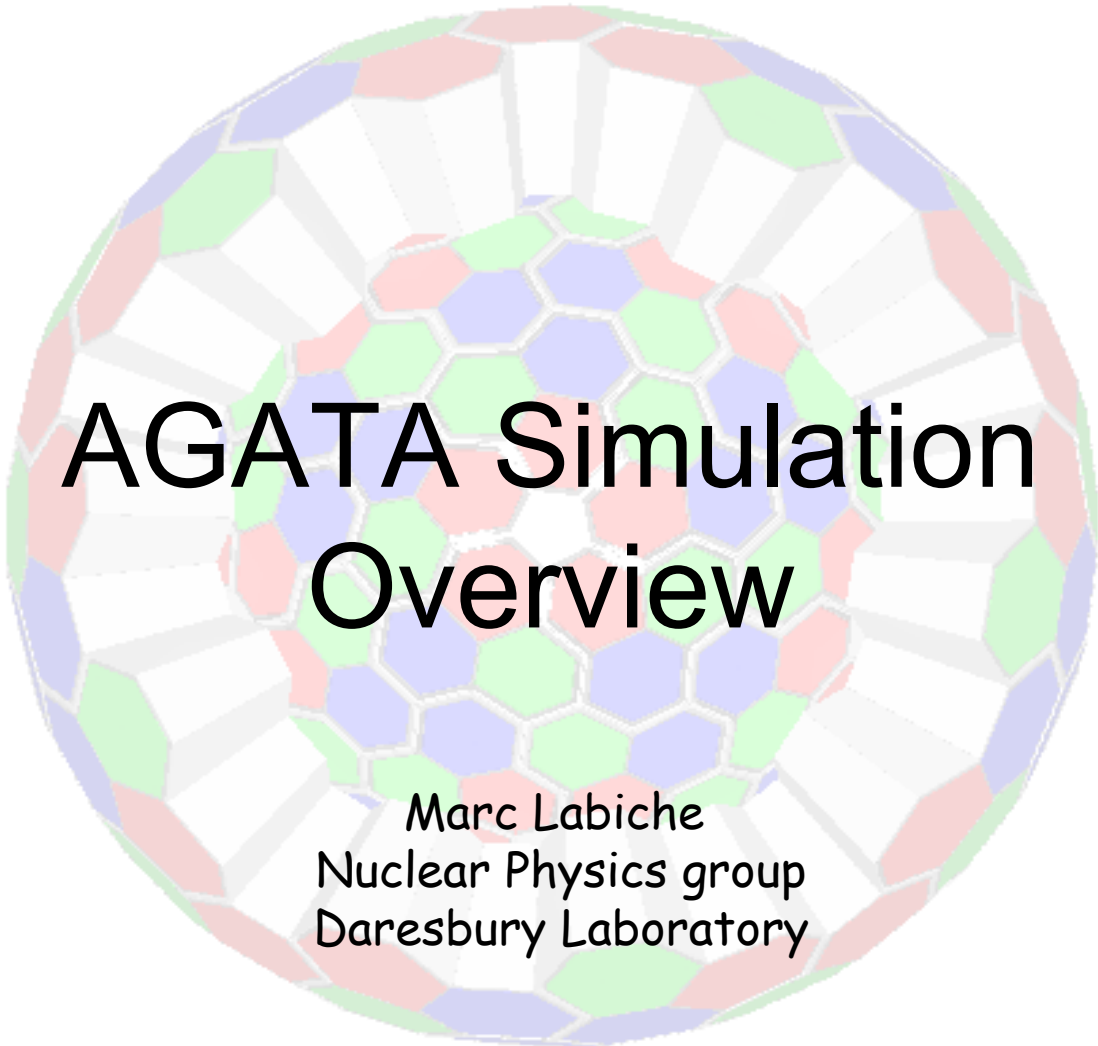
Science & Technology Facilities Council



# AGATA Simulation Overview

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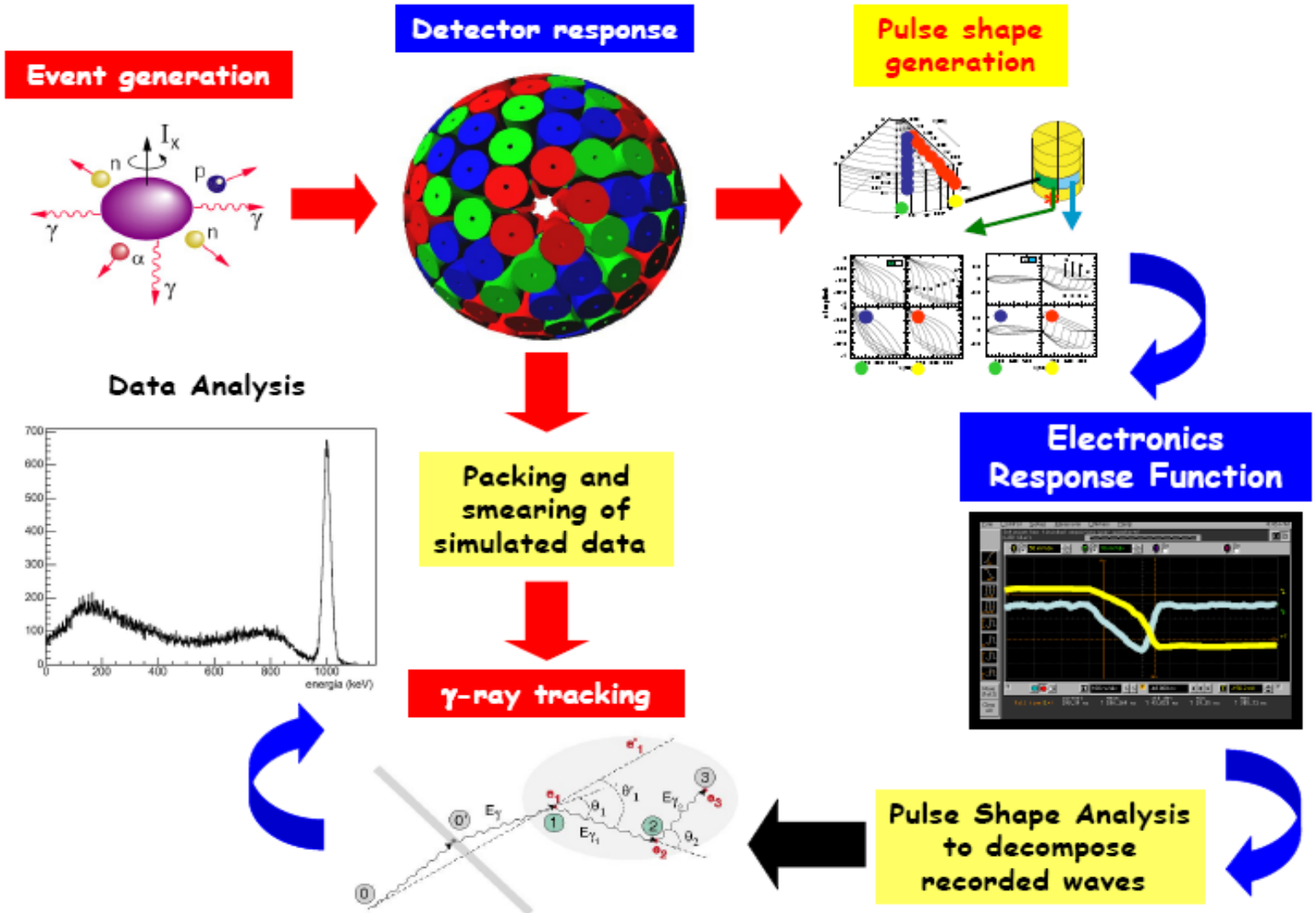
# The simulation process



# Packages required:

- GEANT4 AGATA code (E. Farnea)

- A tracking code:
  - 2 availables:
    - mgt code (D. Bazzacco)
    - oft code (A. Lopez-Martens)
  - An analysis package: xtrackn, ROOT based programs (GammaWare)

- GammaWare (O. Stezowki)
  - Convert files.ags from the Radware/ENSDF level scheme directory to simulation input file

- Production cross section codes
  - Ex: Fusion evaporation (CASCADE, COMPA )

# AGATA code

- Available at:
  - http://agata.pd.infn.it/documents/simulations/agataCode.html
  - Includes a very useful Users' manual with basic tutorials

- Code based on GEANT4
  - Hint: easy GEANT4 installation on Windows (2000, XP, Vista)
    - VMware player (Virtual Machine) on Desktop or Laptop.
    - visit: http://geant4.in2p3.fr

# VMware

- Offers:
  - Operating system : **Scientific Linux** 4.5
  - **Geant4 version 9.2** with all sets of data files and compiled physics lists, including **CLHEP** and **Mesa**.
  - Visualisation tools : **OpenGL**, **HepRApp**, **DAWN**, **VRMLView Pro**
  - Analysis tools : **ROOT**, **OpenScientist** (in order to create hbook/PAW, ROOT and AIDA histogram files in Geant4 applications, more information **here**, and also for visualization), **gnuplot**, **Grace**
  - Integrated development environment : **Source-Navigator IDE**
  - Debugger : **ddd**, **Insight**
  - Other utilities : **CERNLIB** 2005, **Boost**, **Doxygen**, **Firefox**, **Gimp**, **Lyx**, **Motif**, **Python**, **OpenOffice**, **Thunderbird**, **Valgrind**, **Xemacs**, ...

- Also:
  - 1 common directory between Windows and Linux VM
  - Requires 15Go free space on your hard drive
  - Exists also on Mac but as shareware software (not free software).

