Symposium in honour of Dr. Francis TASSET
Institut Laue-Langevin, 6th March 2009

# The tale of Cryopad-II and the COW:

## How the late 1990s saw $^3$He spin-filters and Spherical Neutron Polarimetry taken to the next level at the ILL.

T. W. Roberts

# Outline

- Cryopad-II: Second generation SNP.
- $^{3}$He-COW: Spin-filter filling station.
- First tests of $^{3}$He spin-filters from the COW.

# A Few Credits
# (in addition to Francis!)

- Cryopad-II:
  - John Allibon
  - Eric Bourgeat-Lami
  - Jane Brown
  - Bruce Forsyth
  - Eddy Lelièvre-Berna
  - Serge Pujol
  - Trefor Roberts
  - Luc Thomas
  - Michel Thomas

$^3$He (early days of the COW):

- Ken Andersen
- Eric Bourgeat-Lami
- Jochen Dreyer
- Gaëlle Dupius
- Werner Heil
- Hubert Humblot
- Dirk Hofmann
- Jiri Kulda
- Eddy Lelièvre-Berna
- Sasha Petoukhov
- Trefor Roberts

And many others besides!

# Recap: Polarisation in a Field

The polarisation vector changes in a magnetic field according to the Bloch equation

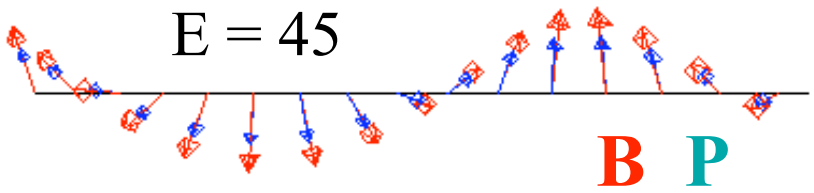
$$\frac{d\vec{\mathbf{P}}}{dt} = -\gamma \vec{\mathbf{P}} \times \vec{\mathbf{B}}, \quad \gamma = -1.832 \times 10^{8} \mathrm{s}^{-1}\mathrm{T}^{-1}$$

If **B** is zero, or **P** is // to **B** then the polarisation vector stays the same.

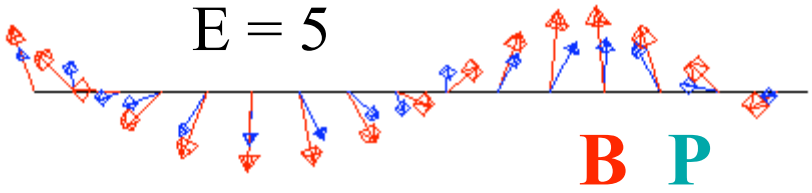
In a constant magnetic field, **P** will precess around **B** at the Larmor frequency $\omega_L = -\gamma B$, the angle between **P** and **B** being constant.

In a varying field the polarisation will behave in one of two ways...

•Adiabatic regime ($\omega << \omega_L$)



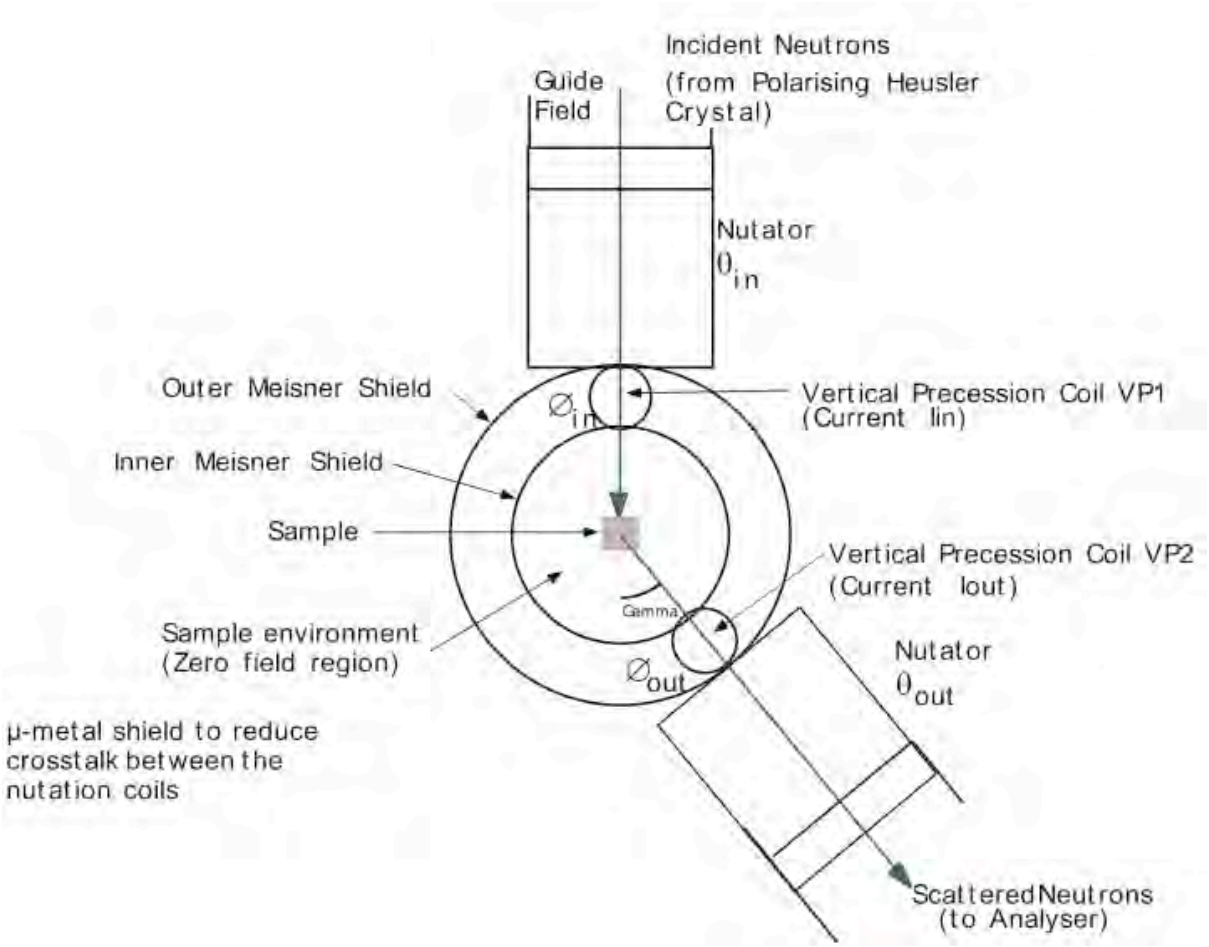

•Non-adiabatic regime ($\omega \approx \omega_L$)

