INSTITUTO TECNOLÓGICO DE ARAGÓN

Super-capacitor characterization system for FTD-ILD sub-detector power distribution system (Rad Test)

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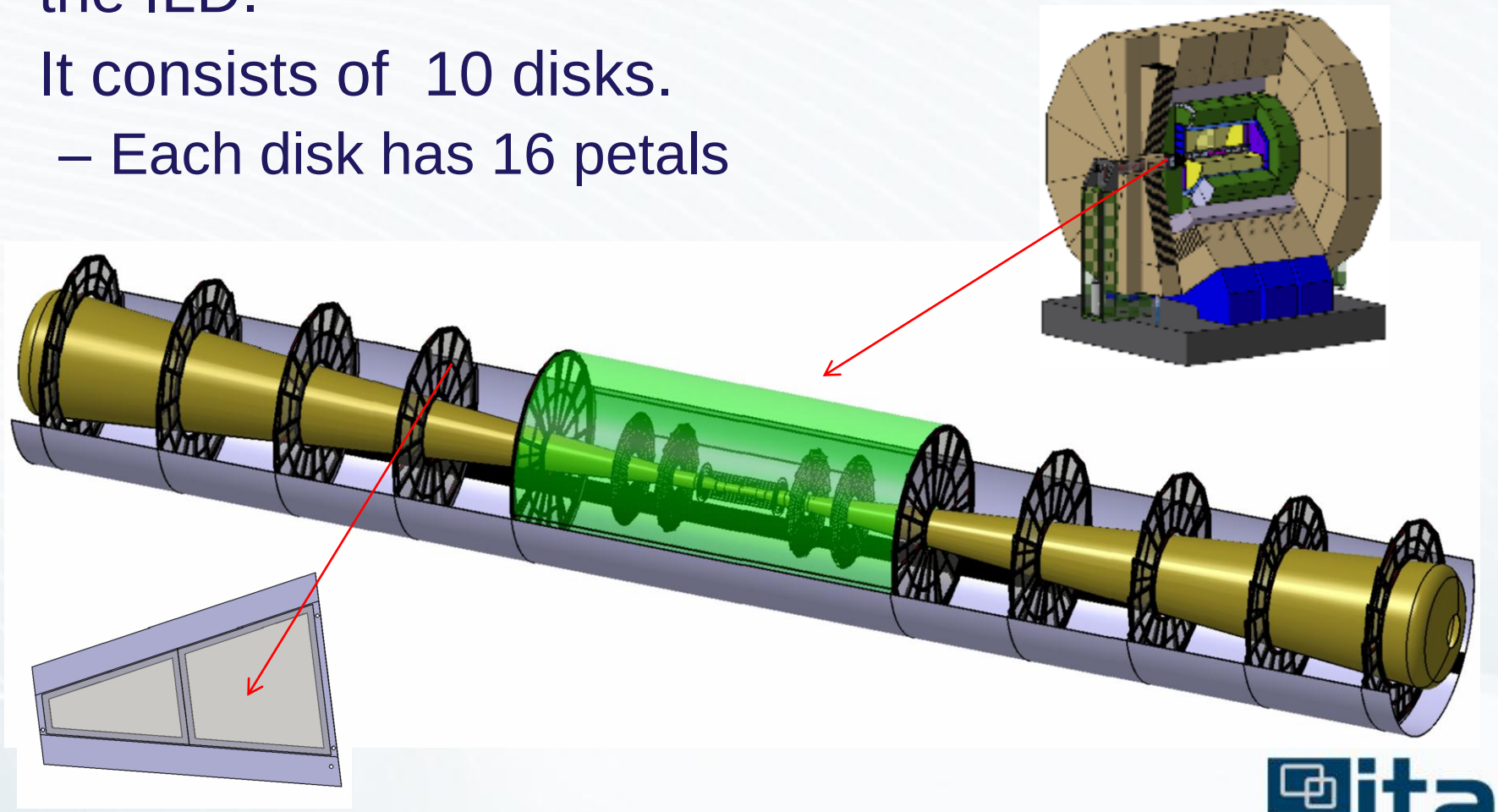
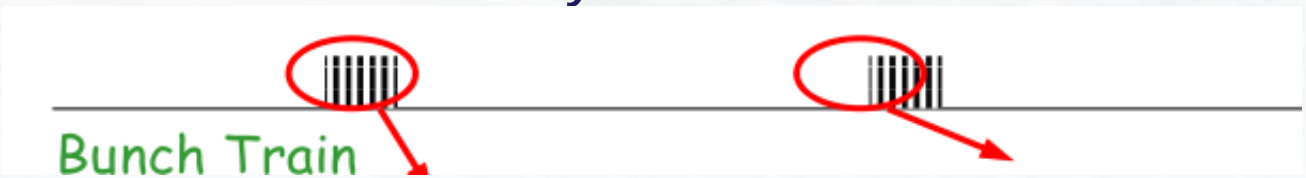
1. Introduction

- The mstrip-FTD system is a silicon strip tracker located in the innermost part of the tracker region of the ILD.
- It consists of 10 disks.
  - Each disk has 16 petals



1. Introduction

- The ILC accelerator has a duty cycle of 0.5%
  - 1 ms bunch train every 200ms

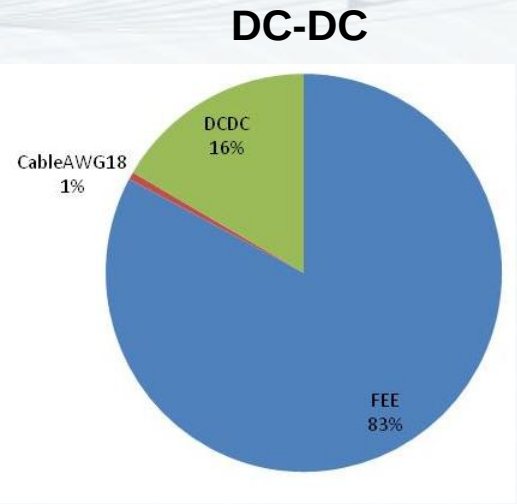


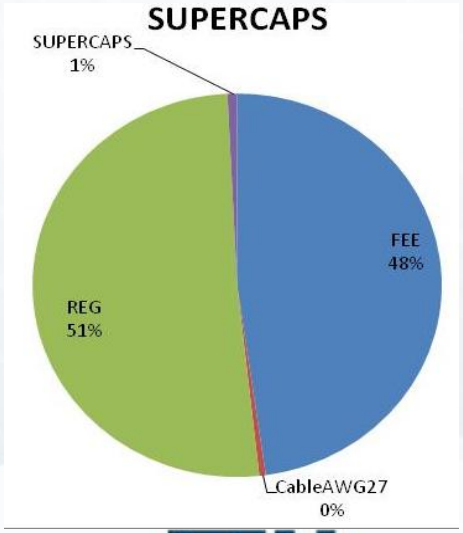
- If the power demanded by the FEE is synchronized to the bunch train, it helps to save energy
- It will force to design a power supply system compatible with this operation mode
- There are several topologies that may be used for FTD.
  - DC-DC-based power distribution
  - Super-capacitor based power distribution
- Each of them has advantages and disadvantages.

1. Introduction

- A detailed comparison between both systems was presented at LCWS 2012 at Arlington

	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	0.48 kW
Primary PS	≈ 36 W	≈ 15 W
Mains protection (UPS effect)	No	Yes



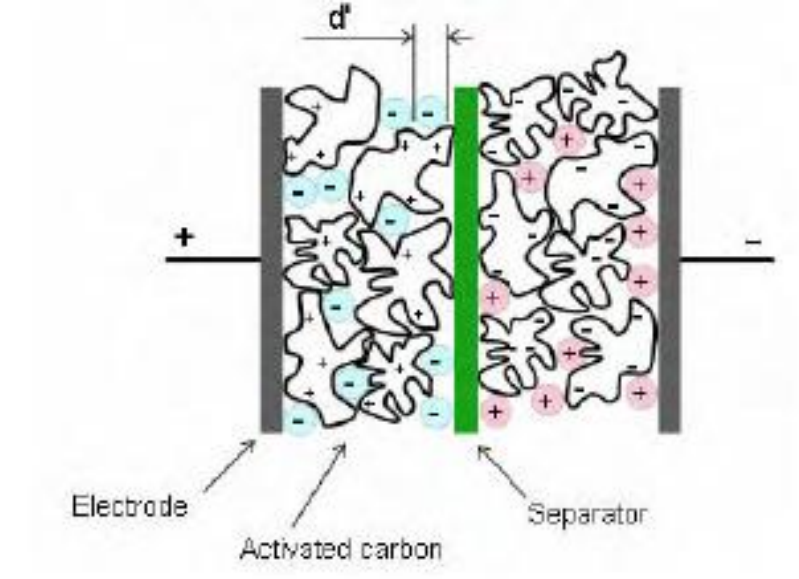


2 Super-capacitors

- The most important element in SC-LV regulation option is the super-capacitor.
  - It is new for HEP but not for industrial applications
- There are two elements that have to be analyzed in detail for HEP applications
  - Cycling issues
  - Radiation issues
- Cycling issues (Reliability).
  - Super-capacitor should be able to operate more that 10 million of cycles per year (DC-DC too)
- Radiation issues
  - Type of radiation: Gammas & electrons
  - Total dose: 1 or 2 Mrad.

