Dark current measurements at X-band

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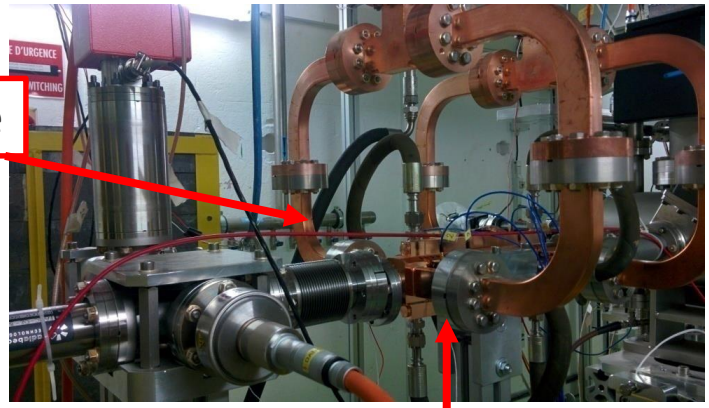
Outline

- Means of Dark current measurements at Xbox2
- Dark current observations and measurements
  - Pulse shape dependence
  - Structure temperature dependence
  - RF frequency dependence
- Summary and next steps

Dark current measurements at Xbox2

- The Xbox-2 is the second generation of CLIC high-power klystron-based test stand at CERN. RF Power capabilities: up to 150 MW 250 ns
- Field emitted electrons, due to high power, are captured and accelerated by the RF fields → Dark current
- Dark current is measured by:
  - Faraday cups: signal only from the FC upstream due to the spectrometer placed downstream
  - Beam Loss Monitors (BLM) (M. Kastriotou) : Cherenkov fibre optic detectors



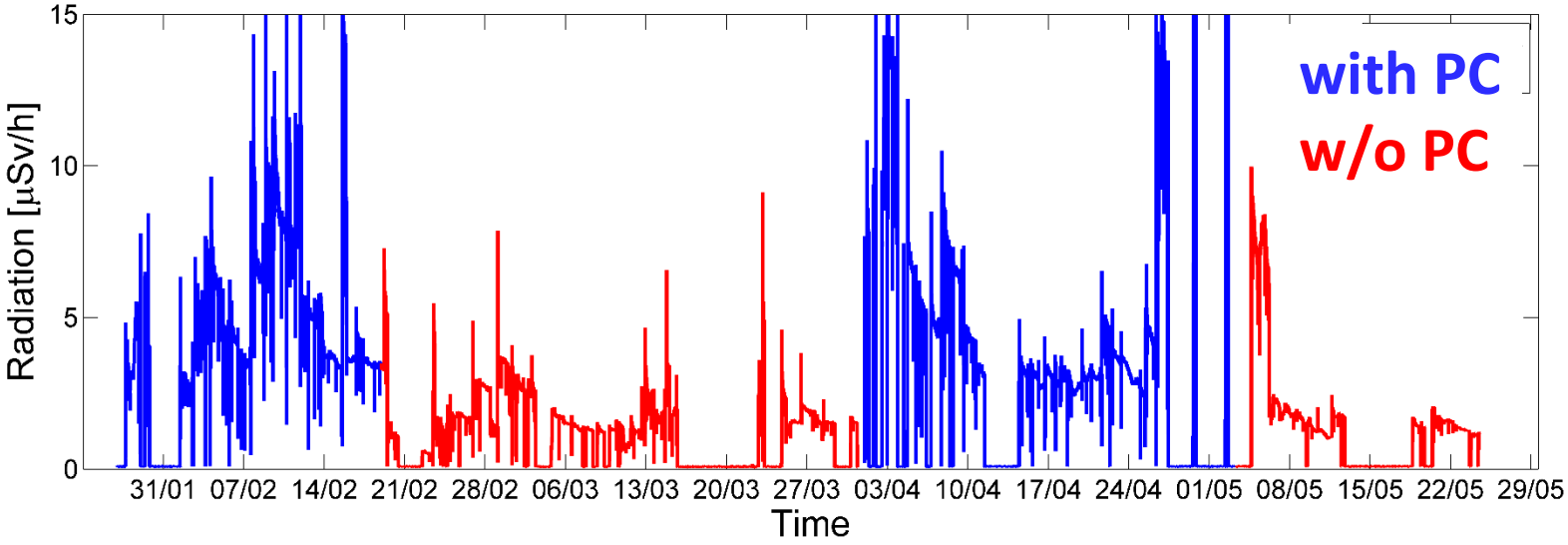
electrons crossing the optical fibre → Cherenkov photons detected by photosensors

