AGATA Local Level Processing
(adapted from E. Clément and D. Bazzacco)

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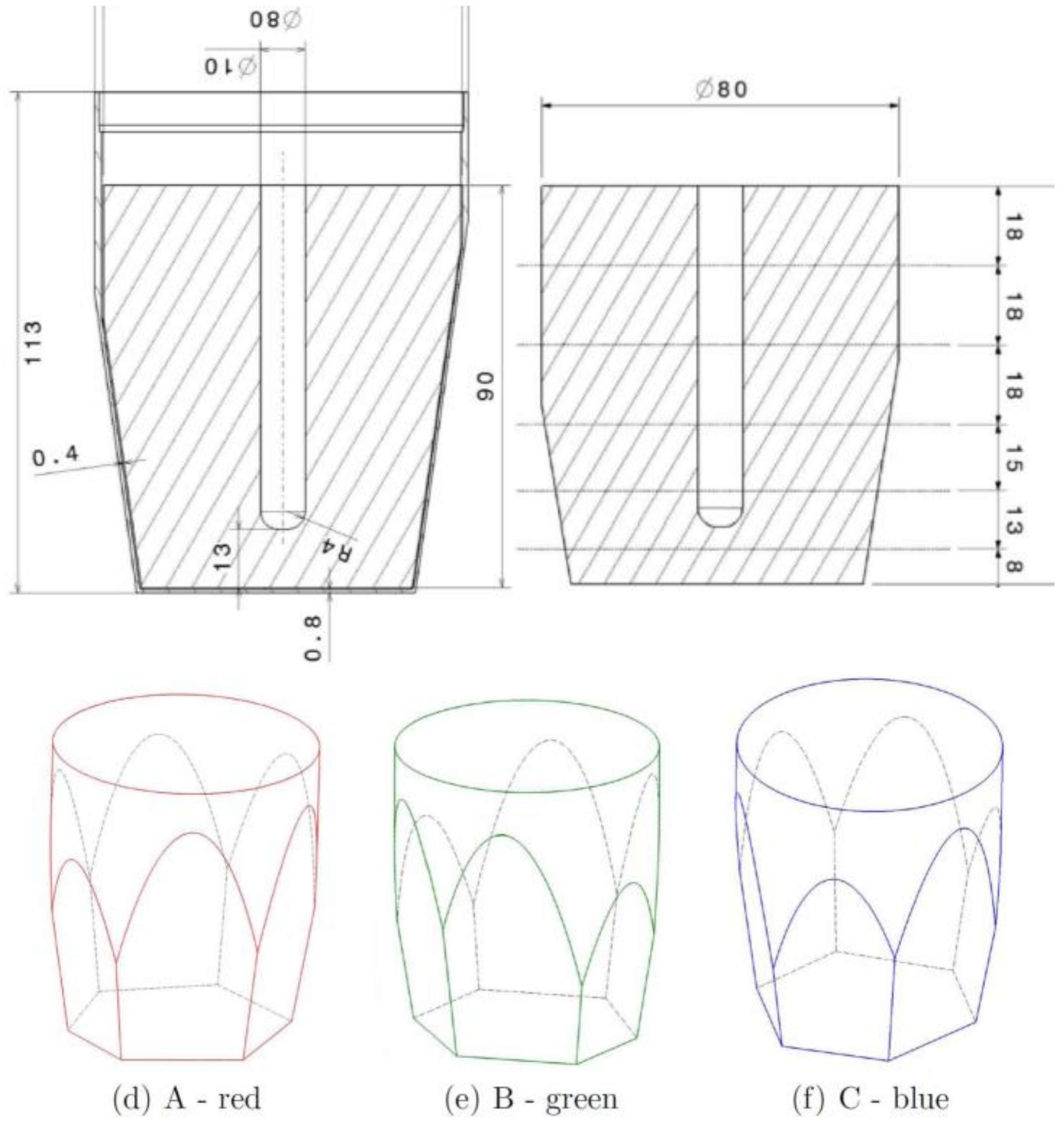
on behalf of the Data Analysis Working Group

AGATA Analysis School: 13/01/2025, Lyon

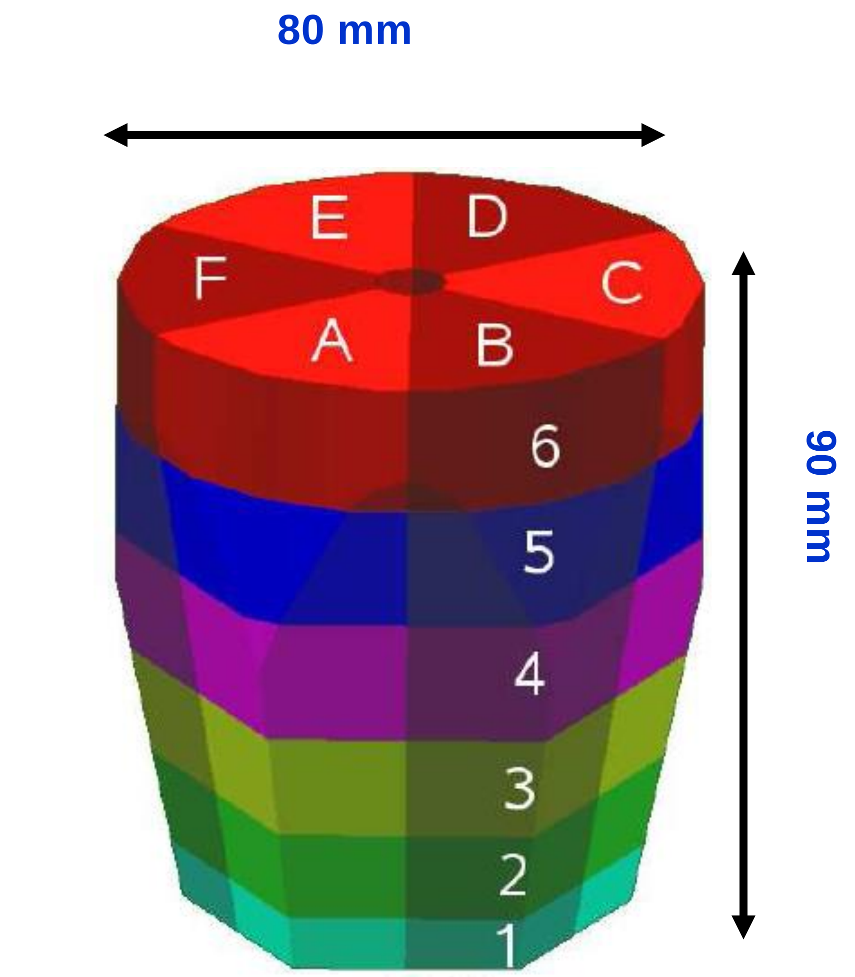
Topics

- General structure of data acquisition
- Data flow ➔ ADF
- Data processing model
- Emulators
- Narval (ADA/C/C++) and actors

AGATA detectors



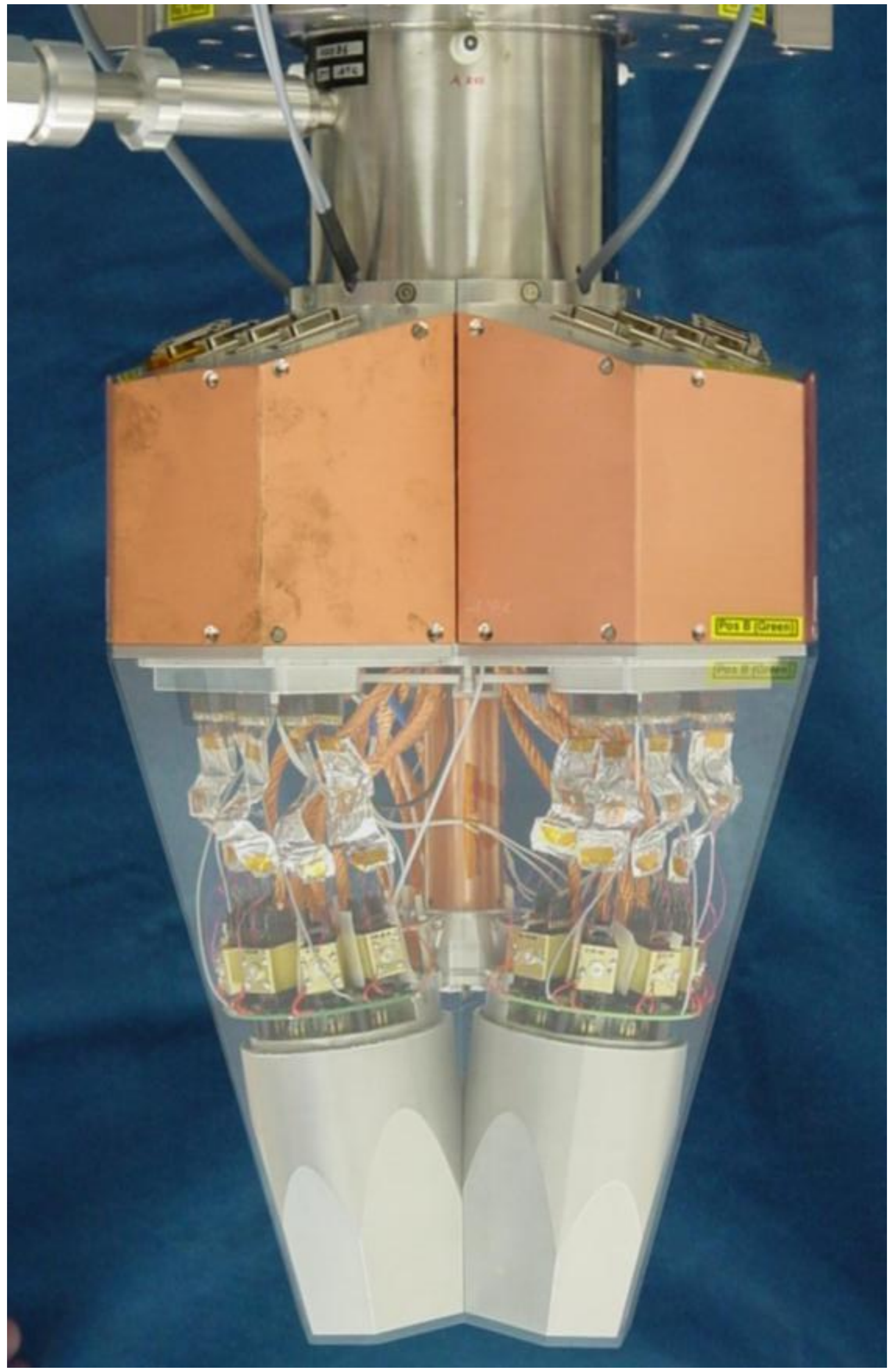
Volume ~370 cc Weight ~2 kg
(shapes are volume-equalized to 1%)



6x6 segmented cathode
Cold FET for all signals

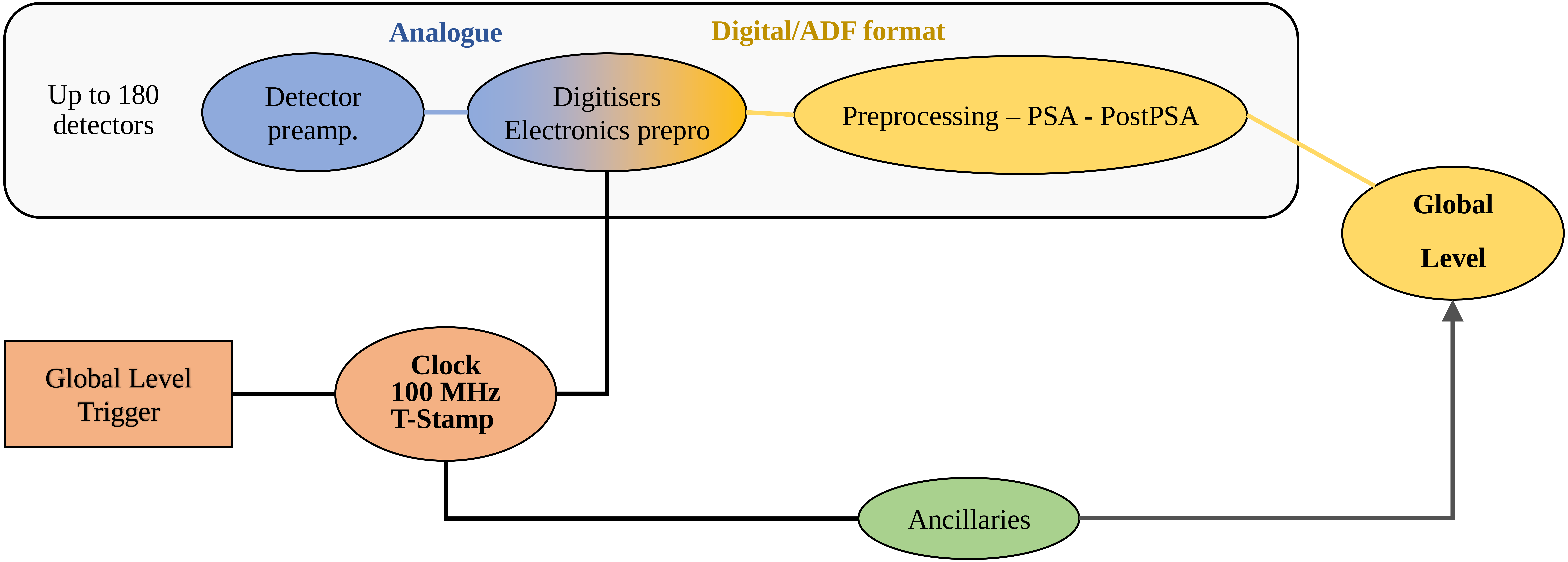
Energy resolution
Core: 2.35 keV
Segments: 2.10 keV
(FWHM @ 1332 keV)
A. Wiens et al. NIM A 618 (2010) 223
D. Lersch et al. NIM A 640(2011) 133

38 high-resolution signals / detector



AGATA Triple/Double Cryostat

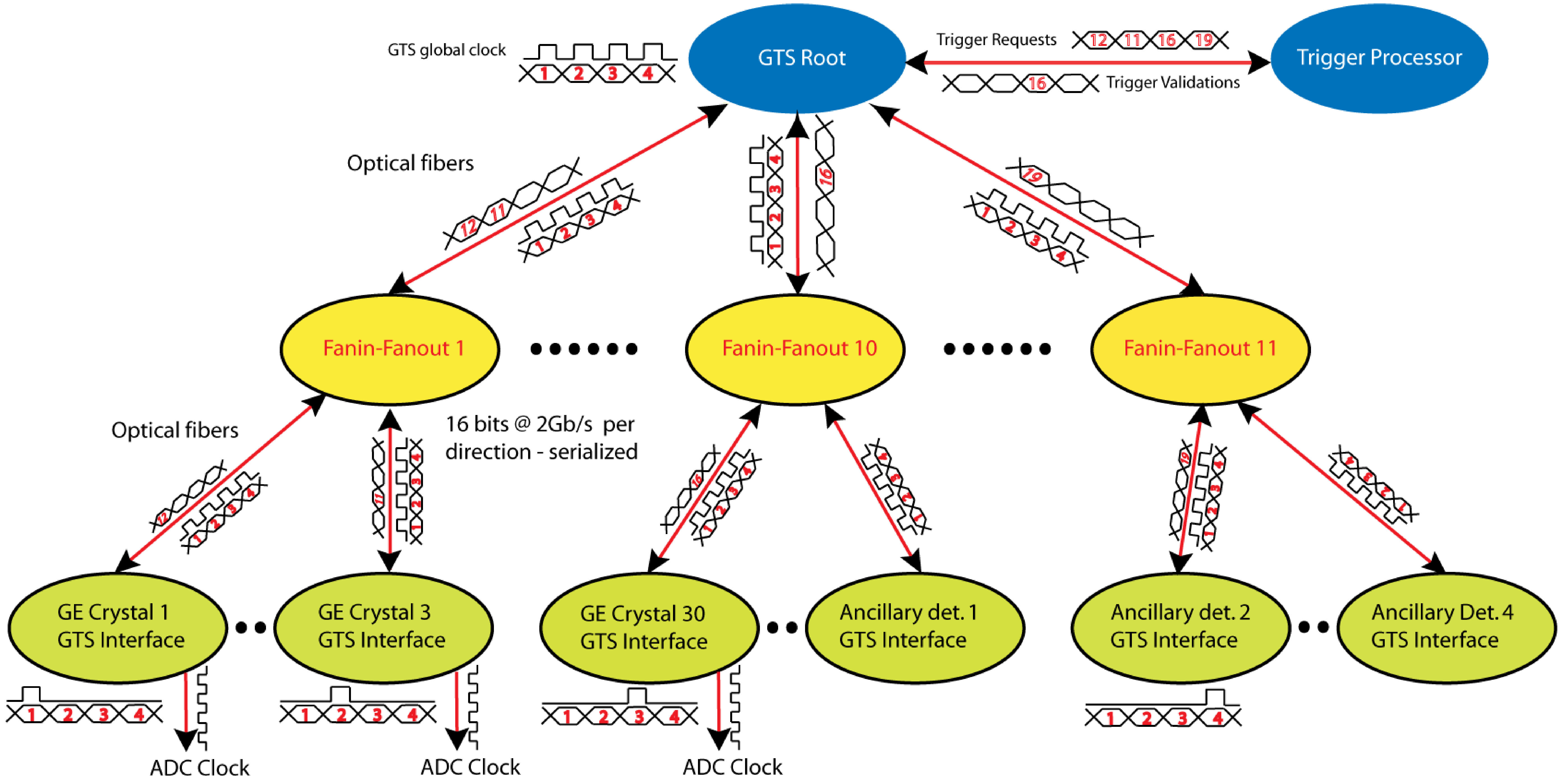
Structure of Electronics and DAQ



GTS : the system coordinator

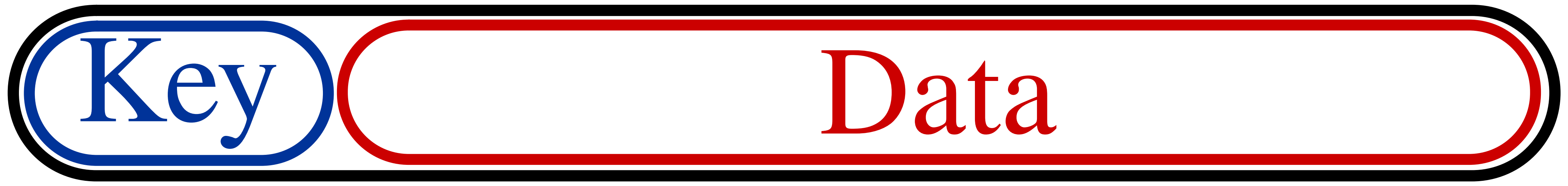
All detectors operated on the same 100 MHz clock