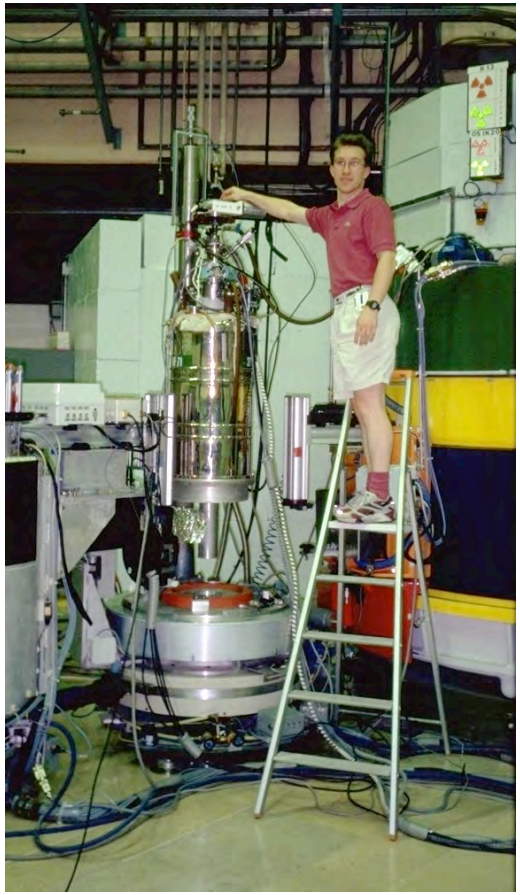



$$E = \frac{\omega_L}{\omega} = \frac{\gamma B_0}{\omega}$$

E is the adiabaticity coefficient
$\omega$ is the rate of change of field
$\omega_L$ is the Larmor frequency

