INSTITUTO TECNOLÓGICO DE ARAGÓN

Powering a low mass detector (FTD- ILD power system)

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OUTLINE

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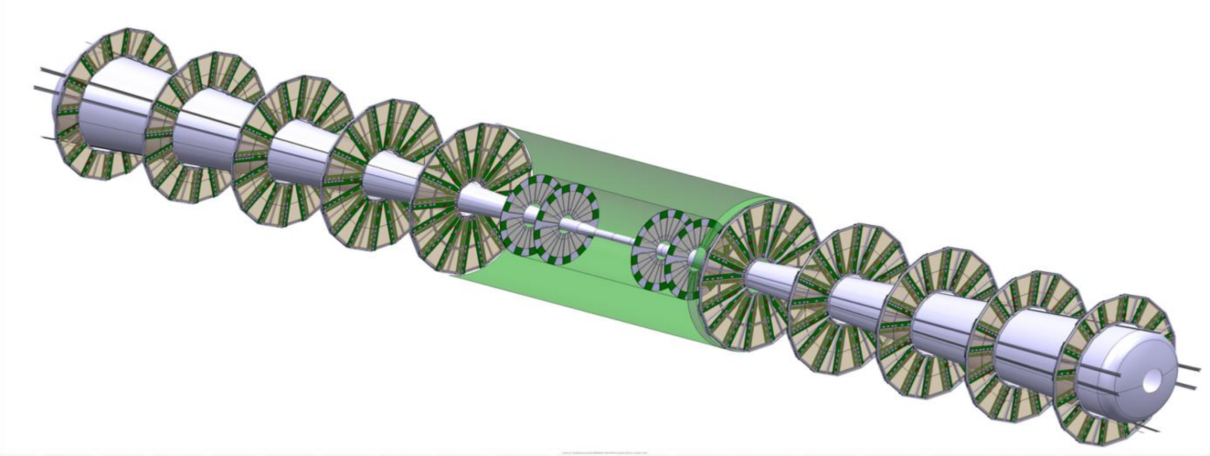
- 5.Conclusions

1. Introduction

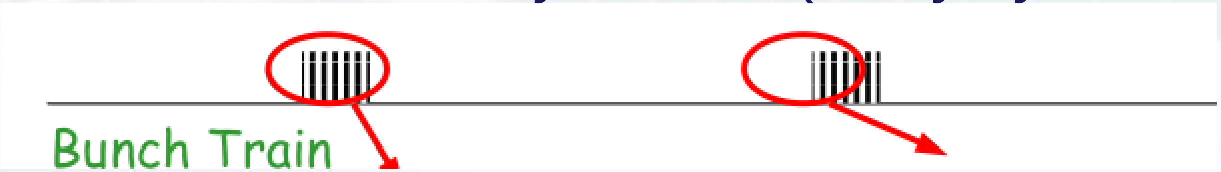
- Future ILC experiments need low mass detectors in order to increase the accuracy of the physics measurements.
  - Minimize or No cooling pipes
  - Low copper/aluminum components
- The powering of low mass detector is a challenging project because it requires:
  - High efficiency system.
  - Cables with small cooper section / Minimum shielding
  - Sensitive electronics
- The synchronization of the FEE power consumption with the accelerator beam duty cycle increase the detector efficiency
  - A big effort is under development from electronics designers
- Special attention should be paid in the design of the power systems.
  - It should be specially designed to be compatible with electronics operation mode.

