Review of clean room procedures for the HL-LHC Crab Cavity Program

Reviewers:

John Mammosser, ORNL (chair); Stephane Berry, CEA;
Vittorio Parma, Mathieu Therasse, CERN

The review committee would like to thank all presenters in this review, the presentations were well organized, structured toward the charge to the committee and were adequate to generate significant discussion on the critical topics. It is a difficult task to communicate a projects strategy in a single day, job well done.

The review committee would also like to thank Frank Gerigk for intrusting us with this important review topic, the review committee members are strongly in support of the projects success.

General Comments:

- The reviewers are aware that there is a small window of opportunity to complete the first RF test of the Crab cavities with beam and to meet this goal it requires a single pass effort. The review committee supports this approach given the limited opportunities to achieve this goal

- The technical team is appropriate and with gained experience should lead to a success for the crab cavity project

- The reviewers were very impressed by the material presented all indicating a large effort has been made by the project team in developing a coherent plan consisting of tooling, assembly concepts and critical areas of concern

- The reviewers take note that a big effort still remains in finalizing the necessary infrastructure and tooling. Therefore we support carrying out project tasks and identified tests as soon as cavity is available except when jeopardizing quality

- It would be valuable to identify dedicated additional resources to help implement and qualify the proposed assembly methodology.

- The overall program and schedule look reasonable as long as a strong coordination is providing to reduce any impact from delays from critical path items.

- Technical staff should start training on key assembly steps with either mock-ups or real components such as the valve, coupler and cavity before attempting the real assembly in order to adjust assembly steps and gain experience quickly

- **Decisions must be driven by data gained from simple experiments**

- The scope of the work is very large and the organisational plan for production was not addressed. The reviewers feel this point could have an impact on achieving the schedule and therefore we recommend this be addressed as soon as possible

- The reviewers feel that given the tight time frame that the end result of this effort must be a detailed document that accurately describes the steps taken and for the completion of the crab cryomodule test. This will serve you much better in the future then developing written procedures at this time. At the end of the project there should be a lessons learned discussion capturing the changes identified during the process to improve production on future tests. This document will serve as a path to improving, retaining and developing assembly steps as more experience is gained. And should lead to formal procedures for production series in the future.

Vacuum and bake out vs workflow

- As suggested in the meeting having a vacuum expert involved in the project is recommended by the reviewers

- After careful consideration we feel active pumping should be in place during RF cold test of the bare cavity. This step will aid in verification of the cavity performance while minimizing multipacting

    - If you pursue active pumping, cryopumping of the pipe first can be achieved during the cool down with little effort

Vacuum and bake out vs workflow

- Critical components must have Low temperature baking at least once (cavity, HOM, FPC, RF field antenna) to maximize success

- The string can be vented with N2 but only if particulates contamination from the gate valve and pumping system is verified to not be a risk to performance

Alignment

- After careful consideration of the alignment scheme our conclusion is that the stiffness trolley as seen in presentation material should be sufficient to cope with misalignment of the bottom rails and would not affect the relative alignment between the cavities

Charge to Reviewers: Assembly procedures (including assembly for vertical cold tests)

- Assembly procedures as presented were adequate to achieve the overall goals for beam testing the first crab cavities in SPS, however the methodology must be verified by simple quality checks in order to gain confidence and experience

Charge to Reviewers: Handling procedures

- Reviewers presented a clear methodology and coherent plan. Much work is still needed to develop confidence and experience to be successful. Several options to handling and assembly steps were discussed during the review and many of the answers can only come from experimentation and data.

Charge to Reviewers: Clean room workflow

- Presenters described a clear production work flow which was heavily discussed through out the review.
- Management of interfaces will be crucial considering the number of teams involved and different projects underway
- Component storage outside the cleanroom will be difficult given the space requirements for components and subassemblies preparation
- The work flow of individual components was excellent and the focus is in the right place

Charge to Reviewers: Installation of fundamental power coupler and HOM couplers

- A clear plan was presented on these topics. Detailed procedures have been presented with a few areas needed to identify best practices. This should be developed with testing

Charge to Reviewers: Cleanroom tooling

- Tooling for all cavity critical procedures have been presented and are in the right direction towards developing a way to accomplish the goal

- More work is needed to apply these tools in a successful way to achieve the goal of contamination control and ease of assembly. Additionally further effort is needed to flush out interfacing of tooling with all identified steps as well as facility setup
  - N2 gas
  - Vacuum equipment and use

Charge to Reviewers: Transport issues into the clean room and transport in the clean room

- Handling means within the clean-rooms are well identified but the transfer of equipment from one work place to another was not specifically discussed in detail to fully understand if adequate interfaces and tooling are ready

Answers to presenters questions

- This is an attempt to answer *your questions!*
- Comment on points discussed during the meeting

T. Jones

How to prevent fastener cold welding?

