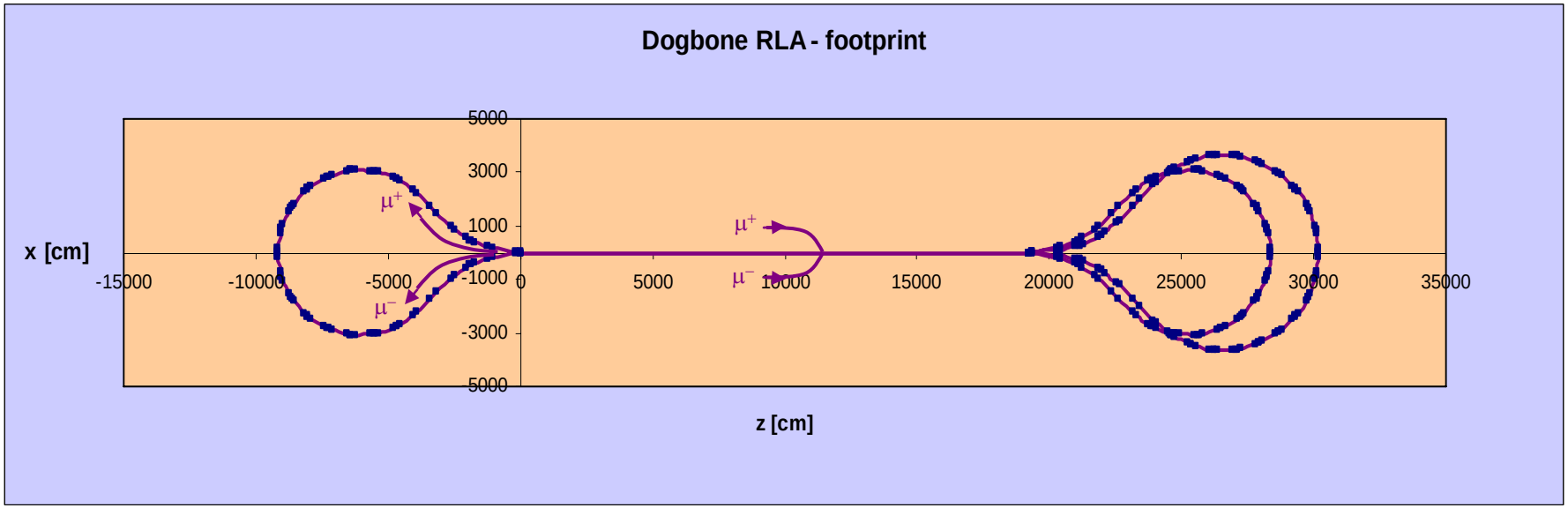
Prospects for 10 GeV 'Dogbone' RLA

Alex Bogacz

Jefferson Lab

- Symmetric 10 GeV 'Dogbone' RLA
  - Pre-accelerator (273 MeV/c – 2 GeV)
  - Multi-pass linac (2 GeV per pass)
  - Mirror-symmetric 'Droplet' Arcs at: 3, 5, and 7 (9?) GeV
  - Arc-to-Linacs betatron matching
- Optimized multi-pass linac focusing (2 GeV per pass)
- 3.5-pass (9 GeV) and 4.5-pass (11 GeV) 'Dogbone' RLAs

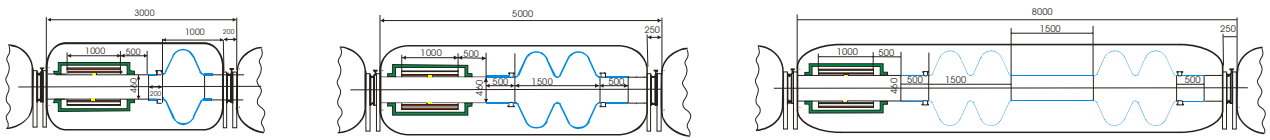
10 GeV Symmetric 'Dogbone' RLA 3.5(4.5?)-pass



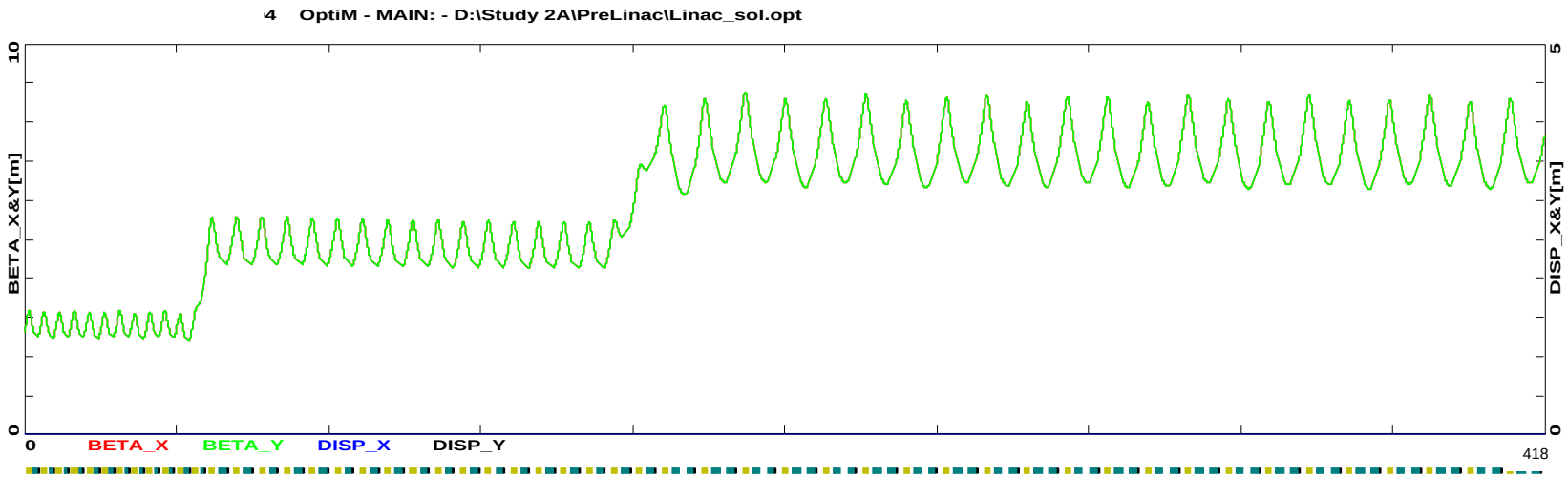
- Start with the baseline 5 GeV 'Dogbone' RLA
- Extended (418 m) Pre-accelerator (273 MeV/c – 2 GeV) - solenoid focusing
- Doubled (385 m) Main Linac (2 GeV/pass) - triplet focusing
- 3 (4?) 'droplet' Arcs based on periodic triplet cells (90^0 betatron phase advance per cell)

