Optics transition between injection and pre-squeeze optics for the IR5/1 with IT gradient of 150 [T/m] and aperture of 140 [mm]

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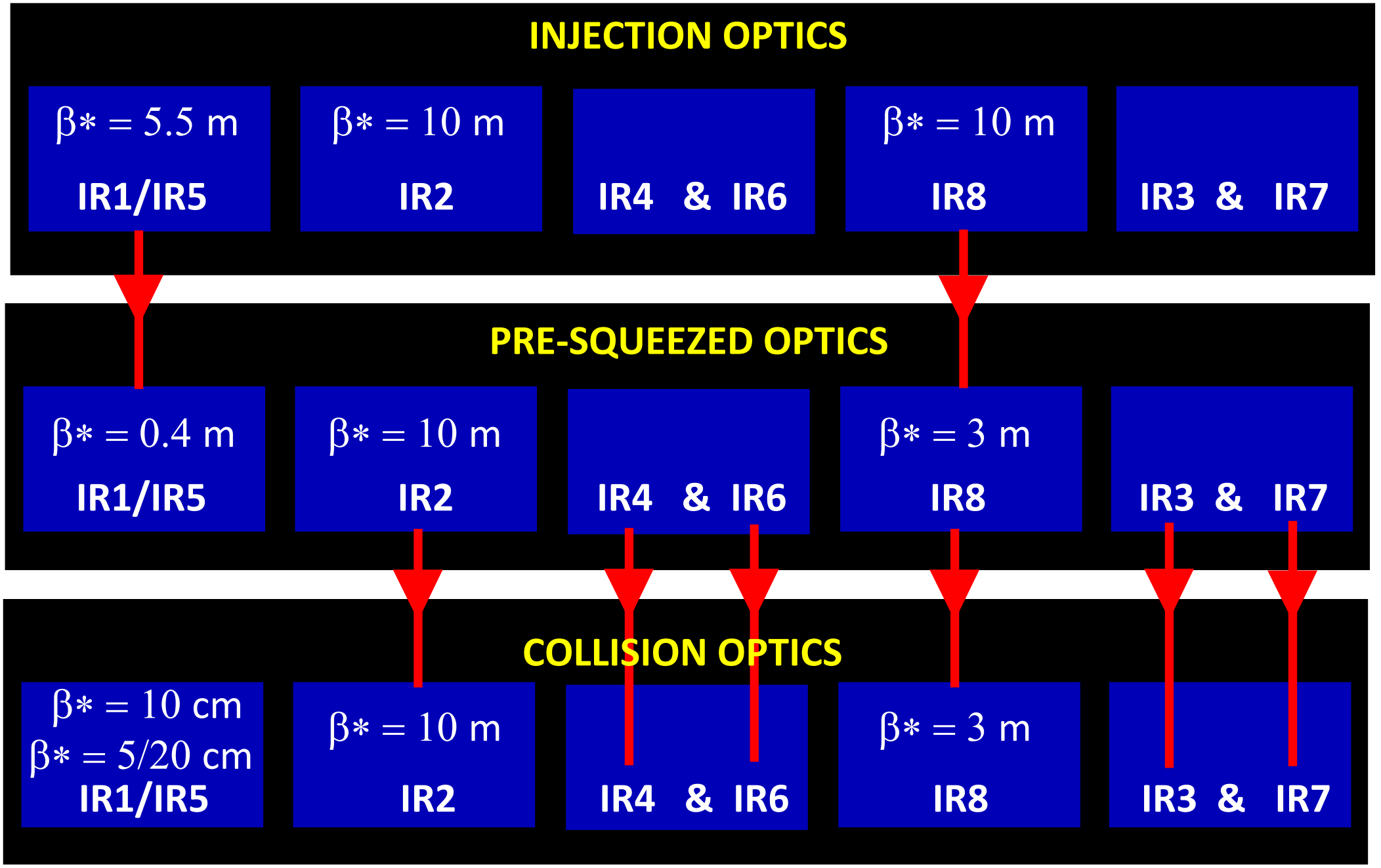
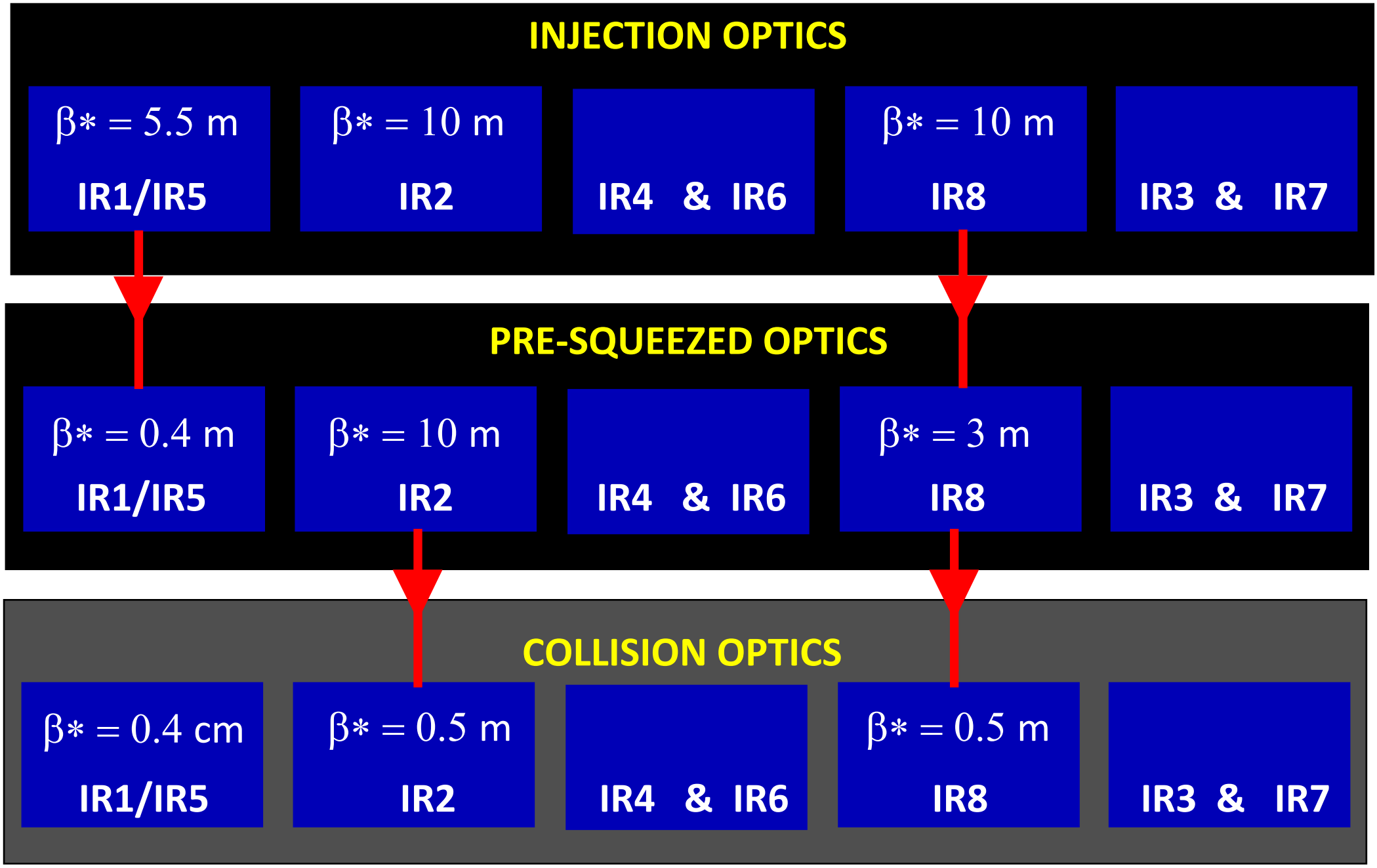
Optics transition from injection to collision for protons



Optics transition from injection to collision for ions



Constraints for IR1/5 optics at injection

- Twiss parameters at the entrance and at the exit of the IR1/5 (beginning of the 1st DS and exit of the 2nd DS in the IR1/5) which are specified by the the non-ATS optics in the ARC.
- Horizontal and vertical phase advance over the IR1/5 are 2.6277 x 2π and 2.637 x 2π, respectively
- Twiss parameters in both IP1 and IP5 are $\beta* = 5.5$ m, Dx = 0.0, D'x=0.0
- Injection optics should provide sufficient aperture for the beam with energy of 450 GeV
- Injection optics for IR1/5 'opt_5500_5500.madx' (Riccardo/Stephane).

