Characterization of Noise Sources in the n3He Parity Violating Asymmetry Measurement

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for the n3He Collaboration

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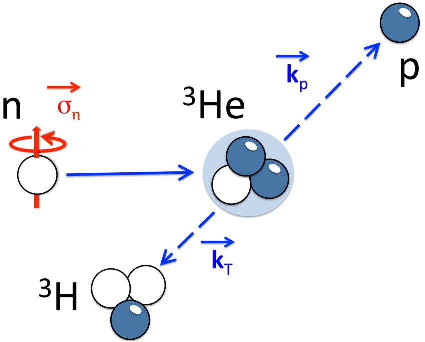
n3He Introduction

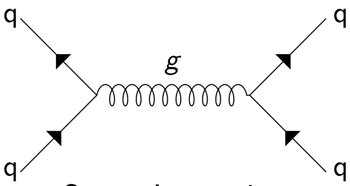
The n3He experimental goal is to make a high precision measurement of the parity violating directional asymmetry in the proton emission direction from the reaction

$$\vec{n} + {}^3He \rightarrow p + T + 765 keV$$

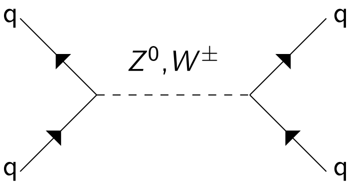


The asymmetry is expected to be small around 10^{-7} and our goal is to measure it to 2×10^{-8}.

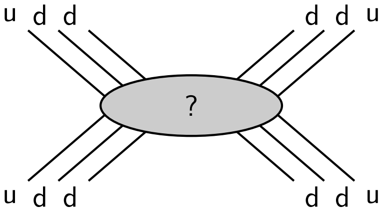
Theoretical Motivation



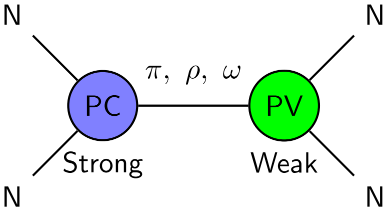
Strong Interaction



Weak Interaction



Uncertain HWI

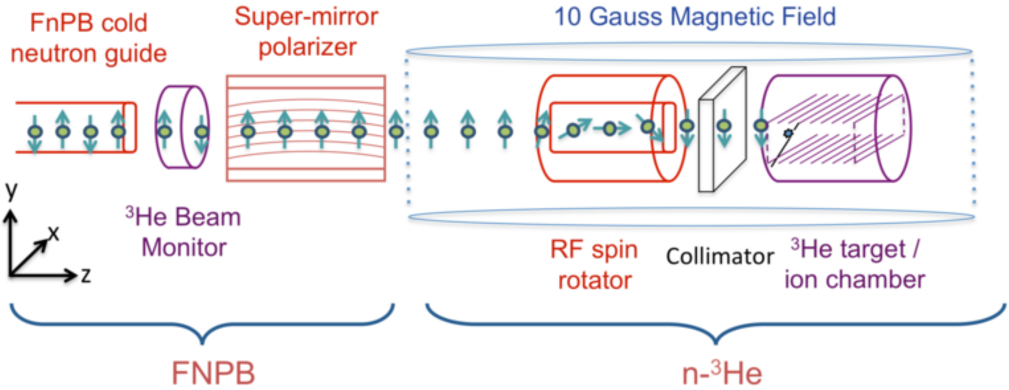


DDH Parameterization

DDH Meson Exchange Parameters:

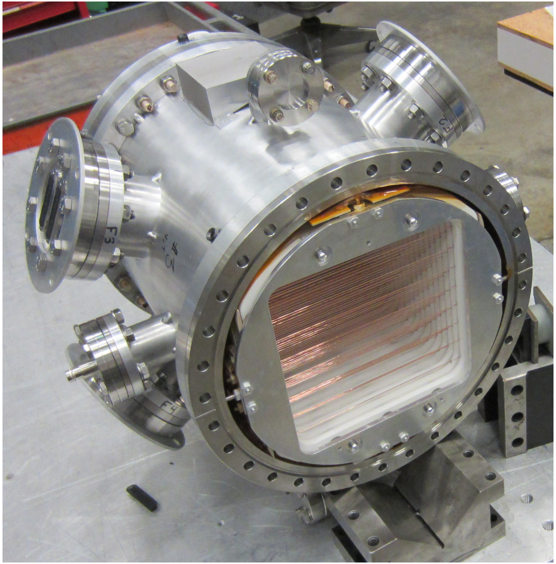
$$O_{pv} = a_\pi^1 h_\pi^1 + a_\rho^0 h_\rho^0 + a_\rho^1 h_\rho^1 + a_\rho^2 h_\rho^2 + a_\omega^0 h_\omega^0 + a_\omega^1 h_\omega^1 + a_\omega^{1'} h_\omega^{1'}$$

