HL-LHC Hollow Electron Lens (production) kick-off meeting

13th April 2021

Minutes and executive summary

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Agenda

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1 Introduction - O. Brüning

O. Brüning thanks **A. Rossi** and **S. Redaelli** for the organization of the meeting. He reminds the participants that the Hollow Electron Lens (HEL) became baseline for HL-LHC after the cost schedule review 2019 and is to be realized as an in-kind contribution by Russia, to be delivered by Budker Institute of Nuclear Physics (BINP). Currently, we are still waiting for a kickoff of the activities at BINP following the delays in the signatures of the agreements.

The purpose of this kick-off meeting is to make sure that all CERN contributing teams are on the same page on what is needed in terms of technical and functional specifications, and what resources are required. CERN technical teams must also be synchronized in terms of expected deliverable when the BINP team are to start the HEL activities.

A. Rossi outlines that the meeting is split into three sessions:

- The first session is dedicated to the definition of the specifications and of a reference design, and the presentation of the work break-down structure and timeline.
- The second session about the technical design as seen by equipment owners/responsible and first estimates on resources.
- The third session to a discussion on the where and how to proceed with cold testing and tests with electron beams.

2 HEL functional specification - S. Redaelli

S. Redaelli presents the functional specifications required from the collimation side. The slides presented are available in Annex 1.. The content of the talk is based on the EDMS 2514085 document that was distributed for engineering check before this kick-off meeting.

Discussion

E. Metral asks when loss spike issues appear, when we go into collision or when we are running with collisions? **S. Redaelli** answers that the HELs should provide the halo depletion functionality for both scenarios. We are sensitive to failures and to orbit jitter. Given that we go into collision at the end of the ramp, we want to start using the HEL at lower energy. We should arrive at flat top with the conditions we want.

T. Lefevre refers to the specification document and asks if the e-beam current of 5A is the only value of current to be used, as it was assumed so far by the BI team. If not, whether a range for the current could be listed in the specification document. For example, the possible use with current that is randomly changed between 0 and 5A was mentioned. **S. Redaelli** answers that the document presents an overview of schemes that were studied and clarifies that the turn-by-turn random variation of current is to be disregarded. We can run turn by turn on/off with the same current with equivalent tail depletion performance. He also clarified that clearly in operation we need the flexibility to tune the e-beam current. The range is from a fraction of A to the maximum of 5 A. We cannot assume that the device works only at 5 A. If the beam diagnostic is optimized for the maximum e-beam current, we could discuss how to accept a reduced performance at lower currents. **S. Redaelli** mentions that one other important aspect is understanding whether we can use the present diagnostics (BPM and BGC) for setup purposes with few proton bunches at 7 TeV. This information is needed as an input for the commissioning strategy. The specification document indicated this as a requirement.

T. Lefevre asks about the operational scenario, when the HEL is supposed to be used starting from approximately 5 TeV. Is it requested to have a feedback system for the electron orbit? Who is going to do that? **S. Redaelli** replies that he does not expect that an active feedback is needed. The HEL could be

used like a collimator and follow the orbit through feed-forward corrections. This is what is specified at this stage, and this aspect could be made clearer in the document. Once we understand the local orbit change in the energy range where we need to operate the HEL, we have to be able to establish repetitive functions to follow it like we do with collimators. This determined the specifications for the ramp-rate of the e-beam correctors. Adding an active feedback could be studied.

O. Brüning underlines the statement that flexibility is a key aspect for HEL. He refers to Fermilab where the HEL was installed for one purpose and finally used for many another activities in Tevatron.

O. Brüning asks what is the deadline for approval of the specification document. **S. Redaelli** answers that the first engineering check was due by mid April. A new version integrating the feedback in EDMS and from the kick-off meeting can be prepared in the timescale of a few weeks.

