

Transfer line from RR to P1 line for Mu2e Project

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Outline

- **Overview**
- **Design 1**
 - *Cartoon of the transfer line*
 - *Lattice functions matching*
 - *Matching parameters*
 - *3D plot of the transfer line*
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 - *Cartoon of the transfer line*
 - *Lattice functions matching*
 - *Matching parameters*
 - *3D plot of the transfer line*
- **Kicker @RR near Q520B**
- **Summary**

Overview the path of the beam transfer

--- The Mu2e project is planned to transfer the Booster beam not used by Nova into the Antiproton Source.

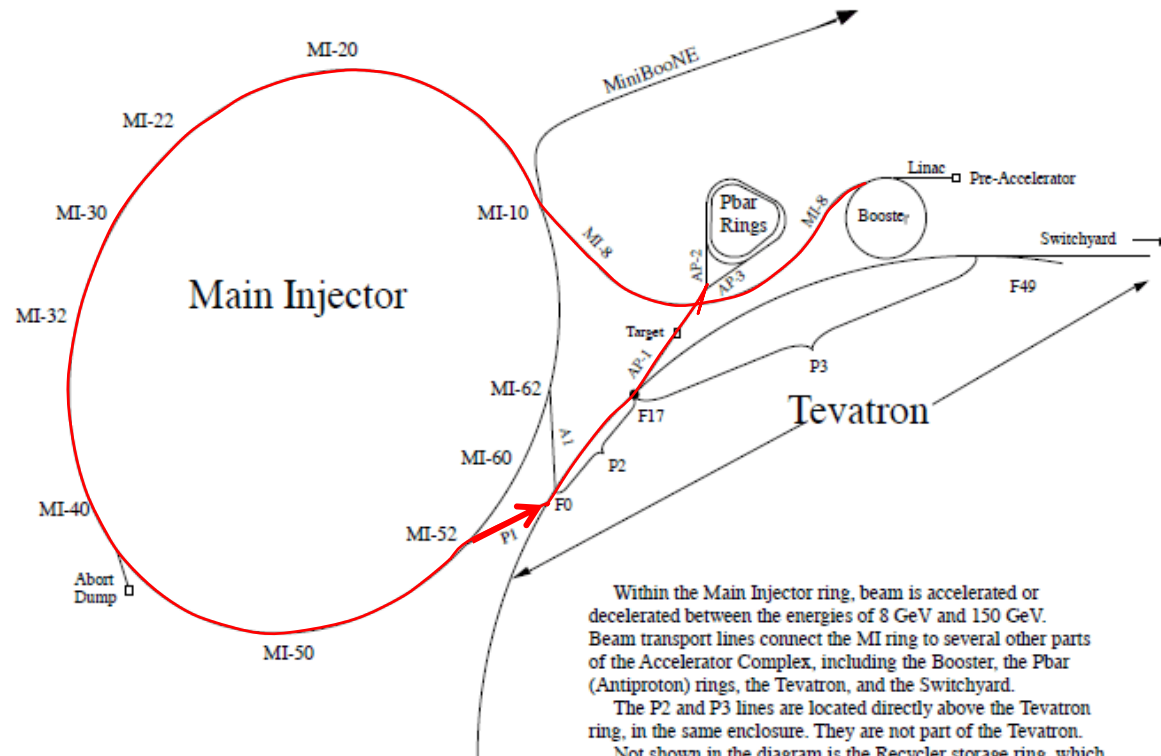


Fig. 1-1
Fundamental Geography
of the Main Injector

Within the Main Injector ring, beam is accelerated or decelerated between the energies of 8 GeV and 150 GeV. Beam transport lines connect the MI ring to several other parts of the Accelerator Complex, including the Booster, the Pbar (Antiproton) rings, the Tevatron, and the Switchyard.

The P2 and P3 lines are located directly above the Tevatron ring, in the same enclosure. They are not part of the Tevatron.

Not shown in the diagram is the Recycler storage ring, which is located directly above the Main Injector ring.

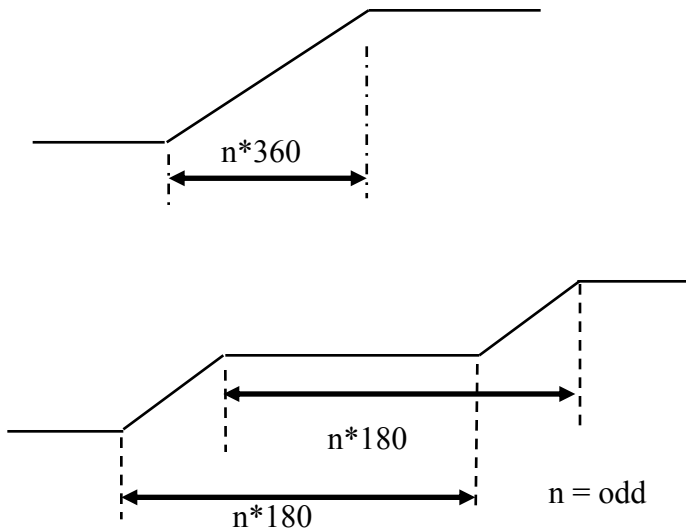
The distance between the Main Injector and Tevatron rings has been exaggerated in order to show the A1 and P1 lines more clearly.

General thoughts of the design

- The planes of injection/extraction

Horizontal kick and vertical bend: traditional kicker and Lambertson

- Generic features for vertical bending



A: Only two bend centers needed but they must be 360° apart.

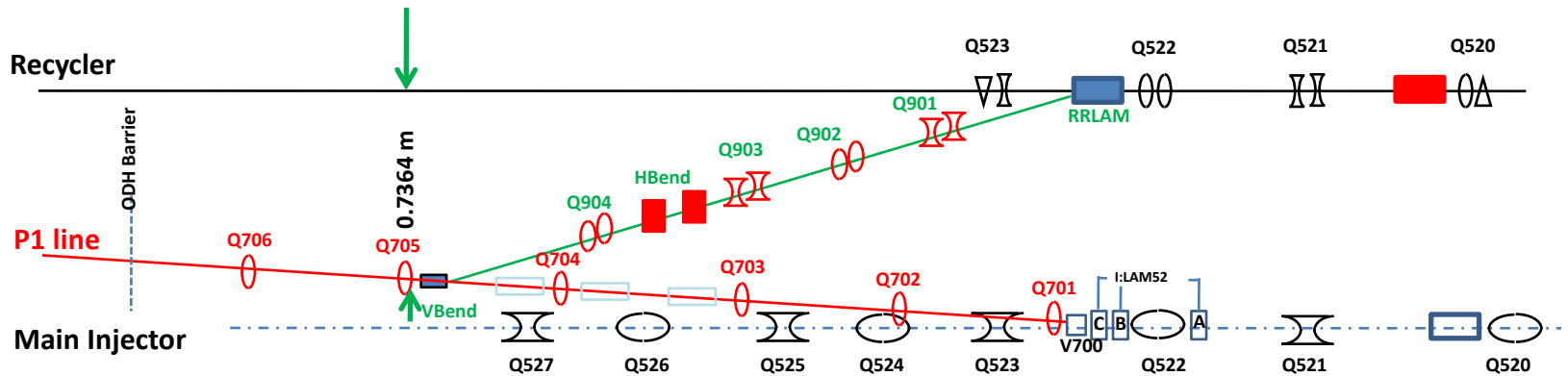
Will be utilized for new transfer lines.

