



MAX IV Ring Status

Magnus Sjöström on behalf of the MAX IV team

ESLS XXIV 2016-11-29

Outline

- 3.0 GeV storage ring
- 1.5 GeV storage ring
- Next steps

Developments and highlights

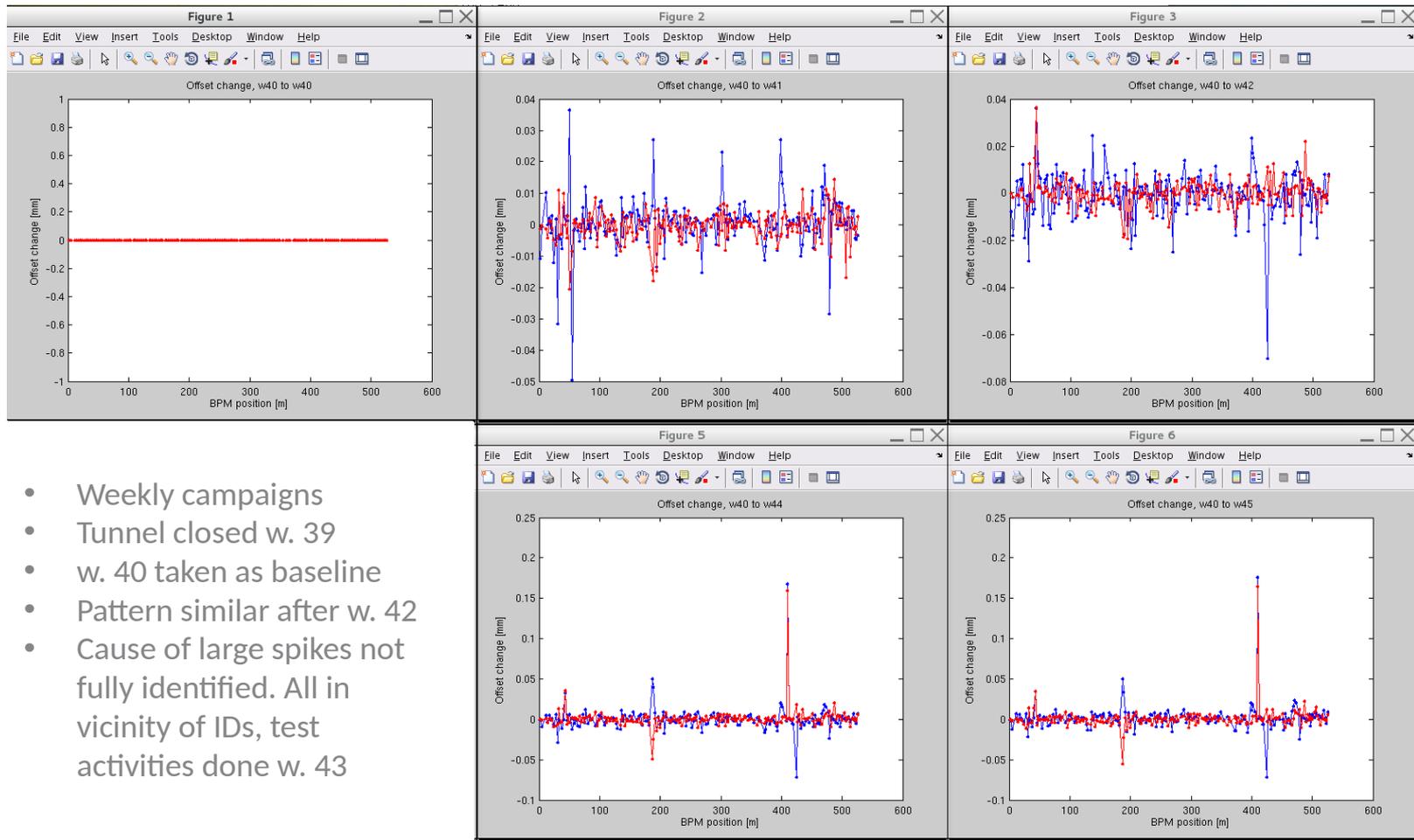
3.0 GEV STORAGE RING

Linear optics: BPM offsets

BPM offsets currently determined using quadrupole trim coils on OXX, SDE, SFI, SFO and SFM higher order multipoles:

- BBA measurement requires de-activation of main coil
- Measurement done using a slightly modified version of quadcenter.m (MML routine)
- Short term (~1 hour) reproducibility: ~1 μm RMS
- Long term reproducibility (w. 40 - 45): 7 μm RMS hor. / 5 μm RMS ver.

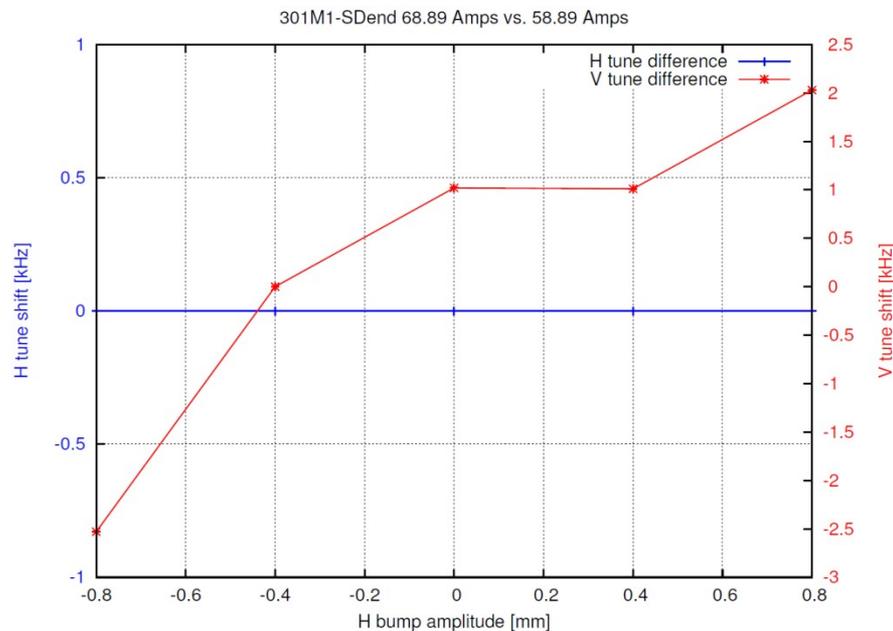
Linear optics: BPM offsets



- Weekly campaigns
- Tunnel closed w. 39
- w. 40 taken as baseline
- Pattern similar after w. 42
- Cause of large spikes not fully identified. All in vicinity of IDs, test activities done w. 43

Linear optics: BPM offsets

Sextupole field center at nominal field strength and trim coil quadrupole field center w. main coil off do not match! → beam is going off-center through at least SDE, and very likely SFI, SFO, SFM.

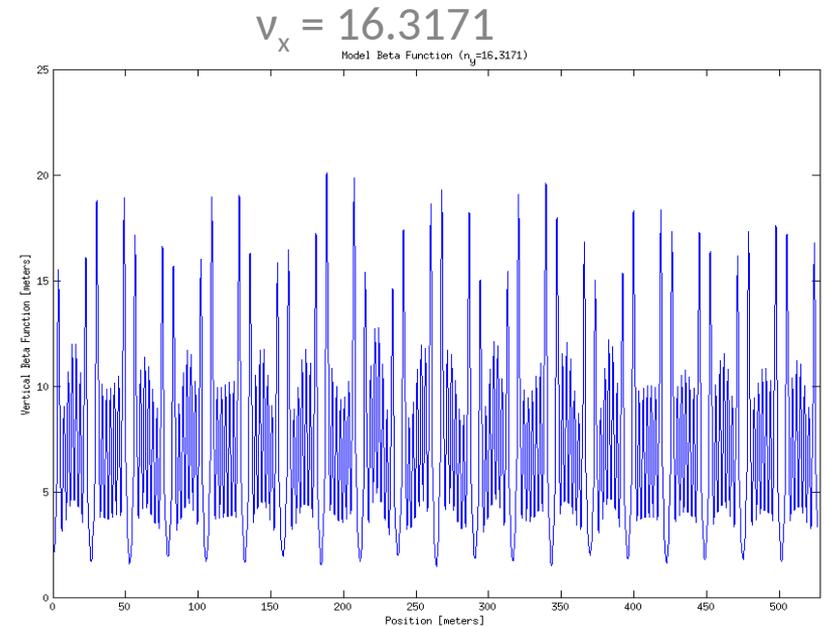
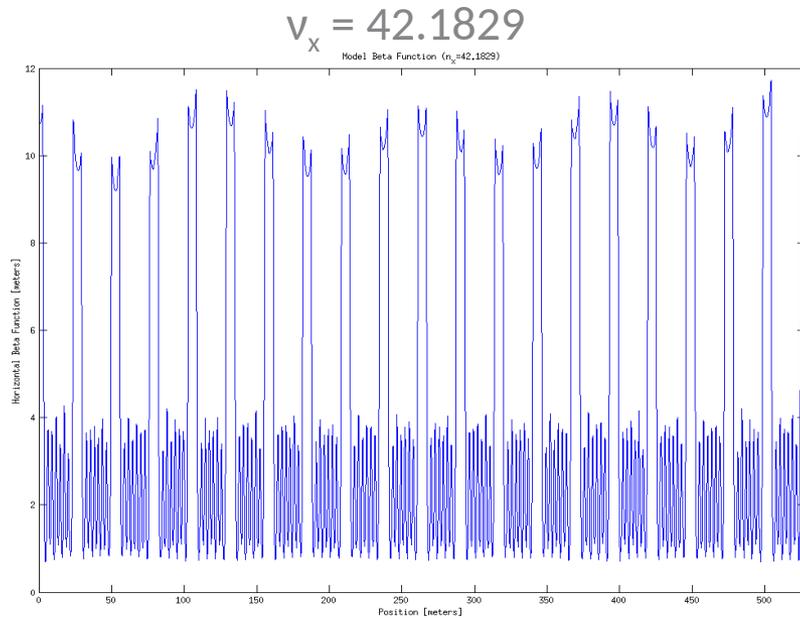