M. Wendt asks if in addition to the two BPMs currently specified in the document (at the beginning/end of the e-lens), we need more BPMs, for example at other locations along the electron beam. He emphasizes that this would be a big cost factor and would have maybe further implications. **A. Rossi** replies that this will have to be decided in a dedicated meeting later, where possible scenarios are discussed. **S. Redaelli** adds that the context is that we need to compensate the e-beam overshoot at entrance and exit of the HEL. It has to be seen if a third BPM could help.

Y. Papaphilippou comments that simulations are done with a single LHC beam. In order to re-fine we need to understand how to use the HEL with colliding beams. **S. Redaelli** replies that we need to make sure that active depletion is possible when the machine is most linear, which justifies that first simulations are for single beam. Hence, the simulations cover the most difficult scenario. He agrees that including beam-beam is a very important next step.

R. Tomas Garcia comments that also ranges of emittances should be mentioned in the document, also for ions.

R. Tomas Garcia comments further that we should also have a commissioning strategy and there should be a paragraph in the document covering it. **S. Redaelli** recalls that the commissioning is done with a few bunches and agrees to clarify this better in the updated document.

3 HEL Overall Design - D. Perini

D. Perini presents the HEL design. The slides presented are available in Annex 2.

Discussion

C. Gaignant asks if the Pressure Equipment Directive (PED) category of the pressure vessel was determined. This was indeed the subject of a recent TCC meeting where the proposal to move to a pressure of about 4-5 bar was brought forward for approval (see also talk be **G. Ferlin**). **D. Perini** comments that 3 bar to 5 bar is similar for this system. If we had to go to 20 bar we could maybe find a solution, but it will be very challenging.

In response to the statement by Diego that the assembly is a critical step requiring high precision, **T. Lefevre** asks who will be in charge of this work. **D. Perini** replies that the HEL is an in-kind contribution from BINP and the respective responsibilities . **A. Rossi** comments that the assembly in Novosibirsk is not easily possible, because the transport could have negative impact on the alignment. **D. Perini** adds that the initial assumption was that Russian colleagues could come to CERN for the welding and the welders could be qualified by CERN. The responsibility of the quality control is with MME supervising manpower from BINP. **A. Rossi** adds that at a certain moment we also have to specify the individual sets of measurements to be conducted at each step. Then it will also be easier to identify who is in charge of what. **J. F. Fuchs** comments that the assembly should be validated or re-measured by CERN to guarantee the final axis and avoid “bad surprises” on the girder.

R. Tomas Garcia asks by when the distance of the gap between the solenoids is finalized. **D. Perini** answers that the distance between the solenoids were defined four years ago and have not changed since

(300 mm from coil to coil). Then we have to add the helium tank and cryostat. So the free space for the beam gas monitor is 200 mm (taking into account that there are rods connecting the solenoids). The position of the rods is relatively free. The distance cannot be decreased because there is space needed for the beam gas monitor. It cannot be increased either because the loss of compression would lead to a very large electron beam dimension, potentially even touching the vacuum pipe.

4 HEL Organization - A. Rossi

A. Rossi presents the HEL organisation. The slides presented are available in Annex 3..

Discussion

M. Martino points out that external busbars not under the responsibility of SY-EPC. **A. Rossi** agrees and will correct this. **Y. Thurel** comments that cables have to involve also EN-EL.

M. Martino comments that for the magnet DC powering EN-EL should also mentioned. For HV he doesn't see why the modulator part is included. **A. Rossi** replies that HV is used as a power supply for gun and collector and the modulator is in between. **M. Martino** will discuss offline to clarify the scope of SY-EPC activities.

L.J. Tavian comments that as of today we do not plan HL-LHC infrastructure works at IP4, and therefore he sees no connection with WP17, but rather with the LHC infrastructure. On Adriana's proposal to prepare an ECR for the installation of the HEL, **L.J. Tavian** comments that it is not foreseen to do individual ECRs for each HL-LHC item but rather a global ECR for the transition from LHC to HL-LHC. **A. Rossi** answers that another format could be found, but it is important to look consistently at all what needs to be done for the HELs. **P. Fessia** comments that there are three different documents in three phases coming. We would have a first document where all interfaces are covered. A second document is a standard document for HL-LHC: integration report for installation, which we normally produce a couple of years before installation. It's a bit premature to write an installation ECR today, because we don't have the detailed information available. There must be a document, but we can see later in which form. **S. Redaelli** adds that he agrees that it's too early for a complete ECR. He asks if there is the need for a formal space reservation. **P. Fessia** replies that the HEL will be part of the layout version 1.6 so there is no need for a space reservation.

