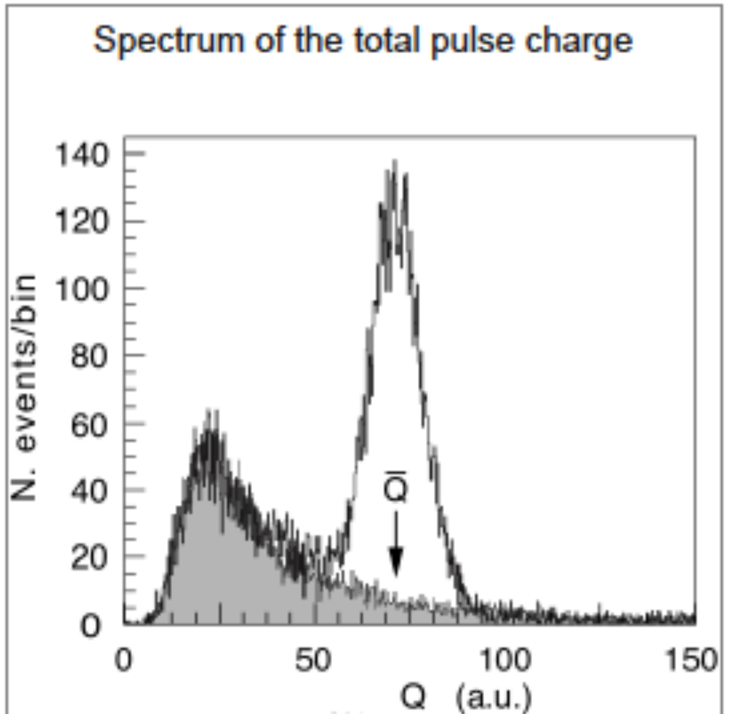
Dependence of the Energy Resolution of a Scintillating Crystal on the Read-Out Integration Time

Motivation of the study

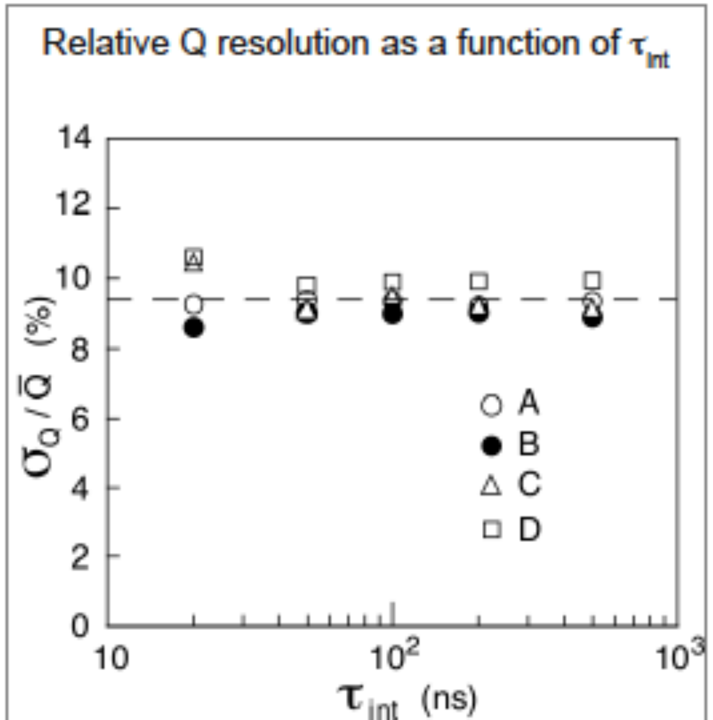
When using detectors made of crystals and photo-detectors in high rate applications it is not always possible to integrate the whole signal because it can be too long compared to the maximum permitted integration time to avoid the pile-up.

An experimental test with a BGO crystal, readout by a photomultiplier and a Monte Carlo simulation demonstrates that, when the number of photoelectrons is large, the energy resolution obtained by a peak-sensitive acquisition scales as $1/\sqrt{N_{int}}$ where N_{int} is the average number of emitted photoelectrons which contribute to the formation of the integrated signal up to its maximum.

We also show that when the integration constant and N_{int} are small, the energy resolution is even better than the one expected by the Poisson fluctuations.



The peak from 662 keV photons is superimposed to a background (grey area) which was measured without the [137]Cs source.



The dashed line represents the behavior expected from the MC for 130 photo-electrons.

We measured the Energy resolution obtained by integrating all the light provided by a BGO crystal to evaluate the number of photo-electrons and to validate a toy-MC developed to simulate the experimental set-up.

