Gate New Digitizer
Gate 9.3

Olga Kochebina
Sébastien Jan

DRF/JOLIOT/SHFJ/BioMaps

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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 modelized 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 modelized 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

→ …
AIMS FOR GATE NEW DIGITIZER (GND)

- 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
NEW FEATURES IN 9.3 AND CHANGES FOR USERS

- **Speed up**
  
  test on cylPET system, Intel® Xeon(R) Gold 5218R CPU @ 2.10GHz, 10 000 000 events
  
  - Hits $\rightarrow$ ~40%
  - Singles $\rightarrow$ ~10%
  - Coincidences $\rightarrow$ 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

Check if you are affected by the changes

Macros commands:
/gate/crystal/attachCrystalSD
/gate/crystal2/attachCrystalSD

Output TTrees:
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
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
```

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
ENERGY RESOLUTION
(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

- 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/digitizerMngr/crystal/SinglesDigitizer/Singles/energyResolution/slope -0.055 1/MeV

- How it was before

/gate/digitizer/Singles/insert blurring/crystalBlurring/localEnergyBlurring/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 monocystal, and false for crystal matrix

**How it is now**

/gate/digitizerMng/crystal/SinglesDigitizer/Singles/insert spatialResolution
/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
Efficency

(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

- **How it is now**

  - How it was before
    /gate/digitizer/Singles/insert crystalblurring
    /gate/digitizer/Singles/crystalblurring/setCrystalQE 0.9

- **Energy mode**:

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.01</td>
</tr>
<tr>
<td>200</td>
<td>0.12</td>
</tr>
<tr>
<td>511</td>
<td>0.43</td>
</tr>
</tbody>
</table>
NEW MODULE: MERGER

- **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_LS0`

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

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- **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`

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

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
  - Intrinistic 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
CONCLUSION AND PERSPECTIVES

- 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 planned
Thanks!
ARCHITECTURE SIMPLIFICATION

Hits in a crystal
\( h_1, h_2, \ldots, h_n \)

PulseCollection
\( (p_1, p_2, \ldots, p_n) \)

Singles
\( (S_1, S_2, \ldots, S_m) \)

Process Single Pulse List

Coincidences
\( (C_1, C_2, \ldots, C_k) \)

Hits converter

Adder Readout Blurring etc.

Single Digi Maker

Coincidence Digi Maker

SingleDigi (G4)
\( (SD_1, SD_2, \ldots, SD_n) \)

CoincidenceDigi (G4)
\( (C_1, C_2, \ldots, C_k) \)

Storing

Adder
Readout
Energy response
Spatial response
Threshold Electronics
Dead time

Single
HPS in a crystal $h_1, h_2, \ldots, h_n$

DigiCollection $(d_1, d_2, \ldots, d_n)$

Adder
Readout
Blurring etc.

Singles DigiCollection $(S_1, S_2, \ldots, S_m)$

Coincidences DigiCollection $(C_1, C_2, \ldots, C_k)$

Hits converter

Storing

Adder  Readout  Energy response  Spatial response  Threshold Electronics  Dead time
ARCHITECTURE SIMPLIFICATION

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

Hits in a crystal
\( h_1, h_2, \ldots, h_n \)

DigiCollection
\( (d_1, d_2, \ldots, d_n) \)

Singles DigiCollection
\( (S_1, S_2, \ldots, S_m) \)

Coincidences DigiCollection
\( (C_1, C_2, \ldots, C_k) \)

Hits converter

Adder
Readout
Blurring etc.

GEANT4
Hits

Pulses

Energy resolution

Threshold

32.10 kHz
2.2 \( \mu \)s
350 keV

Singles

cutLowSingles

Deadtime/block

Noise

40 ns

30 ns

50 ns

511 keV

50 keV

24 ns window
100 ns delay
Multiples rejected

24 ns window
prompts (no delay)
Multiples rejected

GATE
Multiplexed
Coincidences

Depth: 32 coins
1.45 MHz
readout per ev

60 ns
non-paralyzable
NEW FEATURES AND MAIN CHANGES FOR USERS

- **Several SD**
  - Yes
  - Digitizer
    - Yes: Separate outputs for different SD
    - No: Mac conversion tool
- **No**
  - Digitizer
    - Yes: New macro commands
      - Mac conversion tool
    - No: Not concerned by changes

- **Separate outputs for different SD**
  - Yes: Mac conversion tool