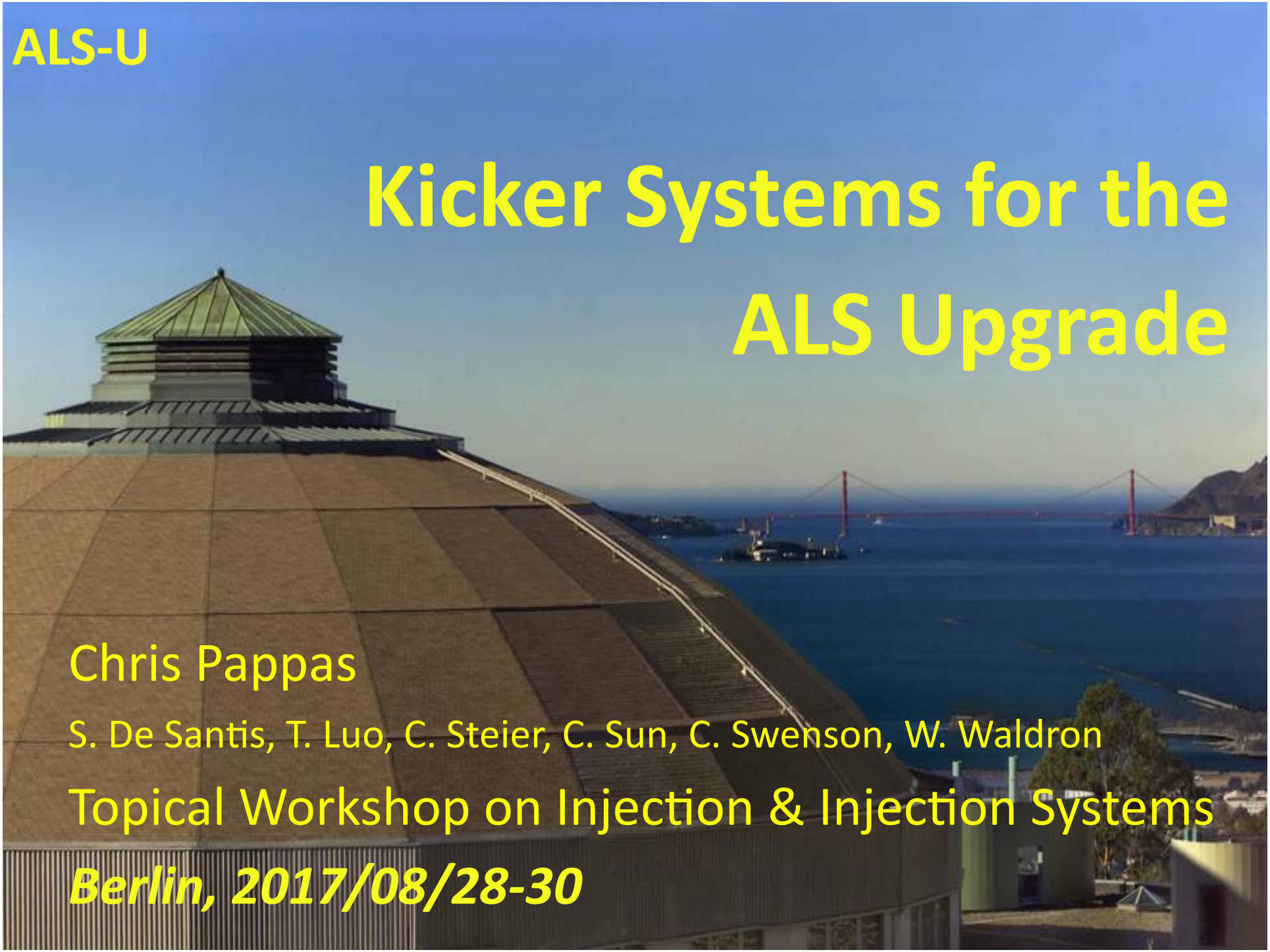
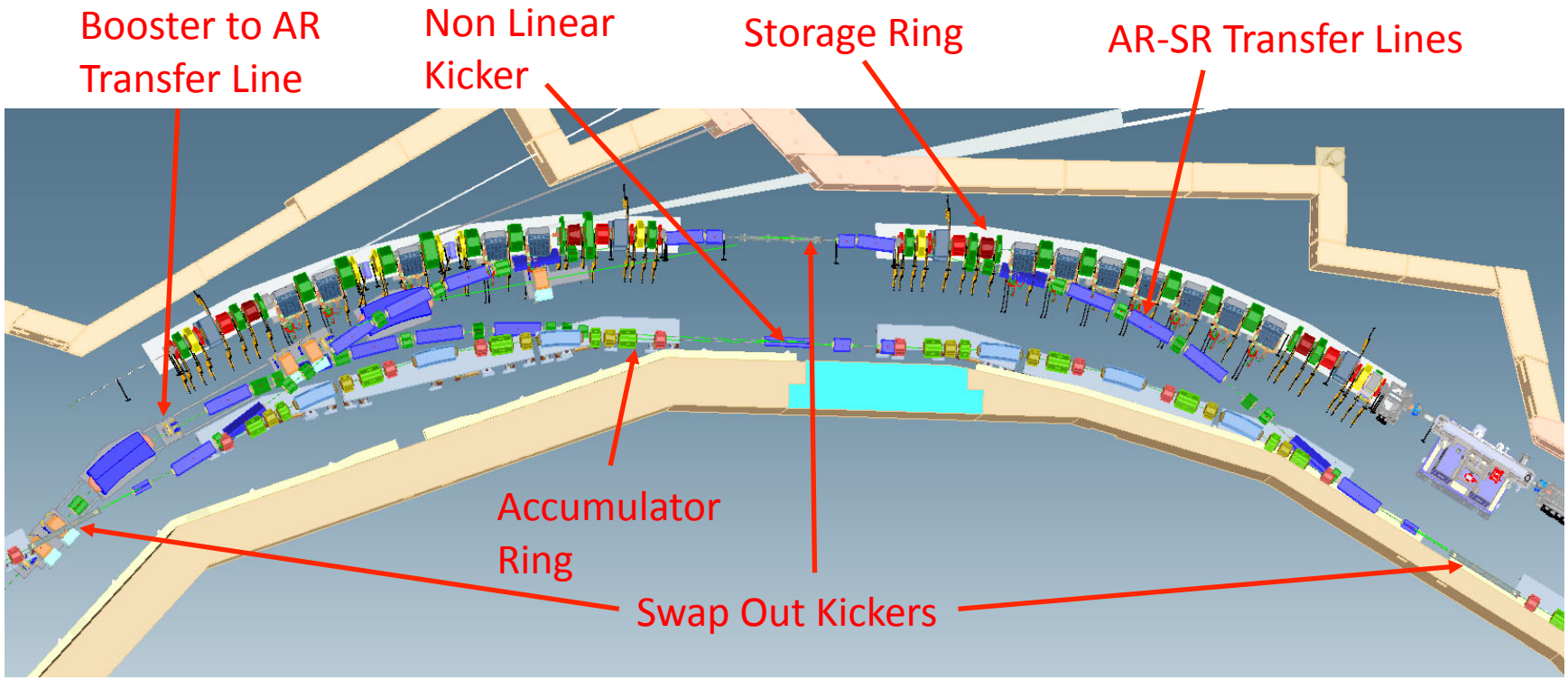

ALS-U
Kicker Systems for the
ALS Upgrade
Chris Pappas
S. De Santis, T. Luo, C. Steier, C. Sun, C. Swenson, W. Waldron
Topical Workshop on Injection & Injection Systems
Berlin, 2017/08/28-30

ALS-U Storage and Accumulator Ring Kickers



A non-linear kicker will be used to inject the beam into the accumulator ring.
Swap out kickers to transfer beam between the accumulator and storage rings are a stripline magnet design, driven by an inductive adder pulser.

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For details on ALS-U project see:
Status of the Conceptual Design of ALS-U, C. Steier, etal, IPAC17

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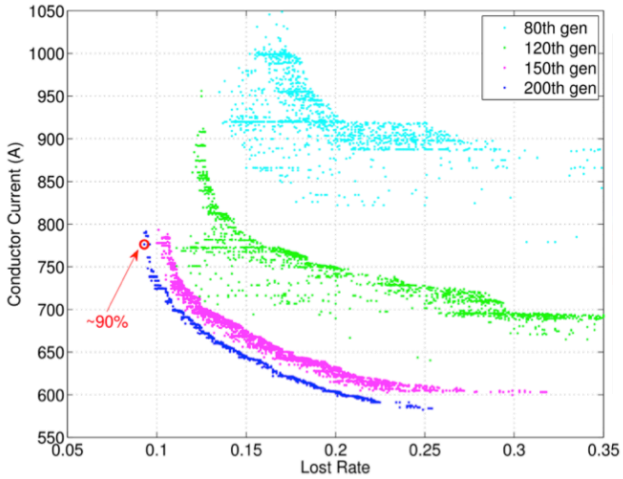
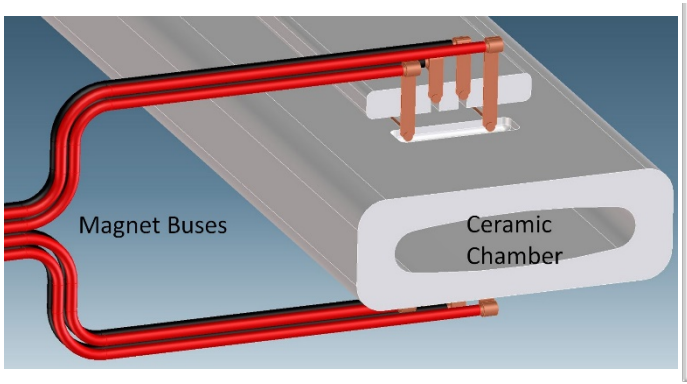
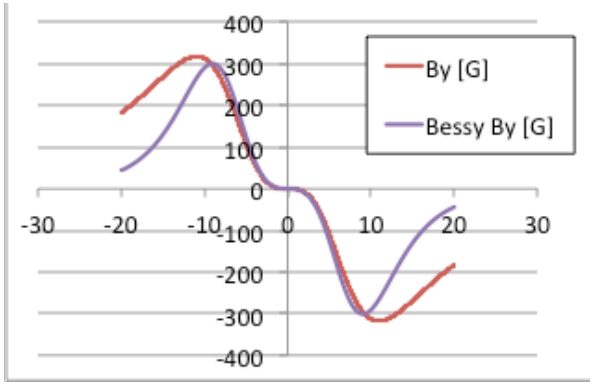
Injection into the Accumulator Ring

- Tracking and NLK optimization studies for injection into the accumulator ring are incomplete.
- A non-linear kicker is being readied for installation into the existing ALS storage ring.







