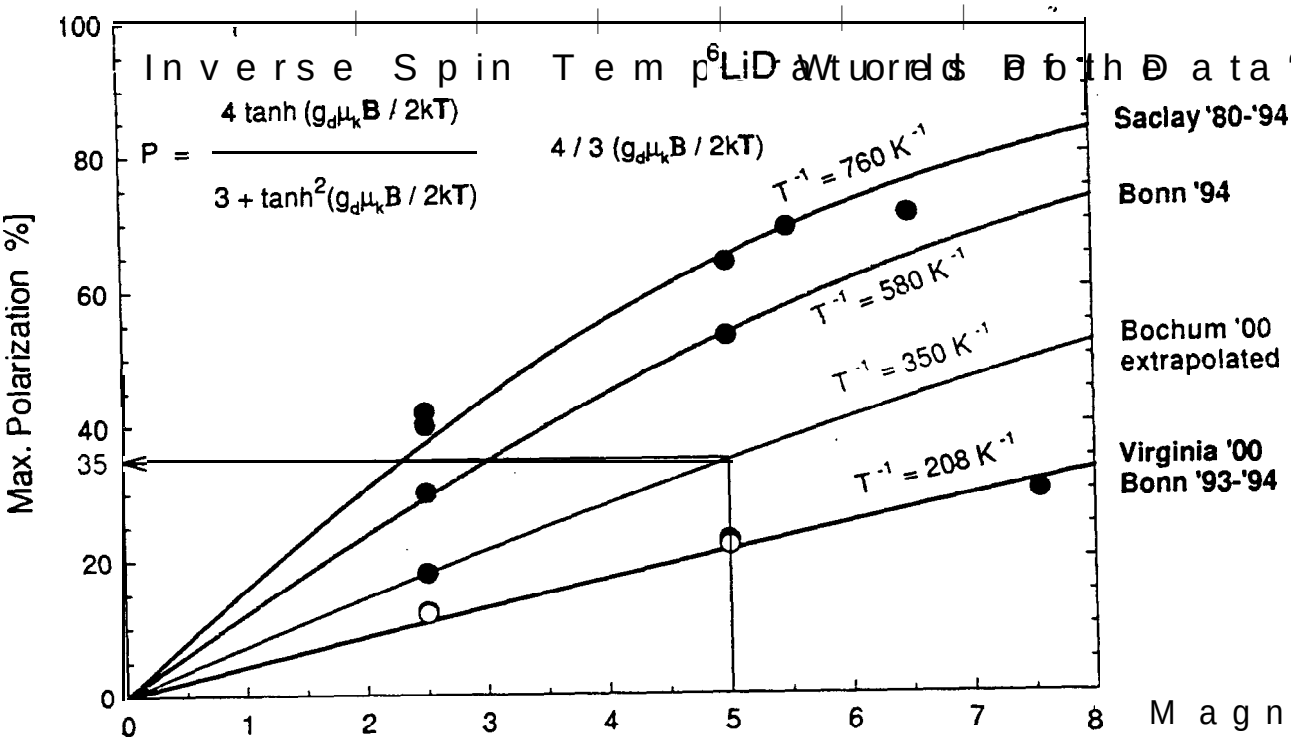
# POLARIZED TARGET for EI59 and EI61

## System for E161

- Dilution Refrigerator
- 7T Solenoid
  - Microwaves
  - NMR
  - $^{6}$LiD

D. Crabb


Inverse Spin Temperatures for the Data
$^6$LiD
$P = \frac{4 \tanh(g_d \mu_k B / 2kT)}{3 + \tanh^2(g_d \mu_k B / 2kT)}$
$4/3\ (g_d \mu_k B / 2kT)$
$T^{-1} = 760\ K^{-1}$
$T^{-1} = 580\ K^{-1}$
$T^{-1} = 350\ K^{-1}$
$T^{-1} = 208\ K^{-1}$
Saclay '80-'94
Bonn '94
Bochum '00 extrapolated
Virginia '00
Bonn '93-'94
Max. Polarization [%]
Magnetic Field [T]
100
80
60
40
35
20
0
0
1
2
3
4
5
6
7
8

