KEK/SLAC (+Others) Proposals for R&D for SuperKEKB and High Luminosity Colliders

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SLAC National Accelerator Laboratory

US-Japan Meeting at BNL

April 19, 2017

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Topics

1) SLAC overview and staff visits to KEK

2) 2016 US-Japan projects used for SuperKEKB

3) 2017 R&D for SuperKEKB and future Electron-Positron Colliders:
   a) High Luminosity Colliders Studies
   b) Transverse Feedback Kickers
   c) Wideband Instability Bunch-by-Bunch Feedbacks
   d) Beam Dynamics
   e) High Speed Bunch-by-Bunch X-ray Beam size Diagnostics

Many thanks to Prof. Makoto Tobiyama (KEK)

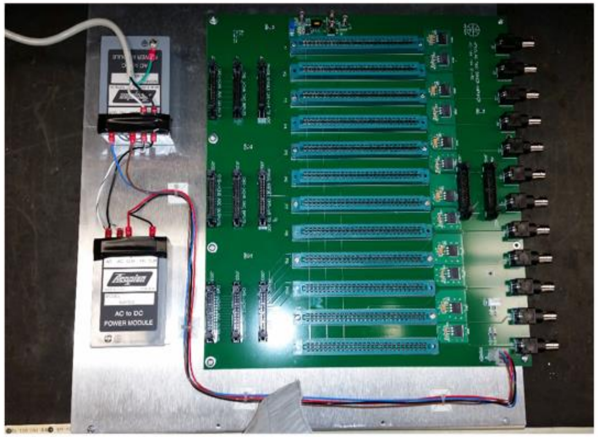
SLAC Accelerator Directorate (AD): Support of SuperKEKB, Circular Colliders, US-Japan Contributions

A) AD-Accelerator Research: Modest support of SuperKEKB for bunch feedback, transverse kickers, IP dither feedback, collimator, IP backgrounds, beam dynamics (CSR, ECI, beam-beam), beam commissioning

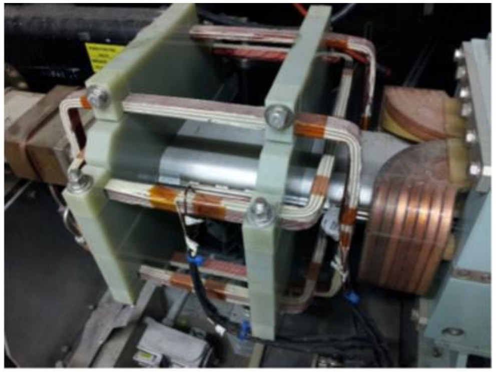
B) AD US-Japan funding from DOE and/or KEK to work on high power feedback kickers, bunch-by-bunch feedback, x-ray size monitors, commissioning, SRF guns.

C) Motivation: DOE funds many US institutions to be a part of the Belle-2 collaboration. Given AD's knowledgeable accelerator staff (e.g. PEP-II), SuperKEKB commissioning and integrated luminosity will reach high luminosity sooner.

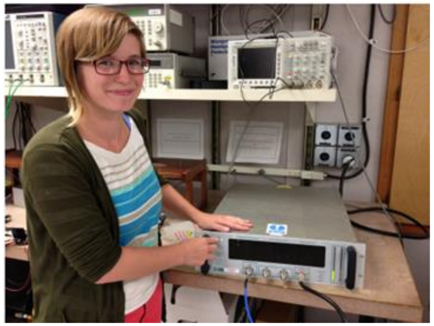
AD Participants: Cai, Fisher, Fox, Krasnykh, Rivetta, Seeman, Sullivan, Sullivan



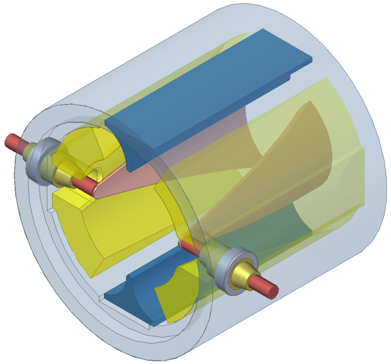
IP dither feedback electronics



IP dither feedback coils



Bunch-by-bunch feedback



High power (~4 A) feedback kicker design

JFY2016-17 Visits of SLAC Accelerator Physicists to KEK

Karl Bane:

Stored beam instabilities (April 2017)

John Fox:

Bunch by bunch feedback work

SuperKEKB Accelerator Review Committee (June 2016)

John Seeman:

Collaboration discussions, transverse feedback kickers

SuperKEKB Accelerator Review Committee (June 2016)

US-Japan global activities (Spring-Fall 2016)

Michael Sullivan:

IR design and background suppression, commissioning

Belle-2 B-PAC Review Committee (February 2017)

Focus Review on Belle-2 Vertex Detector (October 2016)

SuperKEKB Accelerator Review Committee (June 2016)

Five Year Review of KEK and JPARC (May 2016)

Glen White:

Linac collider studies

ATF2 Beams (December 2016)

SuperKEKB Collaboration over Past Few Years:

Development and fabrication of accelerator components important to the construction and operation of the SuperKEKB accelerator

- KEK collaborated with SLAC (+Cornell, University of Hawaii, Wayne State) to develop:
  - IP collision feedback systems
  - Fast luminosity monitor
  - Beam collimators
  - Beam background
  - Machine Detector Interface
  - Accelerator Physics
    - Main Ring commissioning
    - Damping Ring commissioning
    - Linac commissioning
    - Bmad code development related to SAD at KEK
  - BPM for Linac/Beam Transport
  - X-band deflecting cavity
  - Stripline kicker for high beam current X-ray detector
  - Flux Concentrator to increase capture efficiency of positrons
  - Beam energy calibration using laser Compton scattering

IP Dither Luminosity Feedback: Concept

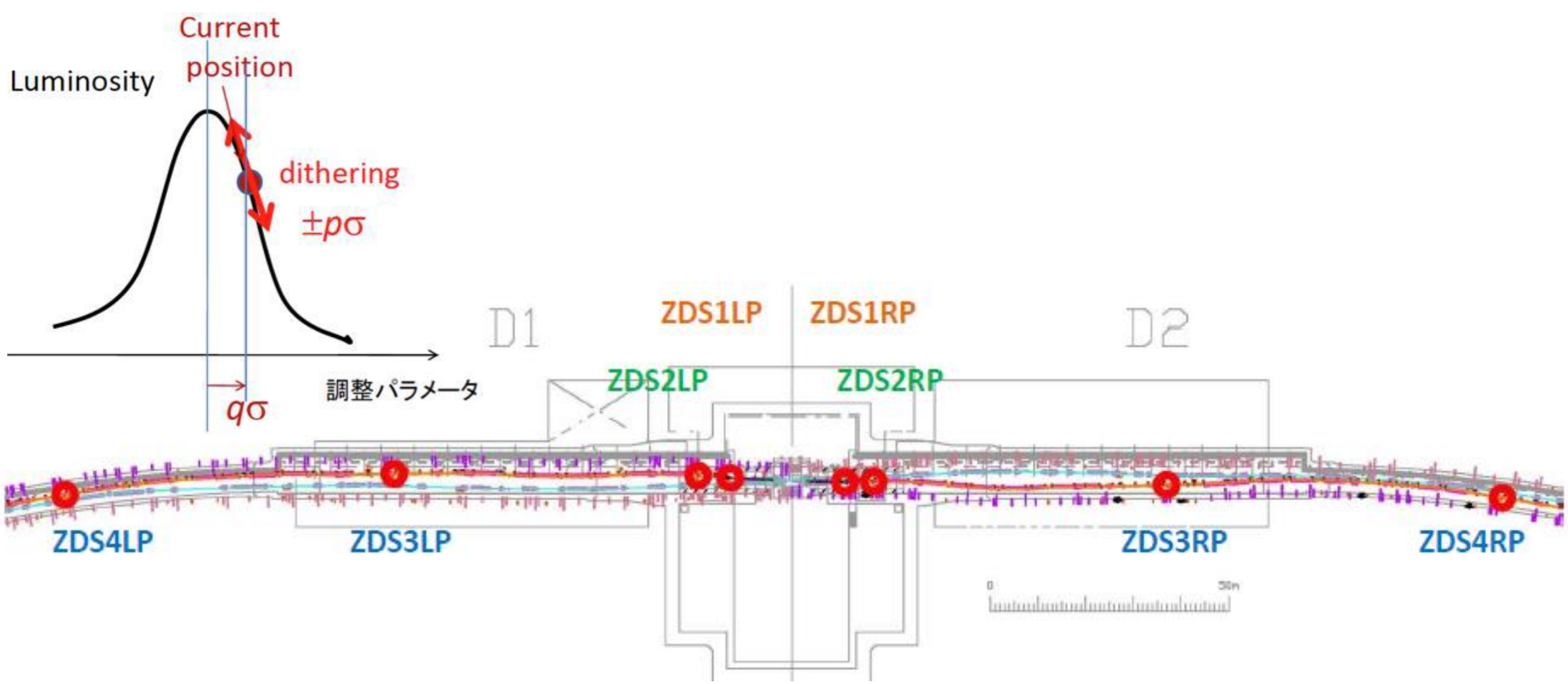
- Goal
  - SLAC developed an IP feedback for PEP-II that maximized luminosity by dithering the LER beam across the HER beam.
  - The LER was driven sinusoidally at small amplitudes in *x*, *y* (transverse position), and *y'* (vertical angle) at 3 different frequencies. At each:
    - A lock-in amplifier detected the amplitude and phase of the corresponding frequency component of the luminosity signal.
    - When the luminosity is at the peak, this amplitude is zero.
    - When off peak, the phase indicates the direction in which to adjust the LER.
  - KEK/SLAC plan to fully implement this scheme on SuperKEKB.

