

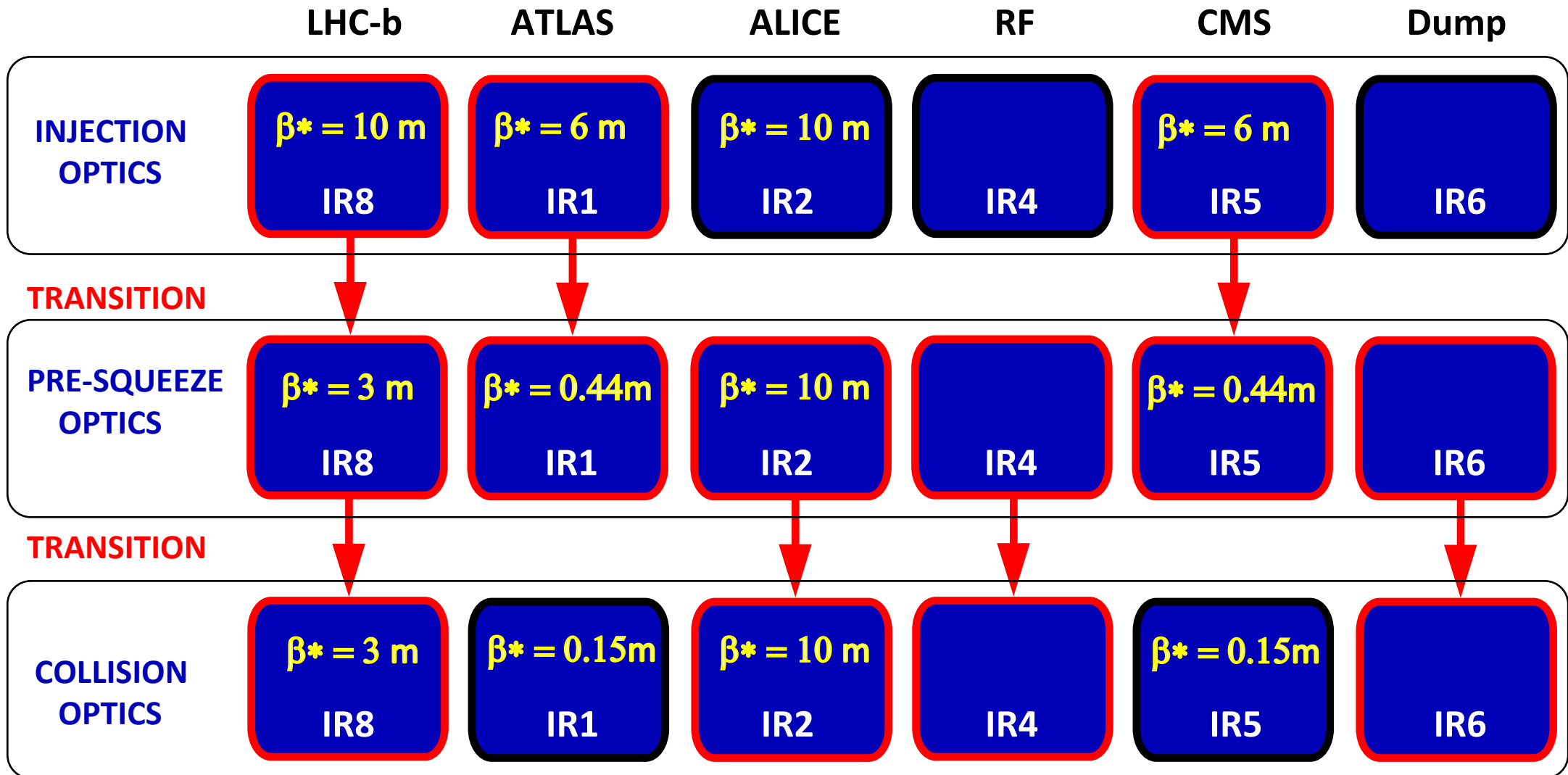
Transition between injection optics and collision optics (including ATS squeeze)

Maxim Korostelev

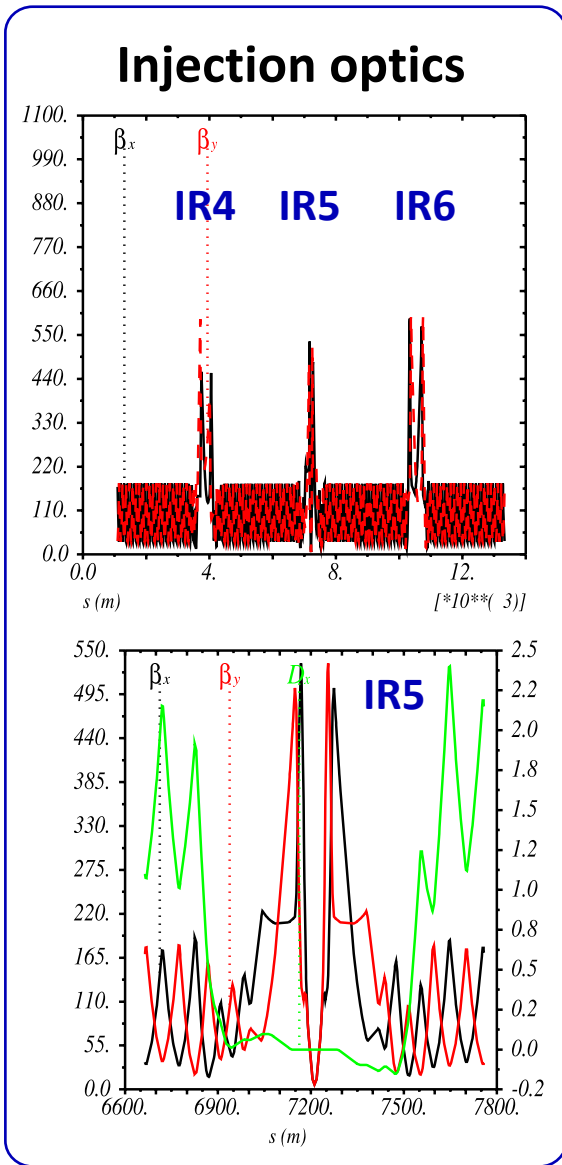
University of Liverpool and the Cockcroft Institute



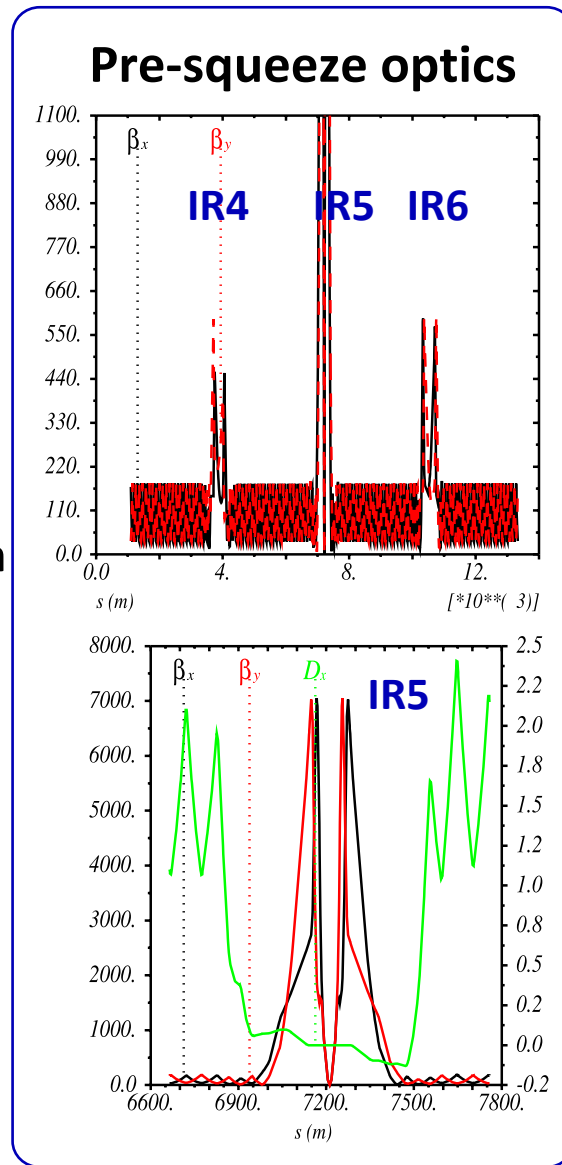
Optics transition from injection to collision optics with round proton beams at IPs



