Measurement of Neutron Beta Decay Parameters with a Polarized Pulsed Cold Neutron Beam

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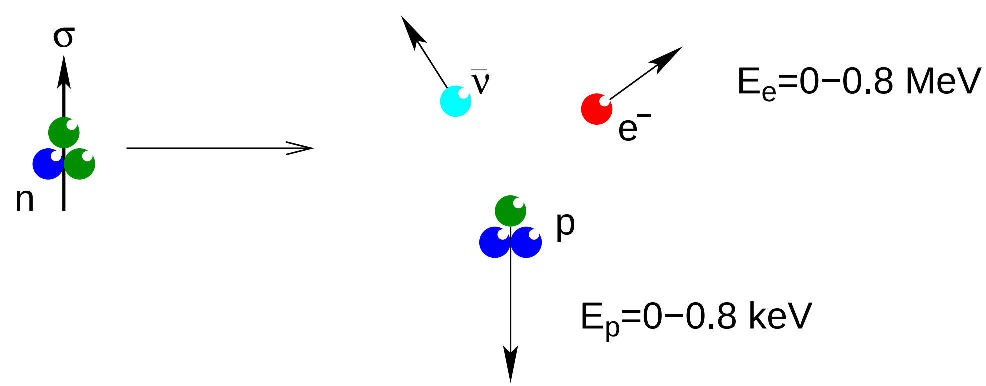
Neutron β-Decay



$$\rho(E_e) \approx \rho_s(E_e)\left\{1 + P_n\left[\beta A\cos\theta_{e\sigma} + B\cos\theta_{\nu\sigma}\right] + \beta a\cos\theta_{e\nu} + b\frac{m_e}{E_e}\right\}$$

$A \sim -0.1$ $B \sim 1$ $a \sim -0.1$ $b \sim 0$

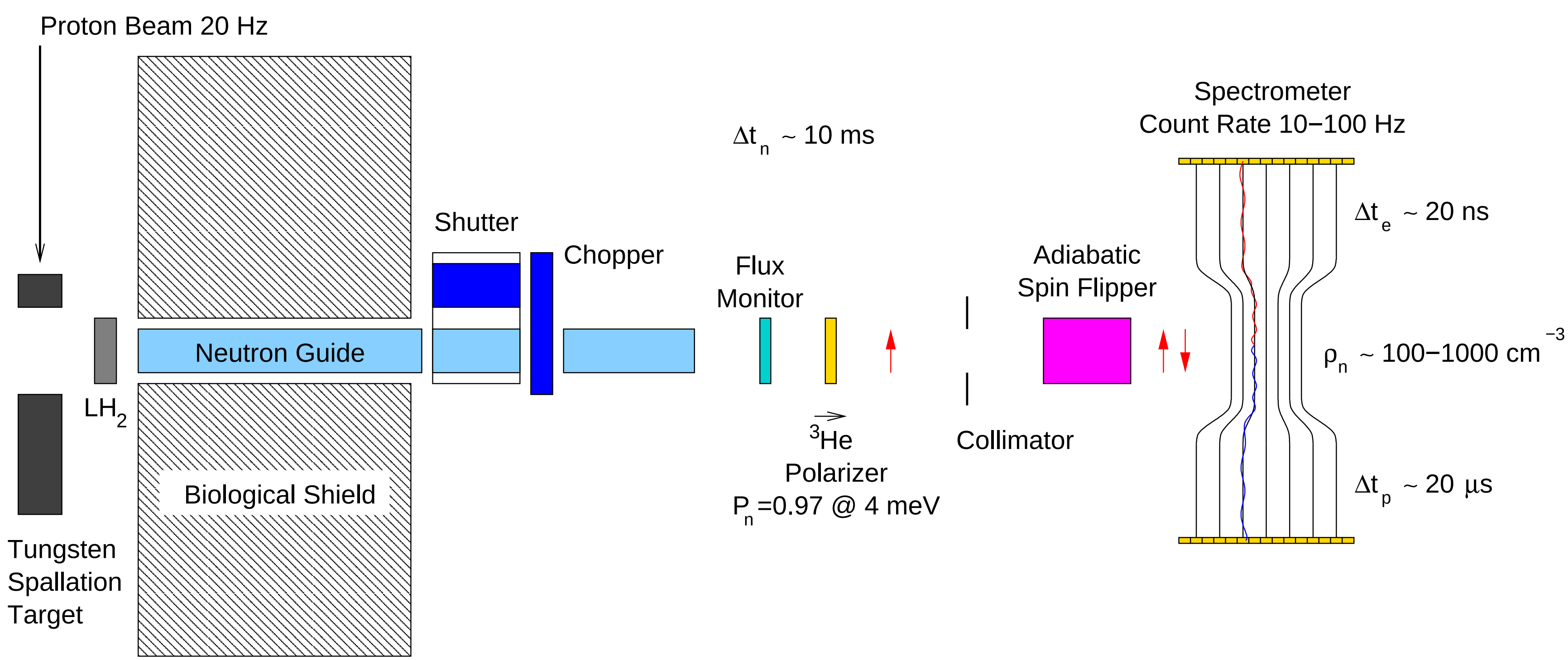
Limitations of Previous Experiments

- Neutron polarization determination
- Backgrounds
- Fiducial volume definition
- Magnetic field pinch
- Scattering from material apertures
- Electron back-scattering
- Detector resolution, efficiency, and stability
- Statistics

