

Gate Scientific Meeting 2023  
Krakow, Poland

DE LA RECHERCHE À L'INDUSTRIE



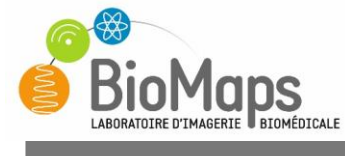
# ***Gate New Digitizer*** ***Gate 9.3***

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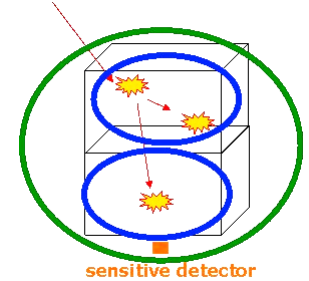
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- Digitizer introduction
  - What and how?
  
- GATE New Digitizer in Gate 9.3
  - Aims
  - Changes for users
  - New features
  
- Modifications in some Digitizer Modules
  - Energy resolution
  - Spatial resolution
  - Efficiency
  - New module: Merger
  
- What is done? What is to be done?

# WHAT DOES DIGITIZER?

- Imaging applications @ GATE: PET, SPECT, CC etc.
- Integrations, *Hits*, are modeled in a crystal, *Sensitive Detector*



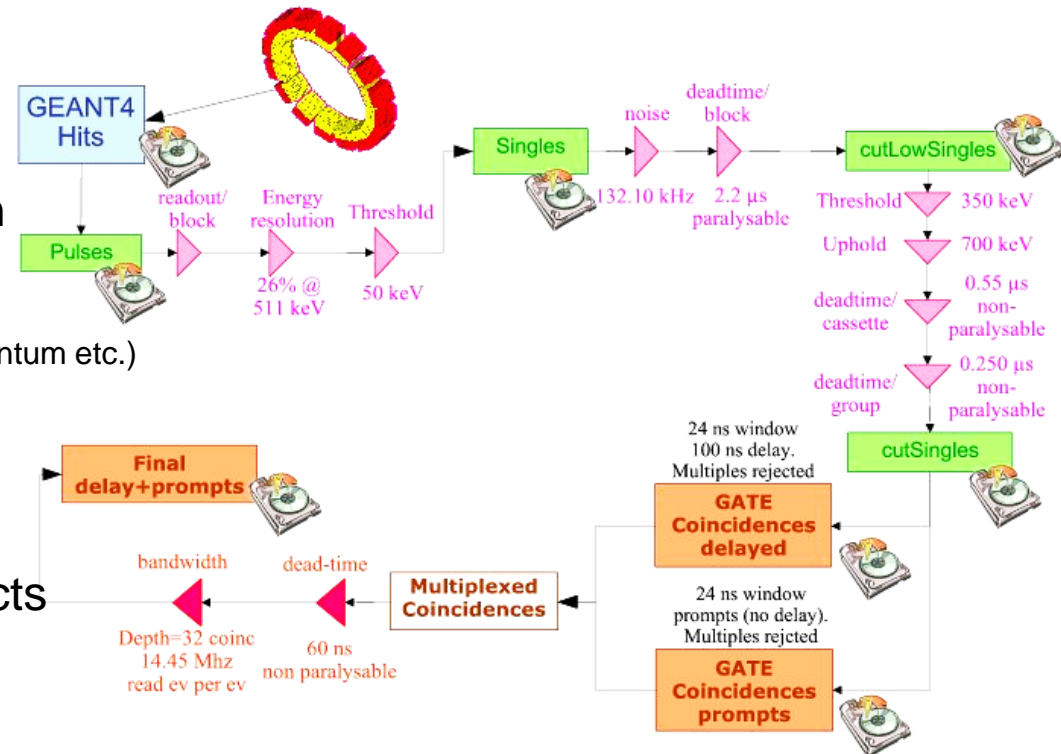
- In real life, each interaction in the crystal is not directly recorded but seen by a photodetector

→ Distortion of the recorded signal

- Digitizer modeled these distortion effects:

- Energy, position, time resolution
- Efficiencies (transport, light production, quantum etc.)
- Energy windows
- Dead time of electronics
- Noise
- etc.

