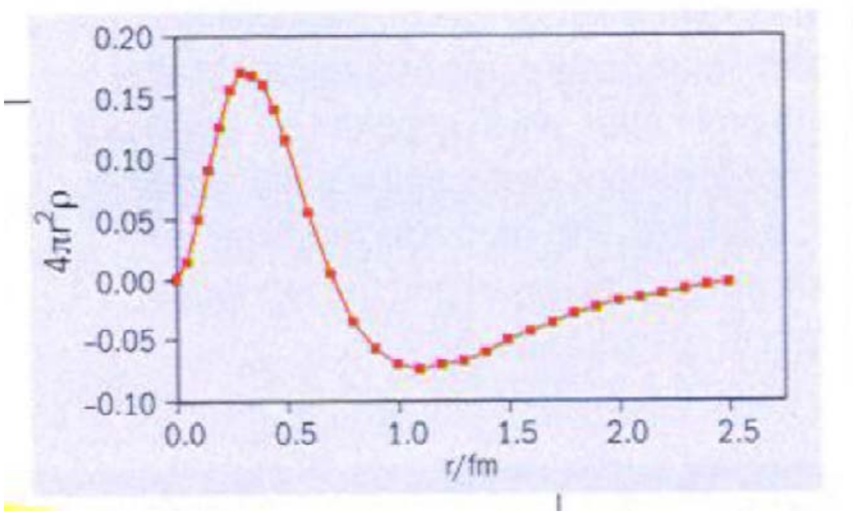
Electric Form Factor of the Neutron

Experiment E04-110

Jefferson National Accelerator Facility

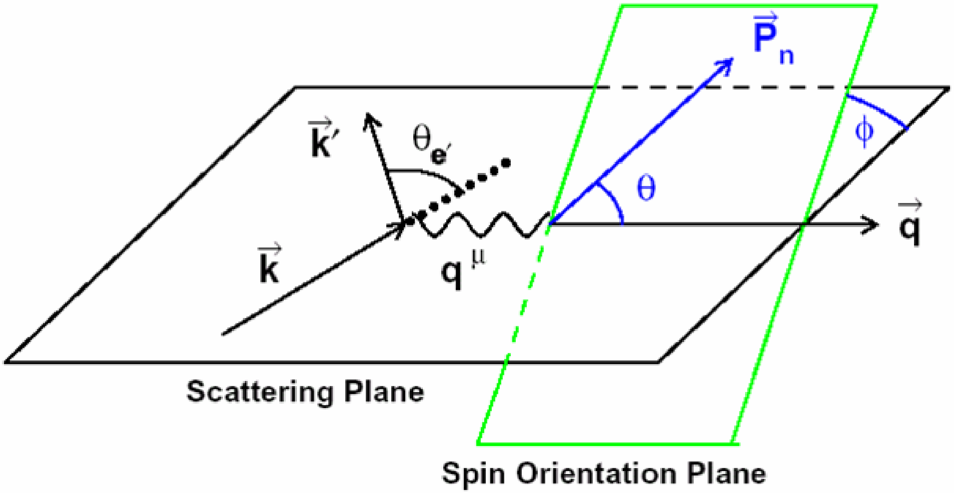
Scientific Motivation

- *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*



In PWIA, the cross-section asymmetry with respect to helicity reversal of the electron is:

$$A(\theta,\phi) = P_e P_n f_D \frac{K_1 \sin\theta \cos\phi G_{En} G_{Mn} + K_2 \cos\theta G_{Mn}^2}{G_{En}^2 + K_3 G_{Mn}^2}$$



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. It can be shown that

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

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

G_E^n *and* G_M^n = *Electric/ Magnetic form factors of the neutron*

$P_{S'}$ *and* $P_{L'}$ = *sideways/longitudinal neutron-polarizations*

P_L = *electron beam polarization*

$I_0 = (G_E^n)^2 + K_0 \, (G_M^n)^2$

K_S, K_L, *and* K_0 *are kinematic functions of* θ_e , *and* Q^2 .

