Experimental Study of the Parity Violating Hadronic Weak Interaction

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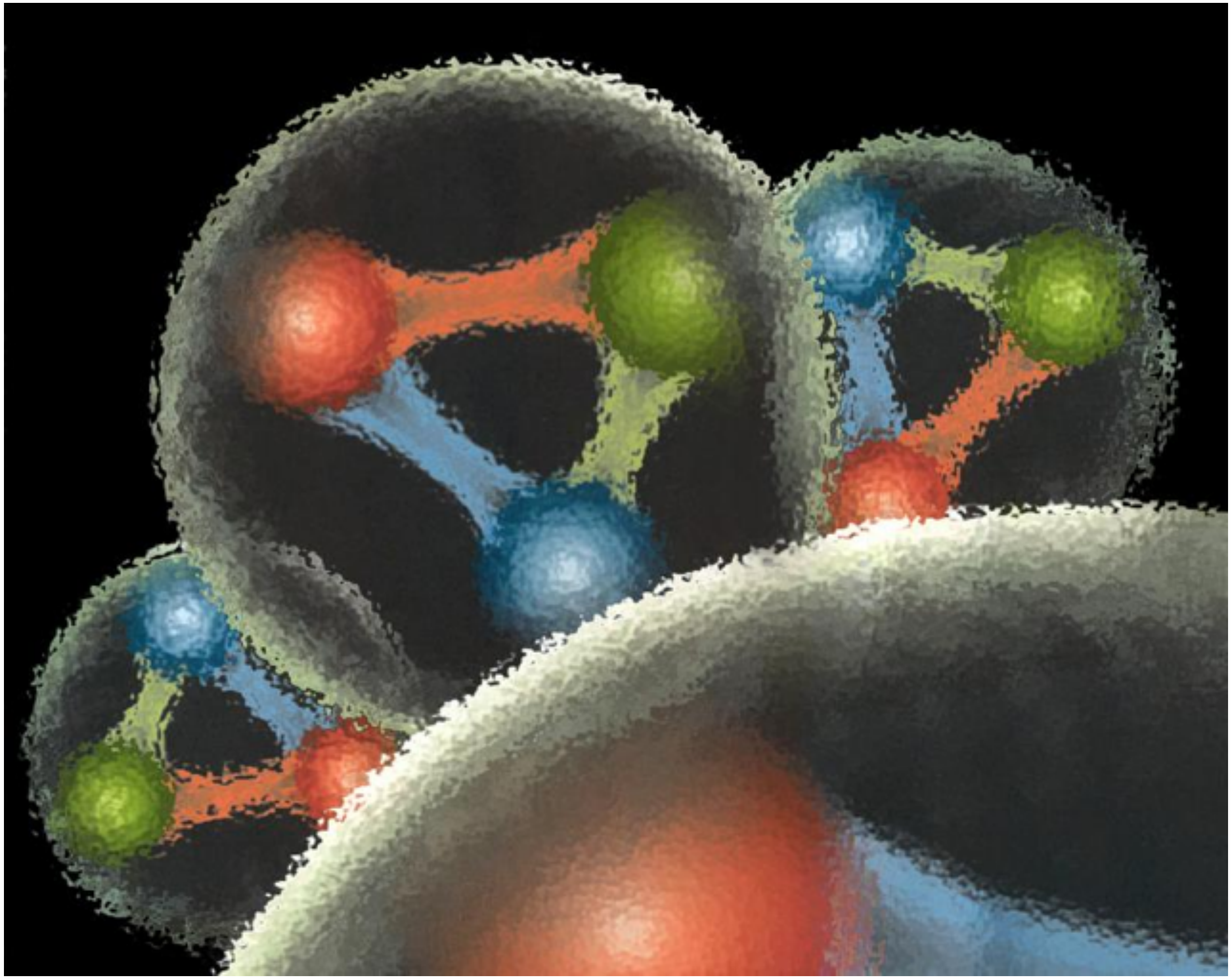
Interactions between hadrons

