Accelerator from Cooling to FFAGs

R B Palmer J S Berg

Jan 24 2004

Riverside

Draft 3 with switchyards

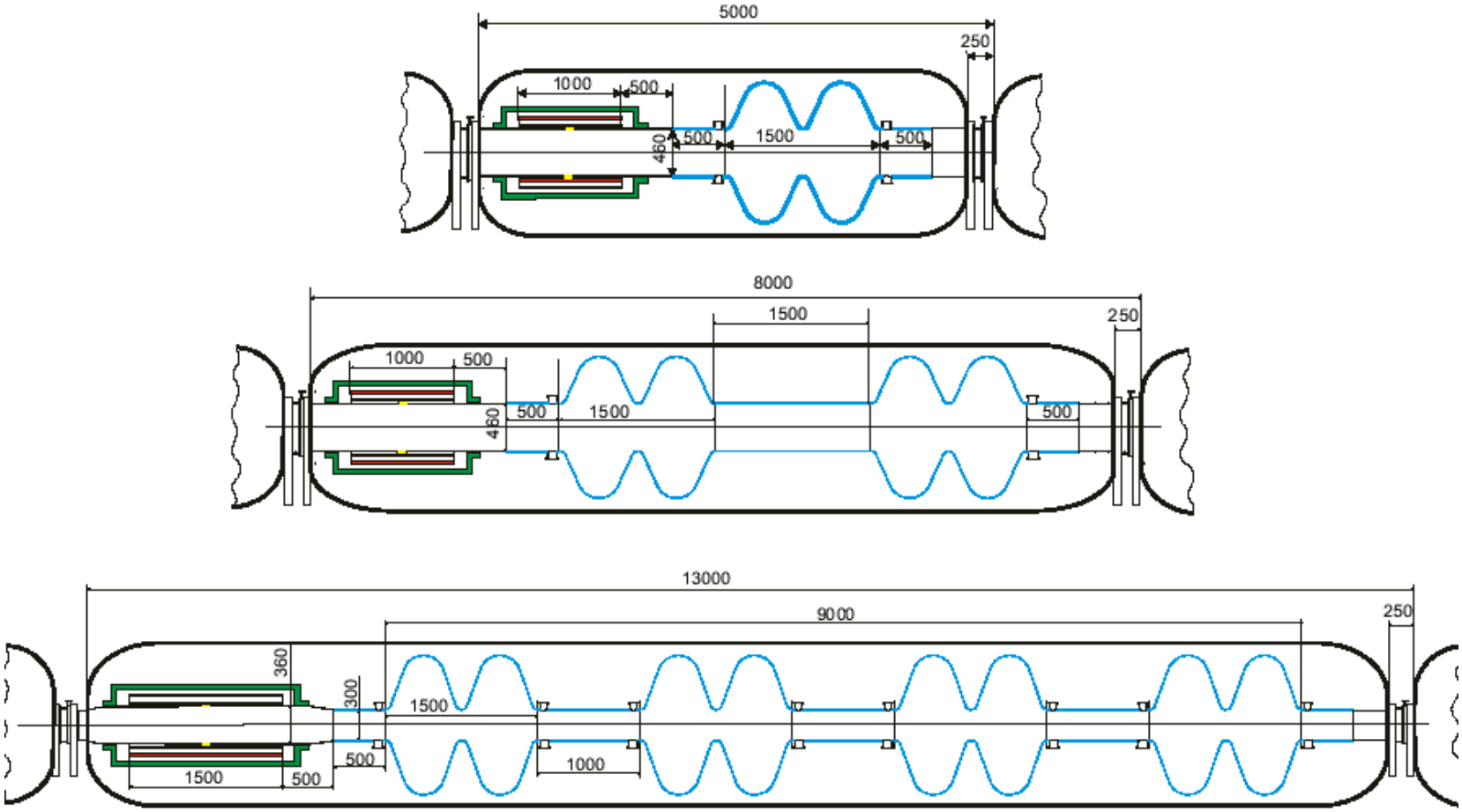
Concept for Acceleration

1. Use Pre-Linac 0.2 to 1.5 GeV/c
2. Use Dog Bone RLA from 1.5 to 5 GeV
   Dog Bone prefered for fewer and easier switchyards
3. Use two FFAG's as now designed: 5-10 and 10-20 GeV

Follow Study II designs where possible

1) Linac 0.2 to 1.5 GeV/c

c.f. Study 2 Pre-Accelerator Cells



Beam size along Study II Pre-Linac

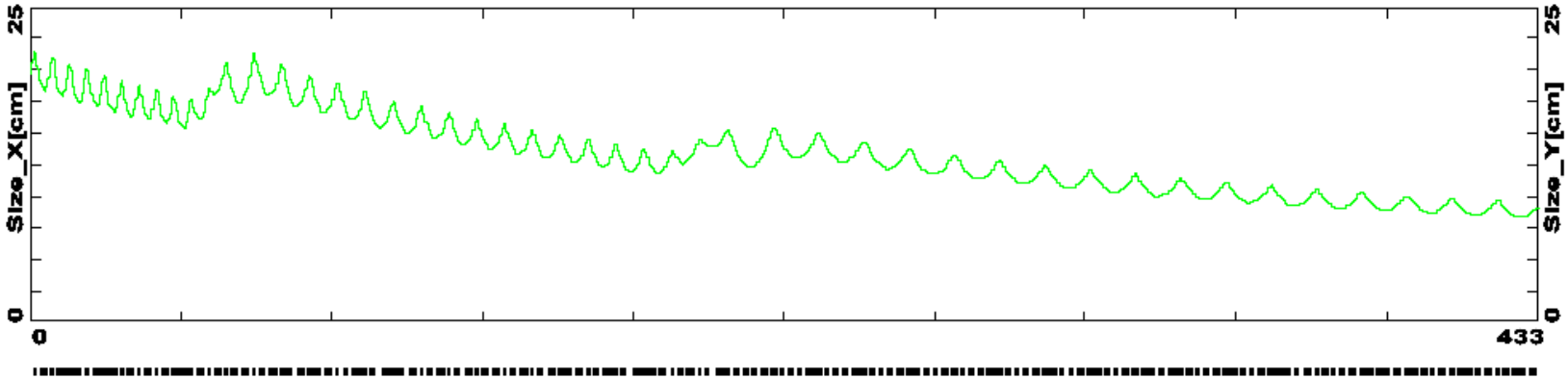
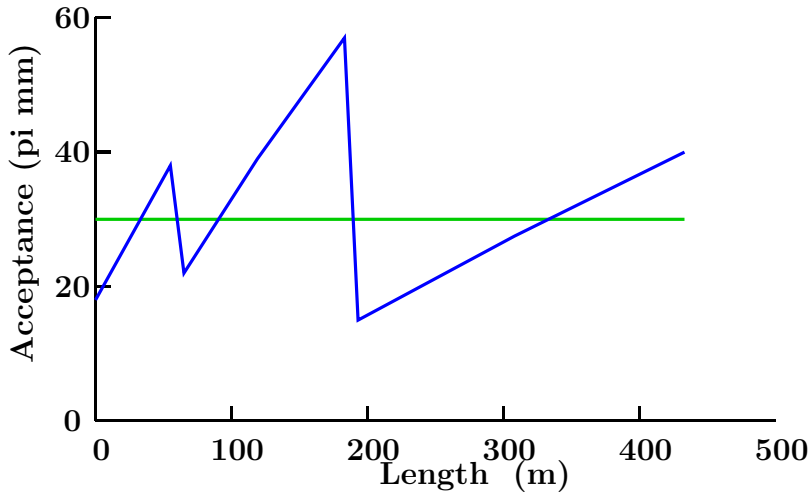