# AGATA code

**Existing geometries**: (found in the directory **Agata/macros/** )

**Symmetrical triple cluster**
(geomSymm.mac)

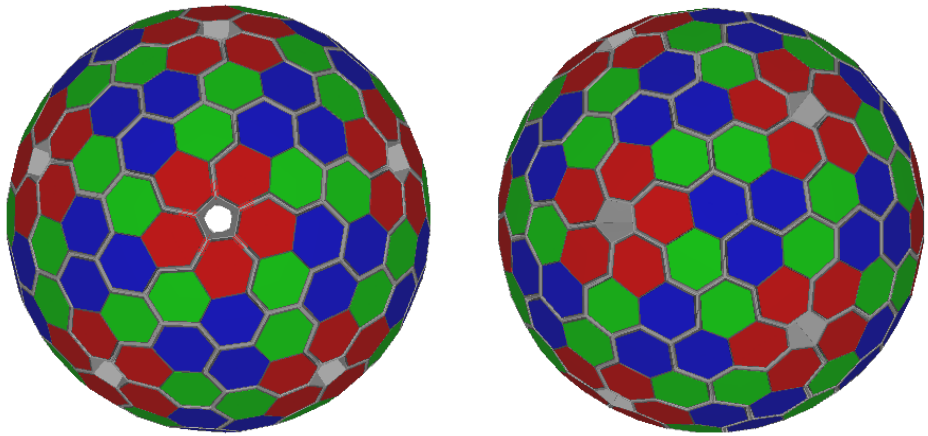
**Demonstrator**
(geom180-demo.mac)

**1pi**
(geom180-1P.mac)

**2pi**
(geom180-2P.mac)

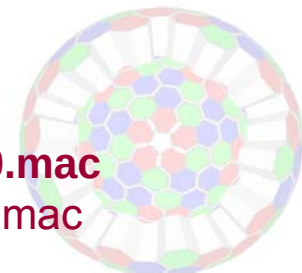
**3pi**
(geom180-3P.mac)

**4pi**
(geom180.mac)



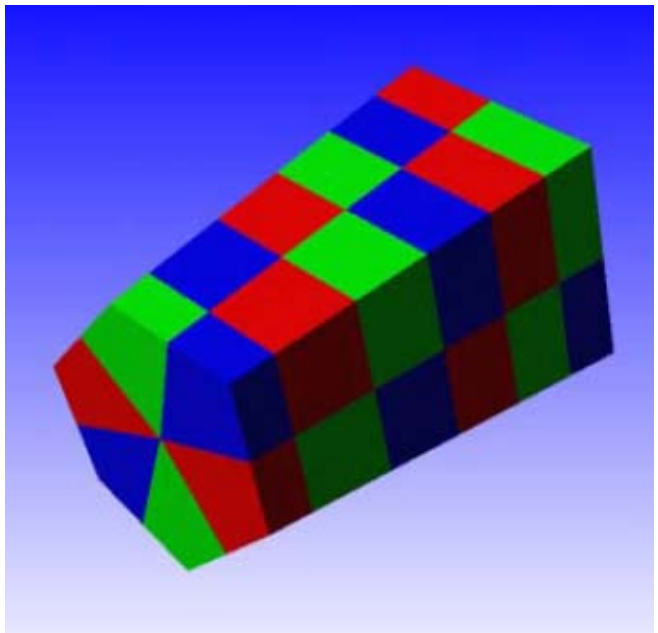
<u>Commands:</u>

$G4BIN/agata
idle>/control/execute macros/**geom180.mac**
idle>/control/execute macros/visVRML.mac



# Segmentations

- 6 transversal slices
- 6 radial sectors



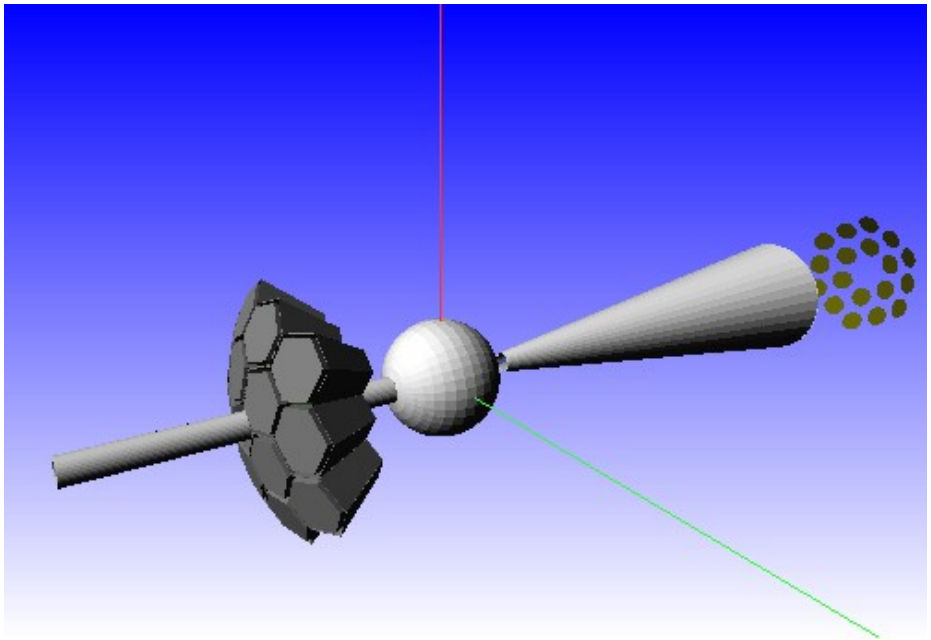
# Ancillary detectors

- Existing ancillaries:
  - Command:
    - $G4BIN/agata -a $N_{anc}$ $ID_1$ .. $ID_{Nanc}$
  - PRISMA not included. Another dedicated code is used instead. The latter accepts the same input file than the AGATA geant4 code. A “merge code” combines the two output files and reconstructs the full event