G. Kirby asks if there is going to be a full string test. **A. Rossi** answers that we will later have a presentation by **A. Foussat** to summarize the tests that are needed.

R. Tomas Garcia asks about the magnetic measurements and outlines that it's important to have complete measurements of all magnetic components and fringe fields. **A. Foussat** replies that a full mapping of field line straightness and uniformity will be conducted, including fringe fields. We can also measure harmonics if it is included in the program. **R. Tomas Garcia** asks if the link will be WP3 as for the triplet magnets and **A. Foussat** clarifies that the responsibility will be held by the magnet group.

5 Overview of vacuum (HEL + test stand) and validation required - G. Bregliozzi , M. Ady , V. Baglin

G. Bregliozzi presents the TE-VSC contribution. The slides presented are available in Annex 4.

Discussion

A. Rossi comments that it was agreed that the responsibility of TE-VSC "ends" at the valves after the gun and before the collector, while these parts are under the responsibility of BI. Nevertheless TE-VSC will assist for the leak detection. **G. Bregliozzi** replied that the valves at gun and collectors are not in their mandate.

S. Redaelli has a question about the budget regarding the figures for the BGC: is it covered by the present WP13 activities or are these new requests? **G. Bregliozzi** answers these are new requests related to the BGC activity in WP13.

6 ABT/RF – Modulator + individual system tests - F. Gerigk

F. Gerigk presents the e-gun modulator. The slides presented are available in Annex 5. This activity can be followed up by SY-RF if the tetrode technology is adopted. **F. Gerigk** pointed out that the RF team cannot start working on this before mid 2022, and a realistic timescale could be to deliver two units by 2023-24. This timescale needs to be checked.

Discussion

A. Rossi asks on the technology depending on type and radiation levels at P4. Is tetroid the only technology that can be envisaged? Is it worth to consider a radiation shielding? Furthermore, **A. Rossi** asks if one could consider to negotiate with BINP send someone at CERN for a long term to assist in the development. Would it help the activities in the RF group? **F. Gerigk** replies that he would not exclude having a colleague from Russia here at CERN to support, but supervision from the teams busy with the machine startup cannot start before mid 2022. Regarding the technological choice, the solid-state solution is not excluded. But will it will be bigger. Even if we stay at 60kW. The shielding has to be substantial.

A. Rossi comments that the modulator location is foreseen to be as closed as possible to the gun to limit the impedance of the cables. **D. Perini** comments that the area around the gun is crowded. But not as crowded as other areas and he thinks there is margin for further optimization.

B. Goddard adds that this is linked to the requirement of 200 ns rise time. How rigid is this? **S. Redaelli** replies that this allows intra-train excitations, which is important for studies and understanding the effect of the HEL on different batches within the train. This specification could be revised now in view of the implications on the HW. **F. Gerigk** adds that if we can relax the requirement on the rise time it is helpful also for the amplifier. **M. Wendt** added that the a longer rise time would affect the reading of the BPM, that would not work beyond a certain value.

7 Instrumentation (BPM and BGC) + individual systems tests - R. Veness

R. Veness presents the beam diagnostics. The slides presented are available in Annex 6.

Discussion

R. Tomas Garcia asks what the intensity range of the BPM is. Is it foreseen to go down to pilot bunch intensity, e.g. 1e10? **M. Wendt** replies that we can go down to smaller intensities, the electronics will also work for low intensities, but we have to see how good we can separate the two frequency regimes (200ns for the electrons /1ns for the protons). He is presently assessing the lowest bunch intensity for proton and electron beams. **R. Tomas Garcia** replies that the accuracy he would like to see is the systematic error between electron reading and proton reading. **M. Wendt** replies that this requirement is clear to him.

