

# Measuring **entry distributions** with and **unfolding** spectra from **tracking detector arrays**

- 1: Introduction: Measuring entry distributions using Gammasphere
- -"- for tracking arrays
- The entry dist for  $^{158}\text{Er}$
- 2: Unfolding spectra from tracking arrays



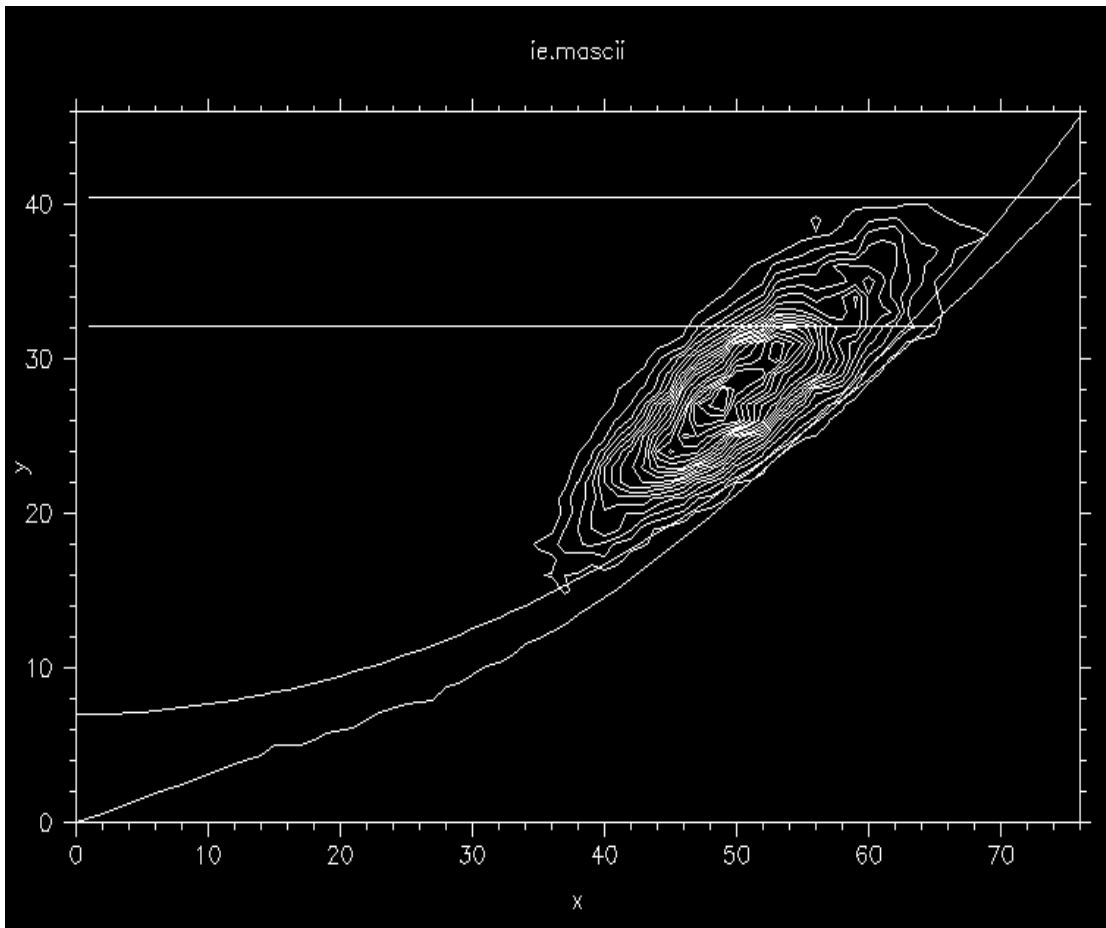
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# What is the entry distribution?

- The location in the spin and energy plane from which gamma de--excitation starts, after the last particle has been evaporated

H: total (summed) energy



$^{152}\text{Dy}$  entry  
distribution (from  
GAMMASPHERE)

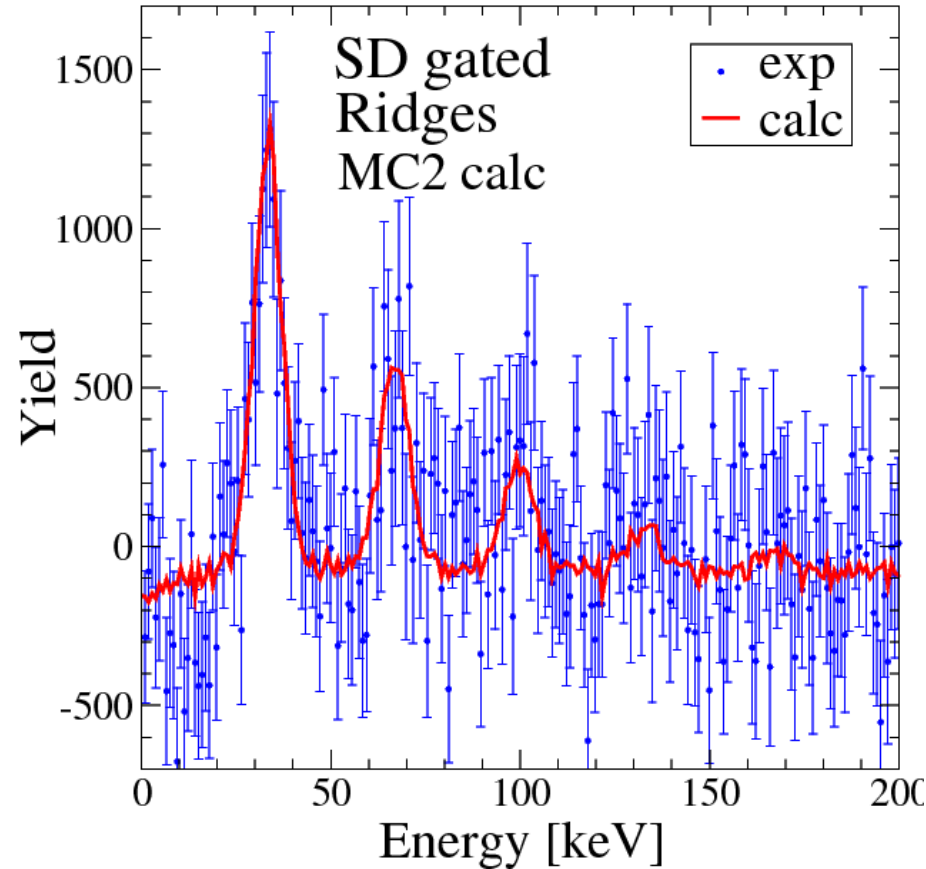
From using GS,  
and now **GT/AG**,  
as calorimeters