# Recap: Cryopad-I

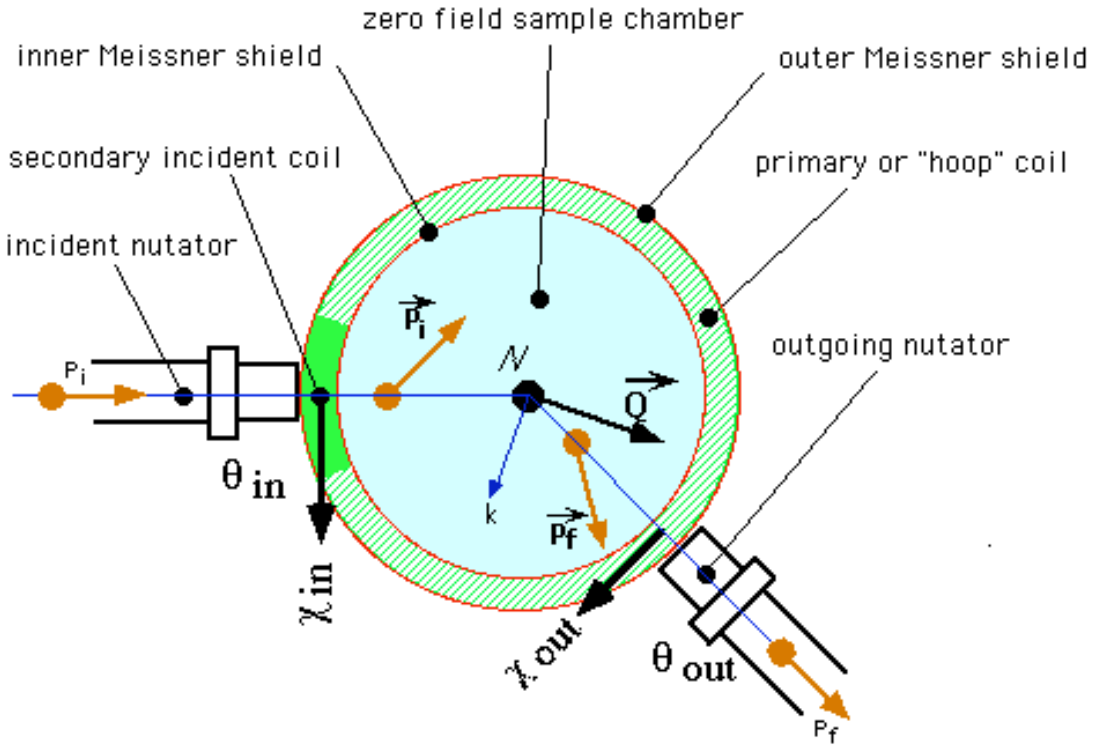


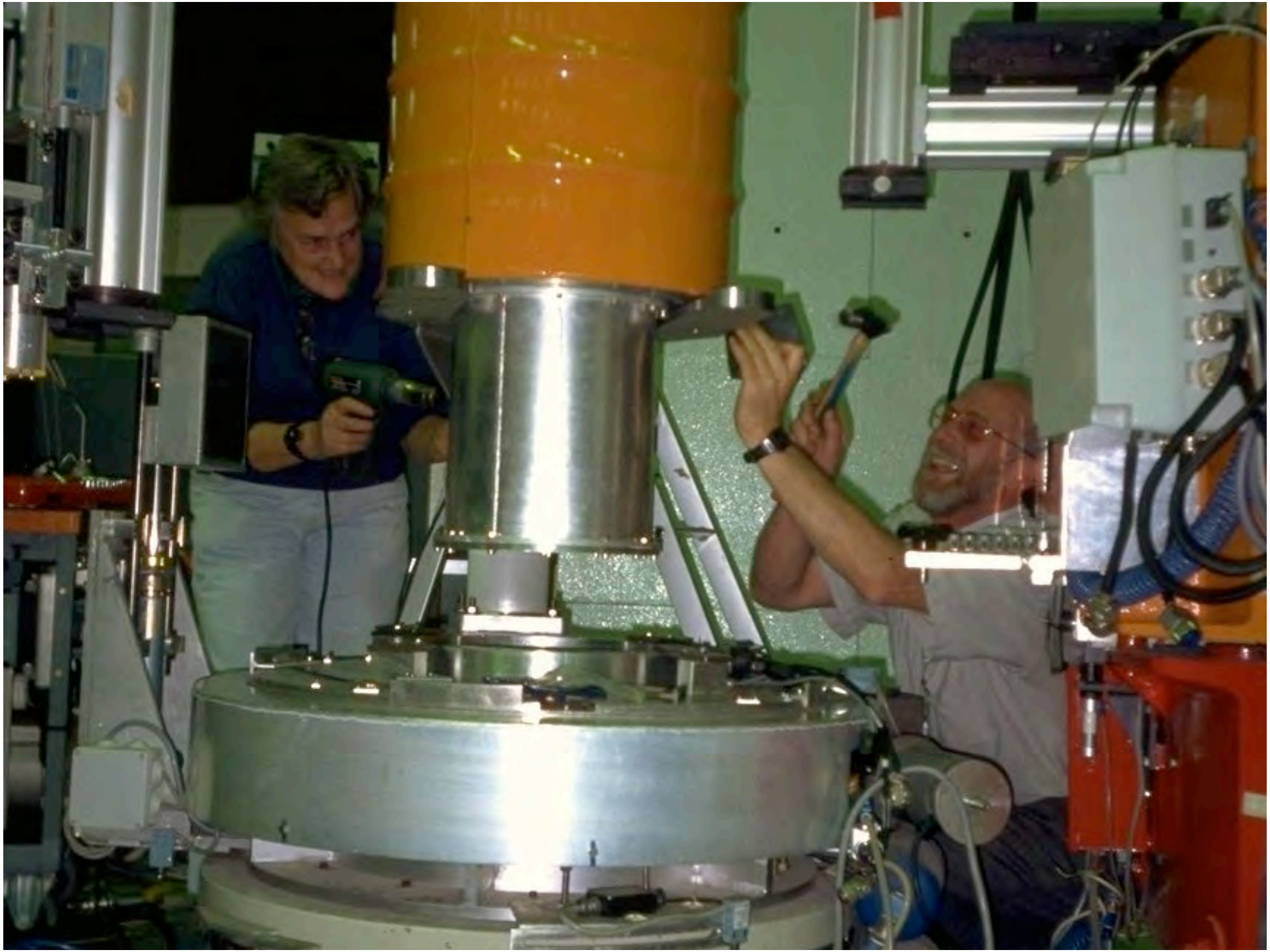
F. Tasset, *Physica B*, **156 & 157** (1989) pp627-630
P. J. Brown, J. B. Forsyth & F. Tasset, *Proc. R. Soc. Lond. A* **442** (1993) pp147-160

# New Features for Cryopad-II

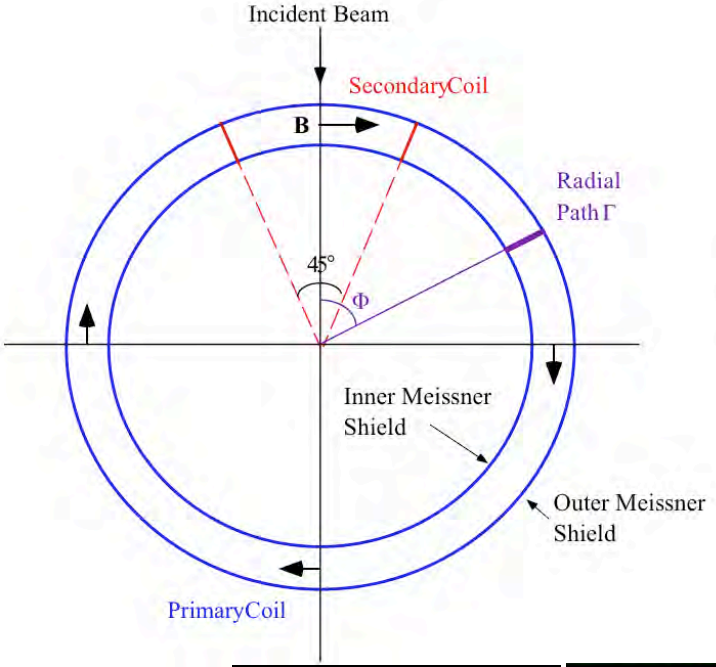
- Horizontal geometry with torroidal precession coils:
  - No moving parts in cryostat.
  - Larger beams.
  - Simpler calibration.
  - Improved precision at high Bragg angles
- Flexible sample environment:
  - Orange Cryostat.
  - Thin-tail Cryostat.
  - Dilution Fridge.
- New Nutators:
  - Less stray field.
  - Can use as Cryoflippers.

