First Results from the NPDGamma Experiment at the Spallation Neutron Source

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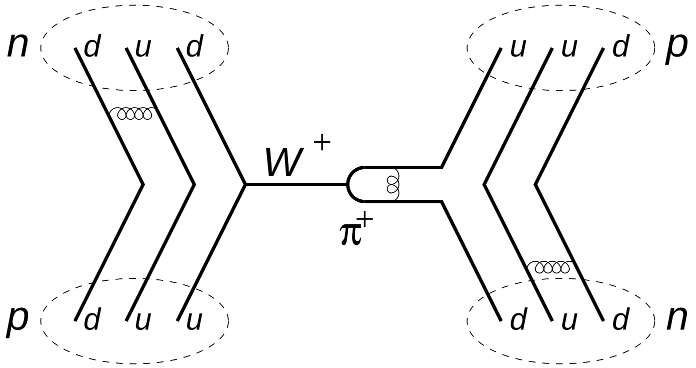
*Thanks to N. Fomin for many slides.

Hadronic Weak Interaction

example: $n + p \rightarrow n + p$



- Weak couplings (f_π, $h_\rho^{0,1,1',2}$, $h_\omega^{0,1}$) modified by strong interaction
- Can calculate approx. from QCD
- Need weak couplings from experiment
- Weak interaction in nuclei:

$$V = \sum_{m,\Delta I} h_m^{\Delta I} V_m^{\Delta I}$$

$$\langle Q_{pv} \rangle = 2 \sum_{m,\Delta I} \langle \psi | Q_{pv} | \phi \rangle \frac{h_m^{\Delta I} \langle \psi | V_m^{\Delta I} | \phi \rangle}{\Delta E}$$

Hadronic Weak Interaction Models

1. **DDH model** – uses valence quarks to calculate effective PV meson-nucleon coupling directly from SM via 7 weak meson coupling constants

$$f_\pi^1, h_\rho^0, h_\rho^1, h_\rho^{1'}, h_\rho^2, h_\omega^0, h_\omega^1$$

- Observables can be written as their combinations

$$A = a_\pi^1 f_\pi^1 + a_\rho^0 h_\rho^0 + a_\rho^1 h_\rho^1 + a_\rho^2 h_\rho^2 + a_\omega^0 h_\omega^0 + a_\omega^1 h_\omega^1$$

	$n+p$▸$d+\gamma$ A_γ (ppm)	$n+d$▸$t+\gamma$ A_γ (ppm)	n-p φ_{PV} (μrad/m)	n-^4He φ_{PV} (μrad/m)	p-p $\Delta\sigma/\sigma$ (ppm)	p-^4He $\Delta\sigma/\sigma$ (ppm)
f_π	-0.107	-0.92	-3.12	-0.97		-0.340
h_ρ^0		-0.50	-0.23	-0.32	0.079	0.140
h_ρ^1	-0.001	0.103		0.11	0.079	0.047
h_ρ^2		0.053	-0.25		0.032	
h_ω^0		-0.160	-0.23	-0.22	-0.073	0.059
h_ω^1	0.003	0.002		0.22	0.073	0.059

$\boxed{f_\pi \sim 4.5\text{x}10^{-7}}$

Weak π–nucleon coupling (long range)

$$\boxed{A_\gamma \approx -0.11 f_\pi^1}$$

HWI Models - Continued

2. *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

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

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

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

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

$$\boxed{A_\gamma^{\vec{n}p} \approx -0.27\tilde{C}_6^\pi - 0.09 m_\mathrm{N} \rho_\mathrm{t}}$$

3. *Lattice QCD* (NEW)

– J. Wasem, PRC C85 (2012)

$$f^1_{\pi NN} = 1.099 \pm 0.505 {}^{+0.058}_{-0.064} \; [x10^{-7}]$$

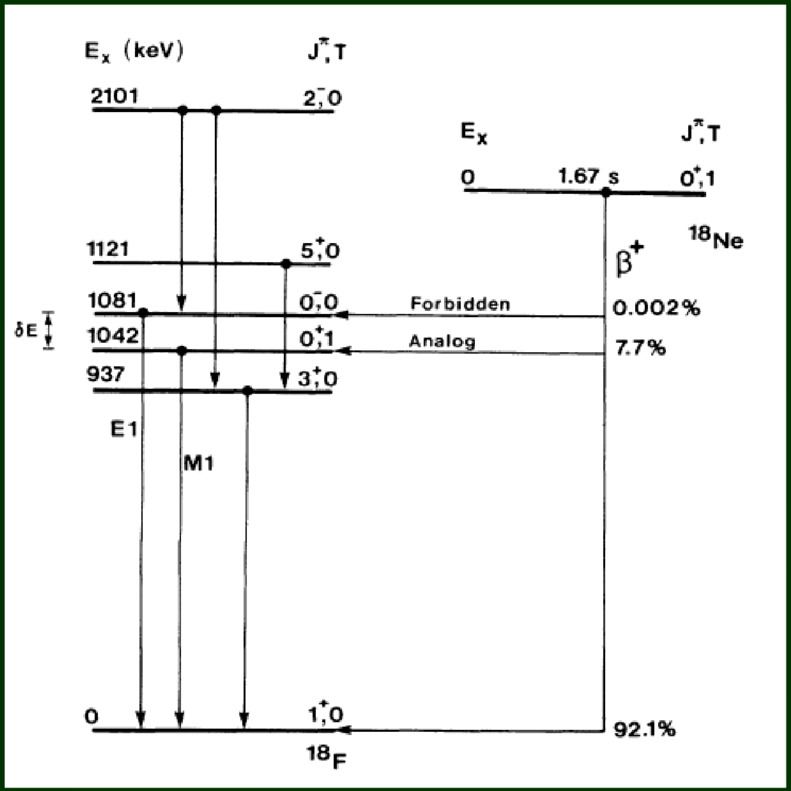
Previous measurements

1. Measurement of the circular polarization of emitted γ rays in the ^{18}F transition 0^- (1.08MeV) $\longrightarrow 1^+$(g.s)