Achromatic Telescopic Squeeze (ATS)



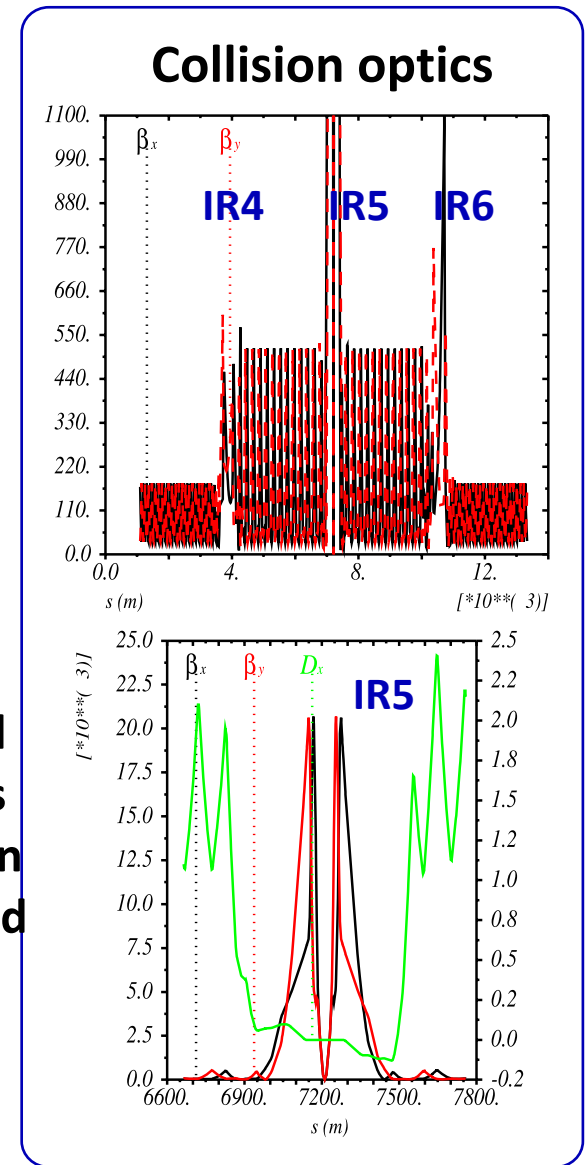
Optics
Transition
in IR5



ATS
squeeze
of IR5



provided
by optics
transition
in IR4 and
IR6



$$\beta_{x,y}^* = 6 \text{ m at IP5}$$

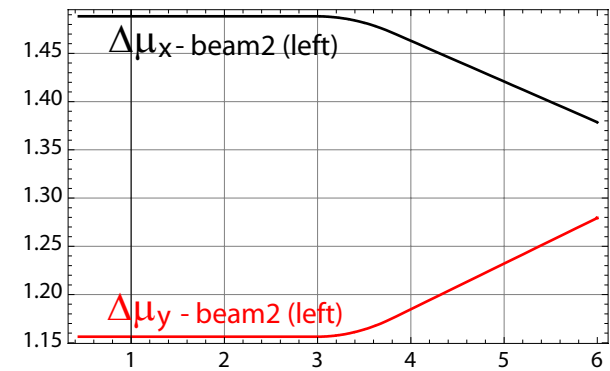
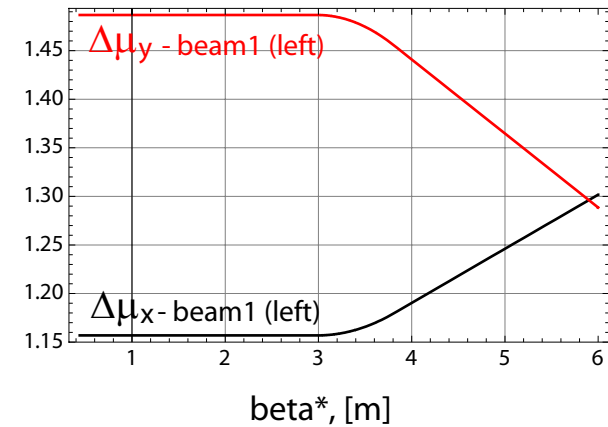
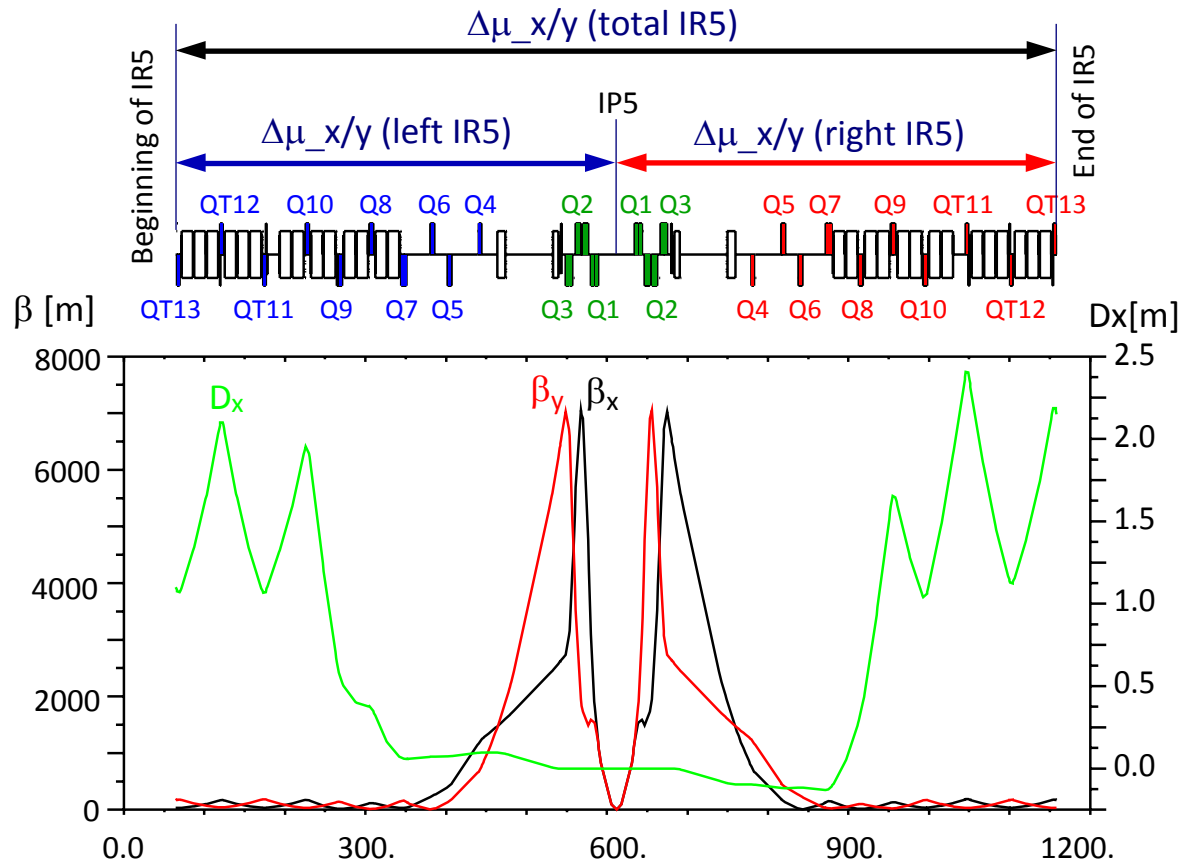
$$\beta_{x,y}^* = 0.44 \text{ m at IP5}$$

$$\beta_{x,y}^* = 0.15 \text{ m at IP5}$$

Requirements during optics transition

- Twiss parameters throughout the IRs involved in the transition.
- Specified values for the phase advances over IRs.
- Specified minimum and maximum strengths of the quadrupoles.
- Variation of the quadrupole strengths should be as smooth as possible, especially for the strongest quadrupoles.
- Avoiding changes of slope of field gradient as much as possible.