- Participants
  - KEK: Mika Masuzawa and Makoto Tobiyama
  - SLAC: Alan Fisher, Michael Sullivan, Uli Wienands (ANL)

IP dither collision feedback system

Constructing Dithering feedback systems collaborating with SLAC

- Modulate IP positions and angles (x, y, y') with a sinusoidal signal (~60Hz) and detect the frequency and phase response of luminosity monitor using lock-in amplifiers.

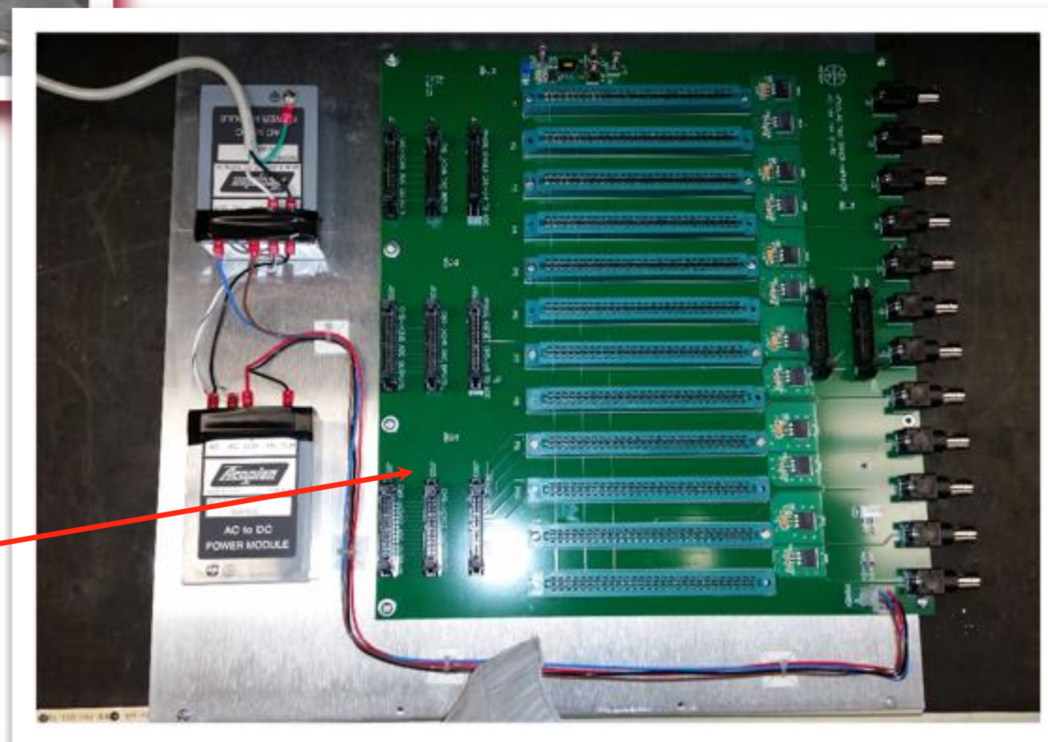


SuperKEKB: IP Feedback Dither coils , Amplifier Driver (Fisher, Weinands, …)

Completed Air-Core Dither Coil Assy (1 of 8)

Installation occurred summer 2015 and tested Spring 2016.

SLAC Contributions



Amplifier Motherboard in Assembly

IP Feedback: Progress and Plans

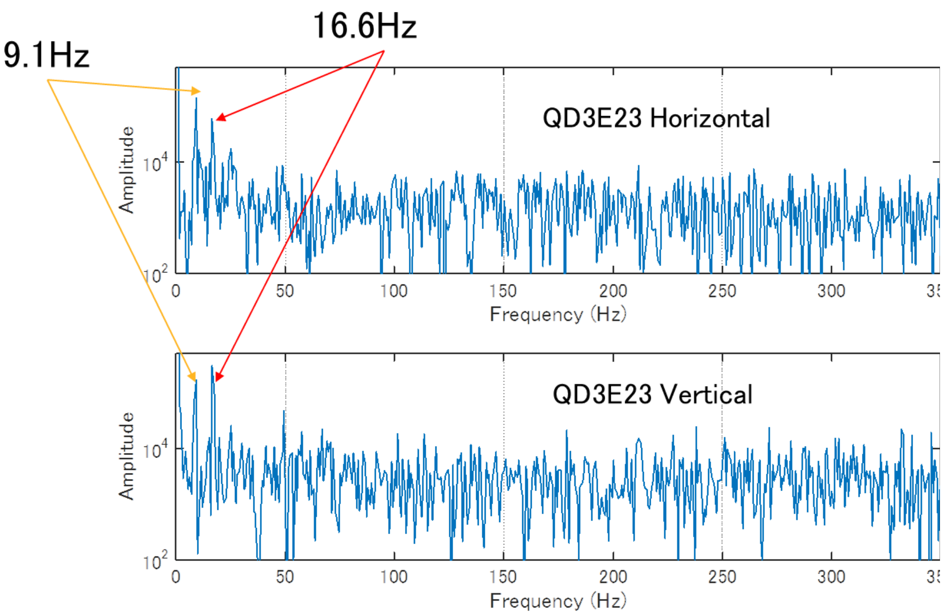
- 2015-2016
  - SLAC
    - 12 air-core Helmholtz dither coils were prepared and measured.
    - New electronics implementing the PEP-2 hardware design were prepared.
    - All hardware was sent to KEK.
  - KEK
    - The dither coils were installed on the LER of SuperKEKB.
    - An interface was prepared to connect the electronics to the SuperKEKB controls.

- 2017-2018
  - KEK is preparing for system-integration tests in the summer, followed by initial tests with beam in the fall.
  - The SLAC team may travel to KEK for these tests.
  - Any modifications needed following these tests will be completed for early Phase-2 commissioning, expected in the winter of 2018.

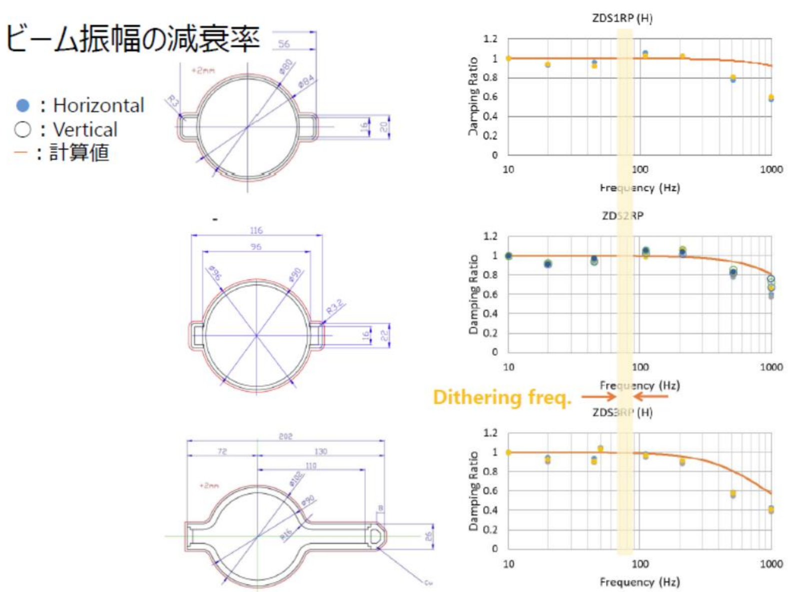
IP Feedback: Achievements in JYF2016:

Measured the slow beam motion using gated turn-by-turn monitor with large beam currents.

