

# High-voltage High Repetition Rate Marx Generators for Breakdown Studies



ENERGY  
PULSE  
SYSTEMS

Luis Redondo<sup>1</sup>, Aleh Kandratsyey<sup>2</sup>, Iaroslava Profatlova<sup>3,4</sup>,  
Sergio Calatroni<sup>3</sup>, Walter Wuensch<sup>3</sup>

<sup>1</sup>ISEL/GIAAPP, Lisbon Engineering Superior Institute, Portugal

<sup>2</sup>EPS, Lisbon, Portugal, <sup>3</sup>CERN, Geneva, Switzerland,

<sup>4</sup>Institute of Applied Physics, National Academy of Sciences of Ukraine, Sumy, Ukraine



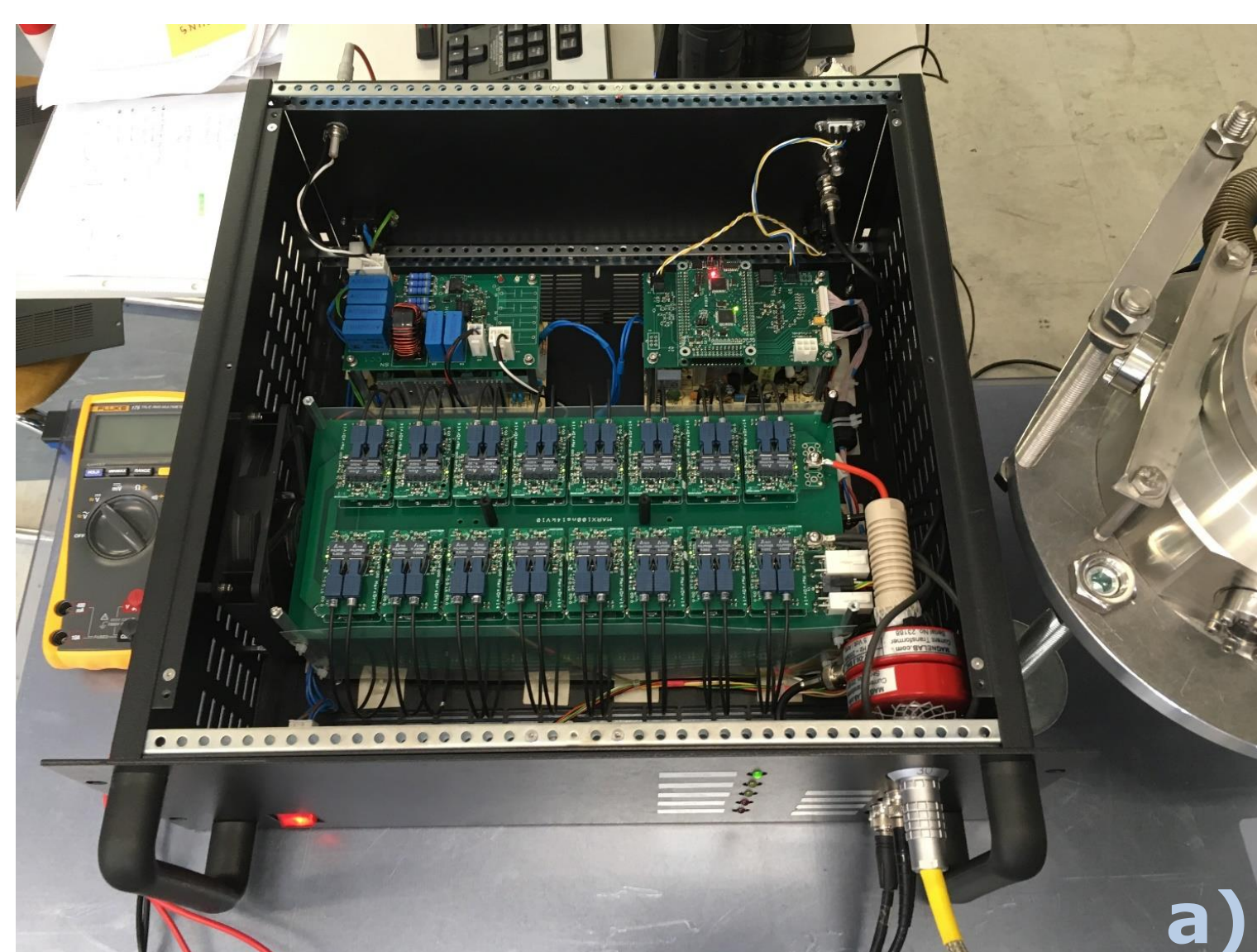
## Overview

Compact Linear Collider (CLIC) is one of the candidates for the next generation of high-energy linear colliders. One of the critical parameters for the successful operation is breakdown rate (less than  $3 \cdot 10^{-7}$  breakdowns per pulse per meter is required for successful operation of accelerator). Pulsed DC systems are available at CERN as a complement of RF tests for the CLIC project.

For studying the conditioning process and dependencies based on breakdown rate for different materials in a faster way than in RF, high-voltage generators with high repetition rate are required. The requirements for the generator include applying positive voltage pulses to loads whose capacitance can be in the range from 150 pF to 650 pF, at a repetition rate from 1 Hz to >1 kHz, with a flattop of up to 10 kV pulse amplitude and a pulse width in the range from 500 ns to 100  $\mu$ s. In addition, rise and fall times of <100 ns, measured from 5% to 95%, are required for the effective load capacitance of 150 pF.

