why do we need a Monte Carlo simulation?

- Optimize detector geometry before construction
- Provide estimates of background counts so that we know what to look for
- Useful tool to test our data analysis algorithms

Simulation: Introduction

- 23 source code files, about 2500 lines of C++ code with full 3D visualization
- CAD files exported to Geant files through third-party software
- Geant sensitive detectors are associated with the proper logical volumes in the CAD file
- Quick and easy process to modify the simulation by changing the CAD files in Inventor

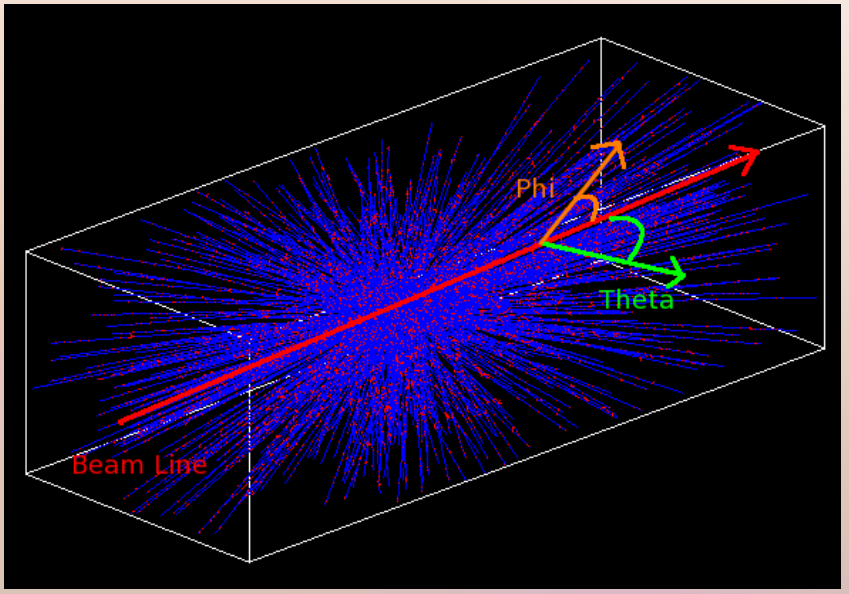


Simulation: Particle Emission

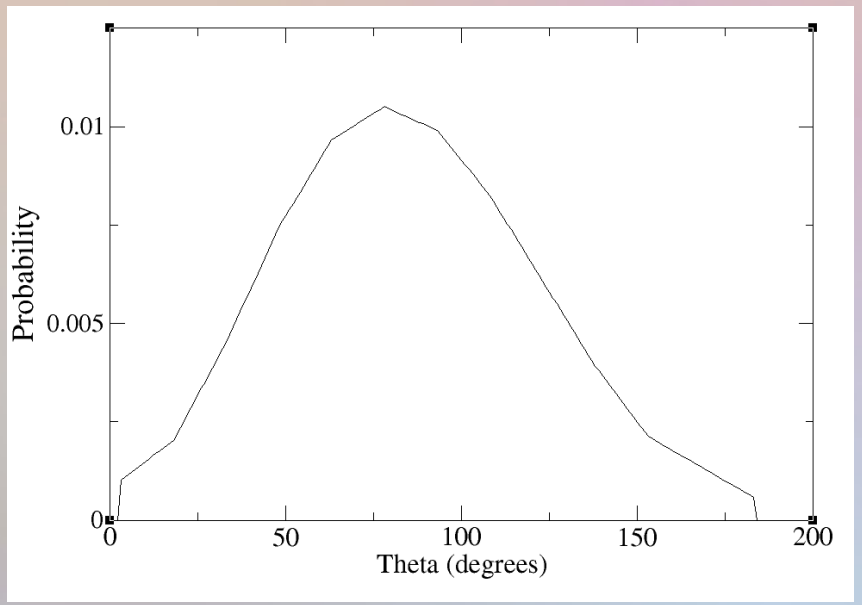
- Emission is not isotropic!
- Probability distribution function for φ is