Measurement and plot by S. Leemann

Linear optics: LOCO correction

- LOCO applied using all PS circuits affecting gradients as knobs:
 - QFE, QDE, QFM, QF (quads) and DIPC, DIPMC (pole face strips)
 - Initially a bug was preventing convergence towards design optics
 - Once fixed, optics converged nicely (2016-10-07)
- Fine tuning on per-magnet basis still to come (magnet shunting required due to lack of individual power supplies)
- All optics tuning up to now done using BPM offsets measured using trim coils in quadrupole mode

Linear optics: LOCO correction

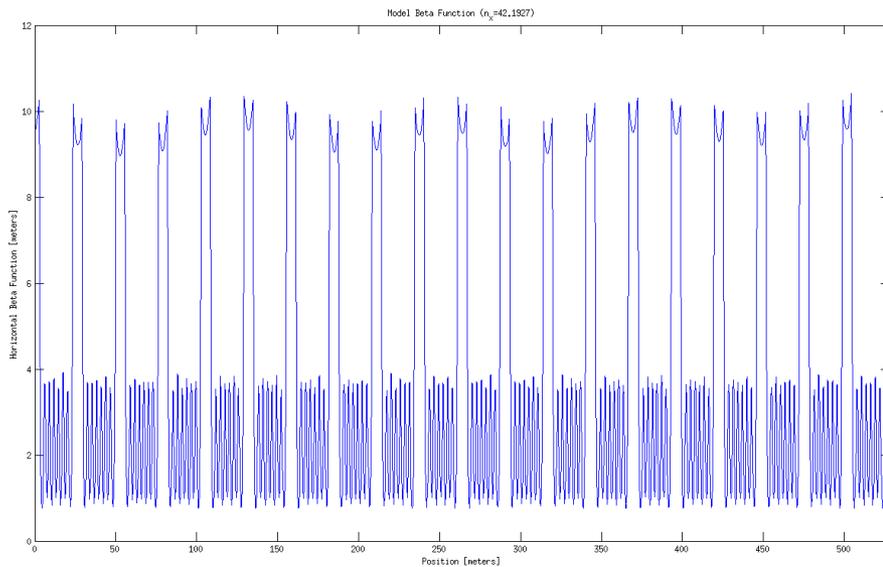


2016-10-07: Pre-LOCO adjustment

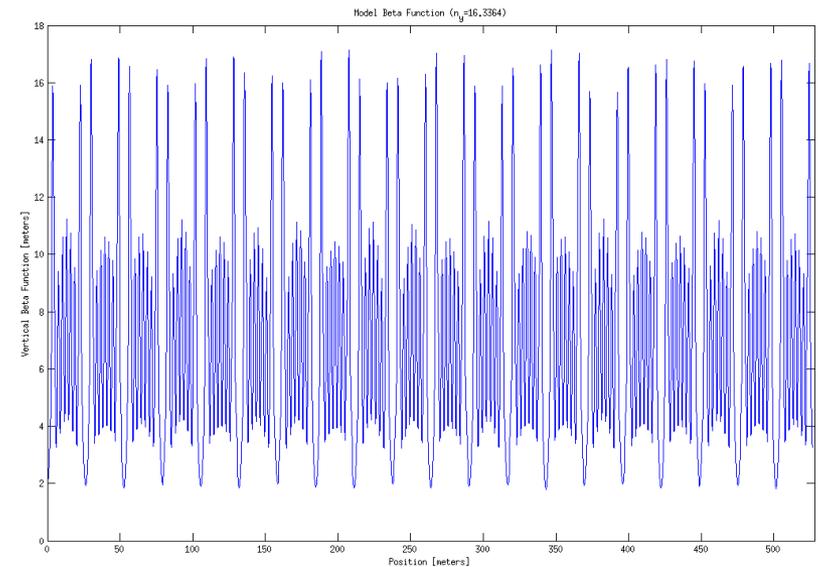
Measurement and plot by J. Sjögren

Linear optics: LOCO correction

$$\nu_x = 42.1927$$



$$\nu_x = 16.3364$$

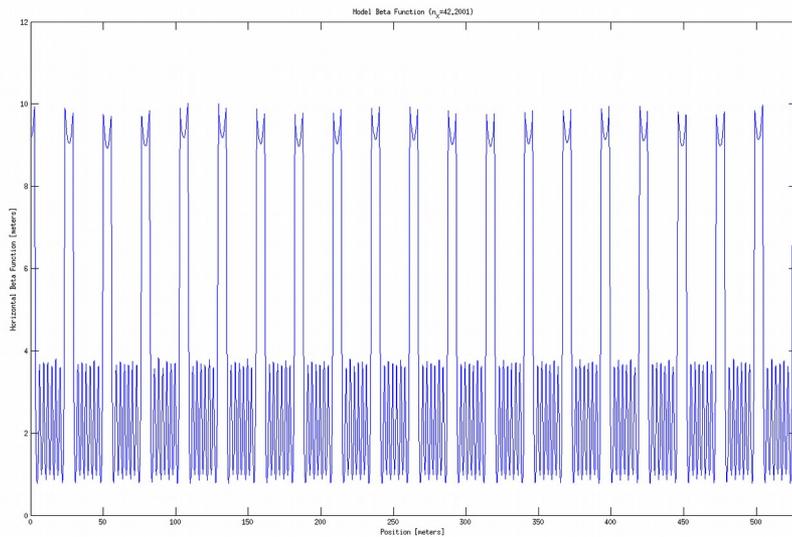


2016-10-07: After 1st LOCO iteration

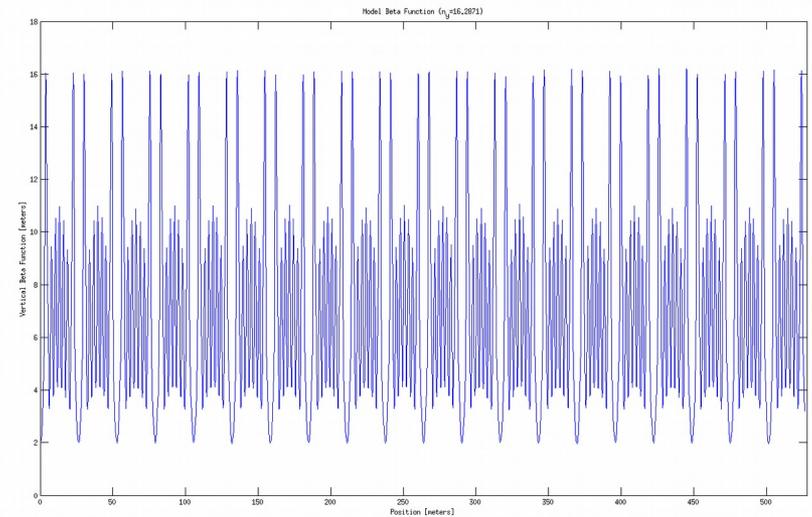