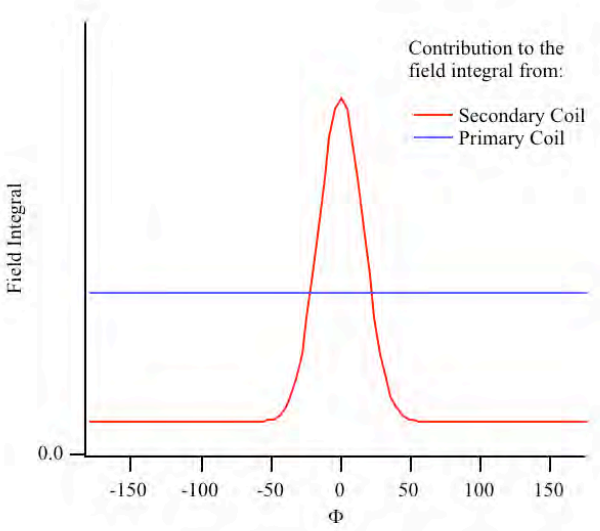


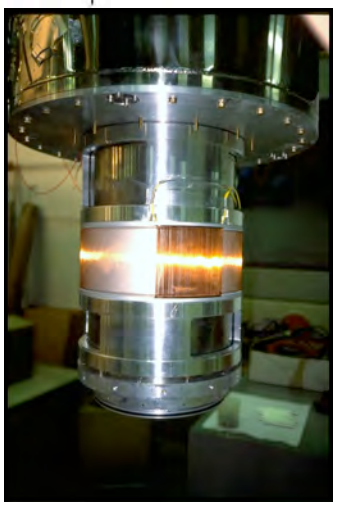

F. Tasset et al, *Physica B*, **241-243** (1998) 177-179



# Precession Coils

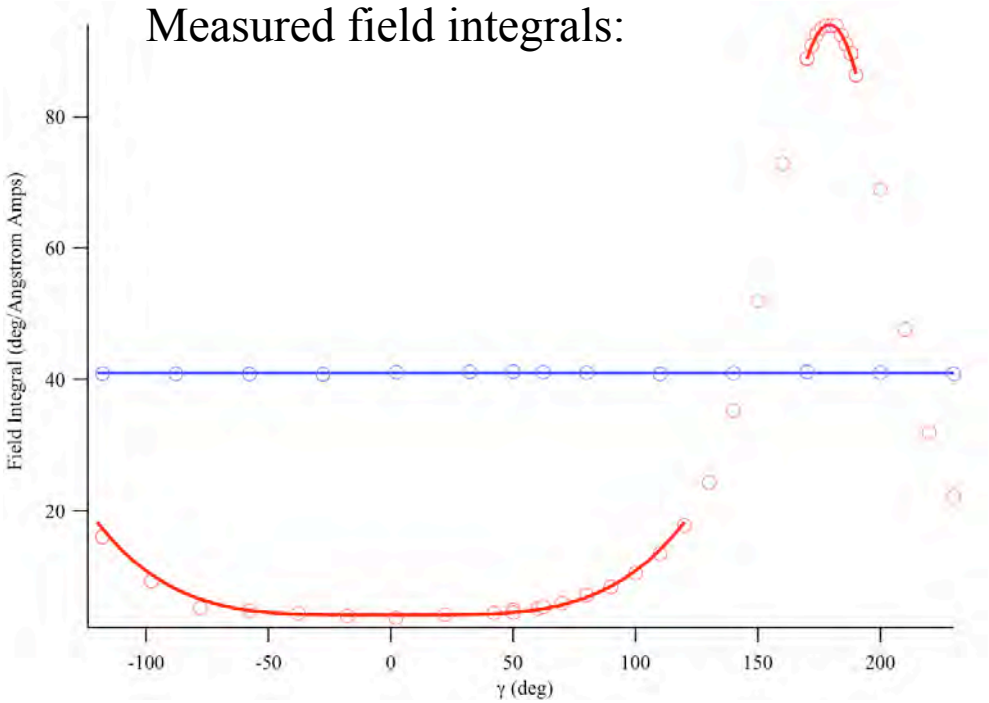


# Precession Coils: Calibration

Measured field integrals:

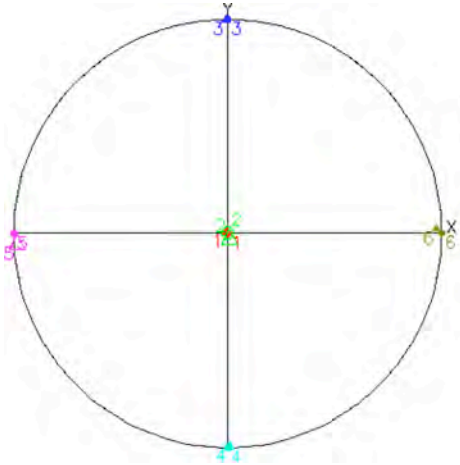



$$\chi_{in} = \lambda_i \left( A(\gamma = 0) I_{\sec} + B I_{prim} \right)$$

$$\chi_{out} = \lambda_f \left( C(\gamma) I_{\sec} - B I_{prim} \right)$$

$$\Rightarrow \begin{bmatrix} \chi_{in} \\ \chi_{out} \end{bmatrix} = \begin{bmatrix} \lambda_i & 0 \\ 0 & \lambda_f \end{bmatrix} \begin{bmatrix} A(\gamma = 0) & B \\ C(\gamma) & -B \end{bmatrix} \begin{bmatrix} I_{\sec} \\ I_{prim} \end{bmatrix}$$

Results post alignment & calibration:




Reflection: 0.00 0.00 6.00

| Point | Polarisation | ϑ | φ |
|---|---|---|---|
| 1 | 0.864(3) | 1(1) | 144(11) |
| 2 | 0.845(3) | 177(1) | -76(3) |
| 3 | 0.860(3) | 90(1) | 90(1) |
| 4 | 0.855(3) | 90(1) | -90(1) |
| 5 | 0.851(3) | 91(1) | -177(1) |
| 6 | 0.858(3) | 89(1) | 1(1) |

Cardinal point scan on (006) of Pyrolytic graphite (nuclear only) at λ=1.532 Angstroms.

