SELECTION AND OPTIMIZATION OF SPECTROMETRIC AMPLIFIERS

FOR GAMMA SPECTROMETRY: PART I -RESOLUTION OF SYSTEM

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ABSTRACT

The objetive of the present work was to establish simple criteria to choose the best combination of electronic modules to achieve an adequate high resolution gamma spectrometer.The energetic resolution variation of a gamma spectrometric system composed by a Hp Ge detector has been studied by using several kinds of spectrometric amplifiers: Canberra 2021, Canberra 2025,Ortec 673 and Tennelec 244.The influence of parameters like shaping time, shape type, analogic to digital converter,count rate,pole zero cancelation function and baseline restorer line has been taken into account in the resolution measurements.The results showed the best amplifier conditions for the best resolutions: shaping time between (3-4) μ s, semigaussian shape type ,fine adjustment in the pole zero cancelation function and baseline restorer line in "auto" position.

INTRODUCTION

Gamma ray spectrometry plays a very important role among several nuclear techniques for analytical purpose.Its requirements greatly vary according to the fields of application.For instance a spectrometer for Activation Analysis has more demanding speed requirements than those entitled to measure environmental contamination[1].

The objetive of the present work was to establish simple criteria so helpful to choose the best combination of modules to achieve an adequate high resolution gamma spectrometry [2, 3] .For one side, the emphasize was directed to evaluate the way that every studied parameter influentiate the resolution of the whole system.These results are presented in this work.On the other hand, live time correction factors were studied as they incide on counting looses and so on the acuracy of quantitative determinations.These results are presented in another work [4] .

This work focused on the following aspects :

- Spectrometric amplifiers: influence of their principal characteristics on the energetic resolution of the system.

METHODOLOGY

In a HP Ge detector (1.8 keV FWHM for Co-60 1332 keV peak specification) with a first step cooled charge sensitive preamplifier, final resoluton is determined by the amplifier capability to solve [1]:

- increase of signal/noise relation (noise is defined as all sort of sources producing an increase of the peak width: ie. detector noise, preamplifier noise, microphony, etc);
-peak pile up effect;
-Degradation of resolution due large time charge collection (ballistic effect).

A comparative study of those effects was conducted for the CANBERRA 2021,CANBERRA 2025,ORTEC 673 and TENNELEC 244 amplifiers arranged in the next traditional schematic block showed in Fig .1:

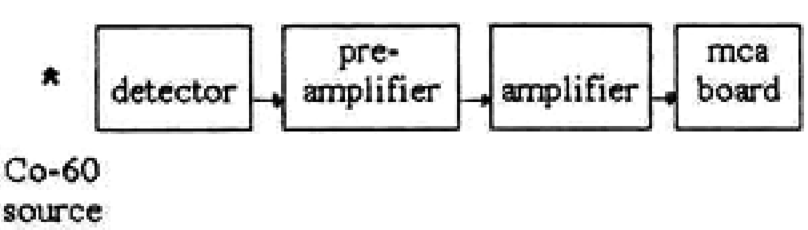

Figure 1.- Gamma Spectrometry Experimental Apparatus.

The detector was a CANBERRA HP Ge model CG 1318-7500, 45 mm diameter x 45 mm depth ,especified 1.8 keV resolution for 1.33 MeV energy, with an adapted CANBERRA model 2001C preamplifier.

The MCA board was an EGG-ORTEC using the analytical software MAESTRO II.

RESULTS AND CONCLUSIONS

The following studies were done to verify the influence of parameters on energetic resolution:

1-Influence Of Shaping Time On Resolution : Resolution measurements for the several amplifiers at 200 cps and 5000 cps count rates versus shaping time are presented in fig. 2 and fig. 3.

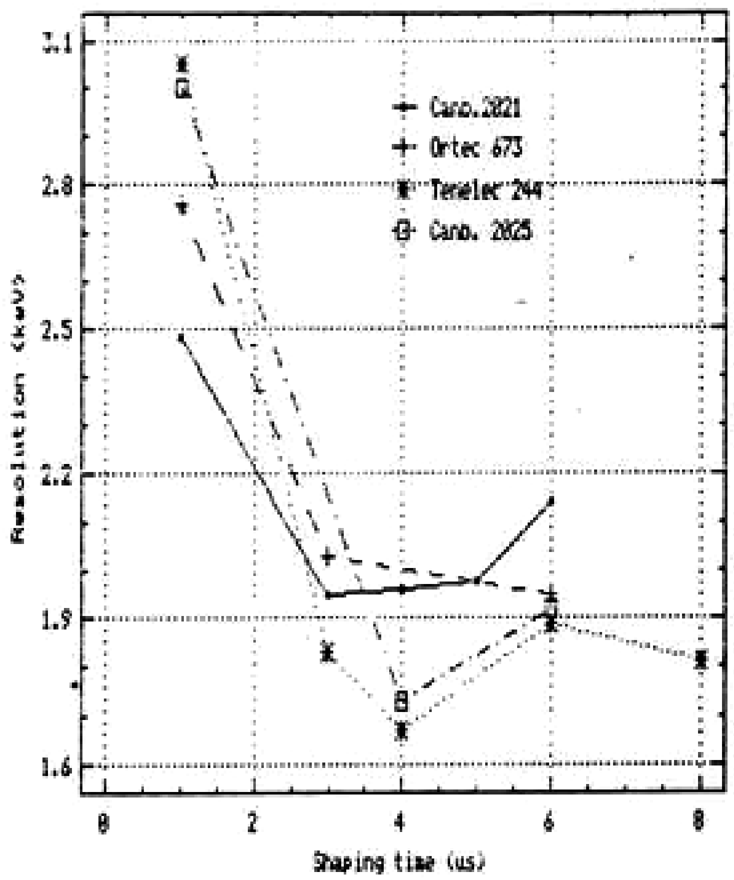

Figure 2.-Resolution vs. Shaping Time For Different Amplifiers: Count Rate 0.2 kcps

