Recent results from the Pulsed DC System

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Pulsed DC System

high-voltage vacuum system for high-gradient studies

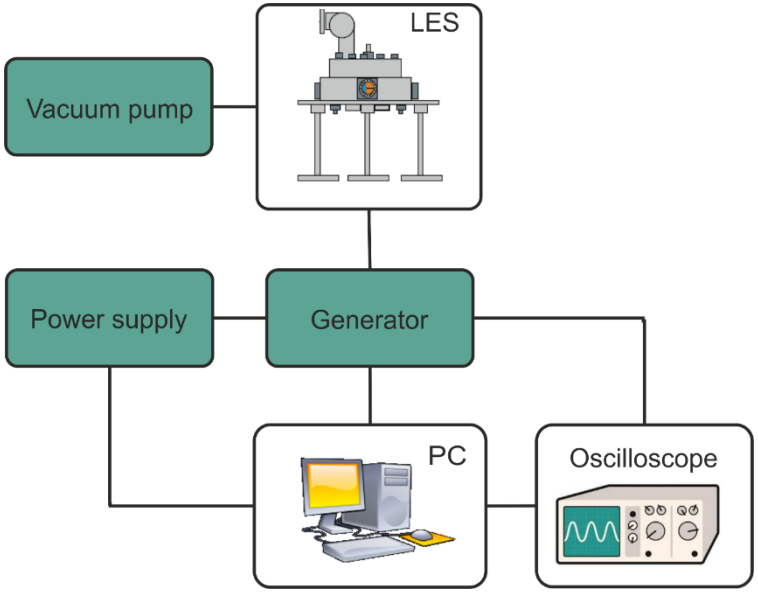
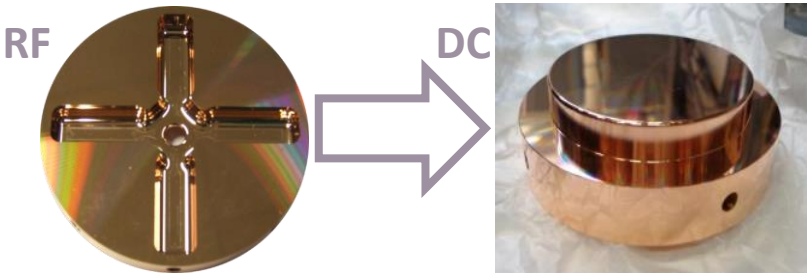


Fig. 2.1. Simplified schematic of Pulsed DC System.



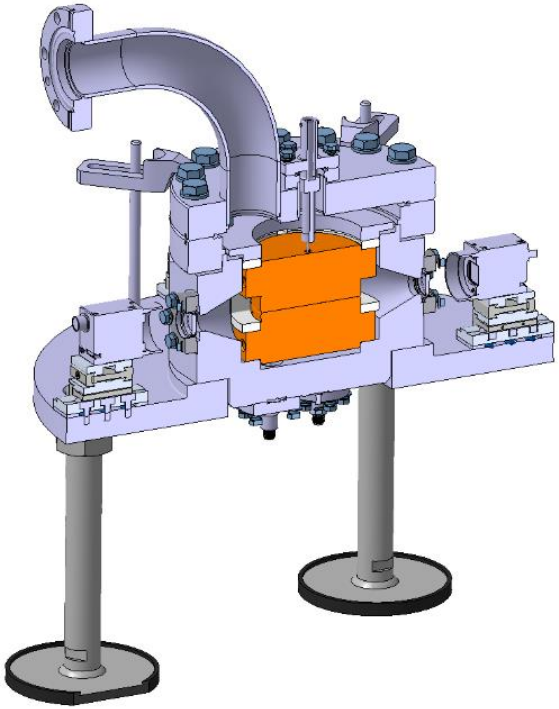
Advantages of the Pulsed DC system compared to RF:

- ✓ Complement for RF test
- ✓ Simple samples
- ✓ Simpler generator
- ✓ Easier diagnostics
- ✓ Faster
- ✓ Inexpensive

Table 1. Materials used for electrodes at Pulsed DC systems.

Material	Description
Hard Cu	OFE-copper, as-machined.
Soft Cu	Hard Cu followed the same treatment methods as Accelerating Structures during bonding procedure (up to 1040°C) and backing (up to 650°C).
Vacuum fired Cu	Provided from SLAC. C10100 OFHC Copper. Run through a simulated H2 braze cycle (~1000°C) then vacuum fired at 700°C for 48 Hrs.
CuAg	Provided from SLAC. C10700 CuAg, with Ag content 0f 0.085%
SS	Provided from SLAC. 304L Stainless Steel Used as Anode at the test with Vacuum fired Cu and CuAg.
Nb	Niobium

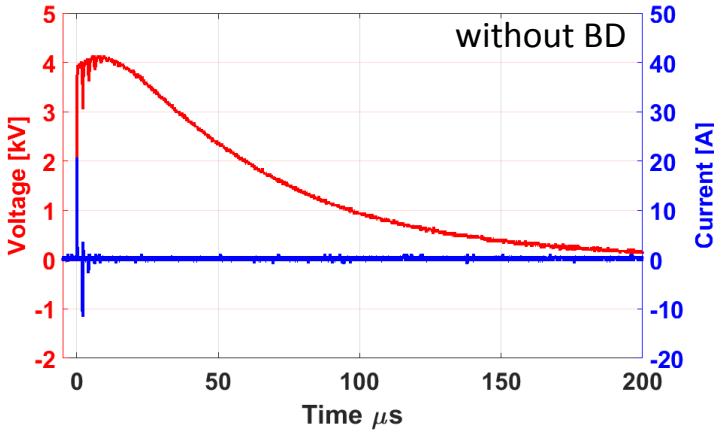
Large Electrodes System (LES)

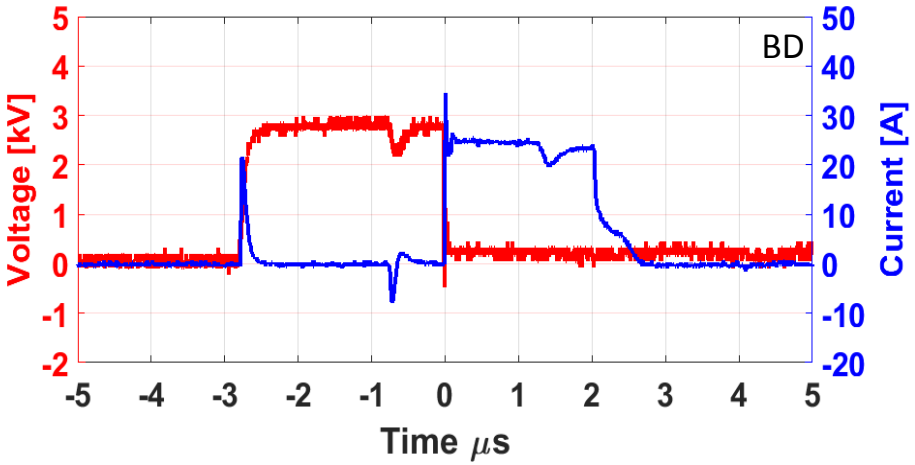


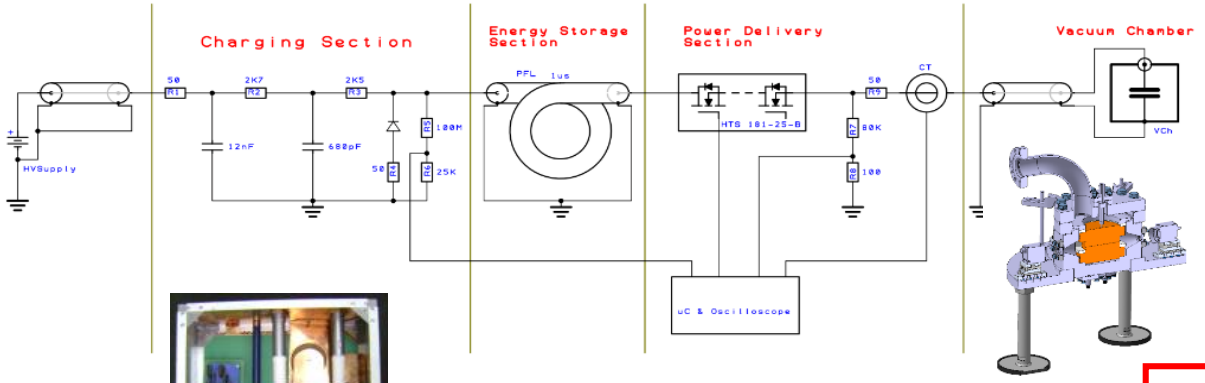
There are 2 Large Electrodes Systems available at CERN. LES has a symmetric electrode setup of two parallel plates (diameter 62 mm). The gap is set through an interchangeable ceramic insert between them. All relevant parts are manufactured to sub-µm precision.

