Simulation of detector signals in $n + {}^3\text{He} \rightarrow p + t$
Geometry Factors and Optimizations using Monte Carlo

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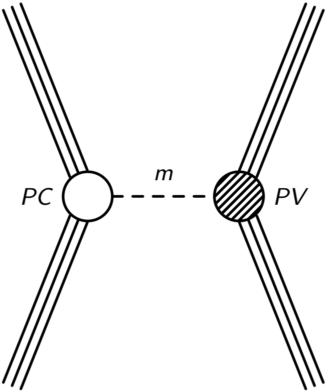
Experimental Outline

Simulation Method

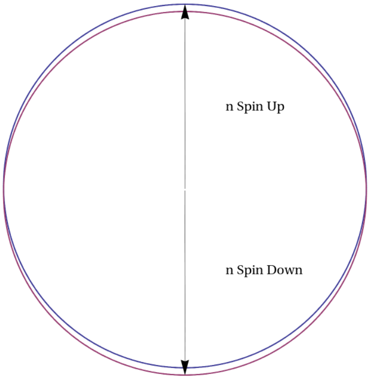
Experimental Outline

Hadronic Weak Interaction



Here is an example of a hadronic weak interaction. In the vertex on the left, a nucleon strongly couples to a meson (in the model we use, this is a π, ρ, or ω). In the vertex on the right, the meson will convert to a weak boson, which will in turn couple weakly to the other nucleon.

Emission Asymmetry

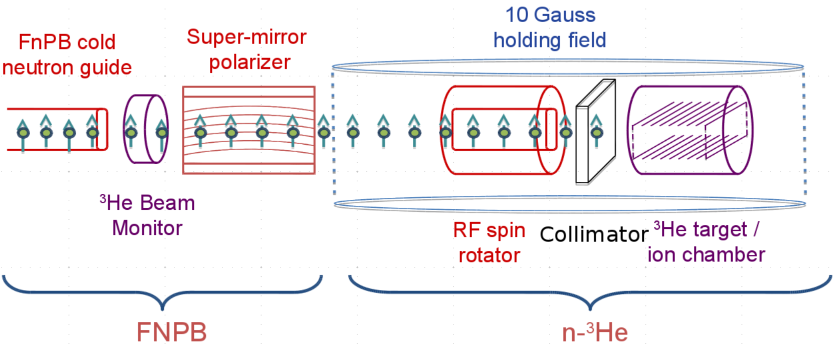


The experimentally measured asymmetry α_{phys} arises from the observable $\sigma_n \cdot k_p$:

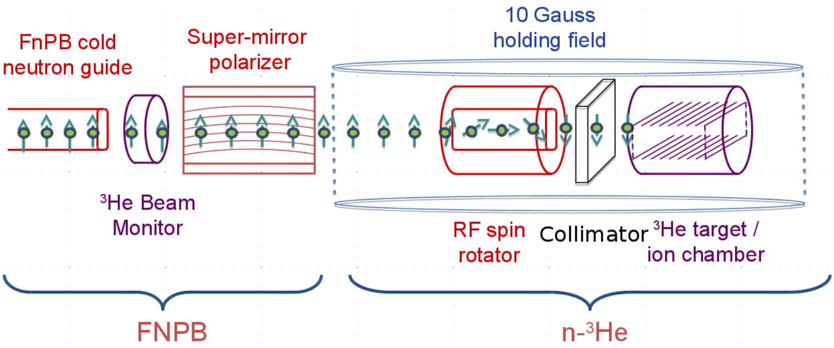
$$\frac{d\sigma}{d\Omega} = \frac{1}{4\pi}(1 \pm \alpha_p \cos\theta)$$

If the polarization of the neutrons is precisely controlled, the parity of the reaction can be observed. Since weak interactions do not conserve parity, any weak coupling will produce an asymmetric distribution in the reaction products. So we can use the measurement of the asymmetry as a test of the strength of these weak couplings.