Measuring $P_{S'}$ *and* $P_{L'}$ *and taking the ratio yields*

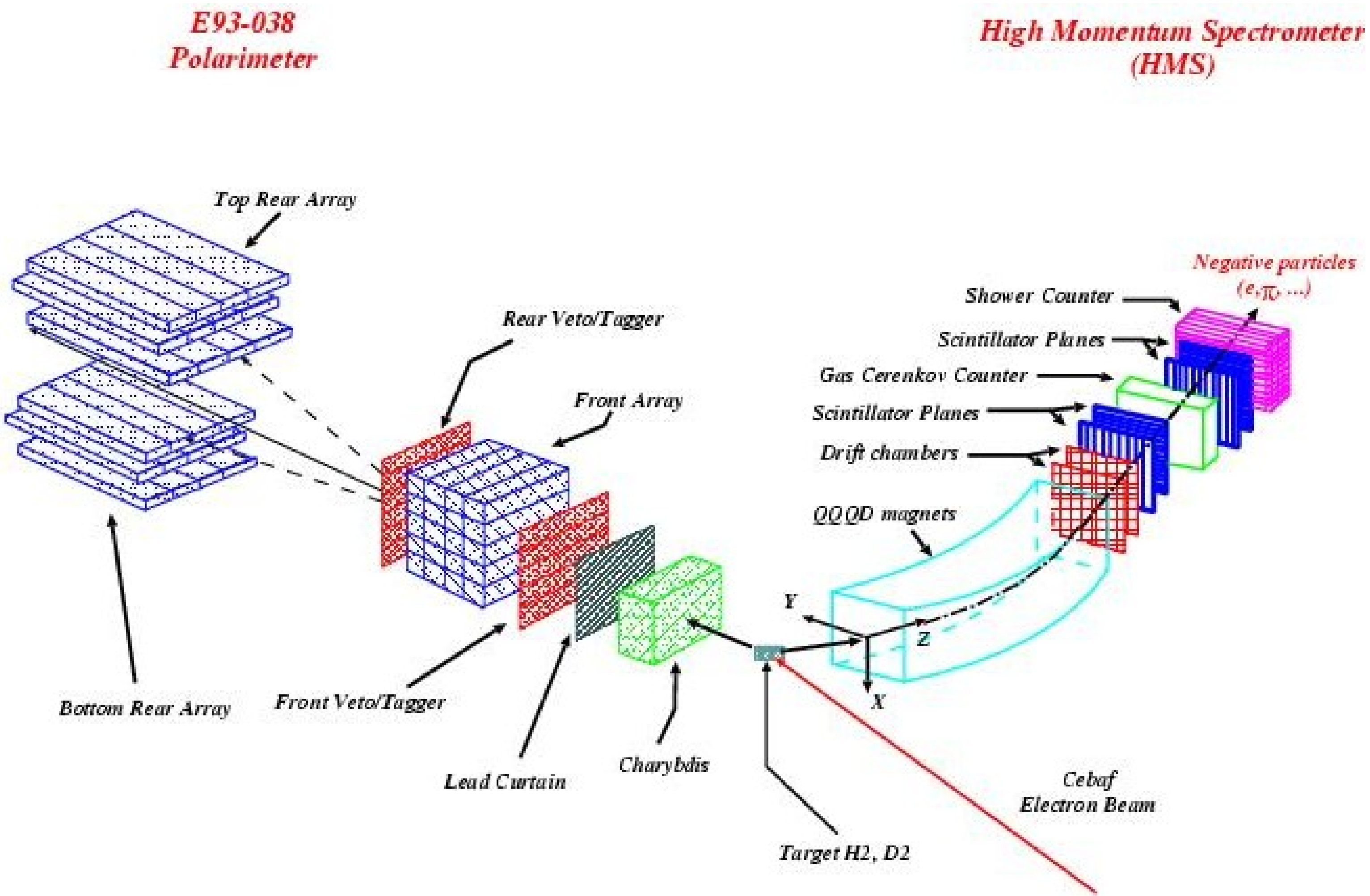
$$P_{S'} / P_{L'} = (-K_S / K_L) \, G_E^n / G_M^n \quad .$$

A significant advantage of this technique is that P_L *and the analyzing power of the secondary reaction cancel in the ratio.*

