Nonlinear analysis and dynamic aperture
- Update of talk at FCC week 2017

Yuri Nosochkov (SLAC), Demin Zhou (KEK)

Acknowledgements:

M. Benedikt, M. Crouch, L. Deniau, R. De Maria, E. Forest, S. Fartoukh, M. Giovannozzi, M. Hofer, K. Oide, T. Risselada, L. Riesen-Haupt, D. Sagan, D. Schoerling, I. Tecker, R. Tomas, P. Thrane, E. Todesco, D. Tommasini, F. Zimmermann

15th HE-LHC design meeting, CERN, 8 June, 2017

Outline

- **Introduction**
  - **HE-LHC optics under design**
  - **See Y. Nosochkov's talk for HE-LHC optics design efforts at FCC Week 2017**
- **Resonance driving term (RDT) and dynamic aperture (DA) calculation**
  - **Only applied to injection optics w/o errors for HE-LHC for this moment**
  - **Only lattice sextupoles taken as sources of non-linear effects**
- **Summary and outlook**

1. Introduction

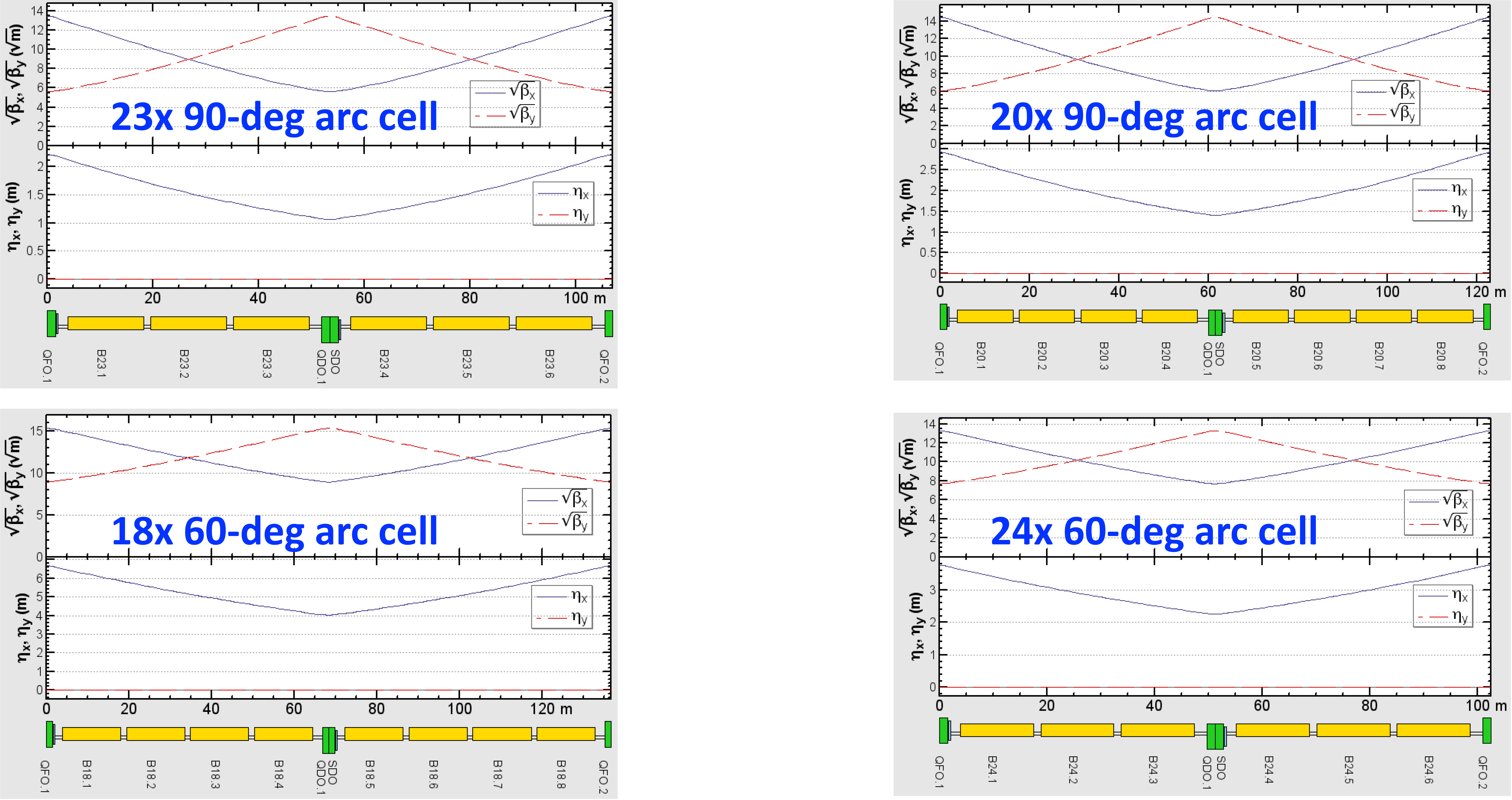
➤ Alternatives for arc cells fitting to the geometry of LHC arcs

- Motivation: simply scaling (HL-)LHC hits the limits set by FCC technologies
- Rules: Assume the same drifts between magnets as LHC; Fit to the arc length of LHC

	LHC-like	24x 60^0 HE-LHC	20x 90^0 HE-LHC	18x 60^0 HE-LHC
Arc cell phase advance [deg]	90/90	60/60	90/90	60/60
Arc cell length [m]	106.9584	102.5018	123.00	136.669
K1 [m^{-1}]	0.02697	0.0199	0.0234	0.01485
$\beta_{max/min}$ [m]	181.3/31.54	176.6/59.48	208.68/36.24	235.74/79.22
$\eta_{max/min}$ [m]	2.21/1.07	3.75/2.26	2.92/1.41	6.67/4.02
Dipole length [m]	14.3 [x6]	13.56 [x6]	12.39 [x8]	14.1 [x8]
Dipole field [T]@13.5TeV	16.06	16.23	15.99	15.61
Filling factor	0.802	0.794	0.806	0.825

1. Introduction

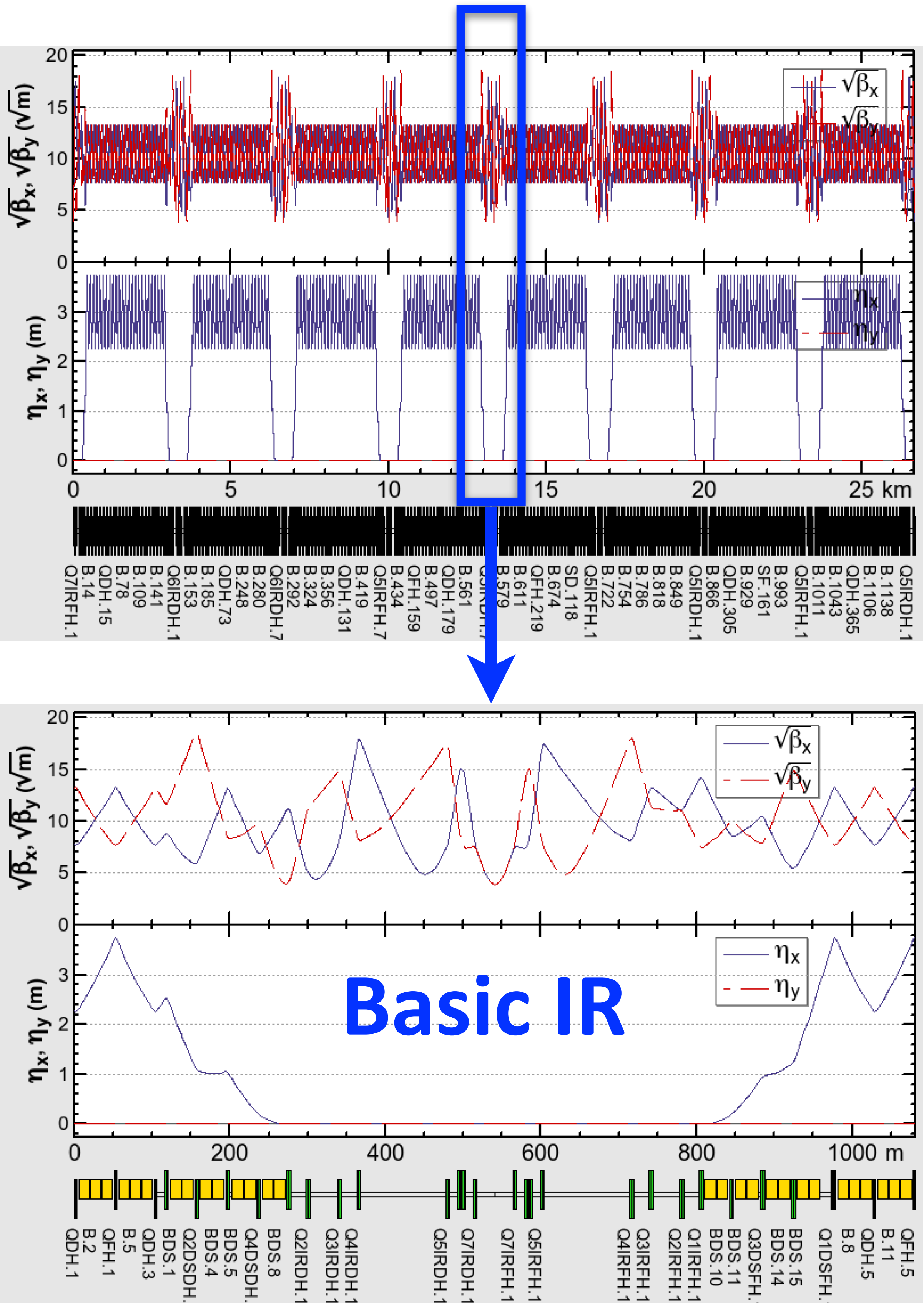
➤ Alternatives for arc cells



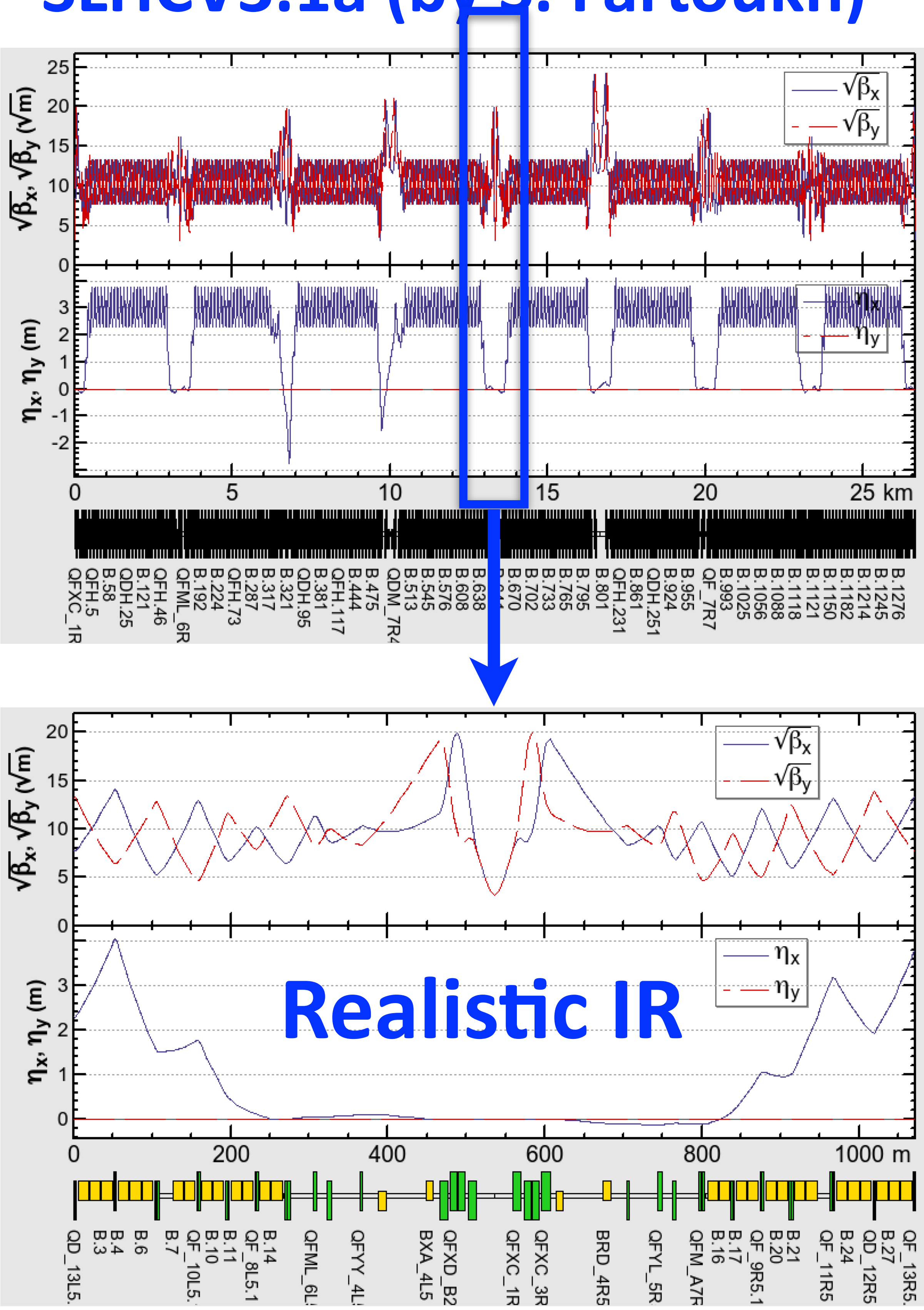
1. Introduction

➤ Integration with IRs (Start from IP1 for plots)

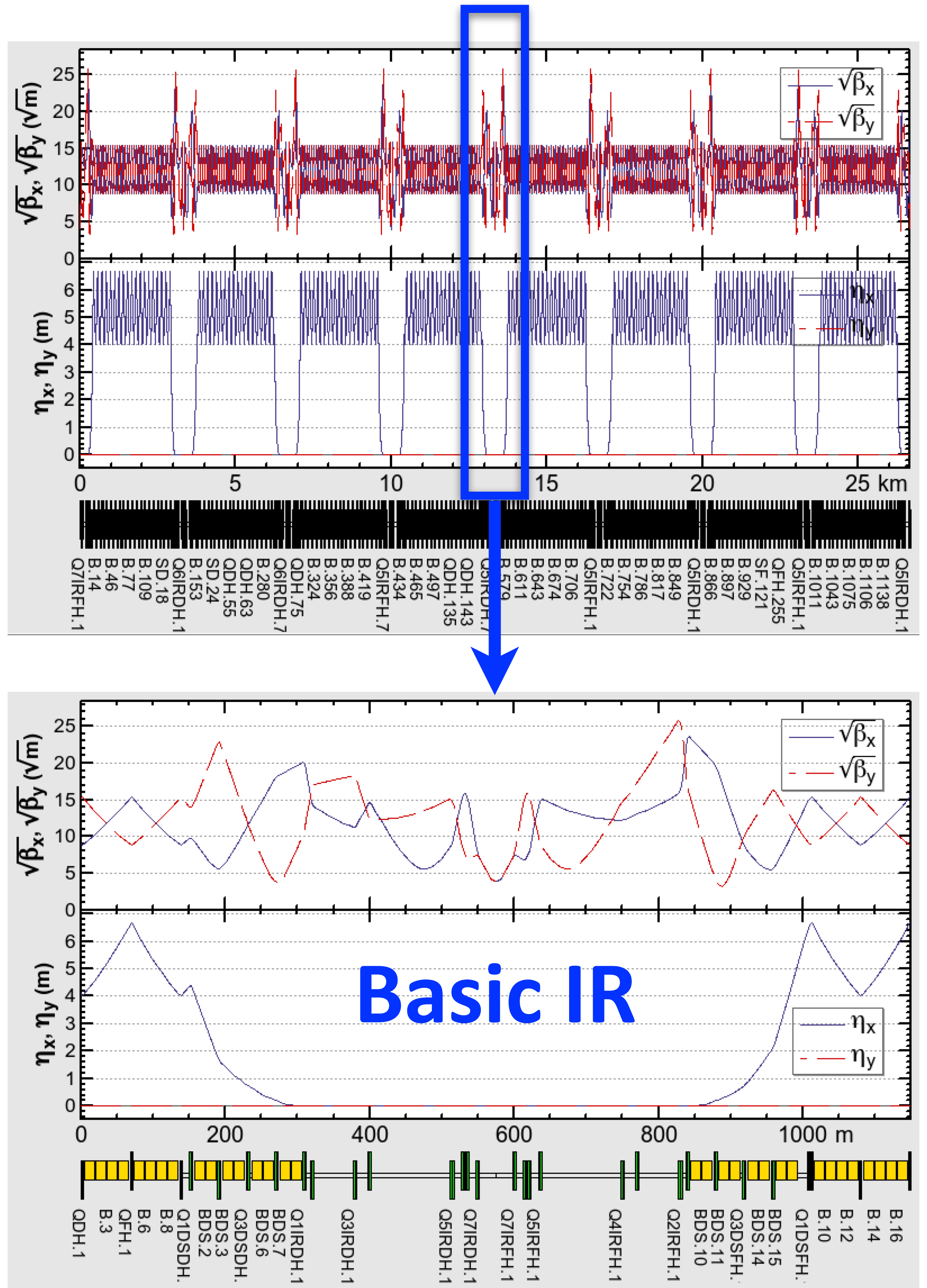
Injection lattice by Y.N.
24x 60-deg arcs



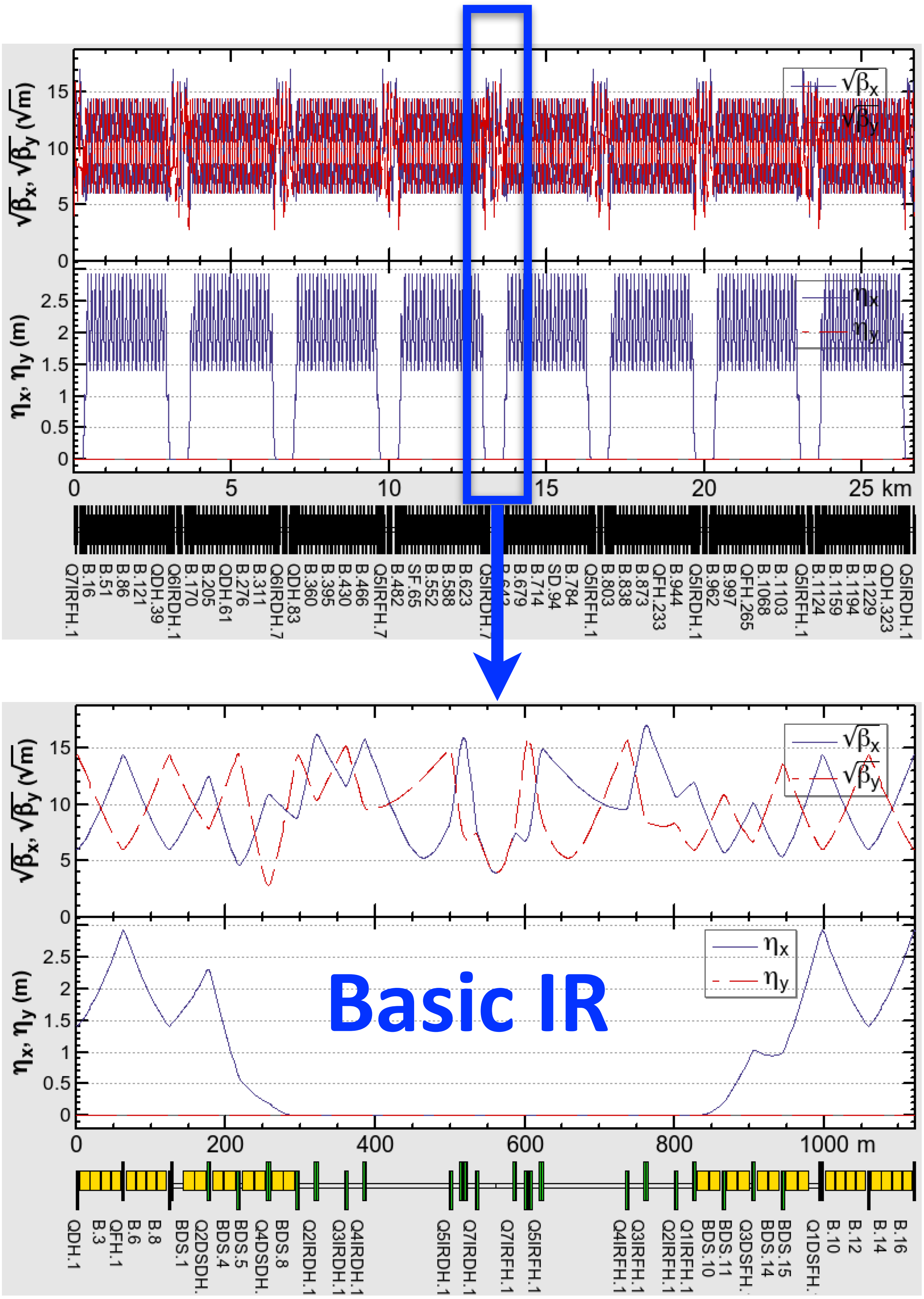
Modified HL-LHC injection lattice by T. Risselada
24x 60-deg arcs + IRs of SLHCV3.1a (by S. Fartoukh)



Injection lattice by Y.N.
18x 60-deg arcs



Injection lattice by Y.N.
20x 90-deg arcs



1. Introduction

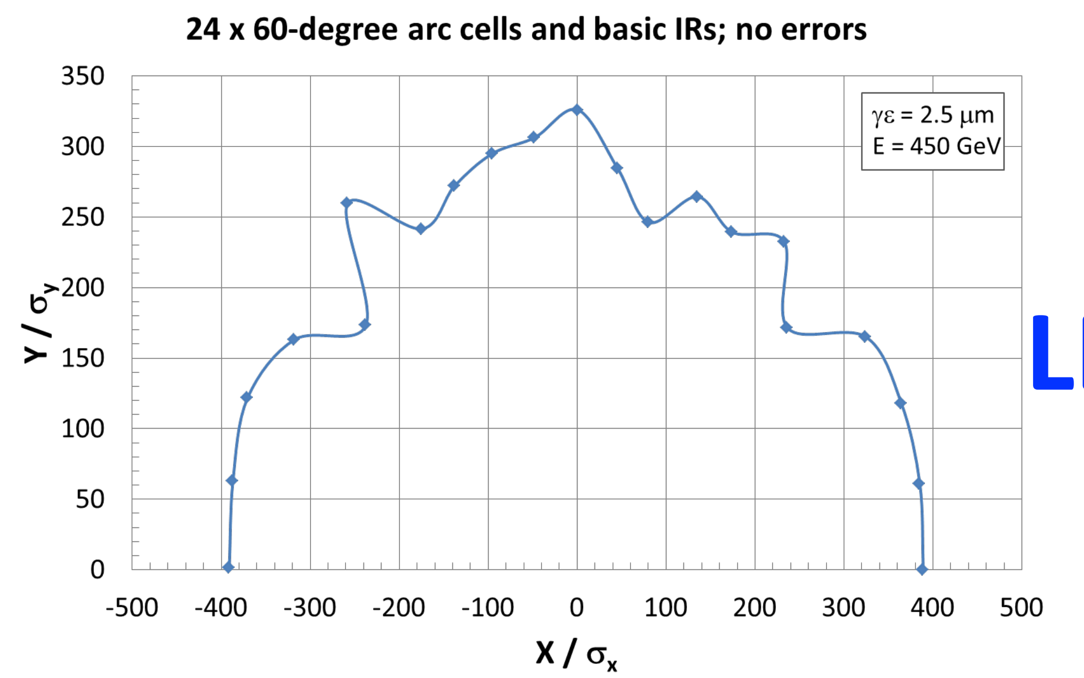
➤ Simulation conditions

- RDT calculation
  * PTC tracking w/o SR, w/o errors
  * Integrate RDTs along beam orbit
- DA calculation
  * SAD tracking w/o SR, w/o errors
  * Use standard FMA algorithm
  * Short-term DA by tracking 1024 turns (also see Y.N.'s talk)
  * Long-term DA by tracking 100k turns
- Normalized emittance $\gamma\varepsilon$=2.5 μm; Beam energy E=450 GeV
- Linear chromaticity set at (Qx', Qy')=(3, 3) for all lattices under consideration

2. RDT and DA calculation

➤ Injection lattice with 24x 60-deg arcs (by Y.N.)

