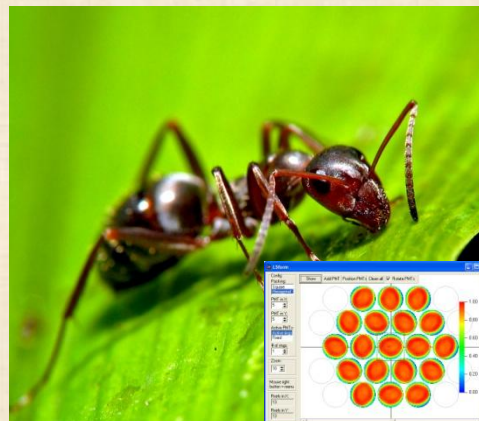
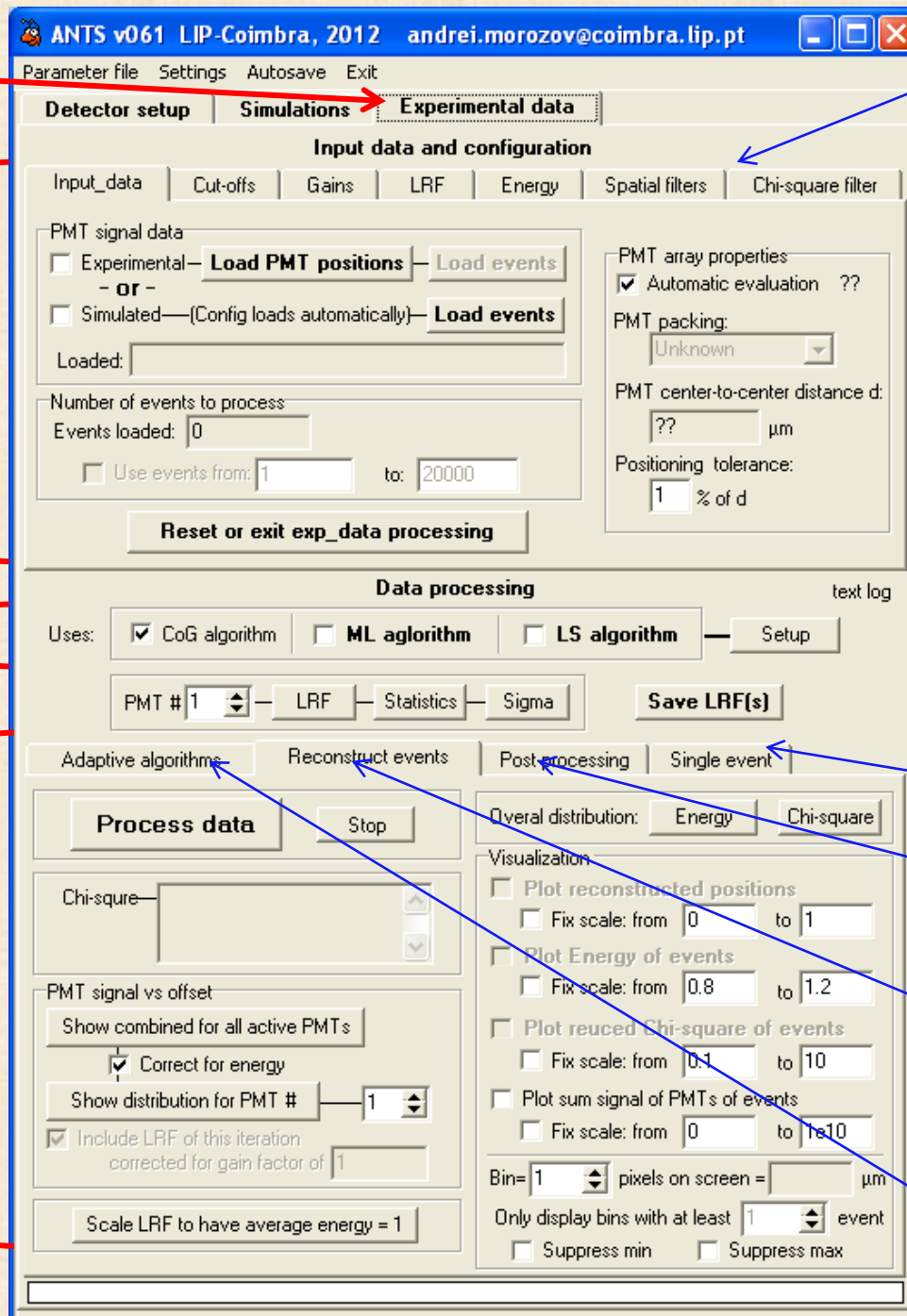


GSPC19 October/November data: event reconstruction using ANTS v061

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F.A.F. Fraga

LIP-Coimbra





We are here

Input data,
configuration,
event filters

Reconstruction
algorithm

Reconstruction
and
post-processing

Other tabs:

PMT signal cut-offs
(individual and sum)

PMT gains
(input/estimation)

Light response function
(model + first guess +
load)

Event energy
(scaling + filter)

Two spatial filters

Goodness of fit filter

Single event processing

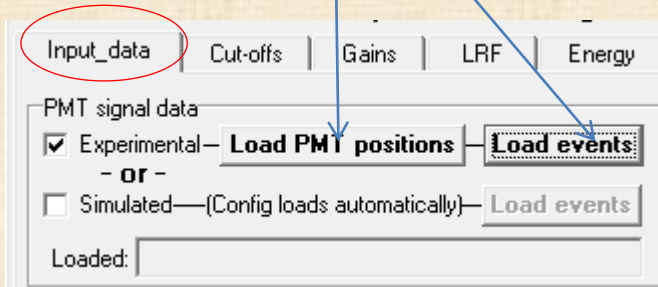
Analysis of
reconstruction results

Reconstruction of
positions and energies
of the loaded events

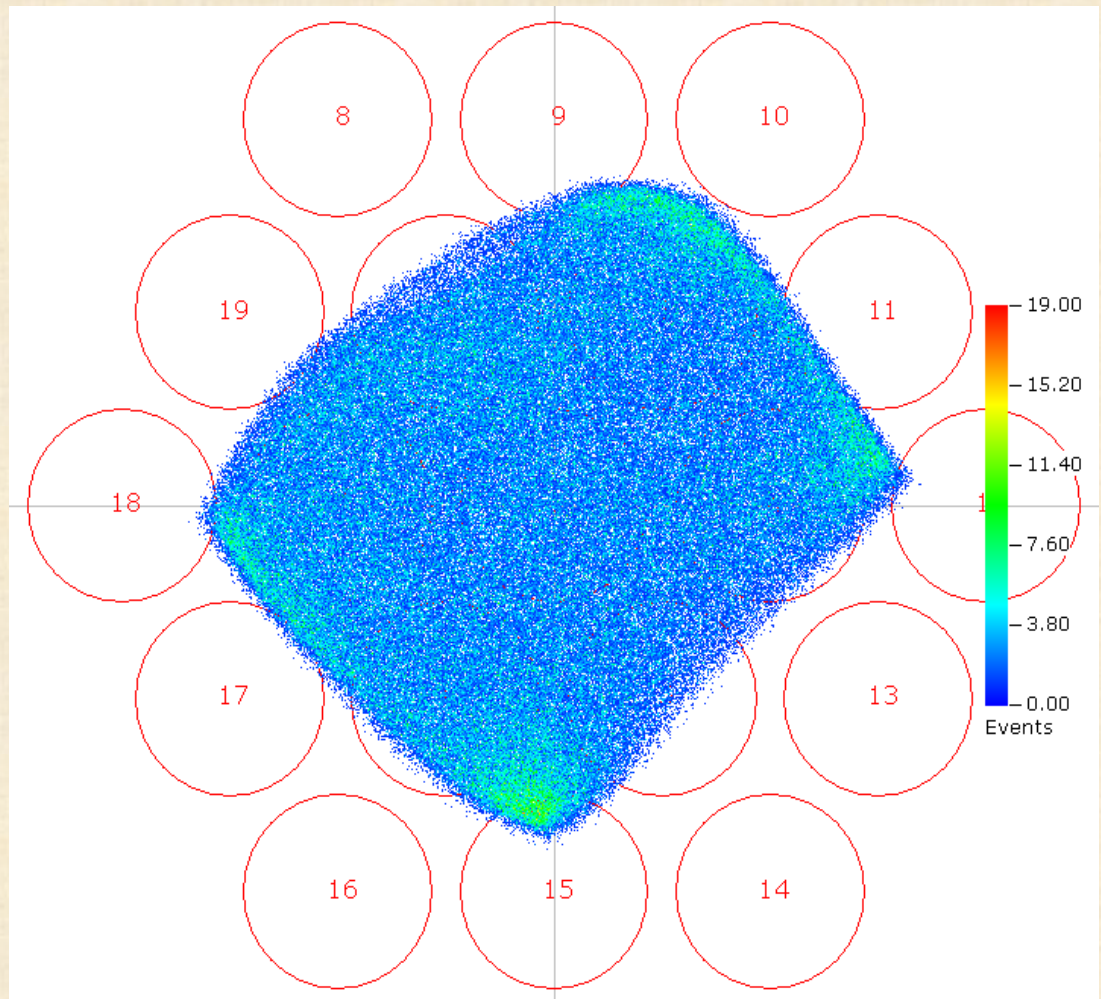
Iterative reconstruction
of LRF / gains

Data input

1) Load the file with
PMT positions
And then the file with
flood field illumination

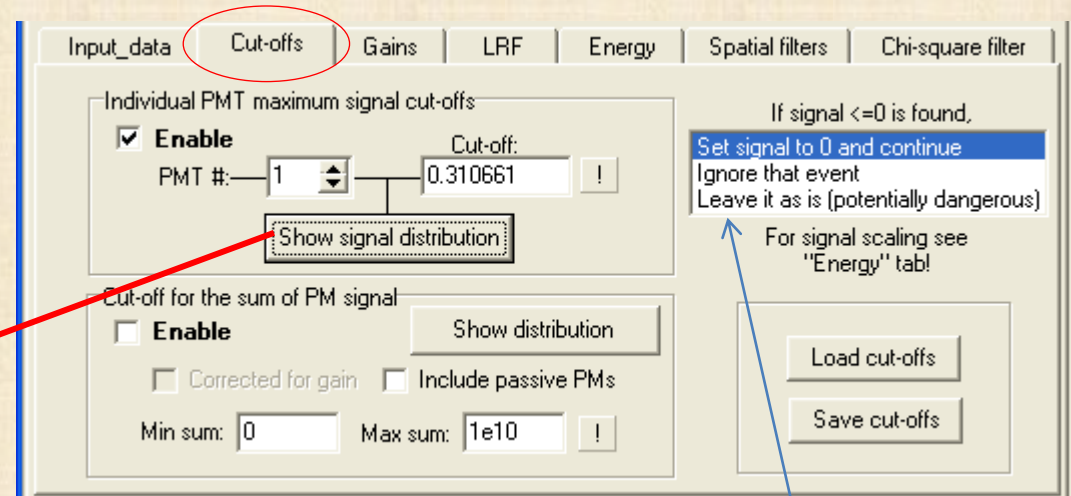
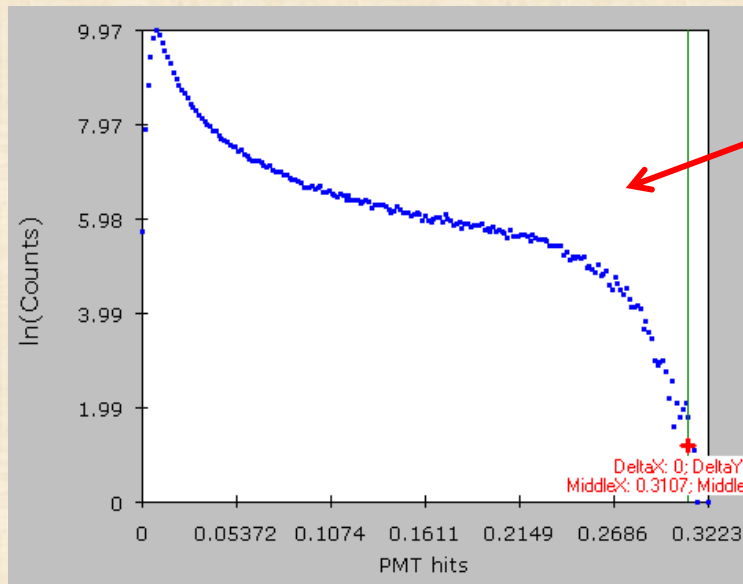


Automatically, the CoG
reconstruction will be shown:



Individual cut-offs

2) Second step is to define the cut-off for the individual PMTs (Cut-offs tab):



Use the mouse right-button menu to set cut-offs

Define how ANTS treat events with zero or negative PMT signals
It is assumed that the signals are already corrected for the offsets
(signals are proportional to the number of photoelectrons!)

Gains

3) Now gains can be estimated:

Select these options

The 'Gains' tab is selected and highlighted with a red circle. It contains the following options:

- ☒ **Use estimated gain factors**
- On graphical window:
 - ☒ Show gain factors
 - ☐ Show gains used in simulation
- Buttons: swap, In log, List gains, Load gains, Save gains
- Set gain factors: PMT# 1 - 1, ☐ auto-increment
- Copy gains from simulation
- Estimate gains** (button)

Select these options

The dialog box 'Estimate gains using flood field illumination data' is open. It contains the following options:

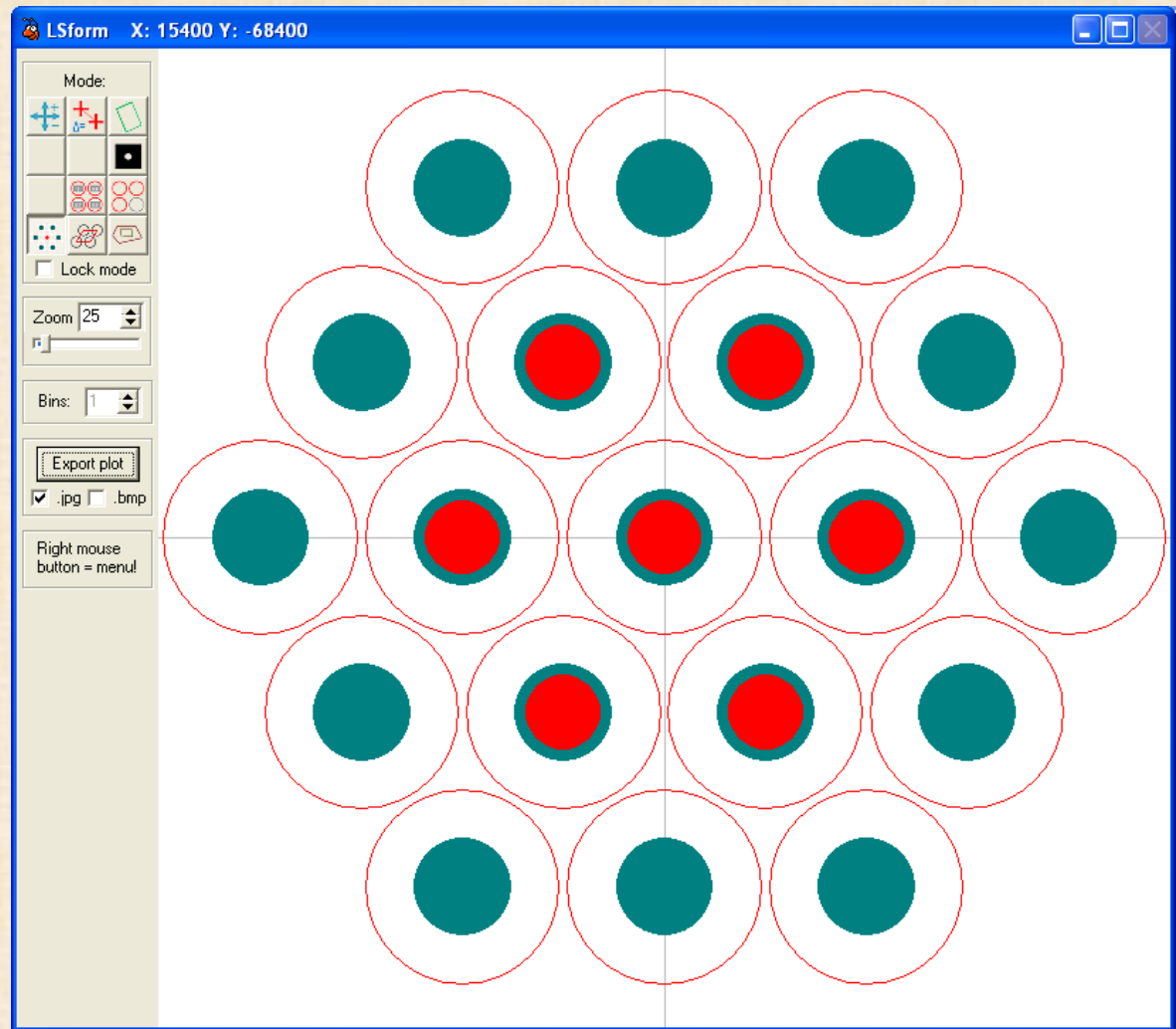
- Estimate gains** (button)
- ☒ Visualize events
- Algorithms**
 - ☐ Use relative cut-offs of _all_ PMTs
 - ☒ Use cut-offs and symmetry
 - ☒ Select central PMTs (Fraction: 0.3 %)
 - ☒ Do not link central PMTs
 - ☐ Use symmetry in sets of 4 PMTs (Zones: 100, Overlap: 2 %)
 - ☐ Use only: 0 sets defined
 - ☐ Mark sets to use
- Advanced options**
 - ☐ Replace cut-offs with average signal using top 1 % of events
 - ☐ Replace cut-offs with average signal
 - Apply energy correction:**
 - ☐ Reconstructed energy
 - ☐ Energy from input file
 - ☐ apply energy filter

Gains

Then on the graphical window indicate (left click) those PMTs which definitely have events in front of their center.

In our case: 7 central PMTs.

The selected method will find events in front of the center of each “red” PMT and find relative gains for all neighboring PMTs (teal) from their average relative signals.



