

# LHC phase 1 upgrade: apertures

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# Motivation <sup>1</sup>

Triggered by a remark by S.Fartoukh who observed aperture limitations for current layout with  $\beta^*$  reduced to 0.25m (report in preparation), it has been raised the necessity to:

Identify whether the insertion magnets are compatible with the new optics as they are installed.

Check if the aperture requirements for the large aperture magnets are fulfilled.

Results are still preliminary. An aperture model for D1 and D2 is not included yet.

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<sup>1</sup>Many thanks to S. Fartoukh and W. Herr for the main ideas and contributions concerning aperture modeling and crossing scheme optimization.

Common methods:

Thick optics for beam 1 and beam 2. Aperture model defined by V6.501 database (machine as installed). MadX aperture parameter:

```
offsetelem=of/offset_ir1_b1  
cor=0.003  
dp=0.00086  
interval=1.0
```

# Nominal LHC

Name	Length	Start p.	Gradient
	[m]	[m]	[T/m]
MQXA.1R5	6.37	22.965	203.718
MQXB.A2R5	5.5	32.05	-203.718
MQXB.B2R5	5.5	38.55	-203.718
MQXA.3R5	6.37	46.965	203.718

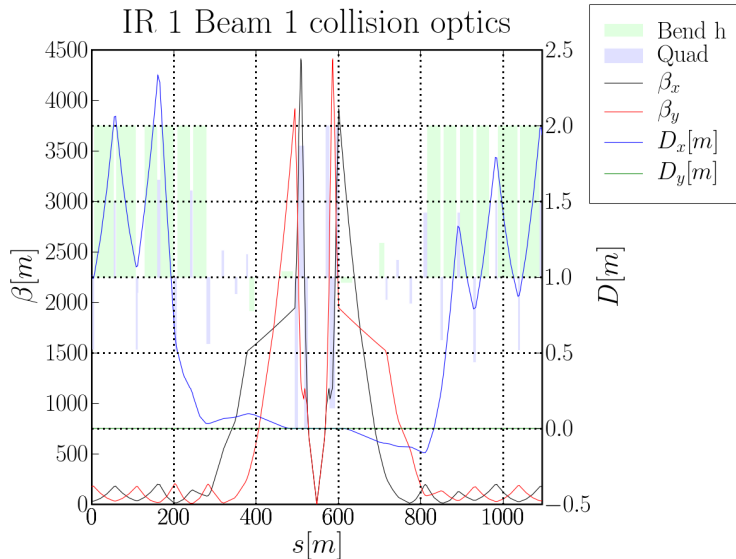
Name	Beta max	Sigma	Beam size*	Coil diam.*
	[m]	[mm]	[mm]	[mm]
MQXA.1R5	2090.73	1.02513	55.8294	63.8137
MQXB.A2R5	4341.9	1.47731	70.7511	63.8137
MQXB.B2R5	4401.74	1.48745	71.0859	63.8137
MQXA.3R5	3908.49	1.40164	68.254	63.8137

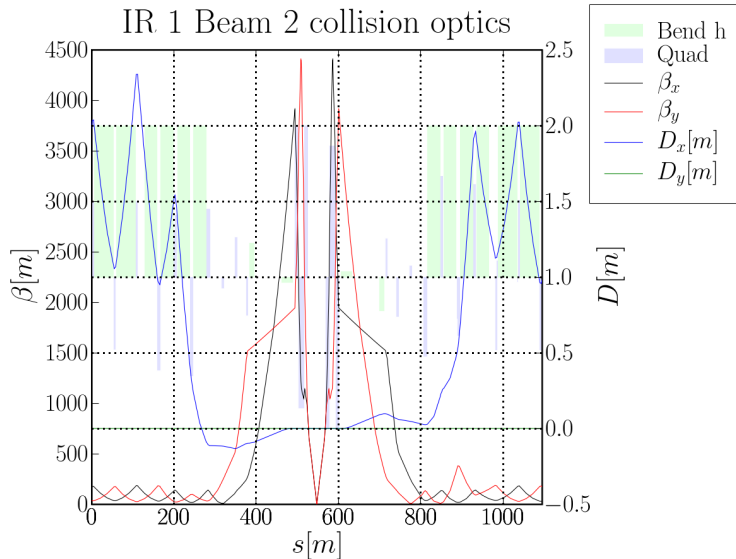
\* Beam size =  $33\sigma + 22\text{mm}$ , Coil diam. =  $2 * 6.5\text{T} / \text{gradient}$

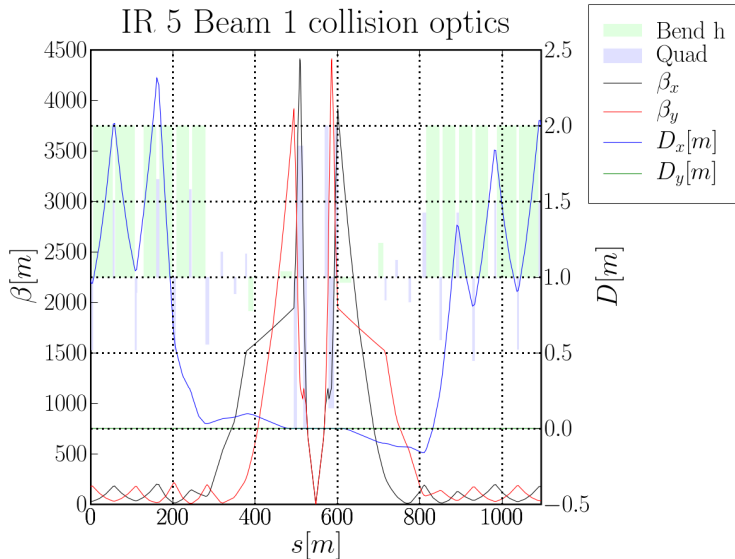
# Nominal LHC aperture model

## Aperture of the final focus

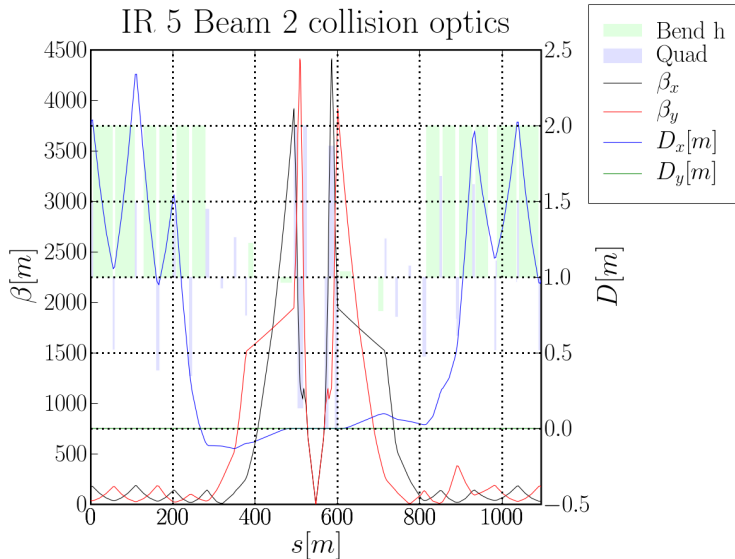
Magnet	Coil D	rect_x	rect_y	tol_r	tol_g	tol_s
MQXA.1R1	0.070	0.01895	0.02385	0.00130	0.00100	0.00100
MQXA.1R5	0.070	0.02385	0.01895	0.00130	0.00100	0.00100
MQXB.B2R1	0.070	0.02400	0.02890	0.00090	0.00060	0.00000
MQXB.A2R5	0.070	0.02890	0.02400	0.00090	0.00000	0.00060



