A Beam Spreader for LCLS-II

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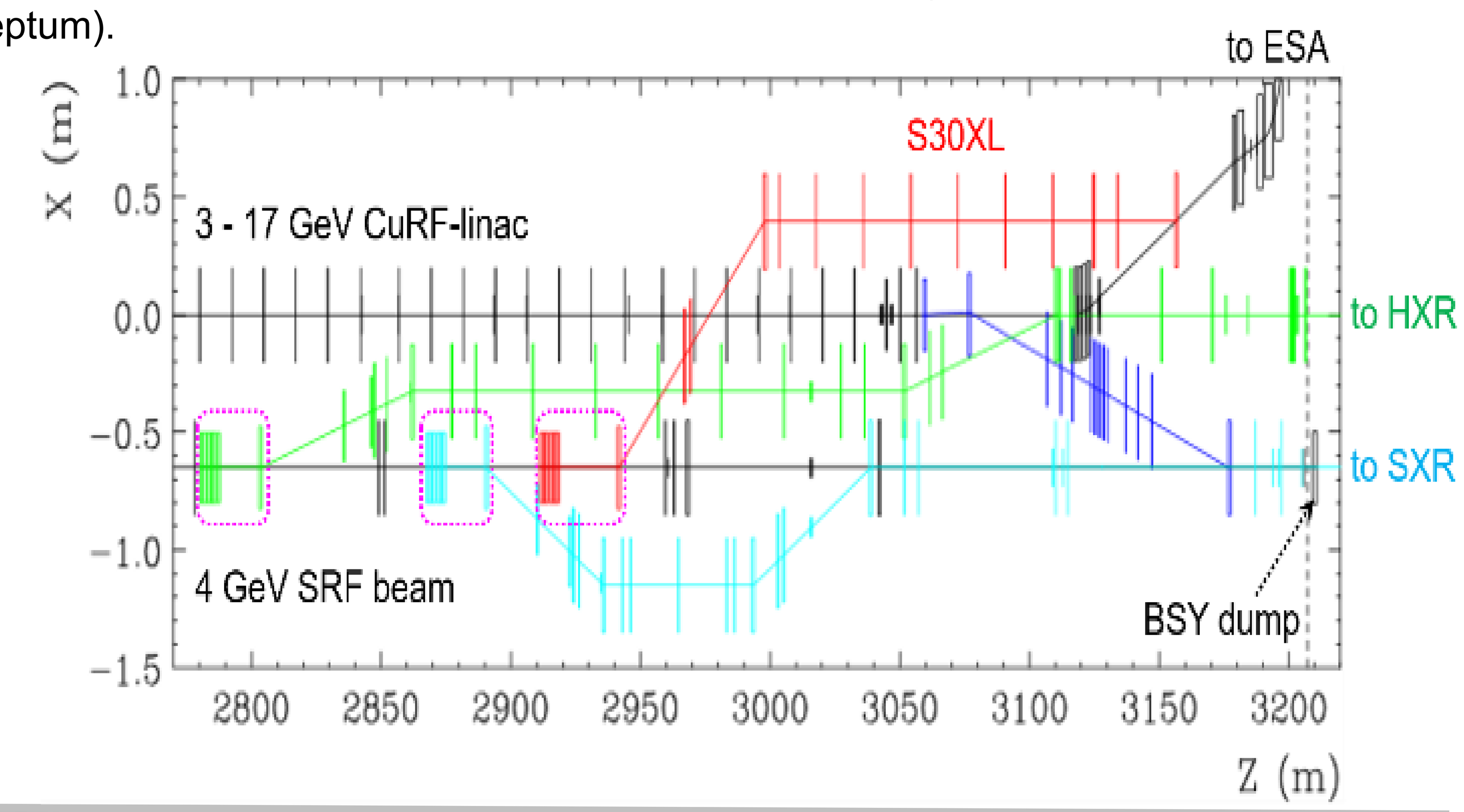
