Development of a Geant4 simulation of the DESPEC setup

Daniele Brugnara

Giorgio Bruni Campanella

Johan Emil Linnestad Larsson

Motivation

- **To have a coherent simulation that includes both AIDA and DEGAS/FATIMA**
- The main drivers are:
  - The need to account for gamma-ray absorption at low energies to evaluate the response of the setup (necessary to extract branching ratios, intensities)
  - The need to investigate the beta tagging efficiency and expected correlation of AIDA
  - Identify the best analysis strategies for AIDA
  - To understand issues of the setup and drive future developments

Public repository

- Hosted on the GSI Gitlab and publicly available
- It is still in a preliminary phase and is currently being tested/verified
- The idea is to have a code that is easy to access and simple to use

D **DEGAS-AIDA Simulation**

main · degas-aida-simulation / + · Find file · Edit · Code

Project information

- **32** Commits
- **2** Branches
- **0** Tags
- **13.2 MiB** Project Storage

- README
- Add LICENSE
- Add CHANGELOG
- Add CONTRIBUTING
- Enable Auto DevOps
- Add Kubernetes cluster
- Set up CI/CD
- Add Wiki
- Configure Integrations

Created on
August 21, 2025

Some details about the code

- Requires to compile Geant4 with GDML support for the geometry
- A Dockerfile is also provided in order to take care of the dependencies automatically
- A singularity configuration has also been added to allow it to work on the Virgo cluster

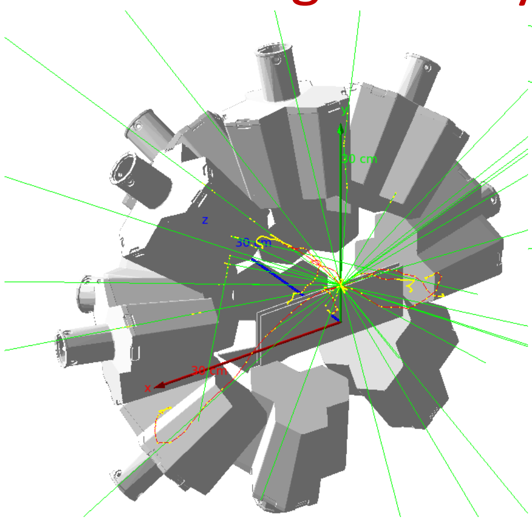
Documentation

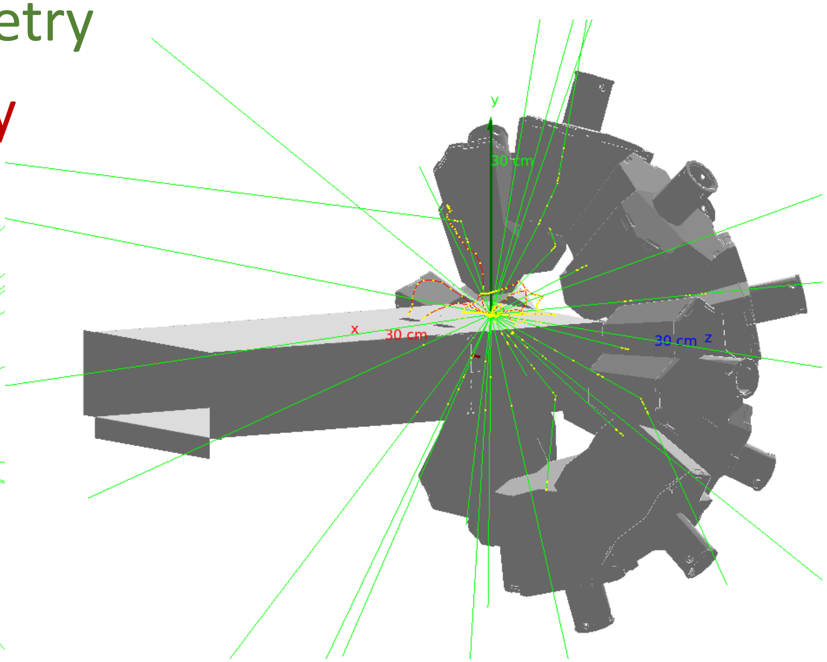
- The documentation is provided in a README.md and describes the installation procedure and how to run the code
- Since the simulation is still in its testing phase the documentation is still scarce
- We plan to provide complete instructions for external users that will be helpful also for proposals and other evaluations or response/efficiency