The main advantage of this system is the large electrode surface that gets subjected to the electric field, making it more analogous to RF structures.

HRR circuit

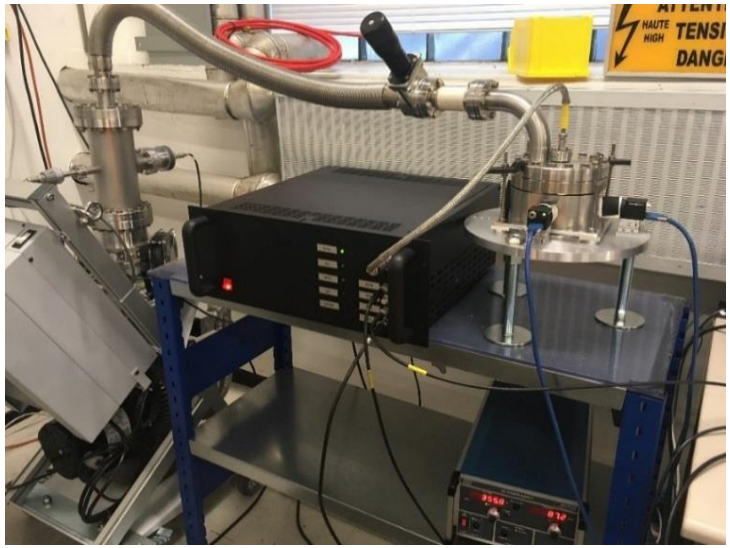


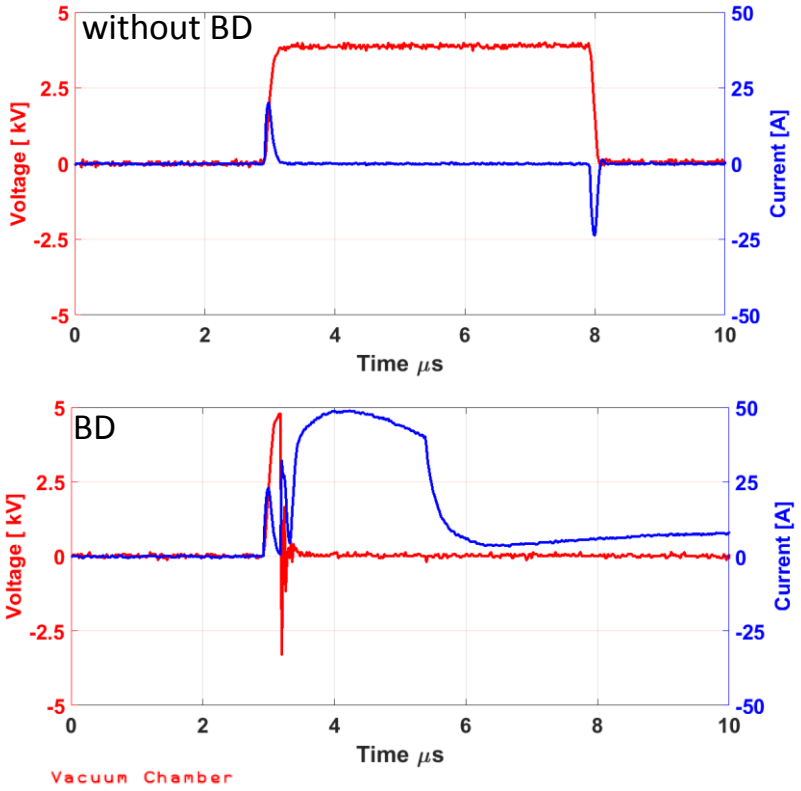


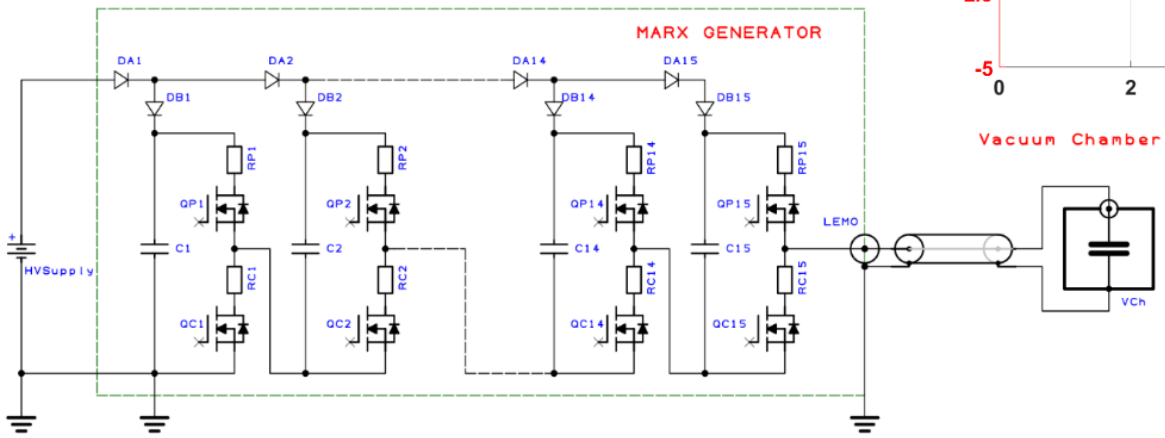


Pulse length ~15-30 µs
Repetition Rate up to 1 kHz

Marx generator



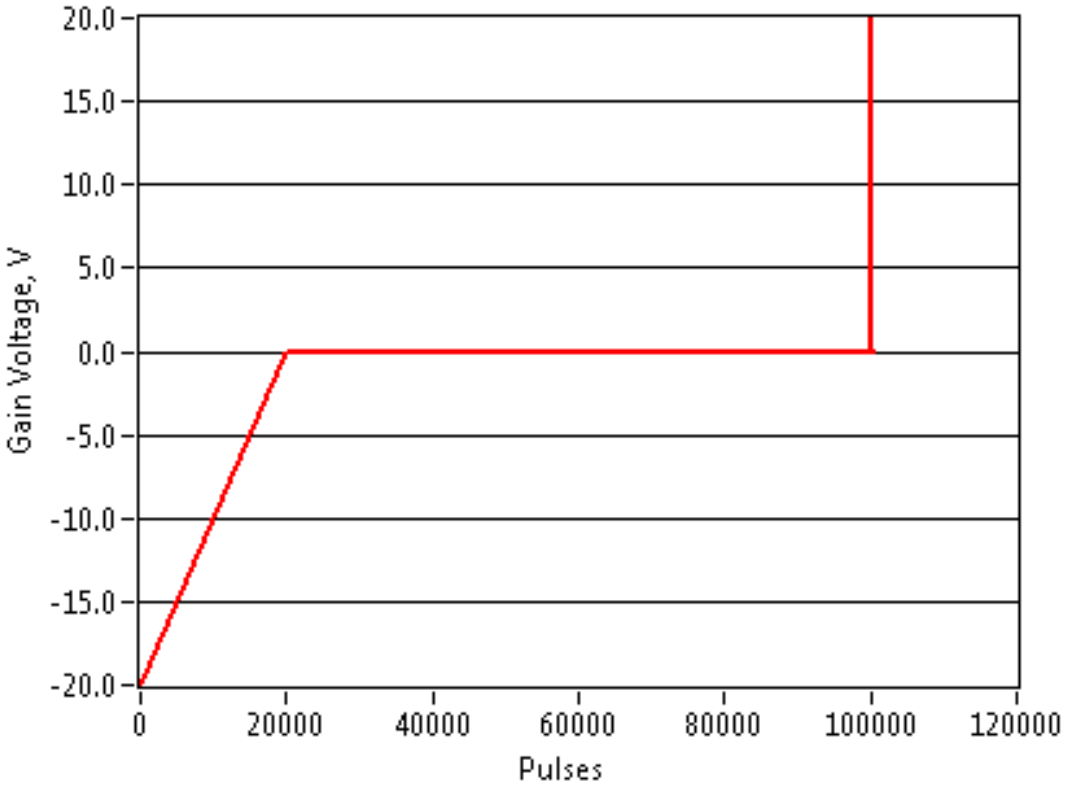




Repetition rate up to 6 kHz!
Pulse length: 400 ns – 100 us.

