SPEAR 3 Kicker Overview

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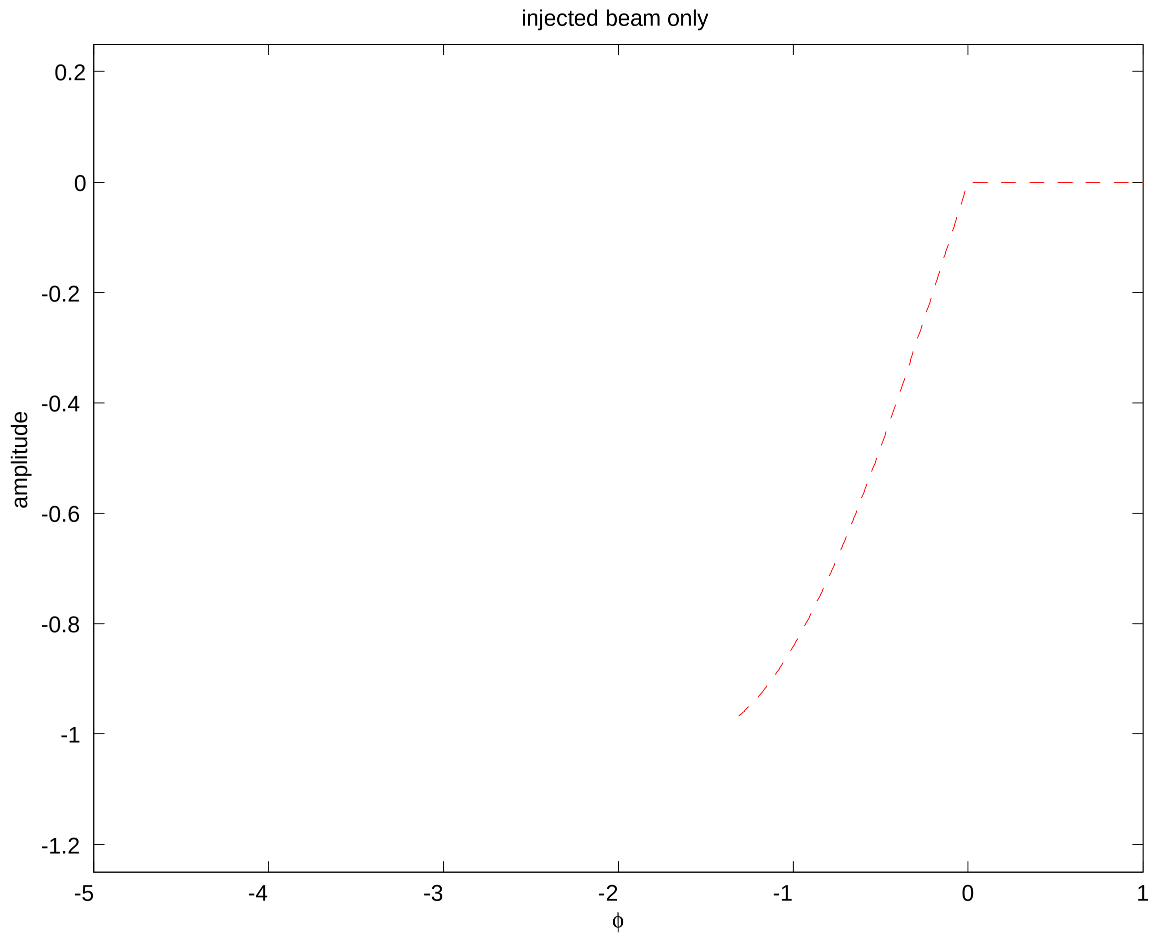
1 Outline

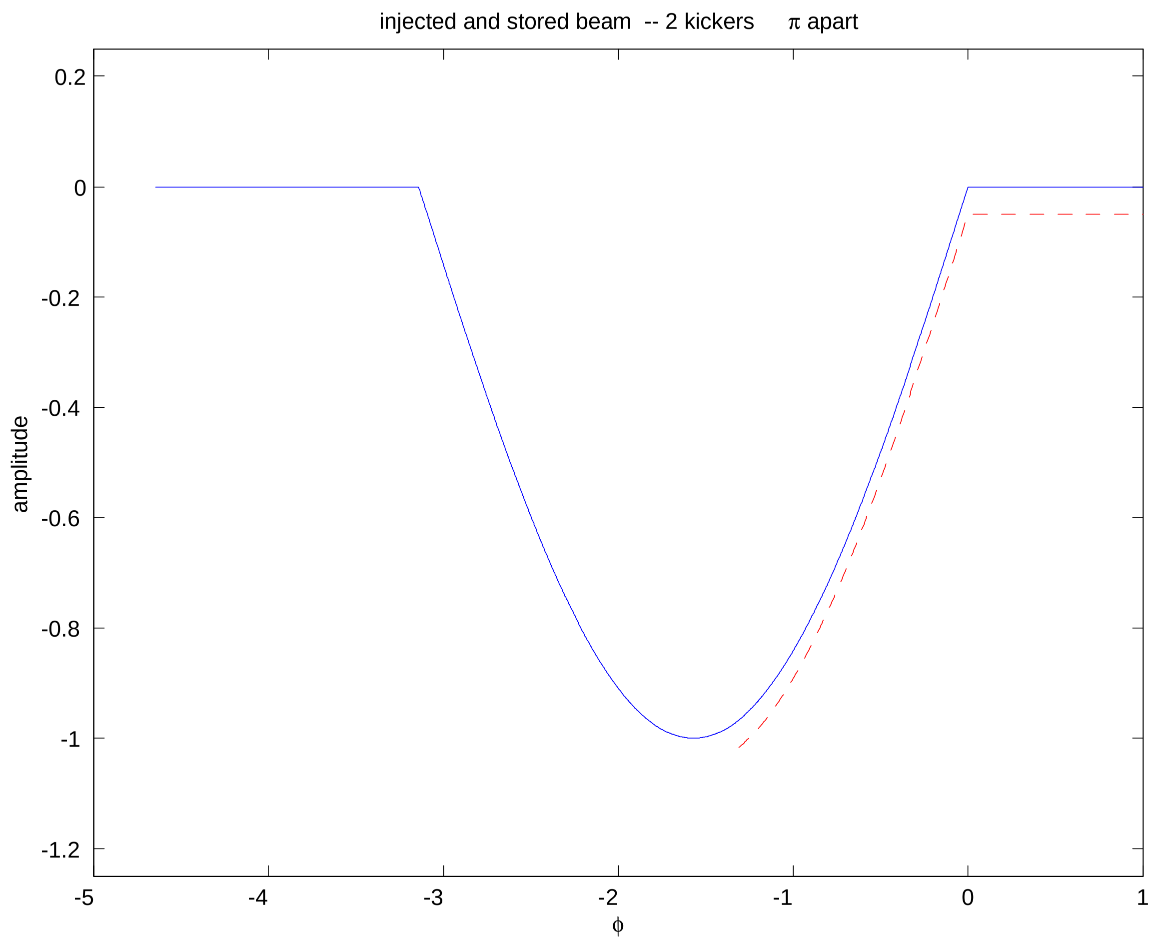
- Purpose of a kicker
- Desired kicker magnet characteristics
- Kicker magnet design
- Desired kicker pulser characteristics
- Kicker pulser design (brief)
- Kicker commissioning

