Update on 200 Ohm kicker driver performance

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PIP – II Technical Meeting

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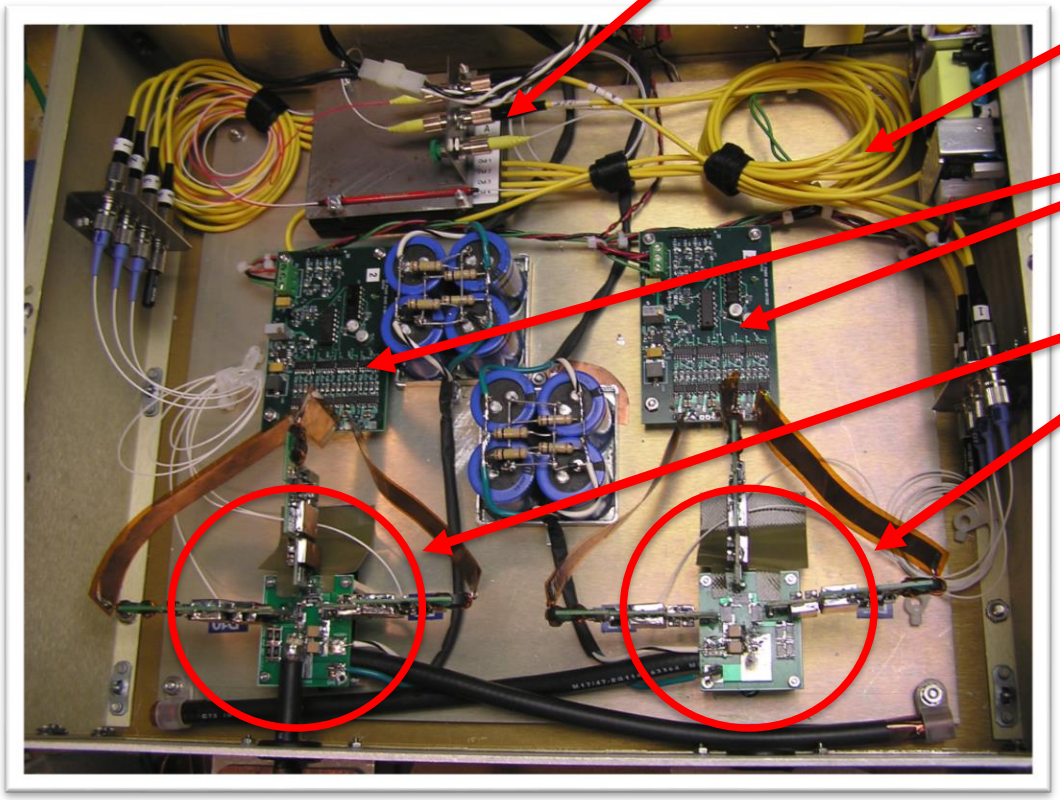
Outline

- Driver updates
  - New driver version
  - Phasing kicker with the beam
    - BPM waveforms
  - Kicker Performance with CDR parameters
    - Arbitrary pattern for Booster injection
    - BPM waveforms
- Developments/issues
  - Driver voltage limitation
  - Driver cooling. Pre-prototype to test cooling idea.
  - What is needed to build CW-compatible driver

