ARC1

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1 Requirements

- The TWISS values for the ARC1 section must be independent of how they are generated. That is, stand alone ARC1 must return the same TWISS values as LINAC1+ARC1 combined.

  – This means that the input TWISS values must be exactly identical to the output of LINAC1.

  – This also assumes that the input TWISS values to LINAC1 are correct.

- The TWISS values in ARC1 are symmetric about MQA1A21

- Between the Arc bending magnets the Quadrupoles K1 and distances are symmetric about MQA1A21

- The ARC proper entrance/exit β values are equal

- The ARC proper entrance/exit α values are equal and opposite

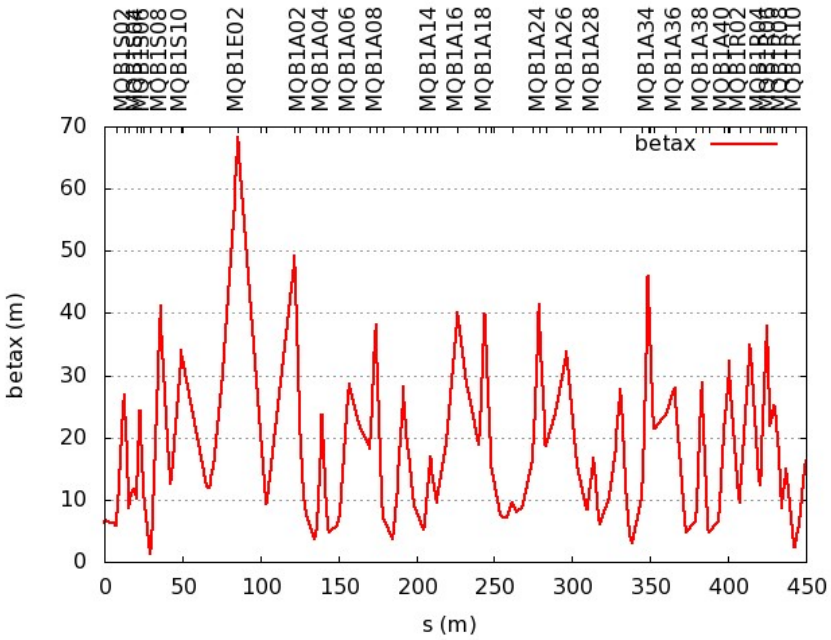
- The TWISS values at the end of the Recombiner are matched exactly to the LINAC2 entrance TWISS.

  – Note, this can be achieved by also modifying the LINAC2 entrance TWISS values to be exactly those of the ARC1 exit values.

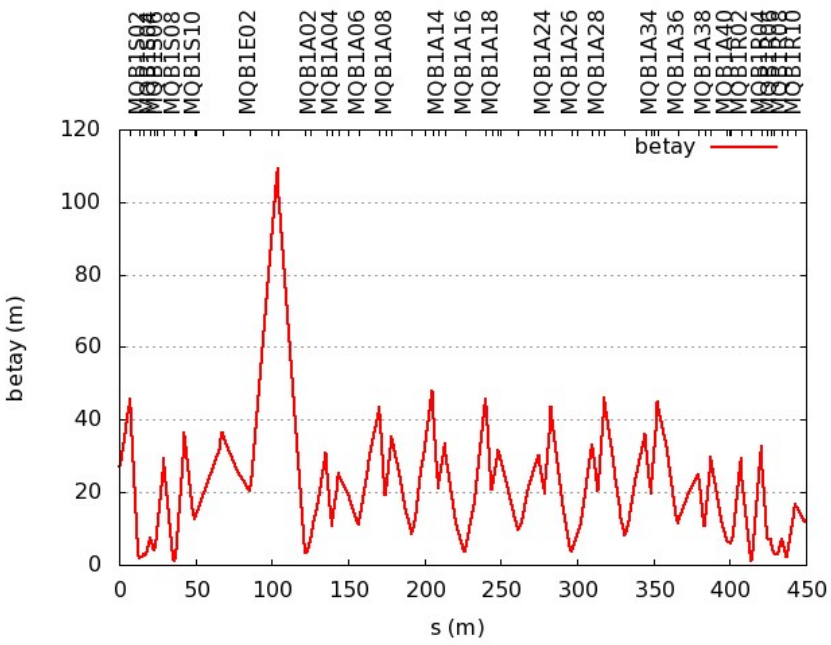
  – Or some combination of the two, fit to match, but transfer the exact final ARC1 values as the LINAC2 entrance values.