B: Procedure used for MI \leftrightarrow Recycler transfers.

Requires 180° between two same sign bends

Use Lambertson, Quads and bending magnets available in Nova's infantry

Design 1: RR @Q522B→P150@Q705

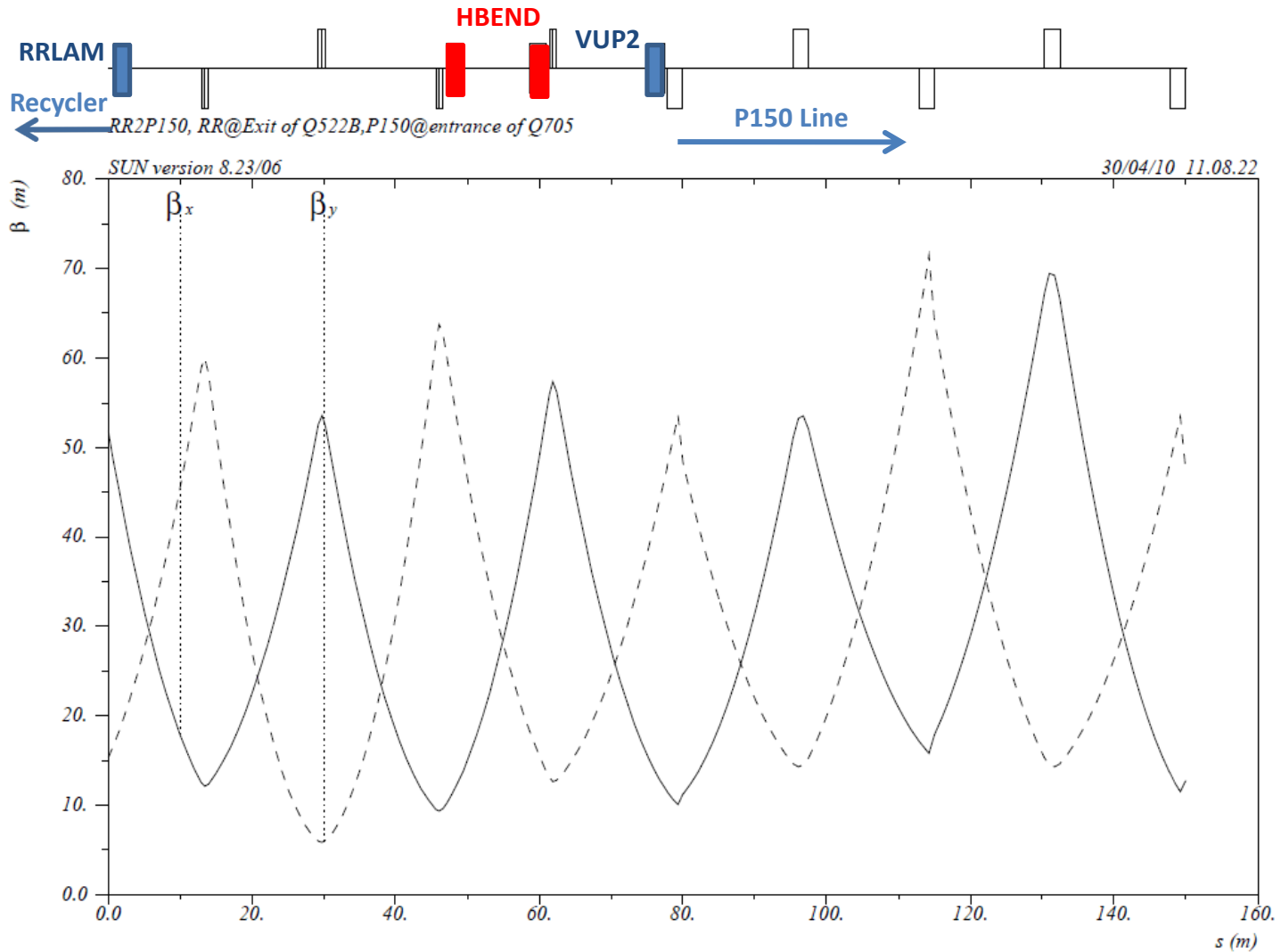


**Twiss functions and the site coordinates
at the exit of Q522B in RR and at the entrance of Q705 in P150 line**

	α_x	β_x	D_x	dD_x	α_y	β_y	D_y	dD_y
Extraction point	2.307	51.828	0.024	0.004	-0.911	15.257	0	0
Injection point@150GeV	0.530	11.699	-0.398	-0.021	-1.858	47.591	0.589	0.024

	$x(\text{East})$ [m]	$y(\text{North})$ [m]	$z(\text{Elevation})$ [m]	$BRNG$ [deg]	$PITCH$ [deg]	$ROLL$ [deg]
Q522B	31116.826516	29471.113031	219.575544	131.20636	0	0
SQ705U	31064.68059	29529.47085	218.8391336	133.35518	0.24167	0

