Start and issues of HE-LHC optics study

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Acknowledgements:
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9th HE-LHC design meeting, CERN, Feb. 07, 2017
Start of the work

➢ **MAD-X/MAD optics for references to HE-LHC design**
  • ATS optics for LHC upgrade (e.g. SLHCV3.1a, [http://proj-lhc-optics-web.web.cern.ch/proj-lhc-optics-web/](http://proj-lhc-optics-web.web.cern.ch/proj-lhc-optics-web/)
    *OpticsSourceAllVersions.link/SLHCV3.1a/)
  • LHC optics for operation (e.g. [http://lhc-optics.web.cern.ch/lhc-optics/www/opt2016/coll400/index.html](http://lhc-optics.web.cern.ch/lhc-optics/www/opt2016/coll400/index.html))
  • Y. Nosochkov’s design for HE-LHC (lhc_v3.mad8, Ref. 8th HE-LHC design meeting, Dec.12, 2016)

➢ **Based on MAD-X: A lot to learn**
  • To understand the complicated optics files (including lots of macros for optics manipulations) for LHC
  • To use the MAD-X code for optics design
  • To go through documents (slides, notes, papers, etc.) describing the features of LHC and HL-LHC designs
Based on SAD: Unexpected obstacles from translators

- **My original scenario:** easier for me to perform optics manipulations, DA calculation, plots, etc.
- **Turns out MAD-X to SAD translation for LHC lattices is not easy:**
  * Complicated files
  * New types of elements (e.g. rcollimator, etc.)
  * Apertures for operation/collimation
  * ... ...

Tools for lattice translation

- **Bmad:** MAD-X <-> Bmad <-> SAD
  * Simple lattice files: OK
  * LHC: Need improvements (debugs, tests, and benchmarks)
- **AML/UAP:** MAD-X -> AML/UAP -> Bmad <-> SAD
  * AML/UAP is a little old? - Need full investigations
- **?:** MAD8 -> MAD-X
  * MAD-X tool available?
Start of the work (cont’d)

➤ Tools for lattice translation (cont’d)

● SAD: MAD-X -> SAD
  * H. Koiso’s scripts: applied to BEPC, LEP, ILC-DR (~10 years ago)
  * A. Morita’s scripts: developed in 2008 (never applied to practical machines?)

● SAD: SAD -> MAD-X
  * K. Oide’s scripts: applied to FCC-ee
  * A. Morita’s scripts: developed in 2008 (never applied to practical machines?) [Ref. https://ab-dep-abp.web.cern.ch/ab-dep-abp/LCU/LCU_meetings/2008/20081021/SAD2MADX.pdf]

➤ Testing the above translation tools on LHC

● Various problems appeared
● MAD-X changed a lot in the last few years?
● Need supports/developments (Very good for IHEP team to join this efforts)
First of all, I want to make a HE-LHC lattice as simple as possible