2 TWISS parameters in original Optim/Elegant files for Arc1

2.1 β_x



2.2 β_y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MQB1S06
MQB1S08
MQB1S10
MQB1E02
MQB1A02
MQB1A04
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MQB1A08
MQB1A14
MQB1A16
MQB1A18
MQB1A24
MQB1A26
MQB1A28
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MQB1A38
MQB1A40
MQB1R02
MQB1R04
MQB1R06
MQB1R08
MQB1R10
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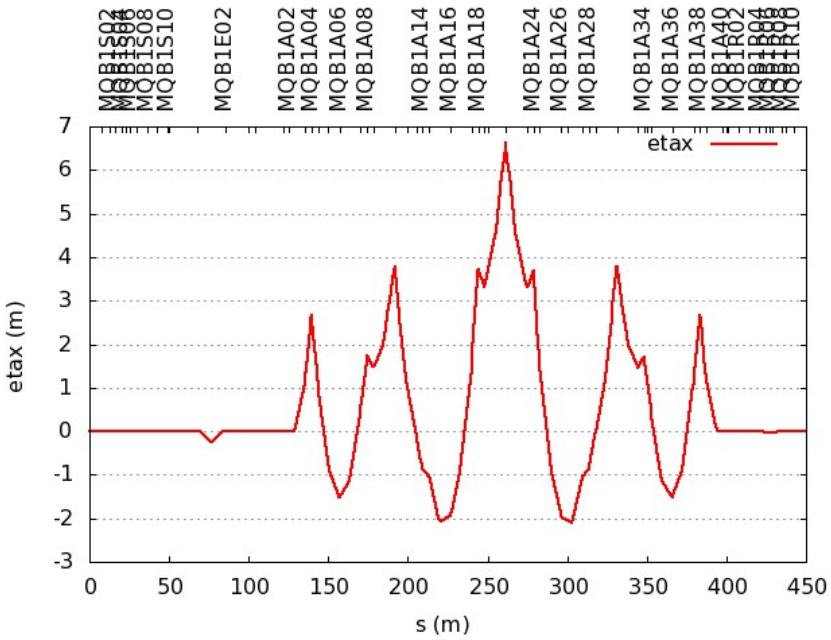
2.3 η_x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MQB1S04
MQB1S06
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MQB1A02
MQB1A04
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MQB1A08
MQB1A14
MQB1A16
MQB1A18
MQB1A24
MQB1A26
MQB1A28
MQB1A34
MQB1A36
MQB1A38
MQB1A40
MQB1R02
MQB1R04
MQB1R06
MQB1R08
MQB1R10
etax
etax (m)
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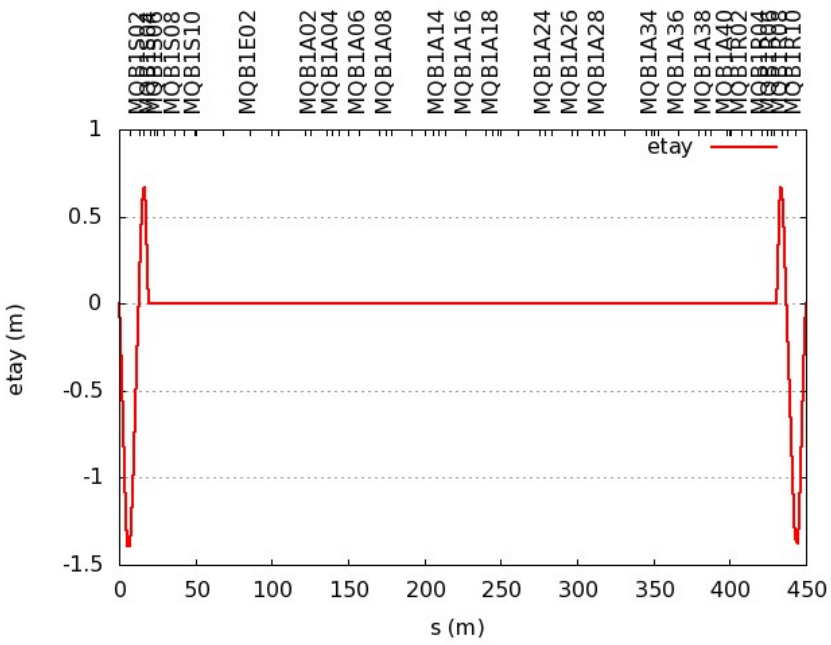
2.4 η_y