Multi-objective genetic algorithm was used to optimize the magnetic field of a BESSY type non-linear magnet, and to match the injected beam Twiss parameters to the ALS.

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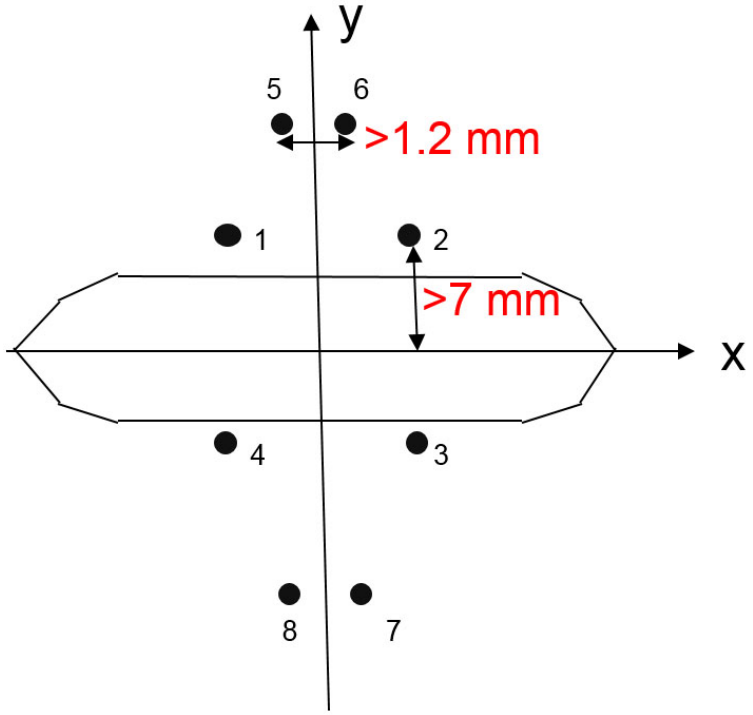
NLK Optimization for the ALS

Optimization Constraints	
Field free region in horizontal	+- 0.5mm (2 sigma)
Dipole field By	By<0.135 G
Quad field dBy/dx*	dBy/dx<1100 G/m
Field free region in vertical	+- 0.05mm
Dipole field Bx	Bx<0.035 G
Quad field dBx/dy	dBy/dx<5040 G/m



Other constraints, bus height > 7 mm, separation of buses > 1.2 mm. Optimum current was 776 A.

Conductor	R [mm]	Theta [Deg]
IB	8.8241	51.9646
OB	17.8089	85.3137

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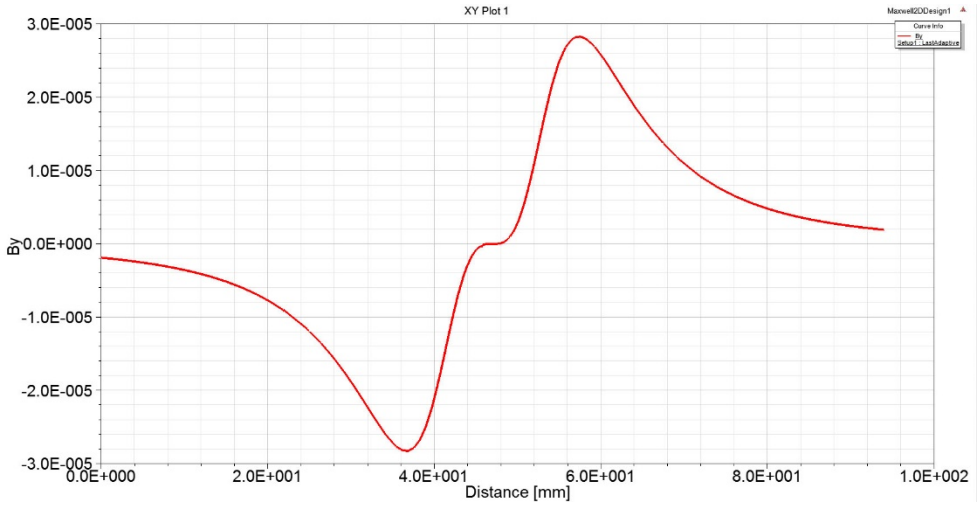
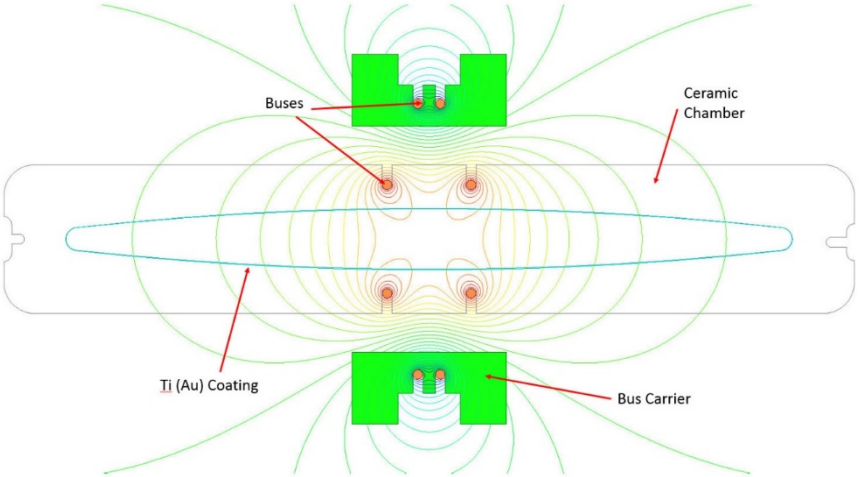
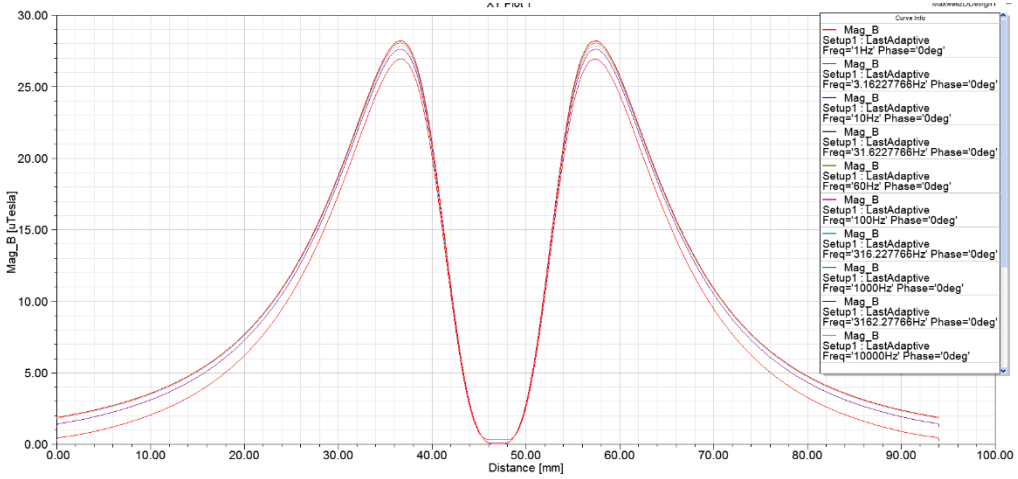
NLK Magnet for the ALS



Magnetic field profile of By along a line through the center of the aperture, in T/A. Field is tunable by moving the bus carrier.



Titanium coating on the inside of the alumina chamber designed to dissipate < 10 W from the beam image current, (<1.05 Ohm).



|B| along the center of the aperture, at different frequencies, approximately 2 % attenuation for our pulse. The time constant of the eddy currents is insignificant.

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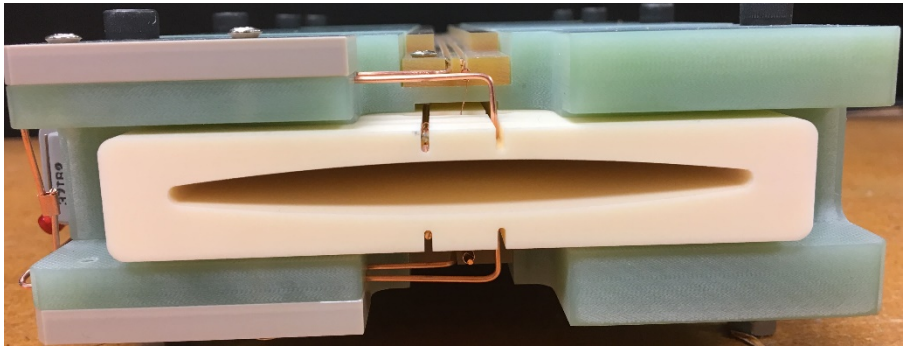
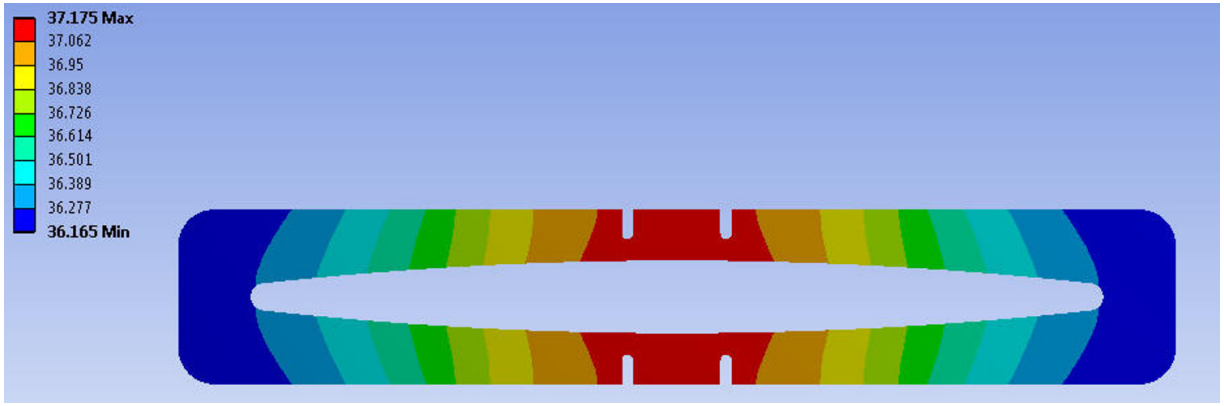
Magnet Model & Cooling





Expected temperature rise with 16.5 W dissipation on the Ti coating is approximately 15 C, with 1 m/s air flow.

