Dynamic Nuclear Polarization

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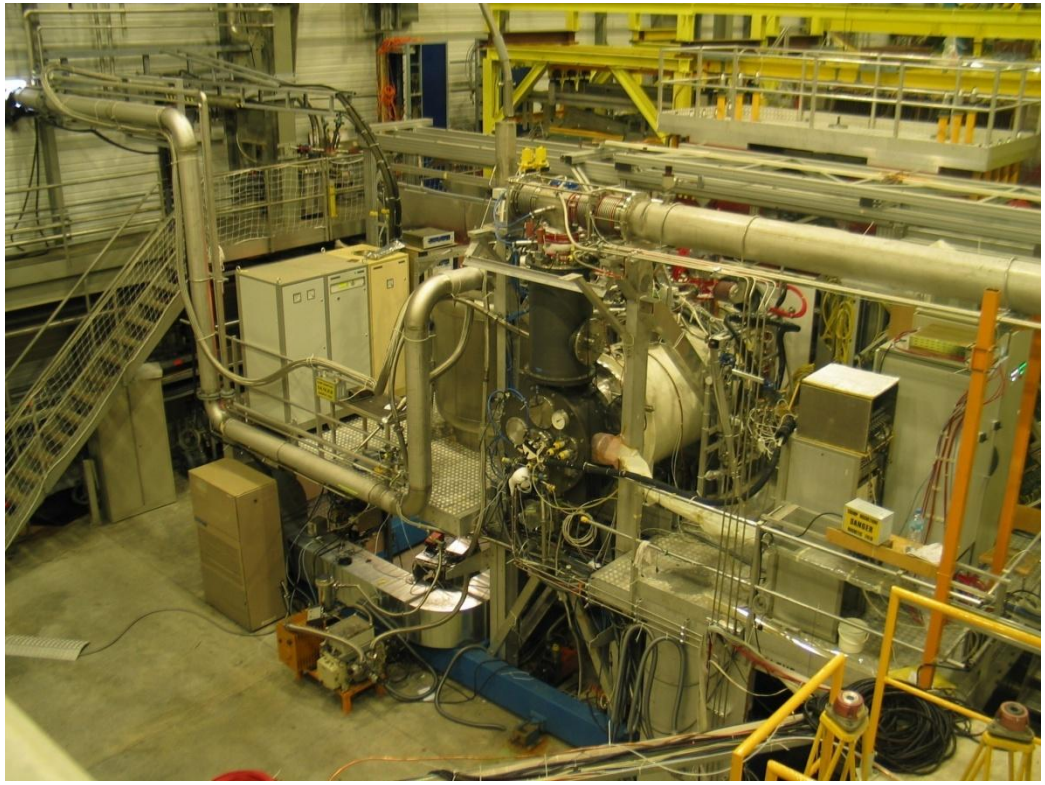
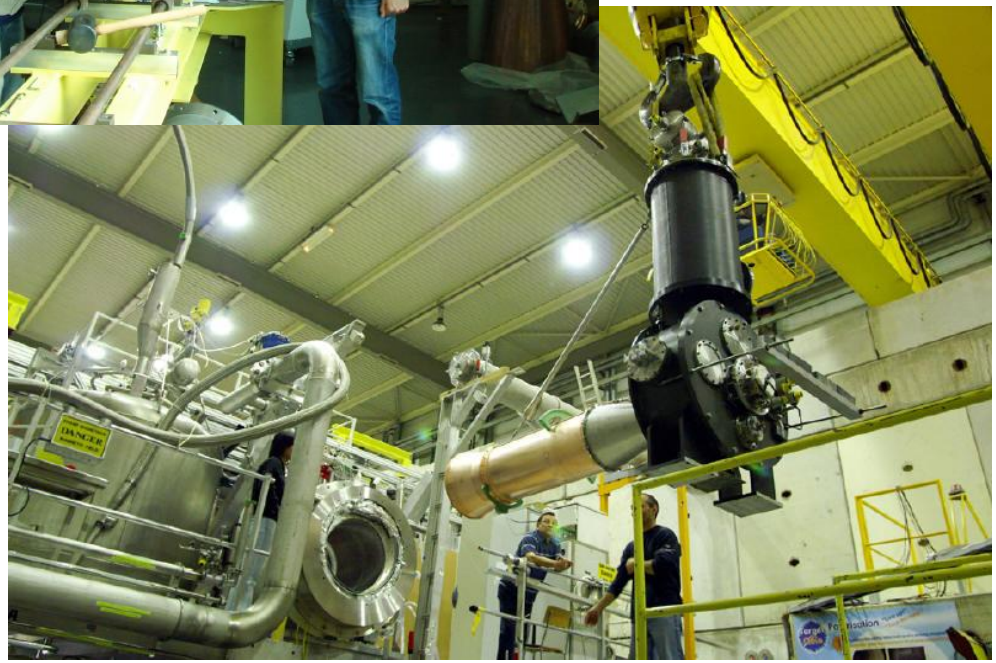
COMPASS PT- team at CERN:

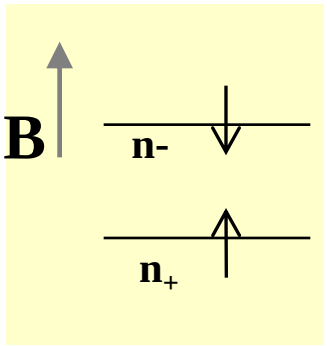
Dynamically Polarized Targets

- How the dynamically polarized targets work?
- Basic apparatus required and techniques
- Recent developments and topics





Elementary consideration S=I=1/2



$$P_{e,p}(S=I=1/2)=\frac{n_+-n_-}{n_++n_-}=\tanh\left(\frac{\mu_{e,p}B}{k_BT}\right)$$

μ_e, μ_p **are electron and proton magnetic moments**

$\mu_e \approx 1000\times\mu_p$

One can see that all parameters in this formulae are fixed but the temperature

B=2.5 T
T=1 K

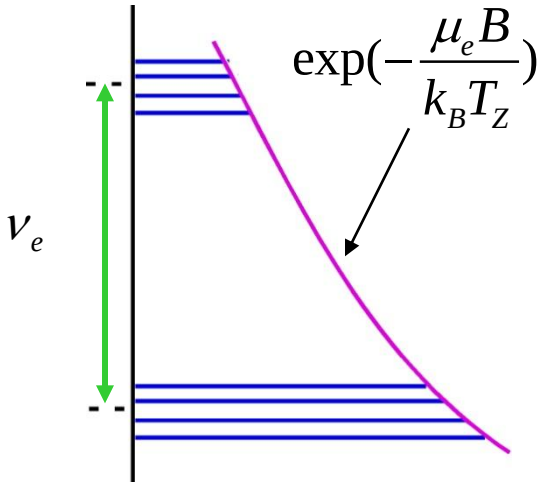
$P_e = 92\%$ ⟸ **large magnetic moment of electron**

$P_p = 0.25\%$ ⟸ **small magnetic moment of nuclei**

Dilution refrigerator may cool the nuclear spins down T~0.1 K, but practice shows that this process takes about 1000 hour due to excellent isolation of nuclear spins from the lattice!

On the other hand, the electron and nuclear spins interact with electromagnetic irradiation, therefore, to reach lower temperatures, It was elaborated very specific method called the Dynamic Nuclear Polarization (DNP).