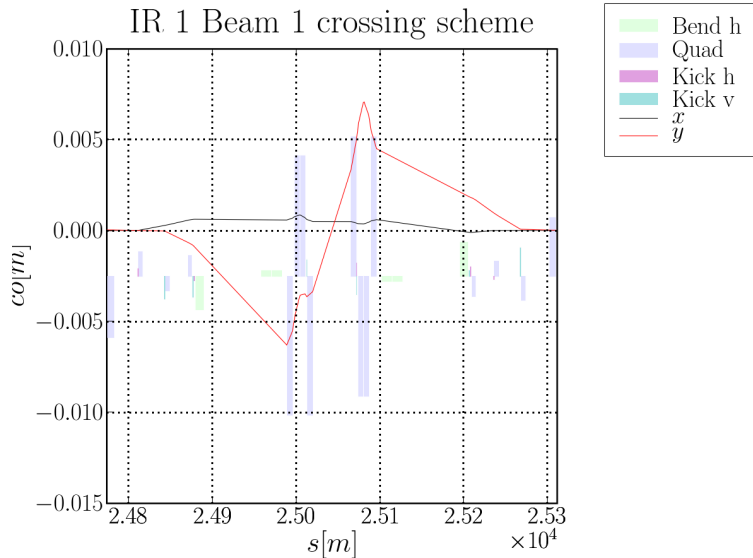


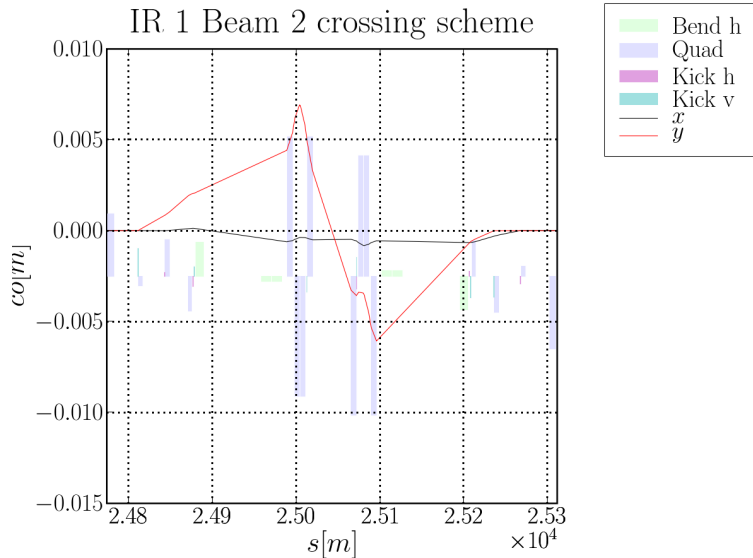


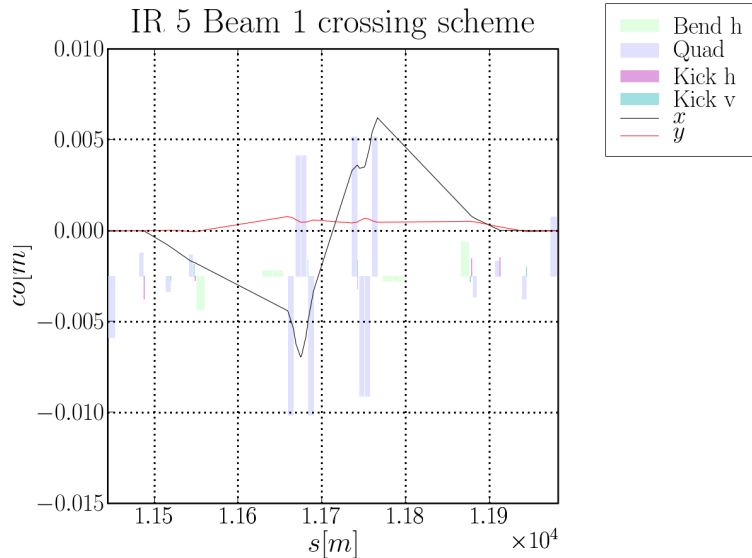


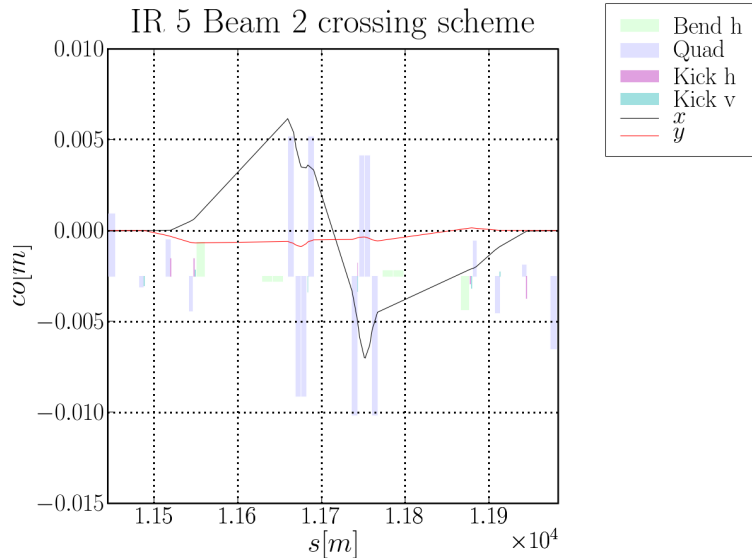


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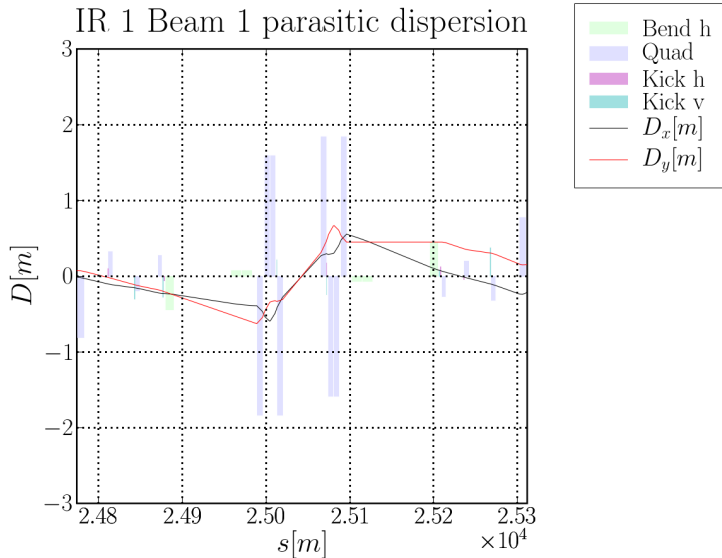


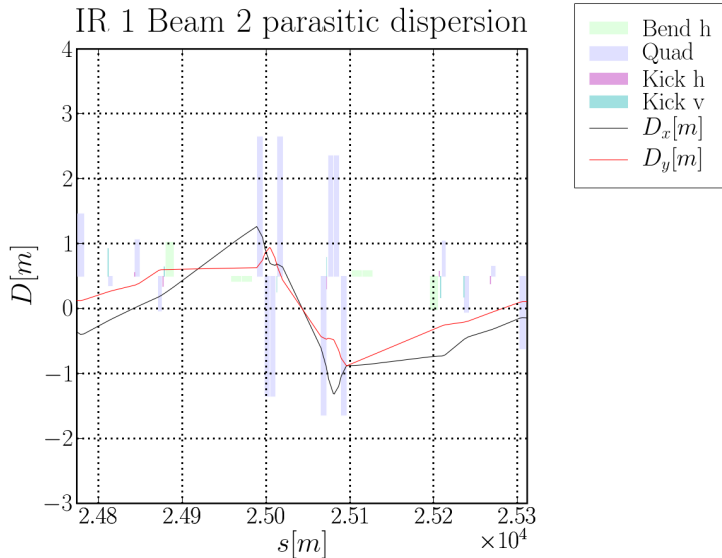


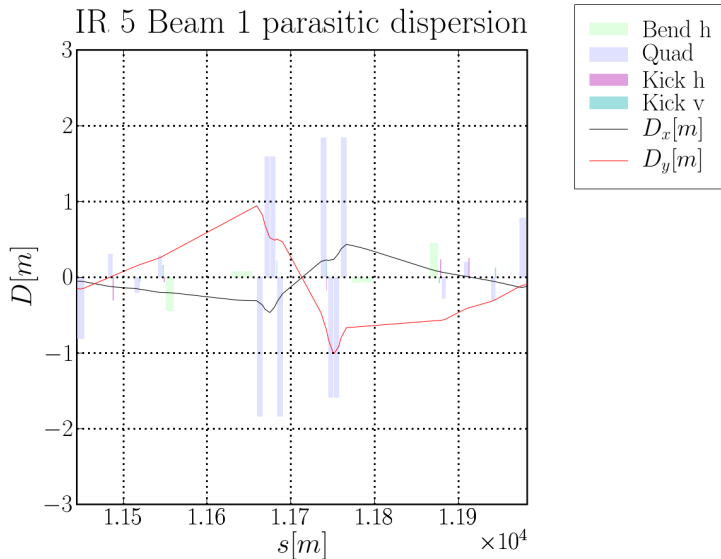




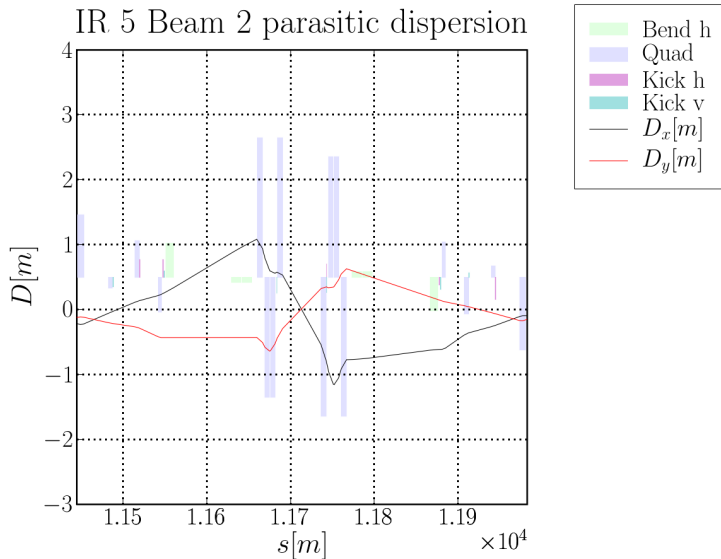
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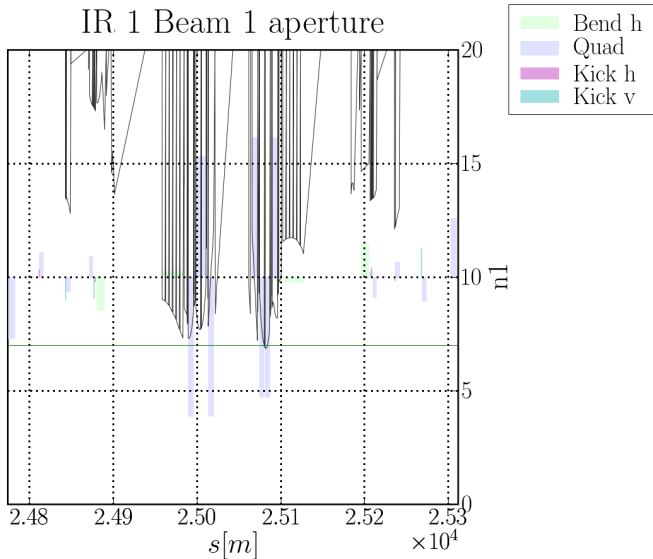


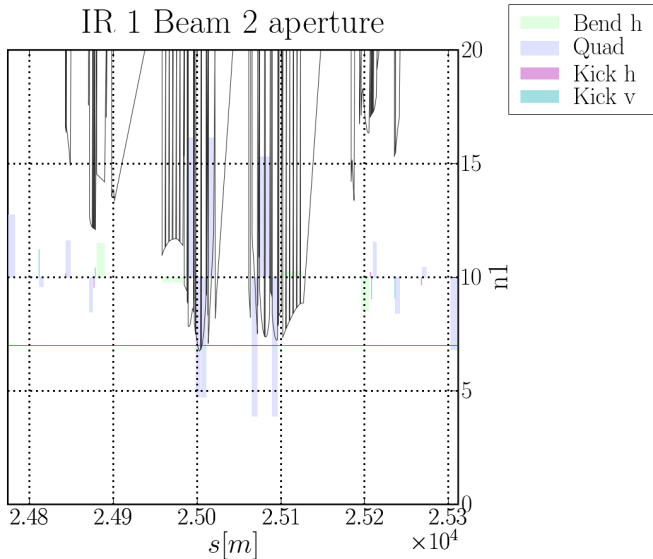


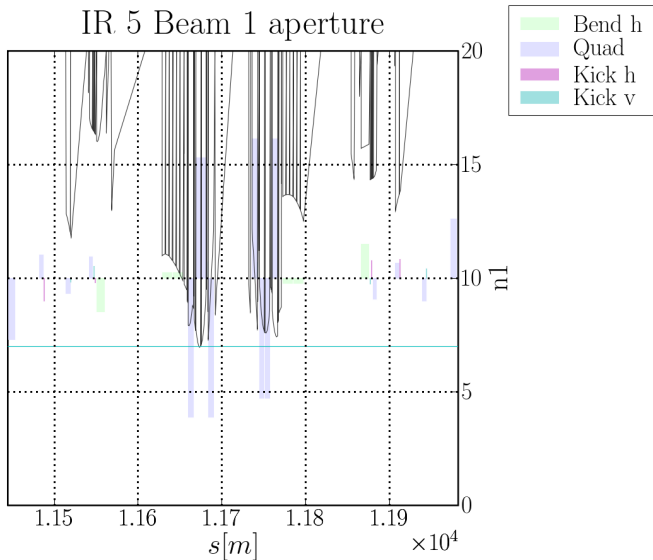


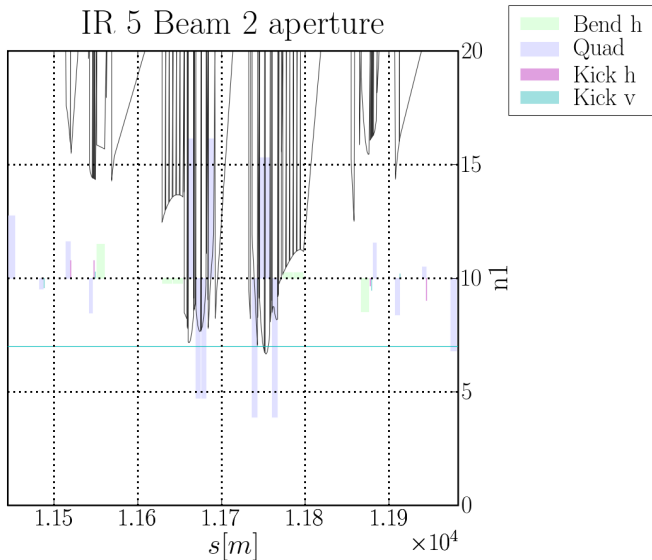












# Lowbetamax

Name	Length	Start p.	Gradient
	[m]	[m]	[T/m]
MQXN1.R5.B1	7.485	24	167.677
MQXN2.R5.B1	5.753	32.912	-121.795
MQXN3.R5.B1	5.753	39.665	-121.795
MQXN4.R5.B1	5.753	46.418	-121.795
MQXN5.R5.B1	4.89	53.37	121.795
MQXN6.R5.B1	4.89	59.27	121.795

