Advances in Machine Subsystems Summary

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High-Brightness Synchrotron Light Source Workshop

April 27, 2017

U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

BROOKHAVEN SCIENCE ASSOCIATES

Advances in Machine Subsystems

- 7 talks
- Experience with ID Magnet Measurement, Commissioning and Optimization of their Radiation at NSLSII – Yoshi Hidaka
- APS Operations and Recent Developments in IDs – Vadim Sajaev
- Review of Beam Instrumentation and Feedbacks – Guenther Rehm
- Alignment and Stability of the Storage Ring Magnets – Sushil Sharma
- RF Systems for High Brightness Light Sources – Jim Rose
- Precision, Noise Performance and Controls of Magnet Power Supplies – George Ganetis
- High-Precision Beam Position Monitors – Weixing Cheng

Field Integrals: Beam-based vs. Flip Coil Meas.

Device	Location	Date	Gap [mm]	Coil ΔI_x [G.cm]	Coil ΔI_y [G.cm]	e-beam ΔI_x [G.cm]	e-beam ΔI_y [G.cm]	RMS Δx [µm]	RMS Δy [µm]
IVU20	C3	2/25/15	6.7	-105.6985	77.558	-11.086	-3.363	1.152	0.501
IVU20	C11	2/25/15	6.7	-33.3001	11.608	17.963	32.457	1.187	0.593
IVU21	C5	11/15/14	6.2	-71.37575	79.664	-104.454	102.777	1.417	1.084
		2/25/15 **	6.5	-170.118	259.042	-81.194	88.924	1.199	2.787
IVU22	C10 (LS)	11/21/14	6	17.743	214.844	-24.237	-15.945	2.419	1.189
		2/25/15	7.2	-394.663	93.299	-63.984	-18.226	2.534	3.014
DW	C8U	12/20/14	15	-22.9726	-51.3981	-105.159	-99.38	8.818	4.485
		2/25/15	15			-62.961	-79.578	5.546	4.252
	C8D	1/23/15	15	137.6943	158.2675	59.702	215.524	6.066	6.634
		2/25/15	15			42.042	199.967	10.021	5.955
	C18U	12/17/14	15	-21.0953	12.2921	-144.666	-76.481	5.795	6.456
		2/25/15	15			-96.179	-67.754	4.659	3.454
	C18D	12/20/14	15	2.4744	-9.4423	-187.691	95.166	5.464	5.249
		2/25/15	15			-213.981	79.656	5.950	9.544
	C28U	12/8/14	15	-95.9395	-24.267	140.991	-57.057	5.106	6.544
		2/25/15**	15			-67.869	-53.881	4.564	3.326
	C28D	12/8/14	15	-95.9395	-24.267	-290.004	178.495	5.134	17.54
		2/25/15 **	15			-205.97	160.369	7.758	6.311

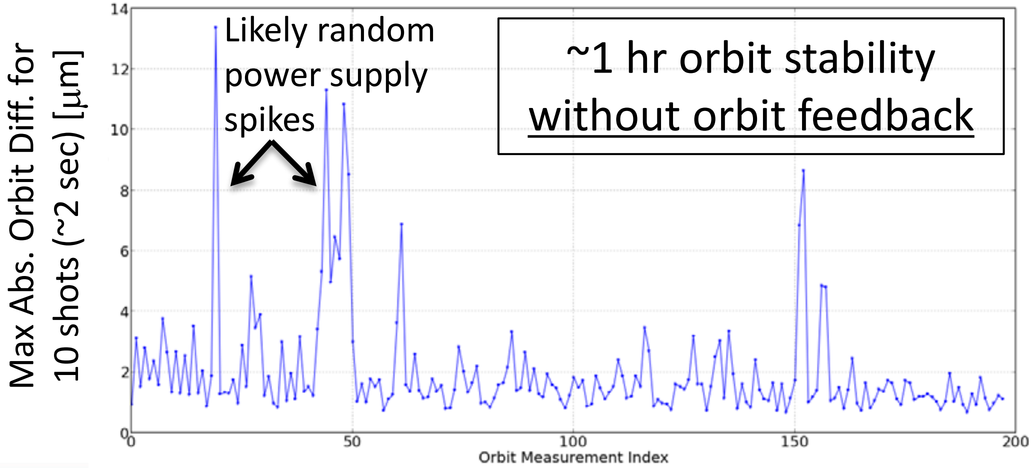
T. Tanbae et al., Synch. Rad. News, 28 (2015)