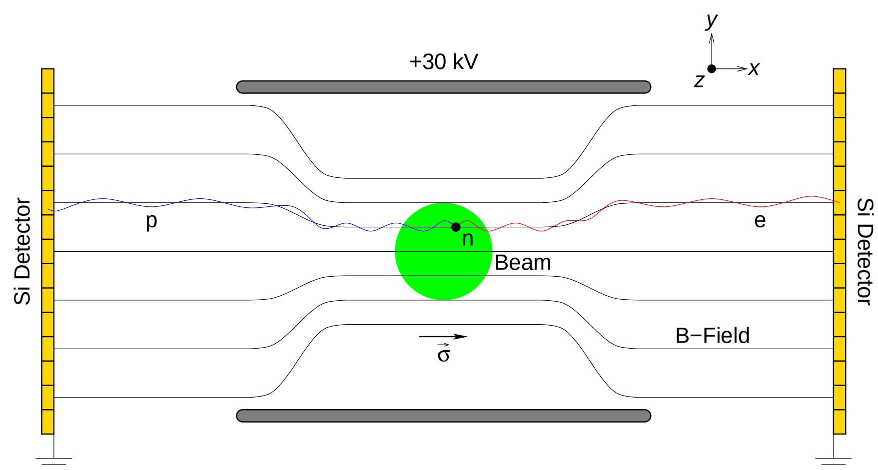
Strategy for LANSCE FP12 Experiment

- *In situ*, absolute neutron polarization measurement
- n, e, and p interact only with B and E fields and detectors
- Fields transport n spin and charged particles adiabatically
- Detect e and p in coincidence
- Measure residual background *in situ* (space and time)
- High-quality detectors: improved ΔE_e, efficiency, stability
- Heavily instrument: do not rely on auxillary calibrations
- Redundancy

Neutron β-Decay with Cold Neutrons at LANSCE



Neutron β-Decay Spectrometer



- Two 2π detectors
- e backscattering monitored
- $\Delta t \sim 1$ ns
- $\Delta E \leq 5$ keV

- $e - p$ coincidence
- Beam imaged by detectors
- *In situ* background measurement
- No material apertures

Neutron Transmission through Polarized ^{3}He

$$n + {}^3\text{He} \longrightarrow {}^3\text{H} + p$$

$$\Phi = \Phi_0 e^{-\sigma x_3} \qquad \sigma = \sigma_u \mp P_3(\sigma_s - \sigma_t)/4 = \sigma_u \mp P_3 \sigma_s/4$$

$$\sigma_s = \sigma_0 (v_0/v) \qquad \sigma_0 = 54 \text{ kbarn at 4 meV} \qquad v = L/t$$

$$\Phi_+ = \Phi_0 e^{-\sigma_u x_3 + \frac{P_3 x_3 \sigma_0 v_0}{4L} t}$$

$$\Phi_- = \Phi_0 e^{-\sigma_u x_3 - \frac{P_3 x_3 \sigma_0 v_0}{4L} t}$$

Neutron Polarization by Polarized ^{3}He

$$P_n = \frac{\Phi_+ - \Phi_-}{\Phi_+ + \Phi_-} = \tanh\left(\frac{P_3 x_3 \sigma_0 v_0}{4L}\, t\right)$$

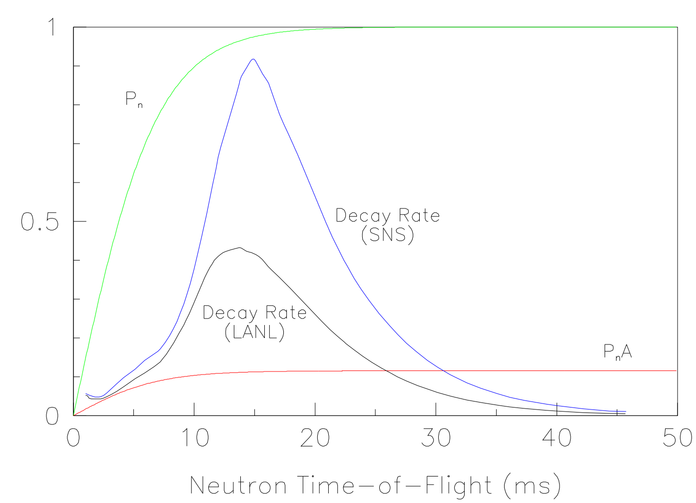
$$P_n = \tanh(t/\tau) \qquad \tau = \frac{4L}{P_3 x_3 \sigma_0 v_0}$$

In Situ **Polarization Measurement**

- Neutrons polarized by transmission through polarized ^{3}He
- Exact relation between neutron polarization and TOF
- Determine A and τ from $P_n A$

