BUNCH CHARGE MONITOR FOR THE ALS UPGRADE

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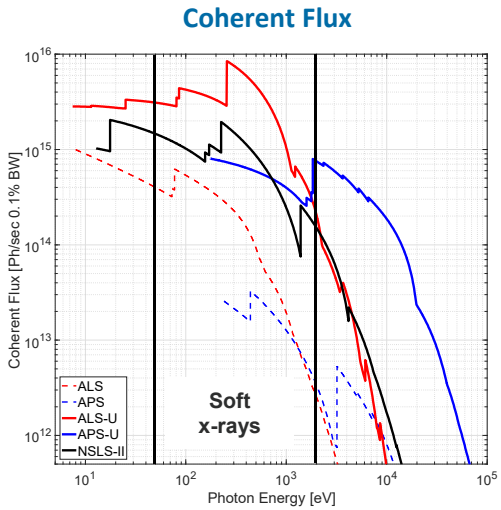
SUMMARY

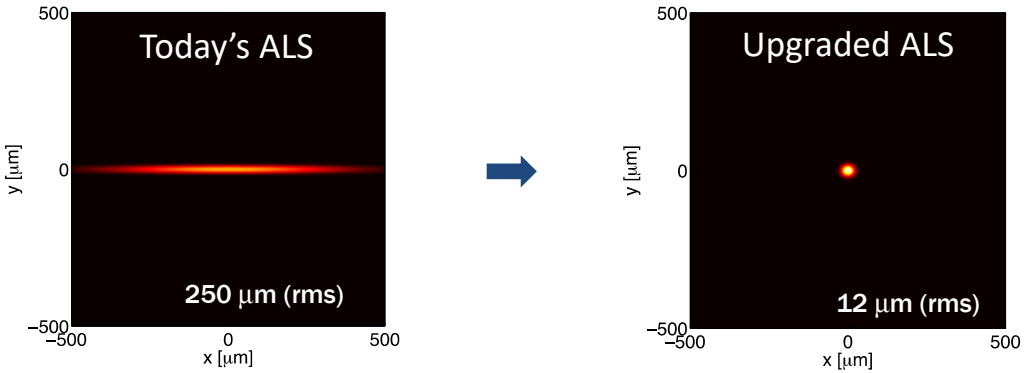
- Introduction to the ALS Upgrade Project (ALS-U)
  - Swap-out Injection
- ALS-U Bunch Charge Monitor (BCM): Objectives
- Overview of the present ALS BCM
- From ALS BCM to the ALS-U BCM
  - Electronics
  - Beam Pickup
- Conclusions

ALS UPGRADE PROJECT OVERVIEW

- Present ALS commissioned in 1993.
- Upgrade project greatly increases the coherent flux at soft x-ray wavelengths by using a new Storage Ring with much reduced horizontal emittance.
- Same building with accelerator tunnel.
- Same injector (linac + booster ring) upgraded to 2 GeV.
- Most existing beamlines and ID's are maintained with a few new ones.
- New Storage Ring based on a 9-bend achromat lattice.
- New injection process with an added Accumulator Ring, new transfer lines.

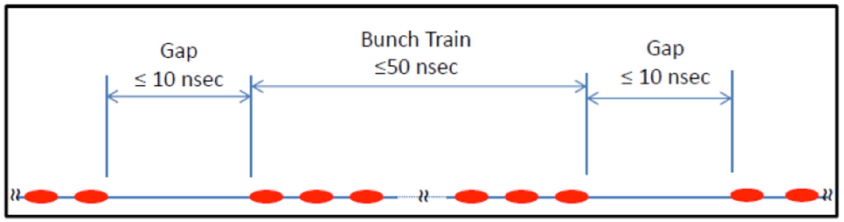


Electron Beam Profile (ID's)