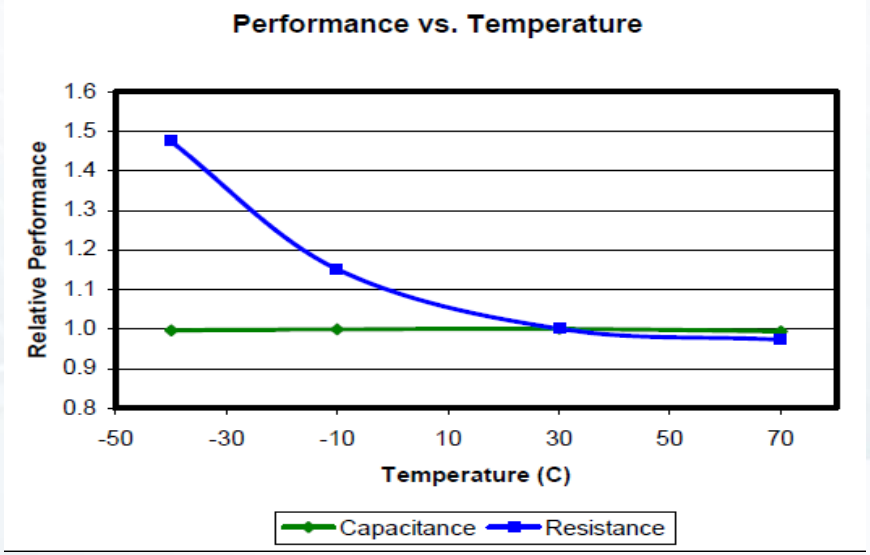
2.1 Super-capacitors: Main characteristics

- Super-capacitors are electrochemical capacitors with very high capacitance (x1000)
- The most common super-capacitor is the double layer capacitor.
- Double layer capacitor structure
  - ALU (anode)- activated carbon-SEP- activated carbon -ALU(catode)
- Most of the material of the capacitor is carbon



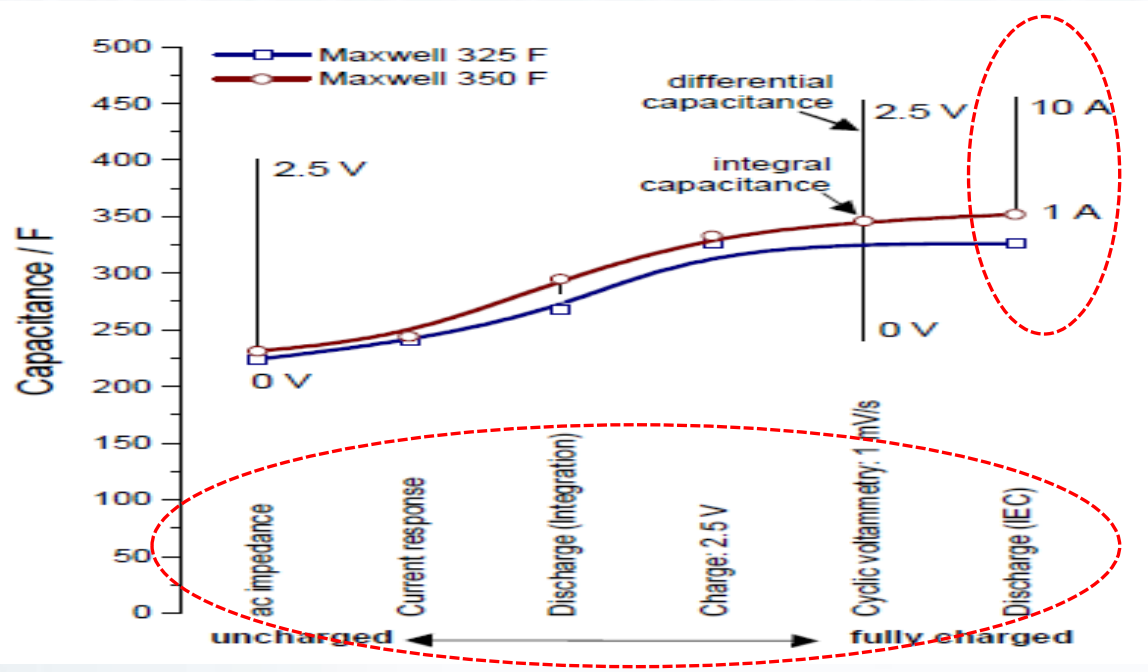
2.1 Super-capacitors : Main characteristics

- Main characteristics
  - It operates at low voltage – Vmax = 2.7 V
  - Large number of cycles
    - It increases if it is not fully discharged
  - High efficiency (Low ESR – High currents – High power)
  - Temperature range - 35ºC up to 65 ºC
  - Temperature dependence (ESR)



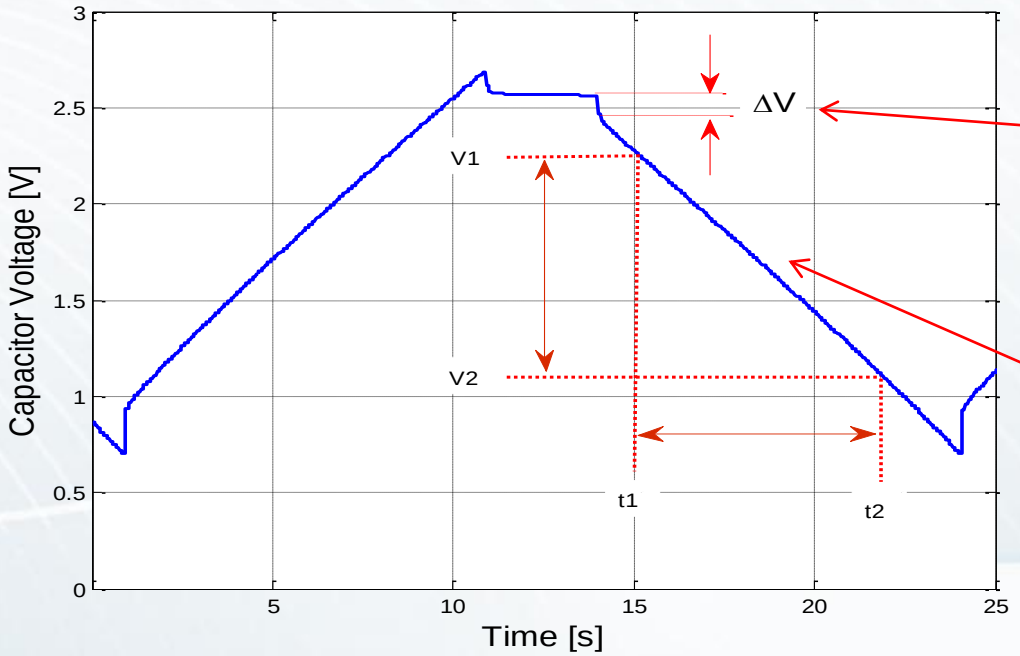
2.2 Super-capacitors: Characterization

- Super-capacitor characterization is complex
- There are a lot of methods
  - Most of them are dynamic measurements
- Each of them may present a different result
  - In some cases the difference can be higher than 50% of the nominal value.



2.2 Super-capacitors: Characterization

- The selected method for SC characterization for HEP is constant current method.
- It consists on charging and discharging the SC continuously at a constant current
- The values of the ESR and C are calculated based on capacitor voltage.
  - It is calculated during the charging and discharging process



$$ESR = \frac{\Delta V}{I}$$

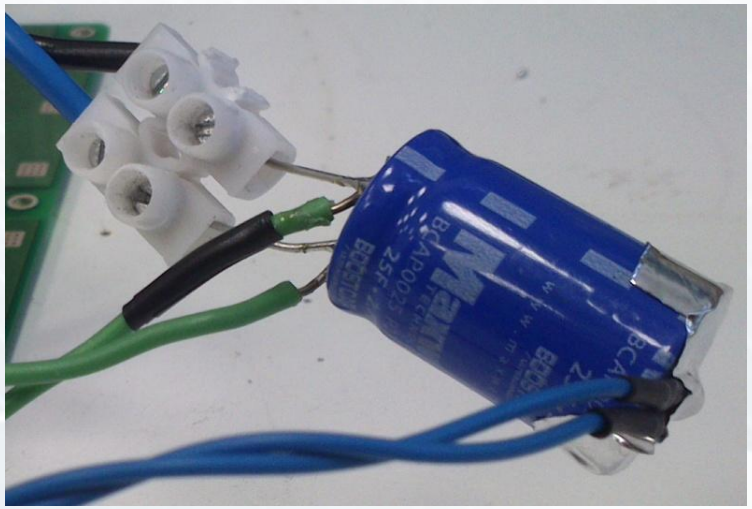
$$C = \frac{I \cdot |t_1 - t_2|}{|V_1 - V_2|}$$

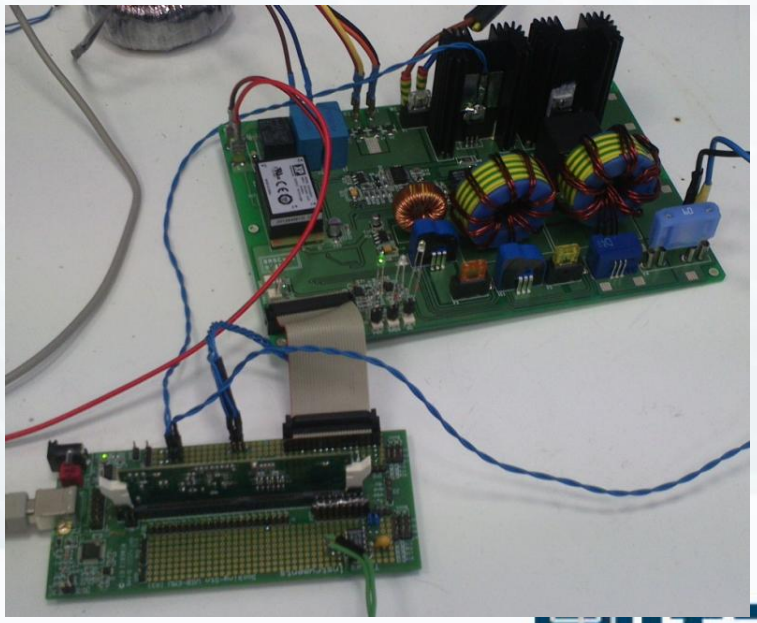
$$V_1 = 80\% \cdot V_{max}$$

$$V_2 = 40\% \cdot V_{max}$$

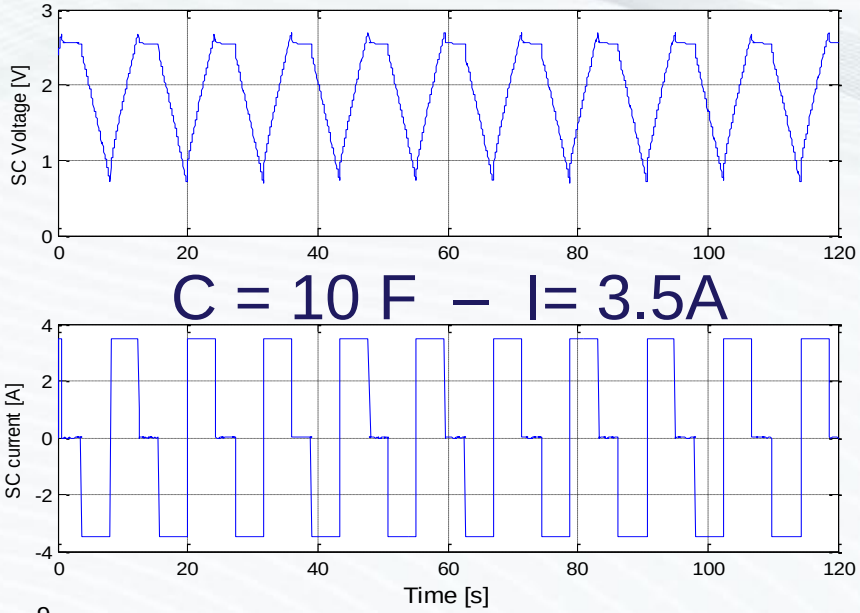
2.2 Super-capacitors: Characterization

- A power converter has been developed to test the super-capacitors for HEP applications.
- It is an automatic system that measures:
  - ESR, capacitance and capacitor temperature (synchronize)
  - It storage of the operational cycles (V, I, t)
  - High dynamic range - 0.1 F up to 6500 F
- The system performs charge and discharge cycles at a constant current (0.5 A to 50 A)

