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bergoz
Instrumentation

VWM-S-1W
sensor parameters choice
(VWM_choice_Rev3.0 program)

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Rev. 3.0

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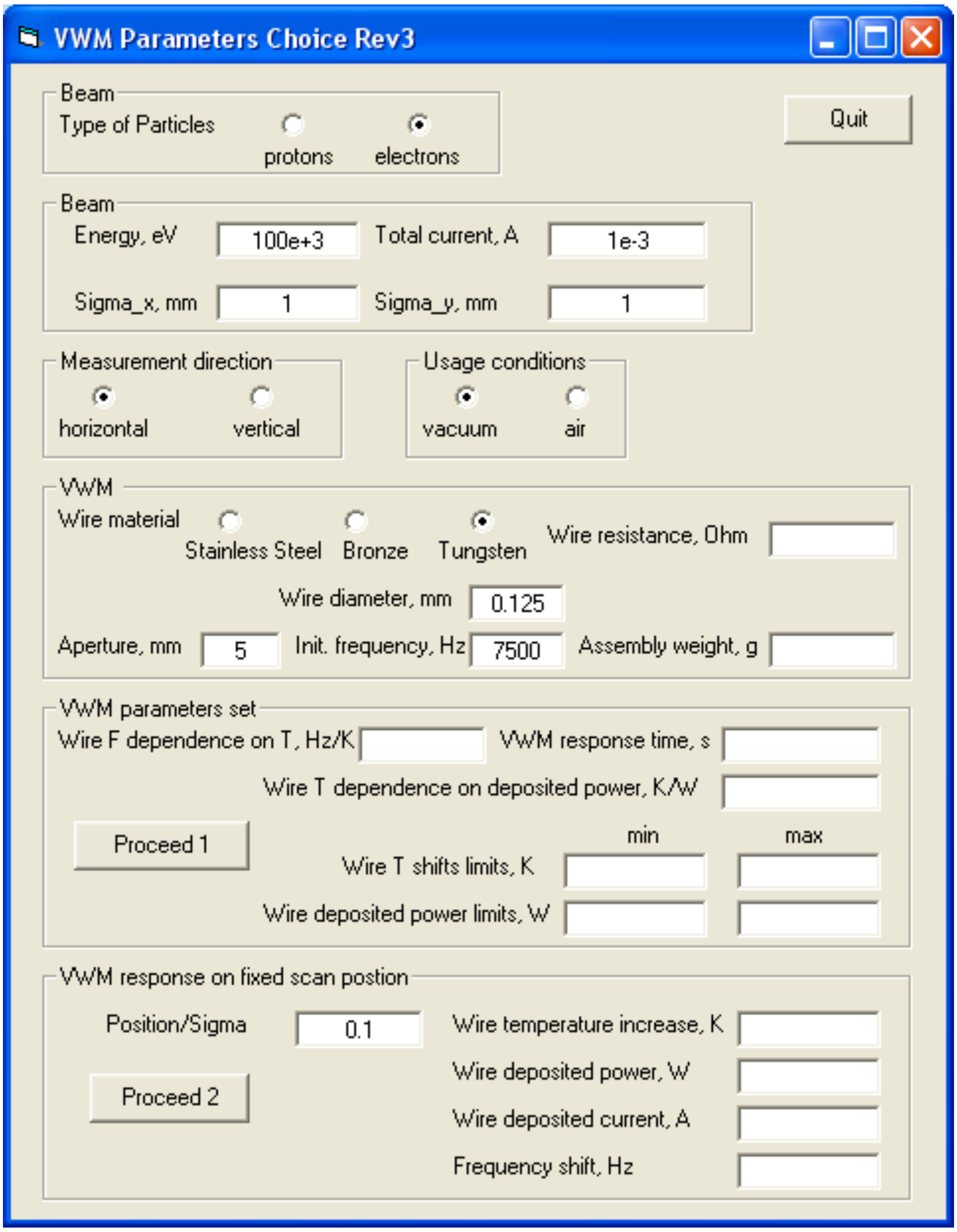
1. Choosing wire material, diameter and initial frequency

