Start and issues of HE-LHC optics study

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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/OpticsSourceAllVersions.link/SLHCV3.1a/)**

• **LHC optics for operation (e.g. 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**

Start of the work (cont'd)

➤ **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)**

Issues of HE-LHC optics study

➤ **First of all, I want to make a HE-LHC lattice as simple as possible**

● **Yuri set a good example (in mad8):**

```
! ---------------------------------------------------
! ARC CELL
! ---------------------------------------------------
... ...
CDD : LINE=(QDH, DQS, SD, DSB, B, DBB, B, DBB, B, DBQ, QFH, &
            QFH, DQS, SF, DSB, B, DBB, B, DBB, B, DBQ, QDH)
CFF : LINE=(QFH, DQS, SF, DSB, B, DBB, B, DBB, B, DBQ, QDH, &
            QDH, DQS, SD, DSB, B, DBB, B, DBB, B, DBQ, QFH)
! ---------------------------------------------------
! DISPERSION SUPPRESSOR
! ---------------------------------------------------
... ...
DSU : LINE=(QFST1H, DBQ1, B, DBB, B, DBQ1, &
            2*QDZH, DBQ1, B, DBB, B, DBQZ, &
            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, DBQZ, &
            2*QF2H, DBQ2, B, DBB, B, DBQ1, &
            2*QDZH, DBQ1, B, DBB, B, DBQ1, &
            QFST1H)
ARC : LINE=(DSU, 24*CFF, DSD)
```

```
! ---------------------------------------------------
! STRAIGHTS
! ---------------------------------------------------
... ...
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=(STRD, STRU)
! ---------------------------------------------------
! one 1-m cavity
! ---------------------------------------------------
... ...
STRURF : 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=(STRURF, ARC, STRD)
RING : LINE=(MMM, OCTANTRF, 7*OCTANT)
```
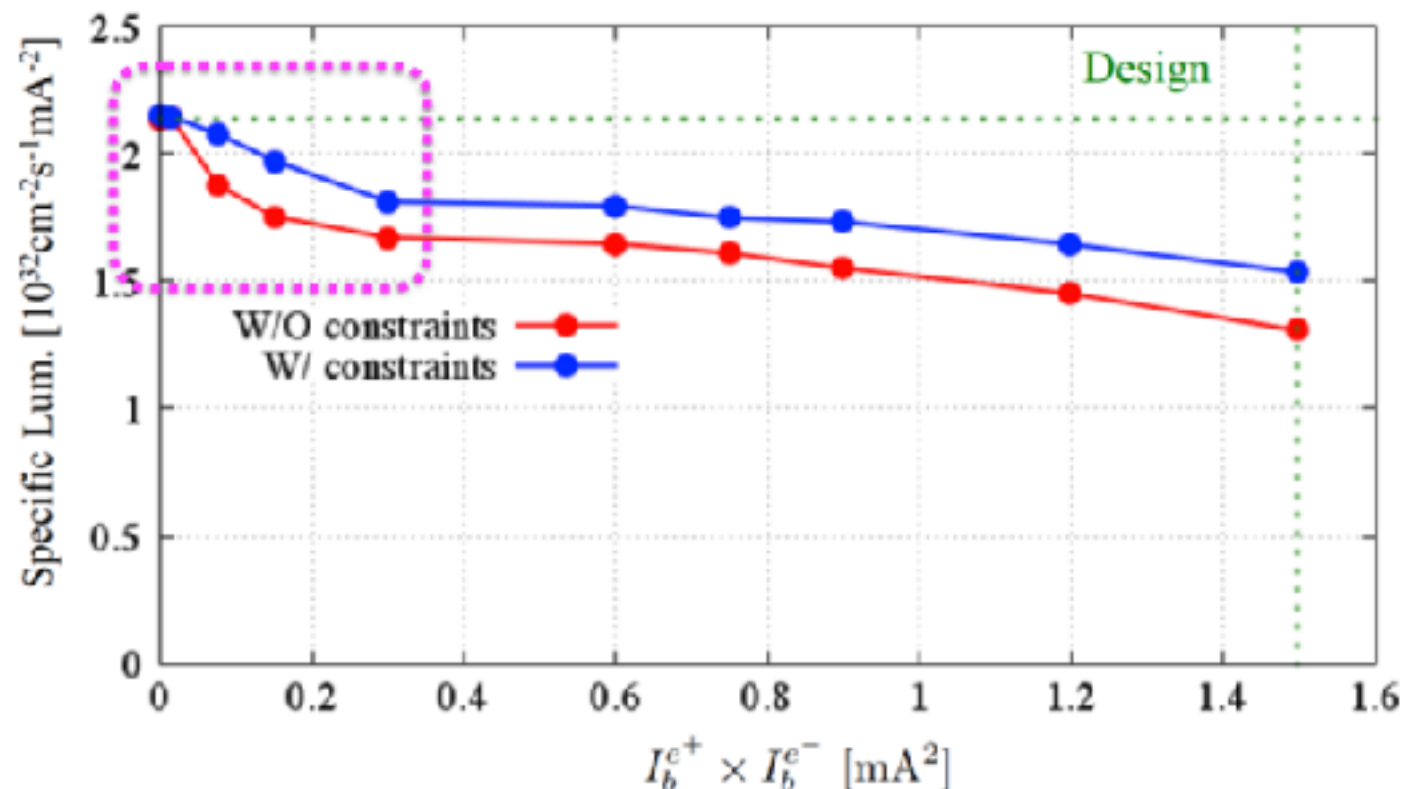
Issues of HE-LHC optics study (cont'd)