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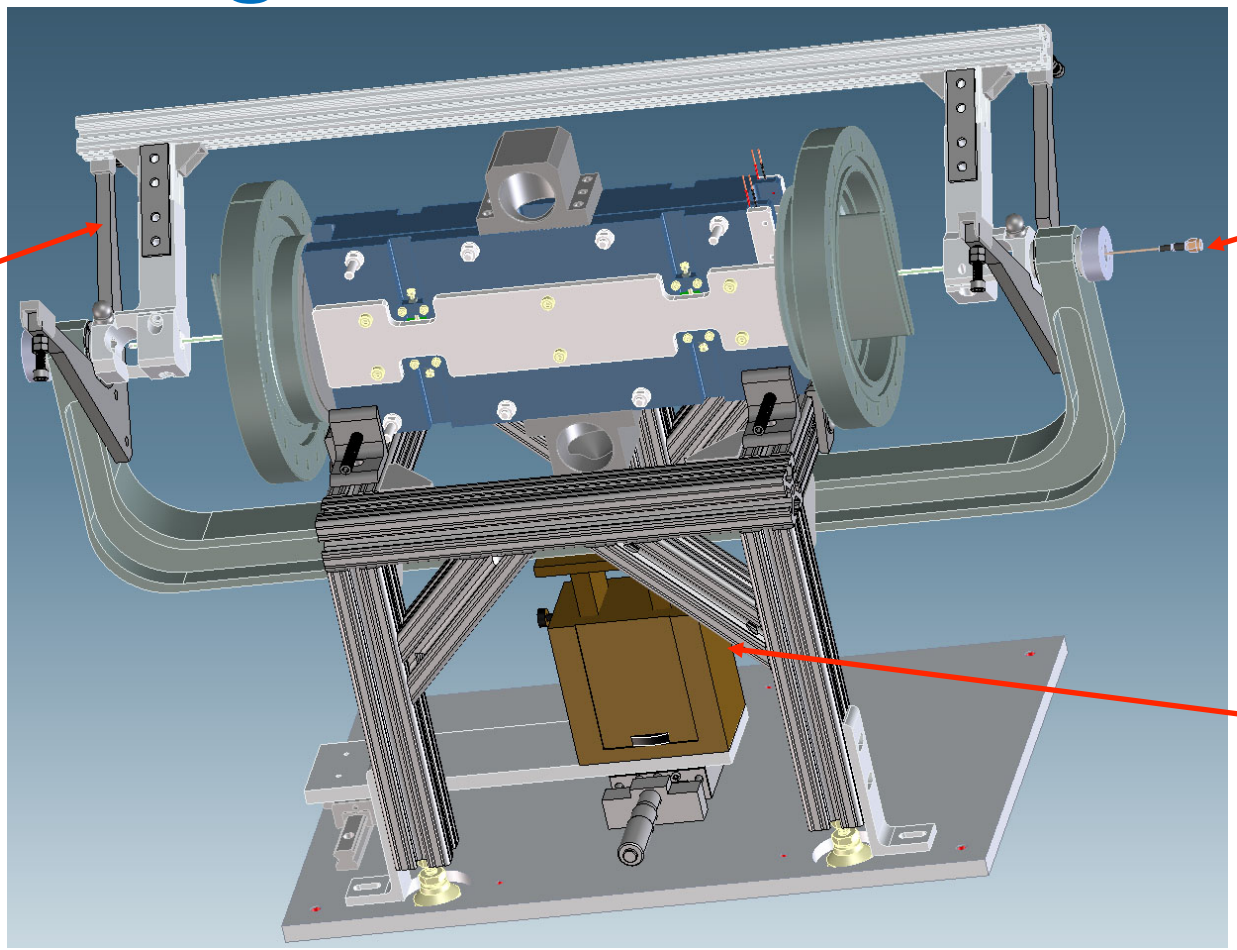
Magnetic Measurements



Both Bx and By across the aperture will be mapped using a B-dot probe. Need a resolution of 1part in 2200, which should be easy with either a nominal current pulse and LNA, or an audio amplifier driving the magnet at ~ 10 A and a lock-in amplifier.

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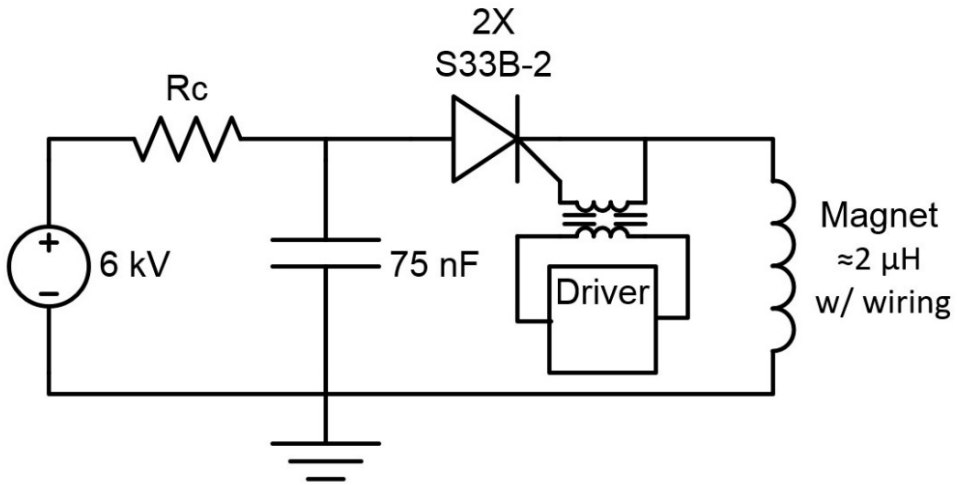
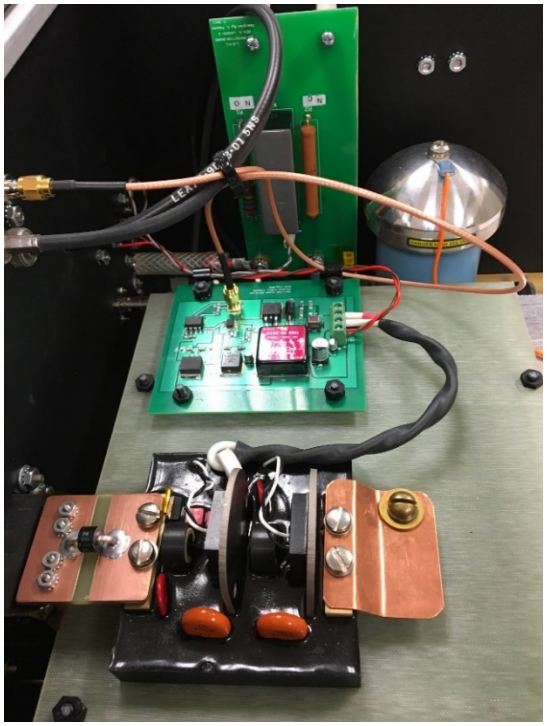
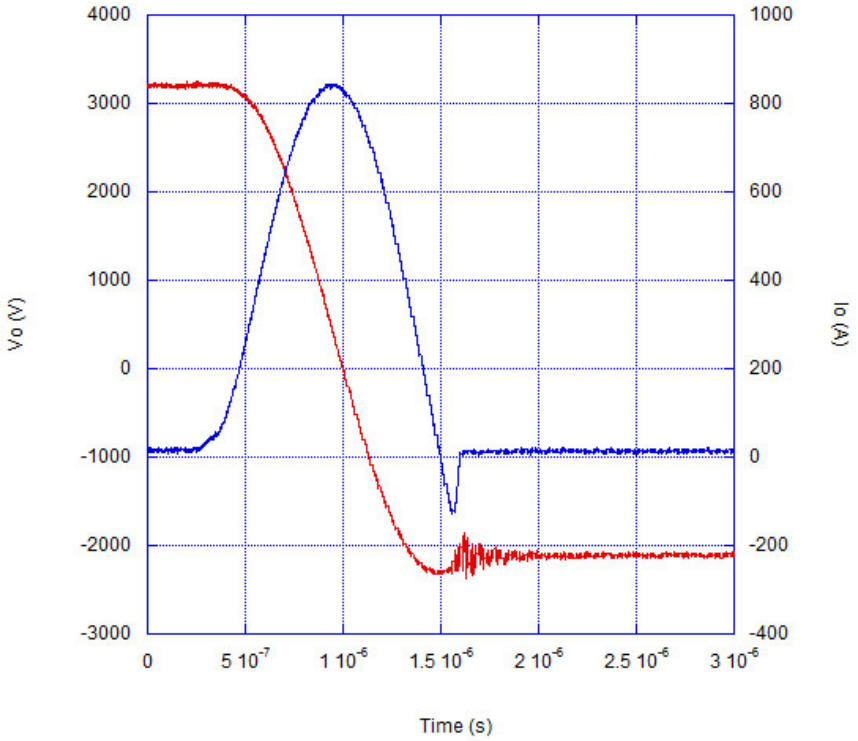
NLK Pulser



Design Parameter	Value	Units
Magnet Current	1000	A
Half Sine Width	1.3	µs
Magnet/Cable Inductance	2	µH
Charge Voltage	6	kV
PRF	1	Hz



Current reversal at end of pulse is recovery of a fast diode in series with the SCR. Pulser is tunable ½ sine modulator. Will be located in tunnel to reduce cable impedance.



NLK Status

- Magnet stand was installed last January
- Modulator is built and tested with dummy 2 µH load.
- Chambers are machined and in house
  - Ti coating process is still being evaluated, both evaporation and magnetron sputtering
  - Brazing of test pieces for the vacuum flanges is in progress
- Fixturing for magnetic measurements has been fabricated. Initial measurements on non-vacuum magnet are proceeding
- Plan is to install the system in Jan. 2018.