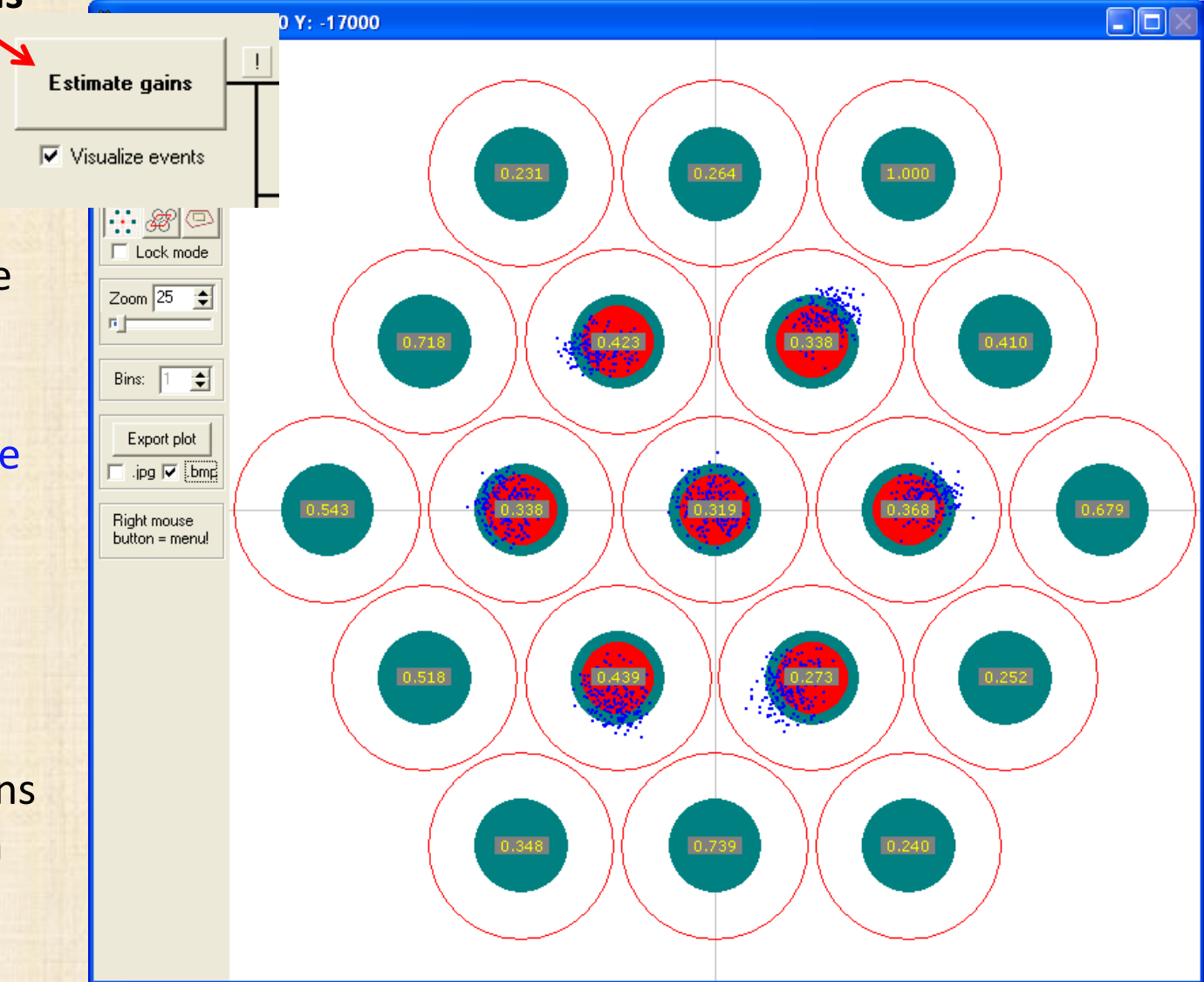
Gains

Press “Estimate gains”

The “**fraction**” parameter can be changed if there are too few events (blue dots) or too many.

Selected events (blue dots) should form compact groups
Offsets from centers are normal

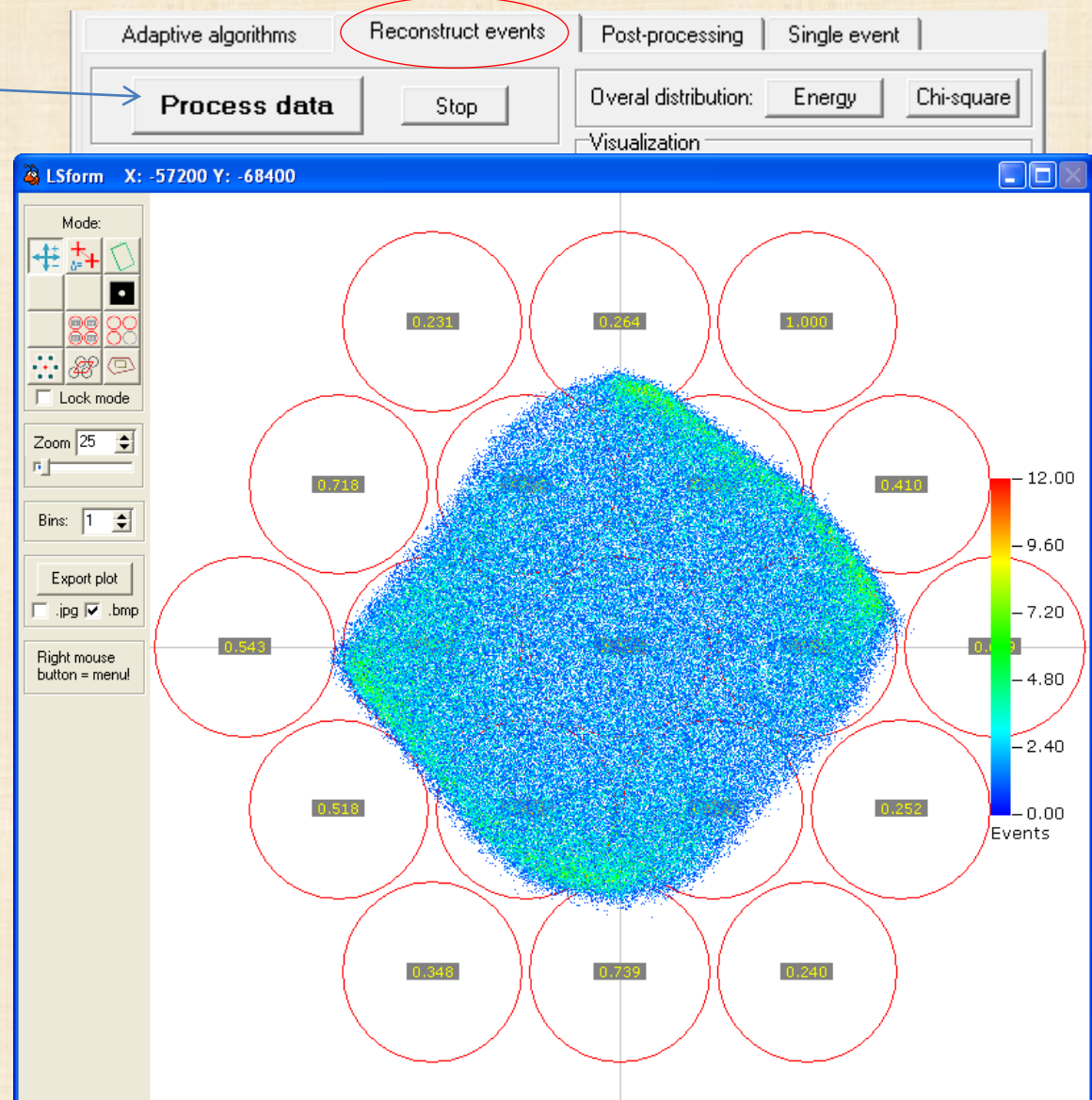
Ideally, obtained gains should not vary with small change of the **fraction** parameter.



Gains

Press “**Process data**”
(button in “**Reconstruct events**”
tab in the lower
tab control)

The CoG reconstruction of
the flood field should
cover a more symmetric
area!



LRF / Energy tabs

4) Next step is to load shaping LRF – it is the first guess on the actual LRF. Also used by adaptive algorithms for shaping of reconstructed LRFs during iterations.

The screenshot shows the 'LRF' tab selected in a software interface. The 'LRF model' section has two options: ☒ 'One LRF for all PMTs' and ☐ 'Individual LRF for each PMT'. A red box highlights the 'One LRF for all PMTs' option with the text 'We start with that model'. Below this, the 'Zero-iteration (shaping) LRF' section contains a 'Load from file' button, a 'Use simulated' button, and a 'Ready?' status showing 'No'. There is also a text input field for 'Non-zero LRF is available from 0 to: ?? μm'. On the right, an optional section titled '** optional **' contains a 'Load LRF(s)' button and a description: 'Load LRF(s) to be used in reconstruction. Replaces data for this iteration, not the shaping LRF'.

5) Since Poisson statistic is used, the signals of PMT has to be converted to integers (number of photoelectrons)

Select this and provide the value of “**Average signal per photoelectron**” or click the “**Evaluate**” button to estimate the value.

The screenshot shows the 'Energy' tab selected in a software interface. The 'Convert PMT signal to photo-electrons' checkbox is checked. Below it, the 'Average signal per one photoelectron' is set to 1.131E-3. An 'Evaluate' button is present. Below this, there is a section for 'Input data contain event energy information' with a checkbox and an exclamation mark icon. At the bottom, the 'Energy filter' section has a checkbox for 'Allow energy from' with values 0.8 to 1.2, and a 'Copy "fixed scale" range' button.

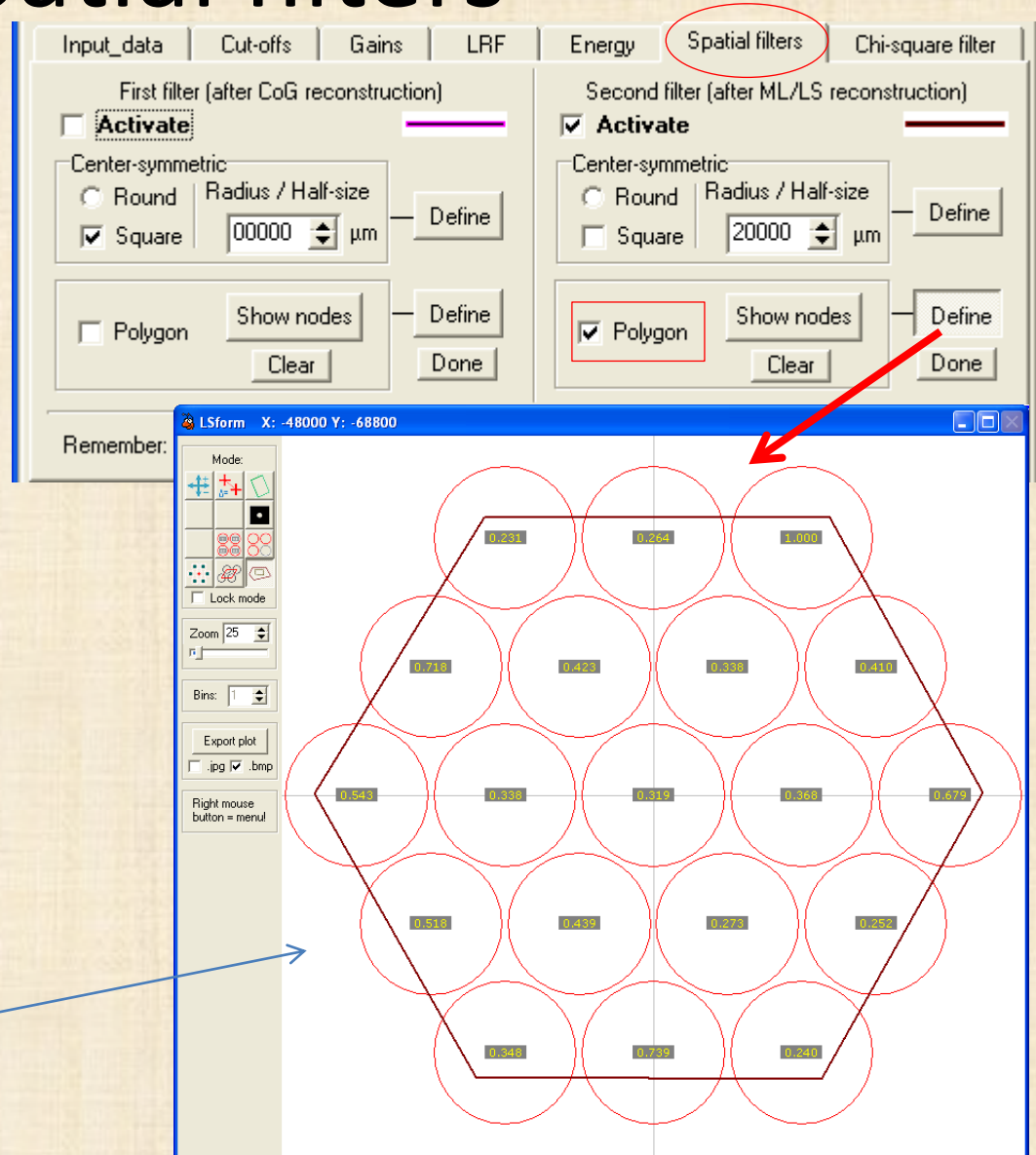
If experimental data contain charge information, this checkbox has to be activated.

Spatial filters

The first spatial filter is checked (if activated) after CoG reconstruction.

The second is checked after ML (or LS) reconstruction. It has to be activated if there are events in the regions where the ML/LS algorithms are known to produce significant errors – e.g. the area outside of the centers of the border PMTs

Select “**Polygon**”, “**Define**” and click at the positions where you want to have the polygon corners.



“Bad events” filtering

“Bad events” – Any event which is not a proper single neutron event.

These events “confuse” the adaptive algorithms – have to be removed.

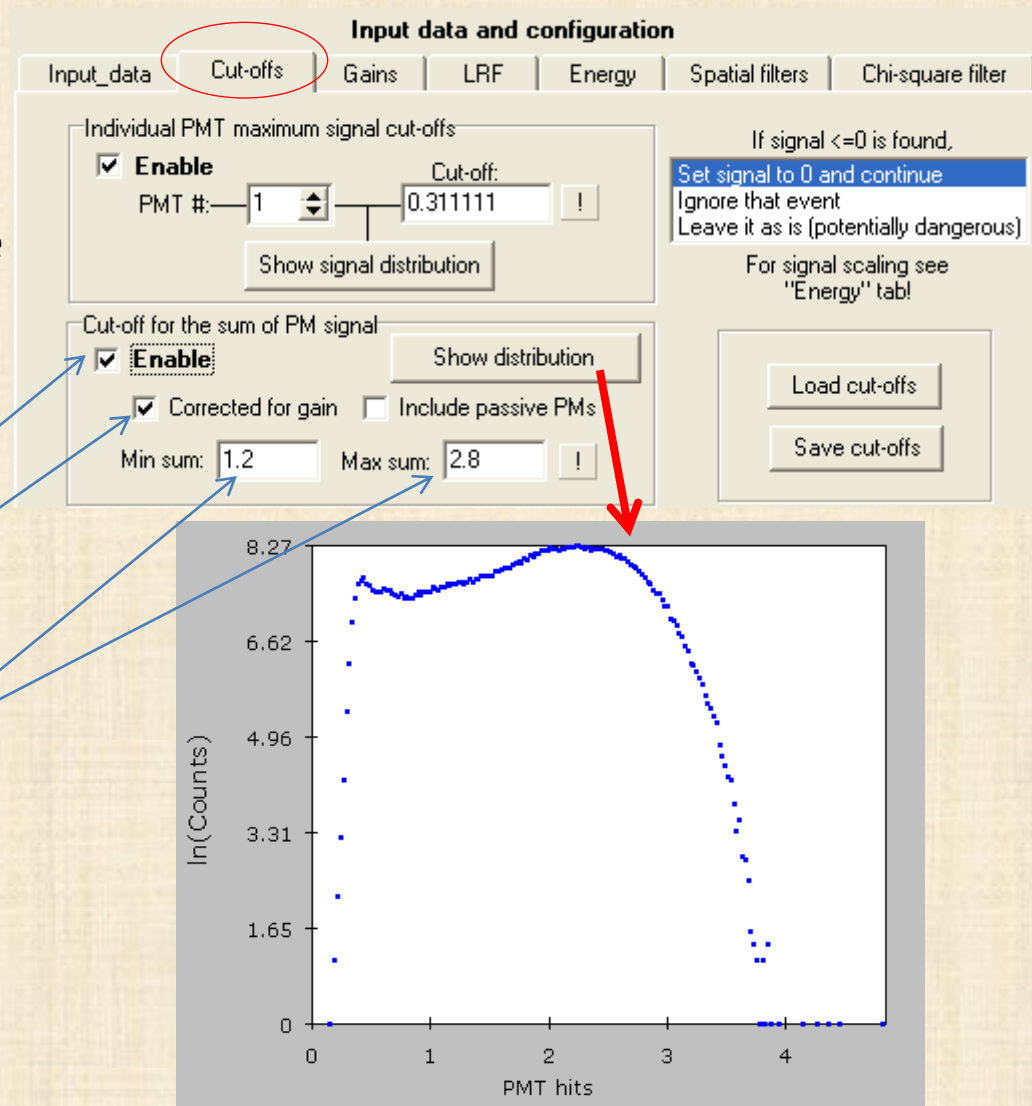
We can use

“cut-off for the sum of PM signal”

With the option

“corrected for the PMT gains”

How to select the proper range?

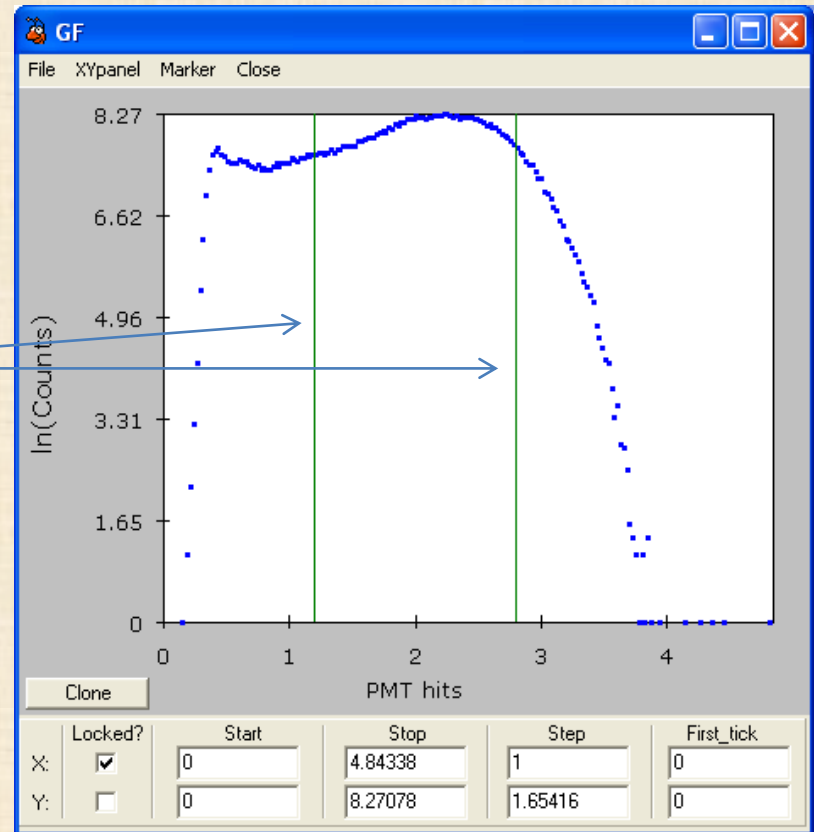
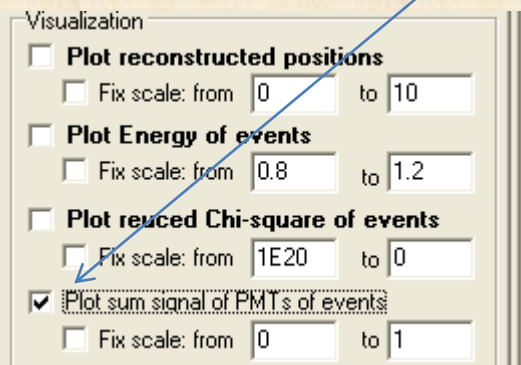


Sum cut-off filter

We would like to avoid low and high energy events, but we do not have yet the energy information! (It could happen we cut too much)

Make a guess on the cut-offs (later we can correct)

Then perform reconstruction with the Sum cut-off filter enabled. Select this visualization option