Figure 6.4: Beam envelopes of the entire beam (2.5σ) along the linear accelerator.

Local Acceptance along Lattice

For each cell design, acceptance rises as beam shrinks

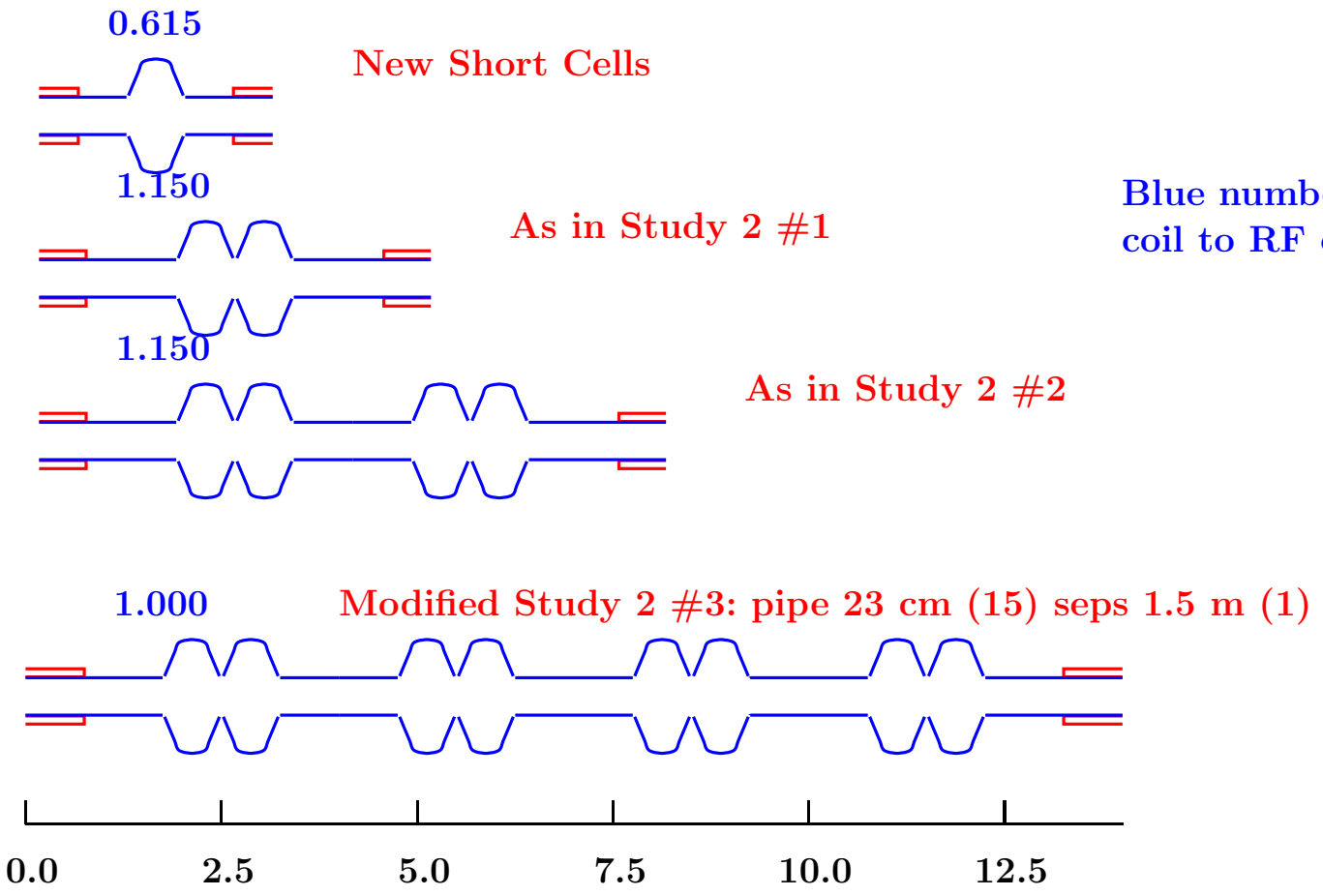
Steps occur for each longer (and higher beta) lattice



