VESPA
Vaso per Esperimenti Su Plasmi ed Altro

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1 Aims

Study the *Vespa* experimental apparatus, and in particular:

- Model the vacuum system behavior, finding the characteristic parameters;
- Obtain the current-voltage and the current-temperature characteristics curves of the filament;
- Draw the voltage-current characteristics curves of the gas discharge, enhancing their behavior as varying pressure;
- Find the Paschen curve, both in DC and RF condition;
- Measurement of plasma parameters through a Langmuir probe, both in stationary conditions and via ionic-sonic wave propagation.

2 Vacuum system

The vacuum inside the VESPA vessel (a cylindrical vessel, with a length of $\sim$ 80cm and a radius of $\sim$ 20cm: $V \sim 0.1\text{m}^3$) is obtained and kept thanks to a rotary pump and a turbomolecular pump. The vessel is not perfectly isolated and some small leaks affect the vacuum keeping. To study this phenomena, the vessel has been taken to a low pressure ($\sim 6 \cdot 10^{-5}$mbar) and all the valves around have been closed. Isolating the chamber from the pumping system one can measure (thanks to a ionization pressure gauge) the pressure in the vessel as function of time. Effects as leaks and degasing contribute to an inflow in the chamber $F_0(p)$ that in principle could depend on the pressure. Assuming instead F_0 constant, its value can be estimated through a linear fit on the data: $P = a + b \cdot t$, $F_0 = V \cdot b$.

Considering the reaction time, the slowness of the ionization gauge in stabilizing and the pressure oscillations, the errors are estimated as 5% on the pressure and a 0.5s error on the time.

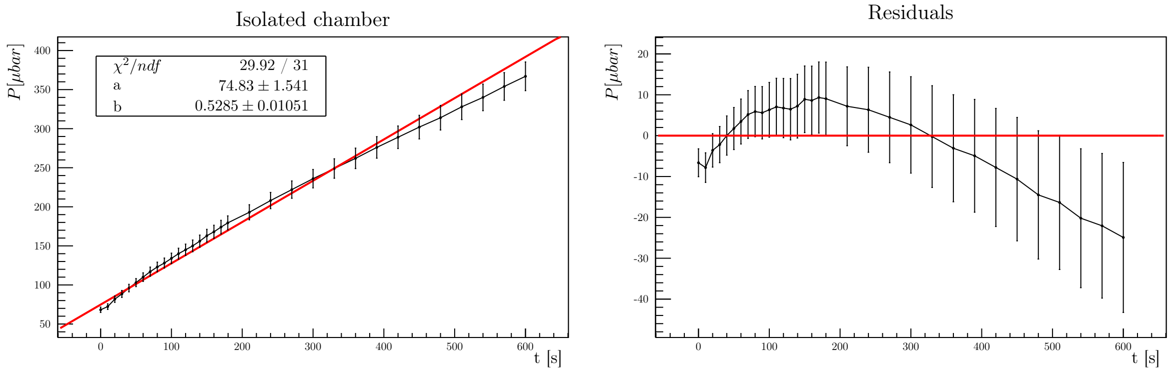

Figure 1: Presure increasing in the chamber

As can be seen from fig 1 there is an evident trend in the residuals, proving that F_0 cannot be assumed constant throughout all the explored range of pressures. A simple way to correct this is to consider a low pressure regime and a high pressure one.

