GRAIN Working Group meeting

7th Apr 2022

Next meeting schedule

The topic of the next meeting was discussed based on a first proposal.

After a small discussion about the order between the second and third meeting, **the final approved schedule is then:**

- Prototyping, design, goal, timeline – 21st Apr 2022
- Cryostat design, current project & constraints – 5th May 2022
- Cryogenic, current project & constraints – 19th May 2022.

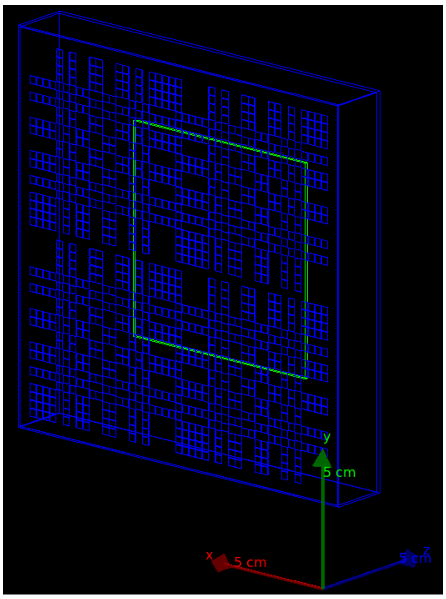
Giuliano suggested focusing on a smaller scale prototype for the cryostat, to better study all the electronics and mechanical aspects before scaling it to the final version.

Technical information about coded mask-based sensor (see talk and slides by N. Tosi)

Different setups have been studied.

The reference design is defined as a camera with the following properties:

- 32x32 SiPM matrix, 1024 channels per camera
- 3.2 mm SiPM pitch, 3 mm active area, 0.2 mm inactive area
- External mechanical support for mask and sensor of about 18x18x2 cm
- Mask composed made by 34x34 of about 2000 holes, 2.71 mm of side each plus a 0.2 mm of border.
- Mask thickness of 0.1 mm



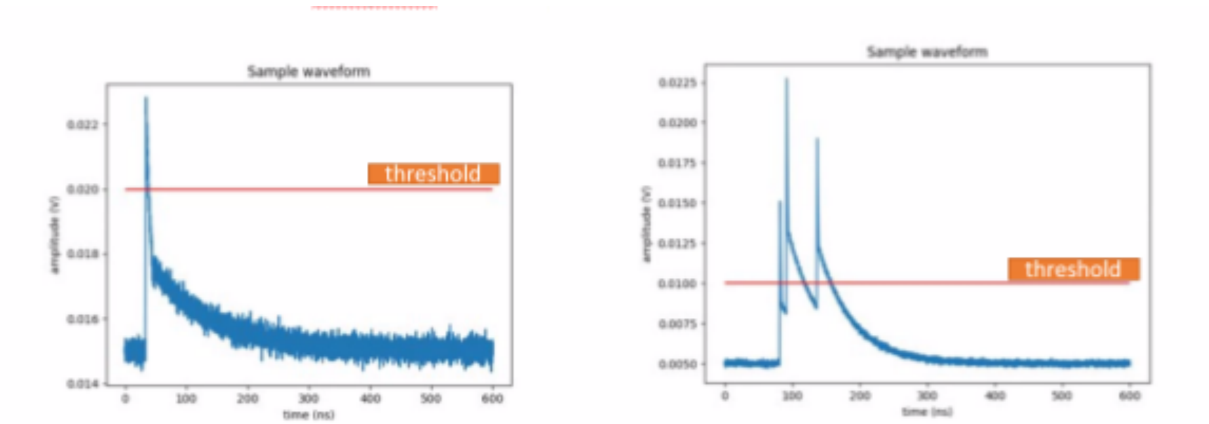
Many more variants were simulated less in detail than the reference one. They are stored in a git repository, one geometry per branch.

The reference sensor is based on the available hardware. A 32x32 array can be constructed starting from existing 4x4 or 8x8 arrays. SiPM performance is simulated as the performance of the Hamamatsu S14160-3050 SiPM. If needed, different SiPM can be implemented.