$$\sigma(\theta,\varphi)=C(\theta)[1+fA(\theta)\cos(2\varphi)]$$

- Approximately goes as $\sin^2(\varphi)$

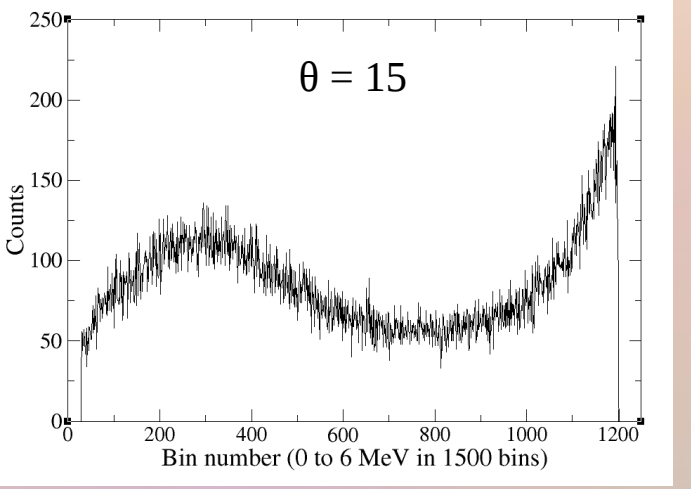


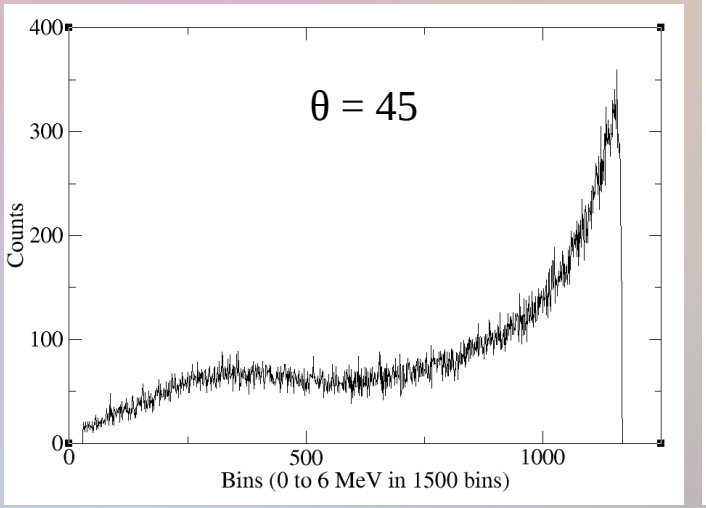
- PDF for θ is defined numerically from a 2D histogram of cross-section as a function of energy and θ

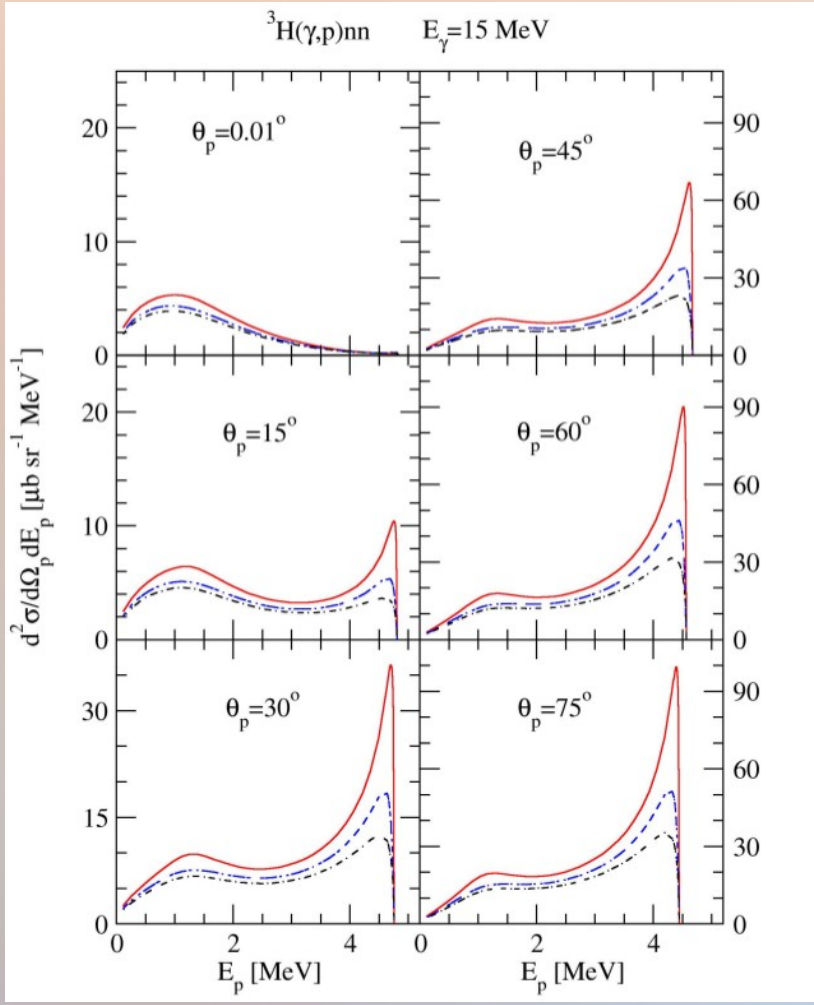


Simulation: Energy of the outgoing particle

- Energy PDF depends on θ, so I discretize the possible values of θ and generate an energy PDF table for each value.



