Geometry Factors pt. II, Error Analysis, and Optimizations

Christopher Coppola

November 11, 2014

Simulation Goals

-Calculate geometry factors
-Optimize pressure and collimation variables
-Estimate running time

Completed Improvements

-Using mersenne twistor generator
-Updated beam divergence model
-Change structure to weighted variables
-Addition of covariant errors
-Many small speedups
-Statisics anomaly resolved

Statistics-dependent effect

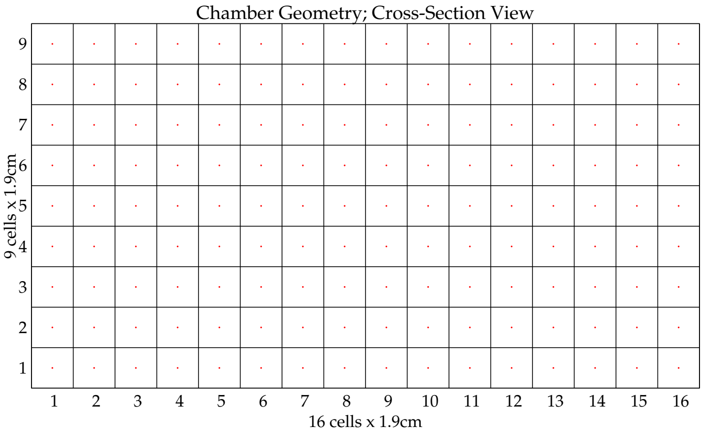
For simplicity, consider the diagonal approximation to the uncertainty:

$$\frac{1}{\sigma_d^2} \approx \sum_{\kappa} \frac{1}{\sigma_\kappa^2}$$

$$\sigma_d = \frac{1}{\sqrt{\frac{1}{\sigma_1^2} + \frac{1}{\sigma_2^2} + \frac{1}{\sigma_3^2} + \ldots}} = \frac{1}{\sqrt{\frac{G_1^2}{c_1} + \frac{G_2^2}{c_2} + \frac{G_3^2}{c_3} + \ldots}}$$

The factors c_i consist of terms which converge very rapidly. The G_κ fluctuate randomly in (-1,1) as sample size is increased. As the sample size gets large, they approach their true value. Since they appear squared in all terms, factors which are slightly too large will have a significant effect on the value of σ_d. For statistically insufficient sample sizes, σ_d is underestimated. With a large enough sample size, the value stabilizes.

Cell Diagram



View in the yz-plane of the wire chamber.

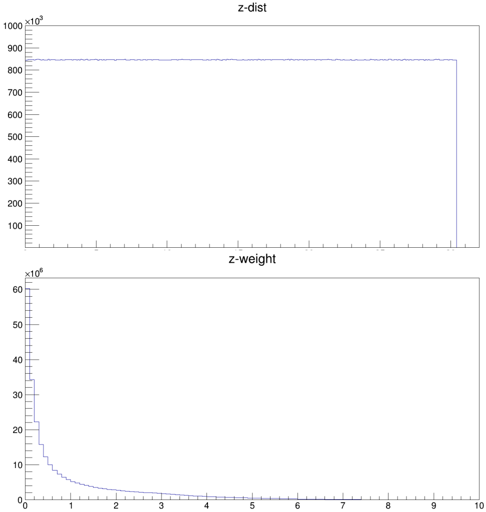
Cell Model

1. Model the wire chamber as 144 cells which collect all charge deposited in a parallelepiped set by the surrounding high voltage wires.

2. Each cell is 1.9 cm x 1.9cm x 17.1 cm. (There is a small correction to the volume of the top and bottom row of cells, since they are smaller).

