HELLAZ

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WHY HELLAZ: the different solar neutrinos experiments all show a large deficit of neutrino flux compared to the standard solar model. This puzzling results have triggered a huge experimental and theoretical effort to interpret that deficit either as a property of the particle neutrino or try to modify the solar model. However, none of the solar neutrinos experiments really show where the problem is. Either they give, after a year or so, a number of neutrinos above a certain threshold, or, in the case of water Cerenkov, they produce a spectrum with a not so good resolution and a very high threshold, much above the fundamental pp neutrinos. What is needed to identify the problem is a good resolution neutrino spectrometer, with a threshold low enough that at least half of the pp neutrinos can be detected and a resolution good enough, not only to separate pp from ^7Be, but also that the modulation of an hypothetical oscillation (MSWand/or vacuum) effect on the pp spectrum can be seen. This means that the resolution in neutrino energy must be better than 10% and the threshold at 200 keV. HELLAZ answers these very difficult goals.

HOW HELLAZ: the basic physics behind HELLAZ is the elastic scattering of neutrinos on the electrons of matter, as with Cerenkov water experiments. The cross sections are well known and well understood. But to reach a low threshold, HELLAZ has chosen the ionisation of a gas instead of the Cerenkov effect in a liquid. A 2000 m^3 Time Projection Chamber, filled with He at 5 bar and 77 K will have $2 \cdot 10^{30}$ electrons , giving 7 pp and 3 ^7Be events per day. The measure of the recoil electron energy T_e and angle θ_e relative to the sun yields the neutrino energy E_ν. T_e is not very difficult to measure with a high precision. If dE_ν/dT_e is not very large, it is not the case for $dE_\nu/d\theta_e$..θ_e must be measured with a precision better than 5° and this is difficult because the tracks have low energies (the threshold for T_e is 100 keV). The only way is to detect each ionisation electron individually, so that no bias is introduced in the track reconstruction after it has drifted in the TPC. We call that a digital TPC. The chamber at the TPC extremity must have a high gain ($>10^5$) to detect single electrons and the pulses should be back to zero in less than 20 ns to avoid too much pile-up. The drift should be slow and the chamber at the end fast. Helium fulfils these requirements.

What kind of background can such a detector stand? We reject electrons that are outside the cone given by the sun position and double Compton events. Then we subtract each spectrum taken, lets say in one hour, from the same spectrum taken 12 hours before. The assumption is that the radioactive background is fixed relative to HELLAZ, while the sun "rotates". That way, one can see very clearly the solar neutrino events in a 10000 background events per day. This corresponds to 10^{-12} g U-Th/g.

The Hardware R&D: Fast chambers are of the microgap type. However, classical microgap do not have a gain higher than 10^3. We have tried 3 solutions:

a) classical microgap with two GEM stages in front (J. Seguinot and F. Sauli).

b) classical microgap chamber where the anodes are replaced by classical 10 μm wires (Marcos Dracos in Strasbourg). We have been able to reach a gain of 10^6 and pulses of 40 ns.

c) Micromegas chambers developed in Saclay by I. Giomataris. There the anode is a classical printed circuit and the cathode is a 3 μm nickel mesh. They are separated by a 100 μm gap. The field is constant, contrary to the field around a wire, so the avalanche develops along the 100 μm. Less charge space leads to high gains: we have reached 10^7. The chamber is inherently "slow", so slow that one begins there to be able to see the signal induced by the avalanche electrons, which is close to impossible with a wire. We have thus made pulses back to zero in 7 ns. This is an absolute record which opens many doors for development.

We measure the chamber properties with a 250 nm laser. The light falls on 2 fibers of different length. The end of the fibers is close to a Ni-Cr photocathode used as the HV electrode of a small TPC. That way, one can make in a controlled way, 2 electrons following each other at a known delay.

We are preparing a 5 liter TPC (He at 5 bar and 77 K) with a 10 by 10 cm chamber to study real tracks. These will be made with the Compton effect in the TPC of the 511 γ ray of a ^{22}Na source. One detects outside the Compton γ in CsI detectors and can then reconstruct the electron track energy and angle and compare to what the back chamber measures.

Radioactive background: We have an ultra-pure Ge detector in the Modane tunnel. With that, one can reach 10^{-10} g U-Th/g sensitivity. The detector is remotely read to Paris. We have studied many samples, specially of Boron oxide that is our foreseen neutron shield.

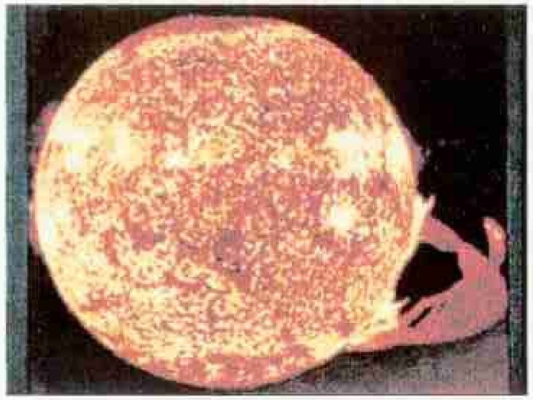
To reach 10^{-12} g U-Th/g, our goal, we a) hope to collaborate with Borexino people and use their Munich reactor to do neutron activation, and b) we build a radon extraction and concentration bench where we will measure the Bi-Po coincidences.

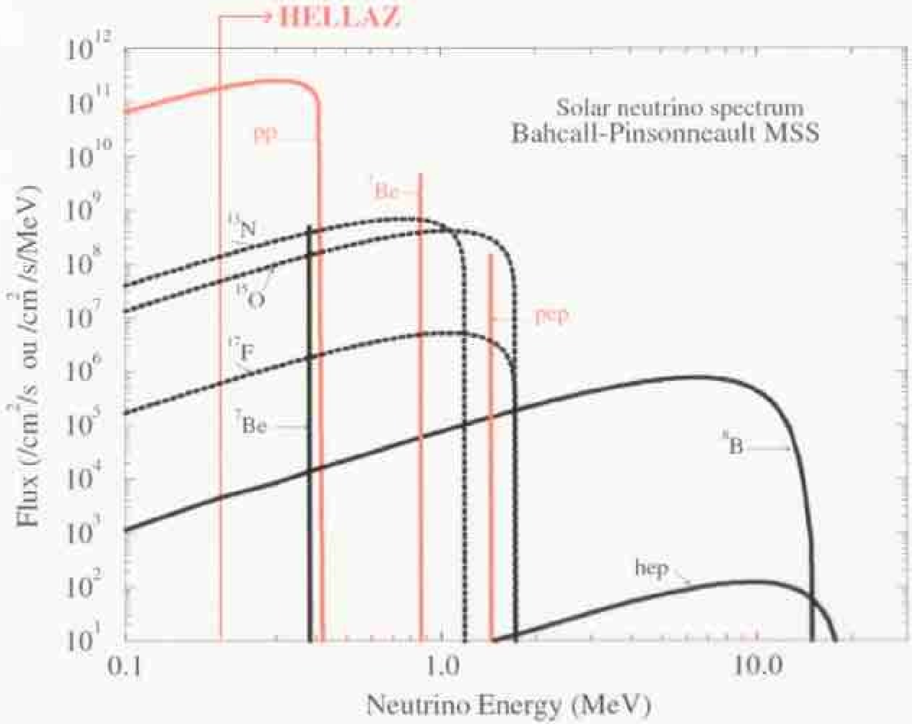
For the chamber studies and for the radon bench, we are installing a clean room, locally class 100, in Paris.