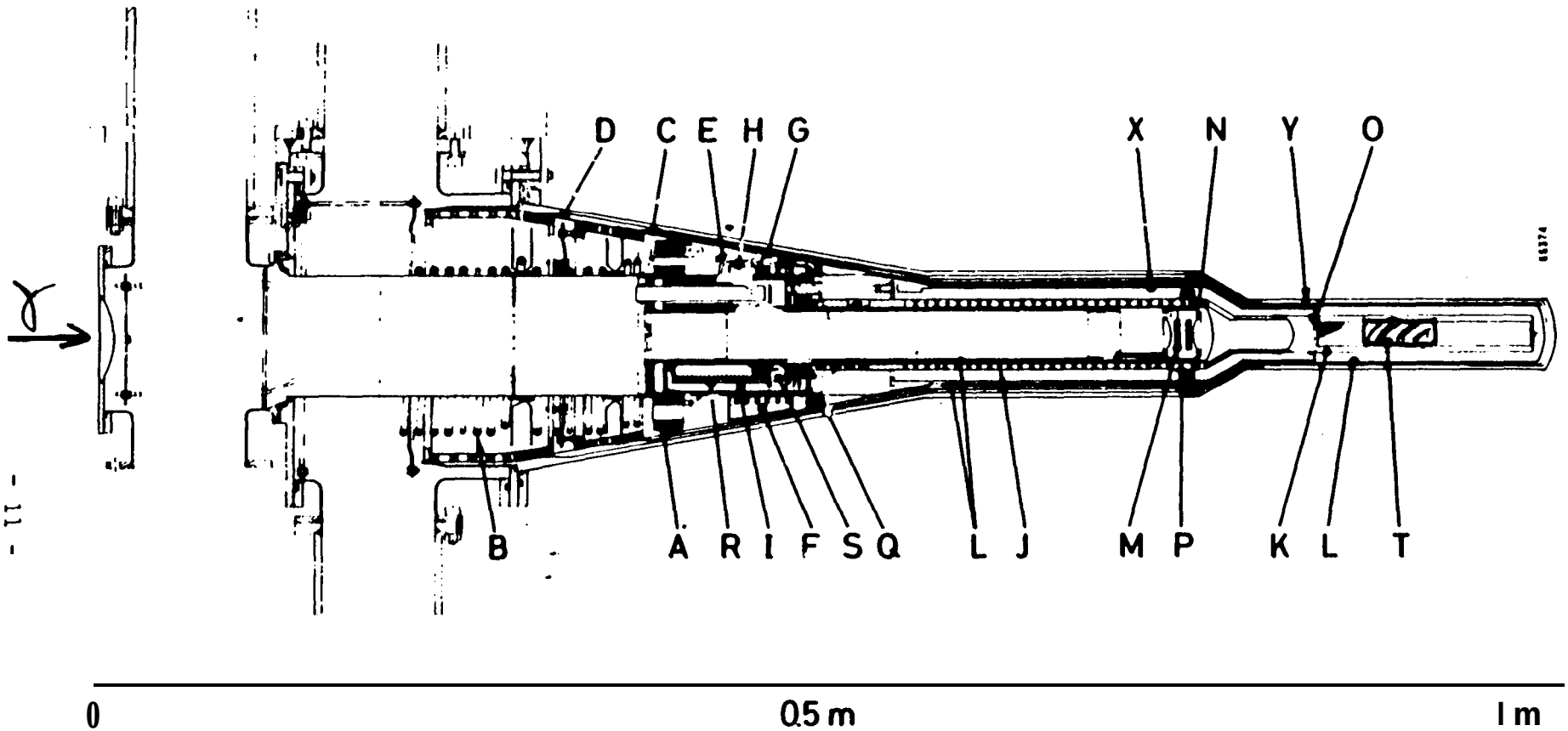
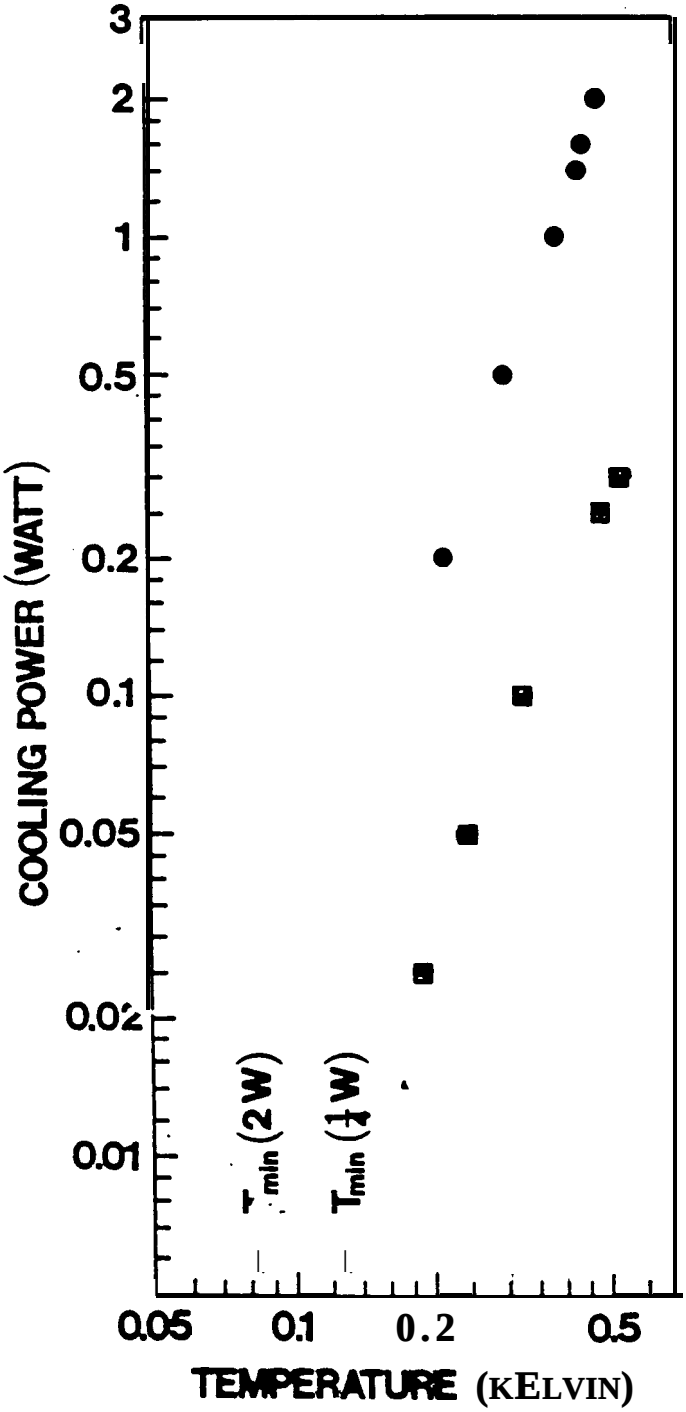
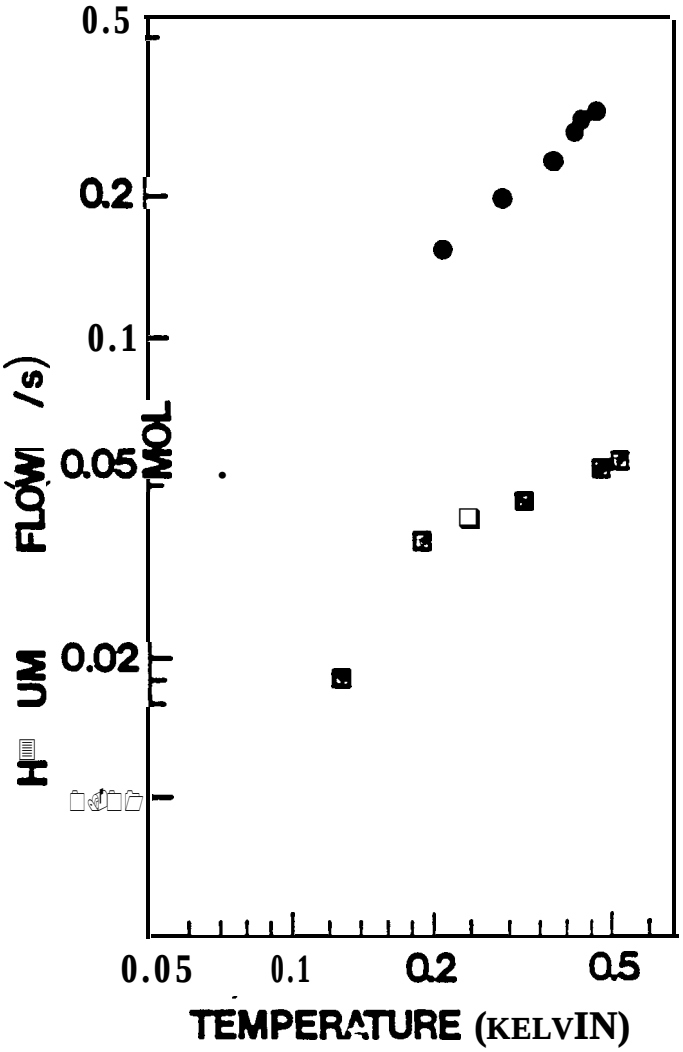
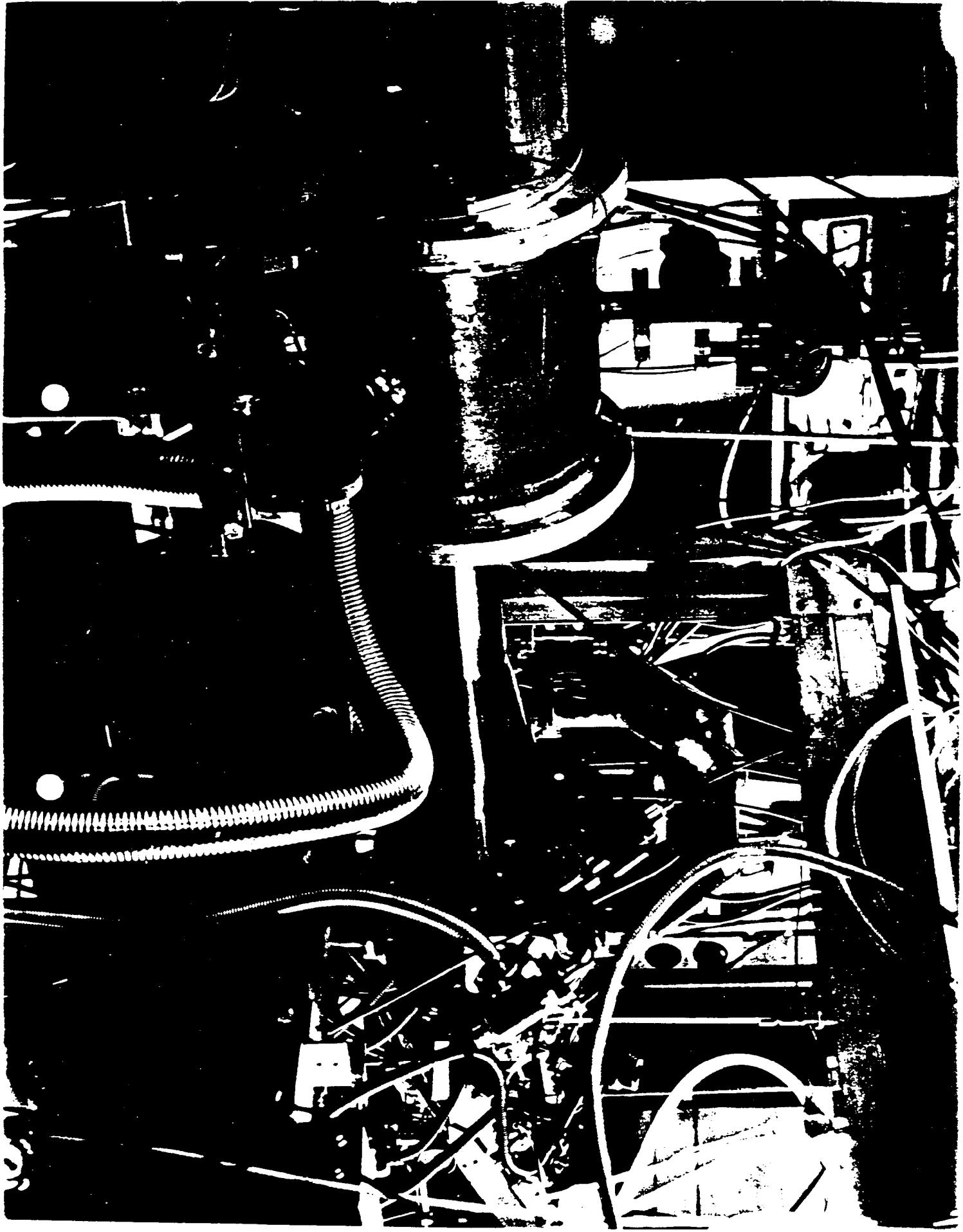



Fig. 5 Assembly drawing of the frozen spin target dilution refrigerator: A - separator, B - tubular counter-current heat exchanger, C - radiation shield I, D - radiation shield II, E - Evaporator needle valve, E - evaporator, C - condensing capillary, H - needle valve for precooling, I - still, J - heat exchanger between dilute and concentrated streams, K - mixing chamber, L - vacuum jacket, M - 2 silicon surface barrier diodes in evacuate/, box, N - 3 thermometers, O - end cap of mixing chamber, P - indium joint, Q - indium joint; R - boiling heater in still, S - still heat exchanger, T - target, Y - spring for thermal contact and centring, X - waveguide holder and thermal link.

