9th International Workshop on Polarized Solid Targets and Techniques

Jaakko Koivuniemi

http://poltarg03.ep1.rub.de/

Monday 27 October

Opening

S. Mango, PSI, *Early target material research with chemical dopants*

J. Ball, Saclay, *Thirty years of research with Lithium compounds in SACLAY*

W. Meyer, Bochum, *Early polarization studies with ammonia targets*

S. Goertz, Bochum, *The dynamic nuclear polarization process*

E. Bunyatova, Dubna, *Free radicals and polarized targets*

J. Ardenkjaer-Larsen, Malmö, *Method for making solutions of molecules with hyperpolarized nuclear spin*

J. Kohlbrecher, PSI, *The dynamics of nuclear spin polarization, investigated by simultaneous NMR and polarized neutron scattering*

H. Stuhrmann, Grenoble, *Polarized neutron scattering from selectively polarized proton domains in catalase*

Monday 27 October

O. Zimmer, München, *The spin-dependent nd-scattering length - a proposed high-accuracy measurement*

P. Hautle, PSI, *A comparison of NMR concepts for polarization experiments*

G. Court, Liverpool, *The Liverpool NMR-system*

G. Reicherz, Bochum, *Pulsed NMR for the determination of the nuclear polarization*

Salvatore Magno

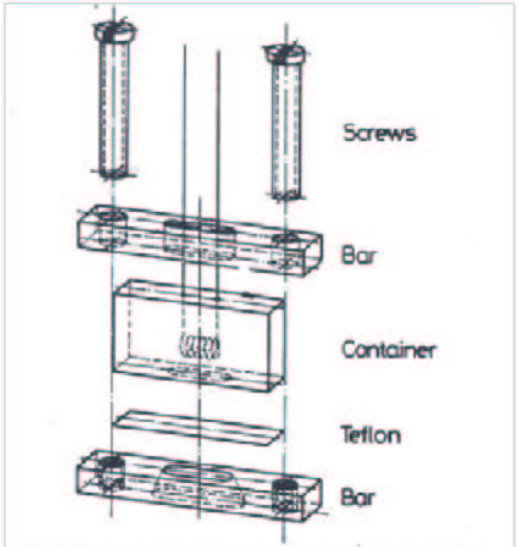
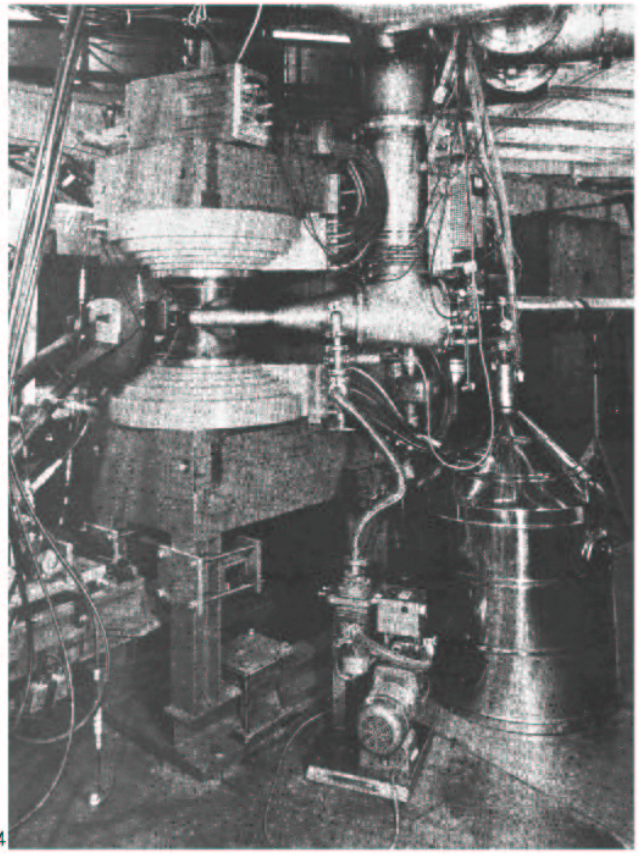


Fig. 2. A container used for small samples.

New „sexy" instruments

CERN 1964



9th International Workshop on Polarized Solid Targets and Techniques, Bad Honnef, 27-29 October 2003 S. Mango 3012/VB30/ 2

Salvatore Magno

CERN
SERVICE D'INFORMATION
SCIENTIFIQUE

NUCLEAR INSTRUMENTS AND METHODS 72 (1969) 45–50; © NORTH-HOLLAND PUBLISHING CO.