K: multiplicity ( $\rightarrow$  spin)

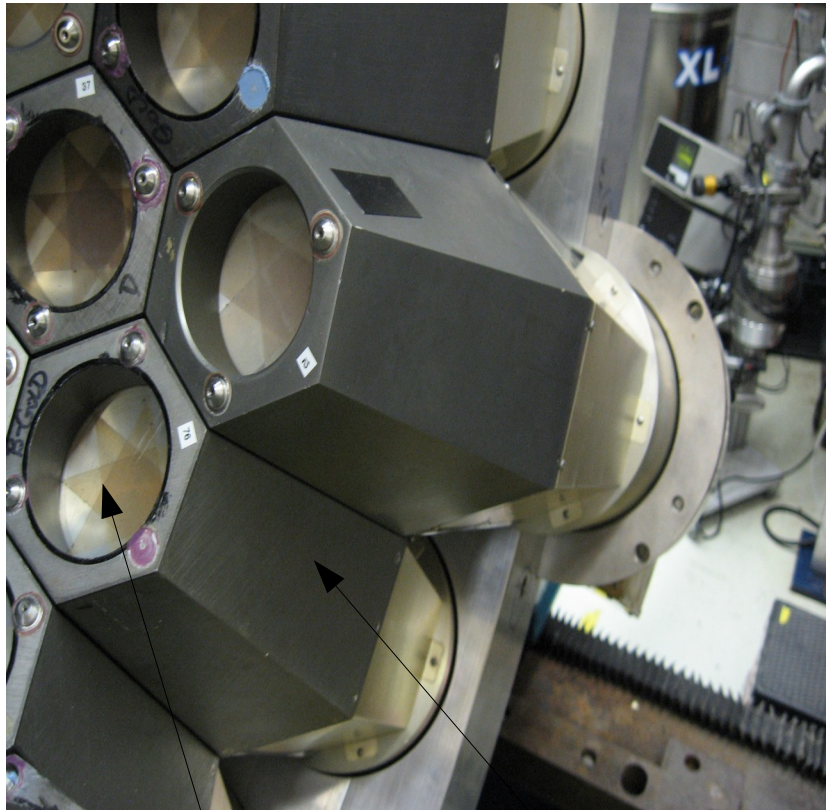
# Why measure?

2D ridges in  
gamma gamma  
matrices

- Used in Monte Carlo code to reproduce the Quasi--continuum of gamma rays (QC) in order to extract the rotational damping at high spins and energy (measure residual interactions)
- Used to extract the height of the fission barrier in **heavy nuclei** (like  $^{254}\text{No}$ , Khoo et. al.)
- With the much better energy resolution in GT/AG, compared to GS, we should be able to see *new features and details*



# The Compton suppressed arrays as calorimeters



Germanium

BGO

Remove Heavimets and add  
Pb absorbers on the BGO



We have a pixelated  
Calorimeter with an  
efficiency of  $\sim 75\text{-}80\%$ , but  
so-so energy resolution

We should be able to do  
better with tracking arrays  
**energy resolution wise**

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**GRETA calorimetric  
efficiency  $\sim 70\%$**

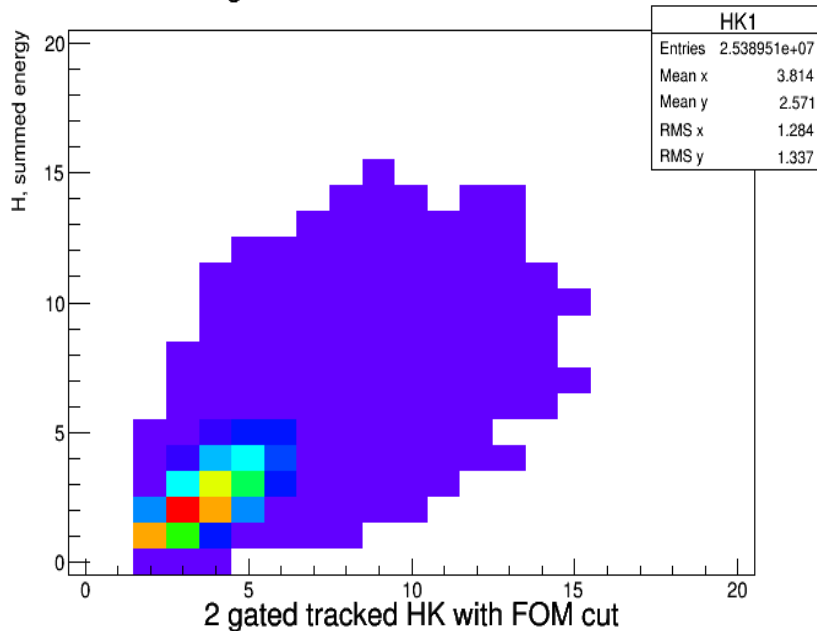
# Procedures: how to measure HK distributions using tracking arrays

- To measure the HK, **we think it is necessary to first track the data.** Without tracking, we are not dealing with gamma rays as such, *just interaction points*. H may be well defined, but K is not!
- That means we have **two extra parameters in play** compared to Gamma sphere: **the clustering angle** and **the FOM cut**.
- We have to correct for trigger conditions too in the response functions.
- **This also means we need to generate the H and K response functions under the same conditions.**
- The HK distributions are produced in ROOT -- with gates on discrete lines: HK, HK1, HK2, HK3 (spike free). Also background subtract.