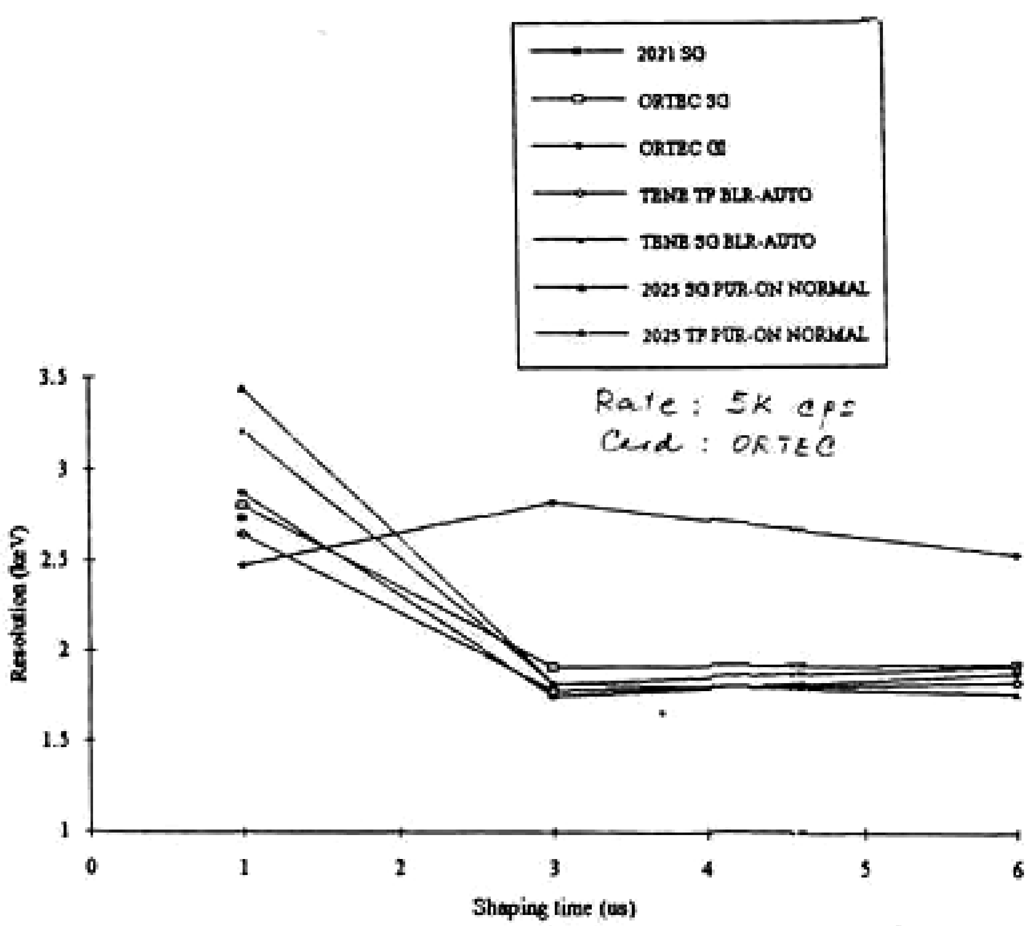

Figure 3.-Resolution vs. Shaping Time For Different Amplifiers:Count Rate 5 kcps

It can be concluded that :

- All amplifiers showed low resolutions at low count rates (200 cps) at small shapping time (1µs).Better results were produced for shaping times between 3 and 4 µs. CANBERRA 2025 and TENNELEC 244 gave the lowest values(better).;

- With the exception of ORTEC 673,for shaping times higher than 4 µs low resolution is observed (Measurements to 4 µs are not possible in this amplifier)

- For medium count rates (5000 cps) and shaping times higher than 1 µs, ORTEC 673 with gate integrator showed a high value of resolution;

-Similar results are obtained to 3 and 4 µs with semigaussian or triangular shape types.

2-Influence Of Shaping Type On Resolution. By using the same measurement scheme, resolution was studied for different shape types.An ORTEC model 673 amplifier (with gate integrator or semigaussian shape types), a CANBERRA 2025 and a TENNELEC 244 (both with triangular and semigaussian shape types) amplifiers were used.Results are presented in fig.4a, fig.4b and fig.4c.

It can be concluded that:

- Triangular shape type gives a significant improvement of resolution for 1 µs and medium count rates (5000 cps).For 4 µs and 6 µs shape times, values are similar to those observed with semigaussian shape type (fig.4a and fig.4c);

- In ORTEC 673 with gate integrator, at 5000 cps,(fig.4b) and 200 cps(fig.2) count rates, resolution values for 3 µs and 6 µs shaping times are bad compared to those with semigaussian type.

- The best results were obtained with semigaussian type, at 5000 cps count rate and 1 µs shaping time.

