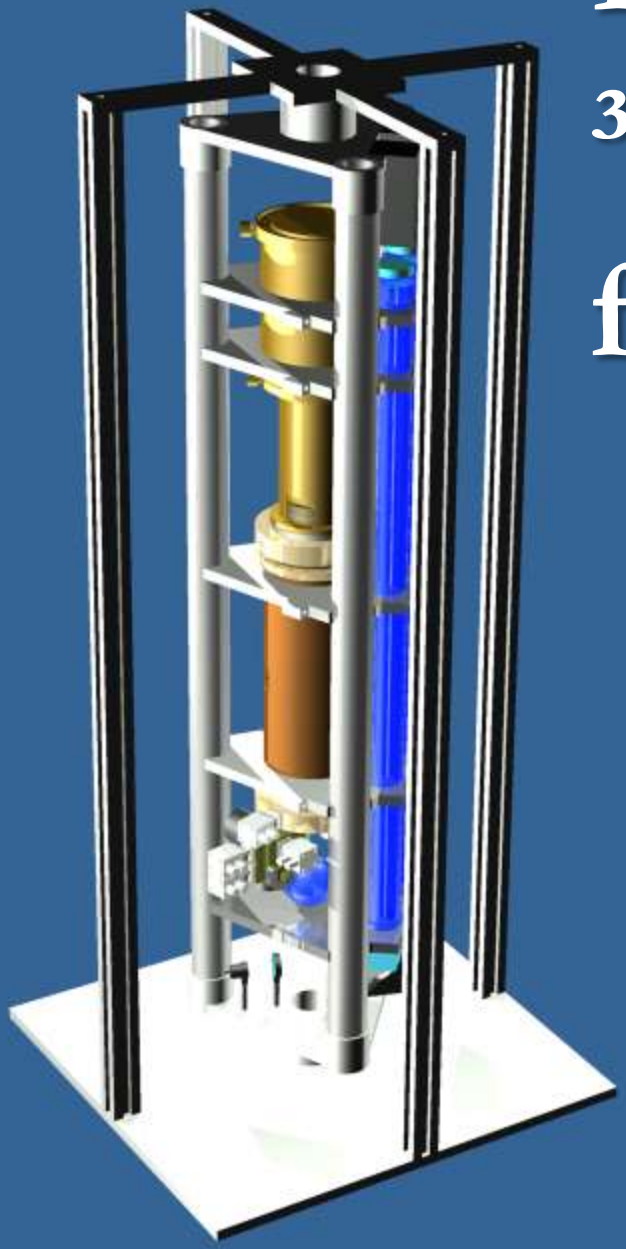


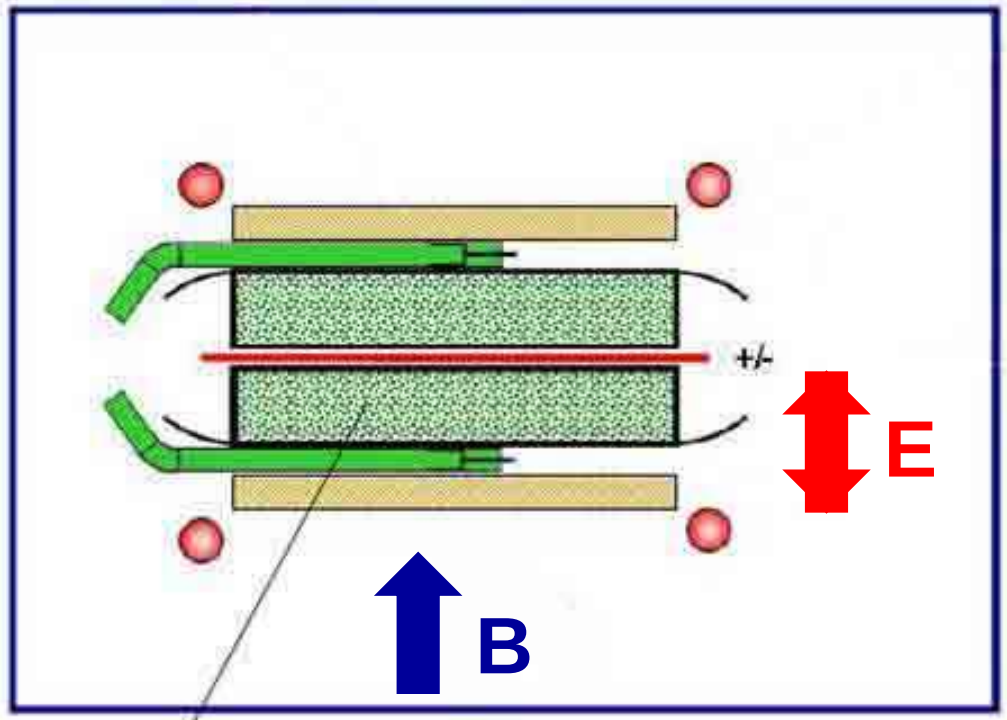
Realization of a ^{3}He-magnetometer for n2EDM

Andreas Kraft

ISINN 20,
Alushta, Ukraine
21-26.May 2012

JG|U
JOHANNES GUTENBERG
UNIVERSITÄT MAIN

Lay-out of n2EDM setup at PSI



UCN spectrometer (double chamber)

$\uparrow\uparrow$

$$h\nu^{\uparrow\uparrow} = 2\mu_N \cdot B + 2d_N E$$

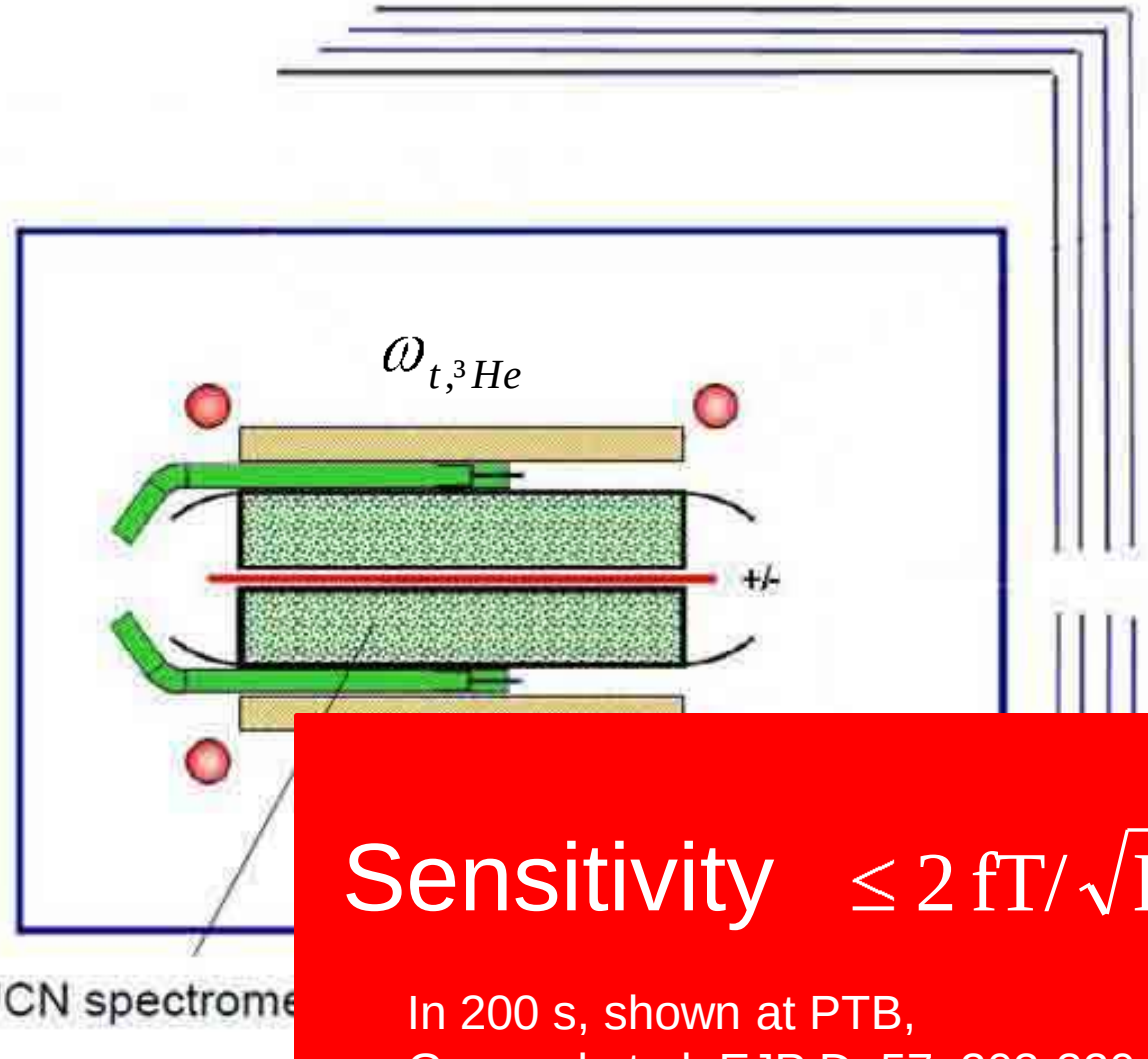
$\uparrow\downarrow$

$$h\nu^{\uparrow\downarrow} = 2\mu_N \cdot B - 2d_N E$$

Electric dipolmoment:

$$d_N = -\frac{h}{4E}\left(\nu^{\uparrow\uparrow} - \nu^{\uparrow\downarrow}\right)$$

Advantages of a sandwich-^{3}He-magnetometer



1) average field

$$\langle B_z \rangle = \frac{\langle \omega_{t,^3He} \rangle + \langle \omega_{b,^3He} \rangle}{2\gamma_{^3He}}$$

2) vertical gradients

$$\left\langle \frac{\partial B_z}{\partial z} \right\rangle = \frac{\langle \omega_{t,^3He} \rangle - \langle \omega_{b,^3He} \rangle}{\gamma_{^3He} \Delta z}$$

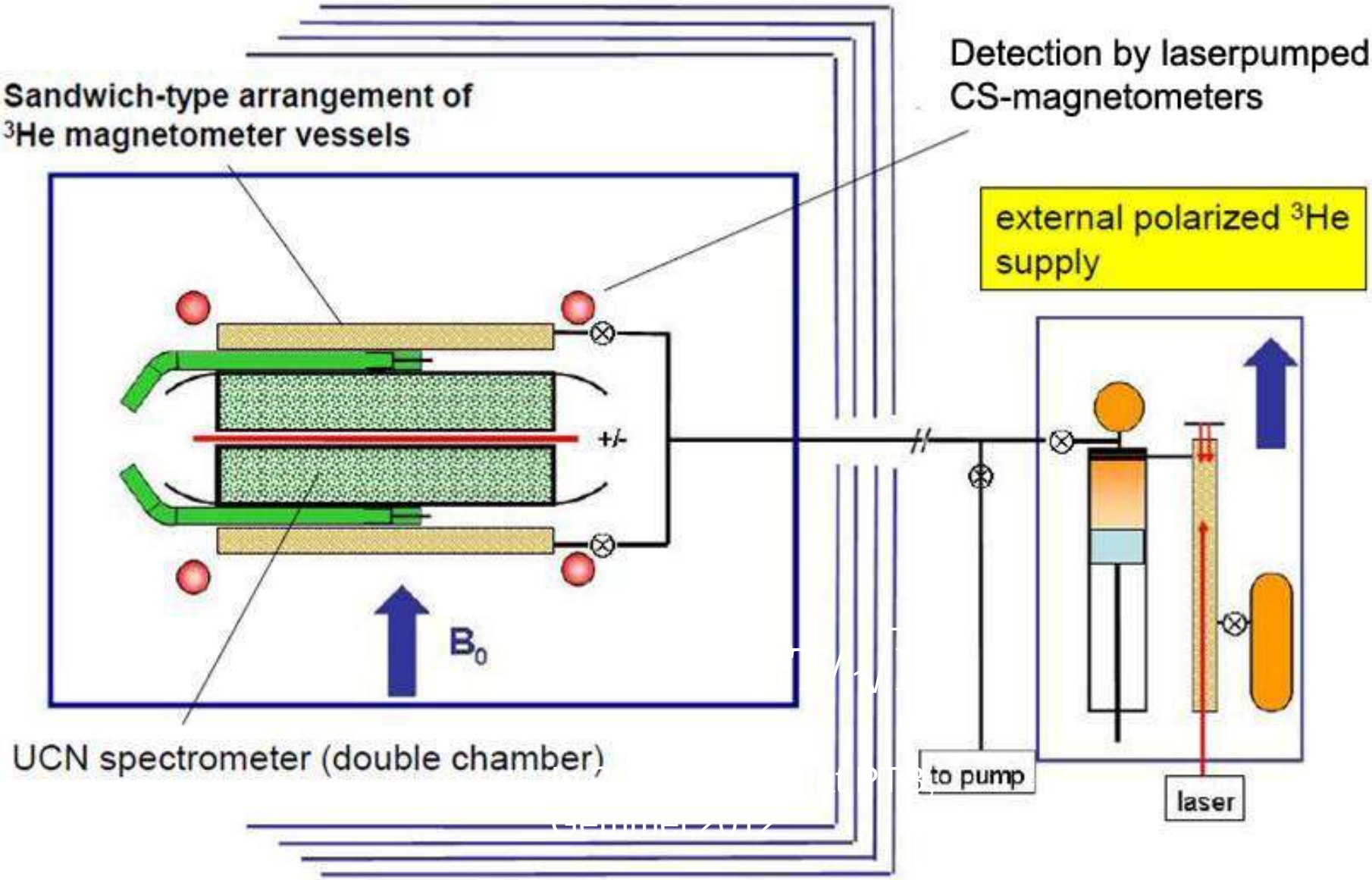
Sensitivity $\leq 2\ \mathrm{fT}/\sqrt{\mathrm{Hz}}$

In 200 s, shown at PTB,
Gemmel et al. EJP D, 57, 303-320, 2010

…tside E-field =
…ometric phase

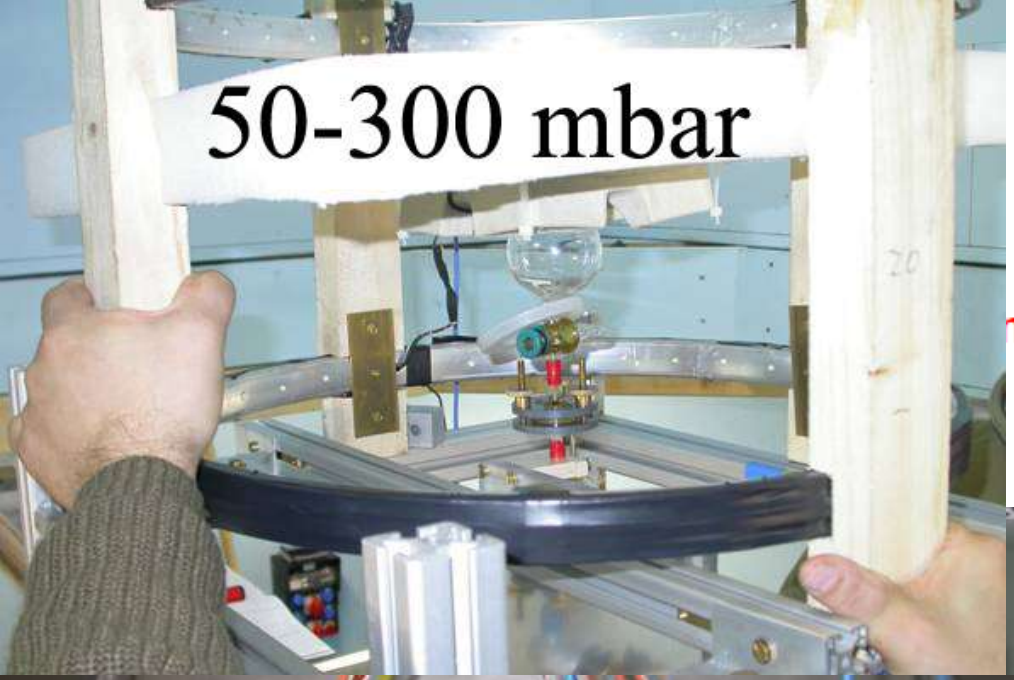
(1) Magnetometercell
(2) Valve

Lay-out of ^{3}He magnetometer for n2EDM setup



1. Proof of Principle

(PSI, November 2009)

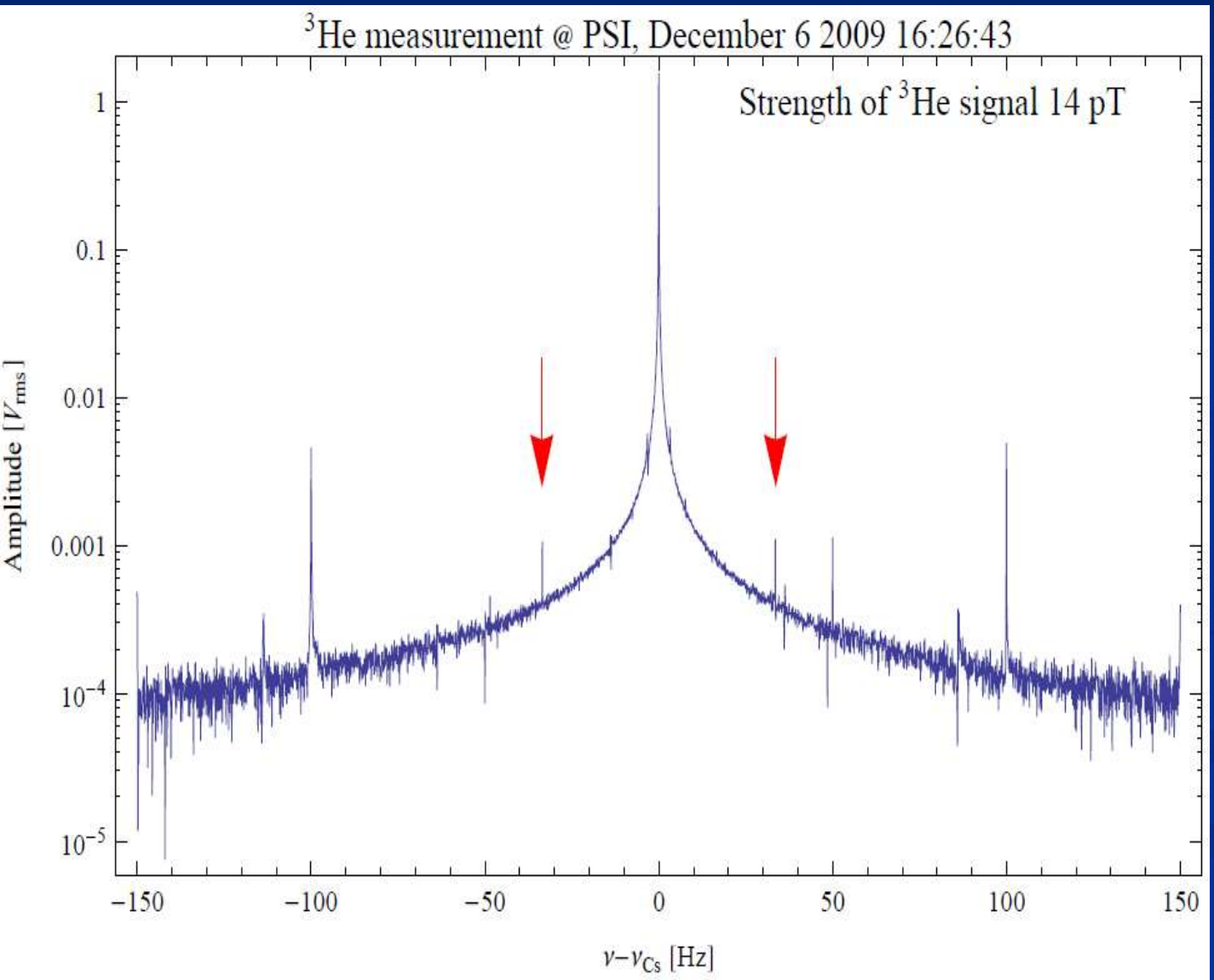


n-transfer (adiabatic)

- Helmholtz-coils: PTB→PSI

- fixation of CsM

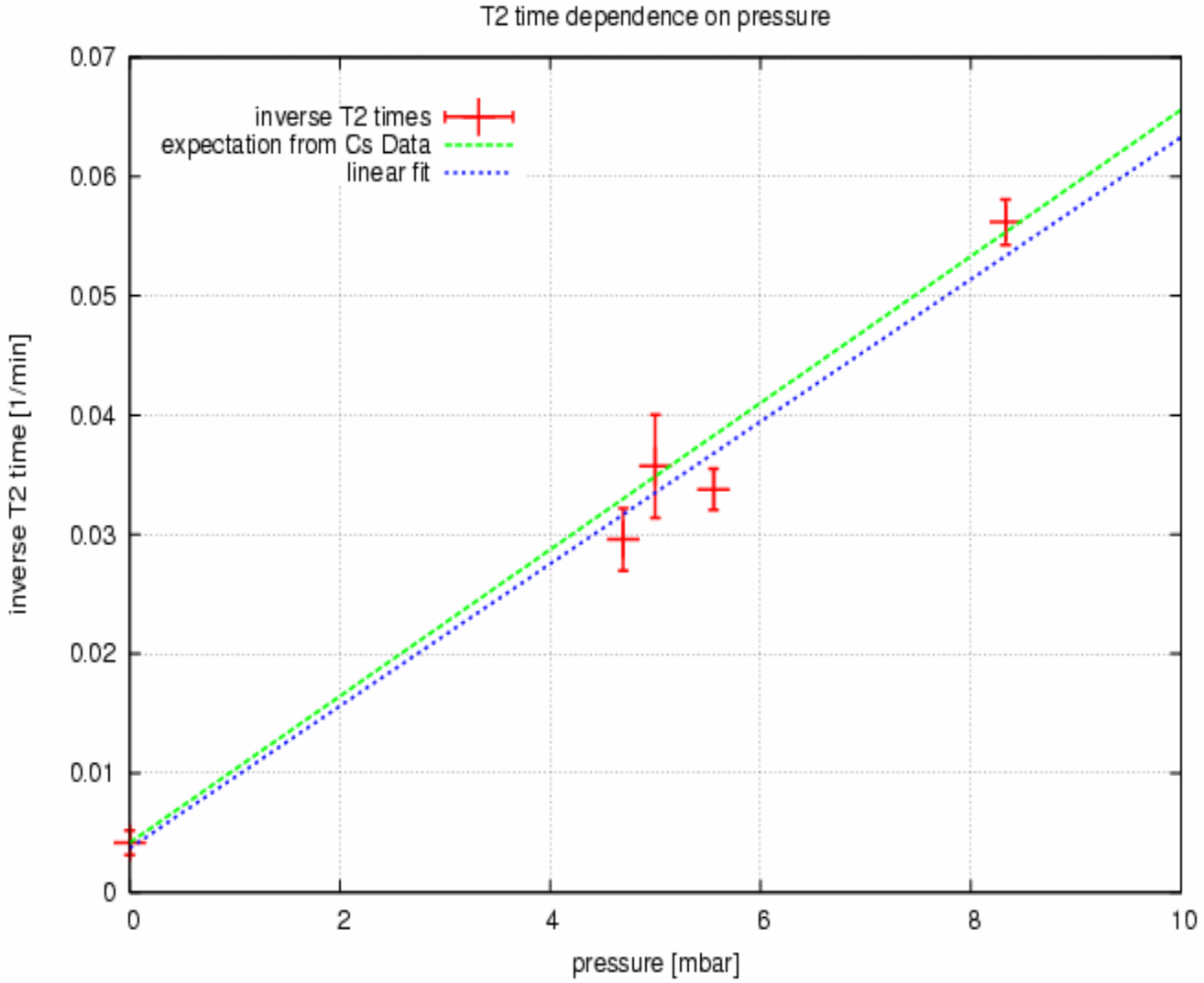
Results : SNR



~10:1

Problems with PI/2, Polarization and Cs-Noise.

