The European Synchrotron

ASD Day : Beam Dynamics

Lee Carver

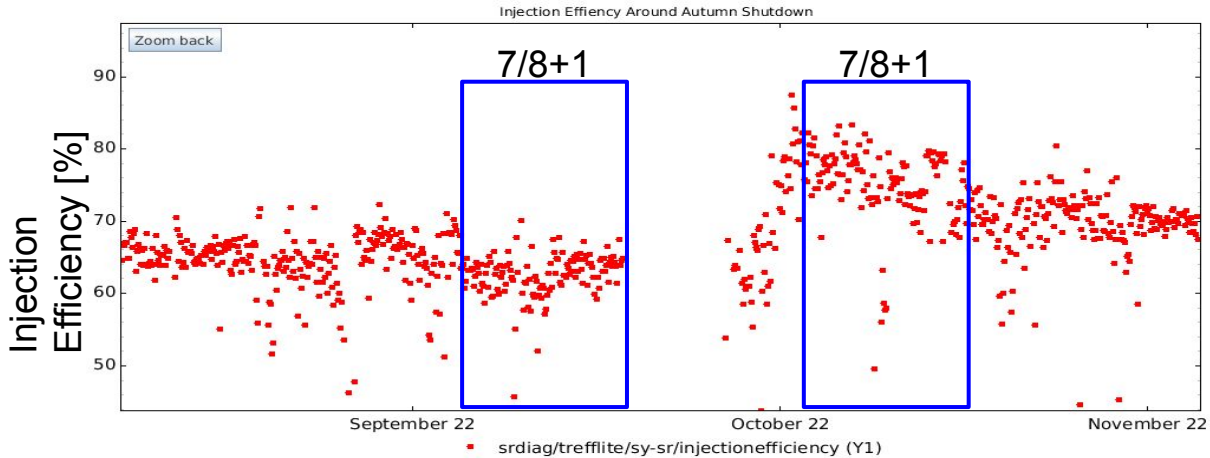
OVERVIEW

- **Operation**
  - Lifetime and I.E. overview.
- **Machine Developments in 2022**
  - Optics Studies
    - Off Energy Optics
    - NOECO
    - TbT with AC Dipole
- **Machine Developments in 2023**
  - Mini-beta Optics
  - Timing Mode Optimisation
    - High Single Bunch Currents
    - Round Beam
  - HALO studies

INJECTION EFFICIENCY

- **Injection efficiency had been lower over 2022 than in 2021.**
  - In general there was a downward trend from around 75-80% to around 65%.
- **Realignment of stripline in TL2 recovered 10% of I.E.**
  - Better trajectory control.
- **Lower RF voltage and improved cycling control also contributed to higher I.E.**

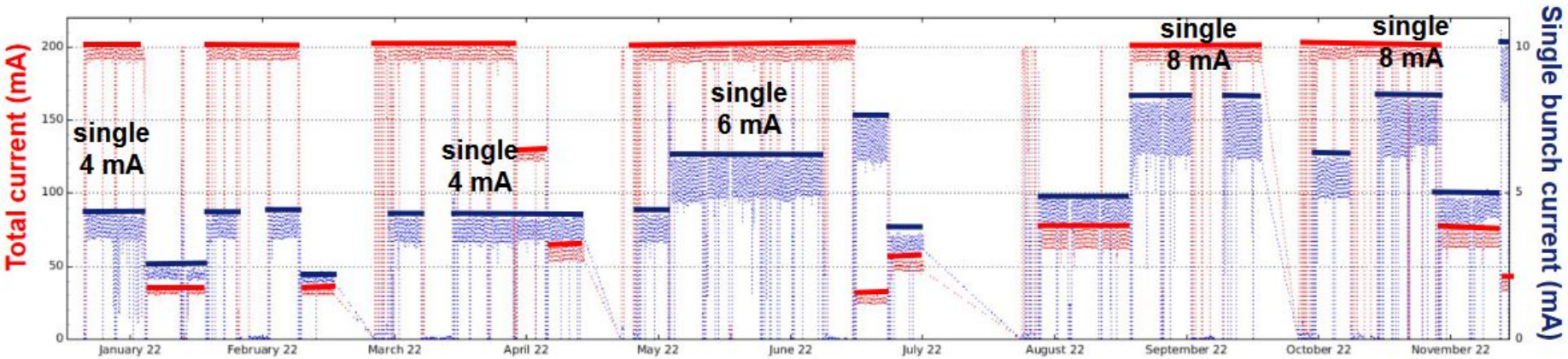
- **We have restarted in January 2023 with 75-80% I.E. in 7/8+1 (8mA).**