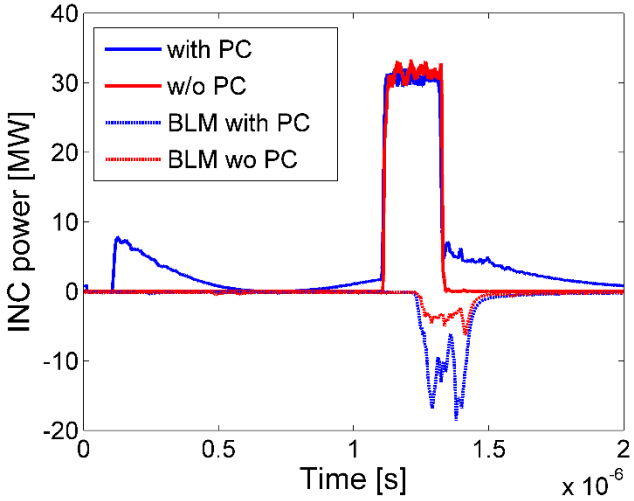
M. Kastriotou ,talk at mini MeVArc 2016

  - Radiation Monitors (CERN Radioprotection group): placed usually downstream of the structure, measure in μSv/h.

Dark current vs Pulse shape

Different dark current levels observed for the different pulse shapes (with and wo Pulse Compressor) → difference in pulse surface heating of a few 10ths of degrees can not explain the higher field emission for clean copper (A. Kyritsakis)