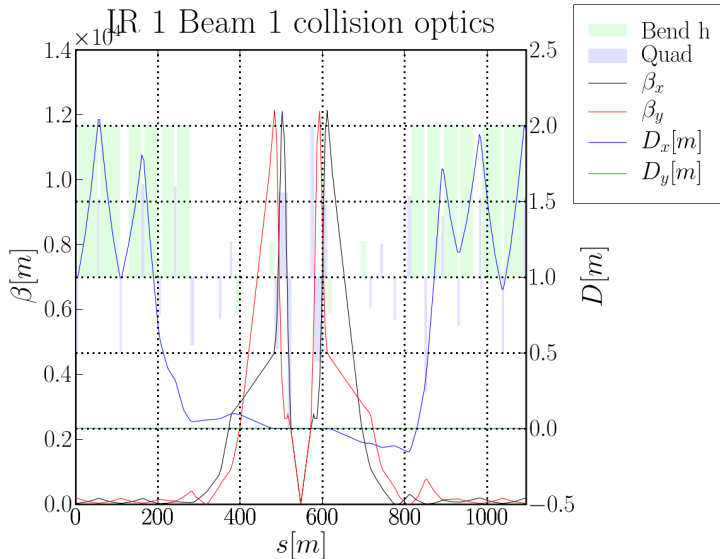
Name	Beta max	Sigma	Beam size*	Coil diam.*
	[m]	[mm]	[mm]	[mm]
MQXN1.R5.B1	5473.23	1.65864	76.7352	77.5299
MQXN2.R5.B1	10681.1	2.31707	98.4634	106.736
MQXN3.R5.B1	12080	2.46414	103.317	106.736
MQXN4.R5.B1	11878.2	2.44347	102.634	106.736
MQXN5.R5.B1	10963.7	2.34752	99.4681	106.736
MQXN6.R5.B1	12118.1	2.46801	103.444	106.736

\* Beam size =  $33\sigma + 22\text{mm}$ , Coil diam. =  $2 * 6.5\text{T} / \text{gradient}$

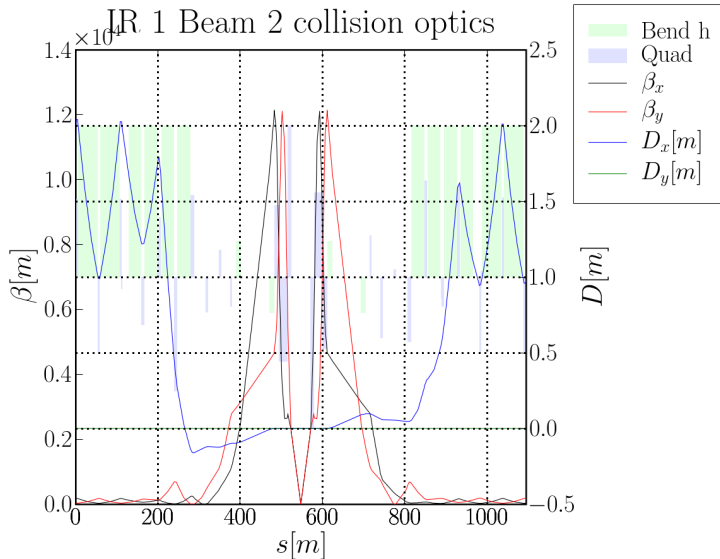
## Lowbetamax aperture model

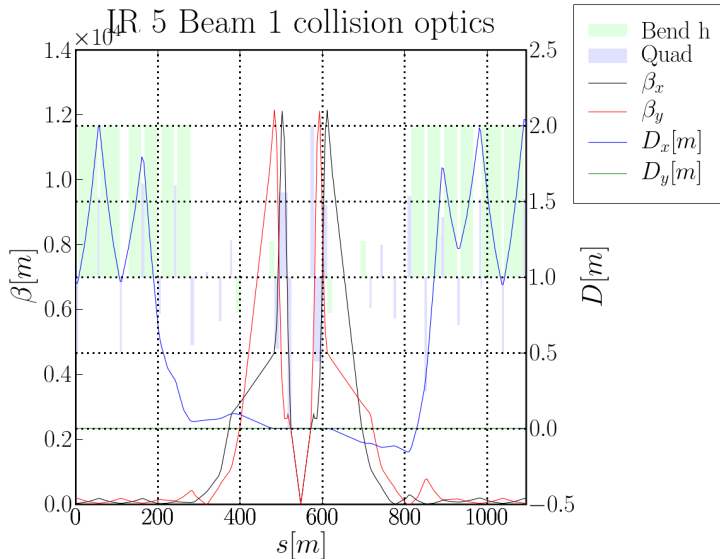
Aperture of the final focus:  $\text{gap}=\text{d}/2-11\text{mm}$ ,  $\text{rad}=\text{d}/2-6\text{mm}$

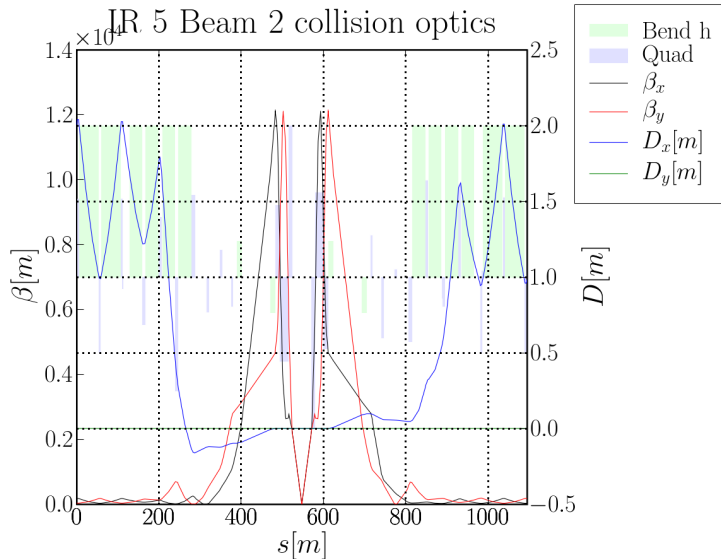
Magnet	Coil D	rect_x	rect_y	tol_r	tol_g	tol_s
MQXN1.R1.B1	0.090	0.03400	0.03900	0.00000	0.00000	0.00000
MQXN1.R5.B1	0.130	0.03900	0.03400	0.00000	0.00000	0.00000
MQXN2.R1.B1	0.130	0.05400	0.05900	0.00000	0.00000	0.00000
MQXN2.R5.B1	0.130	0.05900	0.05400	0.00000	0.00000	0.00000



