The n-^{3}He Experiment at SNS

A Study of Hadronic Weak Interaction

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for the n-^{3}He Collaboration

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Outline

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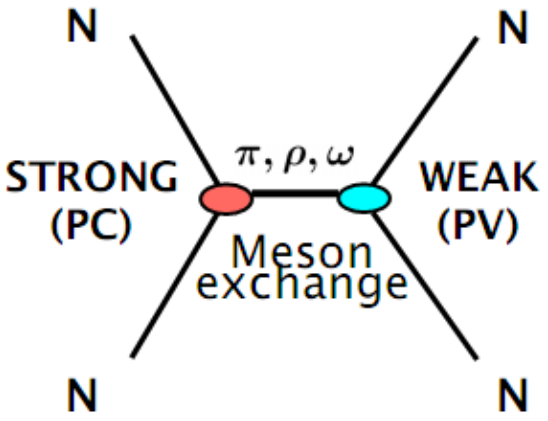
- The n-^{3}He experiment
  - Motivation
  - Experimental Setup
- Major Components
  - RFSF
  - Ion Chamber
  - DAQ & Pre-amps
- Preliminary Data
  - Asymmetry Calculation
  - LR Asymmetry
  - UD Asymmetry
- Current Status

Motivation

- Parity violation (PV) is NOT well-understood for hadronic systems.
- But studies of PV in hadronic systems offer a unique probe of nucleon structure.
- Non-perturbative regime makes calculations and experiments challenging.



DDH Model : The HWI is specified by coupling constants at the vertex, There are six unique coupling constants. $(\pi^{\pm}, \rho, \omega)$

B.Desplanques, J.F.Donoghue,and B.R.Holstein, Ann.Phys. 124,449(1980).

$$\frac{e^2}{M_W^2} / \frac{g^2}{m_\pi^2} \approx 10^{-7}$$

Effective Field Theory:

– developed by Holstein, Ramsey-Musolf, van Kolck, Zhu and Maekawa

– model-independent

▪ NN potentials are expressed in terms of 12 parameters, whose linear combinations give us 5 low energy coupling constants

▪ connect to 5 parity-odd S-P NN amplitudes

$$\lambda_t, \lambda_s^{I=0,1,2}, \rho_t$$

Lattice QCD :

-J Wasem PRC C85(2012)

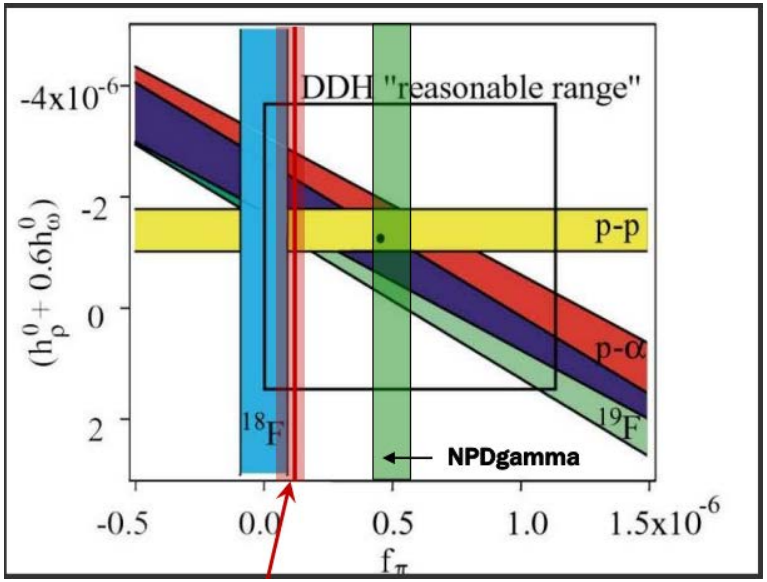
$$h^1_{\pi NN} = 1.099 \pm 0.505 \,^{+0.058}_{-0.064} \; [\times 10^{-7}]$$

Different hadronic nuclear reactions have varying sensitivity to each coupling. The goal of the HWI program is to measure enough different reactions to solve for each of the coupling constants.

	np A_γ	nD A_γ	n^3He A_p	np ϕ	nα ϕ	pp A_z	pα A_z
f_π	-0.11	0.92	-0.18	-3.12	-0.97		-0.34
h_r^0		-0.50	-0.14	-0. 23	-0.32	0.08	0.14
h_r^1	-0.001	0.10	0.027		0.11	0.08	0.05
h_ρ^2		0.05	0.0012	-0.25		0.03	
h_ω^0		-0.16	-0.13	-0. 23	-0.22	-0.07	0.06
h_ω^1	-0.003	-0.002	0.05		0.22	0.07	0.06

$$A_n^{n^3He} = -0.189 f_\pi - 0.036 h_\rho^0 - 0.033 h_\omega^0$$

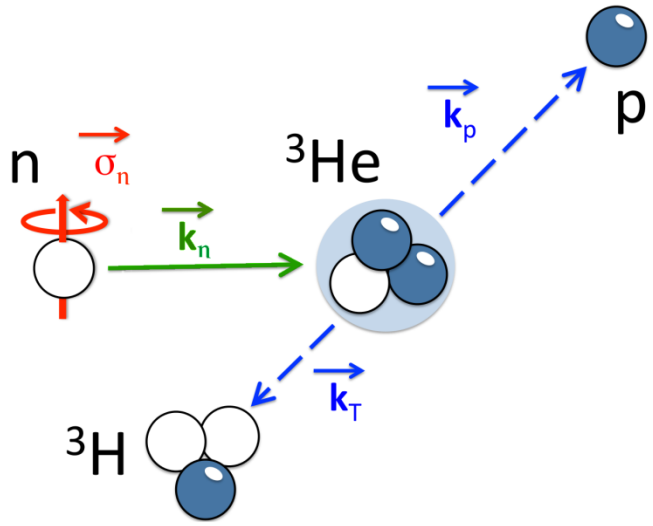
Viviani et al, PRC 82 (2010), 044001

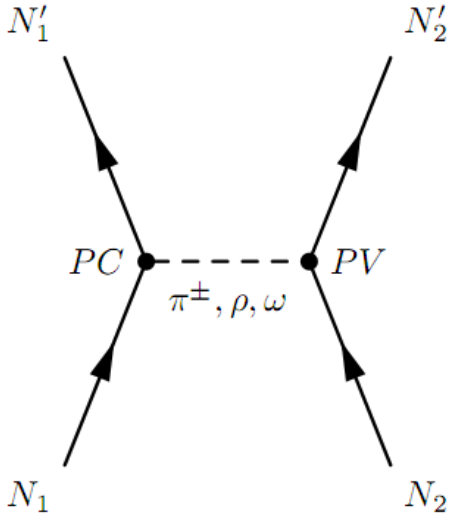


The n-^{3}He Experiment

- High-precision measurement motivated to probe the hadronic weak interaction by measuring the parity violating asymmetry of the proton in the reaction-