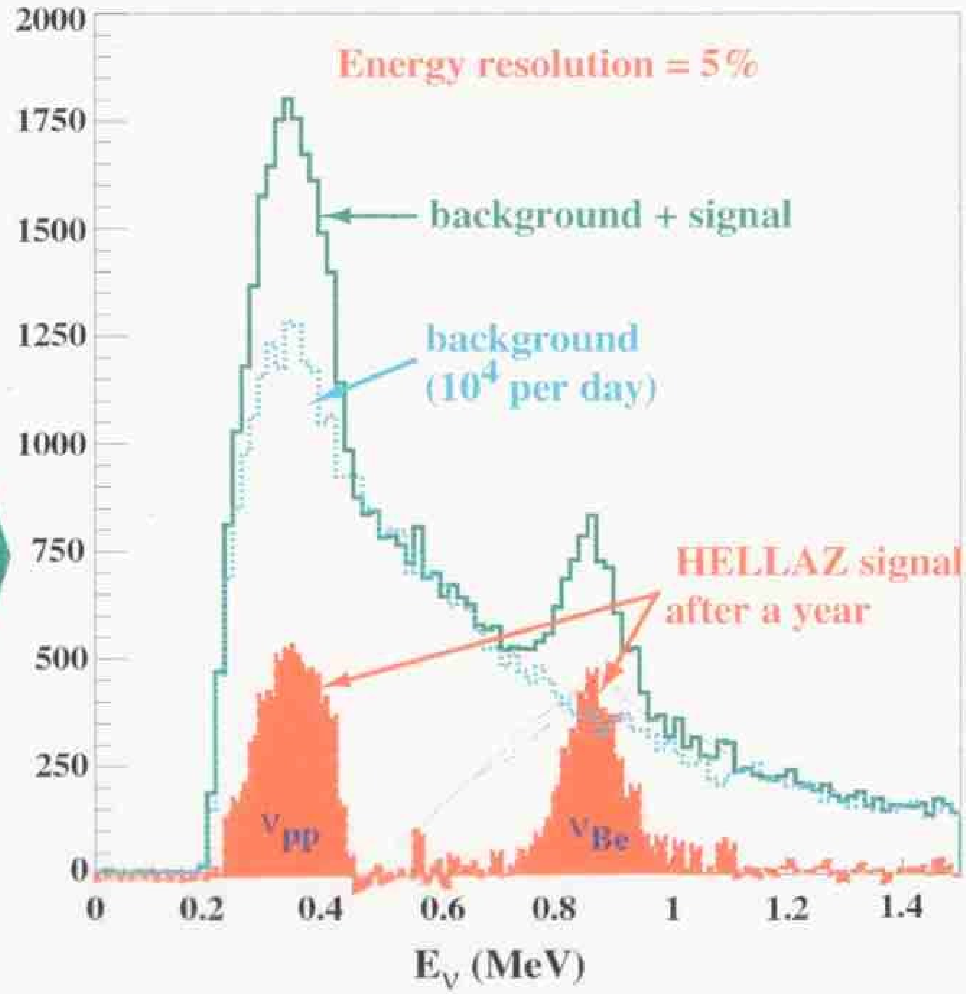
Software: Track reconstruction and background reduction are the main programs we are working on. A special effort is made on the track simulation to check if the angle accuracy that we are aiming for can be reached.