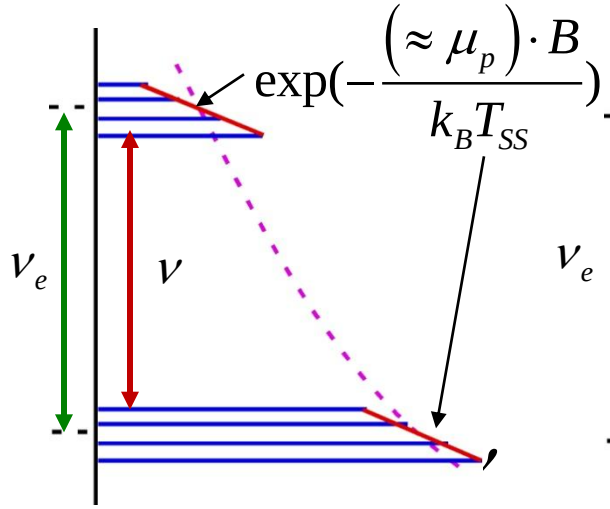
Thermodynamic equilibrium



without Microwave

$$T_{SS} = T_Z = T_L$$

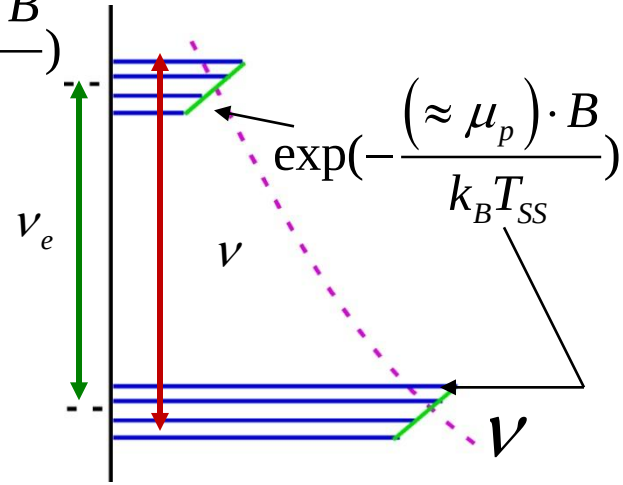
SS-Reservoir Cooled down



with MW at

$$T_{SS} \approx \frac{\nu_e - \nu}{\nu_e} T_Z \approx \frac{T_Z}{300 \div 400}$$

SS-Reservoir Heated up



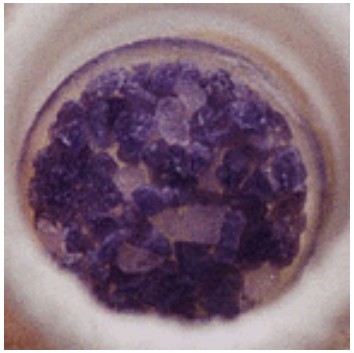
with MW at

$$T_{SS} \approx \frac{\nu_e - \nu}{\nu_e} T_Z \approx -\frac{T_Z}{300 \div 400}$$

To realize DNP we need the free electrons in a target material

Free electron spins are induced by electron beam irradiation at about 90 K temperature with the dose of 10^{16}~10^{17}electrons/cm^2 which generates about 10^{19}spins/cm^2

