From the mass of the neutrino to the dating of wine

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How did a of group of research scientists, whose goal was to measure the mass of an elementary particle, invent a precise mean of measuring the age of a fine wine, without opening the bottle ?

It is no longer necessary to provide a lengthy introduction for neutrinos. Over the past few years, they have formed the subject of numerous articles in non-specialist journals and major newspapers. What accounts for such success? Because these particles, probably the most numerous in the universe, interact only very weakly with the medium they are traveling through. This makes it hard to study them. At present, their mass has not yet been measured. This is not because the scientists looking for them have not displayed great ingenuity and persistence in their research. To prove that the mass of the neutrino is different from zero has been a long-term quest towards which many physicists have devoted themselves over the past twenty or thirty years. For if the mass were indeed non-zero, this would have enormous consequences in astrophysics, as well as in elementary particle physics. The most recent results indicate that the mass of the neutrino is not zero, but they do not provide a precise value.

With the aim of forcing the neutrino to reveal its closely guarded secrets, very large and difficult experiments have been carried out or are currently being proposed. Some study naturally occurring sources of neutrinos, such as the sun, while others use neutrinos from an artificial source, such as a nuclear reactor. Still others attempt to demonstrate that the mass is not zero by an indirect route.

All these experiments have one common feature: they are trying to find a needle in a haystack ! The needle is the signal created by the passage of the neutrino in the medium, while the hay is constituted by all the parasitic signals, which are grouped together under the name of background noise. Those events being sought are so rare that the struggle to eliminate all the various sources of background noise is *sine qua non* for any experiment. The physicist ends up obsessed with the background noise. First of all, to reduce the effects of the ever-present cosmic rays, he/she sets up the experiment far under ground, for example in a mine or a mountain tunnel, when not at the bottom of the sea or deep in polar ice. Next, the detector should be protected against the ubiquitous natural radioactivity, and this is accomplished by surrounding it by shielding made of lead or iron. Finally, the detector itself should be built out of materials countaining only infinitesimal quantities of naturally occurring radioactive elements.

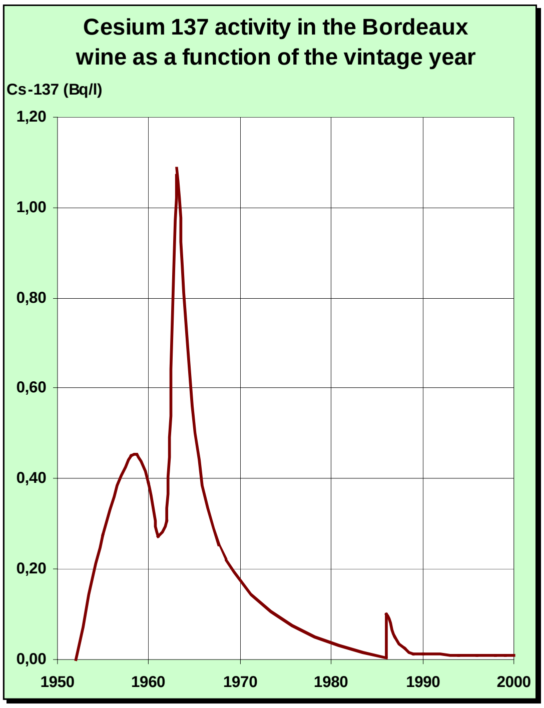
It was in response to these experimental requirements that the Centre of Nuclear Studies of Bordeaux-Gradignan (CENBG) has been for several years working on the development of ultra-low-background-noise gamma ray spectrometers. These spectrometers should be able to detect activities about 100,000 times less than those which occur naturally in most materials.

Such sensitivity in the detection of radioactive isotopes was of obvious interest for other disciplines. Oceanography, geology and environmental science were the first to see the interest of such developments, which for the most part, were carried out in close collaboration with scientists from these disciplines. Well known among radioactive techniques is that of dating. Why not try it on wine ?

Every wine connoisseur begins, before tasting, by reading the label to determine the Château and the vintage year. The vintage year, or millésime, is of great consequence. Certainly for the taster, but also for whoever bought the bottle. How can one be sure of the year ? Did you mention dating through radioactive methods ? And that is how, in seeking to determine the mass of the neutrino, one measures the radioactivity of fine old Bordeaux wine!

To improve the sensitivity of the gamma detection, the first measurements were carried out with wine samples reduced to ashes. They have shown that wine contains essentially the isotope potassium 40 at the level of about 30 becquerels per liter (Bq/l), which corresponds to about 0.9 g of naturally occurring potassium in each liter of wine. Nothing surprising about that, since wine contains a fair amount of the chemical potassium bitartrate, so that the presence of the radioactive potassium 40 is quite natural (remember that you have in your body about 60 Bq/kg of potassium 40). But far more interesting is the fact that certain bottles of wine contain also the isotope cesium 137, a man-made radioactive element (mainly from nuclear weapons testing in the atmosphere). This fact was sufficient to excite the curiosity of the Interregional Laboratory at Bordeaux of the DGCCRF (a French government agency charged with protecting consumers, assuring fair competition and preventing fraud), which was in fact looking for a quick and simple way to verify the millésime, and which -very important- knows how to get hold of some old Bordeaux wine whose years are precisely known, a crucial element of the story.

All that remained was to carry out the measurements of the radioactivity of the wine as a function of the years, and the opposite curve was readily obtained. First, amateurs of wine can reassure themselves, the activities observed are quite small, less than 1 Bq/l. The most interesting aspect is the presence of peaks of activity, which show that the wine keeps in memory the atmospheric nuclear testing (years 1950-1963) and the accident of Chernobyl (1986), which in both cases led to the presence on French soil of measurable amounts of cesium 137.



There is a strong correlation between the rate of cesium 137 decay and the year the wine was produced. It is obvious that such a curve can be exploited as of now to estimate the age of a given wine, and to detect any possible anomalies. For example, a 1930 vintage wine should not contain cesium 137. Conversely, an unknown wine in which activities of about 1 Bq/l or more of cesium 137 are measured can only correspond to the year 1963.

Being able to date the wine was thus very satisfactory, but reducing it to powder, especially for “grands crus” or old vintages, was almost a crime ! The ideal was thus to determine the amount of cesium 137 without opening the bottle. This appeared to be possible, as the gamma radiations emitted during the disintegration of the cesium 137 can easily escape from the wine, pass through the glass of the bottle and interact with the gamma spectrometer (see photograph). After a new series of measurements, and especially after having checked that the cork and the glass of the bottle did not contain notable quantities of cesium 137, the feasibility of the nondestructive dating was established. Dating a wine without opening the bottle is thus possible and the method is now validated. The improvement of this technique is currently under study, in particular to develop complementary methods to date young wines.

In conclusion, one can notice that with the current level of sensitivity of radioactivity measurements, around 1 mBq/l, a whole series of radioactive isotopes could be detected in the wine. Suppose that the distribution of these activities is specific of a given wine ? Then different distributions could be expected for a Bordeaux, a Burgundy or an Australian wine, leading to a possible identification of the origin. However, this is a long term objective and many measurements remain still essential before this concept can be validated.

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