The COMPASS polarized target

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The COMPASS experiment

- Muon program

  -Nucleon spin structure --- gluon contribution

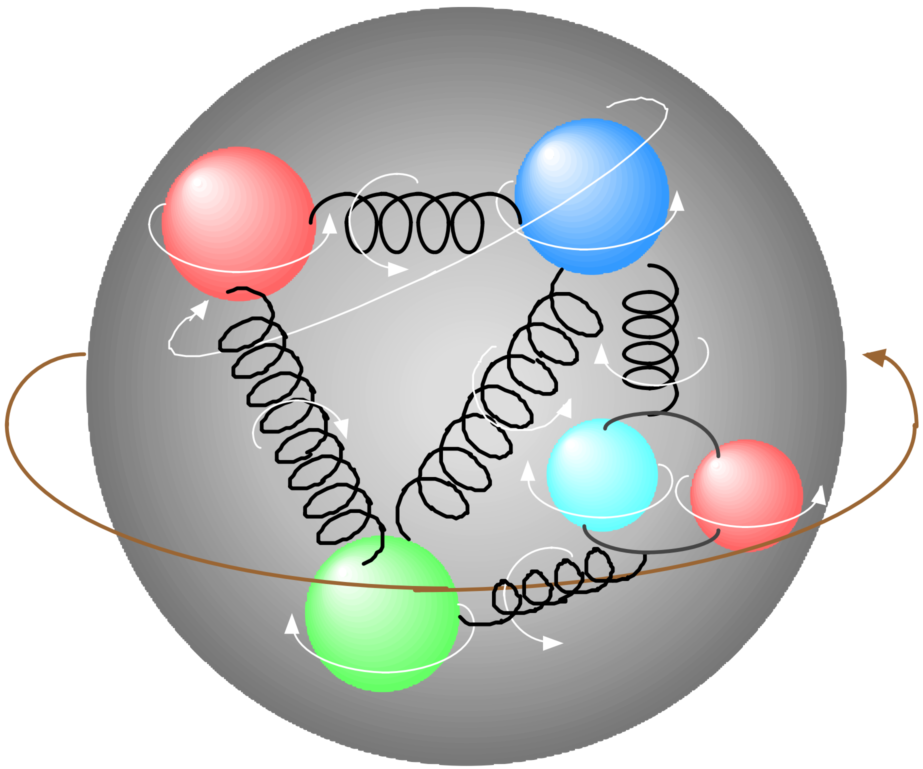
  -Polarized muon beam and polarized nucleon target

- Hadron program

  -Meson spectroscopy

  -hadron beam and Hydrogen, carbon target

Motivation of muon program



Nucleon spin

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + Lq + Lg$$

$\Delta\Sigma$: Quarks spin

ΔG : Gluons spin

Lq, Lg : Orbital angular momentum

SMC, SLAC, HERMES in 1990s

$\Delta\Sigma \sim 0.2$

→ ΔG ??

Gluon polarization measurement in the COMPASS

Double spin asymmetry

$$A^{exp} = \frac{N^{\leftarrow}_{\Rightarrow} - N^{\leftarrow}_{\Leftarrow}}{N^{\leftarrow}_{\Rightarrow} + N^{\leftarrow}_{\Leftarrow}} = P_B P_T f A^{phys}$$

P_B: Beam polarization
P_T: Target polarization
f : Dilution factor
N : Number of events

$\leftarrow$: Direction of beam polarization
$\Leftarrow$: Direction of target polarization

Dilution factor : polarizable nucleon rate in material

A^{phys} $\Leftarrow$ Extraction <u>Gluon polarization</u>

What kinds of events are counted?

- Open charm production events → D_0, D_0^*
- High-$_{PT}$ hadron production events

Low statistics

Requirement of Polarized Target

Statistical accuracy

$$\frac{\delta A^{exp}}{A^{exp}} = \frac{1}{\sqrt{2N}\; P_B \, P_T \, f \, A^{phys}}$$

- -High polarization
- -High dilution factor
- -Large target
- -Stability during long beam period

COMPASS polarized target

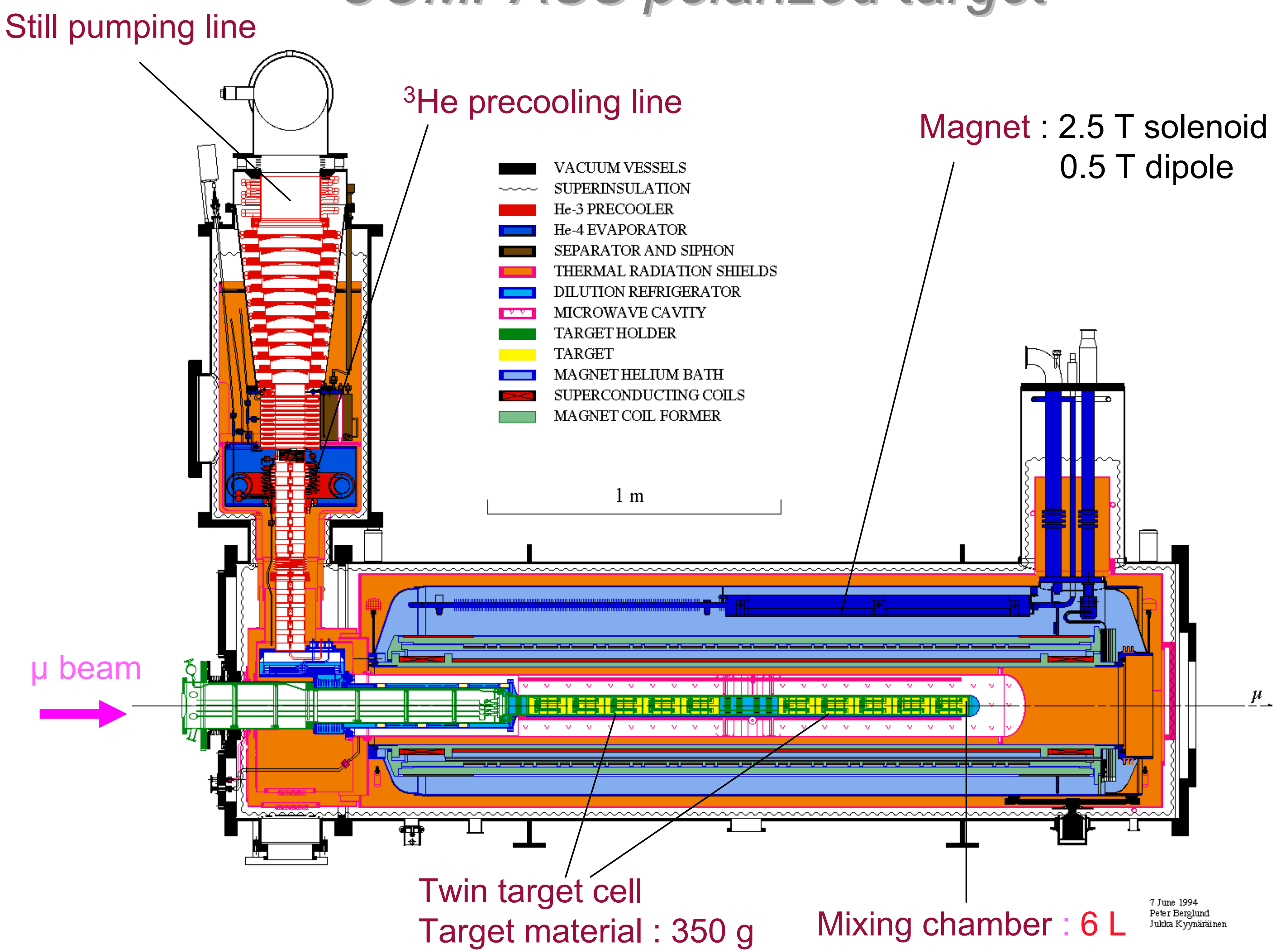
- - Target material → ^{6}LiD (high dilution factor), 350g
- - Magnetic field → 2.5T superconducting magnet
- -Temperature → less than 100mK and high cooling power dilution refrigerator
- - Control system → LabView and PLC

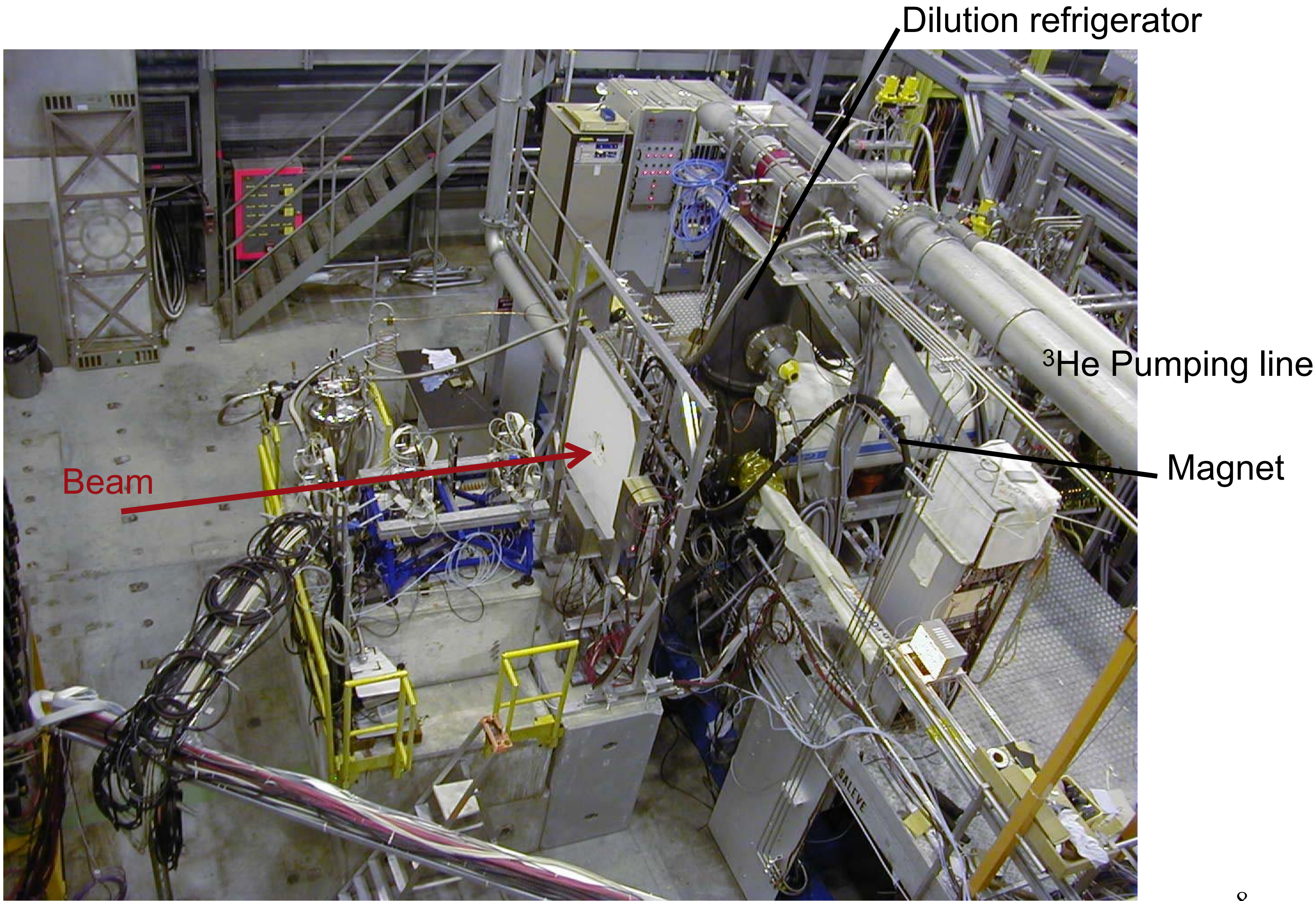
&

Dynamic Nuclear Polarization with Microwave

Deuteron polarization more than 50 %

COMPASS polarized target




Dilution refrigerator
³He Pumping line
Magnet
Beam

Polarization and Target Material

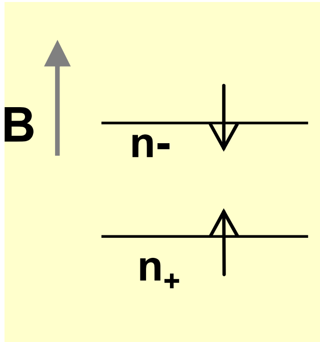
Definition of polarization

Spin 1/2

$$P = \frac{n_+ - n_-}{n_+ + n_-}$$

Spin 1

$$P = \frac{n_+ - n_-}{n_+ + n_0 + n_-}$$



^{6}LiD Polarized target material

- **^{6}LiD -> polarizable nucleons : about 50%**
- **Possibility of high polarization**

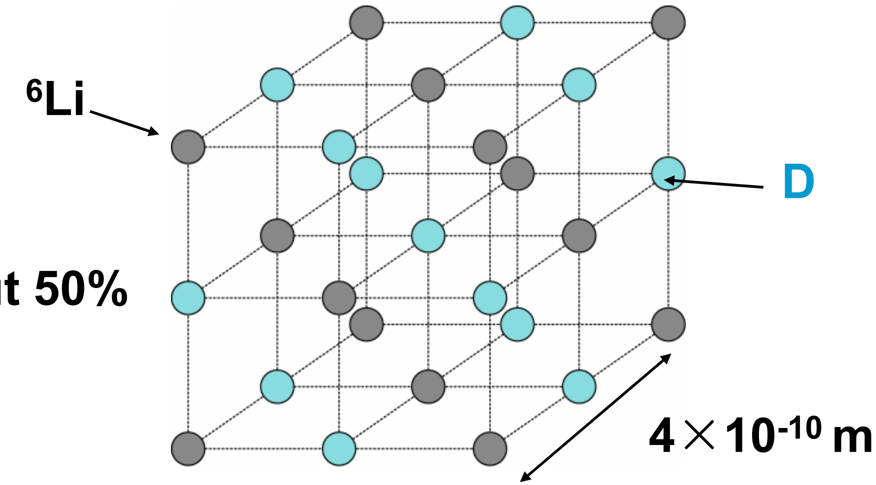


Figure of Merit

The beam time needed to achieve a certain statistical accuracy is inversely proportional to the FoM.

$$\text{FoM} = \rho\kappa(f\text{'}P_T)^2 \quad [\text{kg/m}^3]$$

- ρ : density
- κ : packing factor
- f': effective dilution factor
- P_T : polarization

For the extraction of the real physics Bjorken-x-dependence of dilution factor should be considered.

