The Cockcroft Institute of Accelerator Science and Technology

MANCHESTER 1824 The University of Manchester

LHeC Ring-Ring Interaction Regions

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Overview

- Design Requirements
- Separation Scheme
- 10° Solution
- 1° Solution

Design Requirements

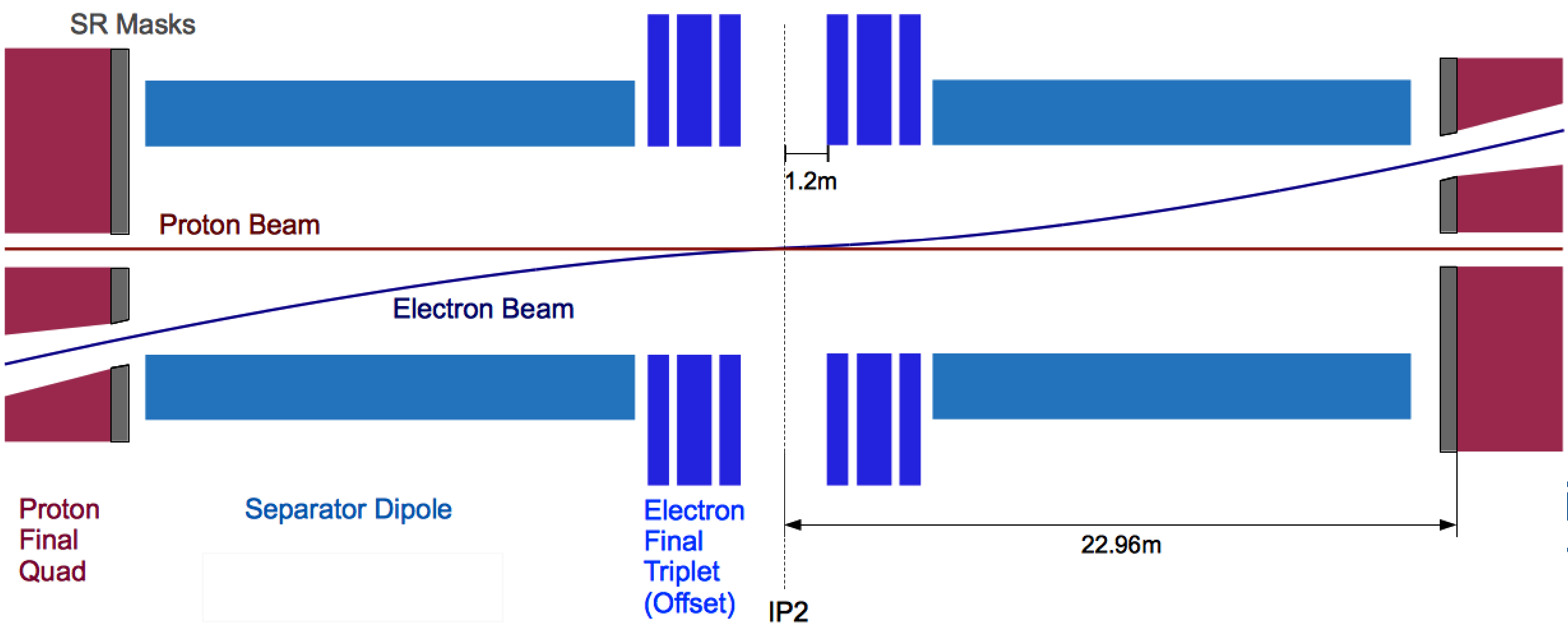
- Luminosity
  - ~10^{33}
- Machine acceptance
  - 1°: Low Q^2, x
  - 10°: High luminosity
- Separation
  - Beam-beam
    - Parasitic crossings every 3.75m
    - $5\sigma_e + 5\sigma_p$ min. separation at each parasitic crossing
  - Proton quad
    - ~50 mm separation

Design Requirements

- Synchrotron radiation
  - Minimise total power and E_c
  - Depends on separation scheme
- Matching to latest ring lattice
  - Matching quads in LSS
  - ‘Smooth’ solution

IR Separation Scheme

- Fundamentals shared by 1° and 10° layouts
- Horizontal S-shaped scheme
  - IP crossing angle
  - Dipole bends
  - Offset quads
- Constant bend radius



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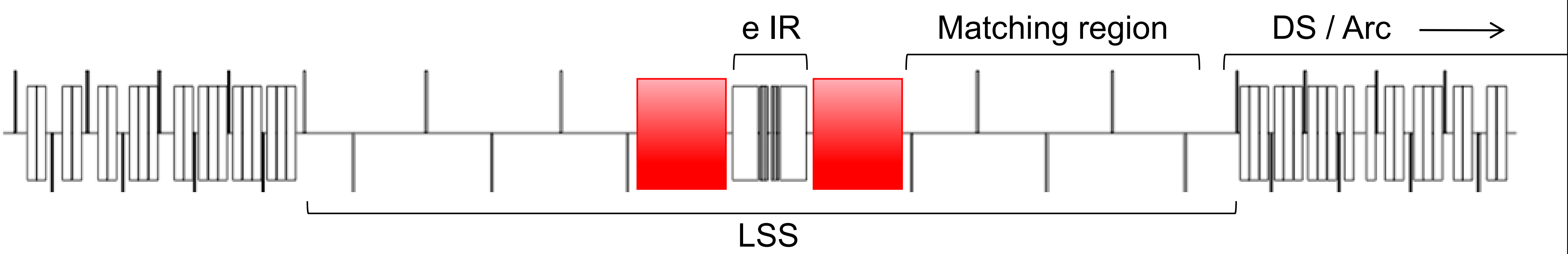
Lattice Solutions

- Matched to M. Fitterer's current ring lattice
- Matched to arcs using matching region in LSS
- Space between IR optics and LSS quads for proton optics

