HEARTS annual meeting 06/02/2024 minutes

Participants:

European Commission: Fabio Vitobello (FV), Simon Conticello (SC)

CERN: Ruben Garcia Alia (RA), Pablo Lopez (PL), Andrea Coronetti (AC), Andreas Waets (AW), Cloe Levointurier-Vajda (CL), Eliott Johnson (EJ), Viktor Varga (VV, online), Antoine Le Gall (AL), Luigi Salvatore Esposito (LS), Natalia Emriskova (NE), Enrico Chesta (EC), Karolina Klimek (KK), Kacper Bilko (KB), Mario Sacristan Barbero (MS), David Lucsanyi (DL, online), Markus Brugger (MB), Viktor Varga (VV), Svetlomir Stavrev (SS)

GSI: Christoph Schuy (CS, online), Tim Wagner (TW, online), Adam Gera (AG, online)

AIRBUS: Renaud Mangeret (RM, online), Mirko Rostewitz (MR, online)

TAS: Stefano Francola (SF, online), Roberta Mancini (RO, online)

COSYLAB: Miha Vitorovic (MV)

External reviewers: Arto Javanainen (AJ, University of Jyväskylä), Isabel Lopez Calle (IL, University of Cadiz)

Advisory panel: Alessandra Costantino (AC, ESA, online), Gilles Gasiot (GG, ST Microelectronics, online), Mike Sivertz (MS, NSRL, online), Stefan Metzger (SM, Fraunhofer institute), Patricia Goncalves (PG, University of Lisbon, online)

Actions

- ➔ WP5: More visibility is needed from the EC on the list of test subjects with justification and motivation. At least in the case of the tests to be done in 2024, this needs to be defined soon to make the tests possible, but longer term plans would be useful to know.
- ➔ WP1: A date should be scheduled for the period review related to payment 1, to be scheduled after the submission deadline in August. The review will be in online format and should show a global view of the progress with respect to the initial plans. The period review should include technical and financial aspects and a summary of the progress of the activities with respect to the initial schedule.
- ➔ WP9: schedule the kickoff meeting.
- ➔ Project office: specify expectations for the advisory panel.

CERN opening

Markus Brugger

Questions & comments:

European Comission opening

Simon Conticello & Fabio Vitobello

Questions & comments:

The European Space Programme for the next few years is in preparation by the Joint Task Force (ESA/EDA) in which heavy ion test infrastructures play an important role for strategic autonomy for the European Union.

WP3: Monte Carlo simulations

Luigi Salvatore Esposito

Questions & comments:

(SC) Will any of the discussed vacuum section extensions be implemented?

- ➔ (RA) We are looking into moving further upstream in the same beam line to test in IRRAD Zone 1 with the same functionality as we have now in CHARM but bypassing the ~30m of air.

(SC) Is the development for high-energy heavy ions in G4SEE aimed to happen within the timeline of HEARTS?

- ➔ (LE) Yes, and in the longer run (5 years) G4SEE functionalities should be incorporated in FLUKA 5.
- ➔ (AJ) The nested volume functionality is very interesting. What is the level of confidence in the Geant4 physics models? Can the project benefit from doing a more nuclear physics experiment measuring single/double differential spectra at VHE ion energies?
- ➔ (CS, RA) These experiments were done at GSI and while it is true that the dataset is incomplete this is not within the scope of HEARTS.

(AJ) Simulating a (GCR) simulator might be a bit confusing.

- ➔ (CS) “Simulating” the space GCR environment is exactly what it does so there is no better word for it.

(AJ) It would be good to update the presentation such that it is clear on each plot which ion is used (U vs. Pb).
(IL) Does the table on slide 9 give all energy/LET combinations possible? How are the LETs determined? Is there also information on the LET range?

- ➔ (AW) This is a representative subset. The values given are the centroid values of the Gaussian distribution but information on the width of the distribution can be given to the users.
- ➔ (AJ) Giving the full LET range is important for testing for destructive events.
- ➔ (RA) For example on the rightmost plot of slide 8, the higher deposited energies/LETs above the primary peak are due to the interaction with the diode case.

WP5: Radiation effects testing with VHE ions

Renaud Mangeret

Questions & comments:

(IL) Is there a difference between the two facilities in terms of TRL definition?

- ➔ (RA) We aim to have a redundancy by using both facilities. We will start the TRL assessment from a single document for the two facilities but the assessments will be done by the users independently, on top of our internal self-assessment.

(IL) What are the last two requirements of Deliverable 5.1, 2.2i and 2.2j?

