

Gate Scientific Meeting 2024
Orsay, France

DE LA RECHERCHE À L'INDUSTRIE



Gate Activates @ BioMaps

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DRF/JOLIOT/SHFJ/BioMaps

22 May 2024

www.cea.fr



- Activates for Gate 9.4
 - Release
 - Digitizer Unit

- Developments for ClearMind project
 - Spatial resolution
 - TB TOF studies
 - Marc: TB and Clear Mind
 - Waveform generator

- Activates for Gate 10
 - Coincidence Sorter

New version of Geant4 11.2.1

→ Gate 9.4 release on the 4th of April 2024

New features

- New Track Length Estimator (TLE) of prompt gamma with time tagging, vpgTLE-tt (by CREATIS @ Lyon)
for prompt gamma production in proton therapy simulations

- BioDose Actor (by LPCA @ Clermont-Ferrand)

- Digitizer modules adaptation continued (by BioMaps @ Orsay)
 - Buffer
 - Intrinsic Resolution
 - Light Yield
 - Transfer Efficiency
 - Quantum Efficiency
 - Calibration
 - CrossTalk
 - 8 Compton Camera digitizer modules

■ 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

■ DONE

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■ Offline digitizer

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- Didion:–

TECHNOLOGY AND CODE article

Front. Phys., 21 March 2024

Sec. Radiation Detectors and Imaging

Volume 12 - 2024 | <https://doi.org/10.3389/fphy.2024.1294916>

This article is part of the Research Topic
Women In Science: Radiation Detectors and Imaging
[View all 4 Articles >](#)

New GATE Digitizer Unit for versions post v9.3

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- C
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The Digitizer Unit plays an important role in modeling using Geant4 Application for Tomographic Emission (GATE), a Geant4-based platform used for numerical simulations in medical imaging and radiotherapy. It simulates the response of the photodetection components using a sequence of analytical and semi-analytical models. The Digitizer Unit was written for the first version of GATE approximately 20 years ago. Since then, it has in parts grown in a code that can be hardly maintained. Some parts of the code were unused or duplicated; some of the functionalities were not working anymore. Therefore, the GATE Digitizer Unit update is required in order to incorporate the novelties of Geant4 to update its current version and add new features. In this article, the implementation of the new GATE Digitizer Unit (since version 9.3) is presented. Added functionalities, the impact of changes on users, the current status of the work, and perspectives are discussed.

<https://doi.org/10.3389/fphy.2024.1294916>

Developments for ClearMind project

Collaboration

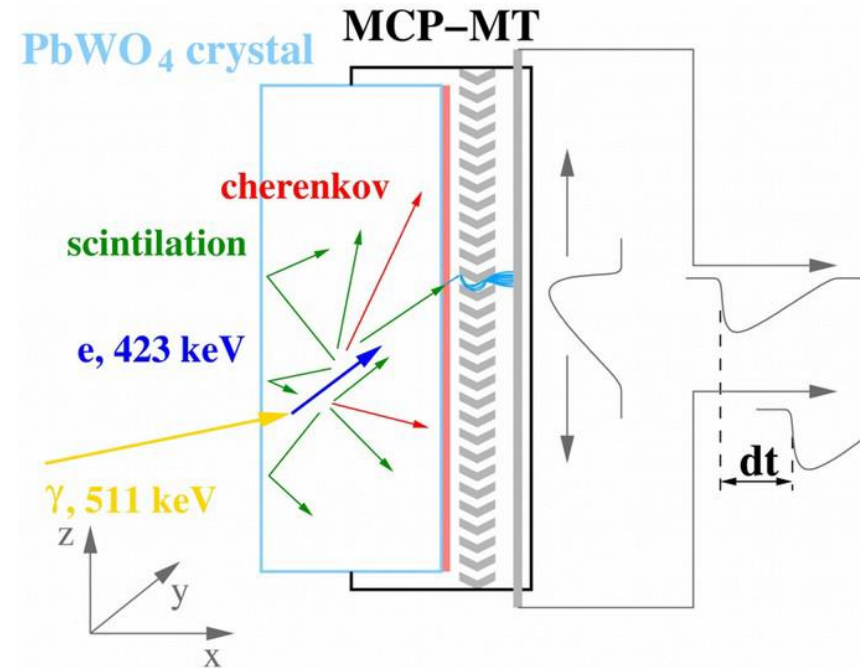
- DRF/IRFU – CEA Saclay
- CPPM – Marseille
- IJCLab – Orsay
- DES/ISAS – CEA Saclay
- BioMaps/SHFJ – Orsay

