The n3He experiment:
Hadronic parity violation in cold neutron capture on 3He.

Michael Gericke
University of Manitoba

for the n3He collaboration

8th International Workshop on Chiral Dynamics

Pisa, Italy 2015

The n3He Collaboration

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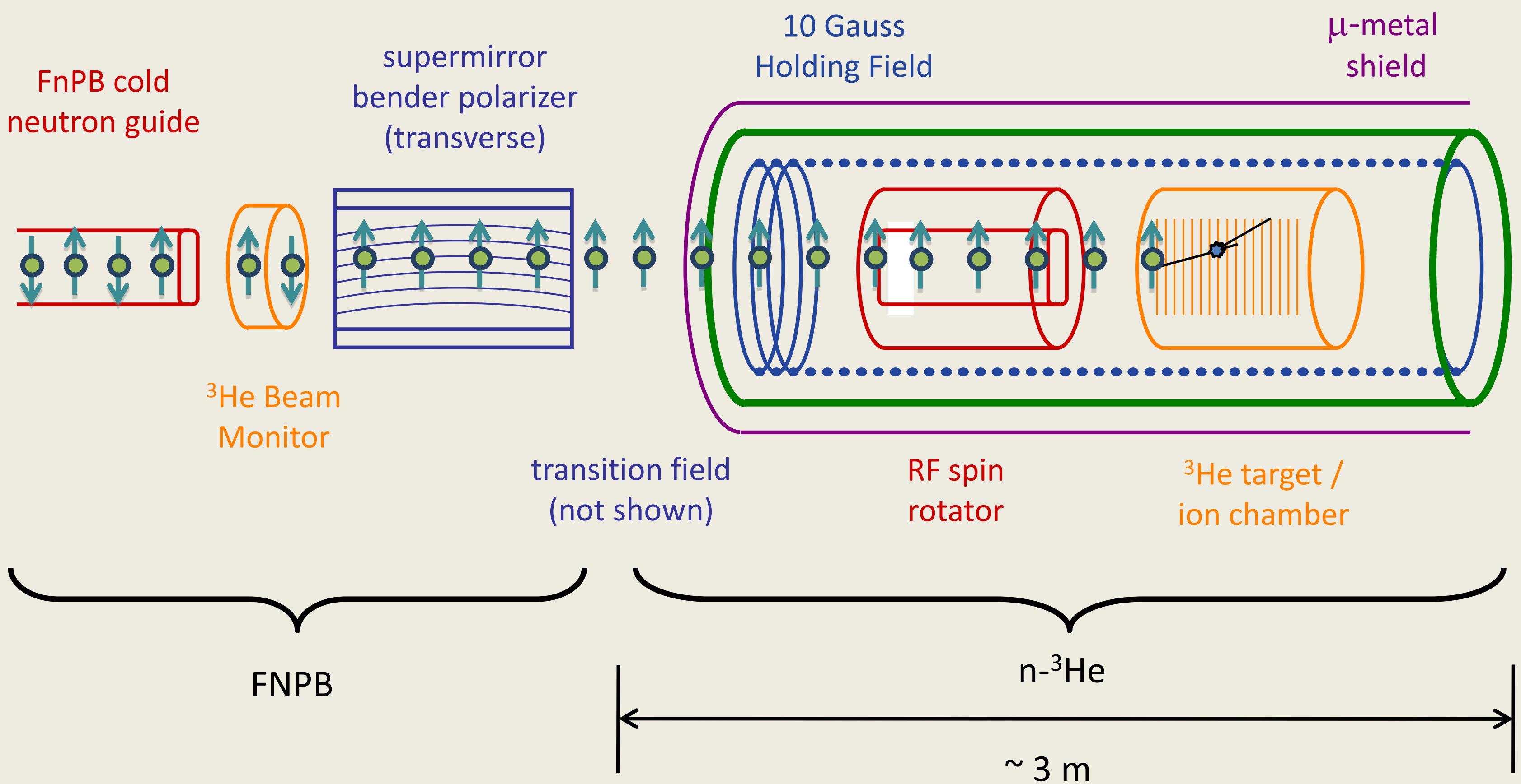
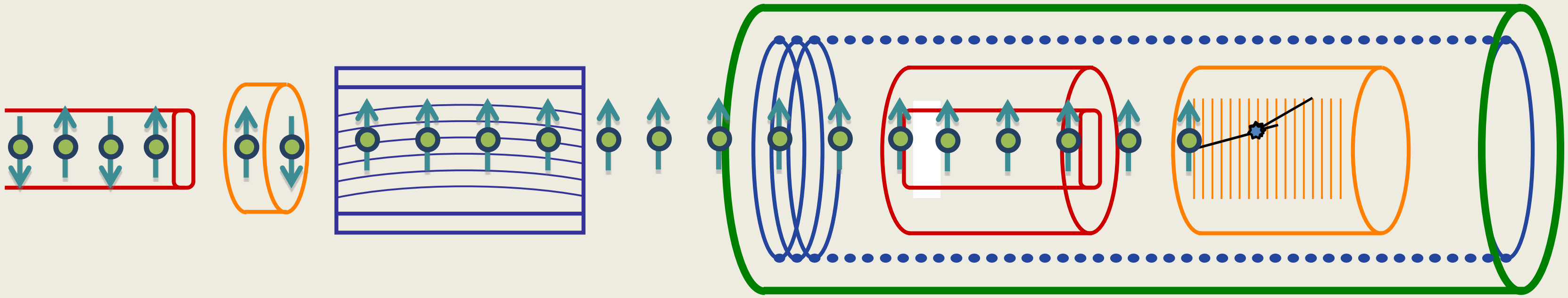
Experimental Setup



- *transverse holding field*
- *RF spin flipper – negligible spin-dependent neutron velocity*
- *^{3}He ion chamber – both target and detector*

Experimental Setup

$$\vec{\mathrm{n}} + {}^3\mathrm{He} \rightarrow \mathrm{p} + \mathrm{t} + 764\ \mathrm{keV}$$



$$A_{PV}^{exp} = f_{exp}\left(A_{PV}\cos\theta_{\vec{n},\vec{k}_p} + A_{PC}\sin\theta_{\vec{n},\vec{k}_p}\right)$$

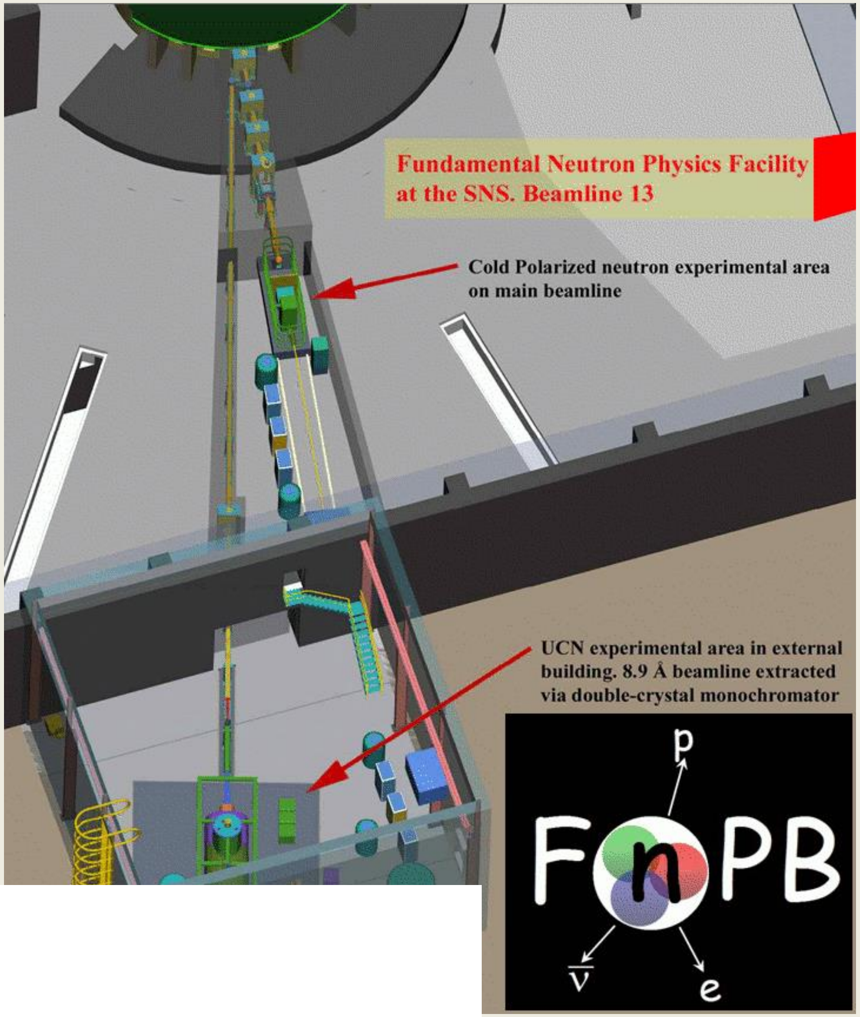
$$A_{raw} = \frac{1}{2}\left(\frac{\sigma_U^{\uparrow} - \sigma_D^{\uparrow}}{\sigma_U^{\uparrow} + \sigma_D^{\uparrow}} + \frac{\sigma_U^{\downarrow} - \sigma_D^{\downarrow}}{\sigma_U^{\downarrow} + \sigma_D^{\downarrow}}\right)$$

