
CERN

Fellowship Update

Feb 2020

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10.02.20

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Accelerator Physicist (BE-ABP-HSI-2020-8-LD)

I feel ready to contribute, and am confident that I'm capable of:

- Learning and **understanding complex situations** quickly and efficiently.
- Applying that knowledge skilfully to **solve problems in previously unknown areas**.
- Using limited **beam instrumentation to perform intelligent measurements in order to probe beam behaviour and ultimately improve performance**.
- **Developing and applying massive single- and multi-particle beam dynamics codes**, including linear and non-linear, and incoherent effects **to improve our understanding**.

Accelerator Physicist (BE-ABP-HSI-2020-8-LD)

I feel ready to contribute, and am confident that I'm capable of:

- Working patiently and effectively with peers and colleagues, encouraging **honest collaboration**, and providing excellent support.
- Educating and **sharing understanding with peers and even members of the public**, in order to further mankind and efficiently run our machines.
- **Leading and mentoring others**, providing what they require to flourish on an individual basis, and monitoring their progress to encourage efficient and results driven research.
- **Asking for help**, identifying the limits of my own knowledge and experience, being able to admit this professionally, and using my considerable network to identify and bring together the experts who can cover gaps in our understanding.

Motivation

When I arrived as a fellow **I was not ready for a staff position**.

- Thanks (mostly) to you, **I now feel prepared**.
- Thanks for being **excellent at sharing your considerable understanding**.
- Thanks for your **patience and encouragement**.
- Thank you for your **contribution to me and mankind**.

I wish to demonstrate and improve my capabilities, and welcome your future encouragement and support in this never-ending endeavour!

- MD4224: Space charge at PS injection.
- Transfer line dispersion mismatch in PS.
- MD211: Longitudinal emittance effect on above two investigations.
- LIU tunespread and emittance growth predictions with PyORBIT.
- Development and support of PyORBIT.
- Education.

SC @ PS Injection: Motivation

Unknown 30-40% emittance blowup between PSB and PS:

Try to **gauge effect of space charge at PS injection** and assess possible contribution, using beam profile measurements.
Understand behaviour by **benchmarking measured data with simulations**.

SC @ PS Injection: Status

- MDs performed, data analysed, **behaviour clear**.
- **Beam blows up as the working point is brought closer to the integer in each plane respectively. No dependence on measurement time (2, 5, 15 ms post injection)**.
- Unfortunately only have one plane of beam profile data.
- **Simulations agree well with measurements**. Emittances from profiles.
- Conclude **quadrupolar resonance at the (half-) integer is driving emittance growth on a very short time scale** < 100 turns (1 turn = 2.287E-6 seconds ->) < 0.23 ms, **when the WP is close to the integer**.
- PFW scan shows no blowup without LEQs active.
- PFW + single quad error gives similar emittance growth to measurement thus **confirming hypothesis**.

SC @ PS Injection: MD vs Simulation

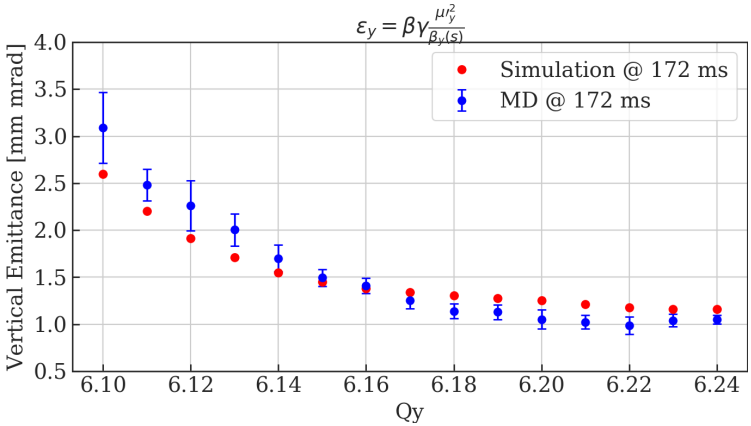


Figure: Emittances comparing measurements with simulation using PTC optics for the vertical tune scan.

SC @ PS Injection: PFW with Quad Error

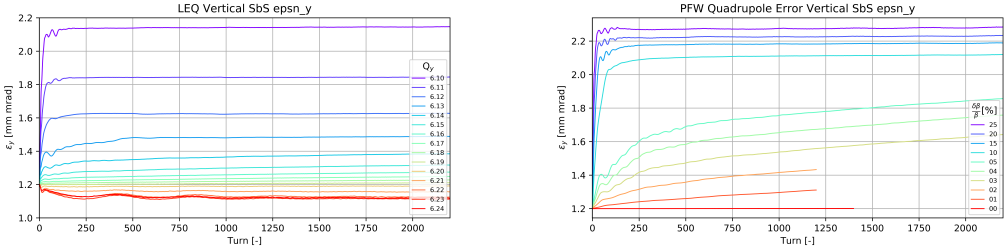


Figure: Emittances comparing measurements with simulation using PTC optics for the vertical tune scan.