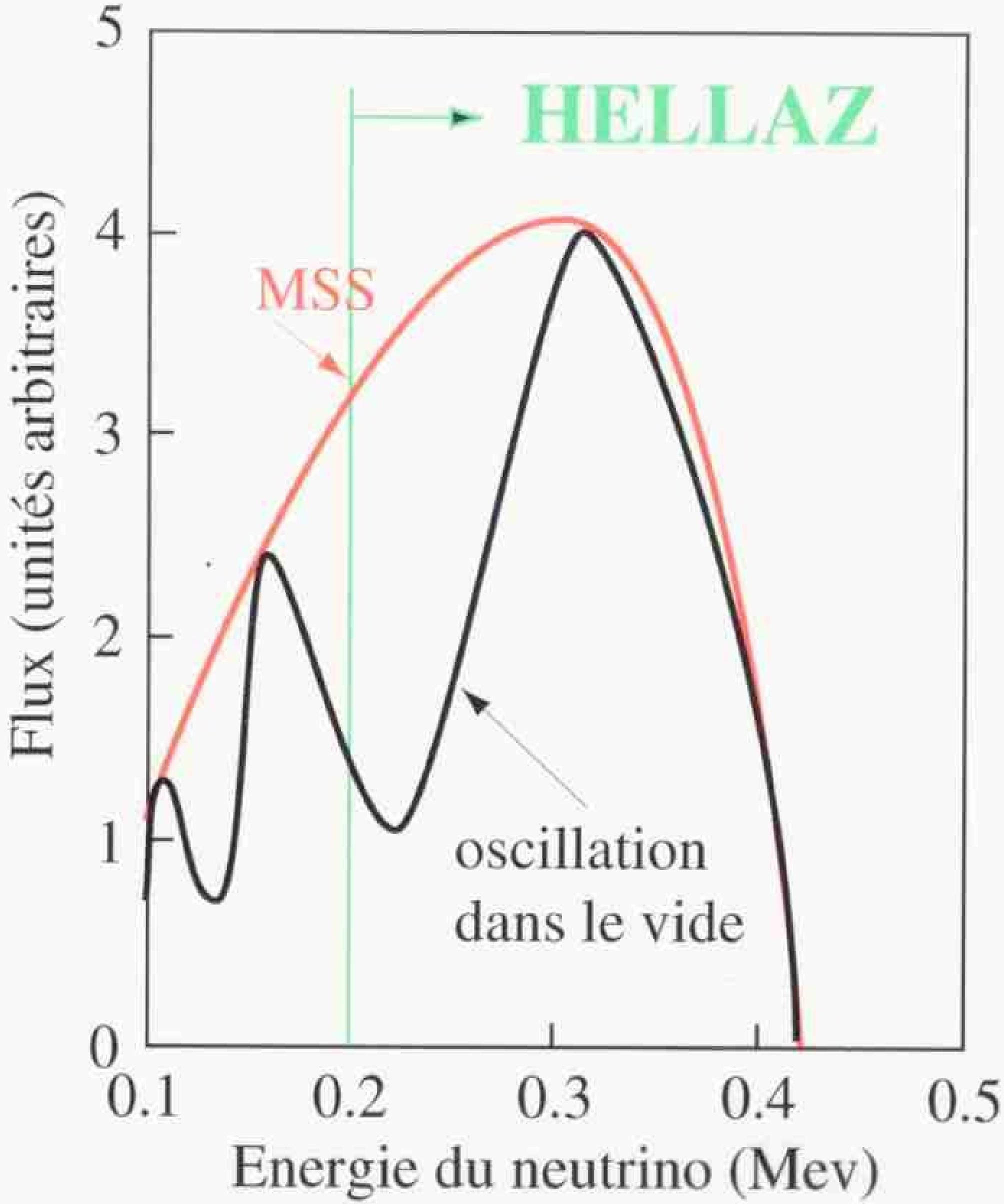
HELLAZ

pp and ^{7}Be neutrino spectrum









$\Delta m^2 = 5.6\ 10^{-12}\ eV^2, \quad \sin^2 2\theta = 1$

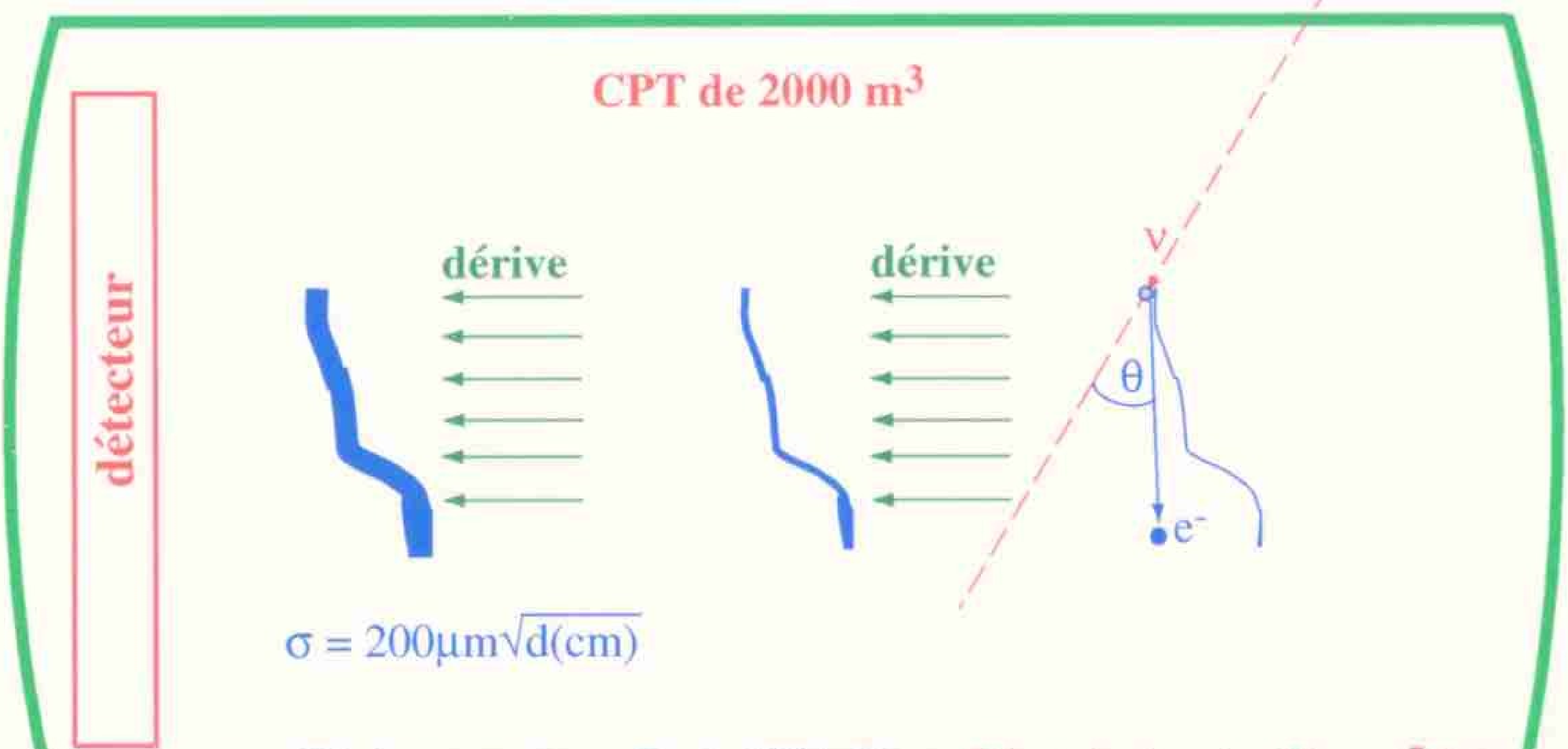
Ref. : Krastev et Petcov,
Phys. Rev. D53 (1996)1665

Principe de HELLAZ:

diffusion élastique neutrino - électron dans He - TPC

$\rho_{He} = 3.124 \times 10^{-3}$ g/cm^3, 6 tonnes de He —> Ne = 2×10^{30}

- mesure de T_e ($\frac{\sigma_T}{T} \approx 3\,\%$) et θ ($\sigma_\theta \approx 35\,mrad$)
- énergie du neutrino: $E_\nu = \frac{m_e}{\sqrt{1 + \frac{2m_e}{T_e} \times cos\theta} - 1}$, $\sigma_{E_\nu} / E_\nu < 10\,\%$



$\Longrightarrow$ taux d'événements (pour $T_e \geq 100$ keV) = 7/jour (pp) et 4/jour (^{7}Be)

$$E_\nu = \frac{m_e}{\sqrt{1+\frac{2m_e}{T_e}}\cos\theta - 1}$$

$\Rightarrow$ 1) $$\frac{dE_\nu}{d\theta} = \frac{m_e \sin\theta \sqrt{1+2\frac{m_e}{T_e}}}{\left(\sqrt{1+2\frac{m_e}{T_e}}\cos\theta - 1\right)^2}$$