A BUTANOL POLARIZED PROTON TARGET

S. MANGO*, Ö. RUNÓLFSSON and M. BORGHINI

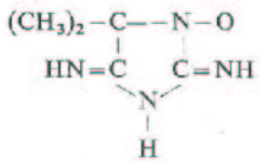
CERN, Geneva, Switzerland

Received 31 January 1969

Dynamic proton polarizations around 40% have been reproducibly obtained in 5 cm³ samples made of 95% 1-butanol and 5% water mixtures, saturated with the free radical porphyrexide, at temperatures close to 1° K in a magnetic field of 25 kOe.

1. Introduction

In the course of a systematic study of dynamic proton polarization in hydrogen-rich organic substances doped with free radicals, we have given special attention to alcohols $CH_3(CH_2)_nOH$ doped with porphyrexide†).



Ethanol was studied first, and it was found that the

TABLE 1
Comparison of lanthanum magnesium nitrate and butanol as target materials.

	LMN	Butanol
Max. polarization	≈70%	≈40%
Hydrogen density (g/cm³)	0.06	0.12*
Total density (g/cm³)	2.0	0.9*
Bound protons / Free protons	15	3.2
Radiation length (cm)	≈10	≈40
Acceptable number of min. ionizing beam particles/cm²	$\approx 2\times10^{12}$ †	$\approx 5\times10^{14}$ §
Polarization build-up time (sec)	300	15

Jacques Ball

Argonne (US) 78 Conference

1978 : Abragam : ^{6}LiD potentially interesting target material. In contrast with other targets materials, linewidth is determined by hyperfine couplings of the F-centres with neighbouring Li.

$\mu(^7Li)/\mu(^6Li) = 4$, same ratio expected between ^{7}LiH and ^{6}LiD ESR linewidths and much lower nuclear Spin Temperature.

And $\mu(^6Li) \approx \mu(D)$ and have both spin I = 1.

If $^6Li \approx D + {}^4He$, in polarized ^{6}Li D, both nuclei have the same polarization $P = P(^6Li) \approx P(D)$. The ratio *r* of the total number of polarized nucleons to the total number of nucleons is 0.5 which is far higher than for other available materials

"Highly speculative but amusing. Among other problems, one would have to lay hands on ^{6}LiD which, if one is not in the thermonuclear business, may prove difficult."

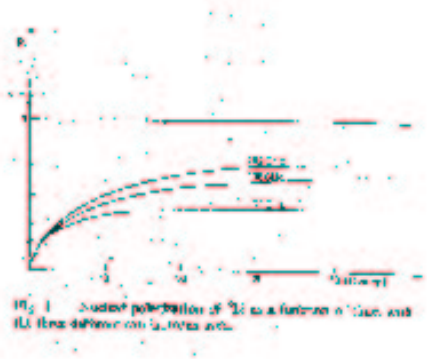
J. Ball / Bad Honnef 03 06/11/2003

Jacques Ball

1980 : Final step of the Abragam group

May : **"A new polarized target material : ^{6}LiD"** (J.Phys.L,309,1980)
Abragam, Bouffard, Roinel, Roubeau.

June : **"Dynamic nuclear polarization in ^{6}LiD"**
(J.Phys. 41,1447,1980)
Bouffard, Roinel, Roubeau, Abragam.



H_0 = 6.5 T P(^{6}Li) = 71 %
4.8 T 64 %
2.5 T 40 %
At 6.5 T, β = 825 K^{-1}.

Building up times range between 20 and 40 hours , not convenient.

"Scaling up 12 mm³ samples to the size currently used in polarized targets would require considerable development work. An important problem that remains concerns the reproducibility of the creation of the F centers. This is believed to depend upon a better control of the sample temperature during irradiation."