Results : T2



~30 min

2. ^{3}He/Cs Testfacility

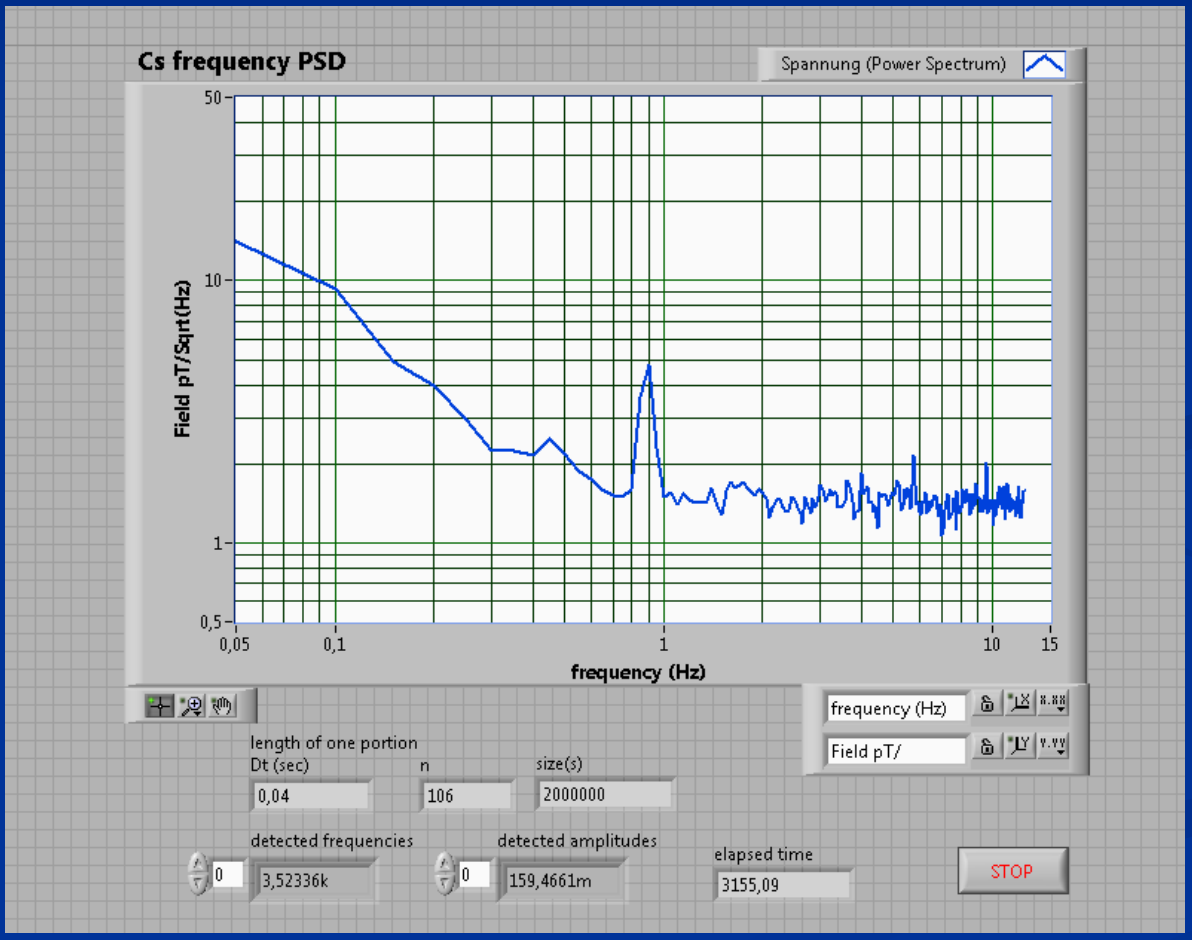
(Mainz, 2010-2011)

4 Layer Mumetall-Shield (from PSI)

Lamp-pumped Cs-Magnetometer

(lent from A. Weis, Fribourg,
Former bought from Alexandrov group)

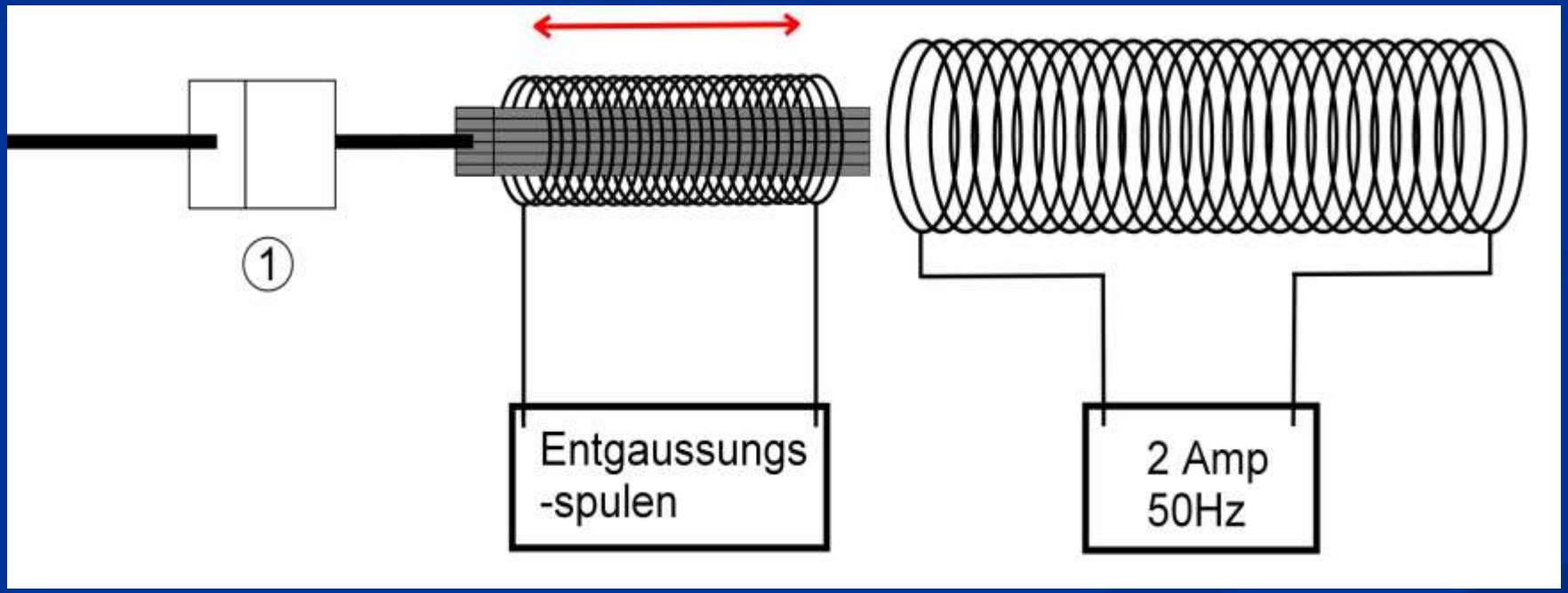
Noise spectrum :



1-2 pT

with papertube,
coilsystem
and PSI test shield

5 Layers of Metglas + Degaussing

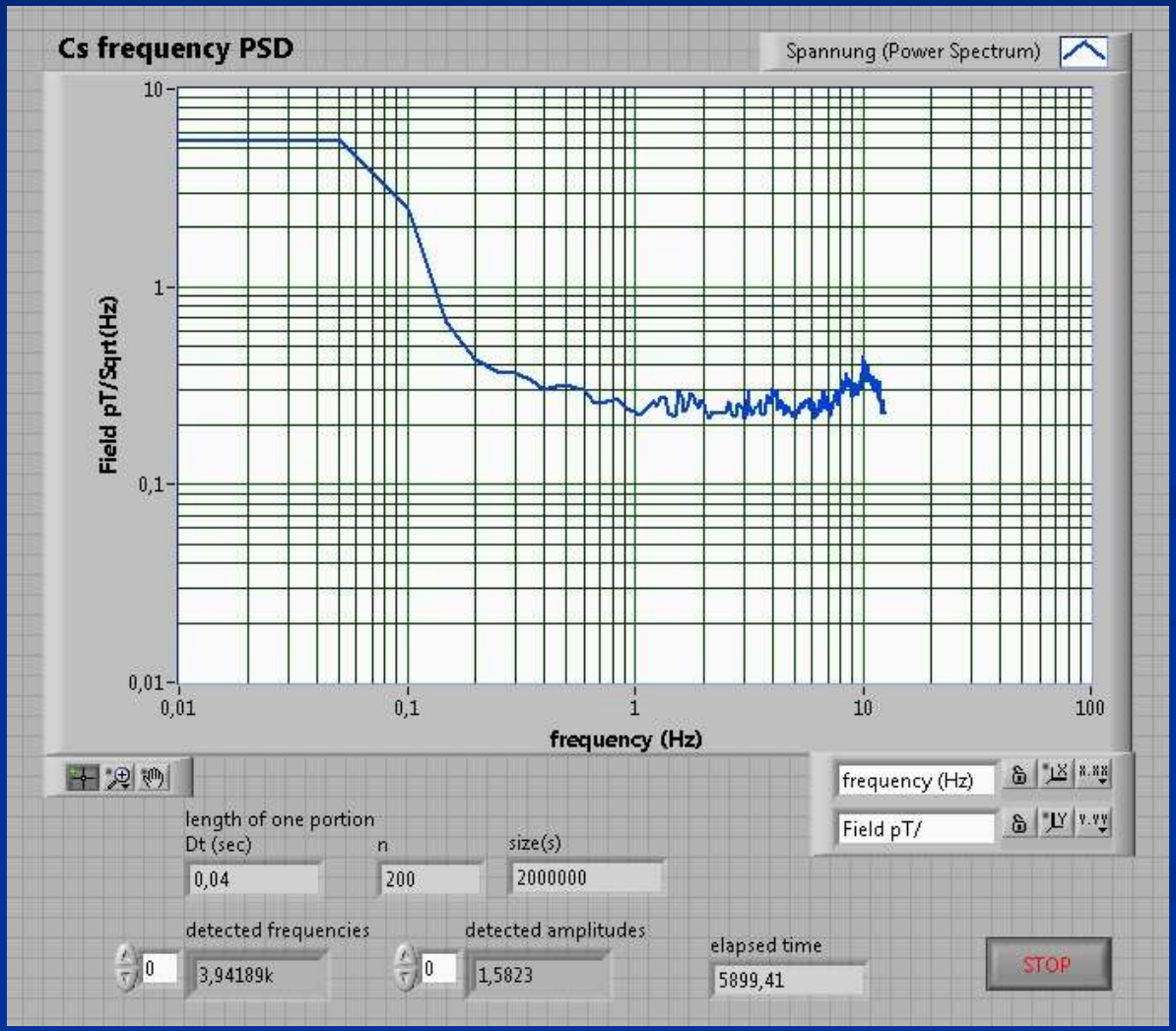


Degaussing Machine: Theory

5 Layers of Metglas + Degaussing

Degaussing Machine: Reality

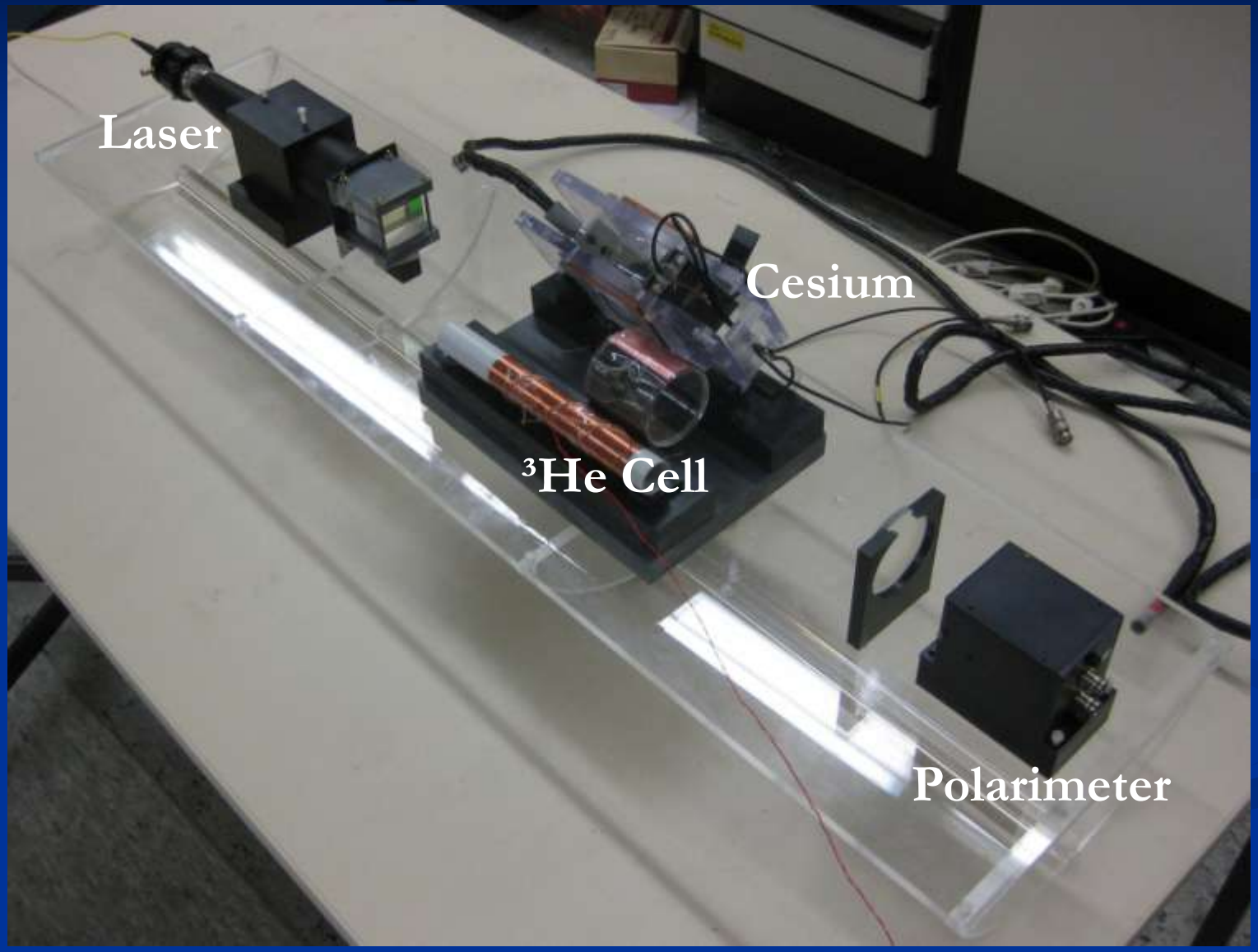
Noise spectrum :



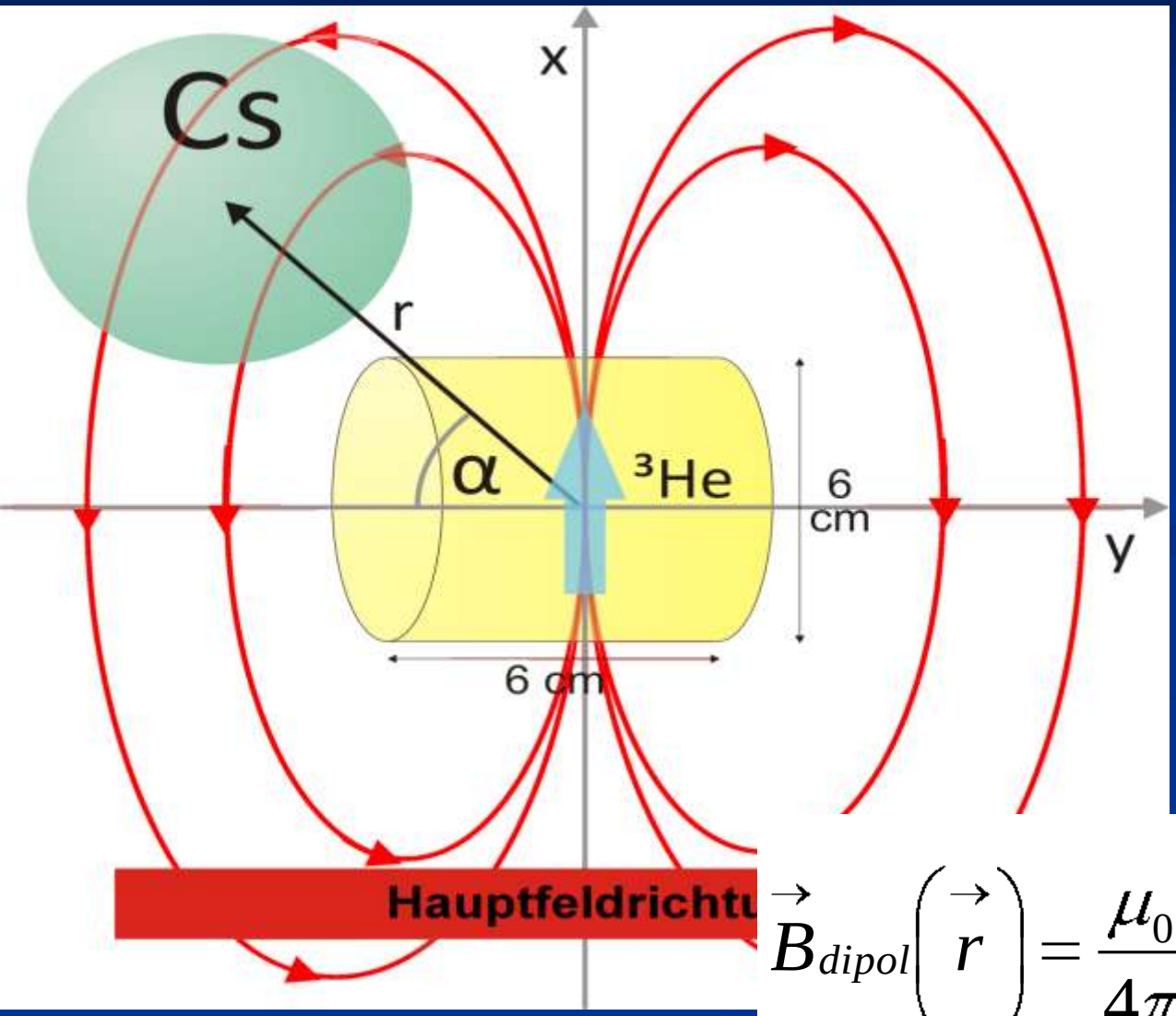
0,2 - 0,3 pT

with 5 layer of metglass and primitive degaussing

Inner setup:



Geometrie of Cs- and ^{3}He-cell:

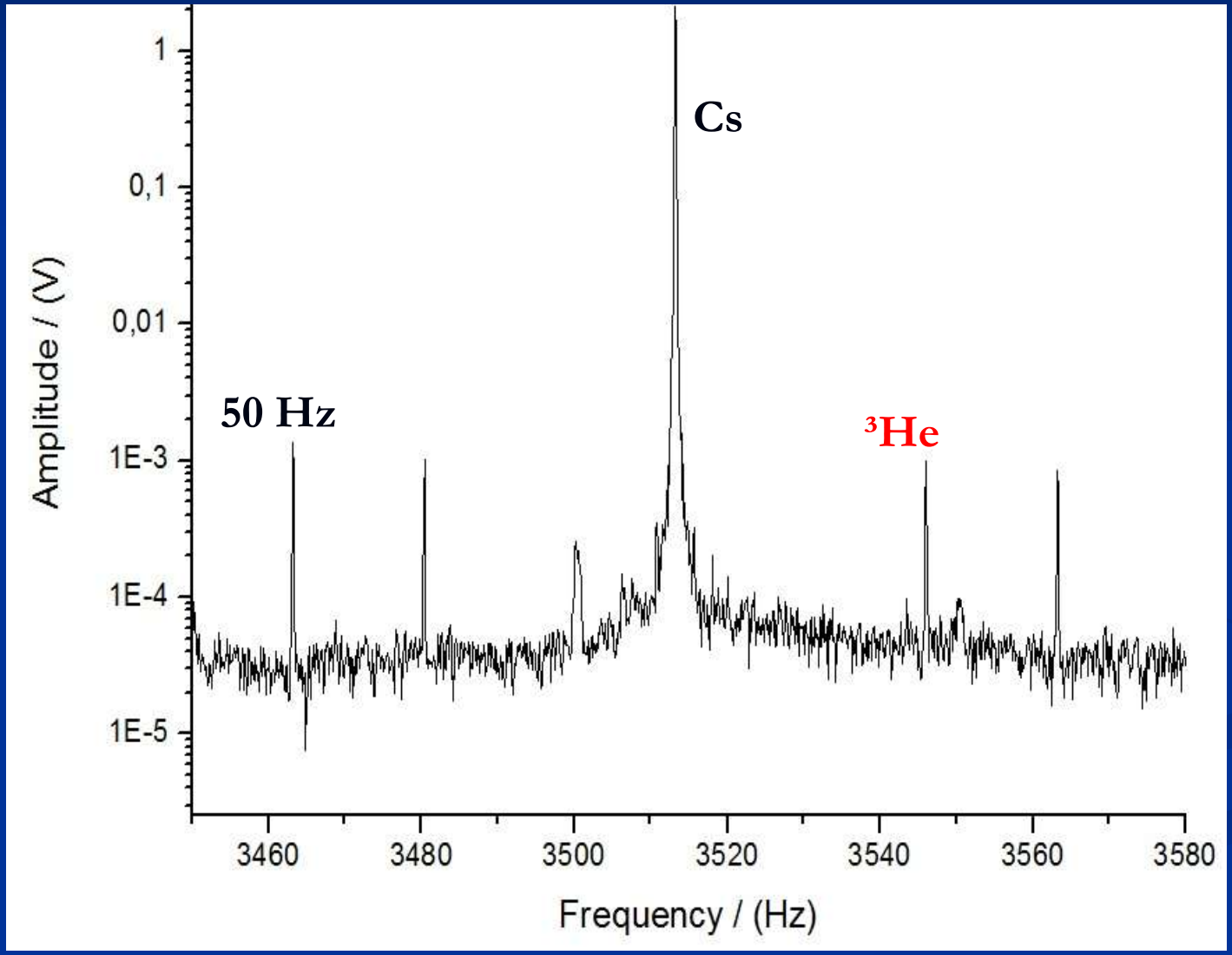


r = 7cm

Angle = 45

$$\vec{B}_{dipol}\left(\vec{r}\right) = \frac{\mu_0}{4\pi}\frac{3\vec{r}(\vec{m}\cdot\vec{r}) - \vec{m}(\vec{r}\cdot\vec{r})}{r^5}$$

Results , June 2011 : FFT

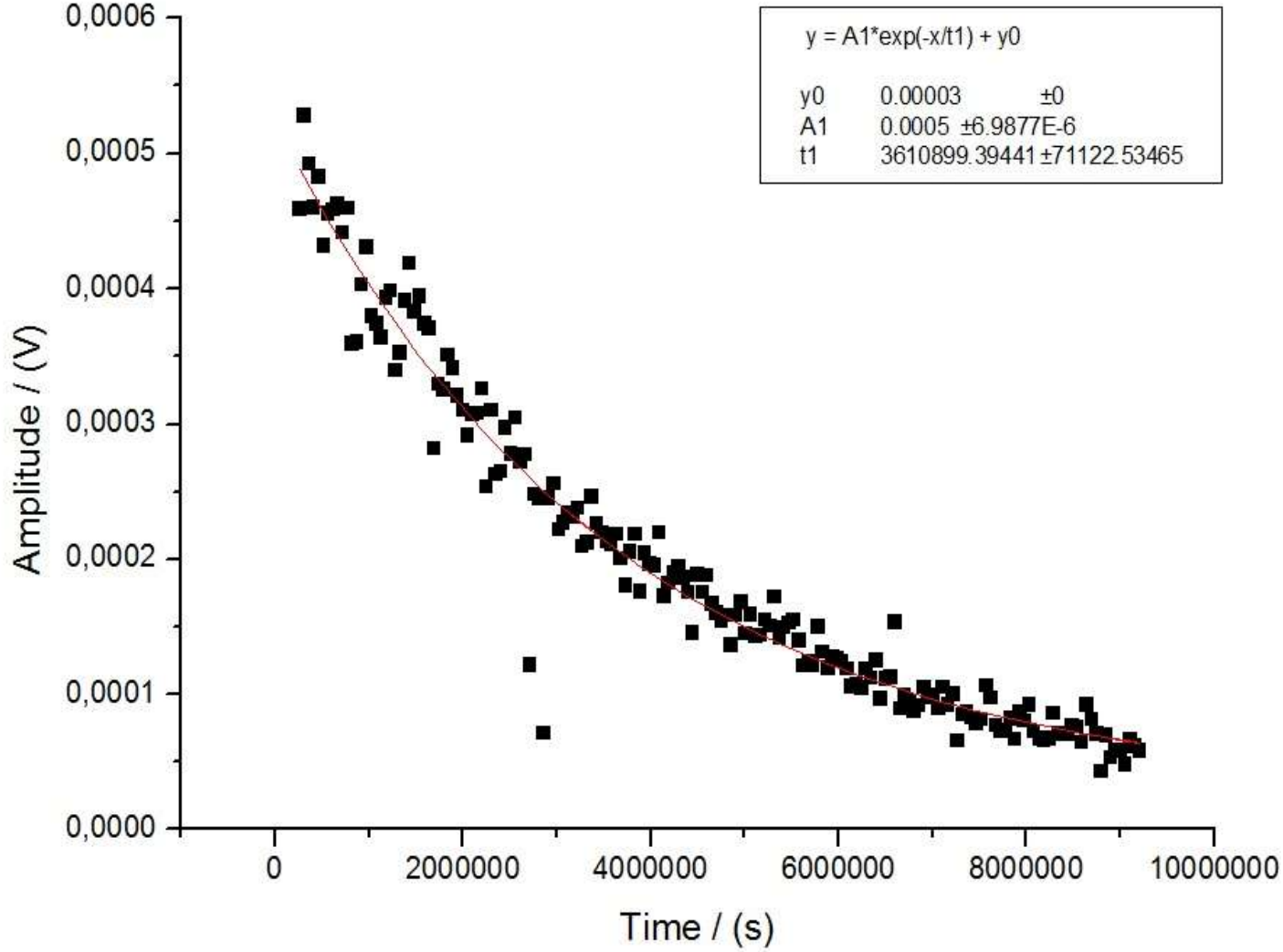


SNR: ~30

with one lamp-pumped Cs-Magnetometer,

@ 1 mbar, 60 % Polarisation

Results, June 2011 : T2

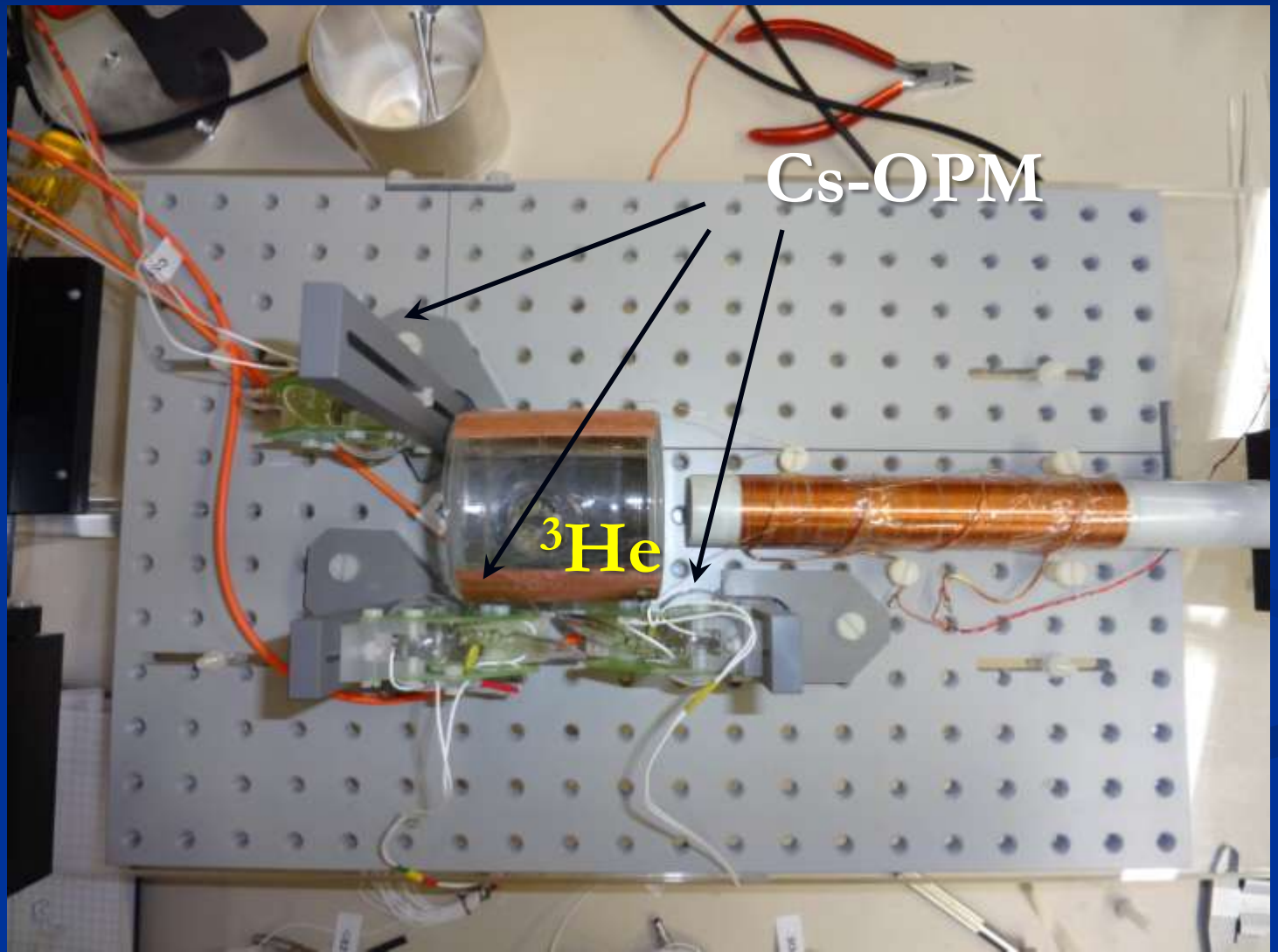


~ 1 h

in Cosine coil or Solenoide

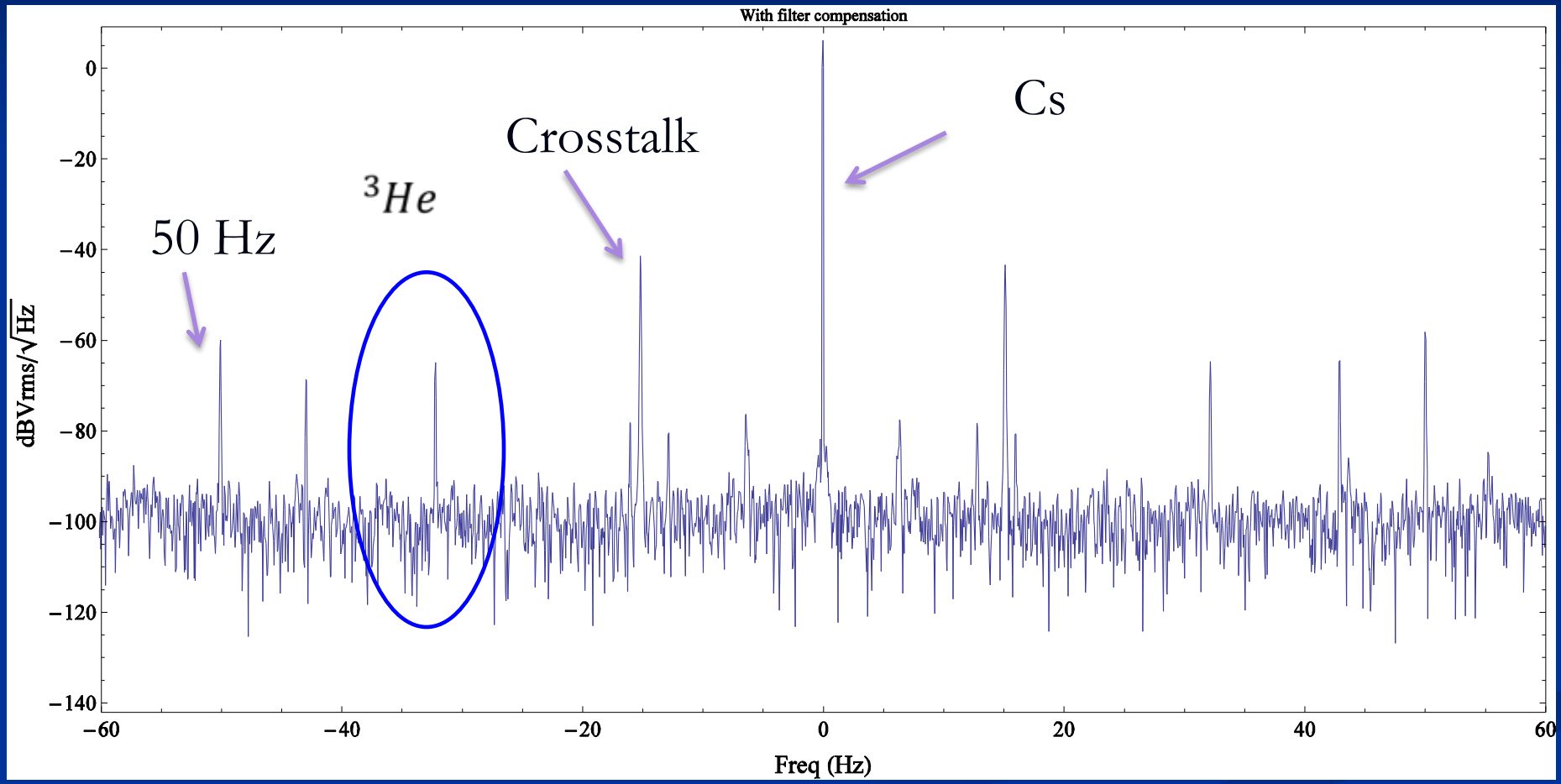
Measurement with Fribourg

(November 2011)



Measurement with Fribourg

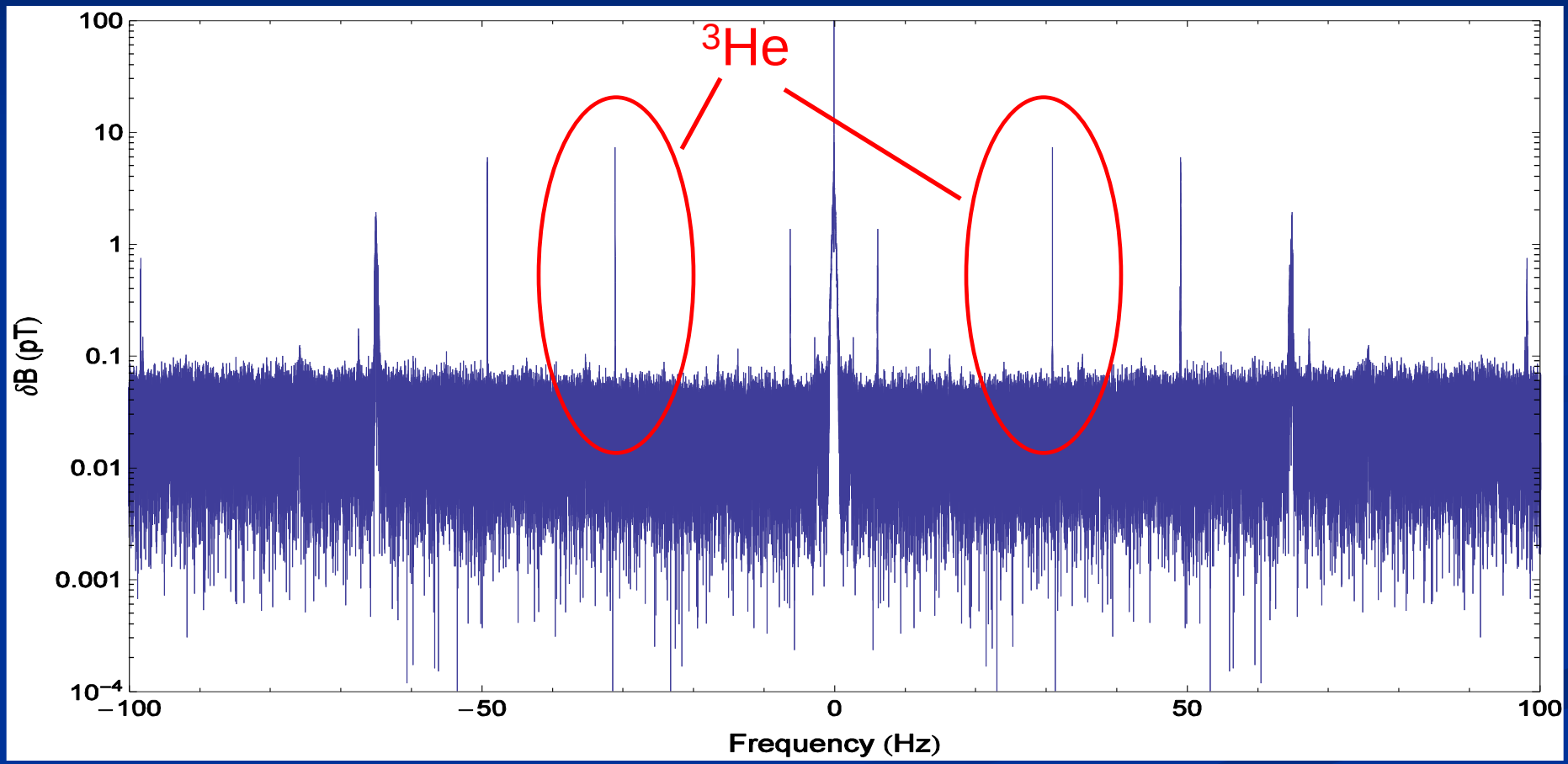
(November 2011)