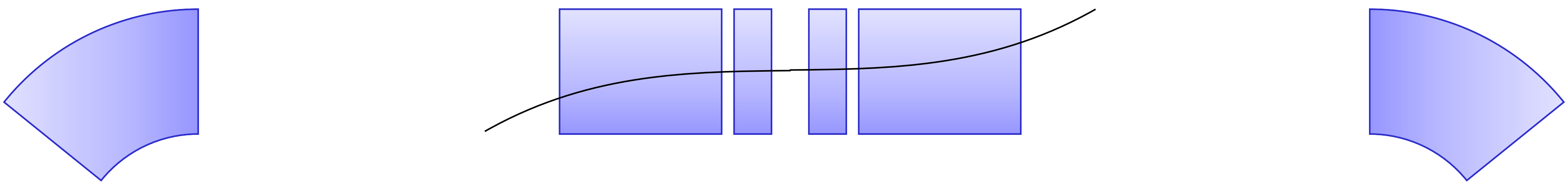


1° Files available at: **/afs/cern.ch/eng/lhc/optics/LHeC/IR1_Lattice1/**

10° Files available at: **/afs/cern.ch/eng/lhc/optics/LHeC/IR10_Lattice1/**

Lattice Solutions

- Space for complete LSS separation scheme
- IR separation only does **not** give real lattice geometry
  - Full IR-matched ring lattice files on AFS have zero IR bend strength by default
- Design dispersion-free bending to return to electron arcs
- Full separation scheme depends on geometry



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10° Files available at: **/afs/cern.ch/eng/lhc/optics/LHeC/IR10_Lattice1/**

Lattice Solutions

- Zero-order solutions
- Do not include
  - Complete separation scheme
  - Dispersion matching
  - Phase advance matching
  - Orbit correction
- Solutions not quite symmetric
  - Dispersion suppressor geometry

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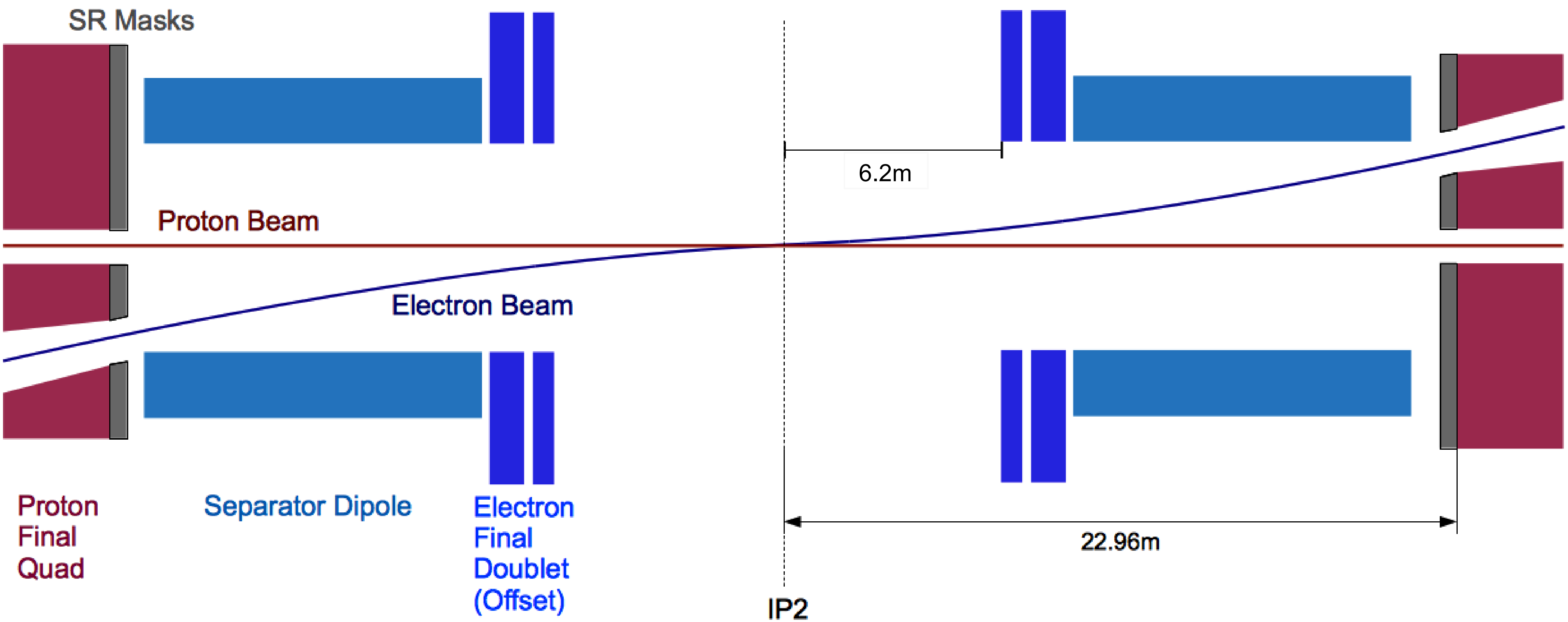
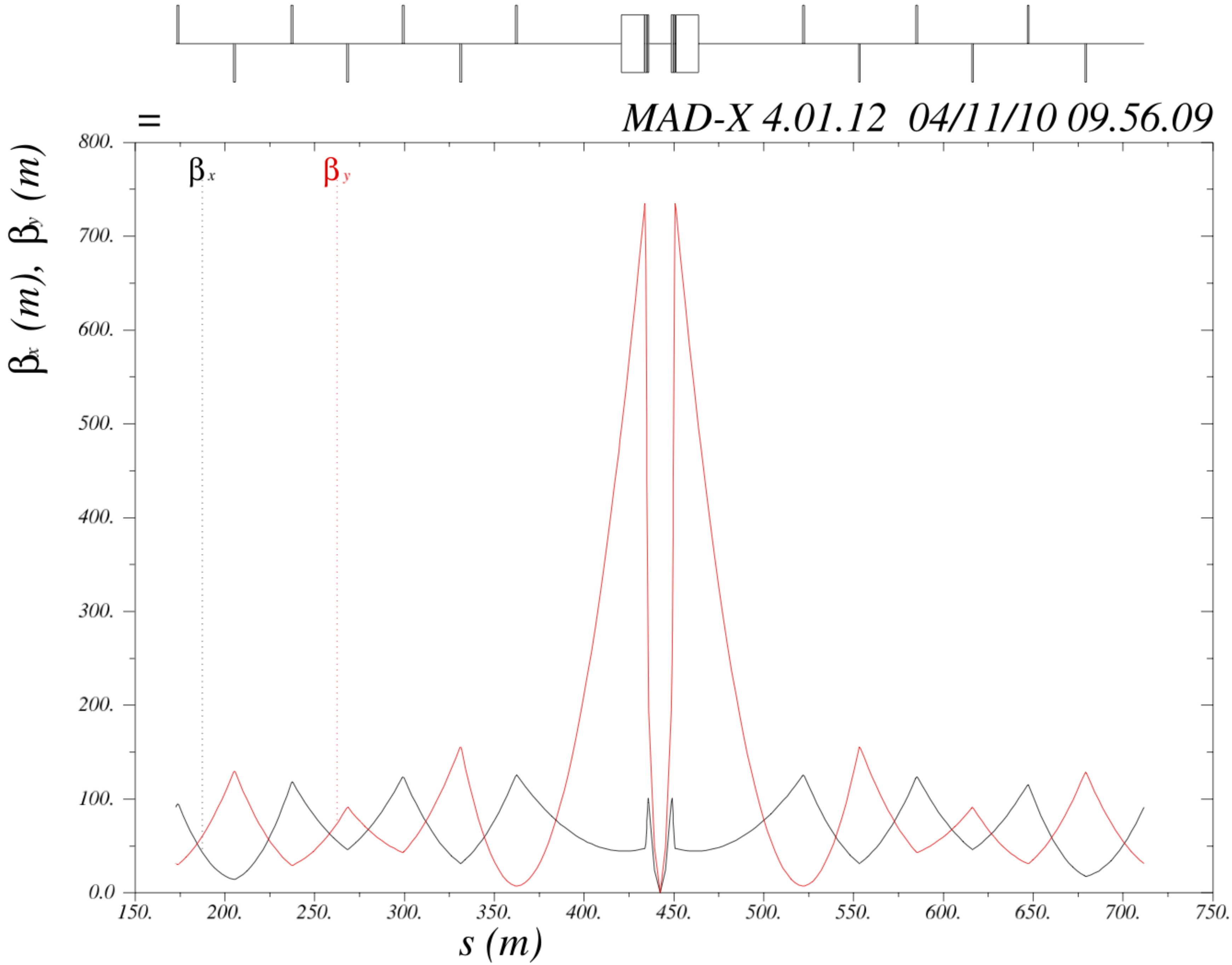
1° Solution