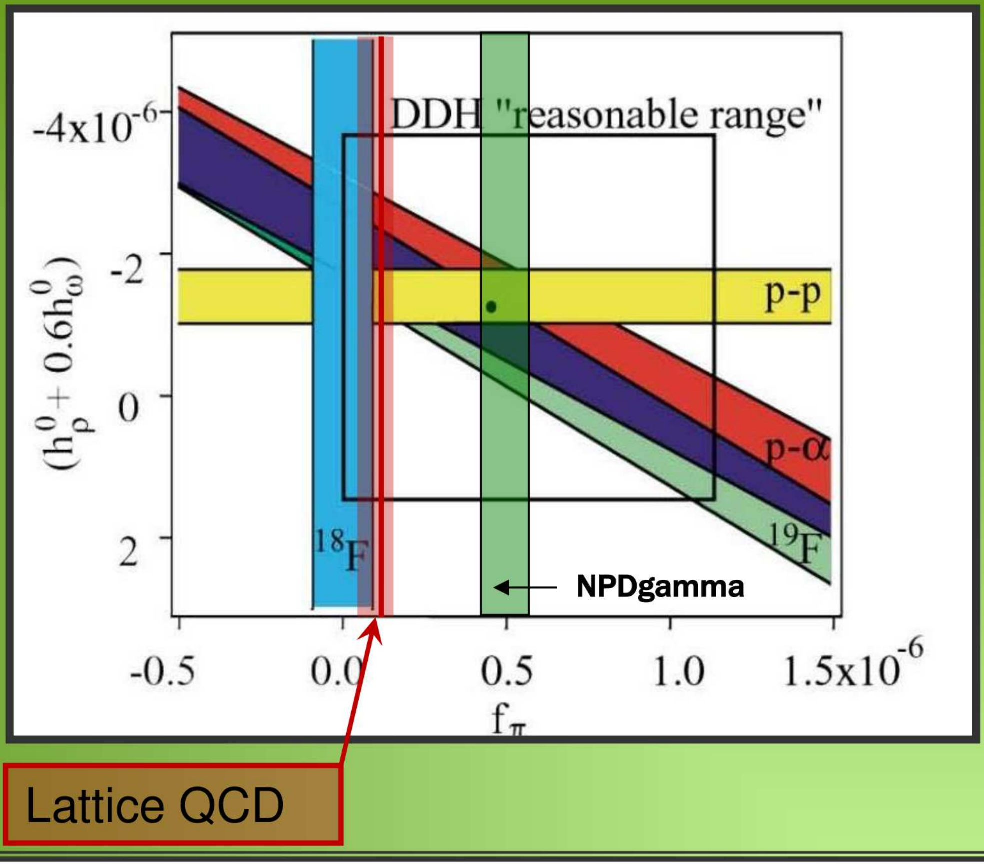
Result: $|f_\pi| \leq 1.3 \times 10^{-7}$

Motivation for NPDGamma

2. ^{133}Cs Anapole moment measurement
   - Atomic Spectroscopy result
     - $(9.6 \pm 2.2) \times 10^{-7}$
   - f_π had to be separated from other effects



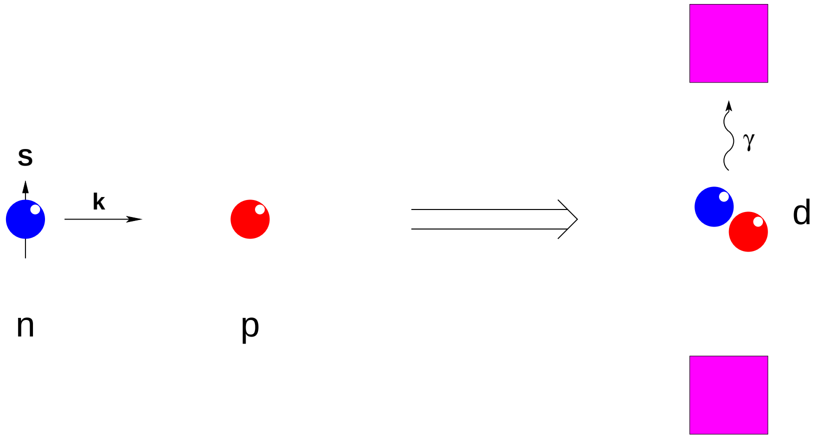
f_π could be very small



Lattice QCD

- Experiments suggest a small f_π (nearly zero)
  - corresponds to ΔI=1 transition (should be large)
  - ΔI=0,2 do not contribute to A_γ
  - Observations are not well understood (ΔI=0 contribution appears to be large, and ΔI=1 appears to be small)

NPDGamma



$$A_\gamma = \frac{1}{P_n}\frac{N_u - N_d}{N_u + N_d} \approx -0.11 f_\pi \sim -5 \times 10^{-8}$$

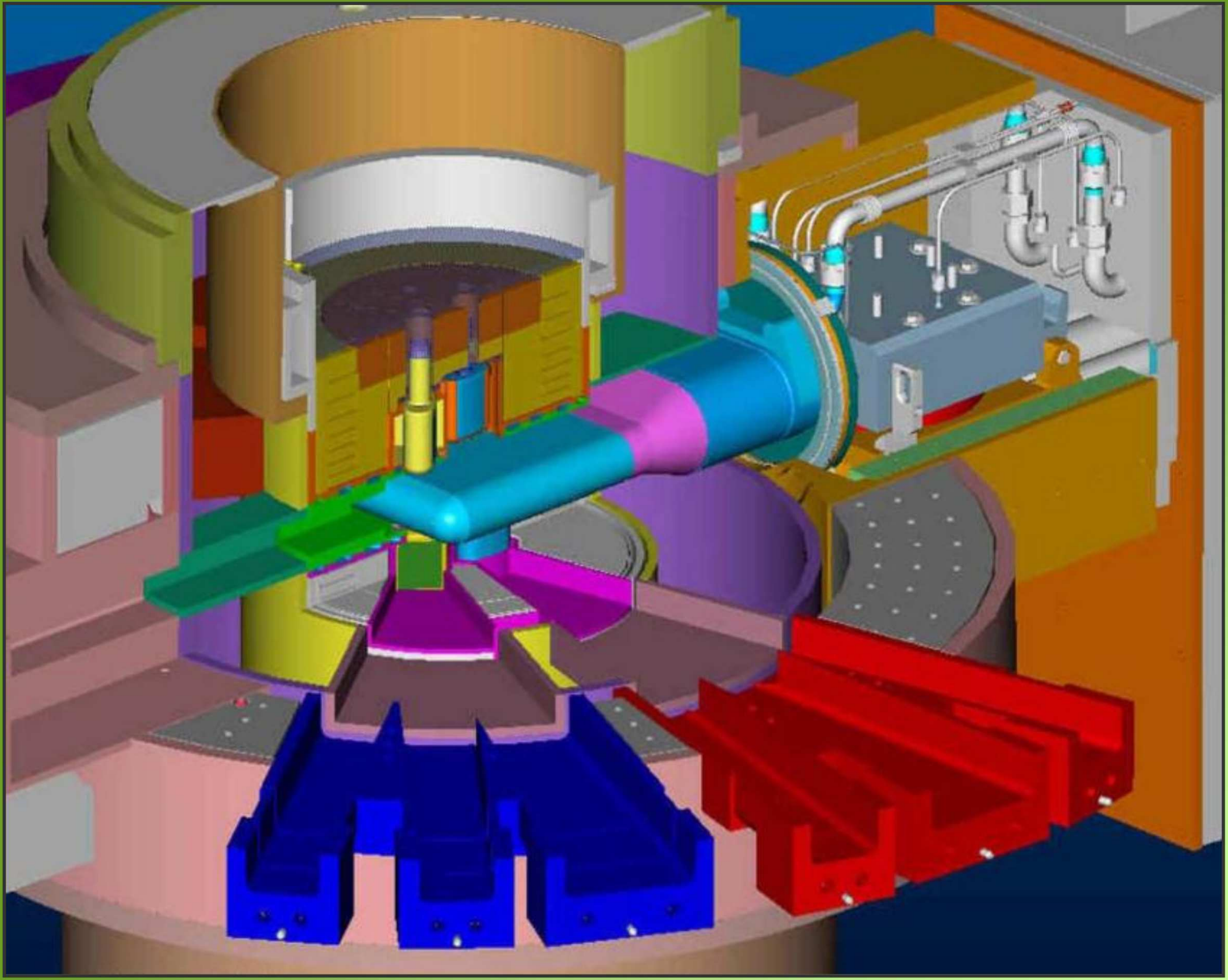
$$\Delta A_\gamma < 2 \times 10^{-7} \text{ (LANSCE)}$$