Measurement and plot by J. Sjögren

Linear optics: LOCO correction

$$\nu_x = 42.2005$$



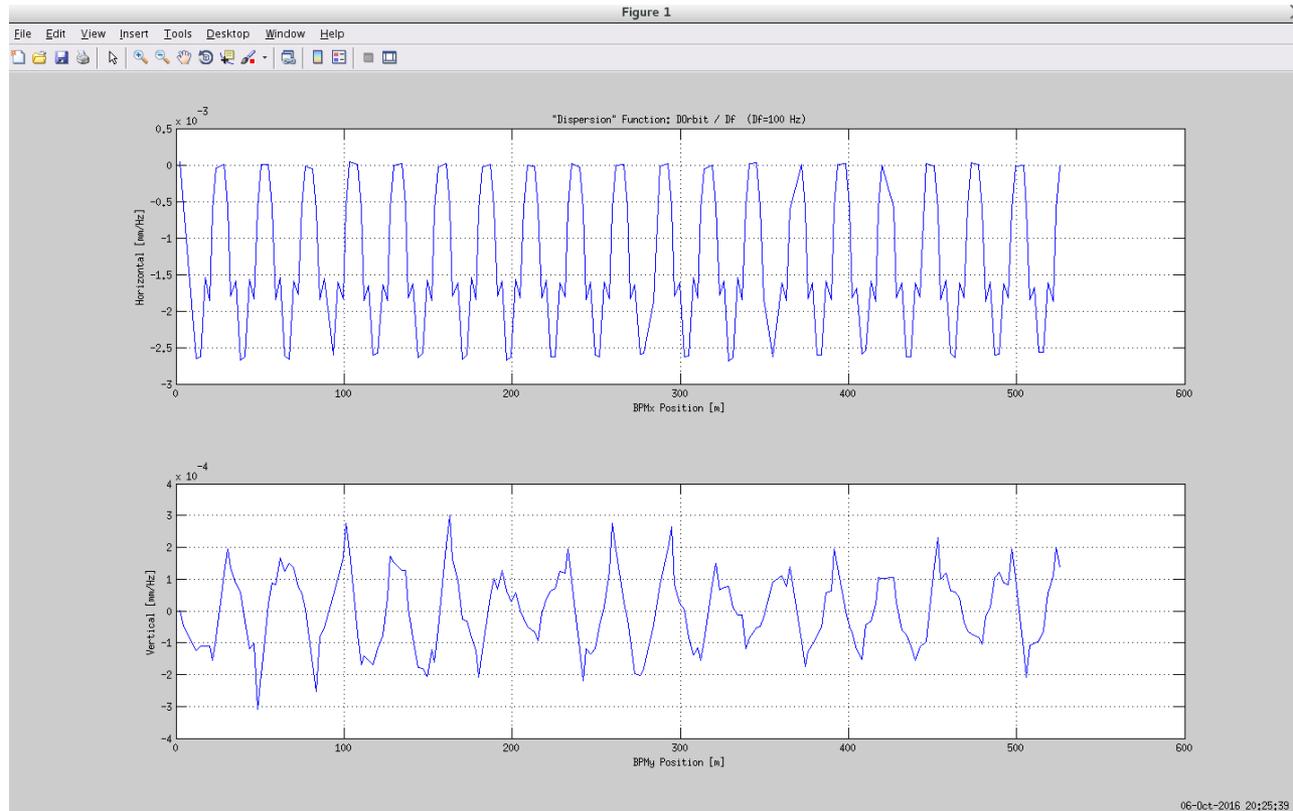
$$\nu_x = 16.2871$$



2016-10-07: After 2nd LOCO iteration

Measurement and plot by J. Sjögren

Linear optics: LOCO correction



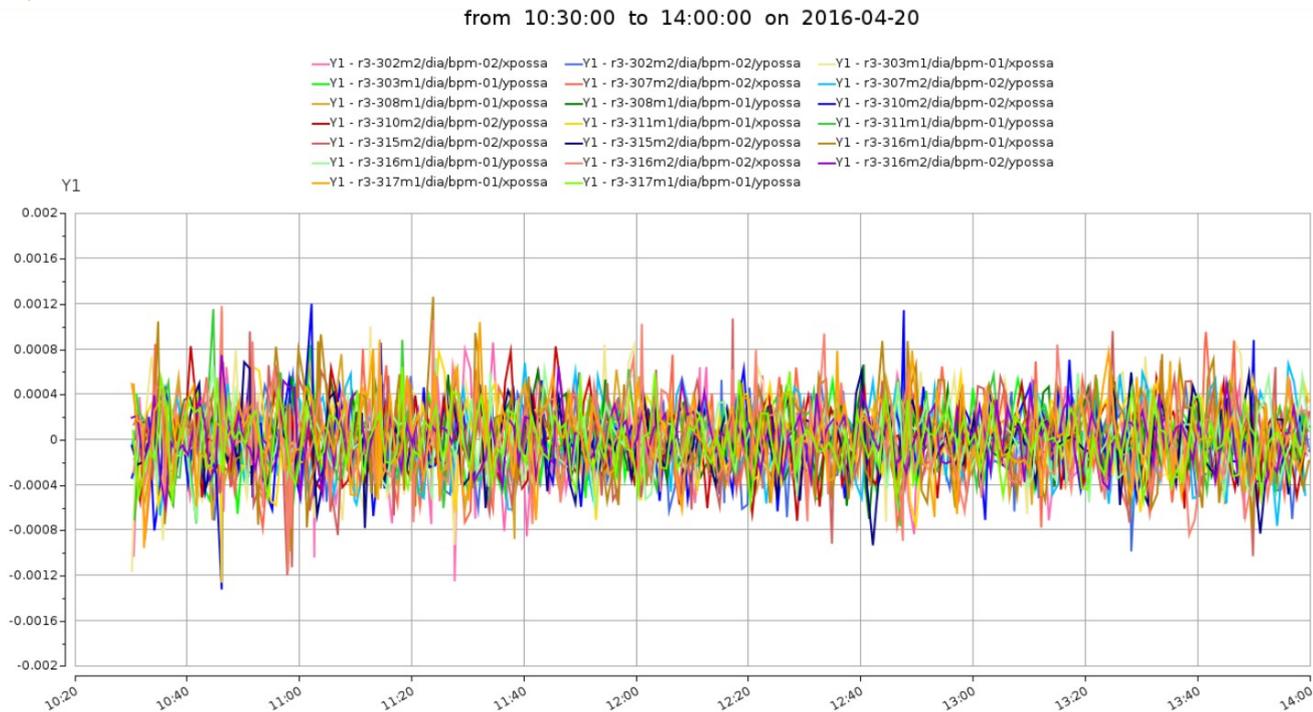
Dispersion post-LOCO: $\eta_x = 8$ cm, $|\eta_y| < 8$ mm

Vertical dispersion minimization w. skew quadrupoles (trim coils) planned

Measurement and plot by J. Sjögren

Orbit stabilization: SOFB

SOFB (setorbitgui, MML app.) active, orbit in long straight BPM (10 Hz data)



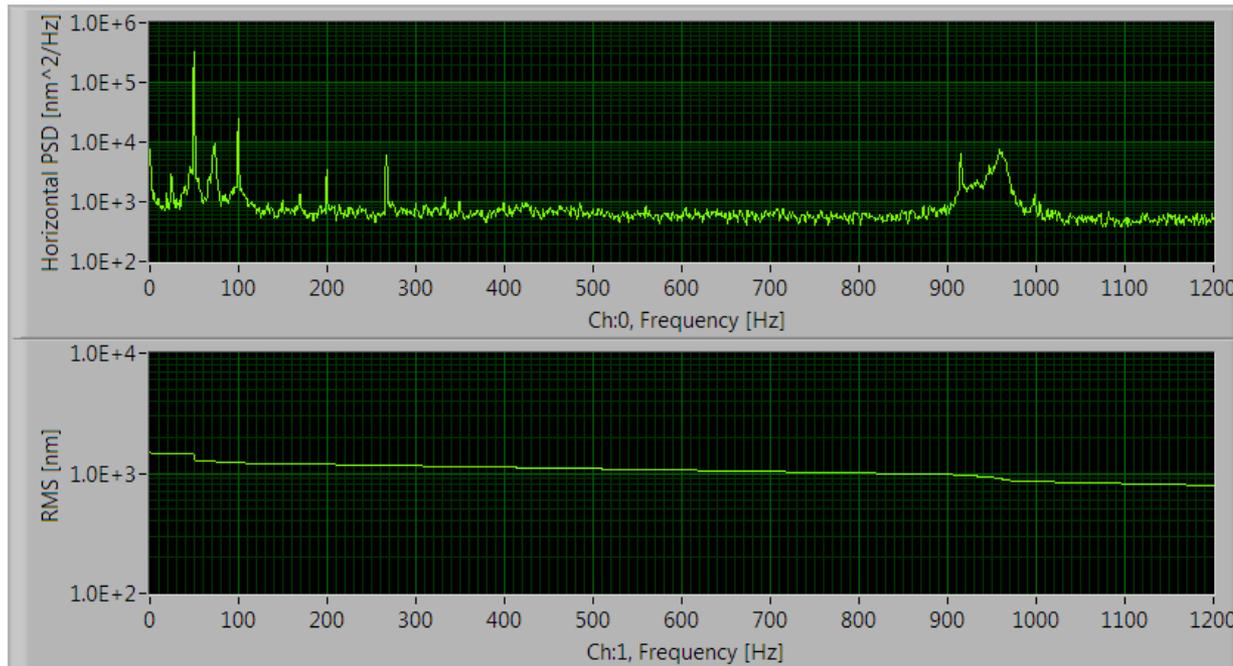
σ_x : 0.37 μm

σ_y : 0.29 μm

Orbit stability: FOFB

FOFB delayed until 2017 (power supply procurement not yet started)

BPM 10 kHz data stream (FA) extracted:

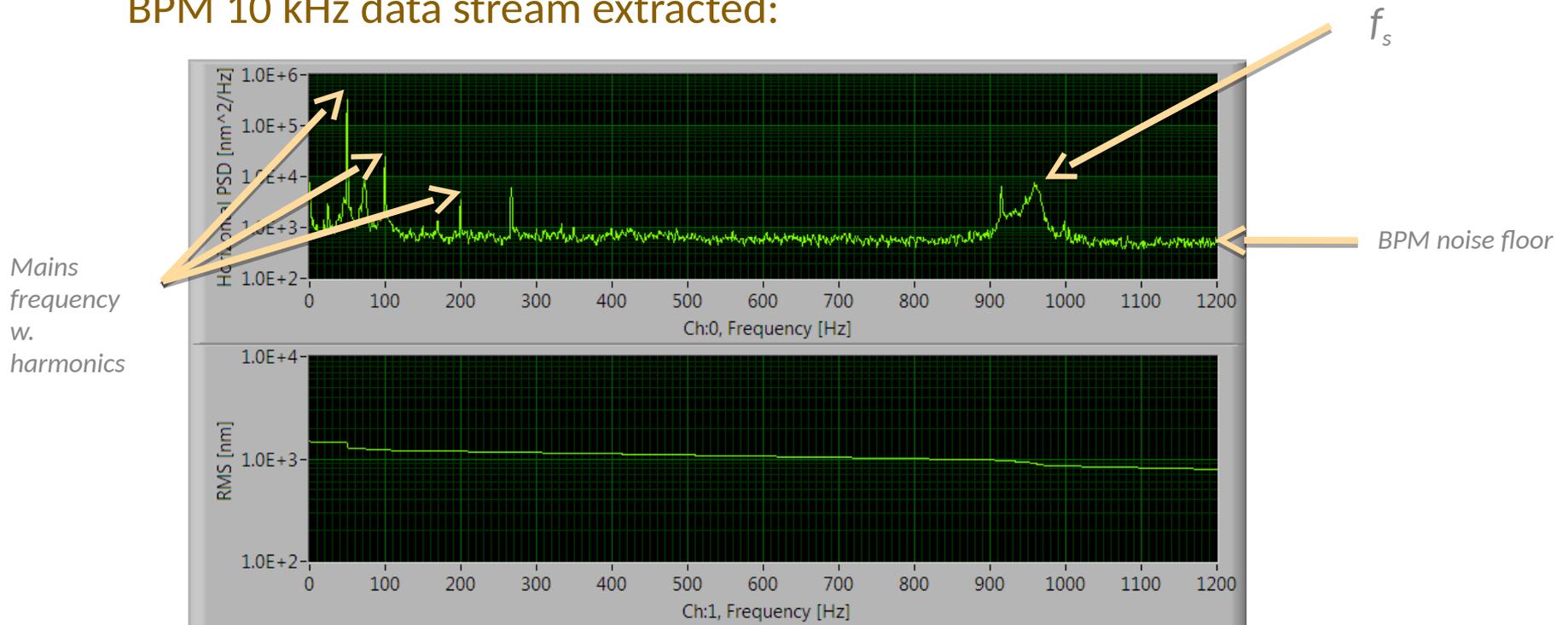


Horizontal data from 2016-06-15 for BPM flanking BioMAX ID. $I_{beam} = 9$ mA. Plots and analysis by B. Jensen.