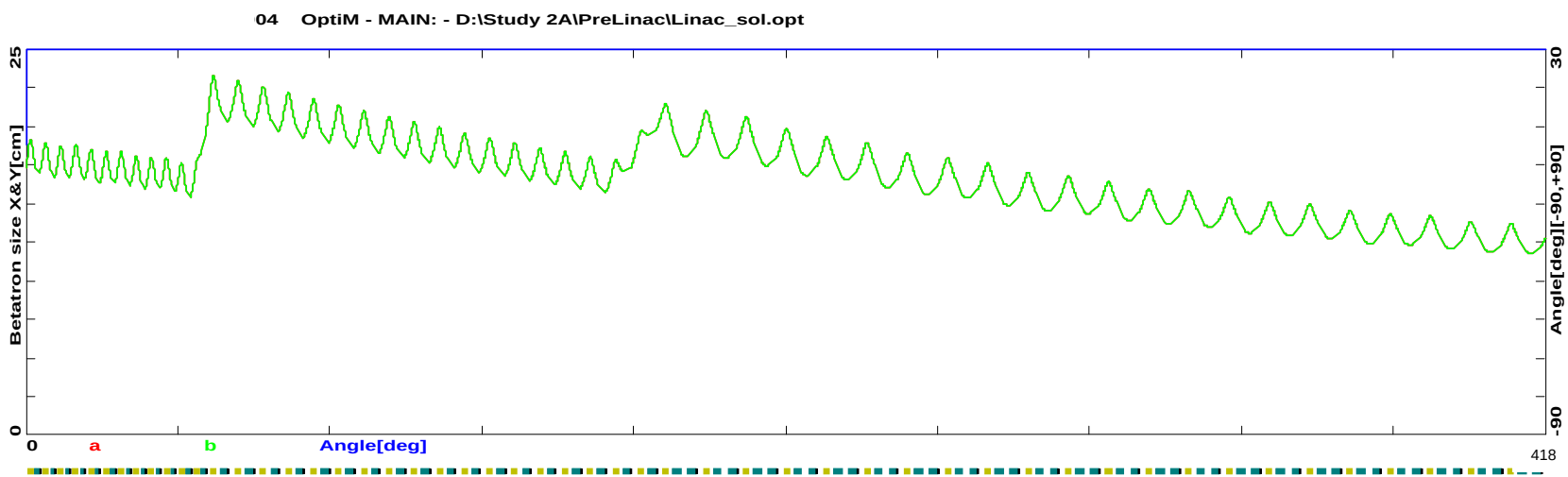
Extended Pre-accelerator – different style cryo-modules

	Short	Medium	Long
Number of periods	14 (12)	24 (18)	32 (22)
Total length of one period	3 m	5 m	8 m
Number of cavities per period	1	1	2
Number of cells per cavity	1	2	2
Cavity accelerating gradient	15 MV/m	15 MV/m	15 MV/m
Real-estate gradient	3.72 MV/m	4.47 MV/m	5.59 MV/m
Aperture in cavities (2*a*)	460 mm	460 mm	460 mm
Aperture in solenoids (2*a*)	460 mm	460 mm	460 mm
Solenoid length	1 m	1 m	1 m
Solenoid maximum field	1.5 T	1.9 T	3.9 T

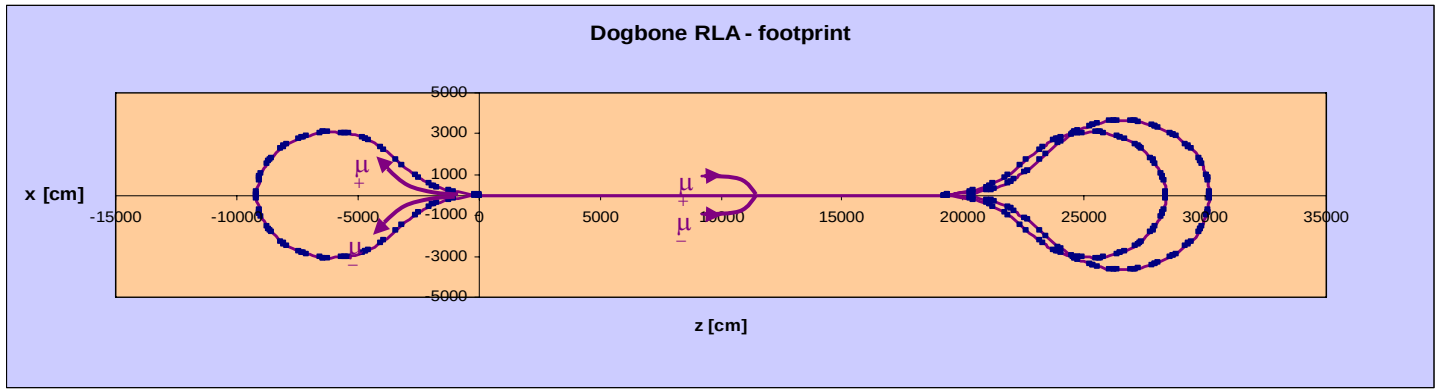


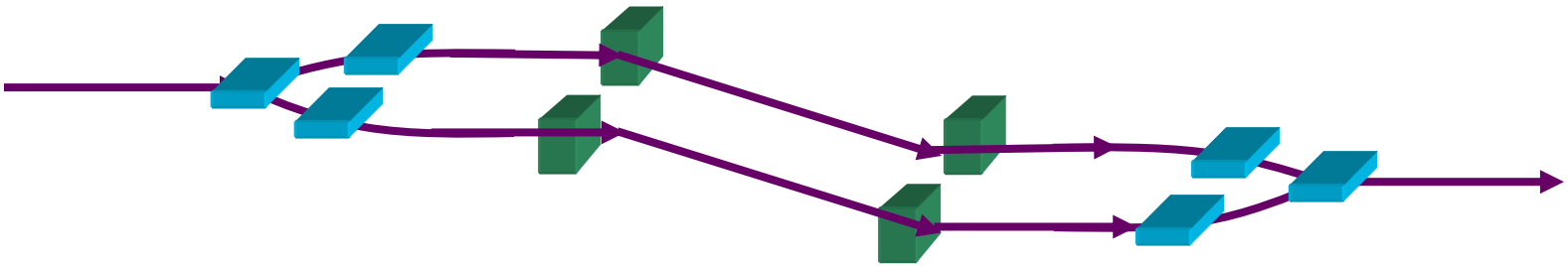
Linear Pre-accelerator – Twiss functions and beam envelope (2.5 σ)

