

# Advance Gamma Tracking Array AGATA

Dino Bazzacco  
INFN Padova

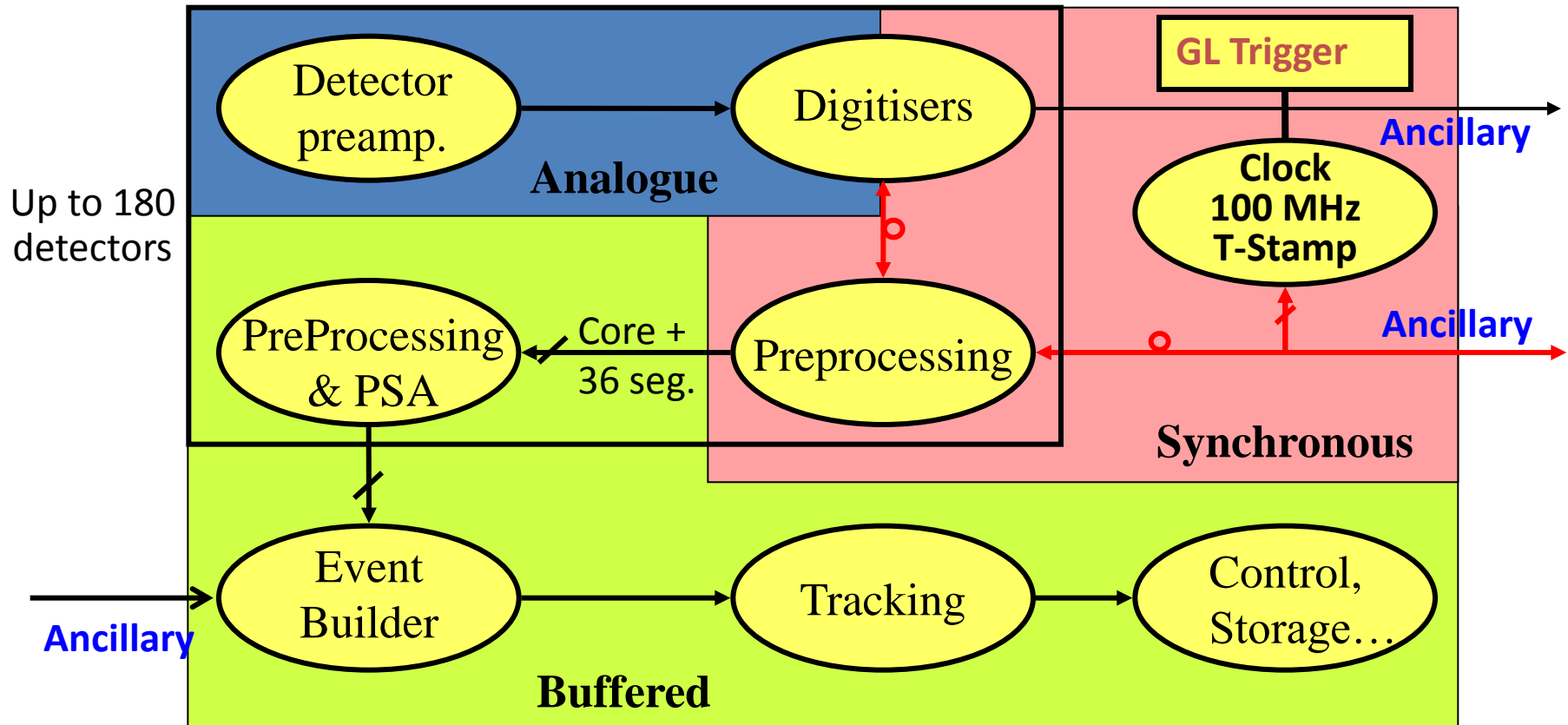
Part 1: Review of AGATA  
Part 2: Data Processing

EGAN school 2011, December 5 - 9, 2011, Liverpool

# Architecture of the system

- **Local Level :** **where the individual detectors don't know of each other.**
  - Electronics and computing follow a model with minimum coupling among the individual elements (detectors), which are operated independently as long as possible
  - Electronics is almost completely digital, operated on the same 100 MHz clock
  - Data processing (in the electronics and in the front-end computers) is the same for all detectors and proceeds in parallel
  - Every chunk of data produced is tagged with a time stamp that gives the absolute time (with a precision of 10 ns) since the last startup of the system. (with 48 bits the roll around takes place every 32.5 days)
- **Global Level :** **where the detectors do know of each other**
  - By means of the real time trigger, which reduce the data rate by selecting the class of interesting events
  - Via the event builder and merger that assemble the event fragments (including the ancillaries) into complete events that are further processed
  - In the tracking and in the Physical analysis stages
- ❖ The fact that 3 (and 2 at GSI) crystals are packed in clusters does not produce any correlation in the data processing (not so for the Detector Support System, but this is not relevant here)

# Structure of Electronics and DAQ



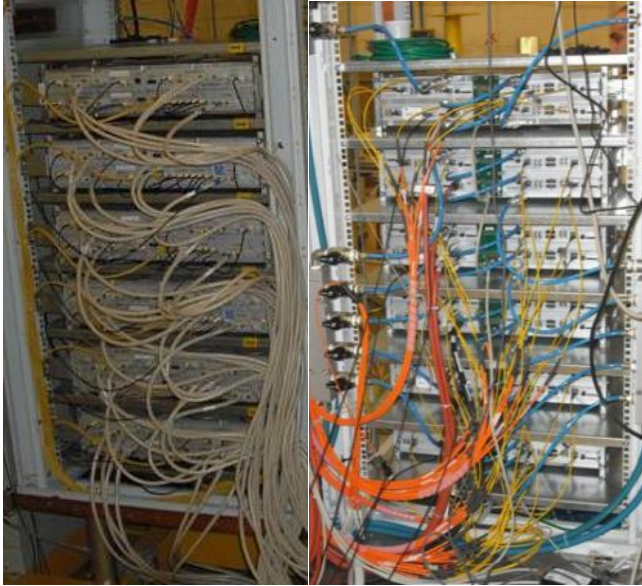
## Other detectors

1. interface to GTS via mezzanine
2. merge time-stamped data into event builder (merger)

# AGATA Data Processing

Digitisers  
in the experimental hall

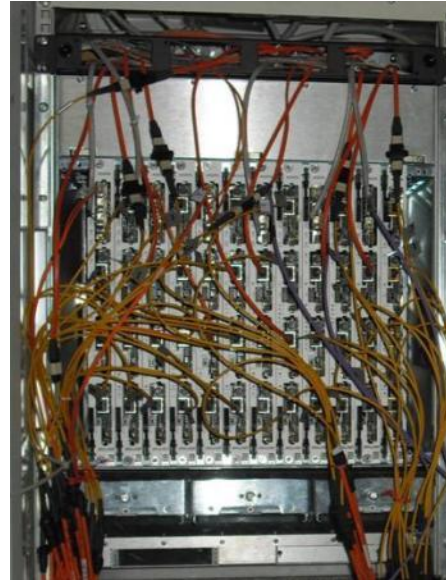
10 m long MDR cables



- One digitizer per crystal:
- core module with
    - 1 core board (clock + 2 cores)
    - 2 segment boards (A B)
  - segment module with
    - 4 segment boards (C D E F)

Digital proc. electronics  
in the users area

80 m long optical fibers



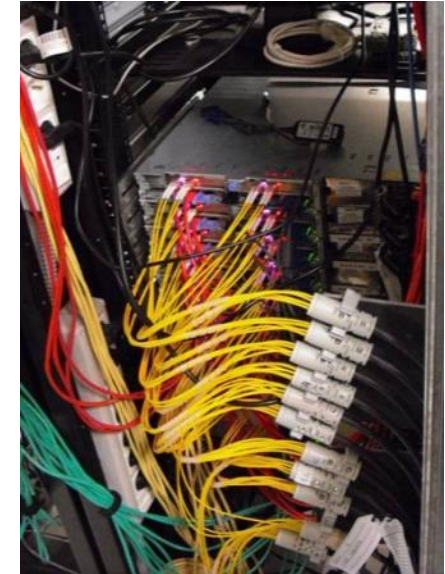
- 2 ATCA carriers per crystal:
- Master with
    - 1 GTS mezzanine
    - 3 proc. mezzanines (Core A B)
  - Slave with
    - 4 proc. mezzanines (C D E F)



6 channels processing mezzanine

Computer farm  
in the computing room

20 m long optical fibers

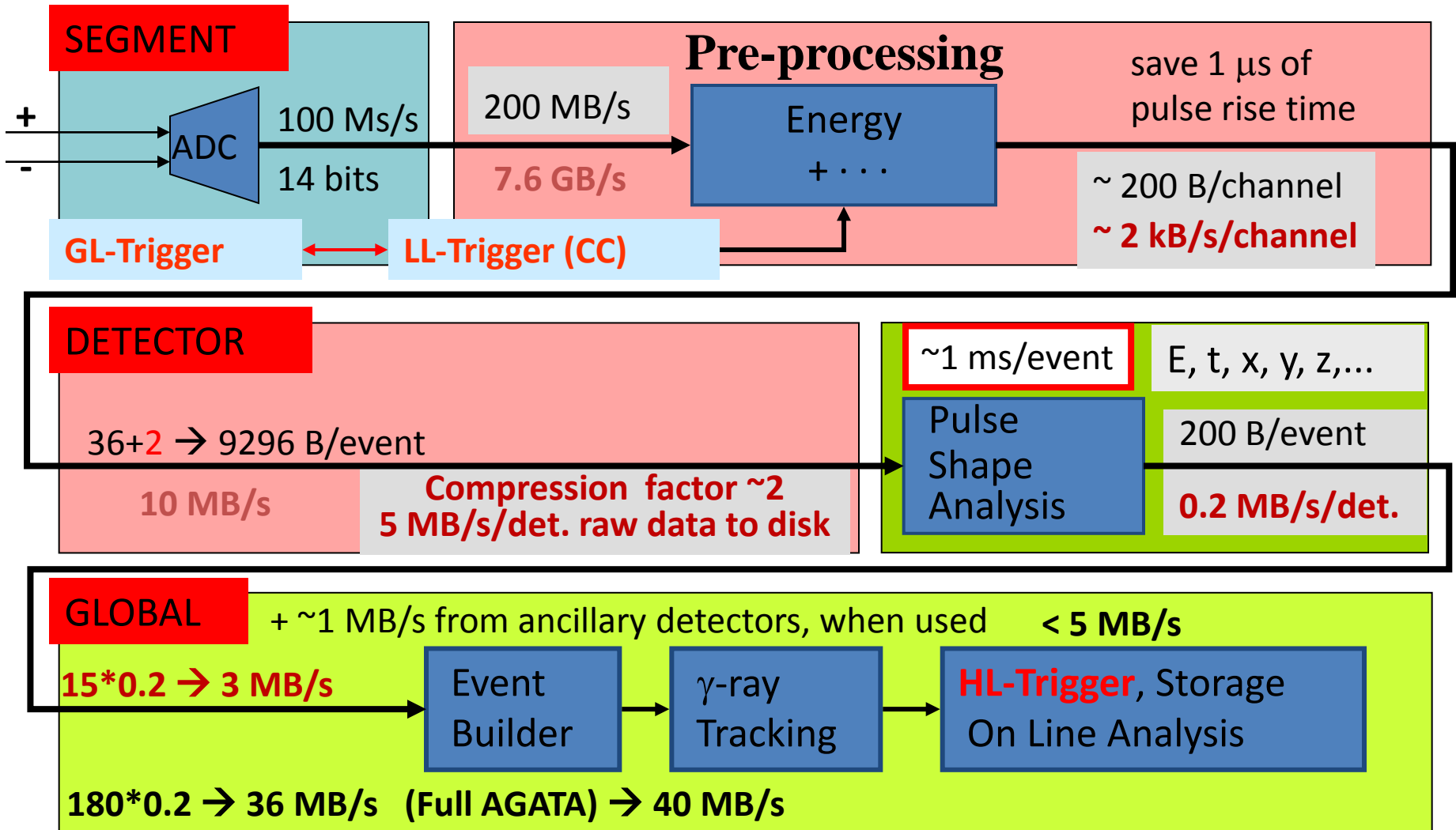


LAN to the disk servers

- 1 pizza-box per crystal:
- Readout and save orig. data
  - Pre-processing of events
  - PSA
- 10 pizza-boxes for
- Event Builder and Merger
  - Ancillary and Tracking
- 120 TB of storage + Archiving on Grid T1

# Data rates in AGATA Demonstrator

50 kHz singles  $\rightarrow$  1 kHz triggered



Saving the original data produces  $\sim 5 \div 30$  TB / experiment

Our disk server (100 TB) is always almost full  $\rightarrow$  data archived to the GRID

# GTS : the system coordinator

All detectors operated on the same 100 MHz clock

Downwards

100 MHz clock + 48 bit Timestamp (updated every 16 clock cycles)

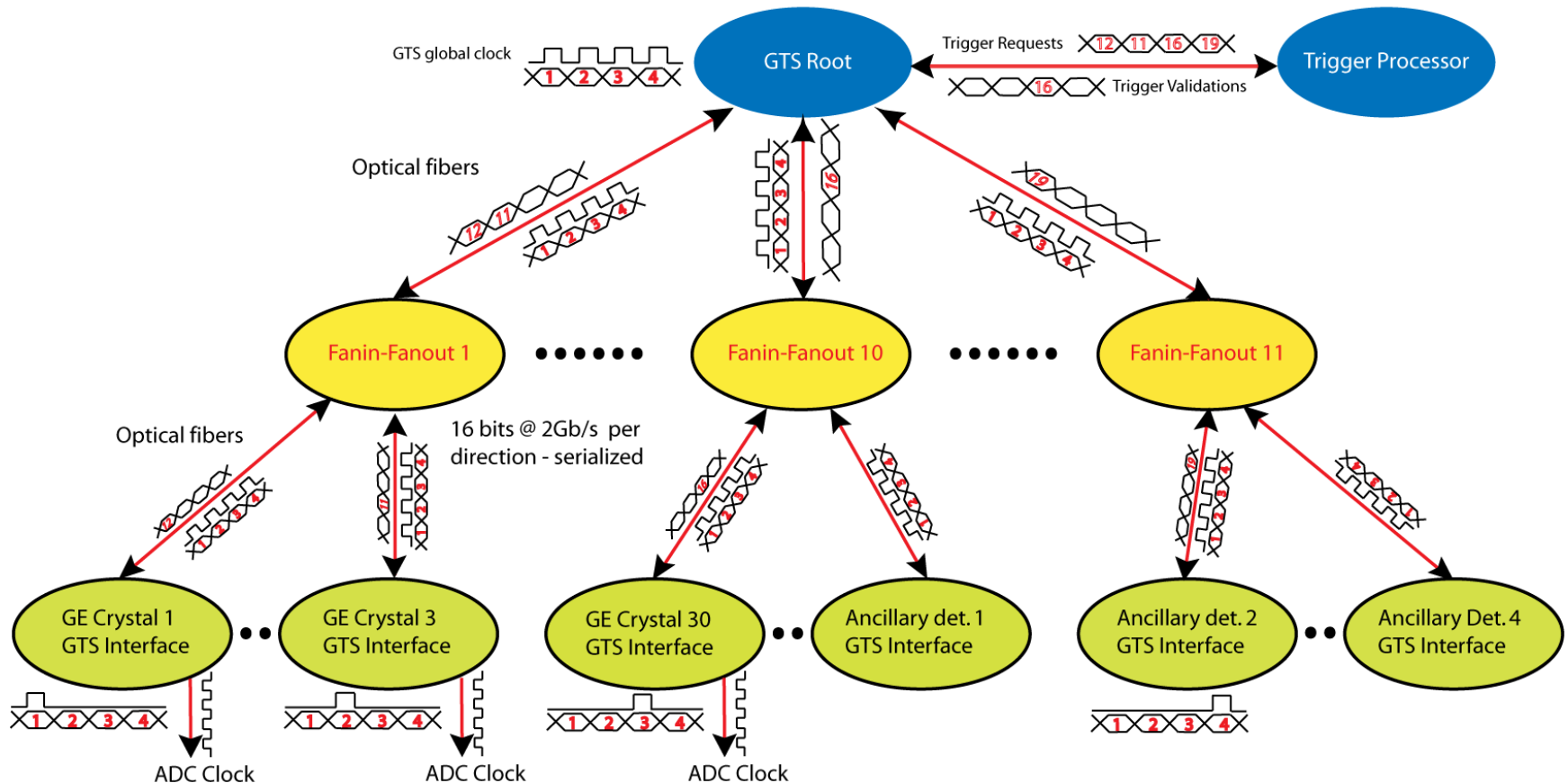
Upwards

trigger requests, consisting of address (8 bit) and timestamp (16 bit)

max request rate 10 MHz total, 1 MHz/detector

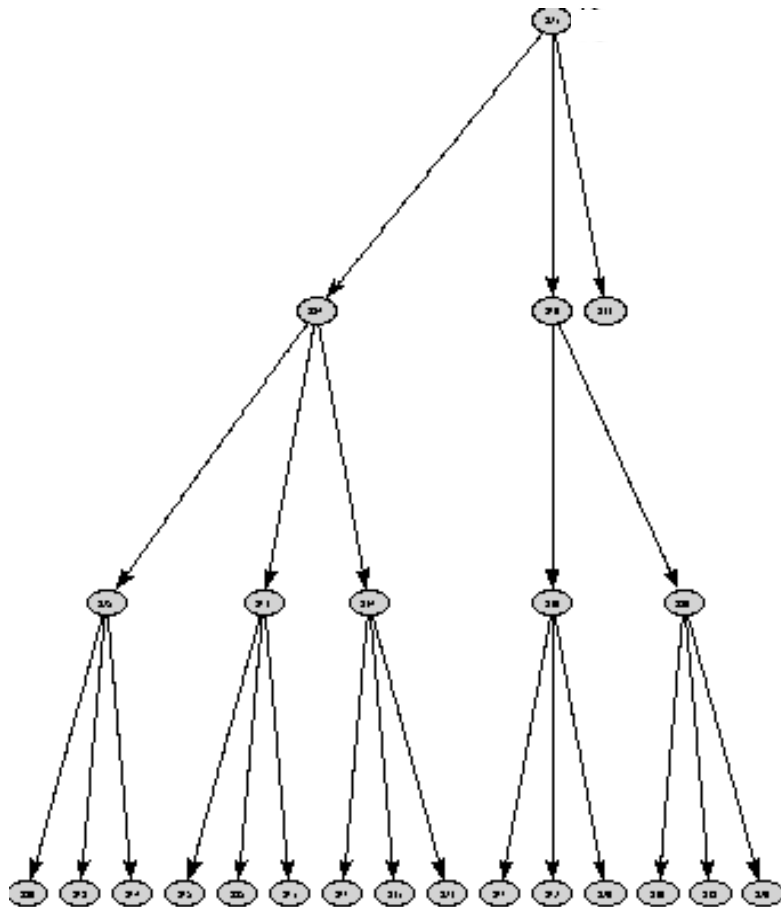
Downwards

validations/rejections, consisting of request + event number (24 bit)





# 1:15 GTS Tree + 1 VME subsystem



# GTS Tree with the Fully Digital Trigger Processor

GTS tree to:

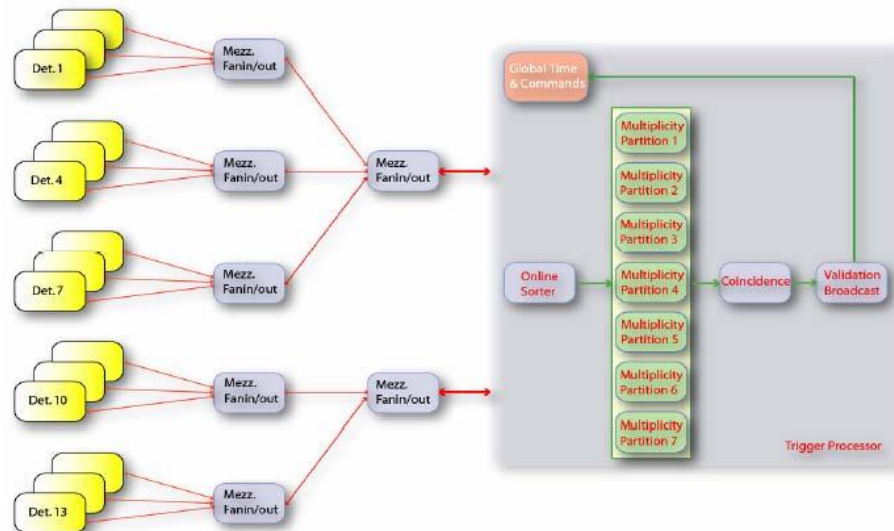
- Distribute the 100 MHz clock
- Collect the trigger requests (i.e. 16-bit time stamp and address of the requesting node)
- Return validations or rejections messages to the requesting node

Max 1 MHz trigger requests/node

Built out of GTS mezzanines



The “3 to 1” structure can be extended up to 3 levels →  
 9 triple clusters or  
 8 triple clusters + 3 ancillaries

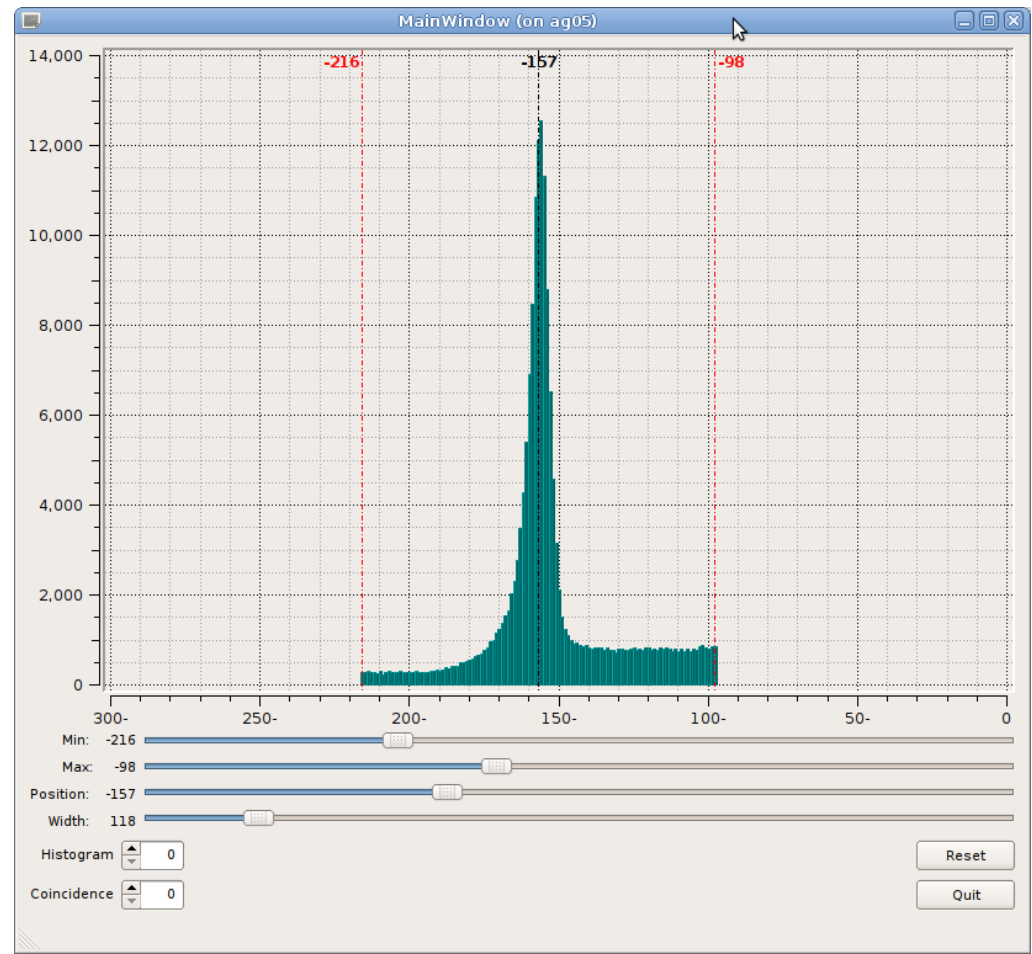


- Runs on an evaluation board with a VIRTEX5 FPGA
- Partitions and sum buses implemented in VHDL
- 2<sup>nd</sup> level logic is implemented in C and runs in the PPC
- **Uses idle-messages to timeout non-participating nodes**
- Present version has 48 inputs and 4 partitions
- Each partition has 4 multiplicity thresholds
- The two partitions can be operated in coincidence
  - P1 with the Ge crystals      Trig1 →  $P1 \geq 1 \ \& \ P2 = 1$
  - P2 with the ancillary      Trig2 →  $P1 \geq 2$
- Handles max 100 kHz of coincidences (limited by PPC)



# Available Triggers

- multiplicity
  - up to 4 partitions(P), each one with 4 multiplicity thresholds
  - often used with 1 partition containing the 15 Ge detectors
  - digital version of the classical multiplicity sum bus
- ancillary
  - P1(Ge) AND P2(Ancillary)  
coincidence condition is a window on the timestamps
- ancillary2
  - (P1 AND P2) OR (P2 AND NOT P1)  
(e.g. validate PRISMA even if there is no gamma coincidence)
- Service triggers
  - validate\_all
  - reject\_all



# Preamplifiers

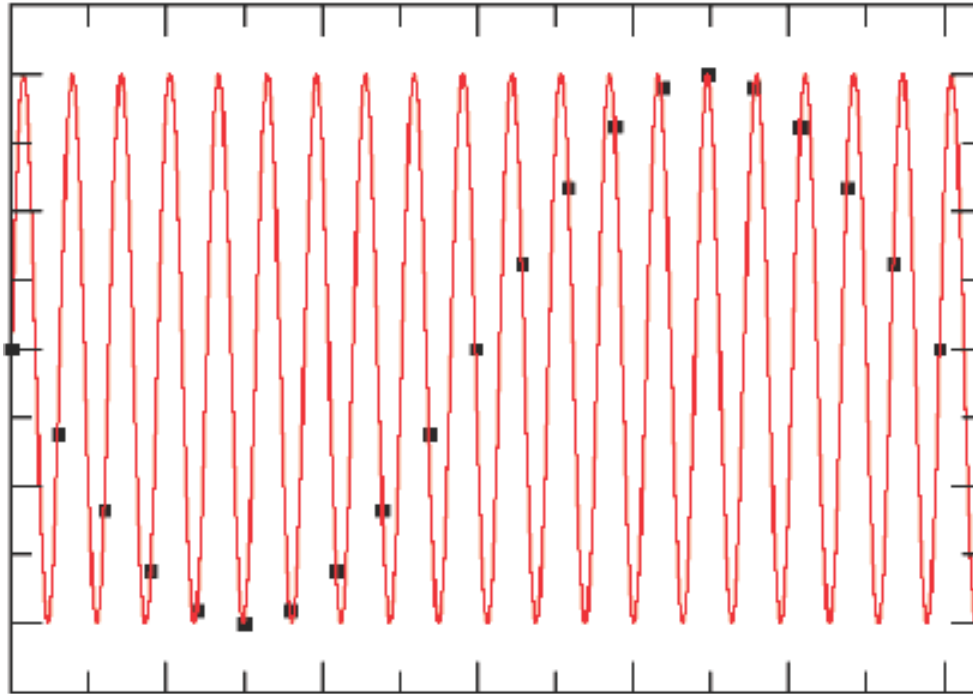
(→Bart)

# Digitizers

- 100 MS/s
  - max frequency correctly handled is 50 MHz (Nyquist)
- 14 bits
  - Effective number of bits is  $\sim 12.5$  (SNR  $\sim 75$  db)
- 2 cores and 36 segments (in 6 boards)
- Core 2 ranges 5, 20 MeV nominal
- Segments either high or low gain
- The digitized samples are serialized and transmitted via optical fibre (1/channel) to the preprocessing electronics. Transmission rate is 2 Gbit/s on each of the 38 fibres.
- Power consumption 240 W
- Weight 35 kg

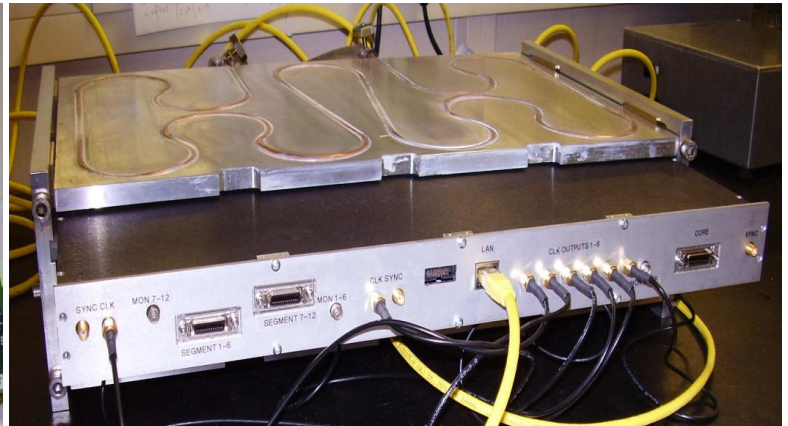
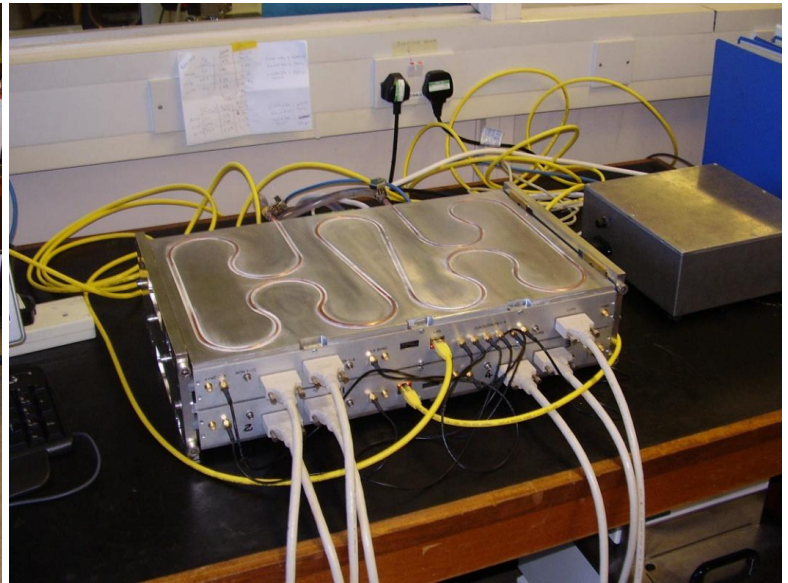
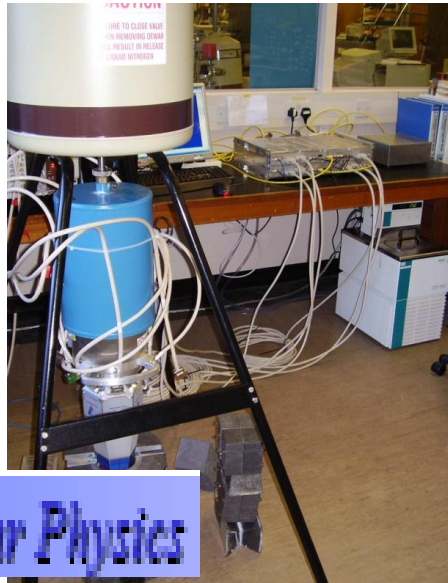
# Beware of aliasing!

**Sampling theorem:** analogue input signals limited to a bandwidth  $f_{BW}$  can be reproduced from their samples with no loss of information if they sampled at a frequency  $f_s \geq 2f_{BW} \rightarrow$  **Nyquist frequency**



At 100 Ms/s, the preamplifier signals must be filtered, at the input of the, the digitizer to remove frequencies above 50 MHz (in practice above ~20 MHz)

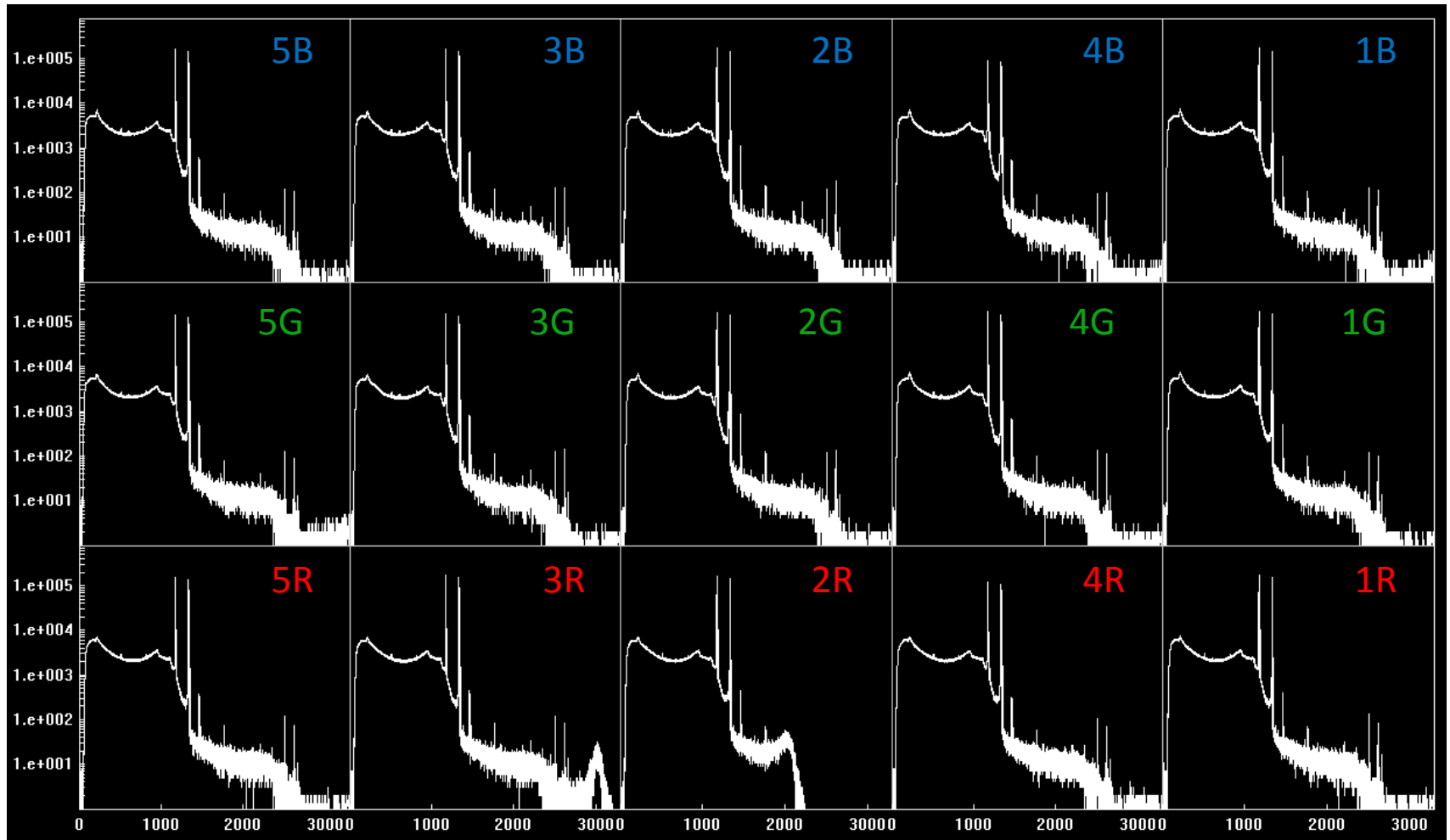
# AGATA Digitisers



As the digitizers just digitize and transmit the sample, they operate very smoothly, need to be power-cycled very rarely, which is good for the gain stability of the signals.