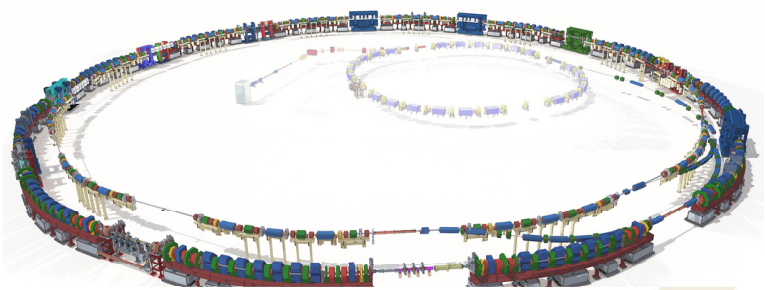


ALS-U SWAP-OUT INJECTION

Storage-ring bunches transferred to accumulator
Accumulator bunches transferred to storage ring



11 trains of 25/26 bunches, 4-bucket gaps

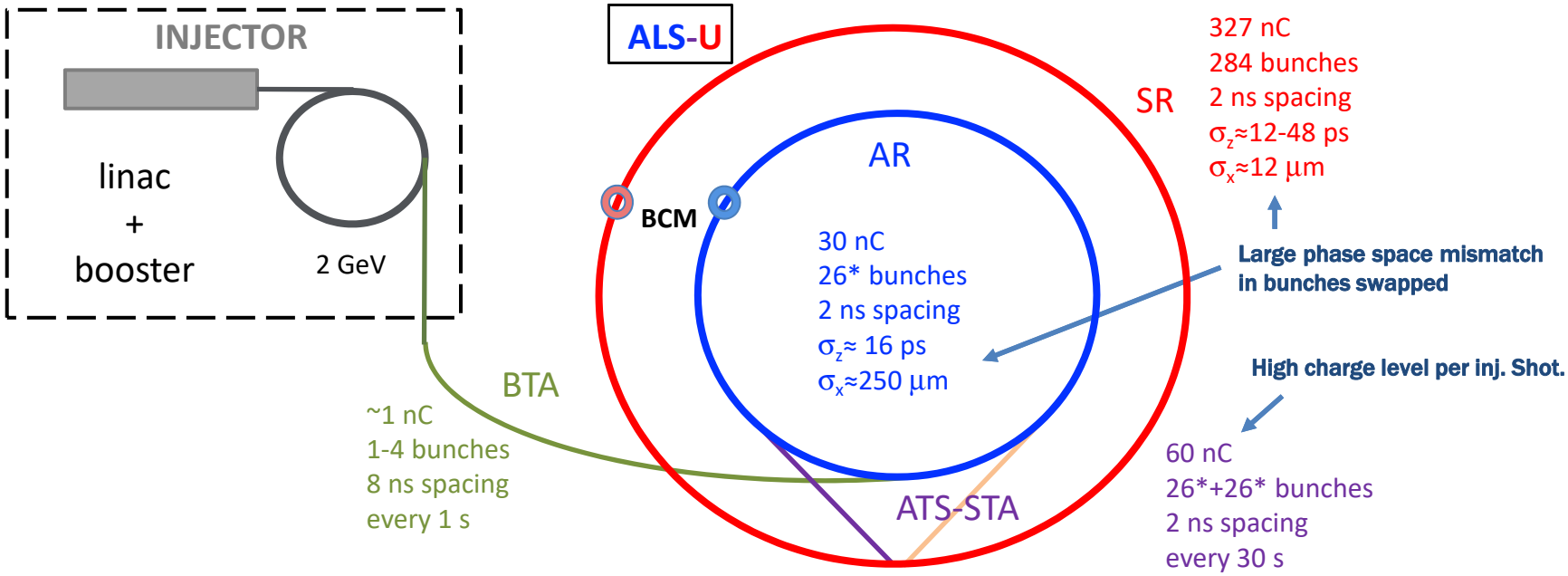


Fast kicker magnets

New accumulator ring

New ALS storage ring

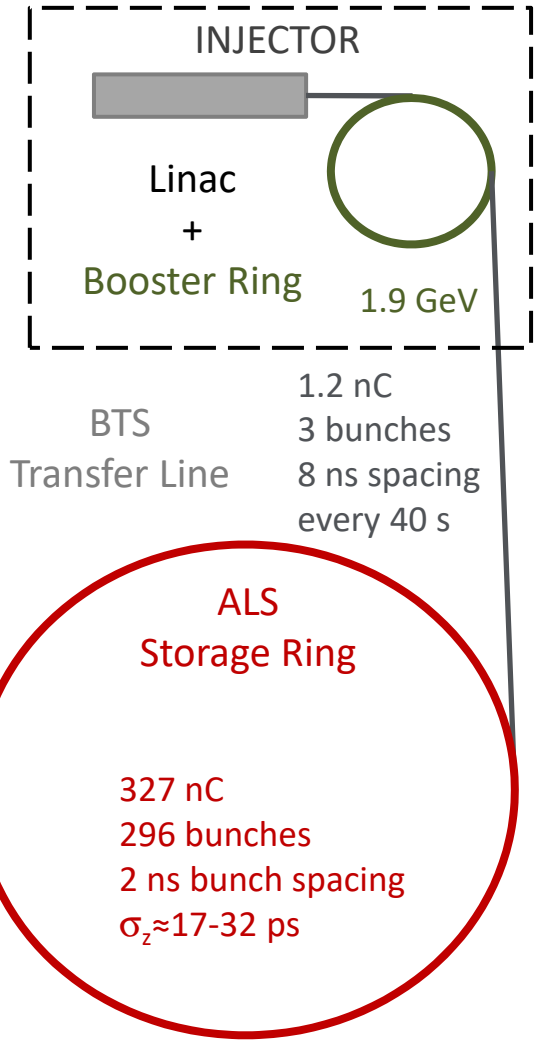
ALS-U BCM OBJECTIVES



- Monitoring bunch charges in SR and AR to control accumulation and swap-out processes.
- Monitoring nominally empty RF buckets in SR and AR to control bunch cleaning process.
- Swap-out losses diagnostics at the individual bunch level by comparing trains immediately before and after swap-out.

ALS BUNCH CHARGE MONITOR