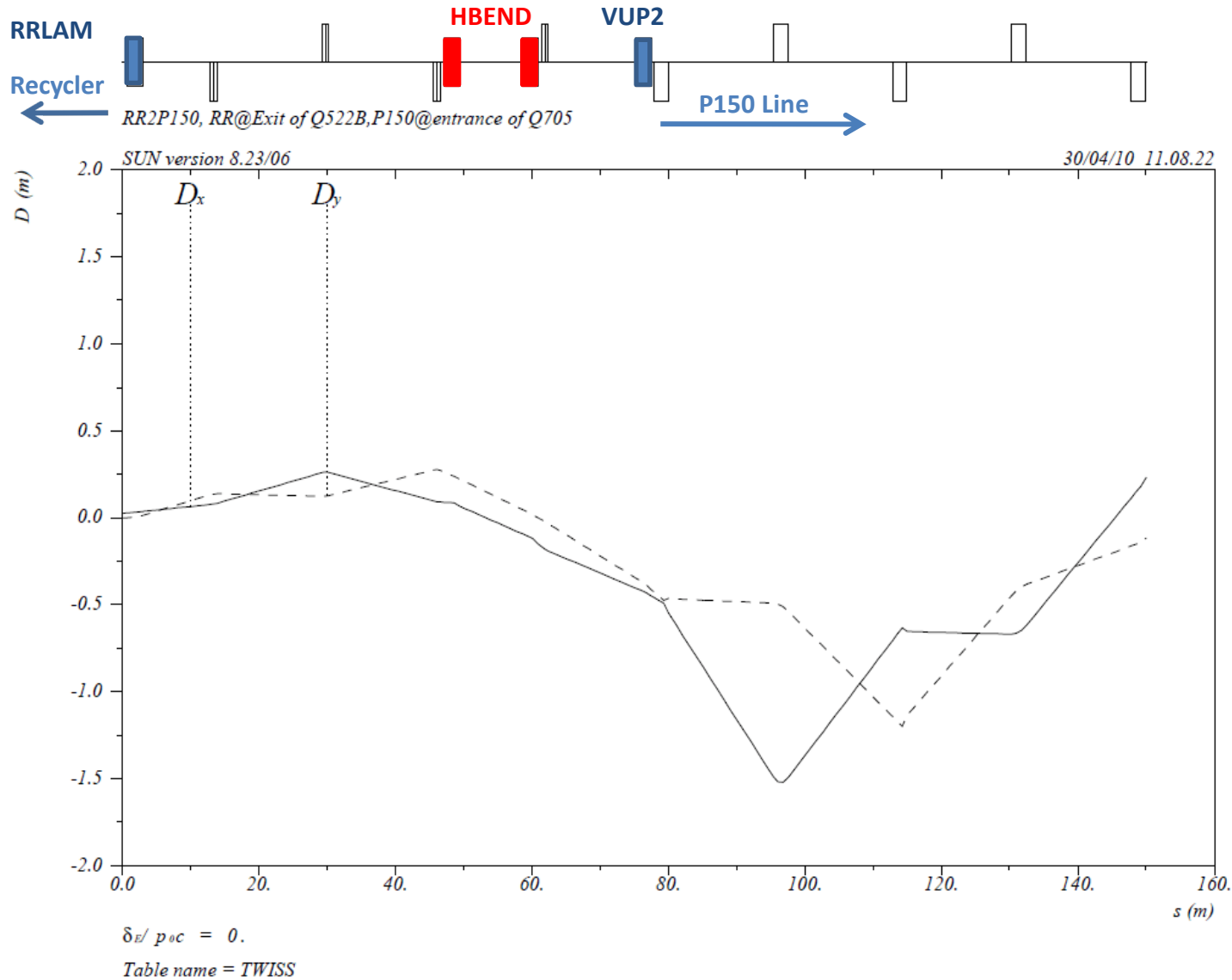
Design 1: Twiss functions match



$\delta_E / p_{oc} = 0.$

Table name = TWISS

Design 1: Dispersion functions propagate

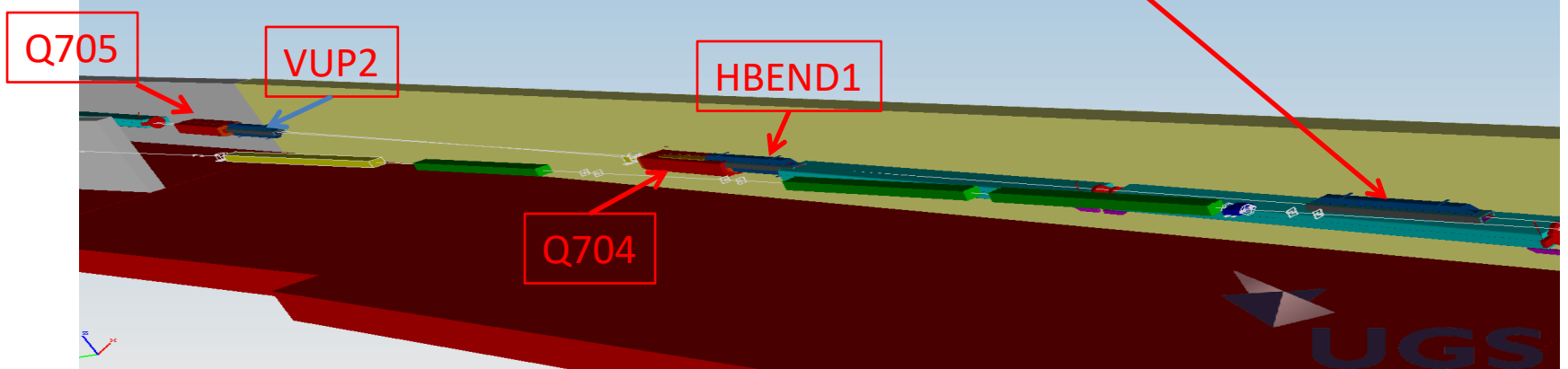
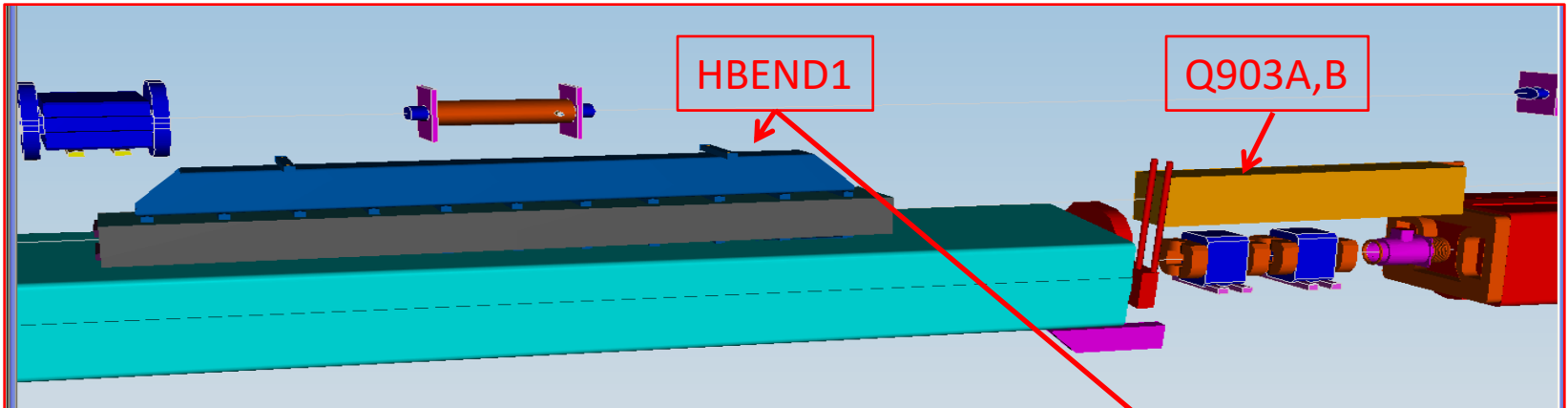
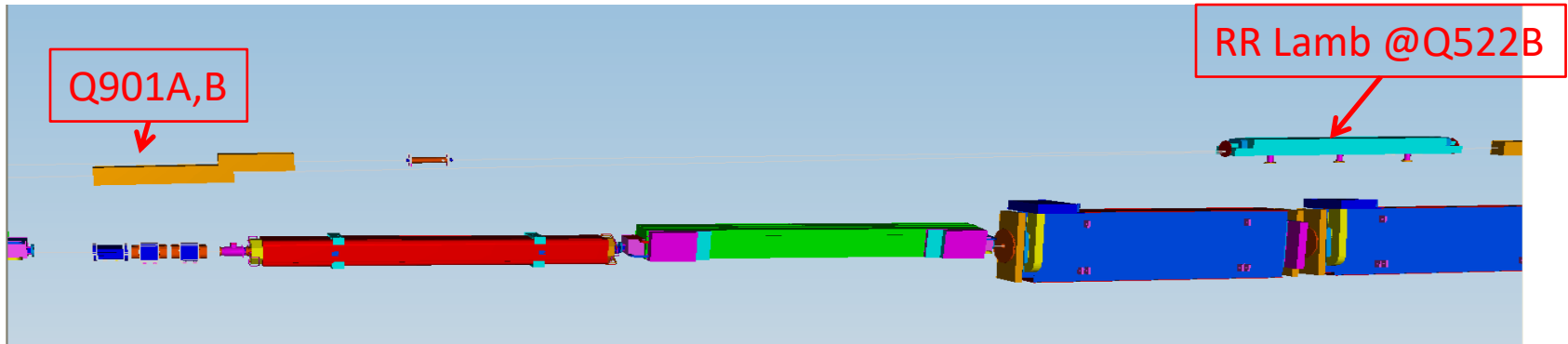


