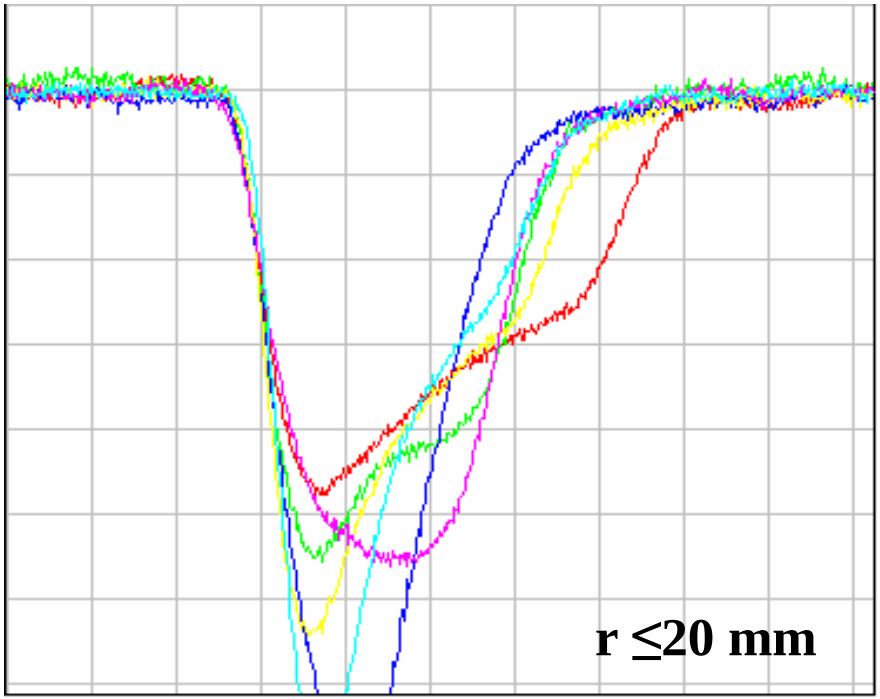
Shape Analysis: IGEX Experience.

Kirpichnikov I., Klimenko A., *Vasenko A.*

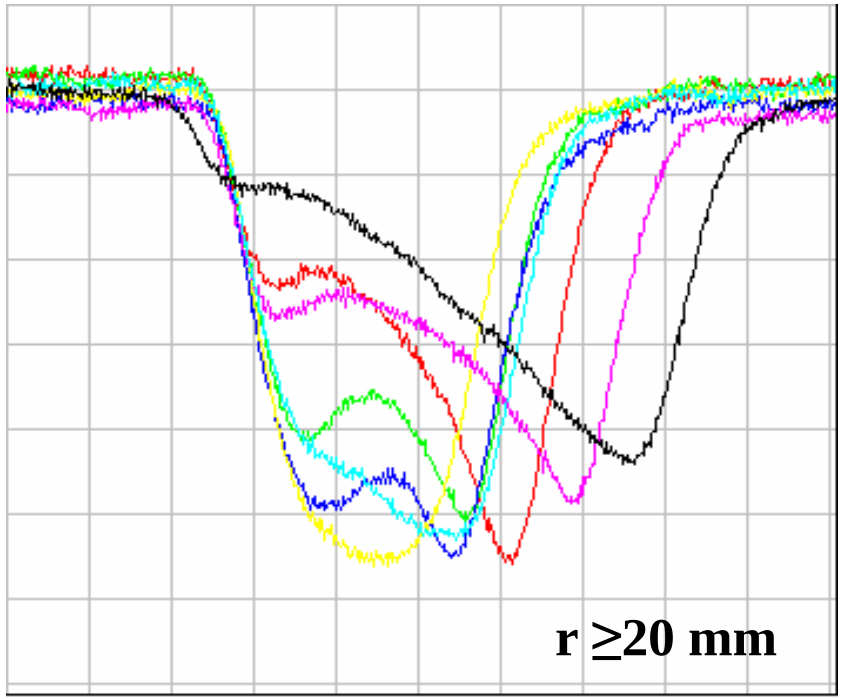
Shapes of signals of coaxial Ge-detectors depend on their origin. In case of a double beta-decay, a signal is produced by two electrons emitted from the same point, with energy deposition within a sphere Ø1-2 mm. It can be treated as almost a single-site event (SSE). On the contrary a gamma-quantum can produce electrons in different points. If these interactions took place at different radiuses of the Ge-crystal, the shape of the resulting signal could be identified as a background MSE event. By this reason, an analysis of shapes of signals (PSA) was used by both the collaborations , IGEX and Heidelberg –Moscow , in their searches for the neutrinoless double beta-decay of Ge-76. The similar PSA method was supposed to use in phase I of GERDA . Let us discuss the IGEX experience more carefully to estimate a possible efficiency of the PSA and its dependence on parameters of the front electronics.