New driver version



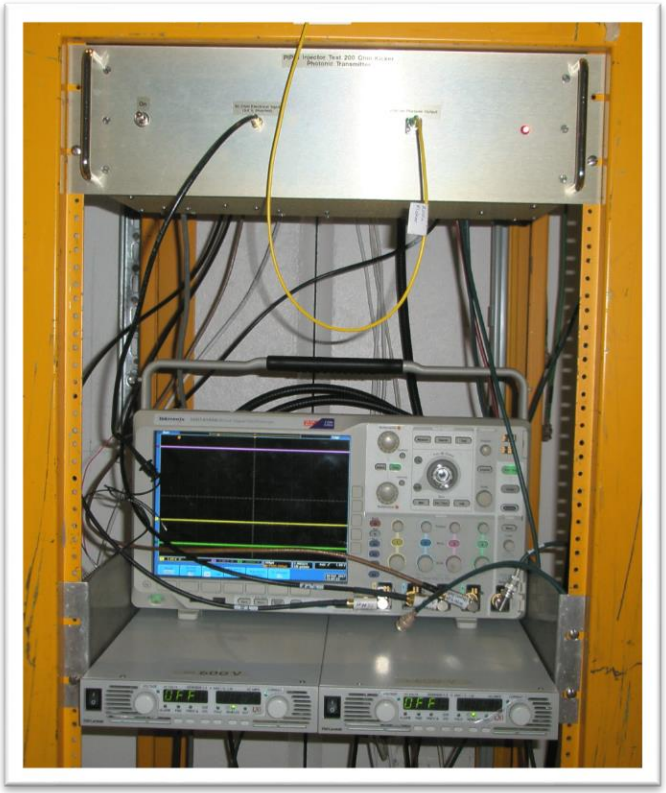
Kicker Control System

Rack 109

Fast Scope

Photonic Transmitter

HV power supplies

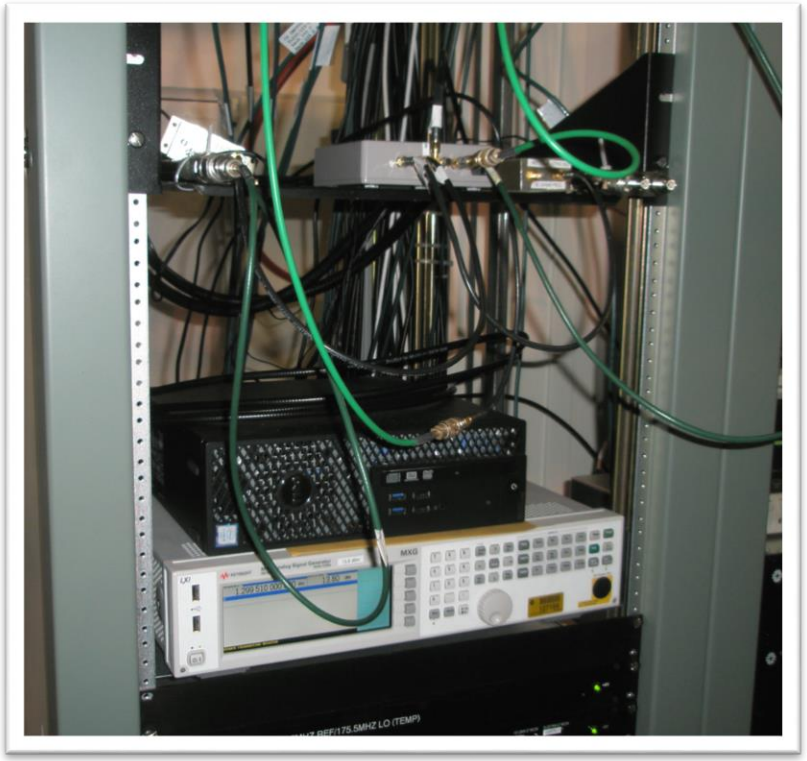


Rack 200

LLRF

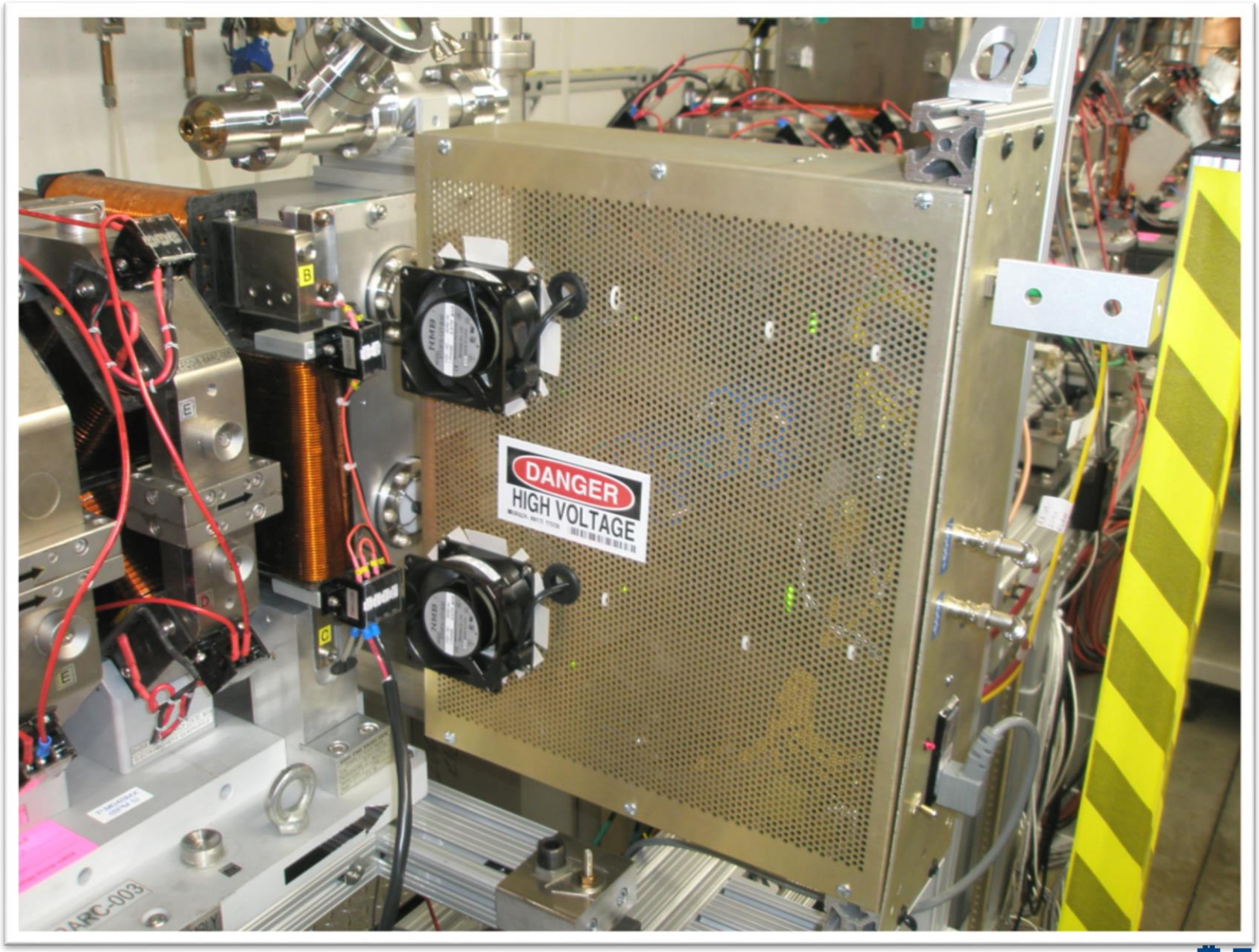
Arb. waveform generator

Computer



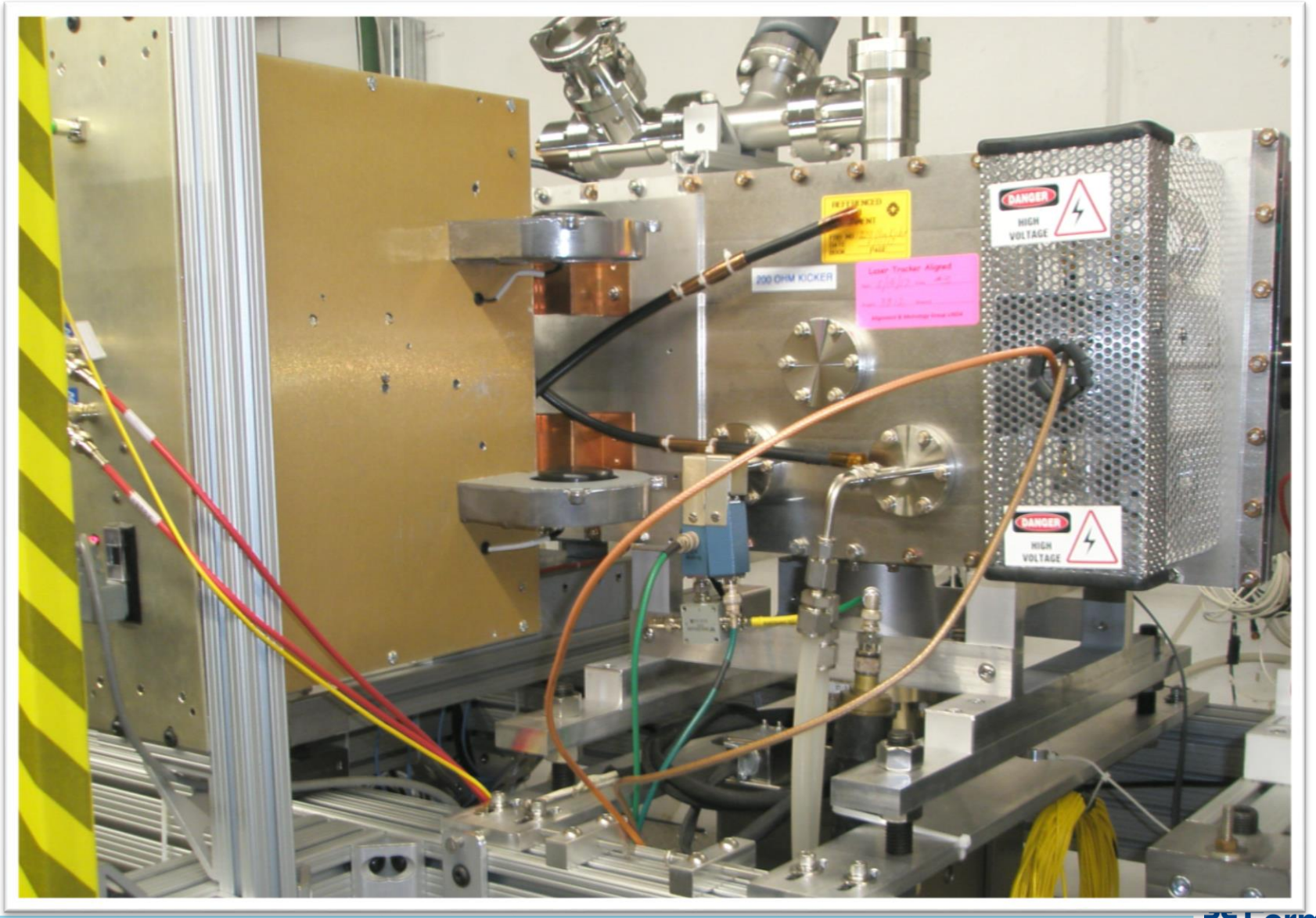
LLRF Delivers 0.6 V signal to Rack 109 where it is converted to light and sent to the kicker over one fiber for two drivers