n3He Schematic Diagram



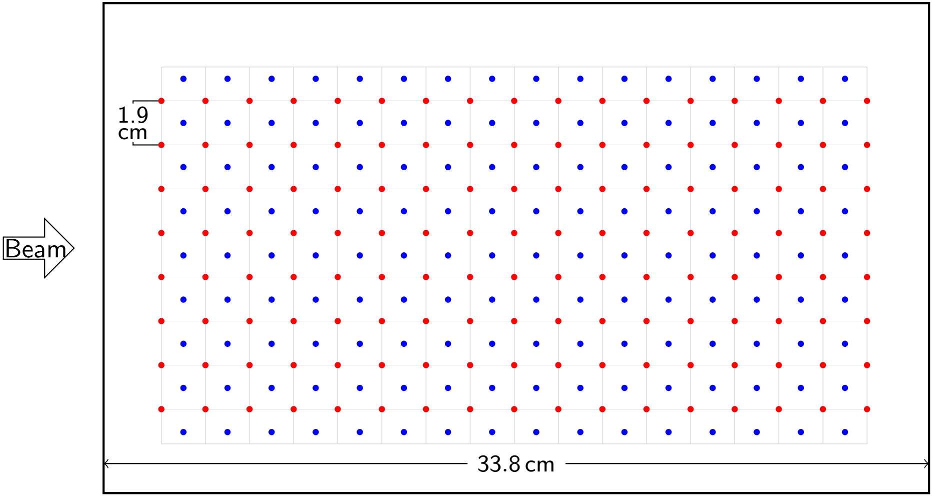
- located at the Oak Ridge National Laboratory (ORNL) in Tennessee
- 60 hertz pulsed spallation source
- n3He took data during 2015 on the Fundamental Neutron Physics Beamline
- 20 K liquid hydrogen moderator for cold neutron beam lines

Target Chamber



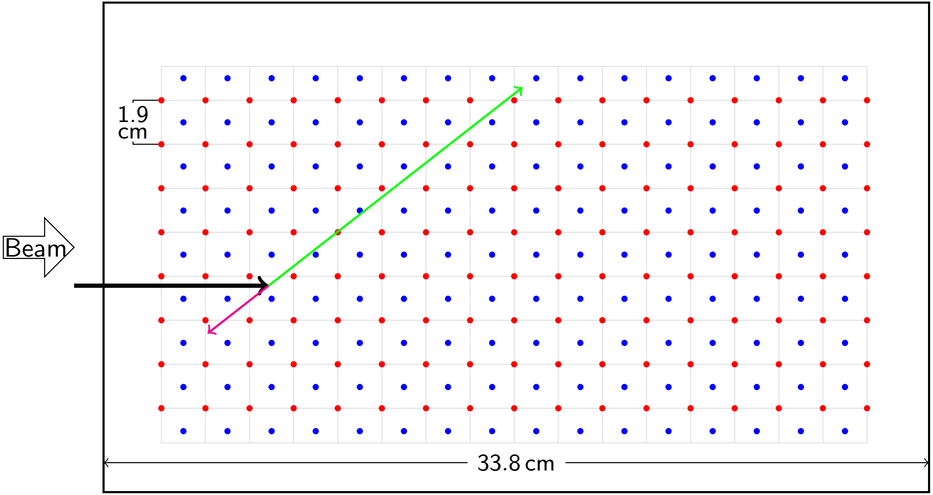
- Multi-wire proportional chamber
- Combined Target and Detector
- 0.47 atm pure He-3 fill gas
- operated near unity gain
- 144 total signal wires

