TECHNISCHE UNIVERSITÄT DRESDEN

Chair for Embedded Systems

Department of Computer Science, Chair for Embedded Systems

INFLUENCE OF OPERATING CONDITIONS ON RING OSCILLATOR-BASED ENTROPY SOURCES IN FPGAS

Entropy Source

Why true random numbers?

- Random numbers are essential for all kinds of cryptographic protocols

Why entropy sources on FPGA?

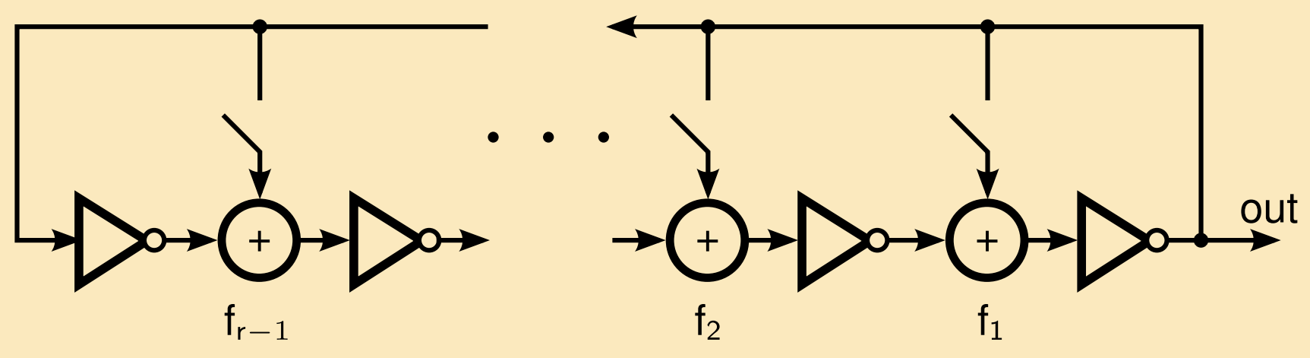
- Self containment is an important property of cryptographic systems

How to build an entropy source?

- Ring oscillators provide as entropy sources and use only digital circuitry, have a simple design and small footprint

Project goals

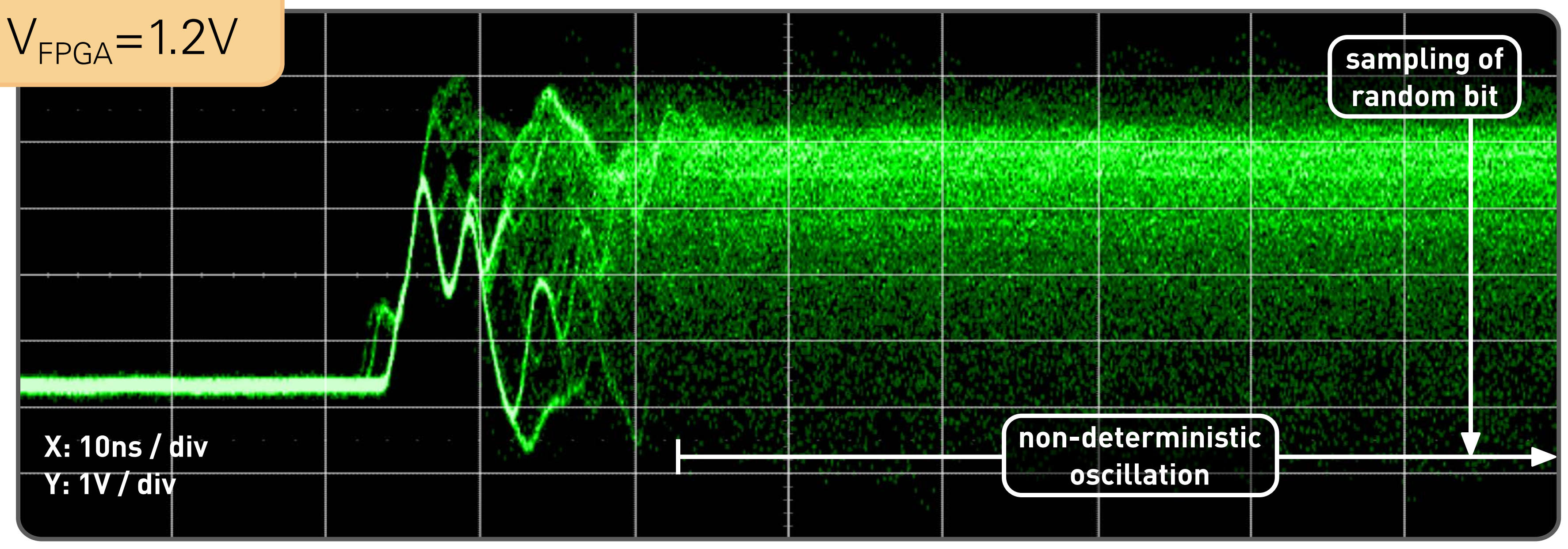
- Investigate the properties of different entropy sources built with FPGAs and possibilities to influence them
- Develop a framework to easily instantiate a random number generator that has certain security properties



