*Nb3Sn IR Quadrupole development Plans*

**Preliminary considerations for case #3: 150 mm aperture and half length coils**

*Version 2, June 4, 2012*

During the last LARP/HiLumi collaboration meeting, we decided to focus on the “case-3” scenario (150 mm aperture and half-length coils) for the next phase of planning discussions. This note presents some preliminary considerations relevant to this case.

References:

[1] “Nb3Sn IR Quadrupole development planning notes”, version 6, March 29, 2012

<https://plone.uslarp.org/MagnetRD/TDWG/2012-03-29/Planning-Notes-V6.docx>

[2] “Risk analysis, milestones and backup options for case 4b”, version 2, March 29, 2012

<https://plone.uslarp.org/MagnetRD/TDWG/2012-03-29/Case4b-analysis-V2.docx>

[3] “Large Aperture IR Quadrupole Development”, May 8, 2012

<https://indico.fnal.gov/conferenceOtherViews.py?view=standard&confId=5072>

Background

* We determined that the main challenge for case-4 (150 mm aperture and full-length coils) is completing a prototype based on 8-10 m long coils with sufficient schedule margin before the start of production. Therefore, the project would have to make significant commitments in the absence of a direct performance demonstration, and it would be difficult to incorporate changes based on the prototype test results.
  + A related issue is completing the 150 mm aperture short model on a time scale that would make it relevant to the design/fabrication of the long prototype
* The use of half-length coils removes these difficulties, since the performance of Nb3Sn coils close to 4 m length is already demonstrated by LQ/LR tests, and the LHQ is expected to confirm/extend these results to 120 mm aperture around 2015. By 2016, we should also be able to demonstrate the performance of “double length” HQ and LHQ models, and the performance of a short model of the 150 mm aperture design. Based on these results we would be able to confidently start construction. In parallel, a “tunnel-ready” prototype would be fabricated and tested before starting the assembly of the production coils.

* + The double-length LHQ will also provide a backup/alternative solution for 120 mm aperture in advance of the start of construction

Similarities and differences with respect to case 4 (150 mm aperture and full length coils):

* Several key elements of the case-4 plan are still relevant and can be incorporated in case-3. In particular, (a) 150 mm aperture short model plan; (b) considerations on resource availability/requirements; (c) timelines and options for prototype design and construction. In these areas, there are only some minor, and mostly positive, differences in perspective:
  + In case 4 it was critical to speed-up the short model development, so that the results could be relevant to the full-length prototype development. With half-length coils, this is not required and the plan presented in Ref. [3] can be used without modifications. This removes the resource conflict due to LS1 at CERN, and the current LARP activities aimed at the technology demonstration
  + In case 4, we considered splitting the prototype development into a fast-track full-length model aimed at demonstrating the cold mass performance, and a tunnel-ready “pre-series” including all accelerator integration features. In case 3, we use a combination of a short model of the 150 mm design and a double-length (4+4m) model of the 120 mm design (LHQ) to demonstrate all the relevant aspects of the final design. Therefore, the prototype development can focus directly on a fully integrated pre-series Quadrupole.
* Considerations and new elements of the plan specific to case 3: In the case of split coils, one can take two different approaches:
  + If the goal is to maximize the magnetic efficiency, one would try to assemble the two coils as close as possible to each other in the same structure, with the return ends facing each other. This configuration is significantly different from that assembly of a single coil. Therefore, a detailed analysis of several design aspects will be required, followed by experimental demonstration of the double-coil assembly using 1 m coils (HQ) and a second demonstration using 4 m coils (LHQ). The issues to be studied/verified include:
    - Magnetic efficiency
    - Mechanical configuration at the lead end(s): is there an additional loss of efficiency due to the space required for the leads/splices, or can it be folded into the space which is anyways required for cryostat terminations, correctors, absorbers etc.?)
    - Longitudinal pre-load: will it reach the return ends stacked against each other at the center of the magnet? Is it required anyways? A test of HQ with reduced end load might help, perhaps something to consider for HQ01e
    - Quench protection: any additional issues for the split coils?

*Note:* Studies and experience for other projects attempting to combine two half coils with maximum efficiency should be looked at, in particular the 11 T dipole

* + On the other hand, more independent assemblies have significant advantages:
    - Possibility to test the half-coil assemblies separately from each other
    - Possibility to sort half coils assemblies for field quality
    - Little performance risk going from half coil assembly to full length magnet

This comes at the price of lower magnetic efficiency (overall longer magnets for same focusing power). Therefore we will need to perform a first analysis, decide which approach we want to take, and then develop this approach in more detail

Updated schedule for case 3



Other considerations:

* Risk analysis: with respect to case 4, technical and schedule risk is generally decreased. The new schedule appears to have sufficient margin to accommodate delays in various areas without affecting the overall outcome. Examples:
  + A delay of the technology demonstration target (LHQ test) by up to 1 year with respect to the current date (Dec 2014) does not seem to affect other tasks or the decision process.
  + The Dec 2016 target for a successful test of the double-length LHQ is quite reasonable but a delay does not seem to affect other tasks or the decision process. One might argue that the successful tests of (a) LHQ, (b) the 150 mm aperture short model, and (c) the double-length HQ, demonstrate all the fundamental elements required to initiate construction
    - Note that the double-length LHQ is primarily meant to demonstrate the performance of a full-length assembly of 4 m coils with high magnetic efficiency, in preparation for the prototype assembly, which is scheduled for 2018. Also see previous comments on approach to assembly of half-length coils.
  + The construction start date of May 2017 could be moved up 6-12 months providing additional margin to the project. Alternatively, the construction start date could be left unchanged but some of the infrastructure and long lead procurements should be taken up by the pre-project allowing the construction project to start directly with line 20.
  + Additional margin of perhaps 6 months could be obtained by overlapping the end of production with the start of installation – however, this would create additional constraints. For the time being, we will keep the two phases independent of each other.
  + Installation of the upgrade in 2022 may not be required by the LHC program (however, availability of the magnets by ~2021 is important regardless of the intended installation date, if failure of current IR due to radiation forces a replacement ahead of schedule)
* Possibility of a hybrid case3/case 4 scenario:
  + If case 3 becomes the baseline, it would still be possible to retain case 4 as an “enhancement” of the baseline. In order to upgrade to case 4, one would need to come up with a plan for test of a prototype based on full length coils on a useful time scale.
    - Looking at the schedule, it seems very unlikely that one could entirely switch the production to full length coils, but as an example, one could do the first part of the production (say Q1/Q3) with half-length coils and the second part (Q2a/b) with full length coils
  + The additional prototype could be initiated around 2015, after the test of the 150 mm aperture short model and a better assessment of available funding/resources as well as the target installation date.
    - The development of a prototype based on full length coils would significantly benefit from the design of the “baseline” prototype using half-length coils, as well as for parts, mechanical structure etc. It would require longer infrastructure for coil fabrication (oven, potting chamber) and a special set of tooling
    - In this scenario, it could still make sense to procure one set of infrastructure for full length coils in the next ~2 years
  + As long as the development of the full length prototype does not detract from resources assigned to the baseline plan, this parallel development would decrease the overall risk and provide some potential for cost savings in production