F. Tasset et al, *Physica B*, **241-243** (1998) 177-179


# LE JOURNAL

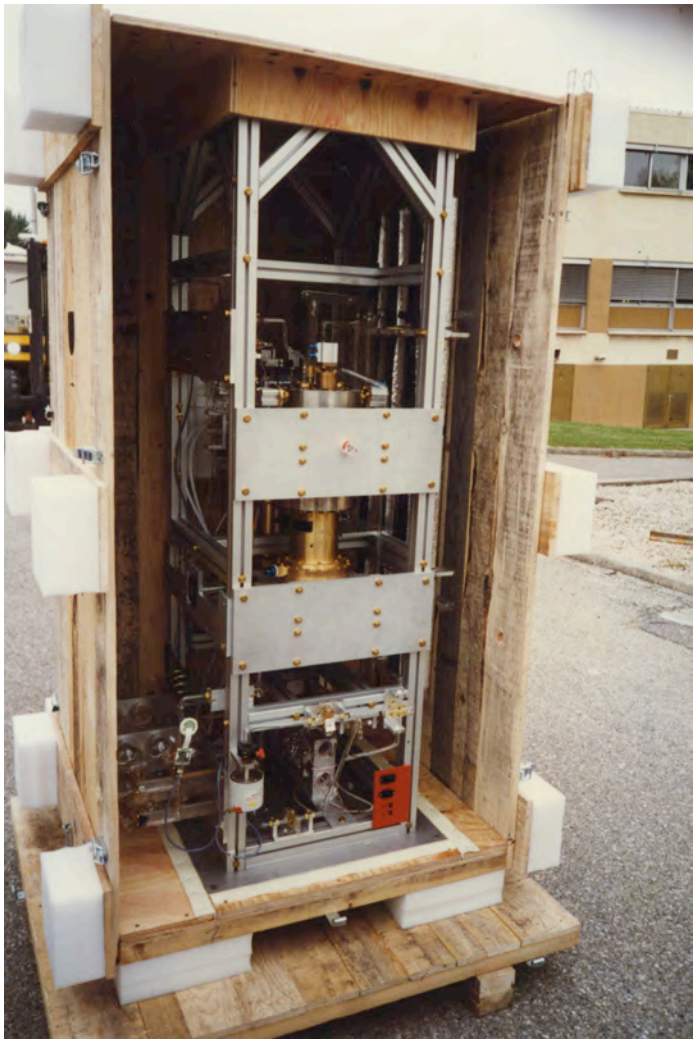
# Recap: Some Advantages of $^3$He spin-filters

- Can polarise/analyse divergent beams
- Broadband
- Optically de-coupled from instrument
- Can produce very homogeneously polarised beams

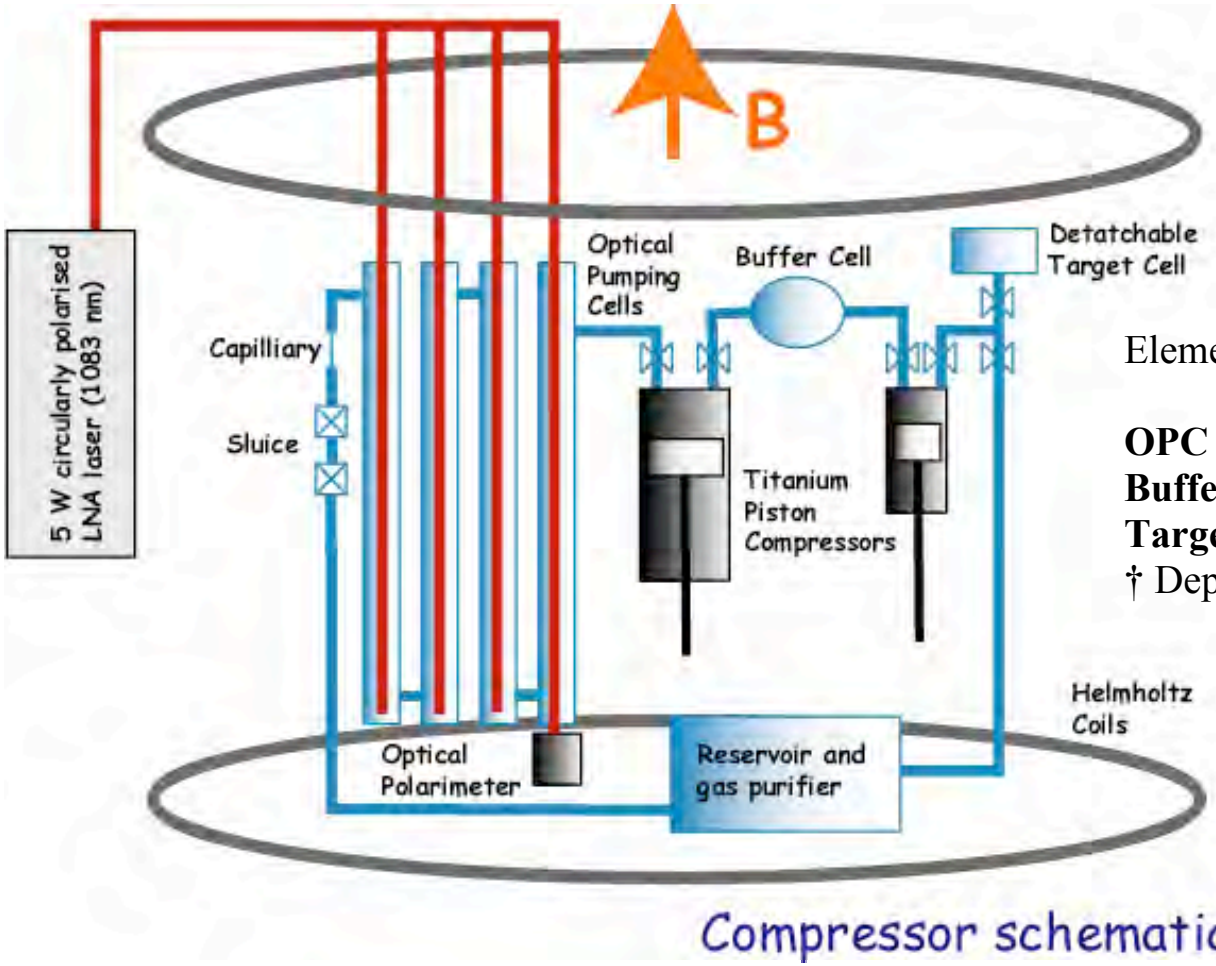
…if only we could make it easily!

# $^3$He-COW: Timeline

- Funded by EU grants.
- Built in Mainz over 2.5 years.
- Completed in July 96.
- Arrived at ILL September 96.
- First neutron test on D3 November 96.
- **COW: C**ompressing **O**ptical **W**idget ☺.