Design 1: matching parameters

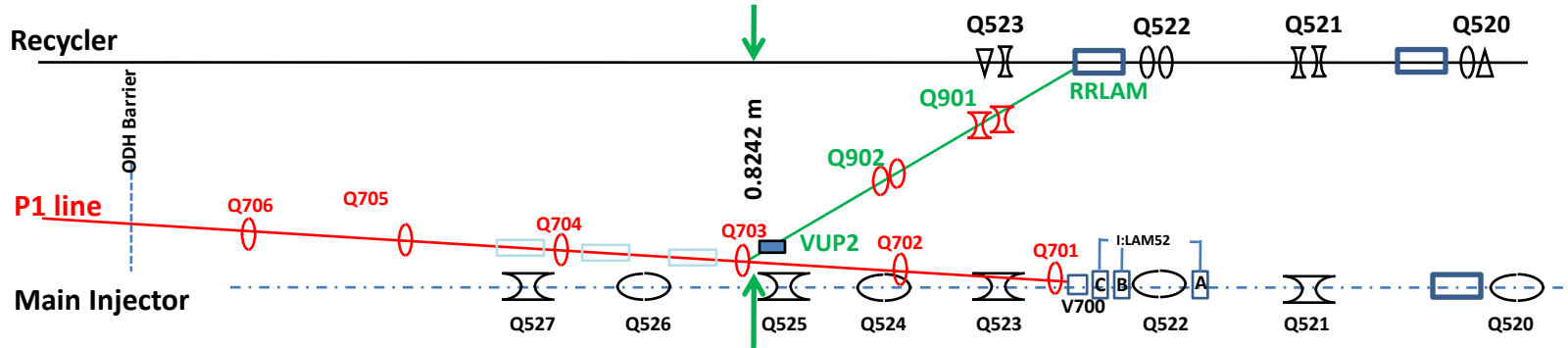
$$\left\{ \begin{array}{l} \mathbf{K1Q901A = K1Q901B = -9.322290E - 02} \\ \mathbf{K1Q902A = K1Q902B = 8.353879E - 02} \\ \mathbf{K1Q903A = K1Q903B = -9.191766E - 02} \\ \mathbf{K1Q904A = K1Q904B = 8.587336E - 02} \end{array} \right.$$

$$\left\{ \begin{array}{l} \mathbf{VANG = 11.9078 \text{ mrad(Vertical bending angle)}} \\ \mathbf{HANG = -15.47970 \text{ mrad(Horizontal bending angle)}} \\ \mathbf{HROLL = 0.1990\text{rad} = 11.40^\circ \text{ (Roll angle of Horizontal bending magnets)}} \\ \mathbf{VROLL = -0.5739\text{rad} = -32.88^\circ \text{ (Roll angle of vertical bending magnet)}} \end{array} \right.$$