SC @ PS Injection: Next Steps

- Analyse turn-by-turn tune footprints etc to **gain understanding of coherent/incoherent nature of beam behaviour**.
- Confirm **injection bump tune** swing has little effect on behaviour.
- Investigate **power supply ripple on injection kickers**.
- Investigate behaviour with **zero-dispersion optics**.
- Combine with **dispersion mismatch study**.

SC @ PS Injection: What have we gained?

- I have a good understanding of measurements, operation, analysis, simulation, etc to gain understanding and optimise machine performance. **Lots of Experience**
- Excellent benchmark of simulation and measurement. **Powerful Tool**
- Confirmation that space charge is not a major contributor to the blowup? **Operational Optimisation**
- Possible confirmation of coherent/incoherent response? **Important Understanding**

PS D Mismatch: Motivation

Unknown 30-40% emittance blowup between PSB and PS:

Try to **gauge effect of dispersion mismatch with space charge at PS injection** and assess possible contribution. Using SEM grid measurements.
Understand behaviour by **benchmarking measured data with simulations**.

PS D Mismatch: Envelope Oscillation Depression

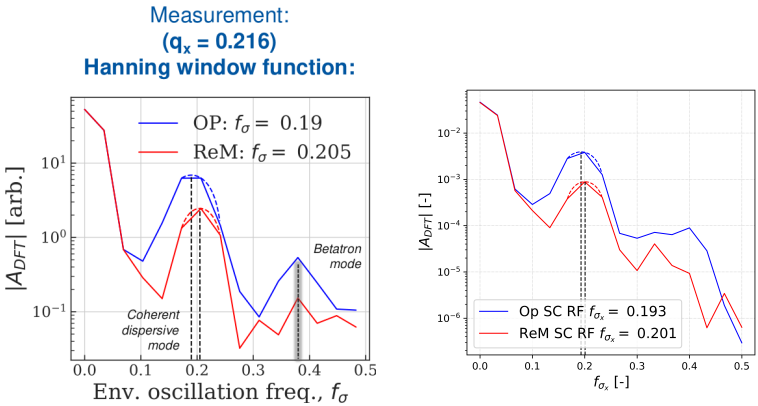


Figure: Measured (left) and simulated (right) envelope oscillation frequencies for various dispersion mismatch cases.

PS D Mismatch: Emittance with space charge

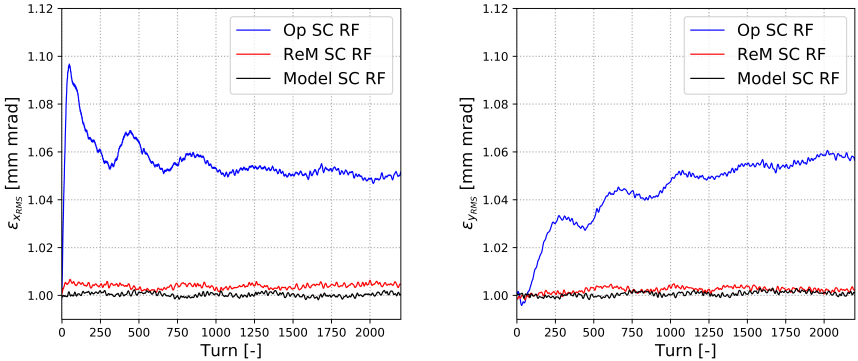


Figure: Emittances for various dispersion mismatch cases.

PS D Mismatch: What have we gained?

- Again, excellent benchmark of simulation and measurement. **Powerful Tool**
- Looks like envelope oscillation frequency is dispersion mismatch dependent? **Operational Optimisation**
- Confirmation that dispersion mismatch results in emittance growth. Space charge causes this blowup to be within first 100 turns, and drives emittance exchange via the Montague resonance. **Operational Optimisation**
- Possible confirmation of coherent/incoherent response? **Important Understanding**

Longitudinal Emittance Dependence: Motivation

Simulation benchmark of MD211 in order to understand measurement results.

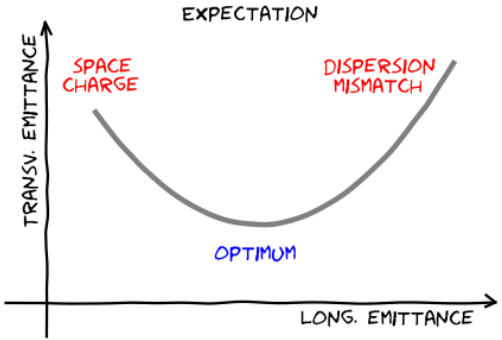


Figure: MD211 Hypothesis.

