Systematics of the SNS n-^{3}He Experiment

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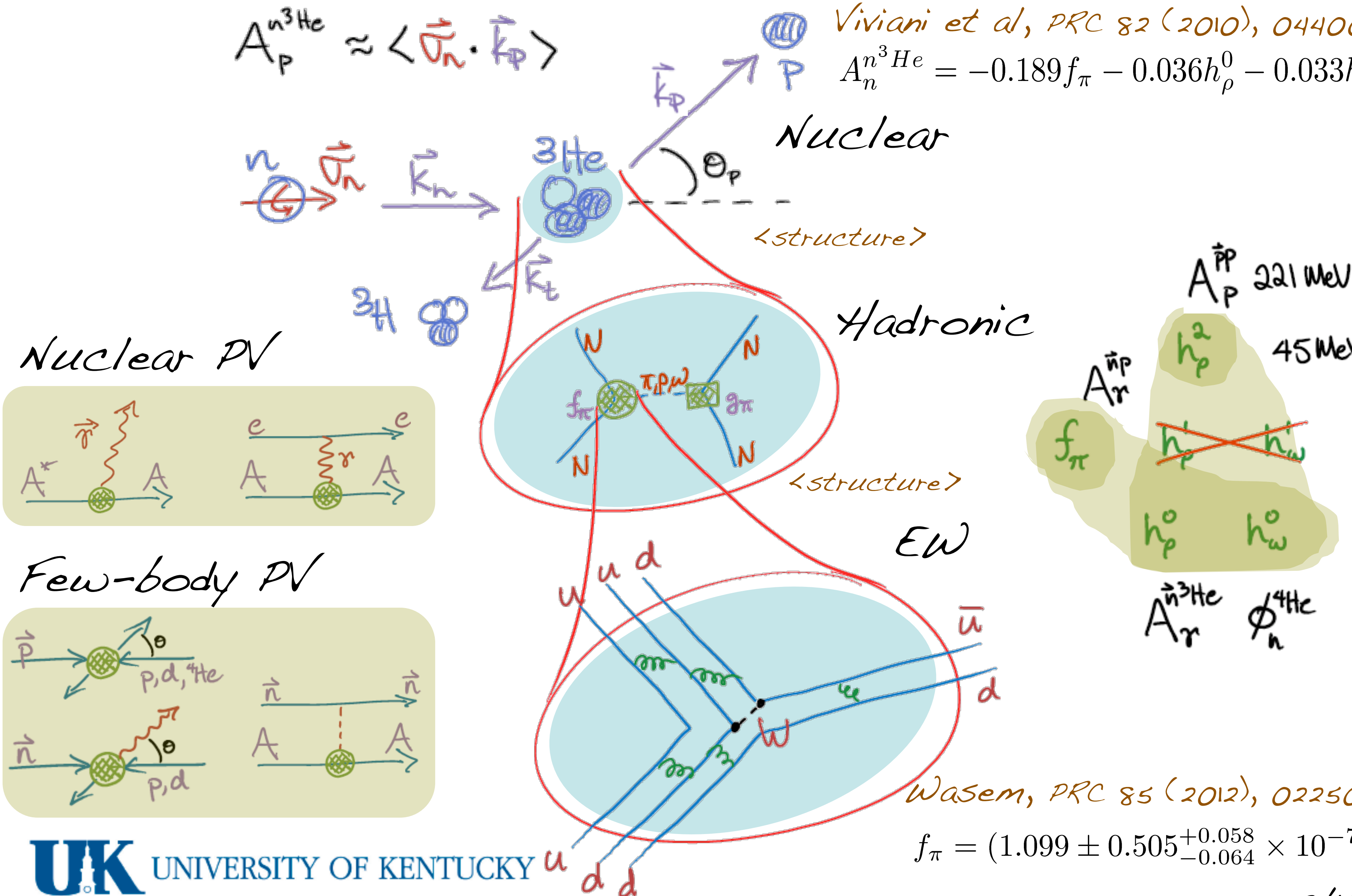
Overview - Hadronic Weak Interaction (HWI)