Constraints for pre-squeeze IR1/5 optics

- Twiss parameters at the entrance and at the exit of the IR1/5 are the same as for the injection optics
- Phase advance between the entrance of IR1/5 and IP1/5 are $\mu x = 1.1569 \times 2\pi$ and $\mu y = 1.4867 \times 2\pi$, while
- Phase advance between IP1/5 and the exit of IR1/5 are $\mu x = 1.4858 \times 2\pi$ and $\mu y = 1.1553 \times 2\pi$
- Twiss parameters in both IP1 and IP5 are $\beta* = 0.4$ m, Dx = 0.0, D'x=0.0
- Pre-squeeze optics for IR1/5 'opt_0400_0400.madx' (Riccardo/Stephane)

Requirements during optics transition

- Smooth variation of the quadrupole gradients during the change from the injection to pre-squeeze optics
- Slope of the quadrupole gradient during the variation should not change its sign
- Optics transition should meet the requirements for pre-squeeze optics in the range of beta* from 0.4 m to 2.0 m.
- Pre-squeeze optics for IR1/5 'opt_2000_2000.madx' (Riccardo/Stephane)
- Since IR5 and IR1 are similar, optics transition in both regions can be similar too.

Variants of the optics transition

- Several variants of the optics transition between injection and pre-squeeze optics have been found. Three of them will be presented where:

  - two variants are calculated by the MADX re-matching routine starting from the gradients specified by the 'opt_0400_0400.madx' pre-squeeze optics

  - one variant is calculated by the MADX re-matching routine starting from the gradients specified by the 'opt_5500_5500.madx' injection optics

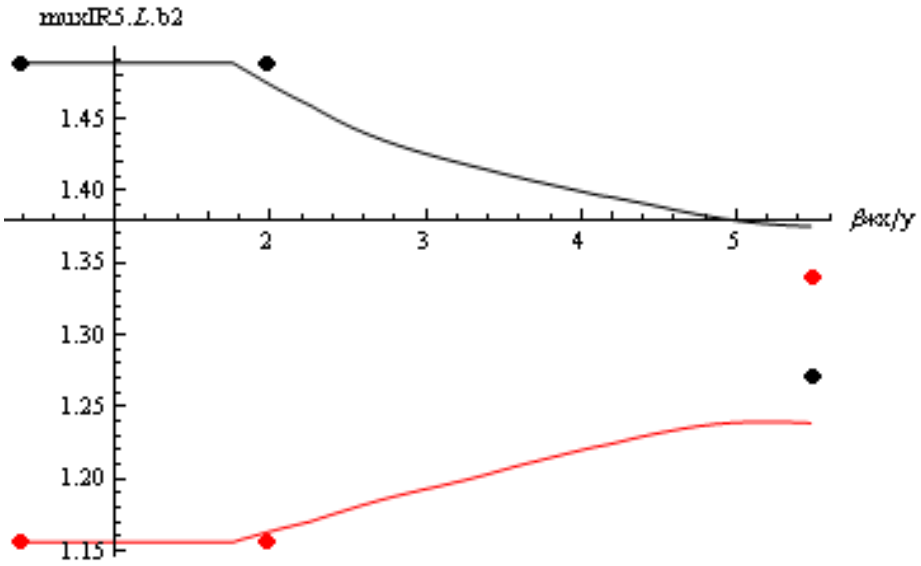
- All three variants meet the required conditions for the pre-squeeze optics in the range of beta* from 0.4 m to 1.8 m.

Optics transition (F5)

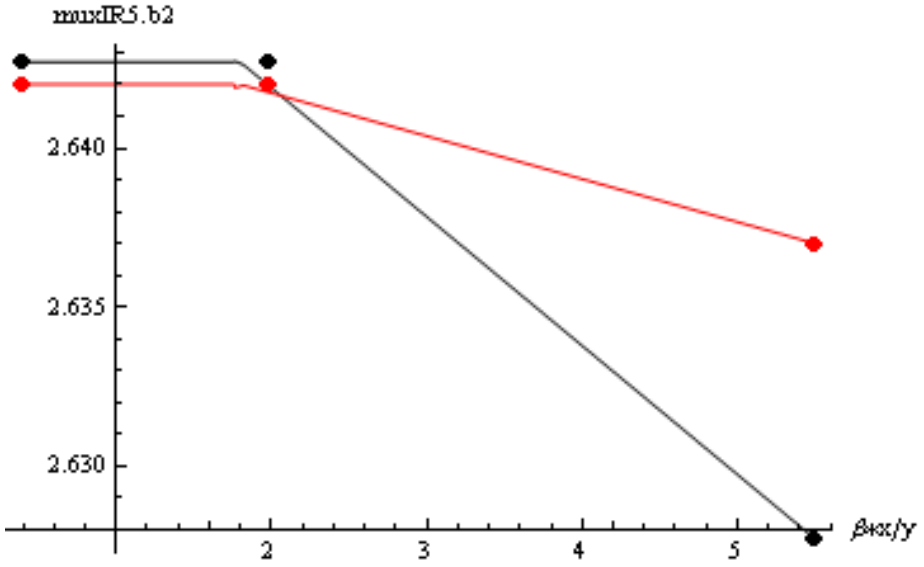
MADX re-matching routine starts from the 'opt_0400_0400.madx' pre-squeeze optics with the following constraints:

1. IT quads Q1/Q2/Q3 do NOT change their strength in the range of beta* from 0.4 m to 5.5 m. Strength of other quads in the IR5 varies within intrinsic upper and lower limits.