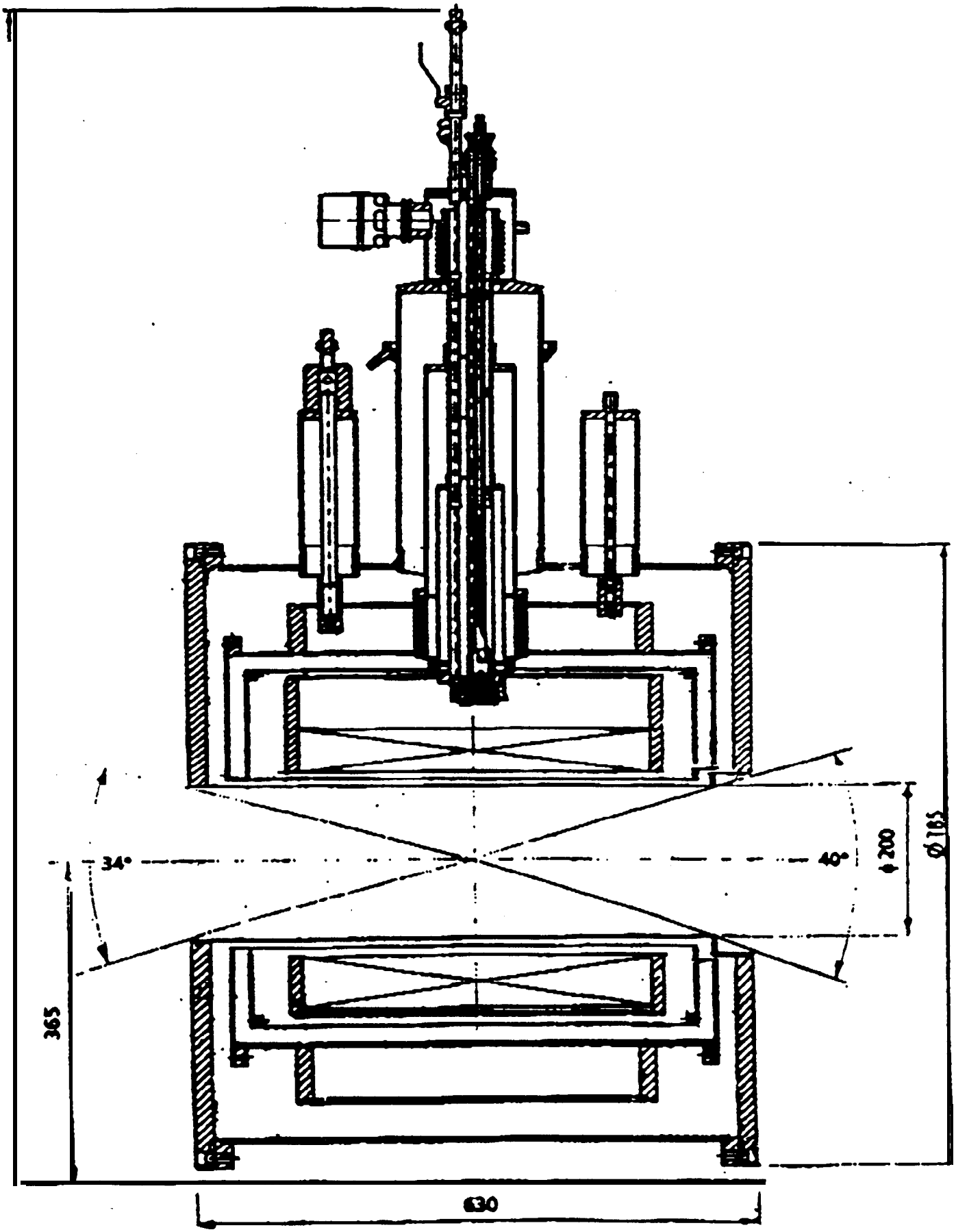
Requires Sealed Roots Pumping System





# 7 TESLA HORIZONTAL BORE CRYOMAGNETIC SYSTEM



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University of Virginia
Charlottesville
VA 22901

Our Ref :- GF / DC
Quotation number :- 00- 6073

June 2, 2000

# QUOTATION

| ITEM | DESCRIPTION | SPRICE |
|---|---|---|
| 1 | 7 Tesla 200mm RT Bore Superconducting Magnet System | |

**7 Tesla horizontal cryomagnetic system**

**Magnet**

| | |
|---|---|
| Central Field | 7.0 tesla at 4.2 K |
| Field homogeneity | $10^{-4}$ over a diameter of 10 mm x 50 mm long (see field map ) |
| Cold bore | 236 mm |
| Operating current | 94 amp |
| Field stability in persistent mode | $< 10^{-6}$ relative $hr^{-1}$ |

**Cryostat**

| | |
|---|---|
| Type | Horizontal bore low loss |
| Ambient temperature bore | 200 mm |
| Overall length | 630 mm |
| Bore access solid angle | 40° at one end, 34° at the other |
| Overall diameter | 785 mm |
| Total helght . | 1520 mm |
| Bore height | 365 mm |
| Helium capacity | 15 L nominal |
| Helium hold time (current lead removed) | > 180 hrs |

2 **IPS120-10** Superconducting magnet power supply:

- 120 A output current
- ± 10 V output voltage
- Current setting to 1 mA from the front panel, 0.1 mA through the supplied software
- Bipolar operation
- Current stability of ±3 mA/°C