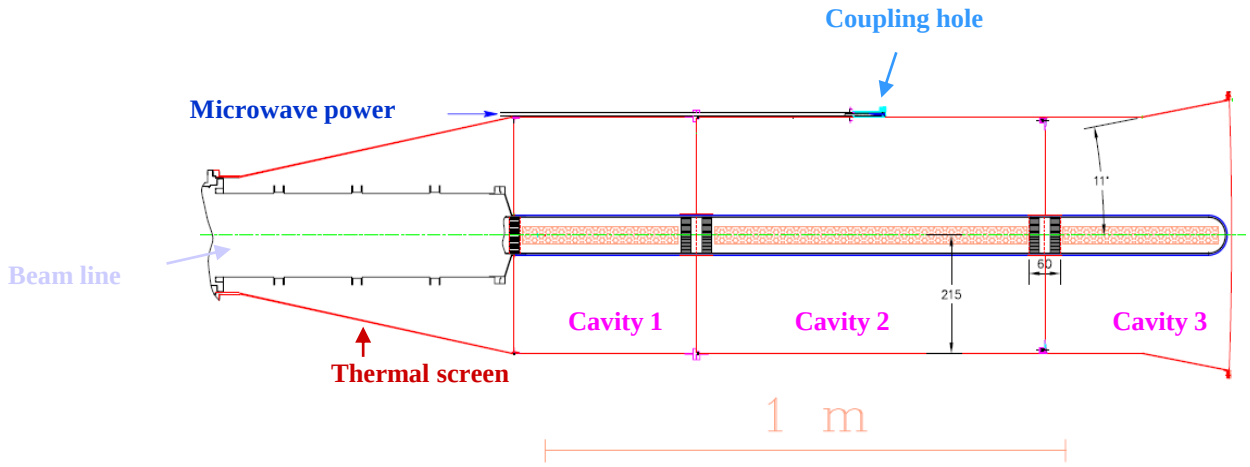
Ammonia: NH_3, ND_3



Lithium Hydrides: ^{7}LiH, ^{6}LiH, ^{6}LiD

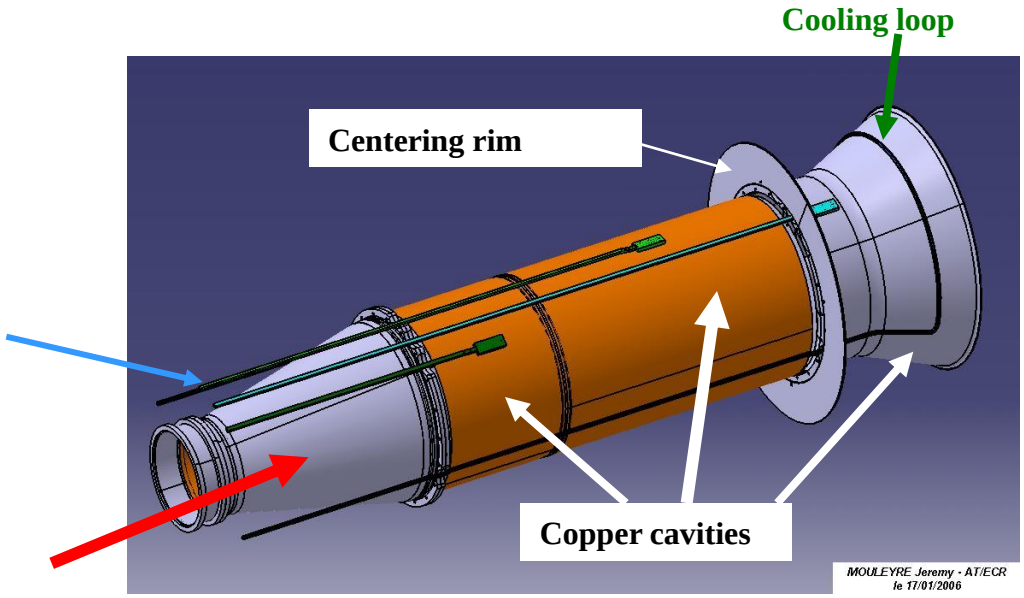
^{6}LiD: ^{6}Li=α+ deuteron

THE COMPASS CAVITY FOR OD-MAGNET

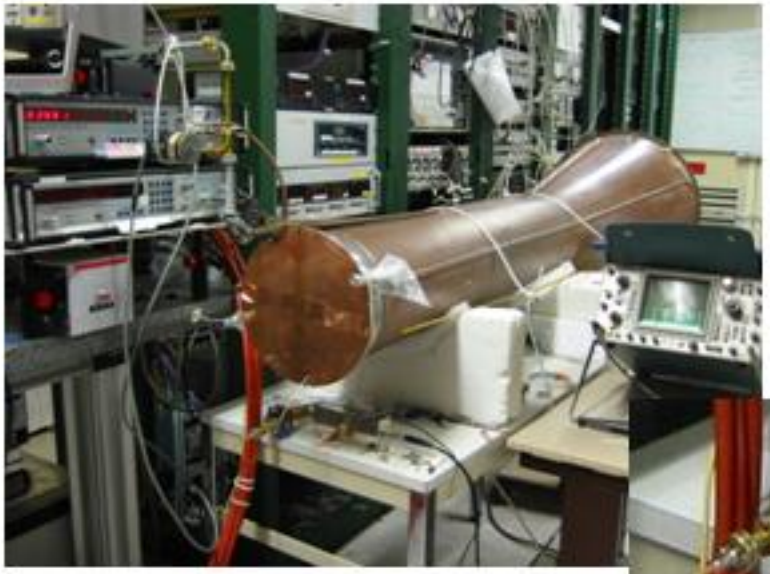


