EGS simulation of an ideal two-shell detector array with 100% solid angle

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The PARIS detector is being conceived as a two shell detector array with the inner detector being LaBr3 and the outer one as BGO, BaF_2 or CsI. One idea is to have the front and back detectors for each module joined along the length and viewed by a single PMT. Assuming that from the pulse shape analysis, event by event, it is possible to find the energy deposited in the two parts separately, one can apply various algorithms of add-back to get the full energy deposited per event. There is no problem for the mono-energetic photons incident in each event on the detector. In the actual case, say in a heavy ion fusion reaction, a high energy (GDR) photon will be accompanied by a number of low energy multiplicity gamma rays. In such circumstances, it becomes difficult to get a good line shape because of the coincident low energy gamma rays entering the same segment of the detector array. In the present work, I address these issues for an ideal two-shell detector array.

The array consists of an inner and the outer shell, (the present case is for no gap between the shells) covering full 4-pi and divided into a number of elements of almost equal solid angle per element. In the present treatment of a "telescopic" configuration of the inner and outer parts of each module, the number of detectors is the same in the inner and the outer shell. The inner radius of the inner shell is chosen as 15 cm, the outer radius of the inner shell (the same as the inner radius of the outer shell) as 20 cm and the outer radius of the outer shell is chosen as 35 cm. The inner shell detectors are LaBr3 and the outer shell detectors are CsI. Thus, the Labr3 are 5 cm thick and the CsI are 15 cm thick.

The source of the gamma rays is at the centre of both the shells. In each event, a high energy gamma ray (energy Egh) is incident on the shell assuming isotropic spatial distribution. At the same time, the multiplicity of the accompanying gamma rays is chosen, following a random number generation, from a triangular multiplicity distribution with maximum multiplicity Mmax. The energy of the multiplicity gamma rays are assumed to increase linearly from 0 to Emax for M changing from 0 to Mmax. (Example: Say Mmax=30 and Emax=3.0. If the randomly chosen multiplicity is 20, the energies of the 20 photons will be 0 to 2.0 MeV, equally spaced. If M=10, the energies will be 0 to 1.0 MeV and so on..). These gammas are also assumed to have an isotropic angular distribution. The energy resolutions of the LaBr3 and CsI are taken as 3.5% and 13.0%, respectively, at 0.662 MeV. While adding the energies to get the full energy for each event the following procedure is adopted.

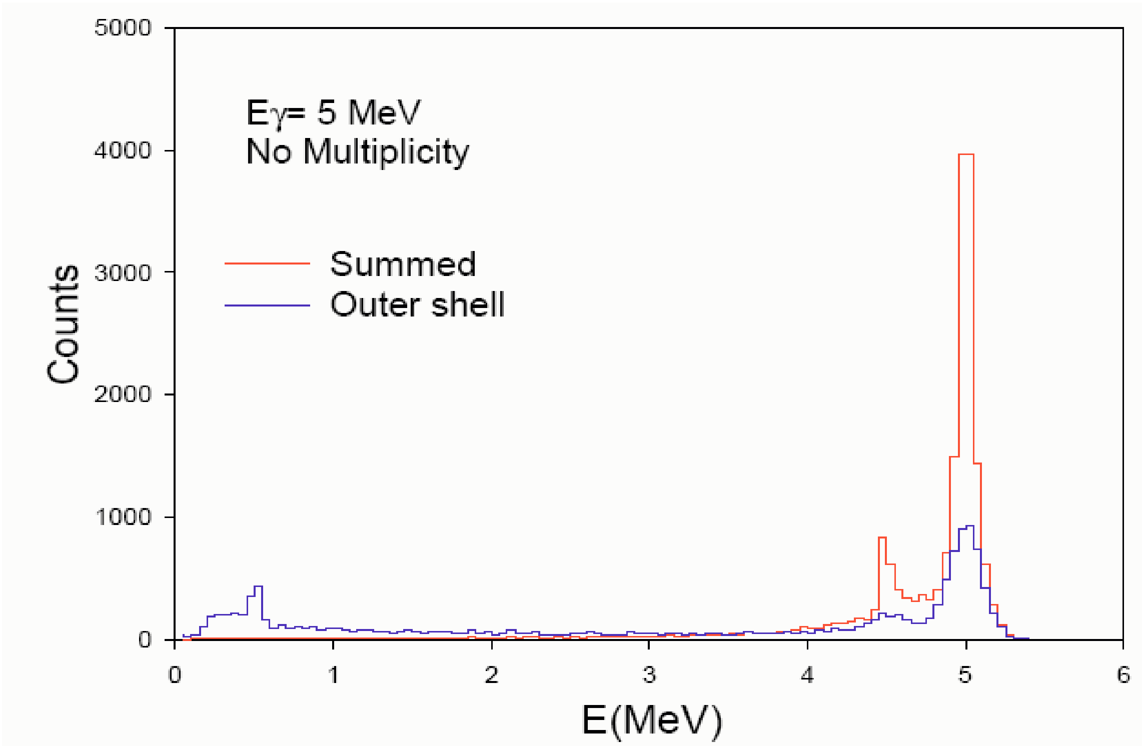
The highest energy deposited in different modules of the inner and the outer shell is first obtained. If the highest energy deposited is in the inner shell, the energies deposited in its nearest neighbours are added to get Einner. The energies of the corresponding detectors in the outer shell are added to get Eouter. If the highest energy deposited is in the outer shell, the energies deposited in its nearest neighbours are added to get Eouter. The energies of the corresponding detectors in the inner shell are added to get Einner. These are finally added to get Esum. Before adding, of course, the energy deposited is spread out following the resolution functions. In the following, I present the results with number of detectors = 240 in each shell, for various cases of Egh= 5, 15, 25 MeV accompanied by a multiplicity distribution with Mmax = 30 and Emax = 2 MeV. The results for no accompanied multiplicity are also shown. The program is run for 20,000 events in each case.

