LHC phase 1 upgrade

Riccardo de Maria

CERN AB-ABP-LCU

October 17, 2007

Introduction

The presentation will cover:

- a survey of the parameter space;
- some results of several case studies.

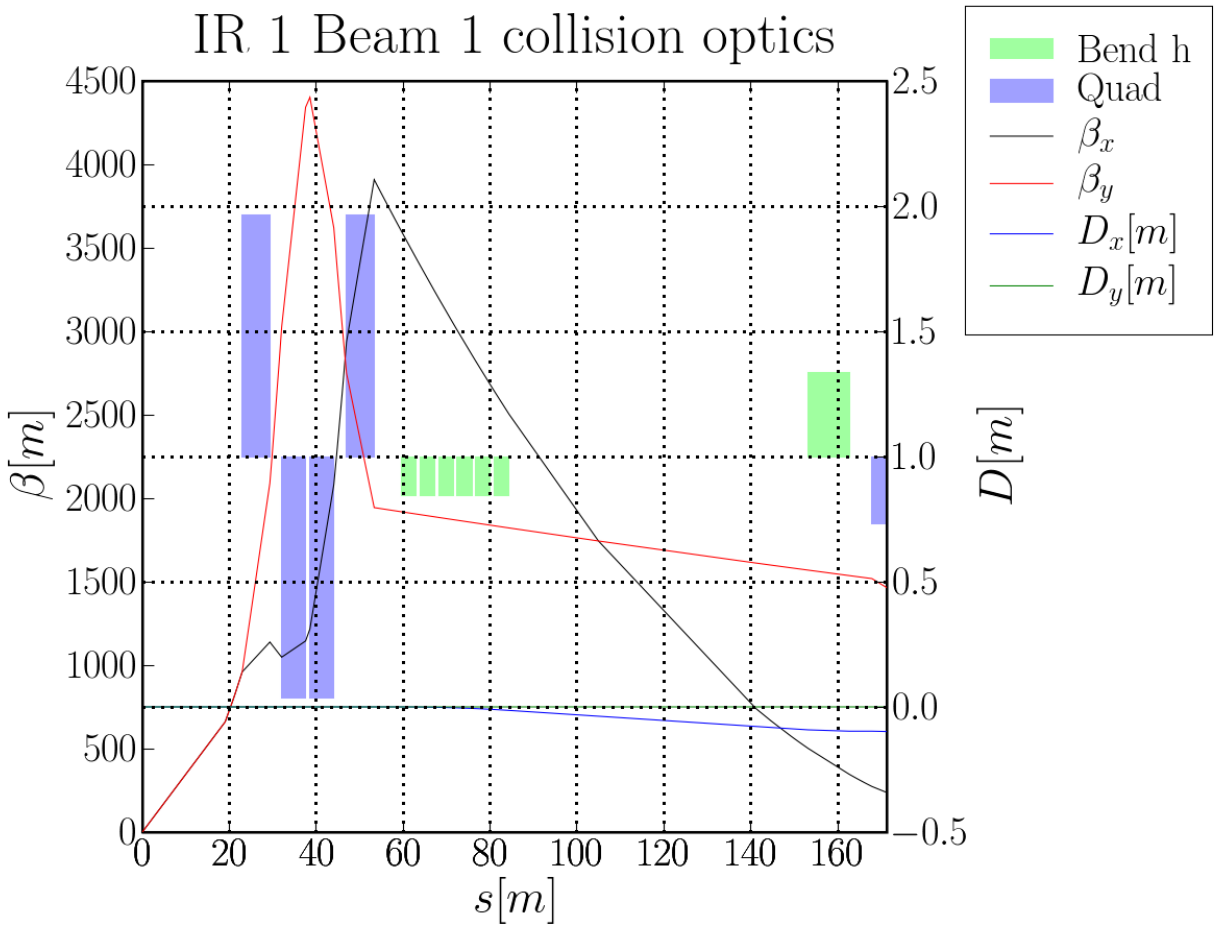
Phase 1 upgrade

Phase 1 upgrade aims at:

- $\beta^* = 25\text{cm}$, $L^* \geqslant 23\text{m}$;
- limiting the beam size in the focusing system (for reducing chromatic aberations and errors sensitivities)
- maximizing the aperture margins in the focusing system (for reducing the heat load, radiation damage and increasing operation margin)
- making the final focusing system as short as possible (for reducing the number of long range beam beam interaction)
- replacing less equipment as possible while maximizing the potential integrated luminosity gain.

