Match before and after kicker

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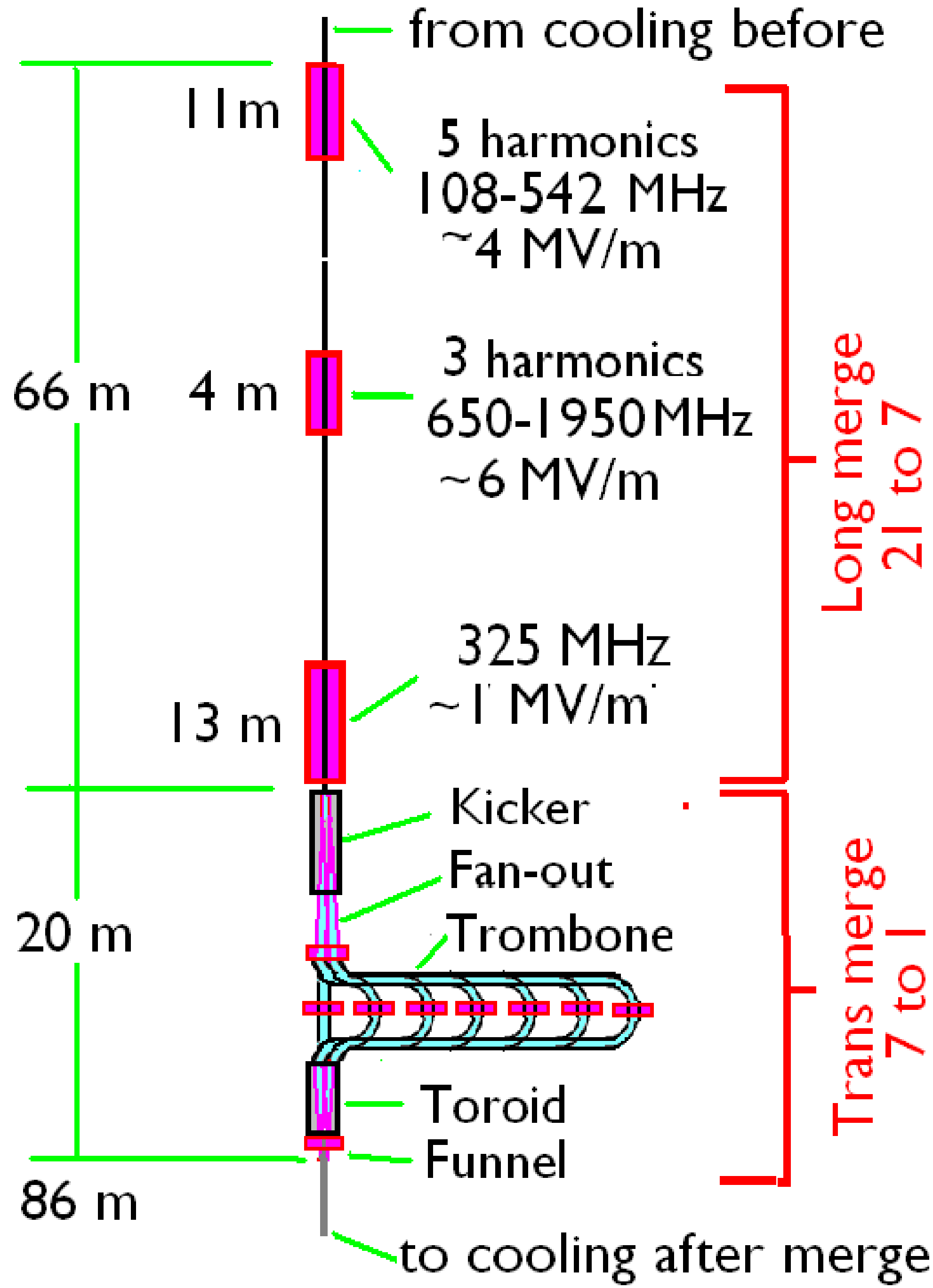
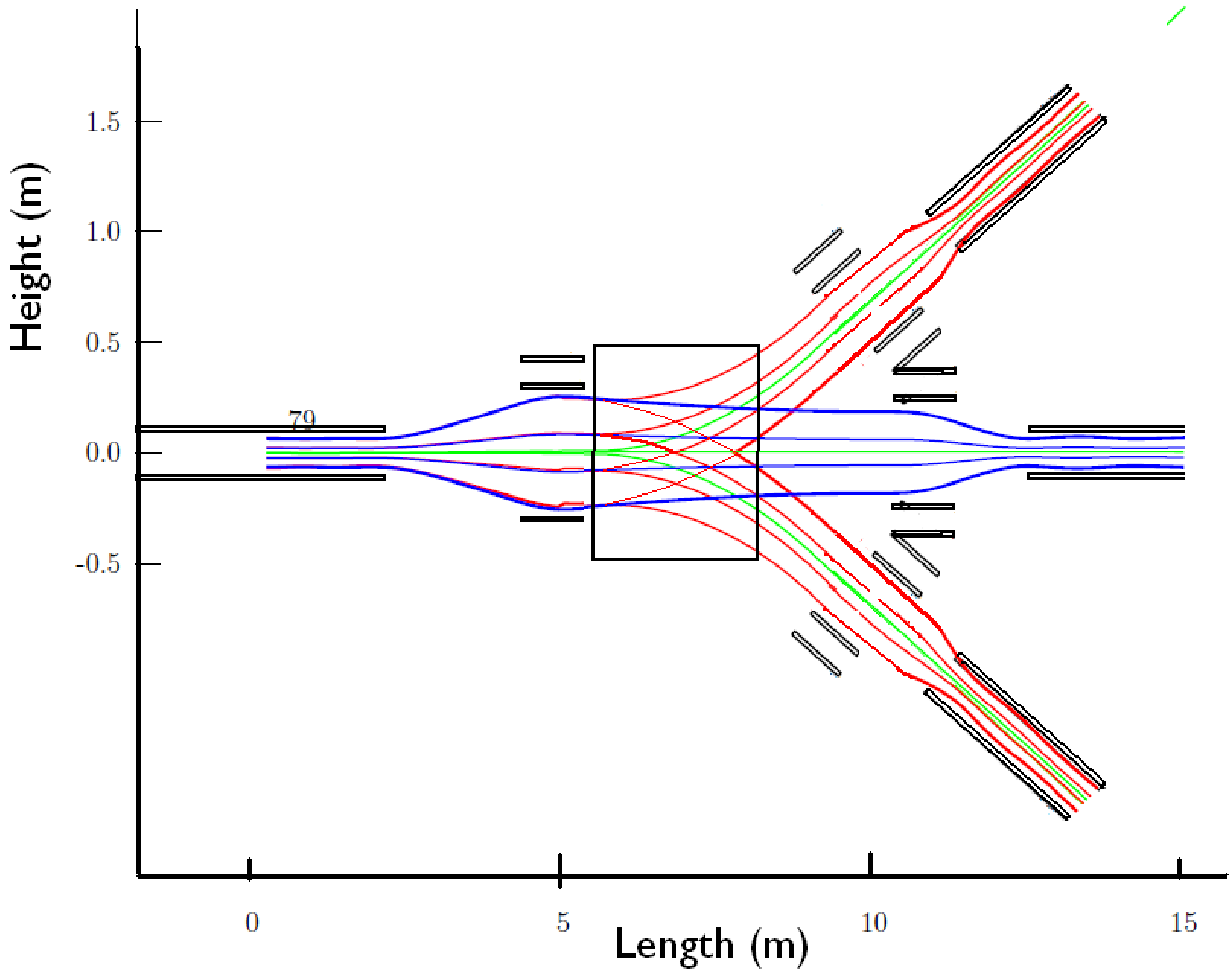
Introduction

- 1D simulation of longitudinal match ok
- Yu Bao has coded it in G4BL with similar results
- Now working on transverse merge
- Starting with kicker into 7 channels



Concept of kicker for transverse merge



Discovered at Riverside with Yu Bao:

- Capture solenoids MUST have bucking coils to stop end fields from other coils to spoil focusing center
- Simple matching from β=.7 m (2 T) longitudinal merge, to β=12 m in kicker, and back to 0.7 m in trombone, caused unacceptable emittance growth.