R. Tomas Garcia also asks if it's foreseen to have turn by turn measurement of position of e-beam? **M. Wendt** replies that this is not foreseen. **R. Tomas Garcia** mentions that in WP2 it was discussed, whether there is a way to measure the jitter of the e-beam. **A. Rossi** replies that there should be no jitters in the eletron beam position. The beam is highly magnetized by the 5T solenoid field. If the magnet line is constant, the position of the e-beam should not move. We are assuming that e-beam is stable and there is no movement of the electrons in the beam. Jitters in the electron beam intensity will be checked at the test stand.

T. Lefevre comments that on proton side there are not many limitations except that there is no

bunch/bunch or turn/turn measurements. For electrons, also related to the modulator parameter, is the rise time. We can only measure the position of electrons at the beginning and end of the pulse unless we add some dedicated modulation in the current, which is under consideration. There is no mean to identify whether there are fluctuations of the positions along the DC electron beam. The measurement is only available at the transient times. We have to consider e-beam as fully reproducible and stable. **R. Jones** mentions that one could get it from the BGC, where one will clearly see if the electron is moving. We should not go for an additional modulation if not clearly needed. **S. Redaelli** agrees and mentions that the specifications were driven by collimation needs. We have to find equilibrium (also for modulator) between what is strictly needed and what is nice to have. For collimation purposes there is no need to have pulse to pulse measurement of the electrons.

8 Electron Gun/Collector + individual systems tests and summary on resources for the Electron Beam Test Stand - A. Rossi

A. Rossi presents the test stand. The slides presented are available in Annex 7.

Discussion

G. Arduini asks if we can measure the shape of the e-beam at the test stand and how we characterise the e-beam. **A. Rossi** replies that we can measure the shape, and spacial distribution of e-beam at extraction (and check homogeneity), with a YAG screen and a movable Faraday cup and, further along the test stand, with BGC. We cannot observe the e-beam after compression as at the HEL (we do not have the magnetic field strength necessary). **G. Arduini** asks if this can answer the questions on e-beam stability raised before. **A. Rossi** answers that this can not be achieved easily, larger beams means lower electron density. Furthermore at the test stand we do not have the bends as in the HEL, which could cause deformation of the e-beam or changes in distribution of velocity.

Action: A. Rossi : - check possibility of measuring pulse-to-pulse stability at test stand.

Y. Thurel asks about support needed from SY-EPC at the test stand. **A. Rossi** answers that the power converters needed at the tests stand are purchased separately from SY-EPC and that there is no need for their support.

S. Redaelli comments that the aspects related to the e-beam current stability should be tested at the test stand, assuming that the final modulator is used. Imminent test using a different modulator will not be conclusive. **A. Rossi** confirms that the test stand will remain available to test the final modulator.

J. F. Fuchs asks if there will be requests to the Survey team to align the test stand. **T. Lefevre** mentions that the support is needed to have realistic conditions. **A. Rossi** replies that it would be good to have.

M. Martino asks about the 5 A/15 kV if this is the worst possible configuration. **A. Rossi** replies that this is the case.

M. Martino points out that presently is is not planned for SY-EPC to provide a complete set of power supplied for a complete cold test facility, but only a few units for individual magnet tests.

R. Tomas Garcia asks what defines the possible azimuthal asymmetries of the e-beam. **A. Rossi** replies that this is determined by possible instabilities of the electron beam that are assessed in simulation (this should be negligible for the present setup with 5 T).

SESSION 3: TECHNICAL DESIGN AS SEEN BY EQUIPMENT OWNER/RESPONSIBLE AND FIRST RESOURCE ESTIMATE

9 Magnets, magnet detection and cryostating and tests - A. Foussat M. Wozniak G. Ferlin

A. Foussat presents magnets, magnet detection and cryostats for the HEL.

The slides presented are available in Annex 8.