Viviani et al, PRC 82 (2010), 044001

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

Wasem, PRC 85 (2012), 022501

$$f_\pi = (1.099 \pm 0.505^{+0.058}_{-0.064} \times 10^{-7}$$

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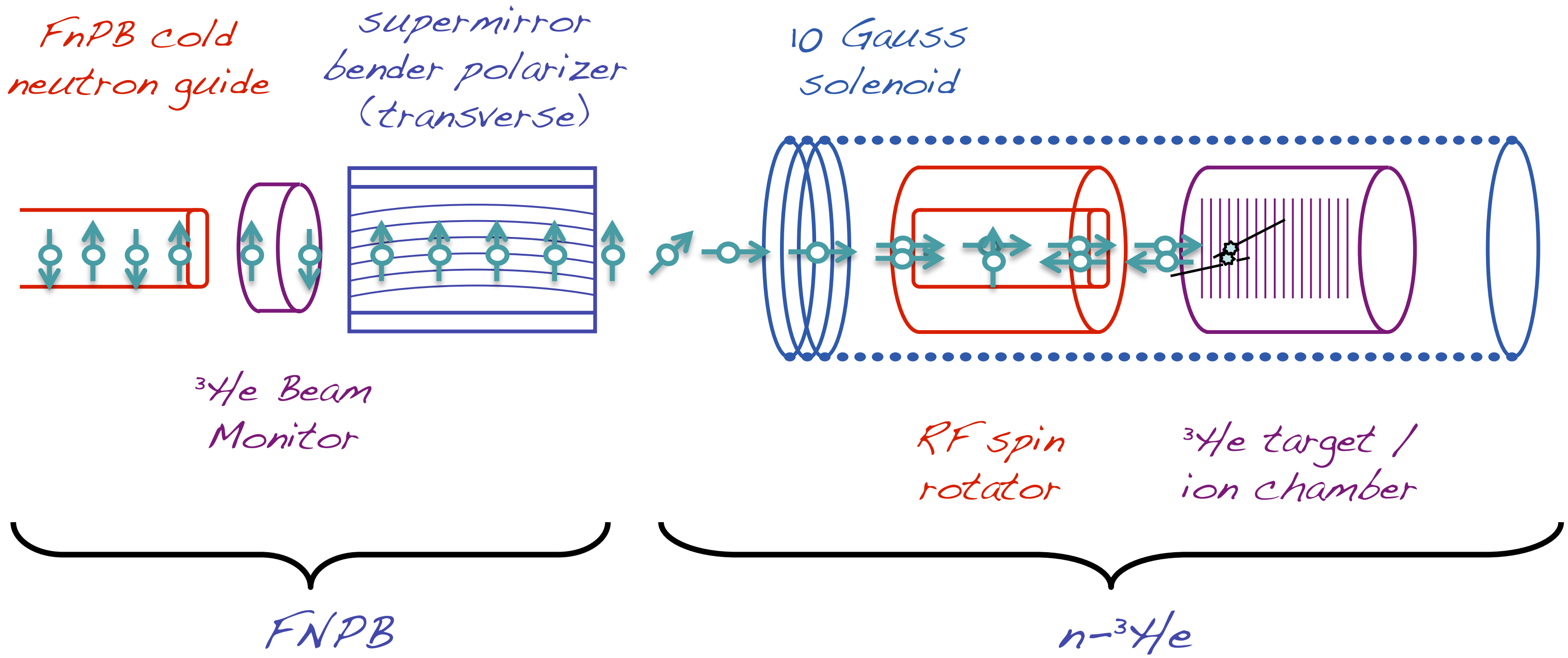
Experimental setup at the FnPB



- longitudinal holding field – suppressed PC nuclear asymmetry
  $A = 1.7\times10^{-6}$ (Hales) $s_n \bullet k_n \times k_p$ suppressed by two small angles
- RF spin flipper – negligible spin-dependence of neutron velocity
- ³He ion chamber – both target and detector

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Asymmetry Measurement - Statistics