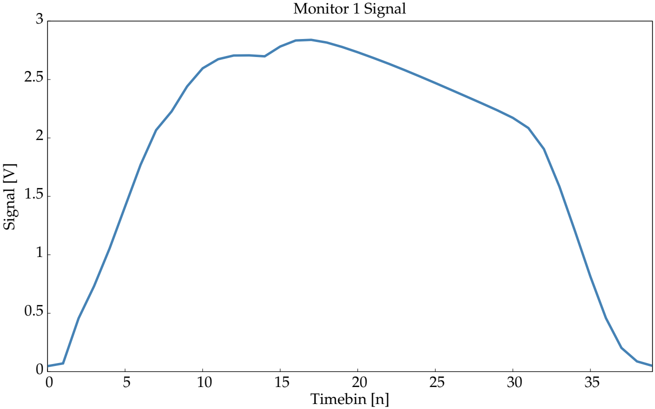
3. Assume the ^{3}He is contained inside the total cell volume. This is the ^{3}He "buffer."

Weighting Scheme



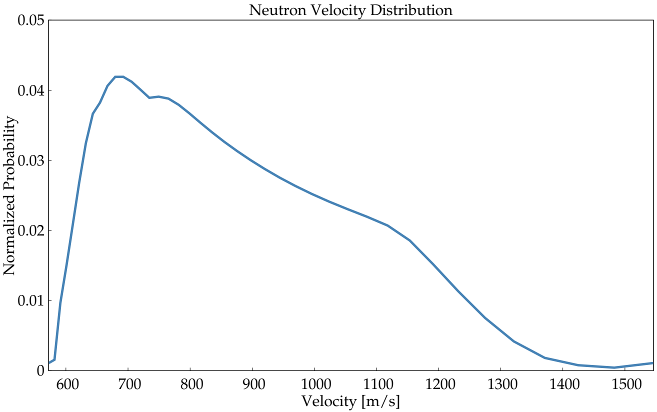
Instead of using kinematic variables, use normally distributed variables in x,y,z, and t, with corresponding weights.

Time Signal



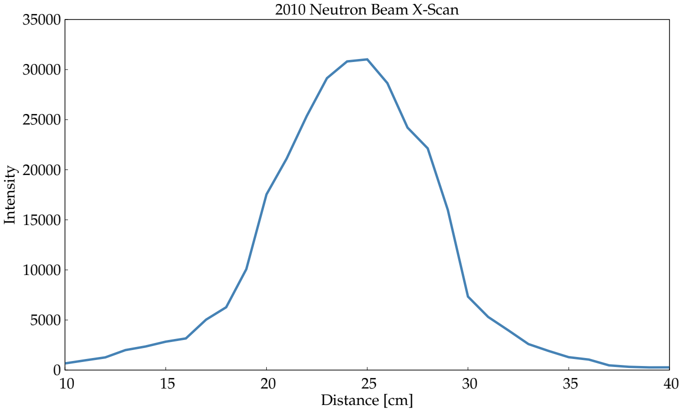
40-timebin neutron intensity signal from Monitor 1.

Neutron Velocity Distribution



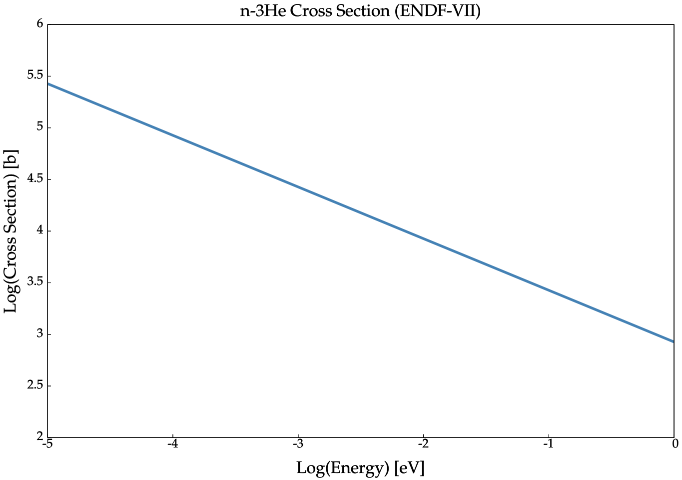
Velocity distribution generated from time-of-flight analysis: $v = \frac{15.15}{.0098 + \frac{tbin}{2400}}$