Driver as installed now in the MEBT



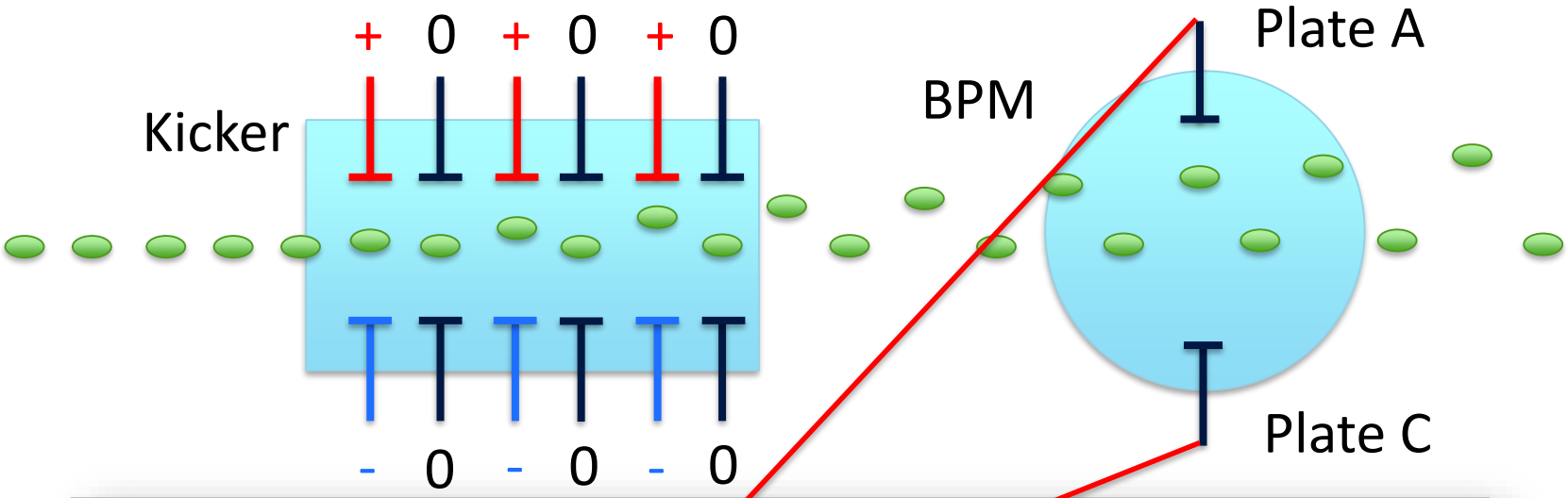
Fermilab

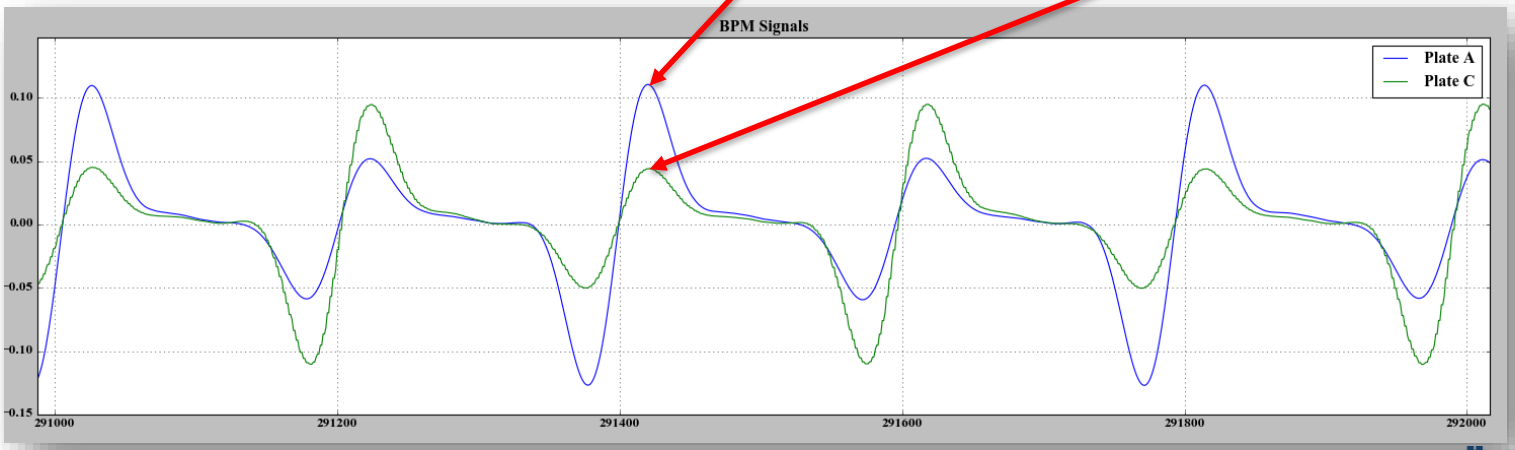
Driver as installed now in the MEBT



Phasing kicker with the beam

- We used BPM60 A & C plates signals to synchronize kicker and beam.
- Procedure: Switching at 81.25 MHz, shift kicker delay with 500 ps steps, record magnitudes of A & C plates each step.