- For PET and CC: Digitizer constructs Coincidences



First versions are developed for the first versions of GATE, i.e. ~20 years ago

→ Developers changed several times since then

→ Parts of the code are obsolete

→ Obsolete with regard to Geant4 updates and new features

→ Duplications

→ Bugs

→ ...

- Simplification of the code architecture
- Code speed up
- Removing of the obsolete and unused modules
- Merge similar Digitizer Modules
- Bugs correction
- Documentation correction
- Simplification of the new module adding
- New features implementation

## **Goals:**

- 1) Minimum discomfort for users**
- 2) Keep all functionalities**

## ■ Speed up

test on cylPET system, Intel® Xeon(R) Gold 5218R CPU @ 2.10GHz, 10 000 000 events

- Hits → ~ 40%
- Singles → ~10%
- Coincidences → same

## ■ Multiple SDs

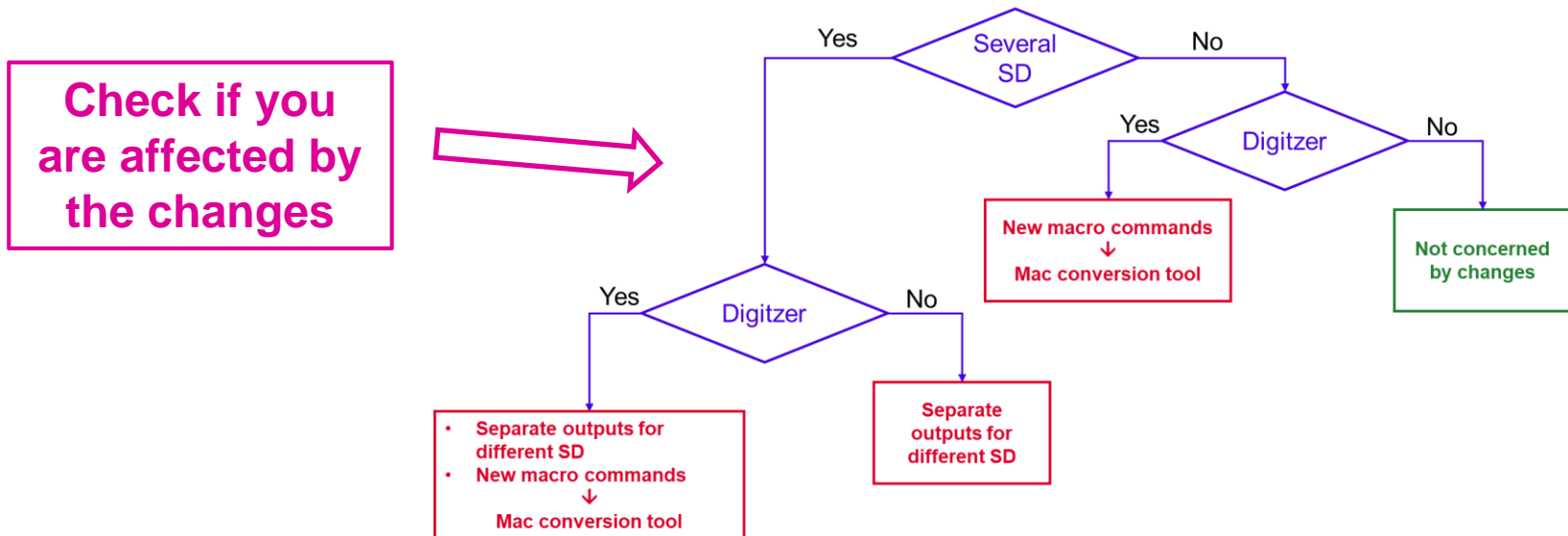
- Separate digitizers
- Separate outputs
- Attachable without system