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



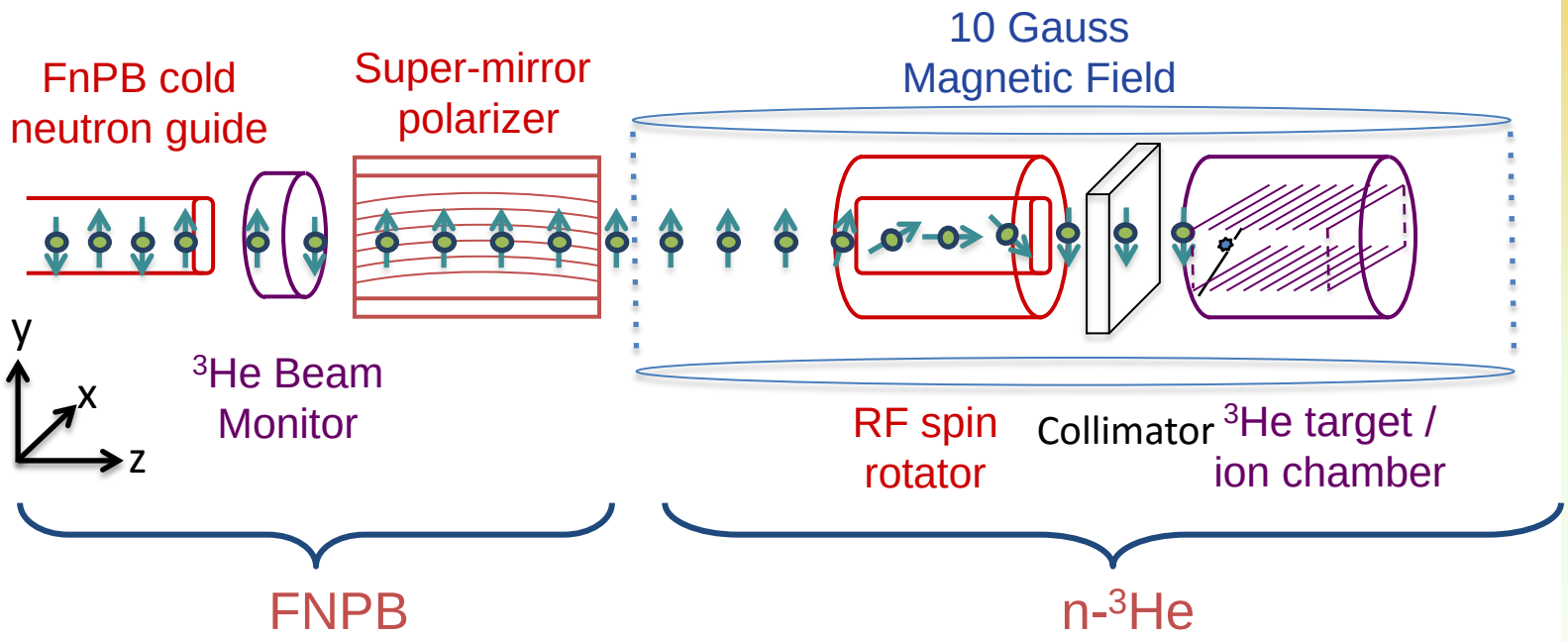


$$\sigma = \sigma_0 (1 + \boldsymbol{\sigma}_n.\mathbf{k}_p A_{pv} + \mathbf{k}_n x \boldsymbol{\sigma}_n.\mathbf{k}_p A_{pc})$$

- Expected to be extremely small (of the order 10^{-7})
- Goal is to measure an asymmetry in the reaction to a precision of 2×10^{-8}

Experimental Setup

- Commissioned at spallation neutron source (SNS) facility of Oak Ridge National Laboratory.
- Uses pulsed neutrons at 60 Hz from SNS.



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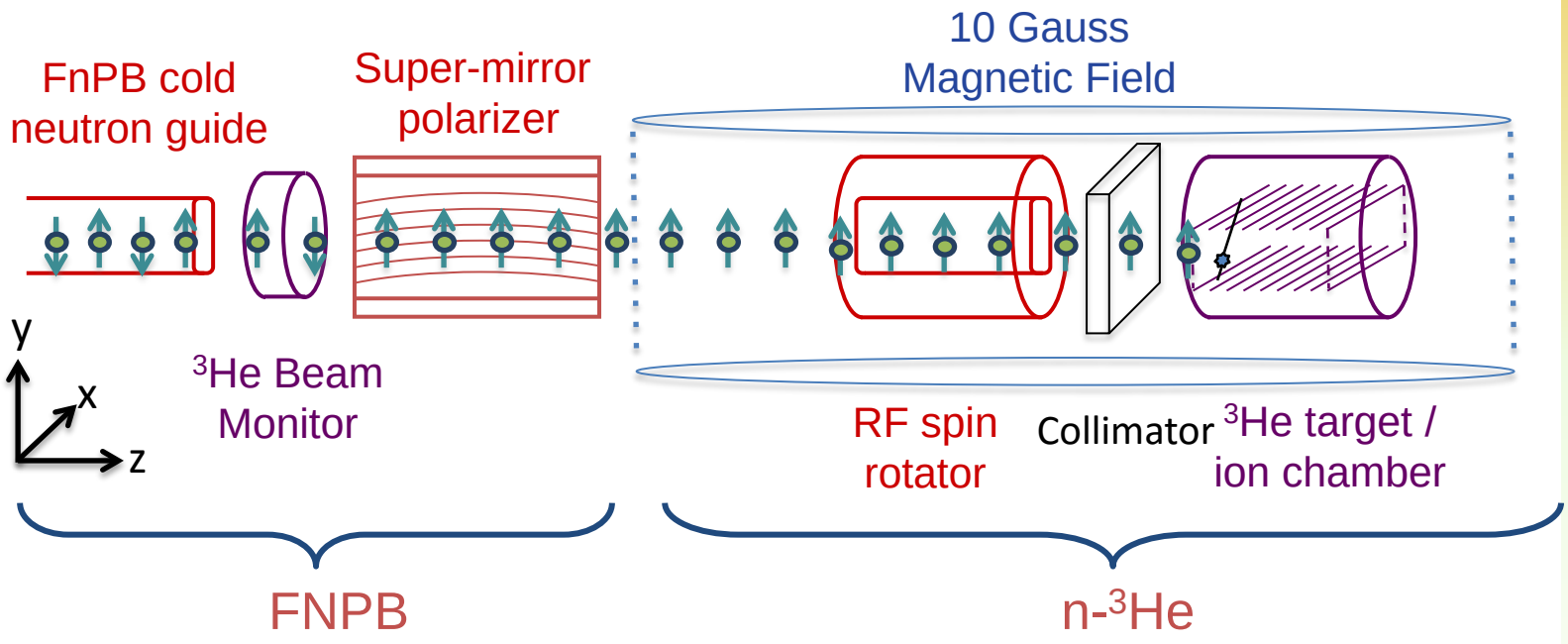