- Use basic IRs
- Working point (49.28, 47.31)



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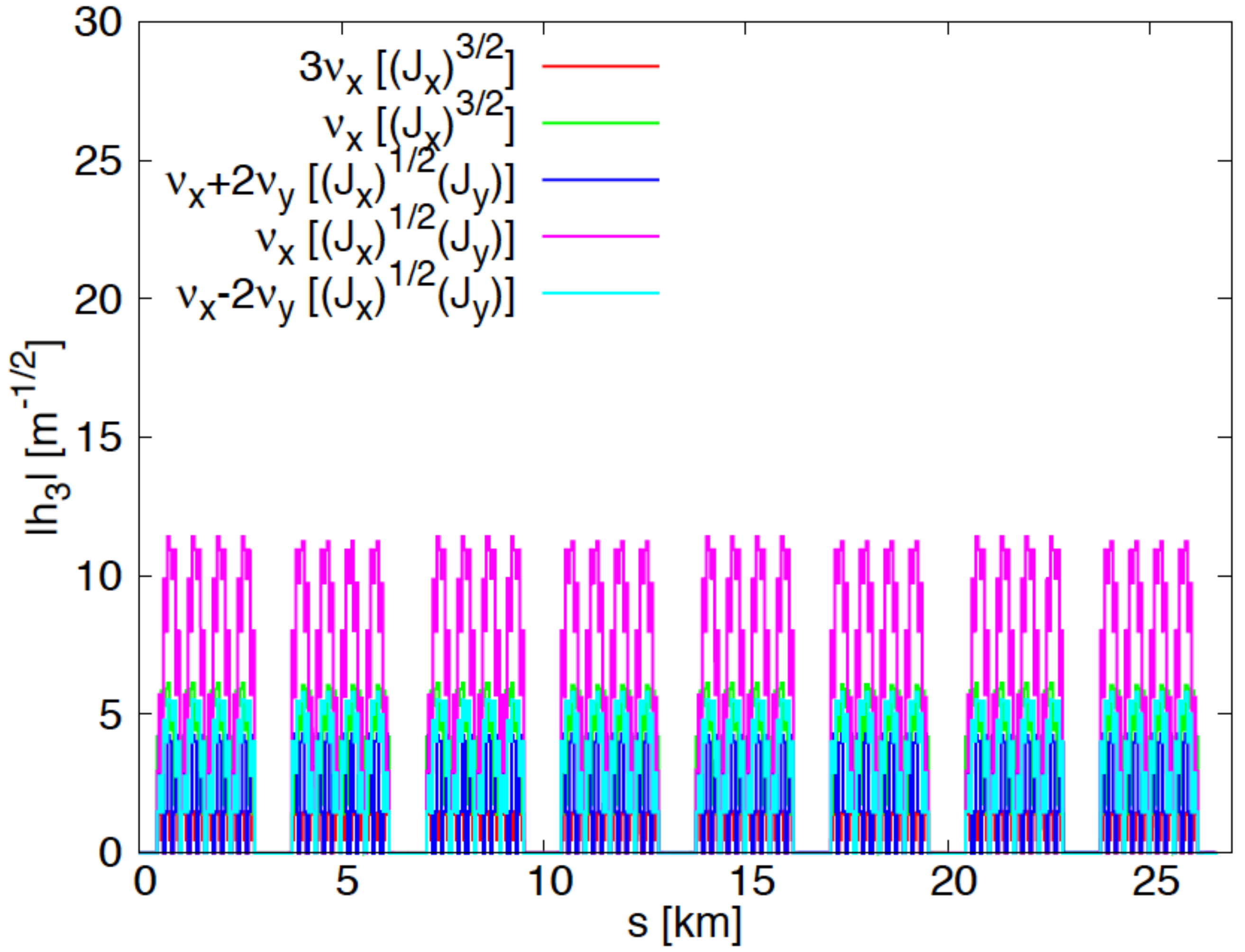
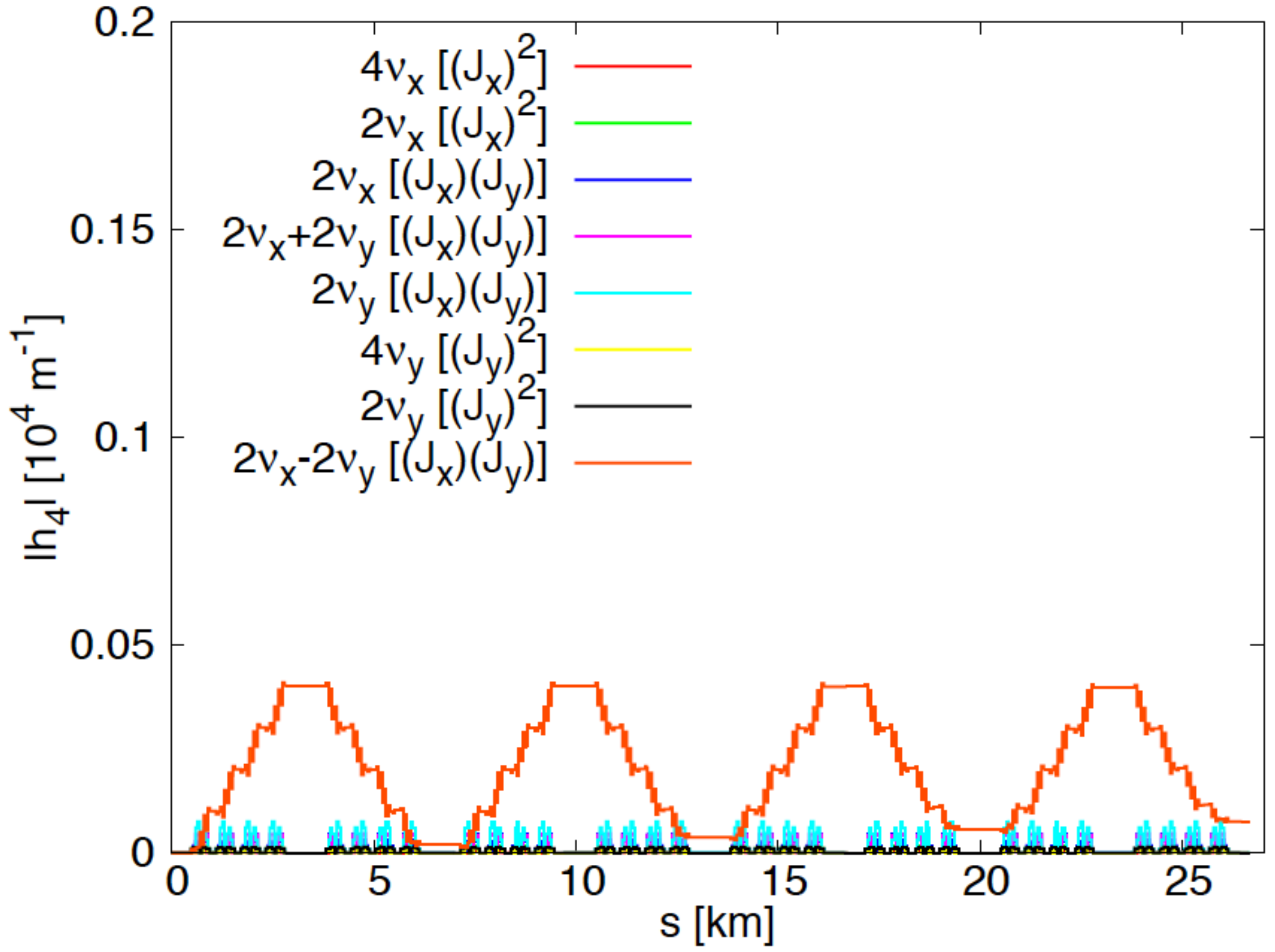
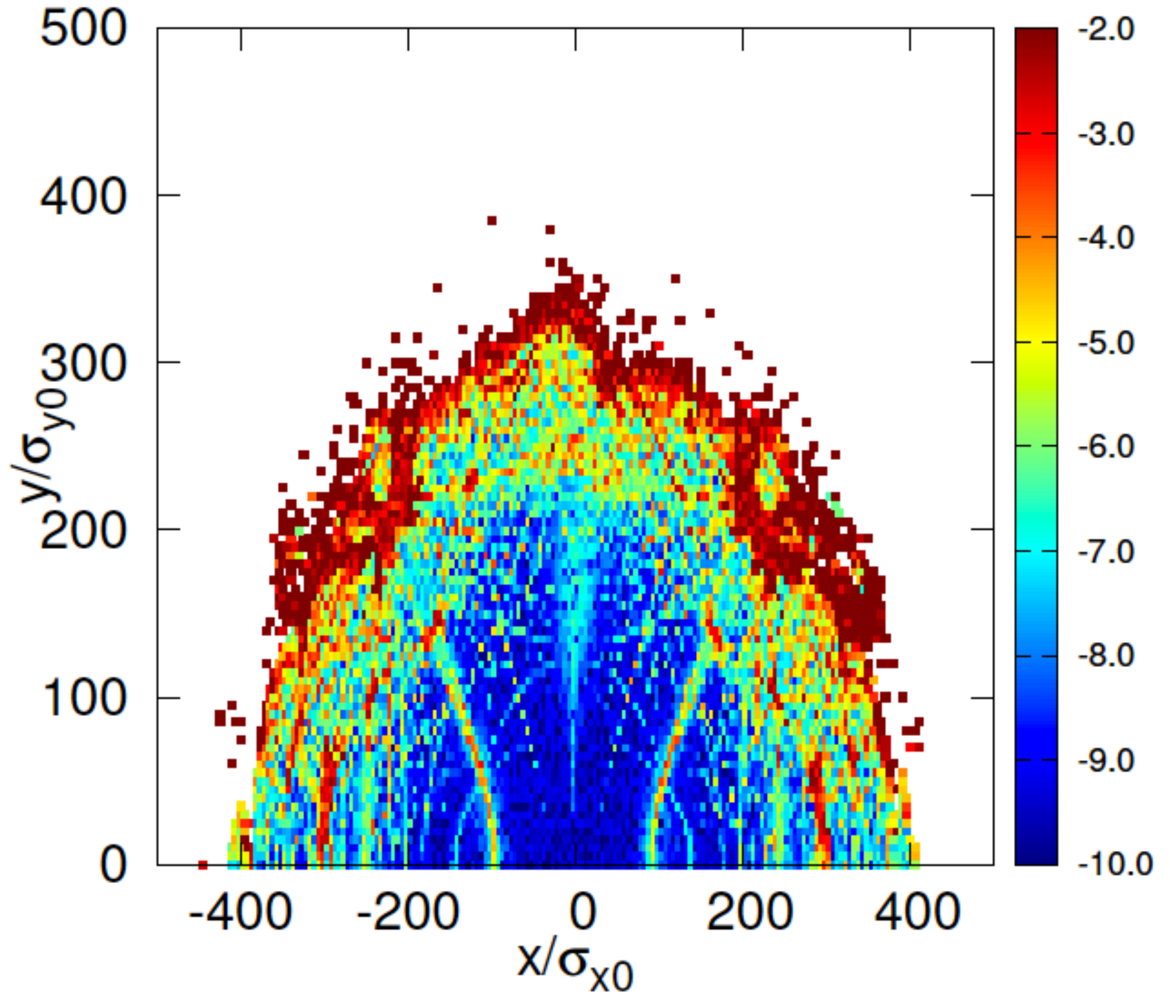
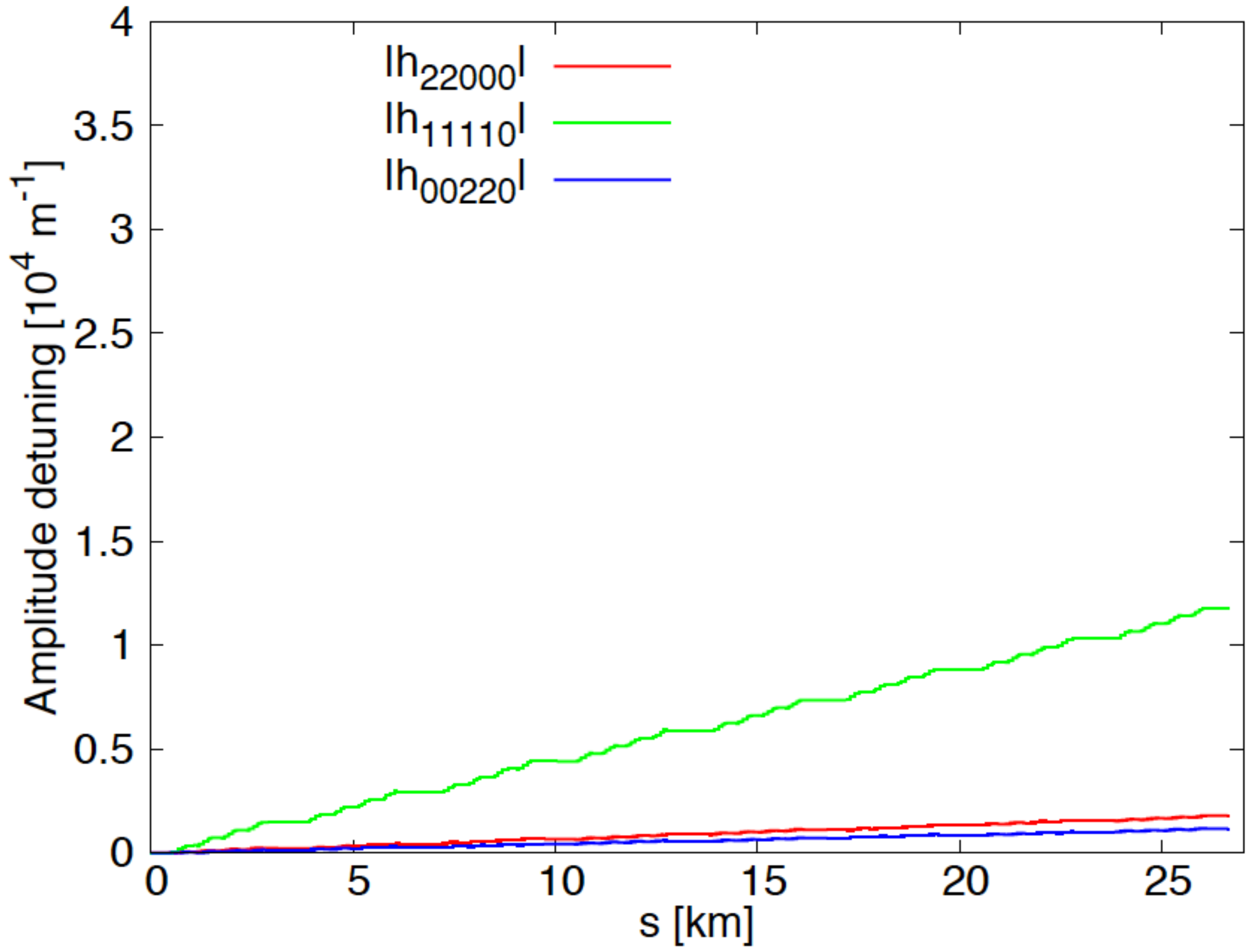
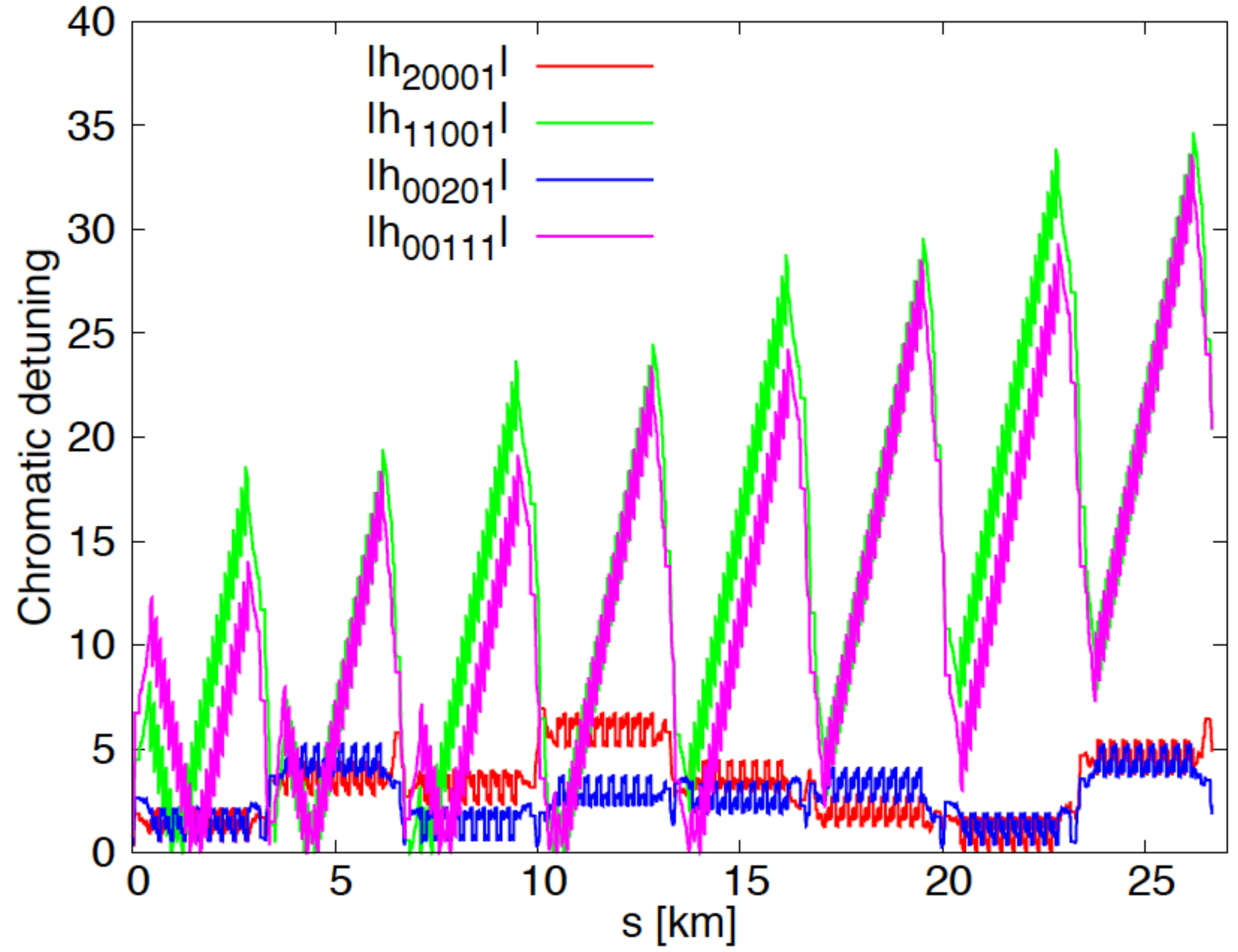
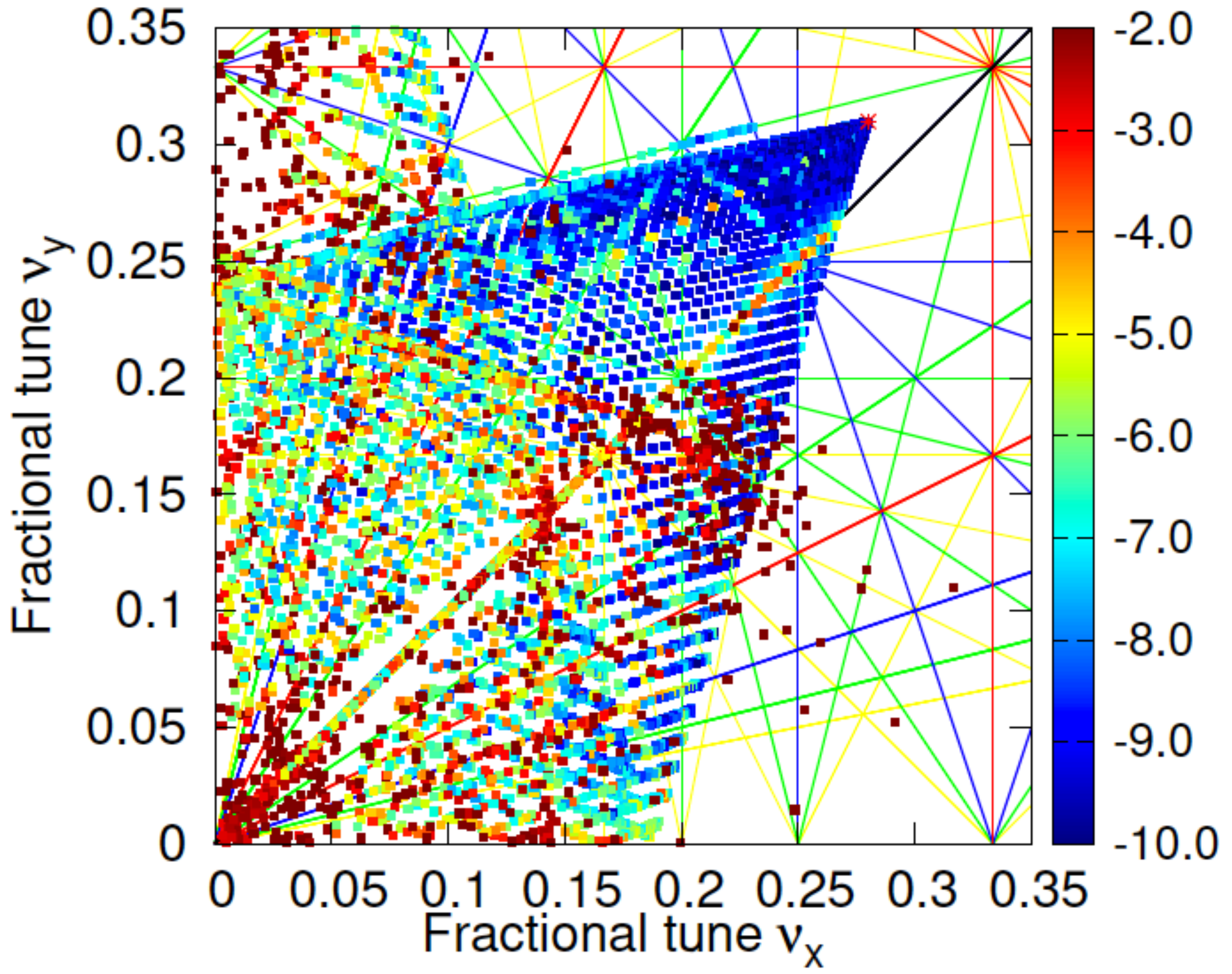