	SMC	SMC	COMPASS
Material	NH_3	D-butanol	^{6}LiD
Polarization	H: ~0.90	D: ~0.50	D: ~0.50
Dilution factor	0.176	0.238	~0.50
FoM	10.3	6.7	16.0

Material loading

Material

Funnel

Liquid N_2 Bath

Target cell

Dilution refrigerator

Target holder

Liquid N_2 bath

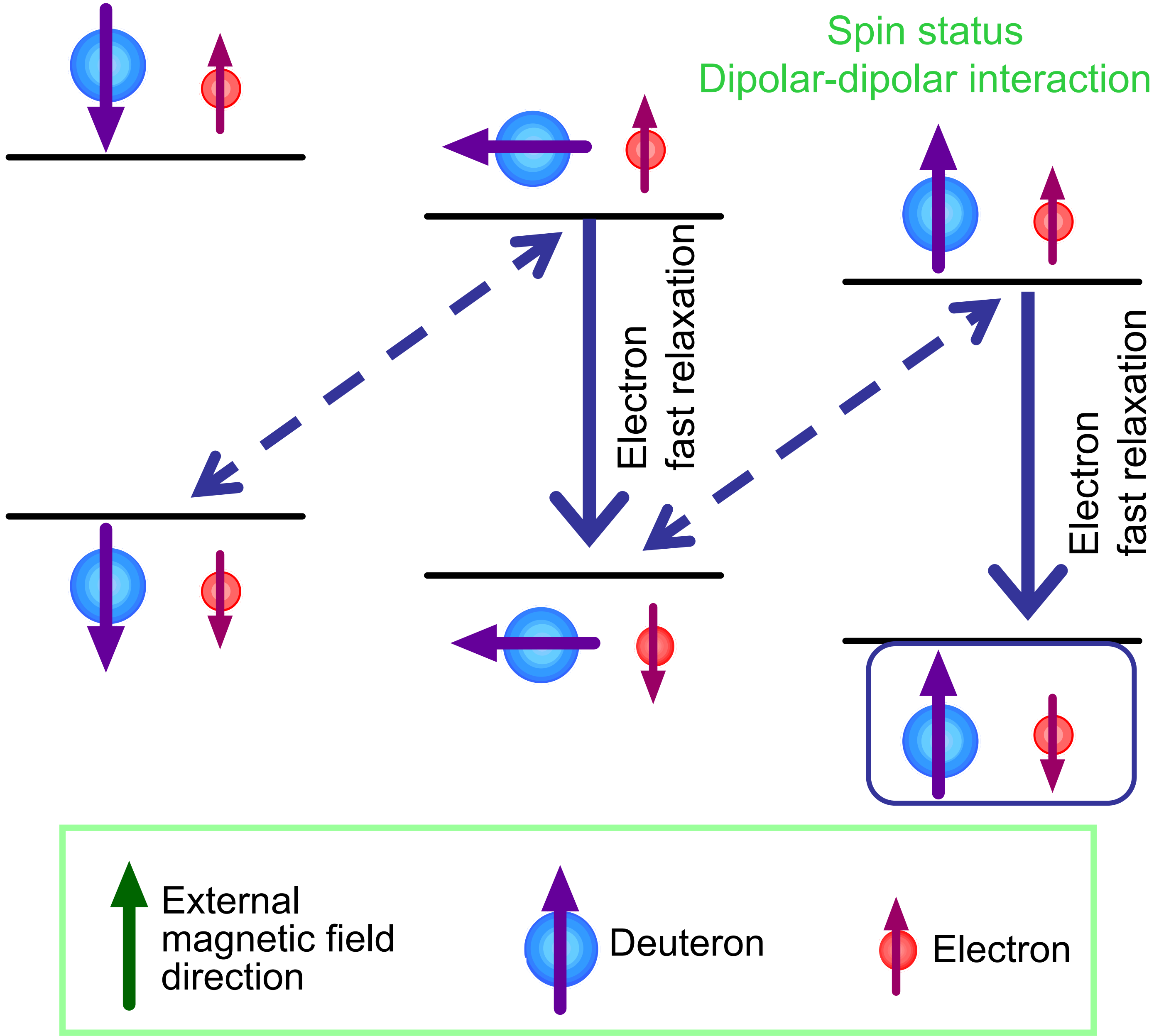
Dynamic nuclear polarization

Paramagnetic centers are needed

Polarization
@2.5T and 0.3K
Electron: 99.9%
Deuteron: 0.17%

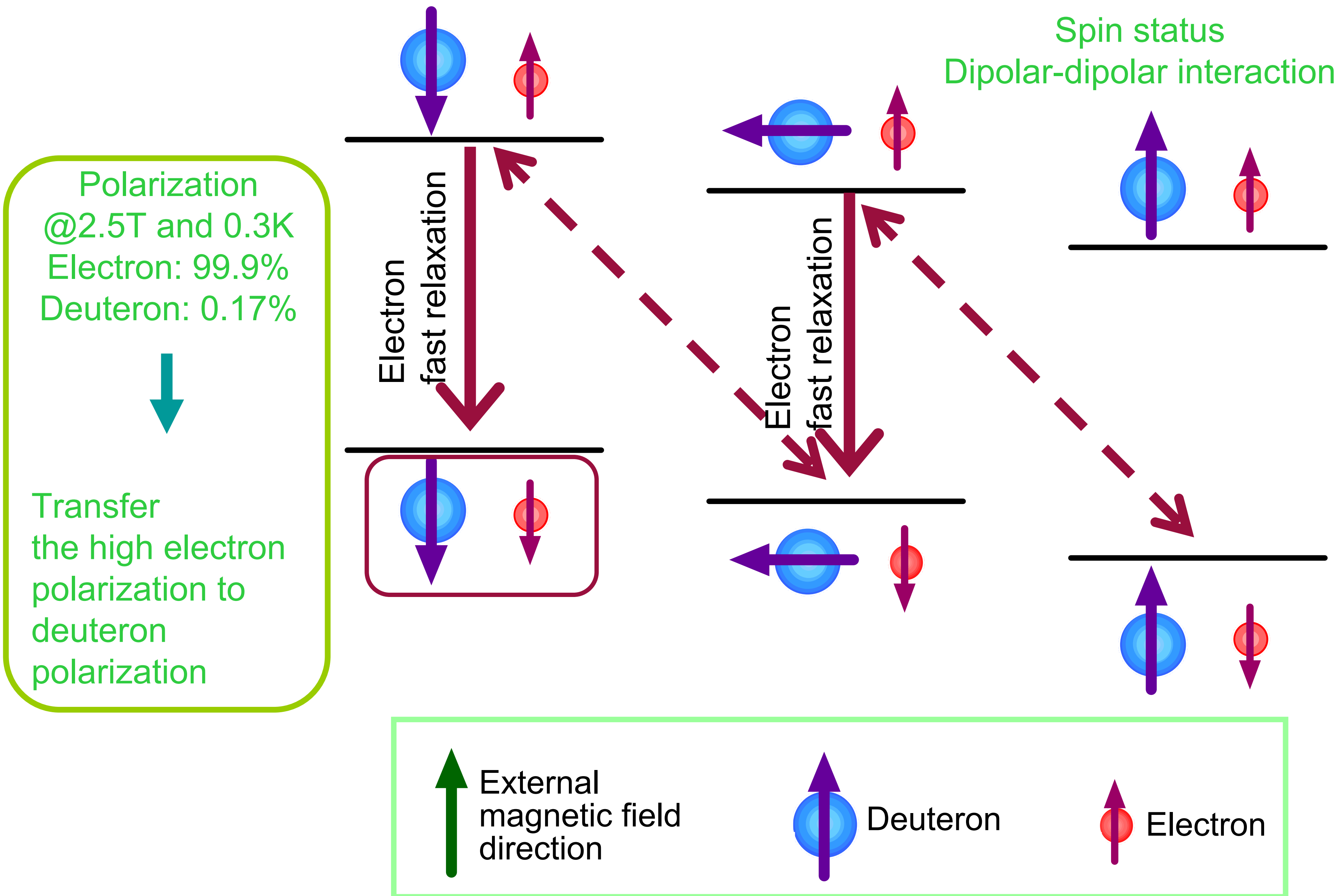
↓

Transfer
the high electron
polarization to
deuteron
polarization



Dynamic nuclear polarization