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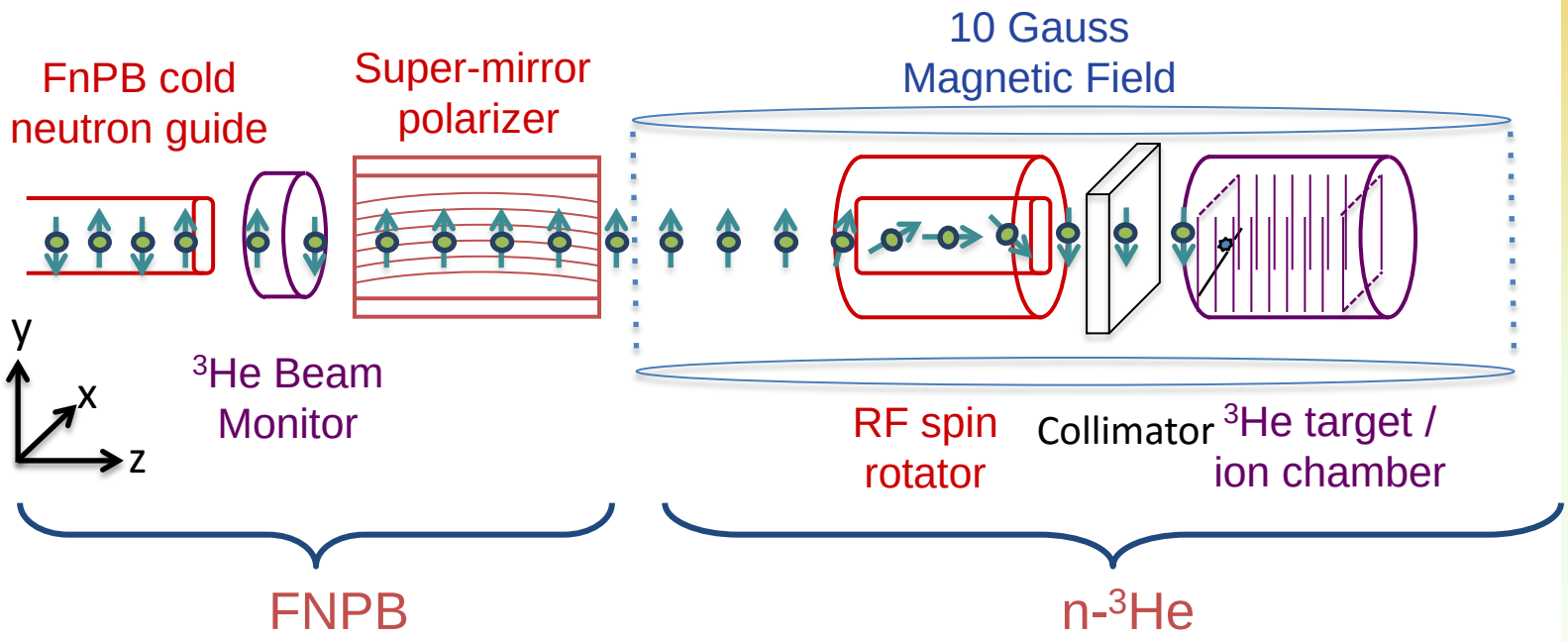