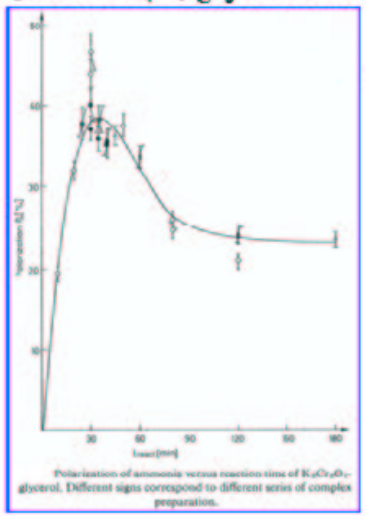
J. Ball / Bad Honnef 03 06/11/2003

1970 : First dynamic proton polarization in AMMONIA

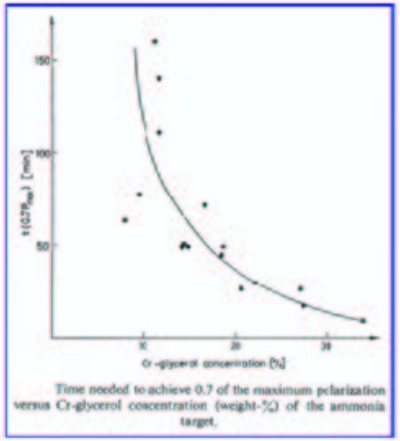
K. Scheffler (CERN); NIM 82 (1970) 205

"After trying a number of paramagnetic centers such as sodium, porphyrexide, porphyrindine, diphenylpicryl-hydrazil, Ziegler's radical, di-tert.-butyl-nitroxide, per-chlorotriphenylmethyl and violanthrone, all of which gave low polarization or none at all, we doped the liquefied ammonia with Cr^V glycerol complexes."

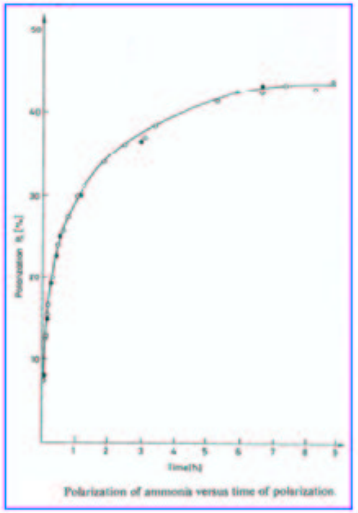
NH_3 with Cr(V) glycerol complexes P ≈ 40 % at 1 K and 2.5 T



Polarization of ammonia versus reaction time of $K_2Cr_2O_7$–glycerol. Different signs correspond to different series of complex preparation.



Time needed to achieve 0.7 of the maximum polarization versus Cr-glycerol concentration (weight-%) of the ammonia target.



Polarization of ammonia versus time of polarization.

glycerol or glycerine : $C_3H_5(OH)_3 \rightarrow f = 0.087$

Conclusions

After 5 years (1979 – 1984) work on irradiated AMMONIA:
Most practical preparation method: High temperature irradiation

Highlight No 1:

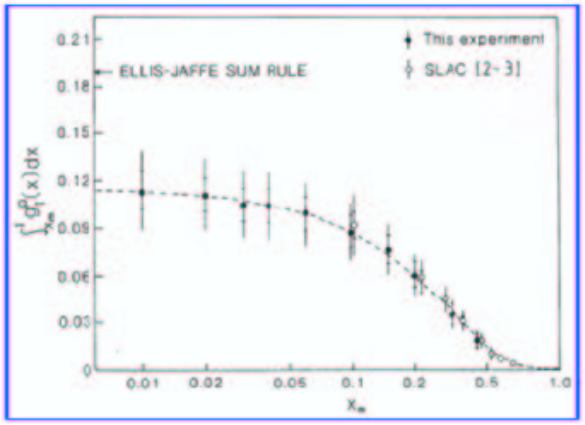
EMC-results from CERN deep inelastic polarized muon-polarized proton scattering experiments with NH_3 → spin problem ! *J. Ashman et al., Nucl. Phys. B328(1989)1*