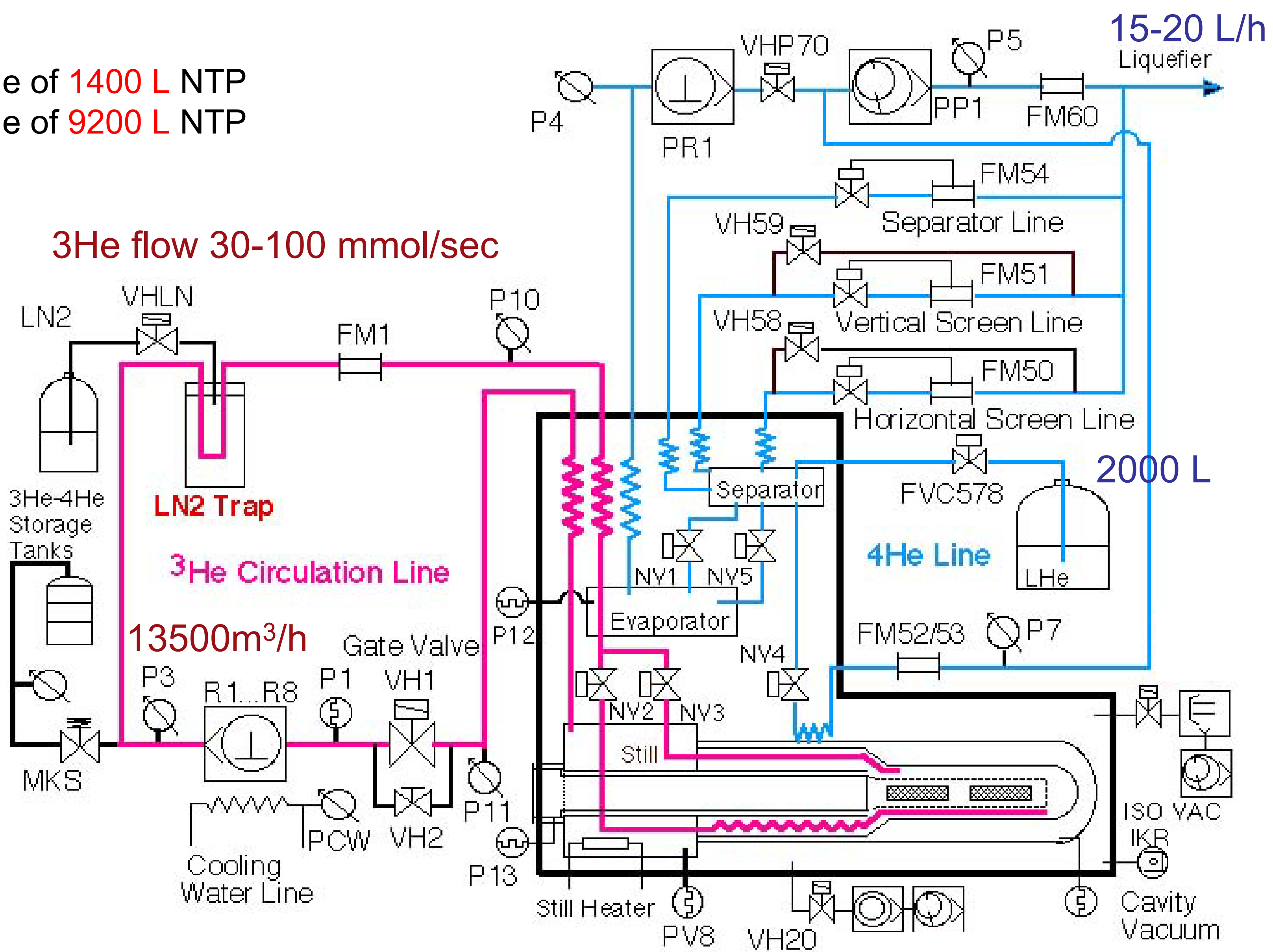
Paramagnetic centers are needed



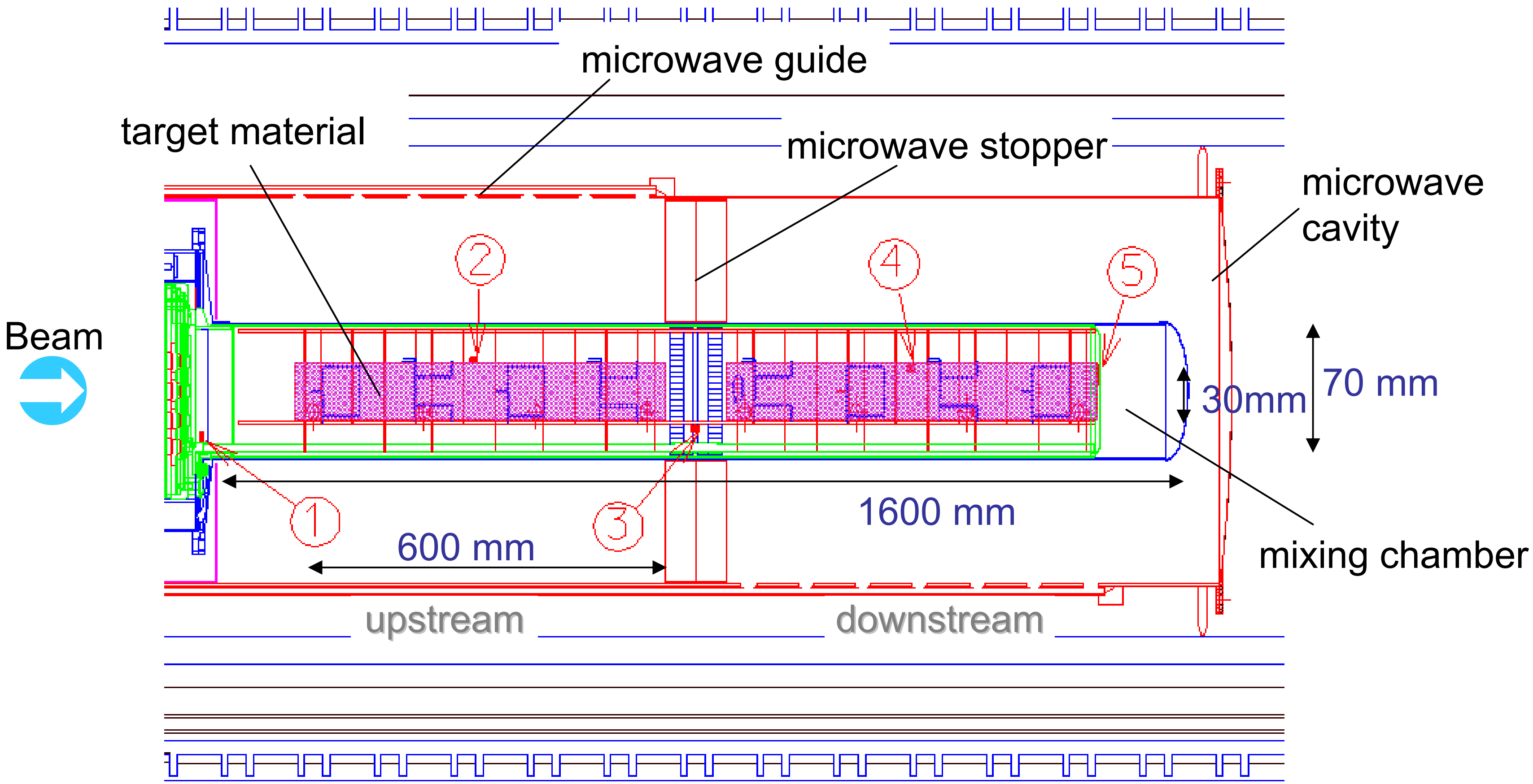
COMPASS dilution refrigerator

^{3}He of 1400 L NTP
^{4}He of 9200 L NTP

3He flow 30-100 mmol/sec



Mixing chamber



Calibrated sensors

①TTH4: RuO

②TTH1: speer 220 ohm

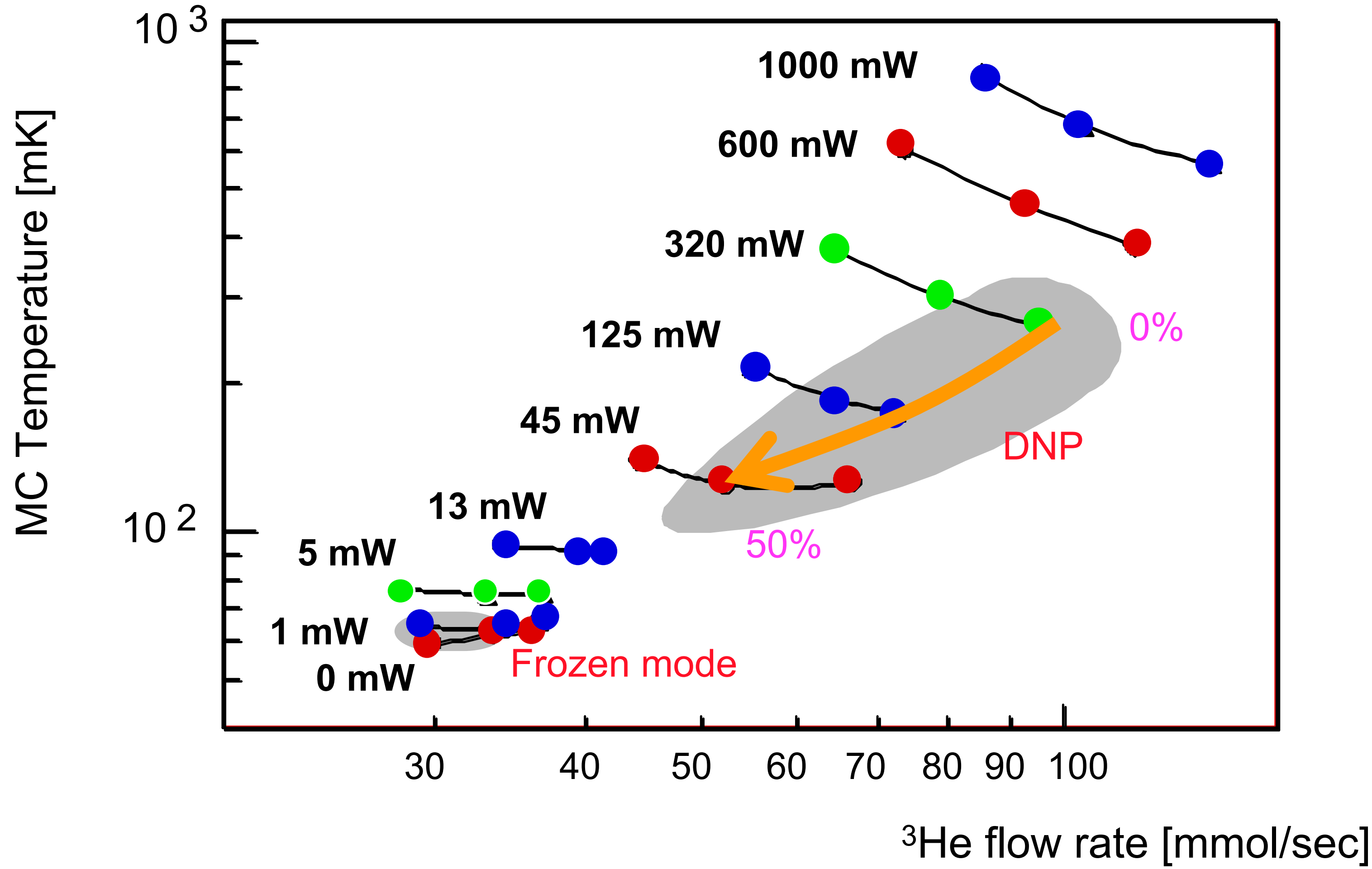
④TTH2: speer 220 ohm

Non-calibrated sensors

③TTH7: speer 220 ohm

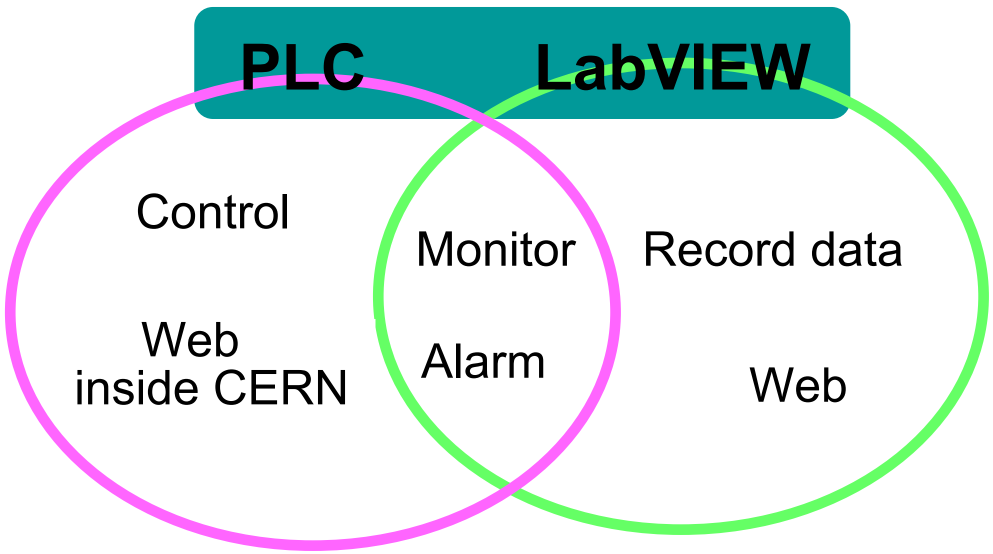
⑤TTH6: RuO

Performance of the dilution refrigerator



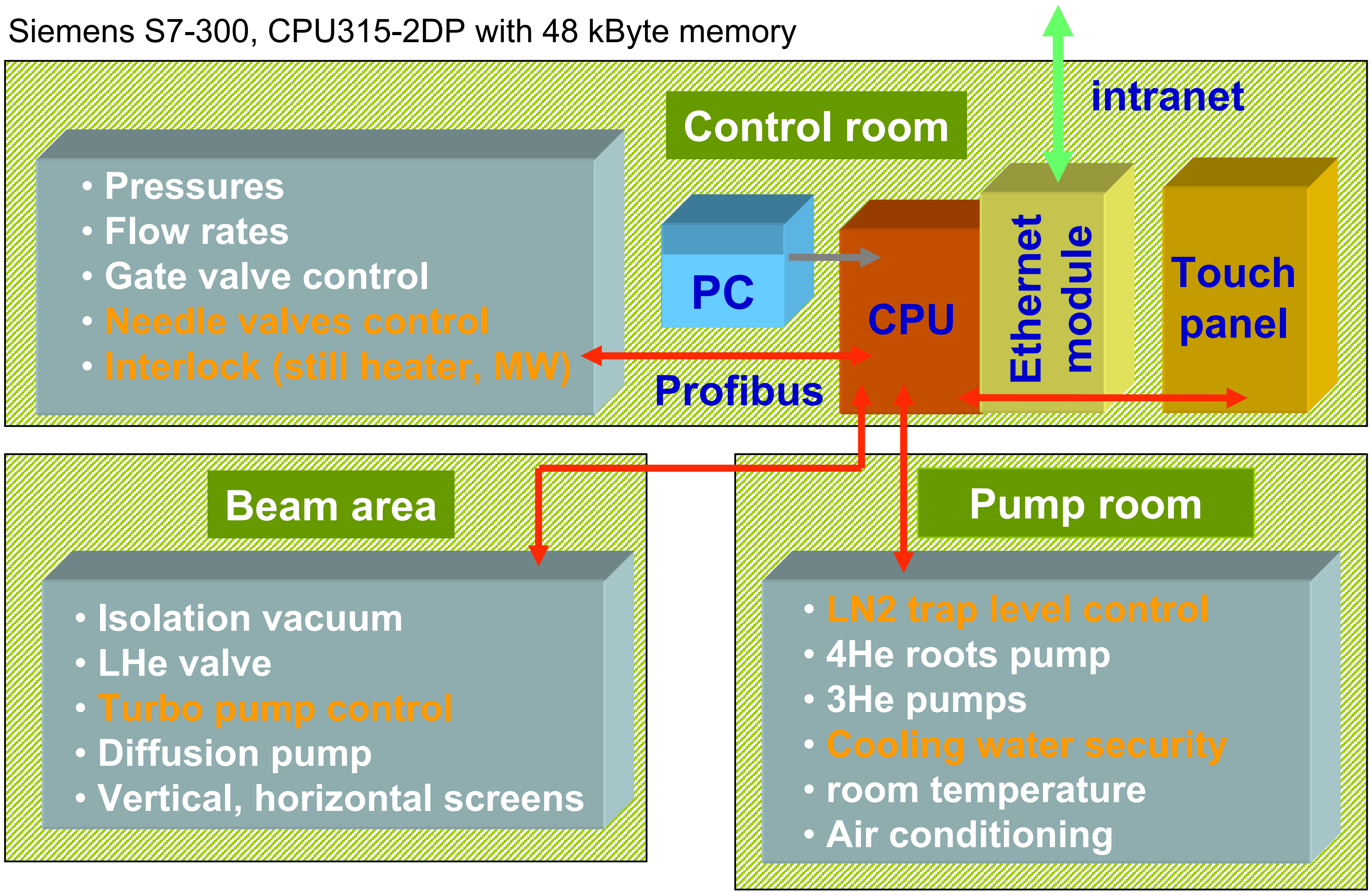
Dilution Refrigerator Control and Monitoring System