2 Purpose

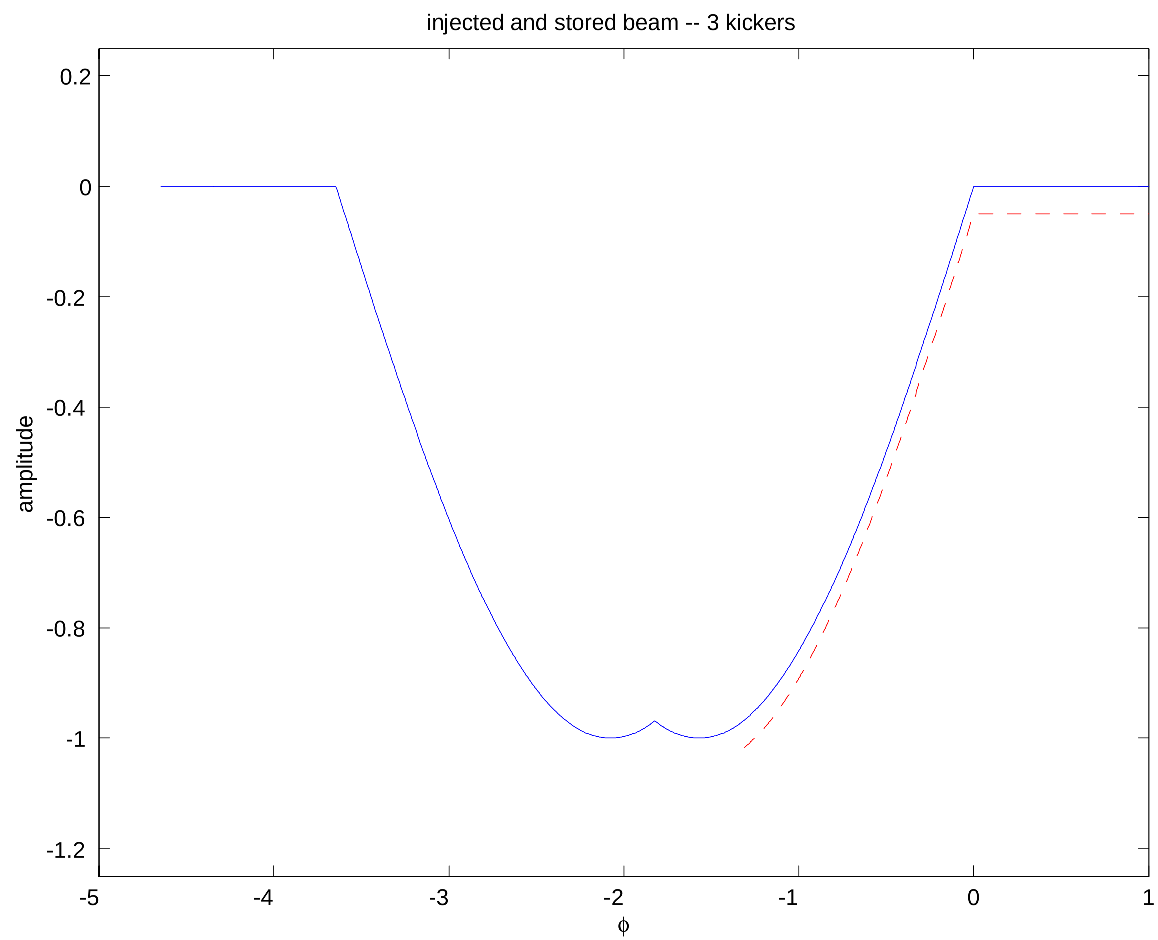
- Normal closed orbit determined by the lattice of static magnets (dipoles, quadrupoles, sextupoles)
- Injected beam does not follow the closed orbit
  - Septum, a static magnet, bends the injected beam close to closed orbit
  - Still far enough away from closed orbit that it is outside the aperture of the ring
  - Kicker gives a fast magnetic deflection to the injected beam to place it within the ring aperture