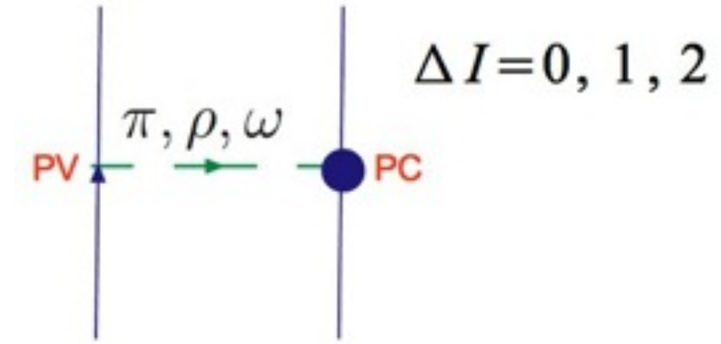


QCD is not perturbative at low energies.

Theoretical description

DDH

- One meson exchange potential
- Model dependent
  Desplanques, Donoghue, Holstein, Annals of Physics 124, 449 (1980).



$$h_\pi^1,\ h_\rho^0,\ h_\rho^1,\ h_\rho^2,\ h'^1_\rho,\ h_\omega^0,\ h_\omega^1$$

EFT

- Not dependent on a model
- Consistent with the symmetries and degrees of freedom of QCD
  Zhu, Maekawa, Holstein Ramsey-Musolf, Van Kolck, Nuclear Physics A 748, 435 (2005).

$$\lambda_s^0,\ \lambda_s^1,\ \lambda_s^2,\ \lambda_t,\ \rho_t$$

$${}^1S_0 \rightarrow {}^3P_0 \quad (\Delta I = 0,1,2)$$

$${}^3S_1 \rightarrow {}^1P_1 \quad (\Delta I = 0)$$

$${}^3S_1 \rightarrow {}^3P_1 \quad (\Delta I = 1)$$

Lattice QCD

- Theoretical exploration of observables in the non-perturbative regime of QCD with quantifiable uncertainties
- Confrontation of theory and experiment
  J. Wasem, Physical Review C 85, 022501 (2012).

Reasons to study the $\Delta S=0$ HWI

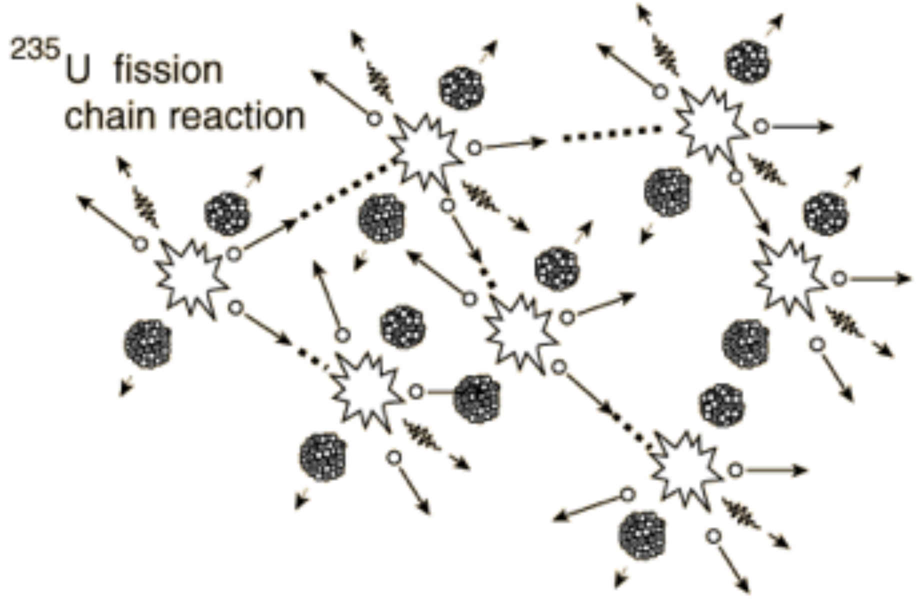
- Unresolved puzzles in the flavour changing HWI
- It offers a possibility to study weak neutral currents at low energies
- Constitutes a probe for quark-quark correlations in nucleons
- The weak quark-quark and nucleon-nucleon interactions are the microscopic source of PV effects in electron scattering, nuclear resonances and decays, and atomic structure