Discussion

R. Veness refers to slide 26 and asks who "owns" the issue of integrating the BGC in the gap. **A. Rossi** answers that technically she owns it, but that it will be solved in collaboration between MME, MSC and the BGC team. It's being looked at as first priority. This is one of the activities where **A. Foussat** will have to work rather towards a detailed design and not a functional design. **R. Veness** agrees that the issue is not trivial. The final decision has to be taken together. **D. Perini** comments that in spite of the complexity, he thinks a solution will be found.

A. Devred comments that we are only supposed to deliver the specifications to BINP and they are supposed to do the detailed engineering design. The human resources TE can invest on the magnet side will be rather scarce. Of course there are some issues for which a detailed design is needed and he's not sure how to proceed. **O. Brüning** replies the he agrees. The discussion on required resources before the HEL became baseline concluded that there were no resources in the CERN magnet group MSC to do the design. The agreement was that it should be a 'build to spec' agreement with BINP. **A. Devred** and **O. Brüning** also emphasize that if there are further delays, we could not meet the deadline of LS3.

A. Siemko mentions that he is surprised that we need BINP engineers on site to complete the functional design. **A. Foussat** replies that we need to have a core team looking into this. Especially if we need to assemble on site. **A. Siemko** asks why the magnet assembly of the cold masses needs to be done on site. **A. Foussat** replies that the baseline so far is to have the final assembly on site. Currently we are re-evaluating with the magnet team which parts of the assembly can be done at BINP and which part has to be done at CERN.

A. Siemko further asks which constraints led to using the lower pressure of cryostat to 4/5 bar. **A. Foussat** replies that from the beginning start of conceptual design there was an incentive to reduce from 20 to 4/5 bar. The design is compact, and the current integration spaces for pressure vessels are not compliant with 20 bar, as we have parts that won't hold 20 bar. The bellows of the current leads are the main weak point. The 4/5 bar arose from protection system simulations.

10 Cryogenics integration in IR4 - G. Ferlin

The slides presented are available in Annex 9.

Discussion

A. Siemko re-iterated the comment on the design pressure for the cryostat. This aspect needs a follow up at the TCC and a final decision.

11 HEL powering system - M. Martino

The slides presented are available in Annex 10.

Discussion

Following **M. Martino** remarks on the fact that the HV system function specifications present in EDMS are obsolete, **A. Rossi** comments that for the HV part there was an intense exchange of emails with SY-EPC. She added that 5 A is indeed the maximum e-beam current, but that pulsing the beam with just the

power needed with the steady state beam would be dangerous, since more power may be required due to oscillations induced by the pulsing. 7A value is an estimate. Therefore we want to do tests of the HV at the test stand.

M. Zerlauth asks with regard to slide 11, showing the latest evolution of powering and protection baseline. This is different from what WP7 currently assumes as a baseline. At a certain moment, WP7 has to finalize the protection baseline.

A. Foussat asks what is the time line to have power converters available for the HEL testing. **M. Martino** answers that individual magnet tests, can be done with a few converters. A test of the electron beam requires the complete system. **Y. Thurel** comments that all the converters that are going to be recuperated from the LHC will not be available before LS3.

12 Integration - J. Oliveira

The slides presented are available in Annex 11.

Discussion

L.J. Tavian has a question regarding the connection between the UA and the LHC tunnel. Will it be possible to use the existing horizontal core or do we have to create a new one? **J. Oliveira** answers that for the UA we can use the passage over the UG, on the top of the UG there are some horizontal cores that are available for the cables that are connected to the UA side.

13 HEL metrology assembly activities and alignment in IR4 - J. F. Fuchs

The slides presented are available in Annex 12.

Discussion

R. Veness asks if there is a new document sent around for approval of the SU guidelines. **J. F. Fuchs** answers that the document in slide 3 is in approval process. It will be published in some weeks. **R. Veness** answers that the equipment groups should be able to comment on it if they have to respect the requirements.