A detailed detector response has been implemented. Most of the important aspects of the SiPM response and the electronics are present. The list includes rise and falling time, pixel amplitude, pde (not yet wavelength-dependent), DCR, crosstalk, baseline noise, and so on.

The simulation pipeline starts from the geant4 output, as a list of detected photons on the sensor's surface (here simulated as ideal and uniform). The simulation result is processed with the detector response tool. This assigns each photon to the correct pixel (or to the inactive area of the border) and simulates a waveform based on all the photons detected in a pixel, including the single photon time resolution. Noise and everything else are added to this waveform. Sampling rate and waveform length influence the computation time of the detector response simulation.

The TRIROC response is already implemented, while the ALCOR response implementation is in progress. TRIROC was used for the warm demonstrator, while ALCOR will be used for the cold demonstrator.



An example of some waveforms is shown in the figure above.

Two possible outputs are possible:

- Drdf, detector response data format, a binary format similar to the PNG format, is used to represent an image. It can be used to simulate the TRIROC output, but it is not able to simulate the ALCOR output.
- Hits list, to be used to simulate the ALCOR output. A proposed structure for this data format is available here.

About the prototype activity, the **warm demonstrator** is available. It's composed of an 8x8 array of 1 mm squared SiPM. It uses a warm temperature readout, and the results are the correct operation of the signal extraction technique as well as the reconstruction of simple point sources (one at a time). No more is possible due to the TRIROC demo board being not yet fully developed. A cryogenic temperature test has been performed to test the mechanical stability of the system. No problems emerged.

For a cold demonstrator, more channels are needed. Works on a 16x16 array are going on. We are working on the firmware, waiting for the PCB and we need to start the mechanical design of the box for the mask.

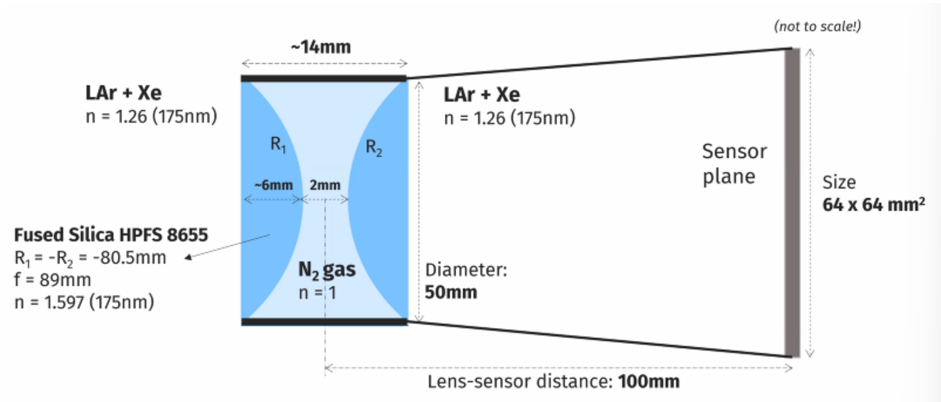
From the questions on the presentation these points emerged:

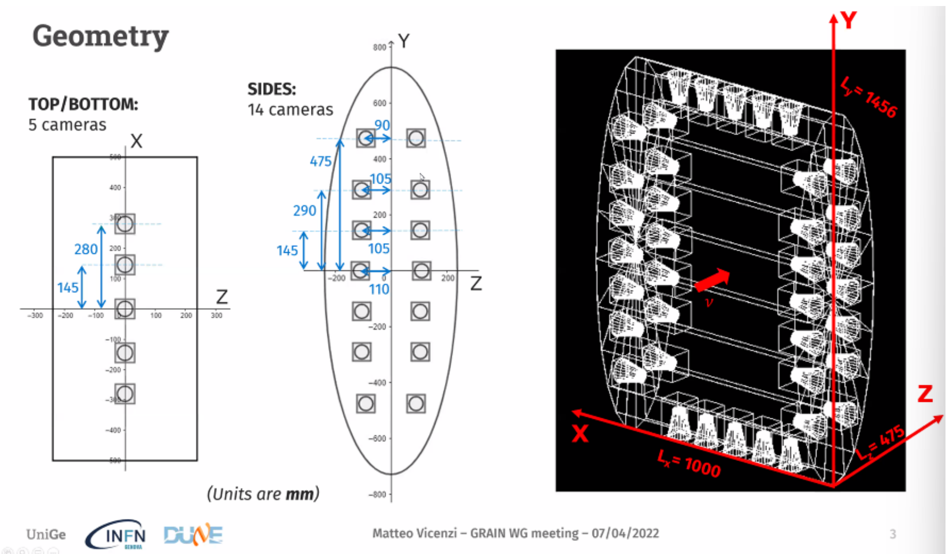
- **The only configuration we are currently thinking of as "serious" is the one with 6 mm SiPM.** This has about the same final box's dimensions but a different type of mask (single mask instead of a 2x2 mosaic).
- **No final layout configuration with mask sensor in GRAIN is available** yet. No studies on which cameras are mandatory or not have been performed yet. **Surely, we need the cameras on the curved faces**, but we need to do a proper study on that.
- Time resolution should not depend on the pixel size but should depend on the single cell size. A larger pixel should not impact the time resolution of the system.

Technical information about lens-based sensor

The reference design for the lens-based camera is as follows:

- two plane-convex lenses with gas between them
- curvature radius of about 80 mm
- max thickness 6 mm
- 50 mm of diameter
- Total lens thickness of about 14 mm
- Total camera thickness of about 11 cm (10 cm from the center of the lens to the sensor)
- Sensor is a 32x32 array of 2x2 mm2 SiPM





In GRAIN the cameras distribution was thought to cover the most volume possible. There are 14 cameras on the lateral faces, seven rows of 2. Both the top and bottom regions have 5 cameras each. In total there are 38 cameras (about 39k channels in total). The sensor simulation in a simple 20% cut on the total number of detected photons.

As for the mask, a quantitative analysis of the most important cameras is not yet ready. The cameras more optimized are the ones on the lateral faces. Removing some of them is possible but we need at least 10 on each side. The top/bottom cameras are slightly worse as the events have a greater mean distance from the cameras. They are important as they help to reconstruct the position along the x direction of the events. Maybe not all the cameras are needed but more studies are needed.

Other designs are being studied for larger distances (where a light problem arises):

- Like the reference one with a larger lens diameter (60 mm)
- A biconvex lens with gas between lens and sensor (instead of inside the lens)

Both configurations will have different total lengths compared to the reference design, a possible range is 80-120 mm.

The prototype for the reference design is ready and being tested. Tests in water have been performed to verify the lens behavior. Simulation results are coherent with the data. The next steps include the design of supports to test the lenses in liquid argon. Works on the other designs are in progress.

From the questions on the presentation these points emerged:

- No final decisions have been made on the gas inside the lens. The need for a valve is still to be clarified. There is no certainty that vacuum instead of gas will be possible.
- The current distribution of the cameras on the lateral faces allows complete coverage of the volume along the beam direction.
- Asked the **mechanical team for feedback on the design**. No major flaws seem present but a gas region on top and the space for the tubes on the bottom must be taken into consideration.
  In particular:
    - in the **top region** about 15 cm will be occupied by gas and the detector will be placed under that level heigth.
    - in the **bottom region** tubes of 5-8 mm will be mounted and thus the detector will be placed at 1 cm from the bottom surface.
    - the **final dimension** of the cryostat in the **x direction** will be in the 1.4-1.6 m range, if we want 1 ton fiducial mass.
    - a small space between SiPM surface and cryostat wall will be necessary (about 5 mm)

Final discussion

- It was requested by Claudio Montanari a **presentation of the argon light emission**. Some details on what geant does, to better understand the characteristics of the light propagation, generation, and so on. There are different models for geant and is important to understand the details of the one we are using.
- Once the lens layout in GRAIN and the coded mask layout in GRAIN will be studied, we have to start to **think of a combined lens+mask setup in GRAIN**
- The cameras on the curved faces will be mounted on mechanical support attached to the lateral faces. This will allow to extract all the cameras from the side with a small quantity of passive materials.

- We should start **to think about the next articles**.