n3He Target Chamber Schematic



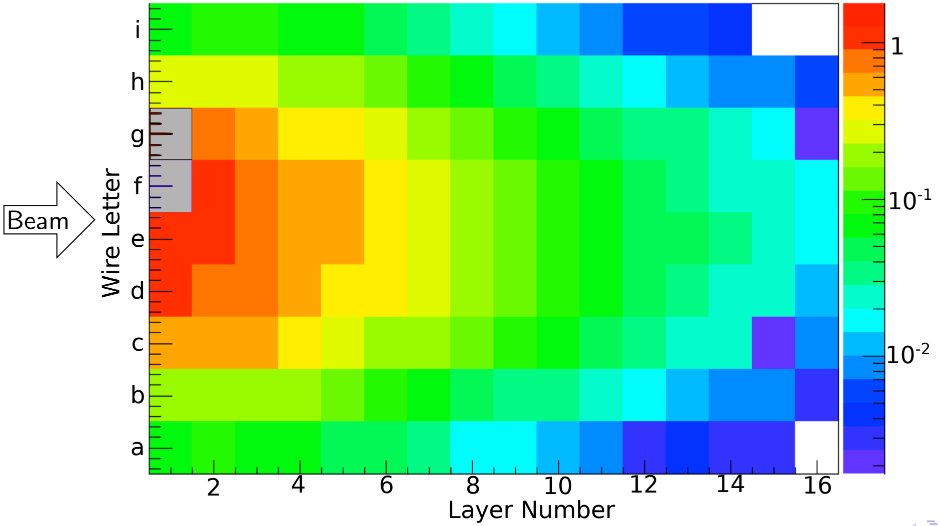
- HV 17 HV Frames with 8 wires each
- Signal 16 signal Frames with 9 wires each

n3He Target Chamber Schematic

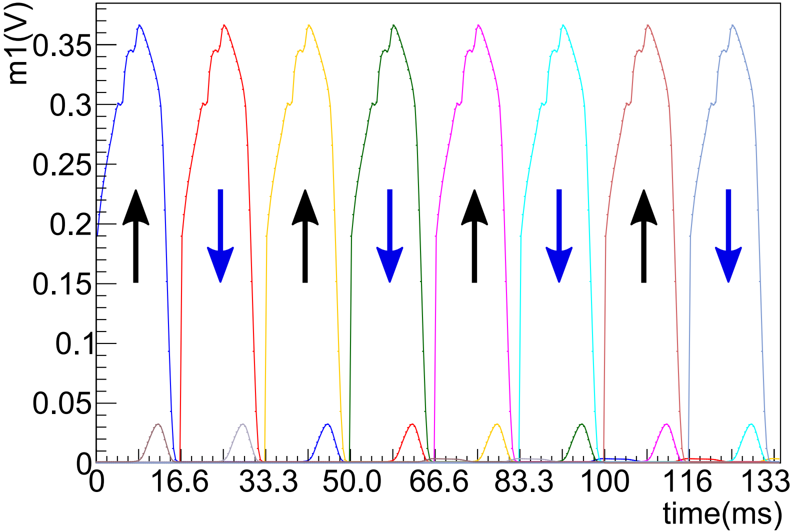


- HV — 17 HV Frames with 8 wires each
- Signal — 16 signal Frames with 9 wires each

Measured Charge Distribution in the Chamber



60 Hz Neutron Pulse Spin Sequence



- ↑ indicates is a neutron pulse with the spin flipper off and the neutron polarization orientated parallel to gravity
- ↓ indicates a pulse with the spin flipper on the neutron polarization anti-parallel

Physics Asymmetry Calculations

For the signal wire i the mean wire yield for a pulse k is:

$$\bar{Y}_i = \frac{1}{40}\sum_{t=5}^{44} Y_{i,t} = S_i + b_i \tag{1}$$

where S_i is the neutron contribution to the signal and b_i is the electronic pedestals. The single wire physics asymmetry is calculated for a pairs of consecutive neutron pulses with the spin sequence $\uparrow\downarrow$:

$$A_i^{phys} = \frac{\bar{Y}_i^{\uparrow} - \bar{Y}_i^{\downarrow}}{\bar{Y}_i^{\uparrow} + \bar{Y}_i^{\downarrow}} \approx \frac{1}{G_i}\frac{S_i^{\uparrow} - S_i^{\downarrow}}{S_i^{\uparrow} + S_i^{\downarrow}} + \frac{1}{G_i}\frac{b_i^{\uparrow} - b_i^{\downarrow}}{S_i^{\uparrow} + S_i^{\downarrow}} \tag{2}$$