➤ **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**
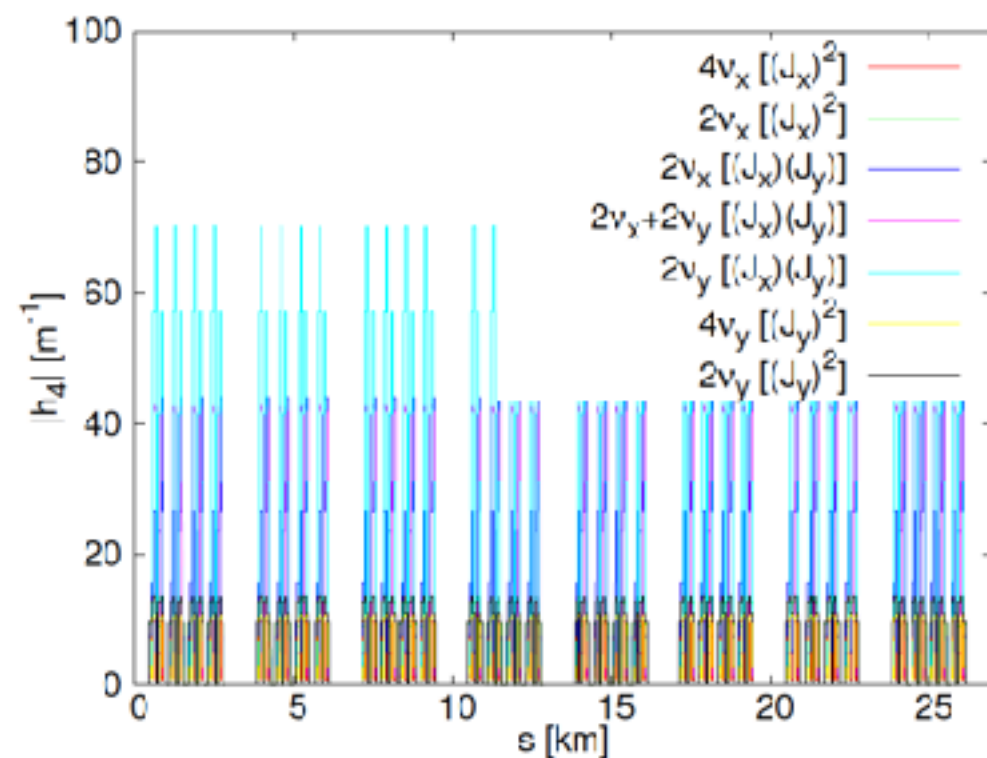