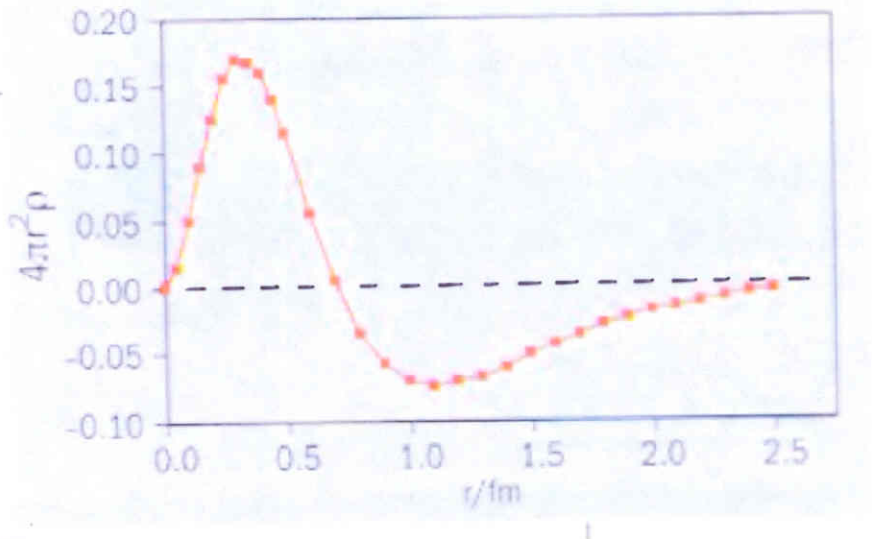
Electric Form Factor of the Neutron

Experiment E04-110

Jefferson National Accelerator Laboratory

Scientific Motivation

- Fundamental quantity for neutron
- Important for understanding internal structure of nucleon
- Provides sensitive test of models of the nucleon
- Crucial for calculation of nuclear charge form factors



G_E^n via Recoil Polarization

In the plane-wave approximation, the recoil polarization produced by a longitudinally polarized electron beam in quasielastic electron-neutron scattering is restricted to the scattering plane.

The longitudinal component, $P_{L'}$, and the transverse (sideways) component, $P_{S'}$, are parallel and perpendicular, respectively, to the recoil neutron's momentum vector. In terms of G_E^n and G_M^n, $P_{S'}$ and $P_{L'}$ can be written as

$$P_{S'}/P_L = -K_S G_E^n G_M^n / I_0 \quad ,$$

$$P_{L'}/P_L = K_L (G_M^n)^2 / I_0 \quad ,$$

Where P_L is the electron beam polarization, $I_0 = (G_E^n)^2 + K_0 (G_M^n)^2$, and K_S, K_L, and K_0 are kinematic functions of the electron scattering angle θ_e, and Q^2. Measurements of $P_{S'}$ and $P_{L'}$ via a secondary analyzing reaction permit an extraction of the ratio G_E^n / G_M^n.

A significant advantage of this technique is that P_L and the analyzing power of the secondary reaction cancel in the ratio $P_{S'}/P_{L'}$.

Use "C" magnet to precess neutron spin to measure both $P_{S'}$ & $P_{L'}$. Need 2 angles: 0°/90° and/or ±45°.