3D plot: RR to P150 line



Design 2: : RR @Q522B→P150@Q703

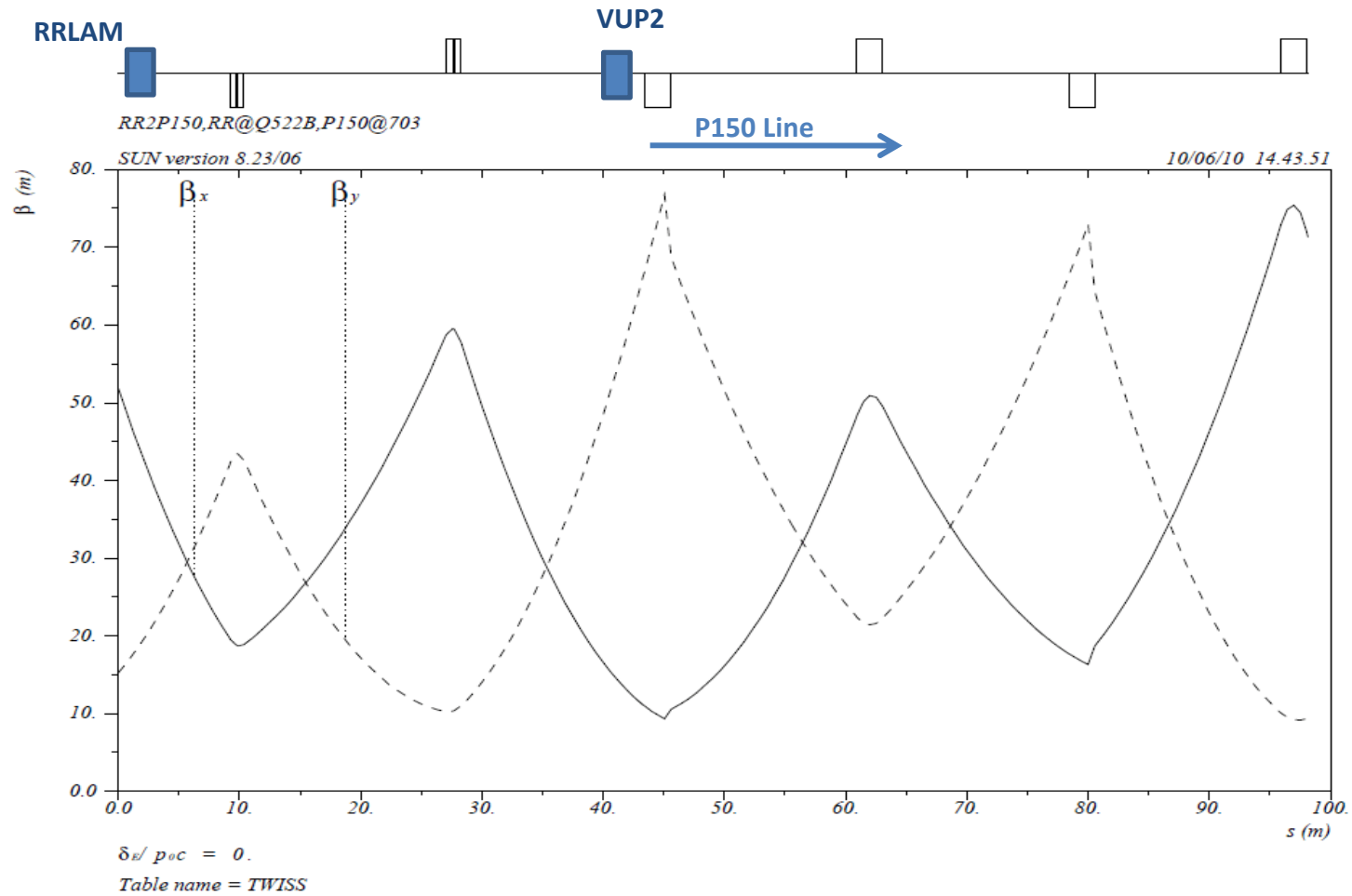


**Twiss functions and the site coordinates
at the exit of Q522B in RR and at the entrance of Q705 in P150 line**

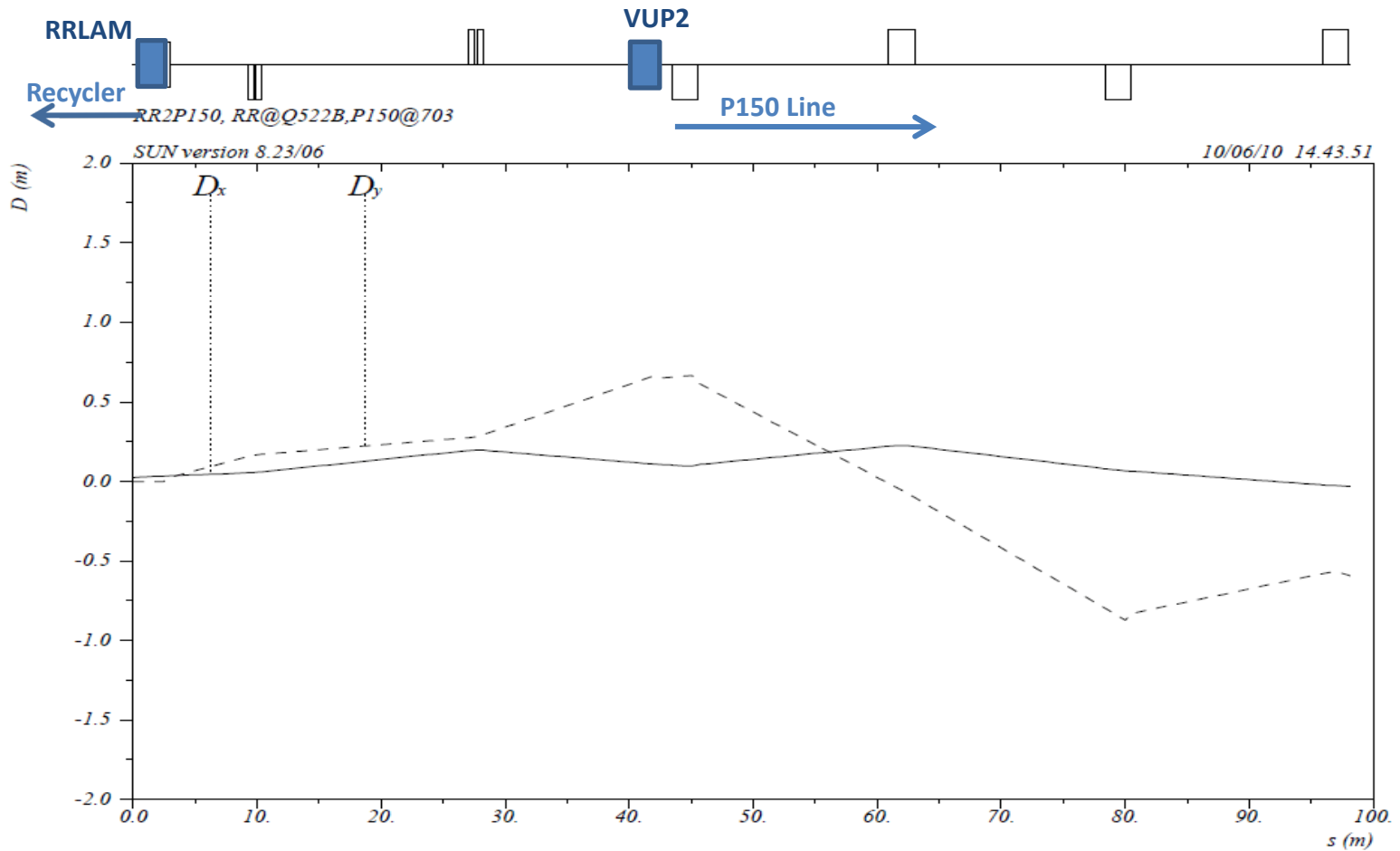
	α_x	$B_x(m)$	$D_x(m)$	dD_x	α_y	$\beta_y(m)$	$D_y(m)$	dD_y
Extraction point	2.307	51.828	0.024	0.004	-0.911	15.257	0	0
Injection point@150GeV	0.618	11.115	0.013	0.001	-2.915	66.278	-0.043	0.007

	$x(East)$ [m]	$y(North)$ [m]	$z(Elevation)$ [m]	$BRNG$ [deg]	$PITCH$ [deg]	$ROLL$ [deg]
Q522B	31116.826516	29471.113031	219.575544	131.20636	0	0
SQ703U	31088.24757	29503.6478	218.751311	131.20619	0.1885	0

