'Dogbone' RLA Lattice

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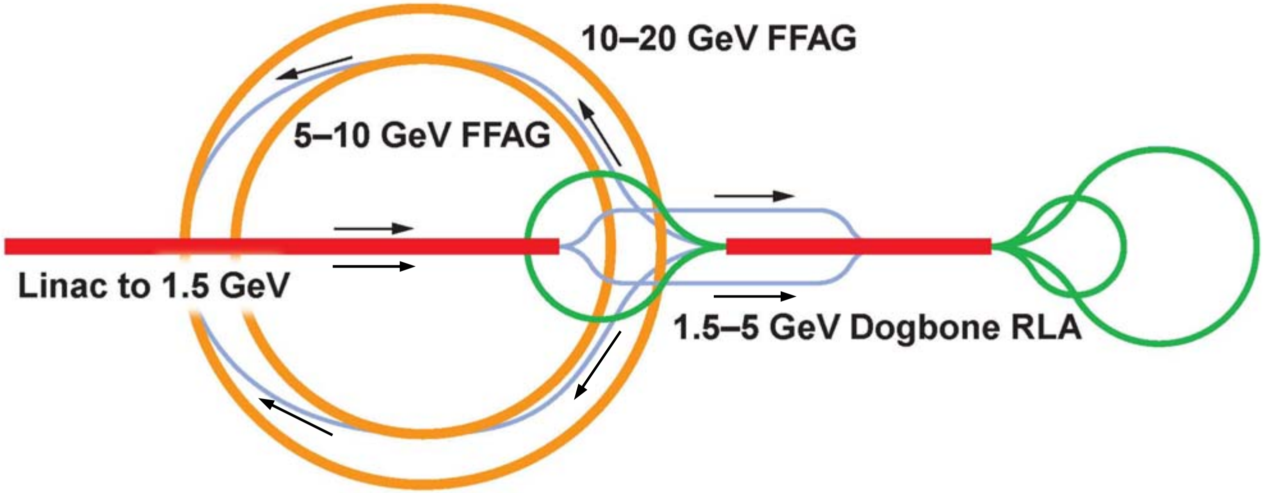
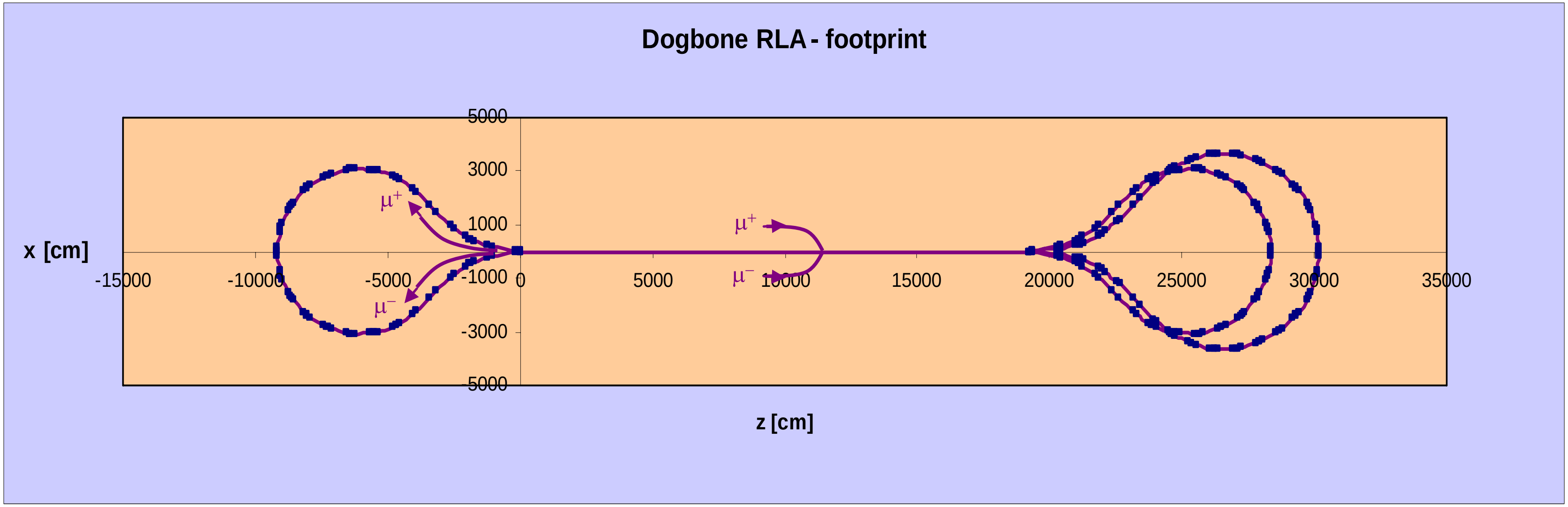
Symmetric Muon Acceleration Complex