$$\Delta A_\gamma = 1 \times 10^{-8} \text{ (SNS)}$$

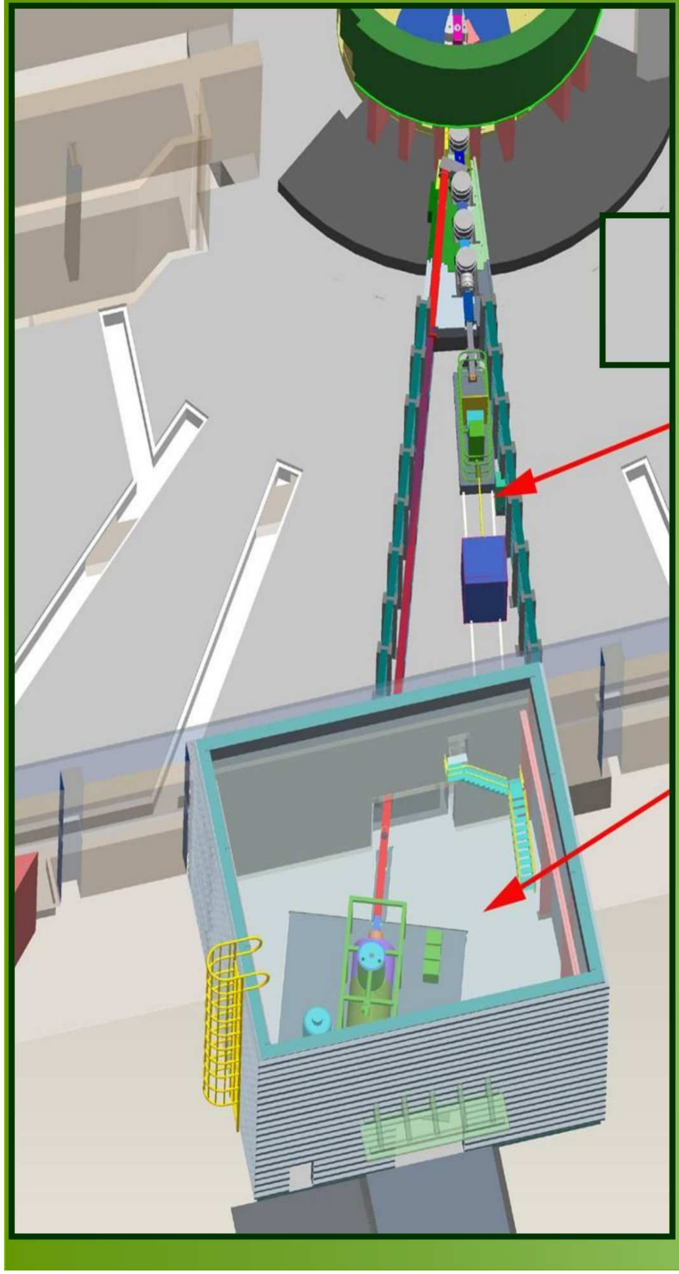
Spallation Neutron Source at ORNL

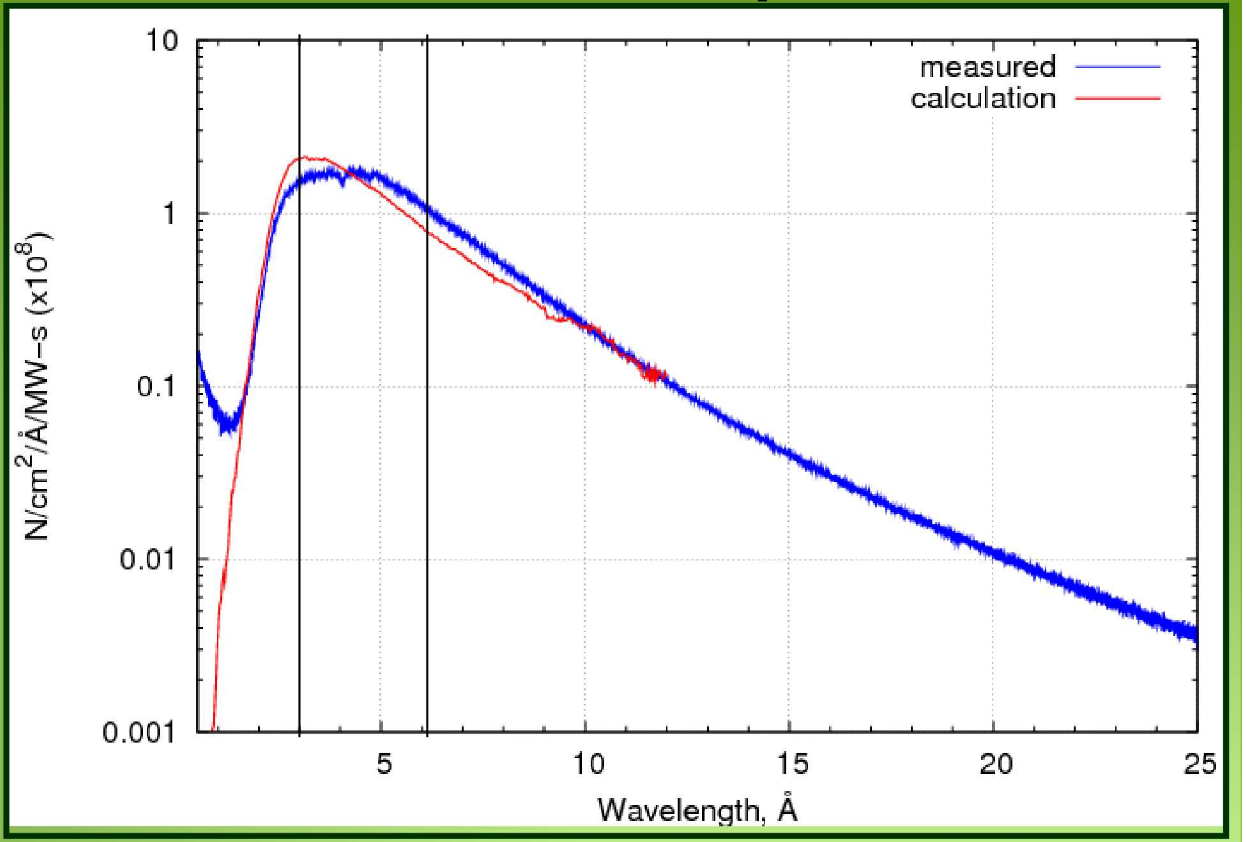
- 1.4 GeV protons, 60Hz
- Hg Spallation target → neutrons
- H_2 moderator
- 17 m SM guide, curved

