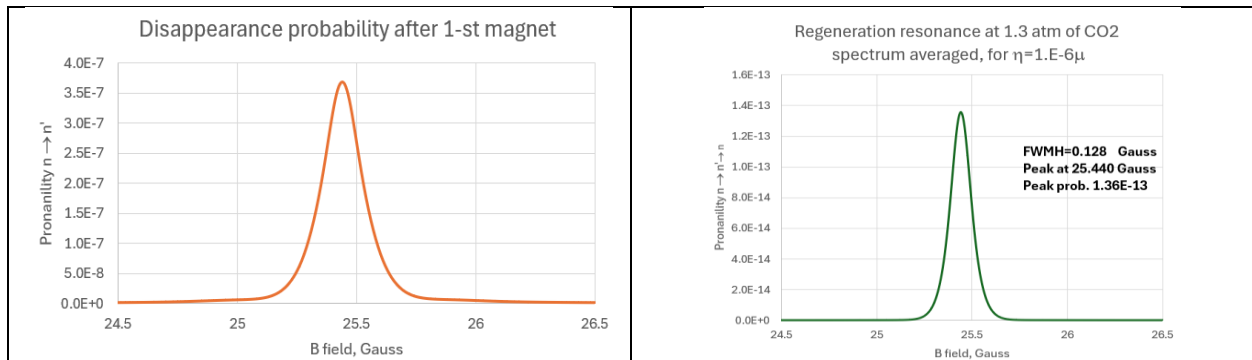


## Accuracy of parameters in nTMM measurement

For nTMM measurements we will use the method of compensation of the optical potential of the CO<sub>2</sub> gas by the energy of neutron magnetic moment in the uniform magnetic field. Optical potential  $V$  is proportional to gas density and the magnetic energy is  $\mu B$ . Only one polarization of the GP-SANS beam is participating in compensation. By varying magnetic field  $B$ , we will look for the resonance at the point where  $\mu B = V$ . We choose  $V$  corresponding to CO<sub>2</sub> gas pressure  $\sim 1.3$  atm. That requires compensation magnetic field  $\sim 25.5$  Gauss. After passing the first magnet a small fraction of neutrons is transformed into the mirror neutrons (left figure below, unobservable). All remaining neutrons will be absorbed in 3.5 mm Cadmium plate but mirror neutrons will pass the absorber. After the second magnet (right figure) mirror neutrons are transformed (regenerated) into observable neutrons that can be detected above the background. Since we will not know reliably the exact values of  $V$  and the magnetic field  $B$ , we will need to scan with the same magnetic field synchronously in both magnets (the gas pressure in both vessels should be the same). If we see a resonance at the expected magnetic field, it will be a discovery; if we see a resonance but at a different than predicted place (field) – that will be a second discovery. Therefore, it will be important to predict  $V$  as accurately as possible and to know exactly the magnitude of the uniform field in the magnet. Scan will cover the region  $\pm 1$  Gauss around the predicted central value  $\sim 25.5$  Gauss.



Since the natural width of the regeneration resonance (right figure) is 0.128 Gauss FWHM with the resonance field 25.5 Gauss, we need to have pressure in both vessels to be the same with the accuracy  $\sim 0.1 \times 0.128/25.5 \sim 0.05\%$ .

Magnetic fields (or the currents) in both magnets should be equal with the same accuracy 0.05%. Step of the change of the magnetic field during the magnetic field scan should be  $\sim 0.025 - 0.040$  Gauss (depending on available run time).