Few nucleon systems

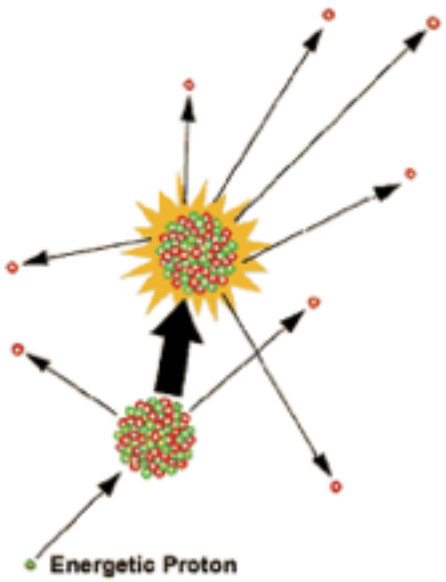
- Reduction of uncertainties related to nuclear structure and more reliable interpretation of observables
- Theoretical calculations are more feasible and in some cases already available for few-body systems
- Intense sources of neutrons and gamma rays are available

Program with low energy neutrons

Nuclear reactor



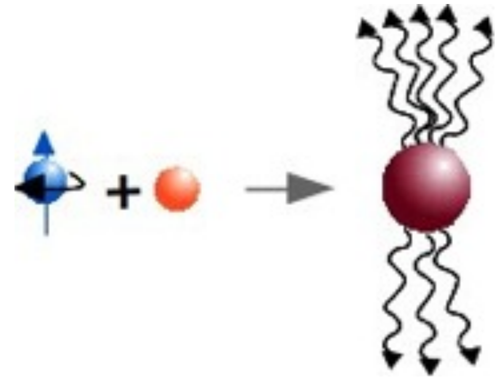
Spallation source



PV observables in experiments with neutrons

NPDGamma

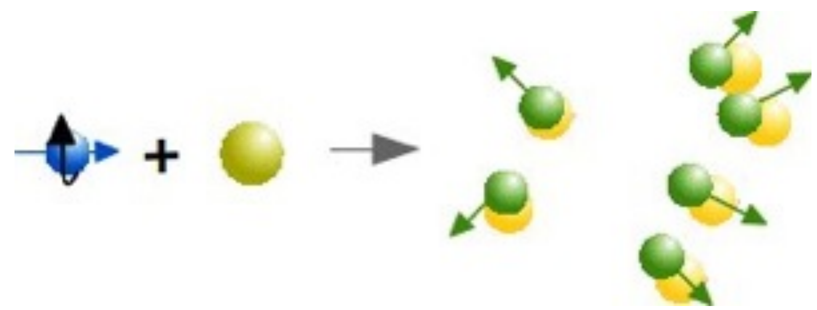
$$\vec{n} + p \rightarrow d + \gamma$$



$$A_\gamma(\vec{k}_\gamma \cdot \vec{\sigma}_n)$$

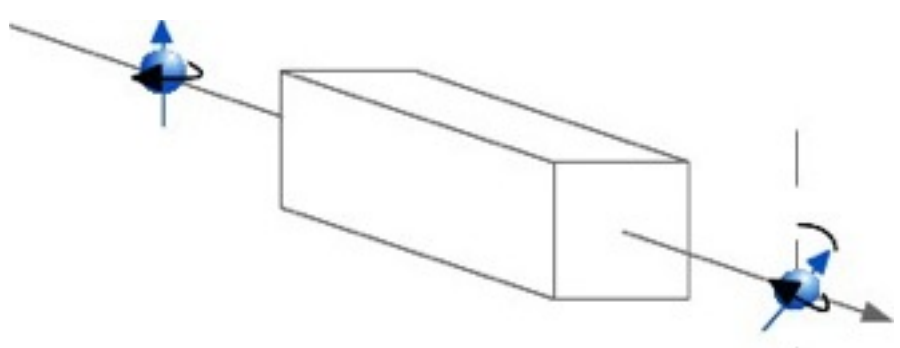
n-^{3}He

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



$$A_p(\vec{k}_p \cdot \vec{\sigma}_n)$$

Neutron Spin Rotation (NSR)