Excited the beam using dithering coils at various frequencies and compared the response including the eddy current effect– almost agreed with the simulation.



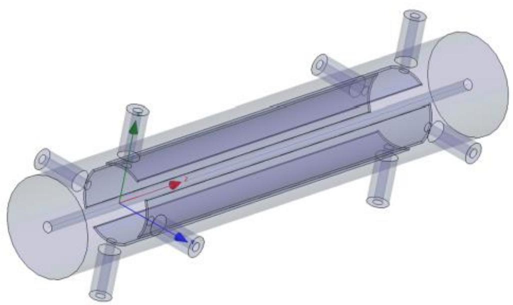
Amplitude of 16.6Hz Vertical ~ 5µm

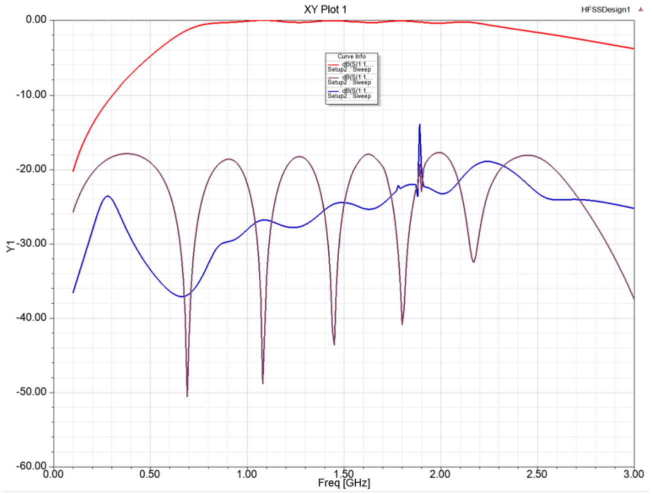


SuperKEKB: High-Current Feedback Kickers (JFY2016-17)

SLAC (A. Krasnykh, A. Benwell, J. Seeman) started on the design, together with KEK, of the transverse feedback kickers able to withstand > 3.5 A beam current at 5 mm bunch length.

- Based on the successful kickers from KEKB (1.6A) and PEP-II kickers (3.2 A).
- Adapted to SuperKEKB (both x-y rather than single-plane).



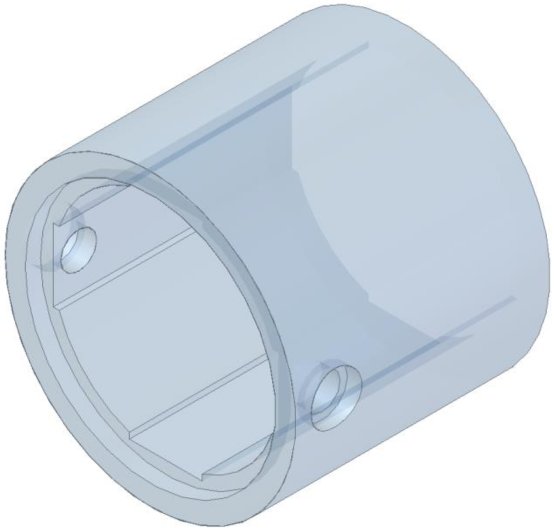


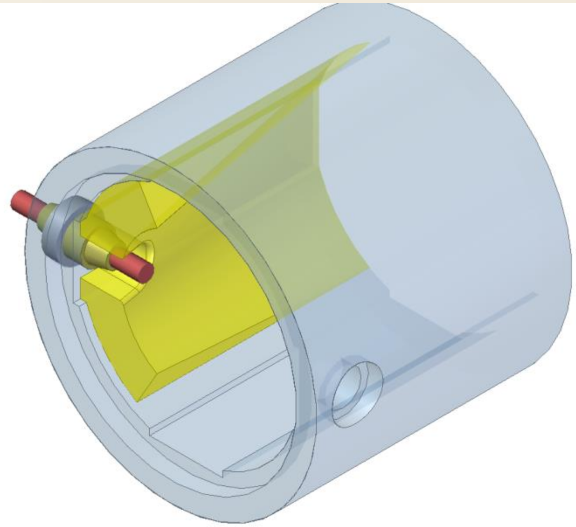
SLAC ready to build the prototype units.
Long-standing interest by KEK in this project.

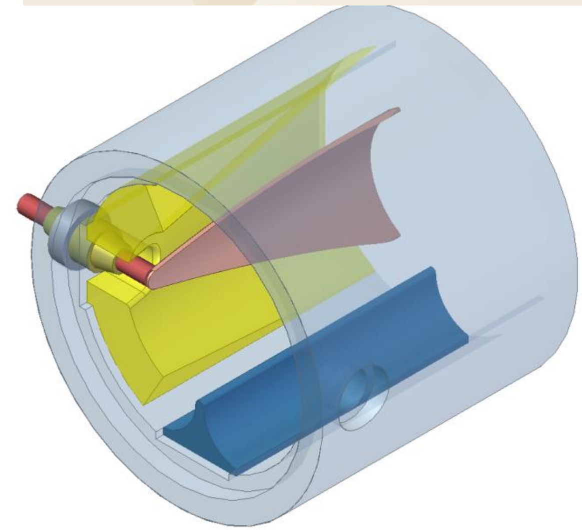
SLAC plans to participate in SuperKEKB beam commissioning as funding allows.

High Power Transverse Feedback Kicker Studies

Al-alloy (yellow), fender (black blue), electrode (light brown)