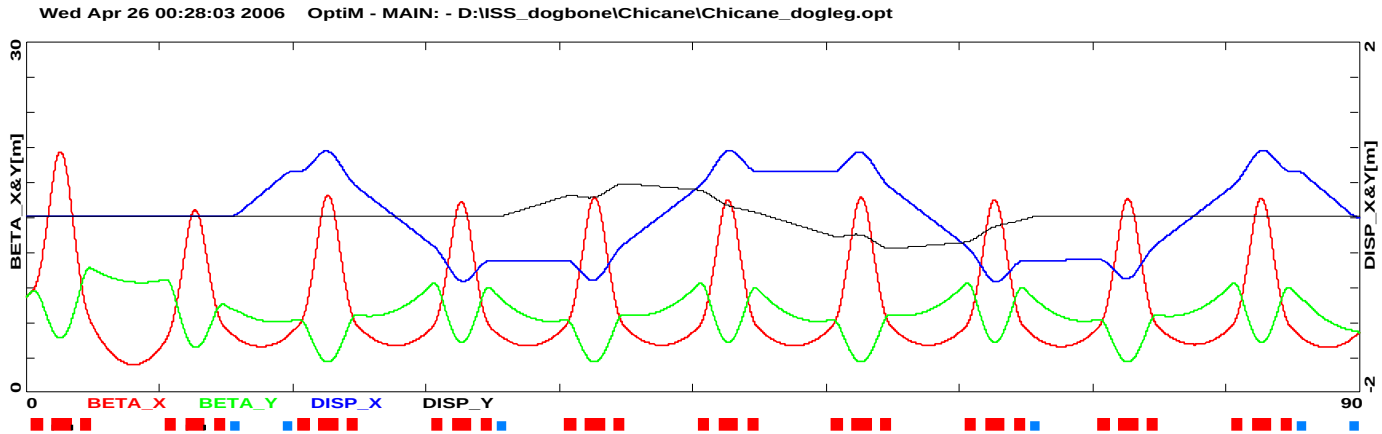




Chicane – 'dogleg'







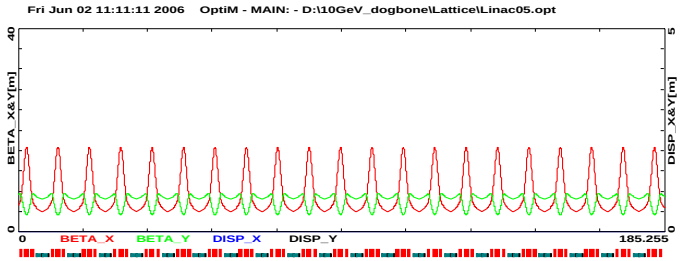
Multi-pass Linac Optics - focusing choices

- **Symmetric 'Dogbone' RLA** (allowing to accelerate both μ^+ and μ^- species) requires mirror symmetry of the droplet arcs – exit/entrance to/from the next linac betas to be equal and alphas to be of the opposite sign.

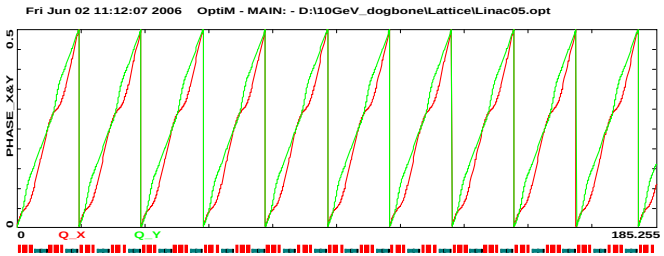
- Two possible 'symmetric' linac scenarios were examined:
  - 'uniform focusing' linac profile
    - 90^0 phase advance/cell is set for the 'half pass' linac (2-3 GeV).
    - as a consequence linac phase advance/cell in the first part of 1-pass drops to about 45^0.
    - to avoid large 'beta beating' one chooses to keep 45^0 phase advance/cell throughout the second part of the linac.
    - the phase advance at the end of 2-pass linac drops by another factor of two (22.5^0).
  - 'overfocused' linac profile
    - 120^0 phase advance/cell is set for the 'half pass' linac (2-3 GeV).
    - as a consequence linac phase advance/cell in the first part of 1-pass drops to about 90^0.
    - one chooses to keep 95^0 phase advance/cell throughout the second part of the linac.
    - the phase advance at the end of 2-pass linac drops by another factor of two (45^0).

'uniform focusing' linac profile

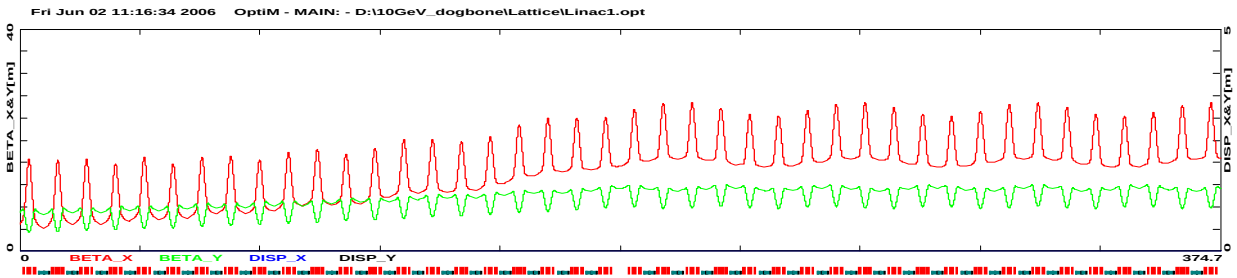
mirror symmetry cond. ($\beta_{out}^{n} = \beta_{in}^{n+1}$,and $\alpha_{out}^{n} = -\alpha_{in}^{n+1}$, n = 0,1 pass index)



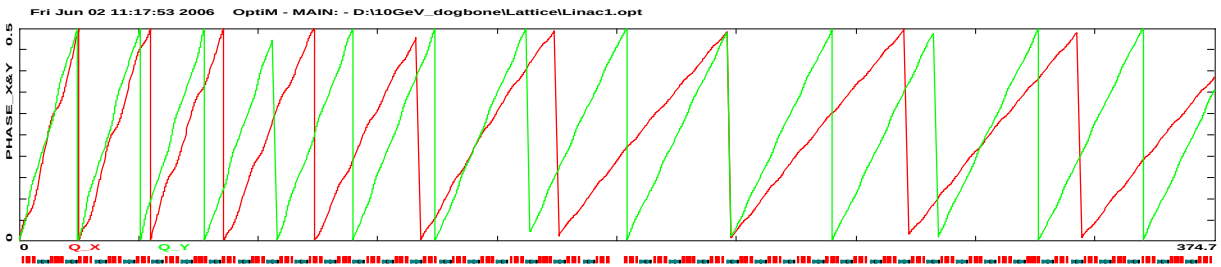
'half pass' (n = 0), 2-3 GeV



uniform phase adv/cell (90/90 deg)