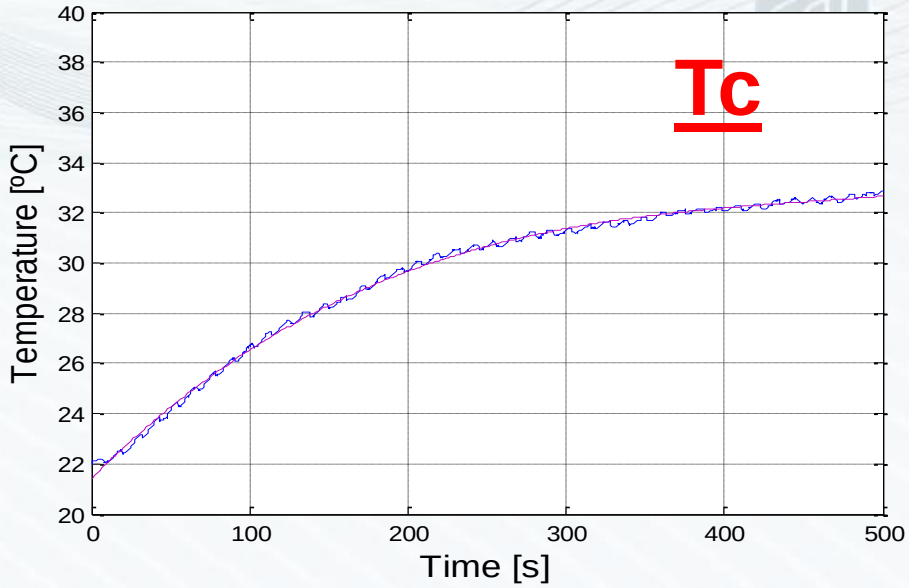


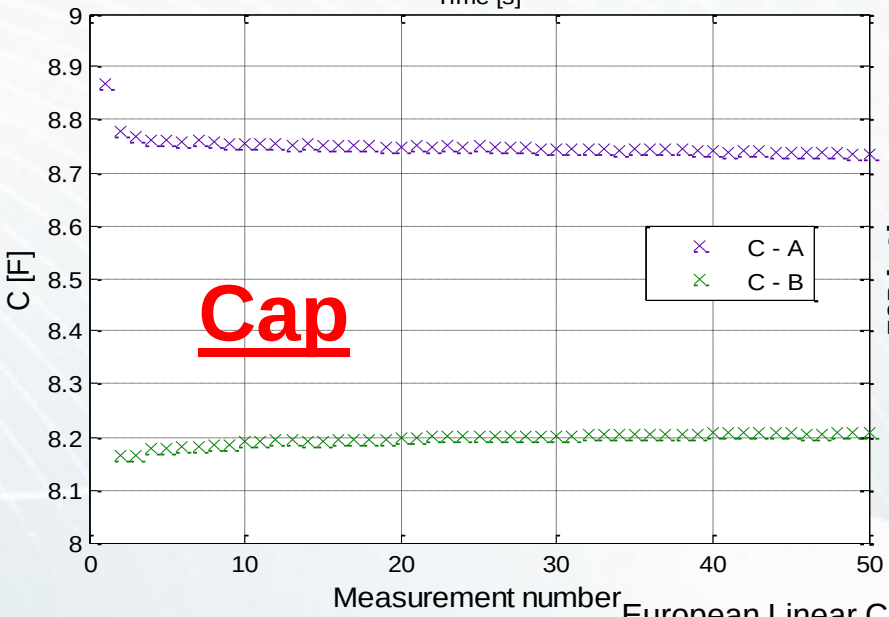


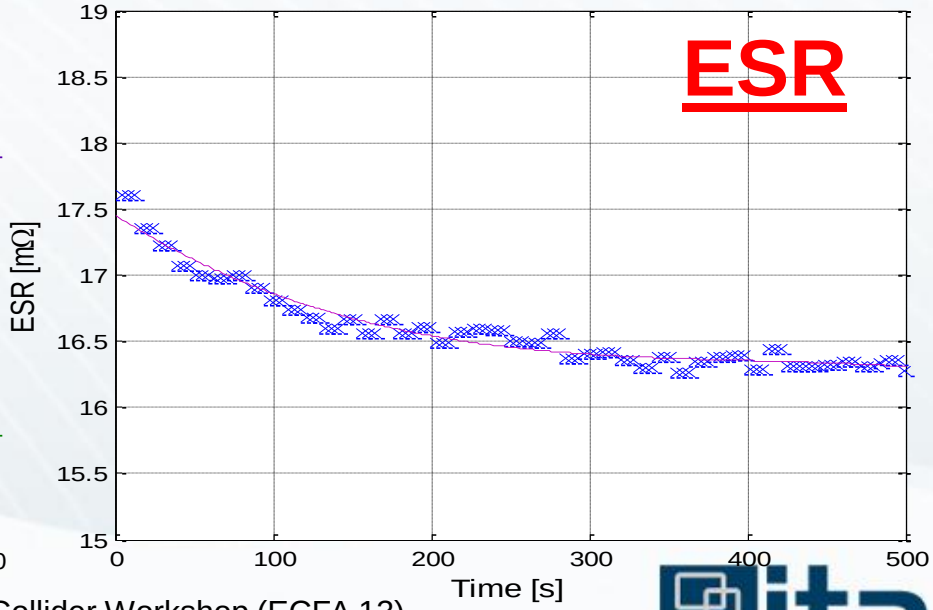
2.2 Super-capacitors: Characterization



C = 10 F – I= 3.5A







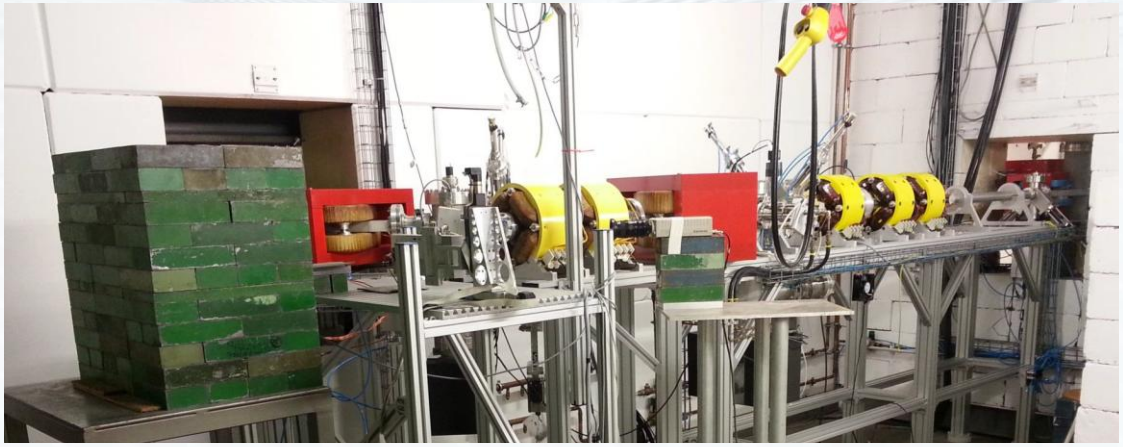
3. Radiation test for Super-capacitors

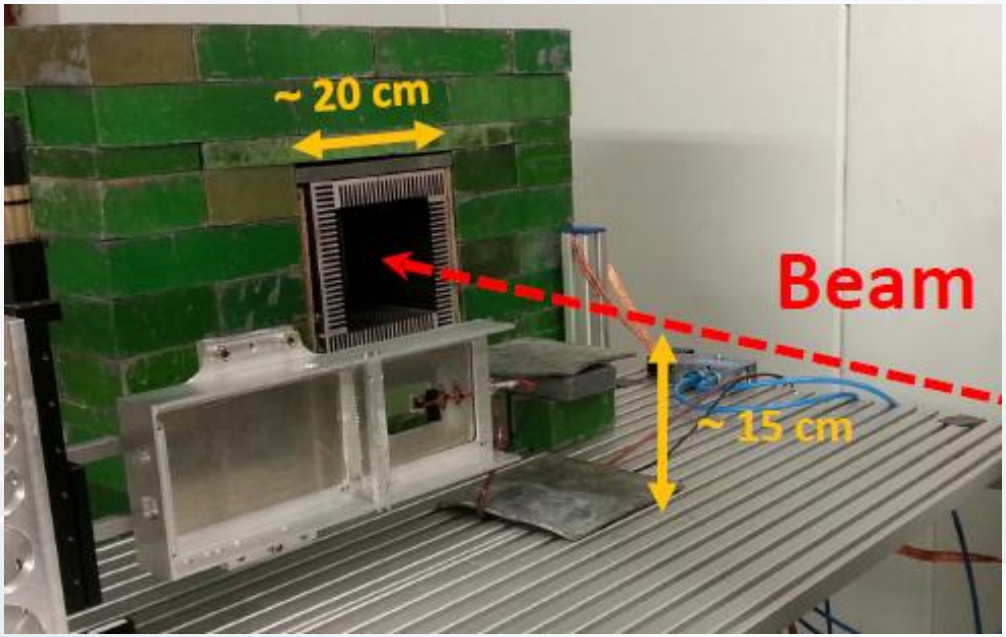
- A radiation test has been carried out in order to start the super-capacitor validation for FTD-ILD
- 5 super-capacitors have been tested:
  - Different rates
    - 3 x 10 F
    - 2 x 25 F
  - Different companies
    - Maxwell
    - Nesscap
    - Panasonic