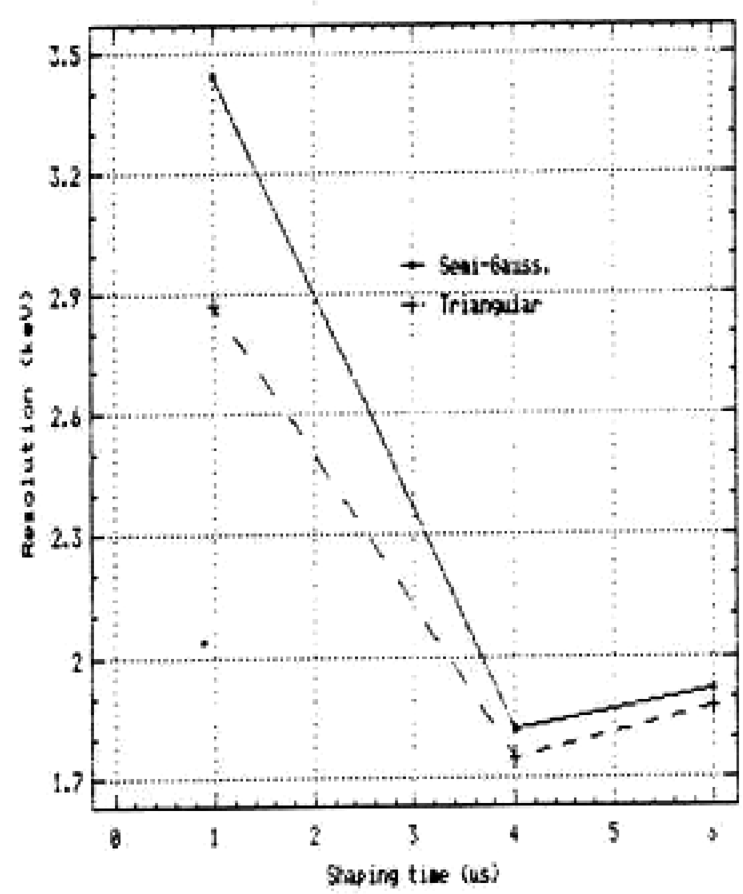

Figure 4a.-Resolution vs. Shaping Time For Canberra 2025 Amplifier: Count Rate 5 kcps.

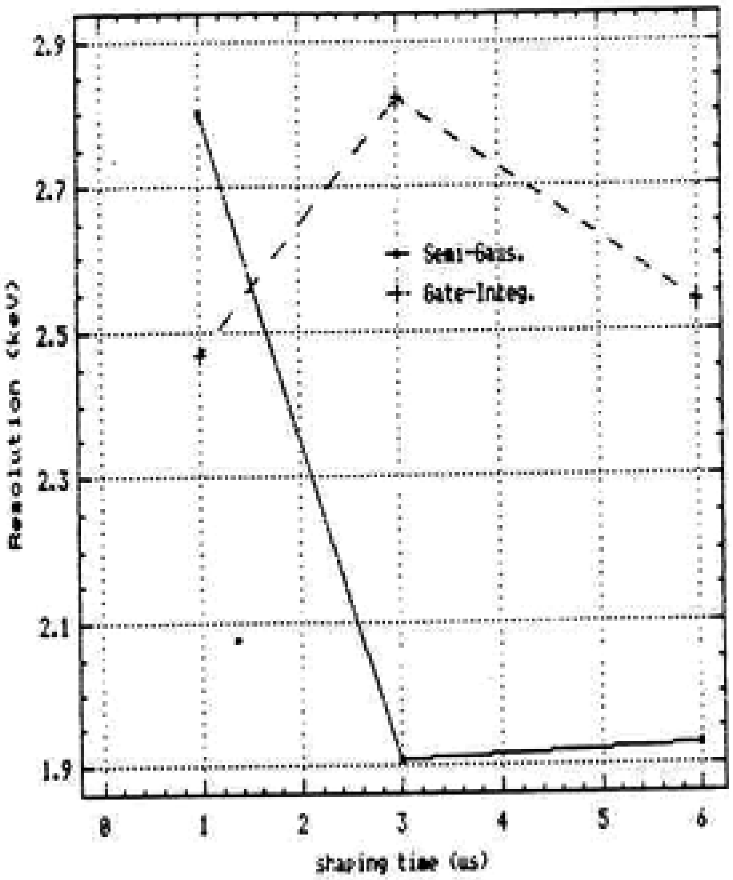

Figure 4b.- Resolution vs. Shaping Time For Ortec 673 Amplifier:Count Rate 5 kcps.

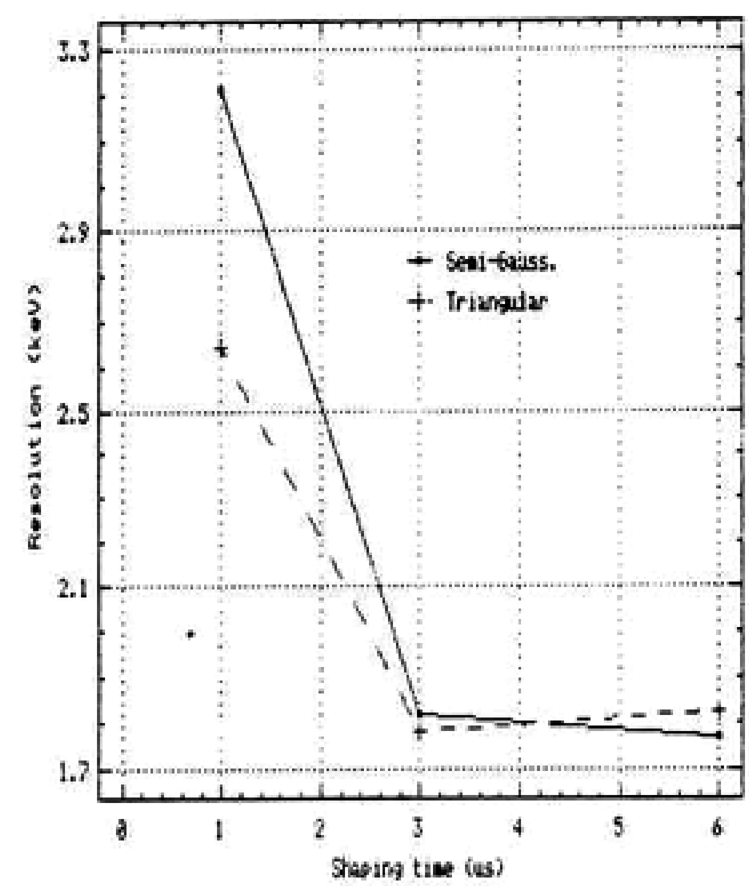

Figure 4c.-Resolution vs. Shaping Time For Tennelec 244 Amplifier:Count Rate 5 kcps.