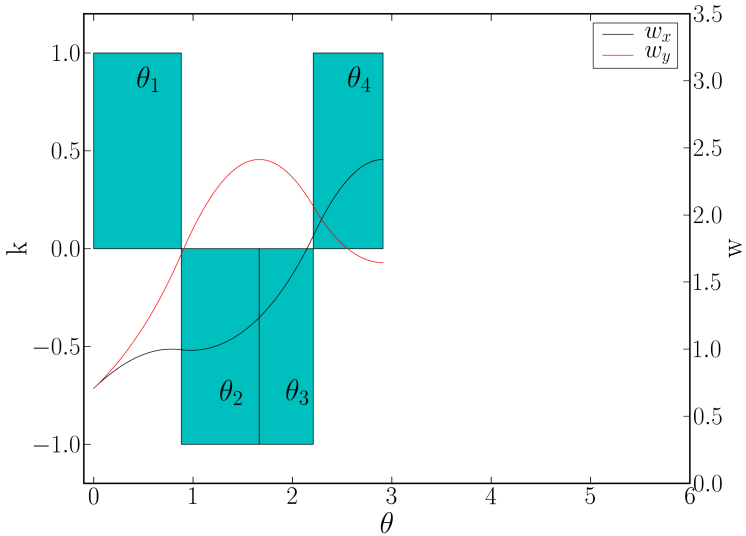
Nominal LHC triplet

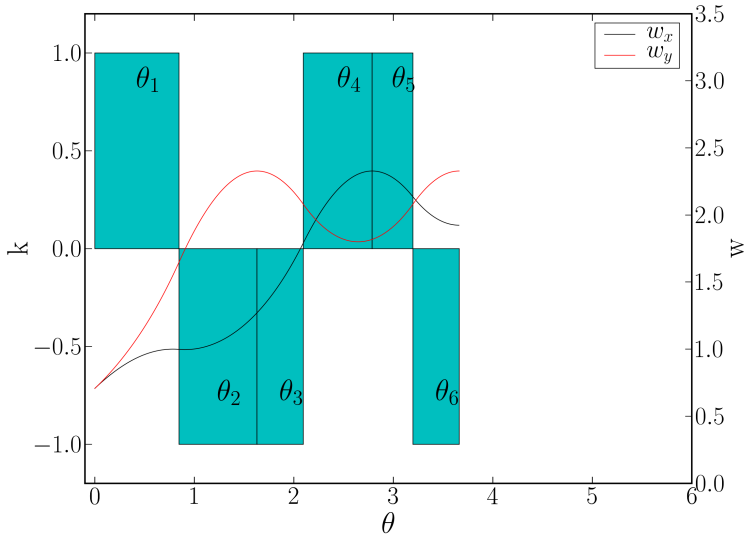
The nominal LHC triplet cannot fulfill the aims because of apeture limitations.



General triplet and quadruplet

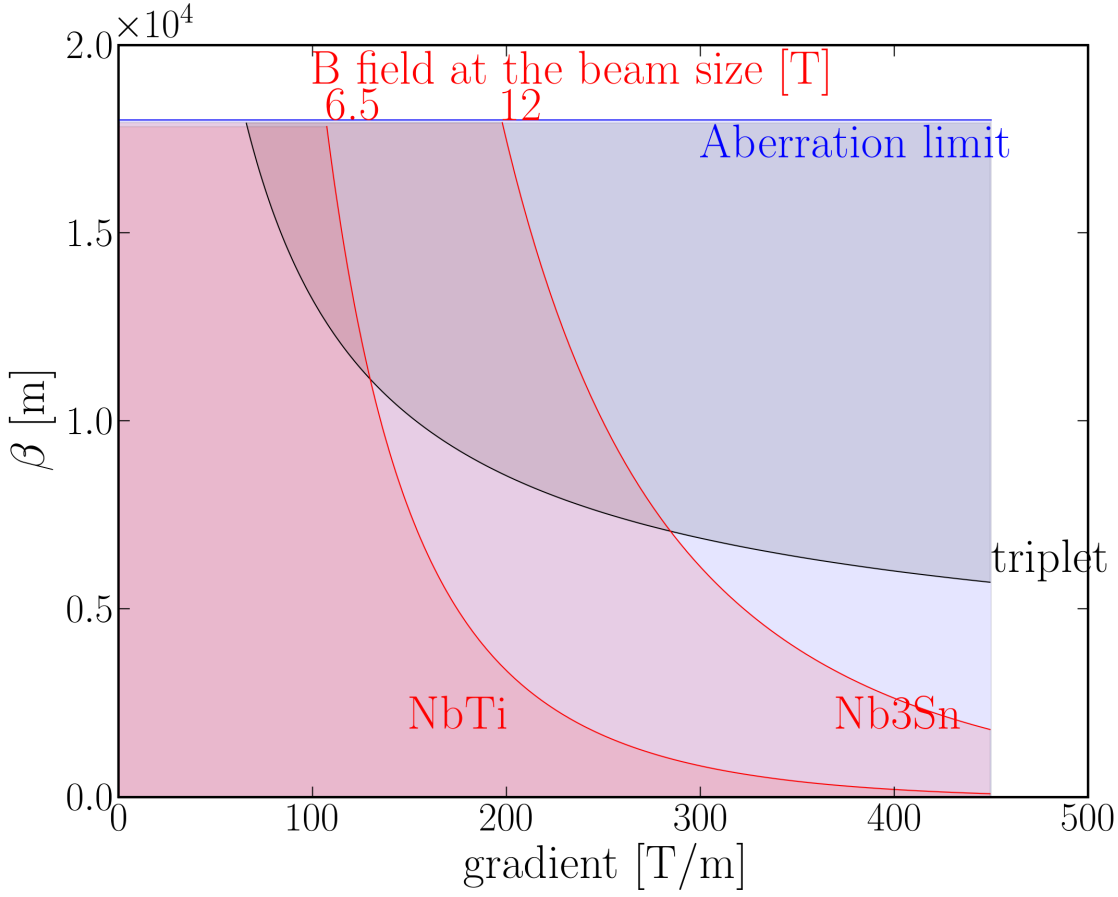
A gapless point to parallel focus system (FS) is a good model for exploring the parameter space of LHC IR Upgrade