3 TODO [11/15] Steps towards self-consistency

3.1 DONE Retrieve NL input parameters from Optim deck

2010-03-02 Tue 12:09

- Art++ Inj and North linac Optim deck at start of D39

  - β_x = 28.9072 m
  - α_x = -2.45782
  - β_y = 6.18386 m
  - α_y = 1.30688
  - η_x = 0.00189354 This should be zero
  - η_y = 0
  - $\eta_x\prime$ = 0.000149481 This should be zero
  - $\eta_y\prime$ = 0

- Present values in LINAC1.ele
  - β_x=2.863532e+01
  - α_x=-2.4307
  - β_y=6.178298e+00
  - α_y=1.3037
  - Z = -154.68952
- AB North linac Optim deck starts at beginning (D1000)
  - β_x = 37.5812 m
  - α_x = -2.80987
  - β_y = 3.15303 m
  - α_y = 0.6171
  - $\eta_x = \eta_y = \eta_x\prime = \eta_y\prime = 0$
  - s = -0.90004 m
  - Z = -153.11452
- Notes

  The difference in Z is 1.575 m between AB Optim and the elegant/Art++ decks, which is the exact length of an added drift in LINAC1.lte (D1000A). This D1000A (elegant) corresponds to D39 (optim). So one must pick TWISS parameters at front of D39, cannot use AB's deck.

  The difference between the Art++ and the elegant decks is small, but enough to cause grief.

3.2 DONE Modify LINAC1.ele to include the correct input parameters

Use the Art++ D39 values:

```
beta_x=2.89072e+01, alpha_x=-2.45782,
beta_y=6.18386e+00, alpha_y=1.30688,
```

3.3 DONE Run LINAC1.ele and extract final TWISS values

2010-03-02 Tue

- β_x = 6.062352e+00
- α_x = -2.087257e-02
- β_y = 2.723758e+01
- α_y = -1.853349e+00
- $\eta_{\mathrm{xy}} = \eta_{\mathrm{xy}}{}' = 0$
- Notes

  These are slightly different than the values in ARC1.ele (revision1.7). TWISS values found for ARC1 entrance.

  ```
  beta_x=6.35476, alpha_x=-0.0575519,
  beta_y=27.1339, alpha_y=-1.86361
  ```

3.4 DONE Modify ARC1.ele to use the LINAC1.ele exit TWISS as input

Modified ARC1.ele to reflect the output of LINAC1, $\mathrm{twiss}_{\mathrm{output}}$ parameters:

```
beta_x=6.06352, alpha_x=-2.087257e-2,
beta_y=27.23758, alpha_y=-1.853349
```

3.5 DONE Verify quadrupole symmetry in ARC1.lte

2010-03-09 Tue 13:03 The quadrupole magnets between the first and last dipole bends should be symmetric (in focal length and location) about the center (MQA1A21) of the Arc. The tables below show that the locations are symmetric at the tens of micron level and the focal lengths (K1s) are spot on.