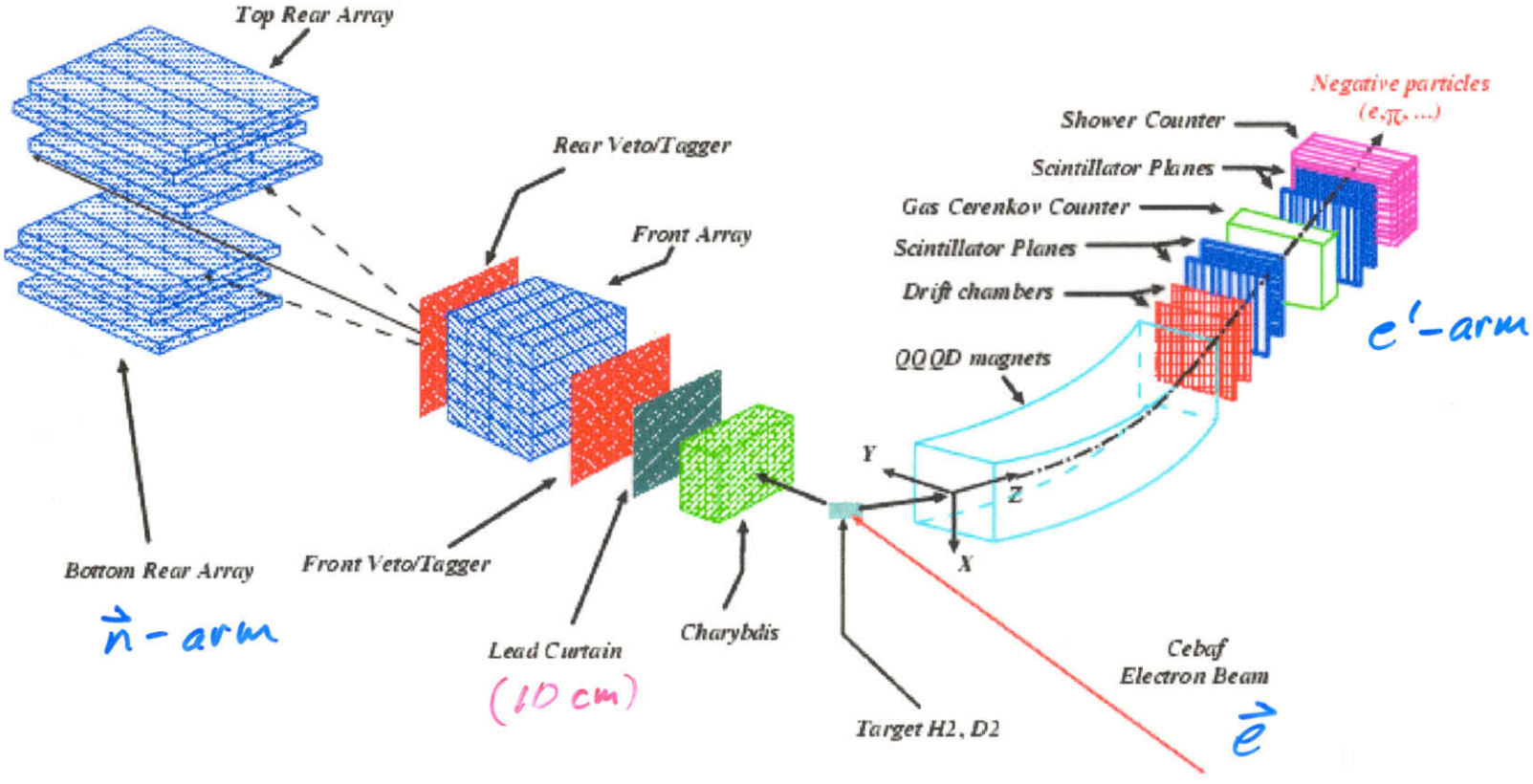
Experimental Technique

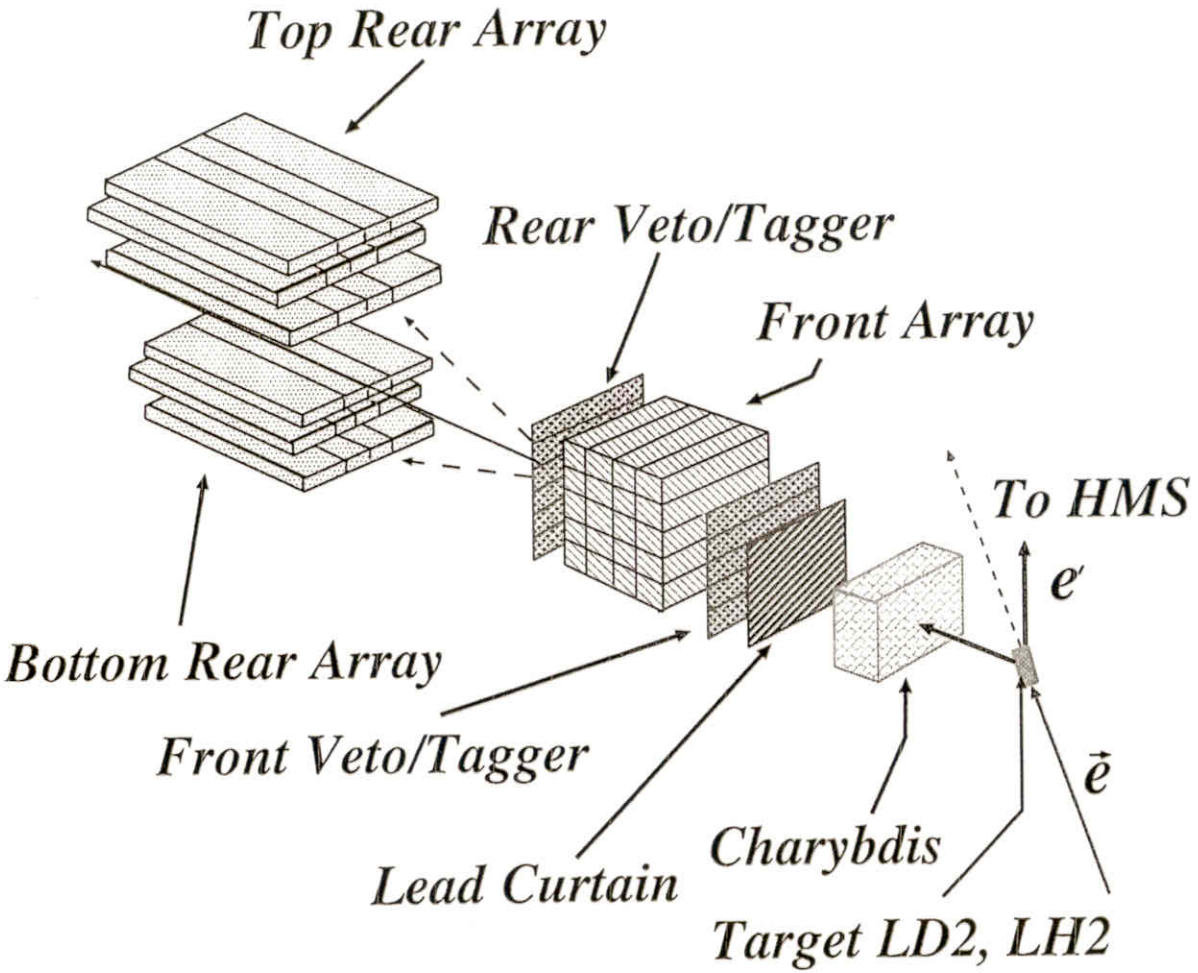
$^{2}H(\bar{e},en)^{1}H$

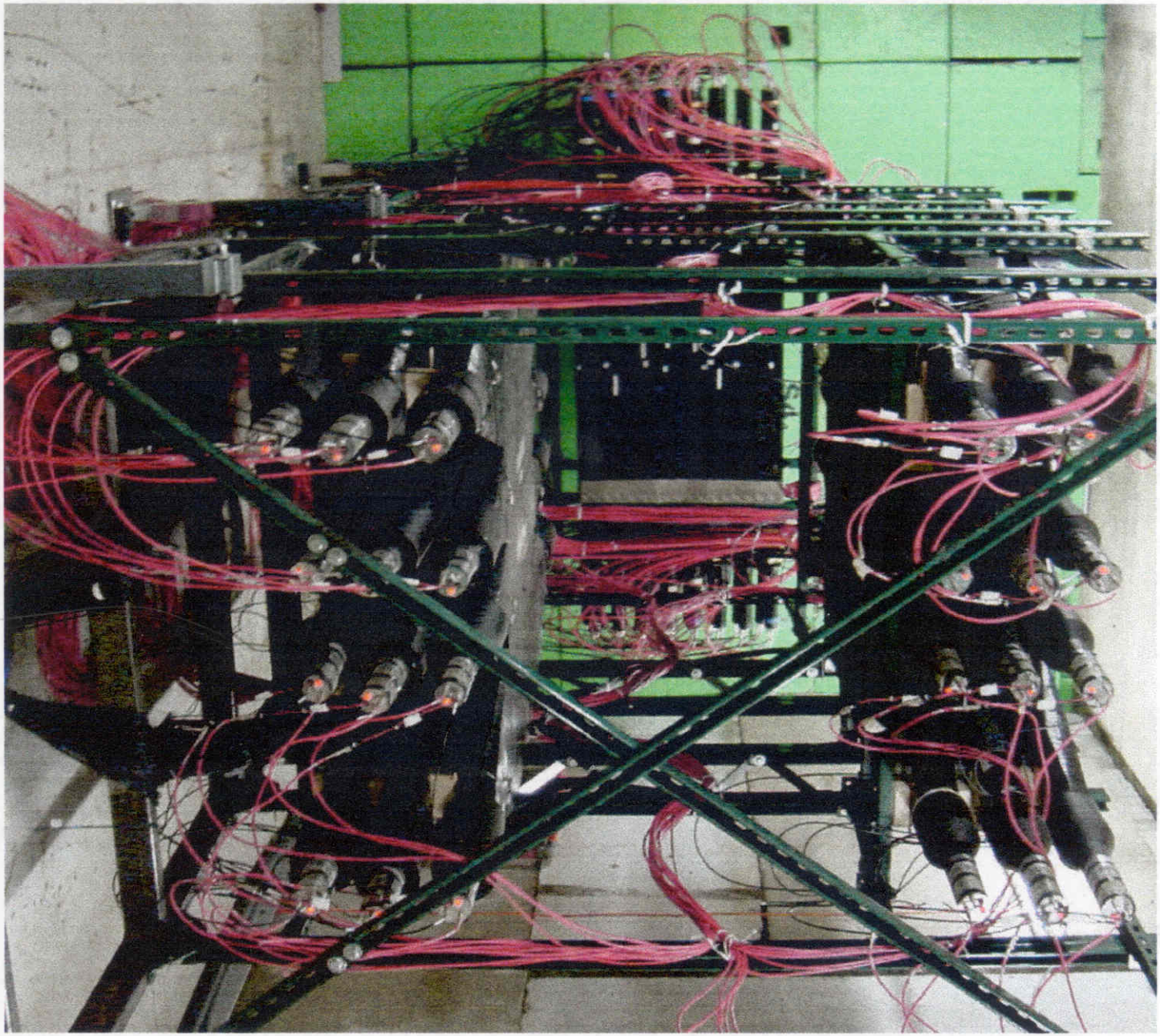
- Double-scattering experiment
- Longitudinally polarized electron beam
- Liquid deuterium target (15 cm)
- Scattered electron detected in magnetic spectrometer
- Knock-out neutron detected in neutron polarimeter