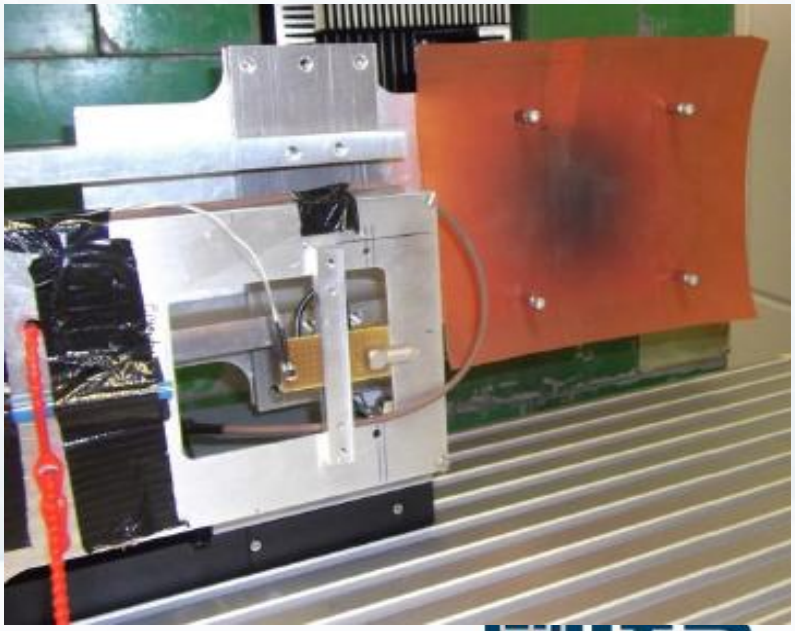
- They have been tested before and after radiation at 4 different current rates
  - C , ESR & T
  - Plots : ESR (T) / C (T)

3.1 Radiation test for SC: Test set-up

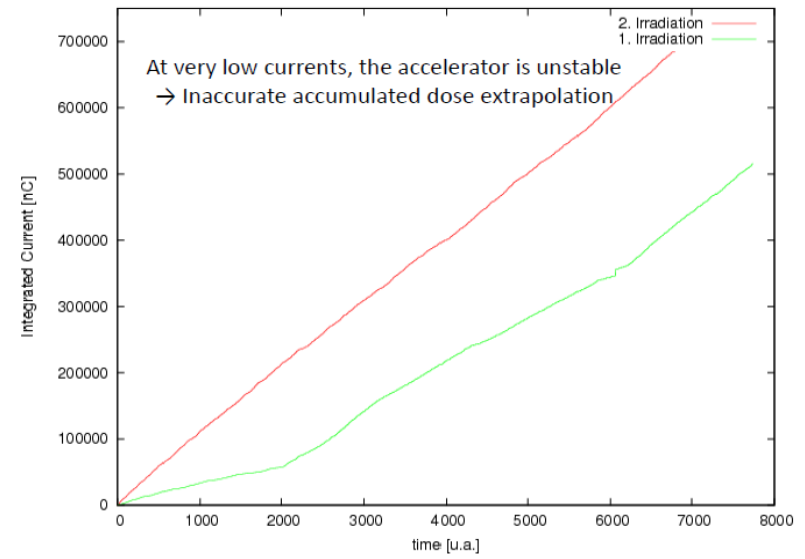
Radiation test has been performed at Electron Stretcher Accelerator **(ELSA, Bonn)**



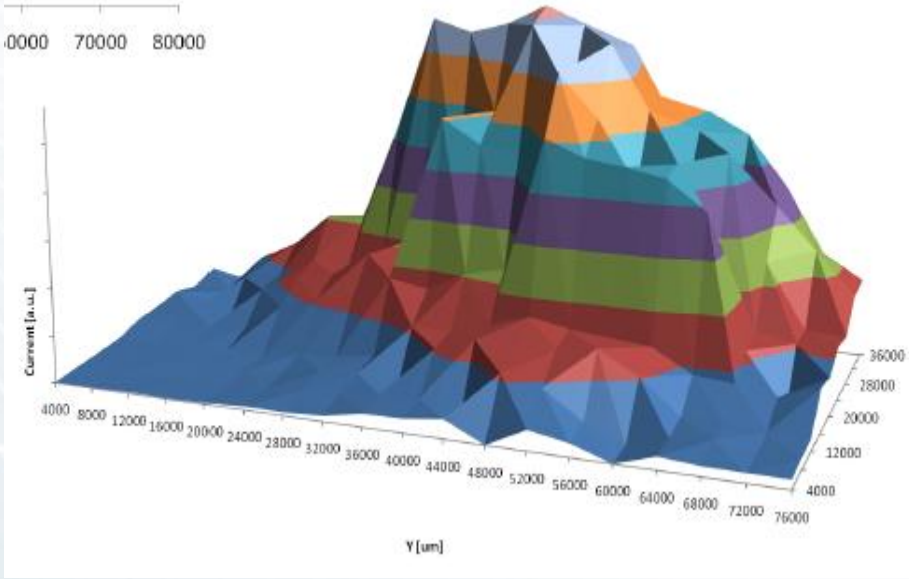


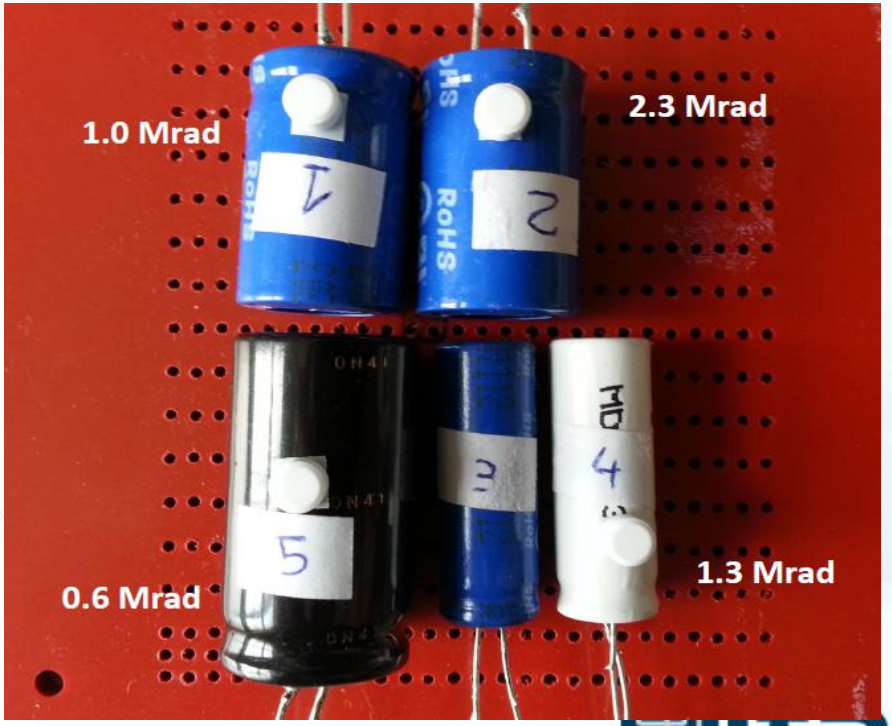


3.1 Radiation test for SC: Test set-up



- Electrons at 20 MEV
- Beam spot – 3x3 cm2
- 4 hours of irradiation.
- Total dose :
  - 0.6 Mrad -2.3 Mrad (3%)