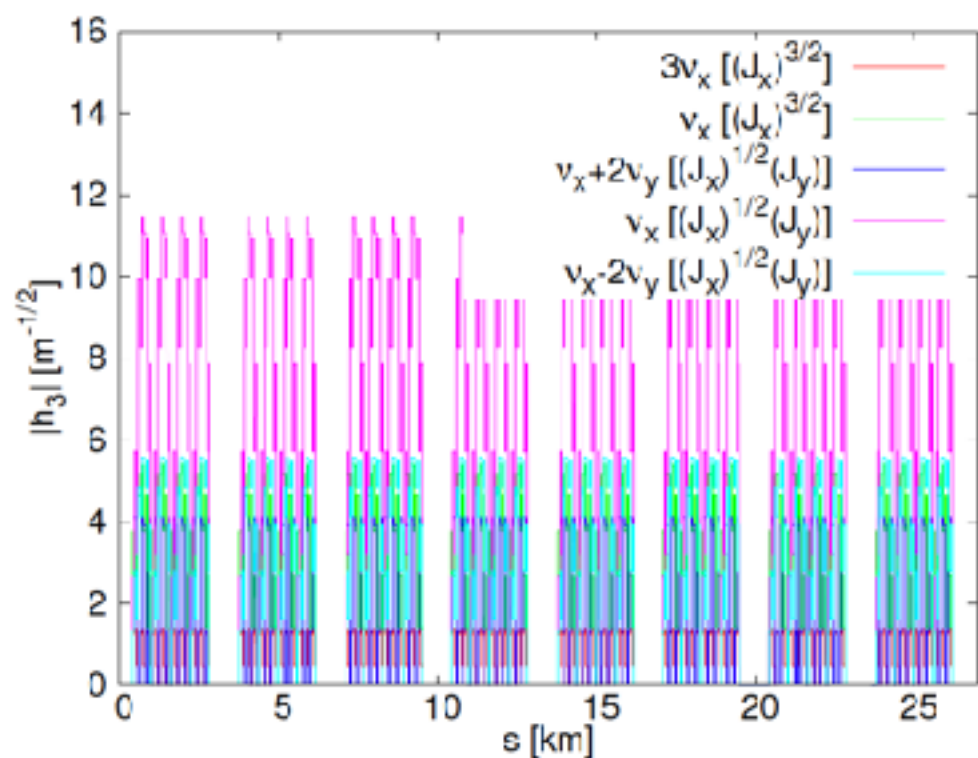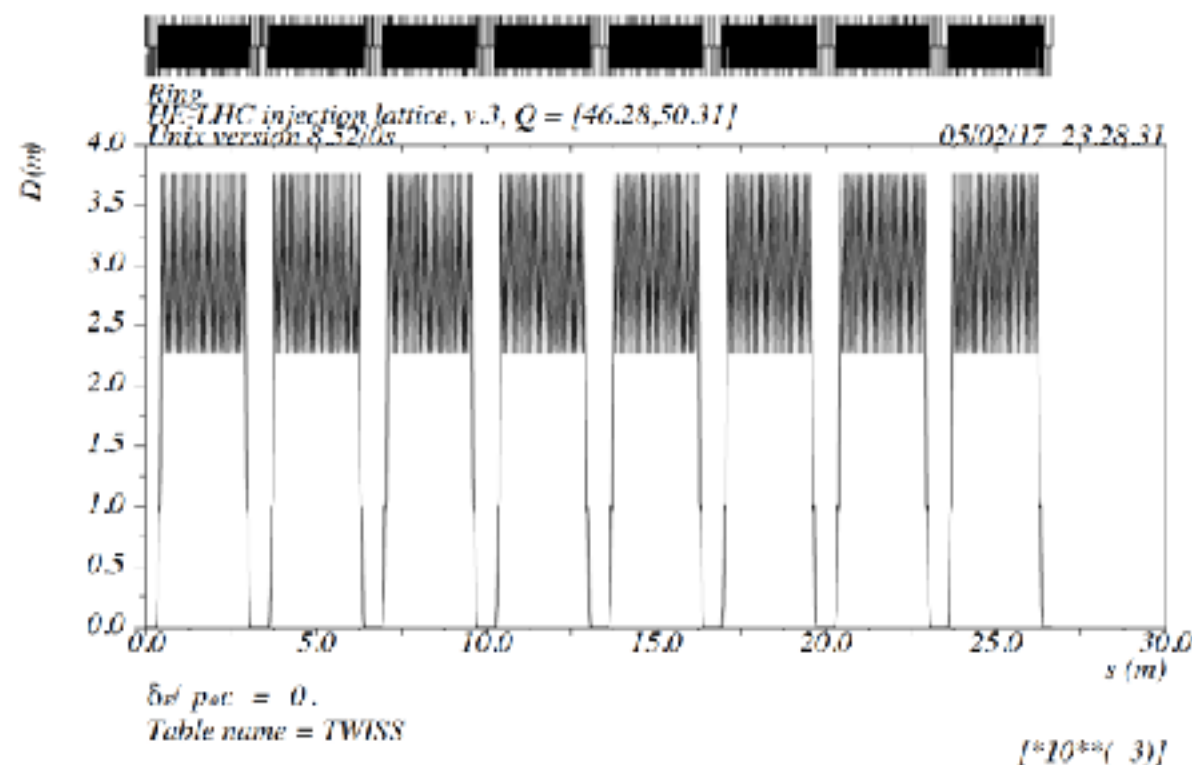
➤ **Demonstration: SuperKEKB**