Monitor	Thermo-sensors, Pressure gauges, Flow meters, Level gauges	⇨ more than 50
Control	Valves, pumps	⇨ more than 10
Location	Beam area, Pump room, Control room	
Running time	6 month × several years	



PLC (programmable logic controller) System

Siemens S7-300, CPU315-2DP with 48 kByte memory



Power : 48V UPS,
49 channels are used

Superconducting magnet

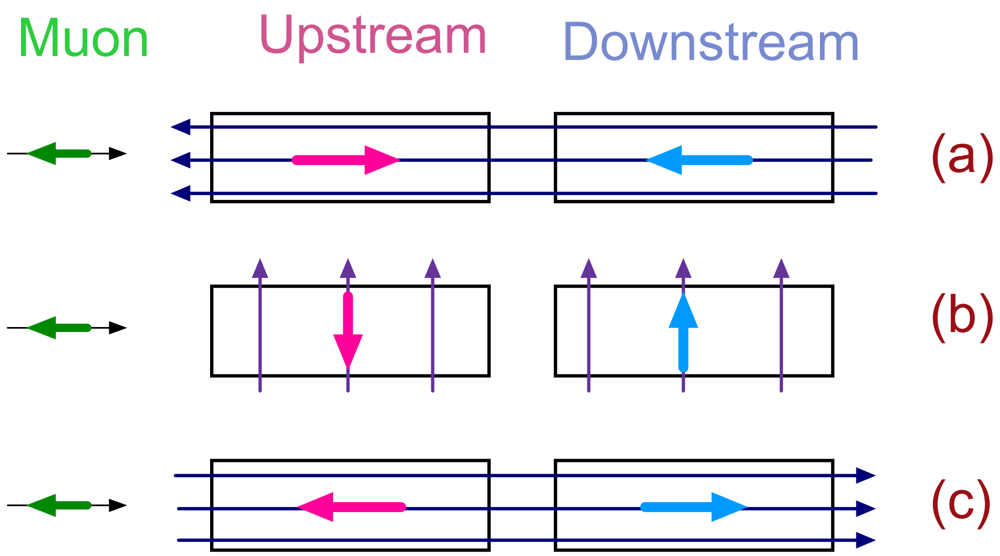
Solenoid magnet longitudinal (horizontal) 2.5T
- field homogeneity : $\Delta B/B < 3.5 \times 10^{-5}$
  with 16 correction coils

Dipole magnet transverse (vertical) 0.5T
- field rotation (changing the spin orientation)
- transverse physics program

Field Rotation

In order to cancel the systematic error

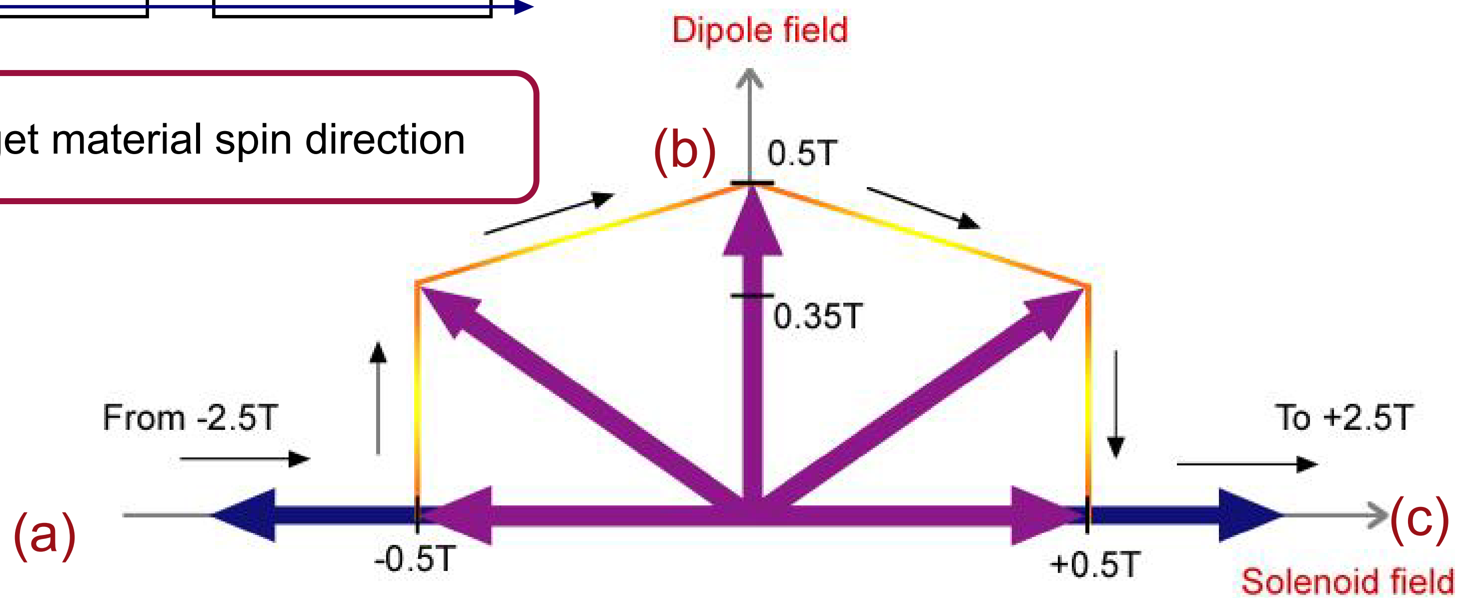
-Spectrometer acceptance
-Time dependence variation



