The influence of SNS intensity fluctuations on the uncertainty of the n-^{3}He asymmetry

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n-3He analysis meeting

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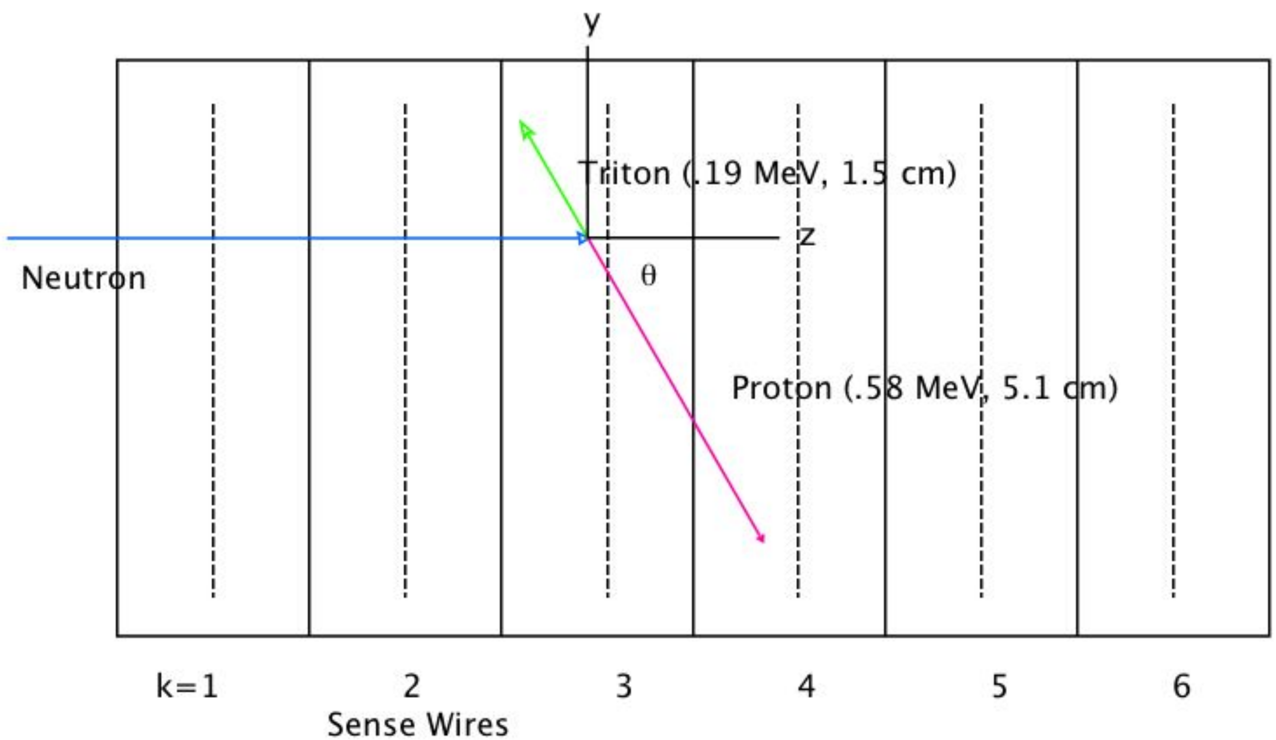
Symplified diagram of ion chamber.



Neutrons are polarized along z. The polarization is flipped on alternate pulses. Pol=h. h=±1.

Neutrons enter from –z

n + ^{3}He ––> p+^{3}T

$W[\theta]=1+A\,\mathrm{Cos}[\theta]$. We seek to measure the asymmetry, A.

The distribution of z values at which neutrons capture is exponential
$P(z) \sim \mathrm{Exp}[-z/\lambda]$
$\lambda \sim 5$ cm.

The reaction products (p and ^{3}T) deposit energy in the detector cells.