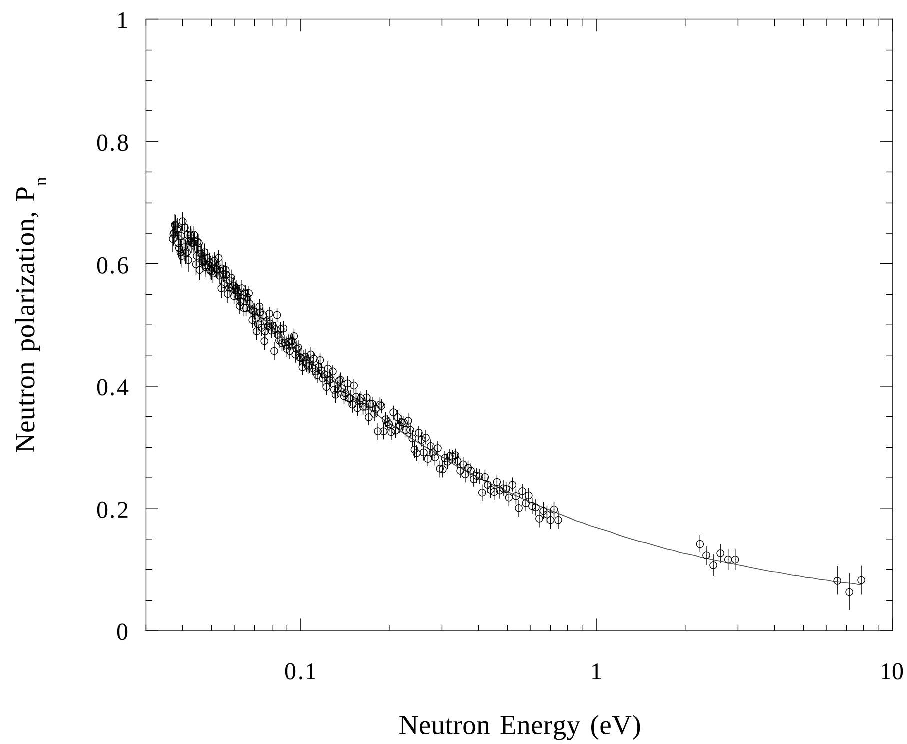
$$P_n = \tanh(-t/\tau)$$

$$AP_n = A\tanh(-t/\tau)$$



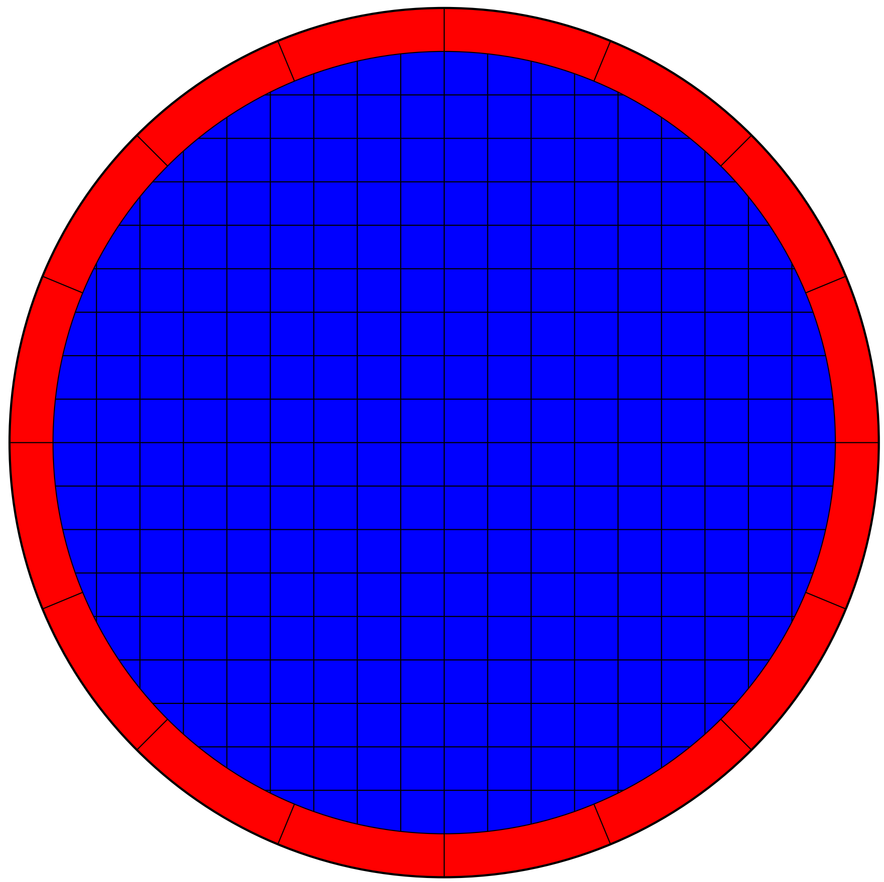