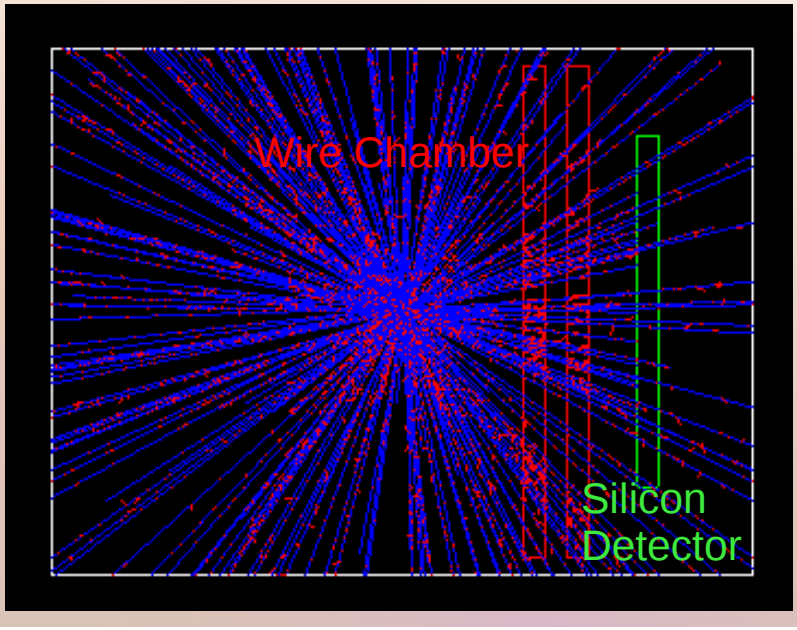




Simulation output

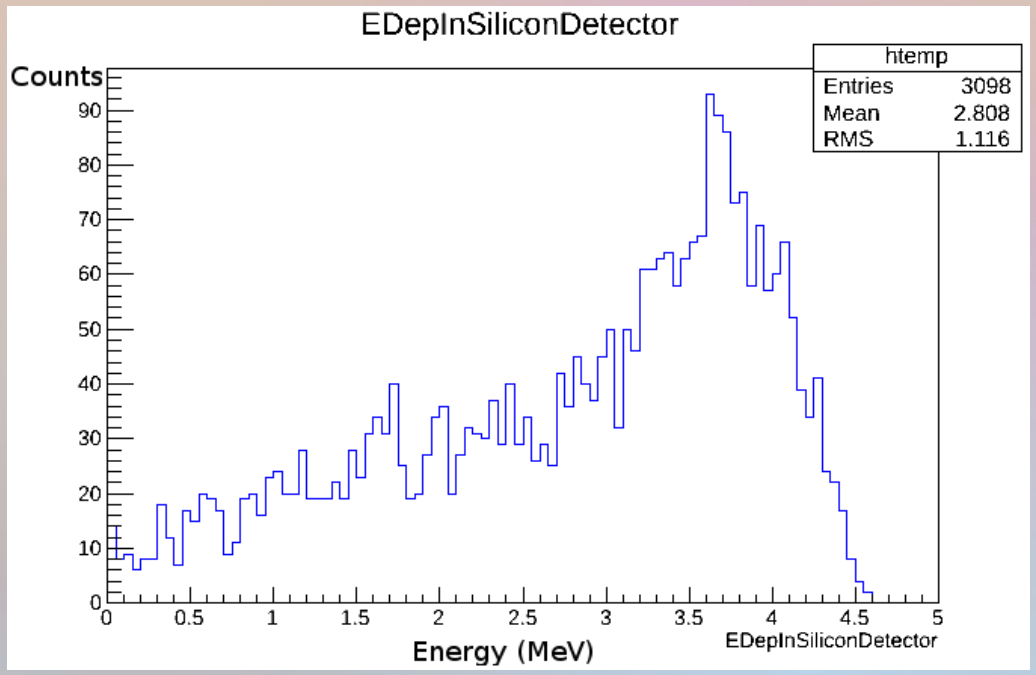
Program records:

- Position
- Time
- Energy
- Particle type



Outputs:

- ASCII files, in a format similar to that of actual data, and
- Root histograms, for easy data processing and testing analysis algorithms



Summary

- Experiment will improve measurements of differential cross-section of two and three-body photodisintegration of tritium
- Simulation will be used to optimize detector geometry, estimate background rates, and test data analysis algorithms
- Essentially complete – can be expanded to incorporate more geometry

References

- 1. C.R. Howell, *Differential Cross-Section Measurements of Two-and Three-Body Photodisintegration of the Triton and Search for a Bound Dineutron State*, [Conference] PAC-13, 2013.
- 2. Witala, Glockle. *The* nn *quasifree* nd *breakup cross section: Discrepancies with theory and implications for the* $^1S_0$ *nn force, Phys. Rev. C 83, 034004 (2011).*