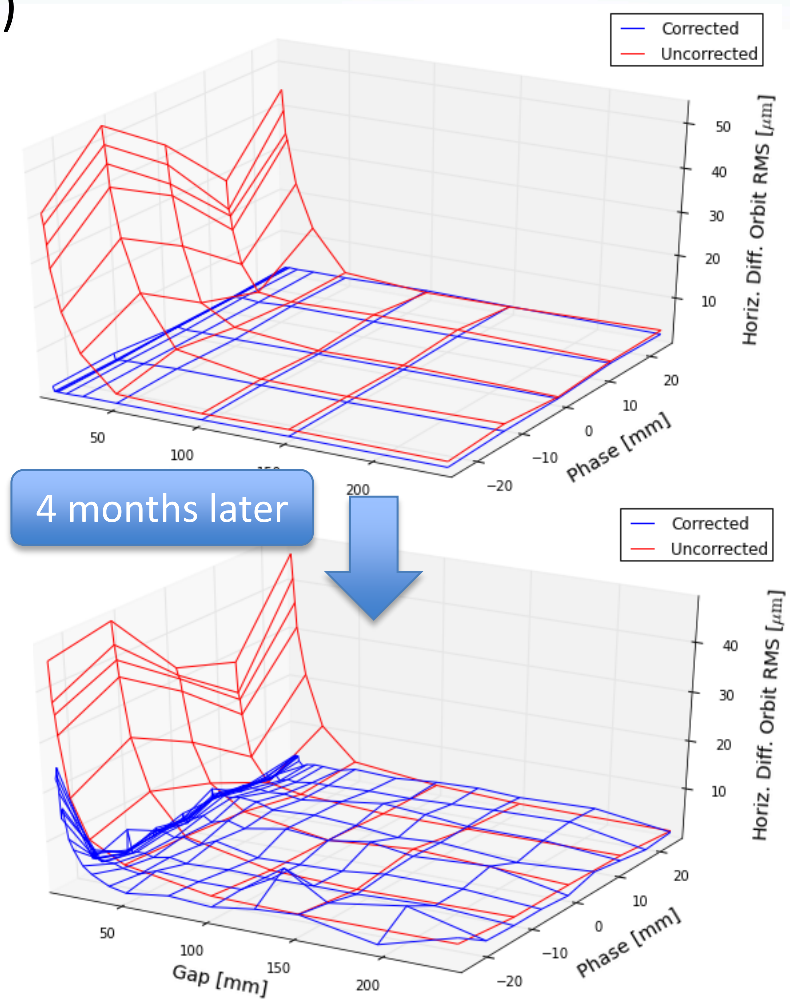
** Realigned after year-end shutdown in 2014

- Beam-based fitting is worse (RMS Δx & Δy) for DWs than for IVUs
  - Stronger focusing effect of wigglers, sensitive to vertical orbit centering
  - Large horiz. wiggling motion => path lengthening
- Many show large discrepancies
  - Potential causes: Earth field variation, nearby ferromagnetic structures, stray B-field, misalignment during installation

Orbit Feedforward Correction Limitation

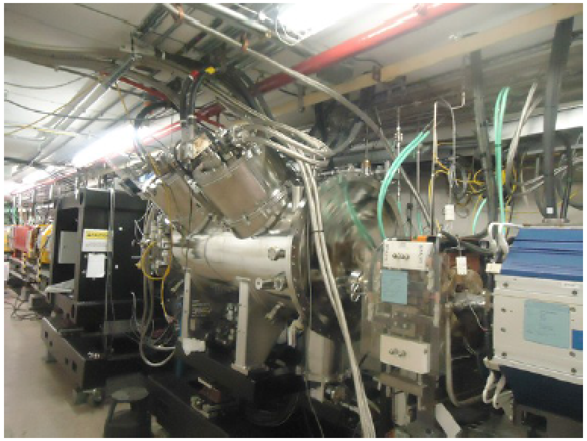
- Long-term drift (e.g., settlement, environmental change, local bump change request from users)
- Orbit jitters w/o feedback => best-case orbit feedforward correction of 1-2 μm
- Table generation/validation very time-consuming for EPUs (e.g., C23 CSX):
  - 2D table for each mode:
    - ORM meas. required at each gap
    - Meas. COD & ORM ~40 min. (10 gaps & 5 phases)
    - Refine computed table ~40 min.
  - 2 parallel & 2 anti-parallel modes (for each of 2 devices)



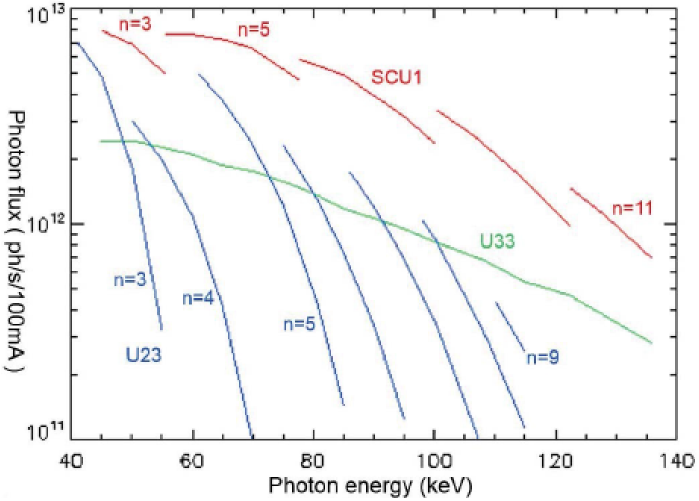


Superconducting undulators (SCU)[1]

- First test SCU device was installed in 2013; currently two SCUs are installed; SCU18-1 is in operation since May 2015 and SCU18-2 since September 2016
- SCUs provide higher flux at high photon energies
- SCUs operate at 80% of critical current
- Trouble-free operation for 7 years (between 3 devices)



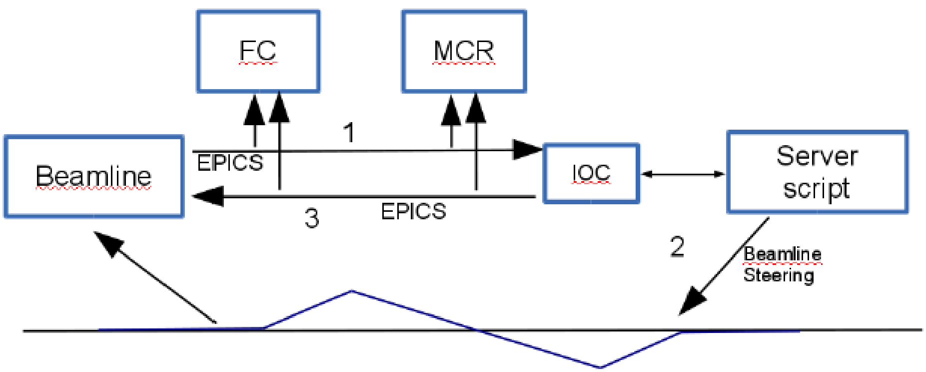
Parameter	SCU18-1 and SCU18-2
Cryostat length (m)	2.06
Magnetic length (m)	1.1
Undulator period (mm)	18
Magnetic gap (mm)	9.5
Beam vacuum chamber vertical aperture (mm)	7.2
Undulator peak field (T)	0.97
Undulator parameter K	1.63