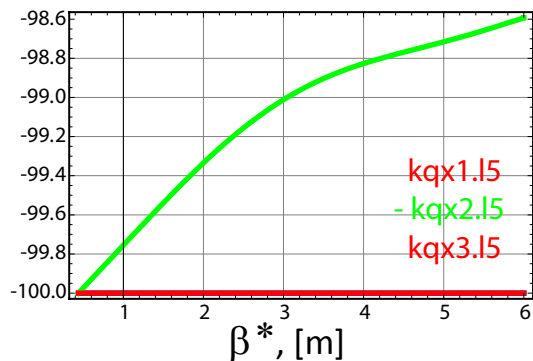
IR5 matching conditions



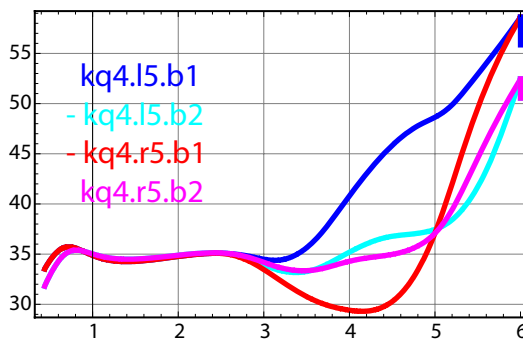
- Twiss parameters at the beginning and at the end of IR5
- Twiss parameters at the IP5: $\alpha_{x/y} = 0$, $D_x = 0$, $D'_x = 0$
- Fixed horizontal and vertical phase advance $\Delta\mu_{x/y}$ (total IR5) during the optics transition
- Fixed horizontal and vertical phase advance $\Delta\mu_{x/y}$ (left IR5) between the beginning of IR5 and IP5 in the range of β^* from 3.2 m to 0.44m

IR5 optics transition

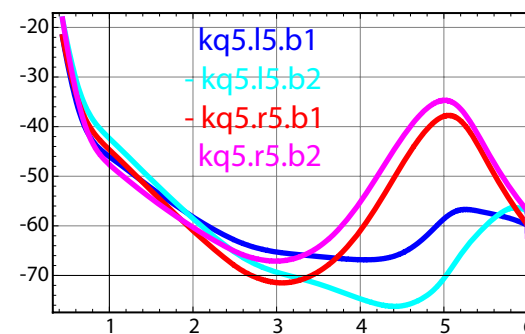
Q1, Q2, Q3, [% of 140 T/m]



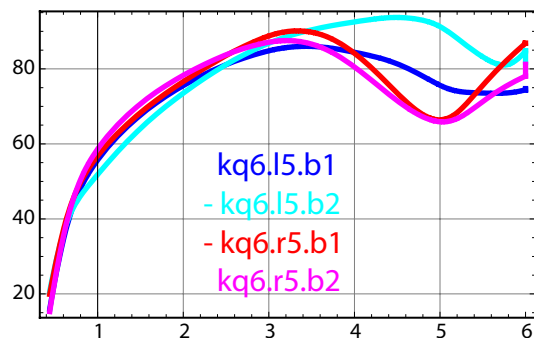
Q4, [% of 125 T/m]



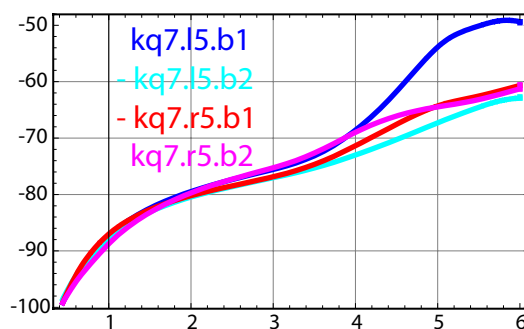
Q5, [% of 160 T/m]



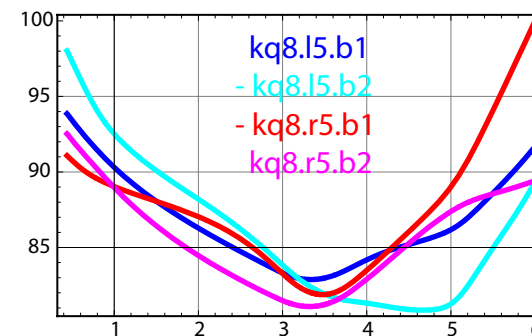
Q6, [% of 160 T/m]



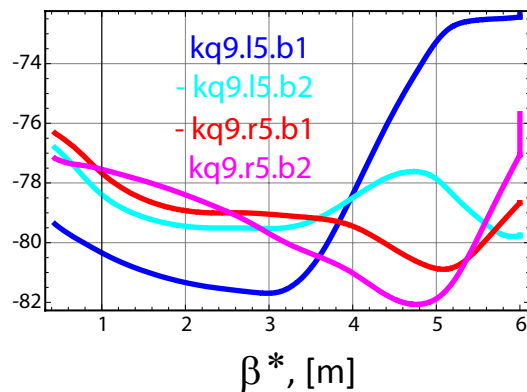
Q7, [% of 200 T/m]



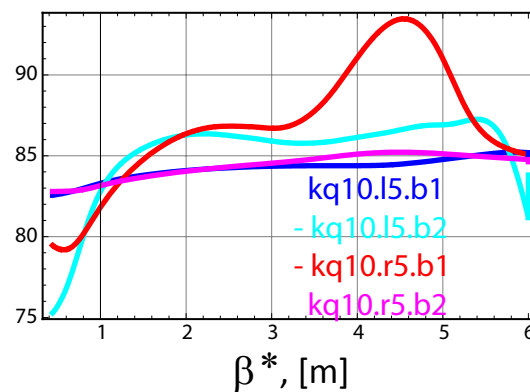
Q8, [% of 200 T/m]



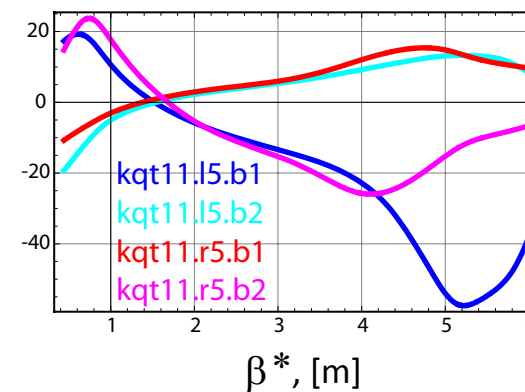
Q9, [% of 200 T/m]