- Extract physics asymmetry from single-wire spin asymmetries
  - operating in current-mode: t, $p_{downstream}$ background
- Two independent simulations:
  1. a code based on GEANT4
  2. a stand-alone code including wire correlations

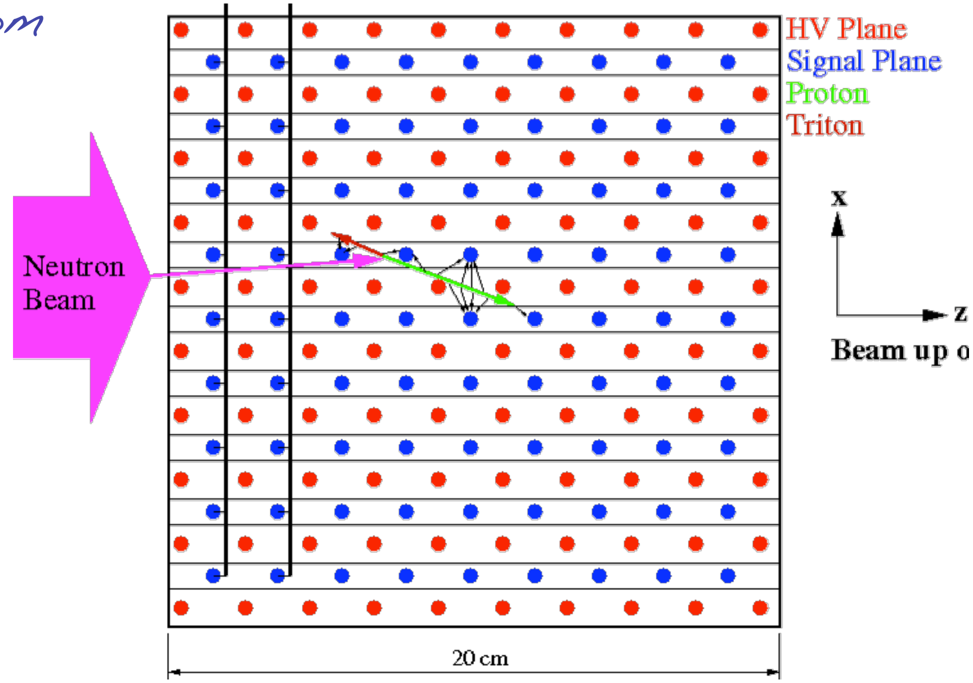
$$\delta A = \frac{\sigma_d}{P\sqrt{N}} = 1.6 \times 10^{-8}$$

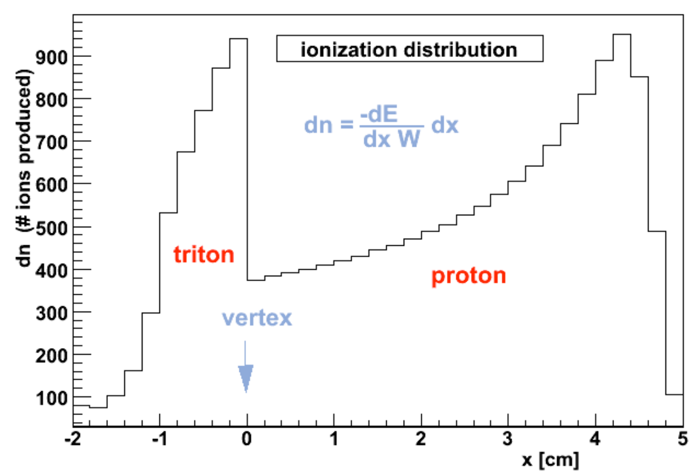
$N = 1.5 \times 10^{10}$ n/s flux (chopped) $\times 10^7$ s (116 days)

$P = 96.2\%$ neutron polarization

$\sigma_d = 6$ detector efficiency

- 15% measurement in 1 beam cycle (without contingency), assuming $A_z = 1.15 \times 10^{-7}$