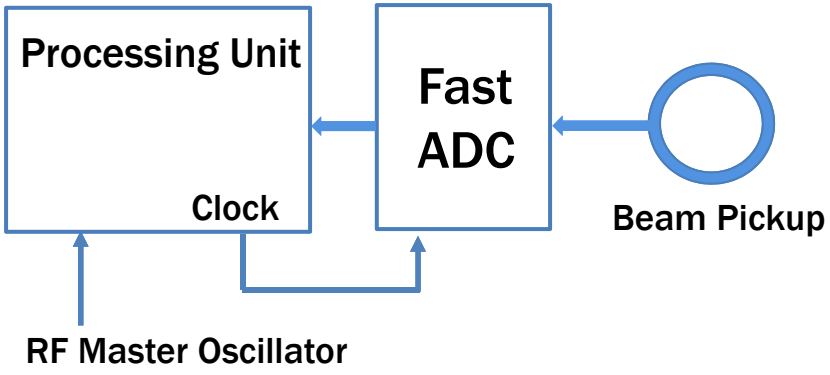
- ALS nominal fill: single train of 296 bunches + 32-bucket empty gap with a camshaft bunch.
- Up to 3 bunches topped off every ~40 seconds (off-axis injection).
- Total current stability better than 0.25%
- BCM measures:
  - Charge of each individual bunch
  - Parasitic bunches in nominally empty RF buckets

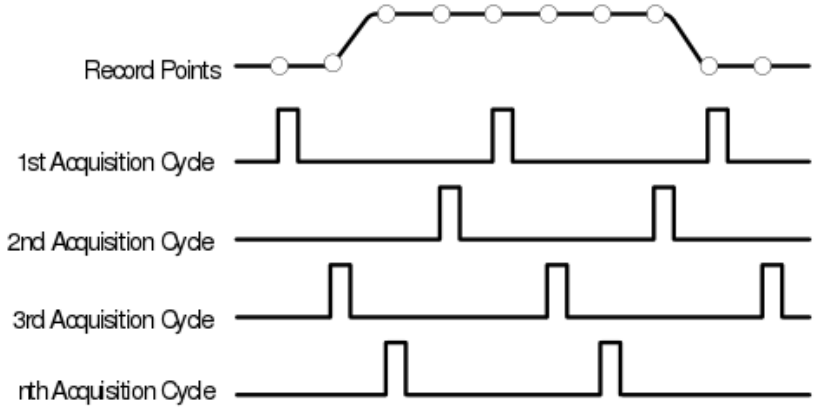


BCM CONCEPT

Objective: mapping charge distribution around a storage ring with time resolution of 10's of ps and sub-pC charge resolution.
Concept: beam pickup with enough bandwidth to resolve individual bunches. Fast ADC samples at the desired rate. Digital data can be averaged to achieve necessary SNR.