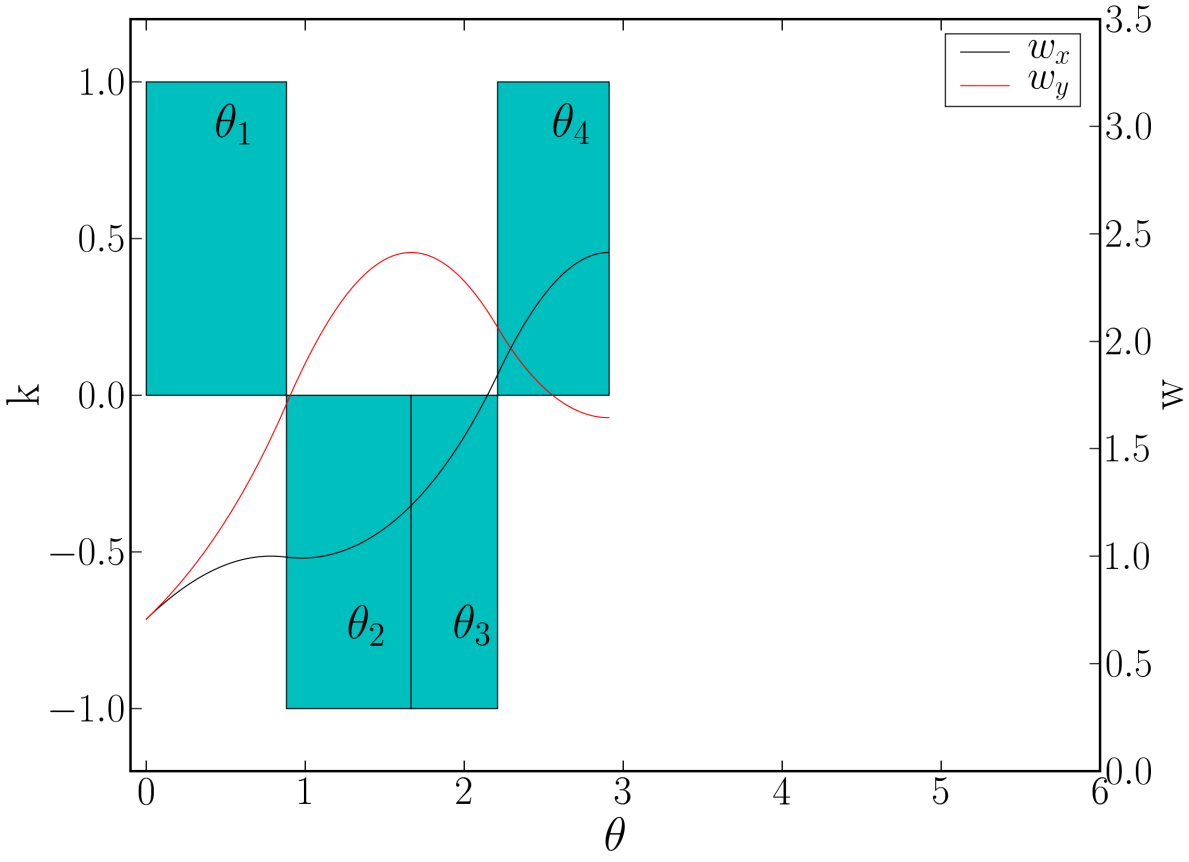
Gradient Vs Beta max

Beam size: $33\sigma + 22\text{cm}$



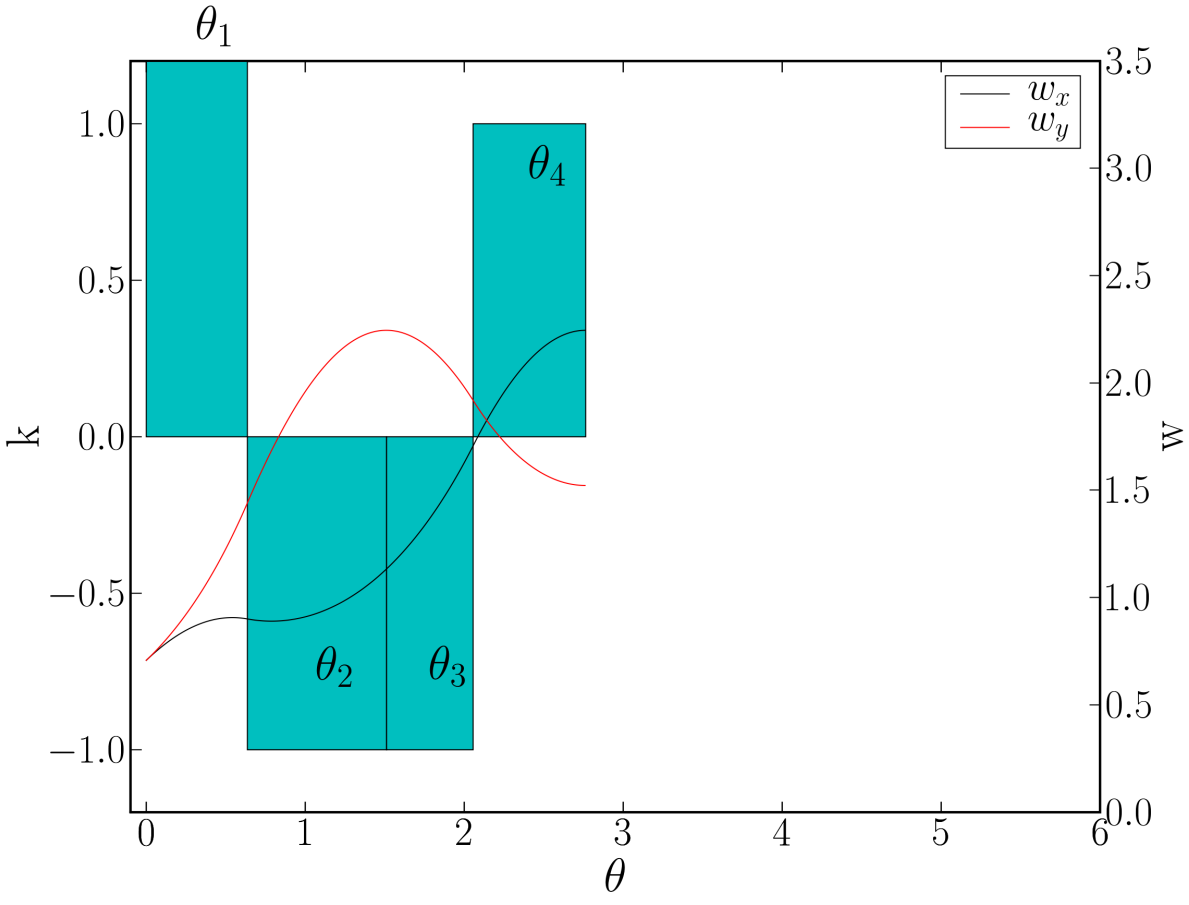
Realistic implementation