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Systematic Uncertainties

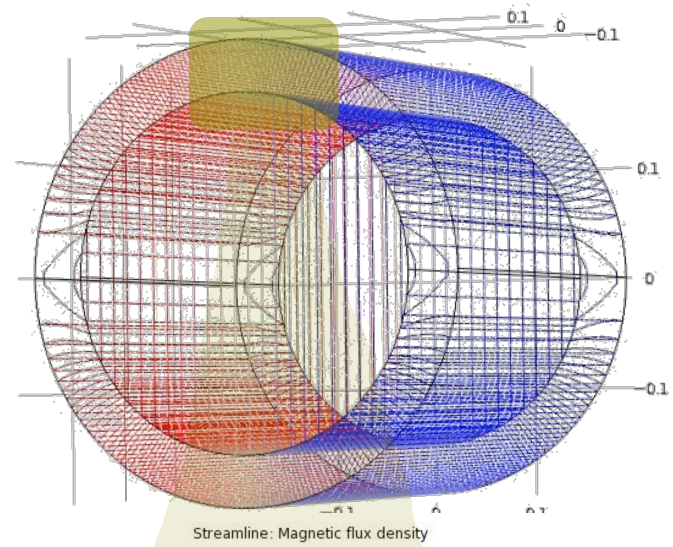
- Beam fluctuations, polarization, RFSF efficiency:
- $k_{nr} \sim 10^{-5}$ small for cold neutrons
- PC asymmetries minimized with longitudinal polarization
- Alignment of field, beam, and chamber: 10 mrad achievable
- Unlike n p -> d γ or n d -> t γ,
  n ^{3}He is very insensitive to gammas (only Compton electrons)

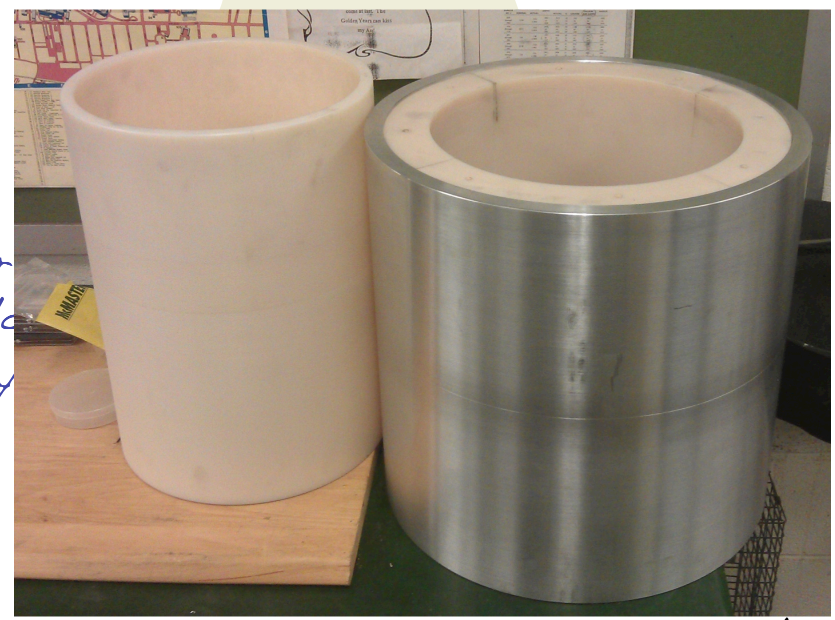
$$A_{exp} = \frac{A_b + PA}{1 + A_p P A}$$

Invariant	Parity	Size	Comments
$\vec{\sigma}_n \cdot \vec{k}_p$	Odd	3×10^{-7}	Nuclear capture asymmetry
$\vec{\sigma}_n \cdot (\vec{k}_n \times \vec{k}_p)$	Even	2×10^{-10}	Nuclear capture asymmetry
	Even	6×10^{-12}	Mott-Schwinger scattering
$\vec{\sigma}_n \cdot \vec{B}$	Even	1×10^{-10}	Stern-Gerlach steering
	Even	2×10^{-11}	Boltzmann polarization of ^{3}He
	Even	4×10^{-13}	Neutron induced polarization of ^{3}He
$\vec{\sigma}_n \cdot \vec{k}_p$	Odd	1×10^{-11}	Neutron beta decay