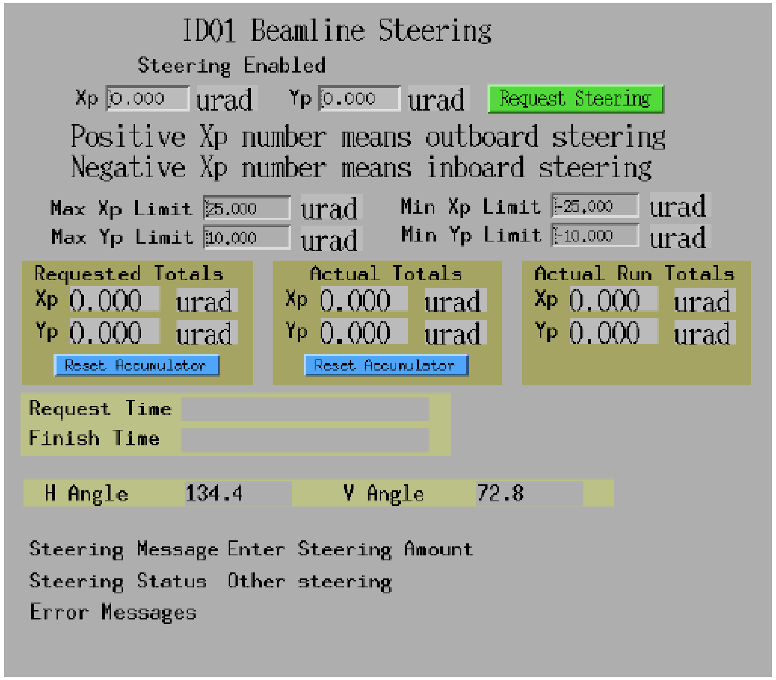


[1]Y. Ivanyushenkov et al., PRST AB 18, 040703 (2015)

Automated user steering[1]

- In May 2016, APS implemented user steering that bypasses the MCR
- Steering is performed by applying feedforward adjustment to correctors and BPM setpoints between orbit correction steps
- Corrector bump coefficients are calculated from an accurate optics model, steering is split into several small steps, so the resulting orbit distortion does not exceed 1µm, which is corrected by the orbit correction on the next step
- MCR and Floor Coordinator are notified of the steering by the server
- Only angle steering is allowed
- Beamline steering optimization is still run by MCR

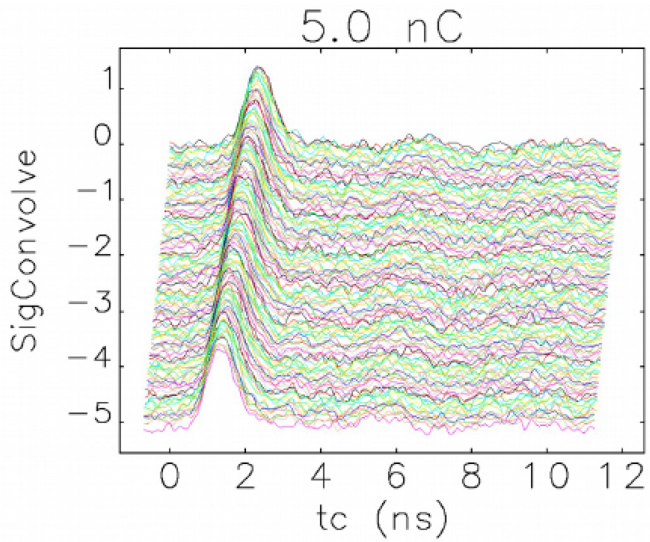


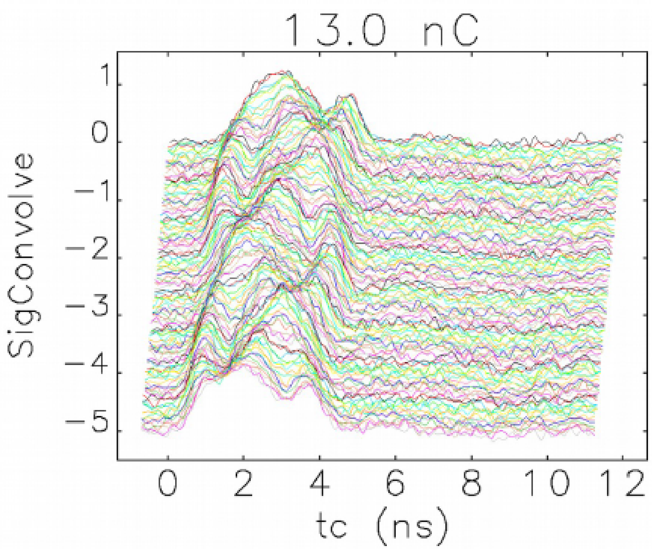


[1]L.Emery et al, NA-PAC 2016, WEPOB04

Increasing injector charge for APS-U

- APS-U will operate in swap-out regime, will require about 20 mA bunch from the injector (presently, we use 1-3 nC for operations)
- Study and upgrade program for injectors is underway
  - Many beam study hours is spent on injectors now
- PAR can accumulate more than 20 nC from linac at 375 MeV
  - Transverse beam size blow-up due to ions does not seem to affect the injection into booster
  - We think that bunch length increase (presumably due to RF cavity beam loading) limits injection to booster at ~10 nC[1]
- Booster work involve:
  - BPM upgrade to allow orbit correction along the ramp
  - Sextupole power supply upgrade to keep chromaticity positive during ramp
  - Tune correction during ramp