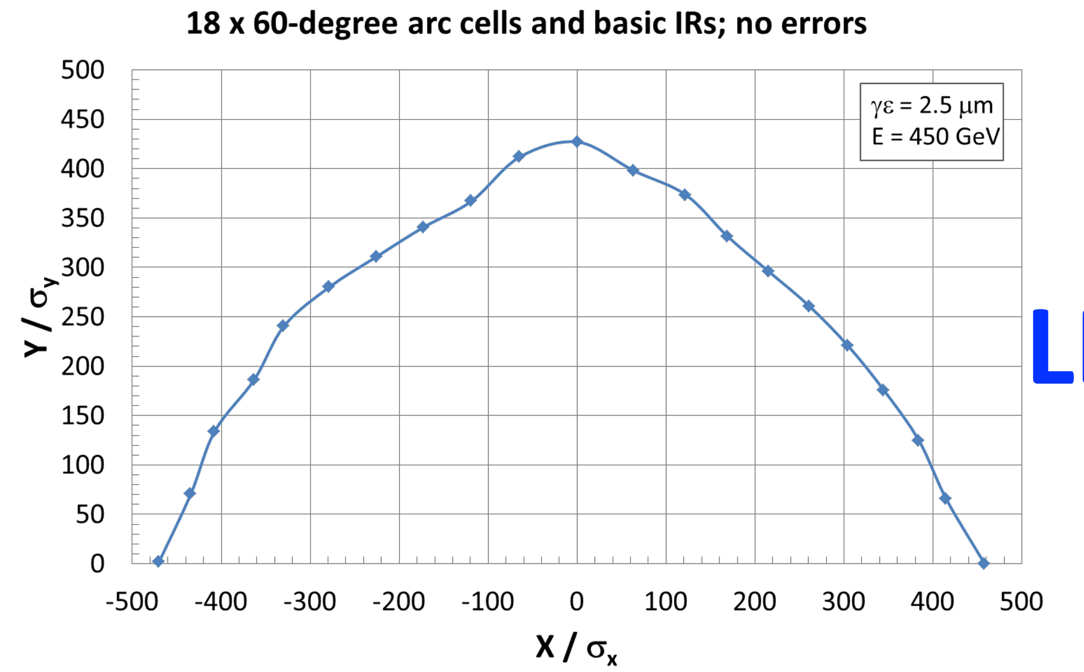




2. RDT and DA calculation

➤ Injection lattice with 18x 60-deg arcs (by Y.N.)

- Use basic IRs
- Working point (37.28, 39.31)



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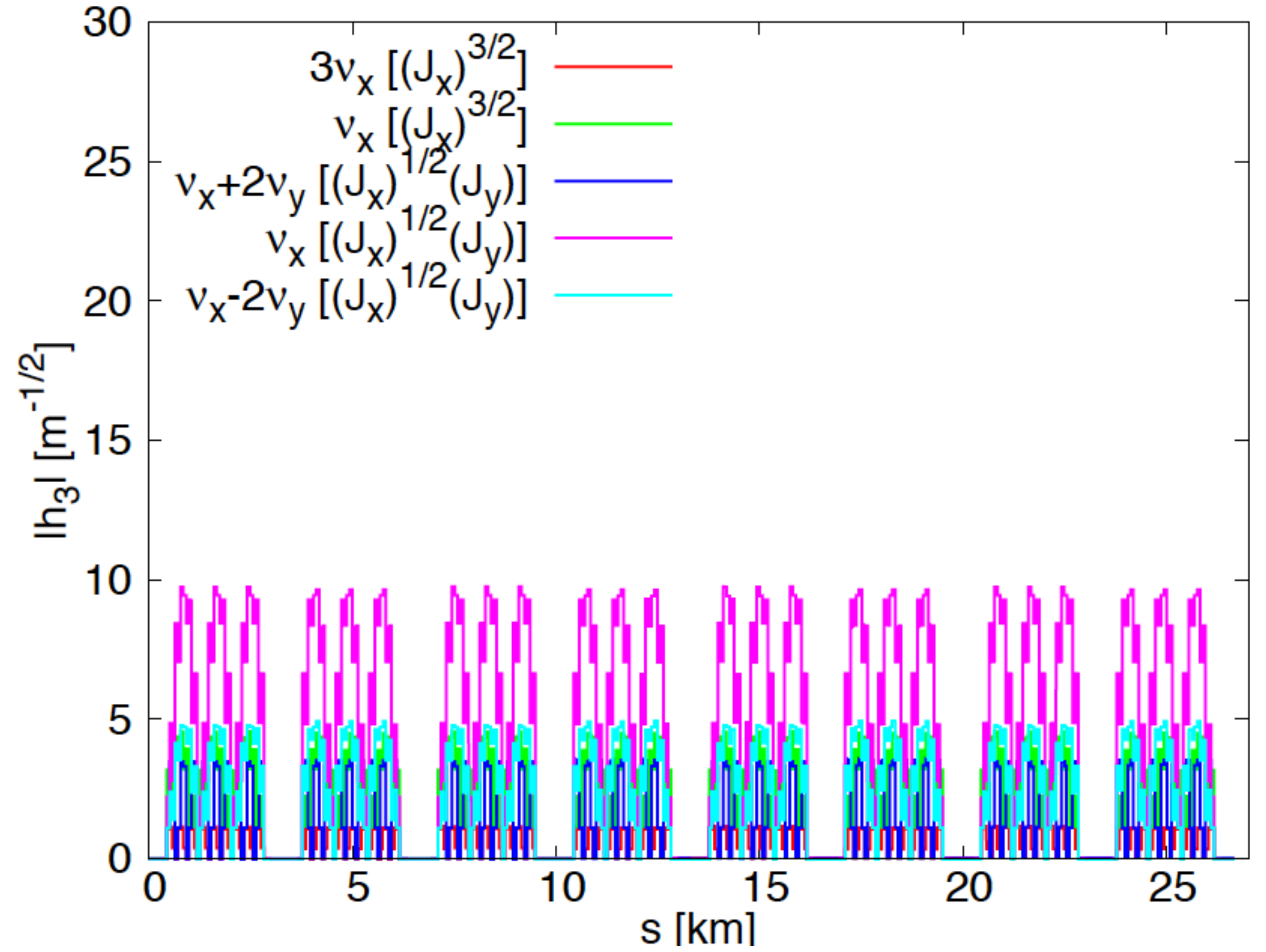
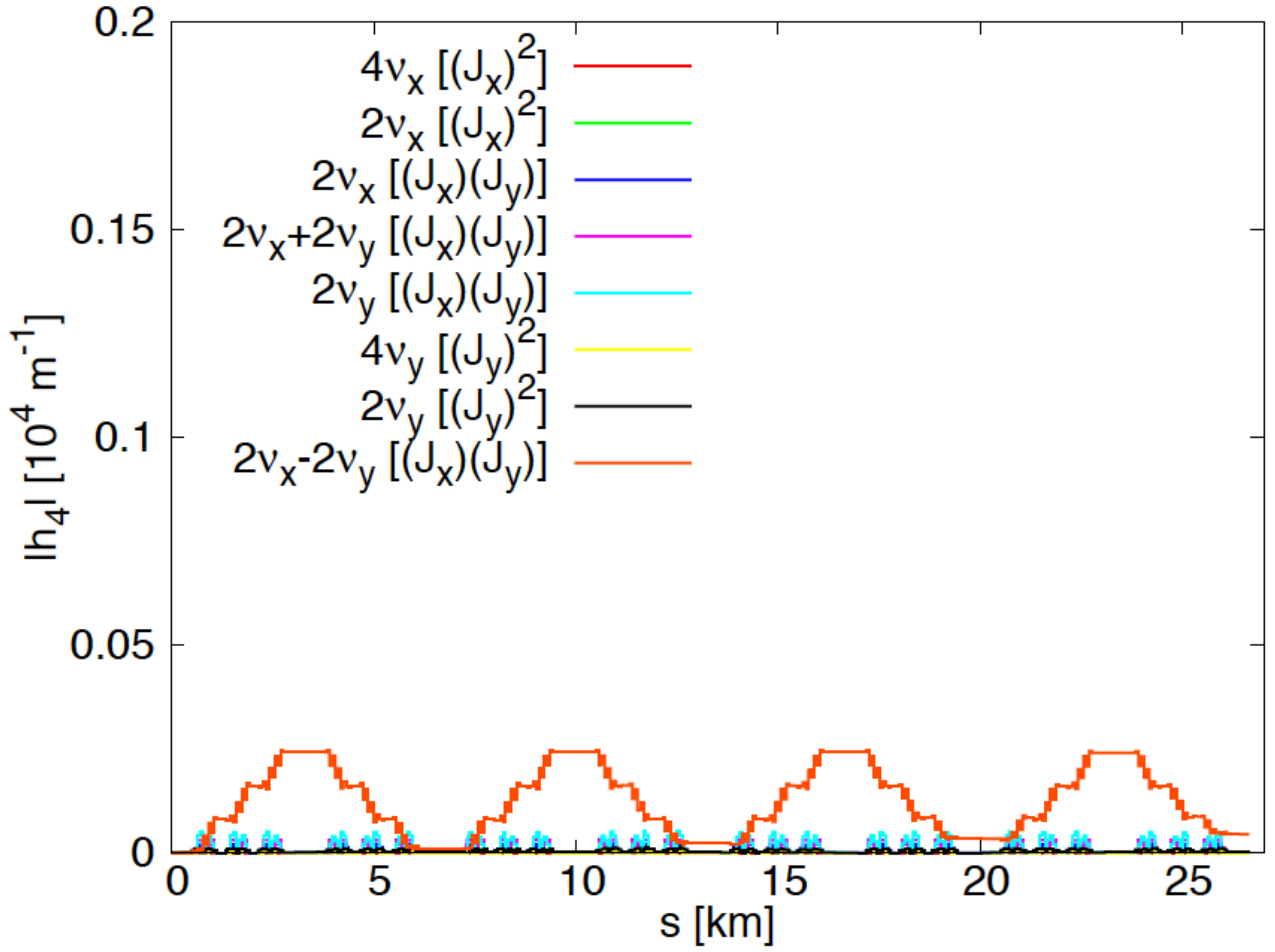
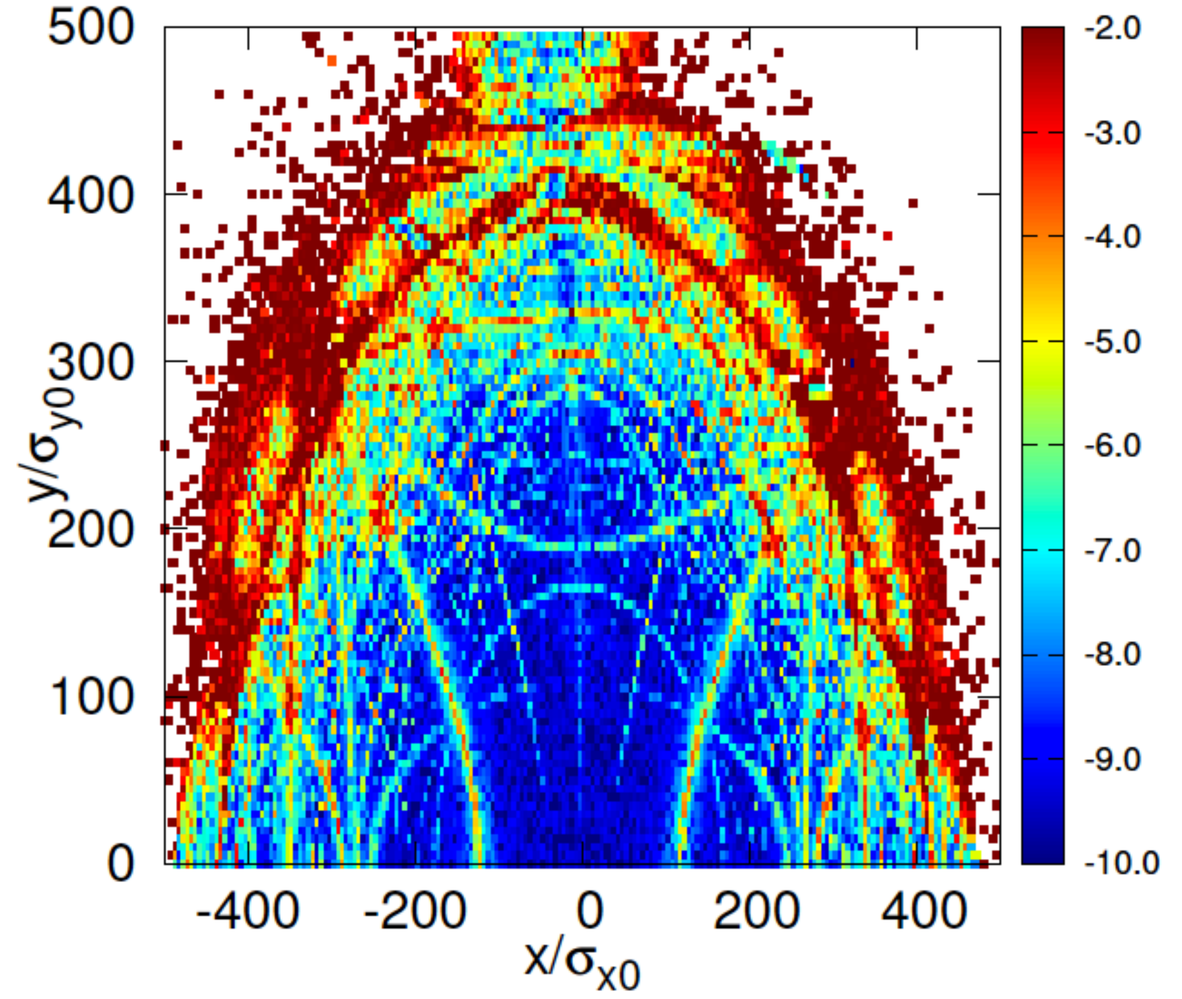
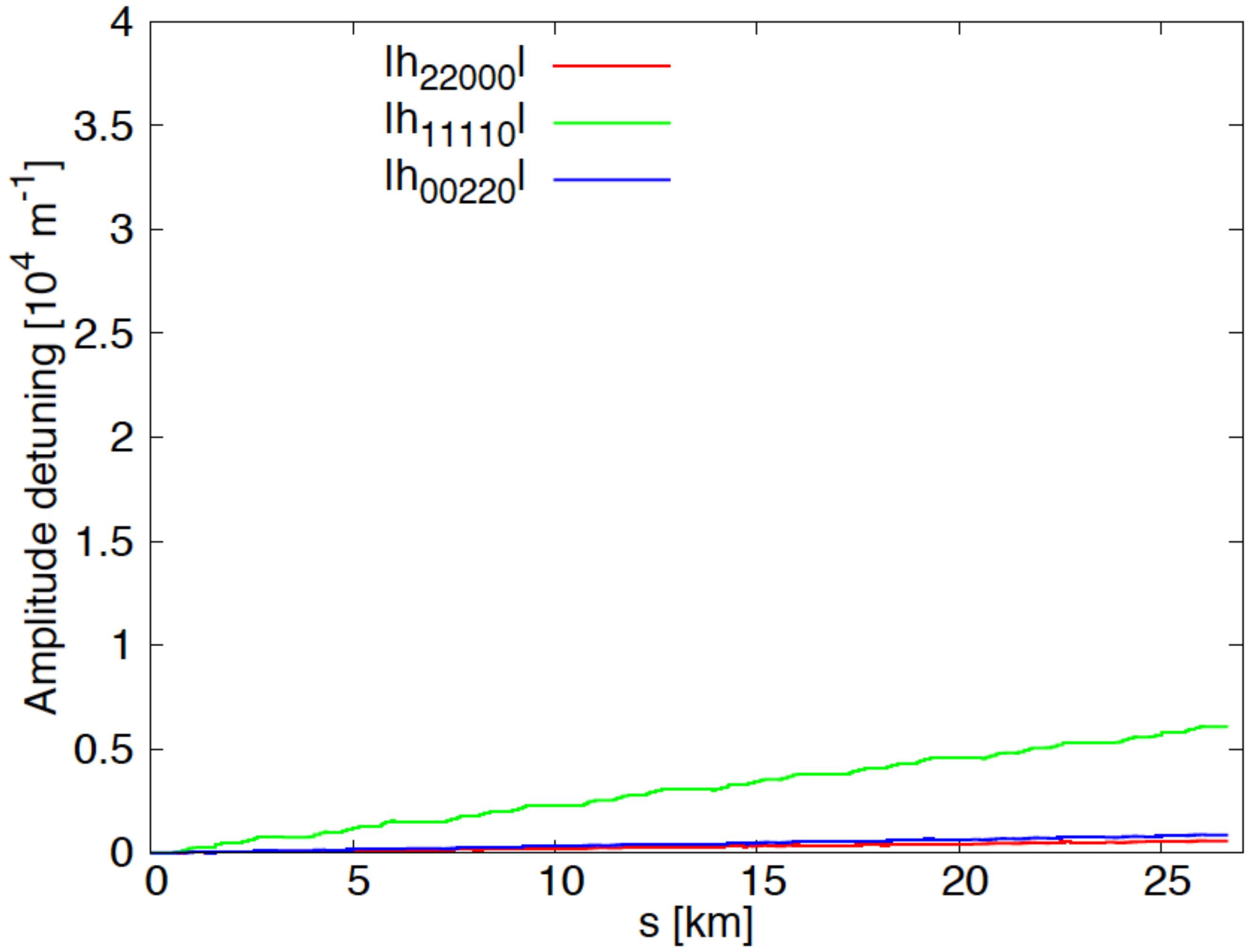
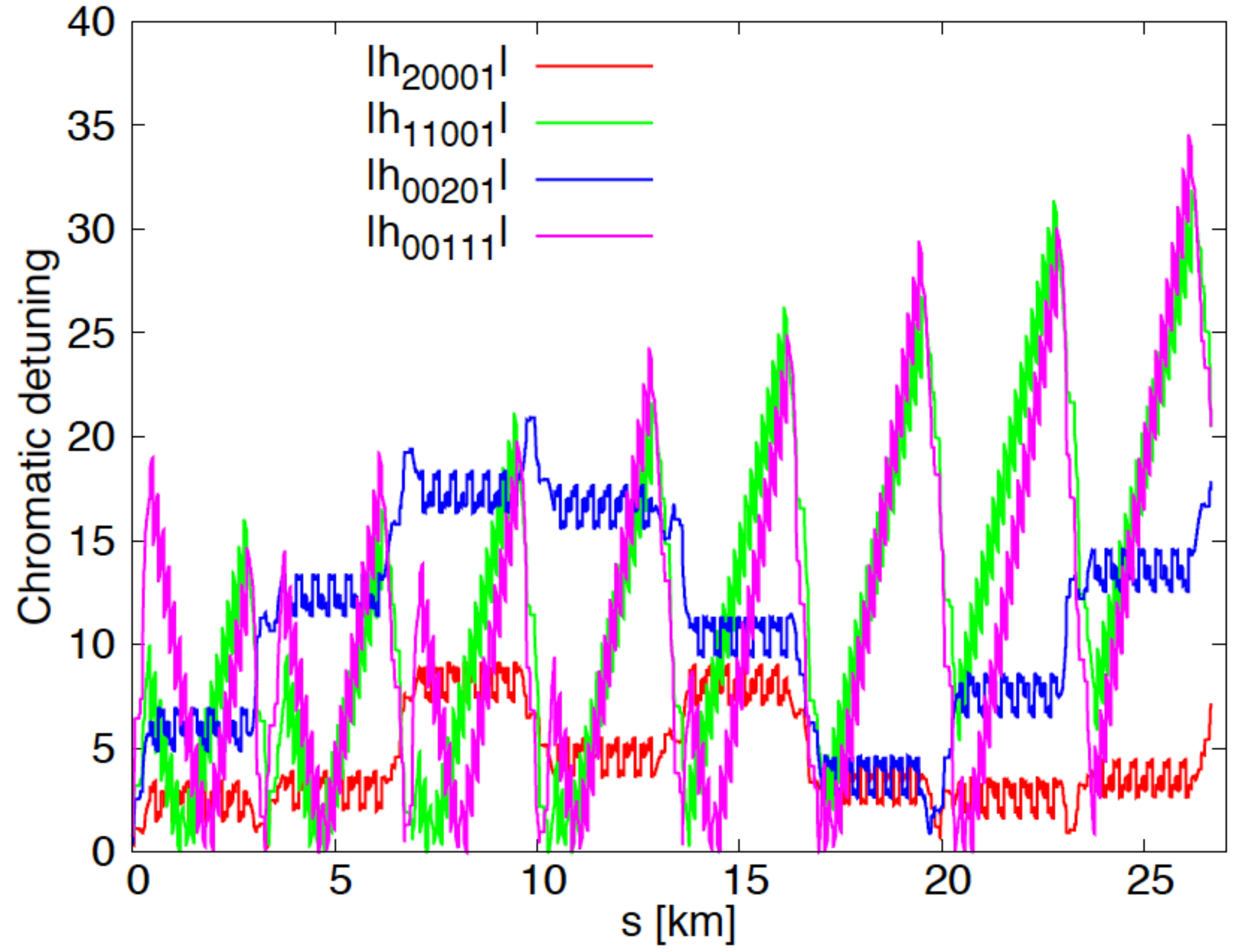
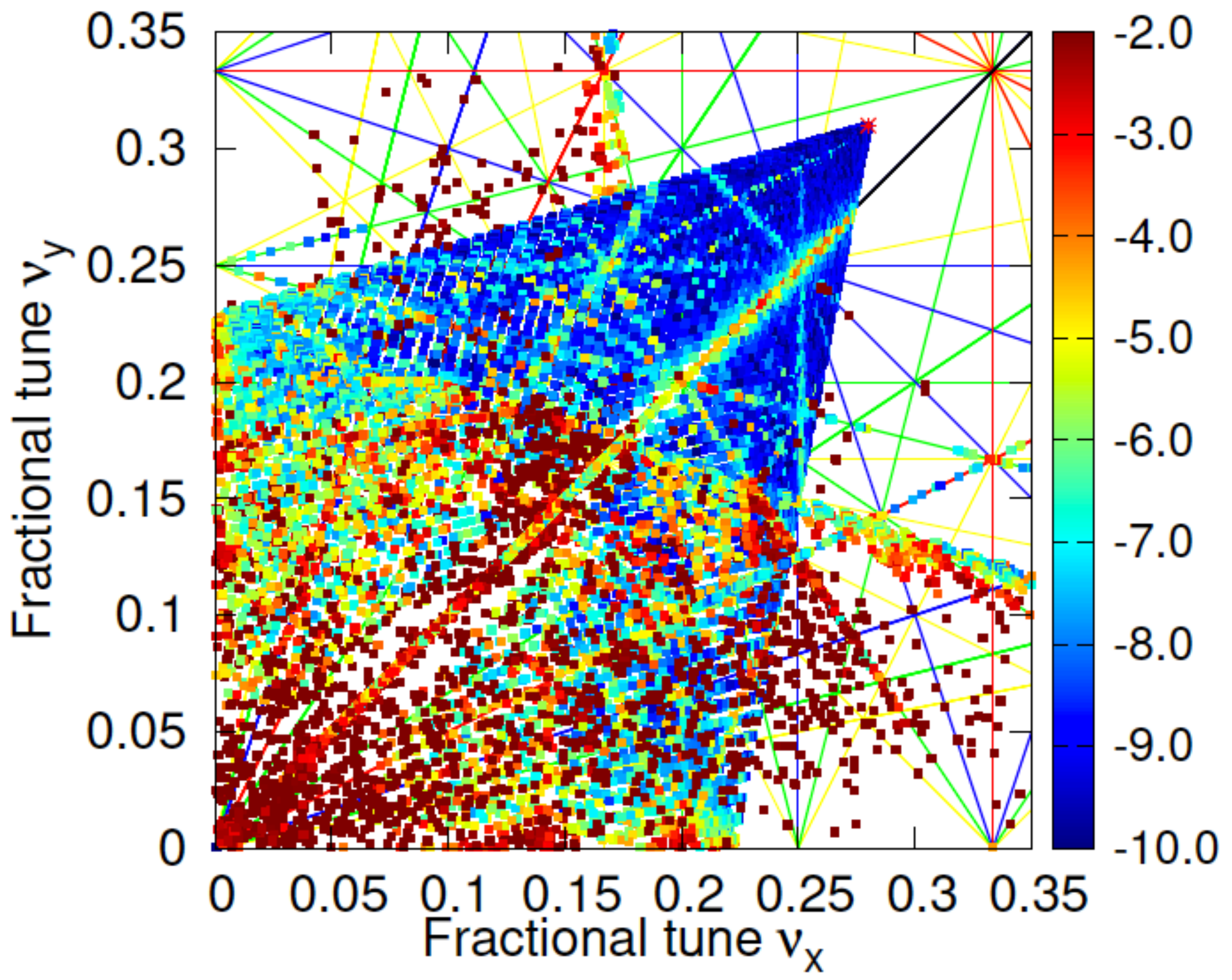