ALS Ring length subdivided in 62.5 ps long intervals ($\approx 2\sigma_z$): 10496 samples. Single turn acquisition would require a 16 GHz sampling rate!
Since beam losses time scale is slow (~10 hr lifetime), we can use the same technique as digital sampling scopes and spread the acquisition over a longer time by progressively shifting sampling at more reasonable rate to eventually cover the entire ring.

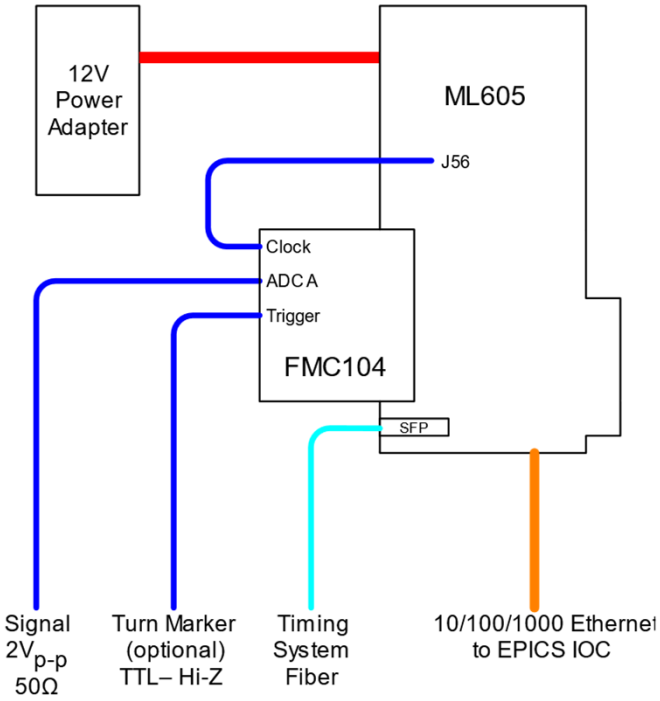




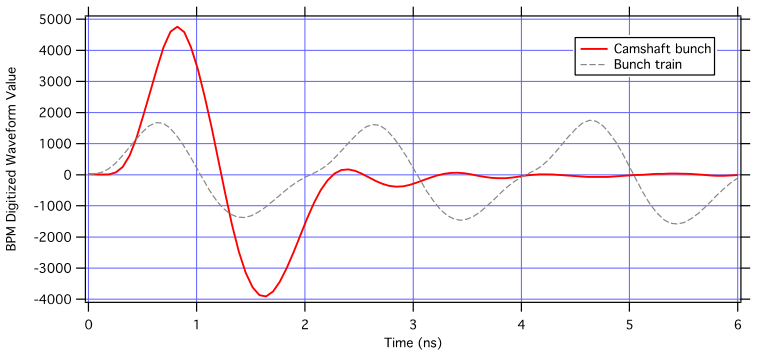
Digital sampling scope

ALS BCM

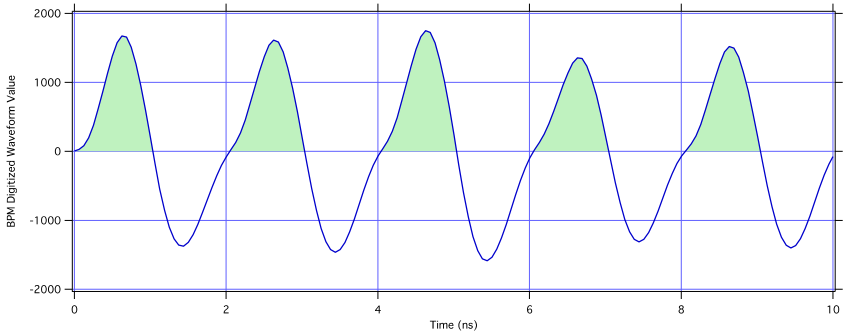
- Beam pickup: single BPM button, unfiltered response (7 mm diam. 3 pF capacitance).
- FPGA based electronics.
- 14-bit, 250 Ms/s, 800 MHz bandwidth ADC.
- ADC rate: 176 MHz, ~115 samples/turn.
- Monitoring period after averaging: 61 ms (1024 averages).