Limiti dei regimi

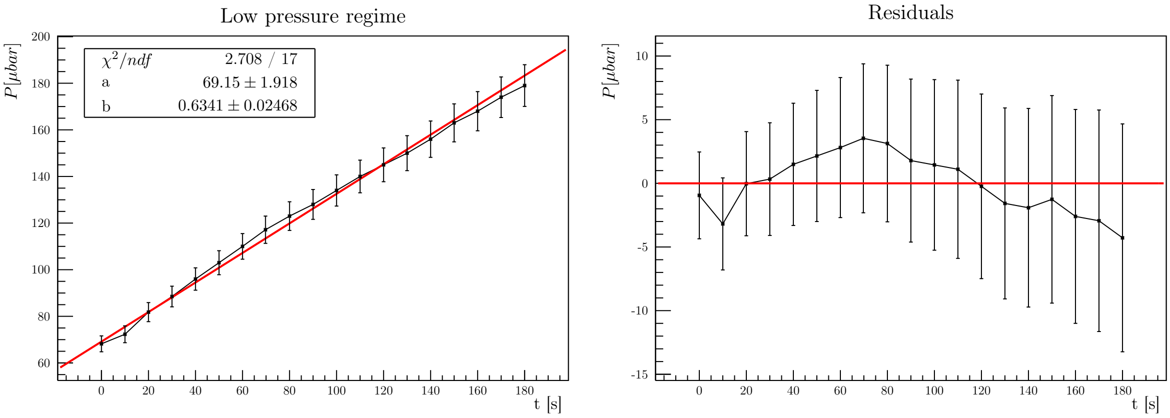

Figure 2: Low pressure regime

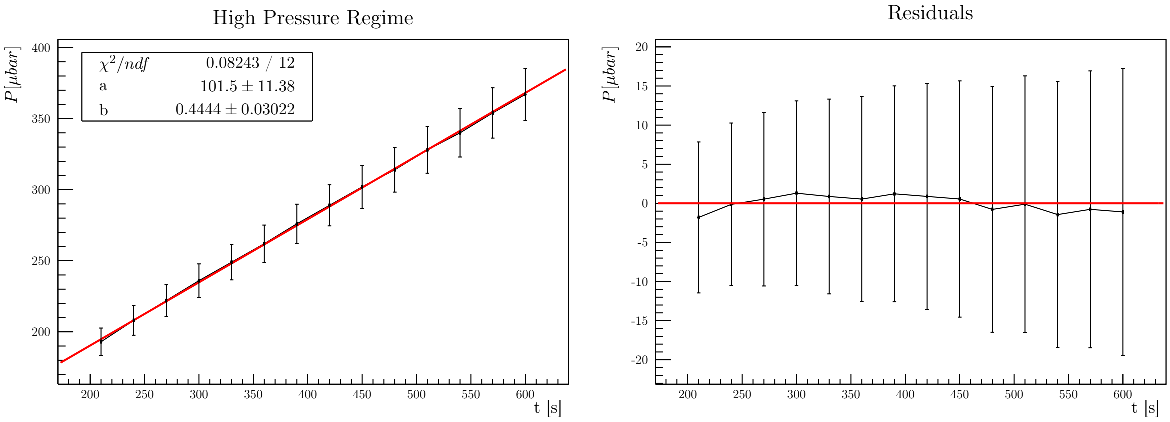

Figure 3: High pressure regime

Splitting the high pressure area and the low pressure area and performing two different fits, the inflow can be estimated as (assuming a 5% error on the volume):

$$F_0^{\mathrm{low}} = (6.4 \pm 0.4) \cdot 10^{-8} \mathrm{Pa\,m^3/s} \quad F_0^{\mathrm{high}} = (4.5 \pm 0.4) \cdot 10^{-8} \mathrm{Pa\,m^3/s}$$

Subsequently, the valve has been opened connecting the chamber to the pumping system. An exponential decay of the pressure is expected: $P(t) = (P_i - P_0)\exp\big(-t/\tau\big) + P_0$, where P_i is the starting pressure and P_0 the asymptotic pressure.

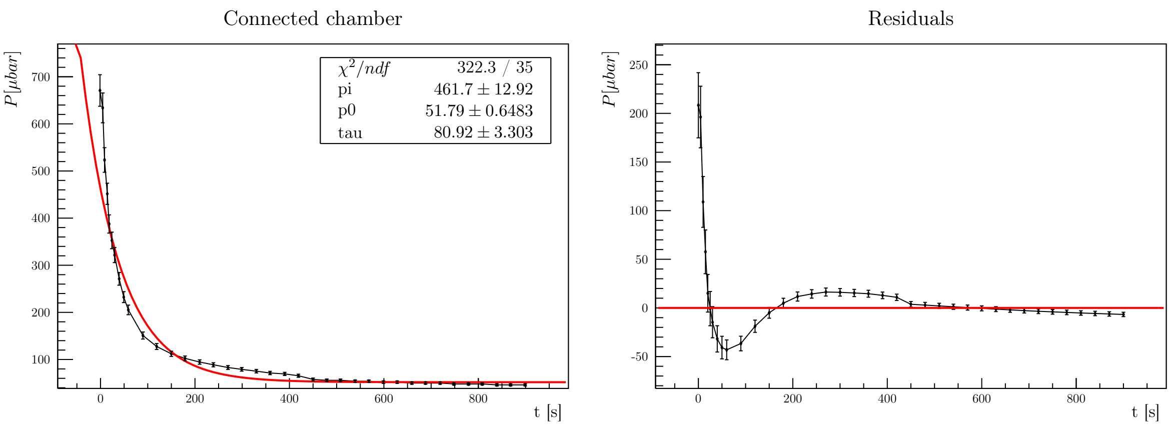

Figure 4: Presure decreasing in the chamber

As can be seen from fig 4 there is an evident trend in the residuals, similarly as what seen before, and as before two regimes can be distinguished . Limits of regimes

