Gate scientific meeting

DE LA RECHERCHE À L'INDUSTRIE

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Gate activities at BioMaps

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BioMaps
LABORATOIRE D'IMAGERIE BIOMÉDICALE

SUBJECTS

Digital Twin for PET

- PhD Thesis of Adrien Paillet

ClearMind project

- Detector developments for TOF-PET

Digitizer optimizations

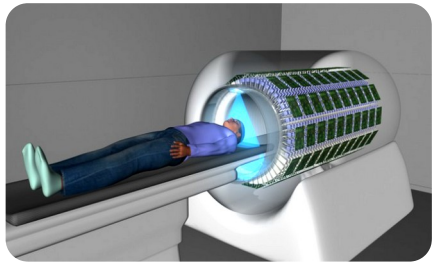
- Is it possible to make it simpler and more flexible?

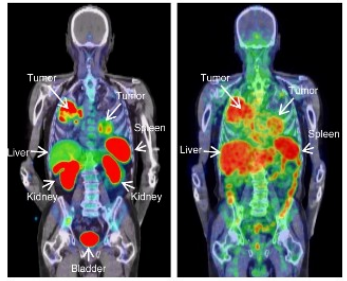
DEVELOPMENT OF A PET CAMERA DIGITAL TWIN

PhD thesis of Adrien Paillet:
Whole-body Monte Carlo simulation in medical imaging: development of a Next Generation PET Camera Digital Twin

Dynamic TOF whole body molecular imaging

- For pharmacological and drug developments
- Diagnosis & measurement of therapeutic efficacy
- Platform for detector prototype simulations





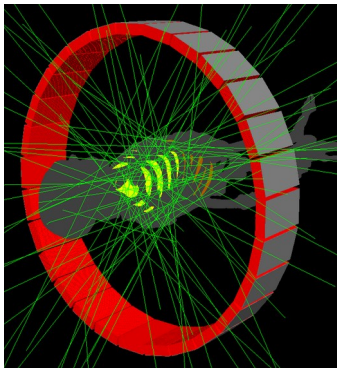
Digital Twin @ PET

Real case

Optimizations and developments

- New generations of detectors
- Scanner geometries
- Data acquisition
- Image reconstruction
- Image analysis
- Database production
- Patient-specific applications

Simulation



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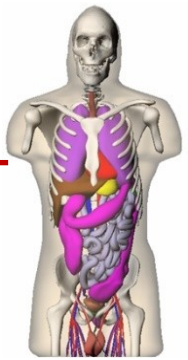
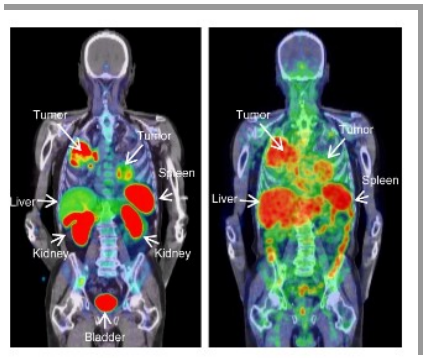


DEVELOPMENT OF A PET CAMERA DIGITAL TWIN



PET digital twin developments with GATE

- **PET camera**
  - Whole-body
  - 4D/Dynamic acquisition
  - Optimizations (detector, geometries etc.)
  - Link with CaSTOR reconstruction
- **Digital patient for biodistribution**
  - Patient data from PET/MRI SIGNA by GE as a “gold standard”

Validations & characterizations of systematic and statistical errors

Static data on a phantom
Dynamic data on a phantom
Dynamic whole body patient data

