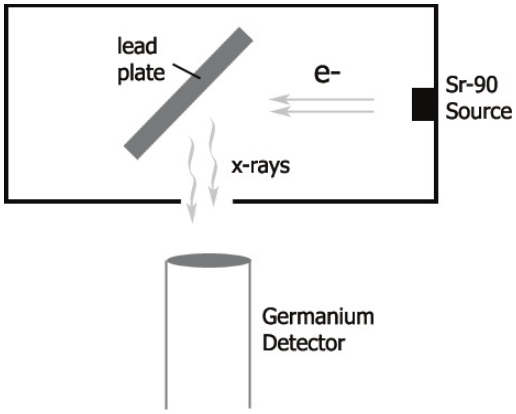
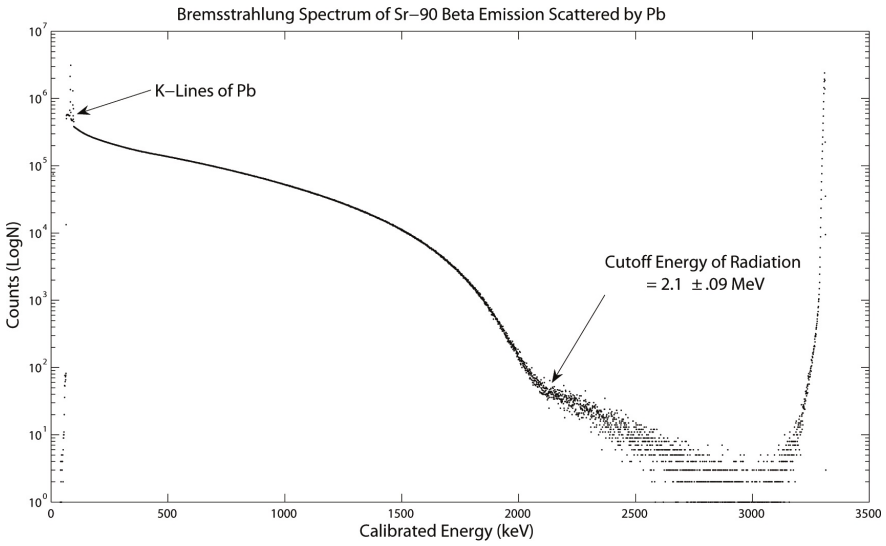
Before starting my first XRF experiments, I was thinking to use beta particles from Sr90 to hit the innermost electrons (K and L shells) of the examined samples in order to induce fluorescence.
I don't know why but I thought clever to use electrons to hit electrons.

Well, I was wrong: I was forgetting bremsstrahlung.



My idea was to build an apparatus similar to this one and, using a suitable NaI or CsI detector, identify the characteristic X Rays of the sample, to be located at the place of the lead plate in the image on the left.

I was forgetting that a decelerating charged particle produces elecromagnetic radiation (X rays in this case) due to the lost kinetic energy (energy has of course to be conserved).
The full continuum of X-rays has energies ranging from zero to the maximum kinetic energy of the incident particles (2.25 MeV in this case).
This continuum overposes to the lines of the examined sample, disturbing a little bit the analysis of the sample.



Here we can see the bremsstrahlung continuum

Photons, on the contrary, do not have electric charge and no inertial frame in which they are at rest is existing so they can't of course decelerate, being their speed always "c" in every inertial frame.
Photons are massless but they carry a momentum p having the magnitude:

p=E/c (E= energy, c= speed of light)

where the momentum is in the direction of propagation.