2. Power requirements

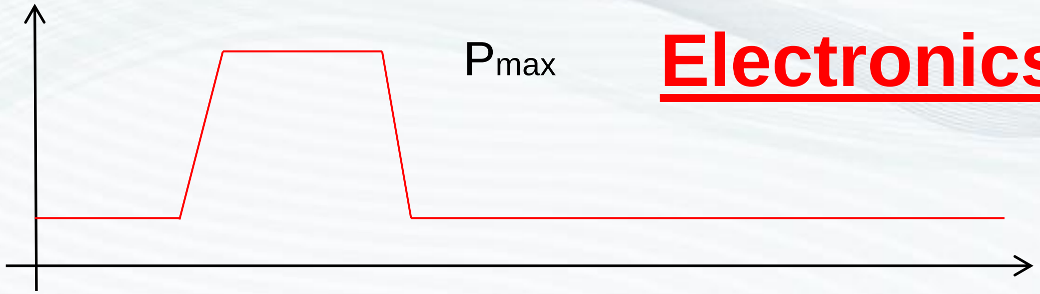
- During the last years several R&D activities focused on the design of the power supply system have been carried out for FTD-ILD.
  - 10 disks – 16 petals



- The FTD electronics will operate synchronously (or coordinated) with ILC accelerator....
  - 1 ms bunch train every 200ms (Duty cycle of 0.5%)



2. Power requirements



Electronics duty cycle /power ?

$P_{standby}$ = 20% P_{max}

- Several conservative considerations have been assumed in the electronics operation:
  - **Electronics duty cycle operation** (2.5% - 5ms / 200ms).
    - 1 ms power up / down
    - 3 ms operation state to stabilize power and operate.
    - It minimizes transients
  - **Power consumption during the standby** (20% Pmax).
    - It is a critical parameter (100W / 20W): 22 W/cycle
      - 2.5W/cycle - FEE ON (11%)
      - 19.5W/cycle – STAND BY (89 %)
    - *If standby power 10W : Ptotal = 12.25 W/cycle*
    - *If FEE operation time 2.5ms: : Ptotal=21W/cycle*

2. Power requirements

- The total Strip-FTD current / power demanded is:
  - Bunch crossing state 458 A (**≈ 860 W**)
  - Stand-by state 91.6A (**≈ 171W**)

	MIDDLE PITCH									
FTD	*FTD3*		*FTD4*		*FTD5*		*FTD6*		*FTD7*	
	INN	*OUT*	*INN*	*OUT*	*INN*	*OUT*	*INN*	*OUT*	*INN*	*OUT*
Nº Readout	***33920***	***61504***	***41600***	***64224***	***45472***	***65504***	***51232***	***67424***	***63424***	
Chips per petal (256 ch)	*24*		*26*		*28*		*29*		*16*	
Optical links per petal	*1/2*		*1/2*		*1/2*		*1/2*		*1/2*	
I1.5 (A) per Petal	*1.75 / 0.35*		*1.9 / 0.38*		*2.05 / 0.41*		*2.12 / 0.42*		*1.16 / 0.23*	
I2.5 (A) per Petal	*1.05 / 0.21*		*1.13 / 0.23*		*1.22 / 0.24*		*1.27 / 0.25*		*0.7 / 0.14*	
I per petal	*2.79 / 0.56*		*3.03 / 0.61*		*3.26 / 0.65*		*3.39 / 0.68*		*1.86 / 0.37*	
I per disk	*44.6 / 8.9*		*48.5 / 9.71*		*52.08 / 10.42*		*54.19 /10 .84*		*29.76 /5.95*	
TOTAL Mstrip- FTD Current (both sides)			*458 A / 91.6 A*							

(CMS upgrade TK elec.)