# MICROWAVES

Operate Magnet 6 – 6.5 T

EIO

μWave Frequency 170 – 180 GHz

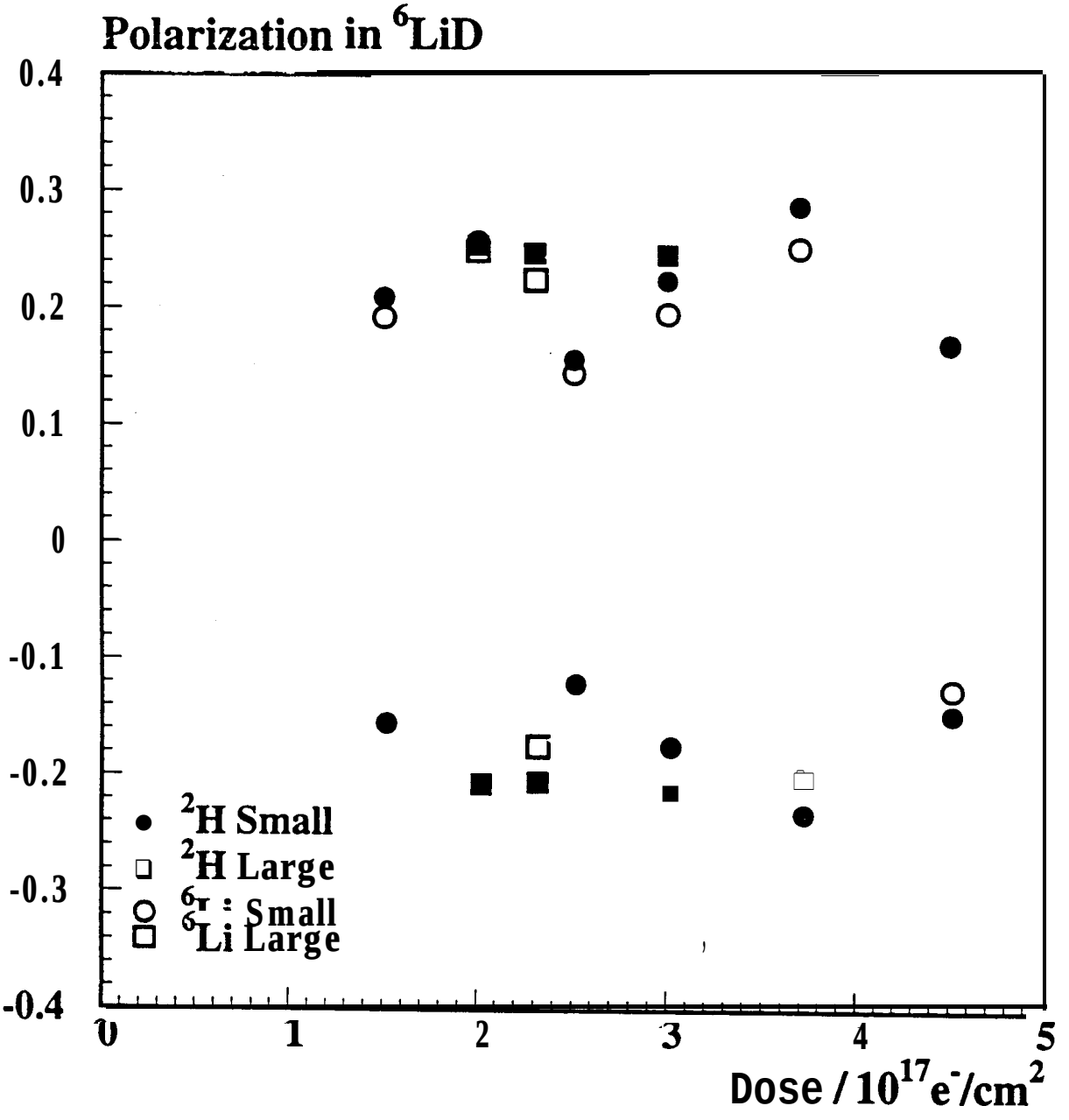
No Mechanical Tuner

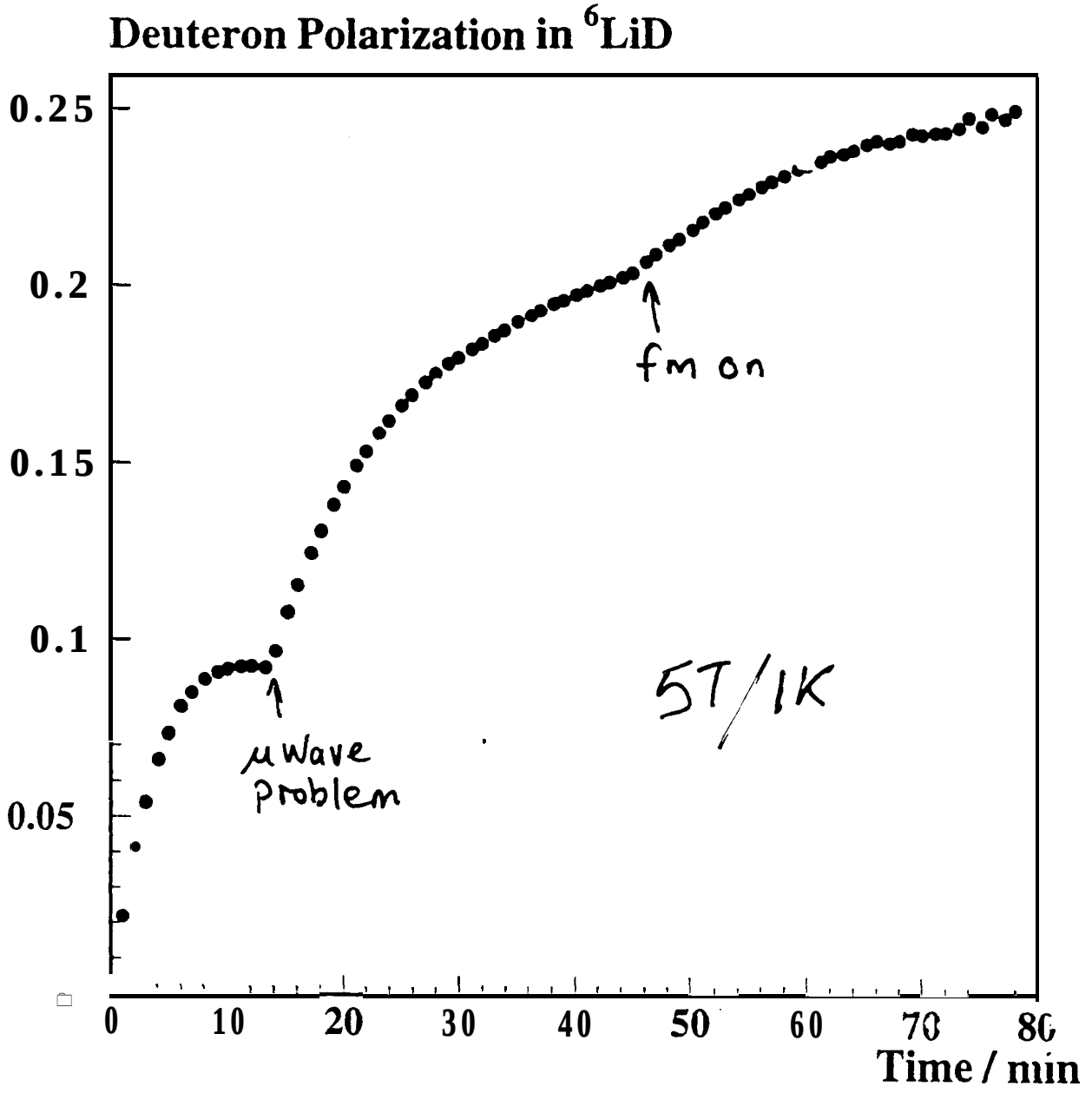
∴ Electrical Tuning Range ~ 200 MHz

OK for $^6LiD$

Power ~ 3W OK for $^6LiD$

Tube(s) need to be acquired


Polarization in $^{6}$LiD
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
1
2
3
4
5
Dose / $10^{17}e^{-}/cm^{2}$
$^{2}$H Small
$^{2}$H Large
$^{6}$Li Small
$^{6}$Li Large


Deuteron Polarization in $^6$LiD
0.25
0.2
0.15
0.1
0.05
fm on
μwave problem
5T/1K
0
10
20
30
40
50
60
70
80
Time / min

**Nuclear Properties of Li**

Cluster models of the ground state wave function:

- $^6Li = \alpha + d$ Many references, e.g. J.V. Noble, Phys Rev. C9, 1209 (1974) Nucl. Phys. A251, 105 (1975)

- Polarized $^6Li$ incident on $^{58}Ni$ and $^{40}Ca$ targets, no D-state between a and d clusters, E.E. Bertosz et *al*., TUNL Report XXXVI, 5 1 (1997)

- Polarized $^6LiD$ neutron polarization in ***a*** + d model. Neutron is 1.5 times more likely to be in D-state of d cluster in Li than in the free deuteron, L.L. Frankfurt and M.I. Strikman, Nucl. Phys. A405, 557, 1983

Neutron pol. $\lambda_n = \dfrac{\lambda_n^D \sigma_D + \lambda_n^C \sigma_C}{\sigma_D + \sigma_C} = \dfrac{(1 - 3/2 P_D)\sigma_D + (1 - 3/2 P_D \gamma^C)\sigma_D}{\sigma_D + \sigma_C}$

using $\sigma_C = 3\sigma_D$

$\lambda_n = 1 - \frac{3}{4} P_D (1 + \gamma^C)$; $\gamma^C = 1.5$

$\lambda_n^{LiD} = 1 - \frac{3}{4} \cdot 0.05 (1 + 1.5) = 90.6\%$; $(\lambda_n^{6Li} = 88.8\%)$

No P-states, no unpolarized EMC correction

- $^6Li$ = ***a*** + n + p neutron polarization in Li in 3-body Fadeev formalism. Incorrect angular momentum decomposition for D and Li overestimates neutron polarization, N.W. Schellingerhout et al., Phys. Rev. C48, 2714 (1993)

Paper: $P_n = P_S + \frac{1}{4} P_D$

True: $P_n^+ = P_S - \frac{1}{2} P_D$

TABLE III. Nucleon polarizations.

| | Model independent | | Model dependent | | | | |
|---|---|---|---|---|---|---|---|
| Nuclide | This work | Ref. [10] | This work | Ref. [14] | Ref. [15] | Ref. [16] | Ref. [13] |
| $^{2}H$ | 0.94 | | 0.926 | | | | |
| $^{3}H$-$^{3}He$ | 0.93 | 0.96 | 0.86 | 0.865 | | | |
| [redacted] | [redacted] | | [redacted] | | [redacted] | [redacted] | [redacted] |
| $^{7}Li$ | | | *0.57* | | | *0.59* | |
| $^{14}N$ | *-0.26* | | *-0.33* | | | | |
| $^{15}N$ | *-0.22* | *-0.24* | *-0.33* | | | | |

[a] $P_n^- = 0.933$

Nitrogen contributes with only one third of the polarizable nucleons in ammonia and it polarizes only up to one sixth of the corresponding hydrogen or deuterium polarization. The net contribution of the polarized nucleons in $^{14}N$ to the hydrogen or deuterium spin asymmetries is then $-1/3 * 1/3 * 1/6 = -0.02$. Given this small size. the accuracy of about 10% of these simple estimates is quite adequate for the corrections needed in DIS spin structure experiments [3.1].