ClearMind PET main goals

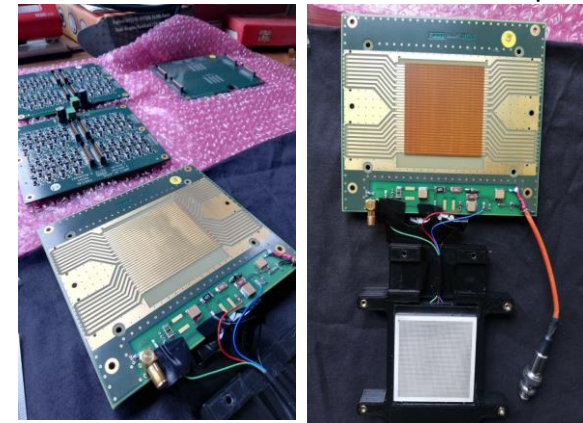
- Total body PET scanner
- TOF - Targeting few 10 ps
- AI for *position* reconstruction
- Spatial resolution of 1 mm³

Detector

- Large (59 x 59 x 5 mm³) *Monolithic* PbWO₄ crystal
- Detection of 20 γ Cherenkov, 150 fast scintillation γ
 - Photo-cathode is deposited directly on the crystal
 - Recons. of γ interaction 3D position, time, energy, etc

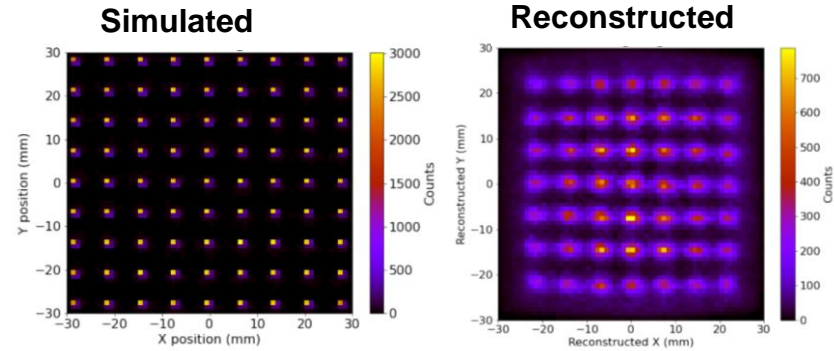


MAPMT253 : Matrix of 64x64 anodes pads



- AAIMME project (CEA, in 2020-2023):
 - Quantitative estimation with AI of the spatial coordinates of gamma interactions within a monolithic scintillator
 - Use waveforms information
 - Consideration of uncertainties on the estimated coordinates
 - Uncertainty is increased toward crystal borders

<https://doi.org/10.1016/j.engappai.2024.107876>

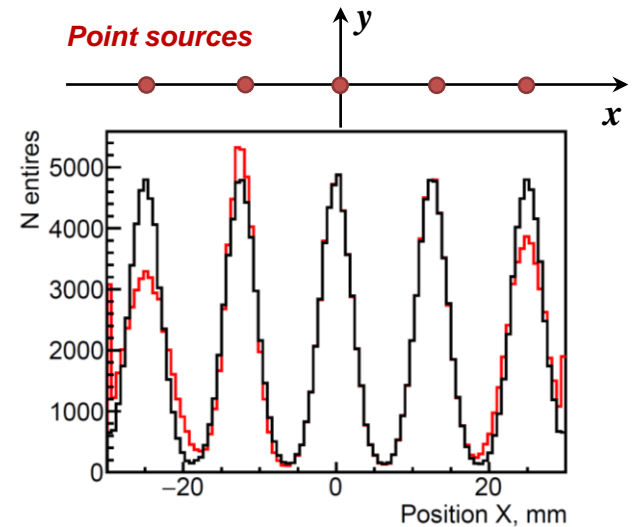
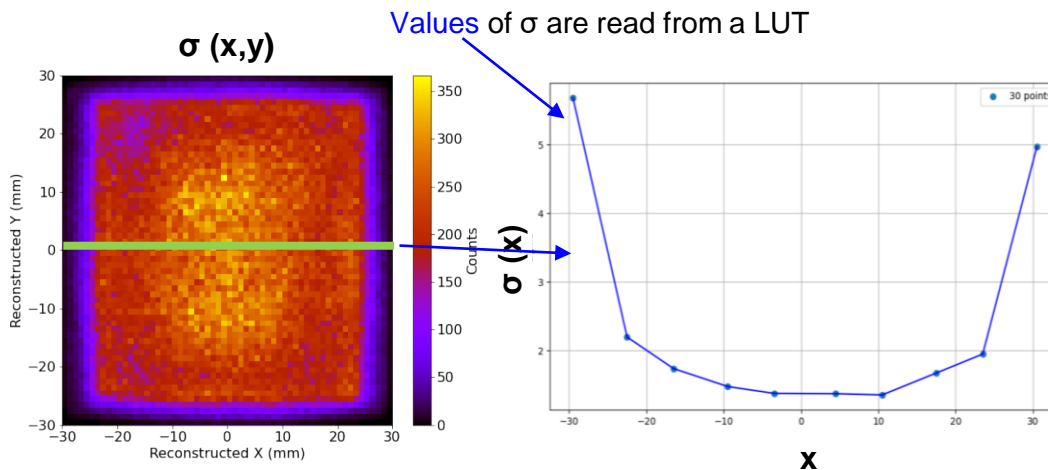


How these uncertainties are propagated into reconstructed image?