Conditioning algorithm

Parameter	Value
Max number of pulses per cycle	100 000
Safe pulses	20 000
Gain voltage at 0	-20 V
Gain after timeout	20 V
Initial voltage	600 V (~10 MV/m)
Max BDR	1E-5
Conditioning goal	6000 V (100 MV/m)



Comparison of heat-treated and as-machined copper

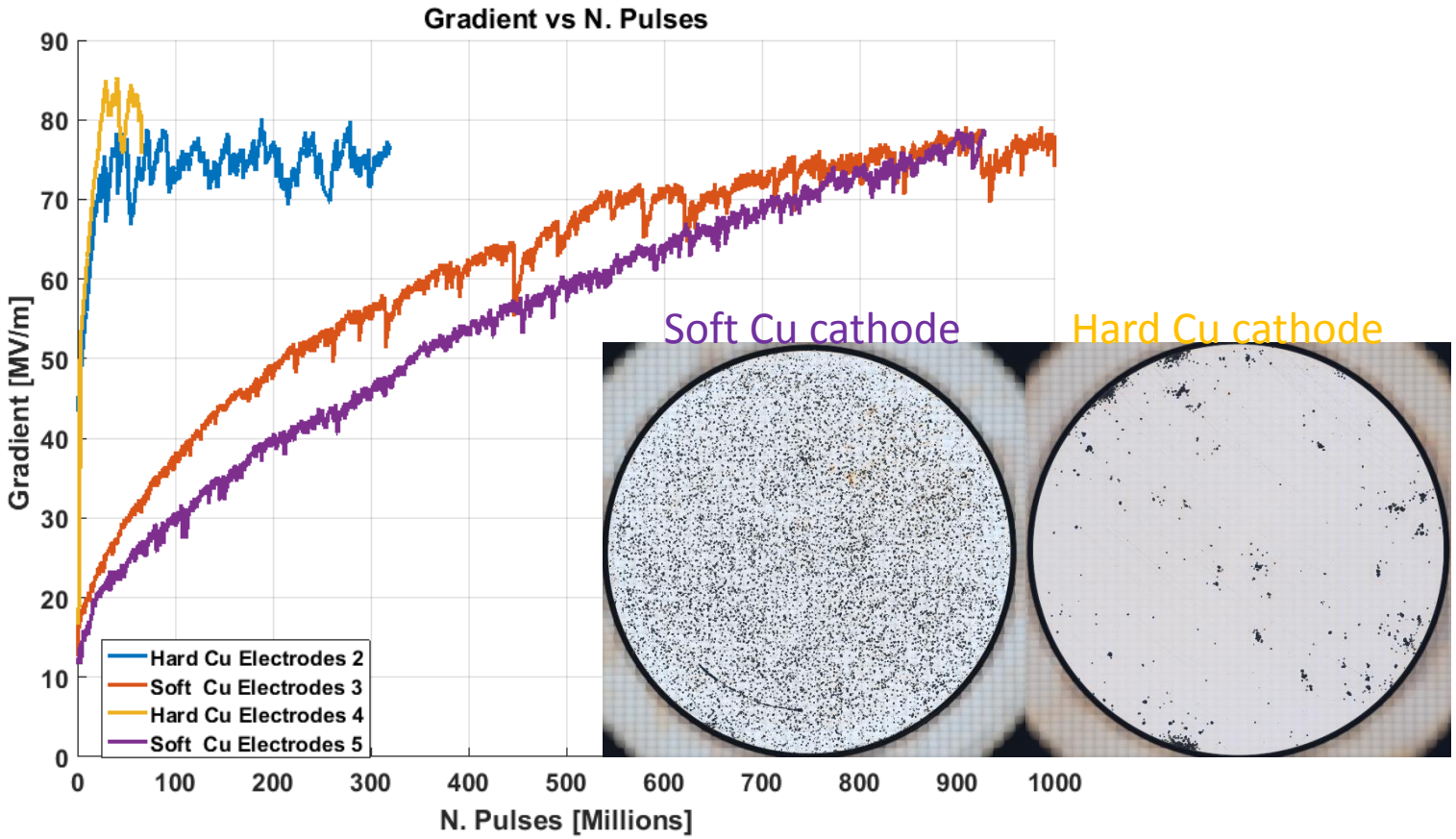


Fig. 7. Conditioning curves from tests at Pulsed DC System taken with HRR circuit, 16.7 µs pulse lengths and 60 µm gap distances.

Comparison of conditioning in DC and RF

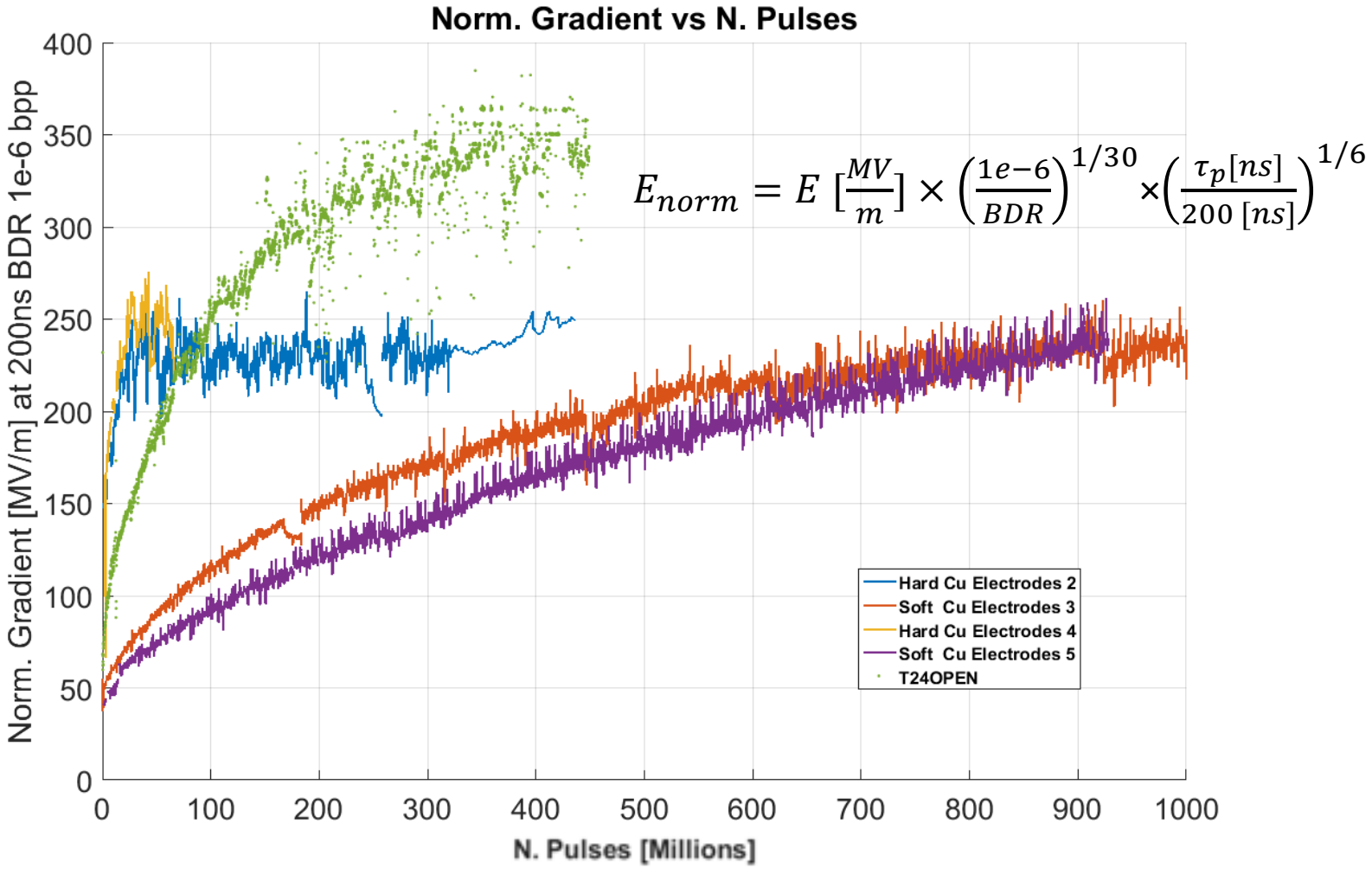
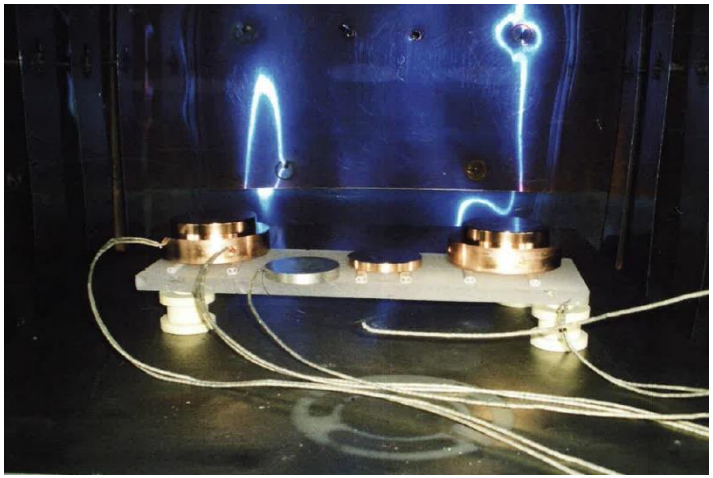