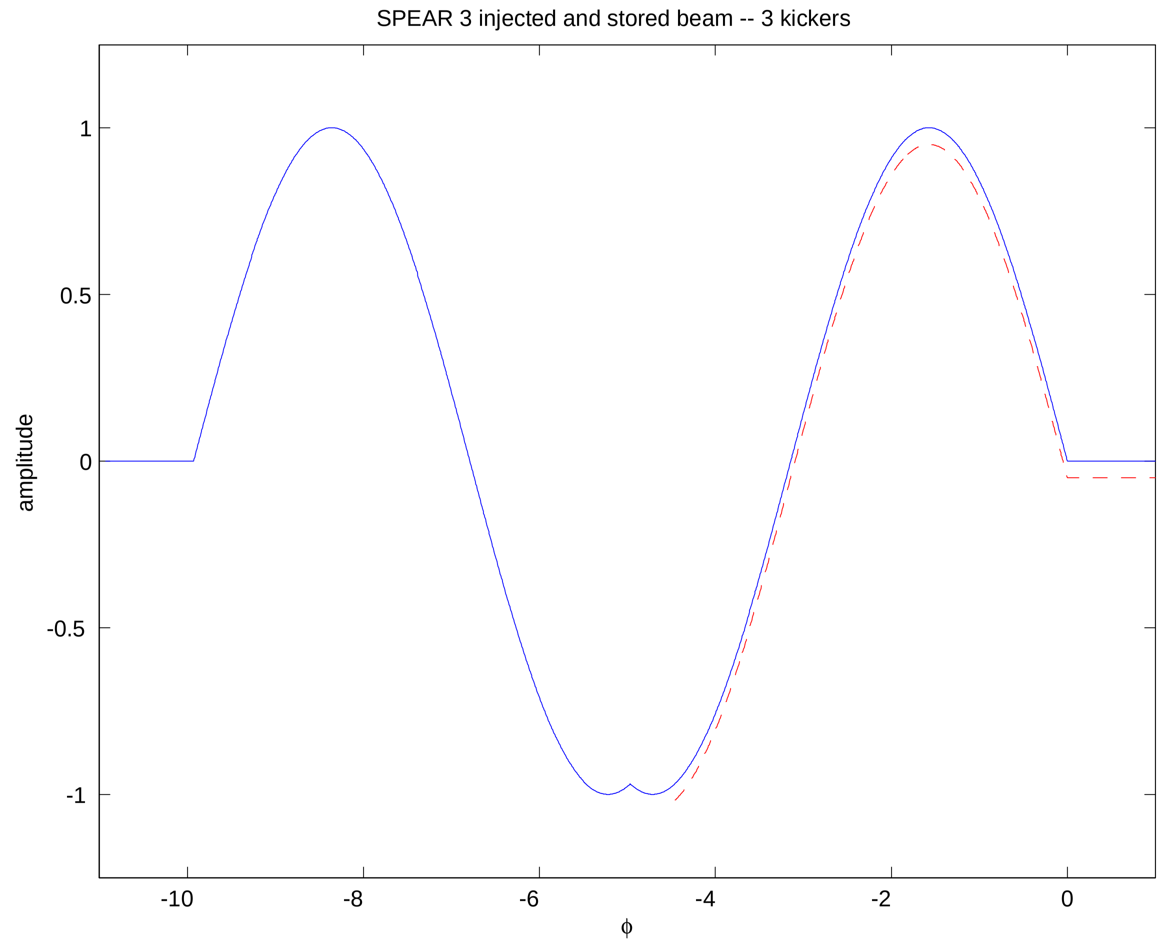
- Injection into Booster uses one kicker
  - Kicker magnet turns on before injection
  - Magnet is off before stored beam returns $(440\,\mathrm{ns}$ later$)$
- Note trajectory is displayed in normalized coordinates, so it is sinusoidal



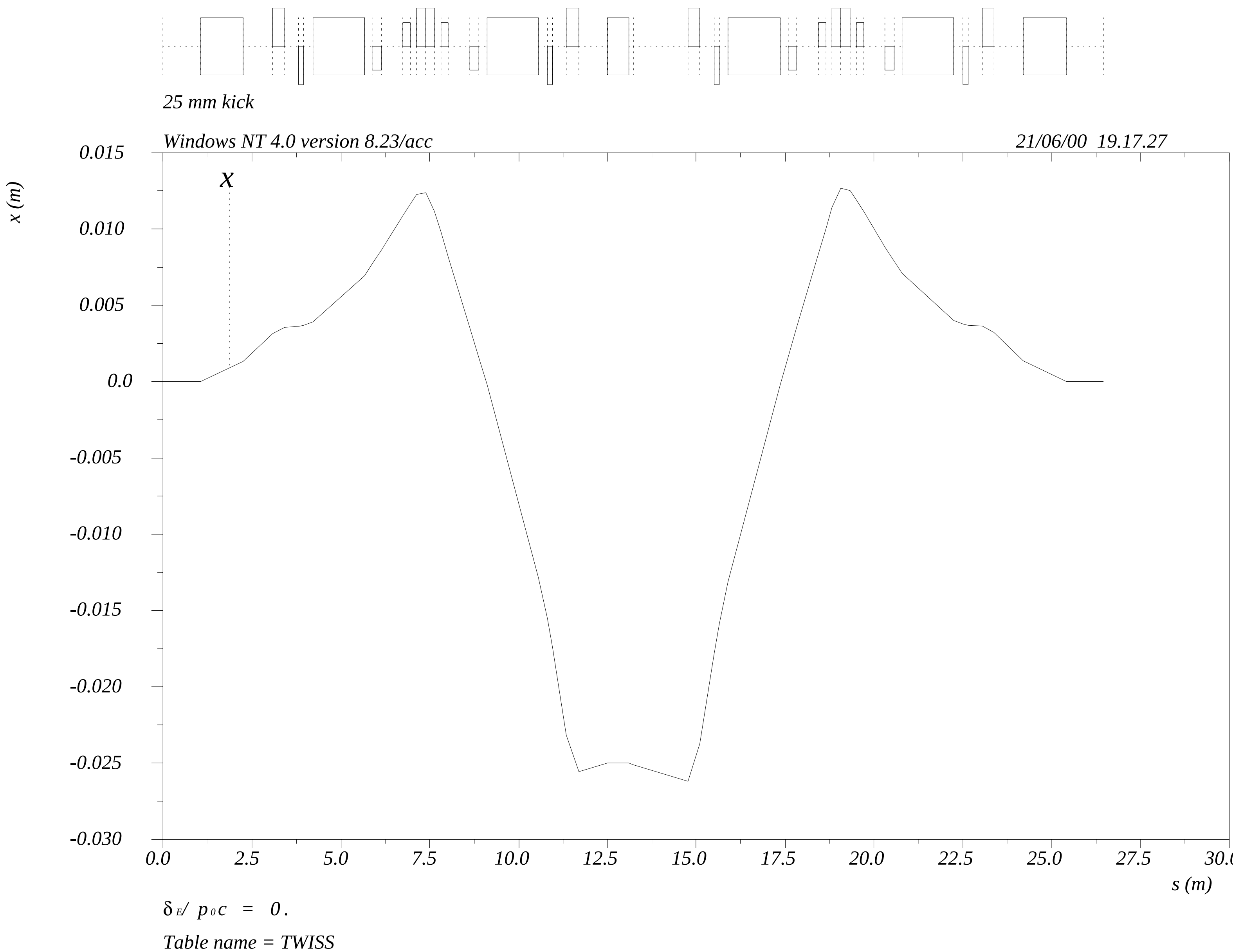
- Single kicker either stores injected beam or keeps stored beam, cannot do both
- Use two kickers placed π radians apart (in normalized coordinates)
  - First kicker displaces stored beam near trajectory of injected beam
  - Second kicker straightens both beams to within the machine aperture



