On MADX sequence file and optics matching for HE-LHC

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Acknowledgements:


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Outline

➤ On MADX sequence file for HE-LHC
➤ Comments on HE-LHC V0.1 via SAD
➤ Future plan
1. Baseline MADX sequence file

➤ Compare the “average beam” of LEP and (HE-)LHC

- **Current baseline:** merged_HE-LHC.18x60_v102.seq (Orange line)
- Need to switch to merged_HE-LHC.18x60_tr.seq, but need further improvement in geometry (by Thys)
- HE-LHC V0.2 can be based on merged_HE-LHC.18x60_v102.seq

**NOTE:**
1) Zero ring separation
2) Offset in DSs
3) IP1: s=0
1. Baseline MADX sequence file

Global variables: Ring separation

- **merged_HE-LHC.18x60_v102.seq:**
  ```
  const aip1 = 0.008285831213598*bsep;
  const aip2 = 0.007899520984845*bsep;
  const aip3 = 0.000566187234257;
  const aip4 = 0.001571604107948;
  const aip5 = 0.008285831213598*bsep;
  const aip7 = 0.000377458178579;
  const aip8 = 0.007899520984845*bsep;
  ```

- **LHC V6.5.seq:**
  ```
  REAL CONST sep_ARC = 0.194;
  REAL CONST sep_IR3 = 0.224;
  REAL CONST sep_IR4 = 0.420;
  REAL CONST sep_IR7 = 0.224;
  REAL CONST AIP1 = ATAN(sep_ARC/2/Dsep1);
  REAL CONST AIP2 = ATAN(sep_ARC/2/Dsep2);
  REAL CONST AIP3 = ATAN((sep_IR3-sep_ARC)/2/Dsep3);
  REAL CONST AIP4 = ATAN((sep_IR4-sep_ARC)/2/Dsep4);
  REAL CONST AIP5 = ATAN(sep_ARC/2/Dsep5);
  REAL CONST AIP7 = ATAN((sep_IR7-sep_ARC)/2/Dsep7);
  REAL CONST AIP8 = ATAN((sep_ARC)/2/Dsep8);
  ```

Comment:
Switch to LHC definitions?
1. Baseline MADX sequence file

Global variables: Others

- **merged_HE-LHC.18x60_v102.seq:**
  
  ```plaintext
  const r0 = 0; ! separation ON
  const bsep = 0.204*(1-r0);
  on_sol_atlas := 0.000000000000000;
  on_x1 := 0.000000000000000;
  on_sep1 := 0.000000000000000;
  on_sep2 := 0.000000000000000;
  on_x2 := 0.000000000000000;
  on_alice := 0.000000000000000;
  on_sol_alice := 0.000000000000000;
  on_x5 := 0.000000000000000;
  on_sep5 := 0.000000000000000;
  on_sol_cms := 0.000000000000000;
  on_x8 := 0.000000000000000;
  on_sep8 := 0.000000000000000;
  on_lhcb := 0.000000000000000;
  phi_ir1 := 90.000000000000000;
  phi_ir5 := 0.000000000000000;
  abas := 12.00/6.0*clight/(7e12)*on_sol_atlas;
  abls := 6.05/12.1*clight/(7e12)*on_sol_alice;
  abcs := 52.00/13.0*clight/(7e12)*on_sol_cms;
  ```

Comment:
Consistency in the dependence of global constants and derived variables to be checked?
1. Baseline MADX sequence file

Global variables: DS

*merged_HE-LHC.seq (24x60 sequence)*:

! inner-outer path length differences in main bends

\[ ds = \text{bsep}/2 \times \text{twopi}/1280; \]

\[ \text{sumds} = 0; \]

... ...

mbds,

\[ \text{at} = \text{sumds} + 277.520526004 + 0.5*ds; \; \text{sumds} = \text{sumds} + ds; \]

mbds,

\[ \text{at} = \text{sumds} + 292.553250504 + 0.5*ds; \; \text{sumds} = \text{sumds} + ds; \]

mq.8r1.b1,

\[ \text{at} = \text{sumds} + 301.737250504; \]

mq.8r1.b1,

\[ \text{at} = \text{sumds} + 304.137250504; \]

mbds,

\[ \text{at} = \text{sumds} + 314.017250504 + 0.5*ds; \; \text{sumds} = \text{sumds} + ds; \]

mbds,

\[ \text{at} = \text{sumds} + 329.049975004 + 0.5*ds; \; \text{sumds} = \text{sumds} + ds; \]

... ...