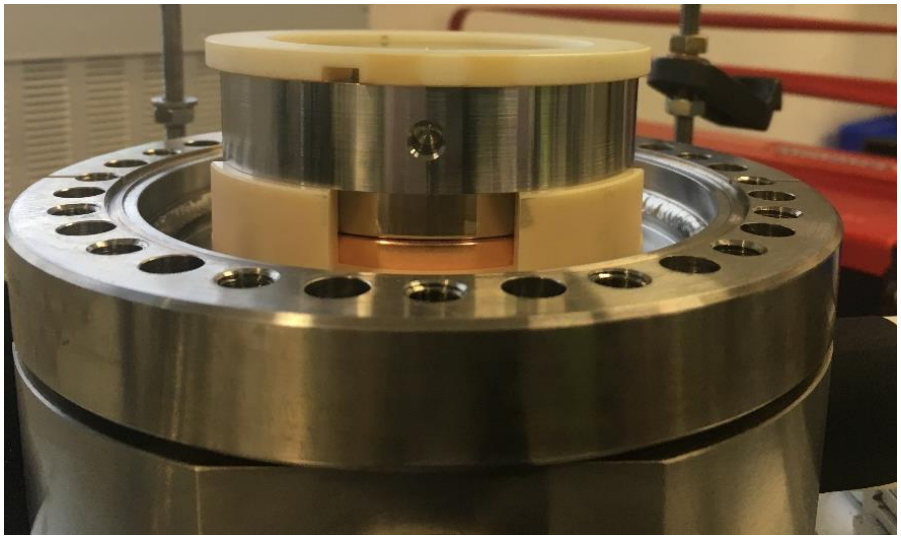
Fig. 8. Comparison of data from tests with the Pulsed DC System (taken with the HRR circuit, 16.7 µs pulse lengths and 60 µm gap distances) and RF.

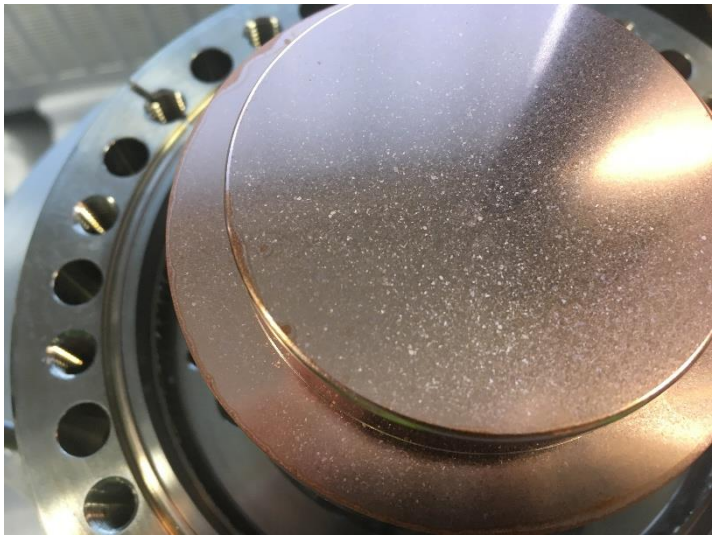
Test with electrodes from SLAC

Motivation and the main idea:

- ❑ Compare breakdown performance of:
  - soft, heat treated copper (from SLAC);
  - hard, as-machined, CuAg (from SLAC);
  - hard, as-machined Cu (from CERN).
- ❑ Swap anode and cathode material and use SS as a cathode.







Results from test with SLAC electrodes

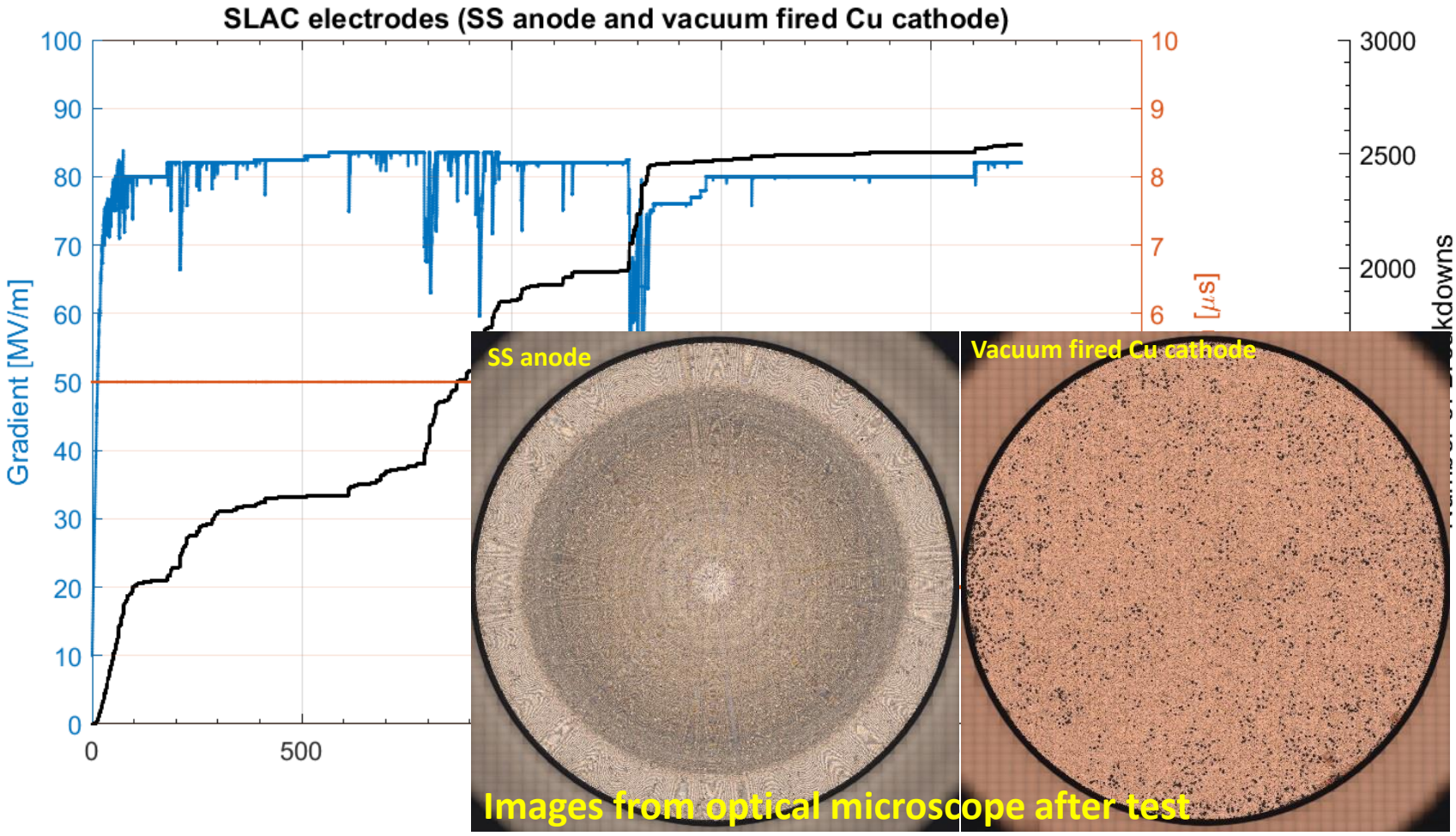


Fig. 10. Conditioning curve from tests at Pulsed DC System taken with Marx generator, 60 µm gap distances.