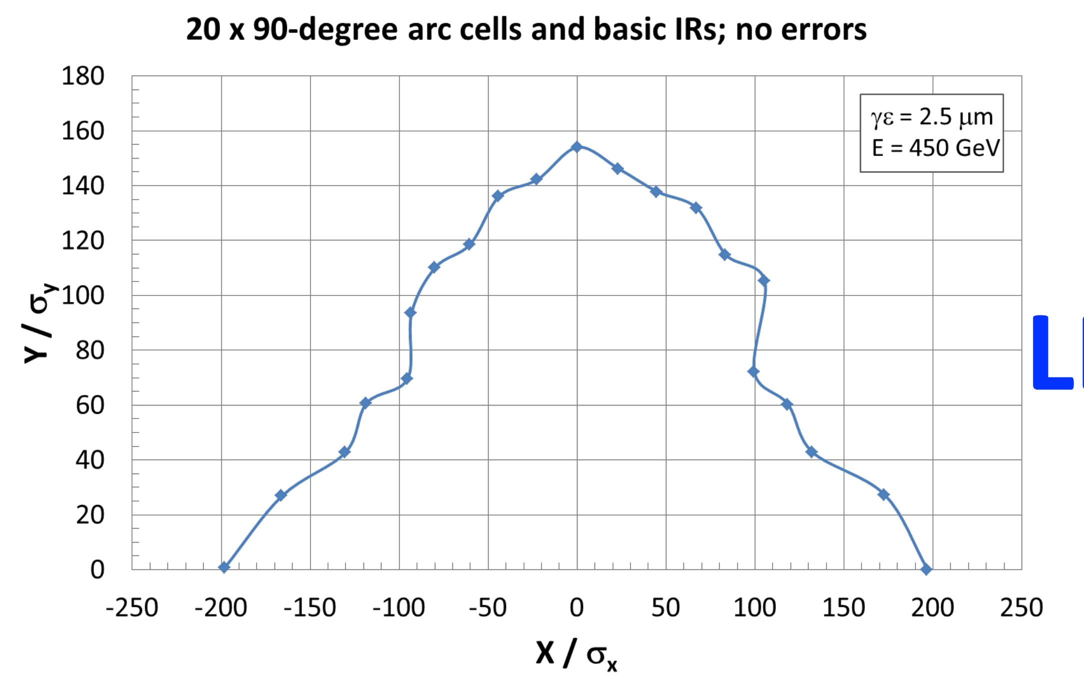




2. RDT and DA calculation

➤ Injection lattice with 20x 90-deg arcs (by Y.N.)

- Use basic IRs
- Working point (56.28, 57.31)



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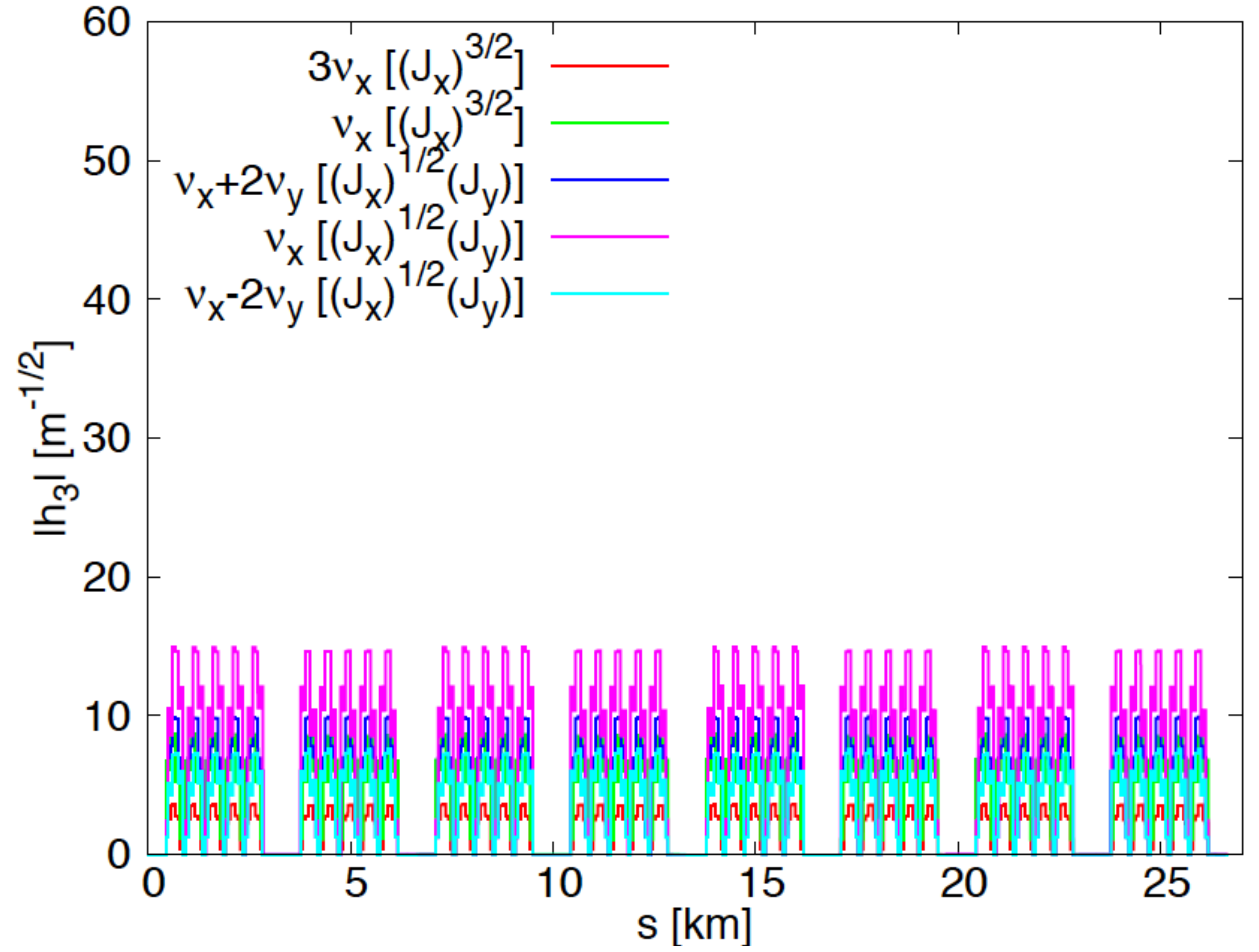
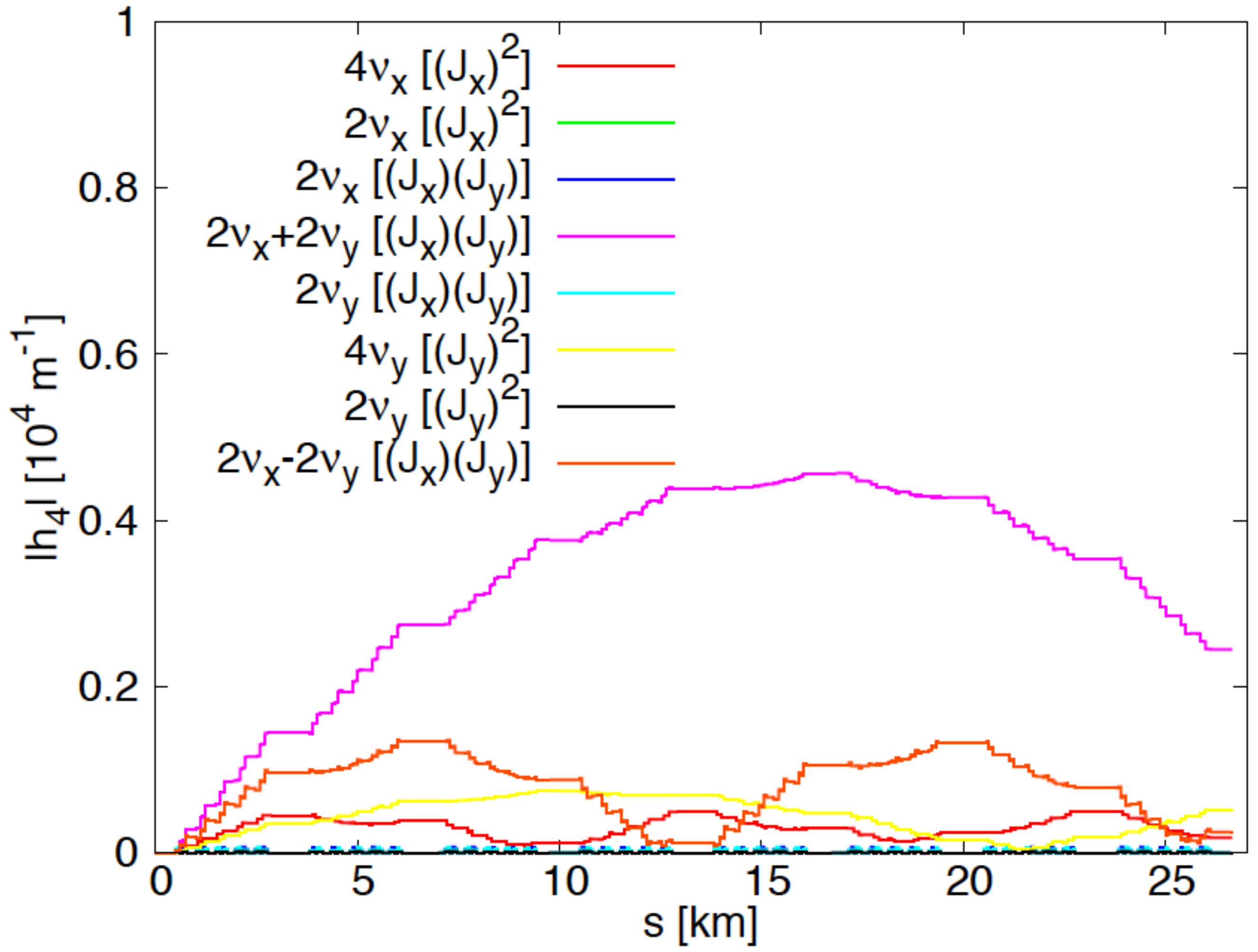
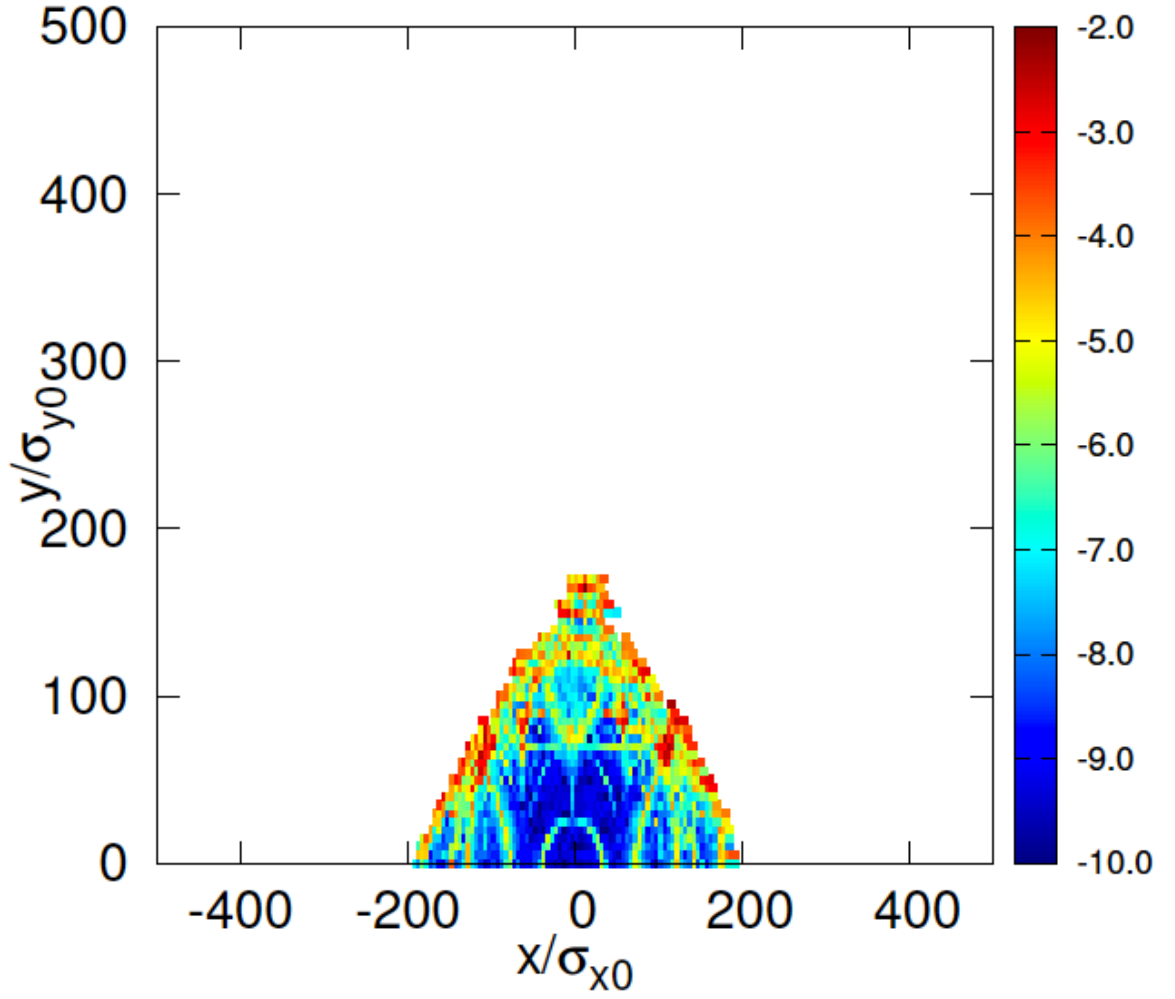
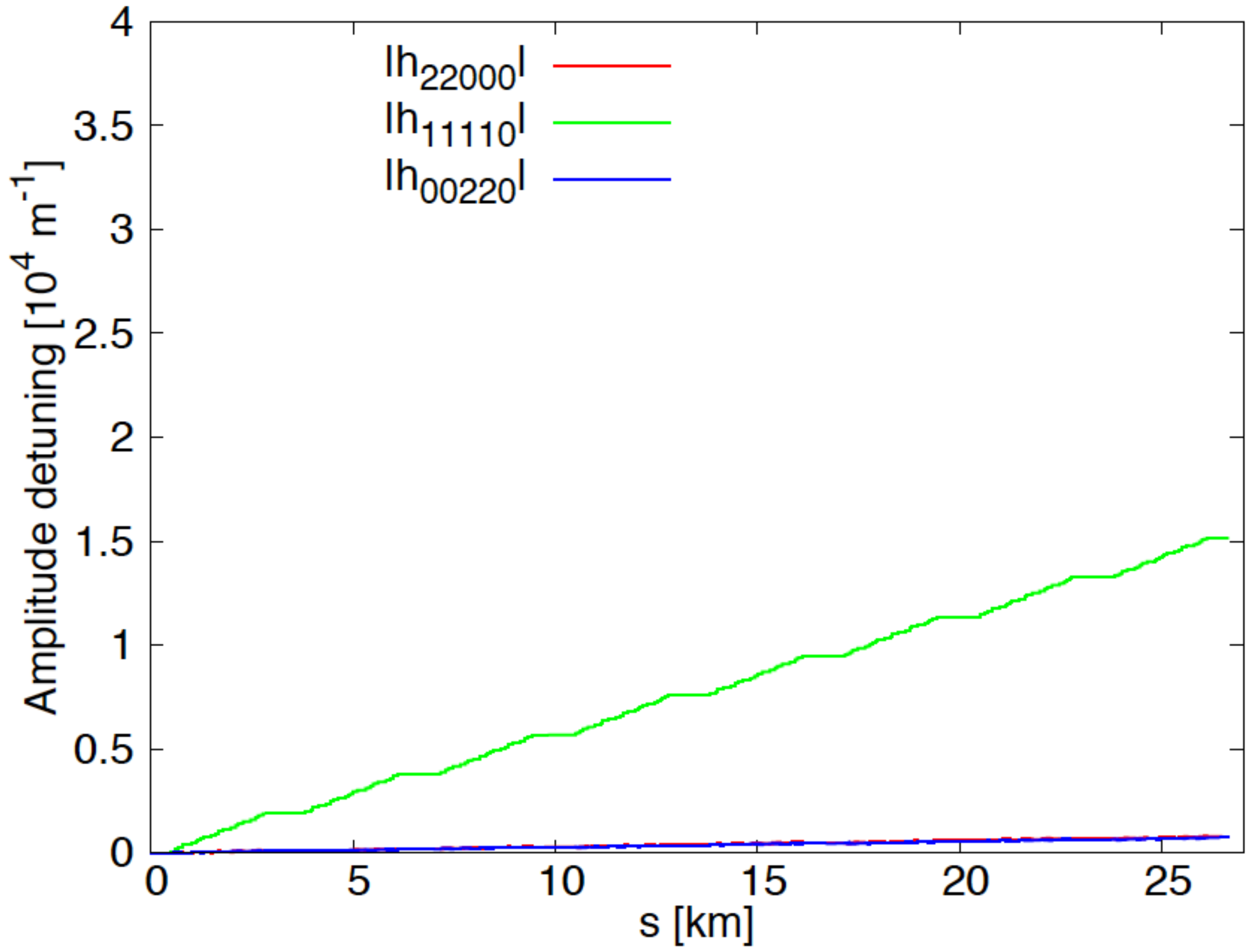
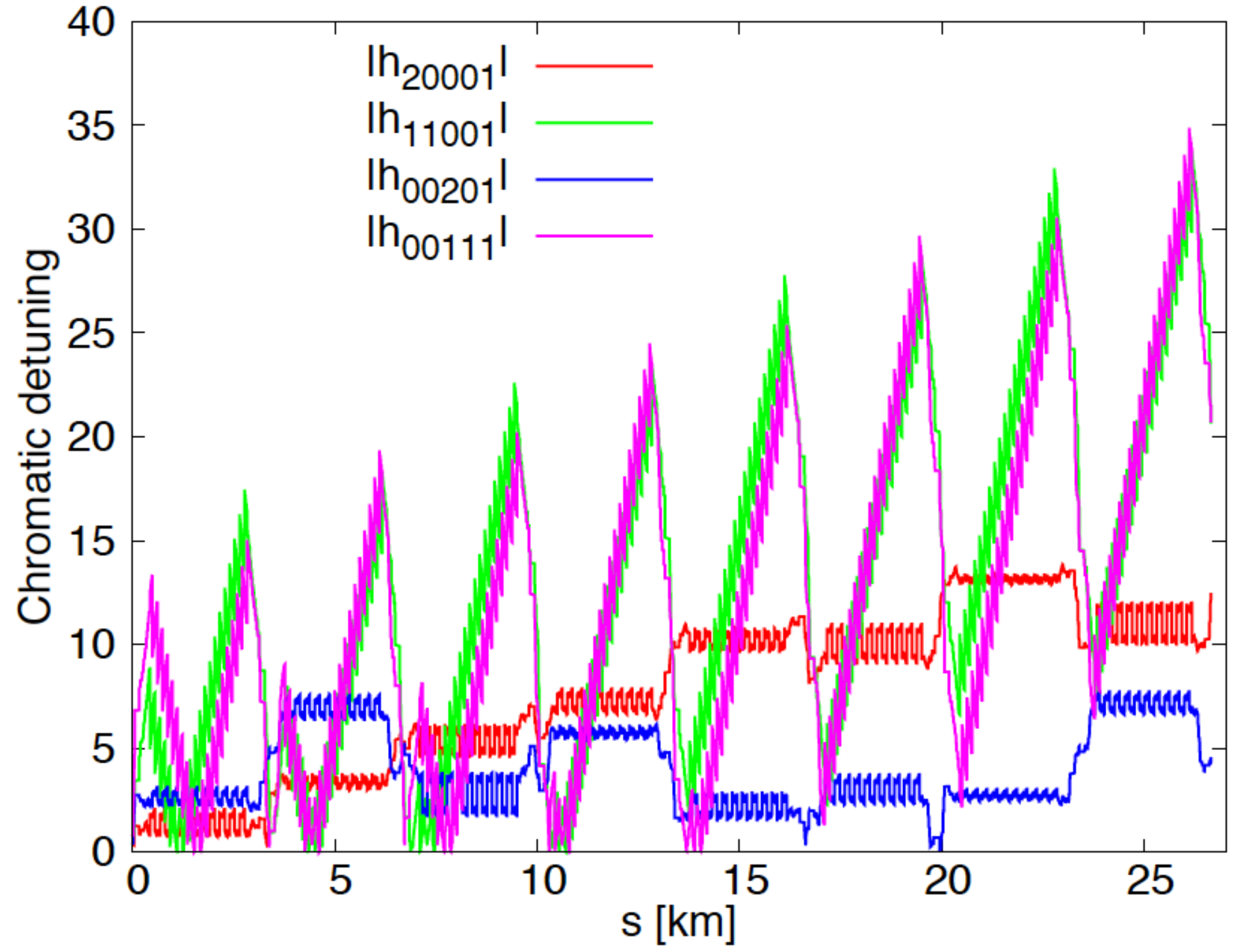
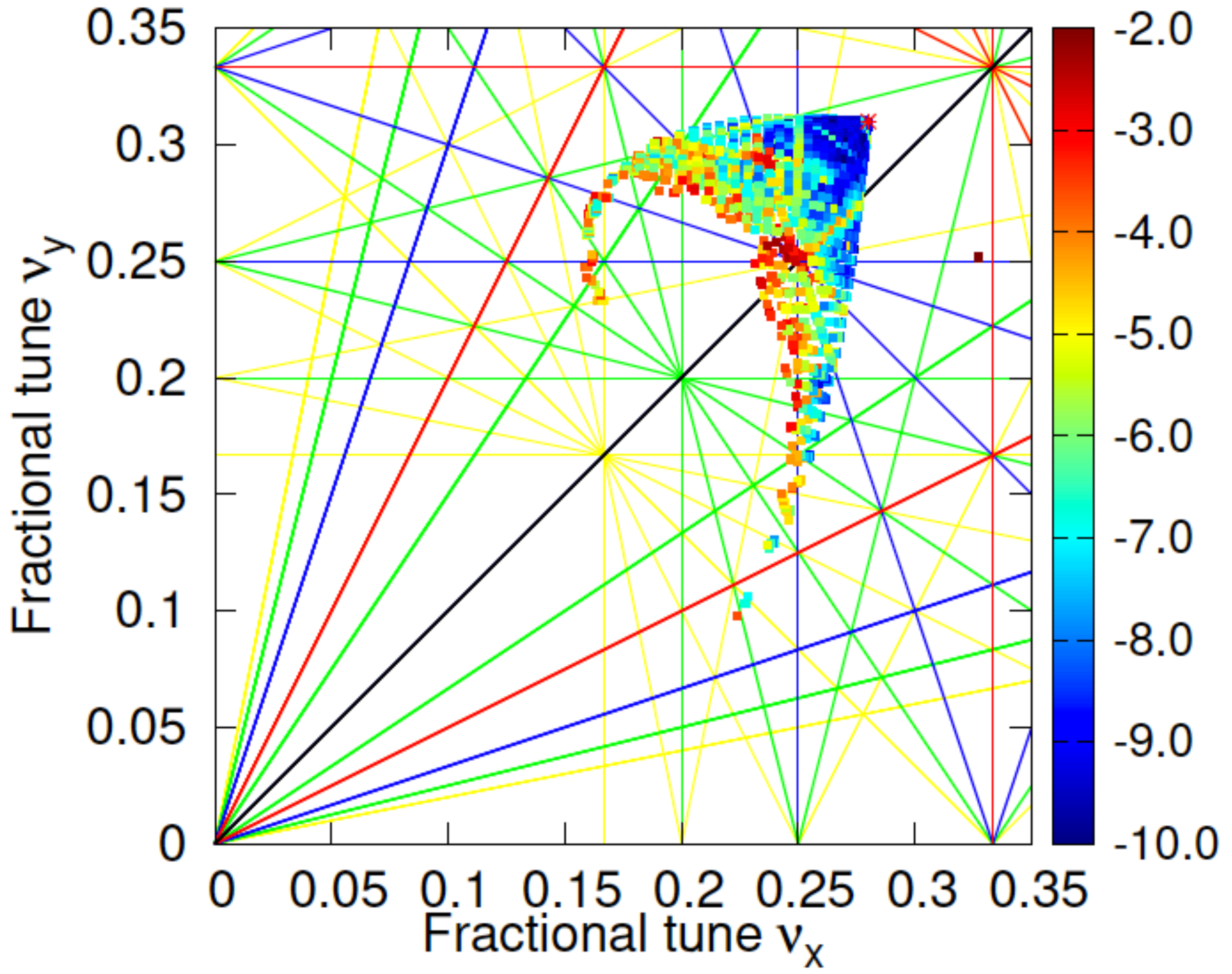








