Power-pulsing supplies and thermal measurements on mock-up

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Thanks to Andreas Mussgiller (DESY), C. Mariñas (Bonn U.)

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Outline

- Motivation
- Power-pulsing systems
  - Supercaps
  - PCBs system
- Experimental setup
- Bragg Fibers
  - Temperature sensor
- Thermal measurements
- Results
- Summary
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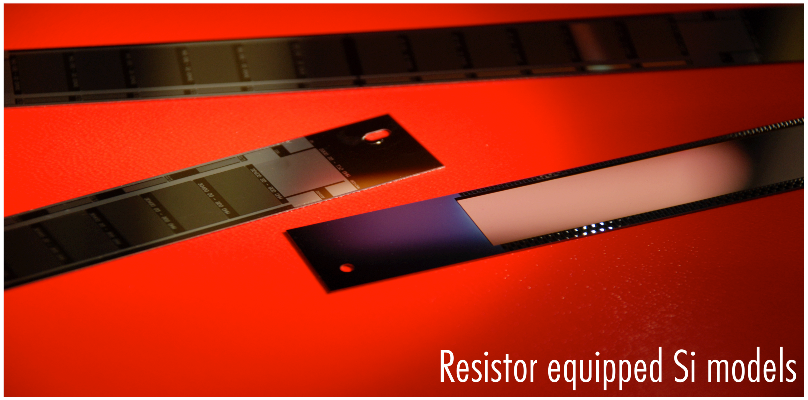
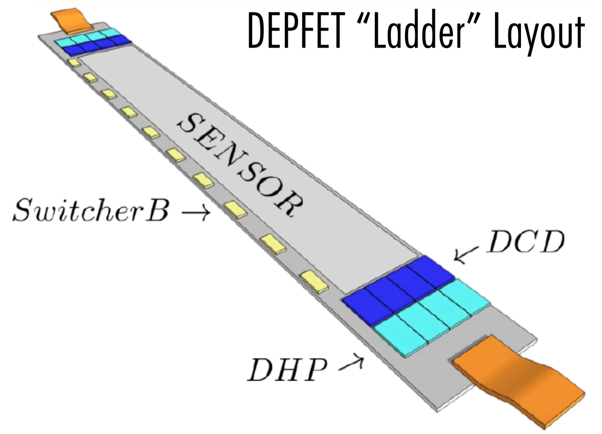
Motivation

- New tracker detectors require **ultra-thin** sensors to reduce multiple scattering:
  - e.g. DEpleted P-channel Field Effect Transistor (**DEPFET**)
  - Chosen technology for Belle II PXD
  - Candidate for ILC
  - But mechanical more generally applicable


Resistor equipped Si models

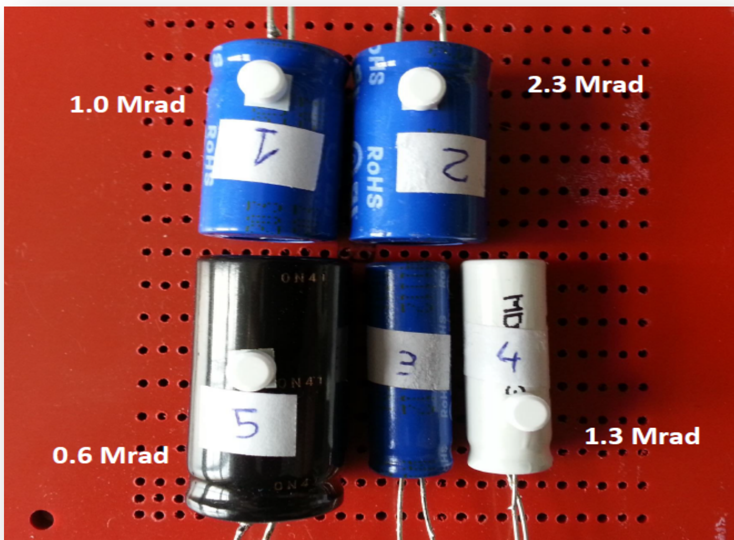


- Layout designed with the highest power dissipating elements in the end flanges
- **All-silicon** technology allows for very thin (**50 micron**) sensors.
- Sensors are powered by a **power pulsing system ->** it could lead to **vibrations** and **periodical changes in the temperature**

LC-Spain studies: **R&D** of electronic systems for **power-pulsing supplies**

1) Super-capacitors (*supercaps*) at ITA

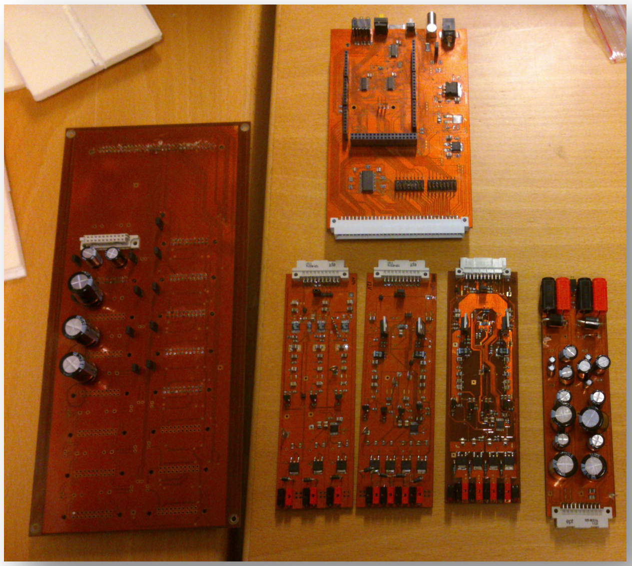
An alternative to DC-DC systems



Fernando Arteche

2) A PCBs system developed at IFIC

Focused essentially for supplying a power pulse to the resistive sensors

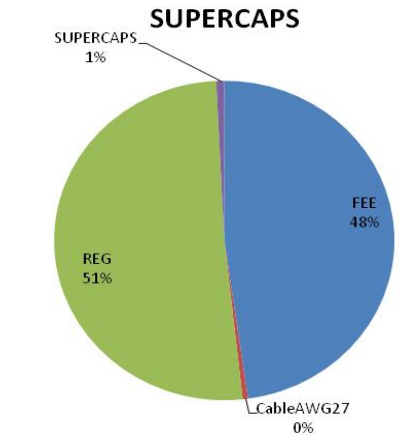


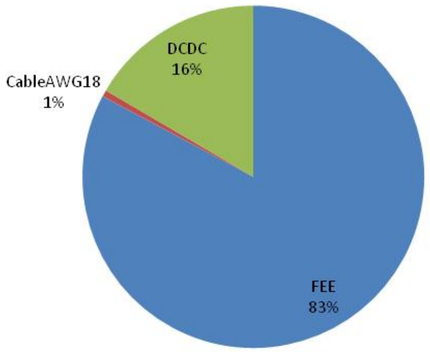
José Manuel Deltoro

Supercaps: power schemes

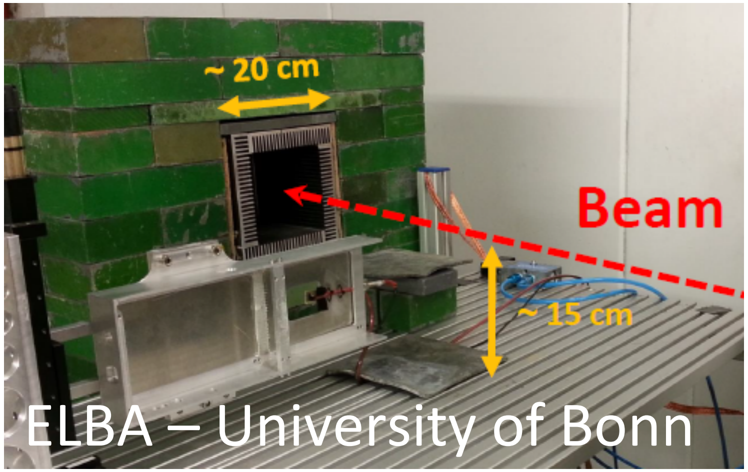
- During the last two years several activities has been carried out focused on power pulsing systems
- **Evaluation of power schemes** - Comparative study
  - DC-DC-based power distribution
  - Super-capacitor based power distribution
- Each of them has advantages and disadvantages

