

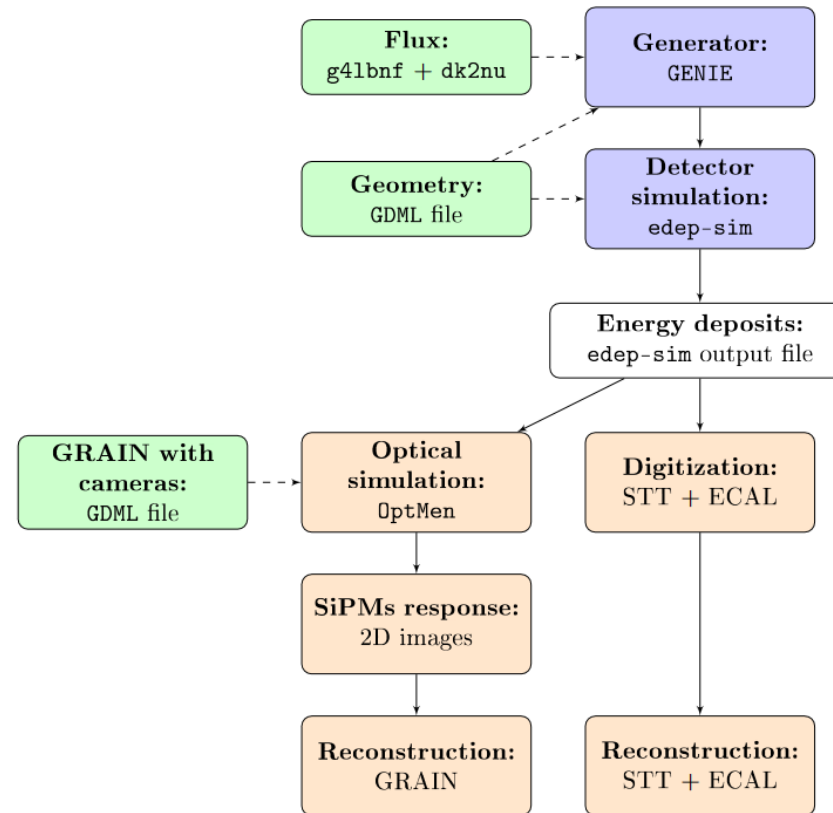
Report WP 5.3: Geant4 simulation of scintillation and photon propagation

