Minutes from GRAIN Working Group meeting – April 21st, 2022

Attendance:

Lea Di Noto (co-chair), Alessandro Montanari (co-chair), Giuliano Laurenti, Paolo Bernardini, Valentina Cicero, Giovanni De Matteis, Roberto Cereseto, Gianluigi Piazza, Valerio Pia, Cristina Guandalini, Nicolò Tosi, Laura Patrizii, Marco Guerzoni, Michele Pozzato, Antonio Surdo, Matteo Vicenzi.

NEWS

- The activity of the last GRAIN WG meetings was reported in the last SAND Technical Meeting on Tuesday April 12th, 2022.
- Claudio Montanari has requested to the GRAIN WG to **nominate 3 observers** that should regularly attend the meetings of other working groups (**STT, ECAL, DAQ**).
    - **Paolo Bernardini** was proposed as observer for the **ECAL WG**.
    - Interested people can contact Lea and Alessandro via email to propose themselves as **observers for the STT or DAQ** working groups.

LENS PROTOTYPING

(See presentation from L. Di Noto)

Planned tests for the lens setup currently include:

- Tests in **water** with a small setup → **already in progress**, needed to cross-check validity of the optical simulations
- Preliminary **cryogenic tests**: checking mechanical properties of lens material at low temperatures, checking gas valves and seal for leakage, type of gas, etc.
- Tests of **prototypes in LAr inside ARTIC**. There are currently three configurations planned to be tested:
    1. Type A: same parameters as in the current GRAIN simulations (focal length 89 mm, effective diameter 50 mm)
    2. Type A: similar (focal length 89 mm), but bigger diameter (60 mm). This will test the possibility of enhancing the depth of focus to larger distances than 1m.
    3. Type B: different technology, a single bi-convex lens with gas between the lens and the sensor.

Mechanical supports have been designed by Robert Cereseto (INFN Genova):

- Drawings are ready for type A (both sizes), few months may be needed for production depending on the availability of the mechanical workshop here in Genova → **ready by the end of June**
- Design still in progress for type B (less urgent, water tests will come first).

Goals of **1st testing phase**:

- Test the prototypes in a cryogenic environment (LAr), but with an artificial light source close to 180nm (no scintillation, no Xe).
- Verify that lenses are working in this simplified setup (including readout), understand the impact of reflections from the surfaces of the cryostat, how to stop reflections, understand readout.
- Cross-check of the optical simulations: evaluate the response (PSF: point-spread function) of the lens with a movable point source (possibly using 2 sensors facing each other) → parameters of the system to be tuned according to real propagation in LAr

Goals of **2nd testing phase**:

- Add Xe-doping, use cosmics as light-source.
- Still far… to be discussed in a year

→ The topic of today's meeting is thinking about the first testing phase (which can be reached soon…), what is missing, how can matrices and lenses be integrated with the same configuration in ARTIC, what is the timescale.

Discussion

Q. (P. Bernardini): Focal distance strongly relates to the volume the lens-cameras need in LAr (in terms of lens-sensor distance), would type B be better in that sense?

- (Lea): Type B can possibly reduce that distance, but not too much (maybe down to 8 cm, instead of 10 cm). Optical properties are currently the focus. The ray tracing simulations for this type give similar results to the reference design used in the full G4 simulations, so this will be a test on whether smaller focal lengths are truly equivalent.

MASK PROTOTYPING

(See presentation by N. Tosi)

- Recent simulations were focused on the GRAIN geometry and not optimized for the prototype
  - For examples: sensors for GRAIN are 32x32, while the prototypes in ARTIC will be 16x16, ARTIC GDML is not implemented, etc
  - Need to think about ARTIC geometry, find best distance for the masks (likely smaller than for lenses), run some simulations → **3 weeks estimated**
- Mechanical production of mask is easy, already done for warm demonstrator via an external company. Laser cutting from thin (100-200 um) metal sheet. Not started, but once the geometry is finalized, it will be quick.
- The design for the outer box and the support of the mask is not yet started, but no issues are expected (rather simple object). Needs information of the current ARTIC setup for how to position the support on the disk at the bottom

Q. (N. Tosi): Is it possible to place masks at different positions than what is planned for the lenses? Are there holes in the disk?

- (Lea+Roberto): Yes. Threaded holes can be made on the disk according to what is needed. The movable source can also be adapted.

Q. (A. Montanari): What is the material of the lens support?

- (Roberto): The support of the two lenses with the gas sealed inside is steel, everything else is aluminum.

READOUT ELECTRONICS

(See presentation by N. Tosi)

- Good news for the readout**: boards and mezzanines have been delivered**!
  - 3 mm variant: 16x16, made by putting together 4 8x8 matrices. Placed as close as possible, but a small gap remains.
  - 1 mm variant: 16x16, monolithic (no cross in the middle)
  - These are standard blue SiPMs (blind below 300nm), because VUV SiPMs are not yet produced in matrices → they require applying TPB.