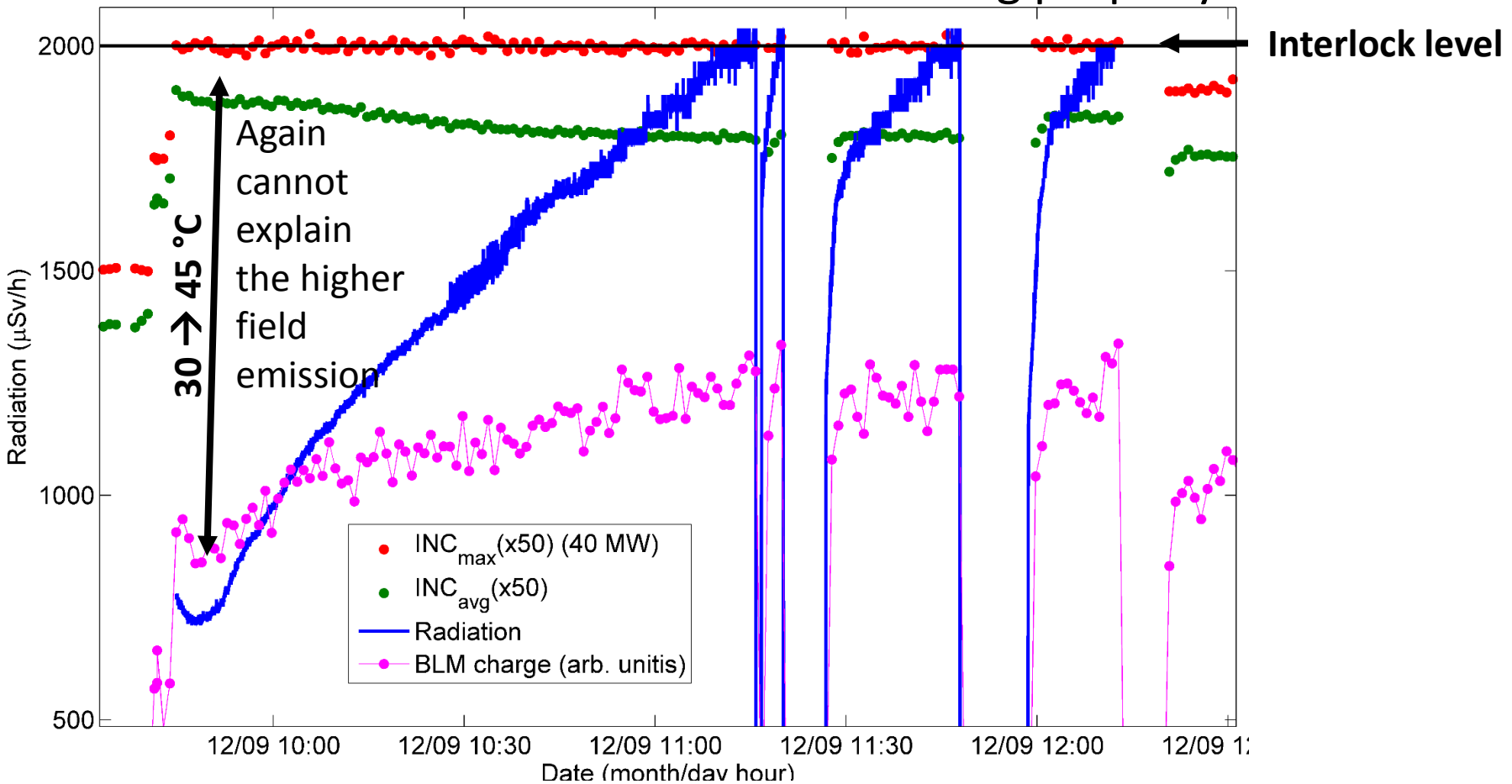


- Example of P = 34 MW
- Very similar main pulse shape
- High BLM signal in the case with PC

Something else should cause this effect → possibly the difference in the phase program (?)

Dark current vs structure's temperature

- Radiation interlock at 11/09/2016.
- Rising of the radiation with constant power!
- Chiller on the structure was not working properly!