3-Influence Of Analogic To Digital Converter (ADC) On Resolution. Among the characteristics of an ADC,Differential Non-Linearity is a a very influentiating parameter on spectrometric resolution.Unfortunately,it was not possible to perform this experiment for the available MCA boards (NUCLEUS and ORTEC) due the lack of an appropriate Ramp Pulse Generator.However, in order to evaluate the influence of ADC and shape type on resolution ,there were several measurements using both ADC boards with their respective software (NUCLEUS PCA and MAESTRO II) at the shaping time constants described in the previous item.Results are presented in fig.5.

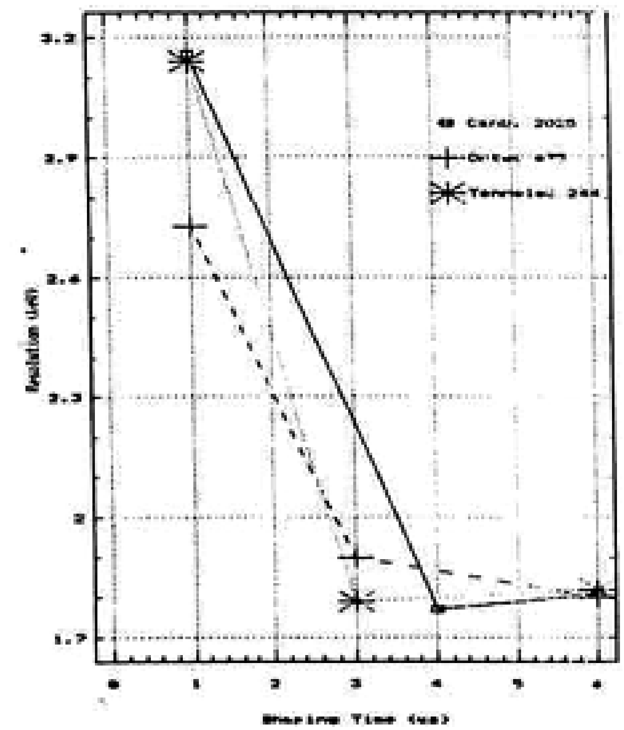

Figure 5.-Resolution vs. Shaping Time For 3 Amplifiers:Count Rate 5 kcps:with Nucleus Card.

It can be concluded that :

- Both ADC s show similar resolution bahaviour as a function of shaping time in semigaussian shape type for a medium count rate of 5000 cps.

4-Influence Of The Count Rate On Resolution. A detailed study to evaluate the effect of the Pile-up Rejector (PUR) on re solution versus count rate was conducted.As it is known, considerable high count rates can be observed during analysis of irradiated samples(ex.:activation analysis).In such cases, the use of PUR is necessary to ensure an acceptable peak shape.Scheme detailed in fig.1 was used along with an Am-241 100 mCi source in order to get a wider range of count rates just by vaying geometry (distance source-detector).Resolution dependence on shape type ,shaping time, and use of PUR for different amplifiers is shown as follows : CANBERRA 2021 (fig. 6),CANBERRA 2025 (fig.7) ,ORTEC 673 (fig.8) and TENNELEC 244 (fig 9a, fig.9b, fig.9c, fig 9d, fig. 9e and fig.9f).

It can be concluded that :

Semigaussian shape type:

- Canberra 2021 (fig.6): resolution degrades as count rate increases; best resolution was obtained for a 3 µs shaping time.It becomes higher than 2 keV at count rates above 40 kcps.

- Canberra 2025 (fig.7) :resolution also degrades as count rate increases; For a 4 µs shaping time with PUR- Off and BLR-Norm ,resolution values are better for the established count rates. They become higher than 2 keV at count rates above 30 kcps.

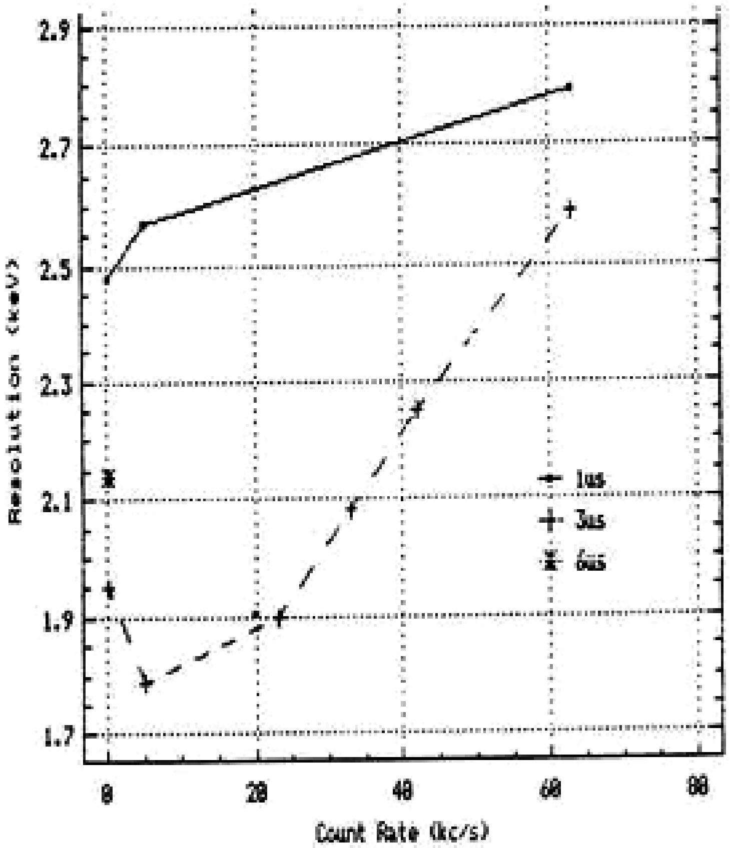

Figure 6.-Resolution vs.Count Rate For Canberra 2021.