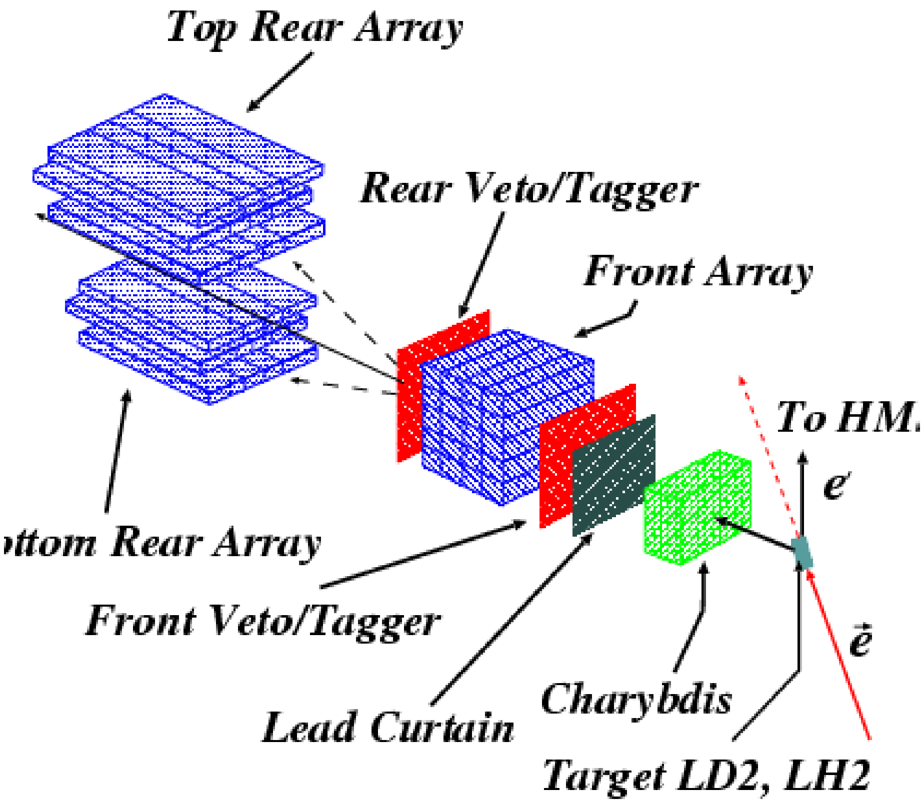
Experimental Technique

- *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*

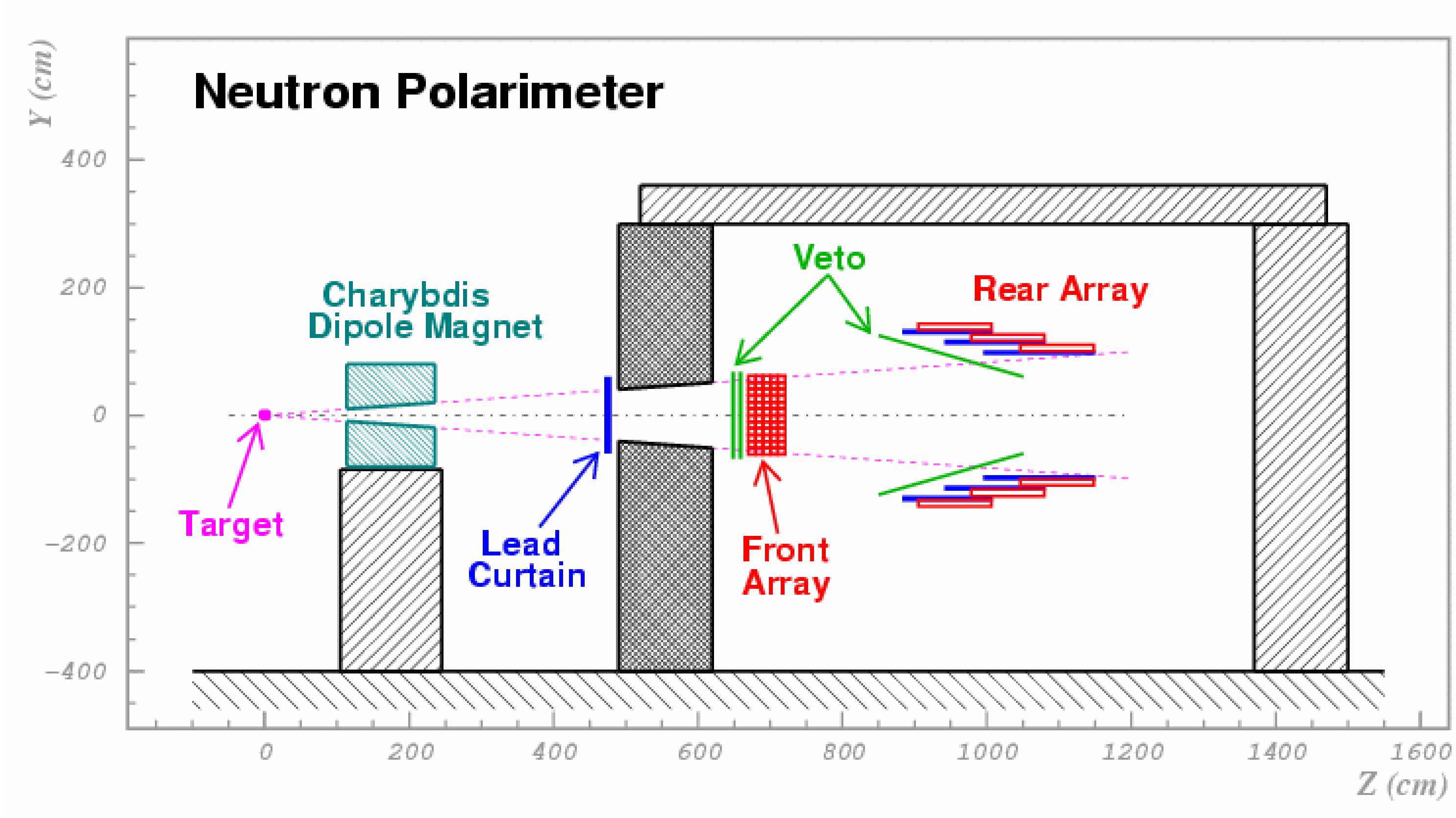