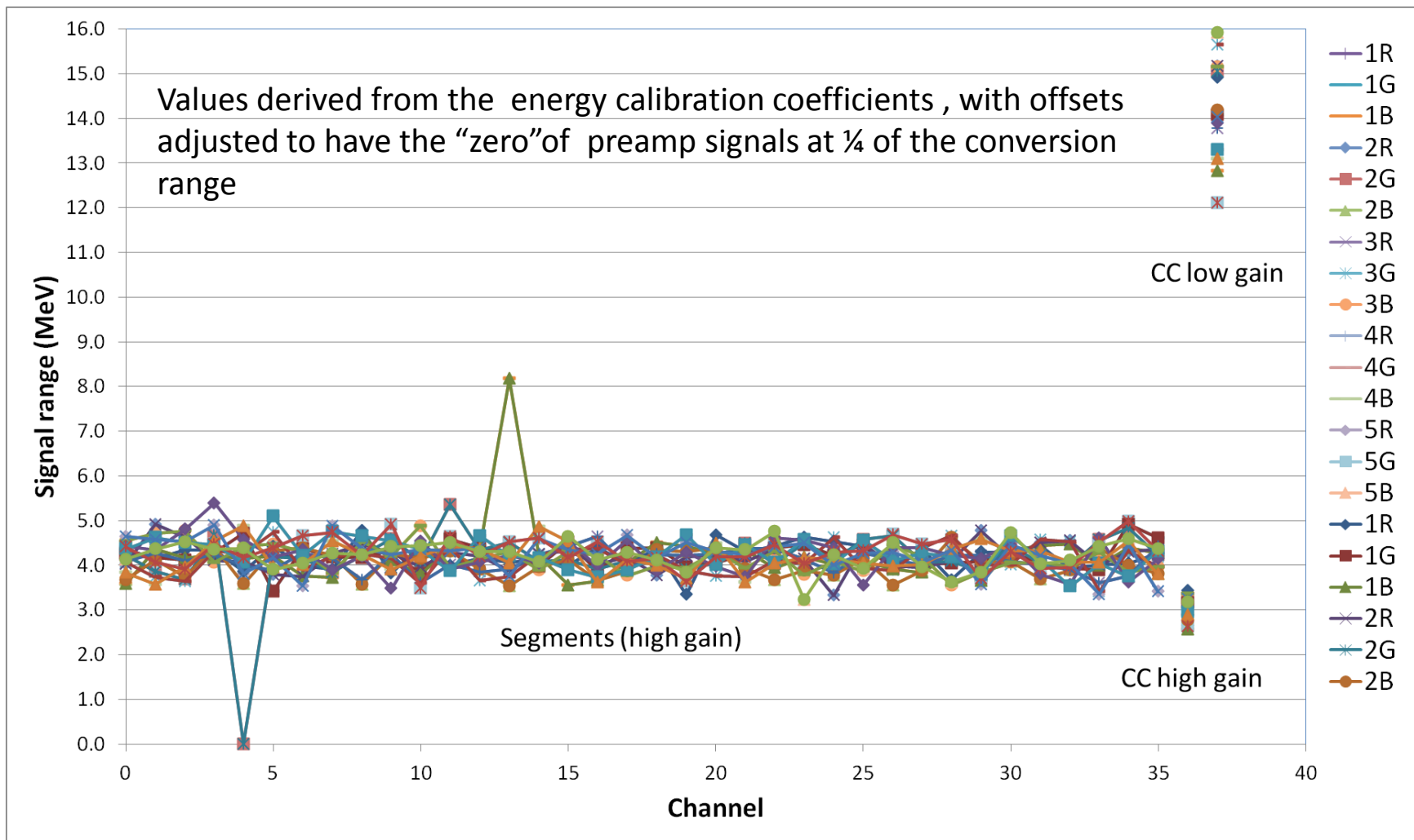


# Range of digitizers 1



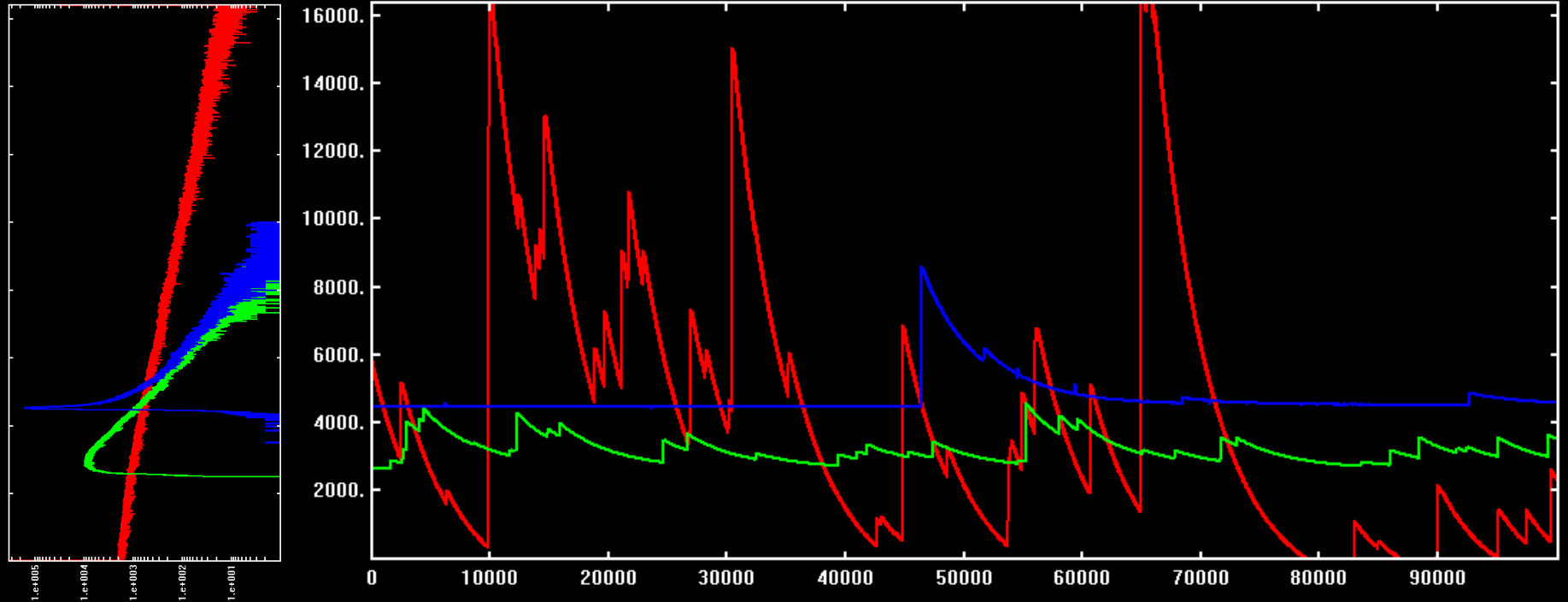
Some cores and segments saturate below 3 MeV on the high-gain range  
Gain in the digitizers should be reduced by  $\sim 30\%$

# Range of Digitizers



# Range of digitizers 2

Operation at high counting rates



1 ms

**1R CC high gain**   **1R CC low gain**   **1R B1 (low gain)**

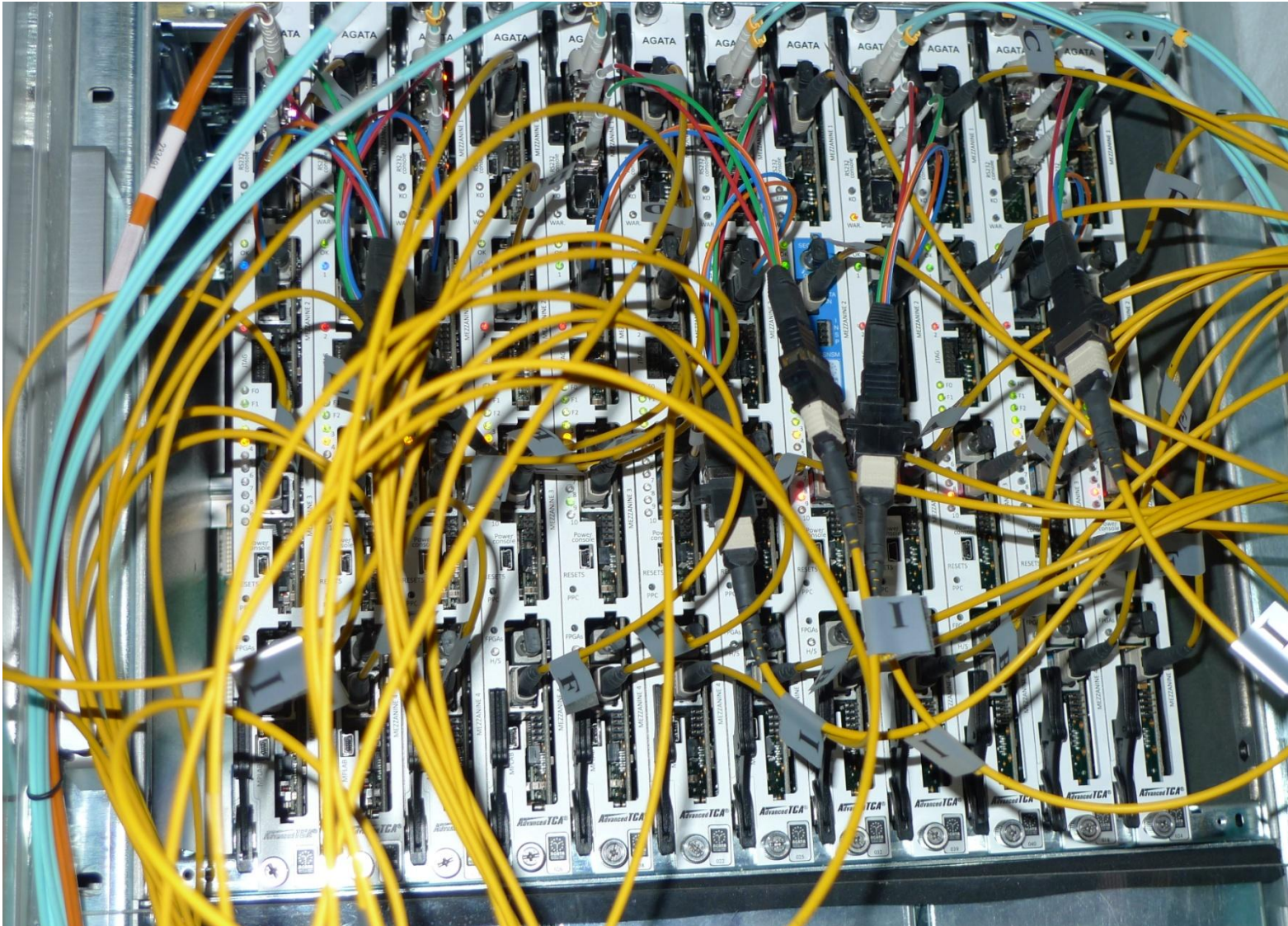
CC ~30 kHz segment   B1 ~7 kHz

# Preprocessing Electronics

- Fully digital, processing 38 channels in parallel for each crystal.
- Receives the continuous stream of samples from the digitizers.
- Generates the energy by means of a trapezoidal shaper
- Generates the local trigger on the core (CC) signal by Leading Edge Discriminator (or CFD)
- Takes a snap shot of 1  $\mu$ s (100 samples) on all 38 channels
- Sends validated events to the front-end computers
- For 1 crystals: 2 ATCA carrier boards, 7 processing mezzanines and 1 GTS node.

# 6 crystals in one ATCA crate

(228 high resolution channels)



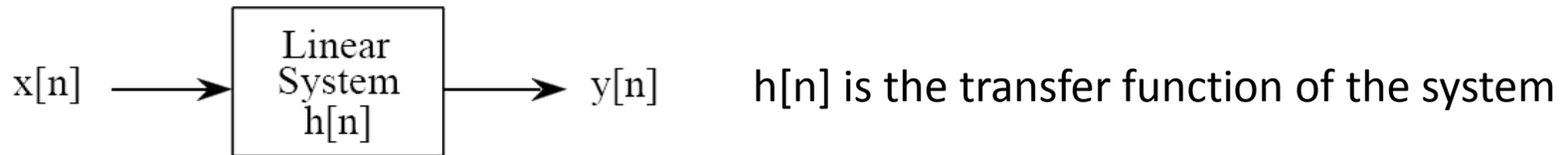


# Signal Processing in the electronics

- Noise and disturbances in the signals
- Effective band width of the signals
- Deconvolution of the main pole
- Deconvolution of 2<sup>nd</sup> order effects in detector/preamp chain (multiple poles)
- Triangular (trapezoidal) shaping
- Adaptive shaping for high counting rates
- More sophisticated BLR
- Treatment of saturated signals by ToT
- ...

# Convolution and Correlation

Signal processing blocks can be often described as linear (and time invariant) systems that act on an the input to produce an output.



- Convolution: how a linear system acts on the input to produce the output

$$y[n] = x[n] \otimes h[n] = \sum_{i=0}^{N-1} x[i]h[n-i] = \sum_{i=0}^{N-1} x[n-i]h[i]$$

- Correlation: evidences similarity of two signals

$$R_{xy}[n] = x[n] * y[n] = \sum_{i=0}^{N-1} x[i]y[i-n] = \sum_{i=0}^{N-1} x[i-n]y[i]$$

- Autocorrelation: short and long term correlations in a signal

$$R_{xx}[n] = x[n] * x[n] = \sum_{i=0}^{N-1} x[i]x[i-n]$$

# Transforms

- Mapping of one space to another (dual) in order to simplify and/or speed-up operations that are difficult and/or slow in the original one space.
- Fourier Transform      time  $\leftrightarrow$  frequency
  - Analysis of noise, detector response function, action of filters and shapers
- Laplace Transform      time  $\leftrightarrow$  s
  - Solving differential equations
- Z Transform              sample number  $\leftrightarrow$  z
  - Solving difference equations and expressing in an analytical way filters and shapers
- Common and useful properties
  - Linearity               $T(a \cdot f(t) + b \cdot g(t)) = a \cdot T(f(t)) + b \cdot T(g(t))$
  - Derivation             $D(f(t)) = s \cdot T(f(t)) + \text{initial condition}$
  - Integration            $I(f(t)) = T(f(t))/s$
  - Convolution           $T(f(t) \otimes g(t)) = T(f(t)) \cdot T(g(t))$
- In general the original and transformed variables are complex .  
In Signal Processing the original data is almost always real and the transformed variable is often also real (e.g. power spectra with all phases set to zero so that only the amplitude is of interest)

# Fourier Transform(s)

Type of Transform

Example Signal

Fourier Transform

*signals that are continuous and aperiodic*



Fourier Series

*signals that are continuous and periodic*



Discrete Time Fourier Transform

*signals that are discrete and aperiodic*

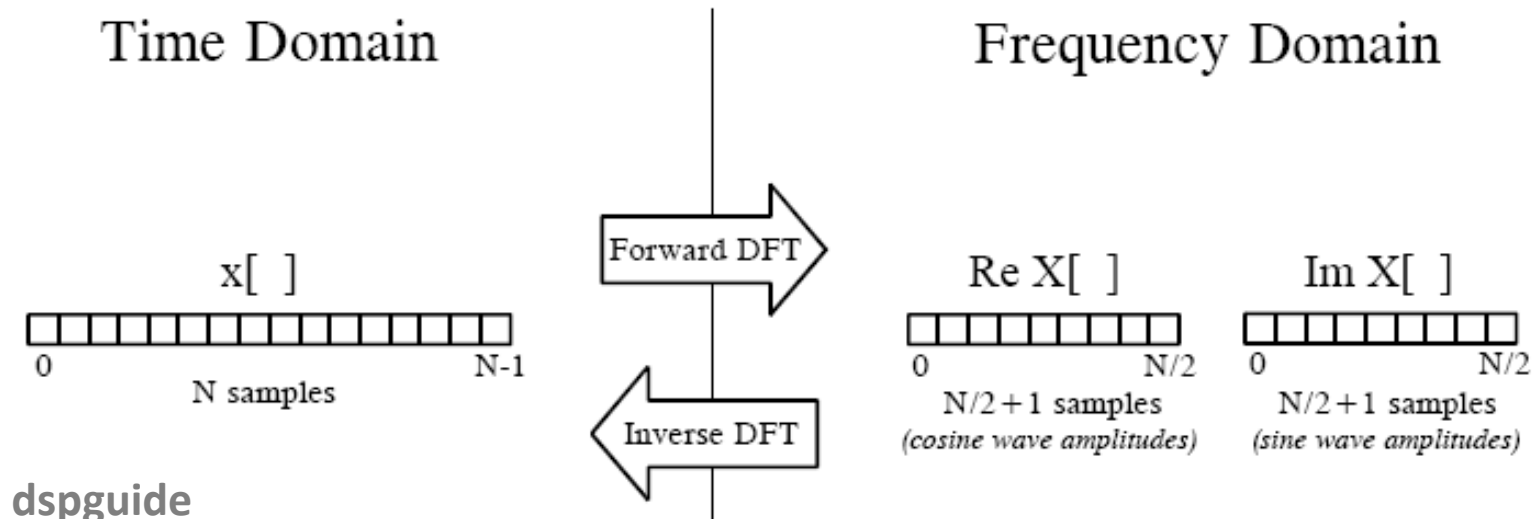


Discrete Fourier Transform

*signals that are discrete and periodic*



# Discrete Fourier Transform of real signals



$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-i2\pi \frac{k}{N} n}$$

Forward → decomposition

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{i2\pi \frac{k}{N} n}$$

Inverse → synthesis

N real signals mapped to N coefficients ( N+2, but 2 are identically zero:  $\sin[0]$ ,  $\sin[N/2]$ )

Vector representation (cos,sin) useful for calculations

Polar representation (magnitude, phase) used for human inspection

For large N, calculated using the Fast Fourier Transform (FFT) algorithm



# Useful theorems

- **Parseval:** correspondence between time and frequency power spectra

$$\sum_0^{N-1} |x_n|^2 = \frac{1}{N} \sum_0^{N-1} |X_n|^2$$

$$\sigma^2 = \frac{1}{N} \sum_0^{N-1} |x_n|^2 = \frac{1}{N^2} \sum_0^{N-1} |X_n|^2$$

$$\sigma = \frac{1}{N} \sqrt{\sum_0^{N-1} |X_n|^2} = \frac{\sqrt{2 \cdot INP}}{N}$$

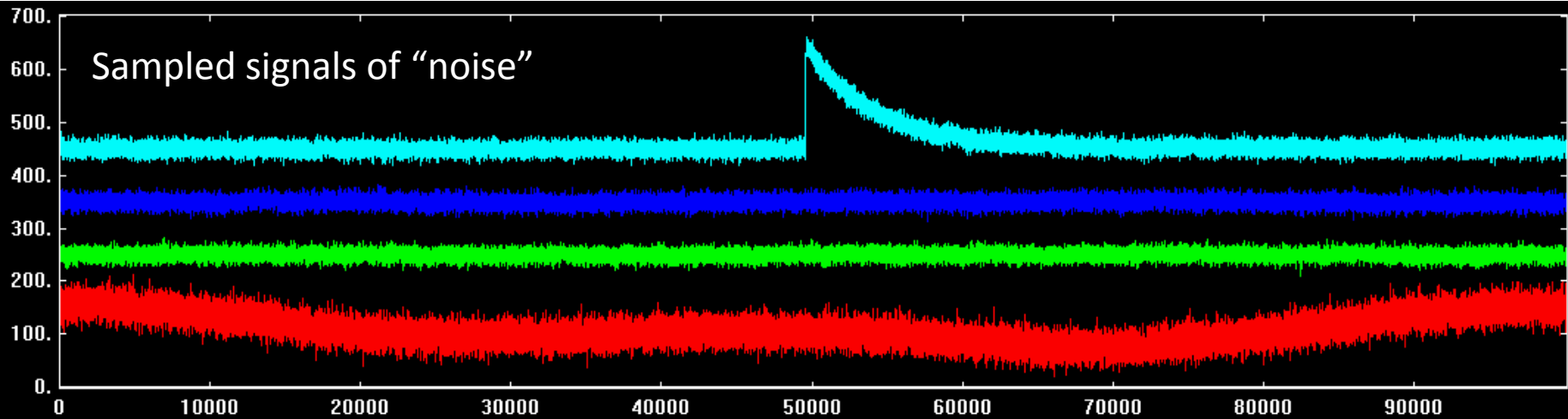
$$FWHM = \sigma \sqrt{8 \ln(2)} = \frac{3.33 \sqrt{INP}}{N}$$

$\sum |x_n|^2 / N$  corresponds to the variance  $\sigma^2$  if the “noise” spectra have  $\langle x_n \rangle = 0$   
 The integrated noise power of the DFT spectra is multiplied by 2 because we use only positive frequencies up to Nyquist (unilateral representations).