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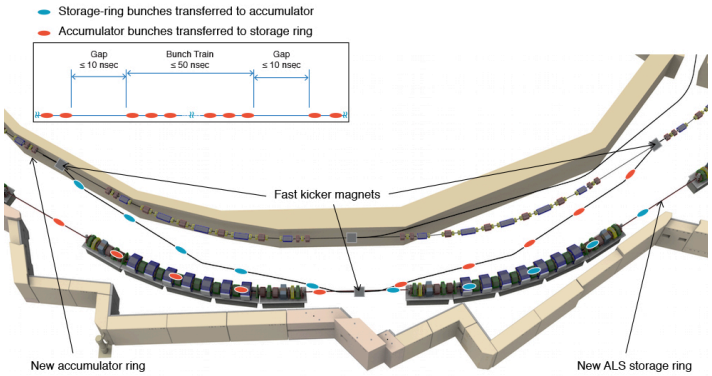
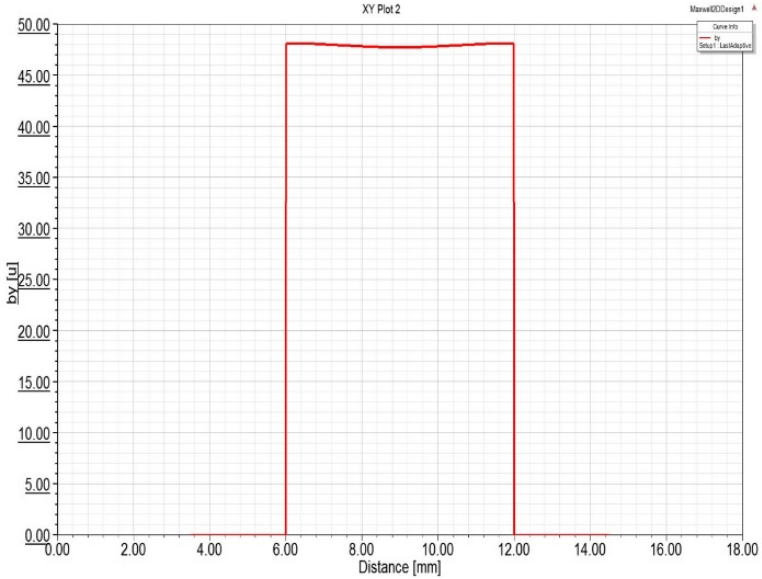
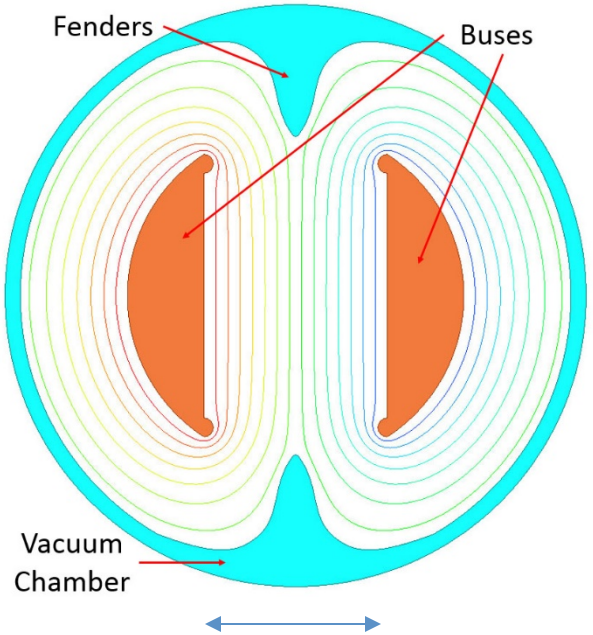
AR-SR Swap-Out Kickers



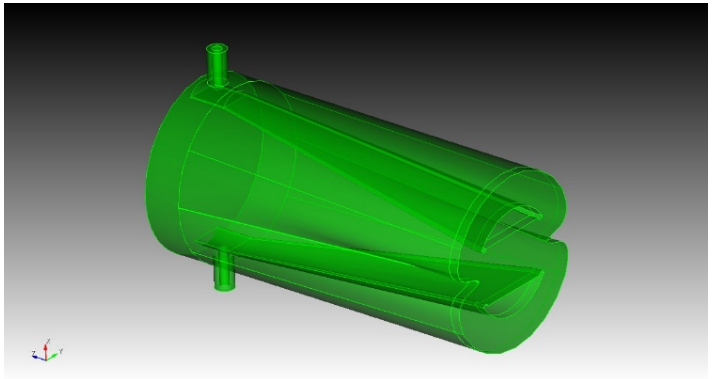


Fenders are used to better match the odd mode impedance of 50 Ω and the even mode impedance of 64 Ω.



Magnetic gain in T/A.

Magnet buses and fenders are tapered at the ends so that both modes are 50 Ω.



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ALS-U Swap-Out Kicker Requirements & Specifications

Parameter	Value
Beam Energy	2 GeV
Bend Angle	3.5 mrad
Magnetic Length	2 m
Aperture	10×6 mm (H×V)
B Field	5.83 mT
E Field	1.75 MV/m
Rise/Fall Time	<10 ns
Pulse Width	50 ns
PRF	1 Hz
Inter/Intra Pulse Ripple	<10/1 % FS

Kicker System Requirements

Parameter	Value
System Impedance	50 Ω
Magnet Current	± 106 A
Magnet Voltage	± 5300 V
# of Adder Cells	8
# of MOSFETs/ Cell	8

Kicker Modulator Requirements

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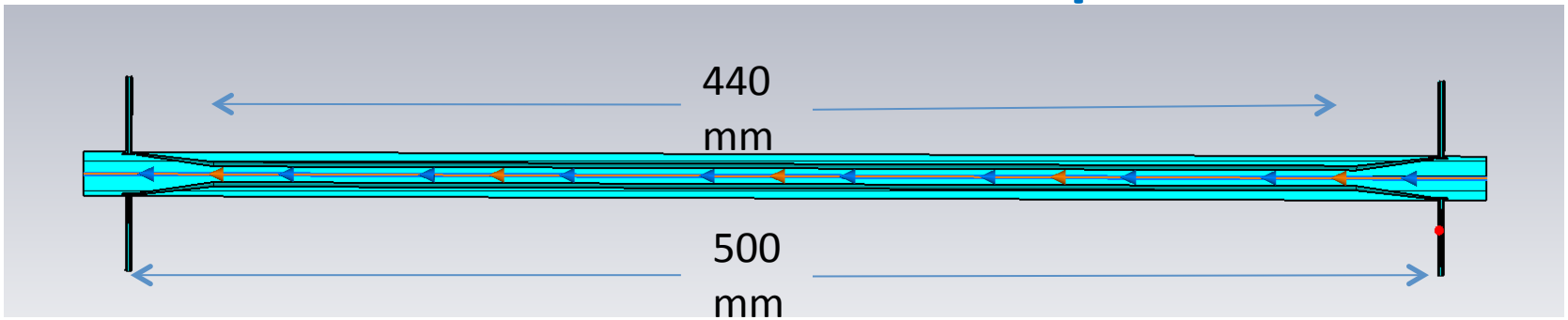
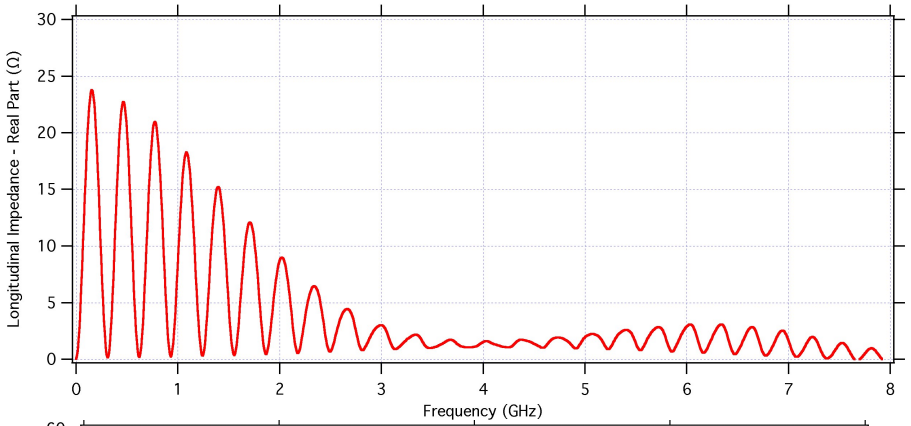
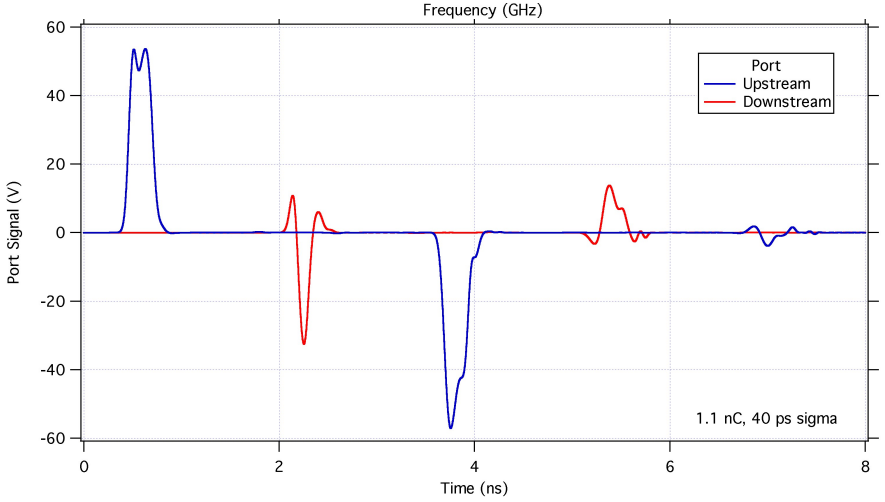
Calculated Beam Impedance



Longitudinal wake impedance.



|E| at magnet terminals.