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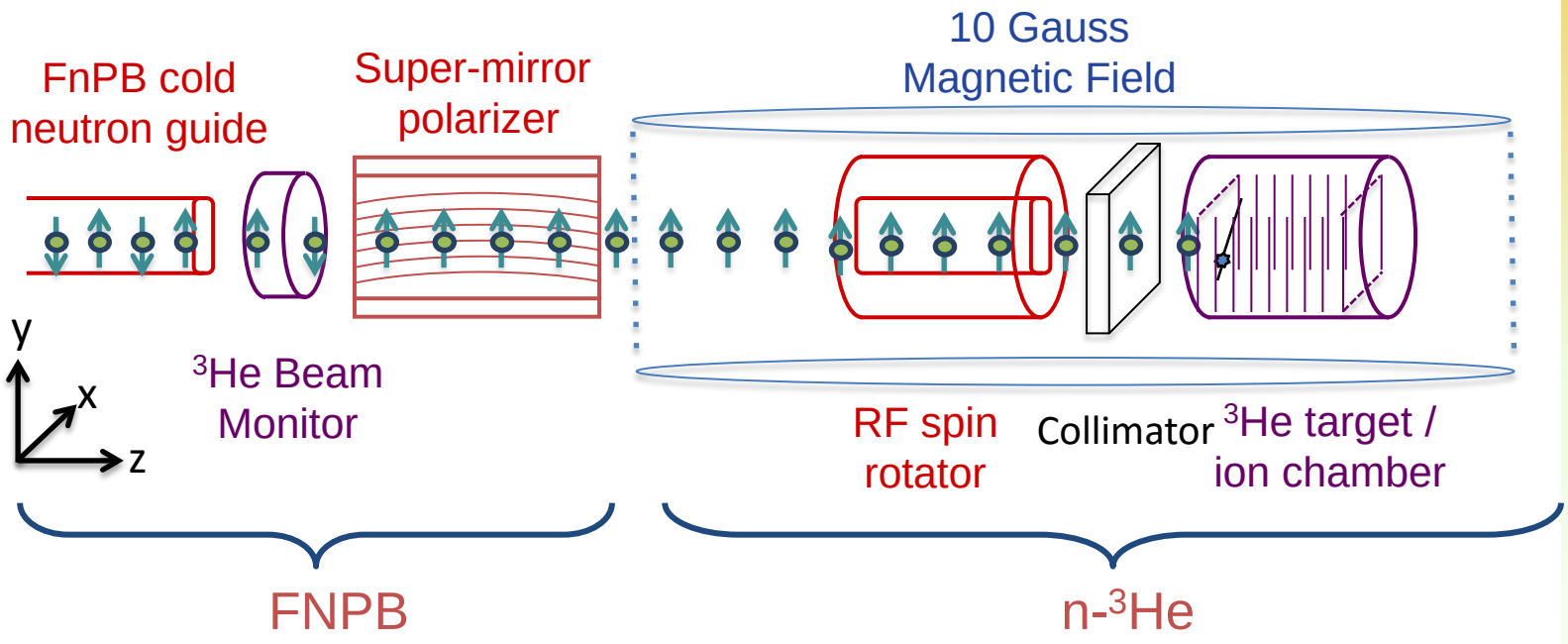
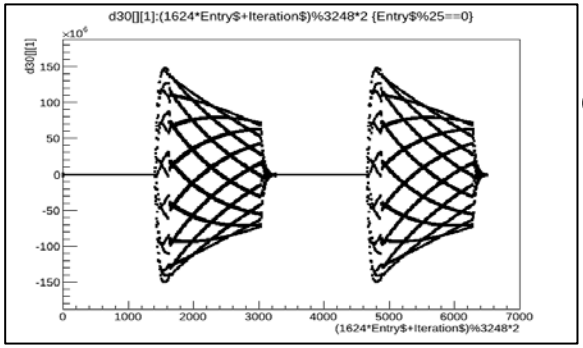
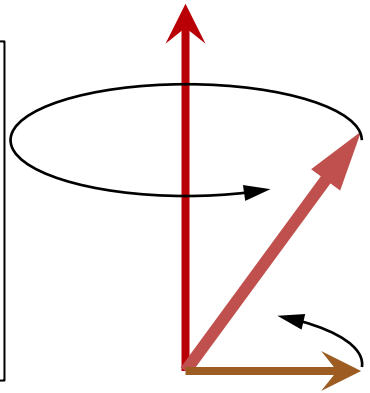
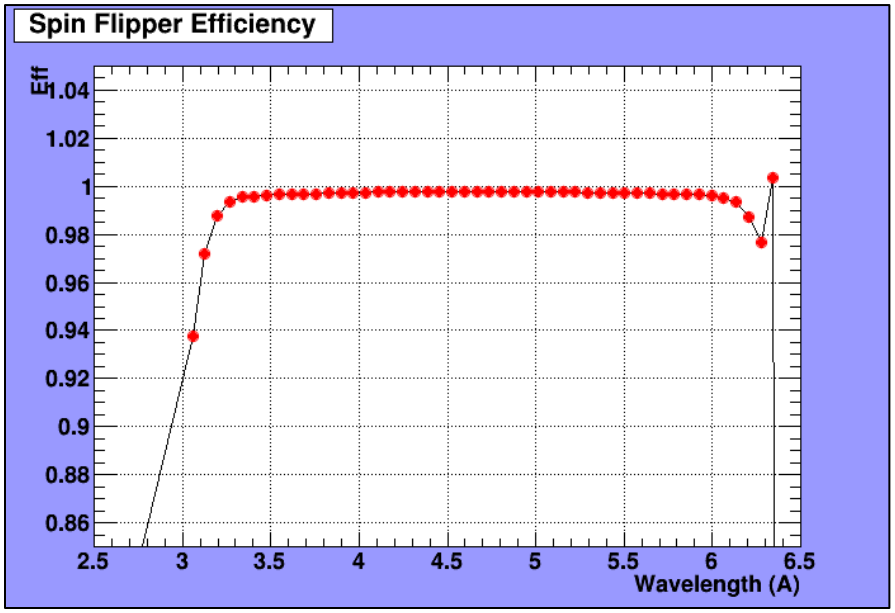


RFSF

- The neutrons enter the experiment with a transverse polarization.
- Spin flipper with transverse windings allows for both longitudinal and transverse spin rotation.







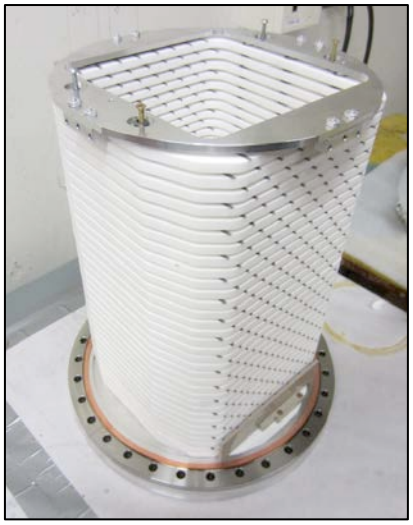
Details in talk by Chris Hayes (HF.00003 , Friday @ 8:30)

