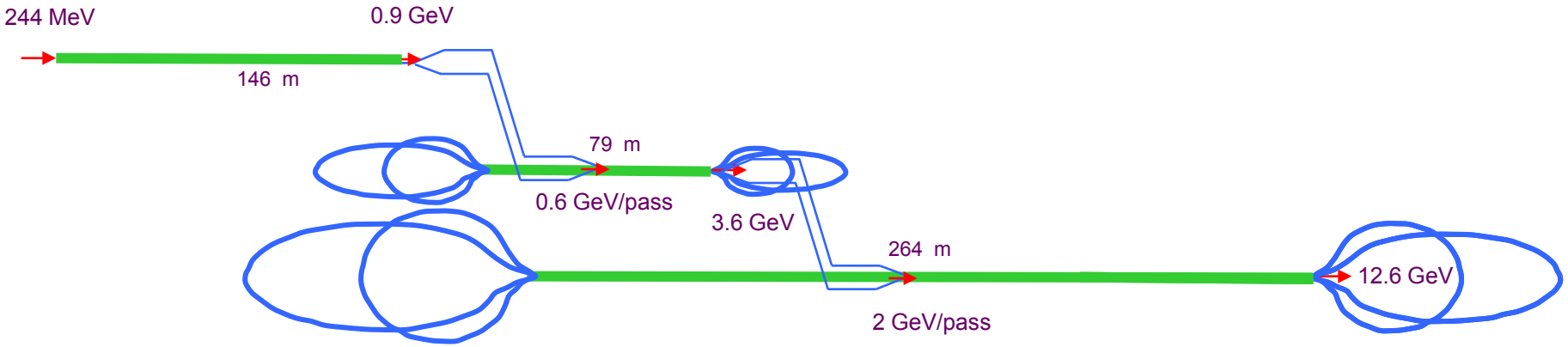
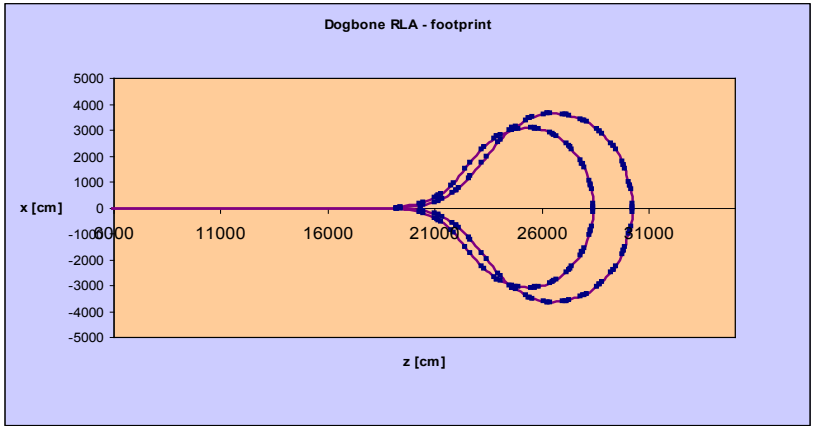
Linacs and RLAs – Status and Plans

Alex Bogacz

Acceleration Scenario – IDS Baseline



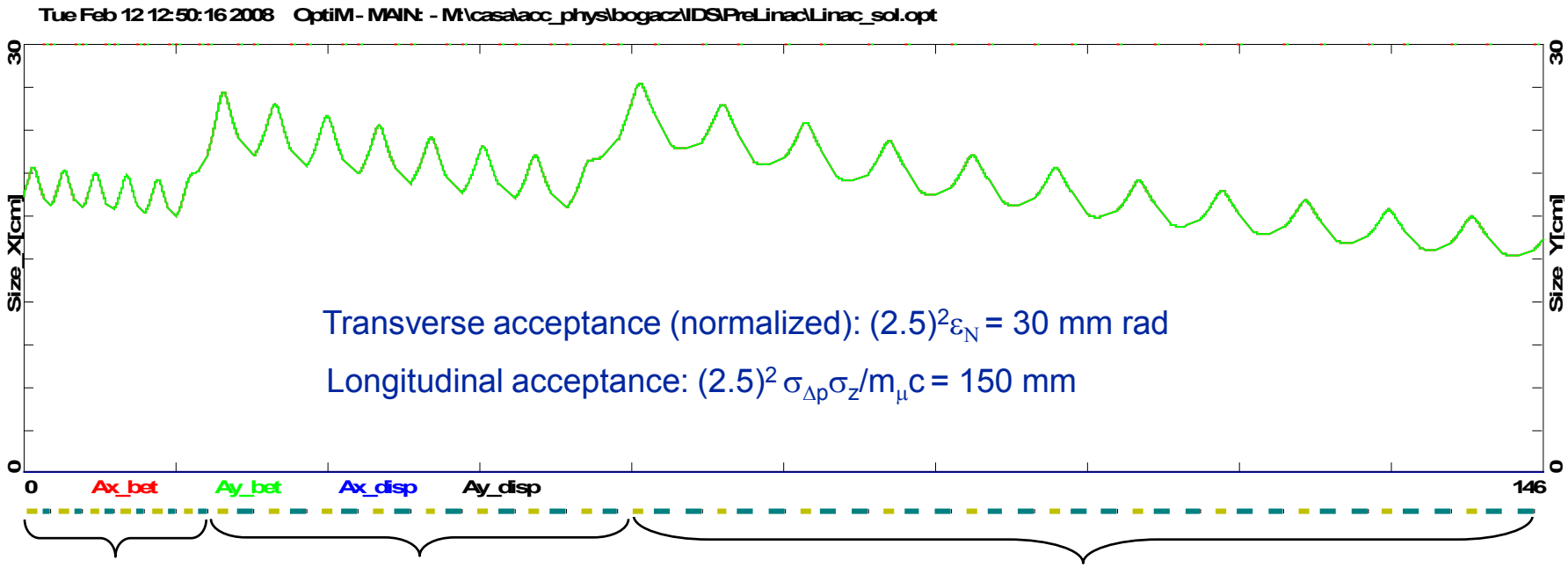


- **Towards Engineering Design Foundation**
  - Define beamlines/lattices for all components
  - Design lattices for transfer lines between the components
  - Resolve physical interferences, beamline crossings etc

‘Dogbone’ RLA

- RLA challenges
  - Simultaneous acceleration of both μ^+ μ^- species
  - Manageable orbit separation at recirculation arcs
  - Large transverse and longitudinal acceptances
- Beam dynamics issues
  - Phase slippage in the linacs
  - Multi-pass linac optics
  - Orbit separation – linac ends
  - Droplet return arc – compact lattice design
  - Chromatic corrections

Linear Pre-accelerator – 244 MeV to 909 MeV



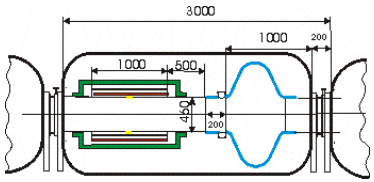
Transverse acceptance (normalized): $(2.5)^2\varepsilon_N = 30$ mm rad