LIFETIME

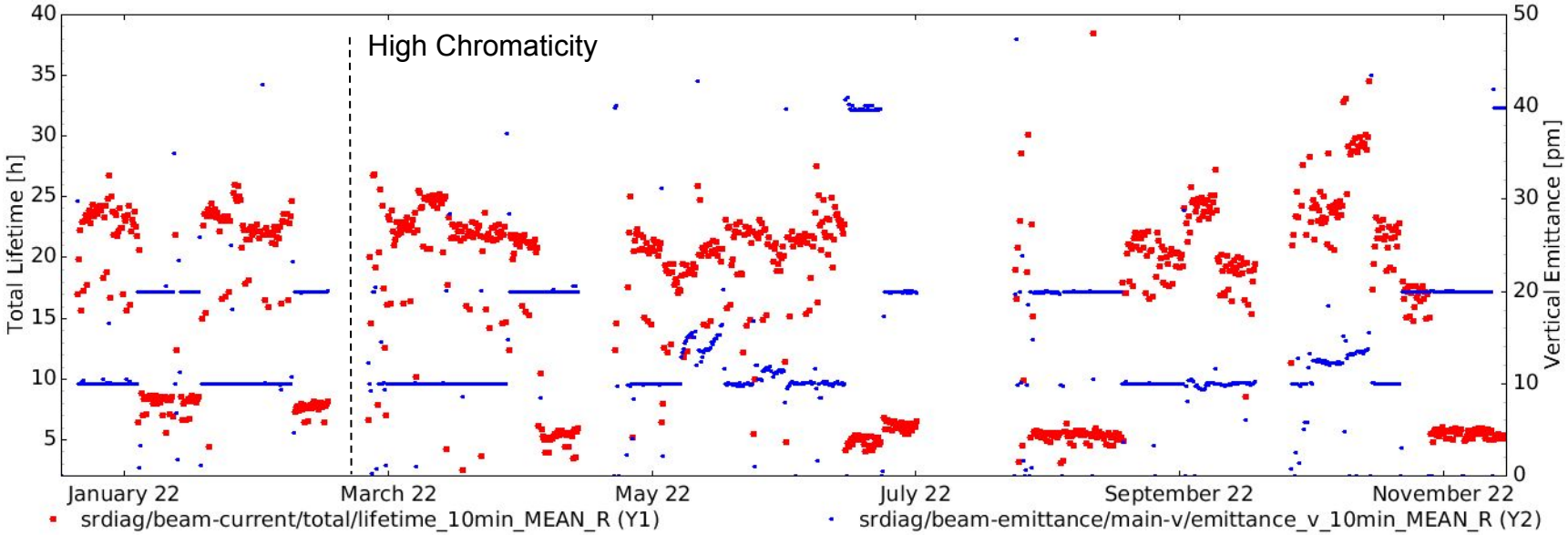
- **The single bunch current has been increased throughout 2022.**
  - 4mA in January. 6mA throughout June. 8mA from September onwards.

- **Decrease in total lifetime of 7/8+1 expected.**



LIFETIME

- **Chromaticity changed from Q'H=11, Q'V=7 to Q'H=10, Q'V=10 in order to guarantee beam stability for high single bunch currents.**
  - Keeps same magnet file for all modes.
- **Some variance on the delivered lifetime**
  - In general the lifetime in 7/8+1 was around 21-22hrs by the end of the year.



