

# Initial Development of a High-Voltage Pulse Generator for a Short-Pulse Kicker

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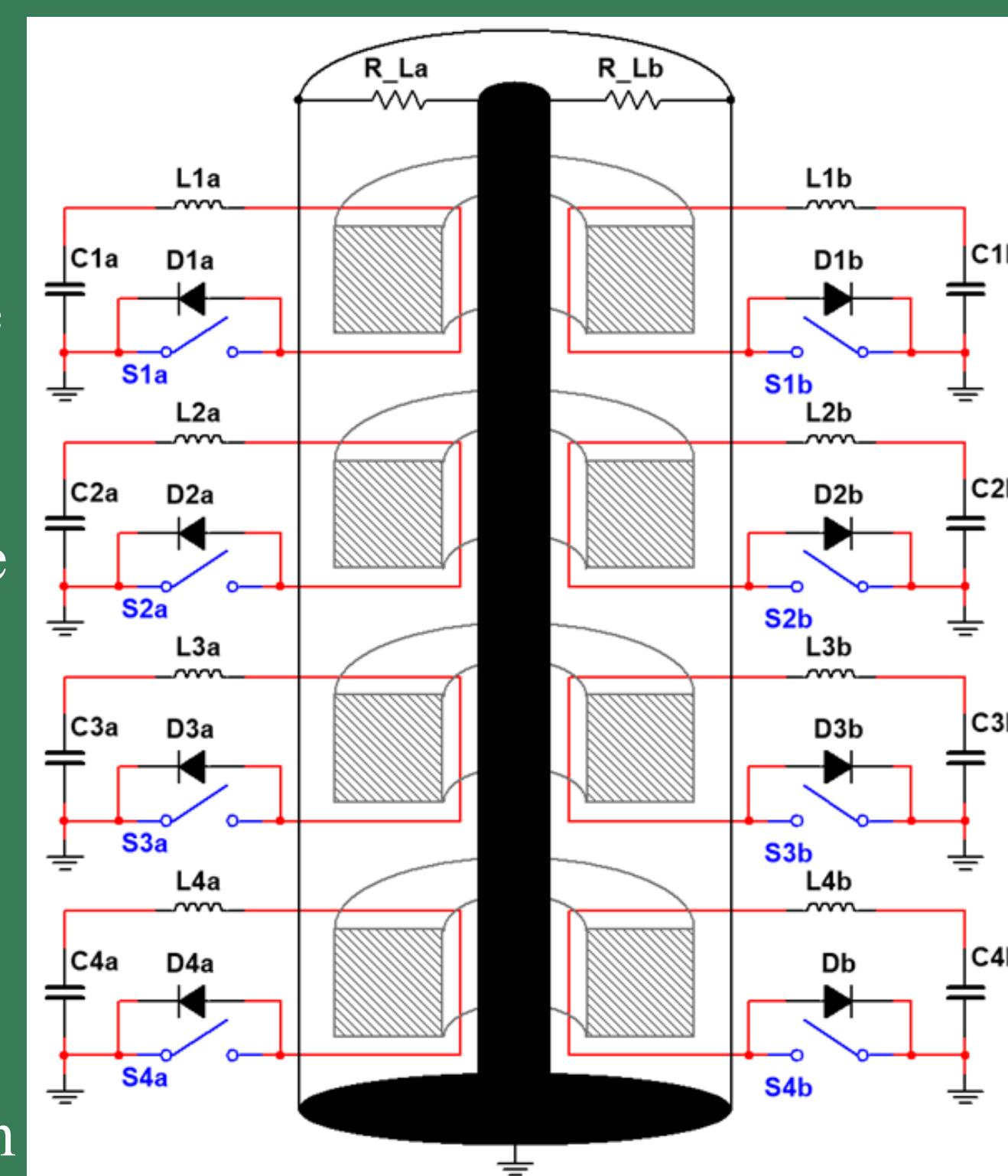
## EAGLE HARBOR TECHNOLOGIES

### Introduction

The future Electron Ion Collider, to be located at Brookhaven National Laboratory (BNL), will require a new short-pulse stripline kicker for the 150 MeV energy recovery LINAC. The pulse generator must produce  $\pm 50$  kV pulses with widths less than 38 ns into a  $50 \Omega$  kicker load and with low jitter. The power system must be highly reliable and robust to potential faults. Eagle Harbor Technologies (EHT), Inc. is leveraging our previous experience developing inductive adders to produce a high-voltage pulse generator that can meet the needs of the BNL kickers. In this program, EHT designed a single inductive adder stage and demonstrated the challenging pulse characteristics including fast rise and fall times, low jitter, and flat top stability while operating at the full current (1 kA). EHT will present the development status and output waveforms.

