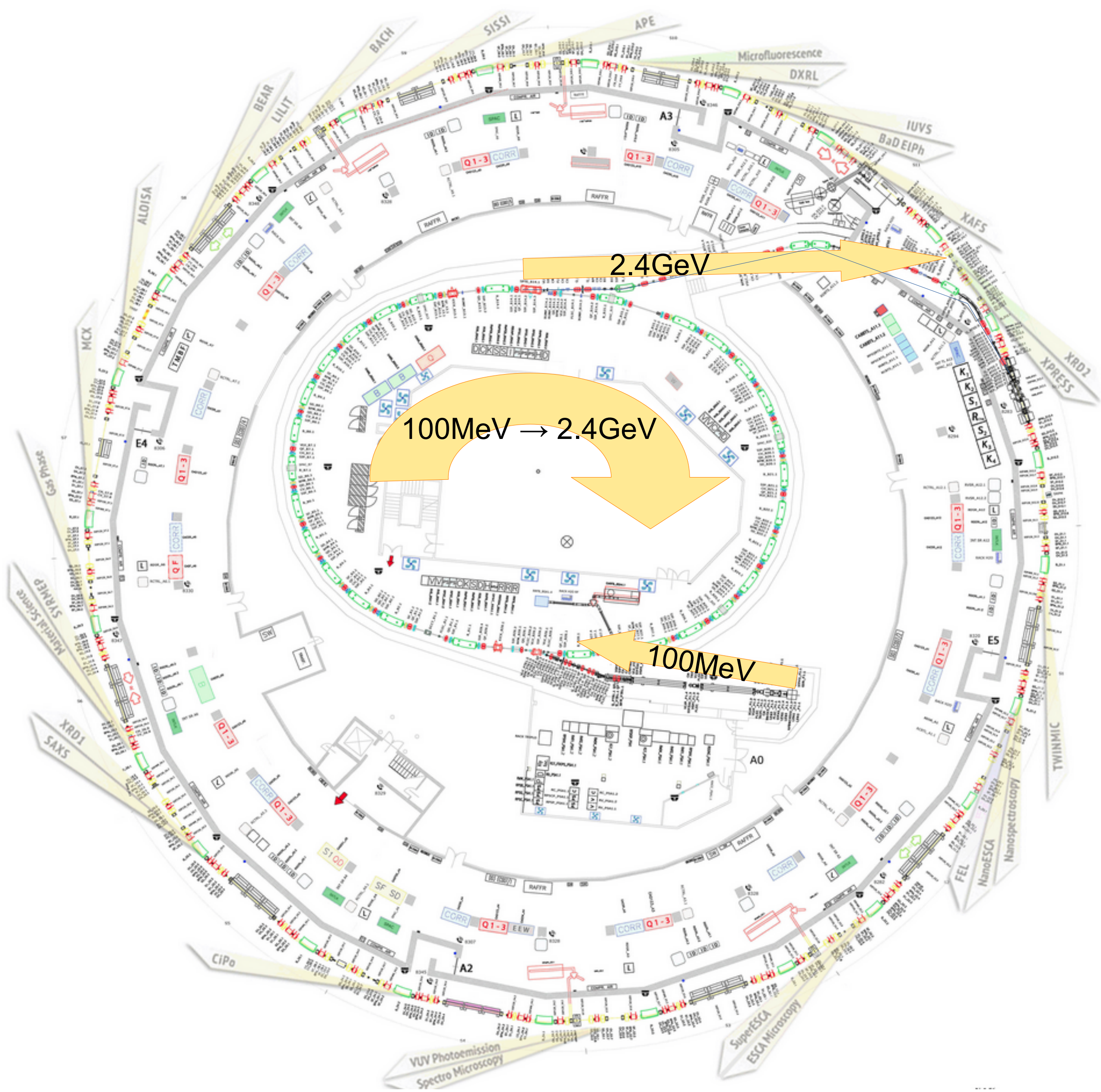
Elettra Sincrotrone Trieste

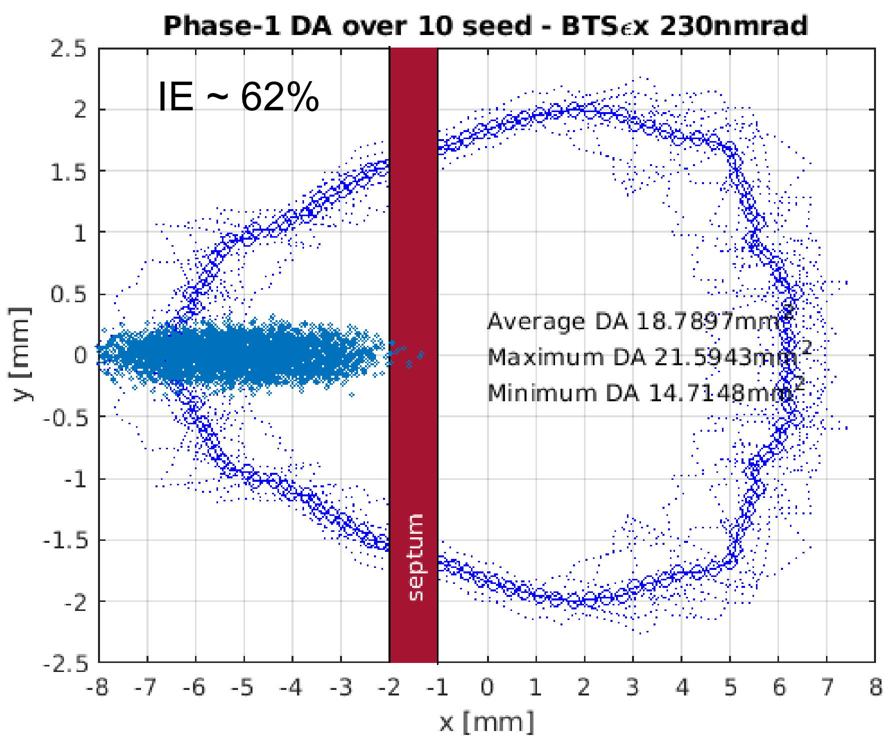
Booster overview

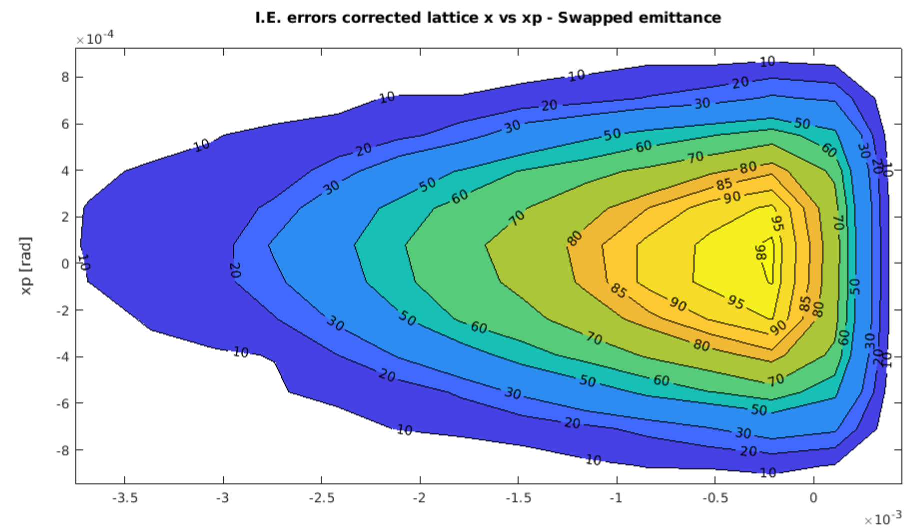


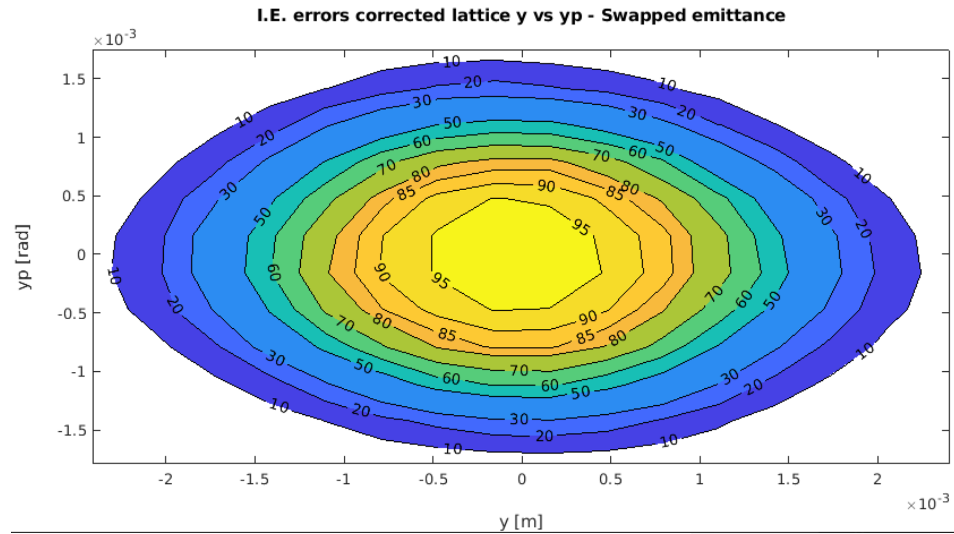
Elettra2.0 Injector requirements – emittance & trajectory stability

In order to have an injection efficiency > 95%:

- Booster EmitX: <50nmrad
- Trajectory stability: x±250um, y±500um







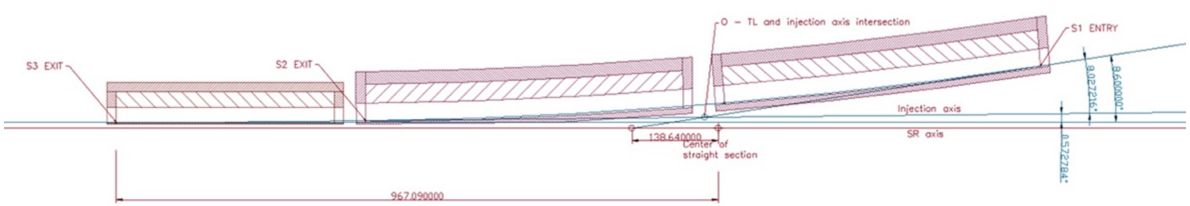
Elettra2.0 Injection scheme

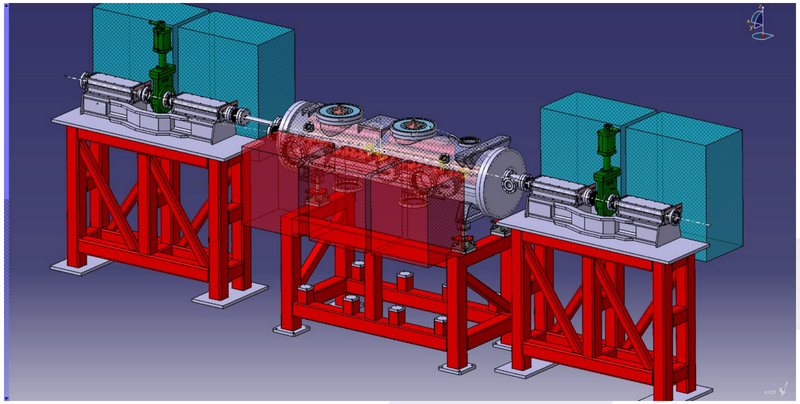
Classic off-axis 4 kickers injection scheme

- Pro: well known
- Contro: big DA is required, stored beam is perturbed

Other method?