$^{15}N$ has $I^\pi = \frac{1}{2}^-$. The shell model gives an even better description of $^{15}N$ than of $^{14}N$. Its magnetic moment is less than 7% away from the Schmidt line value $-0.264\mu_N$, Thus we would expect the proton in $^{15}N$ to be aligned antiparallel to the nuclear spin 1/3 of the time. The model-independent estimates for this isotope agree in sign and are of similar magnitude as the shell-model prediction. The correction to the spin asymmetries due to the presence of $^{15}N$ are even smaller than those due to $^{14}N$. because in the former the neutron contributions are entirely negligible. and its nuclear polarization can be measured with better precision than that of the latter.

Table III summarizes the results of this and other works. The row for $A = 3$ lists only the proton polarization for $^{3}H$ (neutron polarization for 'He).

I would like to thank Keith Gtiffioen for calling my attention to Ref. [16]. and B. Alex Brown. S. Coon. R. Wirinpa. and D. G. Cnbb for helpful discussions. This work was supported by Department of Energy Contract No. DEFG05-86ER40261 and by the Institute of Nuclear and Particle Physics of the University of Virginia.

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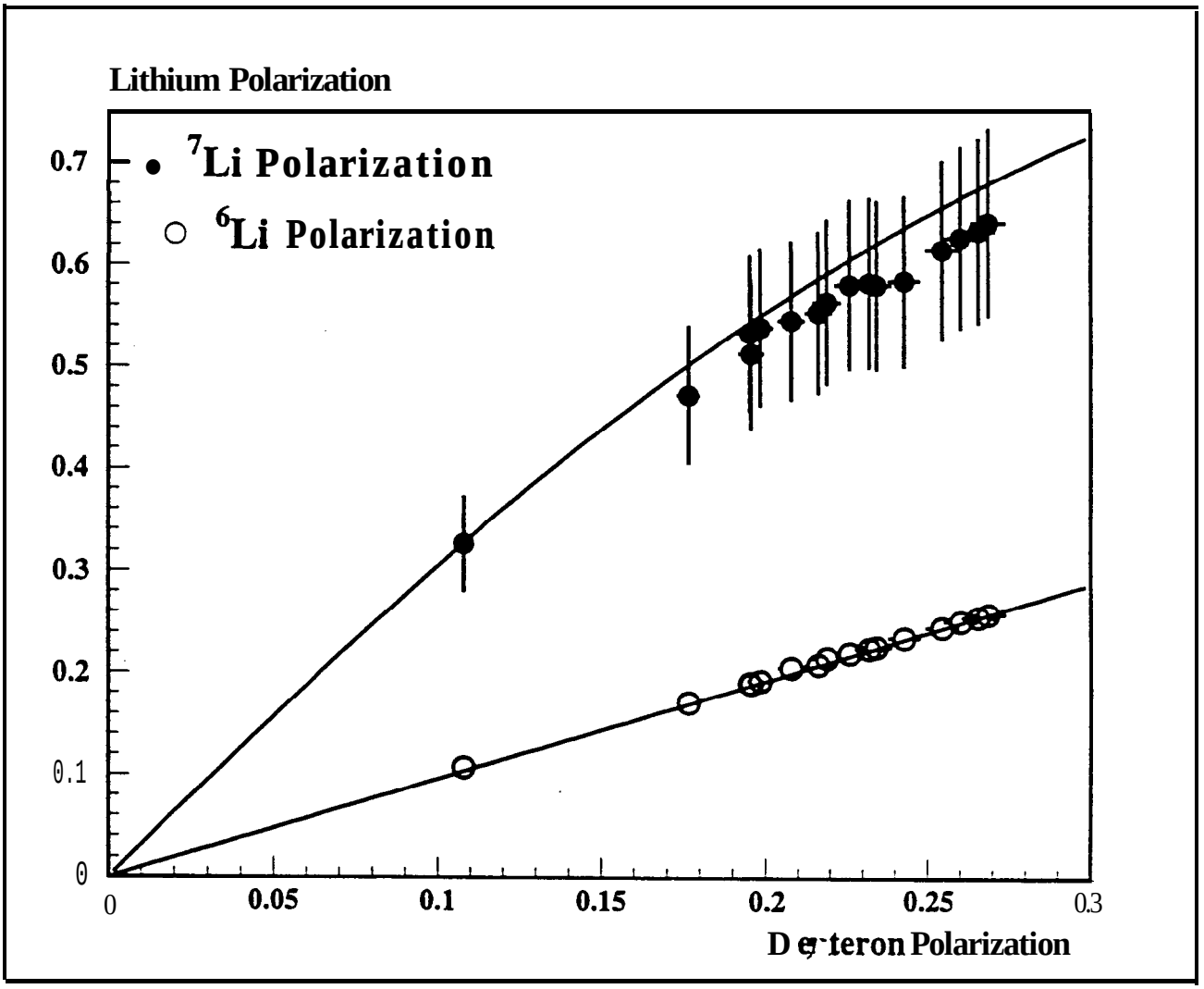
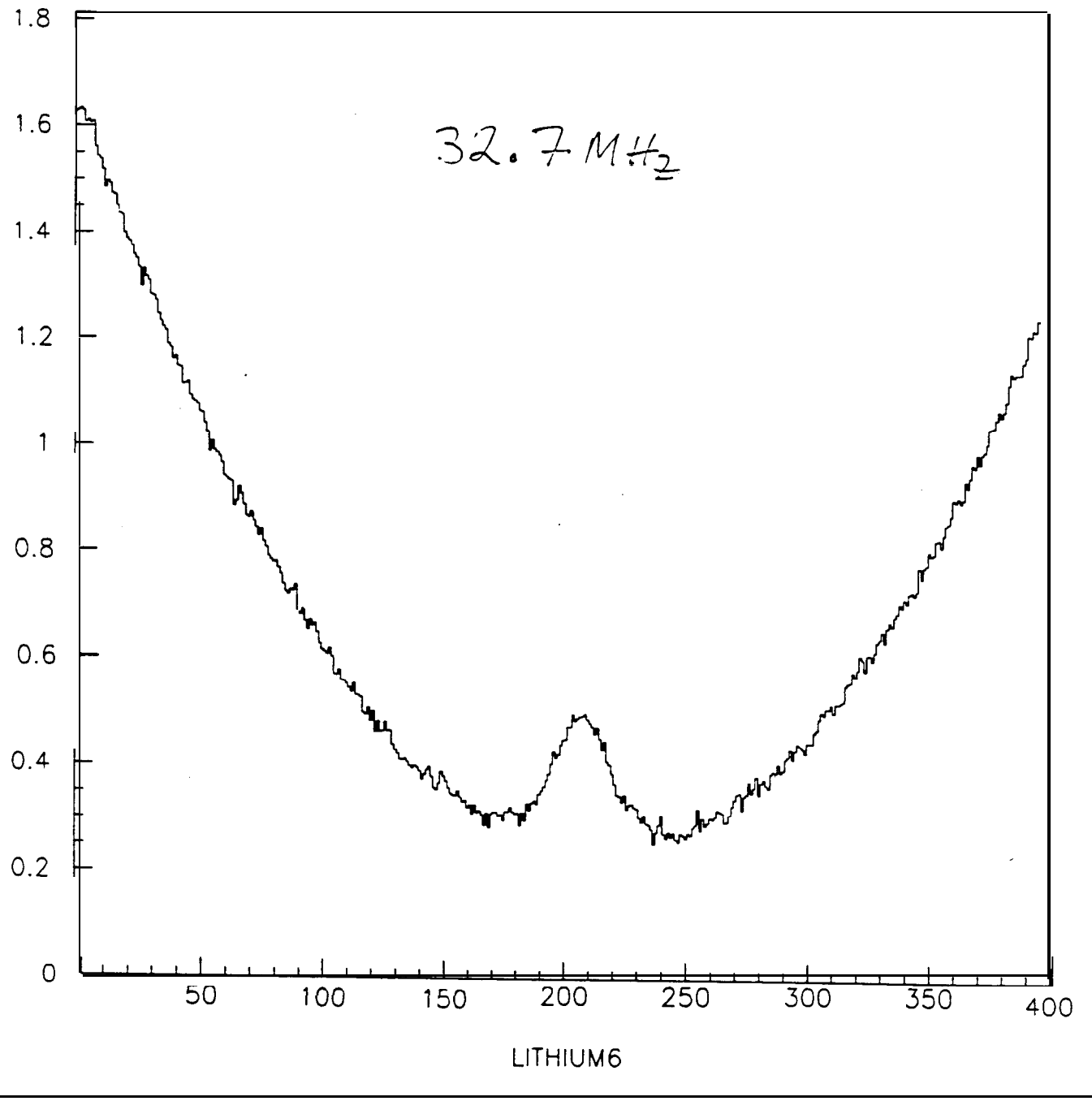
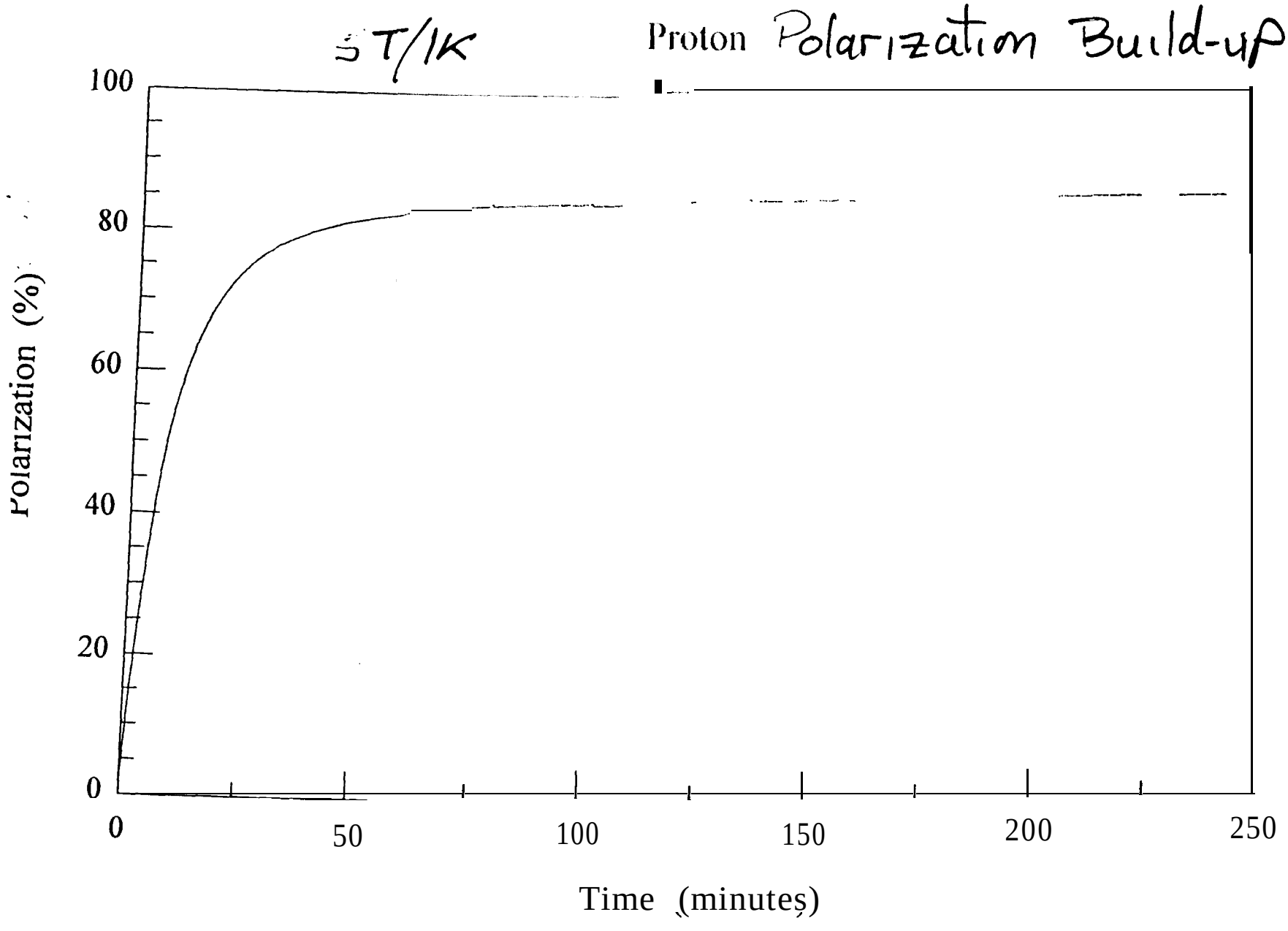