- Arc1 Quad magnet S coordinate symmetry check

First Half	Second Half	Distance from center(first half)	Distance from center(2nd half)	
MQB1A03	MQB1A39	114.52362	114.52363	-
MQB1A04	MQB1A38	110.86681	110.86681	
MQB1A05	MQB1A37	107.21	107.20999	
MQB1A06	MQB1A36	95.0286899999999	95.0286899999997	
MQB1A07	MQB1A35	82.8473899999999	82.8473799999997	
MQB1A08	MQB1A34	79.1905699999999	79.1905699999997	
MQB1A09	MQB1A33	75.53375	75.5337599999998	-
MQB1A11	MQB1A31	63.3524599999999	63.3524599999999	
MQB1A13	MQB1A29	51.1711599999999	51.1711699999999	-
MQB1A14	MQB1A28	47.5143499999999	47.51435	
MQB1A15	MQB1A27	43.85754	43.85753	
MQB1A16	MQB1A26	31.6762299999999	31.67623	
MQB1A17	MQB1A25	19.4949299999999	19.49492	
MQB1A18	MQB1A24	15.83811	15.83811	
MQB1A19	MQB1A23	12.18129	12.1813000000001	-
			Total	

- Arc1 Quad focal length check

First Half	Second Half	K1 (first half)	K1 (2nd half)	Δ
MQB1A03	MQB1A39	-1.16578	-1.16578	0
MQB1A04	MQB1A38	2.13112	2.13112	0
MQB1A05	MQB1A37	-0.84544	-0.84544	0
MQB1A06	MQB1A36	0.79145	0.79145	0
MQB1A07	MQB1A35	-0.849229	-0.849229	0
MQB1A08	MQB1A34	1.56739	1.56739	0
MQB1A09	MQB1A33	-0.757331	-0.757331	0
MQB1A11	MQB1A31	1.235450559220401	1.235450559220401	0
MQB1A13	MQB1A29	-0.897281	-0.897281	0
MQB1A14	MQB1A28	1.39555	1.39555	0
MQB1A15	MQB1A27	-0.854162	-0.854162	0
MQB1A16	MQB1A26	0.539361	0.539361	0
MQB1A17	MQB1A25	-1.00616	-1.00616	0
MQB1A18	MQB1A24	1.29706	1.29706	0
MQB1A19	MQB1A23	-0.5900030000000001	-0.5900030000000001	0

3.6 DONE Match to η_y=$\eta_y\prime$=0 at the 1SD and 1RD match points

2010-03-02 Tue 19:50

- 1S η location (MKMATCH1SD)
  - MQB1S02.K1 = 1.97364878
  - MQB1S03.K1 = -2.6228056
  - η_y = -2.5e-11 m
  - η_{yp} = 1.2e-12
- 1R η location (end of recombiner)
  - magnet:K1 Δ
  - MQB1R09.K1: 1.794174816572240e+00 2.784816572239723e-03
  - MQB1R10.K1: -1.224998094708481e+00 1.905291519221919e-06
  - η_y = 9.931705e-11
  - η_{yp} = -3.497203e-15

3.7 DONE Modify Lattice: set matched quad values

3.8 CANCELED Measure M_{56} across the Spreader, Arc, and Recombiner

2010-03-03 Wed 11:18 Is this really a necessary step? Why not simply require M_{56}(End of 1R) = 0, by adjusting quads in the Arc? No need to measure anything, just null it out.

3.9 DONE Optimize 1A16 1A11 and 1A31 to achieve M_{56} = 0

M_{56}(Arc) = -(M_{56}(Spreader) + M_{56}(Recombiner)) *2010-03-03 Wed 07:30* Are these the right quads? Adjusting these quads will break the symmetry of quad settings across the arc. Would MQB1A11 and MQB1A31 be a better match?