- Absolute charge value derived from DCCT readout.



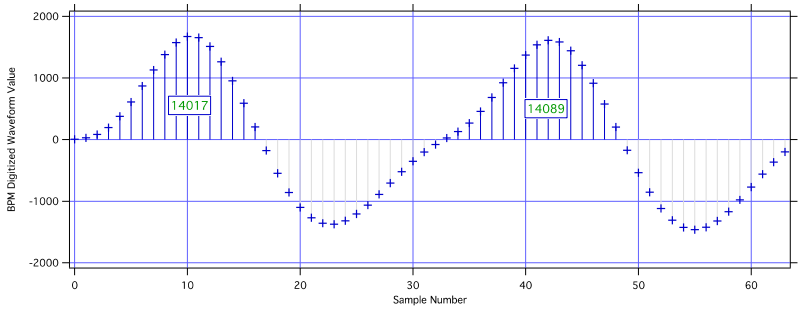
ALS BCM DATA EXAMPLE



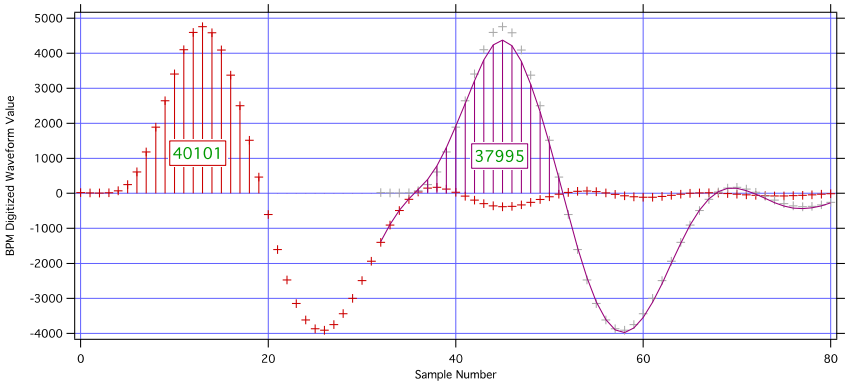
Examples of bunch signals, after averaging. Single bunch (camshaft) showing typical BPM bipolar response and 3 consecutive bunches. Camshaft bunch charge about 3 times larger



First 5 bunches of train. Green area marks signal portion used for bunch charge measurement.



Individual 62.5 ps samples for two bunches from train. Green number shows total sampled value used to calculate bunch charge after normalization to DCCT readout.



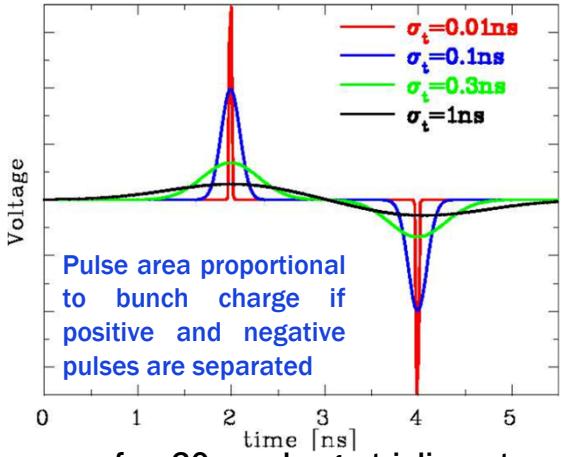
Camshaft sampling. A second identical bunch added 2 ns later to show error(~5%) caused by residual oscillations in individual bunches waveforms due to pickup and ADC bandwidth.