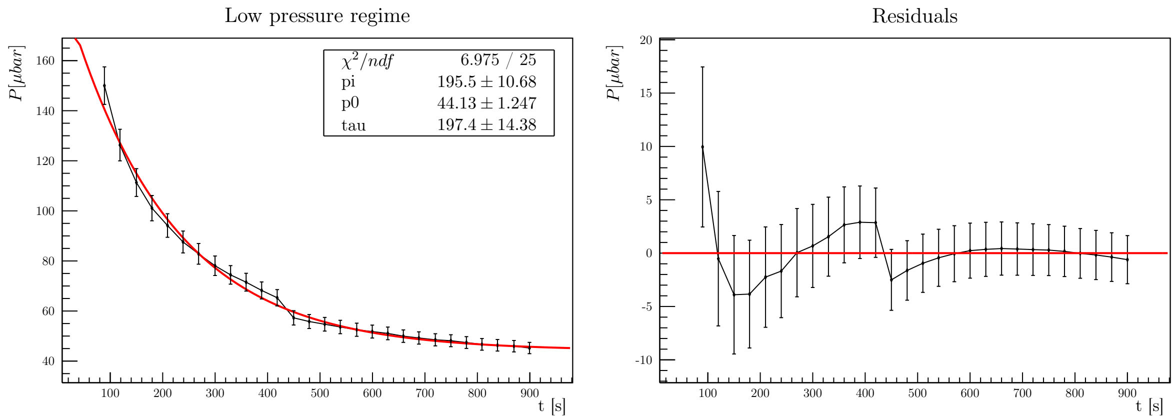

Figure 5: Low pressure regime

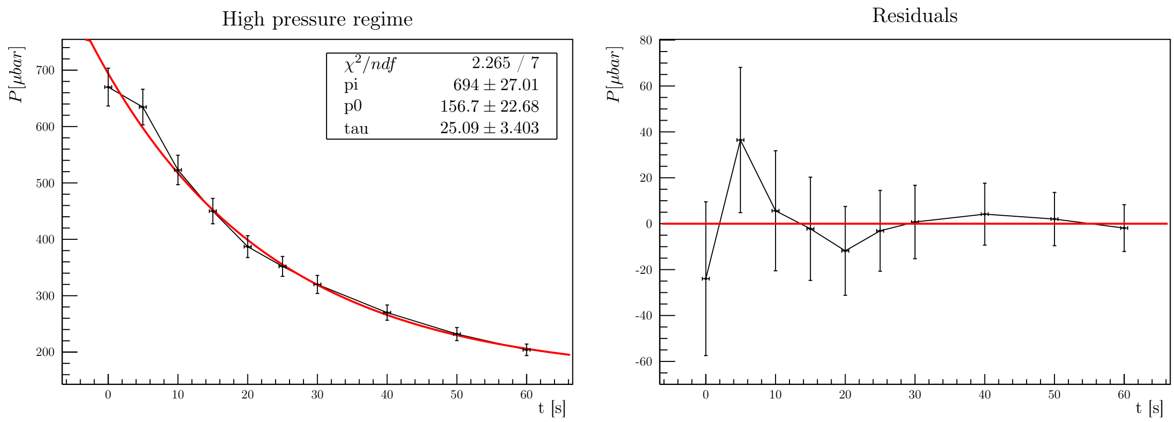

Figure 6: High pressure regime

Performing two different exponential fits, from the values of τ and P_0 the effective pumping speed S_e, the inflow F_0 and, given the nominal value of the pumping speed $S = 33$l/s, the conductance of the chamber-pump connection C can be estimated.

regime	$S_e = V/\tau$ [l/s]	$F_0 = P_0 \cdot S_e$ [Pa m^3/s]	$C = 1/(1/S_e - 1/S)$ [l/s]
jhba	gfjha	bfgjlb	hasgjbha

Table 1: Vacuum parameters

3 Voltage-Current characteristic of the filament

The filament inside the vessel is a tungsten filament with diameter $2r \sim 0.25$mm and length $L \sim 10$cm. Combining Ohm law and emissivity rules, a theoretical characteristic curve can be obtained:

$$V = \frac{A^{10/7} L}{\pi^{13/7} r^{23/7} (2\epsilon\alpha)^{3/7}} \cdot I^{13/7}$$

where ϵ is the effective emissivity, α the StefanBoltzmann constant and A a the resistivity proportional constant, such that the resistivity ρ can be expressed as function of the temperature T as

$$\rho(T) = AT^{6/5}$$

Pumping the vessel to a low density (...), the voltage-current characteristic curve of the filament has been measured, producing the following data: how much?