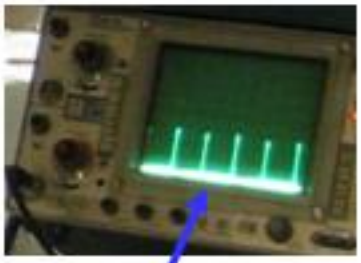
All of cavity elements provide

a very long use



General view of the new microwave cavity in PT control room

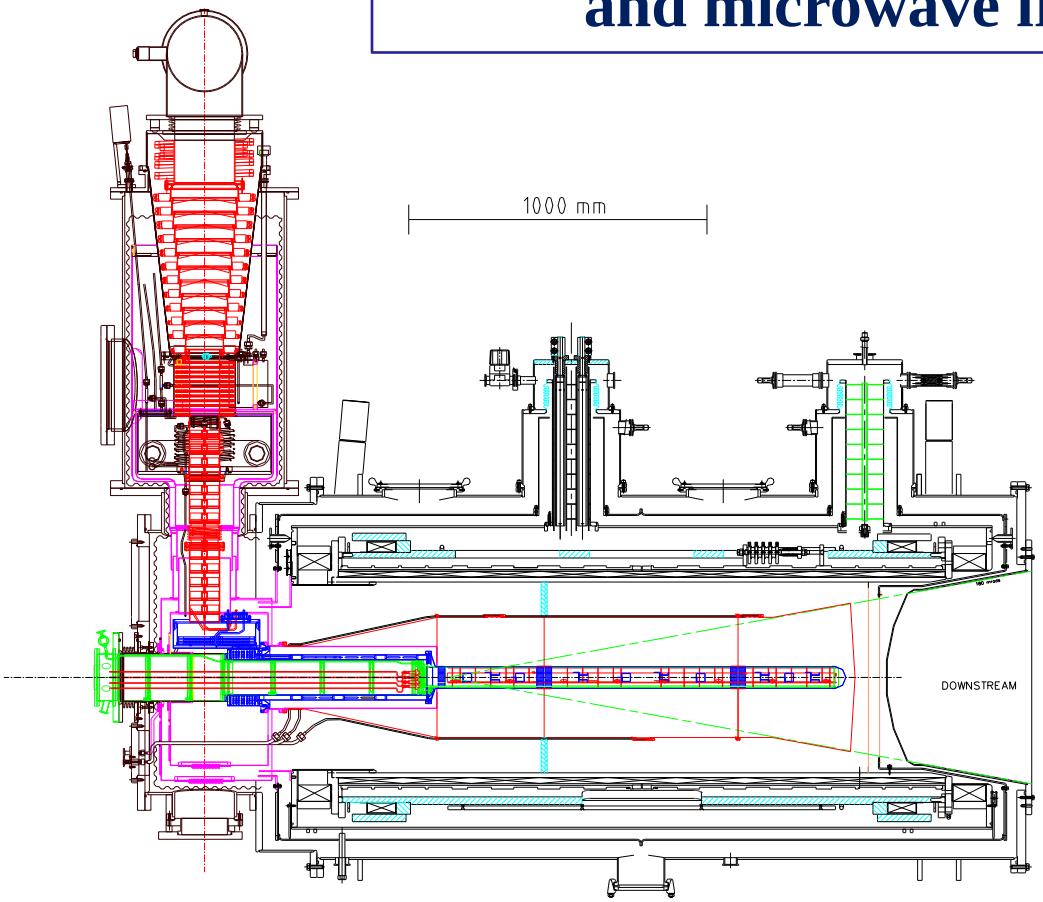




Display

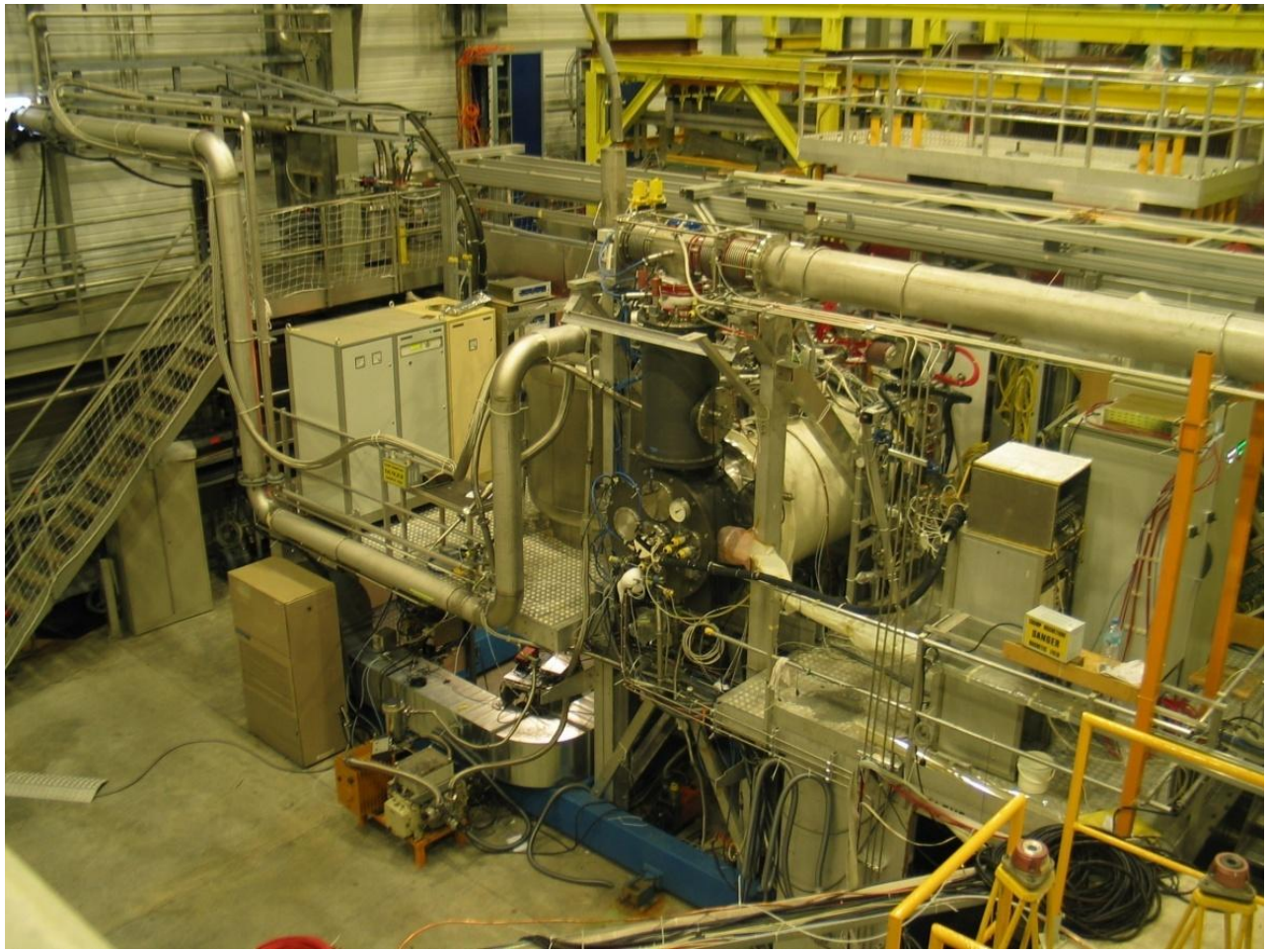
Microwave sensor with preamplifier