- **Wiener-Kintchine:** the autocorrelation function of a signal is the Inverse Fourier Transform of its the power spectral density

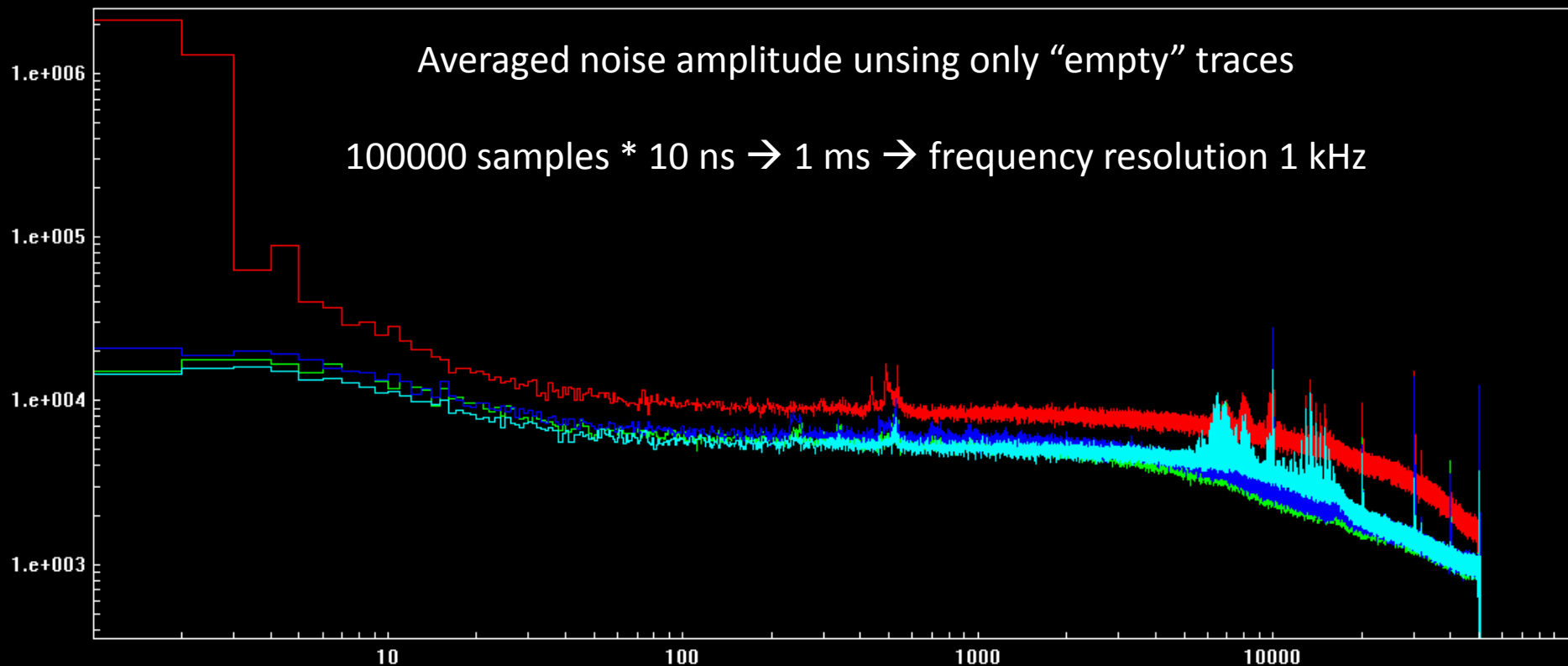
$$R_{xx}[d] = \sum_{n=0}^{N-1} x[n] \cdot x[n-d] = F^{-1}(F(x) \overline{F(x)})$$

# Noise spectrum from “empty” sampled signals

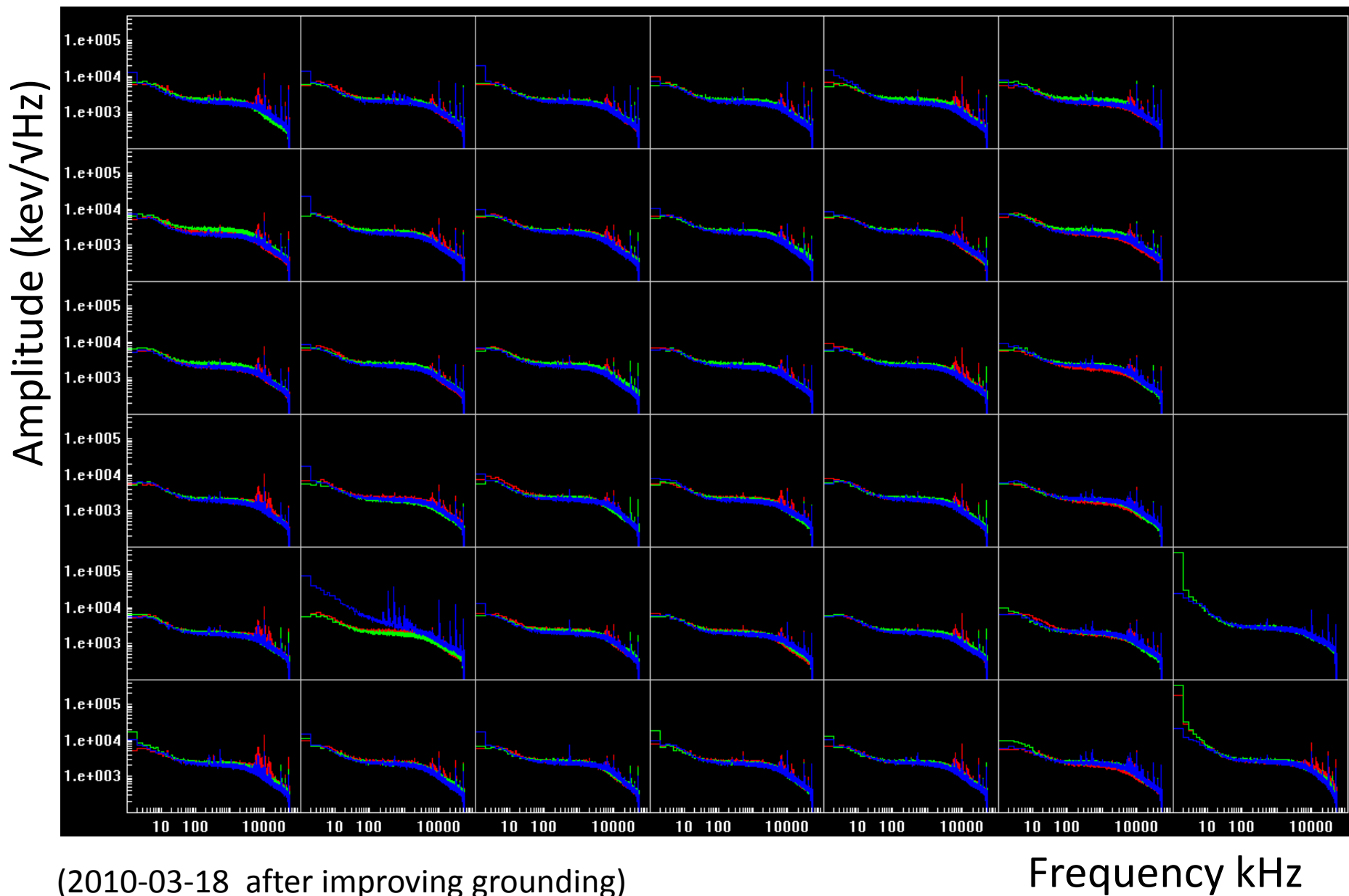


Averaged noise amplitude using only “empty” traces

$100000 \text{ samples} * 10 \text{ ns} \rightarrow 1 \text{ ms} \rightarrow \text{frequency resolution } 1 \text{ kHz}$

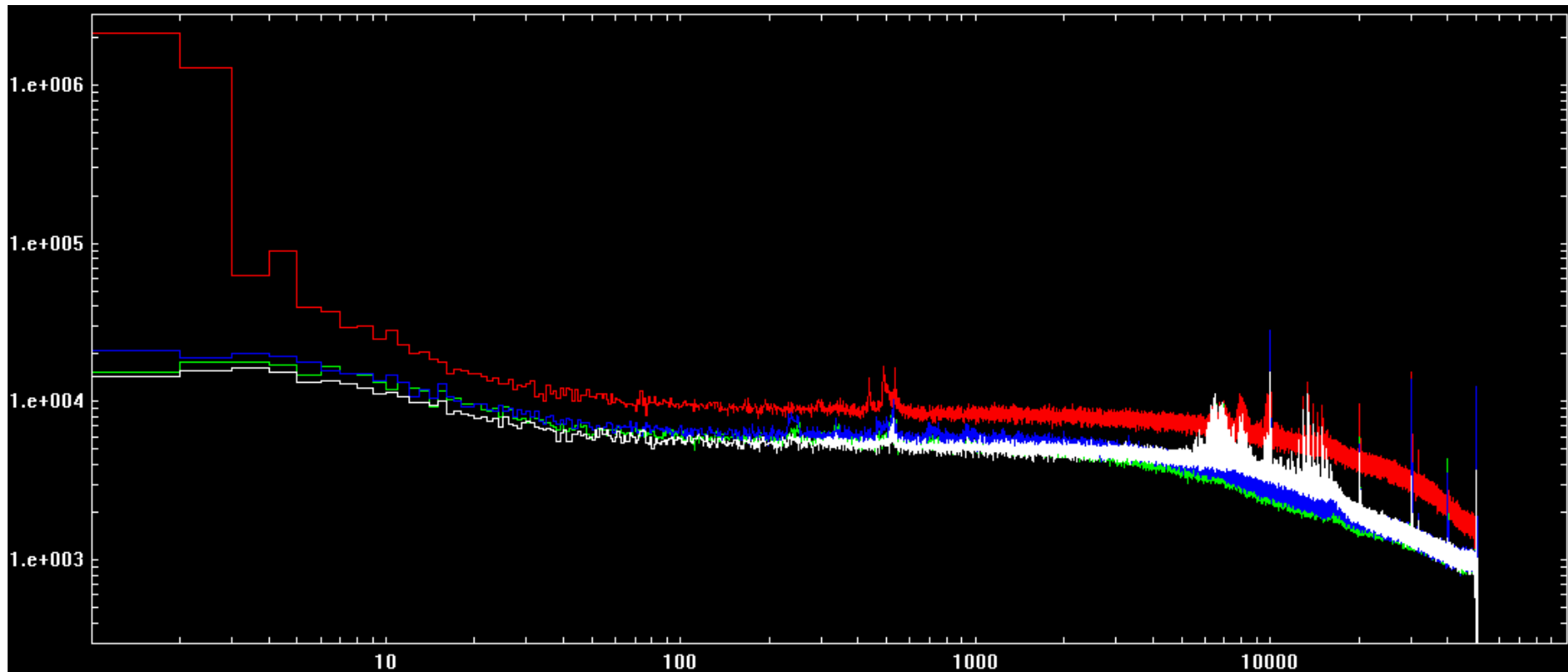


# Noise spectra of ATC1

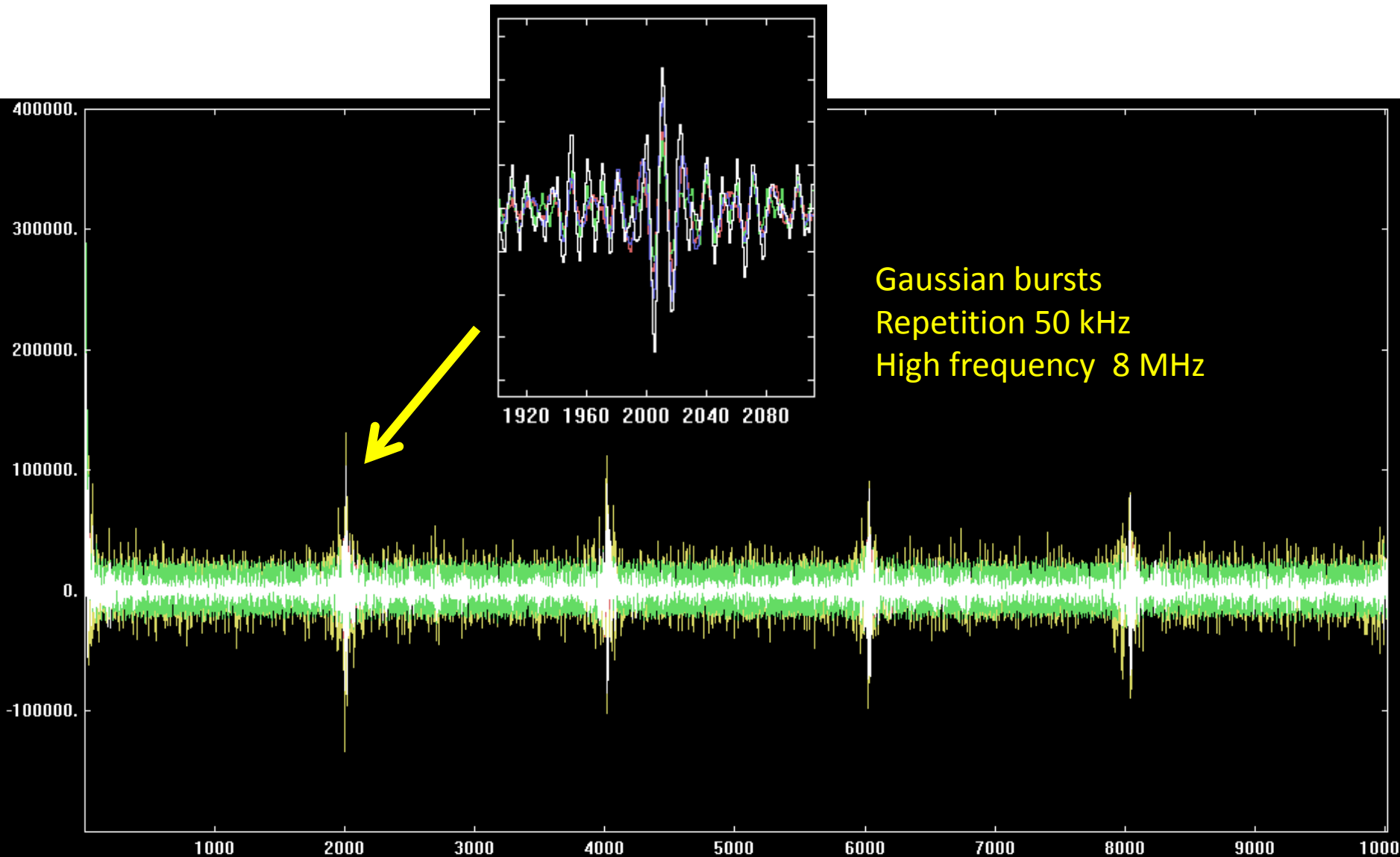


# Autocorrelation of noise

- Autocorrelation determined from the inverse of the noise density power spectrum, obtained by averaging “empty” traces
- Autocorrelation enhances the evidence of periodic disturbances
- Allows to determine the high frequency cut of the total preamplifier+digitizer transfer function



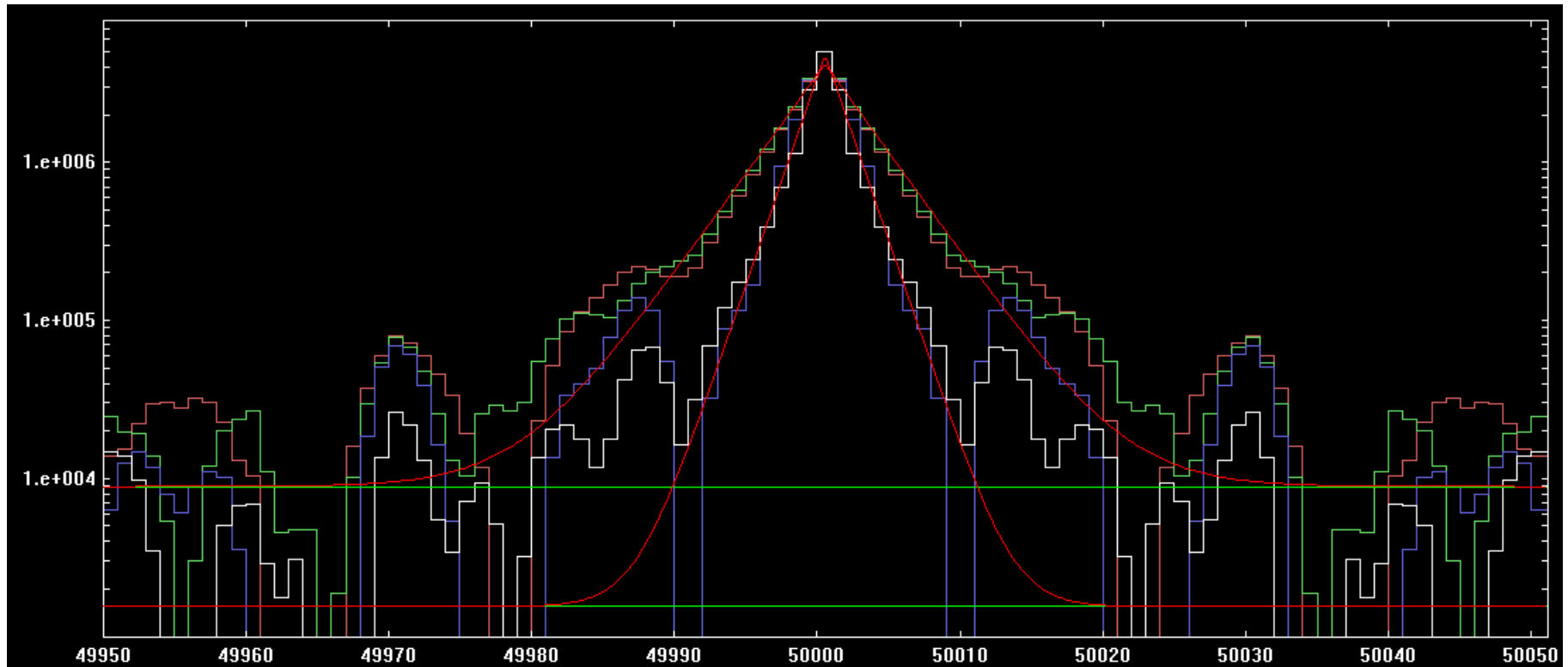
# Repetitive disturbances





# High frequency cut of spectrum

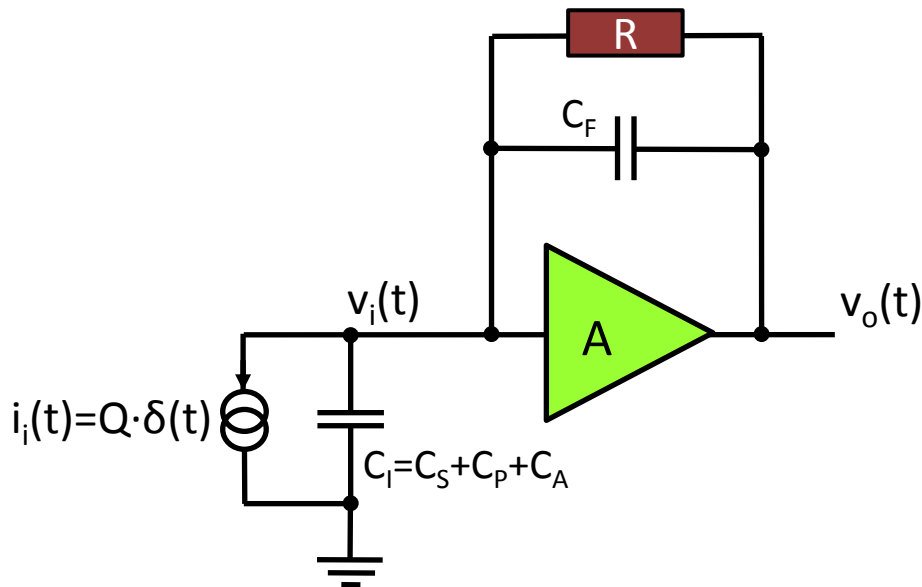
Autocorrelation rotated to the centre; normalized to the maximum for the 4 channels



- CC  $\rightarrow \tau = 16$  ns
- A4,A5  $\rightarrow \tau = 30$ -35 ns as most of the other segments
- A1  $\rightarrow \tau = 14$  ns as A2 and A3 (preamplifier board not slowed down)

# “Deconvolution” of Ge signals

- Signals from Ge preamplifiers are, ideally, exponentials with only one decay constant



In practice the output exponential is produced in stages :

- $RC_F$  charge loop with decay constant  $\tau_0 \sim 1$  ms
- CR differentiation to reduce the decay constant to  $\tau_1 \sim 50$   $\mu$ s
- P/Z cancellation to remove the undershoot and the long recovery (with  $\tau = \tau_0$ ) due to the differentiation of the first exponential.