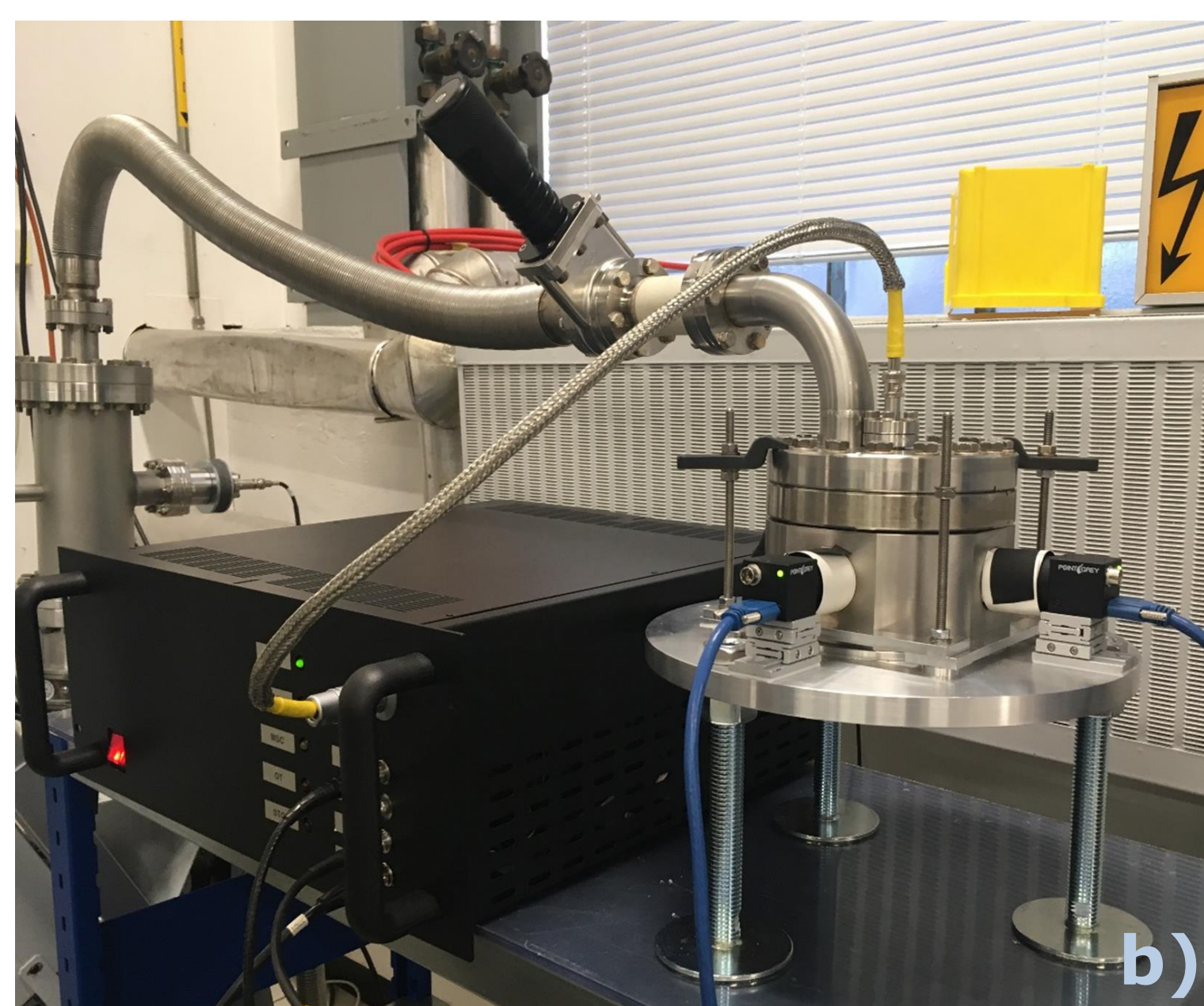
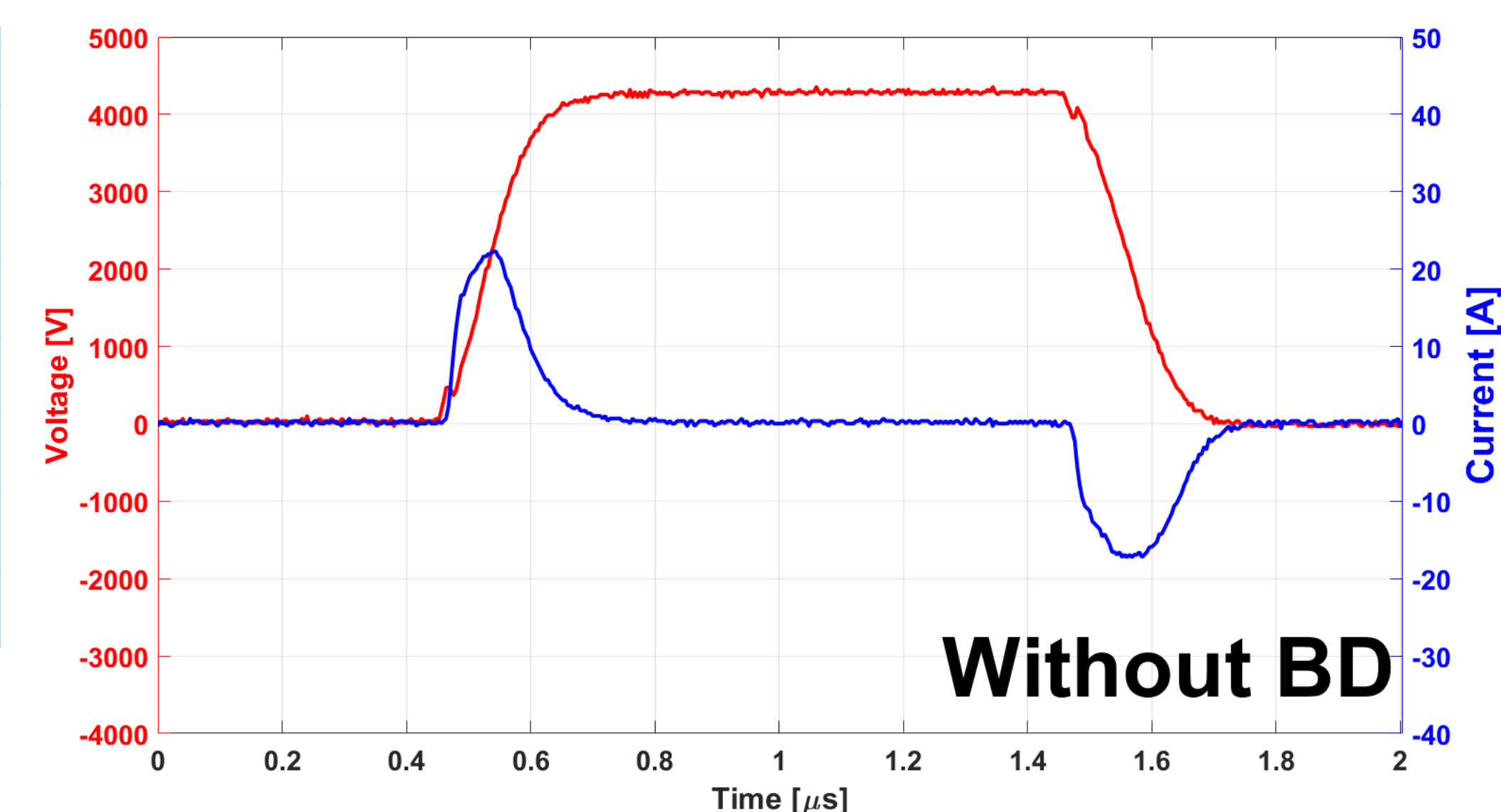
A high repetition rate, semiconductor based, Marx generator has been designed and developed specially for pulsed DC system operated at CERN. The main parameters and improvements for generator are described below.