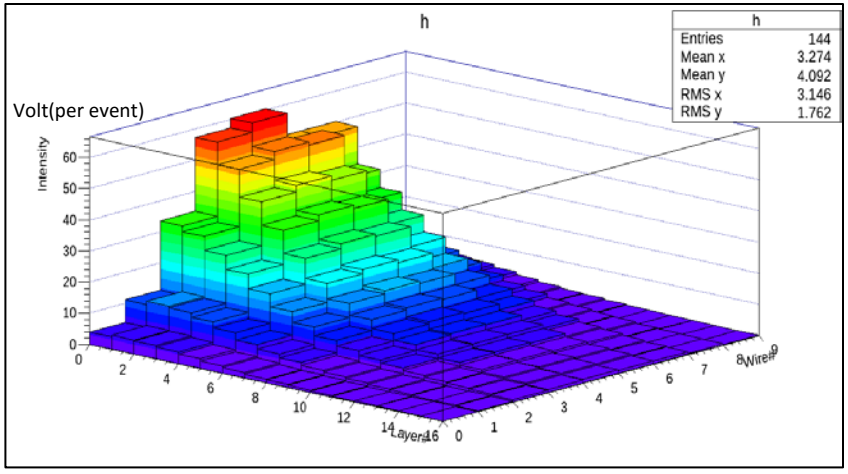
The n^{3}He Experiment at SNS

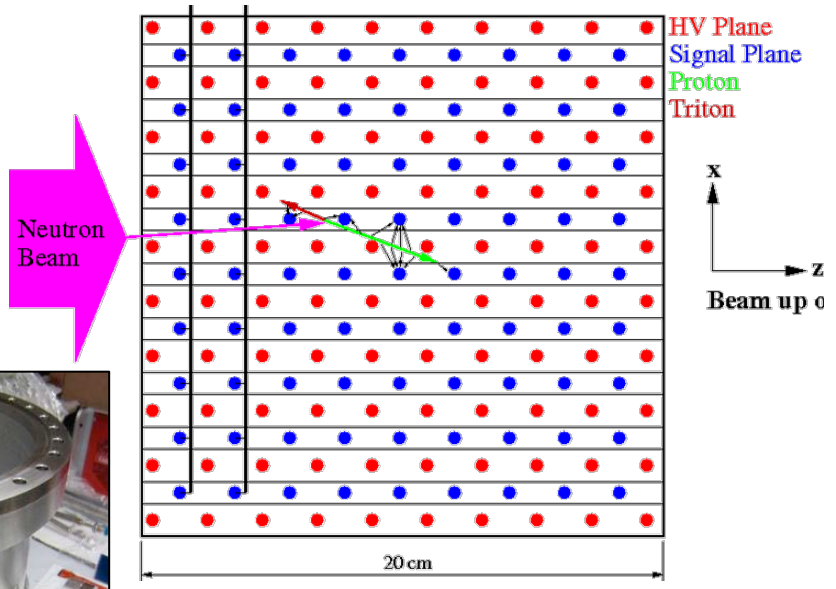
Outline

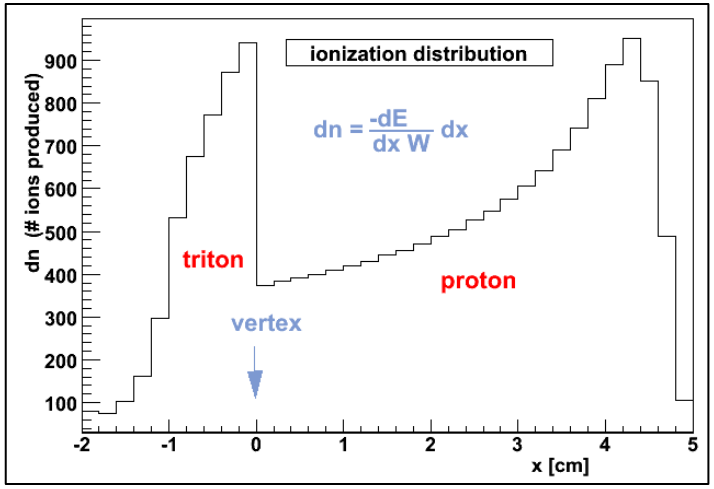
Ion Chamber

- Filled with ^{3}He at 0.5 atm
- 17 HV Frames with 8 wires
- 16 Signal Frames with 9 wires









Details in talk by Mark McCrea (HF.00002,Friday @ 8:42)

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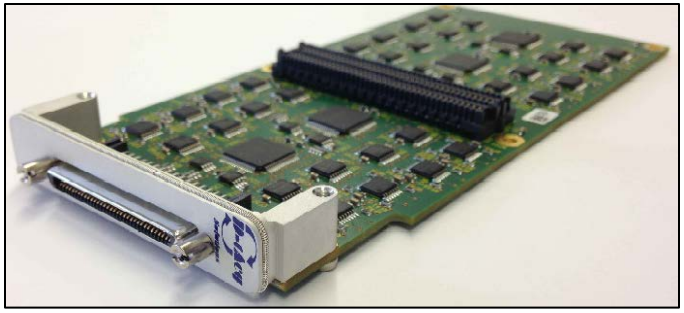
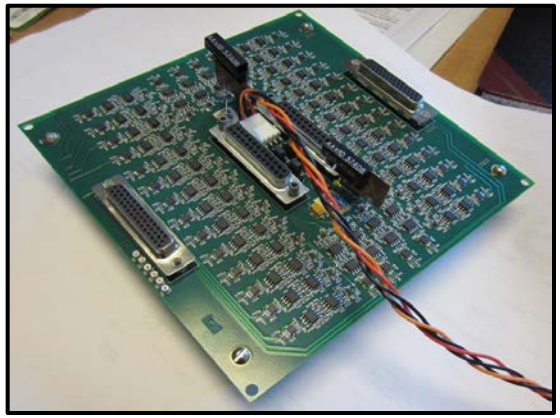
Major Components
- **RFSF**
- **Ion Chamber**
- **DAQ & Pre-amps**

Preliminary Data
- **Asymmetry Calculation**
- **LR Asymmetry**
- **UP Asymmetry**

Current Status

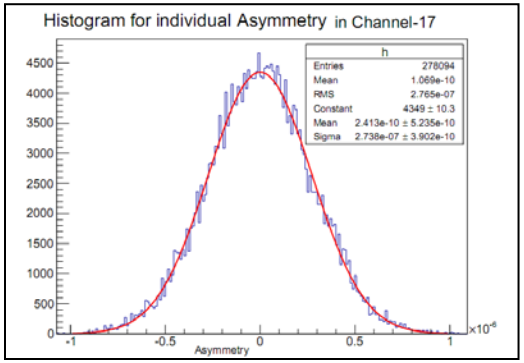
DAQ and Pre-amps

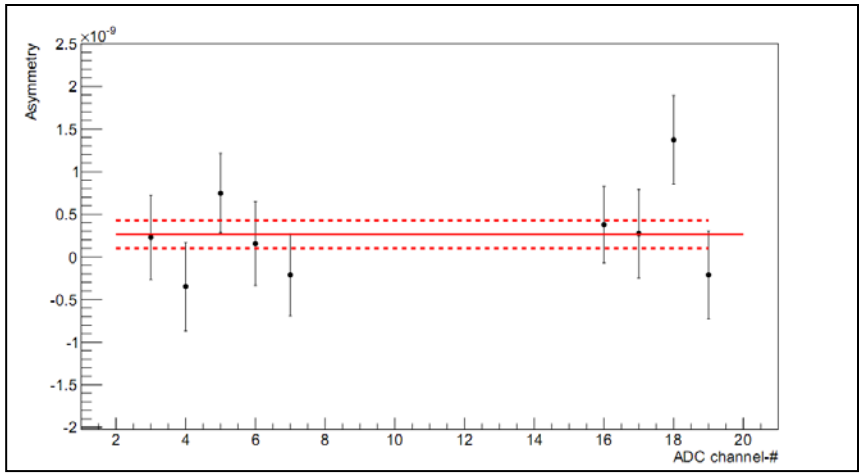




- Analysis of 5 hour of data at 25KHz shows that-

Instrumental Asymmetry = $2.64 \times 10^{-10} \pm 1.64 \times 10^{-10}$





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Asymmetry Calculation

- Cuts:
  -- Pulses around dropped pulses
- Pair of events (one up and one down) considered to form each asymmetry for each wire.
- Each detector signal is normalized by sum of all the detector signals for that event.
- Asymmetry for pair of events,

$$A_K = \frac{Y_+^\kappa - Y_-^\kappa}{Y_+^\kappa + Y_-^\kappa}$$ K= pair of events index