Experimental Overview

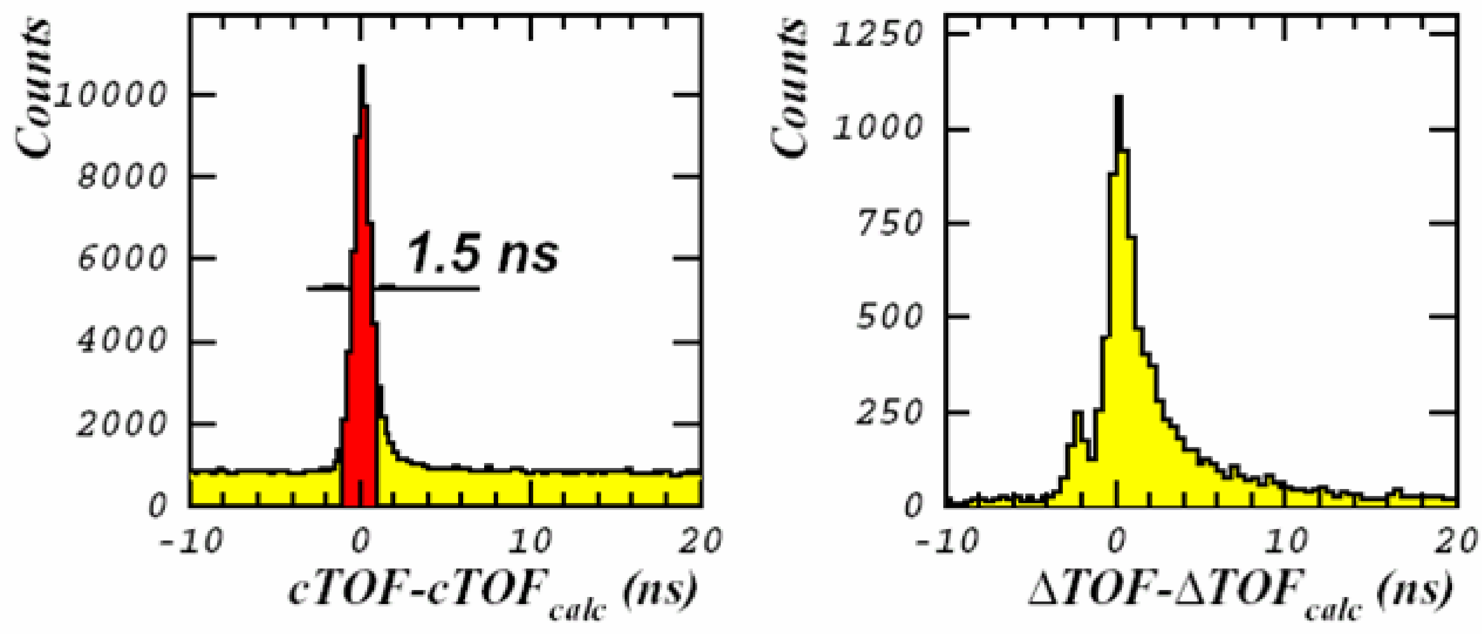


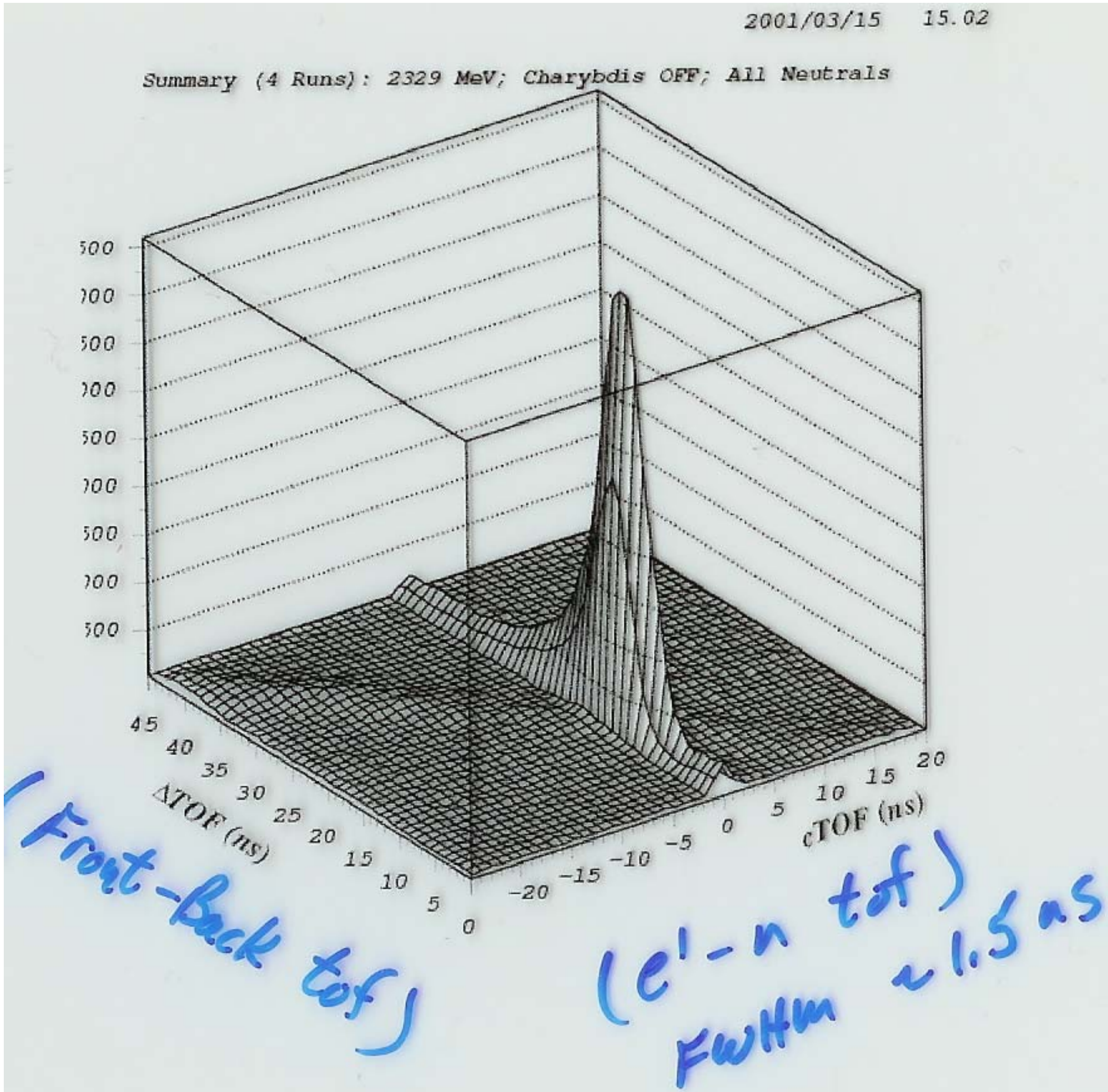
Neutron Arm

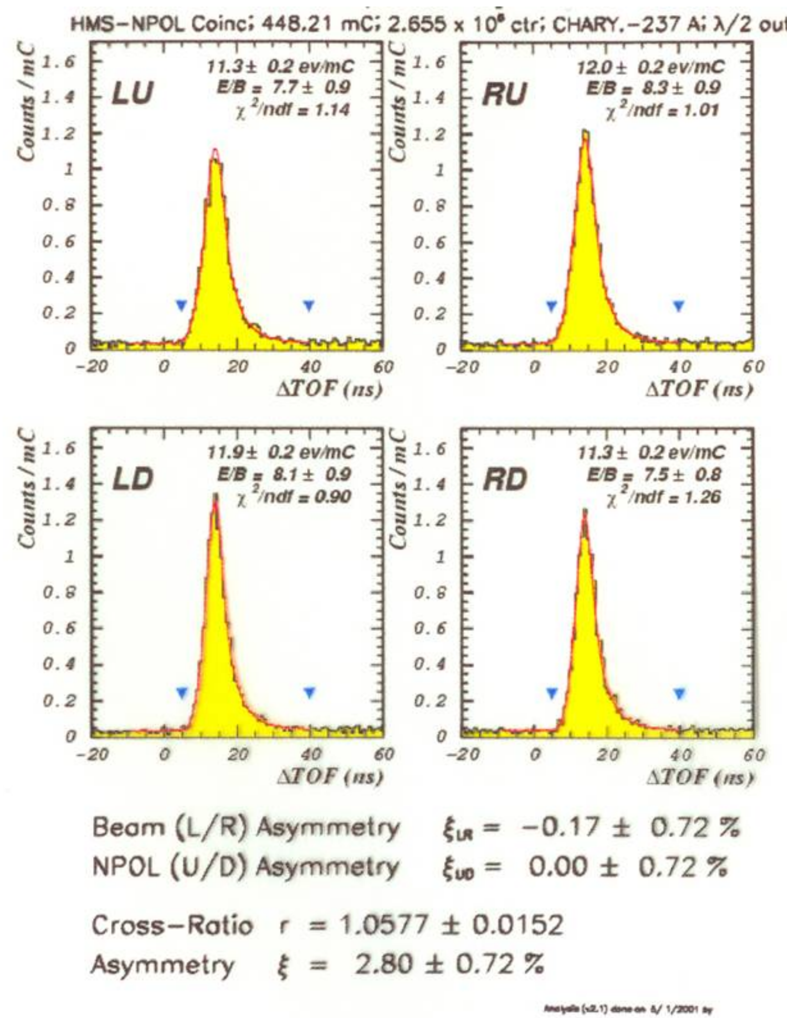

Top Rear Array
Rear Veto/Tagger
Front Array
To HM
e'
ottom Rear Array
Front Veto/Tagger
$\vec{e}$
Charybdis
Lead Curtain
Target LD2, LH2