Design 2: Twiss functions match



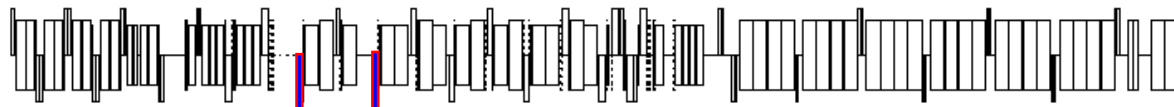
Design 1: Dispersion functions propagate



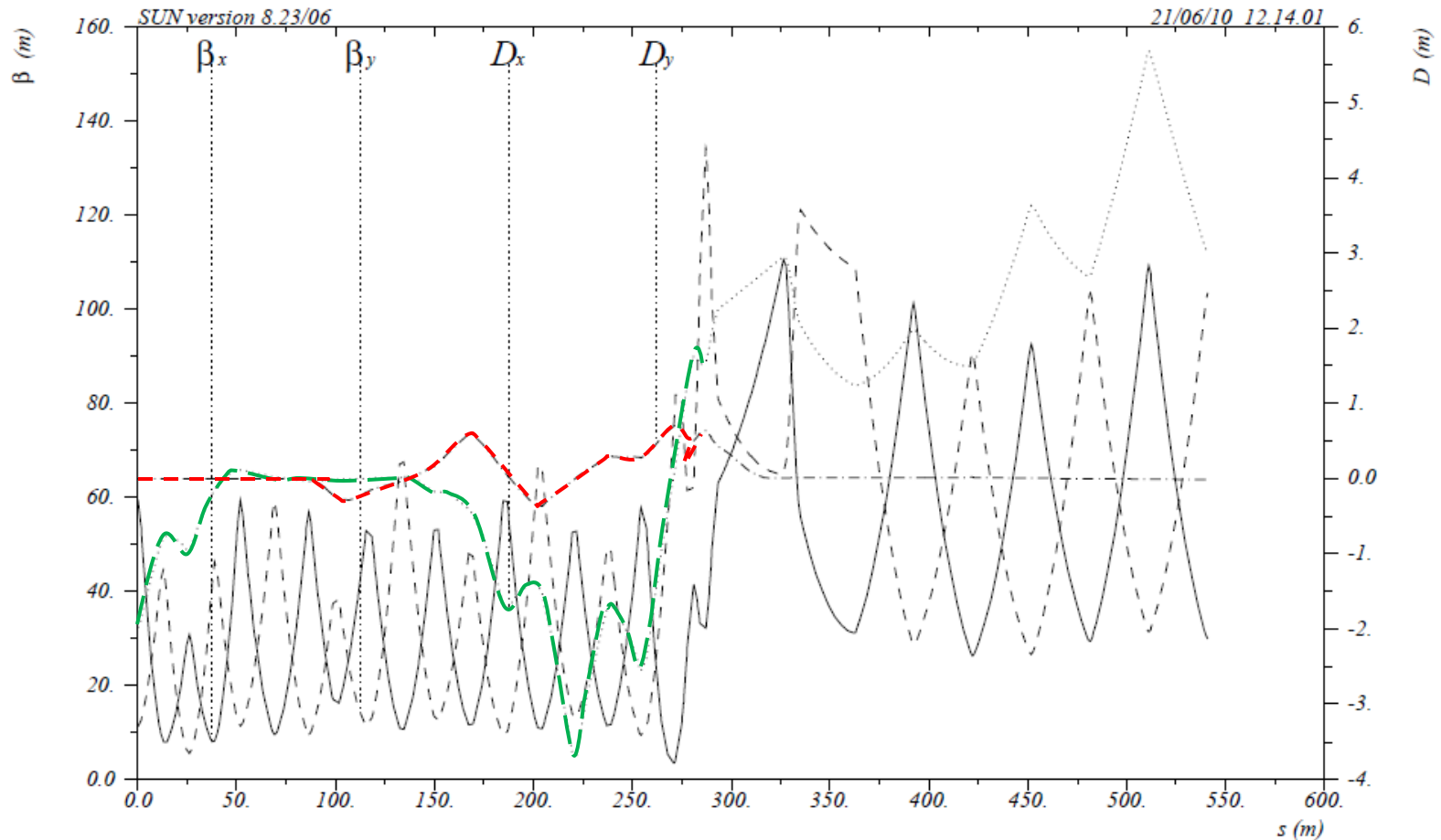
$\delta_s / p_{oc} = 0.$

Table name = TWISS

Lattice function @Existing P1 line@150GeV



P1 roll 3,5,7,9 match @ HV9092 SOL 4
trunc
Q703 Q705



$\delta_E / p_{0c} = 0.$

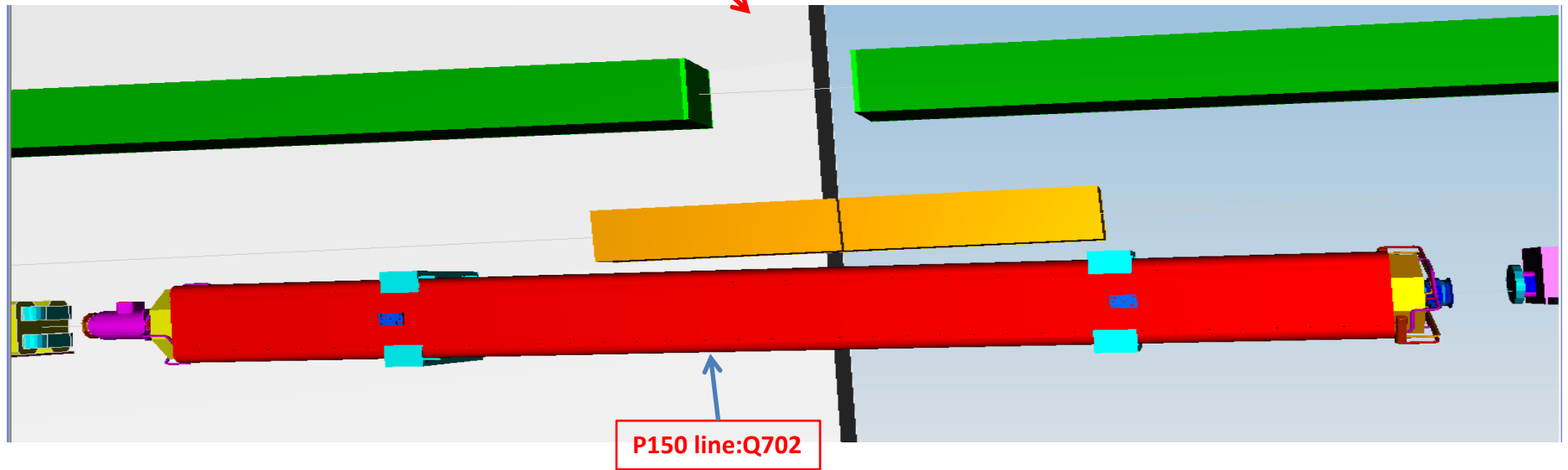
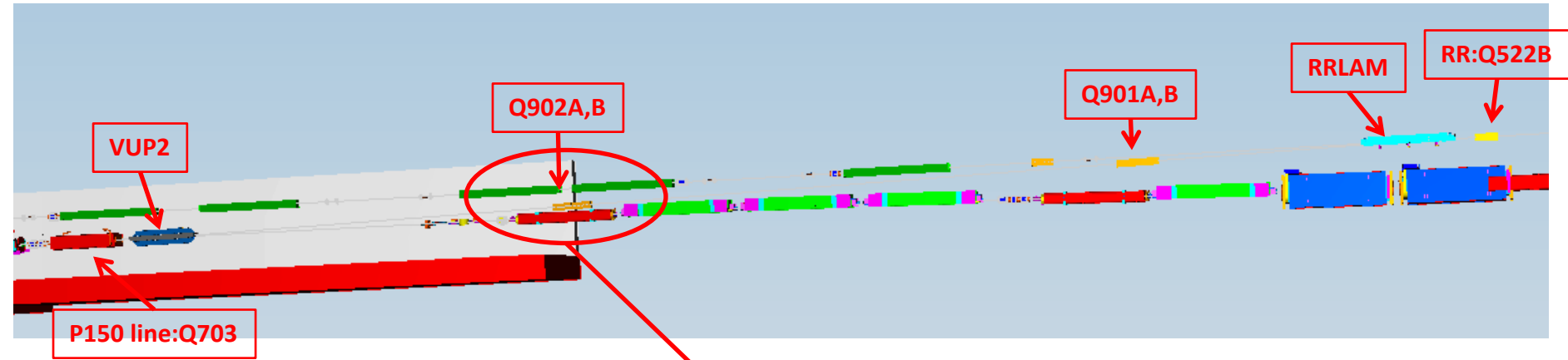
Table name = SIZE