## ■ Changes in digitizer macro commands

- Macro conversion tool in GateTool repository
- The tool works automatically if you have 1 SD

# SEVERAL SENSITIVE DETECTORS

- Multilayer detectors with different materials and/or readout
- Compton Cameras



## Output TTrees:

### Macros commands :

```
/gate/crystal/attachCrystalSD
/gate/crystal2/attachCrystalSD
```

```
/gate/crystal/attachCrystalSDnoSystem
/gate/crystal2/attachCrystalSDnoSystem
```

```
KEY: TTree Hits_crystal;1 The root tree for hits
KEY: TTree Hits_crystal2;1 The root tree for hits
KEY: TTree OpticalData;1 OpticalData
KEY: TTree Coincidences;1 The root tree for coincidences
KEY: TTree Singles_crystal;1 The root tree for singles
KEY: TTree Singles_crystal2;1 The root tree for singles
KEY: TTree LongCoincidences;1 The root tree for coincidences
```

# CHANGES IN DIGITIZER COMMANDS

- Macros commands are longer but more explicit
- Everything is managed by Digitizer Manager

## Current

```
( /gate/digitizer/name HESingles
  /gate/digitizer/insert singleChain )
( /gate/digitizer/HESingles/insert adder )
```

DigitizerMng		
Digitizers for Singles	Coincidence Sorters	Coincidence Digitizers
Digitizer Modules <ul style="list-style-type: none"> <li>• Adder</li> <li>• Readout</li> <li>• Energy Blurring</li> <li>• ...</li> </ul>	Users sorters <ul style="list-style-type: none"> <li>• Delayed coincidences</li> <li>• LongCoincidences</li> <li>• ..</li> </ul>	Coincidence Digitizer Modules <ul style="list-style-type: none"> <li>• Dead Time</li> <li>• Bandwidth</li> <li>• ...</li> </ul>

## New

```
( /gate/digitizerMng/name HESingles
  /gate/digitizerMng/insert SinglesDigitizer
  /gate/digitizerMng/chooseSD crystal )
( /gate/digitizerMng/crystal/SinglesDigitizer/HESingles/insert adder )
```

## Macro conversion tool:

```
gt_digi_mac_converter -i digitizer_old.mac
                    -o digitizer_new.mac
                    -sd <SD name>
                    -multi SinglesDigitizer
```

From Geometry macro:  
/gate/**<SD name>**/attachCrystalSD

- SinglesDigitizer
- CoincidenceSorter



# Modifications in some Digitizer Modules

(ex blurring, crystal blurring, local energy blurring)

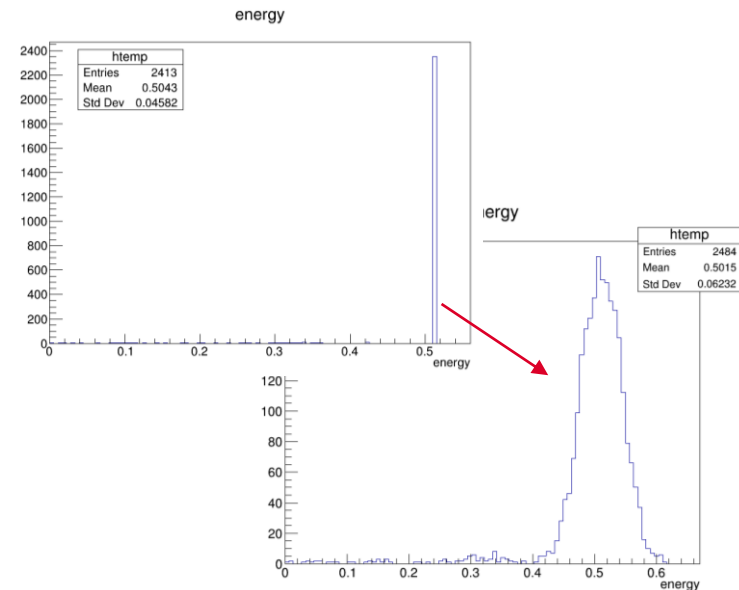
## ■ What it does

- Apply a Gauss on energy  
Resolution (FWHM), at a given energy, E

## ■ Options:

- fwhm for a given E
- fwhmMin, fwhmMax
- Inverse square law or linear
- Use option «slope» to choose linear