2010-03-03 Wed 11:24 1A11 and 1A31 is the correct pair, where did 1A16 come from?

- Results

```
Optimization results:
  optimization function has value 1.09266626400112e-23
Terms of equation:
MKMATCH1R#1.R56 0 - sqr:   1.092666264001120e-23
  A total of 88 function evaluations were made.
Optimum values of variables and changes from initial values:
MQB1A11.K1:   1.237074954941993e+00    1.624395721592231e-03
MQB1A31.K1:   1.237074954941993e+00
```

M_{56} for the entire spreader-arc-recombiner lattice after this fit is:

```
M_{56}(end of 1R) = -3.305550e-12 m
```

3.10 DONE Modify Lattice with matched quad values

3.11 INPROGRESS Optimize Spread matching quads for symmetry

Use the spreader matching quads to achieve the desired symmetry: $\beta_{\text{entrance}} = \beta_{\text{exit}}$ and $\alpha_{\text{entrance}} = -\alpha_{\text{exit}}$

2010-03-03 Wed 11:16 In discussion with Alex, it might be useful to split 1A21 quad in half and require that: $\alpha_{\text{xy}} = \eta_{\text{xy}}\prime = 0$ at the midplane of the ARC. This adds four more constraints and might make convergence faster.

2010-03-04 Thu 14:30 These extra constraints did really provide any benefit

- Need to restrict β_{xy}

2010-03-05 Fri 14:30 The fit is converging to solution with very large β_x. In order to get control the $\text{twiss}_{\text{analysis}}$ command is used and a constraint on the maximum β_x and β_y across Arc proper is invoked.

$\text{twiss}_{\text{analysis}}$:

```
&twiss_analysis
 start_name = "MKMATCH1S"
 end_name="MKMATCH1A"
 tag="ARC1"
&end
```

constraint:

```
&optimization_term
  term="ARC1.max.betax  100  0.1 segt"
&end
&optimization_term
  term="ARC1.max.betay  100  0.1 segt"
&end
```

3.12 DONE Modify Lattice with matched quad values

Optimum values of variables and changes from initial values:

Quad	Original K1	New K1 value	Δ from initial
MQB1S04.K1:	-2.30542	-2.308093368585293e+00	0.0027
MQB1S05.K1:	2.31853	2.275024120883677e+00	0.0435
MQB1S06.K1:	0.0746592	7.818336278920536e-02	-0.0035
MQB1S07.K1:	-1.87678	-1.878658827305099e+00	0.0019
MQB1S08.K1:	1.52092	1.669917945157796e+00	-0.1490
MQB1S09.K1:	-1.50962	-1.500127277897621e+00	-0.0095
MQB1S10.K1:	0.74106	7.585530020790612e-01	-0.0175
MQB1E01.K1	-0.373191	-3.641376337719247e-01	-0.0091
MQB1E02.K1:	0.556494	5.557303950127344e-01	0.0008
MQB1E03.K1:	-0.613057	-6.105642051223680e-01	-0.0025
MQB1A01.K1:	1.05041	1.051848906785837e+00	-0.0014

2010-03-09 Tue 13:16 The above table results in an improved Arc1 TWISS symmetry but it is still not symmetric. The above values were obtained with a fit that did not allow the β_{xy} go above 75m in the Arc. Better symmetries are obtained with large β values. Try again! *2010-03-09 Tue 17:08* Added the 1E quads into the fit. They were not moved much by the optimization. Need to add plots. β_x is visually more symmetric than the initial.