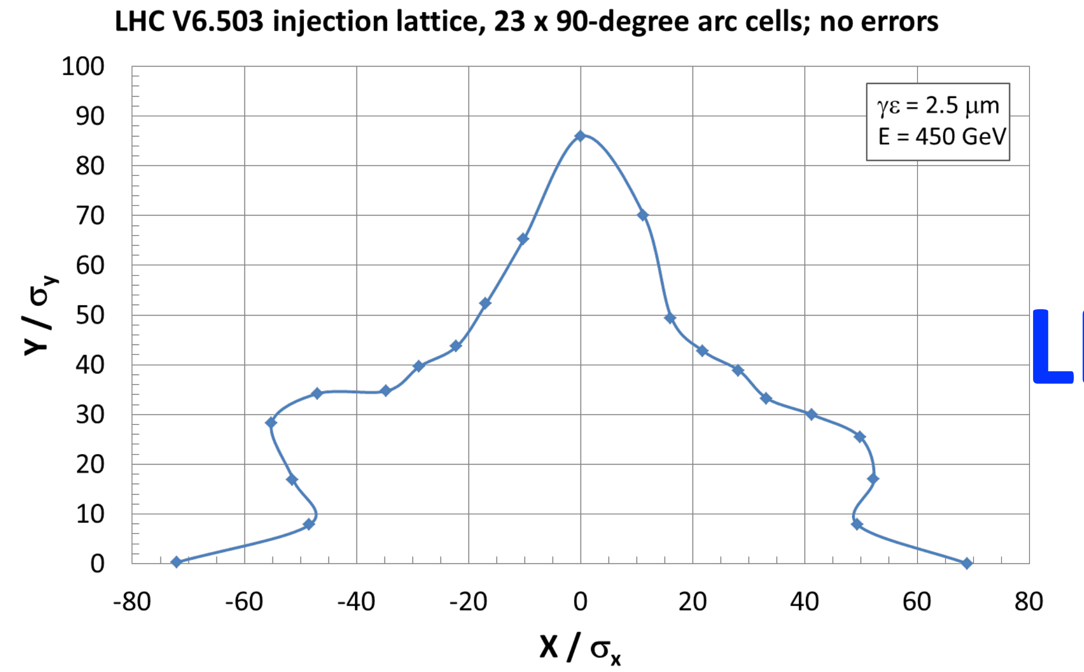




2. RDT and DA calculation

➤ LHC injection lattice (Ver. V6.503)

- **23x ~90-deg arcs, same dipole for both arcs and DSs**
- **Working point (64.28, 59.31)**



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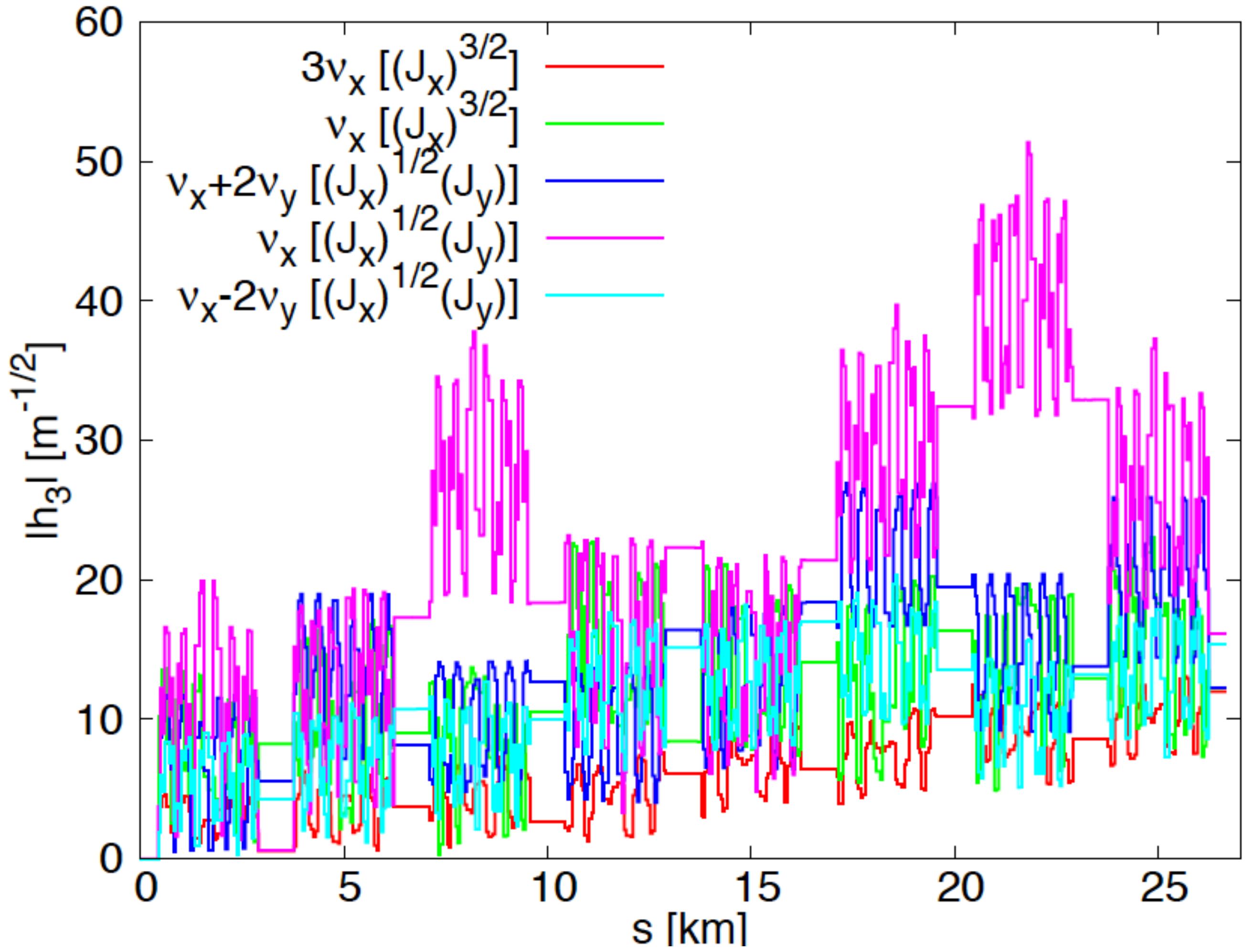
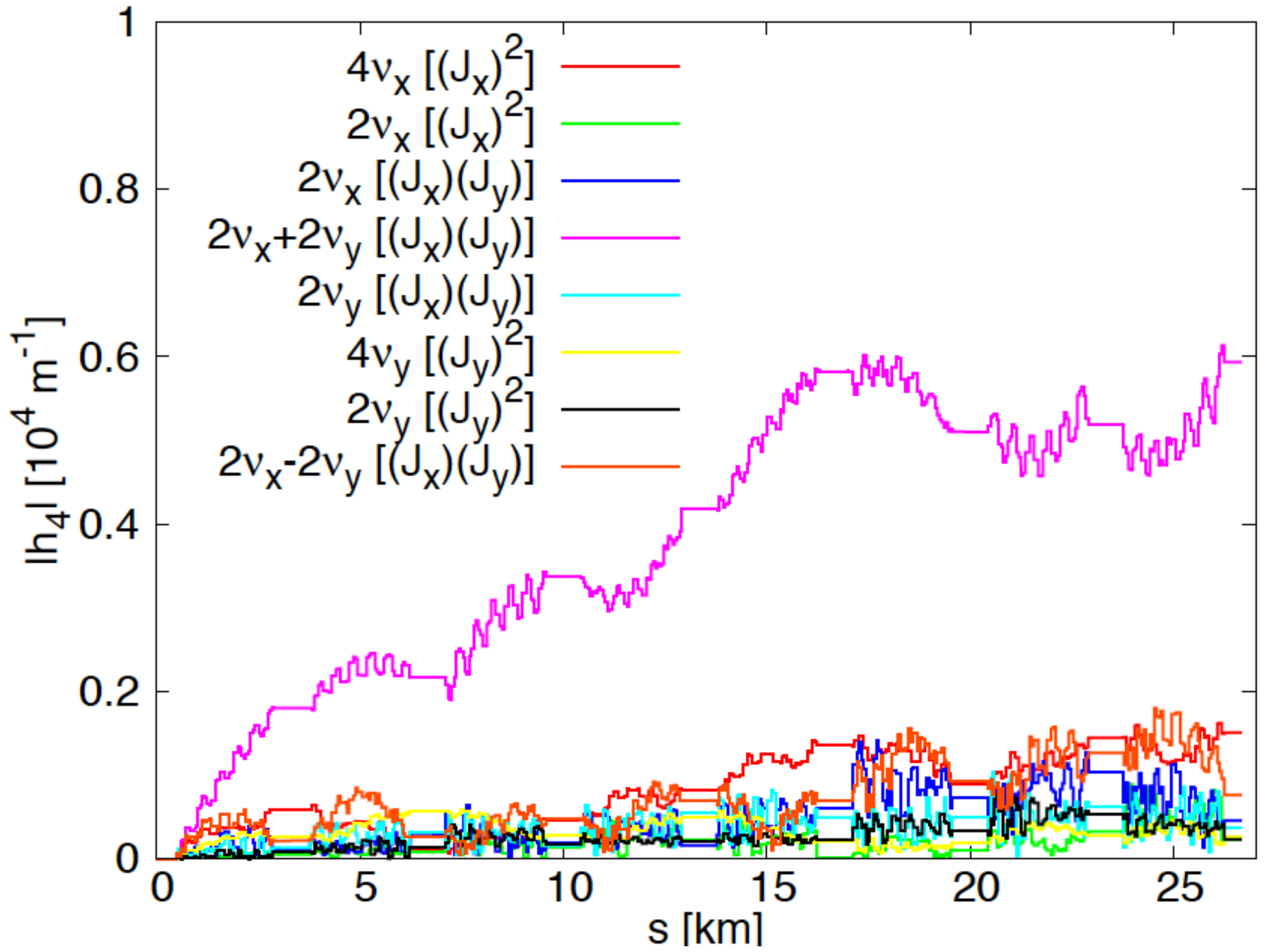
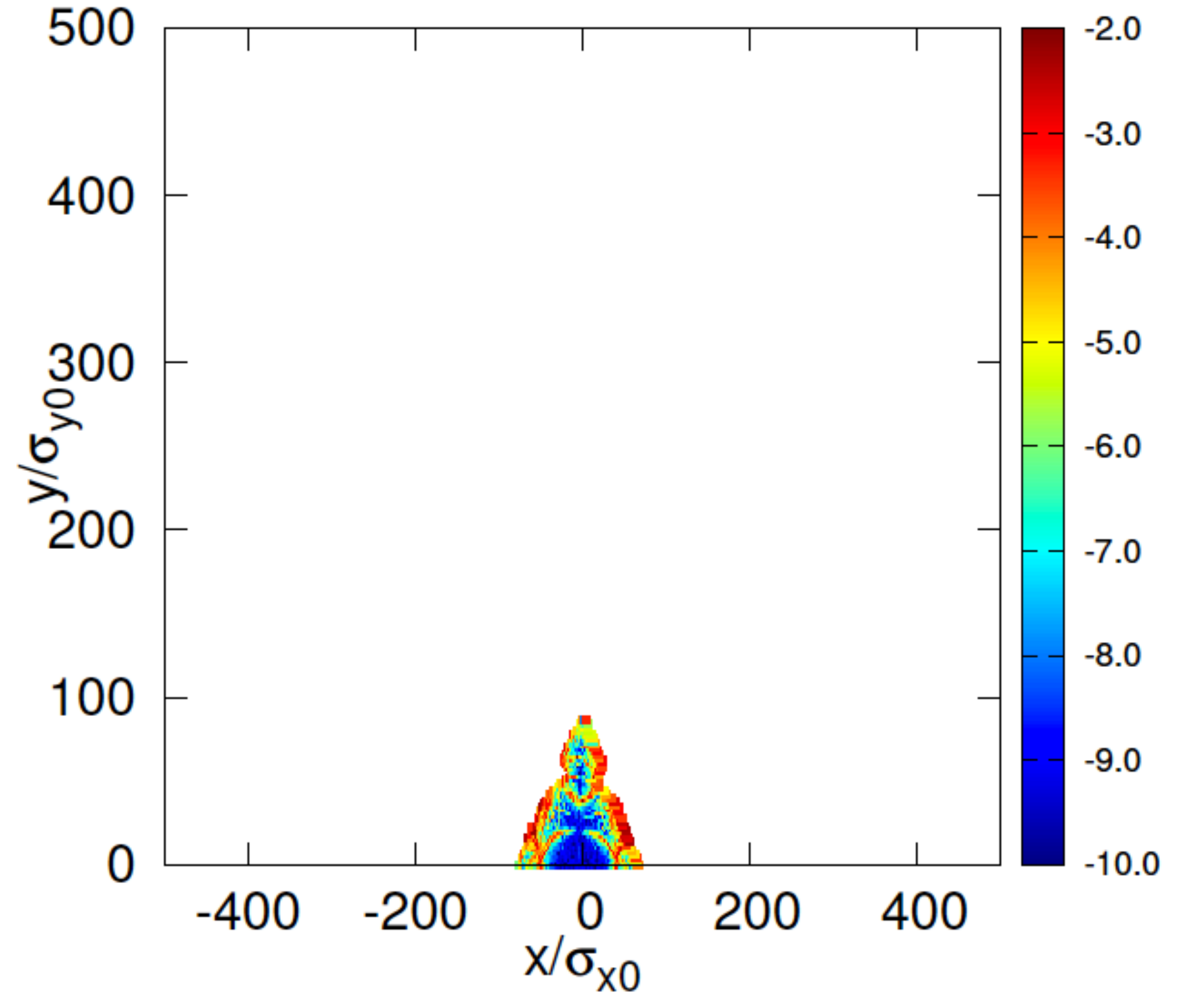
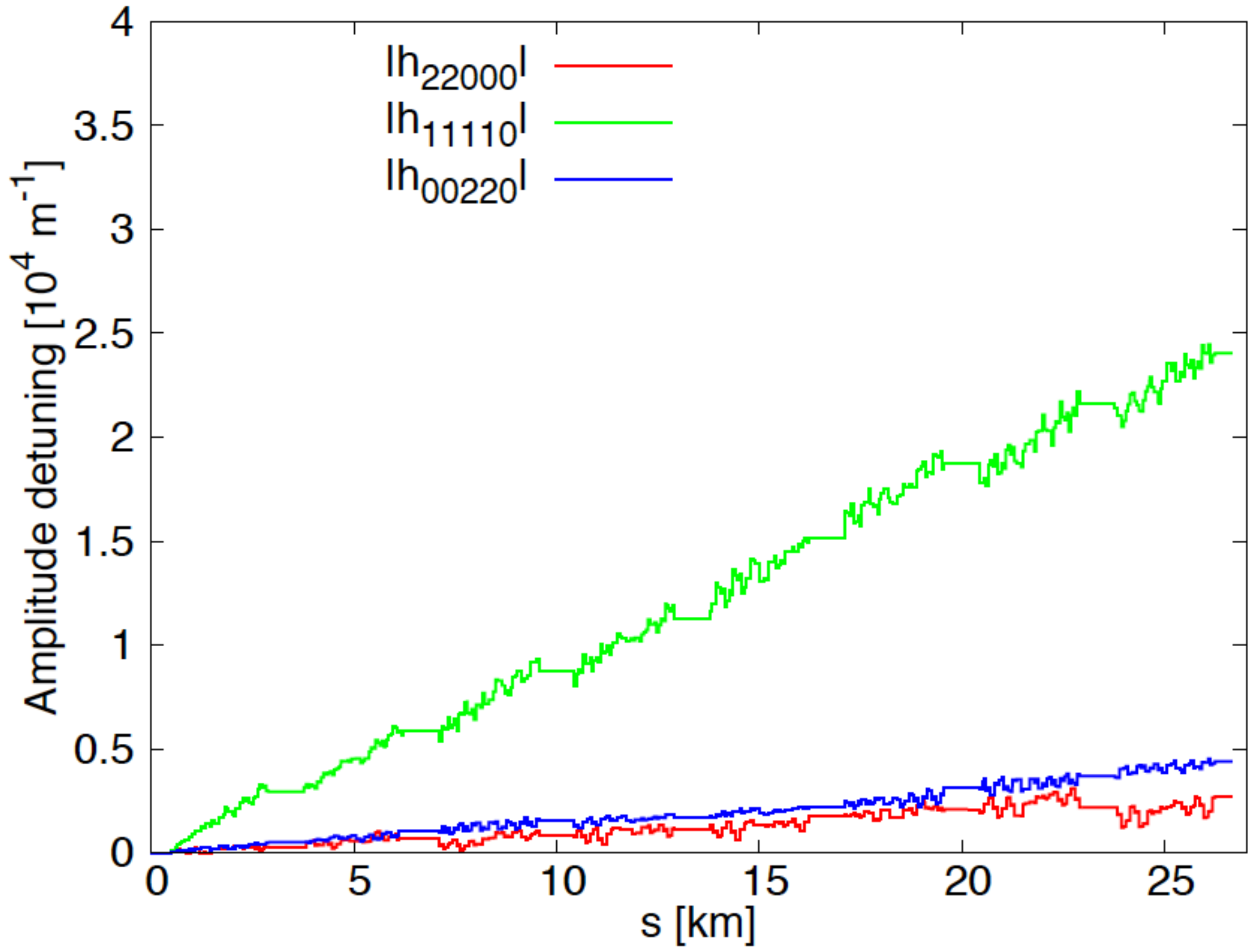
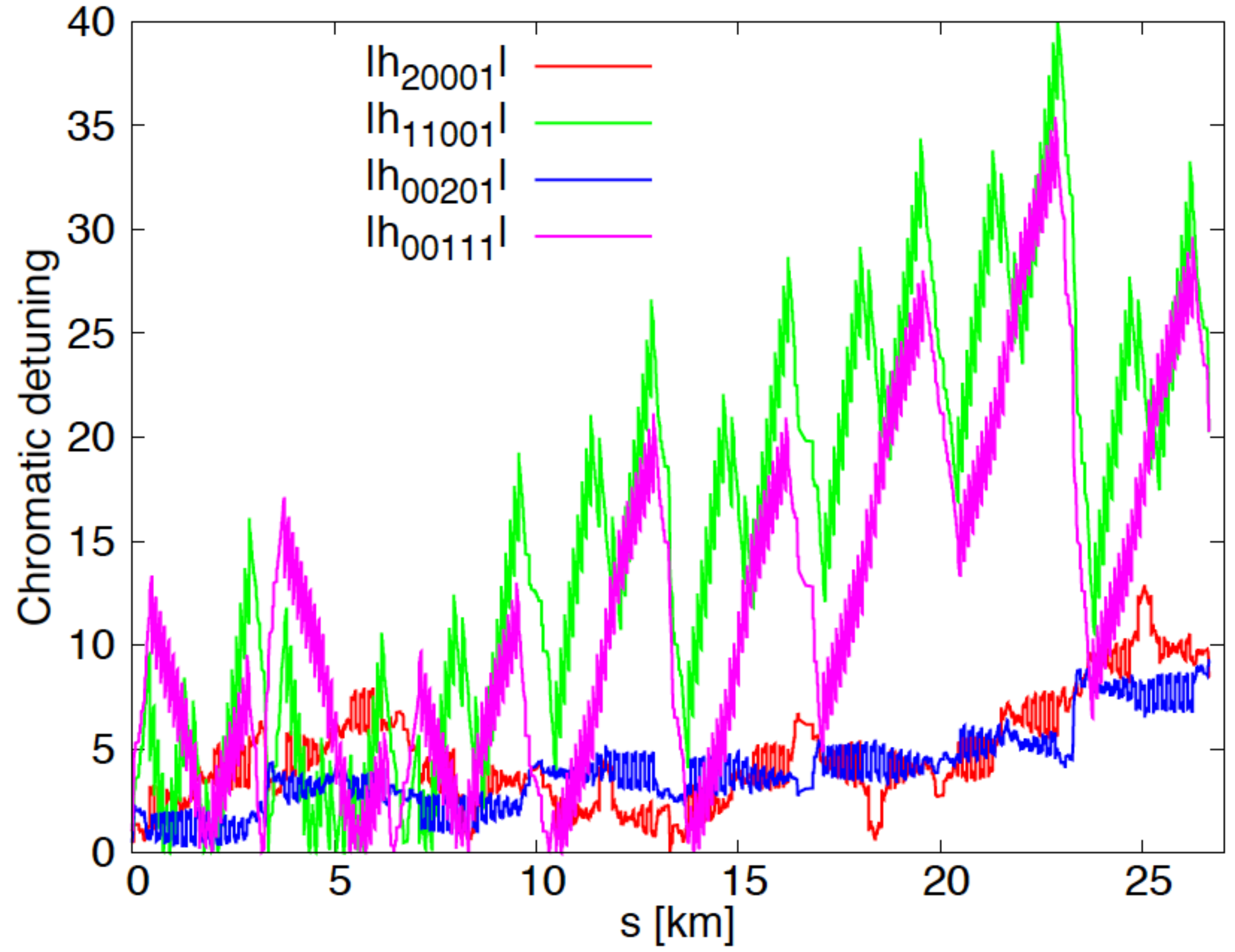
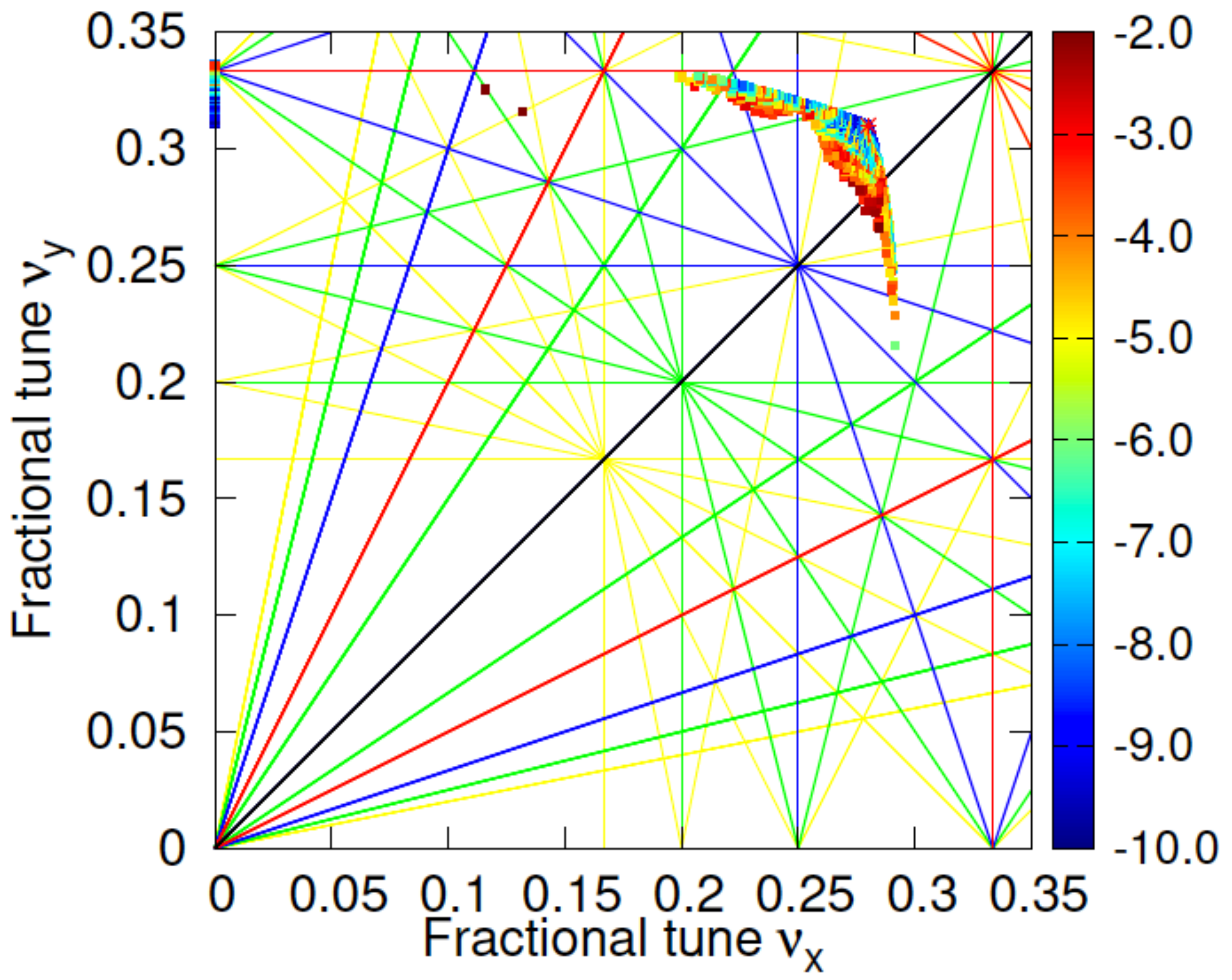