SR Masks
6.2m
Proton Beam
Electron Beam
Proton
Final
Quad
Separator Dipole
Electron
Final
Doublet
(Offset)
22.96m
IP2

1° Solution - Plots



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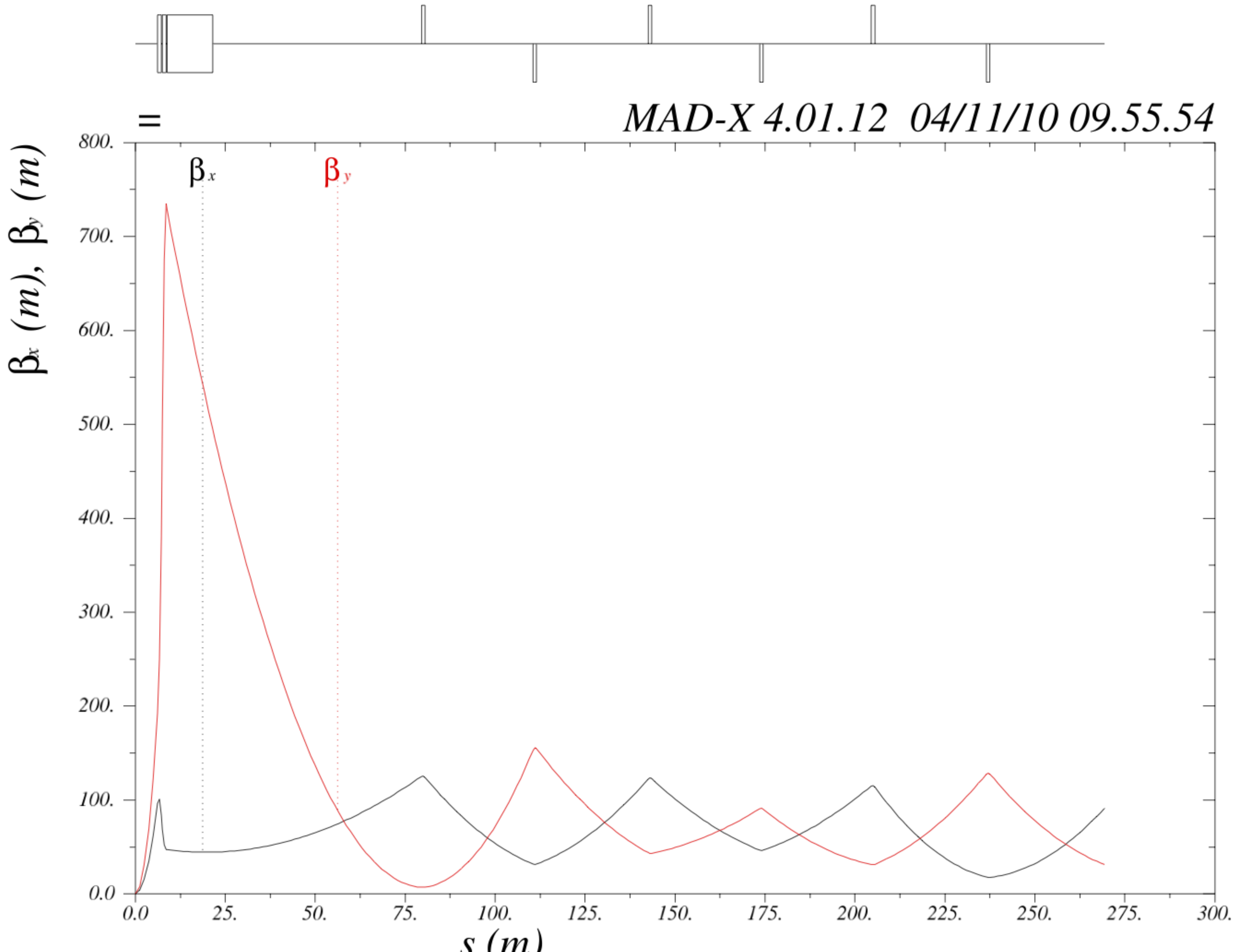
1° Solution - Plots