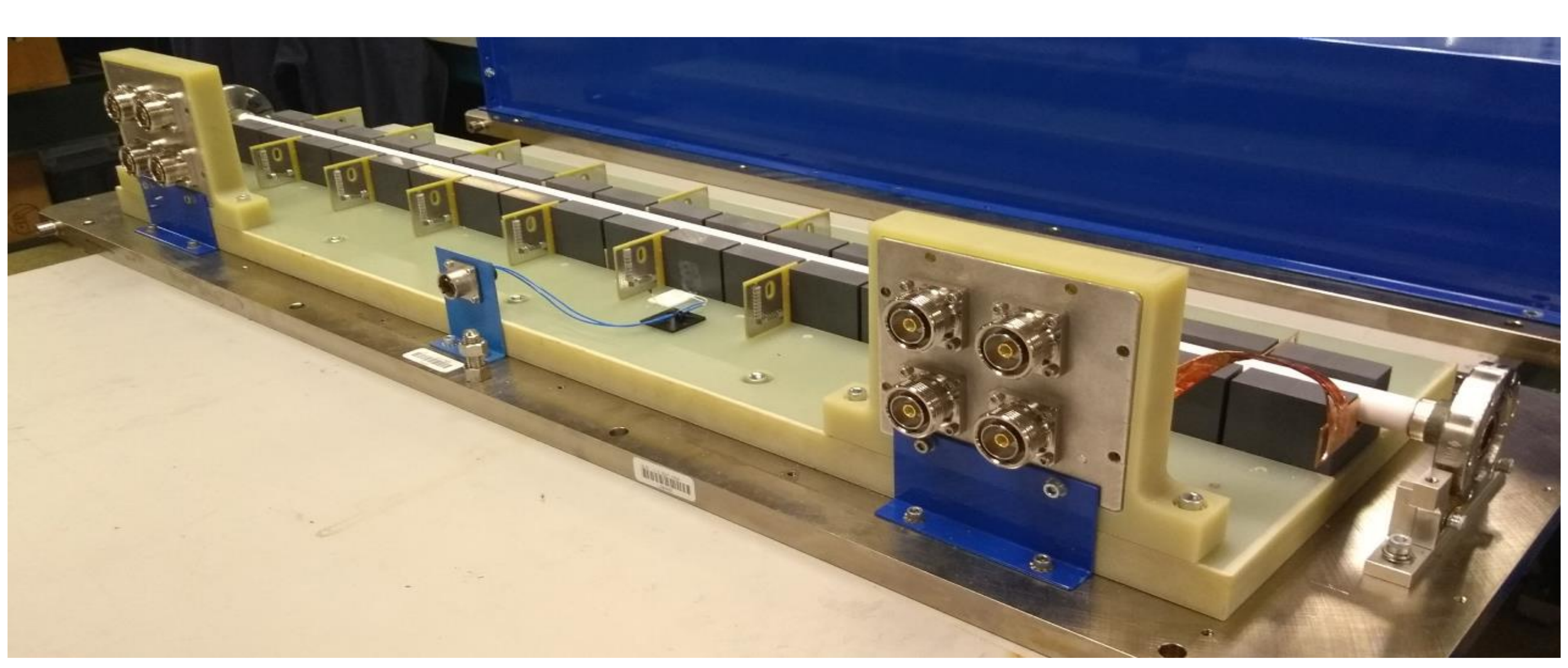
Beam Transport to Undulators via Spreader