- Generalization of GateSpatialResolution
 - Gaussian blurring of a hit position
 - Current version: σ_x , σ_y , σ_z
 - Generalization: $\sigma_x(x)$, $\sigma_y(y)$, $\sigma_z(z)$



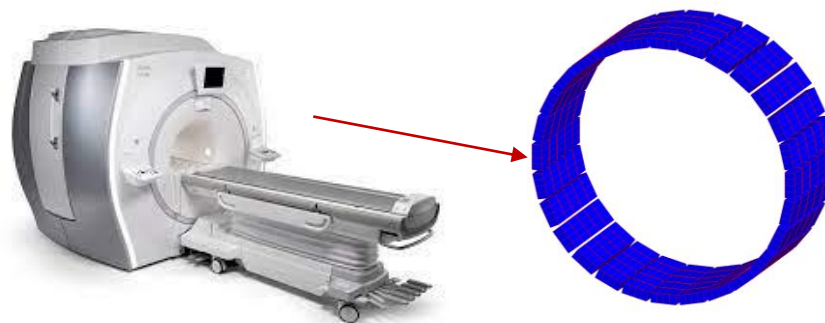
Work in progress:
internship of Radia Oudihat



STUDY OF VERY HIGH TEMPORAL RESOLUTION (<100PS) IN CLINICAL TOTAL BODY PET IMAGING

- Gate Simulation of SIGNA PET/MR by GE

- Matrix of LYSO crystals
- Model NEMA validations for:
 - Sensitivity
 - NECR
 - Spatial resolution
 - Percent Contrast Recovery

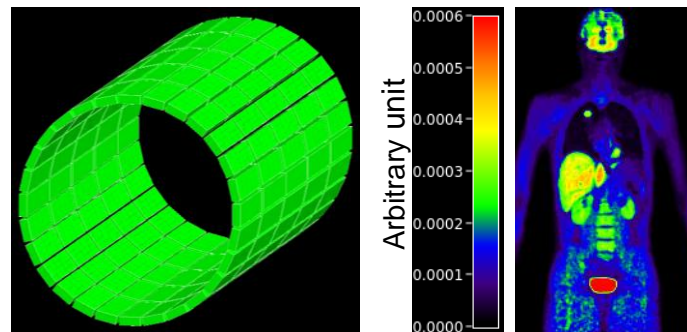


- Gate Simulation of SIGNA PET/MR × 4 → Total Body PET of 1m long

- TOF CTR of SIGNA GE: 390 ps → 100 ps

Study cases:

- Gold Standard: CTR = 390 ps, Acquisition time = 300s
- High CTR: CTR = 100 ps, Acquisition time = 300s
- Short acquisition: CTR = 100 ps, Acquisition time = 60s
- Low dose: CTR = 100 ps, Acquisition time = 300s, dose/10