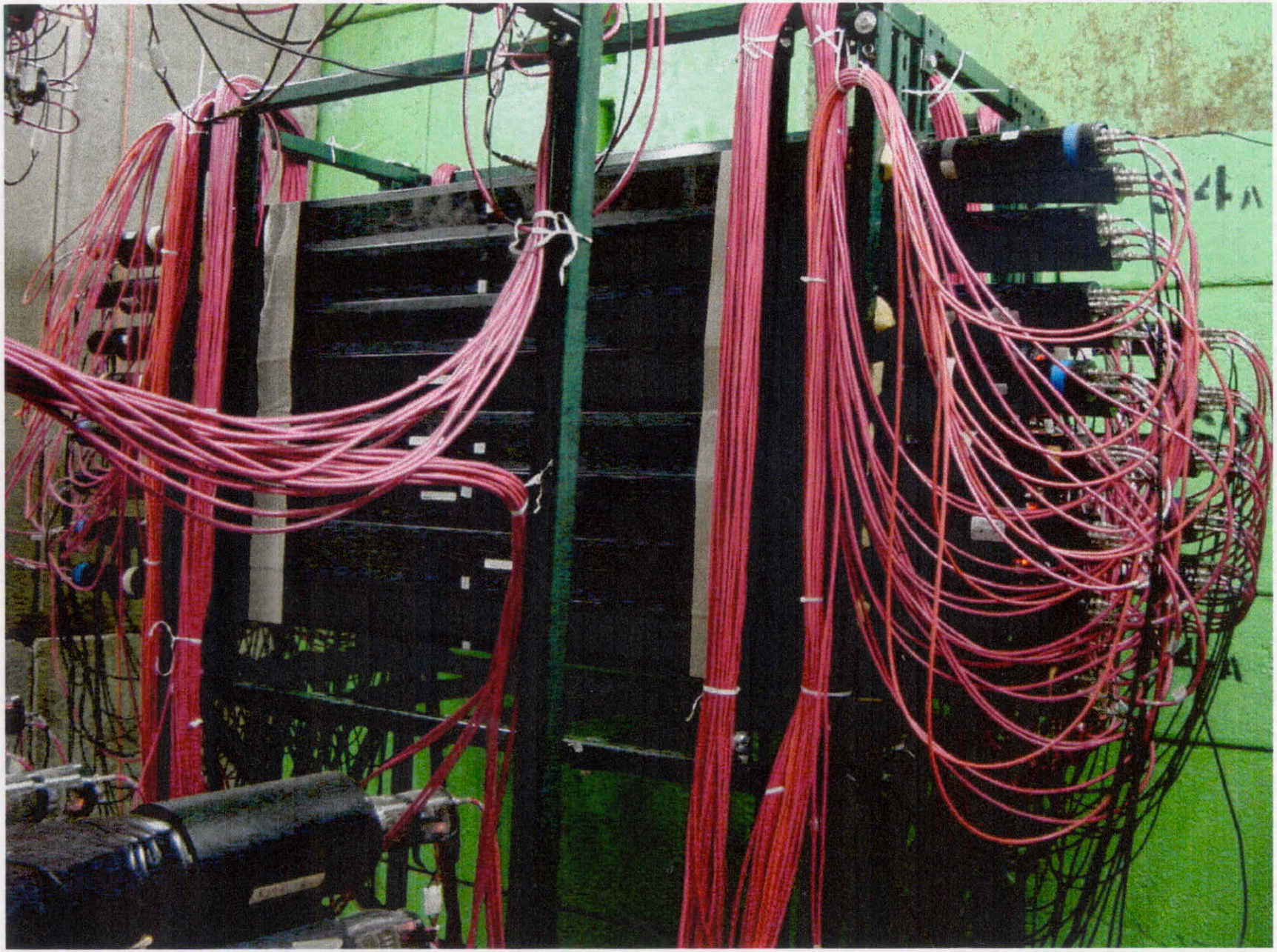
E93-038
Polarimeter

High Momentum Spectrometer
(HMS)

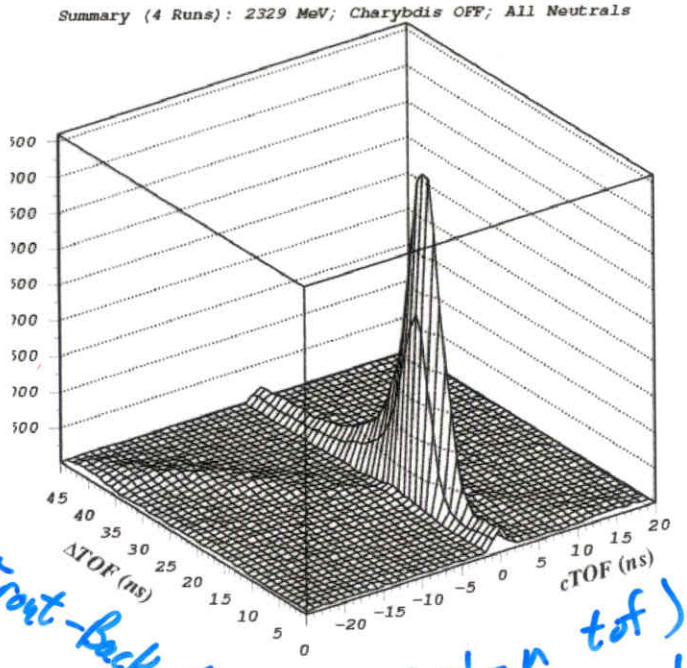



Top Rear Array
Rear Veto/Tagger
Front Array
To HMS
e'
Bottom Rear Array
Front Veto/Tagger
ē
Charybdis
Lead Curtain
Target LD2, LH2





2001/03/15 15.02

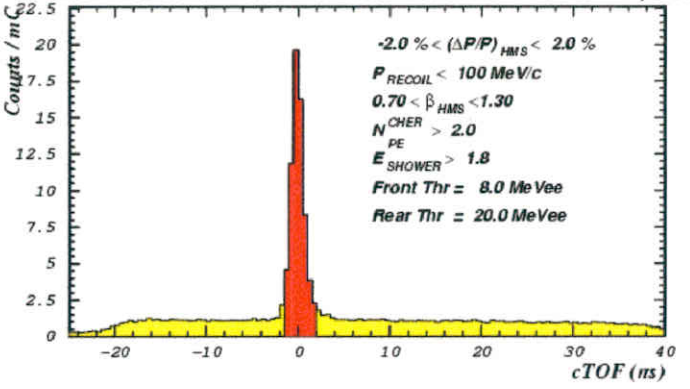


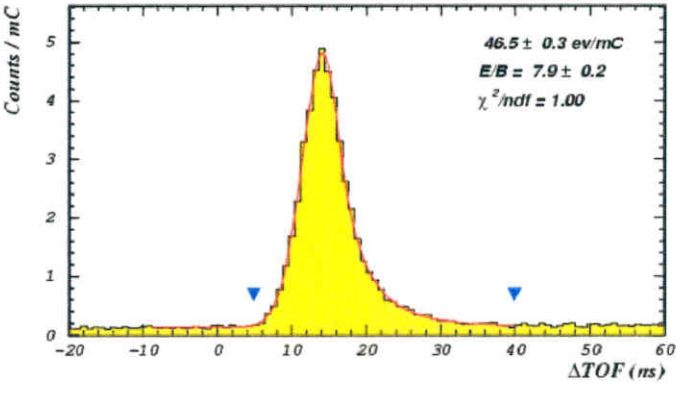
(Front-back tof)