Absolute Neutron Polarimetry at LANSCE

$\Delta P_n \leq 0.2\%$



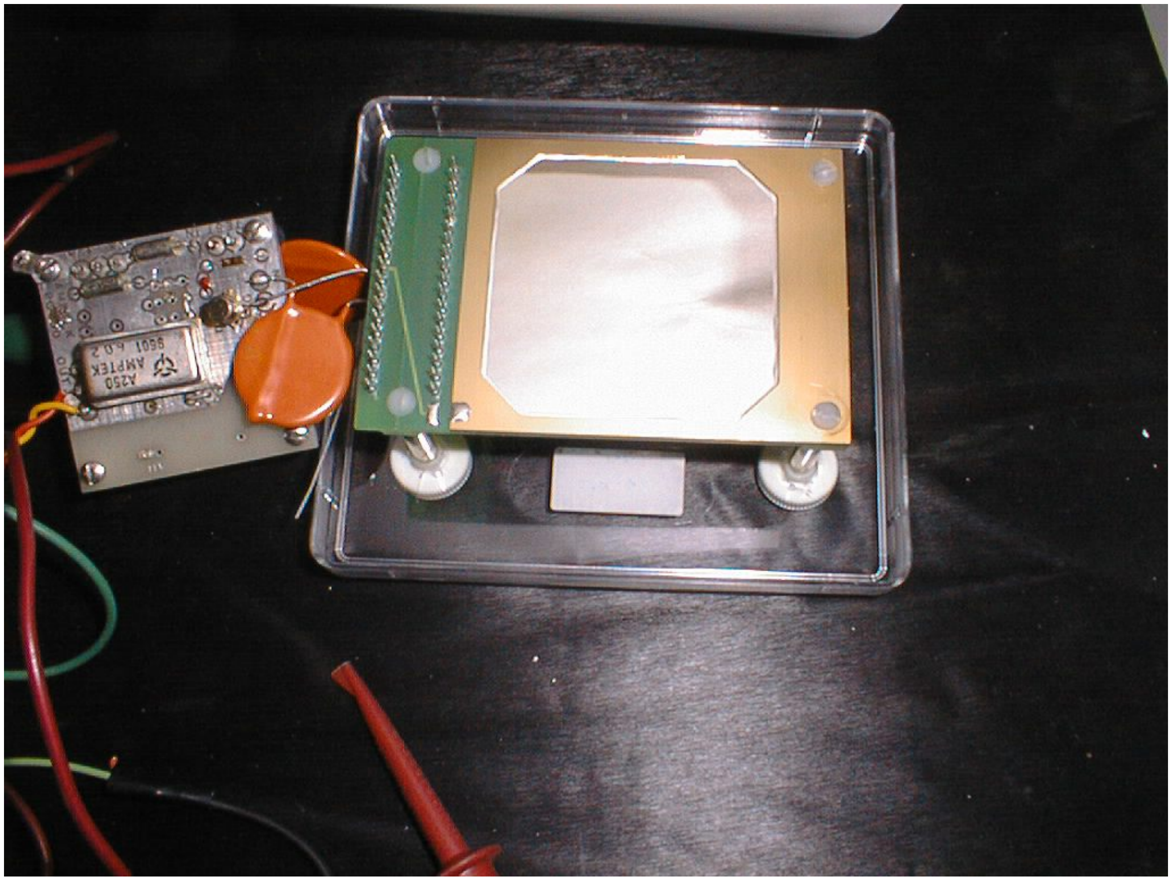
D.R. Rich, *et al.* Nucl. Instr. Meth., In press.