Neutron Polarimeter



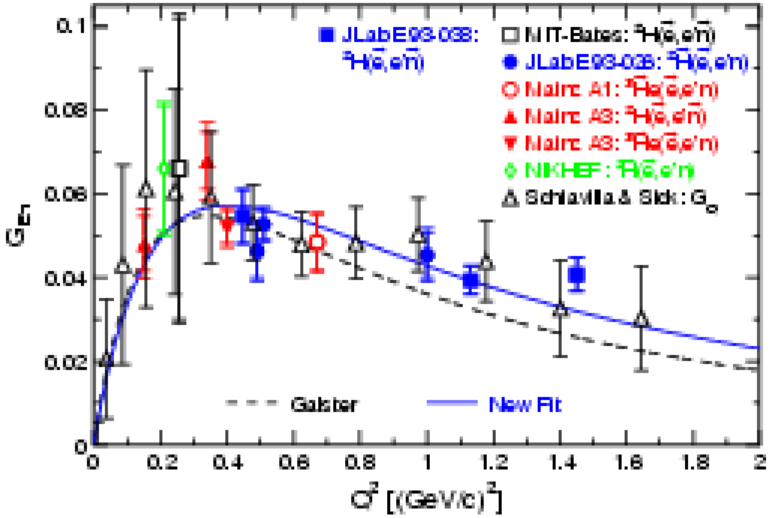

Counts
10000
8000
6000
4000
2000
0
1.5 ns
-10
0
10
20
cTOF-cTOF$_{calc}$ (ns)
Counts
1250
1000
750
500
250
0
-10
0
10
20
ΔTOF-ΔTOF$_{calc}$ (ns)

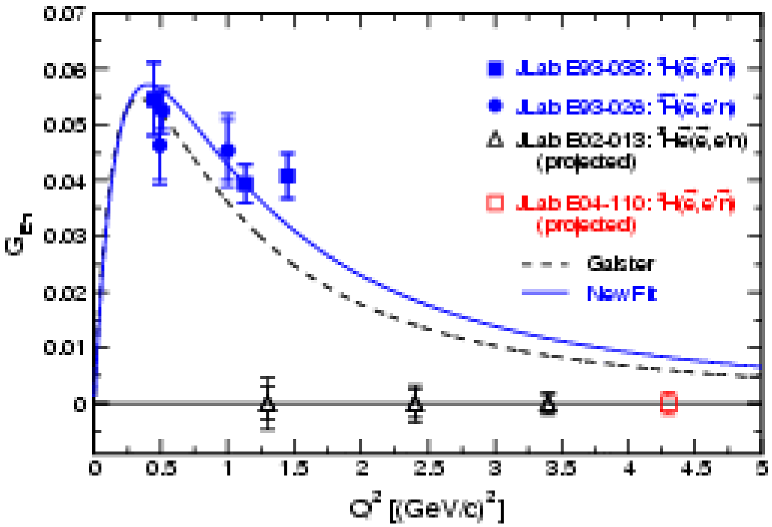

2001/03/15 15.02
Summary (4 Runs): 2329 MeV; Charybdis OFF; All Neutrals
ΔTOF (ns)
cTOF (ns)
(Front-Back tof)
(e'-n tof)
FWHM ~1.5 ns



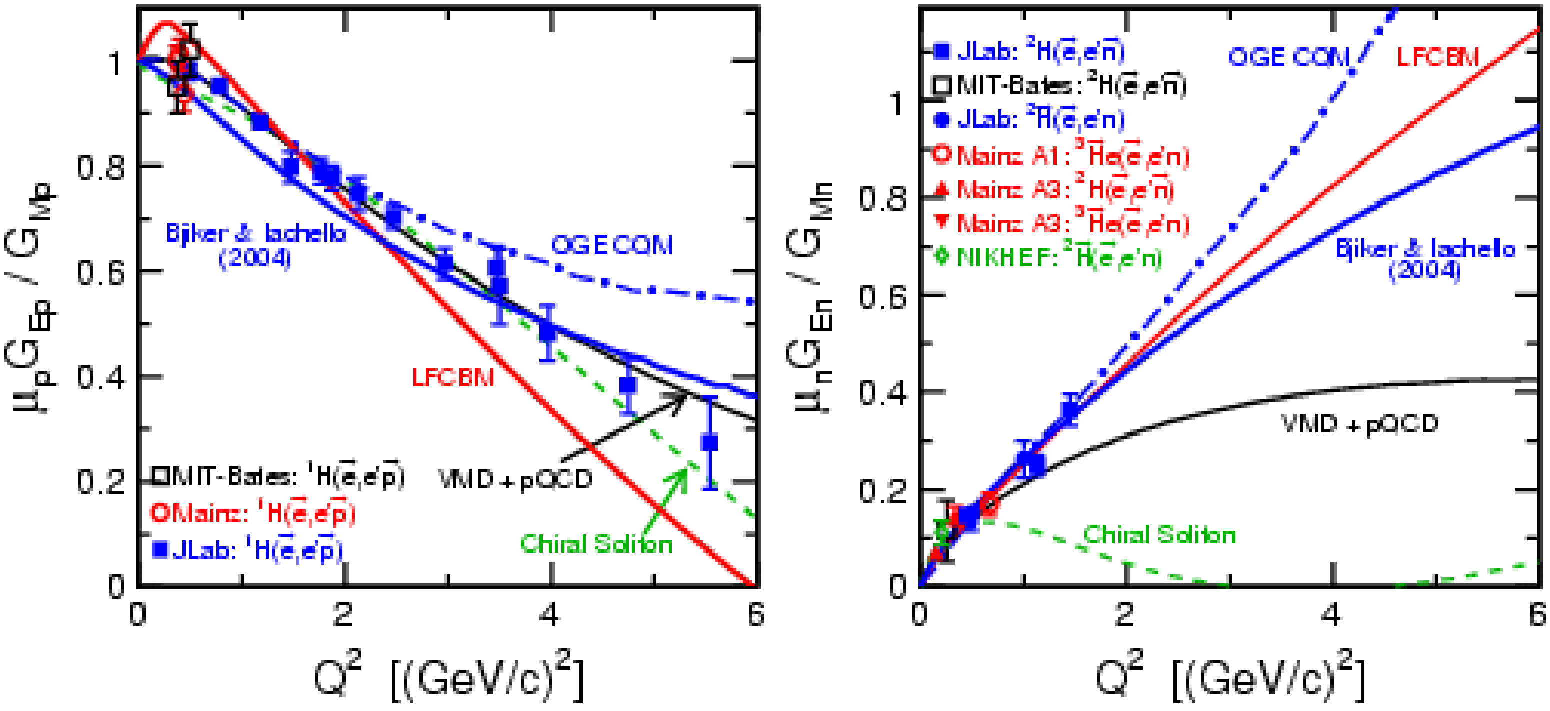
$$r = [\,(RU \cdot LD) / (LU \cdot RD)]^{1/2}$$
$$\xi = [(r - 1) / (r + 1)] / AP$$