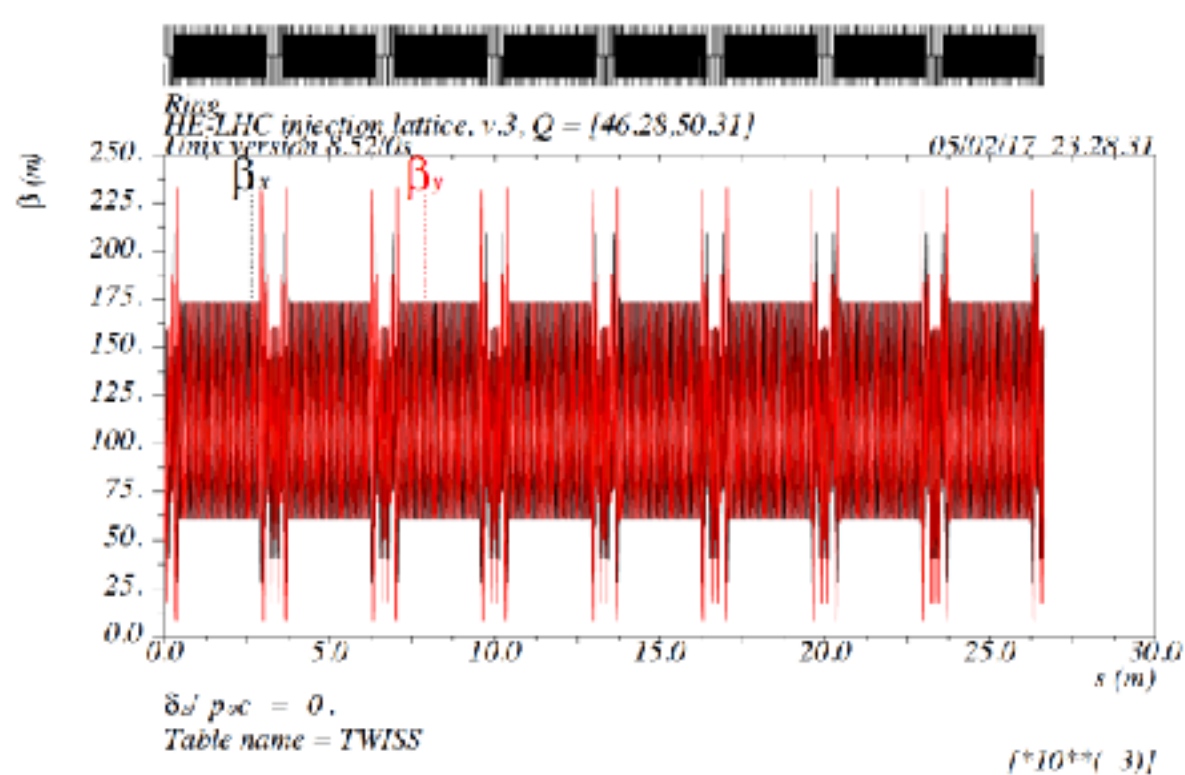**Courtesy of H. Sugimoto**

$v_x - 2v_y \ [(J_x)^{1/2}(J_y)]$
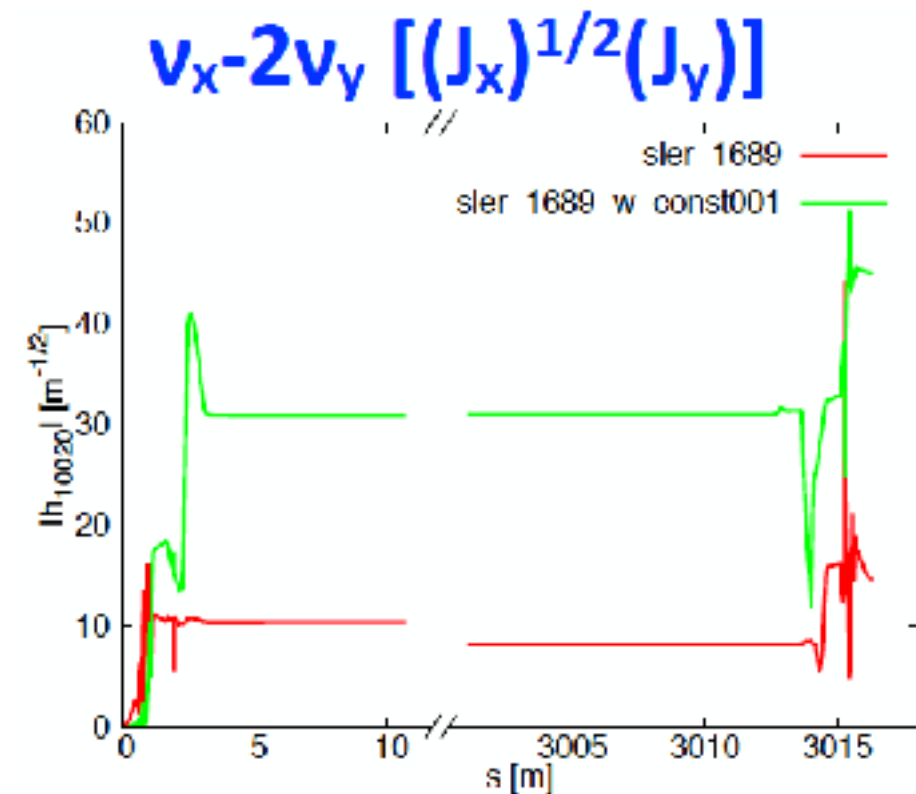
1) Global optimization to suppress RDTs