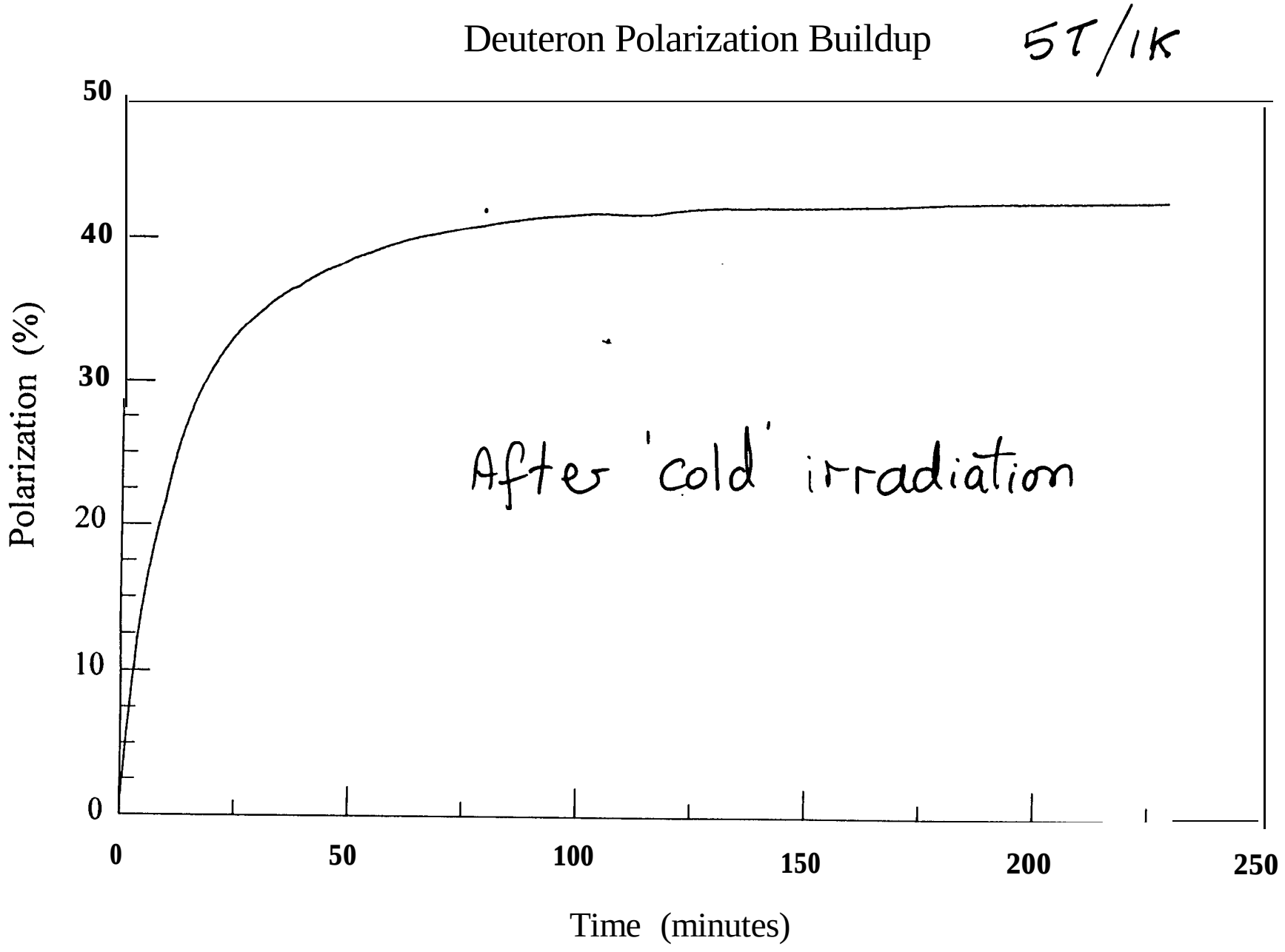

Figure 4: Measured polarization of $^6$Li and $^7$Li nuclei as a function of the measured deuteron polarization. The EST predictions for the lithium polarizations basing on the deuteron polarization are shown by the full lines is validated by the data.