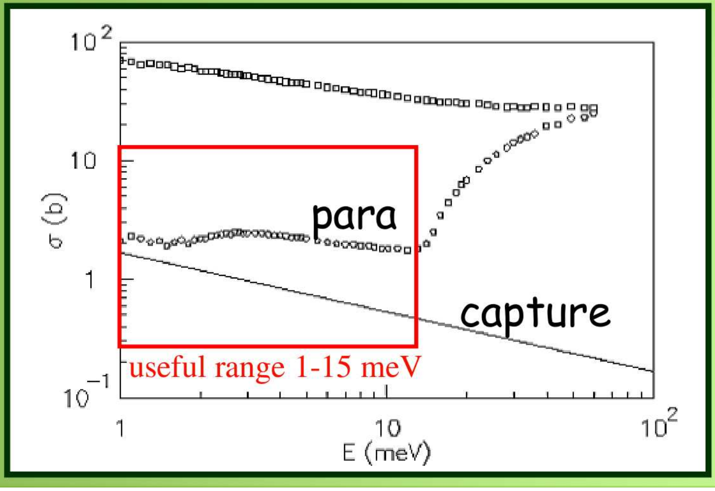
Spallation Neutron Source



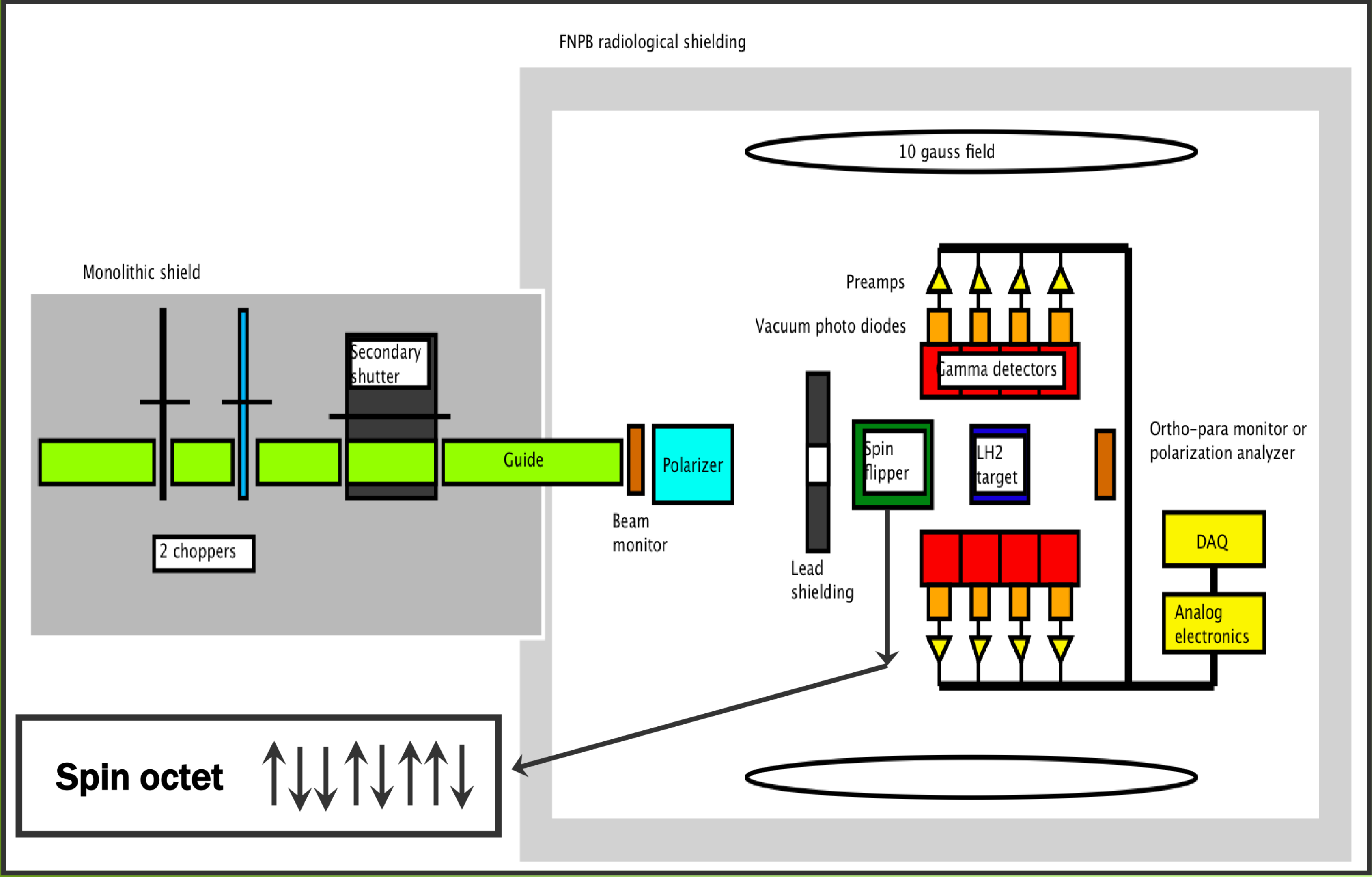
FnPB – cold beamline commissioned on Sep 12th, 2008