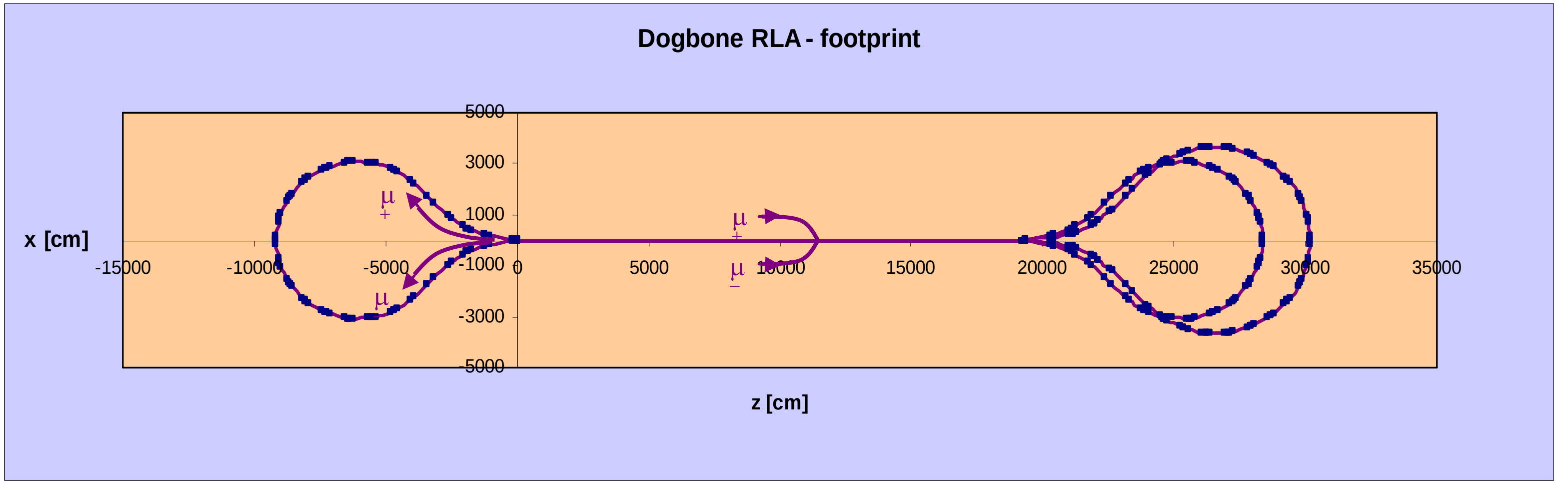
- Linear pre-accelerator (273 MeV/c – 1.5 GeV)
- Symmetric ‘Dogbone’ RLA (allowing to accelerate both μ^+ and μ^- species), 3.5-pass (1.5 – 5 GeV)
- 5 – 10 GeV FFAG
- 10 – 20 GeV FFAG

Symmetric 'Dogbone' RLA (3.5-pass) scheme



- Main Linac (1 GeV/pass) - triplet focusing
- 3 Arcs based on the same number of cells (90^0 betatron phase advance per cell)

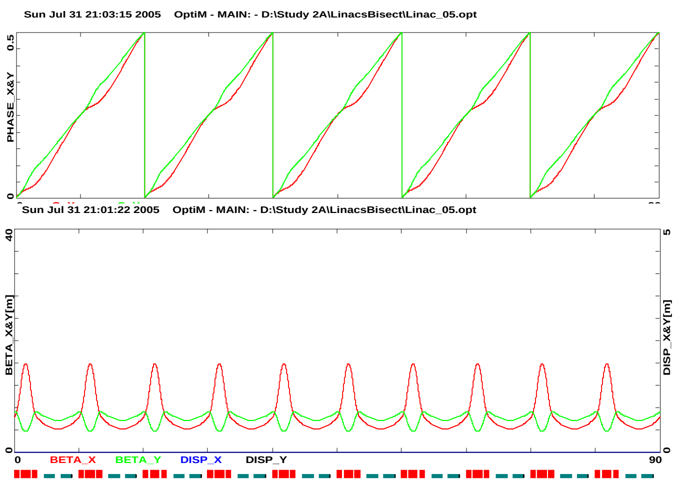
Linac Optics - beam transport choices



- Multi-pass linac focusing scheme guarantees (by design) 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
- Optimized 'bisected' linac was chosen as follows:
  - 90^0 phase advance/cell is set for the 'half pass' linac (1.5-2GeV).
  - 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 (Bob Palmer).
  - the phase advance at the end of 2-pass linac drops by another factor of two (22.5^0).
  - the 'beta beating' is rather small on higher passes (2 and 3)

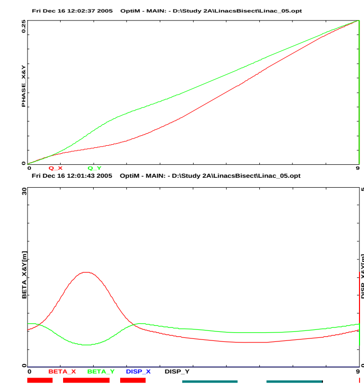
Multi-pass Linac Optics

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

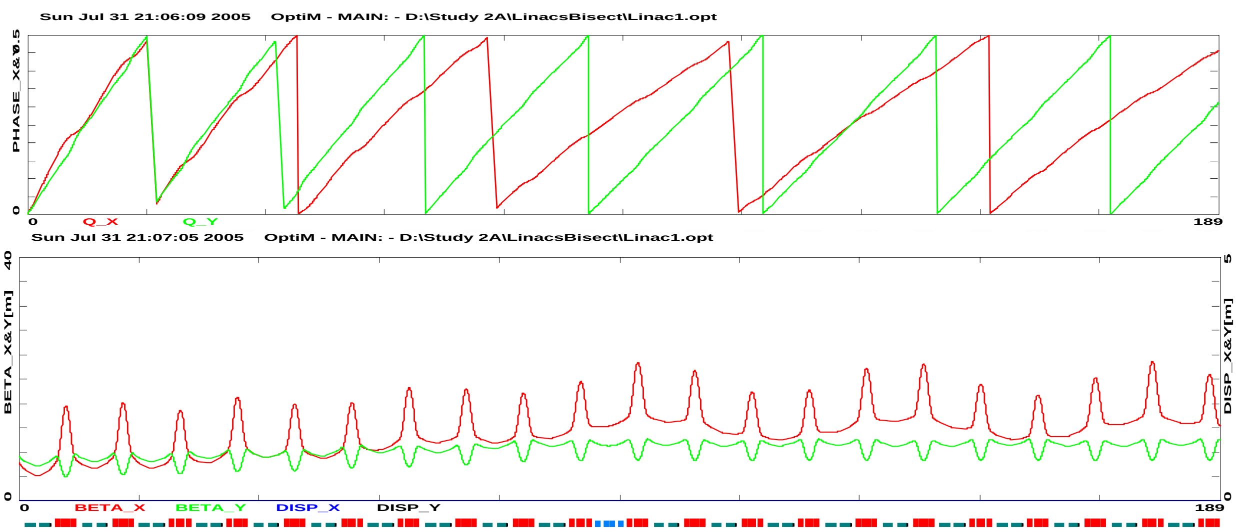


‘half pass’ (n = 0), 1.5-2GeV

uniform phase adv/cell ($\Delta\nu_x$=0.25, $\Delta\nu_y$=0.25)