Transverse RF spin rotator

- Resonant RF spin rotator
  - P-N Seo et al., PRSTAB 11, 084701 (2008)
- Properties suitable for n-^{3}He expt.
  - Transverse horizontal RF B-field
  - Longitudinal or transverse flipping
  - No fringe field - 100% efficiency
  - Real, not eddy currents along outside minimizes RF leaked outside
  - Doesn't affect neutron velocity
  - Compact geometry
  - Matched to the driver electronics of the NPDGamma spin flipper
- Construction
  - Development in parallel with similar design for nEDM neutron guide fiel
  - Few-winding prototype built at UKy
    Production RFSF being built now





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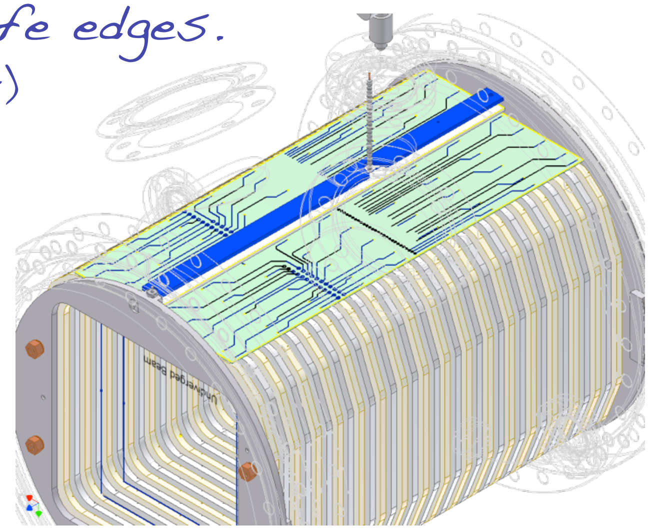
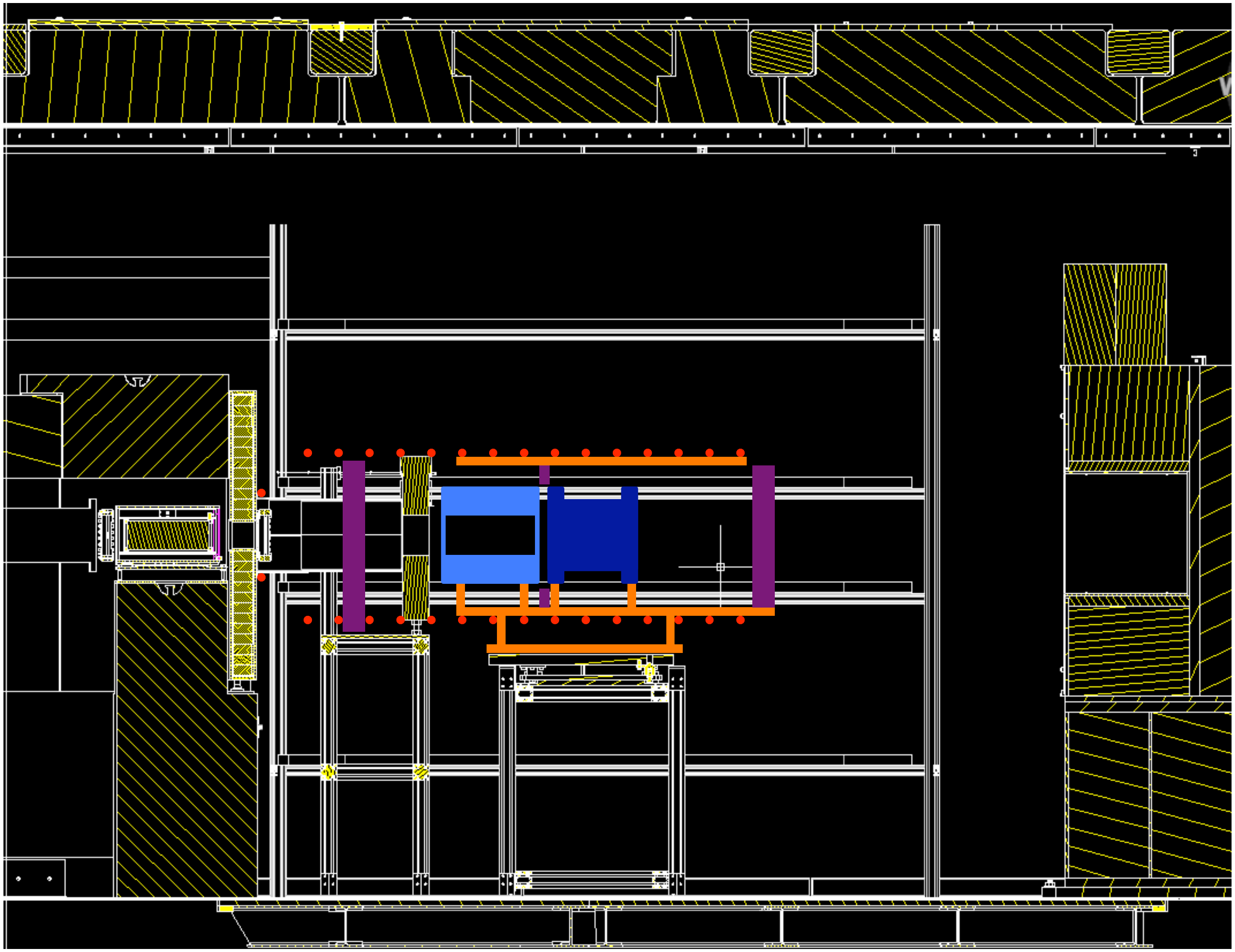
Target Ion Chamber