$$(R = R_0 \frac{\sqrt{E_0}}{\sqrt{E}})$$



## ■ How it is now

```
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/insert energyResolution
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/energyResolution/fwhm 0.15
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/energyResolution/energyOfReference 511. keV

/gate/digitizerMng/crystal/SinglesDigitizer/Singles/insert energyResolution
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/energyResolution/fwhmMin 0.12
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/energyResolution/fwhmMax 0.18
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/energyResolution/energyOfReference 511. keV
/gate/digitizerMgr/crystal/SinglesDigitizer/Singles/energyResolution/slope -0.055 1/MeV
```

## ■ How it was before

```
/gate/digitizer/Singles/insert blurring/crystalBlurring/localEnergyBlurring
/gate/digitizer/Singles/blurring/linear/setSlope -0.055 1/MeV
```

(ex spatial blurring)

## ■ What it does

- Apply a Gauss on position Resolution (FWHM), at a given position

## ■ Options:

- fwhm 1 for X, Y, Z directions
- fwhmX, fwhmY, fwhmZ
- New: `confineInsideOfSmallestElement`  
What to do if outside of a SD? Bring to a border but which one? Of a crystal? Of a module? etc

Set true for monocrystal, and false for crystal matrix

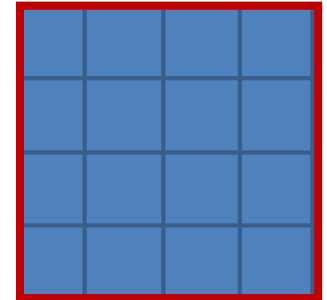
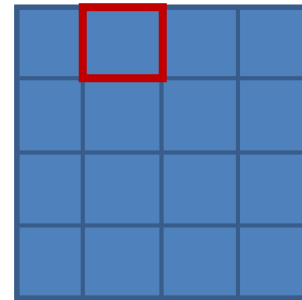
## ■ How it is now

```
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/insert spatialResolutin
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/spatialResolution/fwhm 0.15
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/spatialResolution/
confineInsideOfSmallestElement true
```

## ■ How it was before

```
/gate/digitizer/Singles/insert spBlurring
/gate/digitizer/Singles/spblurring/setSpresolution 2.0 mm
```

confineInsideOfSmallestElement  
true                      false



(ex *Energy Efficiency, Local efficiency, Crystal Blurring*)

## ■ What it does

- Set an efficiency

## ■ Options:

- **Unique efficiency**
- **Energy mode:** efficiency as a function of energy
  - From GateDistributions
  - From a file (energy, efficiency)
- **Crystal mode:** for different crystals, or groups of crystals
  - From a file

Energy mode:	
Energy (keV)	Efficiency
100	0.01
200	0.12
511	0.43

## ■ How it is now

```
/gate/digitizerMng/crystal/SinglesDigitizer/Singles/insert efficiency
/gate/digitizerMng/ crystal/SinglesDigitizer/Singles/efficiency/setUniqueEfficiency
0.93
```

## ■ How it was before

```
/gate/digitizer/Singles/insert crystalblurring
/gate/digitizer/Singles/crystalblurring/setCrystalQE 0.9
```

- What it does
  - Merges two Singles collections into one
- Options:
  - Set input collection
- Macro example

From Geometry macro:

```
/gate/BGO/attachCrystalSD
```

```
/gate/LSO/attachCrystalSD
```