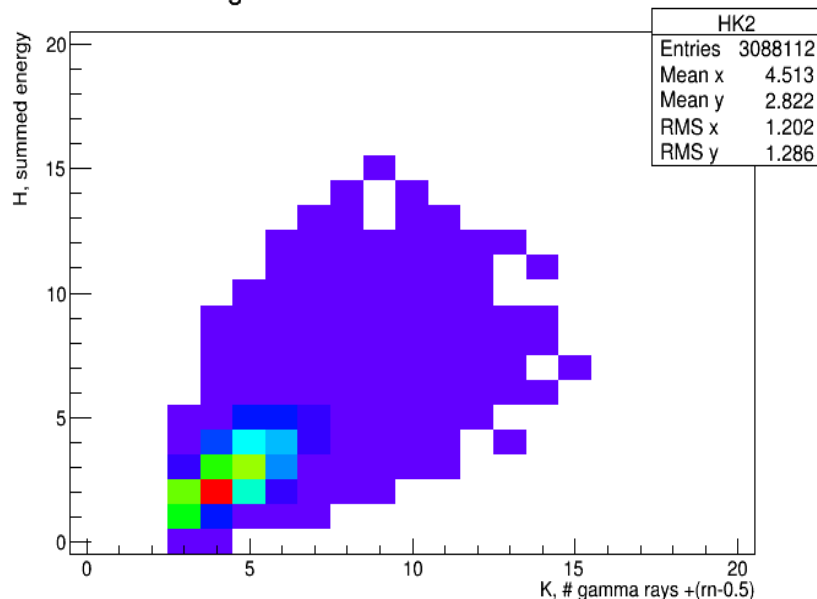
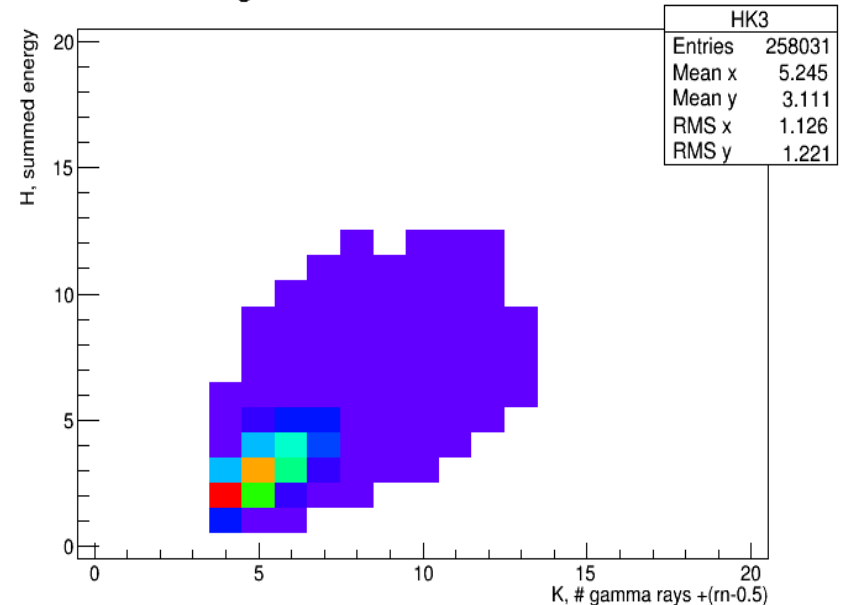


# Measured/observed HK distributions for $^{158}\text{Er}$ (shootout experiment, with just 28 crystals)

1 gated tracked HK with FOM cut



3 gated tracked HK with FOM cut

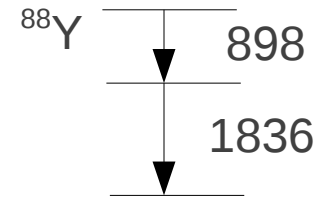


We background subtracted the  
HK matrices

Mean H and K increases with  
gating. Linear interpolation between  
HK1, HK2 and HK3 allow us to  
project back to the unbiased, 'HK0',  
entry distribution



# Measuring the H and K response function



- We use an  $^{88}\text{Y}$  source: 898 - and 1833 keV lines in coincidence and select out events where the 1833 was seen in one and only one crystal (CC).
- That ensures that one 898 keV gamma ray was emitted!! This gamma ray may or may not be seen in GT. We are seeking the response if one was seen by the array
- We manipulate the time stamps in order to artificially create coincidences  
We create 'MMn' files where 'n' 898 keV gamma-rays are emitted. Eg. MM10 contains the response, in H and K, when 10 898 keV gamma rays are emitted at the center of GT.
- If the interaction points in the constructed MMn files get within ~5mm of one another, we combine them. That mimics what would happen if 'n' gamma rays are emitted in a real coincidence
- We also impose the trigger conditions (e.g., 6 CC fires before trigger in GT)