Instrumental Asymmetry Calculations

To measure the effect on the uncertainty of the physics asymmetry by the pedestals beam off data was taken at 1 week intervals during data taking with an instrumental asymmetry calculated for pairs of consecutive neutron pulses with the spin sequence $\uparrow\downarrow$:

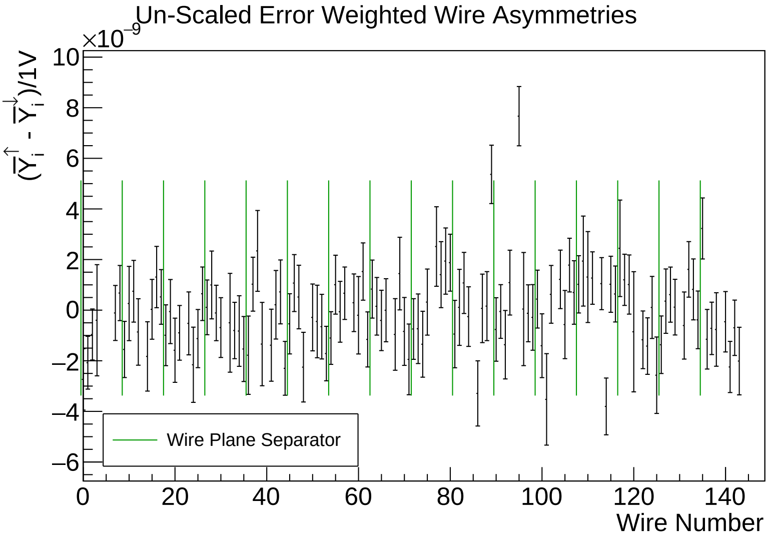
$$A_i^{inst} = \frac{1}{G_i}\frac{\bar{Y}_i^{\uparrow} - \bar{Y}_i^{\downarrow}}{2\bar{S}_i} \tag{3}$$

where $\bar{S}_i$ is the mean wire signal over all beam on running
An additional check called the Null Asymmetry was calculated using four pulse sequences, $\uparrow\downarrow\uparrow\downarrow$ to calculate the asymmetries:

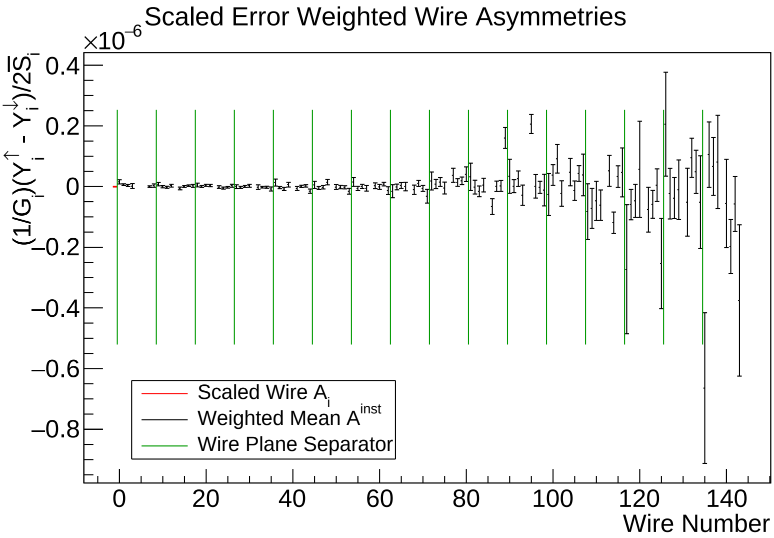
$$A_i^{null} = \frac{1}{G_i}\frac{\bar{Y}_i^{\uparrow} - \bar{Y}_i^{\prime\uparrow}}{2\bar{S}_i} \qquad A_i^{\prime null} = \frac{1}{G_i}\frac{\bar{Y}_i^{\downarrow} - \bar{Y}_i^{\prime\downarrow}}{2\bar{S}_i} \tag{4}$$

which should be zero if there are no non-spin correlated asymmetries.