...

```
/gate/digitizerMng/BGO/SinglesDigitizer/Singles/insert adder
```

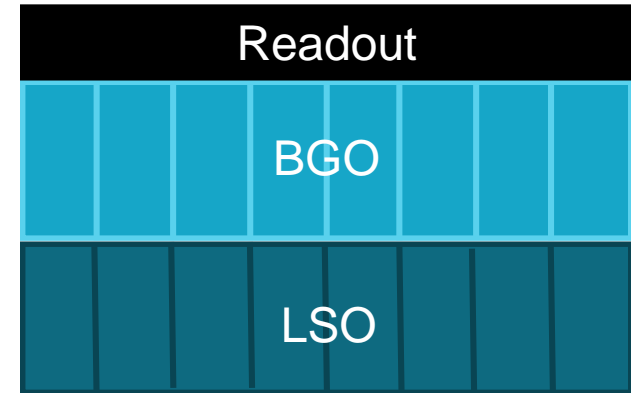
```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/insert adder
```

```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/insert merger
```

```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/merger/setInputCollection adder/BGO
```

```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/insert readout
```

- Use in the output:
  - `Singles_LSO`
- A bit tricky in command line: to simplify in the future



- What it does
  - Merges two Singles collections into one
- Options:
  - Set input collection
- Macro example

From Geometry macro:

```
/gate/BGO/attachCrystalSD
```

```
/gate/LSO/attachCrystalSD
```

...

```
/gate/digitizerMng/BGO/SinglesDigitizer/Singles/insert adder
```

```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/insert adder
```

```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/insert merger
```

```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/merger/setInputCollection adder/BGO
```

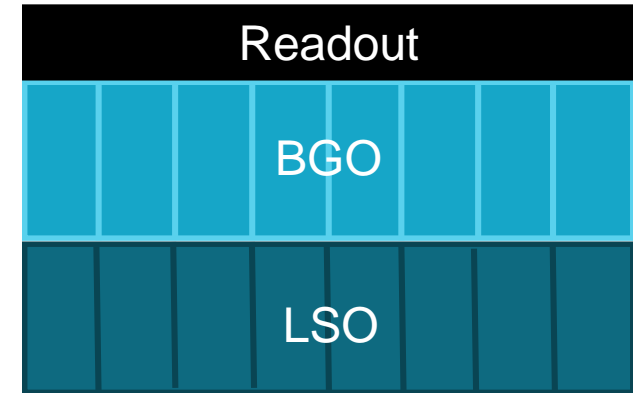
```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/insert readout
```

Must be the second collection (last used)

`Singles_LSO`

Second SD name

Its last digitizer module



- A bit tricky in command line: to simplify in the future

## ■ DONE

### ■ Didigitizer Modules

- Adder
- Adder Optical
- Adder Compton
- Readout
- Energy resolution
- Time resolution
- Spatial resolution
- Energy framing
- Efficiency
- Adder Compton
- Dead time
- Pile-up
- Noise

### ■ Coincidence Sorter

### ■ Outputs

- Root
- Tree
- ASCII
- Binary
- Projection
- Analysis
- FastAnalysis

## ■ Coming next

### ■ Didigitizer Modules

- Buffer
- Intrinsic Resolution
- Light Yield
- Transfer Efficiency
- Quantum Efficiency
- Calibration
- CrossTalk

