**Minutes of the EuCARD2 WP11 kick-off meeting**

CERN, 9-10 December 2013

Partners:

**CERN** (A. Bertarelli, F. Carra, A. Dallocchio, E. Krzyzak, N. Mariani, E. Quaranta, S. Redaelli)**, GSI** (Jens Stadlmann‎, M. Tomut, C. Trautmann)**, Politecnico di Torino** (L. Peroni, M. Scapin)**, RHP Technology** (M. Kitzmantel, E. Neubauer)**, University of Malta** (M. Cauchi, G. Valentino)**, University of Manchester** (R. B. Appleby)**, University of Huddersfield** (S. Fletcher)**, Graz University of Arts** (D. Deboy)**, University of Valencia** (A. Faus Golfe, L. Lari, J. Resta Lopez)**, Royal Holloway University of London** (S. Gibson)**.**

External partner: **Brevetti Bizz** (S. Bizzarro)

**Politecnico di Milano** (prof. M. Beghi)

Please find below the link to the INDICO page of the event.

<http://indico.cern.ch/conferenceTimeTable.py?confId=286096#20131209>

**General summary of the event and main actions for the future**

All presentations given during the two days meeting can be downloaded from the *Timetable* section of the event webpage linked above.

* Day 1: **Introduction to EuCARD2 WP11 and partners presentation**

After a welcome speech of S. Redaelli, A. Bertarelli opened the first day of the meeting reminding he is temporarily replacing Adriana Rossi and providing a brief review of EuCARD WP8 achievements and a general introduction to the main objectives of EuCARD2 WP11. It was followed by short “WP-oriented” presentations given by the partners, in which they briefly summarized:

1. General information about themselves:

* Who they are and what they do
* Which of their capabilities are relevant for WP11

1. Work proposals:

* Present status of their studies/works in WP8
* Brief proposal for further activities (new technologies, new facilities, etc.) in WP11 and first schedule for proposed activities
* Day 2: **Tasks 11.2 and 11.3 dedicated meeting**

During the second day, the meeting was devoted to tasks 11.2 (*Material testing for fast energy density deposition and high irradiation doses*) and 11.3 (*Material mechanical modelling*), i.e. CERN, GSI, Politecnico di Torino, RHP Technology, KUG, BrevettiBizz. Each partner presented possible contributions and work proposals related to these tasks.

At the end of the talks, A. Bertarelli reminded that he will inform all partners by email on date and place proposed for the next WP11 meeting, also based on the outcome of the 3rd EUCARD2 Steering Committee Meeting (Daresbury, 12-13 December 2013).

In the afternoon, a dedicated session to additional discussions among the partners closed the second day of meeting. The present status of the work and the list of higher priority actions were discussed, the role and the contribution of each partner were agreed and a preliminary roadmap for future steps was outlined.

A. Bertarelli and S. Redaelli proposed an aggressive schedule for the collimation objectives at CERN:

* + **Mid 2014:**
* Complete R&D of new Secondary Collimators (TCSx) for HL-LHC, choosing a novel low-Z material (such as Mo-Gr or Cu-CD)
* Investigate alternative, more robust materials for Tertiary Collimators and Absorbers
  + **Early 2015:**
* Design, build and install a test bench for one or more HL-LHC Collimator full jaws in HiRadMat2
  + **Mid 2015:**
* Final design and manufacturing of a full TCSx prototype (min. dimensions of the active jaw inserts: 125 x 40 x 22 mm)
  + **Early 2016:**
* Installation and first tests of the TCSx prototype in the LHC.

A. Bertarelli reminded that it is important to complete the knowledge base on the materials already developed and considered as the most promising (namely Mo-Gr and Cu-CD).

In this respect it is essential to gather additional information on the behavior of novel materials behavior under and after irradiation: **GSI** offered to carry out a comprehensive testing campaign on this subject, profiting of the ad-hoc facilities available at GSI.

M. Tomut stressed the timing constraint due to the shutdown at GSI scheduled for 2015: it means that high energy irradiation has to be performed by the end 2014 and low energy irradiation may no longer be available after 2015.