Beam Profile



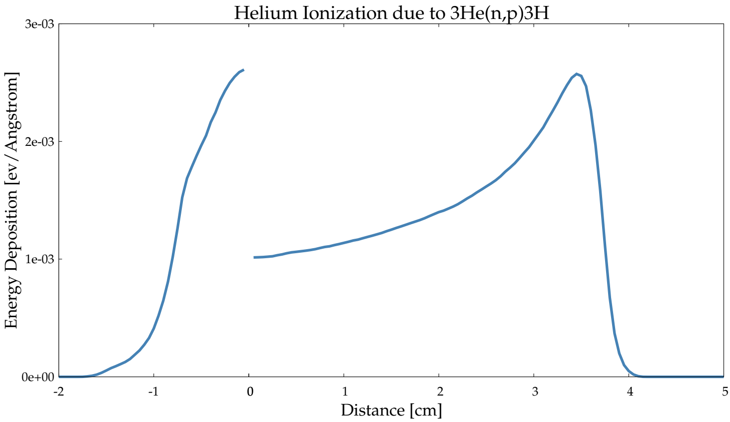
New fitting function for beam profiles based on gaussian dispersion model: $I = \frac{I_0}{2}\left[Erf\left(\frac{\mu - x}{\sigma\sqrt{2}}\right) + Erf\left(\frac{\mu + x}{\sigma\sqrt{2}}\right)\right]$

Cross Section

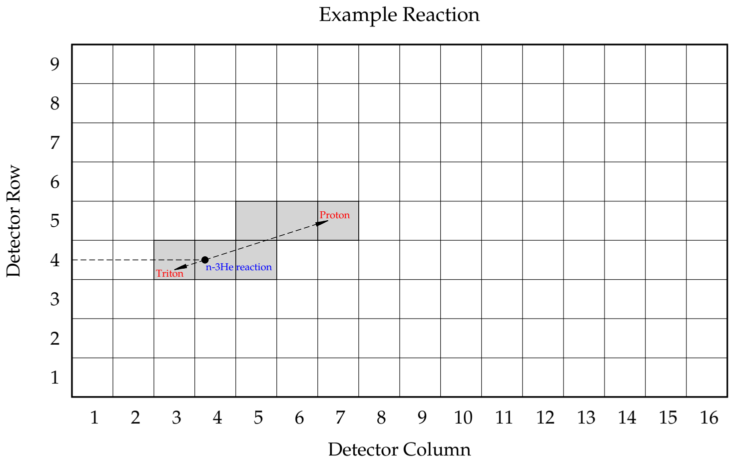


Cross section generated from function, rather than by lookup. Linear parameter found by fitting ENDF data to linear function: $C = 2.92709$

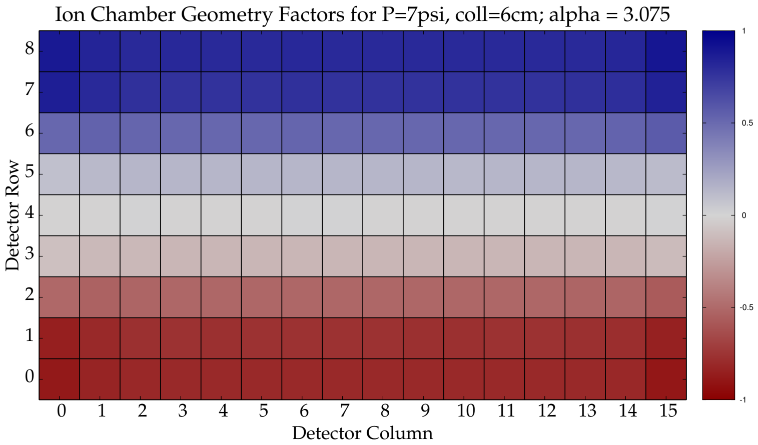
Ion Energy Deposition



Tracking Matrix



Geometry Factors



Quantities

To calculate geometry factors and our dilution factor, we will need to track the mean energy deposited into a cell, the mean energy weighted by the cosine, and the mean covariant energy between two different cells.