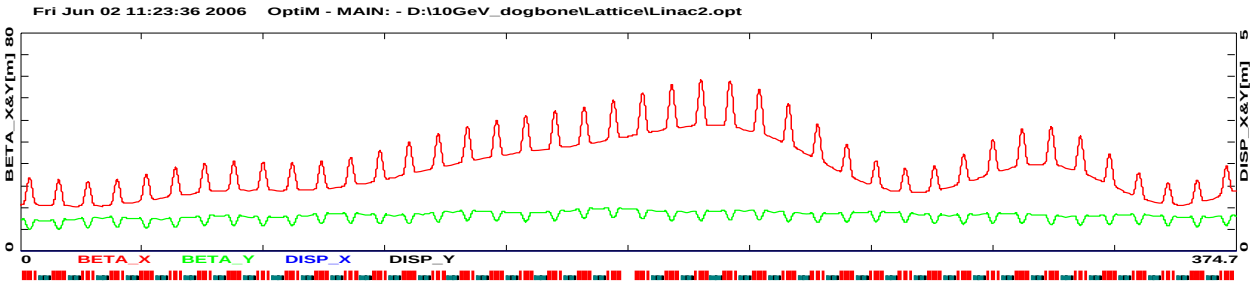
1-pass (n = 1), 3-5 GeV

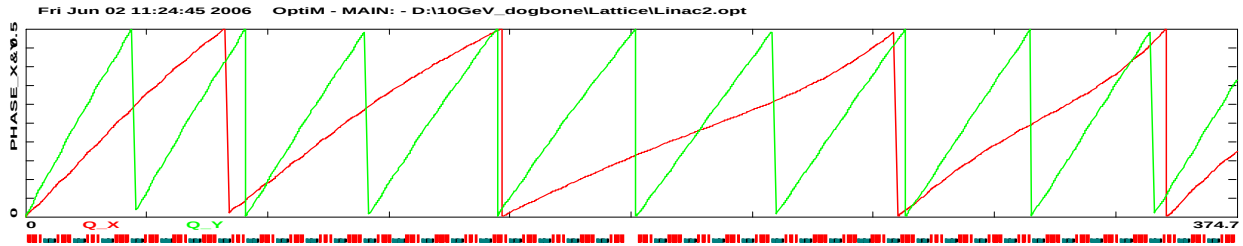


phase adv. drops (30/45 deg)

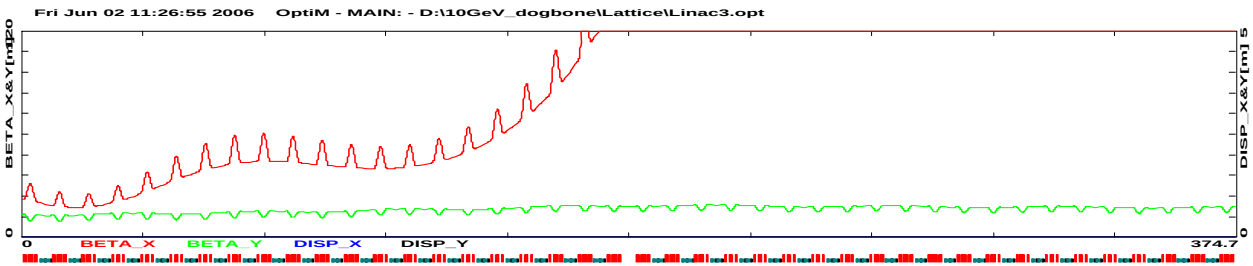
'uniform focusing' linac profile

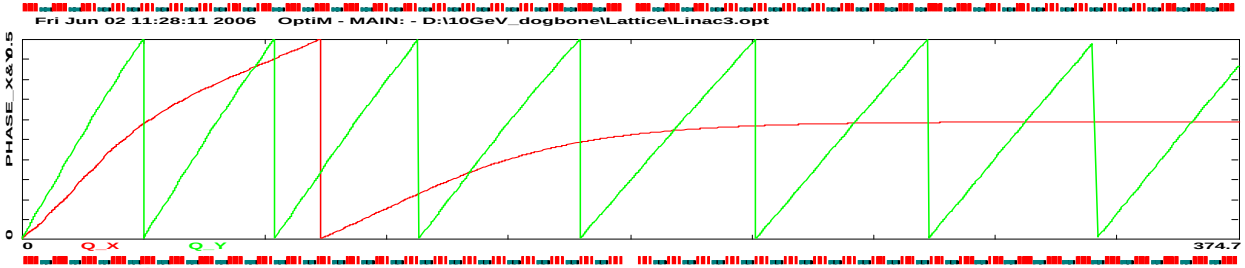
mirror symmetry cond. ($\beta_{out}^{n} = \beta_{in}^{n+1}$,and $\alpha_{out}^{n} = -\alpha_{in}^{n+1}$, n = 2, 3 pass index)





2-pass (n = 2), 5-7 GeV



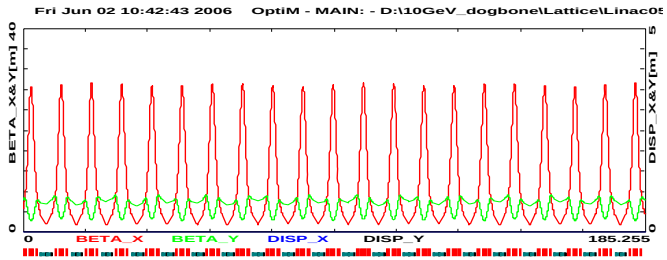


3-pass (n = 3), 7-9 GeV

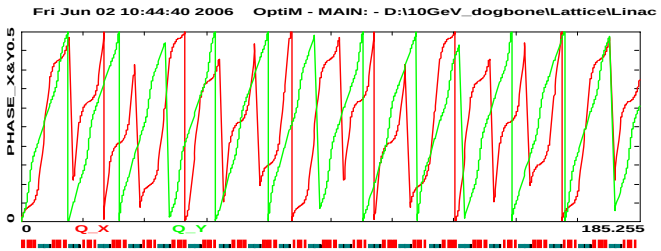
hor. phase adv/cell lost

'overfocused' linac profile

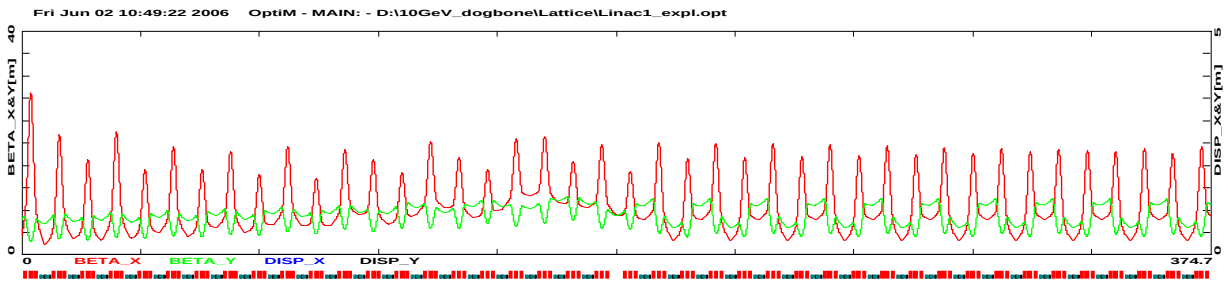
mirror symmetry cond. ($\beta_{out}^{n} = \beta_{in}^{n+1}$,and $\alpha_{out}^{n} = -\alpha_{in}^{n+1}$, n = 0,1 pass index)