- Cannot place kicker magnets exactly π radians apart
  - Physical constraints
  - Lattice flexibility
- Use third kicker as additional adjustment to “close the bump” for the stored beam



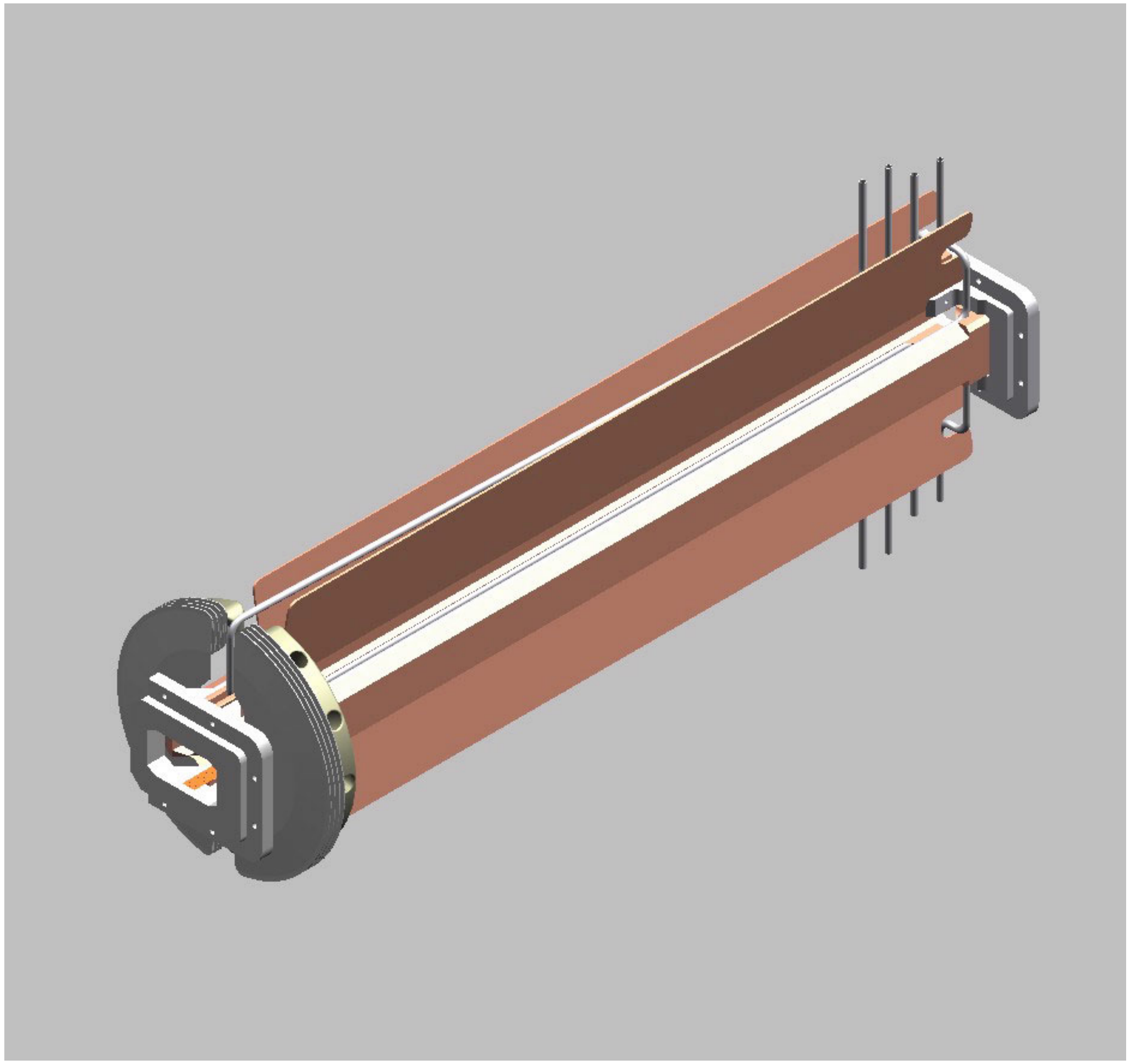
- SPEAR 3 cannot place kickers $\approx \pi$ radians apart because of physical limitation
- Kickers are placed $\approx 3\pi$ radians apart
- Beam returns to closed orbit within a few damping times $(\tau \approx 5\,\mathrm{ms})$