2) One RDT from PTC, clearly tracing sours to solenoid regions

Issues of HE-LHC optics study (cont'd)

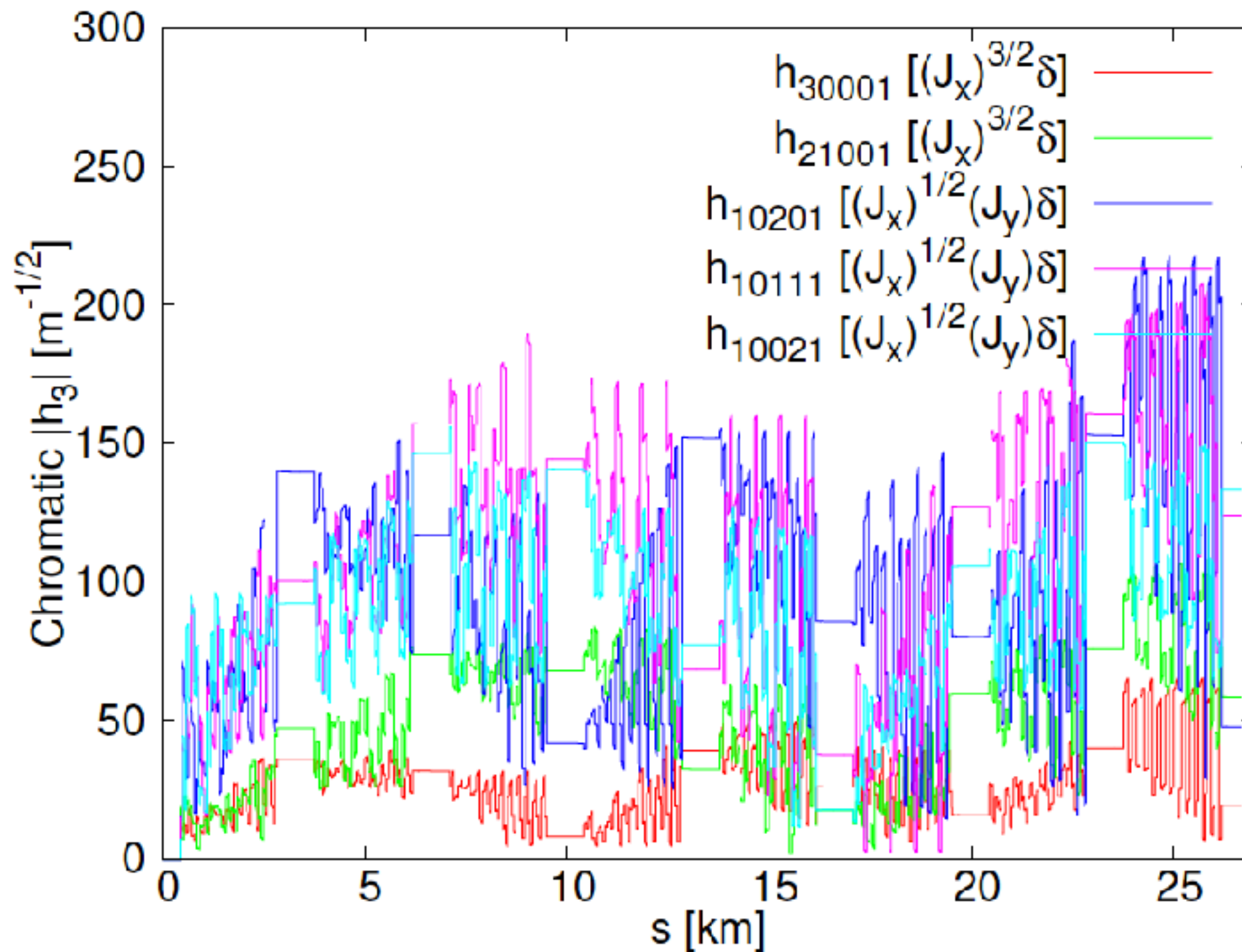➤ **Demonstration: Yuri's HE-LHC injection lattice**