NPDGamma – Experimental Setup



Result from LANSCE run (2006) & Improvements for SNS

$A_{\gamma,UD}=(-1.2\pm2.0\pm0.2)\times10^{-7}$

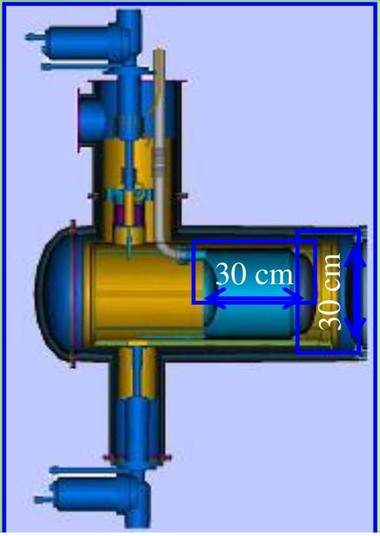
$A_{\gamma,LR}=(-1.8\pm2.1\pm0.2)\times10^{-7}$

	LANSCE	***SNS***
Sensitivity	2×10^{-7}	1×10^{-8}
Polarizer	^{3}He polarizer (average 55% NP)	SuperMirror Polarizer (95% NP)
FOM (NP^2)	8.9×10^7/s	X200 improvement
Target	16L, LH_2	New and improved, thinner windows

LH$_2$ target

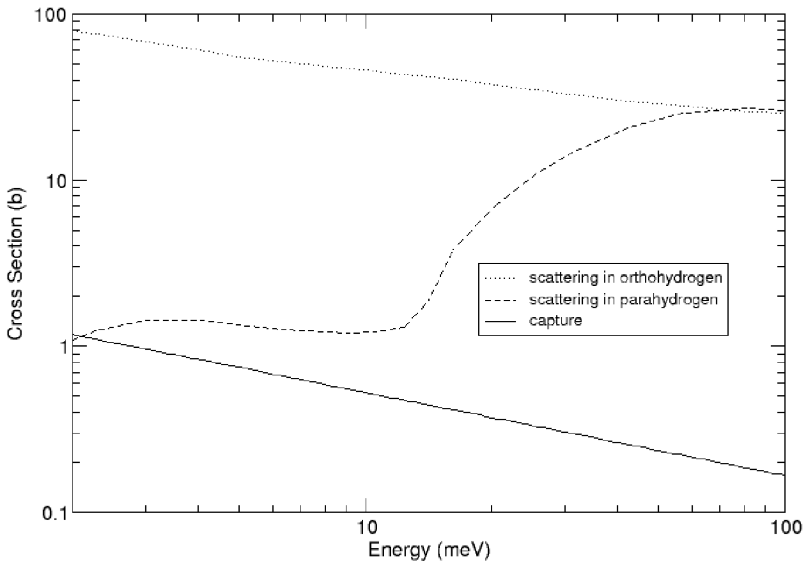
- 16L vessel of liquid parahydrogen
- Ortho-hydrogen scatters the neutrons and leads to beam depolarization

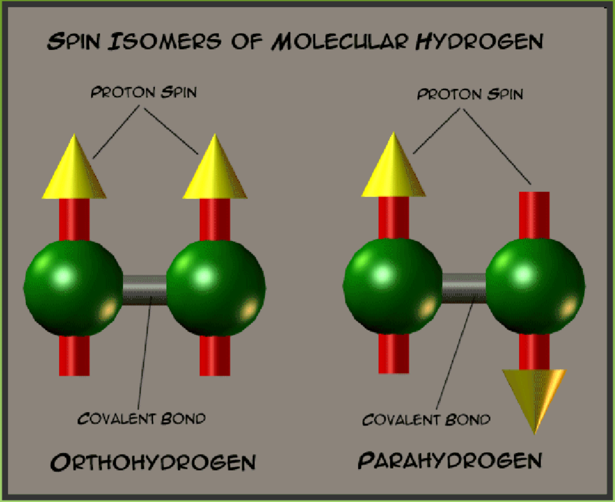
ASME code approved pressure vessel
See stamp!