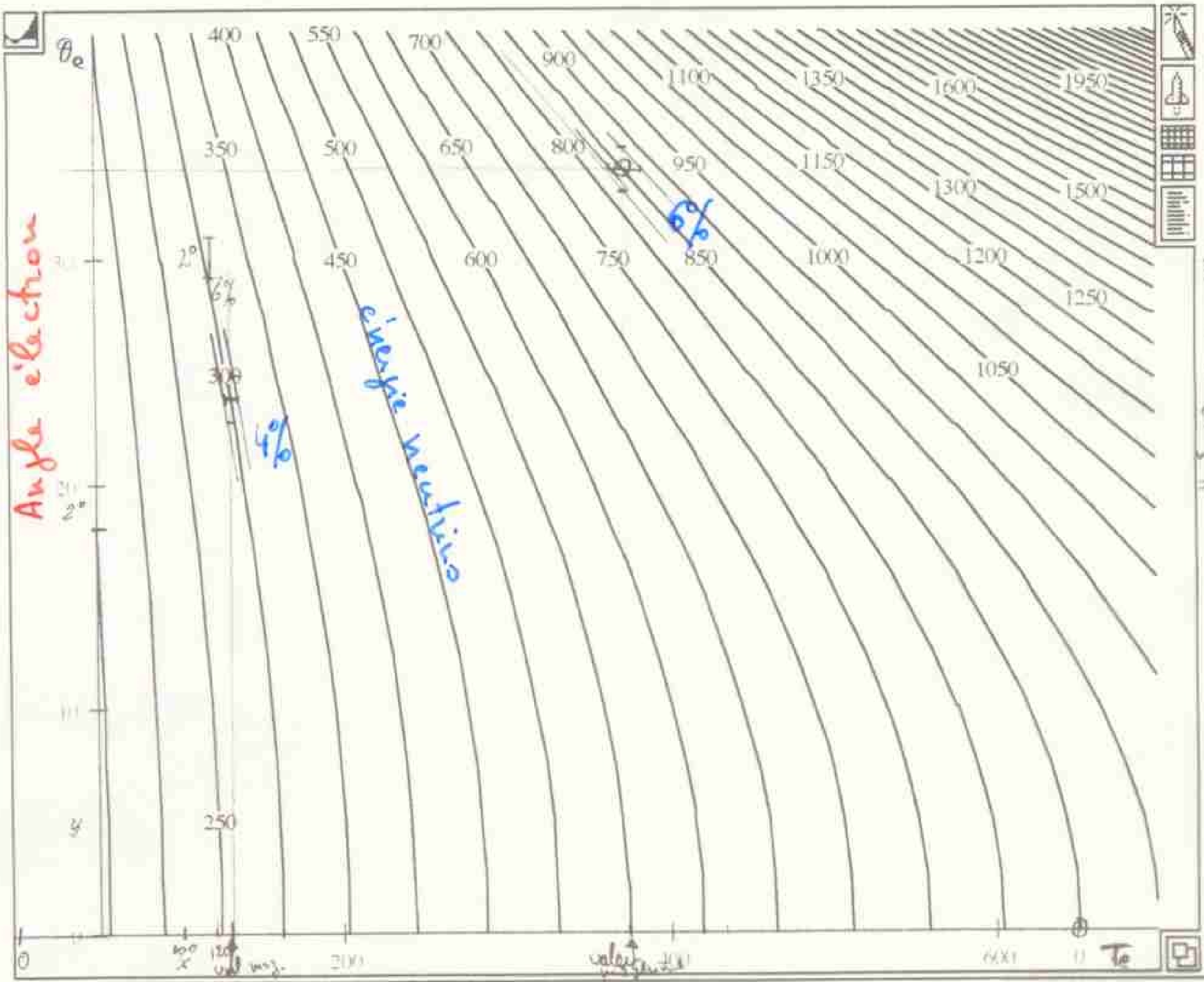
$\Rightarrow$ 2) $$\frac{dE_\nu}{dT_e} = \frac{m_e^2 \cos\theta}{T_e^2 \sqrt{1+\frac{2m_e}{T_e}} \left(\sqrt{1+\frac{2m_e}{T_e}}\cos\theta - 1\right)^2}$$

If $d\theta = 35$ mrad (2°) $dE_\nu \sim 12$ keV

$\frac{dE_\nu}{E_\nu} \sim 4\%$

If $\frac{dT_e}{T_e} = 3\%$ $dE_\nu \sim 0.7$ keV

$\frac{dE_\nu}{E_\nu} \simeq 0.2\%$



50 ... 700 = left...right

0 ... 40 = bottom...top

Stretch to Fit

Declarations

a Constant named left behaves as Horizontal Minimum

a Constant named right behaves as Horizontal Maximum

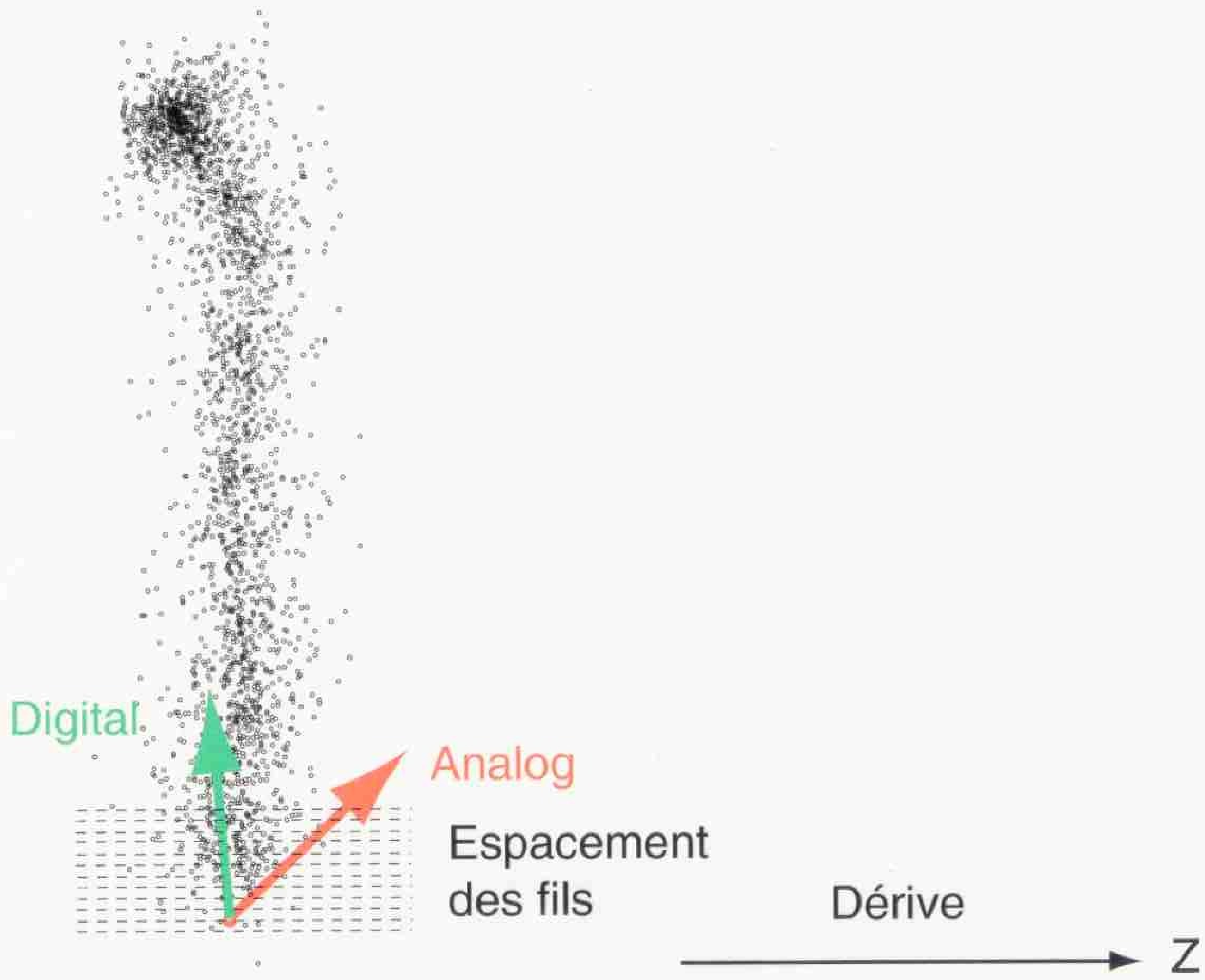
a Constant named bottom behaves as Vertical Minimum

a Constant named top behaves as Vertical Maximum

contours of z spaced very densely at (x, y) where
x = left ... right and y = bottom ... top