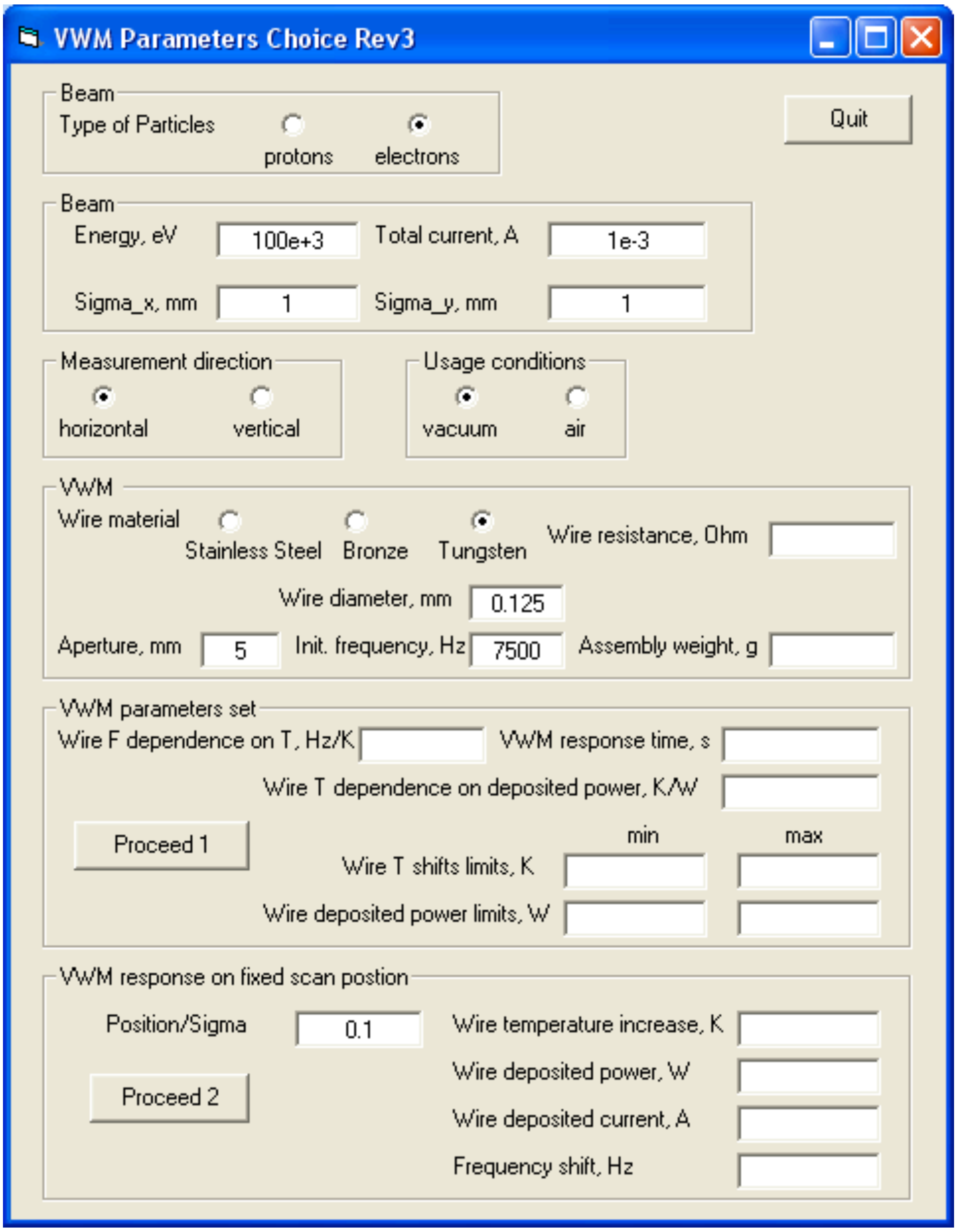
A program: VWM_choice_Rev.3.0 is available on the VWM deliverable CD, written in Visual Basic 6.0 and executable on a PC under Windows XP.... or later.
The program displays this screen:



The initial parameters must be entered:
Type of particles, Energy, Total current, beam Sigma-X, and Sigma-Y, Measured direction and Usage in Vacuum or Air.
Then variables can be entered and modified in search of the largest Frequency Shift at an entered beam Position/Sigma:

Wire material: Stainless steel, Bronze or Tungsten. Wire resistance will be computed.
Wire diameter: Available wires are 100um for Stainless steel and Tungsten, 125um for Bronze.
Aperture of the sensor should be entered, total wire length will be computed.
Initial frequency: Initially, 1000 Hz can be entered and refined later in search of optimum.
Note: Assembly weight is calculated; it is the weight to hang on the wire to obtain the entered frequency (See sensor assembly).
Then "Proceed 1" computes the wire frequency temperature dependence, time constant and operating limits.
"Proceed 2" computes for an entered Position/Sigma, the Temperature, Power, Current deposited and the resulting Frequency shift.
Now, iterating through the available Wire materials and initial frequency allows to find the optimum conditions.
The parameters to optimize depend on application:
It may be resolution in which case Frequency shift is the measure of optimization.
It may be response time, which is essentially wire material-dependent.