Longitudinal acceptance: $(2.5)^2\,\sigma_{\Delta p}\sigma_z/m_\mu c = 150$ mm

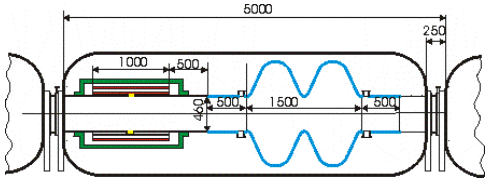
6 short cryos
15 MV/m

8 medium cryos
17 MV/m

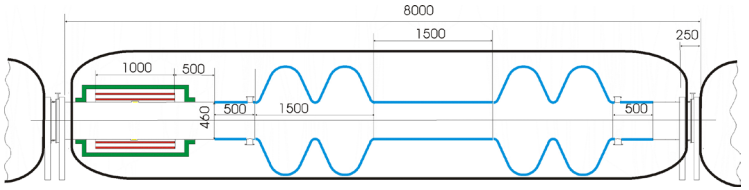
11 long cryos
17 MV/m



1.1 Tesla solenoid

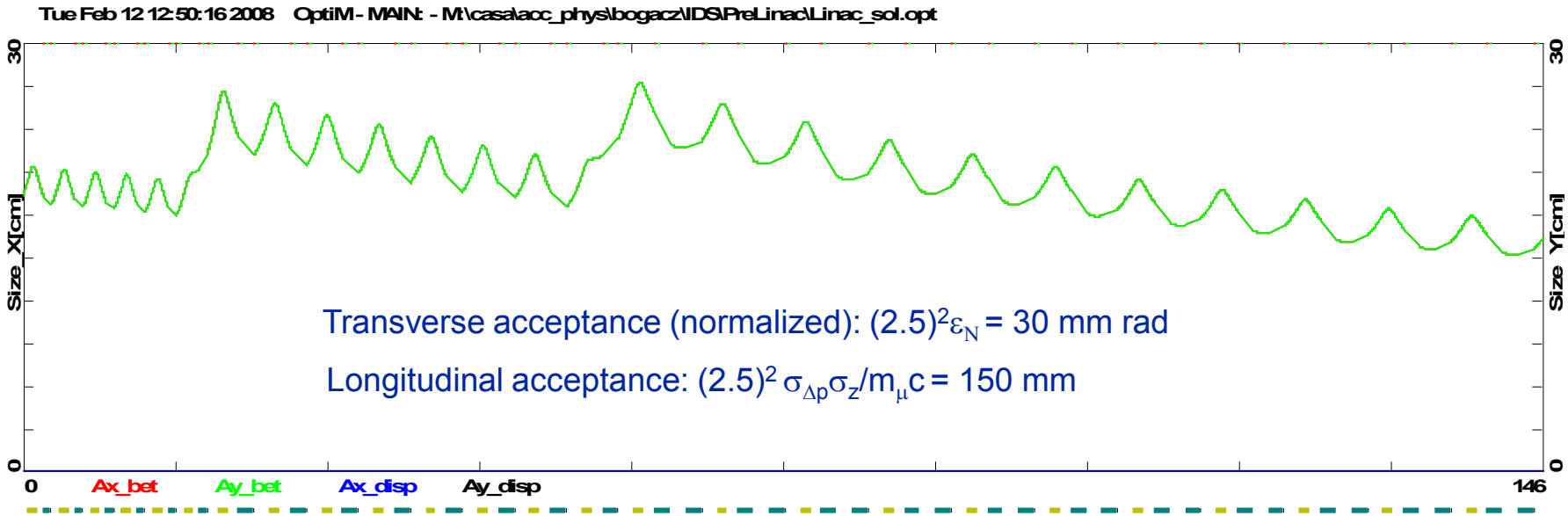


1.4 Tesla solenoid



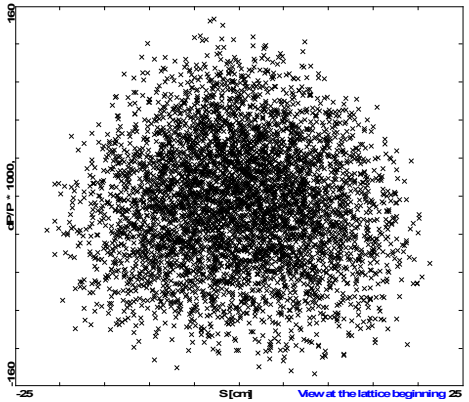
2.4 Tesla solenoid

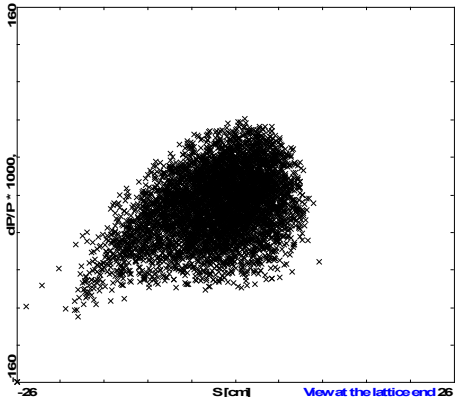
Linear Pre-accelerator – 244 MeV to 909 MeV



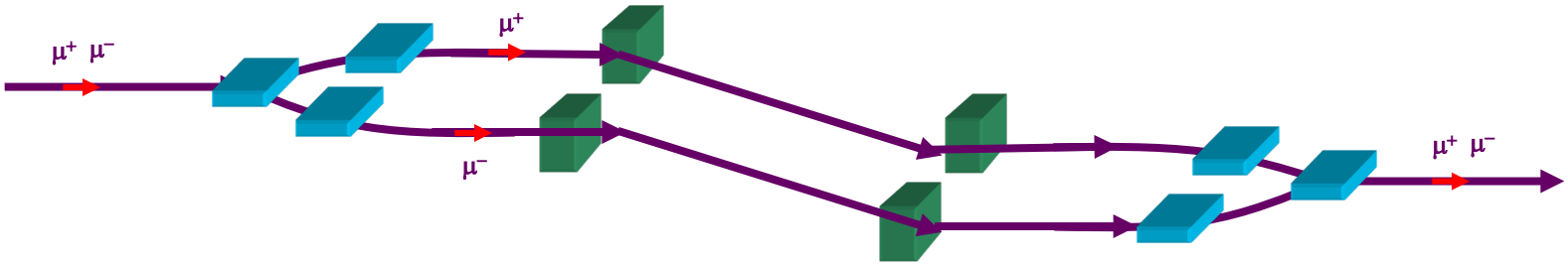
Transverse acceptance (normalized): $(2.5)^2\varepsilon_N = 30$ mm rad

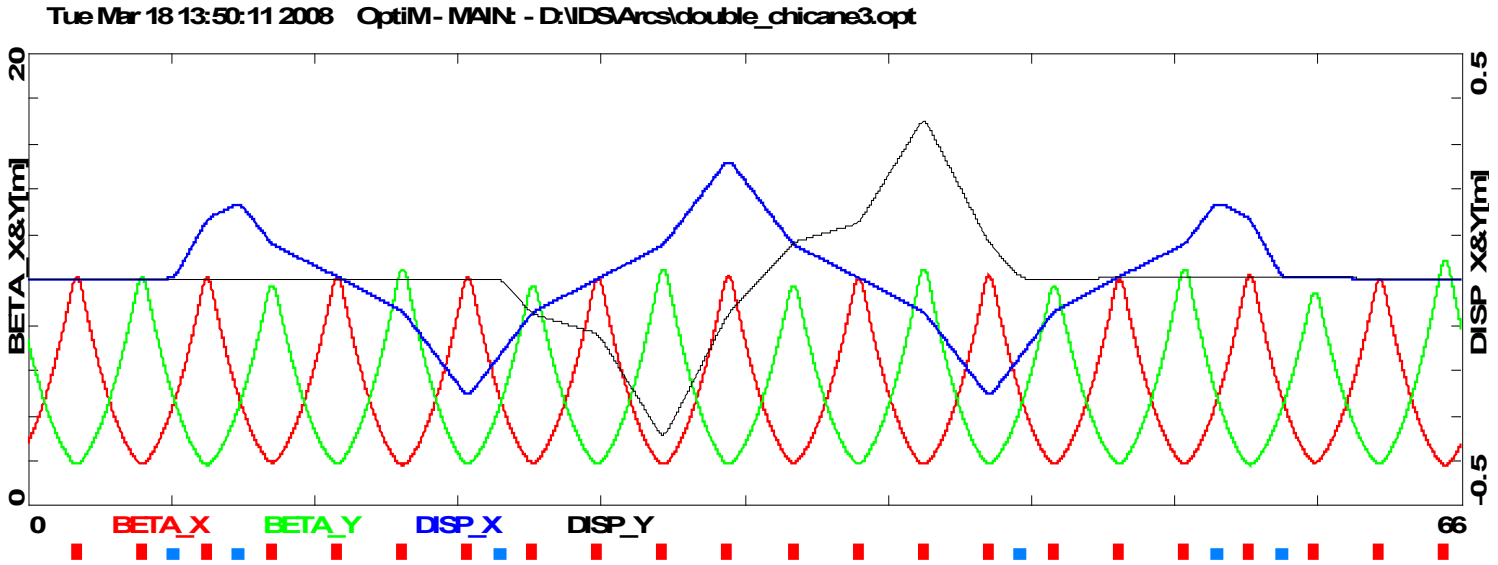
Longitudinal acceptance: $(2.5)^2\,\sigma_{\Delta p}\sigma_z/m_\mu c = 150$ mm