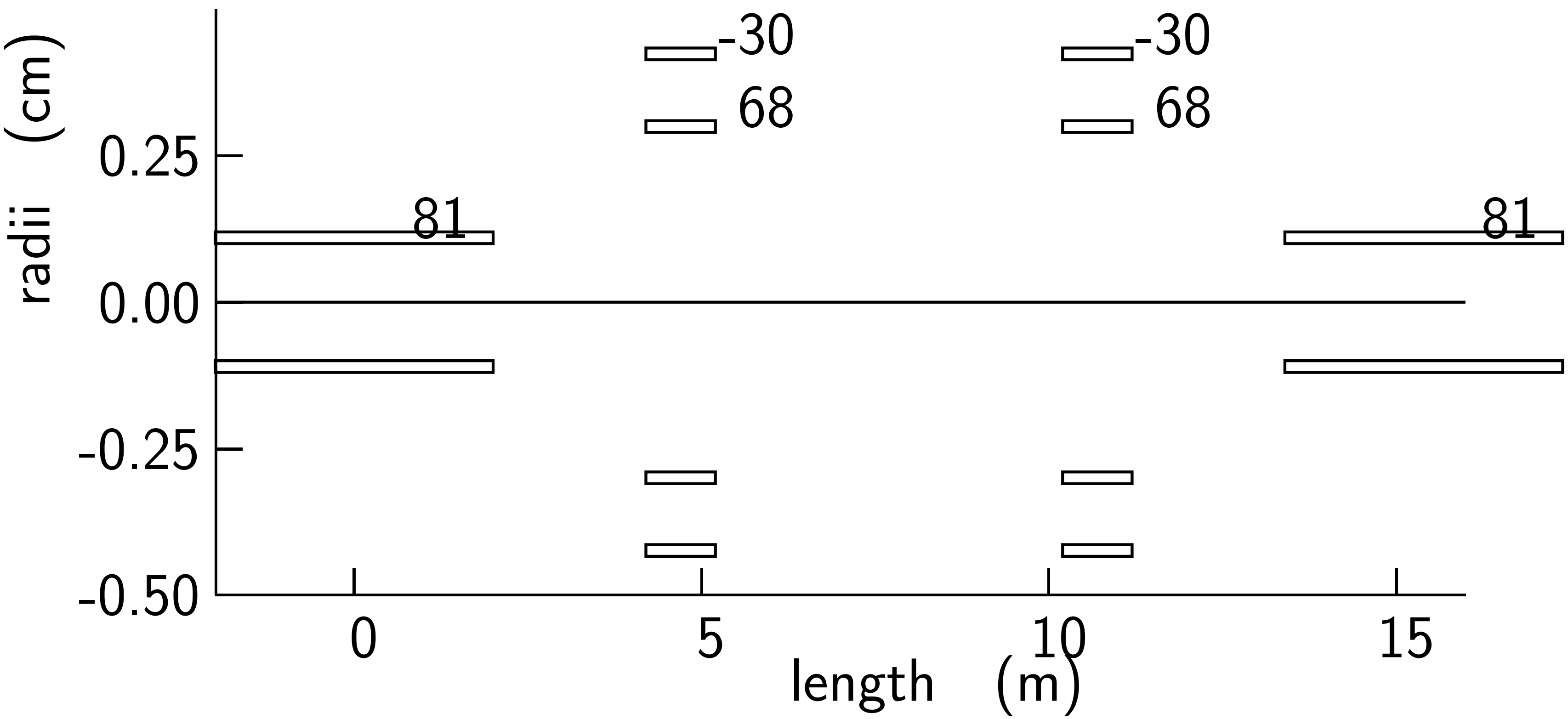
Steps to ease the miss-match problem

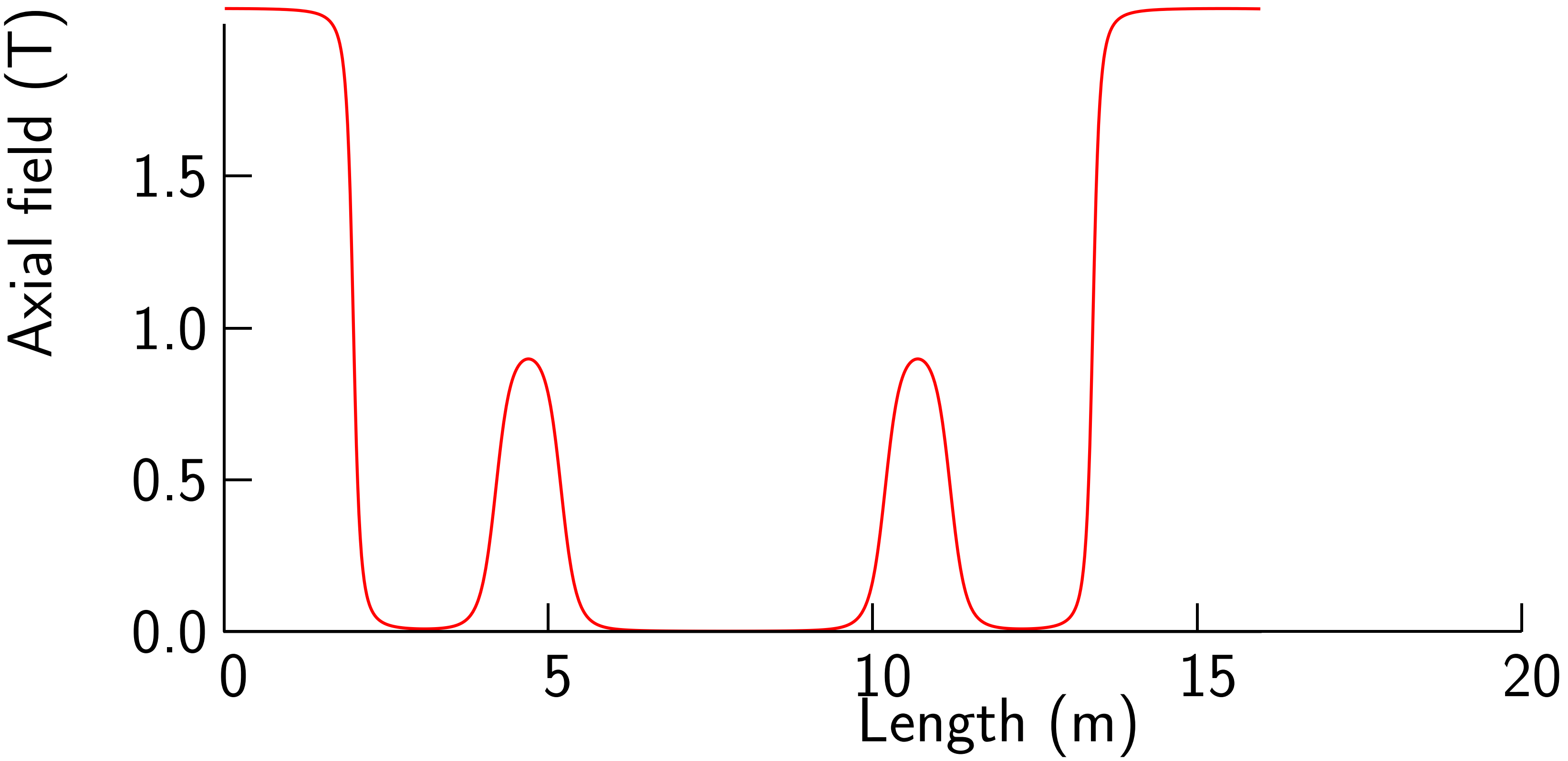
1. Use longitudinal emittance as achieved in my first phase rotation:
   $\epsilon_{\|} = 8.4$ mm
   (Bao had used the higher value from his unoptimized merge)
2. Use a longitudinal beta of 10 m.
   This gives rms dp/p = 2%
   (Bao had used a smaller longitudinal beta giving a 4% dp/p)
3. Lower field used in first part of merge from 2 to $\approx$ 1.1 m,
   thus reducing the ratio of betas from $\approx$ 20 to $\approx$ 10.