- ➔ (RA) The temporal structure and spatial structure are relevant in case of synchrotron facilities and/or where there is magnetic raster scanning, simply because users might be able to use this info. Scanning can be useful for irradiating very specific area, but it introduces the time structure complexity
- ➔ (CS) GSI and CERN are very different, scanning is standard for particle therapy and the adopted beam delivery method at GSI, extraction from synchrotron can happen up to 15s but is not always very stable which is why giving this temporal info is useful. CERN uses a broad beam, without
- ➔ (IL, RA) How can we compare and reproduce results in both facilities then? Dedicated experiments can be carried out.
- ➔ (RM) Scanning is for example used at GANIL and doesn’t appear to be a showstopper for electronics testing.

(IL) What about electronic package encapsulation?

- ➔ (RA) It is the intention to test at both facilities with packaging.
- ➔ (RM, SM) It is particularly interesting to use these facilities since delidding is not necessary.
- ➔ (IL) What about the composition and thickness of the package? This can have an effect on the LET.
- ➔ (RA) The thickness and composition may or may not be known, we target radiation conditions that could apply to any structure (Plastic, ceramic, metal). There is then indeed a tradeoff on the accurate LET knowledge, however concerning the material the density times thickness is most important. We need to define bounds on the uncertainty of the LET at the sensitive area.

- ➔ (IL) All devices in Slide 17 will be tested with lid?
- ➔ (RM) Yes, we would like to compare to results at low- or medium energy facilities such that we can understand the interaction of the beam with the package.

(AJ) Both facilities will test electronics in air, this can be an issue for example for testing high-power devices (power diode/MOSFET) with bare die exposure, where the leakage current increases by charge collection from the ionized air.

(AJ) Getting an LET of 60 is very difficult simply because of physics, the range of the particle is very short. An LET of 40 is already good but what is the lower limit that can be achieved?

- ➔ (RA) Looking into lower-Z ions at CERN.
- ➔ (CS) Fe is available at GSI, however it doesn't make to much sense to e.g. use 200 MeV protons since other facilities provide it on a much more routine basis. GSI can run multiple ions in same blocks, but there are scientific constraints, and typically do U, Fe and C. GSI specializes in high energies, high mass.
- ➔ (RA) Taking NSRL as an example, it is better for users to not go to different facilities to get the full LET range needed, or using the same facility multiple times.

(AJ) There seems to be a systematic factor 2 offset in the SEL cross sections between RADEF and HEARTS@CERN data?

- ➔ (RA) We are still increasing the accuracy on the fluence for these measurements.

(SC) What is the general rationale behind selecting components to be tested? E.g. why this particular NVIDIA Jetson nano board GPU which is very interesting for space applications?

- ➔ (RM) Cannot answer this question on behalf of UniPD. The general idea is to select sensitive devices that are of interest for space applications.
- ➔ (RA) The CERN criteria are that there should already be data available from other facilities/tests and stock of components.
- ➔ (SC) There will be a procurement of components?
- ➔ (RM) The idea is to ensure the traceability to not introduce an unknown parameter in the testing.

(FV) Could you please elaborate on the system-on-chip selection made by TAS? We would like to have more visibility on the selection.

- ➔ (SF) A few candidates have been selected based on their applicability in space and if they have been tested already at standard facilities. Need to discuss internally if this information can be disclosed.
- ➔ (FV) We need to take an action on this and define a timeline since justifications on the selection needs to be given.
- ➔ (RA) The selection has implications on the entire consortium. AIRBUS and TAS select what is in their test path and bring this into the project. HEARTS does not have the capacity to integrate new items in the path due to lack of dedicated resources. We should give the freedom to industrial partners to choose what is in their capacity and interest.

(FV) What is the manufacturer of the SiC MOSFET test candidates?

- ➔ (RM) We wil be in a position to share once the reference part is known.
- ➔ (MR) We already tested several SiC components, what is interesting for this project is a device that is not very strong with sensitivity to medium LETs. We can do a comparison between testing with an open part and with a packaged part but are still in the process of identifying.

(FV, SC) At the kickoff meeting there was the idea of procuring a GaN based DC/DC converter, is this still the idea? Are there still several options? What is the timeline?

- ➔ (SF) Yes there are several options, the picture on slide 28 shows an example setup available, we don't have the resources to produce a brand new test setup.
- ➔ (RA) We would like to get some visibility on what we will test in October, the latest by April we would need the information on how to integrate the setups.
- ➔ (FV) How do we capture the final selection? Do we need a deliverable?
- ➔ (SC) We should have a meeting in April to land on the selection.