**Comment:**

DS: to keep the ring survey closed when beam separation is turned on.
To be added to 18x60, 17x90 and 20x90 sequence files
2. Comments on HE-LHC V0.1 via SAD

➤ IR2

- Injection for beam 1
- To be improved by injection group (?)
2. Comments on HE-LHC V0.1 via SAD

➤ IR3
- Momentum collimation section
- Used for tune matching in V0.1 (to use IR4&6 instead in V0.2)
- Keep features of LHC IR3 (preferred by collimation group?)
- To be reviewed by collimation group

LHC V6.503

HE-LHC
2. Comments on HE-LHC V0.1 via SAD

- IR4
  - To be used for tune matching
  - Quads in the last arc cell individually powered
  - Need to be reviewed by RF and BI groups?
2. Comments on HE-LHC V0.1 via SAD

➤ IR5

- Experimental IR
- Triplets longer than LHC
- Matching sections could be improved? For example, positions of matching quads to be optimized?
2. Comments on HE-LHC V0.1 via SAD

➤ IR6
- To be used as beam dump and for tune matching
- More quads necessary in matching sections?
- To be reviewed by beam dump group?

**LHC V6.503**

**HE-LHC**
2. Comments on HE-LHC V0.1 via SAD

➤ IR7

- Betatron collimation section
- Keep features of LHC IR7 (preferred by collimation group?)
- Dispersion functions acceptable?
- To be reviewed by collimation group
2. Comments on HE-LHC V0.1 via SAD

- IR8
  - Injection for beam 2
  - To be improved by injection group (?)
2. Comments on HE-LHC V0.1 via SAD

➤ Quad. gradient

- $E=13.5$ TeV, $\beta^*=25$cm @IP#1&5
- Quadrupole: $L=3.1$m in arcs [Typical]
- Some quads in IR3&7 exceed FCC tech. limit
- Some quads in IR2&8 critical (to be reviewed by injection group?)

FCC specification:
$B^{(1)}_{\text{max}} \approx 400$ T/m$^{[1]}$ with aperture $\phi=50$ mm

$^{[1]}$A. Chance, FCC-hh magnet-beam dynamics coordination meeting, Mar. 17, 2017
2. Comments on HE-LHC V0.1 via SAD

➤ Sext. gradient

- $E=13.5$ TeV, $\beta^*=25\text{cm}$ @IP#1&5
- Sextupole: $L=0.369\text{m}$ in arcs [Typical]
- Sext. gradient well below FCC tech. limit

\[ K_nL = \frac{B^{(n)}L}{B\rho} \]

FCC specification:

$B^{(2)}_{\text{max}} \approx 7800 \frac{T}{m^2}$\textsuperscript{[2]} with aperture $\phi=50$ mm

\textsuperscript{[2]}D. Schoerling, FCC-hh magnet-beam dynamics coordination meeting, Apr. 28, 2017
3. Future plan

➤ Strategy for optics developments and beam dynamics simulations using SAD

- Assume ring layout fixed
- Translate MADX sequence file to SAD format
- Do matching/optimizations and simulations using SAD
- Use SAD to print strength file in MADX format

➤ Optional optics for HE-LHC

- Improve ring geometry for 17x90 and 20x90 (manually)
- Adapt MADX scripts developed for 18x90 to 17x90 and 20x90 => Create sequence file
- Optics matching in SAD => Create strength file