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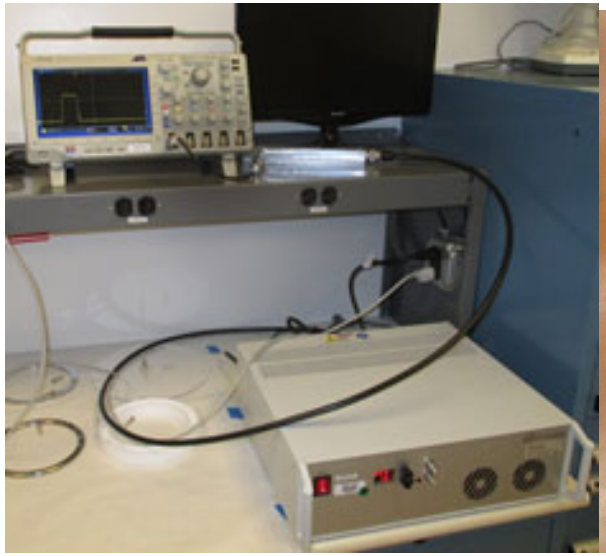
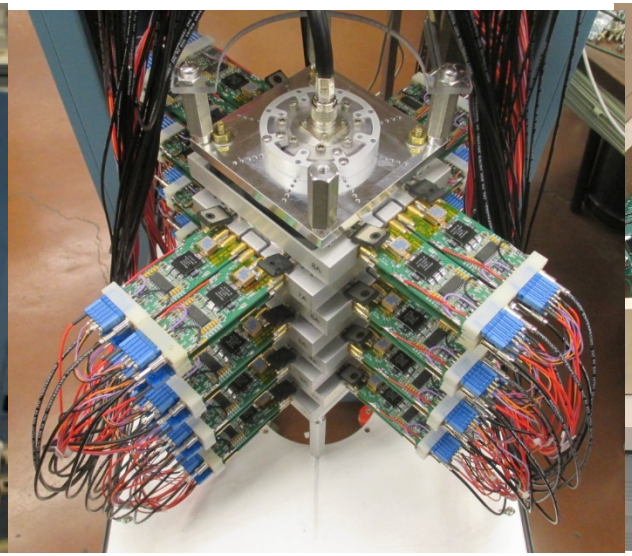
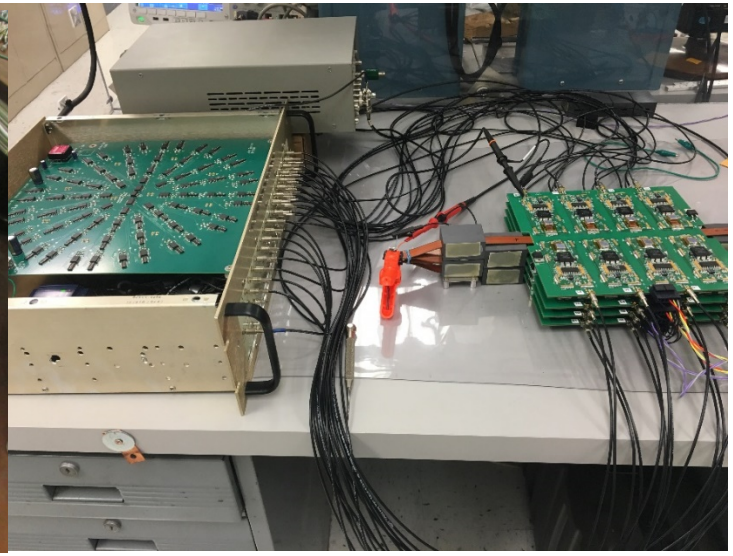
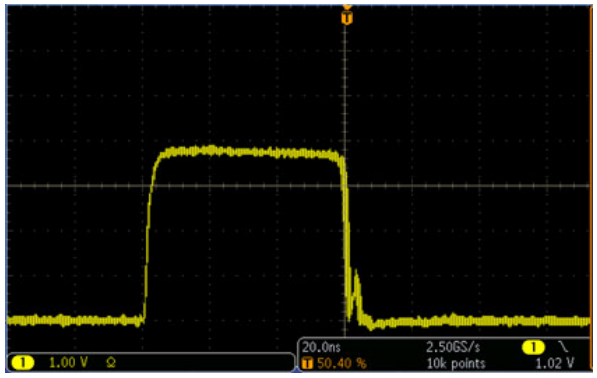
Modulator Options

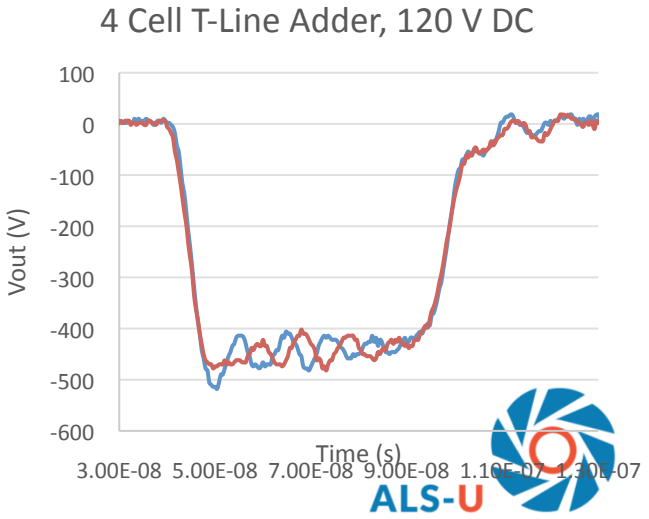








Modulator considered were a LBNL designed inductive adder and a transmission line adder, and a pulser from FID. The inductive adder and the FID pulse mostly met requirements, the transmission line adder had problems with ringing.



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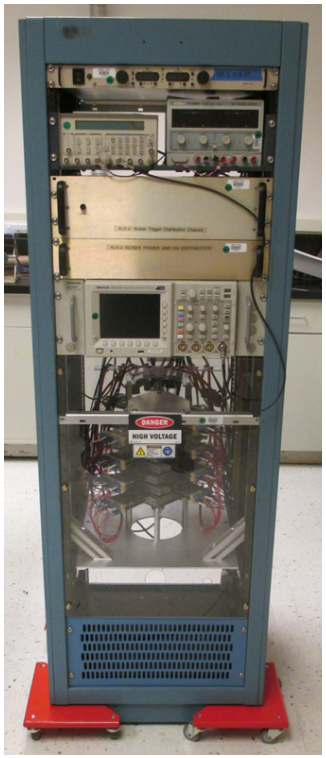
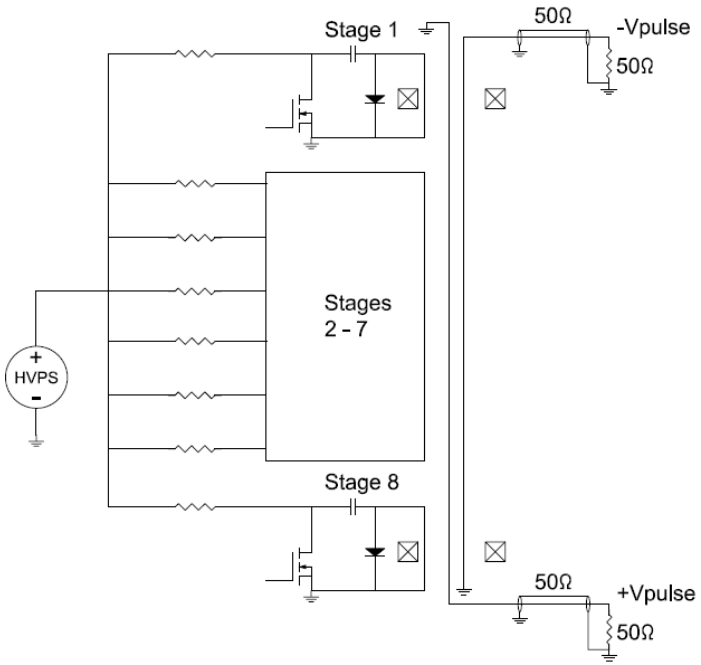
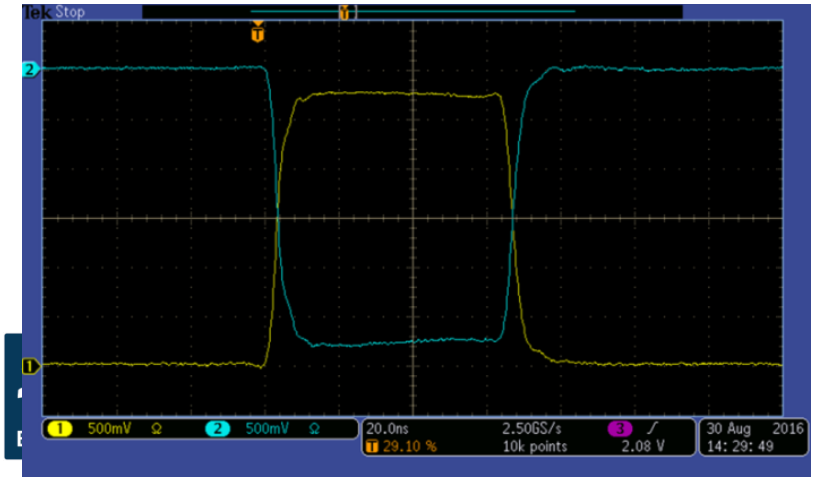
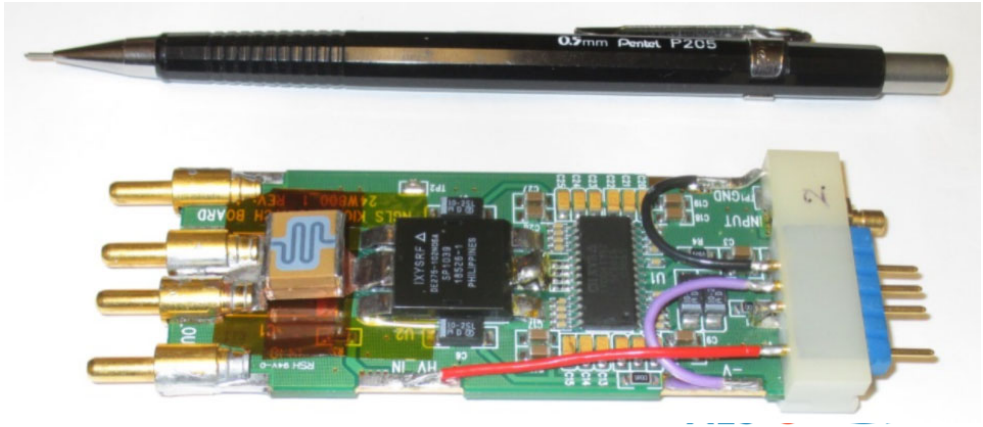
The Inductive Adder



Bipolar inductive adder using RF power MOSFETs and ferrite cores. Eight induction cells, each with eight parallel MOSFETs. In the future, we plan to add more cells and MOSFETs for redundancy and performance.