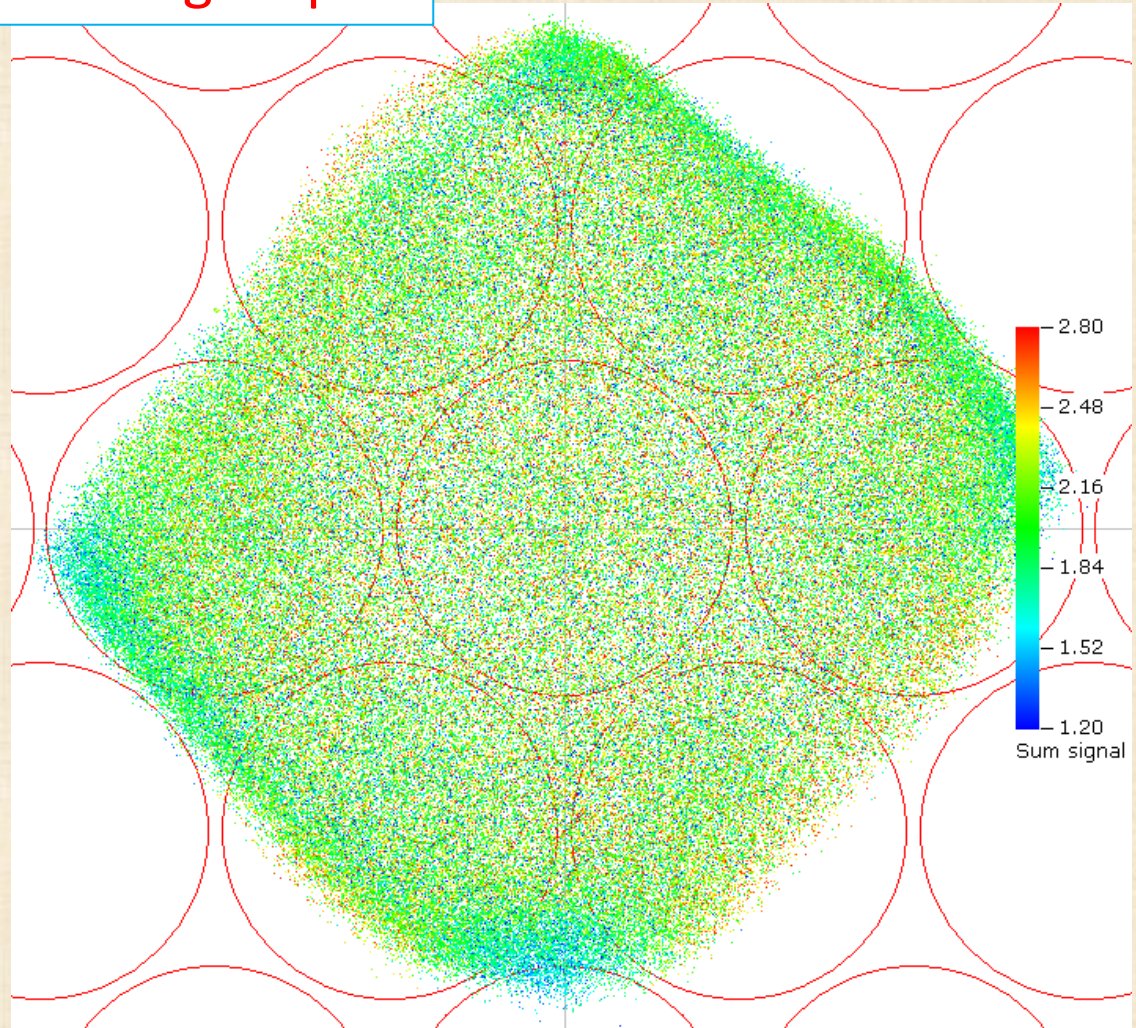
Sum cut-off filter

There should be no areas where events density is significantly reduced.

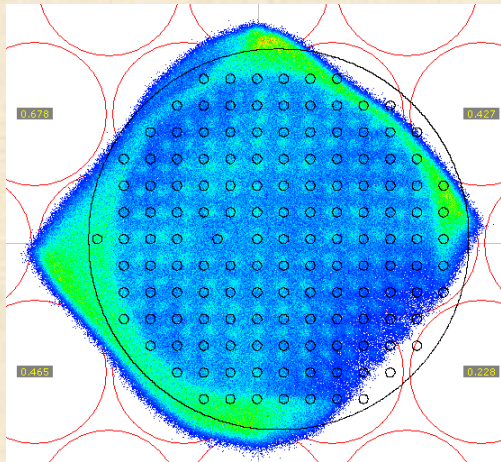
Any “ensembles” with a dominating contribution by events with too low (blue) or too high (red) sum signal are suspicious!

(Rim area?
Wrong gain estimation?
Defect?)

Sum signal plot

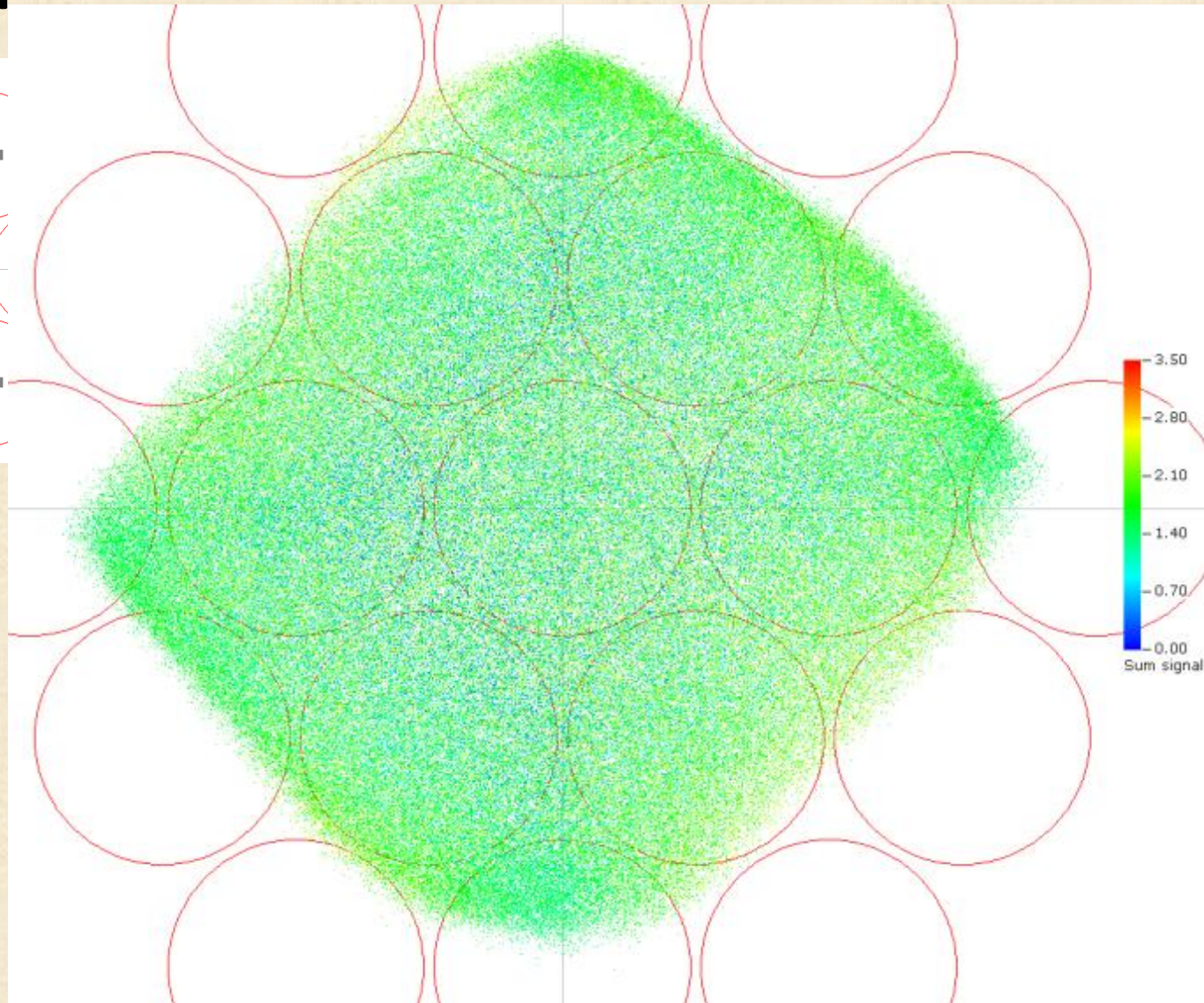


Example of a bad “ensemble”



A diffuse “halo”
is visible in high
statistics CoG
reconstruction

In the “Sum signal”
plot one can see
blue points scattered
over the halo area
(sorry - need high
resolution) .



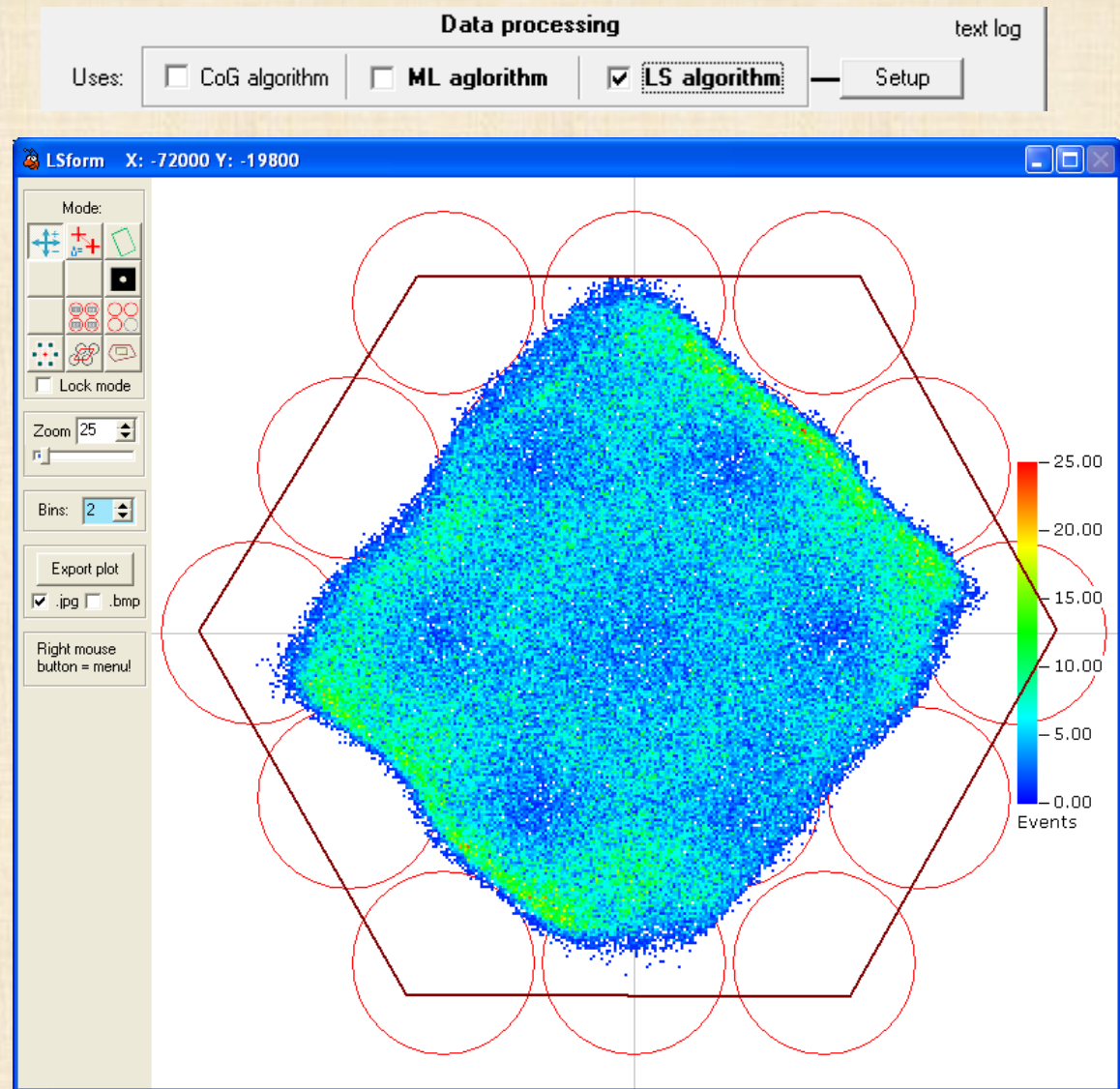
Now we are ready for the LRF
reconstruction

LS reconstruction – first guess

Switch to LS algorithm and use “**Process data**” again.

One can see that the first guess LRF is not adequate

Next step: adaptive reconstruction of LRFs



Configuration for iterations

The screenshot shows a software interface for configuring iterative reconstruction. At the top, under 'Uses:', the 'LS algorithm' is selected. Below this, there are tabs for 'PMT #1', 'LRF', 'Statistics', and 'Sigma'. The 'Statistics' tab is active. On the left, there is a section for 'Adaptive algorithms' (circled in red) with a 'Perform iterations' button and a 'Stop' button. Below this is a section for the 'LS algorithm' with a checkbox to 'Replace sigma with sqrt(LRF)' and a value of '5'. The main 'Iteration configuration' section on the right includes 'LRF shaping' with a '1st adjacent averaging range' of '10' points, a 'Reconstruction range' with a 'Dynamic' checkbox checked and a 'Cut-off at 10 % of max statistics' option, and a '2nd adjacent averaging range' of '10' points. There is also a 'Gains' section with a 'Perform Gain Factor Optimization' checkbox and 'Min R: 12000 μm' and 'Max R: 20000 μm' values. At the bottom, the 'Correct for the event energy' checkbox is checked. Blue arrows point from various text annotations to specific controls in the interface.

1 point = 100 μm

If range is too small, LRF will “wriggle”

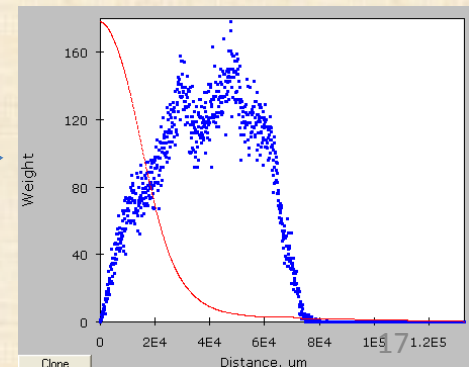
If too large, LRF at short distances will go lower than it should
(will discuss later)

Used to do iterative gain reconstruction.

For GSPC19 data we do not have to do it.

Always keep it activated

Defines the limits where reconstructed data are used: outside them the shaping LRF takes over.
Statistics can be checked here (shows distribution)
After some iterations, 5% can be a better option.

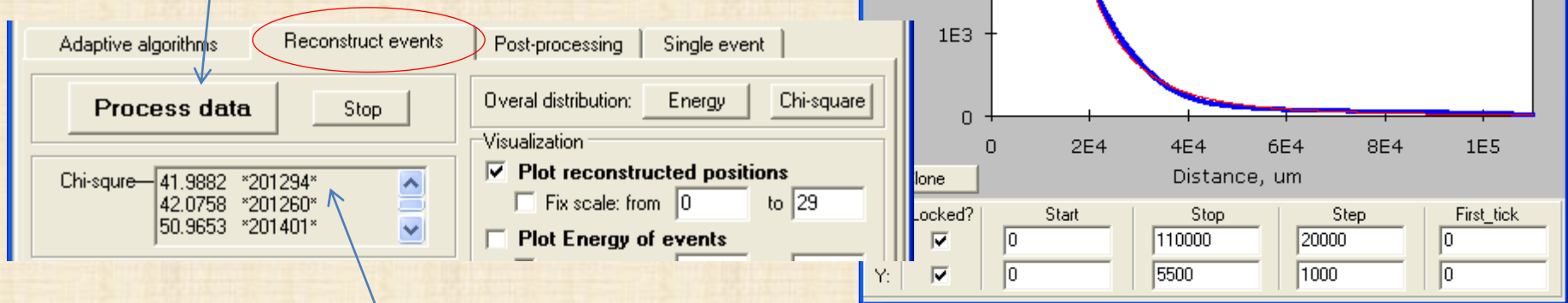


LRF reconstruction: single LRF model

Press **“Perform iteration”**.

When it is finished, a window will pop up which will show the new (blue) and old (red) LRFs.

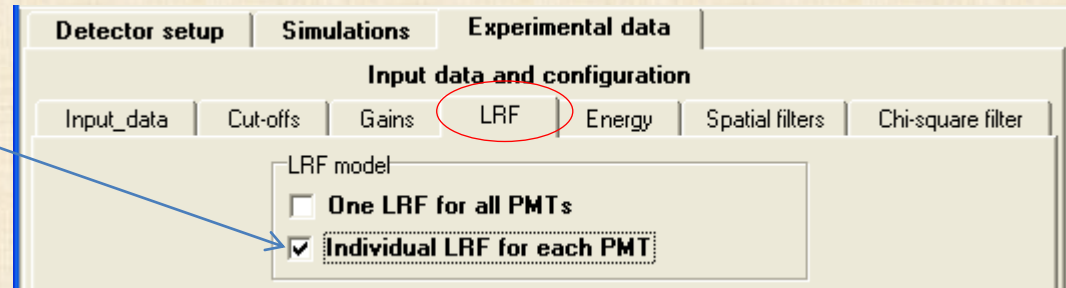
Change to **“Reconstruct events”** tab and press **“Process data”**.



Return back to **“Adaptive algorithms”** and repeat iteration → processing cycle 2 – 3 times. Watch the Chi-square after each processing. When it stopped to increase, it is time to change to another model.

LRF reconstruction: individual LRF model

Select “**Individual LRF for each PMT**” model



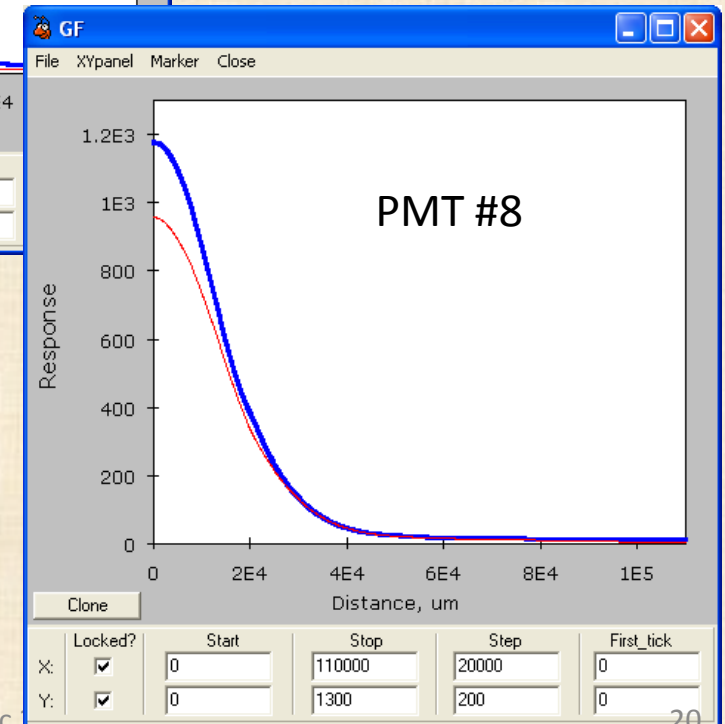
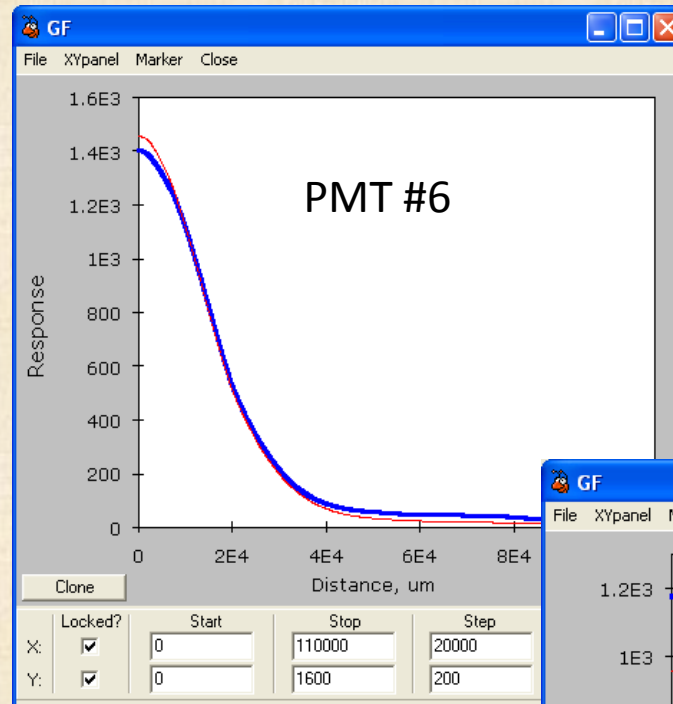
The processed (current) LRF will be attributed to each PMT taking the gain of the PMT as the scaling factor.