– 3 ltr NH_3 irradiated in Bonn by Bonn-CERN-Liverpool activities

S. Brown et al., Proc. 4th workshop (Bad Honnef) p. 66

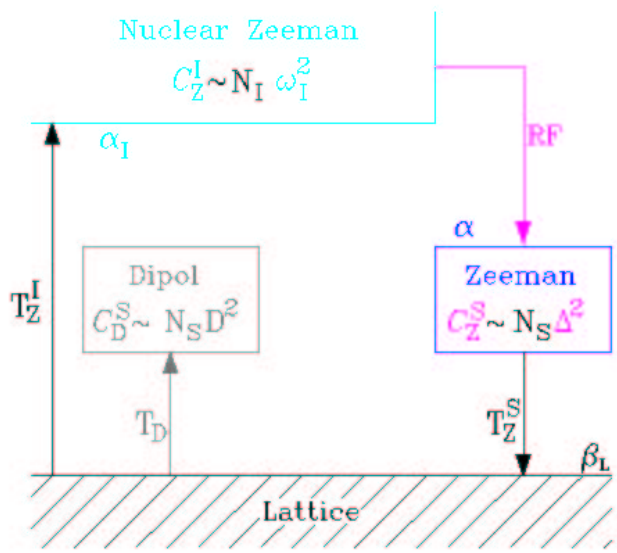
– P = 80 %

Important: high dilution factor

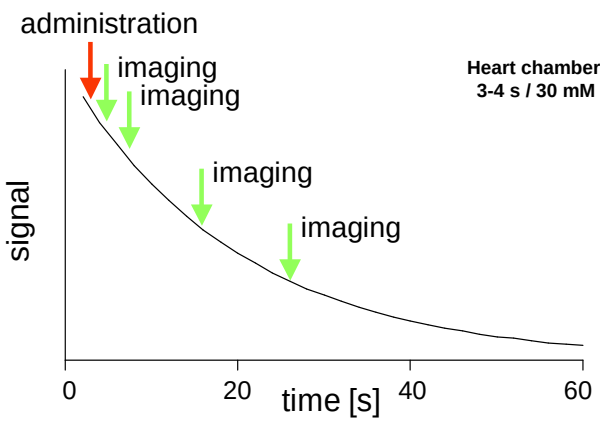


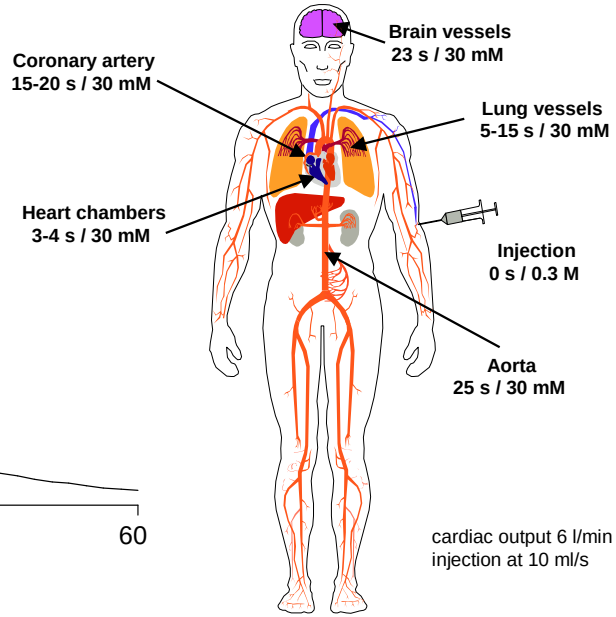
Thermal contact between $\langle Z \rangle_I$ and $\langle Z \rangle_S$ if $\omega_I \gg D$

DNP by the Solid Effect



Signal decays due to relaxation and dilution





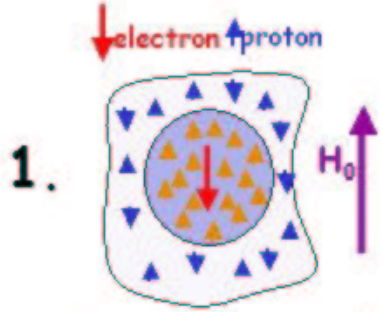
cardiac output 6 l/min
injection at 10 ml/s

Amersham Health

6

PAUL SCHERRER INSTITUT

DNP: a two step process



- protons close to electron polarize first
- time constant: $t_{pol} < 1$ s
- microwave induced direct interaction falls off like r^6

polarization **diffuses** to the bulk protons by flip-flop transitions

time constant: $t_{diff} \gg$ **few seconds**

paramagnetic centre generates **strong local field**

close protons:
- strongly coupled to the p.c.
- weakly coupled to the bulk
- "**poorly visible**" by cw-NMR

bulk protons:
- weakly coupled to the p.c
- "**visible**" by cw-NMR

J. Kohlbrecher, Polarized Solid Targets, Hamref 2003

Tuesday 28 October

S. Goertz, Bochum, *Highest polarizations in deuterated compounds*

D. Crabb, Charlottesville, *Polarization in Radiation doped D-Butanol and CD2*

T. Wakui, Tokyo, *Proton polarization in naphthalene crystal with a CW Ar-ion laser*

X. Wei, Brookhaven, *New improvements leading to higher polarization frozen spin HD-target at the LEGS facility*

J. P. Didelez, Orsay, *Static and dynamic polarization of HD*

E. Radtke, Bochum, *Efforts towards a dynamically polarized HD-target*

Tuesday 28 October

K. Kondo, Nagoya, *Polarization measurement in the COMPASS polarized target*

J. Koivuniemi, Helsinki, *NMR lineshapes in highly polarized* ^{6}*LiD at 2.5 T*

Y. Kisselev, Dubna, *Nuclear Local Fields in LiD polarized target material*

N. Doshita, Nagoya, *Performance of the COMPASS polarized target dilution refrigerator*

S. Neliba, Praha, *Weight measurements of the COMPASS large double-cell target volume*

F. Gautheron, Bielefeld, *Cryogenic control system of the large COMPASS polarized target*

Tuesday 28 October

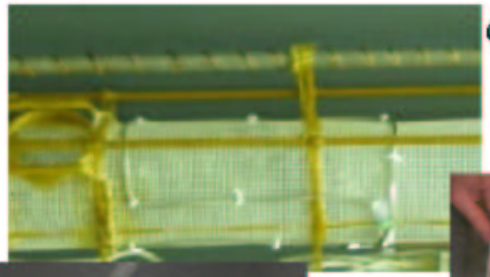
B. van den Brandt, PSI, *DNP with deuterated TEMPO and oxo-TEMPO*