Single Mode : SNR ~ 60:1

Measurement with Fribourg

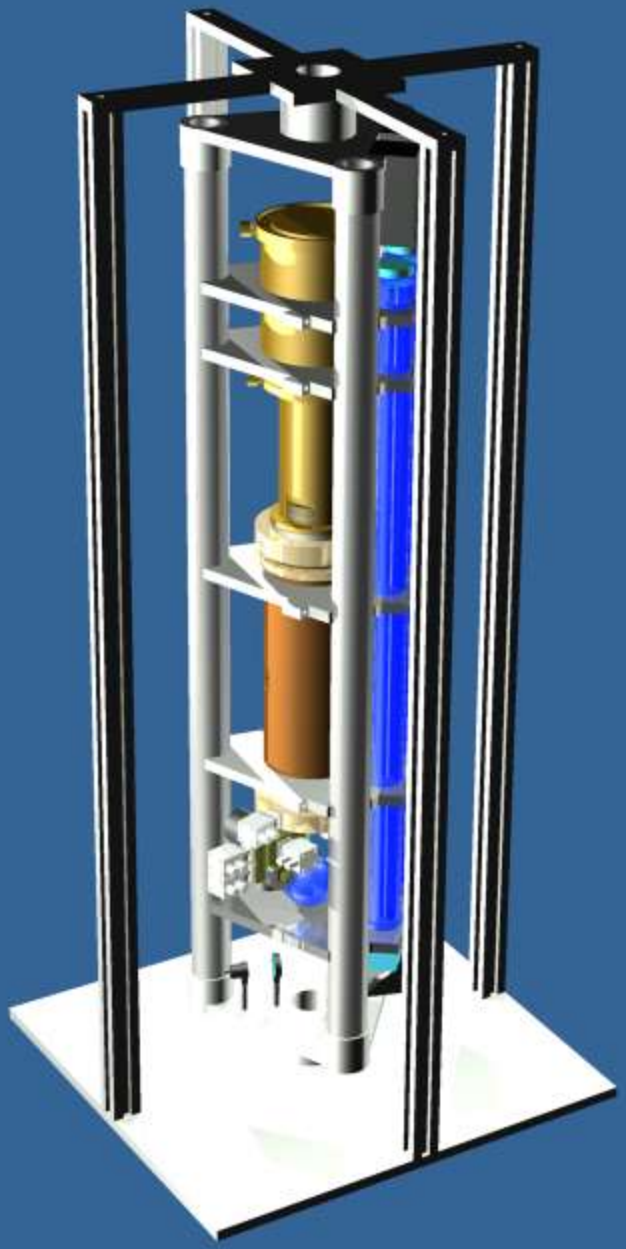
(November 2011)

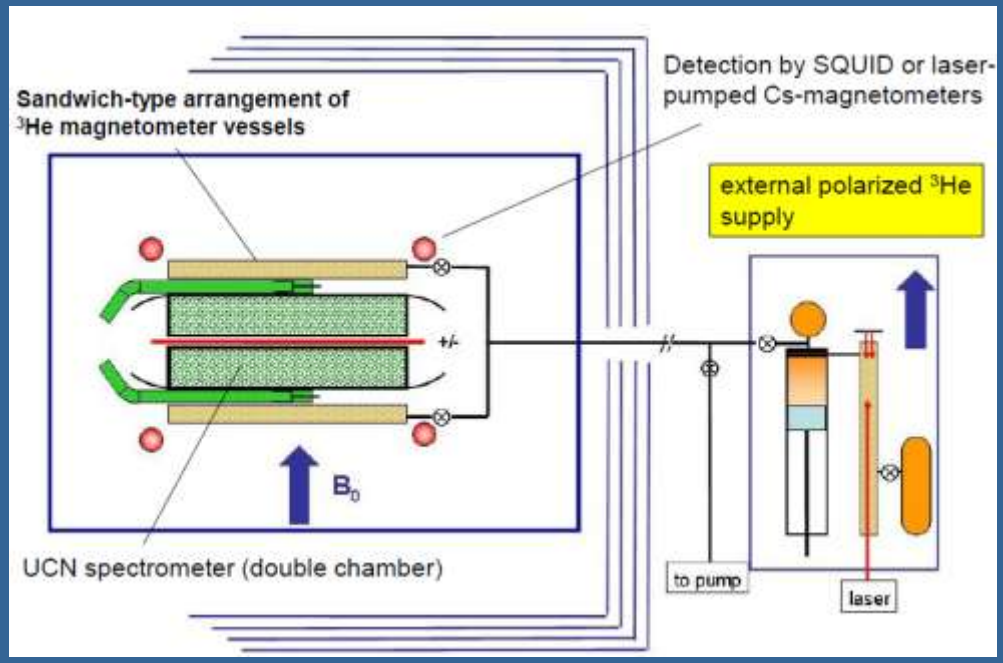


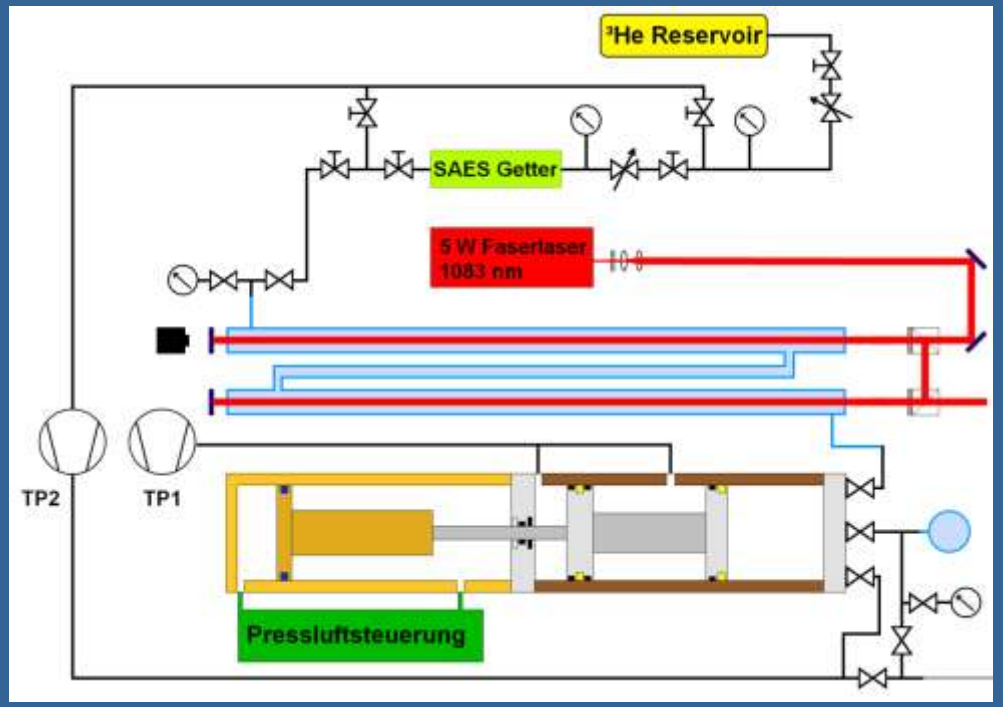
Gradiometer Mode : SNR ~ 300:1, 80 pT@ 2 sec

3. Ultracompact Polarizer Unit

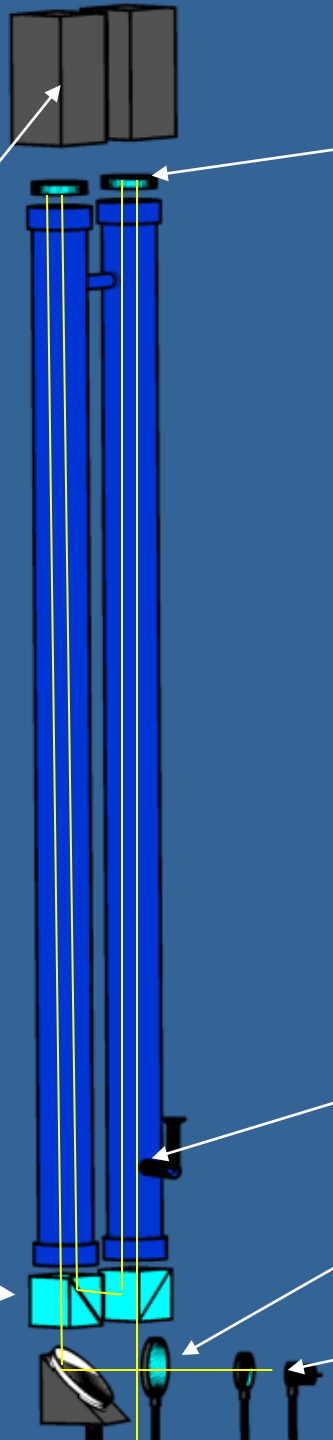
(Mainz, 2009-2011)




Sandwich-type arrangement of
³He magnetometer vessels
Detection by SQUID or laser-pumped Cs-magnetometers
external polarized ³He supply
+/-
B0
UCN spectrometer (double chamber)
to pump
laser


³He Reservoir
SAES Getter
5 W Faserlaser
1083 nm
TP2
TP1
Pressluftsteuerung

OPTICS



dichrotic mirrors

OPN

(Connection to Getter and ^{3}He reservoir not shown)

Optical Pumping cells (each with 3 liters, 1 mbar pressure)

Connection to Compressor

Beam divider cubes

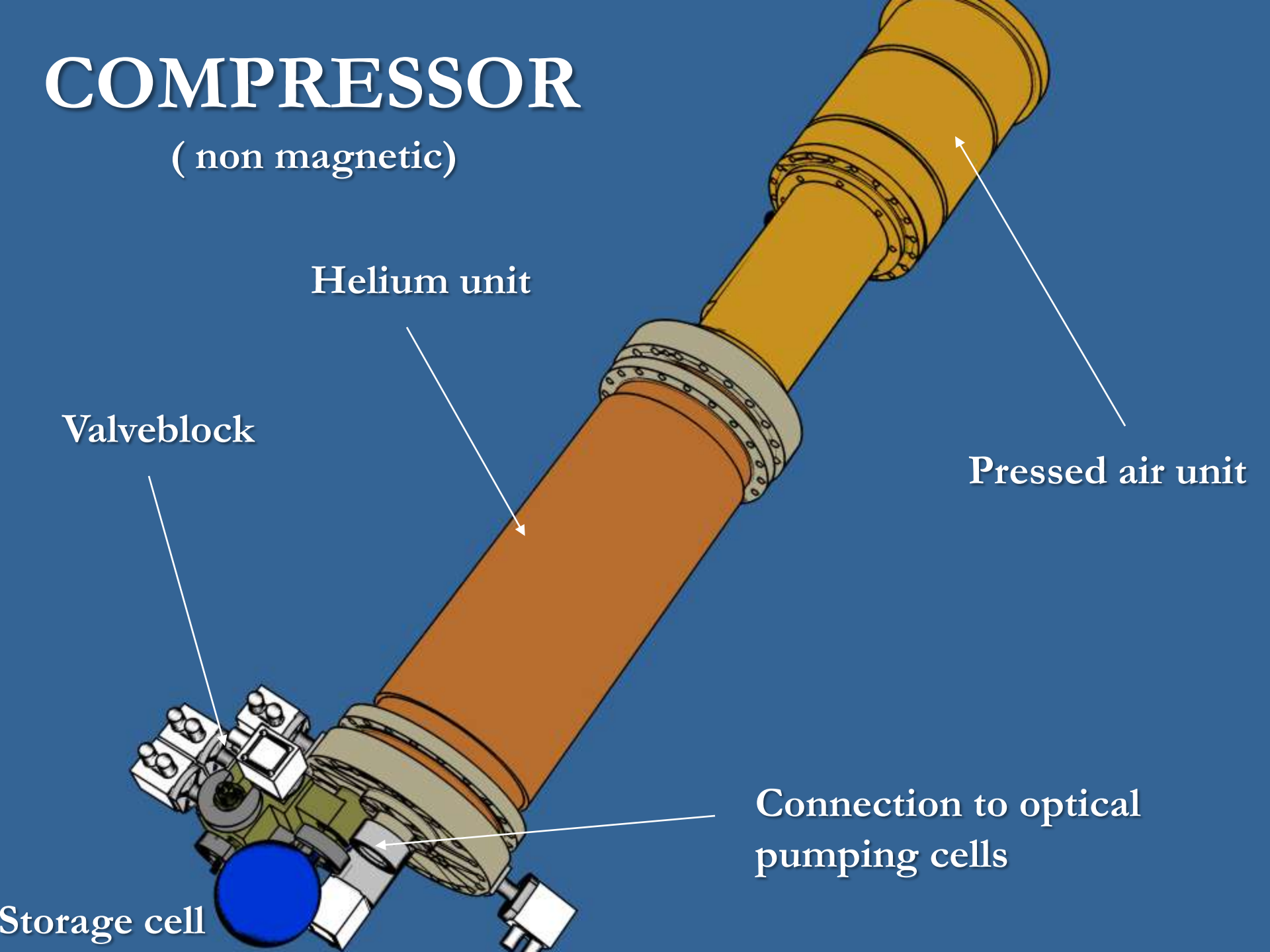
Telescope

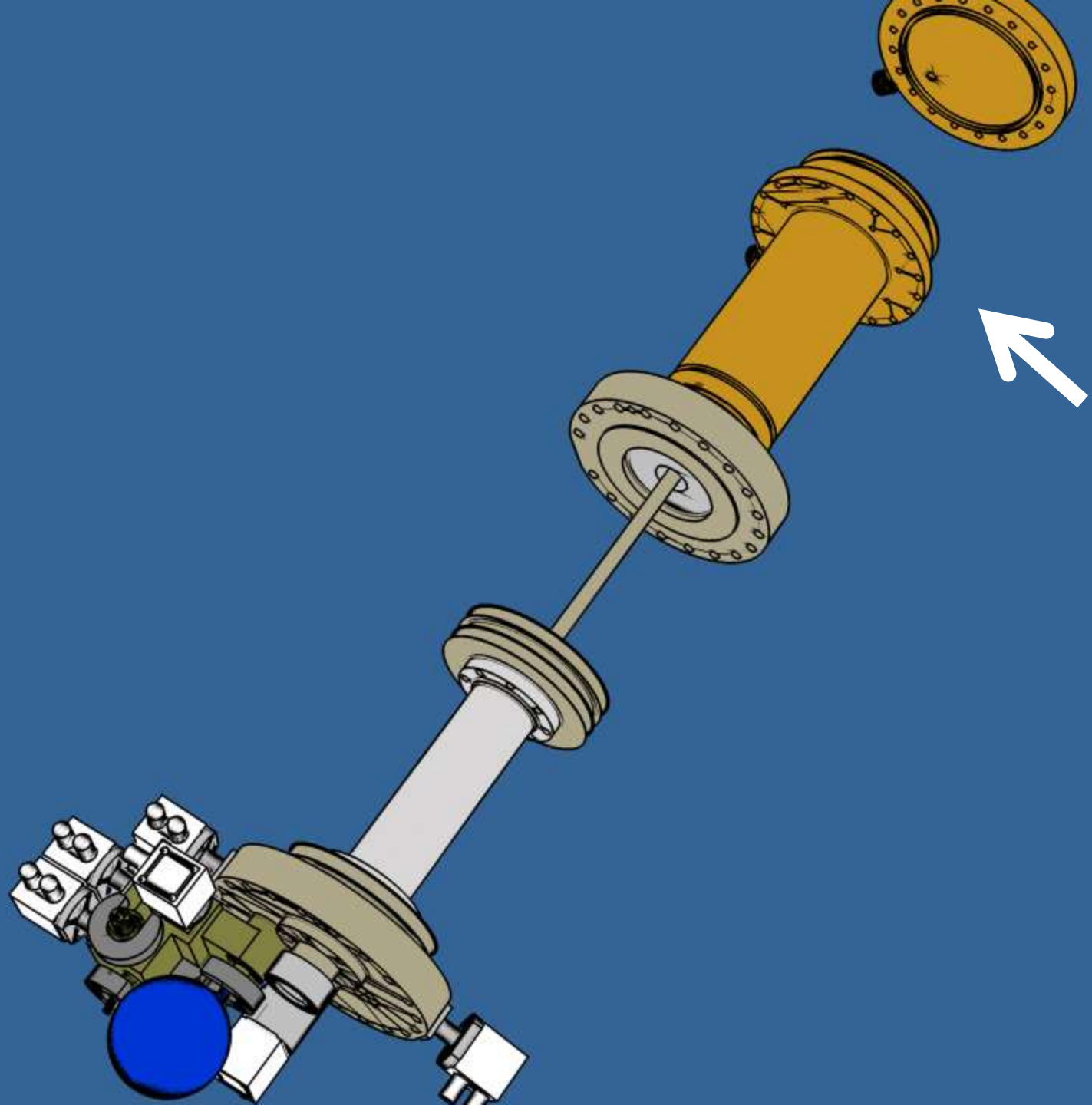
Laser (1083 nm)

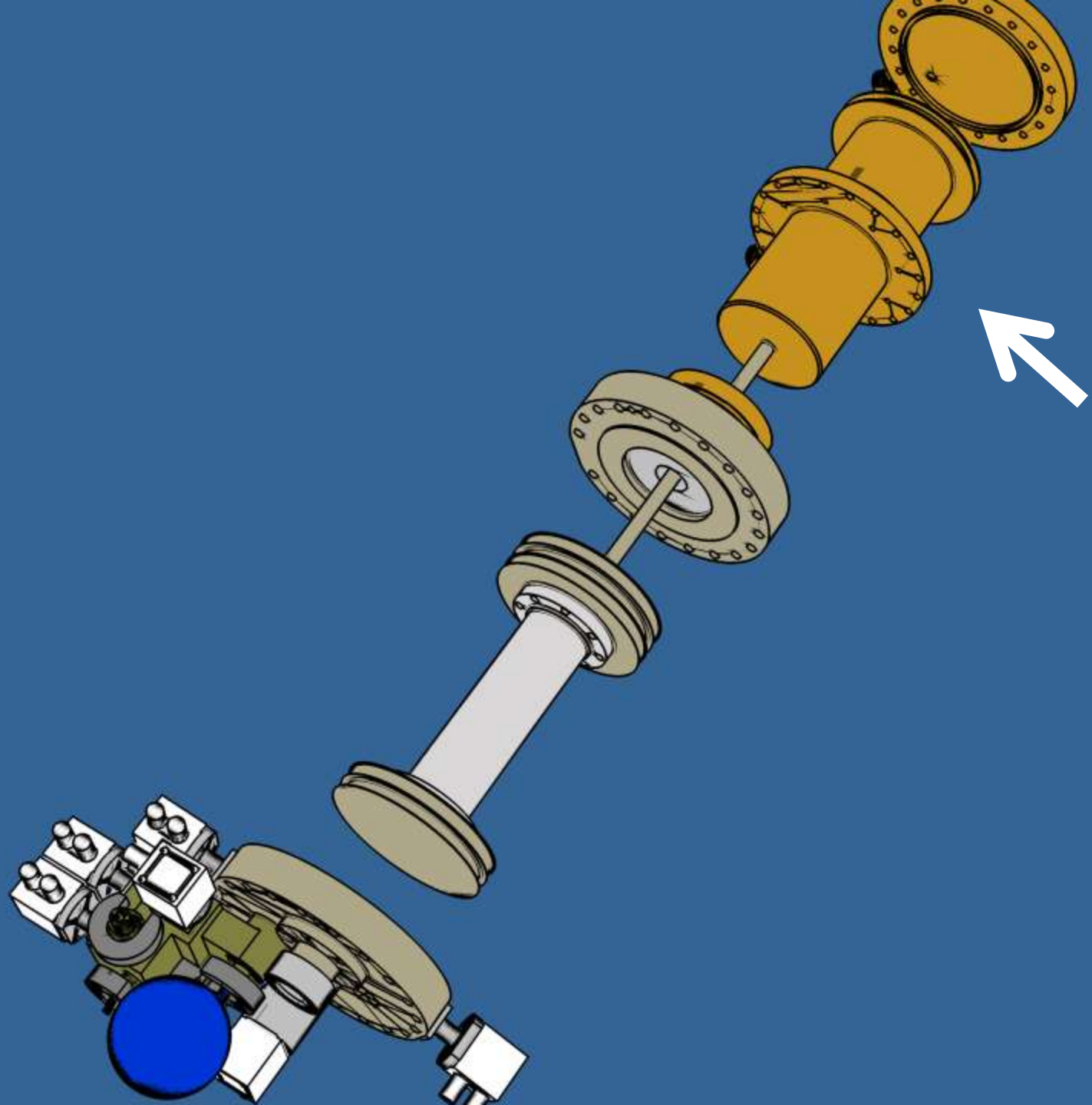
mirror

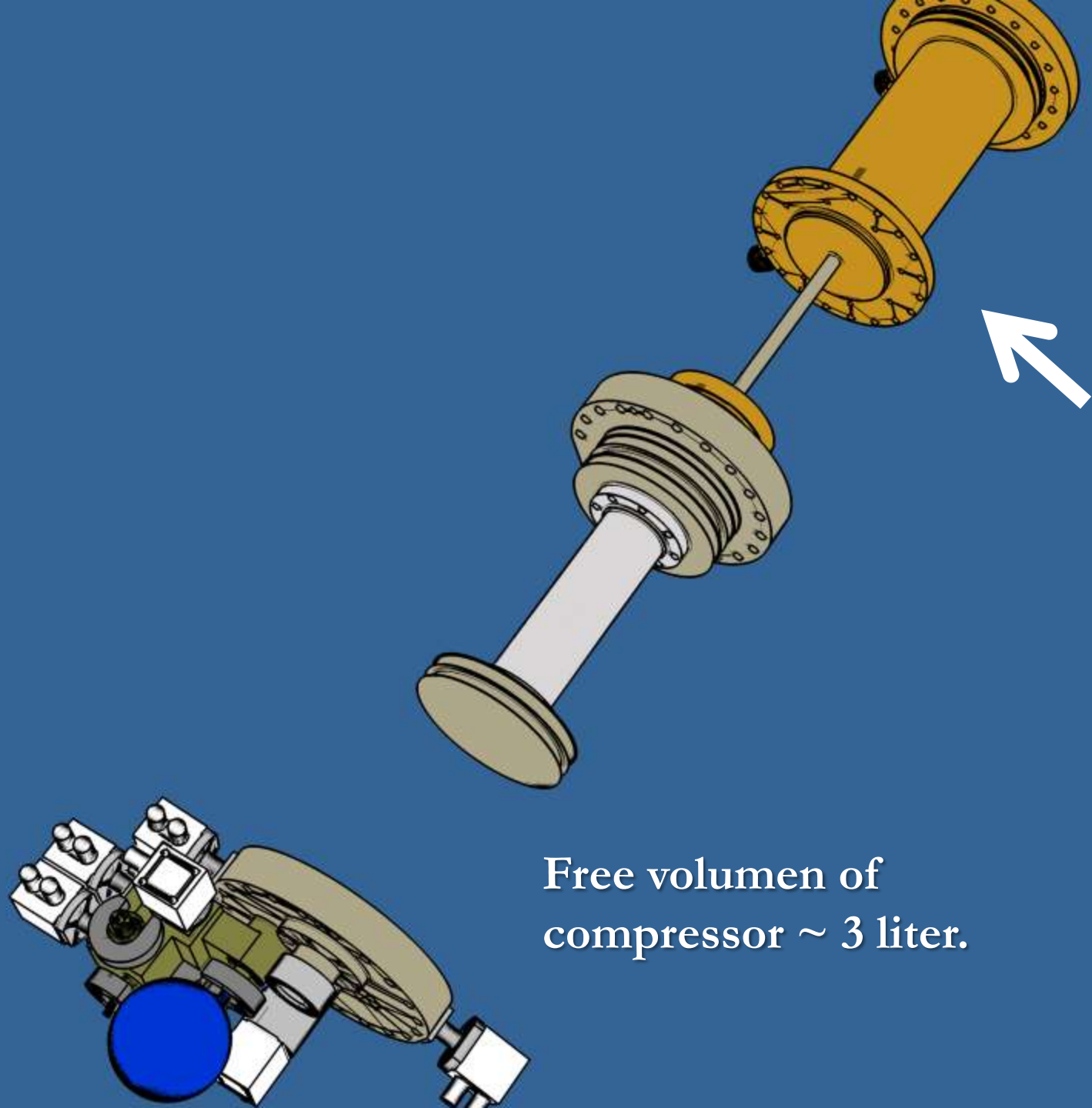
COMPRESSOR

(non magnetic)