A detailed program and list of specimens required is provided at the end of this document (*based on information provided by M. Tomut after the meeting*) (see action list).

**RHP Technology** confirms that, by mid of February 2014, new Cu-CD samples can be produced for irradiation tests in line with requirements specified by GSI

RHP Technology might also be asked to provide some sample of ceramics materials to investigate as potential materials for tertiary collimators, but not before summer 2014.

**Brevetti Bizz** (who is not formally member of the EuCARD2 collaboration, but with whom CERN established a Partnership Agreement) also confirmed that they will continue the development phase on Mo-Gr in view of providing specimens of the selected material grade in time for GSI tests.

Always on the material irradiation tests, **NRC-Kurchatov Institute** is preparing a report on the results of irradiation tests on Cu-CD and is to provide additional reports on Mo-Cu-CD and SiC in the coming months.

An additional collaboration (formally out of EuCARD2 program) has also been established with **Brookhaven National Laboratory** to irradiate and analyze in their facilities samples of Mo-Gr and Cu-CD, along with pure Mo and Glidcop initially in the frame of the U.S. LHC Accelerator Research Program (US-LARP).

**Politecnico di Torino** is actively involved in the material mechanical modelling. From the experimental side, they are investigating Inermet180 and Molybdenum. L. Peroni proposed new spallation tests, reducing sample size from 10 x 10 to 8 x 8 mm and performing tests at high temperature. First, Polito will continue to do tests on graphite specimens in order to make sure that the method works very well with brittle material. Once it is well established, other metal-diamond composites might be analyzed. In Avril-May 2014 Politecnico will be ready to define more precise sample size.

No additional simulations are required by Polito before performing these tests. Simulation will be carried out at CERN by F. Carra (PhD) concerning the development of the collimator design and by E. Quaranta (PhD) for the identification of new scenarios to simulate and, consequently, the specifications required for collimators.

D. Deboy, on behalf of **Graz University of Arts** (**KUG**), proposed to study the response of microphones during the heavy ions impact on materials. The microphone system, for example, might be easily moved to GSI, where they use pulsed U beam. However, it must be checked that the beam intensity is enough to generate after the impact a shock wave strong enough to be recorded by the microphones.

From **University of Malta** side, there is the possibility that a new student may join CERN in order to continue the collimation studies of M. Cauchi and G. Valentino.

Moreover, **University of Huddersfield** will shortly submit a proposal for collaboration.

During the fruitful discussions, a few points emerged which deserve further clarification and understanding.

First of all, it must be understood how to extrapolate the results of the tests (in terms of dpa) to higher energies. M. Tomut replied that it is not simply a matter of dpa (displacement per atom), because the damage is strictly dependent on the target material and on the irradiating species: when increasing the energy of the impacting beam, non-linear clustering behaviour occurs in a different way depending on the material in analysis. Simulations are trying to quantify the damage, but from the experimental point of view the question is not answered yet.

A first proposal could be to test at different energies one material at a time and then extrapolate the trend as function of energy for that material. Then, the same procedure must be repeated for the other materials.

Another important point, stressed by S. Redaelli, is the need to converge about the definition of the Equation of State (EOS) for the analyzed materials: although it is not entirely in their tasks, Politecnico di Torino offered to collaborate with other partners (especially Kurchatov Institute) to build the EOS: this objective appears definitely much easier to reach for pure materials than for the novel composites.

To conclude, all the partners agree on the creation of a working team which actively and strongly cooperate to solve these outstanding issues in relatively short time.