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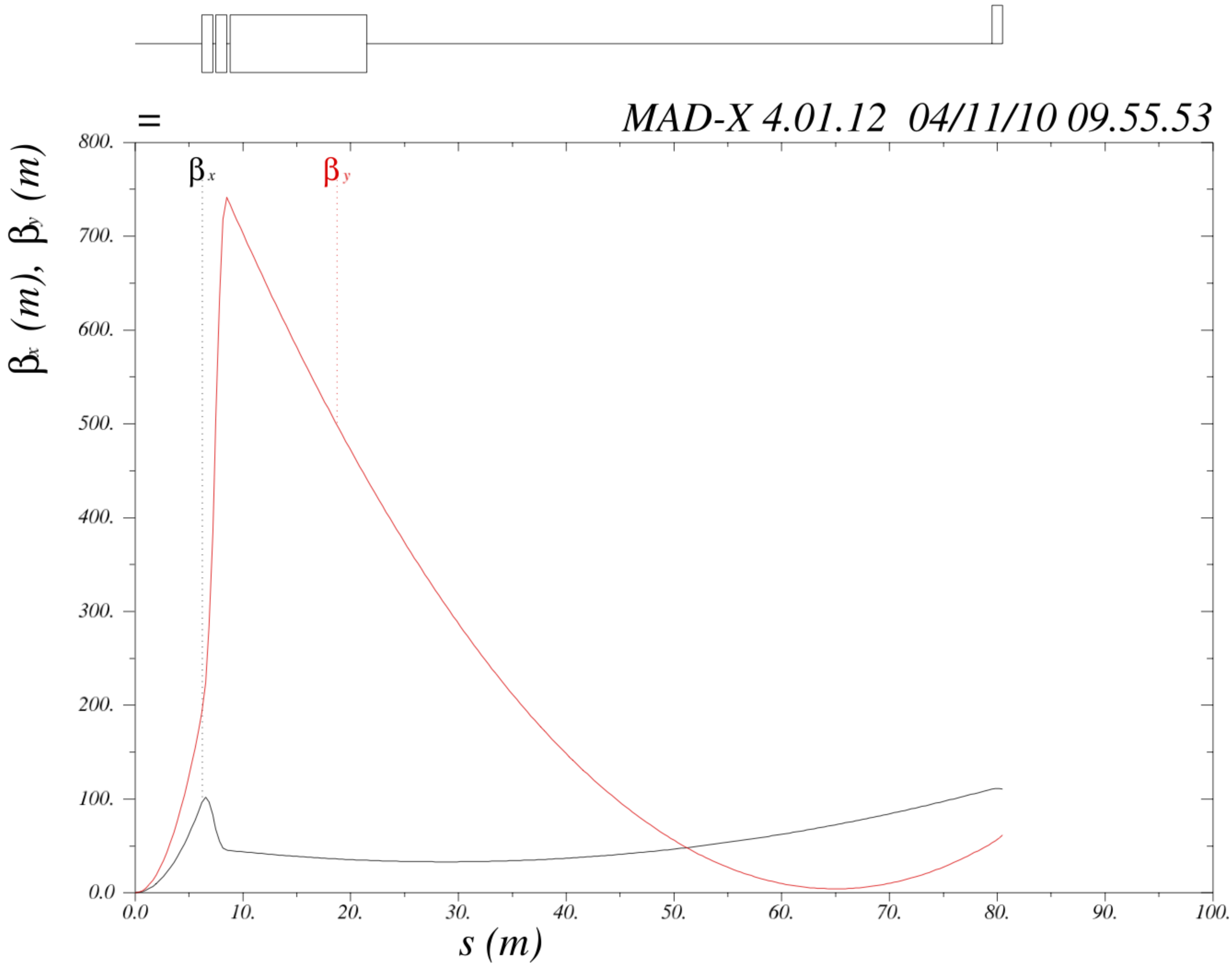
1° Solution - Plots