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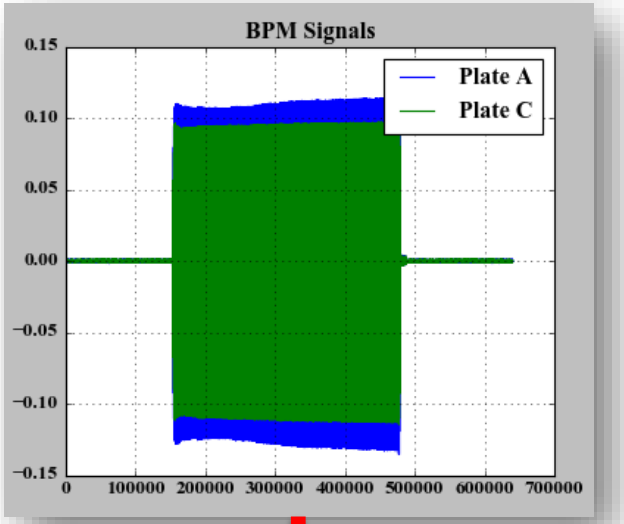
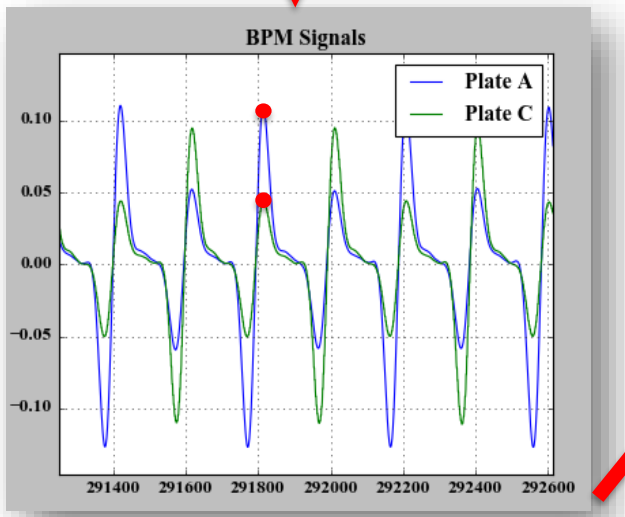
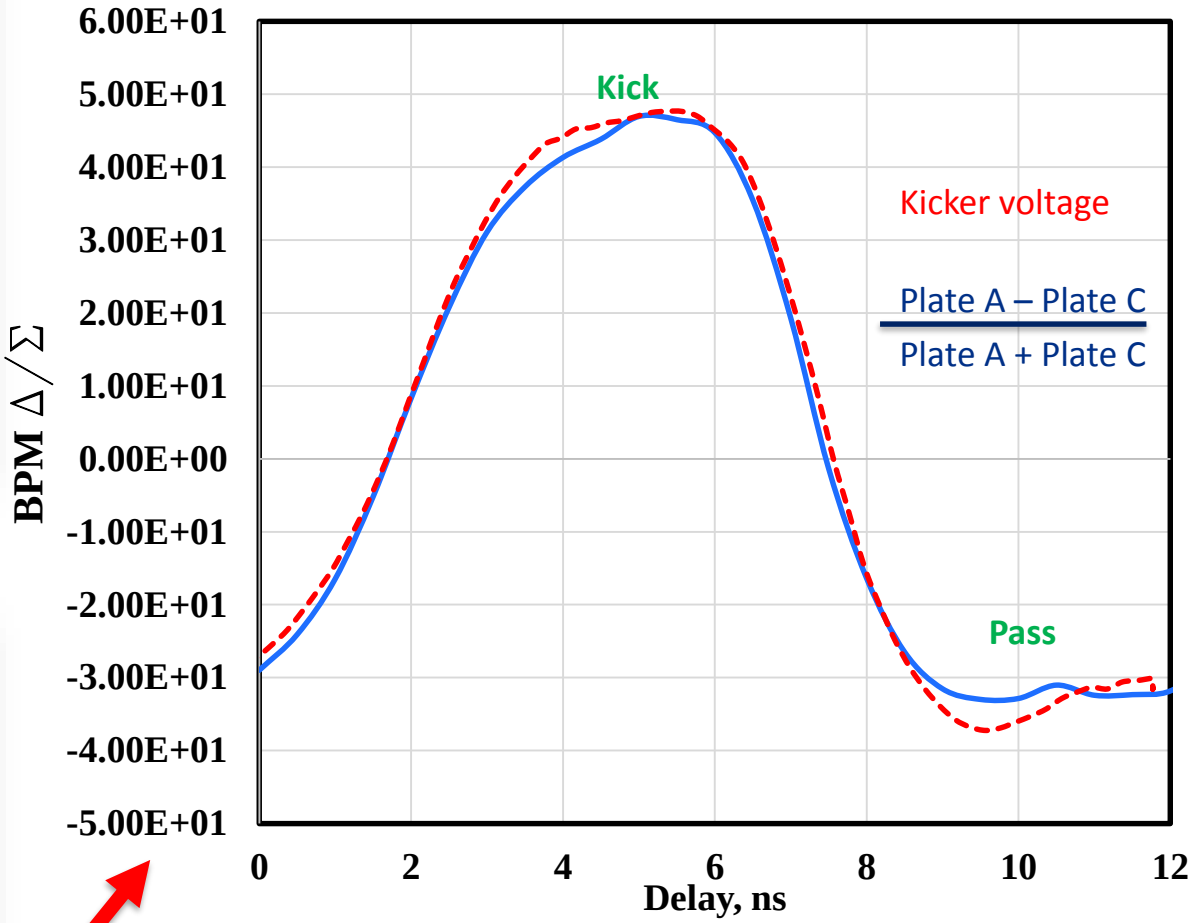
Bunch position vs kicker delay (phase)







- Once the right delay is determined, no other tuning required for different switching patterns if beam phase remains the same.

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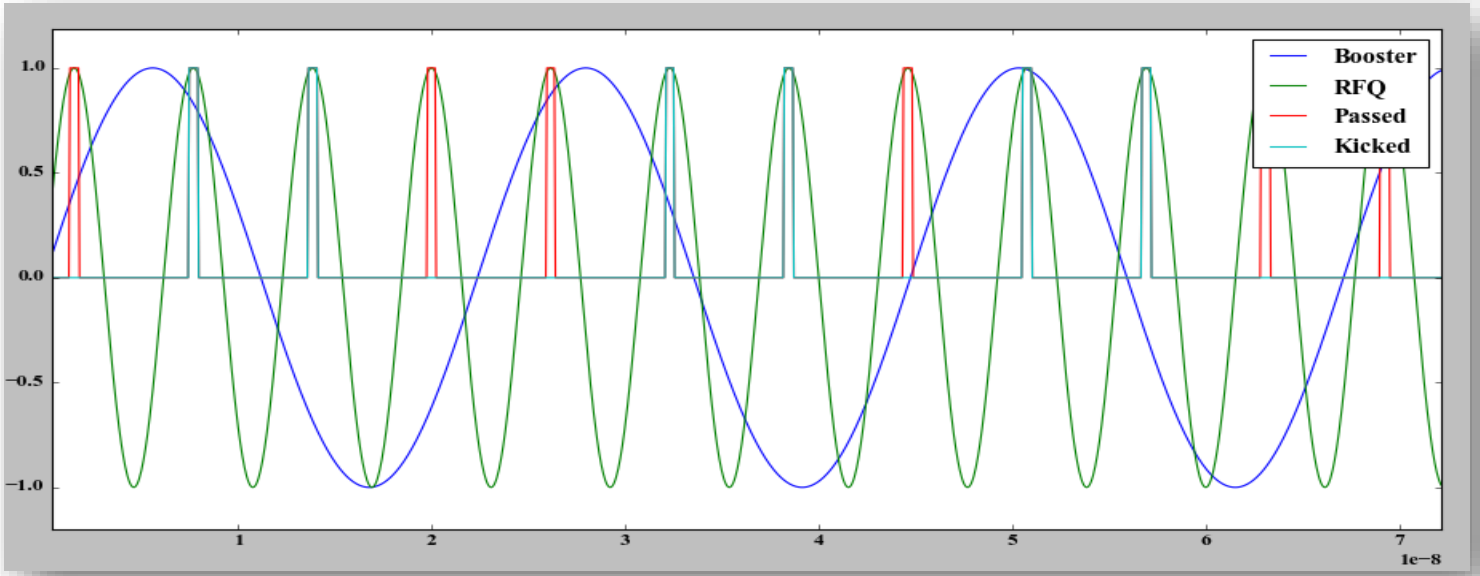
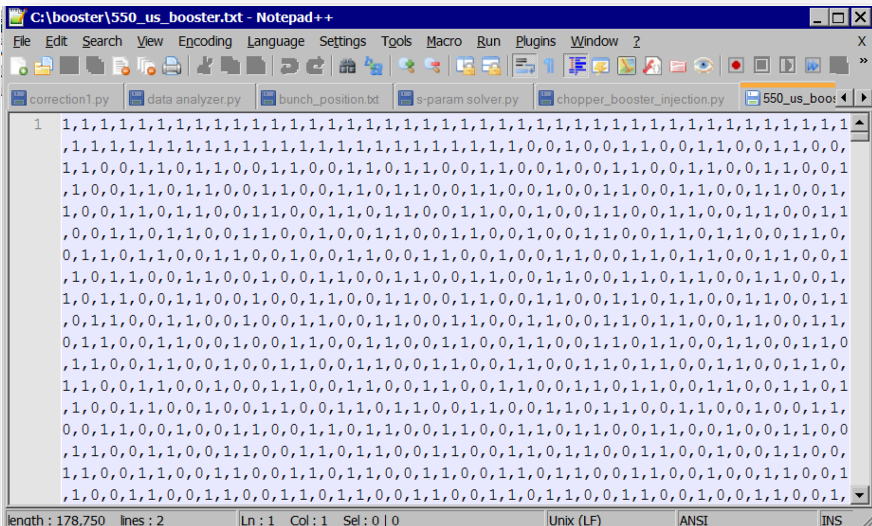
Kicker Performance with CDR parameters