Non-deterministic output

Nominal conditions

T_{FPGA}=30°C • V_{FPGA}=1.2V

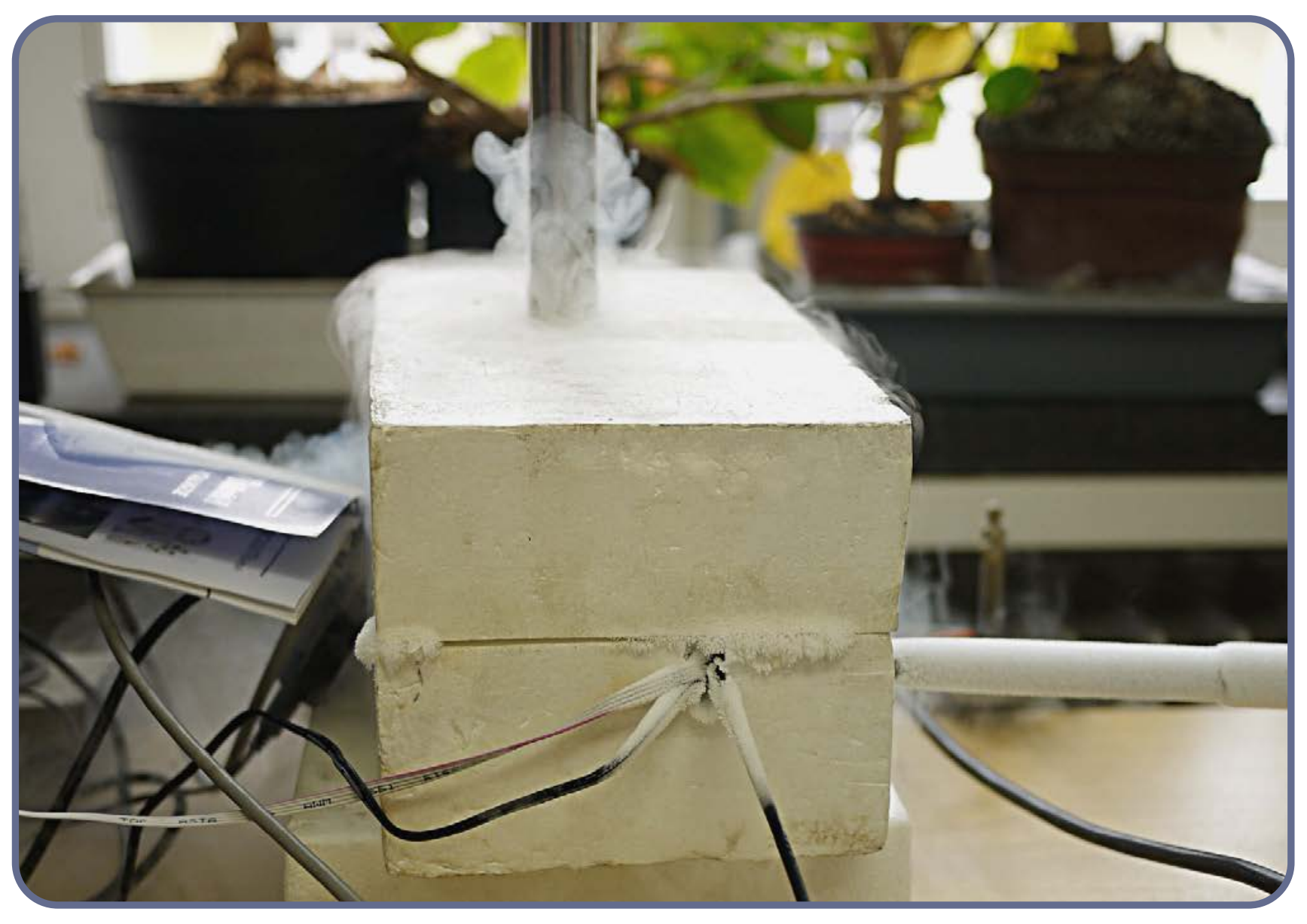


GARO on Lattice ECP3

Tamper-safety under extreme conditions

Temperature +30 ... -130°C

- Nitrogen gas of -160°C fed into insulated box