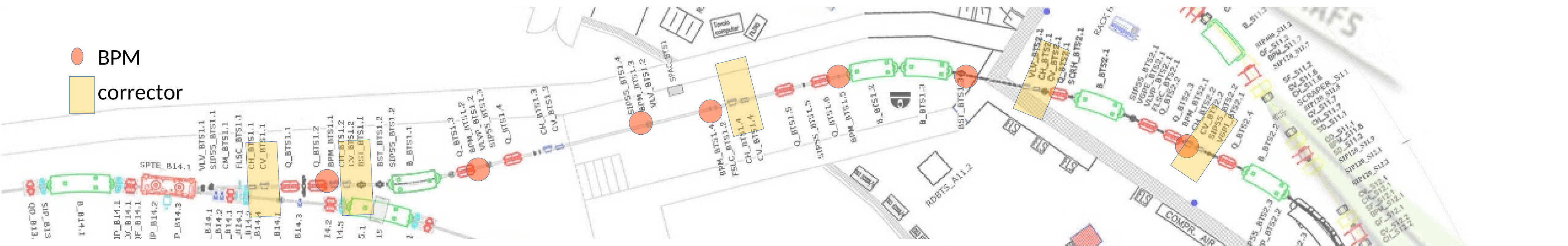
- Multipole? Injected beam too big
  - Not enough budget for a new lower emittance booster and no easy free space to install it inside the storage ring tunnel
- Aperture sharing? No available space for the stripline

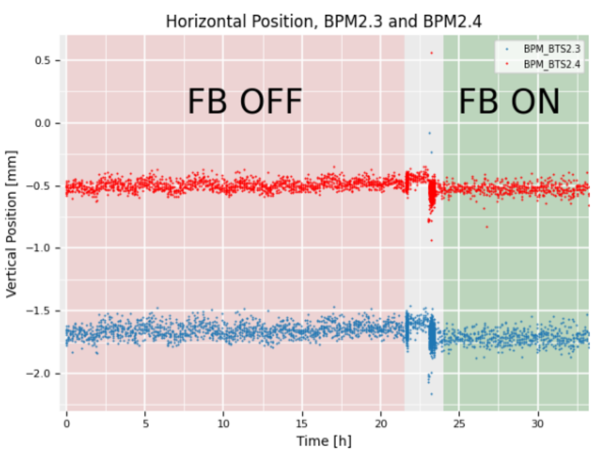


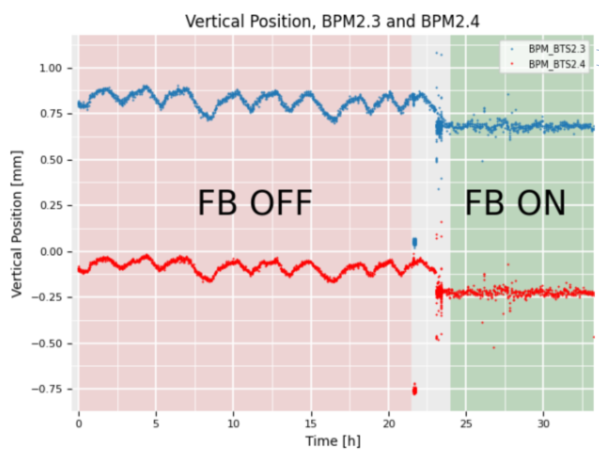


BTS trajectory control

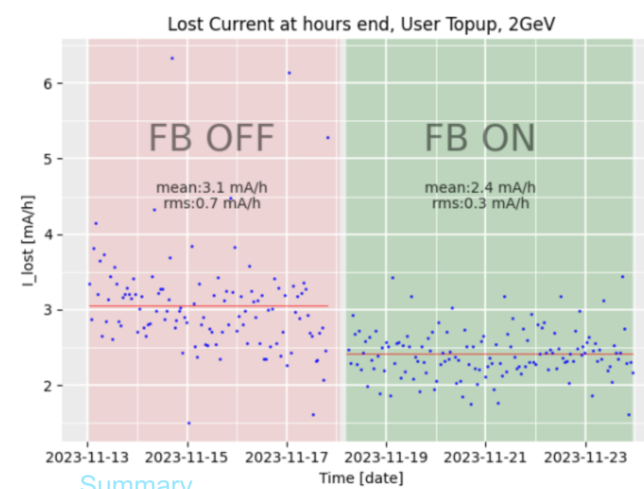
- In first instance, we re-introduce the BPMs in the transferline, installing new Libera Spark frontend and applying a Beam Based Alignment routine. Old Frontend had a rms reading of 1mm.
- Position feedback in the transfer line has been closed to compensate the slow drifts.
- Trajectory stability is under control and satisfy the requirements for Elettra2.0





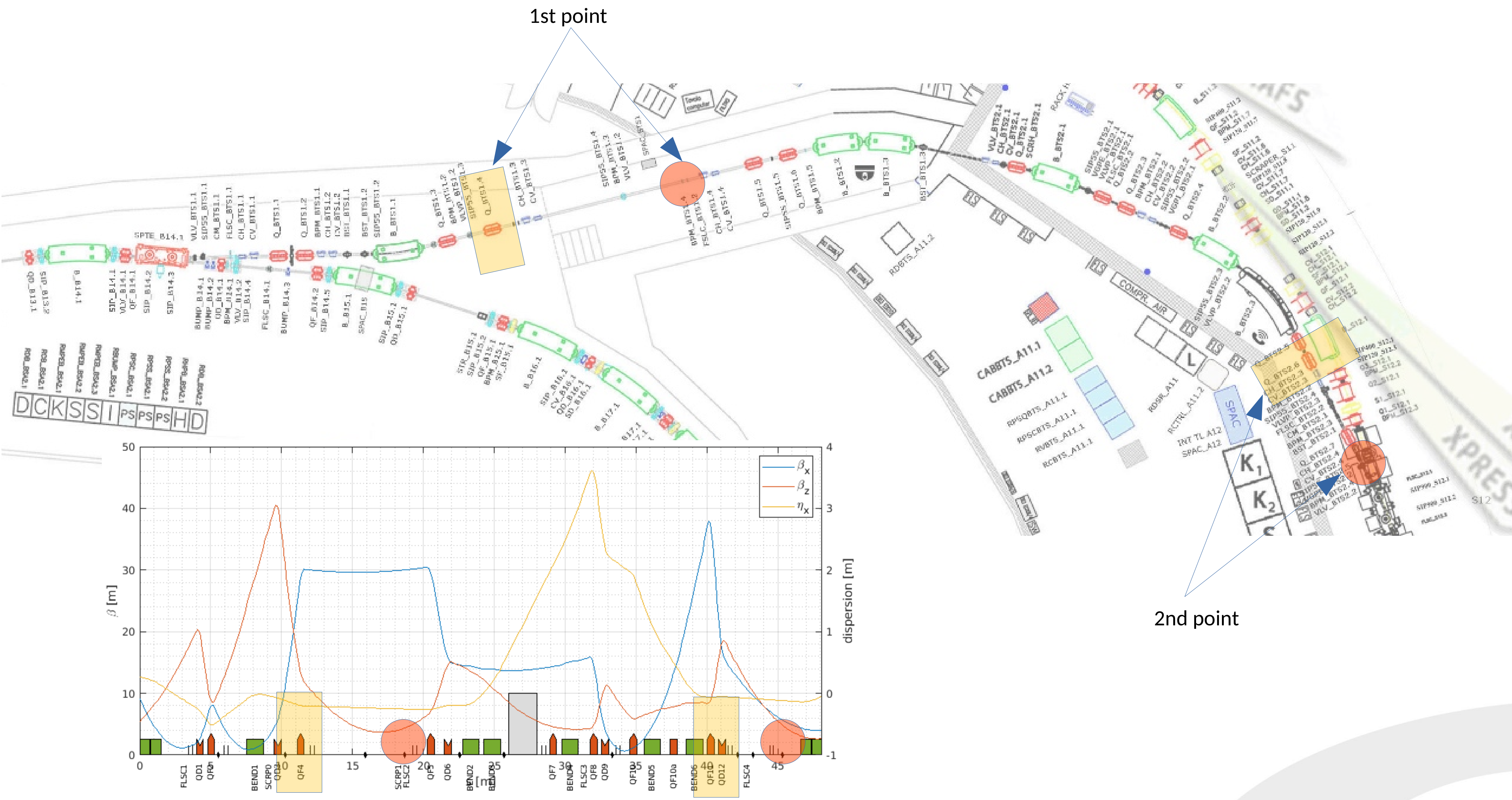


The improved trajectory stability is also reflected in refill efficiency and stability