$$\frac{d\varphi}{dz}(\vec{\sigma}_n' \cdot \vec{\sigma}_n)$$

PV observables in experiments with neutrons

	DDH	EFT	Lattice QCD
NPDGamma	$A_\gamma = -0.11 h_\pi^1$ $A_\gamma = -(0-12)\times 10^{-8}$	$A_\gamma = -0.093 m_N \rho_t$	$h_\pi^1 = 1.099 \pm 0.505 {}^{+0.058}_{-0.064} \left[\times 10^{-7}\right]$
n-^{3}He	$A_p = -0.1892 h_\pi^1 - 0.0364 h_\rho^0 + 0.0193 h_\rho^1 - 0.0006 h_\rho^2 - 0.0334 h_\omega^0 + 0.0413 h_\omega^1$ $A_p = -(2.48 - 9.44)\times 10^{-8}$	$A_p = -0.1293 h_\pi^1 + 0.0081 C_1 + 0.0320 C_2 - 0.0161 C_3 - 0.0156 C_4 - 0.0001 C_5$	
Neutron Spin Rotation (NSR)	$\frac{d\varphi}{dz} = -0.97 h_\pi^1 - 0.22 h_\omega^0 + 0.22 h_\omega^1 - 0.32 h_\rho^0 + 0.11 h_\rho^1$ [rad/m] $\frac{d\varphi}{dz} = \pm 1.5 \times 10^{-6}$ rad/m	$\frac{d\varphi}{dz} = (0.60 \lambda_s^{np} + 1.34 \lambda_t - 2.68 \rho_t + 1.2 \lambda_s^{nn}) m_N$ [rad/m]	

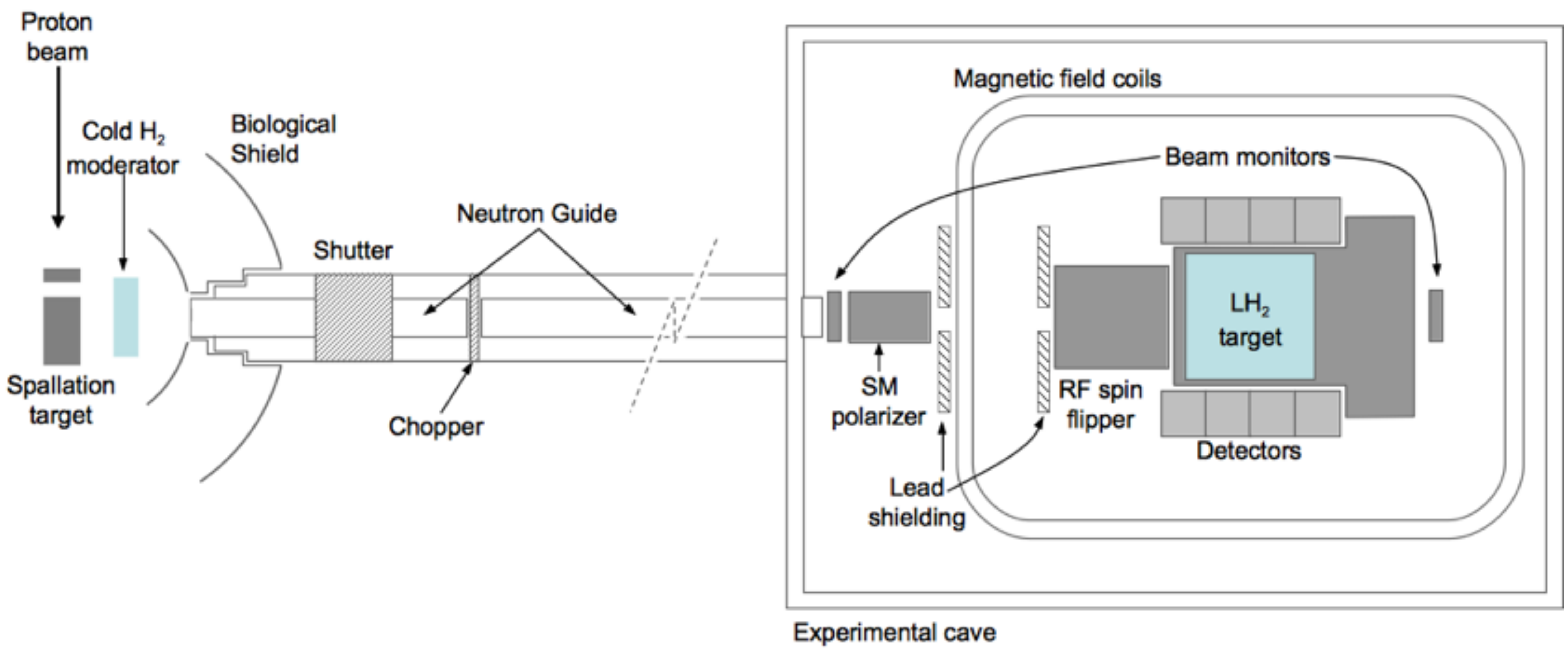
- Desplanques, Donoghue, Holstein, Annals of Physics 124, 449 (1980).
- B. R. Holstein, European Journal of Physics A 41, 279 (2009).
- J. Wasem, Physical Review C 85, 022501 (2012).
- M. Viviani et al., Physical Review C 82, 044001 (2010).
- M. Viviani et al., Physical Review C 89, 064004 (2014).
- V. Dmitriev et al., Physics Letters125, 1 (1983).