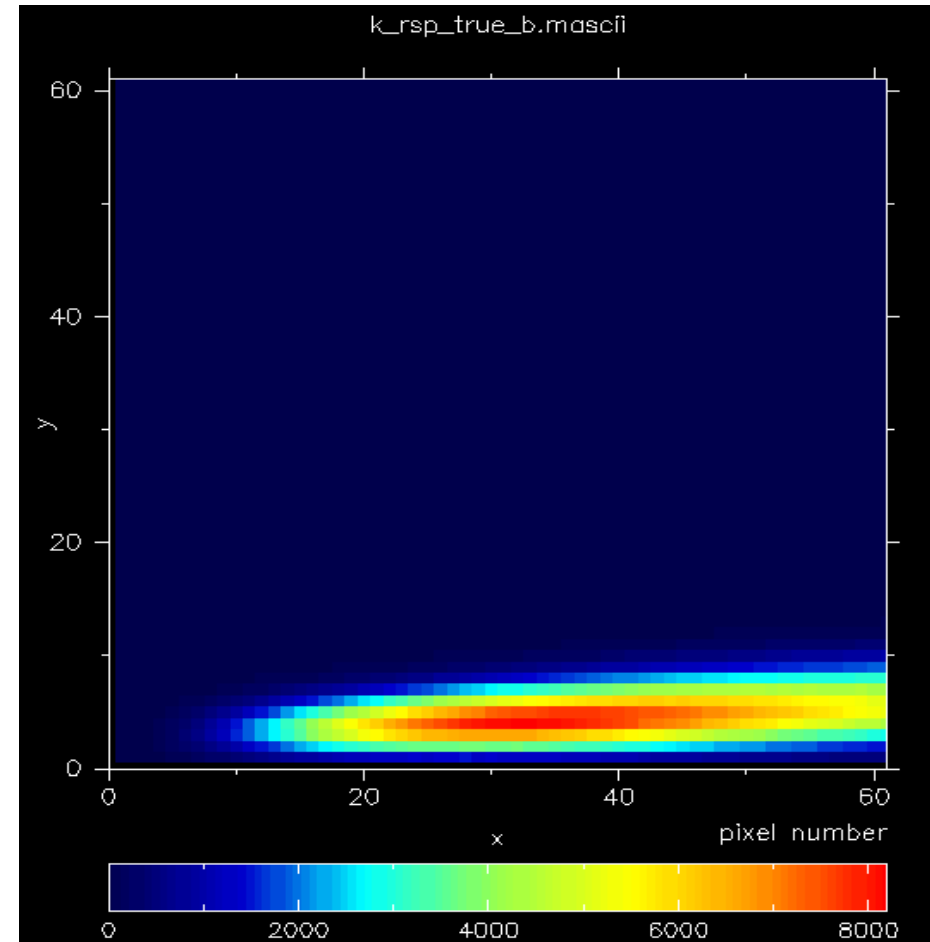
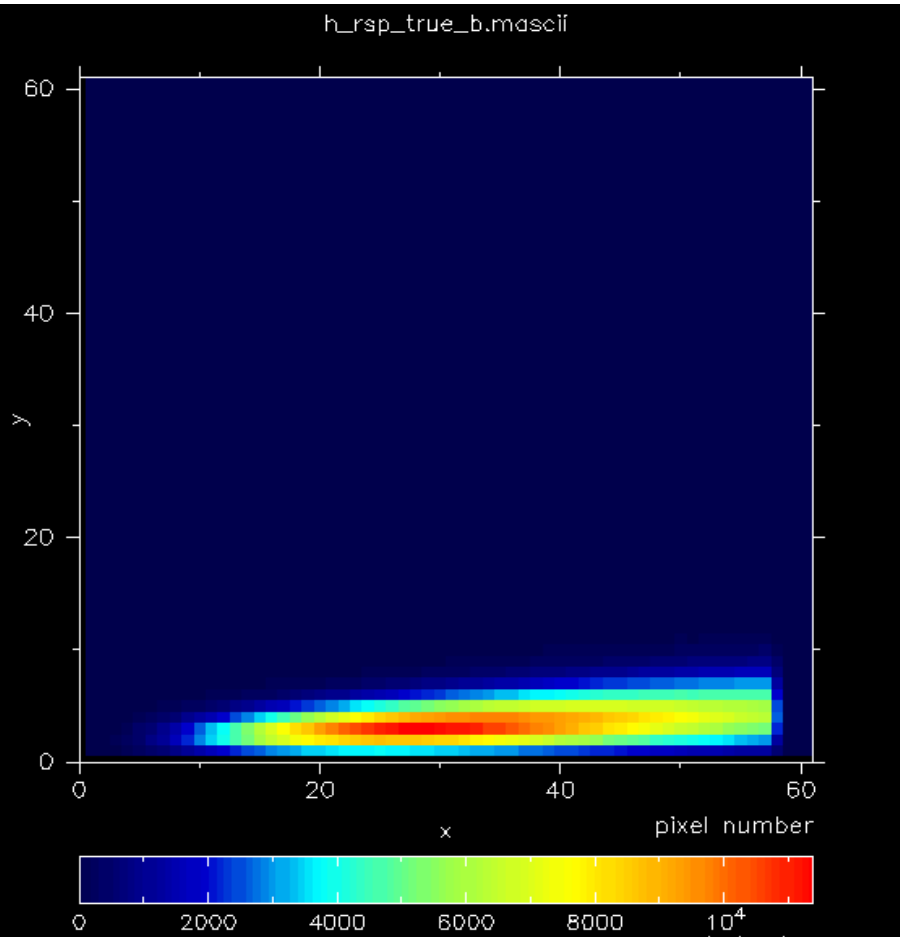


- We now track the MM1, MM2... datafiles individually and sort the mode1 data, extracting the HK matrices for each data file
- We project on the H and K axis from each root file. Those spectra are now assembled to give us the H and K response functions
- -----
- We correct for the fact that one crystal was used to detect the 1833 keV gamma ray (28/27)
- We correct for the small side feeding directly to the 898 keV state
- We scale the efficiency from 898 keV to the mean energy of the gamma rays we see from our nucleus
- -----
- **We now know that if 25 gamma rays (of mean energy) were emitted at the center of GT, how much energy will be seen (H) and how many tracked gamma rays we will see (K), for the given clustering angle and the FOM cuts we used**