Experiment:
Typical shapes of SSE signals.

Central events.



Peripheral events.



100 nsec per division

All pulses are in a range 2000 - 2100 KeV.

IGEX results with shape analysis

Gonzales et al., Pulse Shape Discrimination in the IGEX Experiment, NIM A515:634-643, 2003.

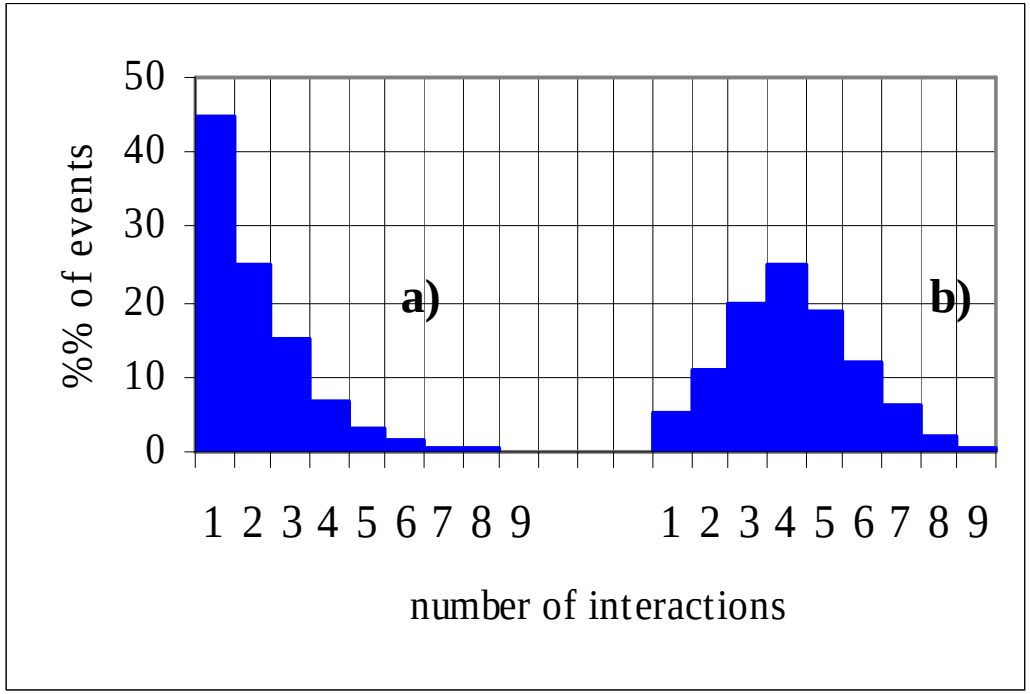
	exposure kg y	b before c/(keV kg y)	b after c/(keV kg y)	rejection factor (%)
RG2	2.75	0.27	0.10	62.19
RG3	1.90	0.26	0.11	57.61
total	4.65	0.26	0.10	60.36

The results (a rejection factor) seemed to be close to the maximum possible value of the gamma-background rejection, because :

There was a principal limit for an efficiency of a shape analysis due to a large amount of single site events amongst gamma-interaction.

Number of 2.6 MeV gamma-quanta (a distributed source) interaction in a 3 kg Ge crystal:

a) energy deposition 2.0 – 2.1 MeV; b) full capture

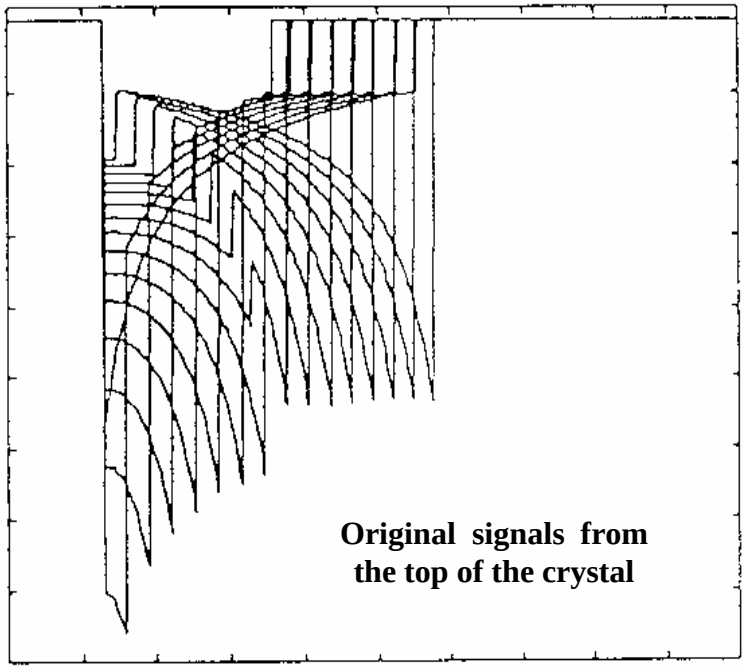


The source was distributed through Si sphere with outside diameter Ø130 cm and a hole in the center Ø30 cm.
The detector was placed in the center of the hole.