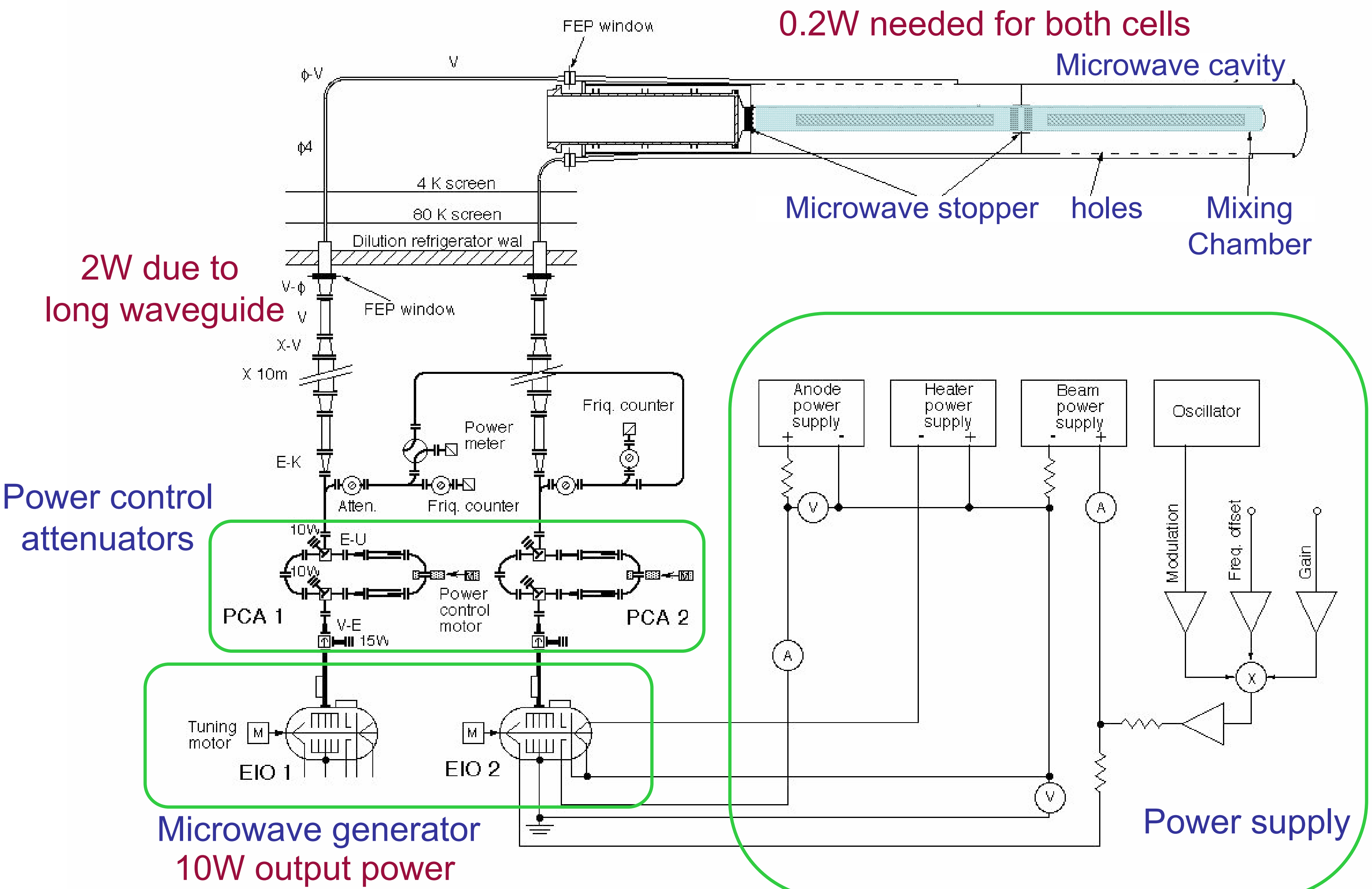
(b) ⇒ Transverse program

Target material spin direction

33 minutes
every 8 hours

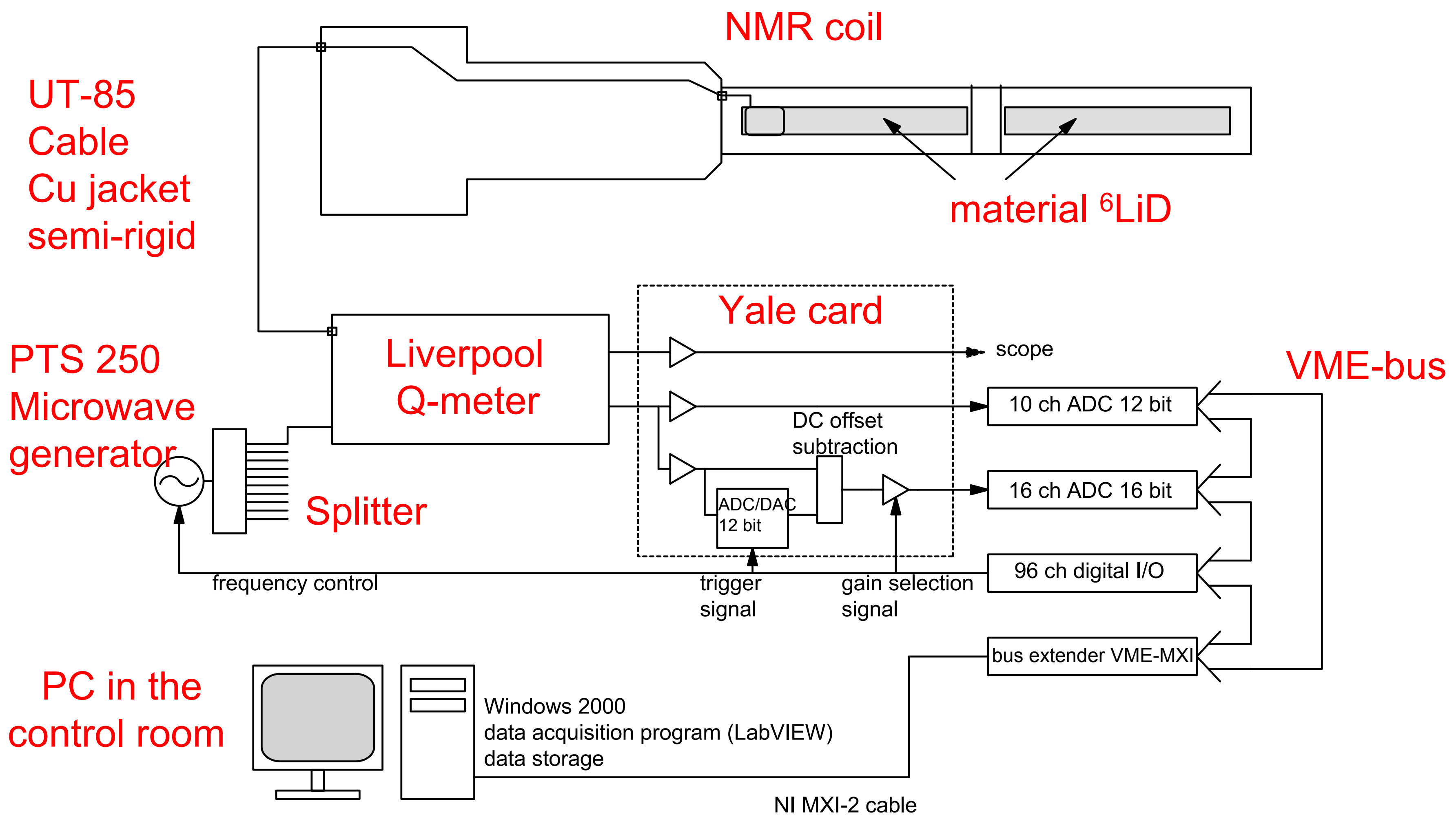


Microwave system



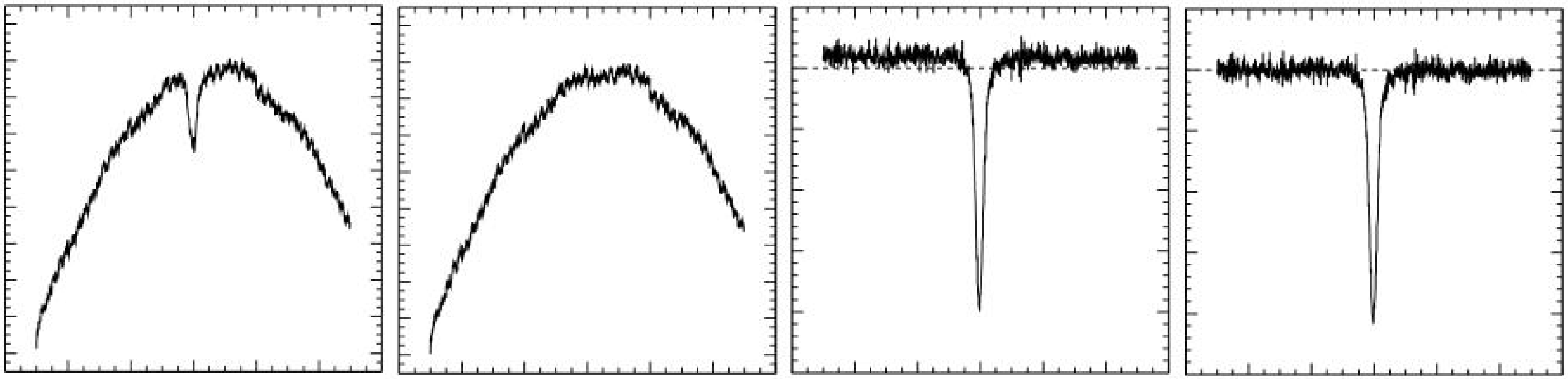
NMR System

10 coils can be operated at the same time.



NMR signal process

Q curve + Signal | Q curve | After subtracting Q curve | signal



Subtract Q curve

Subtract residual background by a polynomial function

Polarization determination with Aria method

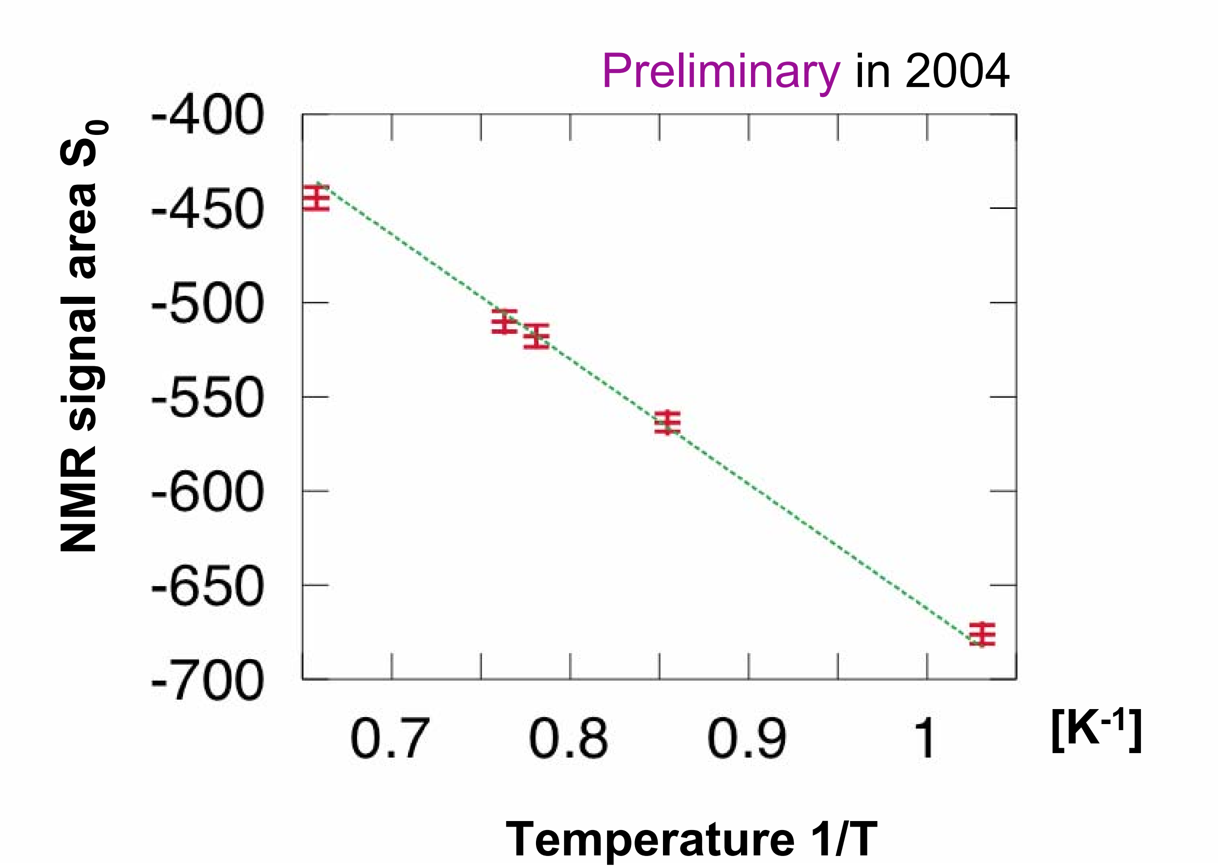
$$P = \frac{P_0}{S_0} S$$

P_0 : polarization at thermal equilibrium → **Calculated by temperature and magnetic field**

S_0 : NMR signal area at thermal equilibrium

Calibration

With several different temperature points



$$S_0 \propto T^{-1}$$

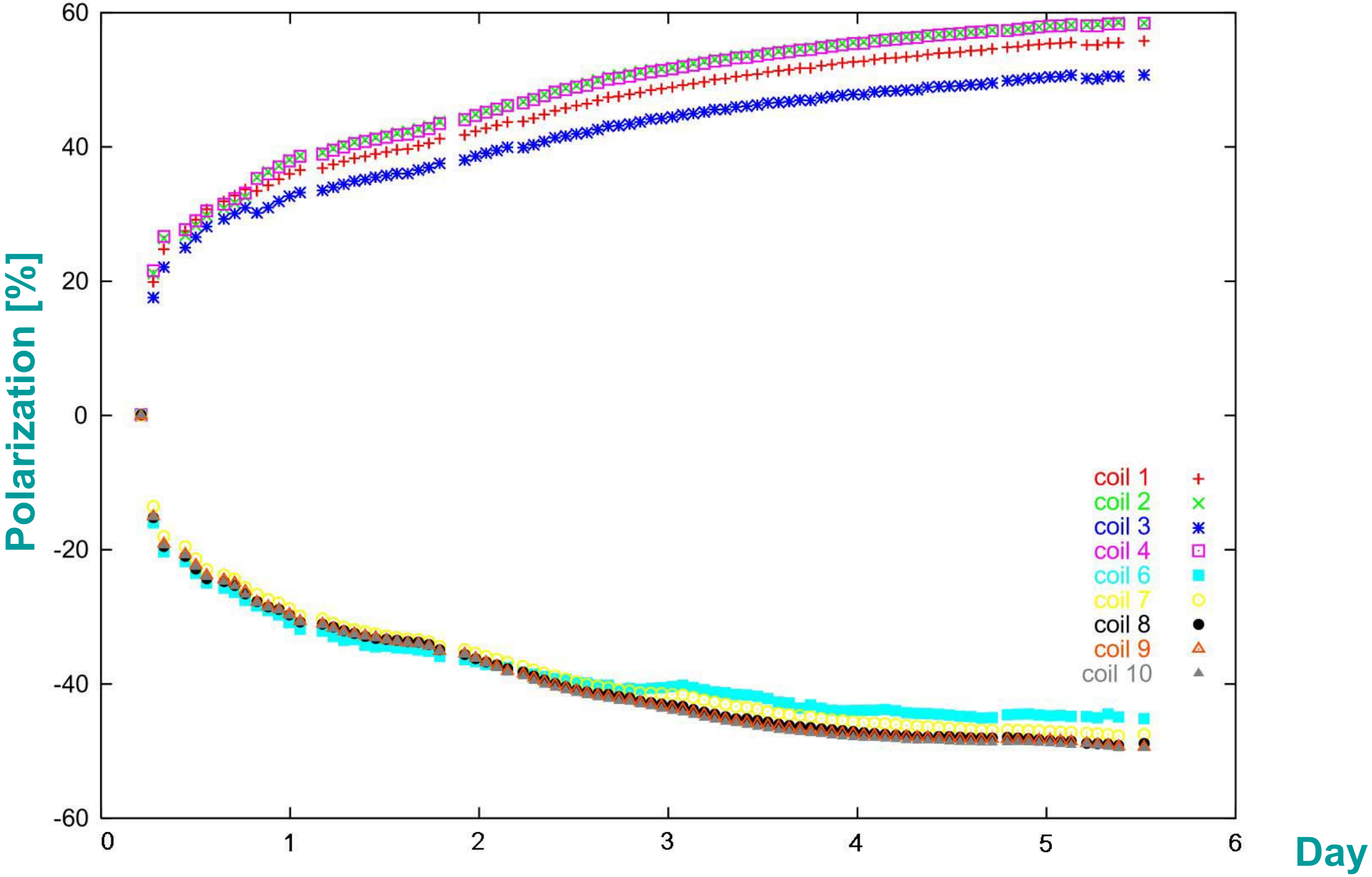
Polarization measurement errors

(in 2003)