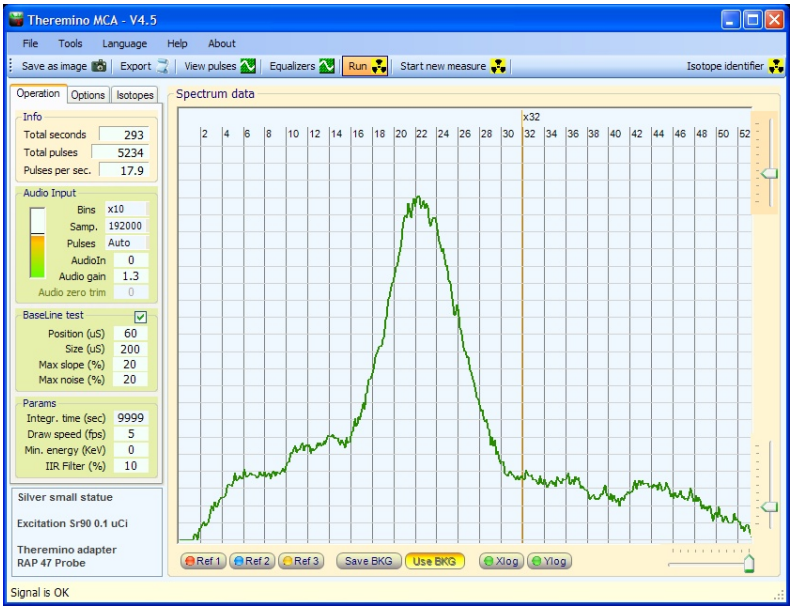
It is so possible to hit and move a particle (electron) with a massless photon.

Photons so appear to be the best choice for electrons hitting.
Their energy should of course be just a little bit higher than the binding energy of the electrons, in order to produce fluorescence. It is the same in optical fluorescence.

I have carried on a few experiments in order to better see the above phenomena.

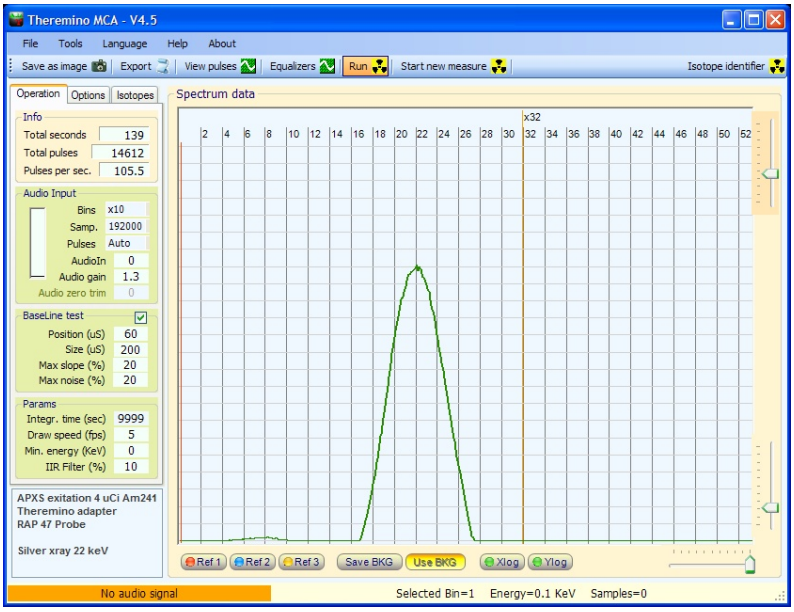
This small statue is 925/1000 silver and it's the purest silver I could find till now.

Let see the difference between the induced fruorescence by Sr90 (electrons) and Am241 (photons)



Here the small statue has been hitted by electrons from 0.1 uCi of Sr90

The silver 22 keV X rays peak is very clear as is the brehmsstralung continuum



Inthis case the small statue has been hitted by photons from 4uCi of Am241

The silver 22 keV X ray peak is very clear but we have no brehmsstralung continuum