Machine Developments in 2022

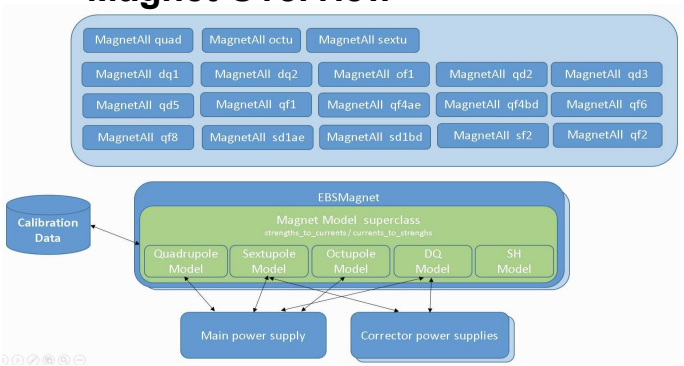
NEW MAGNET ARCHITECTURE - J.L. Pons (ACU)

- Some problems with old magnet architecture
  - Calculation conflicts on magnets with multiple channels (Sextupoles, DQs, SH).
  - Different code running on simulator vs real machine.

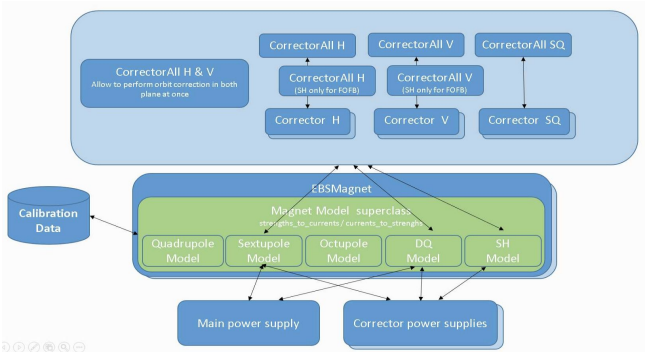
- The user interface is kept the same, but the device servers interaction with the power supplies has changed.
  - See ACU presentation (N. Leclercq) for full details.

- The BD group supported ACU in the deployment of the new magnet architecture.
  - MDTs to solve cycling issues

Magnet Overview

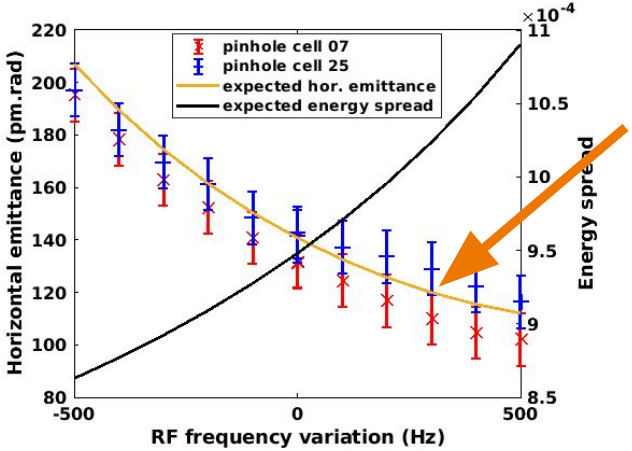


Corrector Overview



OFF ENERGY OPTICS - L. Hoummi (BD)

- Can we reduce the horizontal emittance even further?
- If the energy of the beam is reduced, the dispersive orbit moves the beam off axis in the quadrupoles introducing new dipole fields → increases their emitted radiation in one turn → reduces the horizontal emittance.
- The lattice needs to be rematched including the sextupoles to recover the correct optics.