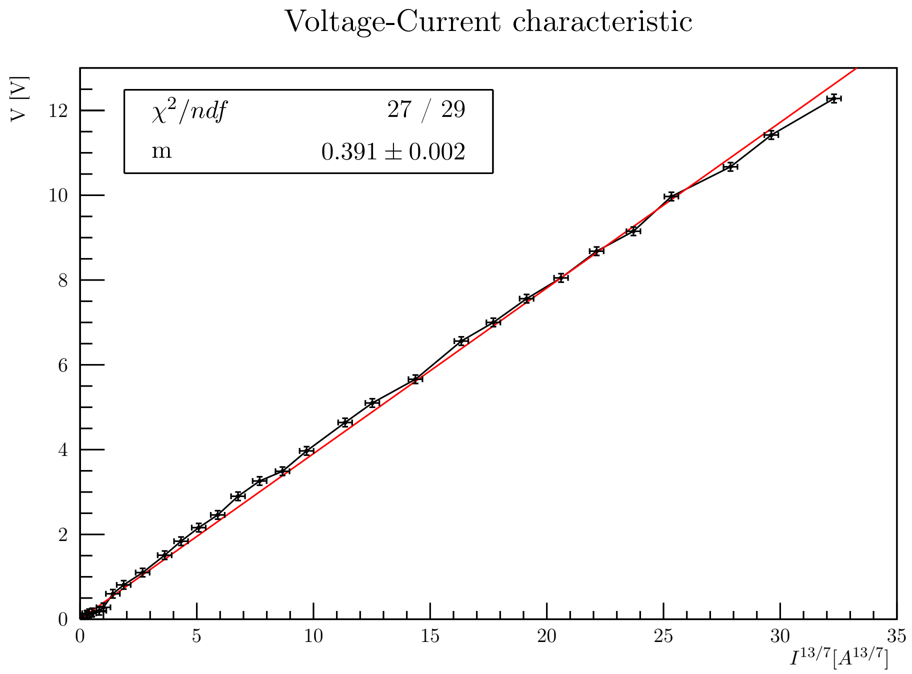

Figure 7: Voltage-Current characteristic for a filament; errors has been chosen as $0.3A^{13/7}$ and $0.1V$, due to the low sensibility of the measure system.

Fitting the data with a $V \propto I^{13/7}$, the following parameters are found:

$$V = mI^{13/7} \tag{1}$$

$$m = (0.391 \pm 0.002)\mathrm{V} \cdot \mathrm{A}^{-13/7} \tag{2}$$

which lead to a value of

$$\epsilon \sim 0.2$$

The χ^2 confirm the meaningfulness of the fit; moreover, the effective emissivity have a value similar to the typical ones.

Finally, the estimated filament temperature as a function of the driven current can be found:

$$T = \underbrace{\frac{A^{5/14}}{\pi^{5/7} r^{15/14} (2\epsilon\alpha)^{5/14}}}_{k} \cdot I^{5/7} \qquad \text{with } k \sim 811\mathrm{K} \cdot \mathrm{A}^{-5/7}$$

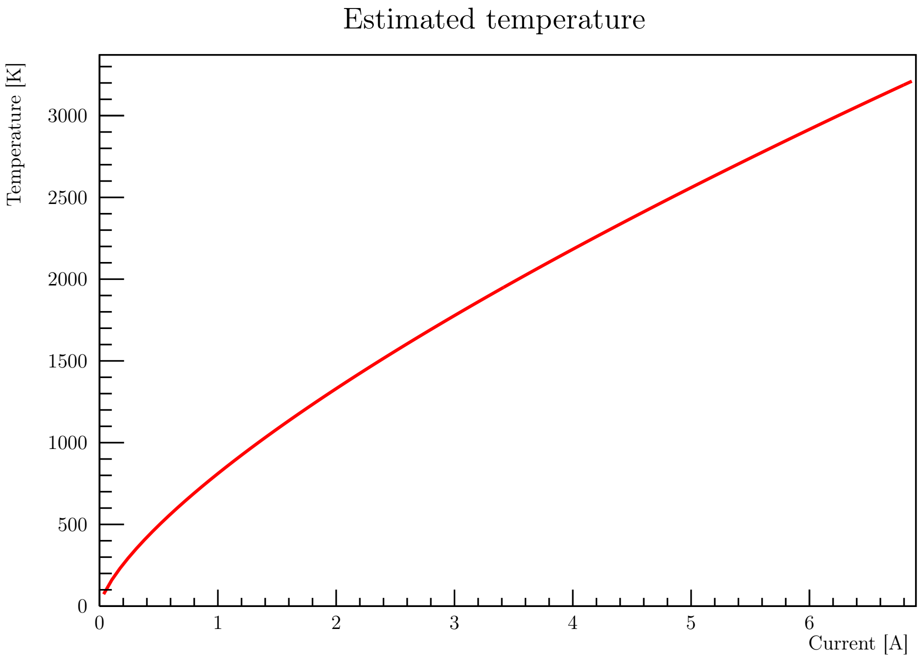

Figure 8: Projection of the filament temperature as function of the current