P. Hautle, PSI, *EPR and DNP of alcohol water mixtures with nitroxyl radicals*

J. Heckmann, Bochum, *High field-/low temperature EPR-spectroscopy*

M. Iio, Miyazaki, *Development of polarized target for nuclear fusion experiments*

Pictures



Outer coil on the target cell

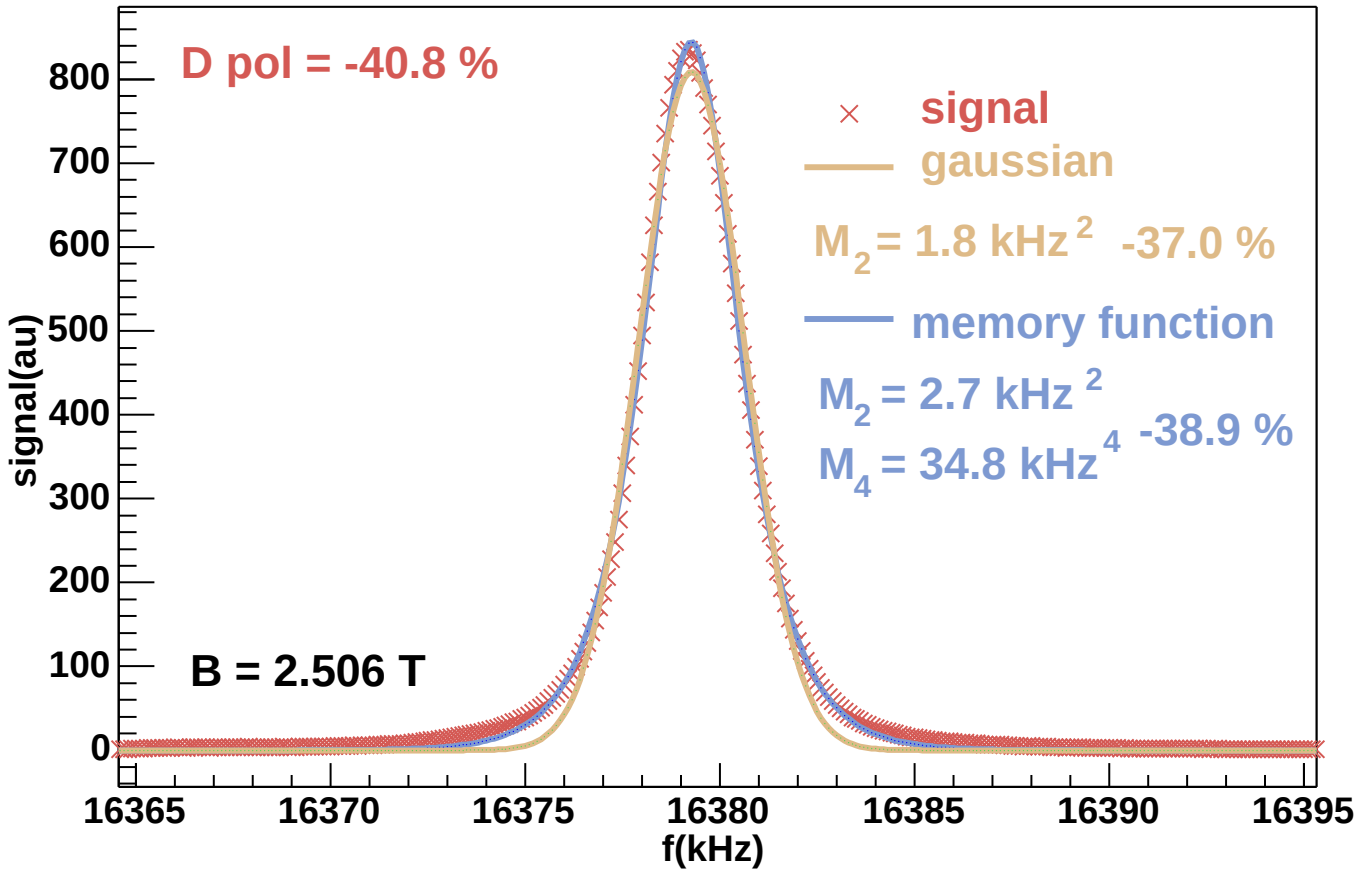
Loading target