Expected 20 pm.rad reduction for a +300Hz shift in the RF frequency

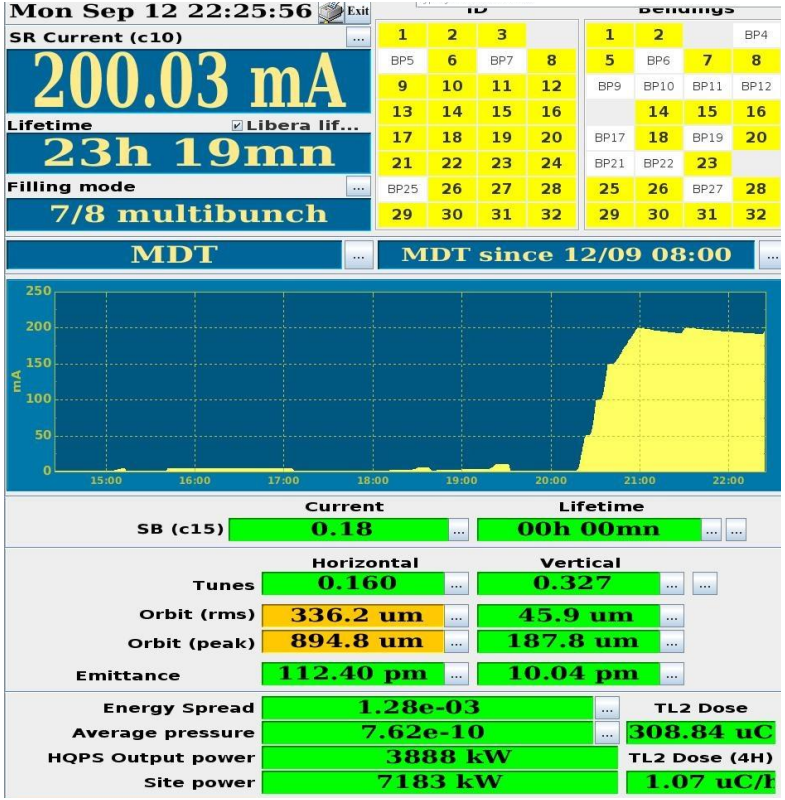
Filling mode	Off-energy lattice	Nominal lattice
7/8	24.4 h	37.0 h
16 b.	2.36 h	2.82 h
4 b.	1.62 h	1.90 h

Comparison of the nominal and the off-energy optics for ESRF-EBS		
Energy deviation	Current optics	-1 %
Tunes (Qx, Qy)	**(76.180, 27.340)**	**(76.184, 27.341)**
Nat. hor. emi εh	**140 pm.rad**	**122 pm.rad**
Energy spread	9.5 E-4	1.0 E-3
Mom. comp. factor	8.6 E-5	7.65 E-5
Energy loss	2.6 MeV	2.5 MeV
Chromaticity	(8.3, 5.5)	(6.6, 6.2)*

OFF ENERGY OPTICS - L. Hoummi (BD)

- Successfully demonstrated in MDT.
- After some simple optimisation, the total beam lifetime was increased from 11h to 23h at 200mA in 7/8 filling.
- The injection efficiency was 70%.
- The horizontal emittance was 108.8 pm rad with gaps open, reducing to 96 pm rad with 3.92 kW ID power (at 5mA).
- Cons: BM source size will increase (~7%) and source position will change.
- Full analysis on impact of off energy optics on the brilliance is still being studied.

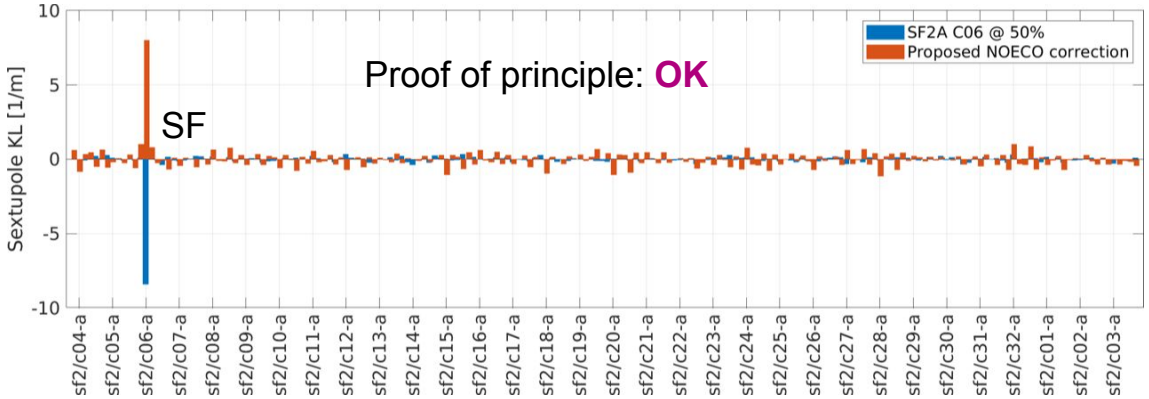
Lifetime [h]	On-energy	-1%	-1% optim.
Vacuum	85 +/- 24	65 +/- 6	126 +/- 26
Touschek	30 +/- 8	13 +/- 1	28 +/- 6



*112pm +- 7pm

NOECO CORRECTION - S. Liuzzo (BD), N. Carmignani (BD)