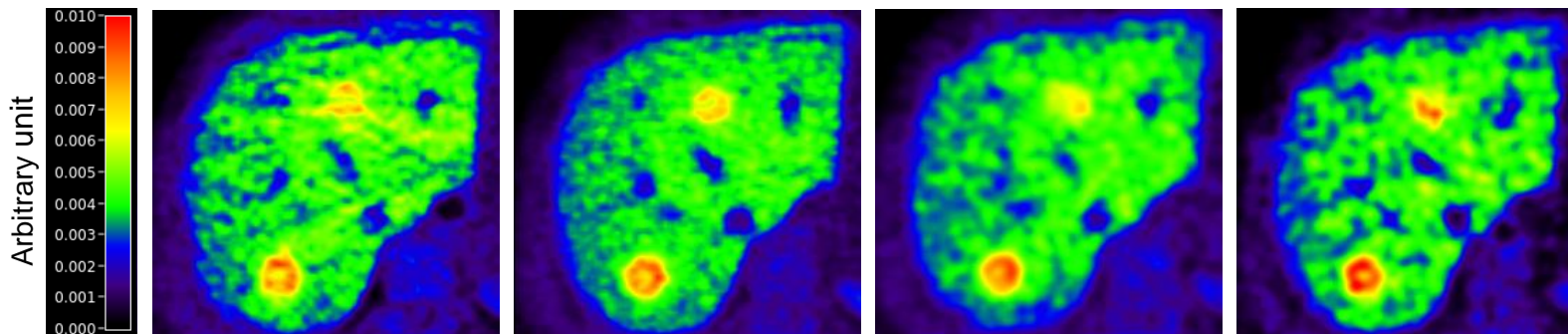


Gold Standard

High CTR

Short acquisition

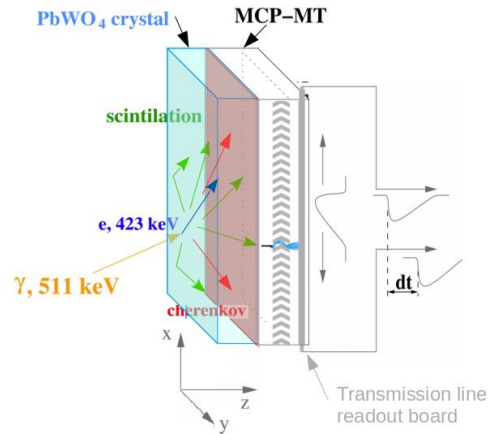
Low dose



PhD thesis of
Adrien Paillet

- ClearMind detection elements

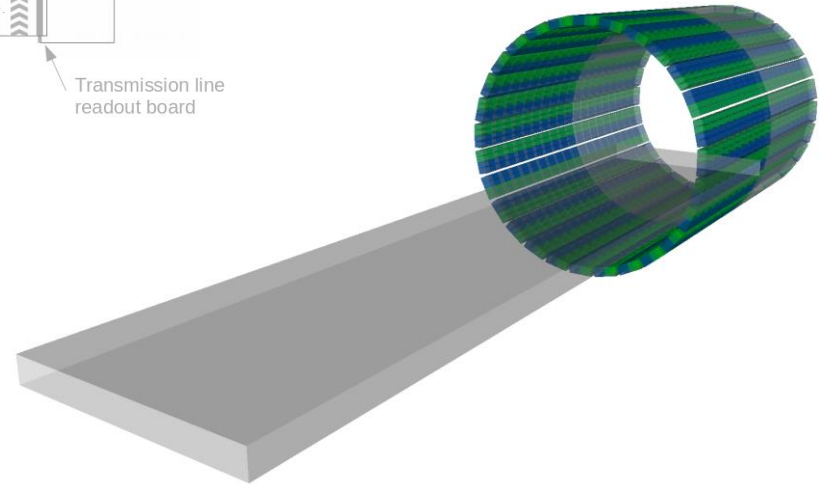
- Material: PbWO₄
- **Monolithic crystal** :
 - 59x59x10 mm³
- MCP-PMT readout on one side
- SiPM readout on other side



*Postdoc work of
Marc Granado*

- Total body PET

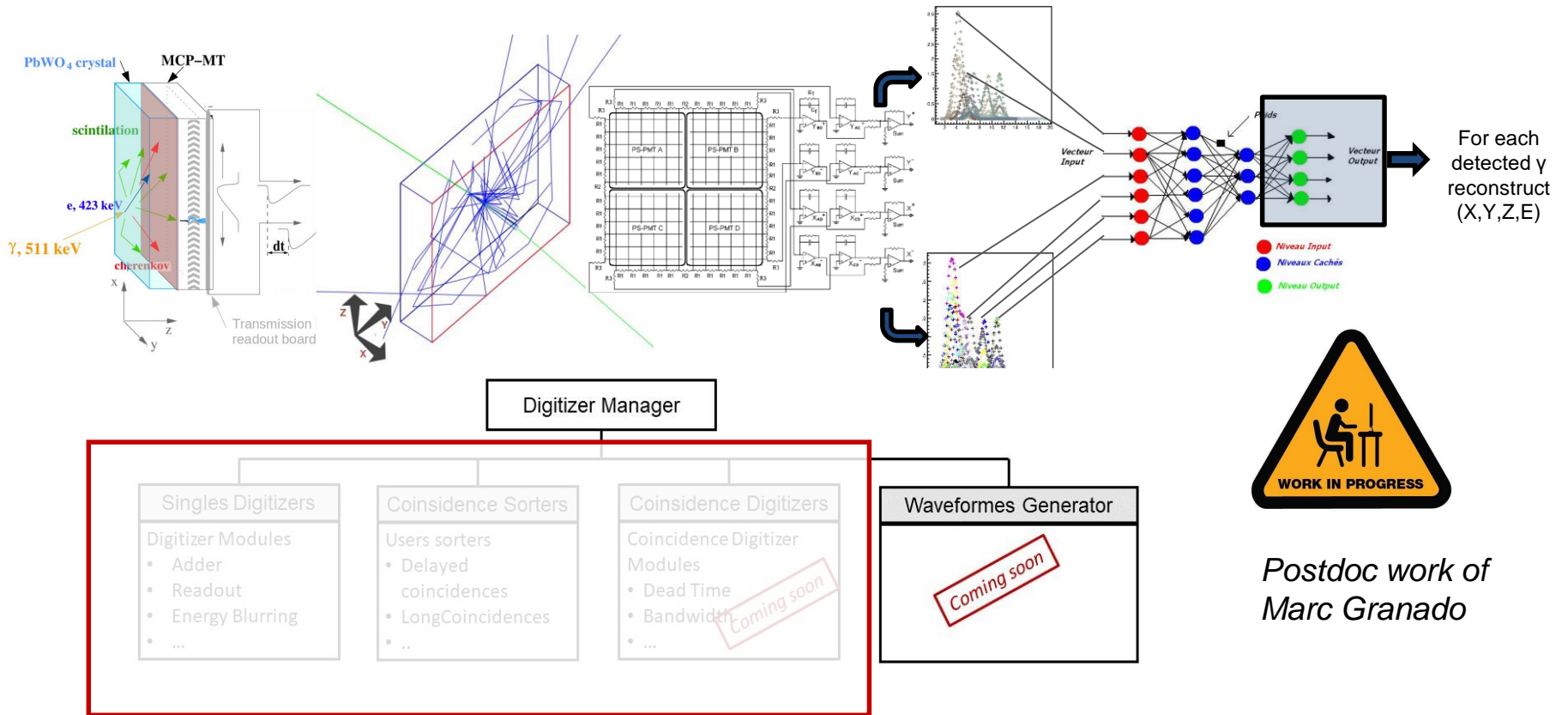
- 1m long
- Digitizer parameters from prototype tests
- Castor reconstruction for monolithic crystals
- Image corrections:
 - Normalization
 - Attenuation
 - Scatter
 - Random