• **3rd and 4th order RDTs canceled as expected**

Issues of HE-LHC optics study (cont'd)

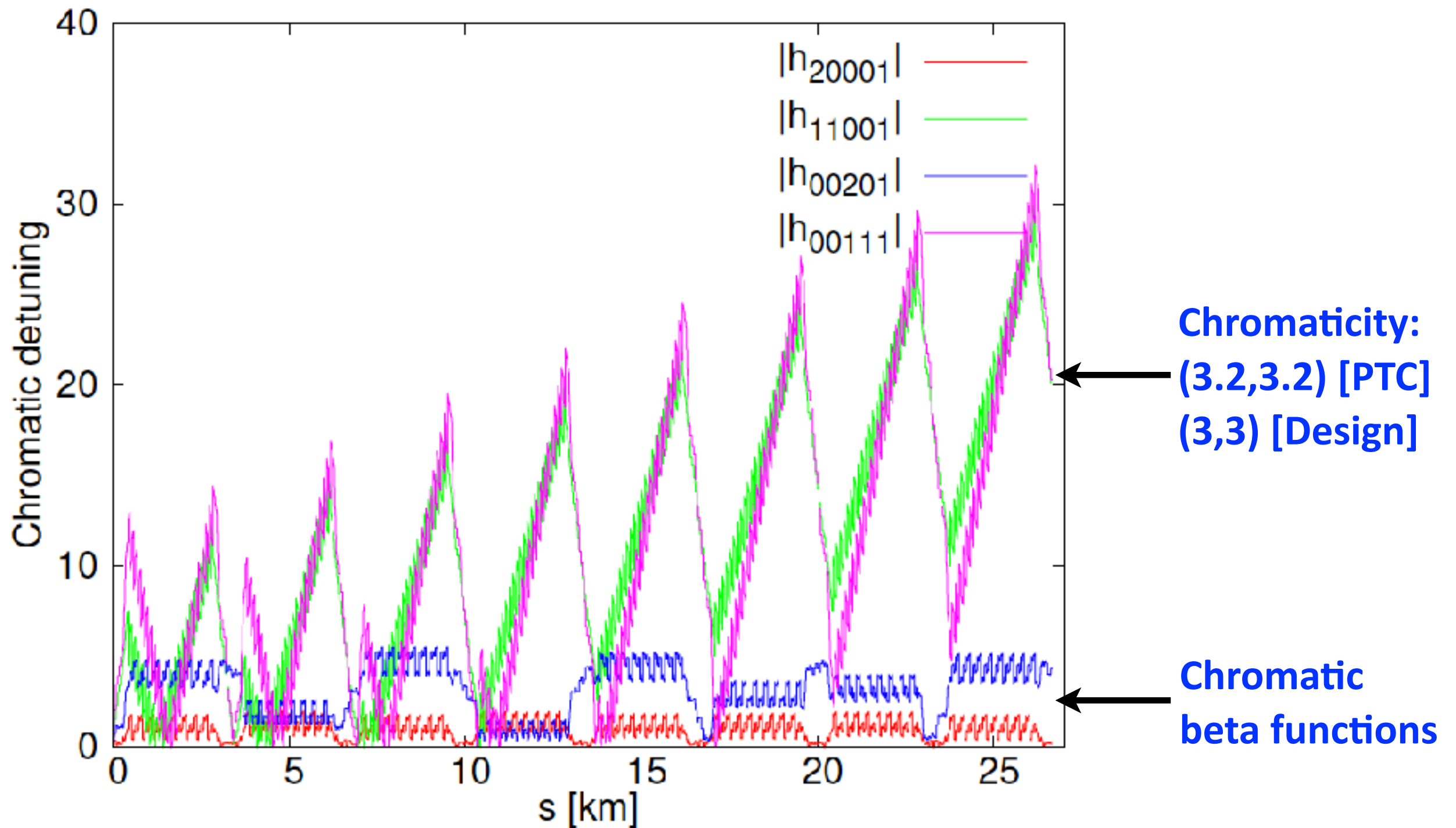➤ **Demonstration: Yuri's HE-LHC injection lattice (cont'd)**