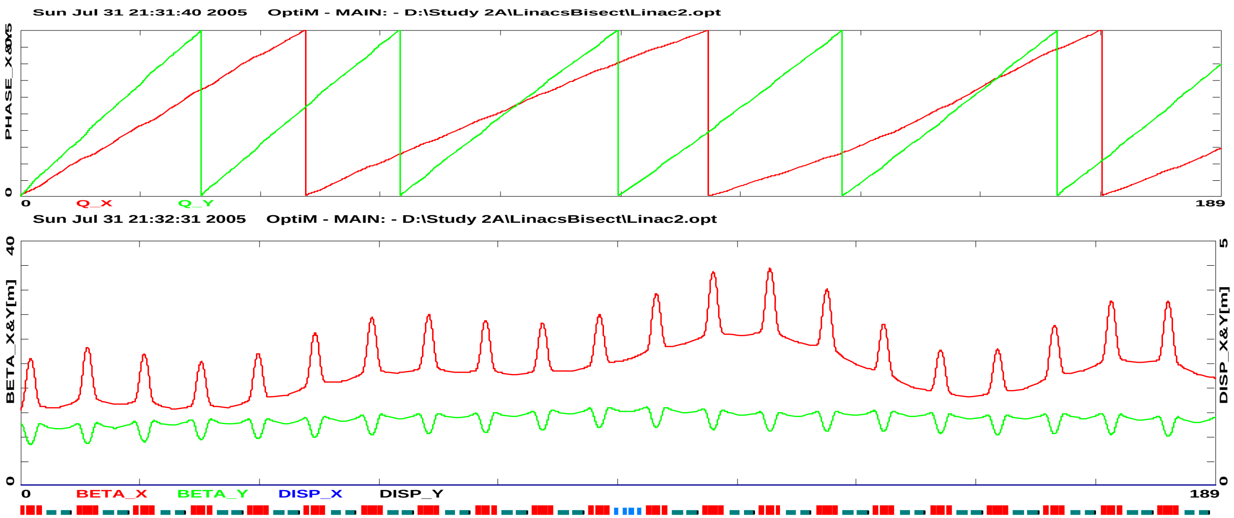
1-pass (n = 1), 2-3GeV



last cell phase adv. ($\Delta\nu_x$=0.11, $\Delta\nu_y$=0.16)

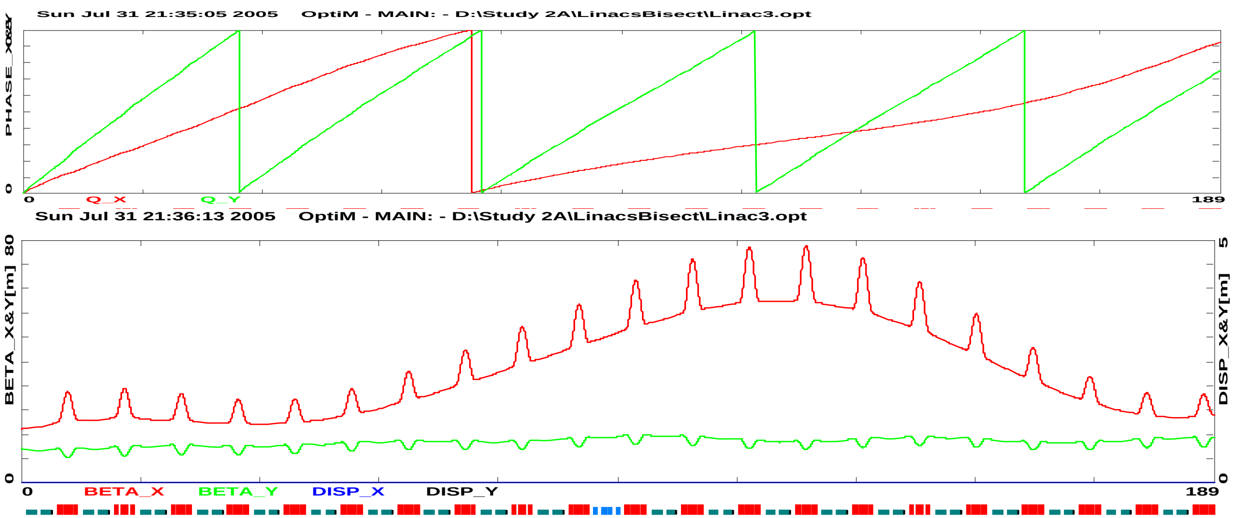
Multi-pass Linac Optics

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), 3-4GeV

last cell phase adv. ($\Delta\nu_x$=0.07, $\Delta\nu_y$=0.14)