2. Program procedure



Initial frequency F_0 of the vibrating wire (second harmonic of natural oscillation) is defined by:

$$F_0 = \frac{1}{L}\sqrt{\sigma_0 / \rho}\ , \qquad (1)$$

where L is the wire length, σ_0 is the wire initial tension, ρ is the wire material density. Parameter σ_0 must not exceed the tensile strength of material. The corresponding weight needed for the VWM wire assembly and its resistance will appear after clicking on **Proceed 1** button.

Wire frequency **F dependence on** wire temperature **T** is defined by:

$$\Delta F / \Delta T = \frac{E\alpha F_0}{2\sigma_0}, \qquad (2)$$

where α is the wire material coefficient of thermal expansion and E the modulus of elasticity of the wire material.

VWM response time is defined by three thermal processes: heat sink through the wire material, radiation losses and convection losses (in case of air).

Response time via thermal conductivity mechanism:

$$\tau_\lambda = c\rho / 8 / (\lambda / L^2), \qquad (3)$$

where c is the specific heat, λ the is thermal conductivity coefficient.

Response time via radiation mechanism:

$$\tau_{RAD} = c\rho / 8 / (2\varepsilon\sigma_{ST\_B} T_0^3 / d), \qquad (4)$$

where σ_{ST_B} is the Stefan–Boltzmann constant, T_0 is the wire initial temperatures (supposed to be room temperature), d is the wire diameter, ε is the emissivity of the wire surface (a measure of the ability of the wire surface to radiate energy).

Response time via convection mechanism in air

$$\tau_{CONV} = c\rho / 8 / (\alpha_{CONV} / 2 / d), \qquad (5)$$

where α_{CONV} is the coefficient of convective losses.

Response time of the wire:

$$\tau_{RESP} = 1/(1/\tau_\lambda + 1/\tau_{RAD} + \delta / \tau_{CONV}), \qquad (6)$$

where $\delta = 1$ in case of **air** and $\delta = 0$ in case of **vacuum**.

Wire temperature **T dependence on deposited power** is defined by:

$$\Delta T / \Delta Q = 1/2/\pi / d^2 / l / (\lambda / l^2 + 2\varepsilon\sigma_{ST\_B} T_0^3 + \alpha_{CONV} / 2 / d). \qquad (7)$$

Wire temperature **T shifts limits** are defined by the VWM electromechanical resonator characteristics:

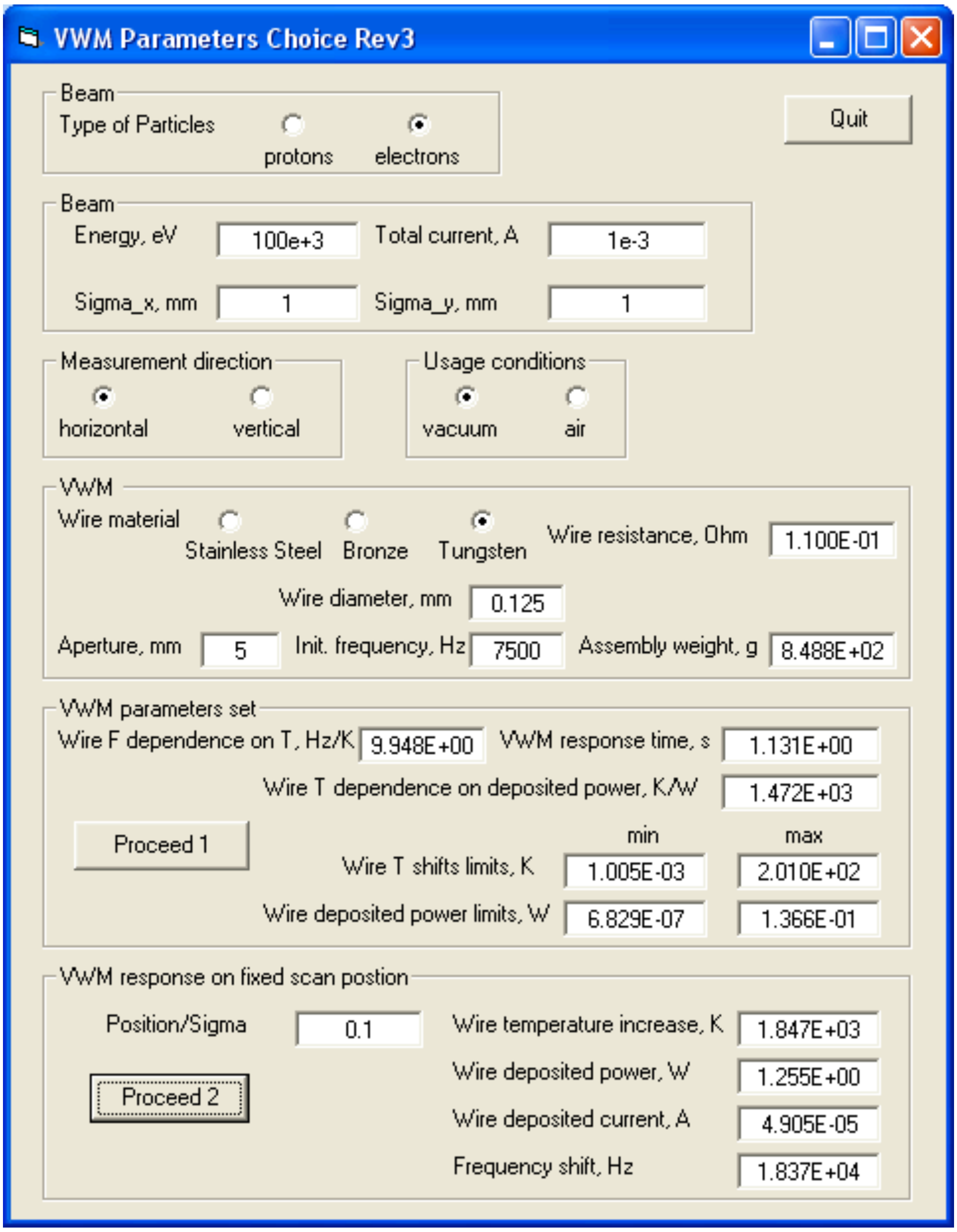
$\Delta F_{MIN} = 0.01 Hz$ (VWM resolution), (8)

$\Delta F_{MAX} = 2000 Hz$ when initial frequency $F_0 > 3000 Hz$ and (9a)

$\Delta F_{MAX} = (F_0 - 1000 Hz)$ when initial frequency $F_0 < 3000 Hz$. (9b)

Wire temperature shifts are calculated by using these values and (2).

Deposited power limits of the VWM are calculated by the same values, taking into account (2) and (7).



Position/Sigma is the position of the wire in units of beam sigma along the scan direction σ_{SCAN}, which is equal to σ_X (horizontal) or σ_Y (vertical) depending on the measurement direction:

$\sigma_{SCAN} = \sigma_X$ and $\sigma_{TRAN} = \sigma_Y$ (in the case of a **horizontal** measurement), (10a)

$\sigma_{SCAN} = \sigma_Y$ and $\sigma_{TRAN} = \sigma_X$ (in the case of a **vertical** measurement), (10b)

where σ_{TRAN} describes the beam distribution along the wire direction.

The current of particles penetrating the wire I_W is described by:

$$I_W = I_0 * K_A * \frac{d}{\sqrt{2\pi}\sigma_{SCAN}} * \exp(-x^2/2), \qquad (11)$$

where I_0 is the beam **Total current**, x is the wire position in units of σ_{SCAN},

$K_A = \int_{-A/2}^{+A/2} dz * \frac{1}{\sqrt{2\pi}\sigma_{TRAN}} * \exp(-z^2/2/\sigma_{TRAN}^2)$ describes the limitation of the particles intersection with the wire caused by the limited VWM **Aperture** A. We assume that d is much smaller than σ_{SCAN}.

Heat transfer from the intersected particles with the wire depends on the particles type and energy, wire material and geometry. In this calculation we assume that the heat transfer is described by the ionization losses in the material, including a heat transfer coefficient k defining the part of losses really converted into heat:

$$\Delta Q = k * I_W * E_Z, \qquad (12)$$

where $E_Z = \rho * E_{NORM}$.

The parameter E_{NORM} is calculated from Bethe-Bloch formula and is about $1.5 MeV * cm^2 / g$ for 3 GeV protons. This value weakly depends on particles **Energy** E and type when $E \geq 1 Gev$.