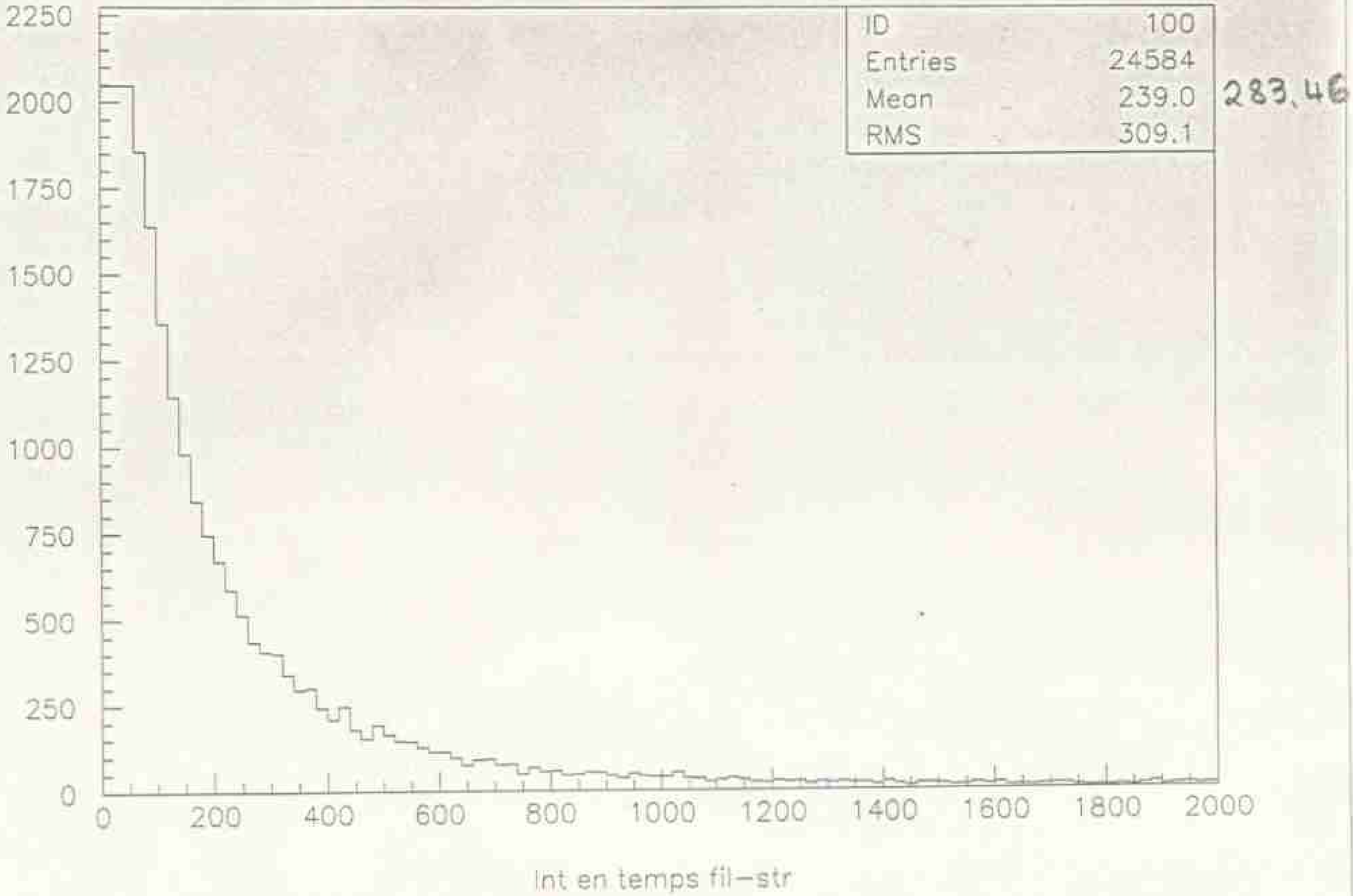
axis at (x, bottom) where x = left ... right labeled x on this side

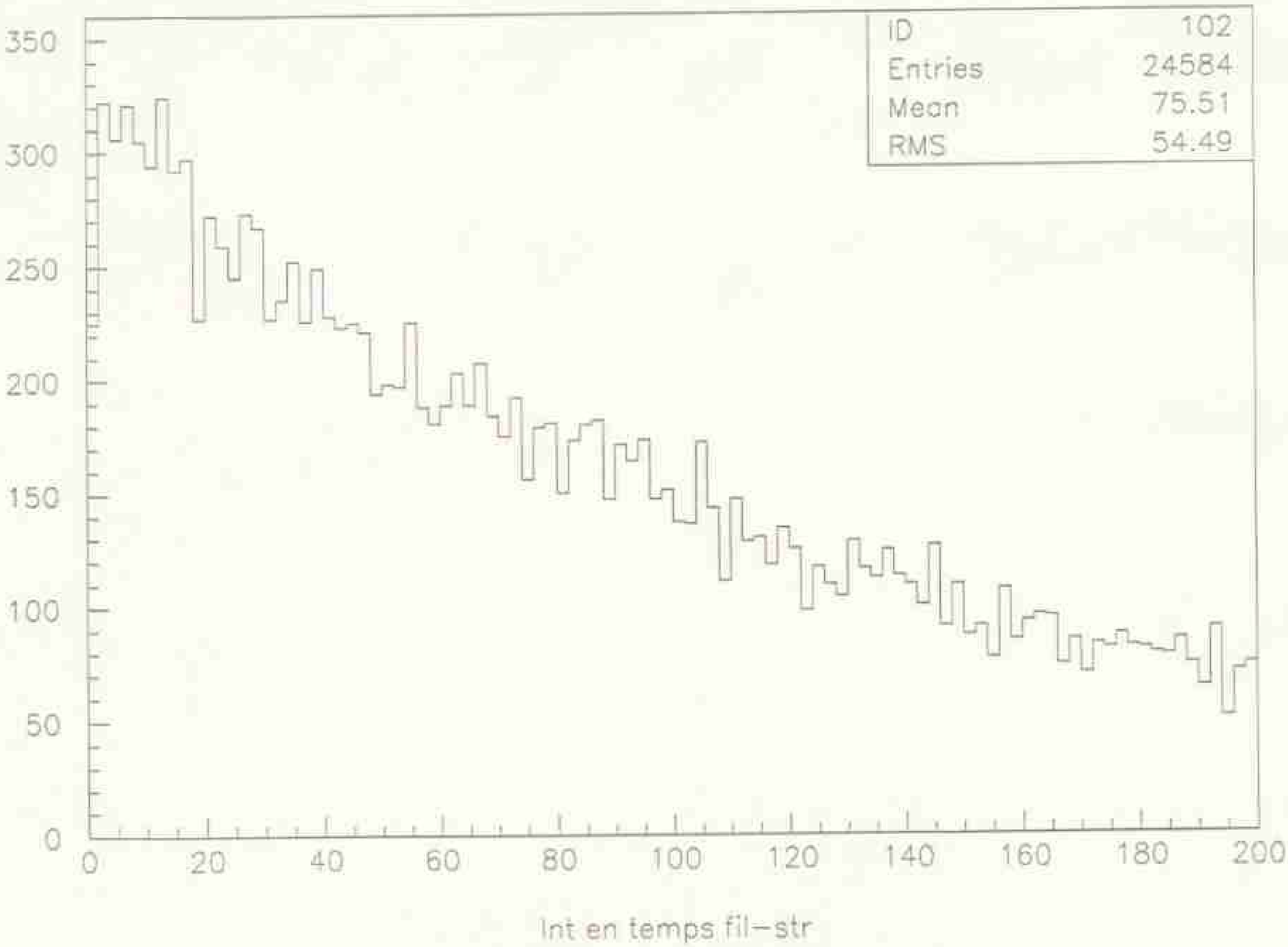
axis at (left, y) where y = bottom ... top labeled y on other side