Polarized Solid Targets, 28 Oct. 2003 Kaori KONDO, Naoya Univ. 5

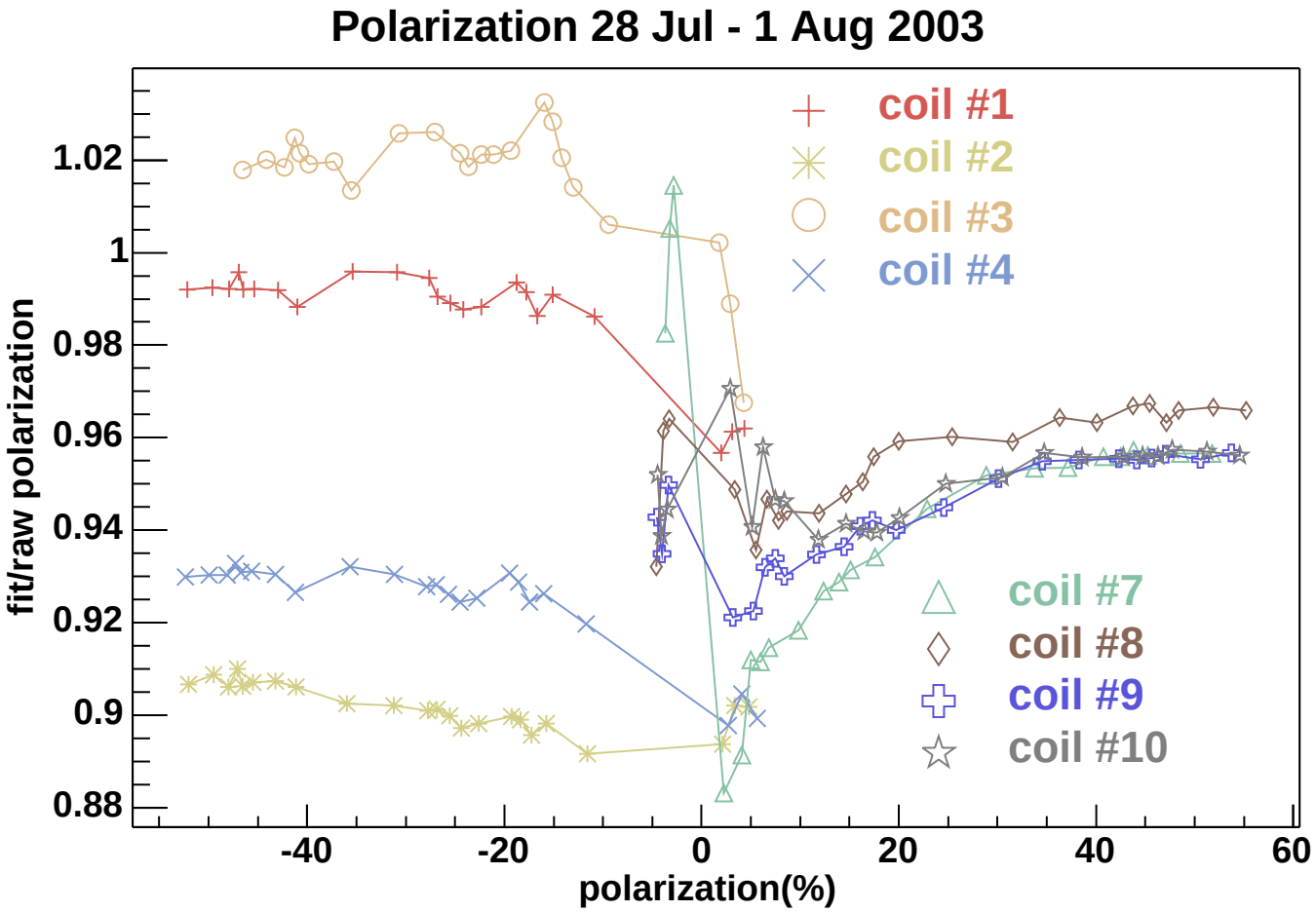
Maximum polarization

	+ pol. (%)	- pol. (%)
2001 upstream average	54.18	-
2001 downstream average	-	-47.40
2002 upstream average	55.49	-52.72
2002 downstream average	56.89	-47.47
2003 upstream average	56.81	-50.67
2003 downstream average	54.07	-48.95