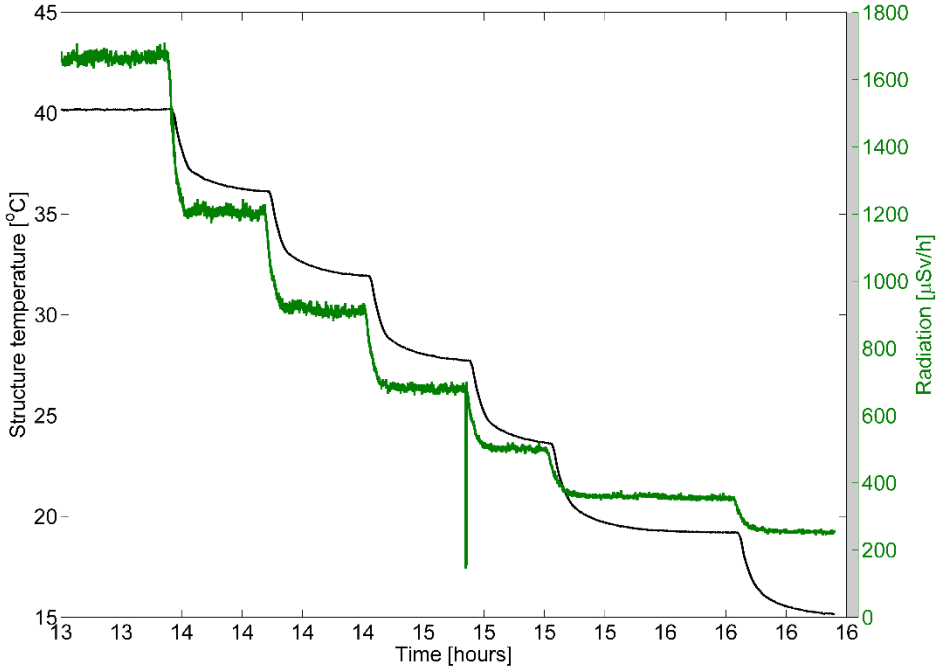


No obvious explanation →more investigation was needed

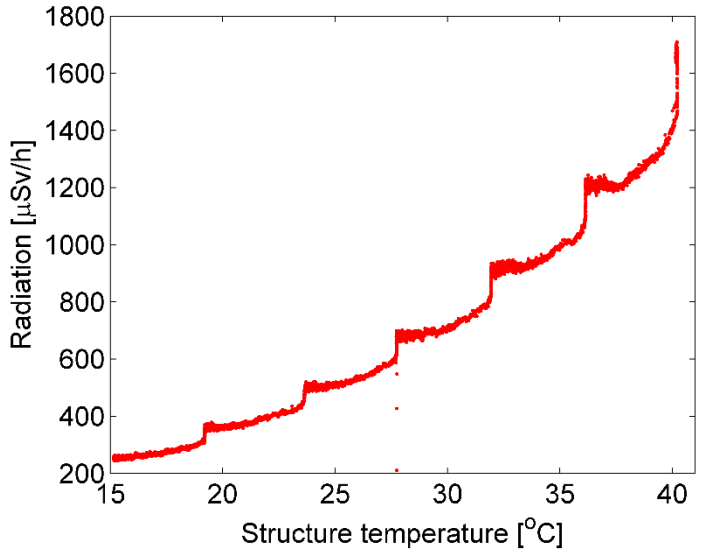
Dedicated measurements to investigate

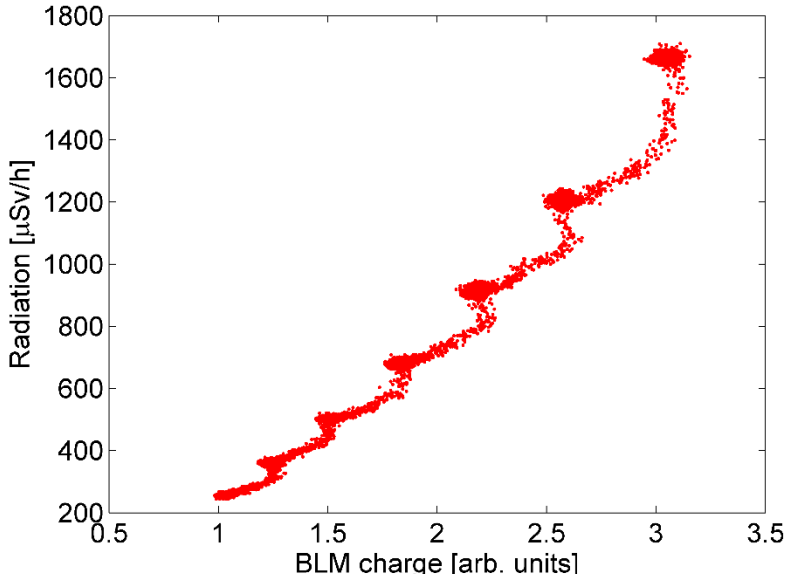
- Repeat a controlled temperature scan
- RF frequency scan to see if the effect is caused by a change in phase velocity → more efficient capture of the FE electrons
- For the frequency scan we were retuning also the Pulse Compressor by changing the temperature of the chillers.
- Only two days to carry out the measurements before replacing the structure!