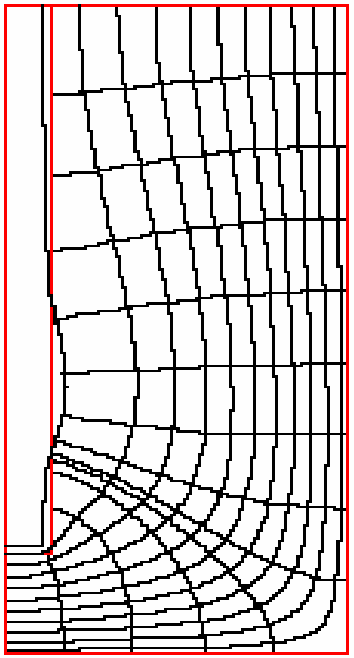
So, in case a), suppression of gamma-background could not be more then ~2!

Calculated original shapes of SSE current pulses.

Craig Edward Aalseth (South Carolina U.), Ph.D. Thesis . UMI-30-06000, 2000.



100 ns per division



a calculated field of RG3

Two approximations were made

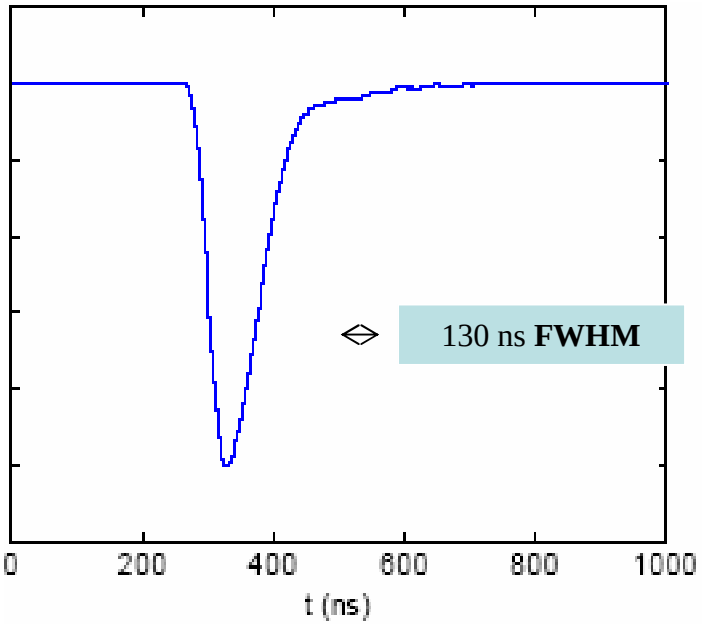
1) an ideal transfer function of the preamp : 0 nsec FWHM

2) a strictly point interactions ; in reality – a sphere Ø(2-3) mm ($\Delta t \leq 40$ nsec)

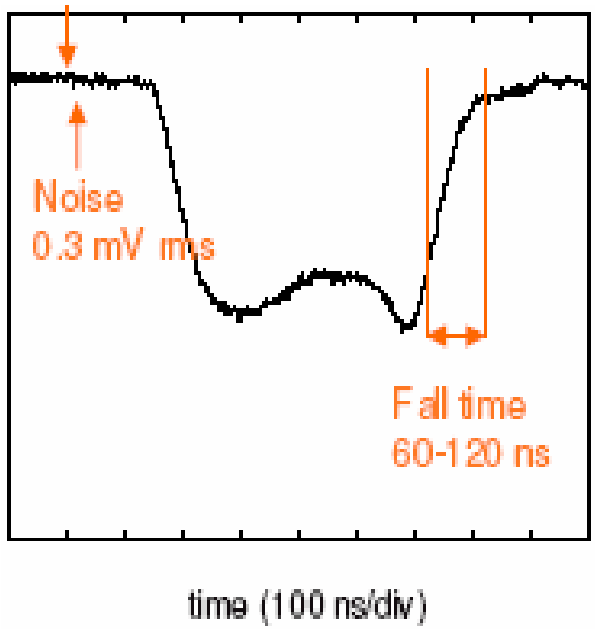
Pulse Shape Discrimination in the IGEX Experiment.