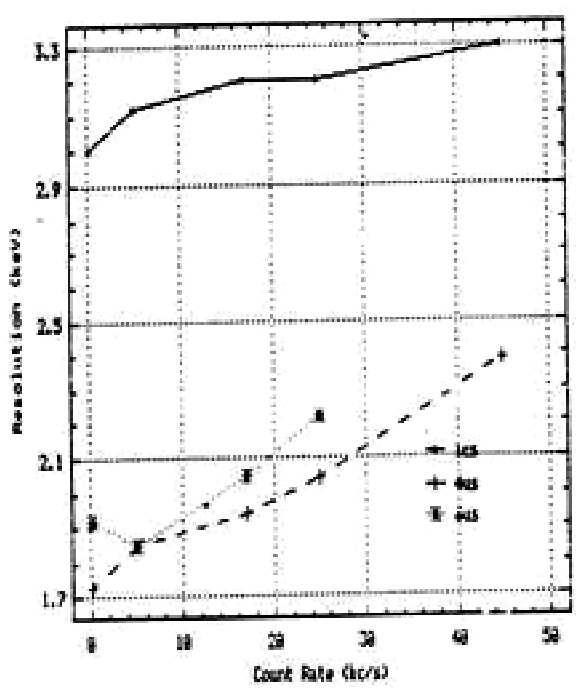

Figure 7-Resolution vs. Count Rate For Canberra 2025:Semi-Gauss.PUR-OFF,BLR-NORM.

- Ortec 673 (fig.8) :for a 3 µs shaping time, as count rate raises resolution degrades; i.e. resolution is higher than 2 keV above 20 kcps.

- Tennelec 244 (fig 9a to fig.9f): for any combination of the PUR and BLR settings, 1 µs count rate shows the worst resolution; with the PUR-off and BLR-auto (fig. 9a) and a shaping time of 6 µ s ,resolution

improves until a 25 kcps count rate is reached.Above this rate, best resolution values are shown at 3 µs.The best resolution results for any count rate are obtained by setting PUR-ON and BLR-auto (fig.9b) at a 3 µs shaping

time. Same behaviour is observed with PUR-ON and BLR-high (fig.9e)

Triangular shape type (fig 9c,fig.9d, fig.9f):

-Resolution degrades for any combination of PUR and BLR at 1 µs shaping time when count rate reaches 30 kcps.Above this value at a 6 µs shaping time,

resolution is even worst.In all cases, the best resolutions are obtained at 3 µs shaping time.

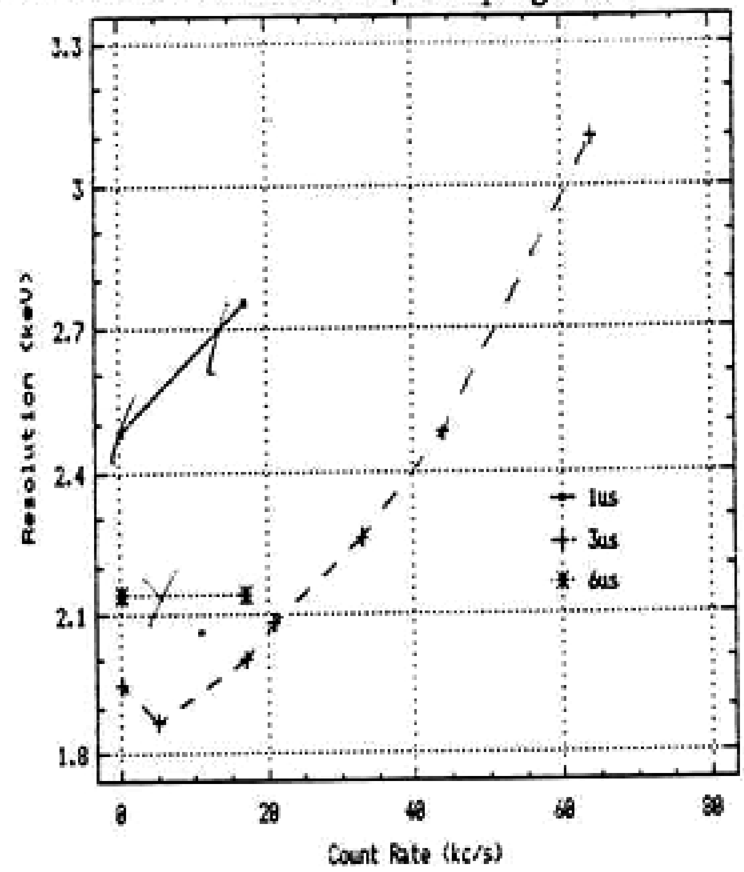

Figure 8- Resolution vs. Count Rate For Ortec 673-Semi Gauss.