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 48 bit timestamp + 24 bit event number


GTS global clock
1 2 3 4
GTS Root
Trigger Requests
12 11 16 19
Trigger Validations
16
Trigger Processor
Optical fibers
Fanin-Fanout 1
Fanin-Fanout 10
Fanin-Fanout 11
Optical fibers
16 bits @ 2Gb/s per direction - serialized
GE Crystal 1 GTS Interface
GE Crystal 3 GTS Interface
GE Crystal 30 GTS Interface
Ancillary det. 1 GTS Interface
Ancillary det. 2 GTS Interface
Ancillary Det. 4 GTS Interface
ADC Clock
ADC Clock
ADC Clock

The AGATA Data Format: ADF

ADF Frame:



Key

Data

The key contains:
- Data lenght
- Data type
- Timestamp
- Event number

The Data contains either:
- data (energies, hits...)
- adf frames

The AGATA Data Format: ADF

The ADF.conf configuration file

```
Frame:   Agata data:crystal         4 0   Agata data:crystal        0 0
Frame:   Agata data:ccrystal        4 0   Agata data:ccrystal       65000 0
Frame:   Agata data:ranc0           4 0   Agata data:ranc0          65000 0
Frame:   Agata data:ranc1           4 0   Agata data:ranc1          65000 0
Frame:   Agata data:ranc2           4 0   Agata data:ranc2          65000 0
Frame:   Agata data:psa             4 0   Agata data:psa            0 0
Frame:   Agata data:tracked         4 0   Agata data:tracked        1 0
Frame:   Agata event:data           4 0   Agata event:data          4 0
Frame:   Agata event:ranc           4 0   Agata event:ranc          4 0
Frame:   Agata event:data:crystal   4 0   Agata event:data:crystal  4 0
Frame:   Agata event:data:ccrystal  4 0   Agata event:data:ccrystal 4 0
Frame:   Agata event:data:psa       4 0   Agata event:data:psa      4 0
Frame:   Agata event:data:ranc0     4 0   Agata event:data:ranc0    4 0
Frame:   Agata event:data:ranc1     4 0   Agata event:data:ranc1    4 0
Frame:   Agata event:data:ranc2     4 0   Agata event:data:ranc2    4 0
Frame:   Agata meta:vertex          4 0   Agata meta:vertex         0 0
Frame:   Agata meta:sync            4 0   Agata meta:sync           0 0
Frame:   Agata meta:scan            4 0   Agata meta:scan           0 0
```

Each key and frame is associated to a version number

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 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 produced data is tagged with a 48 bit number (time stamp) giving the absolute time (with a precision of 10 ns) since the last hard-reset of the system ➔ roll around takes place every 32.5 days.**

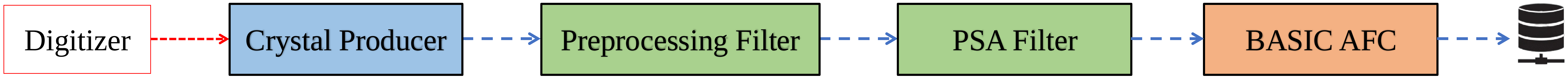
Global Level : where the detectors do know of each other

- By means of the real time trigger
- 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

Data processing: NARVAL/DCOD

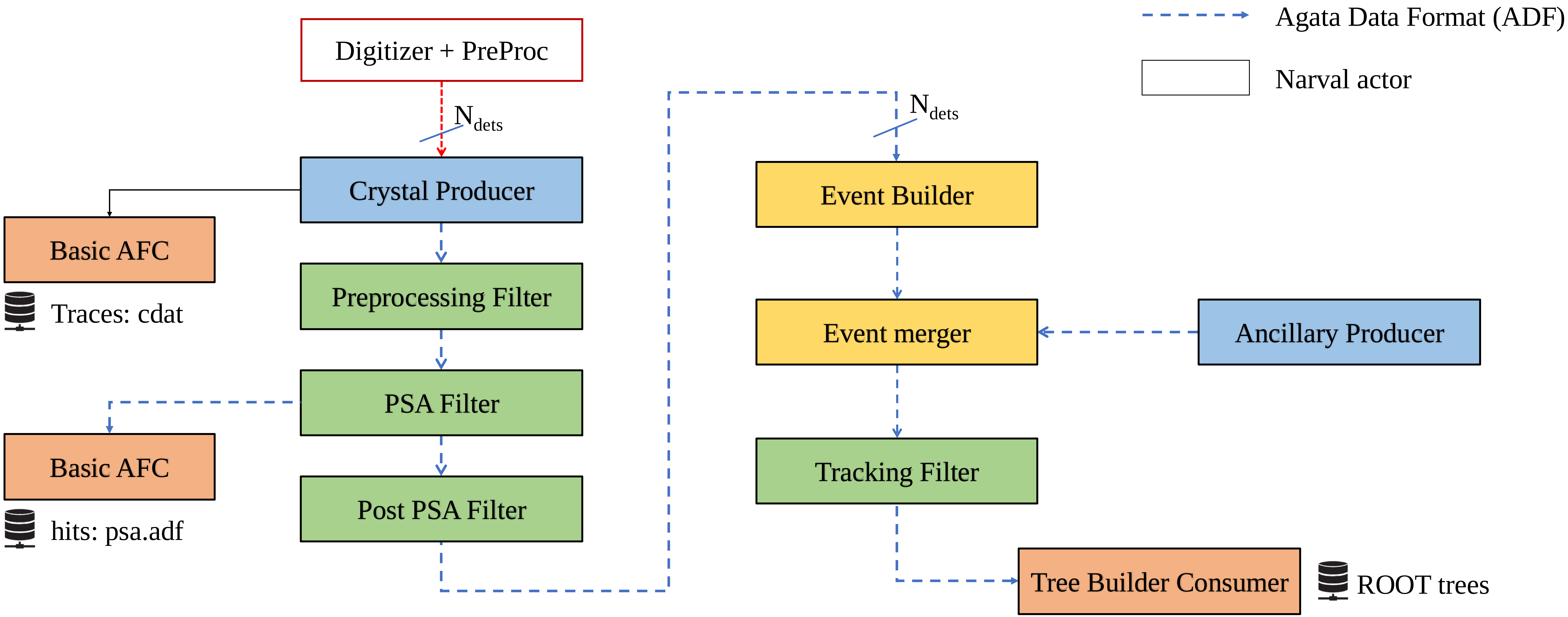
List of actors, applying successive operations on the data flow:

- **Producer:** Read data from outside (electronics/disk) to the NARVAL chain
- **Filters:** Process operations on the dataflow (calibrations/PSA/Tracking)
- **Dispatchers:** Merge multiple entries in the NARVAL chain (Event Builder/Event Merger)
- **Consumer:** Close the NARVAL chain (write data on disk)



Standard actors chain for AGATA LLP

Architecture of the system

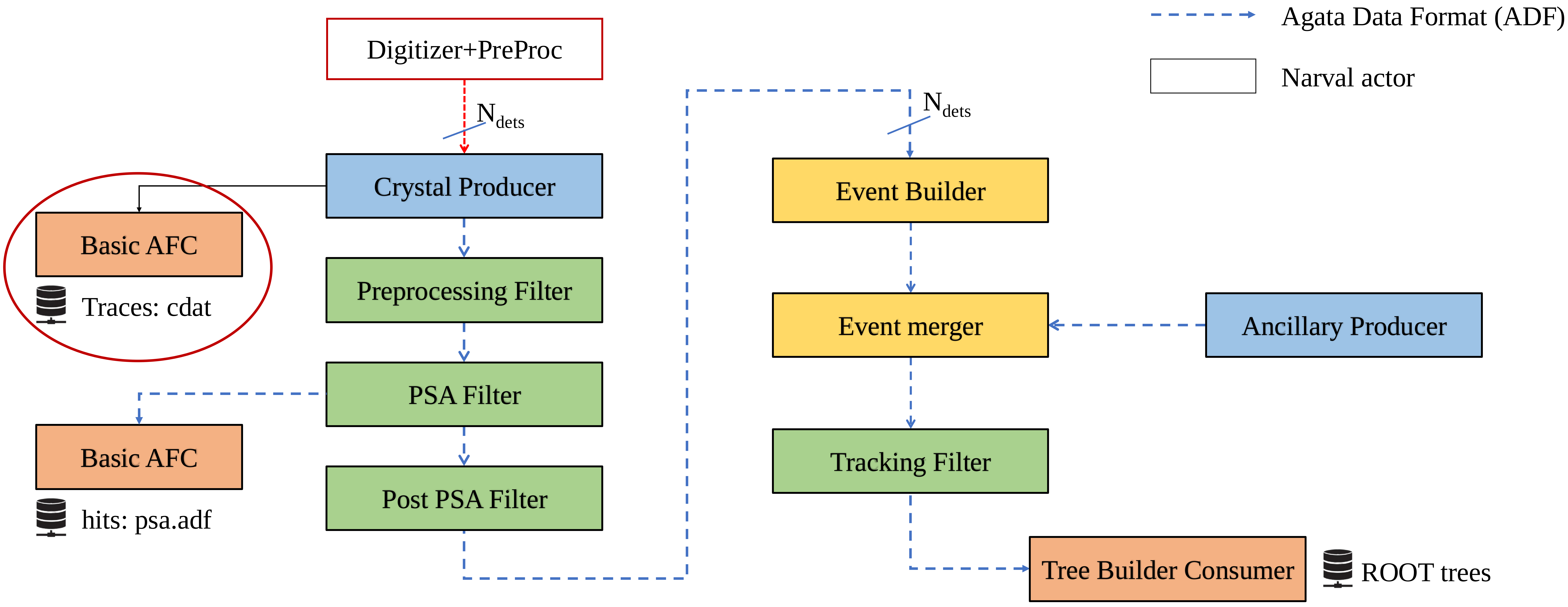


Data replay: the femul emulator

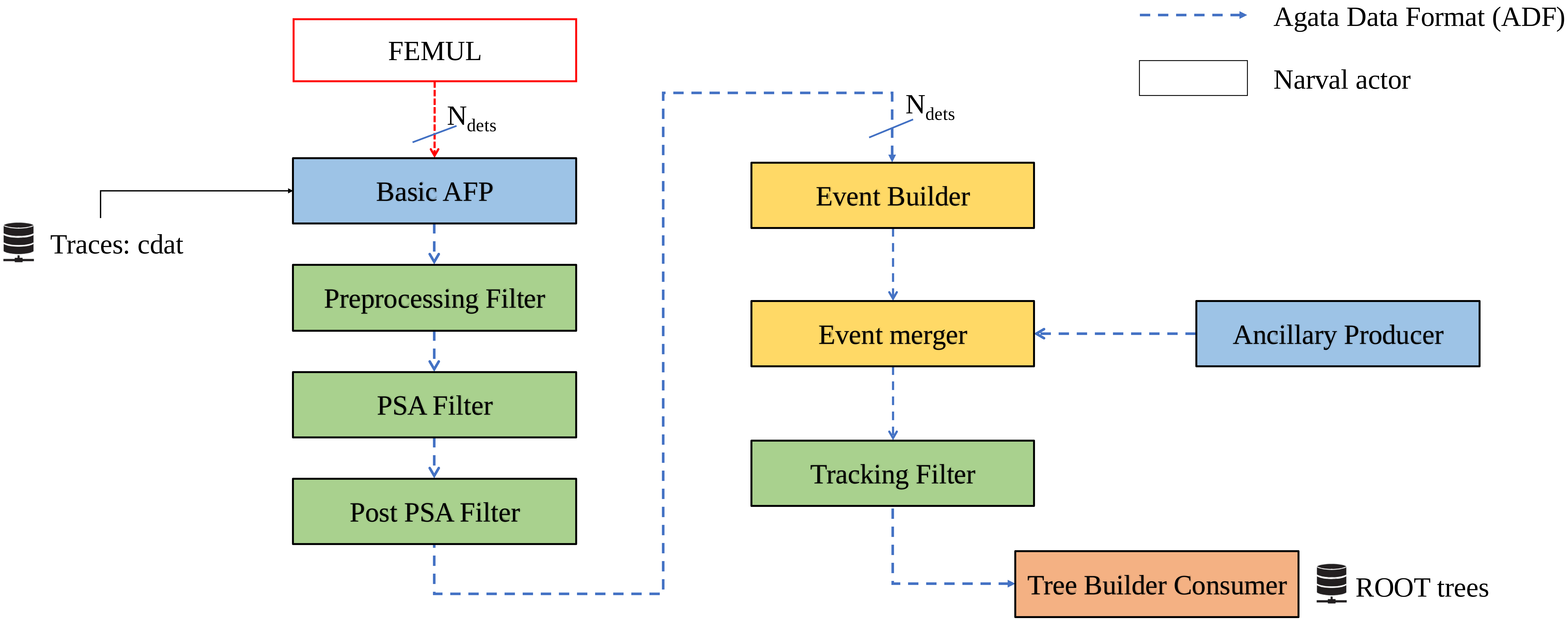
- Originally intended to help developing and debugging the user libraries which is very hard to do in a distributed processing environment like Narval.
- Gradually developed as a full emulation of the Narval framework with the limitation of being a single process running a specific machine (threads used to distribute the work on the available cores).
- Configuration (detectors, actors, ..) specified by a “topology” file.
- Generation of configuration parameters via *gen_conf.py*

➔ **Online == Offline processing**

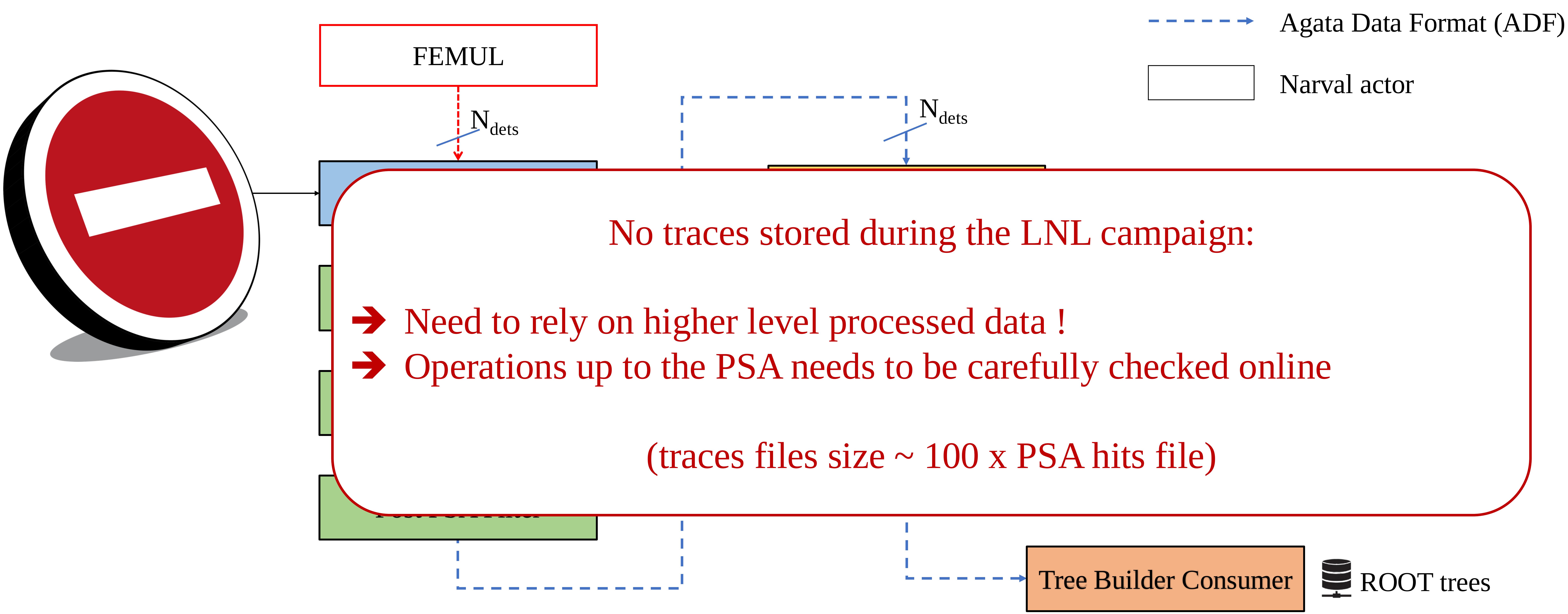
Data replay: the femul emulator



Data replay: the femul emulator



Data replay: the femul emulator



No traces stored during the LNL campaign:

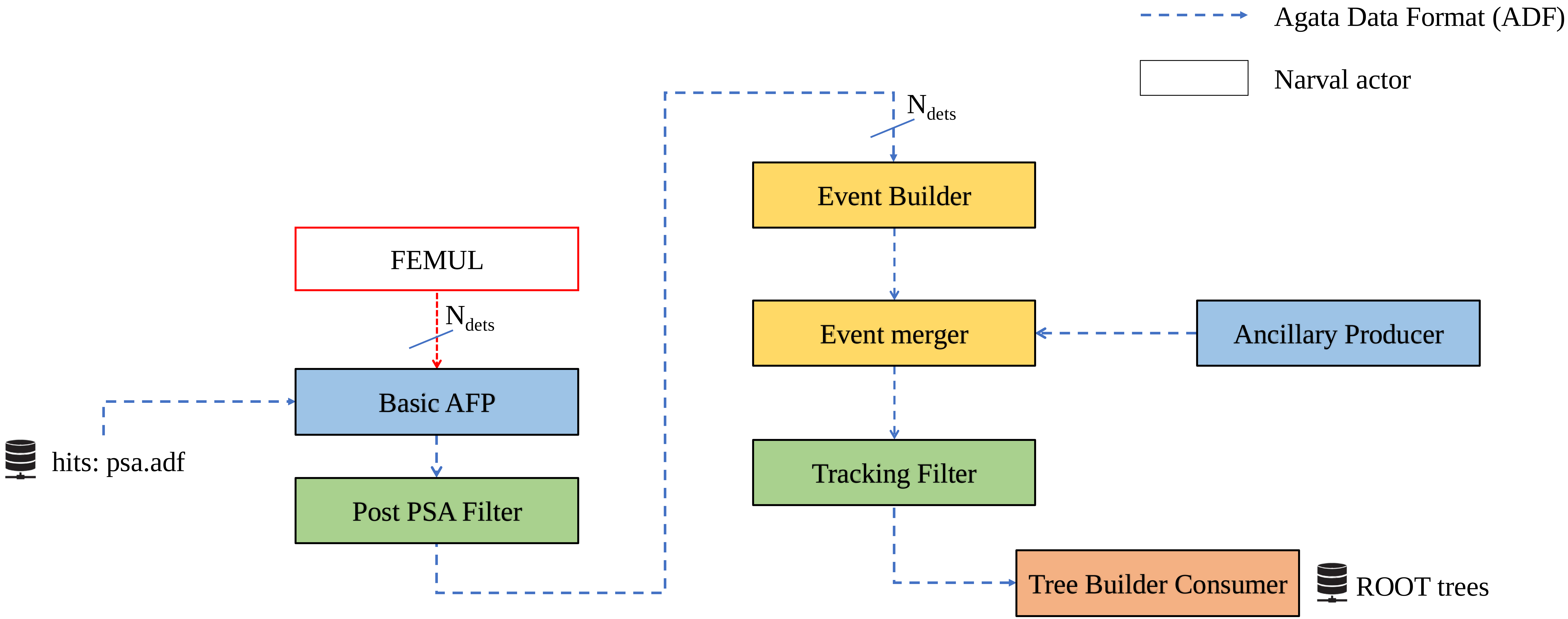
- ➔ Need to rely on higher level processed data !
- ➔ Operations up to the PSA needs to be carefully checked online

(traces files size ~ 100 x PSA hits file)

Data replay: the femul emulator

Agata Data Format (ADF)
Narval actor
FEMUL
N_{dets}
Crystal Producer
Preprocessing Filter
PSA Filter
Post PSA Filter
Basic AFC
hits: psa.adf
N_{dets}
Event Builder
Event merger
Ancillary Producer
Tracking Filter
Tree Builder Consumer
ROOT trees

Data replay: the femul emulator



Structure of analysis directories

The directory where you produce your data contains some standard sub-directories
(e.g. /agatadisks/exptname (EXXX) /(Config EXXX)/run_XXX_date)

Conf: Configuration of actors, calibrations, ... for each detector
→ **00A, 00B, 00C ... Ancillaries, Global, Merger**
with minimal differences between online and offline

Data: Data and spectra produced during the experiment
→ Online writes data here
→ Offline replay takes data from here

Out: Data and spectra produced during data replay
→ Offline writes data here

Typical configuration directories

Conf/12A

- CrystalProducer.conf
- CrystalProducerATCA.conf
- PreprocessingFilter.conf
- PreprocessingFilterPSA.conf
- PSAFilter.conf
- PostPSAFilter.conf
- xdir_1325-1340.cal
- xinv_1325-1340.cal
- BasicAFC.conf
- BasicAFP.conf

Conf/Builder

- EventBuilder.conf

Conf/Merger

- EventMerger.conf
- TrackingFilter.conf
- CrystalPositionLookUpTable
- TreeBuilder.conf

Binary spectra

- Simple C-style multidimensional (max 6) arrays written mostly in binary format
- For historical reasons the format is not recorded in the file

  → Often written as part of the file name:

  Prod__4-38-32768-UI__Ampli.spec is a file dump of an array defined as:
  unsigned integer Ampli[4][38][32768],
  containing **4*38** = 152 spectra of **32768** channels

- The viewers **TkT** and **Mat** can decode and interpret the format.
- Other programs (e.g. RecalEnergy) can interpret the spectrum length and type but the user have to specify the number of spectra to act upon.

Some Useful programs

The number of channels (38 x number of detectors) to be calibrated and checked at each analysis level is too large to be done one by one: **automatic tools and procedures are distributed**

→ **TkT spectrum viewer**: to plot any spectrum produced all along the chain of actors

→ **RecalEnergy:** Analysis of spectra looking for peaks (energy and time calibrations)

→ **SortPsaHits:** Sort of PSA hits (special format) to determine neutron damage correction parameters

→ **gen_conf.py:** Unified procedure to produce configuration files for all actors

→ **solveTT.py:** Optimize time alignment of "equal" detectors (Global time alignment)

Local actors

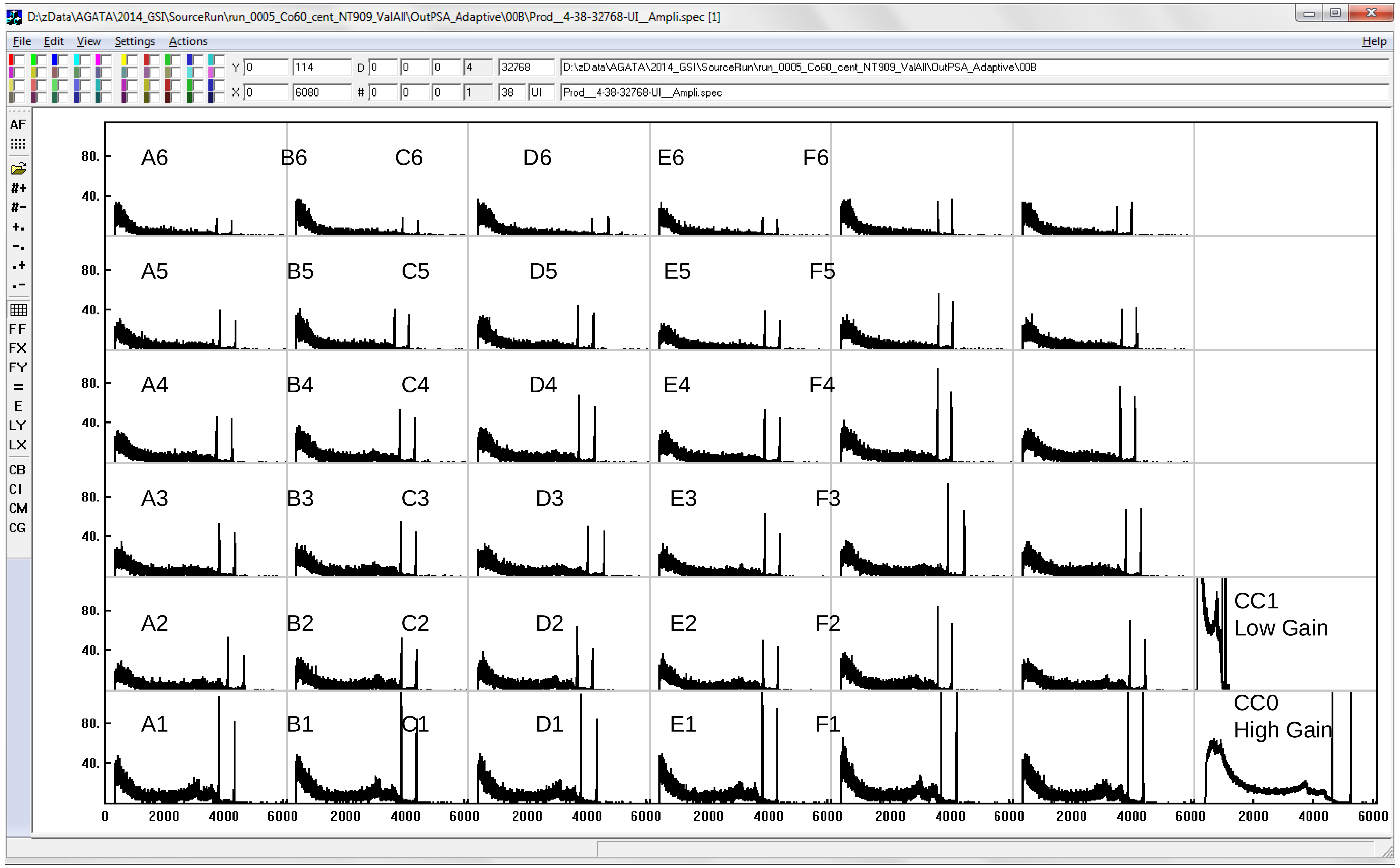
- **CrystalProducer**
  - Readout of electronics, or get raw data from file
  - Save original data to be able to replay experiment
- **PreprocessingFilter**
  - Energy calibrations (no offset)
  - local time alignment of segments and core
  - Cross talk correction
  - Amplitude calibration and time alignment of traces
  - Improved pile-up rejection
- **PSAFilter**
  - Decomposition of calibrated experimental traces by comparison with a calculated signal basis
  - In principle more than one algorithm available but only one used in practice
- **PostPSAFilter**
  - Neutron deficit corrections
  - Recalibrations of energy and time (including offsets)
  - *Smearing of positions (not recommended)*

Crystal Producer

What does it read and write ?

- Raw event: data from GGP electronics
- Traces length (100 samples of 10ns)
- Can write original data on disk (in compressed format)
  - ➢ data files typically split after 1 M events ~ 3.6 GB
    - ✓ event_mezzdata.cdat.0000
    - ✓ event_mezzdata.cdat.0001 …
- Generate raw spectra for amplitudes and baselines
- Format data into a “*data:crystal*” adf frame

Prod__4-38-32768-UI__Ampli.spec
[1]-38-32768 used for energy calibrations



D:\zData\AGATA\2014_GSI\SourceRun\run_0005_Co60_cent_NT909_ValAll\OutPSA_Adaptive\00B\Prod__4-38-32768-UI__Ampli.spec [1]

Y 0 114 D 0 0 0 4 32768 D:\zData\AGATA\2014_GSI\SourceRun\run_0005_Co60_cent_NT909_ValAll\OutPSA_Adaptive\00B

X 0 6080 # 0 0 0 1 38 UI Prod__4-38-32768-UI__Ampli.spec

Preprocessing Filter

Performs:

- **Energy calibrations** and **cross talk corrections**
- Analysis of traces
  - **Calculation of T0** from the core signal
  - **Time alignment** of the segments
  - Energy and time calibration of the trace (amplitude and time shift)
  - Define the segment multiplicity (number of segments with a net charge)

- **After Preprocessing**:
  - energies are stored in units of keV
  - times are in units of samples (10 ns) (but time calibration parameters are in ns)
  - positions are given in mm, when they show up after the PSA

Preprocessing Filter

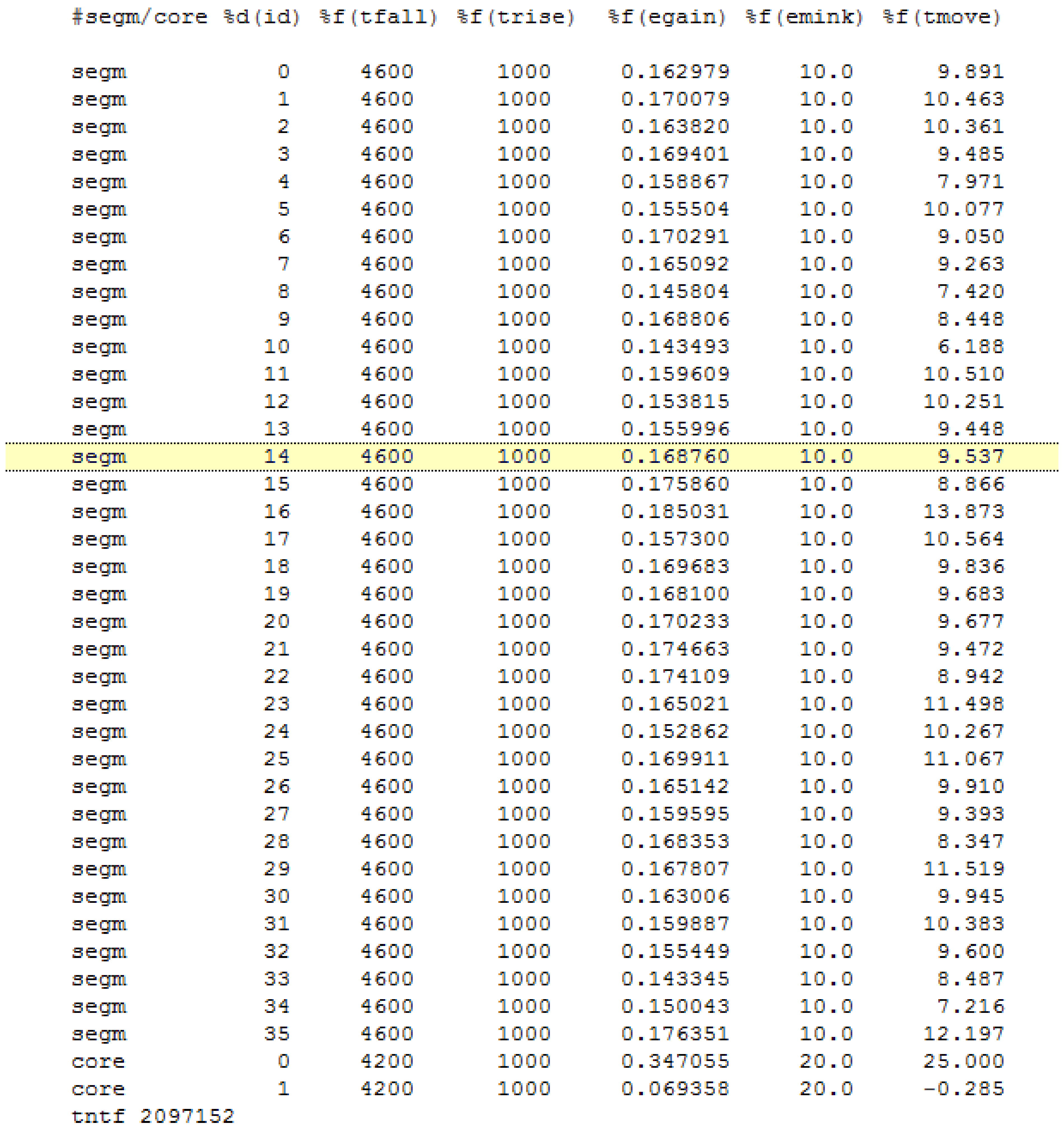
Calibrations:

- **Energy**
  - **Gain-only, no offset** coefficient needed because of the way the amplitude is generated in the preprocessing electronics.

