Fluence Calculation by activation of aluminium foils

Lorenzo Masetti

Supervisor

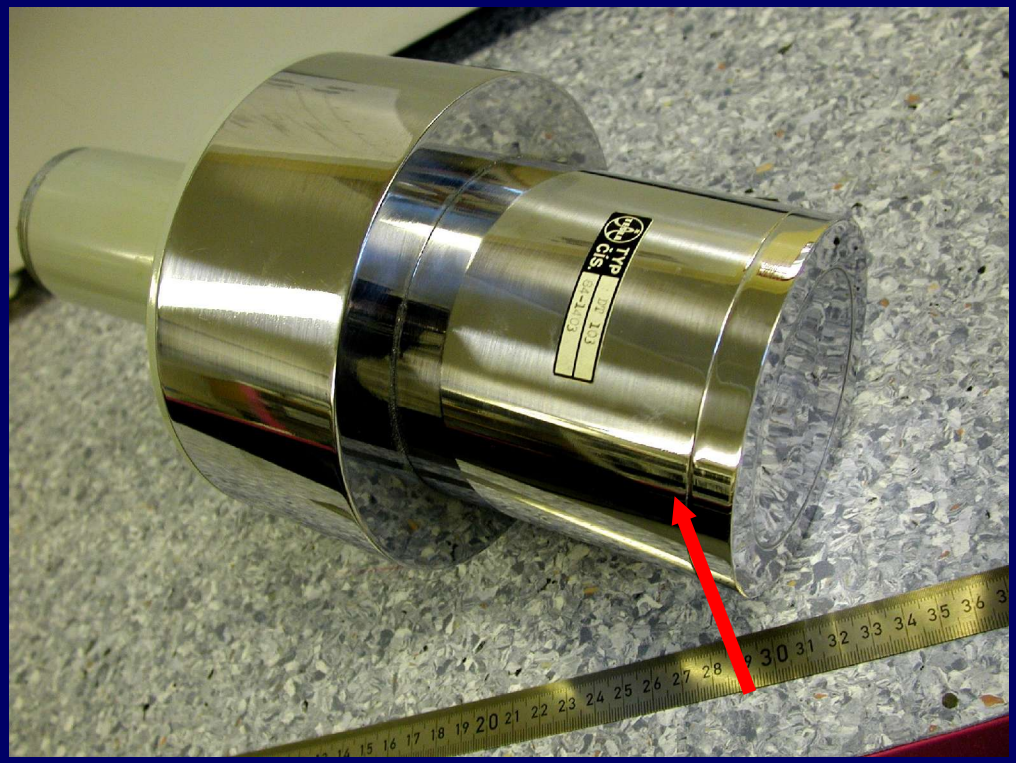
Maurice Glaser

NaI γ-spectrometer

- Aluminium foils irradiated in IRRAD facilities (24 GeV/c proton beam) to be used as dosimeters
- unstable nuclei of ^{24}Na
  - produced during irradiation of ^{27}Al
  - decay with half life time of 15 hours
- decay of ^{24}Na produces the emission of two distinct γ-rays
- emission spectrum is acquired with the NaI spectrometer
- measuring the activity of the aluminium allows us to compute the fluence

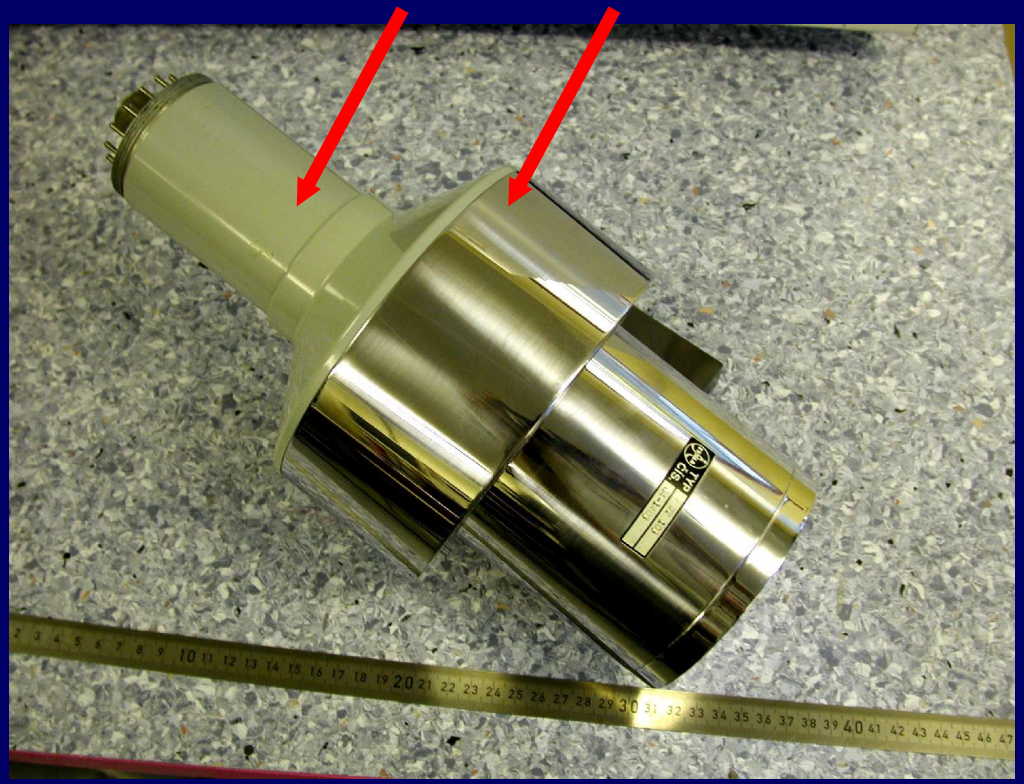
Scintillator

- NaI crystal, activated with Thalium
- 4 x 4 inches
- γ rays transfer part of energy to electrons
- de-excitation with emission of fluorescent radiation



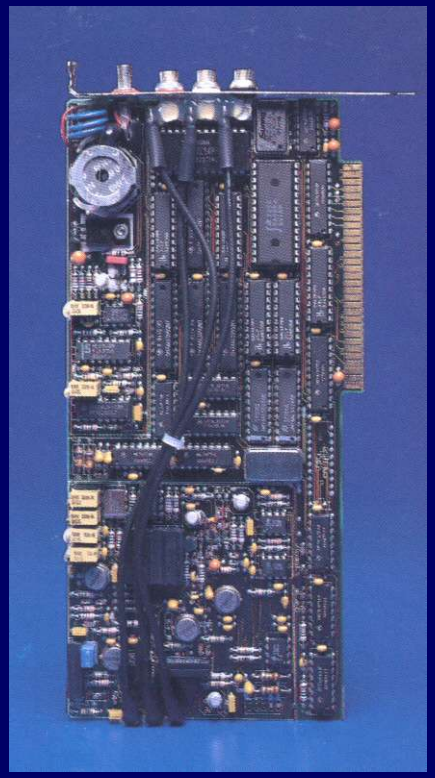
Photomultiplier

- converts the weak light output into electrical signal
- photocatode
  - conversion photons to low energy e^-
- multiplicator tube
  - amplification by secondary emission
  - final signal proportional to initial energy of γ's