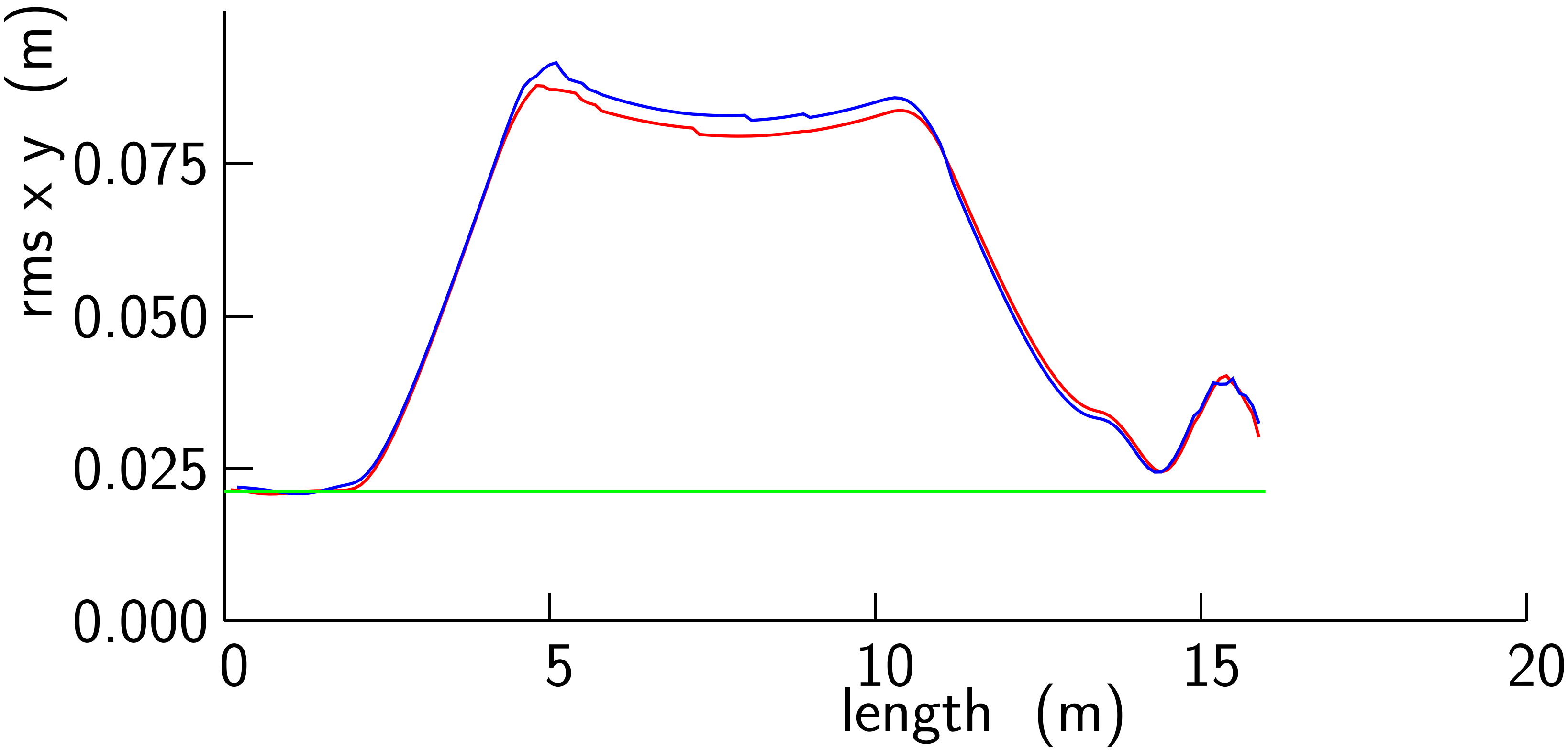
Look at rms beam size now

Beam size with simple 1 stage match

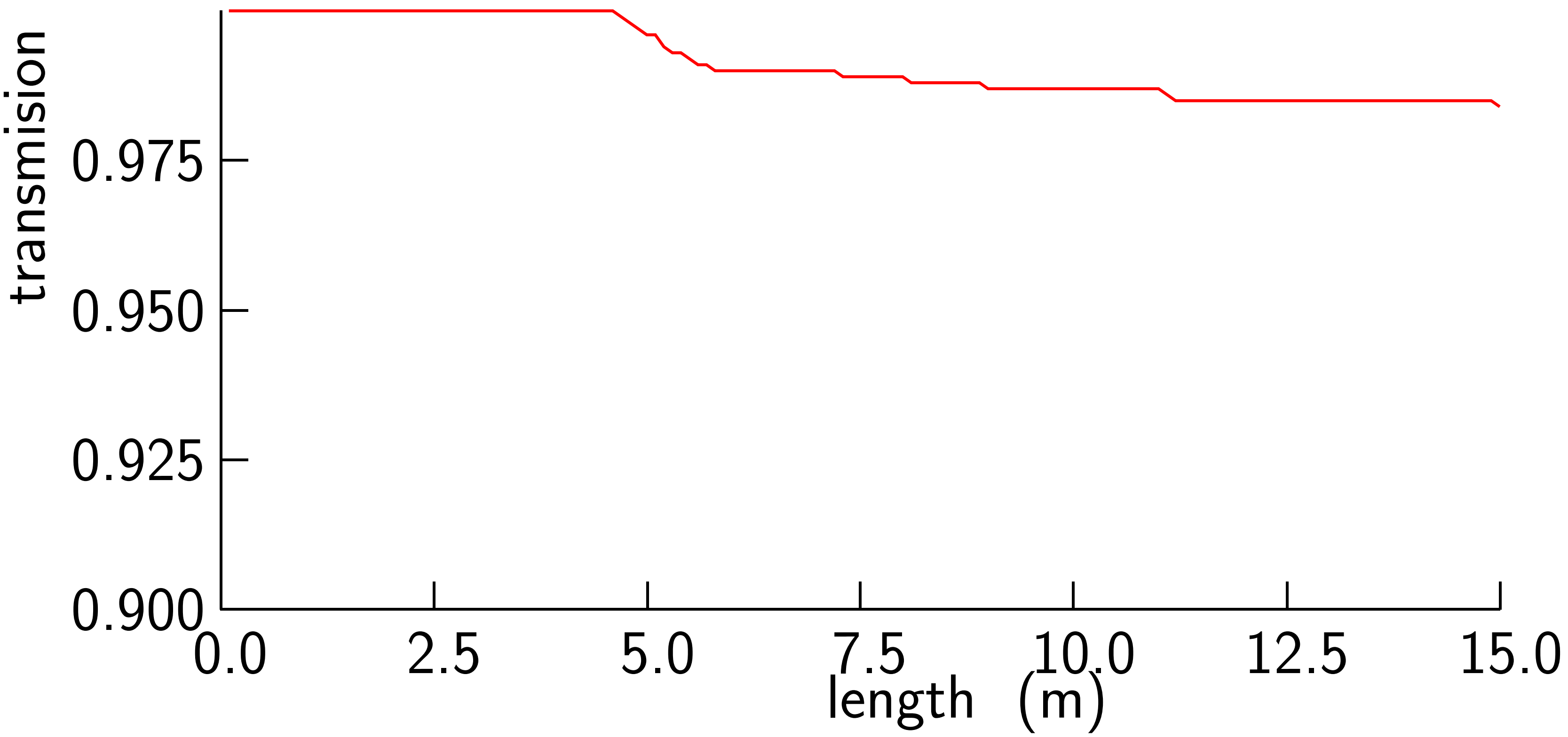
Study a simple case with symmetric match from small betas in long solenoids and larger betas for the kicker. This is NOT the best choice for an actual case, but is easier to understand




Axial field (T)
1.5
1.0
0.5
0.0
0
5
10
15
20
Length (m)



- Beam size shows beta beat
- rms size almost double