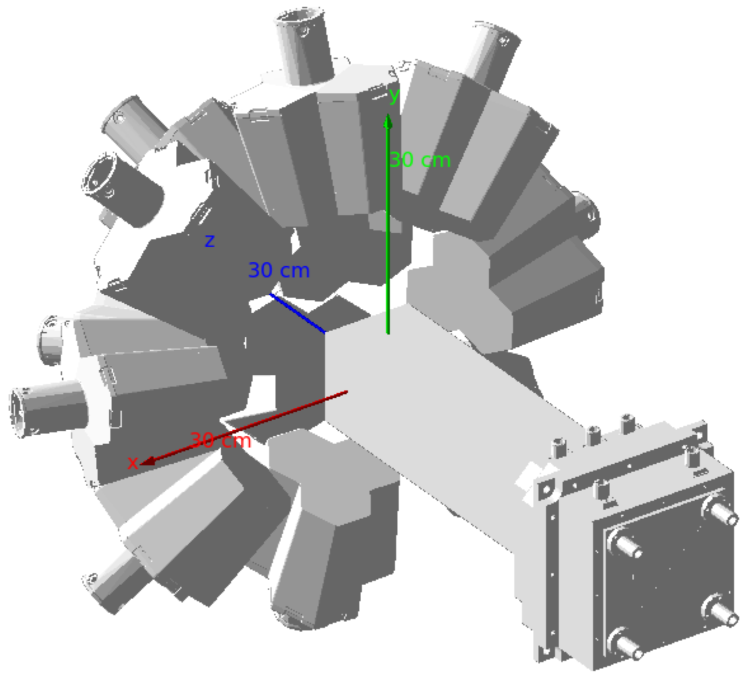
Available geometries

- Wide snout
- Narrow snout
- Hybrid geometry
- Box geometry

Thanks to Marc L. and Guang-shun

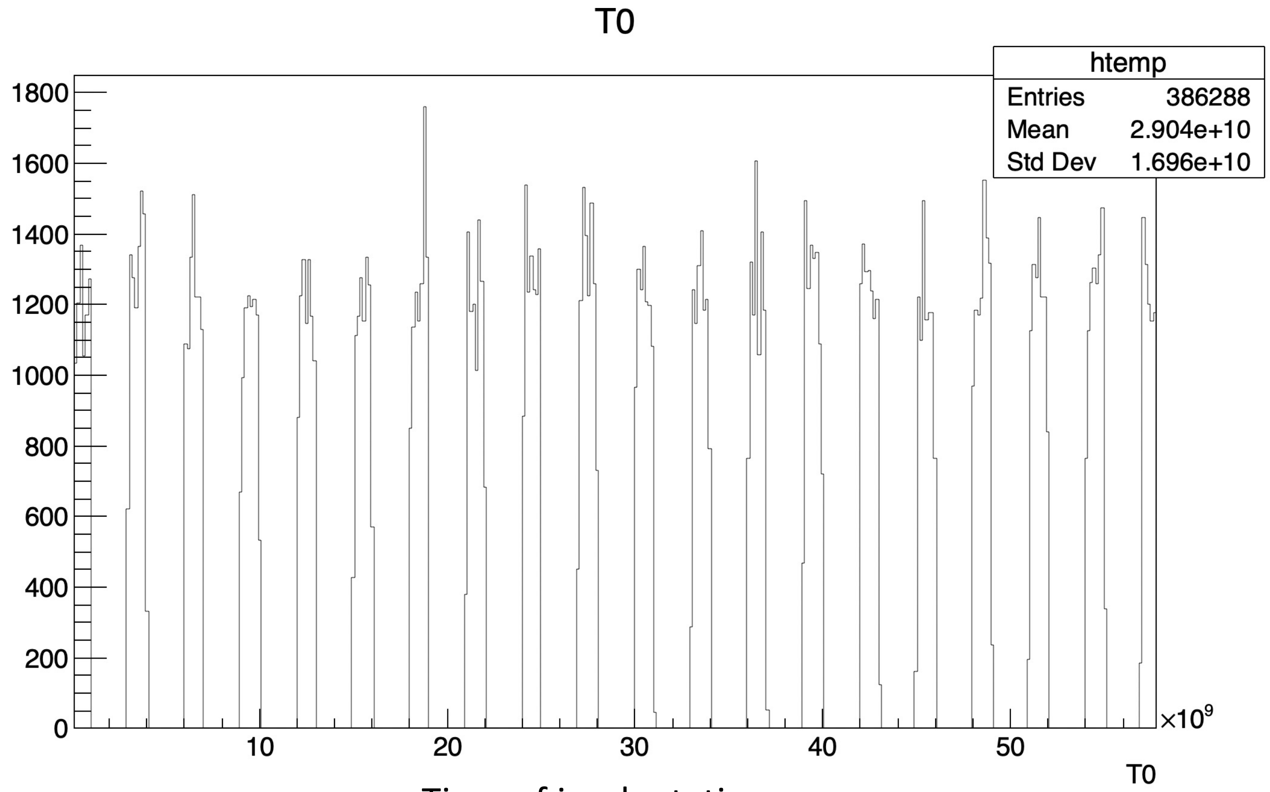






Event generation

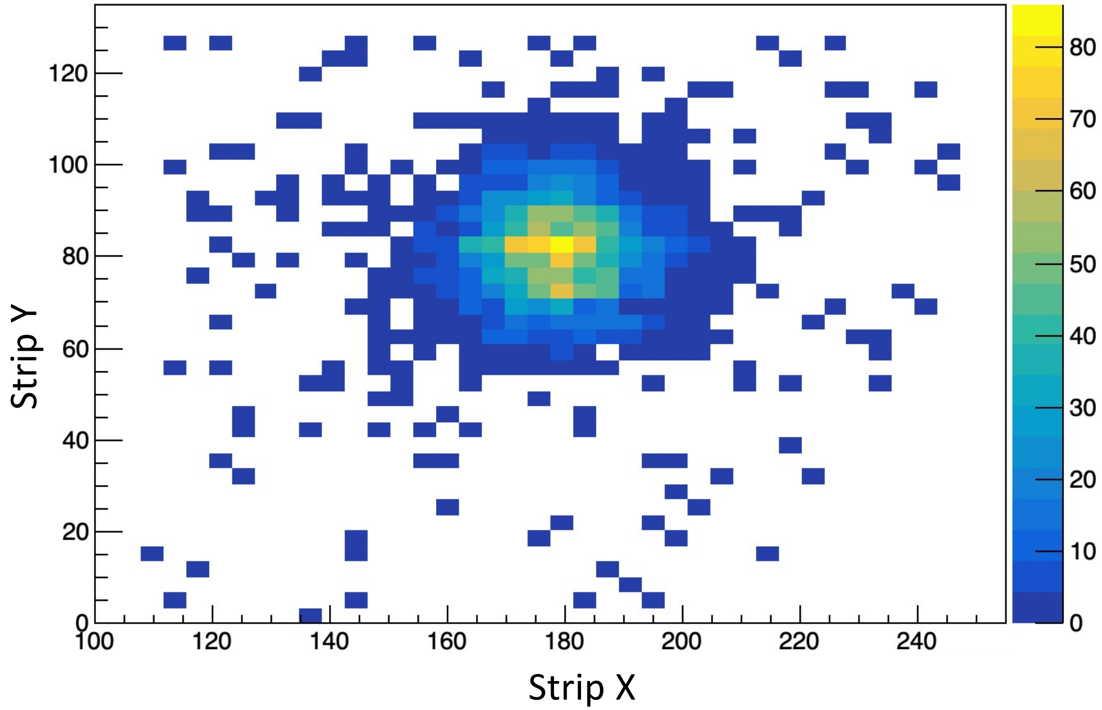
- Poissonian statistic for implantation with spill-on spill-off structure and a settable rate of implantation



Time of implantation

Event generation

- Position of implantation sampled from a gaussian distribution that can be set to reproduce the experimental data



Event generation

- The particle decay modes are configured by the typical Geant4 files and can be personalized

RadioactiveDecay:

```
# 56NI ( 6.075 D    )
#  Excitation  flag    Halflife  Mode      Daughter Ex flag    Intensity           Q
P           0  -        524880
                                MshellEC            0         0.017066
                                BetaPlus            0        1.3014e-05
                                KshellEC            0          0.88513
                                LshellEC            0         0.097791
                                MshellEC            0   -    3.6122e-07      2132.889
                                MshellEC       158.38   -    7.8822e-06      1974.509
                                MshellEC       970.23   -     0.012701      1162.659
                                MshellEC      1450.68   -    0.0083189       682.209
```

PhotoEvaporation:

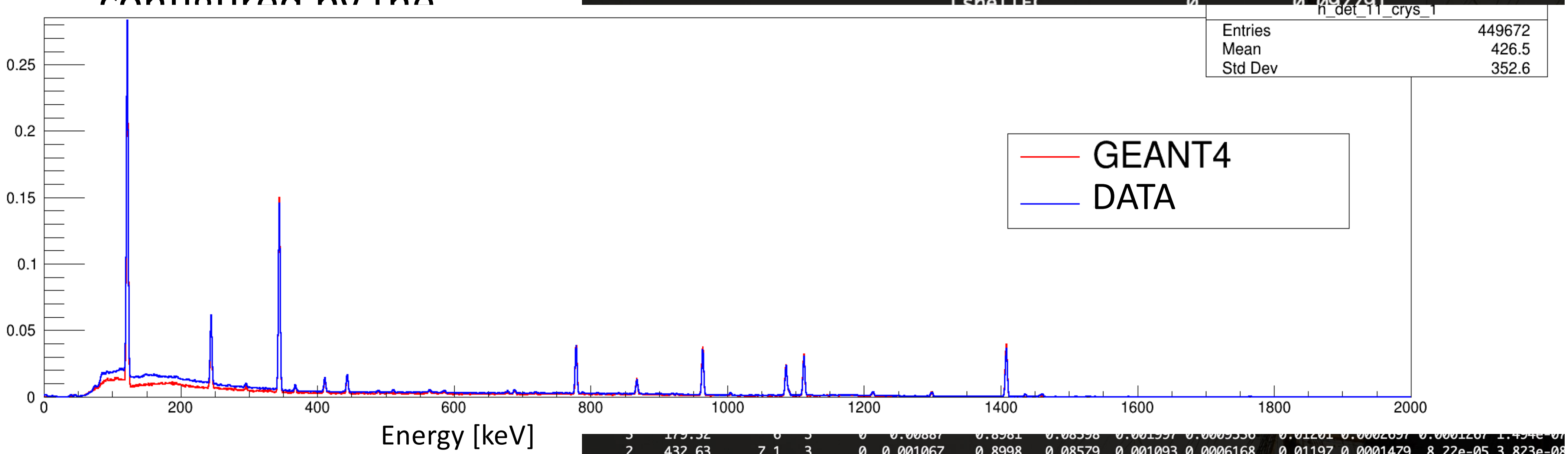
```
 0  -       0 6.67319e+06   4.0   0
 1  -  158.38       1e-10   3.0   1
    0   158.38      100 304  0.016   0.01253    0.8978   0.08602  0.002158  0.001025   0.01201 0.0002915 0.0001362 1.805e-07
 2  -   576.5     2.8e-13   5.0   1
    0    576.5      100 304  -0.16 0.0005713    0.9001   0.08572 0.0009048 0.0005908   0.01196 0.0001224  7.88e-05 2.594e-08
 3  -  829.61     1.7e-12   4.0   3
    2   253.11        2   3      0  0.003781    0.8988   0.08594  0.001599 0.0008028     0.012 0.0002163 0.0001069 8.835e-08
    1   671.23      100 304  -0.09 0.0004054    0.9002   0.08576 0.0007846 0.0005214   0.01197 0.0001062 6.953e-05 1.945e-08
    0   829.61       34 304  -0.43 0.0002725    0.9004    0.0856 0.0007309 0.0006083   0.01194 9.892e-05  8.12e-05 1.785e-08
 4  -  970.23     1.2e-13   2.0   2
    1   811.85      100 304  -0.02 0.0002705    0.9005   0.08572 0.0006676 0.0004761   0.01196 9.034e-05 6.351e-05 1.439e-08
    0   970.23      0.3   4      0 0.0002343    0.9002   0.08524 0.0008652 0.0009911   0.01188 0.0001171 0.0001323 2.573e-08
 5  - 1009.13     3.8e-13   5.0   3
    3   179.52        6   3      0   0.00887    0.8981   0.08598  0.001997 0.0009536   0.01201 0.0002697 0.0001267 1.494e-07
    2   432.63      7.1   3      0  0.001067    0.8998   0.08579  0.001093 0.0006168   0.01197 0.0001479  8.22e-05 3.823e-08
    0  1009.13      100 304   -0.1 0.0001742    0.9007   0.08565 0.0005611 0.0004506   0.01195 7.595e-05  6.01e-05 1.052e-08
 6  - 1114.51     1.9e-13   3.0   3
```

Event generation

- The particle decay modes are configured by the

RadioactiveDecay:

```
# 56NI ( 6.075 D    )
#  Excitation  flag   Halflife  Mode     Daughter Ex flag   Intensity          Q
P           0  -       524880
                               MshellEC              0        0.017066
                               BetaPlus              0      1.3014e-05
                               KshellEC              0         0.88513
                               LshellEC              0        0.097791
```




```
    2    432.63      7.1   3      0 0.001067    0.8998   0.08579  0.001093 0.0006168   0.01197 0.0001479  8.22e-05 3.823e-08
    0   1009.13      100 304   -0.1 0.0001742   0.9007   0.08565 0.0005611 0.0004506   0.01195 7.595e-05  6.01e-05 1.052e-08
6 -  1114.51    1.9e-13   3.0     3
```

