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Monitoring of the pick-up coils

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Abstract

We present here the efficiency of the pick-up coil system during E94010.

1 Monitoring the Pick-up Coils

During E94010, we have regularly monitored the efficiency of the pick-up coils using a small excitation loop glued on the side of the RF mounting. The loop was connected to the RF function generator in the Counting House and the response of the pick-up coils as a function of the excitation frequency was recorded by the lock-in amplifier.

The response of the circuit is the typical response of a parallel AC LRC circuit which can be modelized as shown in figure 1, where :

- e is the EMF induced in the circuit
- L is the coil circuit inductance
- C is the coil circuit capacitance
- R is the lock-in input impedance
- V is the voltage measured by the lock-in amplifier

Using a complex formalism, we have :

$$V = RI = e - iL\omega I_1 = \frac{i}{C\omega} I_2 \tag{1}$$

and

$$I = I_1 + I_2 \tag{2}$$

so we can extract V as a function of e :

$$\begin{aligned} V &= e - iL\omega(I - I_2) &(3)\\ &= e - iL\omega(V/R + iC\omega V) &(4) \end{aligned}$$

and returning to real numbers, we get :

$$V = \frac{e}{\sqrt{\left[\frac{\omega^2}{\omega_0^2} - 1\right]^2 + \frac{L^2\omega^2}{R^2}}} \tag{5}$$

where we have introduced the resonance pulsation $\omega_0 = 1/\sqrt{LC}$.

Defining the Q factor of the circuit as the ratio $Q = R/L\omega_0$, we write :

$$V = \frac{e}{\sqrt{\left[\frac{\omega^2}{\omega_0^2} - 1\right]^2 + \frac{\omega^2}{Q^2\omega_0^2}}} \tag{6}$$

Replacing the pulsation ω by its expression $2\pi f$ as a function of the excitation frequency f and writing the explicit proportionality of the induced EFM with f as $e = kf$, we get the parametrization of the voltage measured by the lock-in as a function of the excitation frequency f :

$$V(f) = \frac{kf}{\sqrt{\frac{1}{Q^2}\frac{f^2}{f_0^2} + \left(\frac{f^2}{f_0^2} - 1\right)^2}} \tag{7}$$

The constants k, Q and f_0 will be fitted to the experimental curve. At the resonance, $f = f_0$ and the voltage measured by the lock-in is maximum and equal to $V(f = f_0) = Qe(f = f_0)$.

Fitted data are shown on figure 2. The gain $G(f)$ of the circuit is usually defined as the ratio V/e, that is :

$$G(f) = \frac{1}{\sqrt{\frac{1}{Q^2}\frac{f^2}{f_0^2} + \left(\frac{f^2}{f_0^2} - 1\right)^2}} \tag{8}$$

At the resonance $f = f_0$, $G = Q$.

2 History

The history of the system is shown on figure 3 and in table 1, giving us the time evolution of the value of the Q factor of the circuit for the 31 measurements performed during the E94010 experiment. Also is shown the evolution of the circuit response at the NMR RF frequency $f = 91$ kHz.

The voltage V measured at the NMR frequency f =91 kHz should be used as a reference to rescale all the NMR measurements performed with the water and Helium cells.