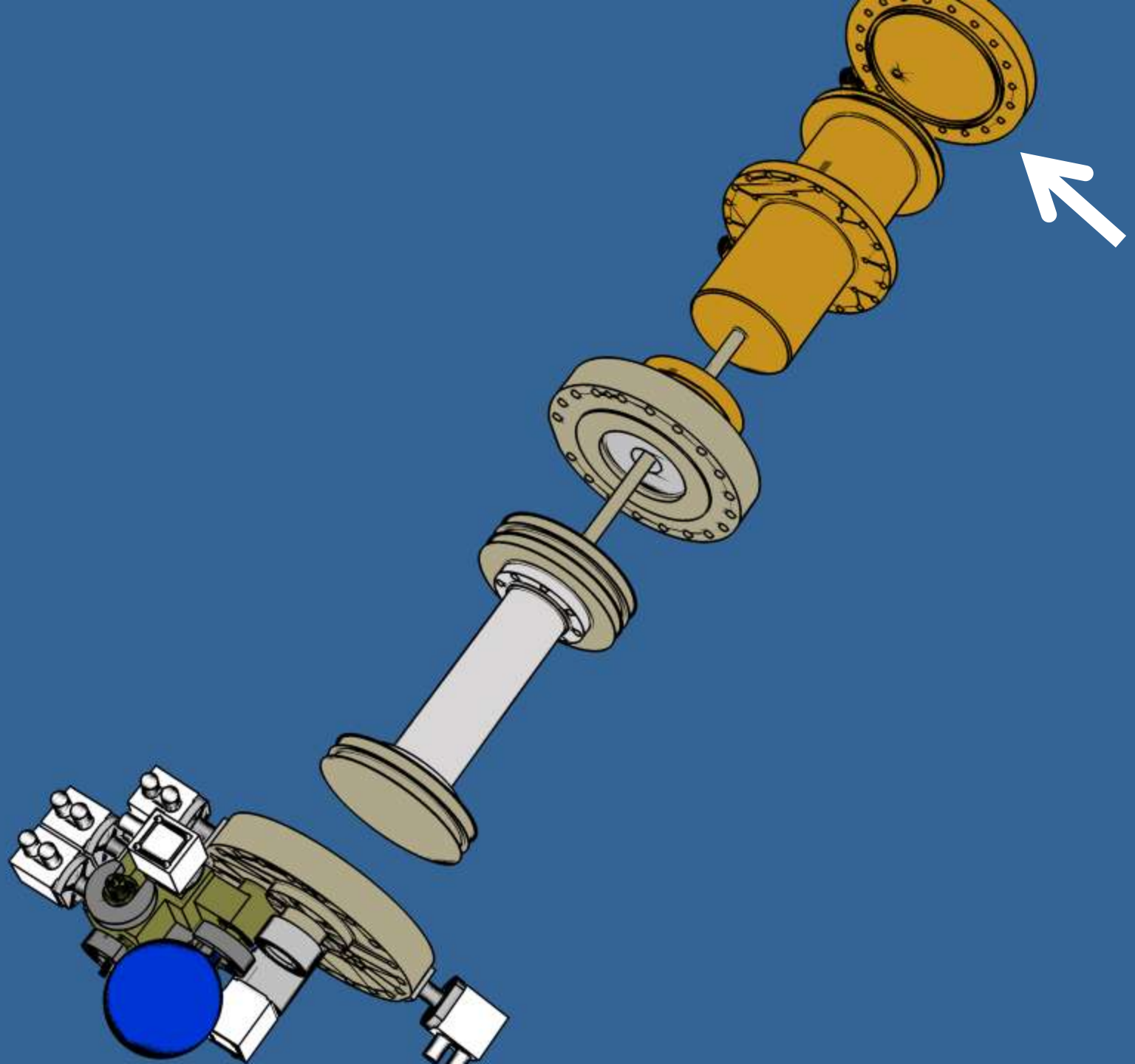


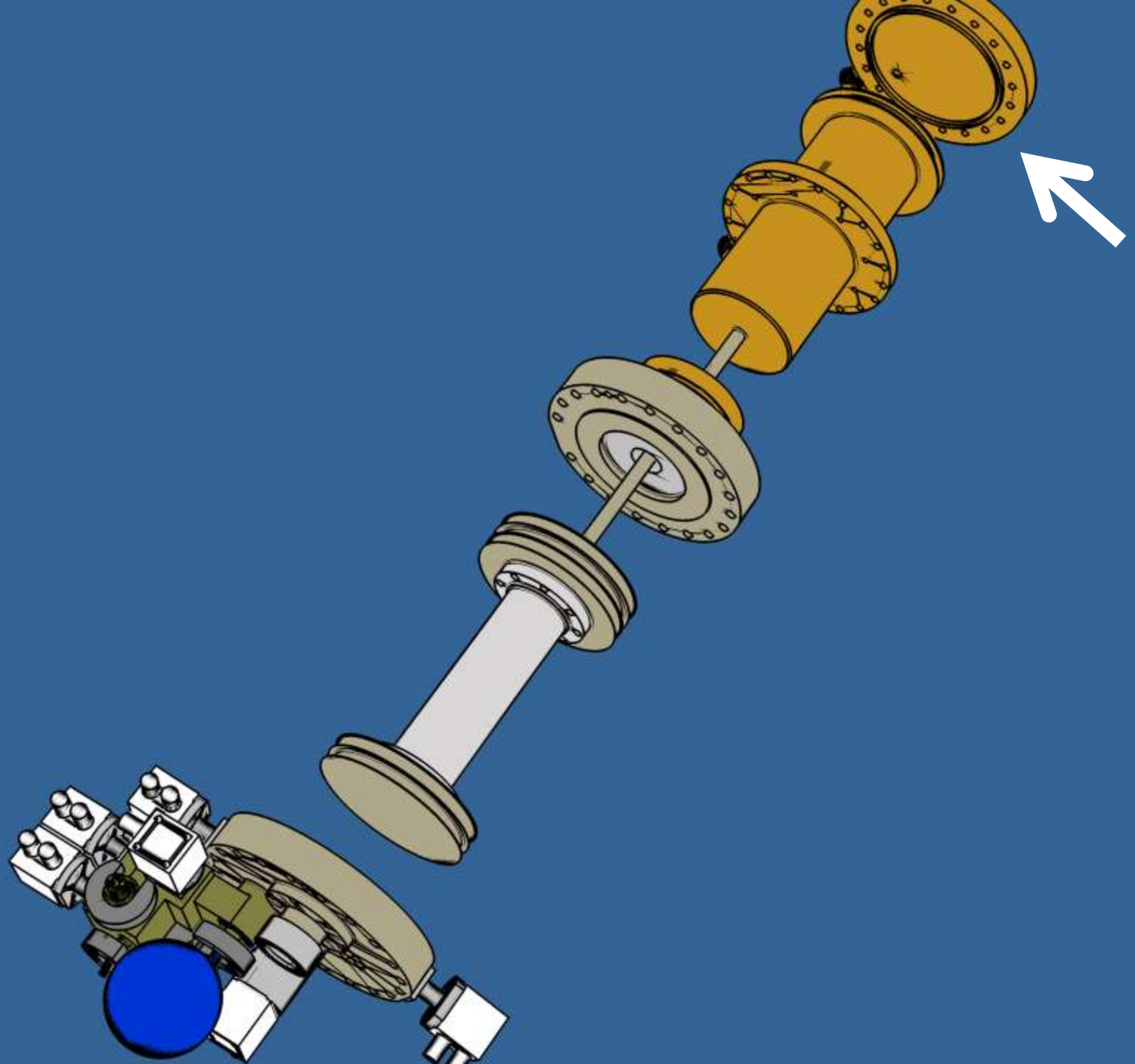


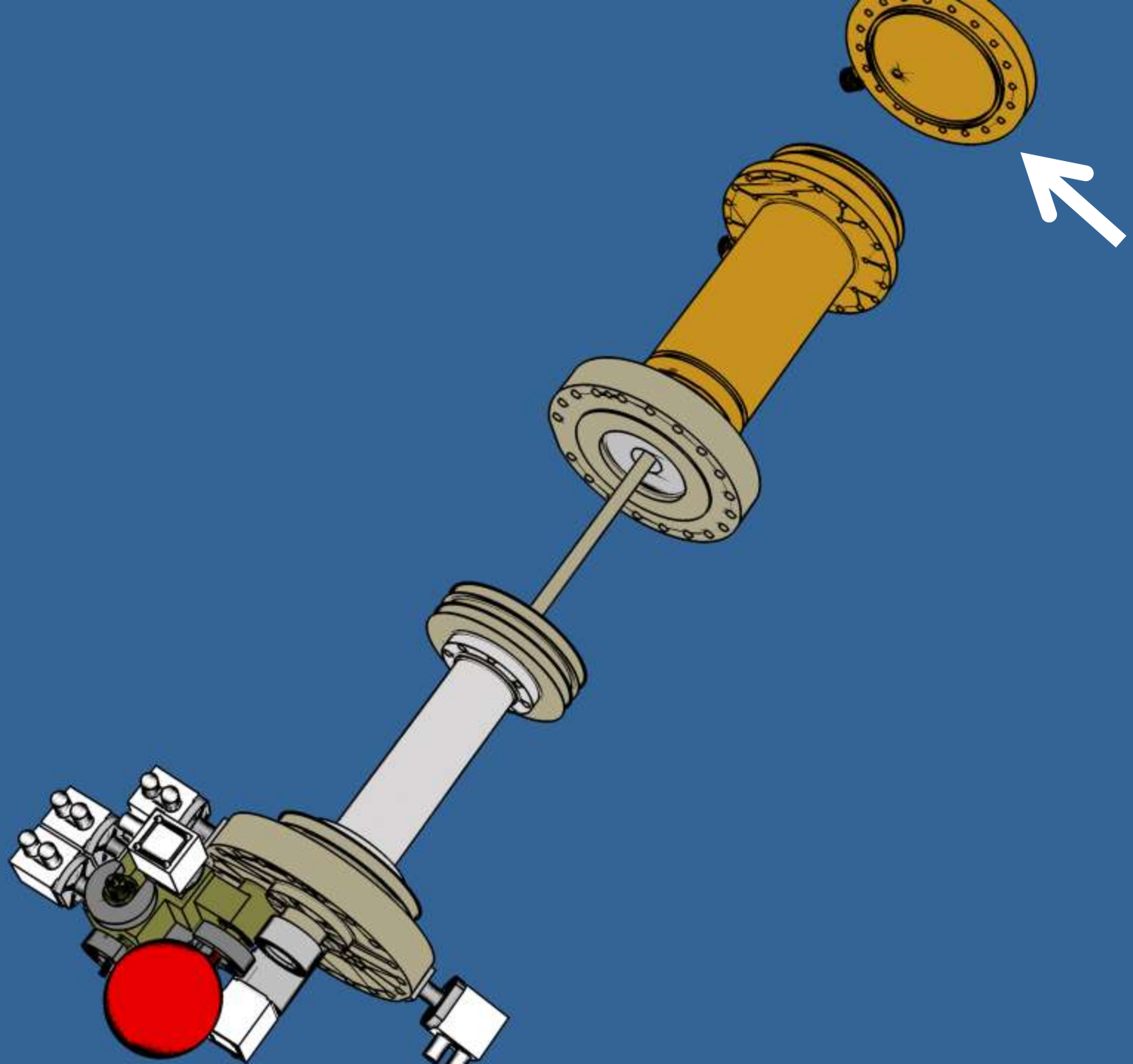




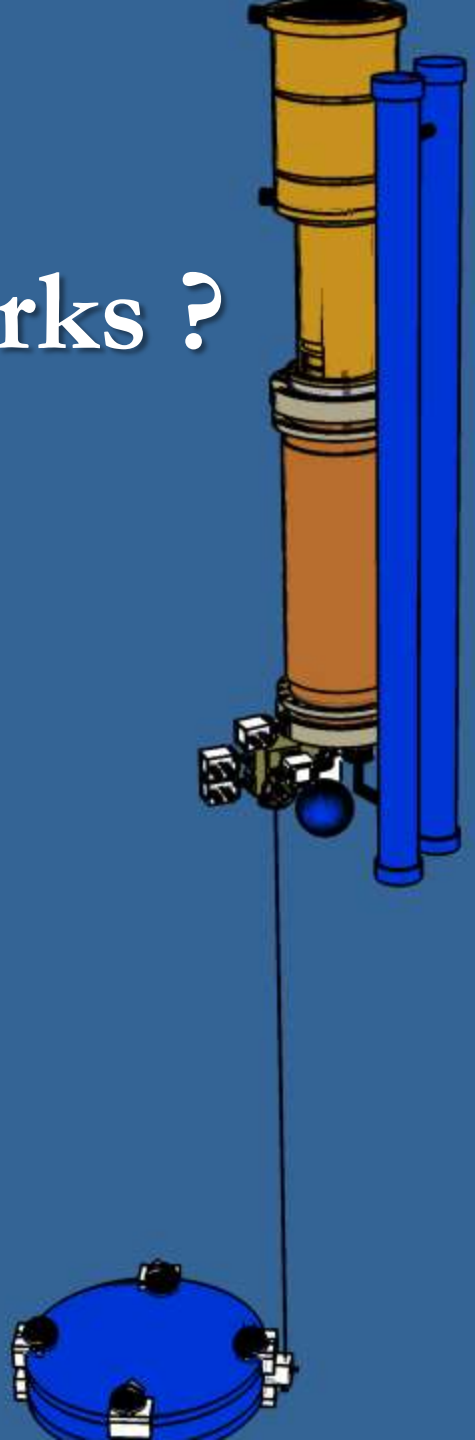
Free volumen of
compressor ~ 3 liter.

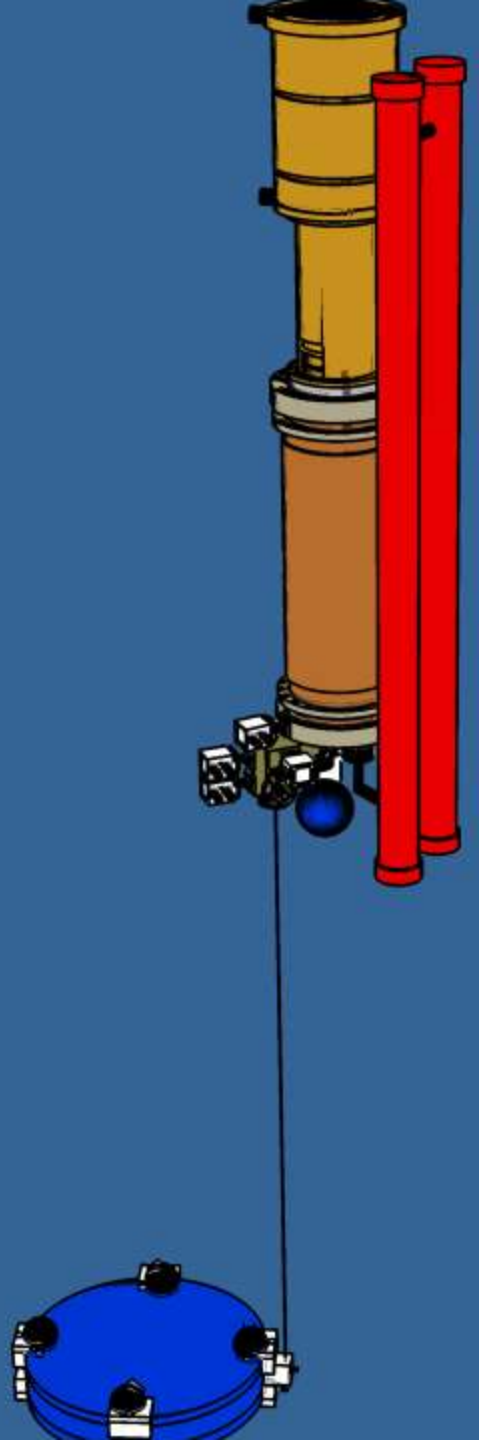






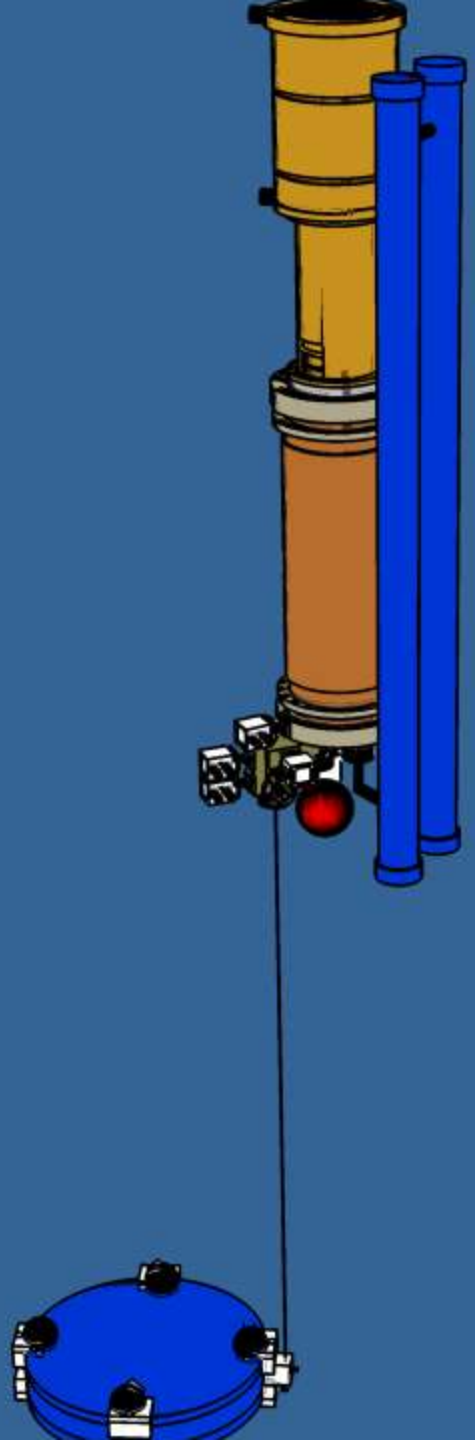
How the system works ?