- Emittance increased by more than twice



- Transmission ok

Examine $\beta_\perp$ vs. length, for different momenta

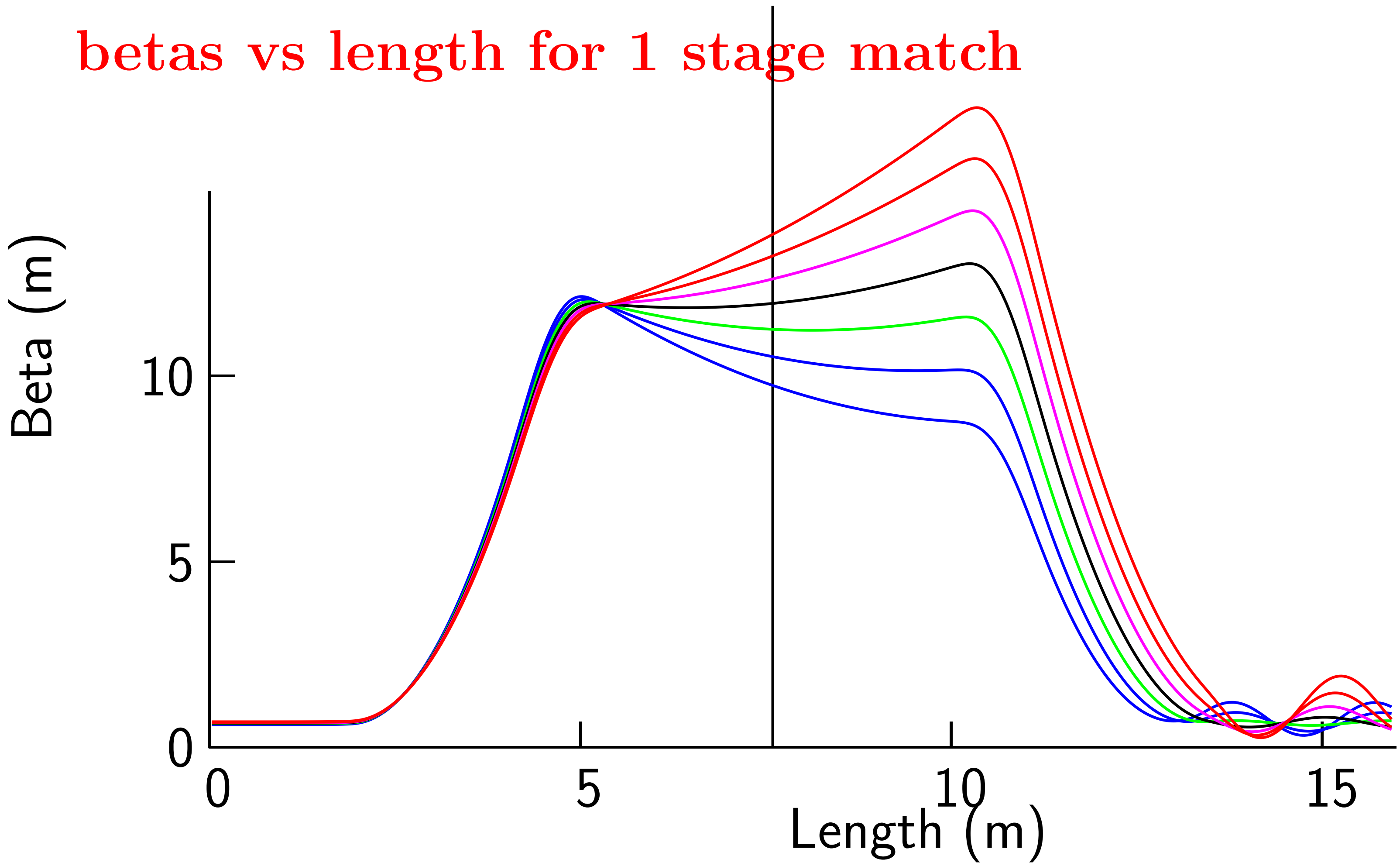
- Calculate field $B(z)$ on axis vs. length z through match
- Step momentum p over required momentum acceptance:
  200 $\pm$ 12 MeV/c
- Calculate solenoid Courant-Snyder α, β, γ for each momentum

$$\alpha \;=\; 0 \qquad\qquad \beta \;=\; \frac{2\;p(GeV/c)}{0.3\;\,B_o} \qquad\qquad \gamma \;=\; \frac{1}{\beta}$$