Detector Design



13 cm Diameter, 2 mm Thick Silicon Wafer, 100 Channel

Prototype Detector

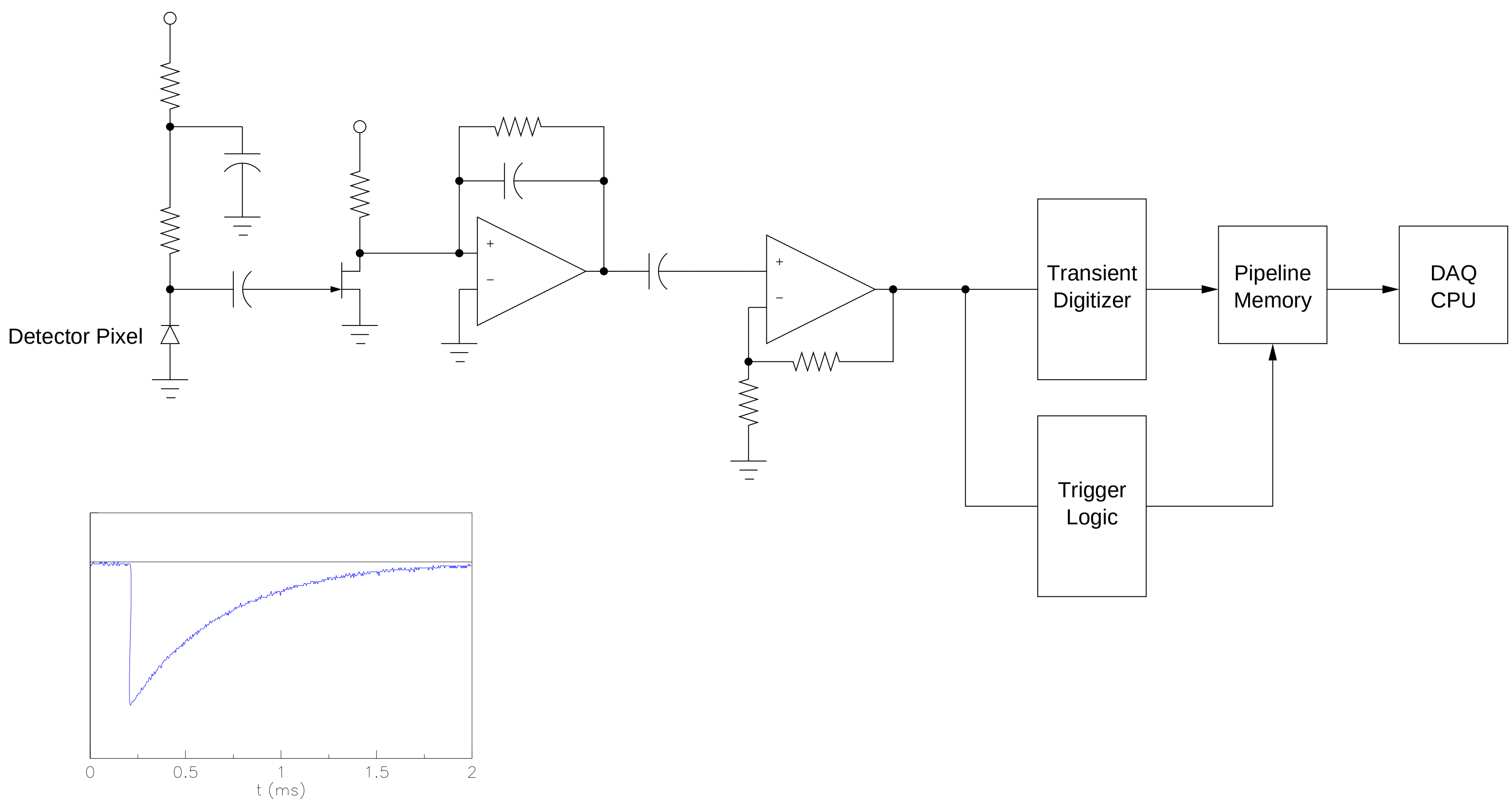


5×5 cm^2, 1.5 mm Thick Silicon, 16 Channel

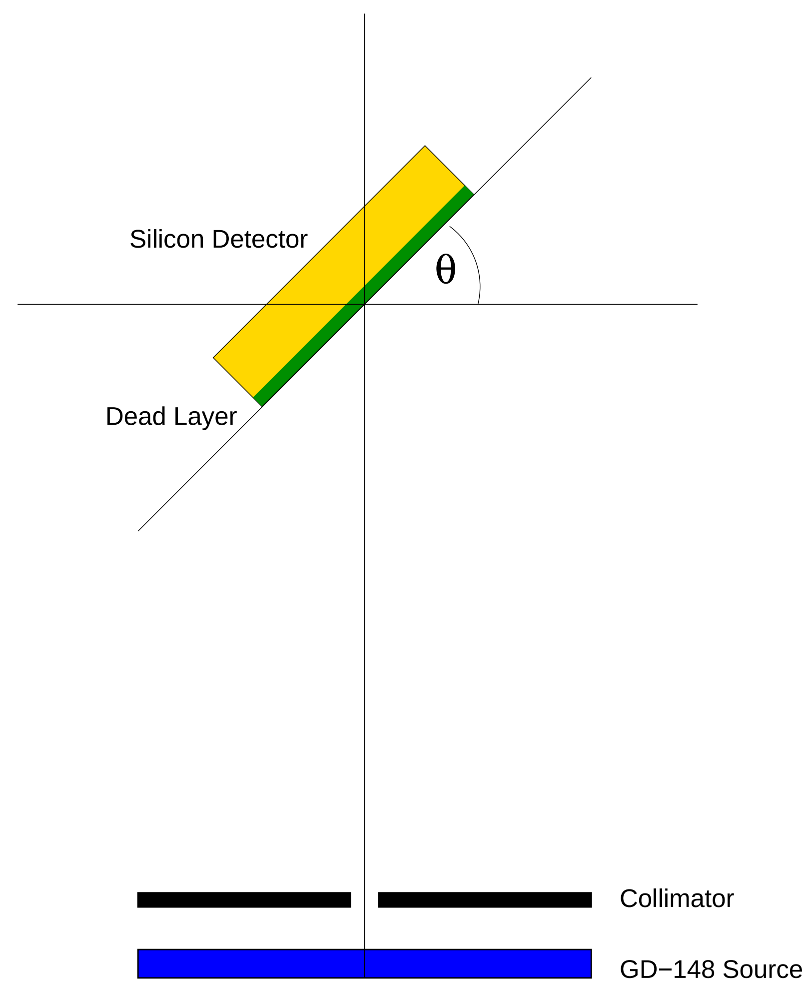
Advantages of Silicon Detectors

- Thin dead layer: $\Delta E_e \leq 5$ eV, $\Delta E_p \leq 5$ keV <u>measured</u>
- Almost unity efficiency: small well-understood corrections
- Extremely uniform dead layer: no wires, foils, supports, etc.
- 4π detection of electrons and protons: coincidence
- Imaging: defines fiducial volume without material apertures, provides *in situ* background measurement