- Task of the **deconvolution** is to remove the exponential to recover the original  $\delta(t)$  at the input of the preamplifier
- Trapezoidal shaping** is then just an integration followed by delayed subtraction followed by a moving average
- In practice **Trapezoidal shaping** is the optimum shaping if the noise is white and the collection time (width of the “delta”) varies a lot as in the large volume semi-coax Ge AGATA detectors

# Essentials of the z-transform

- Development of shapers done using the z-transform formalism.
- The most useful result is: if in the z domain the system function can be expressed as ratio of polynomials, in the time domain it is possible to realize it as a FIR or an IIR recursive filter with coefficients given by the coefficients of the polynomials.
- We proceed in an informal way, assuming that the ROC exists and corresponds to one-sided casual signals
- The relevant z-transform features are:

delta function  $\delta[n] \longleftrightarrow 1$

step function  $u[n] \longleftrightarrow \frac{1}{1-z^{-1}}$

k - units delay operator  $z^{-k} \qquad y_n = x_{n-k}$

decaying exponential  $e^{-\frac{n}{\tau}} \longleftrightarrow \frac{1}{1-az^{-1}} \quad (a = e^{-\frac{1}{\tau}}) \qquad y_n = x_n + ay_{n-1}$

deconvolution of exp.  $D(\tau) \longleftrightarrow 1-az^{-1} \quad (D \otimes e = \delta) \qquad y_n = x_n - ax_{n-1}$

integration  $I(\tau) \longleftrightarrow \underbrace{\frac{1}{1-z^{-1}}}_{\text{z-domain}} \quad (I \otimes \delta = u) \qquad y_n = x_n + \underbrace{y_{n-1}}_{\text{time domain}}$

# Synthesis of Trapezoid by a cascade of filters

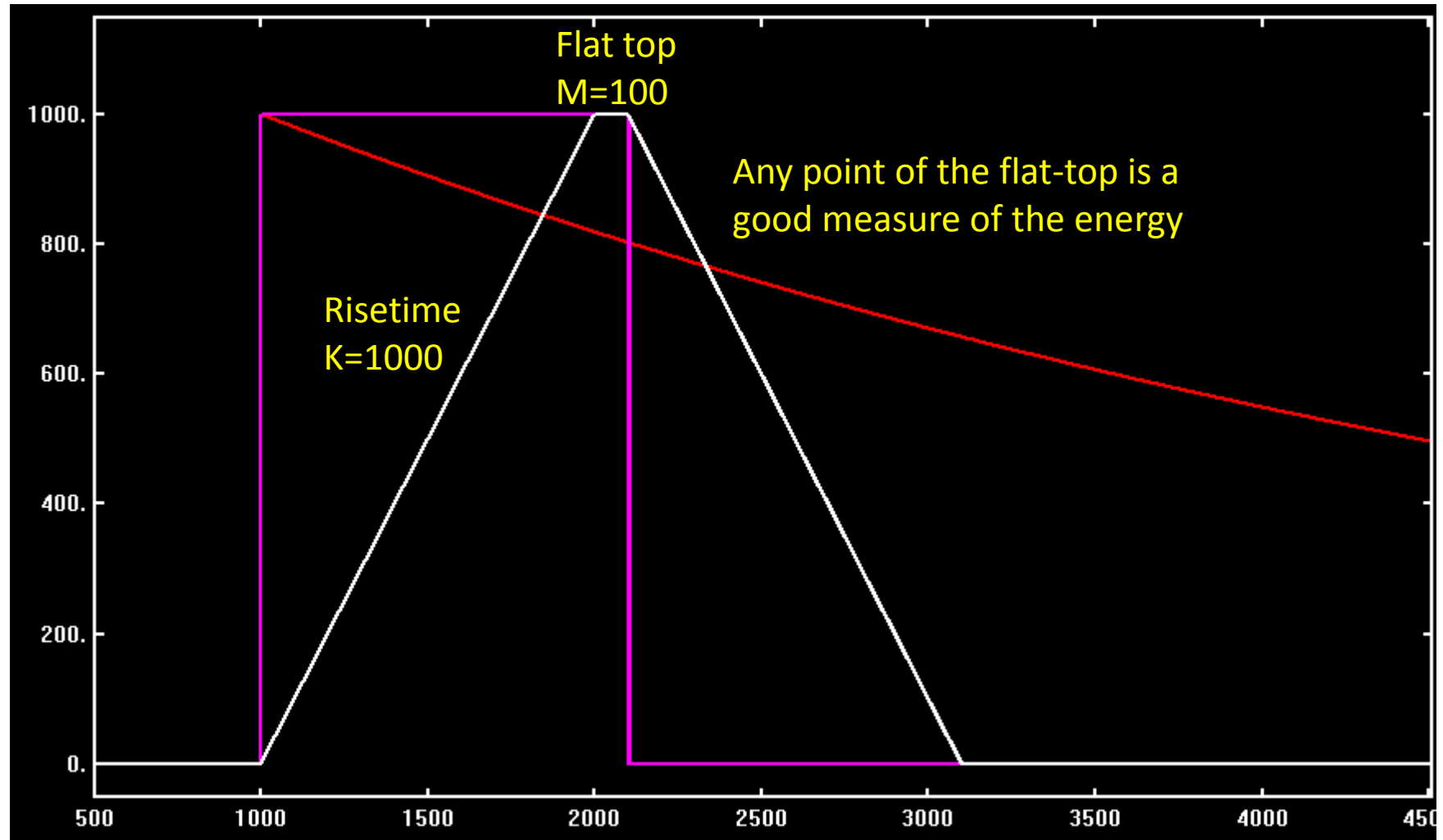
Exponential input signal	$X_1 = \frac{1}{1 - az^{-1}}$	
Deconvolution of exponential	$X_2 = X_1(1 - az^{-1})$	
Integrate to get a step	$X_3 = X_2 \frac{1}{1 - z^{-1}} = X_1 \frac{1 - az^{-1}}{1 - z^{-1}}$	} Moving sum
Delayed step (K + M)	$X_4 = X_3 z^{-(K+M)}$	
Subtract delayed step	$X_5 = X_3 - X_4 = X_1 \frac{1 - az^{-1}}{1 - z^{-1}} (1 - z^{-(K+M)})$	
Integrate	$X_6 = X_5 \frac{1}{1 - z^{-1}}$	} Moving average
Delay by K	$X_7 = X_6 z^{-K}$	
Subtract and normalize	$X_8 = \frac{X_6 - X_7}{K} = X_5 \frac{1 - z^{-K}}{1 - z^{-1}} = X_1 \frac{1 - az^{-1}}{1 - z^{-1}} \frac{1 - z^{-(K+M)}}{1 - z^{-1}} \frac{1 - z^{-K}}{K}$	
Transfer function	$H(z) = \frac{1 - az^{-1}}{K} \frac{1 - z^{-(K+M)}}{1 - z^{-1}} \frac{1 - z^{-K}}{1 - z^{-1}}$	

Other formulations and implementations

*A.Georgiev and W. Gast*, IEEE Trans. Nucl. Sci., 40(1993)770 → "Moving Window Deconvolution"

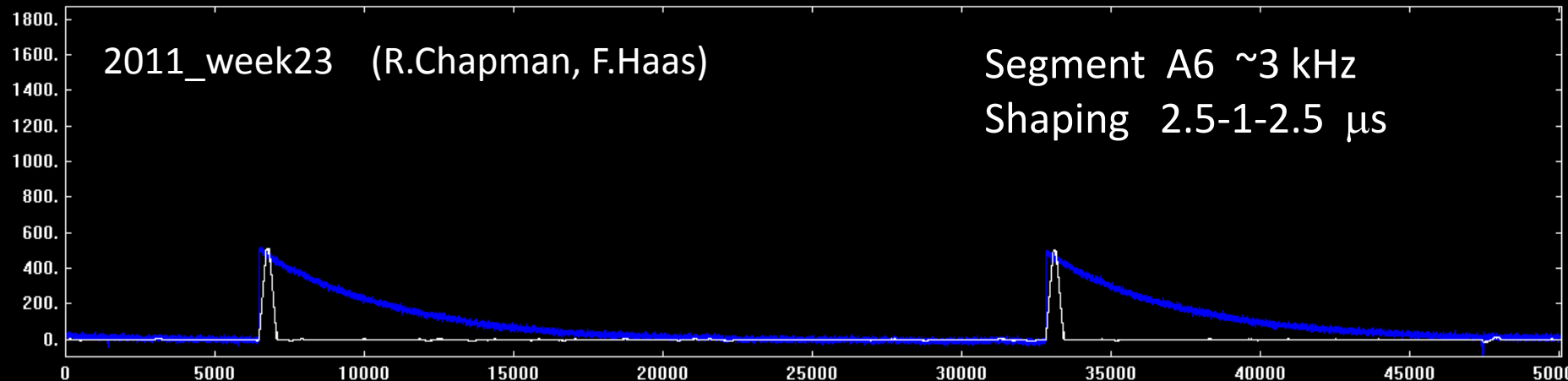
*V.T.Jordanov and G.F.Knoll*, Nucl.Instr.Meth., A353(1994)261

# Deconvolution and shaping: ideal exponential

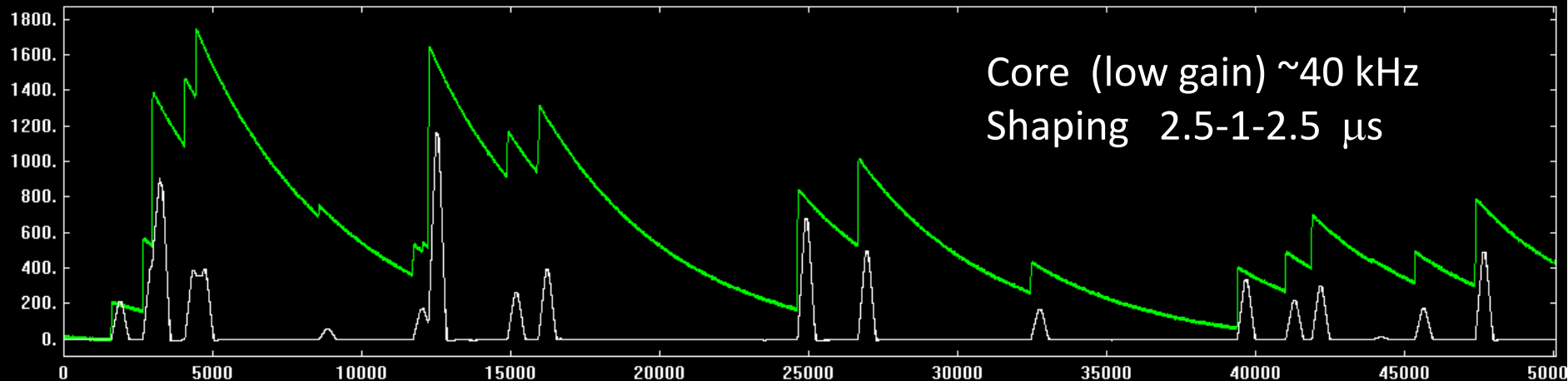


2011\_week23 (R.Chapman, F.Haas)

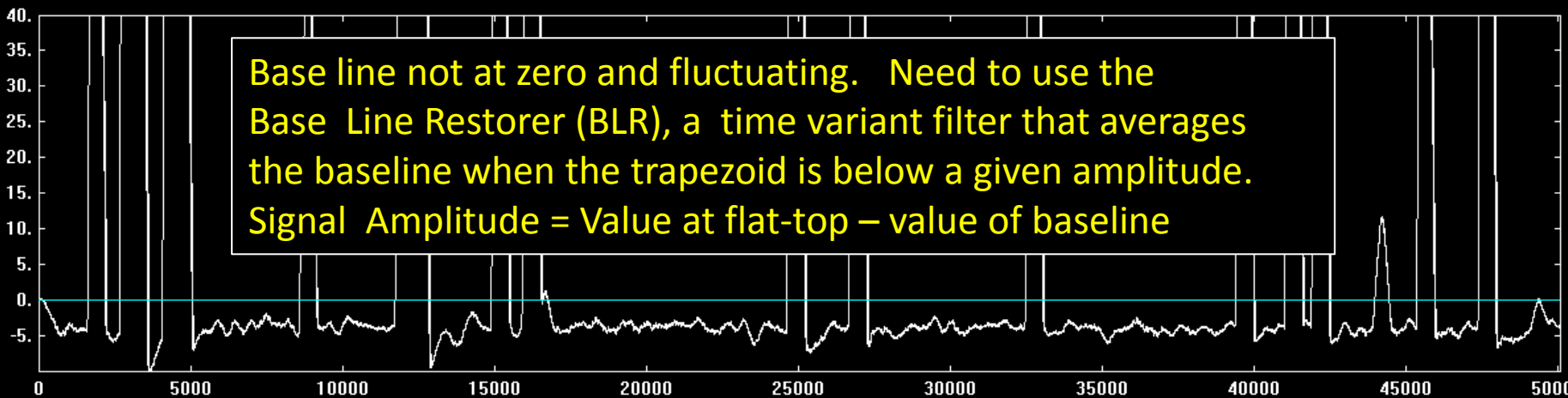
Segment A6 ~3 kHz  
Shaping 2.5-1-2.5  $\mu$ s



Core (low gain) ~40 kHz  
Shaping 2.5-1-2.5  $\mu$ s

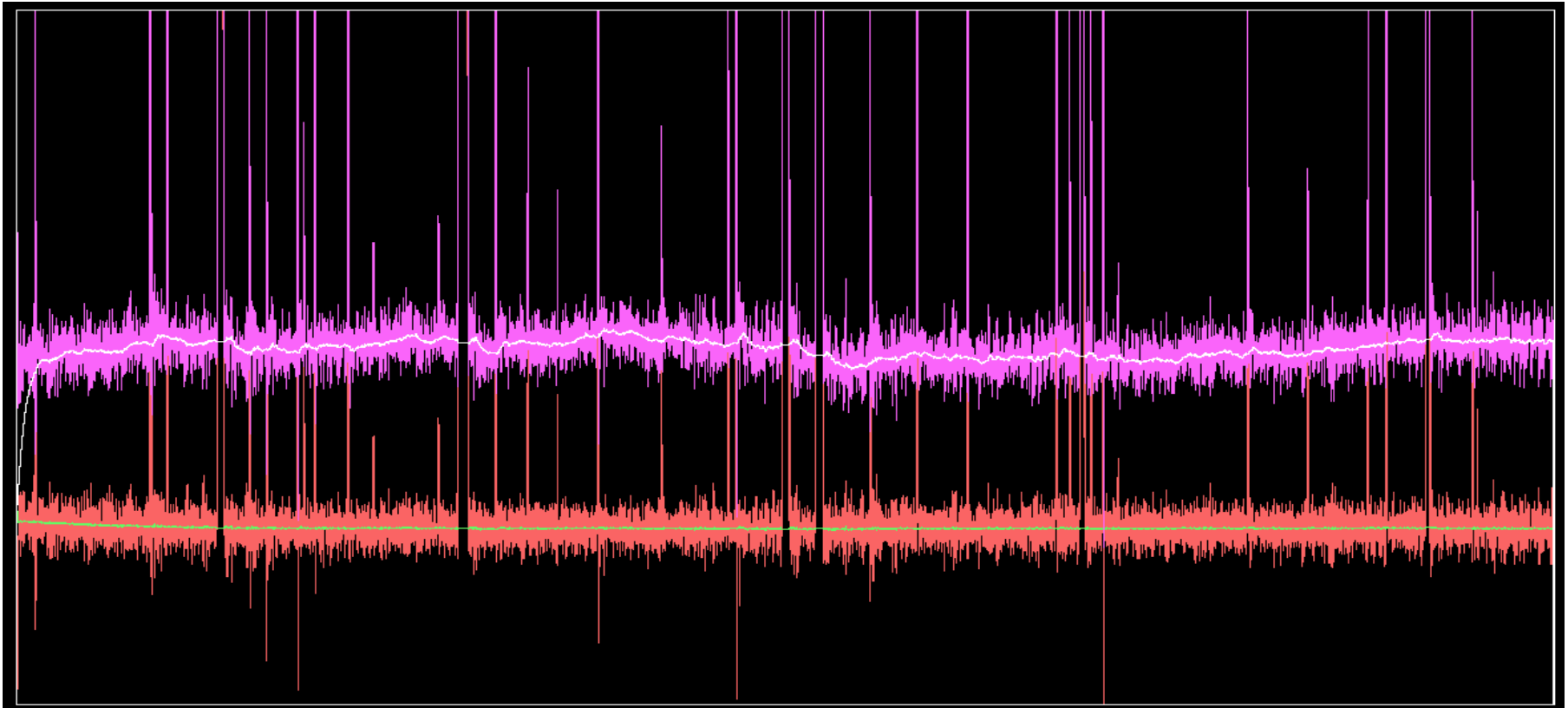


Base line not at zero and fluctuating. Need to use the Base Line Restorer (BLR), a time variant filter that averages the baseline when the trapezoid is below a given amplitude. Signal Amplitude = Value at flat-top – value of baseline



# Base-line stabilisation

- continuous (exponential) average of baseline
- automatic detection of pulses based on variance
- feed-back to deconvolution stage to bring baseline down to zero

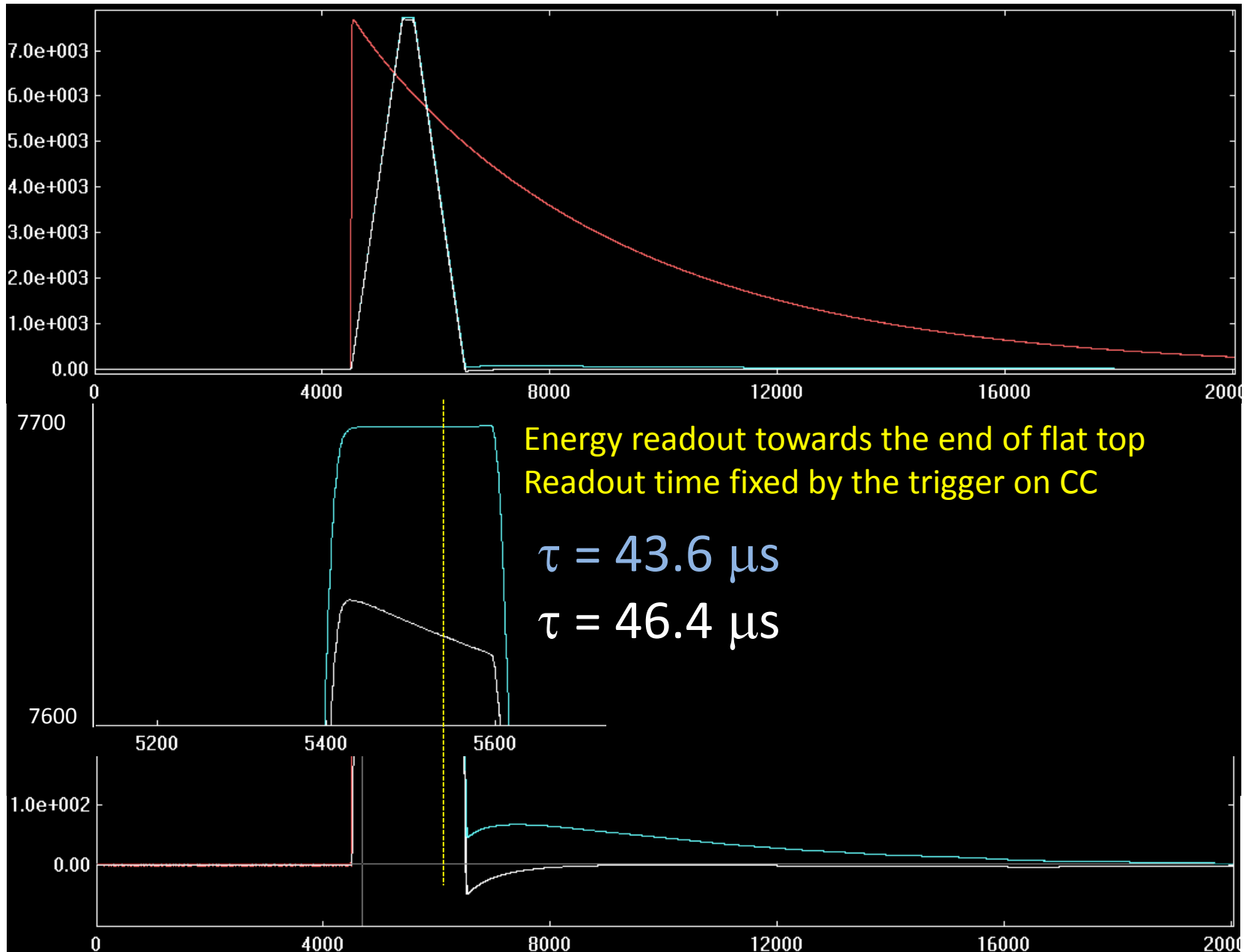


Upper part → without feedback (as used at present)