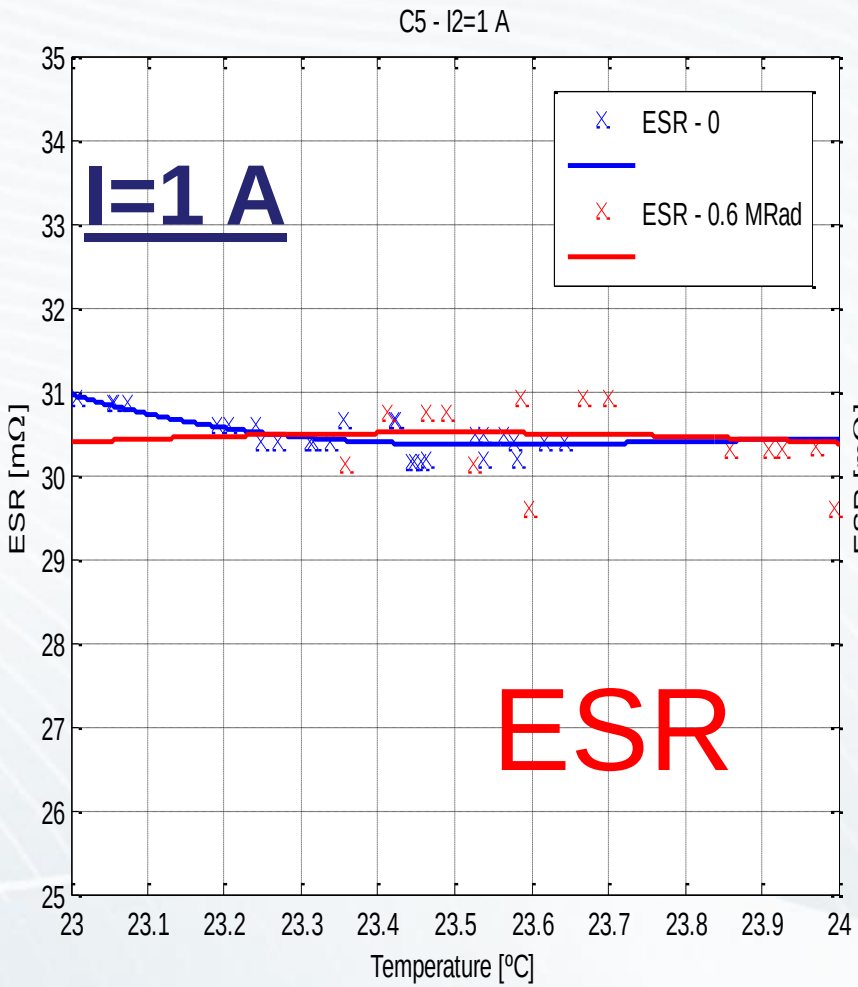


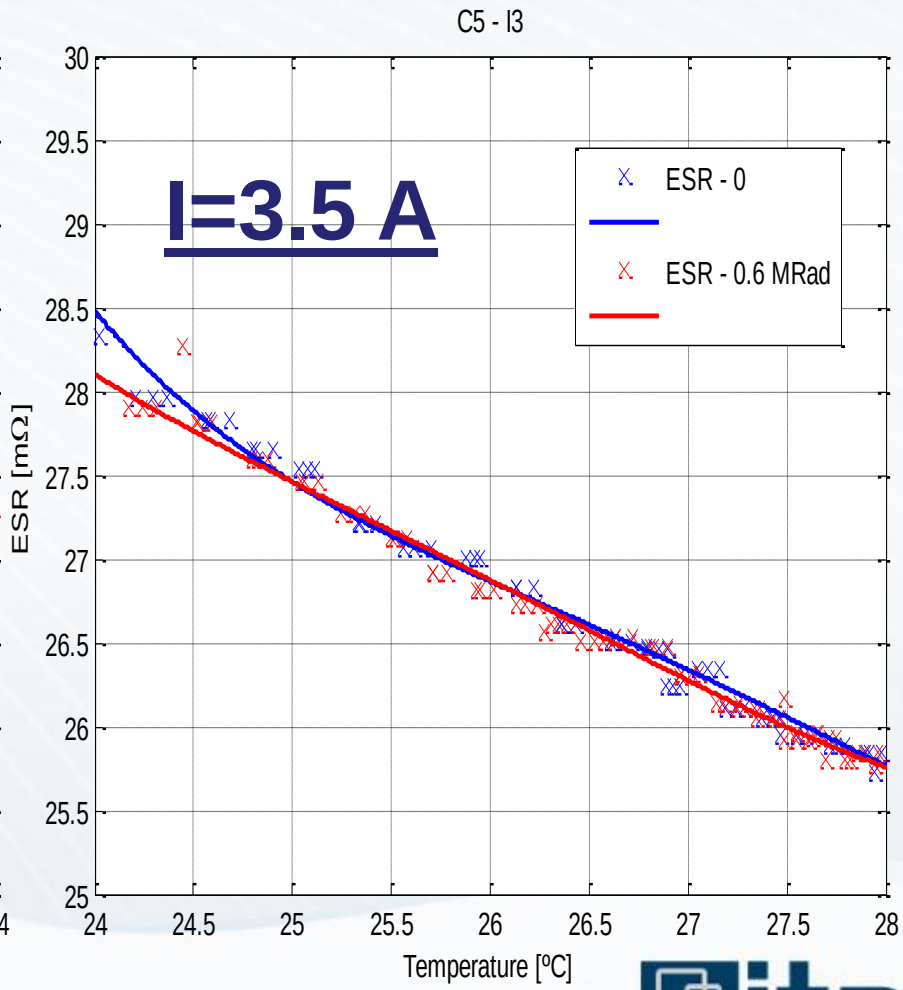
3.2 Radiation test for SC: Test results

Blue – Before radiation / Red – After radiation

X Measured values / - Fitted values

C = 10 F – Panasonic - 0.6 Mrad





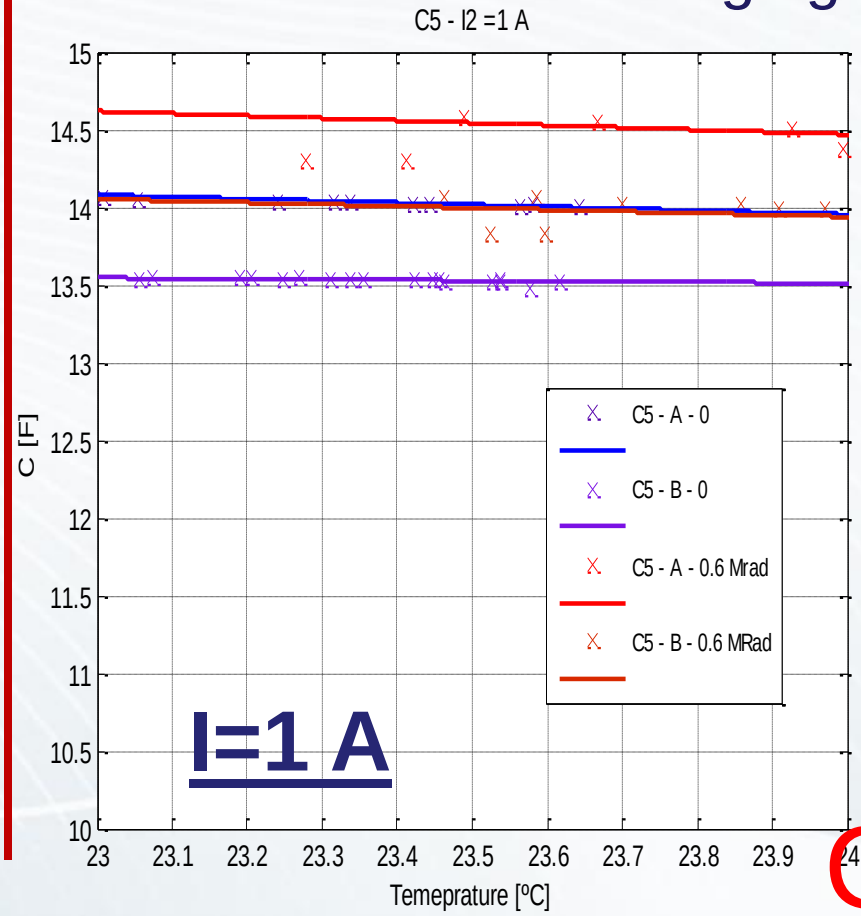
3.2 Radiation test for SC: Test results

Blue – Before radiation / Red – After radiation

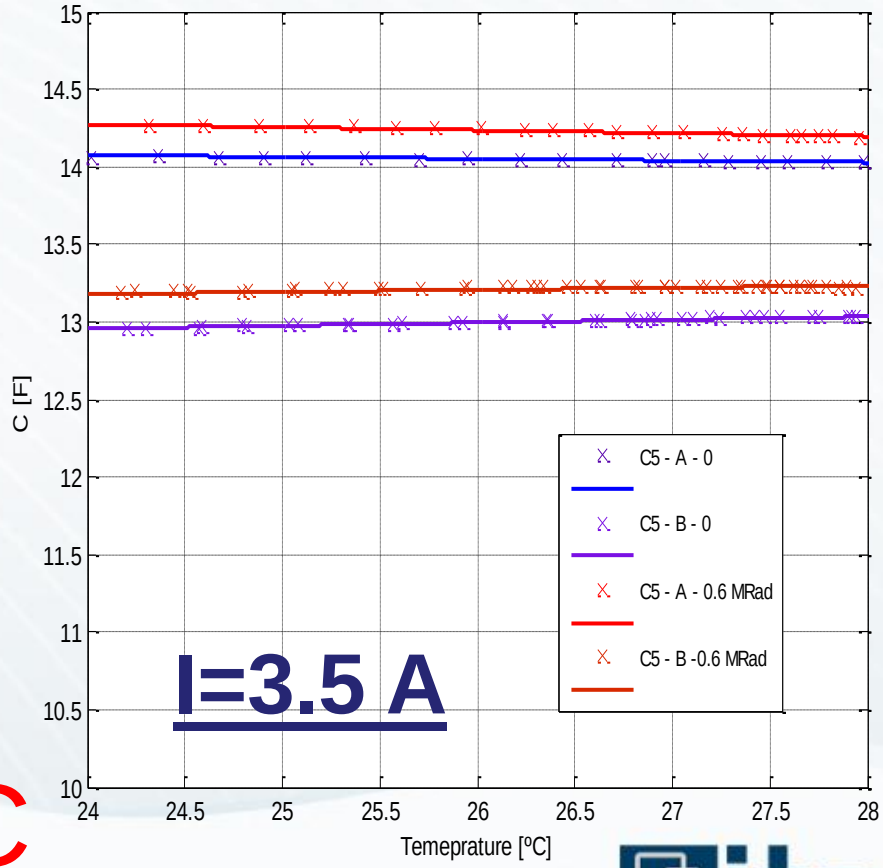
B- Charging capacitance value

A - Discharging capacitance value

C = 10 F – Panasonic - 0.6 Mrad

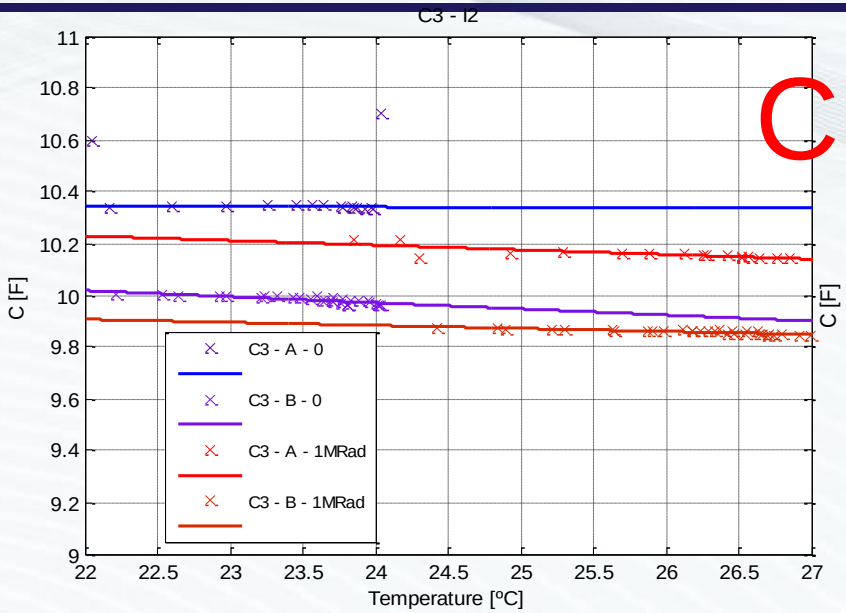