[1] J. Calvey, J. Dooling, private communication

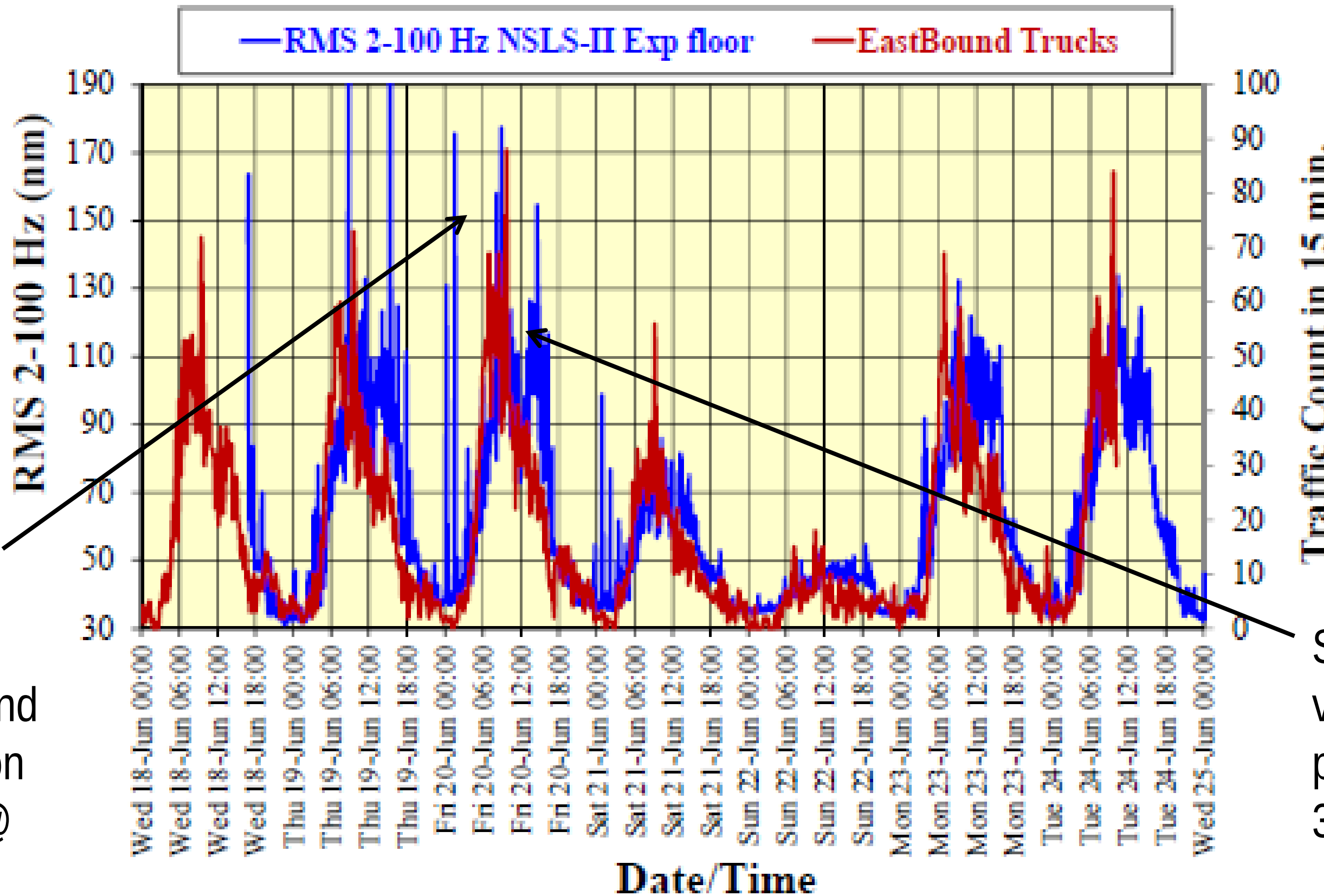
HB-SLS relative to established SLS

- Horizontally lower emittance ~60-300pm
  - Beam sizes shrinks to ~7-17um (1m beta)
- Vertically mostly stays at ~8pm
  - Beam size stays at ~3 um (1m beta)
- Smaller beam pipes
  - Smaller BPM buttons (less signal), but closer to the beam (more signal) *TUPF14, IBIC2014*
  - Higher impedance, potential NEC coating, more driving terms for instabilities? *WEPHA002, IPAC2015*
- More advanced optical lattice
  - Higher requirements on tune stability *TUPWA013, IPAC2015*
  - Smaller dynamic aperture *TUPJE063, IPAC2015*
- General advances on beamlines
  - Faster data collection demands stable beam to higher frequencies *DOI: 10.1107/S2059798316012304*
  - Break down the 'wall' between source and sample with integrated approach to stability *DOI: 10.1107/S2053273315097168*

Summary

- BPMs commercially available with sufficient performance, alternatives increasing
- FOFB still mainly in-house developed, remains best for ultimate performance
- Bunch-by-Bunch feedback/monitor commercially available, alternatives still interesting
- Tune Monitors turn into feedback loops
- Photon beam control might have a revival
- Profile monitors see most new techniques, feedback application to be upcoming
- Final Question: Will every SLS soon be running as much on AutoPilot as commercial airliners?