Jaakko Koivuniemi

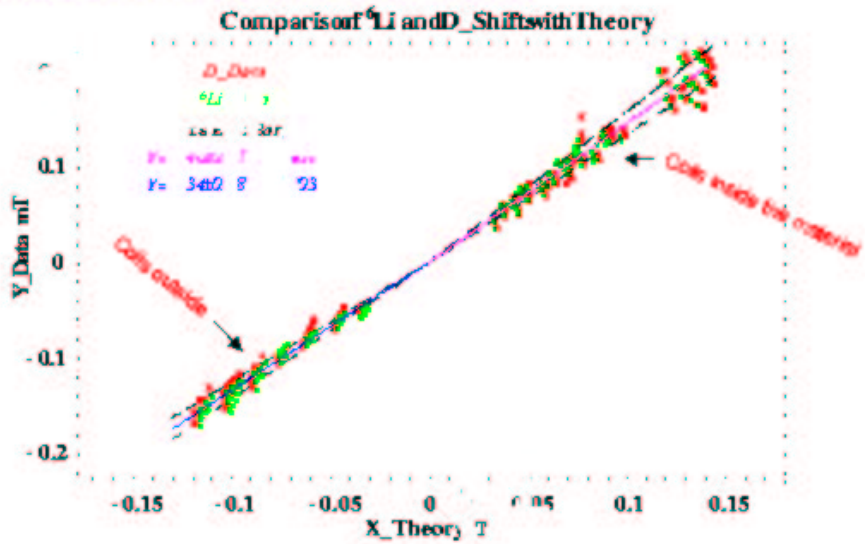


Jaakko Koivuniemi



Nuclear Local Fields in LiD polarized target material

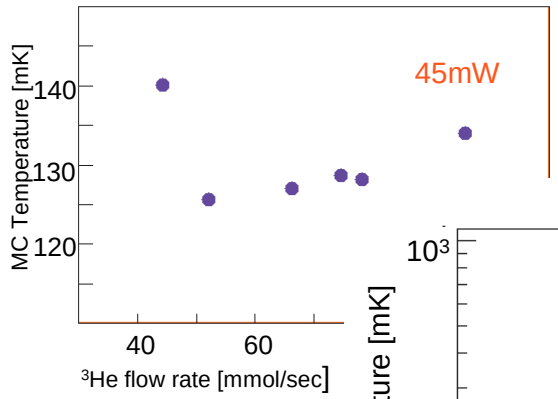
4. For the first time we have measured D, 6Li and 7Li local fields in crystalline LiD material and have compared with the theory elaborated for monocrystal. In Gauss approximation we have:



Y. Kisselev Polarized Target Workshop - Bad Honnef 27-29 october 03 Page 6

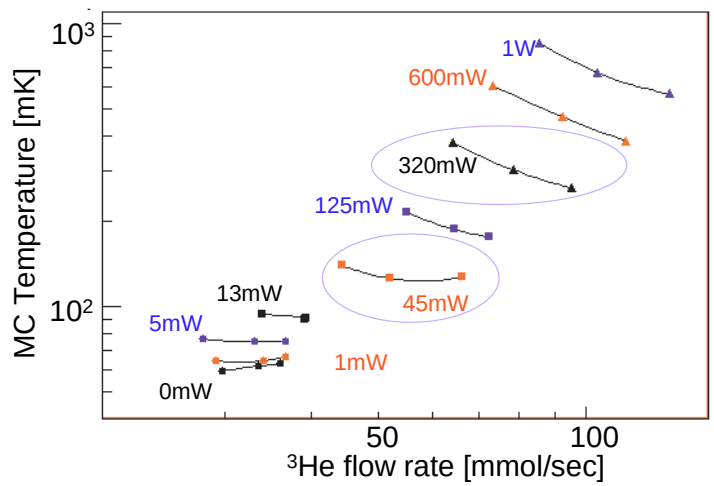
Optimization of ^{3}He flow for DNP

Measured by TTH4



~50mW microwave power at close to 50 % polarisation

~350mW microwave power at the beginning of DNP



Stepan Neliba

Upstream	Downstream
m = 172.1 ± 2.5 g	178.1 ± 2.5 g
V = 413 ± 5 cm^3	416 ± 5 cm^3
PF = 0.508 ± 0.027	0.522 ± 0.027