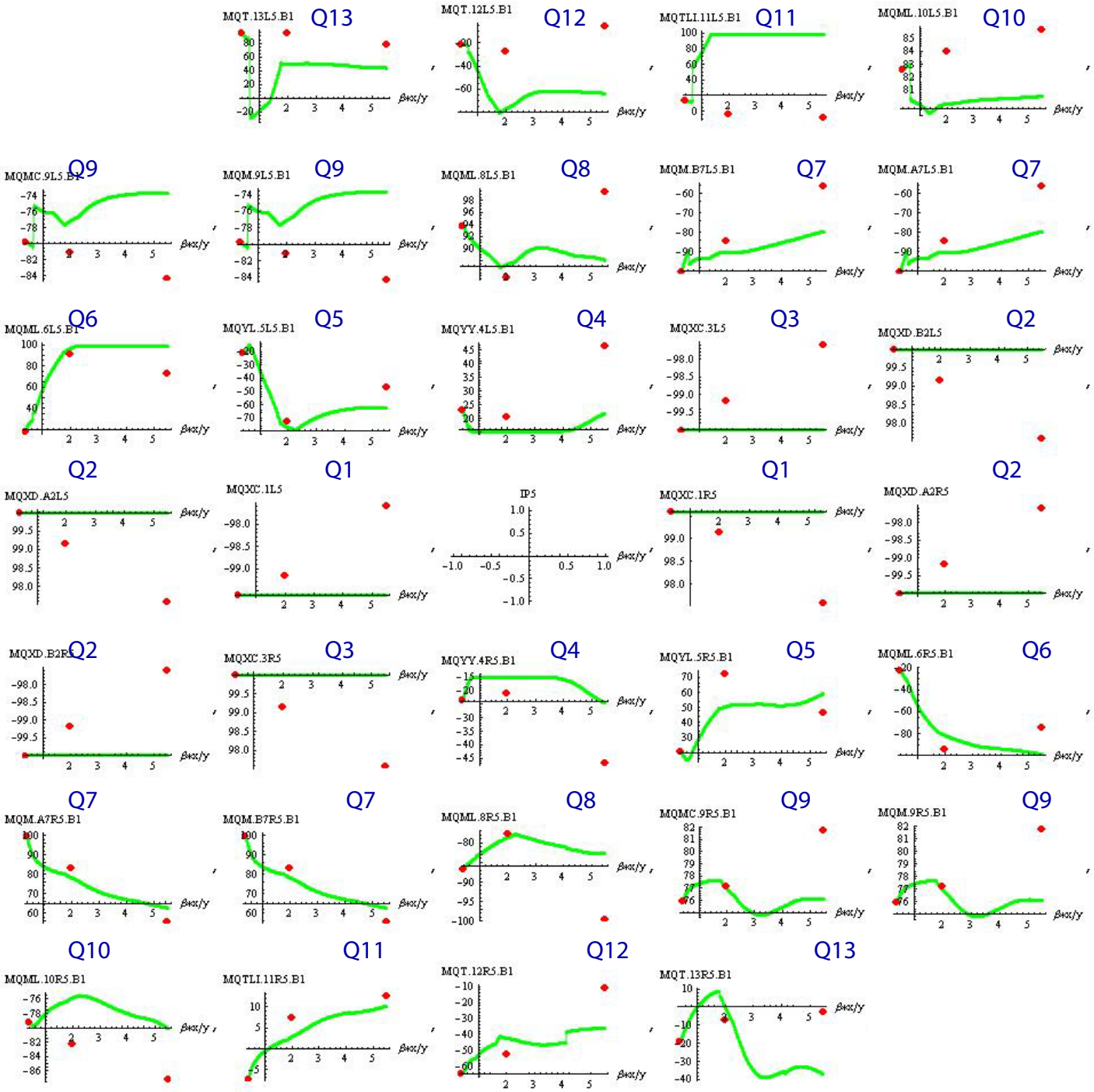
2. Horizontal and vertical phase advance between beginning IR1/5 and IP1/5 in the range of beta* from 0.4 m to 1.8 m



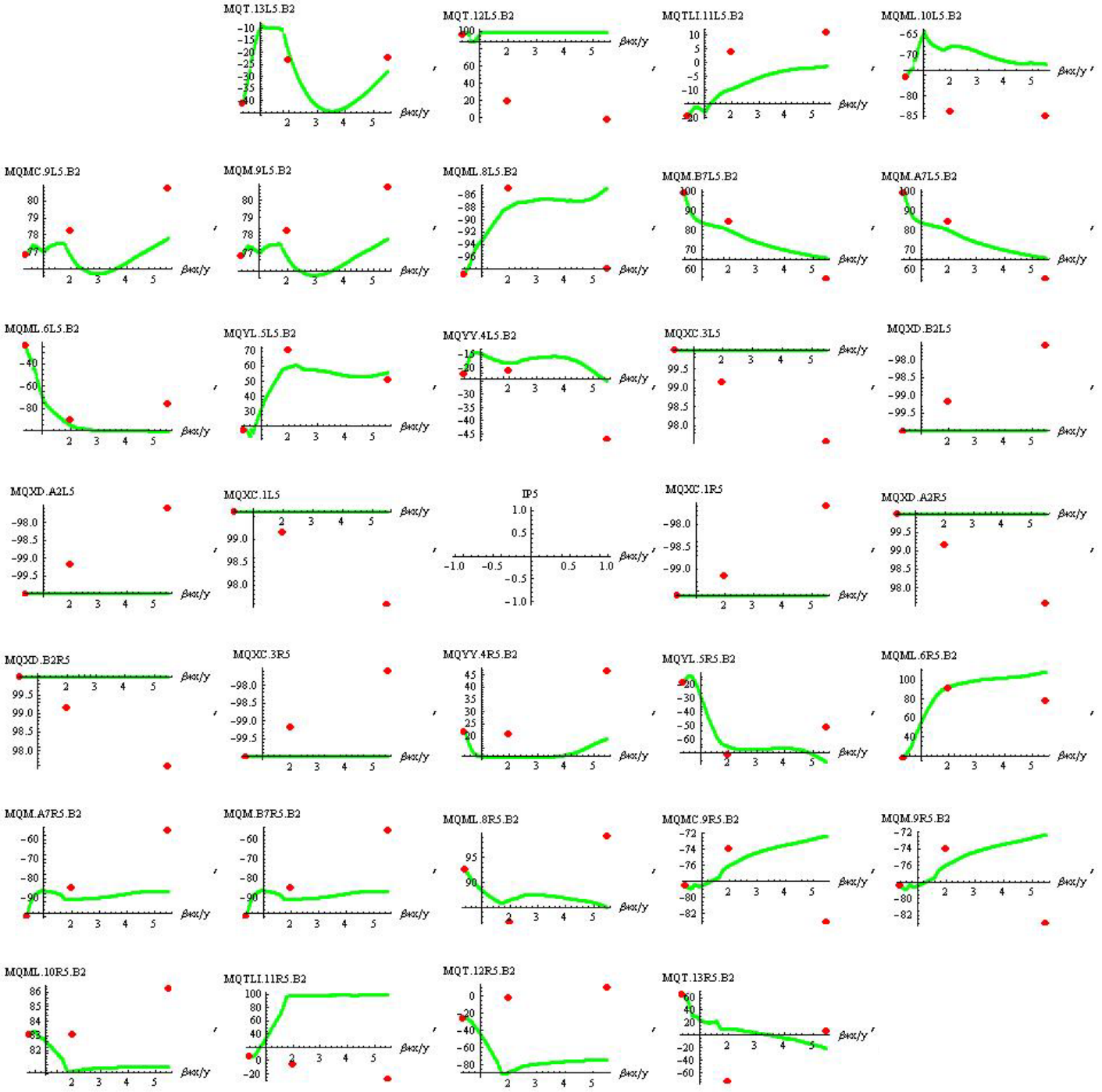
3. Horizontal and vertical phase advance between beginning and the end of IR1/5 in the range of beta* from 0.4 m to 5.5 m