- **Tested a different method of computing sextupole corrections.**
- **NOECO (Non linear Optics from off Energy Closed Orbits) is based on a combination of fast off energy response matrix and dispersion measurements**
- **Large single sextupole modification put in place, proposed NOECO correction finds it.**

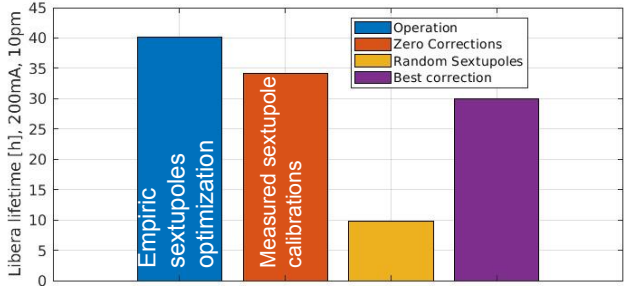


<u>Attempt made with random sextupole pattern.</u>

1) The specific random sextupole corrector <u>pattern is NOT found</u>.

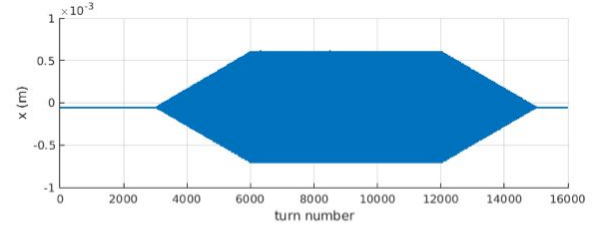
2) Nevertheless, the correction applied recovers the lifetime.

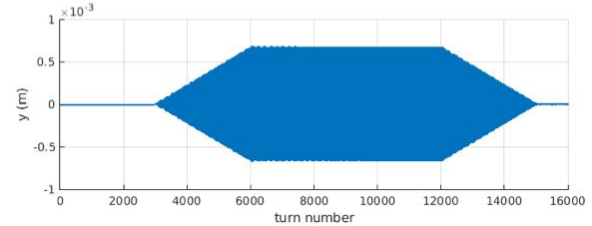
3) Zero correction strengths are better then 1 iteration of NOECO correction

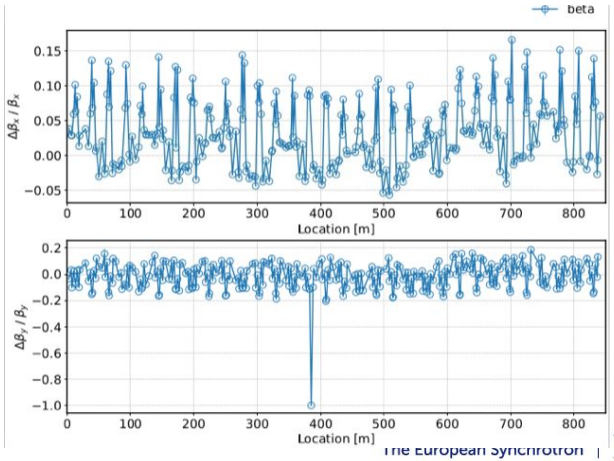


OPTICS MEASUREMENT WITH AC DIPOLE - N. Carmignani (BD), L. Malina (DESY)

- Alternative methods of optics measurements
- Magnetic shaker used with a sinusoidal excitation in H and V at a frequency close to the tune.
- Drives a coherent motion around the ring at a fixed frequency
  - Record the turn by turn bpm data all around the ring for 50,000 turns
  - Perform frequency analysis on each BPM.
  - Extract the phase advances and compute the beta functions (correcting for the impact of the AC dipole)
- Machine was already well corrected (~1%), AC dipole method computed a beta-beating of about 10%.
  - Some refinement is clearly still needed.