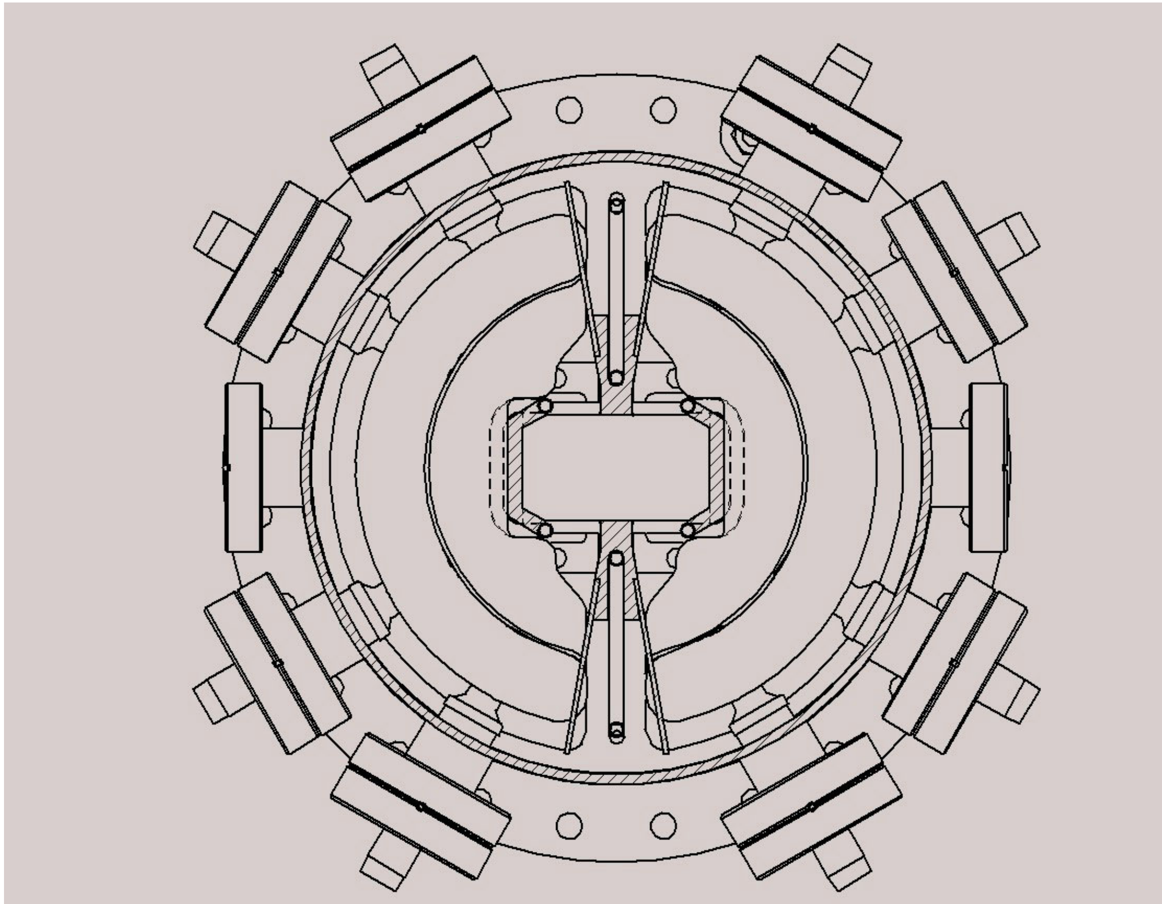
- MAD plot of SPEAR 3 25 mm kick trajectory of stored beam

3 Magnet Characteristics

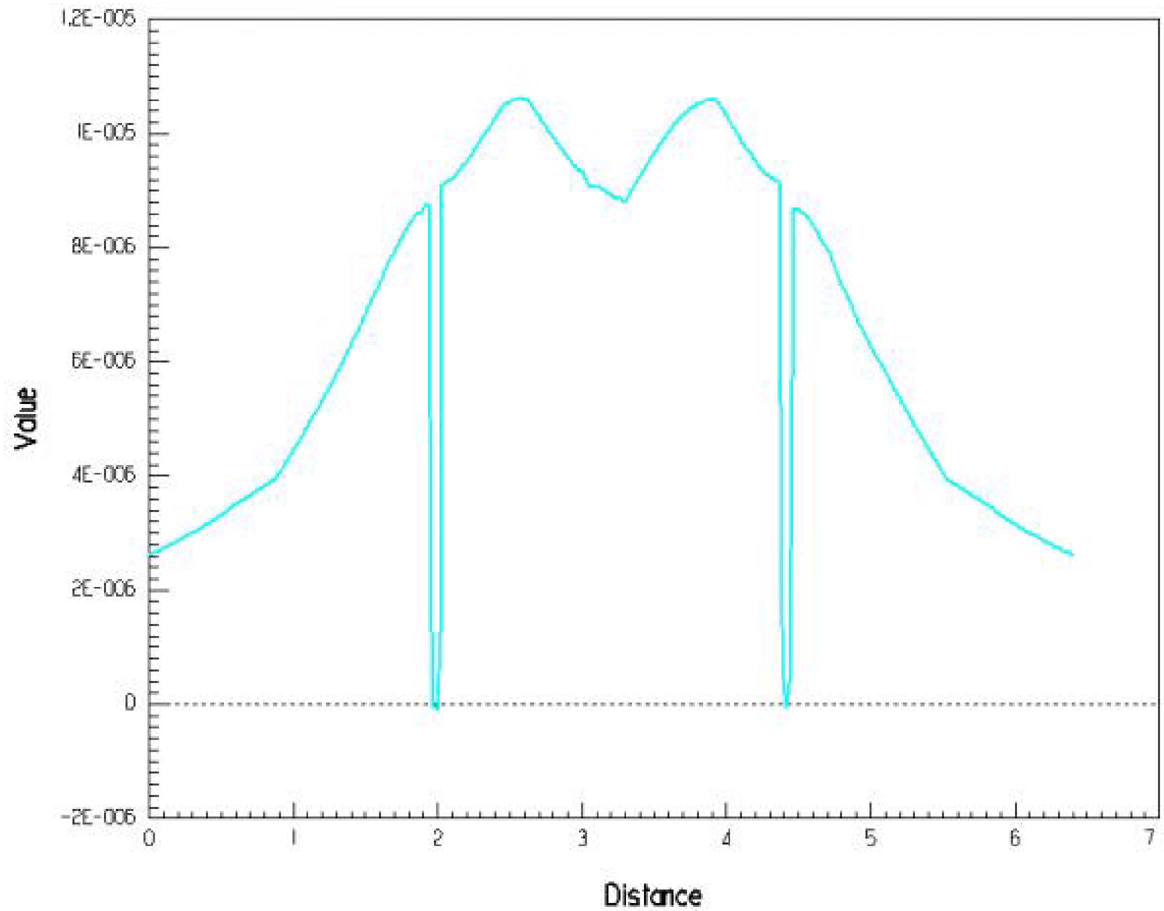
- Duty cycle of kicker extremely low
- Want it to be benign to stored beam after injection
- Beam impedance (Z)
  - High Z resonant structure can cause beam instabilities
  - High Z broadband structure degrades properties of bunch
- A student of K. Wille (DELTA) designed a low-impedance stripline kicker
  - Non-resonant
  - Low broadband beam impedance
  - No ferrites
  - Easy to fabricate



- Strips on top and bottom to carry image currents (minimize Z) at ground potential
- Current carrying conductors on sides