WP7: Upgrade of CHARM beam line at CERN for VHE ion testing

Ruben Garcia Alia

Questions & comments:

(SC) Do you envisage further beam tuning this year?

- ➔ We want a clear view of what users want to test, we want to do quality control of perhaps a smaller set of beams to make sure these are good quality for users. We can expand the limits of phase space of those beams.

(AJ) How will we handle user access to the facility? CHARM requires users to come a long time in advance to setup and prepare.

- ➔ (RA) With the relaxed constraints for heavy ion testing we can access pretty much any time and debugging can be done in place, hence arriving 1 or 2 days in advance is ok.

(AJ) For complex devices we want to irradiate only a specific part of the board, if the collimating mask is put in place, a residual radiation field still remains behind?

- ➔ (RA) True but the SEE risk (combination of LET and fluence) of this particle distribution is orders of magnitude smaller behind the collimator. This point will be studied in more detail.

(AJ) Is a beam start/stop button already implemented?

- ➔ (RA) Not yet ready but this is work in progress, we envisage spill-by-spill control.

(AJ) Could you comment on the pending intensity calibration? How exactly is it done?

- ➔ (RA) The calibration this year will be done ahead of the test campaign. We count the primary peaks in the silicon diode energy deposition spectrum to calibrate secondary emission chambers.
- ➔ (IL) There are no values for lower and higher flux shown, are these the limits we can measure?
- ➔ (RA) There is a good linearity of the devices between 10^2 and 10^5 ions per cm^2 per spill. We could expand this in the future if necessary.

(IL) An LET of 60 is more interesting than 40, why not use more degraders to use this value? Or tilt the devices?

- ➔ (RA) The issue is that the uncertainty on the precise location of this LET 60 value inside the device becomes very large as illustrated with the Bragg peak. For example a Spread Out Bragg Peak method could be used to make sure this LET is reached inside the sensitive volume. We aim to make sure that the spread on the LET at the device under test is within +/- 10% but indicate that there is indeed a spectrum of LETs instead of a single value.
- ➔ (RA, AJ) Is the effective LET representative or not? It should be used with caution.
- ➔ (AJ) At these energies SRIM extrapolates models benchmarked at lower energies and there are significant code differences. Could we provide a service to users by e.g. showing FLUKA and SRIM results for LET and range to give ballpark values to users?
- ➔ (RA) If we have the resources, yes.
- ➔ (CS) We should stick to what we can control: degrading from 2 GeV/n with a thick degrader is not a good idea.
- ➔ (SM) Perhaps one can use a plastic etched detector for passive calibration of the radiation field behind a layer of material.

(FV) Do you see any bottlenecks or margins to increase the time windows of ion testing during the year?

- ➔ (RA) We are in close contact with the injector stakeholders, if a case can be made there is no reason to think it is not possible to setup ions in the machine at an earlier moment in the year, there is no hard limit.
- ➔ (FV) Could it be possible to have 24/7 support in terms of operators, RP officers?
- ➔ (CS, RA) We should keep the constraints flexible for the users but also keep it reasonable for the facility. In case users don't show up for their beam time perhaps we should think of some penalization?

WP2: Communication and Dissemination

Antoine Le Gall

Questions & comments:

(SC) Why is the European Astronautical Conference (EAC) not targeted?

- ➔ (RA) A technical contribution on HEARTS could make sense, a booth can be expensive but we should look into options to piggyback on other booths where possible.
- ➔ (SC) For any conferences or events attended in the US formal approval is needed from the EC project office.

WP1: Project Management

Pablo Federico Lopez

Questions & comments:

(SC) For the first payment a periodic review meeting is required. This can be scheduled for example June or July but September seems more realistic and will also not make a big difference. The period review should include technical and financial aspects and a summary of the progress of the activities with respect to the initial schedule.

WP4: Beam instrumentation, characterization and dosimetry

Tim Wagner

Questions & comments:

(SC) What is the status of the beam instrumentation selection? I seem to recall there is a milestone connected to it?

- ➔ (RA) At GSI the standard beam instrumentation choice was already clear and at CERN a cross calibration was carried out with respect to the GSI instruments. In terms of dosimetry methods there is a good cross fertilization between the two facilities
- ➔ (CS) For the CGR simulator specifically the choice has not been made yet since the upcoming tests in April will point out which detectors are the best suited.
- ➔ (TW) The CERN diode will also be used at GSI for cross-calibration measurements.

(AJ) What is the weight that can be carried by the target station?