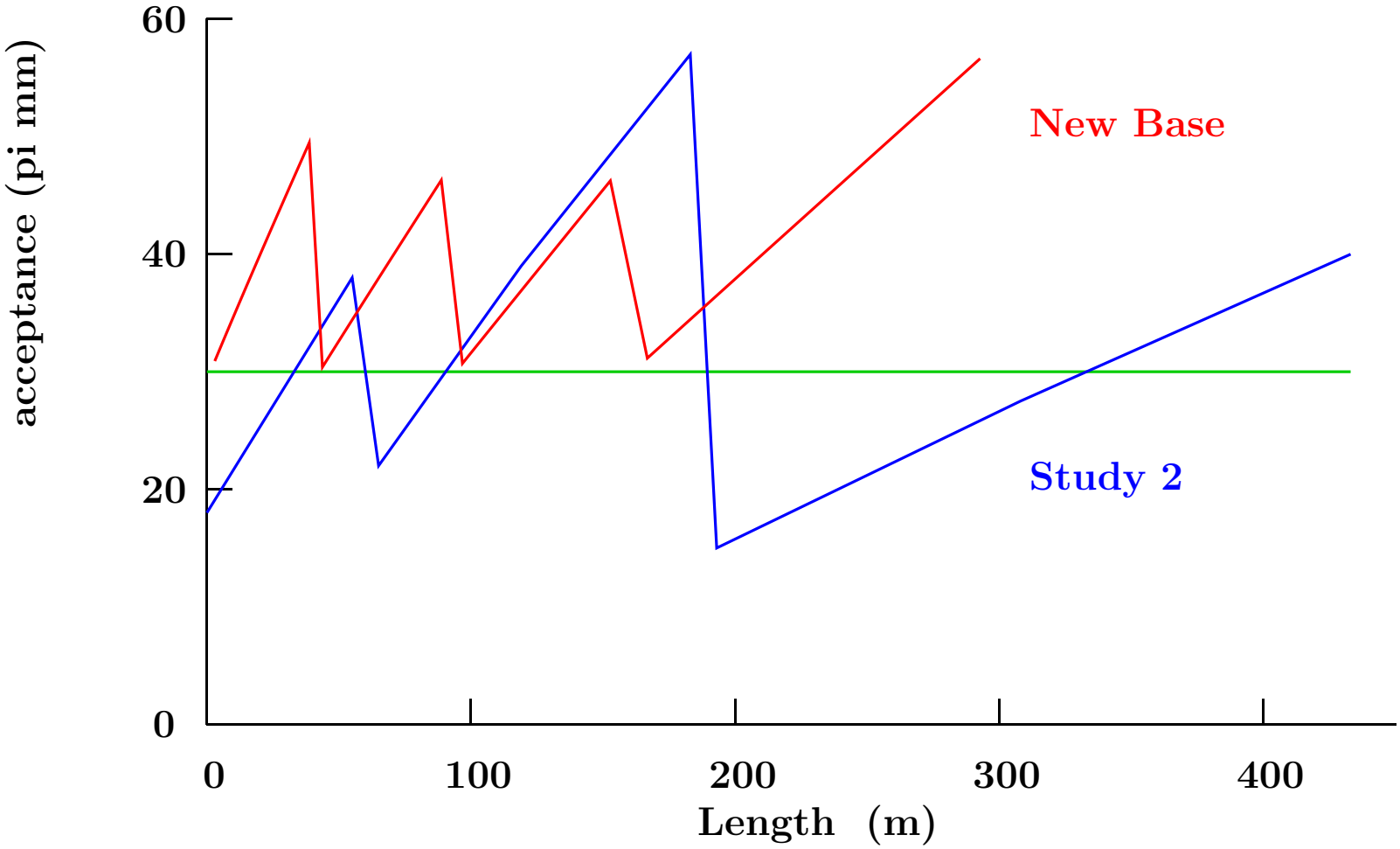
To Increase Acceptance

- Design new single cavity cell
  Short RF-Solenoid length requires sc cold before solenoids on
- Increase aperture and straights of long cell