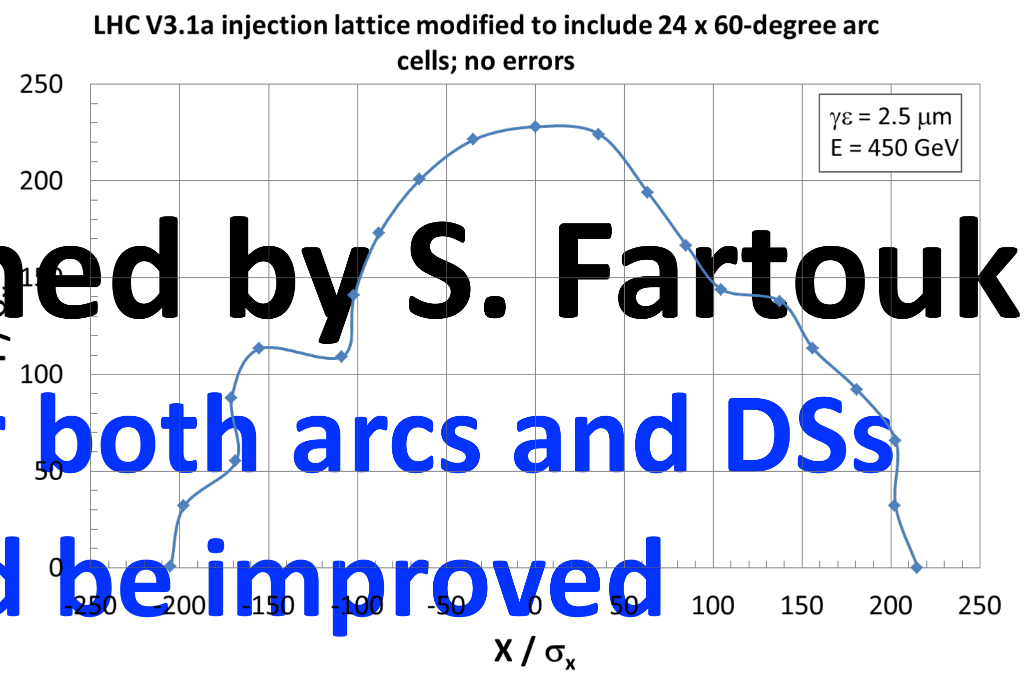






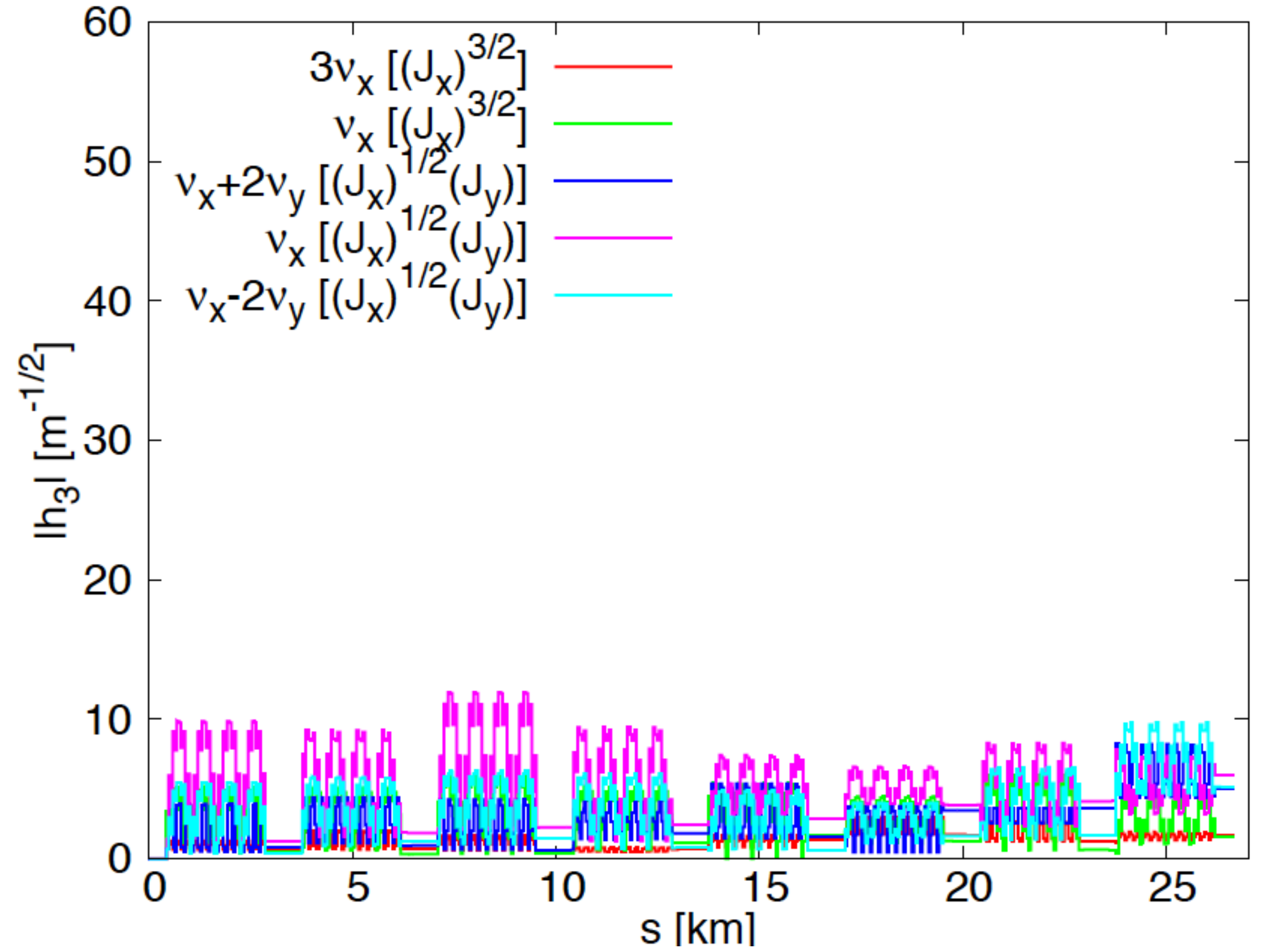


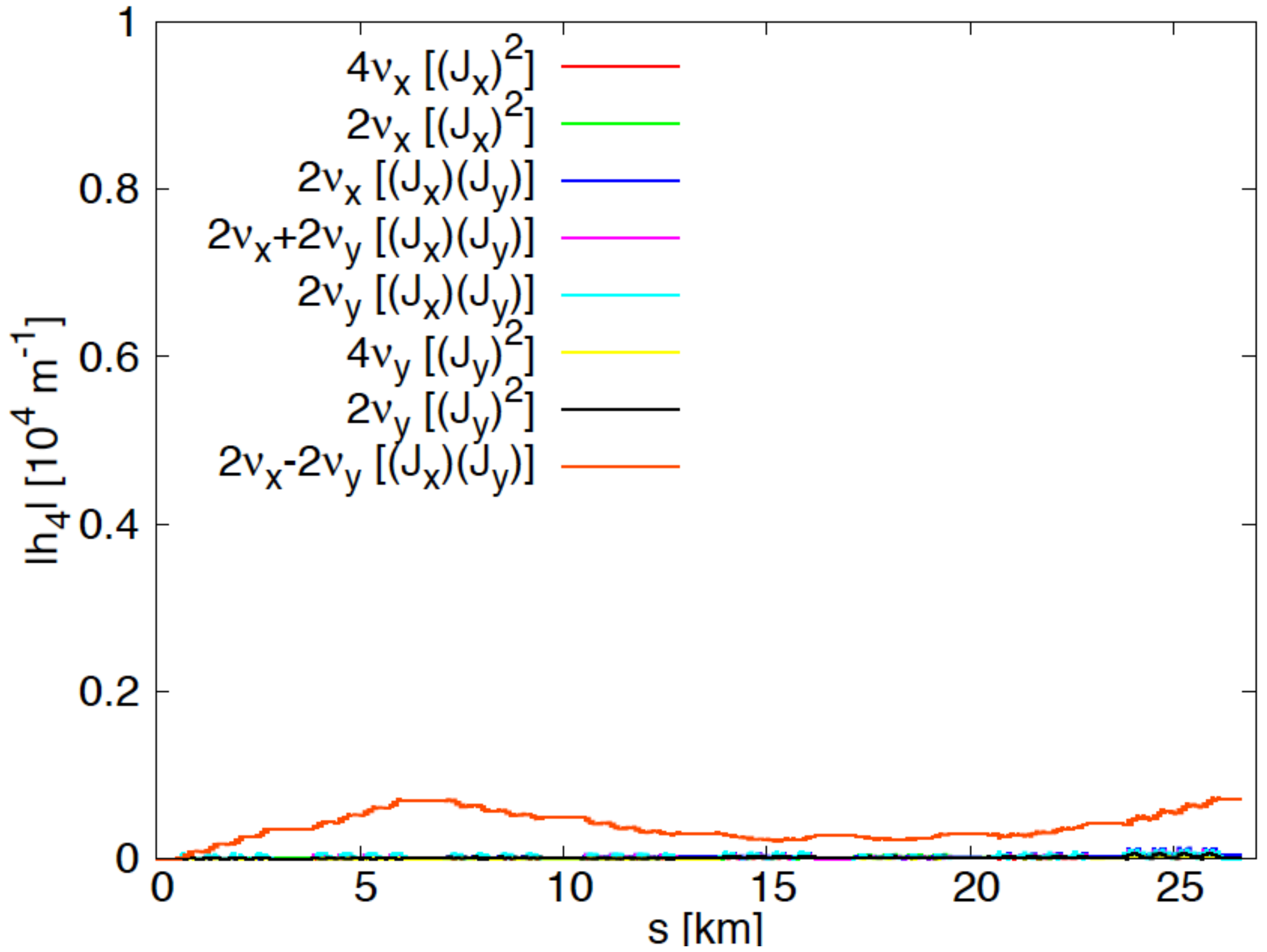
2. RDT and DA calculation

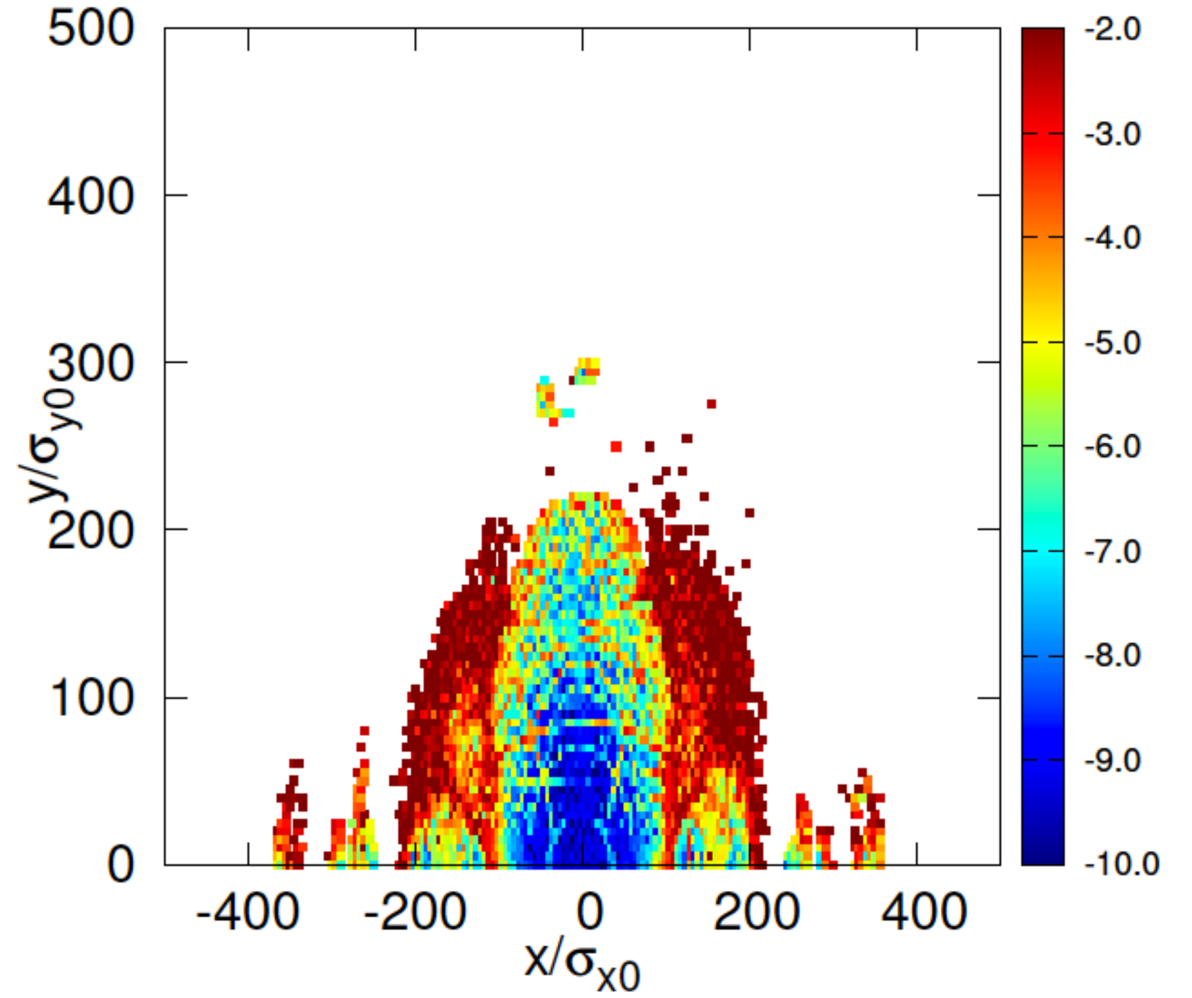


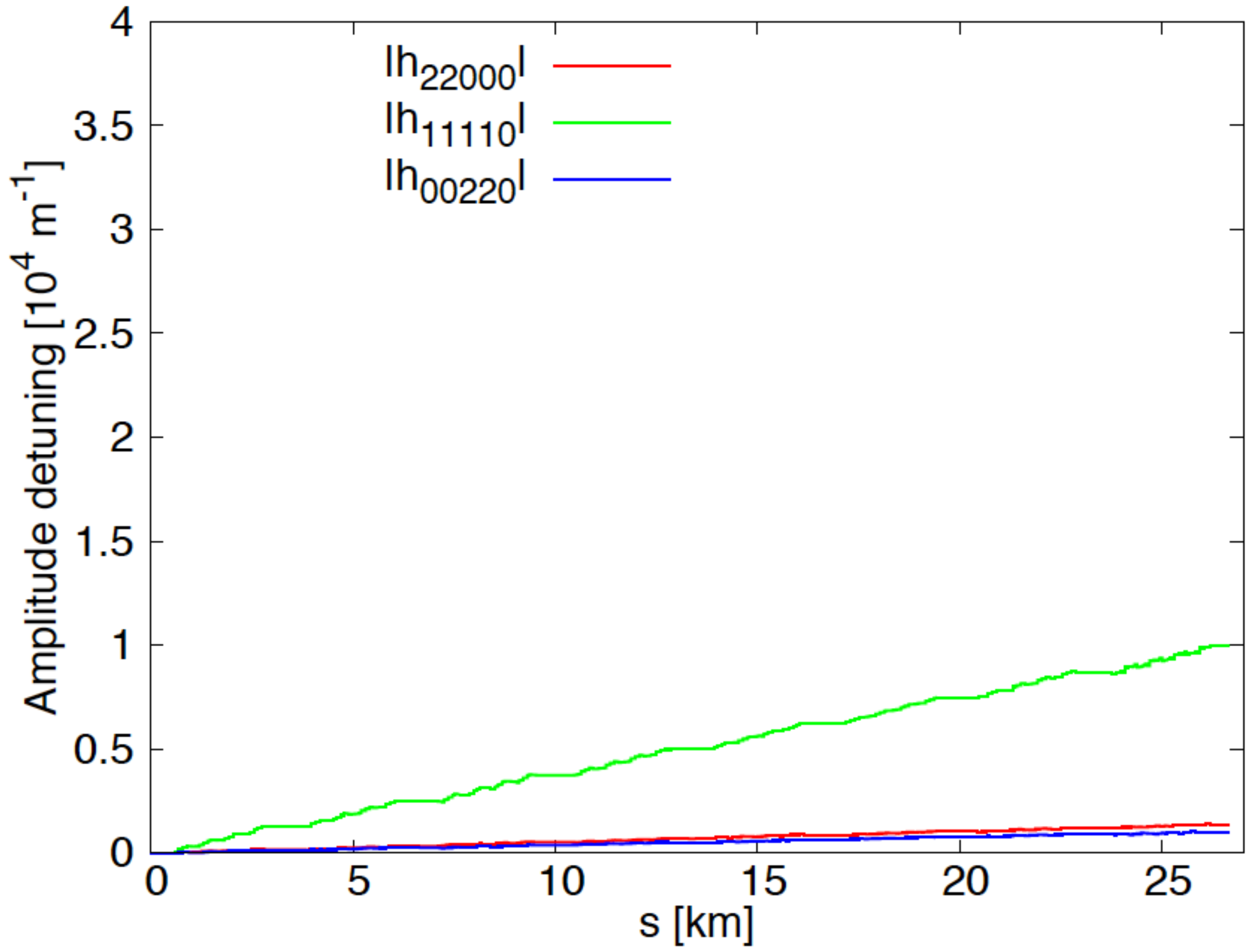
➤ Modified HL-LHC injection lattice (SLHCV3.1a designed by S. Fartoukh)

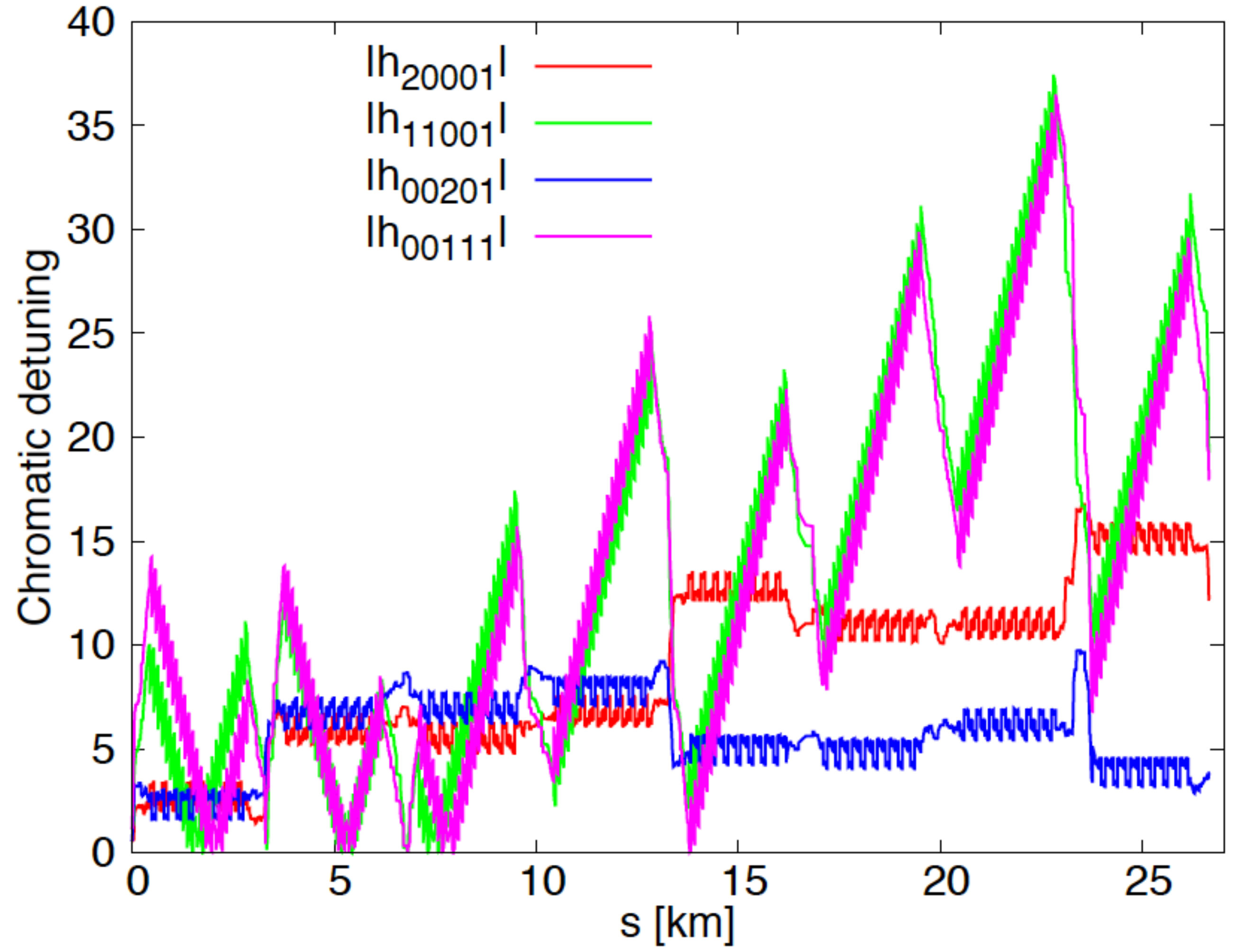
- Use 24x 60-deg arcs (developed by T. Risselada), same dipole for both arcs and DSs
- Tune matched to (46.28, 45.31). No nonlinear optimization could be improved

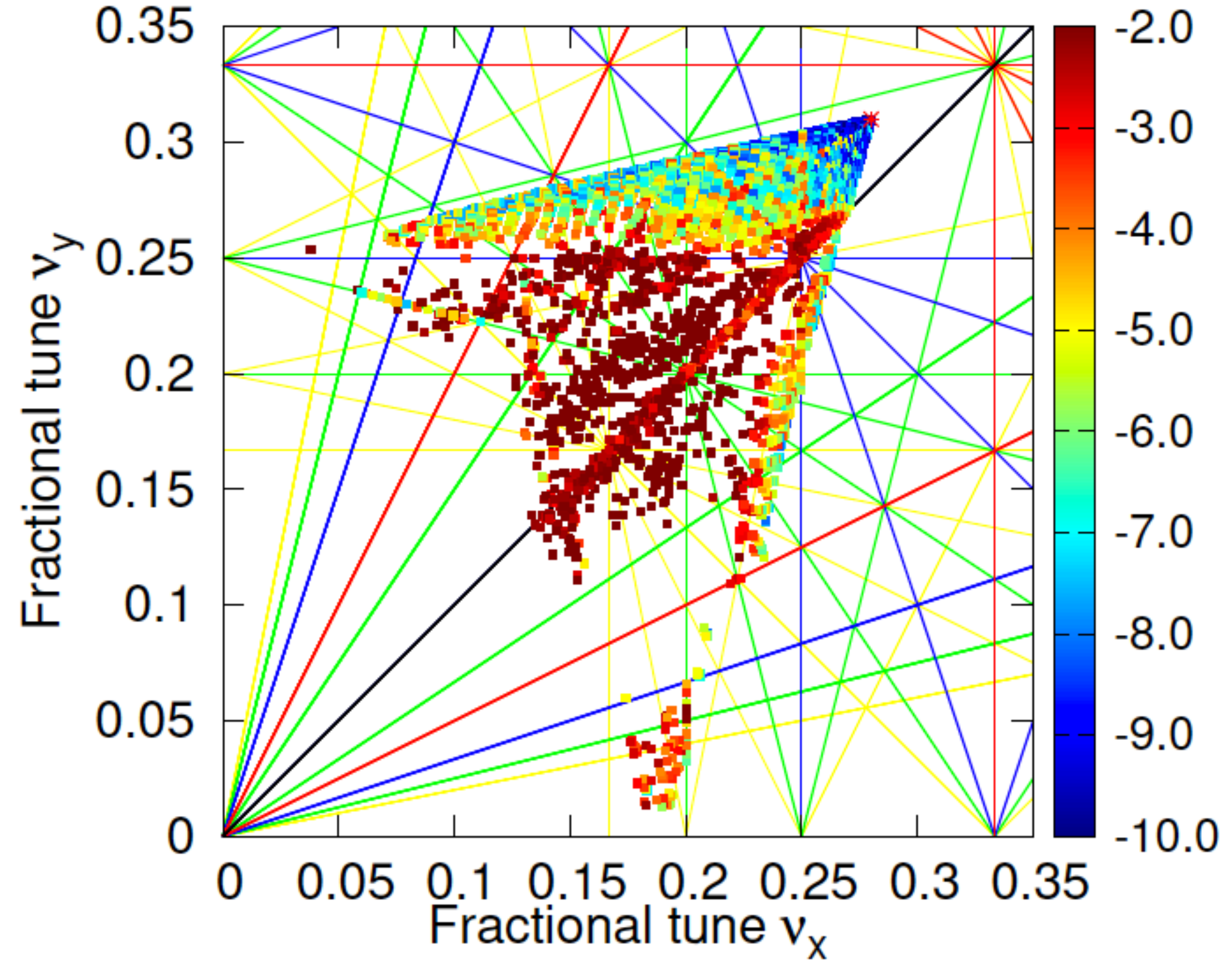












2. RDT and DA calculation

➤ Theory of resonance cancelation

- **Cancellation condition (C.C.):**

  $N_c(n_x\mu_{xc}+n_y\mu_{yc})=2k\pi$ & $(n_x\mu_{xc}+n_y\mu_{yc})\neq 2k'\pi$

  N_c: number of cell; μ_{xc}, μ_{yc}: Phase advance per cell

- **60-deg cell:**

  * C.C.: $N_c=6N$