- ➔ (TW) By design it should carry 15kg or more and should therefore be compatible with system-level tests
- ➔ (AJ) The same fixture/holder will be used at CERN?
- ➔ (RA) It will be a different design but the frame (ESA standard) will be the same.

(AJ) The project should pay attention to coining brand names like the names of the facilities and GCR simulator, will there also be a simulator at CERN?

- ➔ (RA, CS) At CERN there is not such a detailed focus on representing the full GCR spectrum as is interesting for radiobiology studies, only the high-LET part. The CERN concept can be good for system-level or cubesat testing.

(IL) Is there the possibility to rotate the frame, are there constraints on the rotation and is it not better to rotate over the x-axis?

- ➔ (TW) Not taking into account the cables, the frames can keep turning. If one rotates the frame by 90 degrees, rotation of the other axis can be covered as well.
- ➔ (RA) As per the requirements established in WP5, ideally both rotations should be made possible remotely.

WP6: Quantitative estimates of shielding effectiveness using GCR simulator

Christoph Schuy

Questions & comments:

(SC) For the tests to be carried out in April, is the design of the modulator ready? The idea is to irradiate cells in the GCR simulator radiation field?

- ➔ (CS) In total three modulators are needed, two of them can be produced in-house and are ready for production, the third one is pending final optimization through simulation and has to be manufactured outside of GSI.
- ➔ (CS) The goal of the experiments is to compare an already characterized cell line with X-rays (standard) for the Relative Biological Effectiveness (RBE) of the GCR simulator field.

(AJ) What is the composition of each modulator?

- ➔ (CS) Each modulator has a different material and each will be used with a different energy. Plastic will create more fragmentation than e.g. steel for the same amount of stopping capacity. We will check during the experiments if monitoring the primary beam before the modulators is sufficient for dosimetry purposes.

WP8: Upgrade of the FAIR facility for shielding testing

Tim Wagner

Questions & comments:

(AJ) Do the delays of FAIR affect this WP?

- ➔ (CS) The APPA vault was shifted back in time, therefore the CBM cave comes as an alternative to keep the timeline. However the CBM cave has a broad beam and no magnetic raster scanning as was intended for the APPA cave so the GCR simulator design should be different.

(AJ) For the user guide the explanation of the scanning should be included.

- ➔ (CS) The material has already been prepared by Tim and a video or GIF is indeed very useful.

WP9: COSYLAB introduction and WP presentation

Miha Vitorovič

Questions & comments:

(MV) We have long time experience in working with accelerator facilities, for example involvement in CERN WHite Rabbit timing protocol.

(SC) We will be discussing in the next few days concerning everything covered in the Grant Agreement. The kickoff will be planned after the amendment signature. The contribution to the project made by COSYLAB will be the entry tool for users (a standardized test plan document?) and will also help the workflow at both facilities with a streamlined approach.

(SC) Will the tools you develop actually be used to control the facility?

- ➔ (MV) We would rather take a subset of information that is known to the facility and present to users in a more user-friendly way.
- ➔ (RA) Users need a high level of awareness to what is happening during beam time. A centralized monitoring application is needed. In the long run we would like to have users control infrastructure aspects themselves but for now we focus on proper interfacing with the facility operators.

(CS) We should make clear what we mean by the terms “user” and “operator” since sometimes at GSI a person can be both.

- ➔ (RA) Any power over the infrastructure given to the user should not be harmful for the operation.
- ➔ (CS) At GSI it is any way not allowed: a GSI person as operator will always be there.
- ➔ (MV) We already discussed when developing the application and it will also be customized between CERN and GSI separately.

(AJ) Are the requirements for the tools already defined and how is the competency transferred from COSYLAB to the facilities for sustainability?

- ➔ (MV) There will be full knowledge transfer of the source code such that future developments can be fully in hands of CERN and GSI.
- ➔ (AJ) What should we do in case the user wants to keep testing information proprietary? Perhaps a user doesn't want to publish this info, some companies might want to be delicate about the test plan. We need to check the data privacy aspects.
- ➔ (RA) We will not be logging any DUT info. In principle only users and the facilities will have access to the beam data.

(SC, FV) Where will the server be located? Does its location play a role? We have the hard requirement for them to be new.

- ➔ (RA, MV) It does not really matter for COSYLAB. The location is not yet decided,but at CERN we have the IT support.
- ➔ (AJ) Is it a good idea to create an open source or indico-like user support platform that can be stored as an instance?
- ➔ (RA) Good idea, we would not rely on commercial solutions but stick to internal solutions.

- ➔ (MV) We could imagine something like this but it will be subject to the workflow defined by HEARTS and is not necessarily within the scope of the project.