Digital
Analog
Espacement
des fils
Dérive
Z

98/02/25 15.48

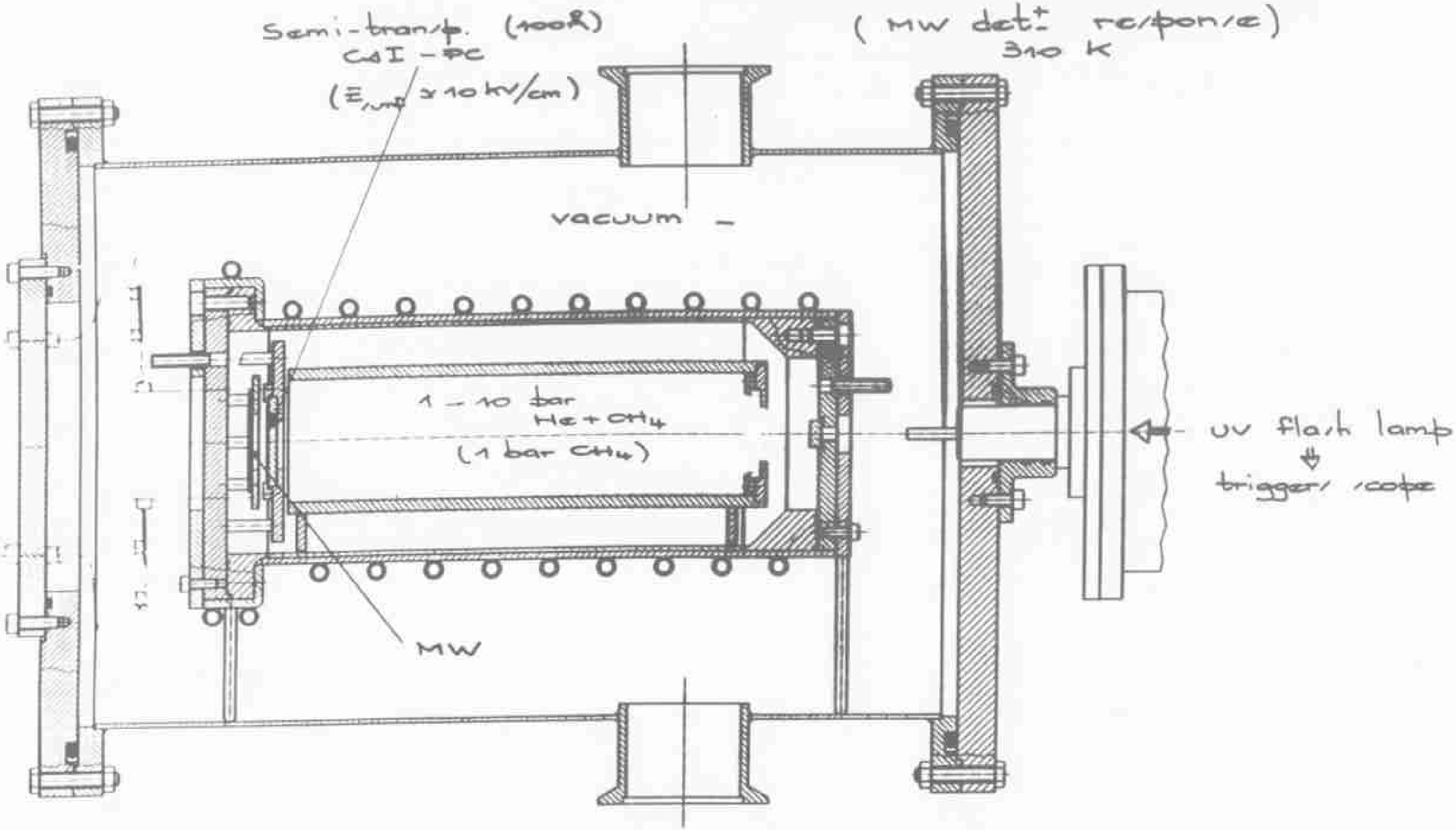
drift 500 cm v=14 200 microns



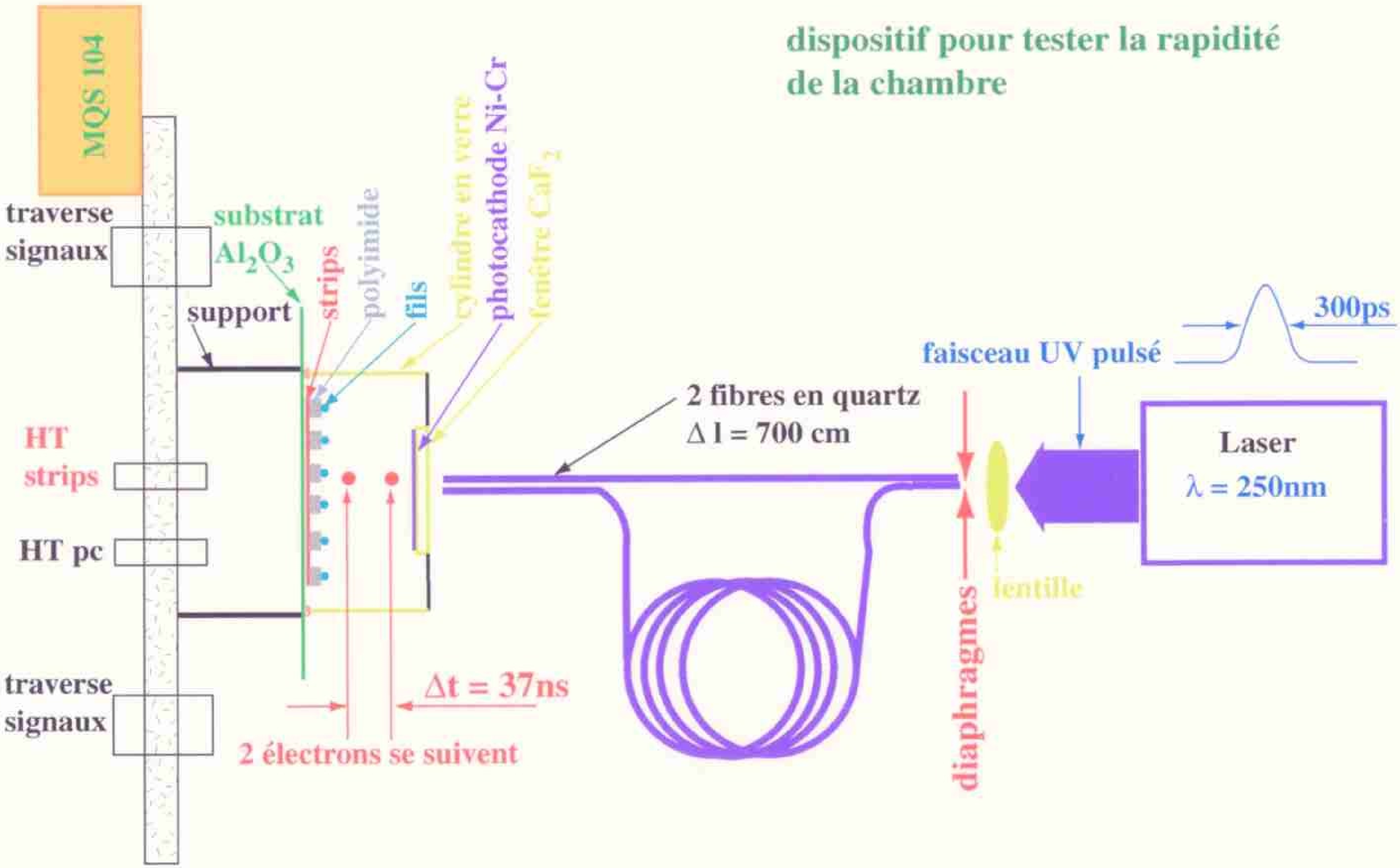