(e'-n tof)
FWHM ~ 1.5 ns

Run 39257: 3409 MeV, 61.9 μA, 15cm LD_2, 10-cm Pb, All Neutrals

HMS-NPOL Coinc; 448.21 mC; 2.655 x 10^6 ctr; CHARY.-237 A; λ/2 out





Run was started on Apr 11, 2001 at 20:48

Omitted Detectors : 22

Analysis (v2.1) done on 5/ 1/2001 by

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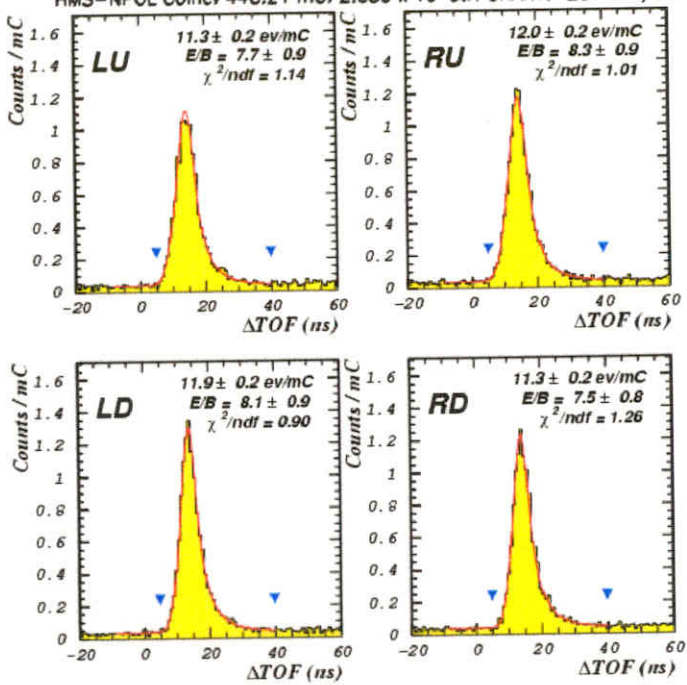
HMS-NPOL Coinc; 448.21 mC; 2.655 x 10^8 ctr; CHARY.-237 A; λ/2 out



Beam (L/R) Asymmetry ξ_{LR} = −0.17 ± 0.72 %

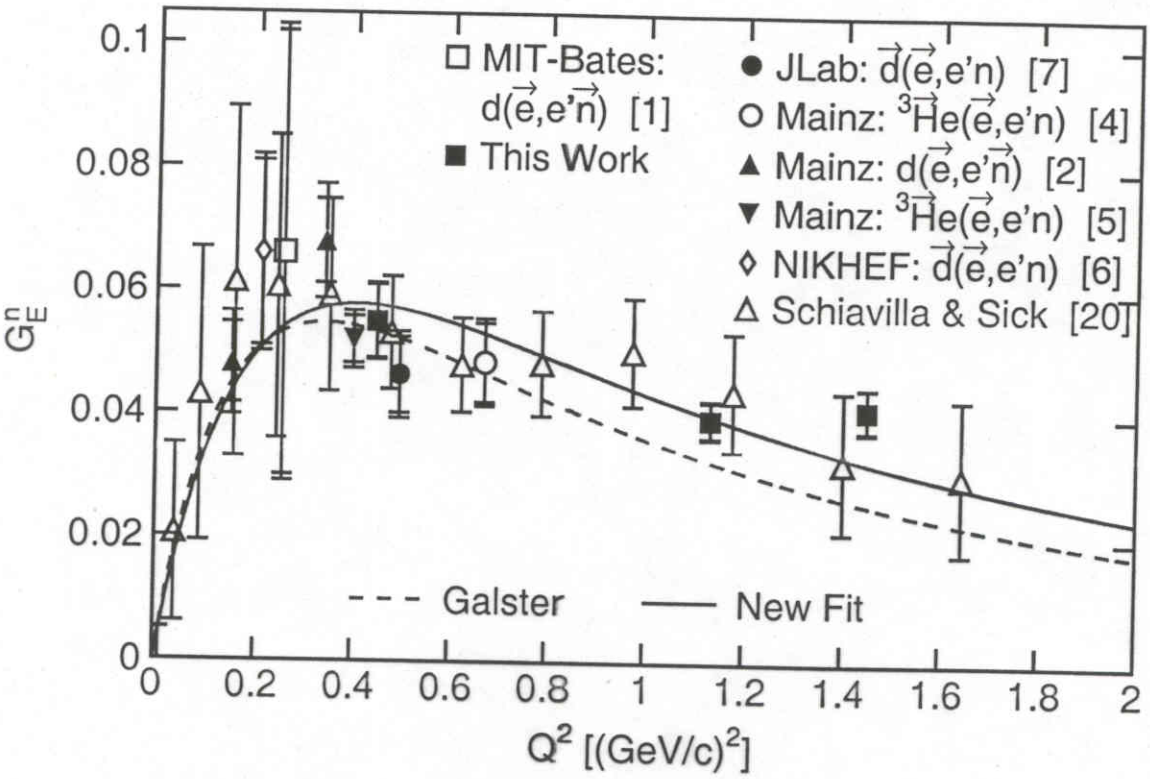
NPOL (U/D) Asymmetry ξ_{UD} = 0.00 ± 0.72 %