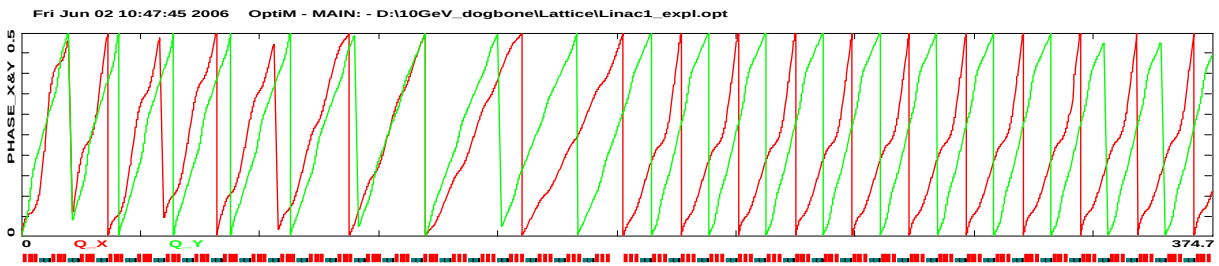
'half pass' (n = 0), 2-3 GeV



uniform phase adv/cell (120/120 deg)



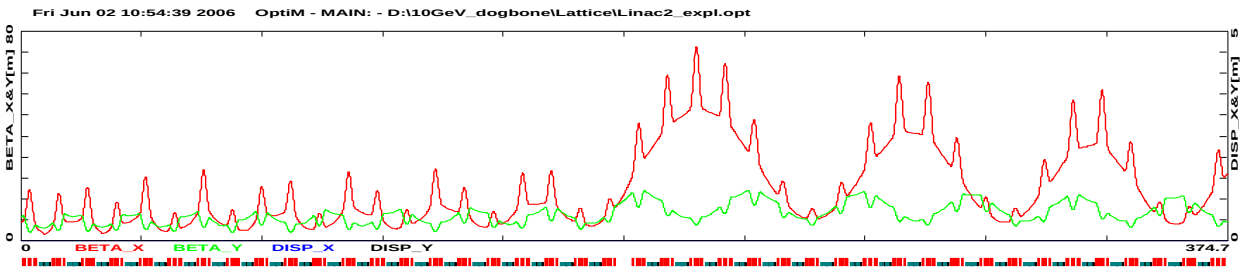
1-pass (n = 1), 3-5 GeV



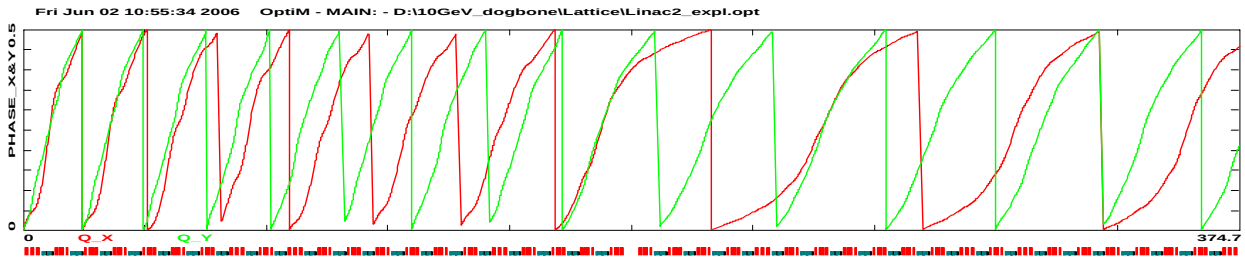
phase adv/cell restored to (90/90 deg)

'overfocused' linac profile

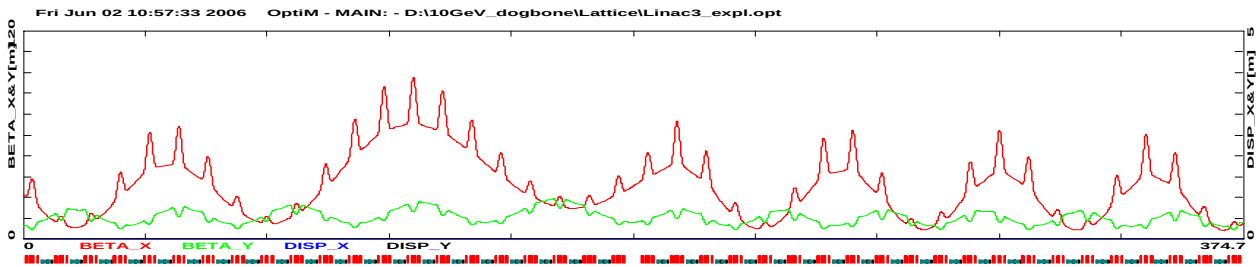
mirror symmetry cond. ($\beta_{out}^{n} = \beta_{in}^{n+1}$,and $\alpha_{out}^{n} = -\alpha_{in}^{n+1}$, n = 2, 3 pass index)



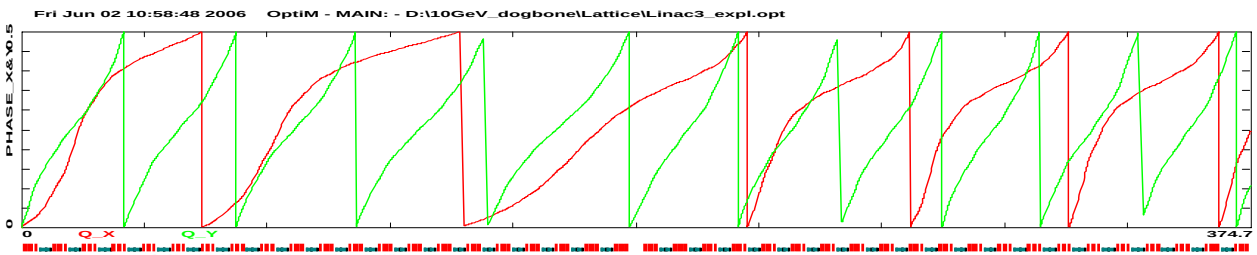
2-pass (n = 2), 5-7 GeV



phase adv/cell drops to (45/45 deg)