V. PIA, M. VICENZI

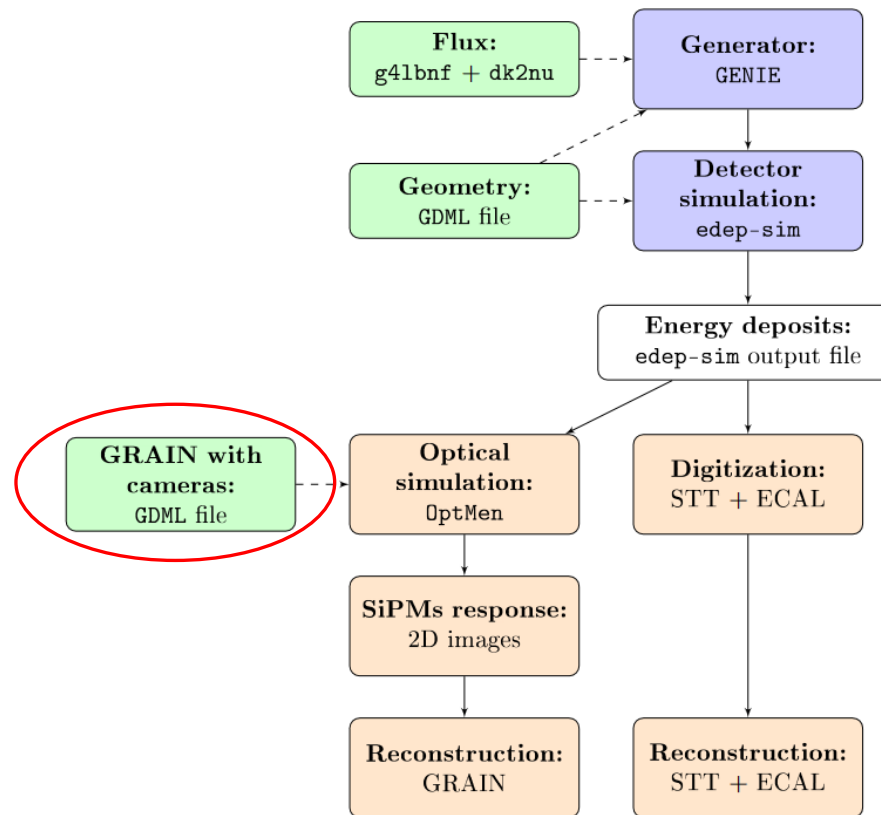
RIUNIONE PRIN 2017

MAR 1, 2023

Simulation pipeline

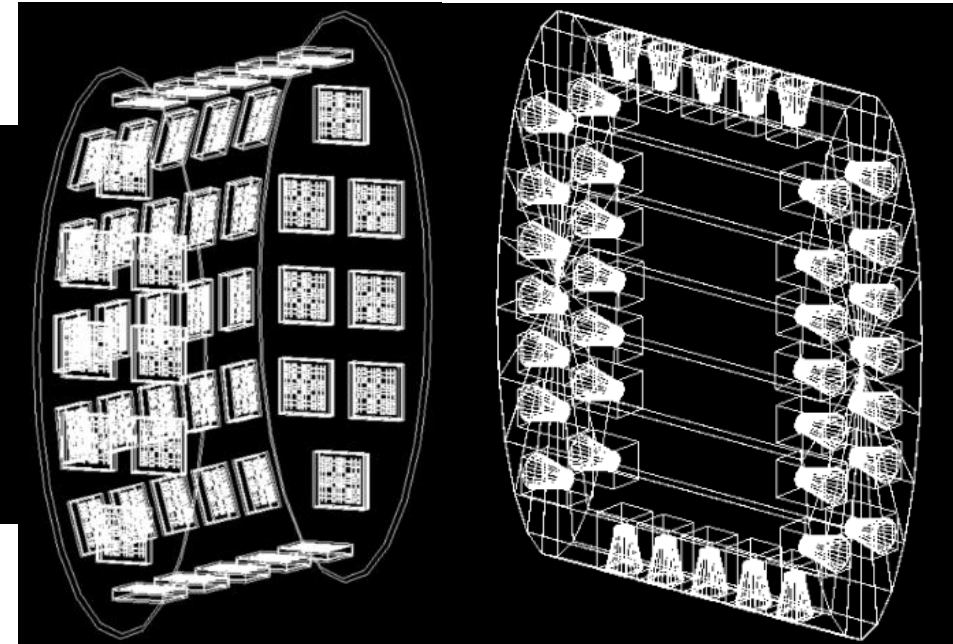
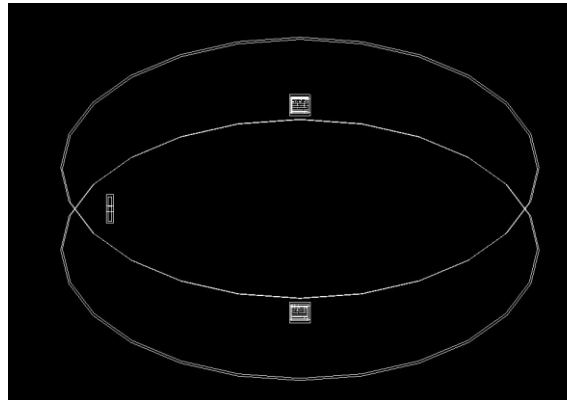