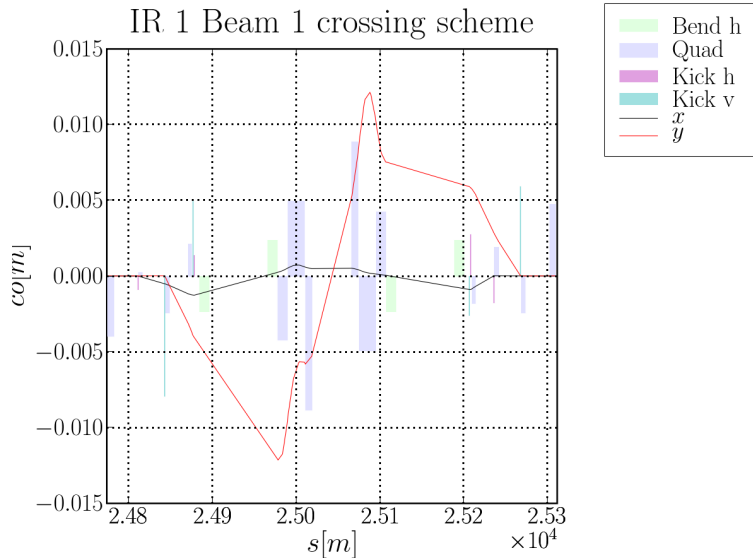


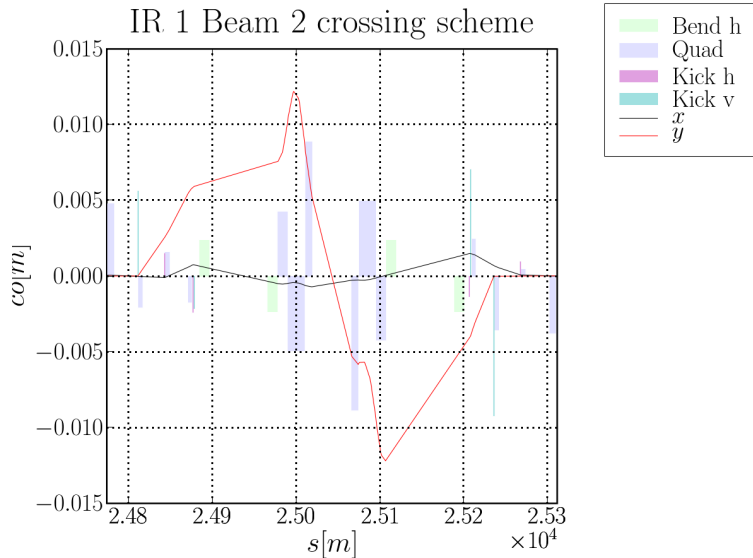


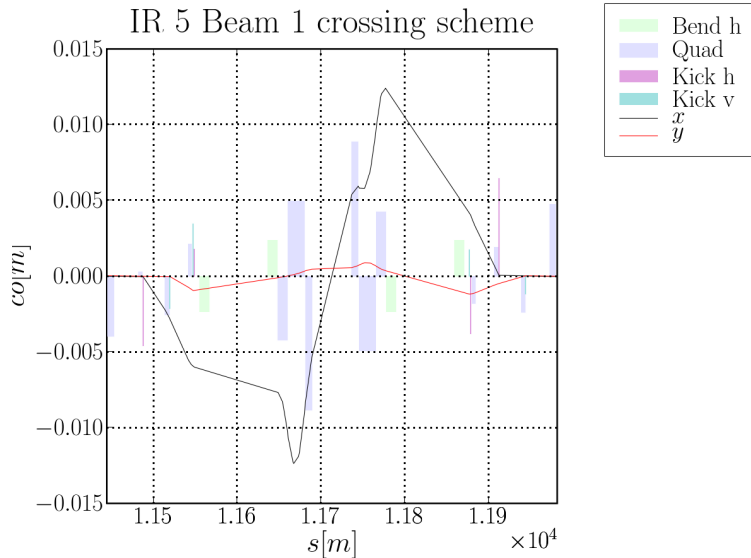


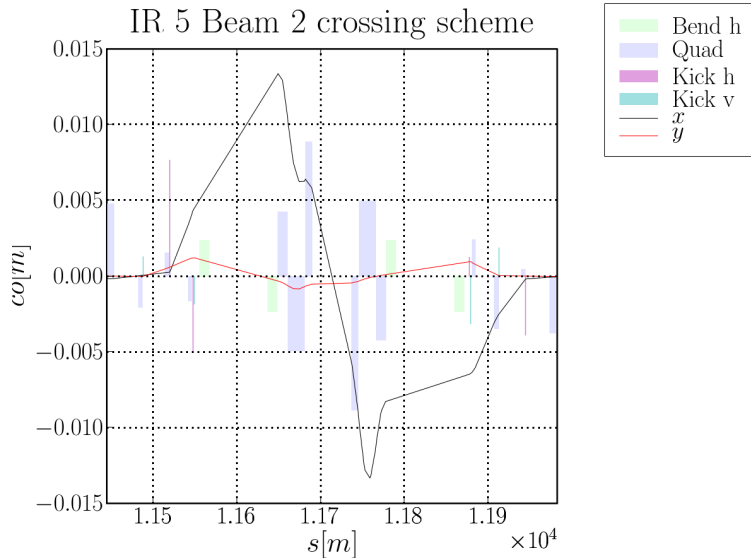


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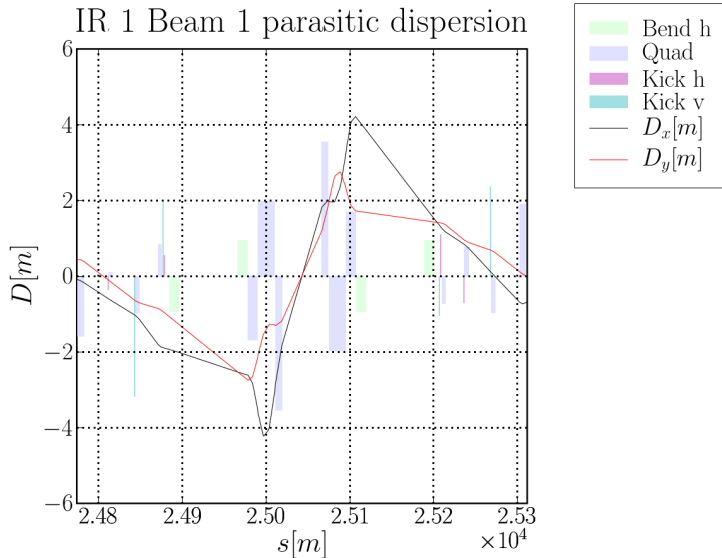




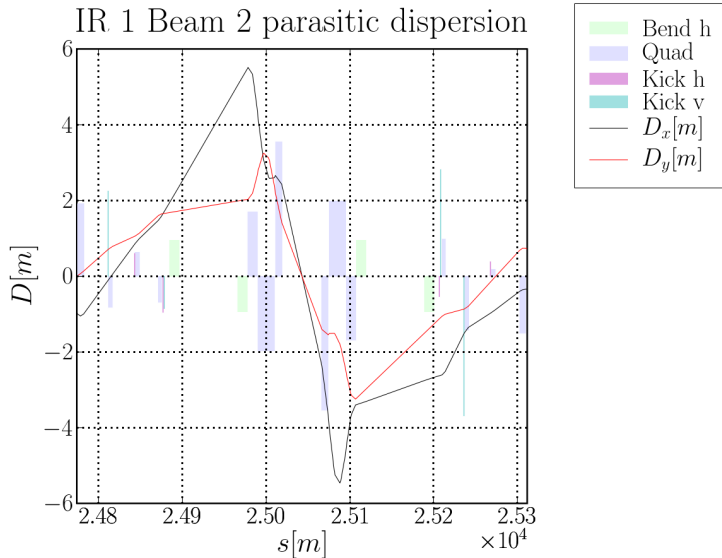


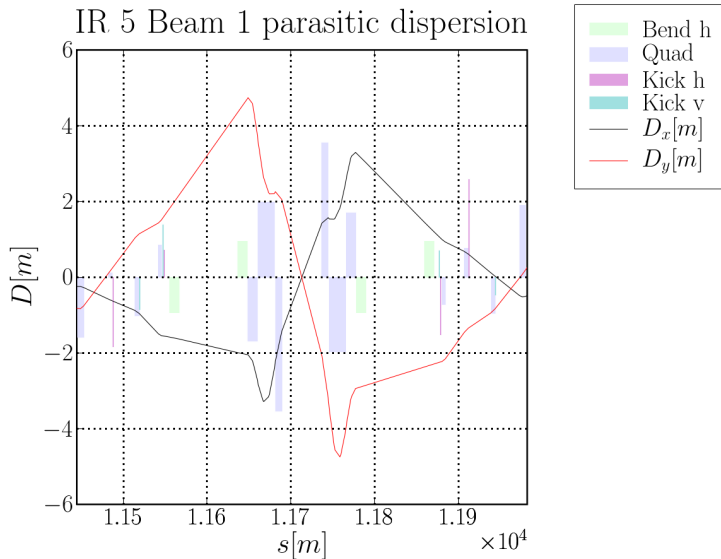


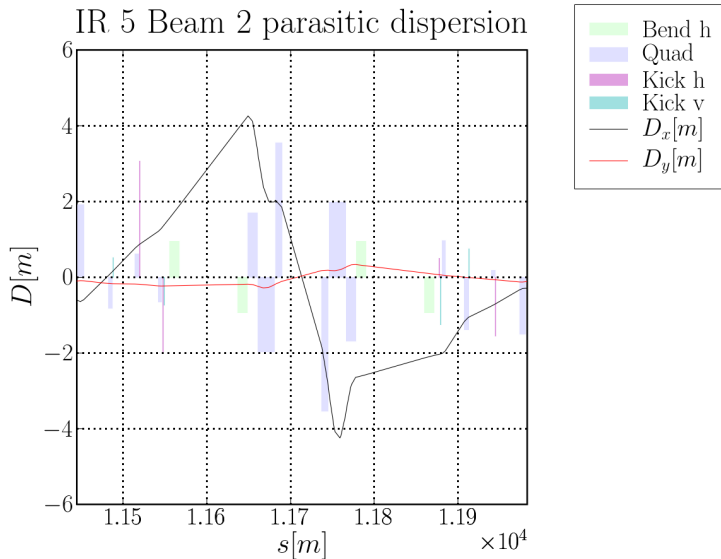
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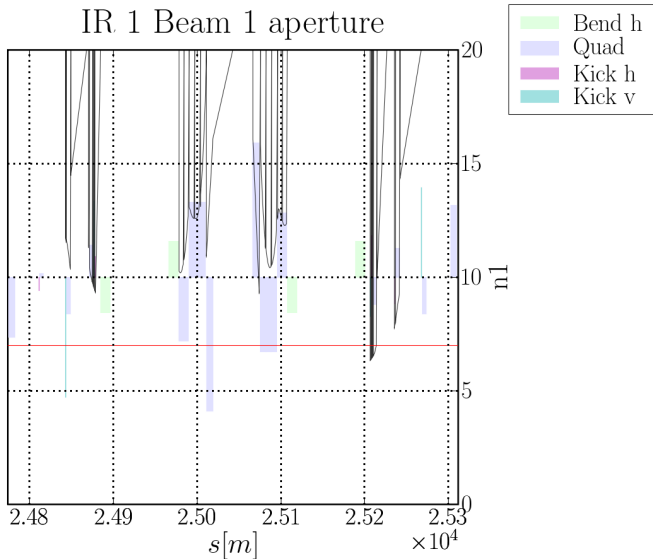


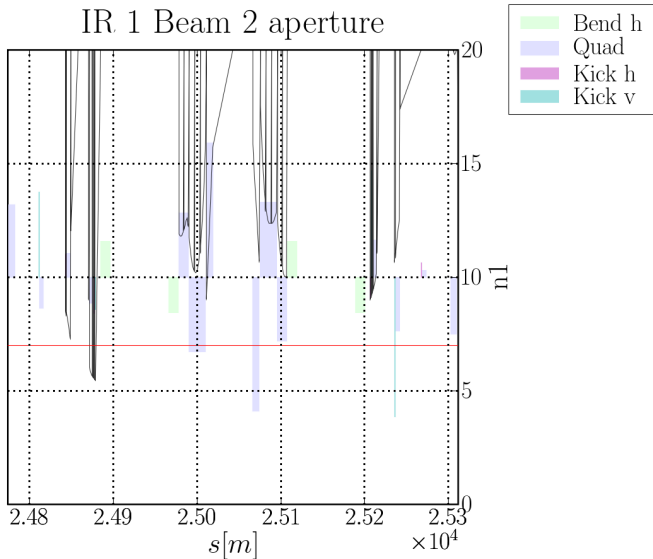


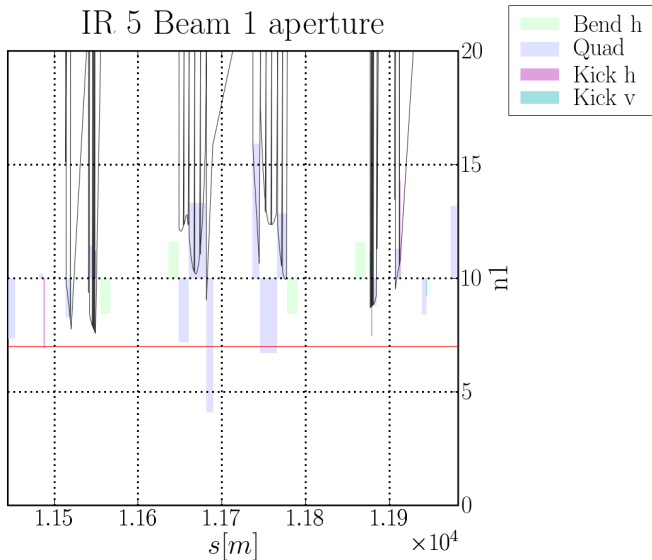


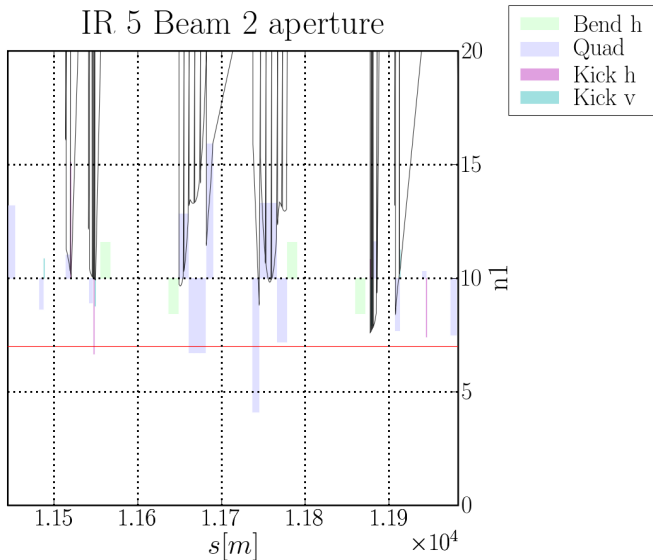












# Modular

Name	Length	Start p.	Gradient
	[m]	[m]	[T/m]
MQXN1.R5.B1	4.8	23	-115.854
MQXN2.R5.B1	4.8	28.8	-115.854
MQXN3.R5.B1	4.8	34.6	88.5221
MQXN4.R5.B1	4.8	40.4	88.5221
MQXN5.R5.B1	4.8	46.2	88.5221
MQXN6.R5.B1	4.8	52	88.5221
MQXN7.R5.B1	4.8	57.8	-82.0402
MQXN8.R5.B1	4.8	63.6	-82.0402
MQXN9.R5.B1	4.8	69.4	-82.0402
MQXN10.R5.B1	4.8	75.2	-82.0402
MQXN11.R5.B1	4.8	81	84.059
MQXN12.R5.B1	4.8	86.8	84.059