C

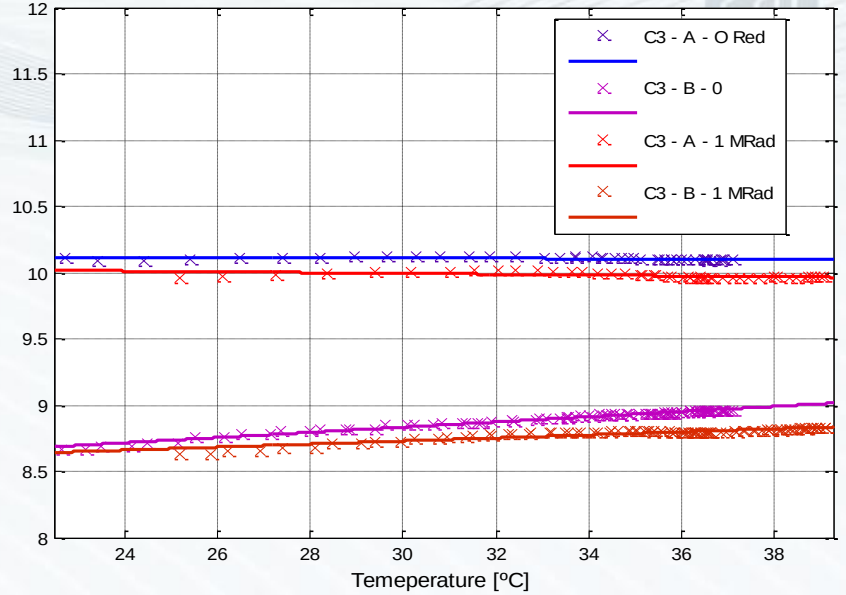


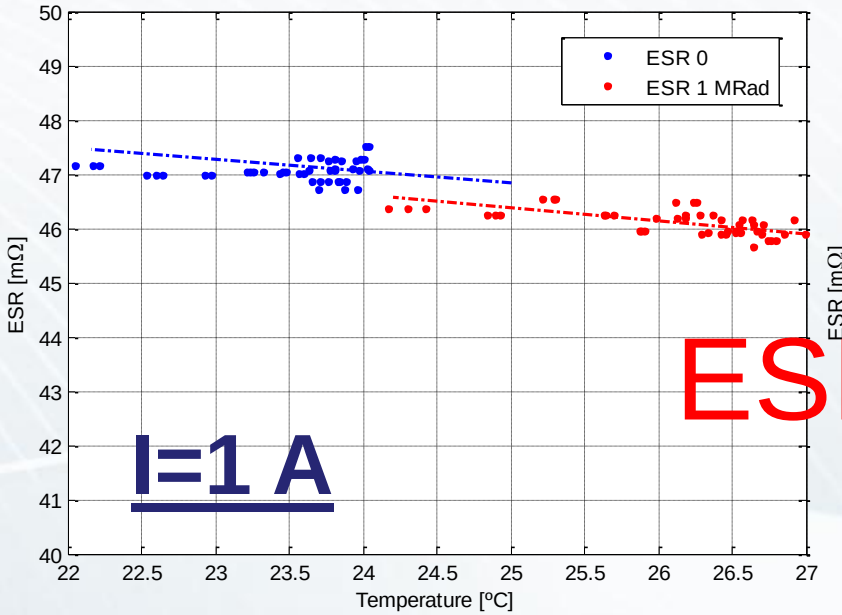
3.2 Radiation test for SC: Test results

C = 10 F – Maxwell - 1 MRad



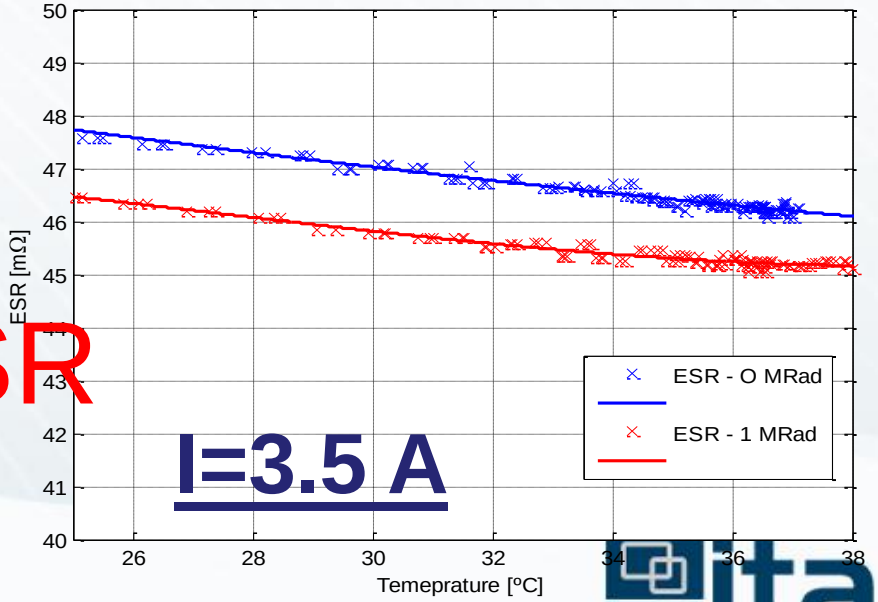
C





ESR

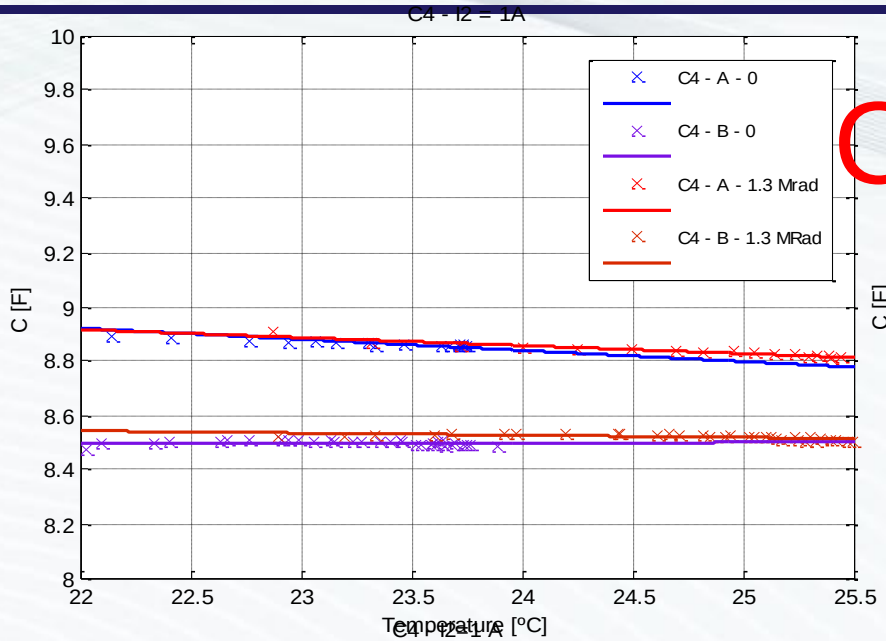
I=1 A



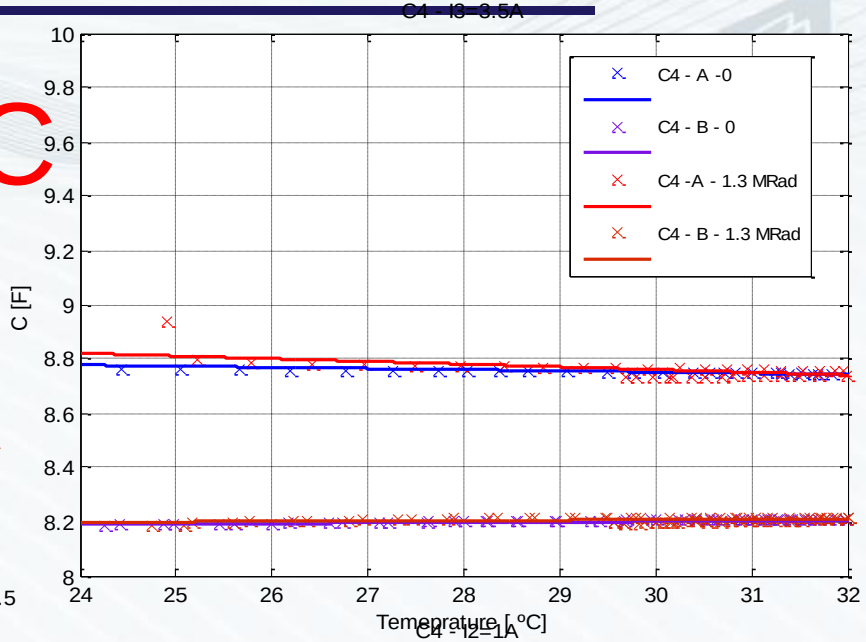
I=3.5 A

3.2 Radiation test for SC: Test results

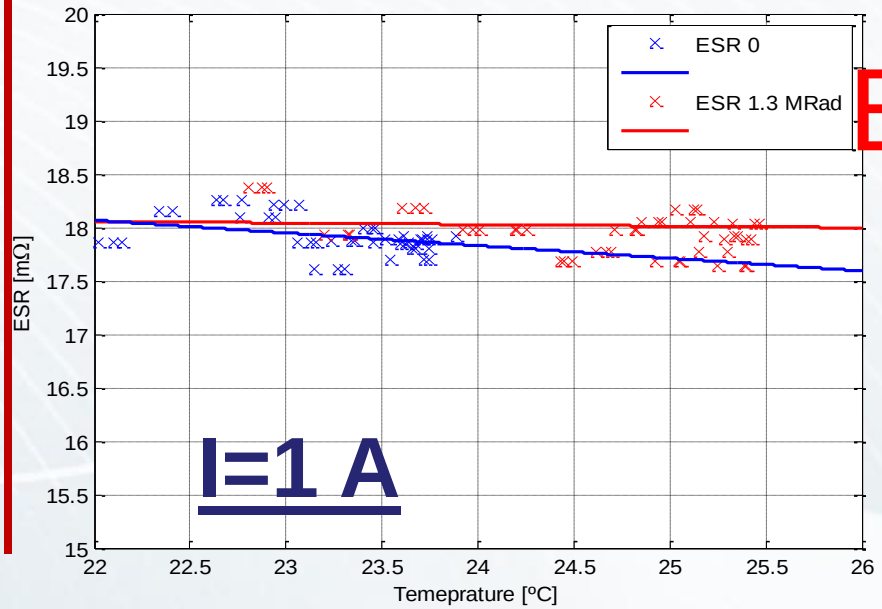
C = 10 F – Nesscap- 1.3 MRad

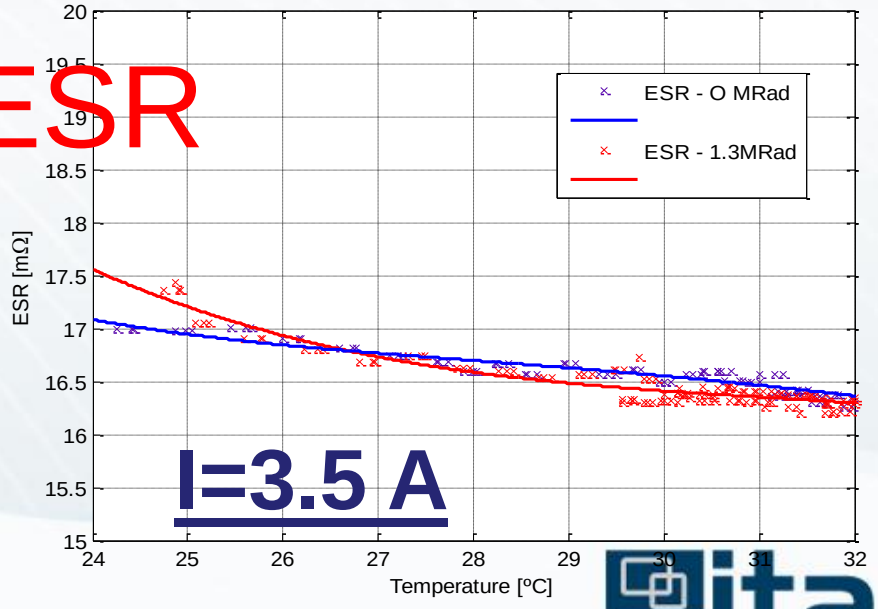


C



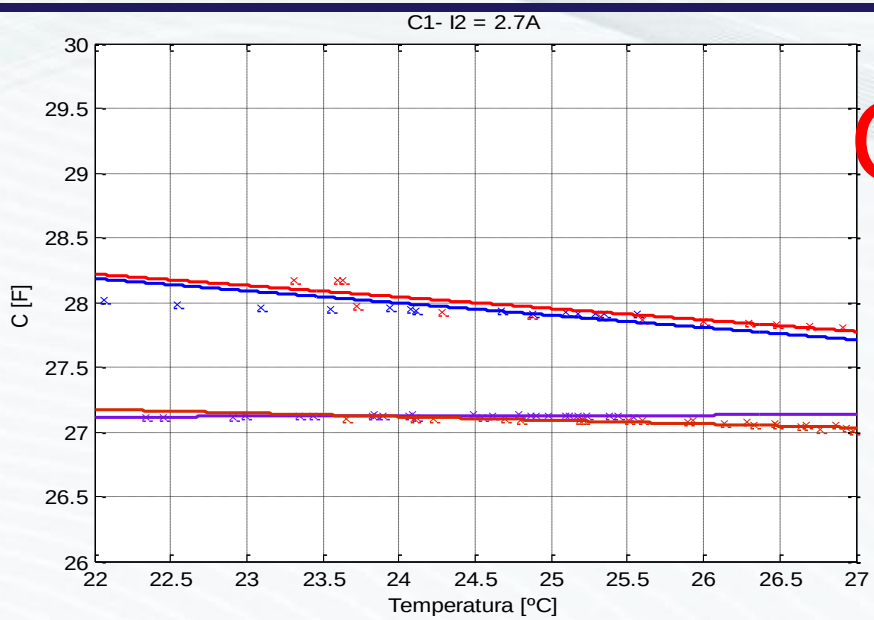
ESR