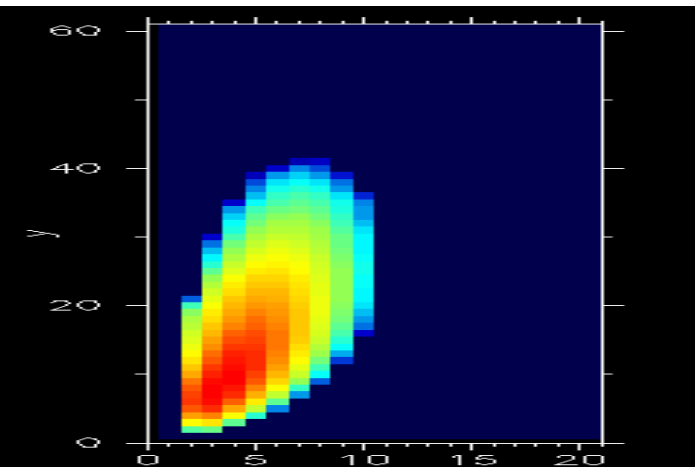
# The measured H and K response functions



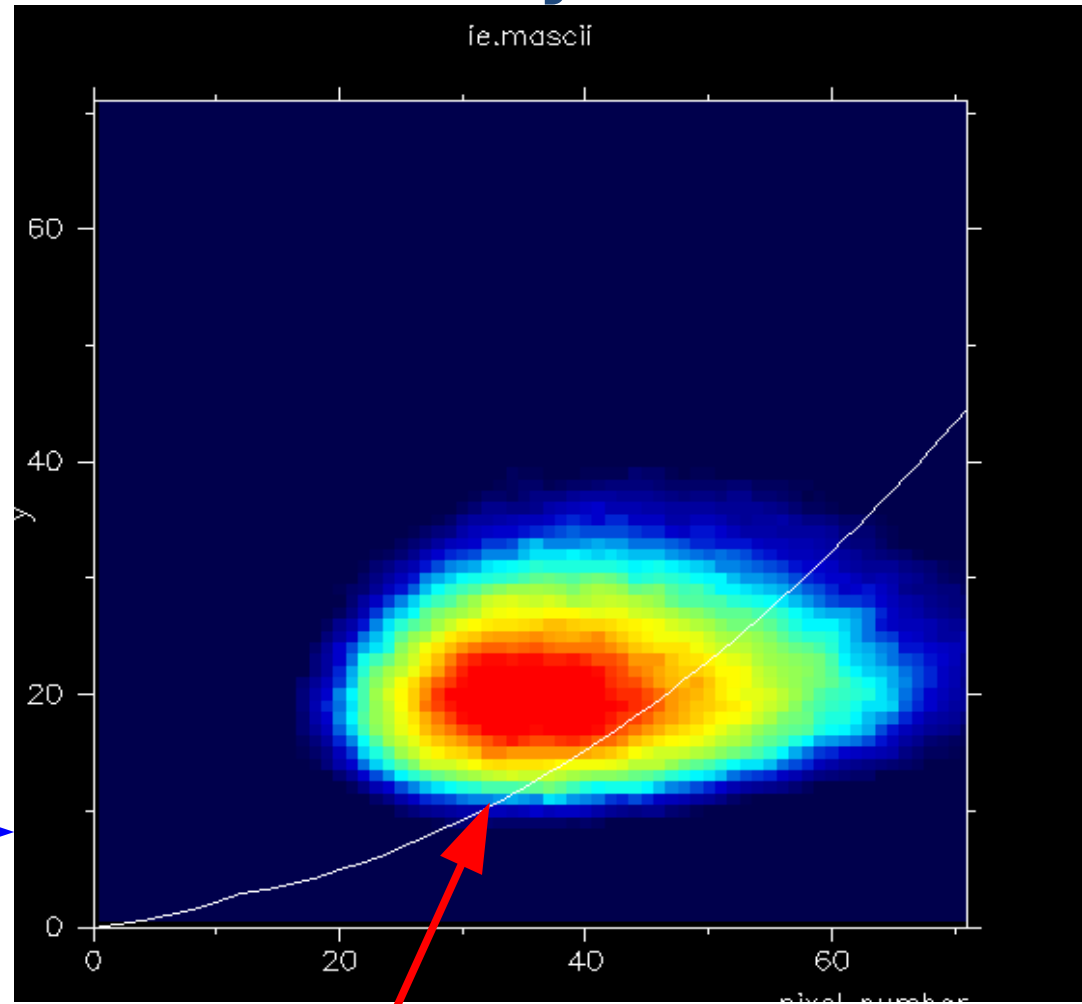
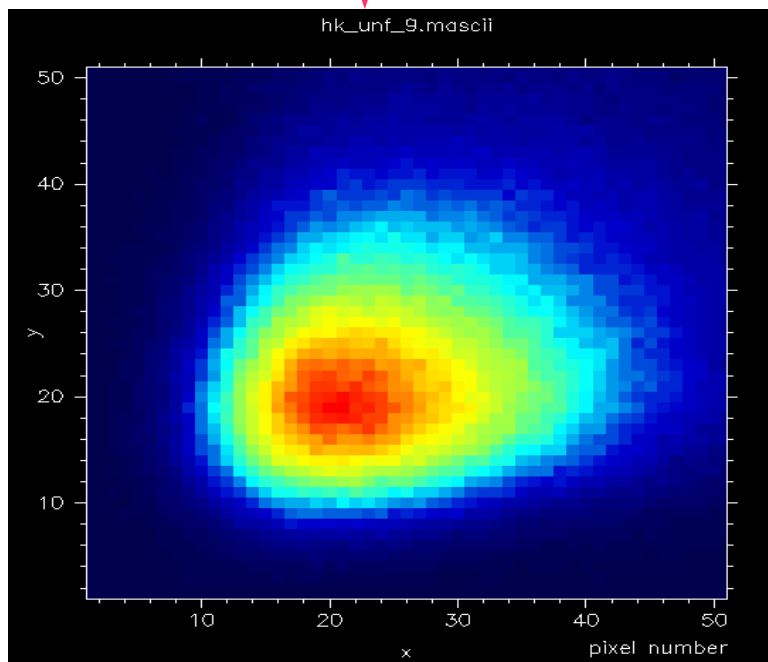
GRETINA H and K response functions  
with 28 crystals