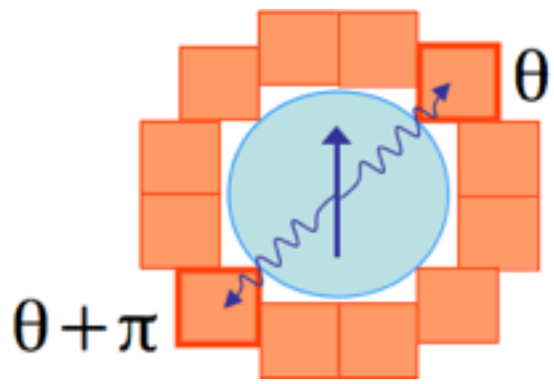
PV observables in experiments with neutrons

	theoretical prediction		measurement	
NPDGamma	$A_\gamma = -5\times10^{-8}$	DDH "best value"	$A_\gamma = 0.6 \pm 2.1\left[\times10^{-7}\right]$	Grenoble
	$A_\gamma = -1.21 \pm 0.55^{+0.06}_{-0.07}\left[\times10^{-8}\right]$	Lattice QCD	$A_\gamma = -1.21 \pm 2.1(\text{stat.}) \pm 0.2(\text{sys.})\left[\times10^{-7}\right]$	LANSCE
n-^{3}He	$A_p = 1\times10^{-7}$	DDH "best value"		
Neutron Spin Rotation (NSR)	$\frac{d\varphi}{dz} = -11.7\times10^{-7}$	DDH "best value"	$\frac{d\varphi}{dz} = 1.7 \pm 9.1(\text{stat.}) \pm 1.4(\text{sys.})\left[10^{-7}\right]$	NIST

- Desplanques, Donoghue, Holstein, Annals of Physics 124, 449 (1980).
- B. R. Holstein, European Journal of Physics A 41, 279 (2009).
- J. Wasem, Physical Review C 85, 022501 (2012).
- J.F. Cavaignac et al., Physics Letters B 67, 148 (1977).
- M. Gericke et al., Physical Review C 83, 015505 (2011).
- A.M. Micherdzinska et al., Nuclear Instruments and Methods in Physics Research A 631, 80 (2011).