- More details in presentation **tomorrow at 10h10** by Marc Ganado :
«ClearMind total body PET simulations with GATE»

Another version of GATE simulation

- Simulation of all optical photons
- Simulation of photo-electrons on a MCP-PMT photo-cathode
- Simulation of signal waveform by electronics (TDC et ADC)



Scheduled 1st meeting on the 28th of May with others working/interested

- Let me know if you want to participate

Activates for Gate 10

- Several work meetings in 2023-2024

- First version of Coincidence Sorter
 - Offline (online is also planned)
 - Available user parameters so far:
 - **Time window**
 - **Multiples Policies:**
 - keepAll (ex-takeAllGoods)*
 - removeMultiples (ex-killAll)*
 - Already available in master branch of Gate 10
 - Test072 as an exemple use

- Next steps
 - Improve tests
 - Other policies (Users survey is coming)
 - Geometry filters (*minSectorDiff*, *maxRingDiff*)
 - TimeOffset for randoms estimation

- Working [google doc](#). You are welcome to contribute !

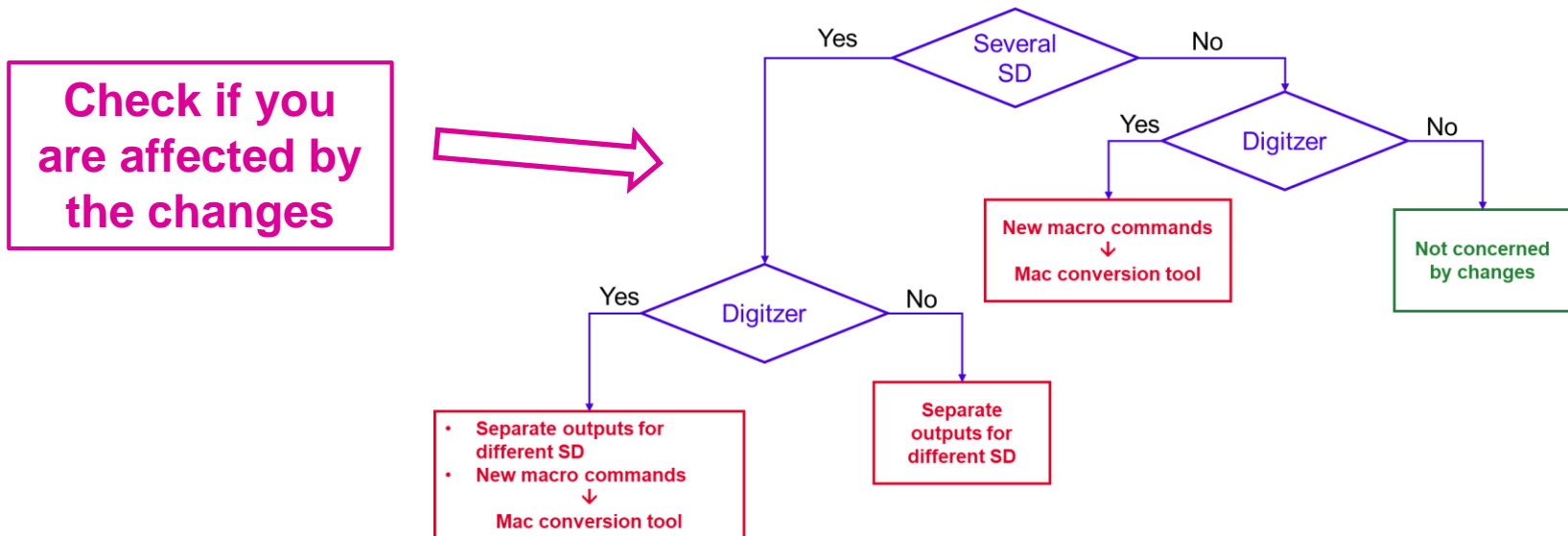
- **Activates for Gate 9.4**
 - The releases follow the Geant4 releases
 - New developments are ongoing but not actively

- **Developments for ClearMind project**
 - Total Body TOF
 - Monolithic crystals
 - Waveform generator

- **Activates for Gate 10**
 - Developments are actively ongoing on Coincidence Sorter

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

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)