In “**Reconstruct events**” tab use “**Process data**”. Reconstruction should be the same as before, but Chi-square factor will change due to scaling.

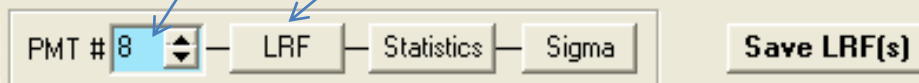
Change to “**Adaptive algorithms**” and perform one iteration using the same settings.

LRF reconstruction: individual LRF model

Now all PMTs will get different adjustment to their LRFs



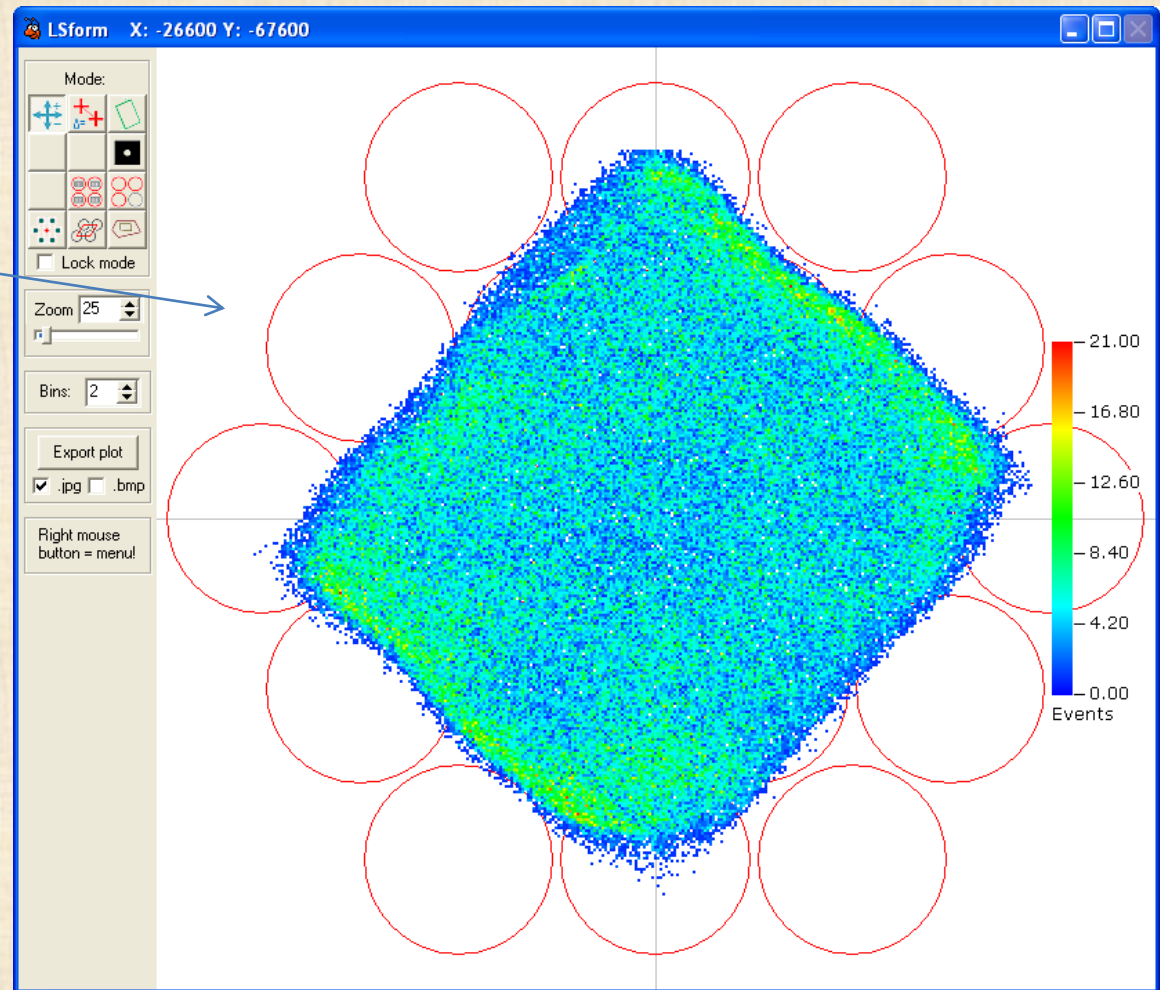
Select the PMT and press "LRF" to see info for different PMTs



LRF reconstruction: individual LRF model

Now the reconstruction image should make more sense

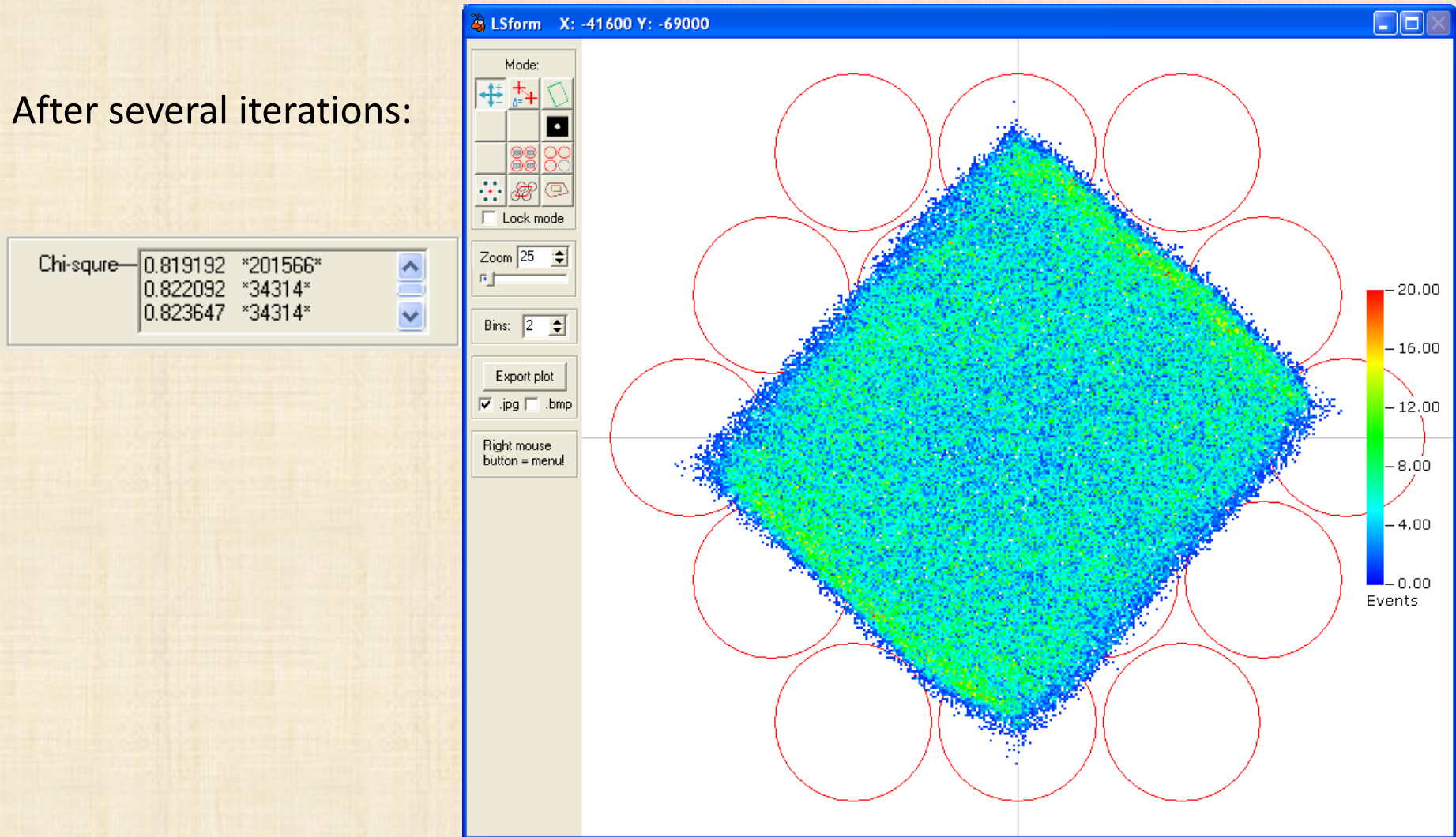
Chi-square also should reduce fast:



Chi-square	5.57029	*201430*
	11.5311	*201284*
	41.9882	*201294*

LRF reconstruction: individual LRF model

After several iterations:



LRF reconstruction: individual LRF model

“Quality control”

Is LRF adequately describe the data for each PMT?
To check, use this tool:

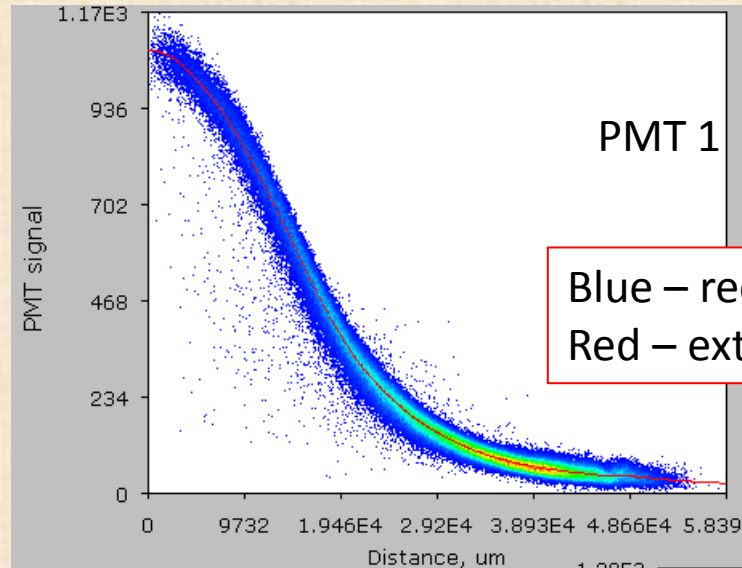
PMT signal vs offset

Show combined for all active PMTs

☒ Correct for energy

Show distribution for PMT #

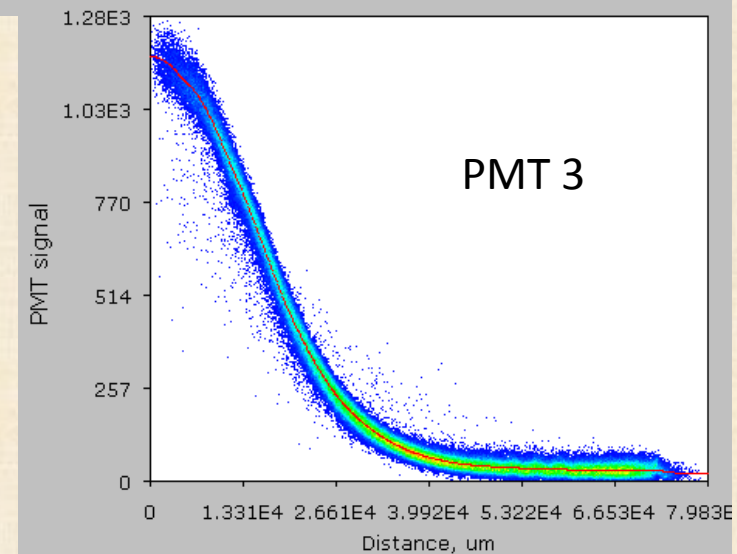
☒ Include LRF of this iteration
corrected for gain factor of



If LRF appears too much below the center of the scattered data – too much averaging was used! Reduce the averaging range!

If there is too much “wriggling” in the reconstructed LRF – averaging was not adequate! Increase the range!

Watch for saturation signs: spread in the scattered points close to the peak is larger than square root of average and blurring downwards!

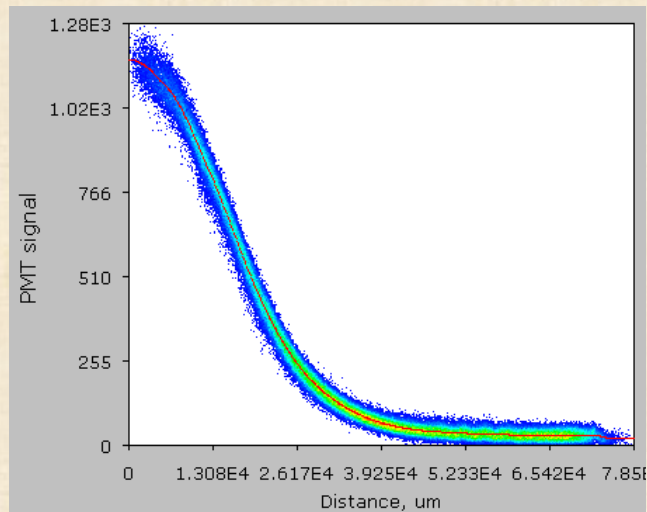


LRF reconstruction: individual LRF model

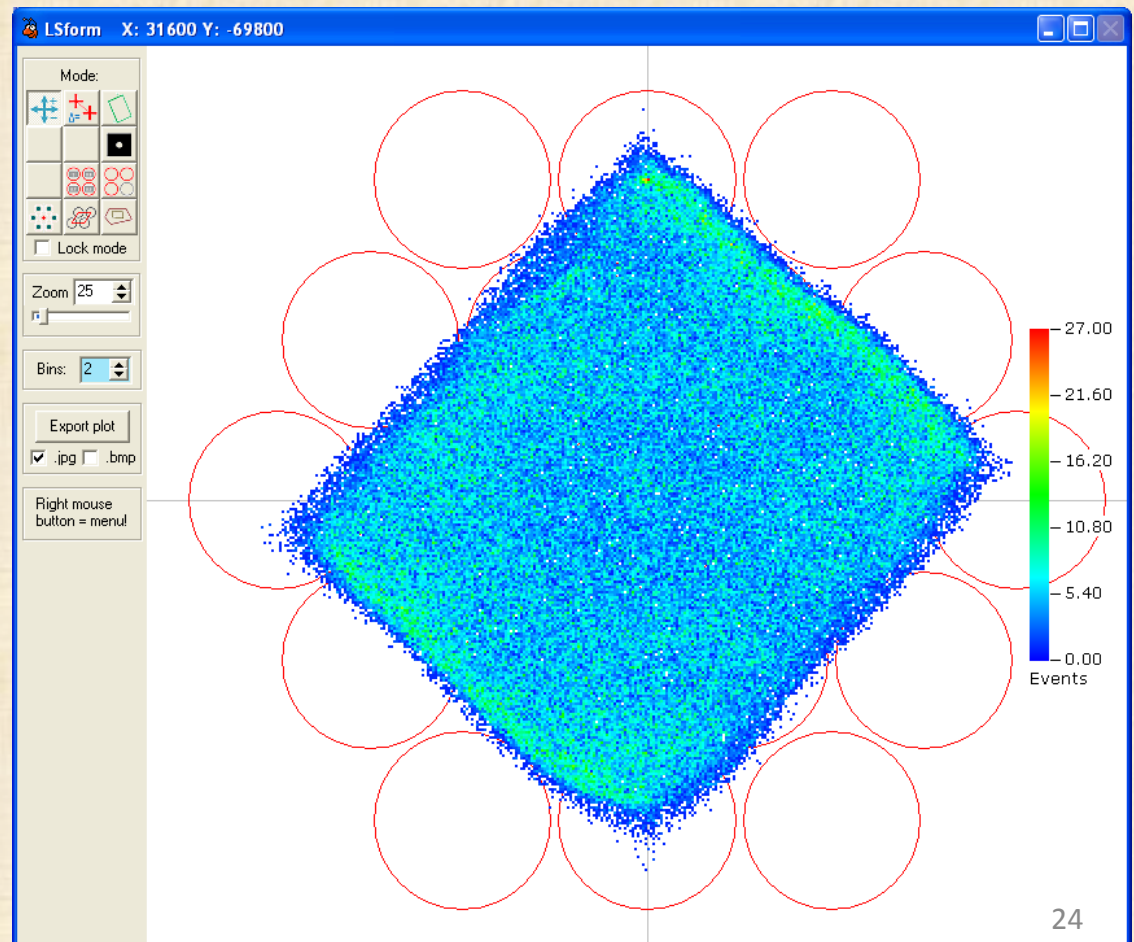
Next step – can introduce energy and chi-square filters.

Energy filter is typically not needed if strong sum cut-off filter is used.

Applying Chi-square filter with the a very relaxed range 0.1 – 10:



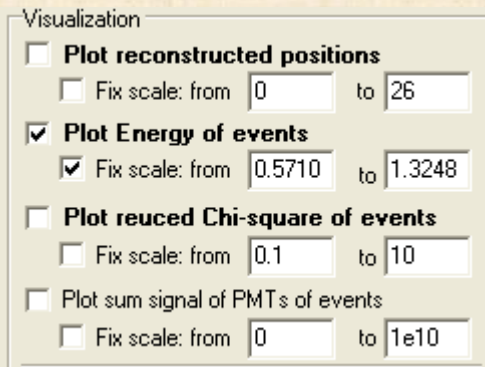
“Noise” is greatly reduced!