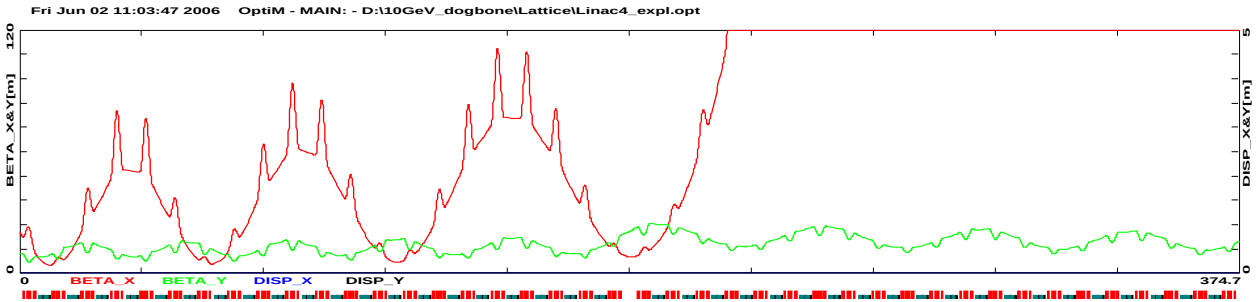
3-pass (n = 3), 7-9 GeV

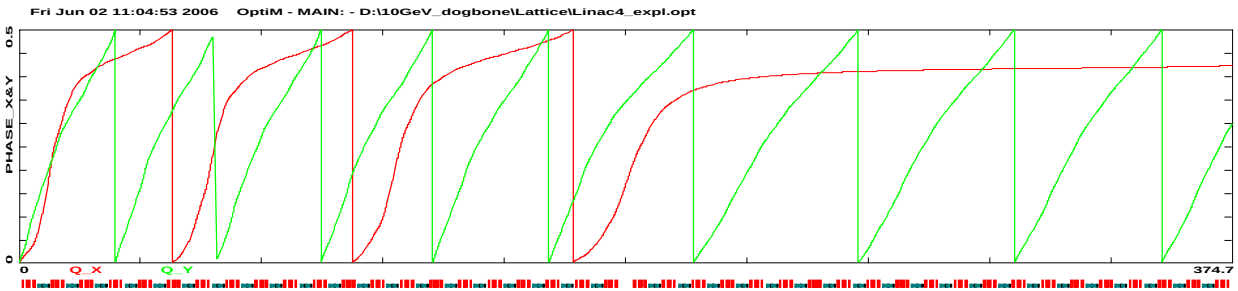


'overfocused' linac profile

mirror symmetry cond. ($\beta_{out}^{n} = \beta_{in}^{n+1}$,and $\alpha_{out}^{n} = -\alpha_{in}^{n+1}$, n = 2, 3 pass index)