**Short-term Action List:**

1. **GSI**: Irradiation campaign on Mo-Gr, Cu-CD and Carbon-Carbon specimens, in two blocks (February-April and July-August) plus a Pb irradiation in September.
   1. High energy ion irradiation (~300 MeV/u) for thermal conductivity measurements:
      1. **Carbon–Carbon**: discs Ø10 mm x 2 mm – **40 specimens** by **20.02.2014** for each orientation (only 10 of each orientation will be used in February irradiation)
      2. **Cu-CD**: discs Ø10 mm x 3 mm - **5 specimens** for high energy Pb irradiation in **September**
      3. **Mo-Gr**: discs Ø10 mm x 3 mm - **5 specimens** for high energy Pb irradiation in **September**
   2. Tests at high irradiation doses on two materials (Mo-Gr and Cu-CD) in **February-April 2014** for Au and U and in **July** for Au.
      1. Thermal conductivity measurements degradation monitoring (on-line qualitatively at the first approach, we need to develop a model for a quantitative approach):
         1. **Cu-CD**: Ø10 mm x 1mm - **20 specimens** (5 for 19.Feb-09.March experiment, the rest for April and beyond)
         2. **Mo-Gr**: 10 mm x 1mm - **20 specimens** (5 for 19.Feb-09.March experiment, the rest for April and beyond)
      2. Off-line in-plane thermal diffusivity as a function of fluence:
         1. **Cu-CD**: Ø 20mm x 30 µm - **5 specimens** for 19.02.2014–05.03.2014 plus **10 specimens** for Au (or Xe beamtime) irradiation up to 07.04.2014 or for the second beamtime block starting from 07.07.214
         2. **Mo-Gr:** Ø 20 mm x 30 µm - **5 specimens** for 19.02.2014– 05.03.2014; **10 specimens** for Au irradiation up to 07.04.2014 or for the second beamtime block starting 07.07.214
         3. Hardness test (off-line mechanical characterization with nano-indentation) for both **Cu-CD** and **Mo-Gr**: **20 samples,** 1 mm-thick 10 mm-large (discs or squares, whatever is easier to produce and machine) for Au irradiation up to 07.04.2014 or for the second beamtime block starting 07.07.214
         4. Possibly, swelling measurements on carbon fibres samples (from Phase 1 and present R&D)- first for off-line test – the longer the fibres the better (fibres 20-35 mm long are possible) - 100 fibres (for statisctics)
   3. Tests at high energy fast deposition with pulsed U beam at low energy **19 February- 9 March 2014**
      1. An estimative calculation (as we don’t know if the volume percentage of diamond can be preserved for small dimensions diamonds ~ 5 µm) would give us the thickness of the foils of 30 µm for fatigue tests
         1. Ideal size **Cu-CD** is Ø 32 mm x 30 µm. If this is not possible we could work with Ø 20 mm and thickness up to 40 µm for Cu-CD – **5 samples**
         2. For Mo-Gr is Ø 32 mm x 30 µm – **5 samples**
2. **CERN** to prepare **40 C/C specimens**, discs Ø10 mm x 2 mm, by **20.02.2014.** Additionally, CERN is to prepare a number of carbon fiber samples from Phase 1 and present R&D.
3. **Brevetti Bizz** to prepare:
   1. **20 Mo-Gr specimens**, discs Ø10 mm x 1 mm available at GSI by **19.02.2014**
   2. **15 Mo-Gr specimens**, discs Ø20 mm x 30 m available at GSI by **19.02.2014**
   3. **5 Mo-Gr specimens**, discs Ø32 mm x 30 m available at GSI by **19.02.2014**
   4. **20 Mo-Gr specimens,** discs or squares 10 mm x 1 mm available at GSI by **07.04.2014**
   5. **5 Mo-Gr specimens**, discs Ø10 mm x 3 mm by **September**
4. **RHP-Technology** to prepare:
   1. **20 Cu-CD specimens**, discs Ø10 mm x 1 mm available at GSI by **19.02.2014**
   2. **15 Cu-CD specimens**, discs Ø20 mm x 30 m available at GSI by **19.02.2014**
   3. **5 Cu-CD specimens**, discs Ø32 mm x 30 m (or in case Ø 20 mm and thickness up to 40 µm) available at GSI by **19.02.2014**
   4. **20 Cu-CD specimens,** discs or squares 10 mm x 1 mm available at GSI by **07.04.2014**
   5. **5 Cu-CD specimens**, discs Ø10 mm x 3 mm by **September**
5. **Polito** to continue dynamic tests on R4550 graphite to evaluate the spallation resistance. Once the method is validate, the same setup will be used to perform tests also on metal-carbon composites.