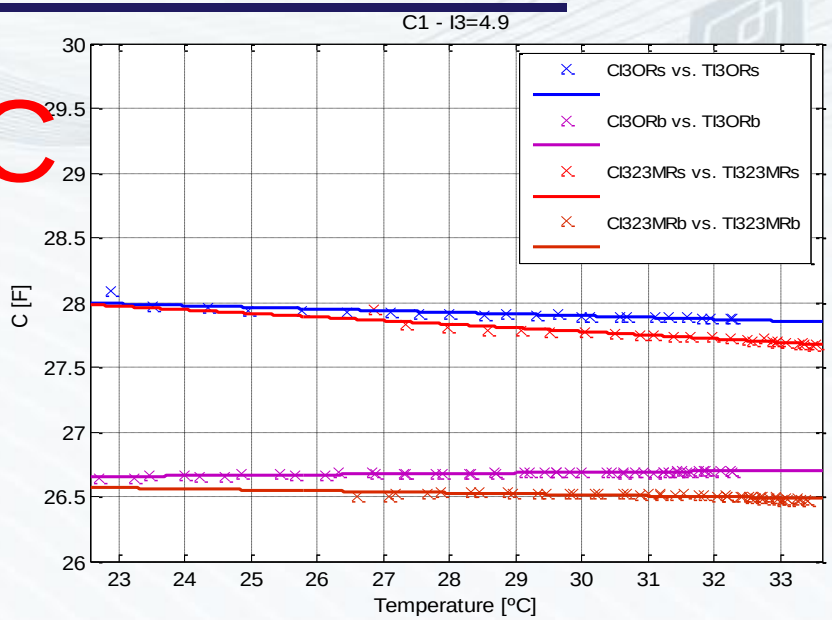


3.2 Radiation test for SC: Test results

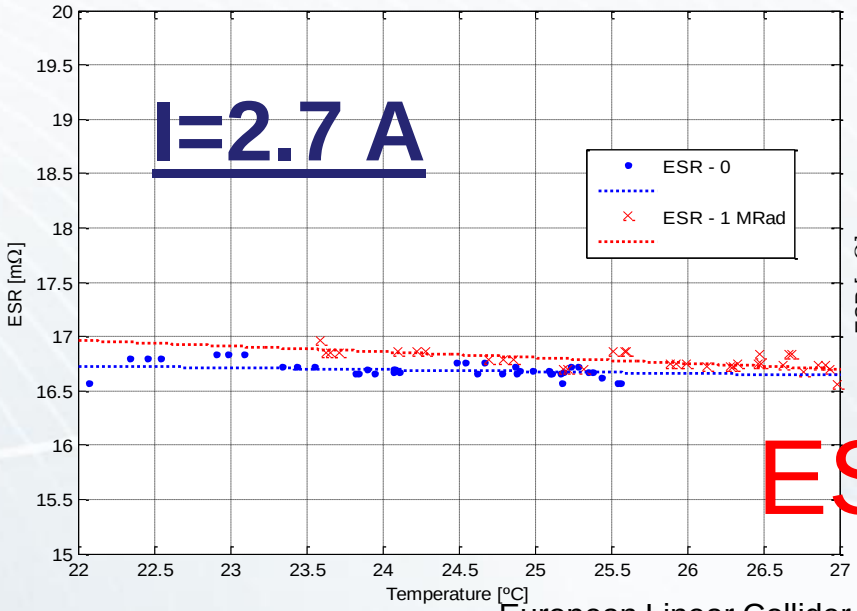
C = 25 F – Maxwell- 1 MRad



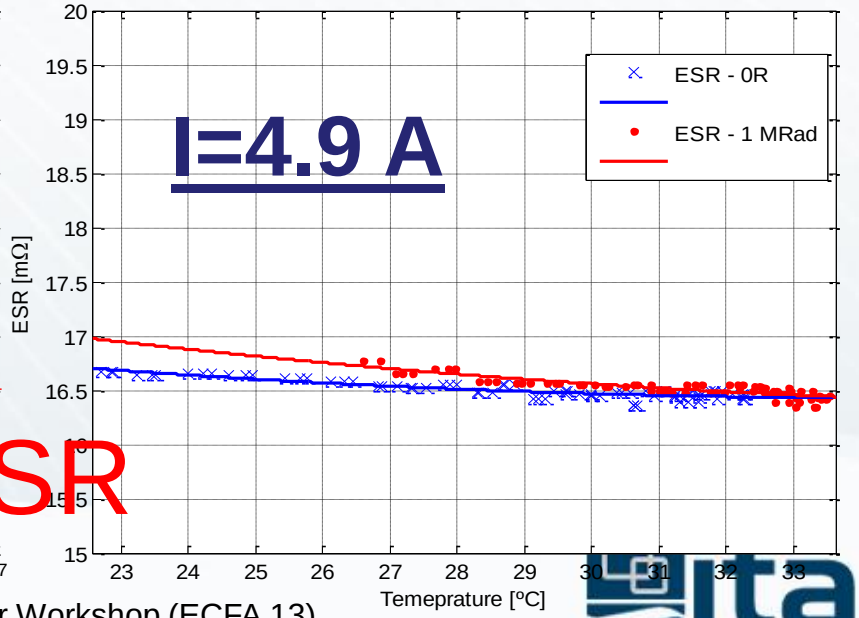
C



I=2.7 A



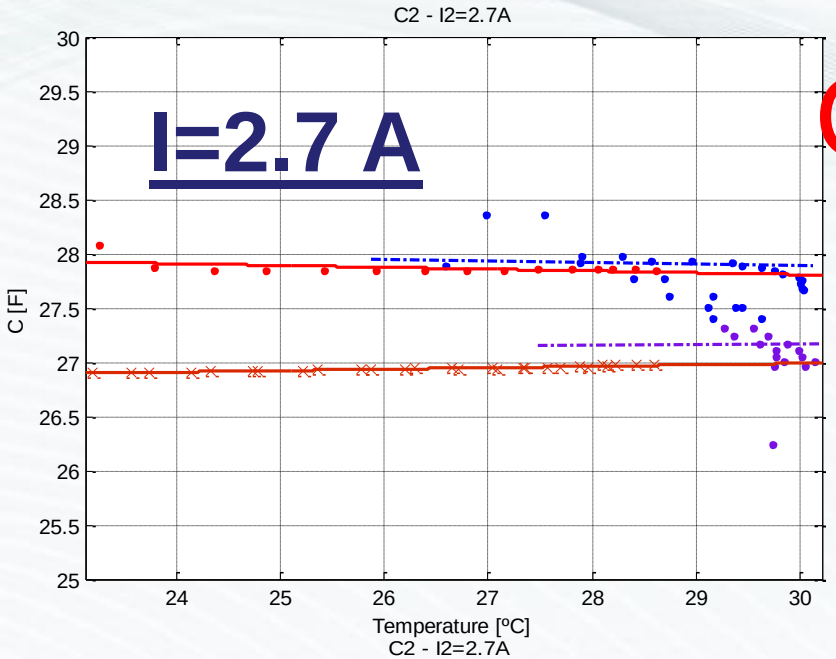
I=4.9 A



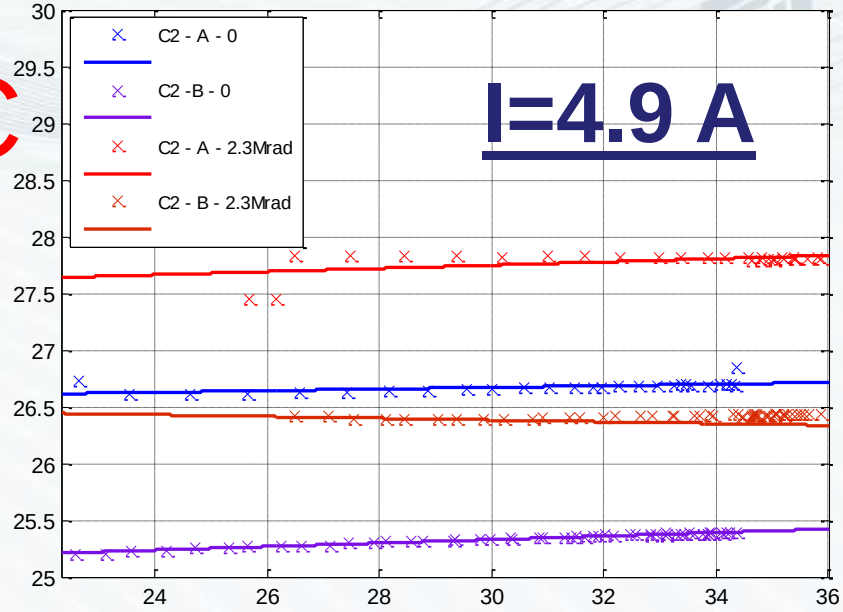
ESR

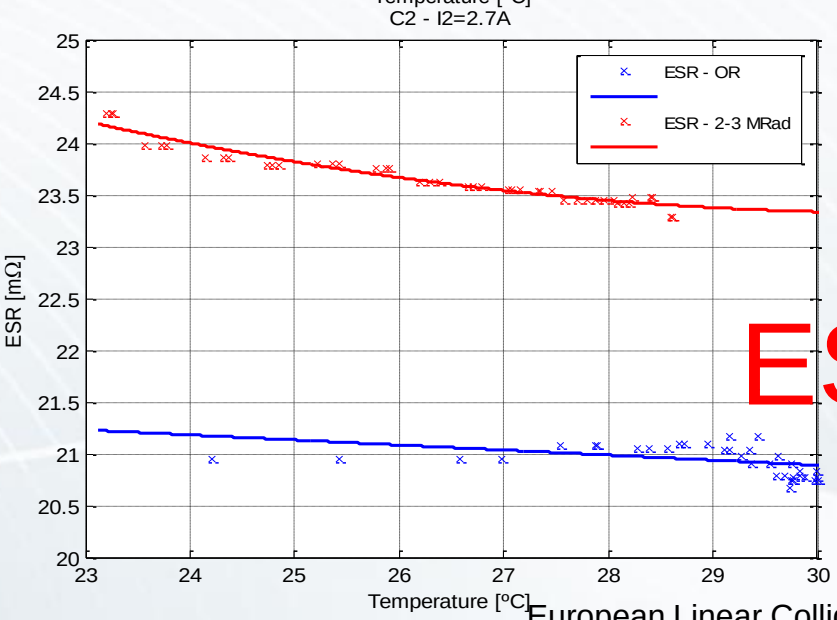
3.2 Radiation test for SC: Test results

C = 25 F – Maxwell- 2.3 MRad

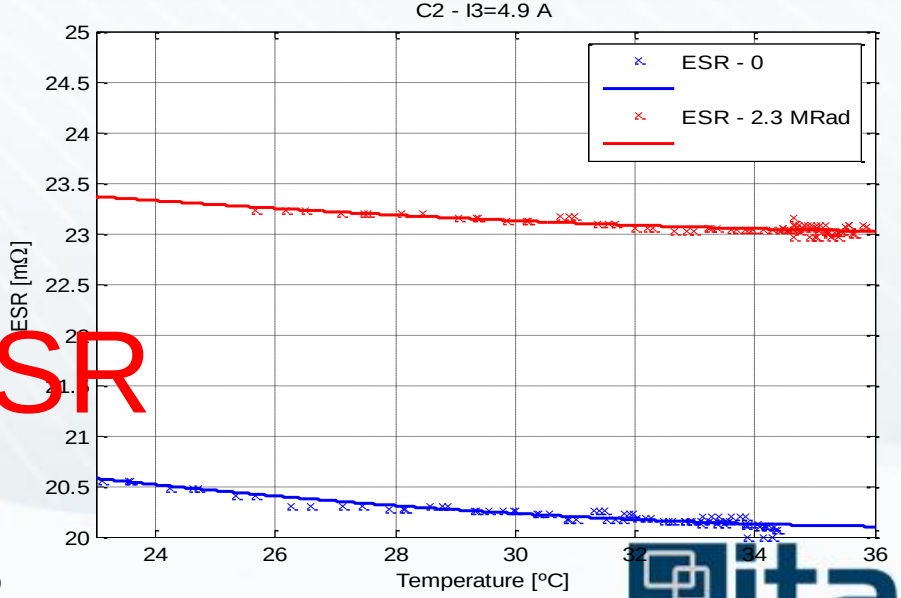


C

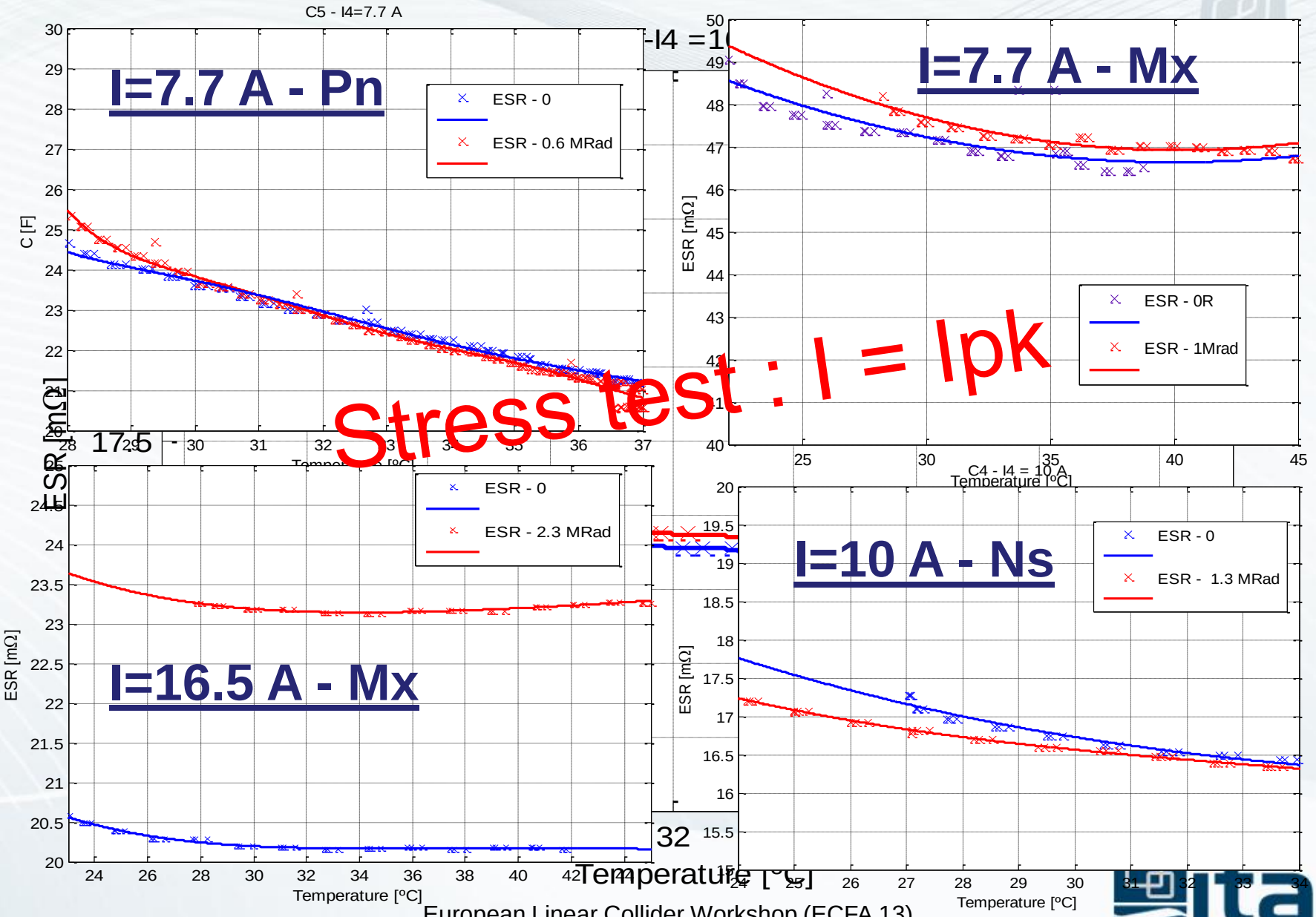




ESR



3.2 Radiation test for SC: Test results



4. Conclusions

- A first radiation test campaign has been carried out to validate super-capacitors for HEP applications.
- 5 Super-capacitors
  - Maxwell, Nesscap and Panasonic (10F & 25F)
- Tests have been performed based on constant current
  - Normal operation (2.7A, 5A)
  - Stress operation (10 A and 16 A)
  - ERS,C and T have been measured
- There was not found big difference on the main characteristics and SC performance
  - No stoppers have been found
- More tests and analysis are planned
  - Temperature & Higher dose.
  - Annealing effects