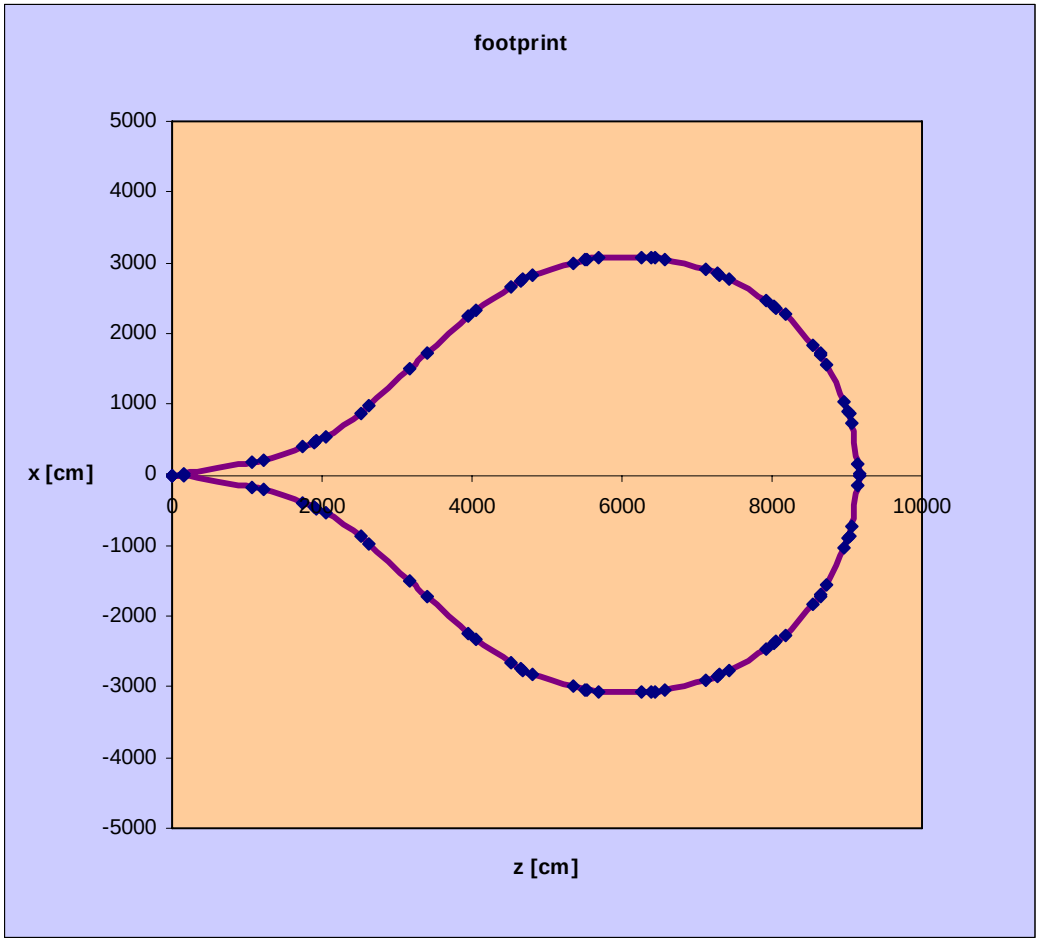
4-pass (n = 4), 9-11 GeV





hor. phase adv/cell lost

Arc 1 – Layout



Arc dipoles

$E = 3 GeV

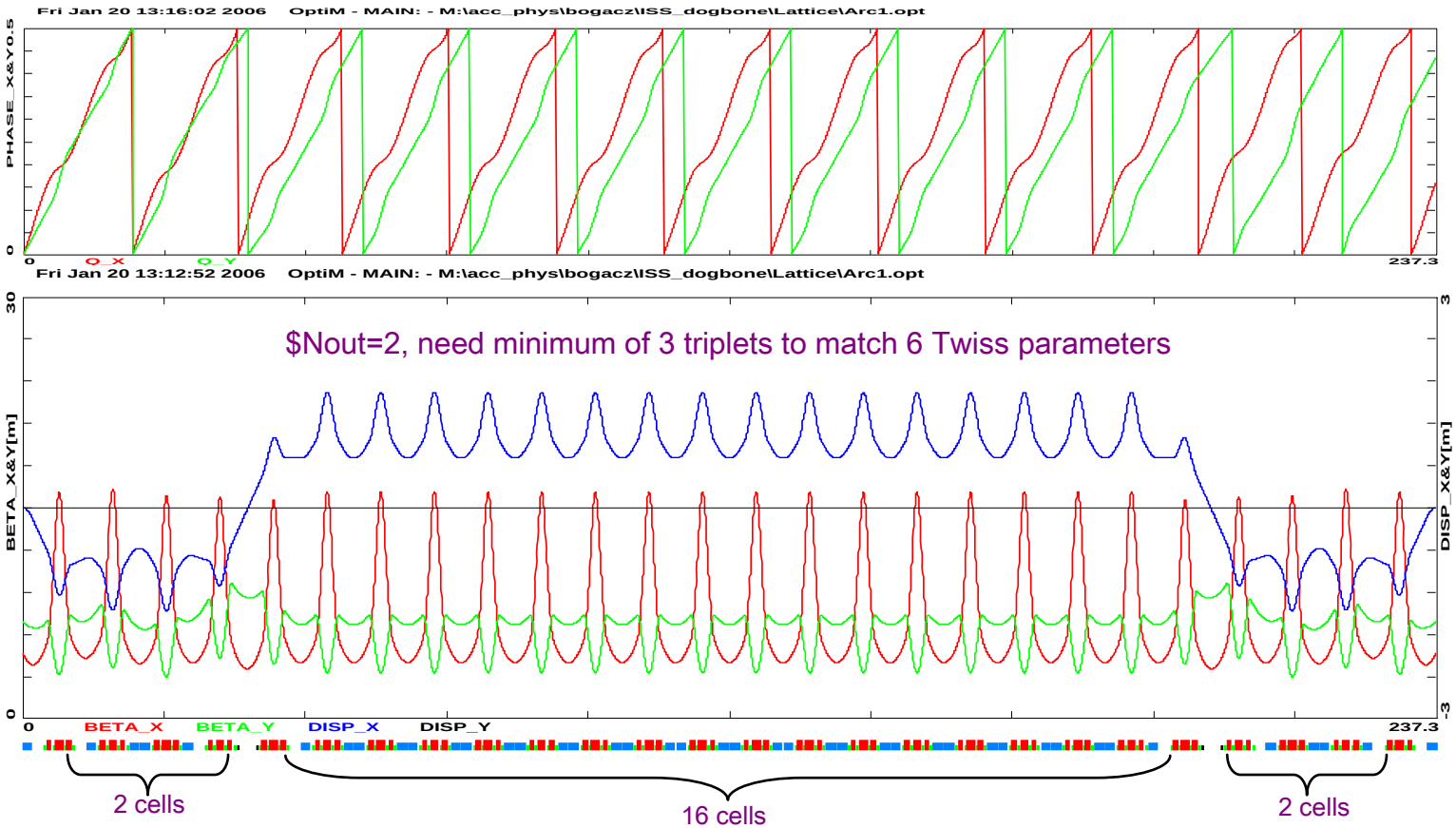
$Lb=150; => 150 cm
$ang0=10.3283; => 10.328 deg
$Nin=16; => 16
$Nout=2; => 2
$ang=(90+$ang0)/($Nin-2*$Nout); => 8.36 deg.
#
$Ang_out=$ang0+2*$Nout*$ang; => 43.77 deg.
$Ang_in=2*$Nin*$ang; => 267.54 deg.

$BP=$PI*$Hr*$ang/(180*$Lb); => 9.8 kGauss

$Lring=227.3 m

Arc 1 – Mirror-symmetric Optics at 3 GeV

($\beta_{out} = \beta_{in}$,and $\alpha_{out} = -\alpha_{in}$, matched to the linacs)



dipoles (2 per cell)

$Lb=150; => 150 cm

$ang0=10.3283 deg

$ang=(90+$ang0)/($Nin-2*$Nout); => 8.36 deg

$B=$PI*$Hr*$ang/(180*$Lb); => **9.8** kGauss

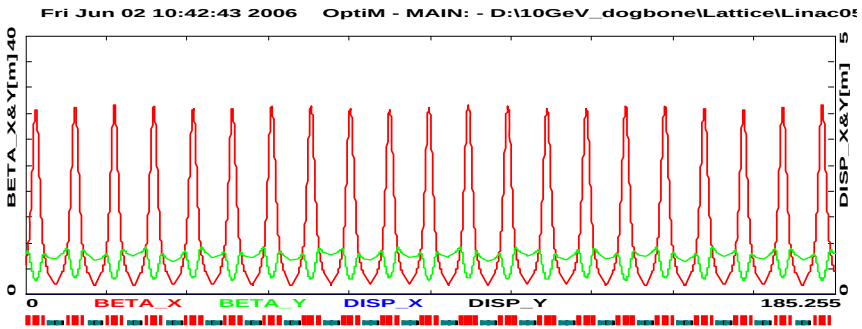
quadrupoles (triplet):

L[cm]	G[kG/cm]
68	-0.489
125	0.492
68	-0.489

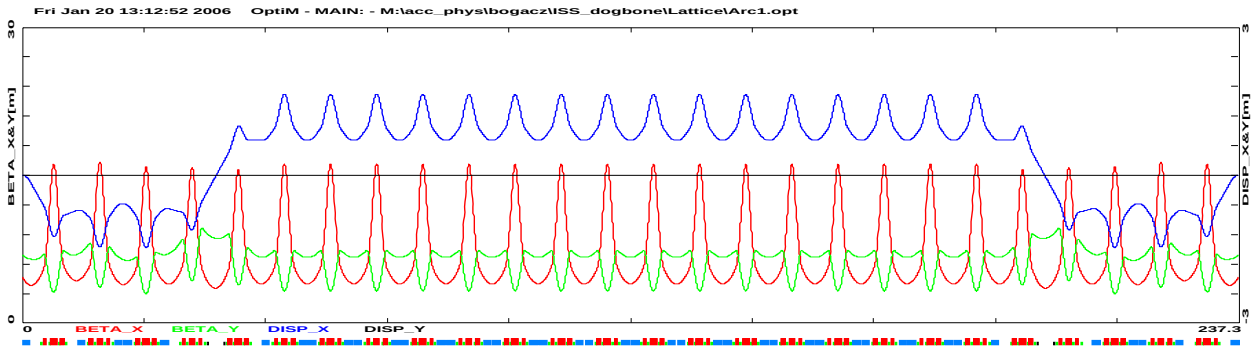
Linac-Arc1-Linac Matching

($\beta_{out} = \beta_{in}$,and $\alpha_{out} = -\alpha_{in}$, matched to the linacs)