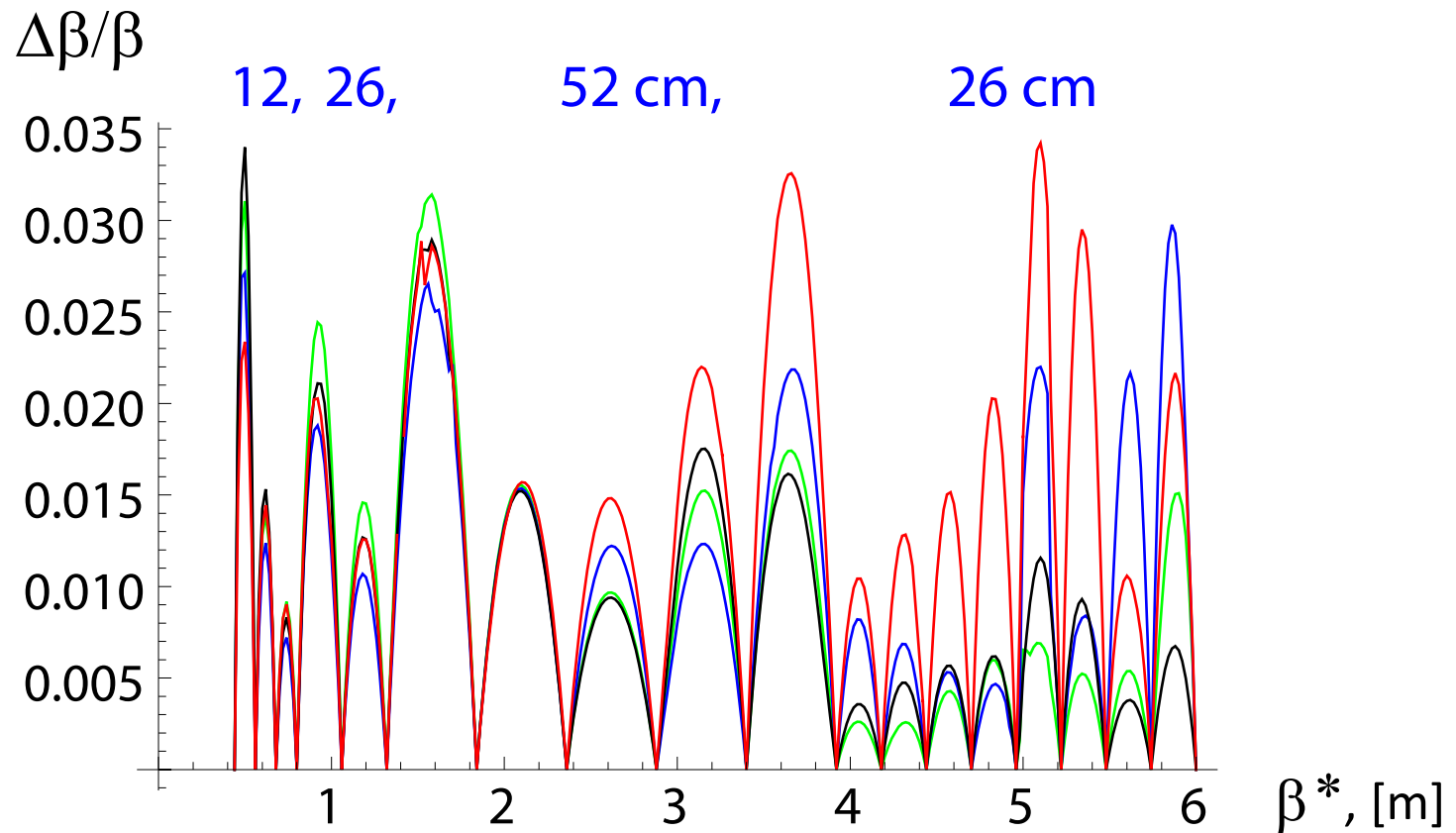
Q10, [% of 200 T/m]



QT11, [% of 125 T/m]



Beta-beating



The maximum beta-beating can be kept below 3.5% by making linear interpolations of the optics transition as follows:

steps of 26 cm from $\beta^* = 6$ m to $\beta^* = 3.92$ m;
steps of 52 cm from $\beta^* = 3.92$ m to $\beta^* = 1.32$ m;
steps of 26 cm from $\beta^* = 1.32$ m to $\beta^* = 0.8$ m;
steps of 12 cm from $\beta^* = 0.8$ m to $\beta^* = 0.44$ m.

IR4 matching conditions

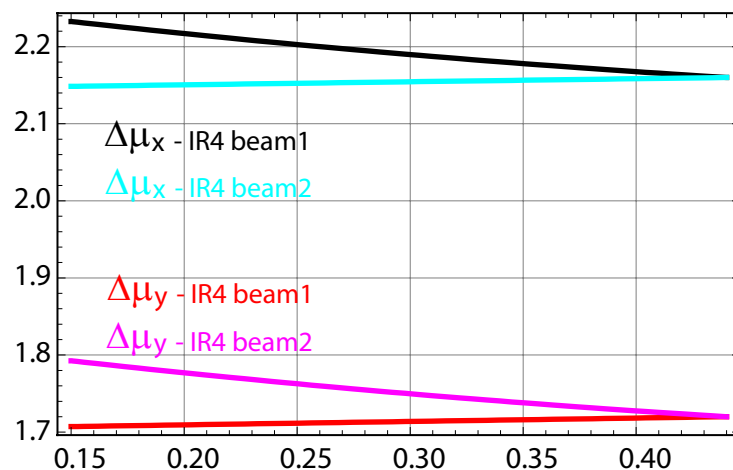
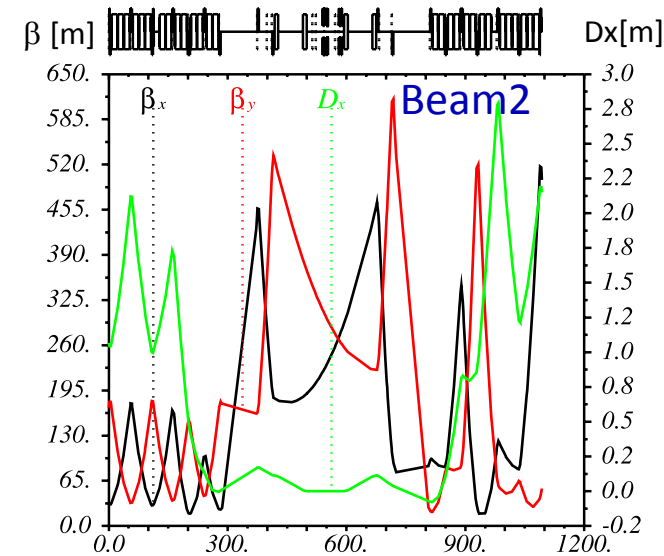
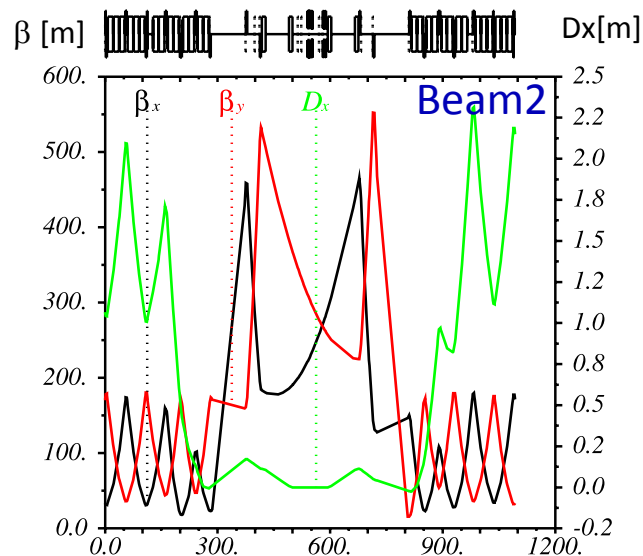
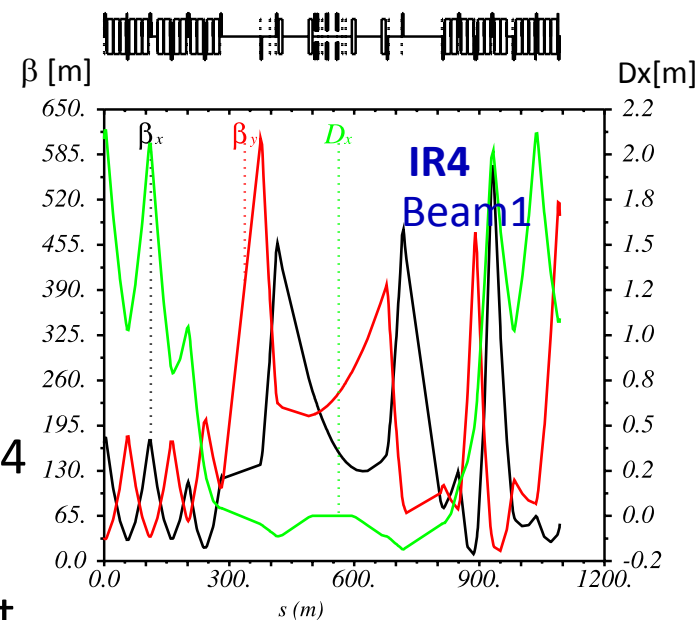
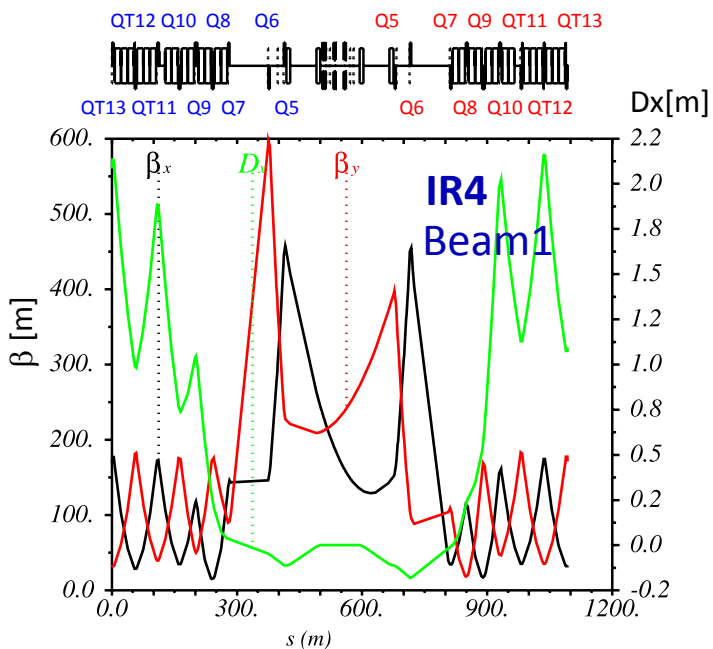
Constraints for Beam1 and Beam2:

Twiss parameters at the end of IR4 as a function of beta* at IP5 during the optics transition

Fixed Twiss parameters at the beginning of IR4

Fixed Twiss parameters at the IP4

Horizontal and vertical phase advance as a function of beta* at IP5 during the optics transition

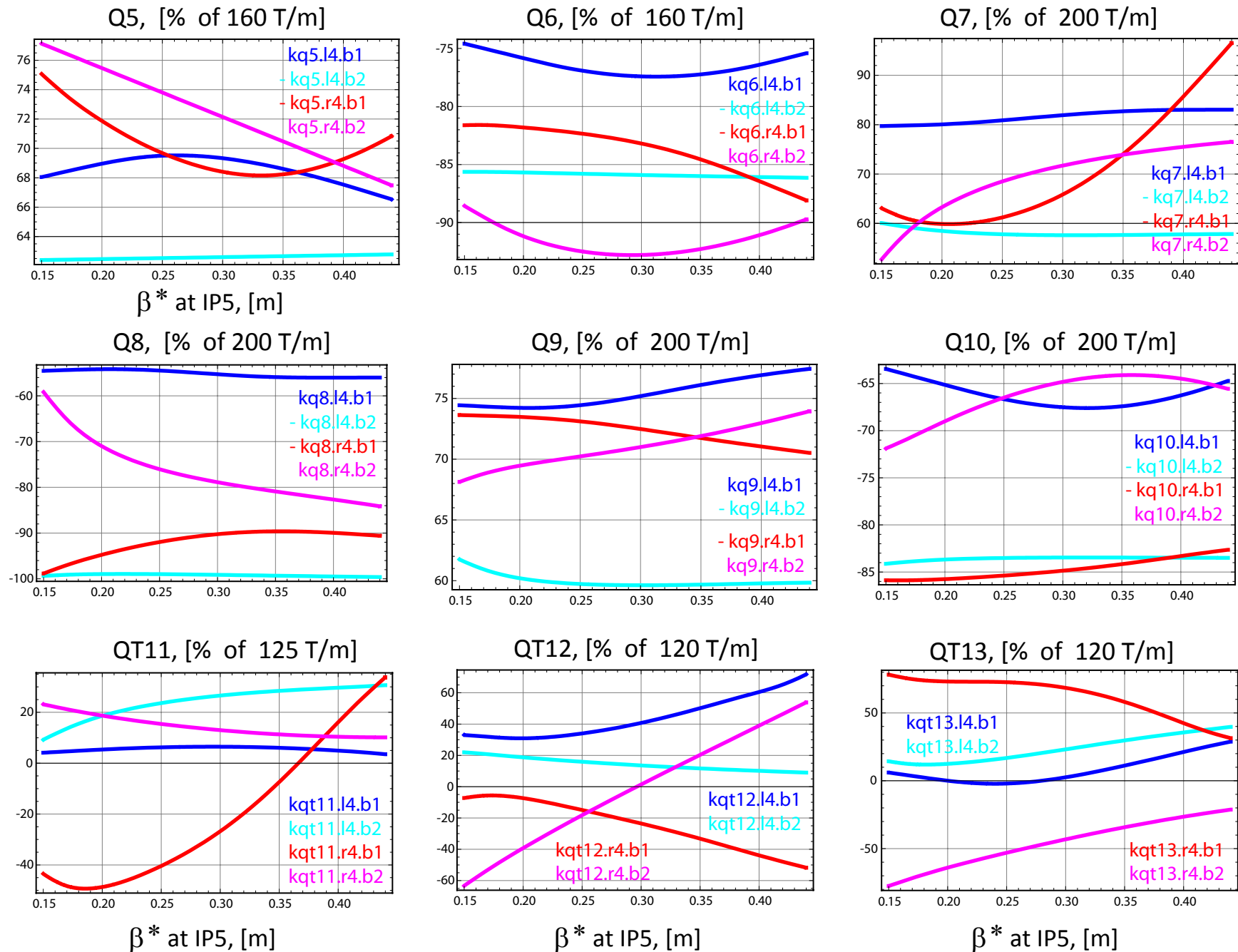


pre-squeeze optics

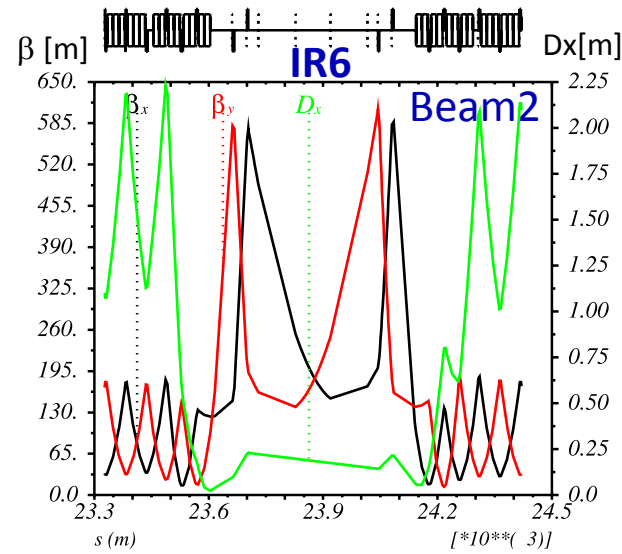
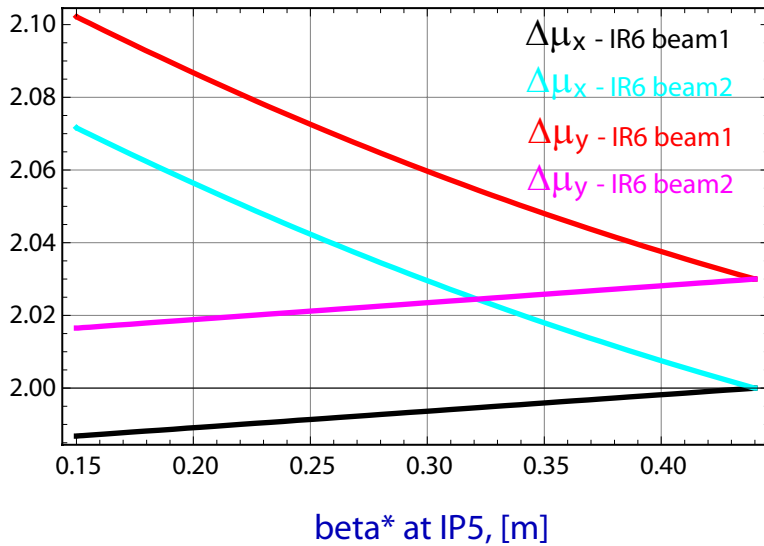
beta* at IP5, [m]