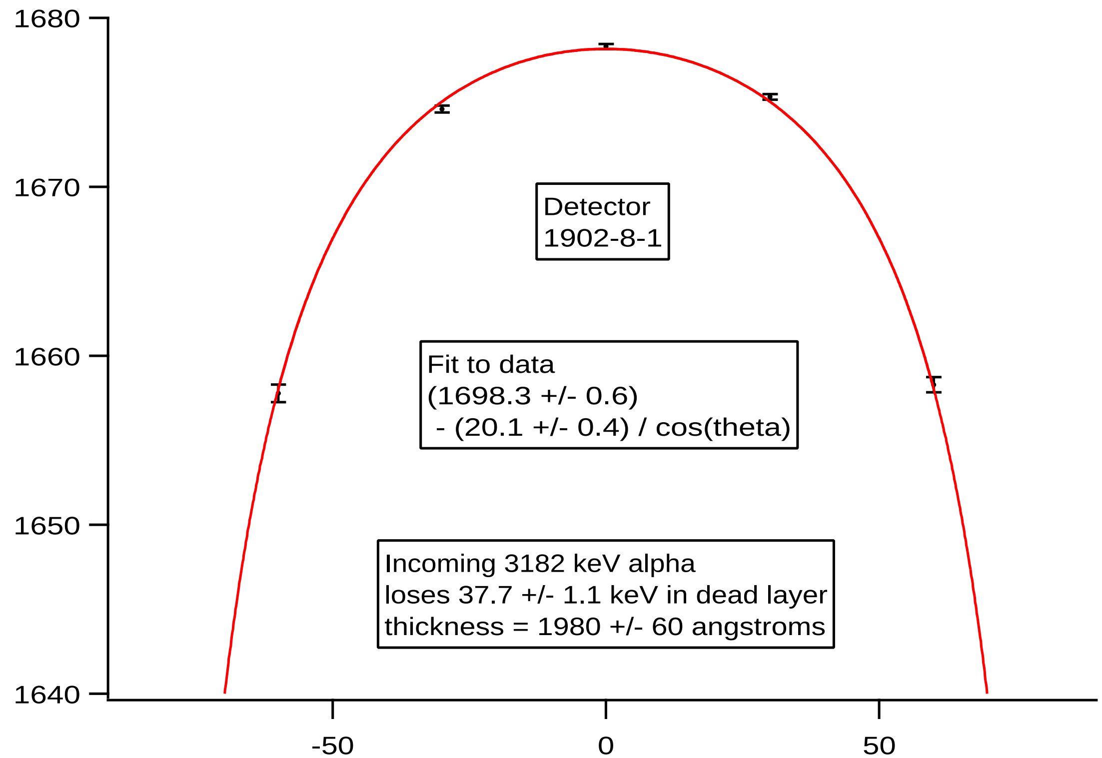
Detector Electronics



Dead Layer Measurements



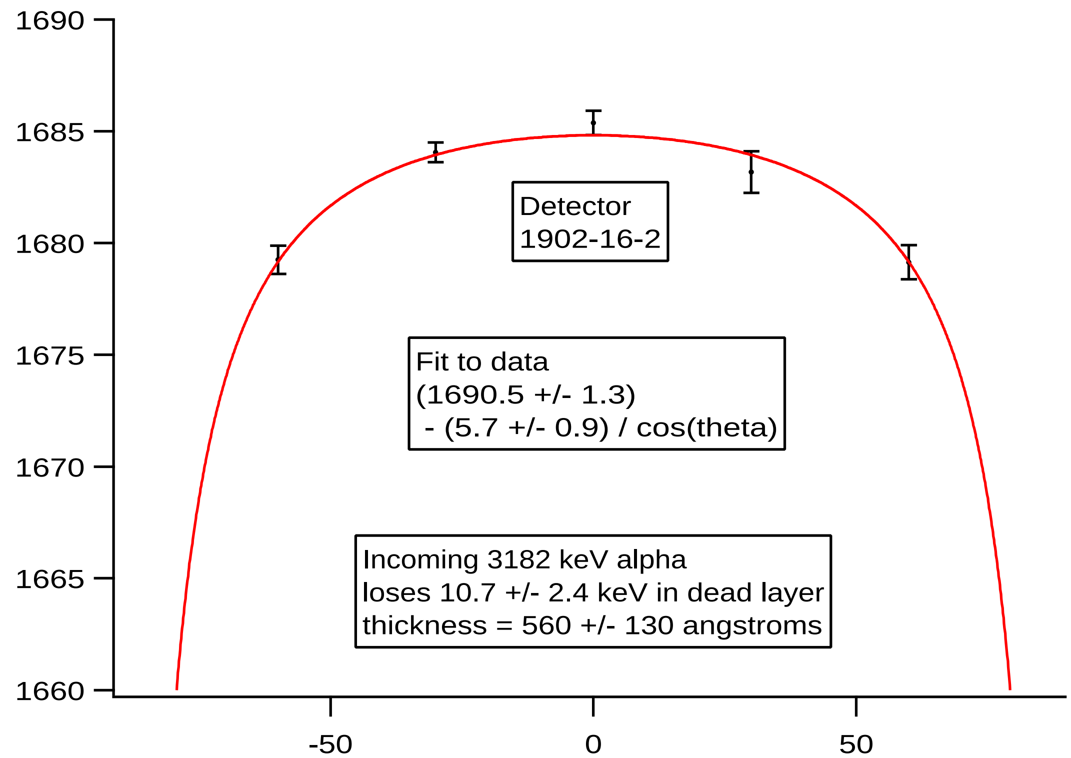
Normal Silicon Detector



200 nm Dead Layer

$E_{\text{loss}} = 14$ keV for $E_p = 30$ keV