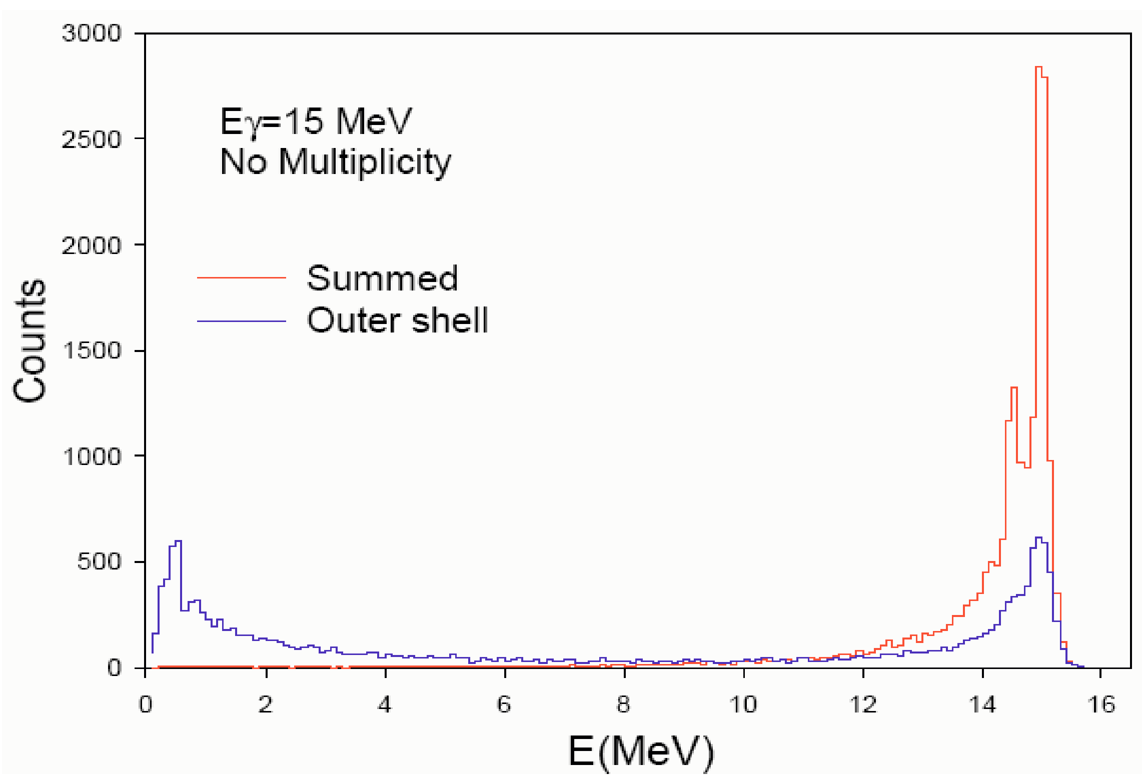
Fig. 1 shows the simulated line shape for Mmax = 0 (no accompanied multiplicity). The comparison between the spectra in the outer shell with the summed spectra shows that, as expected, we gain in efficiency by summing. (See Table I)