Results from test with SLAC electrodes

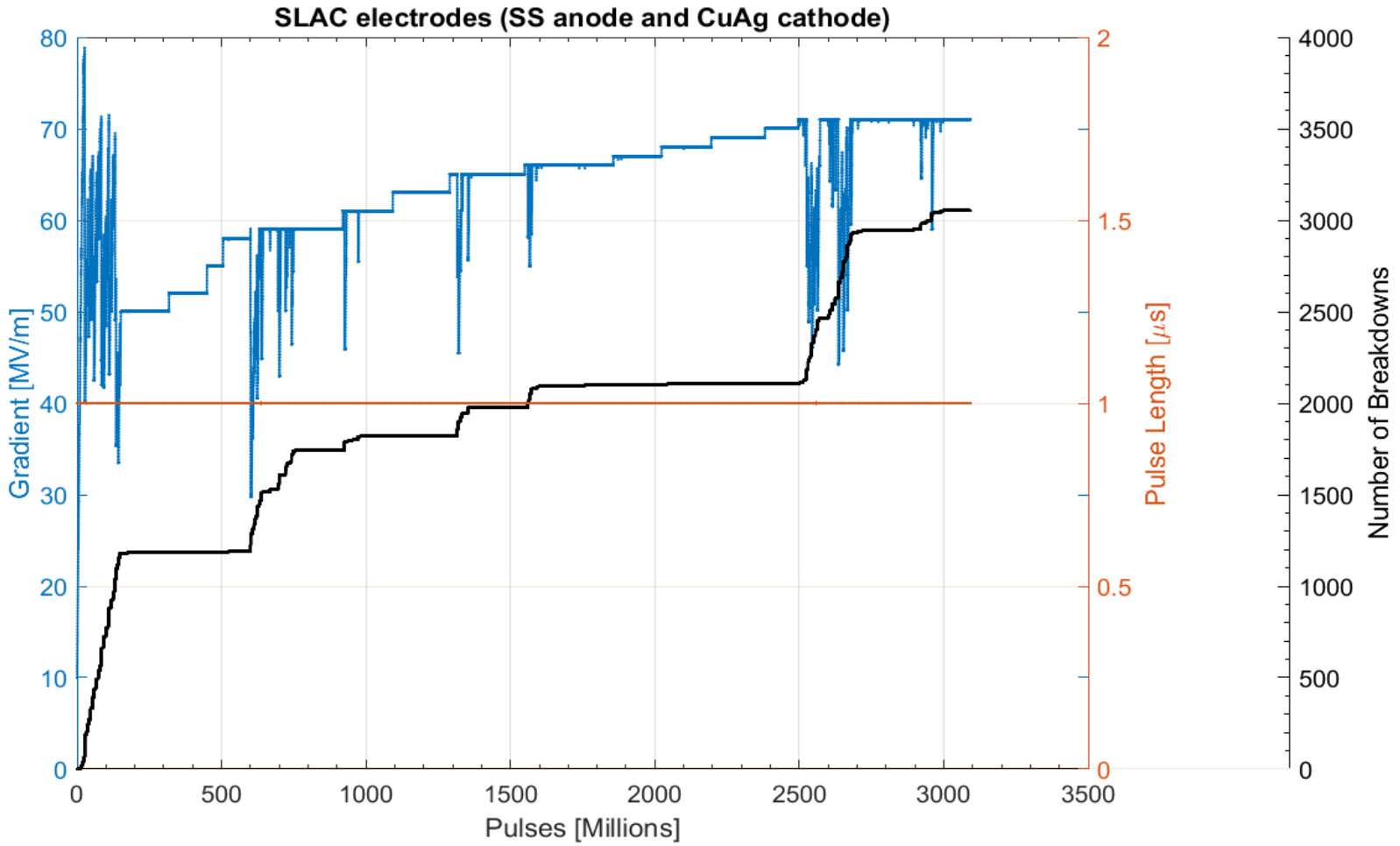
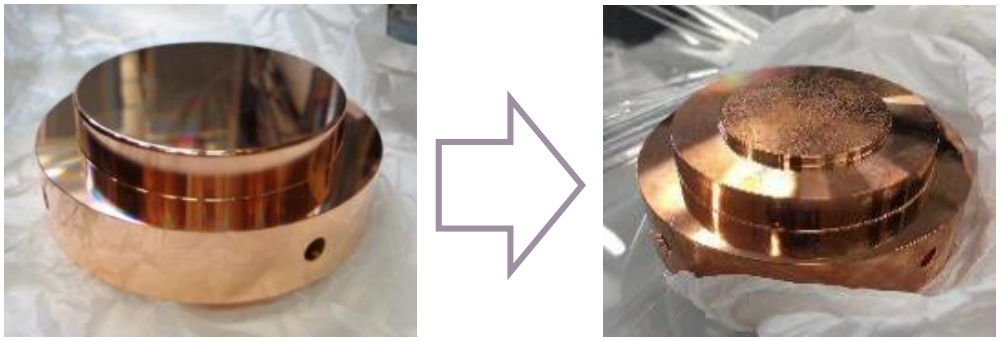


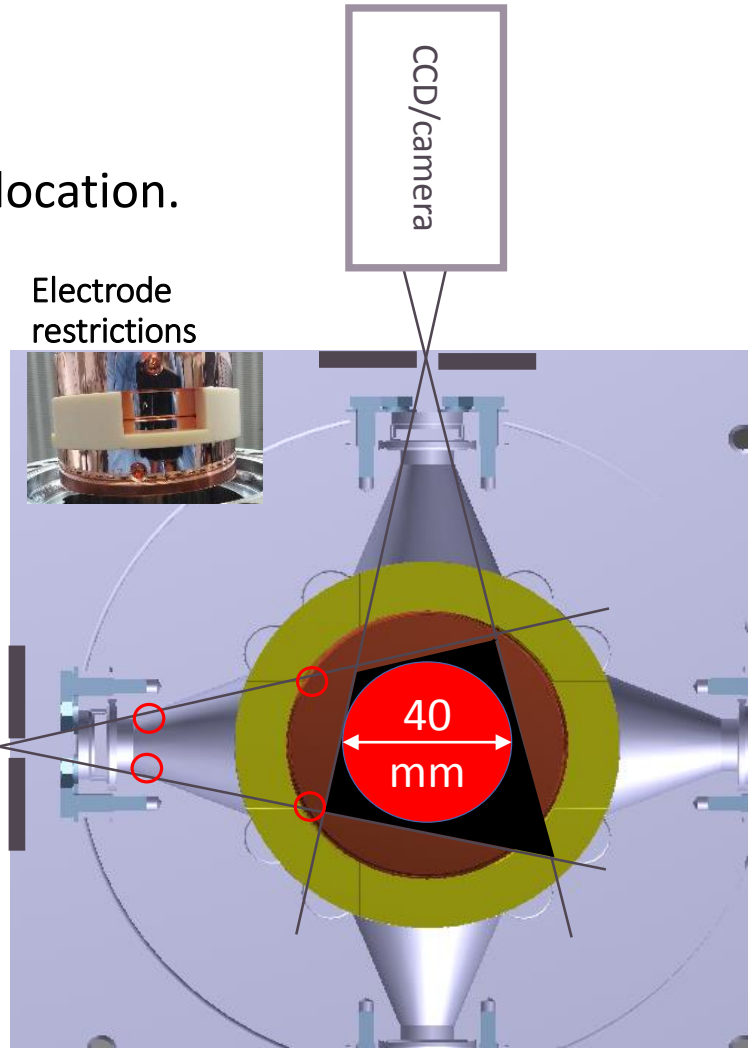
Fig. 11. Conditioning curve from tests at Pulsed DC System taken with Marx generator, 60 µm gap distances.