- **Cross-talk**
  - 36*36=1296 coefficients to correct capacitive coupling correlations between segments and core
  - Used also to recover up to one broken or missing segment per crystal

- **Local Time**
  - 36 coefficients to align segments to the core (**great influence on the performance of PSA)**

PreprocessingFilterPSA.conf

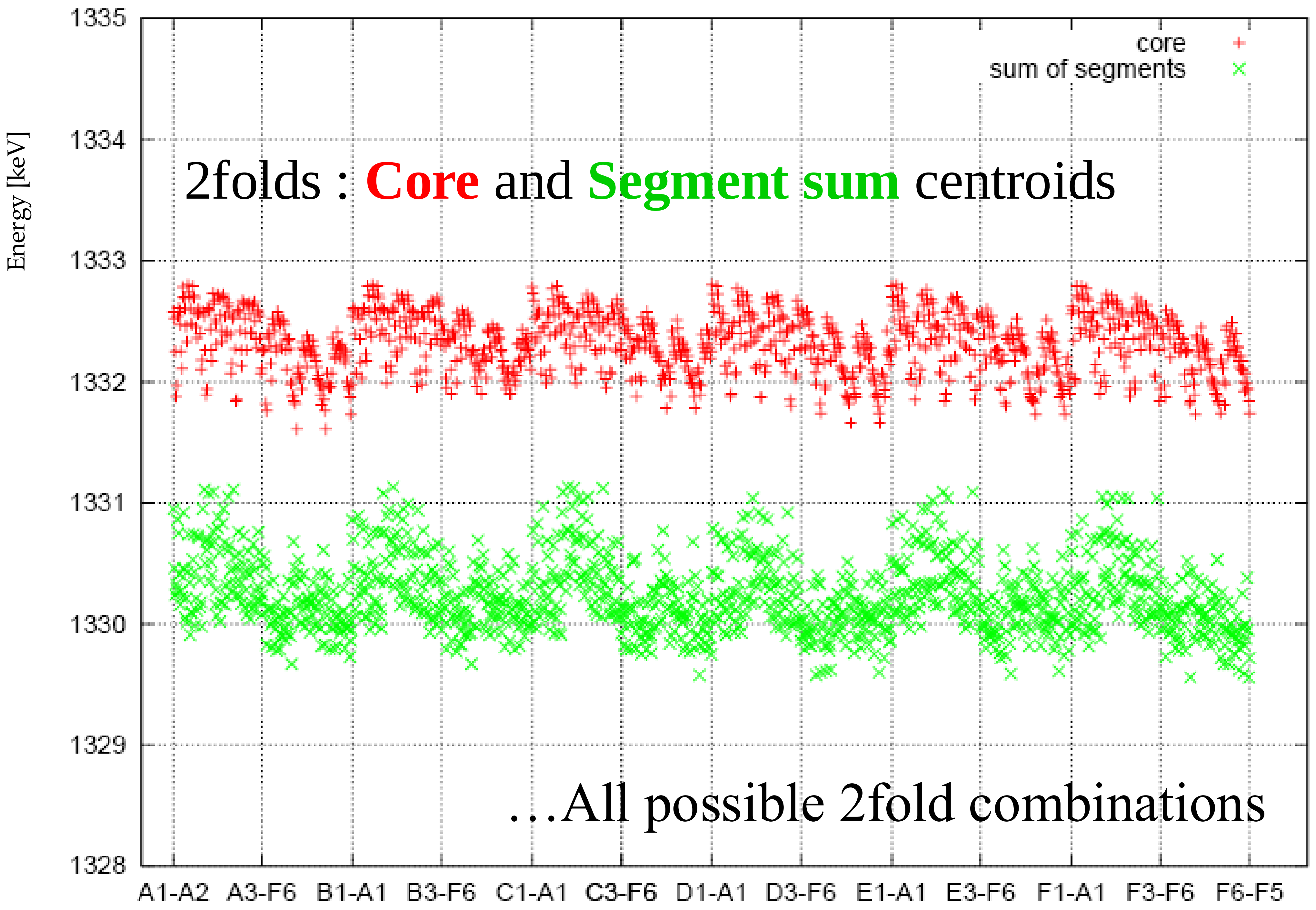


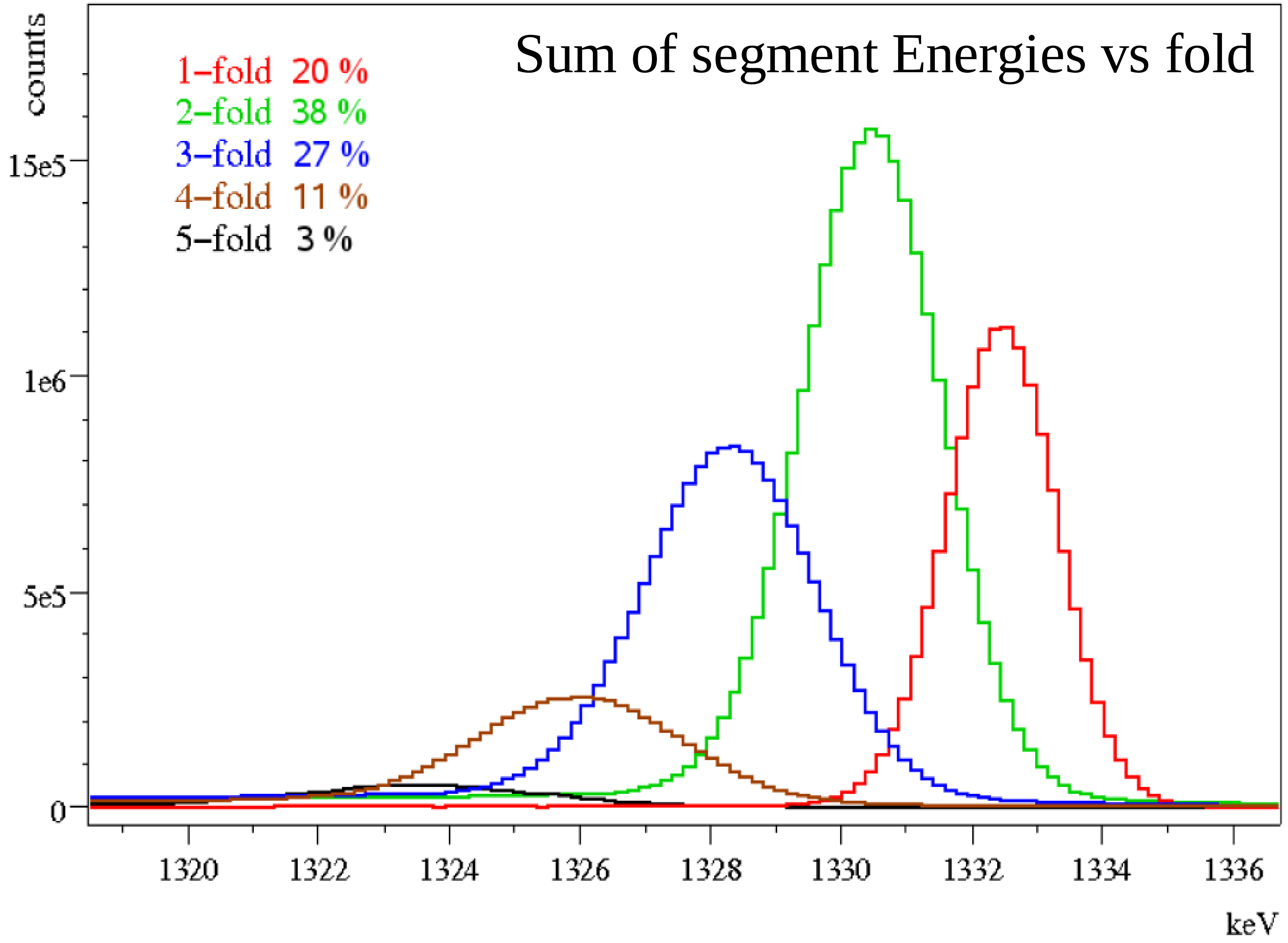
```
#segm/core %d(id) %f(tfall) %f(trise)  %f(egain) %f(emink) %f(tmove)

segm            0     4600      1000    0.162979     10.0       9.891
segm            1     4600      1000    0.170079     10.0      10.463
segm            2     4600      1000    0.163820     10.0      10.361
segm            3     4600      1000    0.169401     10.0       9.485
segm            4     4600      1000    0.158867     10.0       7.971
segm            5     4600      1000    0.155504     10.0      10.077
segm            6     4600      1000    0.170291     10.0       9.050
segm            7     4600      1000    0.165092     10.0       9.263
segm            8     4600      1000    0.145804     10.0       7.420
segm            9     4600      1000    0.168806     10.0       8.448
segm           10     4600      1000    0.143493     10.0       6.188
segm           11     4600      1000    0.159609     10.0      10.510
segm           12     4600      1000    0.153815     10.0      10.251
segm           13     4600      1000    0.155996     10.0       9.448
segm           14     4600      1000    0.168760     10.0       9.537
segm           15     4600      1000    0.175860     10.0       8.866
segm           16     4600      1000    0.185031     10.0      13.873
segm           17     4600      1000    0.157300     10.0      10.564
segm           18     4600      1000    0.169683     10.0       9.836
segm           19     4600      1000    0.168100     10.0       9.683
segm           20     4600      1000    0.170233     10.0       9.677
segm           21     4600      1000    0.174663     10.0       9.472
segm           22     4600      1000    0.174109     10.0       8.942
segm           23     4600      1000    0.165021     10.0      11.498
segm           24     4600      1000    0.152862     10.0      10.267
segm           25     4600      1000    0.169911     10.0      11.067
segm           26     4600      1000    0.165142     10.0       9.910
segm           27     4600      1000    0.159595     10.0       9.393
segm           28     4600      1000    0.168353     10.0       8.347
segm           29     4600      1000    0.167807     10.0      11.519
segm           30     4600      1000    0.163006     10.0       9.945
segm           31     4600      1000    0.159887     10.0      10.383
segm           32     4600      1000    0.155449     10.0       9.600
segm           33     4600      1000    0.143345     10.0       8.487
segm           34     4600      1000    0.150043     10.0       7.216
segm           35     4600      1000    0.176351     10.0      12.197
core            0     4200      1000    0.347055     20.0      25.000
core            1     4200      1000    0.069358     20.0      -0.285
tntf 2097152
```

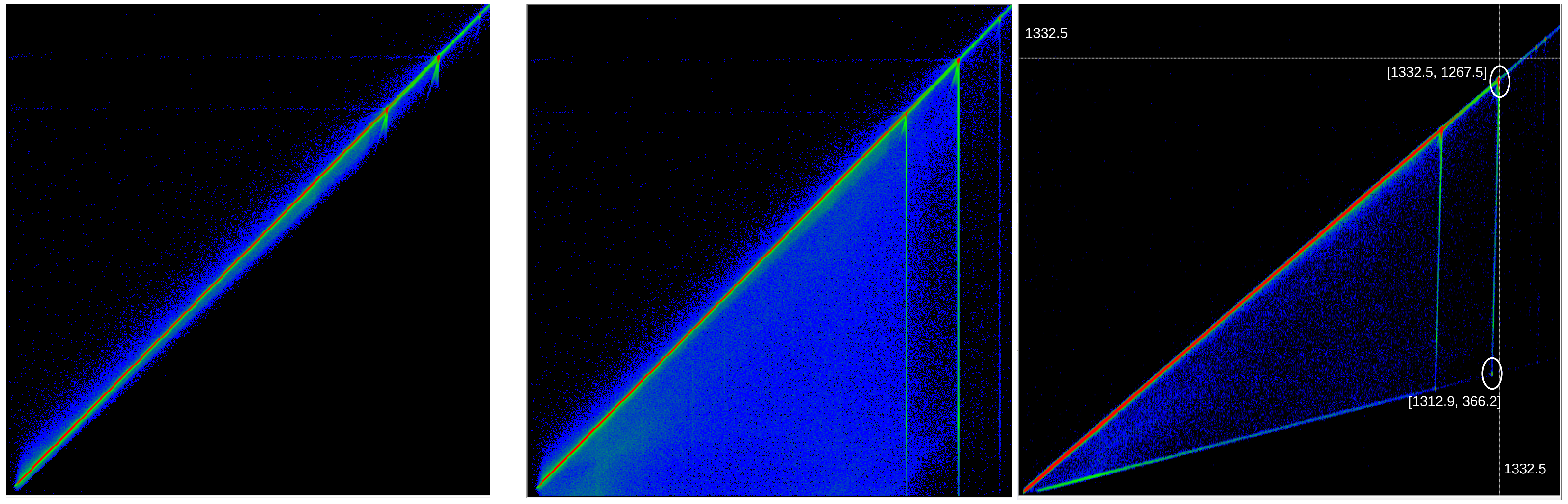
Cross-Talk correction: Motivations

- Crosstalk is present in **any segmented detector**
- Creates strong energy shifts proportional to fold
- Tracking needs segment energies !





Missing/Broken segments

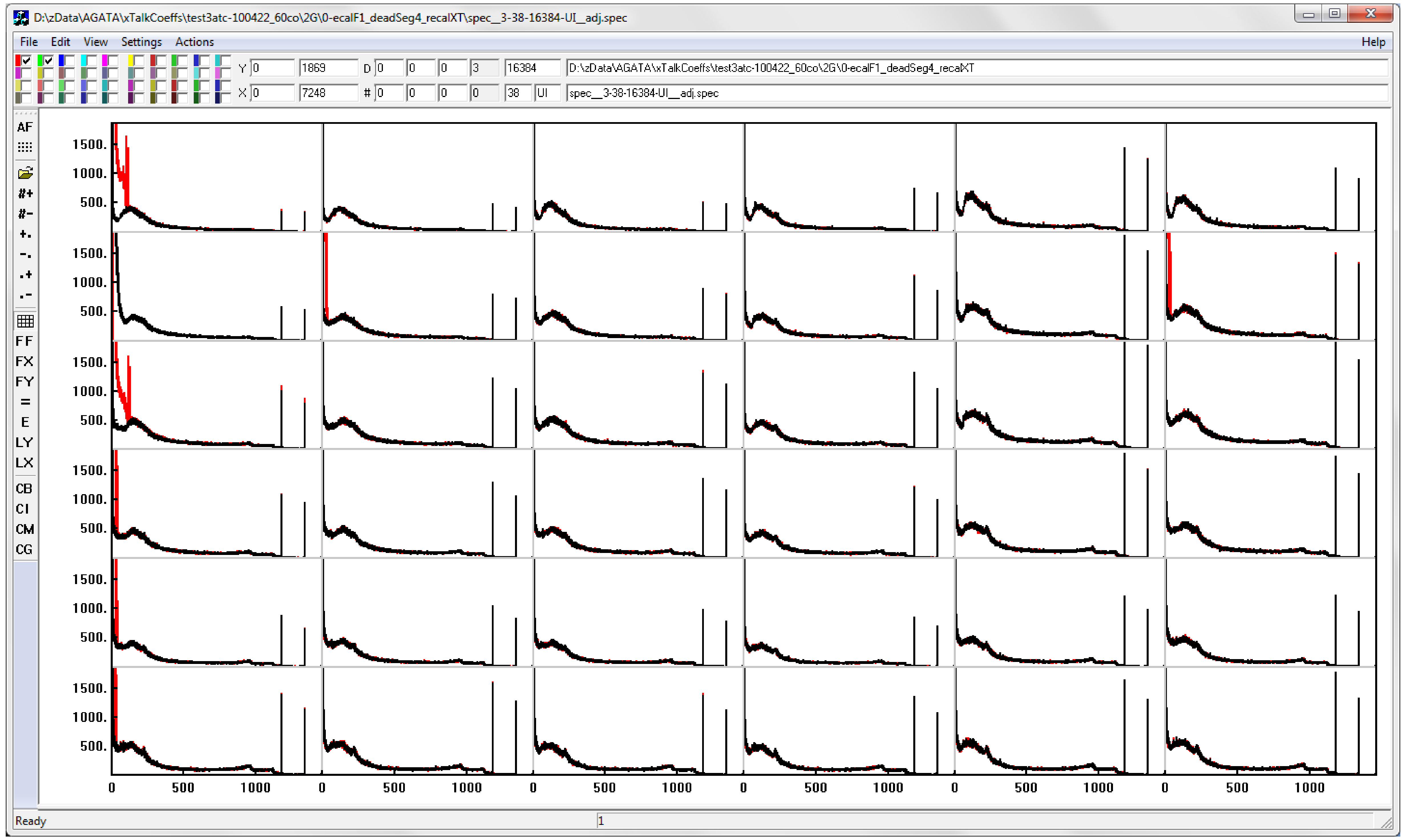


- Exploiting the redundancy:

$$\sum \text{Segs} == \text{Core}$$

- Compensate loss of energy in core
- Assign energy to missing segment

$$E_{\text{missing}} = E_{\text{core}} - \text{Sum}_{\text{Other}}$$


D:\zData\AGATA\xTalkCoeffs\test3atc-100422_60co\2G\0-ecalF1_deadSeg4_recalXT\spec__3-38-16384-UI__adj.spec

Y 0 1869 D 0 0 0 3 16384 D:\zData\AGATA\xTalkCoeffs\test3atc-100422_60co\2G\0-ecalF1_deadSeg4_recalXT