	DC-DC	Super-caps
Power dissipation	228 W	395 W
EMI phenomena	Yes	No*
RAD tolerant	Yes	?
Material budget	(240 DC-DC) ?	(80 SC) ?
Reliability	?	?
Power pulse applications	Not frequent	Yes
Installed power	1.4 kW	0.6 kW
Primary PS	≈ 36 W	≈ 15 W
Mains protection (UPS effect)	No	Yes

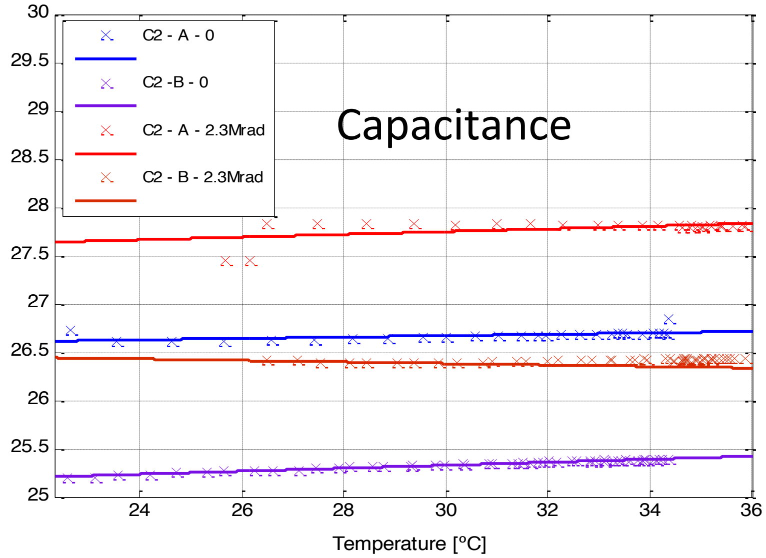


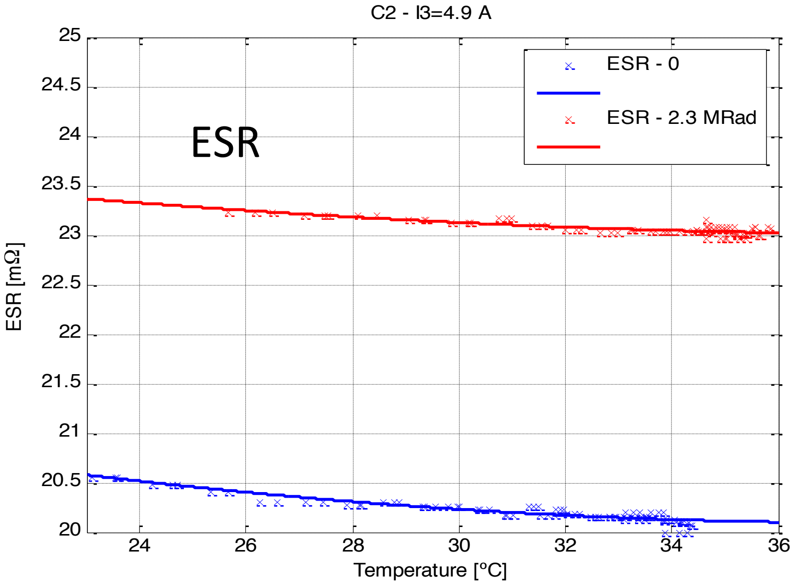


Supercaps: radiation test



- **Evaluation of supercaps to RAD environment**
- Electrons at 20 MeV
- Total dose :
  - 0.6 Mrad -2.3 Mrad (3%)
  - Supercaps are **hardly affected by radiation under 1MRad**

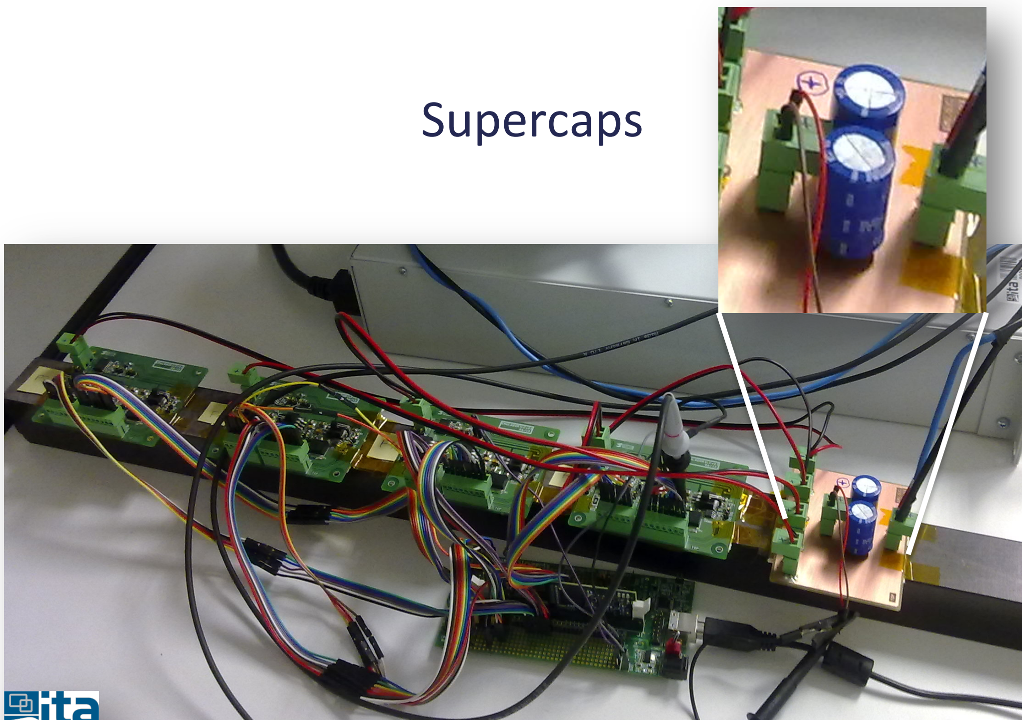


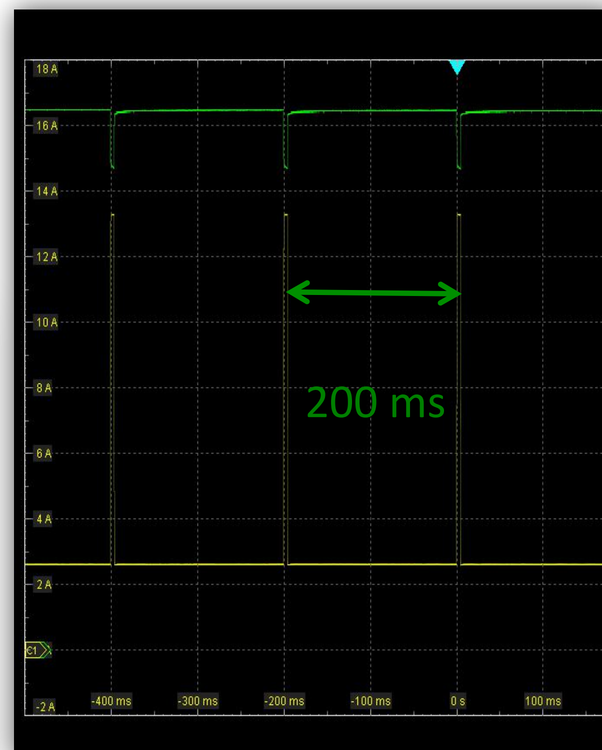


Supercaps: power pulsing system

- **A prototype of power pulsing system** based on **super-capacitors** has been developed
  - 1 ILD-FTD group (1/4 Petal – 4 Petals) – **Full operational**
- Pulsed current -> I_p = 3A - 14A - V_{out1} = 1.5V - V_{out2} = 2.5V