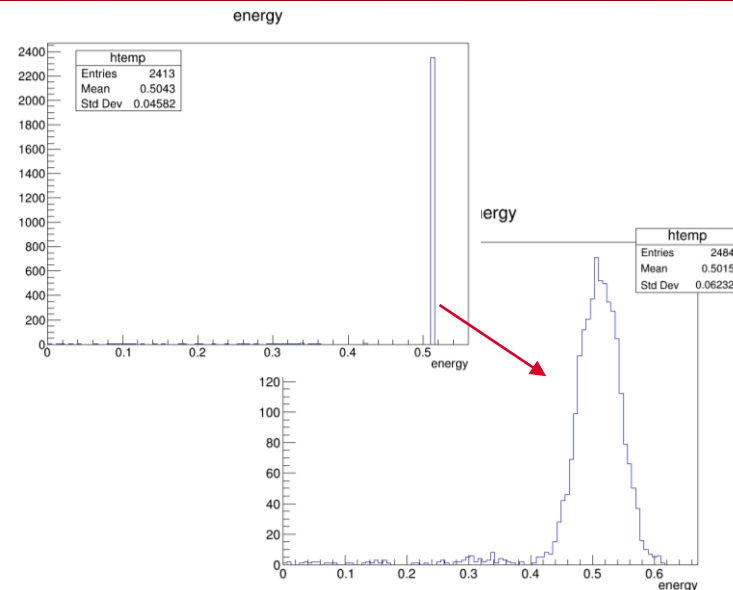
■ What it does

- 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

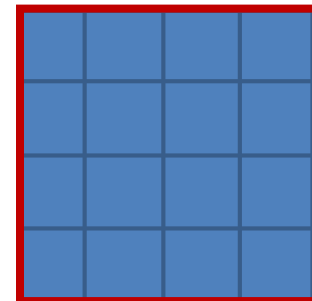
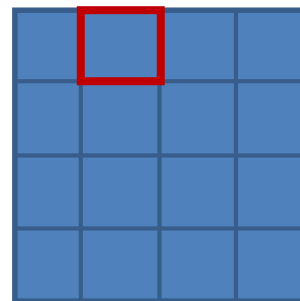
■ How it is now

```
/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
```

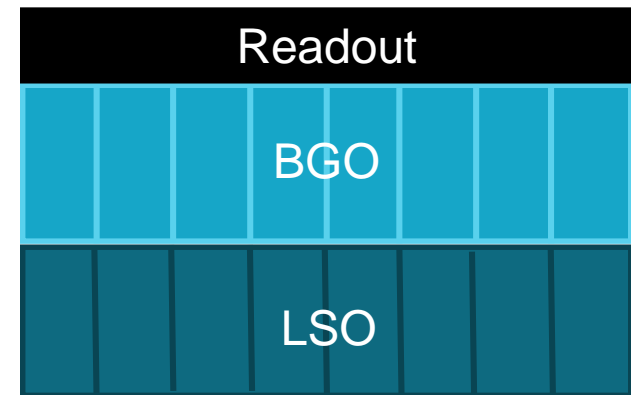
```
/gate/digitizerMng/LSO/SinglesDigitizer/Singles/insert readout
```

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

- 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 ...

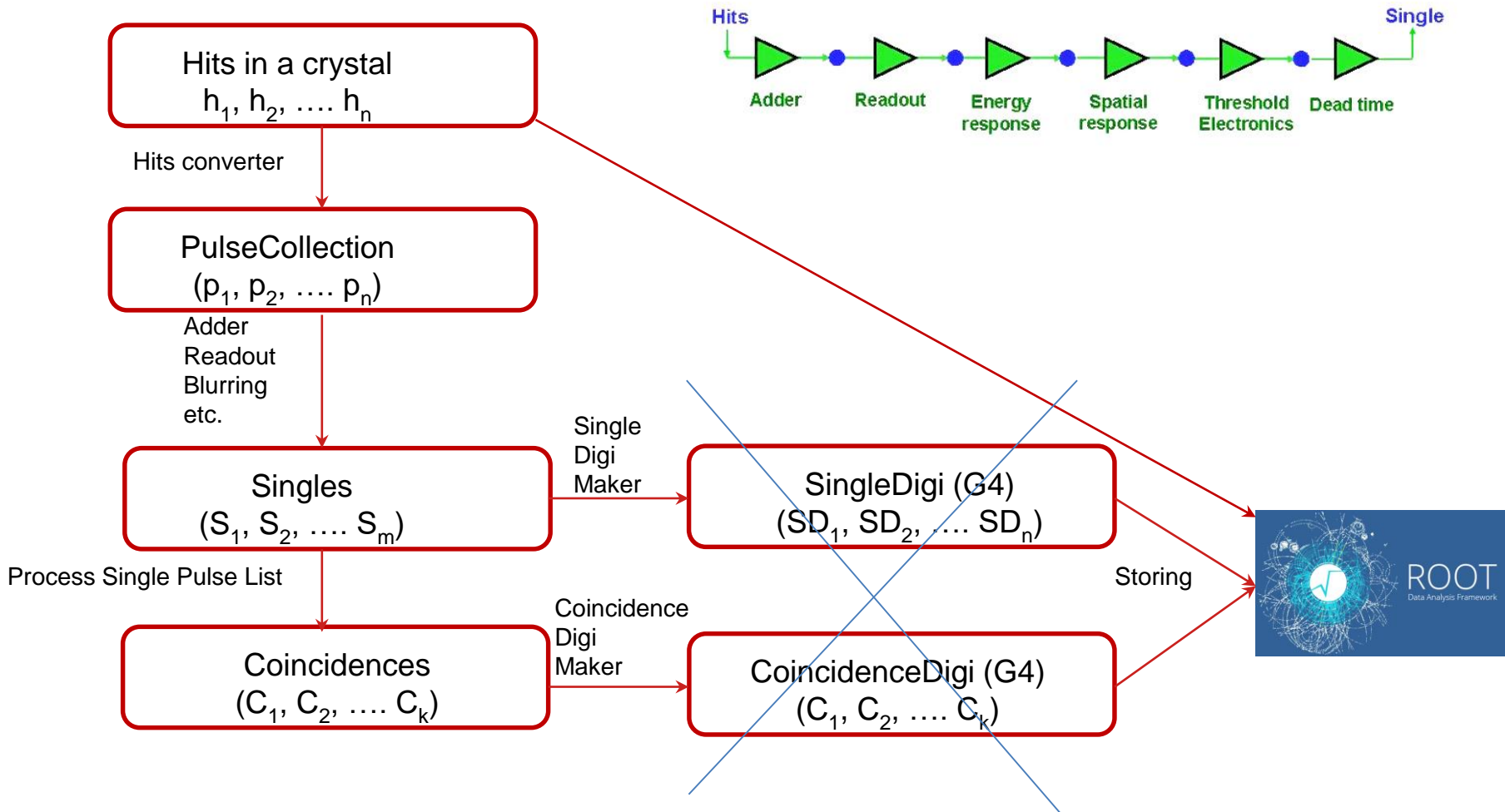
- Next developments of digitizer in Gate 9.3
 - Adapt the modules that are in a “waiting list”
 - Coincidence Digitizer implementation
 - Waveform generator
 - Offline digitizer