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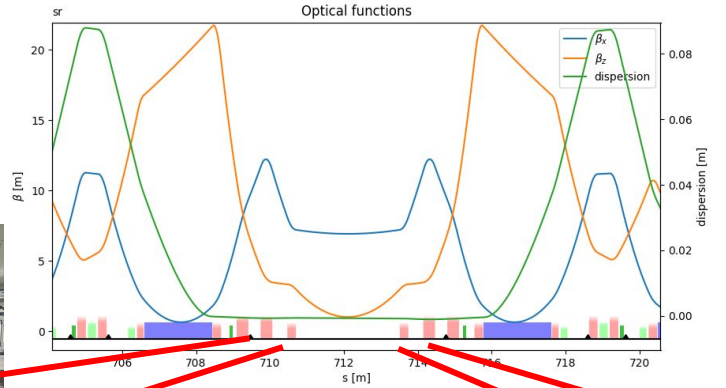
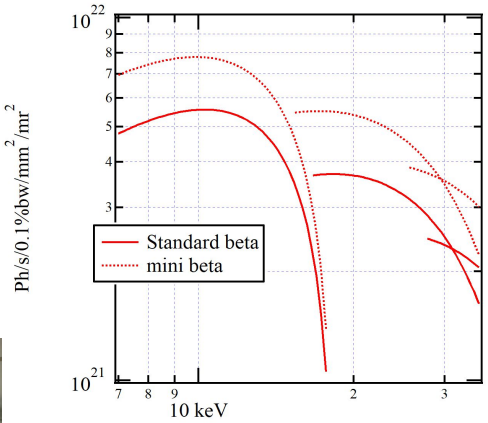
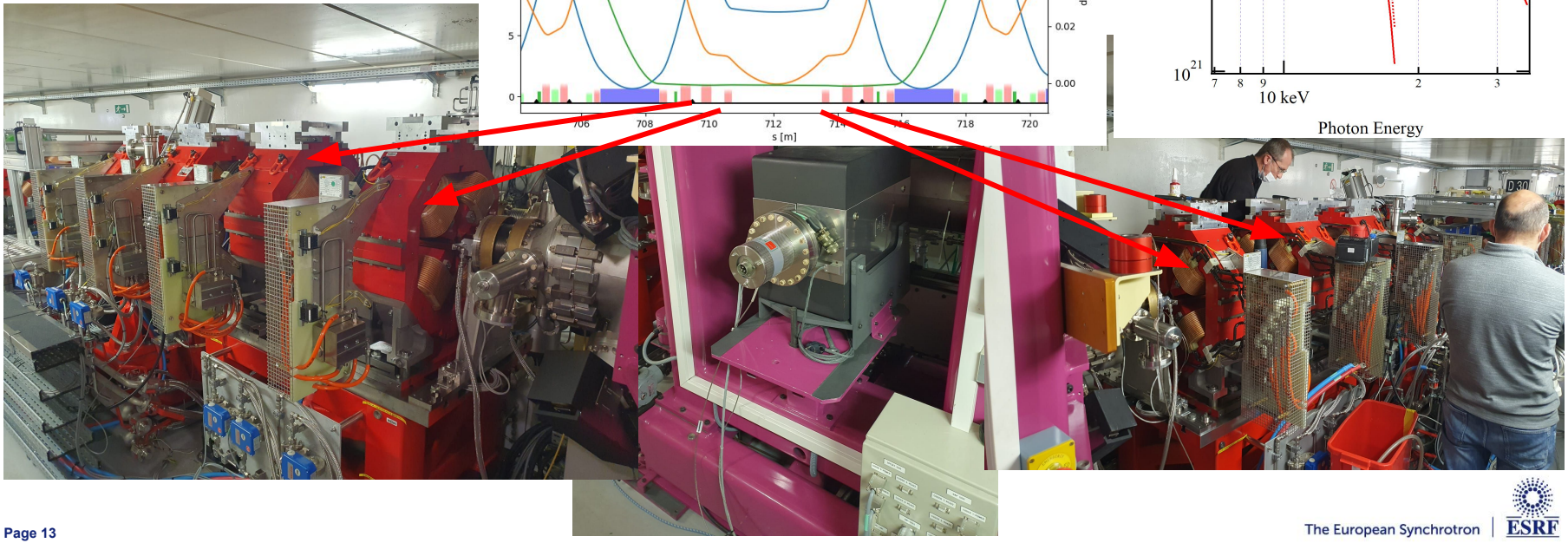
Machine Developments in 2023

MINI BETA - C. Benabderrahmane, N. Benoist, B. Ogier, G. Le Bec, VAC Group

- Repurpose 4 spare quadrupoles to reduce the beta-function.
- Vertical beta function at center of ID reduces from 2.8m to 1m.
- Lifetime will be impacted. (~20% reduction)







MINI BETA - STATUS AND TIMELINE

- The 4 quadrupoles are installed in the machine but are not cabled.
  - Temporary cabling needed to manually cycle so that the remnant fields were close to zero with the correct polarity.