Orbit stability: FOFB

FOFB delayed until 2017 (power supply procurement not yet started)

BPM 10 kHz data stream extracted:

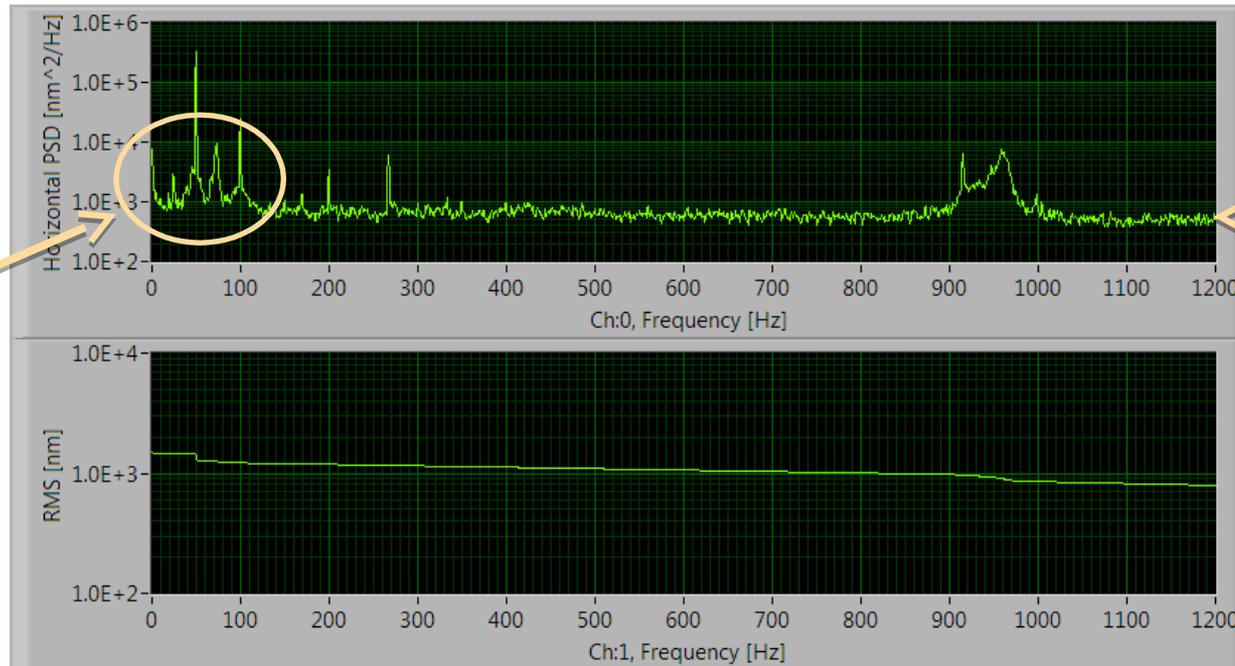


Horizontal data from 2016-06-15 for BPM flanking BioMAX ID. $I_{beam} = 9$ mA. Plots and analysis by B. Jensen.

Orbit stability: FOFB

FOFB delayed until 2017 (power supply procurement not yet started)

BPM 10 kHz data stream extracted:

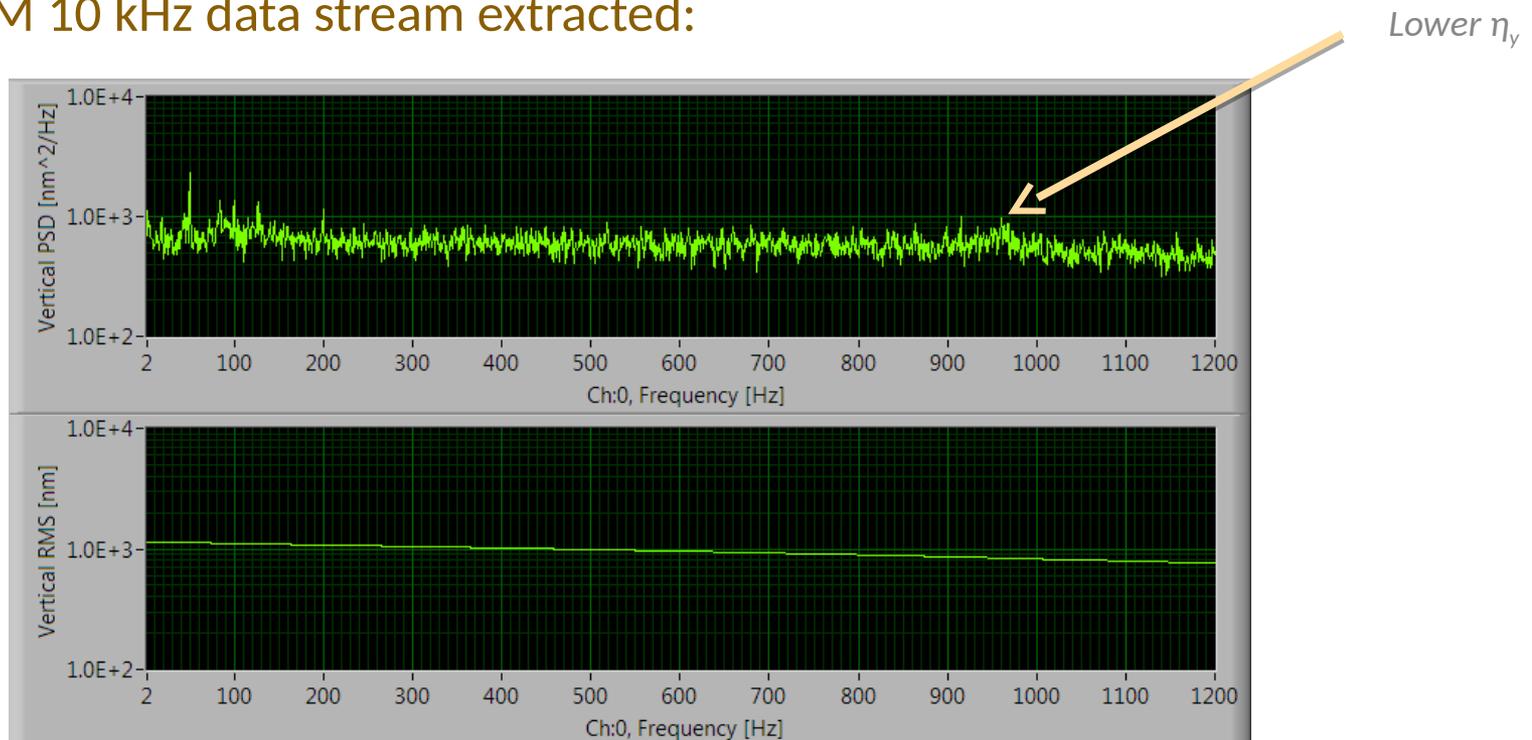


Horizontal data from 2016-06-15 for BPM flanking BioMAX ID. $I_{\text{beam}} = 9 \text{ mA}$. Plots and analysis by B. Jensen.

Orbit stability: FOFB

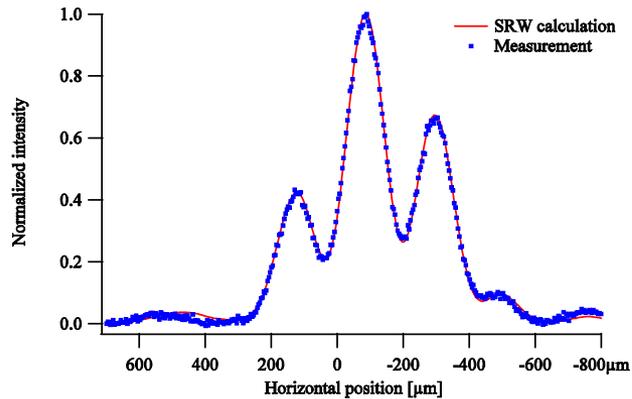
FOFB delayed until 2017 (power supply procurement not yet started)

BPM 10 kHz data stream extracted:



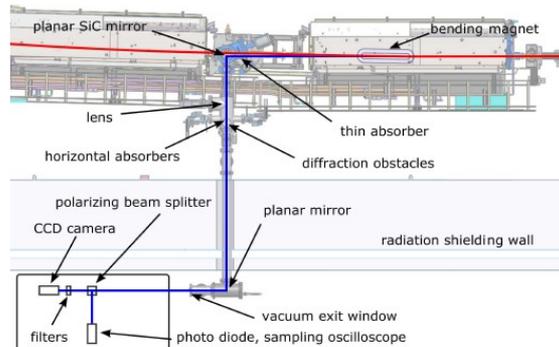
Vertical data from 2016-06-15 for BPM flanking BioMAX ID. $I_{\text{beam}} = 9$ mA. Plots and analysis by B. Jensen.

Emittance Measurement



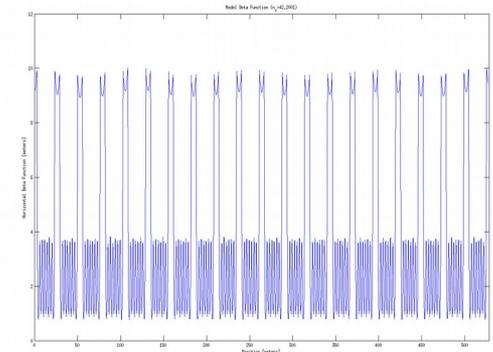
$$\sigma_x = 20.86 \pm 0.14 \mu\text{m (fit uncertainty)}$$

$$\sigma_y = 15.70 \pm 0.15 \mu\text{m (fit uncertainty)}$$



B320B diagnostic beamline
(visible SR radiation)

Figures by J. Breunlin and Å. Andersson



$$\beta_x = 1.26 \pm 0.02 \text{ m}$$

$$\beta_y = 15.66 \pm 0.08 \text{ m}$$

$$\eta_x = 3.59 \pm 0.06 \text{ mm}$$

Errors computed based on 5
separate LOCO measurements

Plot by J. Sjögren

Details re. beamsize measurement from J. Breunlin (Wednesday)

Assuming no significant modelling errors in either B320B optics or the AT lattice, emittances can be computed:

$$\epsilon_x = 339.4 \pm 7.1 \text{ pm.rad}$$

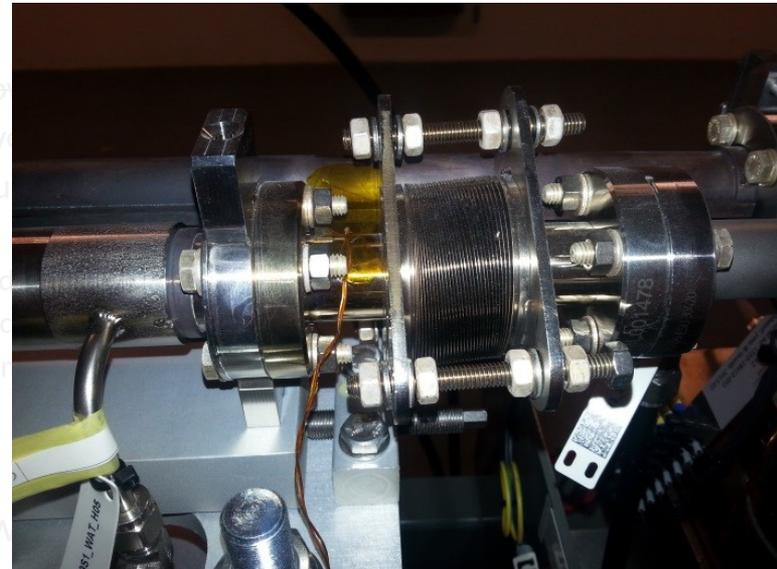
$$\epsilon_y = 15.7 \pm 0.3 \text{ pm.rad}$$