Table I: *Peak and tail efficiencies, with and without associated multiplicity, from the summed spectra (S) and that for the outer shell (O)*

Eg (MeV)	Peak Efficiency (%)	Tail Efficiency (%)	Associated Multiplicity (Y/N)
5	88 (S)	-	N
	34 (O)	-	N
	54 (S)	35	Y
	31 (O)	6	Y
15	74 (S)	-	N
	24 (O)	-	N
	56 (S)	24	Y
	21 (O)	3.5	Y
25	57 (S)	-	N
	14 (O)	-	N
	45 (S)	18	Y
	13 (O)	2.5	Y

However, when there is an accompanied multiplicity distribution, we get a tail above the full energy because of the summing of the multiplicity gamma energies. This is shown in Fig. 2 for the summed spectra with and without accompanied multiplicity and the efficiencies for the tail part are shown in the Table I. The tail contribution is relatively more important for lower energy gamma rays, as expected. The tail contribution in the outer shell spectra are shown in Fig.3


Eγ= 5 MeV
No Multiplicity
Summed
Outer shell
Counts
E(MeV)
0
1000
2000
3000
4000
5000
0
1
2
3
4
5
6


Eγ=15 MeV
No Multiplicity
Summed
Outer shell
Counts
E(MeV)
0
500
1000
1500
2000
2500
3000
0
2
4
6
8
10
12
14
16