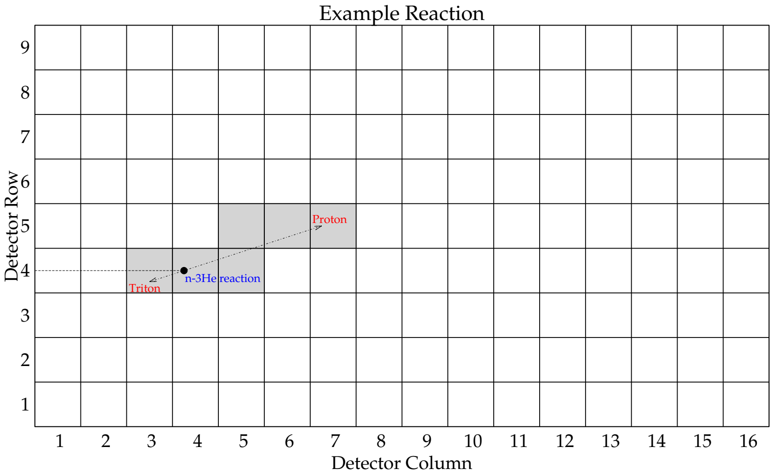
Instrument Diagram – Spin Up



Instrument Diagram – Spin Down



Wire Chamber Model



The proton carries 573 keV away from the reaction, and the triton carries 191 keV. These products will ionize the ^{3}He and travel a total of 12 cm in the gas.

Basic Arithmetic Asymmetry

$$Y^{\kappa} = \langle E^{\kappa}(1 + \alpha \cos\theta) \rangle$$

$$\frac{Y_{+}^{\kappa} - Y_{-}^{\kappa}}{Y_{+}^{\kappa} + Y_{-}^{\kappa}} = \alpha_{\kappa} \frac{\langle E^{\kappa} \cos\theta \rangle}{\langle E^{\kappa} \rangle} \Rightarrow \boxed{G_{\kappa} = \frac{\langle E^{\kappa} \cos\theta \rangle}{\langle E^{\kappa} \rangle}}$$

$$\alpha_{\kappa} = \frac{1}{G_{\kappa}} \frac{Y_{\kappa}^{+} - Y_{\kappa}^{-}}{Y_{\kappa}^{+} + Y_{\kappa}^{-}}$$

We will call the mean sensitivity the geometry factor.

Simulation

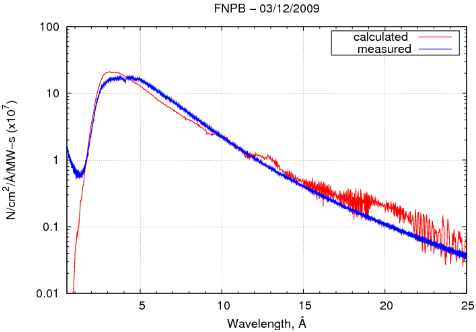
Simulation Objectives

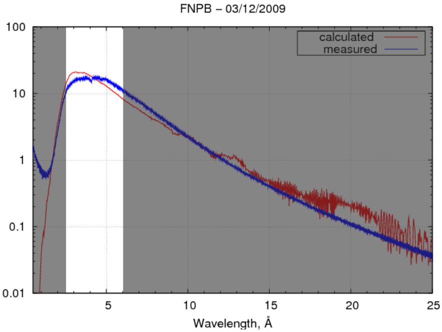
Some desired simulation objectives:

-Calculated geometry factors
-Optimized pressure
-Optimized collimation
-Estimated running time / uncertainty
-Model gains and correlations

In order to construct a successful simulation, one must find the best compromise between complex physics and fast calculations. It also should be scalable and able to take advantage of parallel resources. A custom code will allow the best approximations to be made where available for a given system.

Neutron Wavelength

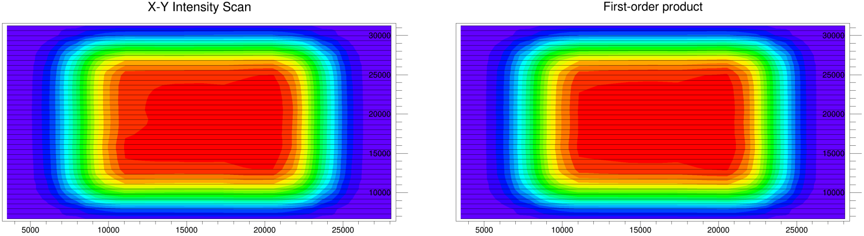




Left: the wavelength distribution of neutrons traveling down the guide of BL-13 at SNS.

Right: the distribution after a pair of choppers blocks neutrons outside of the peak intensity range. The resulting spectrum has energies from approximately 2.5Å to 6Å.