## Basic Marx Generator



Parameters	Value
Max Output Voltage	10 kV
Max Repetition Rate	6 kHz
Pulse Width	400 ns – 1 ms
Stored Energy	~1.5 J
Rise time*	80 ns
Fall time*	85 ns
Delay of pulse during breakdown	0.5 – 6 $\mu$ s

\*values taken at 10-90% with 4.1 kV and 285 pF.



The basic version of generator, shown in Fig. 1, allows the generation of high-voltage positive pulses from relative low voltage power supply, <1kV. This is achieved by charging  $n$  capacitors in parallel and then connecting them in series with the load, using very fast SiC MOSFETs.

The generator includes several possibilities:

- Breakdown detection, with adjustable delay
- Over current limit, with adjustable amplitude
- Voltage amplitude regulation
- Pulse width changing
- Frequency control
- External and internal triggering
- Flat top pulse
- No overshoot or undershoot.

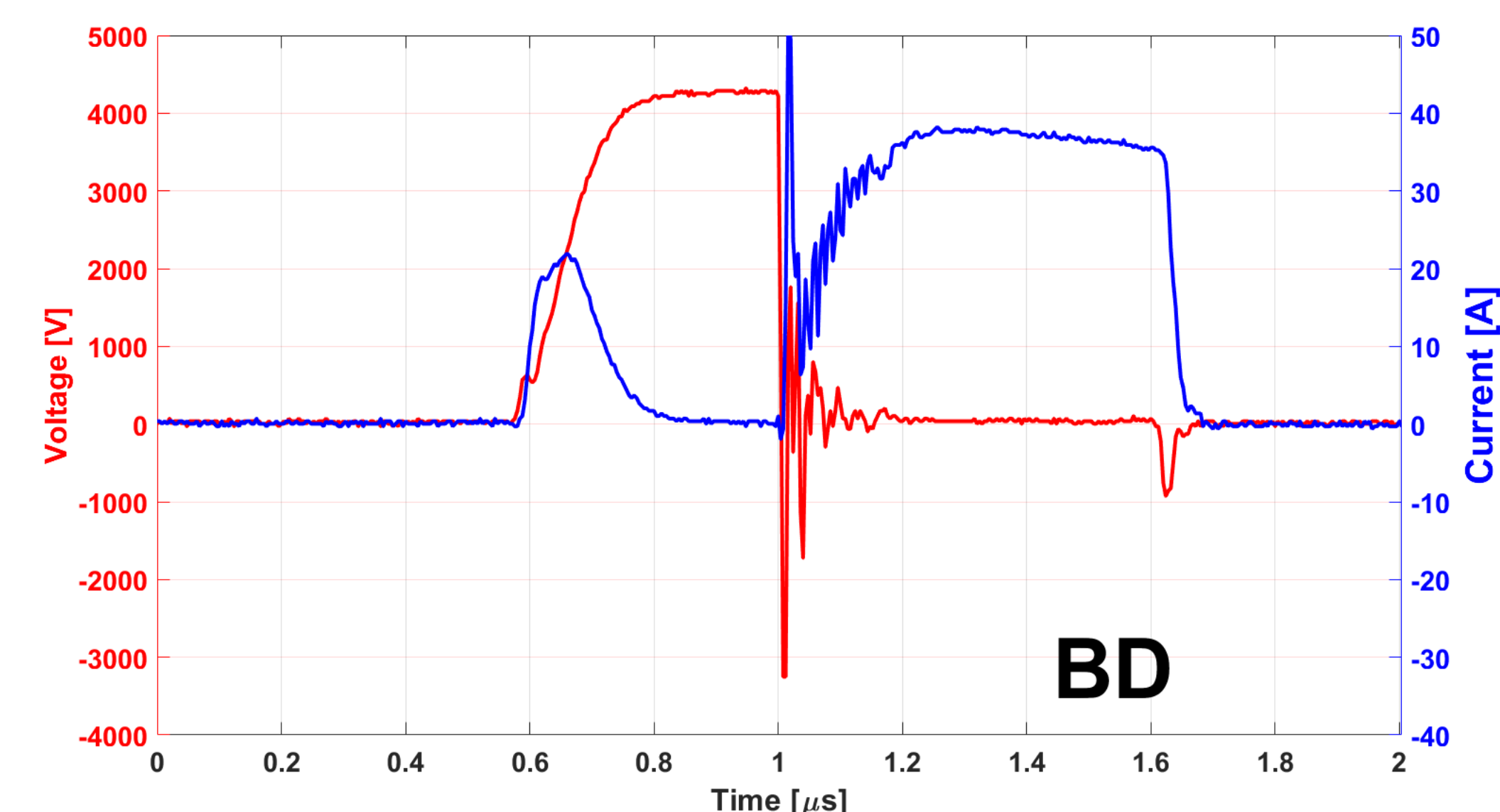


Fig. 1. The equipment available at CERN for breakdown studies in DC: a) view inside the generator, b) together with Large Electrodes System (LES).

Fig. 2. The waveforms taken with Marx generator and Large Electrodes System with 1  $\mu$ s pulse (0.6  $\mu$ s delay is used in BD case).

## Dual-polarity Marx Generator

Dual Marx generator with:

- Possibility to apply positives and negative pulses
- Polarity could be set for each pulse
- Similar parameters as basic version, Fig. 1.

Dual-polarity generator was already tested with experiments in breakdown mode.