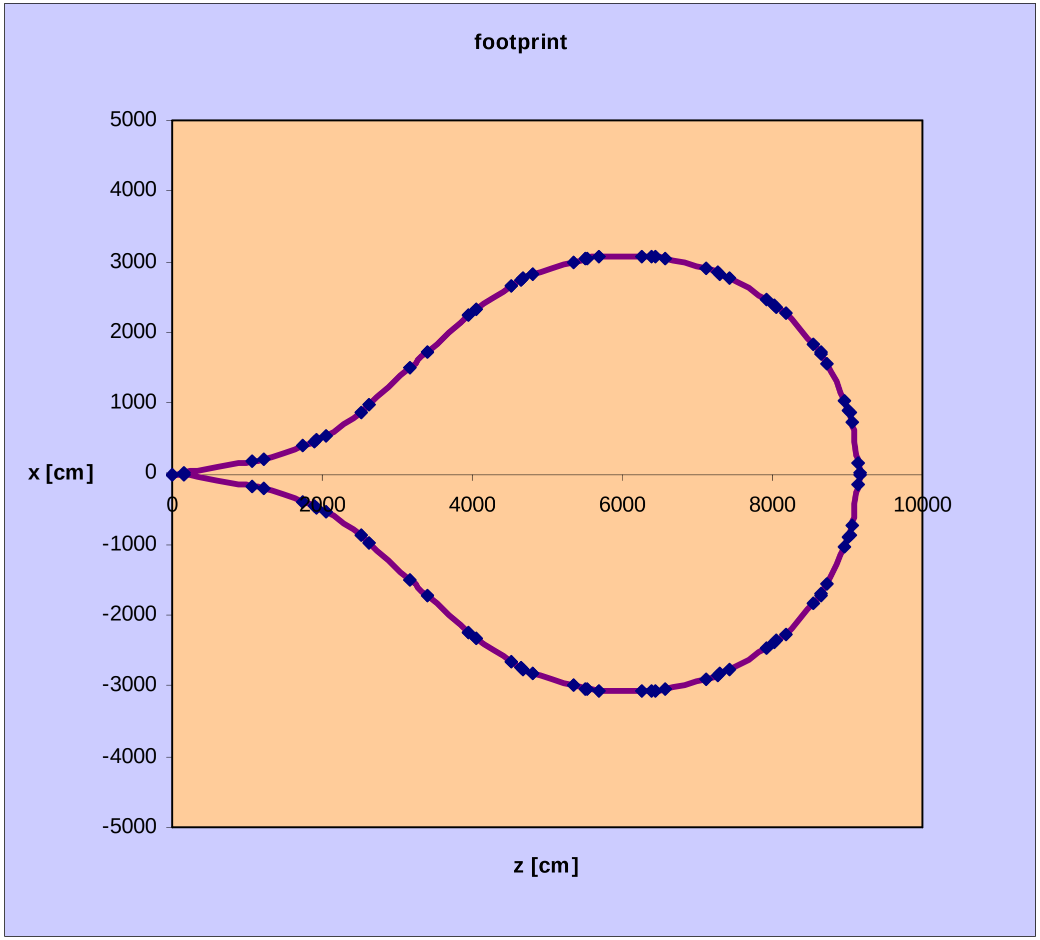


3-pass (n = 3), 4-5GeV

Arc Optics - beam transport choices

- There is great advantage to have 90^0 phase advance/cell in the arcs – cancellation of chromatic effects.
- Phase advance 'mismatch' from/to the linacs is not detrimental - it induces larger 'beta beating' in Spr/Rec regions, but we match betas in this region anyway
- Dipole (horizontal) separation of multi-pass beams in RLA – a pair of dipoles (linac ends)
  - No need to maintain achromatic Spreaders/Recombiners
  - Compact Spreaders/Recombiners – minimized uniform focusing breakdown
- Arc1 and Arc 2 - scaled optics:
  - Keep the same number of cells in each arc (Spr + 2 out + 16 in + 2 out + Rec)
  - Scale Arc1 (bends and quads) by factor of 3/2 to get Arc2
- Arc 3 optics
  - increase number of cells (Spr + 3 out + 20 in + 3 out + Rec)
  - Maintain the same 90^0 phase advance /cell.

Arc 1 – Layout



Arc dipoles

$Lb=150; => 150 cm
$ang0=10.3283; => 10.3283 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.

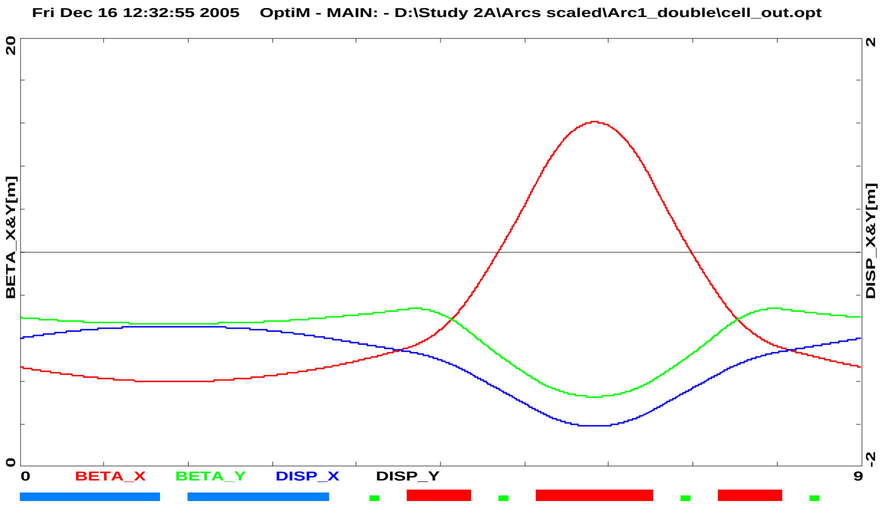
$BP=$PI*$Hr*$ang/(180*$Lb); => 6.537 kGauss