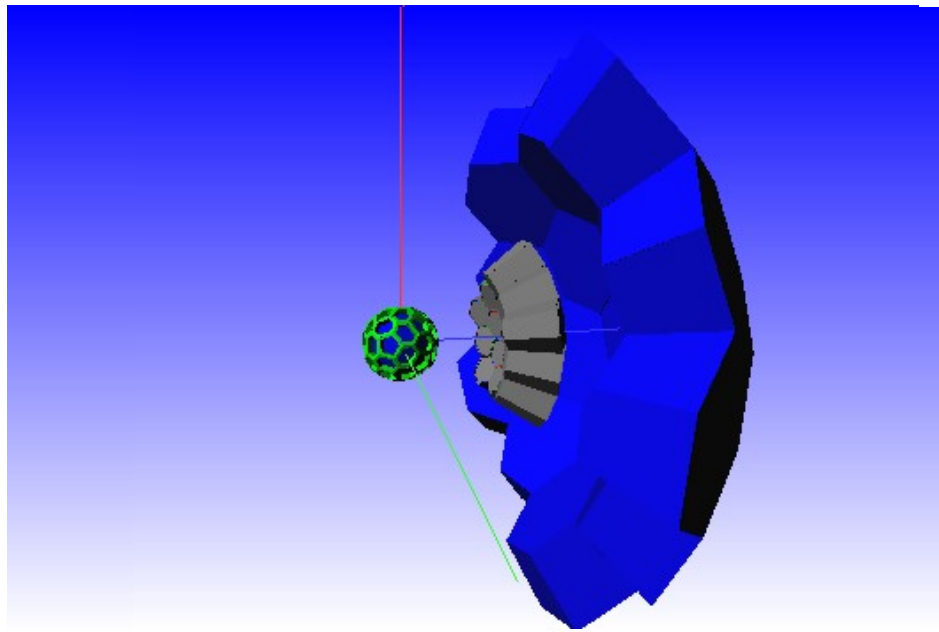
| Ancillary detector | ID |
|---|---|
| *Koeln* | 1 |
| *Shell* | 2 (default) |
| *Mcp (DANTE)* | 3 |
| *EUCLIDES* | 4 |
| *Brick* | 6 |
| *n-Wall* | 7 |
| *DIAMANT* | 8 |
| *EXOGAM* | 9 |
| *HELENA* | 10 |
| *RFD* | 11 |
| *TRACE* | 12 |
| *CUP* | 14 |

- Procedure to add new ancillary detectors is described in the user’s manual (Marcin Palacz: palazc@slcj.uw.edu.pl)

# Ancillary examples:



Demo. + RFD



Demo. + EUCLIDES + Nwall

**$G4BIN/agata -a 1 11**
**Idle>/Agata/detector/enableAncillary**
**Idle>/control/execute macros/geom180-Demo**
**Idle>/control/execute macros/visVRML.mac**

**$G4BIN/agata -a 2 4 7**
**Idle>/Agata/detector/enableAncillary**
**Idle>/Agata/detector/rotateArray 180. 0.**
**Idle>/control/execute macros/geom180-Demo.mac**
**Idle>/control/execute macros/visVRML.mac**

# Event generators

- Built-in event generator (basic)
  - Used to define and optimised the AGATA geometry
  - Source of particles at rest or not.
  - for each event a particle (or set of particles) is emitted
    (ie: no cross sections)

- External event generator (realistic)
  - nuclear reactions are assumed (Beam, Target, E & p conservation)
  - reaction cross sections (CASCADE)
  - realistic gamma cascade with branching ratio (GammaWare/NNSDF)

# Built-in (basic) event generator :

- Commands:
  - Example 1: Monochromatic source

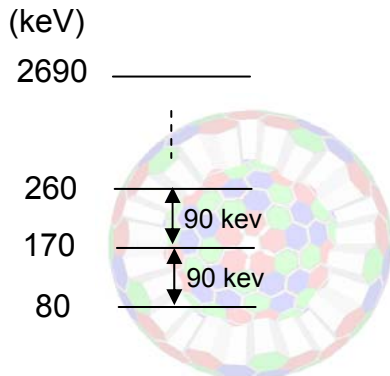
    $G4BIN/agata
    Idle>/control/execute/ macros/geom180.mac
    Idle>/Agata/generator/gamma/energy 1332.5
    Idle>/Agata/run/beamOn 10000