Simulation pipeline



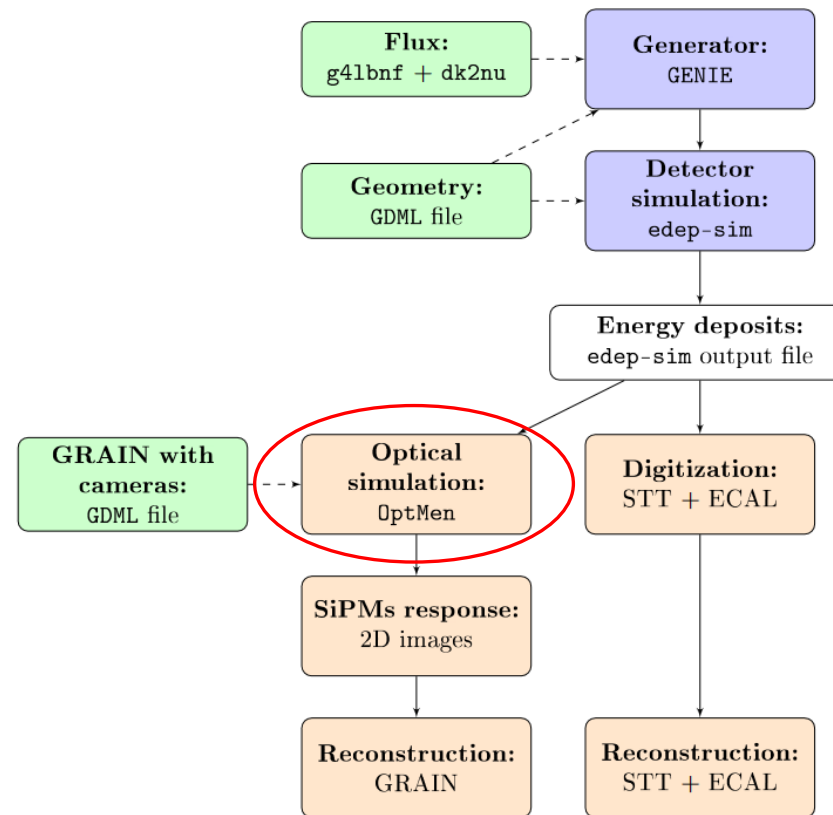
Geometry

- Possibility to simulate different geometries (not only GRAIN).
- Geometry based on gdml file(s)
- Requirements:
 - A lar_volume volume
 - One or more cam_volume
 - One or more volumes with Sensor auxtype



```
<auxiliary auxtype="Sensor" auxvalue="S14160-6050HS">  
  <auxiliary auxtype="cellcount" auxvalue="32"/>  
  <auxiliary auxtype="cellsize" auxunit="mm" auxvalue="3.000"/>  
  <auxiliary auxtype="celledge" auxunit="mm" auxvalue="0.200"/>  
</auxiliary>
```

Simulation pipeline



Optical simulation – Photons emission

- Mean number of photons obtained from edepsim step and argon light yield:

$$N_{mean} = E_{step} [\text{MeV}] \times 40k [\text{ph/MeV}]$$

- Number of photons extracted from a Poisson distribution ($N_{mean} < 20$) or from a Gaussian distribution ($N_{mean} > 20$).

- Position and time of each photon is random between start and stop of edepsim step

$$\mathbf{x}_0 = \mathbf{x}_{start}^{step} + \text{random}(0, 1) \cdot (\mathbf{x}_{stop}^{step} - \mathbf{x}_{start}^{step})$$

$$t_0 = t_{start}^{step} + \text{random}(0, 1) \cdot (t_{stop}^{step} - t_{start}^{step}) + t_{scint}$$

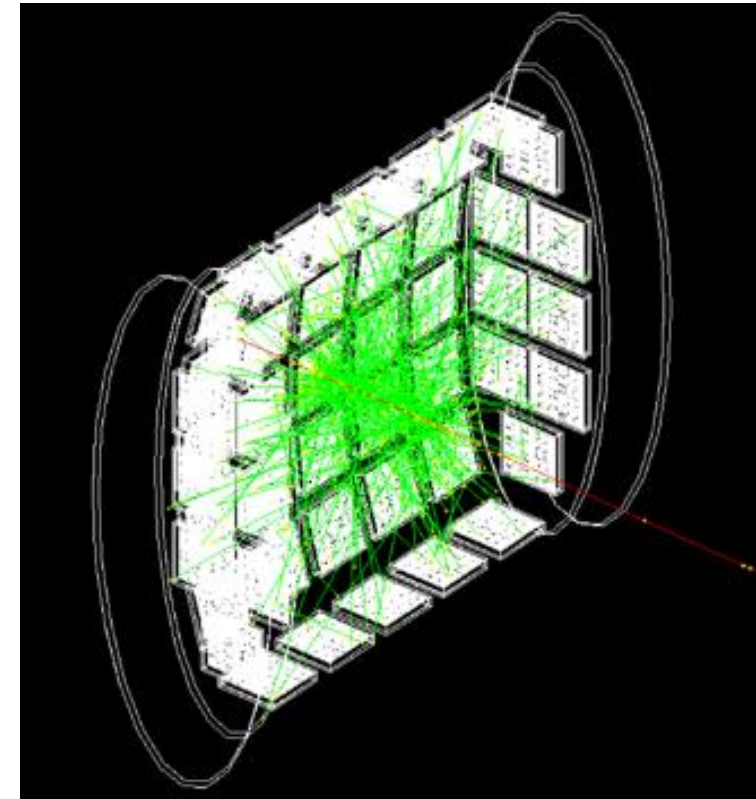
- Fast and slow components selection based on experimental singlet to triplet ratio:

$$fast \sim 25\% (E \gtrsim 1 \text{ MeV})$$

- Photons energy randomly extracted from the emission spectrum

Optical simulation – Photons propagation

- Refractive index parametrized from recent experimental results
- Light propagation is simulated using standard Geant4 optical processes
 - Rayleigh scattering set to 90 cm (in non-doped Argon)
 - Absorption length set to 5 m (in non-doped Argon)
- Vessel and camera mechanical support reflectivity set to 0%, absorption set to 100%