Table 1: *Detailed history*

Date	Time	Last event before the measurement	Q	$V(f = 91\text{kHz})(\text{mV})$
9/25	7:33 PM	Water - DON'T WORRY mounted	49.77790	0.000388055
9/26	8:07 AM	-	n/a	n/a
9/26	8:16 AM	-	n/a	n/a
9/26	8:28 AM	-	49.03250	0.000385999
9/26	9:04 AM	-	50.13150	0.000386343
9/26	9:53 AM	-	49.83660	0.000387713
9/27	3:25 PM	-	49.83690	0.000387713
10/1	10:30 AM	-	50.18700	0.000386686
10/7	10:12 AM	-	50.98520	0.000354784
10/10	6:16 PM	BLUE mounted	50.57780	0.000160668
10/14	4:58 PM	BE HAPPY mounted	51.06810	0.000385999
10/17	3:43 AM	-	n/a	n/a
10/17	4:15 AM	-	51.16390	0.000386343
10/18	7:34 PM	-	23.96890	0.000357169
10/18	8:25 PM	-	24.59220	0.000360212
10/18	8:57 PM	-	24.63790	0.000354099
10/18	10:43 PM	-	24.75830	0.000358862
10/18	11:15 PM	-	24.69920	0.000358524
10/18	11:32 PM	-	24.75480	0.000184217
10/18	11:46 PM	-	22.81860	0.000202392
10/18	11:56 PM	-	46.47720	0.000151746
10/19	12:35 AM	-	24.82020	0.000202392
10/19	12:47 AM	-	22.97380	0.000201344
10/19	1:18 AM	-	24.28080	0.000357847
10/19	1:51 AM	-	24.12460	0.000358524
11/3	9:44 AM	Water - ARMAGEDDON mounted - Death	50.40980	0.000384021
11/4	1:48 AM	-	36.13190	0.000385999
11/12	4:51 AM	Water - NEPHELI mounted - Death	n/a	n/a
11/12	5:26 AM	-	53.69220	0.00038567
11/25	9:33 AM	SYSIPHOS mounted - Water	n/a	n/a
11/25	10:41 AM	-	53.92360	0.00035307

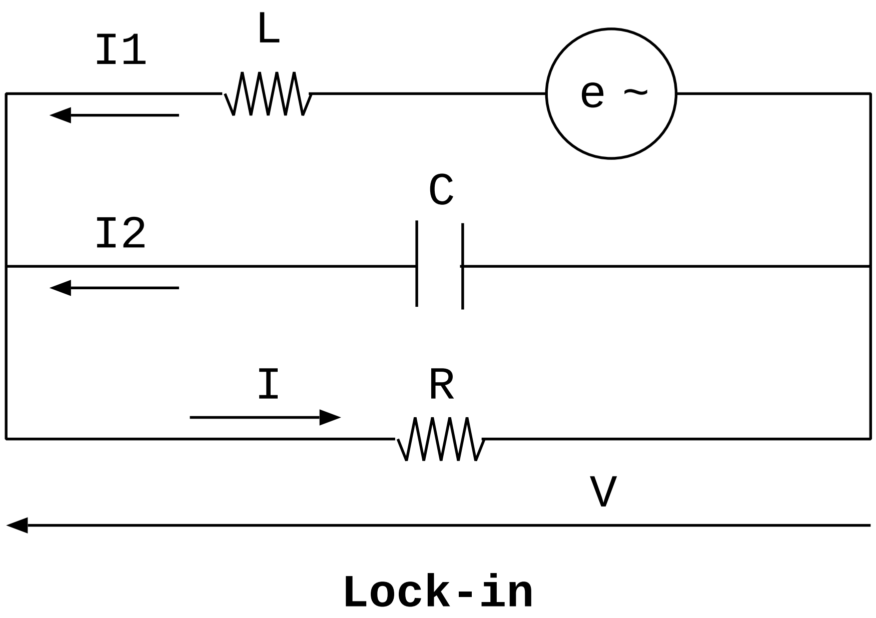

Figure 1: Model of the pick-up coil circuit connected to the lock-in amplifier.