Not as beautiful as the ones from GS  
Because we do not have so much efficiency yet...

# The unfolded HK and the final entry distribution



Monte Carlo unfolding



Extrapolated yrast line in  $^{158}\text{Er}$

$E \sim 1.7 \times K$  (from  $^{152}\text{Dy}$  SD band)  
[We do not have QC analysis]

# Conclusions for HK

- We *believe* we know how to measure an entry distribution using tracking arrays (*it is a little more complicated!*)
- **The trick is to generate realistic, artificial coincidences BEFORE tracking**
- We should be able to pick out more features with the better energy resolution
- **However, we will never surpass the total efficiency of Gammasphere**
- -----
- The measured entry dist in  $^{158}\text{Er}$  does not look as 'good' as we had hoped – we may have more work to do or maybe we just need more efficiency!?
- It might help to use GEANT4 data, using a level scheme in UCGRETINA, but we do not yet have the continuum in that code

# Unfolding spectra from tracking arrays

Unfolding is the process of removing the Compton scattered events that are left in our spectra even after Compton suppression (for GS) or tracking (for GT and AG)

We have experience in unfolding data from GS, but so far we have never tried to unfold spectra obtained from tracking arrays. *Are there complications that we need to be aware of?*



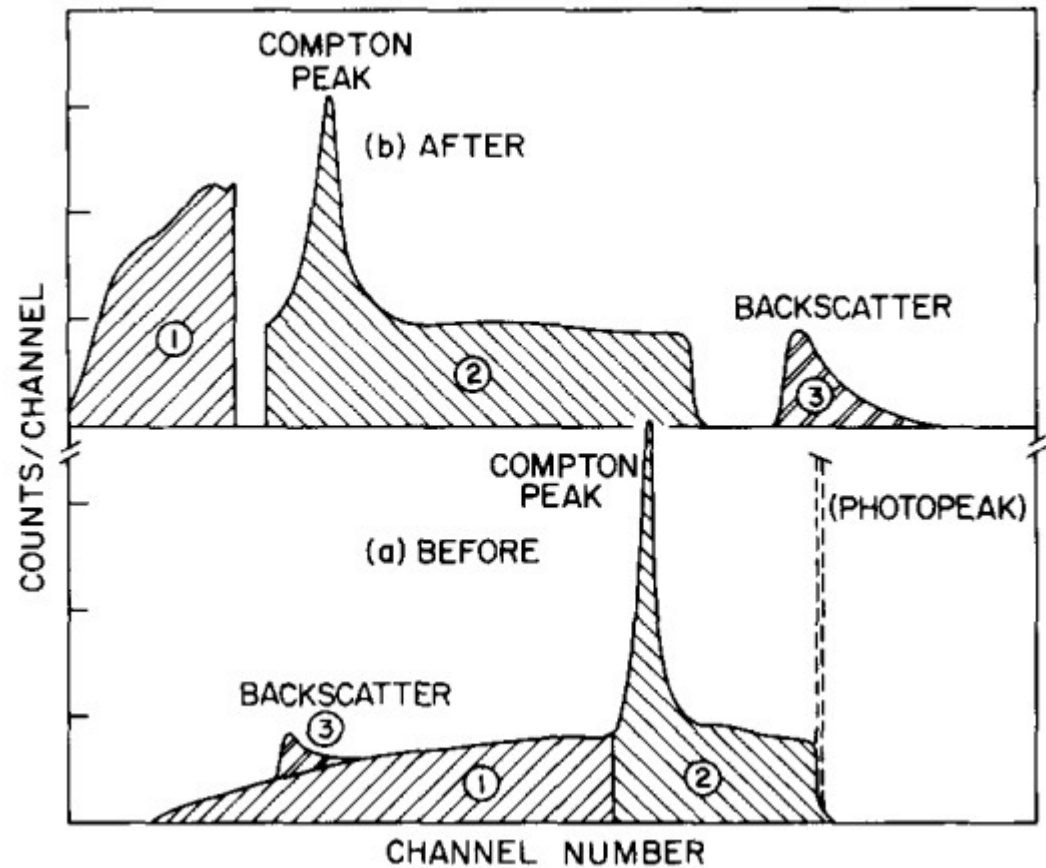
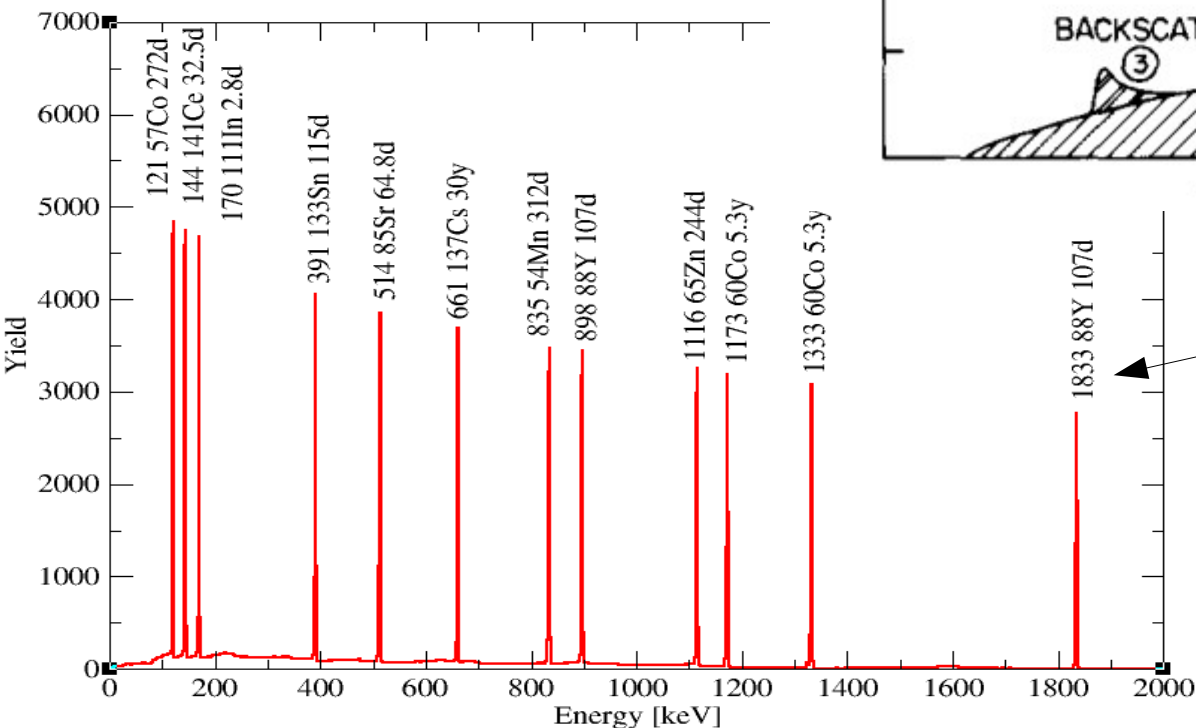
# Unfolding spectra from tracking arrays