# $^3$He-COW: Overview

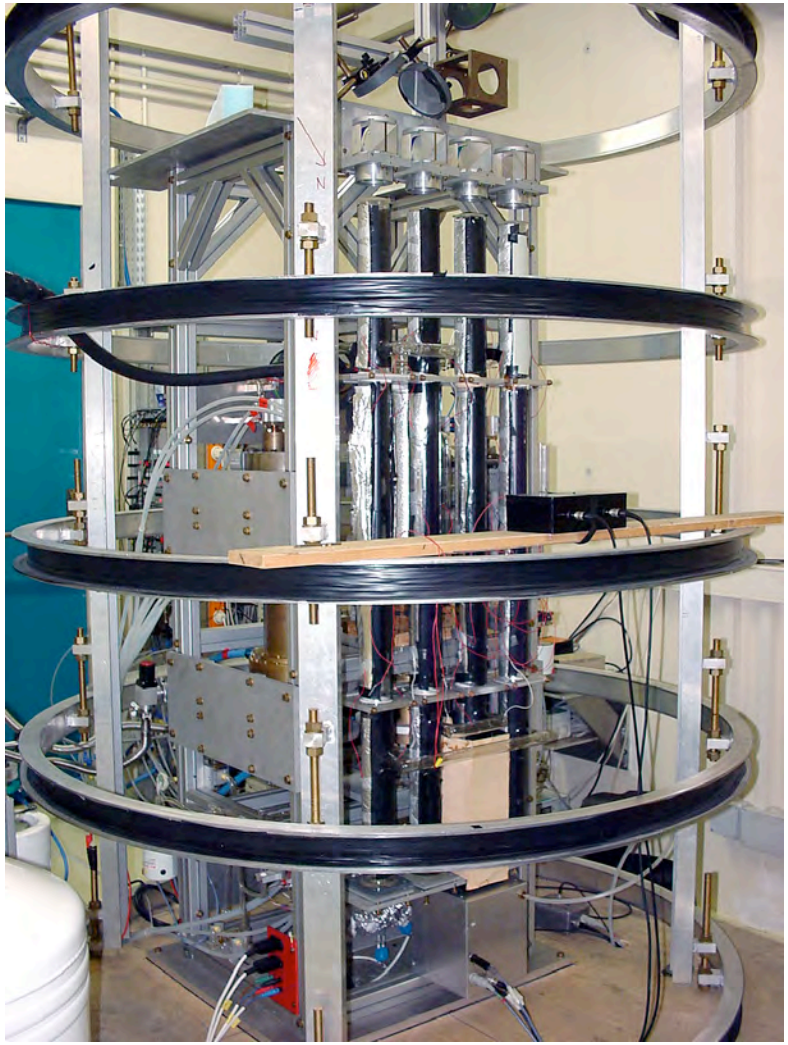



| Element | $^3$He Polarisation | $T_1$ (hrs) |
|---|---|---|
| **OPC** | 71 % | 0.33 |
| **Buffer** | 59 % | 24 - 50 |
| **Target** | 55 % | 30 - 180† |

† Depends upon type of target cell used.

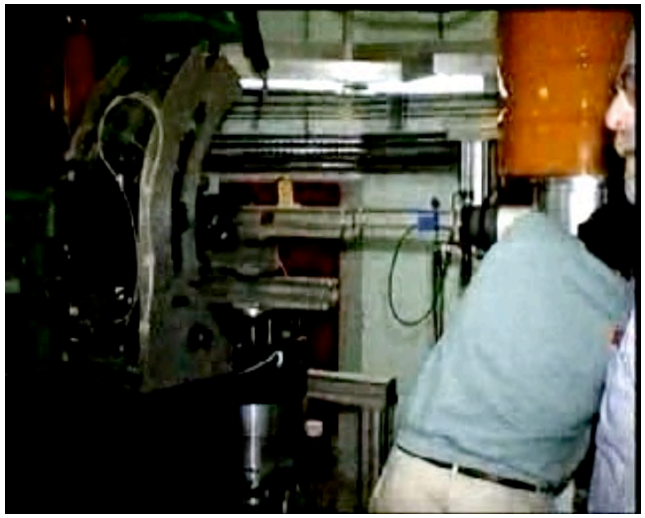
Production rate: ~0.4 bar.litre.hr$^{-1}$