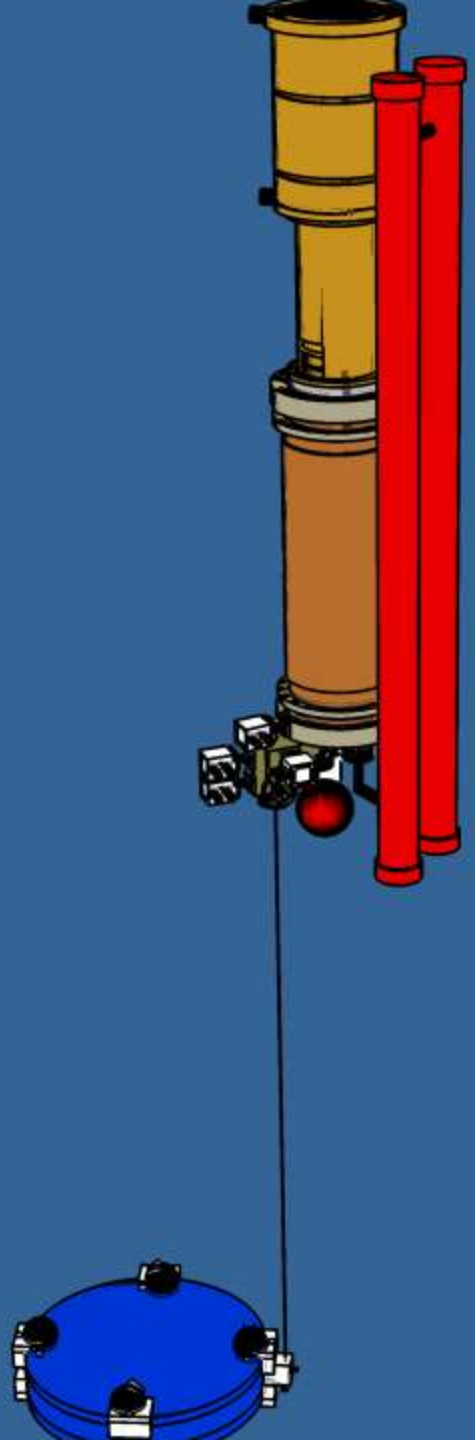


^{3}He filled in from a reservoir into pumpings cells ~ 1mbar

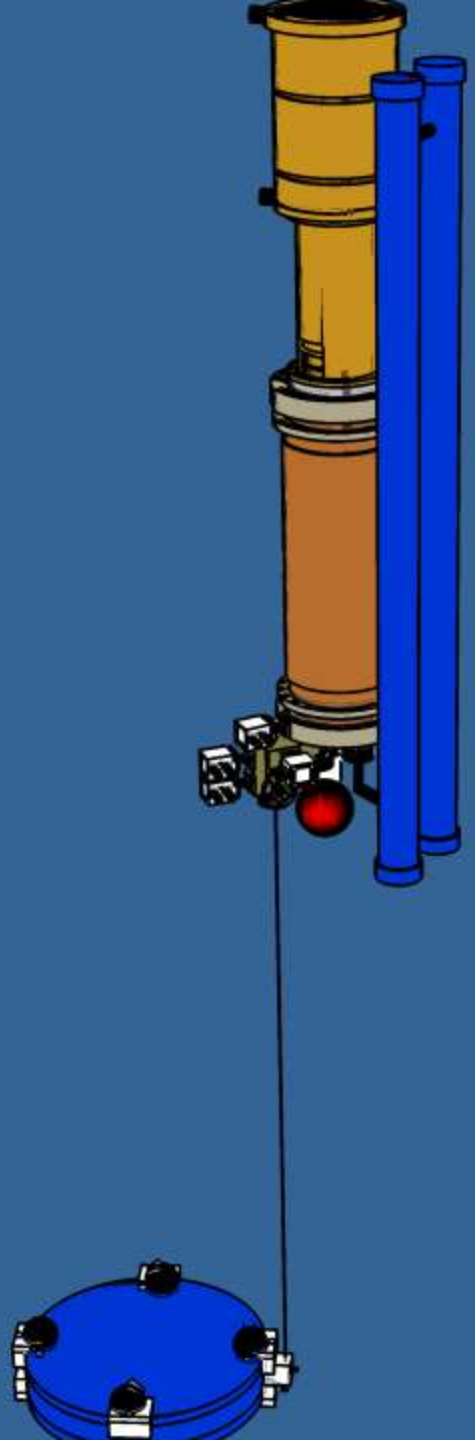
Polarisation of ^{3}He starts.
-> up to ~50-60%



Compressor pumps
^{3}He into the storage cell

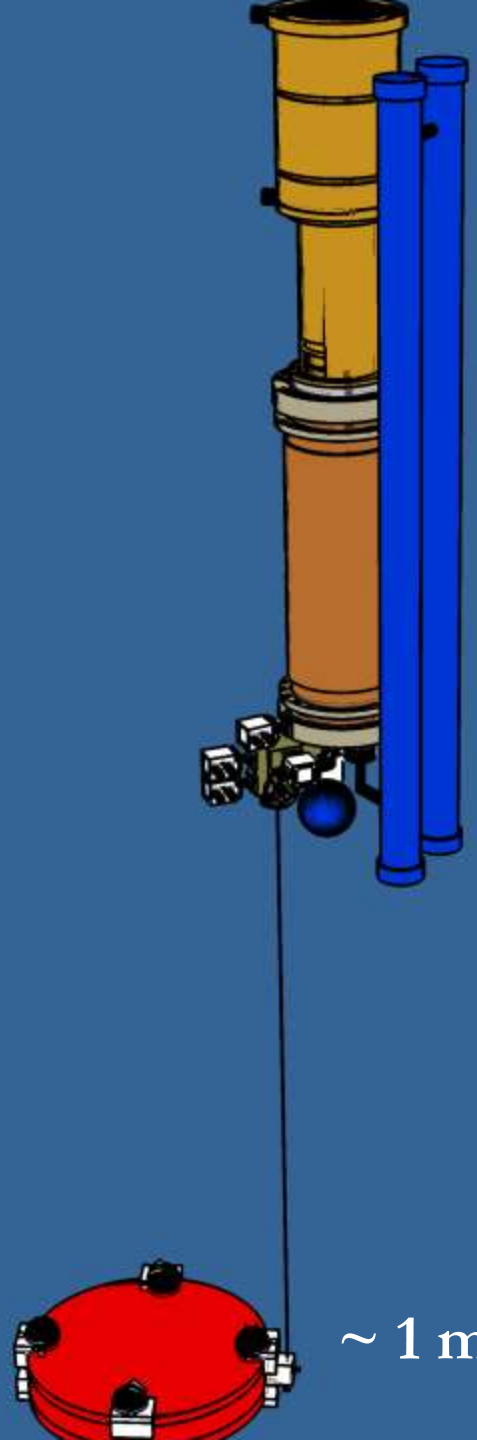


Polarisation of new refilled gas



After 11 Cyles (~8 min)
Storage Cell ~ 16 mbar l

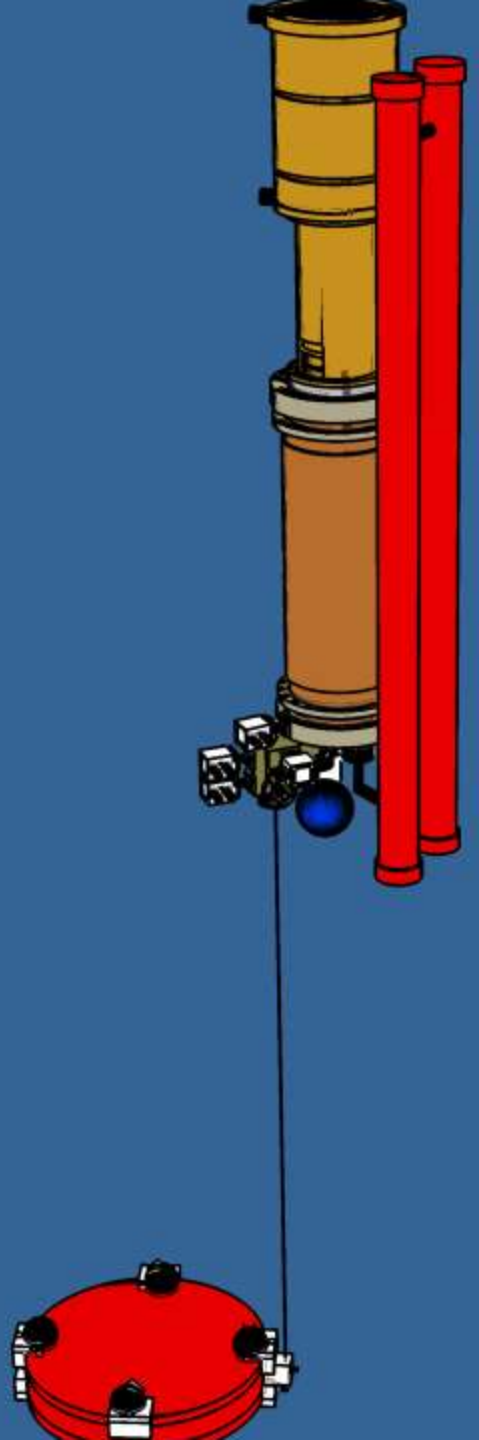
Enough to fill 1 mbar in two magnetometer cells with 16 l volumen.



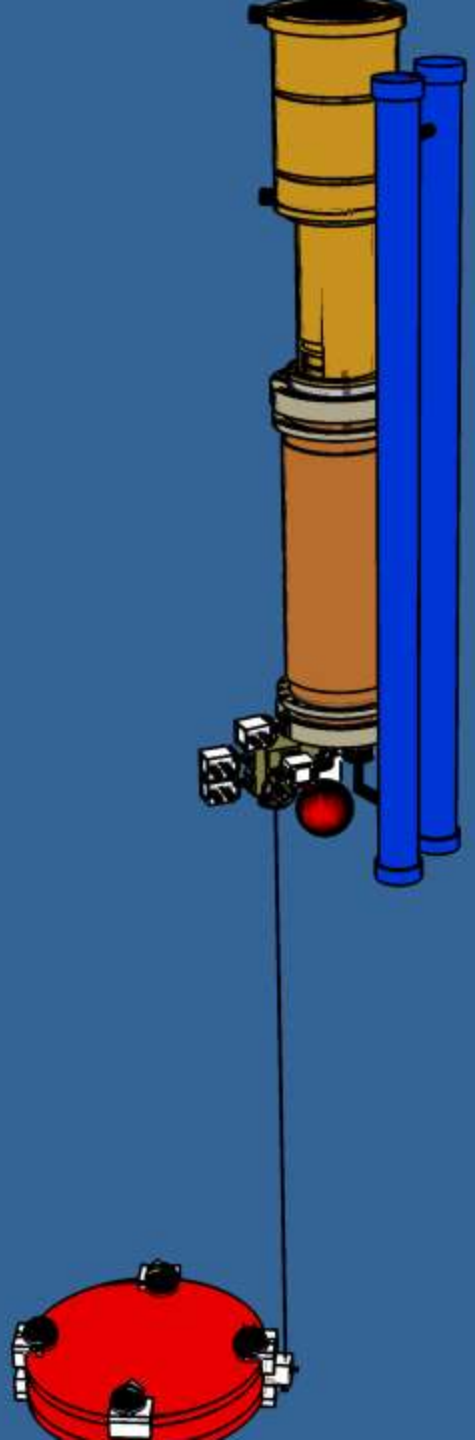
Filling of gas into
Magnetometer-cell

-> Measurement can start

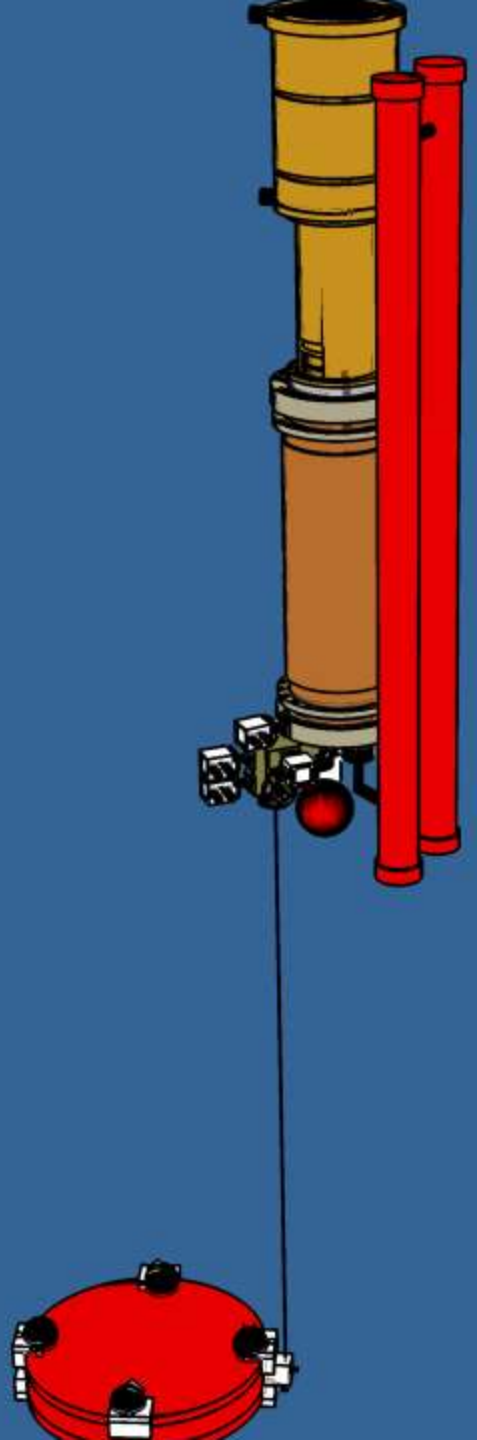
~ 1 mbar, T2~30 min , 2-3 Ramsey Cyl



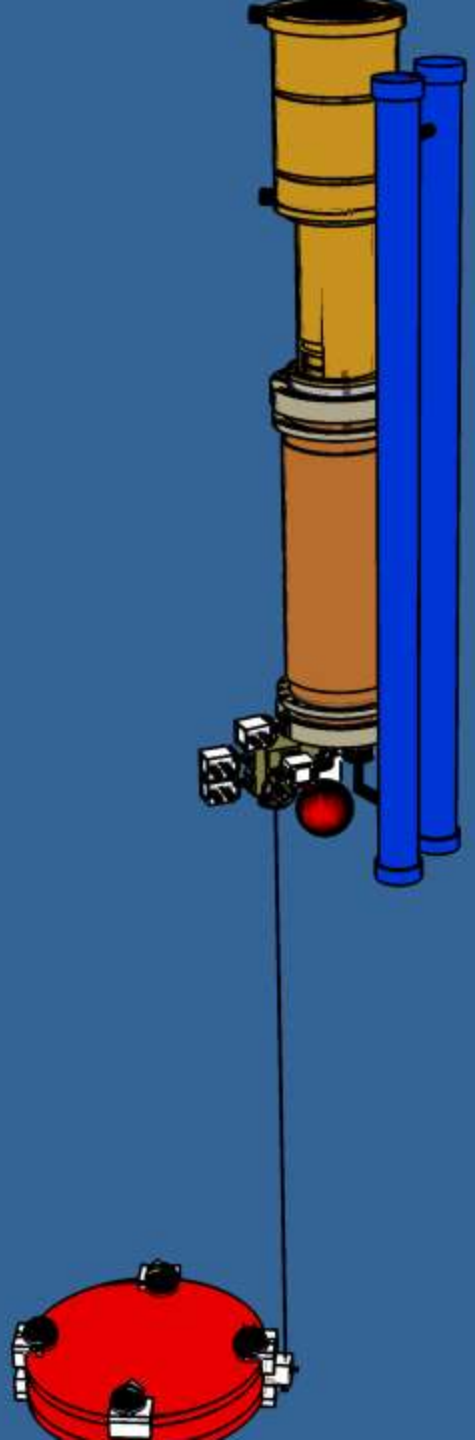
Preparing of new gas



Preparing of new gas

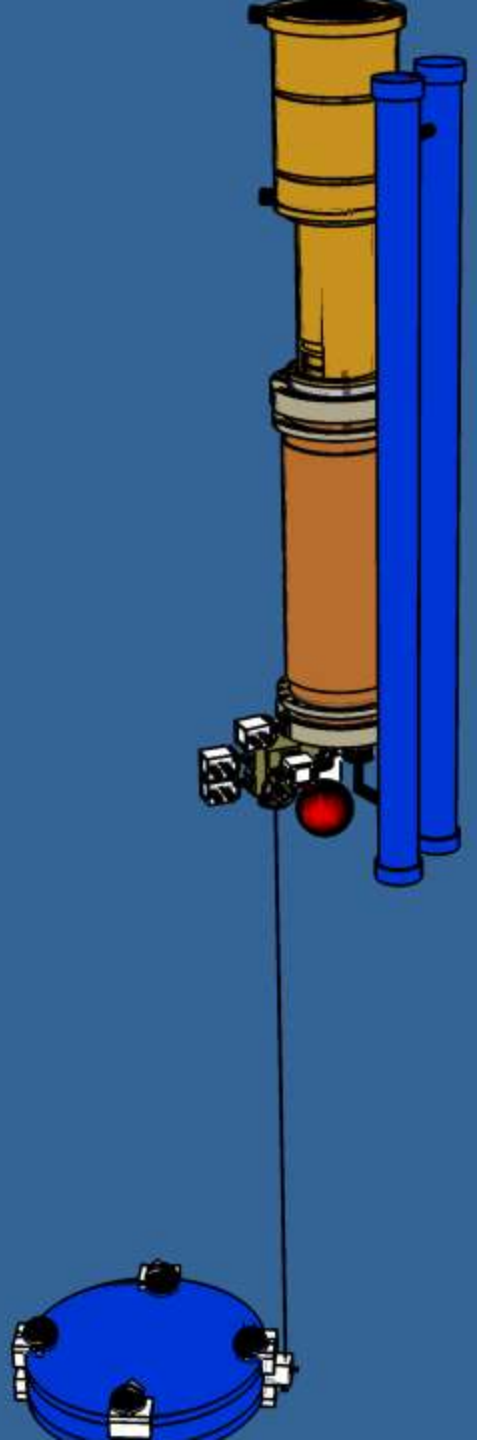


Preparing of new gas



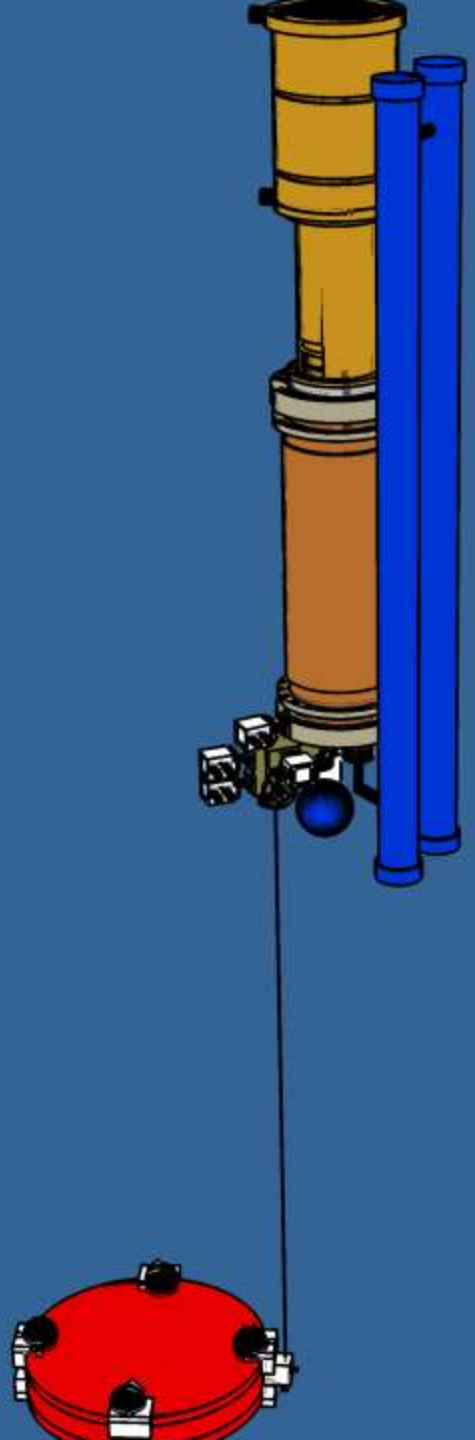
After ~8 min and 11 cyles storage-cell is filled again.

Waiting for end of measurement.