LH_2 target - Parahydrogen

Orthohydrogen	*I=1 (aligned spins)*
Parahydrogen	*I=0 (anti-aligned spin)*



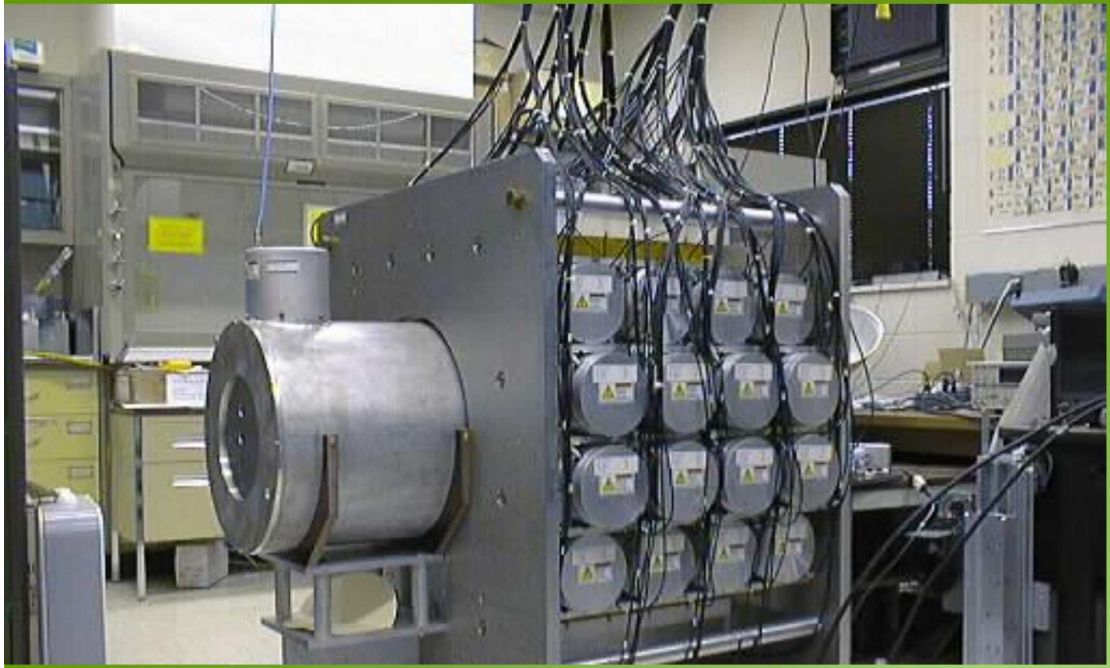


If E_n < *14.7meV*, cannot flip neutron spin

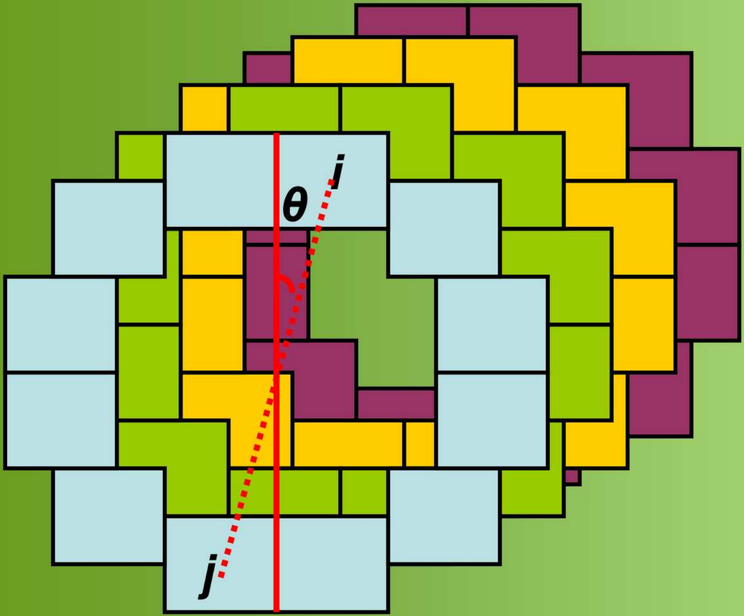
Para state dominates at low temperatures, helped by a catalyst (material with a solid paramagnetic surface)

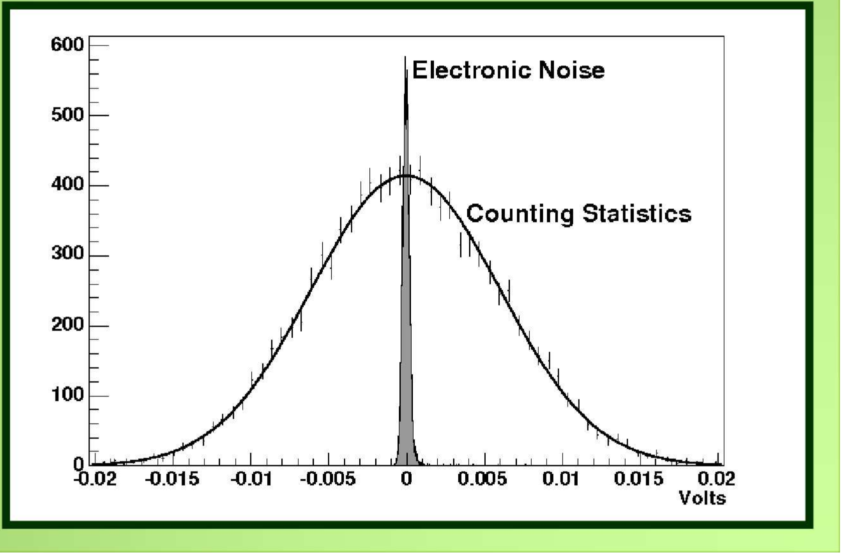
- No safety issues from sensors in the hydrogen system
- Energy dependence of the neutron transmission can be used