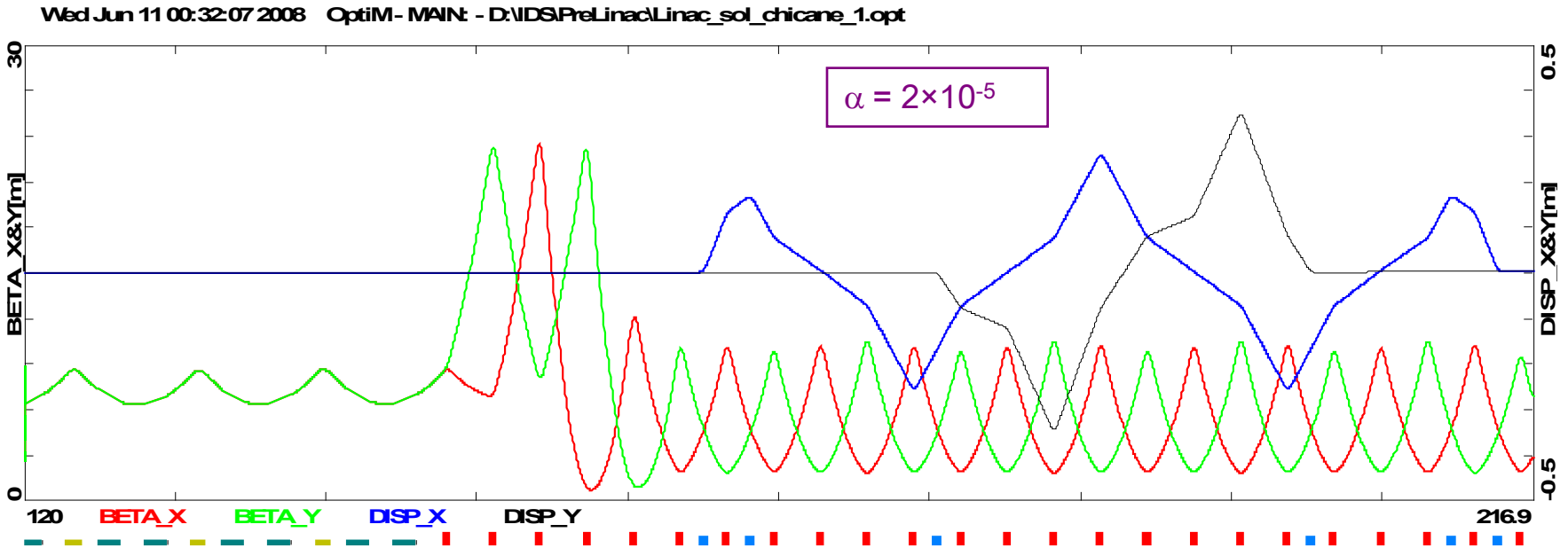


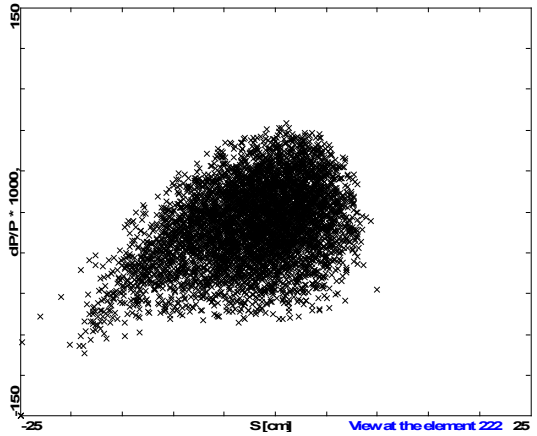
Injection double-chicane

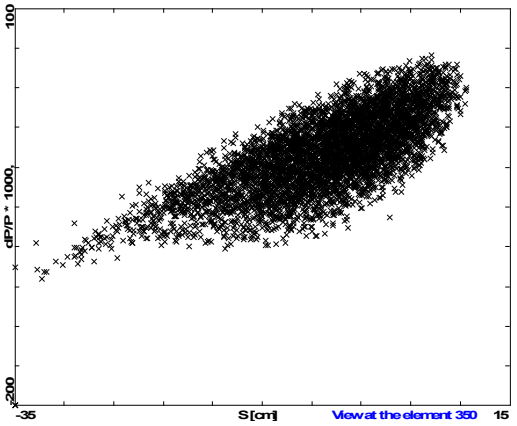




Pre-accelerator–Chicane–Linac Matching

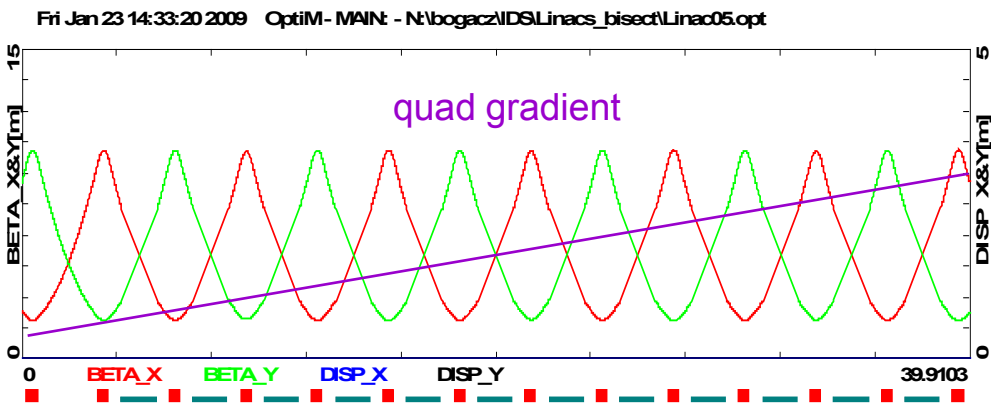






Multi-pass linac Optics

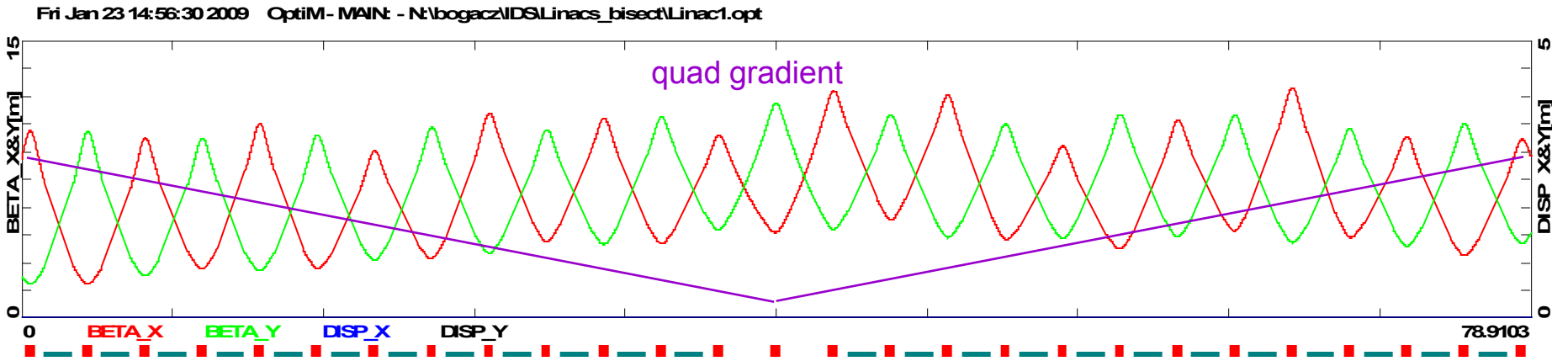
‘half pass’ , 900-1200 MeV



initial phase adv/cell 90 deg. scaling quads with energy

1-pass, 1200-1800 MeV

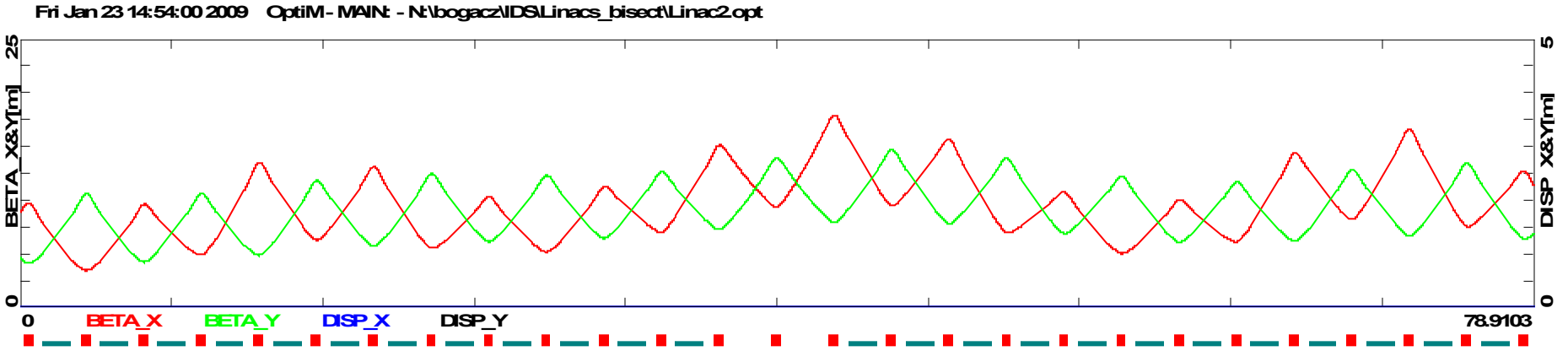