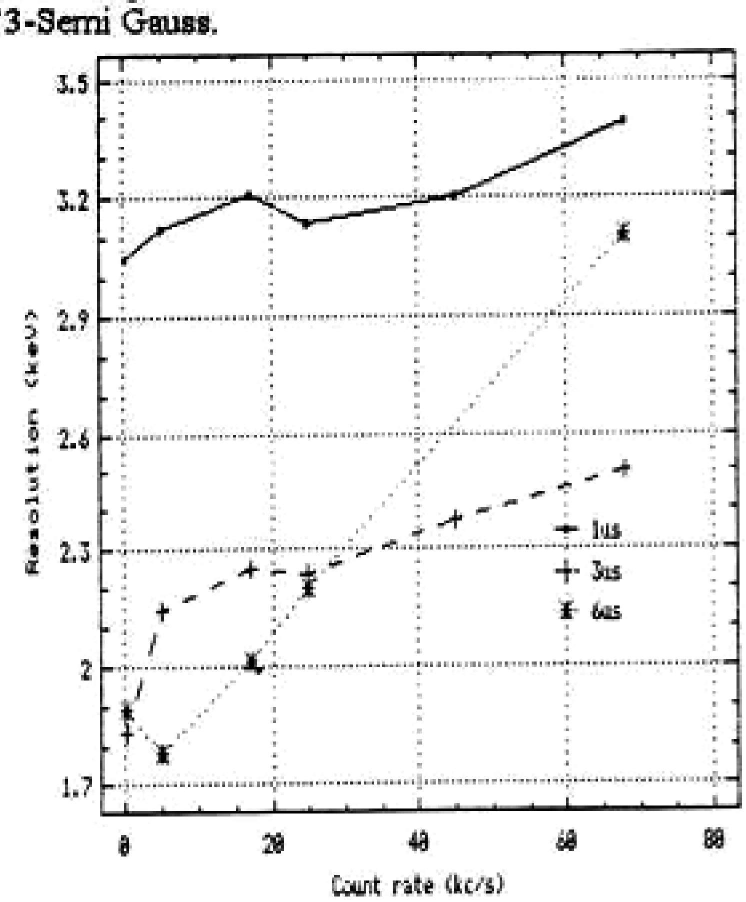

Figure 9a-Resolution vs. Count Rate For Tennelec 244:SemiGauss: PUR-OFF,BLR-AUTO.

5-Considerations On Other Aspects Affecting Resolution. Pole/zero cancelation (P/Z) has a fundamental role in getting an acceptable resolution. A fine adjustment is strongly recommended.As an optimous characteristic of all studied amplifiers, a good adjustment of P/Z was possible for different shaping times. The CANBERRA 2025 does it automatically-which is preferable from the comfort viewpoint, but manual adjustment proved to be equally good provided by a trained operator.The Base Line Restorer (BLR)in every amplifier is another important function.Authors point out a convenient operation of this item in order to get good resolutions.Behaviour of resolution at different count rates and shaping types using BLR (auto/high positions) was tested in the TENNELEC 244 amplifier.Results are given in fig. 10 .In the same manner, the bahaviour of CANBERRA 2025 at a 45 kcps count rate using the BLR in both position was studied. Results are presented in fig. 11.

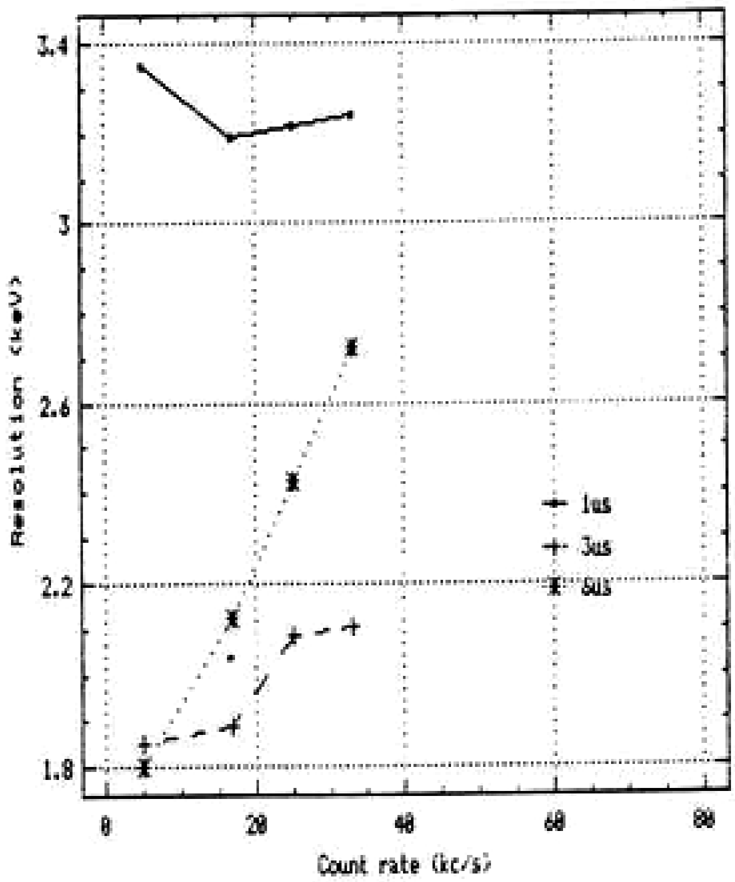

Figure 9b-Resolution vs. Count Rate For Tennelec 244:SemiGauss:PUR-ON,BLR-AUTO.