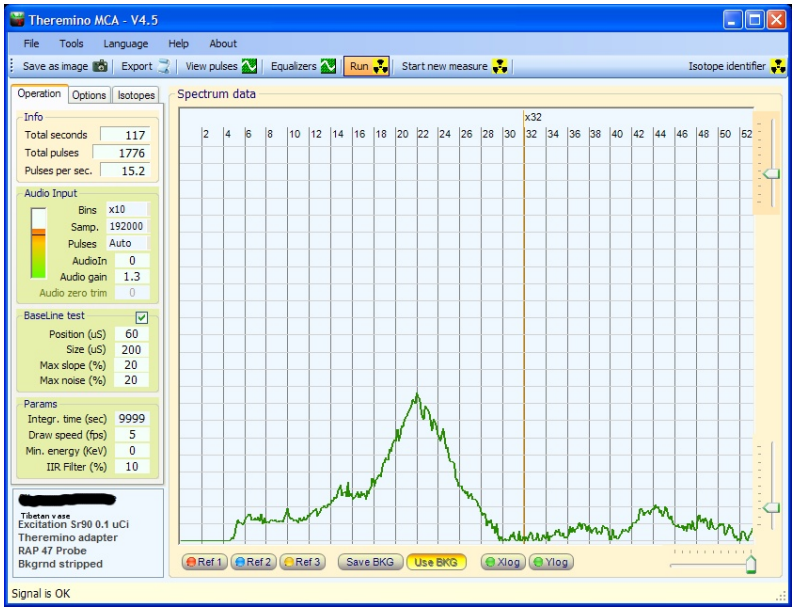
If we check carefully we can see a very little bump at 8 keV, due to the 75/1000 copper in the statue

We may believe that the difference is not so important, we see clearly the 22 keV peak in both cases.

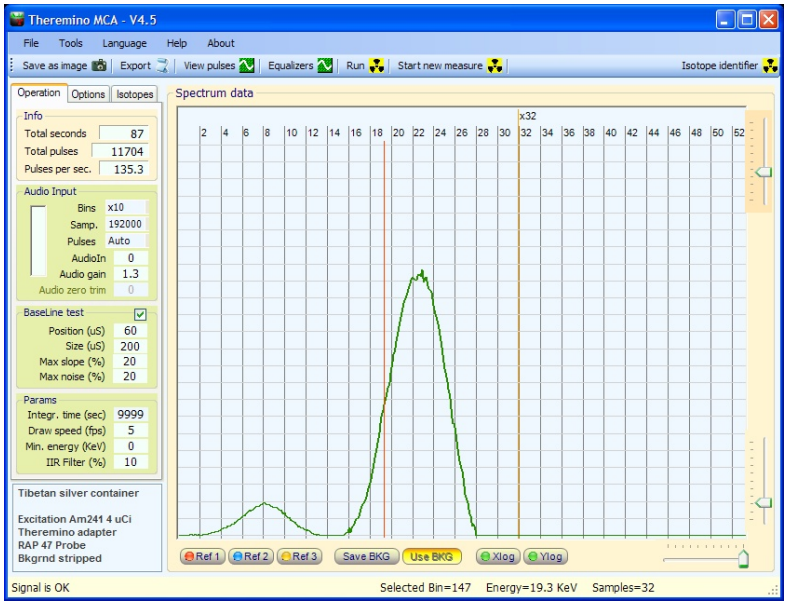
This may be correct in case of pure or nearly pure elements, but let us see what happens if the examined object is not a pure element but it's an alloy.

This is a silver Tibetan bowl borrowed from a friend antiquary.