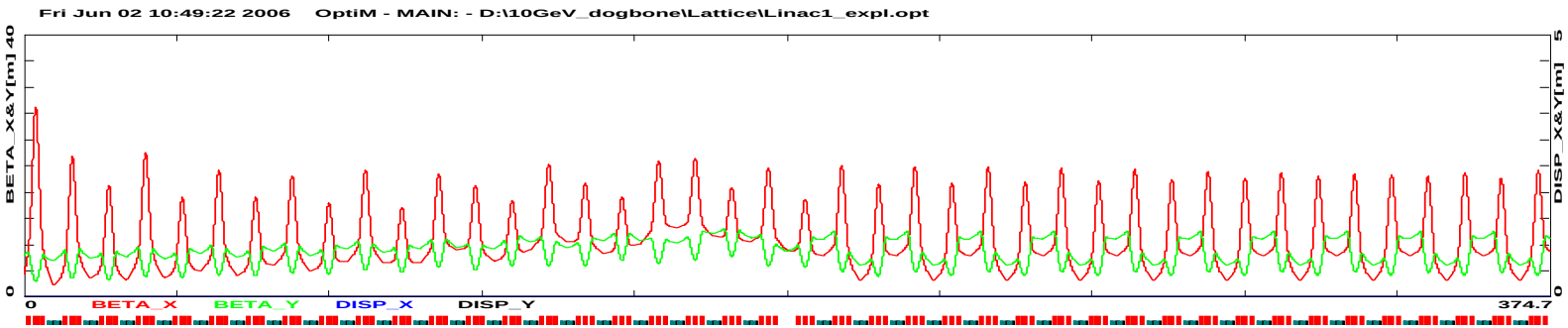
'half pass' (2-3 GeV)



Arc1 (3 GeV)

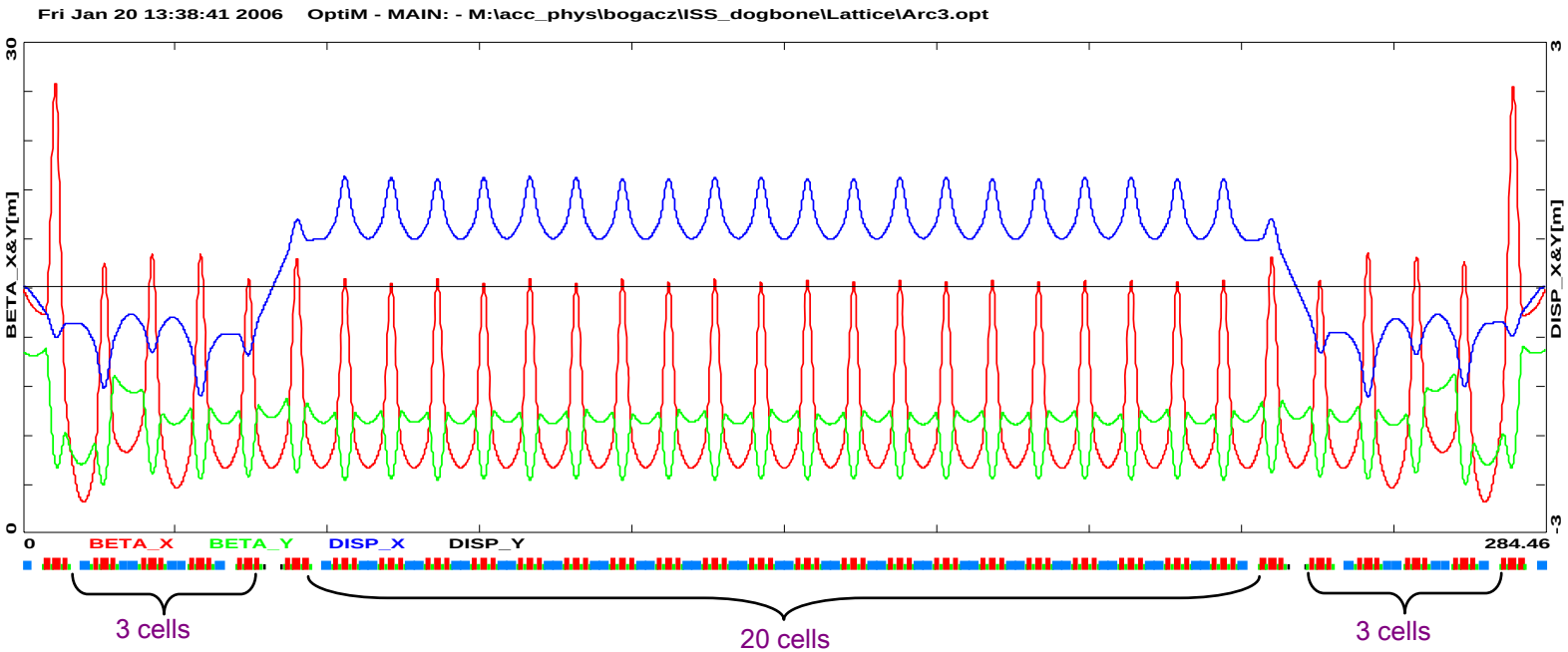


1-pass (3-5 GeV)



Arc 3 – Mirror-symmetric Optics at 7 GeV

($\beta_{out} = \beta_{in}$,and $\alpha_{out} = -\alpha_{in}$, matched to the linacs)



dipoles:

$E=3929.86 MeV
$B0=**14.1** kGauss
$ang0= 5.1577 deg
$BP=$PI*$Hr*$ang/(180*$Lb); => 10.64 kGauss
$ang=(90+$ang0)/($Nin-2*$Nout); => 6.797 deg
$Ang_out=$ang0+2*$Nout*$ang; => 45.94 deg
$Ang_in=2*$Nin*$ang; => 271.88 deg

quadrupoles (triplet):

L[cm]	G[kG/cm]
68	-1.144
125	1.149
68	-1.144

Summary

- 9 GeV (3.5-pass) Symmetric 'Dogbone' RLA would reqiure:
  - multi-pass linac optics (2 GeV/pass) – 'overfocused' linac profile
  - tolerable phase 'slippage' in the higher pass linacs
  - mirror-symmetric 'droplet' Arc optics based on constant phase advance/cell (90^0) compact lattice architecture for Spr/Rec/Trans