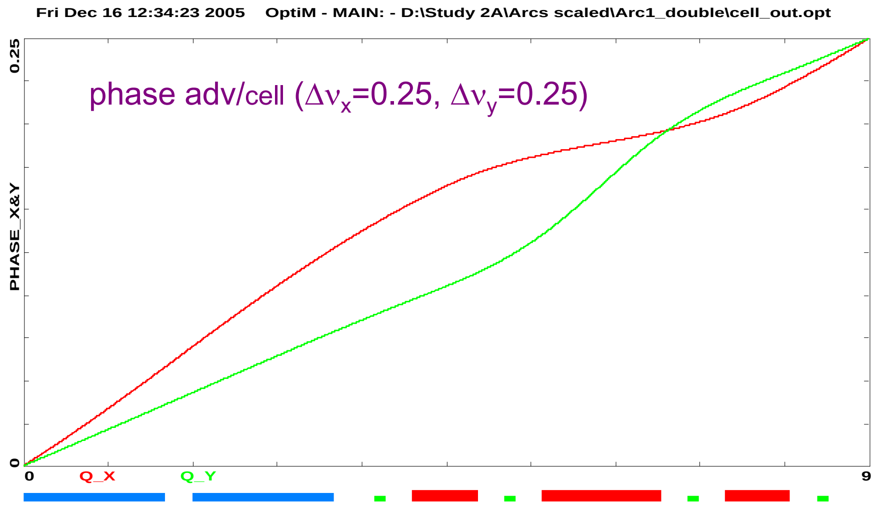
$Lring=227.3 m

Mirror-symmetric Arc1 optics

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

'outward' cell' at 2GeV (T = 1911.64 MeV)





$P= 2014.529

$Hr=$P/$c*1e11; => 6719.745

dipoles (2 per cell)

$Lb=150; => 150 cm

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

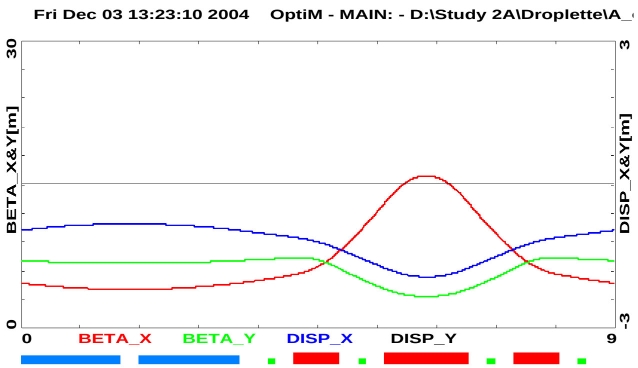
$BP=$PI*$Hr*$ang/(180*$Lb); => 6.537 kGauss

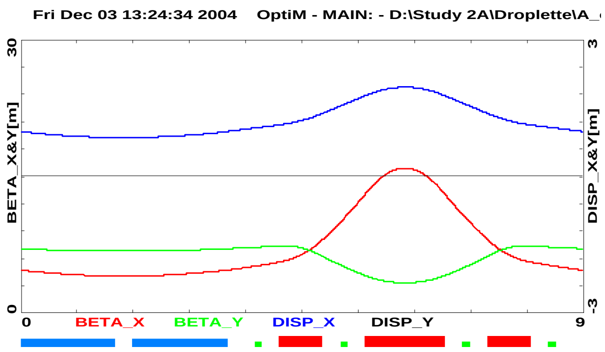
quadrupoles (triplet):

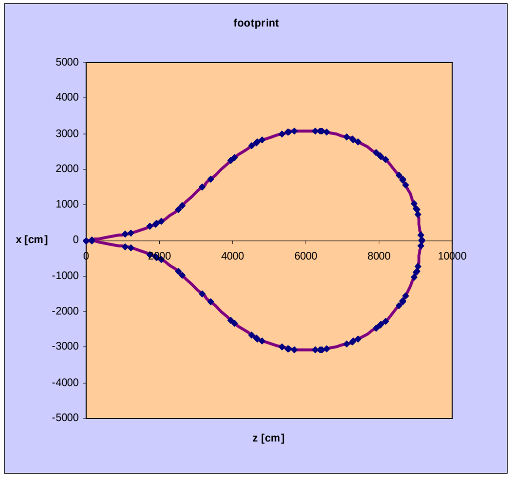
L[cm]	G[kG/cm]
68	-0.326
125	0.328
68	-0.326

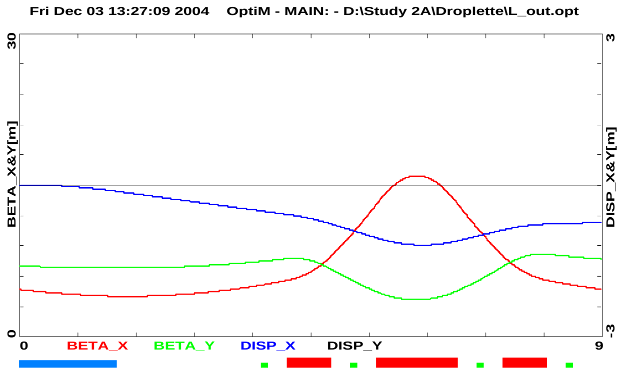
Droplet Arc – Optics building blocks

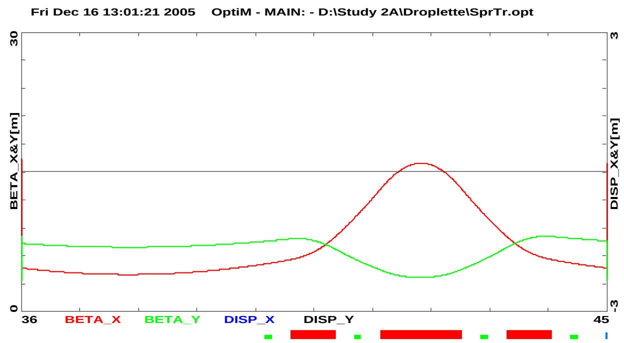
90^0 phase advance/cell: inward and outward cells, missing dipole, empty cells