### ■ CC functionalities

- CC digitizer modules
- CC Coincidence Sorter
- Outputs

### ■ Coincidence digitizers

### ■ Outputs

- Sino
- LMF
- Ecat7

### ■ Offline digitizer

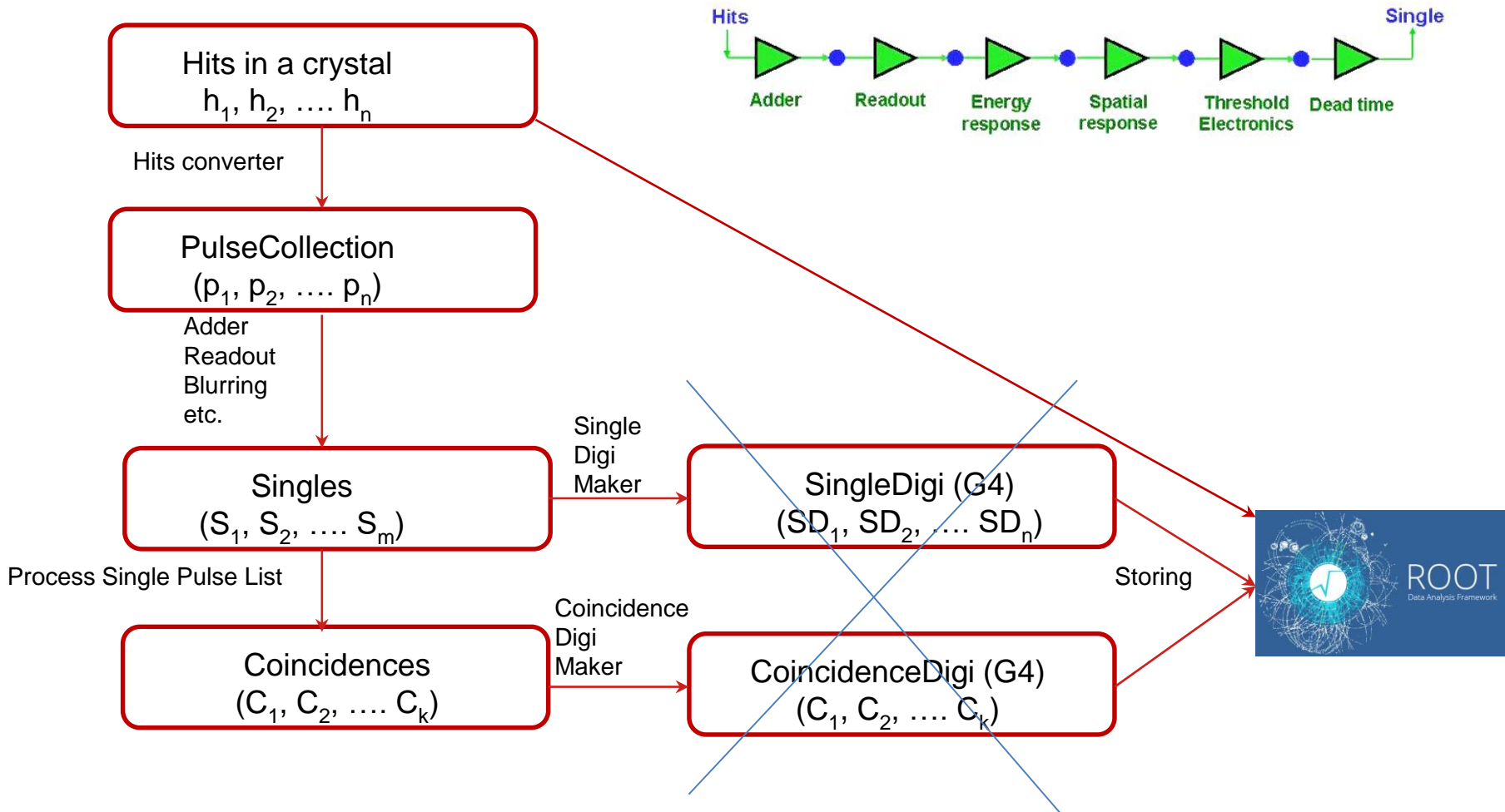
- Gate New Digitizer in version 9.3
  - Multiple Sensitive Detectors that can be attached even without system defined
  - New commands but macro conversion tool
  - Speed-up
  - More coming ...
  