NPDGamma





$$A_{\gamma,\,\mathrm{raw}} = \frac{1}{2}\left(\frac{N_\theta^\uparrow - N_{\theta+\pi}^\uparrow}{N_\theta^\uparrow + N_{\theta+\pi}^\uparrow} - \frac{N_\theta^\downarrow - N_{\theta+\pi}^\downarrow}{N_\theta^\downarrow + N_{\theta+\pi}^\downarrow}\right)$$

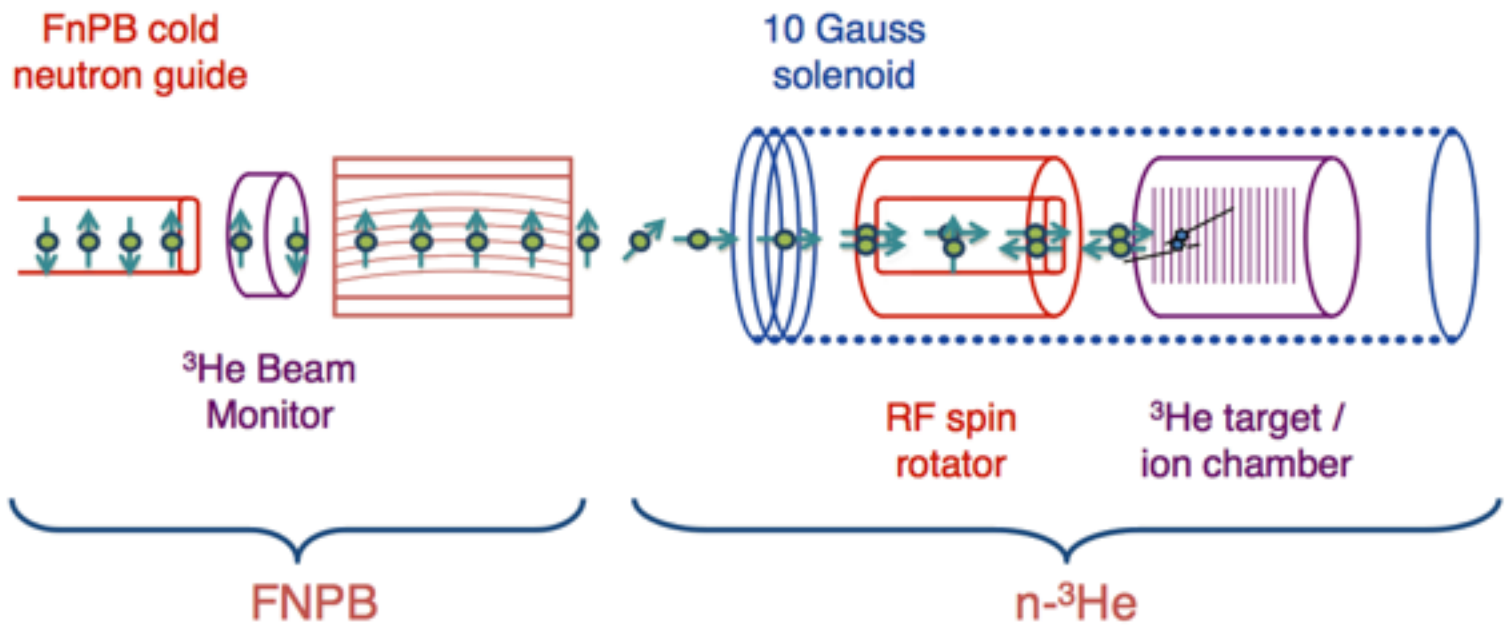
NPDGamma

- The experiment finalized data taking in June, 2014
- Systematics $<10^{-9}$
- Ongoing analysis. Preliminary results indicate the gamma asymmetry is consistent with zero with an expected uncertainty of 1.3×10^{-8}

Other results

- Chlorine asymmetry preliminary result is $25.9\pm0.6[\times10^{-6}]$
- Aluminium asymmetry (largest background) with an uncertainty $\sim3\times10^{-8}$
- Scattering cross section for neutrons on para-hydrogen at low energies