mirror symmetric quads in the linac



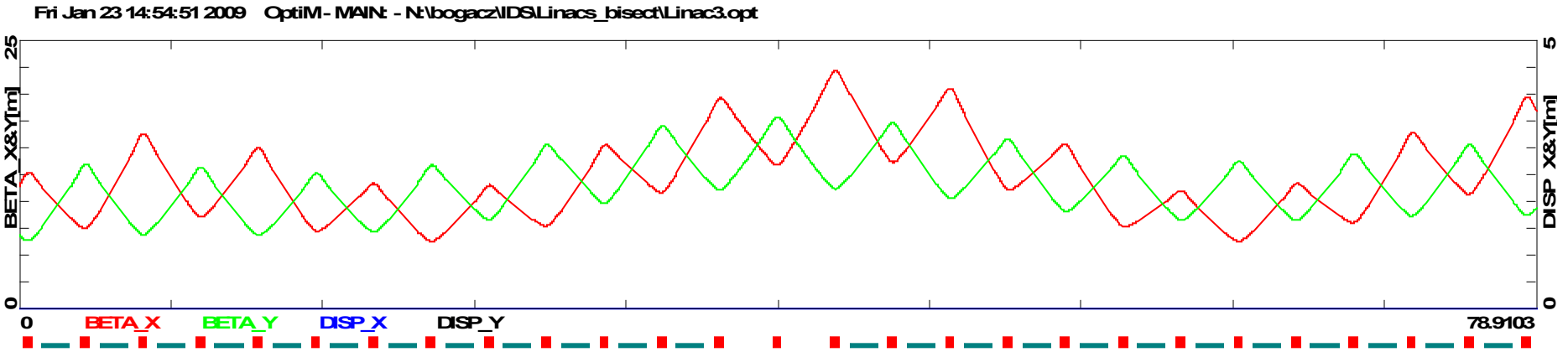
Multi-pass linac Optics

2-pass, 1800-2400 MeV

phase adv. diminish uniformly in both planes



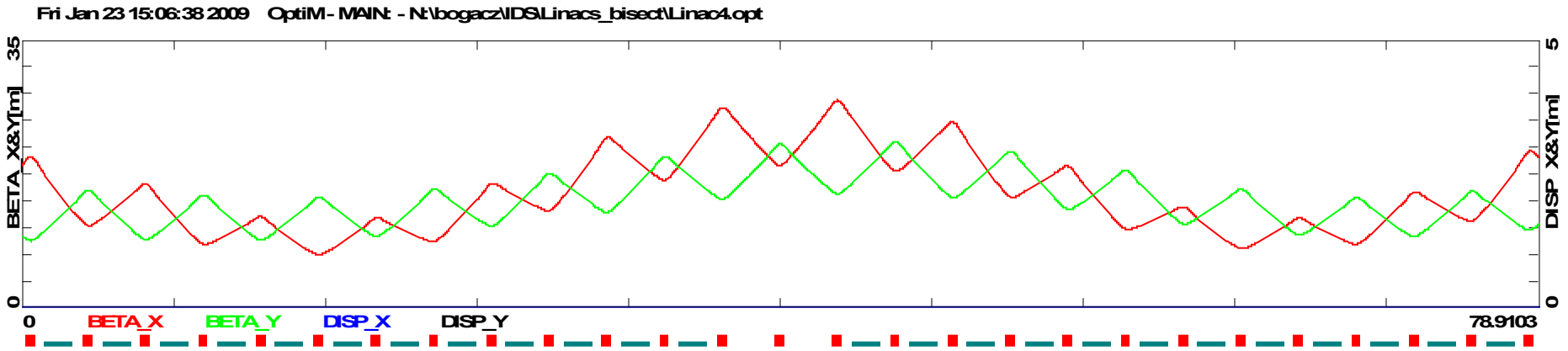
3-pass, 2400-3000 MeV



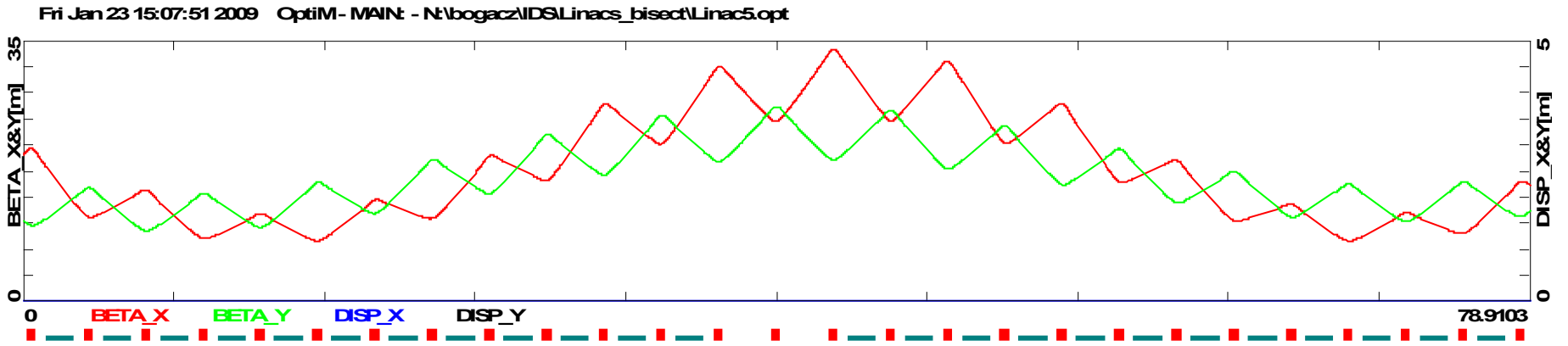
Multi-pass linac Optics

4-pass, 3000-3600 MeV

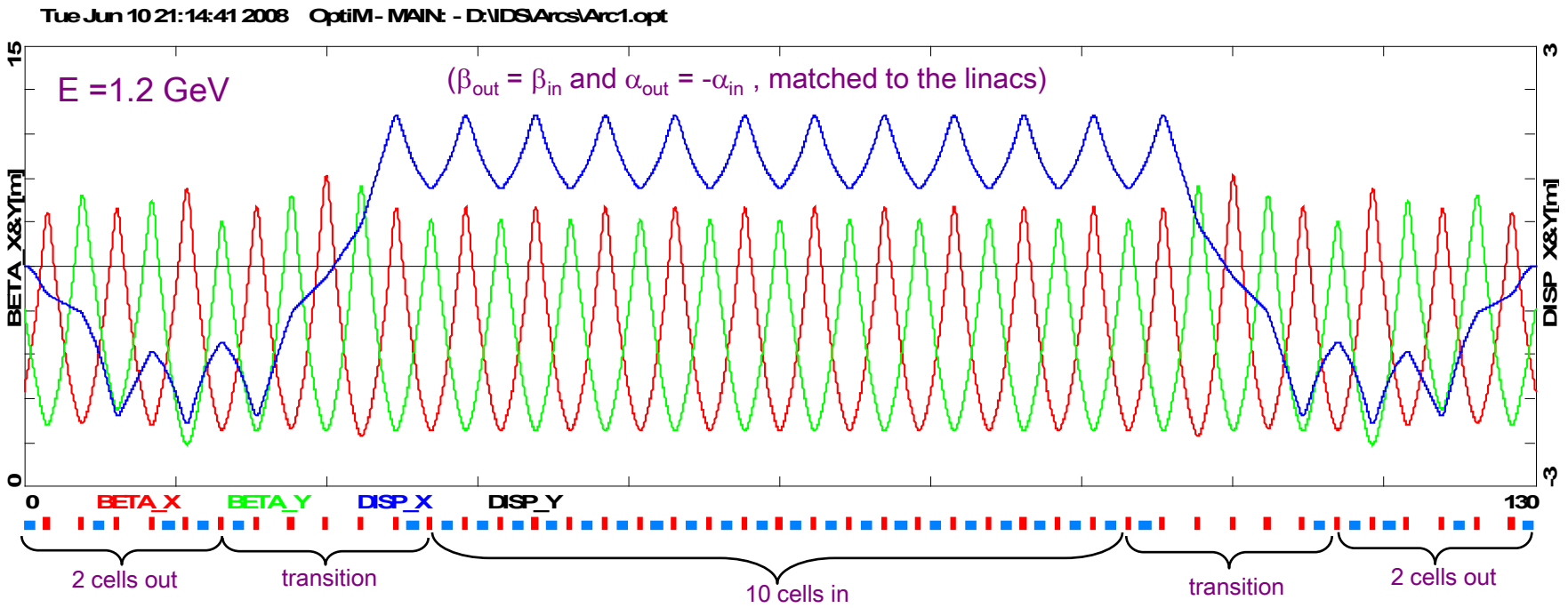
phase adv. still larger then 180 deg. in both planes