- In the next shutdown they will be cabled and added as independent magnets to the control system.
  - Some additional time is needed to ensure the hotswap system was properly integrated with these additional magnets.

- The first powered tests will be able to start during the March restart at the earliest.
  - Beam tests are scheduled for after the May restart.

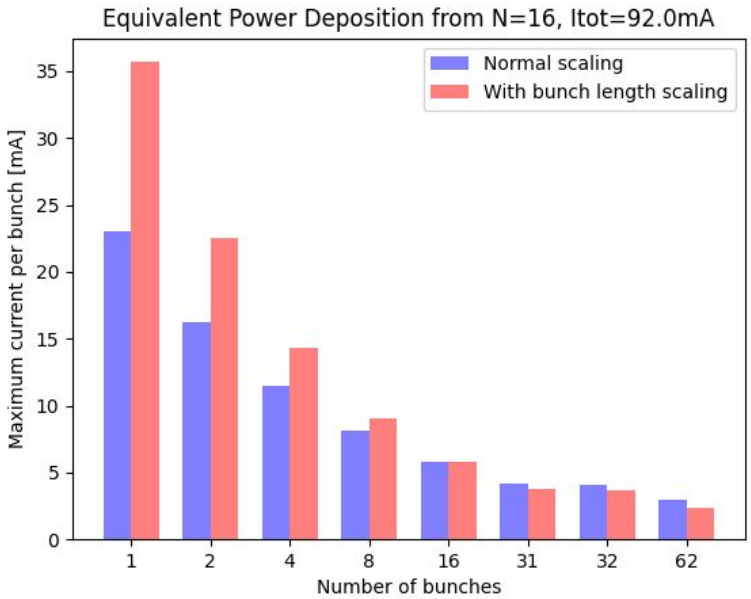
- If the concept is validated, then new magnet procurement will begin and the magnets will be fully integrated into the control system.

HIGH SINGLE BUNCH CURRENTS - L. Carver (BD), S. White (BD)

- **Can we push the currents in timing modes without risking damage to machine components?**
  - Higher currents also means lower lifetimes. A trade-off that needs to be considered.
- **Assuming constant power deposition, how much current can we put in each filling mode?**
  - Does not consider high peak currents, which may be a limiting factor on many active devices (striplines for BBB feedback).
- **MDT is planned to understand these limits, as well as beam stability and performance with these currents.**

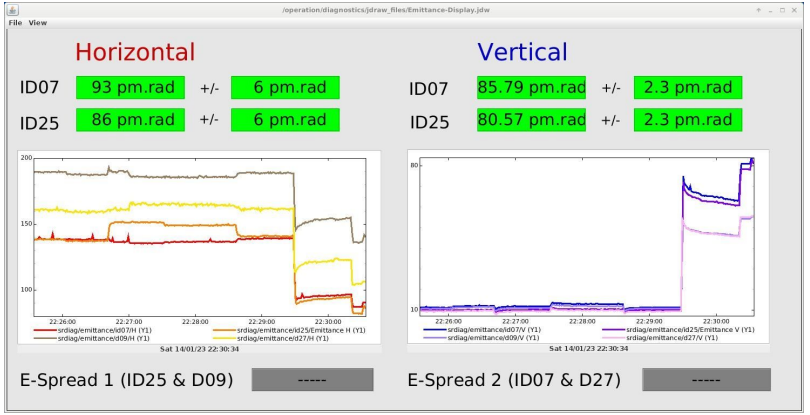
$$P = \frac{N \kappa_{\parallel} I_b^2}{f_0},$$

