LHC Optics MDs: linear and non-linear

M. Giovannozzi

on behalf of HSS team

Acknowledgements: G. Arduini, L. Malina, E. Métral, Y. Papaphilippou, T. Persson, T. Pieloni, P. Skowronski.

Introduction - I

- **The proposed studies cover different needs**
  - Understanding the present -> 2016 run
  - Preparing the medium term -> Run 2
  - Building the long term -> HL-LHC
- **The boundary between the various domains (linear, non-linear optics/collimation/beam-beam…) is not always sharp.**
  - **Some of the studies presented under “linear, non-linear optics” will require, e.g.,**
    - **aperture evaluation**
    - **Analysis of beam-beam effects**
  - **To draw firm conclusions from the results.**

Introduction - II

- **Based on the experience from the 2015 MD sessions:**
  - **The use of the alignment optics proved essential to provide robust calibration of the IR BPMs, which in turns is an essential ingredient for beta* measurement and correction (hence, directly linked with machine performance).**
  - **It is assumed that the alignment optics will be used during the 2016 beam commissioning period. Otherwise, a request to pursue the studies started in 2015 with the alignment optics will be issued.**

Introduction - III

- **MD studies vs. operational development:**
  - **The distinction is not always clear…**
  - **There are plans to put in operation a very high beta* optics in 2016**
    - **The commissioning should start well ahead of the planned operational period, due to the intrinsic difficulties of this optics.**
    - **Enough time should be allocated to study this optics (no matter whether this is taken from the MD budget or from physics time).**

Linear optics - I

- **Pursue studies of linear coupling measurement and correction**
  - The use of the DOROS system enabled accurate measurement of linear coupling in 2015 MD blocks.
  - This could be extended through the ramp and squeeze with the ultimate goal of providing automatic corrections of the coupling.
- **Study different optical configurations at injection energy, e.g., with lower beta***
  - These studies aim at probing different conditions at injection to verify optics correctability, aperture, and impact of field quality on beam dynamics, e.g., to mimic top energy configurations
  - To note that lower beta* at injection might have a mild impact on performance by relaxing conditions for ramp and squeeze.

Linear optics - II

- **Study future optical configurations for collisions, such as pushed round optics (minimum beta* to be defined) or flat optics**
  - This study will aim at characterising special optics configurations, possibly for future LHC runs.
  - Several aspects will be probed in addition to linear optics measurement and control, namely: **aperture** and **beam-beam effects**.
- **Pursue the study of half integer tunes in the LHC**
  - This study was initiated back in 2011 with some initial observations. The study should be resumed as this might be an option for LHC and future colliders. **Includes beam-beam studies**.

Non-linear optics - I

- **Three main themes are addressed by MD studies**
  - Understanding the non-linear model of the LHC (injection and top energy).
  - Devise correction strategies for the existing correction circuits, such as spool pieces and corrector package in the triplets (injection and top energy).
  - Study global observables sensible to non-linear effects and providing indications on machine performance (injection and top energy). Immediate application is the definition of complementary approaches to set the elements of the corrector package.

Non-linear optics - II

- **Injection**
  - **Measurement of natural chromaticity**
  - **b3, b4, b5**
    - Checks locality of corrections using long bumps in the arcs.
    - Understand contribution of MCDOs on Q'' and Q'''.
    - Verify presence of systematic misalignment of spool pieces.
  - **Non-linear coupling**
    - Direct measurement of linear coupling at different amplitudes in the presence of octupolar effects (reverse measurement, detuning vs tune difference, could be tried too).
- **Top energy**
  - **Measurement of nonlinear chromaticity and detuning with amplitude**

Non-linear optics - III

- **Top energy**
  - **Non-linear errors in experimental insertions**
    - Correction of understood errors: To be done in commissioning
  - **Studies of the non-linear errors in the IRs for several optical configurations (to disentangle in a better way the various contributions)**
    - Beta* of 40 cm
    - Pushed round optics
    - Flat optics
    - One IR at a time

Non-linear optics - IV

- **Dynamic aperture studies**
  - **Injection**
    - Probe dependence of DA on b6 corrector strength to find an alternative/complementary way to set it (other than considering feed down effects).
    - Direct comparison of experimental methods to probe dynamic aperture (kick method and intensity evolution method).
    - Direct measurement of short term dynamic aperture with AC dipole.
    - Direct measurement in several configurations, e.g., **strong octupoles**, **off-momentum**, in view of benchmarking numerical simulations.
  - **Top energy (squeezed optics)**
    - Direct measurement using the proposed relationship between DA and intensity evolution.
    - Direct measurement of short term dynamic aperture with AC dipole.

Decreasing priority

Another topic: background studies

- **Background is a potential issue and a better understanding is essential not only for LHC, but also for future machines. These proposals follow LBS discussions:**
  - **Background vs controlled pressure rise**
  - **Search for background from synchrotron radiation**

Proposal of prioritisation of MD studies

- **High priority**
  - Coupling measurement
  - Pushed optics (flat or round)
  - IR non-linearity studies
  - DA studies at injection
- **Medium**
  - Non-linear errors at injection
  - Different optical configurations at injection
  - DA studies at top energy
  - Half integer tunes
  - Background studies