High magnetic field, low temperature and microwave irradiation



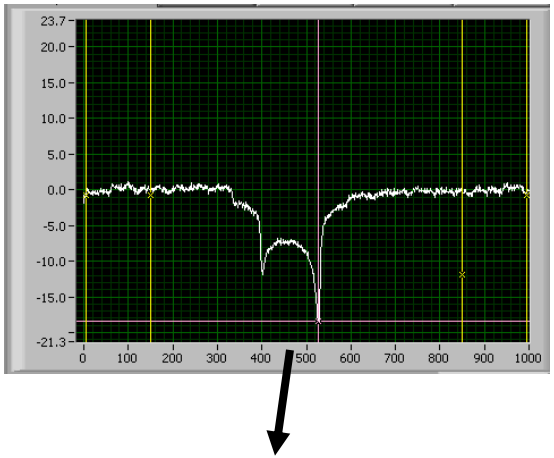
Polarizing magnet: 2.5T with field uniformity, ~100ppm

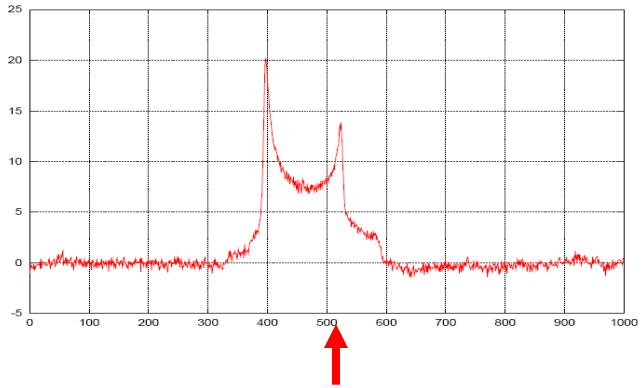
Overview of the COMPASS Polarized Targets