- A Superconducting RF (SRF) linac generates a 4 GeV electron beam with a continuous bunch rate of 929 kHz.
- The spreader system steers bunches to a hard X-ray undulator, a soft X-ray undulator, or a beam dump.
- Each undulator requires a dedicated beam diverter composed of three kickers and a pulsed septum.
- Kickers pulse simultaneously to kick beam vertically by 15 mm into the high field region of the septum where they are strongly steered towards the designated undulator.
- A proposed third diverter will kick micro-bunches spaced between the main 929 kHz bunches to the S30XL (formerly DASEL) transfer line towards End Station A (ESA).
- The CuRF-linac, operating at 120 Hz, also has capability to steer beam to either undulator or ESA via slow kicker based beam diverters (in some case combined with a septum).

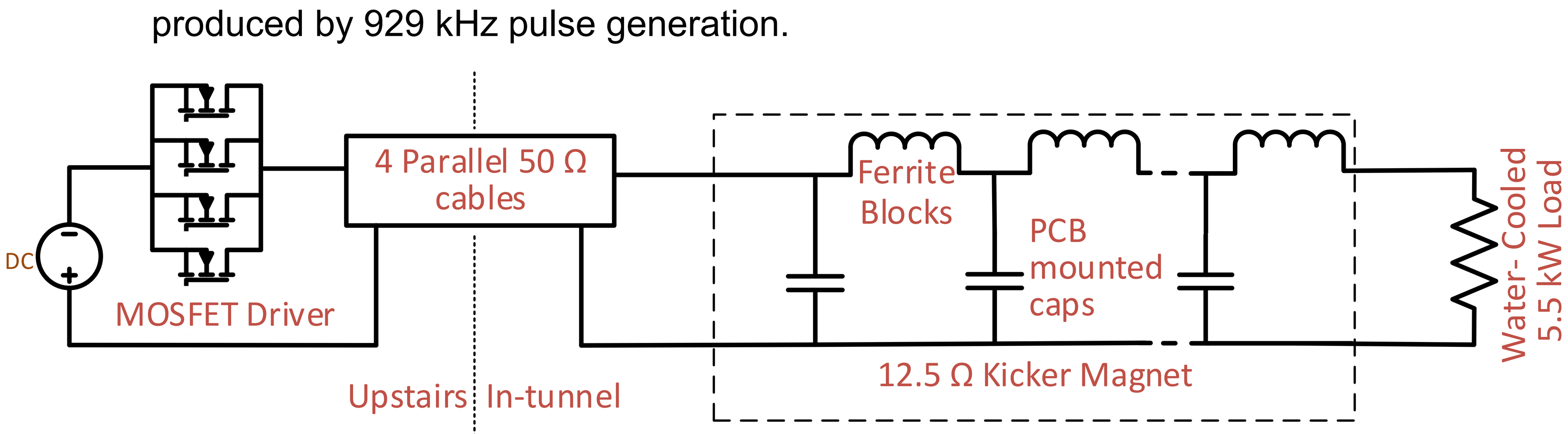


Kicker Design

- Three kickers pulse simultaneously to displace beam at face of septum by 15 mm into the magnets high field region.
- Each kicker is required to generate 4 m-Tm of field at 929 kHz.
- Magnet and load in tunnel while driver electronics located upstairs to decrease MTTR.
- To minimize the field energy and maintain low voltage a ferrite loaded magnetic kicker topology was selected.
- 18 ferrite blocks enclose a ceramic UHV beampipe. Capacitors (mounted on a PCB), are placed longitudinally between the blocks and connect between the supply and return busbars.



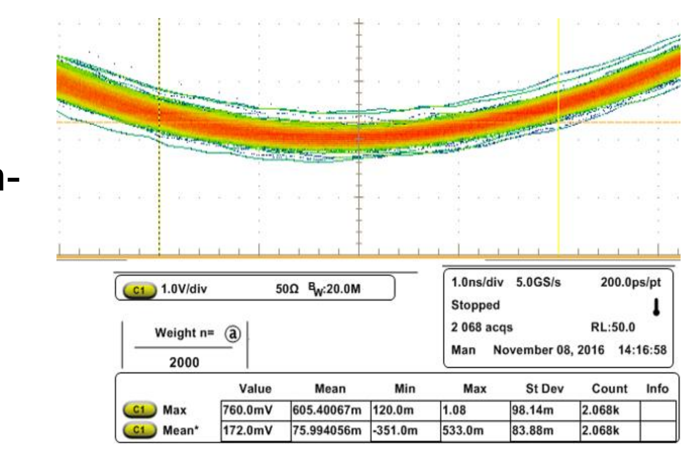
- Combined, the capacitors and ferrites, form a lumped element transmission line that is matched to the cable impedance. This reduces ringing in the system.
- The kicker operates at 900V into 4-parallel 50 ohm cables to match a 12.5 Ω magnet impedance which is terminated into a resistive load capable of absorbing the 5.5 kW produced by 929 kHz pulse generation.



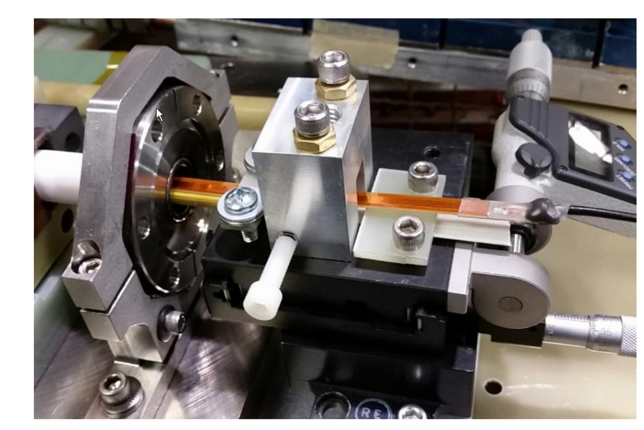
- For use in the S30XL, to divert low charge beam spaced in between the 929 kHz LCLS-II bunches, it is possible to extend the pulses to 525 ns (and perhaps higher).
- For this case, 6 kicker magnets are used at 75% B-field amplitude (compared to the undulator kickers). In this application two magnets can be placed in series and terminated into the same resistors.
- Given the long pulses, each kicker and load must have 3.8 times the power handling capability which can be met by increasing prime DC power and paralleling more transistors and load resistors.

