2007 Proposal & Review

C Identification and Significance of the Problem or Opportunity

It is foreseen that the Large Hadron Collider (LHC) at CERN will start first commissioning of beam during 2008. Although, the operation of the LHC has not began, upgrade to the current machine is being pursued aggressively since several years. It was identified that the life expectancy of the focusing triplet quadrupoles closest to the collision point is less than 10 years due to radiation damage. Therefore, replacement of these complex magnets will be necessary circa 2015. This replacement opportunity is being developed into a major interaction region upgrade to further increase the luminosity by a factor of 3-10 (Phase I & II). This will be mainly acheived by reducing the collision point (IP) β-function to 0.25 m from the nominal 0.55 m and increase the bunch current to 0.85 Amps from the nominal 0.58 Amps.

The first meeting to address the interaction region upgrade was held in 2002 and since then several meetings were held to discuss various novel options to this enhanced luminosity goal. Fig 1 graphically represents the different categories of the perceived upgrade and several variations of each category exist.

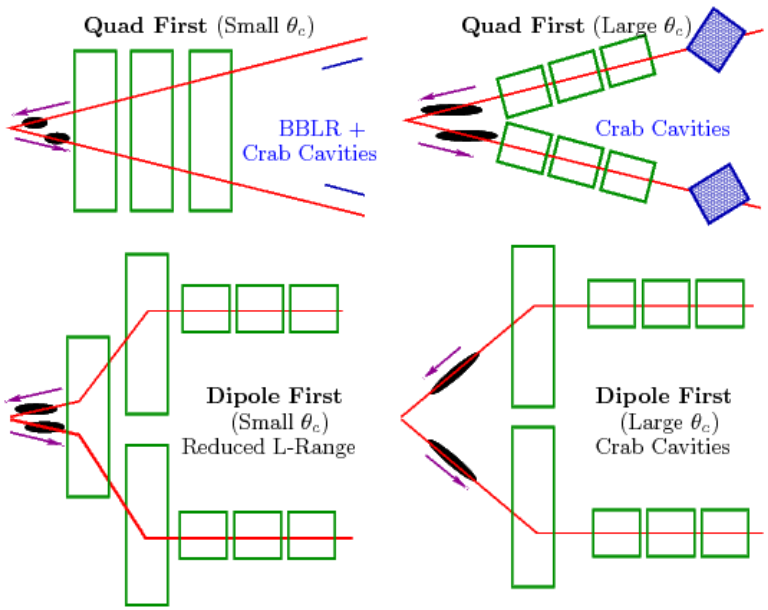

Figure 1: Some LHC IR upgrade options (courtesy F. Ruggeiro).

Criticism:

While this proposal is interesting and sound, it is not clear how the proposed activity is substantially different form the work that has taken or is taken place at other institutions.

The proposed work plan is sound but fairly routine and is essentially an engineering activity.

There is mention of exploring alternative exotic concepts, but little is said that would lead to believe that they would have substantial advantage over the conventional design

It seems, from reading the proposal, that the “scientific” and potentially innovative work would be done at BNL while the activities taking place at the submitted institution would be mostly engineering

Since the proposal is to fund the mechanical design and analysis of the cavity, and conceptual design of the cryomodule, a more developed discussion of mechanical engineering issues and approaches would have been appropriate.

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Merits:

The benefit from the proposed work could be the increased luminosity of the Large Hadron Collider, thus more efficient use of this multi-billion dollar scientific instrument. The increased luminosity may lead to discoveries in the field of particle physics, helping to understand the structure of the Universe.

The technology does have broad application to electron and ion colliders both for nuclear and particle physics and for pulse compression in light sources, enhancing their effectiveness and opening new possibilities for their application. Significant, though certainly soluble, development challenges remain to make the technology useful for most of these applications.

Beyond the physics analysis, the important issues to be addressed by the work proposed to be funded are in engineering a stable an reliable system, for example, damping of parasitic modes, and heating of components, including the cavity, input power coupler, and HOM loads, must be carefully analyzed, tuners designed, and perturbative effects of microphonics on cavity stability analyzed, leading to understanding and mitigation of limitations.

Merits:

LHC beam does not exhibit noticeable damping due to synchrotron radiation, and thus it is much less forgiving to any disturbances that could be caused by the cavities. Correspondingly, the tolerances on the phase stability of the crab cavities are much tighter than in KEK-B. Requirements on the damping of parasitic modes might also be tighter. Thus, development of the crab cavity for LHC will most likely advance the design beyond the current state of the art, and may also have possibility of a breakthrough.

The work could also lead to advances in the design of precise RF phase control, which could have wide application in various fields of science and technology. The cavity design may also have application in other colliders such as a Linear collider, or light sources for ultrafast pulse production, and facilitate other physics experiments requiring beam deflections (e.g. “streaking” the beam as a diagnostic).
The design challenges of the crab cavity itself are augmented by the challenges of integration of the cavities into LHC, where one particular constraint is the separation between the beams and the limited transverse space available for the cavities. In this situation, the applicant suggested to first focus on a crab cavity designed for the small crossing angle case. This is a reasonable approach, which have the highest chances of success.

2008 Proposal

BNL/LBL/SLAC
Cavity body design (2 Cell Elliptical Cavity)

SLAC/LBL/UK/KEK
Cavity/Coupler design

FNAL/CERN/BNL
Cryostat/Tuner design

- 4 SBIRs decided with AES (compact physics significance part underway)
- Template provided to all POCs and people responsible for SBIRs
- Provide a draft version of the 4 SBIRs by **Oct 31** to AES
- Interconnections between the SBIRs done by AES
- Compact cavities SBIR still under discussion (undecided)
- Letter of support from CERN

CERN Support Letter

Dear ...,

Following the CERN white paper initiatives and the European Steering Group for R&D (ESGARD) recommendations for the LHC Interaction Region (IR) upgrade Crab cavities are foreseen as one of the essential and effective tools for reaching the proposed increase in the luminosity. The LHC interaction region upgrade has been divided into to phases:

Phase 1 aiming at a consolidation of the ultimate performance LHC performance with peak a factor two to three higher than nominal luminosity (target timescale is to have this upgrade implemented for operation in 2013) and
Phase 2 aiming at a ten-fold increase of the nominal LHC performance (target timescale for the earliest implementation is 2016).

Two options are currently under study for the Phase 2 IR upgrade program: one aiming at a luminosity upgrade by via hardware modifications of the detector and insertion regions and one aiming at a luminosity upgrade via increased beam intensities. Crab cavities could already significantly improve the LHC luminosity independent of the upgrade phases. Furthermore the feasibility of Crab cavity operation in a Hadron collider is the prerequisite for the first Phase 2 upgrade options.

One year ago I send you a letter expressing CERNs strong interest in the development of Crab cavity technology and its strong support to the SBIR proposed by AES. The R&D of the first prototype crab cavity for Hadron Colliders will enable us to overcome the major challenges associated with a LHC compatible crab cavity. The collaboration over the last year has been extremely fruitful and I would like to reiterate CERNs strong interest to continue this collaboration. A CRAB cavity prototype will be used to investigate several superconducting RF and beam dynamics issues in the LHC and subsequently aid in the first demonstration of crab crossing with Hadron beams.

Sincerely,
Lyn Evans