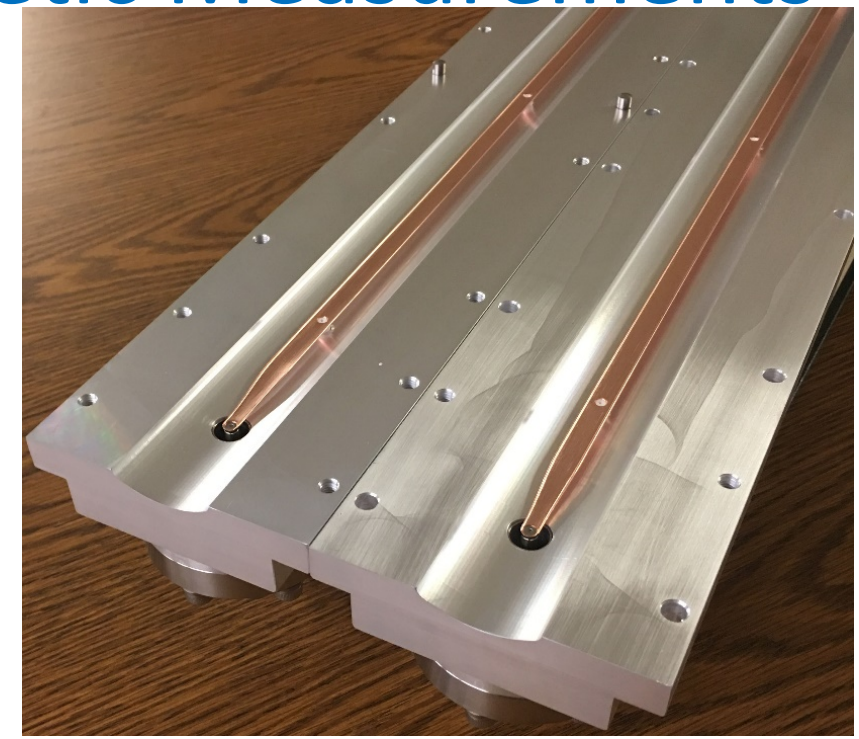




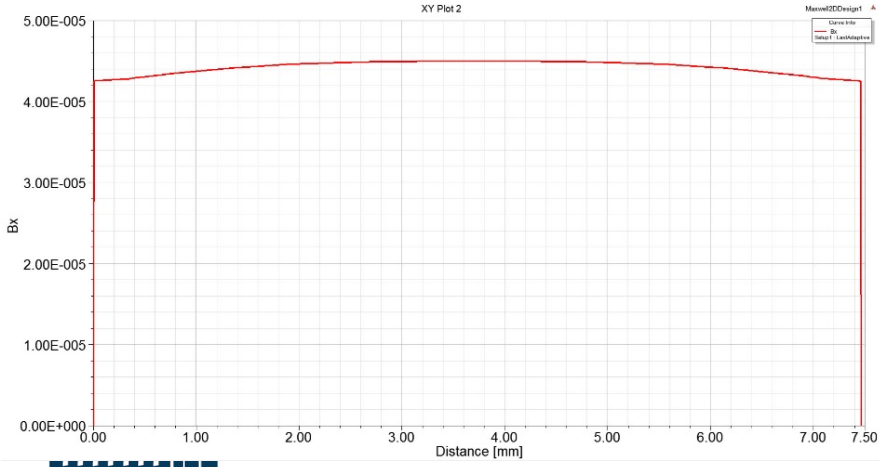


Cold Model & Magnetic Measurements

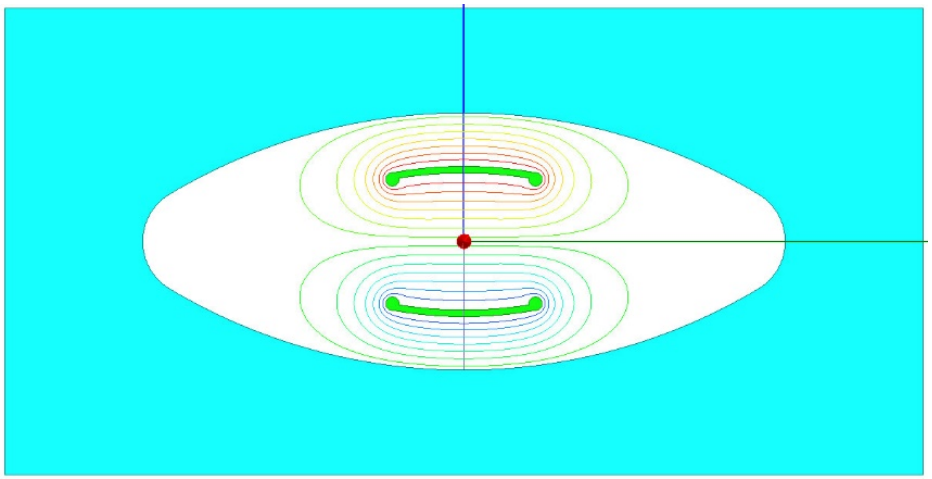
Non-vacuum “cold model” was built to measure field quality, magnet impedance, beam impedance and beam induced voltages.



Z_{Odd} = 50 Ω
Z_{Even} = 75 Ω



Field across center of magnet in T/A.



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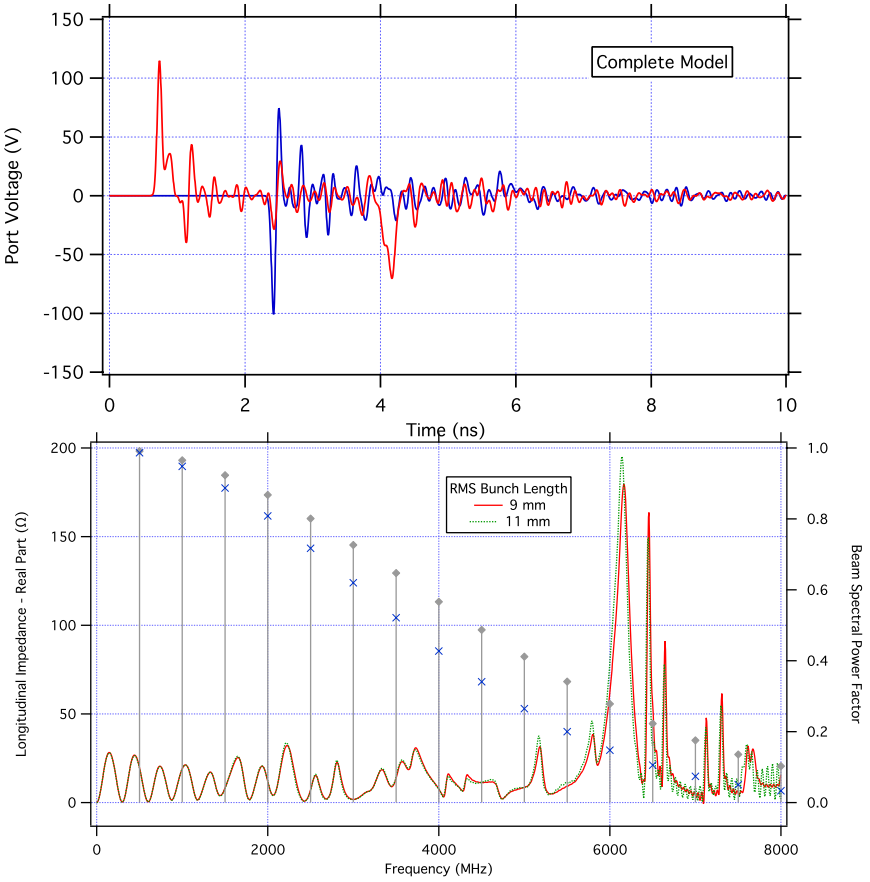
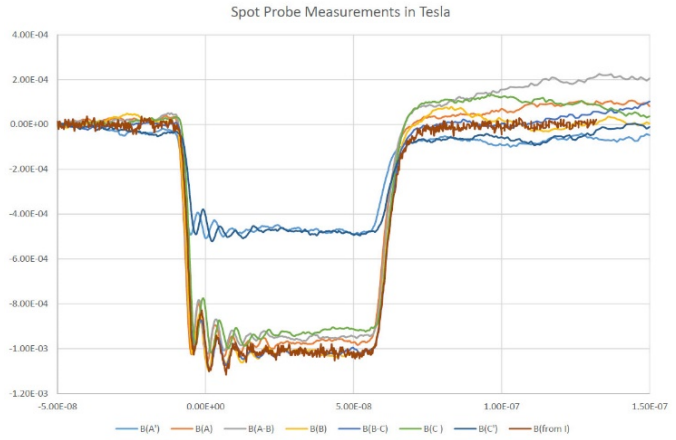
Cold Model Impedance and Field Measurements

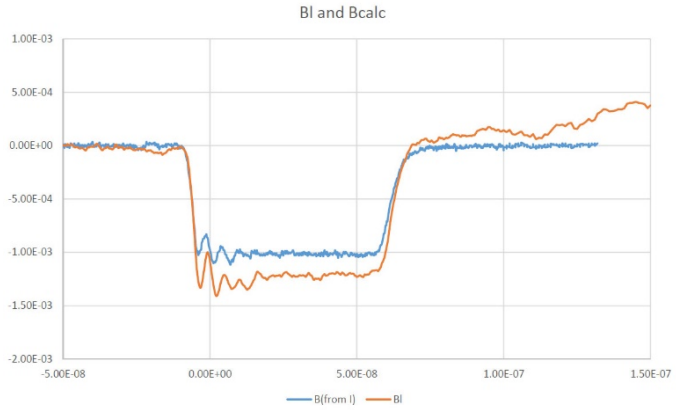


Calculated voltage at magnet terminals, and longitudinal impedance.

Spot B-dot probe at different locations along the magnet, and the calculated field from the drive current.



Integrating B-dot probe measurement and calculated field from drive current. Difference is **E** field coupling.