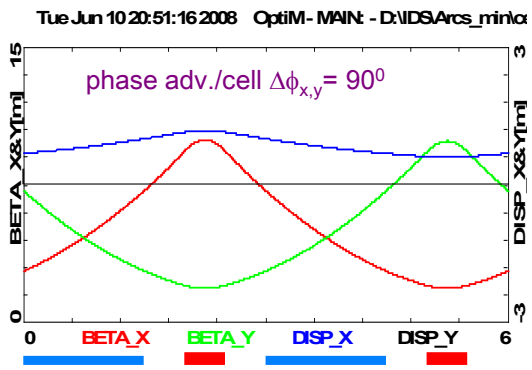


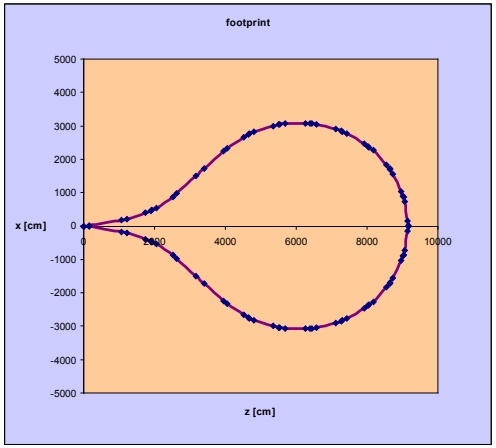
5-pass, 3600-4200 MeV



Mirror-symmetric 'Droplet' Arc – Optics







Arc dipoles

$Lb=100 cm

$B=10.5 kG

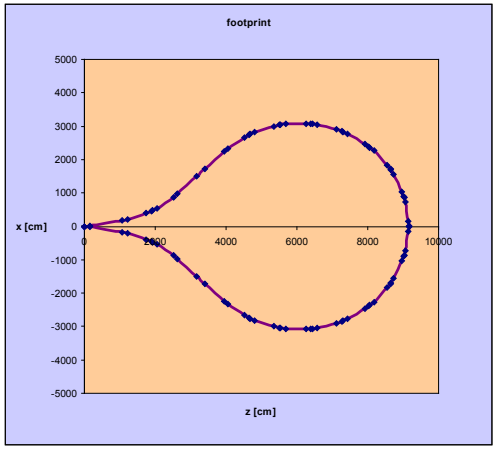
Arc quadrupoles

$Lb=50 cm

$G= 0.4 kG/cm

‘Droplet’ Arcs scaling – RLA I

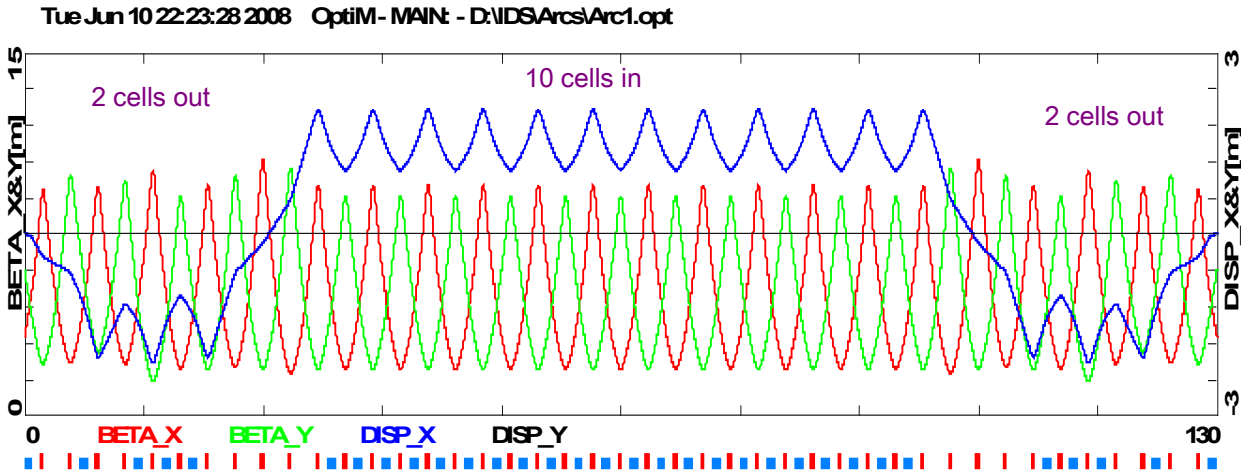
i = 1…4	E_i [GeV]	p_i/p_1	cell_out	cell_in	length [m]
Arc1	1.2	1	2×2	10	130
Arc2	1.8	3/2	2×3	15	172
Arc3	2.4	2	2×4	20	214
Arc4	3.0	5/2	2×5	25	256



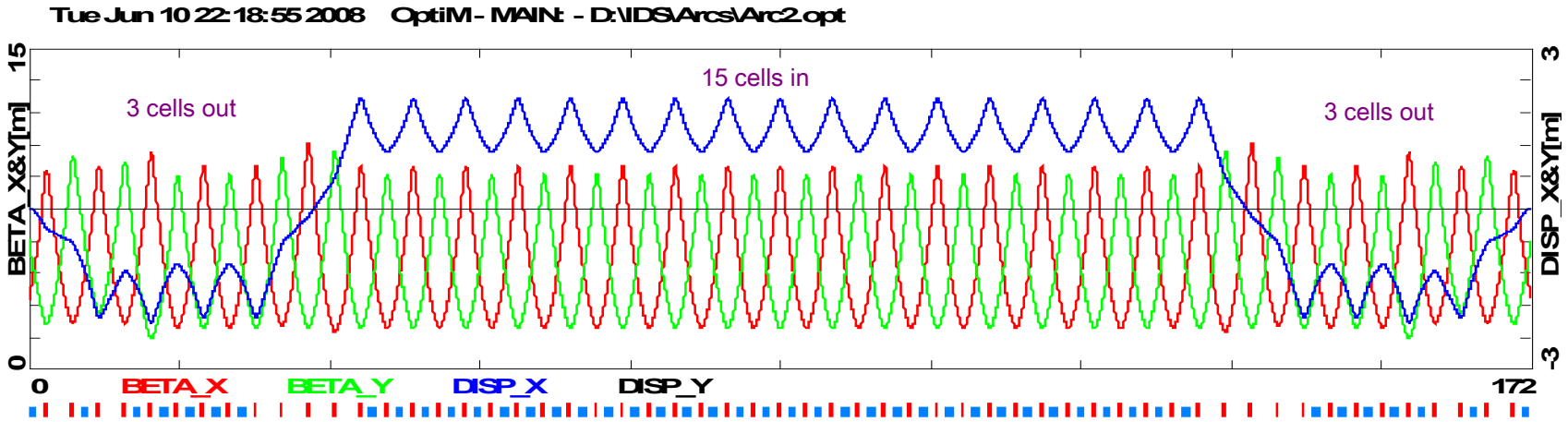
- Fixed dipole field: B_i =10.5 kGauss
- Quadrupole strength scaled with momentum: $G_i = \frac{p_i}{p_1} \times 0.4$ kGauss/cm
- Arc circumference increases by: (1+1+5) × 6 m = 42 m

Mirror-symmetric 'Droplet' Arc – Optics

Arc1 (E =1.2 GeV)

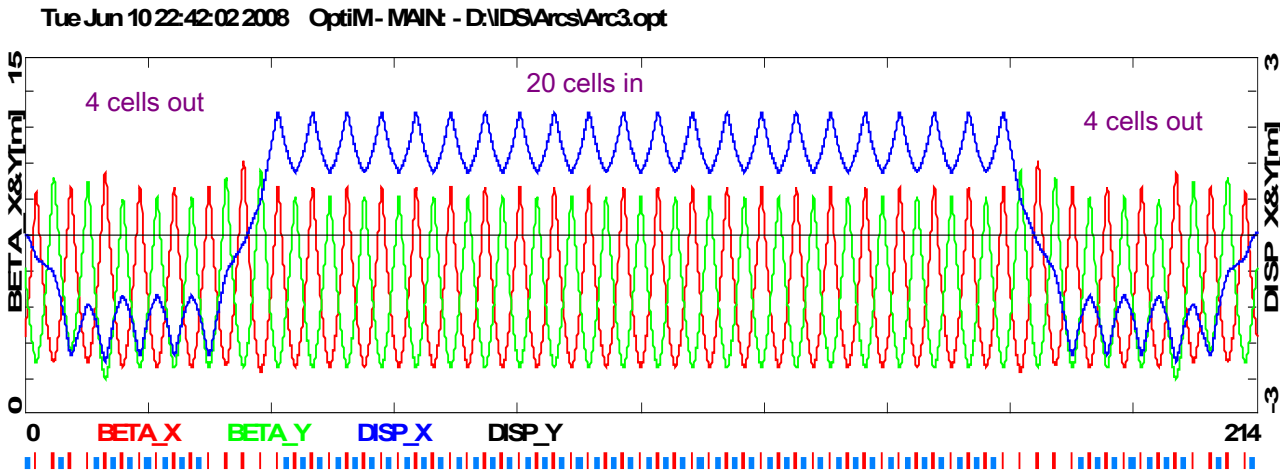


Arc2 (E =1.8 GeV)

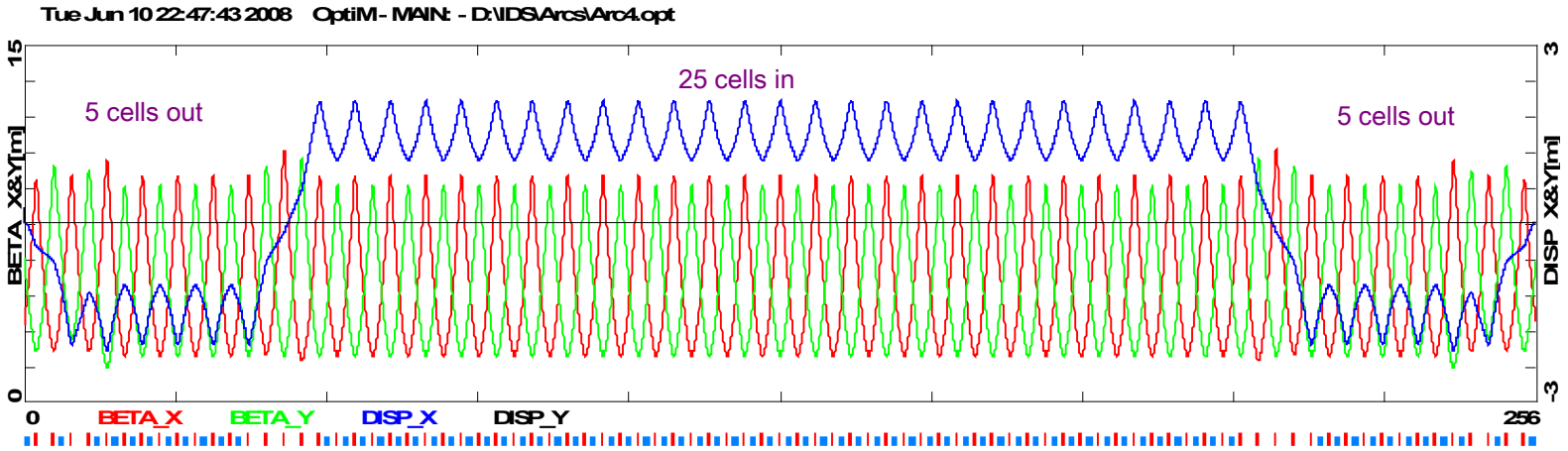


Mirror-symmetric 'Droplet' Arc – Optics

Arc3 (E =2.4 GeV)