Emittance measurement

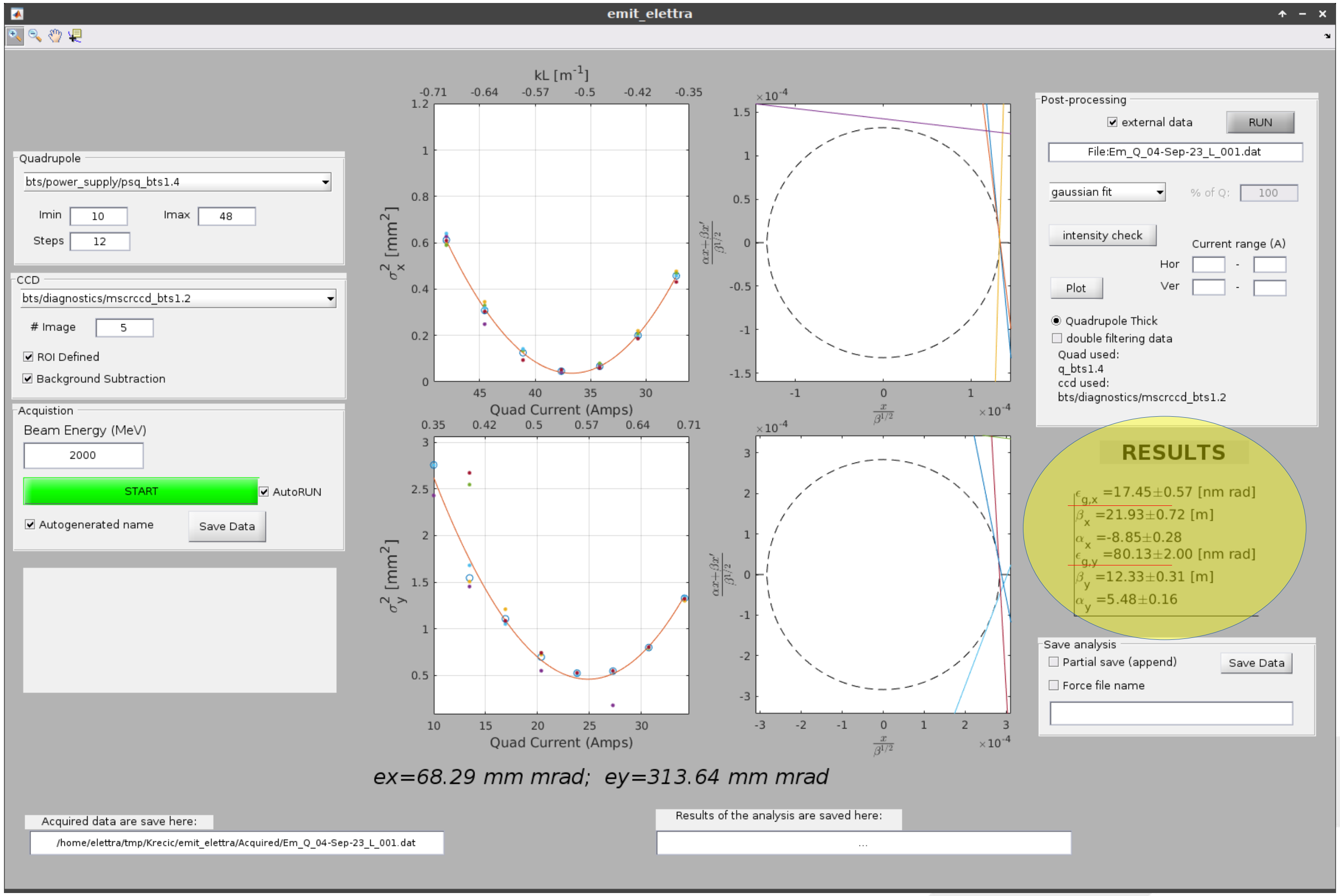
- Emittance measurement is performed in the BoosterToStoragering trasferline - BTS



Emittance measurement

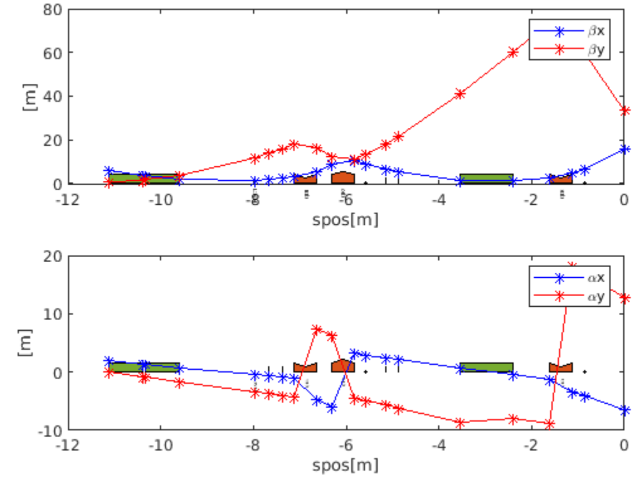
- Emittance measurement is performed by the quadrupole scan method
- Used a well known and debugged tool developed for FERMI facility

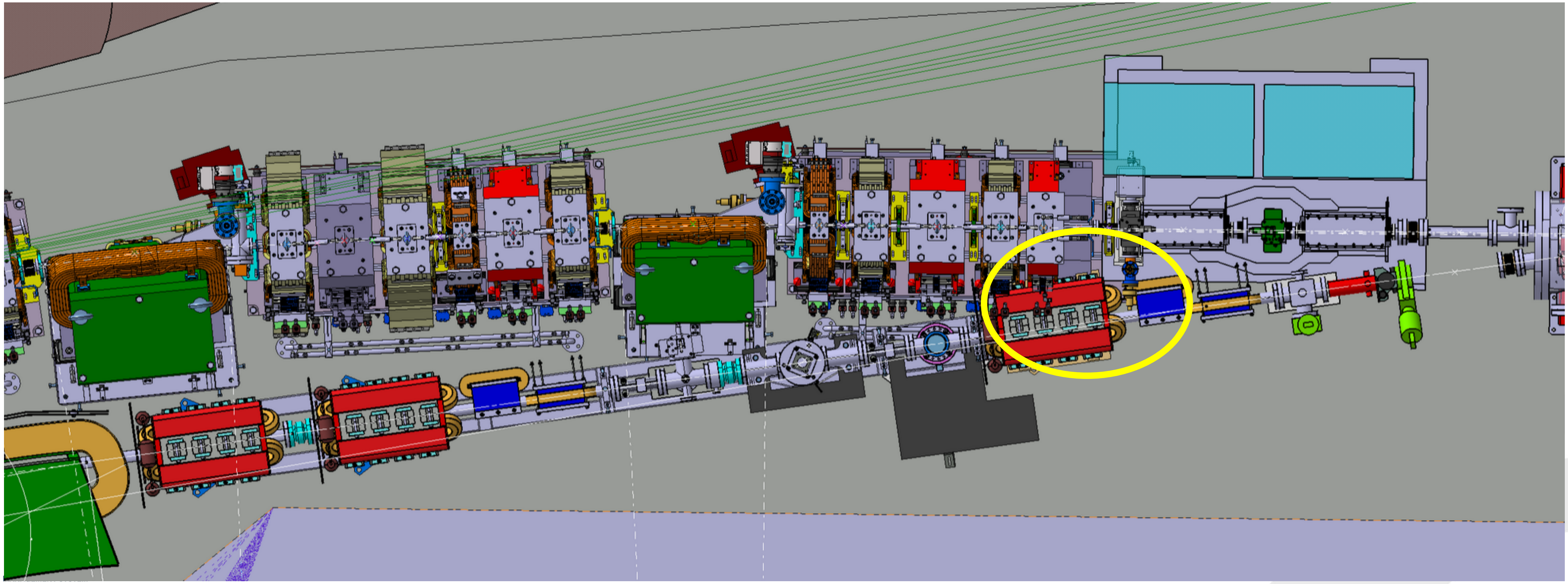
- First measure at 2.4GeV ε_x 320nmrad, coupling 1.5%
- After magnets alignment ε_x 220nmrad



BTS optics

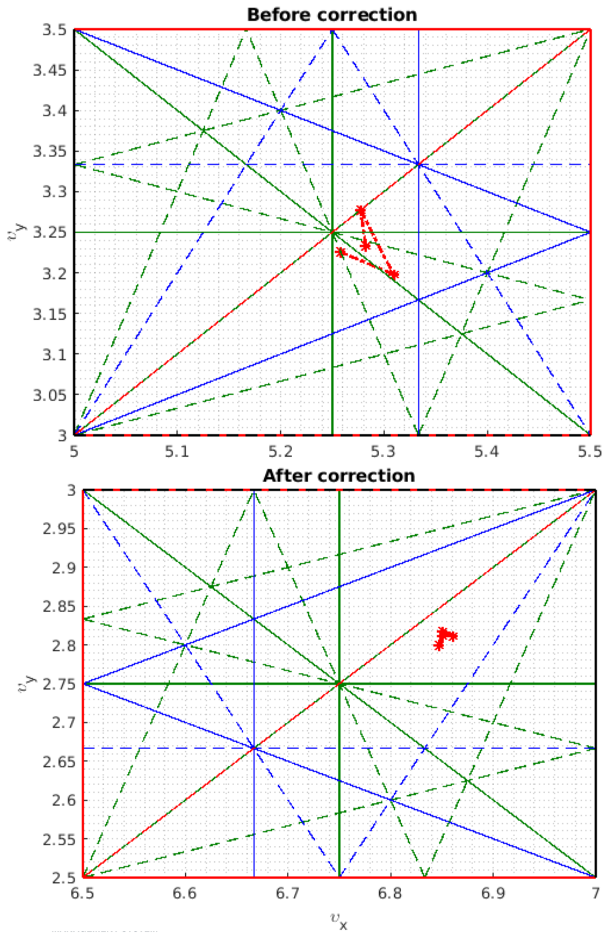
- After backtracking Twiss parameters from emittance measurement point to the extraction point and than forwarding the optics up to the end of the BTS, well agreement by measured emittance and computed emittance
- Knowing the optics, the BTS lattice has been revised excluding the last BTS quadrupole that does not fit the available space with Elettra2.0