- Chamber all aluminum except for the knife edges.
  - 4 feedthrough ports (153 readout channels)
  - 2 HV ports + 2 gas inlets/outlets
  - 12 inch aluminum windows (0.9 mm thick).
- Macor wire frames
  - Platinum-gold thick film wire solder pads
- Filled with 1 atm of ^3He



Assembly in the FnPB cave



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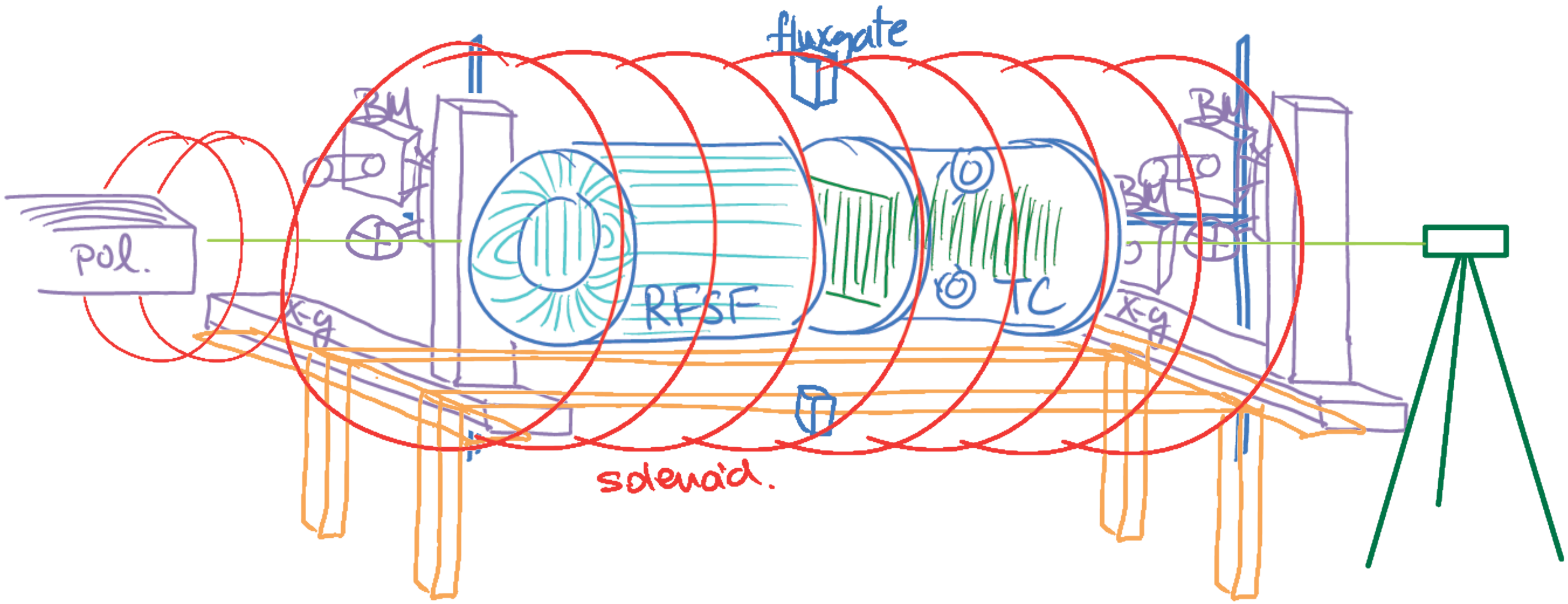
Commissioning / run plan