  - Example 2: gamma + particle (n, p, d, a, e-, e+, generic ions ) source

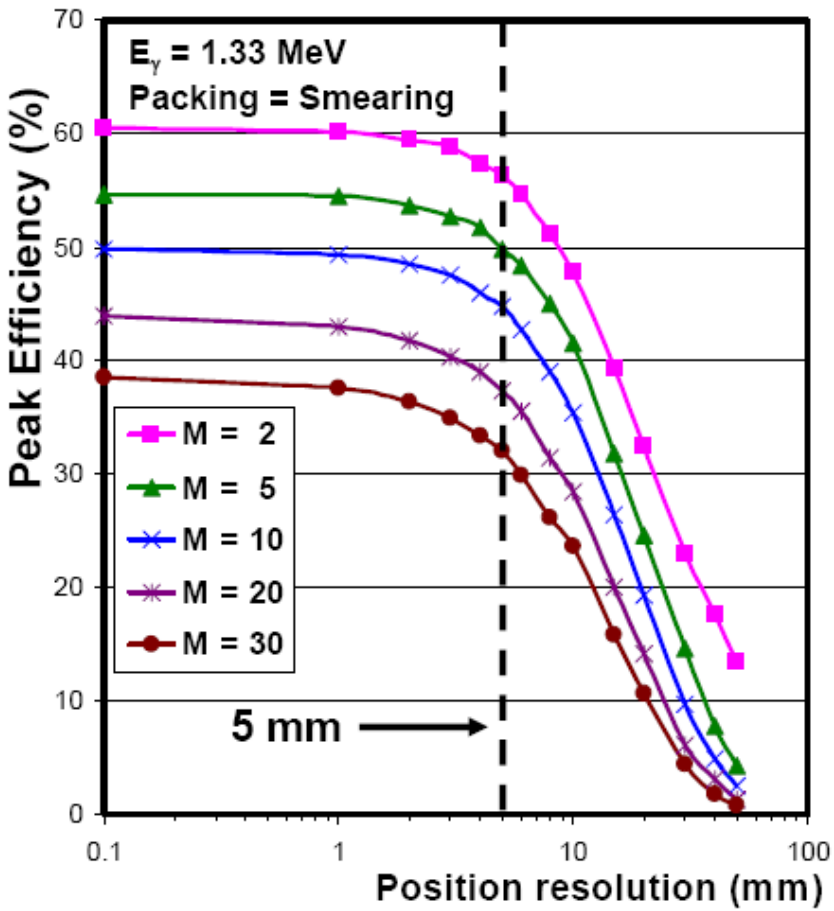
    $G4BIN/agata **-n**
    Idle>/control/execute/ macros/geom180.mac
    Idle>/Agata/generator/gamma/energy 1332.5
    Idle>/Agata/generator/**particlename**/energy 1000
    Idle>/Agata/run/beamOn 10000

  - Example 3: basic rotationnal band

    $G4BIN/agata
    Idle>/Agata/generator/recoil/beta 5 (v/c = 5%)
    Idle>/Agata/generator/gamma/band 80 90 30 (lowest E, Eγ, Mγ)
    Idle>/Agata/run/beamOn 100000

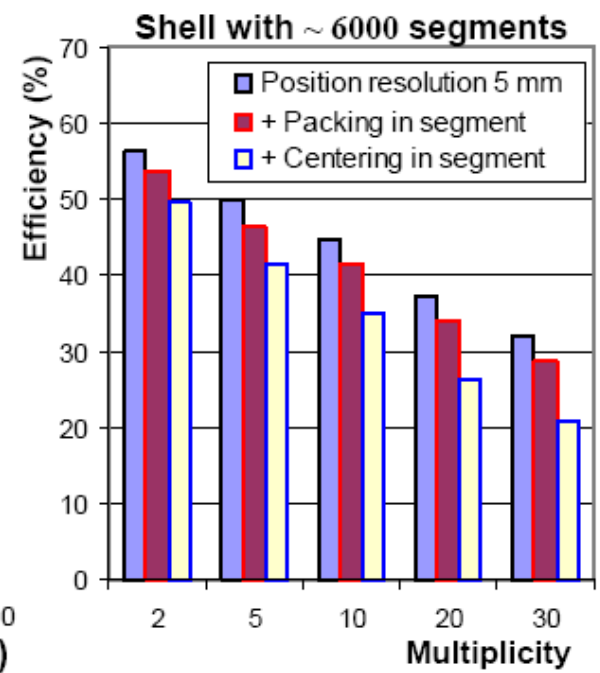


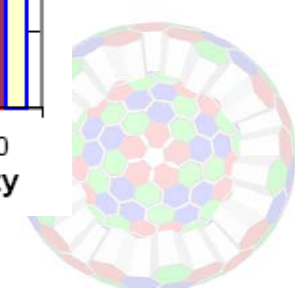
# Efficiency of a Standard Ge Shell vs Position Resolution and $\gamma$ Multiplicity




**The biggest losses are due to multiplicity (mixing of points), not to bad position resolution**

Improve tracking algorithms !!