- Measure PV spin asymmetry to ~2×10^{-8}
- Measure PC nuclear asymmetry:

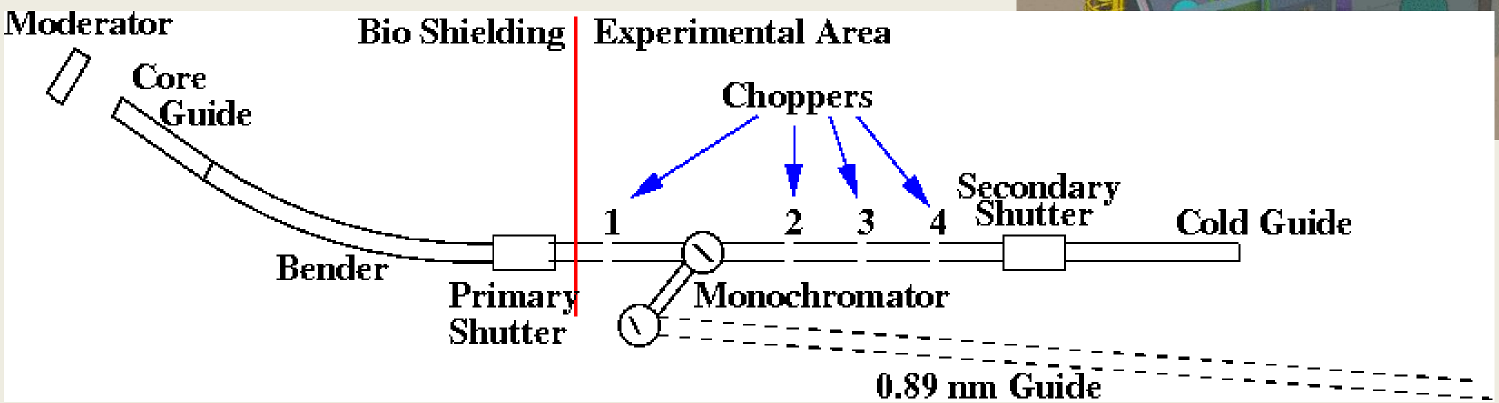
  (~$2\times10^{-6} \propto s_n \bullet k_n \times k_p$ (Hale) suppressed by two small angles

Spallation Neutron Source (SNS)

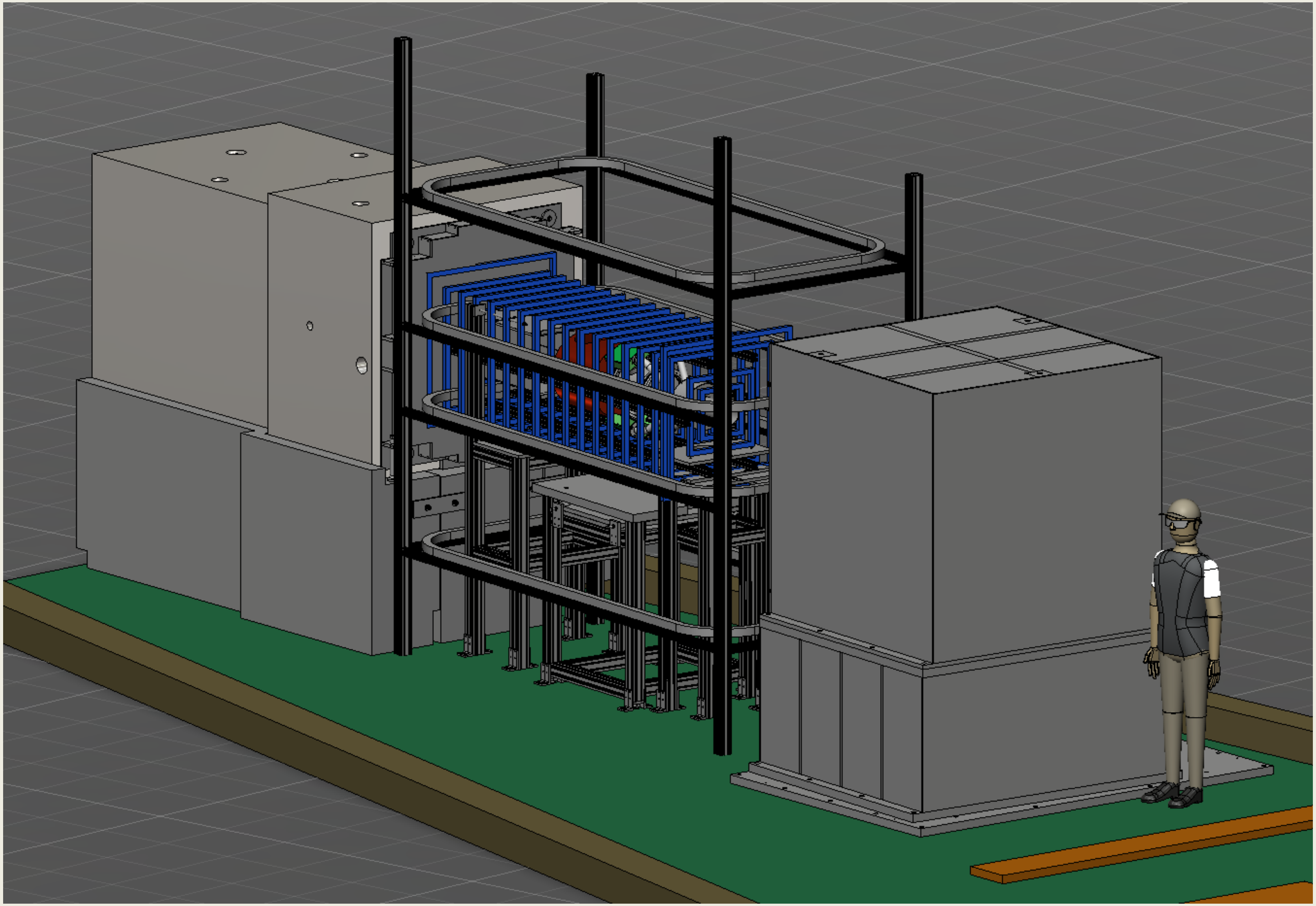
The Fundamental Neutron Physics Beam (FnPB)



- LH2 moderator
- 17 m long guide ~ 20 m to experiment
- one polyenergetic cold beam line
- one monoenergetic (0.89 nm) beam line
- ~ 40 m to nEDM UCN source
- 4 frame overlap choppers
- 60 Hz pulse repetition



n3He Experimental Setup



n^3He Theory

- Full four-body calculation of strong scattering wave functions
- Evaluation of the weak matrix elements in terms of the DDH potential:

$$A_{PV} = a_\pi^1 h_\pi^1 + a_\rho^0 h_\rho^0 + a_\rho^1 h_\rho^1 + a_\rho^2 h_\rho^2 + a_\omega^0 h_\omega^0 + a_\omega^1 h_\omega^1$$

DDH Weak Coupling	(A^p_z) $n^3He \rightarrow tp$
a_π^1	-0.189
a_ρ^0	-0.036
a_ρ^1	0.019
a_ρ^2	-0.0006
a_ω^0	-0.0334
a_ω^1	0.0413

$$A_{PV}(th.) \approx (-9.4 \rightarrow 2.5) \times 10^{-8}$$

M. Viviani, R. Schiavilla, Phys. Rev. C. 82 044001 (2010)
L. Girlanda et al. Phys. Rev. Lett. 105 232502 (2010)

n^3He Theory

- Full four-body calculation of strong scattering wave functions
- Evaluation of the weak matrix elements in terms of the EFT potential:

$$A_{PV} = a_0 h_\pi^1 + a_1 C_1 + a_2 C_2 + a_3 C_3 + a_4 C_4 + a_5 C_5$$

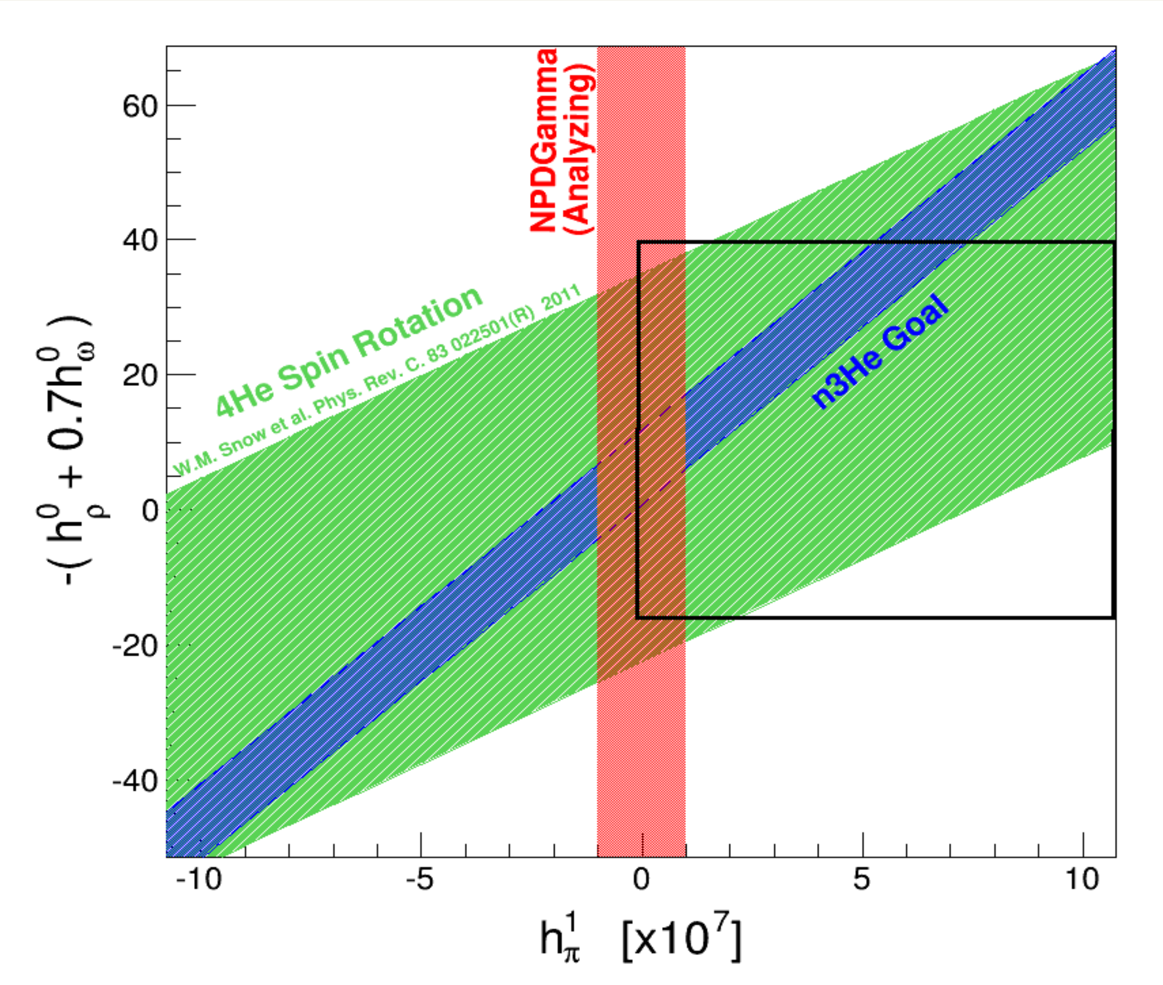
$$A_{PV}(th.) \approx 1.7 \times 10^{-8} \quad \Lambda = 500\ MeV$$

$$A_{PV}(th.) \approx 3.5 \times 10^{-8} \quad \Lambda = 600\ MeV$$

EFT coefficents	Λ = 500 MeV	Λ = 600 MeV
a_0	-0.1444	-0.1293
a_1	0.0061	0.0081
a_2	0.0226	0.0320
a_3	-0.0199	-0.0161
a_4	-0.0174	-0.0156
a_5	-0.0005	-0.0001

M. Viviani, et al. Phys. Rev. C 89, 064004 (2014)

n^3He Theory



M. Viviani, R. Schiavilla, Phys. Rev. C. 82 044001 (2010)
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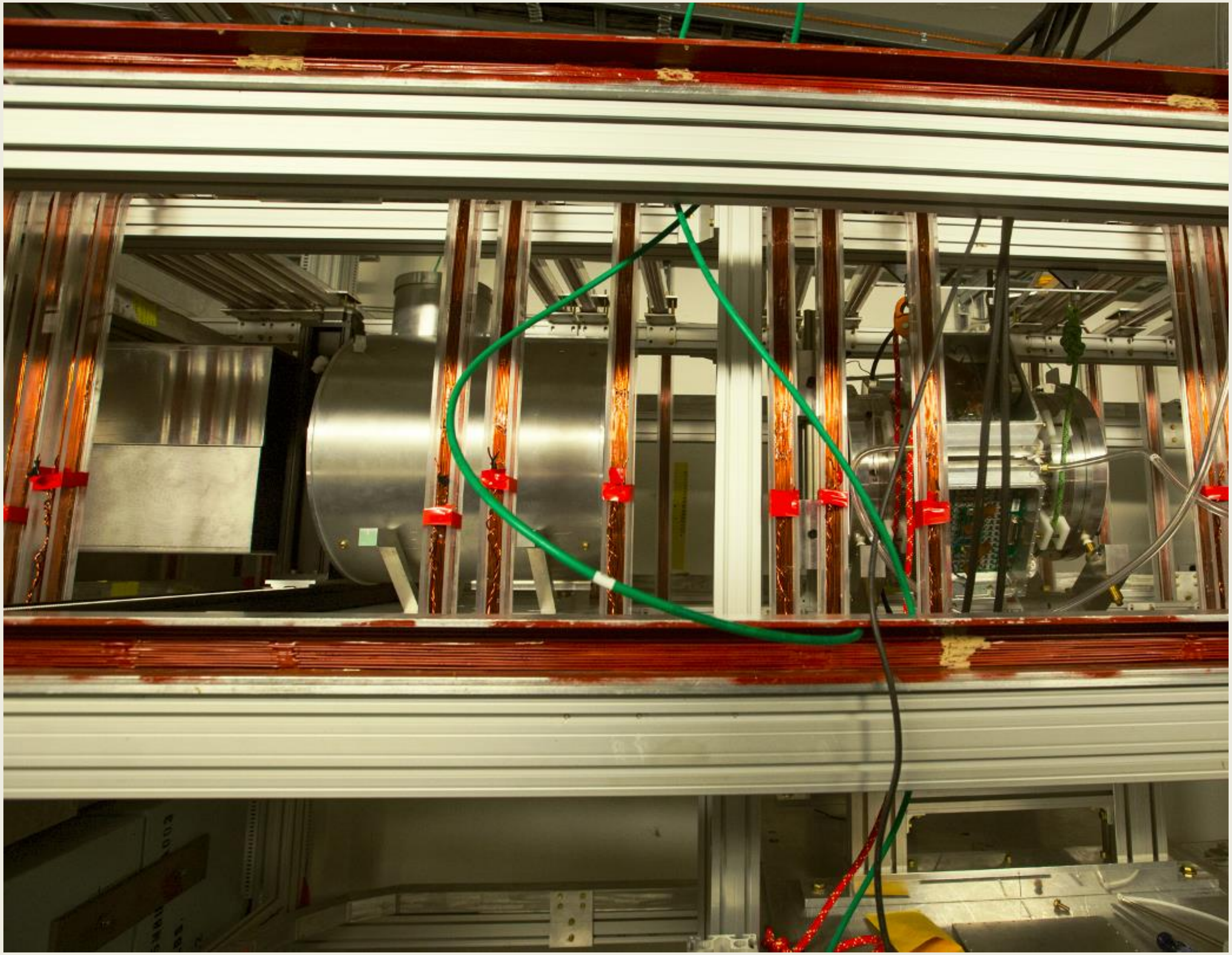
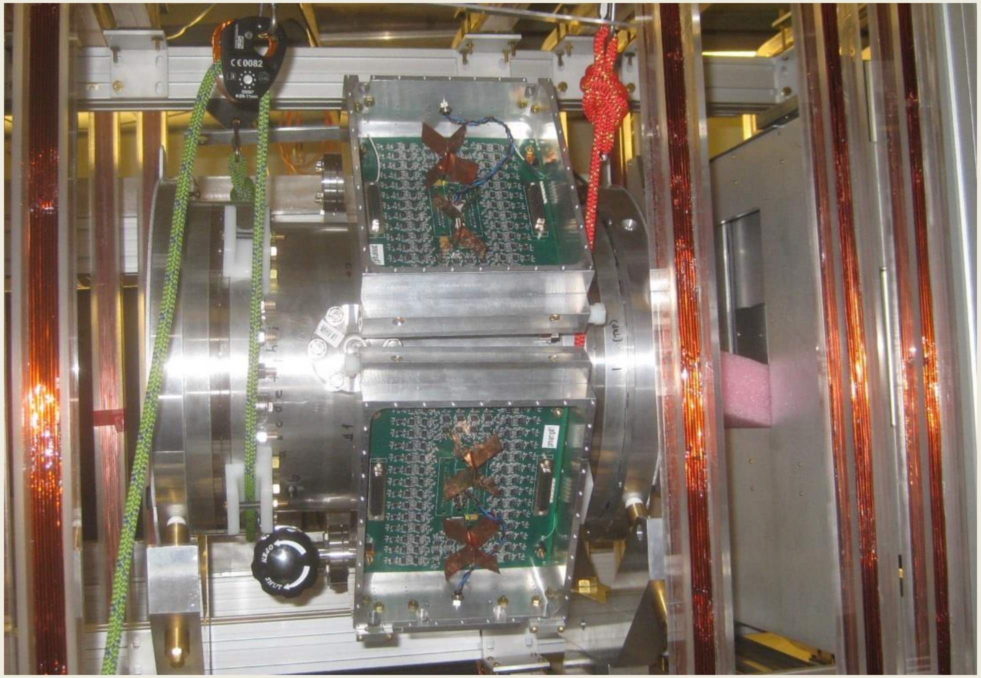
Installed Experiment