M. Wendt comments that two BPMs are located inside the warm bore of the main solenoids, and they are not accessible for alignment. Is there any alignment procedure for the BPMs foreseen? **J. F. Fuchs** answers not yet, and that following the requirements SU can work with BINP how to do it and who does it. **A. Rossi** comments that **J. F. Fuchs** has recently started to work with the HEL and everything else. We haven't yet come to specifying this.

T. Lefevre comments that we have in the specs document some requirements for accuracy for BPM and BGC. Unless there is a change we can use that one. **J. F. Fuchs** answers that we need to define the full list of workflow.

M. Wendt adds that the BPM has to slide in the beam tube inside bore of magnet. We need to support this in some way. The pipe of the bore is defining the alignment of the pickup. Alignment of the center of the pickup needs to be measured before sliding it into this bore. **T. Lefevre** asks to which precision we need to align. **R. Tomas Garcia** comments that in the presentation 200um were mentioned and in the document it says 500um. **R. Jones** comments that the alignment between beams is a different requirement than the alignment between components. Once installed, the BPM will not be moved independently of the HEL. The relative accuracy is more important than the absolute positioning.

14 Tunnel infrastructure, cabling, installation - L.J. Tavian

The slides presented are available in Annex 13.

Discussion

A. Rossi comments that there is a budget foreseen for the integration but a full accounting of all services needs to be done and the required budget need to be sorted out.

L.J. Tavian answers that parts of this project could be transferred to another existing work-package. The project has to define how to structure it and where the different components should be put. **O. Brüning** mentions this should be done together in a dialogues.

SESSION 4: MEASUREMENTS, TESTS AND ASSEMBLY

A. Rossi discusses the need to have the assembly of the magnets and the magnet cold measurements at CERN. She also presents the test stand and what type of tests could be potentially done. She shows e-beam profile measurements made in particular at RHIC during the tests with hollow cathode, and how the beam could be unevenly distributed if the set up is not done correctly. Moreover she shows the simulations on e-beam transport and the needs of measuring the position of the beam at the entrance of the main solenoid to make sure that the insertion in the LHC beam line is smooth and does not cause large residual kicks.

Discussion

O. Brüning raises the question why the HEL can't be constructed in Russia and brought to CERN in assembled state. **S. Redaelli** asks if the installation of the BGC must be potentially done at CERN are can be done in Russia: this should be taken into account for the final decision. **T. Lefevre** answers that the UK should deliver the BGC to CERN, so in theory it could be shipped to BINP for mounting. **B. Di Girolamo** insists that the option of assembling the HELs in Russia should be kept on the table and discussed with BINP. **A. Foussat** points out that the ultimate responsibility is with CERN, and there has to be the possibility to understand the sub-components. **A. Siemko** mentions that the triplet magnet are more complex and are shipped to CERN already cryostated.

Regarding the overshoot of the electron beam at the transition between gun and solenoid, **M. Wendt** comments that in a complete test facility we would have nothing that can assess the e-beam position at this locations. We would only have a YAG screen at the center and the BPM at the beginning/end. Then we have a strip line which is not at the location of the max excursion.

R. Jones adds that the longitudinal distance of the overshoot is anyway probably to short to be measured precisely by the BPMs. He also notes that an offset of only 0.13mm is probably too small to see difference between edges and centre of the HEL. **M. Wendt** argues that if we had four BPMs (two at the center and two at the entrance/exit), and add an intensity modulation over the pulse, we could monitor some changes. But this requires an alignment of these BPMs and the addition of instrumentation that is not foreseen. **T. Lefevre** comments that he doubts that two BPMs can be installed close to the location of the overshoot. In conclusion, it will be very hard to assess this effect in a test facility.

M. Wendt asks what can be tolerated in terms of this overshoot. **S. Redaelli** answers that the s-shape of the design is set up to self-compensate this component in the first order. Tolerances need to be assessed with simulations. This needs to be re-assessed by e-beam simulations by BINP.