X 0 7248 # 0 0 0 0 38 UI spec__3-38-16384-UI__adj.spec

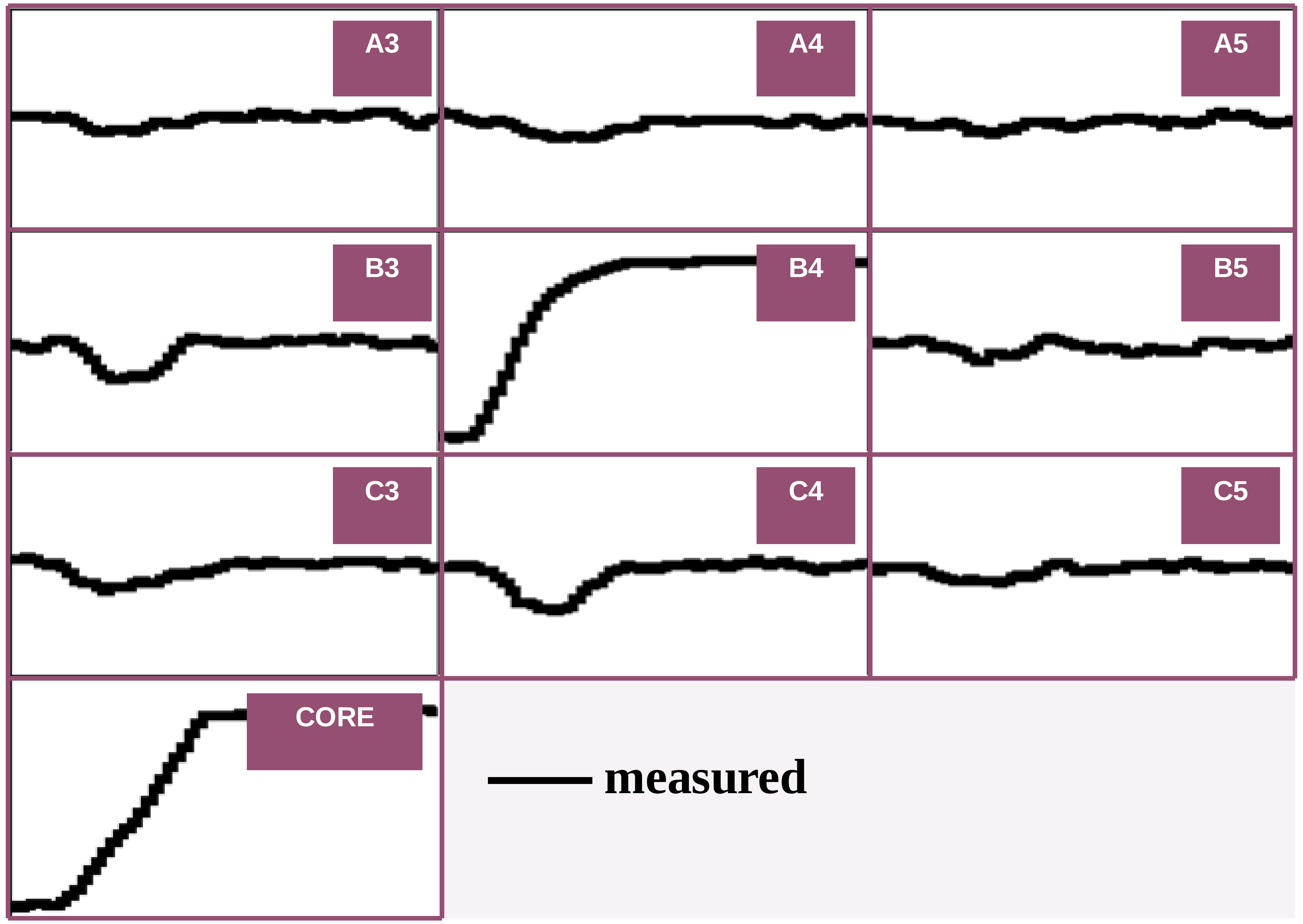
Ready 1

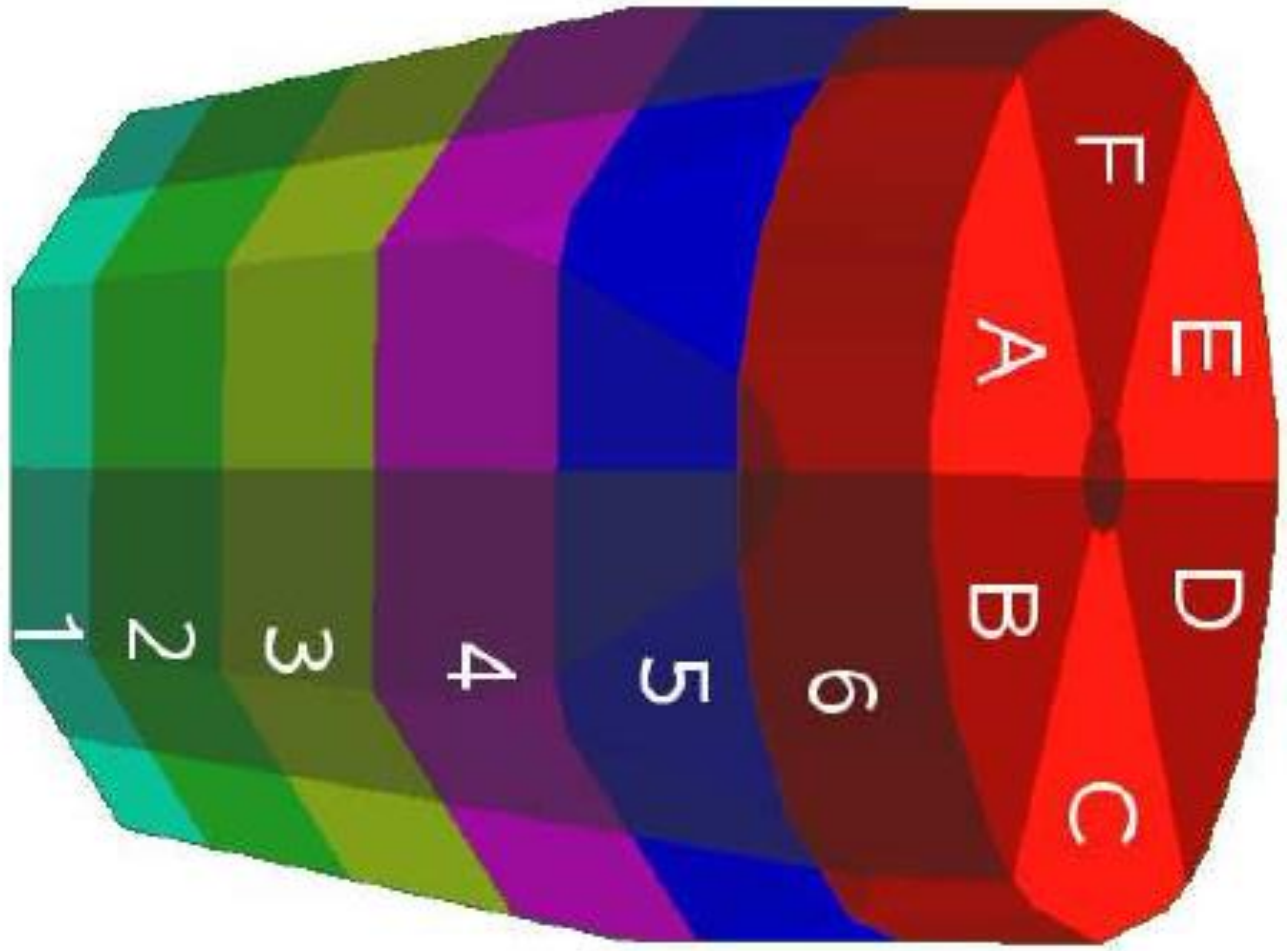
PSA Filter

Performs:

- Read the simulated basis (ADL)
- Apply the preamp response function to the simulated traces
- **Perform the signal decomposition:**
  - ➢ Implemented algorithm is the **Grid Search**
    - ✓ As a full grid search
    - ✓ As an **adaptative** coarse/fine search (AGS) => **Default used online**
- **Reduces size of data by factor ~80**
- Provides the parameters for the correction of neutron damage
- **Is the critical point for the processing speed of online and offline analyses**
  - ➢ Takes ~ 95 % of total CPU time in the AGATA data processing