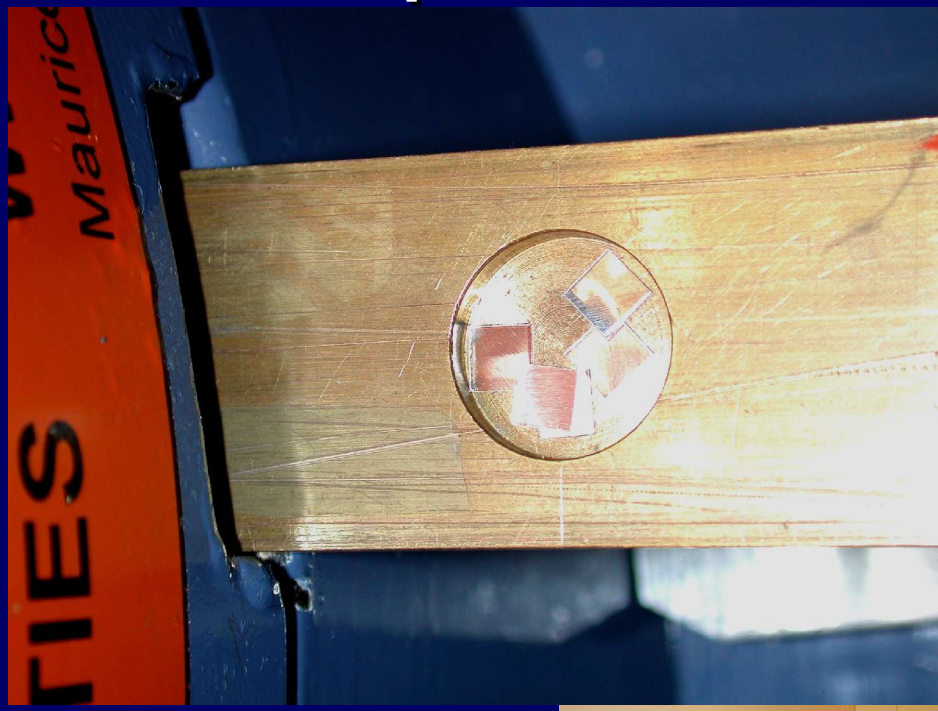
Preamplifier and TISA Card

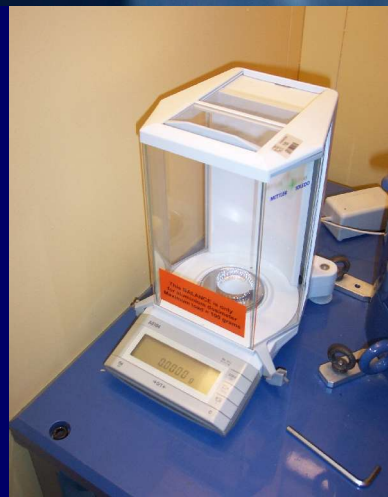
- Preamplifier
  - TC155A
  - amplifies the signal coming from the photomultiplier
  - very high counting rates pileup dead time
- TISA target systemelectronic (Germany)
  - main amplifier
    - 1 μs
  - multichannel analyser
    - ADC
    - depending on the measured energy the counter of a channel is incremented
    - 4096 channels (we used 1500)
  - power supply: 1.25 KV max



Why aluminium samples

- aluminium foils: easy to have same shape of the element we want to irradiate
- easy way to measure fluence:
  - weight the sample at 0.1 mg precision
  - put into the spectrometer
  - start WinFluence
  - when statisfied stop the acquisition





Why an *ad hoc* program?

- a lot of good programs for spectrometry
- but not so easy to use
- with WinFluence
  - every user performing irradiation can do the measurement by himself
  - optimized for our application
  - key features protected against inappropriate handling
- prompt results just after the end of irradiation (the user is still here!)
- error on fluence $\approx$ 7% at best

NaI vs. Ge

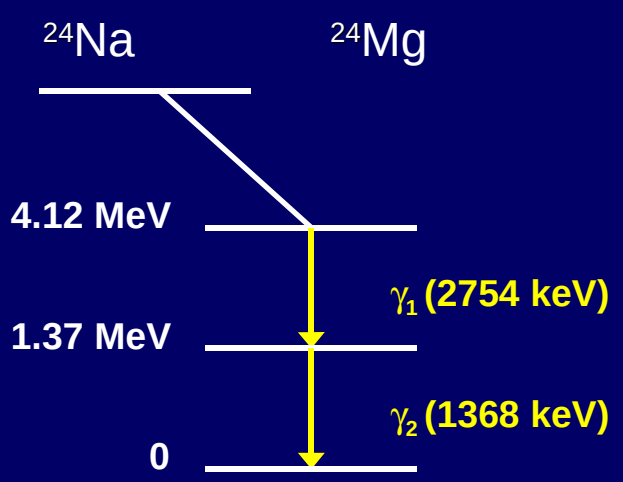
- 30 KCHF
- higher efficiency
- easy maintenance
- minimum 500 Bq

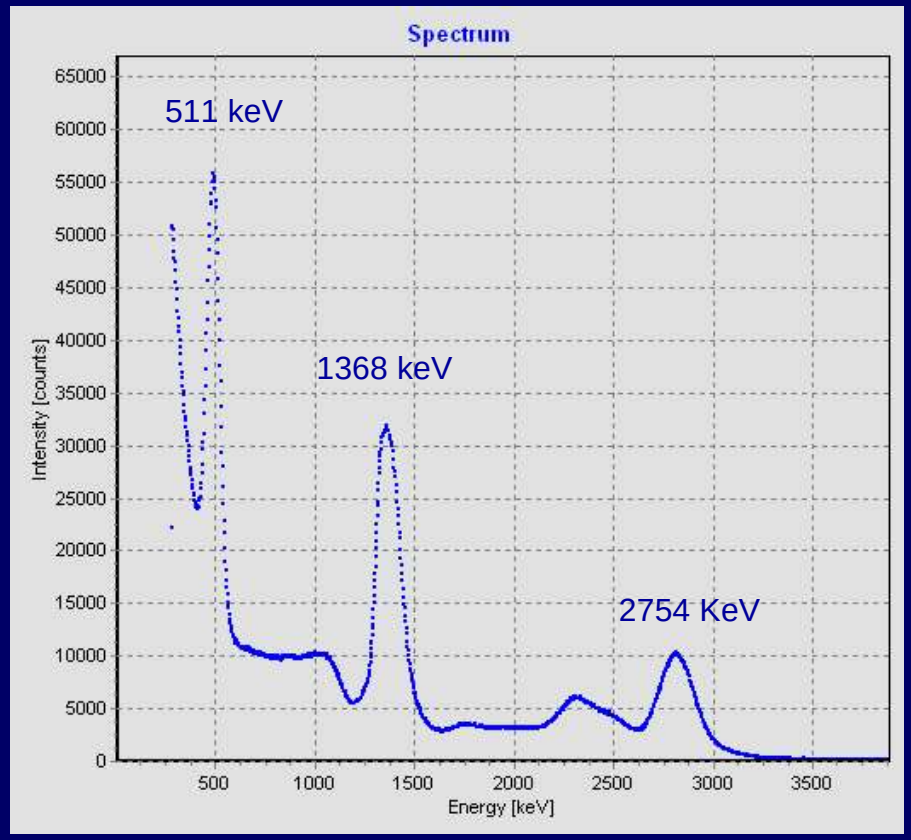
- 100 KCHF
- higher resolution
- better Signal To Noise ratio
- large energy range
- time consuming maintenance
- starts from 1 Bq

BOTH USEFUL!!

Decay of ^{24}Na

- ^{24}Na decays in ^{24}Mg and emits two γ 's of energy 2.754 and 1.368 MeV





- peak at 511 keV: pair production

How to measure the fluence

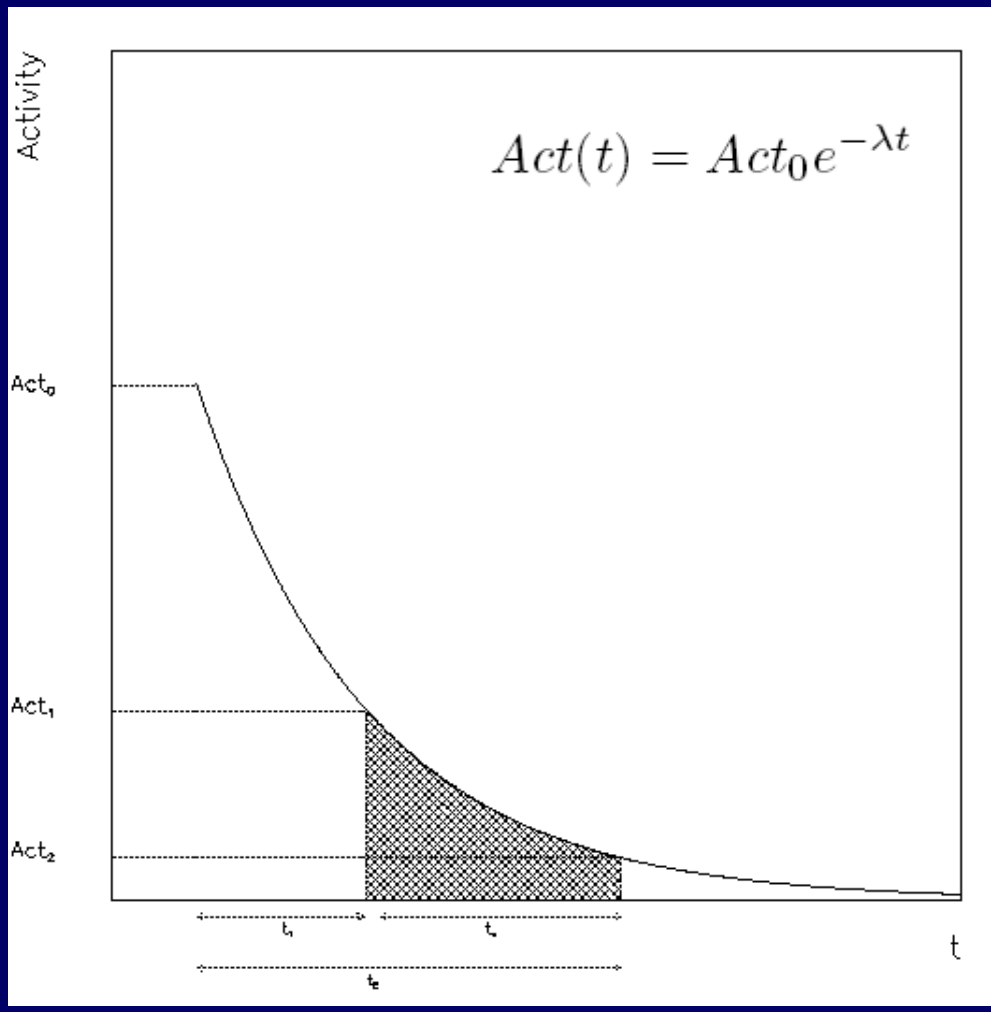
- During irradiation: production and decay