- Gate 10
 - New Digitizer integration for this version is also planed

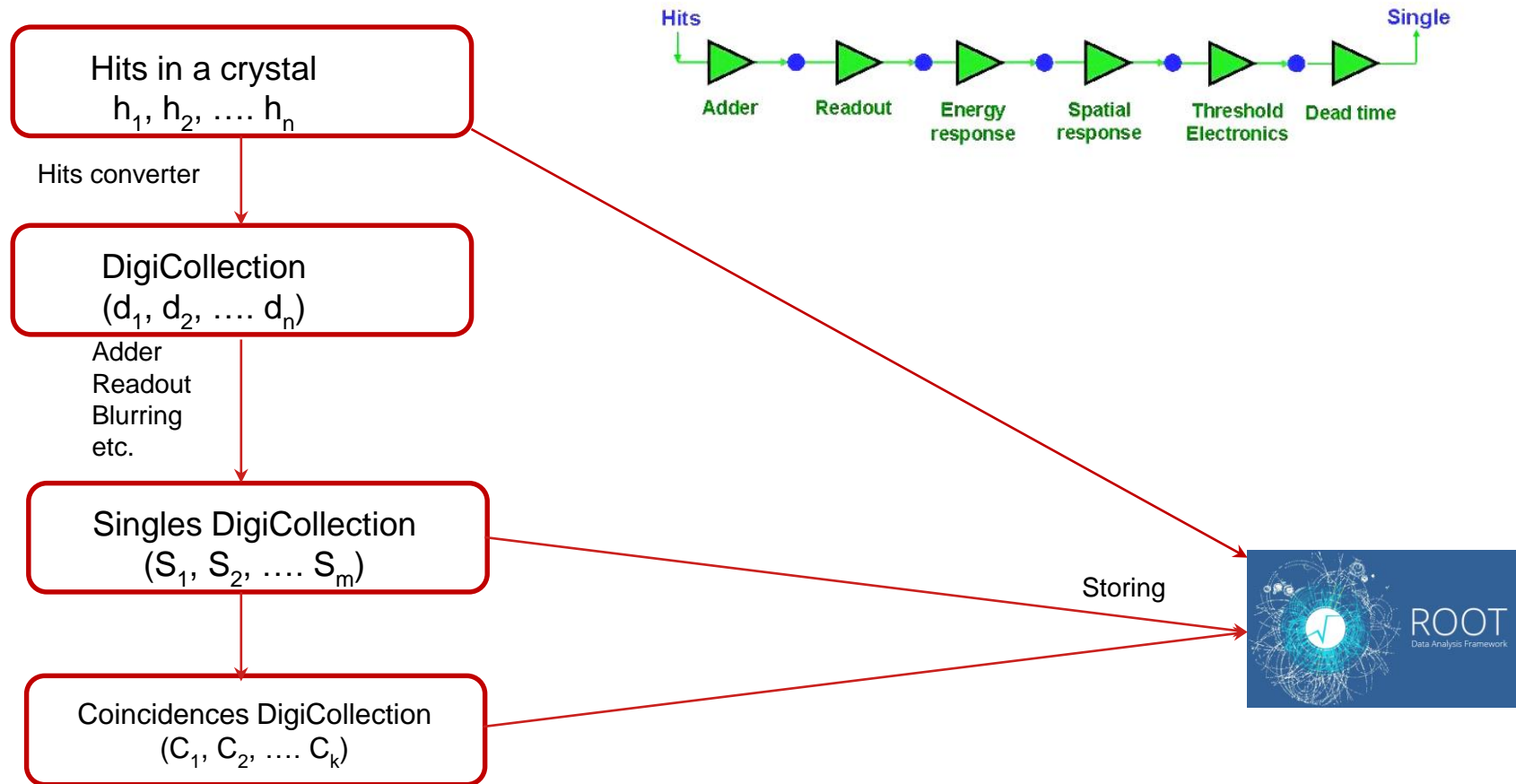


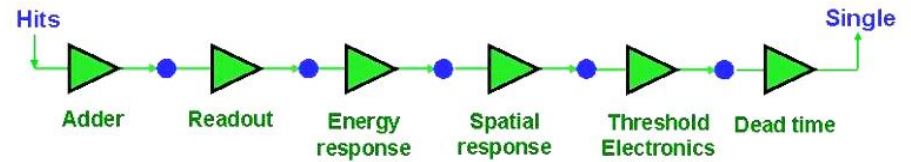
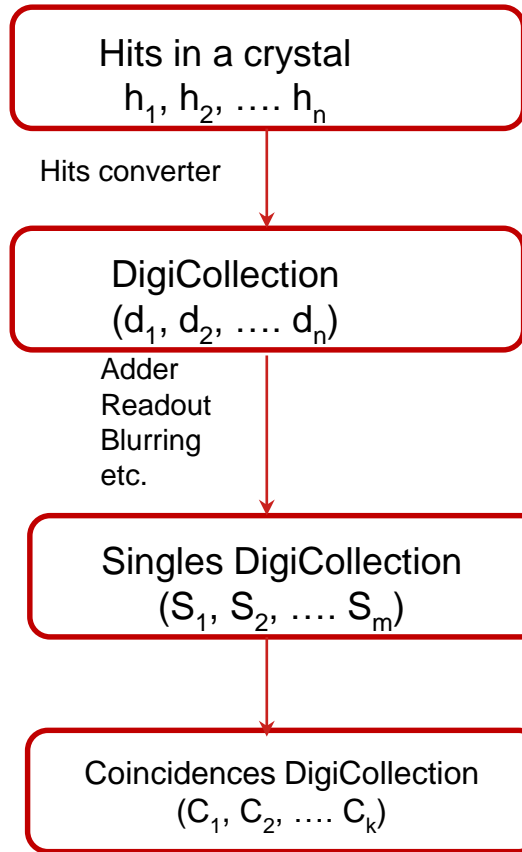
Thanks!