Optical simulation – Xe doping

- Singlet-to-triplet ratio same as in pure LAr. Fast component assumed unaffected by the dopant.
 - Invisible for lens-based camera due to low transmittance
 - A suppression must be included in the simulation when using mask-based camera
- Slow component almost completely shifted to 174 nm: 10% at 127 nm, 90% at 174 nm. $\tau_{slow} = 160$ ns
- Total light yield increased by 20%. Additional photons assumed to be slow component only.
- Parametrization of refractive index, scattering and absorption length is wavelength dependent
 - Abs length: 1000 m if $\lambda < 151$ nm, 3.8 m if $\lambda > 151$ nm
 - Scattering length: [4, 30000] m for λ in the [119, 1200] nm range

Optical simulation – Inputs

- Three possible input files:
 - Geant4 macro
 - Edep-sim
 - Genie
- Macro based on the Geant4 General Particle Source (GPS).
 - It uses Geant4 scintillation model, not the one described earlier.
 - Useful for debug purposes
- Edep-sim uses an edepsim output file and searches for hits in the GRAIN volume.
 - It uses the scintillation model described earlier.
- Genie can be used to propagate the particles produced in the neutrino interactions skipping the edepsim step
 - It uses Geant4 scintillation model, not the one described earlier.

Optical simulation – Inputs 2

- A configuration file is used to set all the options needed for the simulation
- Mandatory fields:

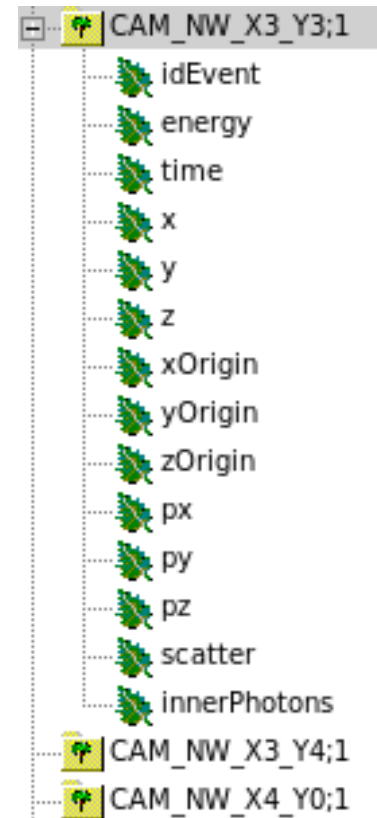
```
inputFile = here_input_path  
generatorType = here_generator  
eventNumber = here_event_number  
geometryFile = here_geometry_path  
destinationPath = here_output_path  
opticalPhotonsFile = no  
sensorsFile = yes  
ui = no
```

Optical simulation – Output

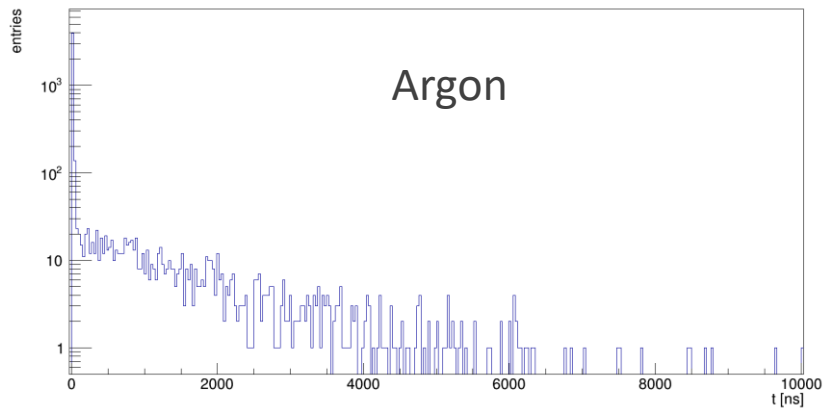
- Up to three output files can be generated:
 - Primaries
 - Used to store information about the primary particles
 - Only working for macro and genie input
 - Optical photons
 - Used to store information about ALL the generated optical photons
 - Useful for debug purposes, it grows in size quickly and it will probably crash everything when used with large productions
 - Sensors
 - Used to store information about the detected photons on all the sensors