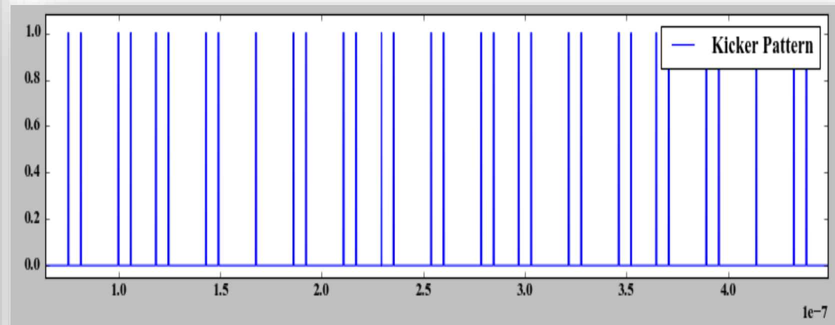
- CDR Parameters require switching at **~ 44 MHz** average for **0.55 ms** bursts at **20 Hz** repetition rate
- The kicker pattern for CDR is function of Booster and RFQ frequencies.



Arbitrary pattern for Booster injection

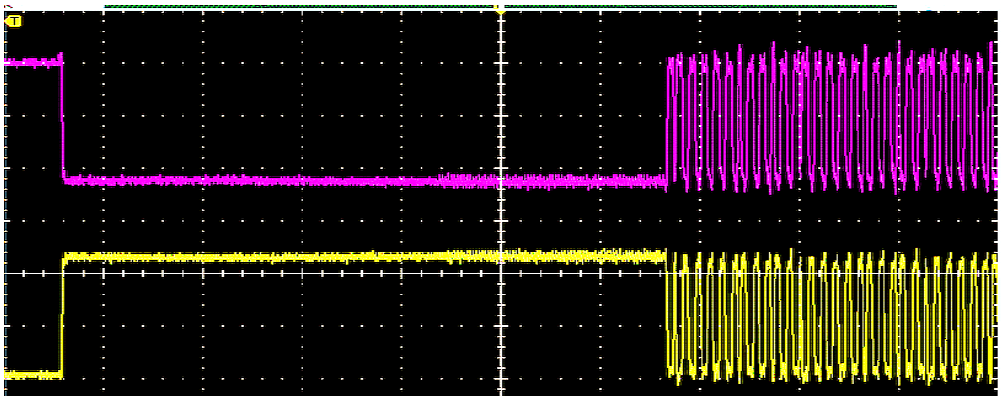
- The Python program generates .txt files with arbitrary pattern for booster injection, based on booster and RFQ frequencies





- Pattern files are then loaded manually to LabView App (Dheeraj Sharma & LLRF), that controls the Arbitrary waveform generator.

Kicking with CDR parameters (0.55 ms) START



-500 V

+500 V

Kicker signals

100 ns/div

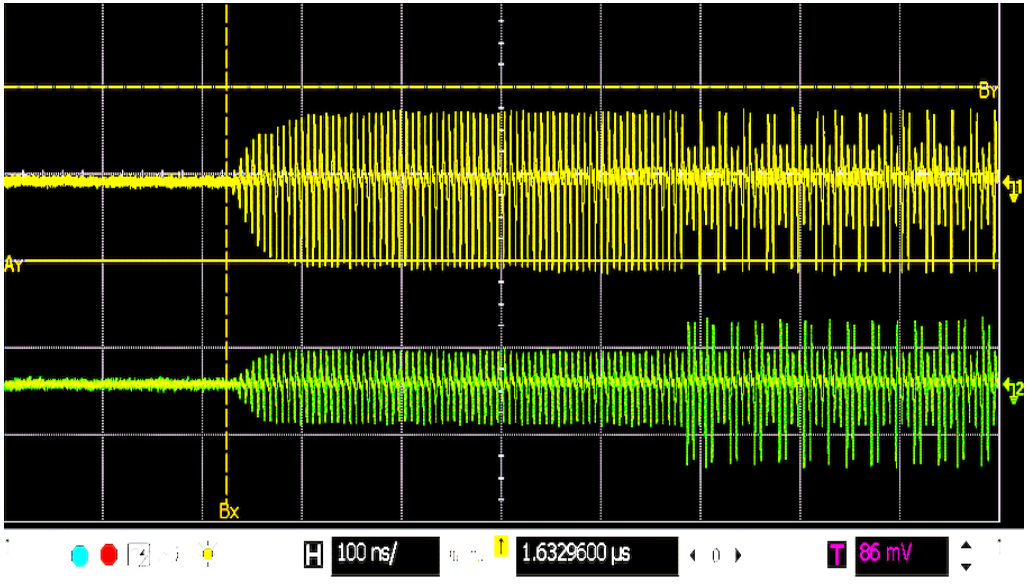


Plate A

Plate C

BPM signals

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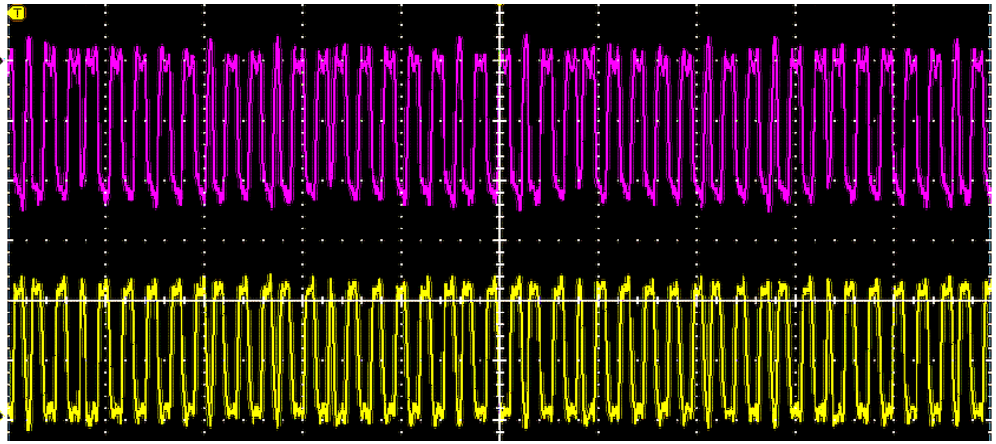
Kicking with CDR parameters (0.55 ms) MIDDLE