Multi-bunch current

- Multi-bunch ring current record at 198 mA
- Max. current limited to 200 mA *temporarily* for two reasons:
 - Chamber heating observed, mainly in photon pipe just downstream of crotch area:
 - Re-alignment and local orbit bumps used to get rid of SR heating
 - Water flow issues due to CuO₂ build-up at flow restrictions:
 - ~~Internal flow restrictions in DANFYSIK power supplies (REMOVED)~~
 - Kytöläs w. needle valves used (nearly) everywhere to balance flows
 - Only one nitrogen bubbling tank, but four K25 cooling circuits in the facility
 - Short term fix to manage the issue:
 - Weekly flow adjustments done on Tuesday maintenance stops
 - Nitrogen bubbling assigned to worst circuit
 - Temporary reduction in flow interlock limits to match a 200 mA max current rather than 500 mA (to buy margin)
 - Long term solutions:
 - construction of additional nitrogen bubbling stations (ongoing)
 - Very close follow-up regarding new water...
- Running at 50 mA since summer shutdown for BL commissioning (no more requested).

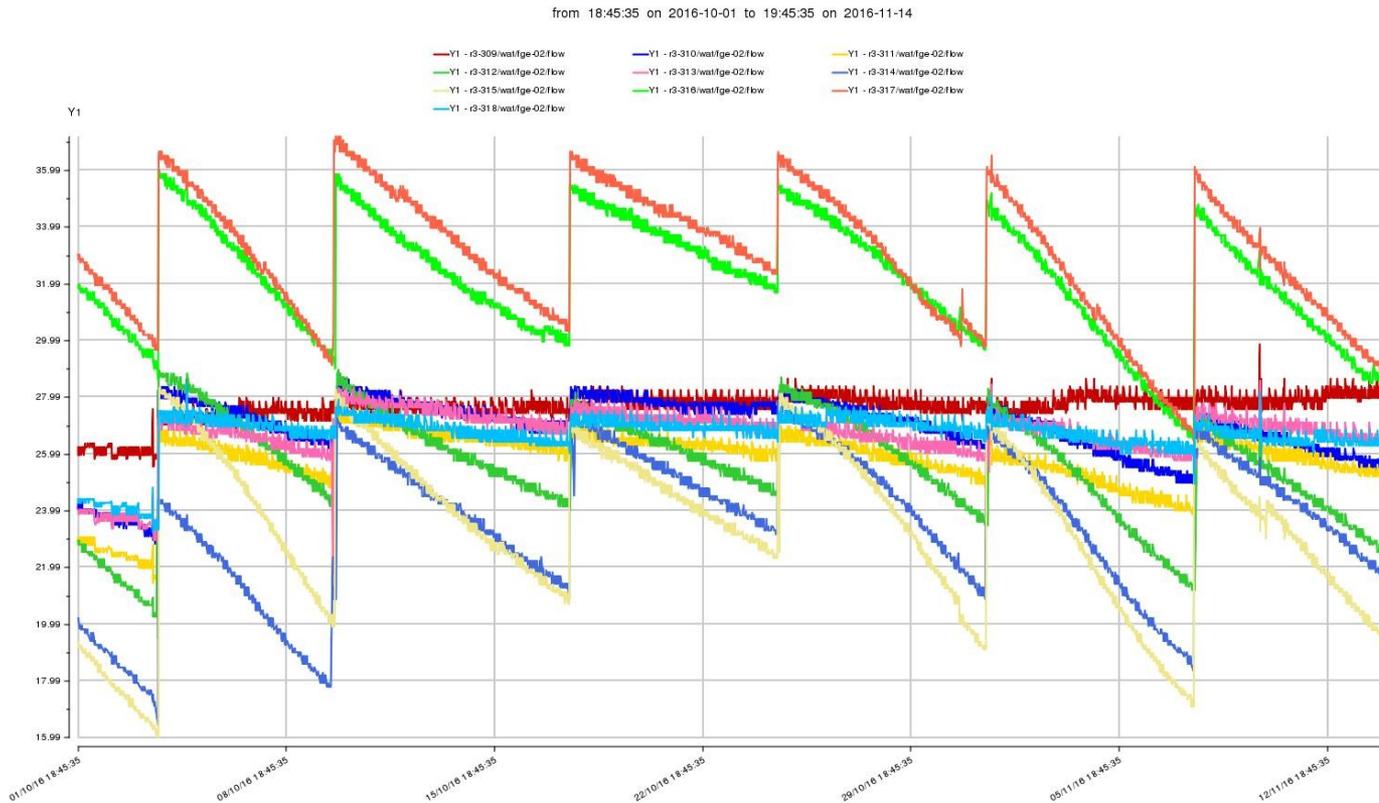
Multi-bunch current

- Multi-bunch ring current record at 198 mA
- Current limited to 200 mA temporarily for two reasons:
 - Chamber SR heating observed, mainly in photon pipe just downstream of crotch area. Managed by absorber and chamber realignment, as well as local orbit bumps. More from E. Al-Dmour...
 - Water flow issues due to CuO_2 build-up:
 - Internal flow restrictions in DANFYSIK pipe
 - Kytöläs w. needle valves used (nearly) everywhere
 - Only one nitrogen bubbling tank, but four locations
 - Short term fix to manage the issue:
 - Weekly flow adjustments done on Tuesdays
 - Nitrogen bubbling assigned to worst circulation
 - Temporary reduction in flow interlock limit (to buy margin)
 - Long term solution: construction of second tank
- Running at 50 mA since summer shutdown



Thermocouple at local hotspot. Picture by M. Grabski

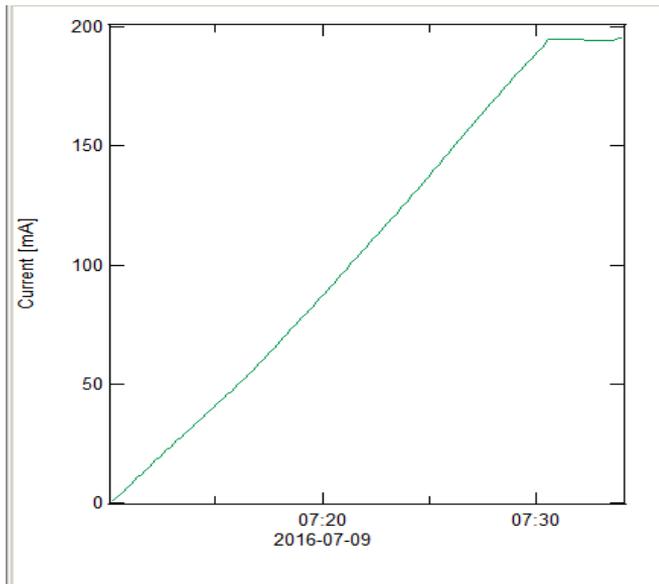
Multi-bunch current



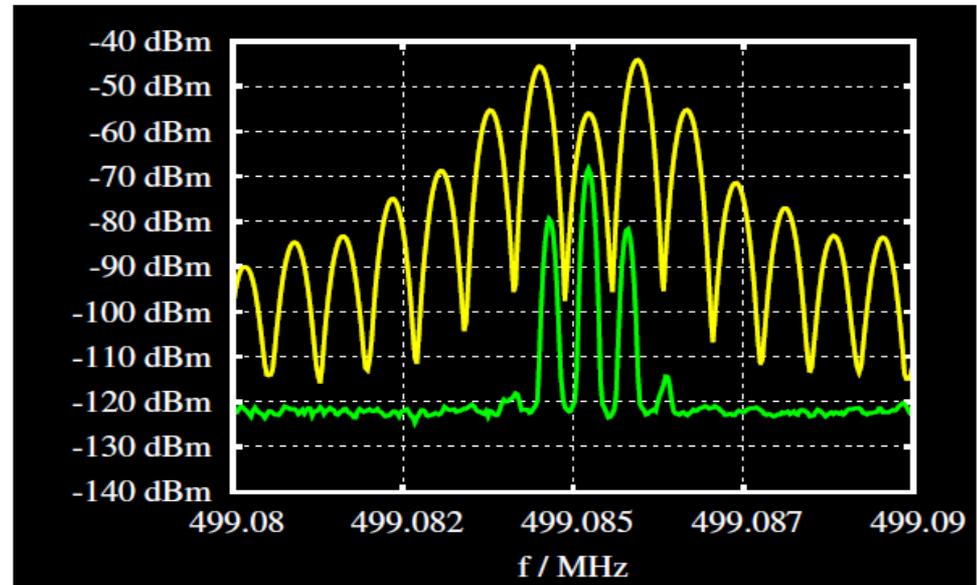
55C02 cooling circuit, vacuum chamber flows during 2016-10-01 -- 2016-11-16 period.
 N_2 bubbling active entire time period; new water added 2016-10-25 during installations.