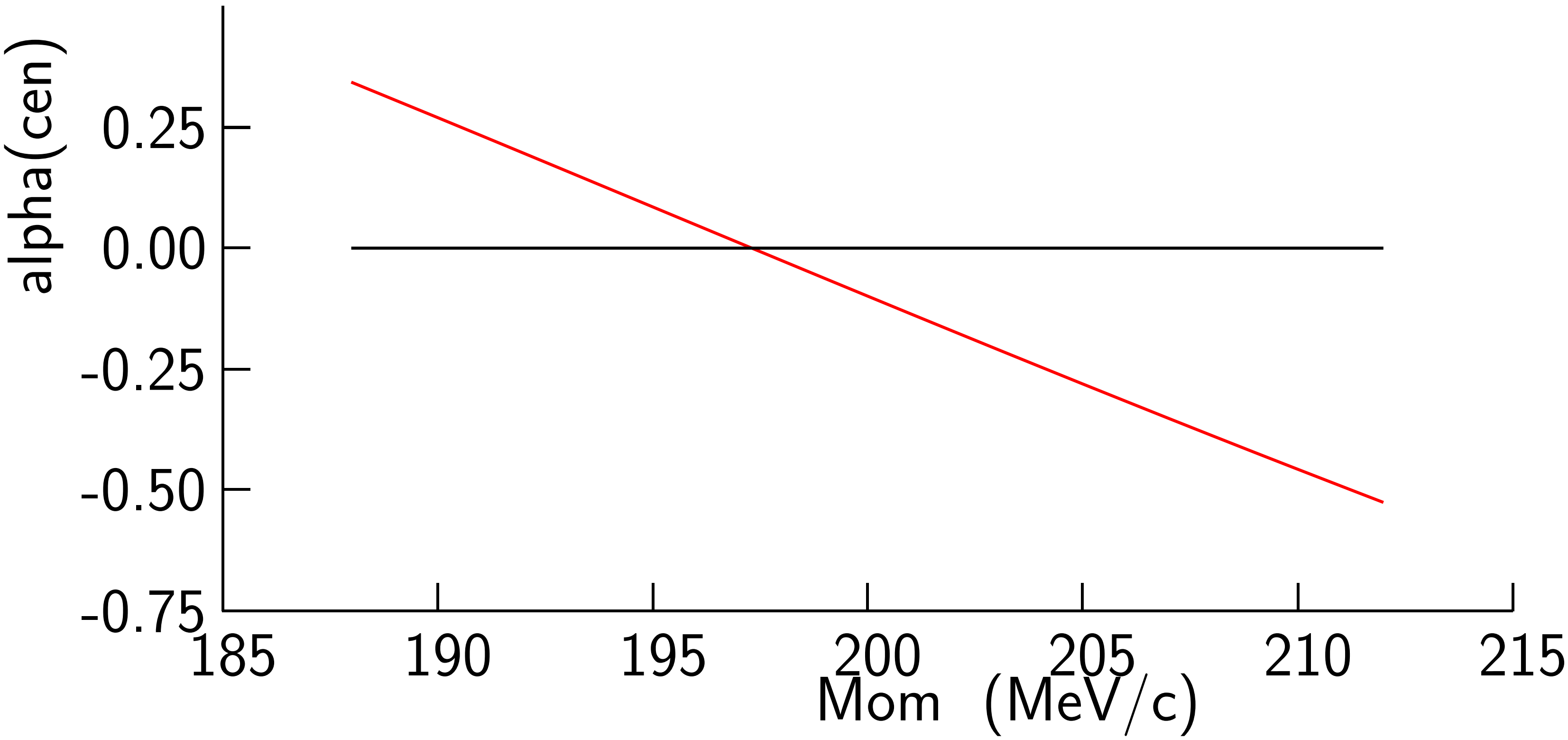
- Propagate $\alpha,\;\beta,\;\gamma$ along z through match

$$\frac{d\alpha}{dz} \;=\; (\beta\,K{-}\gamma) \qquad \frac{d\beta}{dz} \;=\; -2\,\alpha \qquad \frac{d\gamma}{dz} \;=\; 2\alpha\,K \qquad K \;=\; \frac{1}{\beta^2}\left(\frac{B}{B_o}\right)^2$$

betas vs length for 1 stage match



- Match ok at one momentum
- But poor at others



- $\alpha(p) \approx \pm 0.3$ at 3 sigma dp/p of 2%

Matching

- A well matched beam in a long solenoid of field B_o

$$\beta_\perp(p) = \frac{2\,p}{B_o\,c} \qquad \alpha_\perp(p) = 0 \tag{1}$$

p in eV/c, c in m/s

- in an adiabatic taper of B_o, the above is maintained for all p
- We seek a lattice that, after the B and β changes, the above $\beta(p)$ is just like the taper
- Define χ^2

$$\chi^2 = \sum_{ip} \{(\alpha(\mathrm{beam})^2 + \left(\frac{\beta_{ip}(\mathrm{beam}) - \beta_{ip}(\mathrm{cs})}{\beta_{ip}(\mathrm{cs})}\right)^2\}$$

Minimize χ^2, varying coil currents and positions

Special case with symmetry

In this special case there is an even easier thing to minimize:

If ideally matched, then, at the mid point in length, w $\alpha_{ip} = 0$ for all ip and we can minimize $\sum_{ip}(\alpha_{ip}^2)$

I did this minimization by hand. You should write a little program to do this. But for the moment, we should try this solution.

len1 m	gap m	dl m	rad m	dr m	I/A A/mm^2	n I A	n I l A m
0.000	0.000	4.000	0.150	0.020	47.25	3.78	3.80
5.200	1.200	1.000	0.200	0.020	44.10	0.88	1.16
11.200	5.000	1.000	0.300	0.020	28.03	0.56	1.09
18.000	5.800	1.000	0.300	0.020	28.03	0.56	1.09
24.000	5.000	1.000	0.200	0.020	44.10	0.88	1.16
26.200	1.200	4.000	0.150	0.020	47.25	3.78	3.80