Longitudinal Emittance Dependence: Motivation

Simulation benchmark of MD211 in order to understand measurement results.

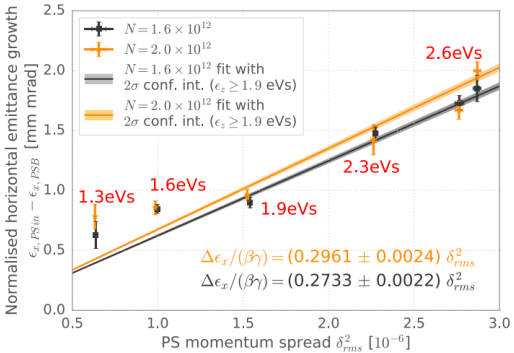


Figure: MD211 Results.

Longitudinal Emittance Dependence: Summary

To do:

- Longitudinal distributions created.
- Transverse parameters to be checked.
- Correct application of dispersion mismatch - later.
- LHC standard 25ns type beam used without chroma correction - check with Alex how to create optics.
- Preliminary scan without space charge.
- Full scan with space charge.

Longitudinal Emittance Dependence: What do we expect to gain?

- Benchmark measurement with simulations to obtain agreement. **Improve our Tools**
- What is happening in the PS at injection? **Important Understanding**
- Dependence of mismatch/SC driven emittance growth on longitudinal emittance? **Operational Optimisation**
- Confirmation of cause of emittance blowup? **Operational Optimisation**

Motivation
Current Projects
Space charge at PS injection
PS transfer line dispersion mismatch
Longitudinal emittance dependence of SC and D mismatch

LIU tunespread and emittance growth predictions with PyORBIT

Development and support of PyORBIT
Education
Conclusion
Acknowledgements

LIU tunespread: Motivation

Use powerful tool to **predict behaviour of LIU beams and compare to analytical/previous expectations**. Gain understanding to **inform commissioning and LIU-era operation**.

LIU tunespread: Summary

- Longitudinal distributions generated with help from A. Lasheen.
- Transverse parameters provided from LIU table.
- Perfect machine, settings as defined by Alex.
- Pre-LIU, and LIU Standard and BCMS type beams simulated.
- **All cases stable except 2021 Standard - large tunespread crosses integer - drives emittance growth**.
- 2021 emittance growth **($\approx 2.5\mu m$) doesn't meet expectation ($\approx 3.5\mu m$)**. Plateau not reached - tune footprint still moving above integer.
- **Long term simulations running** with 0%, 5% $\frac{\Delta\beta}{\beta_0}$.

LIU tunespread: What did we gain?

- Benchmark measurement with analytical expectation to obtain agreement (tunespreads, emittance stability w.r.t SC etc). **Improve our Tools**
- Time taken for emittance growth in LIU Standard 2021 case? **Operational Optimisation**
- Confirmation of cause of emittance blowup. **Important Understanding**
- **Prepared for commissioning**.

PyORBIT:Motivation

Whilst we don't have a CERN-based alternative, provide a fast and reliable simulation tool, benchmarked against measurement data, with examples and support, so that all may benefit from our hard work!

PyORBIT: Summary

- PyORBIT working on HPC-Batch, **allows us to make better predictions**!
- Useful work brought together into scripts (distribution from Tomo, outputs, plotting etc), **gives more realistic results**.
- Gitlab repository with examples - needs updating - **provides new users with a quick start**.
- HPC workshop talk - opportunity to do some benchmarking/optimisation and gather work to update repository, and report back to HPC and clarify our requirements - **hopefully improve future experience**.

Education: Summary

- Tactile Collider - open days, IdeaSquare events, hackathons etc.
- Member of LHC outreach group (LHC injectors representative).
- Regular CERN guide (CCC, LEIR, SM18, SC, ATLAS (above ground), ALICE (above ground), Data Centre, AD, AMS).
- CERN Basketball Coach (10+ hours a week, over 3-5 nights).
- CERN Fellow mentor.
- Mentoring of students etc.
- Assisting with JUAS tutorials.

Conclusion

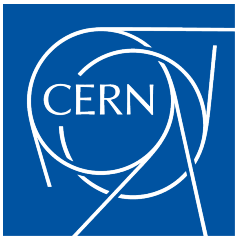
What have we learnt?

- Together we have made some excellent measurements and tools for future problems!
- I feel prepared to take my career to the next level!
- We are greatly improving the understanding of the PS!
- I would like to take on more responsibility, to learn as much as possible before the end of my fellowship!

Acknowledgements

“If I have seen further it is by standing on the shoulders of Giants” - Newton

- You.
- Everyone that I work with.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