-500 V

+500 V

Kicker signals

100 ns/div

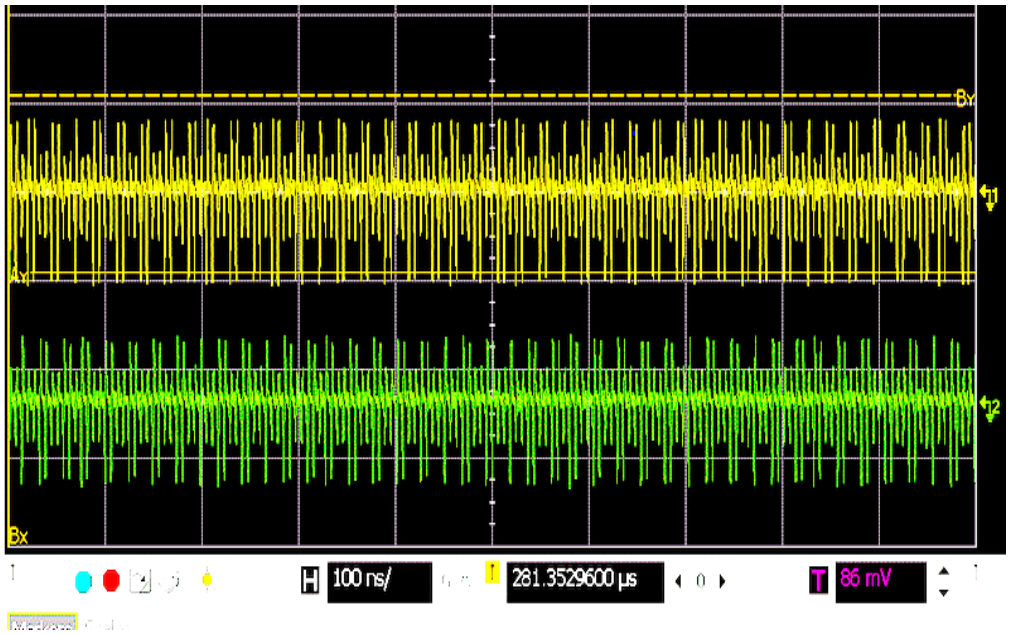


Plate A

Plate C

BPM signals

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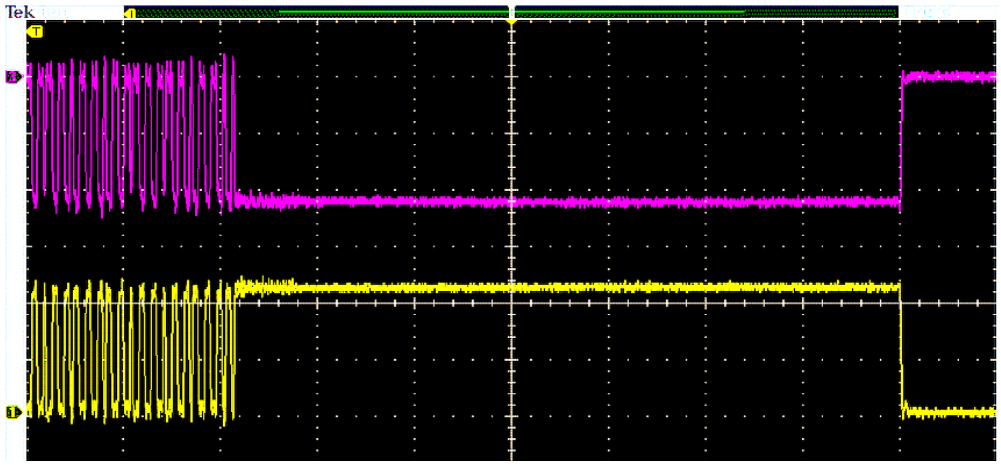
Kicking with CDR parameters (0.55 ms) END



-500 V

+500 V

Kicker signals

200 ns/div

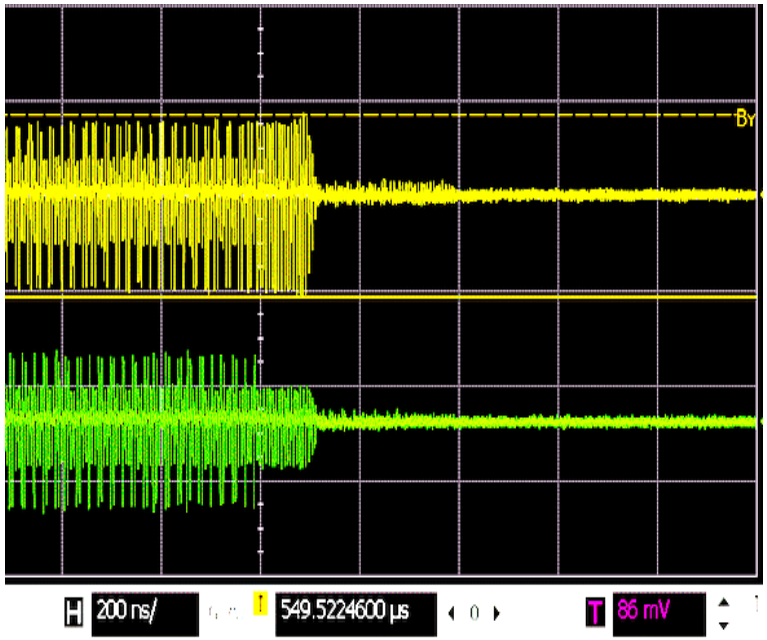


Plate A

Plate C

BPM signals

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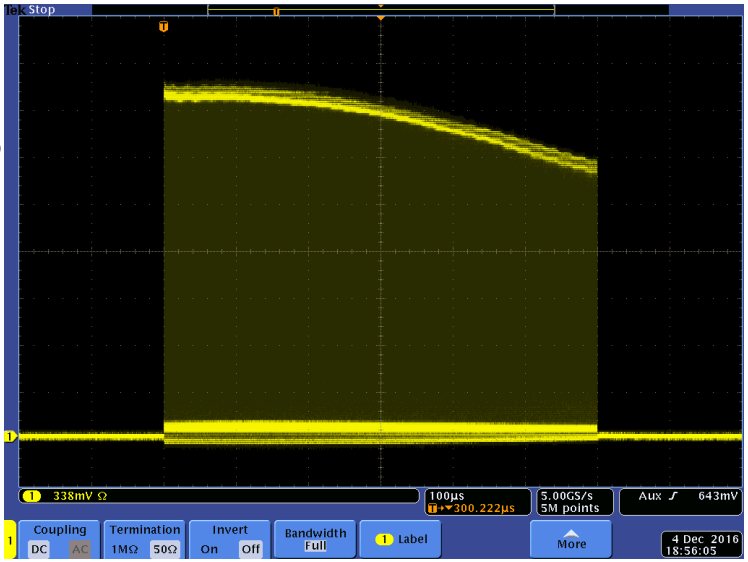
Driver voltage limitation