2003

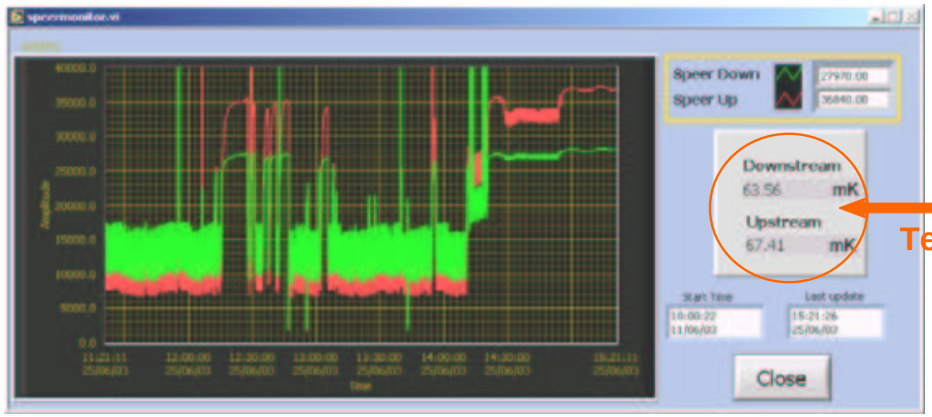
Stepan Neliba

	mass [amu]	up [mol]	down [mol]
H	1.00794	0.11	0.11
D	2.0140	21.23	21.97
^{3}He	3.0169	0.7 ± 0.2	0.7 ± 0.2
^{4}He	4.0026	6.8 ∓ 0.3	6.6 ∓ 0.3
^{6}Li	6.0151	20.44	21.15
^{7}Li	7.0160	0.90	0.93

2003

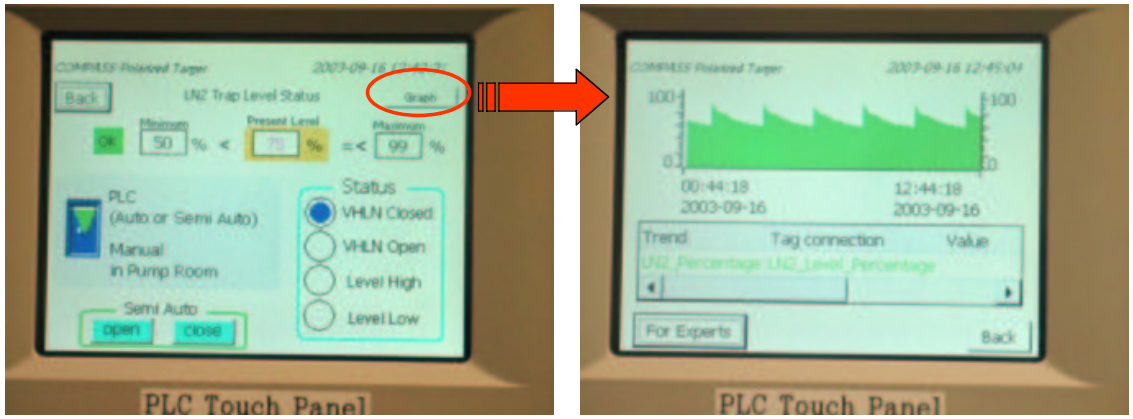
Cryogenic control system of the large COMPASS polarized target

the monitoring of the temperature measured in the upstream and in the downstream cell



Online Temperatures

Cryogenic control system of the large COMPASS polarized target



Wedneday 29 October

T. Uesaka, Tokyo, *CNS polarized proton target*

C. Djalali, Columbia, *Studies of dipole magnets for transversal holding magnetic field for the Jlab Hall-B Frozen Spin Polarized Target*

Y. Usov, Dubna, *Frozen spin solid targets development at the laboratory of nuclear problems*

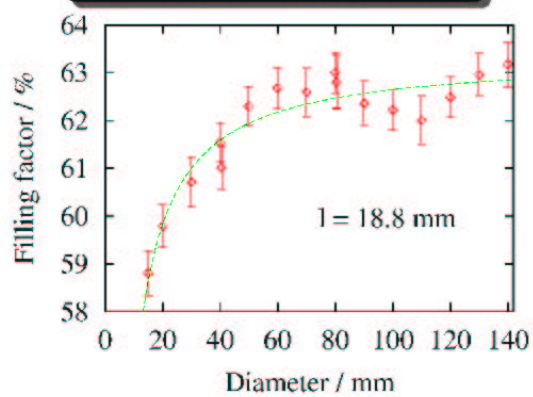
Chr. Rohlof, Bonn, *Effective densities of the polarized targets for the GDH-experiment at ELSA*

P. McKee, Charlottesville, *Radiation damage and recovery in ammonia targets*

H. Dutz, Bonn, *Highlights of the polarized solid target instrumentations*

Closing remarks

Determination of Filling Factor



- ELSA target longer than MAMI target
  → Filling factors differ
- Influence of NMR wire inside?
- Distribution of $f(x, y)$?
  → Convolution with beam profile

$\Longrightarrow$ Numerical Calculation