FIRST TESTS HELLAZ Ø

(MW det.ⁿ response)
310 K



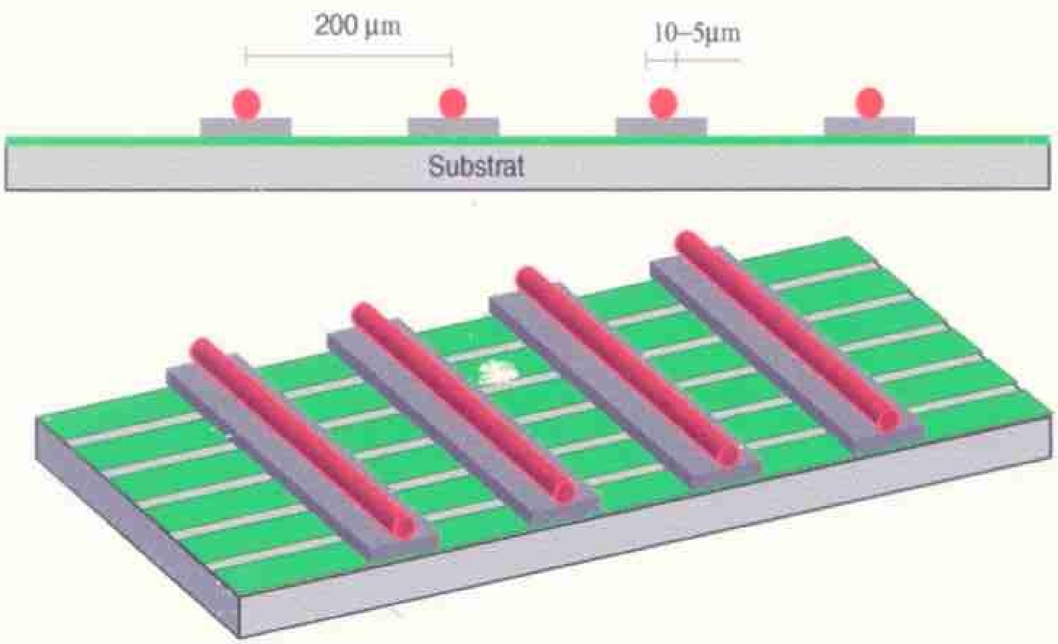
dispositif pour tester la rapidité de la chambre