Gonzales et all, NIM A515:634-643, 2003.

The transfer function of the RG3 IGEX preamp



A real pulse (MSE)

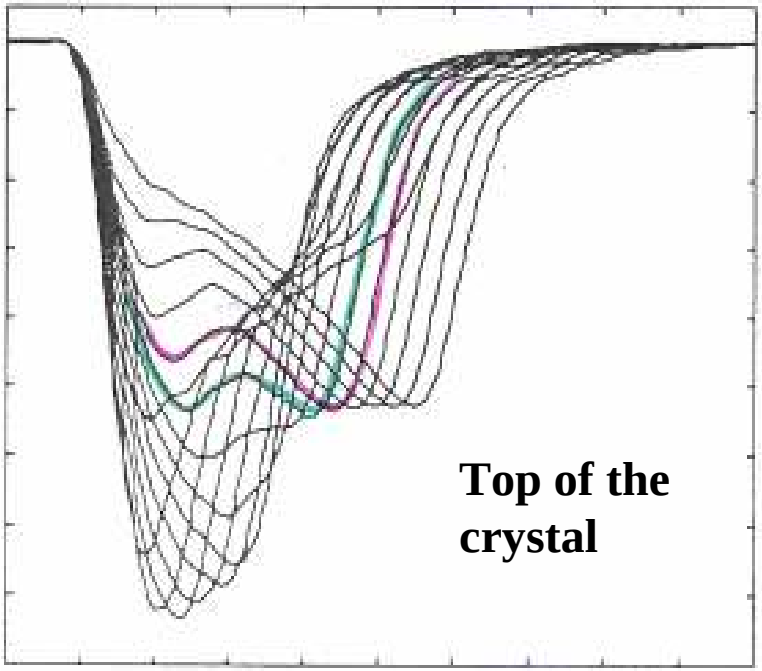


Time scattering due to the distributed energy deposition 20-30 nsec

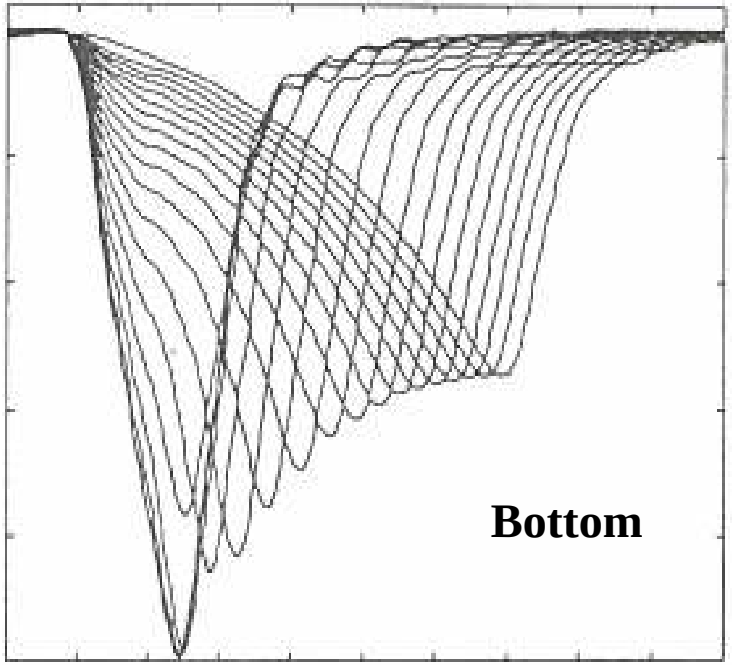
Germanium spectrometer pulse shape discrimination for Ge – 76 double beta decay.

Craig Edward Aalseth (South Carolina U.), Ph.D. Thesis . UMI-30-06000, 2000.