Optics transition (F5) beam1

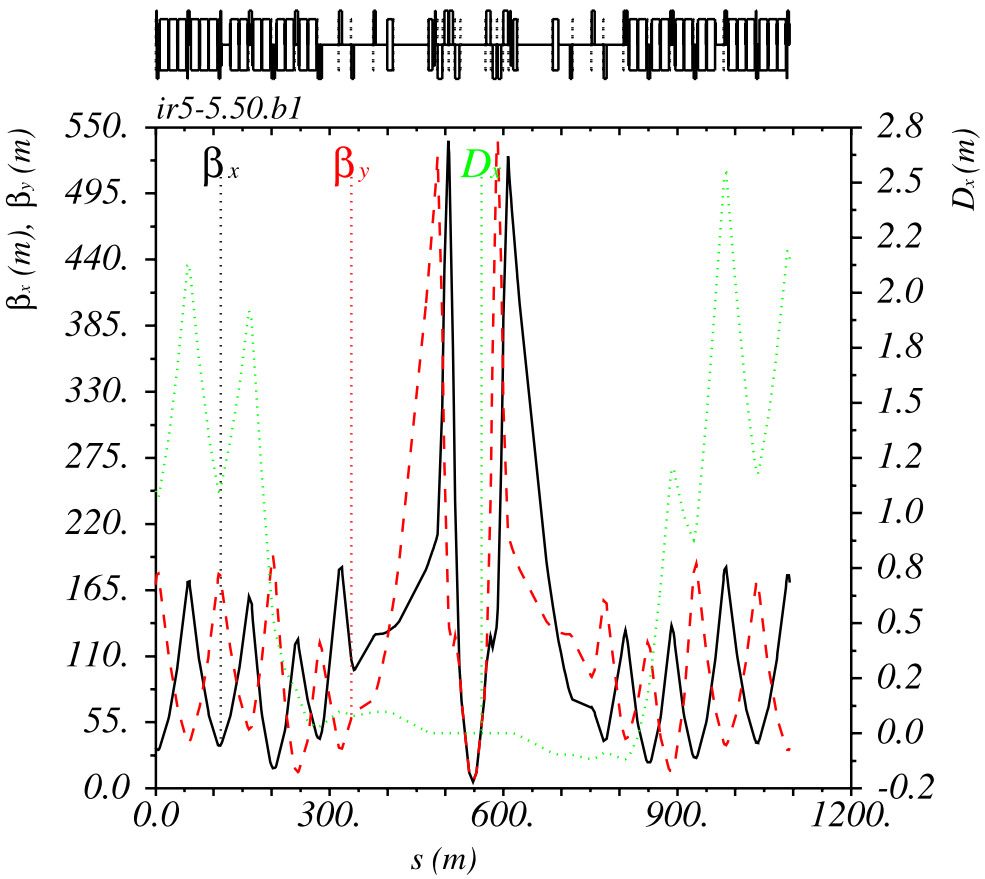


Optics transition (F5) beam2

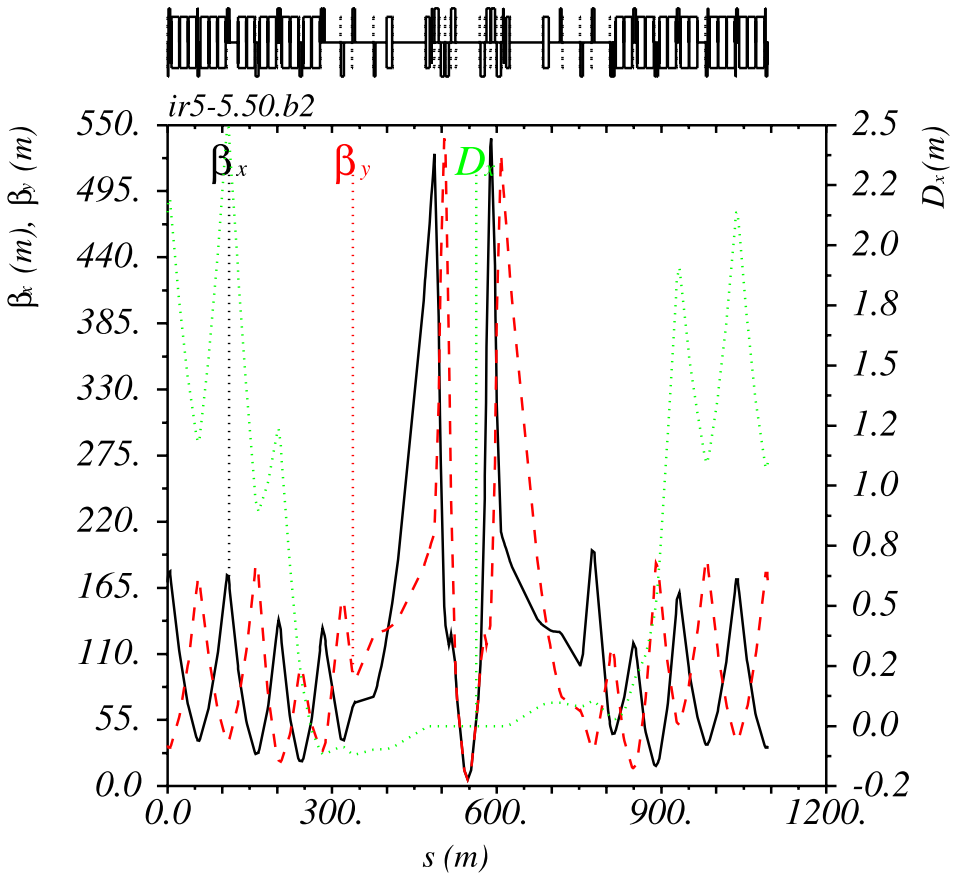


Injection optics resulting from F5 transition

IR5.B1

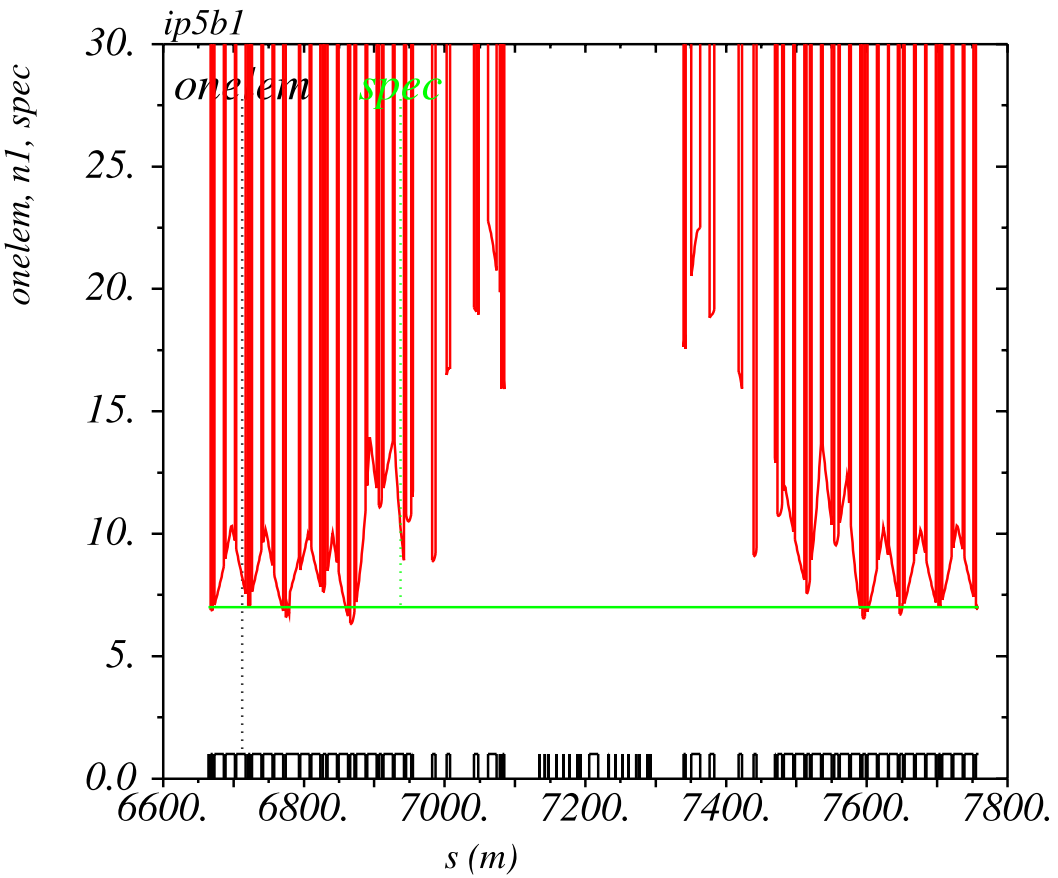


IR5.B2

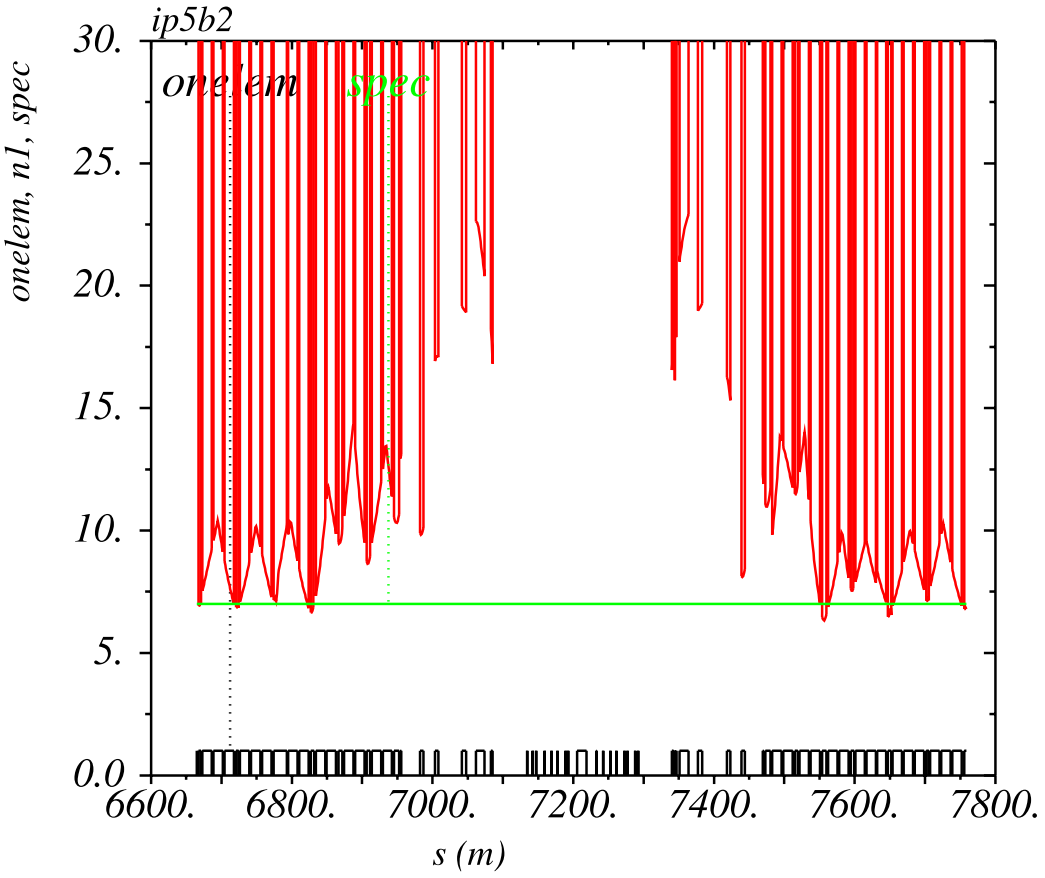


Aperture check for F5 transition at the injection energy of 450 GeV

IR5.B1



IR5.B2

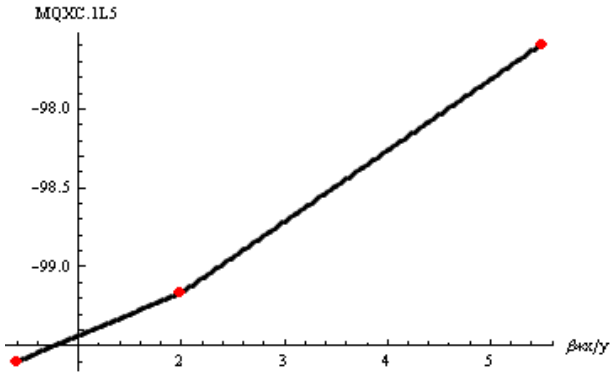


Crossing is ON, beam separation is ON, Alice and LHCb spectrometers are ON

Optics transition (F8)

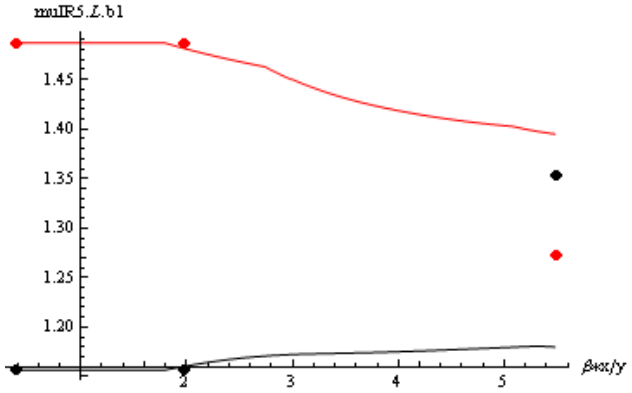