As before: continue shorter cells till next one has 30 Pi mm



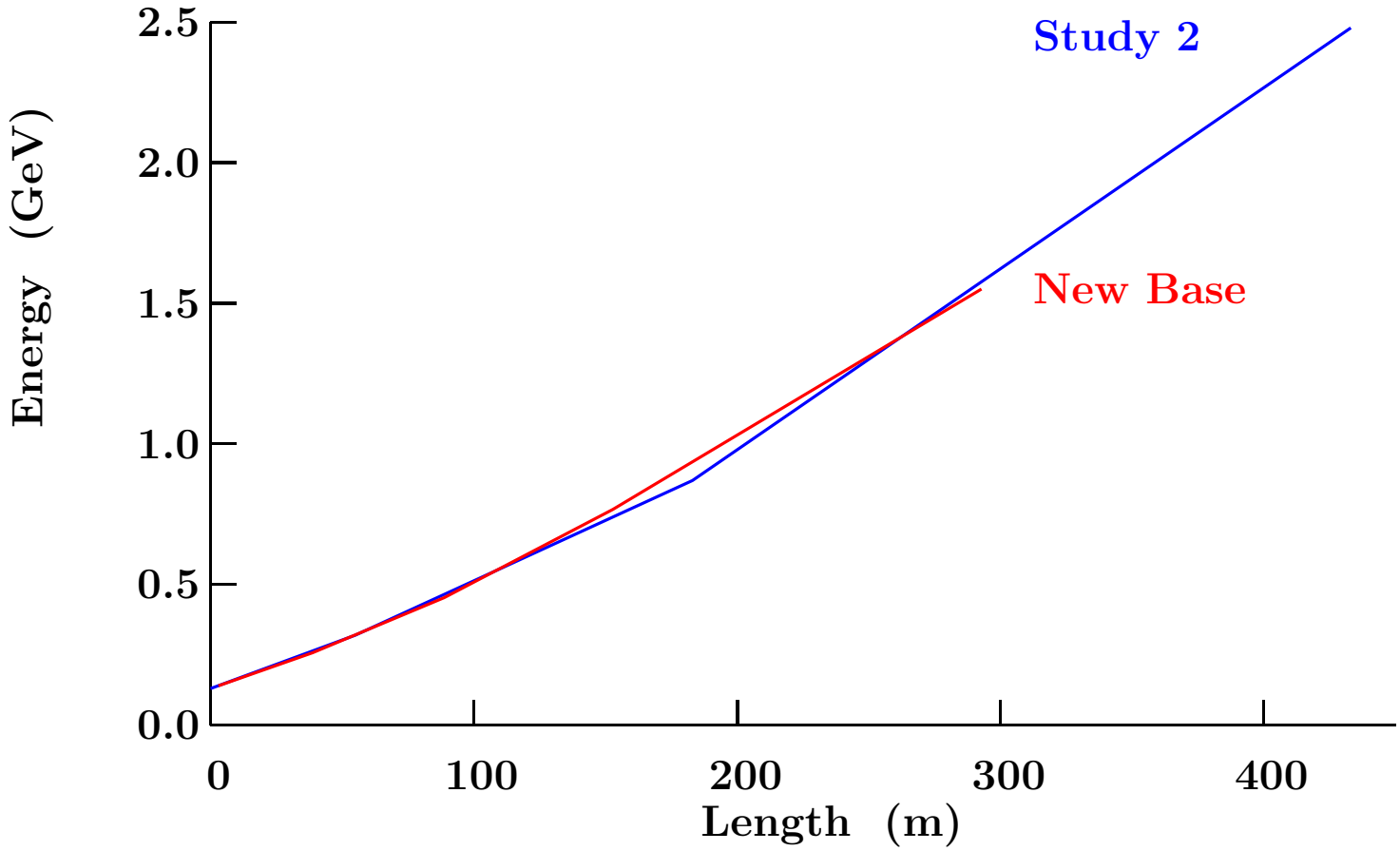
Acceptances vs Length



Blue is for Study 2

Red for new design: always above 30 pi mm

Energy vs. length



Very similar performance
Same number of Cavities
But more Solenoids

Aside on Beta Functions

In Study II, In each Section:

- Solenoid Fields increase with Length
- Beta Functions and Phase Advance per Cell: Constant
- Acceptance Rises

Between cells there is a sudden beta change needing matching

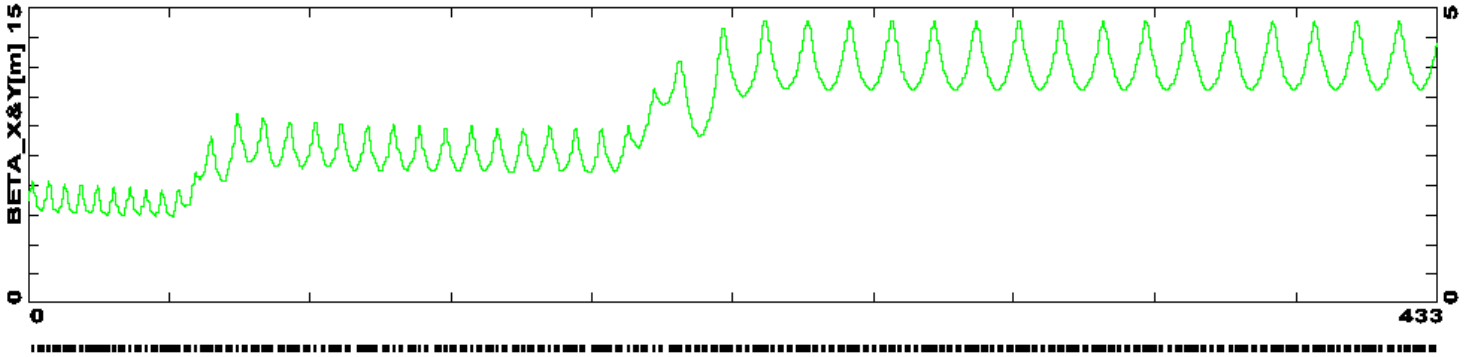


Figure 6.5: Beta functions along the linear accelerator. The beta functions are computed in the frame that rotates with angular frequency $\omega = eB_s/2pc$, so that the beam motion is decoupled.

It may be more sensible to:

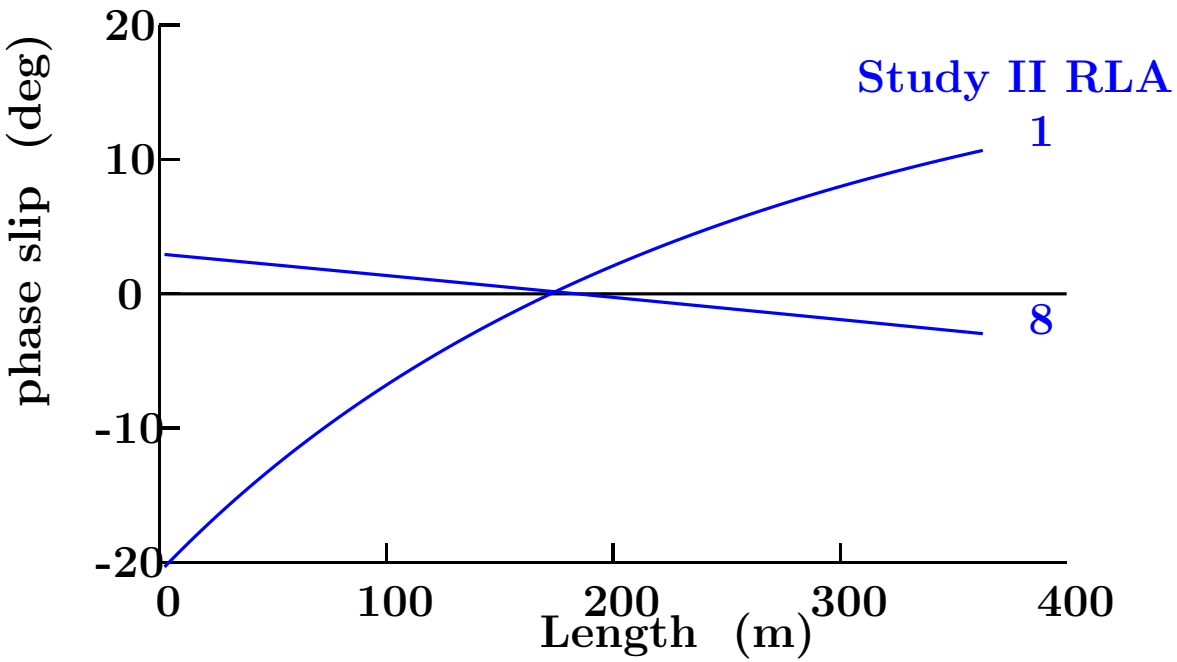
- Keep Solenoid Fields Constant
- Allow Betas to Rise
- This will keep beam size and Acceptance $\approx$ Constant
- Avoid steps in betas between sections

2) Design of 1.5 to 5 GeV RLA

1. Initial 1.5 GeV requires larger pipe for same acceptance and beta
2. Requiring true 30 pi mm also increases pipe for same beta (the acceptance of the RLA in study II was 30 pi mm at end, but not 30 pi mm at start)
3. Keep maximum phase slip same as in Study 2
4. Consider Racetrack or Dogbone designs

Phase Slip Considerations

c.f. Study II first and last pass



Maximum phase swing in first pass = 34 deg.