32.7 MHz
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
50
100
150
200
250
300
350
400
LITHIUM6

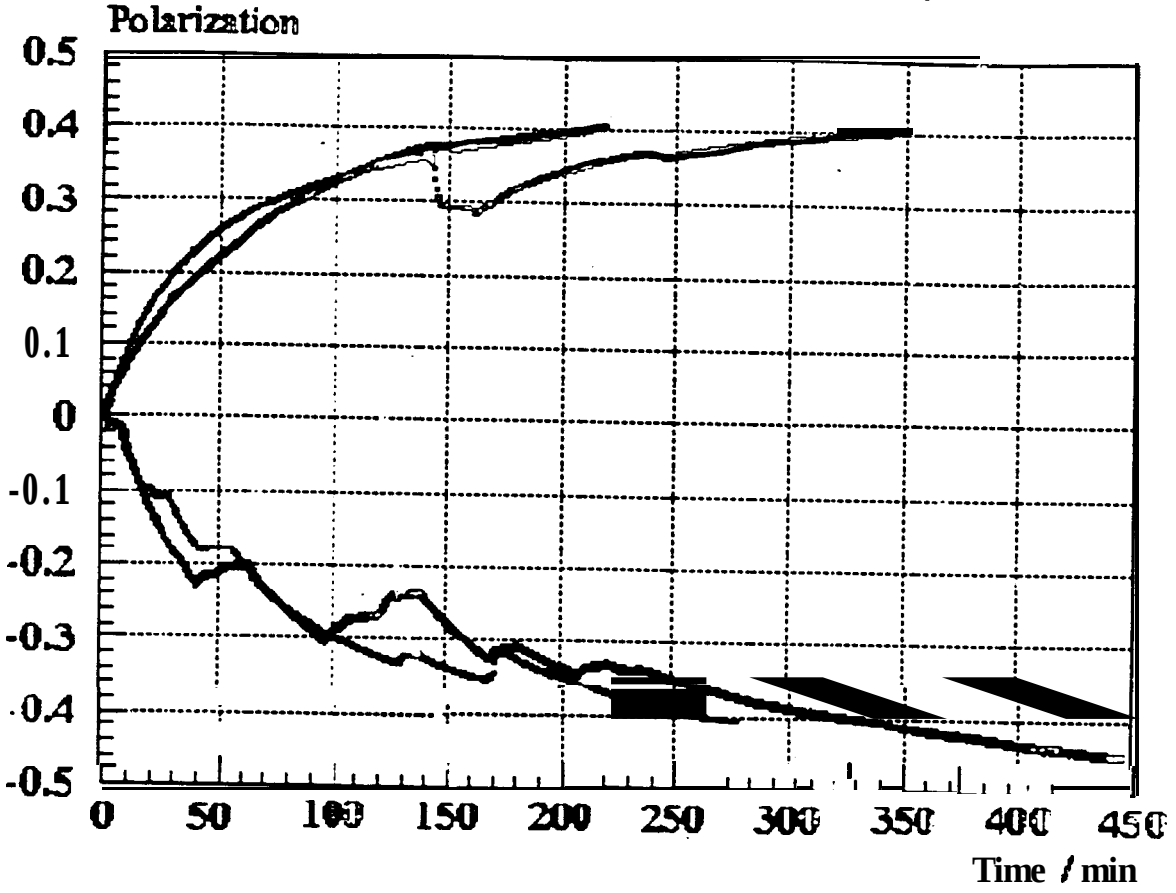
# System for E159

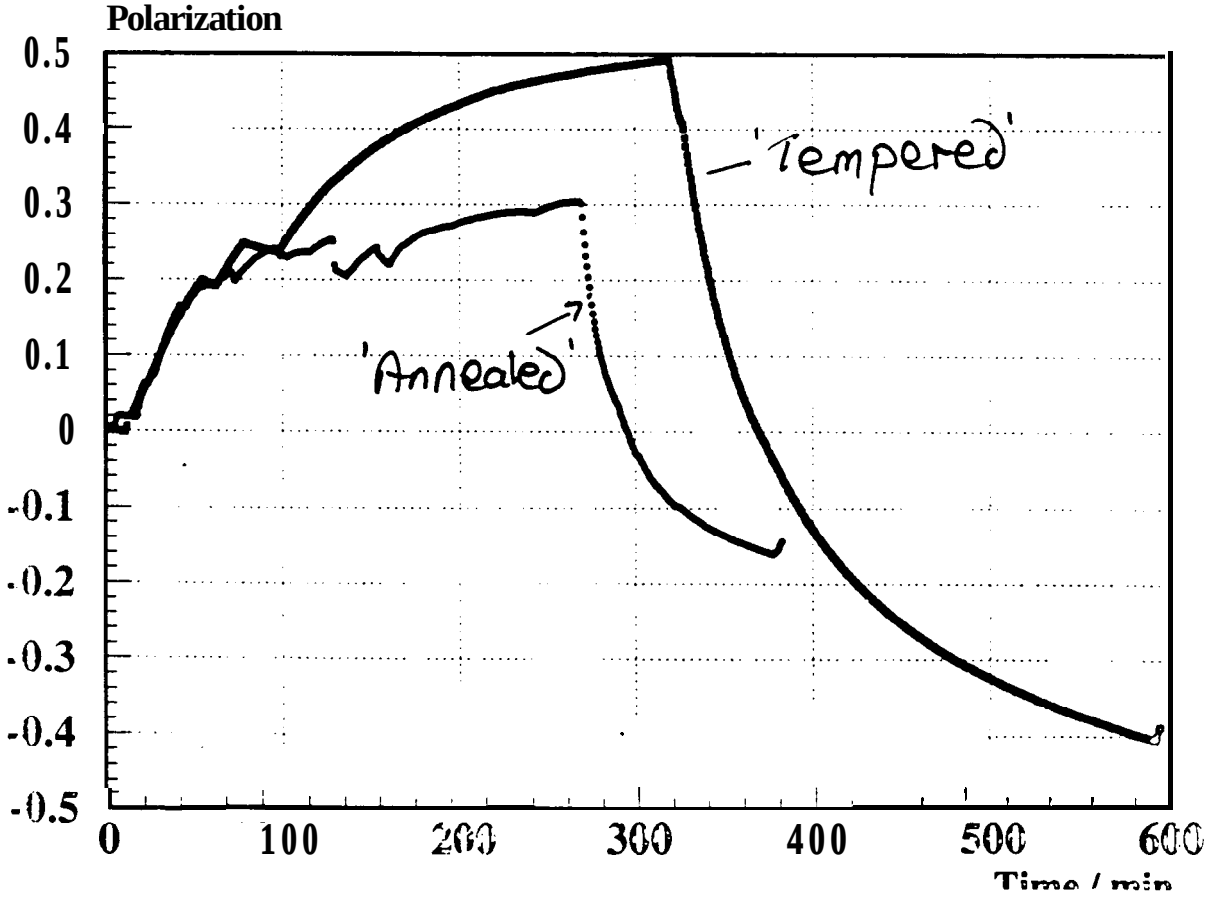
- Same Dilution Refrigerator
- Same magne5T)at
  - $^{15}NH_3$ and $^{15}ND_3$
  - Microwaves
  - NMR expect 2-3% (was 4-5%)


5T/1K
Proton Polarization Build-up
100
80
60
40
20
0
Polarization (%)
0
50
100
150
200
250
Time (minutes)


Deuteron Polarization Buildup
5T/1K
Polarization (%)
50
40
30
20
10
0
After 'cold' irradiation
0
50
100
150
200
250
Time (minutes)

$^{15}ND_3$ 5T/1K


Polarization
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
50
100
150
200
250
300
350
400
450
Time / min