MADX re-matching routine starts from the 'opt_0400_0400.madx' pre-squeeze optics with the following constraints:

1. In the range of beta* from 0.4 m to 5.5 m, IT quad Q1 changes its strength as a function of beta*
according to ->

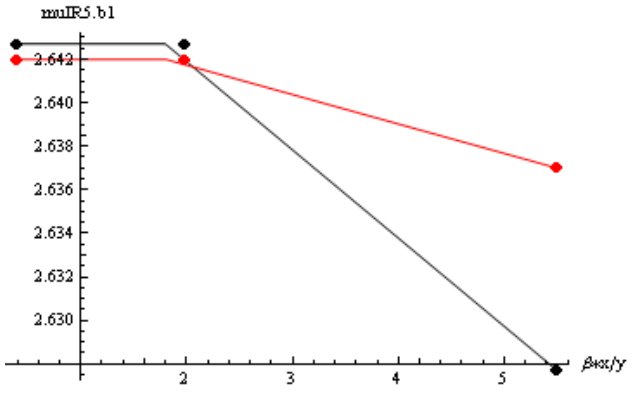


2. IT quad Q3 does NOT change its strength in the range of beta* from 0.4 m to 5.5 m. Strength of other quads in the IR5 varies within intrinsic upper and lower limits.

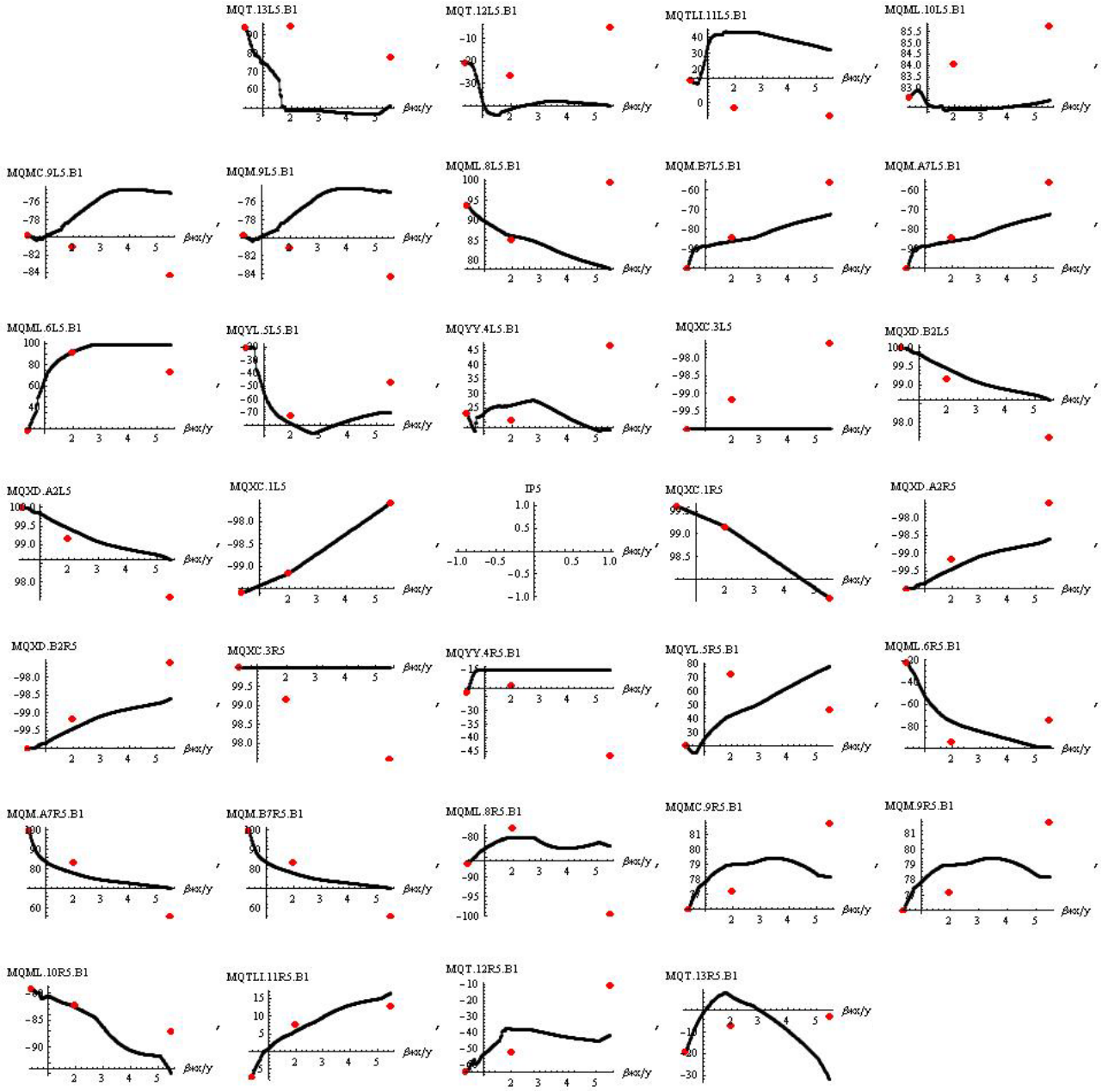
3. Horizontal and vertical phase advance between beginning IR1/5 and IP1/5 in the range of beta* from 0.4 m to 1.8 m