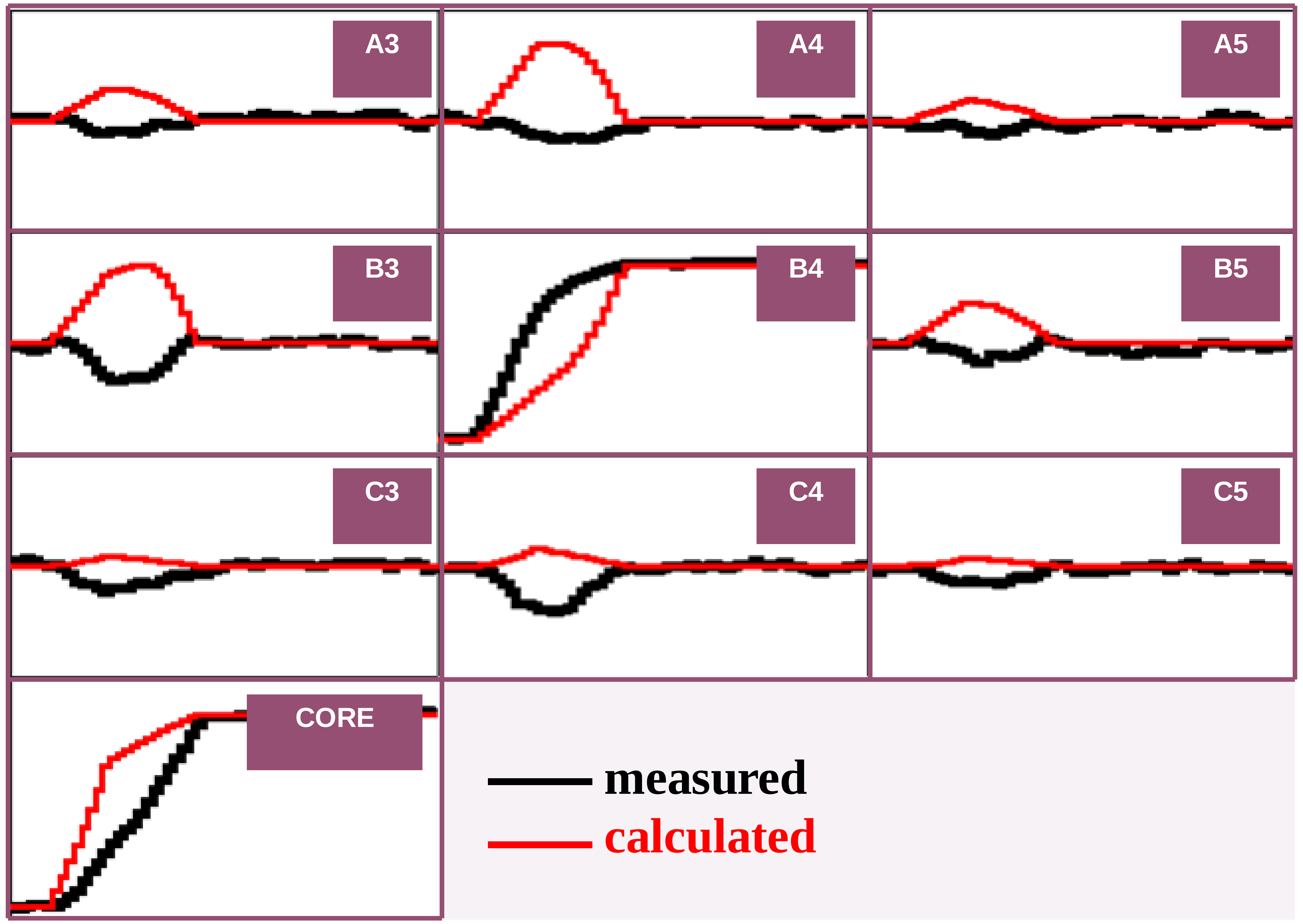
Pulse Shape Analysis concept





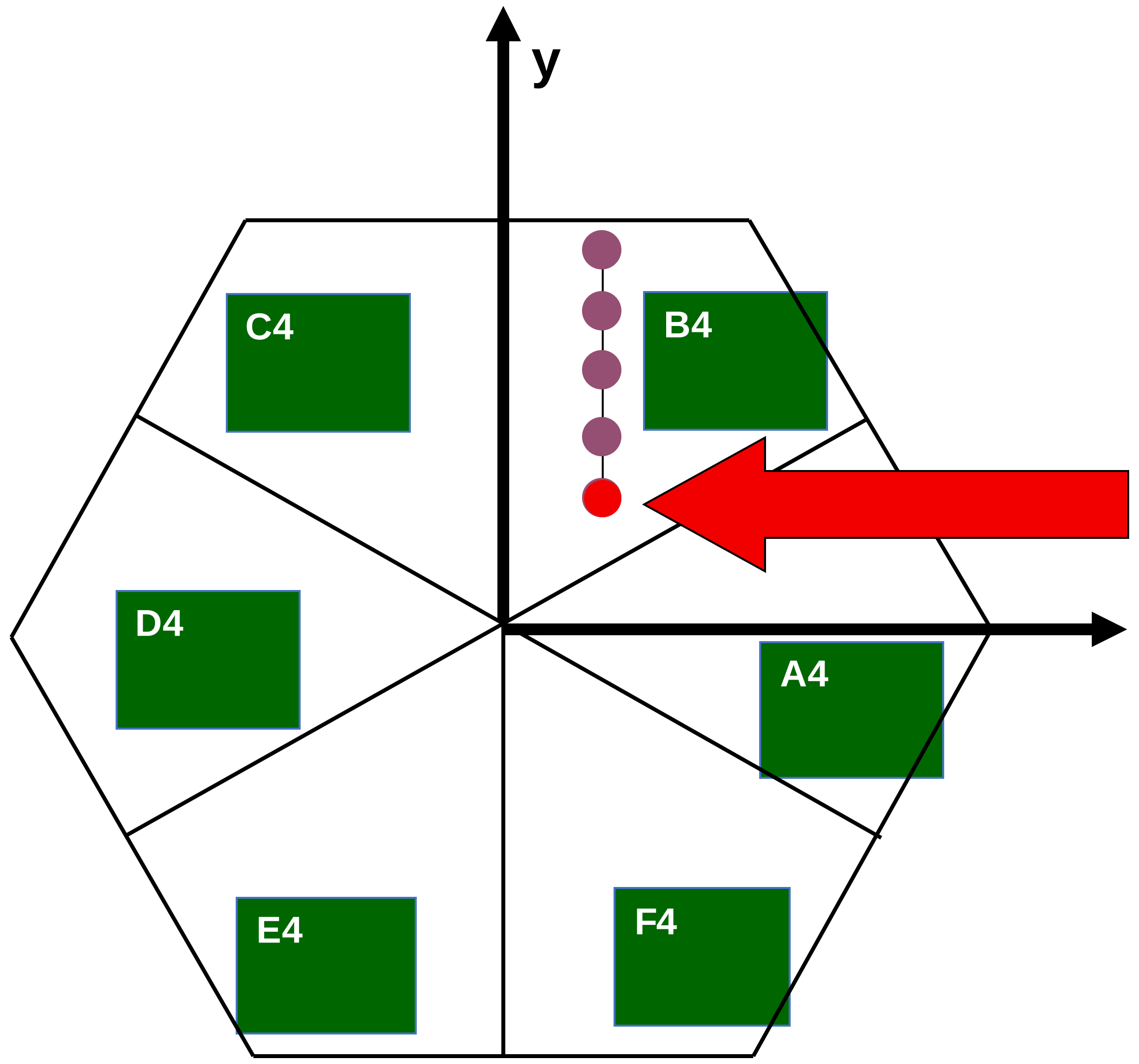
791 keV deposited in segment B4

Pulse Shape Analysis concept

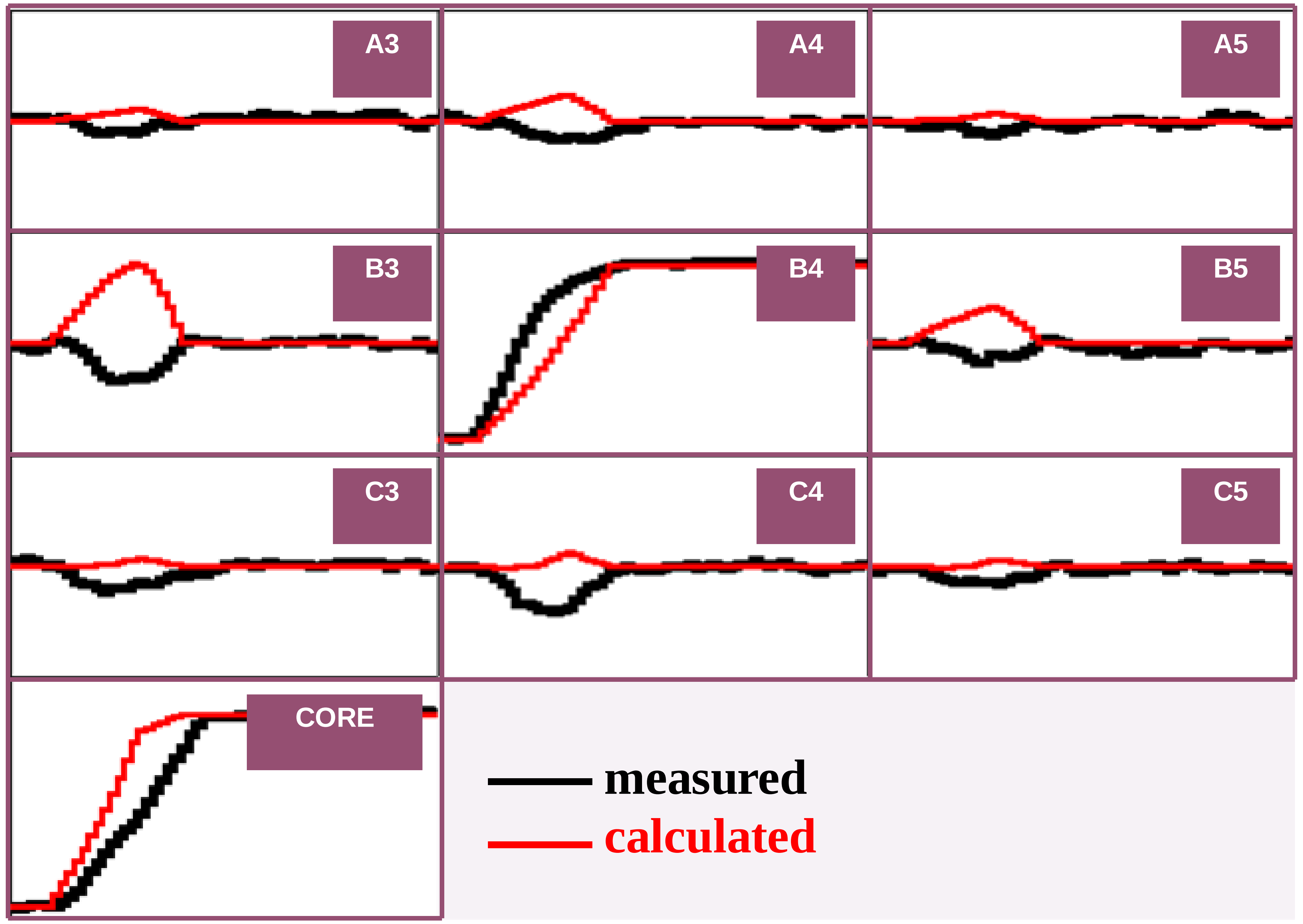


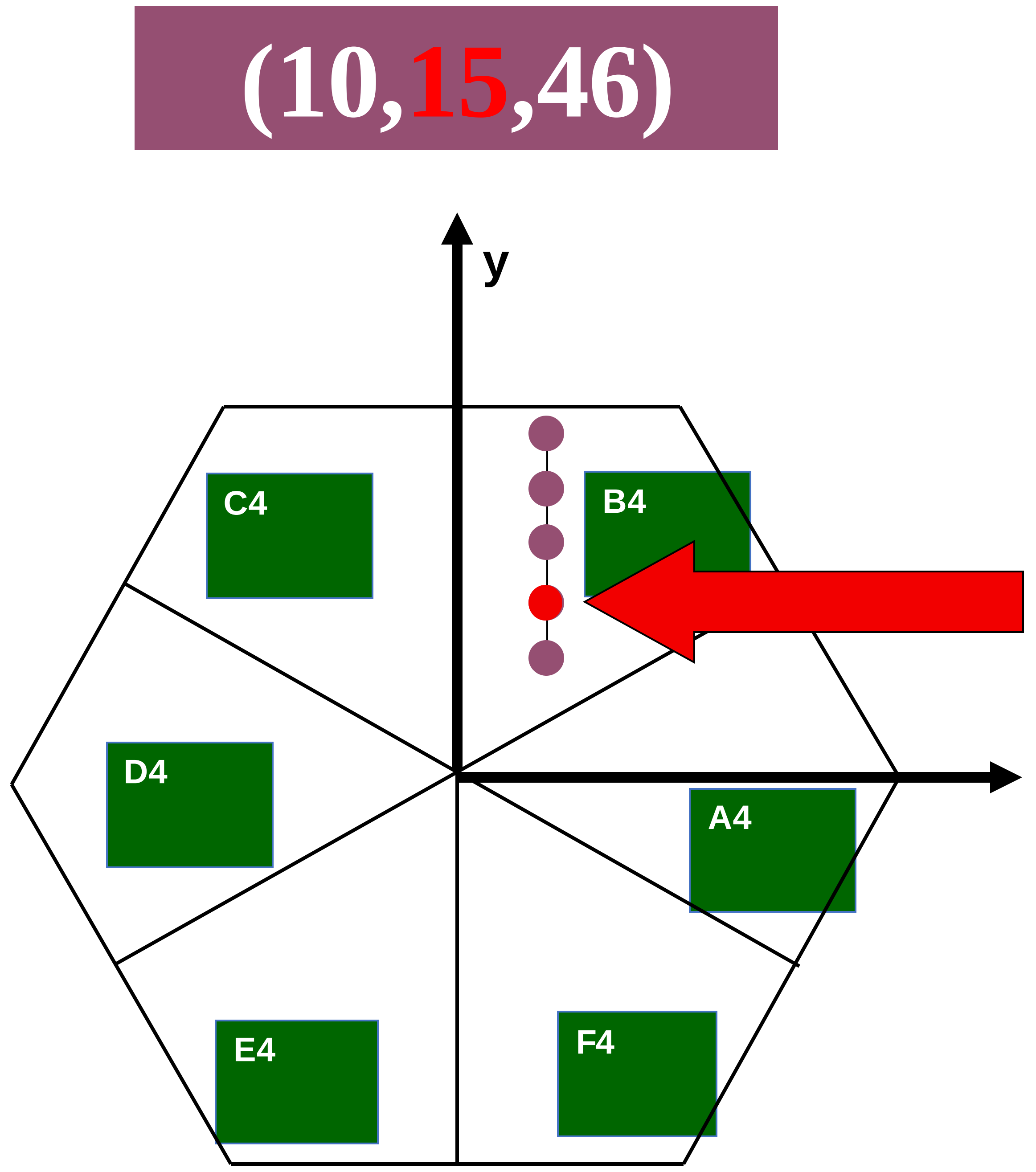
791 keV deposited in segment B4

(10,10,46)