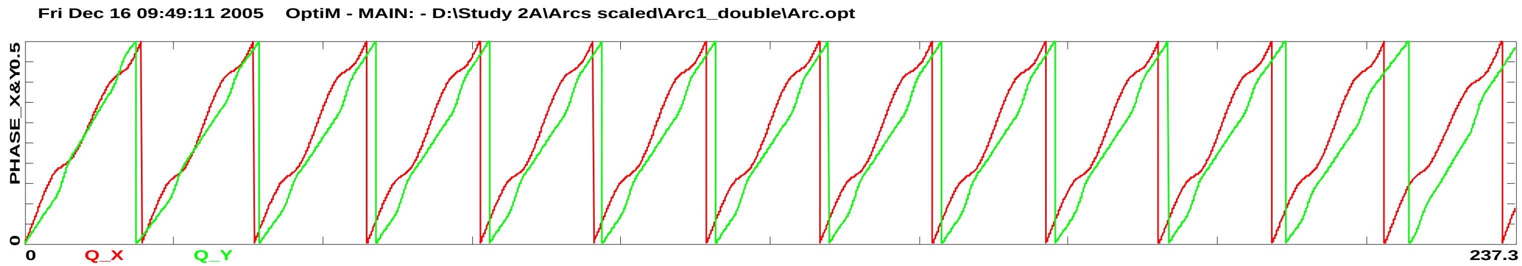


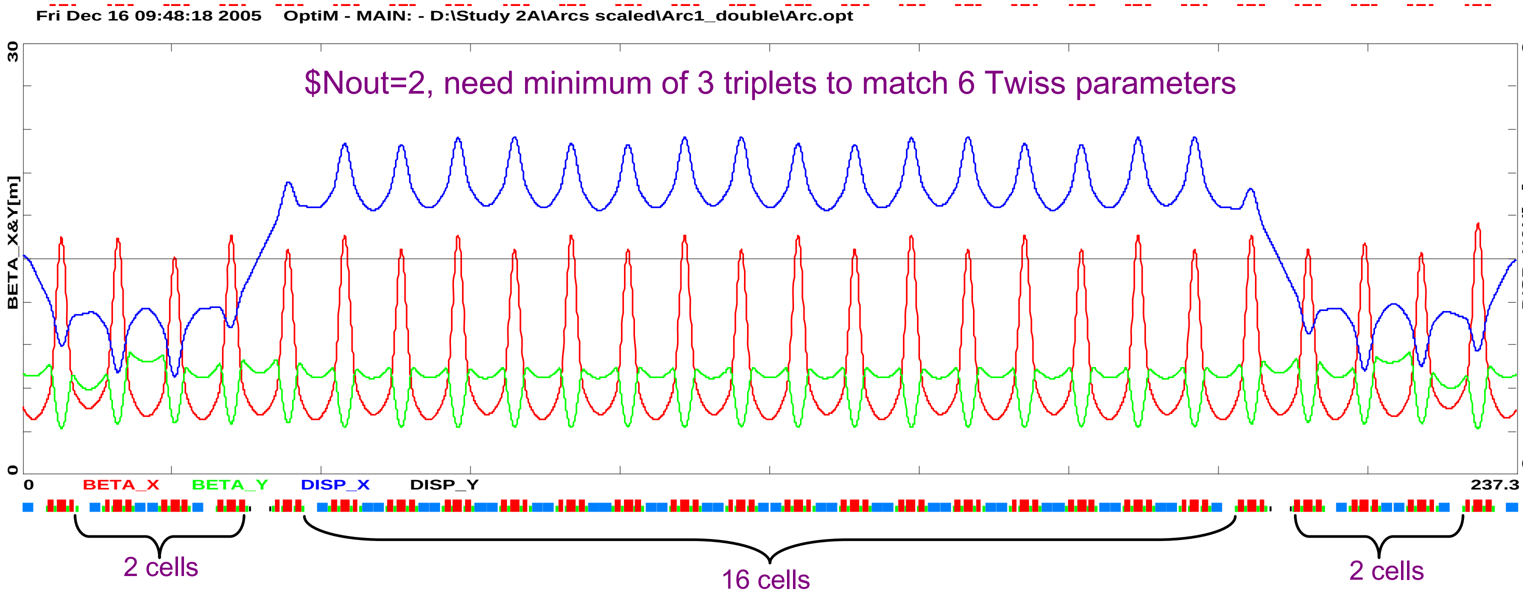




Arc 1– mirror symmetric Optics

($\beta_{out} = \beta_{in}$,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); => 6.537 kGauss

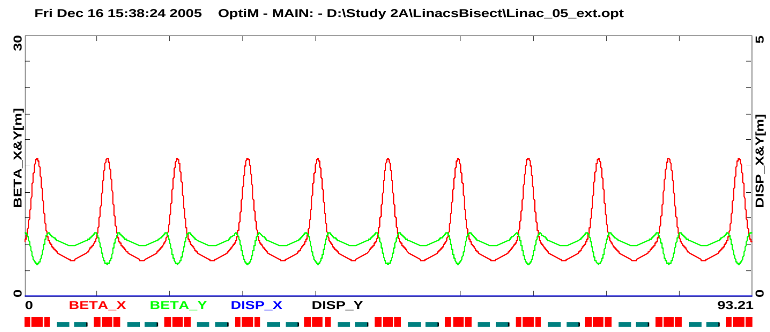
quadrupoles (triplet):