For each pulse pair, the amount of energy deposited in cell k depends on h

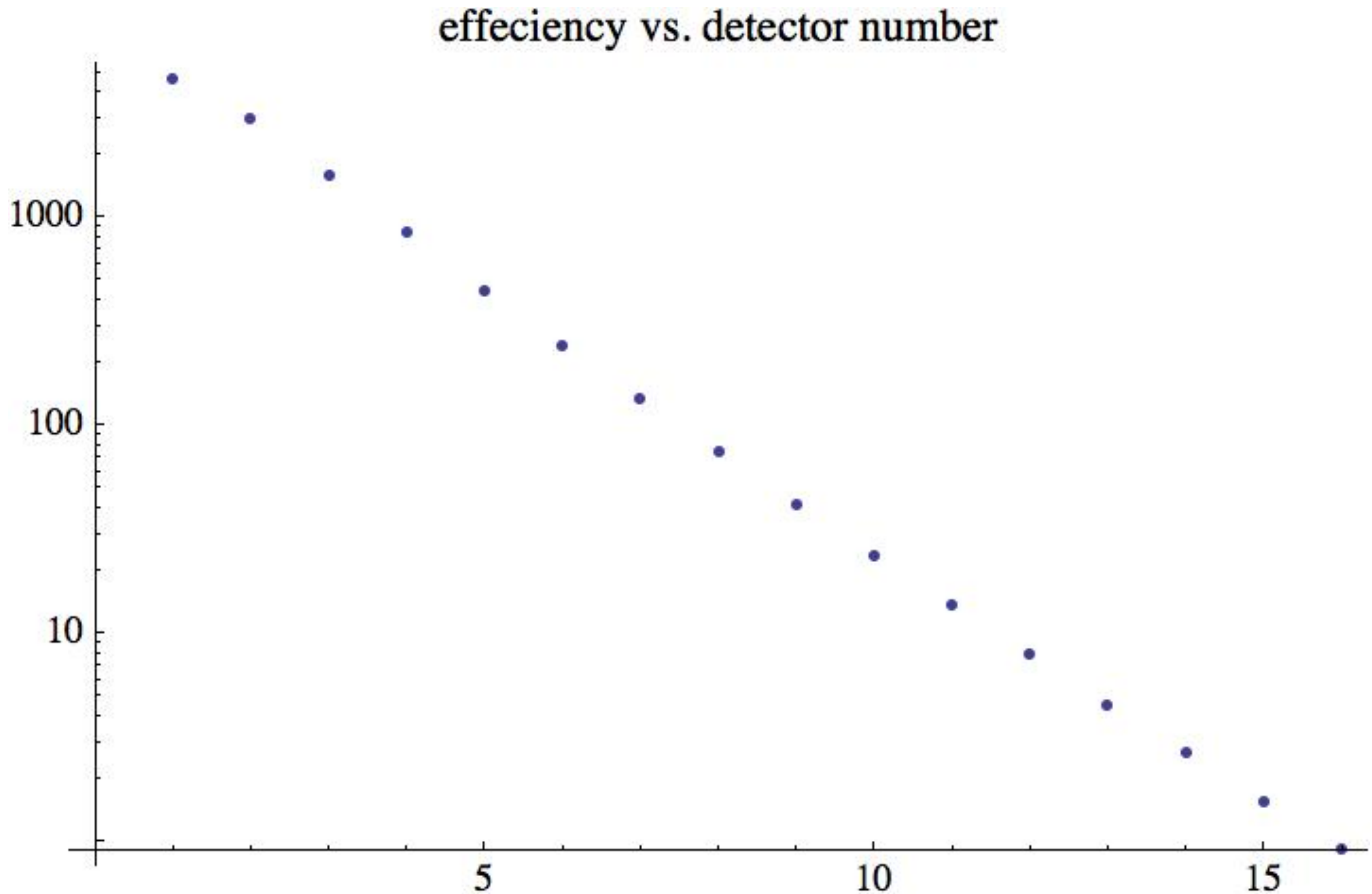
$Y_k = (E_k[+]-E_k[-])/(E_k[+]+E_k[-]) = A\, g_k$. g_k are called geometric factors.
Each pulse pair gives a measure of the asymmetry, A.