(IL) There is the requirement to host external users art CERN on 1st of January 2025 the latest. Will the tool be ready by that time?

- ➔ (RA): It will only be ready by end of the project but pilots can be used before if possible.

Advisory panel round table

(MS):

- ➔ We essentially use all detectors combined, where each has an optimum point of function. Would like to learn about your experience in using Secondary emission chambers.
- ➔ The GCR simulator is indeed not necessarily useful for electronics testing. However, users came to NSRL and wanted to use it without really knowing what they were asking for.
- ➔ NSRL is often not able to provide enough flux vs the cost of the beam time, 1e7 ions/cm2 in a few mins is challenging. We have roughly 10 to 15 spills per minute and user typically need 10 spills to do one irradiation. The cycle time is set by the RHIC accelerator.

(PG)

It is very important to hold Advisory Panel meetings. How can I contribute as advisor, i.e. what is the official format?

- ➔ (RA) A separate advisory panel meeting required for which the format still needs to be defined. Clear instructions and a timeline will be given.

(GG)

- ➔ There are constraints in terms of ion availability and beam time for users. In some cases, 1 or 2 LETs per particle can be enough but it can take several weeks to change ion in the complex.
- ➔ (SC) Can we elaborate on the cost of beam time?
- ➔ (GG, RA) The main cost of a campaign is not beam time, there are ancillary costs to be kept under control (logistics, delidding)
- ➔ (MS) SpaceX tested at NSRL by irradiating chips in parallel on 20x20cm frames, testing 300 components in 5h.

(AC)

- ➔ The selected test devices in WP5 will only serve to assess the beam line functionality without sharing the data?

- ➔ (RM) As a general approach, there will be public dissemination of the results since it is aimed at demonstrating the facility is usable.
- ➔ The minimum distance to the frame for ancillary equipment and maximum weight of devices must be communicated to the users. Also the patch panels should be checked to avoid debugging time.
- ➔ The beam appears to be off-centered, this requires proper realignment. Is there a correlation between position in the transverse plane and the energy? The energy spread and effect on LET (i.e. importance of LET distribution as opposed to single value, especially for degraded beams) needs to be well quantified. Error bars on LET values in cross section plots are needed. We should reinforce that there should be indicative information on what uncertainty on LET is for users when the component is not delidded and there is a difference in material.
- ➔ (RA, RM) NSRL has developed an online tool/excel sheet for this purpose based on SRIM which could meet the needs of users as an engineering tool. In this approach, the LET uncertainty is linked to the uncertainty on the position/depth of the sensitive volume.
- ➔ (AJ) Could we envisage having a CREME-like website using a G4SEE template macro?
- ➔ (CS) We need to be careful that if we give a tool which is too precise, it can be misleading. Why not use SPENVIS?
- ➔ (MS) At NSRL we receive a lot of feedback from users on the use of the tools. As long as testers have a good understanding the tool gives a good map of the LET distribution.
- ➔ (RM) Confidentiality issues could arise if tools on an online platform are used.
- ➔ (CS) Should we have some form of quality control procedure in place?
- ➔ (RA) For 2024 at CERN we should focus on a few predefined cases , offering less flexibility to users but well characterized beams.

(SM)

- ➔ We need to manage external users expectations: we cannot trick physics offering both a very high LET and a high range. Users need help and support.
- ➔ (RA) We try to refer to standards when possible and develop best practices in WP5 for ion beams at these energies. Development of a standard is a long process.
- ➔ (RM) ESCC25100 is partially applicable, but the subject is unpackaged parts, applicable in medium and low energy test facilities.
- ➔ (FV) What is the missing piece in the current standards?
- ➔ (RA) Until now there is always the assumption that there is a single LET value and is constant. The key point is how to deal with varying LET and range within a device.
- ➔ (MS) The NSRL stack tool gives users the LET at different level in the device (if known), the uncertainty on the LET is quoted as the difference between entry and exit LET.

Closing remarks

(SC) A lot of progress has been made in one year, it is looking very positive. After the 2023 test campaign, HEARTS@CERN looks in good shape with HEARTS@GSI results expected soon. A possible "call for interest" can be made to prioritize access for external users according to criteria to be defined. A lot of challenges are ahead related to how to test, what information to characterize and provide to the users (e.g. radiation field behind mask, LET distribution...) There is promising software coming up.

(FV) The results are encouraging, there is solid coordination between the partners. The emphasis should be to keep focusing on meeting the timeline. Based on project evolution, other decisions may follow for further expanding the European capability in this domain.