L[cm]	G[kG/cm]
68	-0.326
125	0.328
68	-0.326

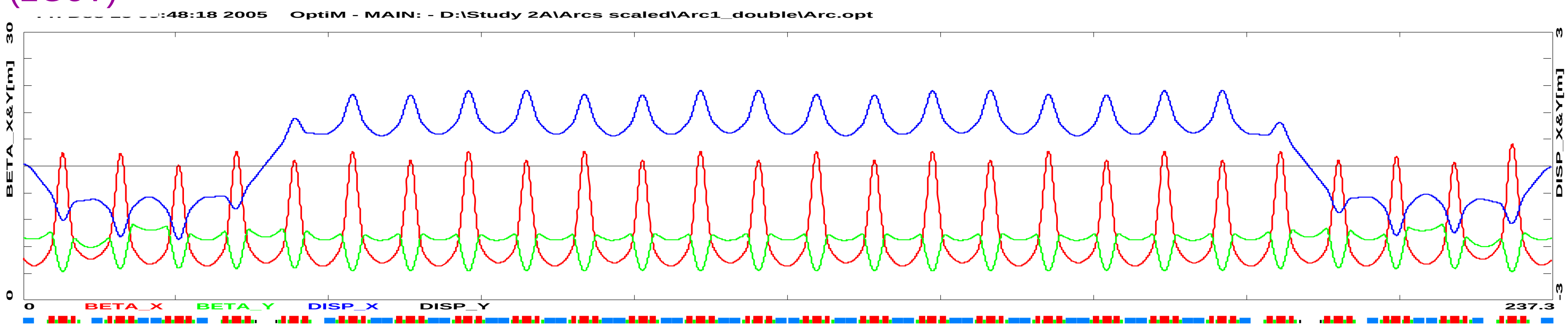
Linac-Arc1-Linac Matching

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

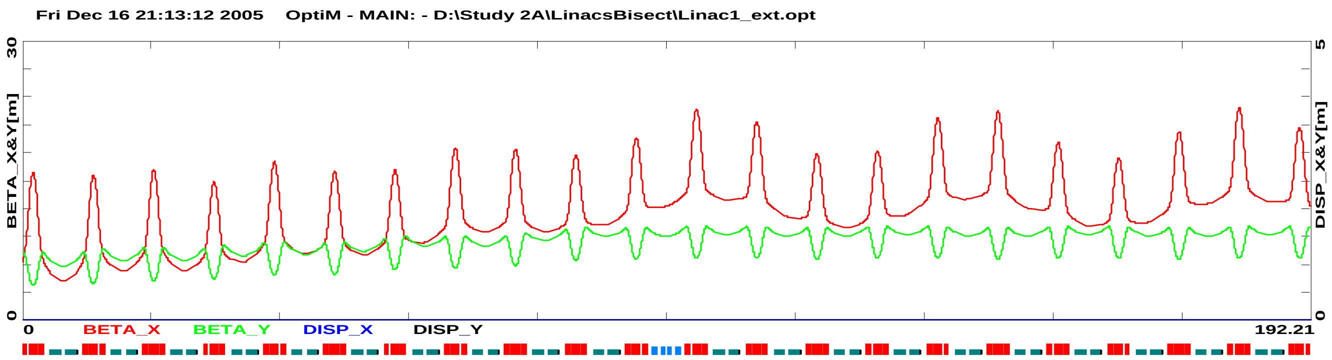
'half pass' (1.5-2GeV)



Arc1 (2GeV)

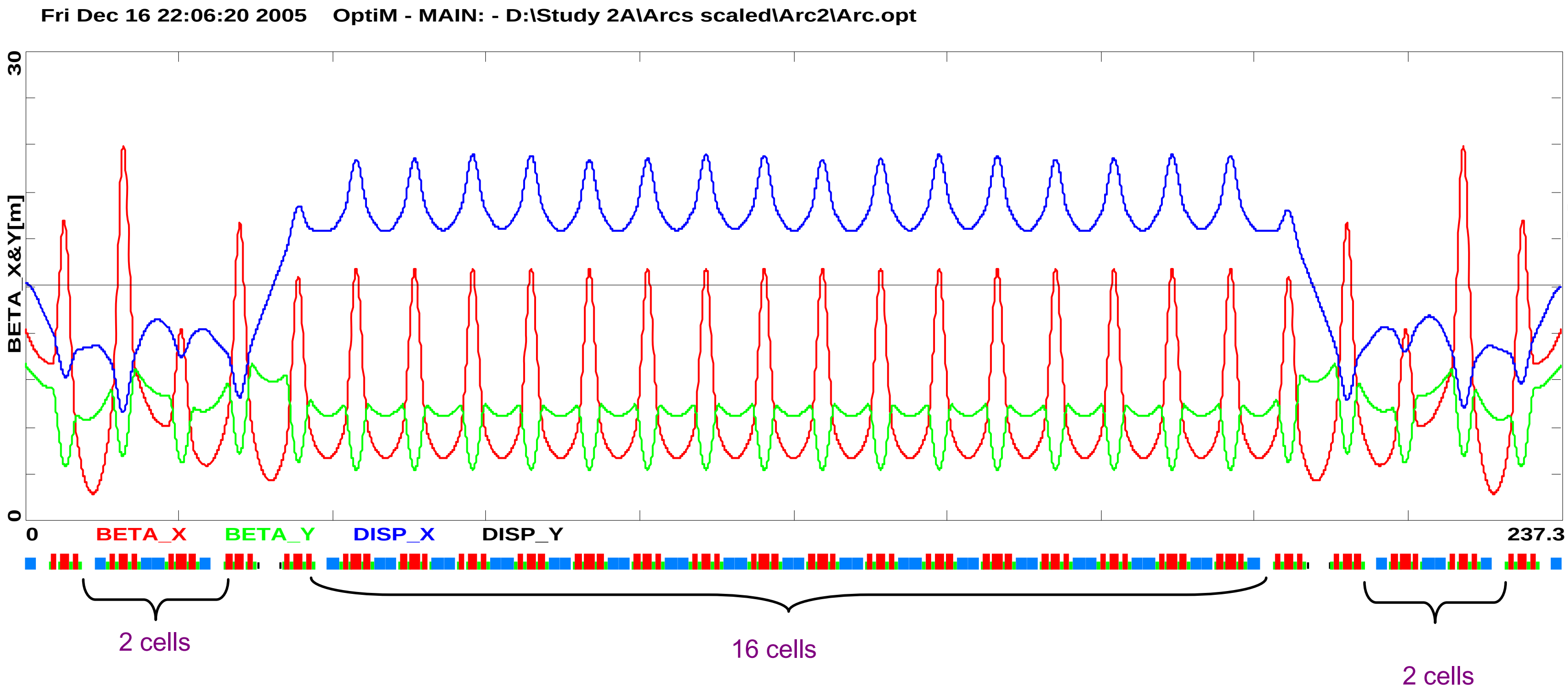


1-pass (2-3GeV)



Arc 2– mirror symmetric Optics

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



dipoles:

\$Lb=150; => 150 cm

\$E=2920.75; => 2920.75 MeV

\$ang0=10.3283; => 10.33 deg.