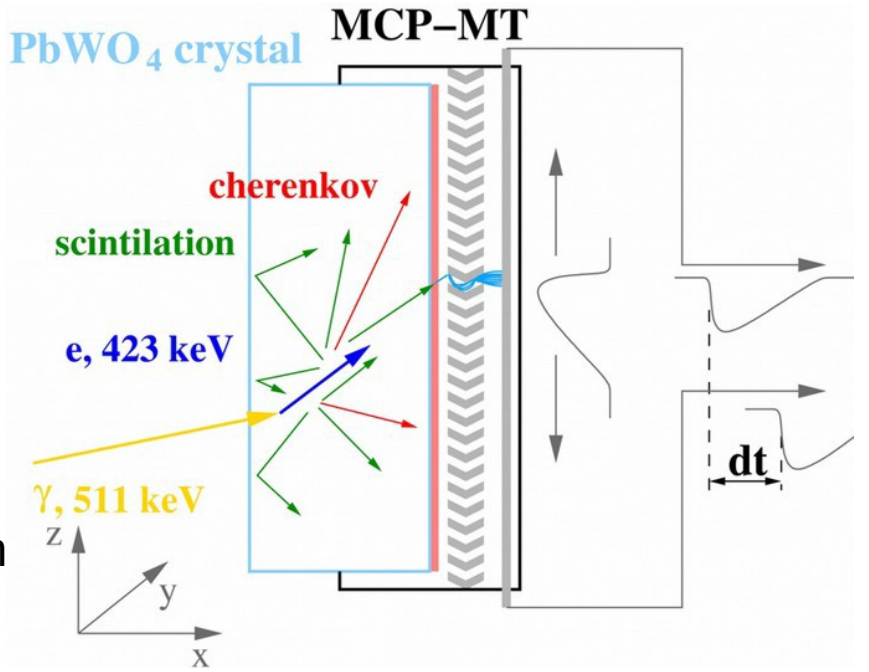
Evaluation of the clinical performance of a new generation PET

Integration of the deep learning approach in the signal detection
Integration of TOF detector performance - 10 ps to 100 ps
Application to "phase 0" studies of bio-distribution of drug candidates

CLEARMIND PROJECT

Collaboration

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



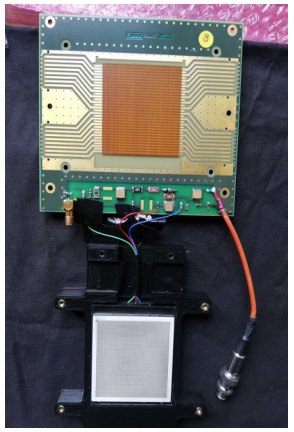
ClearMind PET main goals

- TOF - Targeting few 10 ps
- AI for *image* and *timing* reconstruction
- Spatial resolution of 1 mm^3
- First prototype detector received

Detector

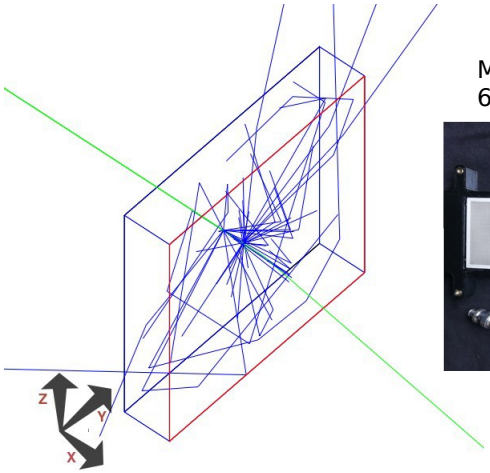
- Large (60 x 60 mm^2) *Monolithic* $PbWO_4$ crystal
- Detection of 20 γ Cherenkov, 150 fast scintillation γ
- Photo-cathode is deposited directly on the crystal
- MCP-PMT with 64 x 64 readout anodes
- Readout by 32 transmission lines
- Recons. of γ interaction 3D position, time, energy, etc

MAPMT253 : Matrix of 64x64 anodes pads

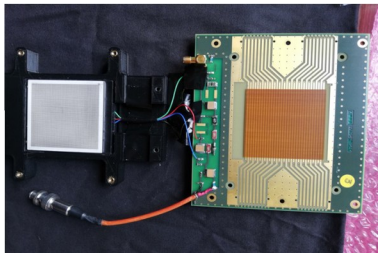


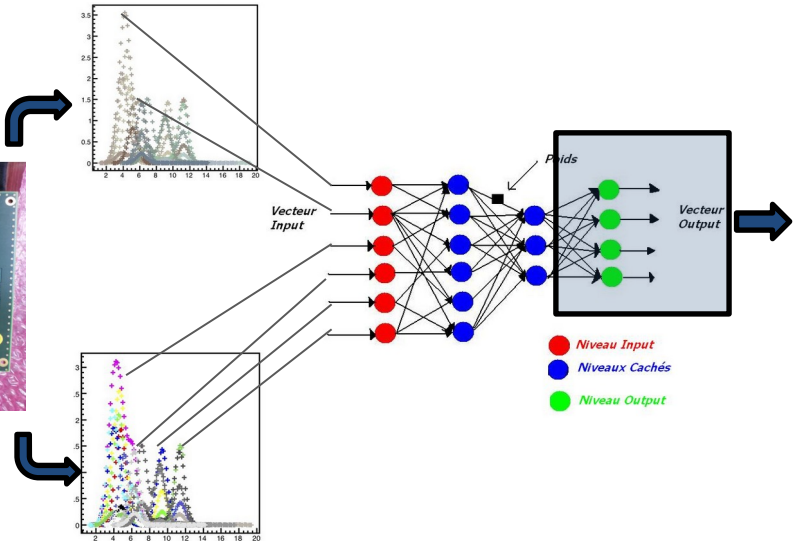
Aimed GATE simulation for full PET scanner