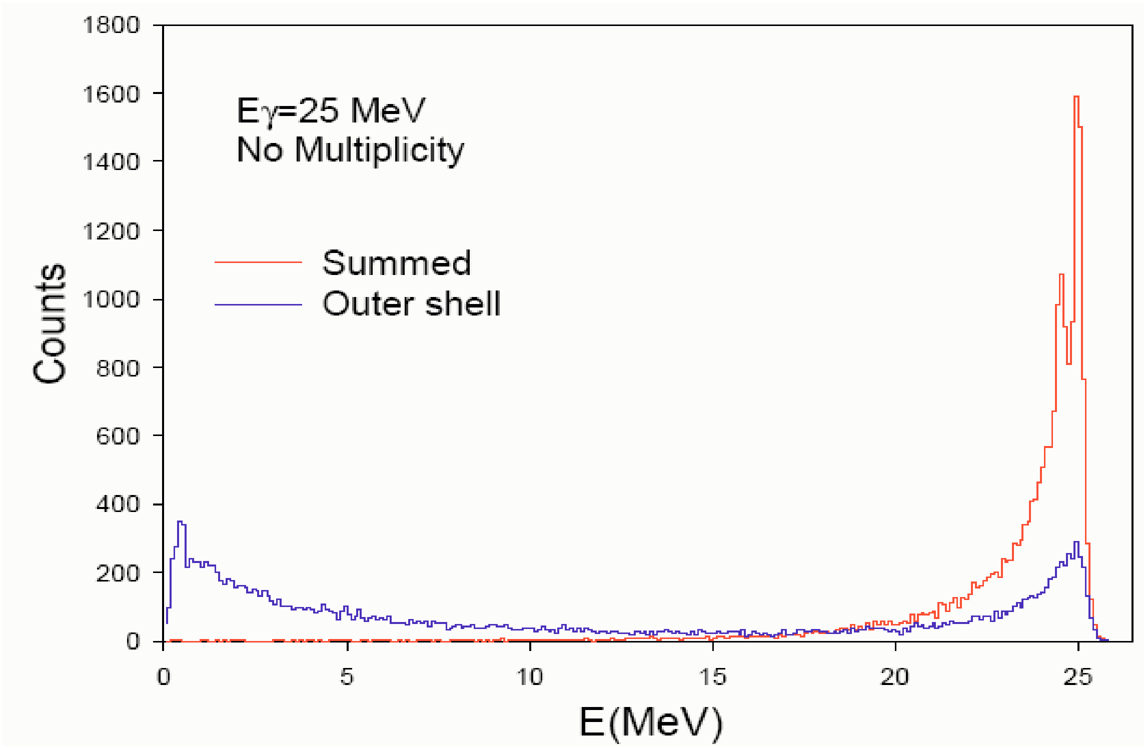
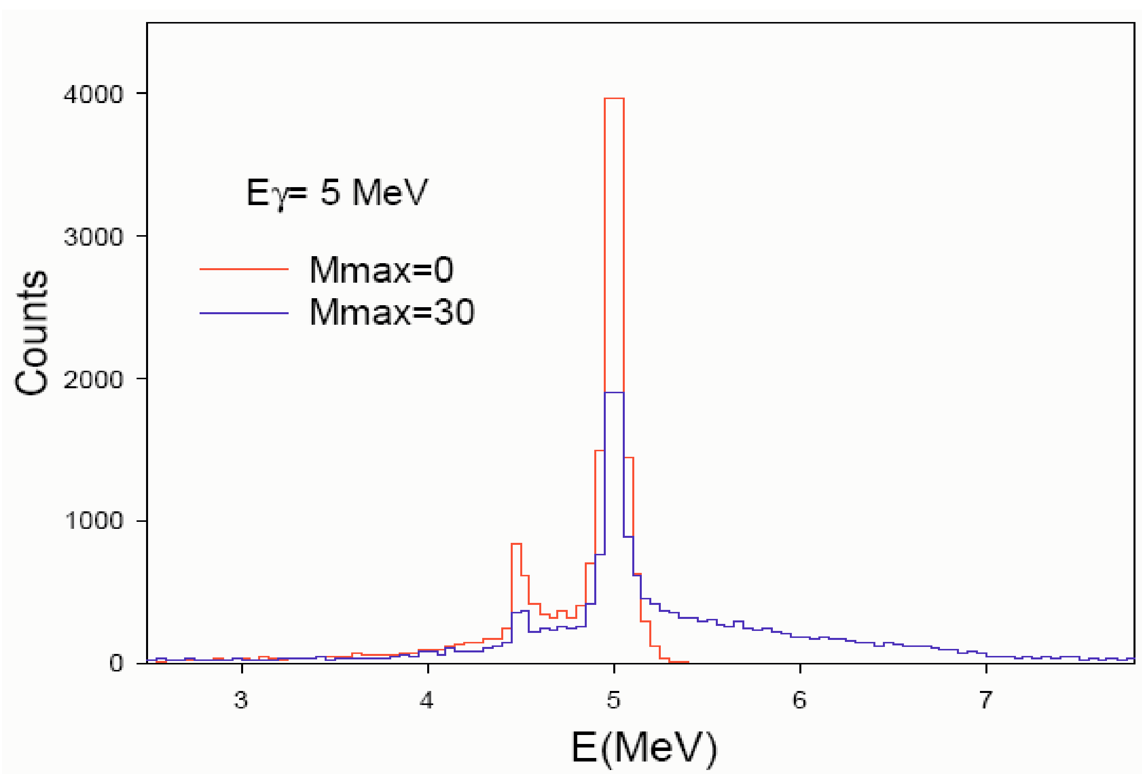


Fig.1: Line shape for gamma rays with no associated multiplicity.