- New photonics trigger system provides good, noise resistance trigger between transistors and allows to generate any arbitrary pattern.
- But losses in transistor increase temperature, which changes the threshold level of the gate voltage. This results in desynchronization between transistors, which leads to more losses…..
- So there is an upper voltage limit

of the driver for long bursts. After this limit the output waveform distorts significantly. For current driver voltage limit is **500 V**, when switching at long bursts



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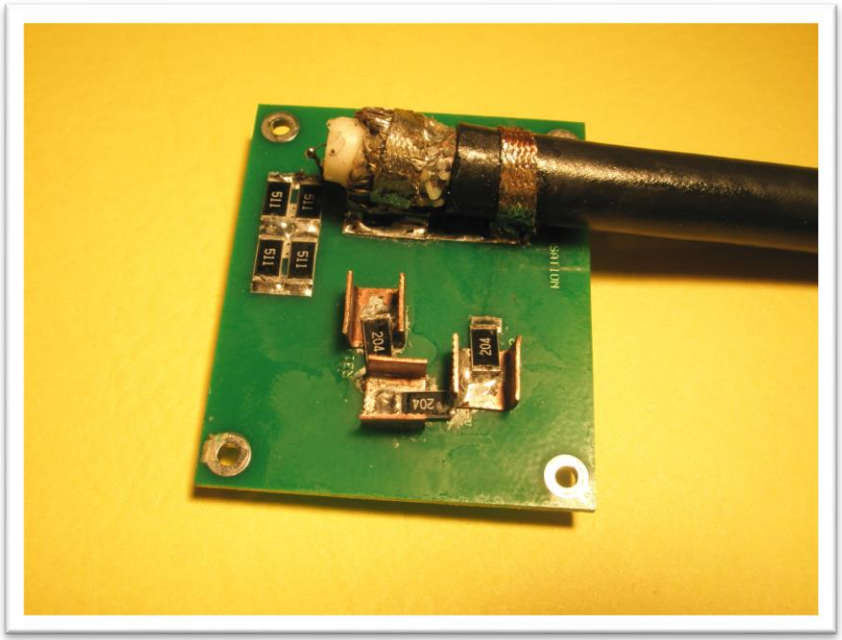
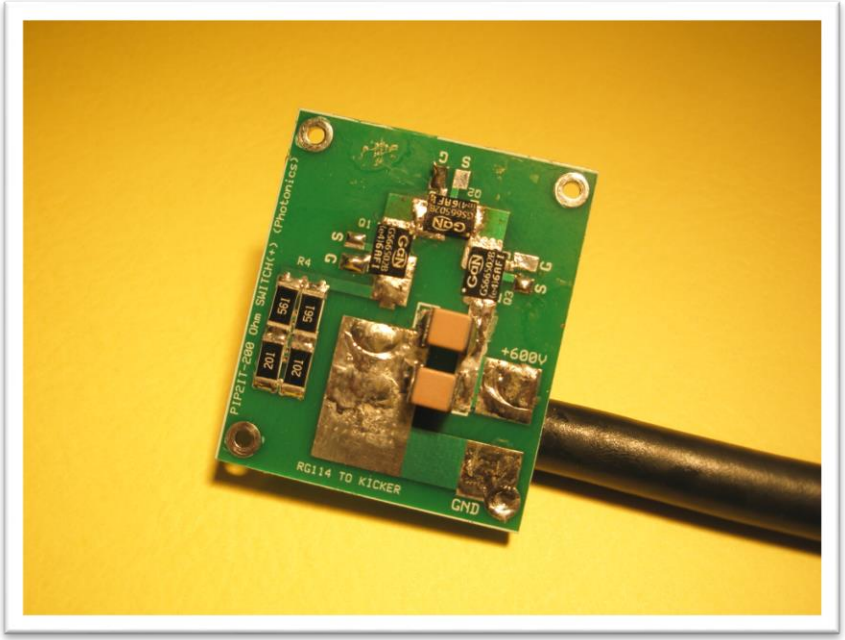
Driver cooling…

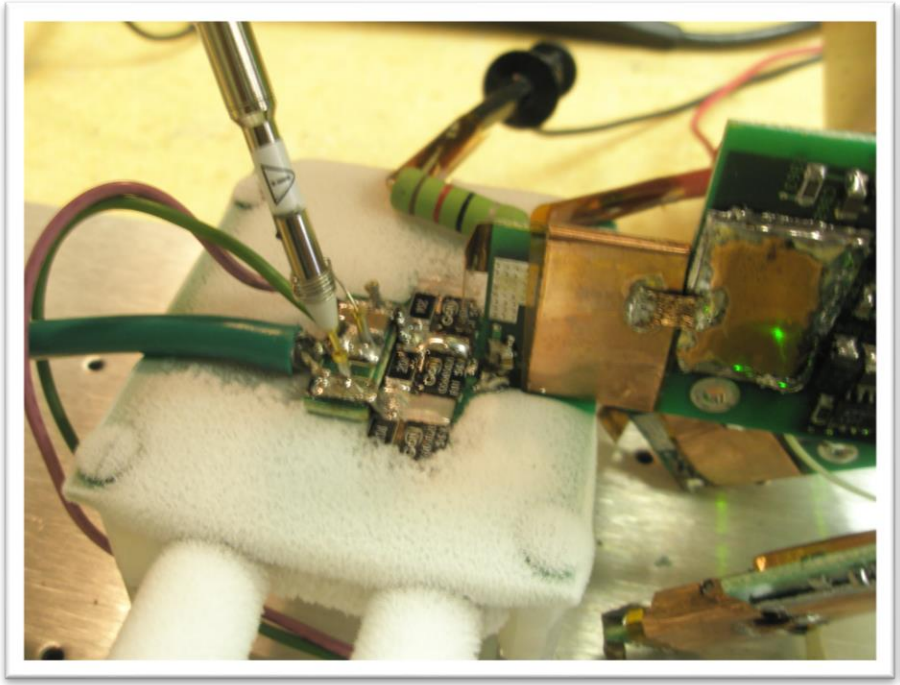
- Many experiments were done to cool transistors to allow CDR parameters operation.
- As a result, CDR parameters can be achieved with air cooling and small heatsinks on the bottom of each transistor. Each driver has a separate blower under it, that cools the heatsinks.
- But CDR parameters are only 1 % power required for CW operation.