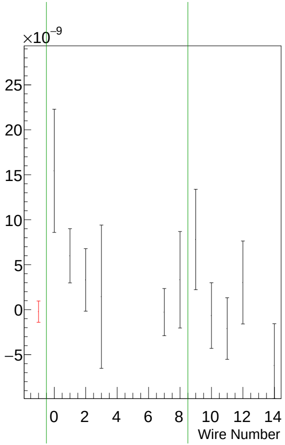
Un-Scaled Wire Instrumental Asymmetry Comparison

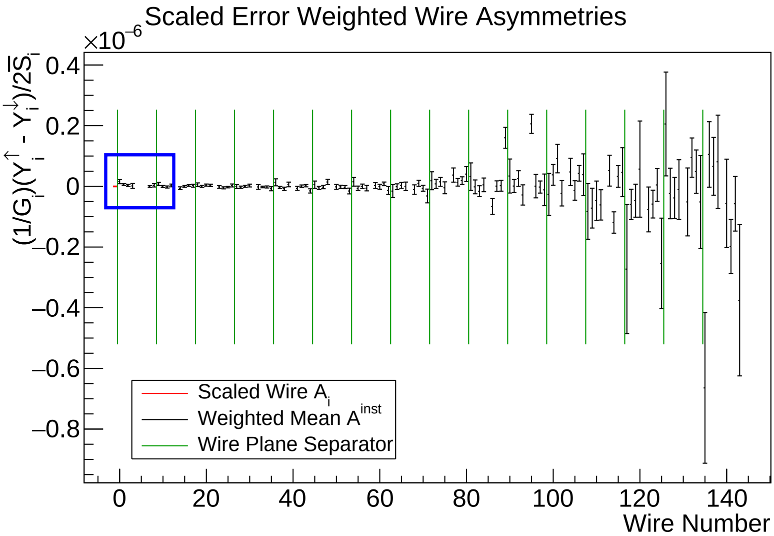


Scaled Wire Instrumental Asymmetry Comparison

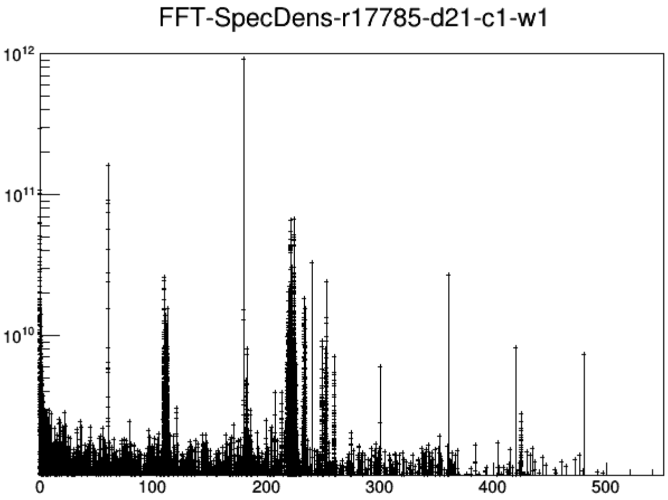


Scaled Wire Instrumental Asymmetry Comparison





FFT Analysis Results



Features of Note:

- large 180 Hertz peak on most wires
- variable cluster of peaks near 210 Hz wire resonance
- other peaks varied with the wire
- No dominant peaks

Conclusion

$$\begin{array}{rl}
\text{Preliminary Physics Asymmetry} & A^{phys}_{prelim} = (10 \pm 10) \times 10^{-9} \\
\text{Instrumental Asymmetry} & A^{inst} = (-0.2 \pm 1.18) \times 10^{-9} \\
\text{Beam Off Null Asymmetry} & A^{null} = (\ \ 0.3 \pm 1.97) \times 10^{-9}
\end{array}$$

- The instrumental and null asymmetries are small and consistent with zero.
- The systematic uncertainty in the experimental result is small compared to the statistical uncertainty.
- The goal accuracy of the experiment has been reached.