- Use this as criterion
- Use Same RF Gradient

THEN

- Starting at 1.5 GeV
- Maximum initial pass is 1.5 to 2.0 GeV

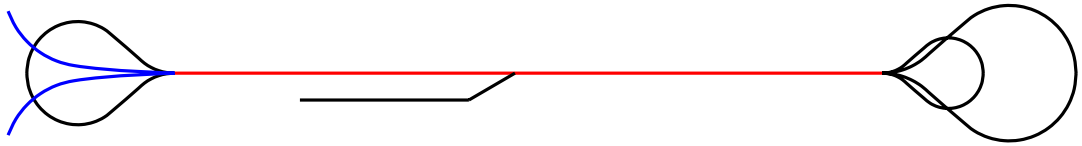
Two Solutions

1) Race Track

- Two 0.5 GeV Linacs
- Three arcs at each end

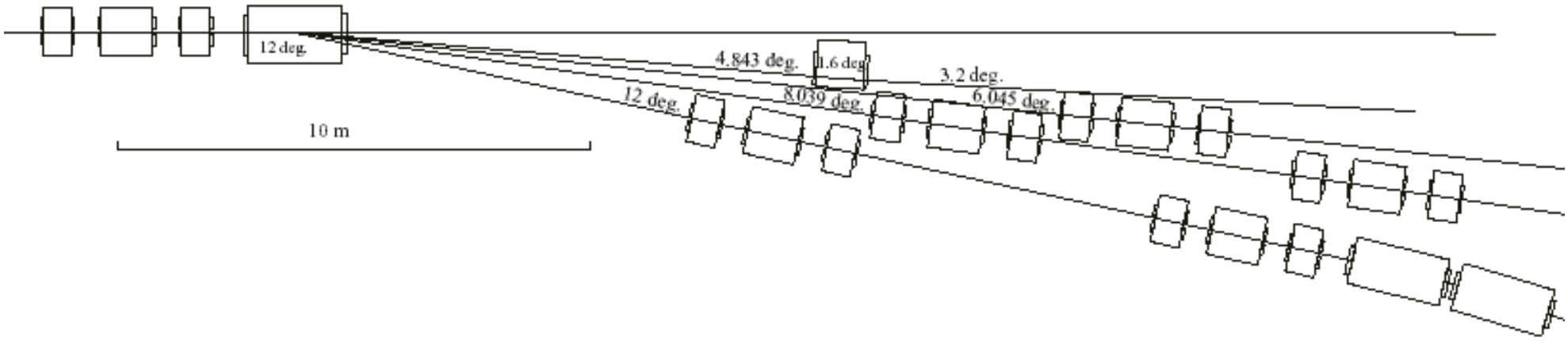
2) Dog Bone

- One 1 GeV Linac
- Injection half way down
- Two arcs one end, one at the other



Switch Yards

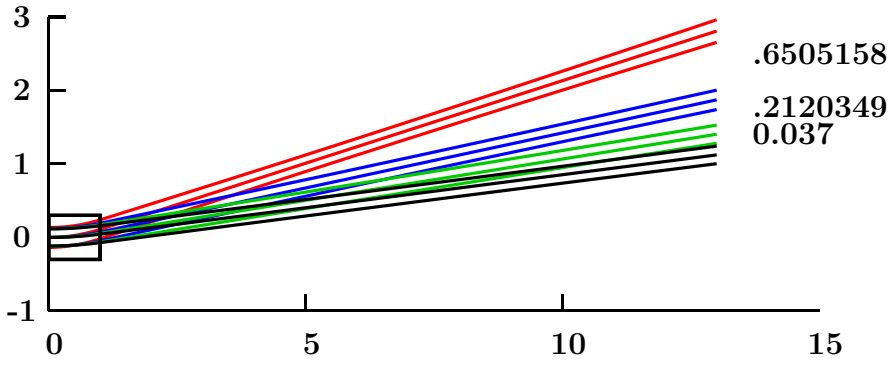
c.f. Study II First Spreader



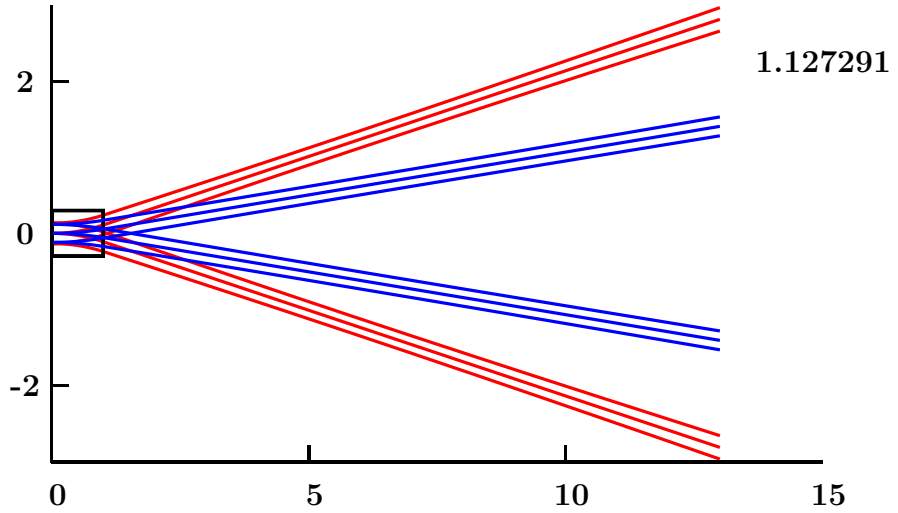
Harder now with lower energy and larger emittance