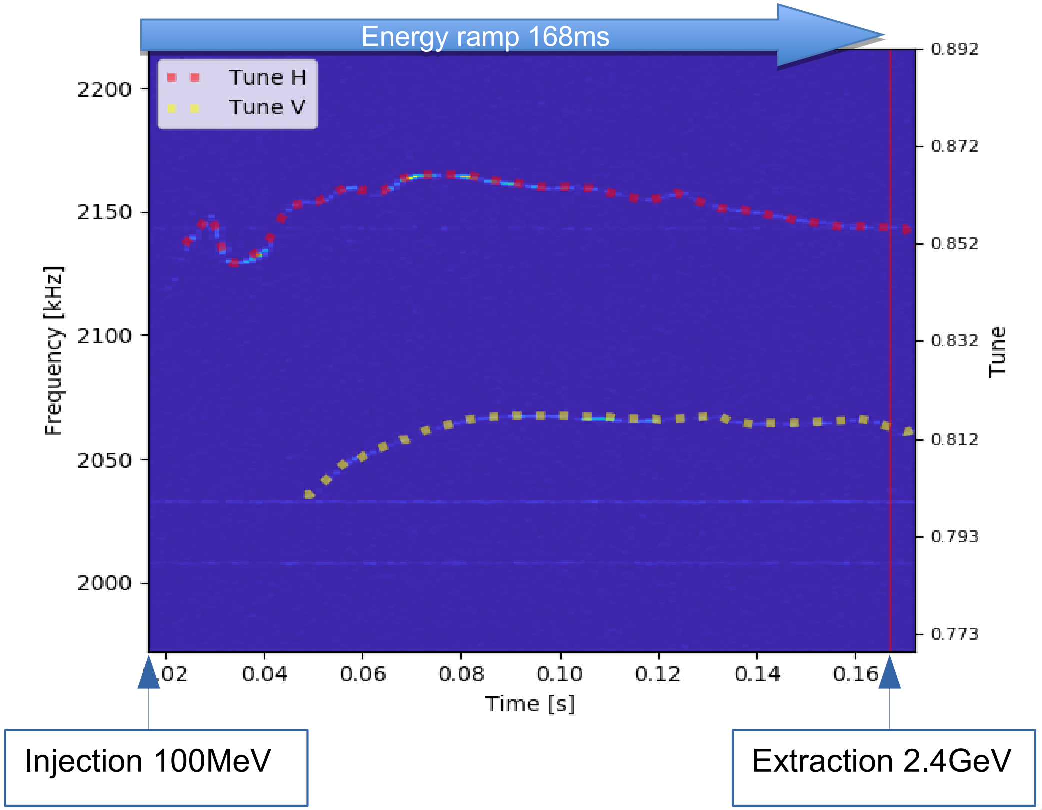




Tune measurement along energy ramping

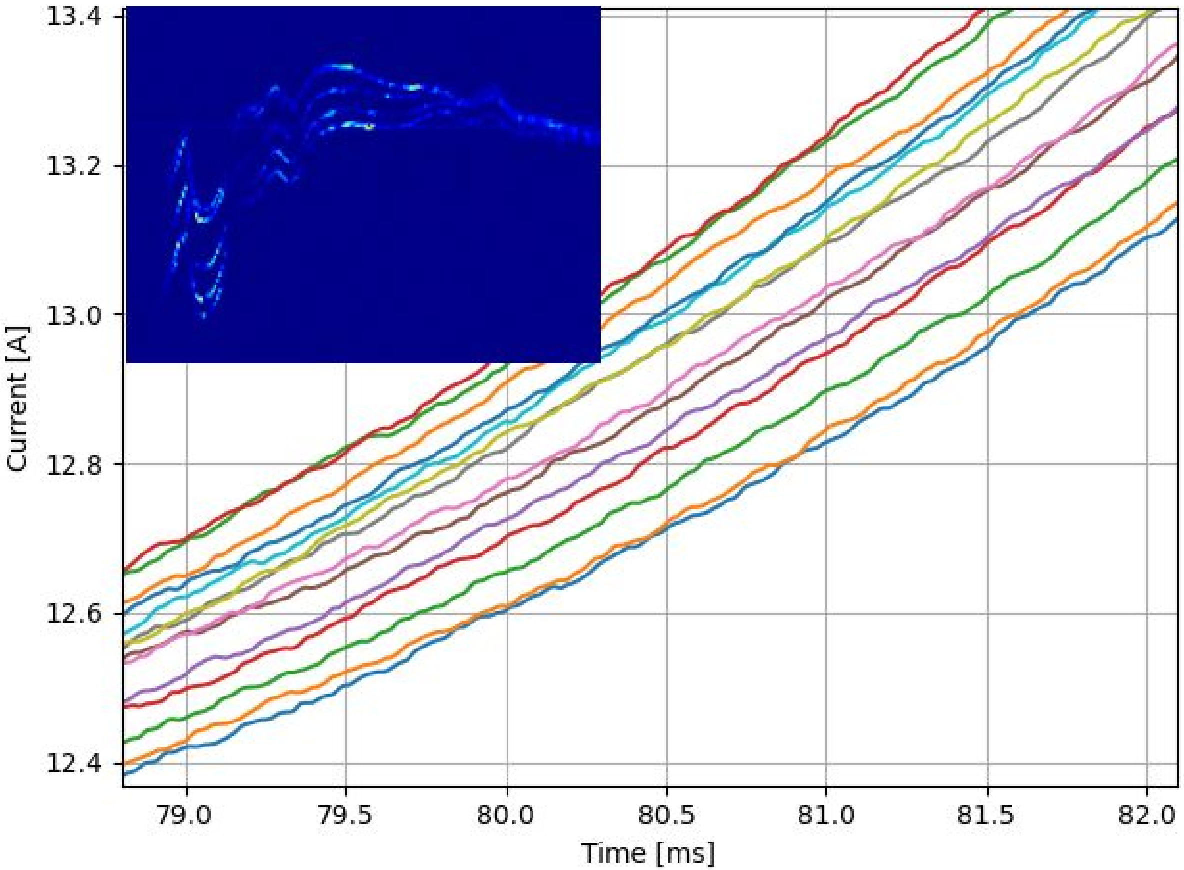
- Re-established a working tune measurement system by classic stripline-bpm system
- The maximum resolution of the frequencies read on the tunes is 1 kHz with a sampling rate of 2 msec.
- Developed a semi-automatic tool to correct the tune along the ramp, more or less 3 cycle to a complete correction; 1 minute each iteration. In order to change the power supply current waveform, the power supply can not be in ramp status





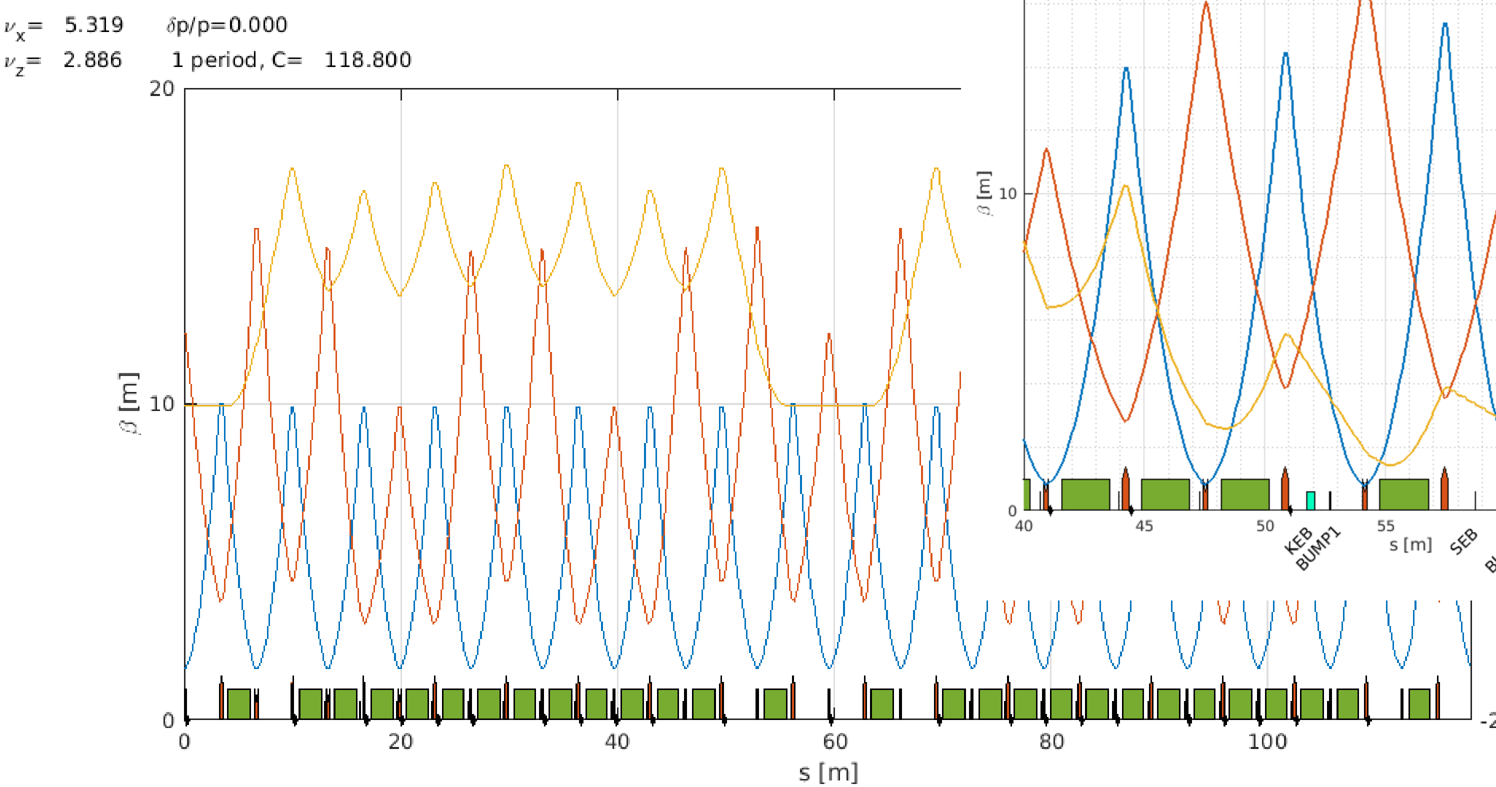
PS stability

- A non-repeatability of the output current of the power supplies between one ramp cycle and the next was found. This variation is approximately 300 mA peak-to-peak for the bending and 200 mA for the quadrupoles. This results in an unwanted change in tune frequency shot-to-shot, on the horizontal plane of 40 kHz and 10 kHz on vertical one.
- A maximum shot-to-shot variation less to 50 mA is requested for the next PS

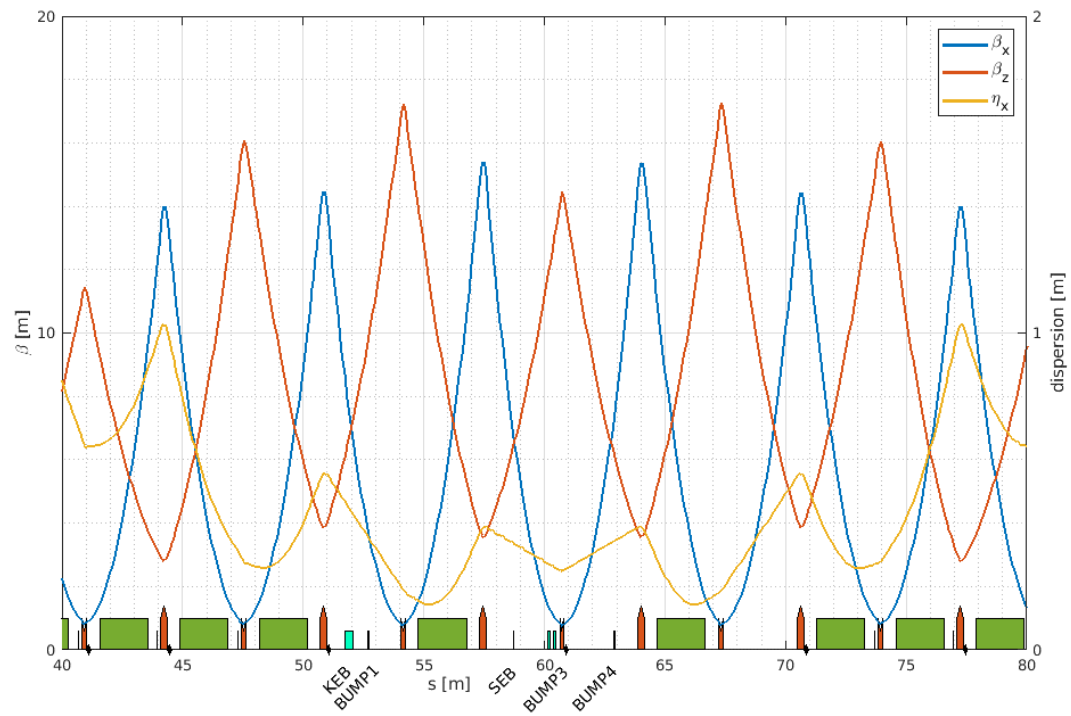


Low emittance optics

tune 5.32, 2.89 : NEO nominal emittance optics (neo)
- Emitx=231nmrad(2.4GeV) – 160nmrad(2GeV)