Collective Effects - Multibunch

- Possible to store ~ 200 mA without feedback and without harmonic cavities. Predicted RW threshold was only ~ 40 mA!
- HOM driven longitudinal motion is evident at a few mA in uniform fill.
- Temperature tuning has proved effective in fighting longitudinal CBI.
- Longitudinal kicker (cavity) is in design, procurement to start



Up to 198 mA in multibunch mode

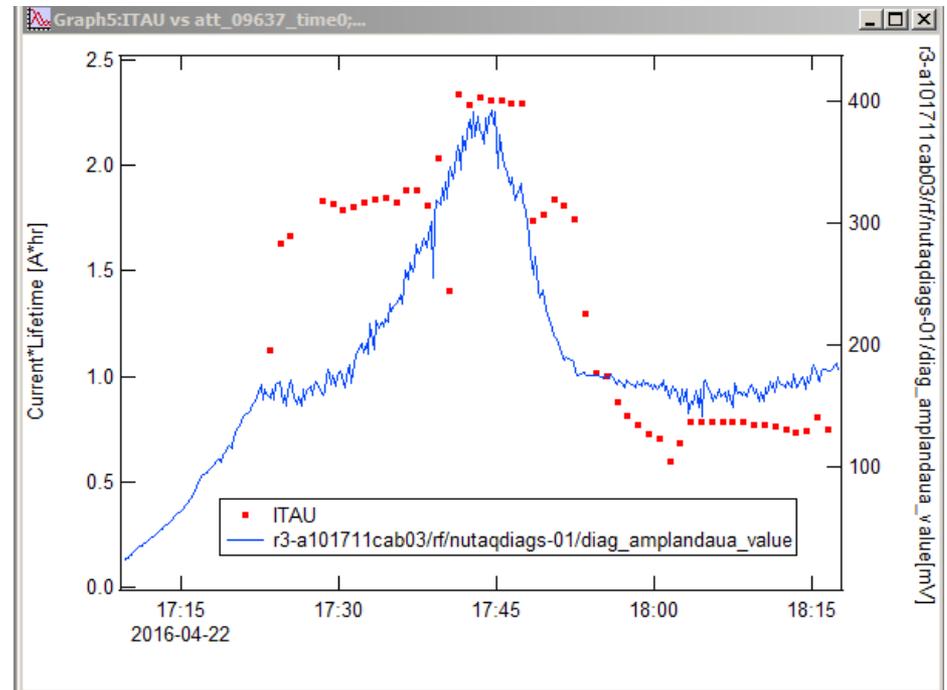


HC stabilization of CBMs at 120 mA

Slide by P. F. Tavares

Lifetime and HCs

1. HCs are tuned in gradually
2. 17:42 - All HCs tuned in
3. HCs are then tuned out, fully out at 18:30

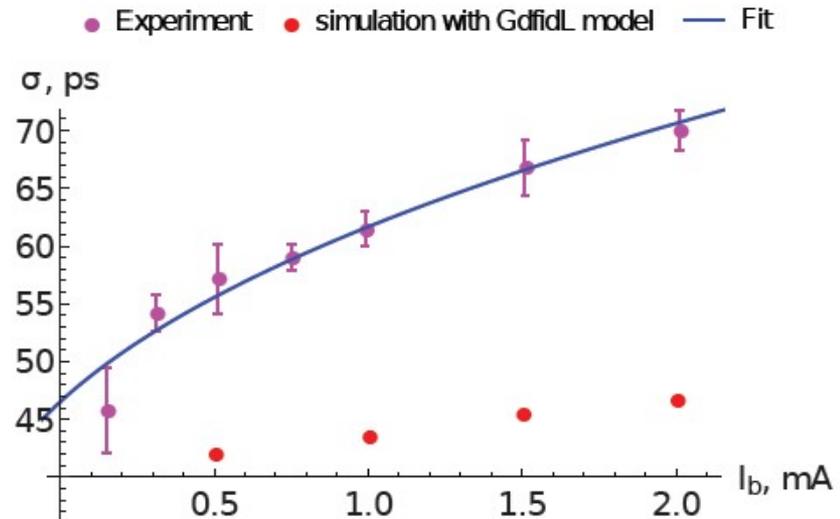
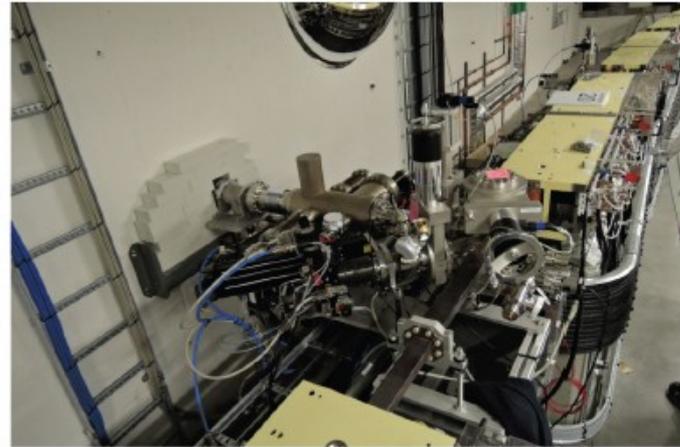


F. Cullinan, P. F. Tavares

Longitudinal

- Diagnostics beamline taking synchrotron radiation from a dipole bending magnet
- Effective impedance from simulation about 2 times smaller than estimated from measurement
- 6 GHz resonator fit to reproduce lengthening:
 - Shunt impedance = 732 Ω
 - Quality factor = 1

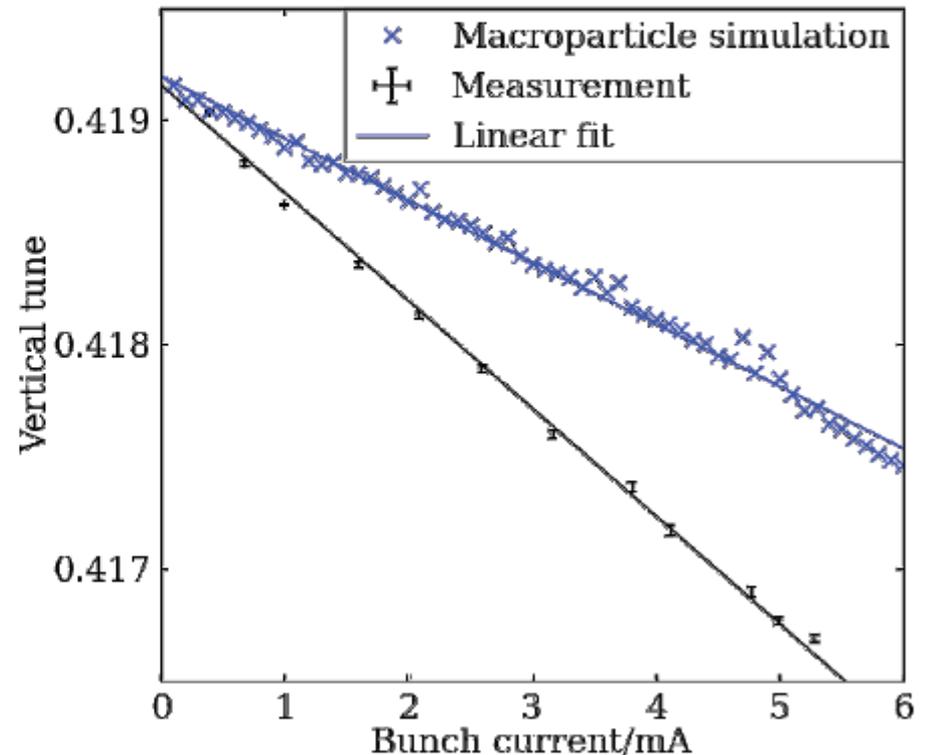
Beam line inside ring tunnel



Slide by F. Cullinan (NAPAC 2016)

Single-Bunch Transverse

- Close to zero chromaticity
- Vertical tune shift with bunch current measured using turn-by-turn BPM data
 - Detuning: $-0.481 \pm 0.002 \text{ A}^{-1}$
- Detuning about a factor of 1.8 larger than predicted in simulation
 - Similar discrepancy to longitudinal plane
- No clear signs of TMCI such as hard limit on injection or sudden beam loss
 - Simulation predicts threshold of 5.5 mA



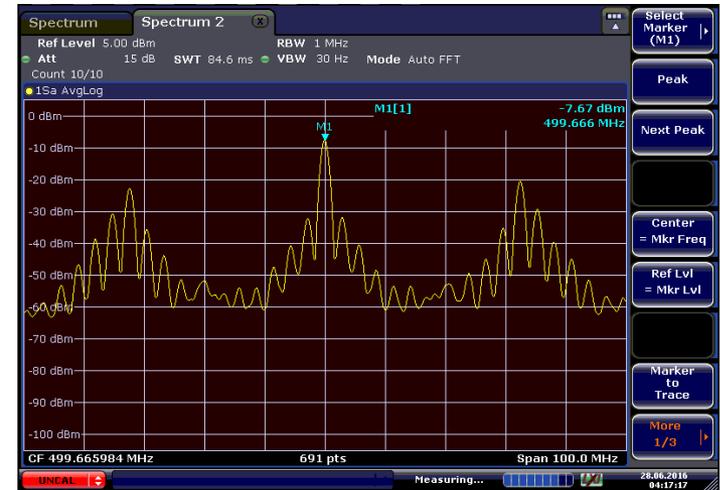
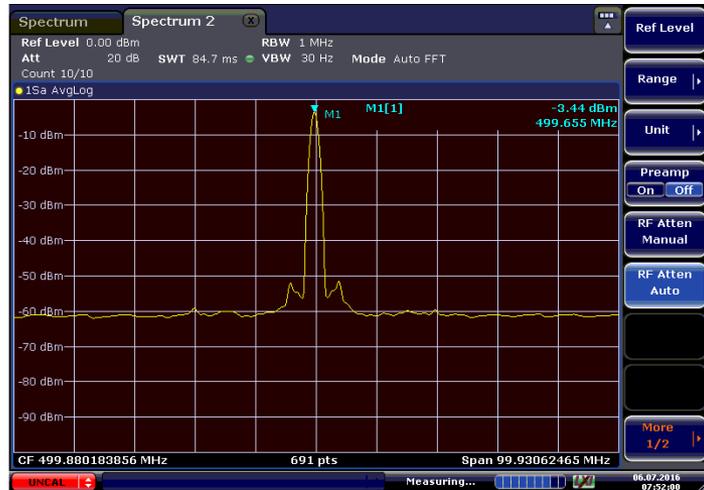
Slide by F. Cullinan (NAPAC 2016)