collision optics

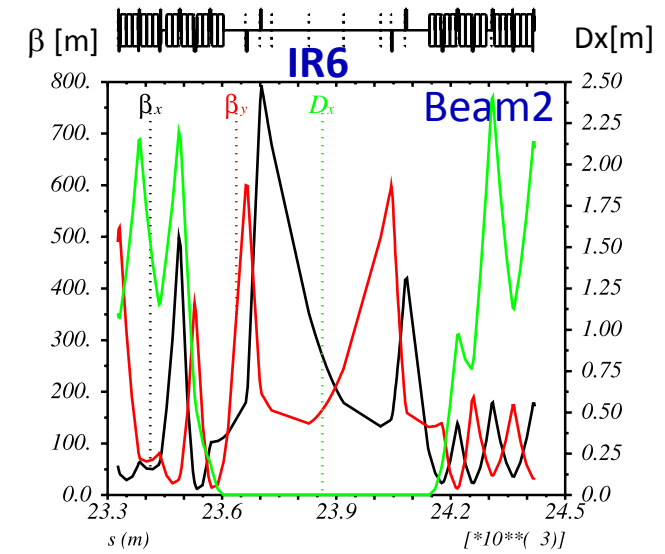
IR4 optics transition



IR6 matching conditions



pre-squeeze optics



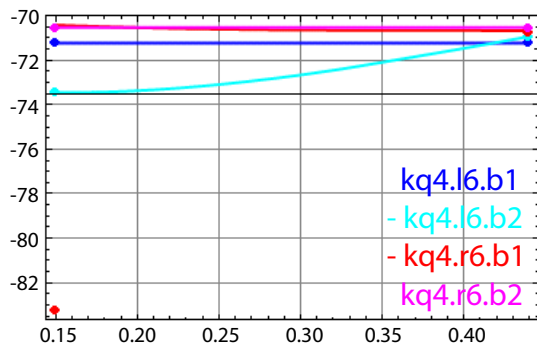
collision optics

- Twiss parameters at the beginning of IR6 as a function of β^* at IP5 during the optics transition
- Fixed Twiss parameters at the end of IR6
- Horizontal and vertical phase advance as a function of β^* at IP5 during the optics transition
- Horizontal and vertical beta functions at the dump

for Beam1:	$\beta_x > 5012$,	$\beta_y > 3955$
for Beam2:	$\beta_x > 5052$,	$\beta_y > 3698$
- Phase advance between the kicker and septum magnet is 90 degree when β^* at IP5 is 0.15 m

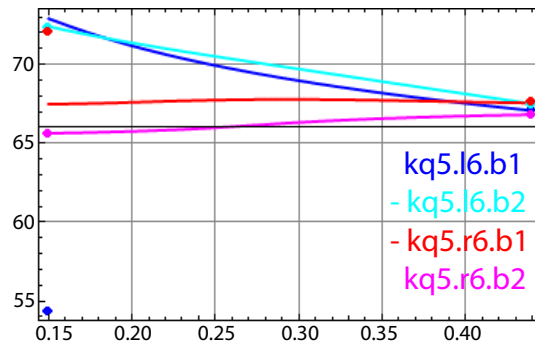
IR6 optics transition

Q4, [% of 160 T/m]

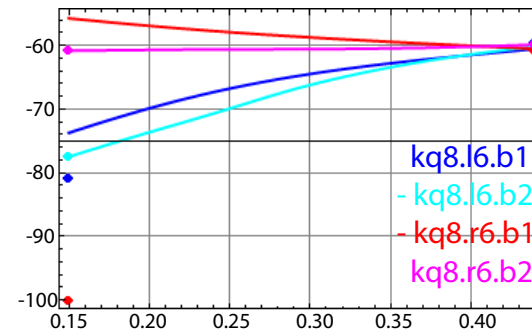


β^* at IP5, [m]

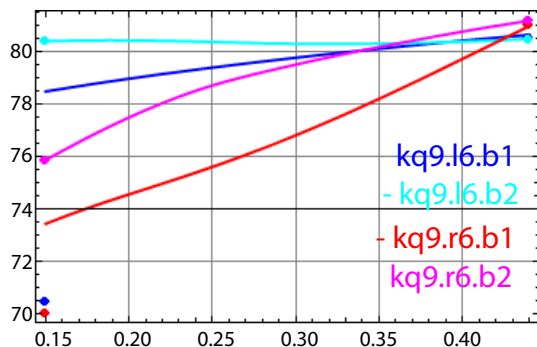
Q5, [% of 160 T/m]



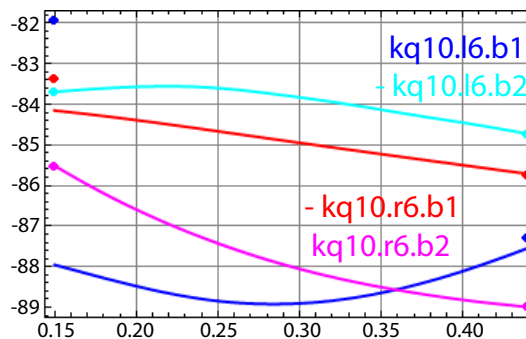
Q8, [% of 200 T/m]



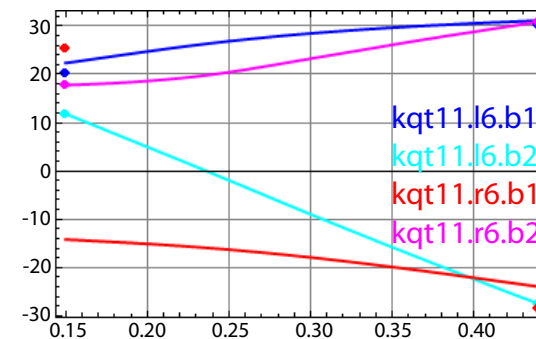
Q9, [% of 200 T/m]



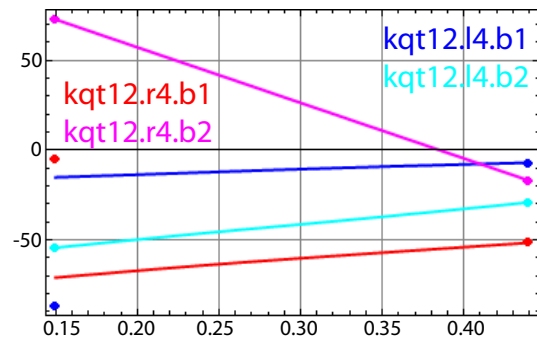
Q10, [% of 200 T/m]



QT11, [% of 125 T/m]

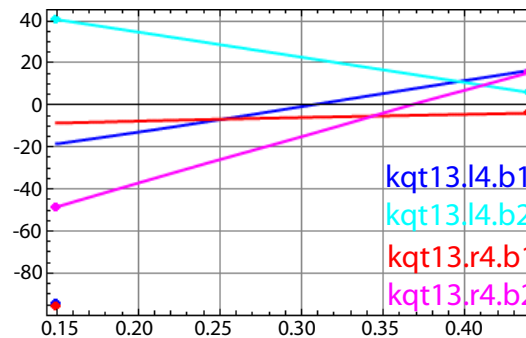


QT12, [% of 120 T/m]



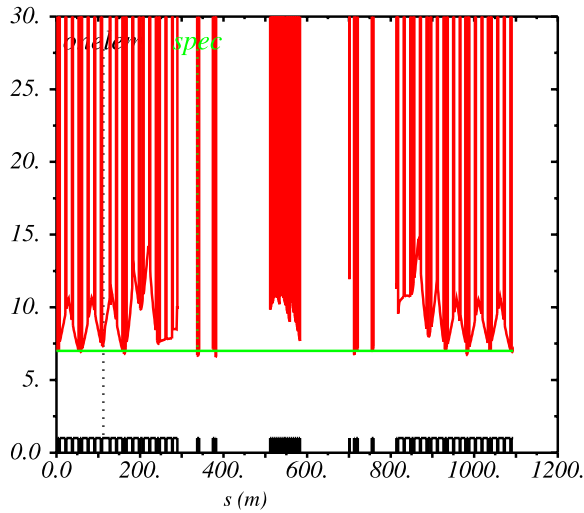
β^* at IP5, [m]