- Physics asymmetry for each wire is calculated using,

Details on GF in talk by Christopher Coppola (HF00001,Friday @8:30)

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

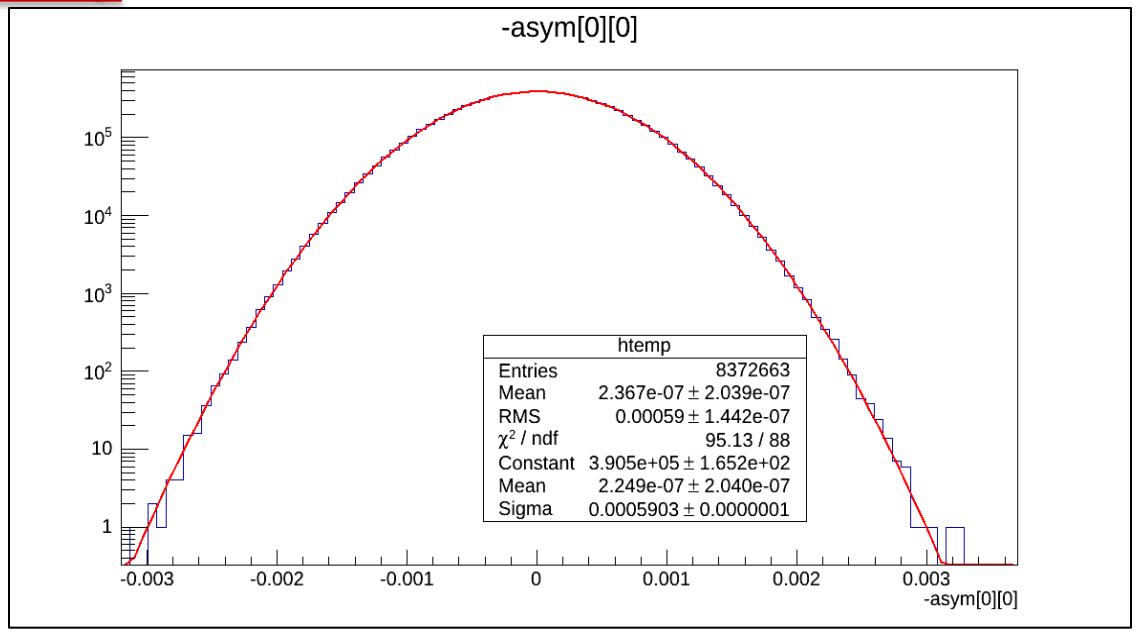
And error , $\delta\alpha_k = \frac{1}{|Gk|}\delta A_k$ Where G_K is the geometric factor .

- The final asymmetry is obtained after correcting for correlations.