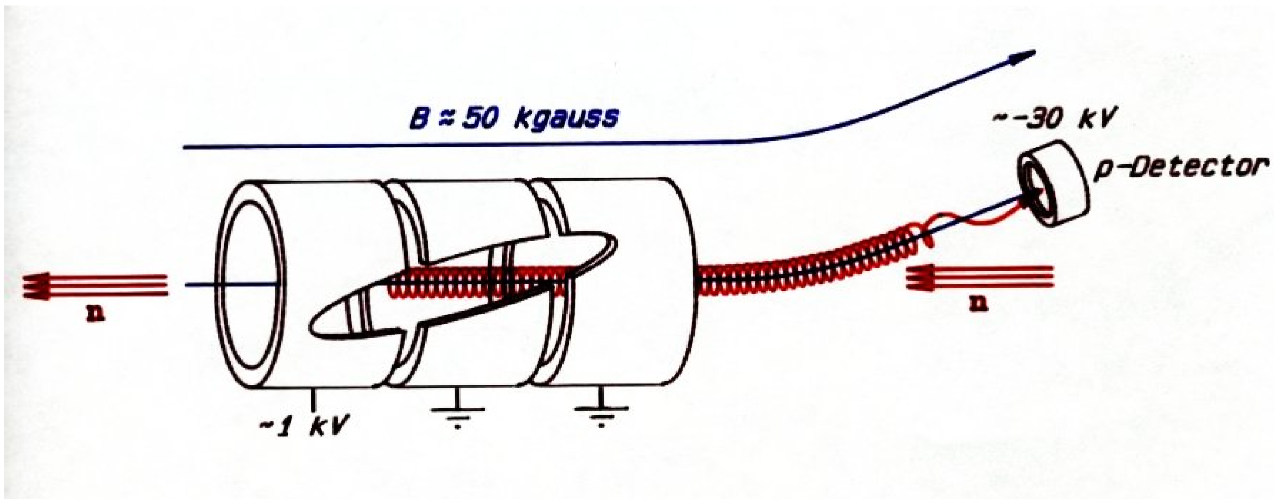
Thin Dead Layer Silicon Detector



56 nm Dead Layer

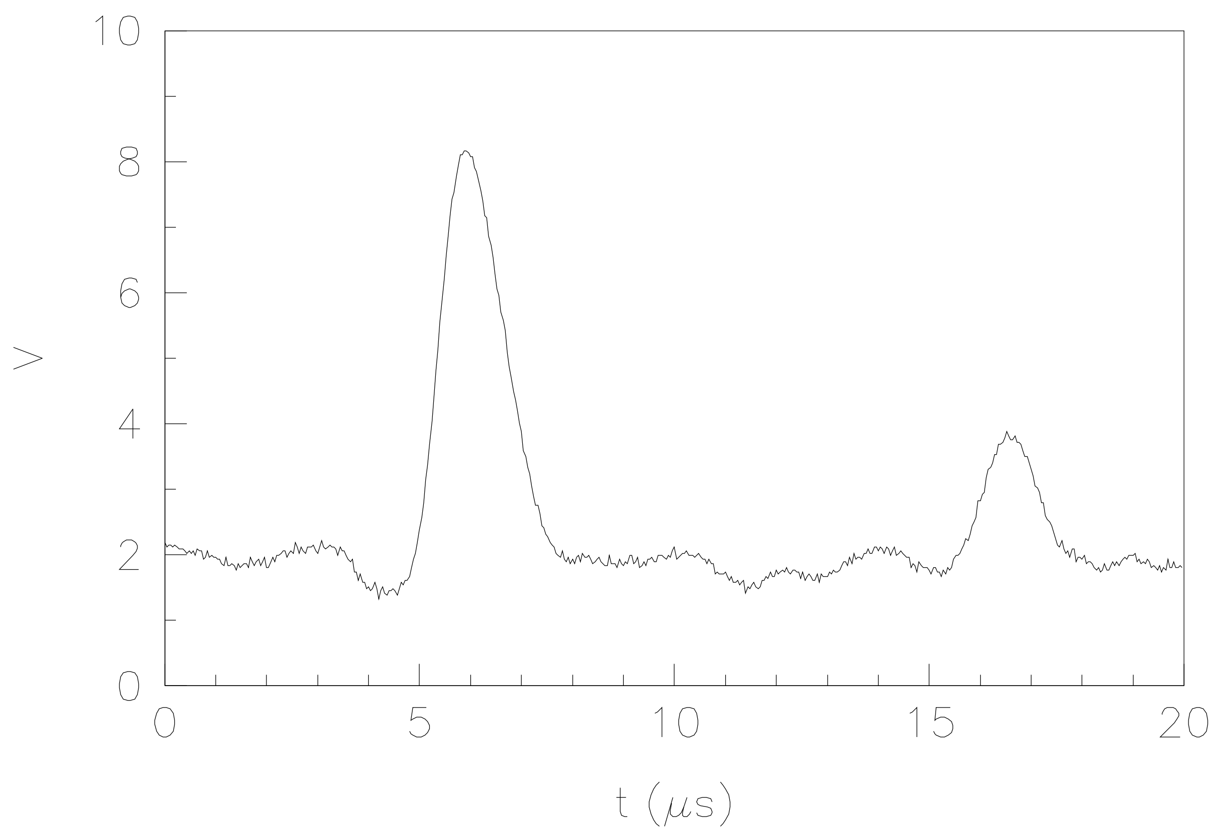
$E_{\mathrm{loss}} = 5$ keV for $E_p = 30$ keV