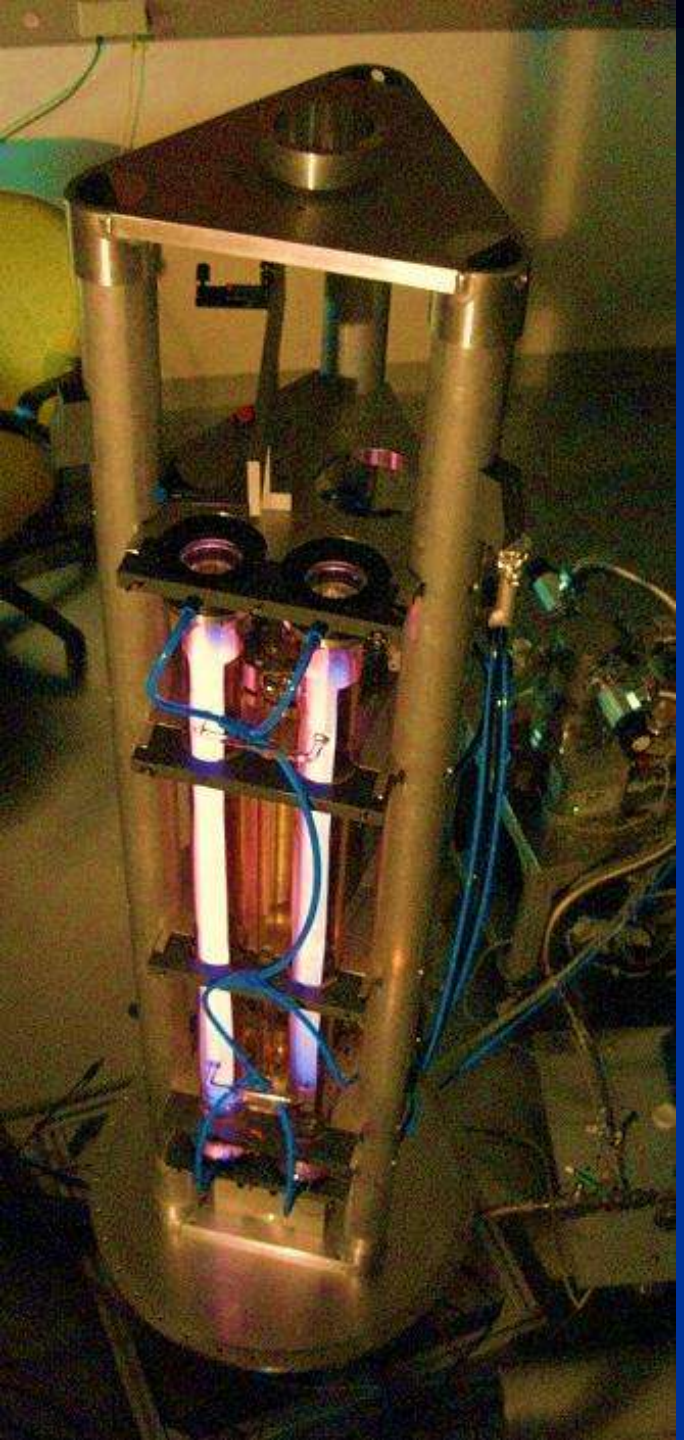
Old gas is pumped out of magnetometer cell by drag pump into getter between reservoir an pumping cell. Gas will be cleaned and recyled.

-> nearly closed system



New gas is filled in.

-> New measurement starts
-> New cycles of preparing gas is starting



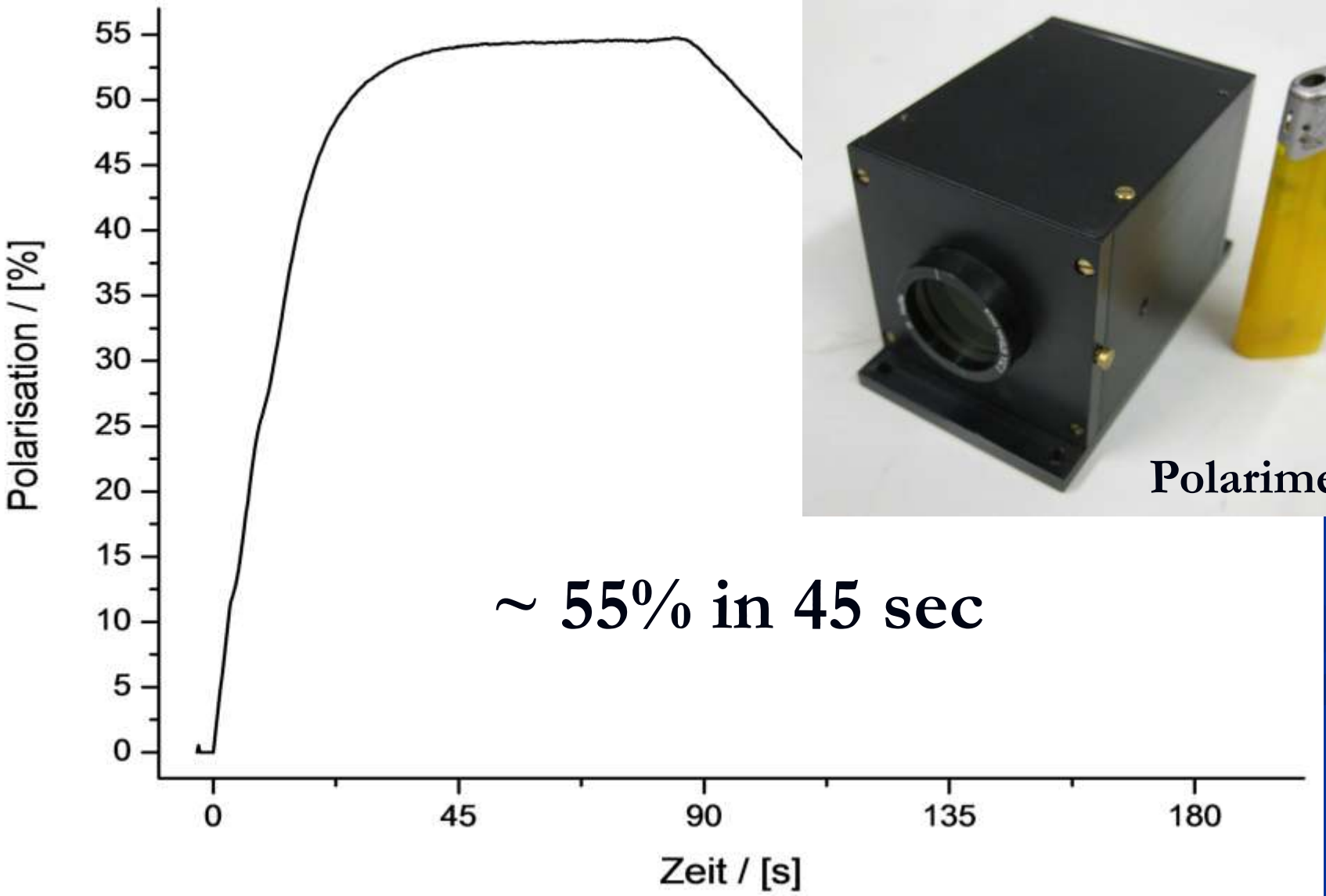
Status:

- ^{3}He polarizer operational

- No polarization loss during compression

- 7 min for 16 mbar·L

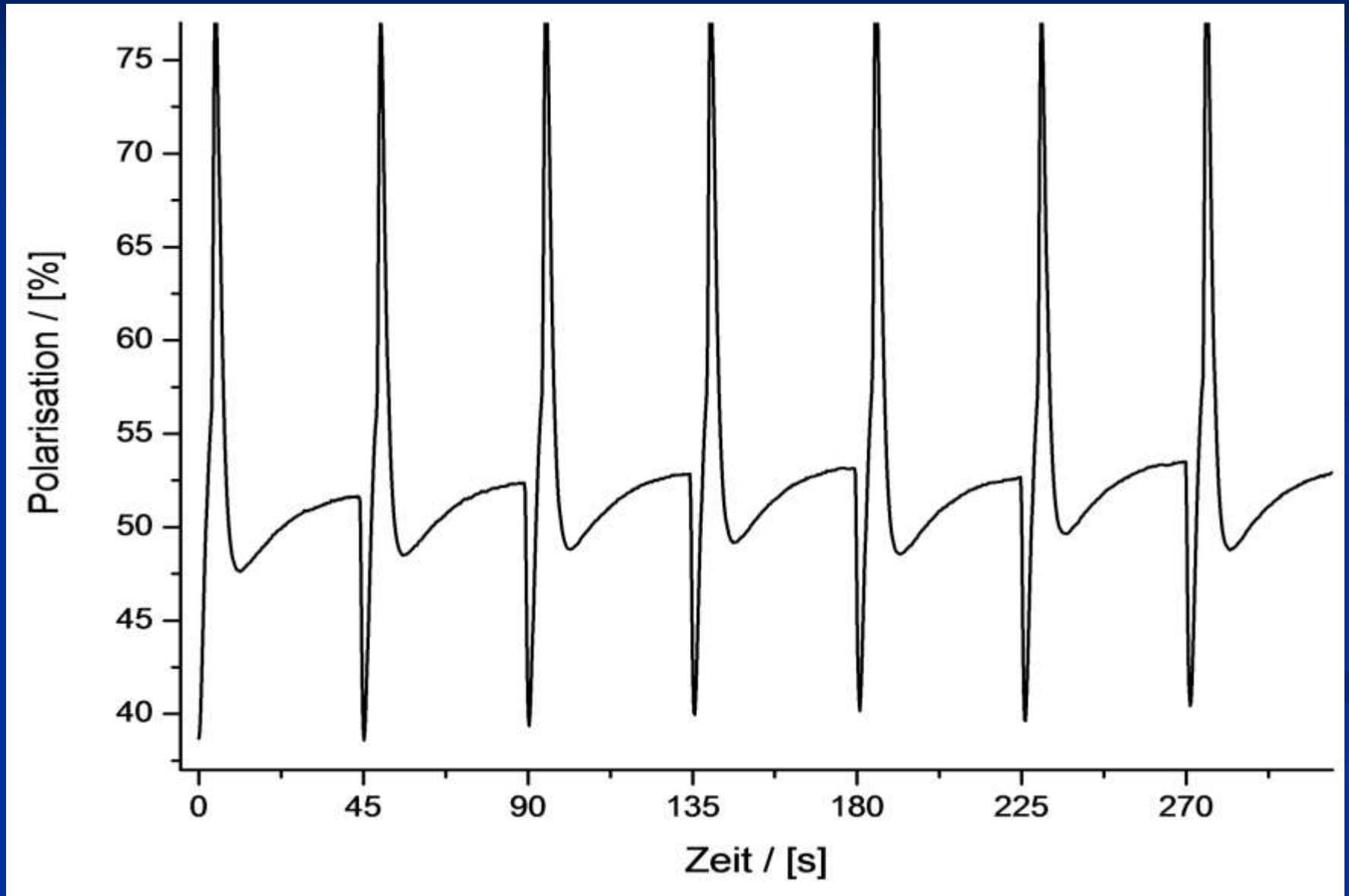
Polarization-Curve:



Polarimeter

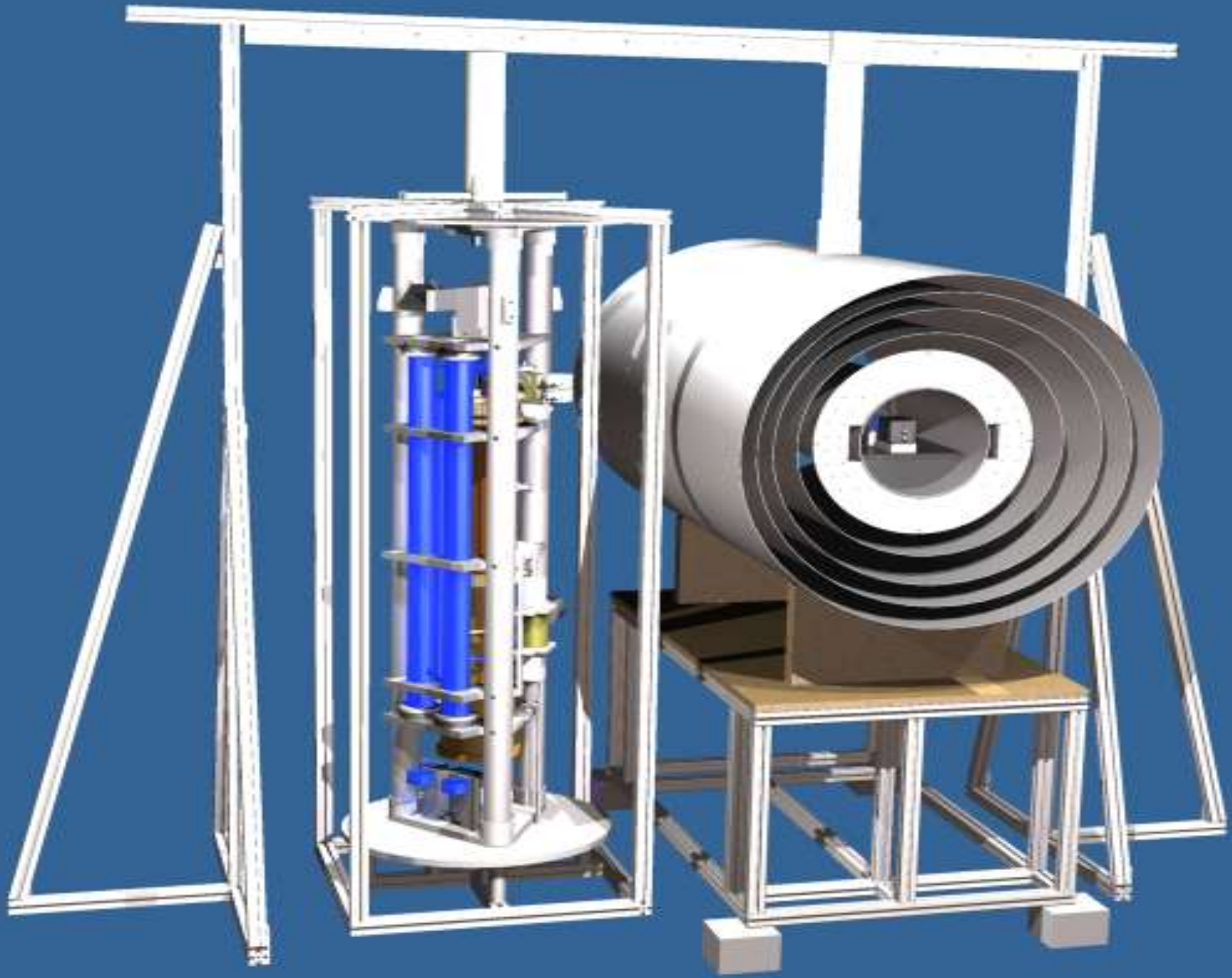
~ 55% in 45 sec

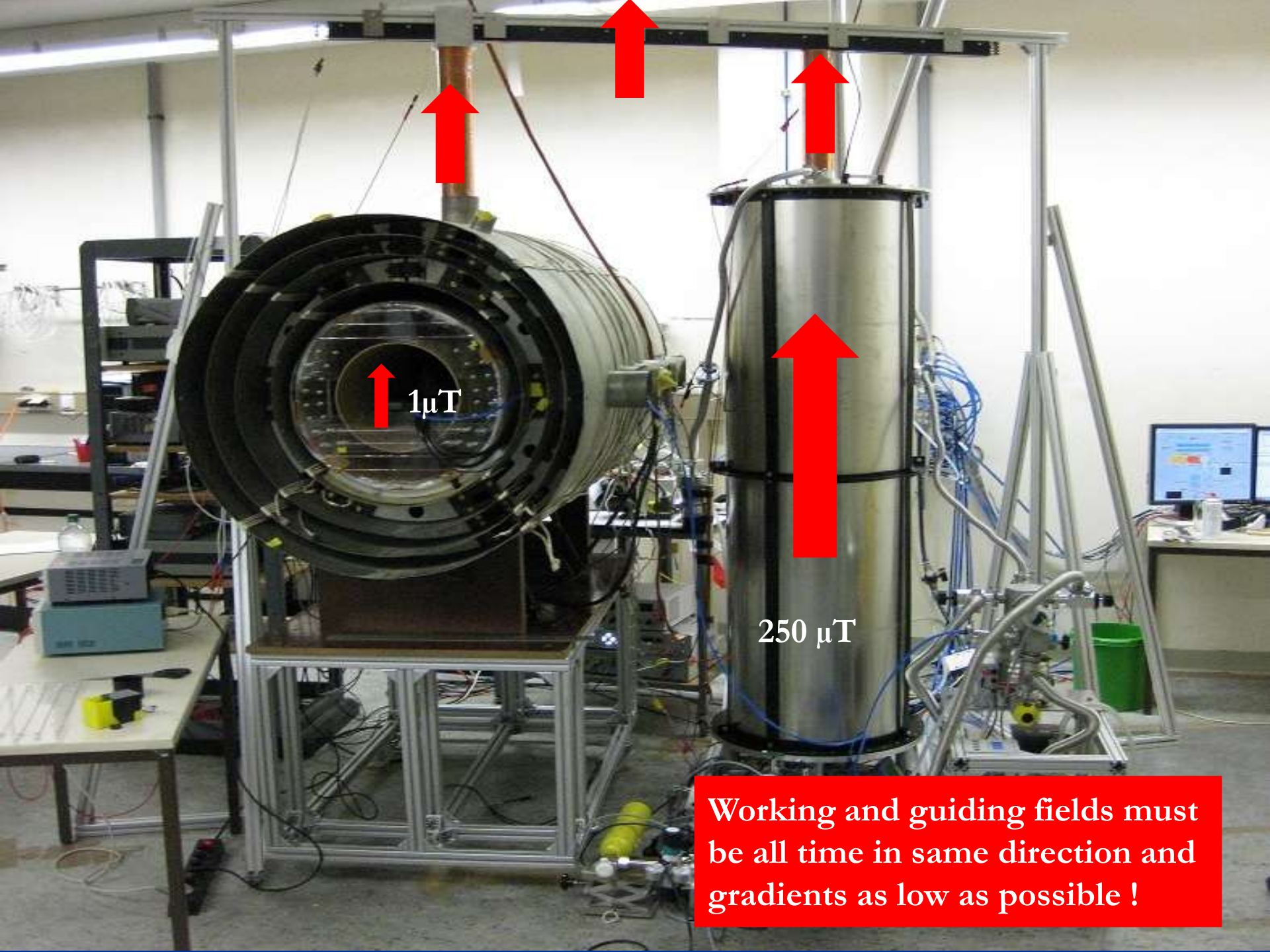
Periodical Cycles, Dezember 2011:

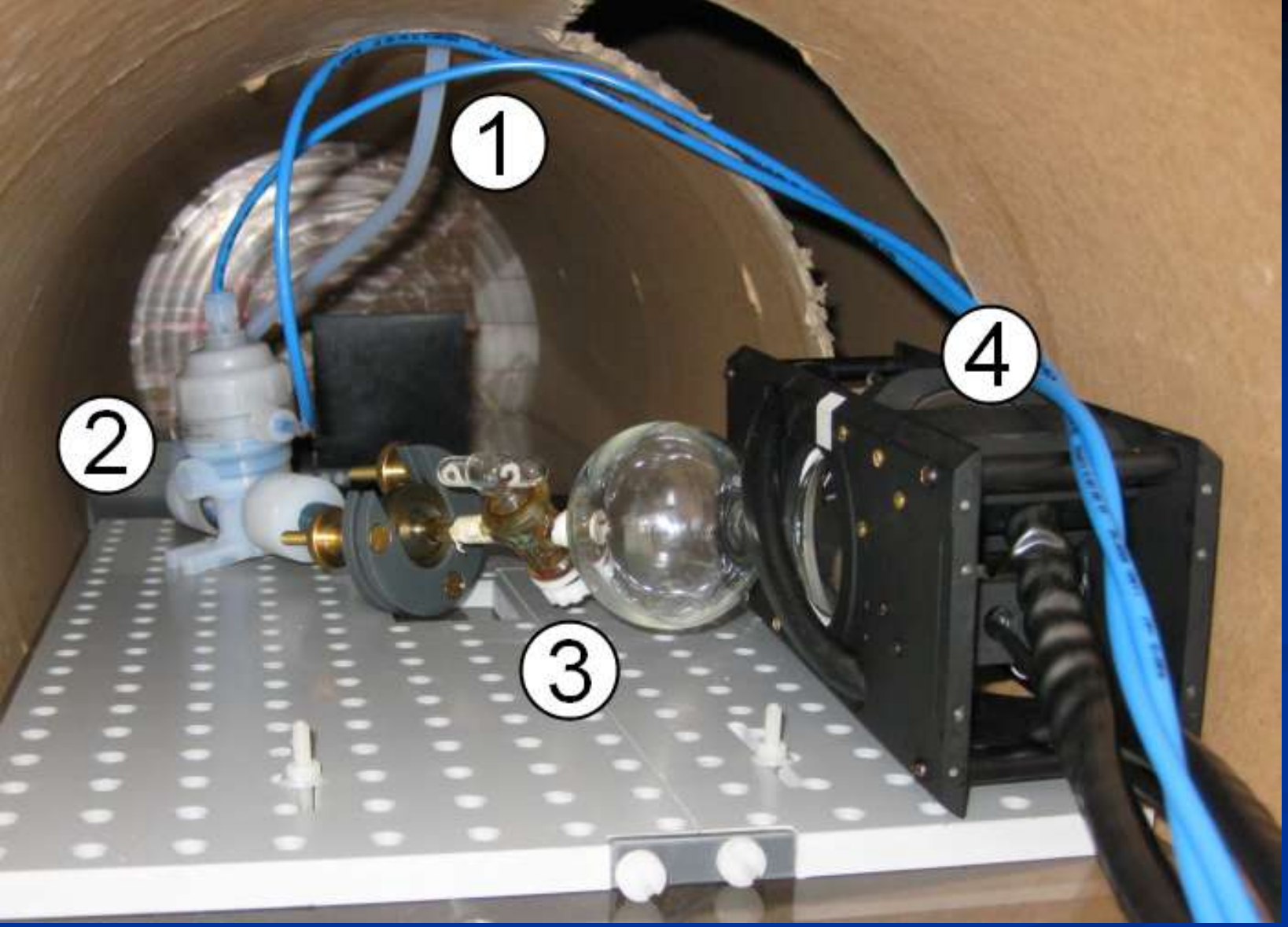


3. Transfer of ^{3}He into Testshield

(Mainz, January 2012)