Signal amplitude

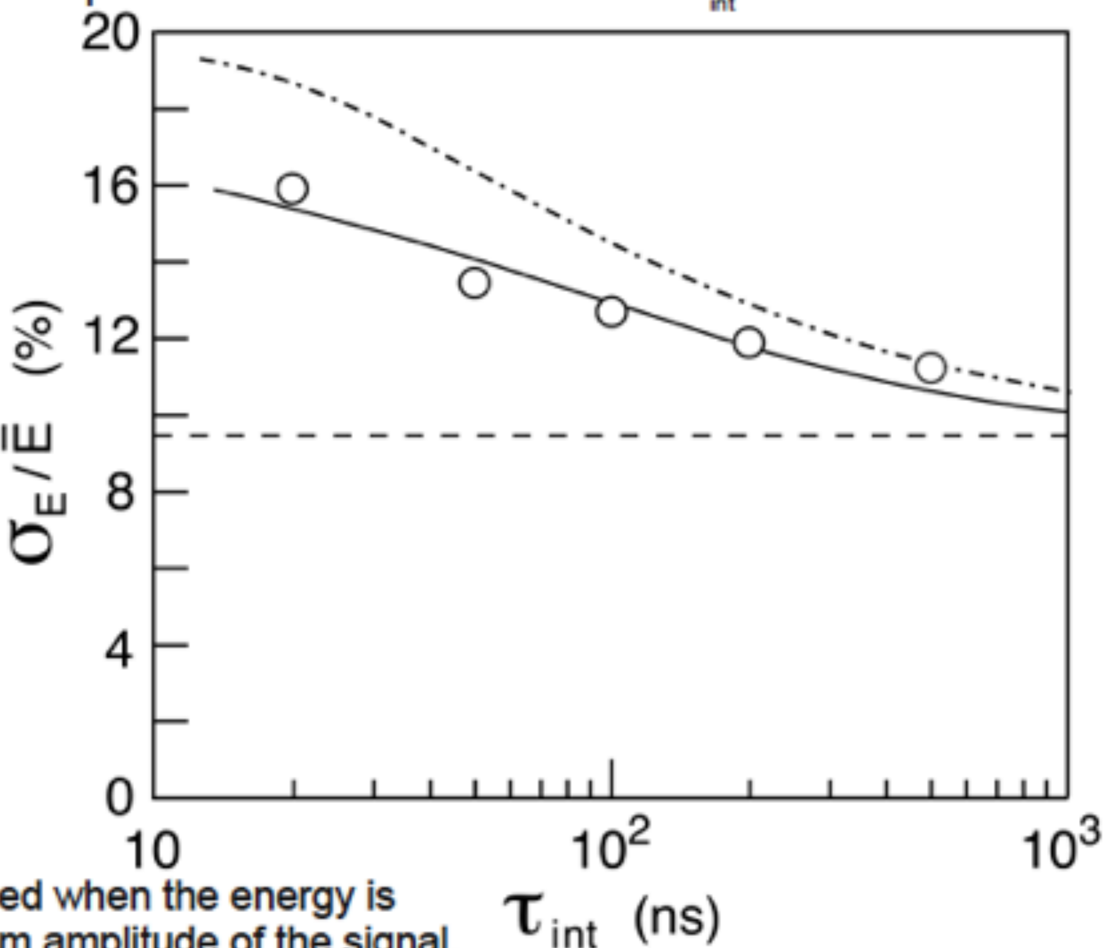
In high-rate experiment the measure of the total charge Q takes too long, so the energy deposited in the crystal is often inferred from the maximum amplitude A of the signal integrated with a time constant $\tau_{int} \leq \tau_{BGO}$.
This procedure, leads to a faster response at the cost of a worse resolution.
To determine how this effect depends on τ_{int}, the average values and the widths of the maximum amplitude distributions were evaluated by means of a gaussian fit.

Maximum amplitude resolution as a function of τ_{int}

The curve is the prediction of the MC calculation for 130 photo-electrons.

The dashed line is the asymptotic limit of the curve for $\tau_{int} >> \tau_{BGO}$.

The dashed-dotted line represents the behavior of the statistical fluctuations of the number of the photo-electrons integrated before the maximum amplitude.



A better resolution is obtained when the energy is evaluated from the maximum amplitude of the signal.

A fast measurement of the energy can be obtained, at the cost of a lower resolution, by integrating the output signal of the photomultiplier over a time shorter than the scintillator decay time and by acquiring the peak amplitude of the integrated signal.

Our studies show that the energy resolution obtained with this method is of the order of the statistical fluctuations of the number of photoelectrons integrated before the peak and even better when this number is relatively small as in the present case.