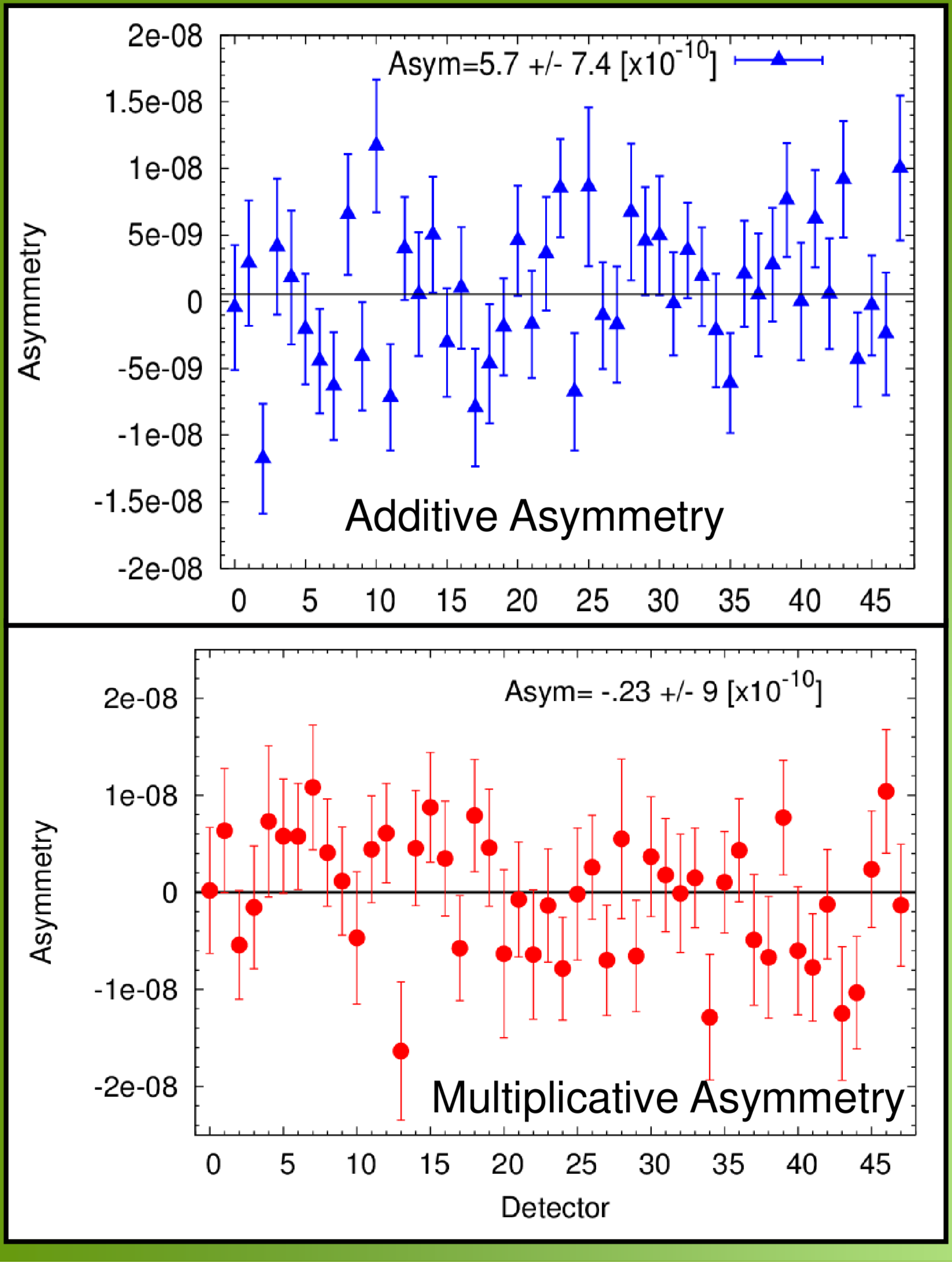
Detector Array



- 3π acceptance
- Current-mode experiment
- γ-rate ~100 MHz (single detector)
- Low noise solid-state amplifiers







Goal of the experiment: $dA_\gamma = 1e\text{-}8$

- Any instrumental asymmetries must be consistent with zero at 1e-9

Improved Understanding of systematic effects

PV asymmetries

- Stern-Gerlach force	2×10^{-11}
- Circularly polarized γs	9×10^{-13}
- In-flight β decay	1×10^{-11}
- Capture on ^{6}Li	2×10^{-11}
- Al γ's	1.3×10^{-8}
- Al β decay	1×10^{-10}

Last two must be measured

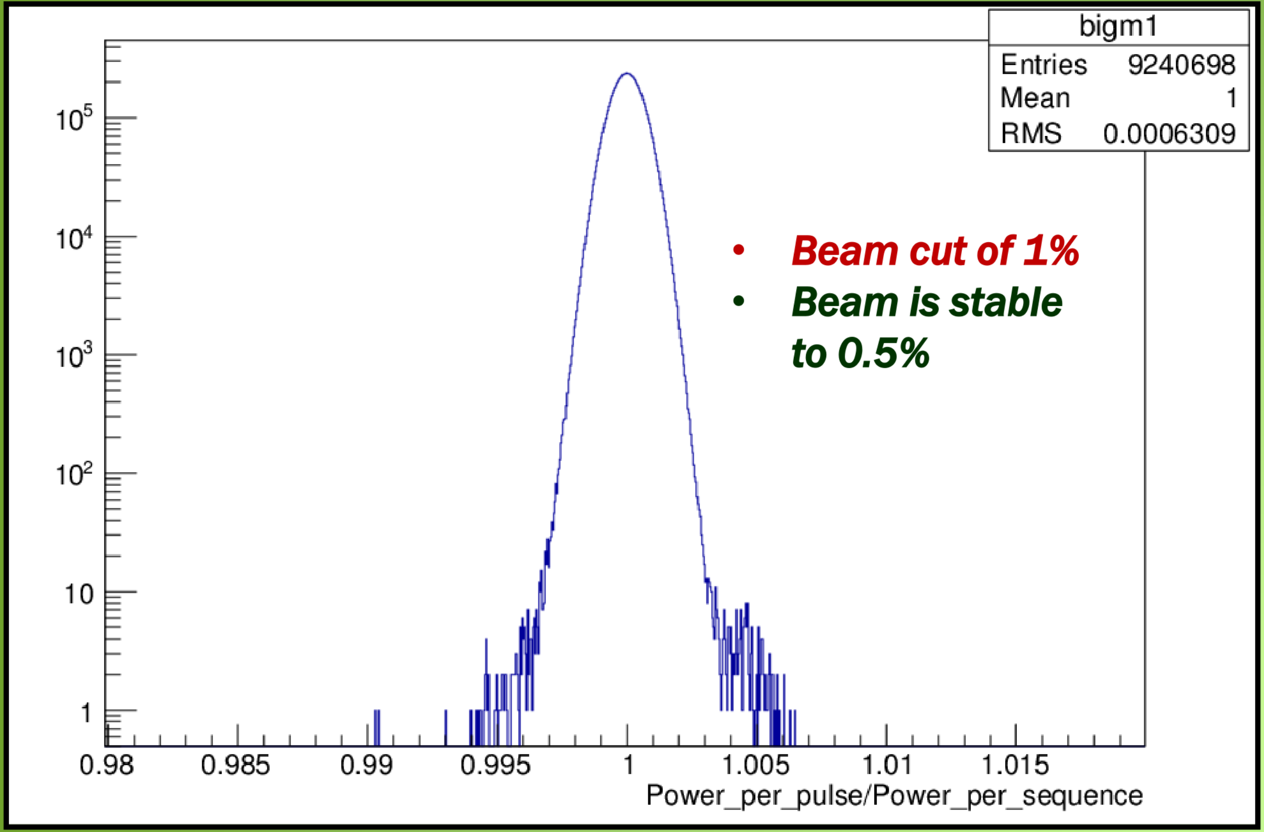
PC LR asymmetries

- Mott-Schwinger in LH_2 (must be modeled)
- Parity-allowed $n+p \longrightarrow d+\gamma$ 2×10^{-8}
- Parity-allowed LR asymmetry in capture on Al=0

- These asymmetries can mix into the U-D channel if the detector and guide field are not aligned

Current Status of Hydrogen Data Collection

- Production Hydrogen Running → Early May, 2012
- Have collected over 12,000 “good” data runs