Compare Switchyards

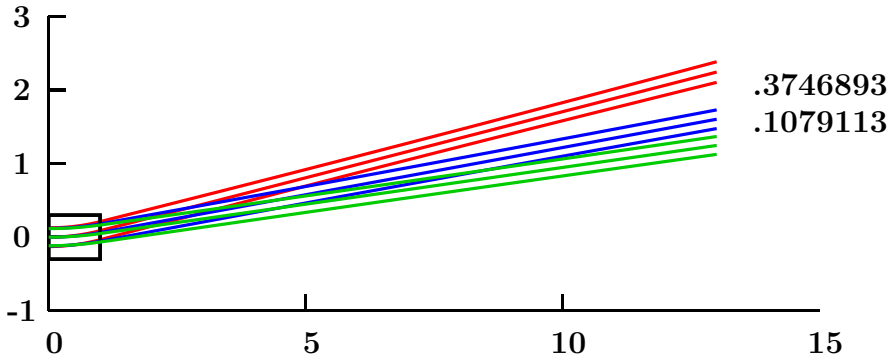
Racetrack End 1



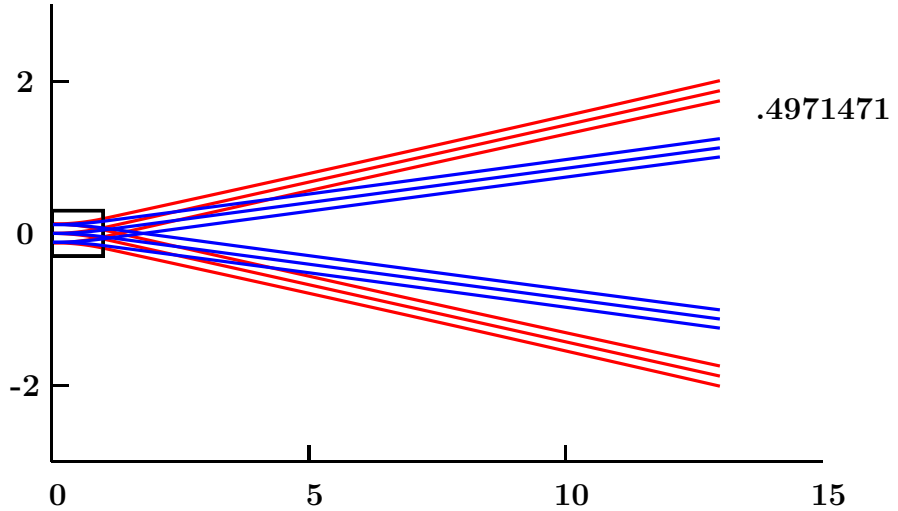
Dogbone End 1



Racetrack End 1

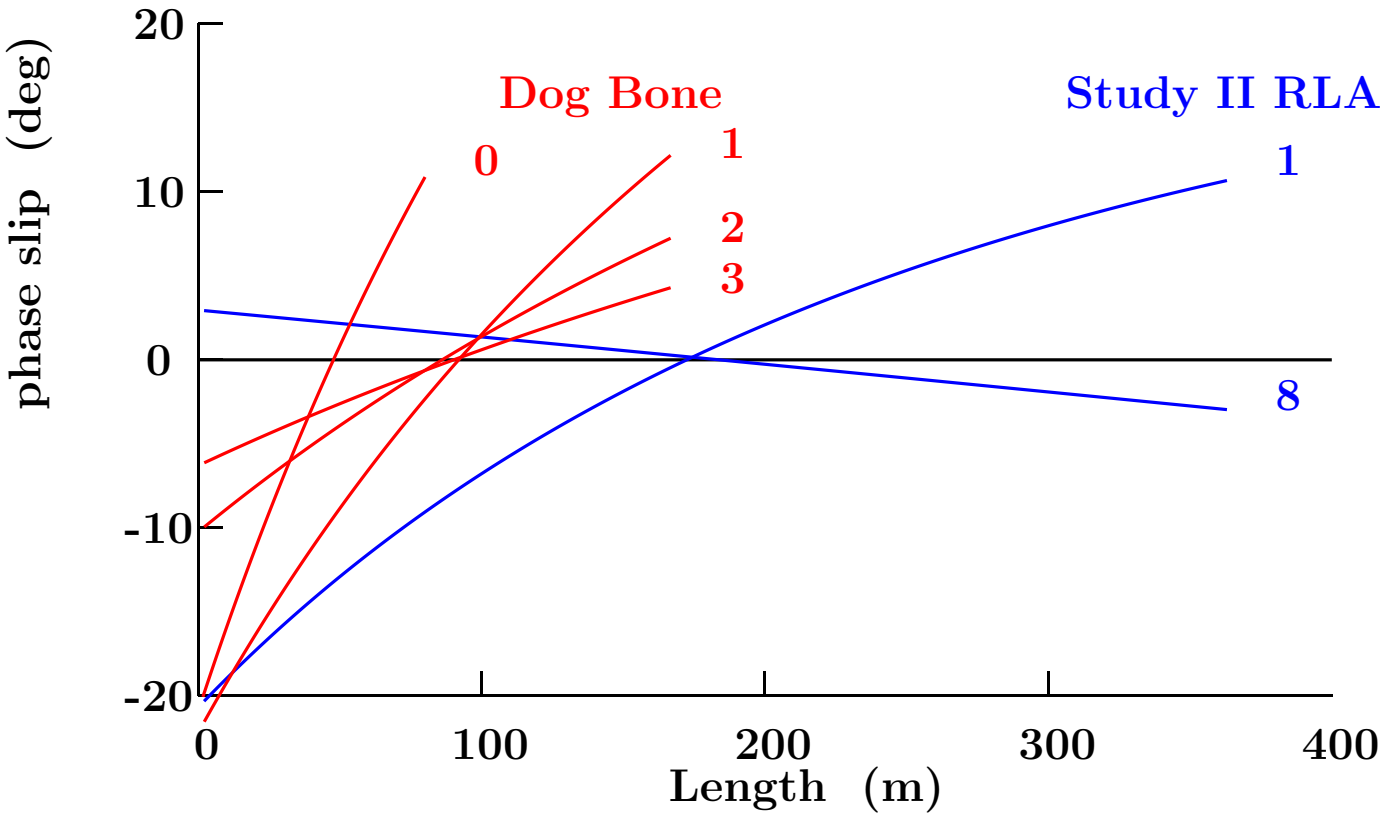


Dog End 2



Dogbone Swithchyards are easier and will allow us to keep the same cell lengths through the switch