$$\langle E^{\kappa} \rangle$$

$$\langle E^{\kappa} \cos\theta \rangle$$

$$\langle Q^{\kappa\beta} \rangle$$

Calculation of α_κ

The element asymmetry α_κ depends on G_κ and the measured yields of that element.

$$Y_h^\kappa = \langle E^\kappa (1 + h\alpha \cos\theta) \rangle$$

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

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

Calculation of α

We will combine each element asymmetry to form the combined physics asymmetry.

$$\alpha = \sum_{\kappa} w_{\kappa}\alpha_{\kappa} = \vec{w} \cdot \vec{\alpha}$$

$$\sum_{\kappa} w_{\kappa} = 1$$

Choose weighting that minimizes uncertainty.

Error in α

$$\sigma_\alpha^2 = \sum_i \sum_j \frac{\partial \alpha}{\partial \alpha_i} \frac{\partial \alpha}{\partial \alpha_j} \sigma_{\alpha_i \alpha_j} = \sum_i \sum_j w_i w_j \sigma_{\alpha_i \alpha_j} = \vec{w}^{\mathsf{T}} \cdot \hat{\sigma}_{ij} \cdot \vec{w}$$

Must have method to calculate $\hat{\sigma}_{ij}$ from fundamental quantities:

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

For diagonal elements, this reduces to:

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

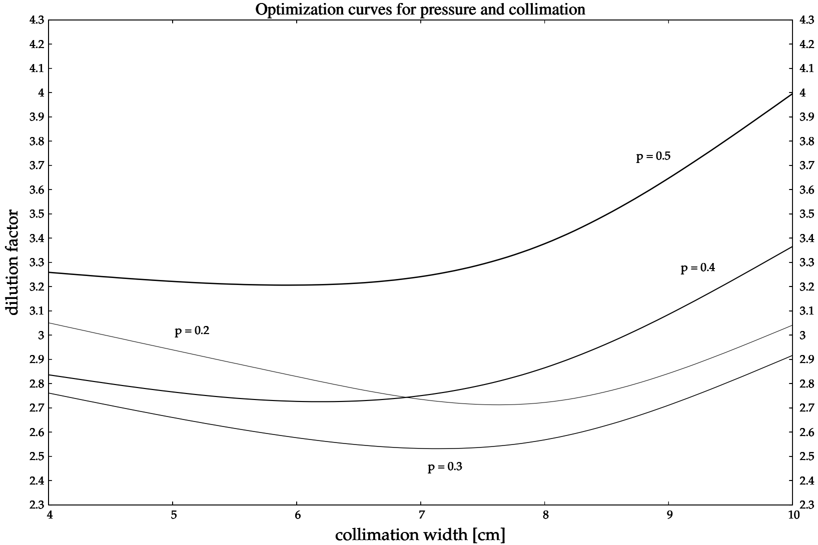
Optimization

$$\frac{\partial \sigma^2_{\alpha_\kappa}}{\partial w_k} = \lambda_k \frac{\partial(\sum_i w_i - 1)}{\partial w_k}$$

$$\Rightarrow \textit{minimized } \sigma^2_{\alpha_\kappa} = \sum_i \sum_j \hat{\sigma}_{ij}^{-1}$$

Apply to pressure and collimation parameters.

Results


Optimization curves for pressure and collimation
dilution factor
collimation width [cm]
p = 0.5
p = 0.4
p = 0.2
p = 0.3
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
4
5
6
7
8
9
10

Planned Improvements

-New beam scan will improve precision of x-y positioning.
-Drift time analysis will give more realistic signal timing.