Name	Beta max	Sigma	Beam size*	Coil diam.*
	[m]	[mm]	[mm]	[mm]
MQXN1.R5.B1	3415.4	1.31024	65.238	112.21
MQXN2.R5.B1	6567.99	1.81697	81.9599	112.21
MQXN3.R5.B1	11126.9	2.36493	100.043	146.856
MQXN4.R5.B1	14133.9	2.6654	109.958	146.856
MQXN5.R5.B1	14390.7	2.68951	110.754	146.856
MQXN6.R5.B1	14095.5	2.66177	109.838	146.856
MQXN7.R5.B1	12097.4	2.46591	103.375	158.459
MQXN8.R5.B1	14276.2	2.67878	110.4	158.459
MQXN9.R5.B1	14389.8	2.68942	110.751	158.459
MQXN10.R5.B1	13419.3	2.59715	107.706	158.459
MQXN11.R5.B1	13947.1	2.64772	109.375	154.653
MQXN12.R5.B1	14390.2	2.68945	110.752	154.653

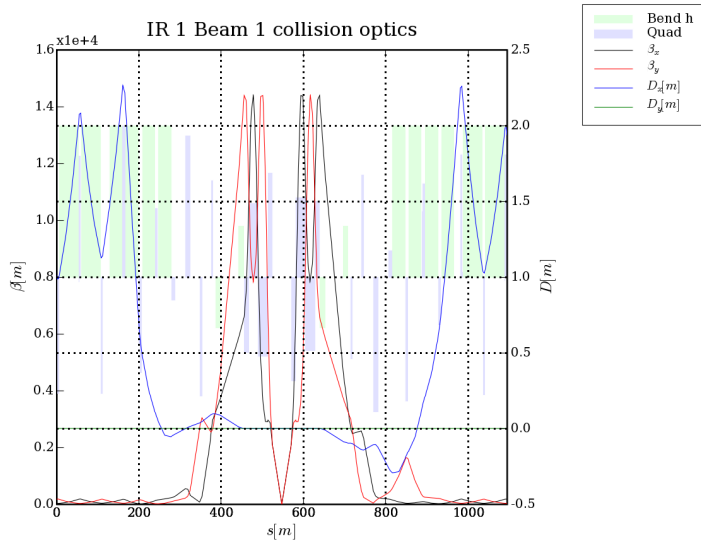
\* Beam size =  $33\sigma + 22\text{mm}$ , Coil diam. =  $2 * 6.5T / \text{gradient}$

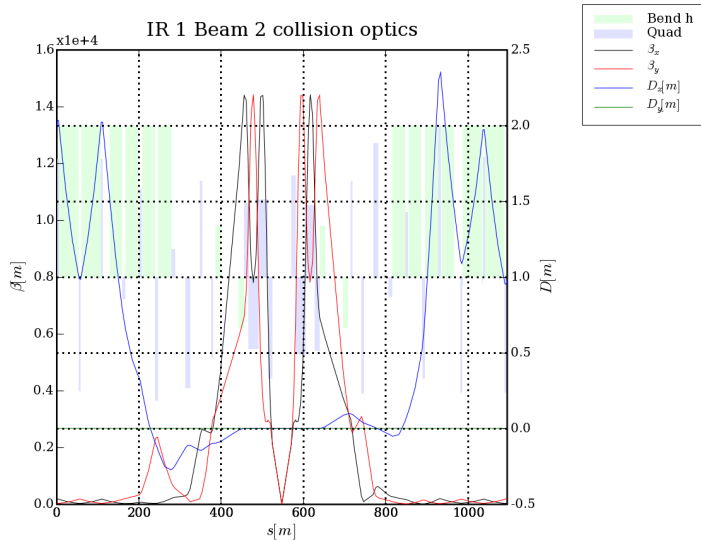


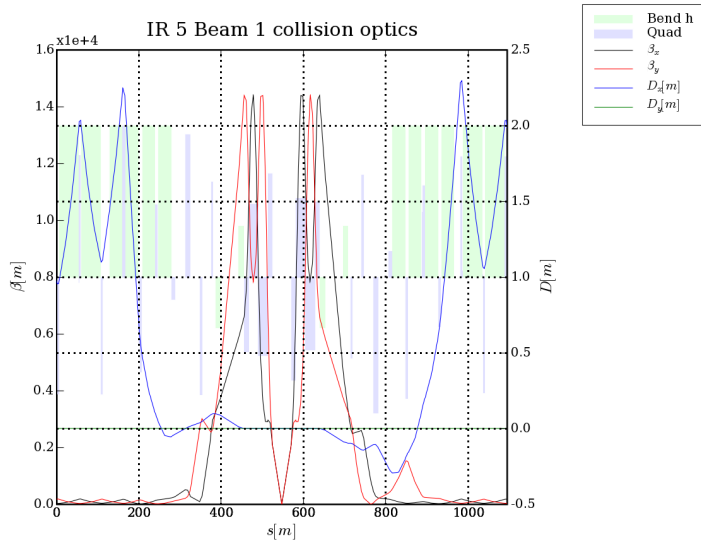
# Modular aperture model

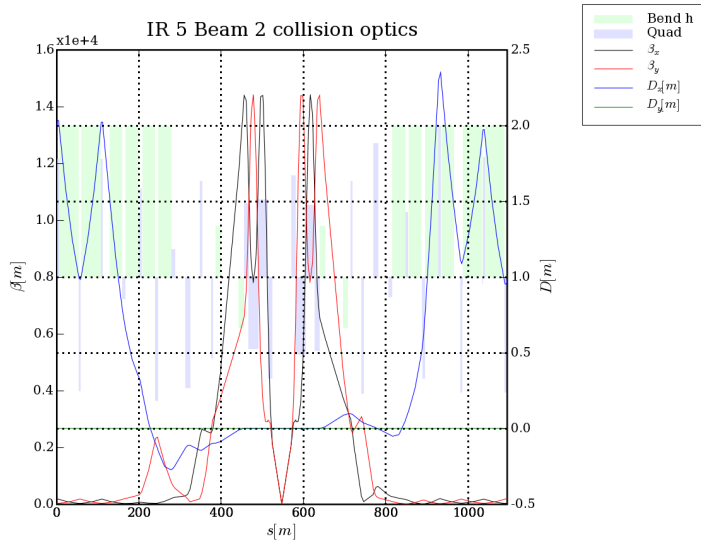
Aperture of the final focus:  $\text{gap}=\text{d}/2-11\text{mm}$ ,  $\text{rad}=\text{d}/2-6\text{mm}$

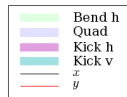
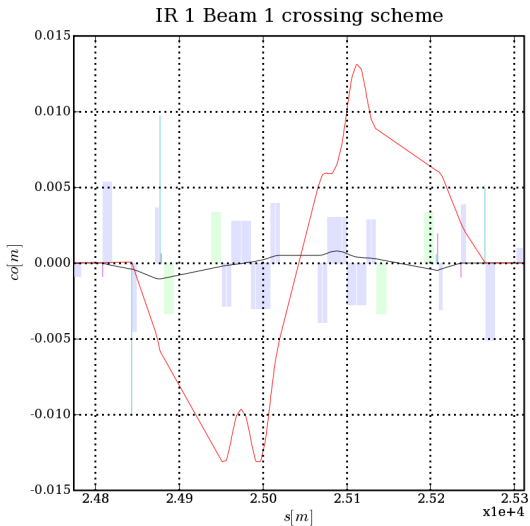
Magnet	Coil D	rect_x	rect_y	tol_r	tol_g	tol_s
MQXN1.R1.B1	0.130	0.05400	0.05900	0.00000	0.00000	0.00000
MQXN1.R5.B1	0.130	0.05900	0.05400	0.00000	0.00000	0.00000
MQXN2.R1.B1	0.170	0.07400	0.07900	0.00000	0.00000	0.00000
MQXN2.R5.B1	0.170	0.07900	0.07400	0.00000	0.00000	0.00000