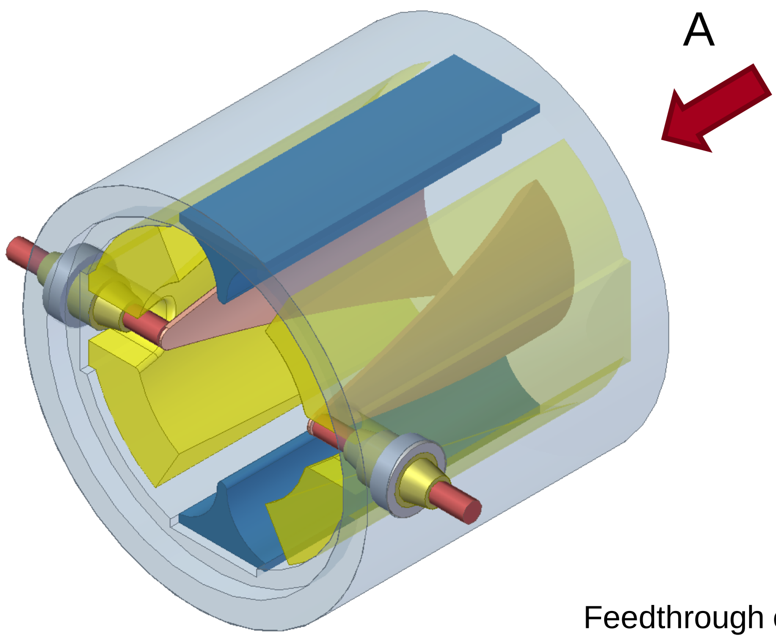


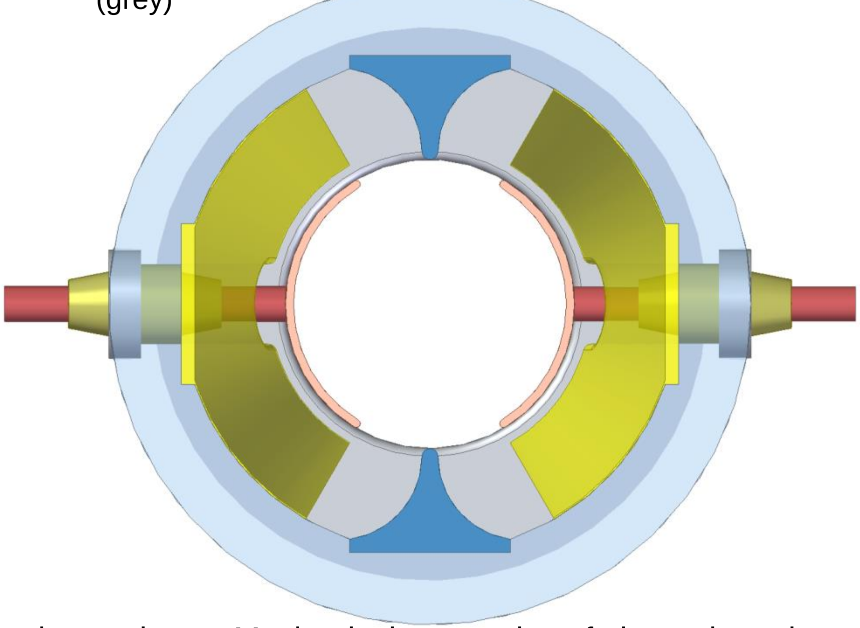




Kicker End Assembly without Front End Flange.

“A” view, “Clear Beam Aperture “ with Front End Flange (grey)

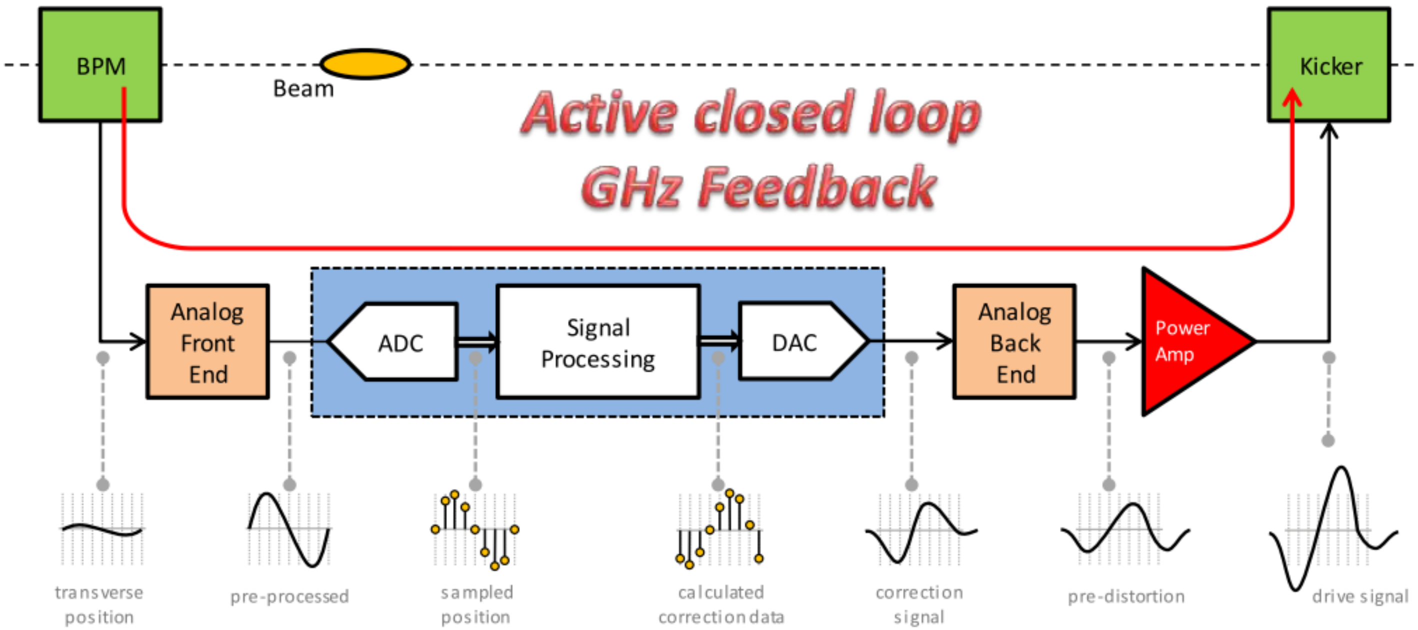




A. Krasnykh, J. Seeman Feb 2017

Feedthrough cooling is not shown. Mechanical connection of electrode and feedthrough needs more study and design. Issues: broadband, vacuum, bake out.

SuperKEKB: Wideband Feedback for Instability Control (Fox et al)



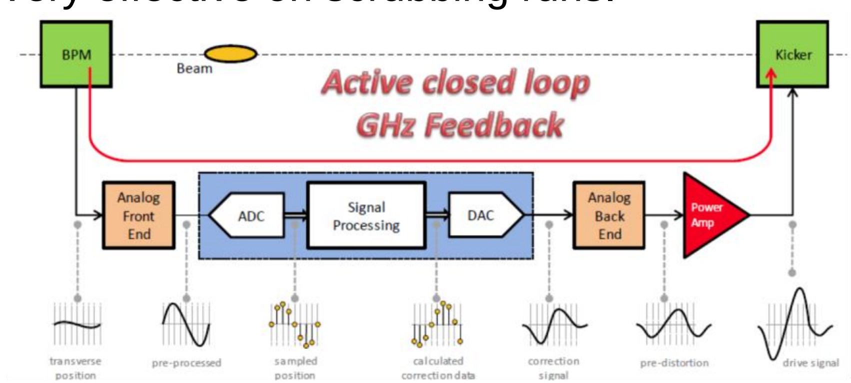
- Ongoing US Japan Research area - value to SuperKEKB, HL-LHC, JPARC, future colliders
- Technology development and Accelerator physics/measurement/control
- Electron Cloud and TMCI driven instability - (intra-bunch feedback Proton Machines)
- Coupled-Bunch instabilities in longitudinal and transverse planes - control formalisms
- Multi-lab effort - SLAC, KEK, CERN, LBL, INFN-LNF
- US Japan supports Stanford Graduate Students and Postdocs through lab prototypes, simulation and analysis tools

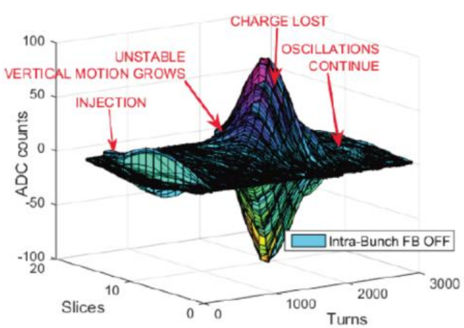
Bunch Feedback Systems

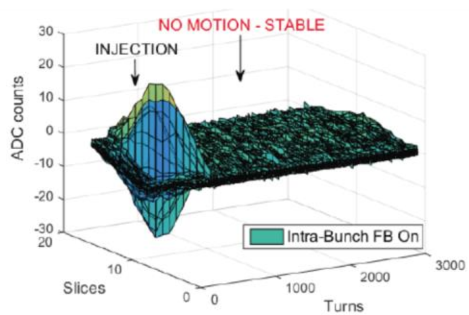
Extend the 4 to 8 GSPS system to multi-bunch feedback for SPS and demonstrated the effect on the scrubbing run of SPS.

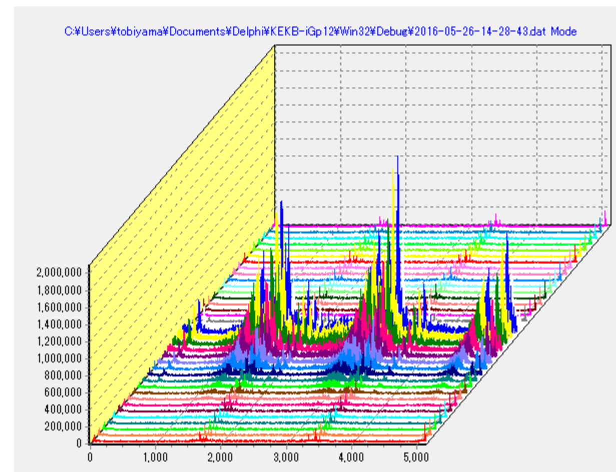
Demonstrated the effect of Next Generation bunch feedback systems on SuperKEKB.