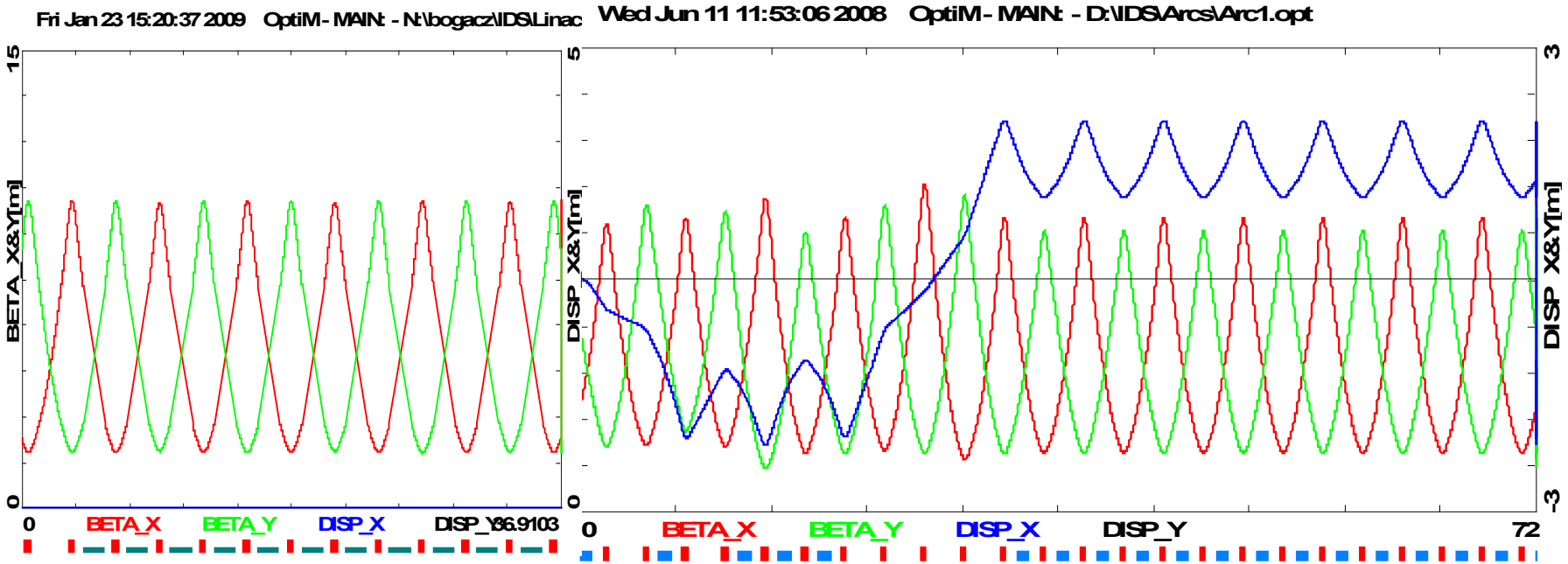


Arc4 (E =3.0 GeV)



Linac ½-to-Arc1 – Beta Match

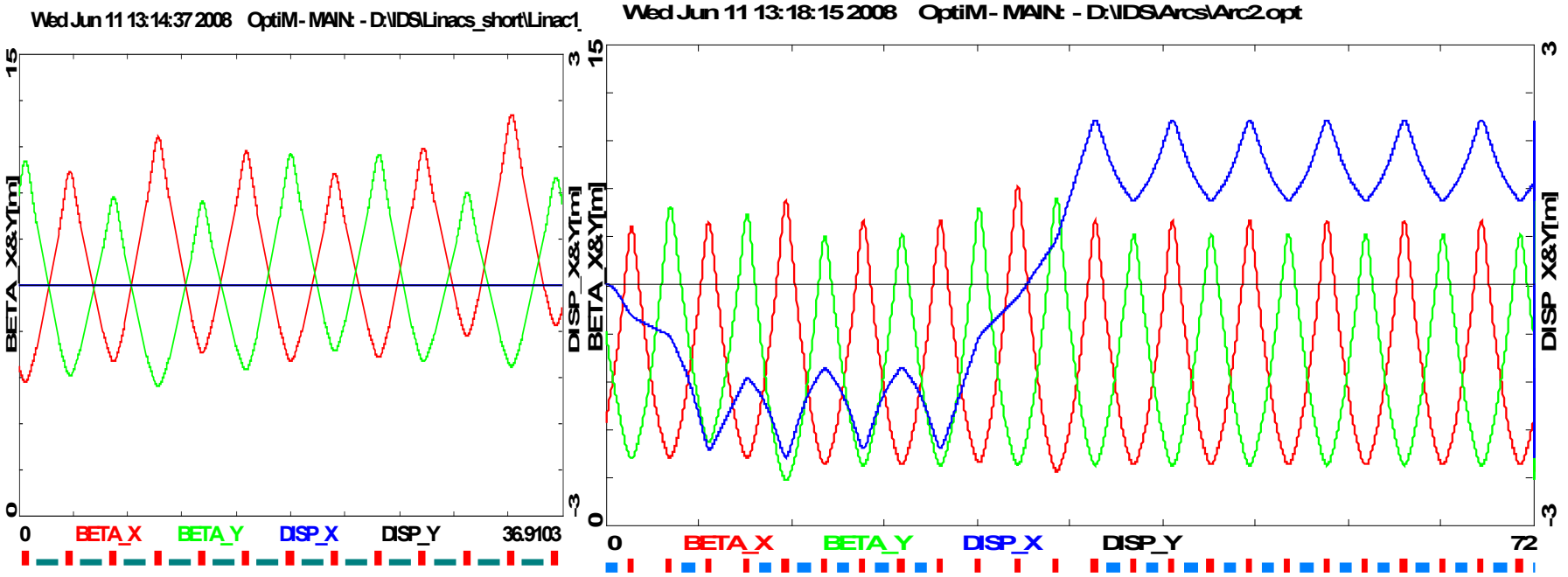
E =1.2 GeV



- Already matched 'by design'
- 90^0 phase adv/cell maintained across the 'junction'
- No chromatic corrections needed