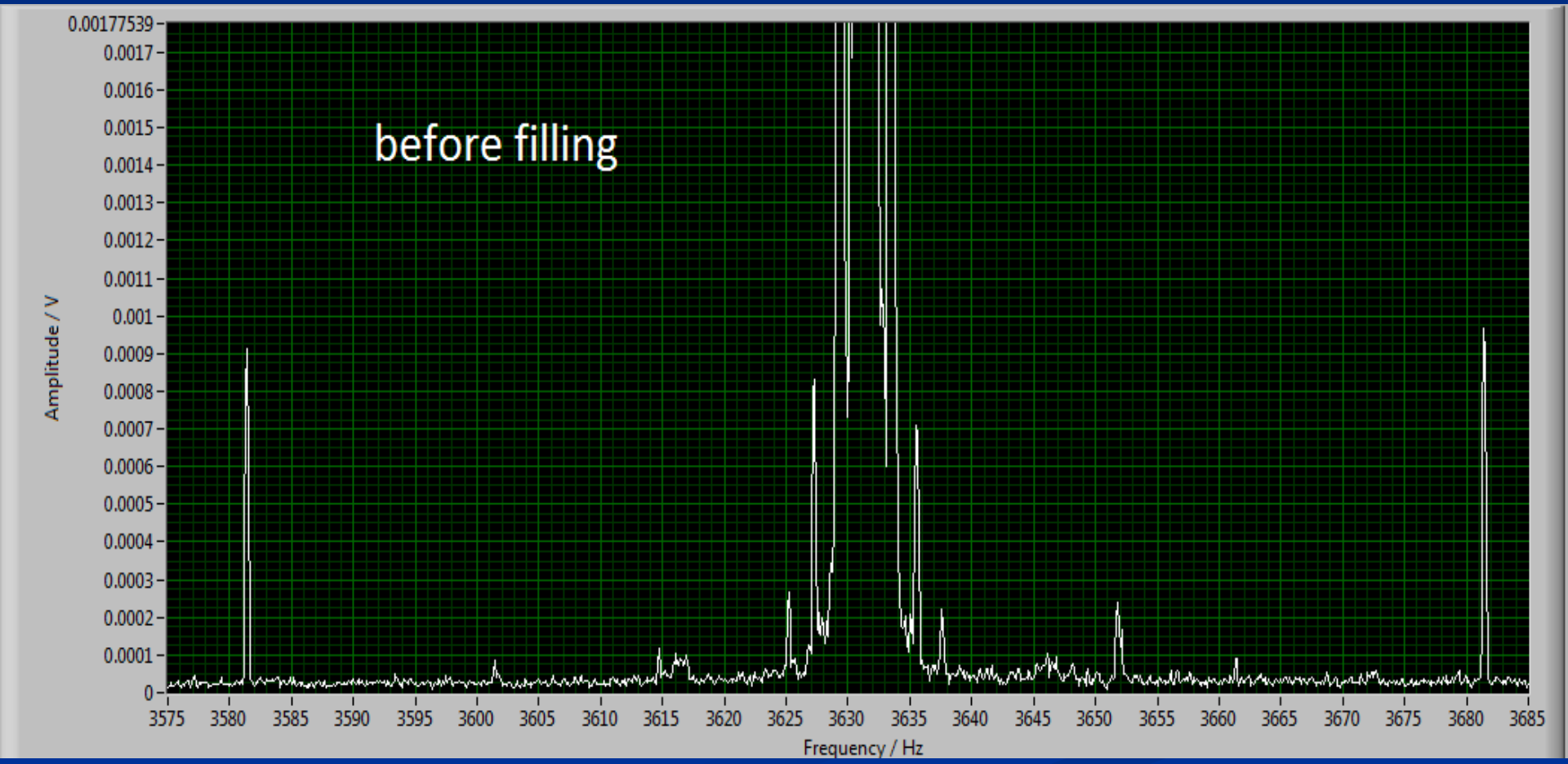



1μT
250 μT
Working and guiding fields must be all time in same direction and gradients as low as possible !

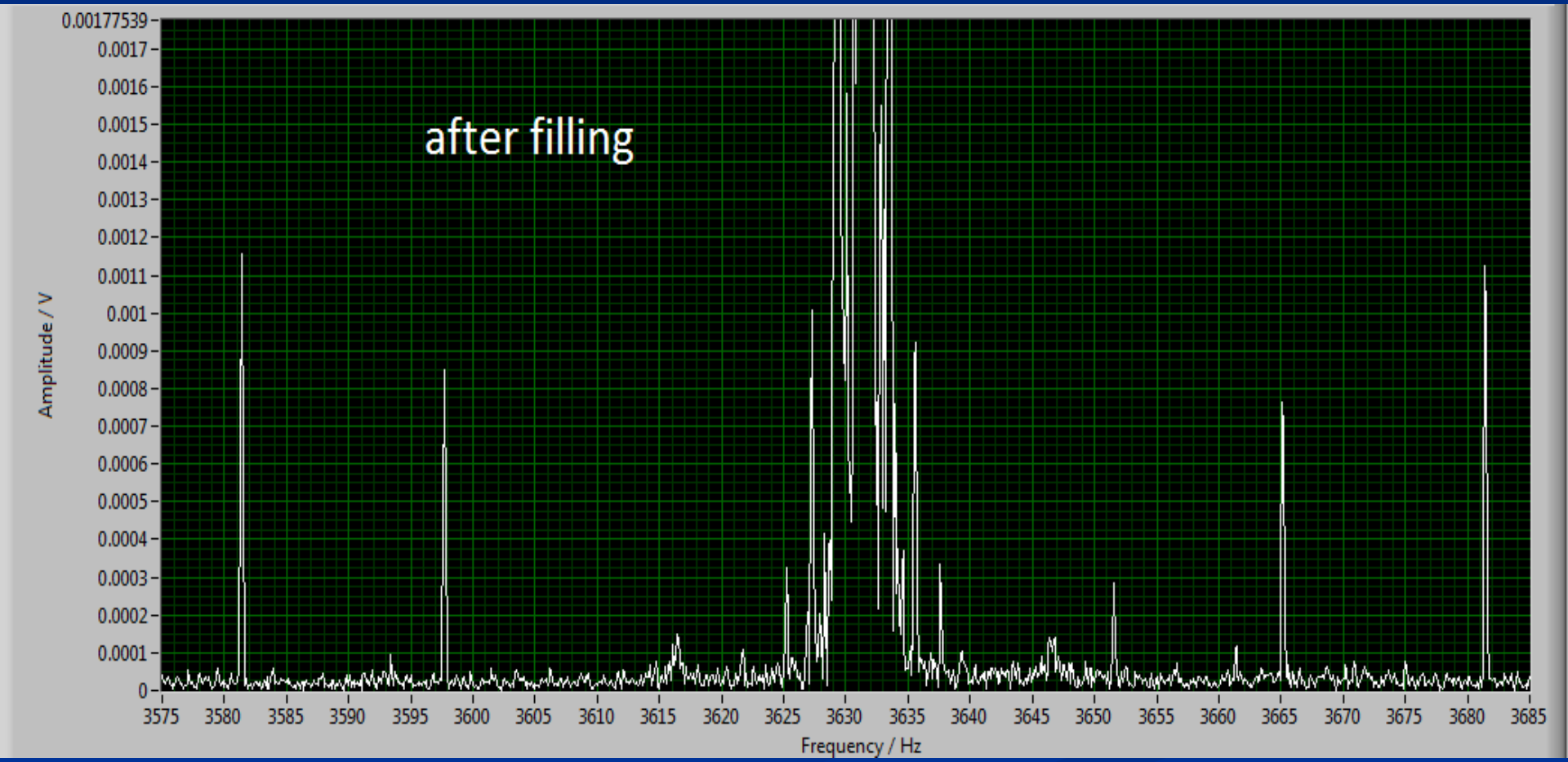


(1)Transfertube, (2) Valve, (3) small Magnetometercell and (4) Cs-Magnetometer.

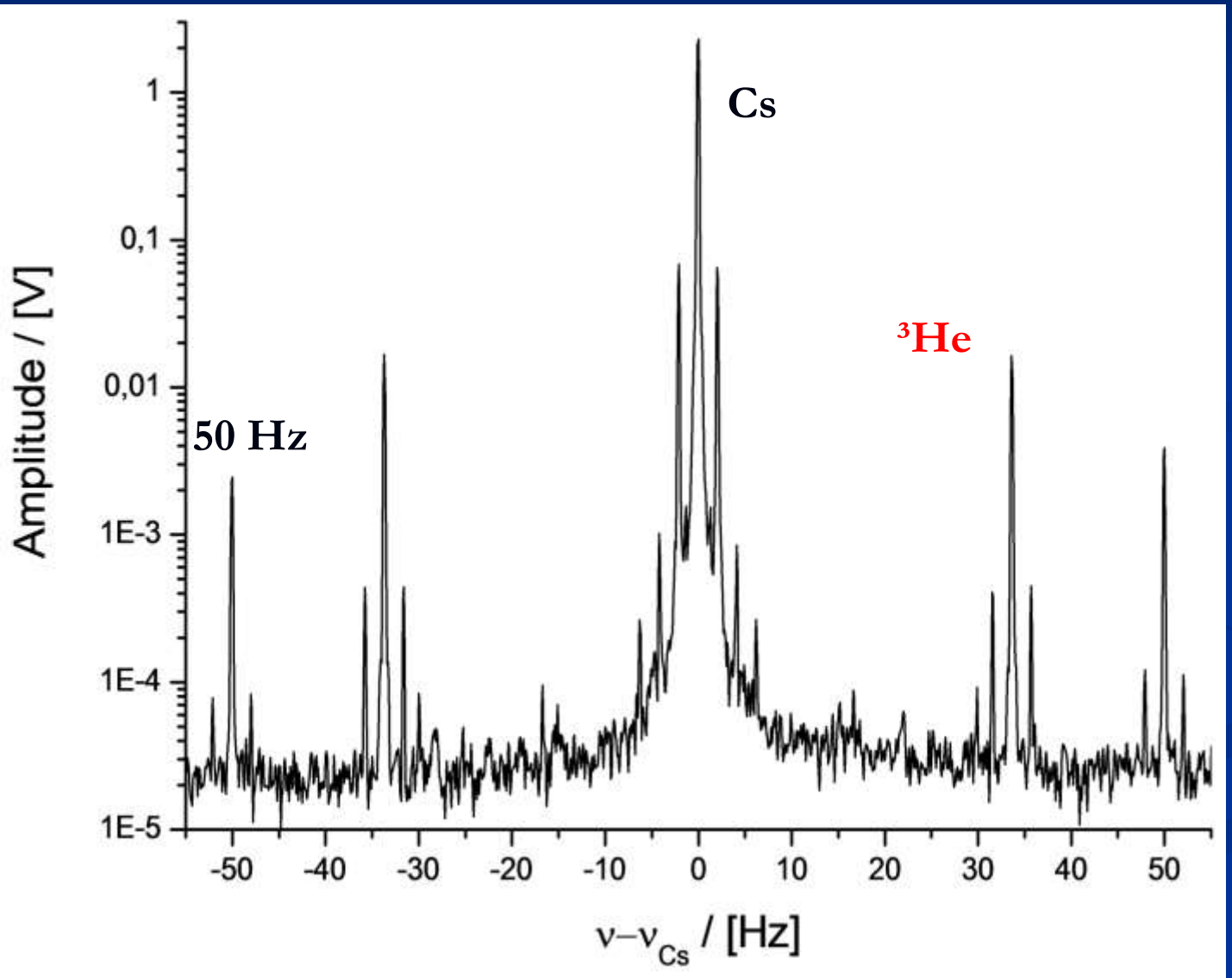
Results, January 2012 :



Results, January 2012 :



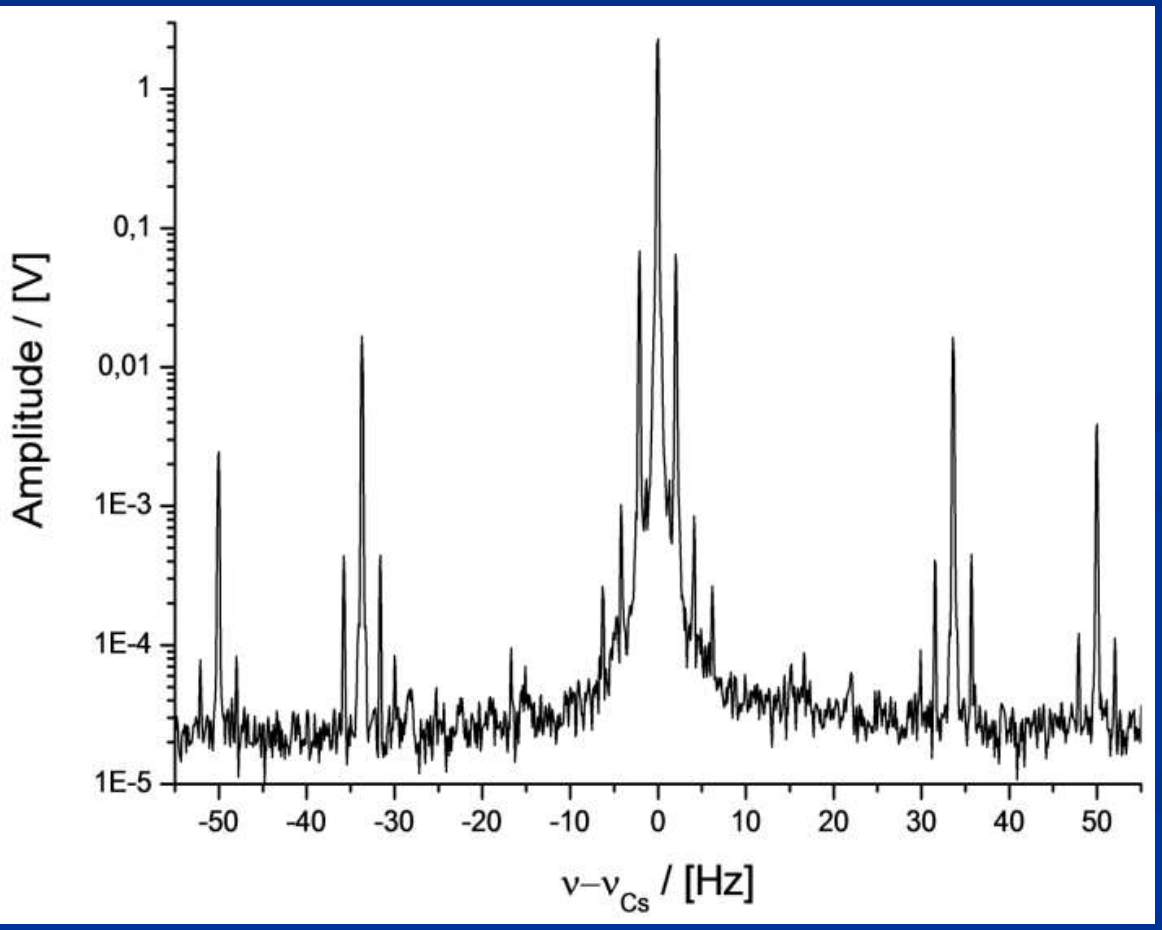
Results, January 2012 :



SNR: 780:1
@ 30 mbar

SNR: 26:1
@ 1 mbar

Transfer-Losses :

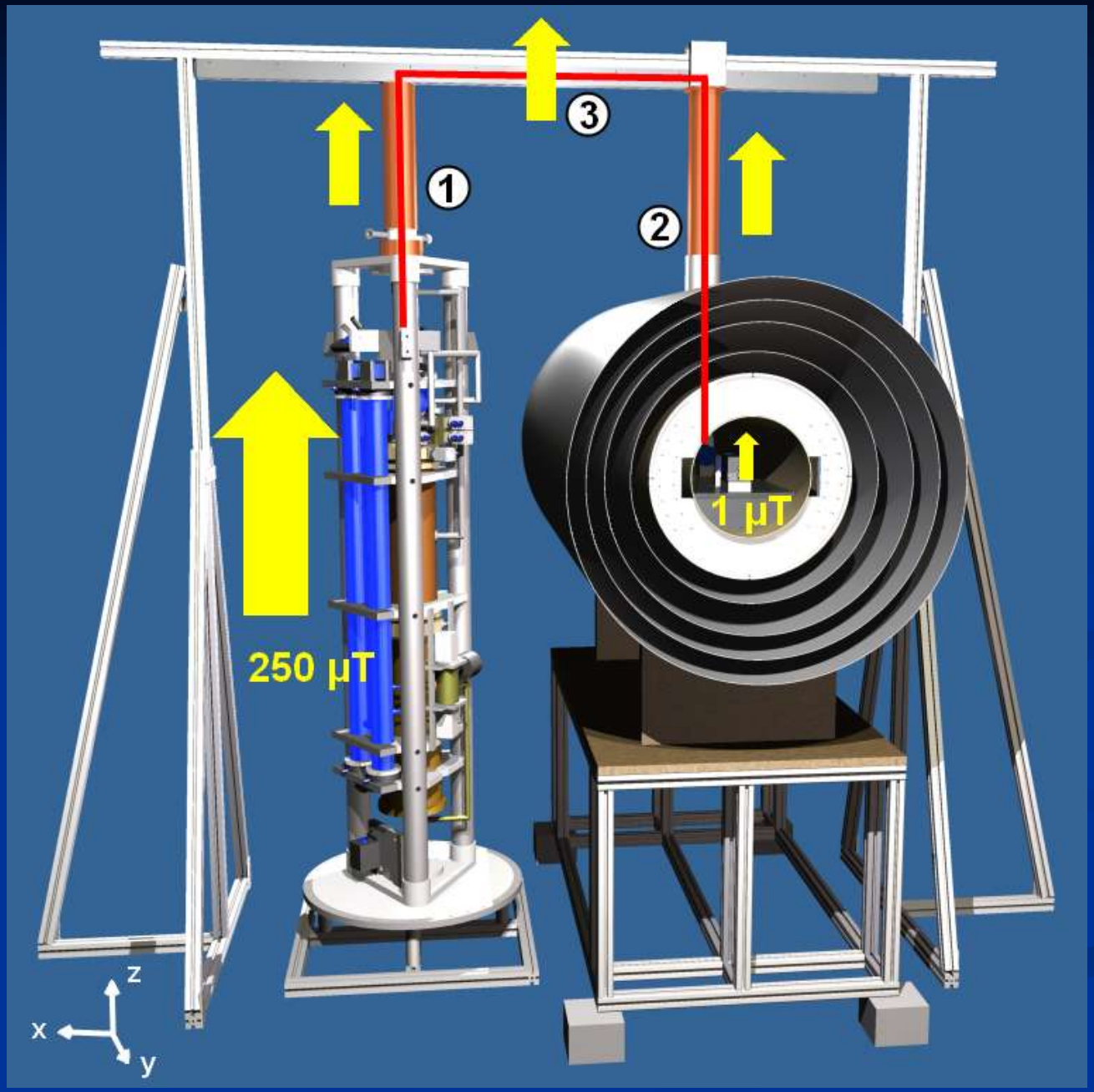


Magnetization b seen by Cs

$$b = \frac{4\pi \cdot \nu_{^3He}}{\gamma_{Cs}} \frac{A_{^3He}}{A_{Cs}} = 157\,pT$$

Simulation: 162 pT

NO LOSSES


1
2
3
250 µT
1 µT
z
x
y

Thanks for your attention