3.13 WAITING Re-run ARC1 elegant deck for verification

- Verify that η=$\eta\prime$ = 0 at the 1SD and 1RD match points
- Verify that the TWISS parameters are symmetric

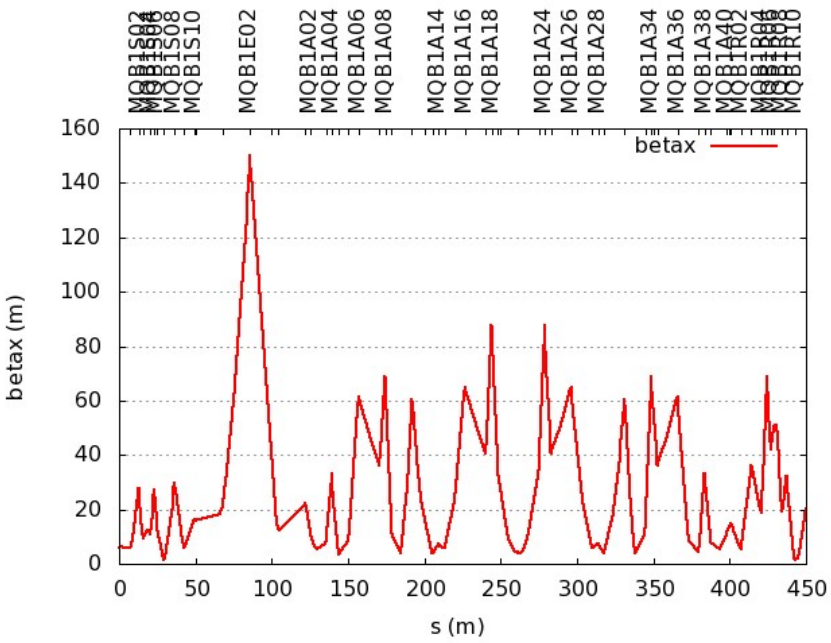
2010-03-09 Tue 13:15 The ARC1.lte deck as saved still has a visible asymmetry. Trying improve the fit.

3.14 TODO Add LINAC1+ARC1 together

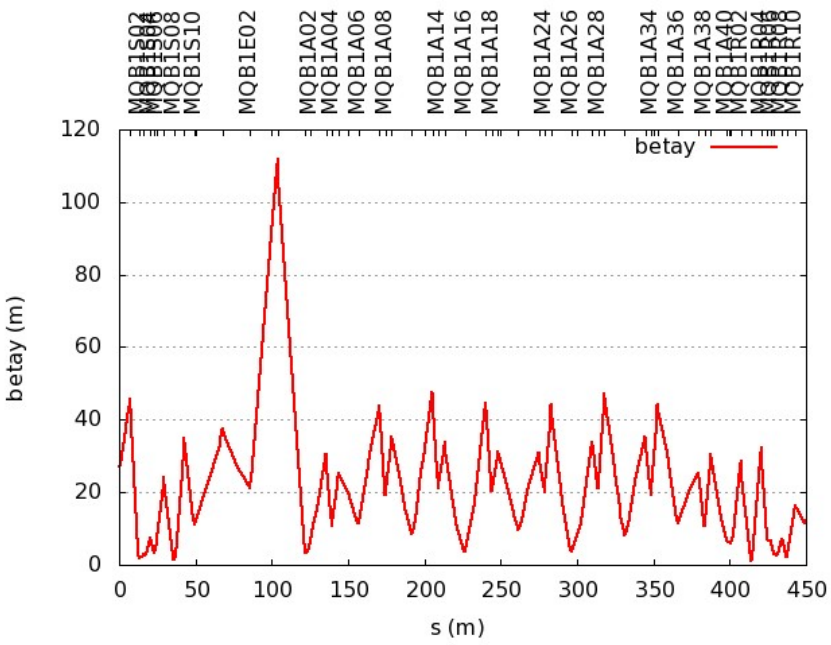
3.15 TODO Run LINAC1$_{\mathrm{ARC1}}$ and compare TWISS with stand alone ARC1