G_E^n World Data





G_E^p / G_E^n vs Theory



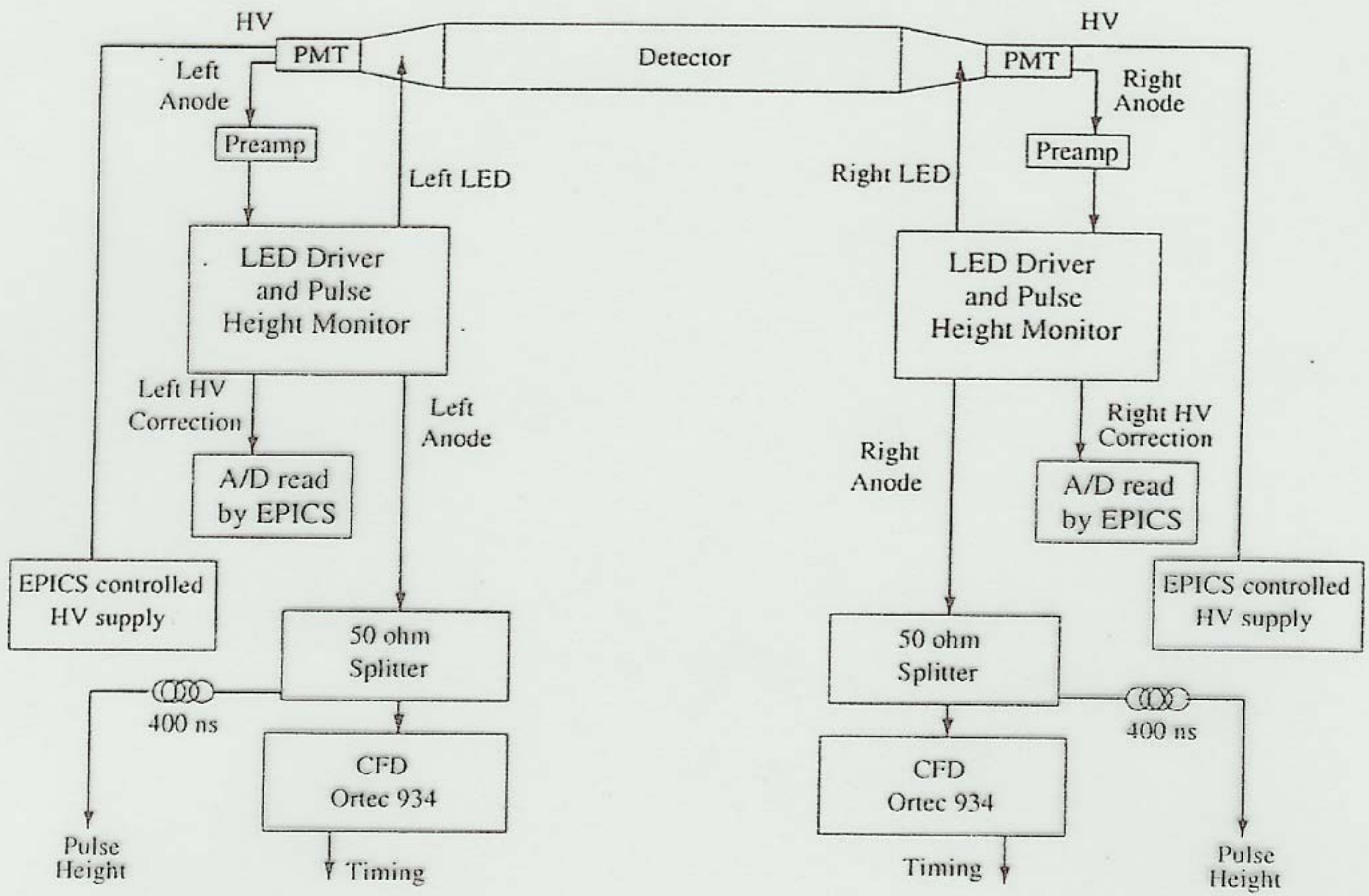
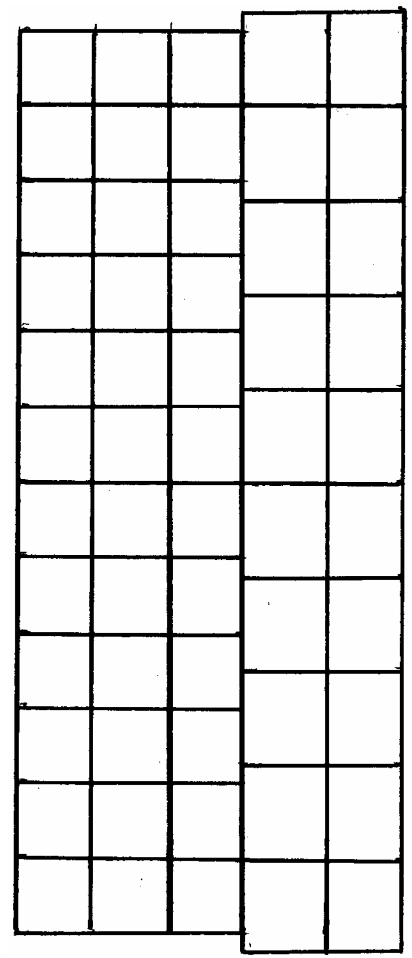