Starting from the ideal case



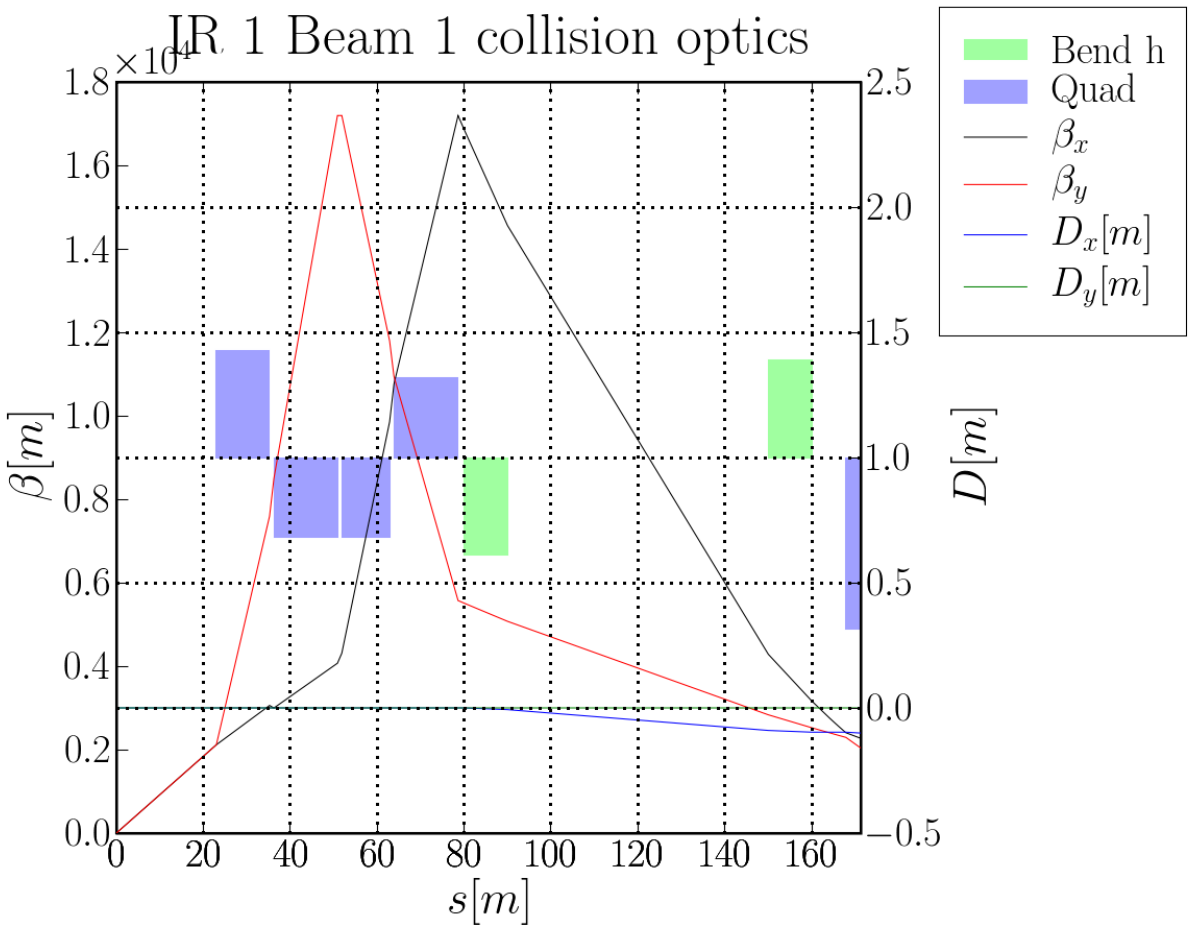
Realistic implementation

Optimize Q1

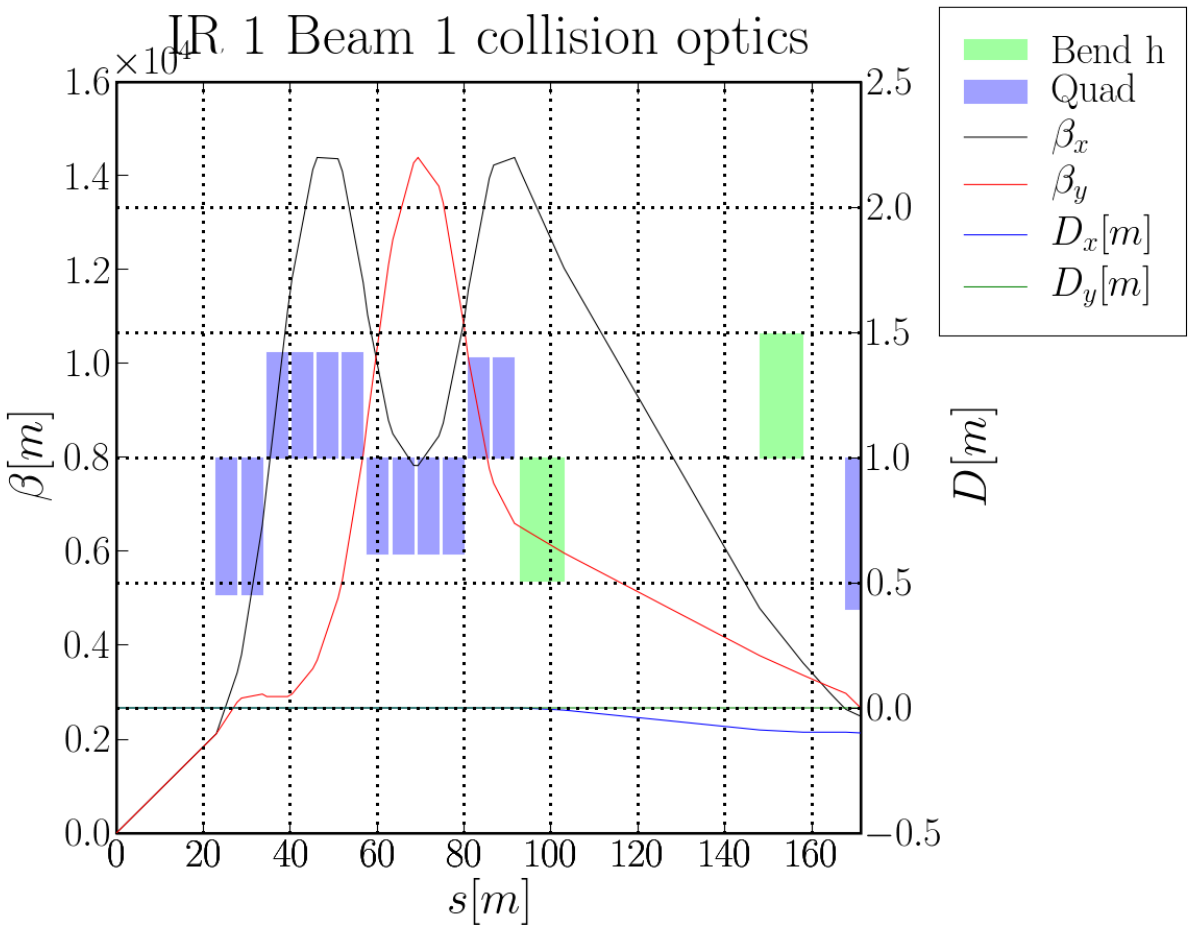