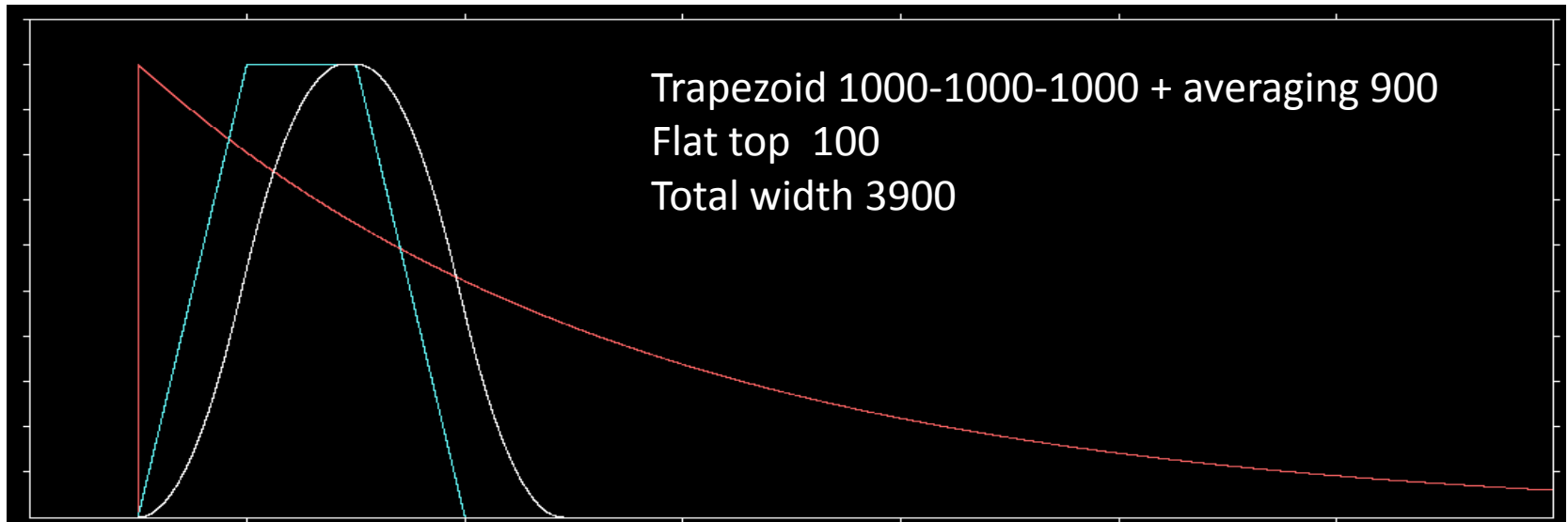
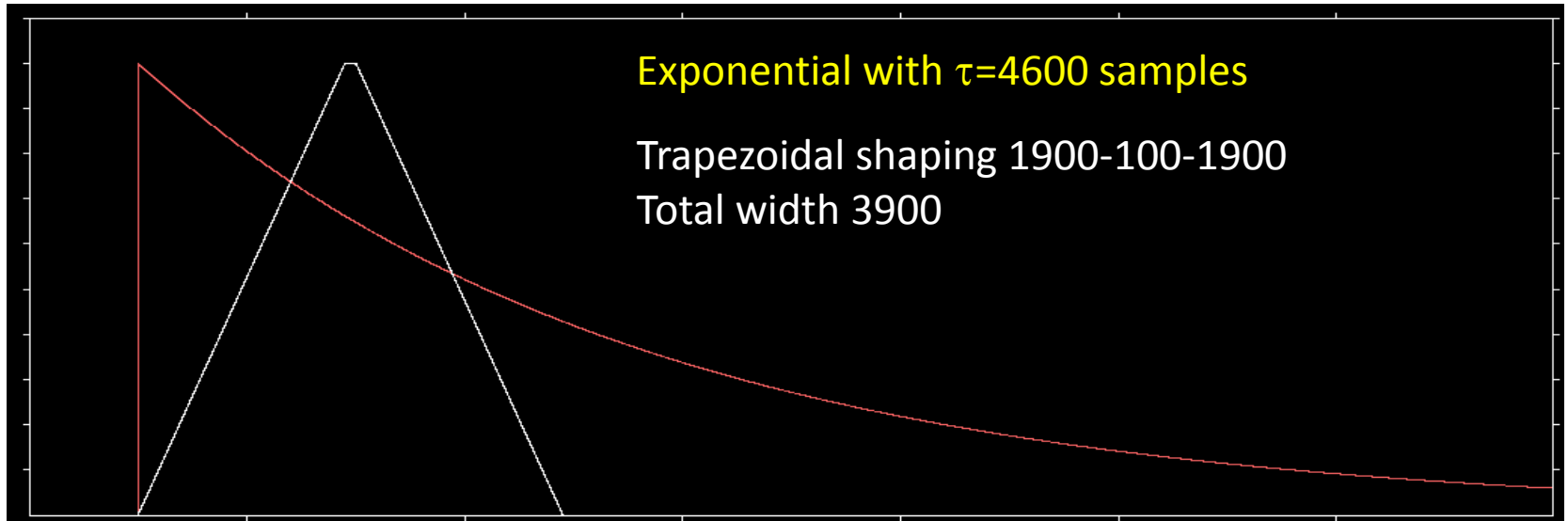
Lower part → with feedback (used in the next electronics)

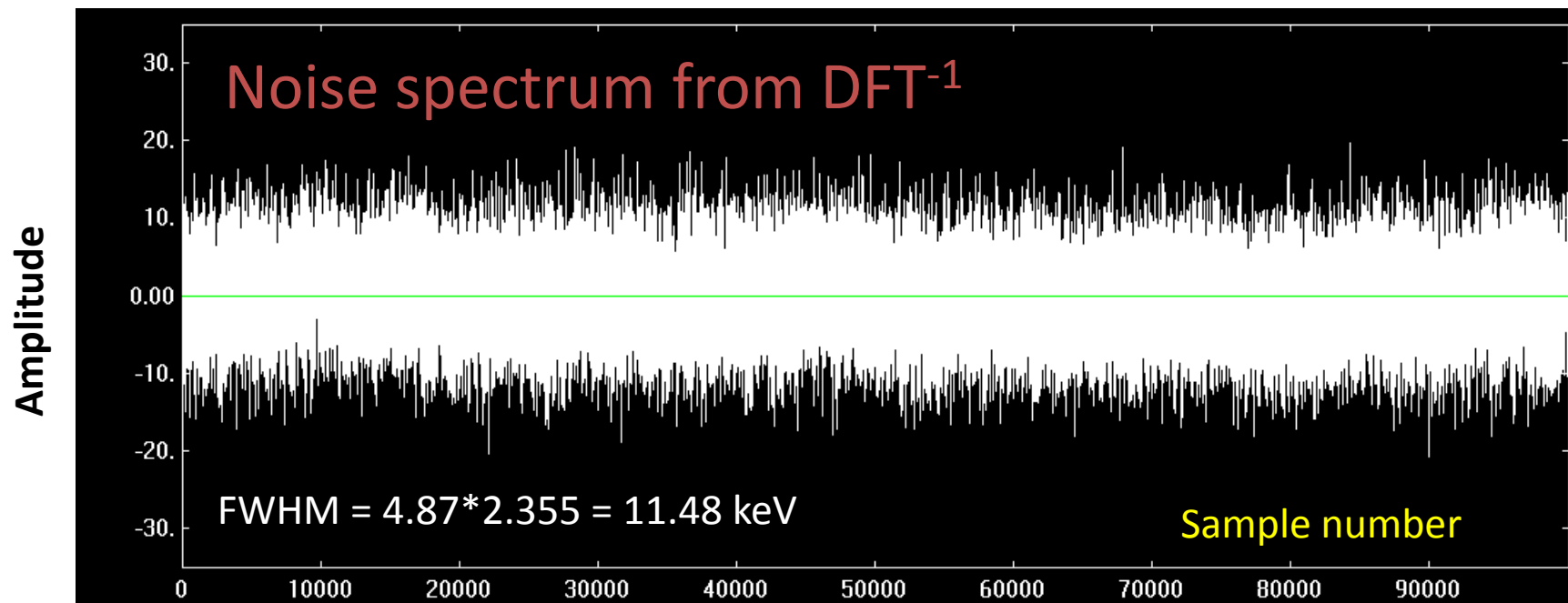
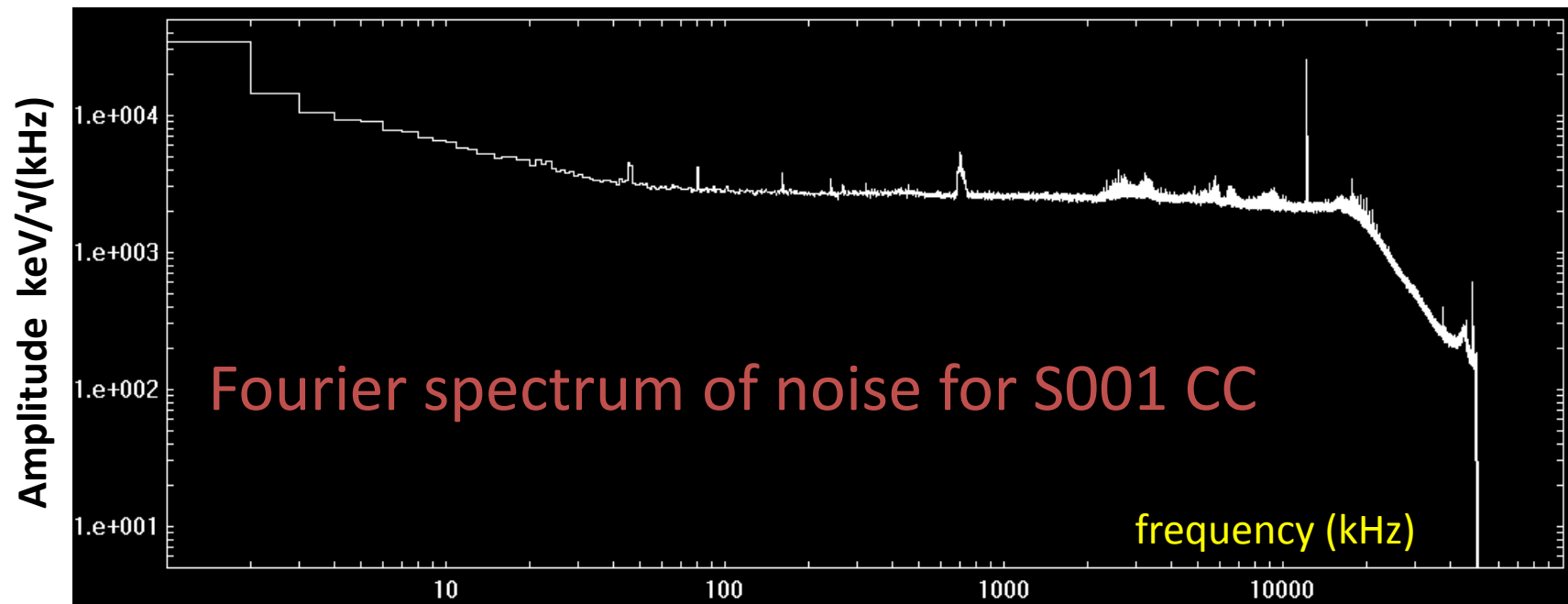


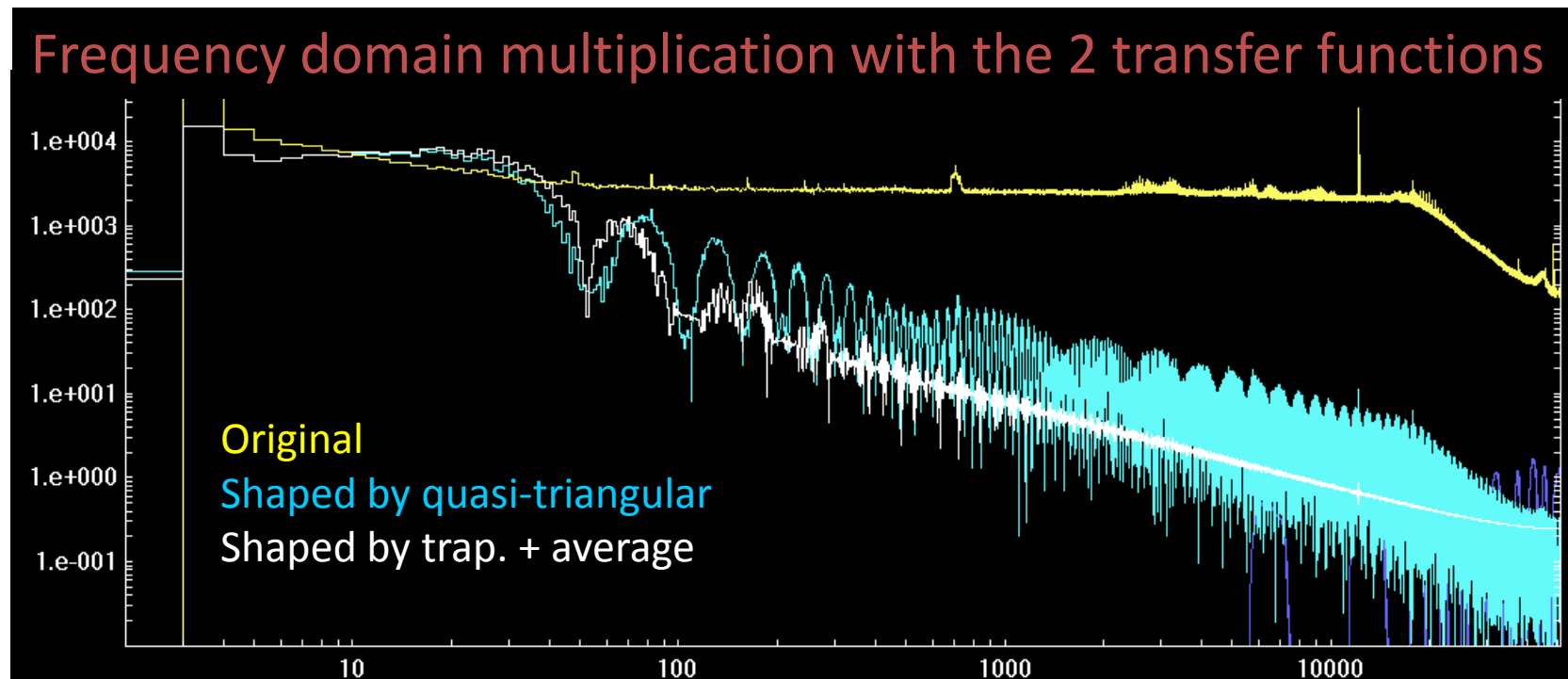
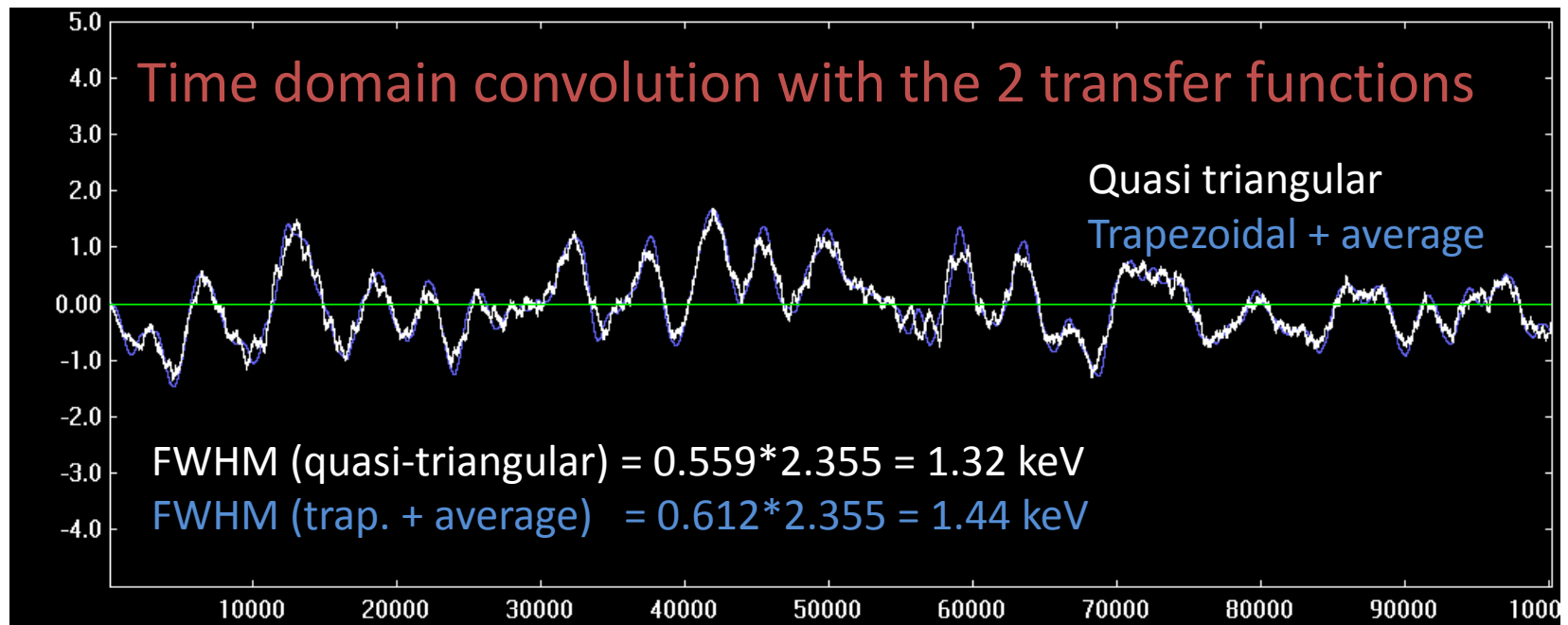
# Adjustment of decay constant is critical for a good flat top