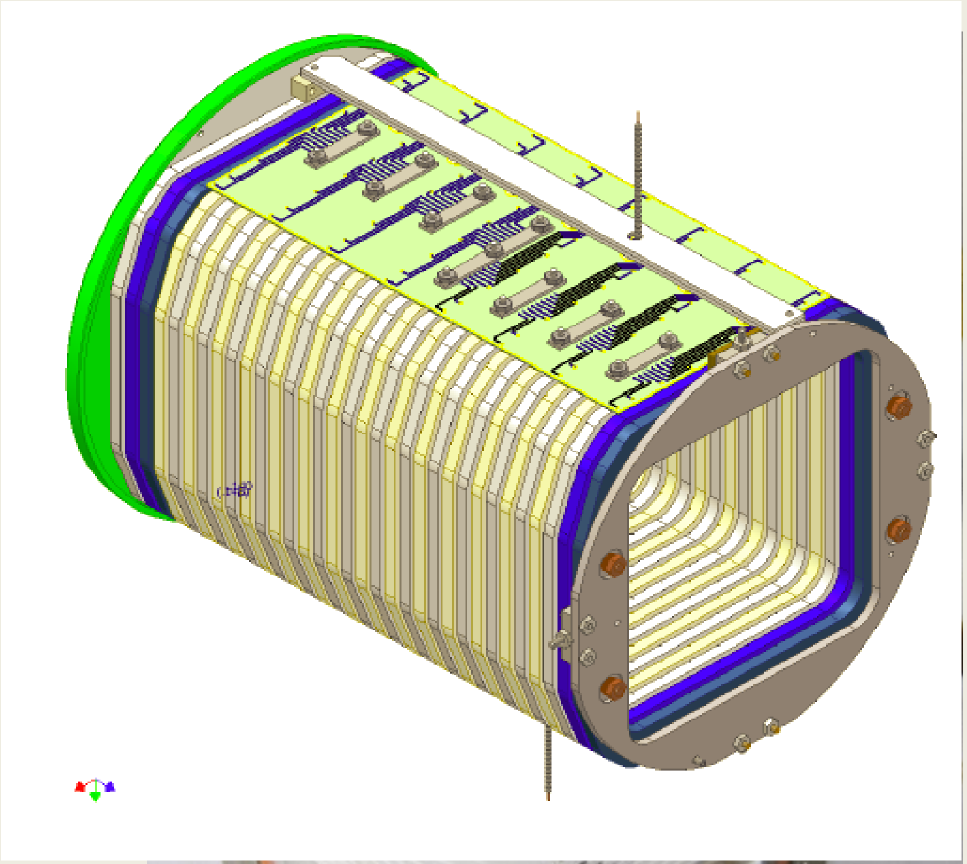
Detector Target Chamber

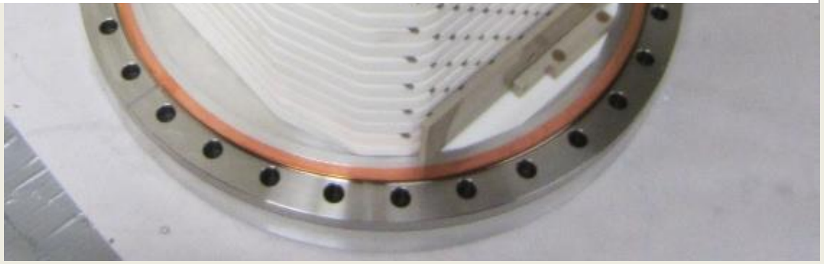


Mark McCrea Ph.D. Thesis Project

Detector Target Chamber

- 17 HV planes
- 16 signal planes
  - 144 signal wires





Detector Target Chamber

- 17 HV planes
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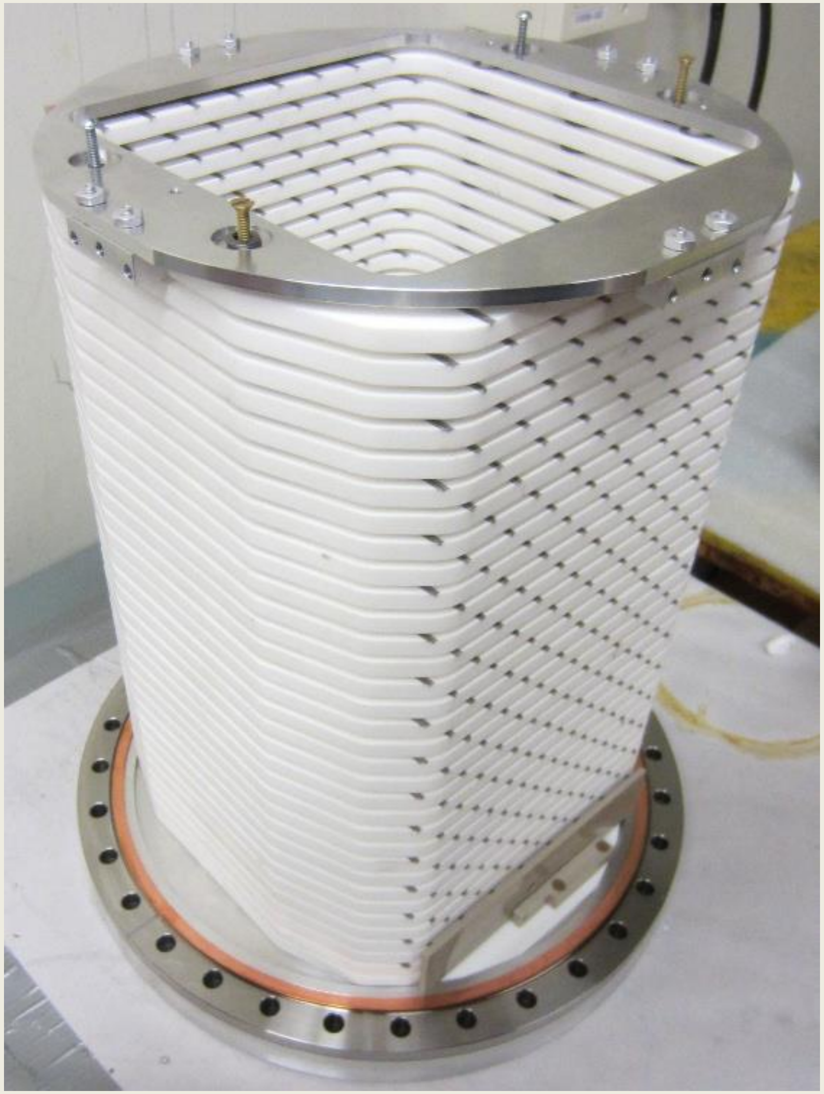
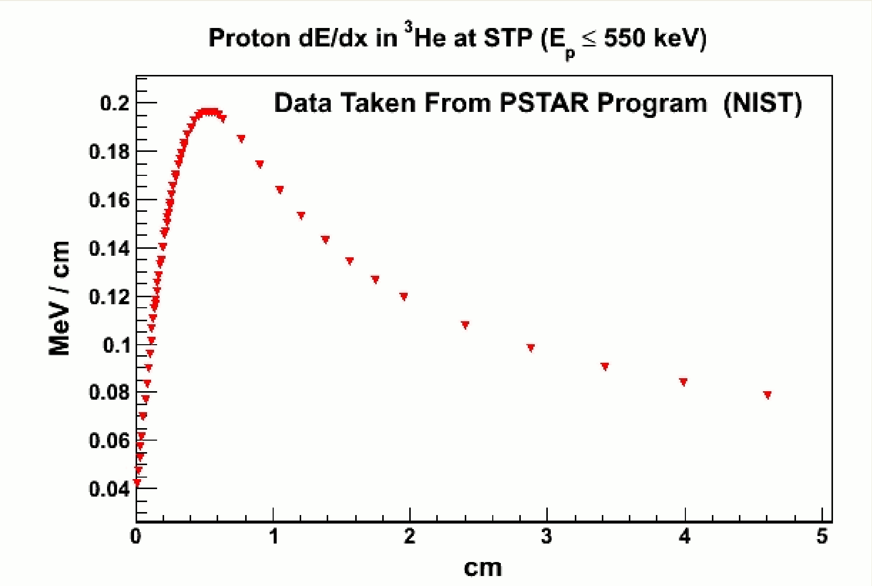
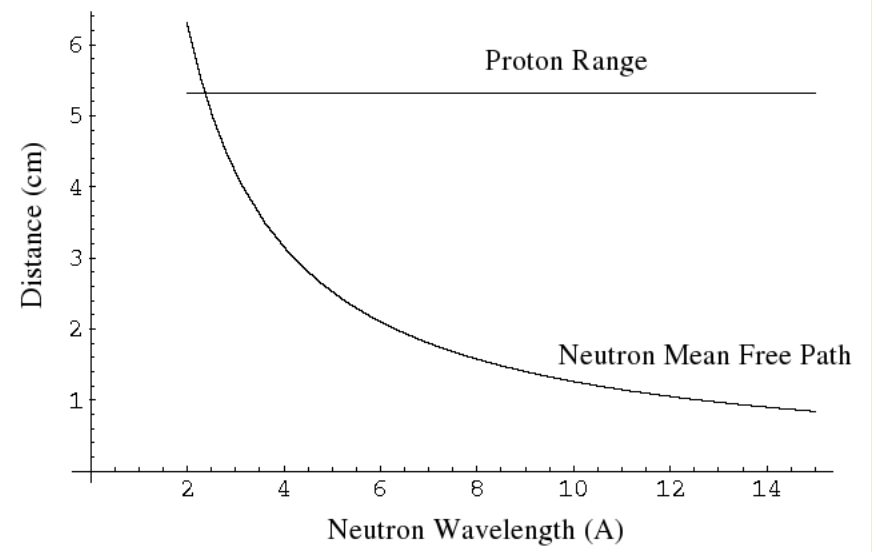
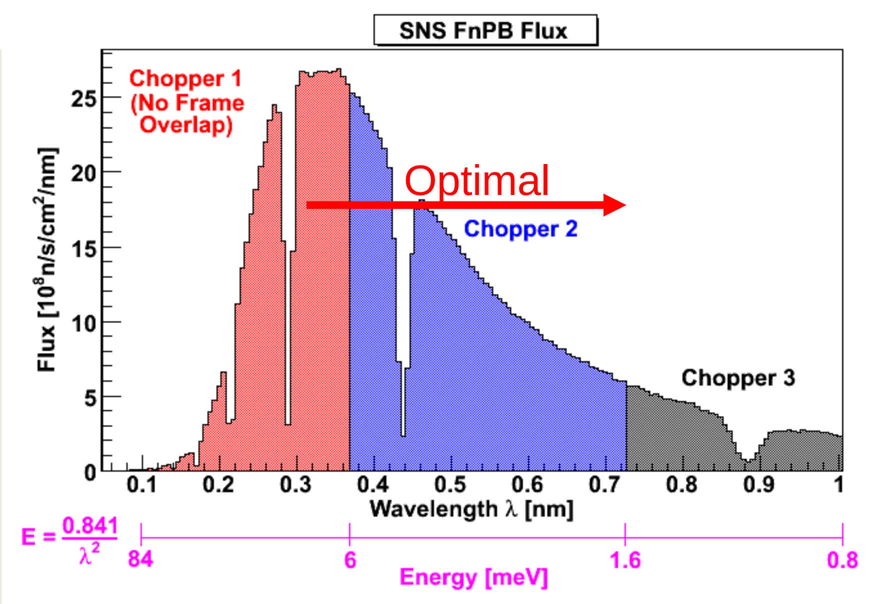
  - 144 signal wires