Then split and focus to match to the arc.

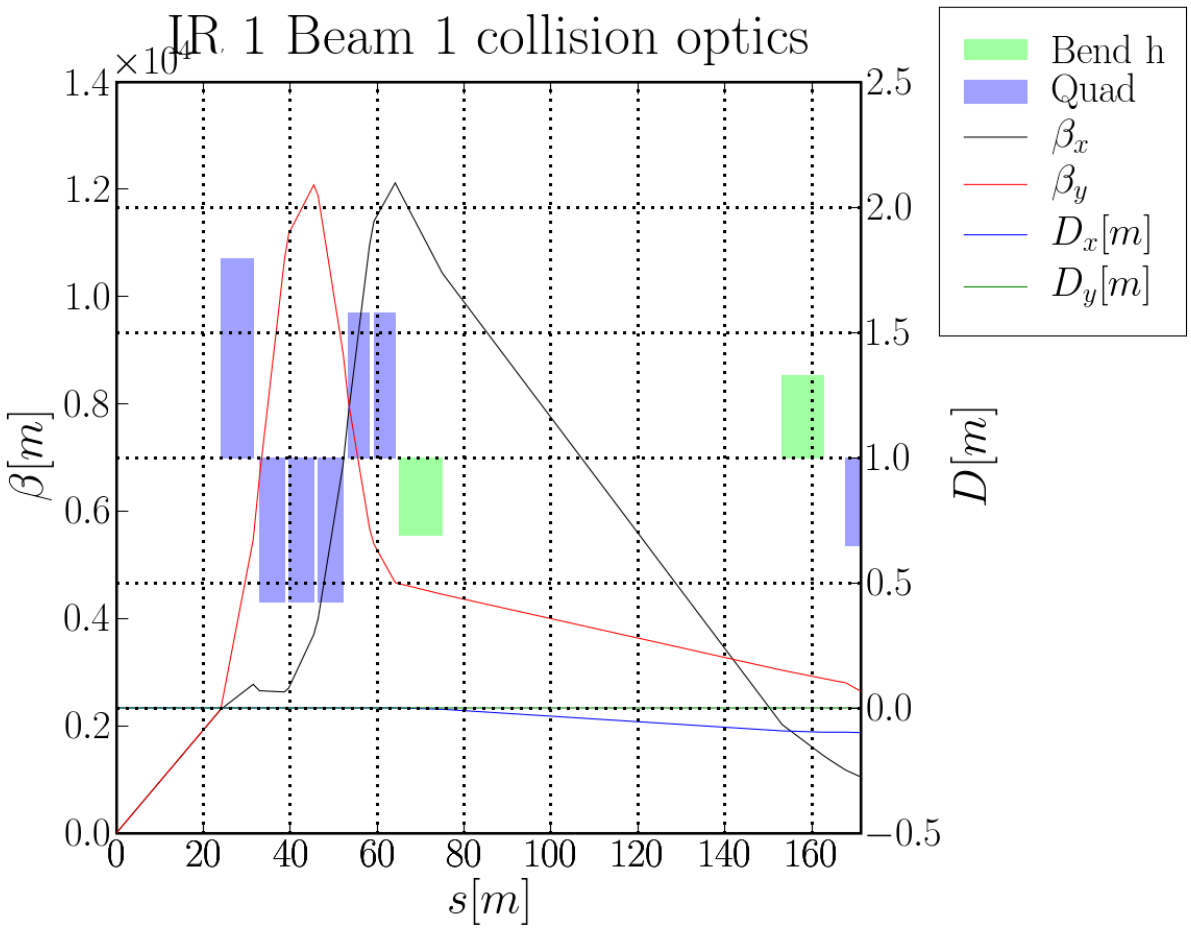
Compact


IR 1 Beam 1 collision optics
$\times 10^{-4}$
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
$\beta[m]$
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
$D[m]$
0
20
40
60
80
100
120
140
160
$s[m]$
Bend h
Quad
β_x
β_y
$D_x[m]$
$D_y[m]$