$$\frac{\mathrm{d}N_B}{\mathrm{d}t} = \varphi N_A \sigma_A - \lambda N_B$$

- After irradiation activity goes down exponentially
- With WinFluence we measure the average activity during the counting time
- With some math we can compute the flux and the fluence

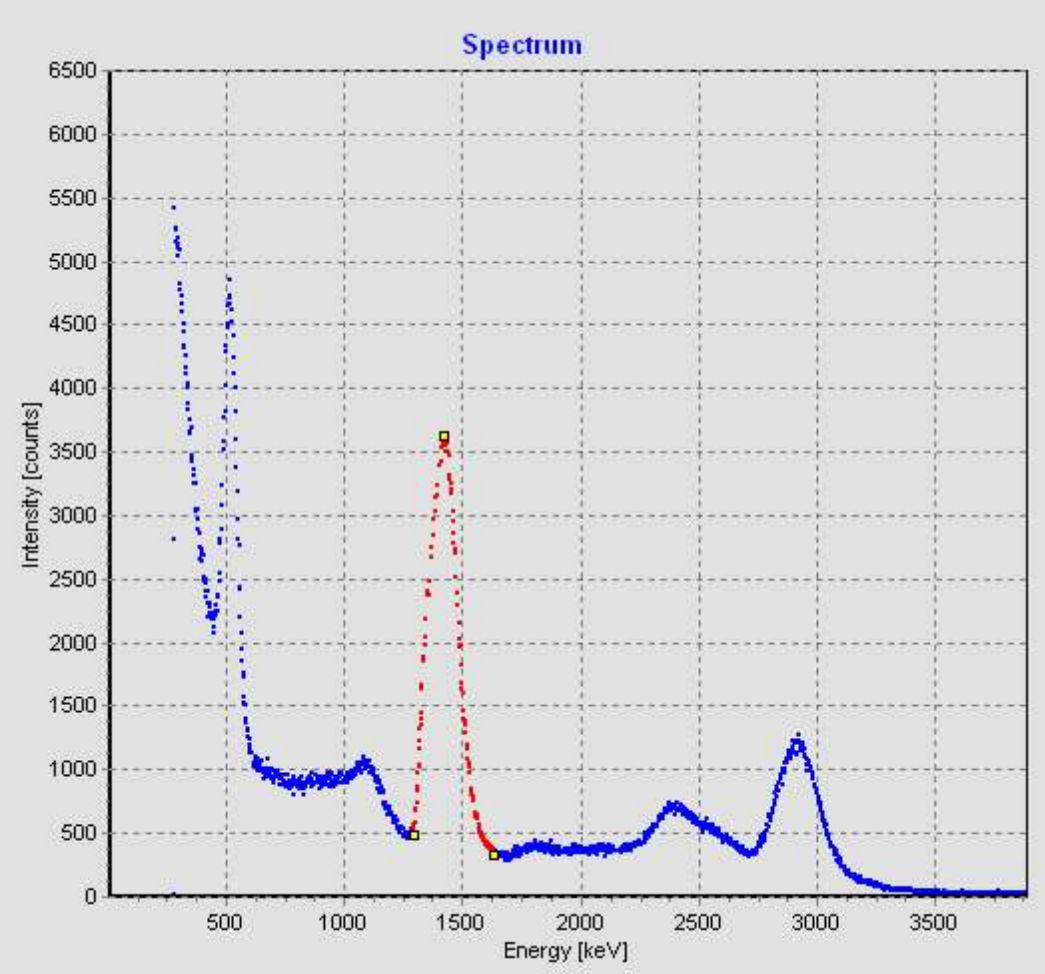
$$\varphi = \frac{Act_0}{N_0 \sigma_A (1 - e^{-\lambda t_i})}$$

$$\Phi = \varphi t_i$$



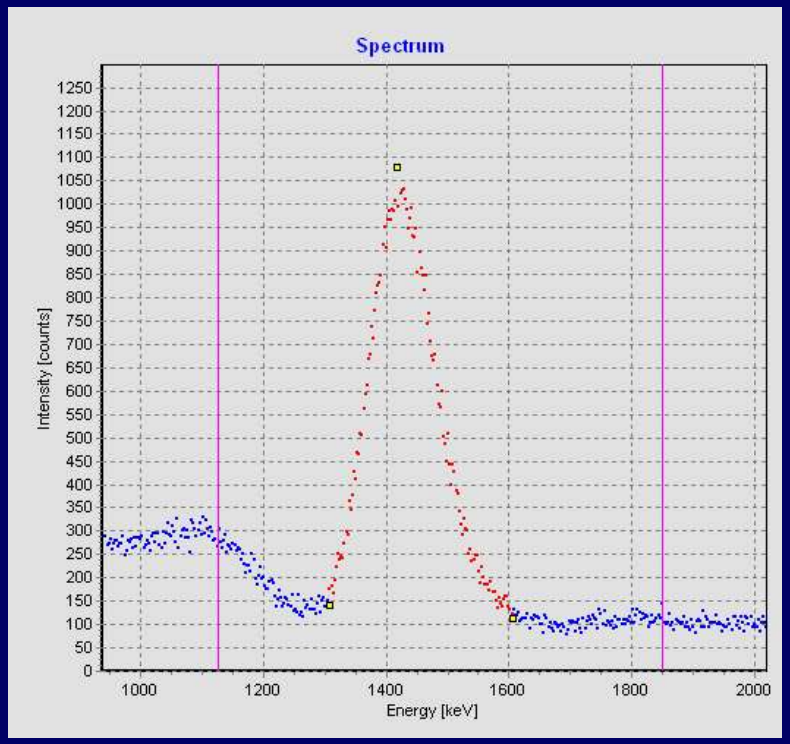
A typical spectrum

- A typical spectrum acquired by Fluence has several peaks
- we are interested on the peak at 1368 keV