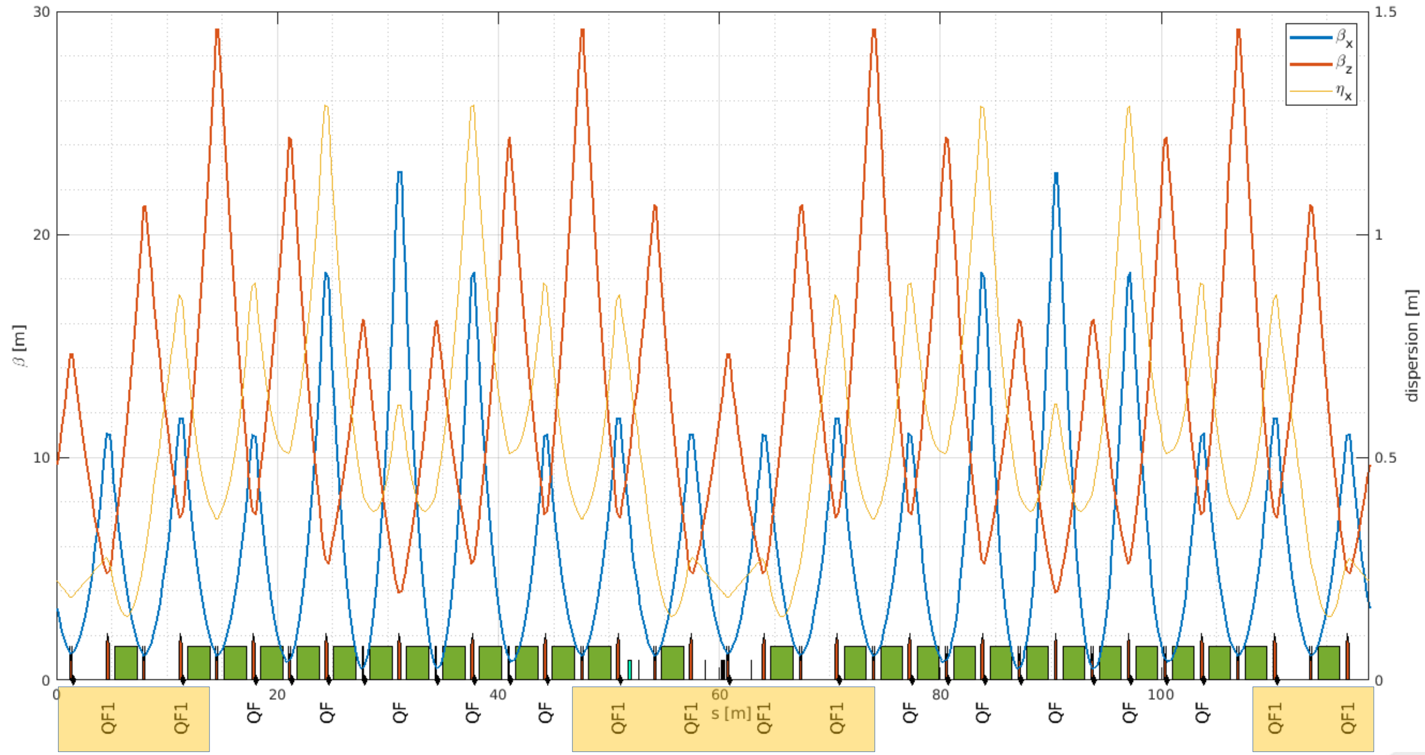
tune 6.8, 2.85 - LEO low emittance optics (leo)
- EmitX=164nmrad(2.4GeV) – 114nmrad(2GeV)
- bumper necessary to extract the whole beam (slow



Low emittance optics

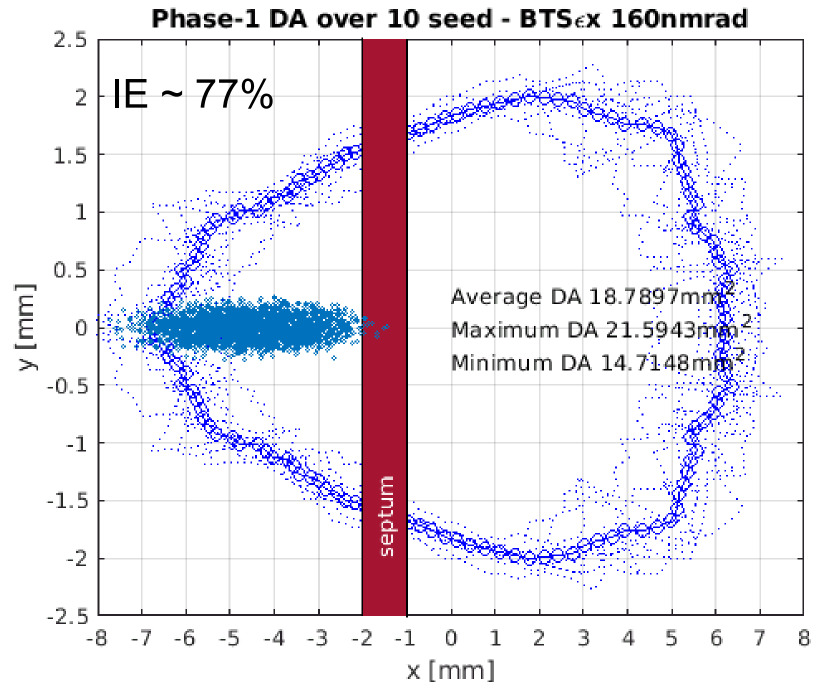
- Adding a new family of power supply for the focusing quadrupole magnet, and using the tune working point 6.8 1.8, the horizontal emittance goes down to 136nmrad.
- 18 de-focusing quadrupole QD under single power supply as before
- 2 family of focusing quadrupole; QF1 8 magnets, QF2 10magnets.
  The new power supply will be installed during the dark period at the end of 2025

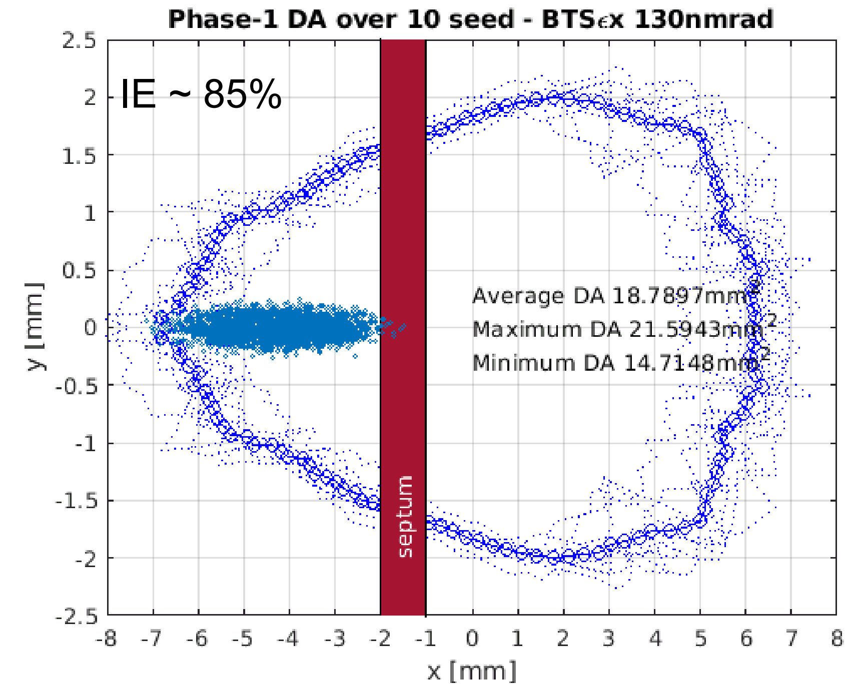
- Higher Dynamic aperture respect to LEO
- Any modification to the extraction system is necessary