Phase Slips Now



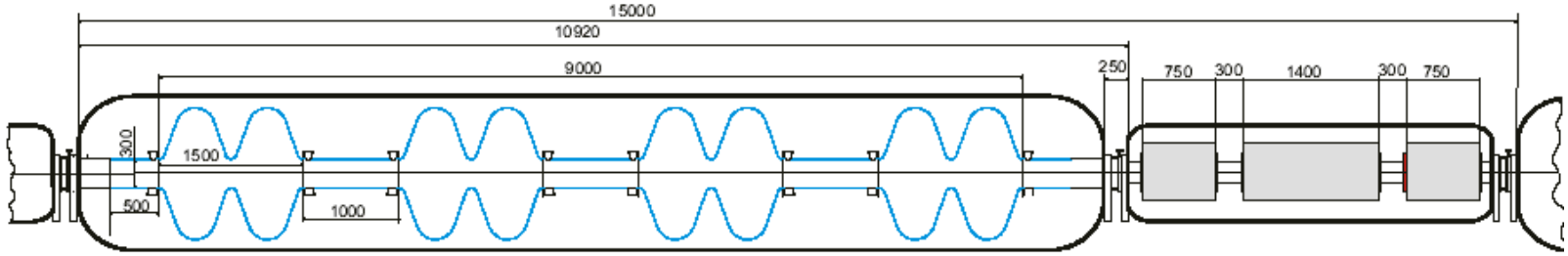
Note: in Dog Bone we cannot set phase velocity $< c$

Maximum phase swing in any pass $\approx$ 34 deg.

same as Study II

Linac Lattice Cell

- **Study II Cell (Length and betas ≈ End of Pre-Linac)**



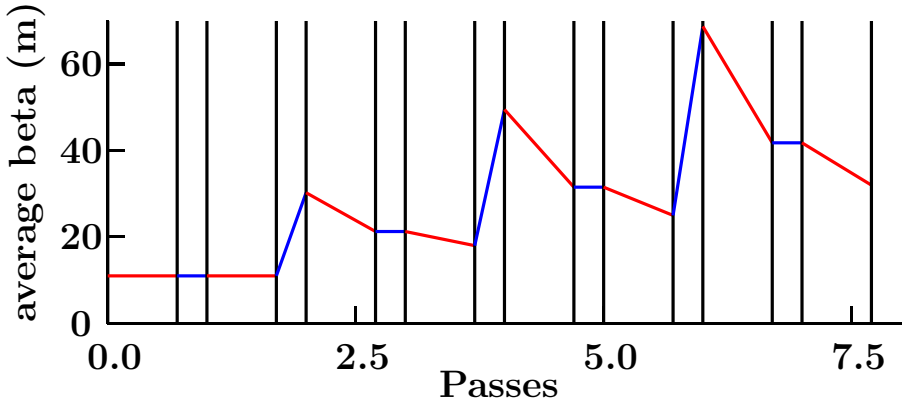
- **Lower gradients in triplets so that the betas at 1.5 GeV/c ≈ those in study II at 2.5 GeV/c.**
- **Increase apertures in F quads to 23 cm rad (from 15)**
- **Increase D quads & SC cavity radii to 18 cm (from 15)**
- **Pole tip fields are reduced**
- **If Needed to keep coupling down:**
  Increase straights from 1 to 1.5 m
  Increasing Cell length from 15 to 16.5 m

$$a_{\mathrm{F}} = \sqrt{\frac{\beta\ A}{\beta_v \gamma}} = \sqrt{\frac{24\ 0.03}{14}} = .23 \quad (\mathrm{m})$$

$$a_{\mathrm{RF}} = \sqrt{\frac{\beta\ A}{\beta_v \gamma}} = \sqrt{\frac{15\ 0.03}{14}} = .18 \quad (\mathrm{m})$$

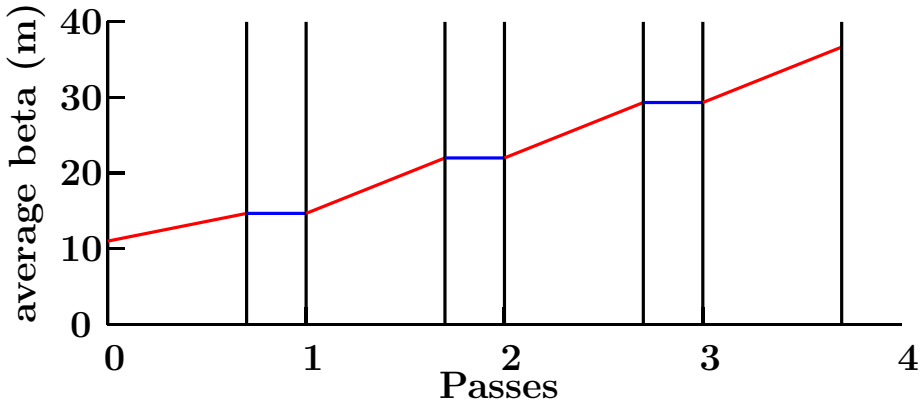
Betas During Acceleration

In Study II quad strengths adjusted to give constant betas in pass 1&2 but betas have ugly behavior at higher energies