Design 2: matching parameters

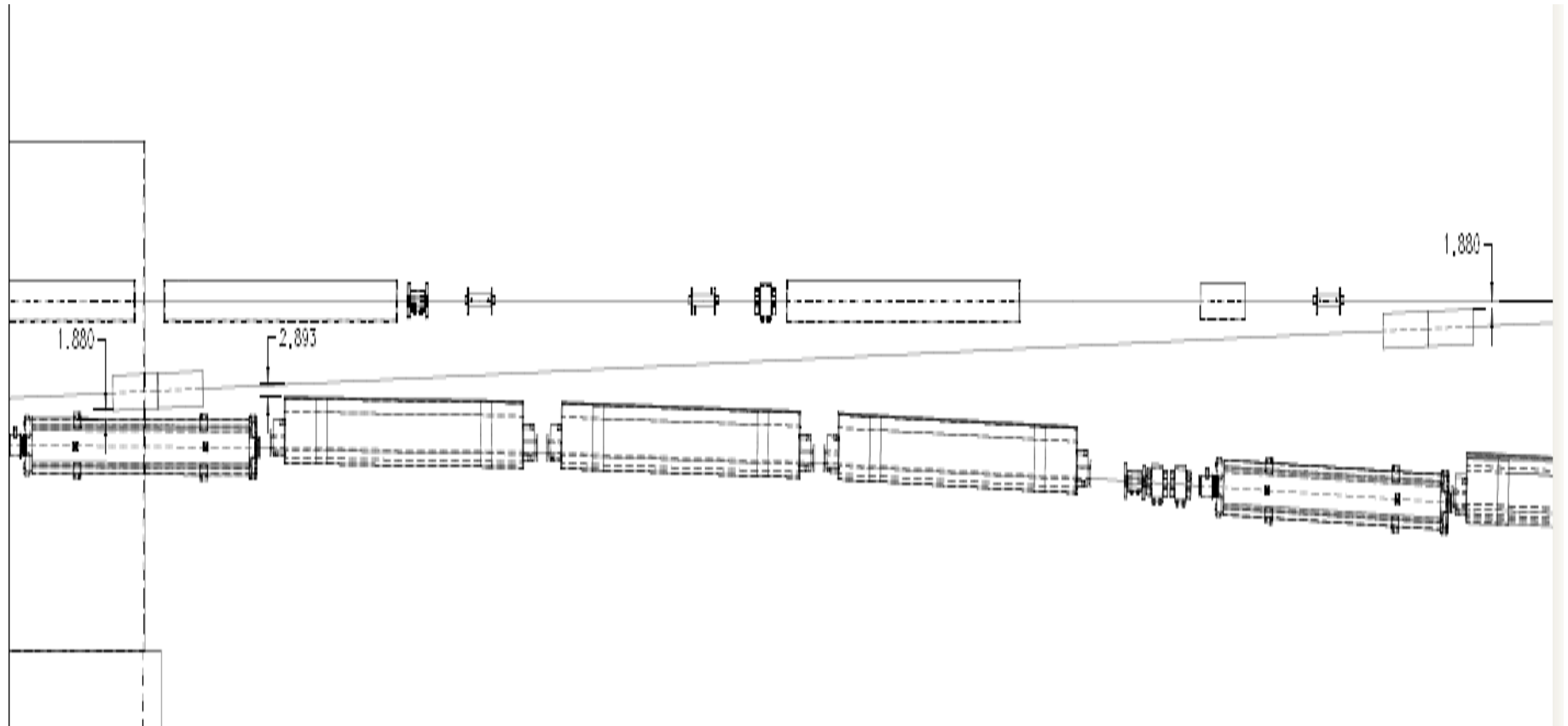
$$\begin{cases} \mathbf{K1Q901A = K1Q901B = -0.08847728} \\ \mathbf{K1Q902A = K1Q902B = 0.07210001} \end{cases}$$

$$\begin{cases} \mathbf{VANG = 20.9964 \text{ mrad (Vertical bending angle)}} \\ \mathbf{RLROLL = 0.047193671 \text{ rad} = 2.7^\circ \text{ (Roll angle of RR lambertson)}} \\ \mathbf{VROLL = -0.069245109 \text{ rad} = -3.97^\circ \text{ (Roll angle of vertical bending magnet)}} \end{cases}$$

3D plot: RR to P150 line @Q703



2D project view for the line of RR to P150 line @Q703



Kicker@RR Q520B

- Similar to the kicker design for Nova @R232
- the bump size at RR lambertson is +25 mm
- the separation of the center orbits at the lambertson between circulate beam and the extracted beam is 50 mm.