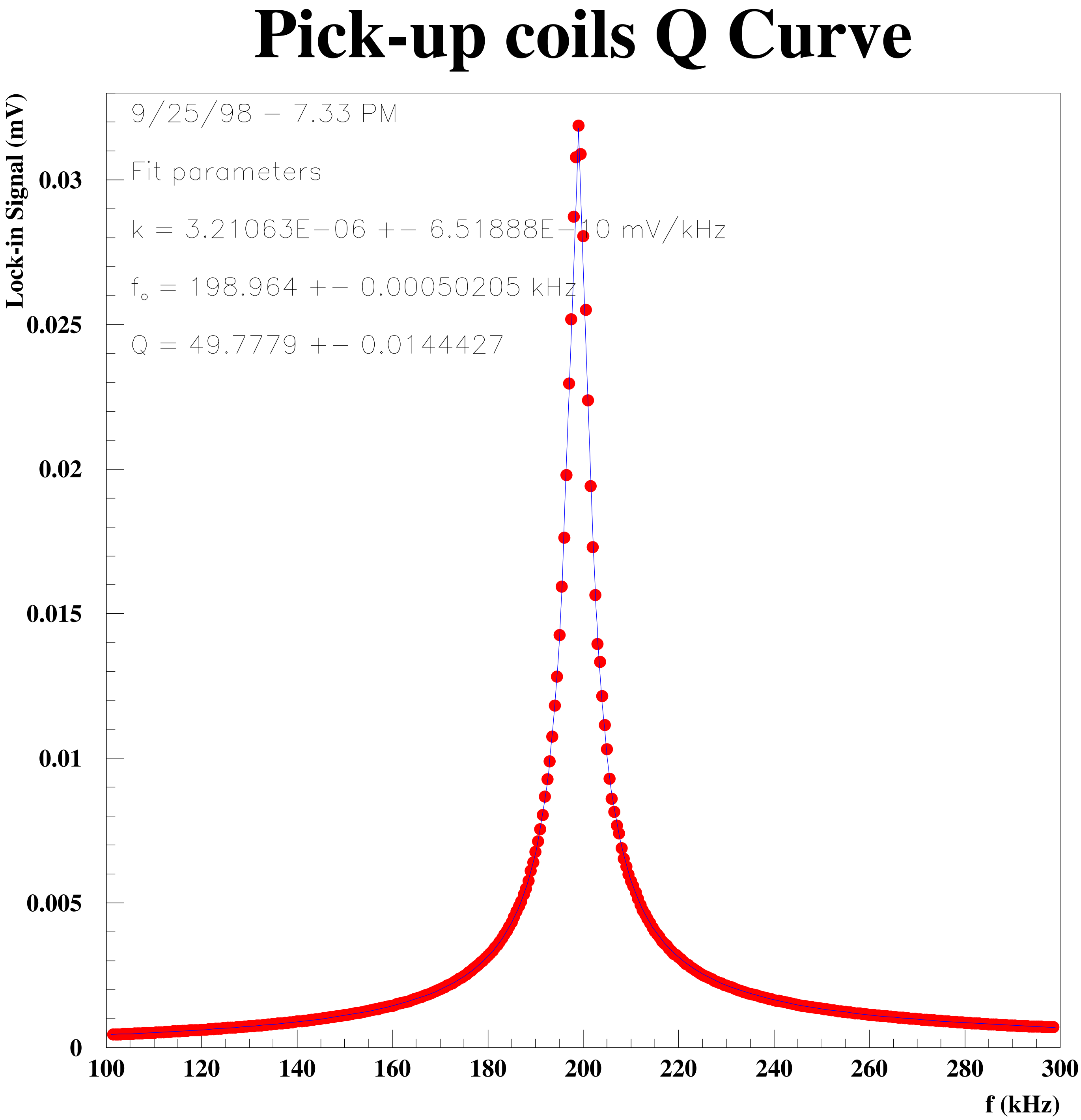

Figure 2: Q curve obtained on 9/25/98 at 7:33 PM. Each plain circle represents the root mean square of 50 successive lock-in measurements at the given frequency. The line represents the shape predicted from our model adjusted to our data, assuming a fluctuation of 0.00001 mV affecting each lock-in measurement.