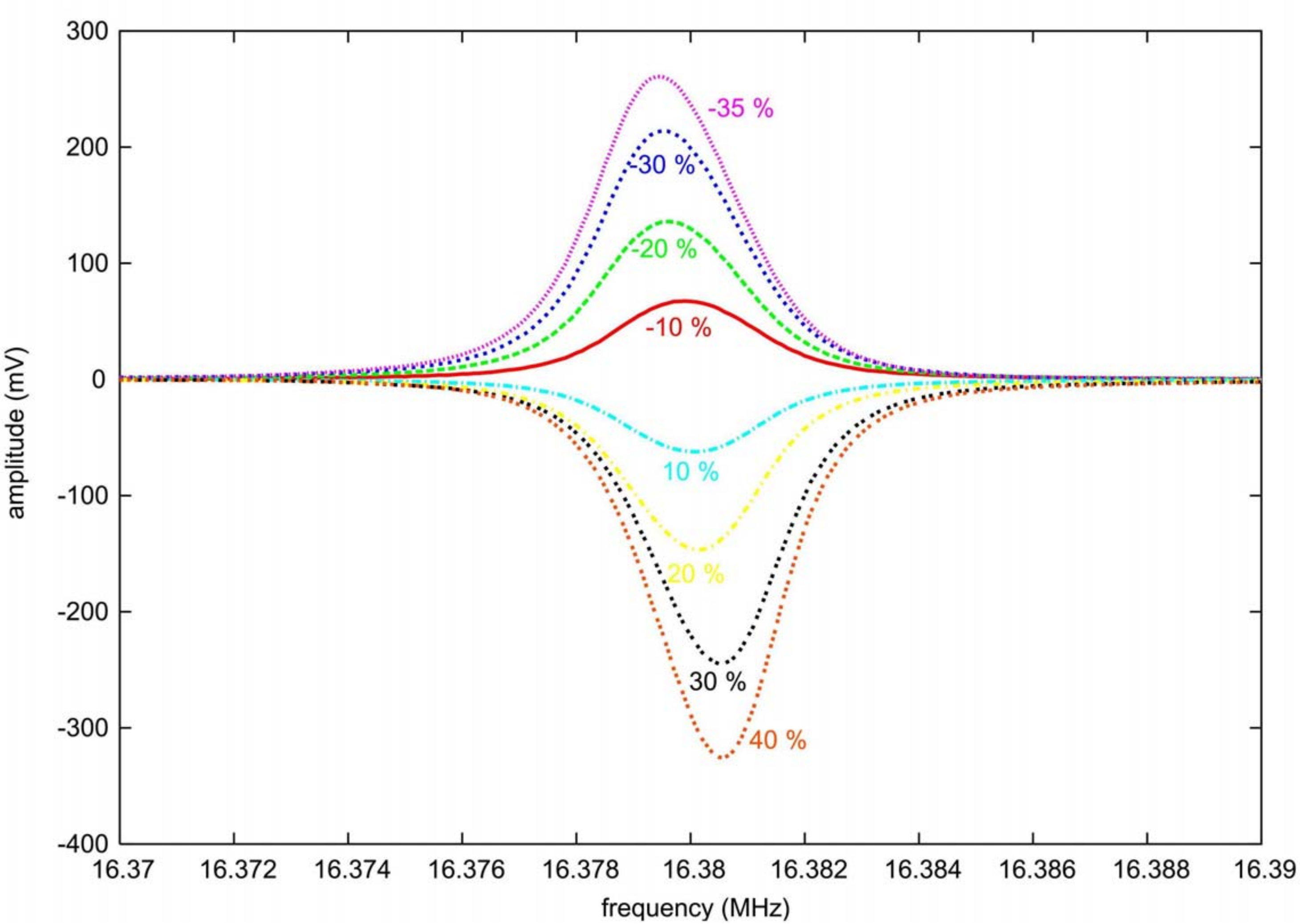
	Upstream (%)	Downstream (%)
TE calibration error	3.38	1.84
Circuit nonlinearity	< 0.5	< 0.5
Enhanced signal fitting	0.1	0.1
field polarity	0.2	0.2
field shift	0.18	0.07
Q-curve off-centering	0.15	0.17
LF gain variation	0.087	0.037
subtotal	3.43	1.83
microwave effect	0.1	0.1
total	3.5	1.9

relatively

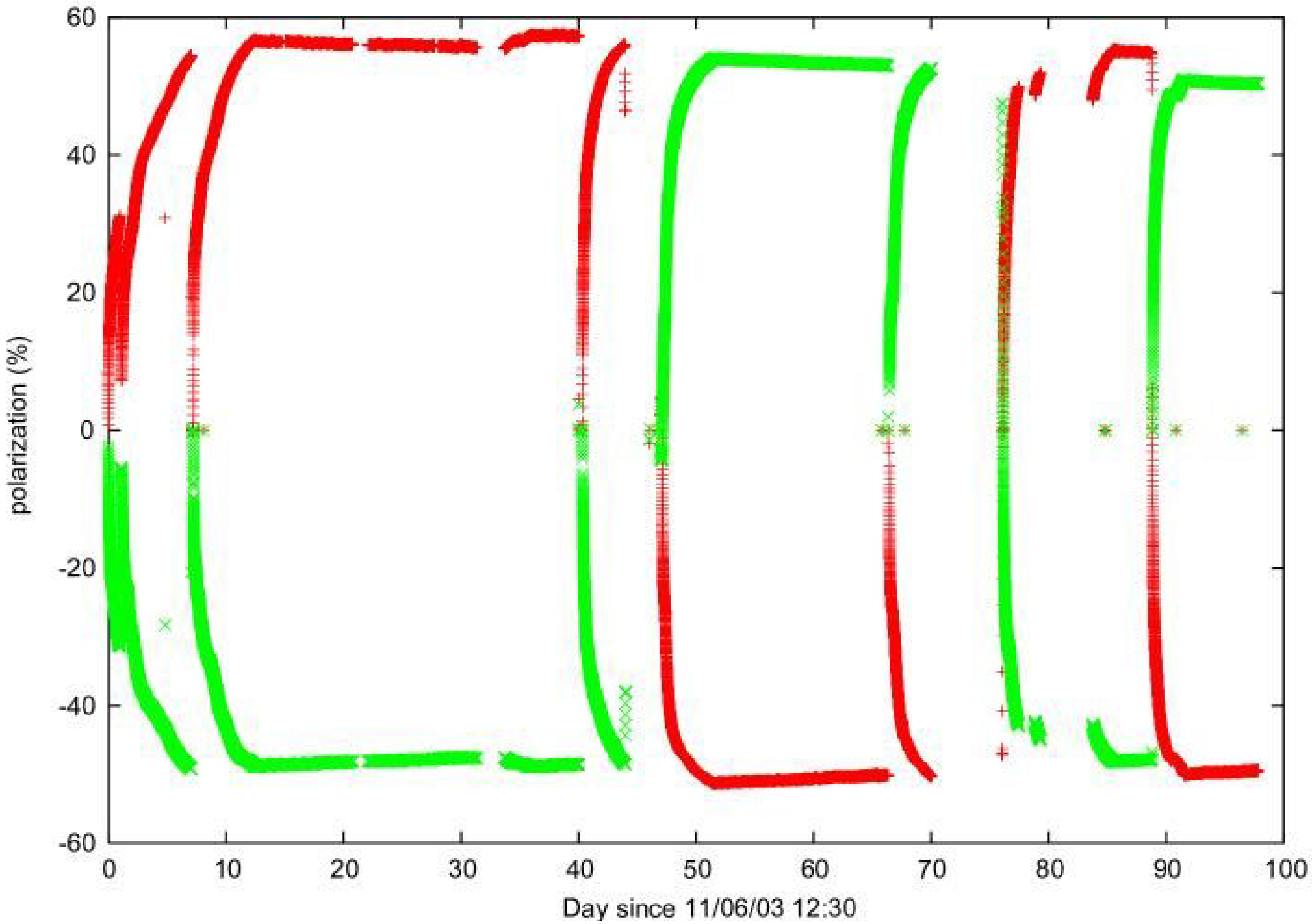
Polarization build up



Enhanced NMR signals



Average polarization in the whole physics runs in 2003



Red : Upstream
Green : Downstream

Polarization results

	+ 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

2004 polarizations almost have same values as 2003.

Summary and Outlook

-In order to obtain high statistics
Large ^{6}LiD target with 2.5 T magnet and dilution refrigerator

-In order to cancel the systematic error
Field rotation

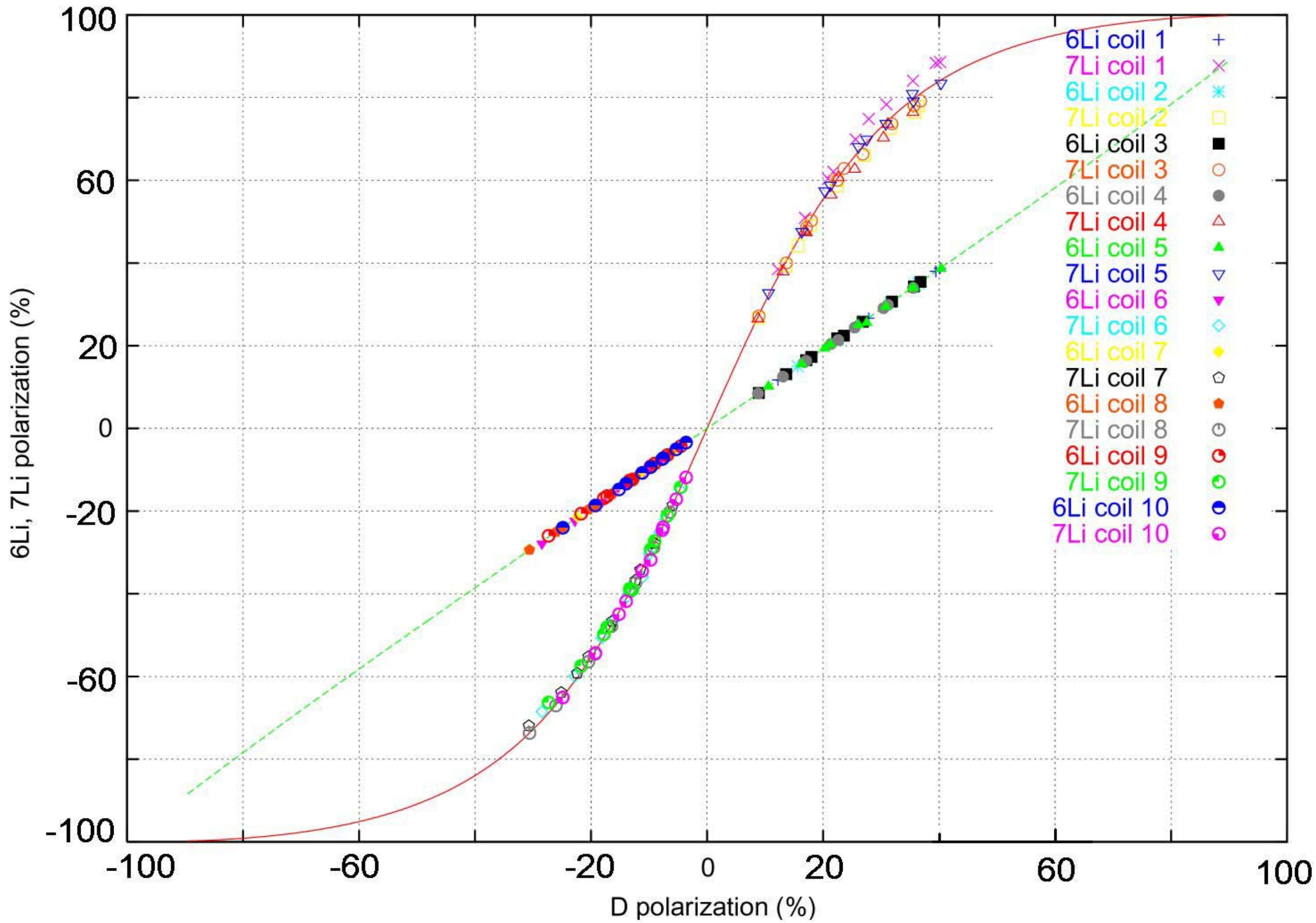
-The system has been working since 2001 without any big problems.

-2004 run
It also has same polarizations as 2003.

-New magnet
Large acceptance

-New target material test in 2005??