### Inductive Adder

- Limits the presence of high voltage to the transformer.
- Ground-referenced switches increases robustness, simplifies gate drive design, and reduces jitter.
- Solid-state switches like MOSFETs and IGBTs allow for user-adjustable pulse widths.
- Off-the-shelf components are used within manufacturer specifications.
- Single stage failure does not fail the entire power system.
- The output can be modulated to improve the flat top with the addition of a modulation stage.



Four-stage inductive adder.

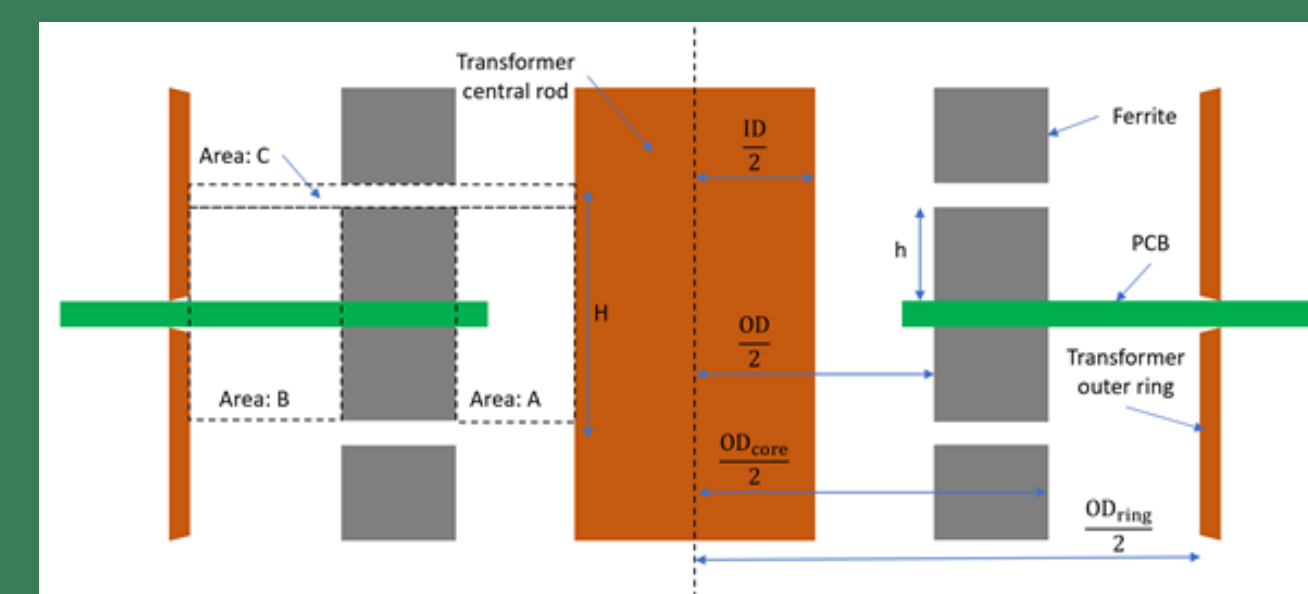
### Previous EHT Inductive Adders

Prior to this work EHT has constructed inductive adders for other customers for HV triggers and high power microwave source drivers.