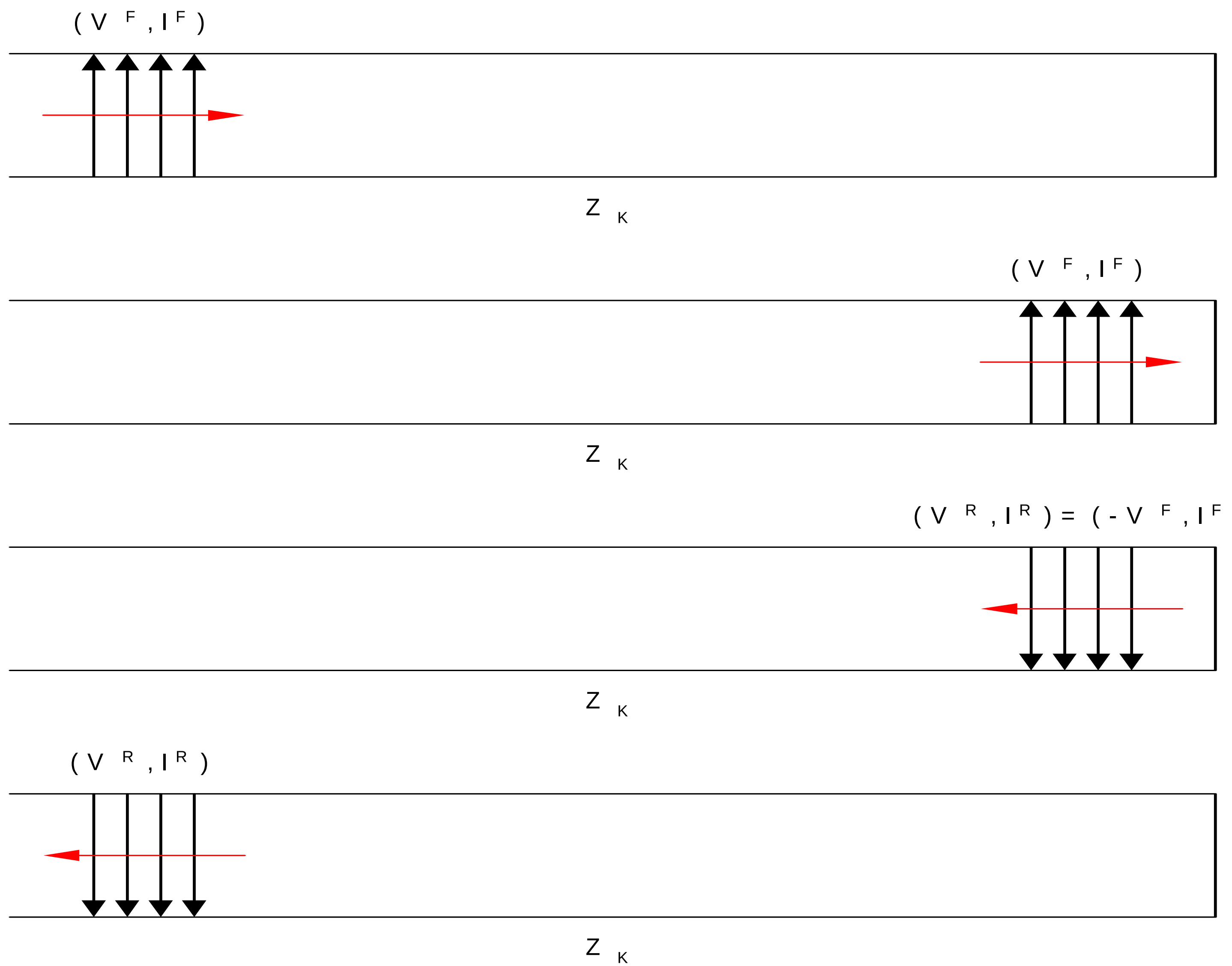
- Cross section similar to that of standard vacuum chamber
  - Slightly smaller to gain field strength
- Width of top and bottom ground strips compromise between
  - Beam Z
  - Magnetic field strength and uniformity



- Total field is the sum of that from the two electodes
- All bunches of the beam at center of K1, K3
- Different bunches of the beam sweep through non-uniform field of K2

4 Magnet Operation

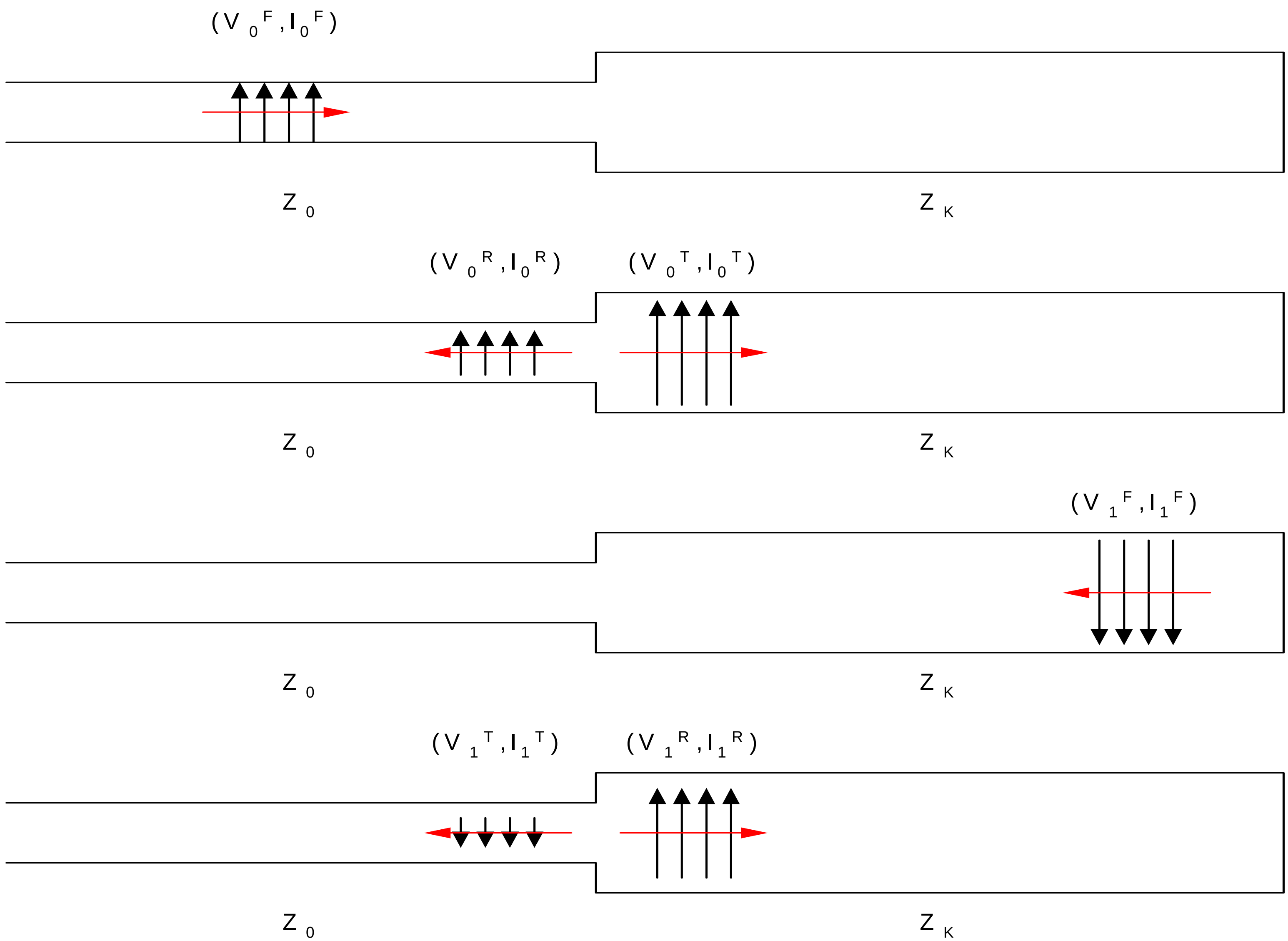
- Electrodes are shorted transmission lines $(Z_0 = 62\Omega)$
- Voltage pulse applied to transmission line carries current
- Pulse reflects off of the shorted end
  - Voltage of reflected pulse changes sign
  - Current of reflected pulse keeps sign
    - $(-Q)(-v) = Qv$