Y. Papaphilippou asks if we can measure the fluctuations of the e-beam and also understand the impact on the proton beam. The Tevatron experience shows that this fluctuation was important to be controlled up to a level of 1%. **S. Redaelli** replies that the e-beam current stability pulse to pulse depends on the stability of the extraction voltage, which could be tested at a simpler test facility. **A. Rossi** argues that the transverse position stability should be minimal for the final lenses. **Y. Papaphilippou** adds that he does

not only refer to pulse to pulse stability, but intra-pulse stability as well. **S. Redaelli** comments that for the effect on noise we had random kick applied to core. The study was done independently of the real field, scanning the kick to determine a tolerance value before seeing emittance blowup.

R. Jones asks if RHIC/FNAL tested their complete system on the surface before installation on the machine. **S. Redaelli** answers that to his knowledge this was not the case. RHIC had a test stand in which they re-used superconducting magnets to test components (see this article), then tested the final assembly after installation. FNAL uses a warm test facility that was also used to test CERN guns.

R. Jones stresses that one should identify what can really be gained from a full e-beam facility. First of all, it is even not sure that there will be time to re-act, in case issues were found (which is not clear from the discussion on the available beam instrumentation). We need to find converters and other items to install, which will result in an overhead. All components are anyway tested individually. If we cannot demonstrated a substantial gain from a test stand, we should consider testing in the HEL in 2026 as initially planned. **O. Brüning** adds that there is a long period in which the lens is installed in the tunnel, but not yet used. **S. Redaelli** recalled the baseline strategy established a few years ago after assessing pro's and con's of a final test facility at CERN (following discussions with BNL and FNAL): testing components at the warm test stand and commissioning the electron beam directly in the tunnel . The new element that could be now taken into account is the availability of space at the blg 180 facility, which we were not aware of back then and could allow tests with less resources than what was estimated in the past by H. Schmickler.

A. Siemko comments that he doubts that the testing of the full assembly is compulsory. Certainly, this is the case for the magnet system. **A. Rossi** agrees that it is only compulsory to test the individual components.

On testing the full setup, **G. Arduini** comments that the comparison with RHIC and Fermilab is only possible to a certain degree because of the different applications of the electron lens compared to LHC. We should try to identify what we are really worried about and then find out how we can measure it with the lightest setup possible.

A. Siemko comments again that the system could be assembled in Russia. There was previous experience with the inner triplet magnets. **O. Brüning** replies that we can ask the colleagues at BINP what they think the implications of an assembly in Russia would be.

B. Di Girolamo recommends to not drop the option of having it assembled in Russia. **A. Foussat** comments that it's also a matter of responsibility. They are the responsible owner of the system, he would be uncomfortable to receive the fully assembled and untested device from BINP. What he thinks would be acceptable is to test each individual magnet and then ship in already in cold magnets. Alternative is that they conduct the assembly at CERN and we follow each step of assembly and alignment in order to prepare taking over the ownership.

O. Brüning comments that we should carry out a cost/benefit analysis. He recalls again that the device was incorporated as a full in-kind contribution. If the testing and assembly conducted at CERN would require too much budget we could jeopardize the whole plan and risk to lose the HEL for HL-LHC. **A. Rossi** answers that we could ask BINP if they could do a full test. But since we provide the power converters we would have to ship them there. **O. Brüning** replies that cost like the shipping of the power converters should be taken into account in such a cost/benefit analysis. **D. Perini** recalled that they have a facility limited in size, only for individual coils. He believes that this option will not be easy to implement.

M. Zerlauth adds that we should discuss with the planning team what would be possible to be done in Point 4. **O. Brüning** recalls that the present operational assumption is not to use the HEL in the first year of Run 4. The system will be fully connected but not used in operation, and electron beam tests could be organized in the periods without protons. **S. Redaelli** agrees and recalls that this was indeed the planned strategy. **G. Arduini** stressed again the need to define what we are worried about and how we can test to make sure these concerns are addressed.

15 Conclusions - All Participants

A. Rossi and **O. Brüning** conclude that it was a very productive meeting with lots of information. **O. Brüning** adds that we should re-launch a similar meeting with the Russian collaborators.