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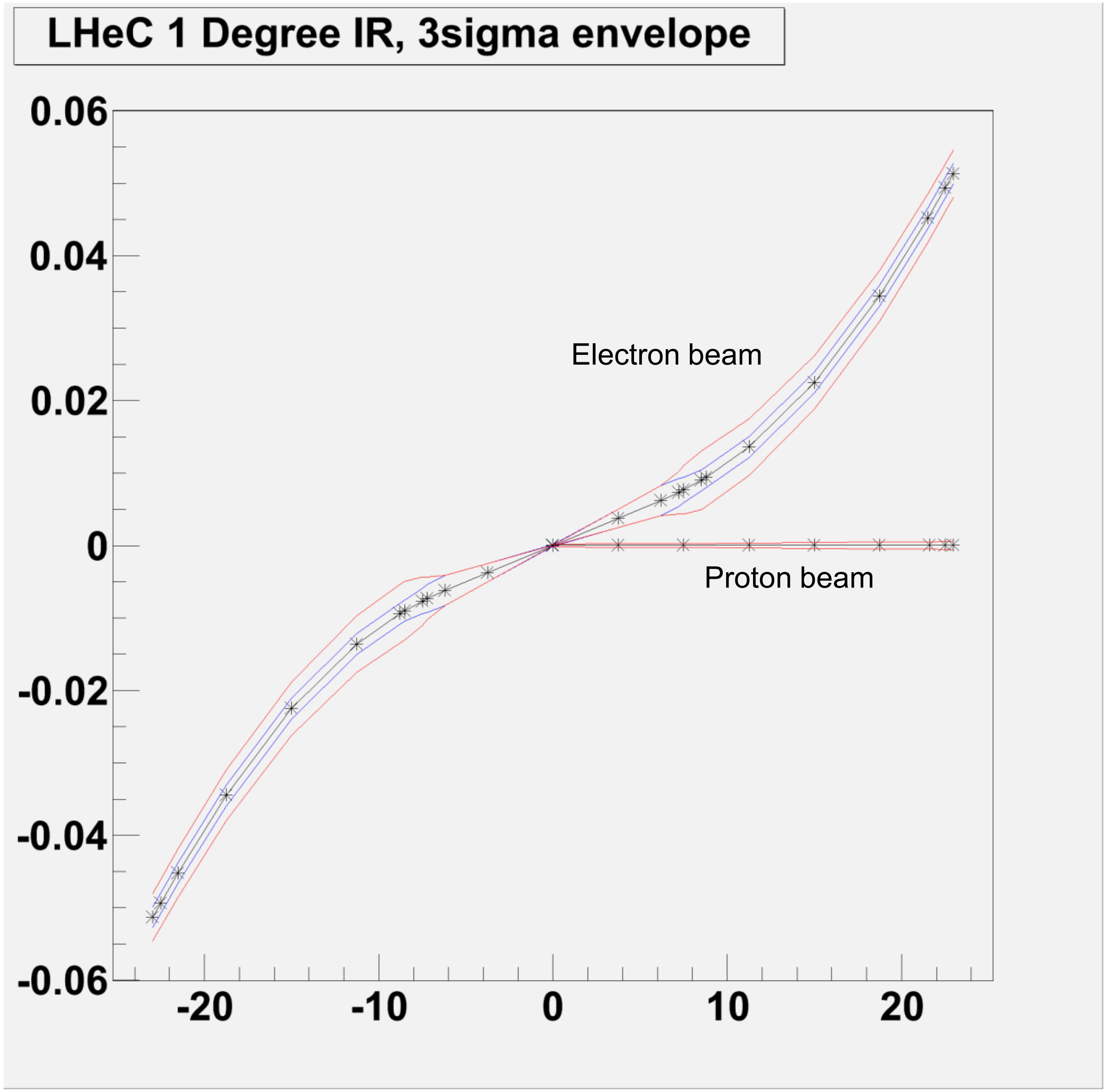
1° Solution - Separation

- FD quad doublet
- β_x stays low
- Peak in β_y
  - B_y = 735 m
  - S_{IP} = 8.5 m
- First parasitic interaction before *l**
  - Minimum crossing angle largely dependent upon β* - ~ 0.7mrad
  - Choose 1 mrad for this layout
- *l** = 6.2m
  - Less room for dipoles
  - Dipole strength increased to achieve ~50 mm by proton triplet

1° Solution - Separation



X beam envelope

Y beam envelope

1° Solution - Parameters

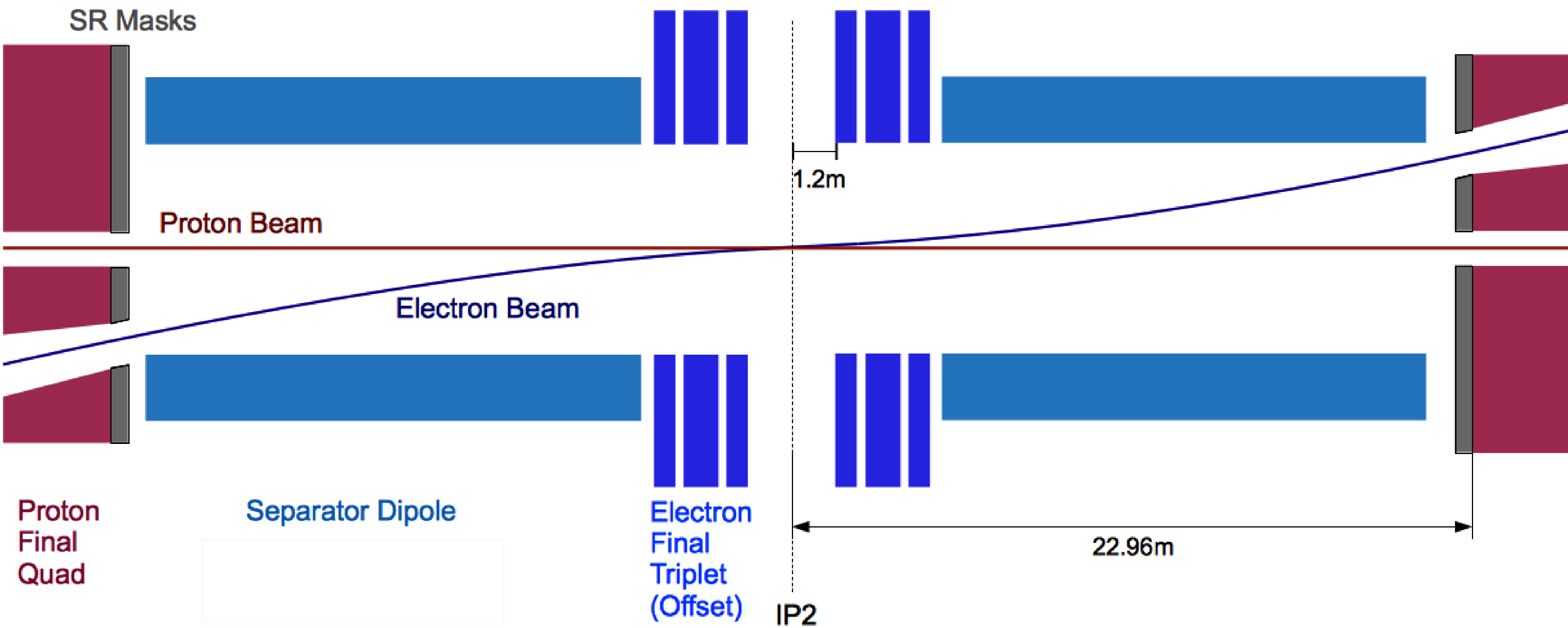
$L(0)$	**8.54×10^{32}**
θ_{IP}	1 mrad
$S(\theta)$	0.858
$L(\theta)$	7.33×10^{32}
β^*_x	0.4 m
β^*_y	0.2 m
l^*	6.2 m
ρ	4.6 km
SR Power	44 kW
SR E_c	156 keV

Note: θ_{min} for this layout from beam-beam considerations is ~0.7 mrad.