Low emittance optics

- With the new optics the injection efficiency improves a lot

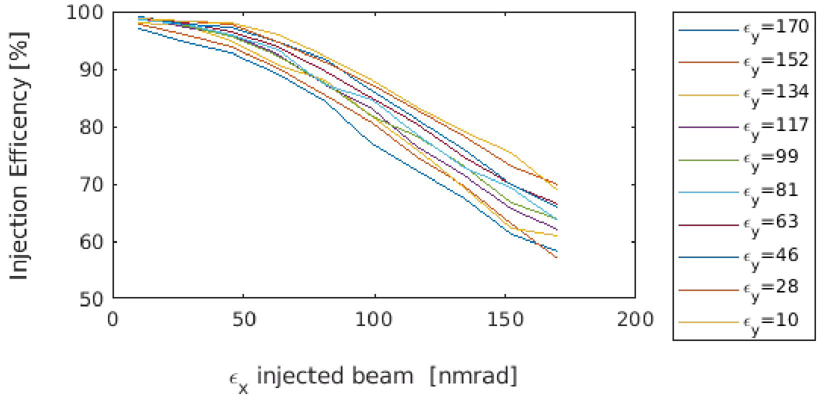


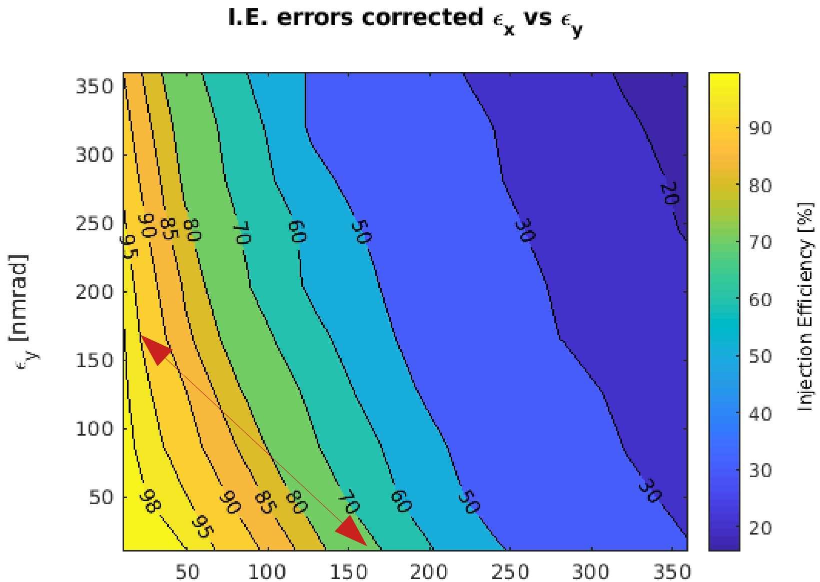


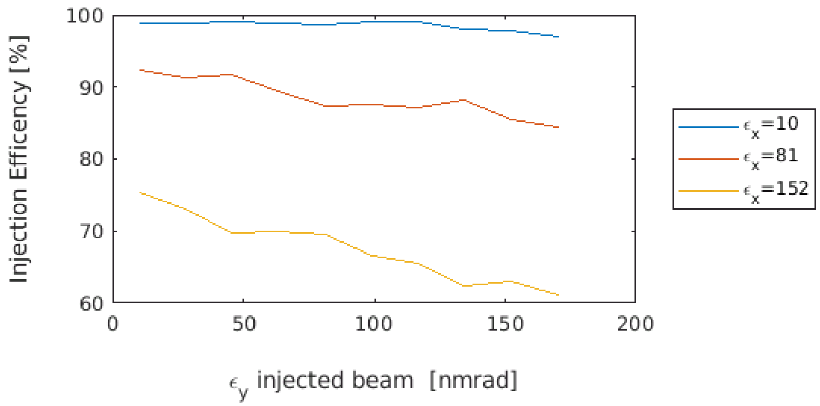
	Tunes (x-y)	εx 2.4-2 GeV [nmrad]	IE [%]
NormalEmittanceOptics	5.39-3.42	231-160	62
LowEmittanceOptics	6.8-2.75	164-114	77
futureLowEmittanceOptics	6.8-1.75	137-95	85

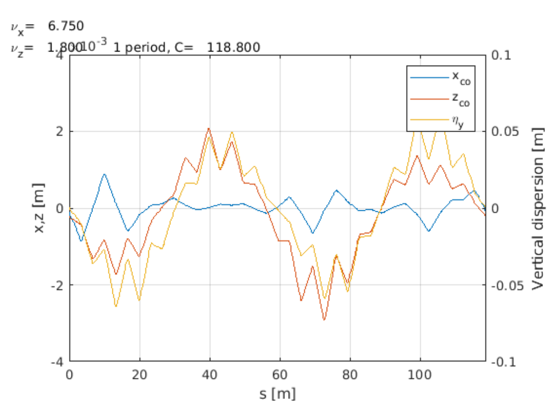
Emittance exchange

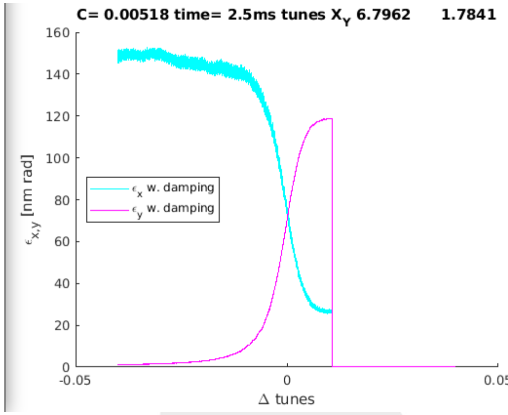
- Emittance exchange by crossing a coupling resonance
- From simulation, for a good swap it's required to cross the resonance in 2.5ms
- We have also investigated for other solutions to swap the emittances, ie emittance exchange in the trasferline, pulsed skew quadrupole, AC skew quad, but the method to cross a coupling resonance has been preferred to not overload the magnet designer