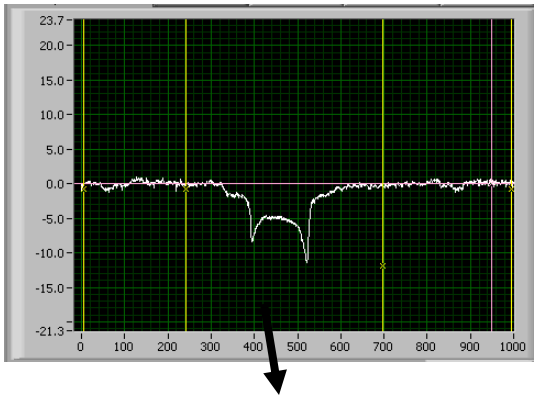


First polarization with our new set-up (measured June 14th)

D-butanol





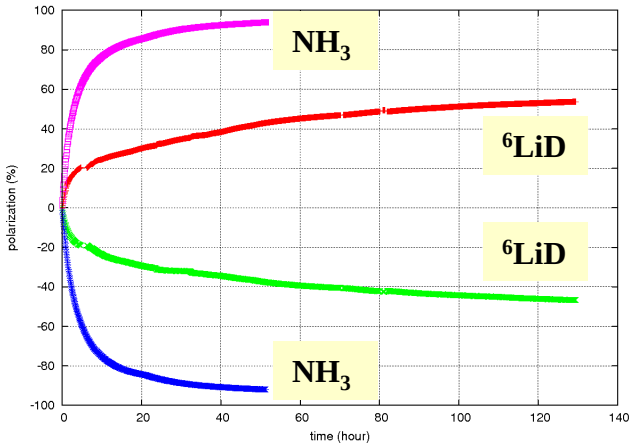


Upstream cell

Central cell

Downstream cell

P=-36±2 % in ~ 2-3 hours



Built-up the target polarizations

Polarization measurements

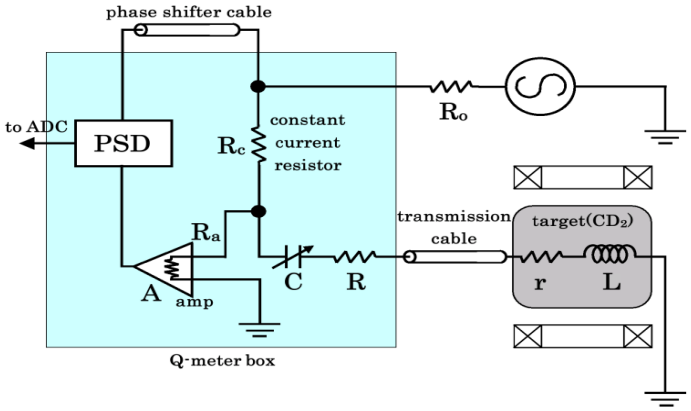
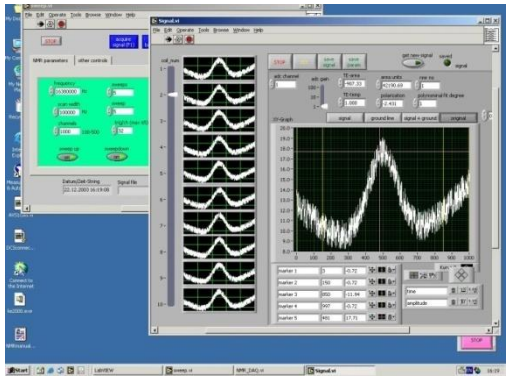
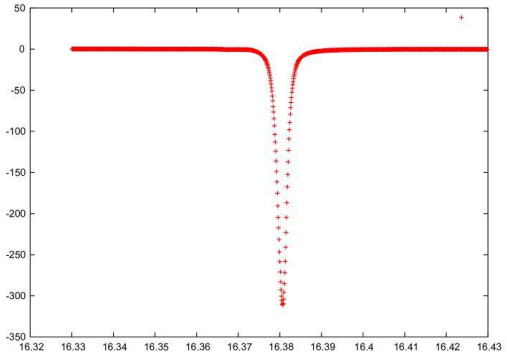


Fig4.3 NMR 信号検出回路

Q-meter circuit for polarization measurements



The typical signal-to-noise for protons on the display



After the signal accumulation Kaori receives almost an the free electrons ideal proton signal

Summary

- Dynamically Polarized targets have been used in many experiments.
- The techniques are well established although complicated apparatus is needed.
- The targets are still being developed for various applications.