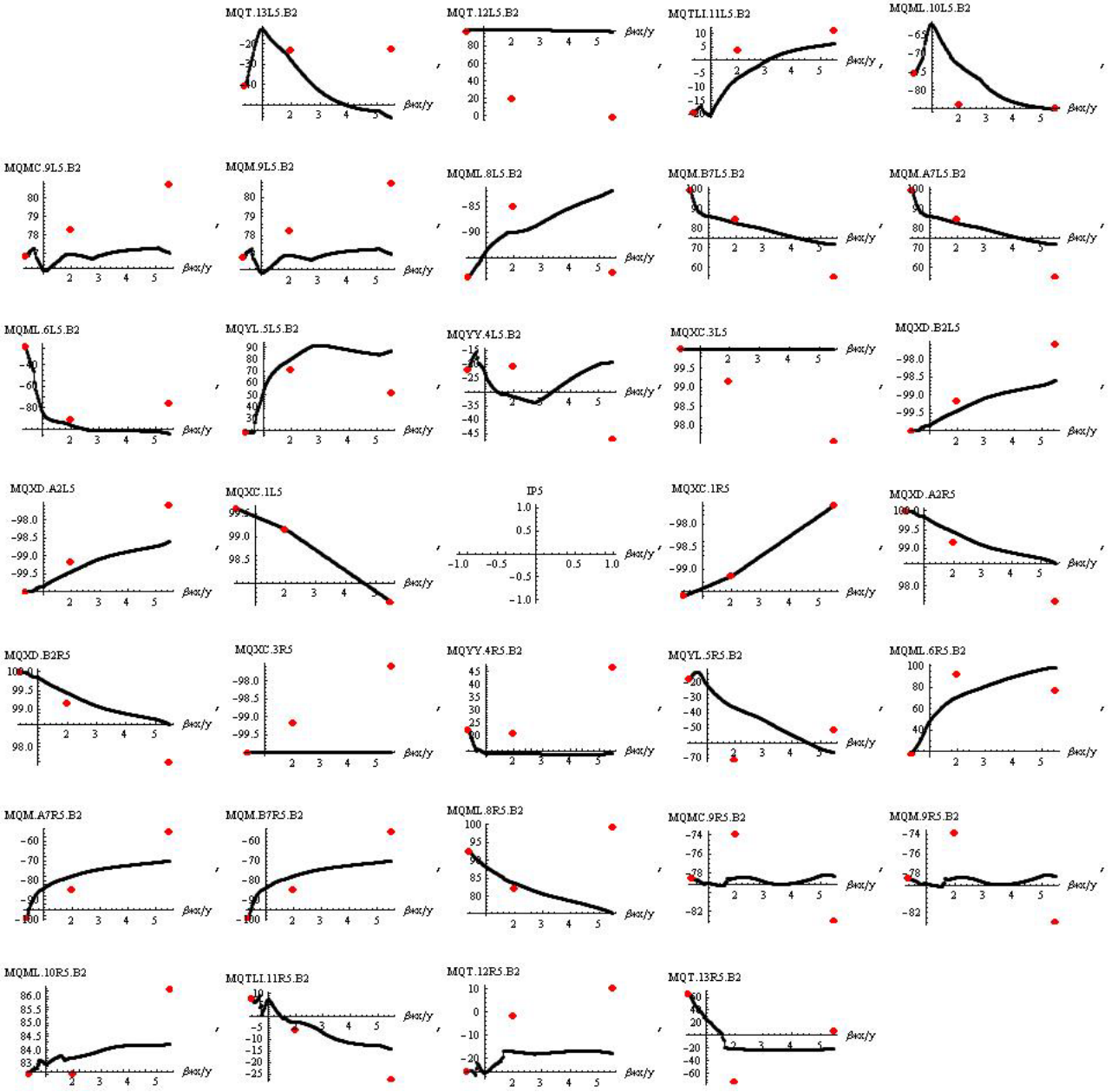
4. Horizontal and vertical phase advance between beginning and the end of IR1/5 in the range of beta* from 0.4 m to 5.5 m