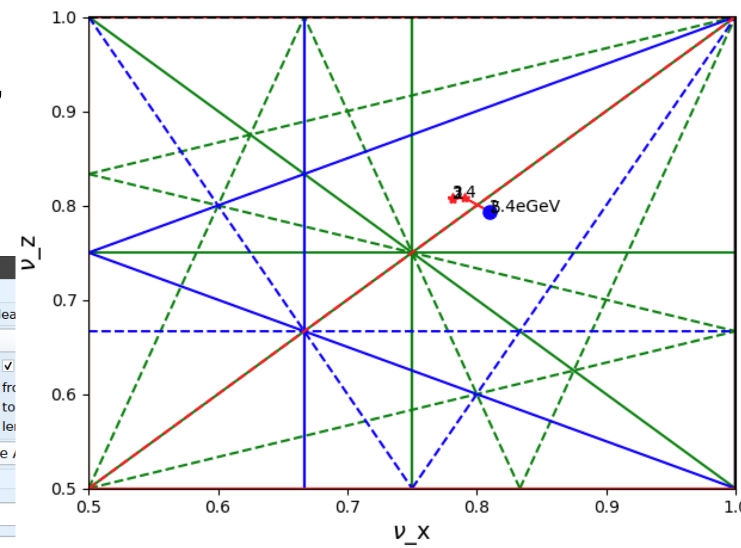


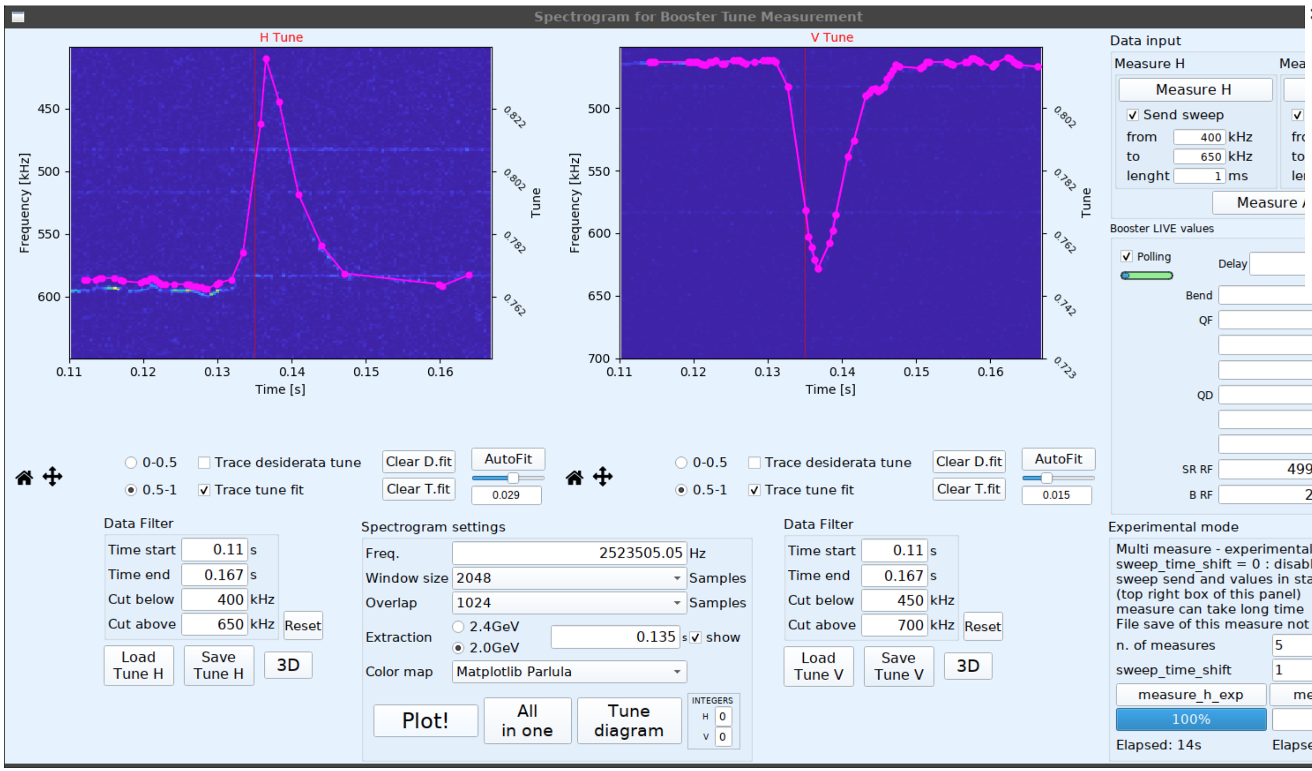


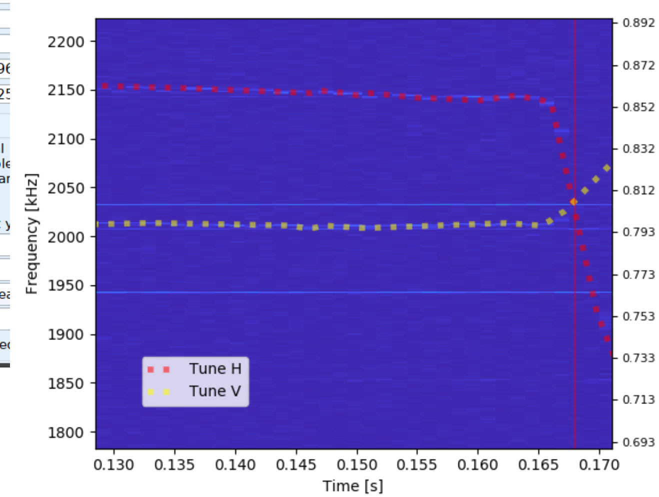


Emittance exchange

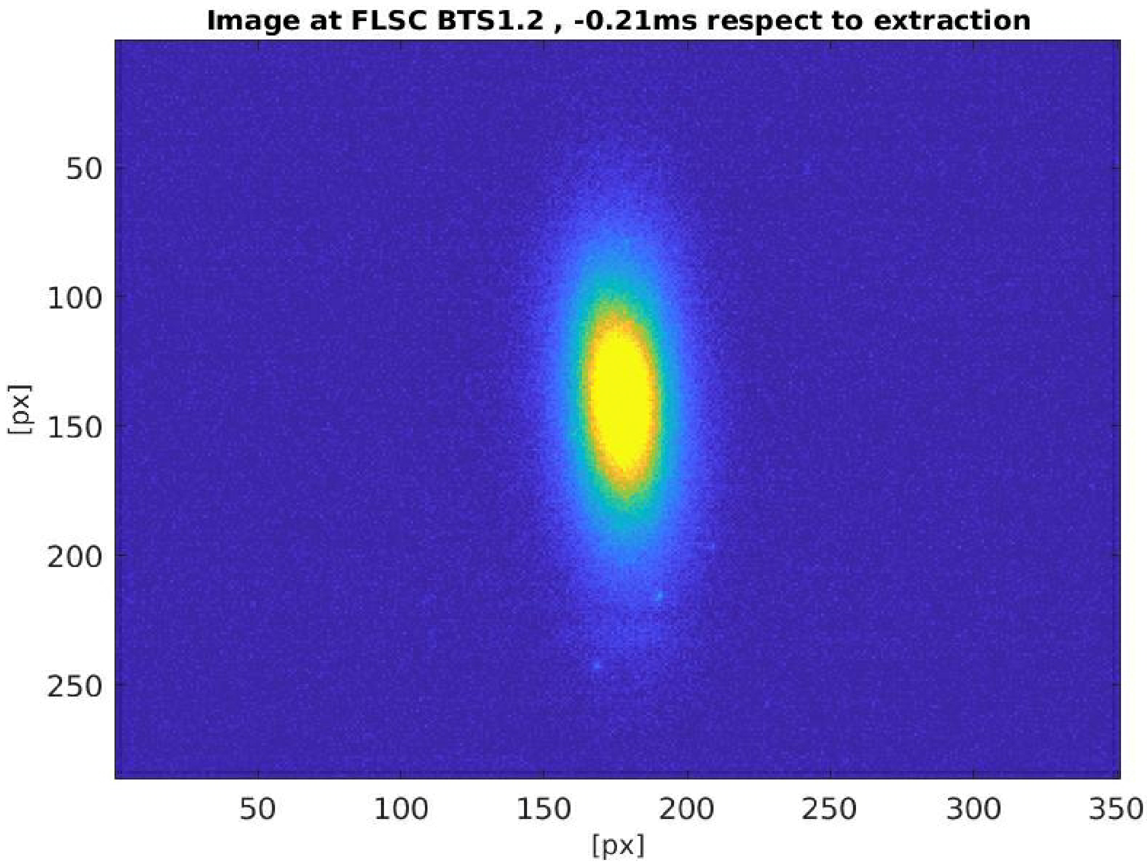
- @2.0GeV εx=17nmrad εy=97nmrad
- @2.4GeV εx=43nmrad εy=115nmrad
  - Initially unstable measure due to PS jitter and unstable horizontal tune, solved forcing a 5ms flat-top at the end of the ramp

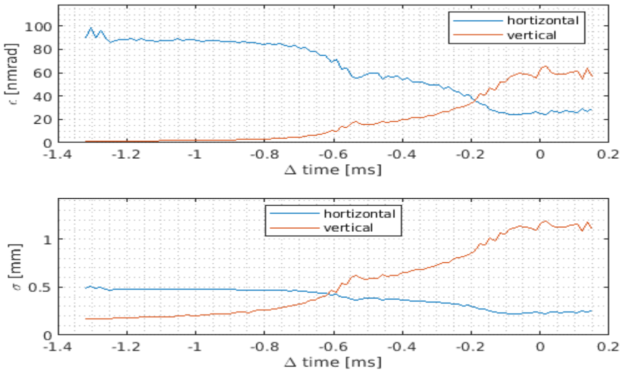






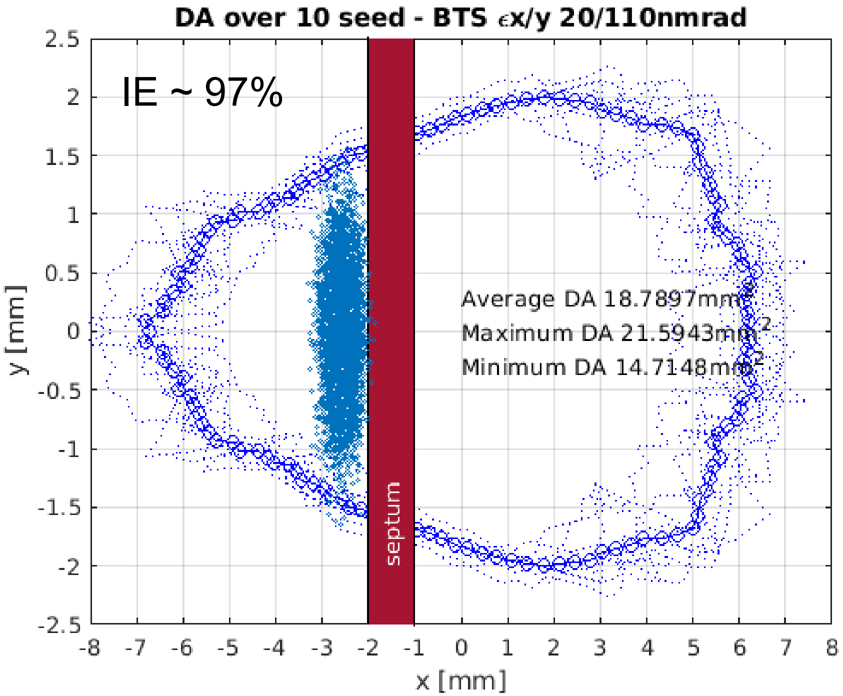
Emittance exchange

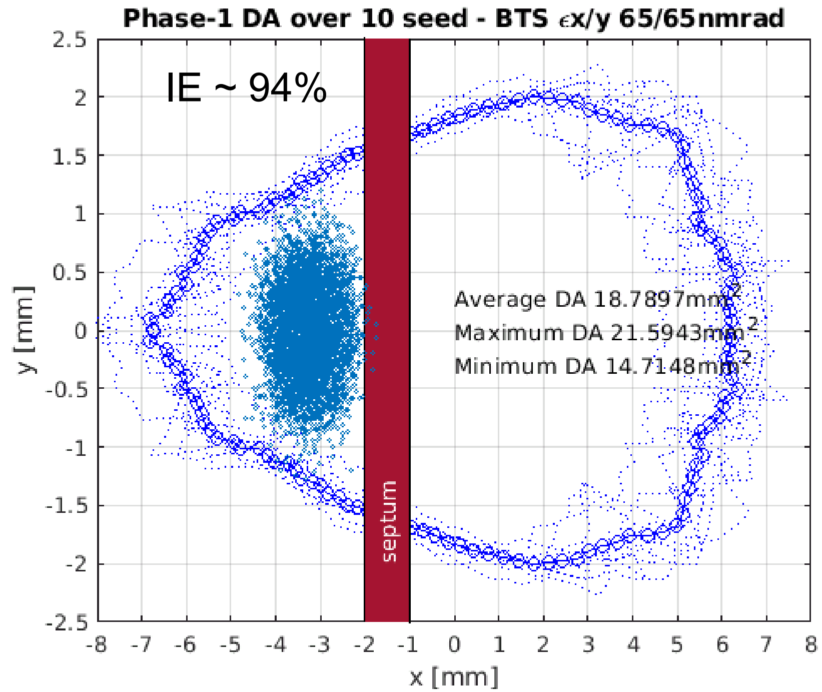




Emittance exchange

- The emittance exchange improves the injection efficiency
- The higher vertical emittance create losses at the invacuum undulator (full gap 5mm), the round beam is the good compromise

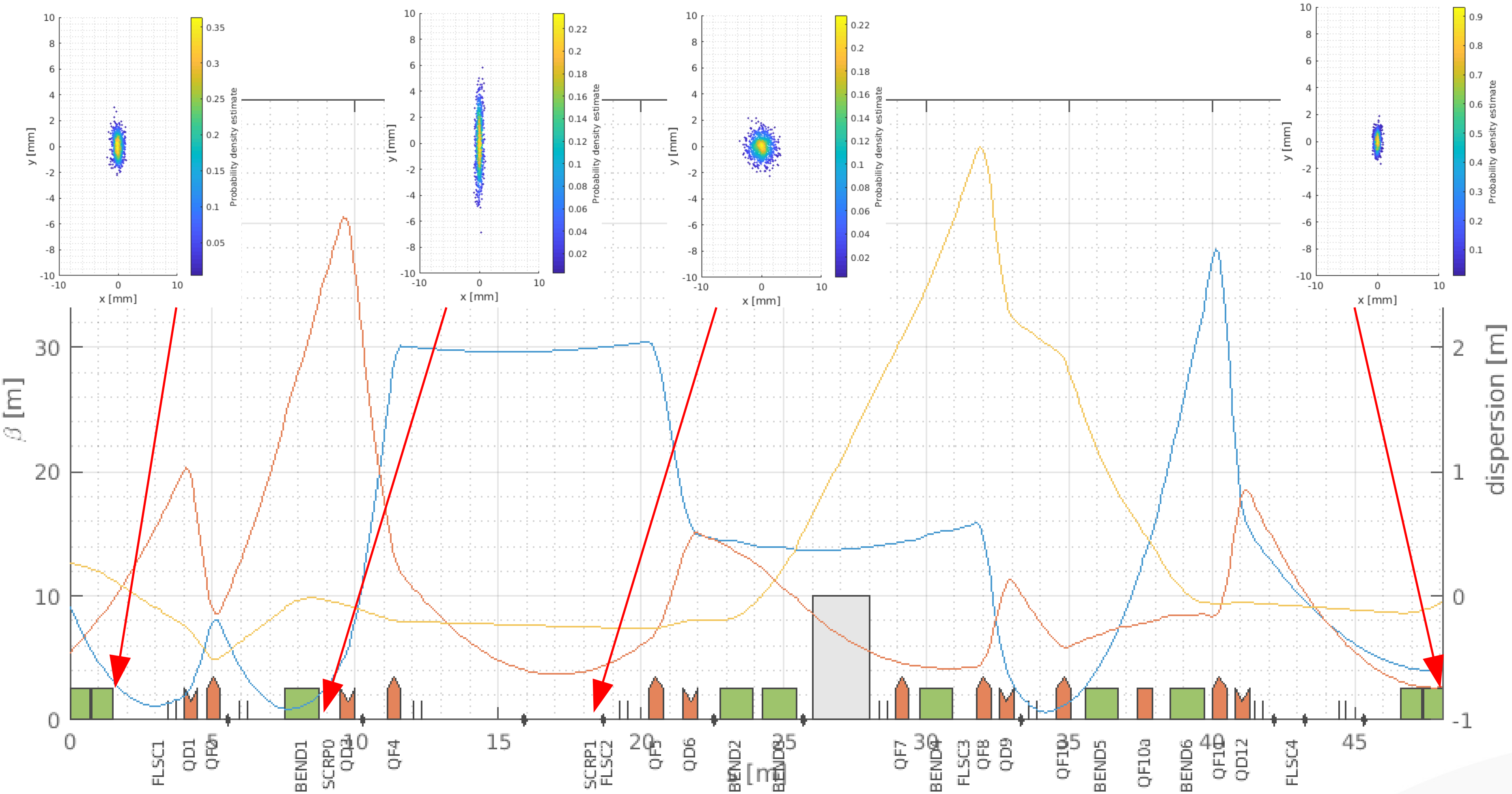




	Tunes (x-y)	• εx 2.4-2 GeV [nmrad]	IE [%] - IE [%] swapped beam
NormalEmittanceOptics	5.39-3.42	231-160	62
LowEmittanceOptics	6.8-2.75	164-114	77 - 94
futureLowEmittanceOptics	6.8-1.75	137-95	85 - 97