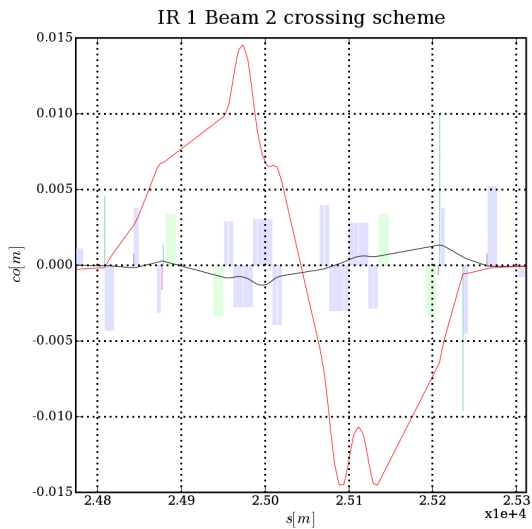


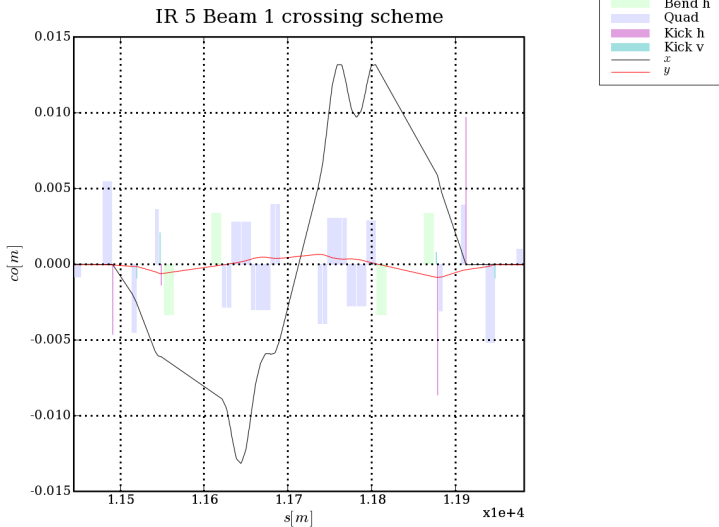




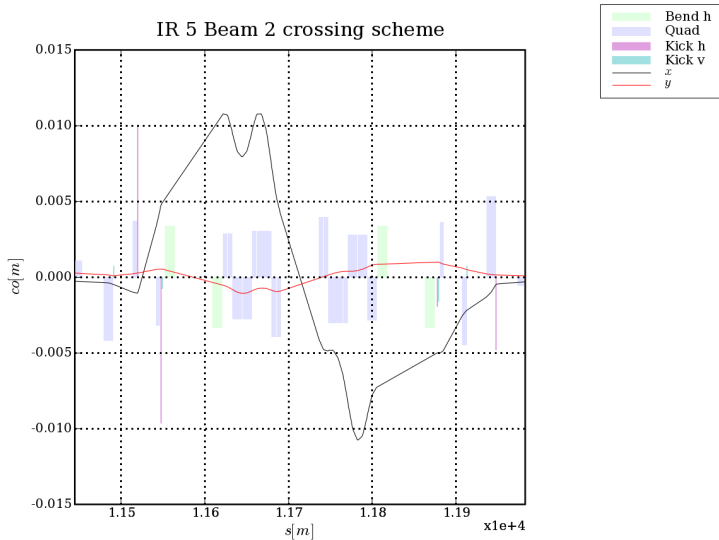


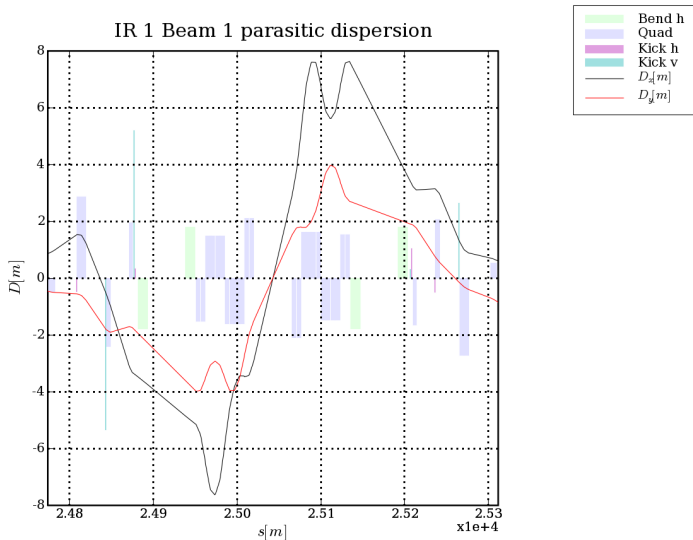


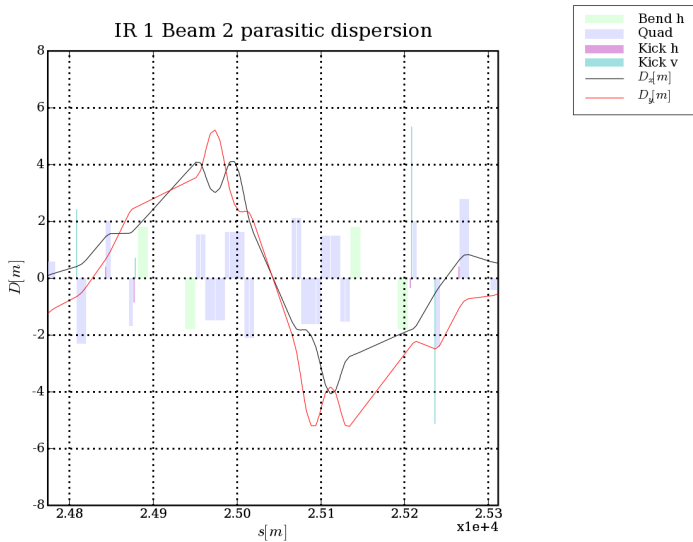


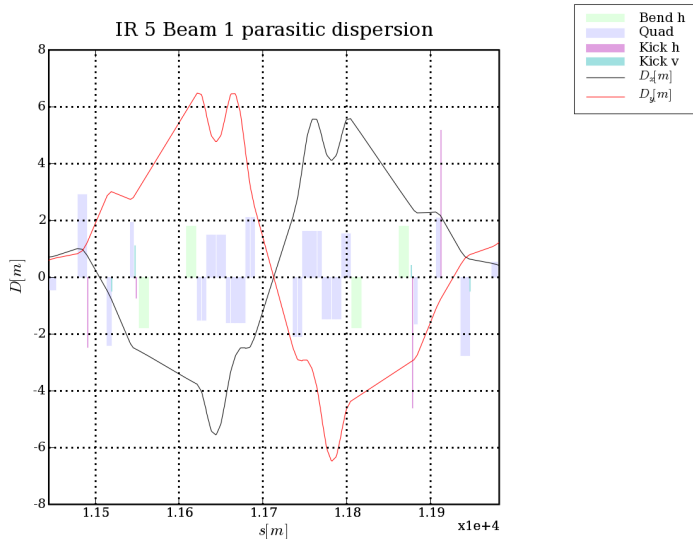


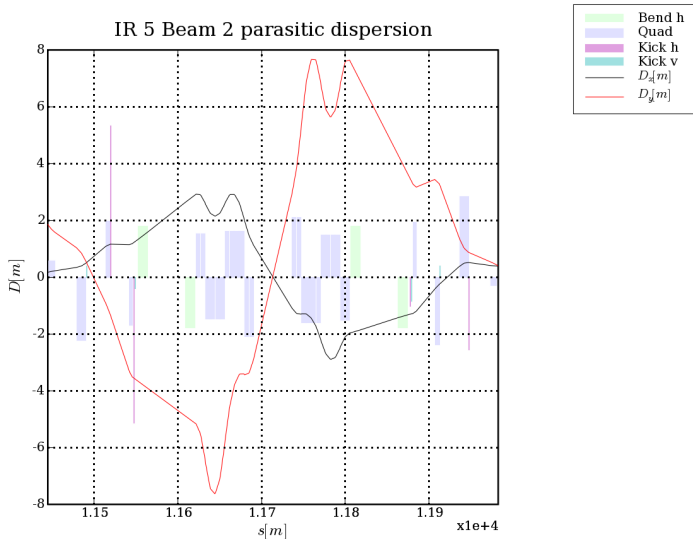


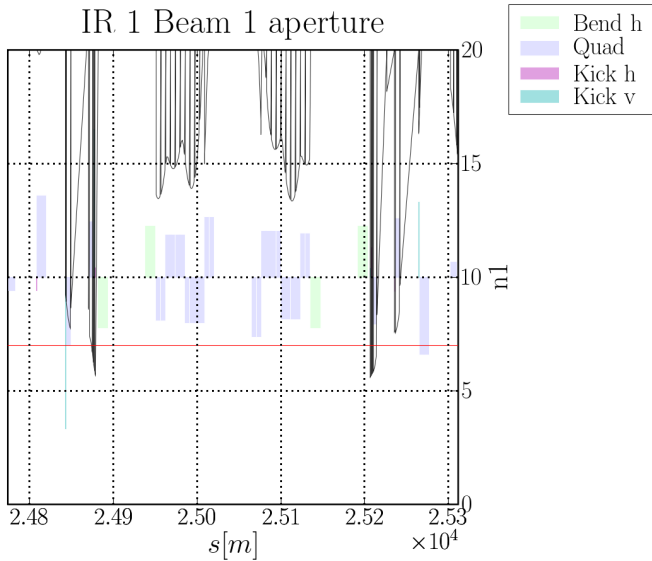


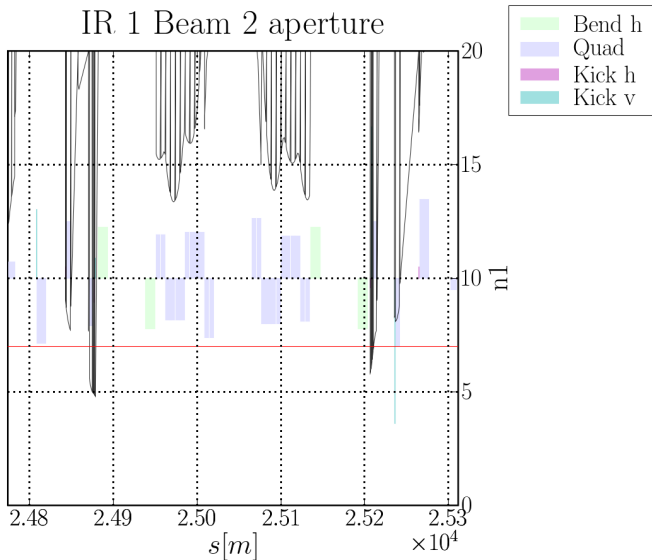


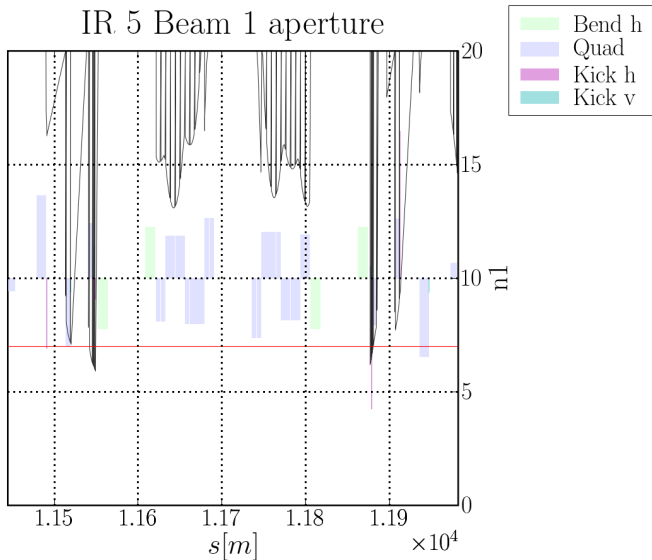




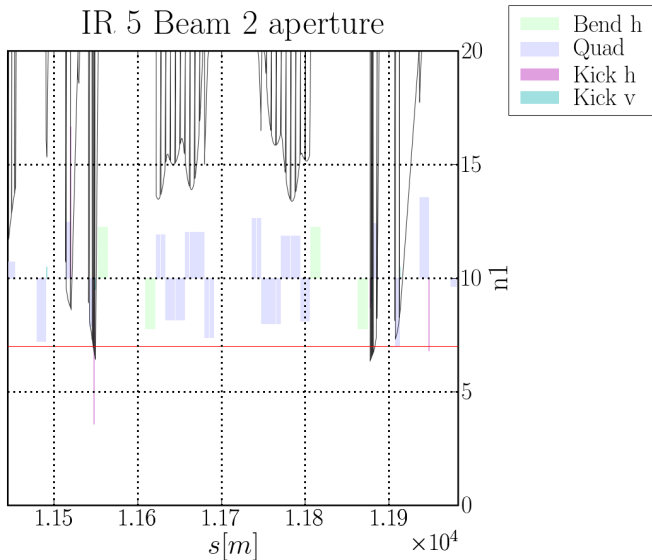












## Compact

Name	Length	Start p.	Gradient
	[m]	[m]	[T/m]
MQXN1.R5.B1	12.2444	23	91.4487
MQXN2.R5.B1	14.6249	36.2444	-68.3344
MQXN3.R5.B1	10.9992	51.8693	-68.3344
MQXN4.R5.B1	14.7506	63.8684	68.3344