Optical simulation – Output 2

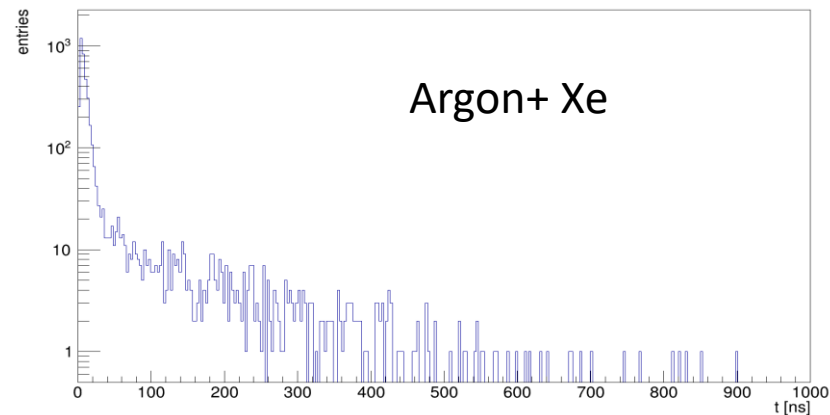
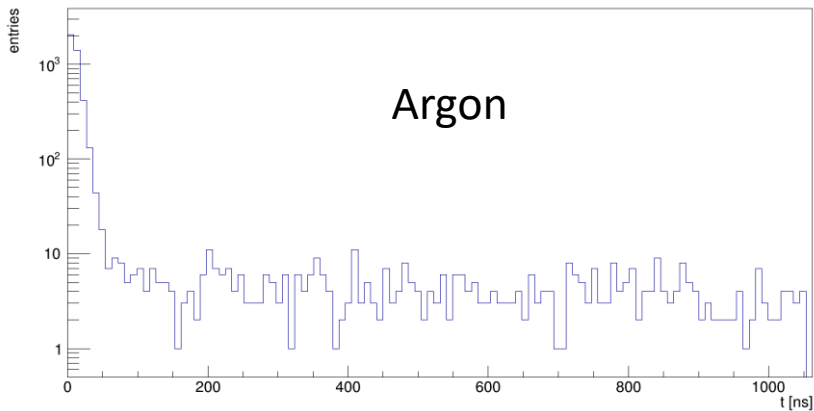
- Sensors
 - Used to store information about the detected photons on all the sensors
 - One tree per sensor in a root file
 - Multiple branches with local coordinates on the sensor, arrival time, energy, direction and more
 - Each entry is an event. One event is what genie and edepsim consider a single entry (neutrino interaction, spill, other?)



Optical simulation – Output 3



Example of arrival time for all the detected photons on one camera for pure Argon and Xe-doped Argon.



Optical simulation – Tools

- Different tools to process the simulation output:
 - 2D images with and without electronic simulation
 - Mask gdml generator
 - Docker file with geant+root+edepesimIO+optical simulation
 - Time profile of each channel

The screenshot shows the GitHub organization page for 'sand-optical'. The organization name is 'sand-optical' with a shield icon and 'Group ID: 1453'. There are buttons for 'New subgroup' and 'New project'. Below the organization name, there are tabs for 'Subgroups and projects', 'Shared projects', and 'Archived projects'. A search bar and a dropdown menu for 'Name' are also visible. The main content is a list of subgroups and projects, each with a colored icon, name, description, star count, and last update time.

Icon	Name	Description	Stars	Last Update
D	Detector Response		0	1 year ago
D	Detector Response GPU		0	6 months ago
D	Dockers		0	2 weeks ago
D	drdf	Detector Response Data Format libraries and tools	0	5 months ago
F	FastElectronics	Simple converter from OptMen output to TH2	0	1 week ago
G	gdmlParser		0	10 months ago
G	geometry	GDML geometry description	0	4 days ago
LAr Lenses	LAr Lenses	Reconstruction and analysis code for LAr lenses	0	3 months ago
O	OpticalMeniscus		0	2 weeks ago
O	Optical to Full		0	10 months ago
P	ProdScripts	Scripts for Simulation Production	0	1 month ago
T	Tools	Miscellaneous tools and utilities	0	5 months ago
V	VolumeReco	Voxel based event reconstruction	0	1 week ago

Next steps and conclusions

- Update the simulation to support more recent geant versions
- More complete Xe doping implementation
- The simulation is working without major bugs
- Flexible input parameters set with a configuration file
- Multiple output files for debugging and physics