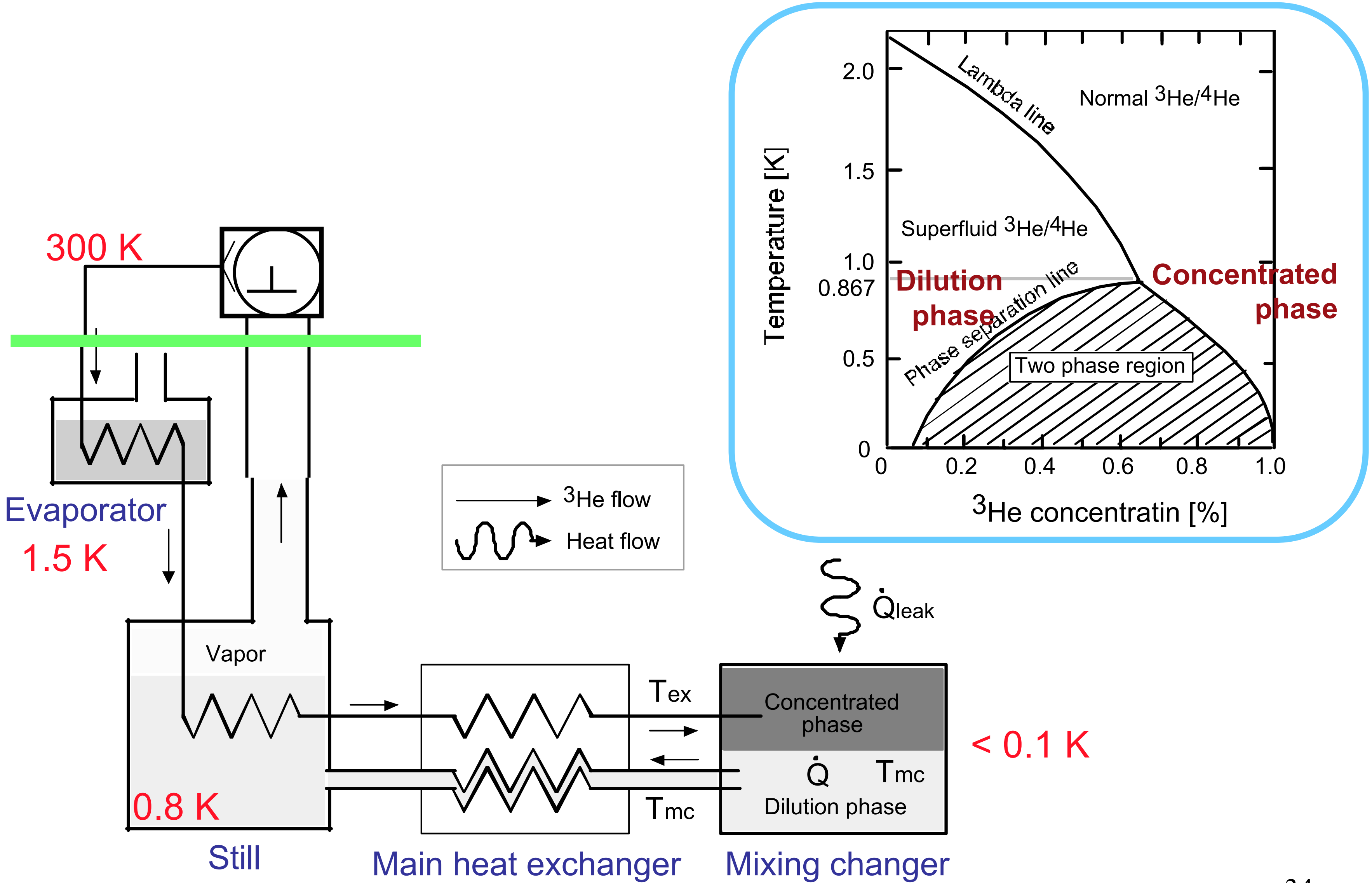
Equal Spin Temperature



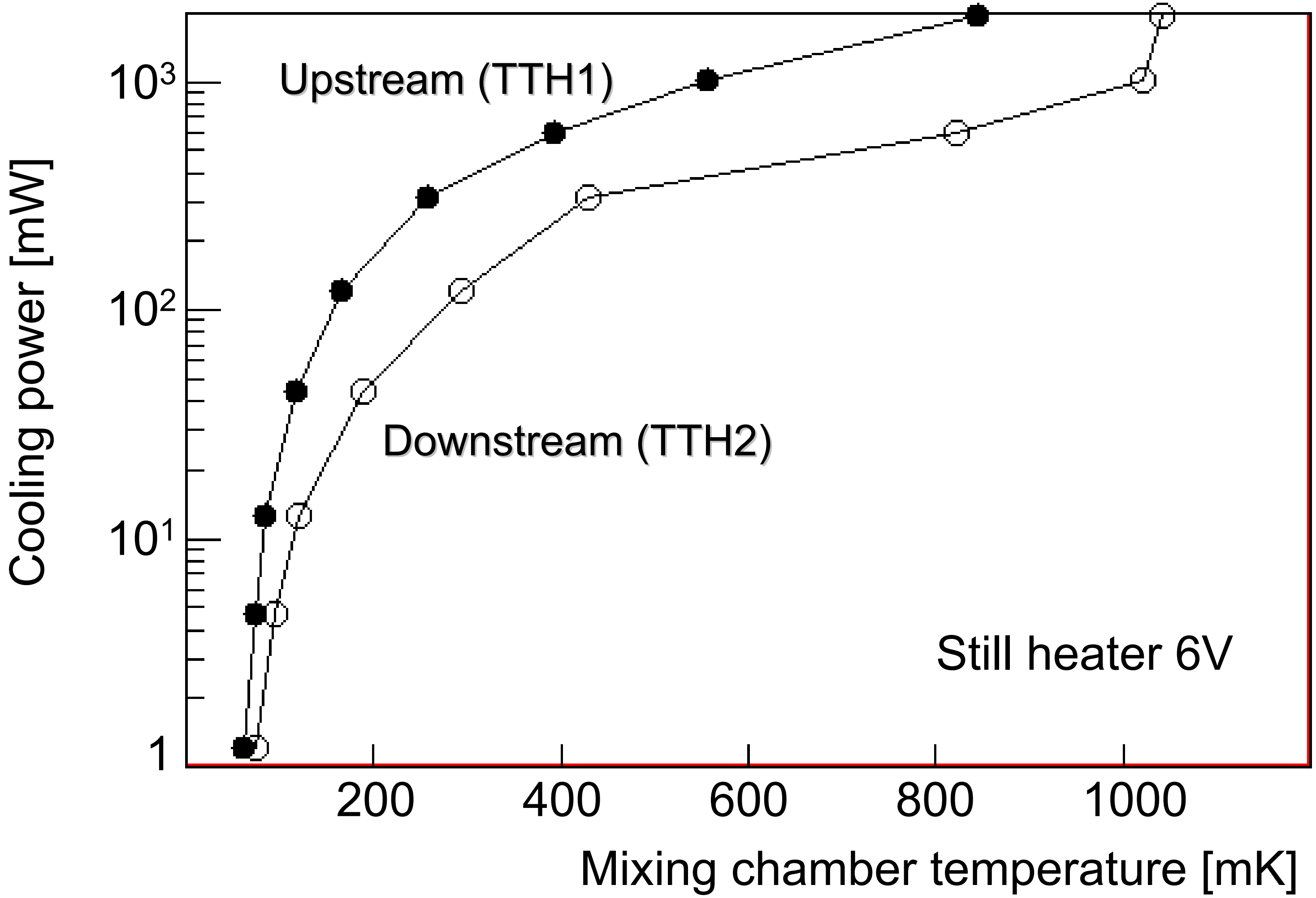
Roles of the LabView and PLC

LabView		PLC
X	Thermometers	
X	Pressure gauges	X
X	Level meters	X
	Valves	X
	Interlocks	X
X	SMS	
World wide	Web info	CERN intranet

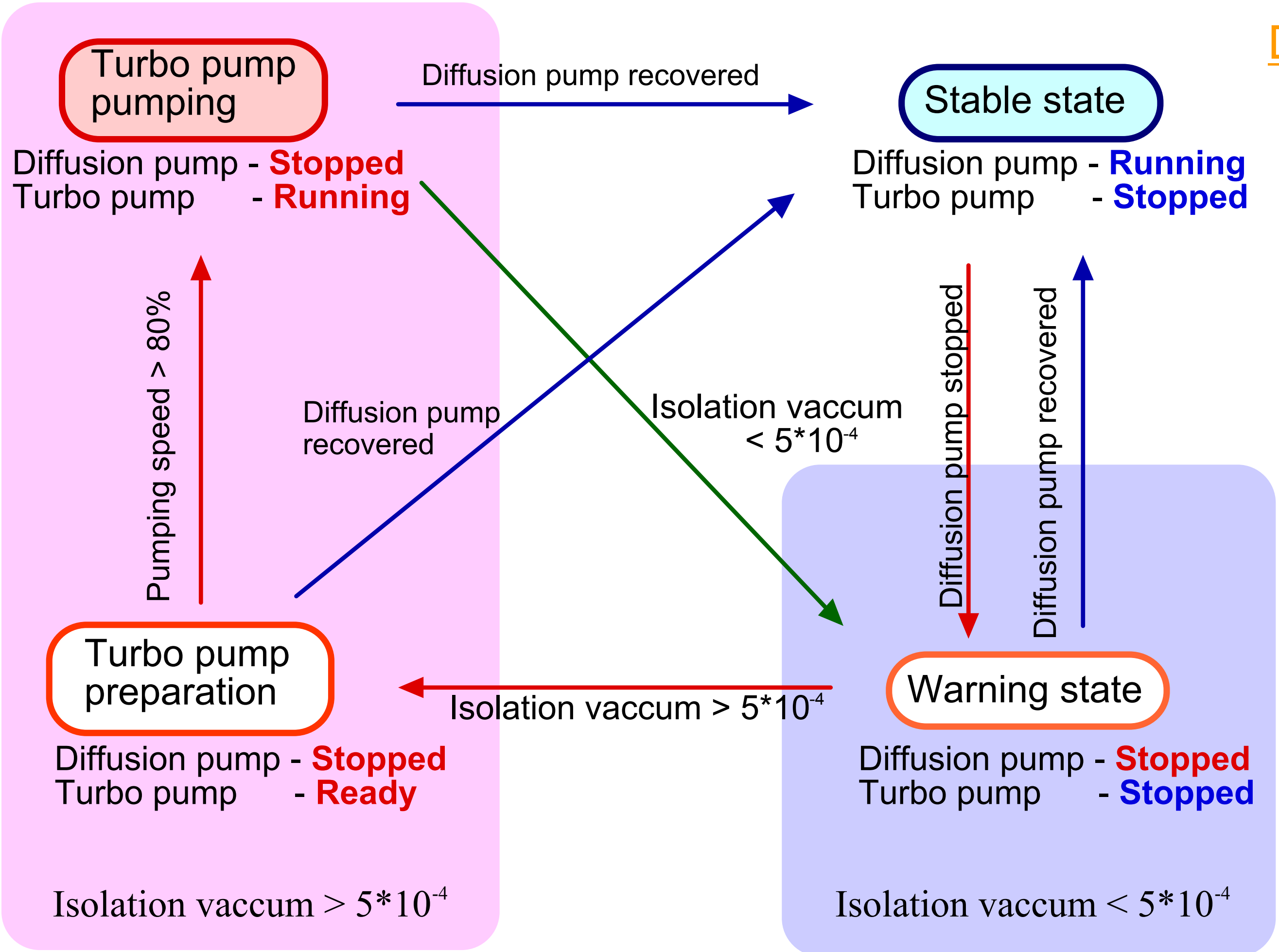
Principle of cooling



Cooling power measurement



Emergency isolation vacuum pump (Turbo pump)



Diffusion Pump

- large volume pumping
- need cooling water
- need high-pressure air

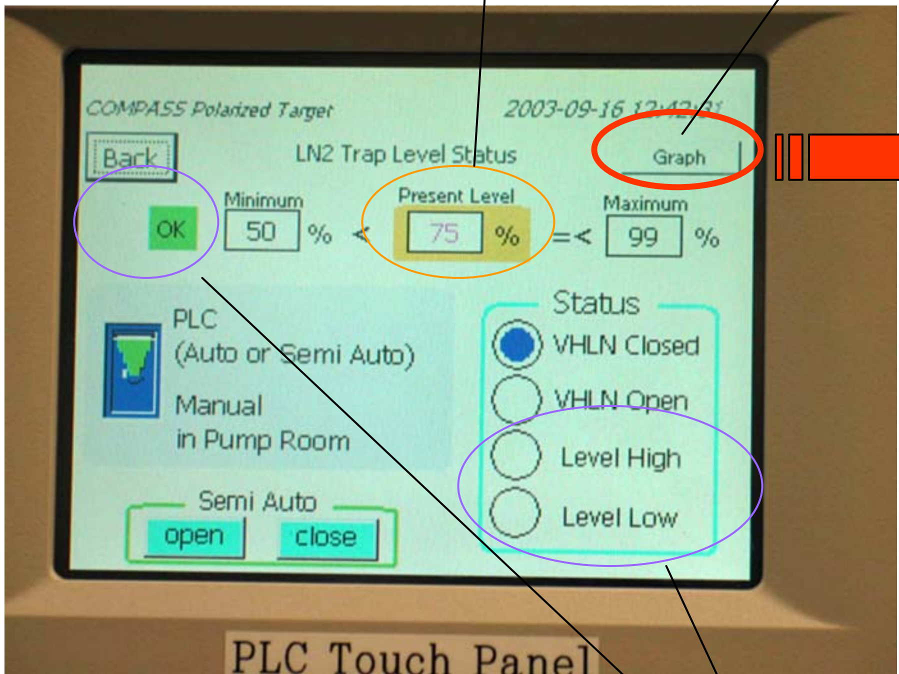
Turbo Pump

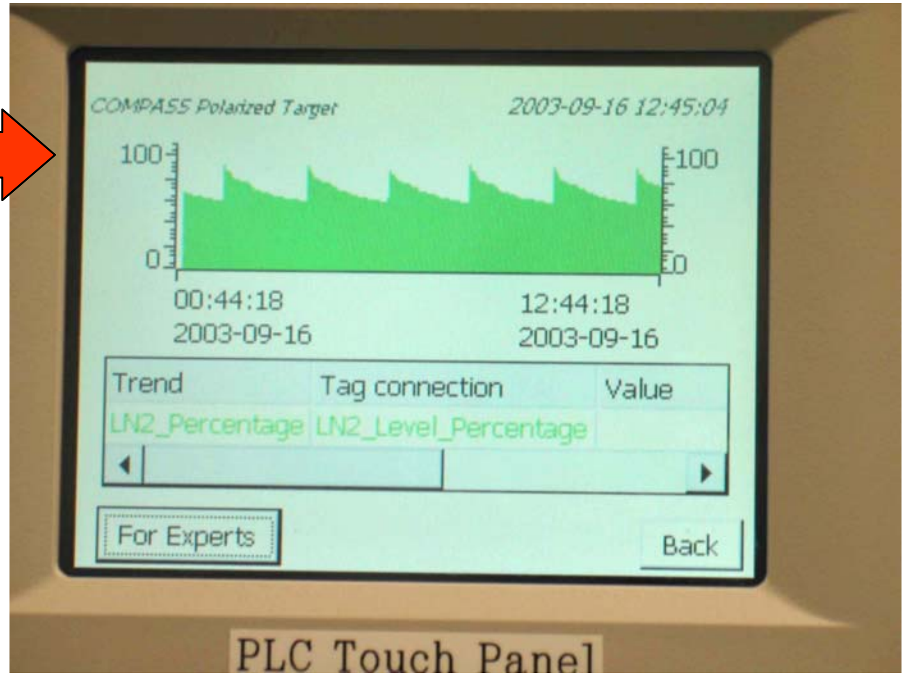
- small volume pumping
- powered by 48V UPS