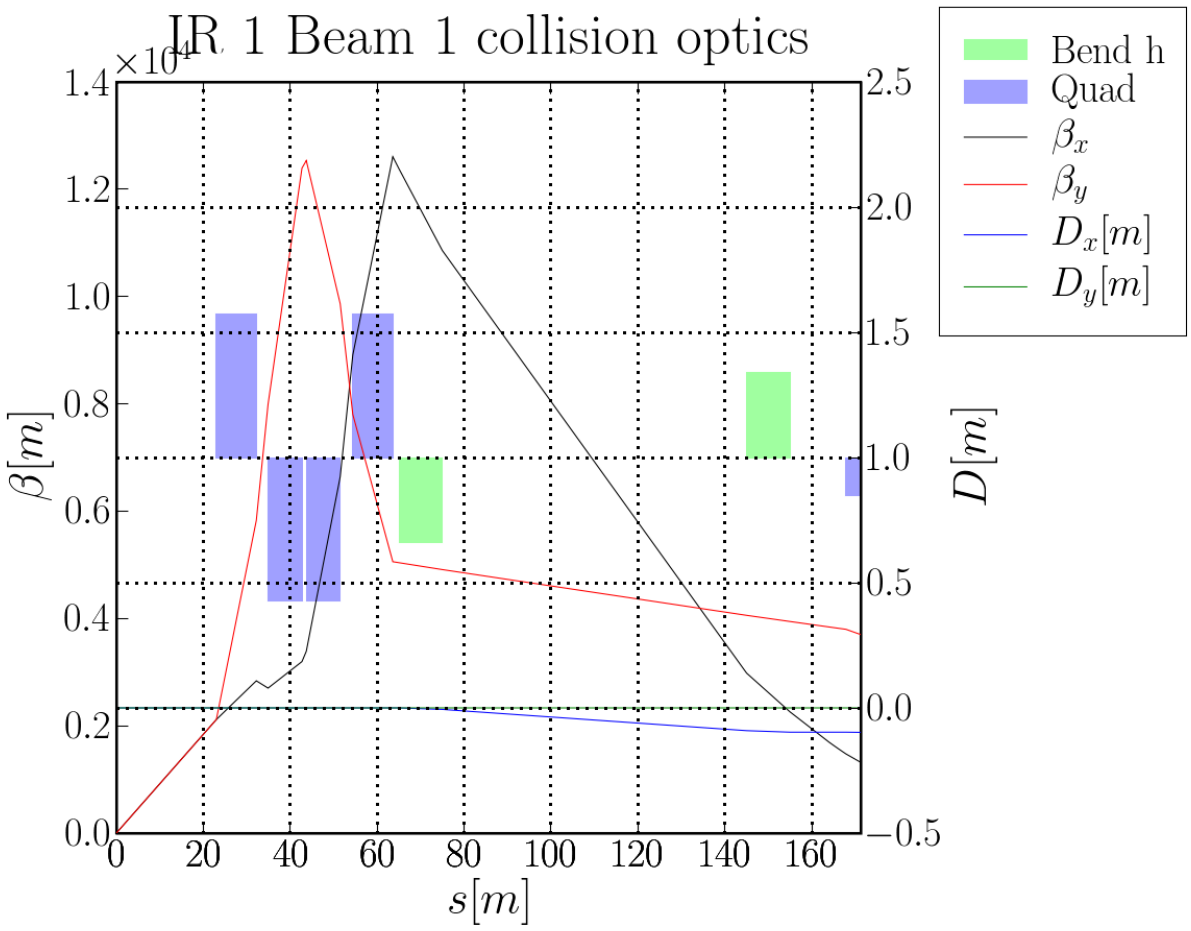
Modular


IR 1 Beam 1 collision optics
Bend h
Quad
β_x
β_y
$D_x[m]$
$D_y[m]$
$\times 10^{4}$
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
$\beta[m]$
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
$D[m]$
0
20
40
60
80
100
120
140
160
$s[m]$