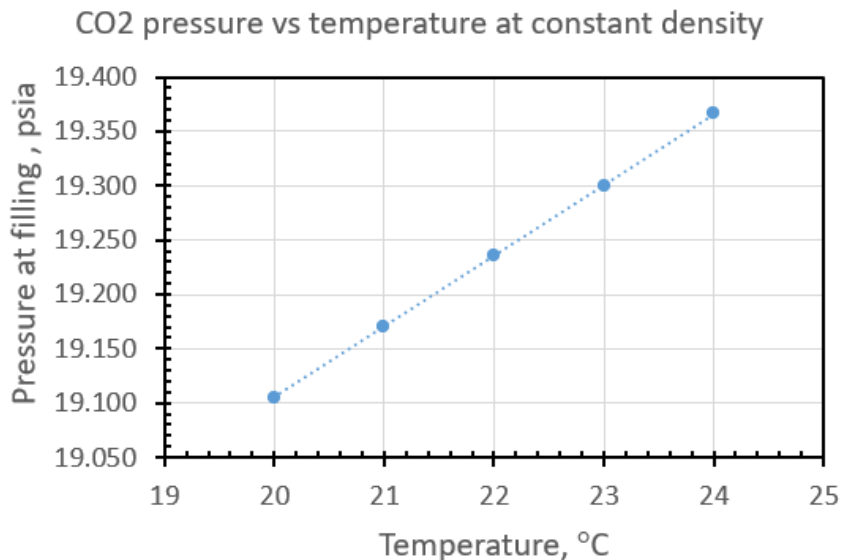
For the maximum designed magnetic field 30 Gauss the magnet power is 20.5 W. It will be less for operating range of magnetic field. Thus, at  $B=24.5$  Gauss it will be 13.5 W, at  $B=25.5$  Gauss 14.4 W, and at  $B=26.5$  Gauss 15.6W. Note, that at 20.5 W increase of the temperature was 30°C. This test result can be described by an “effective” emissivity  $\epsilon = 0.0885$ . With this  $\epsilon$  we should expect following increase of the temperature over the room temperature during the variation of magnetic field:

$\Delta T_{min} = 20.7^{\circ}\text{C}$ ,  $\Delta T_{central} = 21.9^{\circ}\text{C}$ ,  $\Delta T_{max} = 23.6^{\circ}\text{C}$ , or  $\Delta T = (22 \pm 1.5)^{\circ}\text{C}$ . That is to assume that at the initial central point there was enough time to reach thermal equilibrium. If the “effective” emissivity will be higher, variation of the temperature during the magnetic scan will be smaller.

**When initially filling vessel with CO2** at different environmental temperature, the pressure should be different if some particular density is desired. Here we choose density 2.4068 kg/m<sup>3</sup>. Aluminum vessel volume 52.875 liters. Volume expansion coefficient for Aluminum  $72 \times 10^{-6}/\text{K}$ . That means that density changes as  $\Delta\rho/\rho = -T \cdot 72 \times 10^{-6}/\text{K}$ . It is taken into account in the last column below. Thus, with the temperature measurement accuracy  $<0.1^{\circ}\text{C}$  and pressure measurement accuracy 0.01 psia, the density can be controlled at the level  $\sim 0.05\%$ .

T, °C	p, psia	p, Pa	p, torr	mbar	p, bar	p, atm	density kg/m <sup>3</sup>	density kg/m <sup>3</sup>
							w/o expansion	with Al expansion
20	19.105	131724.34	988.01	1317.24	1.3172	1.30002	2.40682	2.40682
21	19.171	132179.39	991.43	1321.79	1.3218	1.30451	2.40703	2.40686
22	19.237	132634.45	994.84	1326.34	1.3263	1.30900	2.40718	2.40683
23	19.304	133096.39	998.30	1330.96	1.3310	1.31356	2.40739	2.40687
24	19.371	133558.34	1001.77	1335.58	1.3356	1.31812	2.40754	2.40685

Refs: <https://www.nist.gov/pml/sensor-science/thermodynamic-metrology/unit-conversions>  
[https://www.peacesoftware.de/einigewerte/co2\\_e.html](https://www.peacesoftware.de/einigewerte/co2_e.html)



Under the constant density pressure should increase linearly with temperature

If filled by CO2 with density 2.4068 kg/m<sup>3</sup> the magnet vessel operates with magnetic field, i.e. with the temperature increase  $\Delta T = 22 \pm 1.5^{\circ}\text{C}$  at room temperature  $22^{\circ}\text{C}$ , i. e. at  $44 \pm 1.5^{\circ}\text{C}$ . The density will change due to aluminum vessel thermal expansion to the density  $2.4030 \pm 0.0003 \text{ kg/m}^3$ . That is a variation of 0.013%. Local variation of the gas density due to thermal gradients and possible convection effects should not exceed this value 0.013%.

Now, let’s recalculate the optical potential and peak operational magnetic field for the gas density 2.4030 kg/m<sup>3</sup>:  $V_{opt} = 0.15631 \text{ neV}$  and  $B_{center} = 25.92 \text{ Gauss}$ . That corresponds to the filling density 2.4068 kg/ m<sup>3</sup>.