Supercaps

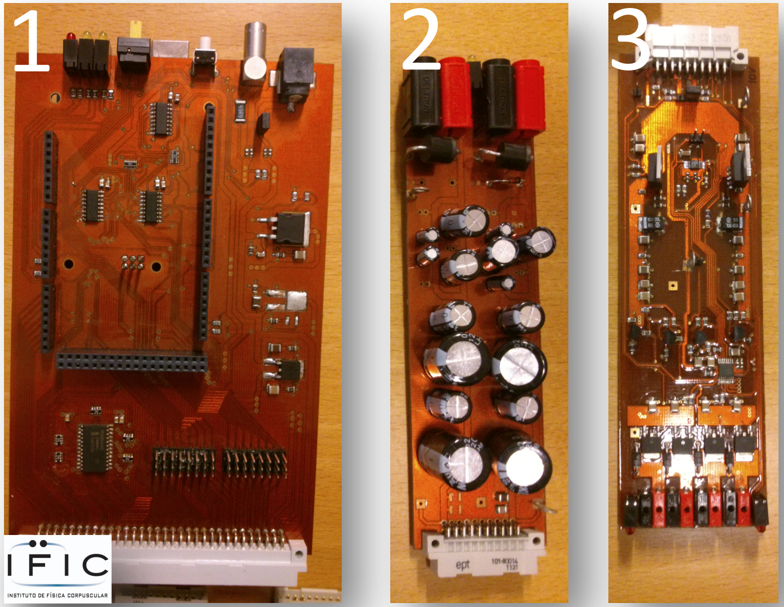


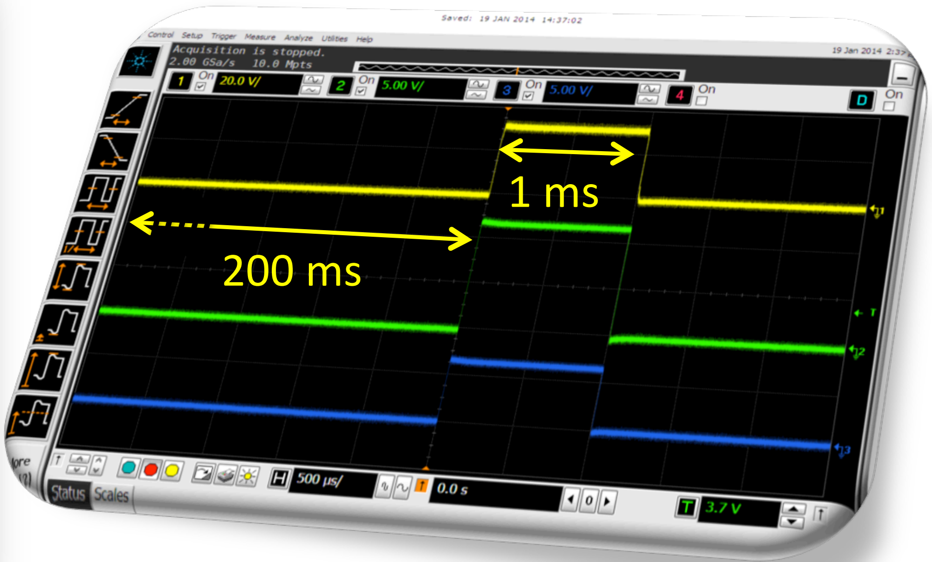


PCBs

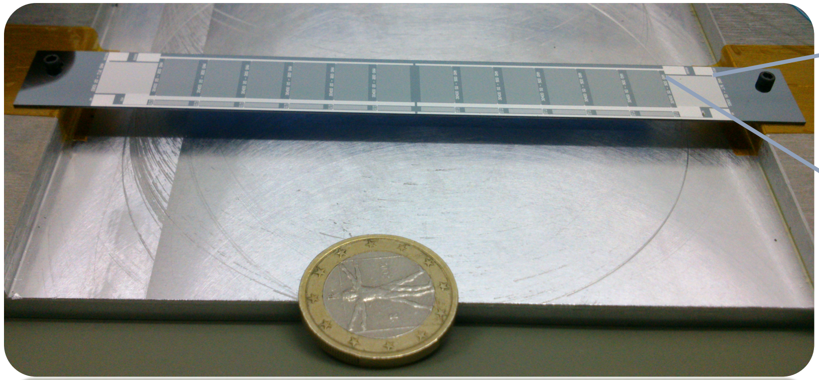
- **Power-pulsing system at IFIC:** Several PCBs with different functions

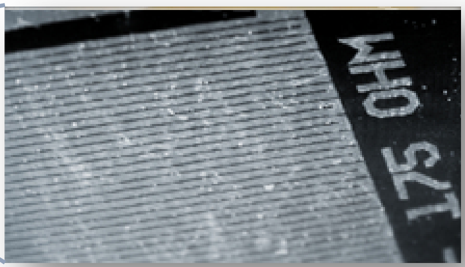
  1. **Control PCB**: programed with *Arduino* to manage the time of the pulse
  2. **Capacitors PCB**: supply the charge through the electrolytic capacitors
  3. **Output PCB**: read the sequence of the control PCB and generate the pulse





- **The resistive ladder**
  - A 135 mm Si module with the designed dimensions of the detectors
  - The sensor area is thinned to **75 μm**
  - This module does **not include** the **real electronics**
  - But is a resistive dummy with impressed cooling tracks -> **simulate the power distribution**





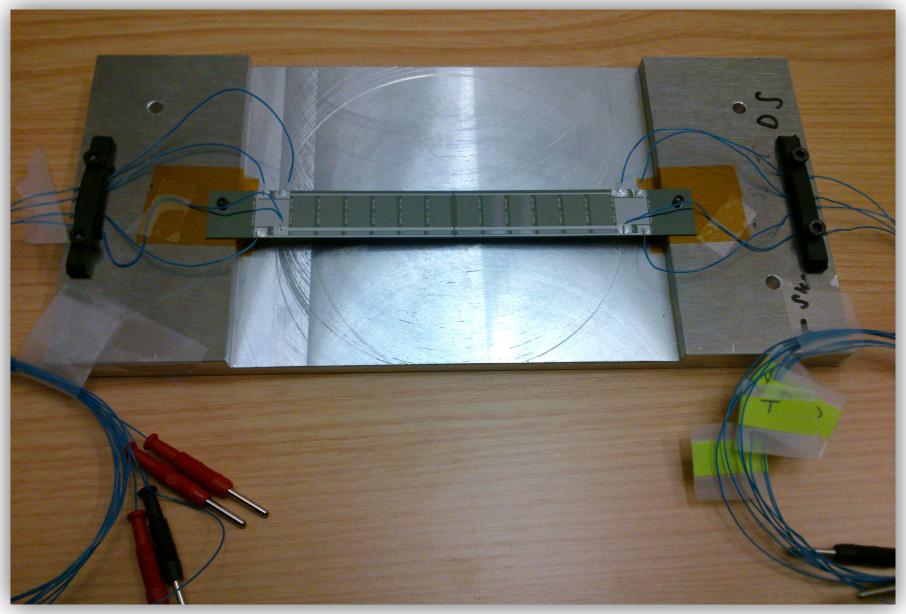
DCD resistor

- **Working parameters**

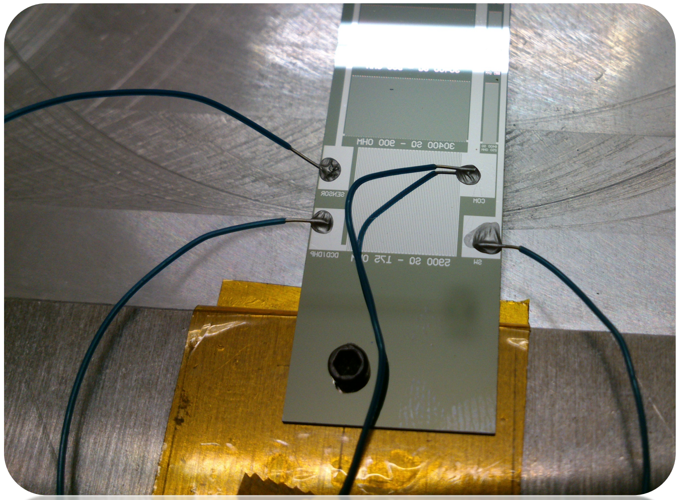
Element	R (Ω)	R_{total} (Ω)	V (V)	I (mA)	P (W)
Sensor	900	150	8.66	58	0.5
DCD	175	175	37.42	214	8
Switcher	250	41.6	4.56	110	0.5

Experimental setup

- **Mechanical support**
  - Aluminium base (20x10 cm) with the lowered central part
  - The ladder is screwed to the base separated by a non-conducting material
  - Thin wires are joined to the pads of the ladder with a conductive silver paste