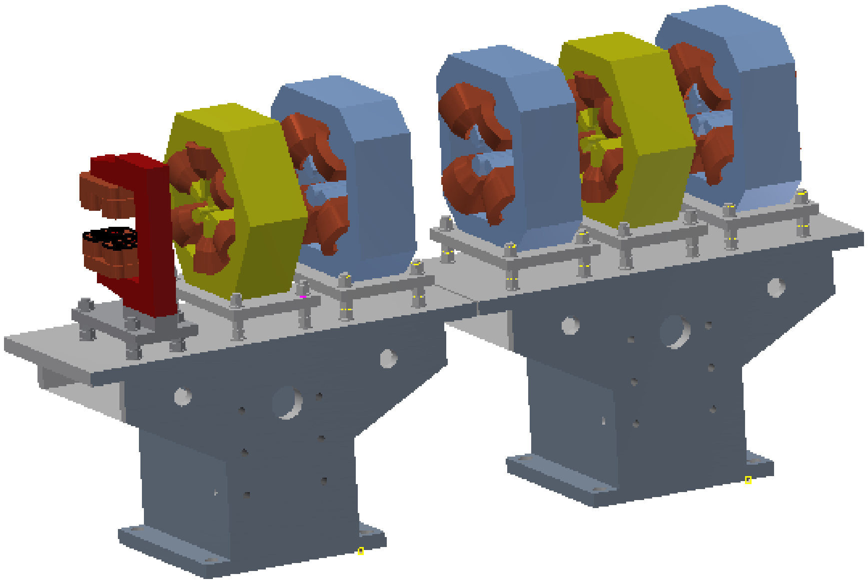
Exper. Floor Vibration Levels vs LIE Eastbound Truck



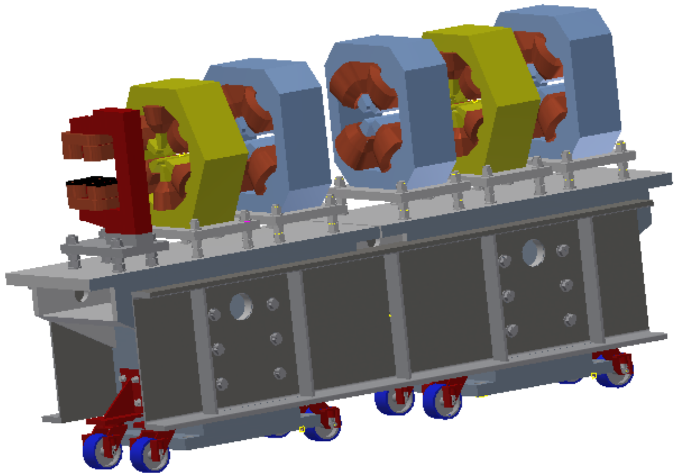
The eastbound truck traffic shows a peak in the morning consistent with the vibration pattern but does not explain the second vibration peak in the afternoon.