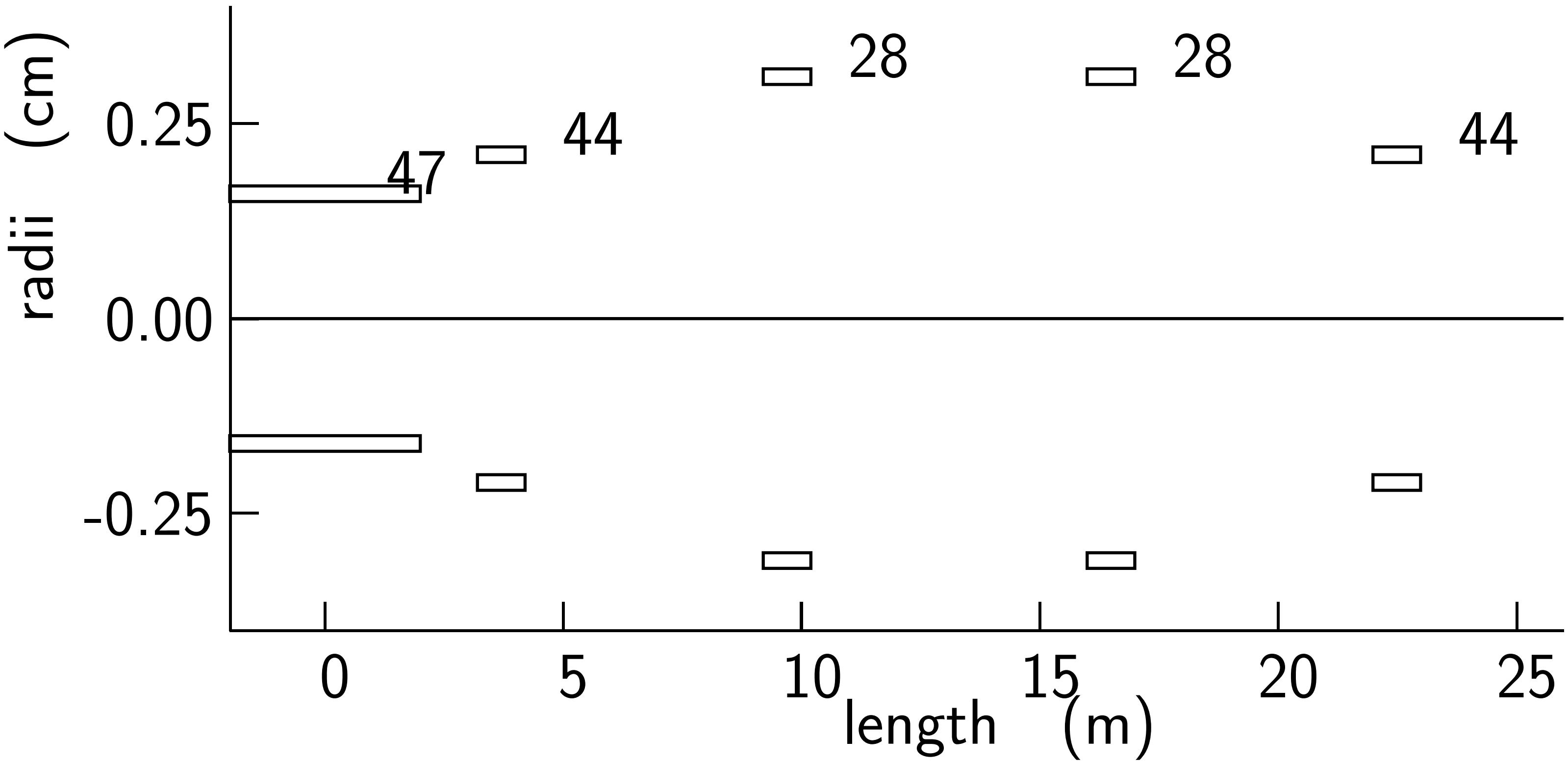


Fig. 1

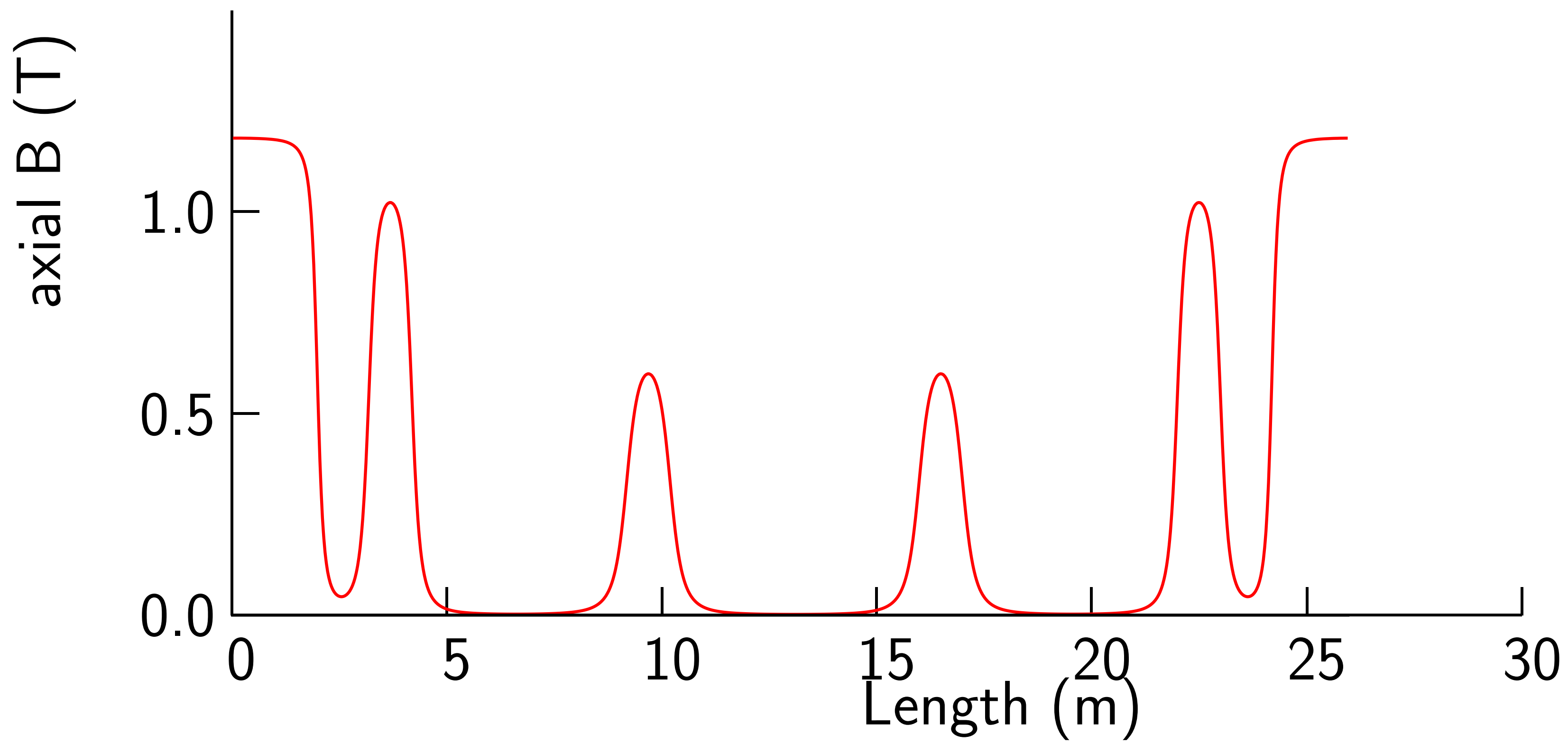


Fig. 2