Calculated expected experimental shapes of SSE
2 mm radial steps

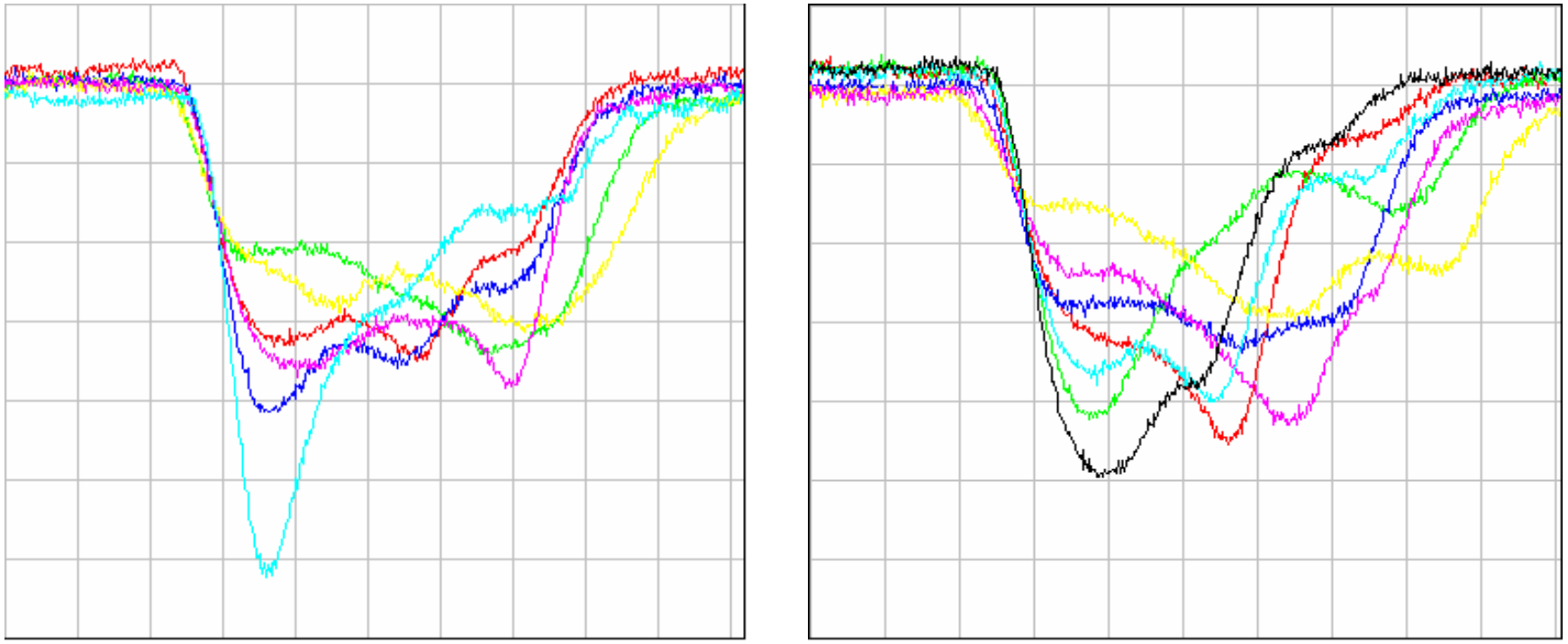


100 ns per division



100 ns per division

Experiment:
Typical shapes of the evident MSE signals.