Breakdown localization technique

Motivation:

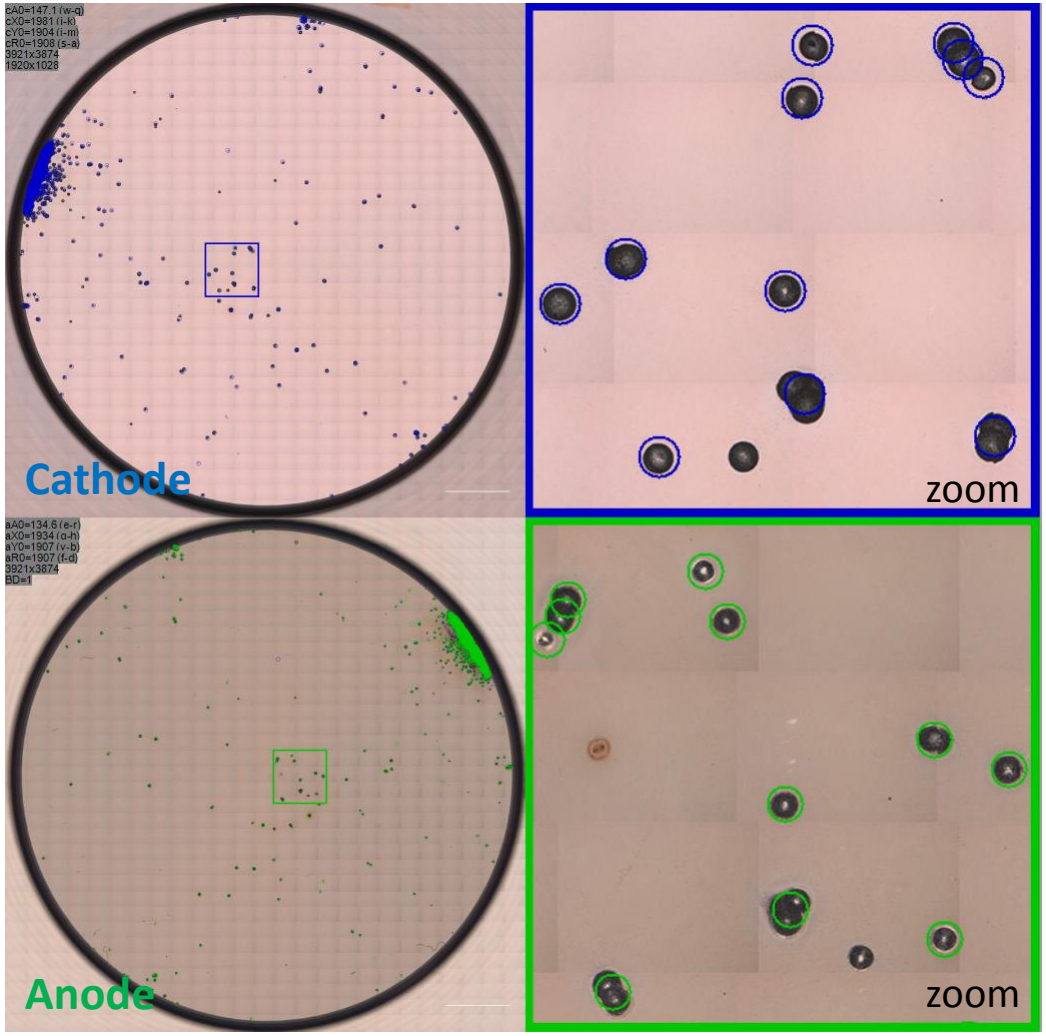
- ❑ find the position of BDs
- ❑ find how crater after BD relates to the next BD location.





More information about technique could be found from Xavier's Stragier slides there: http://indico.cern.ch/event/527301/

First results from BD localization

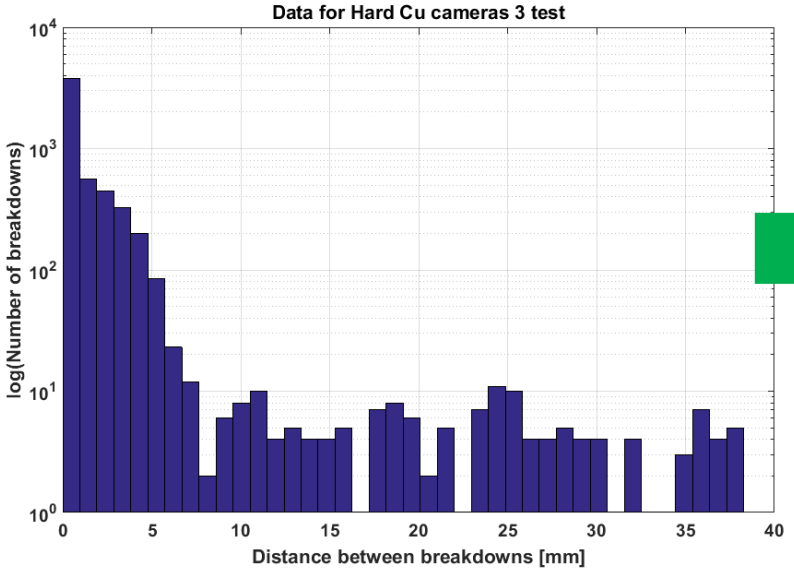


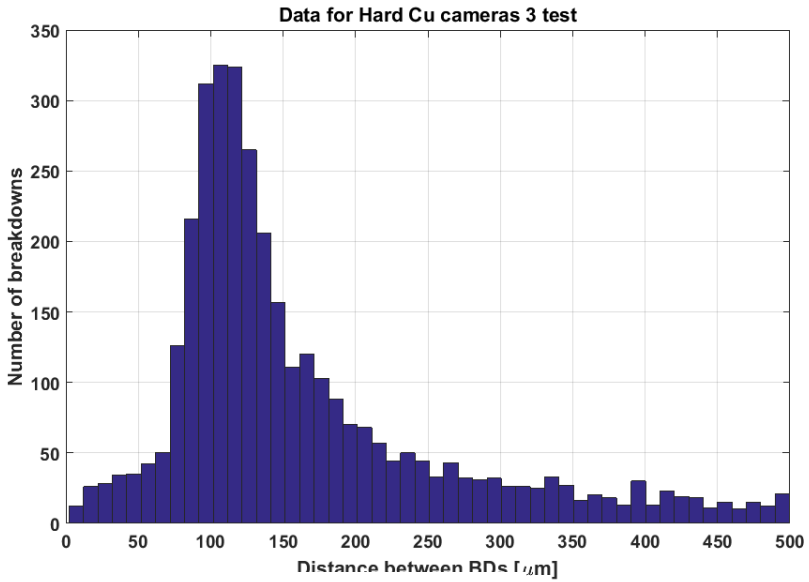
The main data from test:
Number of breakdowns detected by Marx generator: 5690.
Number of breakdowns detected by cameras: 5665.
Difference in data: ~0.5%.

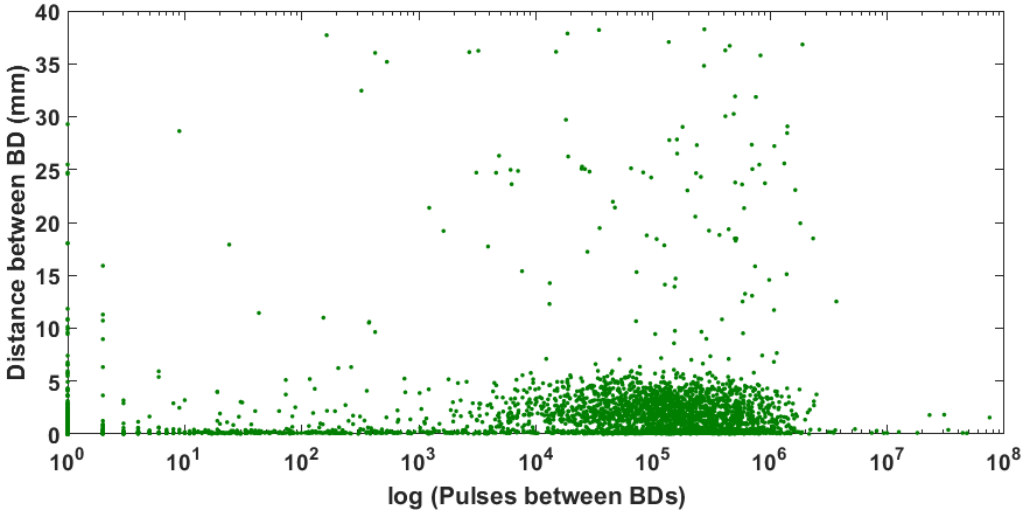
Conclusion
It works!

Fig. 15. The images of hard Cu (as-machined) electrodes from optical microscope together with data from cameras.