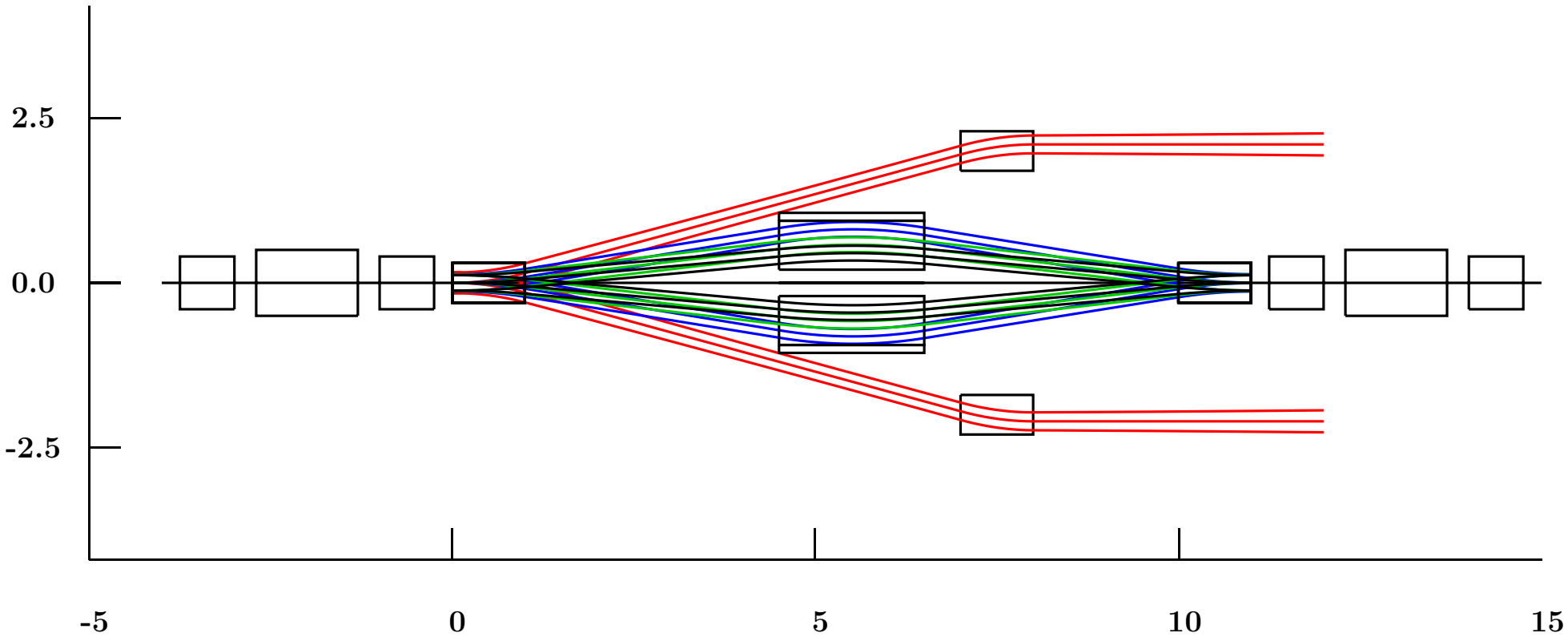


In a dog bone linac used both directions, this is not possible, so we keep gradients constant

The betas now rise in all passes, but look easier to match

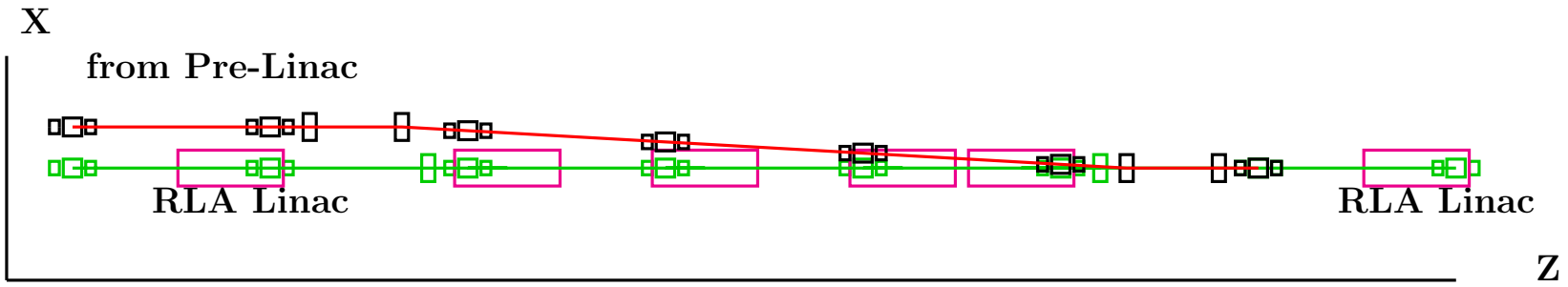


Injection Half Way

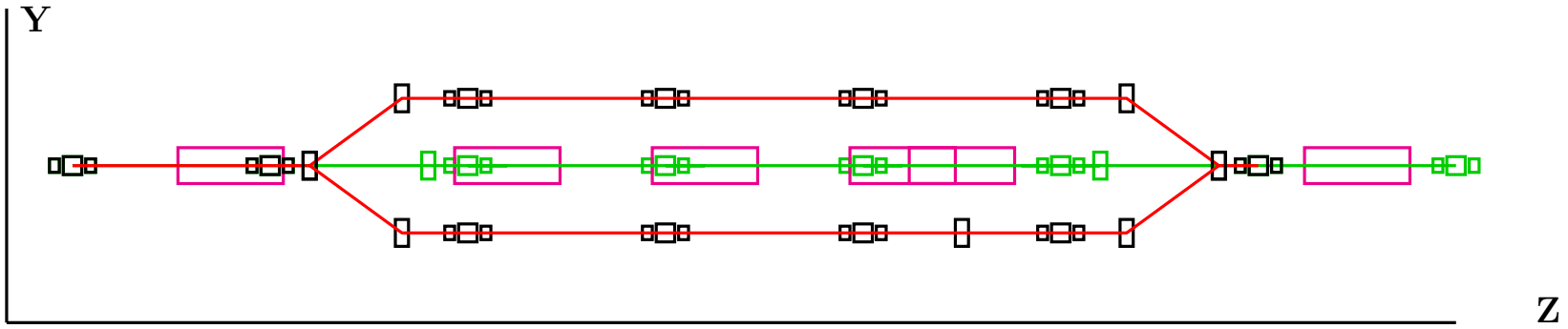


Note: Injection of different signs is from different sides!

Chicane with Displacement



Plan



Elevation

As in Study II, bending elements are 2 pi apart and cancel dispersion

Conclusion

- **Total RF in this .2 to 5 GeV/c is the same as Study II .2 to 2.5 GeV/c**
- **No serious problem in raising acceptance to 30 pi mm**
- **Both signs accelerated**
- **No major problem yet**

To Be Done

- **Look at arcs**
- **More serious design**
- **Simulation**
- **Costing**