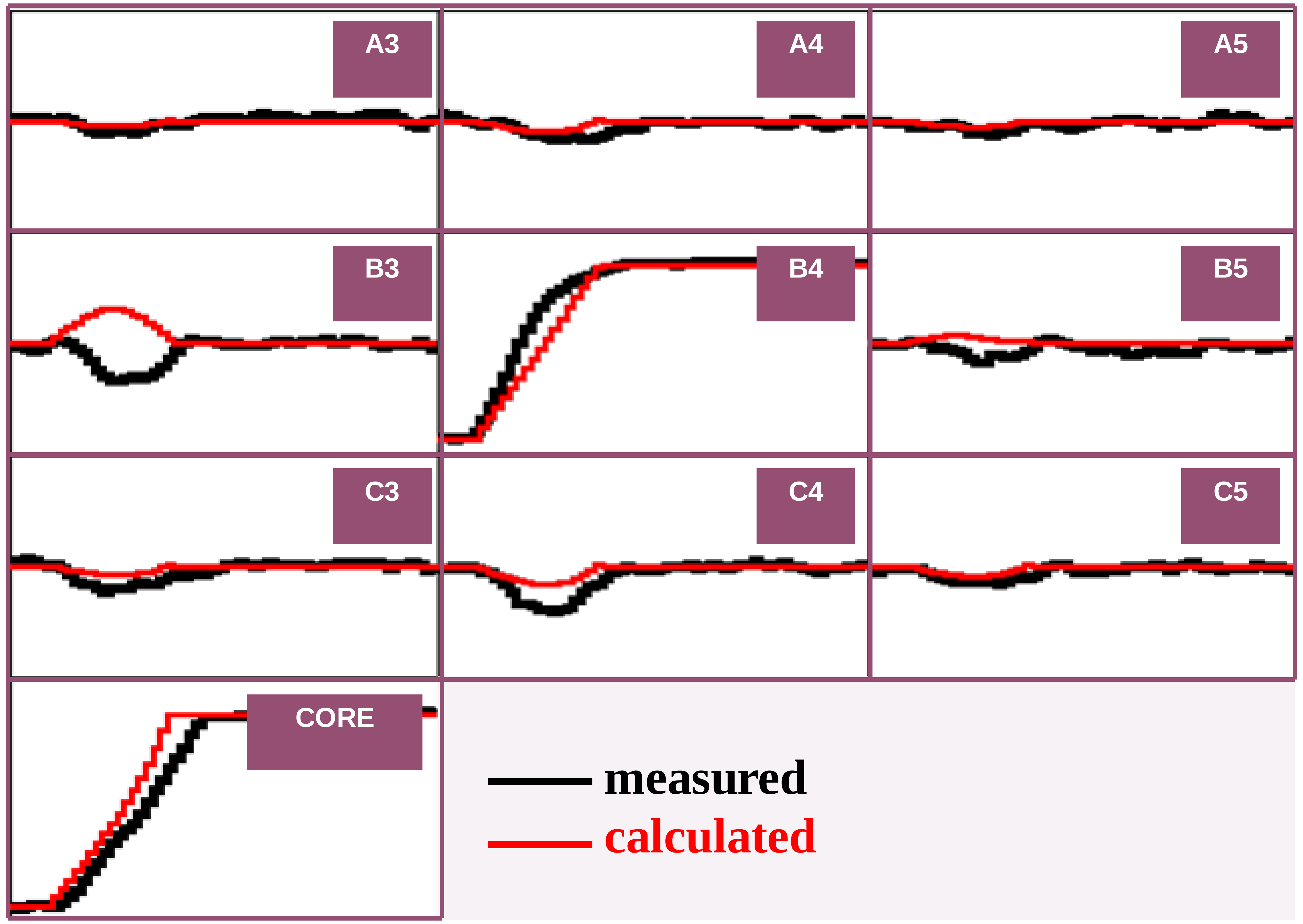
Pulse Shape Analysis concept

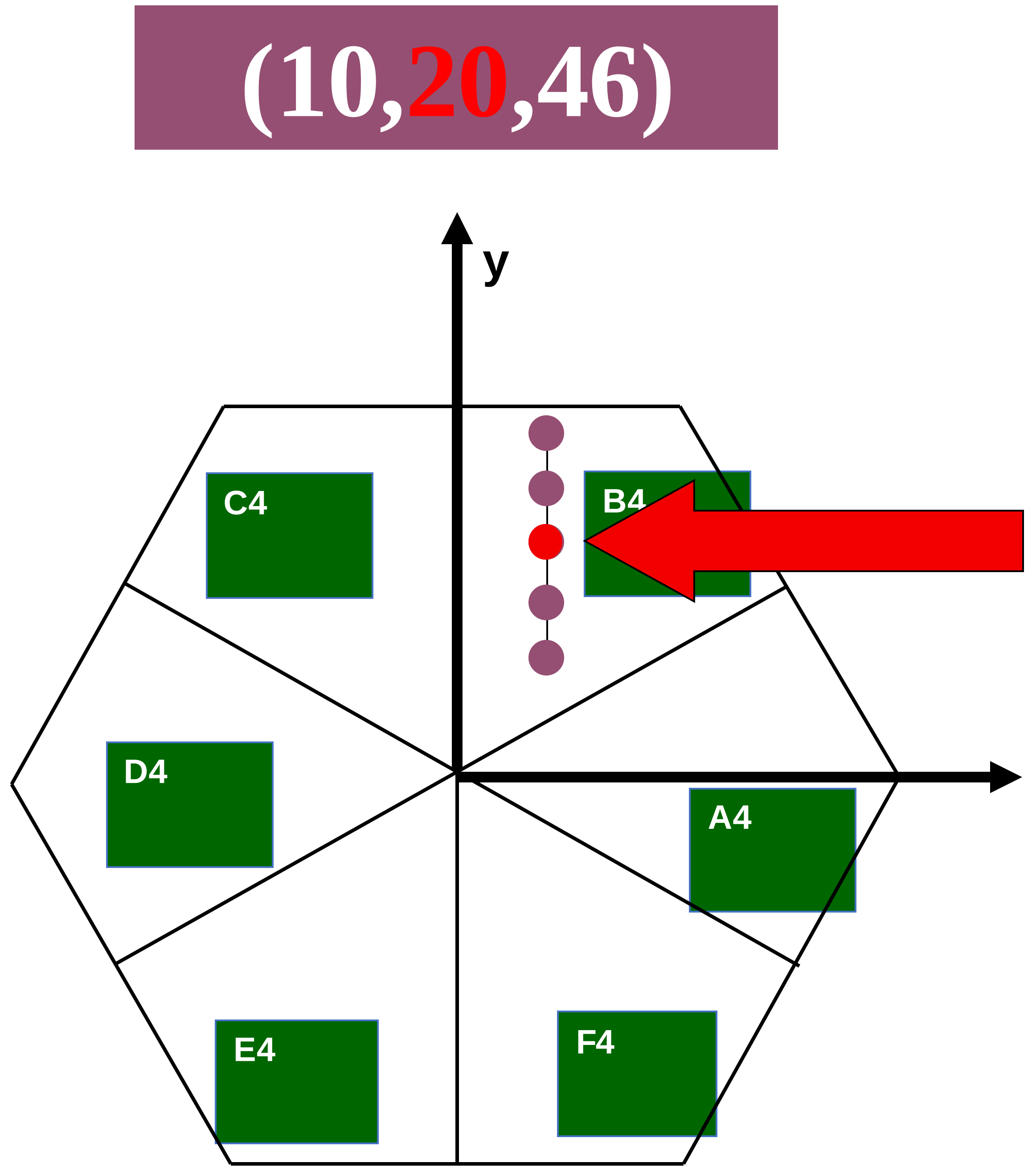




791 keV deposited in segment B4

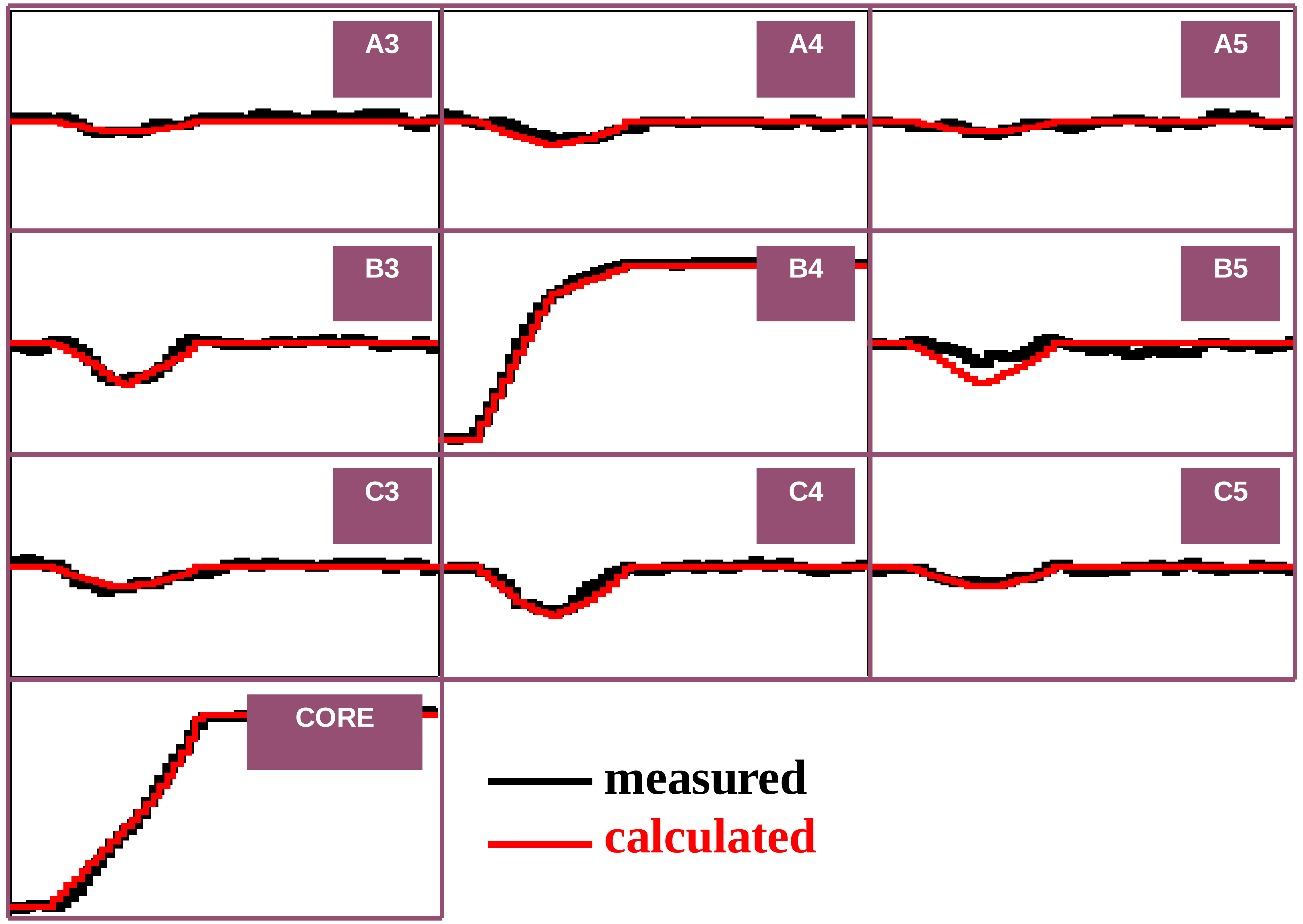
Pulse Shape Analysis concept



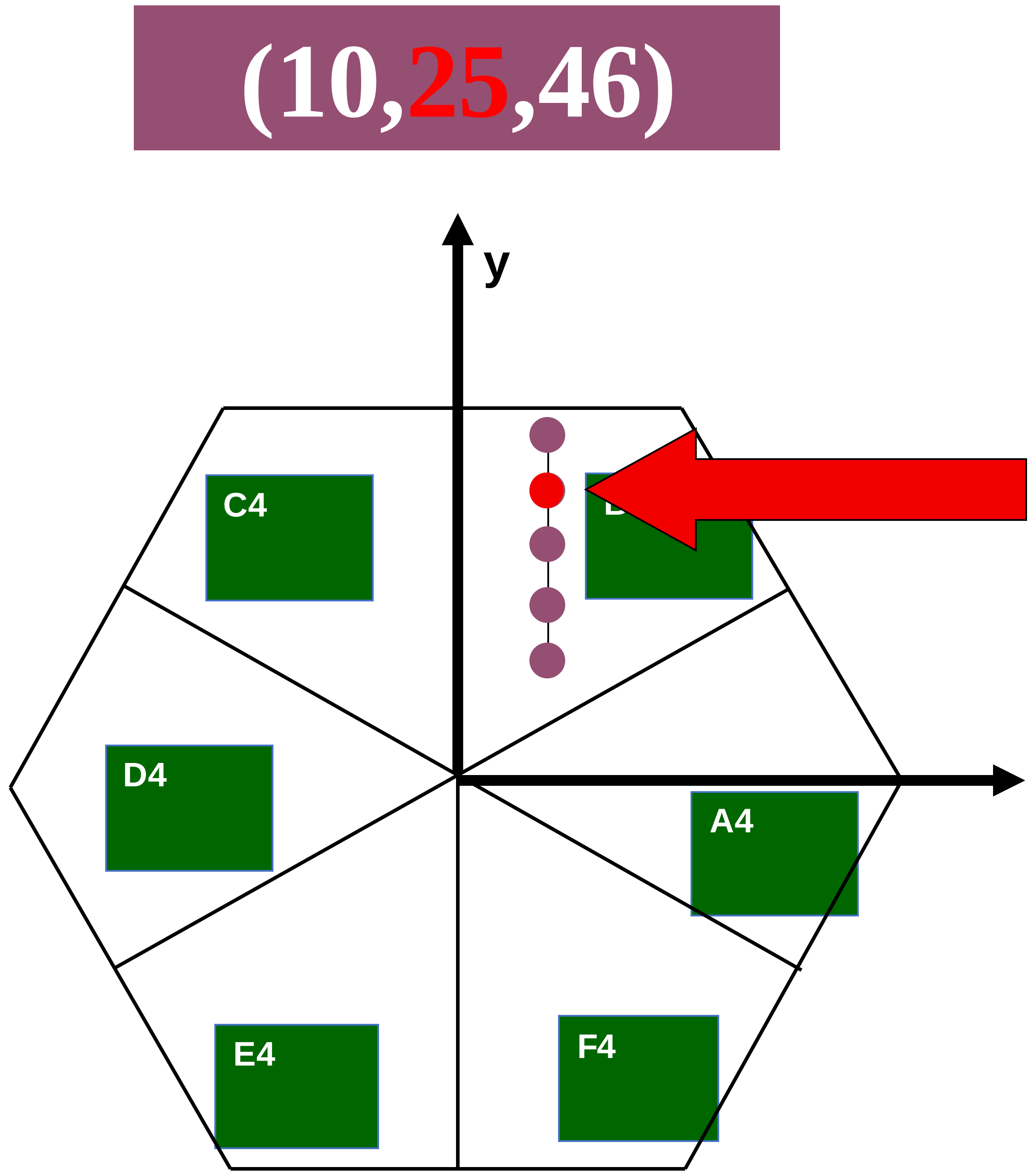


791 keV deposited in segment B4

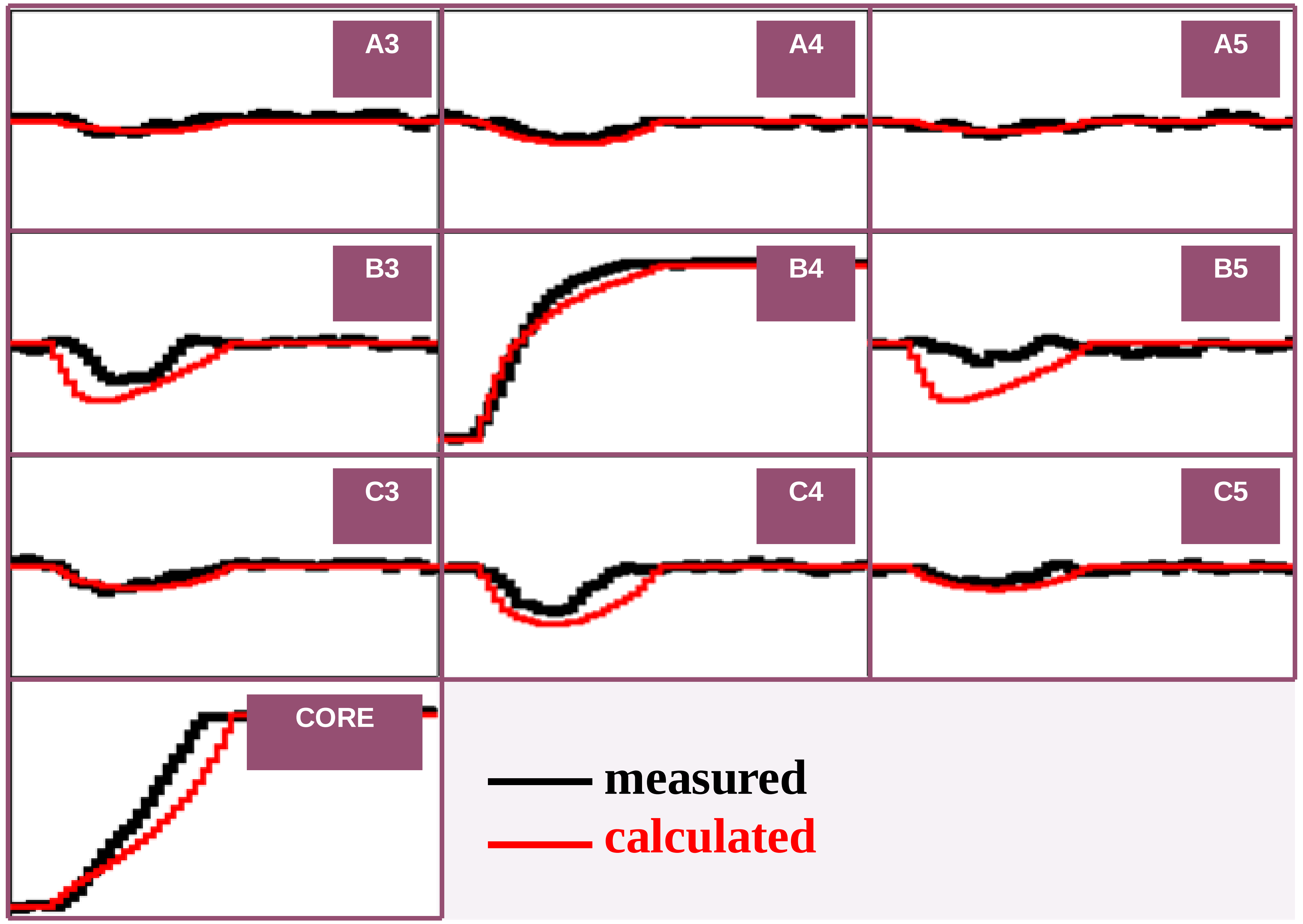
Pulse Shape Analysis concept



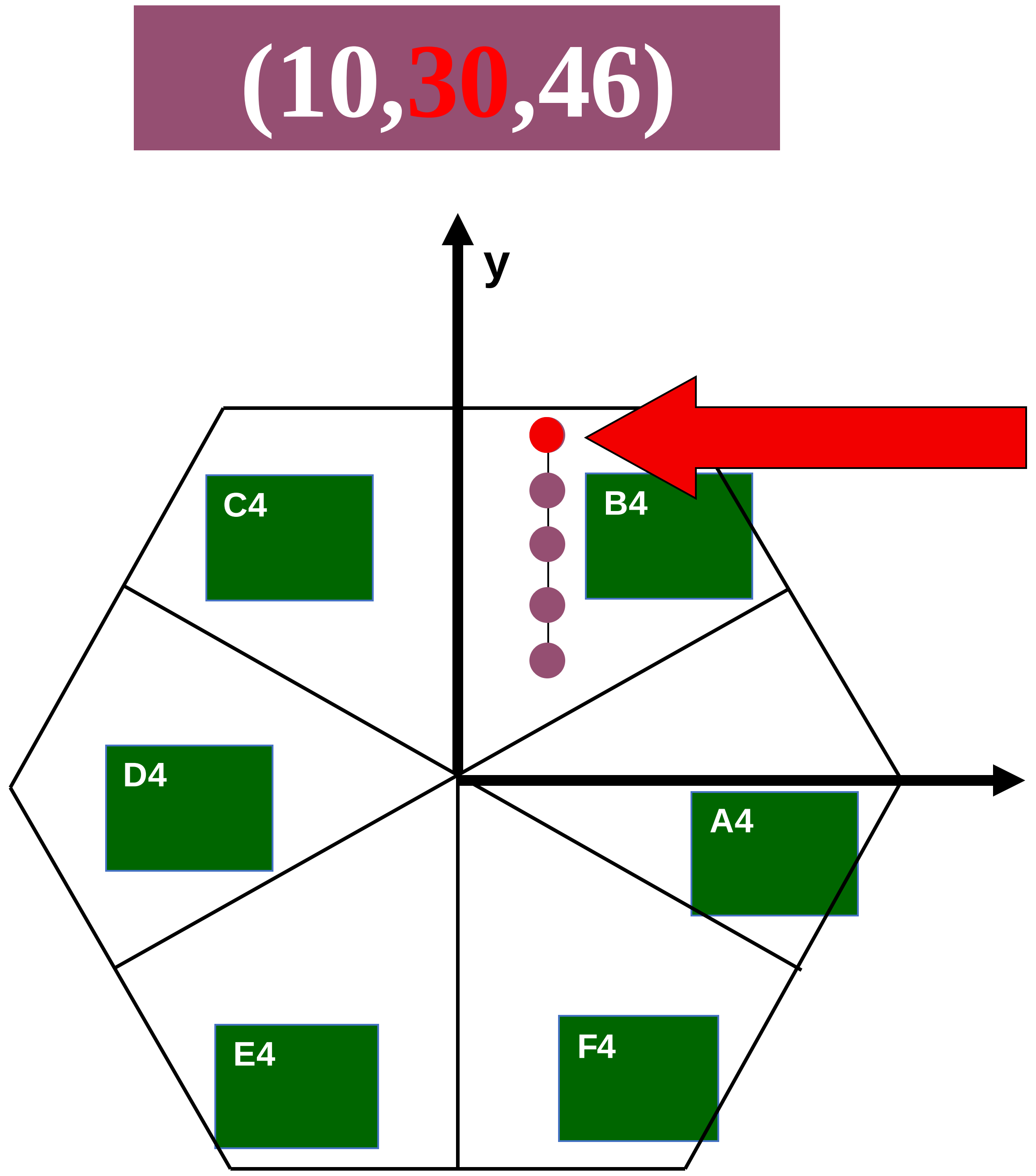
791 keV deposited in segment B4



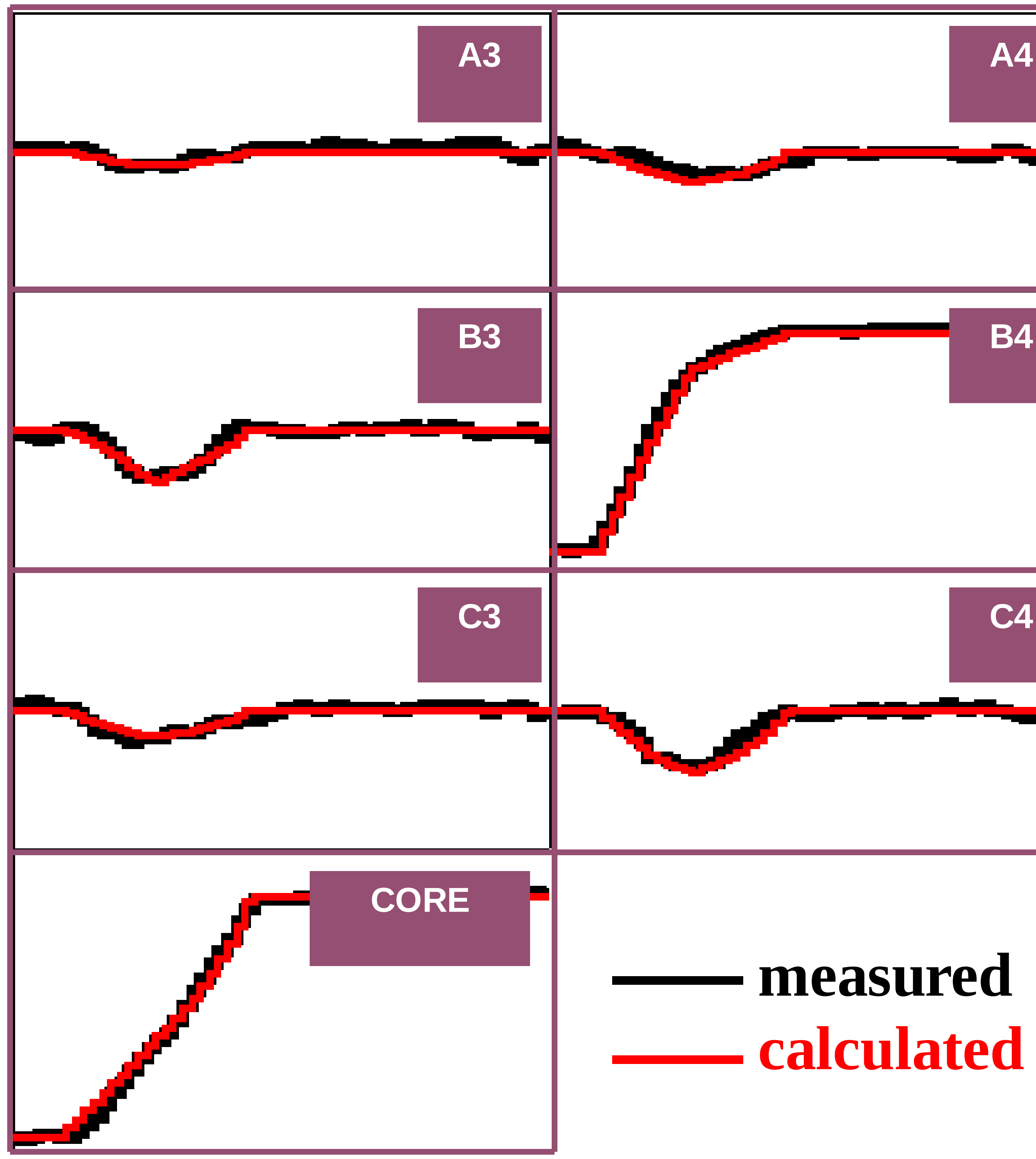
Pulse Shape Analysis concept



791 keV deposited in segment B4



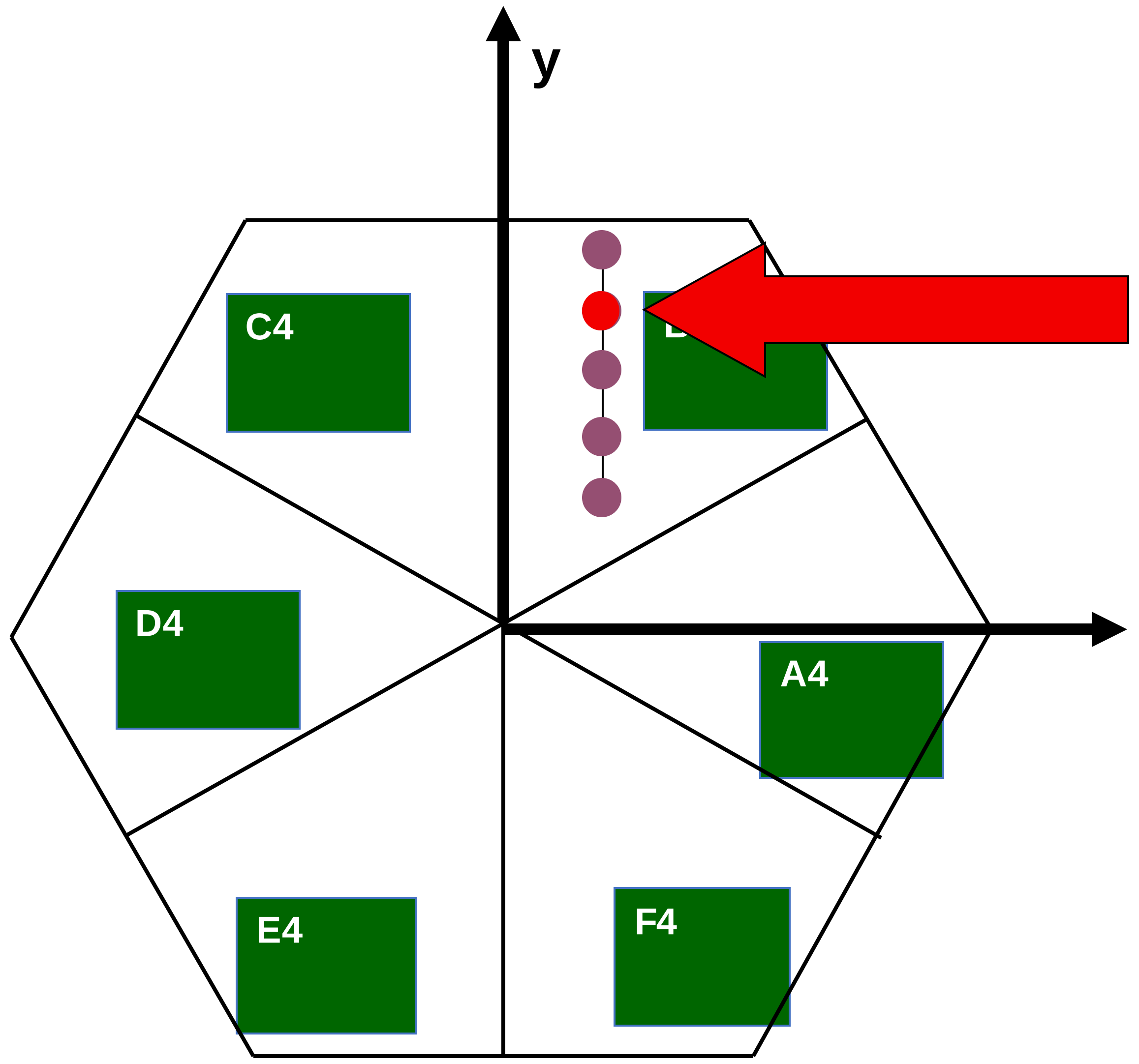
Pulse Shape Analysis concept



791 keV deposited in segment B4

Result of *Grid Search* Algorithm

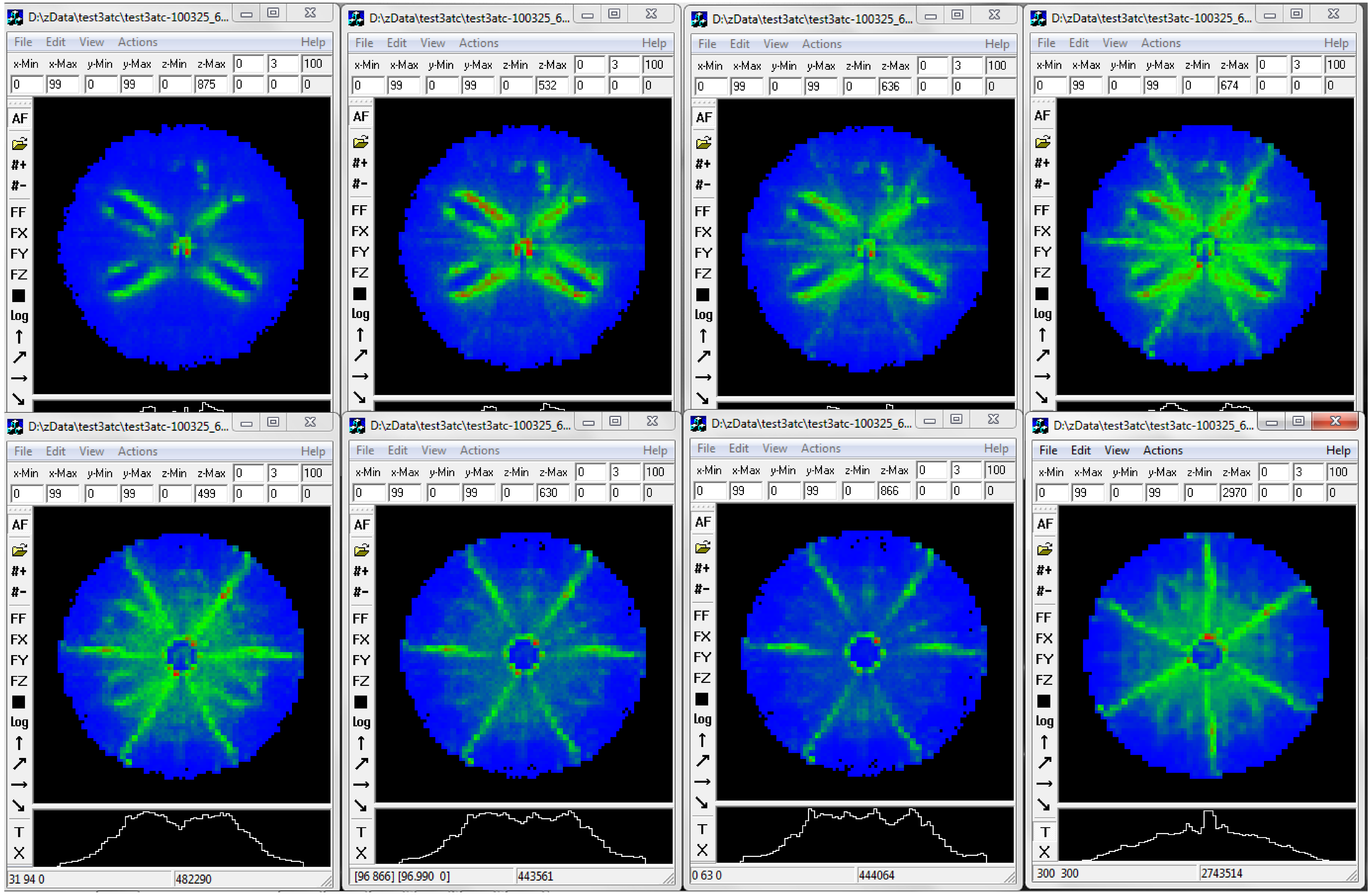
(10,25,46)



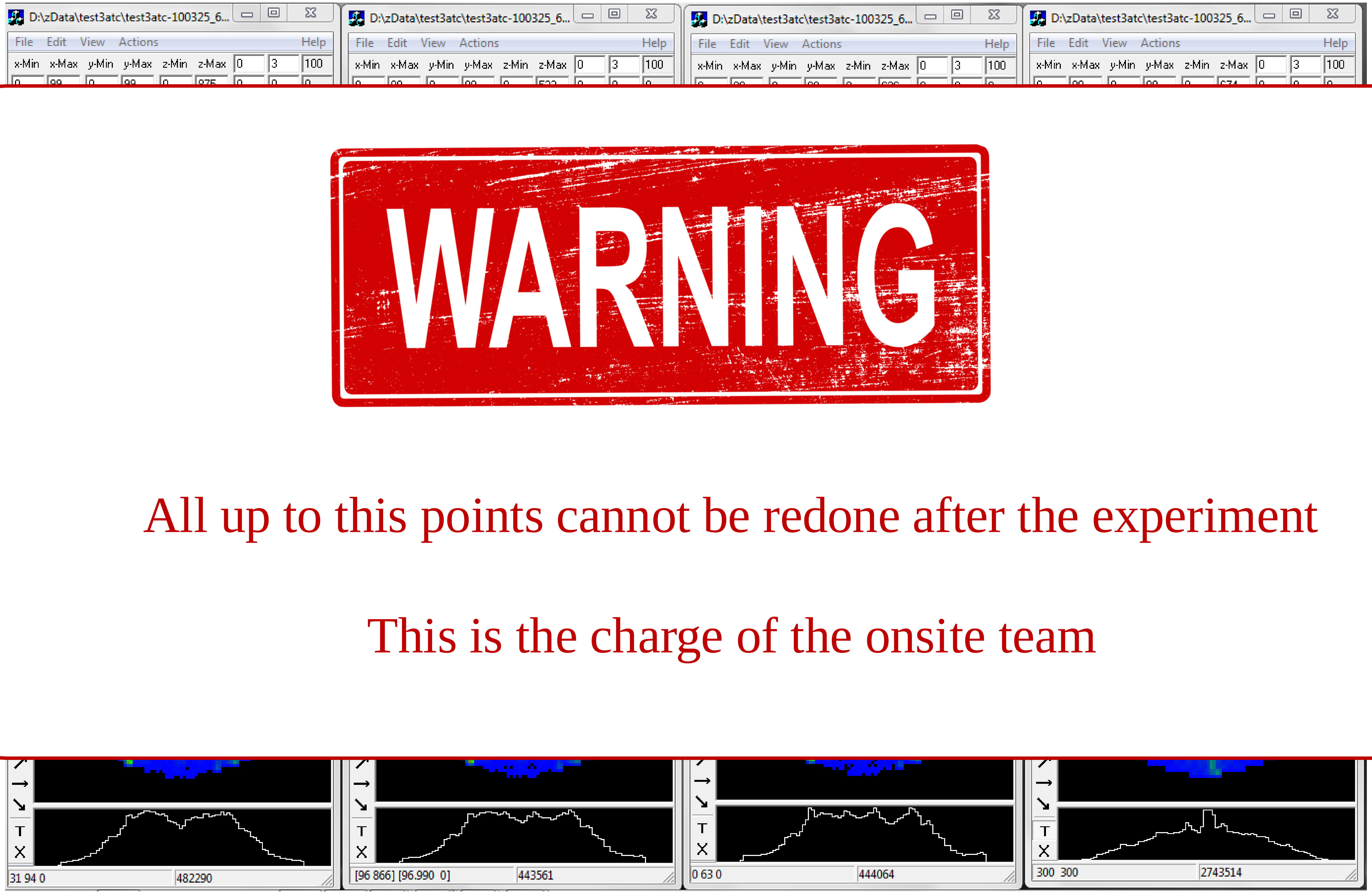
The Grid Search algorithm

- Signal decomposition assumes **one interaction per segment**
- The decomposition uses the transients, the net charge segment, and core pulses
- **Proportional** and **differential cross-talk** are included using the xTalk coefficients of the preprocessing
- 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
- Using ADL bases (Bart Bruyneel)
  - Fine grid: 2 mm step: → **~ 48000 grid points in a crystal** (700-2000 points/segments)
- Speed is:
  → ~ 150 events/s/core for the Full Grid Search
  → ~ 1500 events/s/core for the Adaptive Grid Search
- To speedup execution, **parallelism has been implemented** with
  → blocks of ~ 300 events passed to 5 parallel threads of execution

Effect of time alignment



Effect of time alignment


File Edit View Actions Help
x-Min x-Max y-Min y-Max z-Min z-Max
T
X

D:\zData\test3atc\test3atc-100325_6...

31 94 0 482290

[96 866] [96.990 0] 443561

0 63 0 444064

300 300 2743514

WARNING

All up to this points cannot be redone after the experiment

This is the charge of the onsite team

Post PSA Filter

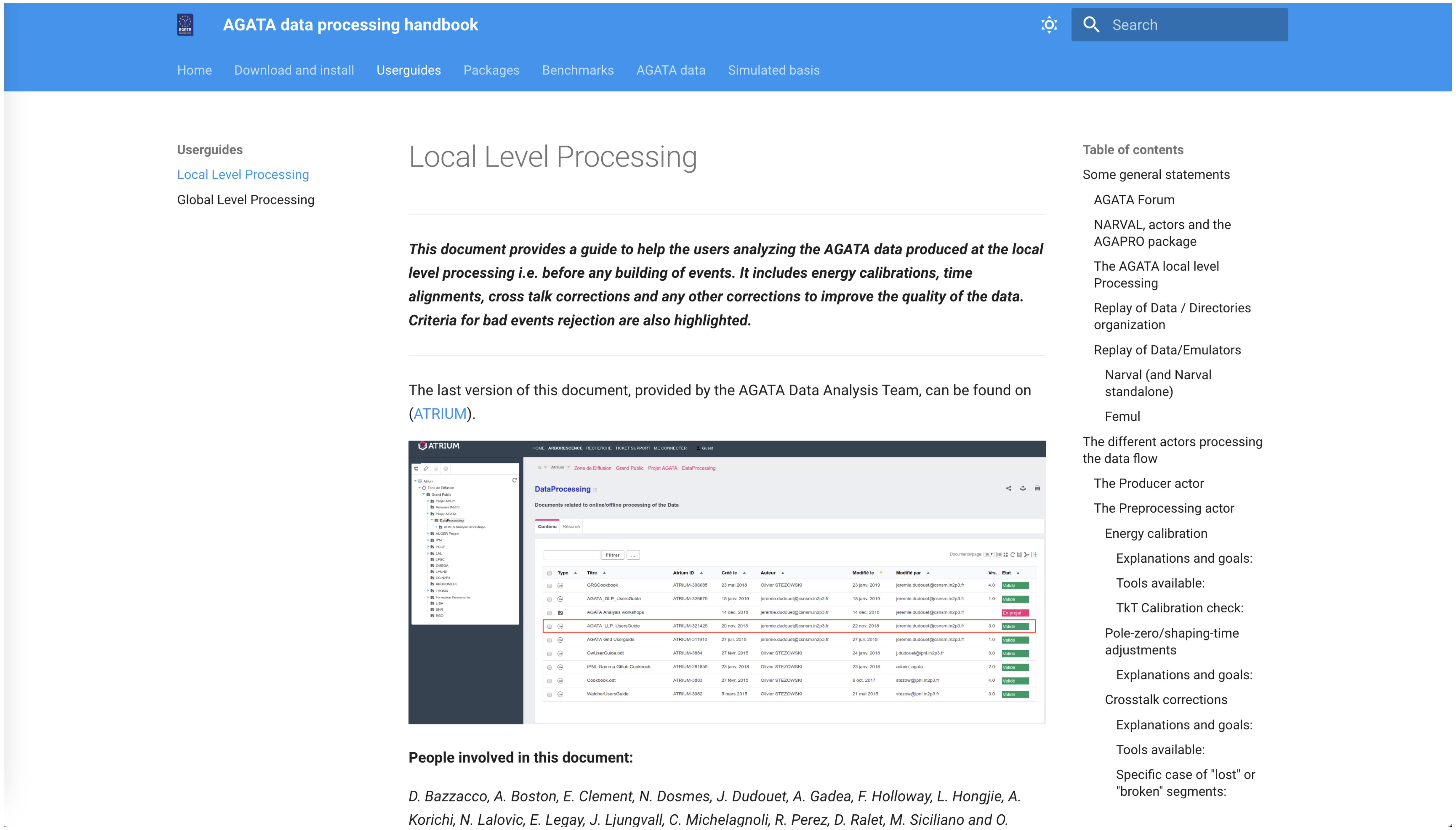
Performs:

- Final energy calibrations of cores and segments (with offset)
- Force segments to core (optional)
- Recovery of neutron damage
- Global time alignment of crystals → important to reduce random coincidences

Global actors

- **Event Builder**
  - Merge all AGATA crystal in events on the basis of timestamps
- **Event Merger**