# External (“realistic”) event generator

Example: Event00 file in Agata/events:

| | |
|---|---|
| FORMAT 0 0 | = Emitter info , Emitted info |
| # | (Level of external information: 0 to 4) |
| # | |
| REACTION 6 12 16 32 88.0 | = $Z_{beam}$, $A_{beam}$, $Z_{target}$, $A_{Target}$, $E_{beam}$ |
| # | (Default= 1, 1, 6, 12, 0) |
| # | |
| EMITTED 2 1 4 | = $N_{total}$, $Type_{i=0}$, …, $Type_{i-N}$ |
| # | |
| $ | = Beginning of event |
| -101 12 26 44. 0. 0. 1. 0. 0. 0. | = Emitter: z, A, E, $x_{Dir}$, $y_{Dir}$ ,$z_{Dir}$, $x_S$, $y_S$ ,$z_S$ |
| 1 3000. 0. 1. 0. 0. 0. 0. 0. 0. | = 1st emitted: E, $x_{Dir}$, $y_{Dir}$ ,$z_{Dir}$, $x_S$, $y_S$ ,$z_S$, [t, P] |
| 4 5000. 1. 0. 0. 0. 0. 0. 0.5 1 | = 2nd emitted: E, $x_{Dir}$, $y_{Dir}$ ,$z_{Dir}$, $x_S$, $y_S$ ,$z_S$, [t, P] |

| index | Type |
|---|---|
| 1 | gamma |
| 2 | neutron |
| 3 | proton |
| 4 | deuterium |
| 5 | Triton |
| 6 | 3He |
| 7 | alpha |
| 8 | Generic ion |
| 97 | Electron |
| 98 | Positron |
| 99 | Geantino |

Command:

```
$G4BIN/agata -n
Idle>/control/execute/ macros/geom180.mac
Idle>/agata/generator/emitter/eventFile  /Path/to/Eventfile/EventfileName
```

# External ("realistic") event generator

- Fusion evaporation with EUCLIDES + AGATA

  $^{28}$Si(100Mev) + $^{28}$Si

  - Production cross section and energy of evaporated particles calculated by CASCADE (statistical code)
  - Discrete gamma transitions from Radware/ENSDF

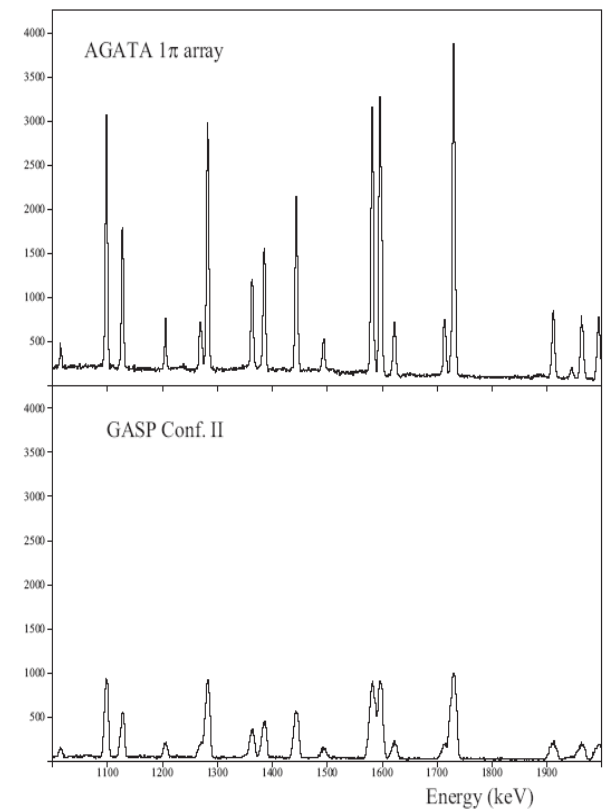



Figure 1.4: *Comparison between the performance of GASP+EUCLIDES and AGATA 1π+EUCLIDES for the reaction $^{28}$Si(100 MeV)+$^{28}$Si. The information from EUCLIDES has been used to select the 1α2p evaporation channel and to perform the Doppler correction. No conditions on the detected photon multiplicity was applied.*

# Typical simulation output

- ASCII file: GammaEvents.XXXX
  - With XXXX= run number
- Header part with general information on the input
- Event part:

Beginning of an event

Event#

```
100        1
-101   0.06022  0.00000  0.00000  1.00000
-102     0.000    0.000    0.000
-1   3000.000  0.00000  1.00000  0.00000   0
55    75.557   -16.144  273.343    1.699   25
104    6.938     1.848  309.156   65.450   52
101   11.067    11.489  312.137   82.980   52
101    3.240    11.490  312.137   82.982   52
101   88.191    11.484  312.138   82.984   52
101    1.223    11.472  312.108   82.998   52
101    8.386    11.472  312.108   82.998   52
55   168.370   -19.890  287.472   -6.734   35
55     4.372   -19.890  287.472   -6.734   35
```

Emitter beta & Direction

Emitter position

Emitted particle, energy, Direction & event#

Detector ID

Segment number
1st digit = slice
2nd digit = sector

Energy loss

Laboratory position in which the interaction occurs

Command to save on file

Idle>/Agata/file/enableLM

# Tracking codes

To disentangle the interaction points identified in all crystals and reconstruct the trajectory of the incident photons

- MGT code (D. Bazzacco)
  - C program: mgt.c
  - Produces ~140 1D spectra all in one file: spec.dat
    - Note: Energy-channel# matching lost during tracking process ⇒ spectra need "calibrations"
  - Spec.dat read via xtrackn(GASPware), MGTana.C (ROOT), GammaWare

- OFT = Orsay Forward Tracking code (Araceli Lopez-Martens)
  - C program
  - 2 versions:
    - 1 for built-in event generator: **forward_n.c**
    - 1 for reallistic event generator: **forward_external.c**
  - Produces one unique 1D spectrum in ASCII file called spectrum
  - Read via OFTana.C (ROOT), GammaWare

hints to compile OFT: use a bash shell and the commands:

```
ulimit –s 65563
gcc forward_n.c –lm –o forward
```

# Packing

Consists of grouping close interaction points within a same segment and take the energy-weighted barycentre

- Can be done in the simulation:
  /Agata/file/packingDistance 1.