- Continuous capturing of random bits while temperature decreased by approximately 2-5K/min



FPGAs under test

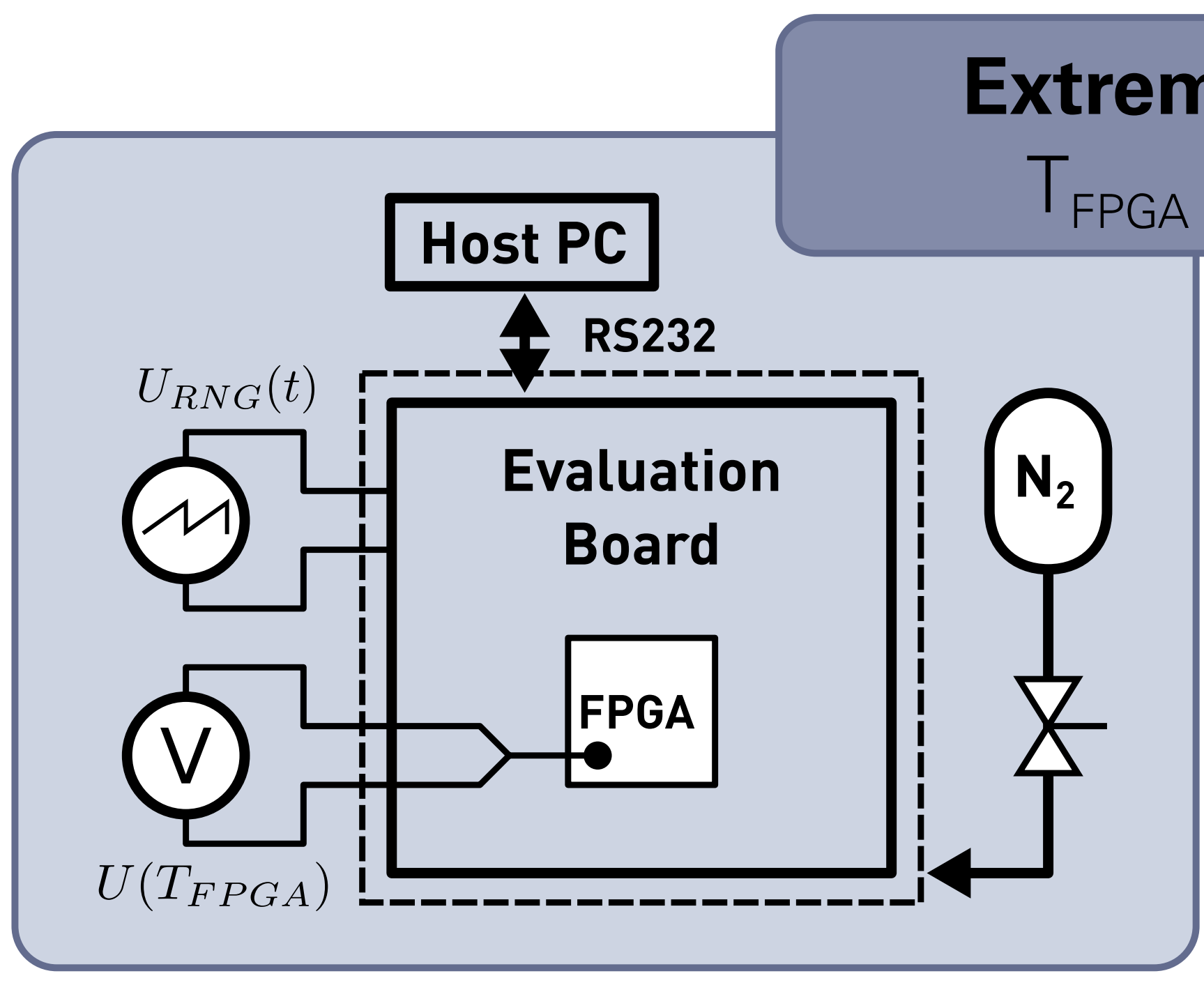
Xilinx	Spartan-6 LX45	45nm	45k LUTs
Lattice	ECP3 LFE3-35	65nm	35k LUTs