Entire setup: Aluminium with the set ladder



Ladder pads and wires

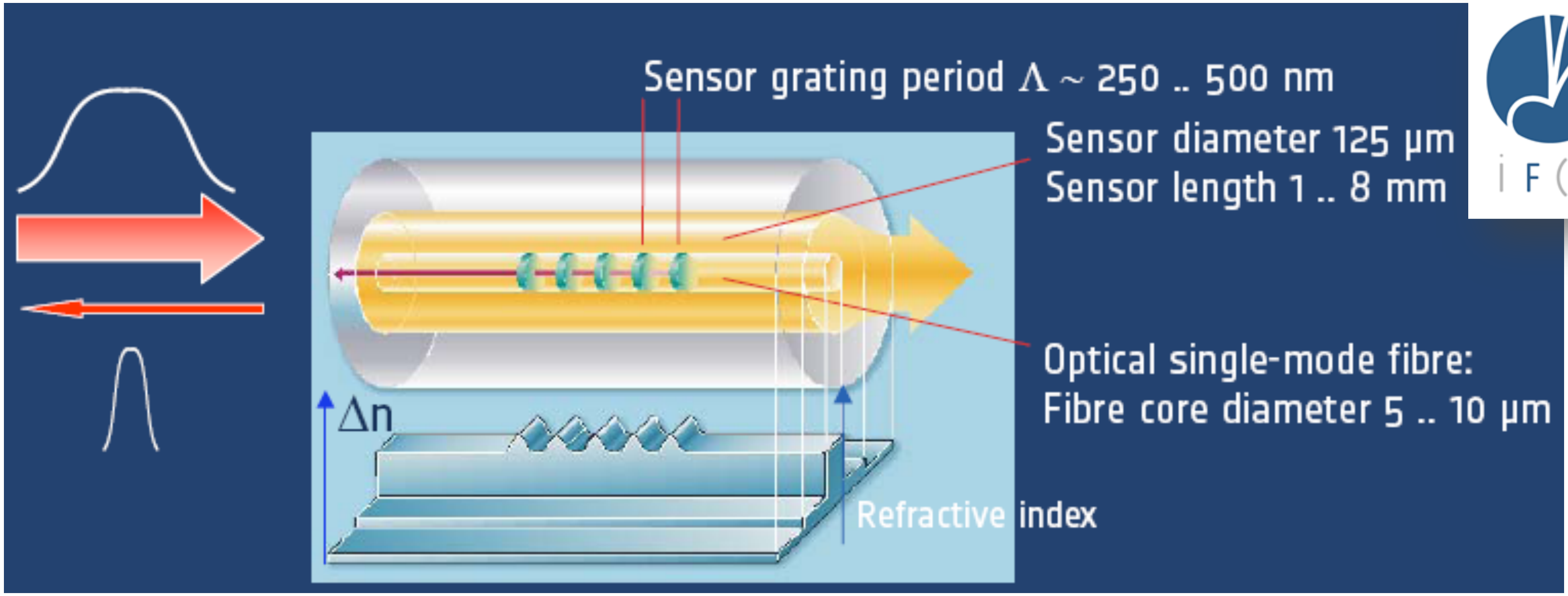
Thanks to the IFIC engineers D. Santoyo, J.Vicente and J.Mazorra

Fiber Optic Sensors (FGBs)

- **FGB** (Fiber Grating Bragg)
- An FBG sensor is a **grating of reflective index periodic variation** in the core of a fibre
- Physically, FGB sensors have a **section of an optical fiber** with a length of few millimeters
- FBG sensor reflect the light at a defined wavelength

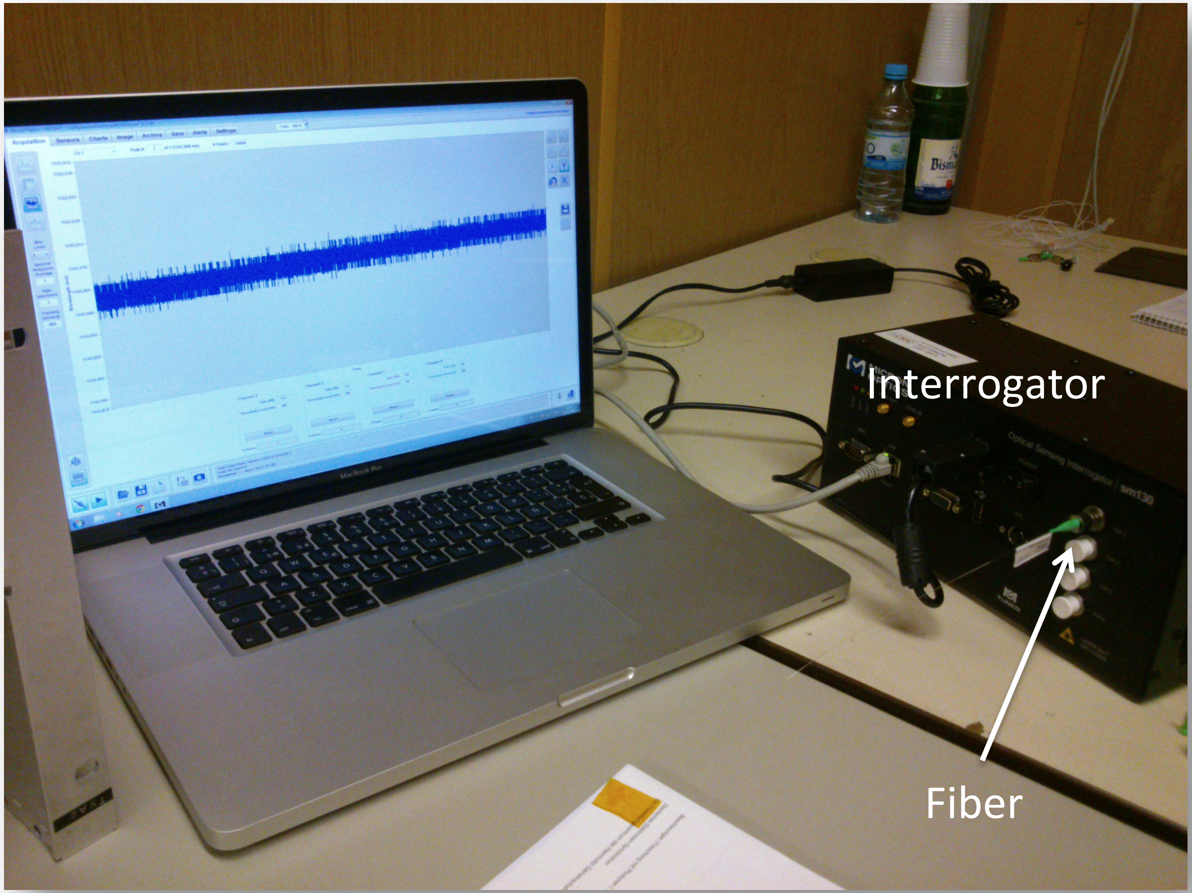
Bragg wavelength $\lambda_B = 2 \cdot \Lambda \cdot n_{eff}$