  - Merge AGATA built events with ancillaries on the basis of timestamps
- **Tracking Filter**
  - Apply the tracking algorithm using segments energies and positions
- **Tree Builder**
  - Dump the data on disk using ROOT tree format

AGATA user guides



Local Level Processing

This document provides a guide to help the users analyzing the AGATA data produced at the local level processing i.e. before any building of events. It includes energy calibrations, time alignments, cross talk corrections and any other corrections to improve the quality of the data. Criteria for bad events rejection are also highlighted.

The last version of this document, provided by the AGATA Data Analysis Team, can be found on (ATRIUM).

ATRIUM
HOME ARBORESCENCE RECHERCHE TICKET SUPPORT ME CONNECTER Guest
Atrium > Zone de Diffusion > Grand Public > Projet AGATA > DataProcessing
Contenu
Résumé
Filtrer
...
Documents/page: 30

DataProcessing

Documents related to online/offline processing of the Data

Type	Titre	Atrium ID	Créé le	Auteur	Modifié le	Modifié par	Vrs.	Etat
	GRSCookbook	ATRIUM-306685	23 mai 2018	Olivier STEZOWSKI	23 janv. 2019	jeremie.dudouet@csnsm.in2p3.fr	4.0	Validé
	AGATA_GLP_UsersGuide	ATRIUM-326679	18 janv. 2019	jeremie.dudouet@csnsm.in2p3.fr	18 janv. 2019	jeremie.dudouet@csnsm.in2p3.fr	1.0	Validé
	AGATA Analysis workshops		14 déc. 2018	jeremie.dudouet@csnsm.in2p3.fr	14 déc. 2018	jeremie.dudouet@csnsm.in2p3.fr		En projet
	AGATA_LLP_UsersGuide	ATRIUM-321425	20 nov. 2018	jeremie.dudouet@csnsm.in2p3.fr	22 nov. 2018	jeremie.dudouet@csnsm.in2p3.fr	3.0	Validé
	AGATA Grid Userguide	ATRIUM-311910	27 juil. 2018	jeremie.dudouet@csnsm.in2p3.fr	27 juil. 2018	jeremie.dudouet@csnsm.in2p3.fr	1.0	Validé
	GwUserGuide.odt	ATRIUM-3884	27 févr. 2015	Olivier STEZOWSKI	24 janv. 2018	j.dudouet@ipnl.in2p3.fr	3.0	Validé
	IPNL Gamma Gitlab Cookbook	ATRIUM-281859	23 janv. 2018	Olivier STEZOWSKI	23 janv. 2018	admin_agata	2.0	Validé
	Cookbook.odt	ATRIUM-3883	27 févr. 2015	Olivier STEZOWSKI	6 oct. 2017	stezow@ipnl.in2p3.fr	4.0	Validé
	WatcherUsersGuide	ATRIUM-3982	5 mars 2015	Olivier STEZOWSKI	21 mai 2015	stezow@ipnl.in2p3.fr	3.0	Validé

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Table of contents

https://agata.pages.in2p3.fr/handbook/

Thank you !

And have fun with your data analysis 😉