

Elettra Sincrotrone Trieste











CERTIFIED MANAGEMENT SYSTEM

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UNI EN ISO 9001:2015 UNI ISO 45001:2018

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





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_{v} 320nmrad, coupling 1.5%
- After magnets alignment ϵ_x 220nmrad





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BTS

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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

BTS





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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







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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





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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





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Summary



- 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





 @2.0GeV εx=17nmrad εy=97nmrad 1.0 • @2.4GeV εx=43nmrad εy=115nmrad Initially unstable measure due to PS jitter and unstable horizontal tune, _ 0.9 solved forcing a 5ms flat-top at the end of the ramp 8.4eGeV 0.8 Ν Data input 0.7 Measure H Mea Measure H 450 500 Send sweet v fro from 400 kHz 0.6 650 kHz to [KHZ] 500 to [kHz] 550 le longh 1 ms ncy Measure nbar 550 ster LIVE values 600 0.5 0.5 0.6 0.7 0.8 0.9 1.0 νх 650 Bend 600 12.005 A O 1.014 scaling 700 2.002 k 0.11 0.12 0.13 0.14 0.15 0.16 0.11 0.12 0.13 0.14 0.15 0.16 Time [s] Time [s] 11 824 A QD 0.892 2200 0-0.5 Trace desiderata tune Clear D.fit AutoFit 0-0.5 Trace desiderata tune Clear D.fit AutoFit 0.872 SR RF 4996 * + • 0.5-1 ✓ Trace tune fit Clear T.fit • 0.5-1 Trace tune fit Clear T.fit 25 2150 0.029 0.015 B RF 0.852 Data Filte Data Filte Spectrogram settings Experimental mode 2100 0 11 s Multi measure - experimental 0.832 Time start 2523505.05 Hz Time start 0.11 s Frea sweep time shift = 0 : disable Time end 0.167 s Time end 0.167 s Window size 2048 Samples sweep send and values in star [kHz] 2050 0.812 (top right box of this panel) Cut below 400 kHz 1024 Cut below 450 kHz Overlap Samples measure can take long time 650 kHz Reset Cut above 2.4GeV Cut above 700 kHz Reset File save of this measure not 0.793 0.135 s ✓ show 2000 Extraction 2.0GeV n. of measures Load Save Load Save 3D 3D Matnlotlib Parlula sweep time shift Tune H Tune H Color map Tune V Tune V 0.773 1950 mea measure_h_exp INTEGERS All Tune нО 0.753 Plot! in one diagram 1900 v 0 Elapsed: 14s Flapse 0.733 Tune H 1850 Tune V - 0.713 1800 0.693 0.130 0.135 0.140 0.145 0.150 0.155 0.160 0.165 0.170 CERTIFIED Time [s] MANAGEMENT SYSTEM



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Booster

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BTS

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- 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

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BTS - Scraper

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• 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 \rightarrow 16% reduction of the emittance
- Increasing RF cavity voltage from 0.6MV to 1MV \rightarrow 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]
Nor	malEmittanceOptics	5.39-3.42	231-160		0
Lo	wEmittanceOptics	6.8-2.75	164-114	133-92	0.376
future	eLowEmittanceOptics	6.8-1.75	137-95	118-80	0.26
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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





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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Stefano Krecic

Summarv







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Summary