The uncertainty in Y_k is $\sigma_k^2 = <E_k^2>/<E_k>^2 \;\; 1//(2N\Omega_k)$.
N is the number of neutrons per pulse. Ω_k is the fraction of neutrons
That deposit energy in cell k. <> denotes average over events.

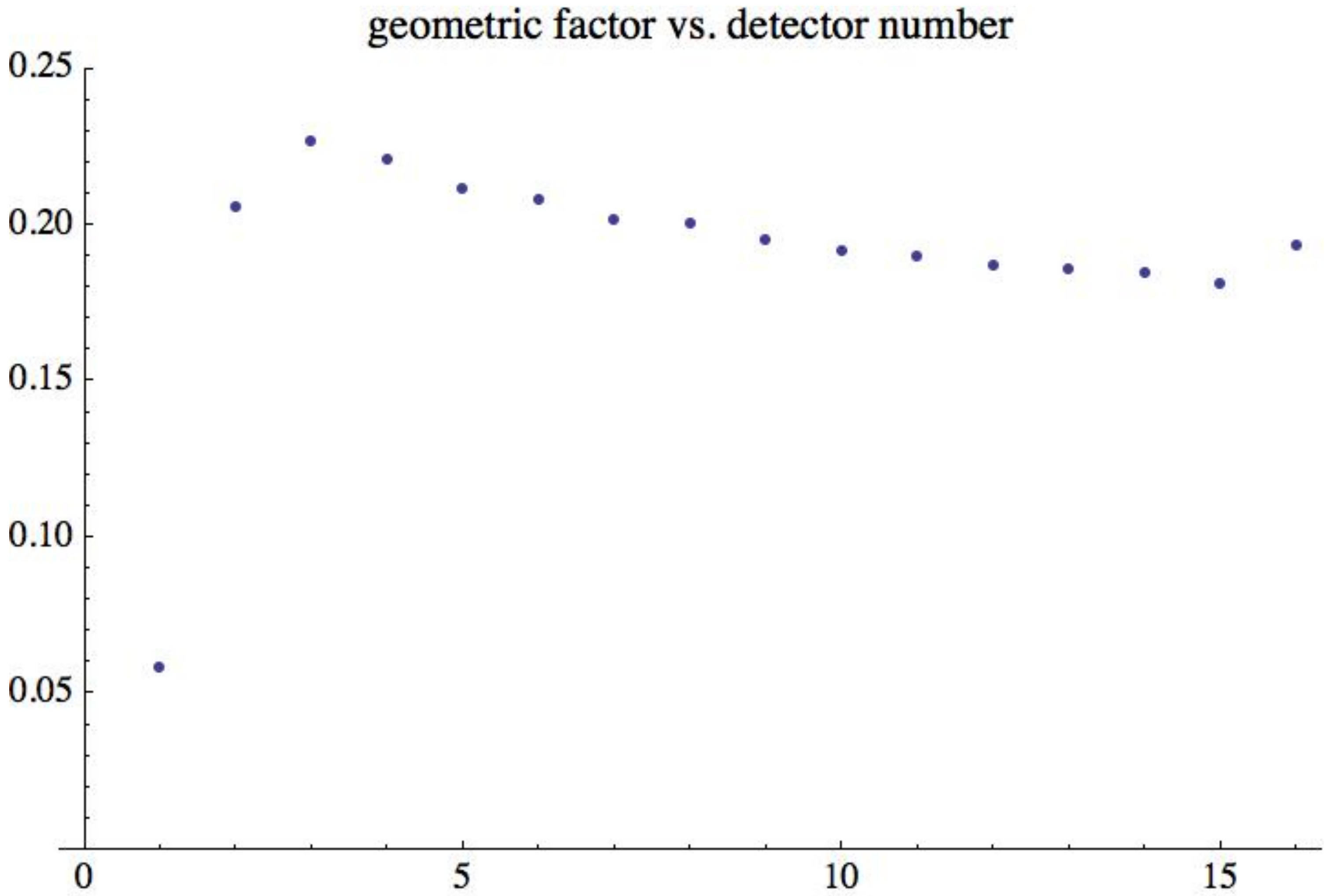
Determine A using a least-squares fit

$$\chi 2(A) = \sum_k \left(A\, g_k - Y_k\right)^2 \frac{2N\Omega_k \left\langle E_k \right\rangle^2}{\left\langle E_k^2 \right\rangle}$$

$$\sigma^2(A) = \frac{1}{2N} \frac{E_k^2}{\sum_k g_k^2\, \Omega_k \left\langle E_k \right\rangle^2}$$