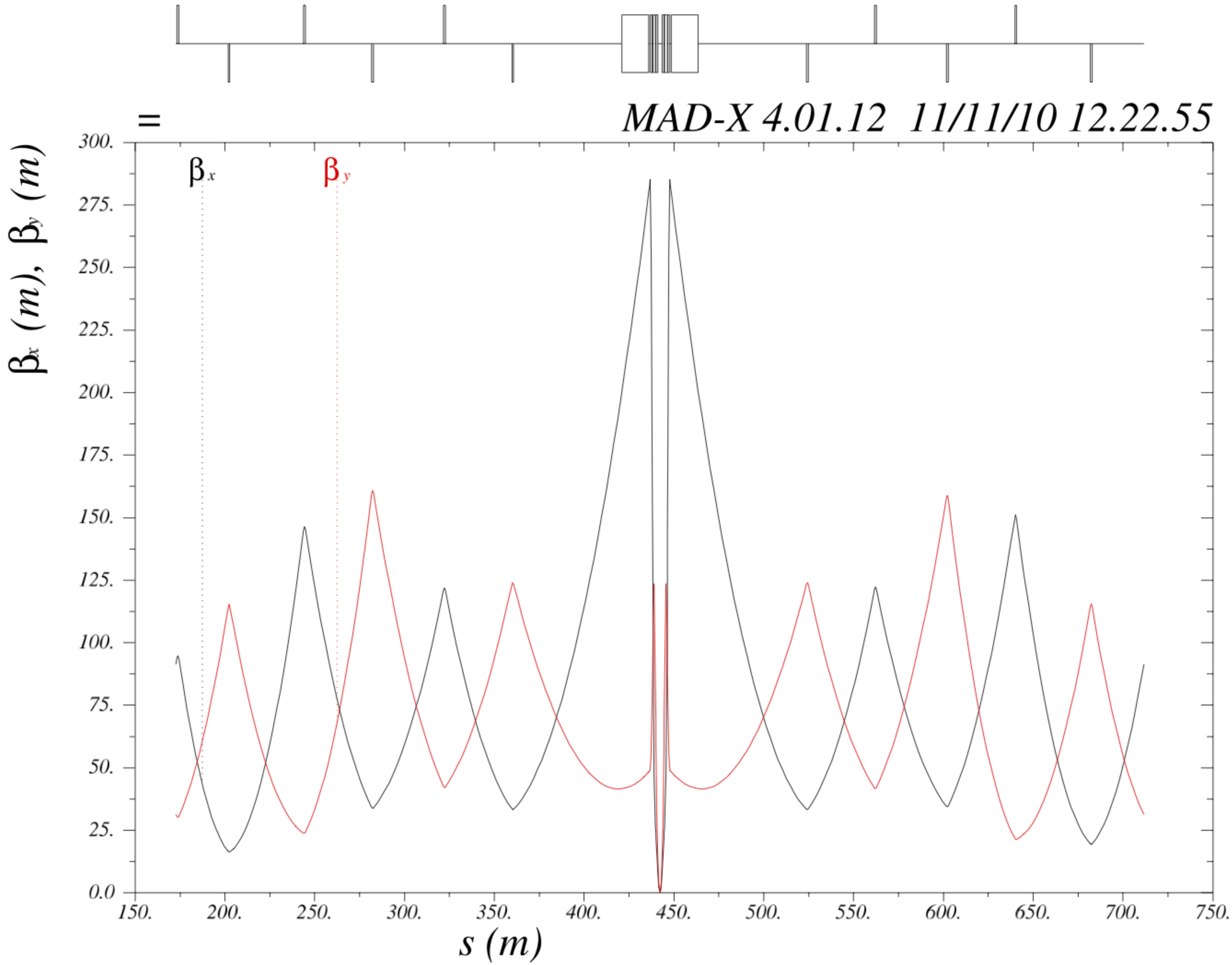
0.7 mrad requires increased bend strength to attain 50 mm separation at s = 22.96 m, raising SR power to 56 kW. 1 mrad has been chosen as a trade-off between SR power and luminosity, and also as a direct comparison to the 10° layout.

$L(0.7 \text{ mrad}) = 7.88 \times 10^{32}$

10° Solution


SR Masks
1.2m
Proton Beam
Electron Beam
Proton
Final
Quad
Separator Dipole
Electron
Final
Triplet
(Offset)
IP2
22.96m