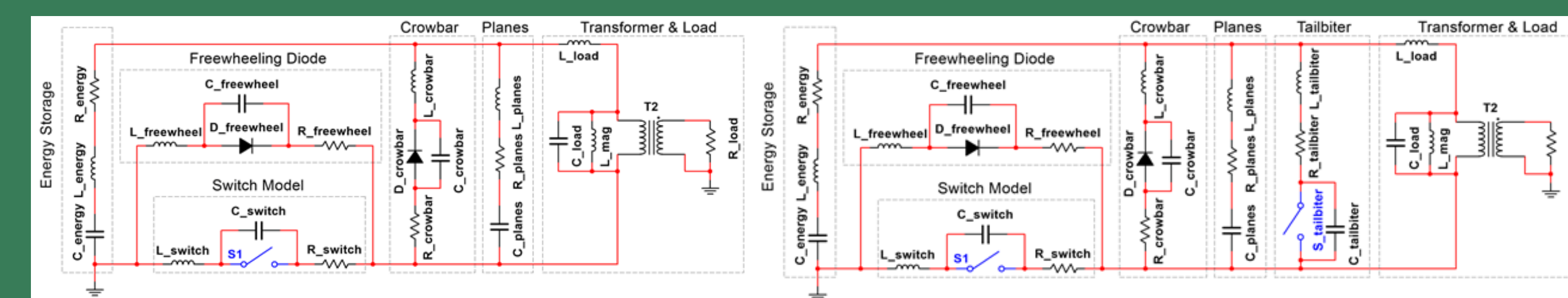
Customer	Output Voltage [kV]	Min Load [ $\Omega$ ]	Output Current [A]	Rise Time [ns]	Min Pulse Width [ns]	Repetition Frequency [kHz]	Peak Power Density [MW/ft <sup>2</sup> ]
ONR	30	50	600	11	30	25	2.7
UMKC	12	50	240	< 8	30	11	1.2
National Lab	24	25	960	< 10	30	50 (1000 pulse)	5.0
Purdue University	24	25	960	< 10	30	1 (CW) 25 (burst)	5.4
Multi-turn IA with NTLT	30	50	600	< 3	150	Single pulse (Not tested)	25.7
Kicker (this work)	50	50	1000	< 6	< 20	0.1	5.4

### Circuit Modeling

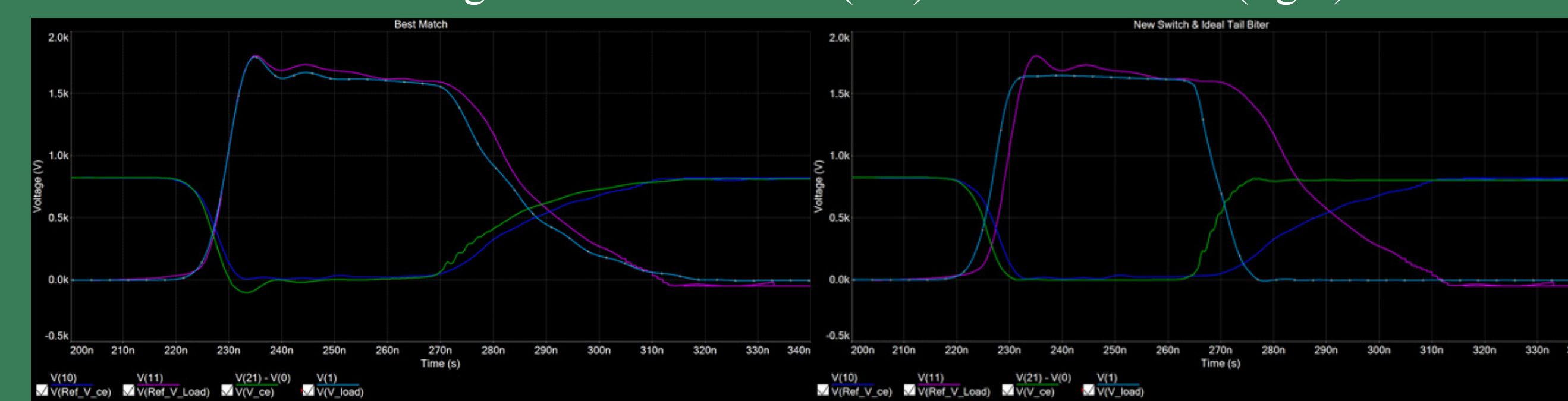
- Stray component values calculated from analytic analysis.
- Switch model is proprietary and ideal switch doesn't match behavior.
- Developed R(t) "switch" to mimic IV behavior.
- Manufacturers' C(V) curves used for diode and switch capacitance
- Reduced plane and switch capacitance
- Decreased output inductance
- Added tailbiter circuit



Block diagram of single inductive adder PCB used to calculate stray inductances and capacitances.