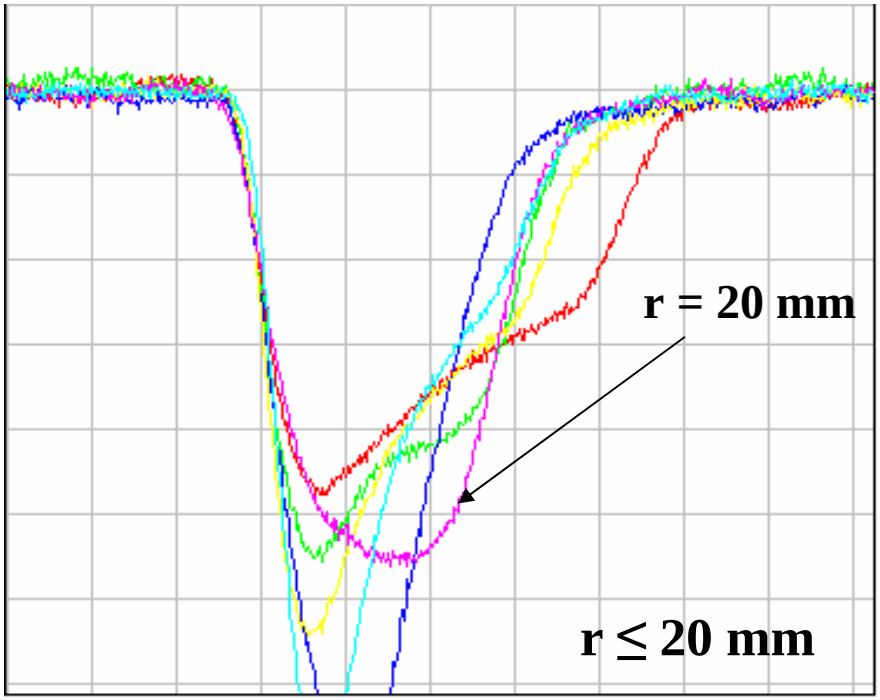


100 nsec per division

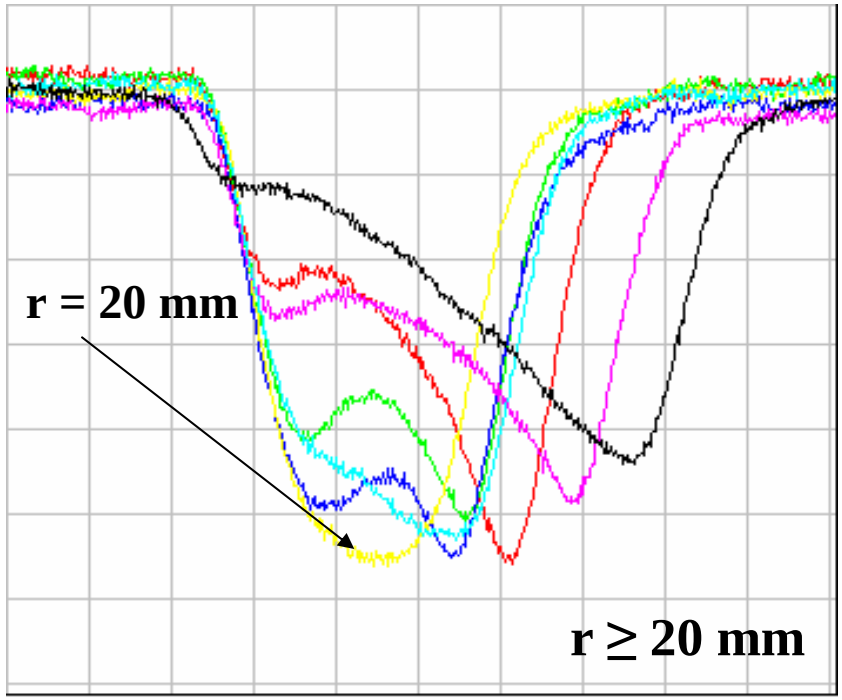
The evident MSE signals: three maxima, two maxima and a shoulder, etc.

Experiment:
Typical shapes of SSE signals.

Central events.



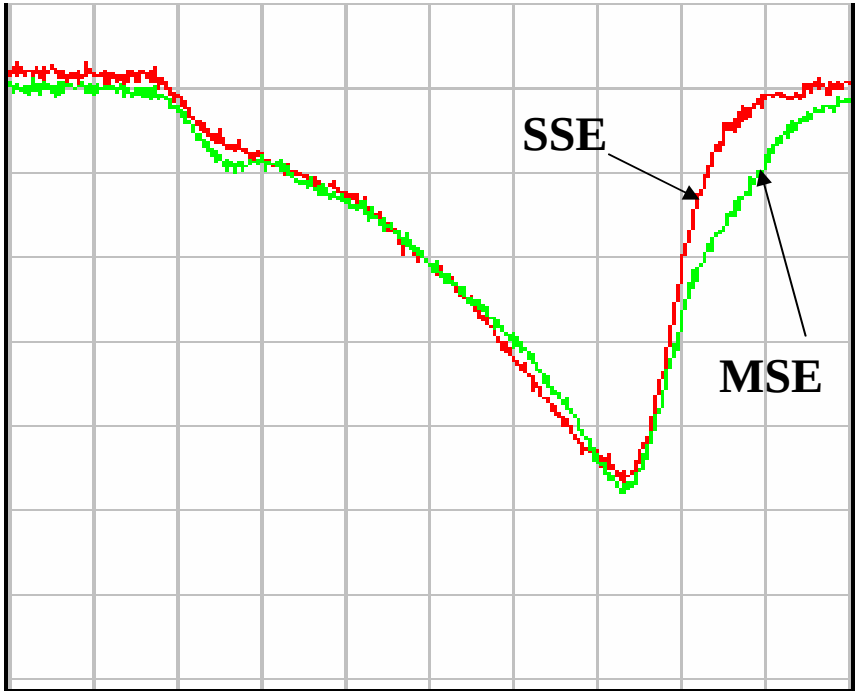
Peripheral events.