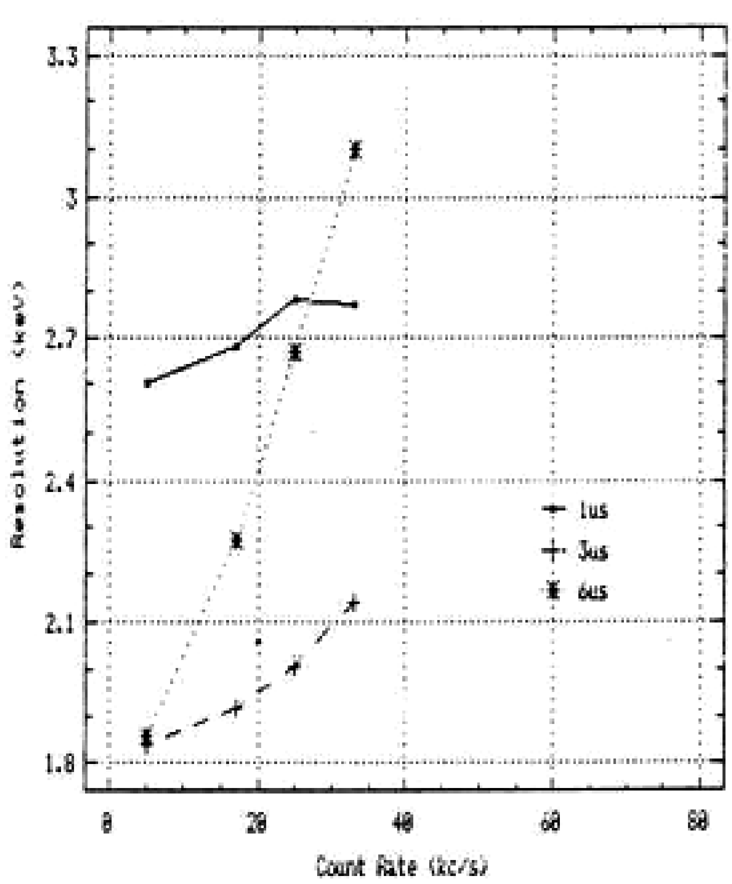

Figure 9c-Resolution vs Count Rate For Tennelec 244:Triangular : PUR-ON,BLR-AUTO.

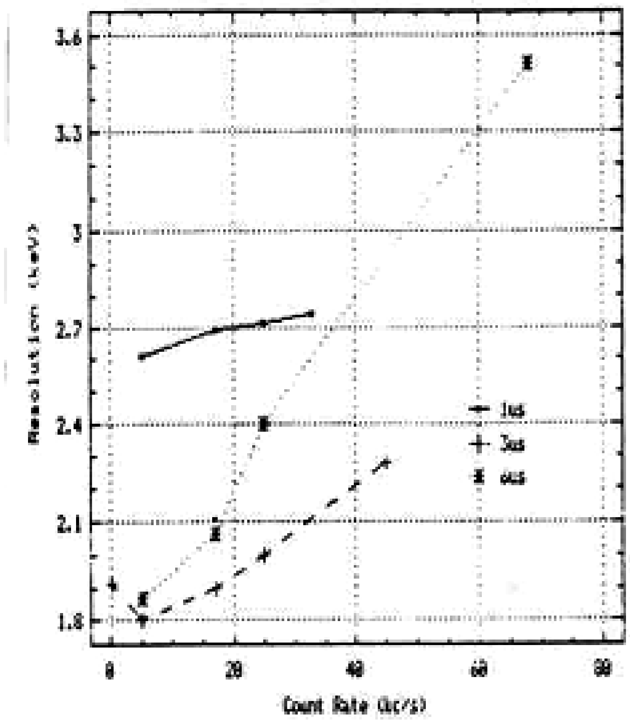

Figure 9d-Resolution vs. Count Rate For Tennelec 244:Triangular:PUR-OFF,BLR-AUTO

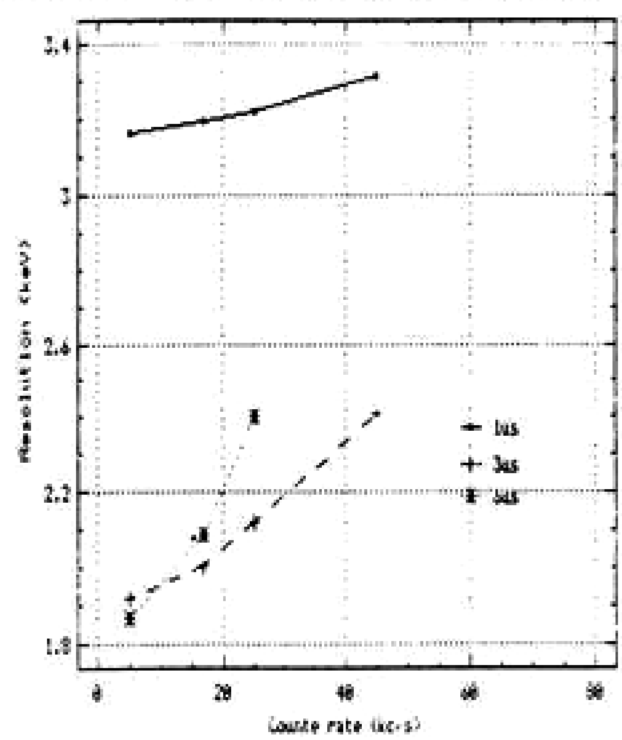

Figure 9e-Resolution vs. Count Rate For Tennelec 244:SemiGauss: PUR-ON,BLR-HI.