During re-assembly at the ILL in late 1996

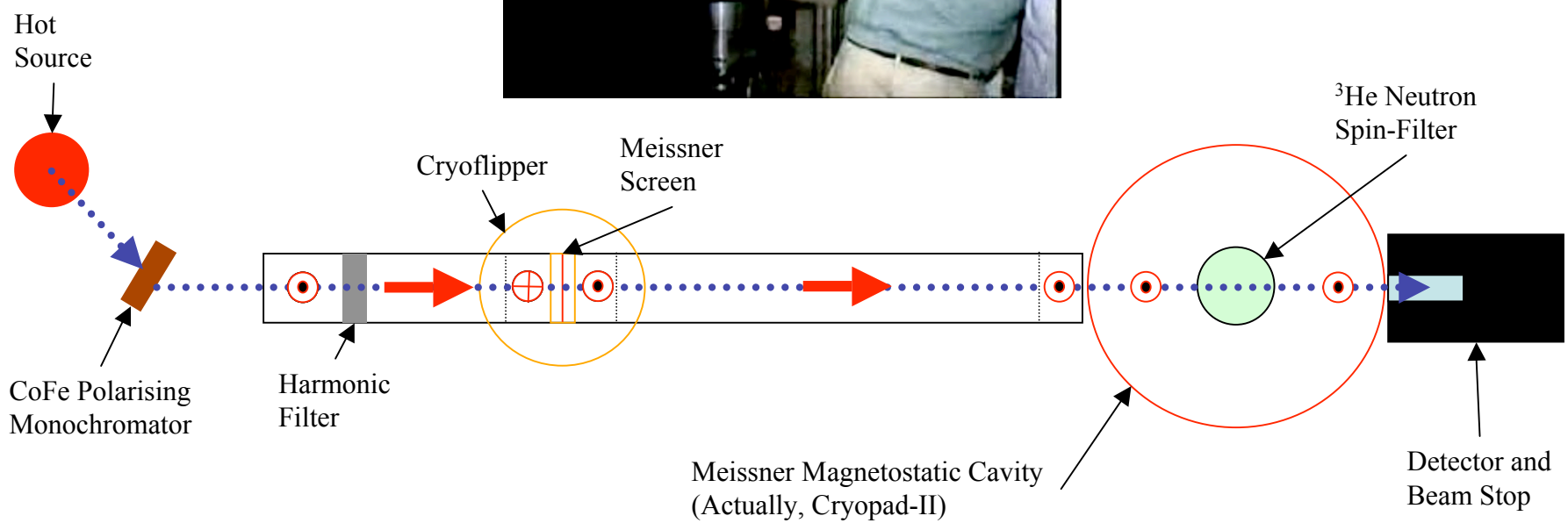


COW in 2002

# D3 Test: Setup

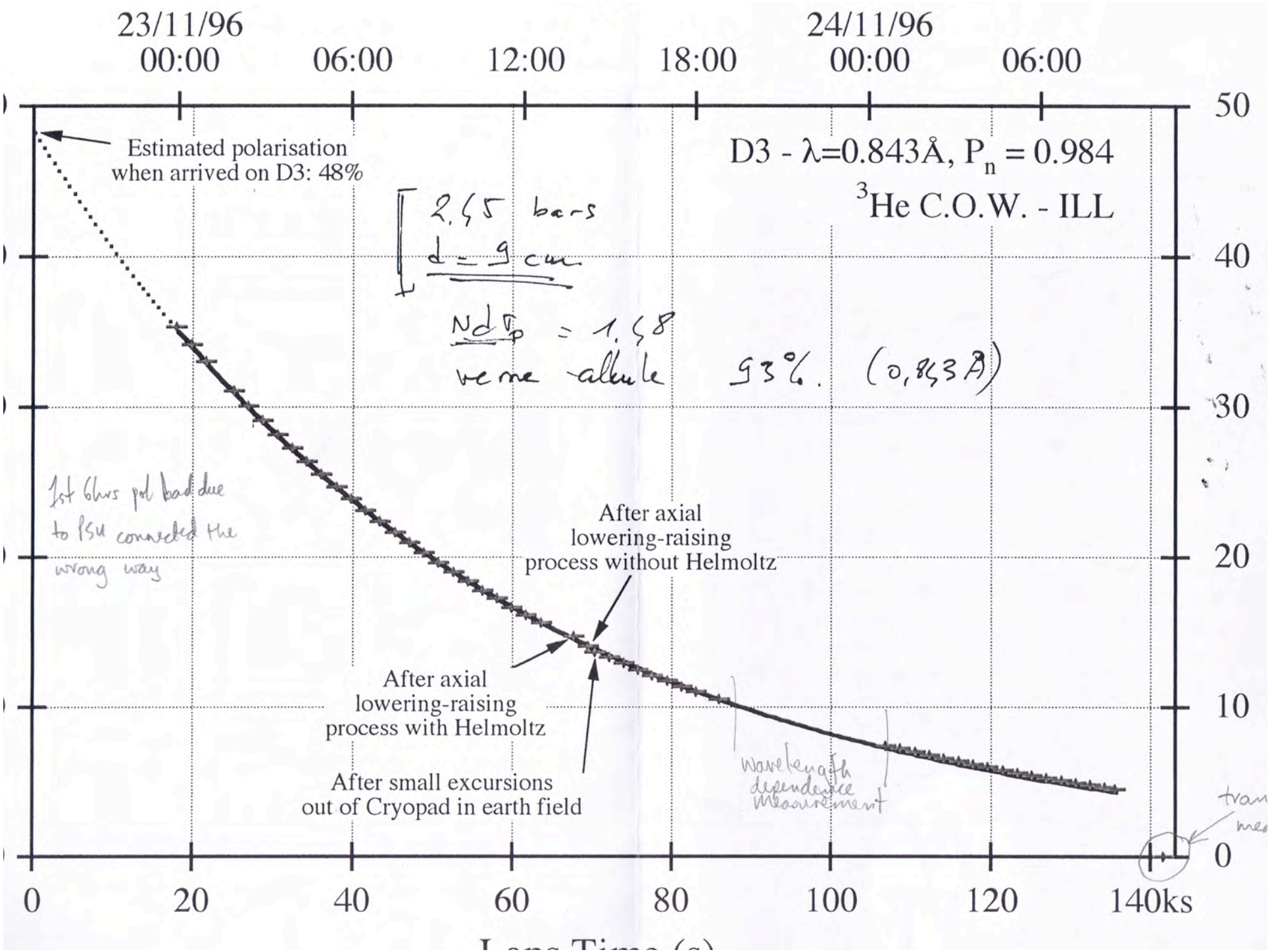


Configuration for spin-down transmission shown.

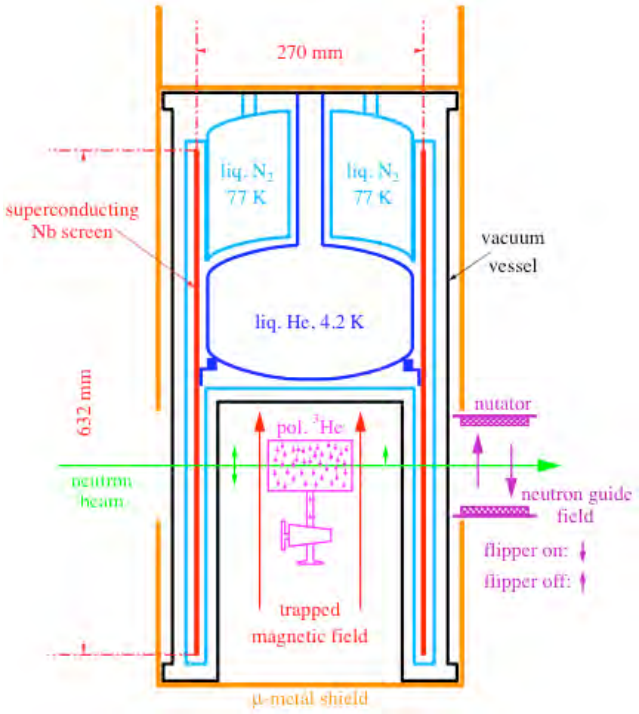



F. Tasset, W. Heil, H. Humblot, E. Lelièvre-Berna and T. Roberts
*The 3He neutron-spin filter at ILL,* ILL Annual Report 1996:
http://www.ill.eu/fileadmin/users_files/Annual_Report/AR-96/pages/39newdev.htm