\$B0=-\$PI*\$Hr*\$ang0/(180*\$Lb); => -12.12 kGauss

\$ang=8.36069167

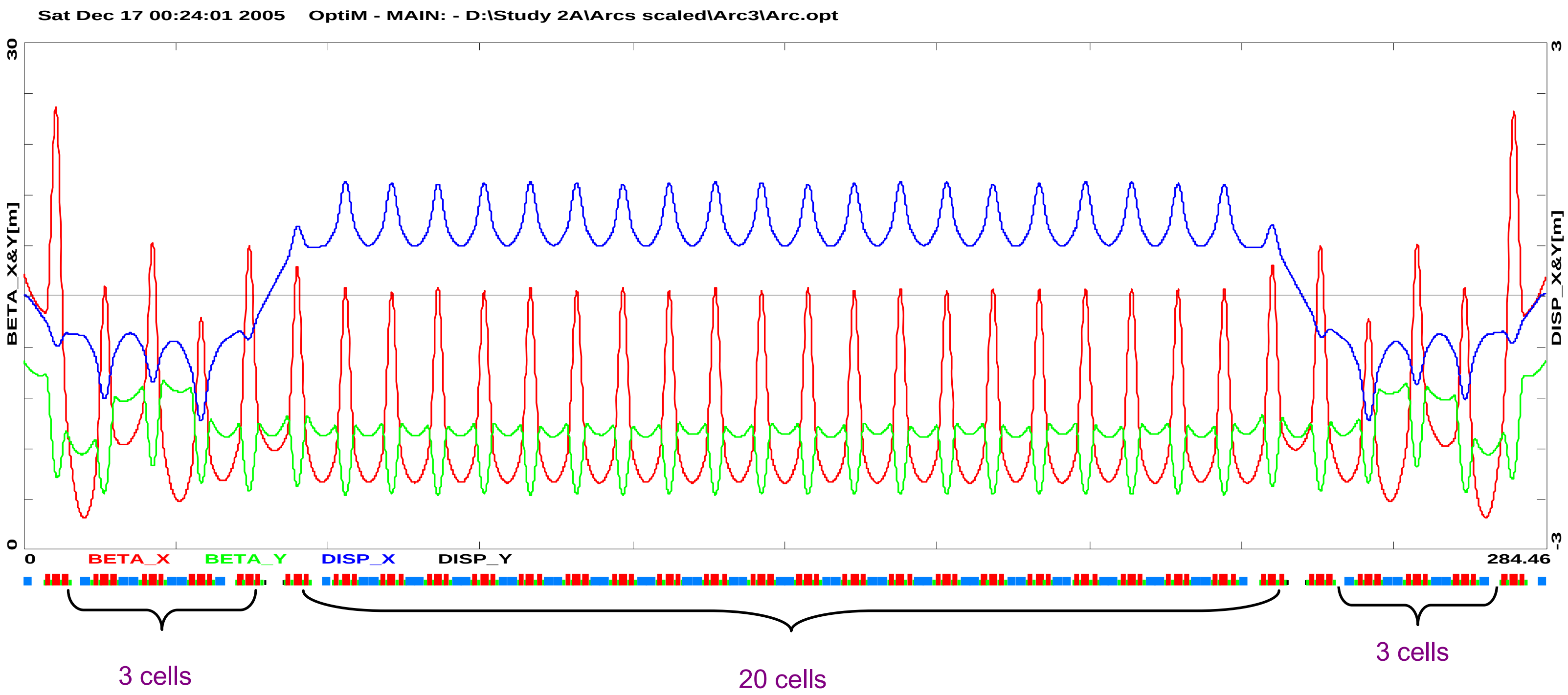
\$B=\$PI*\$Hr*\$ang/(180*\$Lb); => 9.81 kGauss

quadrupoles (triplet):

L[cm]	G[kG/cm]
68	-0.490
125	0.492
68	-0.490

Arc 3– mirror symmetric Optics

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



dipoles:

$E=3929.86 MeV

$B0=-8.0755 deg

$ang0= 5.1577 deg

$BP=$PI*$Hr*$ang/(180*$Lb); => 10.64 kGauss

$ang=(90+$ang0)/($Nin-2*$Nout); => 6.797 kGauss

$Ang_out=$ang0+2*$Nout*$ang; => 45.94 deg

$Ang_in=2*$Nin*$ang; => 271.88 deg

quadrupoles (triplet):

L[cm]	G[kG/cm]
68	-0.6537
125	0.6565
68	-0.6537

Summary

- Symmetric 'Dogbone' RLA (allowing to accelerate both μ^+ and μ^- species), 3.5-pass (1.5 – 5 GeV) scheme - Linear Optics
  - multi-pass linac optics – optimized focusing profile
  - tolerable phase 'slippage' in the higher pass linacs
  - mirror-symmetric Arc optics based on constant phase advance/cell (90^0) and equal number of cells in each arc
  - compact lattice architecture for Spr/Rec/Trans
  - Geometric 'closing' of the 'droplet' Arcs