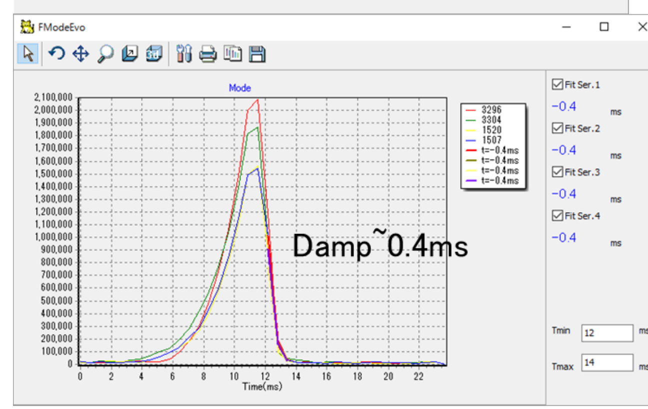
- Very effective on scrubbing runs.







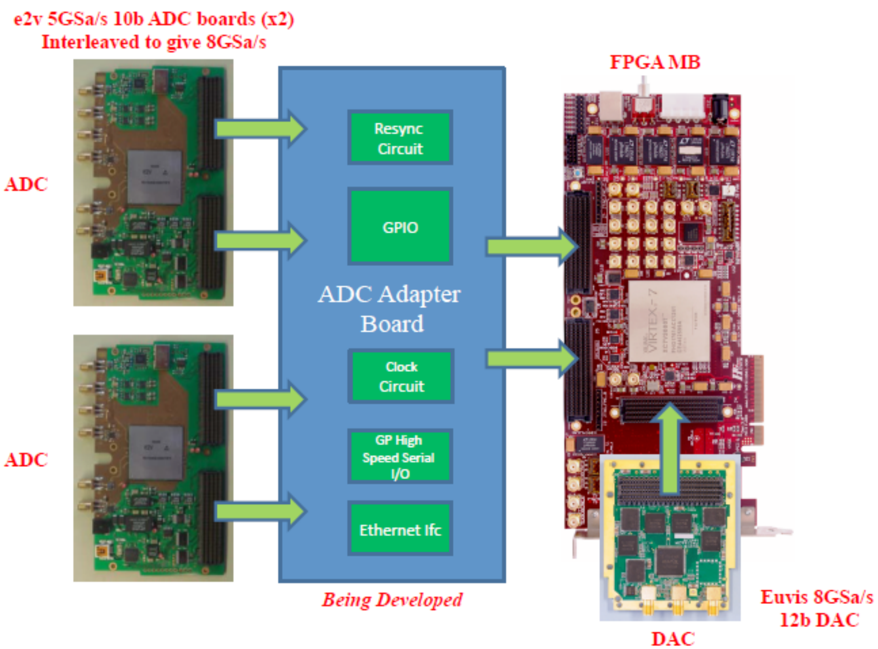




Feedback: Next Generation Technology Development

- Develop High-Speed DSP Platform consistent with 4 -8 GS/sec sampling rates

8GSa/s System

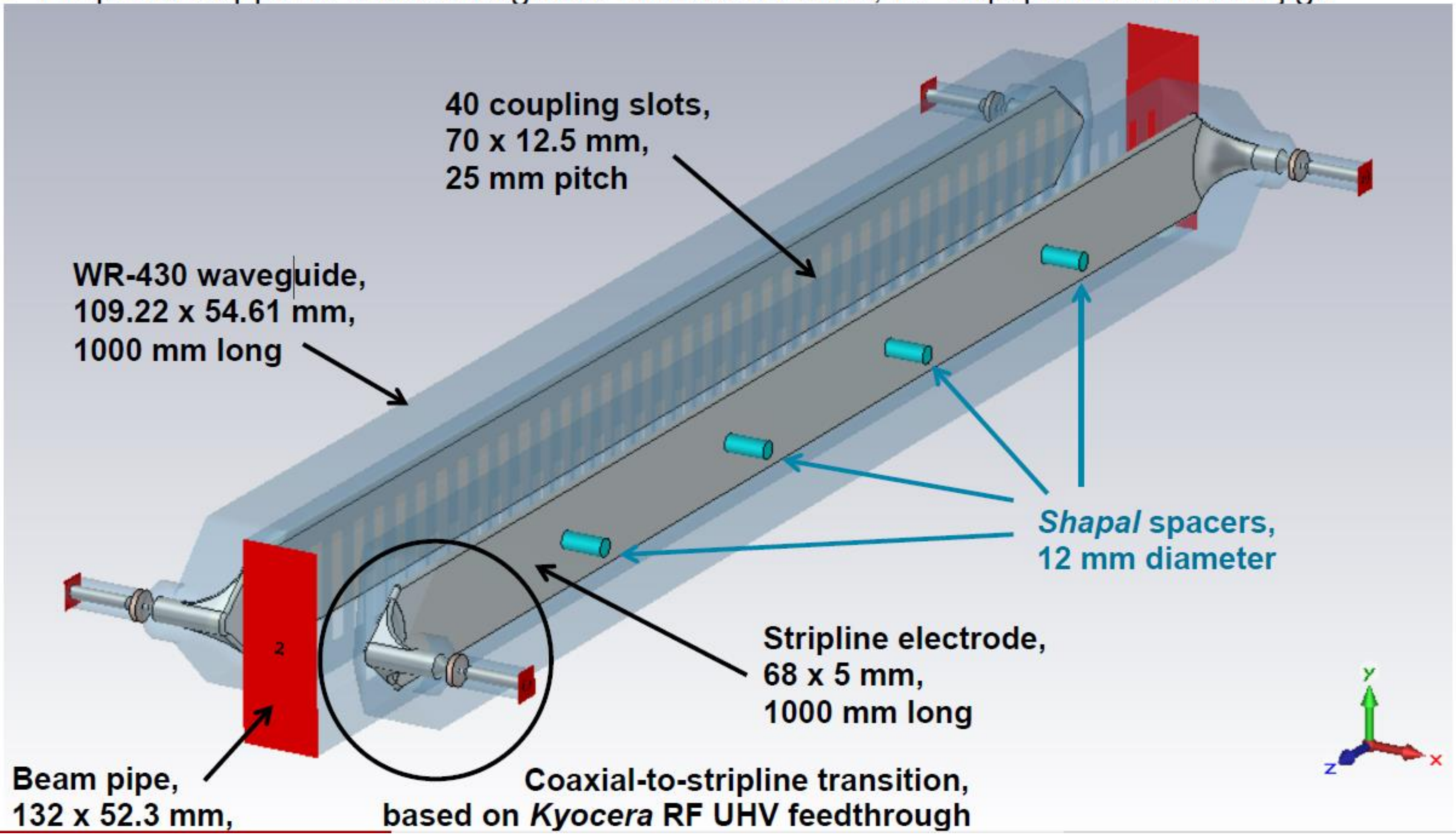


- Proposal supports fabrication of new processing testbed

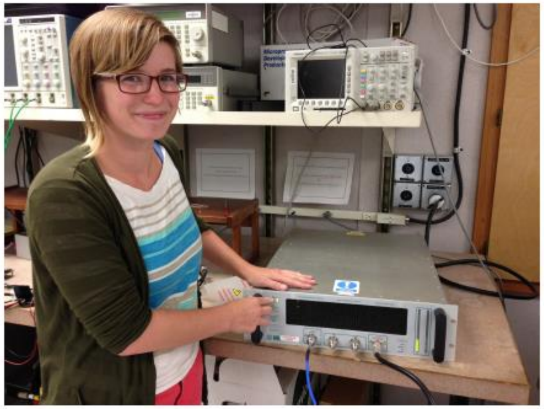
- Two 4 GS/sec input ADC streams, single 8 GS/sec data path, or two 4 GS/s data paths
- Explore ΔΣ front end, with charge normalization
- Low-noise transverse coordinate receivers, orbit offset/dynamic range improvements, pickups
- Capability to exploit computationally intensive control (MIMO)
- Allow multiple kickers, $\pi/4$ separation, higher gain
- Greater FPGA resources, allows more complex modal filters, higher sampling rate filters
- Reconfigurable FPGA processing allows targeting to multiple facilities