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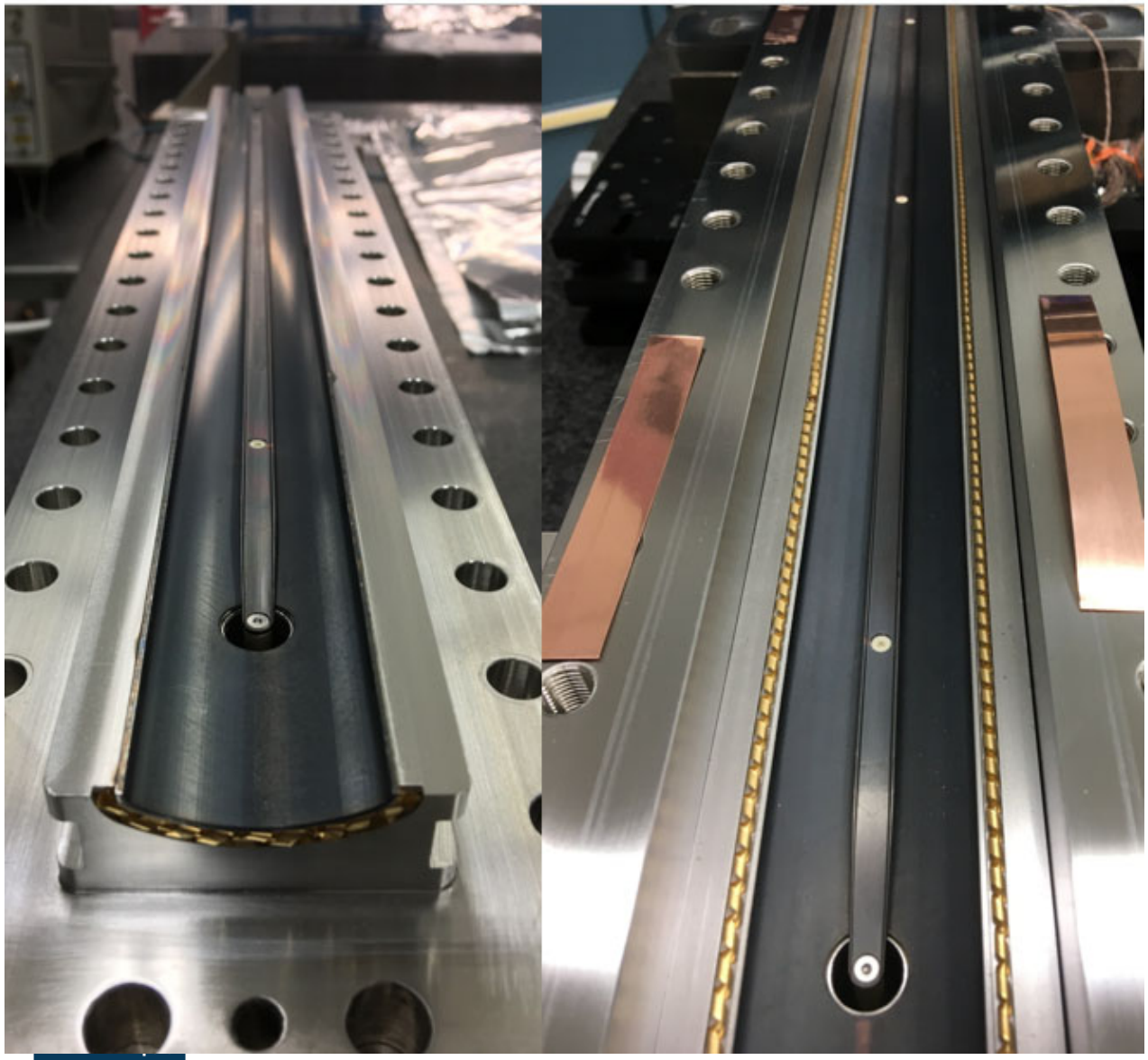
DOE Fast Kicker

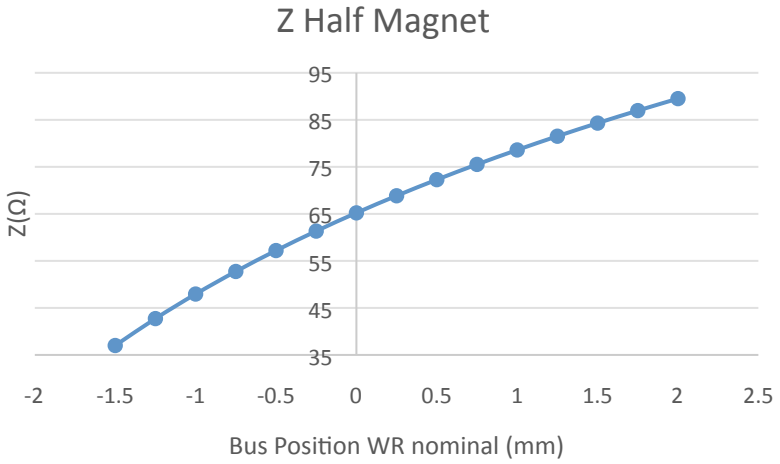


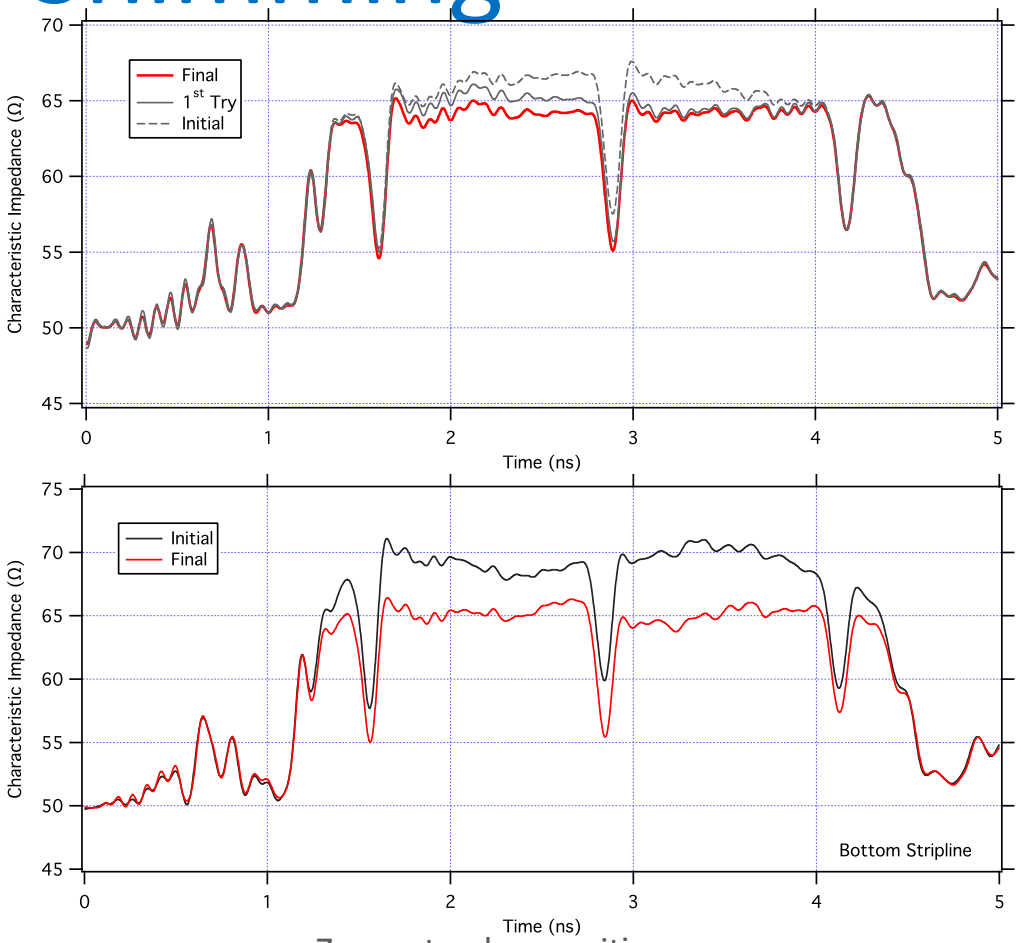
Magnet was designed for installation at ALS to test a stripline kicker system with small aperture (6 mm between buses). Vertical kick due to large horizontal beam emittance.

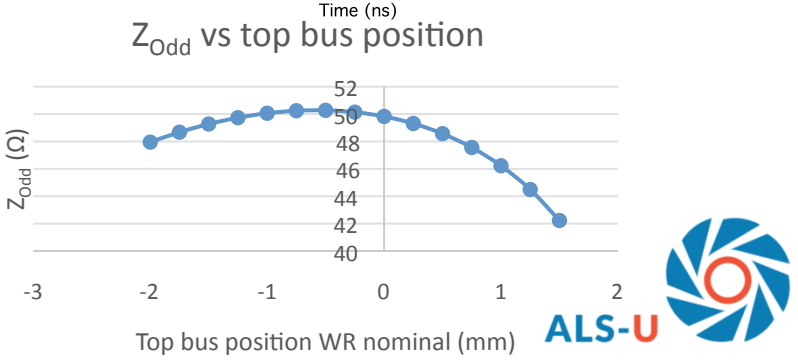
The inductive adder was installed to drive the magnet.

Magnet Shimming

To correct for mechanical tolerances, provisions were made to install various thin washers under the ceramic post to adjust the height of the buses. EM calculations were made of various bus heights to compare with TDR measurements to predict the amount of shimming required.







We also used a “mirror plane” to measure the Odd mode impedance.

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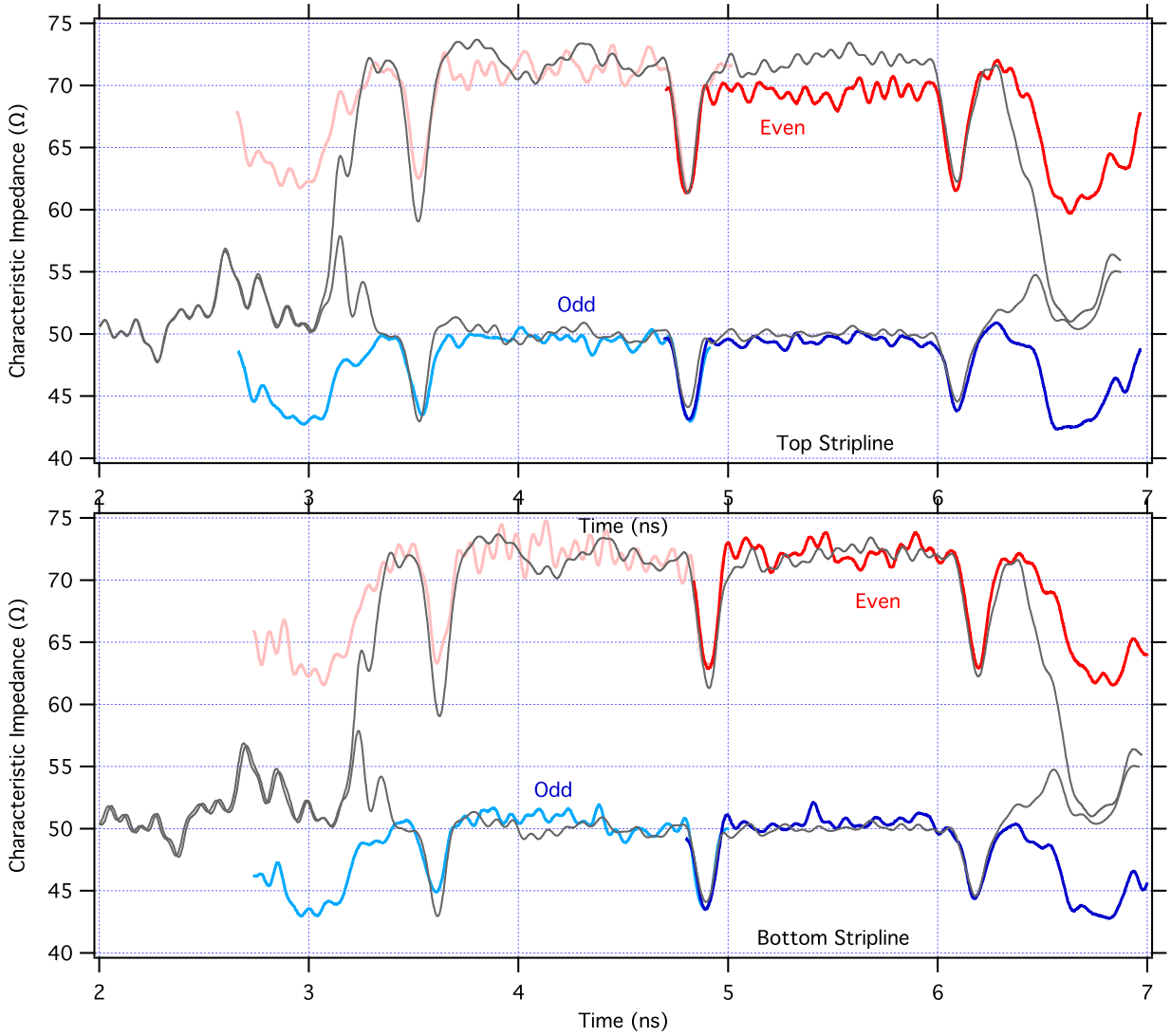
Impedance Verification