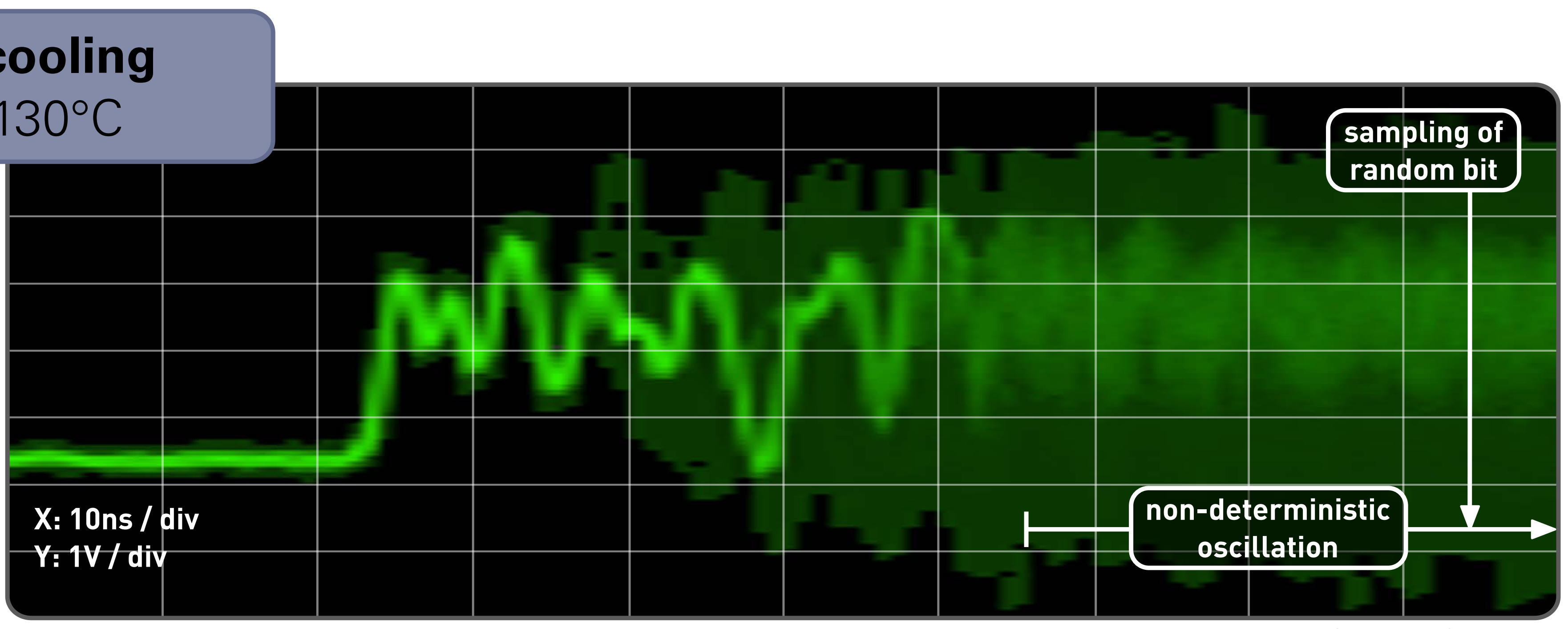
Core voltage 1.2 ... 0.9V

- On-board voltage regulator replaced by external supply input
- Random bit sequences captured at each voltage level decreasing in steps of 50mV