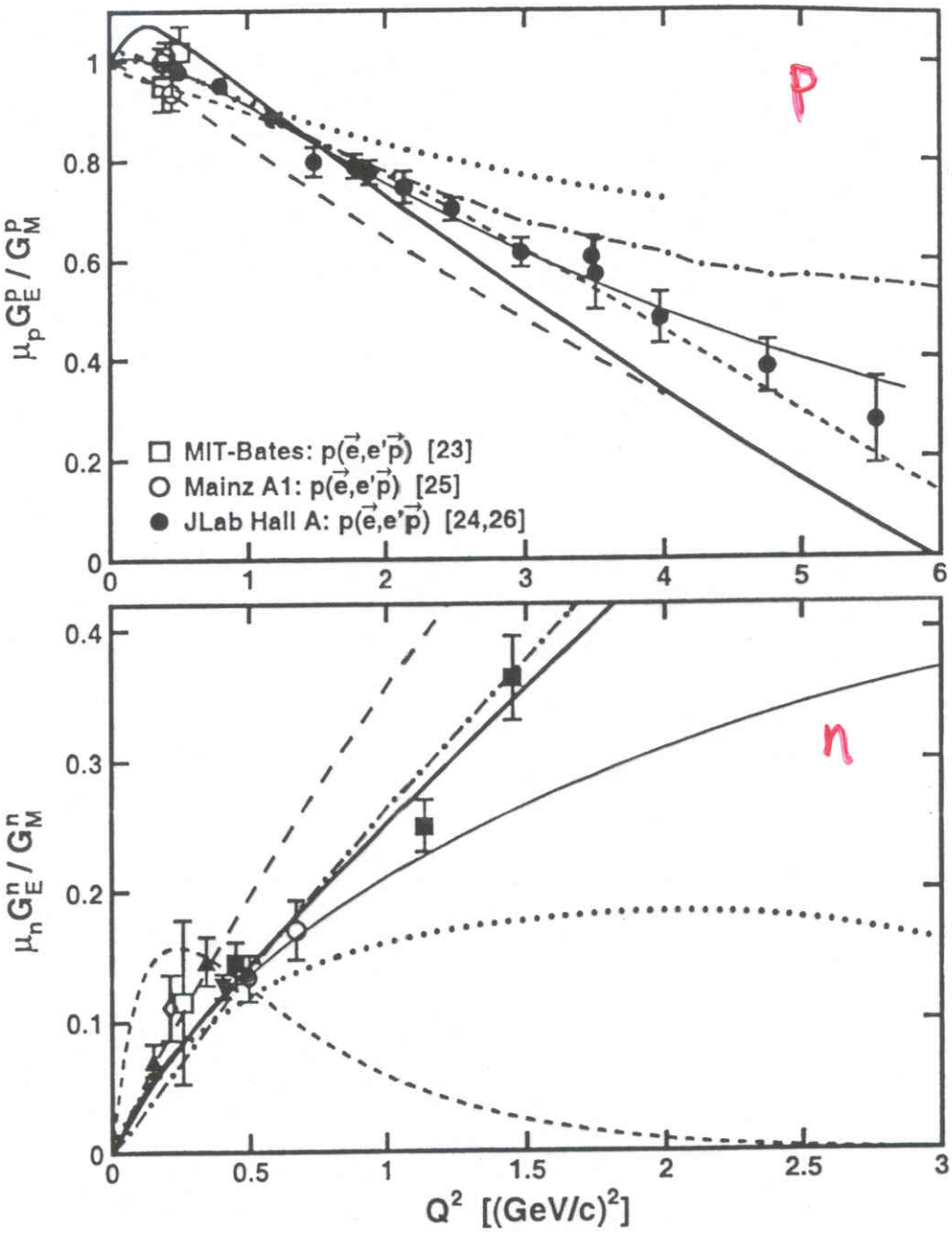
Cross-Ratio r = 1.0577 ± 0.0152

Asymmetry ξ = 2.80 ± 0.72 %

Analysis (v2.1) done on 8/ 1/2001 by

$$r = \left[\frac{RU \cdot LD}{LU \cdot RD}\right]^{1/2}$$


0.1
0.08
0.06
0.04
0.02
0
G_E^n
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Q^2 [(GeV/c)^2]
MIT-Bates: d(e,e'n) [1]
This Work
JLab: d(e,e'n) [7]
Mainz: ^{3}He(e,e'n) [4]
Mainz: d(e,e'n) [2]
Mainz: ^{3}He(e,e'n) [5]
NIKHEF: d(e,e'n) [6]
Schiavilla & Sick [20]
Galster
New Fit



--- Chiral Soliton

— — — Light-cone diquark

..... Point form spectator + Boson exch. int.