4 TWISS parameters after self-consistent effort: Elegant files for Arc1

4.1 β_x



4.2 β_y


MQB1S10
MQB1E02
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MQB1A16
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MQB1A24
MQB1A26
MQB1A28
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MQB1A36
MQB1A38
betay
betay (m)
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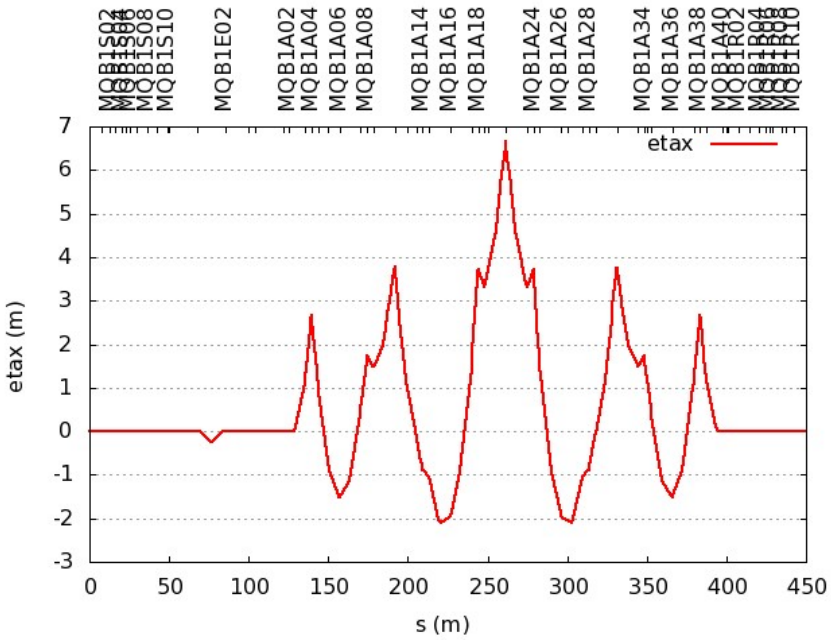
4.3 η_x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etax
etax (m)
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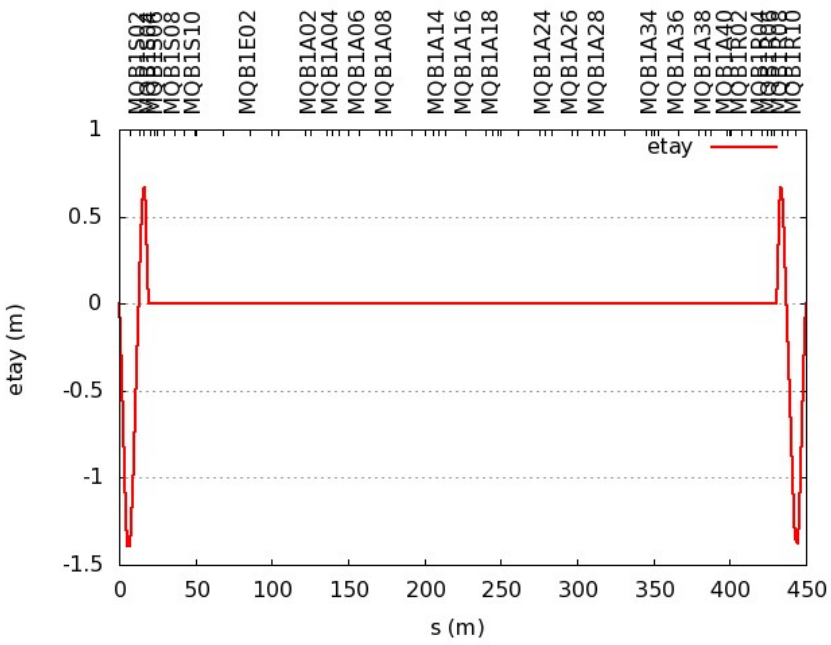
4.4 η_y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