ALS-U BCM MODIFICATIONS: BEAM PICKUP

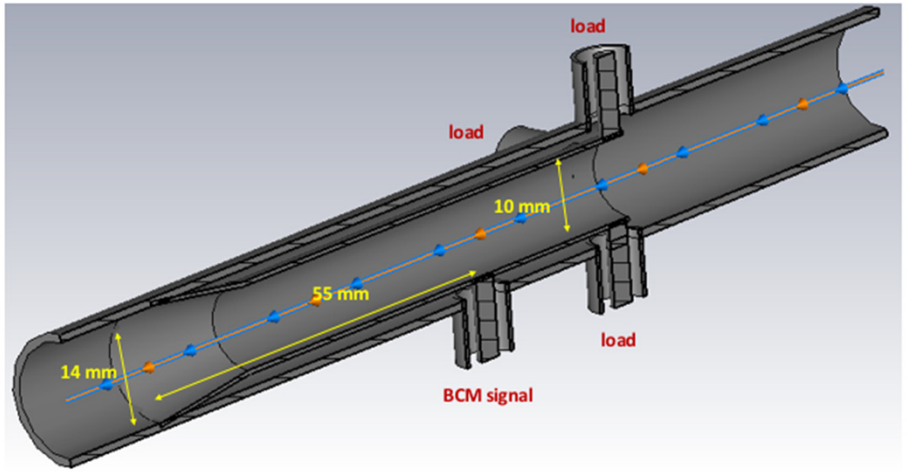
- Sensitivity to bunch length is a more serious issue
  - ALS bunch length during user operations is essentially constant. Top-off does not affect bunch length of targeted bunches.
  - ALS-U SR and AR exchange entire trains during swap-out, which are longitudinally mismatched by a factor 3. Damping to the equilibrium bunch length takes many synchrotron periods.
- Storage Ring BPM buttons are substantially smaller and therefore more sensitive to bunch length changes.
- In order to increase BCM accuracy we plan a dedicated beam pickup:
  - Less sensitive to bunch transverse position. Ideally, able to provide an absolute measurement of charge.
  - Less sensitive to bunch length changes.
  - With response oscillations that affect less readout of the trailing bunch.
  - With larger transfer impedance to improve SNR.

LOADED COAXIAL STRIPLINE

- A stripline response is proportional to the bunch charge (if it is long enough).
- 360° coverage makes response independent on bunch transverse position and maximizes transfer impedance.
  - Combining 4 standard stripline electrodes on a large bandwidth is problematic at best.



Ideal response of a 30 cm long stripline at various bunch lengths

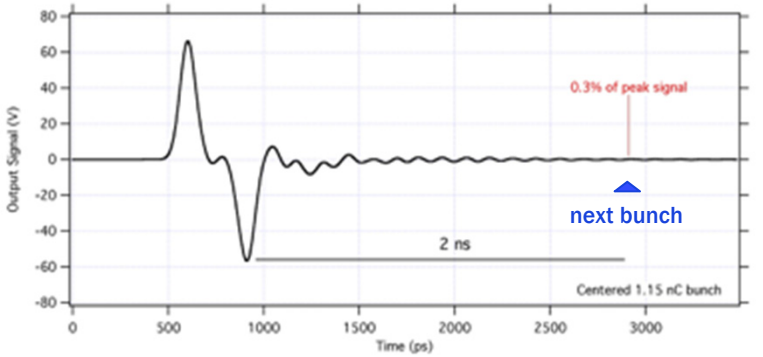


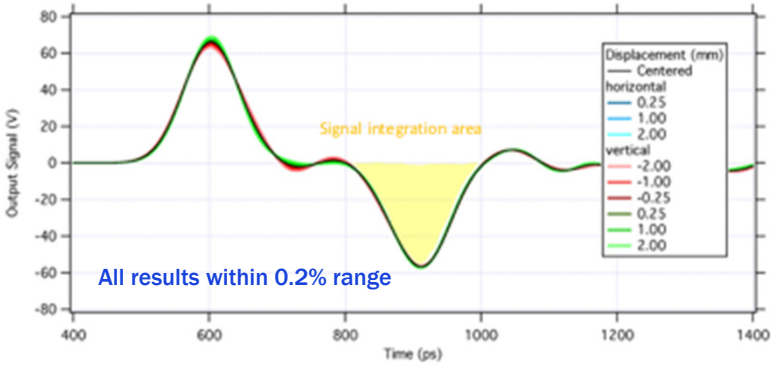
Section of BCM pickup in the SR vacuum chamber