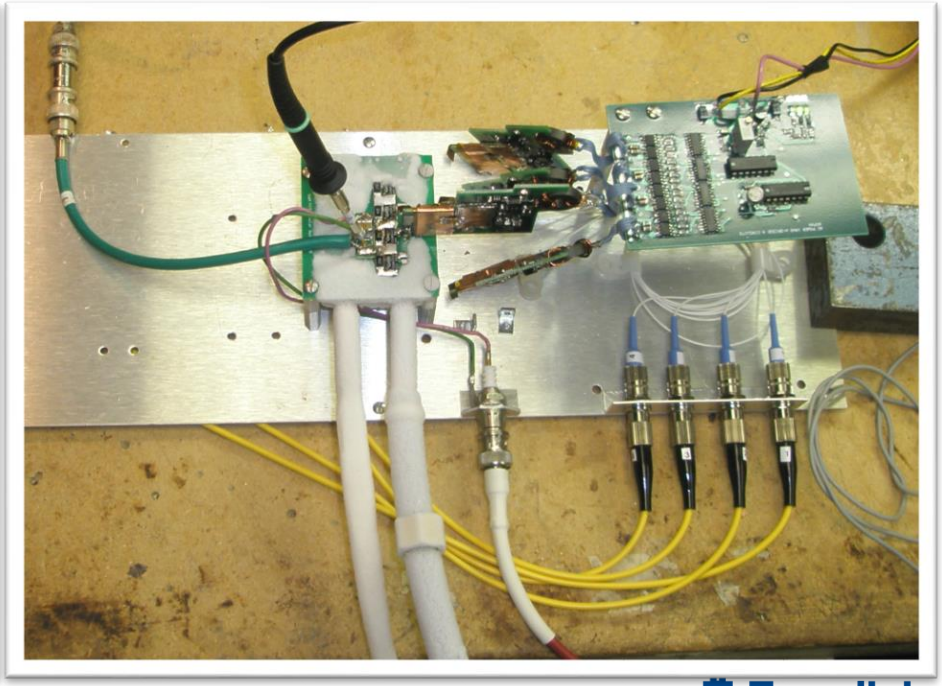




Driver cooling…

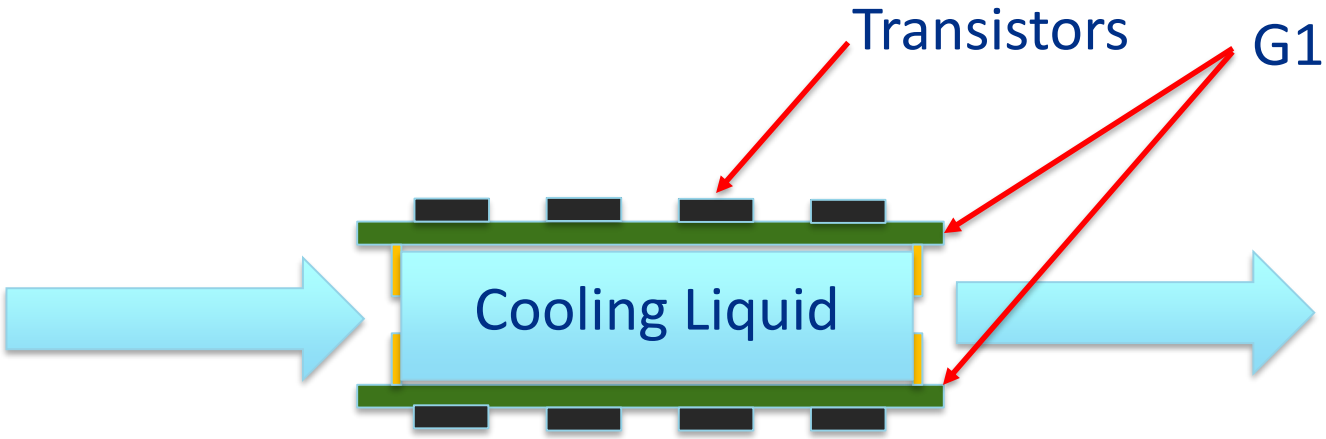
- Significantly intensive cooling is required for CW operation.
- Cryogenic tests made in March 2017, showed that heat load per transistor will be about 200 W/cm^2.
- And even very ineffective nitrogen cooling allowed to achieve CW operation at **20 MHz, 150 V with 1 transistor driving 50 Ohm**.
- This shows that it is possible to build 600 V driver, if we had effective cooling system





What is needed to build CW-compatible driver

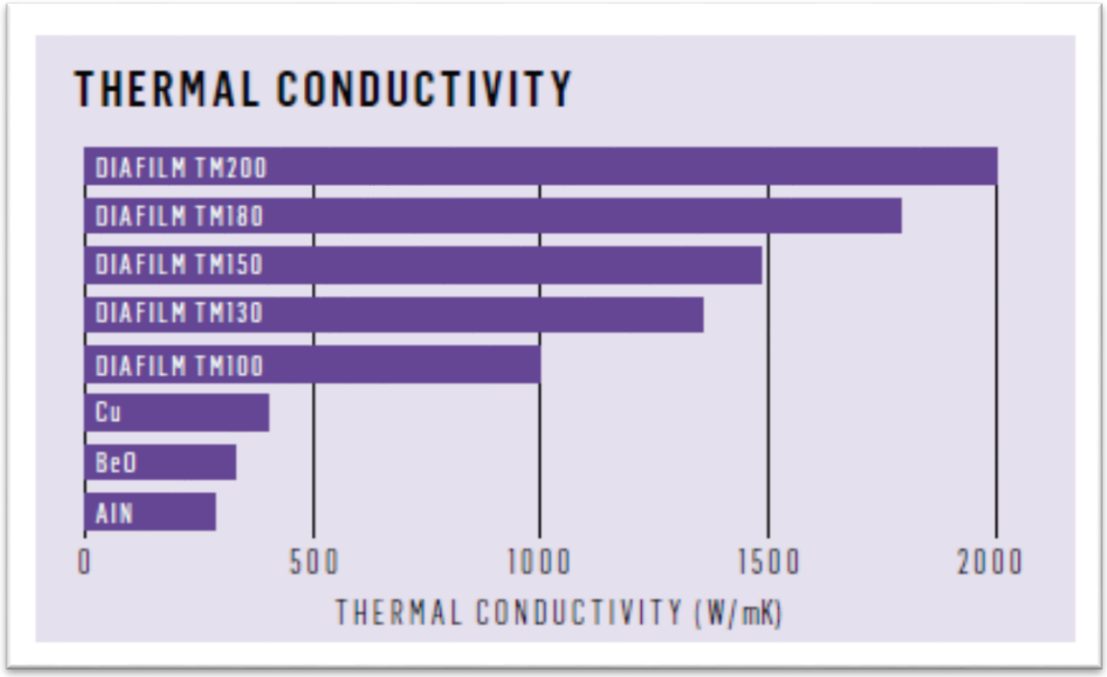
- We will built a pre-prototype of the switch, that will use liquid to cool transistors.



- This prototype will allow us to test idea and work out **best electrical layout** for the printed circuit board.
- And work out also the mechanical design of how the driver will be mounted on the kicker itself.

What is needed to build CW-compatible driver

- We will need mechanical engineering resources to design a printed circuit board based on high thermal conductivity substrate (CVD diamond will be the best choice, but we can try beryllium oxide at first).
- We will also need to design cooling system for this board.



Element Six Ltd

100 mm OD,
2 mm thick CVD substrate

Summary

- Current driver is capable to deliver CDR parameters
- Results that we got with the beam showed some minor issues (reflections, parasitic ringing etc.), that will be fixed in the next version of driver.
- 0.55 ms, 500 V, at 45 MHz and 20 Hz is the limit for this driver, but it can deliver any arbitrary pattern within this limit.
- Thermal tests show the possibility to build CW-compatible driver, but additional R&D are required, the proposal is:

- *Prototype driver on G10 material, working on final layout*

- *Mechanical design of the cooling system and PCB on ceramic or diamond substrate*

- *Build one CW-compatible driver prototype.*