

US LHC Accelerator Research Program
Task Sheet

Task Name: Crab Cavities Studies

Date: May 31, 2006

Responsible Person(s): D. Li (LBNL), R. Calaga (BNL)

Budget for FY07: BNL \$10K, LBNL \$65k

Statement of work:

1. Summary:

The objective of this task is a study of technical requirements and feasibility of crab system

Crab crossing offers an interesting opportunity to enhance LHC luminosity in a future IR upgrade, most likely for the second round of upgrades. While the approach has been studied for several other colliders, its implementation in the LHC presents several difficulties that lie in the present limitations of RF technology, both in terms of RF deflecting voltage and phase control. The proposed task is to perform a detailed beam dynamics study to better define the system requirements in the LHC, and to integrate this study with a parallel effort aimed at an optimal RF deflecting cavity approach, based upon state of the art cavity as well as RF (amplitude and phase) control.

2. Task Description:

Crab cavity is an RF cavity that works in a dipole mode. The transverse electromagnetic fields of the dipole mode deflect the front of each bunch to one direction, and the rear to the other direction while leaving the center of the bunch intact, thus enabling “large” crossing angles at the collision point without any attendant loss of geometric luminosity. Large crossing angles are fundamentally desirable because they would allow long range beam-beam interactions to be almost completely ameliorated. They may also be technically advantageous, since they may permit side-by-side quadrupole first interaction region optics.

An LHC interaction region upgrade with large crossing angles becomes necessary if and when beam-beam interactions become intolerable to higher luminosities. This would be a major upgrade, and is not likely to be the first LHC upgrade. Because of the long-term and radical nature of such an upgrade, crab cavity issues are unsupported by current LARP funding – except for modest preliminary accelerator physics studies. A single crab cavity in one of the KEK B rings is being tentatively introduced into operations in 2006. If these ground-breaking studies are successful, and if supplemental funding were available, LARP activities would first focus on accelerator physics and engineering

design studies.

The scope of LARP involvement in crab cavities needs to be better defined and delimited, within a very broad potential range. It is therefore not easily costed at this preliminary stage. Preliminary studies should include feasibility of using crabbing cavities for the upgrade, questions need to be answered at this phase are:

- What deflecting voltages at what frequency needed for the proposed crossing angle?
- Frequency selection to cope with rf nonlinearities and to achieve the maximum deflecting voltage
- For the given space and the state-of-art SC RF technology, what transverse RF gradient (MV/m) can one achieve?
- Beam impedance budget for the lower order mode (LOM) and higher order modes (HOM)?
- Emittance growth due to RF non-linearities and beam beam effects
- Inclusion of a 2nd or 3rd harmonic crab cavities to reduce this non-linearity
- Effects of the other degenerate dipole mode on the beam, what frequency separation is required or what is acceptable impedance if we damp this mode?
- Studies of phase stability requirements from beam dynamics considerations to prevent emittance growth
- Technological limits of phase stability controls
- Other possible options for cavity design (TM010)

In accomplishing this task, we plan to fully leverage the existing knowledge in the community and our recent direct experience working on similar issues for other machines, including the ILC.

BNL Personnel and tasks:

Rama Calaga – beam dynamics studies and system requirements

LBNL Personnel and tasks:

Derun Li – Cavity design and system requirements

Larry Doolittle – RF controls feasibility

CERN liaison:

TBD

Follow on funding request:

We anticipate completing this study in one fiscal year. Additional funds may be requested as an extension depending upon the result of this work.