10° Solution - Plots



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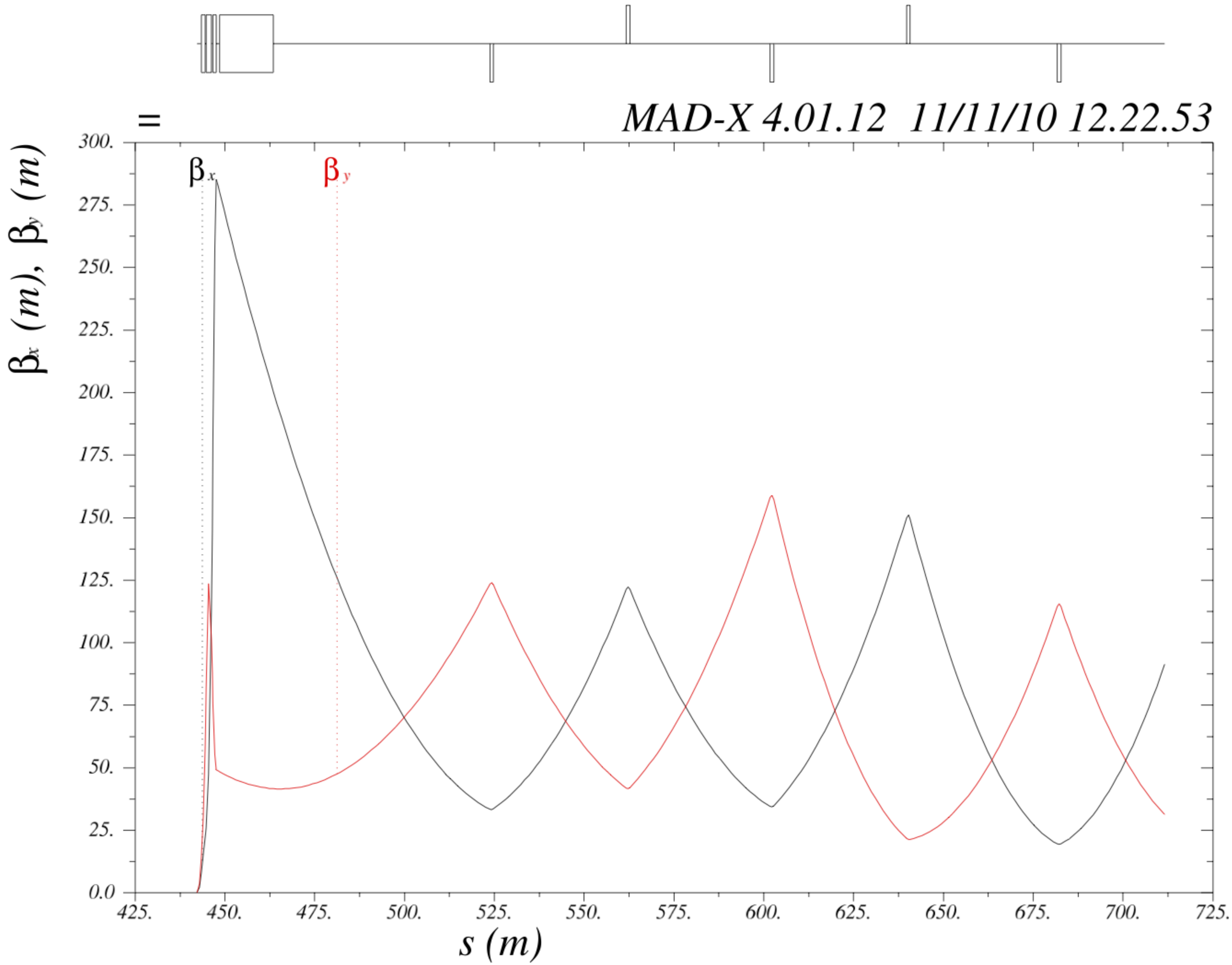
10° Solution - Plots



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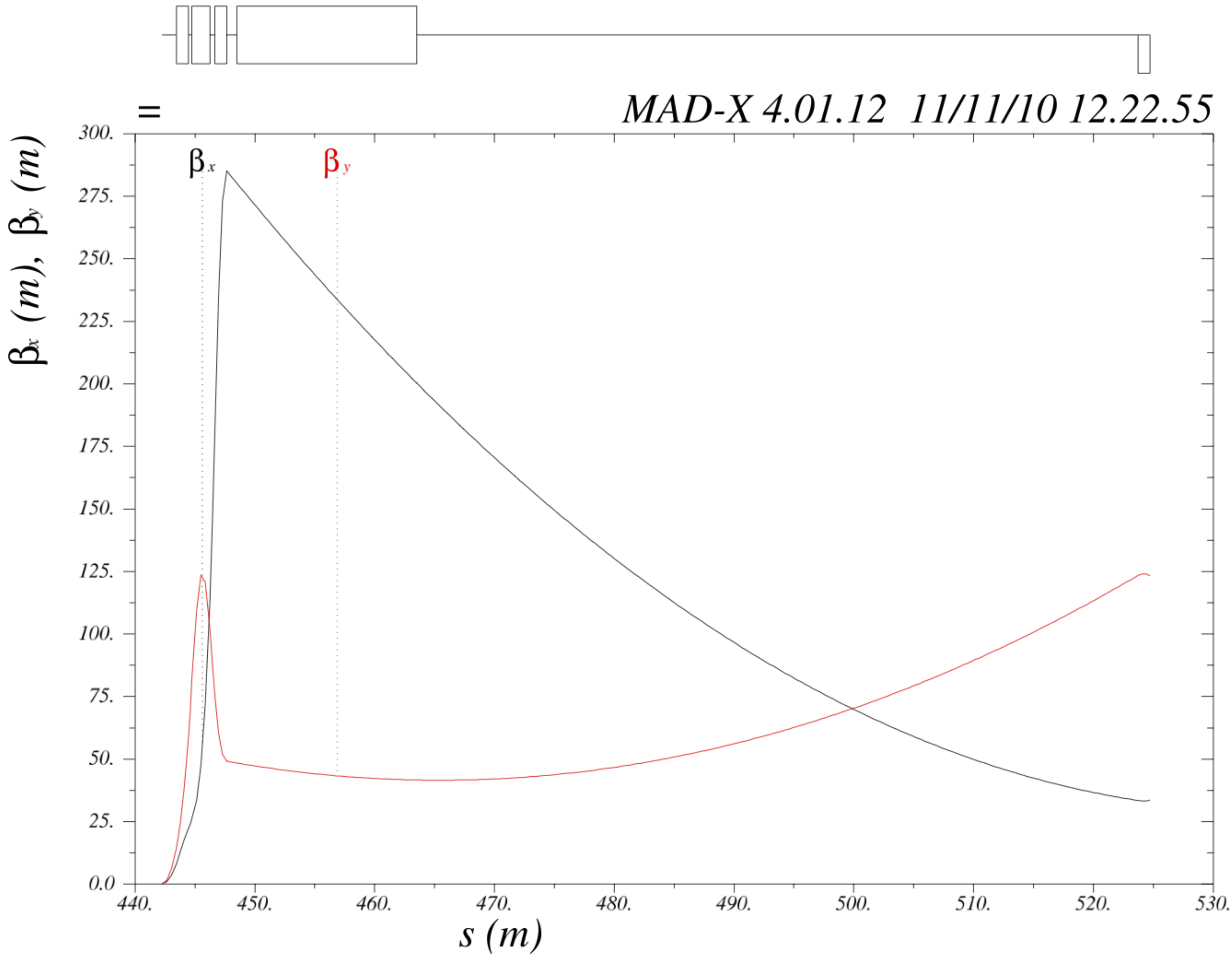
10° Solution - Plots