CEA use either sliver coated screws (H or CHC head) or electropolished SS stud with CuNiSi nut

SNS and Jlab use both silverplated (mostly valves) and SS with CuNiSi (nuts and nut plates)

Filtered nitrogen or filtered air in re-circulating cleanroom?

Filtered nitrogen from boil of Dewar is preferable method and employed at many labs

Voltage/polarization settings of blow off gun?

There should be no difference

Is UV inspection of components required?

NO, not routinely, but can be applied in identifying candidates sources for contamination (troubleshooting)

Best method of beamline vacuum component storage?

If copper plated under vacuum or dry nitrogen

If no copper: plastic caps can be used minimizing hardware

Plastic bags for long storage are worthwhile

In laminar flow drying and waiting for assembly

General Guidelines

Personnel gowning is not exactly reverse procedure "try to keep cleanroom suit dust inside until out of the clean area"

Ultra Sonic Power should be > 10 W /l at DESY; 20 W/gallon USA, this can easily be measured

Particulates count threshold:

CEA use **1/3** of the ISO compliance concentration (ex.: with 28,3L/min ISO4 give 29 counts; not more than 10 particles/min of size ≥ 0.3µm are allowed)

SAS with laminar flow is good idea for production

A. Castilla

The reviewers were very impressed that ΔTOC and particle counts were used as quality control for the HPR, Job well done

The reviewers believe using the same robot for multiple tasks is the right approach as opposed to having additional tooling or using the table for assembly

We strongly recommend the cavity should be leak checked in ISO5 as opposed to on vertical insert

The robot lifting fixture interface to tooling should be designed to minimize friction and thus contamination

When connecting the cavity to the test stand the use of portable cleanroom with a particle counter and N2 gun are highly recommended to ensure particulate control. Active pumping is recommended, take care of the delta P when opening the cavity valve

Additional protection in ISO5 on the blind flange of the angle valve can help to reach cleanliness level when making connection in test stand

A. Castilla

- The sequence after qualification test should be to isolate the cavity vacuum bring into ISO5 for venting to nitrogen and removal of flanges for helium vessel welding
- Interfaces should be worked out among the various groups to facilitate success

E. Montesinos

- Vacuum supports for HOM and antenna can be used to bake out components inside clean room with silicon heater for example
- The simulation of the cavity for HOM assembly tests can be used with a hole for particles counter at the bottom
- Stainless Steel Sliding parts as far as possible from the aperture is a good approach, this can also be accomplished by N2 flushing plus simple guides on the flange should be good enough
- The reviewers recommend ensuring that the helium tank is suitably clean for ISO4 or protected from cross contaminating cavity and cleanroom

- Reviewers support testing the center flange alignment positioning the double wall pipe instead of the FPC flange
- Discussion on load transfer: silicone blocs under vessel flange might help make a soft contact, or FPC can be assembled to a gimble above to allow 3 degrees of freedom
- The protection of DWP should be used to flush during FPC assembly to reduce contamination (T23)

- The FPC protection cover is a good approach and shows the particulate control concern is in the right place
- When flushing the cavity with 20L/min flush a cap with no hardware might generate contamination due to vibration

A Macpherson

T22 : is N2 flushing plan ok, discussion of your proposal after closeout

T26 : 10-6 mbar enough ? It would be preferred to pump to 10-8 to increase sensitivity

T32 : the particulates contamination of the gate valve with the cleanroom pumping system has to be verified to know the risk

Pressurizing with nitrogen during string assembly: team should develop a sequence for the SA using pressurize N2 to accomplish SA with minimum impact for contamination (for ex. Preparing the partially dressed cavity)

Bake out the string: reviewers are not recommending

Should we expect "ISO4" ready bellows from supplier: these must be checked to gain confidence with vendors quality

Is vertical end valve subassembly the best way: is likely to be done correctly in this comfortable position.

Is N2 Boil is considered preferable: Yes, provided safety can be maintained

Safety is improved with compressed air but there is no experience if contamination control can be maintained

There are systems " zero air station"

Recommendation is to not use gas bottles