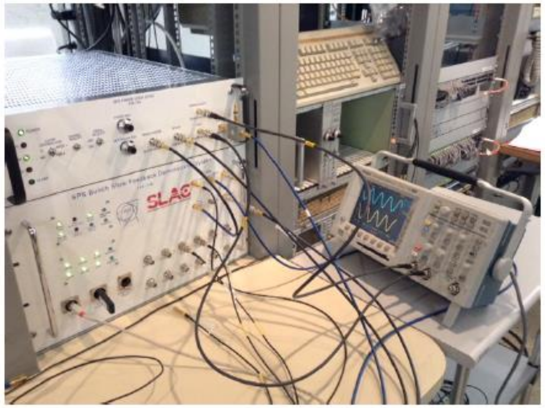
Feedback: 4GHz wideband slot-line kicker development

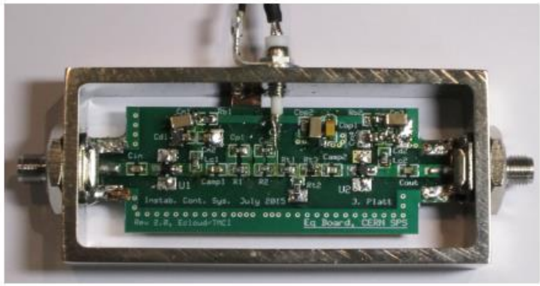
- Proposal - study 4 GHz bandwidth transverse kicker
- Based on existing Design Report SLAC-R-1037
- Similar in concept to stochastic cooling pickups, run as kicker
- Proposal supports construction of low-power model to validate simulations
- Proposal supports electromagnetic simulation tools, RF equipment and test jigs



US-Japan supports Technology Development, Beam Measurements, and Graduate Education

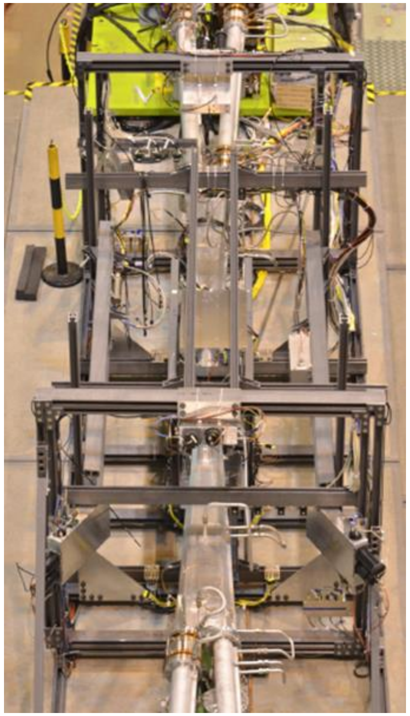






Beam Dynamics Studies for US-Japan for SuperKEKB and Future Colliders

1) Interaction/ vertex region design (Sullivan/SLAC)
2) IP beam backgrounds (Sullivan/SLAC)
3) Bmad code upgrade (Cornell) to test SAD code at KEK.
4) Beam instability studies (Bane/SLAC, Sagan/Cornell)
5) CSR studies (Cai+Stupakov/SLAC)
6) Weak strong Electron Cloud (Rubin/Cornell)
7) Fast luminosity measurements (Wayne State)
8) Collimator wakefields (Novokhatski/SLAC)
9) LLRF controls/feedback for high current gap transients (SLAC/KEK)



SuperKEKB Temporary IR 2016

Collimator and HOM absorber: JFY2016 -17

T. Ishibashi
S. Terui
Y. Suetsugu

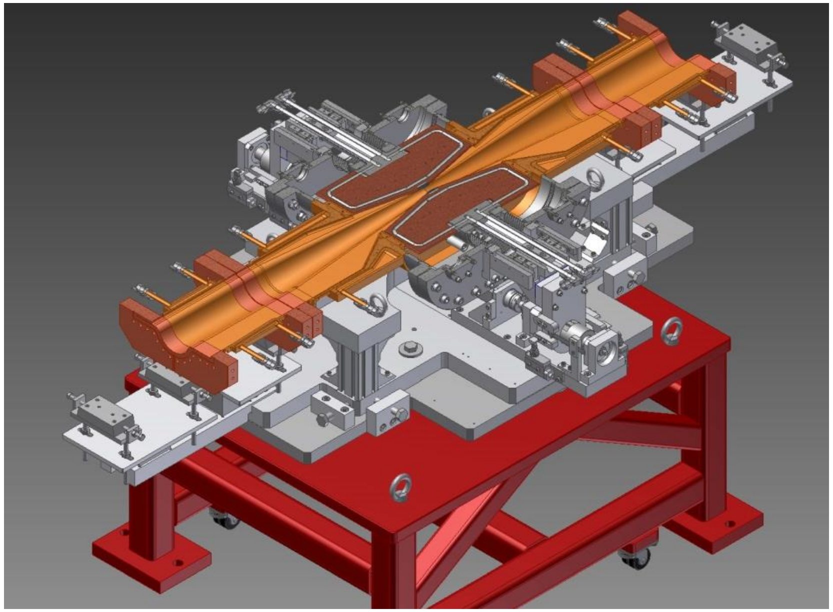
Two horizontal-type collimators were installed in the SuperKEKB positron ring (LER) for test last year.

- Designed on the base of SLAC-type Low-impedance collimators.

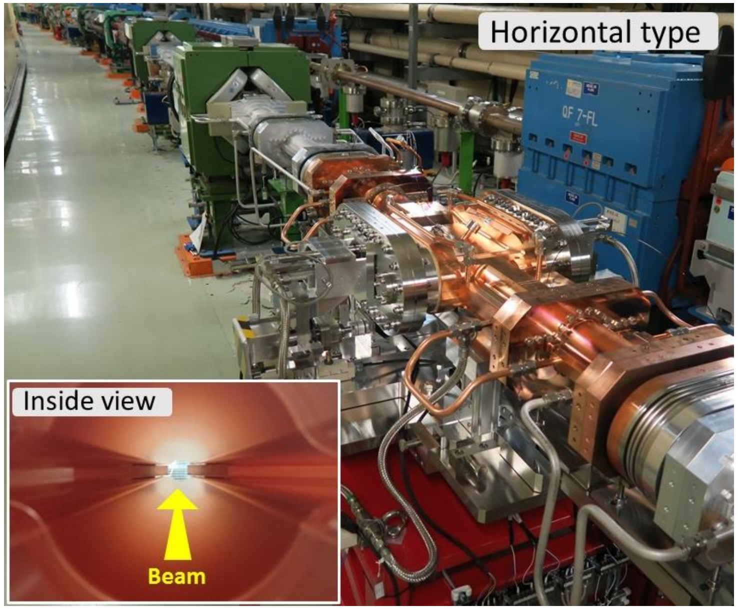
- The performance was checked with a high-current beam around 1 A during the Phase-1 commissioning.

SLAC: J. Seeman
E., Bong, A. Novokhatski

Schematic of a horizontal-type collimator



Horizontal–type beam collimator installed in an arc section of the positron ring (LER)