1. Scan beam profile upstream and transfer centroid to crosshairs
2. Scan beam profile downstream
3. Align theodolite to crosshairs
4. Align B-field to theodolite
5. Field map in RFSR/Target region
6. Align the position / angle of target with theodolite / autocollimator
7. Tune RSFR / measure polarization
8. Measure physics asymmetry

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Summary

n-^{3}He collaboration

- Last measurement for the a characterization of the Hadronic Weak Interaction
- 15% projected uncertainty will be the most accurate HWI experiment in a few-body system
- Scheduled FnPB beam time June 2014 - Dec 2015

Institution	Researcher	Category	2013 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	50
	David Bowman	Research Staff	20
	TBD	Postdoc	20
University of Kentucky			
	Chris Crawford	Faculty	35
	TBD	Grad Student	100
Western Kentucky University			
	Ivan Novikov	Faculty	70
	TBD * 2	Undergraduate	100
University of Manitoba			
	Michael Gericke	Faculty	30
	Shelley Page	Faculty	10
	WTh. Van Oers	Faculty	10
	Rob Mahurin	Postdoc	20
	V. Tvaskis	Postdoc	10
	Mark McCrea	Grad Student	100
	D. Harrison	Grad Student	100
Universidad Nacional Autónoma de México			
	Libertad Baron	Faculty	30
	TBD	Grad Student	100
University of New Hampshire			
	John Calarco	Faculty	50
University of South Carolina			
	Vladimir Gudkov	Faculty	5
	Young-Ho Song	Postdoc	5
	TBD	Grad Student	10
Univeristy of Tennessee			
`	Geoff Greene	Faculty	10
	S. Kucuker	Postdoc	20
Univeristy of Tennessee at Chattanooga			
`	Josh Hamblen	Faculty	30
University of Virginia			
	S. Baessler	Faculty	20

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Timeline

- Construction of subsystems in parallel
  - Will be ready for beam at beginning of cycle Aug 2014
  - Critical path: preamp design and construction (possibly DAQ)
  - Will stage experiment in EDM building and perform dry run of field map, beam map, and alignment procedures
  - See Gantt chart for details
- Milestones
  - 2014-04-21 Begin assembly and testing in EDM building
  - 2014-07-18 Begin installation in FnPB cave
  - 2014-10-27 IRR – begin commissioning phase
  - 2015-02-?? Physics data taking at beginning of beam cycle
- Time budget
  - 76 days commissioning (all equipment pre-assembled)
  - 15 days PC transverse asymmetry $1.7 \times 10^{-6} \pm 0.5 \times 10^{-7}$
  - 116 days PV longitudinal asymmetry $1.15 \times 10^{-7} \pm 1.6 \times 10^{-8}$