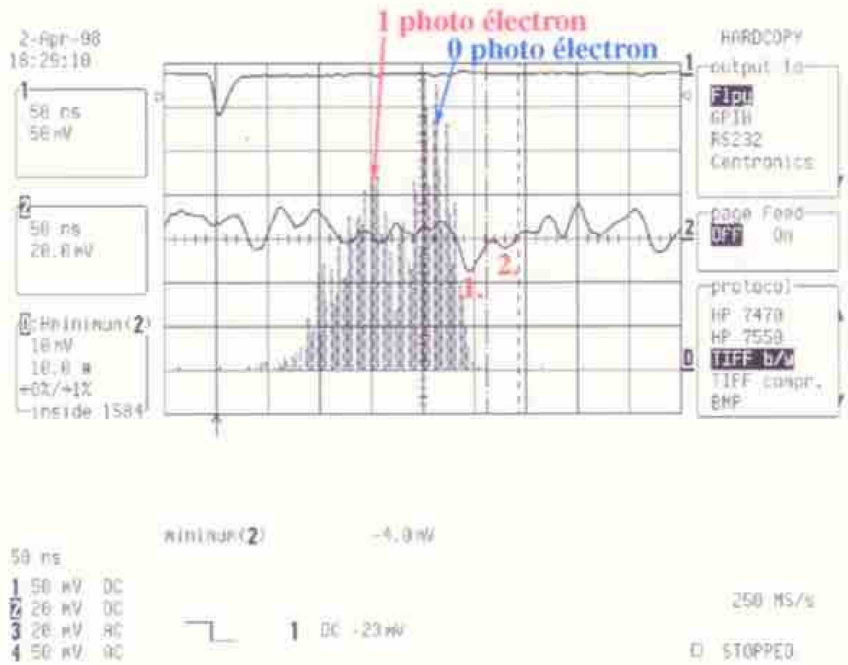


deux électrons séparés par ≈ 37 ns

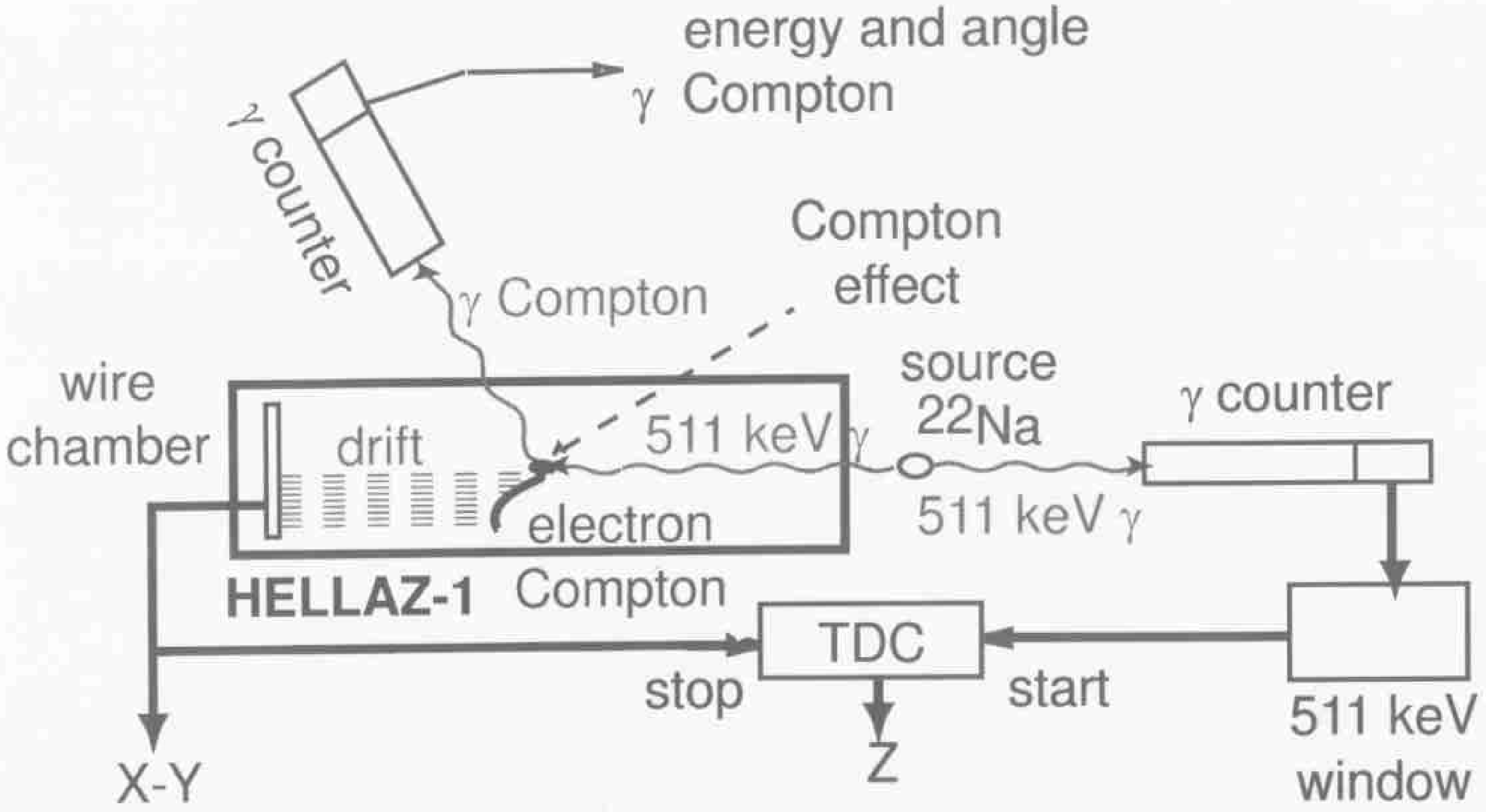
Micro Gap Wire Chamber (MGWC)

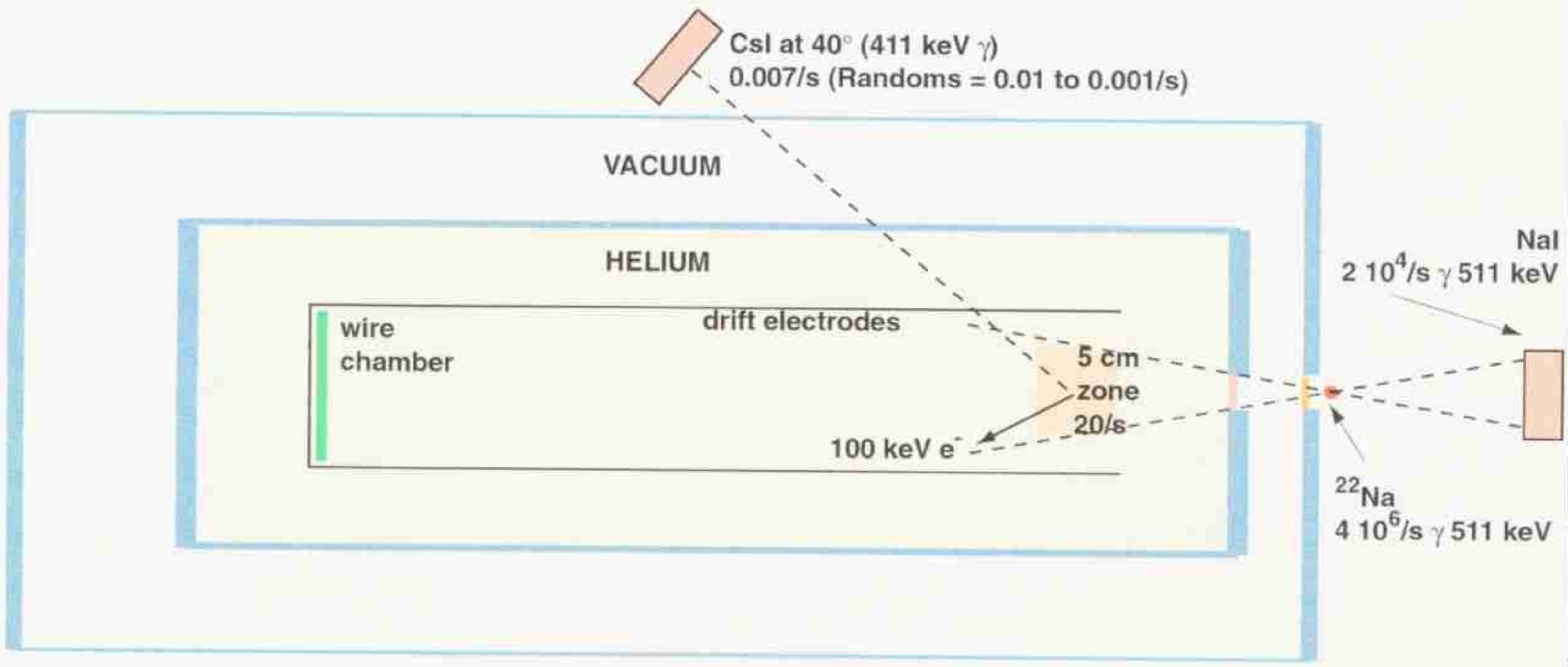
amplificateur: MQS 104
HT(strips) = - 530V, HT(pc) = - 1170V, gaz = Argon, Ethane (50%, 50%),
distance photocathode - fils = 10mm





Design of HELLAZ1 R & D




CsI at 40° (411 keV γ)
0.007/s (Randoms = 0.01 to 0.001/s)
VACUUM
HELIUM
wire
chamber
drift electrodes
5 cm
zone
20/s
100 keV e⁻
NaI
2 10⁴/s γ 511 keV
²²Na
4 10⁶/s γ 511 keV