- Tracking of all optical photons → root File
- Simulation of photo-electrons on a MCP-PMT photo-cathode
- Simulation of signal waveform by electronics (WF Recoder)



MAPMT253 : Matrix of 64x64 anodes pads



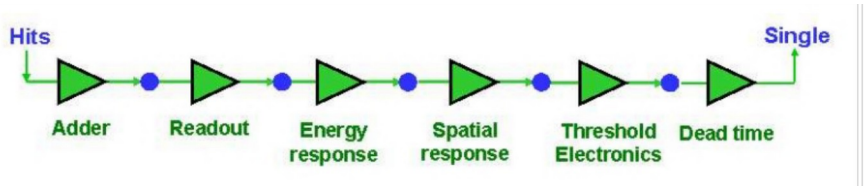


For each detected γ reconstruct (X,Y,Z,E)

Reconstruction

- CaSTOR
- Spatial resolution: optimize *Timing* and *3D positioning* in crystal
- Use signal waveforms that are complex and cramped
- Machine Learning and AI with trained on MC data

Signal Processing @ GATE



Hits in a crystal
$h_1, h_2, \ldots h_n$

Hits converter

Crystal Hit Collection
$(h_1, h_2, \ldots h_n)$

Adder
Readout
Blurring
etc.

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

Single Digi Maker

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

Process Single Pulse List

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

Coincidence Digi Maker

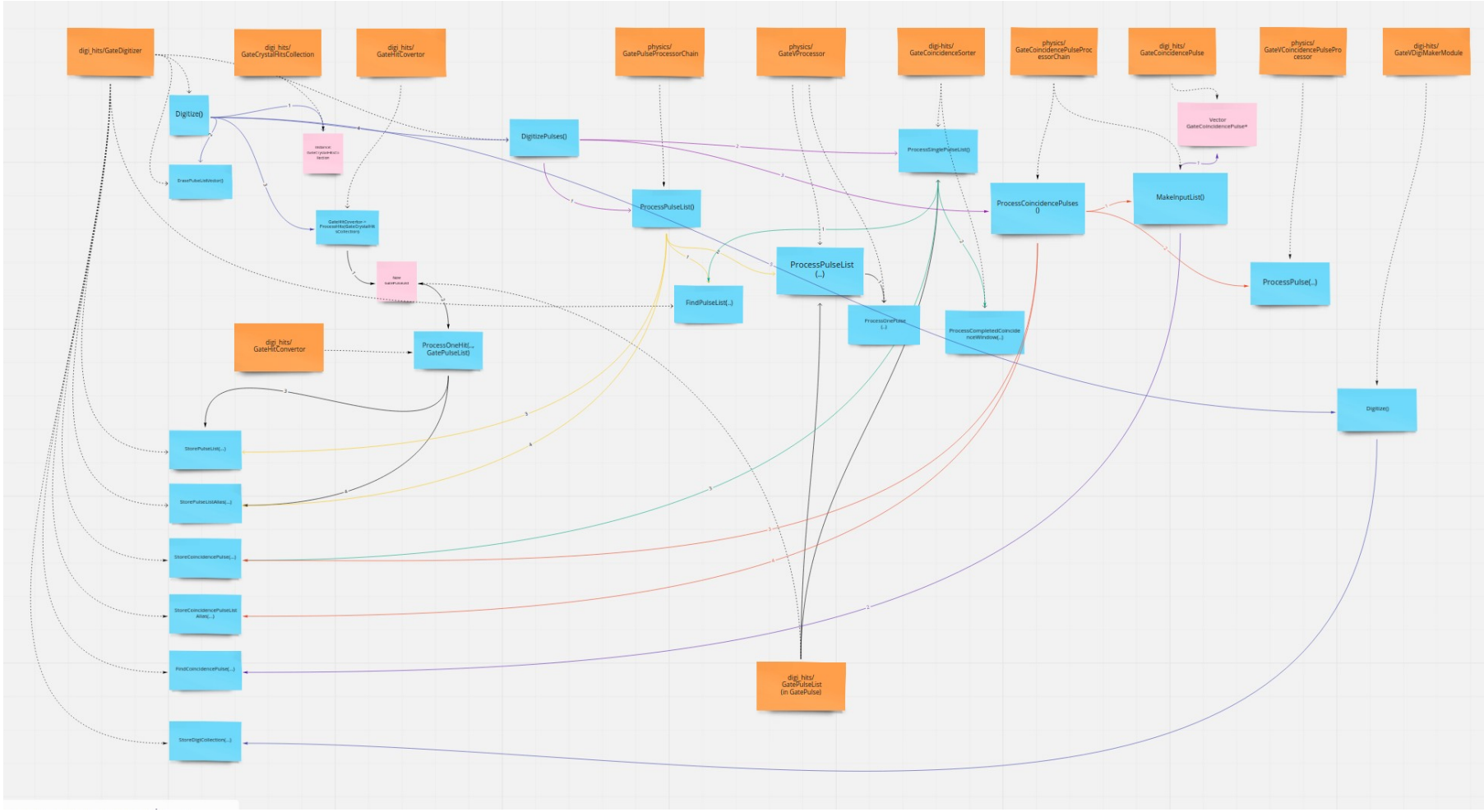
CoincidenceDigi (G4)
$(C_1, C_2, \ldots C_k)$