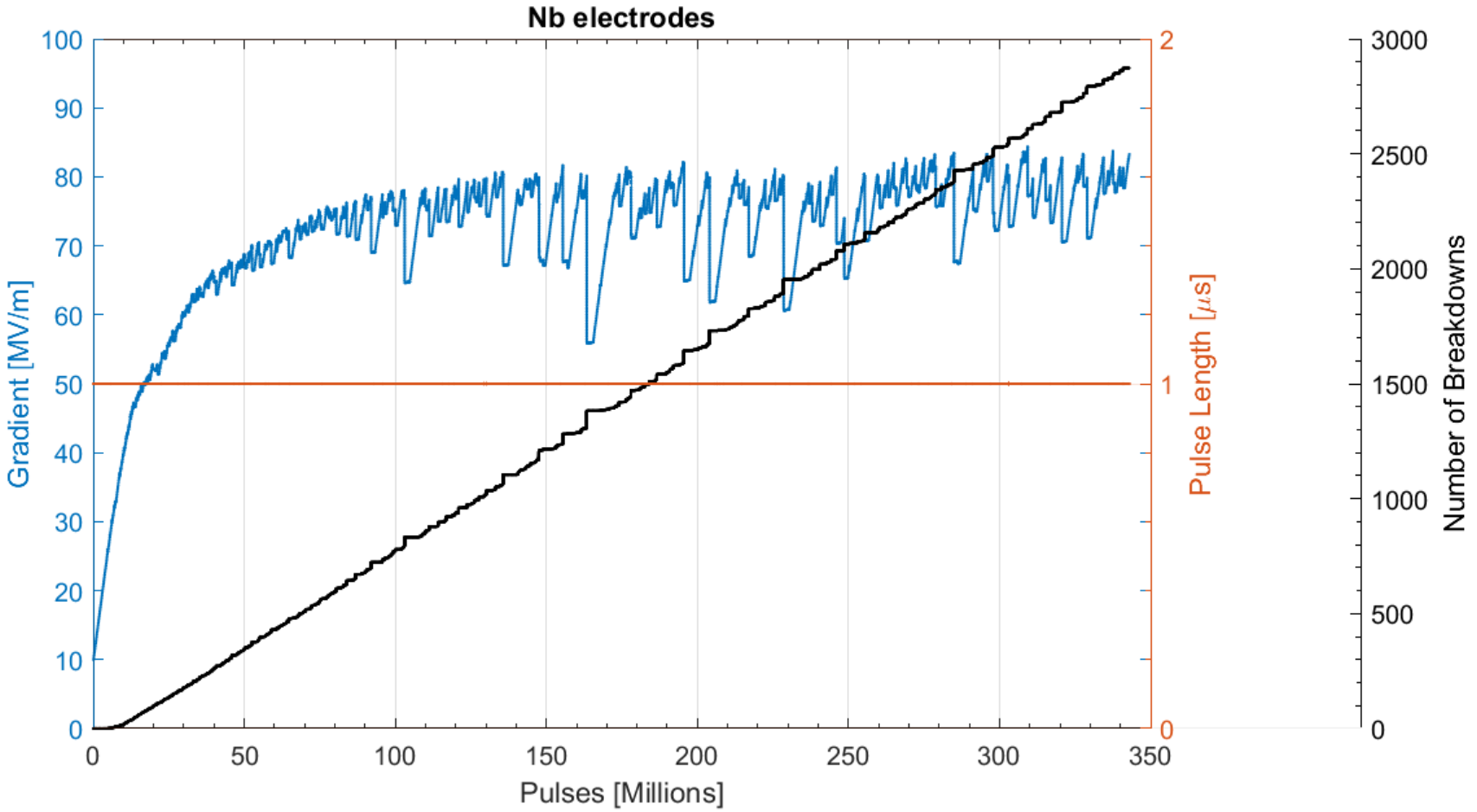
First results from BD localization



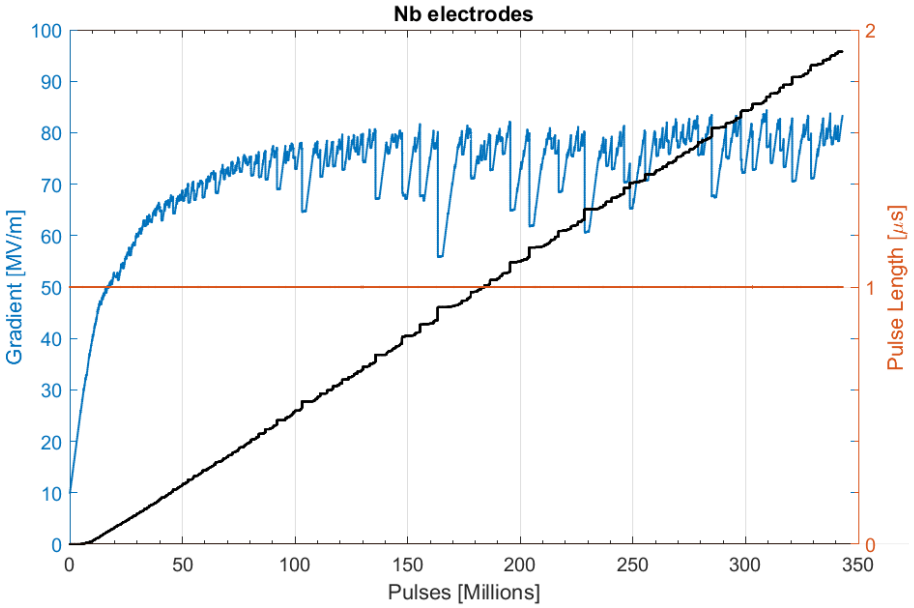


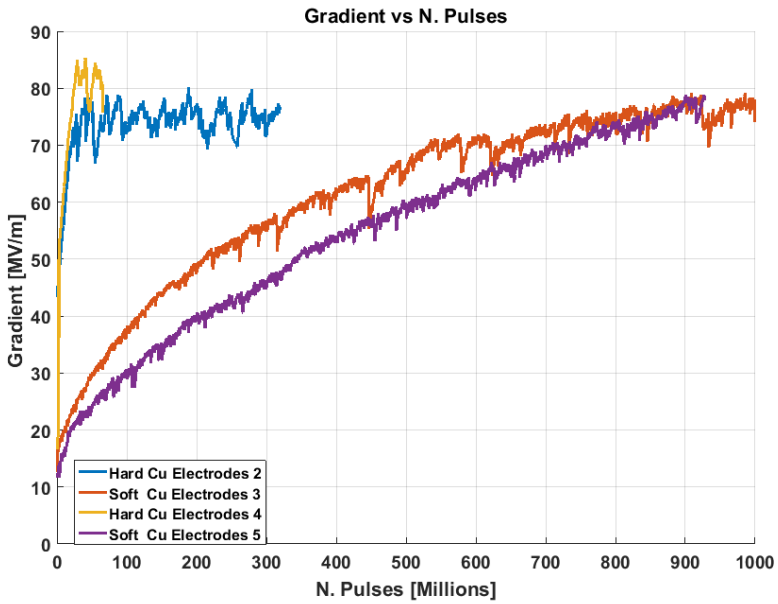


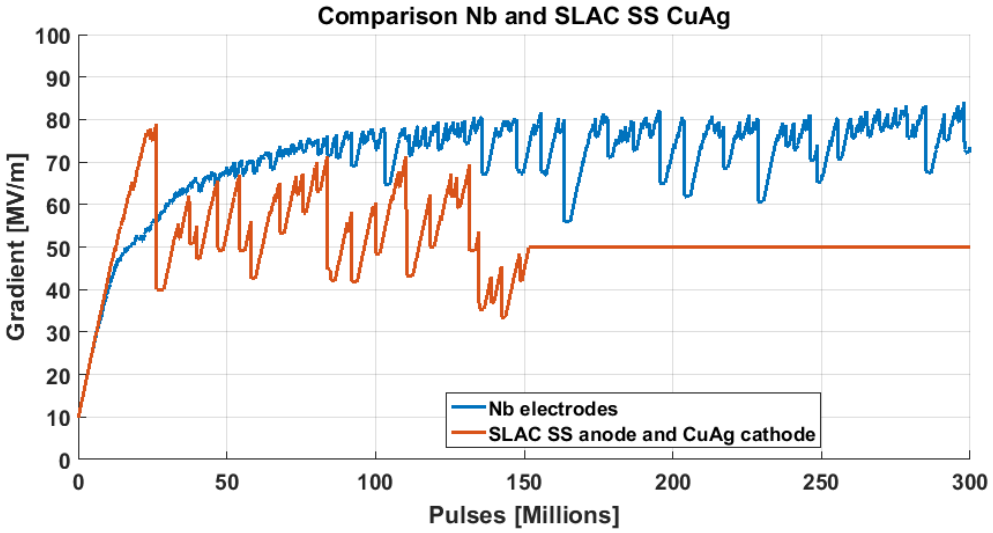
Nb electrodes



Nb electrodes comparison







Summary

- Two Pulsed DC Systems available at CERN.
- Breakdown localization technique is implemented.
- Conditioning tests for different materials are ongoing.