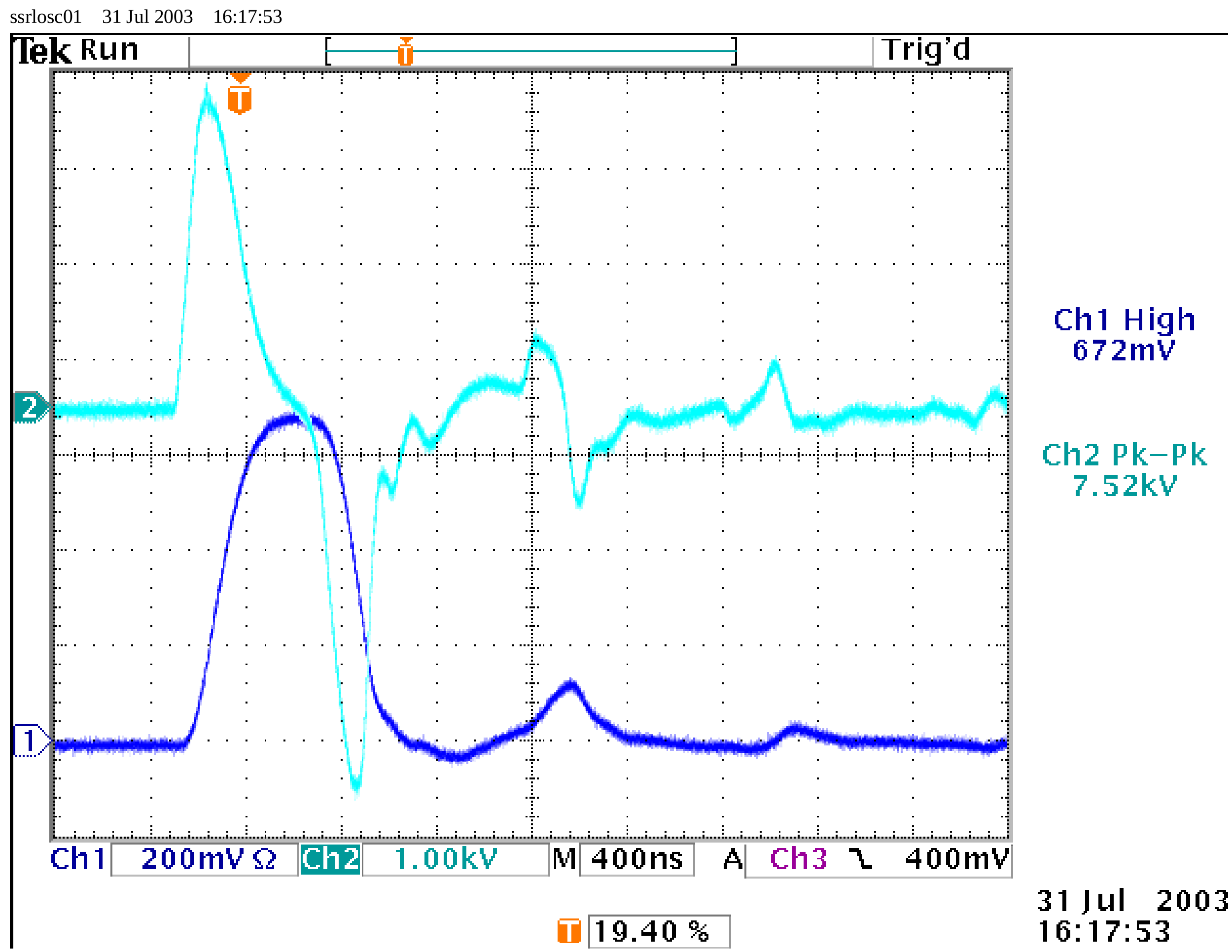

(V^F, I^F)
Z_K
(V^F, I^F)
Z_K
$(V^R, I^R) = (-V^F, I^F)$
Z_K
(V^R, I^R)
Z_K

- When pulse overlaps the length of the kicker $(K1, K3 = 1.2\,\mathrm{m};\ K2 = 0.6\,\mathrm{m})$
  - Voltage along kicker goes to zero
  - Currents double
- Magnetic field strength determined by total current in the two electrodes
- Ideal situation would be to match cable impedance to kicker impedance $(Z_0 = 62\Omega)$
- But $1500\,\mathrm{A}$ of pulser current are needed

$$1500\,\mathrm{A} \times 62\Omega = 93000\,\mathrm{V}$$

  resulting in a voltage that is prohibitively high
- Feed current from pulser on lower Z cable
  - Reflections at the cable-kicker interface limit the rise time of the system
  - Important result of current doubling still holds if the rise time is short compared to the pulse length