Configuration macro

The geometry can be configured in the macro and allows to disregards the HPGe or the silicon detectors

```
/geometry/widesnout false
/geometry/widesnoutshift -20 mm
/geometry/narrowsnout false
/geometry/germanium true
/geometry/silicon false
```

The event generation allows to:

- Set the spill-on spill-off structure and the rates
- Set the ion that will be implanted
- Set the distribution of implantation
- Use the standard GPS event generation

```
/ge/enableSmear true
/ge/smearp0 0.000       # keV
/ge/smearp1 0.000     # dimensionless
/ge/smearp2 0.000     # dimensionless
/ge/edepThreshold 10 keV
/ge/timeThreshold 500 ns
/ge/writeoutput true

/si/edepThreshold 150 keV
/si/timeThreshold 20 us
/si/nstripsX 358
/si/nstripsY 128
/si/pitchX 0.56 mm
/si/pitchY 0.56 mm
/si/writeoutput false
```

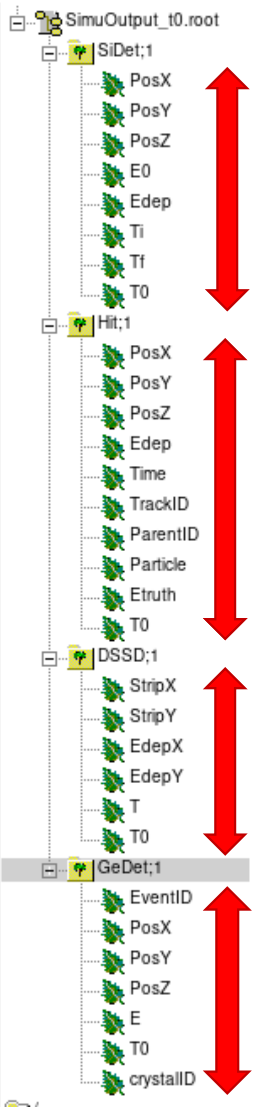
The parameters that merge the Geant4 hits to make them analogous to the data can also be configured. Relevant parameters are:

- The parametrization of the energy resolution of DEGAS
- The time window to merge different hits
- The number of strips of the silicon detector

```
#these are all meaningless if /primary/usegps is true
/primary/spillOn   1 s
/primary/spillOff  0 s
/primary/implantRate  10 Hz
#this needs to be used for an eu source otherwise geant4 dr
/process/had/rdm/thresholdForVeryLongDecayTime 1.0e+60 year
/primary/ionZ  56
/primary/ionA  133
/primary/pos/mean  0 0 0 mm
/primary/pos/sigma 0.1 0.1 0.1 mm

#/primary/usegps true
#/gps/particle gamma
#/gps/ene/mono 1 MeV
#/gps/ang/type iso
#/gps/time 0 s
#/gps/pos/centre 0 0 0 mm
```

The output of the simulation



"Perfect" silicon detector data

Hit data from Geant4

AIDA Data-like format

DEGAS data

- With the simulation we can have access to the ground truth and a data-like format
- This can help us to understand:
  - the amount of miss-correlation
  - The overall expected efficiency of the setup given the experimental conditions

AIDA simulation

- The electronics of AIDA is complicated, as its data is multiplexed. In order to simulate properly and understand its response we need to simulate properly the multiplexing and de-multiplexing.
- We can add noise and study the impact on the data quality
- We can define the best strategy for the analysis

See Giorgio's talk!

DEGAS specific motivation

- In our decay spectroscopy experiment we populate isomers and observe the decay of all the states that branch from the isomer
- The intensity of each gamma ray in a lecel scheme should “balanced”
- Having under control the intensity means, for example, that we can infer the presence of unobserved branching if there is missing intensity
- There are however some technicalities:
  - The implantation position does not correspond to the

See Johan Emil’s talk!

Perspectives

- **The most important step is now to validate the simulation with real data**
- We also need to implement the box configuration
- Do we also need to simulate the implantation?
- Add the presence Dead layer/passivation in the silicon detectors
- Data structure compatible to experimental data in order to have a 1:1 correspondence of the analysis procedure

Thanks