Liquid nitrogen filling system

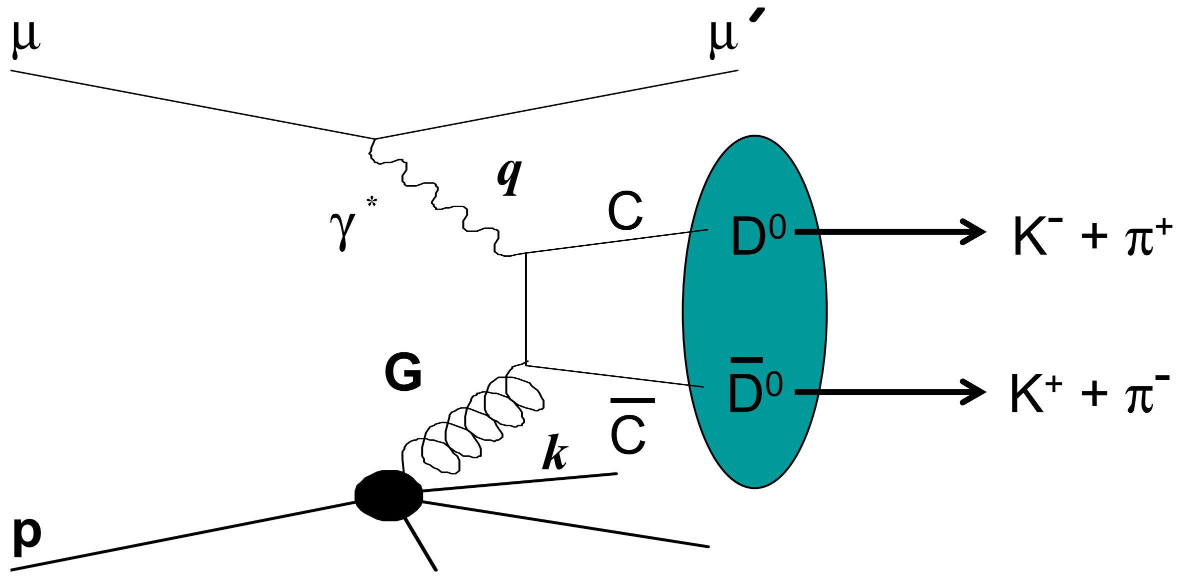
Present nitrogen level

If you press here, ….





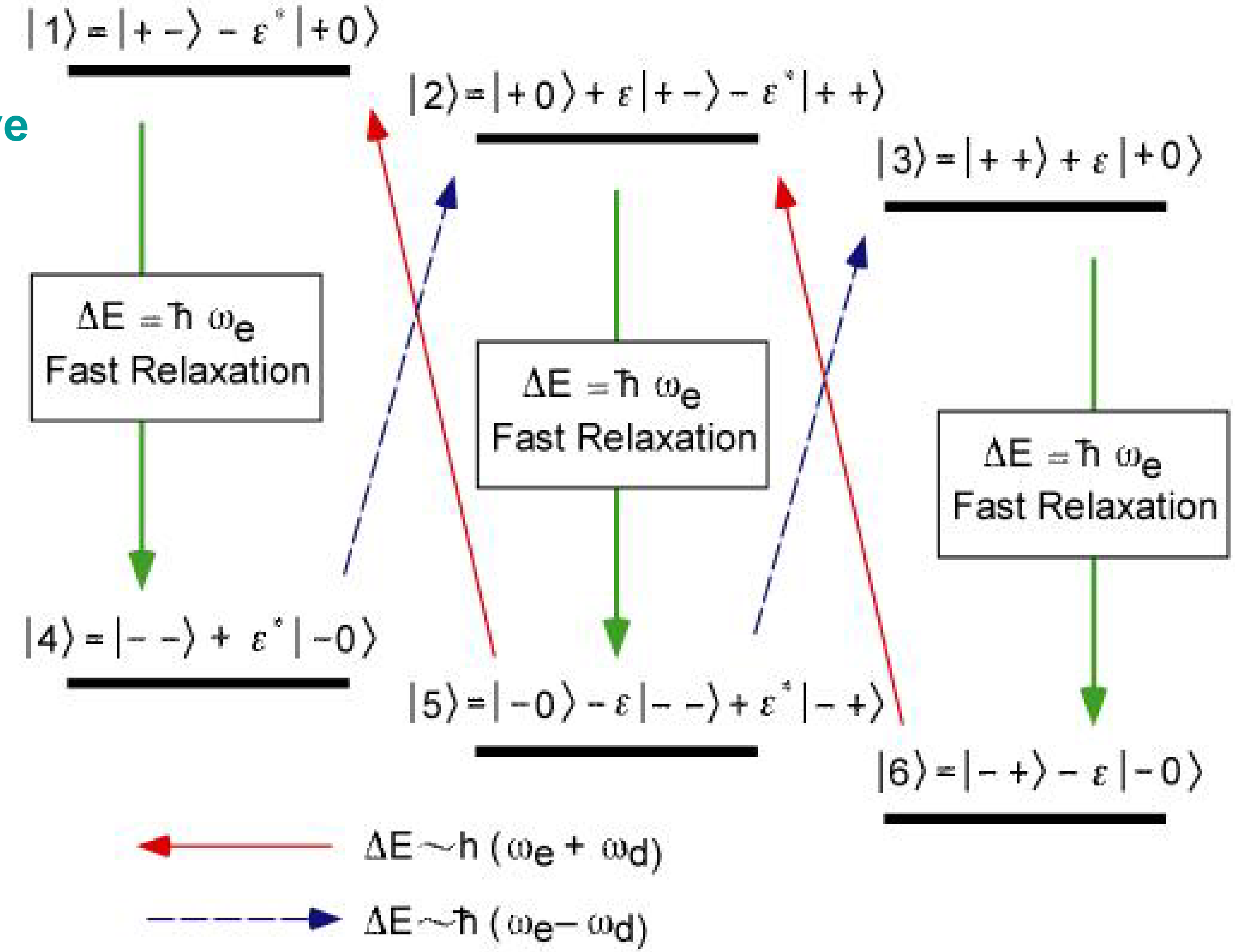
Alarm


μ
μ´
q
γ *
C
D0
K- + π+
G
D̄0
K+ + π-
C̄
k
p

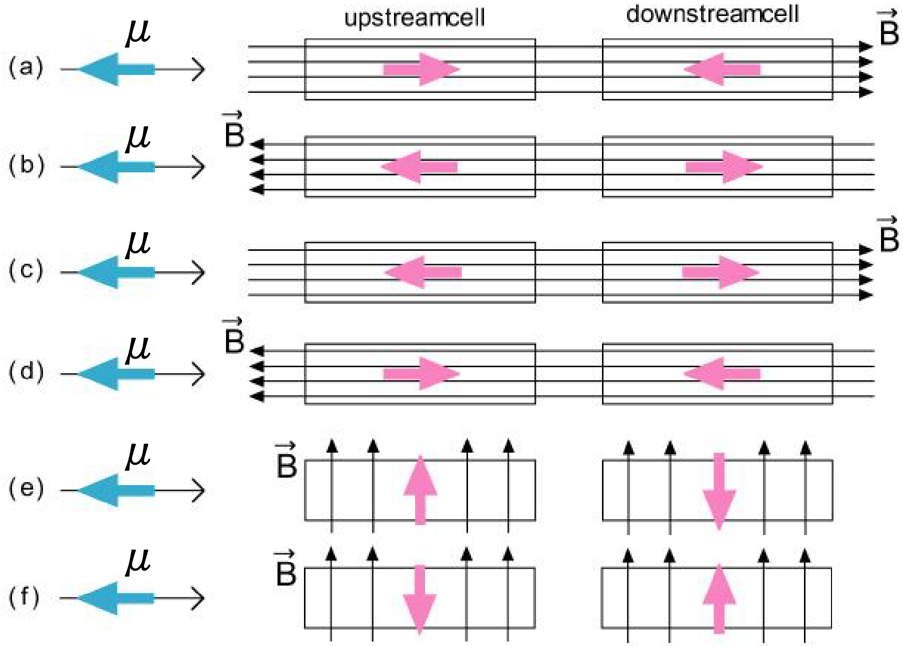
Dynamic nuclear polarization

With Microwave

電子スピンの
高偏極
(> 99 %)
を核子スピン
に移す



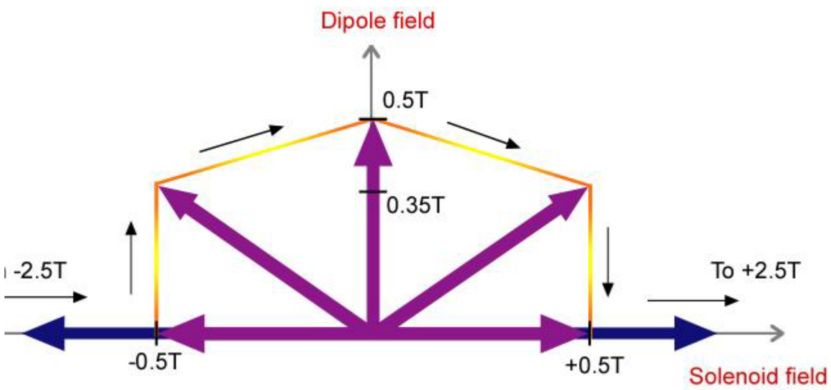
Superconductive Magnet

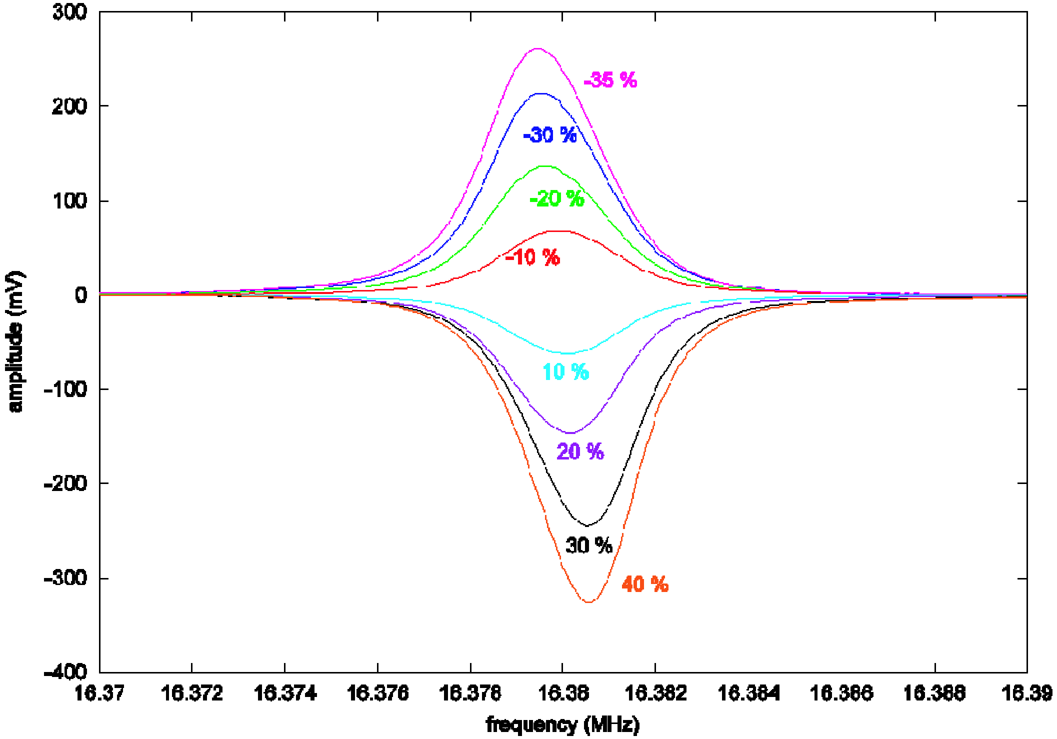


偏極方向

垂直方向磁場を用いた
磁場回転

偏極度を減らさずに
磁場方向を変えて
核子スピンを反転させる




300
200
100
0
-100
-200
-300
-400
amplitude (mV)
16.37
16.372
16.374
16.376
16.378
16.38
16.382
16.384
16.386
16.388
16.39
frequency (MHz)
-35 %
-30 %
-20 %
-10 %
10 %
20 %
30 %
40 %