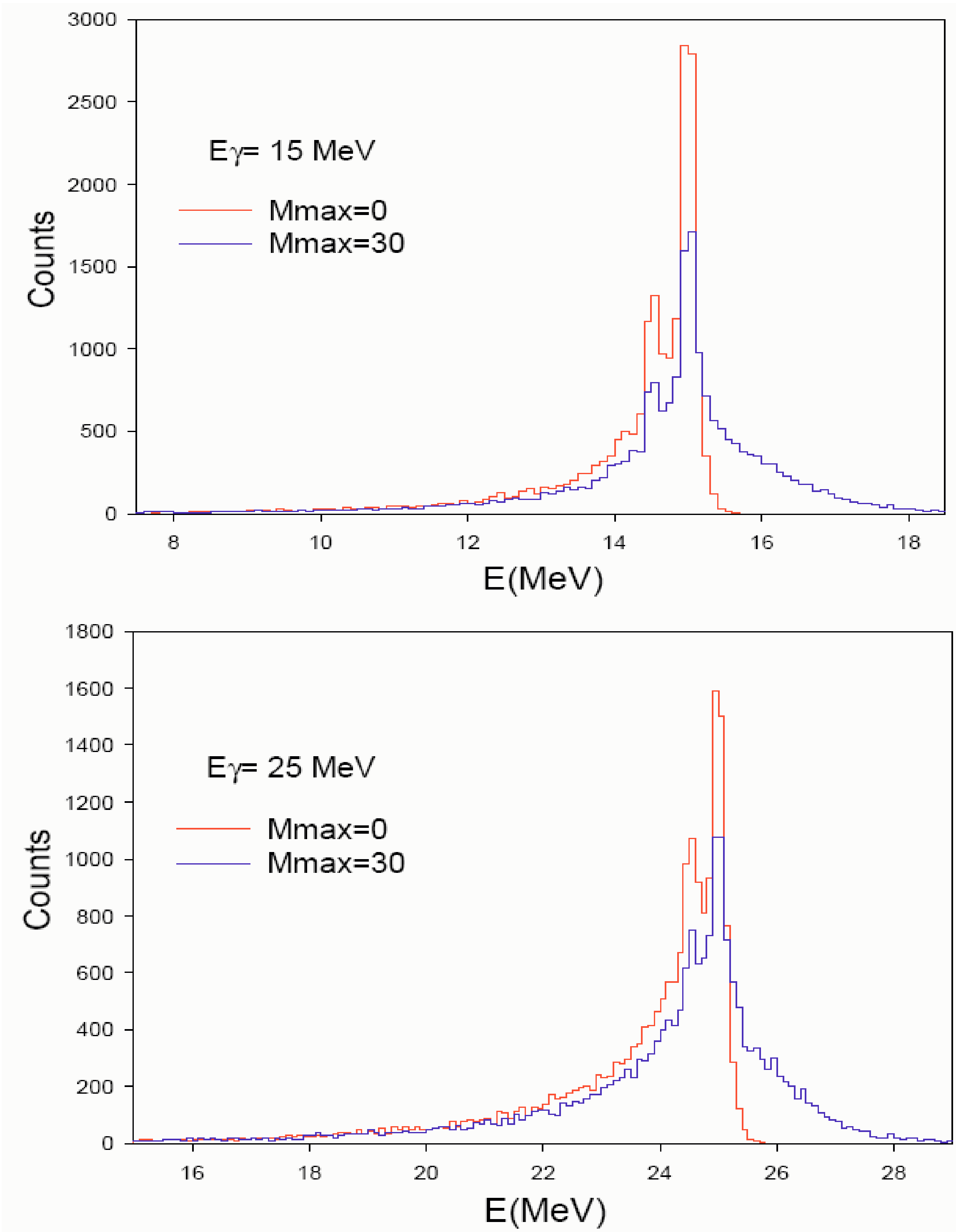
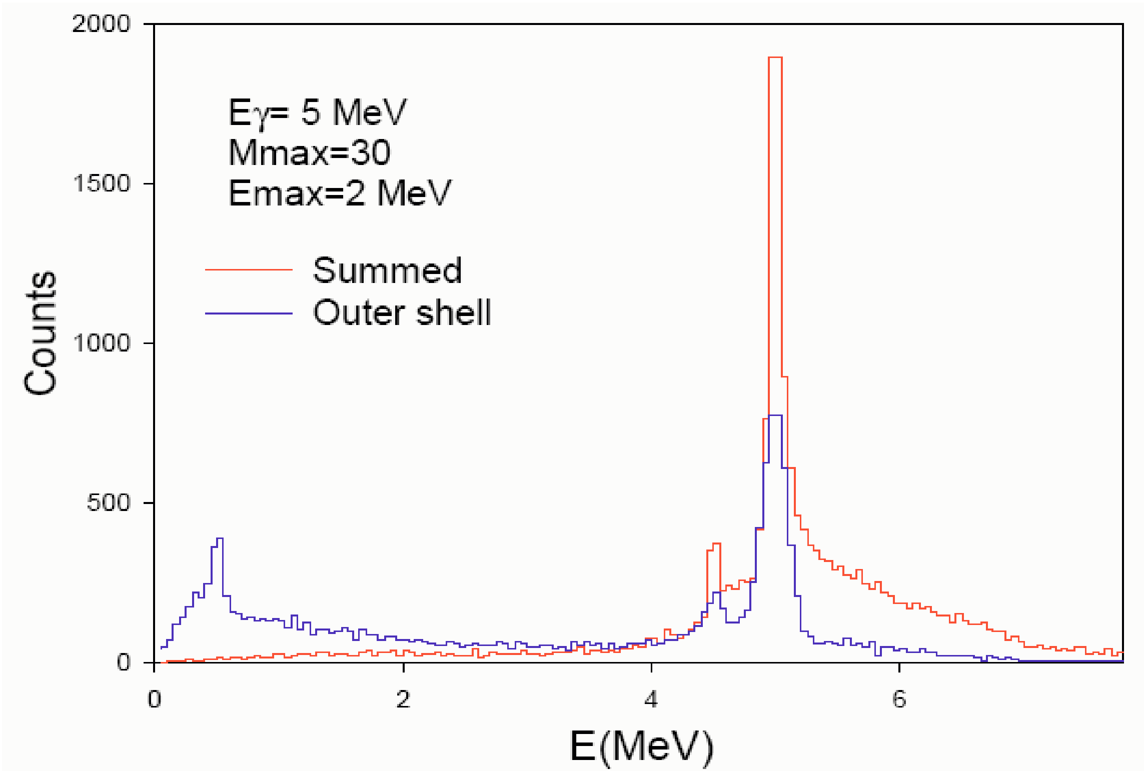