ARCHITECTURE SIMPLIFICATION

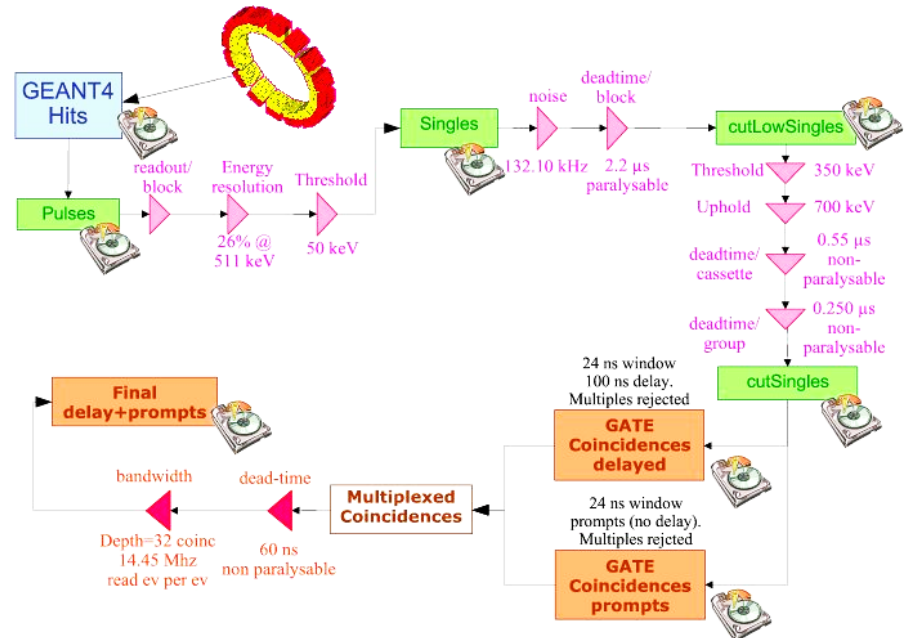


ARCHITECTURE SIMPLIFICATION





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



NEW FEATURES AND MAIN CHANGES FOR USERS