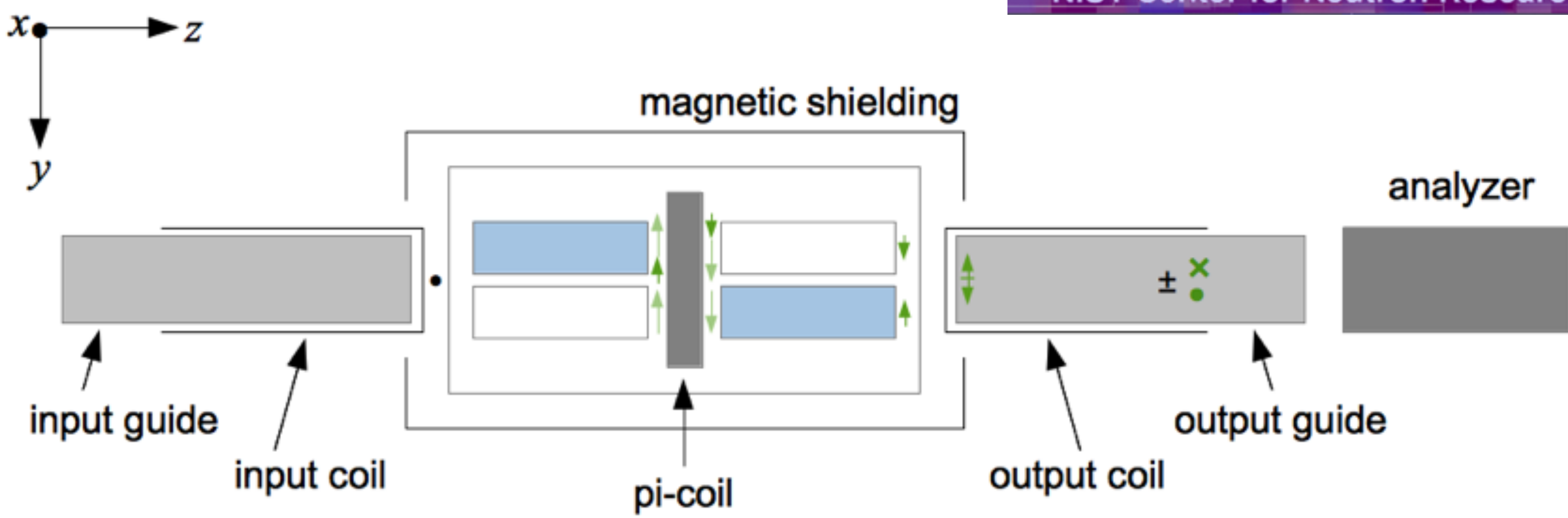
n-^{3}He



Currently being installed and evaluating running in transverse and longitudinal modes