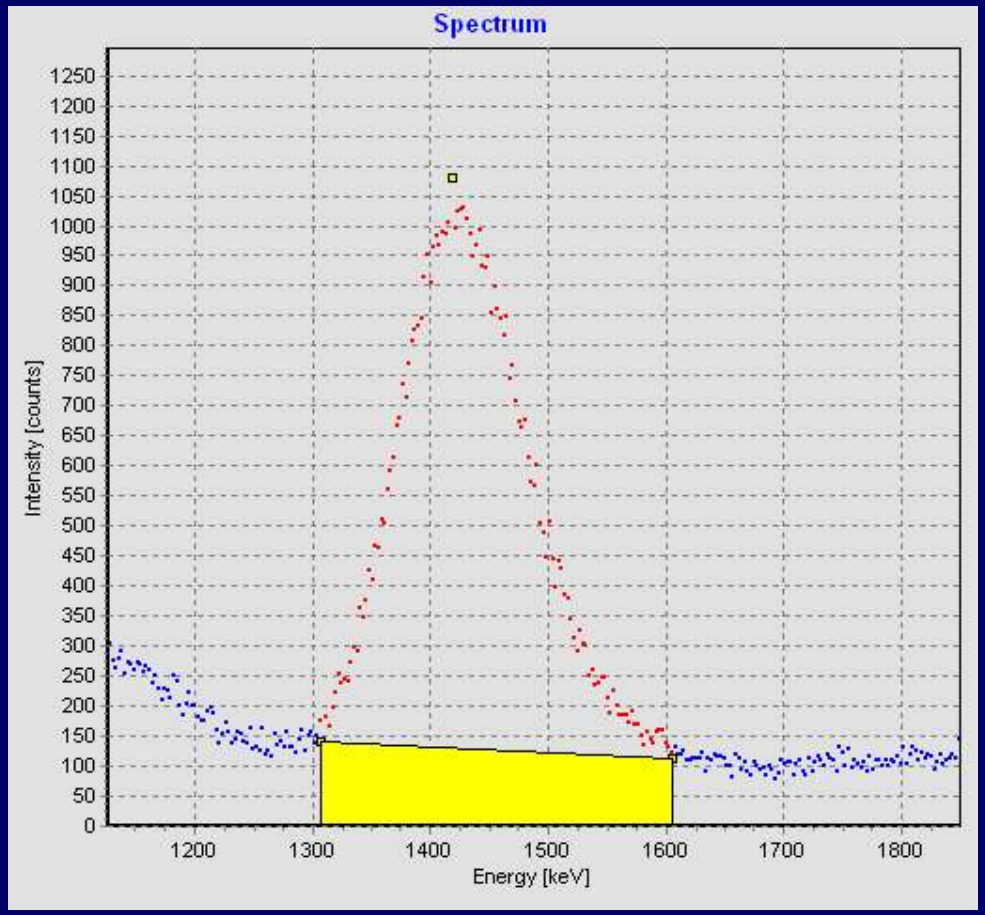
How to find the integration bounds

- search starts from two points given by the user
- by default ROI is around 1368 keV
- values of the channels are summed 10 by 10 to avoid the sensing of false marks
- the mark is found when there is a significative increase



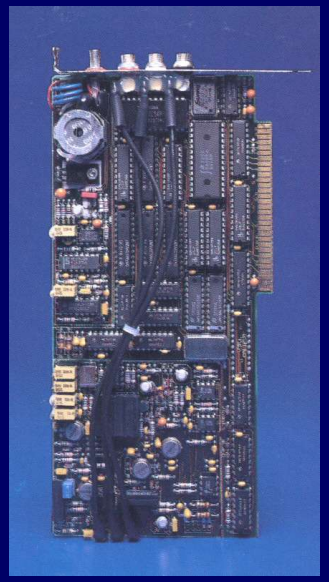
Subtracting the background

- background noise must be subtracted
- the trapezoid area is subtracted from the total counts
- height of the points: average of the values of 20 channels on each side



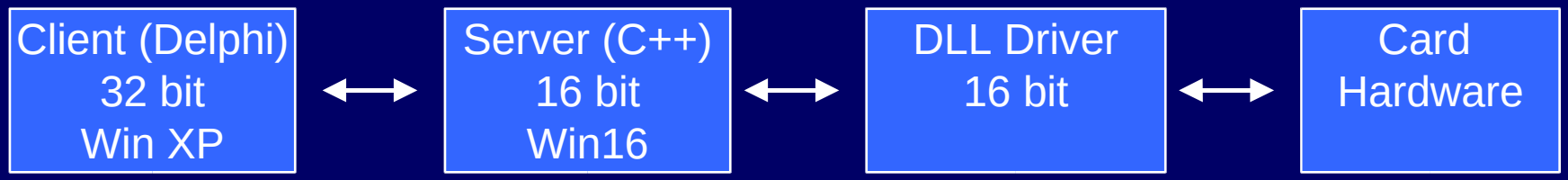
My work on the program

- an old program for MS-DOS written in Pascal was still working on 2004 (since 1998)
- it was outdated and will be replaced by the new program written in Delphi and running under Windows XP
- …but still using the old ISA card (not PCI !!)



Client – server architecture

- TISA card is old (1997) and has only 16 bit drivers
- communication only possible through a 16 bit server
- works on the network



Absolute efficiency

- Counts per second:

  (Peak Area) / (Counting Time)

- Absolute Efficiency is

  (Counts detected) / (Total Gammas Emitted)

- around 1.4 %

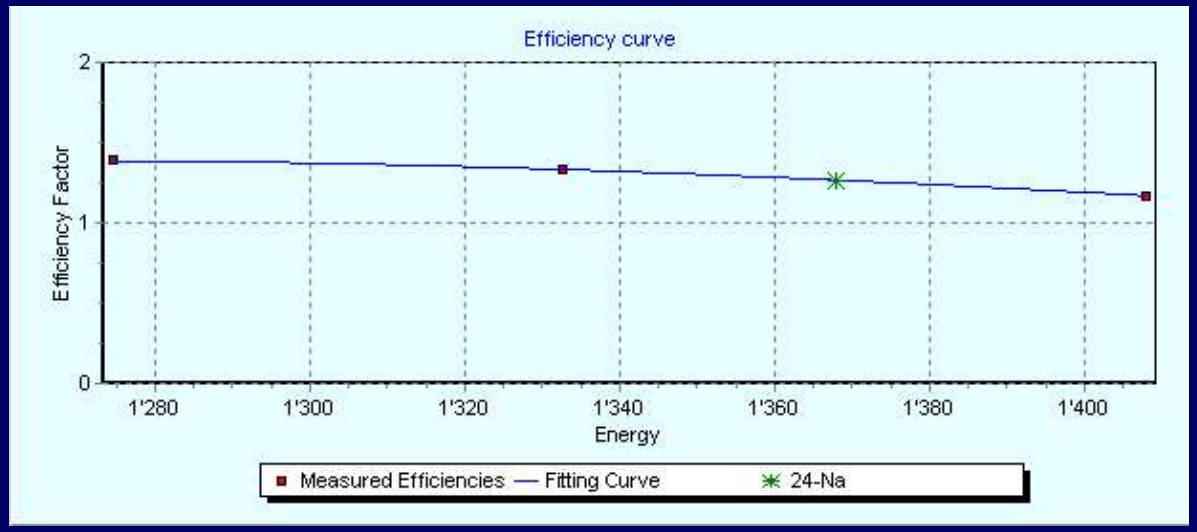
$$\overline{Act} = \frac{Net/t_c}{Abs_Eff_\%} \times 100$$

Efficiency Calibration

- measurement depends on absolute efficiency of the system
- to estimate absolute efficiency we used certified radioactive sources
- sources certify:
  - activity at a certain time
  - half life time
  - peak energy
- to calibrate the spectrometer..
  - measure present counts per second
  - compute the absolute efficiency

Efficiency interpolation

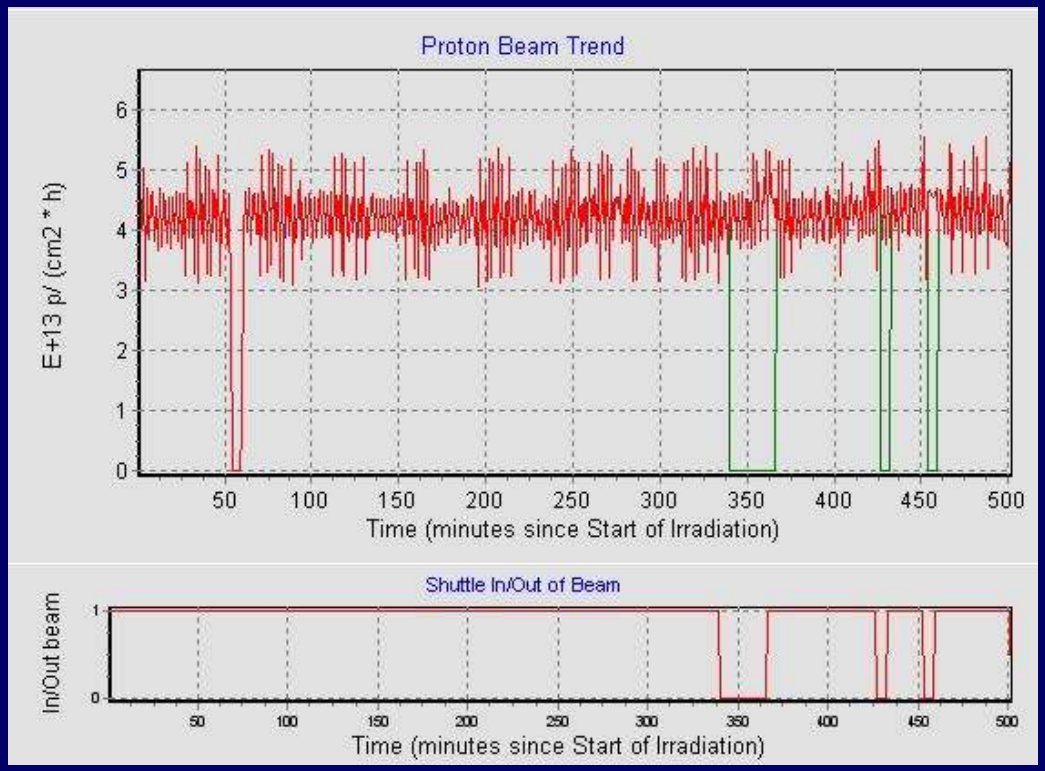
- efficiency is not constant for all energies
- estimating the efficiency
  - measure the efficiencies for different peaks
  - interpolate in the point of interest