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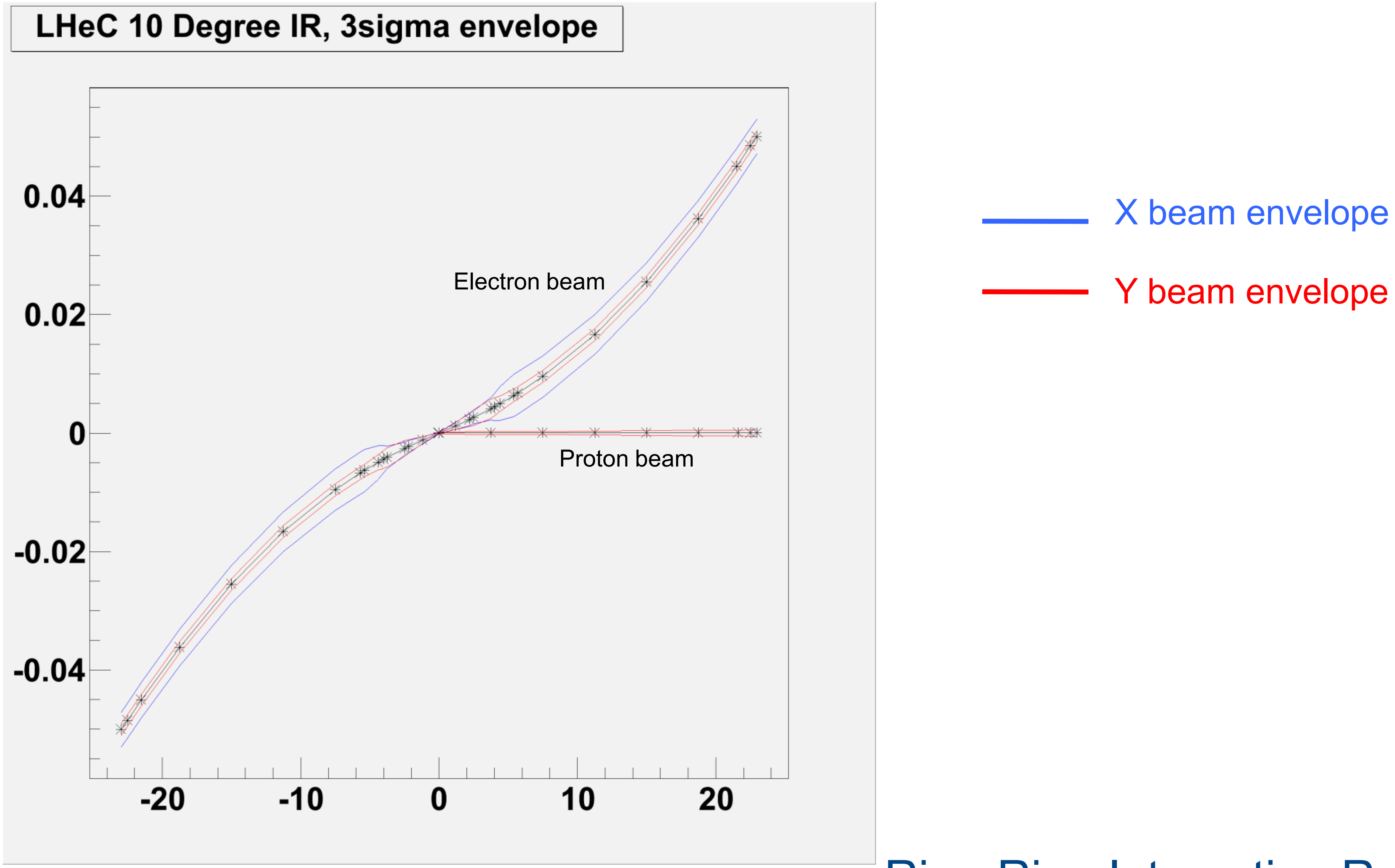
10° Solution - Separation

- FDF quad triplet
- Peak in β_x
  - $\beta_x = 285$ m
  - $S_{IP} = 5.4$ m
- Due to initial F quad, peak is later than in a DFD triplet
  - Separation does not suffer
  - Peak is between parasitic crossings
- First parasitic interaction after *l**
  - Minimum crossing angle dependent upon offset quadrupoles
  - No ‘absolute’ minimum angle
  - Some flexibility – 1 mrad chosen for reasonable SR

10° Solution - Separation



10° Solution - Parameters

***L*(0)**	**1.80x10^{33}**
θ_{IP}	1 mrad
$S(\theta)$	0.746
$L(\theta)$	1.34x10^{33}
β^*_x	0.18 m
β^*_y	0.1 m
l^*	1.2 m
ρ	8.0 km
SR Power	29 kW
SR E_c	124 keV

Note: 1 mrad is not the minimum θ_{IP} for this layout since this depends upon bend strength.

For this bend strength, θ_{min} ~ 0.9 mrad; however this would require increased bend strength to attain ~50 mm separation at s = 22.96 m.

With sufficient bend strength, θ_{min} = 0. However this would be infeasible in terms of SR.

Parameter Comparison

	1° IR Layout	10° IR Layout	Comments
L(0)	8.54x10^{32}	1.80x10^{33}	Factor of ~ 2.1
θ_{ip}	1 mrad	1 mrad	Not minimum angles
S(θ)	0.858	0.746	Lower for smaller beam spot
L(θ)	7.33x10^{32}	1.34x10^{33}	Factor of ~ 1.8
β^*_x	0.4 m	0.18 m	
β^*_y	0.2 m	0.1 m	
*l**	6.2 m	1.2 m	
ρ	4.6 km	8.0 km	More dipole length in 10°
SR Power	44 kW	29 kW	Without detector dipoles
[illegible]	[illegible]	[illegible]	[illegible]

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