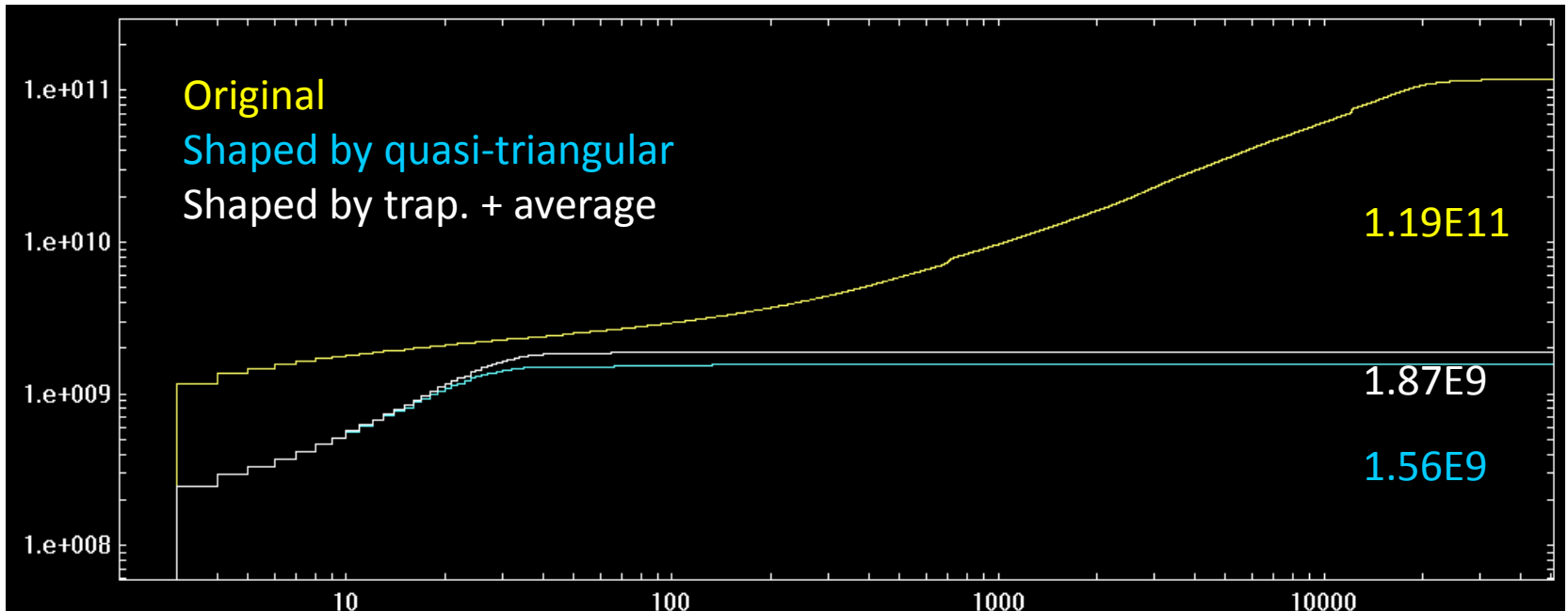
# Effect of shaping on noise







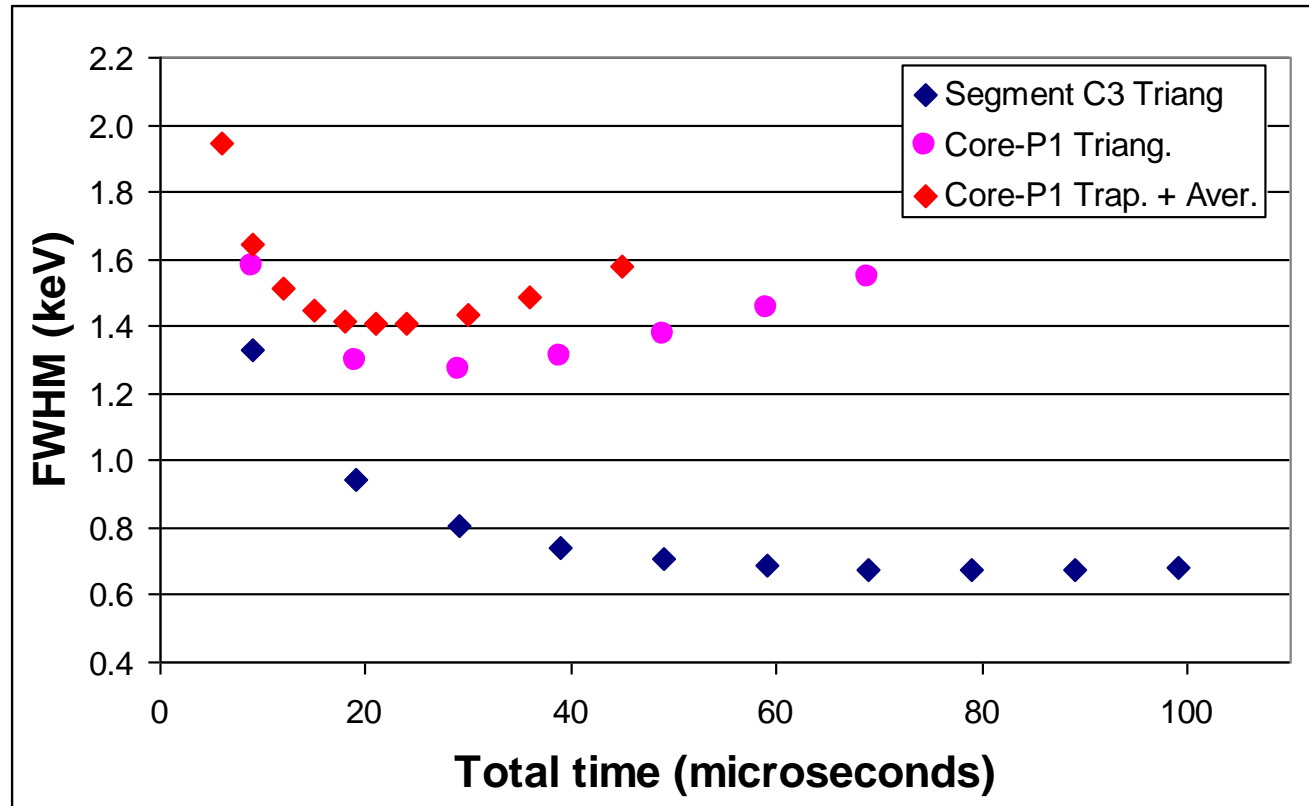
# Noise component of energy resolution from Integrated Power Spectra



Original	$\text{FWHM} = 3.33 \sqrt{(1.19 \cdot 10^{11}) / 10^5} = 11.49 \text{ keV}$
Quasi-Tr.	$\text{FWHM} = 3.33 \sqrt{(1.56 \cdot 10^{11}) / 10^5} = 1.32 \text{ keV}$
Trapz.+Av	$\text{FWHM} = 3.33 \sqrt{(1.87 \cdot 10^{11}) / 10^5} = 1.45 \text{ keV}$

# Noise performance of shapers

## Core and Segment C3



In the limit of very low counting rate and perfect BLR, the best resolution would be :

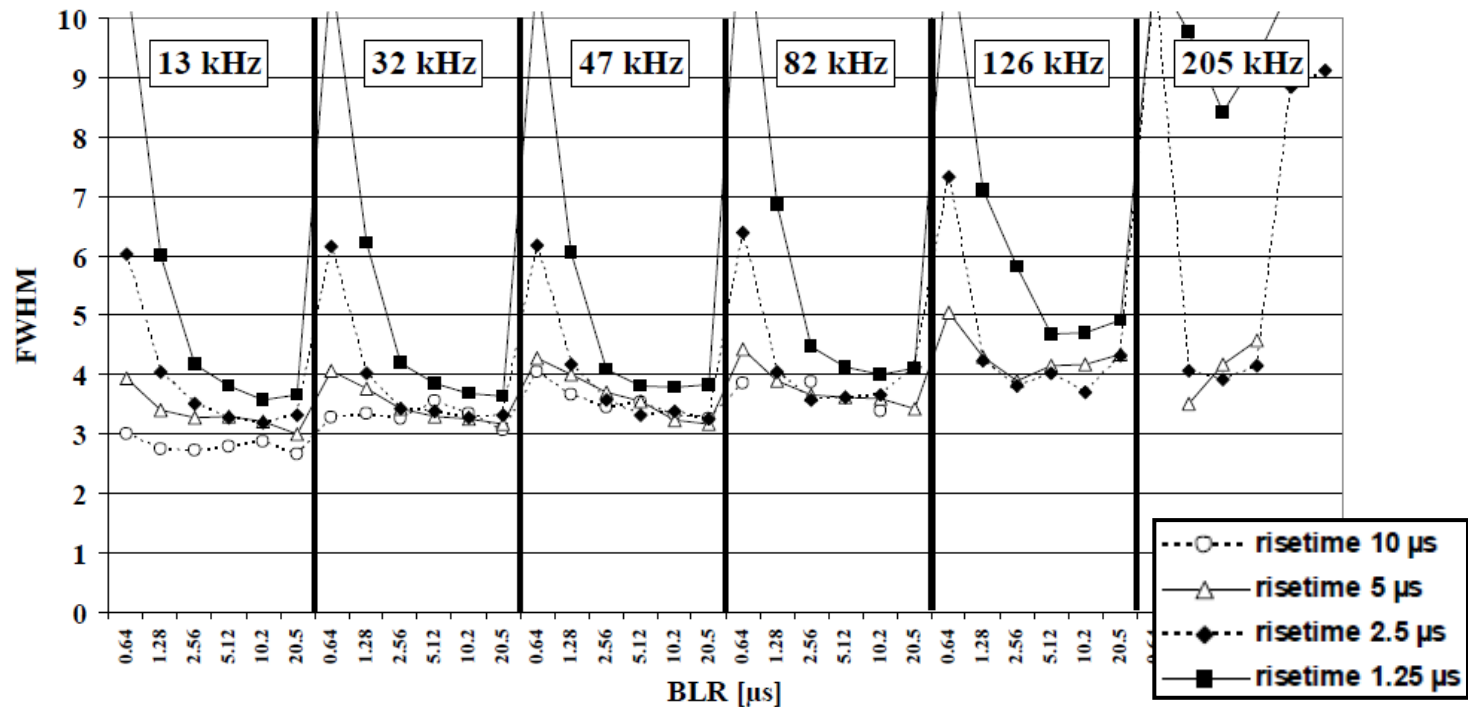
C3: 0.675 keV at [39-1-39] (Pt=40 Tt=78) Triangular with 1  $\mu$ s flat top

CC: 1.269 keV at [14-1-14] (Pt=15 Tt=29) Triangular with 1  $\mu$ s flat top

CC: 1.406 keV at [7-7-6] (Pt=14 Tt=27) Trapezoidal + Average with 1  $\mu$ s flat top

# Singles rates and shaping time

6 different rates x 4 trapezoid risetimes x 6 BLR lengths



Two independent sources  
of dead-time: pile-up  
rejector and GTS



# Structure of Data Processing

- Local level processing

- AGATA

- Readout
    - Pre-processing
    - PSA

- Ancillaries

- Readout
    - Pre-processing

- Global Level processing

- Event builder

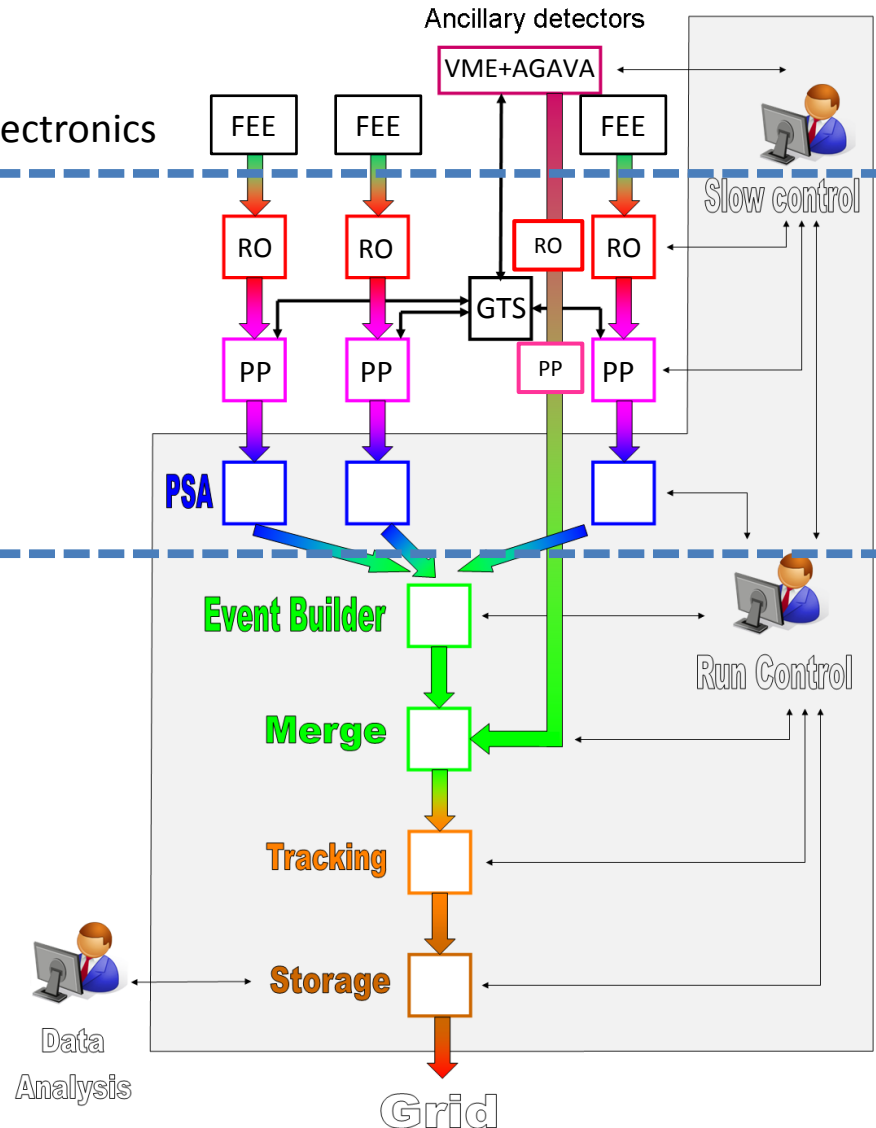
- Event merger

- Pre-processing

- Tracking

- Post-Processing

Front end electronics



# DAQ Farm



11 IBM pizza-box servers  
(+ 1 pizza/crystal)  
1 Host gateway  
1 KVM, 2 Switches, ...



60 (+60) TB storage  
15 TB for local backups  
Permanent storage and data distribution  
→ exploring GRID-approach via CNAF



1 U pizza-box server  
2 4-core CPUs  
16 GByte memory

1R 1G 1B ....