Linac1-to-Arc2 – Beta Match

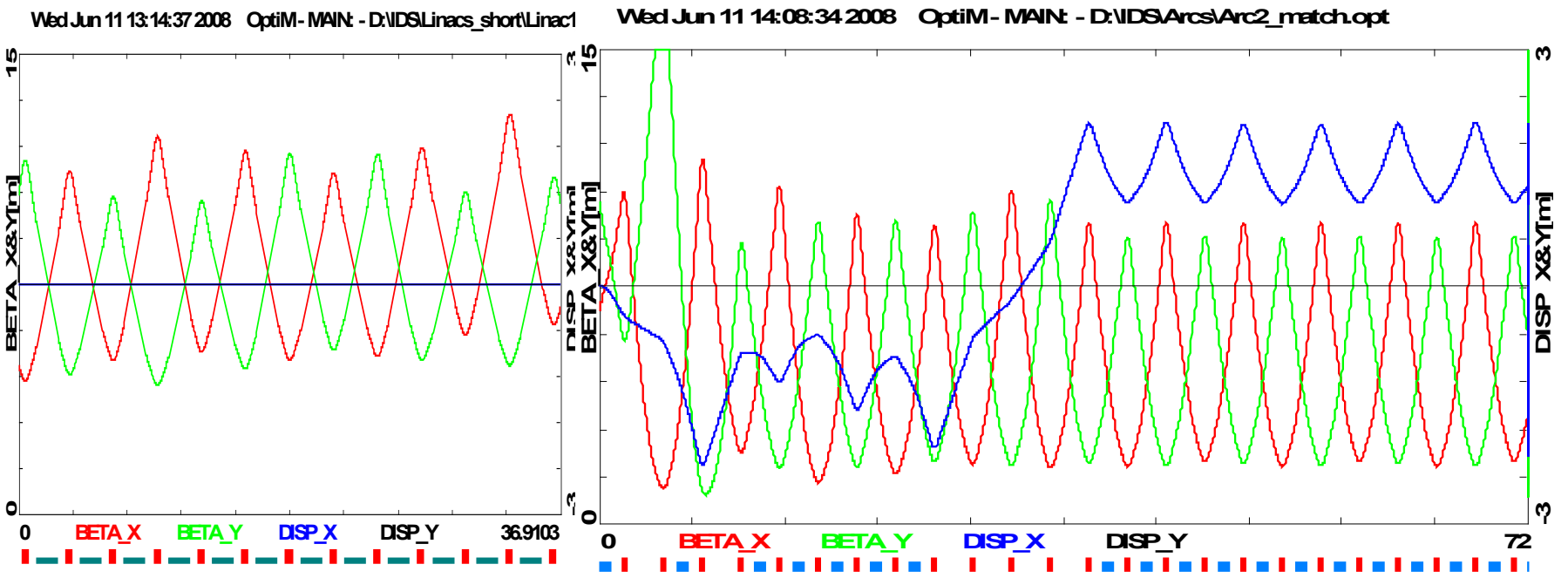
E =1.8 GeV



- Noticeable mis-match at the end of Linac1
- 'Matching quads' are invoked

Linac1-to-Arc2 – Beta Match

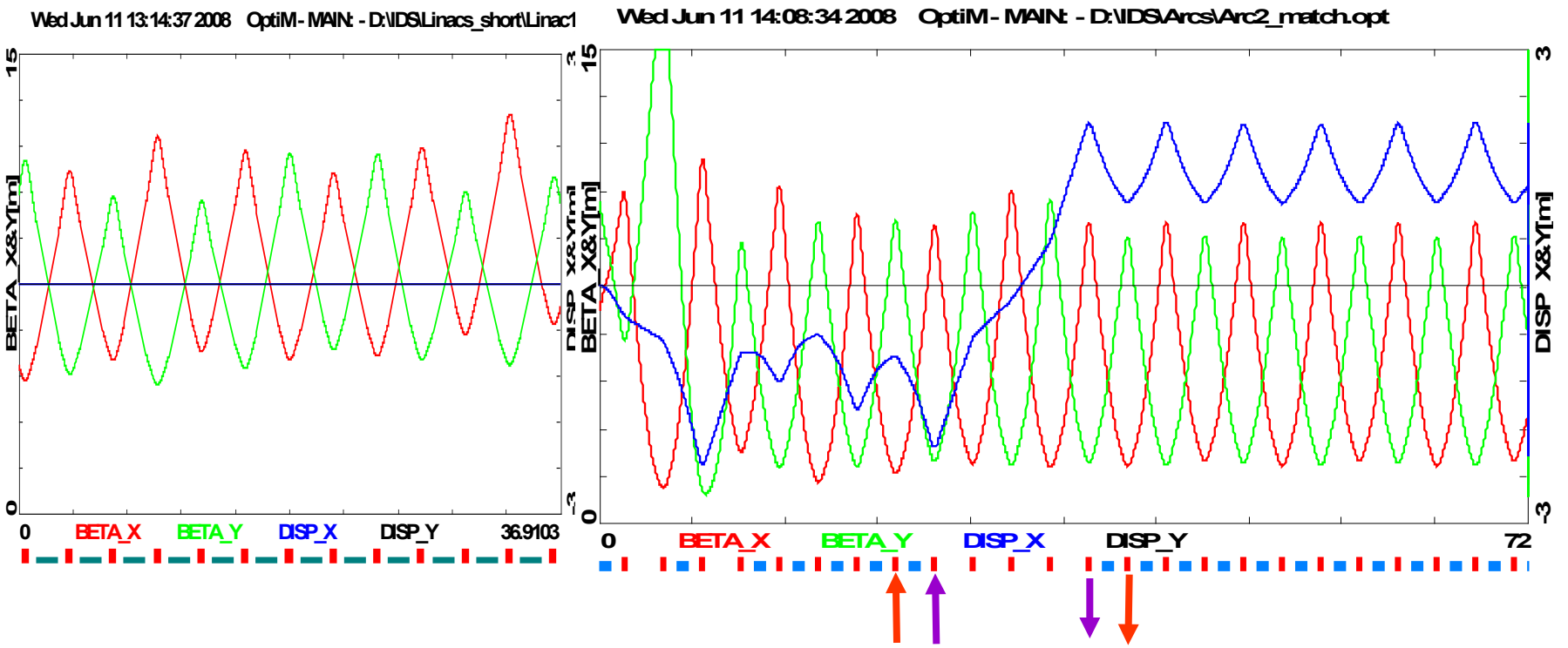
E =1.8 GeV



- No 90^0 phase adv/cell maintained across the 'junction'
- Chromatic corrections needed

Linac1-to-Arc2 – Chromatic compensation

E =1.8 GeV



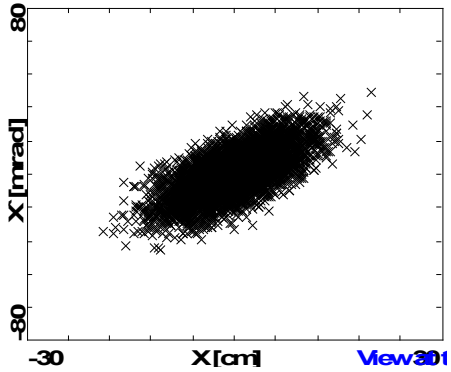
- Chromatic corrections with two pairs of sextupoles

$$G_{sext}\ [kGauss/cm] = S \times \frac{\Delta p}{p} \times \overline{D} = 0.2 \times 0.01 \times 150 = 0.3\ [kGauss/cm]$$

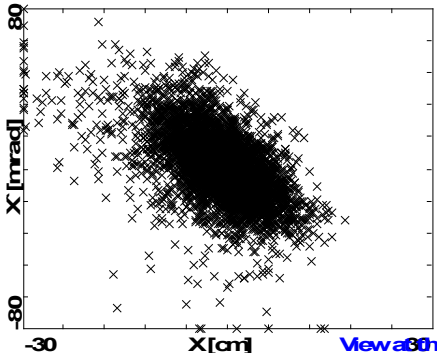
$$G_{quad} \approx 10\ [kGauss/cm]$$

Linac1-to-Arc2 - Chromatic Corrections

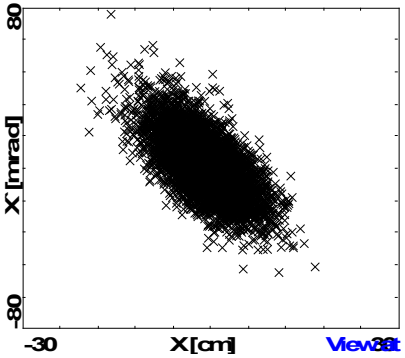
initial

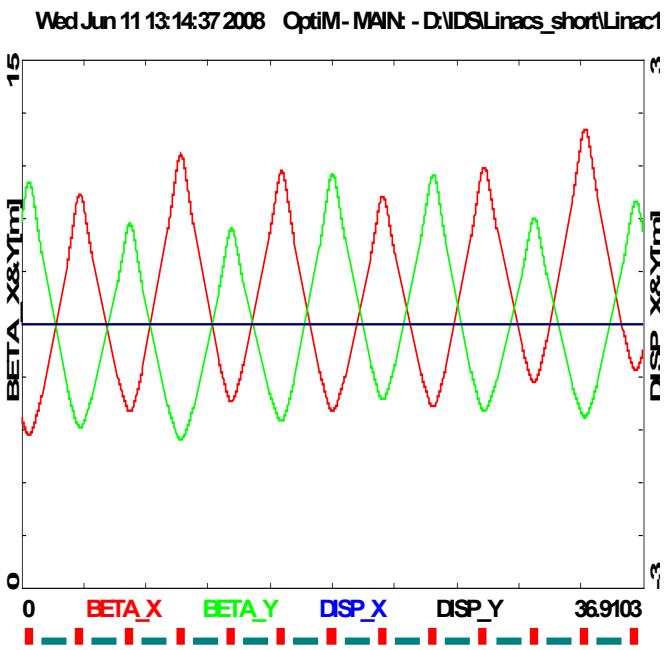


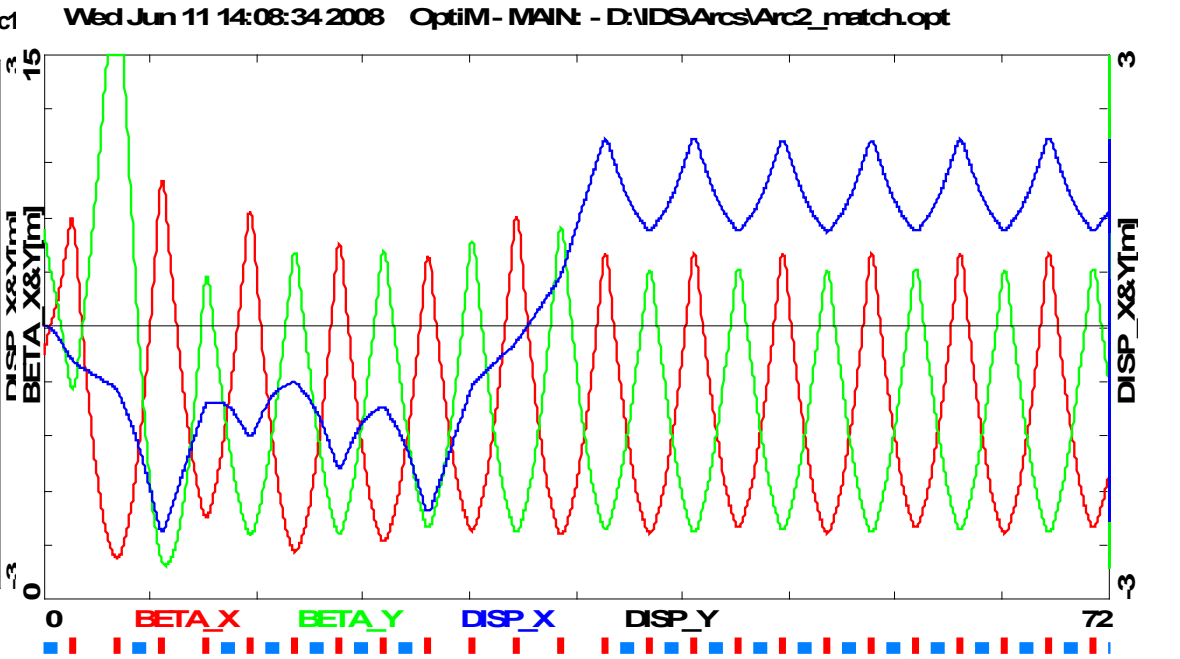
uncorrected



two families of sextupoles

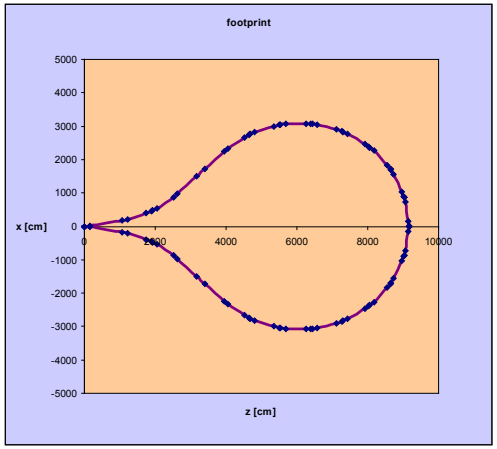






‘Droplet’ Arcs scaling – RLA II

i = 1…4	E_i [GeV]	p_i/p_1	cell_out	cell_in	length [m]
Arc1	4.6	1	2×2	10	260
Arc2	6.6	3/2	2×3	15	344
Arc3	8.6	2	2×4	20	428
Arc4	10.6	5/2	2×5	25	512