- Λ changes with **mechanical and thermal deformations**

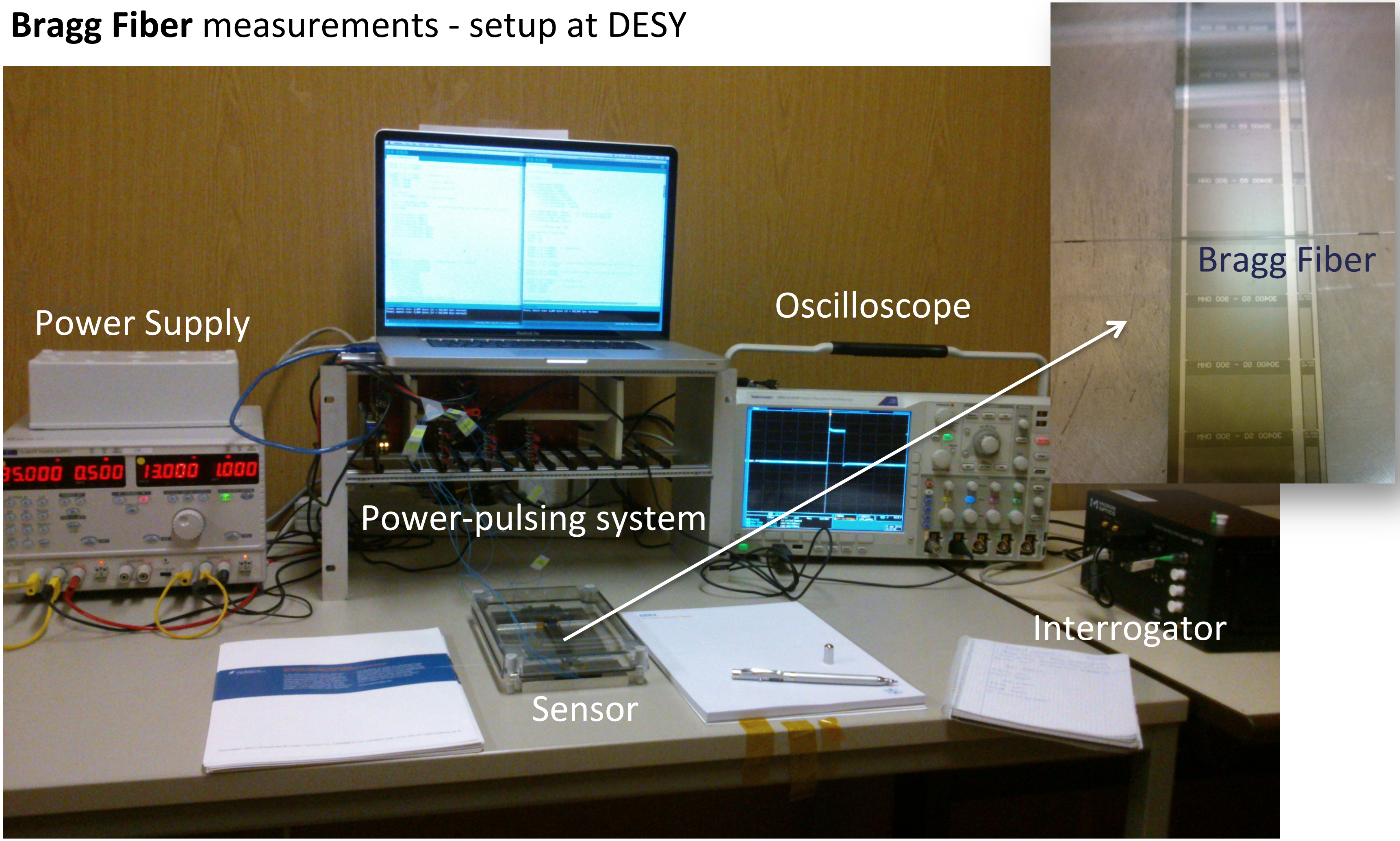


Interrogating system

- The interrogating system interprets the signal of the fiber
- Monitoring of the interrogator data with the software *MOI-ENLIGHT* of *Micron Optics* in a PC

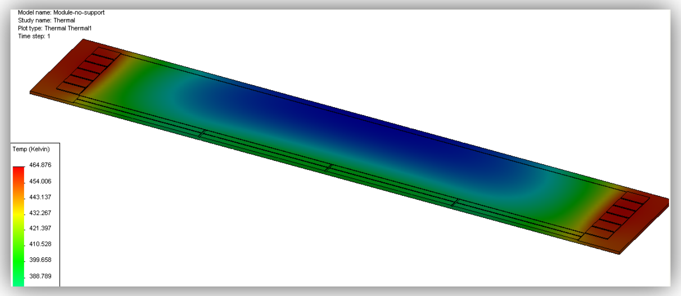


Bragg Fiber measurements - setup at DESY

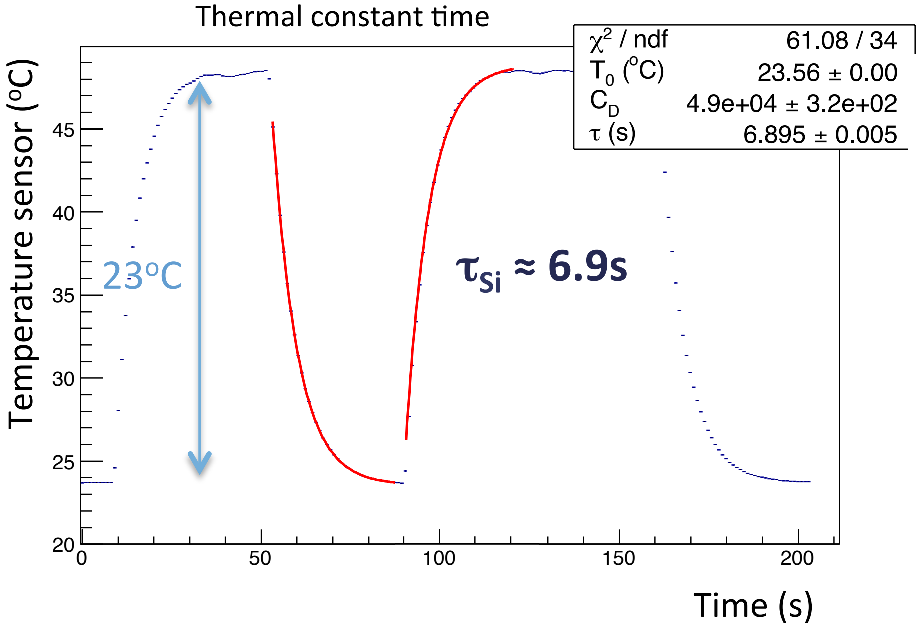


Bragg Fiber 1543 nm

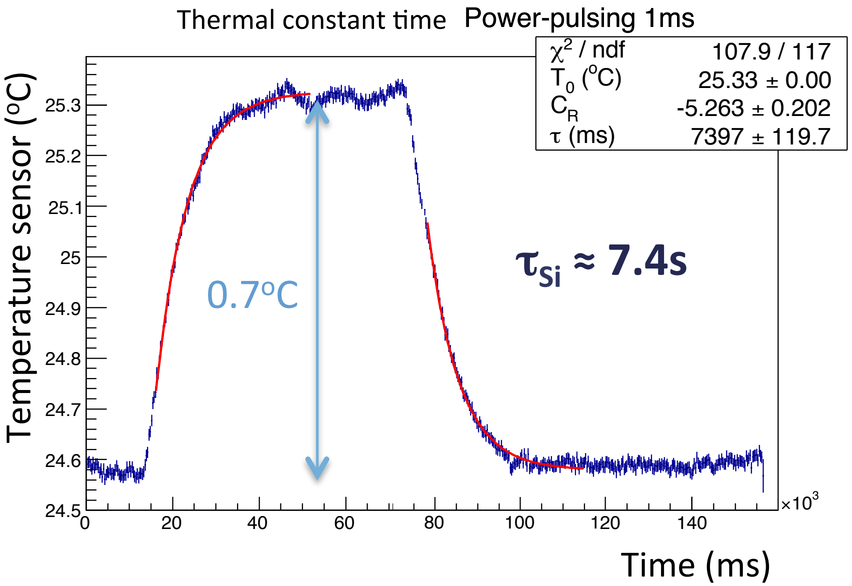
- **Switch on/off** power during a few minutes
- Monitoring of the fiber data *Λ(nm)* at **1 kHz**
- Apply **calibration of the fiber** (*Λ(nm) -> T(°C)*)
- Measure the thermal constant time