- Next developments of digitizer in Gate 9.3
  - Adapt the modules that are in a “waiting list”
  - Coincidence Digitizer implementation
  - Waveform generator
  - Offline digitizer
  
- Gate 10
  - New Digitizer integration for this version is also planed



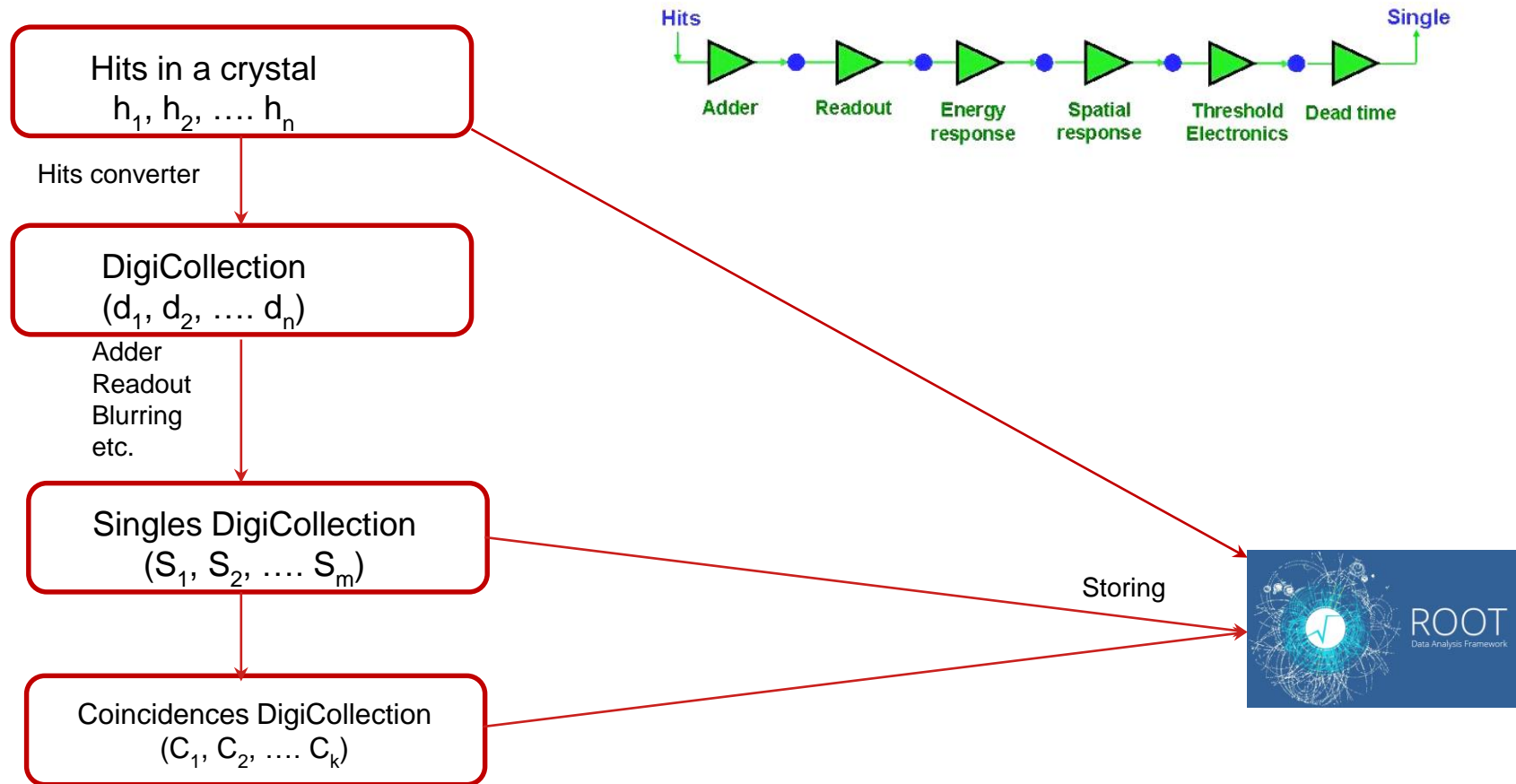


Thanks!