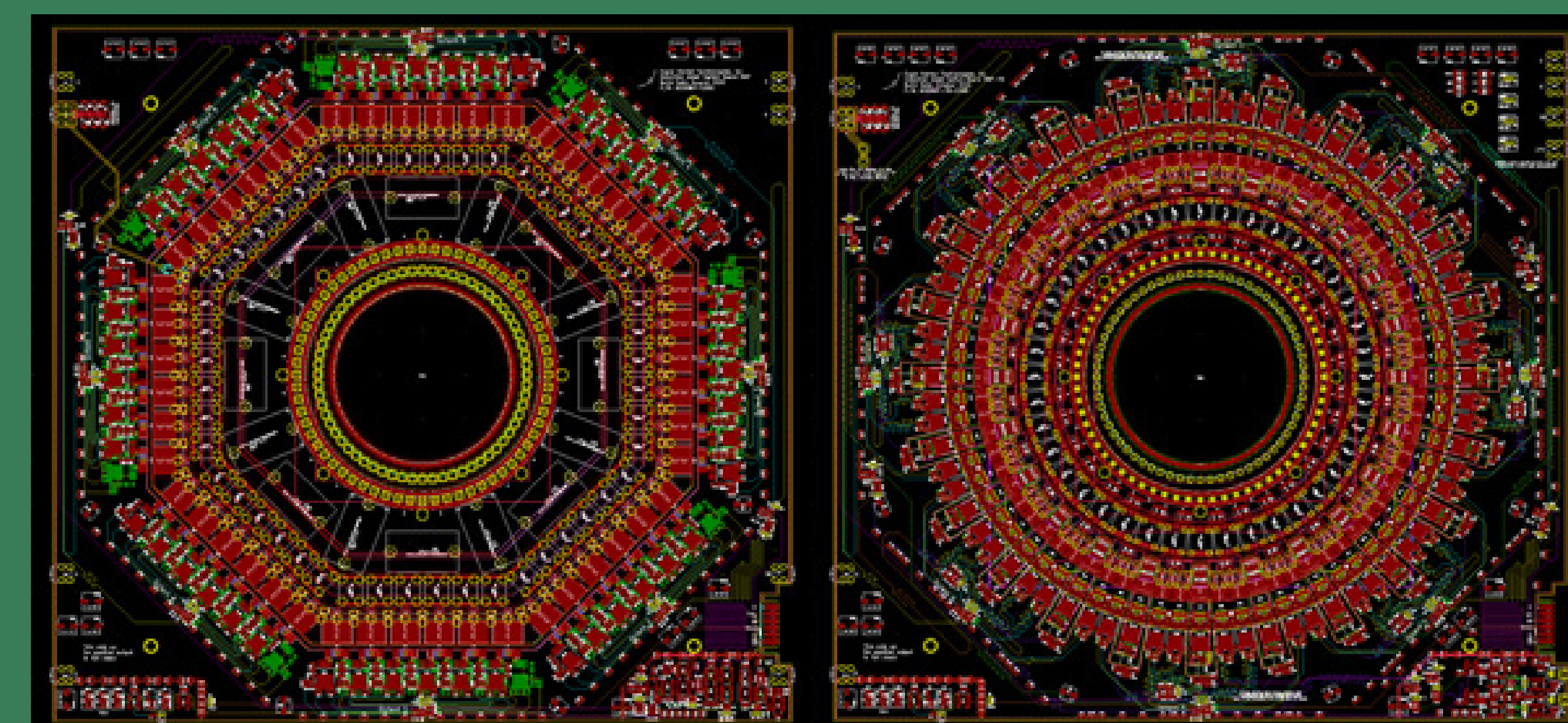
SPICE model circuit diagrams for Purdue IA (left) and BNL kicker (right).



Left: Purdue model (output - light blue &  $V_{DS}$  - green) and data (output - magenta &  $V_{DS}$  - dark blue). Right: Kicker model (output - light blue &  $V_{DS}$  - green) and Purdue data (output - magenta &  $V_{DS}$  - dark blue).