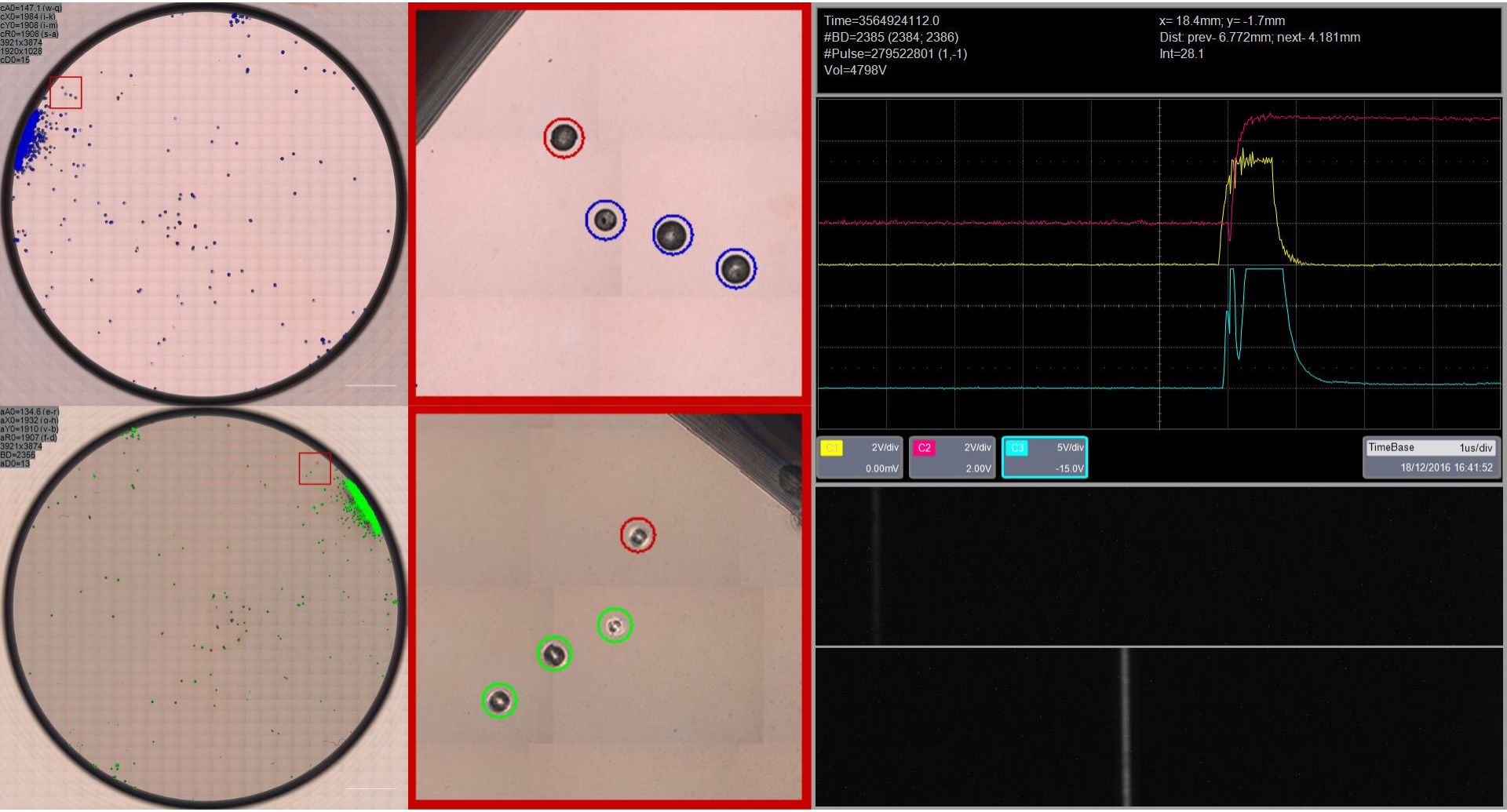
Main plans:

- Continue tests with Nb electrodes and electrodes from SLAC.
- Repeat conditioning tests with Hard and Soft Cu with smaller pulse length and together with cameras.
- Gradient and pulse length dependencies.
- Dark current measurements.

Thank you!

Extra slides

Correlation between DAQ parts



Manufacturing of electrodes from SLAC

- Material
  - C10100 OFHC Copper
  - C10700 CuAg, with Ag content 0f 0.085%
  - 304L Stainless Steel
- Maschining
  - Rough machining in Stanford Physics shop
  - Final machining at SLAC
- Cleaning
  - Cu and CuAg cleaned to standard SLAC process used for high gradient structures, including 30 sec etching
- Baking
  - Only copper parts run through a simulated H2 braze cycle (~1000°C) then vacuum fired at 700°C for 48 Hrs before being bagged in N2 for shipment

Comparison HRR circuit and Marx generator

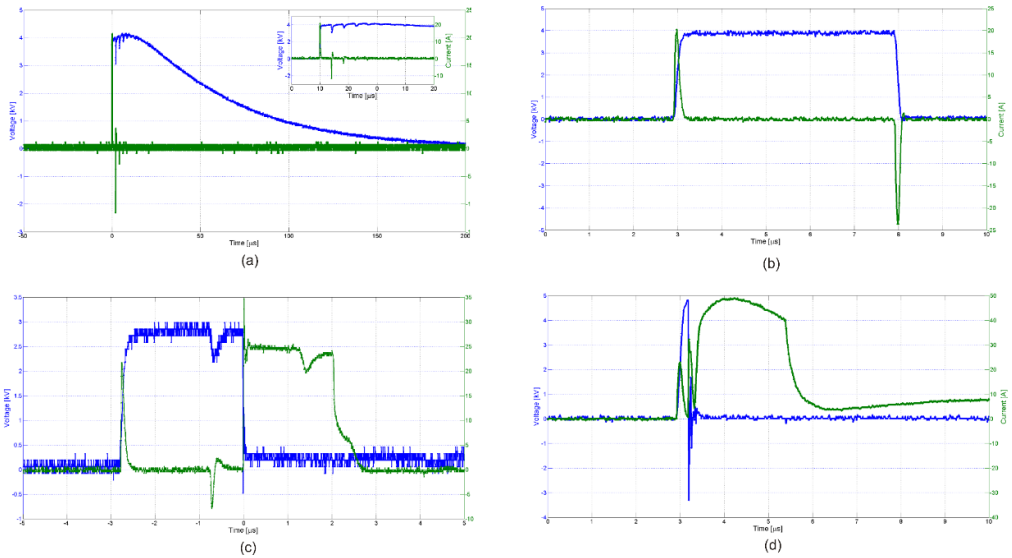


Fig. Typical waveforms taken with the Large Electrodes System and: (a) HRR circuit without breakdown at 4 kV and 5 µs pulse signal sent to the controller, (b) Marx generator without breakdown at 4 kV and 5 µs pulse signal to the controller, (c) HRR circuit with breakdown at 2.9 kV; (d) Marx generator with breakdown at 5.12 kV. Current signals are shown in green, voltage signals are shown in blue.

Table 1. Comparison of main parameters HRR circuit and Marx generator.

No	Parameter	HRR circuit	Marx generator
1.	Max output voltage	12 kV	10 kV
2.	Max frequency	1 kHz	6 kHz
3.	Pulse length	3 – 7 µs *	400 ns – 100 us
4.	Stored energy	~1.4 J	~1.4 J
5	Rise time (10-90%, for 4 kV)	200 ns	180 ns
6	Fall time (90-10% for 4 kV)	130 µs	100 ns

* This is the pulse length of signal sent from the controller to switch. Effective pulse length much longer. For example, by sending 5 µs signal, the effective pulse length (at 90% of height) is ~20 µs.