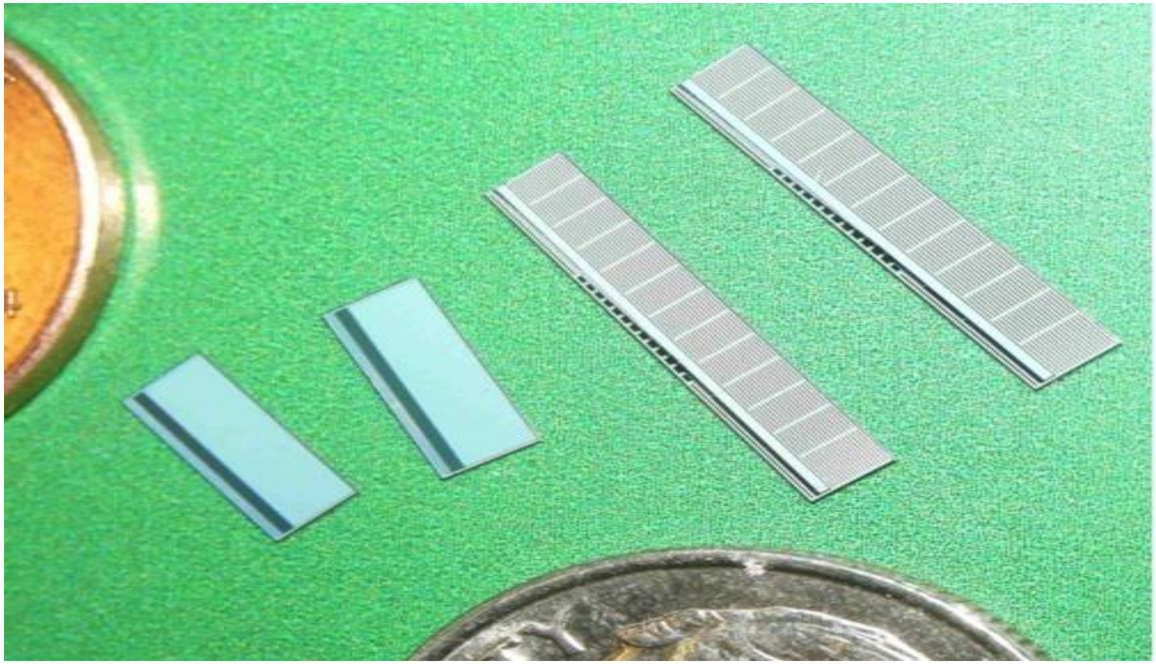
C. Kenney: X-ray beam size monitors: JFY2017 plan

Test Deep Si Pixel detector (SLAC) and 128-ch fast readout system (University Hawaii) at KEK-PF.

Construct real system for Phase 2 of SuperKEKB

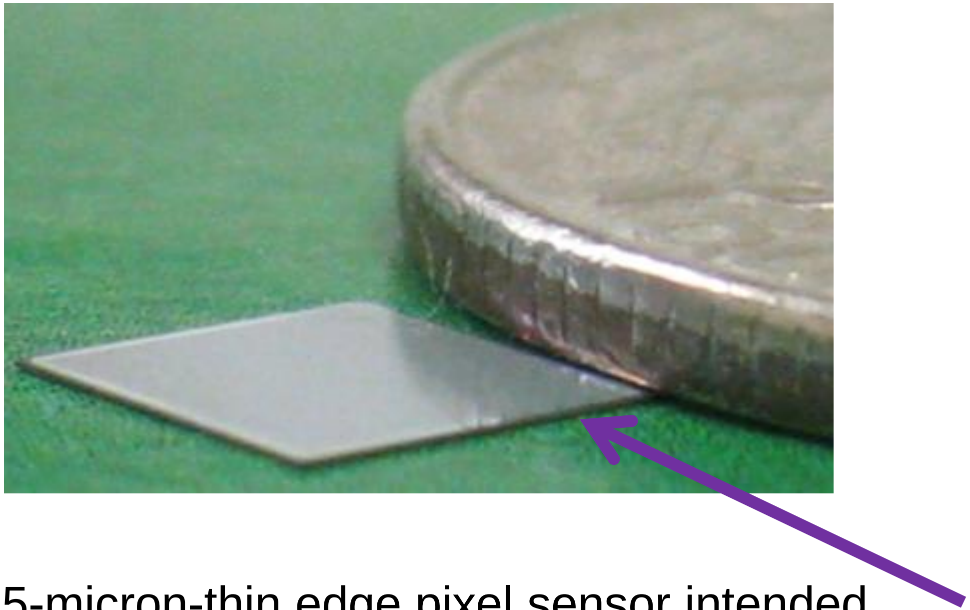
Design, fabricate new X-ray mask and evaluate in Phase 2.

High-speed, bunch-by-bunch x-ray beam diagnostics for monitoring nanometer dimension bunches (C. Kenney SLAC)



High-efficiency deep-Si pixel detector and spectrometer chips for the X-ray monitor, developed at SLAC.

Silicon Edge-on Pixel X-ray Detector



X-rays

75-micron-thin edge pixel sensor intended for bump bonding to an integrated circuit chip.

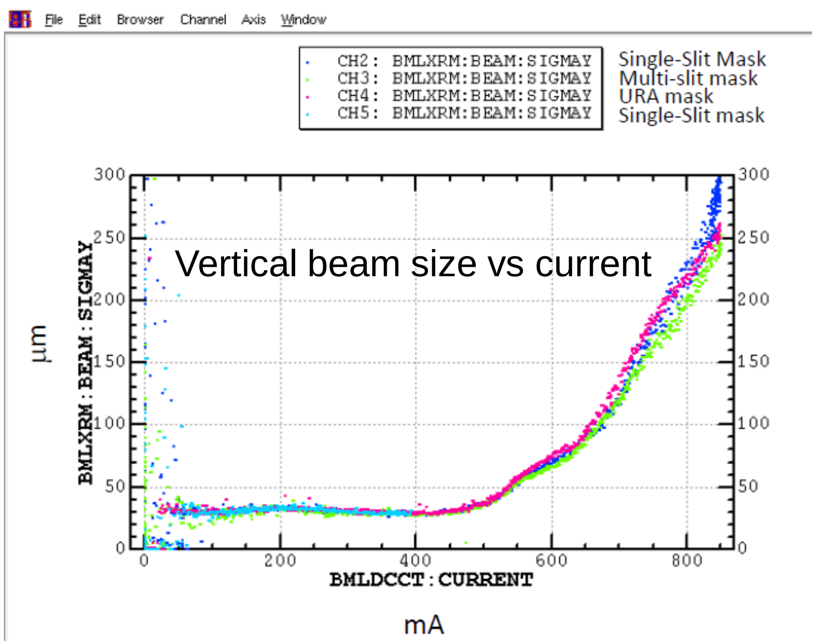
Development of X-ray size monitor

Trial installation of 48-channel fast readout system (by University Hawaii) on LER X-ray line.

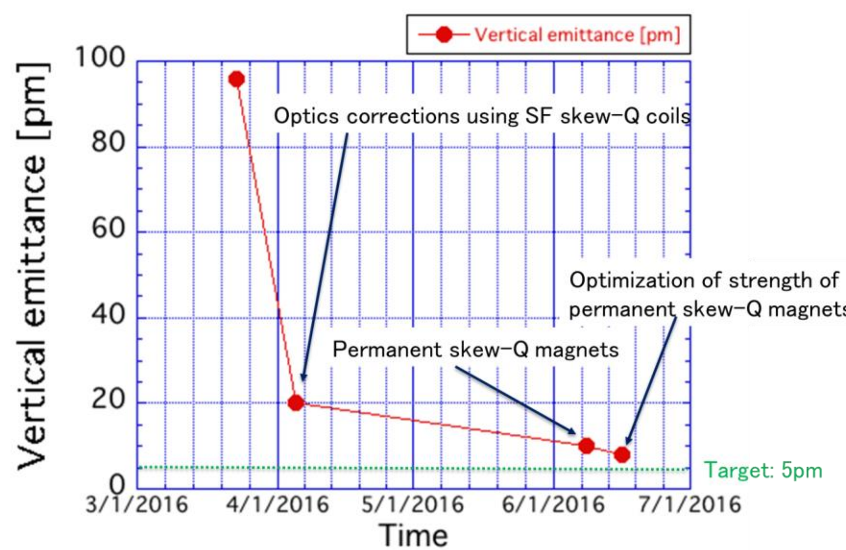
- Difficulties with S/N, stability... deferred usage in Phase 1.

Installed YAG scintillator + CCD camera for slow readout.

Demonstrated excellent reproducibility of beam size measurements at LER and contributed to the optics correction and study of E-cloud instability in Phase 1.