Temperature scan on 10/11/2016

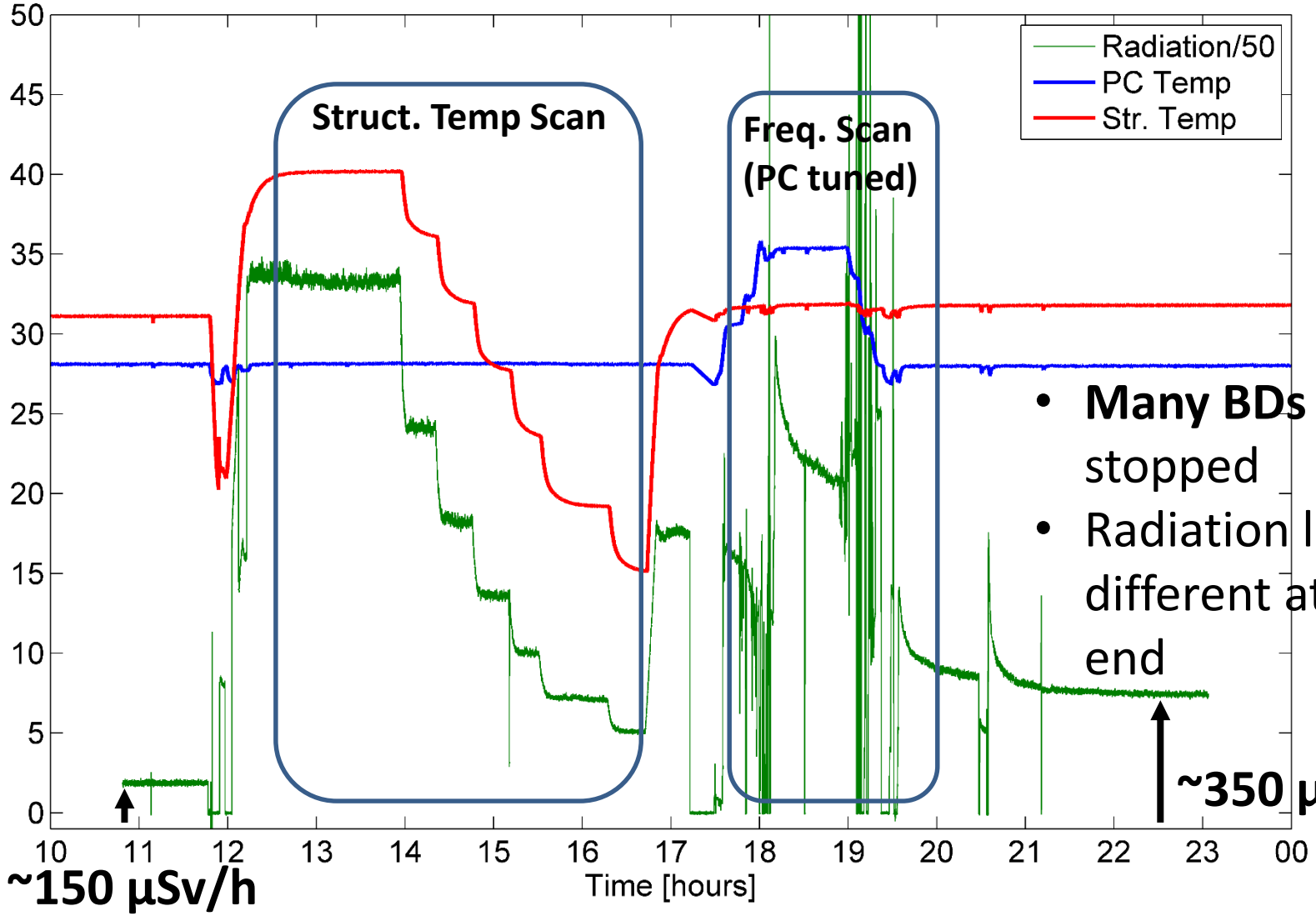


- 15 °C < T < 40 °C
- Constant input power (45 MW)
- Large change in radiation levels
- Also measured by the BLM





RF frequency scan on 10/11/2016



- **Many BDs** →test stopped
- Radiation levels different at the end

Measurements at 11/11/2016

- A 2D scan was attempted the next day
- To tune the structure in the new frequency