Storing

ROOT
Data Analysis Framework

DIGITIZER

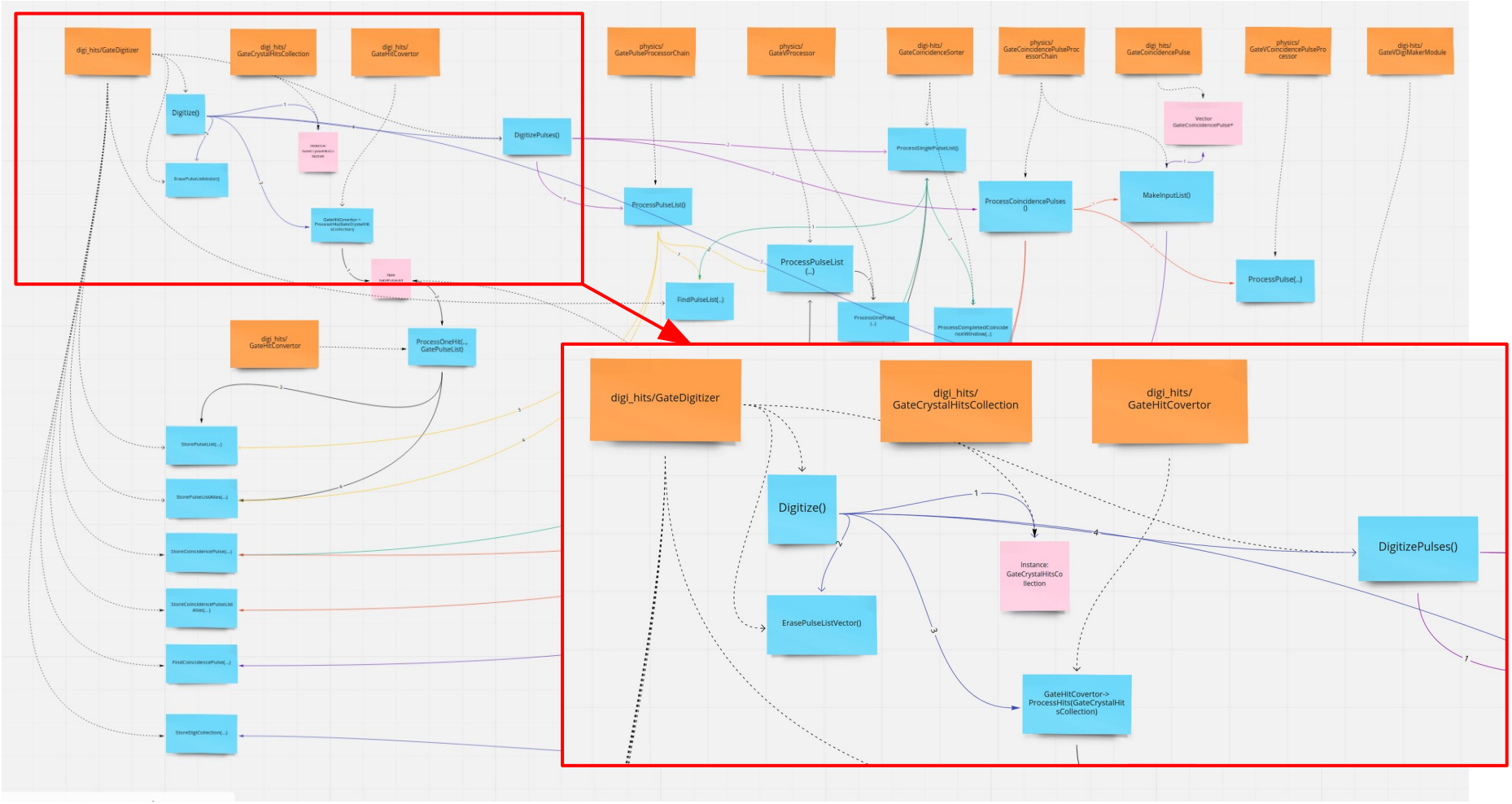
Digitizer in real life



Work in progress

DIGITIZER

Digitizer in real life



Work in progress

DIGITIZER

Aims

- Clean up of existing digitizer code
  - Simplification
  - Bug searches and corrections

- Adding new functionalities
  - New options for output (like for ClearMind project needs)

Bug example

No usable hits
but still trying to go
thought all steps !

```
[GateDigitizer::Digitize]: starting
[GateDigitizer::Digitize]: erasing pulse-lists
[GateDigitizer::Digitize]: launching processor chain 'digitizer/Singles'
[GateDigitizer::FindPulseList]: Looking for pulse-list 'Hits'
[GateDigitizer::FindPulseList]: Could not find pulse-list 'Hits'
--------------------------coincidence sorters ------------------------
[GateDigitizer::Digitize]: launching coincidence sorter 'digitizer/Coincidences'
[GateDigitizer::FindPulseList]: Looking for pulse-list 'Singles'
[GateDigitizer::FindPulseList]: Could not find pulse-list 'Singles'
--------------------------- digitizer module -----------------------
end of GateDigitizer::DigitizePulses
[GateDigitizer::Digitize]: launching digitizer module 'digitizer/Singles/digiMaker'
[GateSingleDigiMaker::Digitize]: retrieving pulse-list 'Singles'
[GateDigitizer::FindPulseList]: Looking for pulse-list 'Singles'
[GateDigitizer::FindPulseList]: Could not find pulse-list 'Singles'
[GateSingleDigiMaker::Digitize]: pulse list null --> no digits created
[GateDigitizer::Digitize]: launching digitizer module 'digitizer/Coincidences/digiMaker'