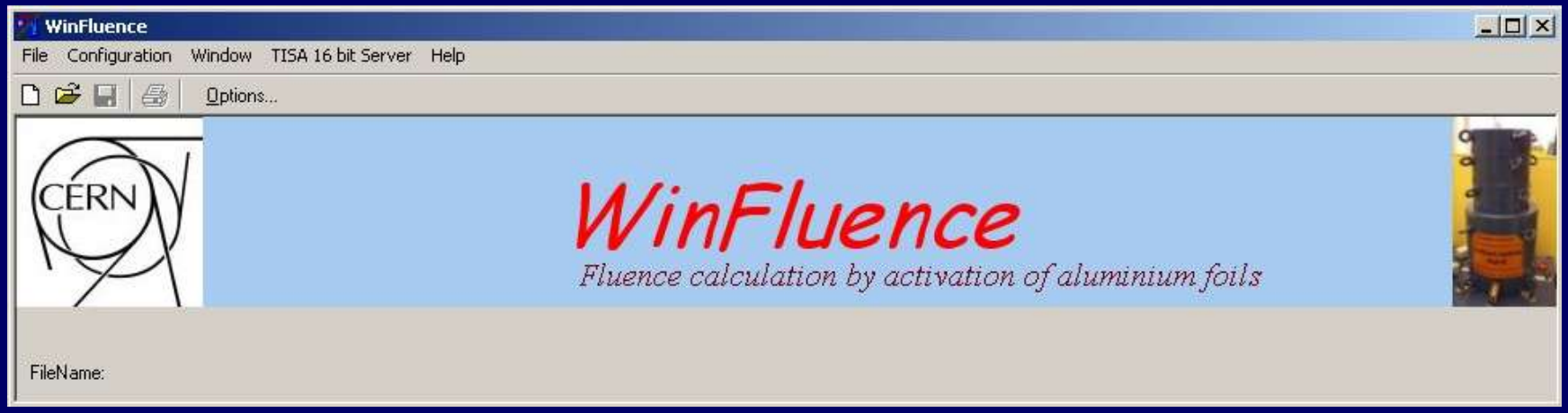
- fitting curve is a polynomial on the logarithm of the values

Monitoring the beam trend

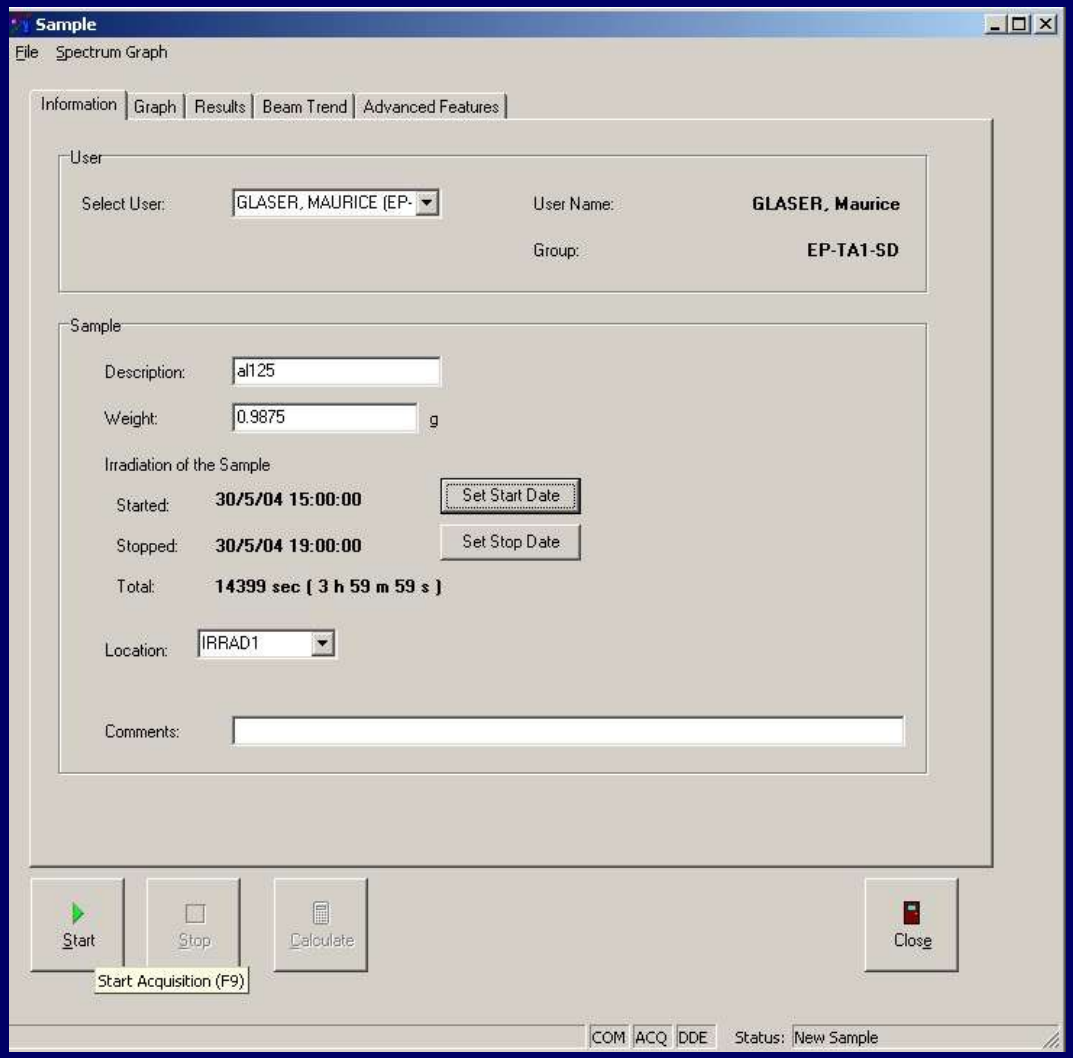
- WinFluence can access the database of SEC measurement for the beam flux (if it exists)
- check if the shuttle was in beam during “irradiation”
- to avoid errors
- possibility to compute a factor to correct the value of the fluence