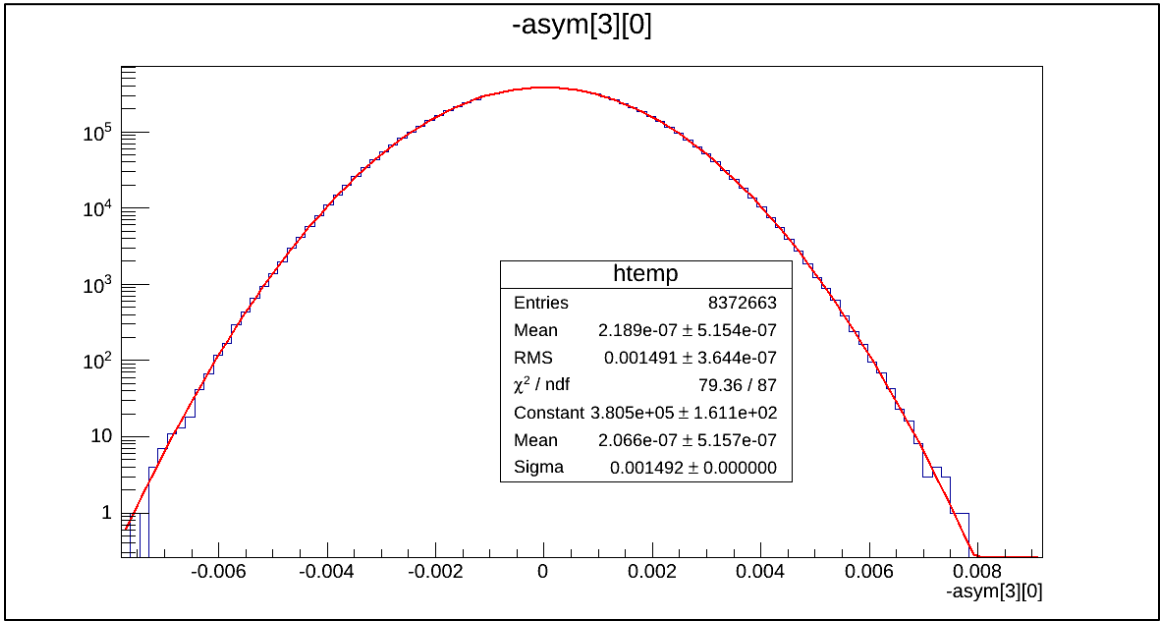
LR Asymmetry

Runs Considered : 684

Layer-1, Wire-1



Layer-10, Wire-1



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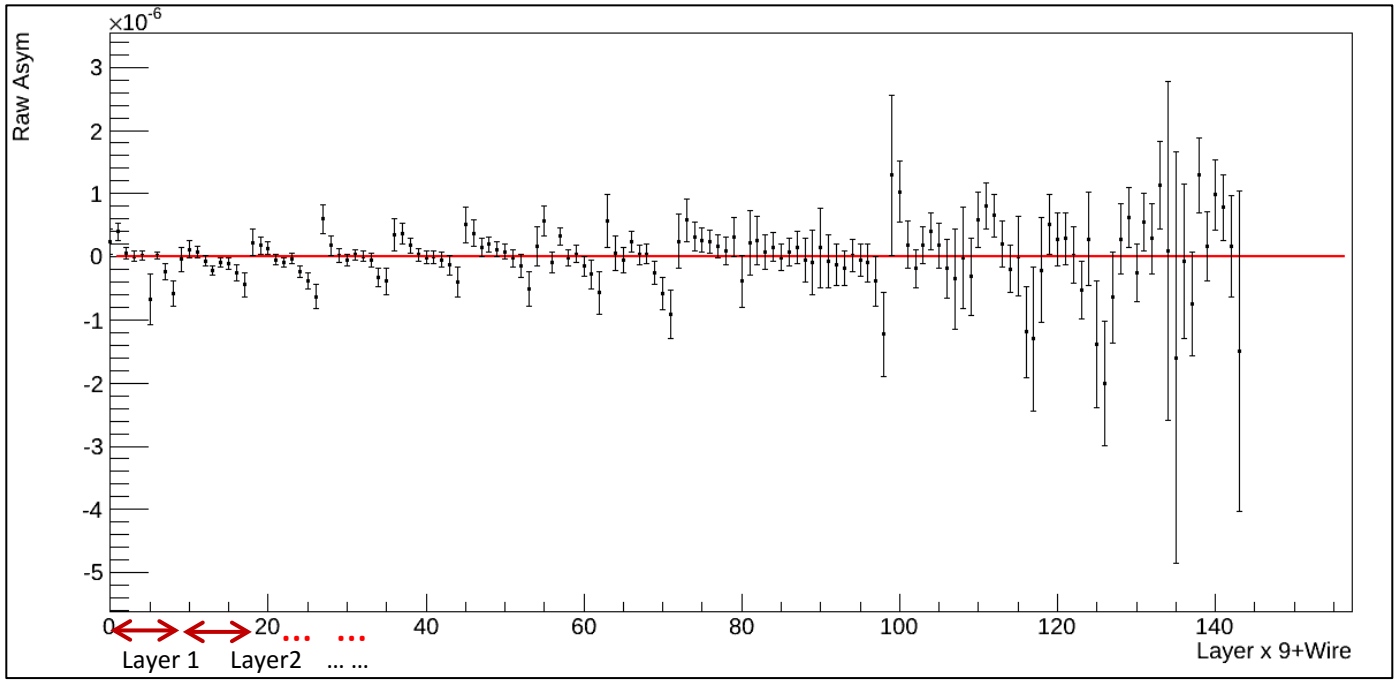
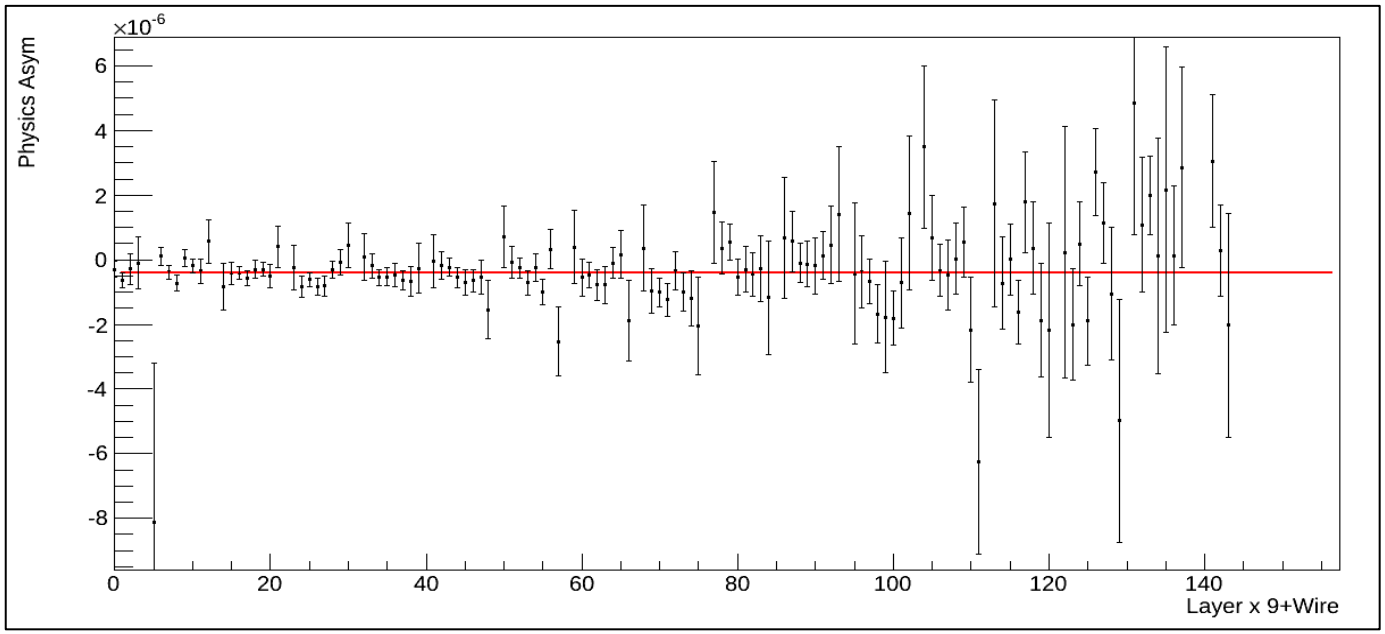
LR Asymmetry