LRF reconstruction: individual LRF model

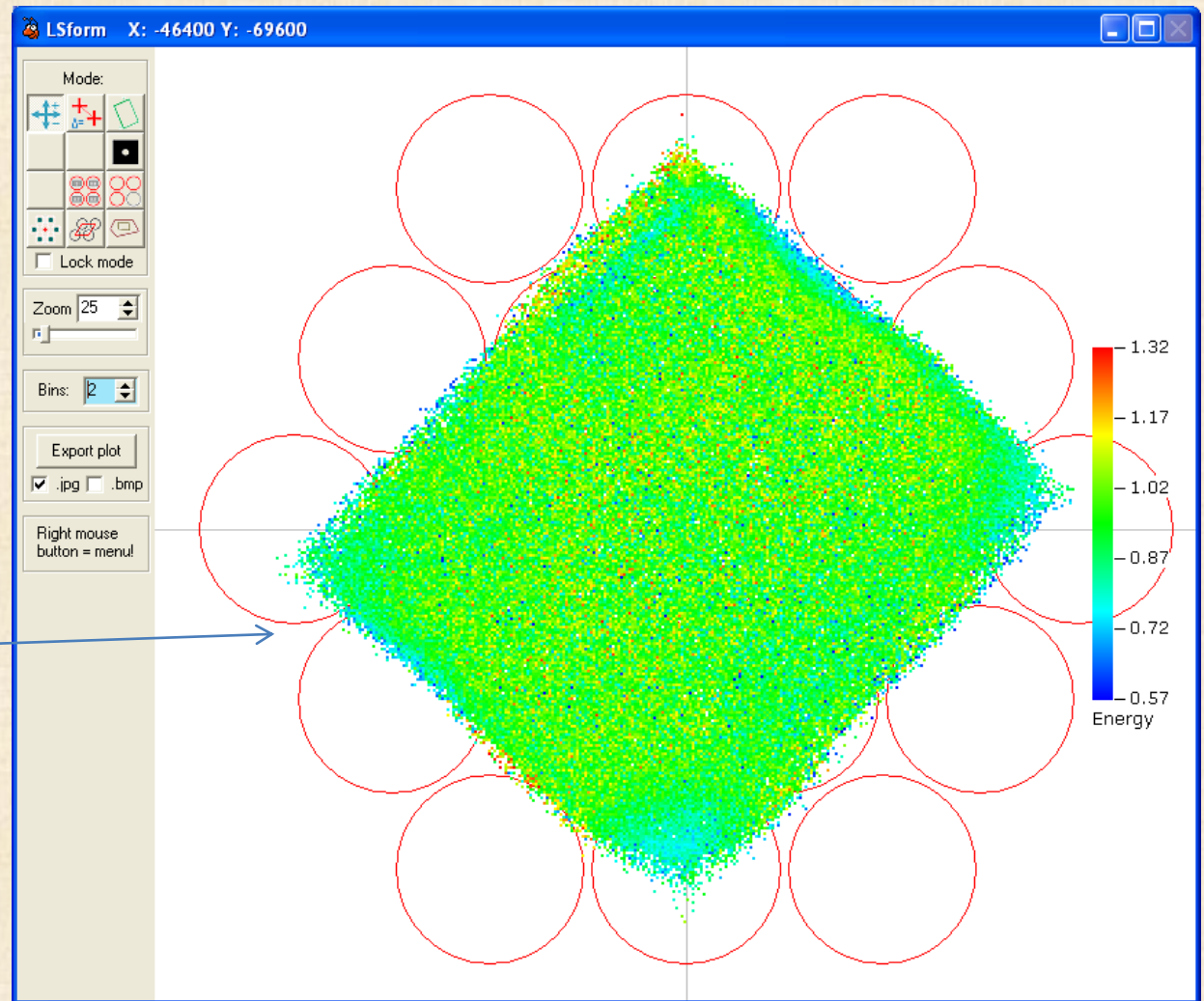
Now have to perform two quality-tests

1) Area distribution of energy – should be \sim uniform



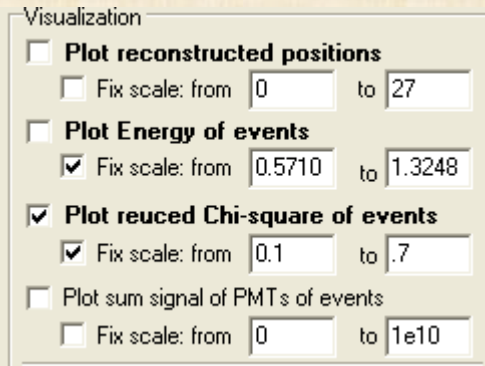
Essentially flat!

(only very small problems in corner areas – as expected)



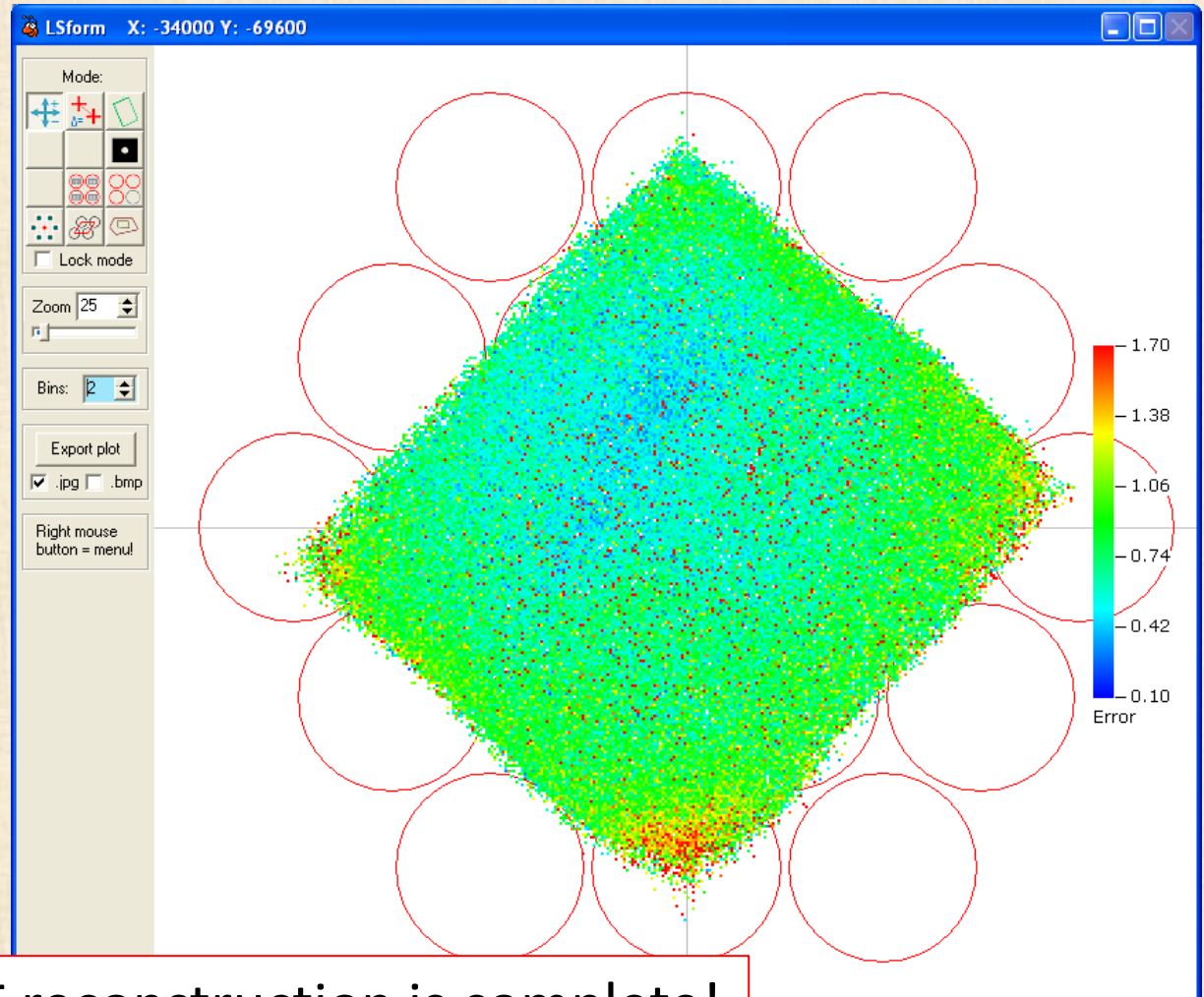
LRF reconstruction: individual LRF model

2) Chi-square distribution:



It is expected to have minimum in the center and have symmetric distribution.

Small problem (again) with the lower corner (need more strict sum cut-off filter?)

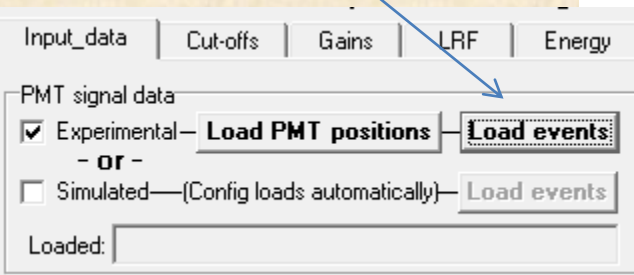


LRF reconstruction is complete!

Checking how good was the LRF reconstruction

“Multihole” mask data

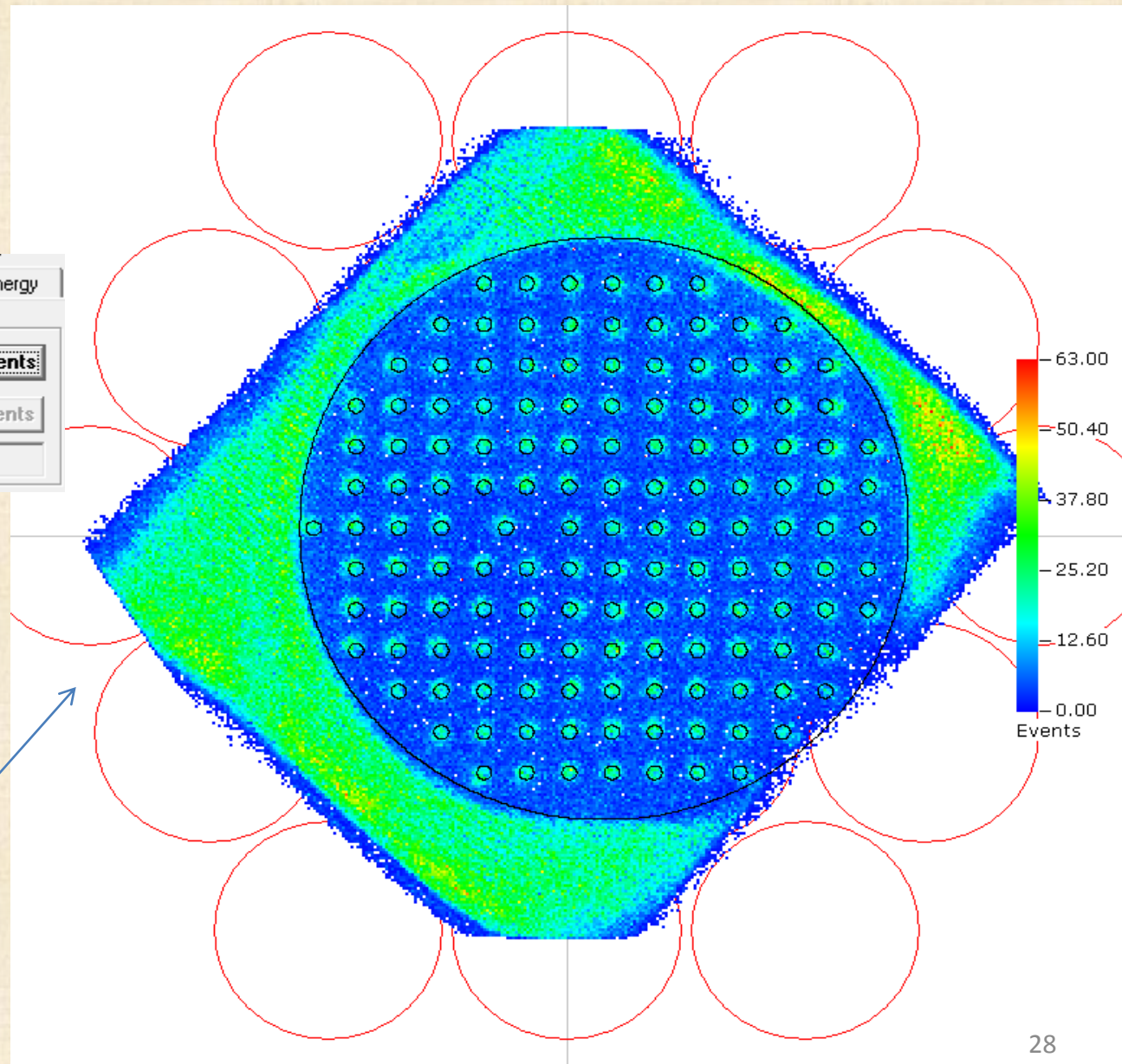
Loading data recorded
with the ISIS
“multihole” mask



All LRF/settings are
conserved!

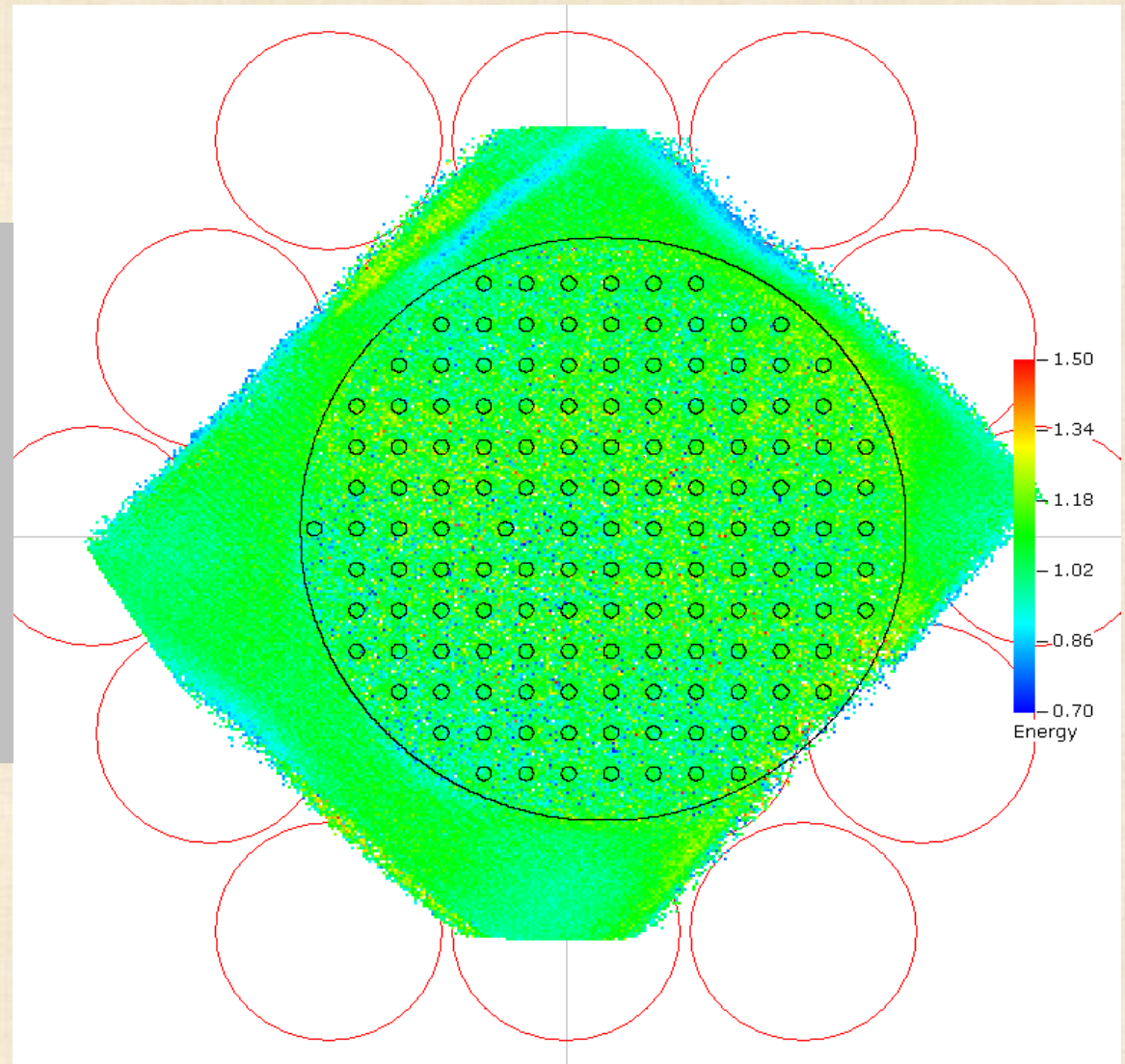
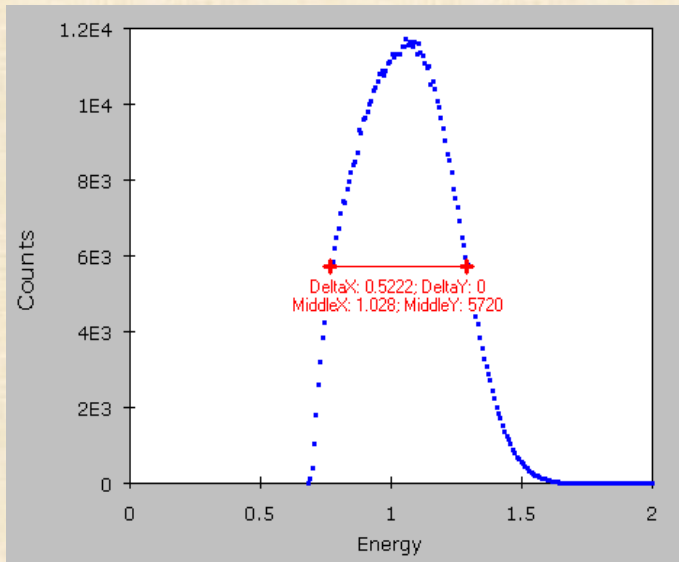
Running ML
reconstruction gives:

Good quality!