  * Lowest order resonances: $n_x-n_y=0$ and $n_x+n_y=6$

- **90-deg cell:**

  * C.C.: $N_c=4N$

  * Lowest order resonances: $n_x-n_y=0$ and $n_x+n_y=4$

Proceedings of the 1999 Particle Accelerator Conference, New York, 1999

RESONANCE FREE LATTICES FOR A.G. MACHINES

A. Verdier
CERN SL Division

2. RDT and DA calculation

➤ Compare short- and long-term DA

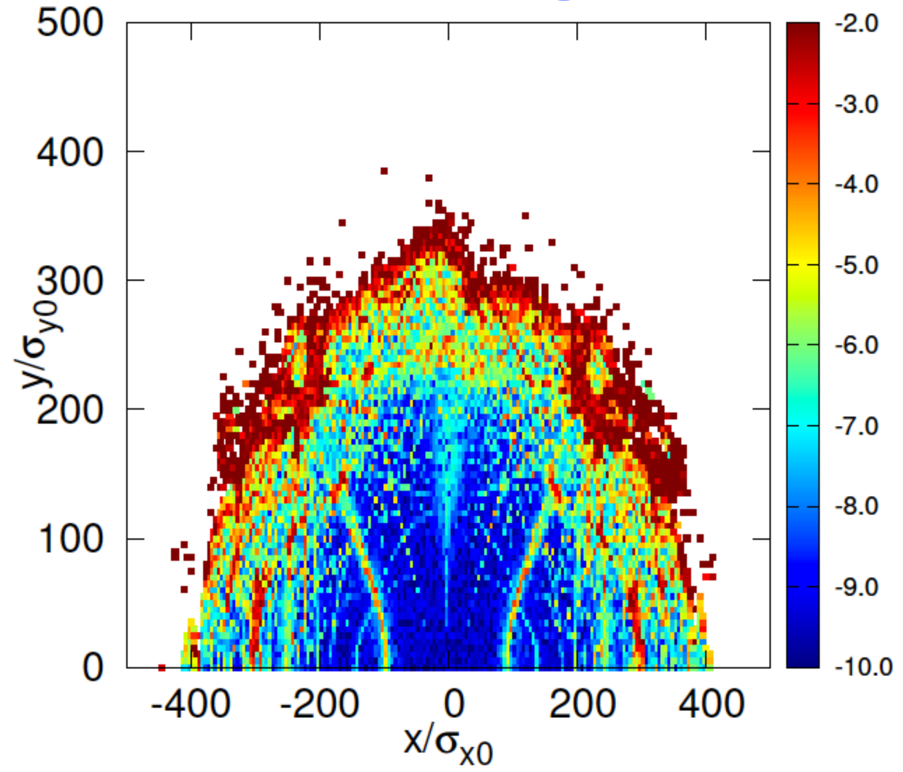
- Short-term (upper): colorful dots => survived over 1024 turns
- Long-term (lower): colors scale as survival turns

2. RDT and DA calculation

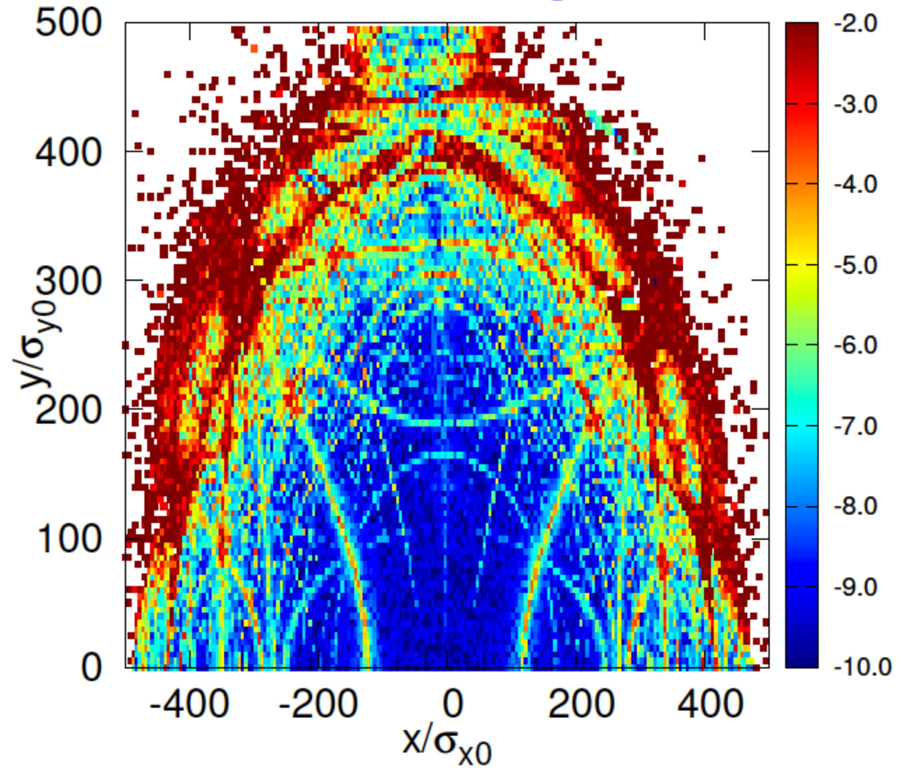
➤ **Compare short-term DA w/o and w/ systematic errors**

- systematic errors: b3s=+6, b5s=-1 in dipoles
- 90-deg arcs are more robust against errors?

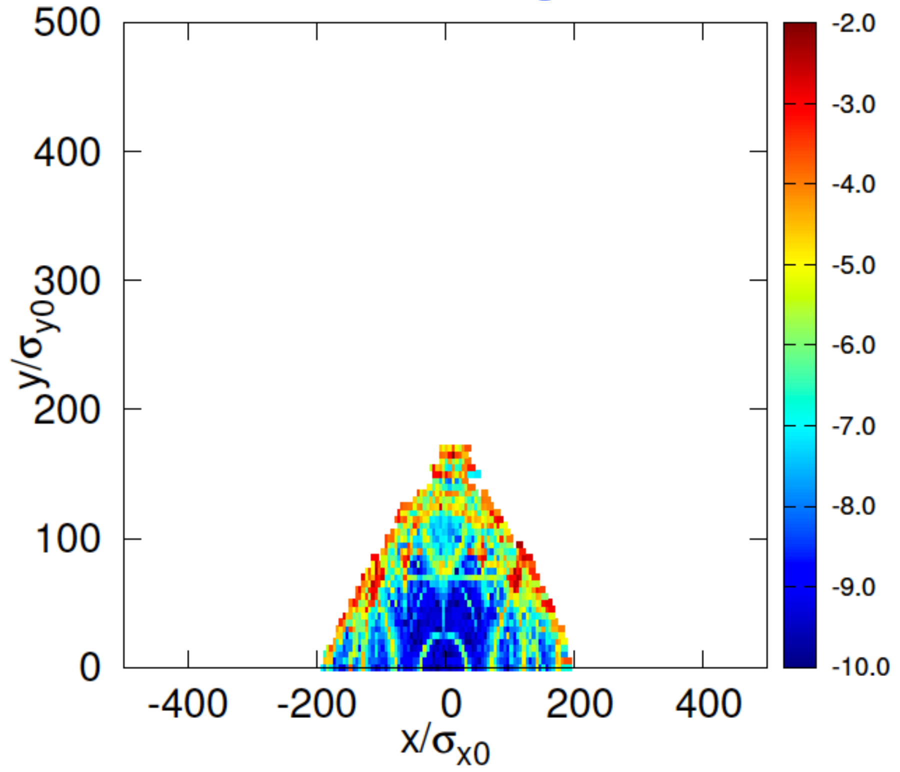
24x 60-deg (Yuri)



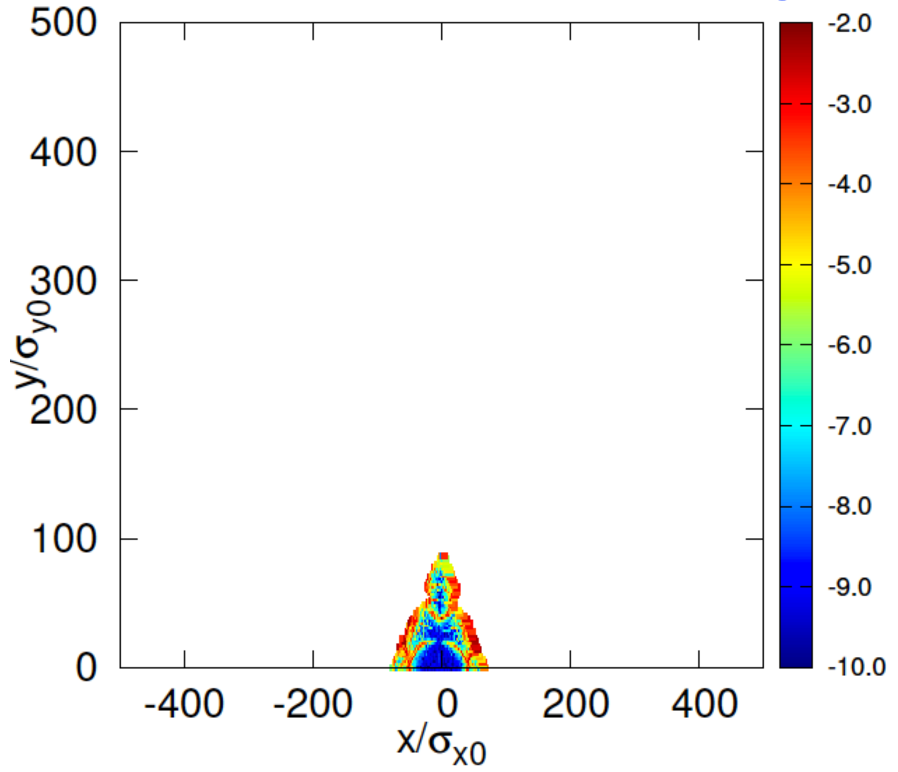
18x 60-deg (Yuri)