Hammerhead Column Supports

S. Sharma, MEDSI2016



Assembly

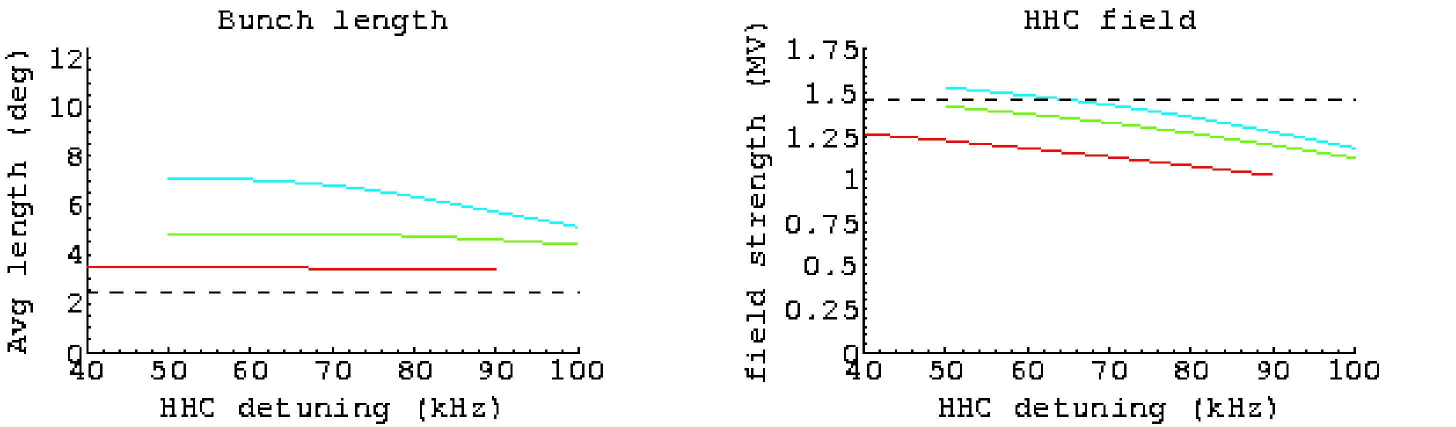


Transportation

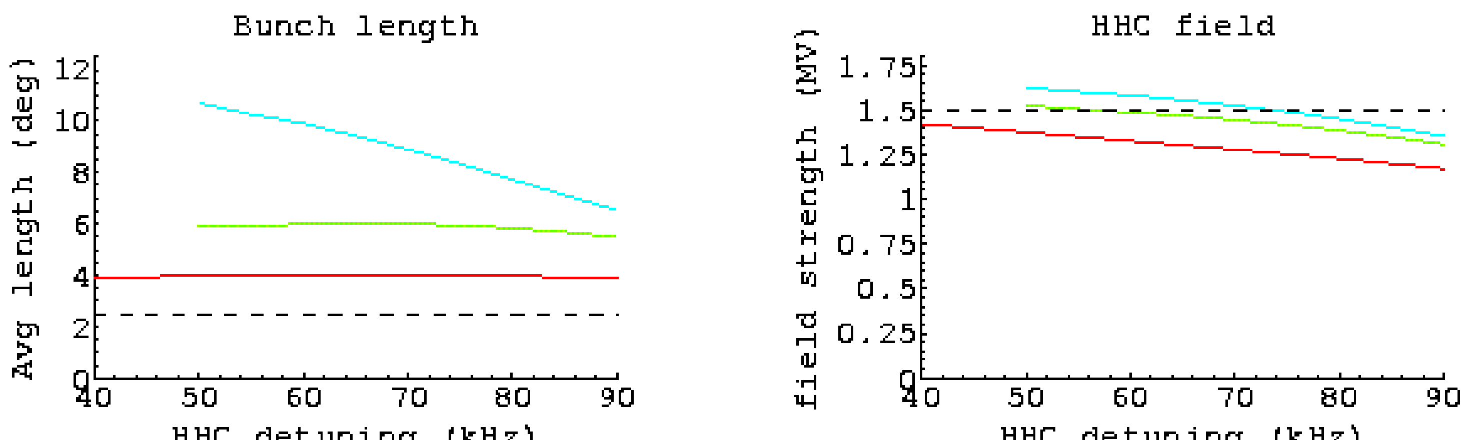
- Assemble magnets, vacuum chambers and other components on 2 hammerhead supports each of ~ 1.5 meter length.
- Align the magnets and vacuum chamber. Magnet alignment is simpler because of shorter span.
- Join the supports with two removable C-Channel beams for transportation and installation.

Stretched Bunch length dependence on R/Q

N. Towne



NC bunch lengths (rms) and harmonic cavity (HHC) fields as a function of detuning for one ion gap (red) two gaps (green) and four gaps (blue). Dotted line is unstretched bunch length or optimal HHC field.



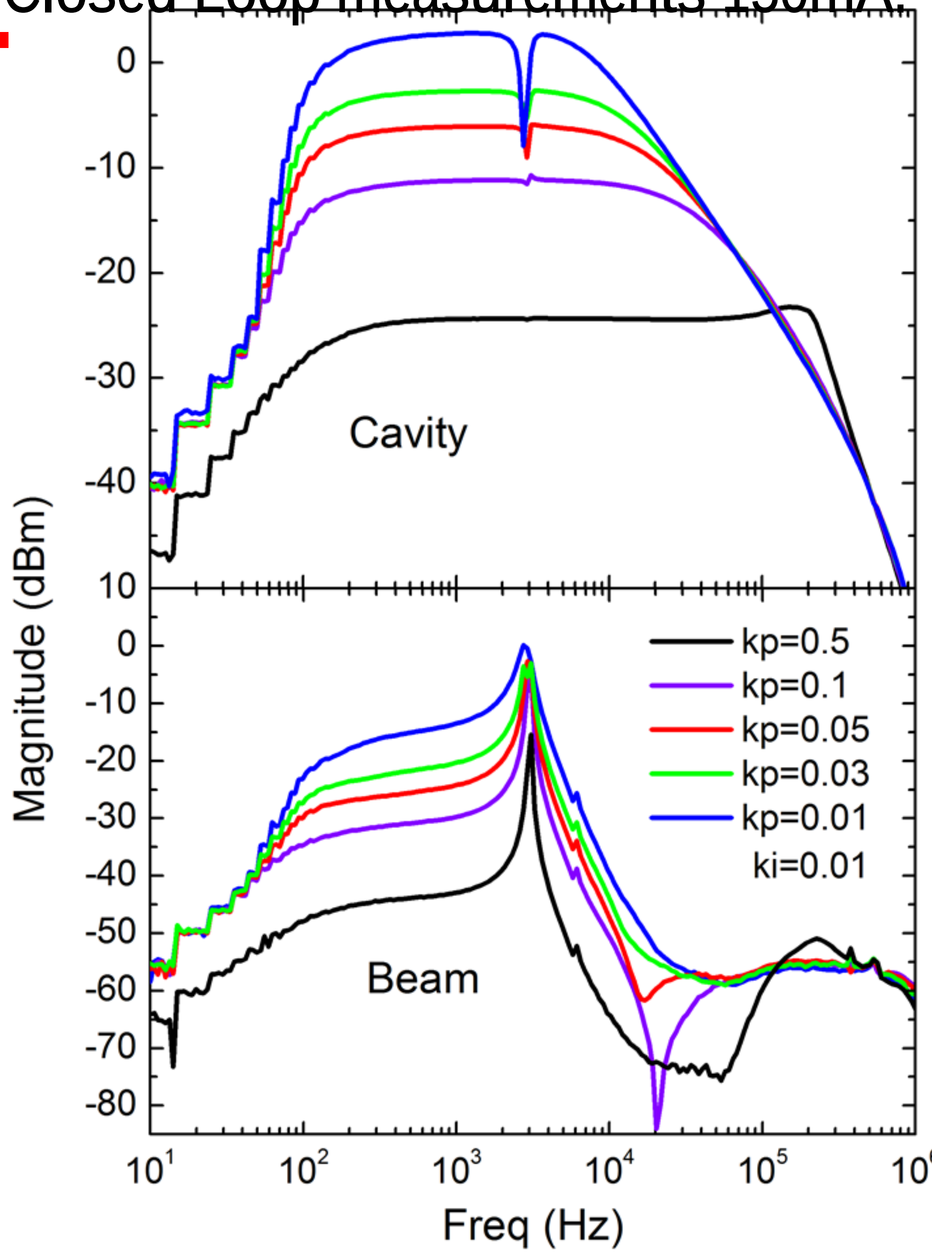
SC bunch lengths (rms) and harmonic cavity (HHC) fields as a function of detuning for one ion gap (red) two gaps (green) and four gaps (blue). Dotted line is unstretched bunch length or optimal HHC field.