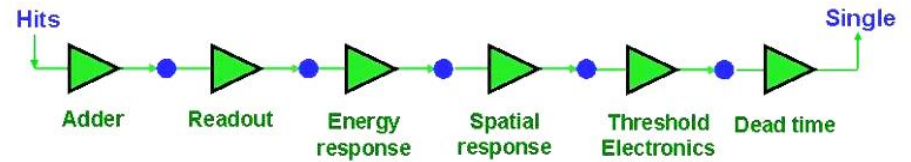
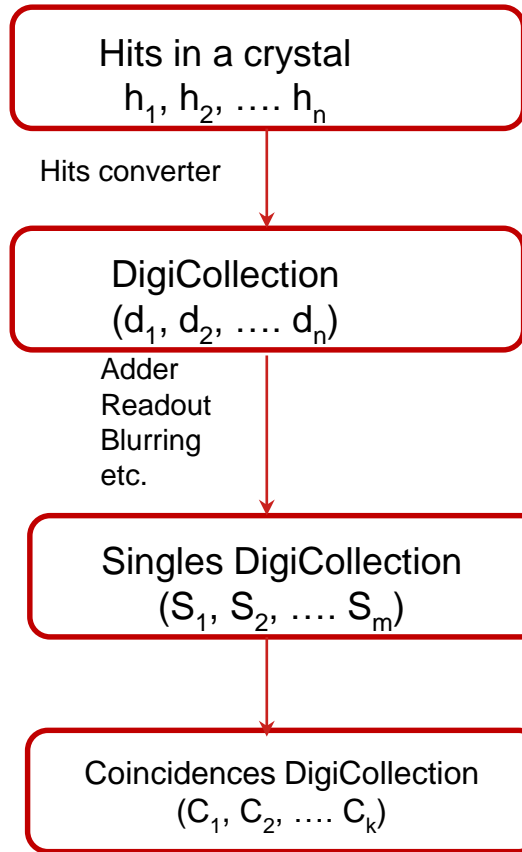
# ARCHITECTURE SIMPLIFICATION



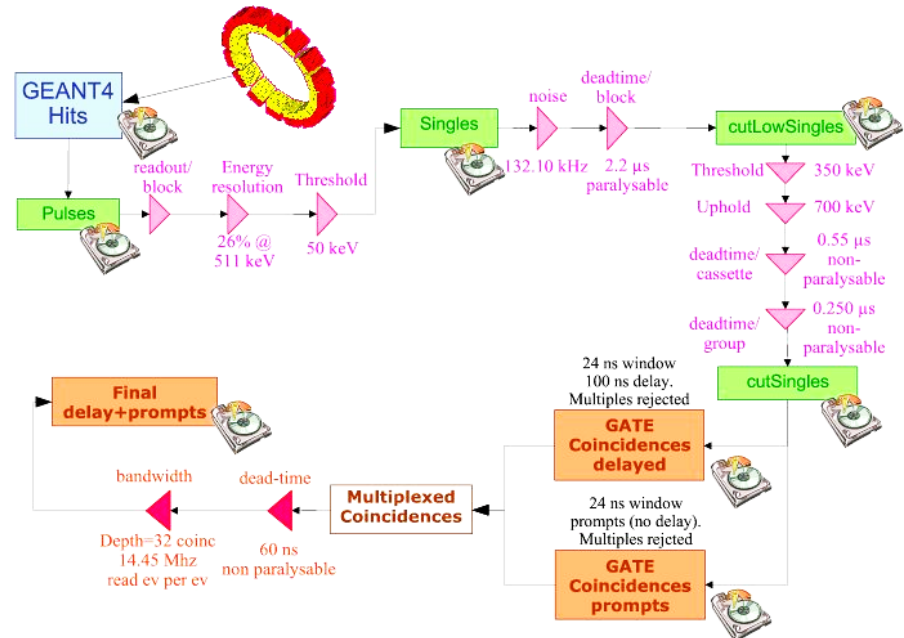
# ARCHITECTURE SIMPLIFICATION



# ARCHITECTURE SIMPLIFICATION



**Example of simplest case: only one type of Singles and Coincidences**



# NEW FEATURES AND MAIN CHANGES FOR USERS