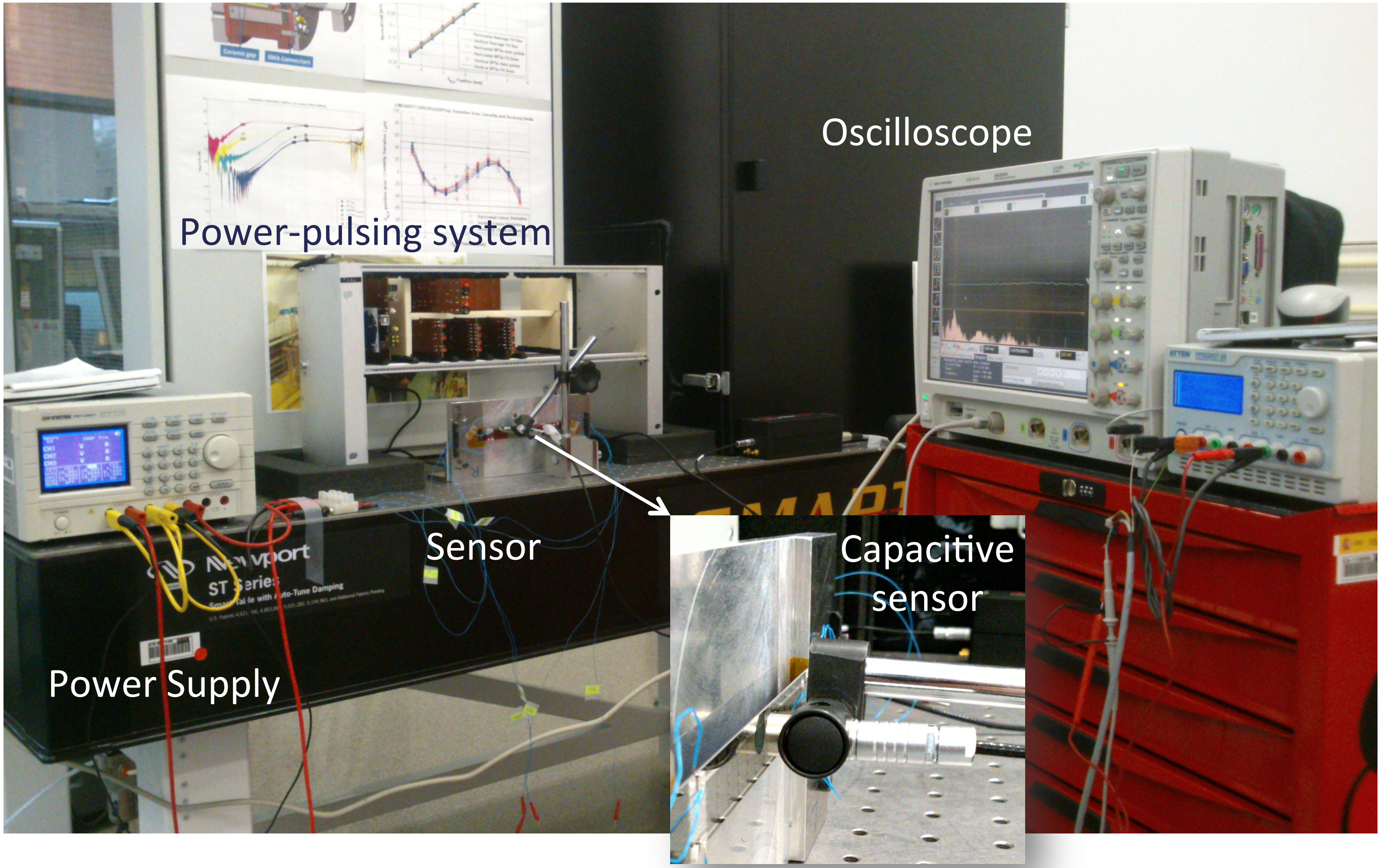
8V DC supplied to sensor part in the resistive ladder



Power-pulsing applied in the entire ladder (switchers, DCDs, sensor)



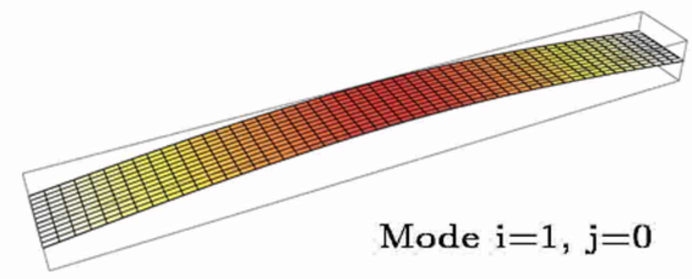
Capacitive sensor measurements - setup at IFIC



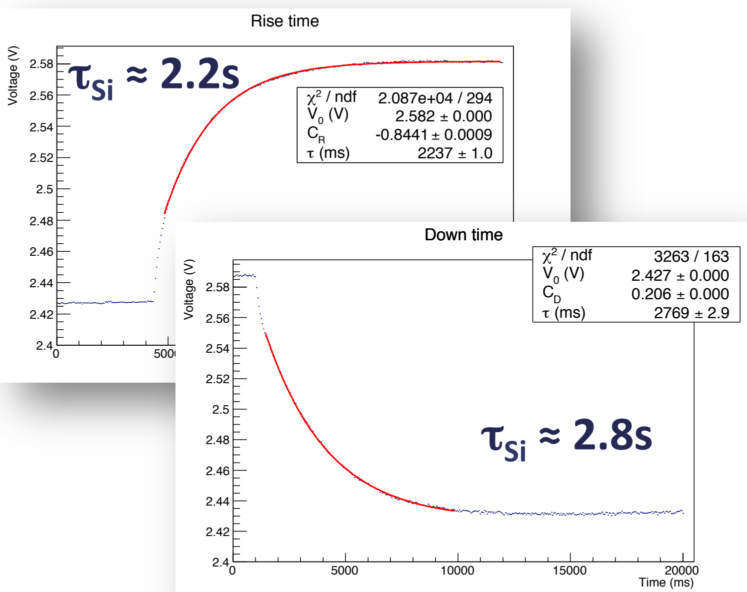
Capacitive sensor measurements

Capacitive sensor (Micro-Epsilon Capa NCDT 6100)

- Sensitivity: 0.15µm
- **Switch on/off** power during a few minutes
- Monitoring of *V* vs *Time* in the oscilloscope
- Measure the thermal constant time



DC current. 10V: sensor, 32V: DCDs
6V: switchers



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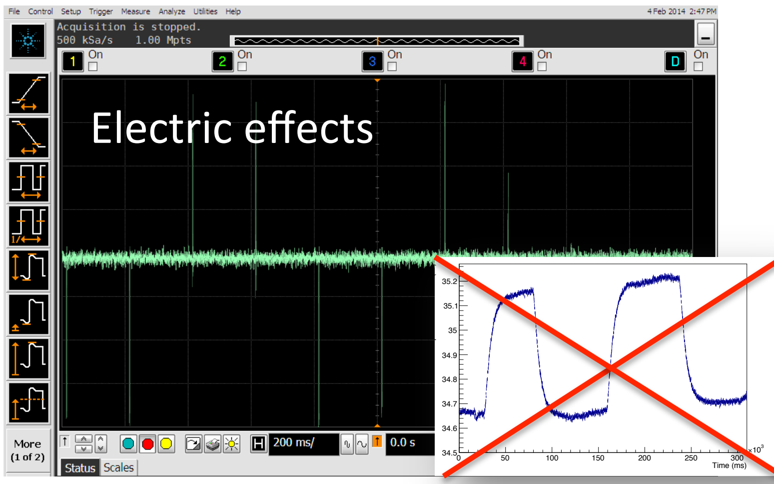


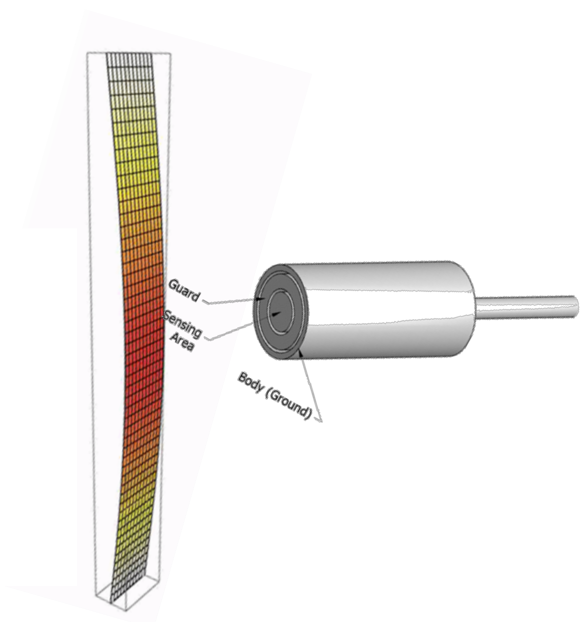
Flat distribution of voltage → noise is greater than the 0.7 °C observed with Fibers