Design Criteria For the Chamber







- Chamber mostly filled with Helium 3
- Want to let protons range out
- Proton range r_p~5.5 cm
- Neutron mfp should be < r_p / 2
- Optimal wavelength range > 4.7 A
- Will have 6.5 x 10^{10} n/s

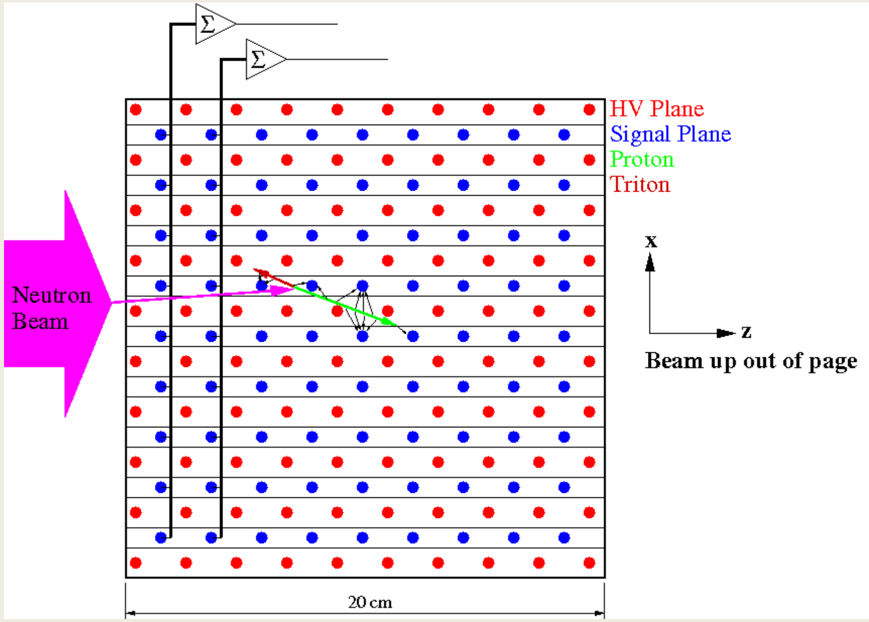
n^3He Principle of Measurement

Measure the asymmetry in the number of forward going protons in a ^3He wire chamber as a function of neutron spin:

$\vec{\sigma}_n \cdot \vec{k}_T$ *Directional PV asymmetry in the number of tritons*

$\vec{\sigma}_n \cdot \vec{k}_p$ *Directional PV asymmetry in the number of protons (much larger track length)*

- *wire chamber is both target and detector*
- *wires run vertical or horizontal*
- *no crossed wire: keep the field simple to avoid electron multiplication (non-linearities)*



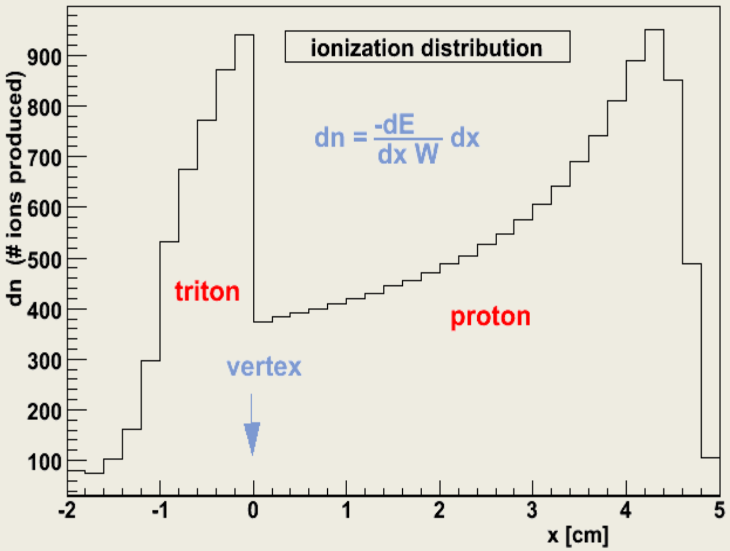
$$\vec{n} + {}^3\mathrm{He} \rightarrow \mathrm{p} + \mathrm{t} + 764\ \mathrm{keV}$$

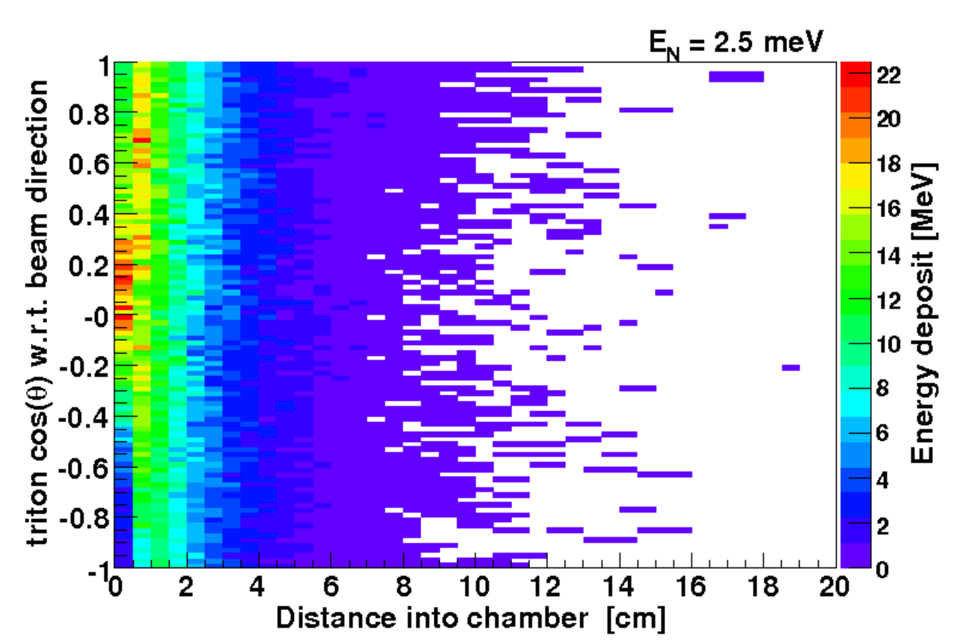
Design Criteria For the Chamber

- MC simulations of sensitivity to proton asymmetry
  - including wire correlations
  - $$\delta A_{ph} = \frac{1}{\sqrt{N}P_N}\sqrt{\sigma_D^2 + \sigma_{coll}^2}$$