[GateDigitizer::FindCoincidencePulse]: Looking for coincidence pulse 'Coincidences'
[GateDigitizer::FindCoincidencePulse]: Cound not find coincidence pulse 'Coincidences'
[GateCoincidenceDigiMaker::Digitize]: coincidence pulse null --> no digi created
[GateDigitizer::Digitize]: launching digitizer module 'digitizer/digitizer/Singles/adder/digiMaker'
[GateSingleDigiMaker::Digitize]: retrieving pulse-list 'digitizer/Singles/adder'
[GateDigitizer::FindPulseList]: Looking for pulse-list 'digitizer/Singles/adder'
[GateDigitizer::FindPulseList]: Could not find pulse-list 'digitizer/Singles/adder'
[GateSingleDigiMaker::Digitize]: pulse list null --> no digits created
[GateDigitizer::Digitize]: launching digitizer module 'digitizer/digitizer/Singles/readout/digiMaker'
[GateSingleDigiMaker::Digitize]: retrieving pulse-list 'digitizer/Singles/readout'
[GateDigitizer::FindPulseList]: Looking for pulse-list 'digitizer/Singles/readout'
[GateDigitizer::FindPulseList]: Could not find pulse-list 'digitizer/Singles/readout'
[GateSingleDigiMaker::Digitize]: pulse list null --> no digits created
[GateDigitizer::Digitize]: launching digitizer module 'digitizer/digitizer/Singles/blurring/digiMaker'
[GateSingleDigiMaker::Digitize]: retrieving pulse-list 'digitizer/Singles/blurring'
[GateDigitizer::FindPulseList]: Looking for pulse-list 'digitizer/Singles/blurring'
[GateDigitizer::FindPulseList]: Could not find pulse-list 'digitizer/Singles/blurring'
[GateSingleDigiMaker::Digitize]: pulse list null --> no digits created
[GateDigitizer::Digitize]: completed
```