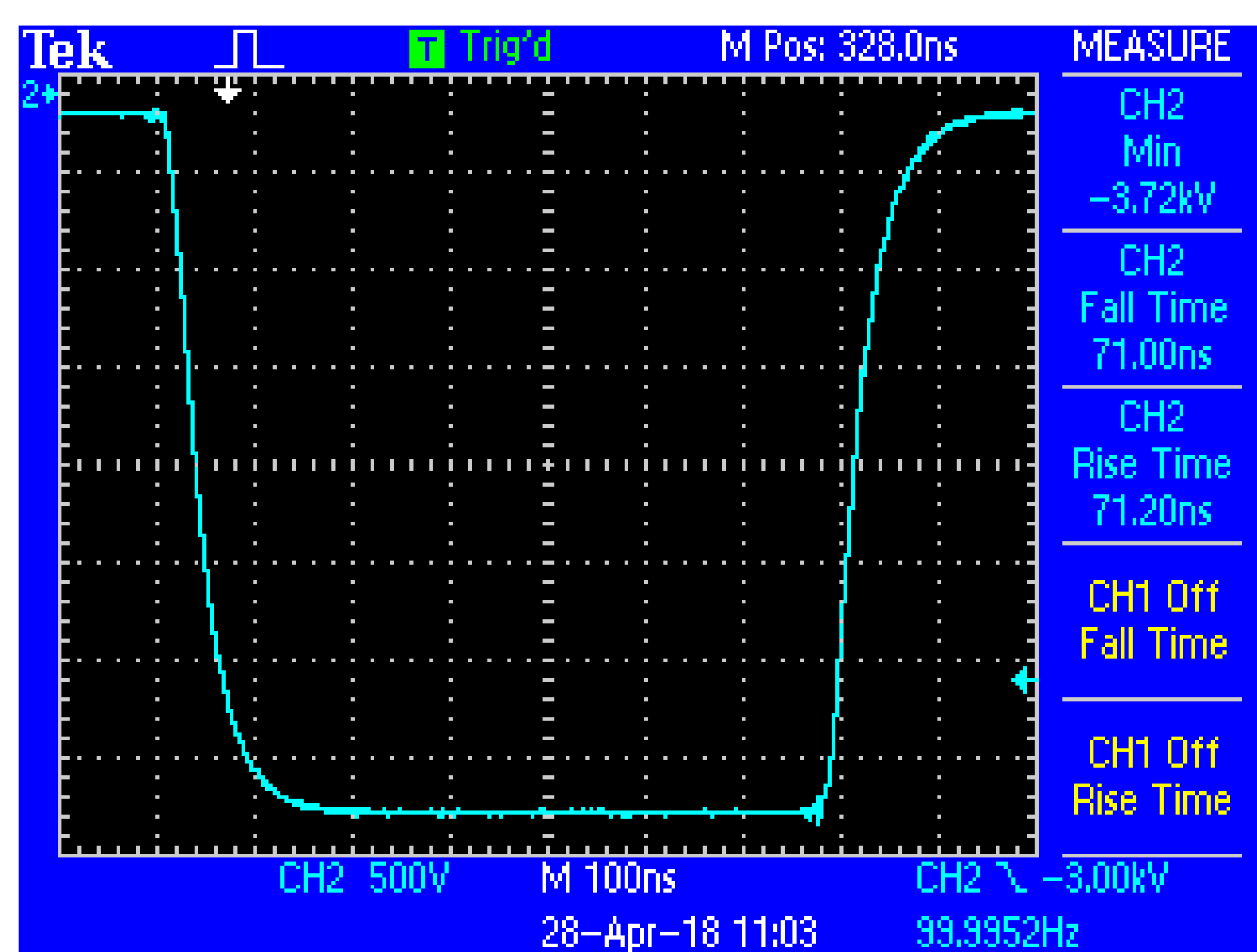


Fig. 3. Waveform for the 4 kV output negative pulse on a 300pF from dual Marx generator.

## Fast Marx Generator

Positive Marx generator with improved capability:

- Coaxial topology with lower inductance
- Three times less rise and fall times, ~ 25ns for 300pF
- Shorter pulse width, from ~ 150ns

(comparable with RF pulse width for CLIC 50 – 250 ns).