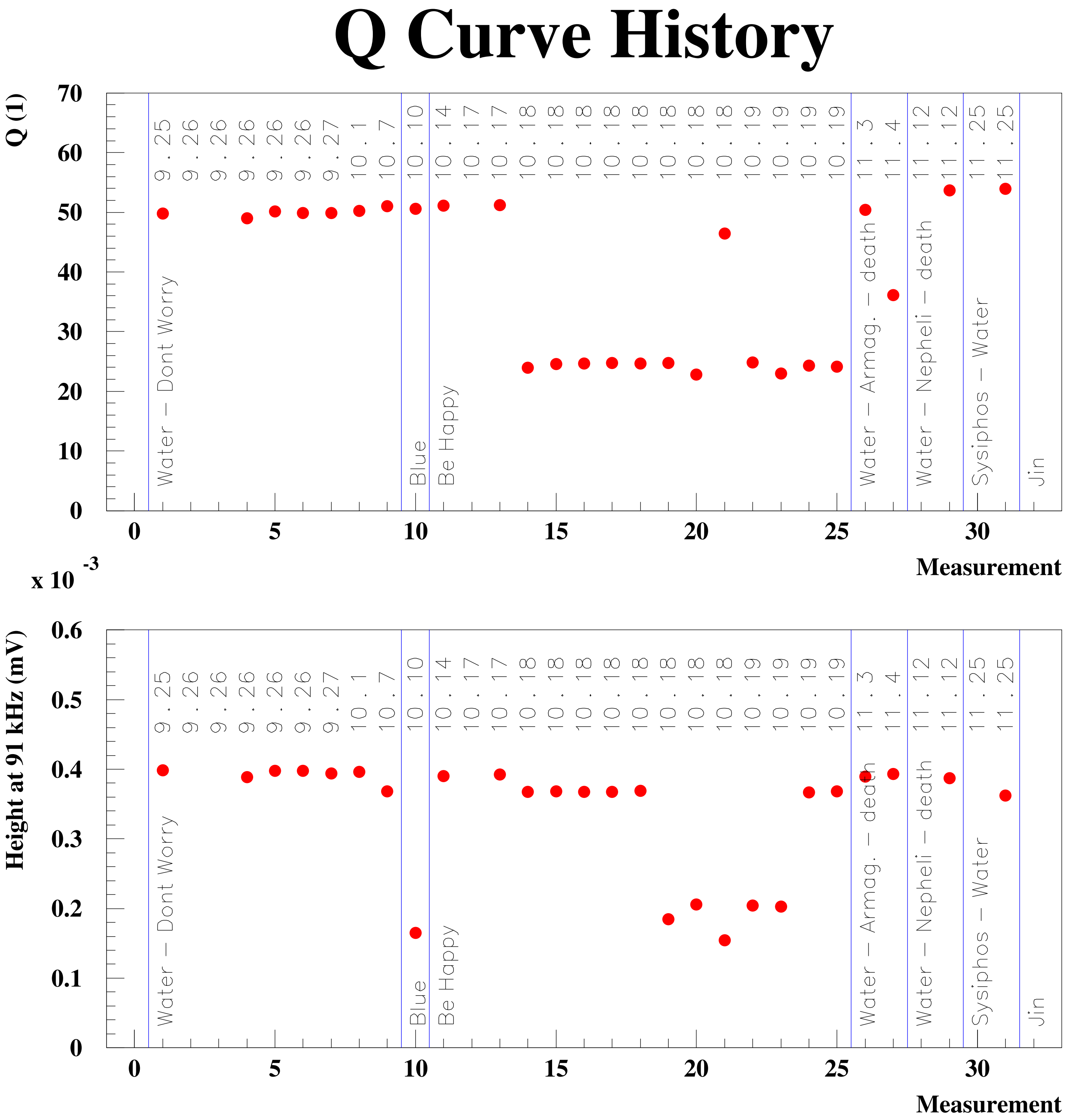

Figure 3: Q curve history for E94010 (top). The error on Q is given by the fit and is smaller than the circle size. The date of each measurement is indicated above in the format month.day. The bottom plot shows the history of the voltage V measured at f =91 kHz.