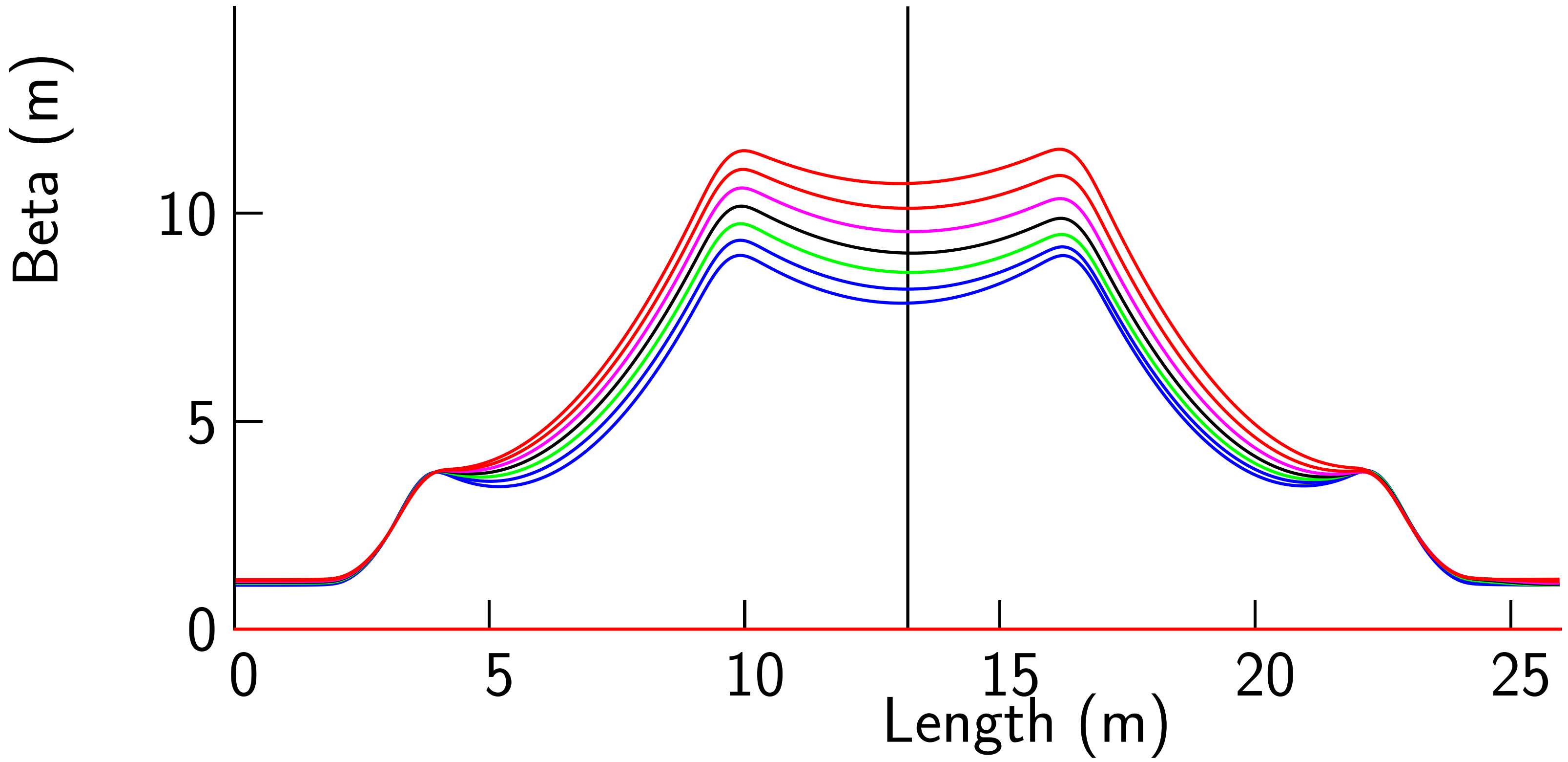
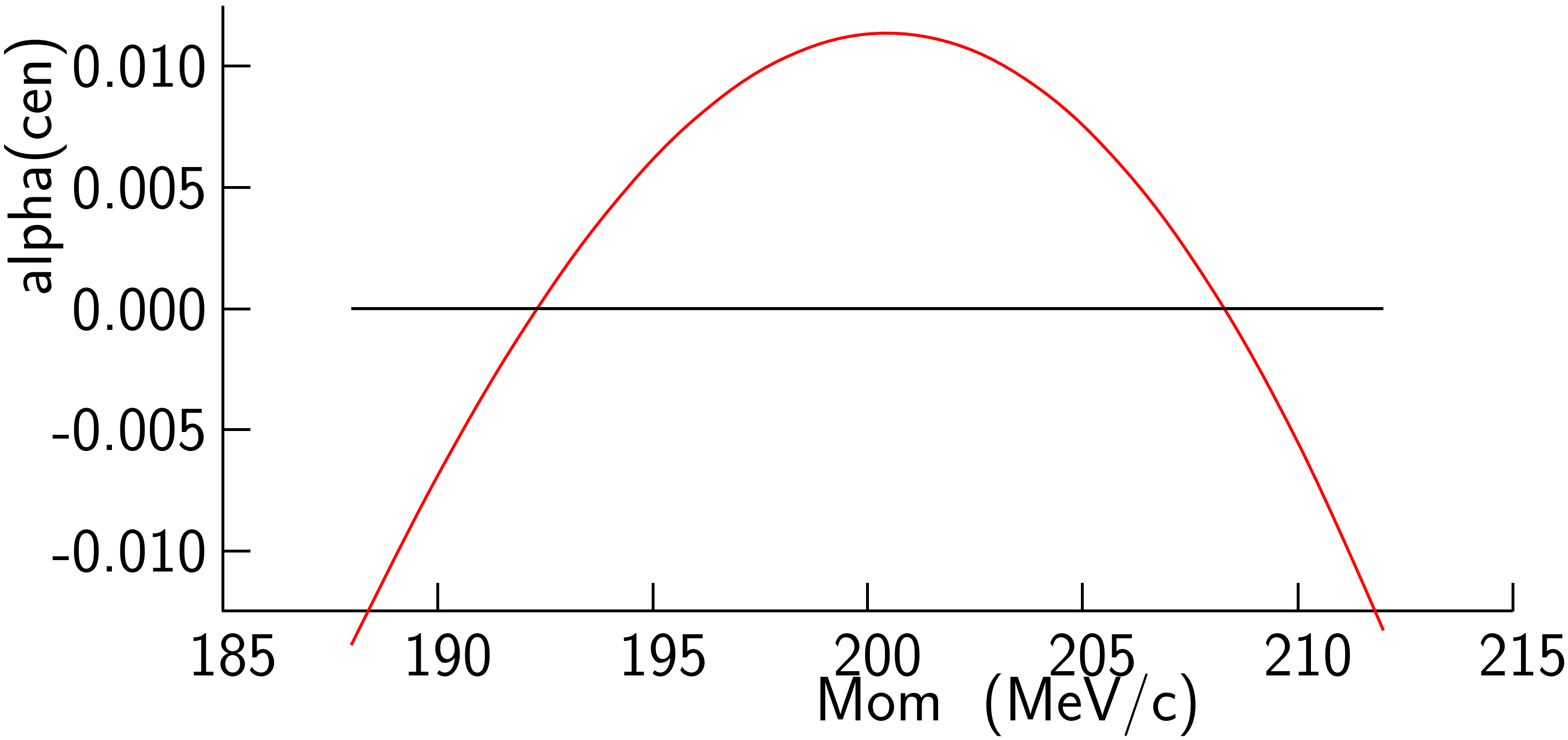
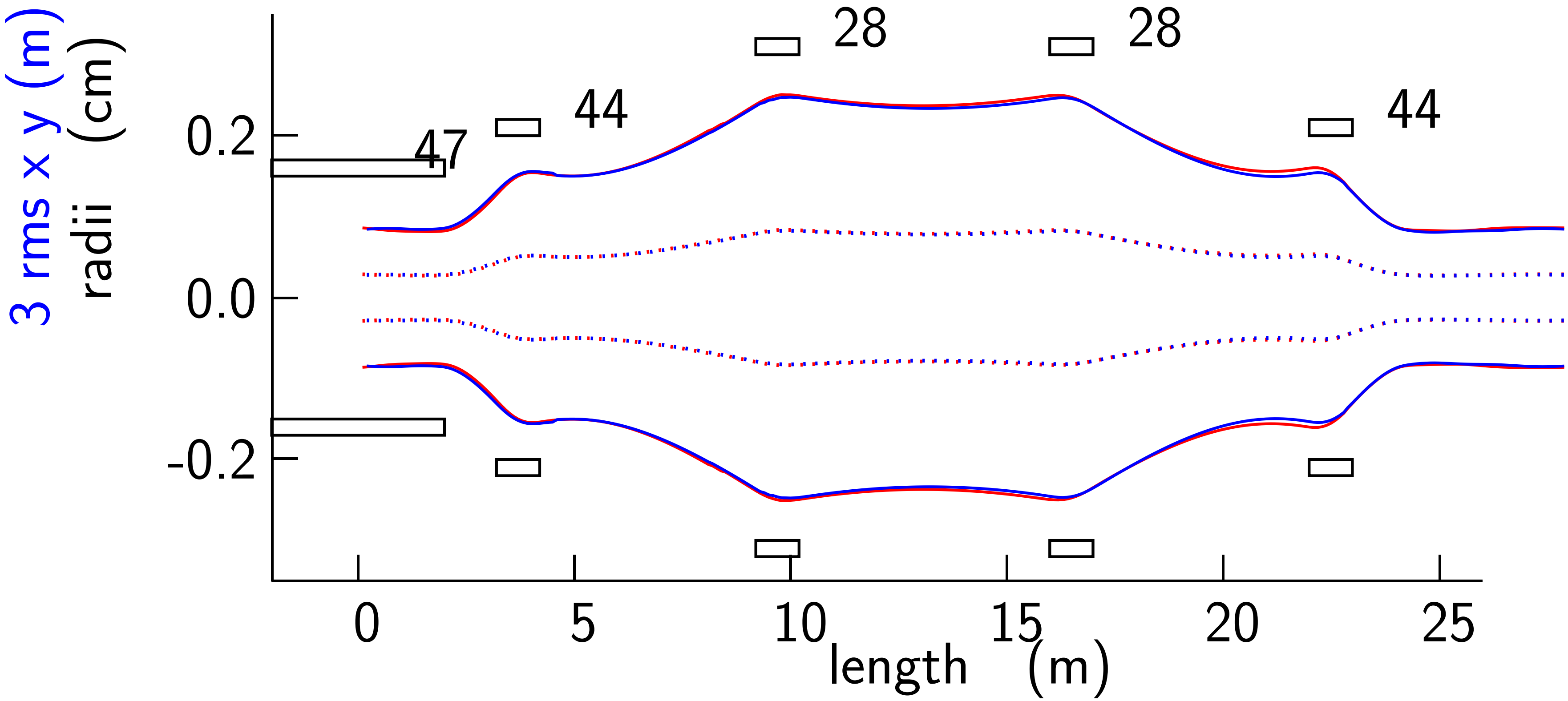