$$\frac{\Delta f}{f} \sim \frac{\Delta l}{l} = \alpha \, \Delta T,$$

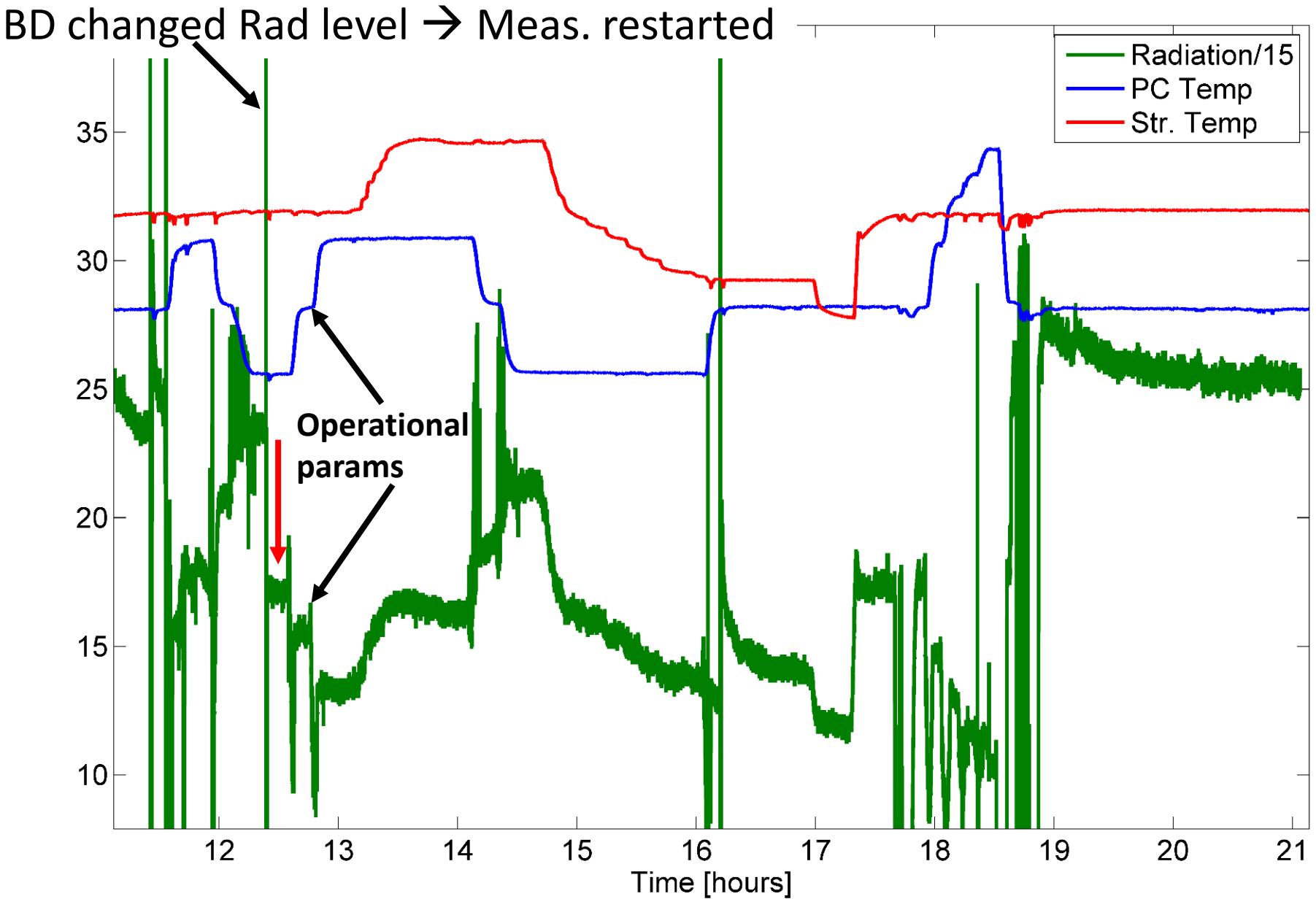
α :thermal expansion coefficient

operational conditions

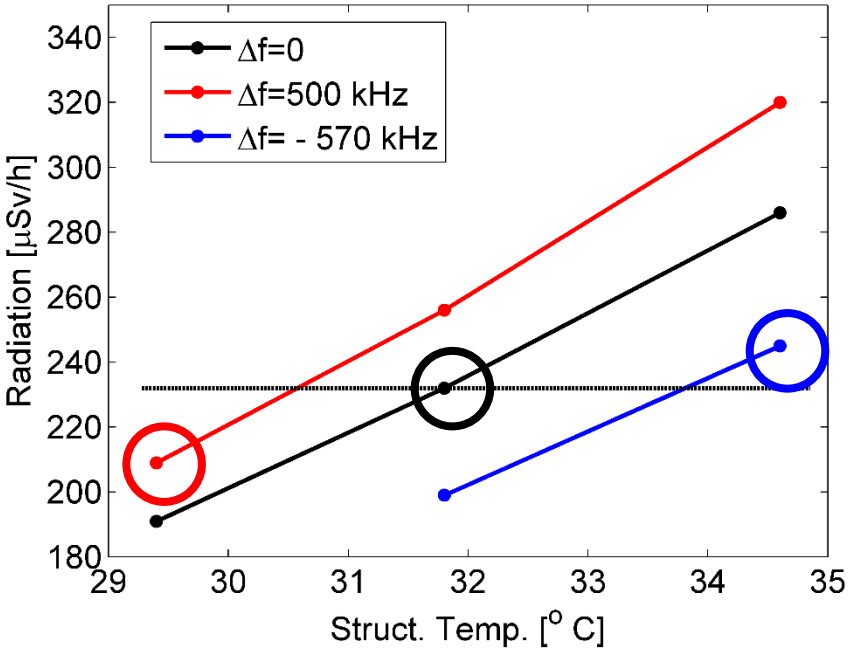
→ :Parameters for tuned system

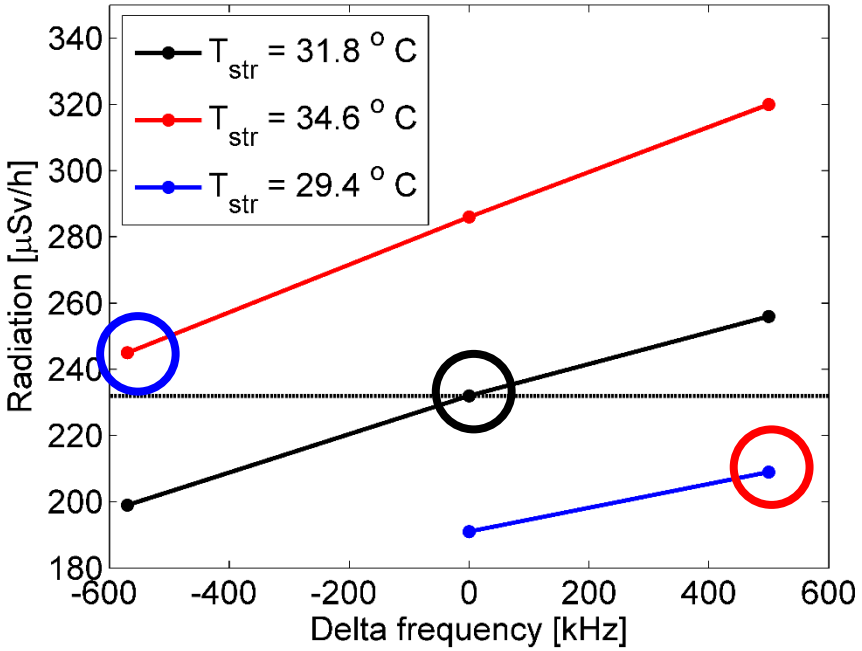
Structure temperature (°C)	Frequency shift (PC temp change) (kHz)	Radiation (µSv/h)
34.6 →	-570 →	245
	0	286
	500	320
31.8 →	-570	199
	0 →	232
	500	256
29.4 →	-570	
	0	191
	500 →	209

Measurements at 11/11/2016



Measurements at 11/11/2016 - summary



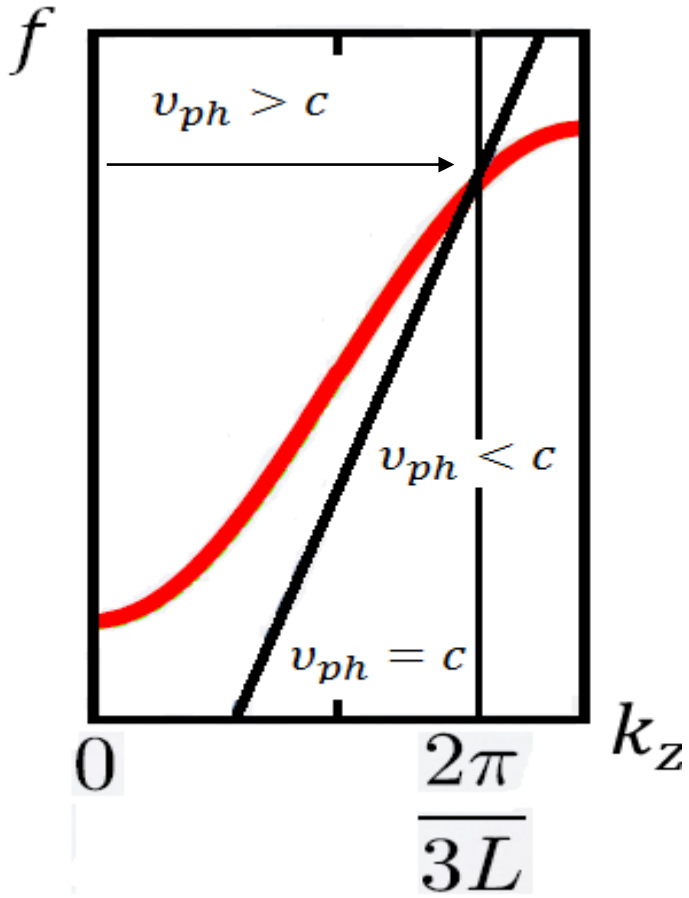


○ : when system is tuned.

- Radiation proportional to Temperature and Frequency
- Difficult measurements → take a lot of time
- Again BDs changes the Radiation level during the end

Qualitative understanding

Schematic dispersion diagram of a disc loaded travelling wave structure



- Increasing the structure's temperature → dispersion diagram shifts down → for the same driving frequency $\upsilon_{ph} < c$ → more effective capture of the FE electrons
- Similar effect when we increase the frequency of the RF signal

Summary and next steps

- Strong dependence of the dark current measurements on the RF frequency and structure's temperature
- Not conclusive results from dedicated measurements due to lack of time
- Repeat the measurements more systematic with the new structures (need to be well conditioned)
- Dark current simulations are also very important
  - Simulations are on going using the CST Microwave Particle Studio or self developed code (T. Geoffrey Lucas, S. Benedetti)