——— Light front with pointlike q's & pion cloud

—·—·— one-gluon light front w/ const. q's

——— Vector-meson dom. w/ pQCD

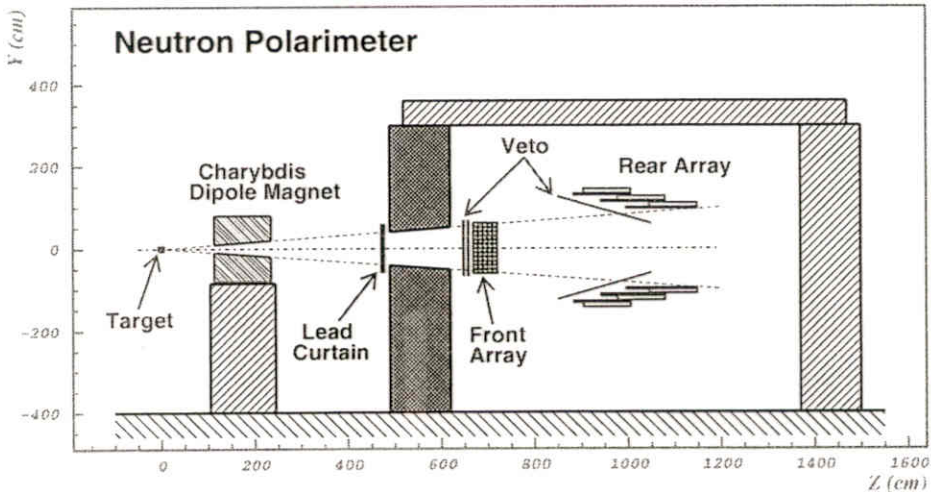


Figure 4: Neutron polarimeter to be used in the measurements.

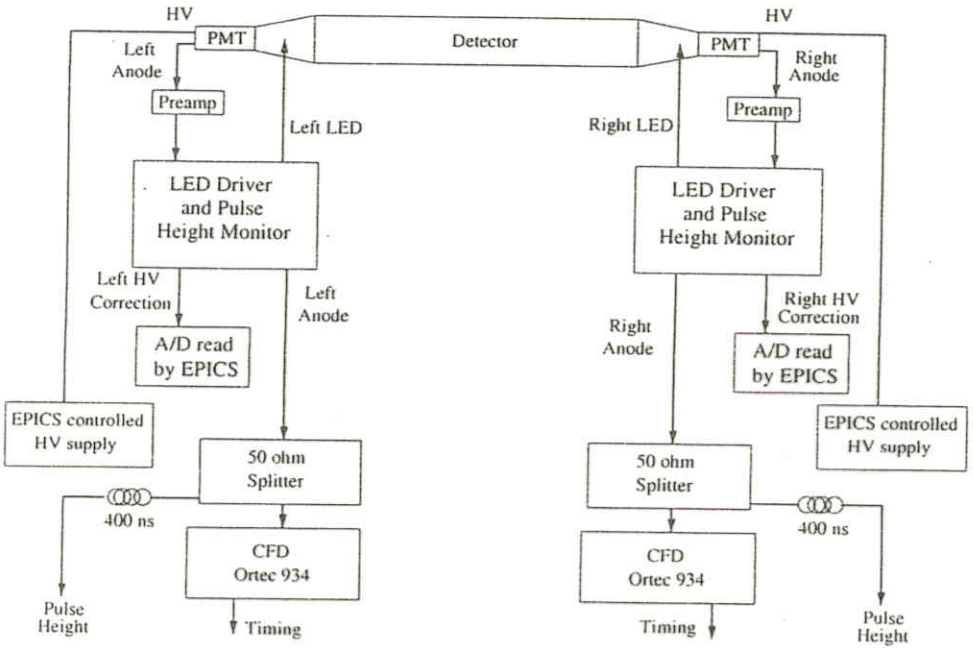


Figure 3.4: This is a schematic of the electronics used to produce the timing and pulse height signals for the 44 neutron detectors in NPOL. All electronics were installed in the NPOL detector enclosure under the detector platform.

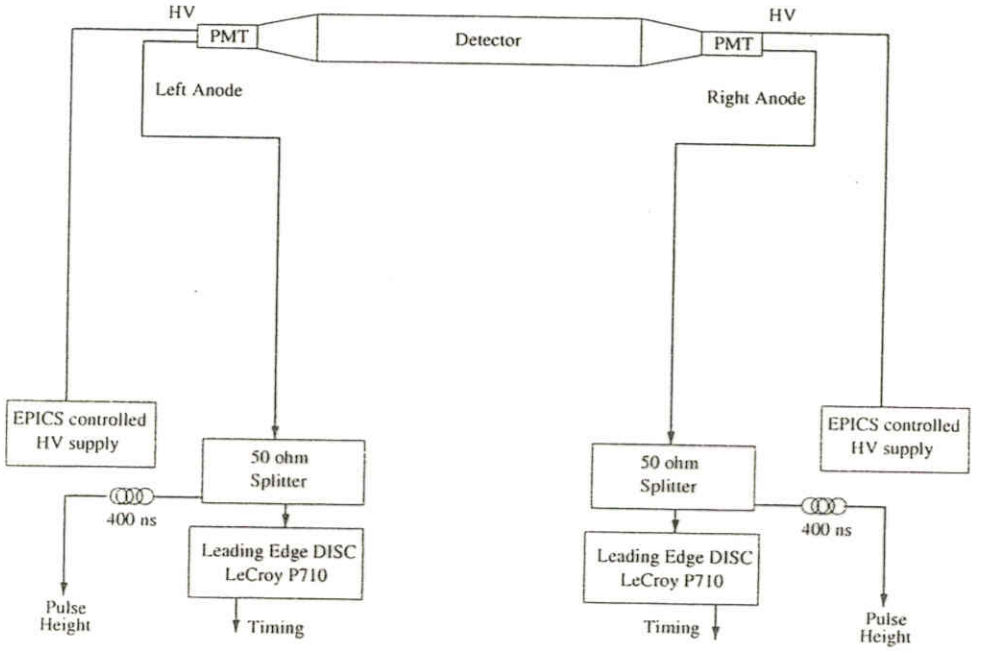


Figure 3.5: This schematic shows the electronics used to produce the timing and pulse height signals for the 26 charged particle detectors in NPOL. All electronics were installed in the NPOL detector enclosure under the detector platform.