$\sigma_d \simeq 6$

tritons



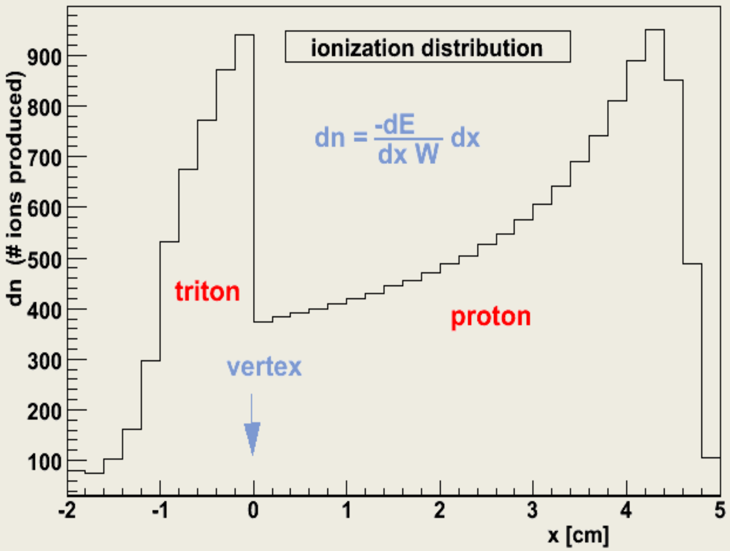


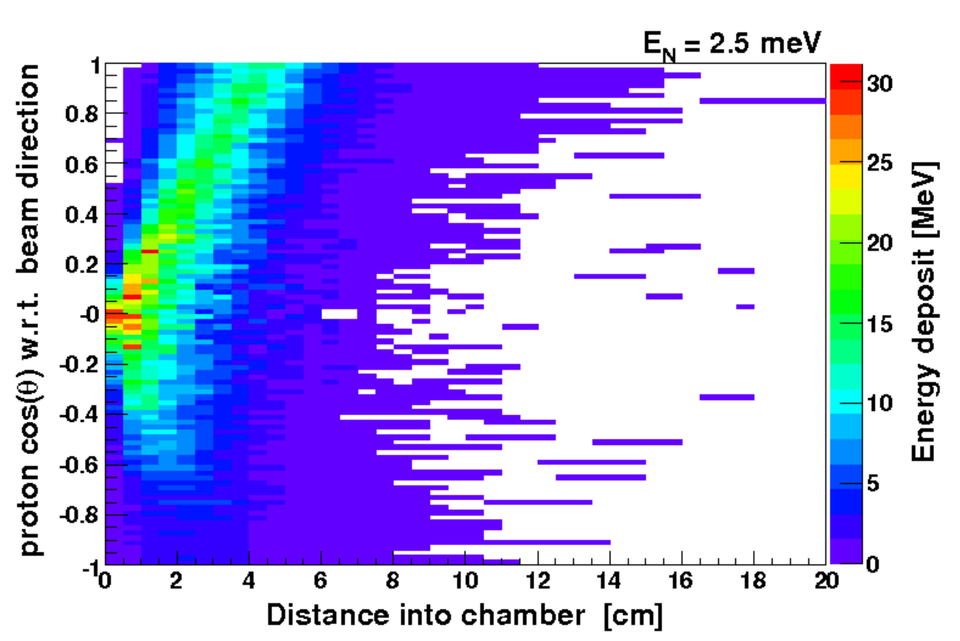
Design Criteria For the Chamber

- MC simulations of sensitivity to proton asymmetry
  - including wire correlations
  - $$\delta A_{ph} = \frac{1}{\sqrt{N}P_{_N}}\sqrt{\sigma^2_{_D} + \sigma^2_{coll}}$$

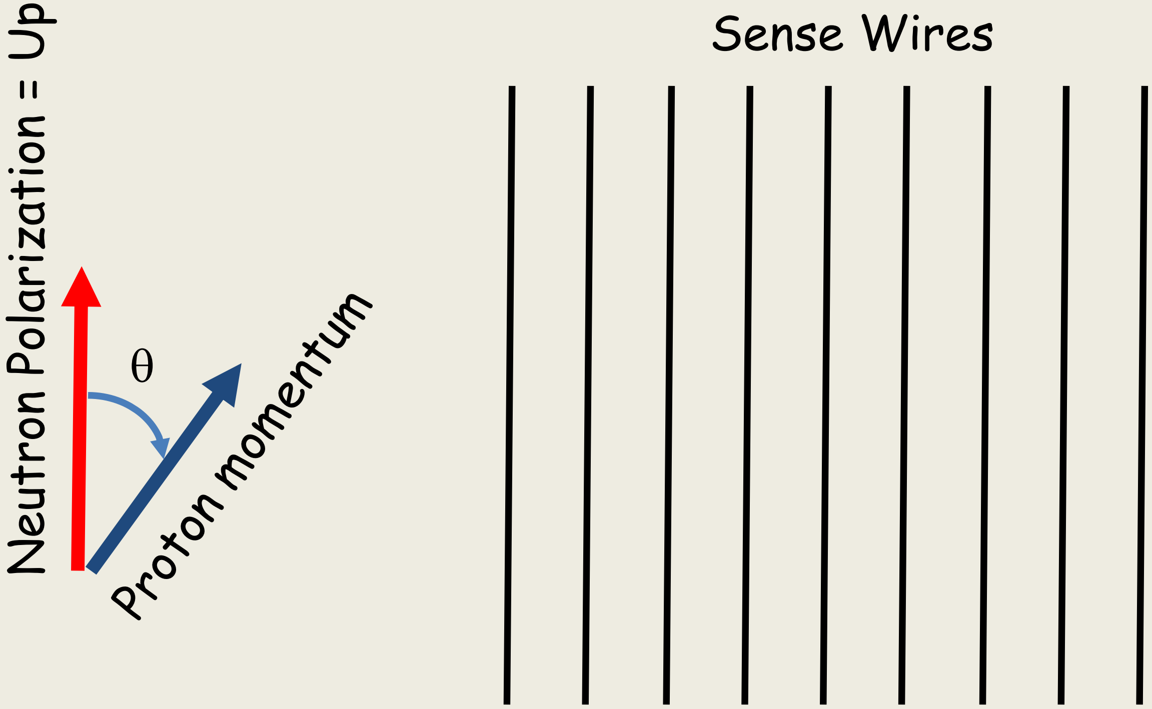
$$\sigma_d \simeq 6$$

protons





n^3He Principle of Measurement



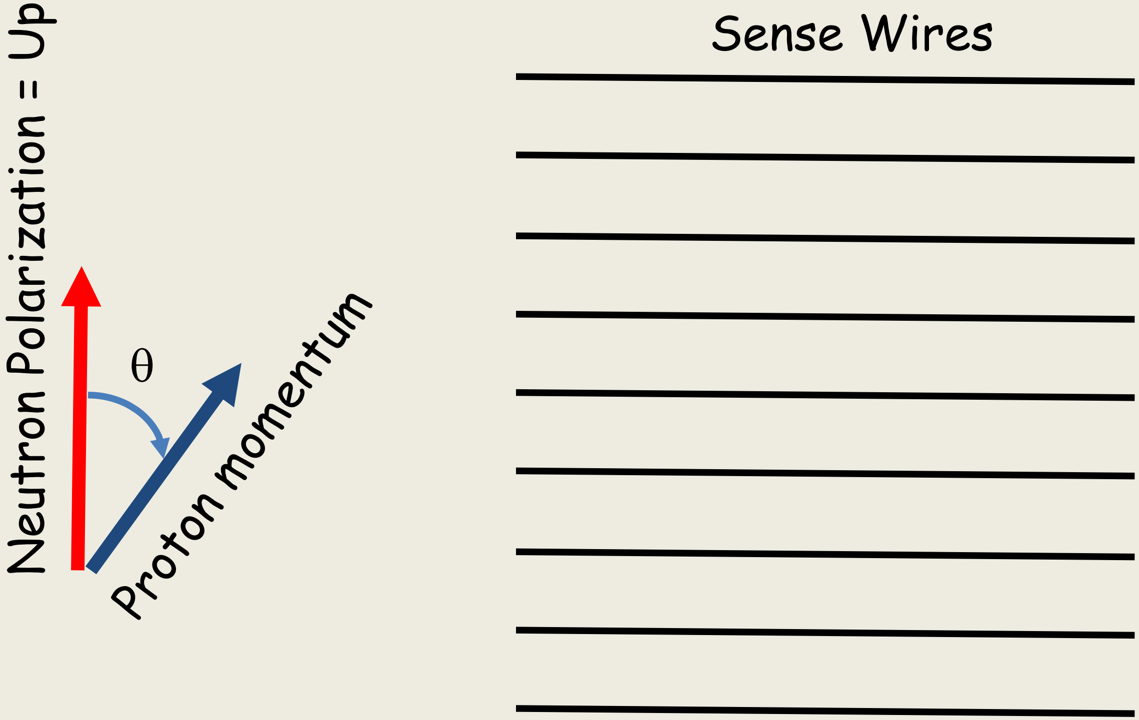
Beam into page

Left-Right (PC)