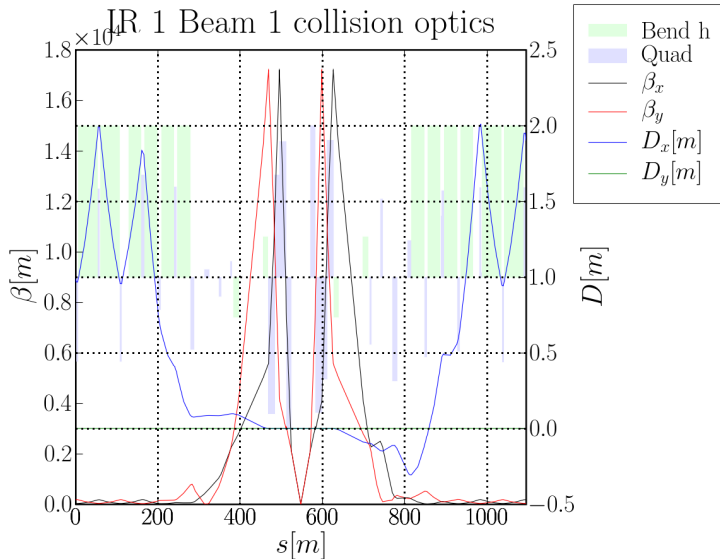
Name	Beta max	Sigma	Beam size*	Coil diam.*
	[m]	[mm]	[mm]	[mm]
MQXN1.R5.B1	7593.14	1.95363	86.4697	142.156
MQXN2.R5.B1	17194	2.93981	119.014	190.241
MQXN3.R5.B1	17194	2.93981	119.014	190.241
MQXN4.R5.B1	17193.3	2.93975	119.012	190.241

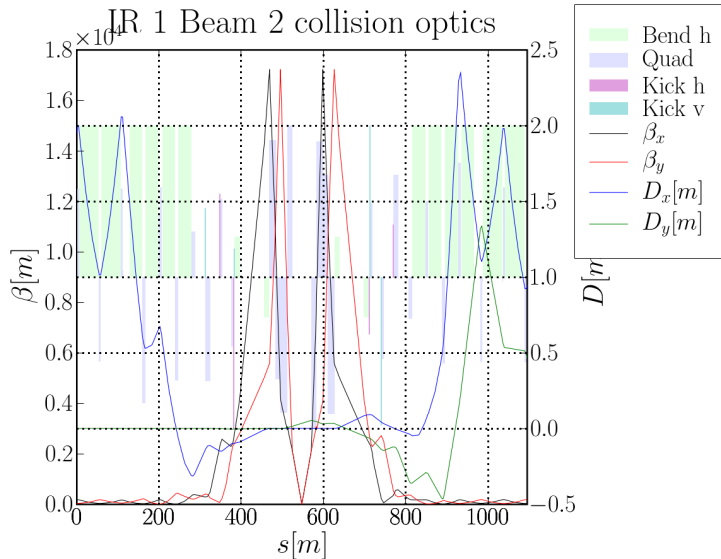
\* Beam size =  $33\sigma + 22\text{mm}$ , Coil diam. =  $2 * 6.5\text{T} / \text{gradient}$

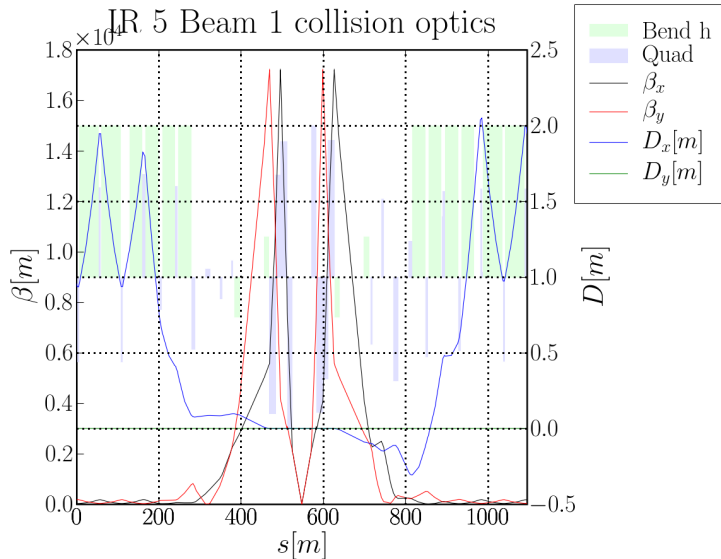
## Compact aperture model

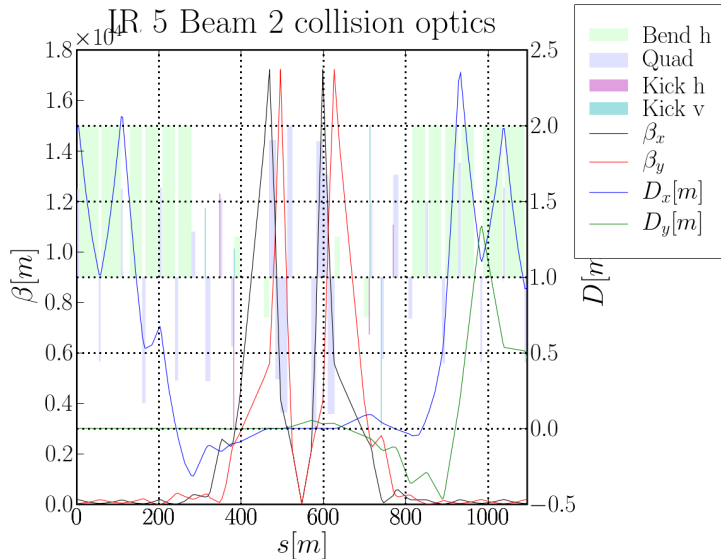
Aperture of the final focus:  $\text{gap} = d/2 - 11\text{mm}$ ,  $\text{rad} = d/2 - 6\text{mm}$

Magnet	Coil D	rect_x	rect_y	tol_r	tol_g	tol_s
MQXN1.R1.B1	0.170	0.07400	0.07900	0.00000	0.00000	0.00000
MQXN1.R5.B1	0.170	0.07900	0.07400	0.00000	0.00000	0.00000
MQXN2.R1.B1	0.220	0.09400	0.09900	0.00000	0.00000	0.00000
MQXN2.R5.B1	0.220	0.09900	0.09400	0.00000	0.00000	0.00000