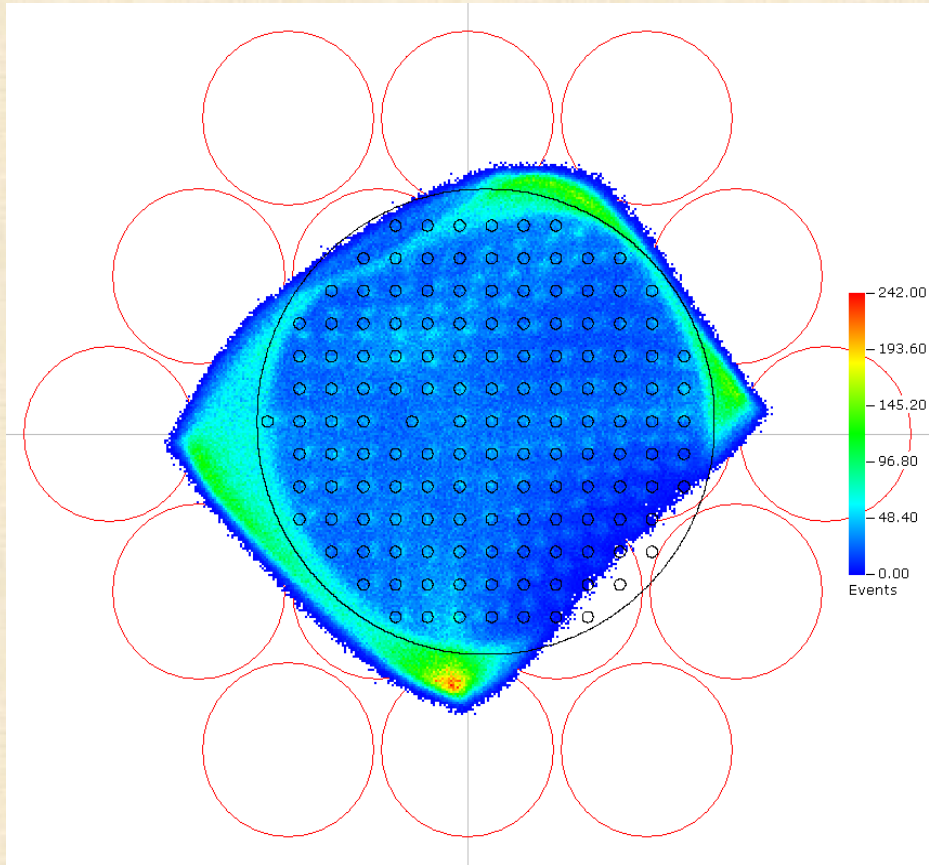


“Multihole” mask data

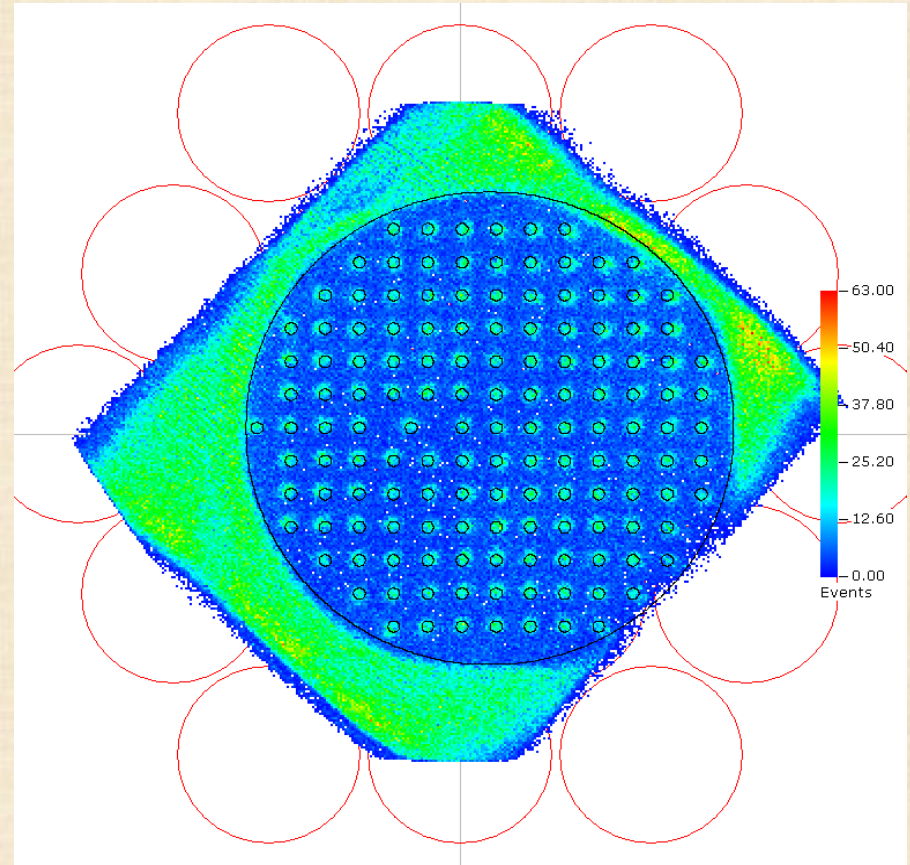
Checking energy distribution:



CoG vs ML reconstruction:



CoG, no gains



ML, individual LRFs

October run (another MSGC installed)

Two read-out systems:

Jülich and **Acqiris** data

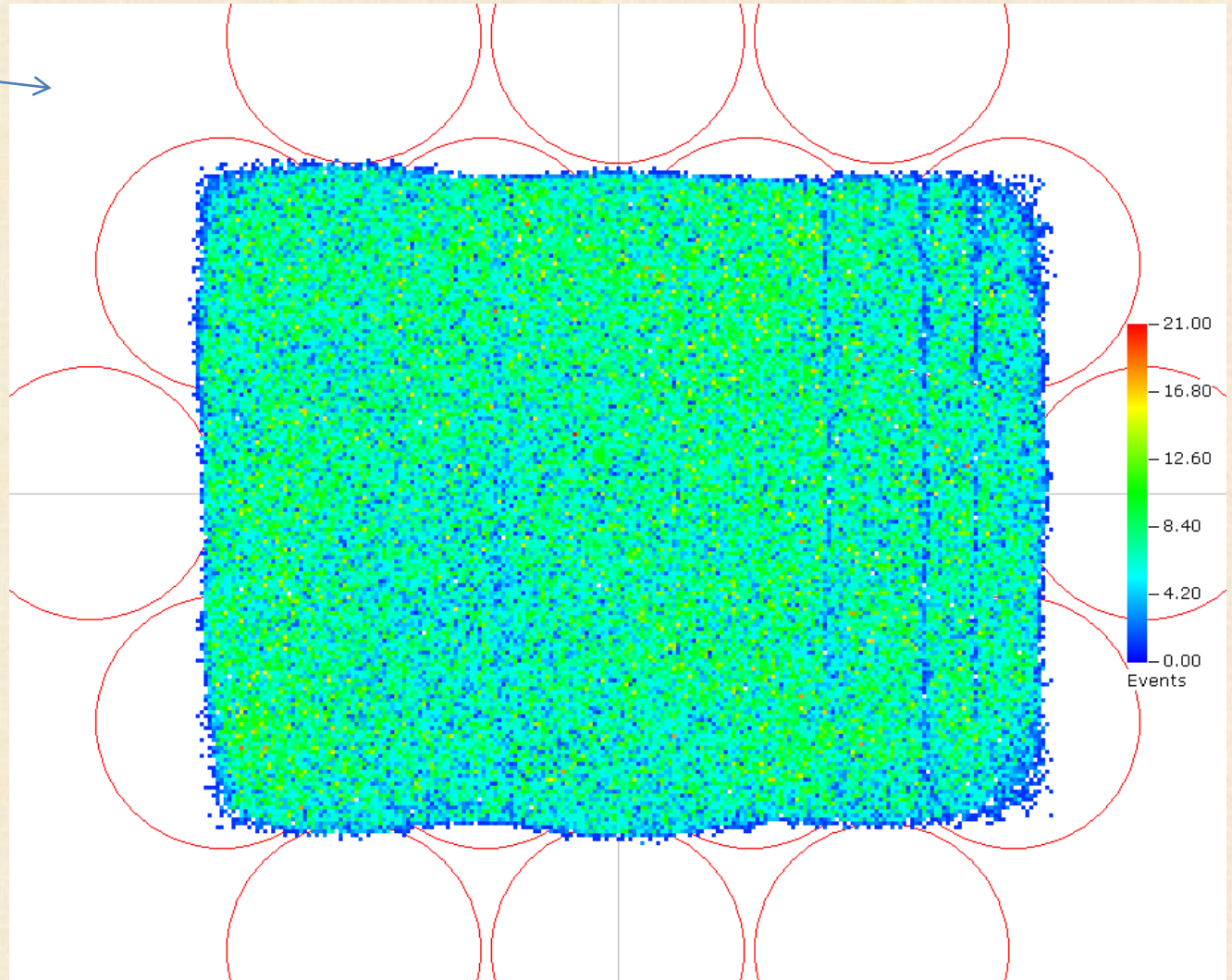
Jülich read-out data

Applying the same adaptive reconstruction technique, we get the following data:

Flood field →

Broken anodes still
show some bending

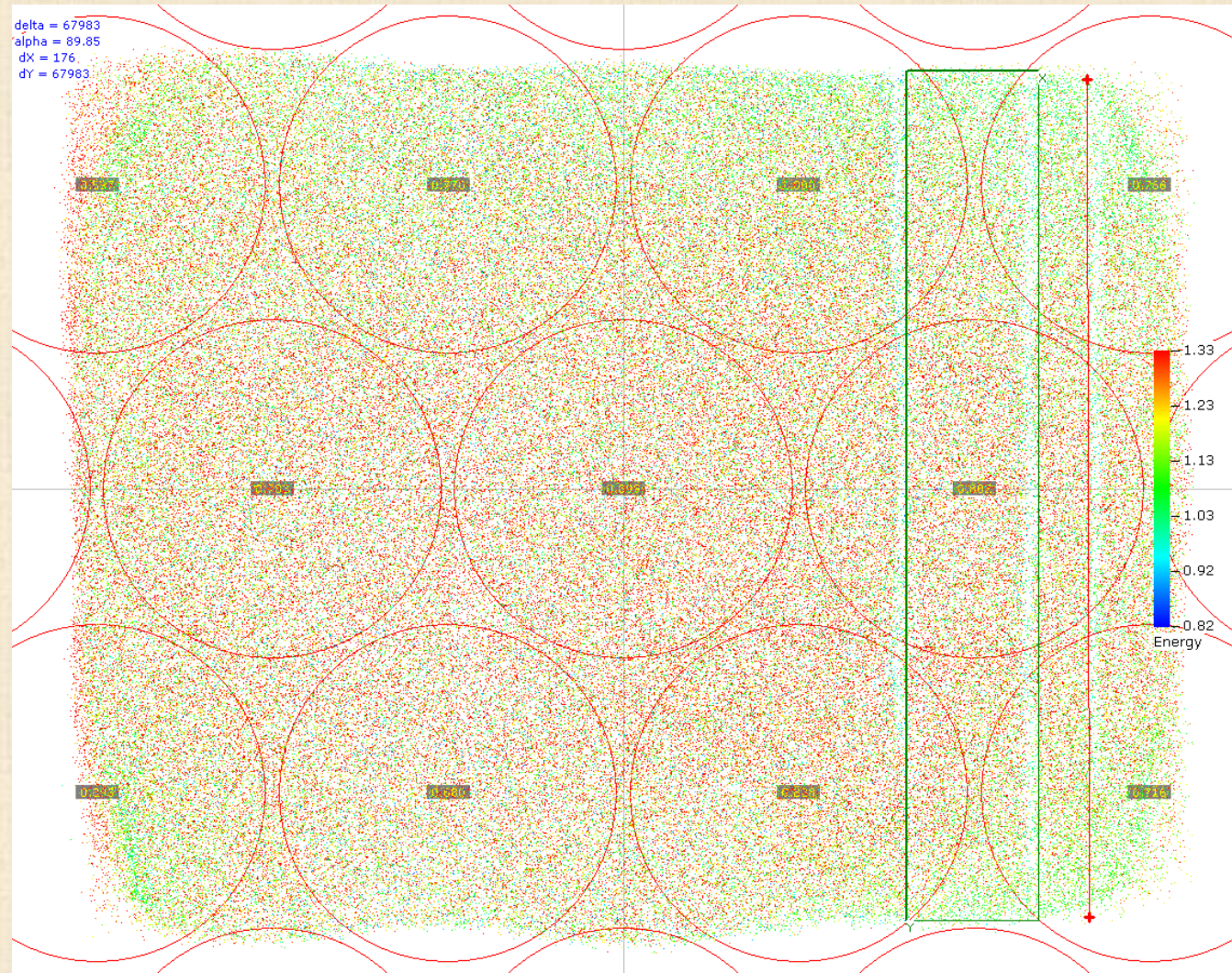
The MSGC rim
shows strong
“undulation”
Probable reason:
Scattered light
on HV connectors
and metalized
border areas of the
MSGC



Jülich read-out data

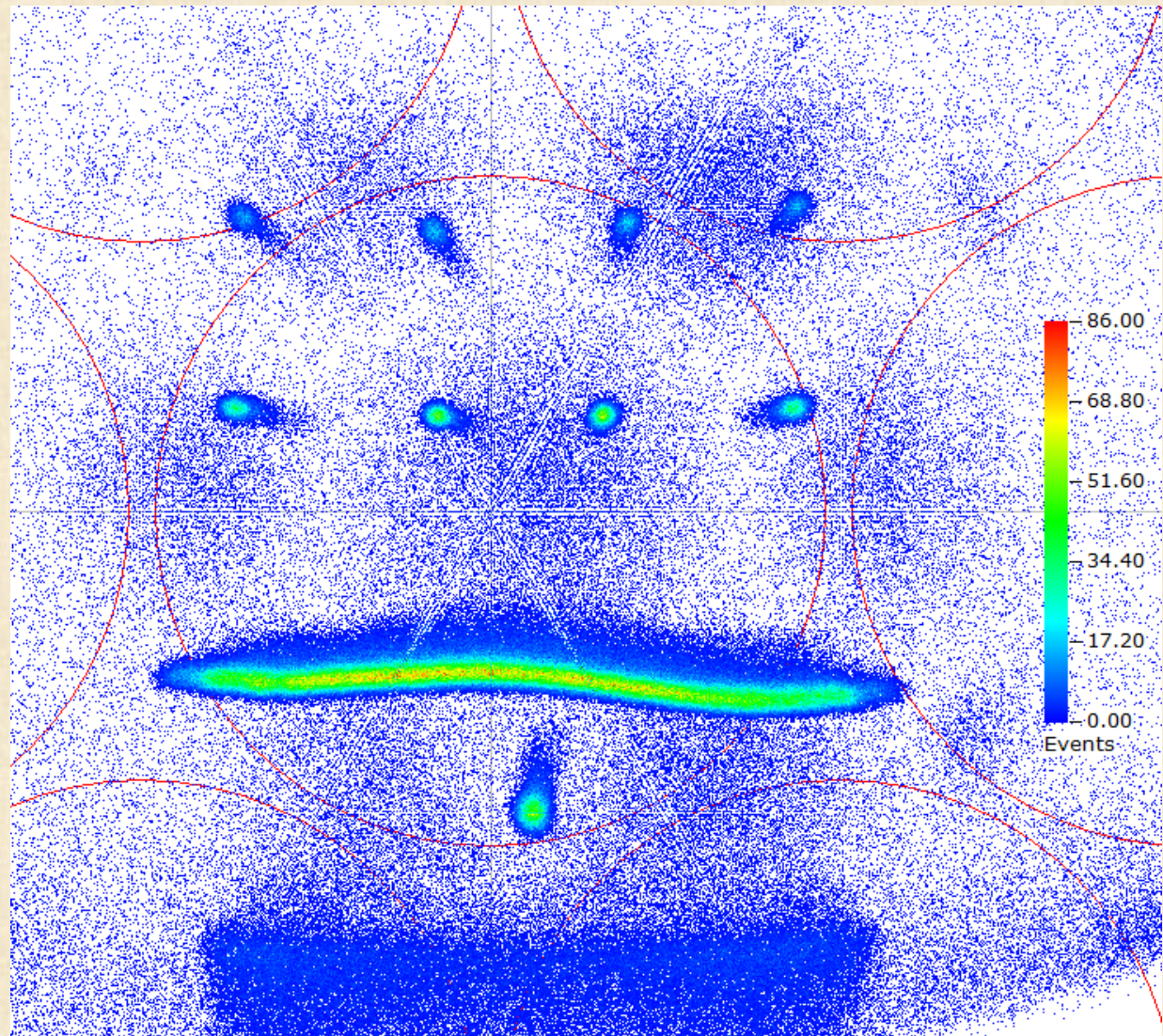
Another flood
Image (not final data!),
LS reconstruction,
plot of
energy distribution.

One can see that
that there are two
distinct ensembles
of events in the
corners!