Kicker Results

- Reliable operation at 4 mT 500 kHz CW has been demonstrated.
- Stability of the pulse measured over several thousand non-consecutive pulses by using an offset amplifier to zoom in on the load voltage.
- Load stability better than 101 ppm at all rates. Given that this noise is random, the stability of three kicker systems should improve by sqrt(3).
- Long term stability (minutes and longer) will be corrected with beam based feedback.



- Bdot measurements were integrated to measure the transverse field quality. The Bdot probe was moved with +/-1 mm horizontal and vertical offsets from the center of the magnet. In the worst case the variation from the center was 0.21%.



- In order to not perturb following bunches the field must quickly decay to zero by the time the next bunch arrives, 1.1 μs later.
- The voltage across the capacitor at each stage is measured (figure 1). This voltage is proportional to the current flowing in this stage of the magnet.
- In figure 2, all stage voltages are summed providing a quantity proportional to the magnetic field in the magnet.
- A special voltage clamping probe is used to zoom in on the base of the pulse at each stage. The waveforms are summed to produce figure 3, a zoomed in waveform that shows by the next pulse the field has decayed to ~131 ppm of the main pulse.

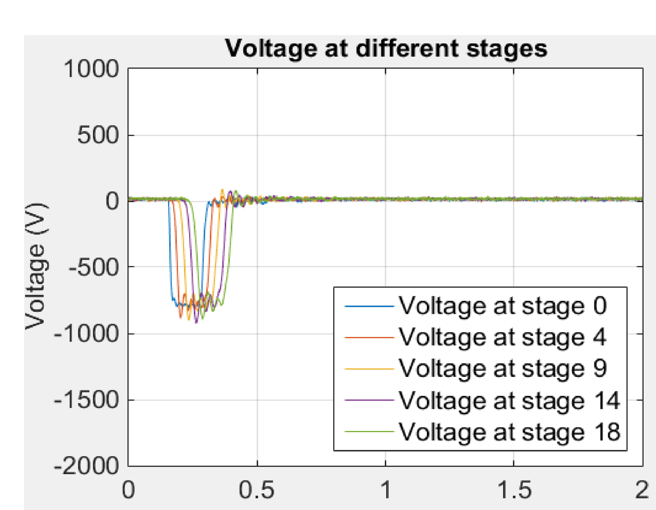


Figure 1

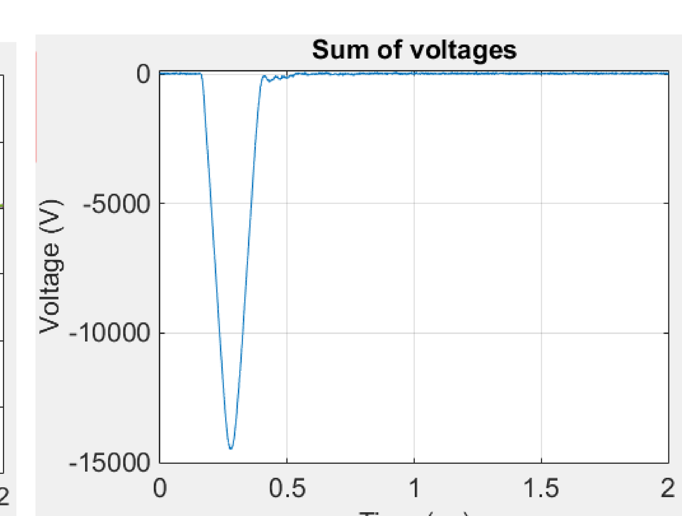


Figure 2

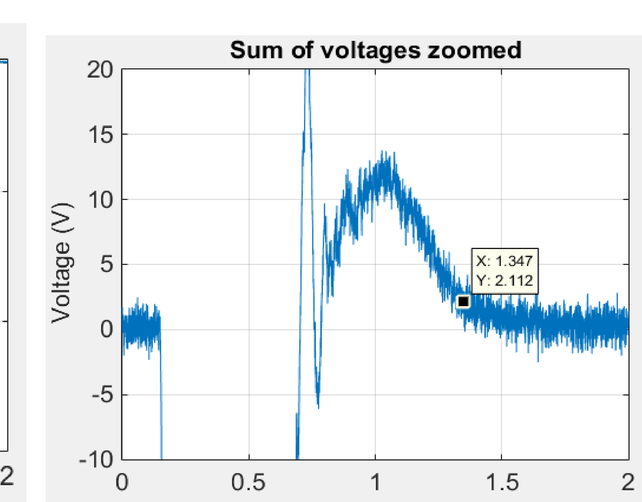
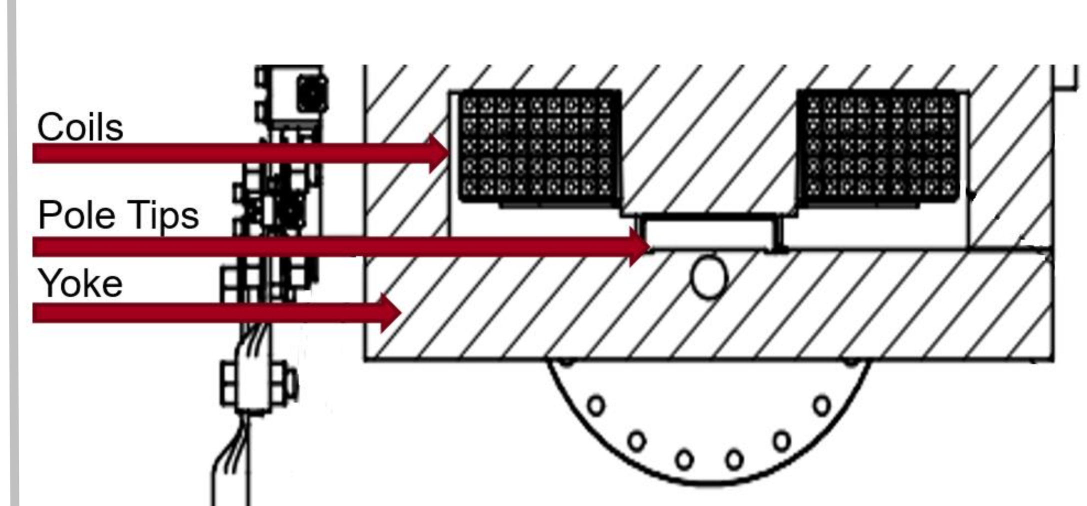


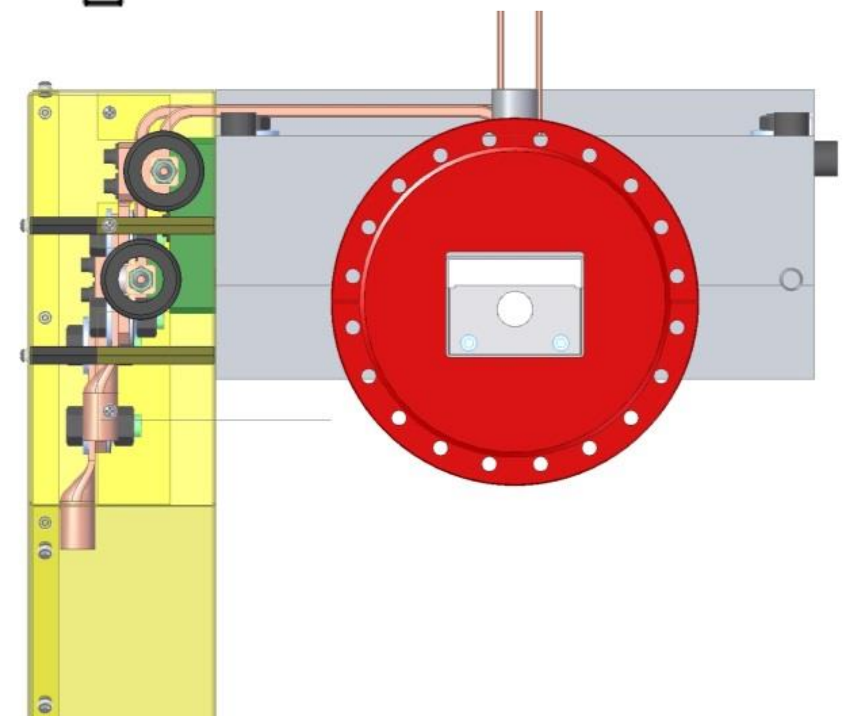
Figure 3

Septum

- Lambertson type septum. Sufficient for 10 GeV beam.
- In-vacuum pole enclosed by a vacuum chamber.
- Enclosed steel pole is plated with electroless NiB plating to minimize outgassing.
- The NiB plating can be applied uniformly and lacks undesirable ferromagnetic properties.



Parameter	Value	Units
Max. Integrated Field	3.689	kG-m
Trim Coil Range	+/- 2	%
Max. Quadrupole Field @ r = 5 mm	<0.05	%
Max. Sextupole Field @ r = 5 mm	<0.2	%
Max. Decapole Field @ r = 5 mm	<1	%
Magnet Gap	0.625	inches
Effective Length	1.03	m
Main Coil Max. Current	124	A
# of Main Coil Turns	45	turns
Trim Coil Max. Current	6	A
# of Trim Coil Turns	20	turns



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