QT13, [% of 120 T/m]

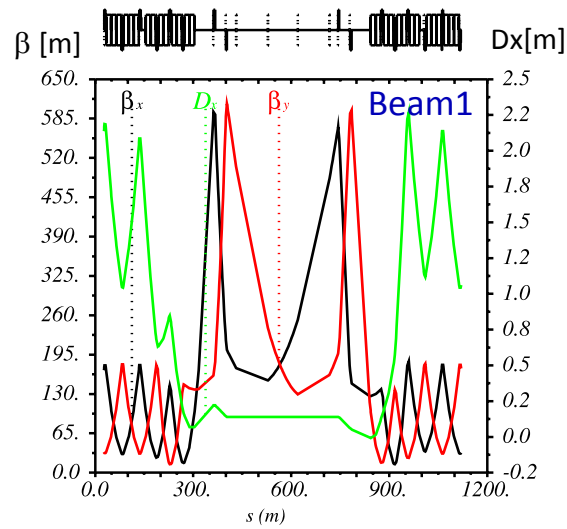


β^* at IP5, [m]

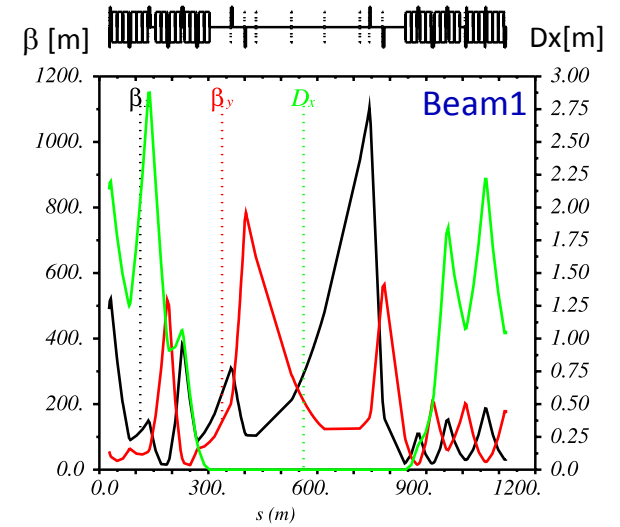
New optics in IR6 for beam1



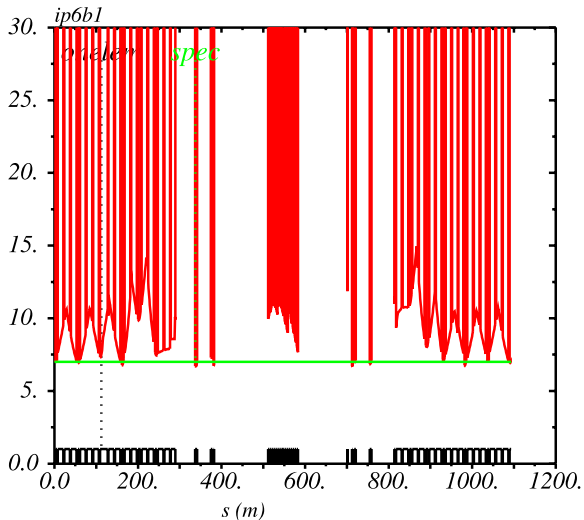
Aperture at injection (450 GeV) for predefined pre-squeeze/injection optic



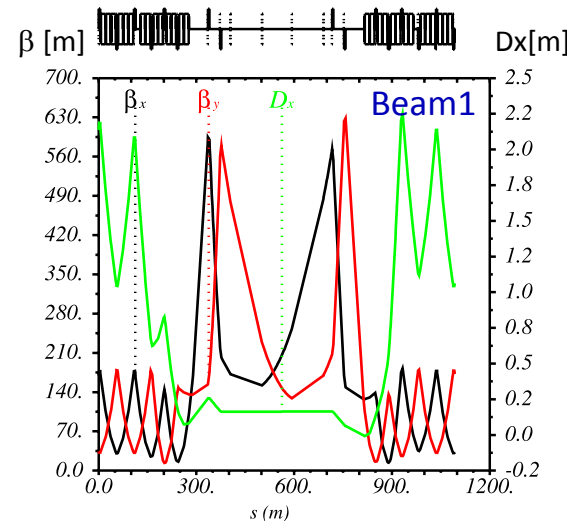
predefined pre-squeeze optics



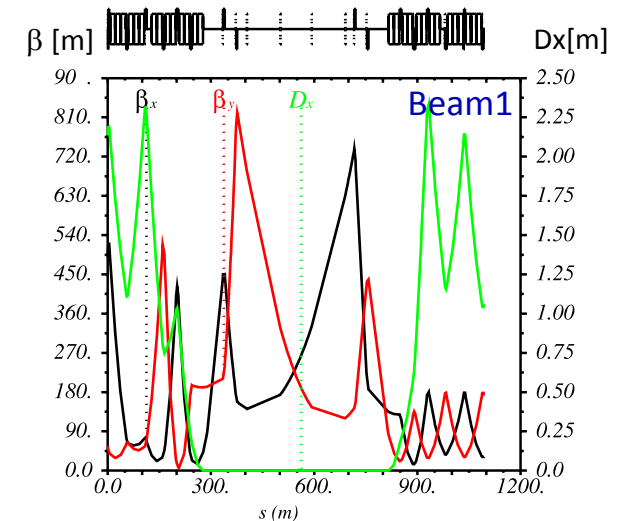
predefined collision optics



Aperture at injection (450 GeV) for new pre-squeeze/injection optic



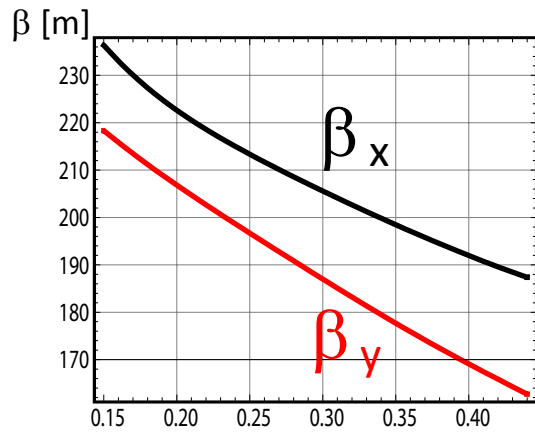
new pre-squeeze optics



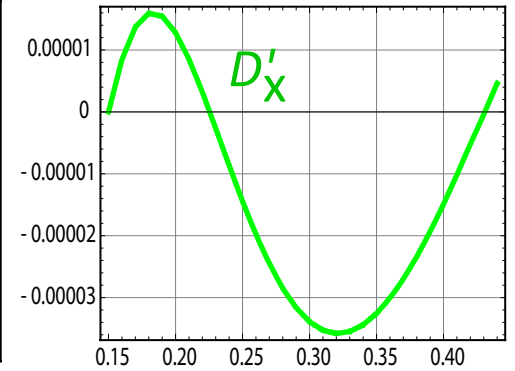
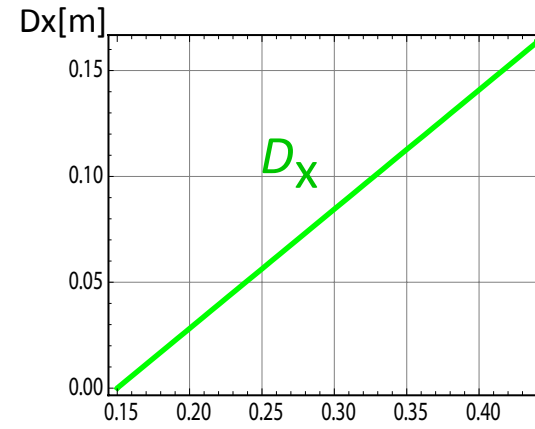
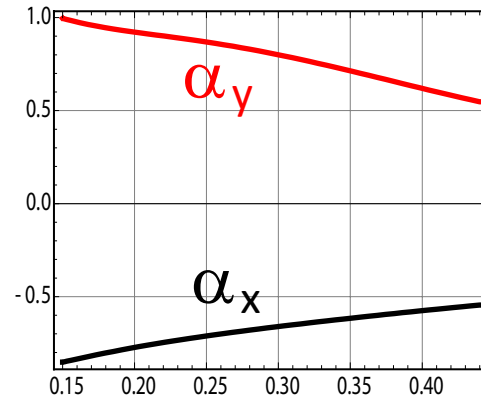
new collision optics