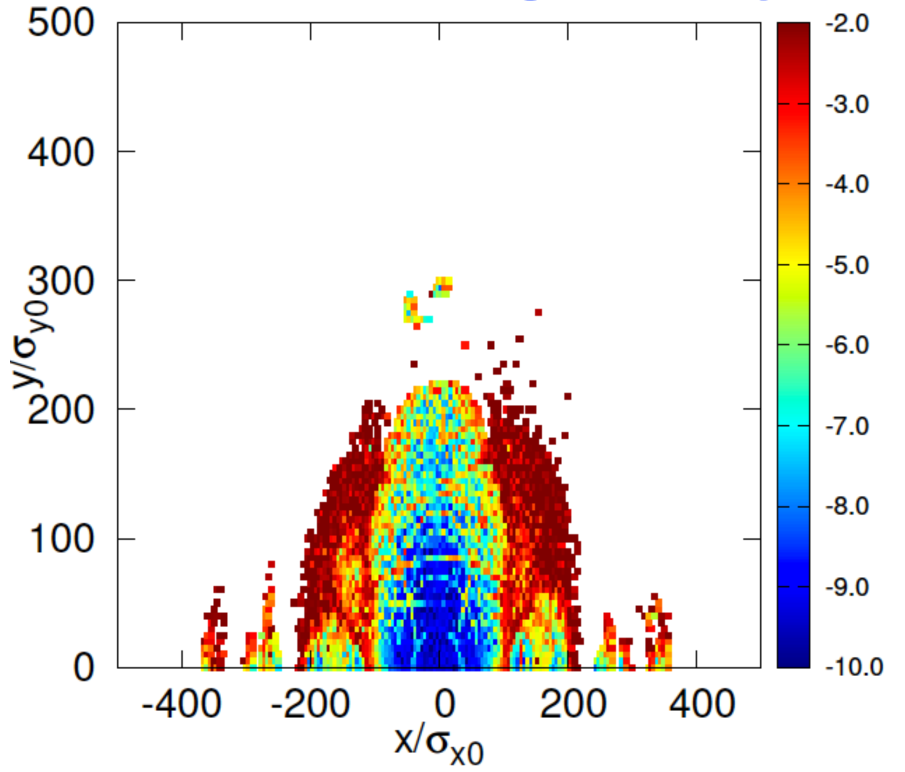
20x 90-deg (Yuri)

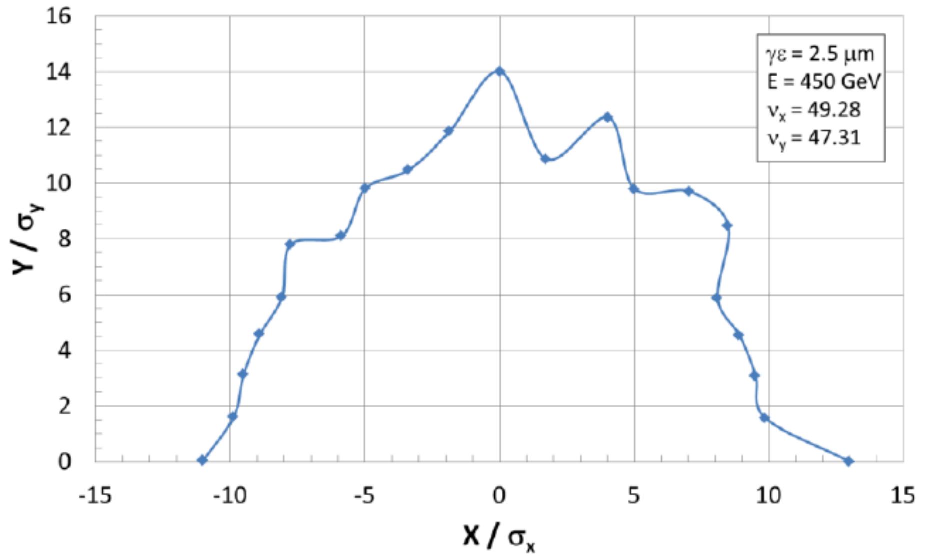


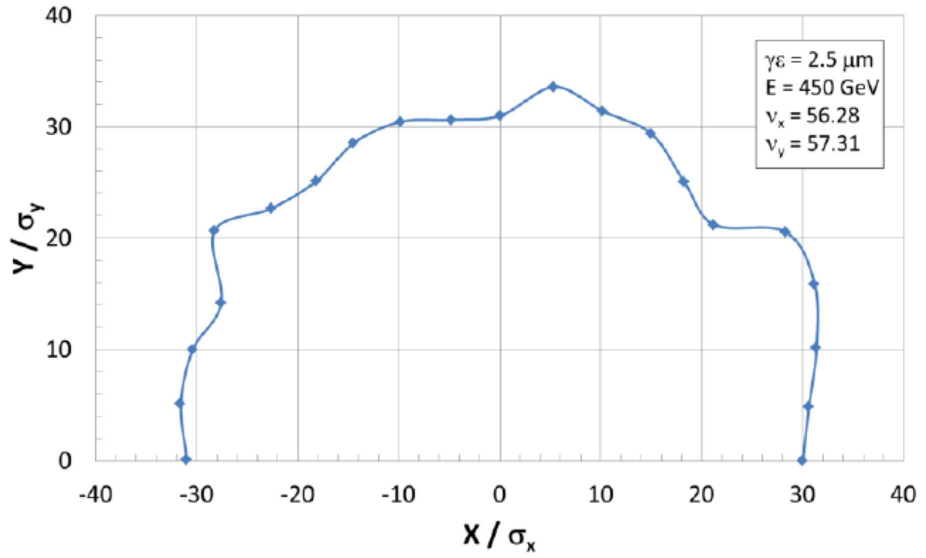
LHC V6.503 (Inj.)

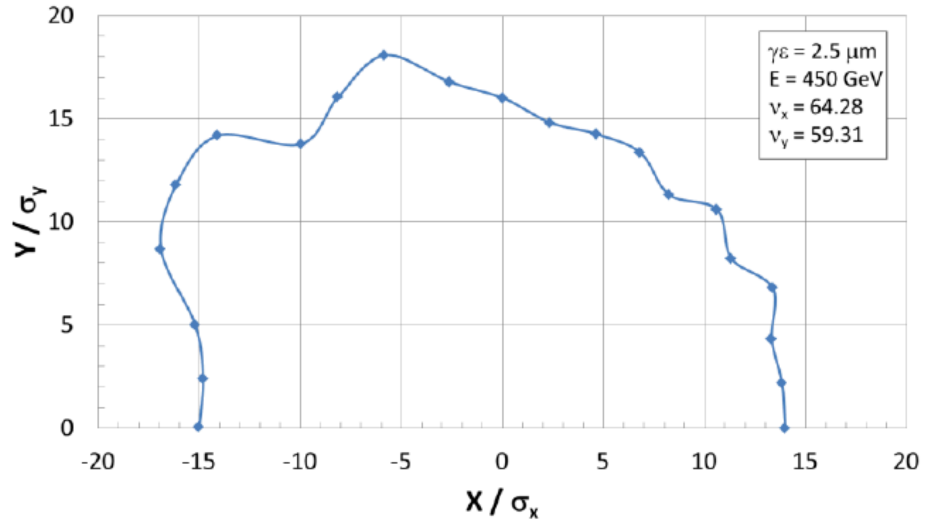


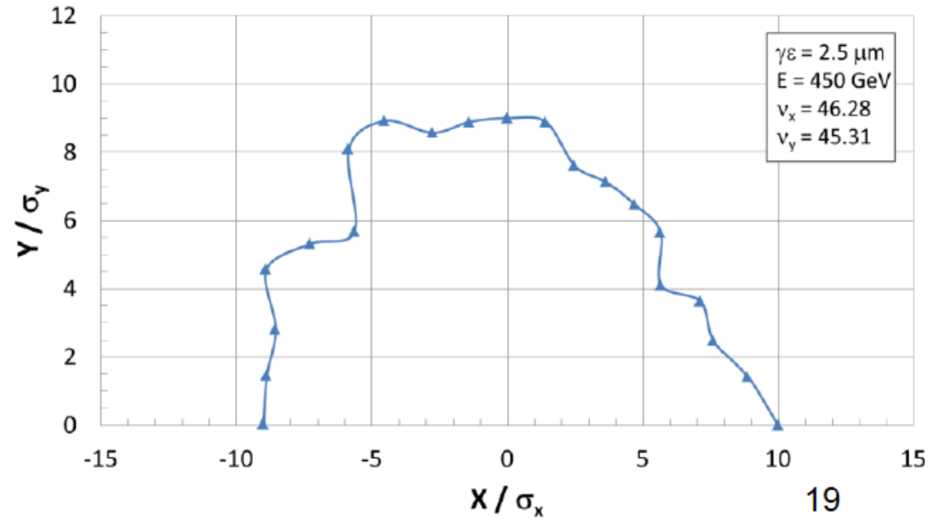
24x 60-deg (Thys)











From Y.N.'s talk at FCC Week 2017

3. Summary and outlook

➤ **RDT and DA calculation for HE-LHC injection lattices w/o errors**

- 60-deg arc cells show huge DAs mainly resulted from:
  * Large beta and dispersion functions, and weaker sextupoles
  * Well-suppressed 3rd and 4th RDTs
- 90-deg arc cells show relative smaller DAs mainly resulted from:
  * Stronger sextuples
  * 4th RDTs not well-suppressed

➤ **Outlook**

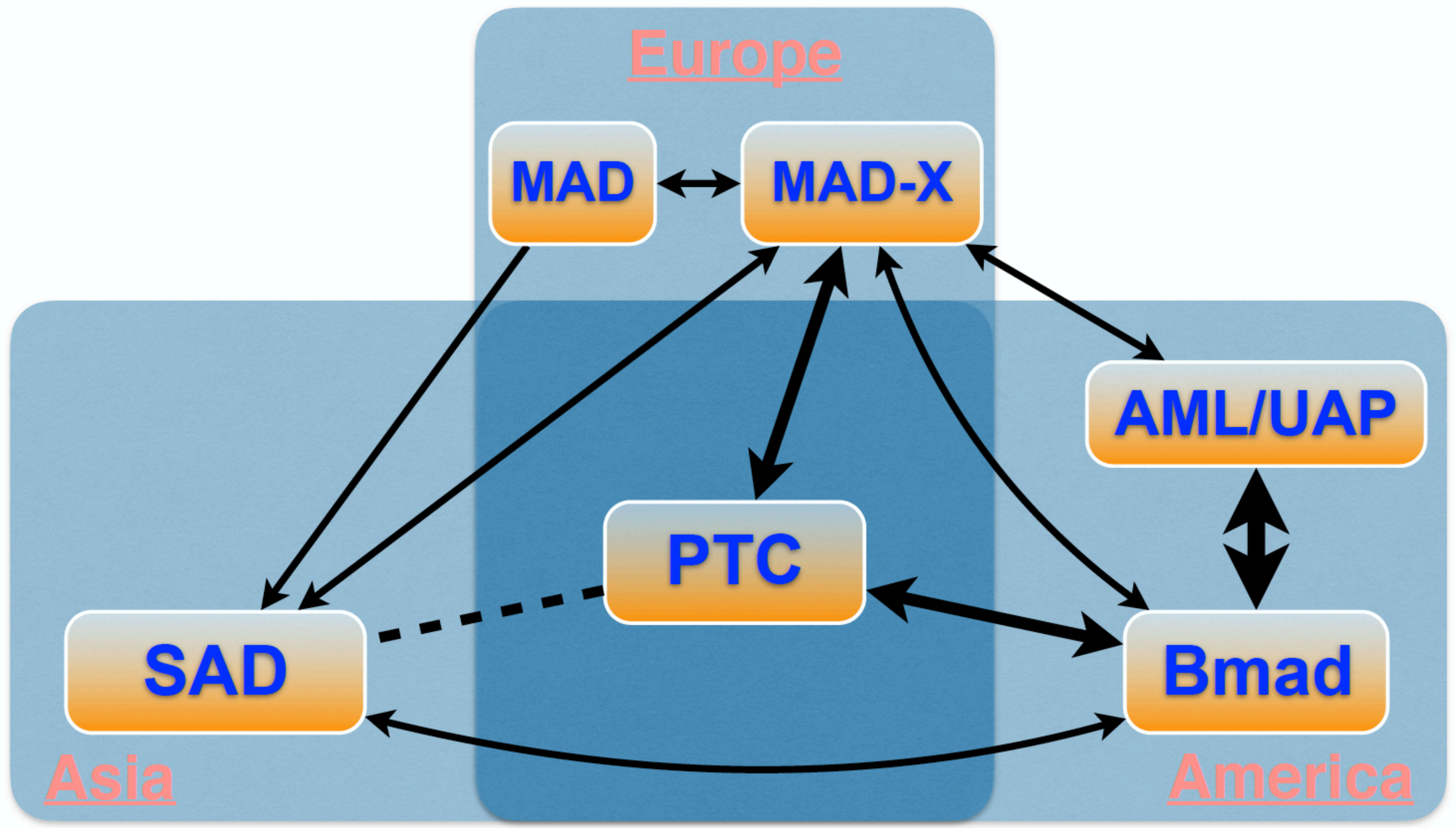
- Impact of errors and relevant tolerances to be investigated
- Integration of new arc cells to collision lattices (in parallel to design efforts on insertions of HE-LHC) to be investigated
- To check long-term (10^6 turns of tracking) DA with SixTrack (by M. Crouch)

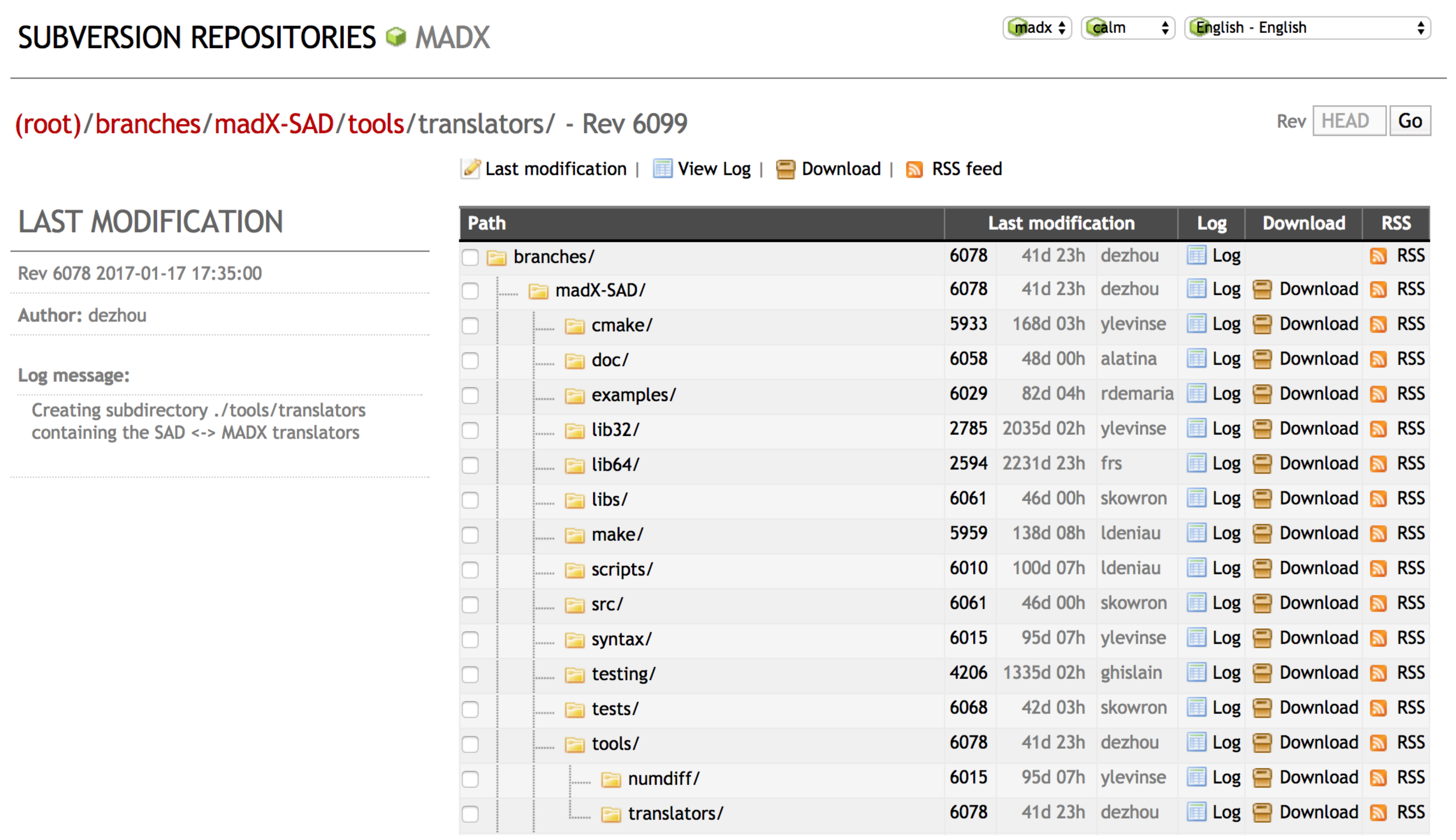
Backup

1. Introduction

➤ Simulation tools

- **PTC developed by E. Forest at KEK**
  - *** MAD8/MAD-X lattices translated to PTC flat format via Bmad or AML/UAP**
- **SAD developed by K. Oide et al. at KEK**
  - *** MAD8/MAD-X lattices translated to SAD via Bmad or SAD scripts**
- **Translators developed (still under development, and collaborations always welcomed!) with collaborative efforts by M. Biagini, L. Deniau, E. Forest, M. Giovannozzi, H. Koiso, A. Morita, K. Oide, D. Sagan, D. Zhou, et al., and strong support from M. Benedikt and F. Zimmermann.**





SUBVERSION REPOSITORIES MADX

(root)/branches/madX-SAD/tools/translators/ - Rev 6099

Rev HEAD Go

Last modification | View Log | Download | RSS feed

LAST MODIFICATION

Rev 6078 2017-01-17 17:35:00

Author: dezhou

Log message:

Creating subdirectory ./tools/translators containing the SAD <-> MADX translators

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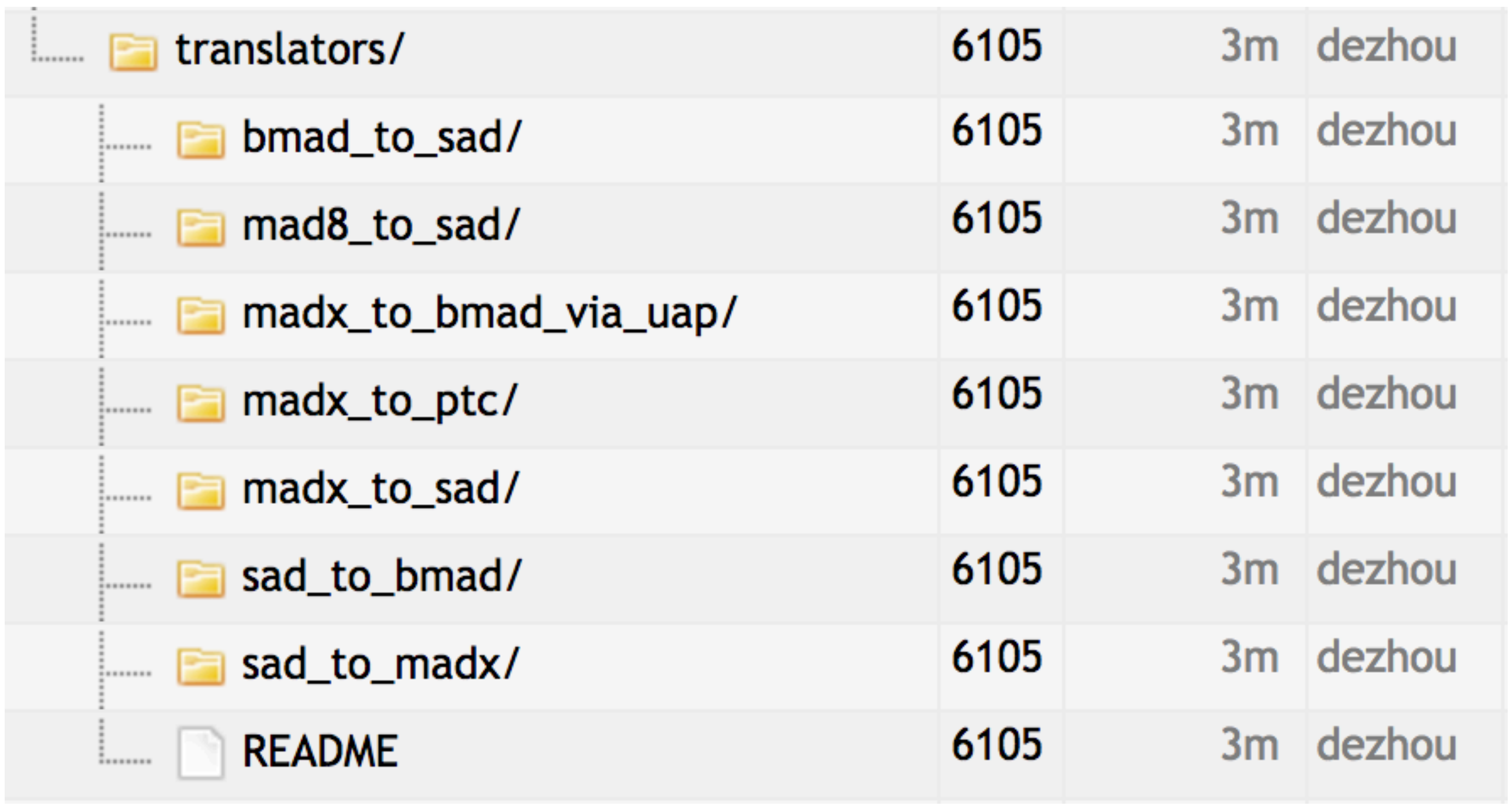

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madx_to_sad/	6105	3m	dezhou
sad_to_bmad/	6105	3m	dezhou
sad_to_madx/	6105	3m	dezhou
README	6105	3m	dezhou

See webpage: http://svnweb.cern.ch/world/wsvn/madx/branches/madX-SAD/tools/translators/