Silicon Detector Tests at NIST



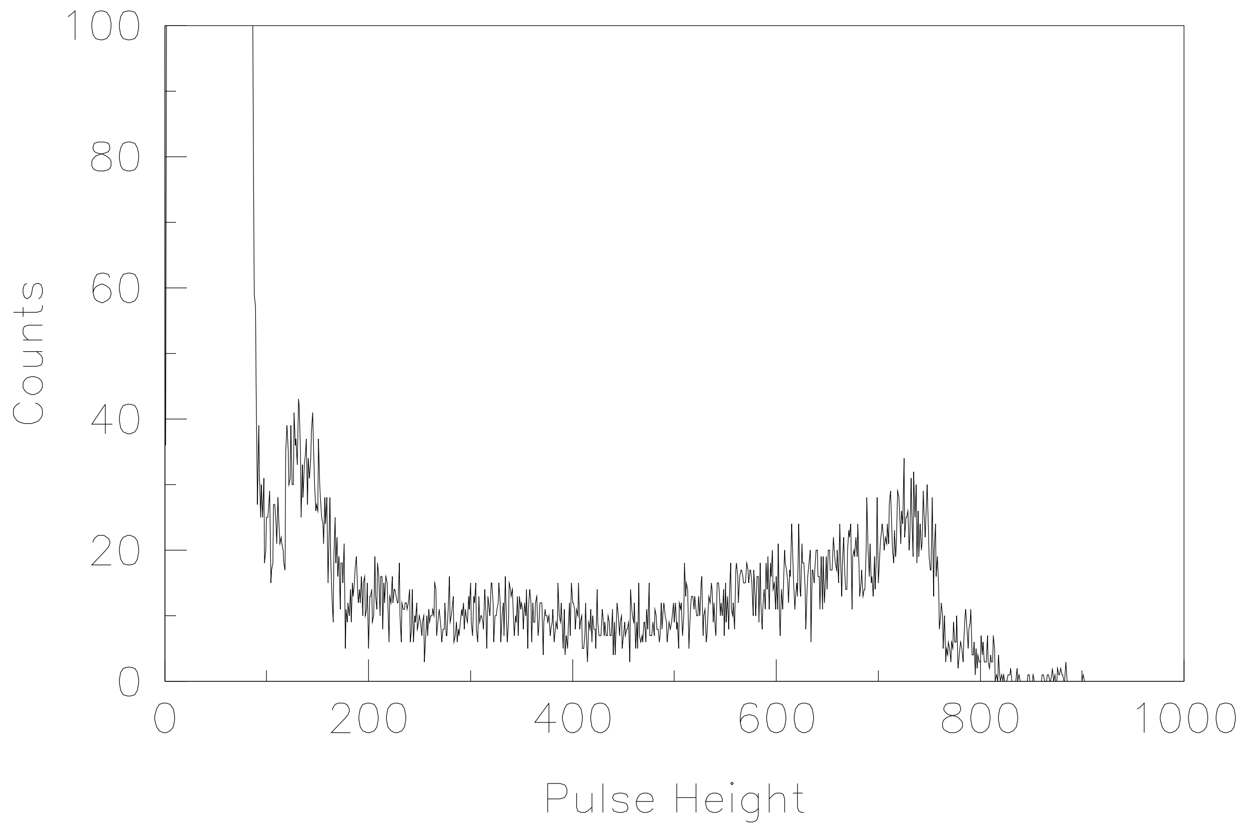
- Neutrons decay in magnetic solenoid
- Charge particles guided to detector by magnetic field
- Protons accelerated to 30 keV

Electron-Proton Coincidence



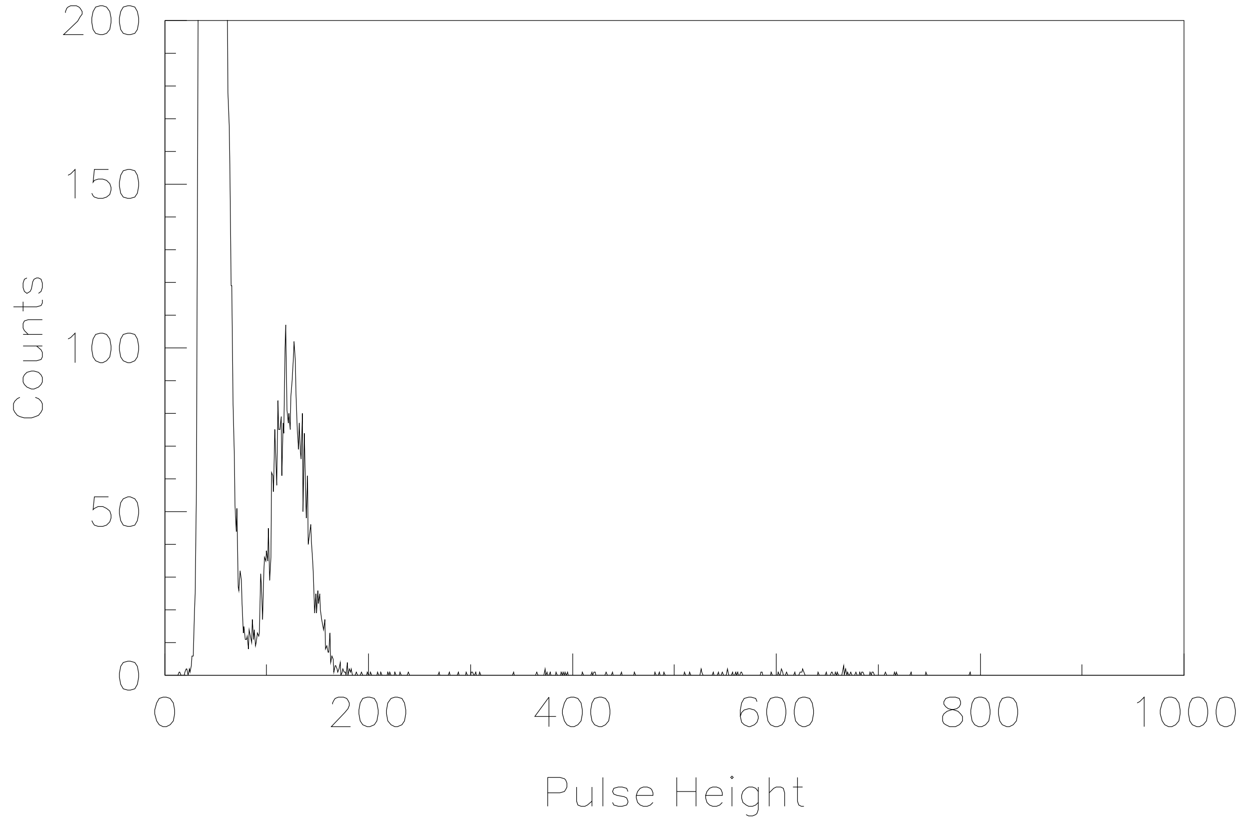
e and p seen in same detector

Neutron Decay Spectrum



No Coincidence

Neutron Decay Spectrum



$e - p$ Coincidence

Footprint of Experiment