Jülich read-out data: Slit mask

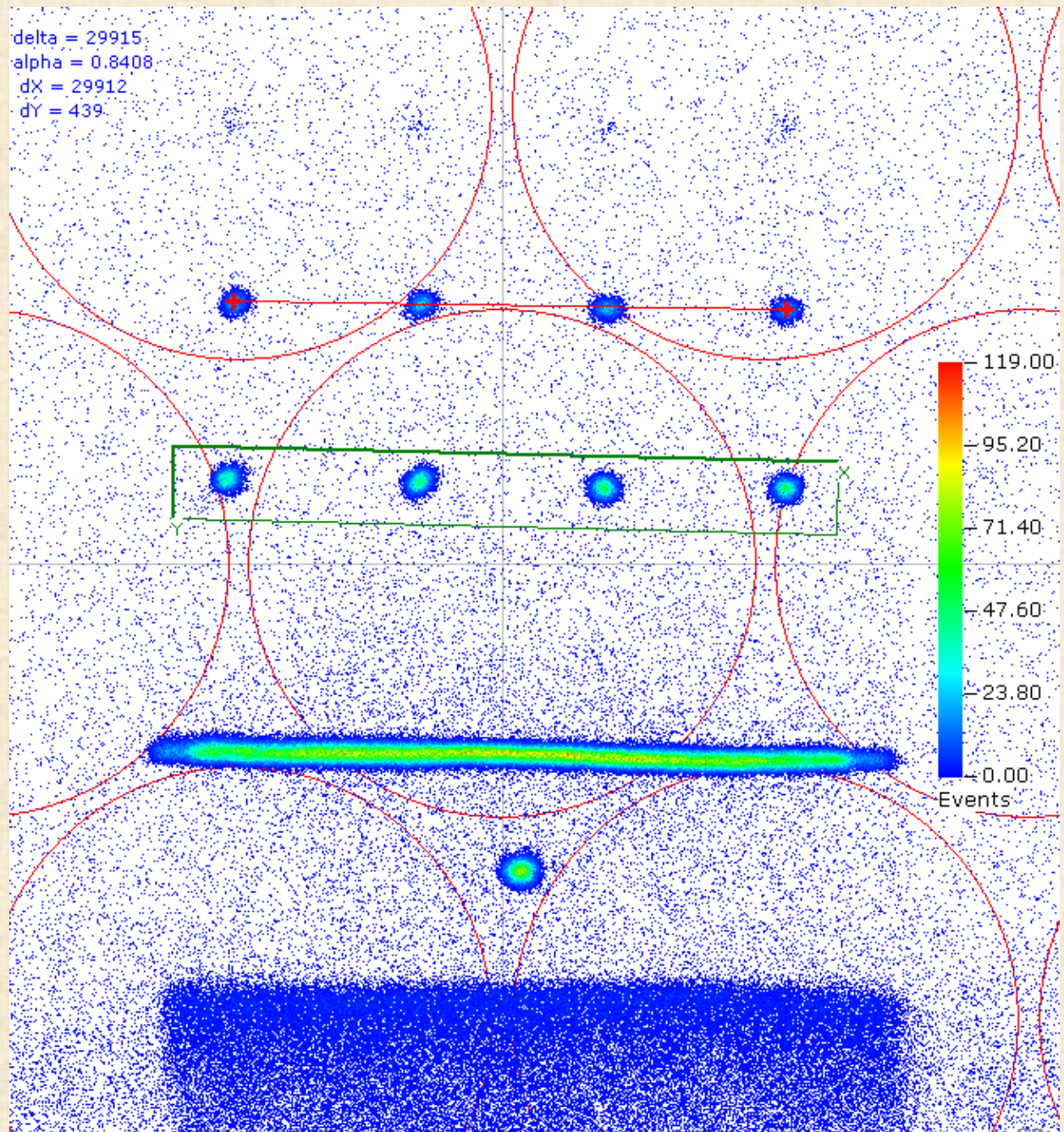
CoG
reconstruction,
no gains



ML
reconstruction,

Individual LRFs

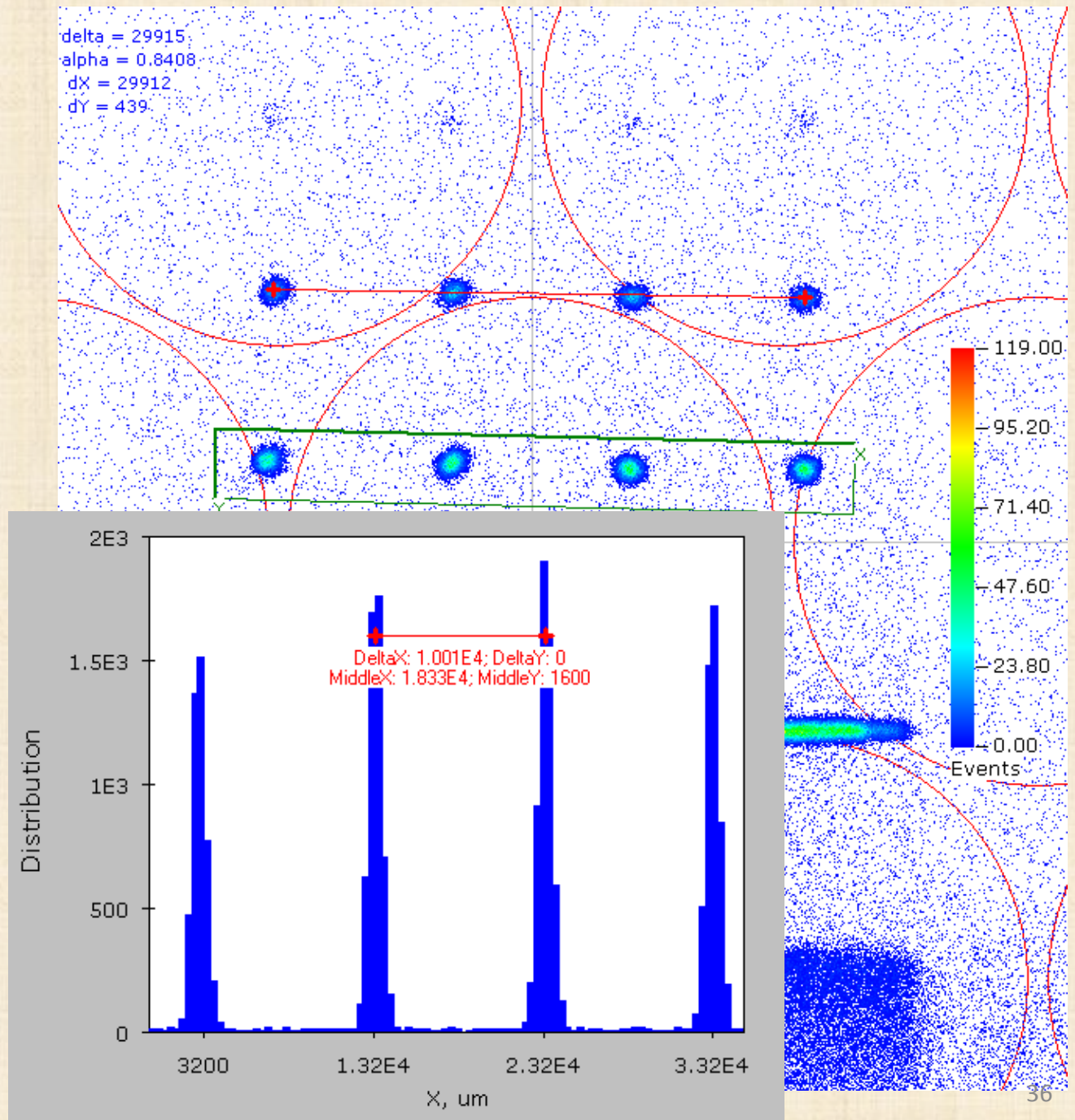
10 mm hole-to-
hole distance



ML
reconstruction,

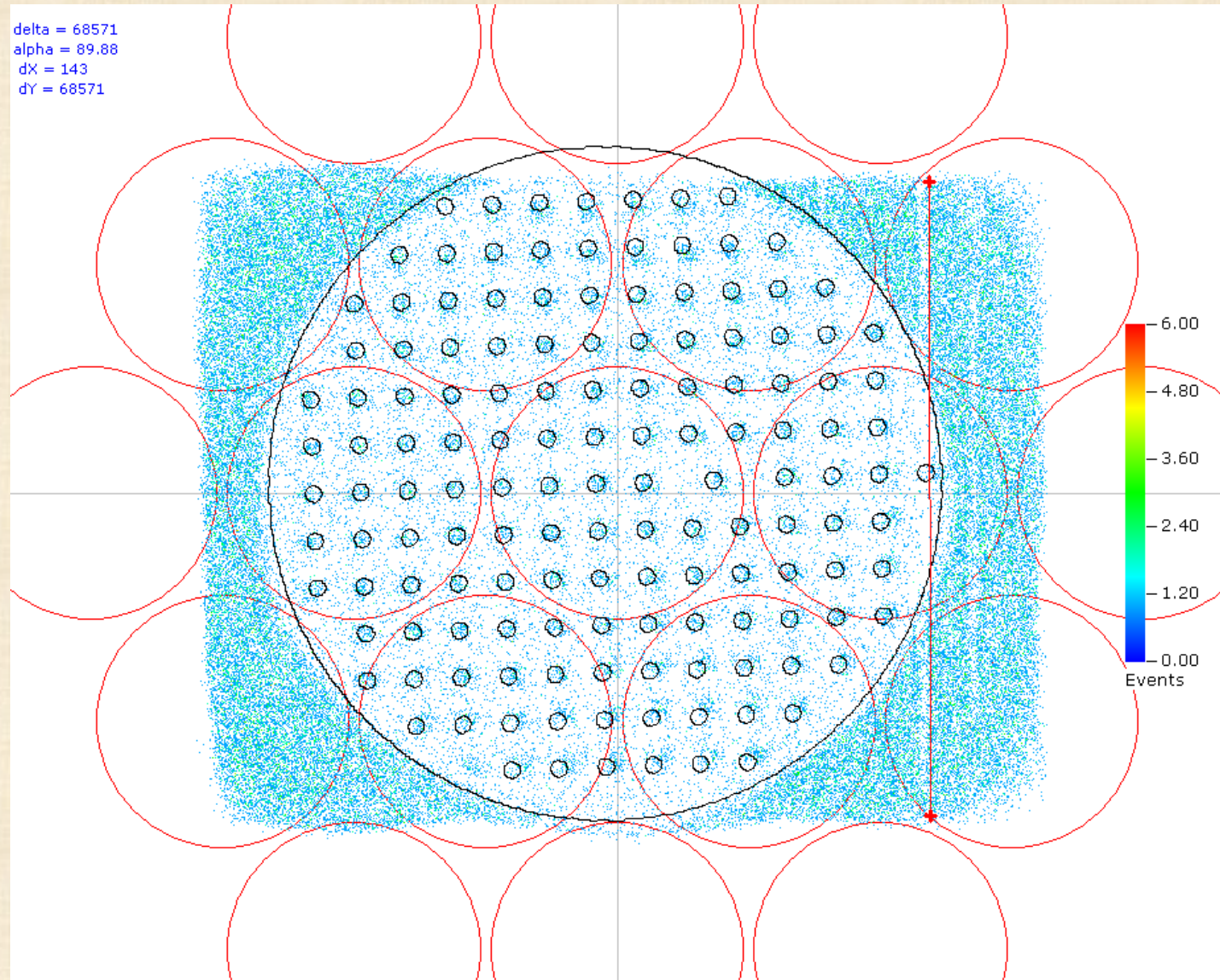
Individual LRFs

10 mm is well
reproduced!



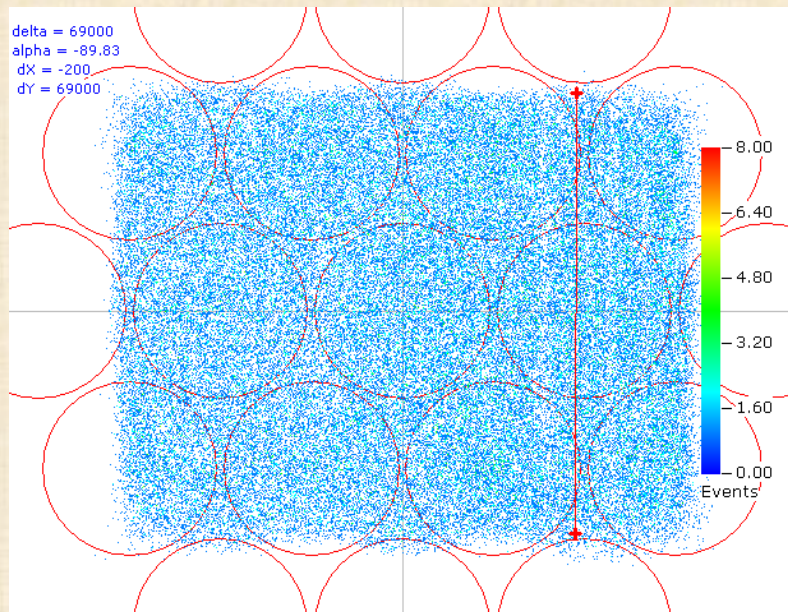
Jülich read-out data: Multihole mask

ML
reconstruction,
Individual LRFs

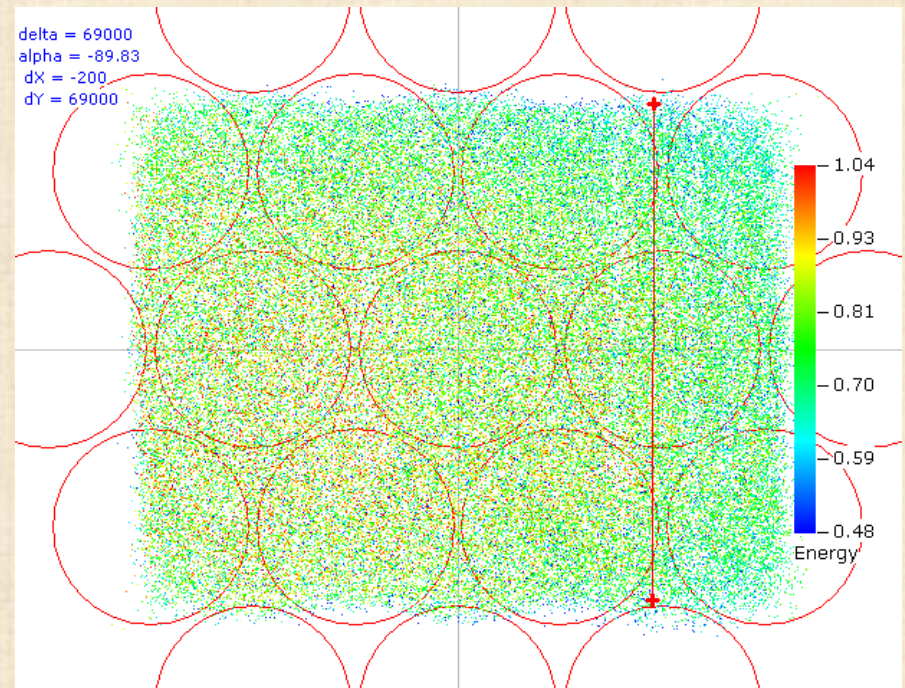


Acqiris read-out: Flood data

Problem – in the PMT signal data, the offsets were not corrected for, and some of them were negative!



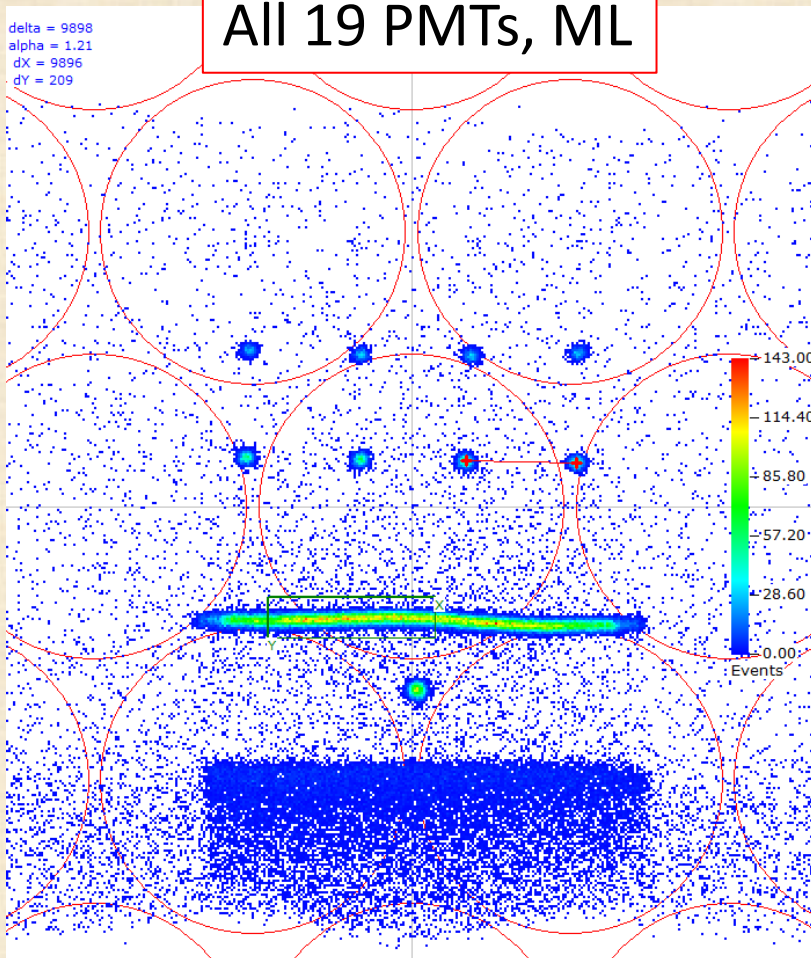
Positions, LS
reconstruction,
Individual LRFs



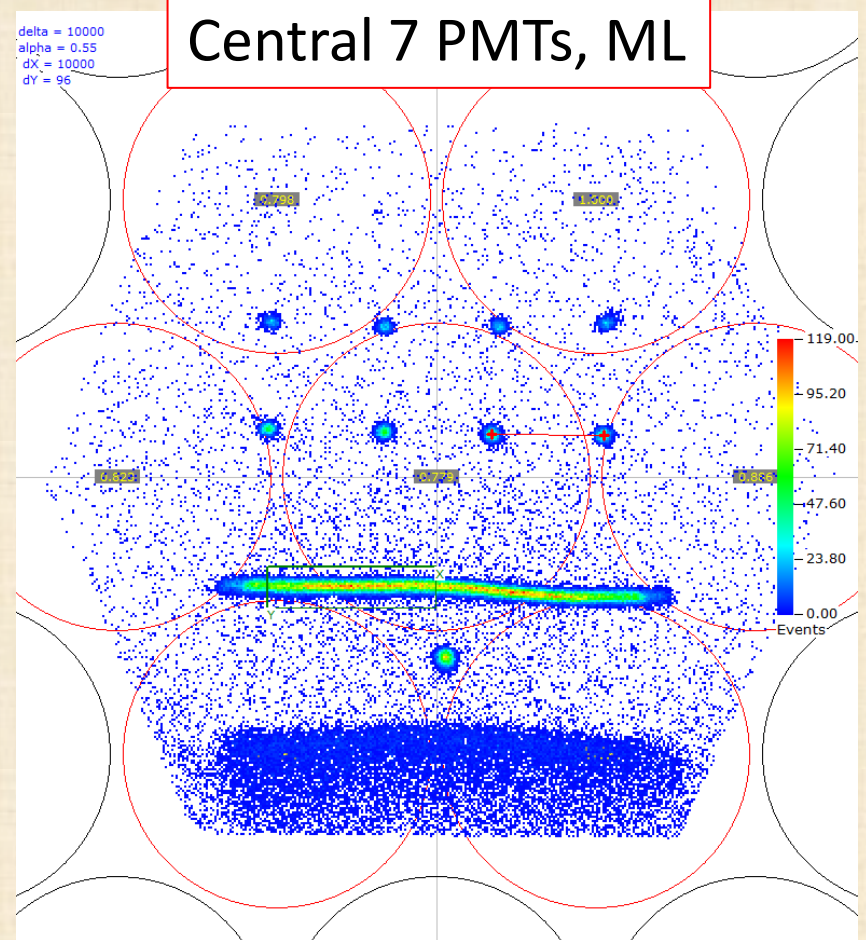
Energy, LS
reconstruction,
Individual LRFs

Acqiris read-out: Slit mask

All 19 PMTs, ML



Central 7 PMTs, ML



ML perform significantly better than LS
7-PMT reconstruction is better than 19-PMT one!

Post-processing in ANTS

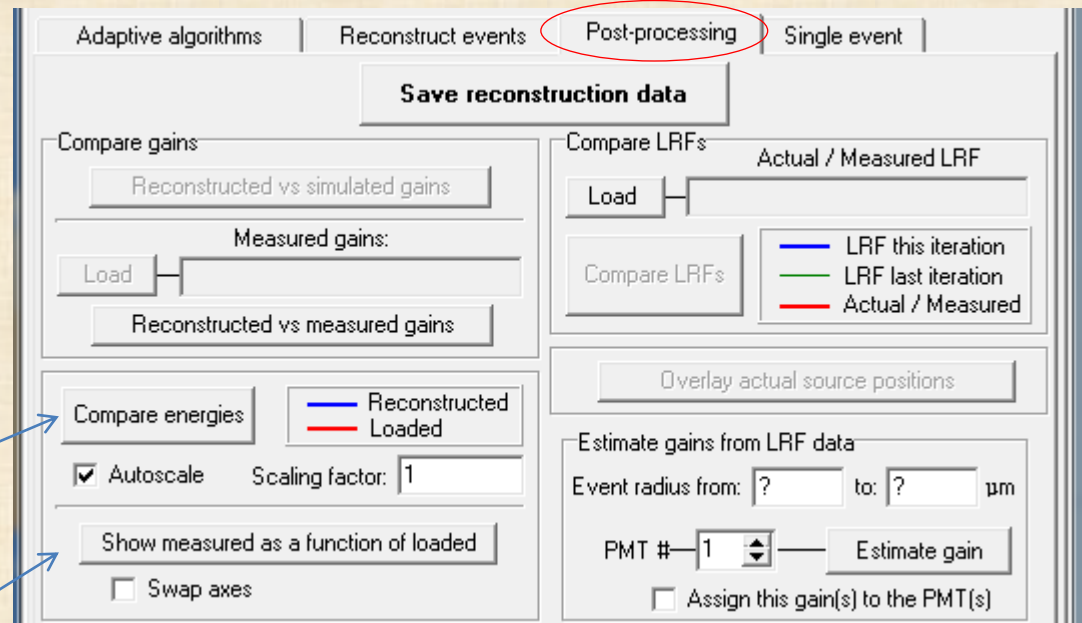
Just a few features

Post-processing

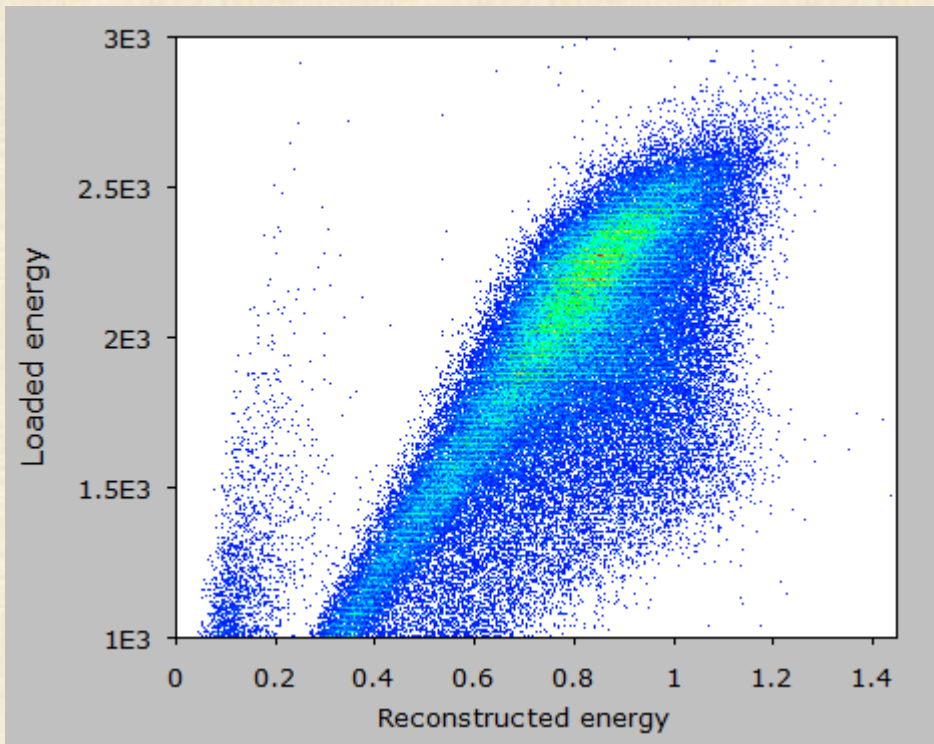
With Acqiris, the energy of events was recorded (anode signal).