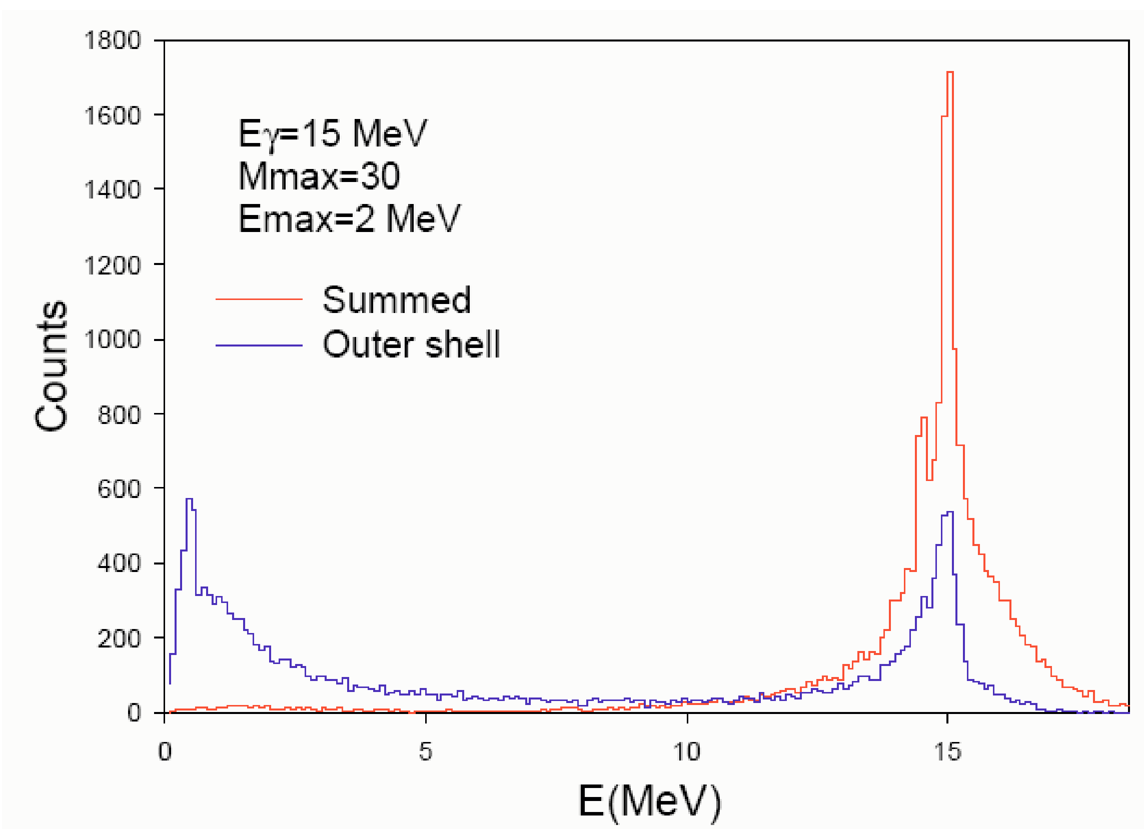