First test
of an $^3$He
neutron spin filter
© 1996-2008, Institut Laue-Langevin


23/11/96
00:00
06:00
12:00
18:00
24/11/96
00:00
06:00
Estimated polarisation
when arrived on D3: 48%
D3 - λ=0.843Å, P_n = 0.984
³He C.O.W. - ILL
2.5 bars
d = 9 cm
Nd P_p = 1.58
we me alcule 93%. (0,843 Å)
1st 6hrs pol bad due
to PSU connected the
wrong way
After axial
lowering-raising
process without Helmoltz
After axial
lowering-raising
process with Helmoltz
After small excursions
out of Cryopad in earth field
wavelength
dependence
measurement
50
40
30
20
10
0
0
20
40
60
80
100
120
140ks

# Cryopol



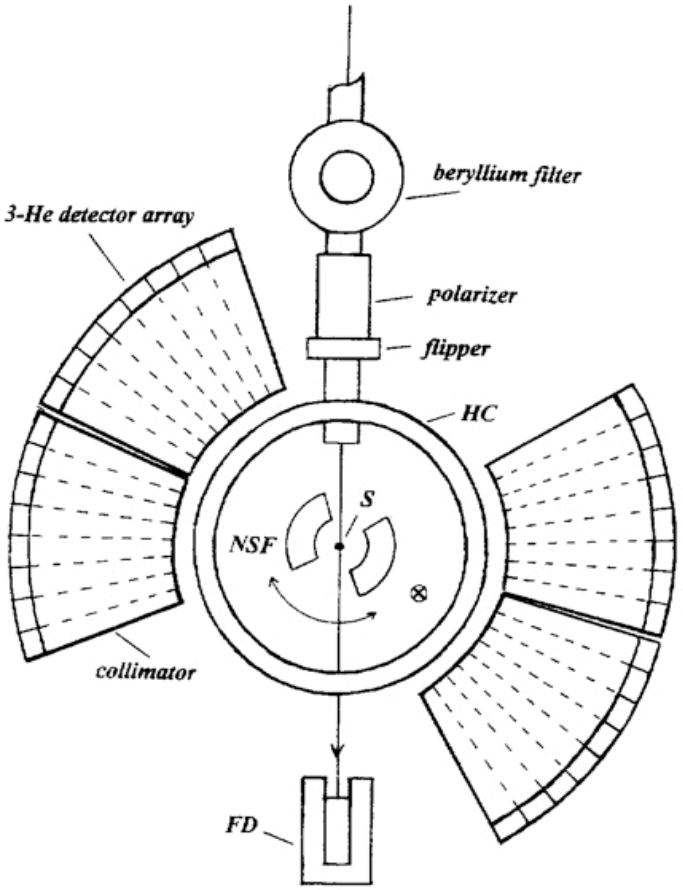

Cryopad-II on D3 with Cryopol as Analyser:

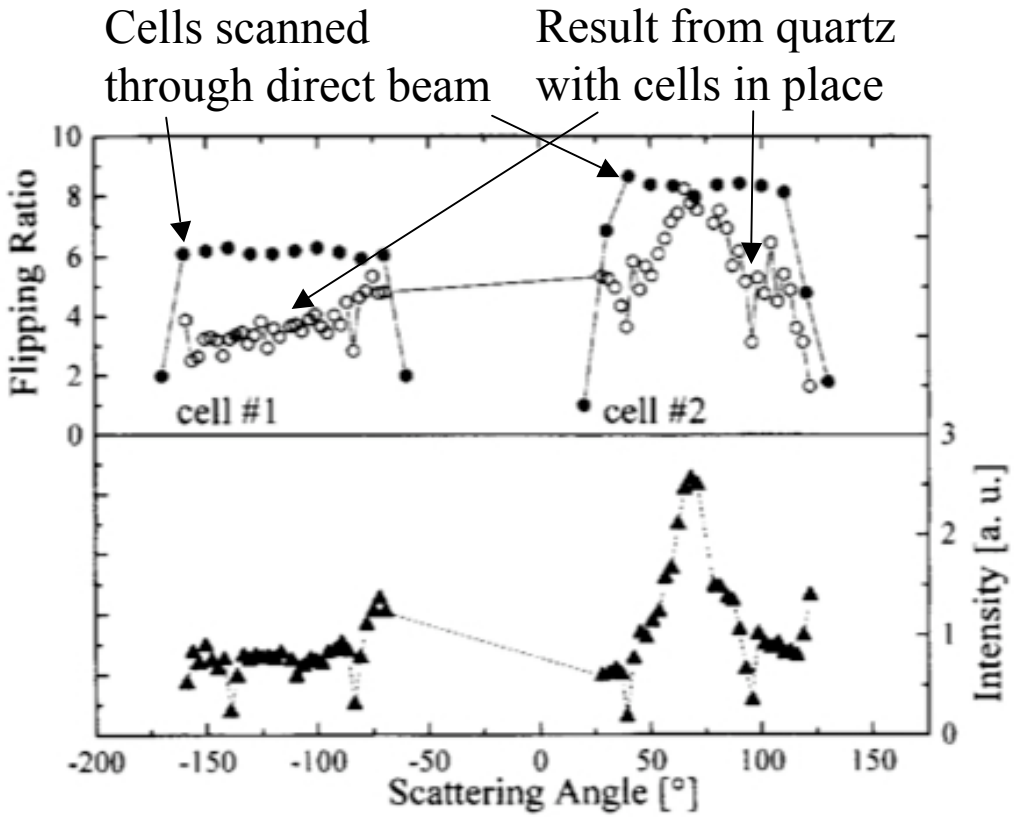

Cooling Cryopol in Field:

- Magnetostatic Cavity for $^3$He spin-filters
(Born out of the use of Cryopad-II in the D3 test)
- Single Nb Cylinder, with mu-metal screen
- Optimised for Homogeneity (~10G holding field)
- Can be used near large stray fields (e.g. D3 cryomagnet)

Tasset et al, *NIM A* **449** (2000) pp638-648

# D7 Test: Large Solid Angles




W. Heil et al, *Physica B*, **241-243** (1998) pp56-63

# Conclusions

- Cryopad-II came on stream on IN20 making SNP much more reliable and accessible.
- Practical $^{3}$He spin-filters for neutron scattering with helium polarisation ~50% at last became a reality at the ILL.
- Marked the beginning of a wave of development on containment fields, cells and the new compressor…

# Some Personal Reflections