Extreme cooling

T_{FPGA} = -130°C

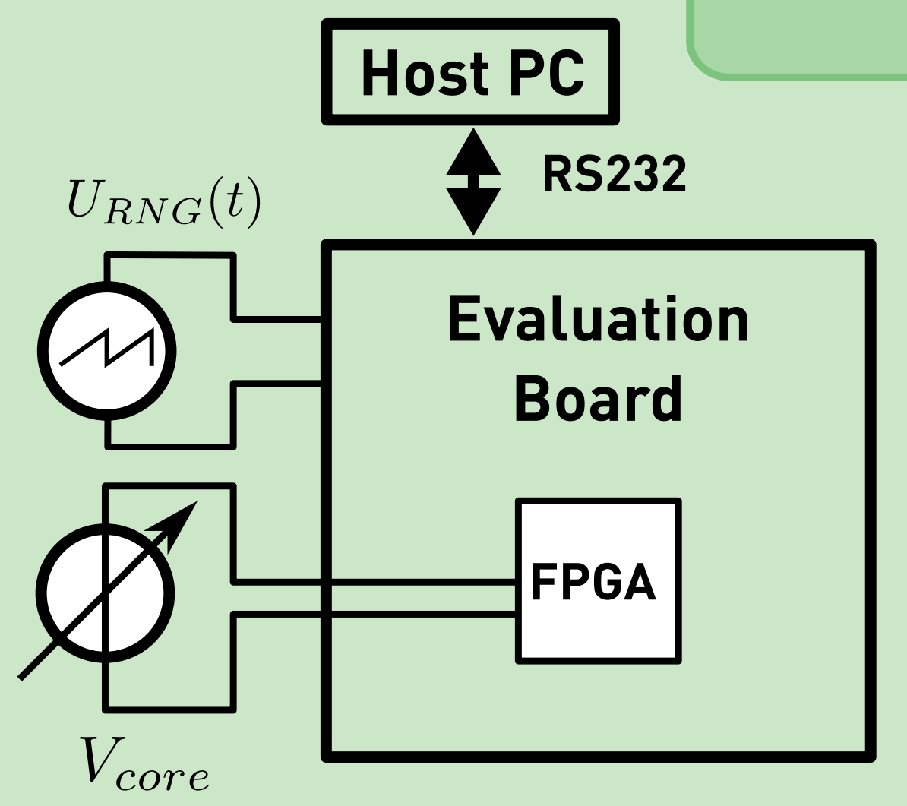


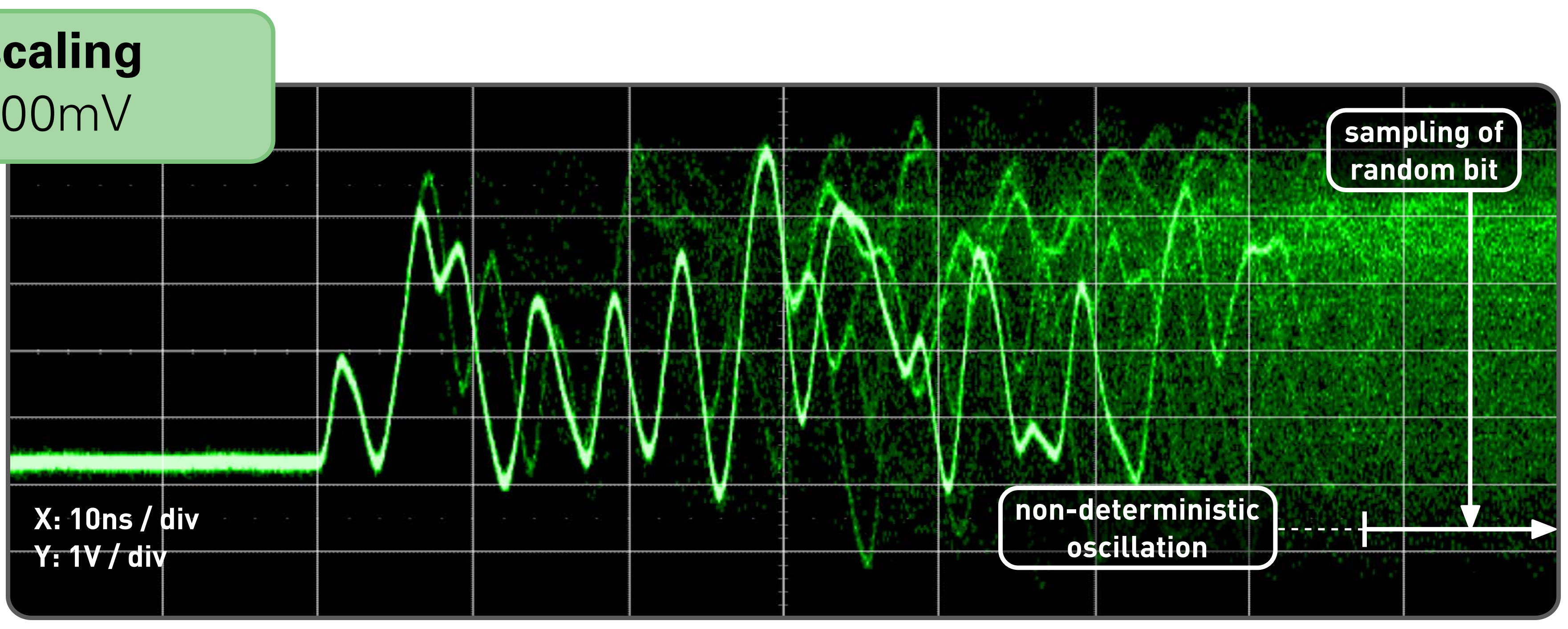


FIRO on Xilinx Spartan6

Voltage scaling

V_{FPGA} = 900mV

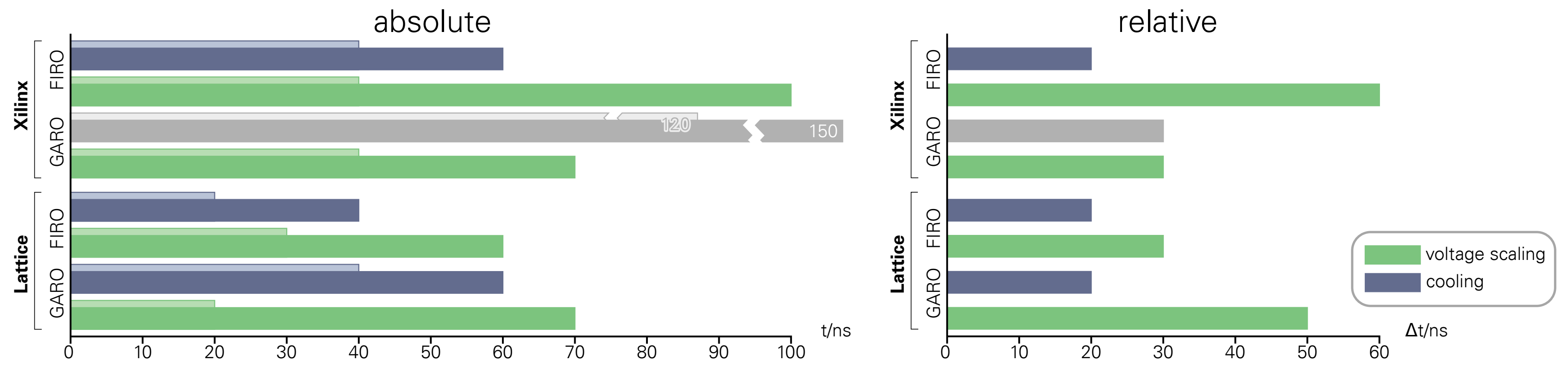




GARO on Lattice ECP3

Results and future work

Increase of acquisition-time under extreme conditions depending on architecture and type of TRNG



- **No serious degradation of randomness was seen at low temperature or low voltage regardless of observed variation in one-zero distribution.**
- Duration to pass deterministic oscillation increases under such conditions, while voltage has stronger impact than temperature
- No indication of complete failure or loss of entropy output which is further proved by statistical tests (NIST)
- Random number generators can be secured against such types of influence with attention to the sampling point
- Current research covers experiments on the influence of radiation and strong static magnetic fields

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