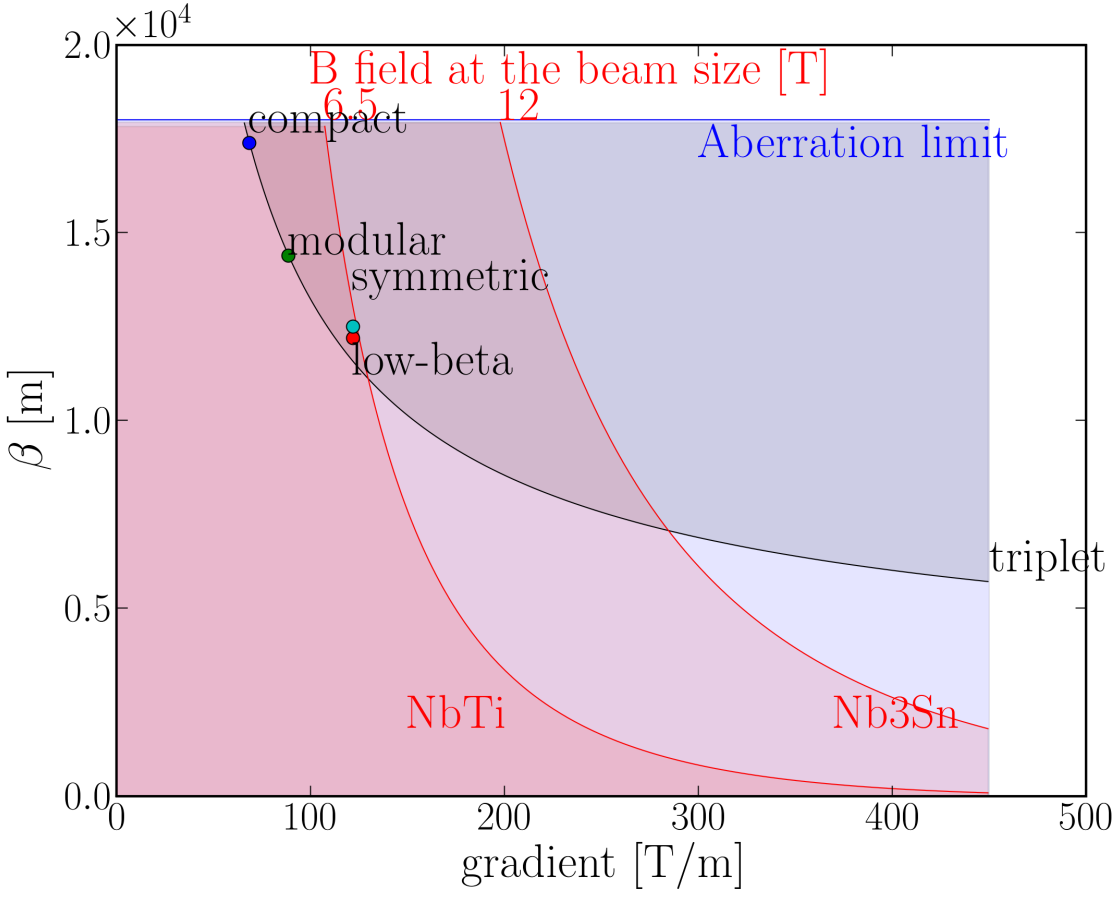
Lowbetamax


IR 1 Beam 1 collision optics
$\times 10^{-4}$
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
$\beta[m]$
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
$D[m]$
0
20
40
60
80
100
120
140
160
$s[m]$
Bend h
Quad
β_x
β_y
$D_x[m]$
$D_y[m]$

Symmetric


IR 1 Beam 1 collision optics
Bend h
Quad
β_x
β_y
$D_x[m]$
$D_y[m]$
$\times 10^{4}$
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
$\beta[m]$
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
$D[m]$
0
20
40
60
80
100
120
140
160
$s[m]$

Choice of a the gradient



Fine tuning and match

I have choosen the slope at the end of the triplet to improve the matchability, but not optimize aperture in Q4, Q5.

Layout

	Compact	Modular	Lowbeta	Symmetric
L* [m]	23	23	24	23
Gradient [T/m]	91,68	115,88,82,84	168,122	122
Module L [m]	12.2,14.6,11	4.8	7.4,5.7,4.9	9.2, 7.8
Total L [m]	78	91	63	64
LRBB	21	20.4	17	17
Aperture [mm]	170,220	130,170	90,130	130
B. S. [mm]	74,79,99,104	54,59,99,104	34,39,54,59	54,59

Chromatic aberrations

	Compact	Modular	Lowbeta	Symmetric
Sextupoles [%]	73,45	85,55	73,45	73,45
Chrom. beat. $3\,10^{-4}$ [%]	40	40	30	30
Chrom. beat. $8\,10^{-4}$ [%]	150	150	100	105

Dynamic aperture

	Compact	Modular	Lowbeta	Symmetric

Strengths limitations

	Compact	Modular	Lowbeta	Symmetric
Q6	yes	yes	no	no

Aperture bottlenecks

	Compact	Modular	Lowbeta	Symmetric
mqx	20,17	20,12	8,9.5	8.7
d1	???	???	???	???
d2-q4	4.8,6.8	4,5.8	8.5	5.7,7.5
q5	5	3.6	10	7.5

Anti symmetry

Is that an issue???

Conclusion

The exercise was useful for understanding the real limitation for the implementation of a new focusing system compatible with the aims of Phase 1 upgrade.
The favorite option is the lowbetamax, for the good trade between aperture in the triplet and in the rest of the LSS.
Many refinements are still needed for a final solutions:

- redesign the final focus system to reduce the beam size at Q4
- make sure that an injection optics exists
- determine if the gap are in the right location for the BPM, if not move the whole assembly or find a different splitting.