Fig. 3

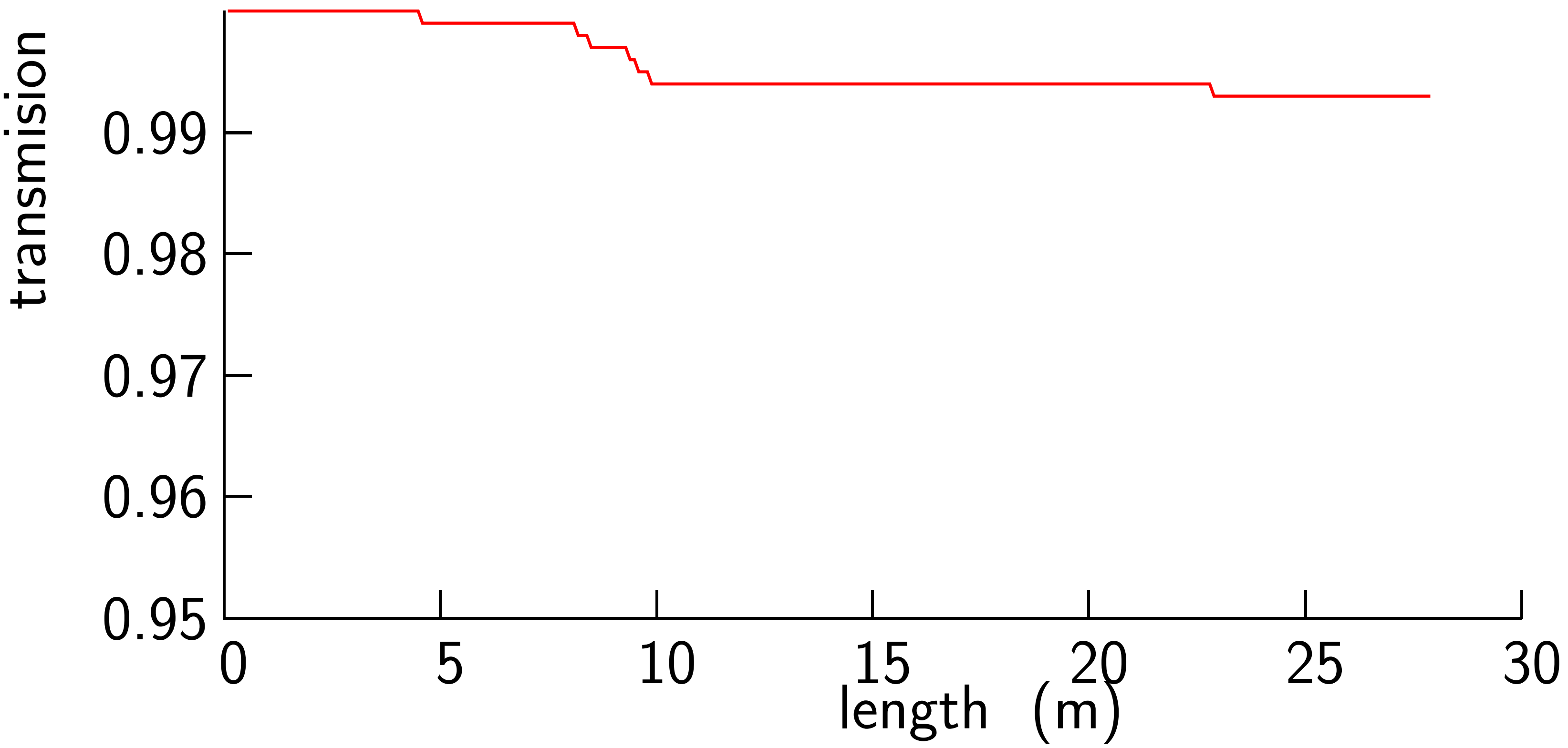


Delta α now only 0.01, compared with 0.3 with simple match

3 sigma beam size



- No significant beam size or emittance increase
- This looks like overkill
- We could probably allow somewhat more dp/p and still get good enough match



- Losses less than 1 % are ok
- But it will be interesting to know why we get ANY loss, given beam limits at over 4 sigma
- It may be from focus non-linearities