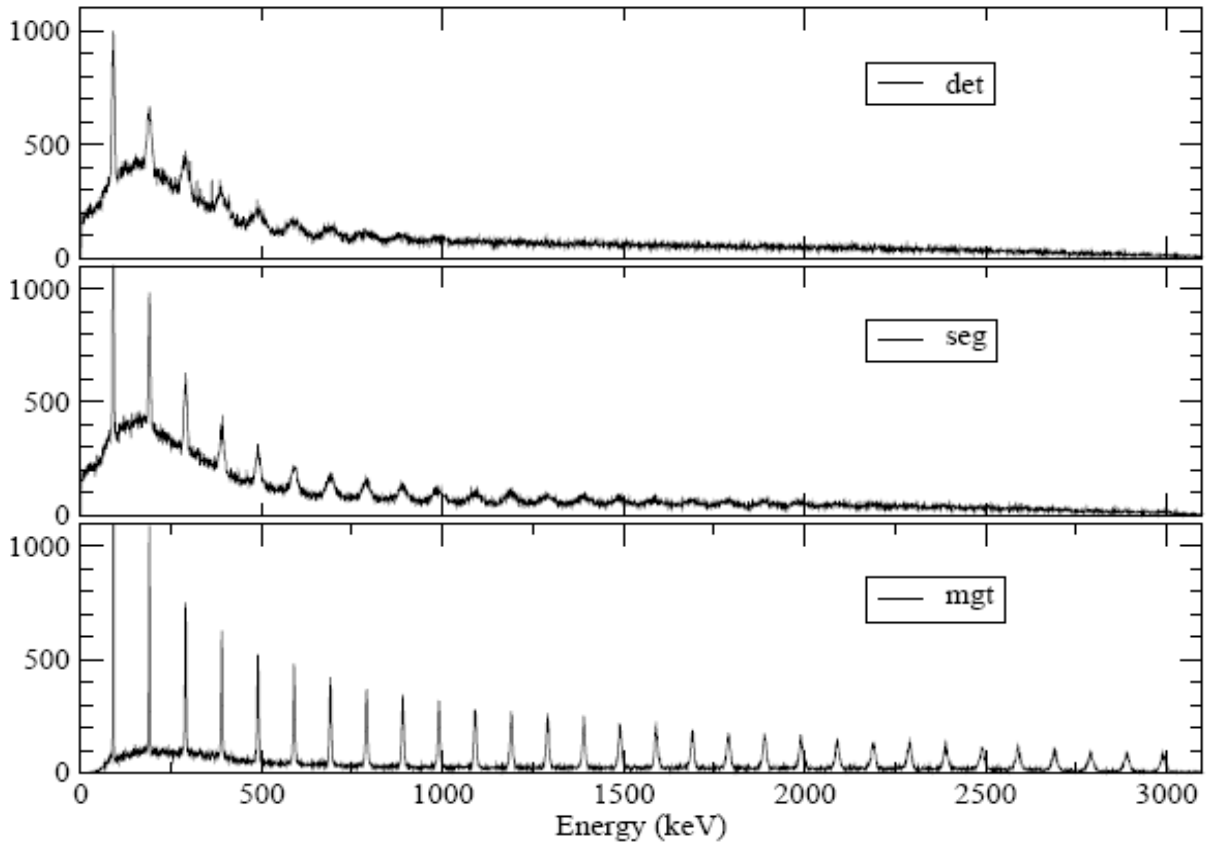
- Can be done in both tracking codes.

# Smearing

- Not done in the AGATA GEANT4 code but in the tracking codes:
  - in mgt:
    - emitter position and momentum
    - interaction position (energy-dependant ?)
  - in oft:
    - emitter (?)
    - energy loss for each interaction
    - interaction position (energy-dependant)

# simulation + tracking

Response of AGATA for a rotational cascade of 30 photons emitted from a moving source ($\beta$=50%) along z axis, after Doppler correction from the detectors position (top), the segments position (middle) and from the mgt 1st interaction point (bottom)