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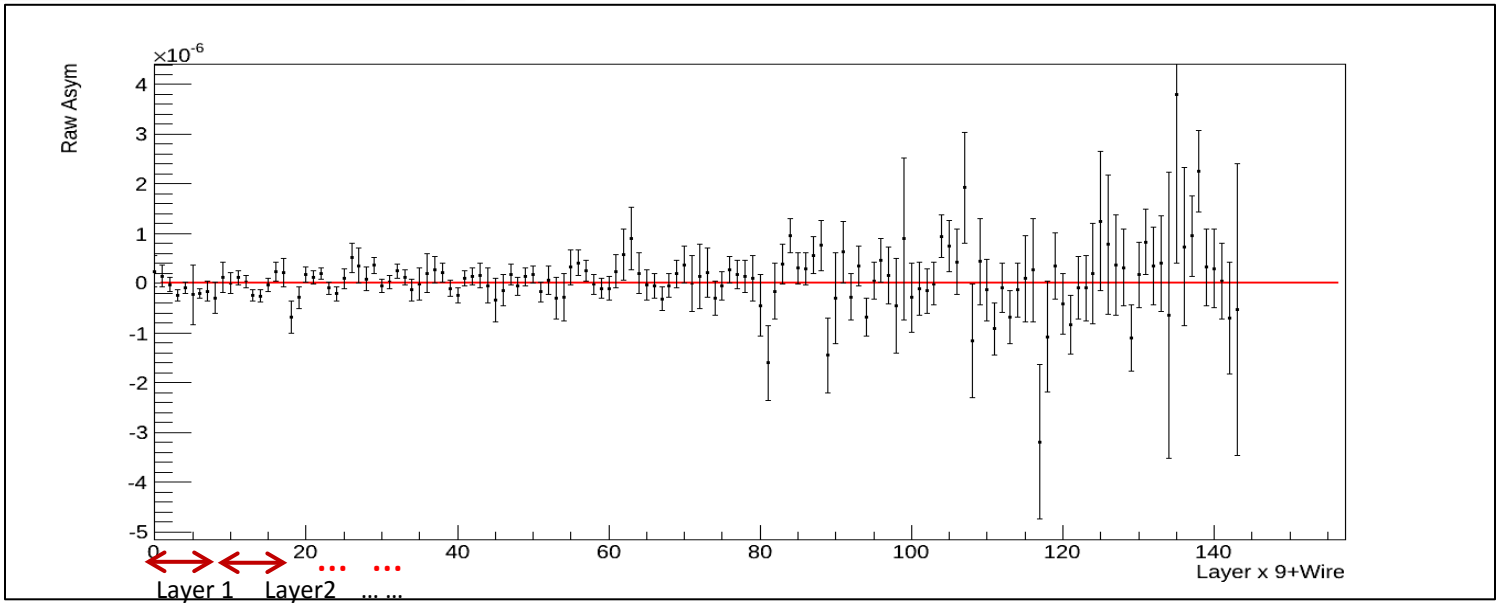
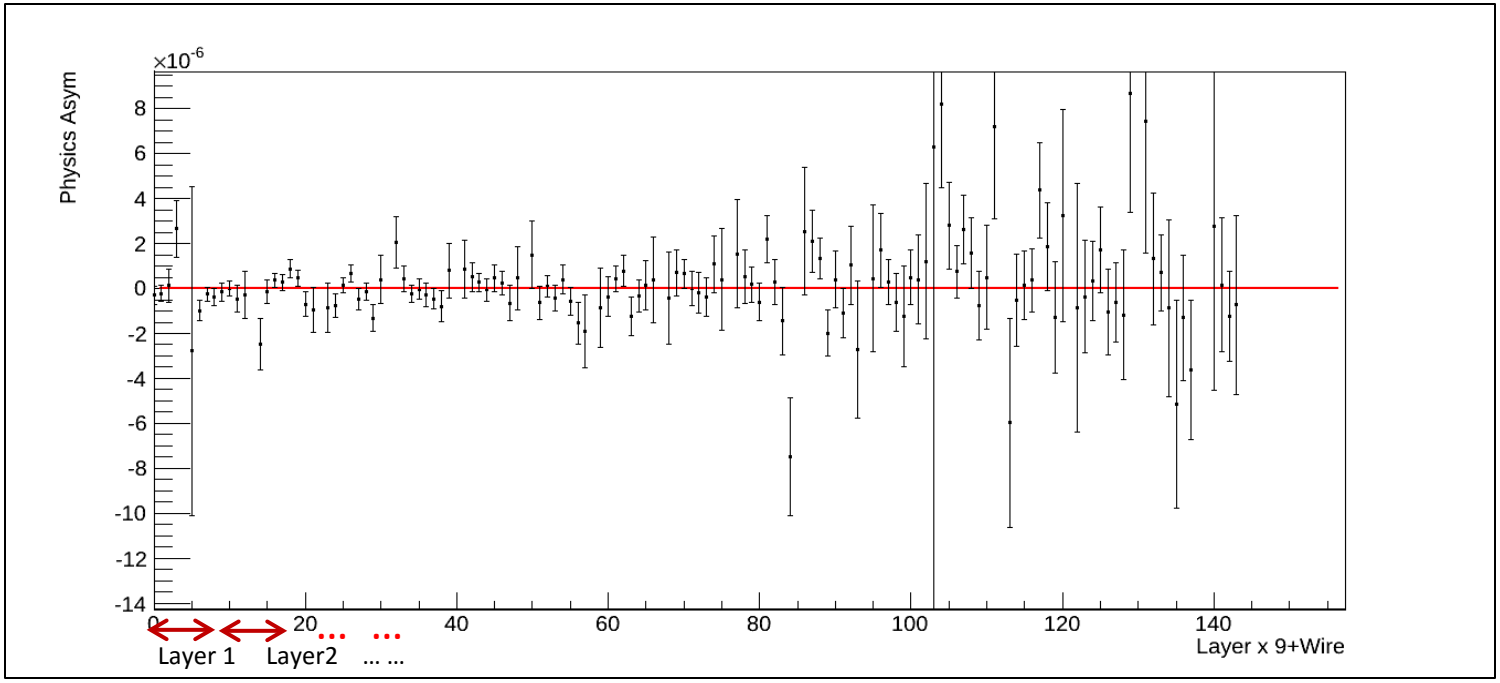
UD Asymmetry

Runs Considered 280





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Current Status

- Successfully finished beam cycle-1 data taking phase with data having 2050 hours of beam with an average power of 1MW (17500 runs).
- This includes data both for PC and PV asymmetry.
- Data taking for second beam cycle is going on, with 950 hours of beam already taken.
- This gives desired statistics according to, $\delta A = \frac{\sigma_d}{P\sqrt{N}}$

  Where, P=99%, σ_d = 3.4 , N=1.4x10^{10} n/sec x 3000 hr
- Preliminary analysis shows current precision < 2 x 10^{-8}
- Data taking will continue till the end of the year.

n-^{3}He Collaboration

Institution	Researcher	Category	2014 Effort
Duke University, Triangle Universities Nuclear Laboratory			
	Pil-Neo Seo	Research Staff	10
Istituto Nazionale di Fisica Nucleare, Sezione di Pisa			
	Michele Viviani	Research Staff	15
Oak Ridge National Laboratory			
	Seppo Pentillä	Research Staff	70
	David Bowman	Research Staff	70
	Vince Cianciolo	Research Staff	10
University of Kentucky			
	Chris Crawford	Faculty	50
	Kabir Latiful	Grad Student	100
Western Kentucky University			
	Ivan Novikov	Faculty	70
	TBD	Undergraduate	100
University of Manitoba			
	Michael Gericke	Faculty	30
	V. Tvaskis	Postdoc	10
	Mark McCrea	Grad Student	100
	Carlos Olguin	Grad Student	100
Universidad Nacional Autónoma de México			
	Libertad Baron	Faculty	50
	Andrés Naranjas	Grad Student	100
University of New Hampshire			
	John Calarco	Faculty	50
University of South Carolina			
	Vladimir Gudkov	Faculty	5
	Young-Ho Song	Postdoc	5
Univeristy of Tennessee			
	Geoff Greene	Faculty	30
	Nadia Fomin	Faculty	30
	Irakli Garribaldi	Postdoc	50
	Chris Hayes	Grad Student	100
	Chris Coppola	Grad stduent	100
Univeristy of Tennessee at Chattanooga			
	Josh Hamblen	Faculty	75
	Caleb Wickersham	Undergraduate	100
University of Virginia			
	S. Baessler	Faculty	20

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