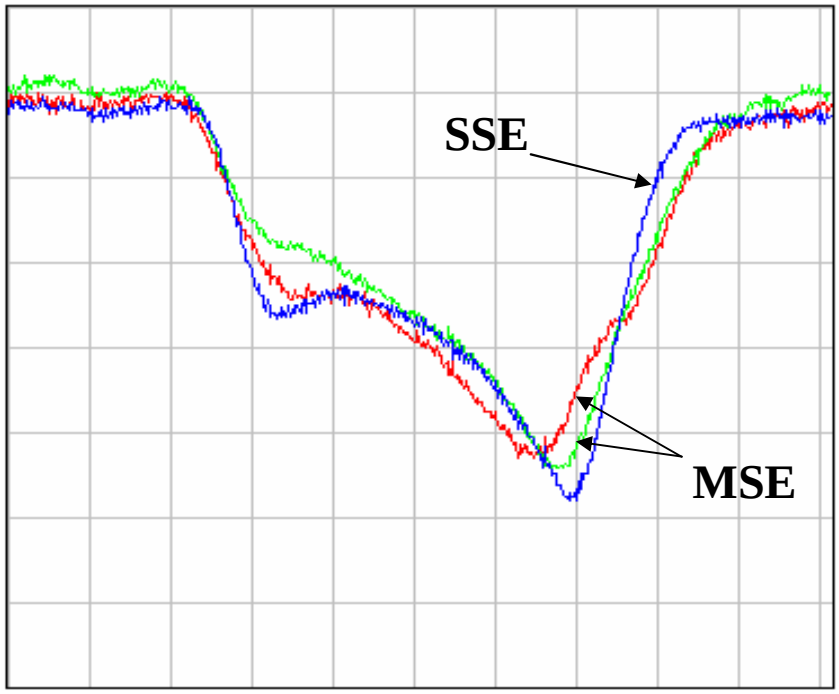


100 nsec per division

All pulses are in a range 2000 - 2100 KeV.

Experiment:
Examples of signals with wrong fall times
(BBF MSE signals – bad back front signals)

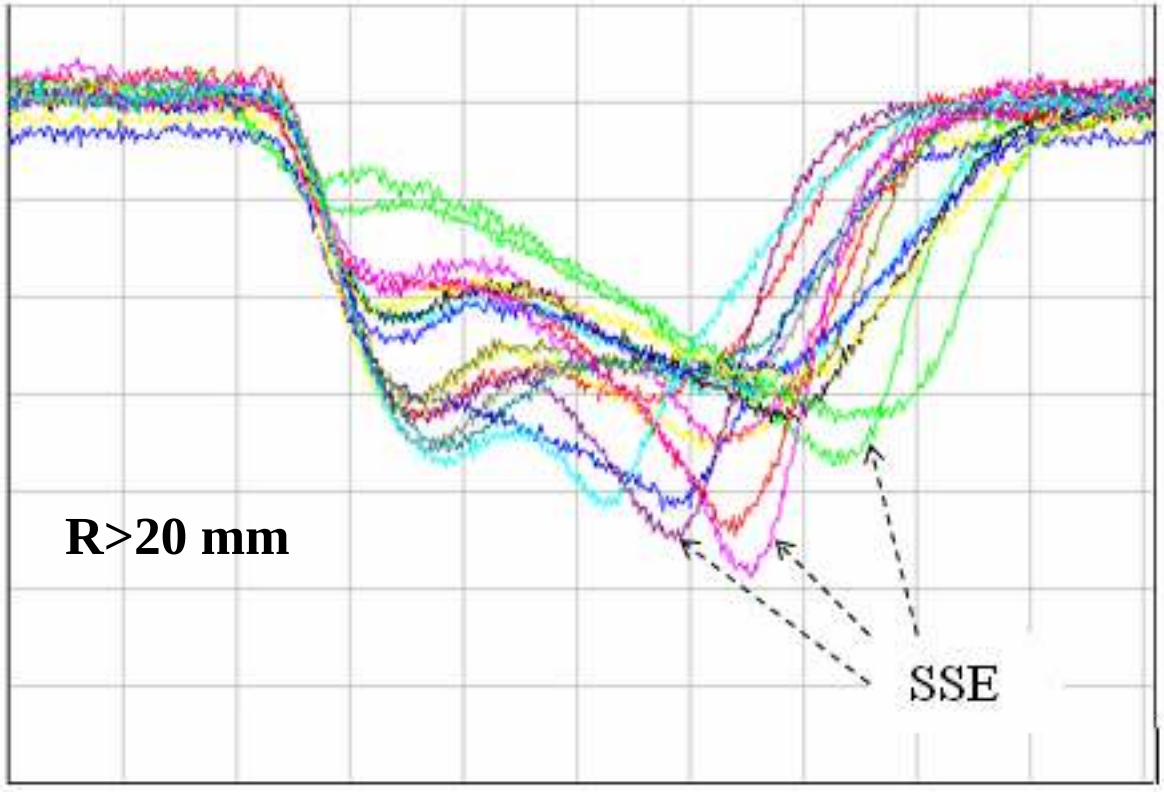




100 nsec per division

BBF signals had the back fronts with a fall time longer then 100 nsec.