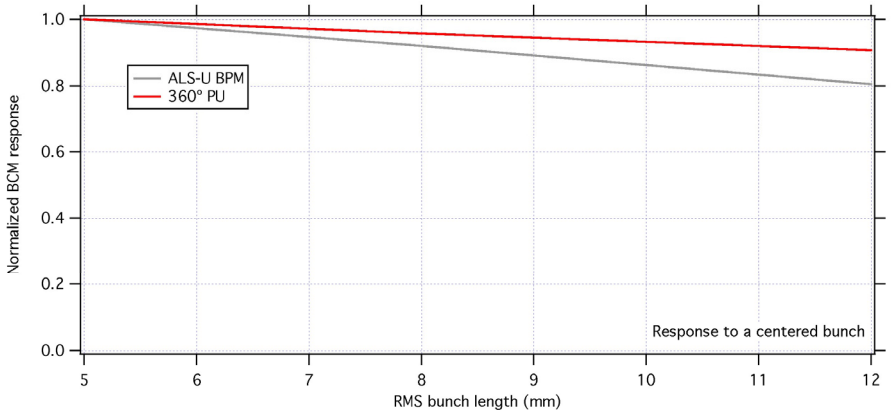
- Stripline shorted for better thermal and mechanical properties.
- Loads dissipate reflections to limit response duration.
- Signal port recessed from stripline front edge to further minimize dependence on bunch transverse position.

LOADED COAXIAL STRIPLINE RESPONSE

- CST Particle Studio simulations show improved pickup response vs. BPM button.
- Minimal residual signal affecting trailing bunch readout.
  - Cable effect to be included.
- Back-end pulse area essentially unaffected by bunch transverse position.







- Dependence on bunch length about half compared to a standard ALS-U BPM button.

ALS-U READOUT ELECTRONICS UPGRADE

- Faster ADC
  - 500 Ms/s acquisition.
  - 6 GHz input bandwidth.
- Improved time resolution
  - From 62.5 ps to 25 ps sampling.
- Averaging factor increased to 2048 compatible with 10 Hz measurement rate.
- We will assess effect of beam pickup higher SNR
  - Some applications may require faster acquisition (i.e. reduced averaging).
  - Since each RF bucket is sampled once per turn, option to measure only the bunch core at higher rate, or increase resolution on bunch core at same rate.
- New electronics to be tested on the ALS
- Planning to test new beam pickup on APEX (750 keV e^- test facility).

ALS-U BCM TARGET PERFORMANCE

- Storage Ring – Bunch Charge
  - Few pC (better than 1% resolution) at 10 Hz rate.
  - Consistent with better than 1% total current stability.
- Storage Ring – Swap-Out Losses
  - Individual bunch losses at 1 pC level within ~1 second following injection.
  - Consistent with measuring swap-out efficiency at sub-1% resolution.
- Storage Ring – Background Losses
  - Detect 0.2 pC loss in individual bunches at 1 Hz rate.
  - Consistent with 1 hr lifetime.
- Storage Ring/Accumulator Ring – Parasitic Bunches
  - Measurement noise level under 0.1% of nominal bunch charge.

CONCLUSIONS

- The ALS Bunch Charge Monitor currently supports user operation by measuring individual bunch charges at a >10 Hz rate and with a few % resolution.
- Due to different injection scheme and substantially shorter lifetime in the ALS-U, we want to improve the instrument resolution.
- A new beam pickup and upgrade readout electronics are currently being developed at LBNL.
- The new BCM should be able not only to support the injection cycle and keep total circulating current at its nominal level within the allowed margin, but also to provide information on the losses location during swap-out and support accelerator physics studies.