This energy can be compared with the reconstructed energy.

“**Compare energies**” shows both distributions, and the “**Show measured as a function of loaded**” plots one versus the other (over all events).

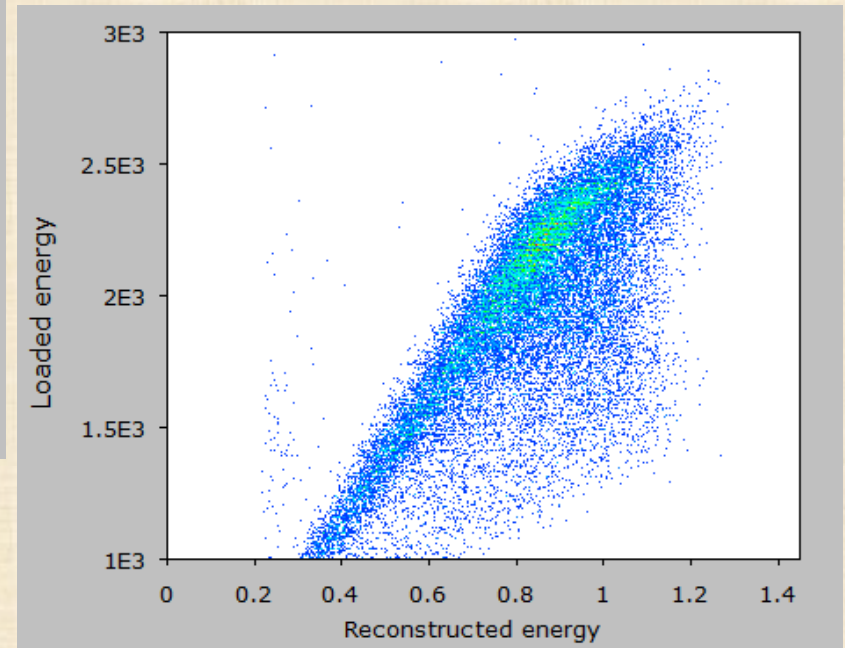


Compare energies



No cut-offs, all MSGC area

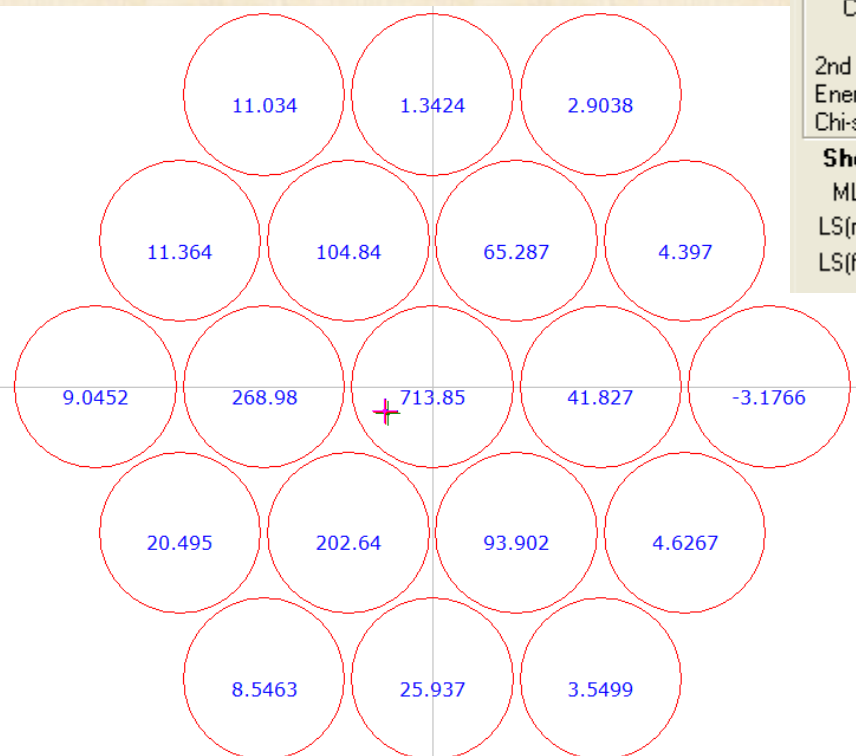
All event filters are respected!



Sum cut-off on, 20 mm x 20 mm central area

Single event processing

Example of a “good” event



Adaptive algorithms | Reconstruct events | Post-processing | **Single event**

Events number: 89 Refresh

☒ Show PMT signals on graphical window
☒ Apply signal/photoelectron scaling
☐ Scale loaded energy by: 1

Status of filters:
 Cut-offs of individual PMTs: Pass
 Cut-off fir the sum signal: Pass
 1st spatial: --
 2nd spatial ML: -- LS(ml): -- LS(fit): --
 Energy ML: -- LS(ml): -- LS(fit): --
 Chi-square ML: -- LS(ml): -- LS(fit): --

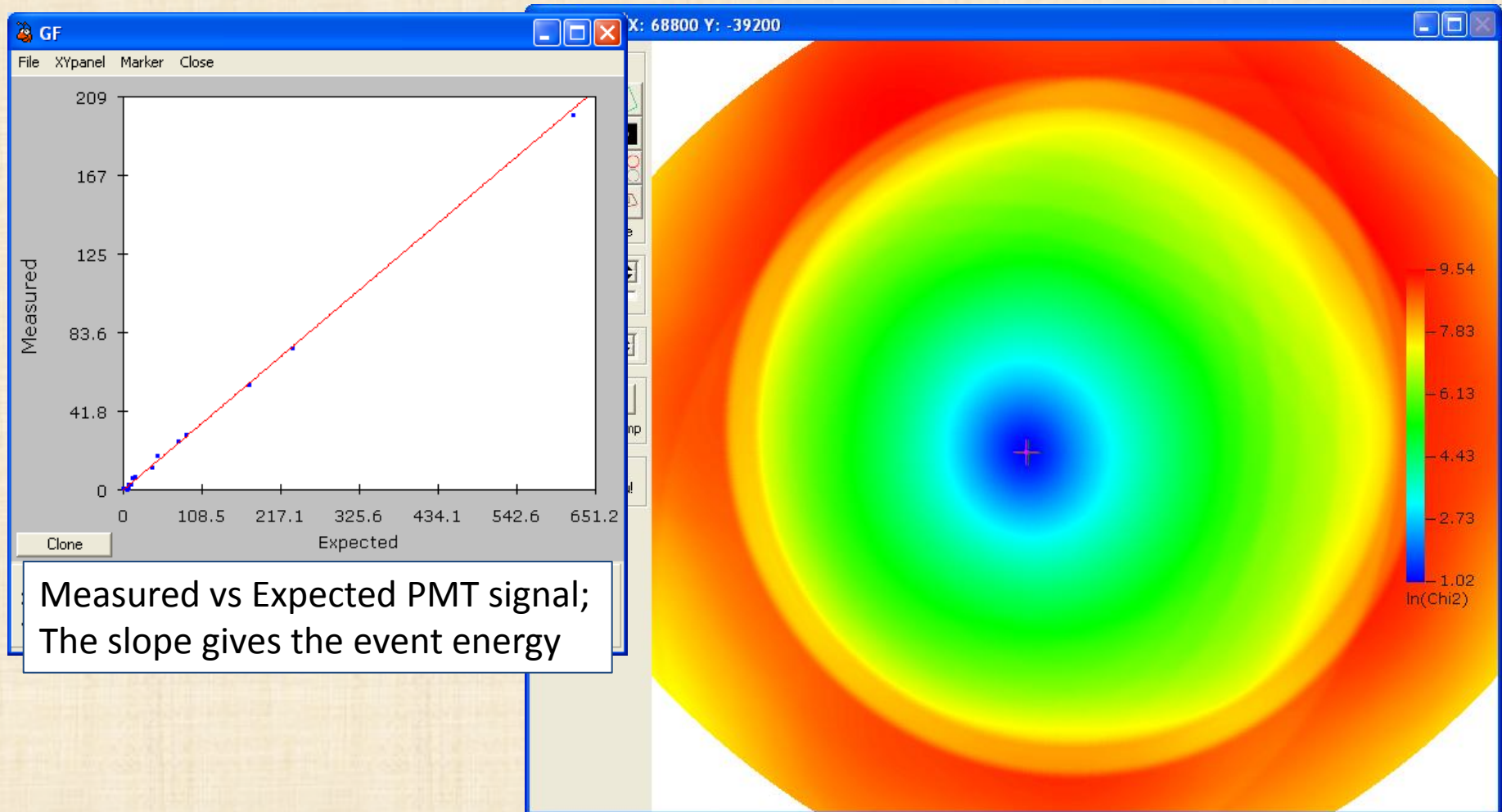
Show: Energy ☒ Probability ☐ Chi-square ☒

	X, um	Y, um
CoG:	-7698	4342
ML:	-7998	3892
LS (ml energy):	-8065	4152
LS (fit energy):	-8058	4148
----- Energy -----		
ML:	0.32661	
LS (ml energy):	0.32523	
LS (fit energy):	0.32389	
----- Chi-square -----		
ML:	0.81674	
LS (ml energy):	0.83129	
LS (fit energy):	0.83655	

	X, um	Y, um
CoG:	-7698	4342
ML:	-7998	3892
LS (ml energy):	-8065	4152

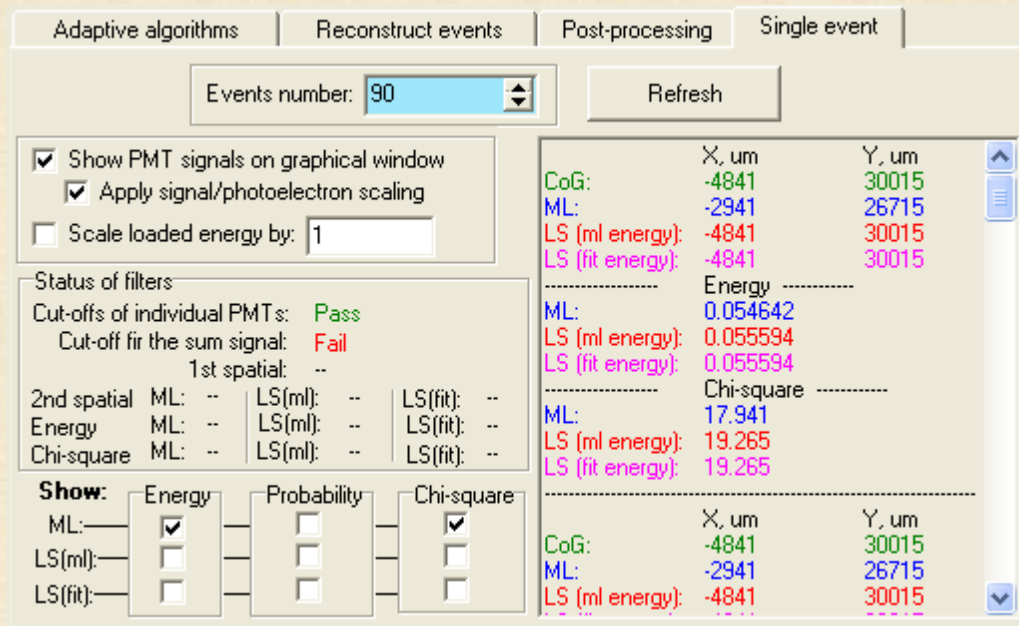
Information shown (ML and two LS algorithms):
 Reconstruction position, energy
 and chi-square;
 Status of all event filters;
 PMT signals;

Single event processing: good event

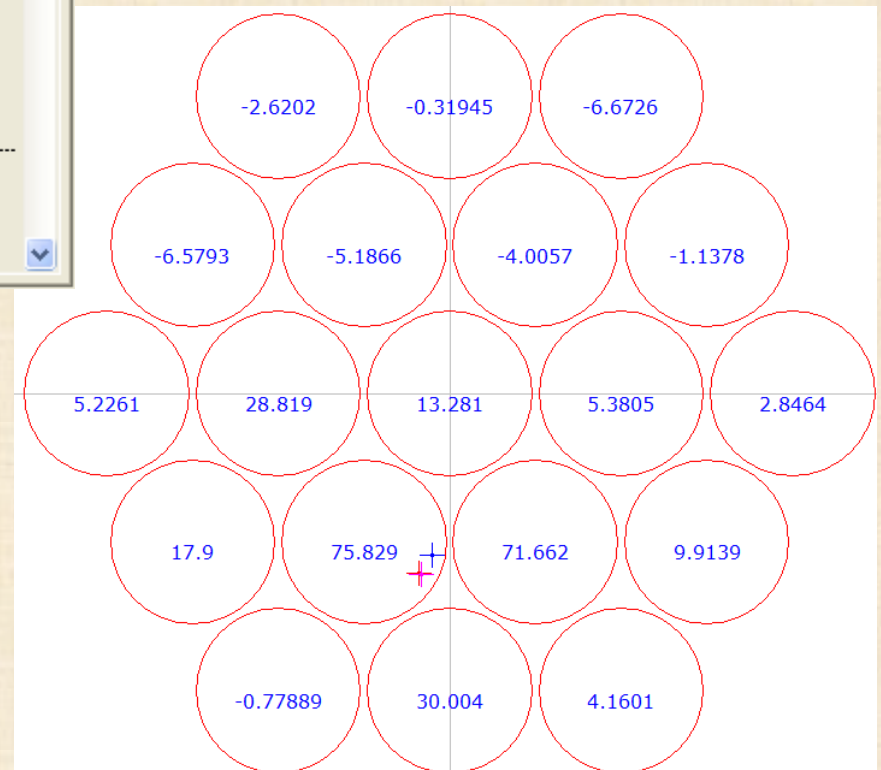


Chi-square vs position: Visible area is scanned (source position is assumed at each location) and the Chi-square is reported.

Single event processing: bad event



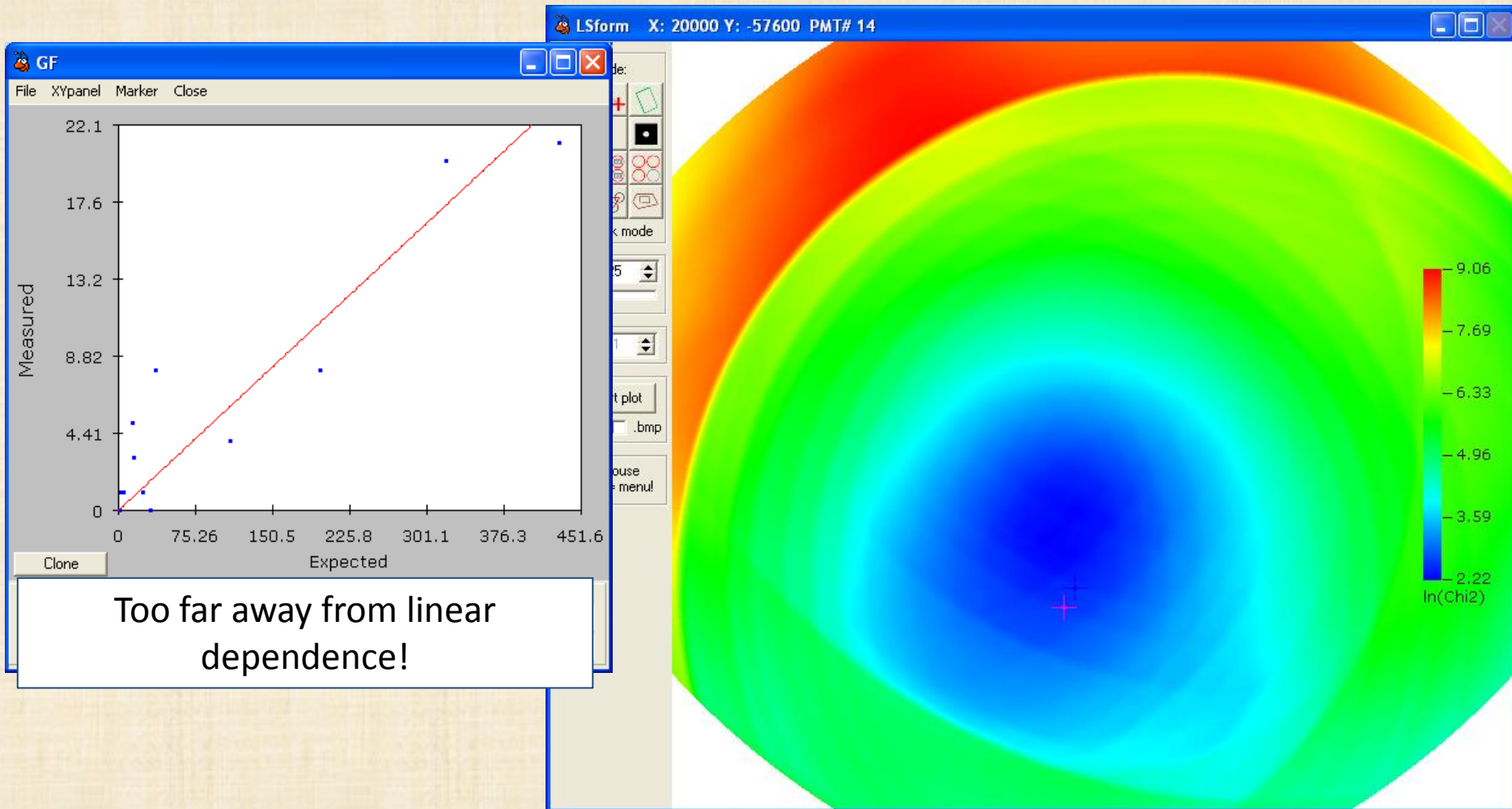
Example of a “bad” event



Too low energy,
Too large Chi-square;
LS position = CoG position.

Failed Sum cut-off filter.

Single event processing: bad event



Broad min area; Many local minima.

Can be used as an advanced event filter!

GSPC 19
contributing to the
modern art ☺

Artifacts in the
CoG reconstruction
due to discreteness
of the PMT signals:
There are
“forbidden bands”
in space
(60 degrees symmetry)