Experiment:
Separation of the BBF signals, E = (1758-1769) KeV.



100 ns per division

Statistics: RG3 background, 280 days.

Energies, KeV	N(tot)	Evident MSE/N(tot)	BBF/ N(tot)	Rejection, %
1800-2195	170	55 (32%)	30 (18%)	50%
1461+1764	96	19 (20%)	30 (31%)	51%

The evident MSE signals: three maxima, two maxima and a shoulder, etc.
BBF signals had the back fronts with a fall time longer then 100 nsec.

IGEX results with shape analysis

IGEX	Exposure Kg y	B before c/(kev kg y)	B after c/(kev kg y)	Rejection (%)
RG3	1.90	0.26	0.11	57.6

The rejection factor was close to the maximum possible value.

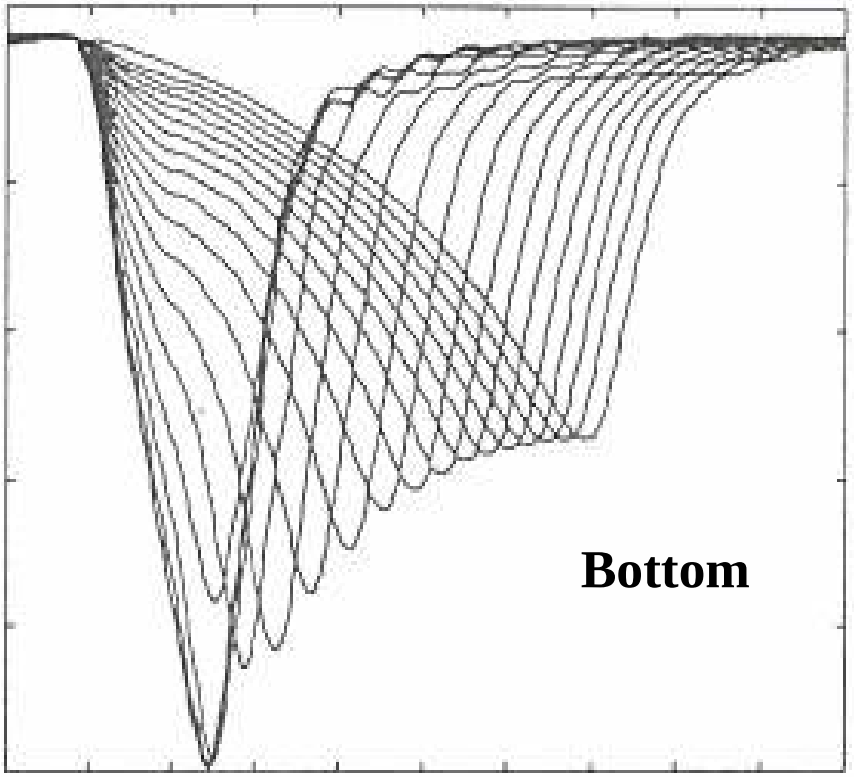
CONCLUSIONS:

1. A rejection factor of gamma-background about 60% is possible. A transfer function of the preamp should be triangle with FWHM less then ~ 100-150 nsec. It is necessary for rejection of pulses with bad back fronts.

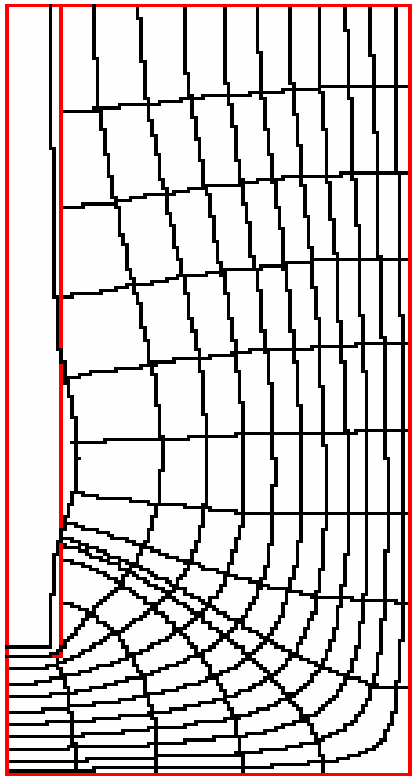
2. Ratios N(BBF)/N(tot) for peaks are approximately 1.6 times more than for the flat component of the background. It can be connected with much higher number of a gamma-quantum interactions in case of the full (a peak) capture.

3. The detector should be close to a true coaxial (at least one end opened).

Craig Edward Aalseth (South Carolina U.), Ph.D. Thesis . UMI-30-06000, 2000.



100 ns per division



a calculated field of RG3