I have checked it with Sr90 and with Am241



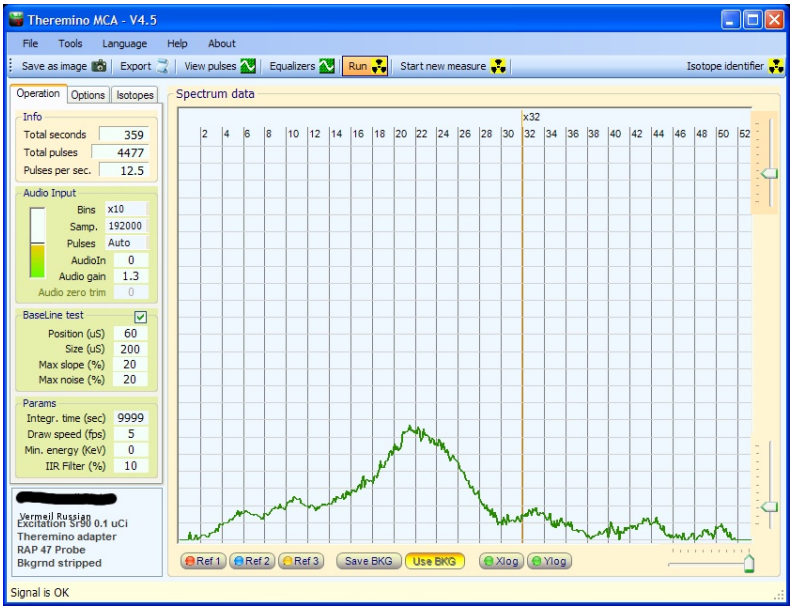
This is the result of electrons hitting using Sr90.
The 22 keV of silver is very clear, but it is quite difficult to state if other elements are inside the alloy because of the brehmsstralung continuum.



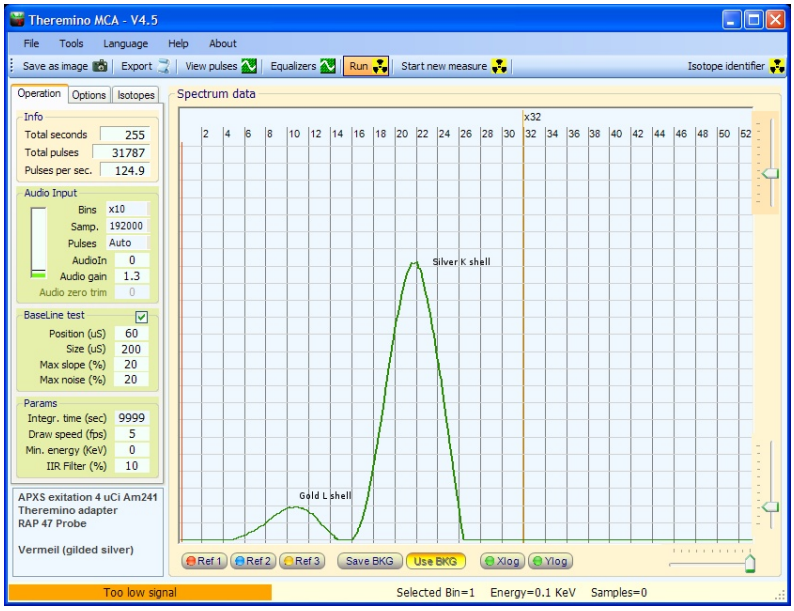
The photons from Am241 on the contrary show clearly that the bowl is composed by silver and copper.
It is also possible to make a rough extimation of the percentage of the two elements in the alloy.

I bought this vermeil (gilded silver) tea infuser during a journey in URSS in 1987, in a shop for foreigners. The seller stated that the gold layer was very thick.

The green plastic disc is the Spectrum Techniques source of 0.1 uCi Sr90



This is the result of electrons hitting using Sr90.
The 22 keV of silver is very clear, but in this case too the brehmsstralung continuum makes the analisys quite difficult.



Using just 4 uCi of Am241 it has been possible in four minutes to see clearly the 22 keV of silver K shell and the 11 keV of gold L shell.
The purchased tea infuser is really vermeil and the gold layer appears really to be thick (the area under the gold peak is big enough).

Well, after the above results I decided to use just Am241 for XRF experiments, keeping the Sr90 source for other kind of tests.

Milan, December 2013

In case of interest the following texts may be useful to deepen the exposed concepts:

Berkeley Physics Course Vol.4, Quantum Physics - Chapter 5, 1971

Experiments in X-Ray Physics, Lulu Liu - MIT undergraduate, October 22, 2007