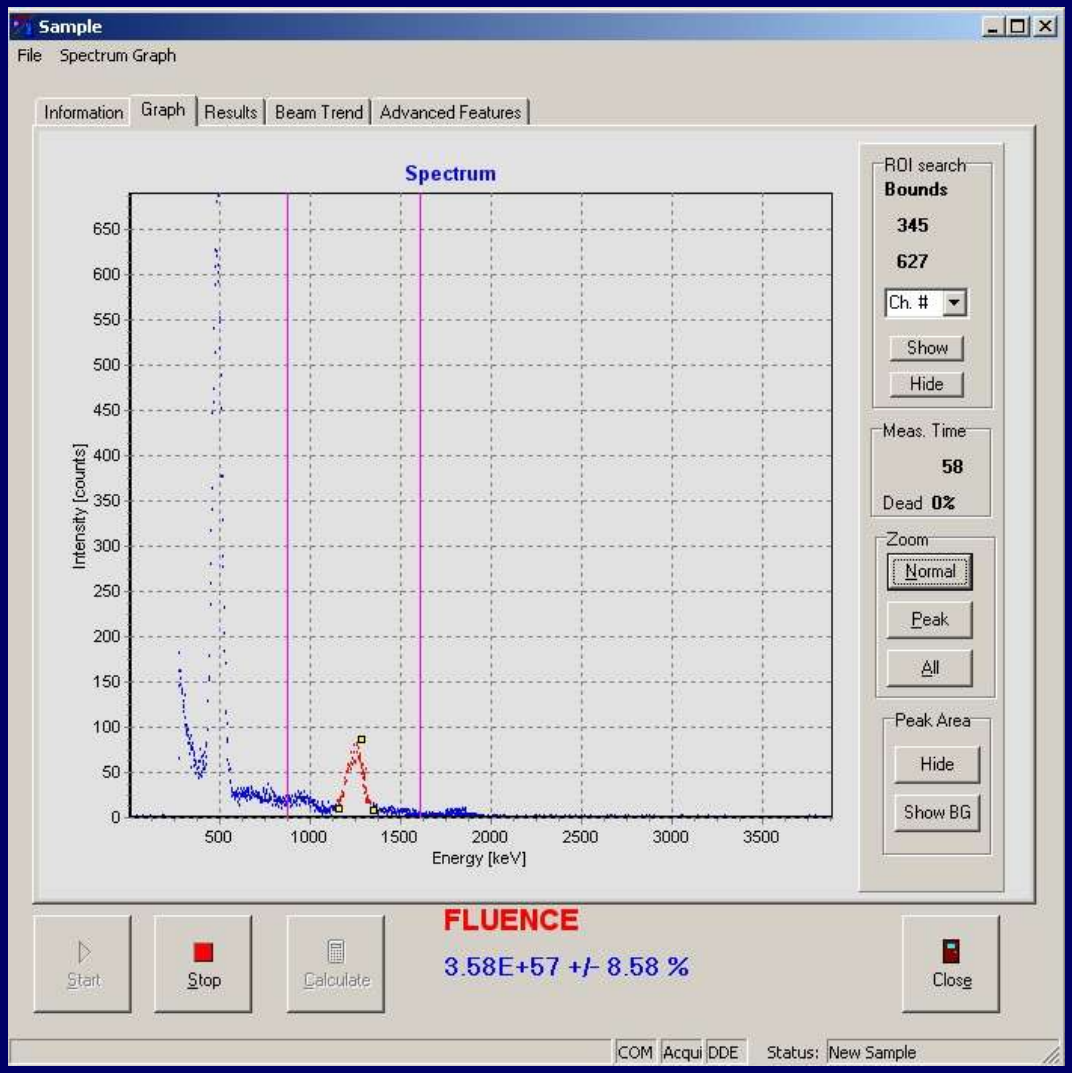
Screenshot: first form



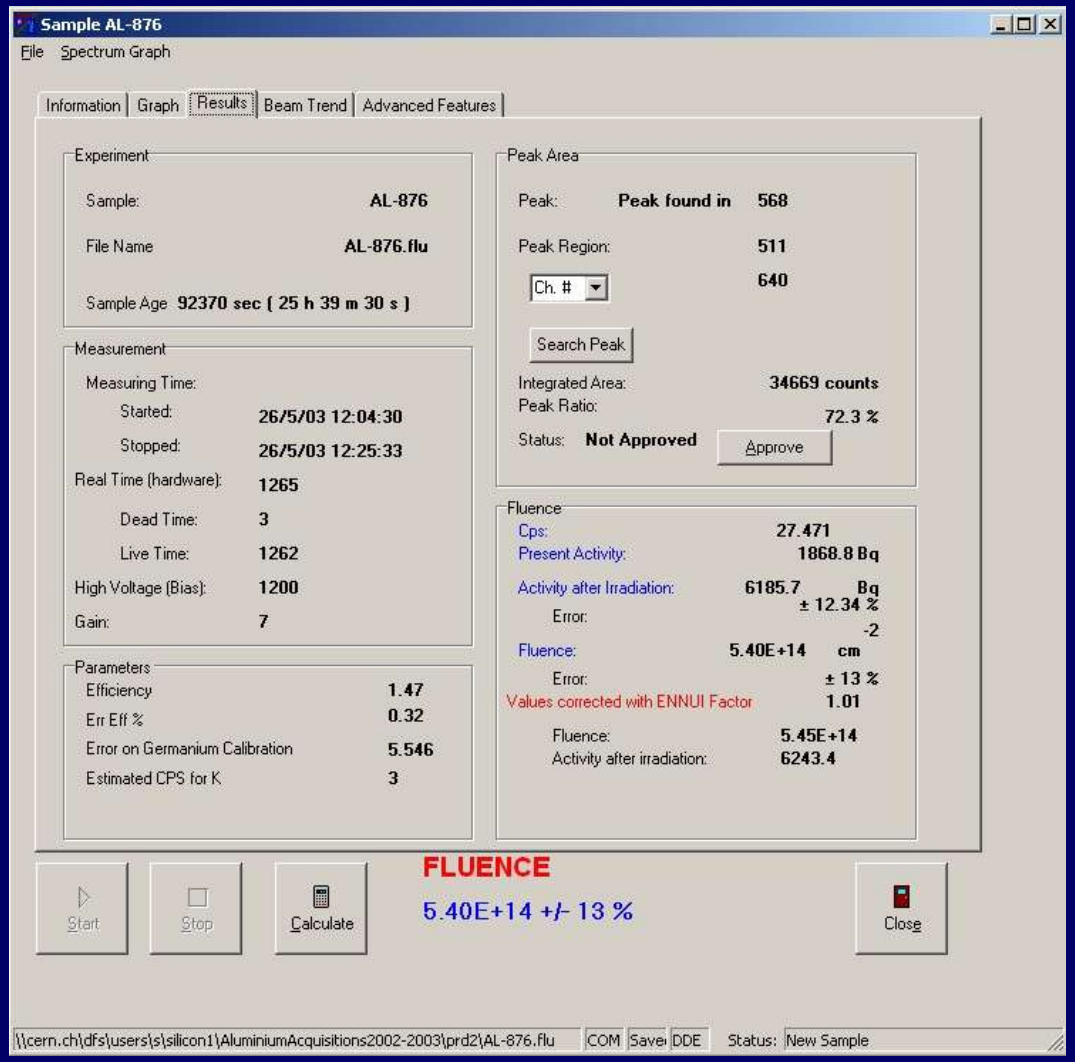
Screenshot: information form



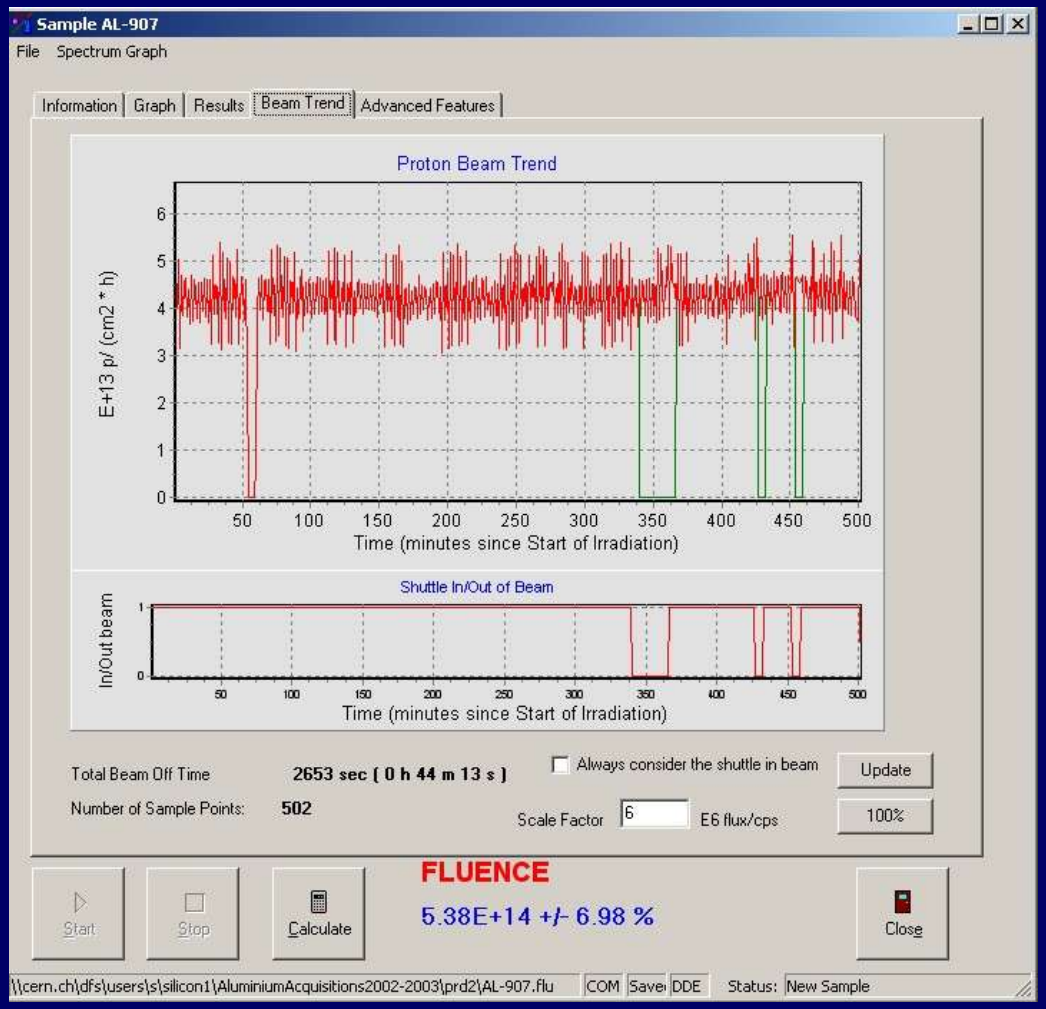
Screenshot: acquisition



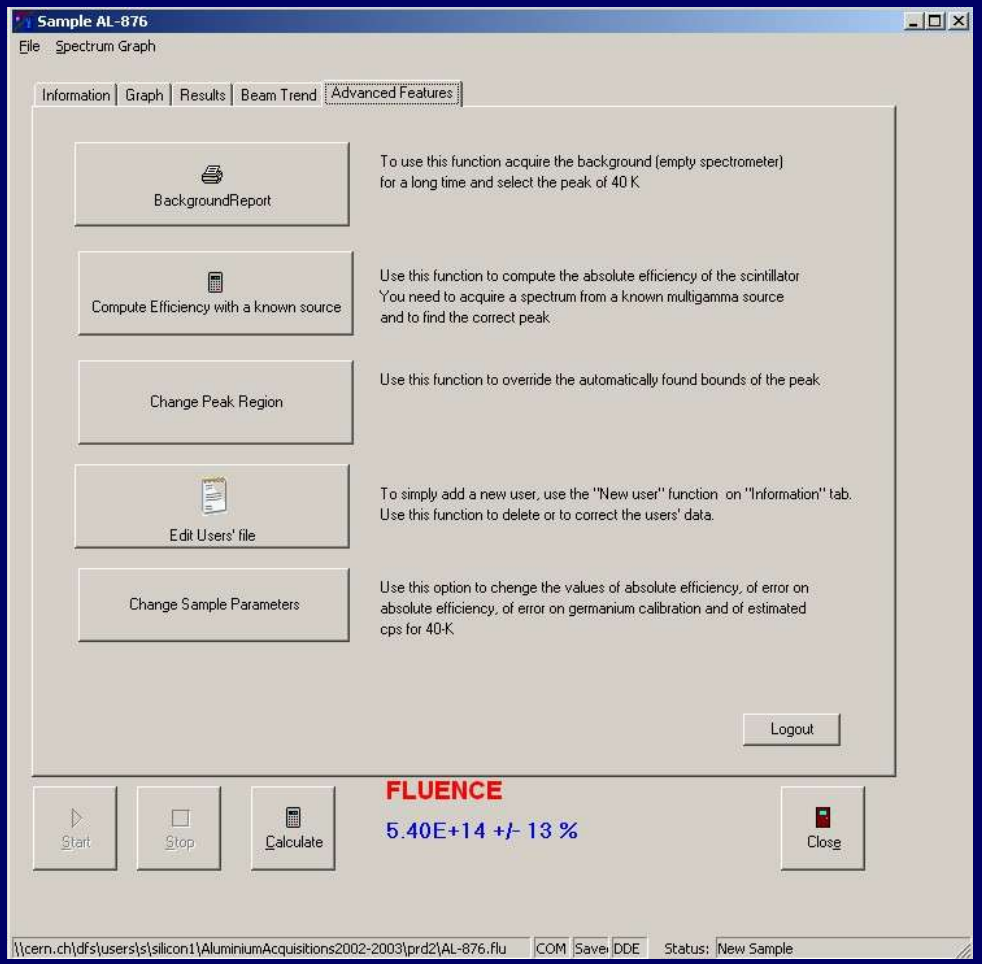
Screenshot: results



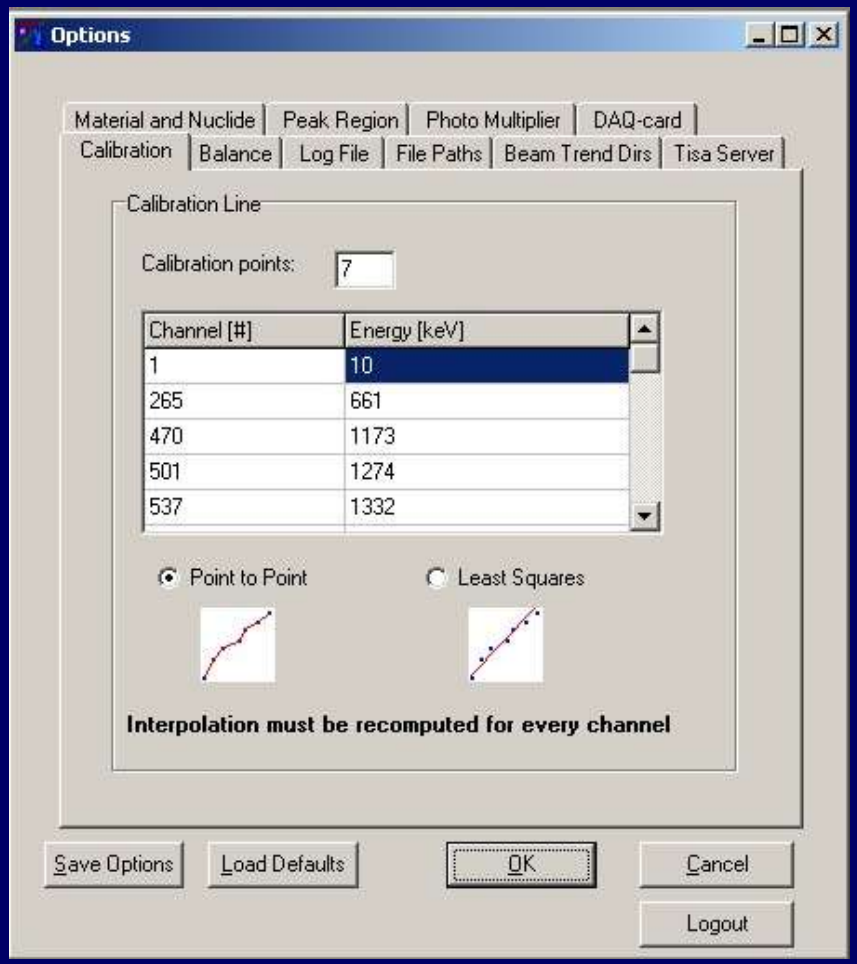
Screenshot: beam tren



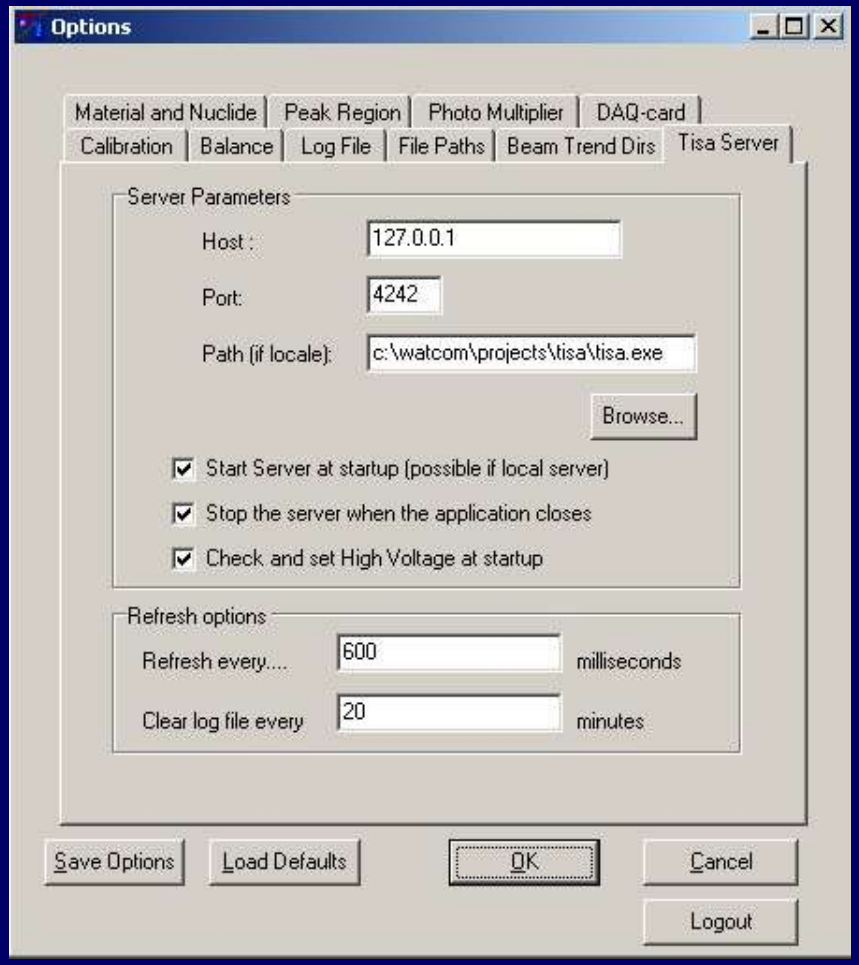
Screenshot: advanced features



Screenshot: channel calibration

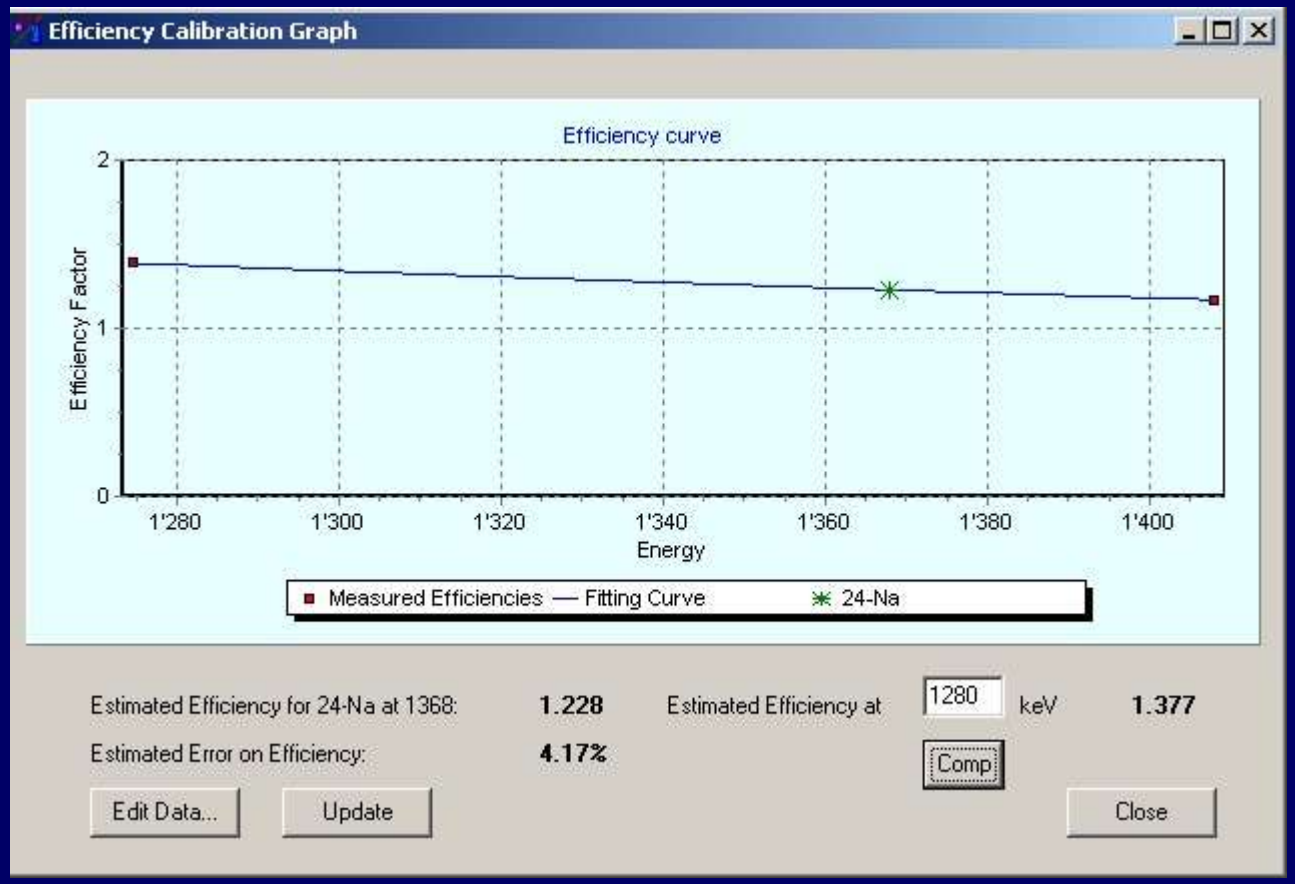


Screenshot: server options



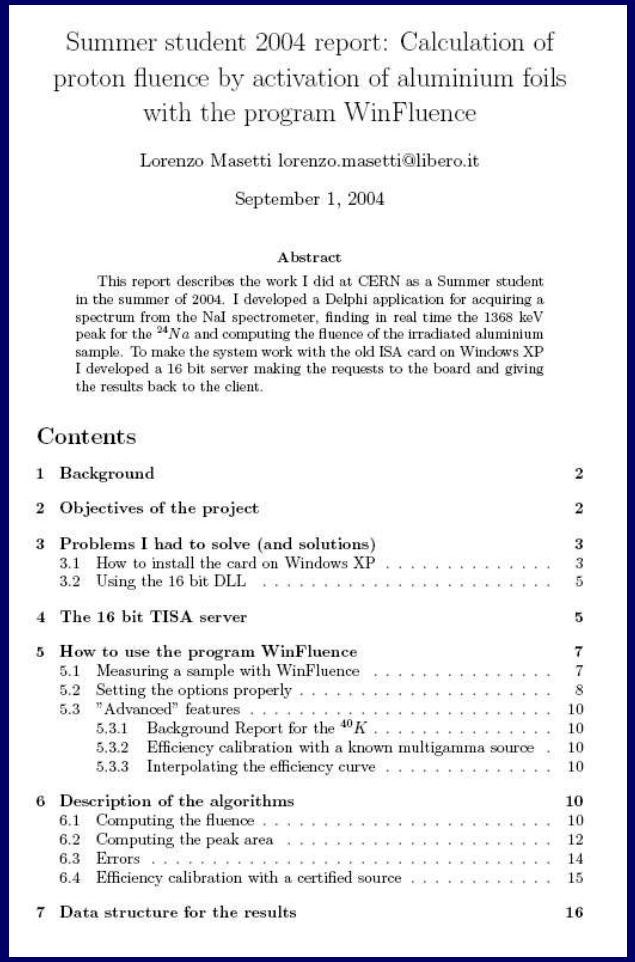
- 10 tabs like this!

Screenshot: efficiency interpolation



For the future…

- 18 pages of documentation
- Possibility to modify the program
- I hope to do my thesis on this project