Bunch-By-Bunch feedback

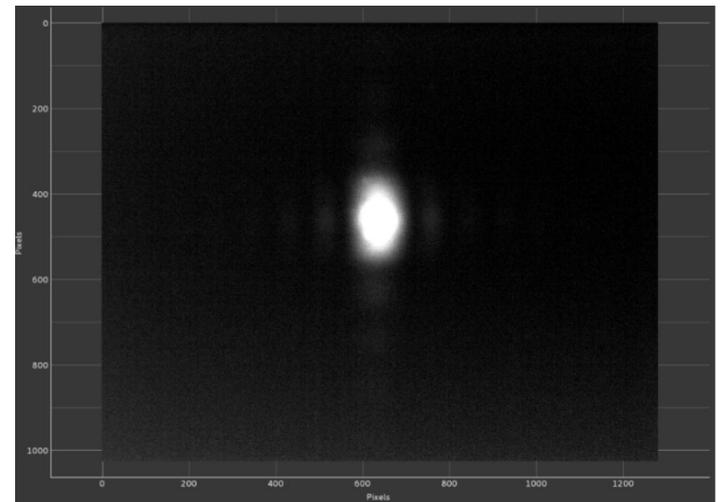
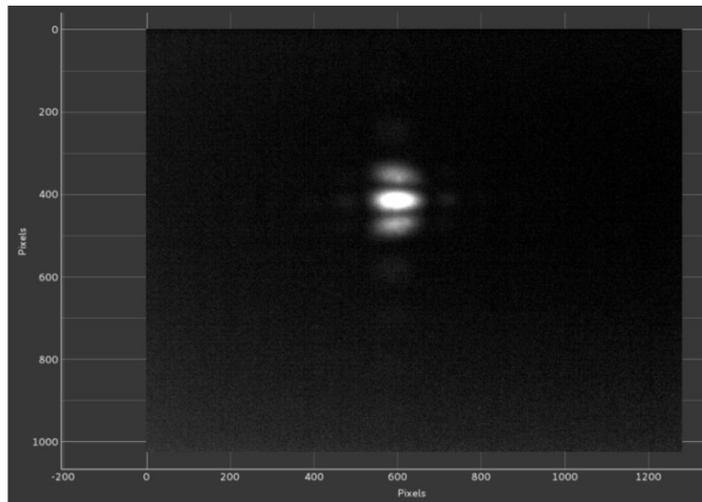
Stable beam with **feedback on** at 90 mA

Unstable beam with **feedback off** at 100 mA

Longitudinal
Spectrum



Transverse
Profile



Slide by P. F. Tavares

Highlights

1.5 GEV COMMISSIONING

1.5 GeV ring timeline

R1 installations and tests

- Final installations for R1 done during summer SD (w. 28-34); transfer line, final achromat, etc.
- Subsystem tests (SST):
 - Scheduled in parallel with installations up to and including w. 35
 - Reality:
 - SSTs continued to run during w. 36-37 (TIM, VAC, RF)
 - Unexpected issues (signal grounding in particular) surfaced
 - SSTs got priority/time according to immediate needs for commissioning progress

Lessons:

- No plan survives contact with the enemy \square replanning necessary

1.5 GeV ring timeline

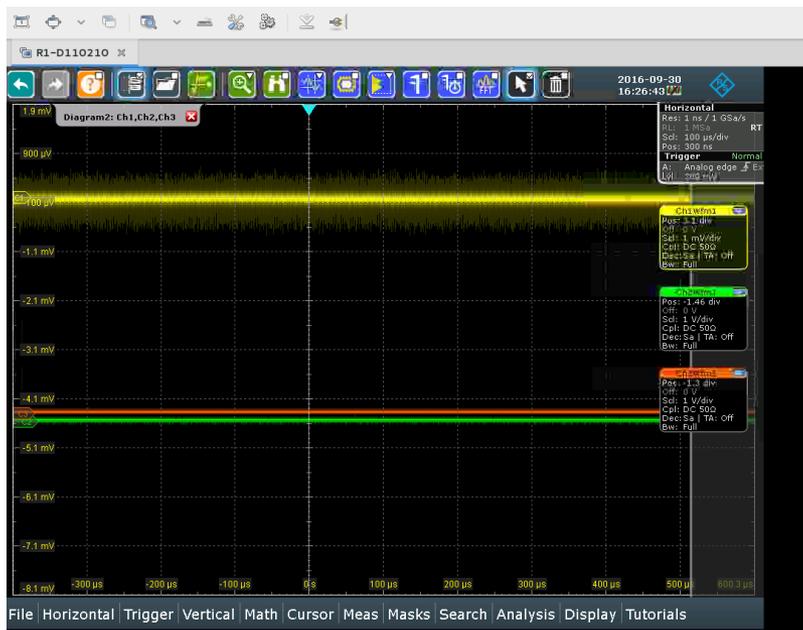
- Week 37, different parallel activities:
 - Transfer line tuning and beam threading
 - Grounding reinforcement for RF
 - Tuesday (2016-09-13): RF conditioning reaches 4 + 24 kW in cavities \Rightarrow required fields for stored beam possible
 - **Wednesday (2016-09-14) \rightarrow First turn achieved!**
 - Thursday – Friday used for required radiation surveys



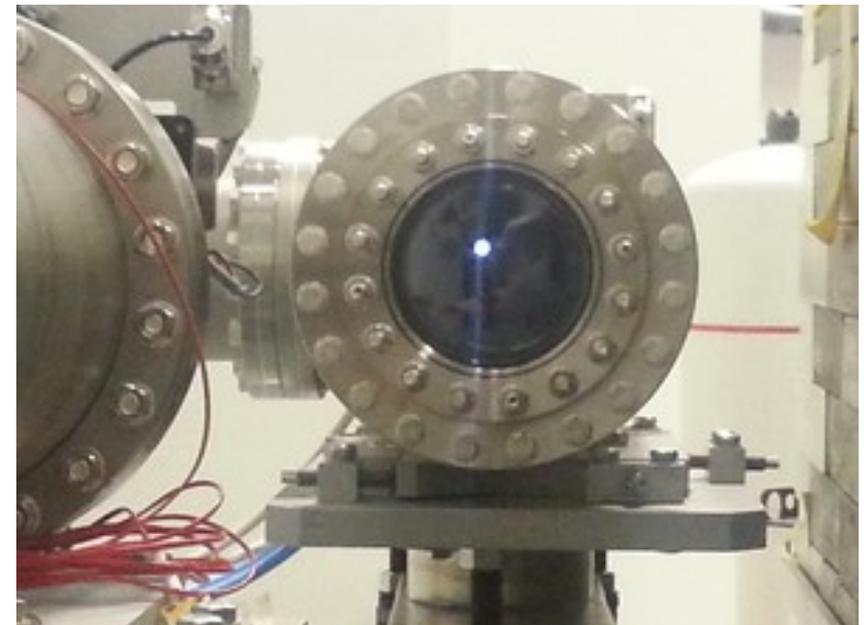
1.5 GeV ring timeline

- Friday 2016-09-30 15:30 -- stored beam achieved!

Picture by Å. Andersson



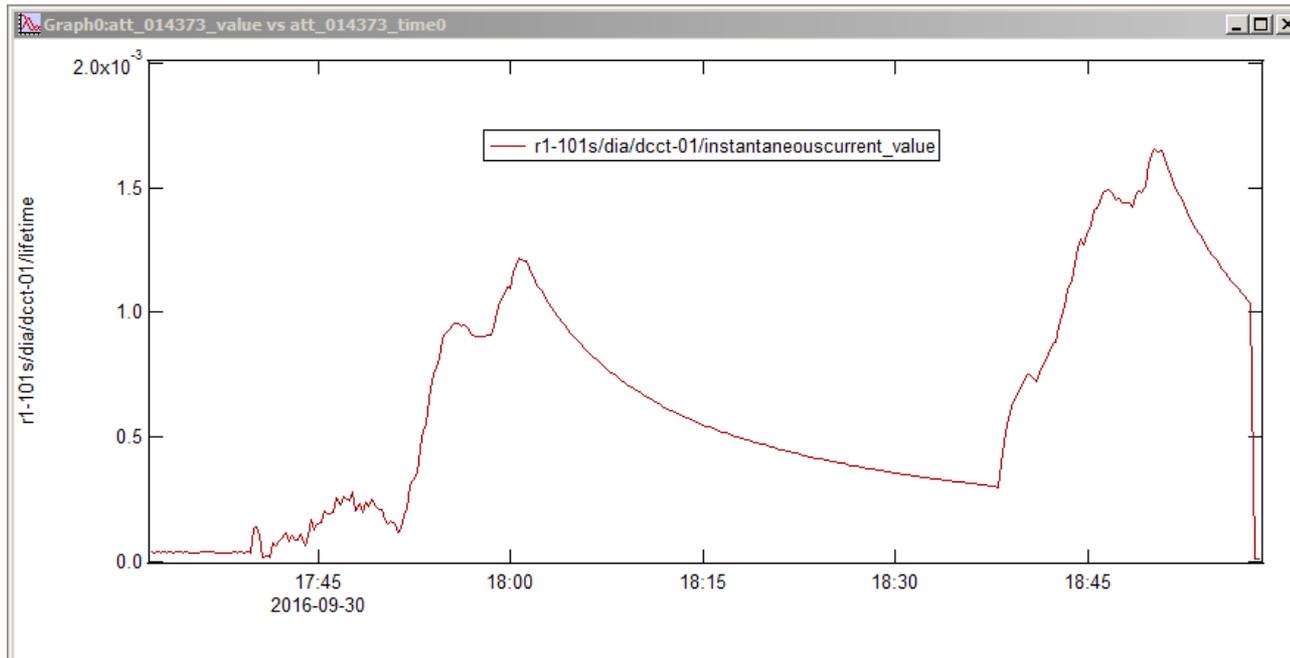
BPM sum-signal on oscilloscope



Synchrotron radiation visible in the B105A diagnostic beamline port

1.5 GeV ring timeline

- Friday 2016-09-30 15:30 -- ... also stacking!



... but at 19:00, the SQFI magnets go down!