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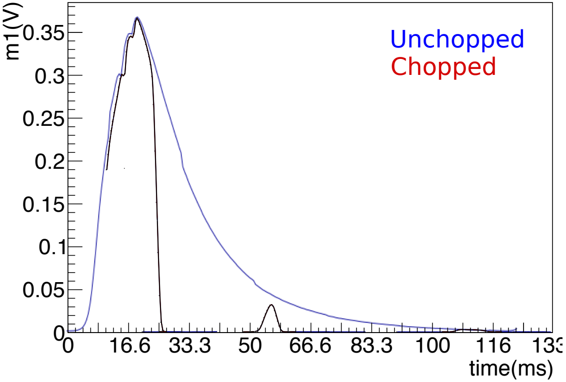
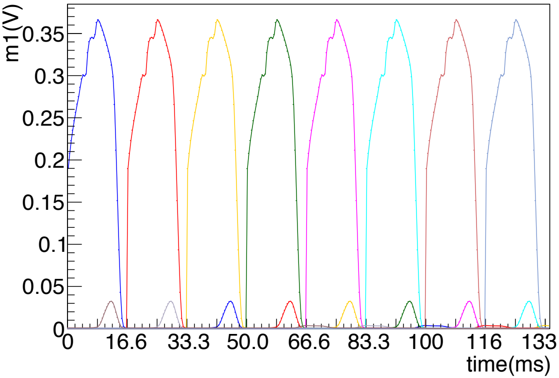
Additional Slides

Spallation Neutron Source Neutron Pulses



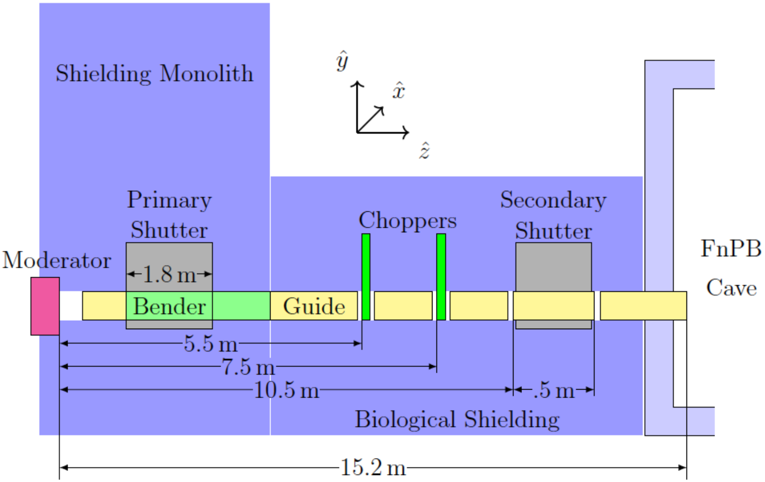
1 Hz Pulse



60 Hz Pulses

- located at the Oak Rdge National Laboratory (ORNL) in Tennessee
- 60 hertz pulsed spallation source
- n3He will located at the FnPB
- 20k liquid hydrogen moderator for cold neutron beam lines

FnPB Schematic



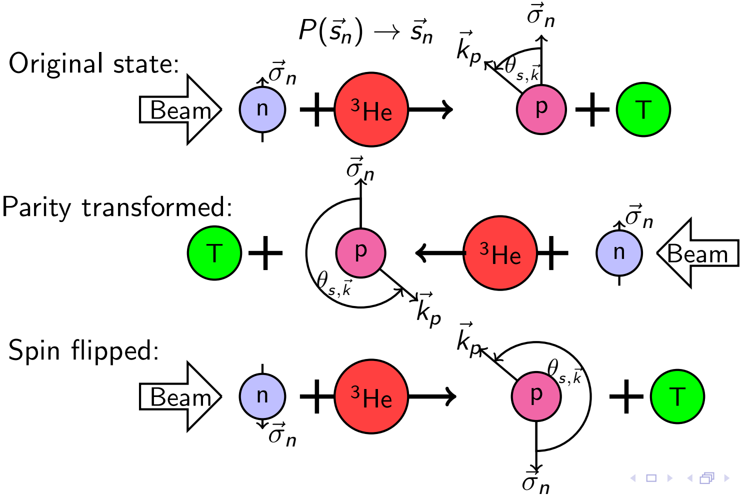
- n3He ran at the SNS FnPB at the Oak Ridge National Laboratory in Tennessee
- 60 Hertz pulsed spallation source
- 20K liquid hydrogen moderator for cold neutron beam lines