- Yuri set a good example (in mad8):

```plaintext
! -------------------------------------------
! ARC CELL
! -------------------------------------------

... ...
CDD : LINE=(QFH, DQS, SD, DSB, B, DBB, B, DBB, B, DBQ, QFH, &
         DQS, SF, DSB, B, DBB, B, DBB, B, DBQ, QFH)
CFF : LINE=(QFH, DQS, SF, DSB, B, DBB, B, DBB, B, DBQ, QDH, &
         DQS, SD, DSB, B, DBB, B, DBB, B, DBB, B, DBQ, QFH)

! -------------------------------------------
! DISPERSION SUPPRESSOR
! -------------------------------------------

... ...
DSU : LINE=(QFST1H, DBQ1, B, DBB, B, DBQ1, &
           2*QD2H, DBQ1, B, DBB, B, DBQ2, &
           2*QF2H, DBQ2, B, DBB, B, DBQ1, &
           2*QD1H, DBQ1, B, DBB, B, DBQ3, &
           2*QF1H, DQQ, &
           QFH)
DSD : LINE=( QFH, DQQ, &
           2*QF1H, DBQ3, B, DBB, B, DBQ1, &
           2*QD1H, DBQ1, B, DBB, B, DBQ2, &
           2*QF2H, DBQ2, B, DBB, B, DBQ1, &
           2*QD2H, DBQ1, B, DBB, B, DBQ1, &
           QFST1H)
ARC : LINE=(DSU, 24*CFF, DSD)
```

```plaintext
CSTR : LINE=(QFST3H, DST, 2*QDST3H, DST, QFST3H)
STRD : LINE=( QFST1H, DST, 2*QDST1H, DST, &
           2*QFST2H, DST, 2*QDST2H, DST, &
           2*QFST3H, DST, 2*QDST3H, DST, &
           QFST3H)
STRU : LINE=( QFST3H, DST, 2*QDST3H, DST, &
           2*QFST3H, DST, 2*QDST2H, DST, &
           2*QFST2H, DST, 2*QDST1H, DST, &
           QFST1H)
STR : LINE=(STRU, STRU)

! -------------------------------------------
! one 1-m cavity
! -------------------------------------------

... ...
STRUFR : LINE=( QFST3H, DSTRF, CAVITY, DSTRF, &
               2*QDST3H, DST, &
               2*QFST3H, DST, 2*QDST2H, DST, &
               2*QFST2H, DST, 2*QDST1H, DST, &
               QFST1H)

! -------------------------------------------
! RING
! -------------------------------------------

MMM : MARKER
OCTANT : LINE=(STRU, ARC, STRD)
OCTANTRF : LINE=(STRUFR, ARC, STRD)
RING : LINE=(MMM, OCTANTRF, 7*OCTANT)
```
Issues of HE-LHC optics study (cont’d)

➤ A simplified LHC/SLHC lattice should
  ● Only contain DRIFTs, BENDs, QUADs, SEXTs, and RFs (and others?)
  ● Minimum definitions of variables, cells, and sections

➤ With such a lattice, I can try
  ● replacing the LHC/SLHC arcs by Yuri’s PEP-X type arcs (As proposed by Frank)
    ● comparison of various lattice designs via nonlinear lattice analysis using PTC
      ● optics matching with minimum constraints/variables
      ● lattice translations with minimum efforts

➤ Choosing MAD-X or SAD is a problem for me
  ● MAD-X: need frequent helps, or hand-on training
  ● SAD: need to improve the translations first (multi-purpose task), or simplify the MAD-X lattices first
Issues of HE-LHC optics study (cont’d)

➤ Nonlinear analysis using PTC

- A “once-for-all” calculation: Resonances, detuning as a function of momentum/amplitude, Montague functions, etc.
- RDTs correlate to FMA, DA, etc. (even lifetime, luminosity, etc.)
- Identify sources of nonlinearities along the beam line
- Should be powerful in overall evaluation of lattice design

➤ Demonstration: SuperKEKB

1) Global optimization to suppress RDTs
2) One RDT from PTC, clearly tracing sources to solenoid regions
Issues of HE-LHC optics study (cont’d)

➤ Demonstration: Yuri’s HE-LHC injection lattice
  ● 3rd and 4th order RDTs canceled as expected
Issues of HE-LHC optics study (cont’d)

➢ Demonstration: Yuri’s HE-LHC injection lattice (cont’d)

- Momentum-dependent 3rd resonances
Issues of HE-LHC optics study (cont’d)

➤ Demonstration: Yuri’s HE-LHC injection lattice (cont’d)

- Chromatic detuning

Chromaticity: (3.2, 3.2) [PTC]
Chromatic beta functions

(3,3) [Design]
Issues of HE-LHC optics study (cont’d)

- Demonstration: Yuri’s HE-LHC injection lattice (cont’d)
  - Amplitude-dependent detuning: useful for estimate of tune footprint

![Graph showing amplitude detuning vs. s (km)](image_url)
Issues of HE-LHC optics study (cont’d)

➢ Demonstration: Yuri’s HE-LHC injection lattice (cont’d)
  ● Chromatic dispersion in horizontal direction
Summary

➤ Tools for optics design/simulations
  - MAD-X: Reading the LHC optics files with help of MAD-X manual
  - SAD: Translation tools to be improved
  - Bmad/PTC: Ready to run if lattice translation succeeded

➤ Strategy
  - Need help/supervision
  - Welcome collaboration on HE-LHC design