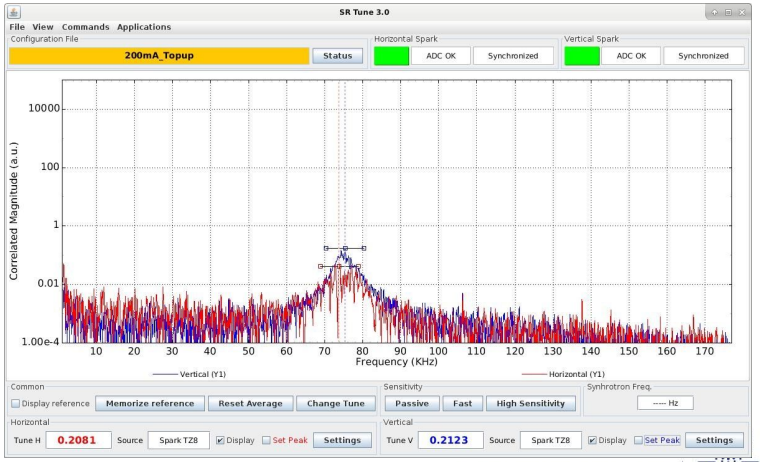
- Complicated variation with bunch length.
- For increasing current, bunch length becomes longer, k becomes smaller.
- Approximate scaling assuming an ideal impedance is used.



TIMING MODES WITH ROUND BEAMS - L. Carver (BD), S. White (BD)

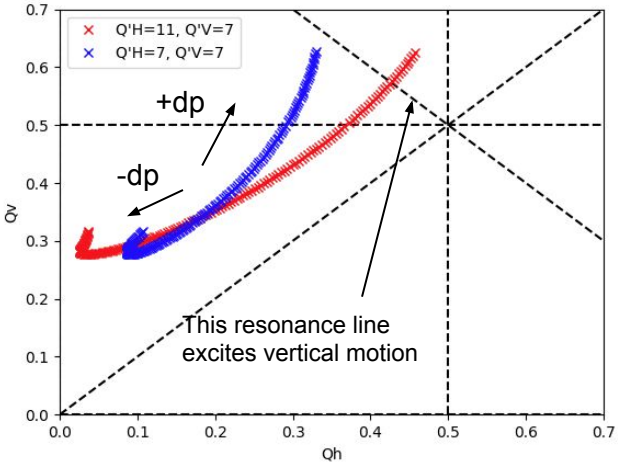
- **In the 4x10mA filling mode, ID18 is not sensitive to vertical emittance.**
  - Not necessarily valid for all timing mode beamlines.
- **How can we use this to improve the performance?**
- **Set Qx=Qy (coupling resonance)to create a round beam, reduced horizontal emittance and larger vertical emittance.**
  - Emittance becomes approximately 85pm in each plane.
- **Tested during January 2023 restart.**
  - Possible reduction of injection efficiency with gaps close. To be confirmed.

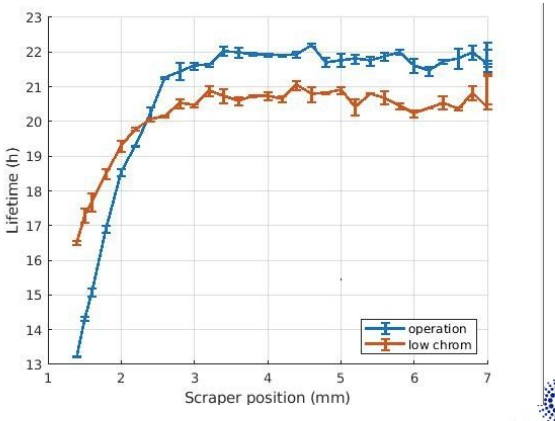




HALO STUDIES - N. Carmignani (BD), L. Carver (BD)

- **Minimum gap of IVUs are limited due to losses on the vertical jaws**
  - The IVU gaps are on the order of mm, but the vertical beam size is on the order of 10s of micrometers. How is this possible?
- **Particles scatter off each other, can be kicked outside of the RF bucket, resulting in Touschek losses.**
  - But particles are kicked at all angles, so there are many particles that are kicked to the very edge of the energy acceptance, but are not lost.
  - These particles then decay over time, returning to the beam core
- **Depending on the chromaticity (tune variation with energy offset), the particles may pass through resonance lines which can excite horizontal or vertical motion.**
  - This creates a beam HALO, a region of particles with large amplitude that is constantly repopulated.
- **High chromaticity is needed to keep the single bunch stable at injection.**
  - Is it possible to create a low chromaticity optics file for uniform mode that will allow a smaller minimum gap in the IVUs? 2023 will tell us!





Thank you