Under a parity transformation P polar vectors such as the momentum transform as

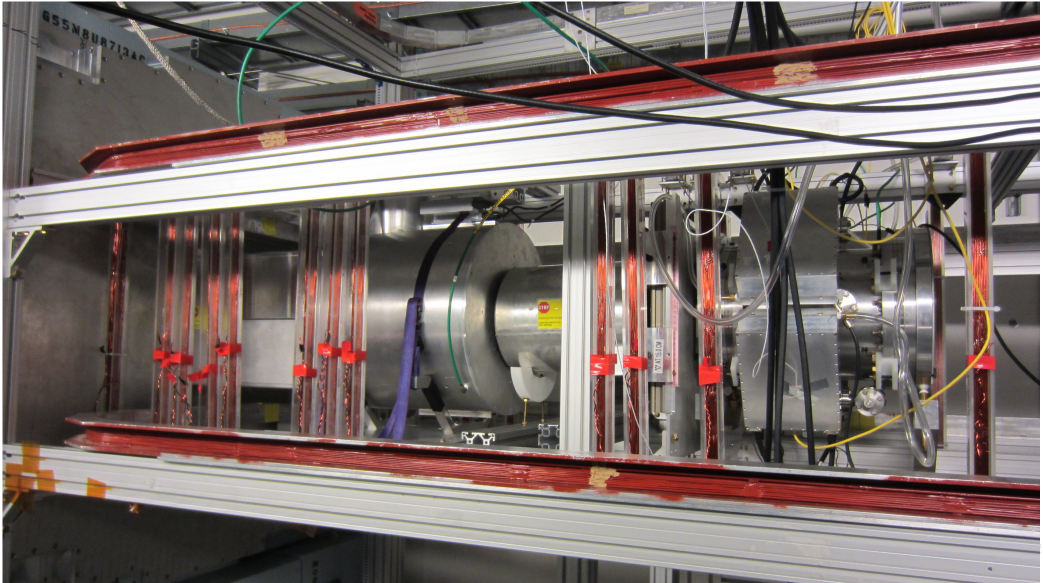
$$P(\vec{k}_n) \rightarrow -\vec{k}_n \qquad \text{and} \qquad P(\vec{k}_p) = -\vec{k}_p$$

but axial vectors, such as the neutron spin, remain unchanged

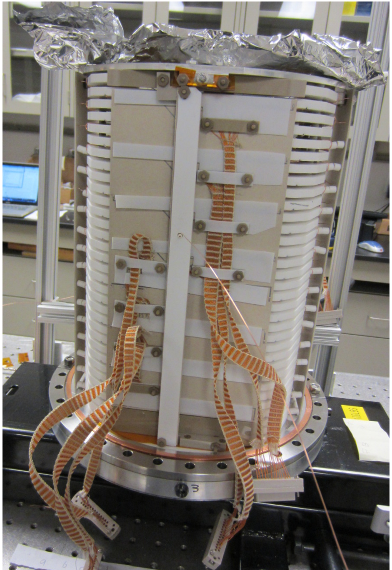
$$P(\vec{s}_n) \rightarrow \vec{s}_n$$



n3He In FnPB



Target Chamber Assembled Frame Stack



- 17 HV frames
- 16 signal frames
- 9 signal wires per frame
- 144 signals to read out
- 0.02” diameter wires

Signal Wire Numbering

Beam

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
i	8	17	26	35	44	53	62	71	80	89	98	107	116	125	134	143
h	7	16	25	34	43	52	61	70	79	88	97	106	115	124	133	142
g	6	15	24	33	42	51	60	69	78	87	96	105	114	123	132	141
f	5	14	23	32	41	50	59	68	77	86	95	104	113	122	131	140
e	4	13	22	31	40	49	58	67	76	85	94	103	112	121	130	139
d	3	12	21	30	39	48	57	66	75	84	93	102	111	120	129	138
c	2	11	20	29	38	47	56	65	74	83	92	101	110	119	128	137
b	1	10	19	28	37	46	55	64	73	82	91	100	109	118	127	136
a	0	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135

17 HV Frames with 8 wires each

16 signal Frames with 9 wires each

- Signal