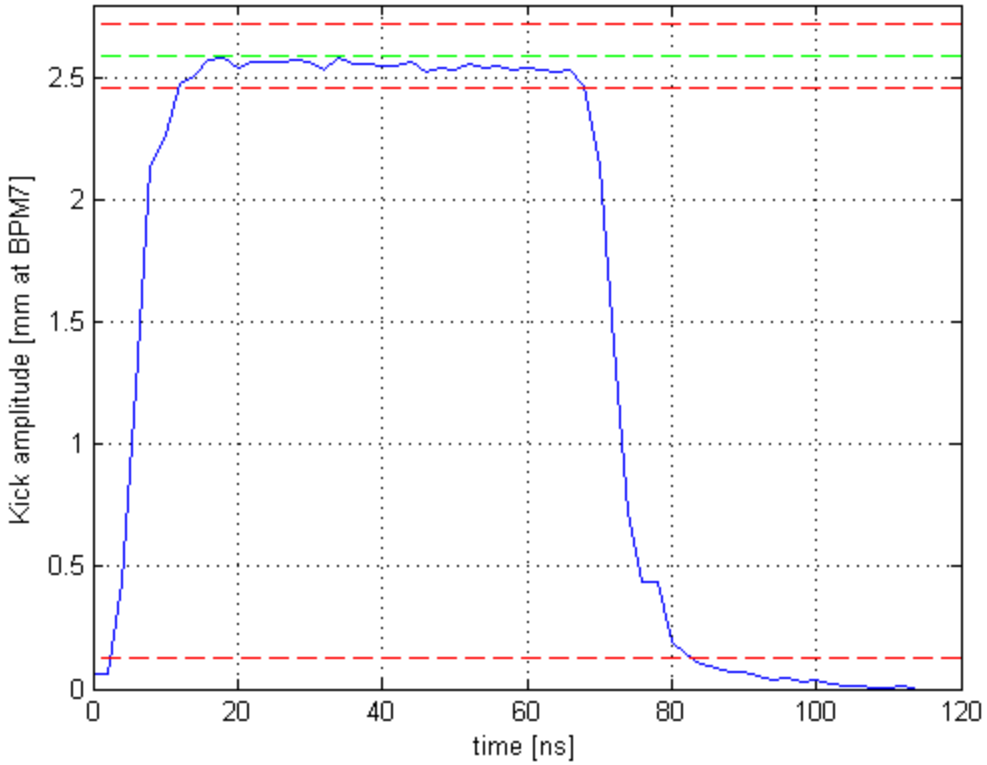


After assembling the two halves, we can calculate the Even and Odd modes by using the TDR to measure the impedance of one bus with the opposite bus both shorted and open.

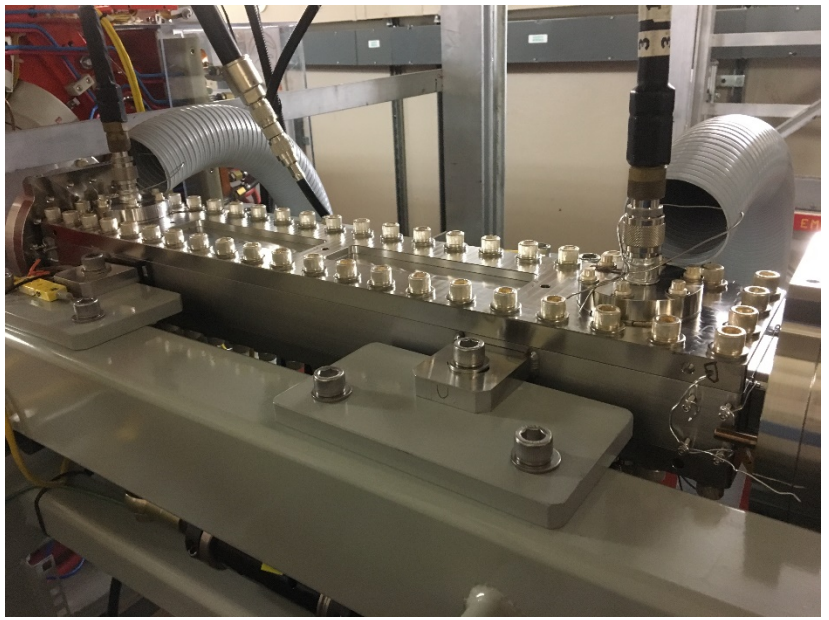
The technique is not valid for the first third of the magnet because the feedthrough opposite the TDR connection acts as a stub. Taking measurements from both ends give the full magnet impedance.

$$Z_{even(odd)} = Z_{open} \pm \sqrt{Z_{open}(Z_{open} - Z_{short})}$$

ALS Installation and Commissioning



Kicker pulse measured with a BPM in Sector 7.



Magnet Installed at the end of ALS-SR Sector 2.

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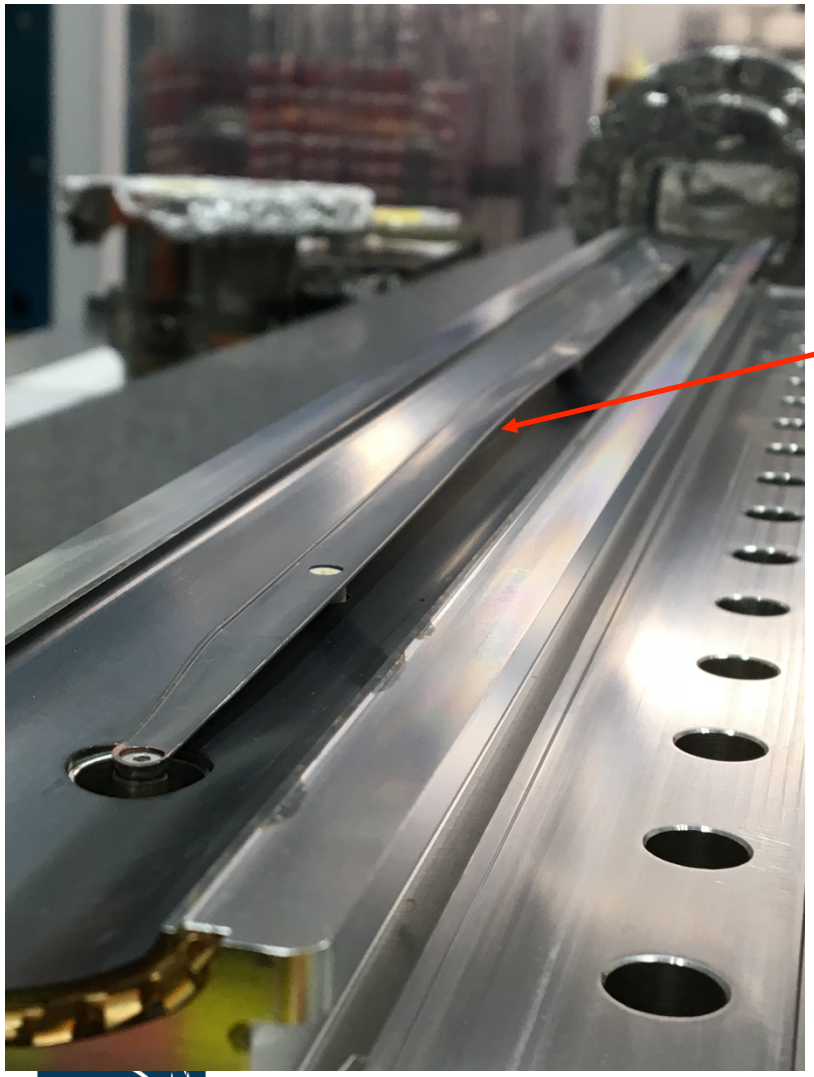
Redesign of DOE Kicker Buses



During ALS start-up in March, the current was run up to 500 mA without engaging the 3rd harmonic cavities. This was a condition we never anticipated during the design, and caused one of the buses to warp.

A thicker bus was designed as well as having more compliance in the expansion joints. The magnet is being reinstalled this week.

In addition, a power meter is being installed at the load to act as an interlock if it detects too high of power (should only be dangerous in multibunch mode over several hundred mA).

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Swap-Out Kicker Status

- A prototype magnet and power supply were built and installed at ALS, which demonstrated most of the key parameters needed for ALS-U.
- We plan to continue testing the magnet and power supply at ALS to gain experience with magnet heating, beam induced voltages, and reliability.
- Next step is to build a magnet for the smaller ALS-U emittance, and a modulator with built in redundancy.

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ALS-U

Conclusions

- The prototype stripline kicker (DOE) and inductive adder have proven to work as designed. We now have confidence we can deliver a system for swap-out injection for ALS-U.
- The non-linear kicker is progressing more slowly since it is not required for either ALS or ALS-U operation. We need to demonstrate an injection efficiency over 90 % for success.
- A NLK systems is planned for ALS-U, still developing requirements.

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