By adding a BPM sum signal, Measure beam transfer functions!

Closed Loop measurements 150mA.

Cavity magnitude response from field pickup

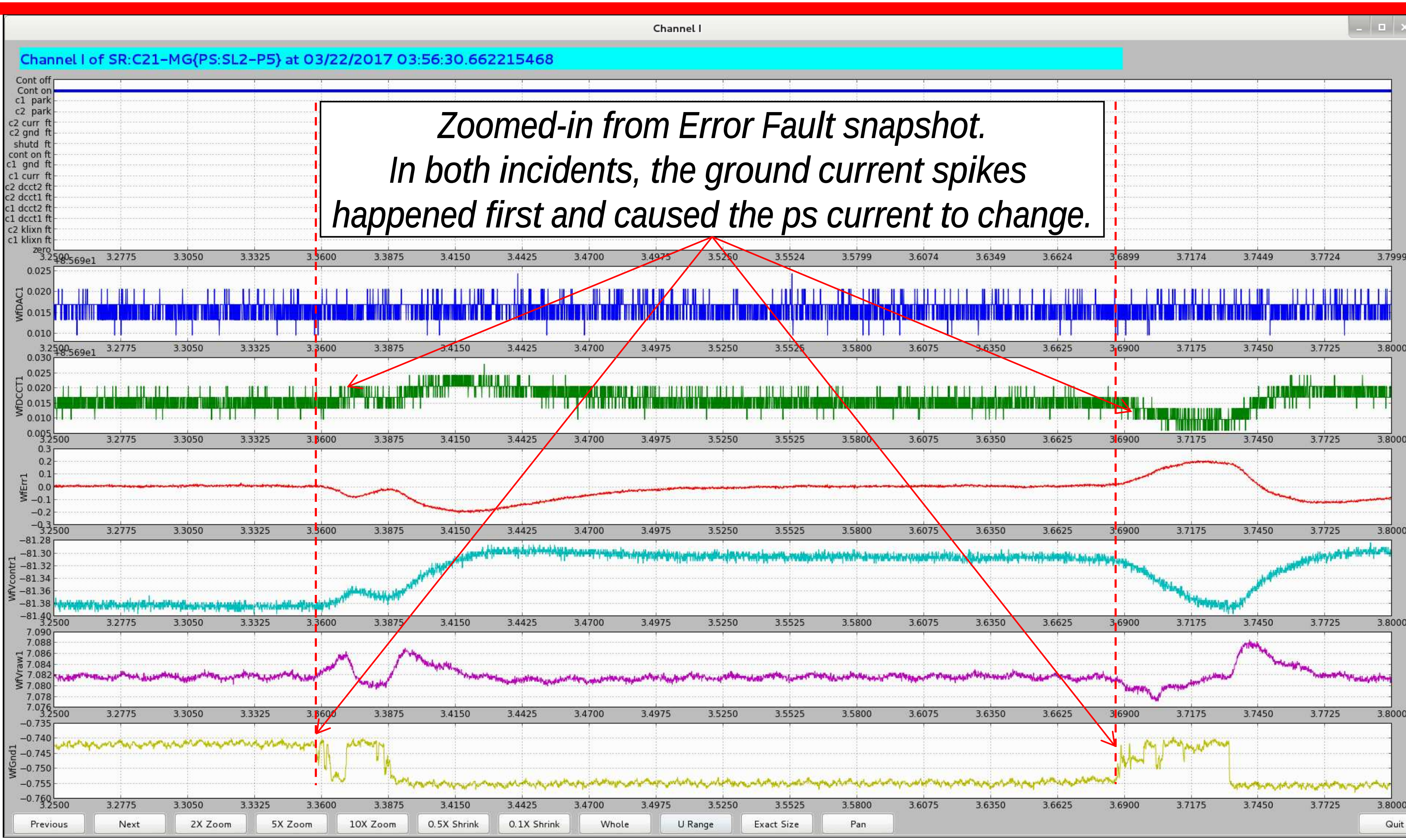
Beam response from BPM sum signal



Carlos Marques,

Jim Rose

Snapshot Features - Fault Analysis

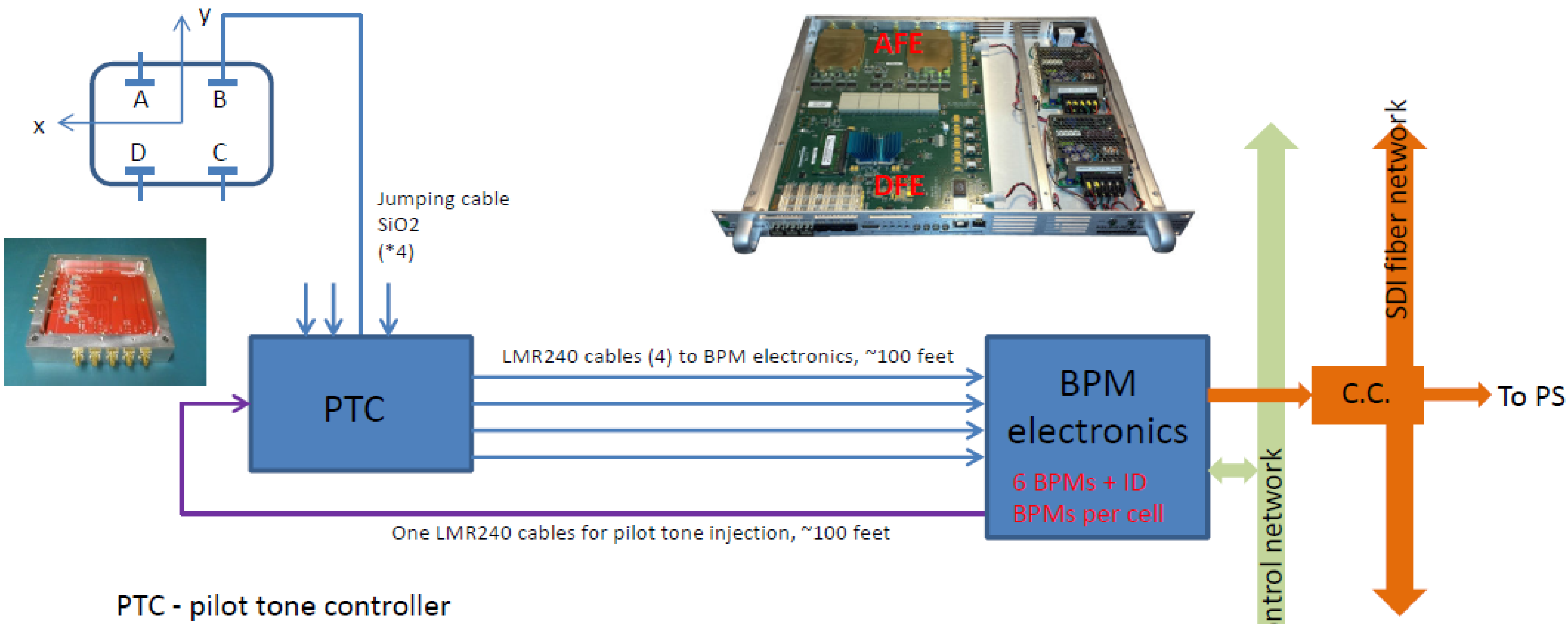


Challenges to Maintaining Stability in NSLS-II

- Large ground currents through the water isolators have been a cause of large errors in some power supplies. (up to 1000 ppm)
- Small Offset changes in DCCTs when control power is cycled – 10 to 100 ppm has been seen. The system has provisions to correct for this but a process to do this correction needs to be developed.
- Large number of power supplies with a large data set to analyze. We need to develop software that can create simple reports for engineering to review.
- Presently we rely on Accelerator Physics to identify a power supply problems and then we can look at archived data to analyze the problem. (We continuously monitor ground currents because they cause the biggest stability problems to date.)
- We would like to use the current transfer standard (see back up slide) to re-calibrate the current loop on the critical power supplies. This take time and resources .

Courtesy of George Ganetis

BPM data acquisition and processing