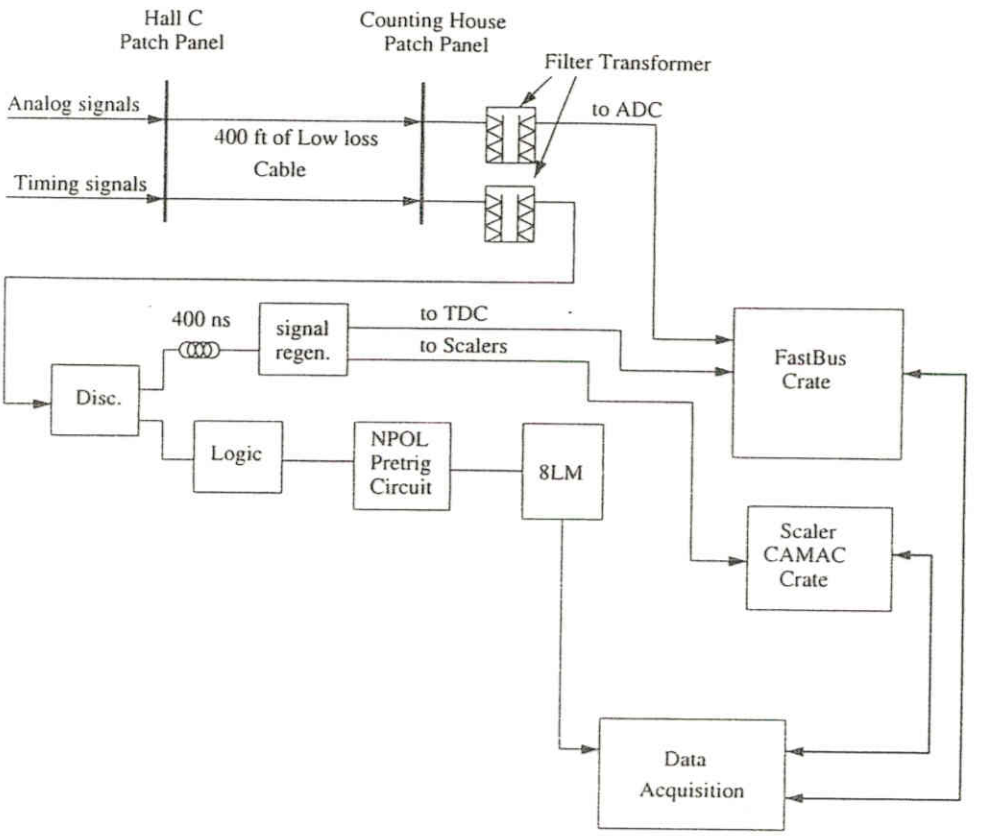


Figure 3.6: This schematic shows the NPOL side of the counting house electronics.

4 January 2005

G^E_n Equipment:

1. Front Array	
60 [10cm x 10cm x 100cm] Scintillators & Light Pipes Have 20, need 42 more (2 spares)	$60,000
30 [1cm x 10cm x 106 cm] Veto Scintillators & Light Pipes All New	27,000
180 Photomultiplier Tubes (2-in diam) Need all new?	150,000
180 Magnetic Shields (for 2-in diam PMT) Have 40, need 140	19,000
2. Rear Array	
36 [20cm x 10cm x 100cm] Scintillators & Light Pipes Have 12, other 24 will come from cutting existing detectors and making new light pipes at Kent	
10 [1cm x 50cm x 106cm] Veto Scintillators & Light Pipes All new	29,000
72 Photomultiplier Tubes (5-in diam)	150,000
20 Photomultiplier Tubes (2-in diam)	17,000
144 Magnetic Shields (for 5-in diam PMT) Have 80, need 44	11,000
3. Electronics	
48 Quad CF Discriminators Have 22, need 26 more	74,000
3 32-Channel Gain Stabilization Units Have 3 (Made at Kent)	
10 Octal Leading-Edge Discriminators for Veto Have, or will borrow	
TOTAL	537,000

4 January 2005

G^{E}_{n} Neutron Polarimeter Equipment Needs from JLab:

1. Cables:

   Need 4 Low-loss cables for each detector (PH + Timing from each end)
   Polarimeter consists of 96 neutron detectors (60 in Front array + 36 in Rear), plus 40 veto detectors. This is a total of 136 mean-timed detectors.

   272 30-ft cables from ends of detectors to electronics in Detector Hut
   272 Low-loss cables from detector hut to Counting House. (This involves 100-ft cables from Detector Hut to Experimental Hall patch panel plus about 400-ft cables up to Counting House.)
   272 Low-loss 400ns delay cables to delay signals to coincide with signals from Electron Spectrometer.

2. HV Supplies:

   Need 3kV supply for each PMT (2 per detector) 272 HV Supplies
   (HV Supplies for rear detectors must be 10mA: 72 Supplies)

3. Electronics:

   For each channel (PH + Timing) need a discriminator to regenerate signals from experimental Hall, need a logic unit, and either a TDC or ADC input to FastBus.

4. Detector Hut:

   Need detector Hut to shield neutron polarimeter from room background, similar to that used in E93-038.

   Need stand for neutron polarimeter. Table for front arrary, plus "scaffolding" for rear array, similar to that used for E93-038 – but stronger.

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