Polarization
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
100
200
300
400
500
600
'Tempered'
'Annealed'

# MICROWAVES

Magnet at 5T

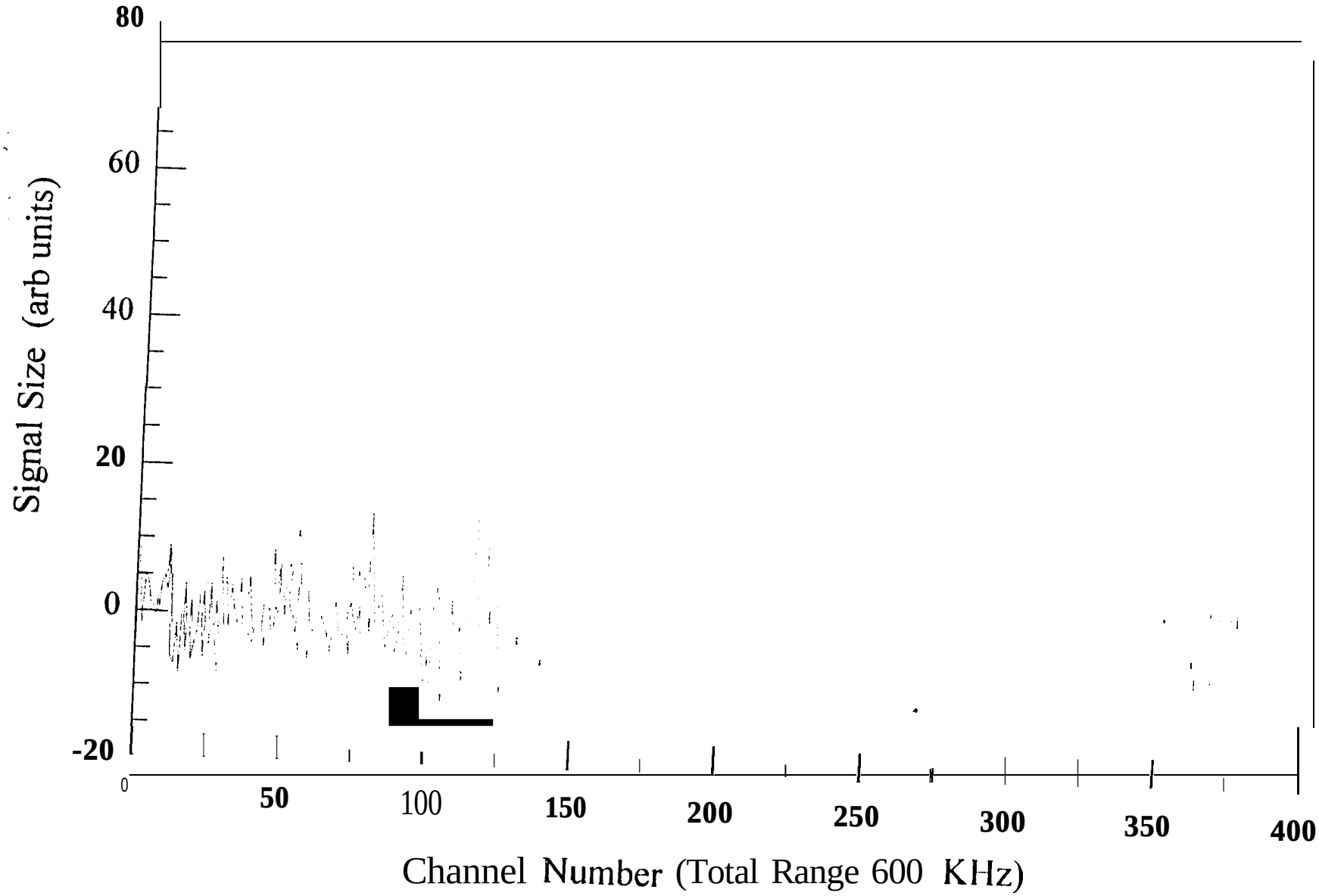
μWave frequency ~ 140 GHz

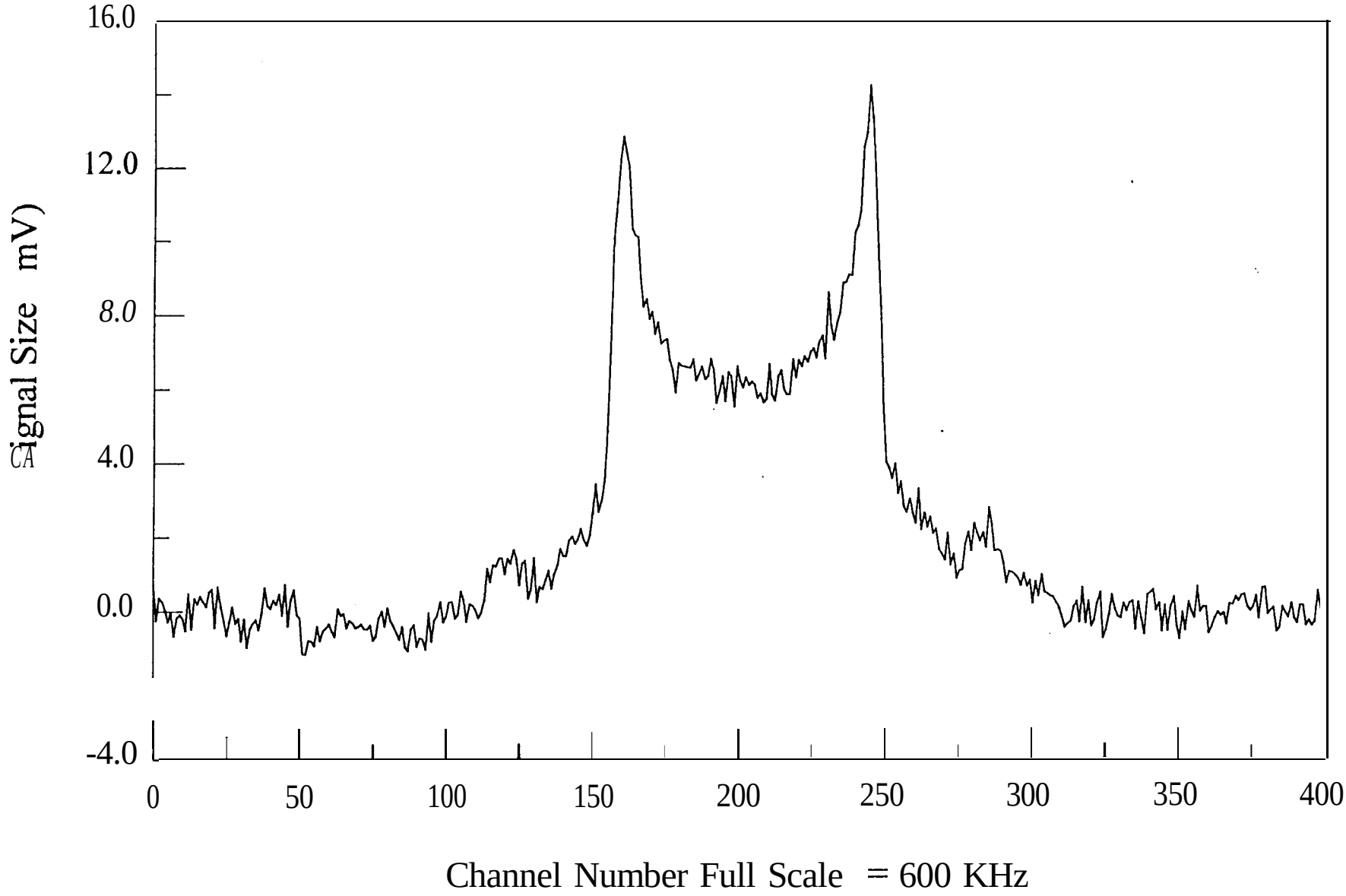
Same conditions as for

E143, E155, E155x and $G_{EN}$ (JLAB)

Reproducible & well understood

Have all necessary equipment


d - butanol TE Conventional NMR
80
60
40
20
0
-20
Signal Size (arb units)
0
50
100
150
200
250
300
350
400
Channel Number (Total Range 600 KHz)


d - butanol Raw TE Signal - Baseline
16.0
12.0
8.0
4.0
0.0
-4.0
Signal Size (mV)
0
50
100
150
200
250
300
350
400
Channel Number Full Scale = 600 KHz