Summer student 2004 report: Calculation of proton fluence by activation of aluminium foils with the program WinFluence

Lorenzo Masetti lorenzo.masetti@libero.it

September 1, 2004

Abstract

This report describes the work I did at CERN as a Summer student in the summer of 2004. I developed a Delphi application for acquiring a spectrum from the NaI spectrometer, finding in real time the 1368 keV peak for the ^{24}Na and computing the fluence of the irradiated aluminium sample. To make the system work with the old ISA card on Windows XP I developed a 16 bit server making the requests to the board and giving the results back to the client.

Contents

1 Background **2**

2 Objectives of the project **2**

3 Problems I had to solve (and solutions) **3**
3.1 How to install the card on Windows XP . . . 3
3.2 Using the 16 bit DLL . . . 5

4 The 16 bit TISA server **5**

5 How to use the program WinFluence **7**
5.1 Measuring a sample with WinFluence . . . 7
5.2 Setting the options properly . . . 8
5.3 "Advanced" features . . . 10
5.3.1 Background Report for the ^{40}K . . . 10
5.3.2 Efficiency calibration with a known multigamma source . 10
5.3.3 Interpolating the efficiency curve . . . 10

6 Description of the algorithms **10**
6.1 Computing the fluence . . . 10
6.2 Computing the peak area . . . 12
6.3 Errors . . . 14
6.4 Efficiency calibration with a certified source . . . 15

7 Data structure for the results **16**

Thanks..