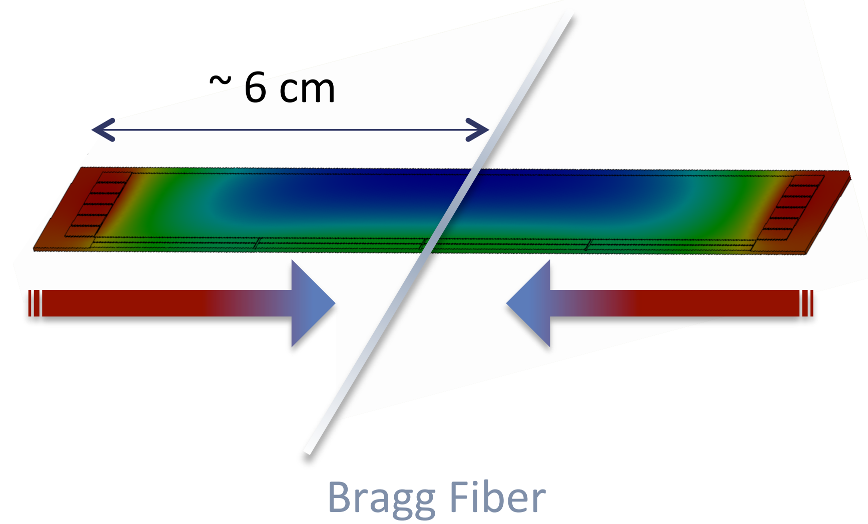
τ_{Si} ~ 3s
capacitive sensor

<

τ_{Si} ~ 7s
Bragg Fiber

- The reason is that the **main focus of heat** is in **end of the ladder** (at DCDs)
- The **most of the heat has to travel along the sensor**, therefore the center of the dummy is heated with some delay
- **Little deformations** can be **measured faster** with the **capacitive sensor**





Results

$\tau_{Si} \sim 3s$
capacitive sensor

<

$\tau_{Si} \sim 7s$
Bragg Fiber

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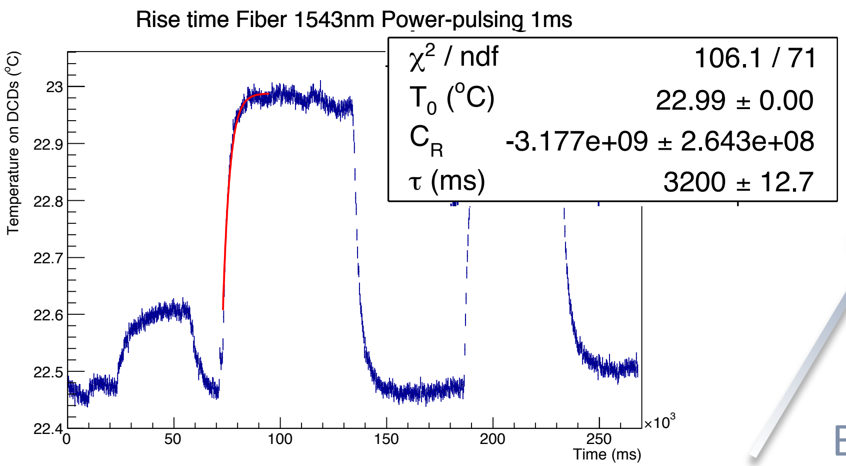
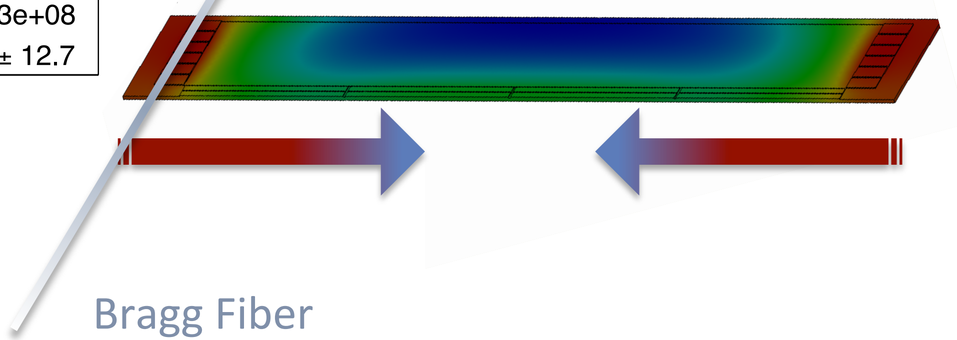
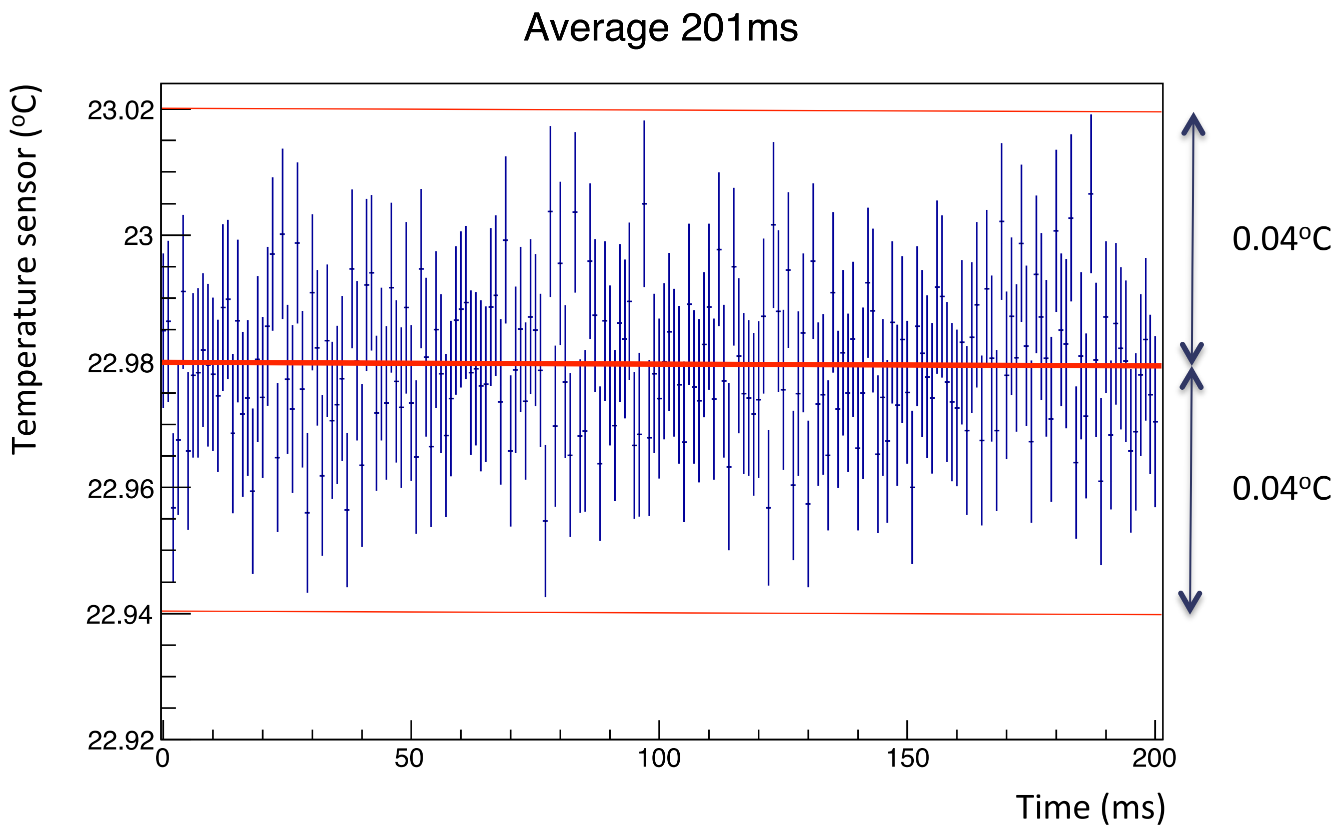


Bragg Fiber on DCDs
τ_{Si} **~ 3s** *checked*



Results

- **No thermal effect observed** at the *ms* scale due to the **power-pulsing supplied**
- If it exists → < 0.1ºC
- We only see an **average increase of the temperature** of the Si (<1ºC)