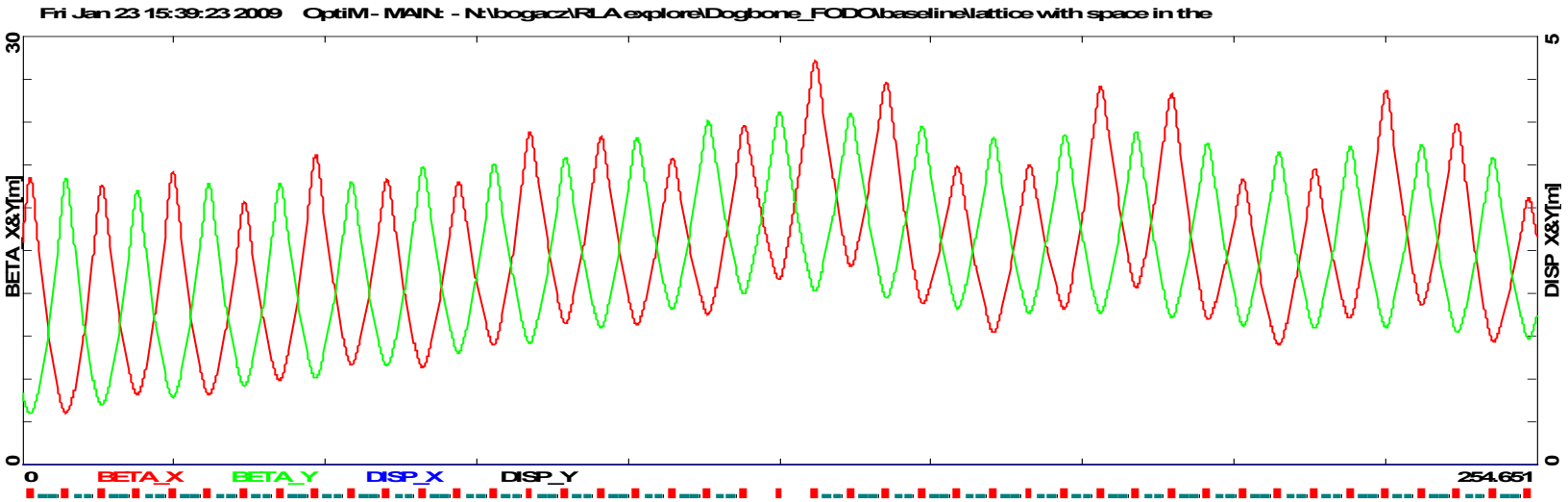


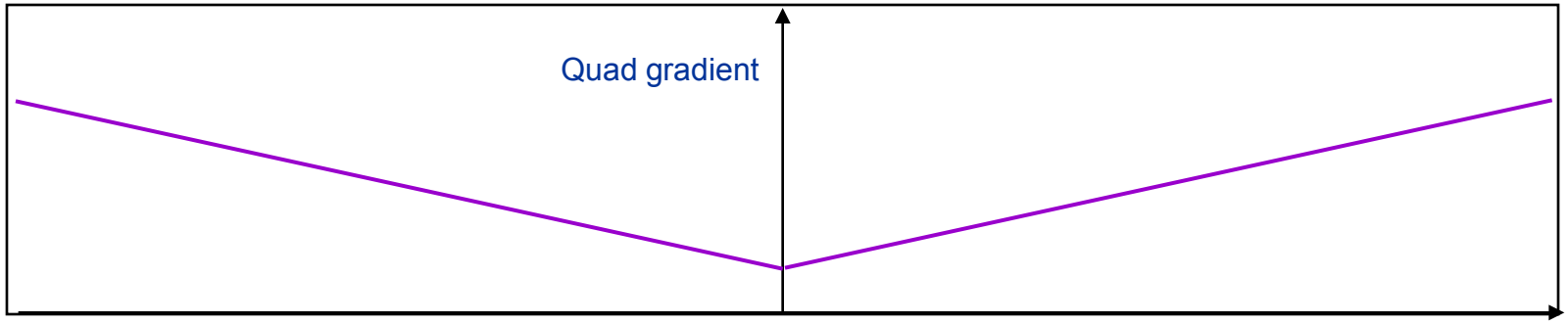
- Fixed dipole field: B_i = 40.3 kGauss
- Quadrupole strength scaled with momentum: $G_i = \frac{p_i}{p_1} \times 1.5$ kGauss/cm
- Arc circumference increases by: (1+1+5) × 12 m = 84 m

RLA II - linac Optics

1-pass, 4.6 -6.6 GeV

mirror symmetric quads in the linac





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Agenda

Sunday, 14 December 2008

10:00-12:30	Joint front end and acceleration session	
	Introduction	Juergen Pozimski
	Status of preparations and plans for E2E simulations	Chris Rogers
	Some thoughts about beam loading	Juergen Pozimski
	Status, Plans for ISS Cooling Channel	Rick Fernow
	Recent work on Capture and Phase Rotation	Dave Neuffer
12:30-13:30	Lunch	
13:30-17:30	Front end session - capture and phase rotation	
	Front end studies	Cary Yoshikawa
13:30-17:30	Acceleration session - linac and RLAs	
	First results of muon linac lattice studies with MADX	(JPo obo) Morteza Aslaninejad
	Development of Linac/RLAs	Alex Bogacz

Agenda

Monday, 15 December 2008

09:00-12:30	Front end session - cooling and end2end simulation	
	Discussion of ICOOL, GEANT4 Material Model	All
	Alternate lattices; optimisation algorithms	Chris Rogers
09:00-12:30	Acceleration session - FFAG	
	FFAG lattice with chromaticity correction	(JPa obo) Shinji Machida
	FFAG injection studies	Jaroslaw Pasternak
	FFAG studies	Scott Berg
12:30-13:30	Lunch	
13:30-16:00	Joint front end and acceleration session	
	Front end - plans and schedule	Fernow/Rogers
	Acceleration - plans and schedule	Bogacz/Pozimski

Files Page

Work Plan

IV. Acceleration [Coordinators: A. Bogacz (JLab), J. Pozimski (ICL)]

A. Normal-conducting acceleration from cooling to superconducting linac, matched to both of these systems.

1. Lattice design.
   Deliverable: ICOOL lattice file.
   Depends on: III.B.1, IV.B.1.
   Status: Unnecessary due to results from IV.B.1.
2. Tracking through lattice.
   Deliverable: Output from ICOOL tracking, starting with results from III.B.2, analysis to determine transmission and emittance growth.
   Depends on: IV.A.1, III.B.2.
   Status: Unnecessary due to results from IV.B.1.

B. Superconducting pre-accelerator linac.

1. Lattice design.
   Deliverable: Lattice file.
   Target date: March 2008.
   Responsible person: A. Bogacz.
   Status: Complete.
2. Tracking idealized lattice.
   Deliverable: Results demonstrating transmission and quantifying emittance growth for full transverse and longitudinal acceptance.
   Depends on: IV.B.1.
3. Propagate distribution from normal-conducting accelerator
   Deliverable: Output distribution, analysis of emittance growth and transmission.
   Depends on: IV.A.2, IV.B.1.

Work Plan cont.

C. Dogbone RLAs.

1. Mid-linac injection system, including all chromatic corrections.
   Deliverable: Lattice file.
   Target date: March 2008.
   Responsible person: A. Bogacz.
   Depends on: Linac design from IV.C.2.
2. Full lattice designs, including chromatic correction, switchyard layout, and arc crossings.
   Deliverable: Lattice file.
   Responsible person: A. Bogacz.
3. Engineering of switchyard and arc crossings.
   Deliverable: Sufficiently detailed design and drawings to demonstrate feasibility.
4. Transfer line between RLAs.
   Deliverable: Lattice file.
   Depends on: IV.C.1, IV.C.2.
5. Tracking idealized lattice.
   Deliverable: Results demonstrating transmission and quantifying emittance growth for full transverse and longitudinal acceptance.
   Depends on: IV.C.2.
6. Propagate distribution from previous stages.
   Deliverable: Output distribution, analysis of emittance growth and transmission.
   Depends on: IV.B.2, IV.C.1, IV.C.2, IV.C.4.

Summary

- IDS Goals – laying **engineering design foundation**
  - Define beamlines/lattices for all components
  - Design lattices for transfer lines between the components
  - Resolve physical interferences, beamline crossings etc ⇒ Floor Coordinates
- Chromatic corrections with sextupoles implemented
- Presently completed Optics design
  - Pre-accelerator (244 MeV-0.9) + injection double chicane
  - RLA I (0.9-3.6 GeV) and RLA II (3.6-12.6 GeV)
    - 4.5 pass linac
    - Droplet Arcs1-4
- Still to do….
  - End-to-end simulation
  - Engineer individual active elements (magnets and RF cryo modules)
  - Element count and costing