- ***Beam cut of 1%***
- ***Beam is stable to 0.5%***

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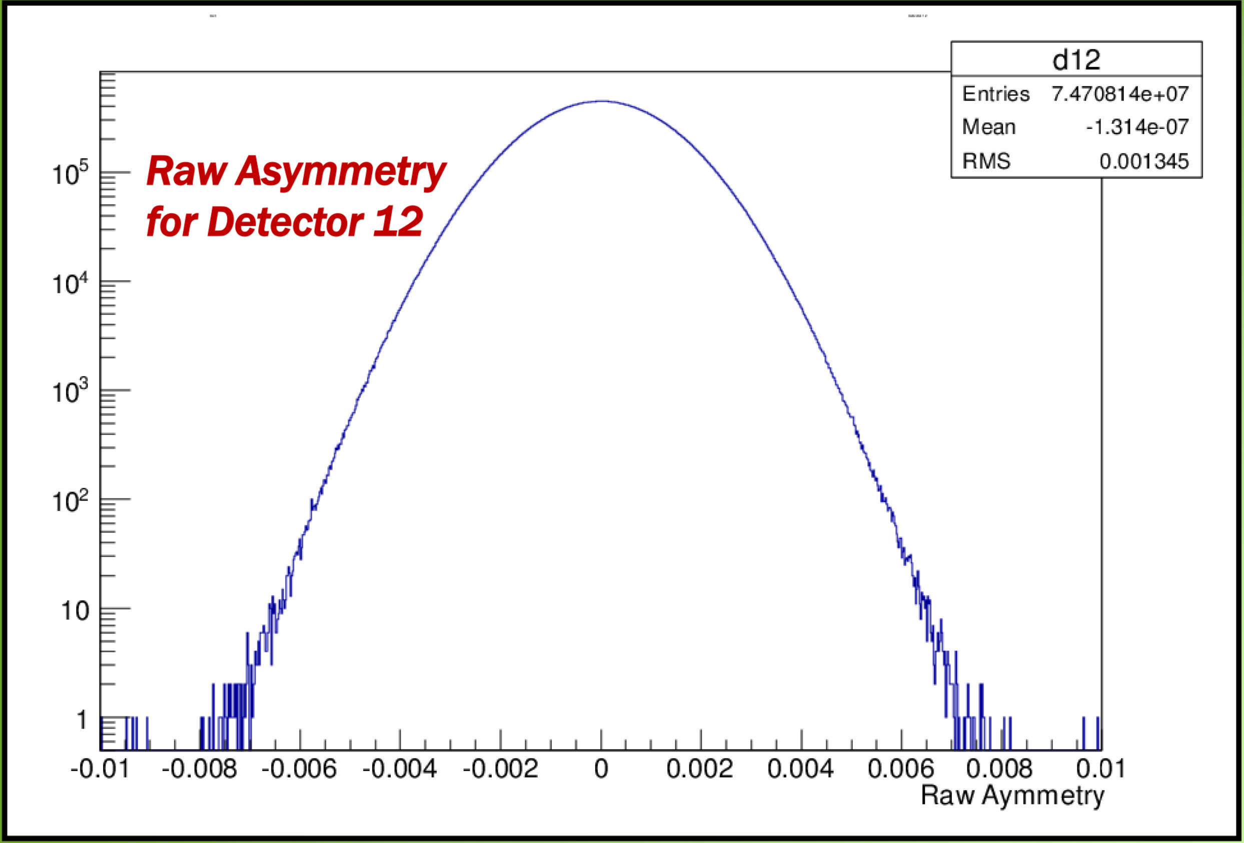
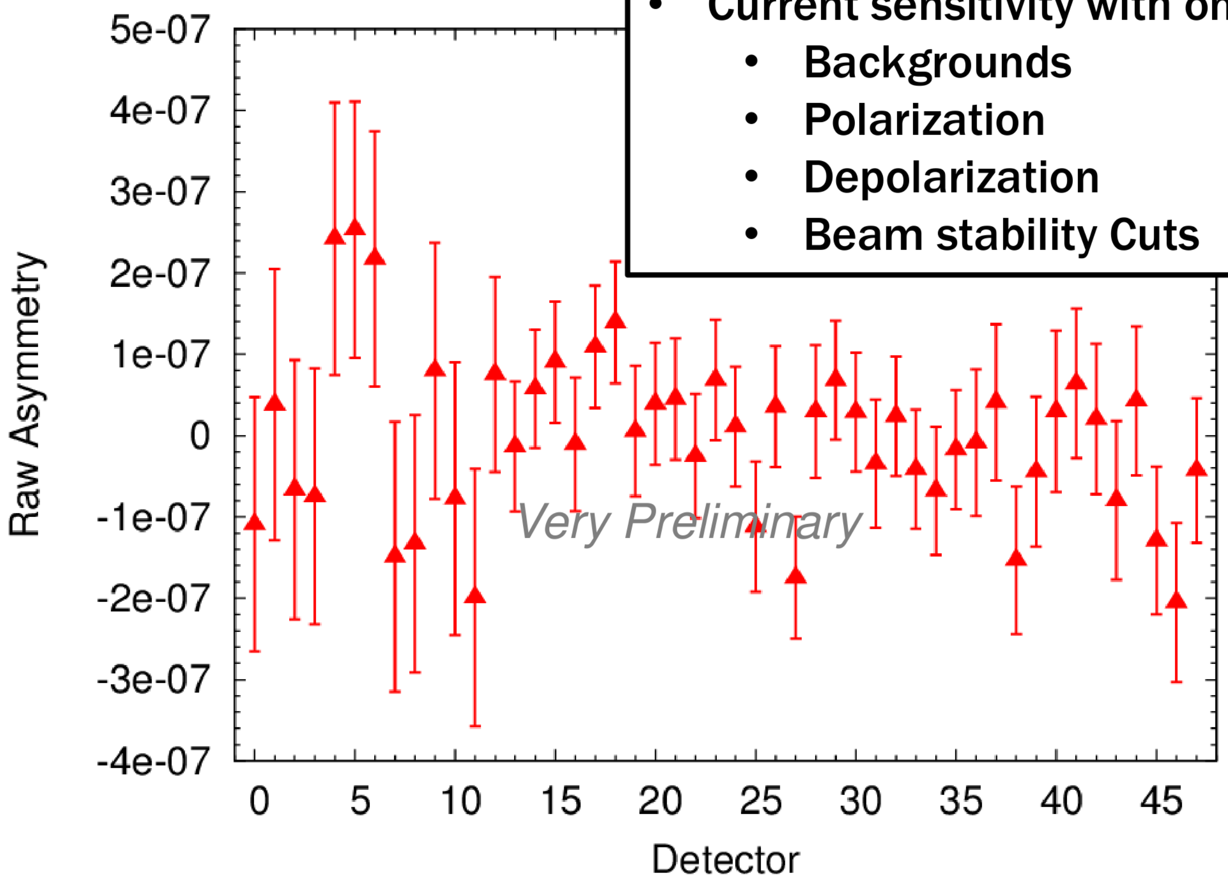


Raw Asymmetry for Detector 12

Current Status of Hydrogen Data Collection

- Production Hydrogen Running → Early May, 2012
- Have collected over 12,000 "good" data runs
- Current sensitivity with online corrections
  - Backgrounds
  - Polarization
  - Depolarization
  - Beam stability Cuts

$dA<5x10^{-8}$



Summary

- A measurent of A_γ that will test theoretical predictions is underway
- NPDGamma will make a 20% measurement of the predicted effect: -5×10^{-8} (DDH)
- Data is currently being collected
- Preliminary results ($\Delta A_\gamma < 5 \times 10^{-8}$) coming soon

The NPDGamma collaboration

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