Configuration

$$A_{PV}^{exp} = f_{exp}\left(A_{PV}\cos\theta_{\vec{n},\vec{k}_p} + A_{PC}\sin\theta_{\vec{n},\vec{k}_p}\right)$$

n^3He Principle of Measurement



Beam into page

Up-Down (PV)

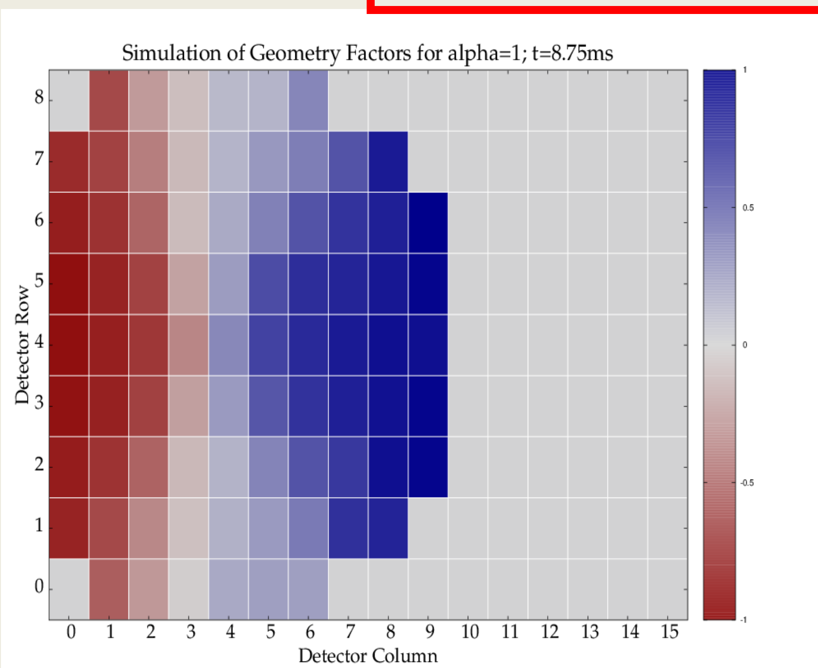
Configuration

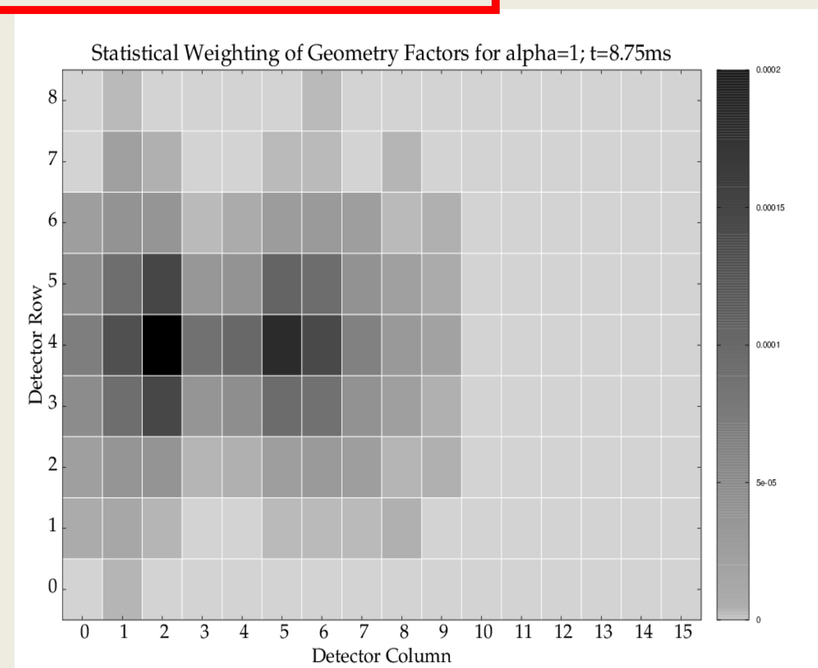
$$A_{PV}^{exp} = f_{exp}\left(A_{PV}\cos\theta_{\vec{n},\vec{k}_p} + A_{PC}\sin\theta_{\vec{n},\vec{k}_p}\right)$$

Geometry Factors Calculation

- Based on SNS beam analysis, TRIM deposition data, and ENDF
- Calculated using MC simulation
- Dependent on time of flight and channel: 144 wires, 40 times

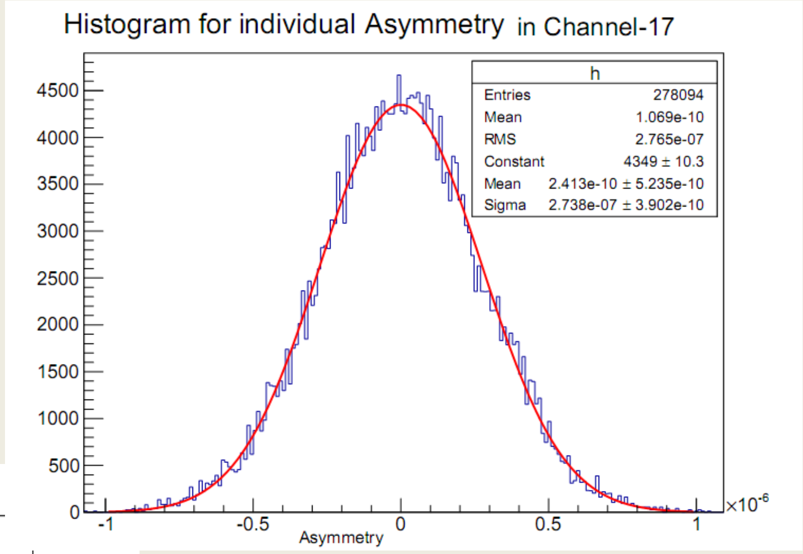
$$A_{PV}^{exp} = f_{exp}\left(A_{PV}\left\langle \cos\theta_{\vec{n},\vec{k}_p}\right\rangle + A_{PC}\left\langle \sin\theta_{\vec{n},\vec{k}_p}\right\rangle\right)$$