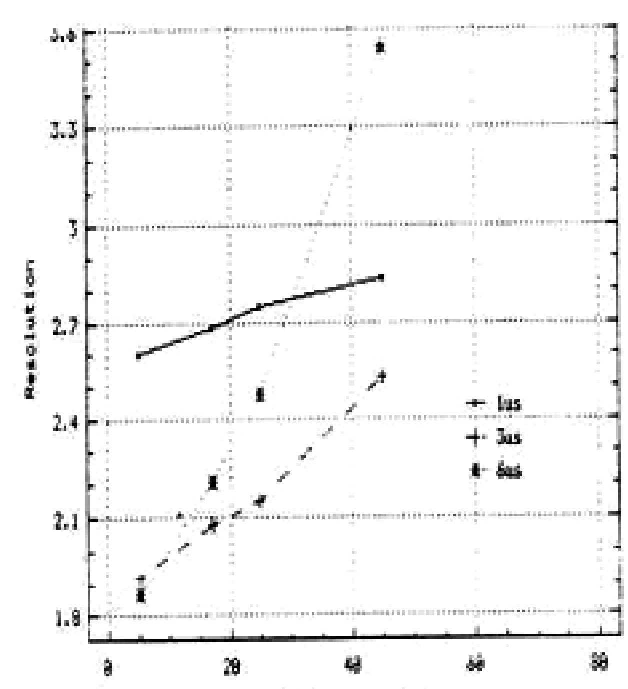

Figure 9f-Resolution vs. Count Rate For Tennelec 244:Triangular : PUR-ON, BLR-HI.

It can be concluded that :

- Best resolutions were obtained in all tested amplifiers with the BLR-AUTO,(fig.10 and fig. 11);
- Semigaussian shape type gives better results than triangular for count rates over 17 kcps;
- Triangular shape proved to be better for a 25 kcps count rate.

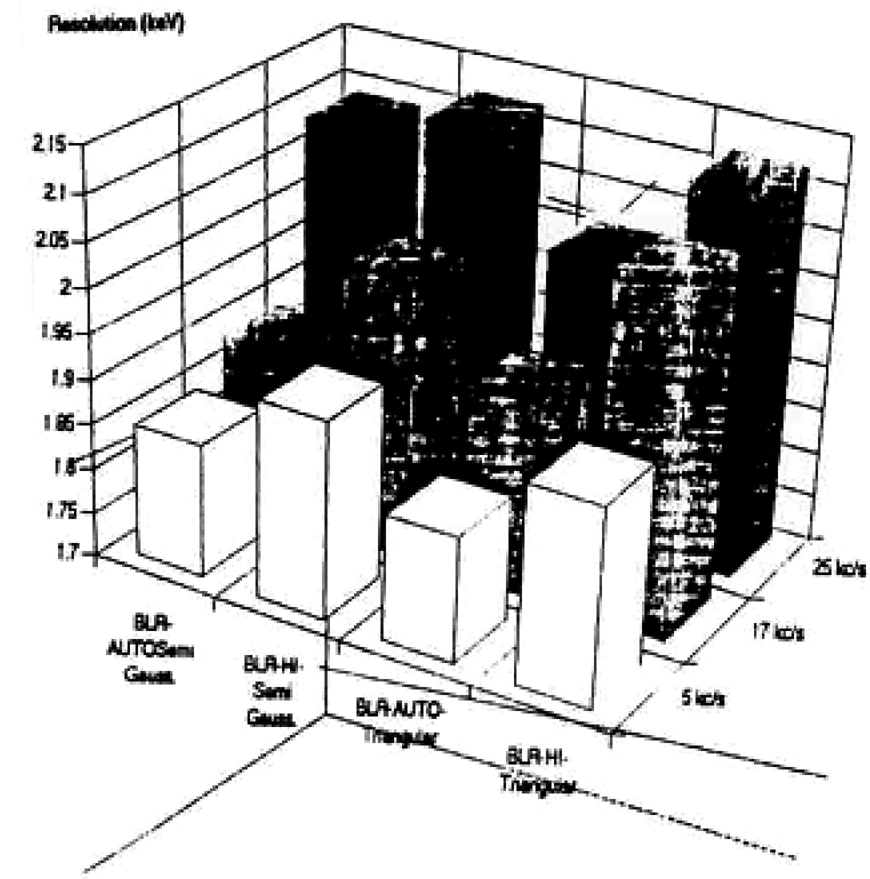

Figure 10-Resolution For Tennelec 244 at 3 µs.

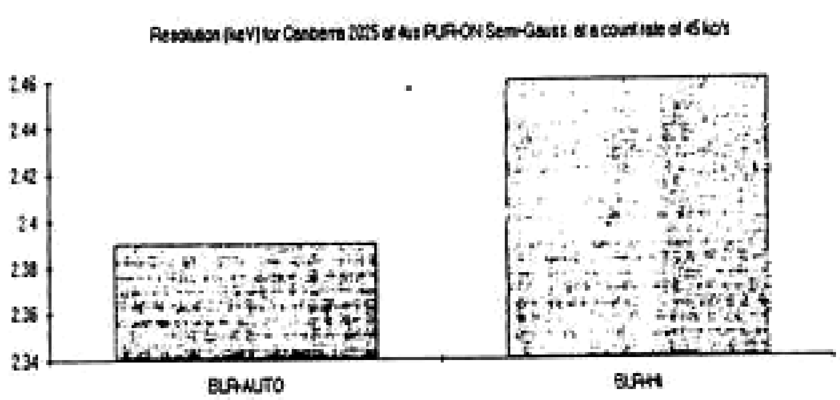

Figure 11-Resolution For Canberra 2025 at 4 µs PUR-ON,SemiGauss : Count Rate 45 kcps.

FINAL RECOMMENDATIONS

For the selection and optimization of gamma spectrometers system,the choose amplifier should be operated:

- (3 - 4) µs shaping time;
- semigaussian shape type;
- fine adjustment with the pole/zero cancelation function ;
- Base line Restorer in the "auto " position.

REFERENCES

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[3]-Moraes,M.A.P.V., **Cnen/Copesp relatory number R40000984003,** 1993.

[4]-Moraes,M.A.P.V.,Pugliesi,R. **,Seleccion y Optimizacion de amplificadores espectrometricos para espectrometria gamma:Part II: linealidad, tiempo vivo y softwares,**submitted to VI CGEN Conference(General Conference on Nuclear Energy) to be held in Rio de Janeiro, October 27-31, 1996.