Digitizer  
or raw data file

CrystalProducer

PreprocessingFilter

PSAFilter

Consumer  
Save PSA output

Ancillary

VME  
or raw data file

AncillaryProducer

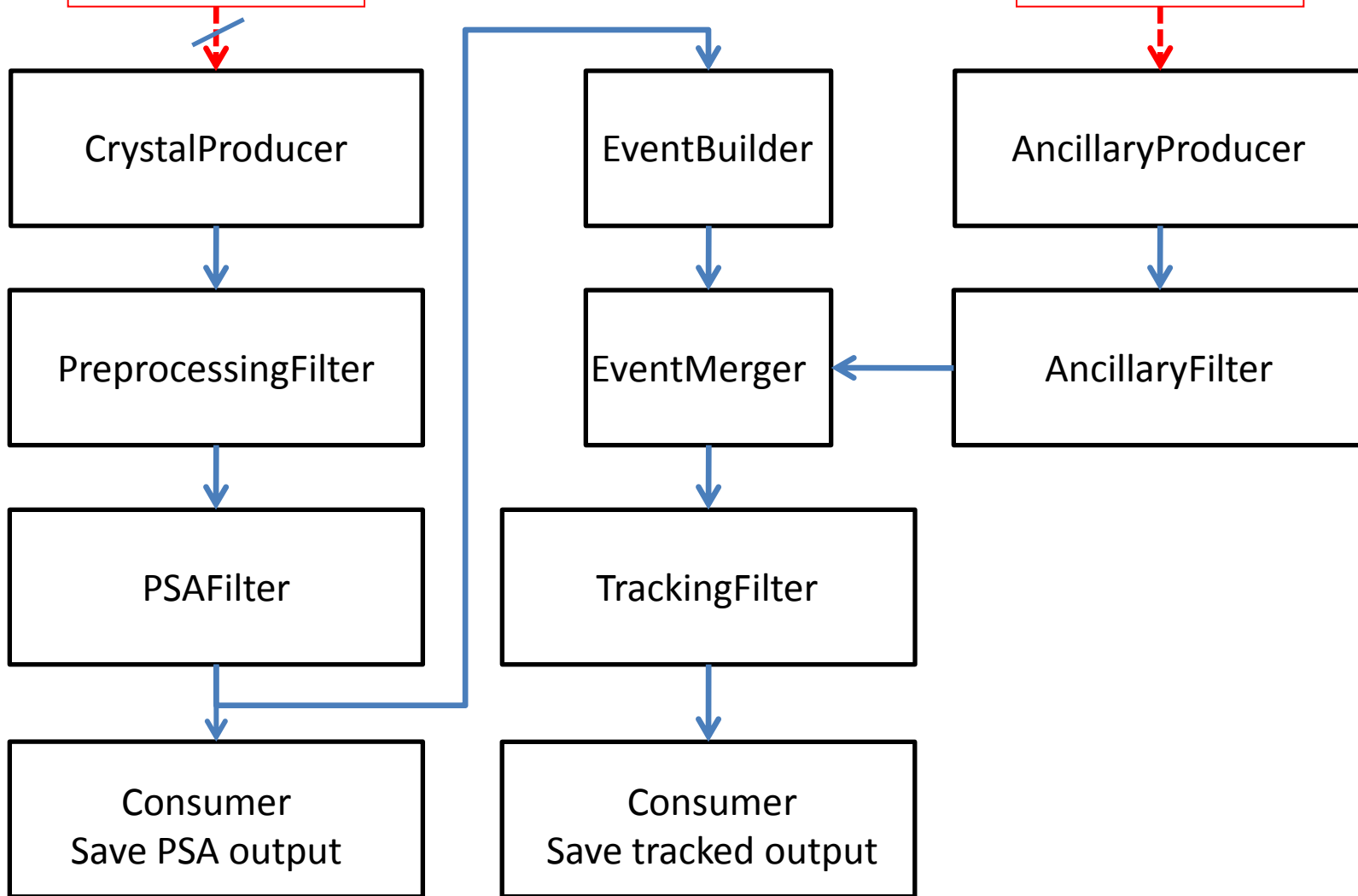
AncillaryFilter

EventBuilder

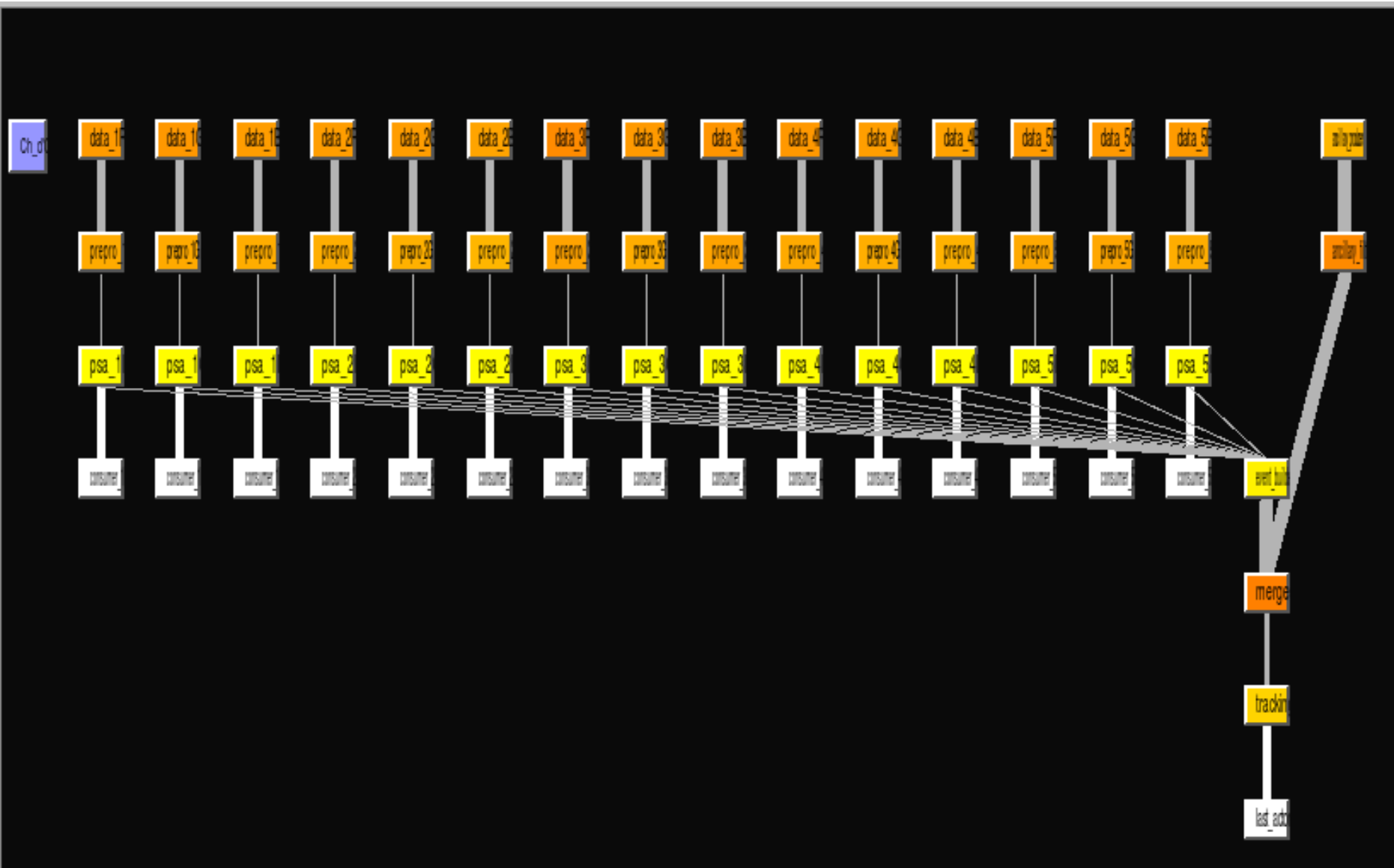
EventMerger

TrackingFilter

Consumer  
Save tracked output



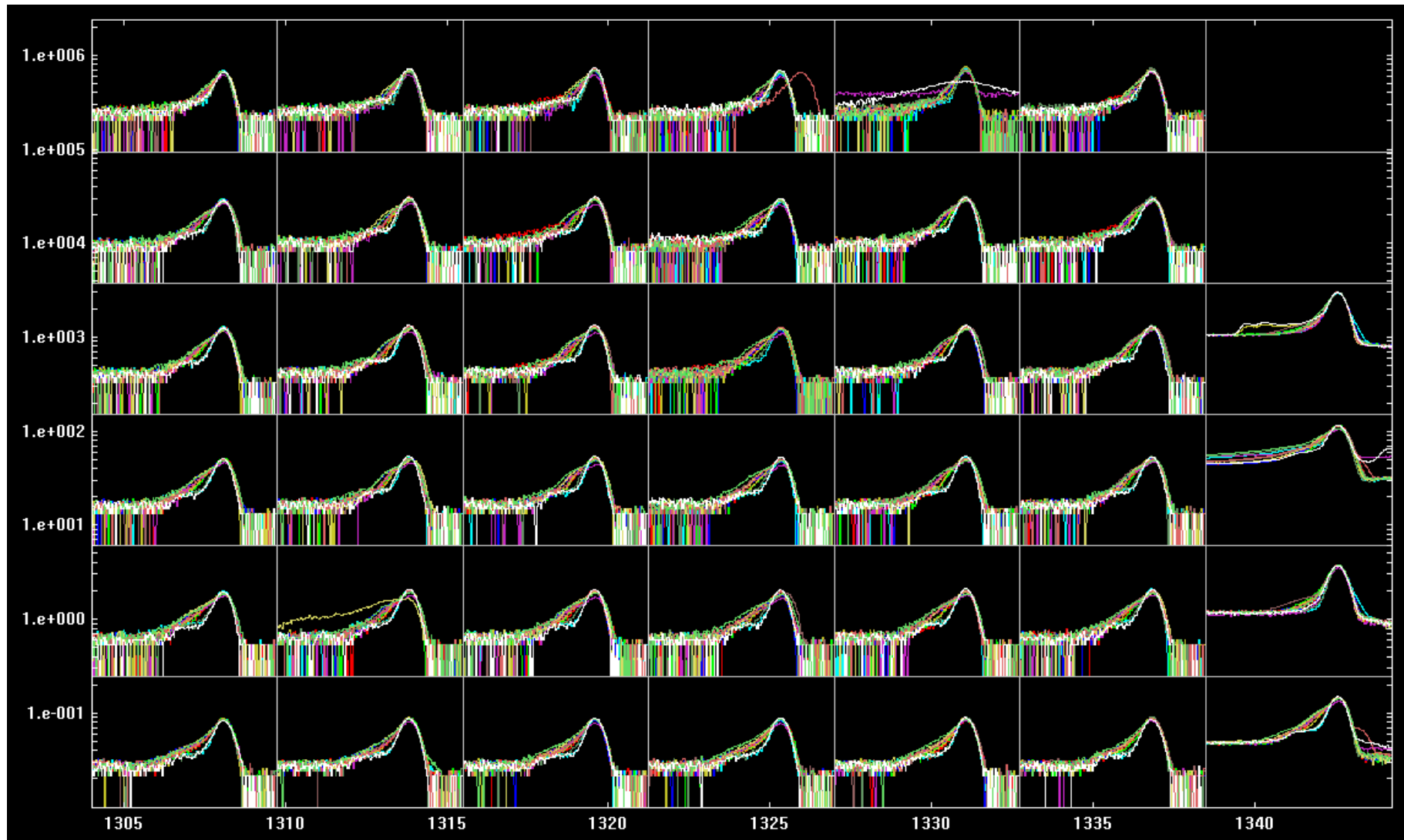
# Narval Topology for 5 ATC + Ancillary



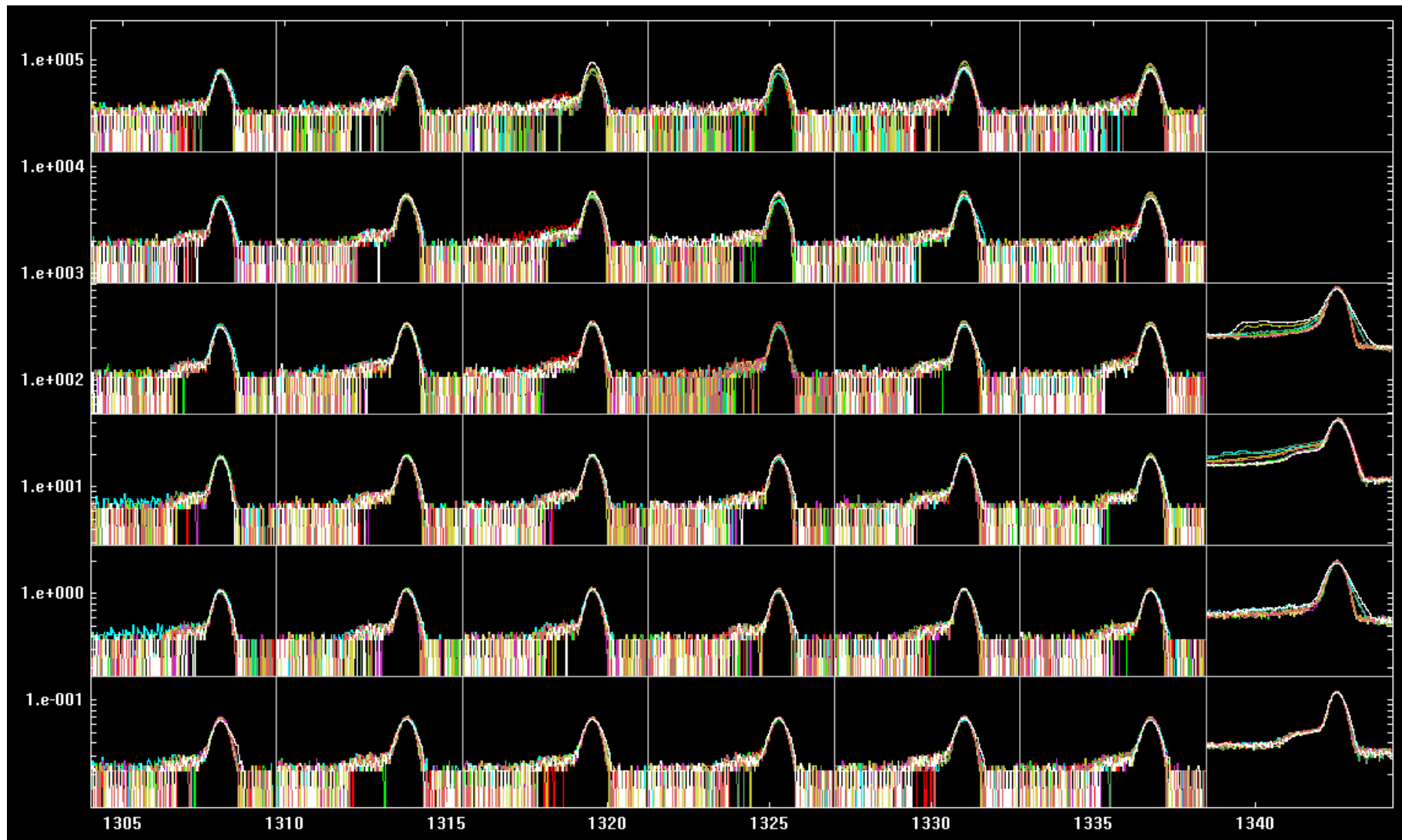
# Data processing and replay

- Online = Offline
- A series of programs organized in the style of Narval actors
- Director of the actors
  - **Online : Narval**
  - **Offline : Narval** or narval emulator(s)
    - Depending on the available computing resources
    - Single computer
    - Farm with distributed processing
- The system is complex and “difficult” to manage
  - Very large number of detectors  $\text{NumberOfCrystals} * 38 \rightarrow 5 \text{ ATC} = 555$
  - No chance to take care of them individually
  - Rely on automatic procedures
  - Hope that the system is stable
  - Result depends on average performance

# Several “problematic” segments



# Problems fixed





# Data processing and replay

- **Online = Offline**
- A series of programs organized in the style of Narval actors
- Director of the actors
  - **Online : Narval**
  - **Offline : Narval** or narval emulator(s)
    - Depending on the available computing resources
    - Single computer
    - Farm with distributed processing
- The system is complex and “difficult” to manage
  - Very large number of detectors  $\text{NumberOfCrystals} * 38 \rightarrow 5 \text{ ATC} = 555$
  - No chance to take care of them individually
  - Rely on automatic procedures
  - Hope that the system is stable
  - Result depends on average performance
- **Need GUIs, Histogram Viewers and and scripts to manage the work**
- Processing/Analysis model developed with contributions of several people
  - Xavier Grave Olivier Stezowski and their groups for the architecture and the basic tools
  - Joa Ljungvall, Daniele Mengoni, Enrico Calore, Francesco Recchia
  - The users and their feedback

# Structure of analysis directories

- The directory where you produce your data  
( e.g. /agatadisks/data/2011\_week41/zCurrentNarvalDataDir)  
contain some standard sub-directories
  - Conf → contains configuration of actors, calibrations, ...  
for each detector  
1R 1G 1B 2R ... 5B Ancillary Global  
with minimal differences between online and offline
  - Data → contains the data produced during the experiment  
1R 1G 1B 2R ... 5B Ancillary Global  
Online writes data here  
Offline takes data from here
  - Out → where we write the offline data  
1R 1G 1B 2R ... 5B Ancillary Global  
Offline writes data here

Conf, Data and Out are often symbolic links to actual directories

# The actors

- Producers
  - CrystalProducer / CrystalProducerATCA
  - AncillaryProducerTCP
  - BasicAFP
- Filters
  - PreprocessingFilter / PreprocessingFilterPSA
  - PSAFilter / PSAFilterGridSearch
  - TrackingFilter / TrackingFilterOFT
- Consumers
  - BasicAFC
- Builders
  - EventBuilder/EventMerger
    - ADA version for the online
    - C++ version in the femul emulator

# CrystalProducer

- Reads the data from:
  - The PCI express driver connected to the ATCA electronics
  - Raw data files (event\_mezzdata.bdat) for the offline
- Acts as a local event builder to check and merge the sub-events coming from the ATCA readout (or from the raw data file)
  - For the online has to work in nonblocking-mode to avoid blocking the ACQ
  - This feature was implemented with boost::threads
  - Damiano has now implemented the “select” and threads have been removed
  - The local event builder and the management of the mezzanine data should be completely rewritten ...
- Can write the original data with the format of the ATCA electronics, and various other formats (e.g. only the energies for calibrations)
- Prepares data:crystal frames, without using adf (version using adf exists, maybe slower)

# PreprocesssingFilter

- Performs
  - Energy calibrations and xTalk corrections
  - Analysis of traces
    - Calculation of T0 from core (Digital CFD or linear fit of the first samples)
    - Time calibrations and shifts
    - Vertical normalization of traces
    - Define the net-charge segments
  - Reformats the data as data:ccrystal frames
- The calibration files are produced by external programs as part of the calibration procedures; these programs work on more compact data files written by the CrystalProducer.

# PSAFilter

- Signal decomposition
- Implemented algorithm is the Grid Search
  - As a full grid search
  - As a coarse/fine search (AGS)
- Reduces size of data by factor 20
- Provides the parameters for the correction of neutron damage (can also perform it)
- Must be expanded to improve timing
- **Takes ~95 % of total CPU time**
- Is the critical point for the processing speed of online and offline analyses

# AncillaryProducerTCP

- Written as a tcp server
- Is not an ADF::NarvalProducer (but, for the sake of the emulators can inherit from it)
- Reads data via tcp
- Decodes the AGAVA structure and VME data
- Formats the data as data:ranc0, not using adf
- Can write the input data as raw binary files  
event\_vmedata.bdat



# AncillaryFilter

- Analysis of Ancillary data
- Changes a lot from experiment to experiment
  - PRISMA
  - Dante
  - Silicon strip detectors
  - Scintillators
- Almost impossible to set int up properly during the experiment
- In the last experiments, people gave up trying to analyse them on-line and usually opt for root-like methods
- What remains is simply raw or calibrated projections of VME data

# EventBuilder/EventMerger

- Work on data filtered by the real-time digital trigger
- The software builders use the timestamp of the data coming from the detectors
  - Could also reconstruct using the eventnumber but this is given with only 24 bits and rolls over every 16M events → modulo electronics
- The online Narval builders had a hard life in keeping up with the variability of data flow and sometimes lost synchronization.
  - A solution was to have very large timeouts in the reconstruction algorithms but this slowed too much down the stop procedures
  - The latest improvements by Xavier Grave have not yet been tested
- The offline builders have a simpler life because data flow from files is (?) more smooth (and the timeouts in the reconstruction algorithms can be very large)

# TrackingFilter

- This is the first point where we can check integrity of global events and analyse them
  - As AGATA only
    - Build global spectra: energy, time and  $T_{\gamma\gamma}$
    - Adjust gain of CC (and SG, not implemented) → should be moved to postPSA
    - Force sum energy of segments to energy of CC → small loss of resolution but removes extra left tail
  - As AGATA + Ancillary
    - Spectra of Ge in coincidence with ancillary
    - Gate on  $T_{\text{Ge}} - T_{\text{anc}}$  (still timestamp only) to select the data for tracking
- Input of tracking can be written in mgt-style for offline tracking with OFT or MGT
- **Tacking algorihm**
  - TrackingFilterOFT
  - Waely's, parameter-free cluster tracking algo
  - Has been a bottleneck, but now can achieve 20 kHz
  - Problem: Timing not reported well
- Output of Tracking written as adf or root tree
  - Both outputs keep the input hits (and the Ancillary data if present), adding the tracked gammas and the Ancillary filter
  - Timing is not yet reported properly

# For the workshop?

- Energy calibrations
- Cross talk calibrations and corrections
- Time calibrations



# Details on the configuration files

- The Conf directories contain, for each used actor, one file with “keyword value” pairs to control the details of the actual analysis.
- The name of the configuration file is always **actorName.conf**
- If the actor is organized as a mother-class/daughter-class the daughter can also have its configuration files (e.g for energy calibrations, xTalk corrections, description of ATCA and VME hardware ...), but these are specific and, unfortunately, the names are not standardized
- The configuration files for the crystals are very similar; the changes to adapt them to the specific experiment/analysis have been done often using tools like sed → **error prone**
- Clearly, we need some graphics interface
- As a temporary solution there is now a python script “**gen\_conf.py**” which simplifies the job
- For energy calibrations, xTalks, n-damage, ..., there are (or there should be) dedicated programs which should produce and copy to the target directories the proper files
- The Narval API puts constraints on how some of the parameters are passed to the system

# The Grid Search algorithm

## implemented in Narval as `PSAFilterGridSearch`

- Signal decomposition **assumes one interaction per segment**
- The decomposition uses the transients and a differentiated version of the net charge pulse
- Proportional and differential cross-talk are included using the xTalk coefficients of the preprocessing.
- The minimum energy of the “hit” segments is a parameter in the `PreprocessingFilter` → 10 keV
- No limit to the number of fired segments (i.e. up to 36)
- The number of used neighbours is a compile time parameter (usually 2 as Manhattan distance)
- The algorithm cycles through the segments in order of decreasing energy; the result of the decomposition is removed from the remaining signal  
→ subtraction method at detector level
- Presently using ADL bases (Bart Bruyneel) with the neutron-damage correction model (the n-damage correction is not yet fully implemented in this actor)
- Using 2 mm grids → ~48000 grid points in a crystal; 700-2000 points/segments
- Speed is
  - **150 events/s/core for the Full Grid Search**
  - **1000 events/s/core for the Adaptive Grid Search**
- To speedup execution, parallelism has been implemented (using `boost:threads`) with blocks of ~100 events passed to N parallel threads of execution

# Speed does not increase linearly with the number of threads

Amdahl's law  $T = T_{\text{serial}} + T_{\text{parallel}}/N_{\text{threads}}$