Plot by P. F. Tavares

Current status

- **Achieved multibunch current:**
 - 5 mA (until 2016-11-17, due to MPS limit)
 - 91 mA (after 2016-11-17)
- **Vacuum conditioning as of today: 6 Ah**
- **Optics:**
 - Tunes $v_x = 0.427$, $v_y = 0.249$ (LOCO + spectrum analyzer)
 - First rough offsets measured (quad shunt method)

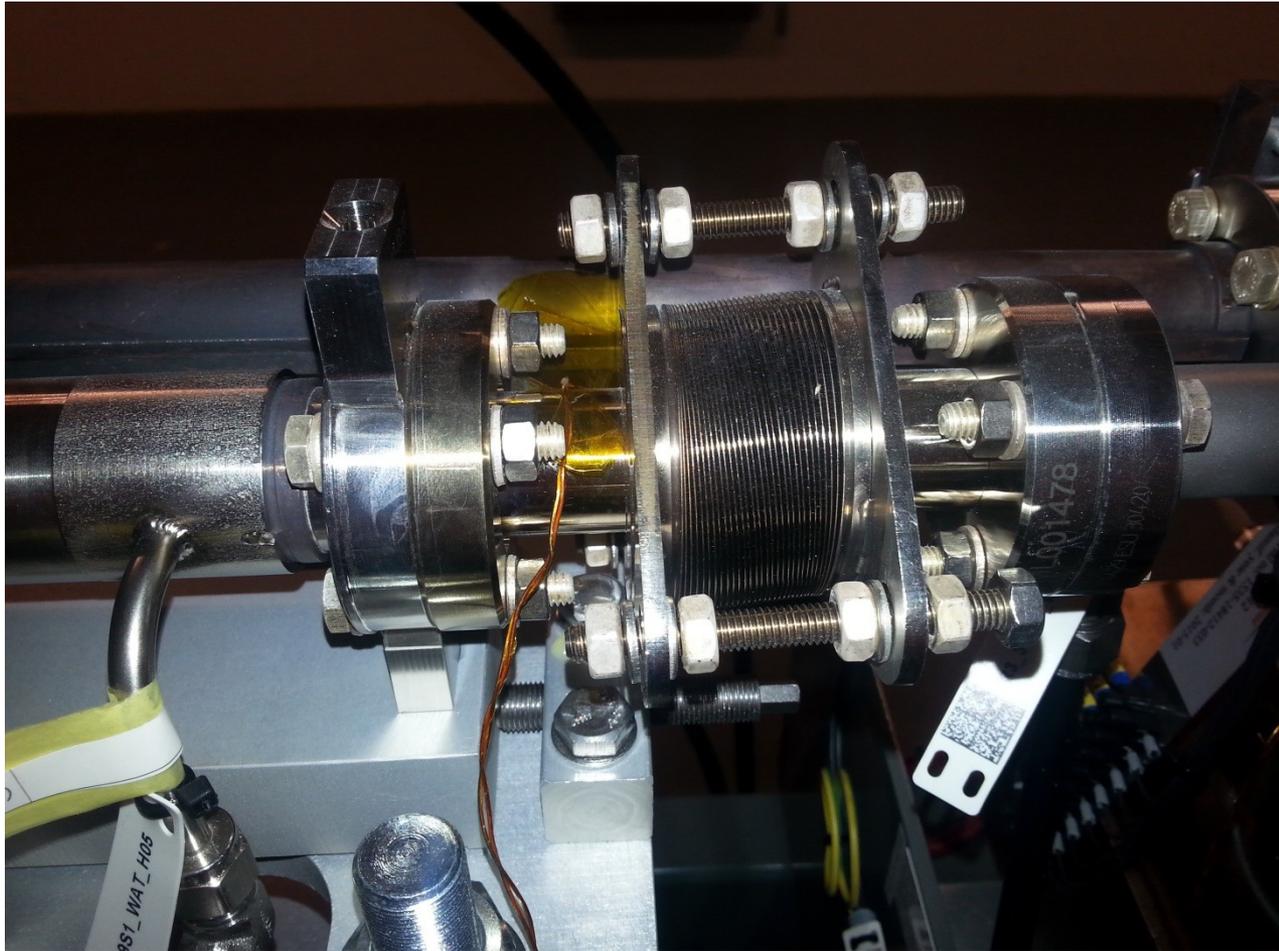
Next steps

- 3 GeV ring:
 - Further conditioning and tuning of RF cavities
 - Main cavities
 - Harmonic cavities
 - Optics:
 - Further sextupole offset studies
 - LOCO w. shunting
 - Non-linear optics tuning
 - Collective effects studies post-ID installation (ongoing)
 - Bunch-by-Bunch feedback commissioning (ongoing)
 - Beamline commissioning (NanoMAX, BioMAX, HIPPIE, BALDER)
- 1.5 GeV ring
 - Commissioning period continues Q1 2017
 - ID vacuum chamber installation

THANK YOU FOR YOUR ATTENTION!

EXTRA SLIDES

Chamber hot spot R3_309S1/DIA/TCO-01



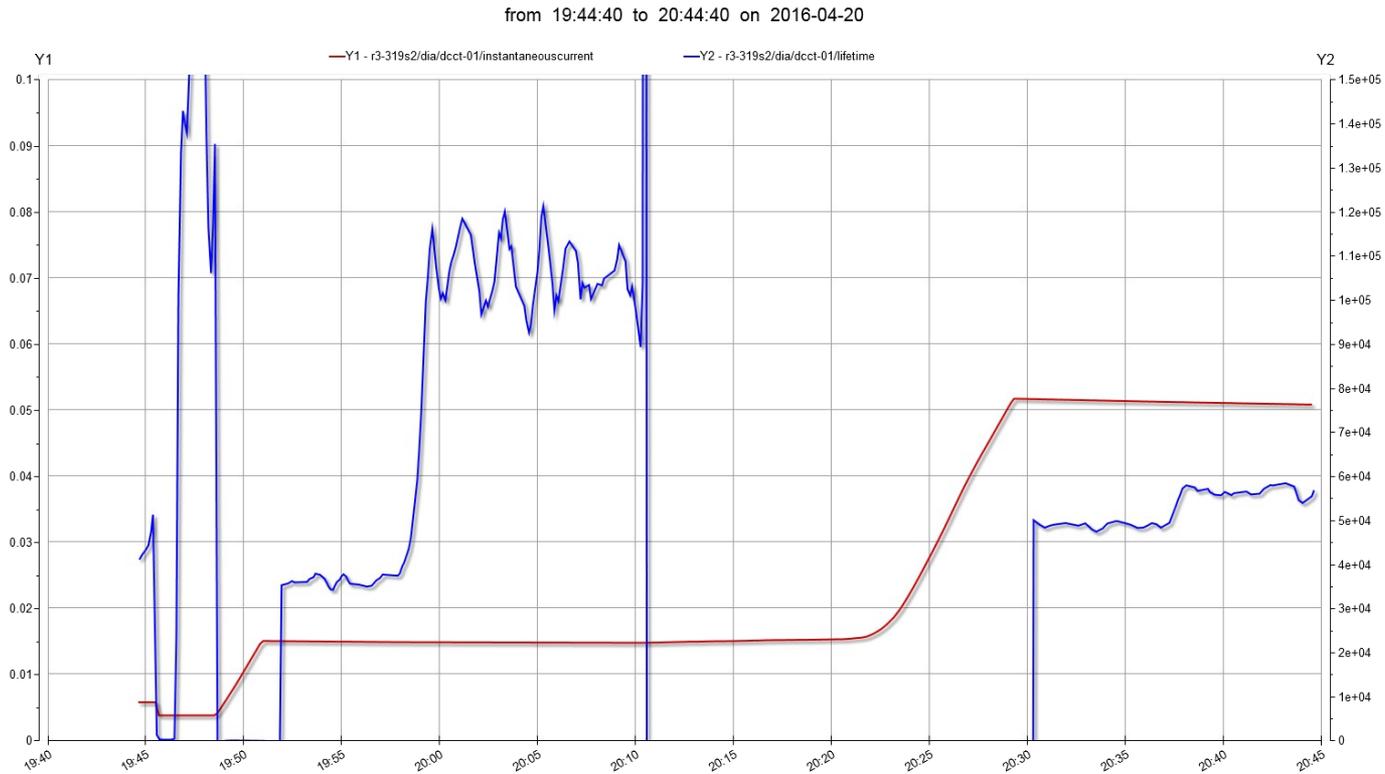
2016-11-28

ESLS XXIV - MAX IV ring status

MAXIV

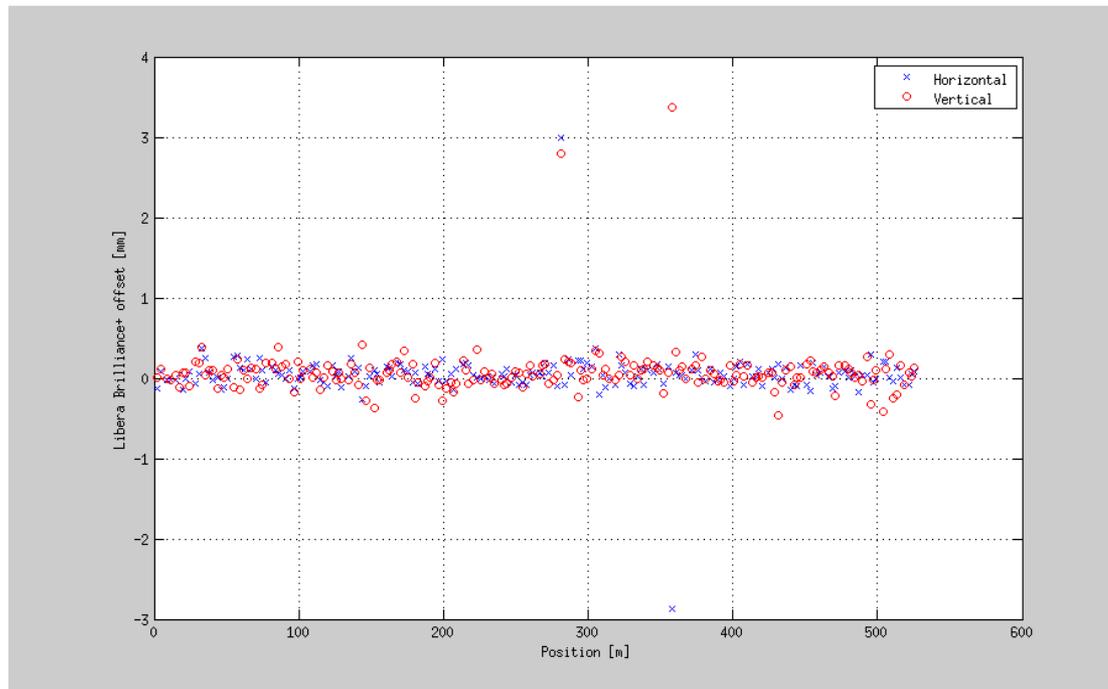
Alternate optics (spring 2016)

SOFB active, "lockdown2" optics. 90 kW power from 3 cavities, no HC



Offsets

- Measured by BBC using trim coils in sextupole magnets



RMS:
113 μm H
143 μm V