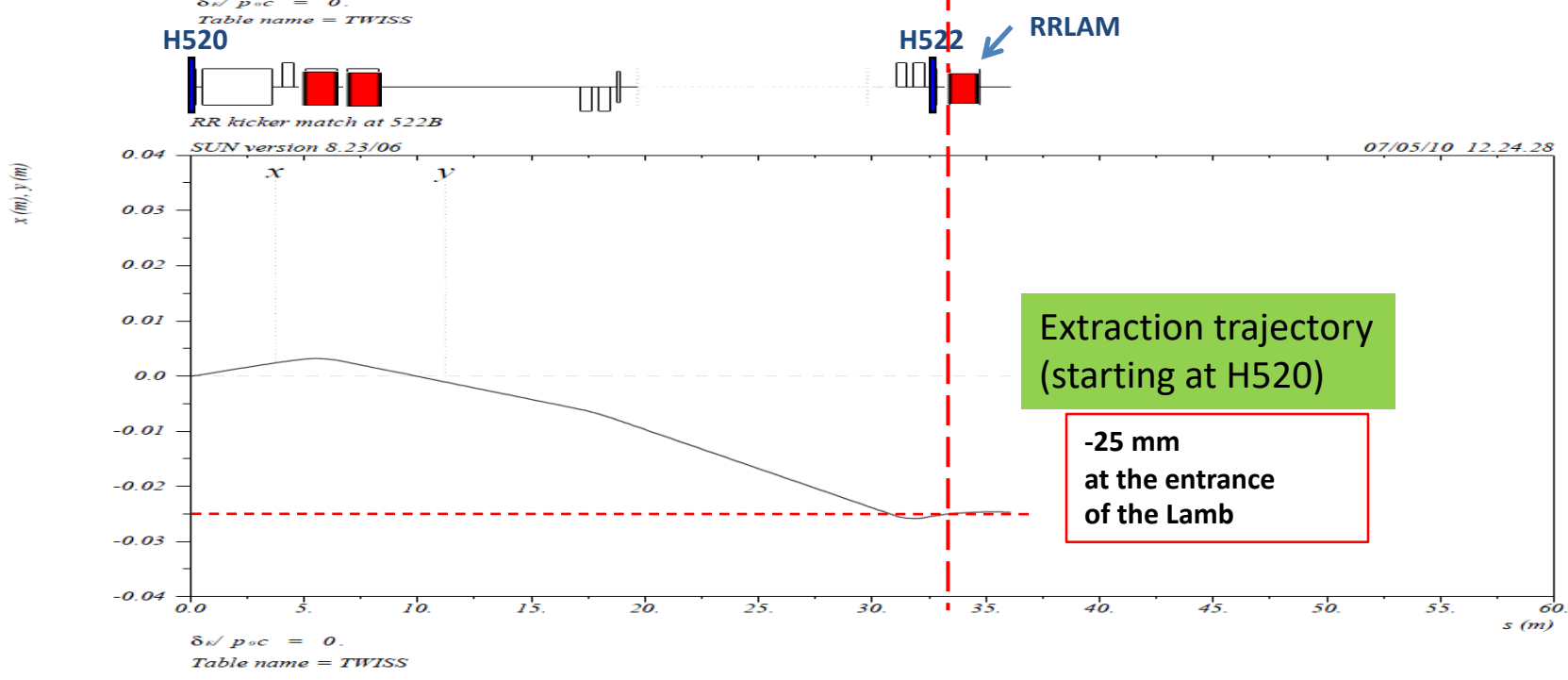
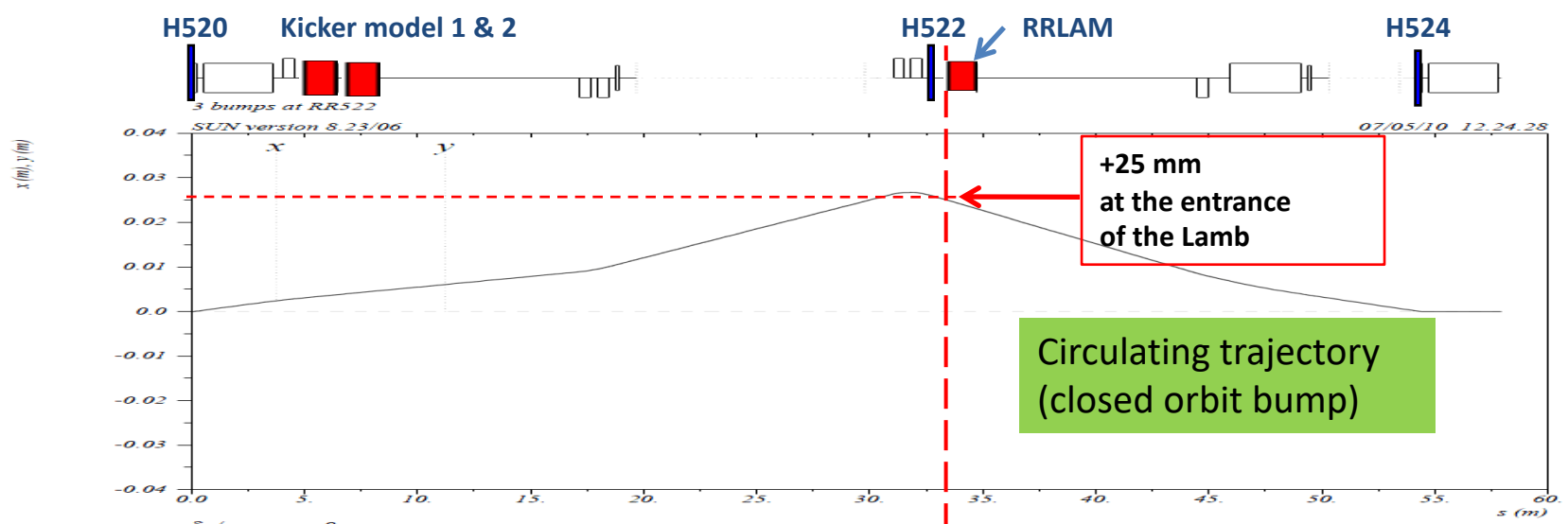
$$\begin{cases} \text{HK524} = 7.514117\text{E} - 04 \\ \text{HK522} = -3.865025\text{E} - 04 \\ \text{HK520} = 6.951826\text{E} - 04 \end{cases}$$

Borrow the same kicker module used in Nova, the kicker strength obtained is:

$$\text{K522B_ang} = -1.317214\text{E}-03$$

It is equivalent to: $\text{K522B_ang} * (B\rho) = 390.563 \text{ Gaussian/m}$

Just for the reference, the RR extraction kicker for Nova at 232 is 358 Guassian/m



Summary

- Preliminary design was done.
- Site coordinates were fitted in detail from RR to P150 line @Q703
- 3D models have been constructed for the transfer line to make sure there are no magnet interferences with the other beam lines.
- Apertures will be checked soon
- Survey/Stakeout file can be generated for Survey group if needed.