Summary

- The **PCBs** system for **power-pulsing** developed at **IFIC** works **successfully**
- The **effect of the power-pulsing** in the sensors has been tested with two **fast readout tools** (Bragg Fibers: 1kHz and capacitive Sensor: 2kHz)
- We've **not observed a periodical change in the temperature** of the sensor due to the power-pulsing because τ_{Si} ~ 3s
- **1 ms is not enough time to heat the Si** and produce a visible effect at this time scale
- New thermal measurements and vibration measurements are ongoing

Bibliography

- DEPFET active pixel detectors for a future linear e+e− collider
  - http://arxiv.org/pdf/1212.2160.pdf
- Capacitive sensor (Micro-Epsilon Capa NCDT 6100)
  - http://www.micro-epsilon.com/displacement-position-sensors/capacitive-sensor/capaNCDT_6100/index.html
- Structural and environmental monitoring of tracker and vertex systems using Fiber Optic Sensors
  - http://arxiv.org/abs/1203.0109
- Thermomechanical characterization of the Belle II Pixel detector (PXD)
  - http://digital.csic.es/handle/10261/64311

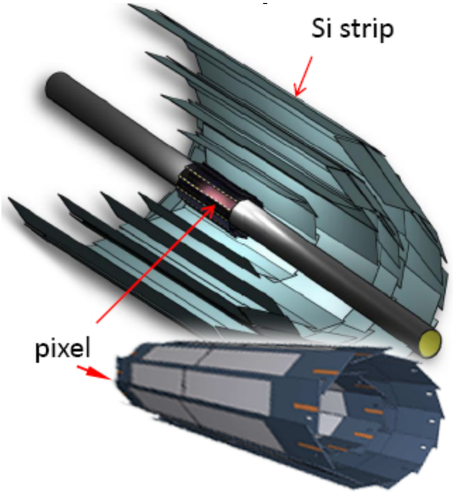
Thank you for your attention

DEPFET at Belle II and ILD

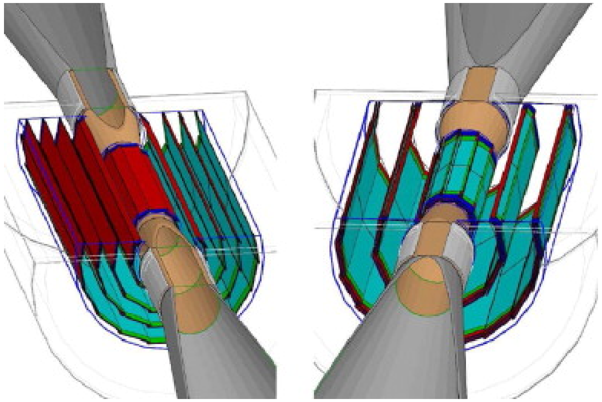
- <u>Belle II Pixel detector</u>
  - 75 µm thin sensors in a 450 µm support frame
  - 12 Ladders in the outer layer and 8 Ladders in the inner layer
  - Power dissipated
    - 1 Watt in the sensor region
    - 1 W in the switchers
    - 8 W in each FEE end
  - Angular acceptance ranges from 17º to 150º
  - 360 W entire pixel detector

- <u>ILD Pixel Detector</u>
  - Naively ~900 to ~1080 W total
  - ~4 to 5 W with power-pulsing (ideal 1:200 ms duty cycle)
  - 2 ladder designs:
    - The double-sided ladder design (~ 50 µm) silicon pixel sensors
    - The single-sided, silicon-only, ladder design is pursued by the DEPFET collaboration

Belle II SVT and PXD

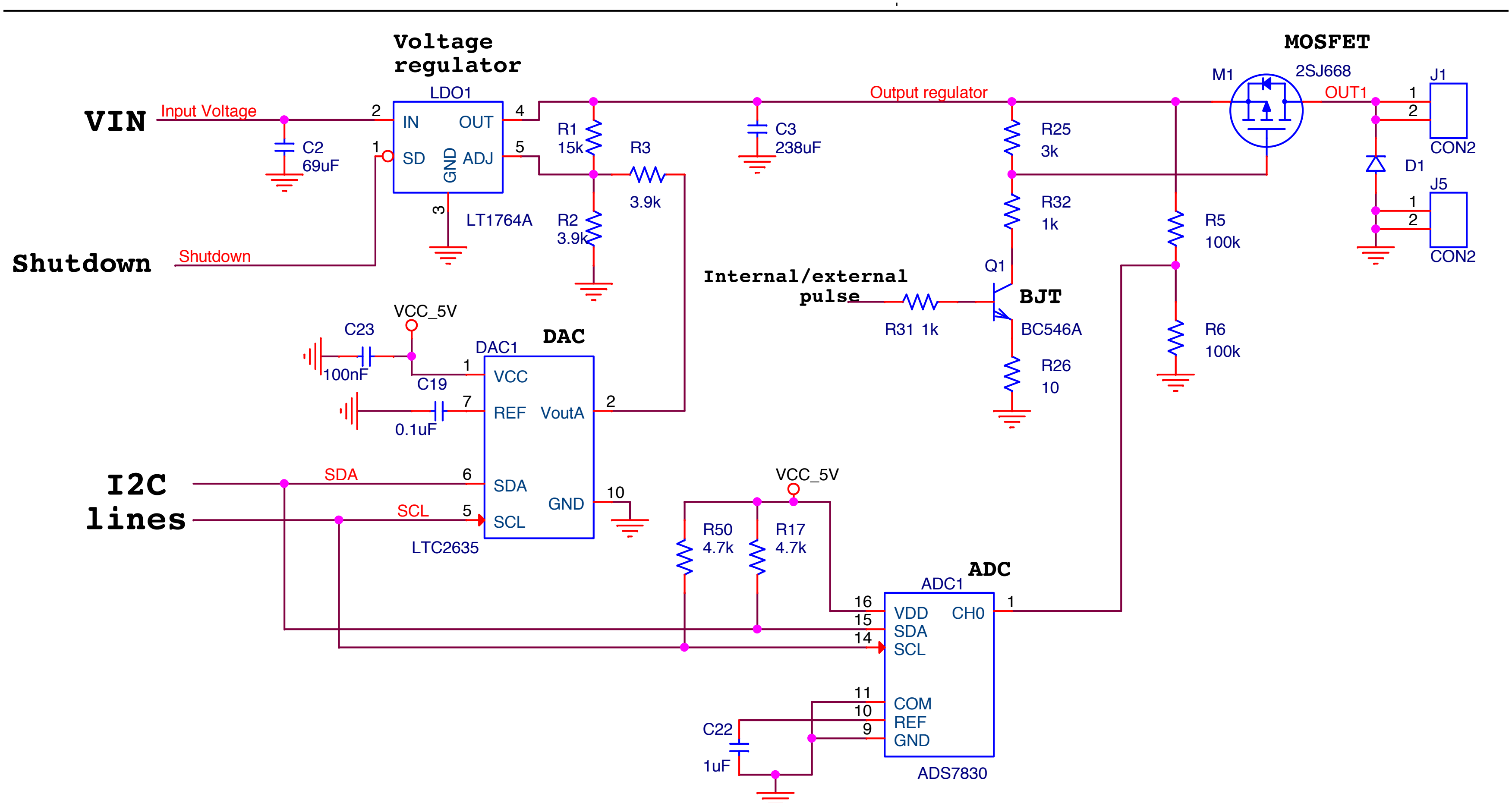


ILD tracker layout options



Single sided 5 layers | Double sided 3 layers

PCB output signal



Advantages of FBG sensors

- General attributes of Fiber Optic Sensors:
  - Immunity against:
    - High electromagnetic fields, high voltages.
    - High and low temperatures.
    - Nuclear radiation environments (not in all the cases)
  - Light-weight, miniaturized, flexible, low thermal conductivity.
  - Low-loss, long-range signal transmission("Remote sensing")
- Specific FBG attributes:
  - Multiplexing capability (sensor network)
  - Embedding in composite materials.
  - Wavelength encoded (neutral to intensity drifts)
  - Mass producible at reasonable costs.
  - Very high and low temperatures (4 K to 1200 K).

Calibration of the Bragg Fibber with an oven

$T(^{o}C) = 96.4 \cdot \Lambda(nm) - 1.49x10^{5}$