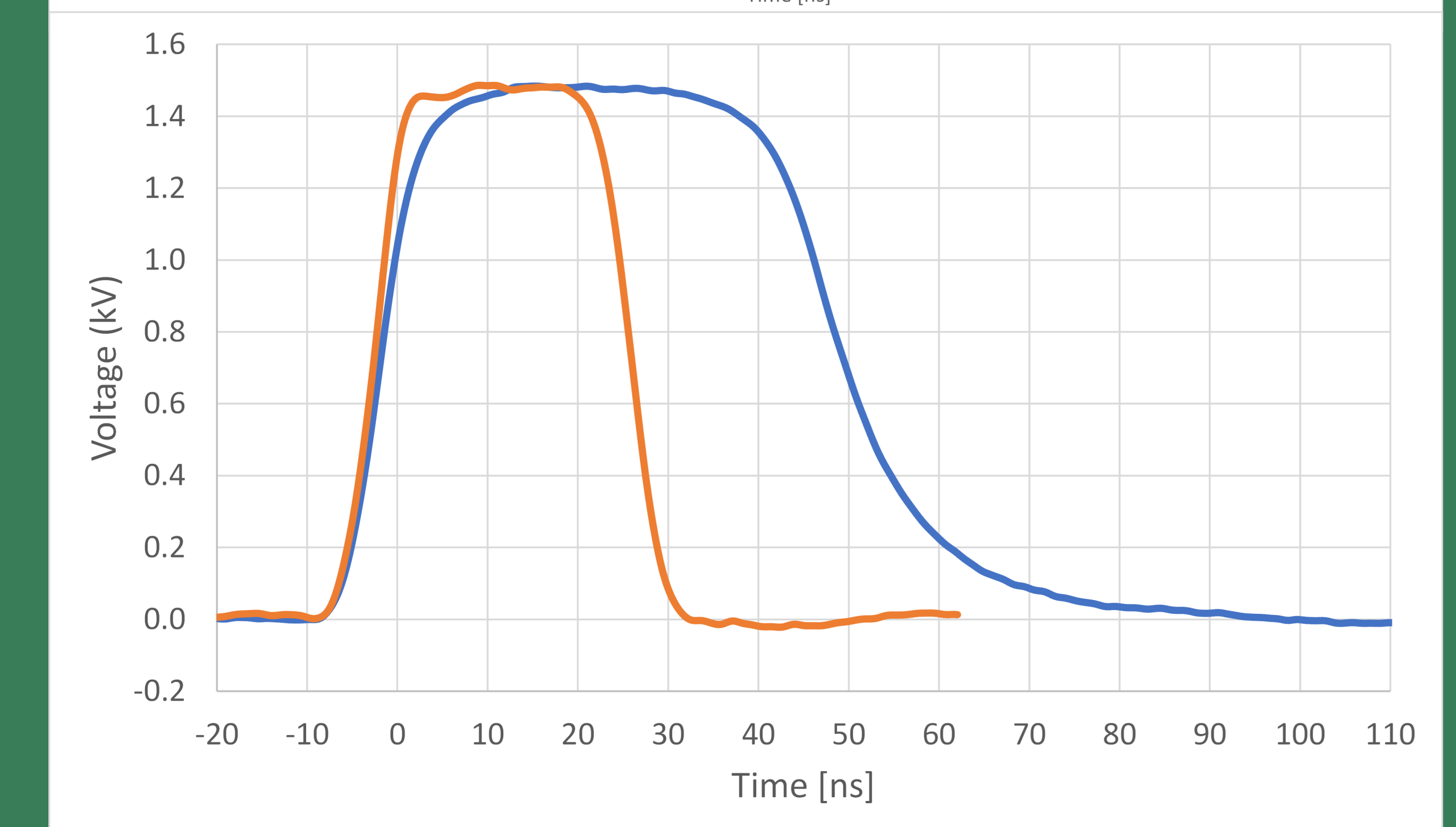
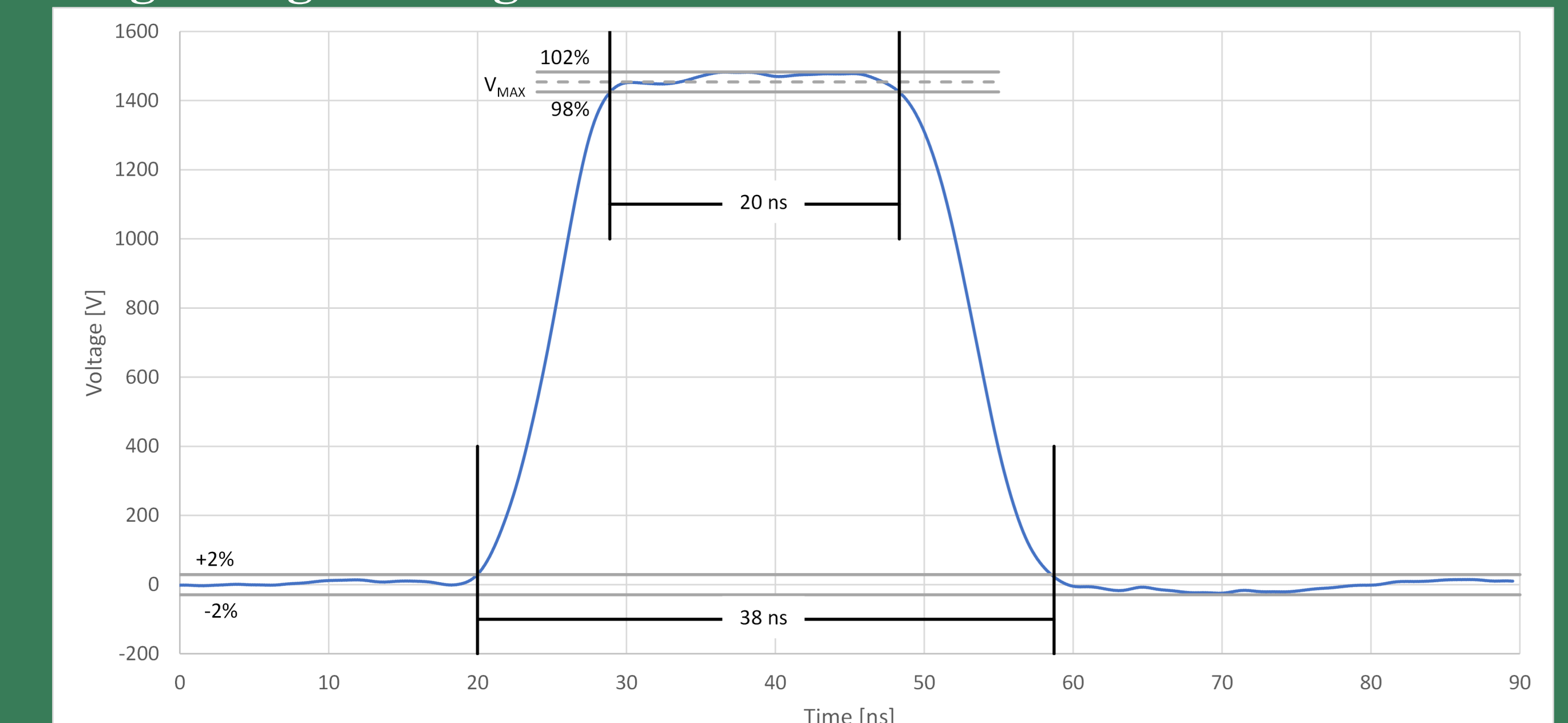
### Inductive Adder PCBs

EHT updated the PCB design from our previous generation (Purdue). The major layout change was switching from an octagonal geometry to a circular unit. This allowed us to increase the power density while allowing space for the tail-biter switches.



Comparison of Purdue PCB (left) and BNL Kicker PCB with tailbiters (right).

### Single Stage Testing



Top: Annotated waveform showing that the single stage meets the BNL specifications. Bottom: Comparison of min pulse from Purdue IA (blue) and BNL IA (orange).

### Conclusion

The stripline kickers at BNL will require a high voltage pulse generator that is capable of producing 50 kV pulses with fast rise (< 6 ns) and fall times (<12 ns) with a flat top ripple below 2%. EHT redesigned our inductive adder PCB to improve the flat top stability and decrease the fall time compared with our previously designed inductive adders. Testing of the single stage showed that this new design can meet the BNL specifications. In the awarded Phase II program, EHT will build and test a 50 kV inductive adder for BNL.

For more information: <http://www.eagleharbortech.com/>

### Acknowledgment

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