Simulation data from Chris Crawford



Simulation data from Chris Crawford

Now consider beam intensity fluctuations. The plot thickens

$\delta I = (I[+] - I[-])/(I[+] + I[-])$ is the fractional difference for a pulse pair

The expression for Y_k gets an intensity term.
$Y_k = (E_k[+] - E_k[-])/(E_k[+] + E_k[-]) = A\ g_k + \delta I$

Each pulse pair depends on both the asymmetry, A, and δI.

As before, use a least-squares fit, but now determine both A and δI.

All the detectors have the same δI.

Assume that $\frac{\langle E_k \rangle^2}{\langle E_k^2 \rangle}$ is independent of k.

$$\chi 2(A, \delta I) = \sum_k \left(A\, g_k + \delta I - Y_k\right)^2 \frac{2N\Omega_k \langle E \rangle^2}{\langle E^2 \rangle}$$

The measurement matrix is

$$M = \frac{2N\Omega_k \langle E \rangle^2}{\langle E^2 \rangle} \begin{pmatrix} \sum_k g_k^2 \Omega_k & \sum_k g_k \Omega_k \\ \sum_k g_k \Omega_k & \sum_k \Omega_k \end{pmatrix}$$

The uncertainty in A is the 1,1 component of M^{-1}

$$\sigma^2(A) = \frac{\langle E^2 \rangle}{\langle E^2 \rangle} \frac{1}{2N} \frac{\sum_k \Omega_k}{\sum_k g_k^2 \Omega_k \sum_k \Omega_k - \left(\sum_k g_k \Omega_k\right)^2}$$

The uncertainty in A is increased by the addition of intensity fluctuations to the fit. The ratio of the uncertainty in *A* with and without intensity fluctuations does not depend on the common Factors in *M*.

$$Rat = \frac{\sum_k g_k^2 \Omega_k \sum_k \Omega_k}{\sum_k g_k^2 \Omega_k \sum_k \Omega_k - \left(\sum_k g_k \Omega_k \right)^2}$$

First case: All the *g*’s are the same

$$Rat = \frac{\sum_k g_k^2 \Omega_k \sum_k \Omega_k}{\sum_k g_k^2 \Omega_k \sum_k \Omega_k - \left(\sum_k g_k \Omega_k \right)^2} = \frac{g^2}{g^2 - g^2} = \infty$$

Second case: Pairs of g’s have equal and opposite values,
As in NPDGamma.

$$\sum_k g_k \Omega_k = 0$$

$$Rat = 1$$

The opposite g_k terms in $\chi 2$ cancel and M is diagonal.

Finally use the results of Chris Crawford's simulation

$$M = \begin{pmatrix} .0278 & .1482 \\ .1482 & 1.0 \end{pmatrix}$$

$$M^{-1} = \begin{pmatrix} 170.5 & -25.3 \\ -25.3 & 4.75 \end{pmatrix}$$

$$Rat = 4.75$$

$$\sigma(A)_{\text{with } \delta/\text{l}} = 2.2\,\sigma(A)_{\text{without } \delta/\text{l}}$$

What can we do to reduce the increase in $\sigma(A)$

- Increase the thickness of M2 to better measure beam intensity
  - Fewer neutrons hit the detector. reduced statistics
- Increase M1 thickness
  - 2 times better measurement of I than with M2 for the same fraction of beam loss.
  - M1 is highly activated

- Run with vertical polarization
  - g's cancel in pairs
  - g's are ~ 2 times larger
  - In order to control systematic uncertainty from the parity allowed asymmetry, we must adjust the polarization to be parallel to B to within .002 rad.

Not clear what to do.
In order to make a decision, careful analysis and modeling of options are required