- **Momentum-dependent 3rd resonances**

Issues of HE-LHC optics study (cont'd)

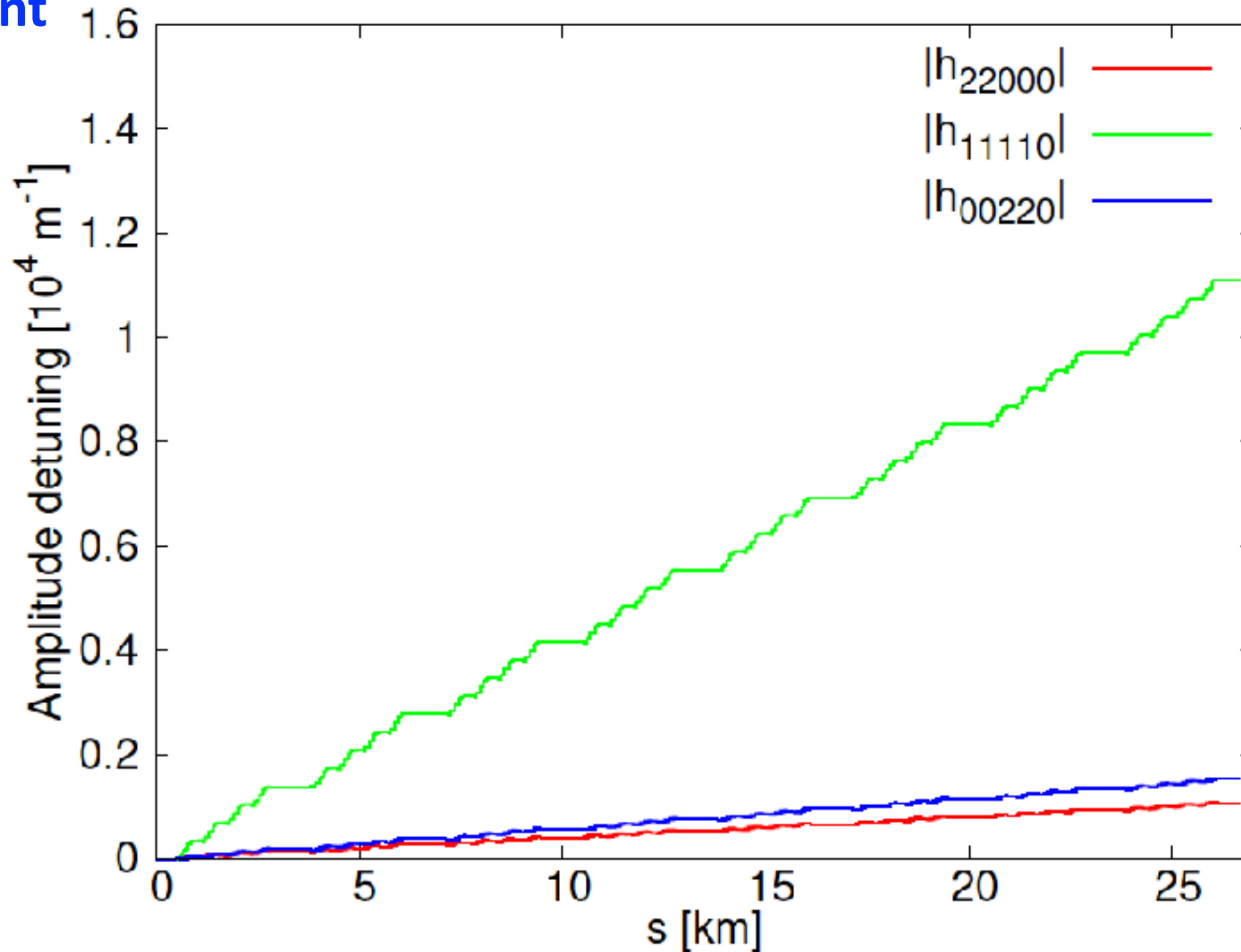➤ **Demonstration: Yuri's HE-LHC injection lattice (cont'd)**

