Magnetic field for

“PANDA*”

*Proton Asymmetry in Neutron Decay

For the SNS-FnPB Magnet meeting

Prepared by Tim Chupp
The proton Asymmetry

Asymmetry: $\frac{N_+ - N_-}{N_+ + N_-} = C P_n A F (1-f) + A_{\text{false}}$

$C = k(A+B) = 4k \frac{|\lambda|}{1+3|\lambda|^2}$

$\lambda = \frac{g_A}{g_V}$ \hspace{1cm} k=0.27484

Standard Model

$\frac{dW}{dE_e d\Omega_e d\Omega_\nu} = S(E_e) \left[ 1 + a \frac{p_e \cdot p_n}{E_e E_n} + b \frac{m_e}{E_e} + \frac{J}{J} \left( A \frac{p_e}{E_e} + B \frac{p_\nu}{E_\nu} + D \frac{p_e x p_\nu}{E_e E_\nu} \right) \right]$
C and \( \lambda \) 

\[
C = k(A + B) = 4k \frac{|\lambda|}{1 + 3|\lambda|^2}
\]

<table>
<thead>
<tr>
<th>PDG 2005</th>
<th>( \frac{\sigma_{\lambda}}{\lambda} / \frac{\sigma_x}{x} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda )</td>
<td>-1.2695( \pm )0.0029</td>
</tr>
<tr>
<td>a</td>
<td>-0.103( \pm )0.004</td>
</tr>
<tr>
<td>A</td>
<td>-0.1173( \pm )0.0013</td>
</tr>
<tr>
<td>B</td>
<td>+0.983 ( \pm )0.004</td>
</tr>
<tr>
<td>C</td>
<td>+0.238 ( \pm )0.011*</td>
</tr>
<tr>
<td>D</td>
<td>-0.0004( \pm )0.0006</td>
</tr>
<tr>
<td>( \phi )</td>
<td>180.06( \pm )0.0029</td>
</tr>
</tbody>
</table>

* Abele, 2005

\[
\frac{dW}{dE_e d\Omega_e d\Omega_v} = S(E_e) \left[ 1 + a \frac{p_e \cdot p_n}{E_e E_n} + b \frac{m_e}{E_e} + \frac{J}{J} \left( A \frac{p_e}{E_e} + B \frac{p_v}{E_v} + D \frac{p_{e x p v}}{E_e E_v} \right) \right]
\]

JTW-57
Rudimentary Layout

For adiabatic neutron spin transport

Neutron spins transported Through detector

Detailed design work needed.

Uniform field B
General Design Issues

Goal: $\sigma_x/x \sim 10^{-3}$ or better

- Neutron spin transported adiabatically from polarizer to analyzer (through detector)
- Uniform B in decay region: mitigates proton reflections from magnetic traps
- Proton orbit: $d= 8 \text{ mm}/B(T)$: 1-2T Needed (2 T for emiT proton segment)
- Electrostatic proton energy resolution desired: requirements on B in proton drift region TBA
- Vacuum requirements: TBA
Neutron Polarization and Polarimetry

\[ \Gamma_\pm = \Sigma \pm \Delta \]
\[ R_{\text{Exp}} = \Sigma (\uparrow + \downarrow) + \Delta (\uparrow - \downarrow) = N_0 T_1 T_2 T_P [\Gamma_0 + \Delta PR] \]
\[ M_1 = N_0 \varepsilon_1 + B_1 \]
\[ M_2 = N_0 T_1 T_2 T_P T_A \varepsilon_3 [1 + PAR] + B_2 \]

<table>
<thead>
<tr>
<th>P/A</th>
<th>( P_n (5\text{Å}) )</th>
<th>( T_n )</th>
<th>( P^2T )</th>
<th>features</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSM</td>
<td>99.x%</td>
<td>10%</td>
<td>0.1</td>
<td>fixed; limited ( \lambda ) bite</td>
</tr>
<tr>
<td>(^3\text{He (60%)})</td>
<td>80%</td>
<td>30%</td>
<td>0.2</td>
<td>flip ( P_3 ); ( P_3 ) varies</td>
</tr>
</tbody>
</table>

Flipper: \( R^u = 1 \) (unflipped); \( R^f = F \approx -1 \) (flipped) (-0.999 for AFP)

\[ \frac{(M_2^u - M_2^f)}{(M_2^u + M_2^f)} \sim PA(1-F) (1-f_2) \]

BR (1% need to know to 0.1%)
Detector

Detailed design work needed.

Uniform field B

Ideal: $A_1=A_2=1$, $\varepsilon_1=\varepsilon_2=1$, $f_1=f_2=0$

- with adiabatic spin transport $J\parallel B$
- with adiabatic proton orbits, $A=1$
  (scattering: resid. gas, baffles, etc.)

Proton detection: e.g. emiT2
\( \rho_n \sim 10^3/\text{cm}^3 \)

We expect about 0.5 decays per pulse: about 2.5 million events per day.
0.1% precision requires < a few days
NOT STATISTICS LIMITED
Focus on systematics…
Systematics

\[ \frac{N_+ - N_-}{N_+ + N_-} = C \left( P_n A F (1-f) + A_{\text{false}} \right) \]

Need to know: neutron polarization
analyzing power
spin flip efficiency
backgrounds
spin independent
spin dependent (false asymmetry)

e.g. False asymmetry from electrons emitted from \( \bar{n}\)-decay (BR)
- study of proton energy dependence
Noise, gain shifts, etc.
- flip \( ^3\text{He} \)

C is INDEPENDENT of \( P_n, \ xy, \ L, \ \text{tof}, \ ^3\text{He}, \ B, \ \text{BR}, \ … \) statistical power