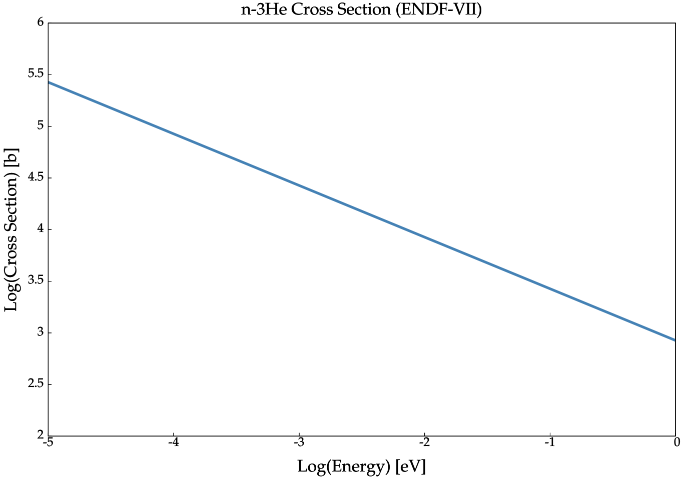
Physical Beam Profile



The beam was scanned on a grid to determine the centroid and shape. Shown on the left is the upstream scan, right after the neutrons exit the guide aperture.

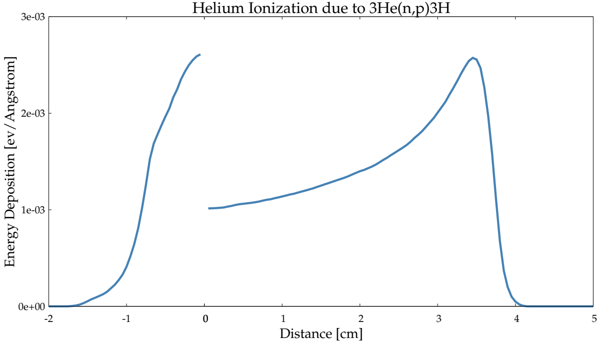
On the right is a model for the beam shape which is calculated using two one-dimensional generators instead of a two-dimensional one, approximating the shape well, ($\chi^2 = 0.01$), and making the computation considerably faster.

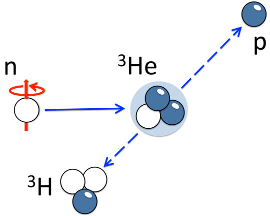
Time-dependent Cross Section



Cross section generated from function, rather than by lookup, by taking advantage of $\frac{1}{v}$ behavior. Linear parameter found by fitting ENDF data to linear function: $C = 2.92709$

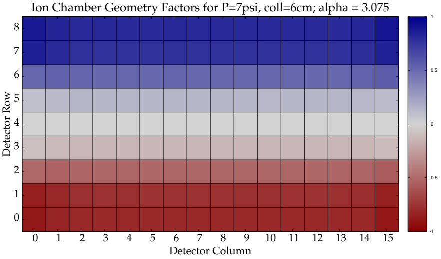
Ion Energy Deposition

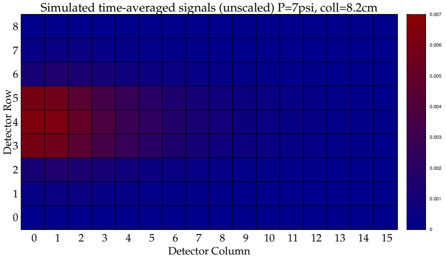




Energy deposition curve at 1 atm. This is adjusted depending on simulated pressure. Pre-integrate deposition curves and interpolate the difference instead of integrating every time!

Geometry Factors and Yields



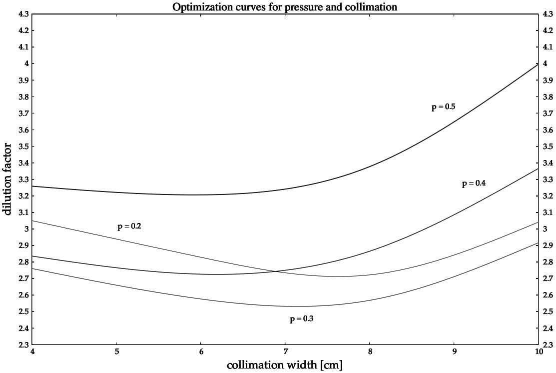


Left: plot of the sign and size of the geometry factors in the chamber.
Right: an unscaled simultation of the time-summed signals observed in each element.

$$\alpha_\kappa = \frac{1}{G_\kappa}\frac{Y_\kappa^+ - Y_\kappa^-}{Y_\kappa^+ + Y_\kappa^-}$$

Apply to Experimental Optimization

The uncertainty in alpha can be calculated from simulation. This can then be used as an optimization metric.



$$\sigma_{\alpha_\kappa \alpha_\beta} = \frac{\langle E^\kappa E^\beta \rangle}{2\langle E^\kappa \cos\theta \rangle \langle E^\beta \cos\theta \rangle}$$

$$\boxed{\frac{1}{\sigma_\alpha^2} = \sum_i \sum_j [\sigma_{\alpha_\kappa \alpha_\beta}]_{ij}^{-1}}$$

n3He Collaboration

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