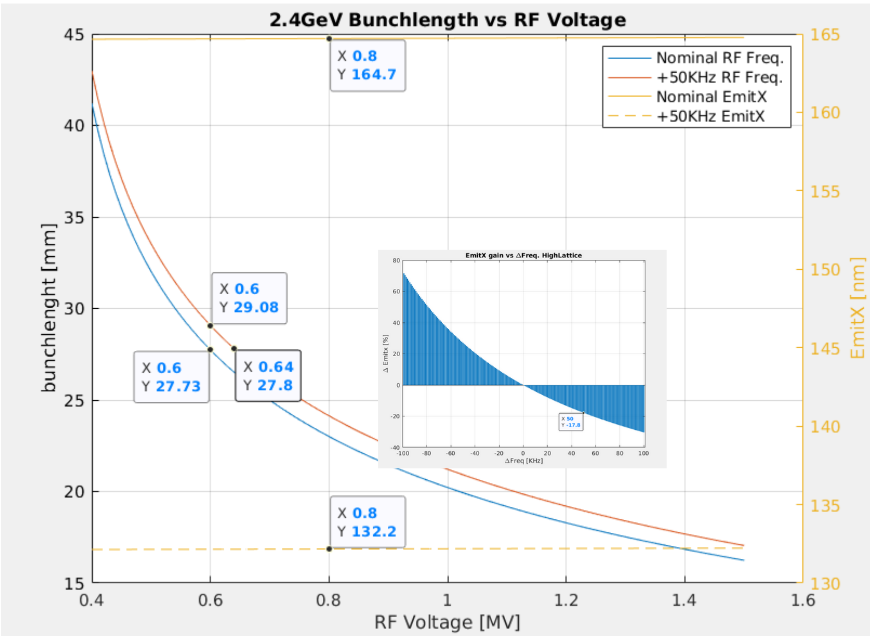
BTS - Scraper

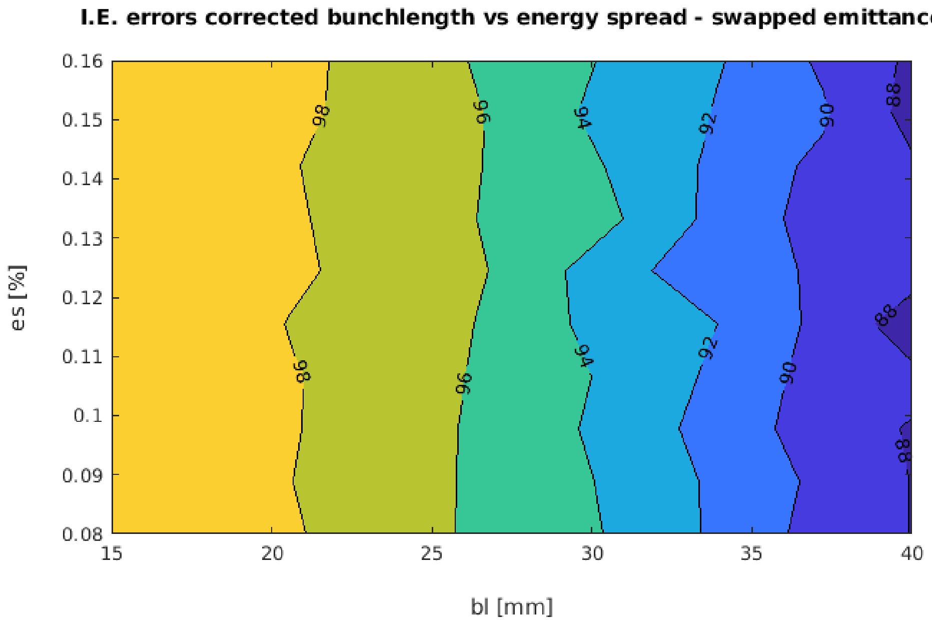
- 2 pair of scrapers H/V will be installed to ensure the possibility to scrape the beam and reduce the emittance to acceptable value. It's imposed a 90°C phase advance separation between the pair of scrapers



Off-energy operation

- Off-energy operation decreasing by 2 mm the booster radius → 16% reduction of the emittance
- Increasing RF cavity voltage from 0.6MV to 1MV → the bunch length reduces from 28mm to 20.5mm

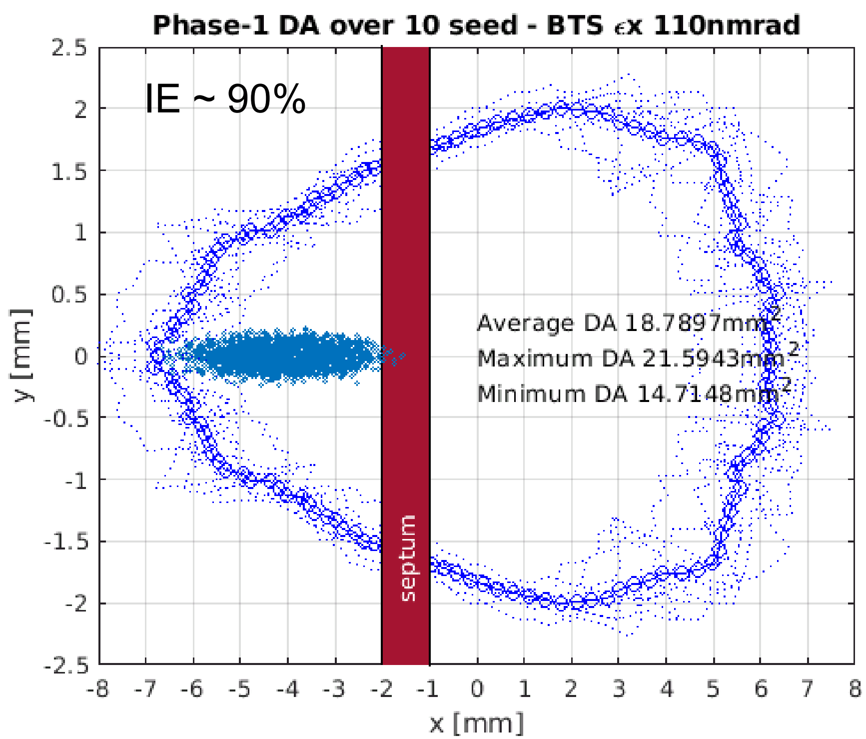


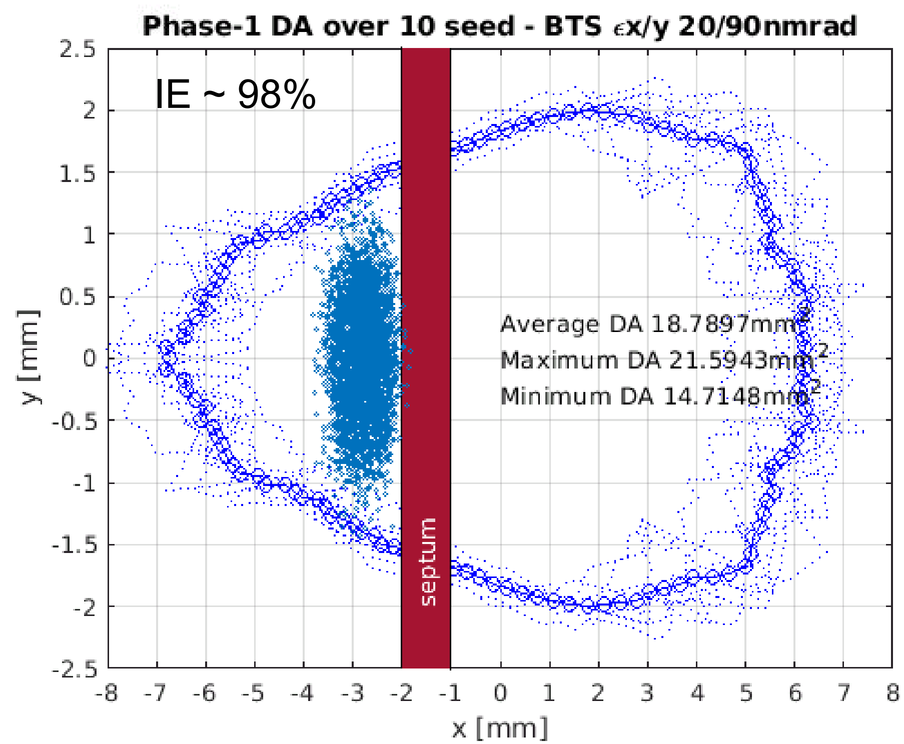


	Tunes (x-y)	εx 2.4-2GeV [nmrad]	εx 2.4-2GeV [nmrad] + off energy	Disp [m]
NormalEmittanceOptics	5.39-3.42	231-160		0
LowEmittanceOptics	6.8-2.75	164-114	133-92	0.376
futureLowEmittanceOptics	6.8-1.75	137-95	118-80	0.26

Off-energy operation – fLEO case

- In the case of round beam 55/55, the IE is ~96%
  A vertical emittance lower than 80nmrad doesn't cause any losses at the invacuum undulator





	εx 2.4-2 GeV [nmrad]	εx 2.4-2 GeV [nmrad] + off-energy	IE [%]	IE [%] off-energy	IE [%] Emit swapped	IE [%] Emit swapped + off-energy
futureLEO	137-95	118-80	85	90	97	98

Summary

- Magnet alignment survey
  - Emittance from 320mrad to 220nmrad ~ model
- Implemented the tune measurement & manipulation
  - Poor PS stability during ramping
  - Limit in the PS firmware (slow current waveform manipulation)
- Implemented the emittance measurement in order to appreciate the Booster improvement in terms of emittance reduction
- Implemented the transfer line optics measurement and manipulation for a better matching of the injected beam with the storage ring
  - Removed BTS quadrupole
- Implemented the Trajectory feedback along BTS
- Changed Booster optics, reducing the emittance down to 160nmrad
  - 130nmrad with additional QF2 family
- Implemented emittance exchange by crossing a coupling resonance
  - @2.0GeV εx=17nmrad εy=97nmrad
  - @2.4GeV εx=43nmrad εy=115nmrad
- Exploring off-energy Booster operation
- Increasing RF power for lower bunchlength
- Scraper in the BTS to reduce injected beam emittance as B-plane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