Fig.2: Line shape for gamma rays (derived from the summed spectra) with and without associated multiplicity distribution.



Eγ= 5 MeV
Mmax=30
Emax=2 MeV
Summed
Outer shell
Counts
E(MeV)



Eγ=15 MeV
Mmax=30
Emax=2 MeV
Summed
Outer shell
Counts
E(MeV)

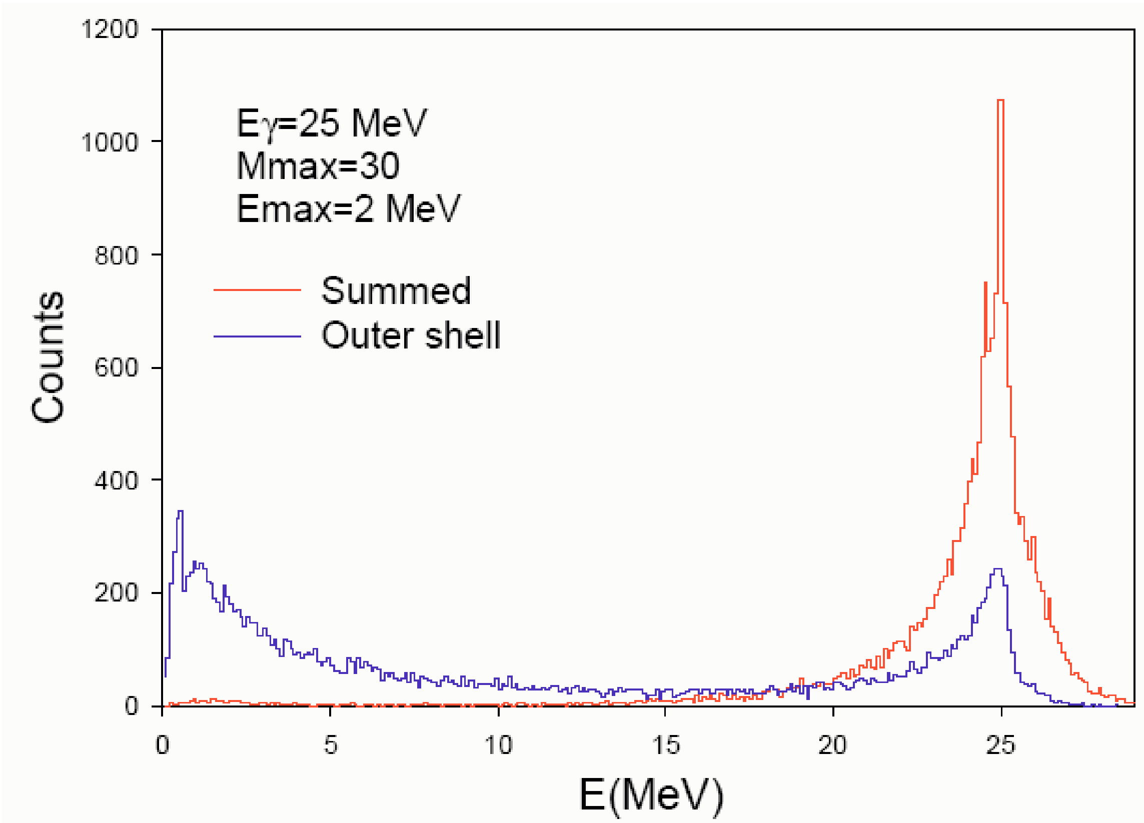


Fig.3: Line shape for gamma rays with associated multiplicity distribution.

This shows that the multiplicity gammas are not fully stopped in the inner shell. The extent of the tail will obviously depend on the value of Mmax and Emax.

The tails in the line shape, in principle, can be included in the data analysis. However, the situation is a little difficult and one should be very careful, because the line shape depends on the multiplicity distribution.