- Mezzanines look okay: connectors are lined-up with the motherboard.
    - Few SiPMs have a different color… probably coming from different wafers
    - Difficult to test SiPM individually (very dense layout): we can try to test some channels (those we can access easily with some probes) and rely on characterization from Hamamatsu.
- Motherboards are completed, except for ALCORs
    - Basic tests are planned (power, the few active circuits), also in a cold environment
    - After these tests, **within 2 weeks**, the plan is to go to INFN Turin to do the bonding of the first ASIC (not all at the same time → one first, then check and learn → the rest will be done after, possibly in INFN Bologna)
    - Planned the installation of plexiglas to protect the wire bonds of the ALCOR
- **Firmware**:
    - communication with FPGA, clock distribution and slow control are working, tested in single demo-board from AlCOR. Bytes received are valid.
    - Working on DAQ core: capacity to build event/images → **1 month needed, but debugging will continue**
    - Many parameters need to be set for the ASIC; default parameters might need to be optimized… it could time some time to adapt it exactly to our use. We didn't have the chance to do it on the test board (we need the final configuration).
    - Software is minimal, just to talk with the firmware… it will improve at the same space of the firmware

Possible testing plan:

- Verify ALCOR boards, including performing the bonding. (**3-4 weeks**)
- Find correct ALCOR configuration, calibrate discriminators, DACs… needing some calibration runs (**4-5 weeks**)
- Check response from all SiPMs in a warm black box, using 3 axis motorized stage with 405nm laser (**2 weeks**)
    - Scan the SiPM matrix automatically, measure the gain, dark count rate (with no laser)
- Check SiPMs in LN
    - Which test? What do we want to characterize in LN before ARTIC? → **still to be decided**
    - Important: each SiPM has its own breakdown voltage, but the bias is common to all. The equalization of the response to account for different gains done in the warm environment might not be working the same in LN → maybe checking also with a mask + led to reconstruct a point and see an image.

Connections in ARTIC:

- Procurement of FMC cables (motherboard to FPGA) **completed**:
    - **6x 1 meter** (maximum length)
    - You can put them in a chain (2 together, worsen the signal but we can live with it; no other option given our signals)
- Cable is 2 meters in total:
    - Electronics will sit on top of ARTIC (1 for each sensor, thinking of a box to protect it)

Discussion

Q (N. Tosi): What is available in ARTIC. An open top or do we need a flange?

- (Lea). At the beginning it's okay to keep it open, losing a bit of gas. However, for final test in LAr+Xe there is the need of a recirculation system, and the system needs to be closed → we also need to think about it anyway also for GRAIN in the end.
- (Nicolò): It might be useful to start thinking about it. Normal connectors for flanges are not enough (too many signals, not fast enough). Possible use of PCB in flanges with two connectors.
- (Laura): **Try asking people from INFN Padova**, Alberto Guglielmi. Similar problems might have been already faced in ICARUS.
- (Nicolò): Need to study this issue for GRAIN: what are our limitations? If in liquid we will also be bringing heat in by conduction, another thing to consider on top of thermal dissipation from the electronics. Even if not immediately of use, it is a critical point to consider it.

Q (P. Bernardini): You mentioned DCR is higher for a single photon?

- (Nicolò): No, I meant that with the ALCOR we can measure the DCR (dark count rate) with a threshold above 1 photon (at warm temperature, the rate for a single photon will be too high to measure), but maybe by measuring the rate for 2 or 3 photons then we can also estimate 1 photon rate → anyway at cold we don't really care, it will be very low.
- (Alessandro): The **cold dark count rate is 20 mHz/mm^2** → 200 mHz for 3 mm ones

Q (L. Di Noto): What is the relative position of the motherboard vs the mezzanine? Can two sensors be put close to each other? What is the total thickness of motherboard + mezzanine?

- (Nicolò) The mezzanine is exactly above the square part of the motherboard (see the connectors). The motherboard can of course be rotated so that the "code" sticks up and does not interfere with other sensors. This is also a better position for the cable. Among the golden connectors, only HV is strictly necessary.
- (Nicolò + Alessandro): Mezzanine + motherboard is probably 5mm. Then you need to add the SiPMs (1mm) + the ALCOR and its protective box. → Assume a **total 1.5 – 2 cm**.

Q (L. Di Noto): When is the TPB deposition scheduled according to the above plan?

- (Nicolò): After test in Bologna? We have laser red/blue to test, so we don't need it. If we want, we can also go in parallel. We can keep a matrix and send the others… More generally, it does not bother us to have TPB on top.
- (Alessandro): It would be better to test it completely in warm first. We should understand what the treatment consists of and how much time it takes
- (Lea): We need to plan it: the group is doing us a favor, so we need to **take serious contact** once we have clarified ourselves what we want to do, how much time it takes.

PUTTING TOGETHER A TIMELINE

(See presentation from L. Di Noto)

Common items

- Light sources: just ordered, test to check if it works (**by end of the summer**)
- General mechanics in ARTIC (drawing ready) (**by the end of June/July**)
- TPB deposition: ?? → to be defined
- Electronic readout (**ready by October**)

Lens

- Cryogenics test, mechanical supports (**end of June**)

Mask

- Mask production, mechanical supports (easy → **can go in parallel**)

The slower step is the electronics → TEST in LAr of phase 1 (artificial source at 180nm) can be expected to begin around **November/December**.

Possible delays?

- What if the PCB is wrong? → can be fixed, losing time (we'll know in a month)
- What if the ASIC does not work? → CRITICAL: we don't have a second option (we'll discover at the end of the summer). Colleagues say they are happy with them, but they are working at -40 and in different conditions.

CLOSING

The next meeting is going to be focused on the design of the cryostat, as discussed last meeting. A reminder will be sent by the chairs to the relevant people.

Q (L. Patrizii): Are there plans for the collaboration meeting in terms of GRAIN?

- (Lea): The structure of the sessions has not yet been decided. Most likely they will ask for updates on simulations/prototypes. We can discuss it in the next meeting.