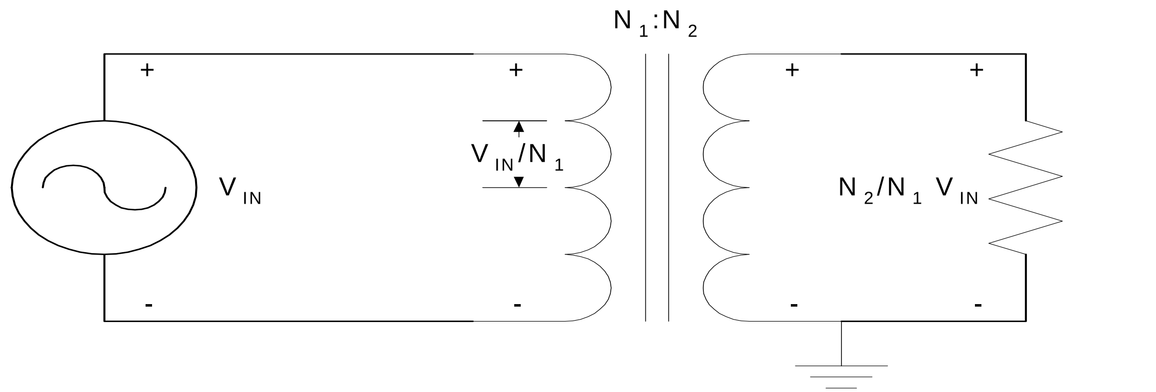

(V_0^F, I_0^F)
Z_0
Z_K
(V_0^R, I_0^R)
(V_0^T, I_0^T)
Z_0
Z_K
(V_1^F, I_1^F)
Z_0
Z_K
(V_1^T, I_1^T)
(V_1^R, I_1^R)
Z_0
Z_K

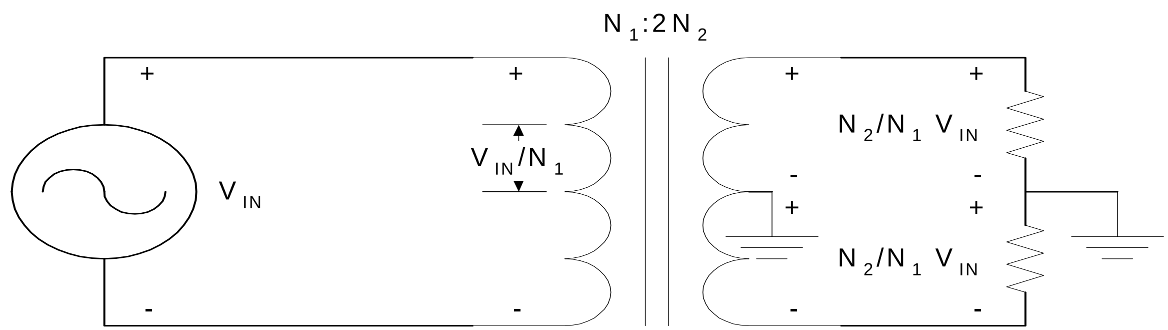


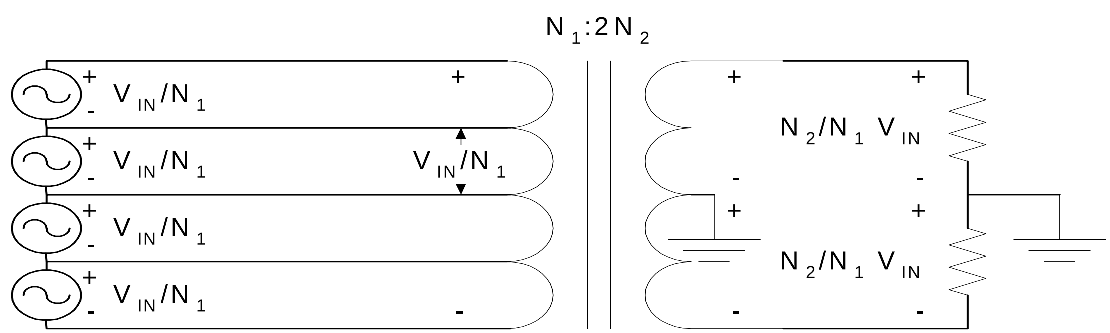
- Upper trace is the voltage at the K1 cable-kicker interface
- Lower trace is the current waveform on one electrode

5 Kicker Pulser

- Refer to talk of C. Pappas
- Past kickers used thyratrons to switch
  - Timing jitter
  - Stability with time, temperature
- SLAC PCD built high voltage pulser for NLC modulators using IGBT technology
  - Increased reliability
  - Increased stability
- Pulser properties
  - Needs to produce two equal and opposite pulses (one for each electrode)
  - Needs to produce close to $25000\,\mathrm{V}$
- Use high voltage, high current transformer
  - Use two secondaries to create opposite voltage pulses
  - Add voltages of individual stages in series


N1:N2
+
+
+
+
V IN/N 1
V IN
N 2/N 1 V IN
-
-
-
-


N1:2N2
V IN/N 1
V IN
N 2/N 1 V IN
N 2/N 1 V IN


N1:2N2
V IN/N 1
V IN/N 1
V IN/N 1
V IN/N 1
V IN/N 1
N 2/N 1 V IN
N 2/N 1 V IN

6 Kicker Commissioning

- Have tested kickers with pulsers before final assembly
- Kickers will be retested after installation
- Current transformer on one cable of each kicker will monitor current through one cable
  - Monitor cable transit times will be measured to enable proper timing of kickers
- Pulse widths of the three independent kickers will be set via SRS units
- Appropriate delays will be calculated from transit time difference of beam at the kicker
- Delays will be adjusted using current monitor pulses
- Current amplitude vs kicker voltage will be calibrated for all kickers
- Set kickers for nominal strengths
- Adjust K3 until beam is acquired
- With one bunch, adjust three kickers so that stored beam is maintained in ring