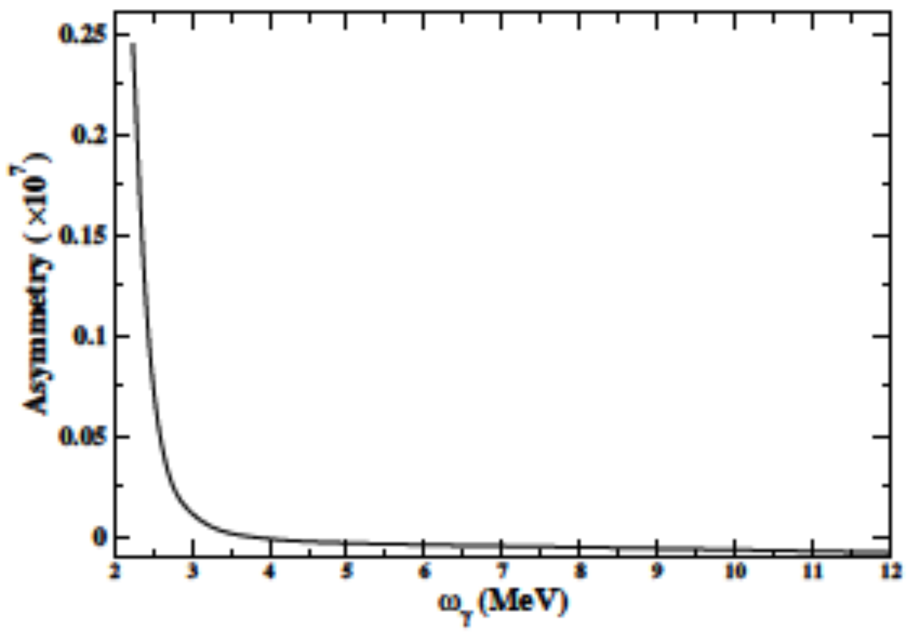
Neutron Spin Rotation

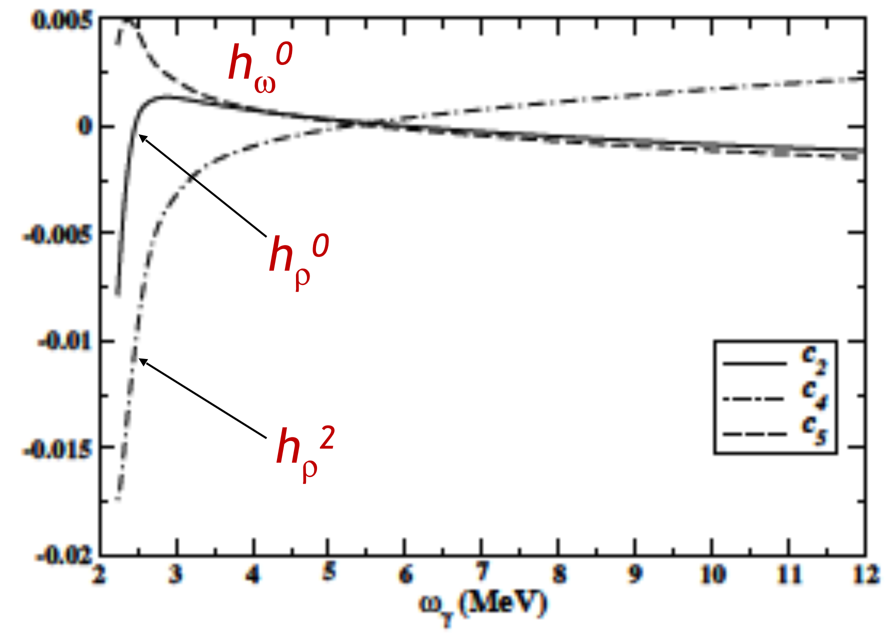
NIST Center for Neutron Research



- Planned for NIST (NG-C)
- Components ready or under construction
- Part of the apparatus will be used in the search for exotic forces at LANSCE (end of 2014)

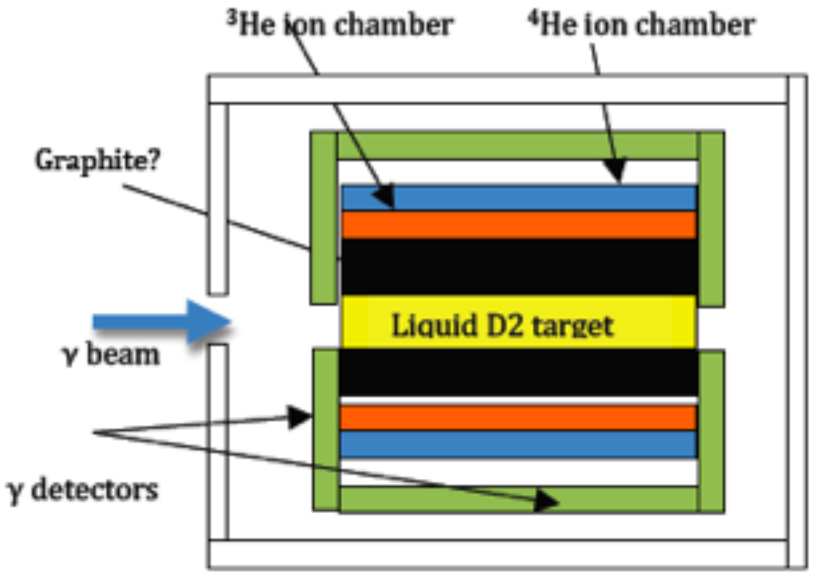
PV deuteron photodesintegration





- The only known PV NN observable sensitive to ΔI=2
- ΔI=2 NN PV might be calculable in lattice gauge theory

Experiment at HIGS2?



long term possibility

Gracias