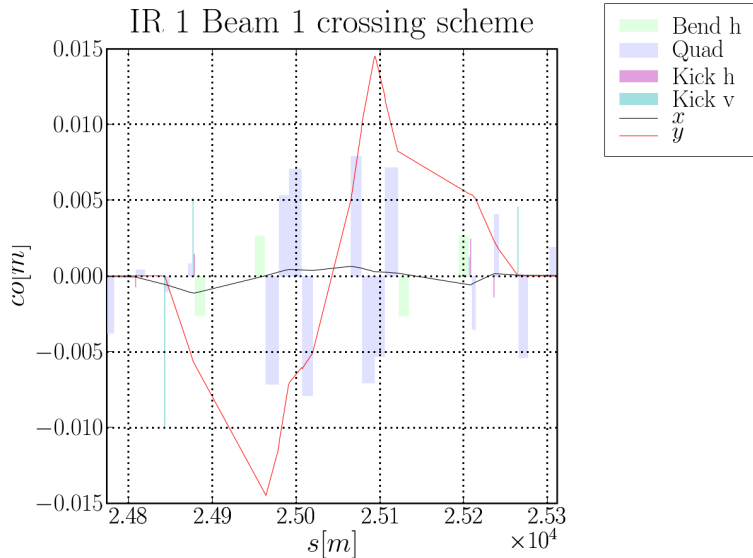




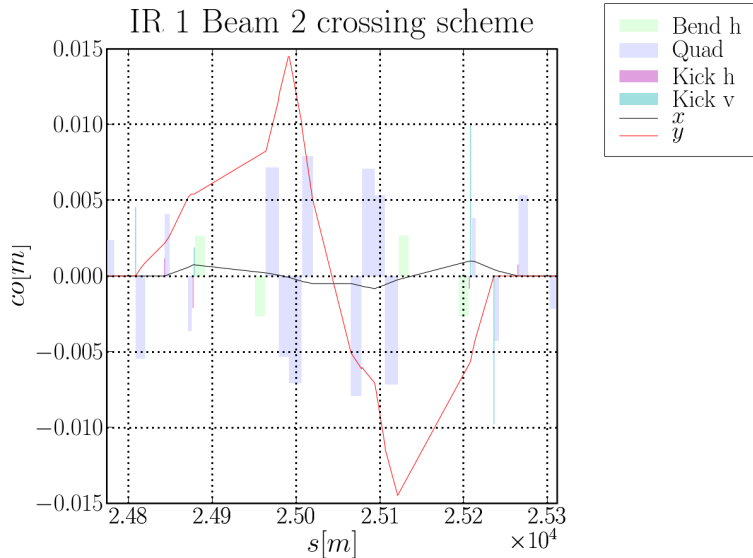


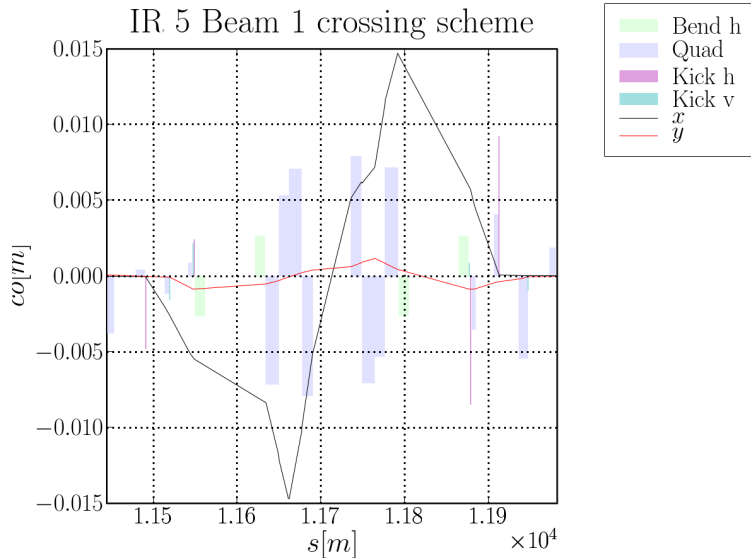


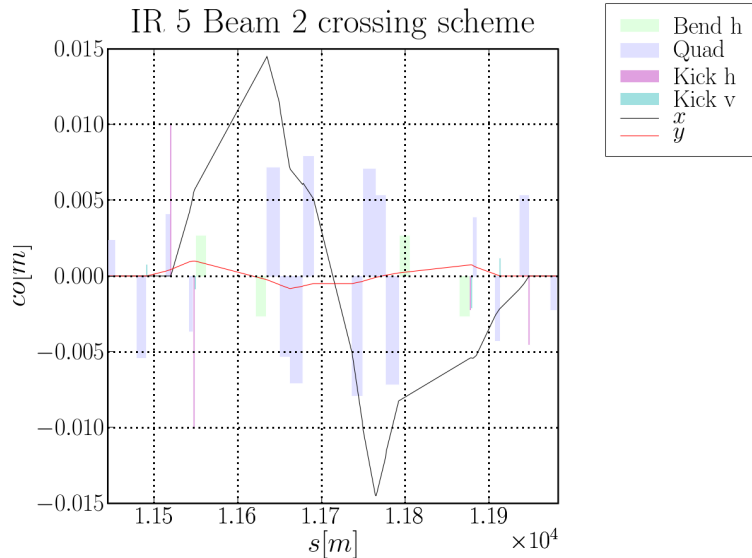
orb.ir1b1



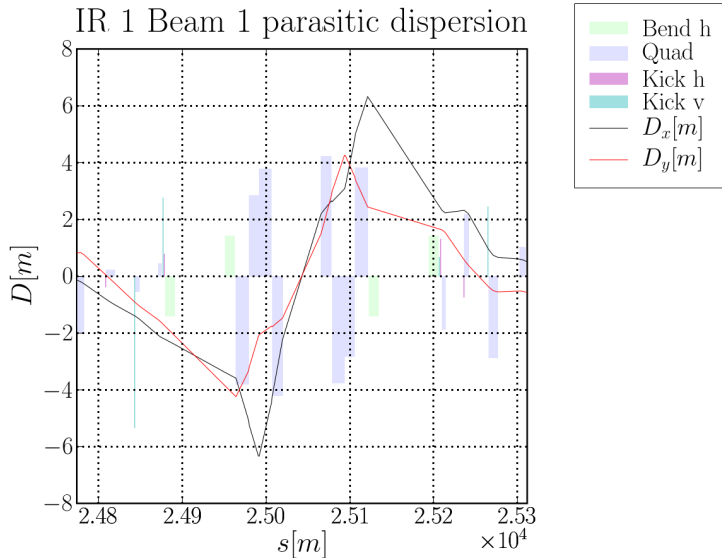


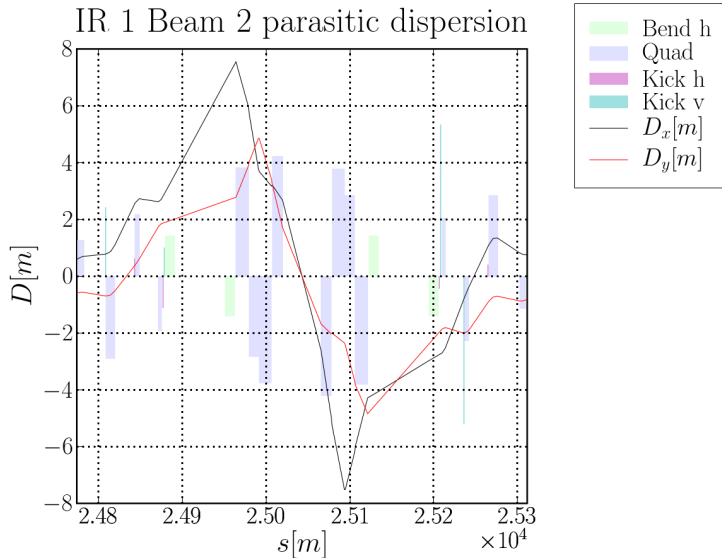


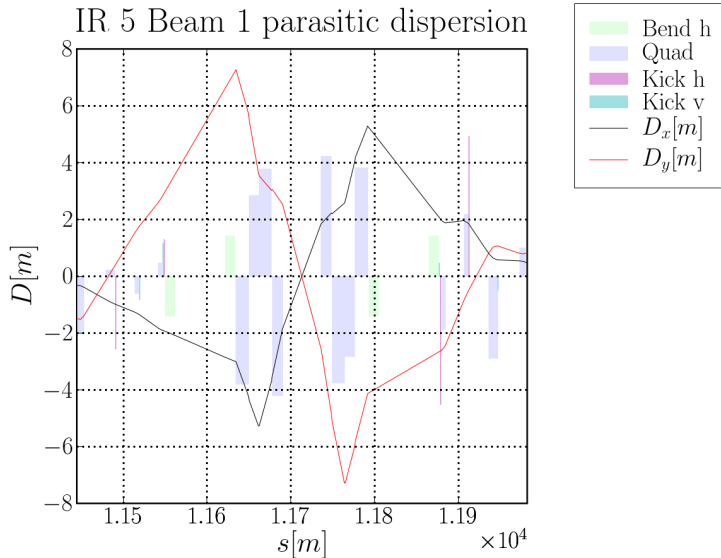


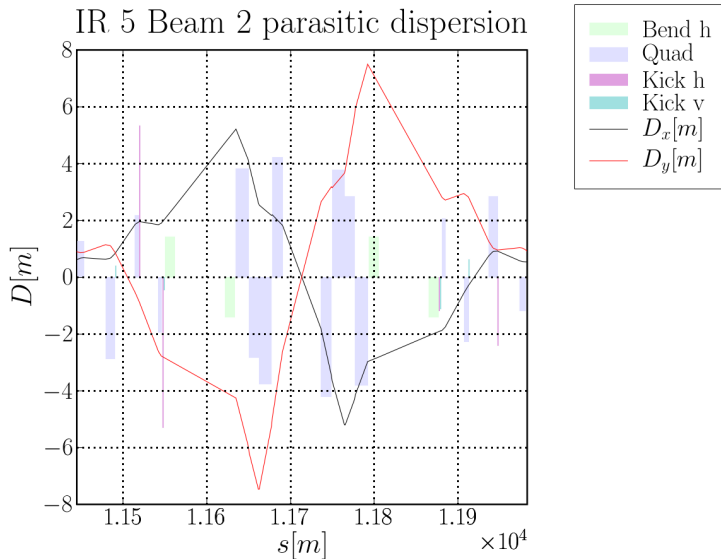


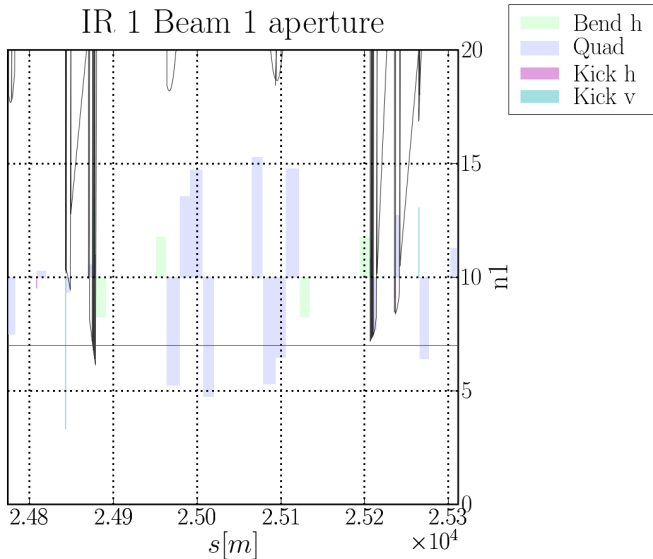
disp.ir1b1



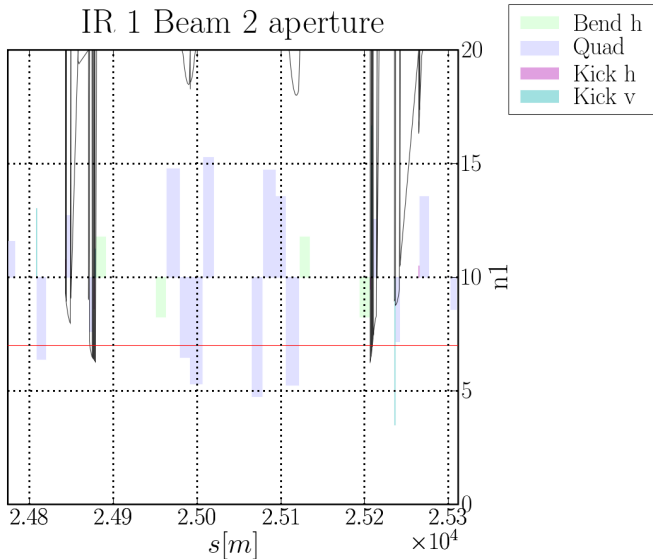


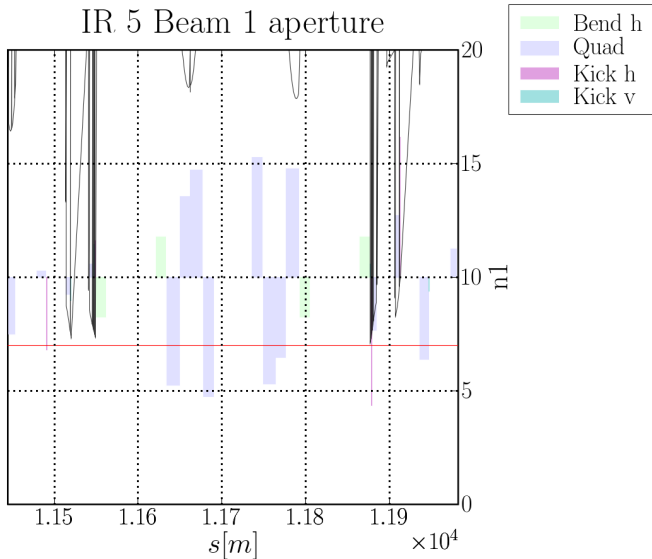


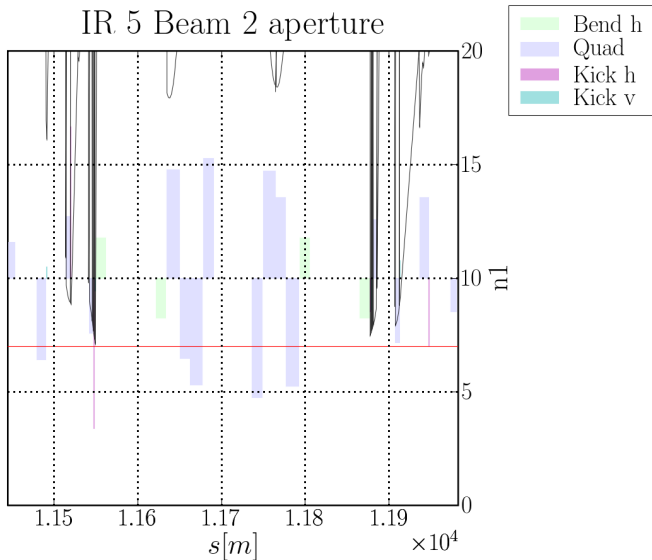












# Summary

The are problems in

LBM	ir1b1 Q4R	v cross
LBM	ir1b2 Q4L	v cross
MOD	ir1b1 Q4RL	v cross
MOD	ir1b2 Q4RL	v cross
MOD	ir5b1 Q4RL	h cross
MOD	ir5b2 Q4RL	h cross
COM	ir1b1 Q4L	v cross
COM	ir1b2 Q4RL	v cross

# Nominal LHC aperture model

## Aperture of the final focus

Magnet	rect_x	rect_y	tol_r	tol_g	tol_s
MQY.4R1.B1	0.028900	0.024000	0.000840	0.000960	0.000570
MQY.4L5.B1	0.028900	0.024000	0.000840	0.001430	0.000410
MQY.4R5.B1	0.028900	0.024000	0.000840	0.000810	0.000670
MQY.4L1.B1	0.028900	0.024000	0.000840	0.001050	0.000810
MQY.4R1.B2	0.028900	0.024000	0.000840	0.000960	0.000410
MQY.4L5.B2	0.028900	0.024000	0.000840	0.000780	0.000610
MQY.4R5.B2	0.028900	0.024000	0.000840	0.001000	0.000730
MQY.4L1.B2	0.028900	0.024000	0.000840	0.001320	0.001720