A. Siemko adds that it is first necessary to define what to expect. **O. Brüning** replies that all was well defined in the morning session. We only have to further distinguish between imperative items and nice to have items.

A. Siemko adds that it should be clarified what is expected from the different groups and who is the owner of the individual items. **A. Rossi** replied that the magnets by default belong to the magnet group. **O. Brüning** comments that the magnet group must have all the drawings and documentation required. To be able to maintain it afterwards. The drawings have to be delivered in their standards. A colleague from BINP can come to CERN to make sure that everything can be delivered on the required standards. CERN must be able to intervene on the hardware afterwards.

16 EXECUTIVE SUMMARY

This section summarizes the salient actions emerged at the kick-off meeting and brought up in the different discussion sections.

- Update the functional specification document (**S. Redaelli** for the WP5 team). The following points, in particular, emerged at the meeting. Additional aspects are reported in the EDMS document following the first engineering loop.
  - Clarify commissioning strategy and more explicitly the electron and hadron beam parameters for commissioning scenarios of the HELs;
  - Clarify the alignment requirements: overall for the HEL as input to survey; absolute and relative (protons vs electrons) accuracy of the BPM system.
  - Clarify the needs to operate with electron beam at currents lower than 5 A, as input for the beam instrumentation presently design for 5 A only. The lowest limit of proton current that the BGC can measure needs to be assessed.
  - Define longest acceptable integration time depending on the type of operation.
- Finalize the assembly strategy for the HELs and its instrumentation (e.g., the BGC provided by UK), comparing the scenarios based on assembly at BINP and at CERN (**A. Rossi** , **D. Perini** , **A. Foussat** with input from other teams). Identify argument for the preferred solution based on an assembly at CERN supported by manpower from BINP, to be trained (e.g., qualification of welders by MME);
- Evaluate pro's and con's of a cold electron beam facility at CERN as a risk/cost benefit exercise (**A. Rossi**). This should take into account the open points in the present design, if/how dedicated measurements at the test stand can address the issues (e.g., identifying needs for additional instrumentation). Can such test stand allow improving the design prior to the installation in the LHC? The test stand scenario should be evaluated against the possibility to measure the final HELs in the LHC after installation, before the start of the run or during the first year of operation. Note that this evaluation should consider the availability of converters.
- Review specifications for the modulator (**S. Redaelli**) and assess the compatibility of the timeline proposed by the RF group versus the HEL masterplan and the testing needs at the warm test facility (**A. Rossi**). Assess commercial solutions fulfilling the present modulator specifications.
- Establish a beam test planning for the warm electron test facility at CERN (**A. Rossi**). Points emerged in the discussion are:
  - Validation of the final, small cathode design gun and confirmation of the target output current of 5 A at 10 kV;

  - Stability of the electron beam current over a pulse and pulse by pulse, with the final modulator technology;
  - Homogeneity of the electron beam at the exit of the cathode;
  - Final beam diagnostics: BPMs and BGC;
  - Validation of the collector through a test of the prototype

- Discuss with the planning team a strategy for testing the electron beam in P4 prior to the start of proton beam operation in Run 4 (**A. Rossi** , **S. Redaelli**).
- Provide simulations of the electron beam with the final magnet arrangement with optimized overshoot at entrance and exit of the HEL (**A. Rossi** through the BINP team).
- Finalize the documentation for the final choice of the design pressure of the HEL cryostat, with input to **C. Gaignant** (**A. Rossi** , **G. Ferlin** and TCC).
- Overall assessment of resource taking into account the new inputs and updated figures from various sub-system. Report to the project management (**A. Rossi** , **S. Redaelli**).
- Produce a rough planning to check availability of components as needed for tests and installation (**A. Rossi**)
- Finalize the WBS, identifying responsibilities and equipment ownership of different groups and WPs (**A. Rossi**).

Minutes reported by **P.D. Hermes** , **S. Sadovich**