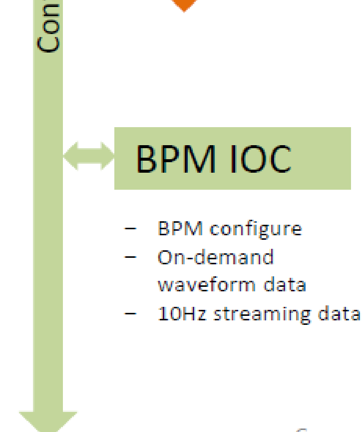


PTC - pilot tone controller

BPM electronics includes AFE + DFE
AFE: BPF + Amplifier + Var. Att + ADC
DFE: Xilinx Virtex 6, integrated uBlaze, SRAM

Local SDI and global SDI network share the 10kHz data around the ring
30 cell controllers for FOFB calculation, corrector settings send to PS
Same SDI 10kHz data is used for Active Interlock

BPM IOC for 10Hz streaming data and on-demand ADC/TbT/FA waveform data



Summary

- Various types of **BPM button pickups** have been designed, constructed, installed and commissioned, together with the in-house developed electronics.

- The NSLS-II **BPM electronics** has been developed and commissioned in ~5 years (2009-2014). Continuous improvement/development are only possible with experts around.
  - High resolution achieved (200nm@10kHz rate, <1um@TbT rate)
  - Short term orbit stability (~1% beam size horizontally; ~5% vertically)
  - Long term BPM electronics stability < 200nm RMS
  - Derivative instruments have been developed
    - Cell Controller (FOFB and Active Interlock)
    - X-ray BPM electronics (xBPM), Sydor xBPM
    - LBNL EBPM

- New DFE and other developments underway to continuously improve the overall system performance.

Acknowledgements:
Original BPM electronics team (**K. Vetter**, A. Dellapenna, K. Ha, M. Maggipinto, J. Mead, Y. Tian etc.)