- We do not have all the experimental data yet: *we are missing the low energy sources.*
- However, **we have GEANT4 simulated data**. We will use that data to try and unfold some (simulated) spectra
- That is an interesting exercise in itself that we could not do for GS because we do not have a G4 simulation for GS. Response is from multiplicity 1 or 2 sources; but in-beam data has much higher multiplicity!
- -----
- 1: We G4 simulate the 'usual sources' and a high multiplicity SD/ND band with same clustering angle and FOM cuts
- 2: We make a QC response function usual way
- ...and we unfold the spectra



# Unfolding idea (Radford)

Measure components, 1-3, at  
different energies. Then  
interpolate at other energies



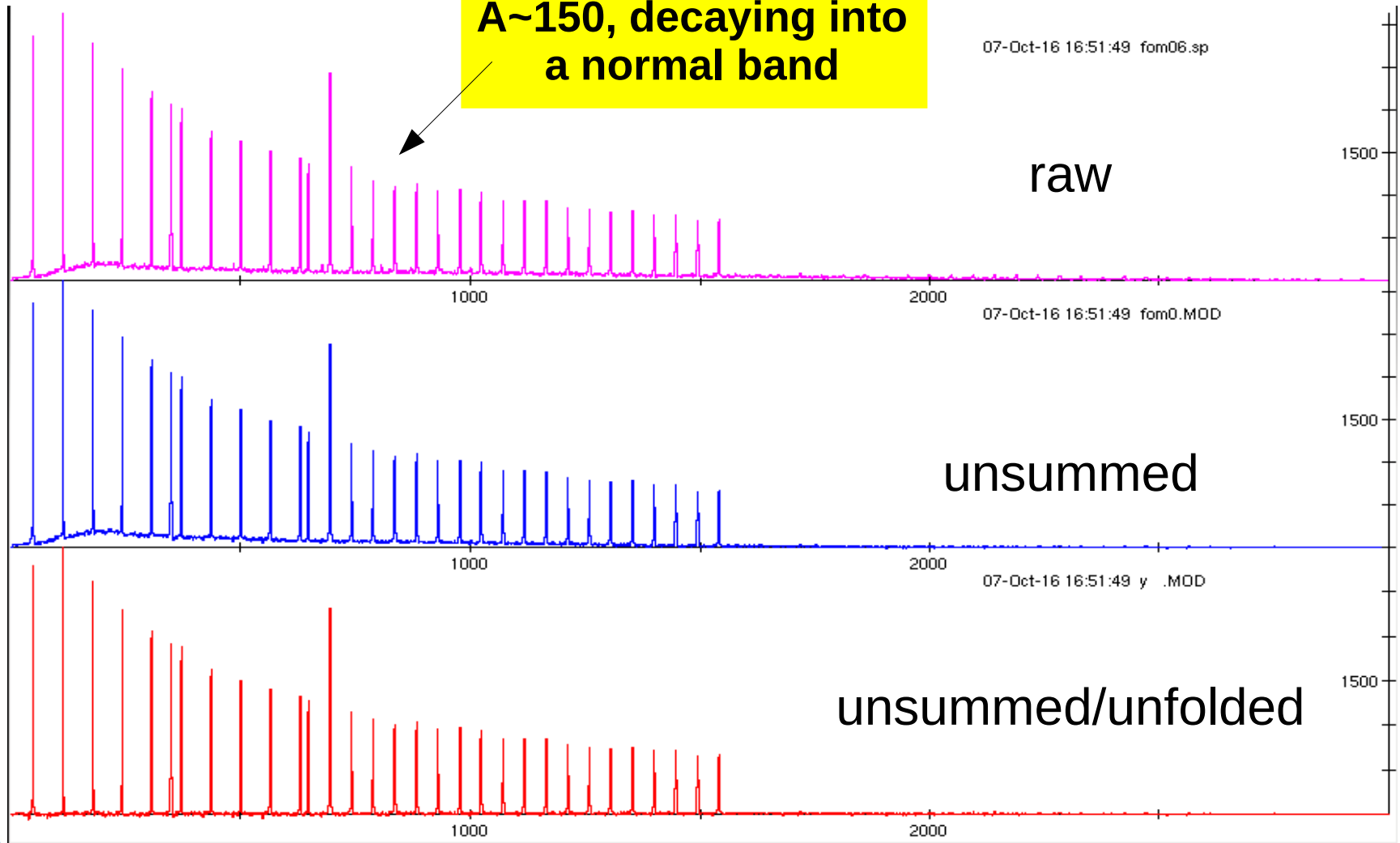
Typical sources

Low energy sources  
are typically short lived

# High multiplicity SD/ND band

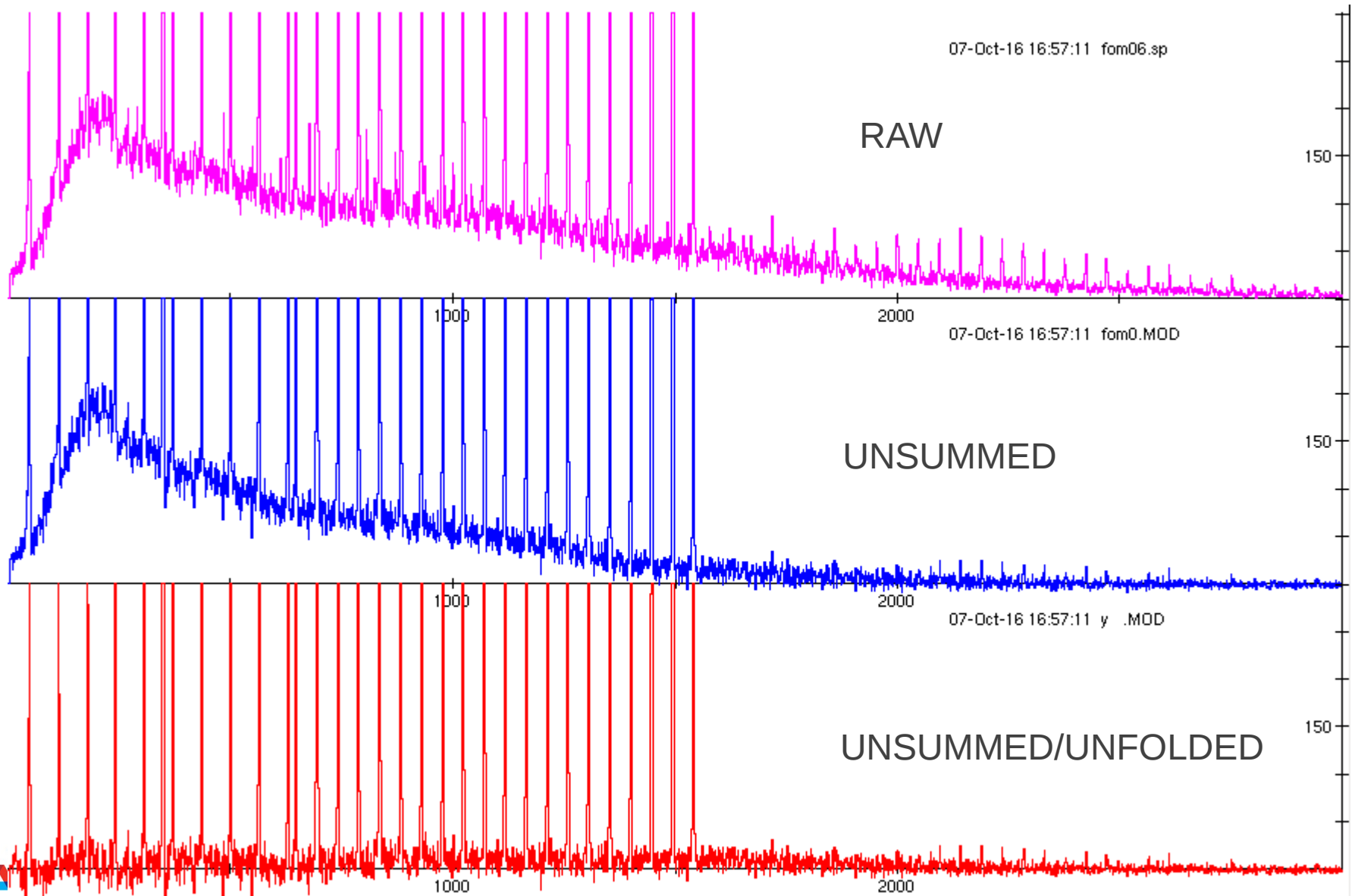
## UCGretina G4 simulation (30 gamma rays)

Typical SD band,  
A~150, decaying into  
a normal band





# High multiplicity SD/ND band (blow up) UCGretina G4 simulation (30 gamma rays)



# Conclusions for QC

- The GEANT4, very high multiplicity simulated data unfolds quite well!
- It is important to carefully correct for summing
- :: It looks like unfolding spectra from tracking arrays should be reasonably straight forward. **We are ready for QC data work!**
- *But; using what sources we have from the shootout experiment, the  $^{152}\text{Eu}$  source did not unfold so well... so stay tuned for experimental confirmation*
- We will propose GT exp for  $^{152}\text{Dy}$  where we have a well measured entry dist (and QC spectra) from GS to compare to
- We may need more efficiency to measure a good entry dist (wait for early GRETA days with 12 or more modules/48 crystals)