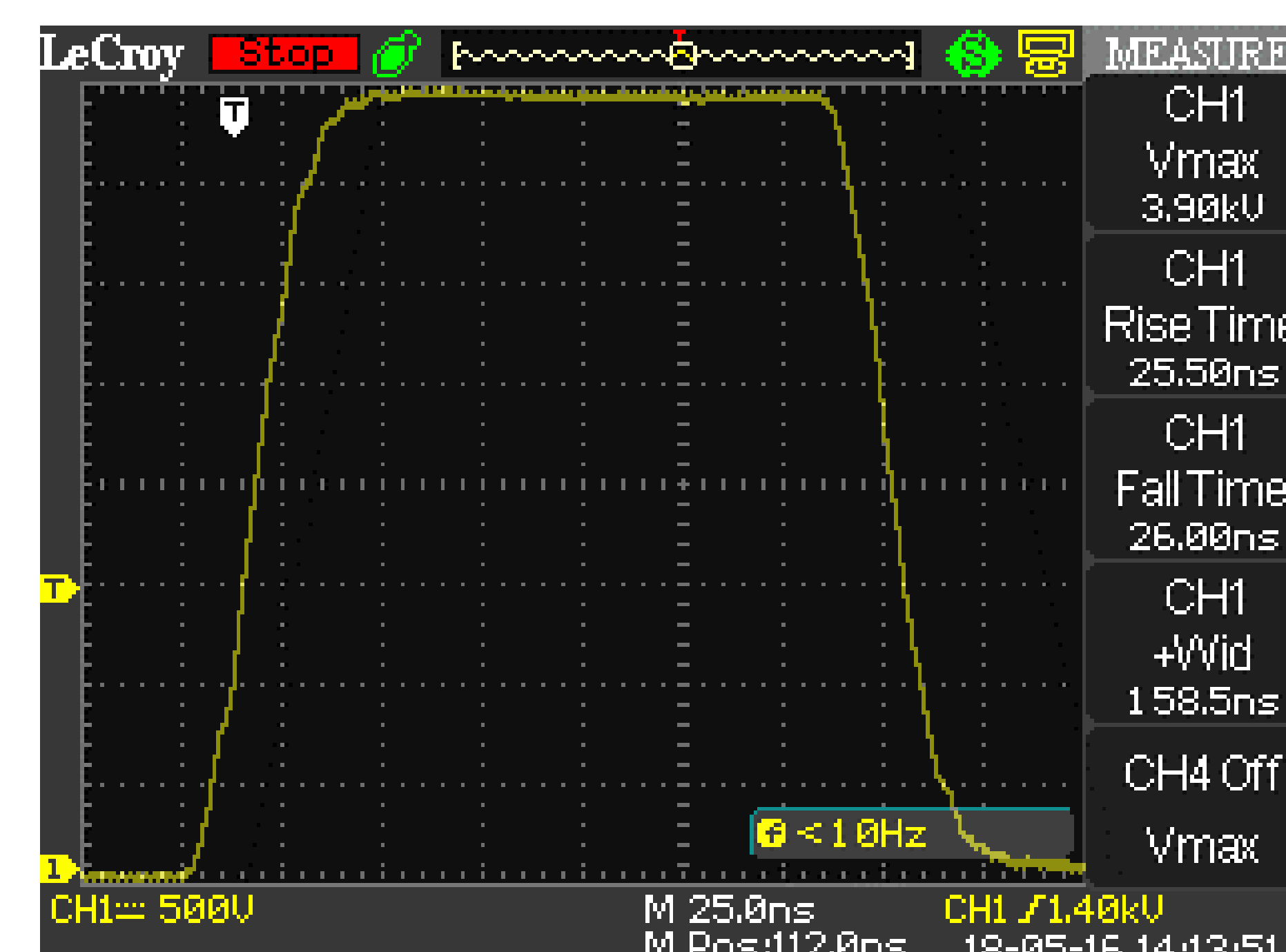


Fig. 4. Waveforms taken with 4 kV output pulse on a 300pF load from fast Marx generator.

## Conclusion and plans

Three Marx generators of basic version successfully work together with Large Electrodes Systems for breakdowns studies. Two of them are located at CERN and one in Helsinki Institute of Physics. The improvements were done in each next basic version of generator to be able to follow the ideas for future tests.

First prototypes for Dual-polarity and Fast Marx generators are already designed by Energy Pulse Systems and will be soon involve to the breakdown studies at CERN. All three versions of Marx generator share the same control software and hardware, and it's possible to change from one version to another by changing only the switching board.

## References

1. <http://energypulsesystems.pt/>
2. L.M.Redondo, A.Kandratsyey, M.J.Barnes, S.Calatroni, W.Wuensch, Solid-State Marx Generator for the Compact Linear Collider Breakdown Studies, Power Modulator and High Voltage Conference (IPMHVC), 2016.
3. I.Profatlova, High Field studies for CLIC Accelerating Structures Development, Proceedings of the CERN-BINP Workshop for Young Scientists in e+e-Colliders, Geneva, Switzerland, 22 – 25 August 2016, edited by V. Brancolini and L. Linssen, CERN Proceedings, Vol. 1/2017, CERN-Proceedings-2017-001 (CERN, Geneva, 2017).