Optics transition (F8) beam1

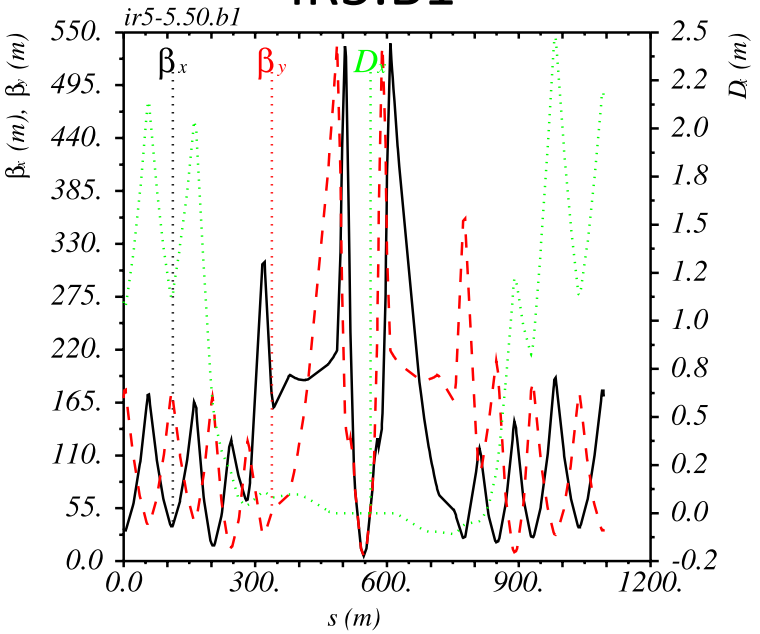


Optics transition (F8) beam2

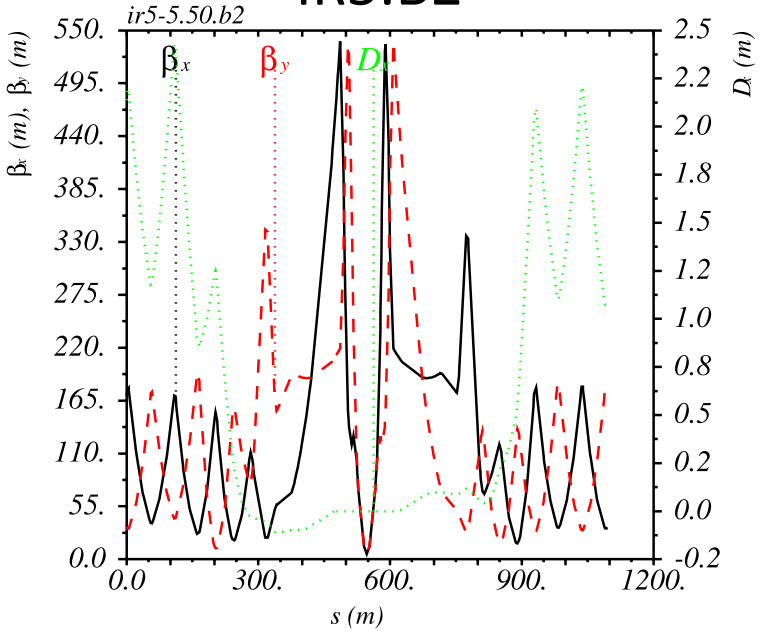


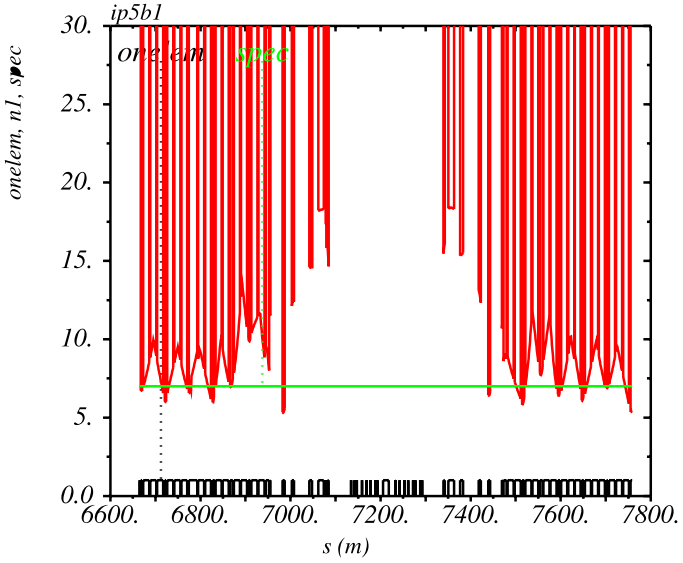
Injection optics resulting from F8 transition

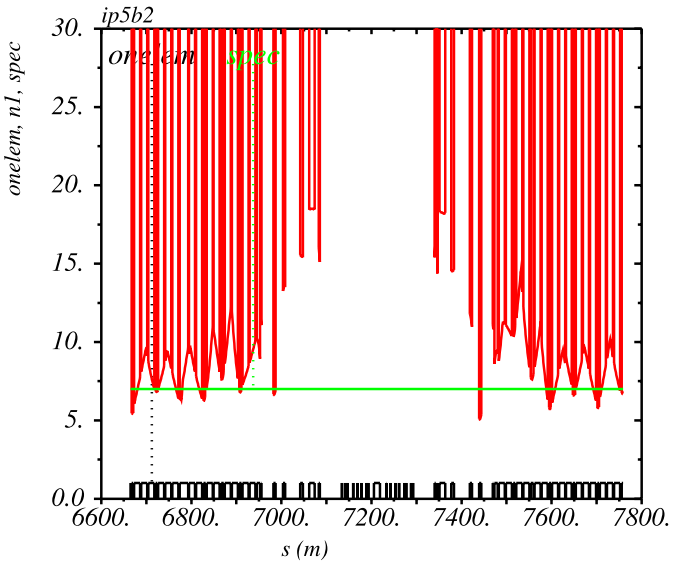
IR5.B1



IR5.B2





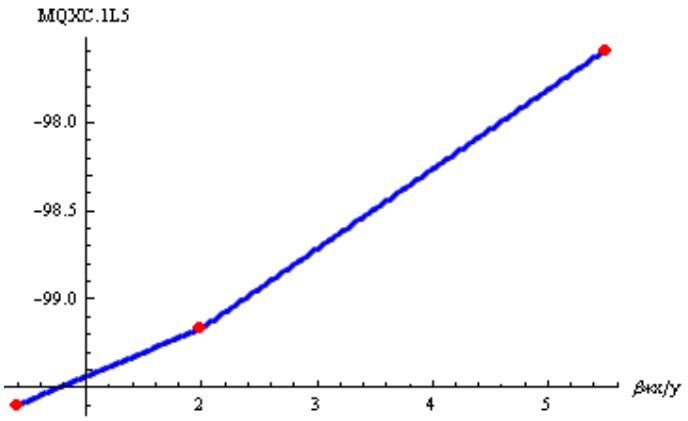


- Aperture restriction in DS and Q6... further optimization is needed for F8

Optics transition (F9)

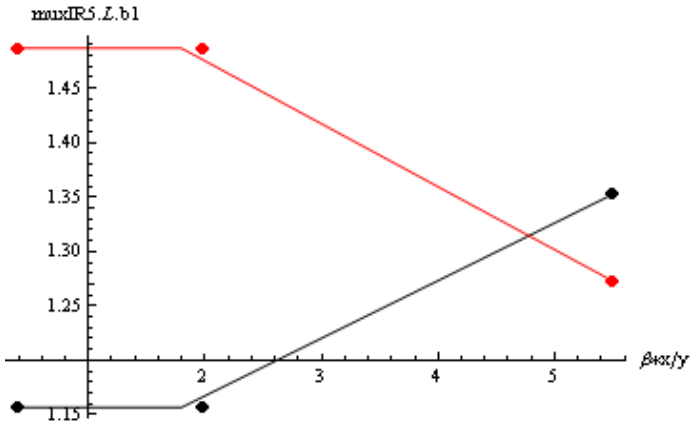
MADX re-matching routine starts from the 'opt_5500_5500.madx' injection optics with the following constraints:

1. In the range of beta* from 0.4 m to 5.5 m, IT quad Q1 changes its strength as a function of beta*
according to ->

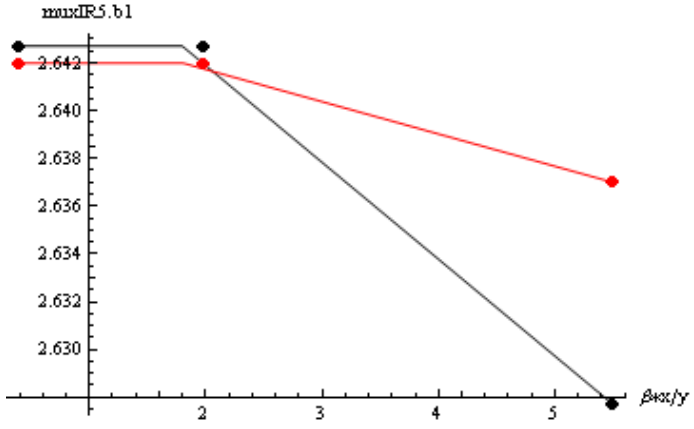


2. Strength of other quads in the IR5 varies within intrinsic upper and lower limits.

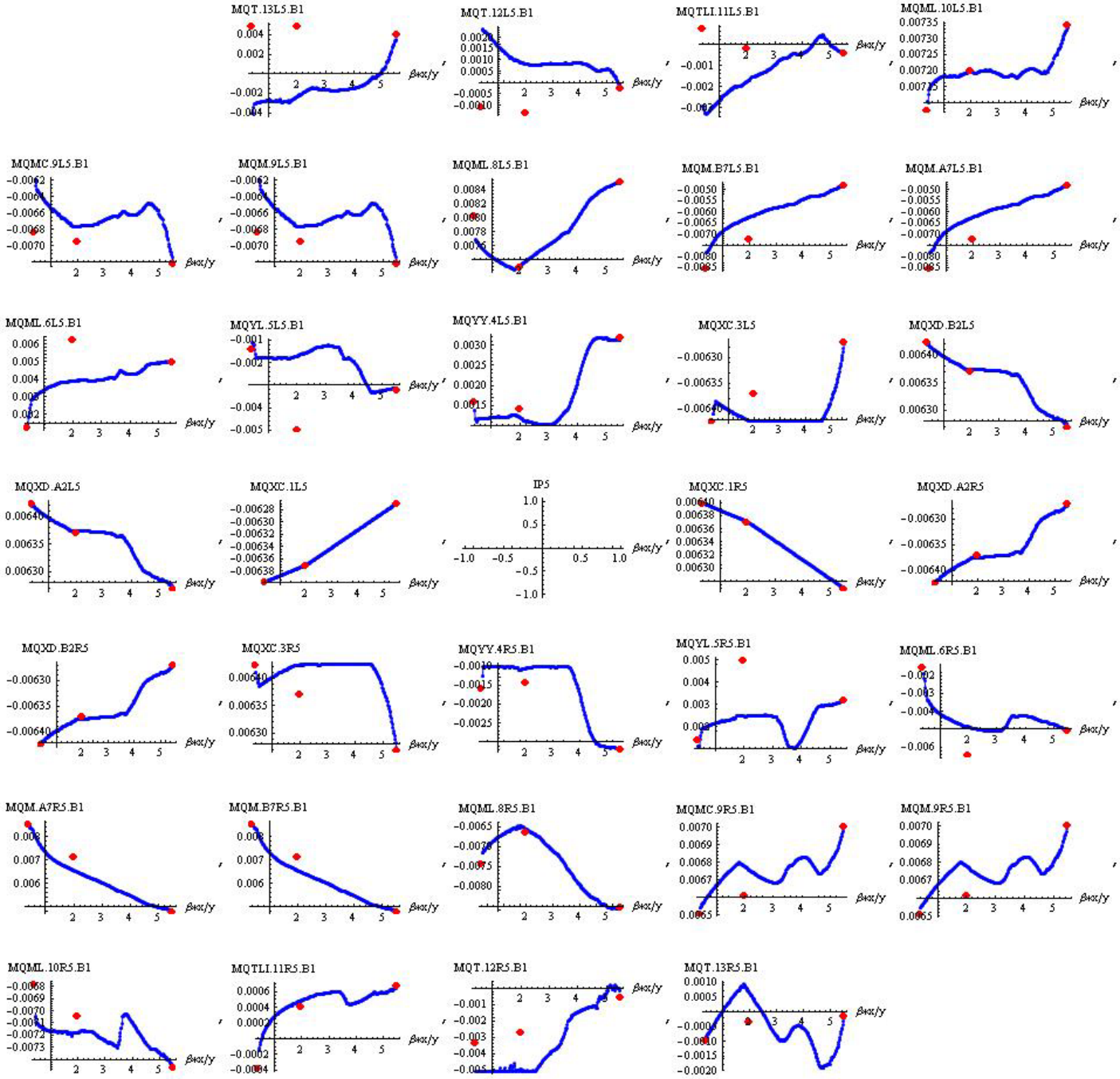
3. Horizontal and vertical phase advance between beginning IR1/5 and IP1/5 in the range of beta* from 0.4 m to 5.5 m



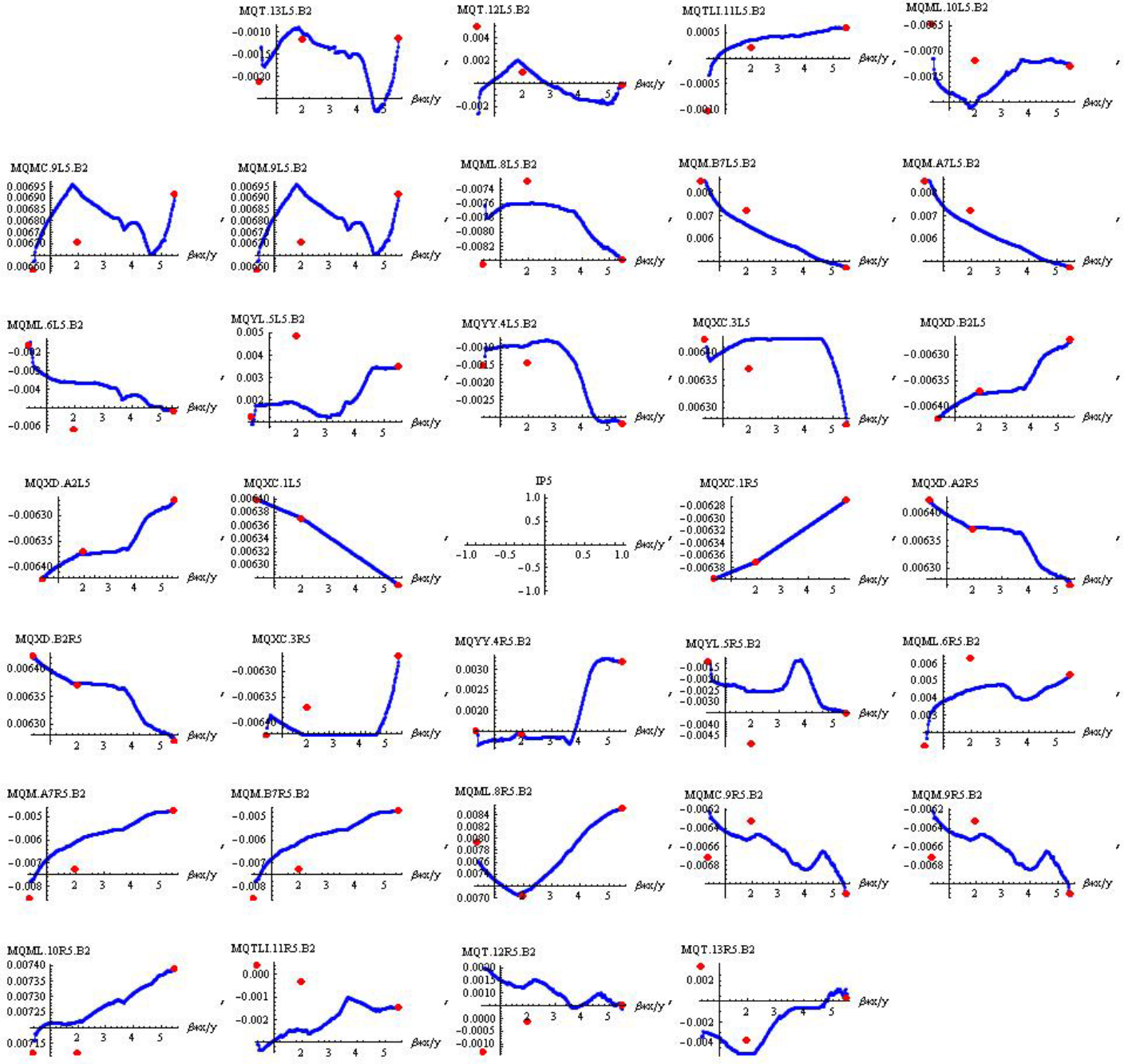
4. Horizontal and vertical phase advance between beginning and the end of IR1/5 in the range of beta* from 0.4 m to 5.5 m



Optics transition (F9) beam1



Optics transition (F9) beam2



Summary

- In all presented variants of the optics transition, there are quads where slope of the quadrupole gradient changes its sign during transition.

- Optics transition F5 does not require to vary gradient of IT quads during the transition and results in the new injection optics that looks like acceptable(?). Additional optimization is needed to make more monotonic transition in the range of beta* from 0.4 m to 0.5 m.

- Optics transition F8 looks like the most monotonic solution found by the moment but results in aperture restriction in the dispersion suppressors and Q6.

- Optics transition F9 does not change existing injection optics 'opt_5500_5500.madx'.