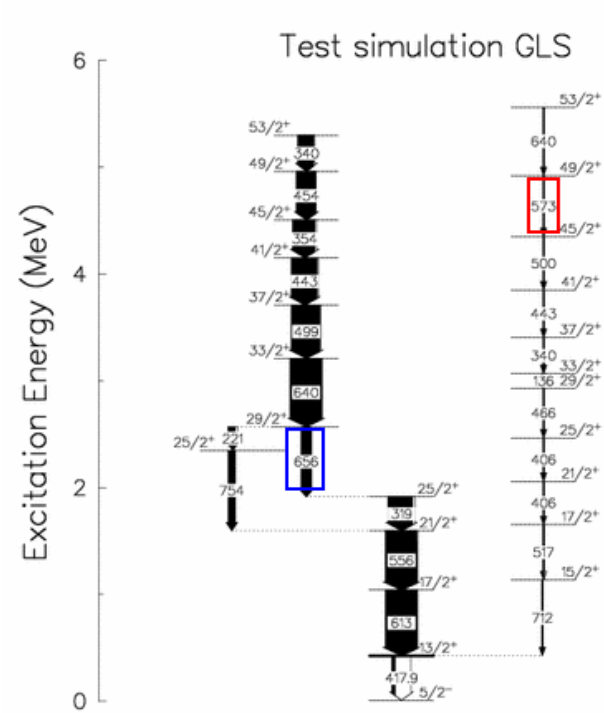
# GammaWare

- Based on ROOT
- Allows to :
  - to read Radware and ENSDF level Schemes
  - to simulate real gamma-ray cascades
  - to store them in files that can be read with AGATA GEANT simulations
  - to simulate AGATA like gamma-ray cascades by applying an experimental filter
  - to generate gamma-ray cascades together with charges particles (thank's to Francesco)
  - to convert spectrum from different format (gpsi, midas, radware, root)
  - ...

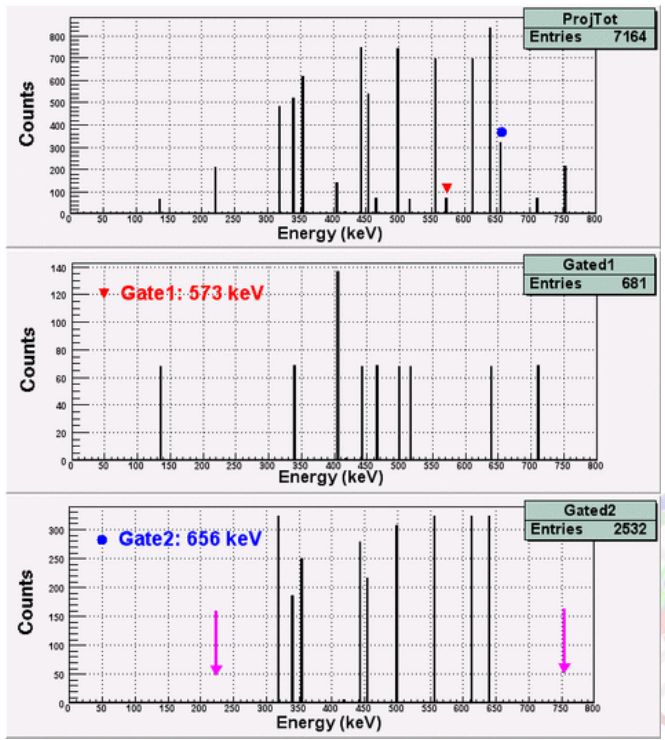
# GammaWare

ToGeant.mac (in gammaware/macros) produces sequences of g-ray energies from a radware file (.ags) and format them in an input file (.event) for GEANT4 AGATA code.

Commands: root [0] .L ToGeant.C
root [1] toGEANT1("file.ags", Ncascades, "file.event")




A root file (toGEANT101.root) is automatically generated to store the simulated cascades



# UK contribution

WP3: Experiment simulations and verification of tracking ( R. Wadsworth)

- Task1: Implementation of experimental facilities into GEANT4
  - Implement full experimental setups in the GEANT4 AGATA simulation package
- Task2: Simulation of key experiments and reaction mechanism
  - Simple source test runs
  - Fusion evaporation reactions (light target & inverse kinematics)
  - **Coulomb excitation reactions** (medium mass beam in inverse kinematics)
  - High multiplicity reactions
  - **Multinucleon transfer reactions** (PRISMA)
  - Relativistic many-particle fragmentation (GSI)
- Task3: Verification of tracking algorithms
  - test with first in-beam test experiment

# Status & near future plans

- A UK AGATA WG is being formed (mailing list, regular meetings)

- Obtain, install and learn how to use the AGATA simulation
  - Get the packages running
    - GEANT4 AGATA code (✓)
    - tracking codes (✓)
    - GammaWare (✓)
    - Cross section codes (to get)
  - Reproduce the simulation results previously report (on going)

- Simulate source runs and compare with data
  - $^{137}$Cs or $^{60}$Co
- Simulate first in-beam test and compare with data
  - $^{80}$Se + $^{9}$Be @230 MeV to produce $^{86}$Sr
  - or $^{82}$Se + $^{12}$C @250 MeV to produce $^{91}$Zr

# Other possible contributions

- Use CAD + GEANT4 ?
  - CAD Step files → FASTRAD → gdml files → GEANT4

- Implement PRISMA in Geant4
  - or use the existing PRISMA code

# Summary

- AGATA simulations require several packages
  - Need to learn and understand
- Good progress made in installing and learning most of those packages.
  - Capable to reproduce simple simulations with the built-in event generator.
  - Capable to simulate realistic $\gamma$-cascades using GammaWare
- For more realistic simulations:
  - Need to get/learn reaction cross section codes
  - Need to get /learn the PRISMA code

# Thank you !