Twiss parameters at IP6

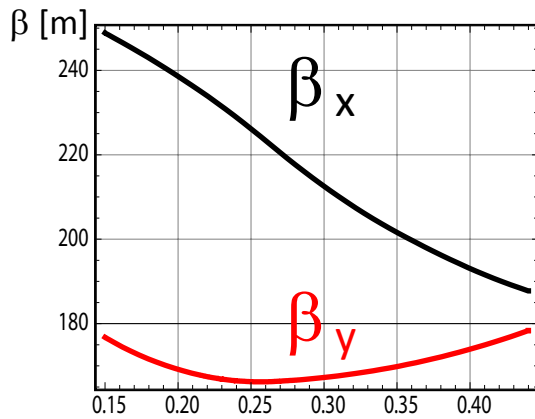
BEAM 1



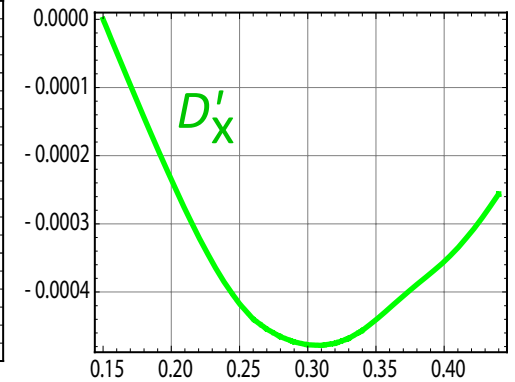
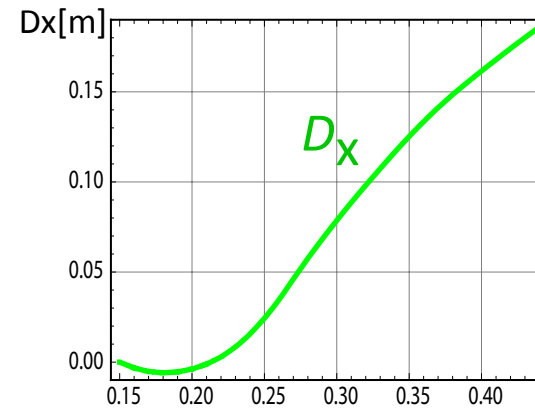
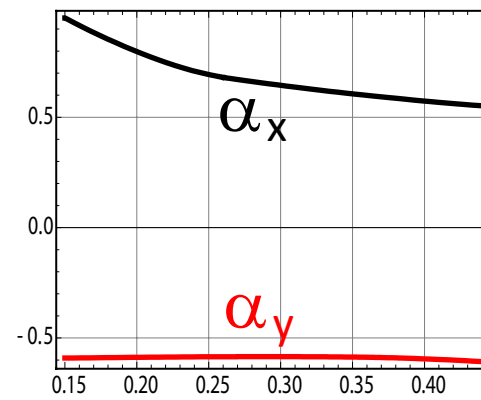
Beta* at IP5, [m]



BEAM 2

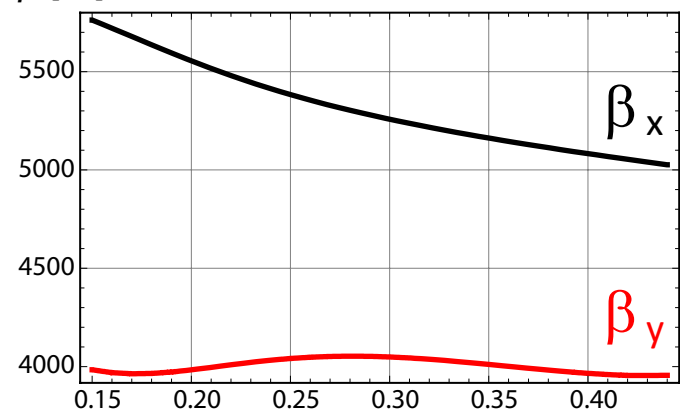


Beta* at IP5, [m]



Beta functions at the beam dump and phase advance between the kicker and septum magnet in IR6

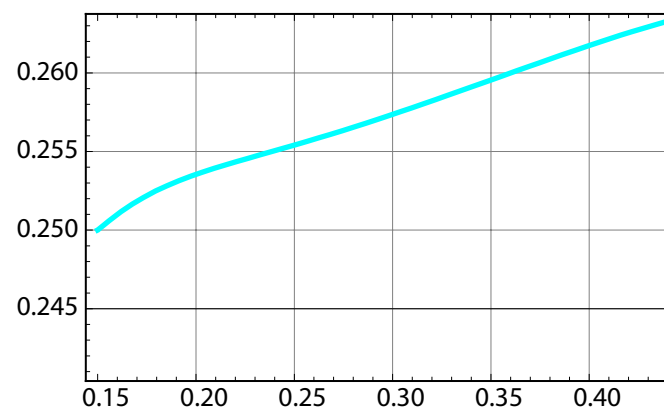
β [m] Beta functions at the beam dump



Beta* at IP5, [m]

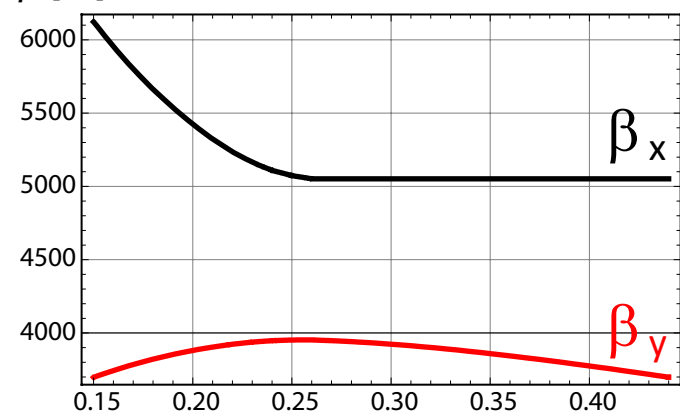
Beam 1

Phase advance between the kicker and septum



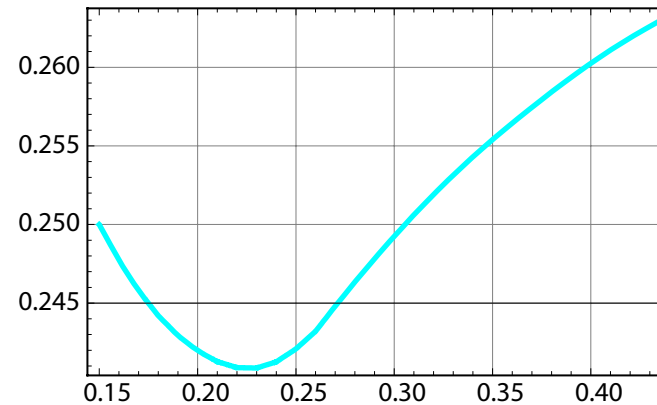
Beta* at IP5, [m]

β [m] Beta functions at the beam dump



Beam 2

Phase advance between the kicker and septum



Conclusions

- Solutions for the optics transitions in IR5, IR1, IR4 and IR6 which meet all required matching constraints have been found.
- Optics transition in IR5 and IR1 provides ATS pre-squeeze optics in the range of β^* from 3.2 m to 0.44 m. Any changes of slope of field gradient take place far from the low-field domain.
- Optics transition in IR6 results in the new optics for the beam1 at collision.
- Next steps: to find solutions for the optics transition in IR8 and IR2