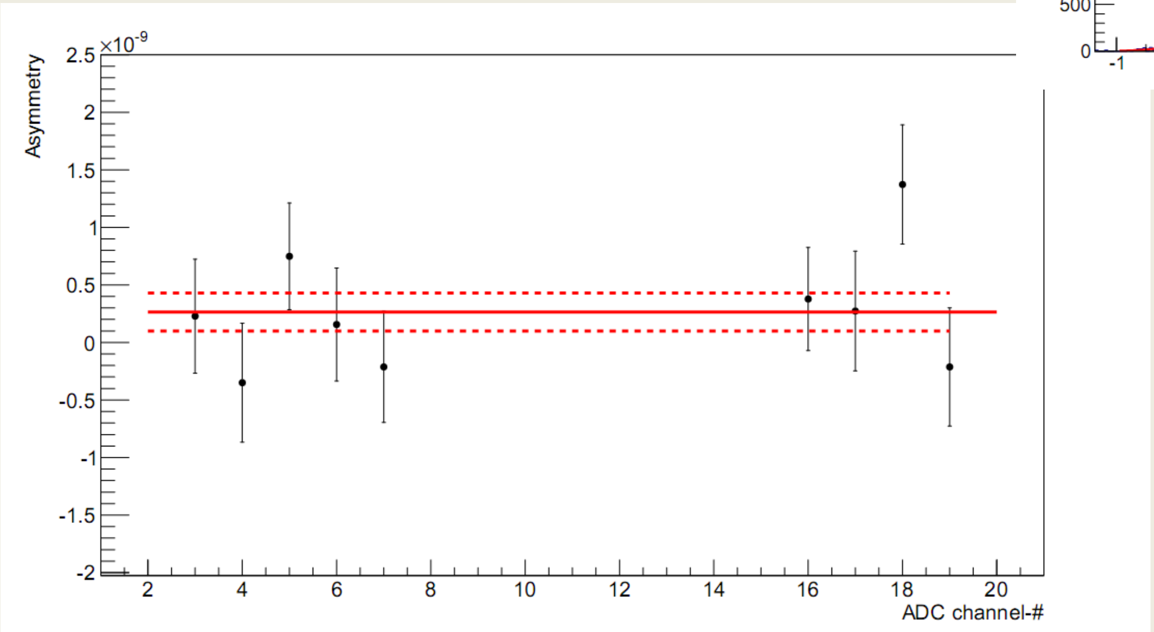




Instrumental false asymmetry measurement

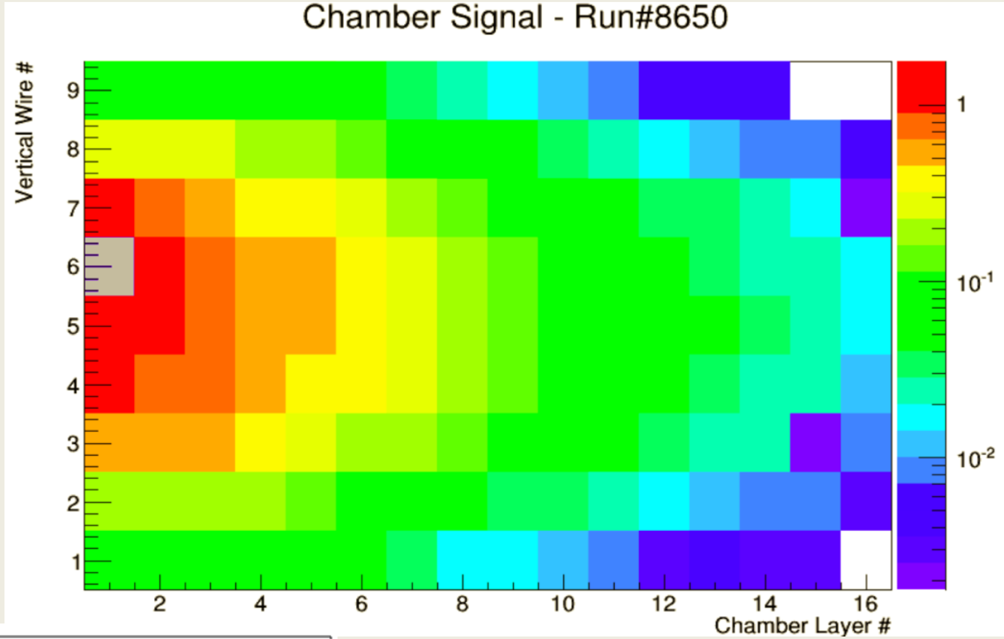
- Data taken for 5 hours
- $A = (2.64 \pm 1.64) \times 10^{-10}$

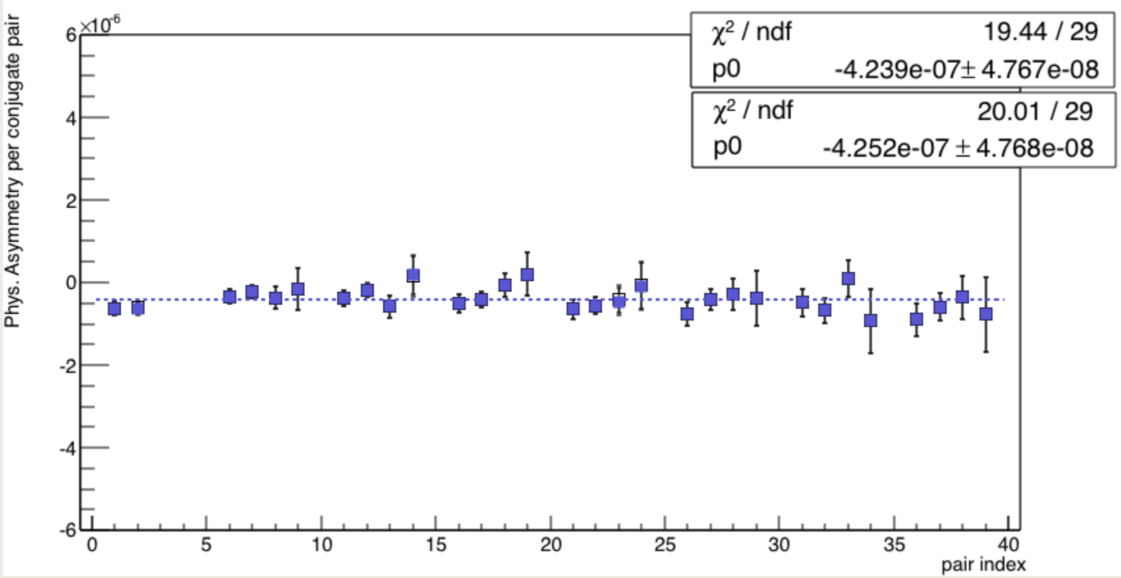




First Data

Relative signal size for each wire

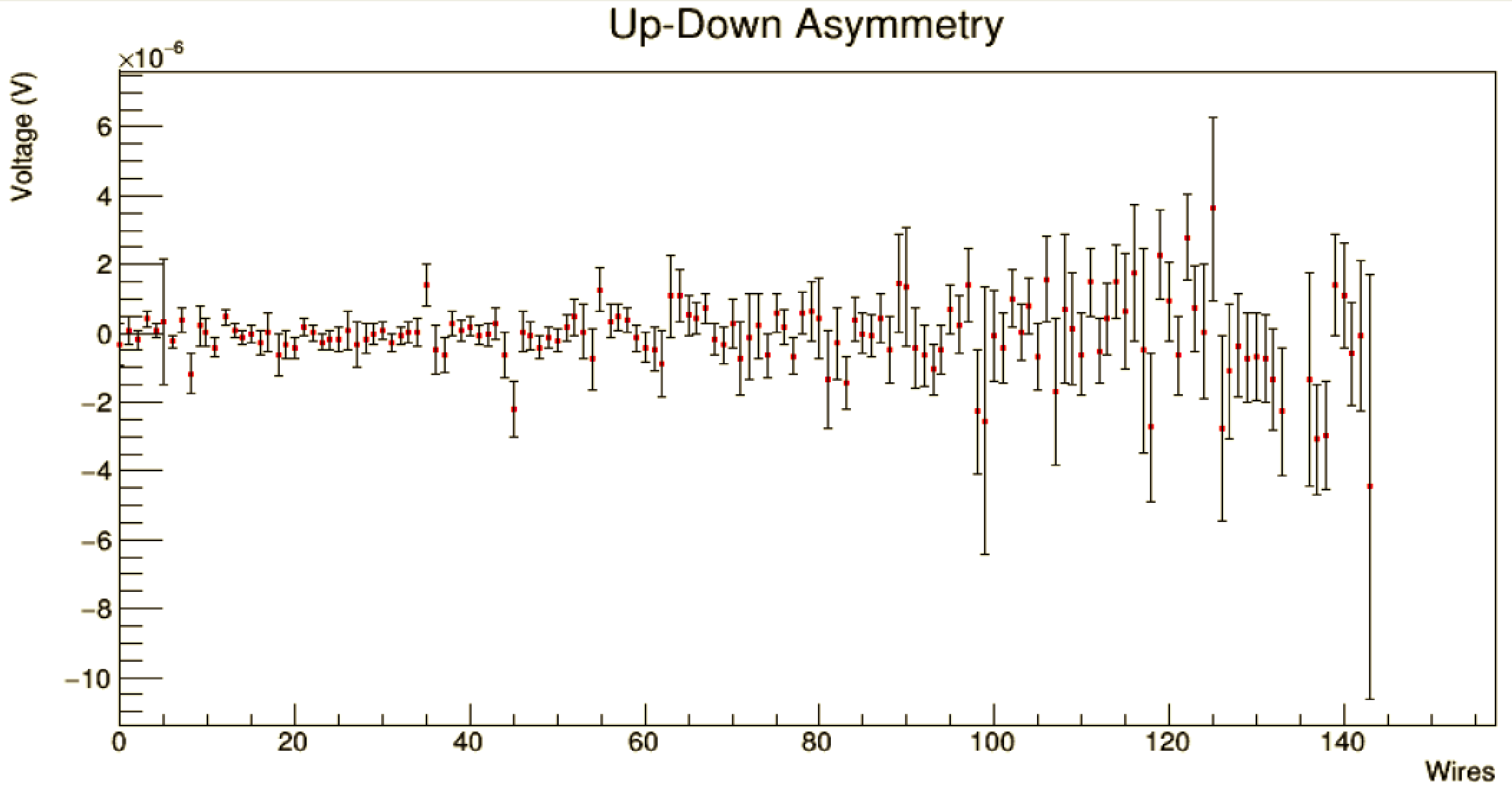




Preliminary (uncorrected) measurement of the PC (left-right) asymmetry.

First Data

100 runs (15 hours) of measurement of the PV asymmetry



UD= -4.95×10^{-8} (+/-) 6.69×10^{-7}

Schedule Overview

• Development and Construction	2010 - 2014
• Installation	Fall 2014
• Commissioning	Fall 2014 – January 2015
• Production Data Taking	February – December 2015

Thank you