- **Chromatic detuning**

Chromaticity:
(3.2,3.2) [PTC]
(3,3) [Design]

Chromatic
beta functions

Issues of HE-LHC optics study (cont'd)

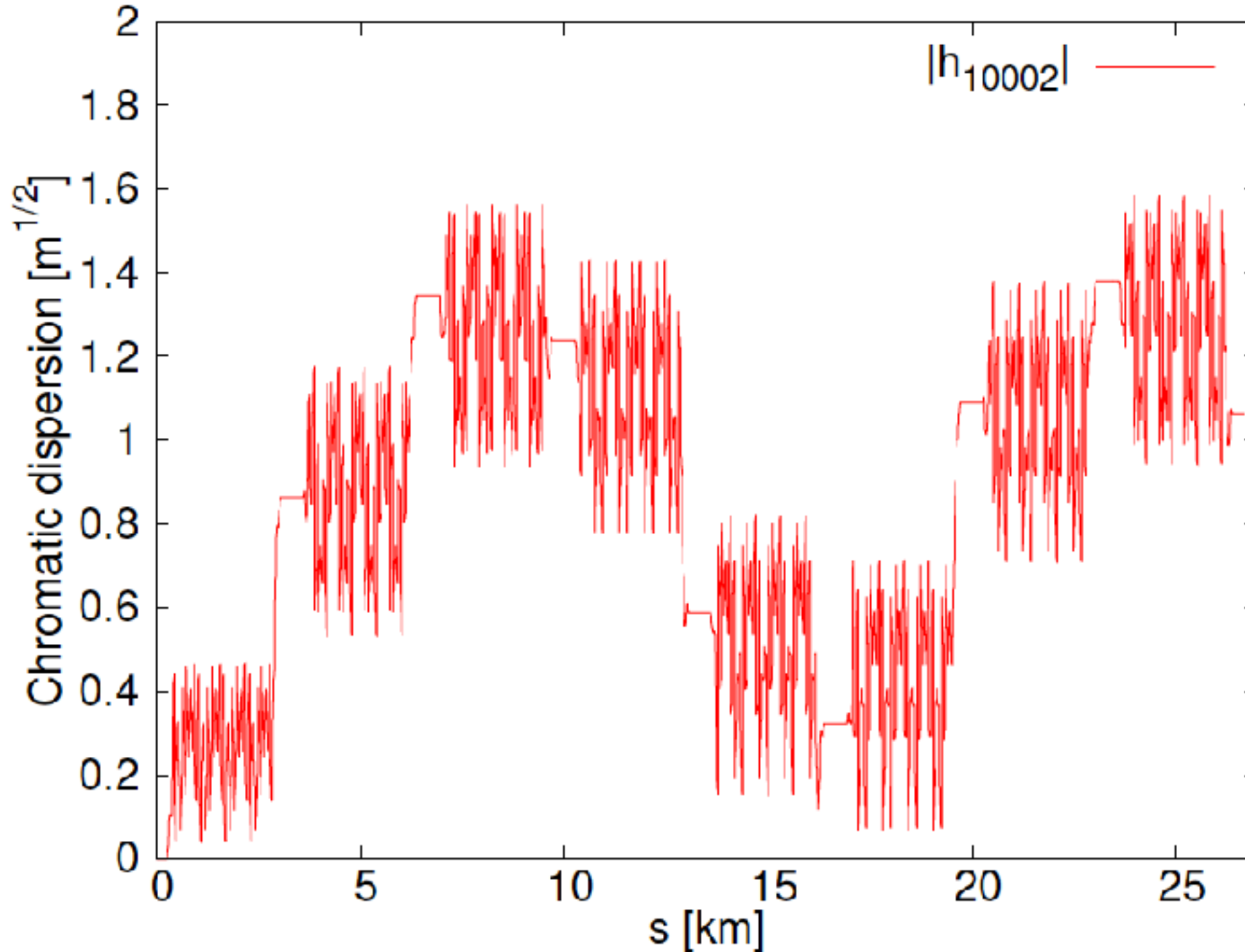➤ **Demonstration: Yuri's HE-LHC injection lattice (cont'd)**

● **Amplitude-dependent detuning: useful for estimate of tune footprint**

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**