Figure 3.4: This is a schematic of the electronics used to produce the timing and pulse height signals for the 44 neutron detectors in NPOL. All electronics were installed in the NPOL detector enclosure under the detector platform.

Front Array

36 10x10x100 cm bars



20 10x12.5x100 cm bars

E04-110: G_E^n EQUIPMENT: 26 January 2007

1. FRONT ARRAY	
36 [10cm x 10cm x 100cm] Scintillators & Light Pipes	
Have 32, need 6 more (2 spares)	$14,000
20 [12.5cm x 10cm x 100 cm] Scintillators & Light Pipes	
Existing in Hall A array (IU detectors)	
30 [1cm x 10cm x 106 cm] Veto Scintillators & Light Pipe	27,000
All neutron detectors have PMT's & Mag Shields	
(Veto detector PMT's & Mag Shields may be obtained from veto detectors in E93-038 Gen Exp.?)	
20 Replacement 2-in diam PMT's (First 3 layers)	20,000
2. REAR ARRAY	
OPTION 1:	
Use existing neutron detector array.	
Replacement PMT's for neutron detectors (10)	20,000
Rear Array Veto detectors	
20 [1cm x 25 cm x 106 cm] vetoes & light pipes	40,000
40 2-in diam PMT's & Mag Shields	46,000
OPTION 2:	
Cut all existing 20x40 detectors (12) into two 10x40 detectors.	
Cutting and new Light Pipe fabrication will be performed at Kent.	
24 5-in Diam PMT's & Mag Shields	52,000
3. ELECTRONICS	
46 Quad CF Discriminators	
Have 22 (KSU) + 10 (Tel Aviv) + 10 (MSU-Tennelec)	
Need 4 more for Option 2 @$3K/ea	12,000
3 32-Channel Gain Stabilization Units - Have (Kent)	
10 Octal Leading-Edge Discriminators for Veto - Have/borrow	
TOTAL: OPTION 1	180,000
OPTION 2	232,000

“12 GeV” Measurement:

$Q^2 = 6.0\ (GeV/c)^2$ $E_{beam} = 10$ GeV

Neutron polarimeter at $\theta_n = 29.7°$

HMS at $\theta_e = 17.08°$

Central electron momentum = 6.8 GeV/c
(HMS max = 7.5 GeV/c)

Estimated count rate (MONQEE/GEANT) assumes I_{beam} = 100 μA with beam polarization = 80% on a 15 cm LD_2 target and that A_y and ε of neutron polarimeter remains constant from estimations for measurement at $Q^2 = 4.3$ $(GeV/c)^2$.

Count rate ~ 0.45 Hz

→ $\Delta G_E^n \approx 0.0019$ in 30 Days