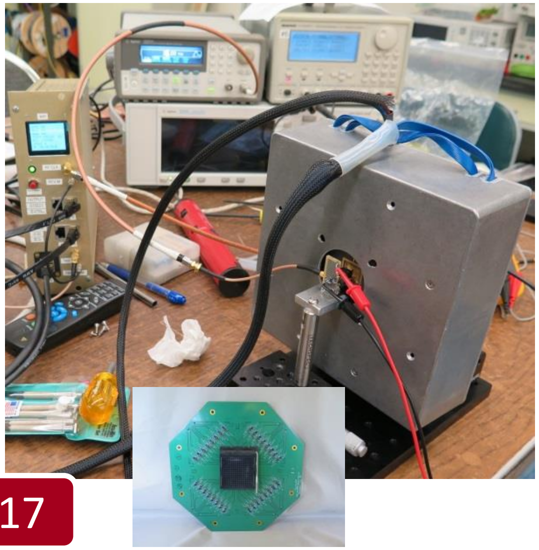


Reducing vertical emittance

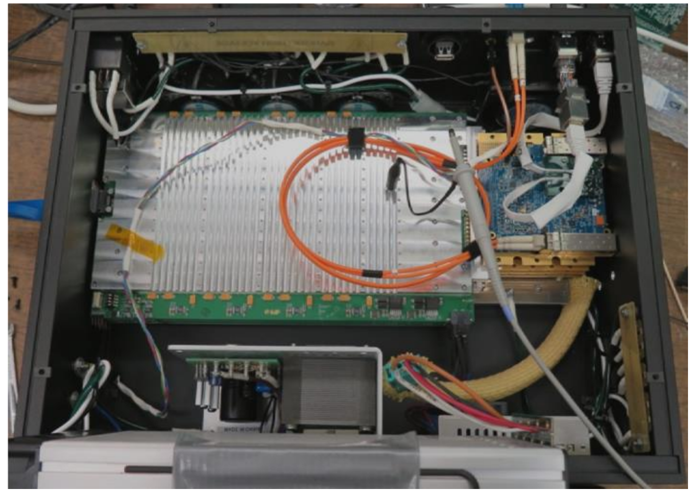


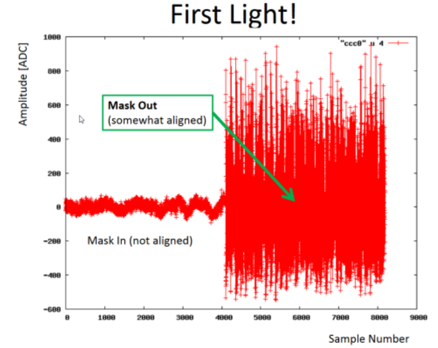
2016

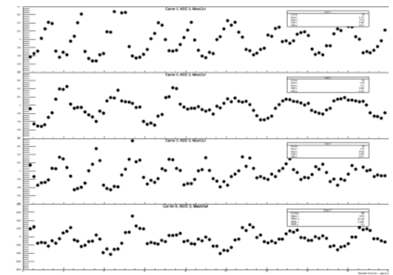
X-Ray Size Monitor Progress in FY2016



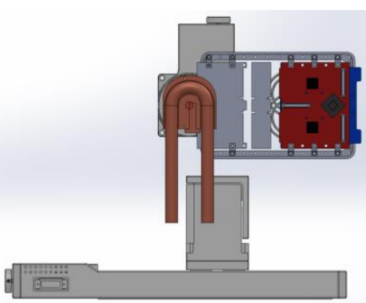
2017

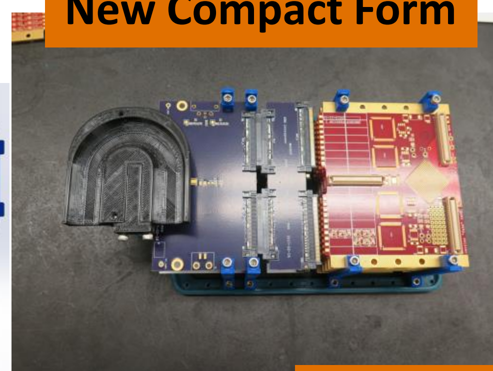




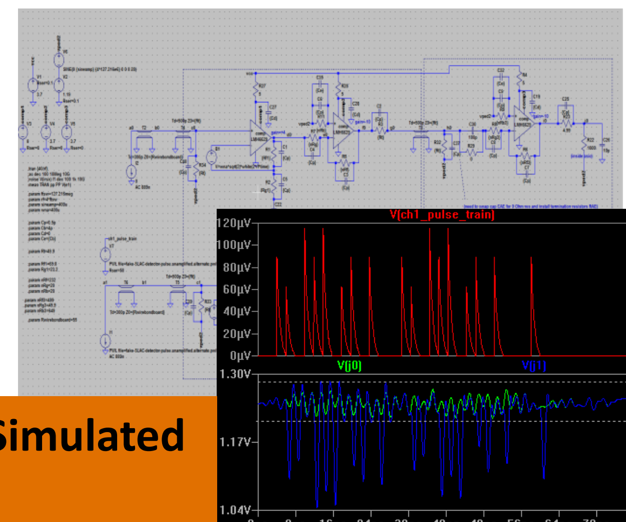


New Revision

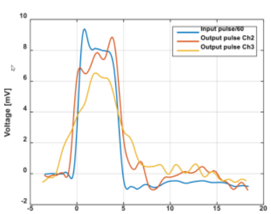


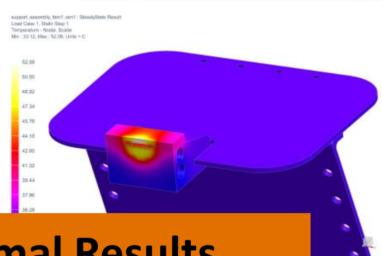


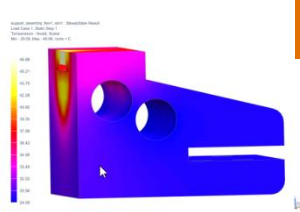
New Compact Form



Amplifier Simulated Result







Thermal Results

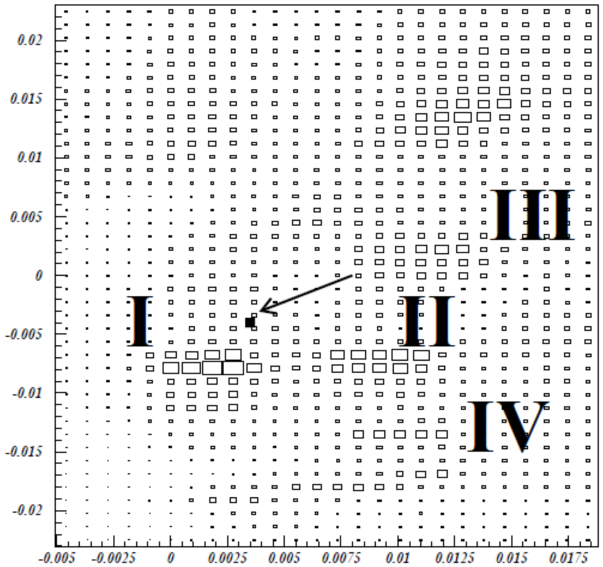
SuperKEKB

University of Hawai'i

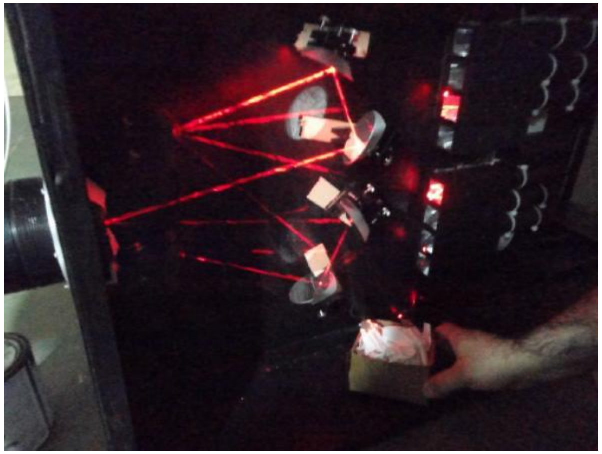
SLAC NATIONAL ACCELERATOR LABORATORY

Wayne State University: The Large Angle Beamstrahlung Monitor (LABM) 2016

Evaluation of the system performance using background SR in Phase 1.



Angular scan of red light (575-650 nm), of the LER beam, taken with X-Ray detector. The direct beam sweep is indicated by “I”. Other labeled images are reflections off the inside of the Beam Pipe. The IP location is indicated by a black square.



US-Japan for SuperKEKB and Future High Luminosity Colliders:

US-Japan Projects have been very helpful in advancing the state of the art for Storage Ring Accelerators and Colliders.

Thank you!