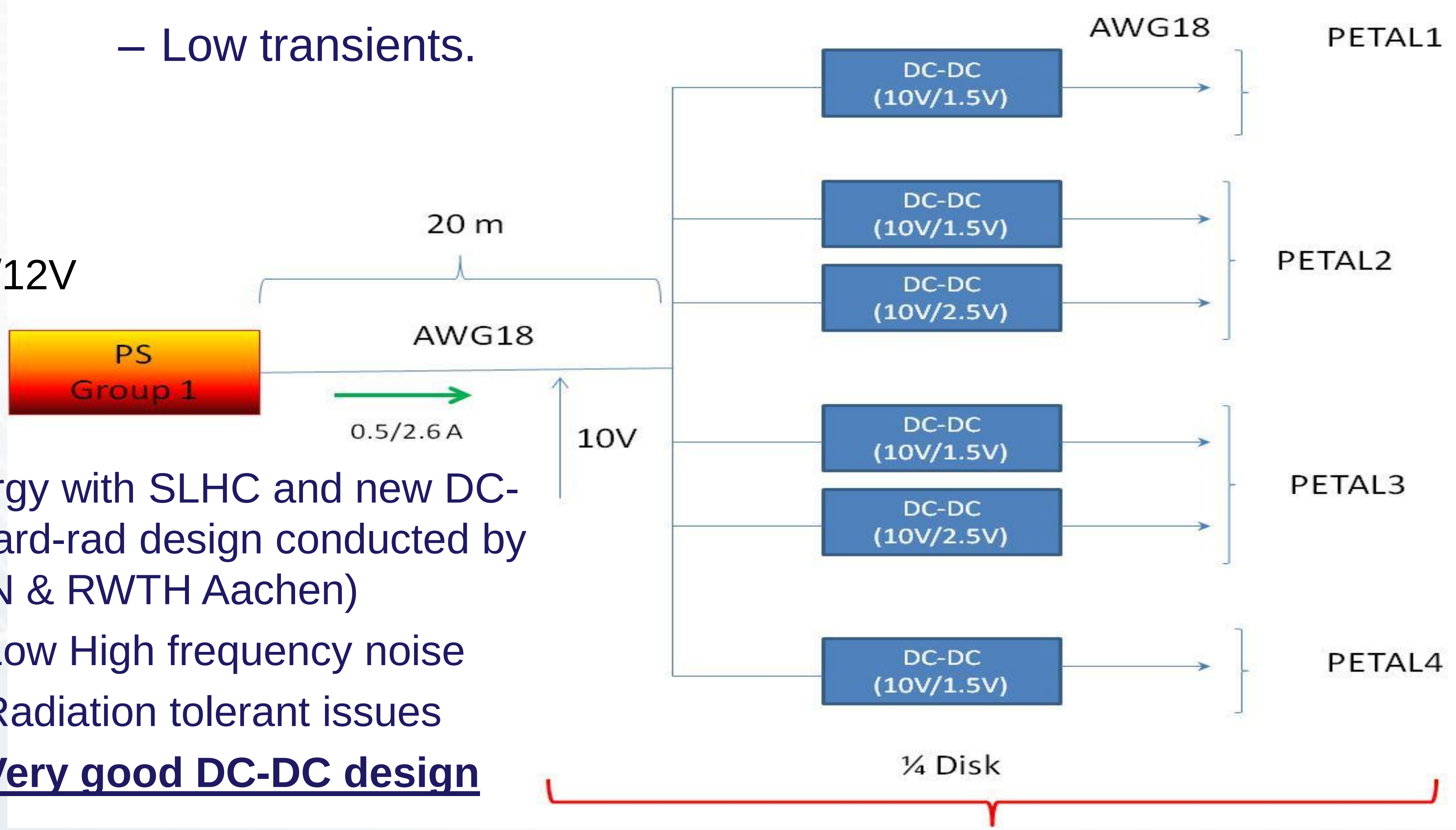
3. Powering schemes

- Several important issues have to be considered during the design of the power system:
  - Transient phenomena
  - EMI phenomena
  - Power dissipation effects
- All these phenomena have an impact on the design of the power supply distribution system
  - Topology / Granularity (1/4 petal)
  - Cooling
  - Material budget
- There are several topologies that may be used for FTD.
  - **DC-DC-based power distribution**
  - **Super-capacitor based power distribution**
- Power system evaluation based on:
  - Sim. / Measu.

3.1 Powering schemes: DC-DC-based Power System

- It is based on the installation of DC-DC converter at FTD level.
  - It absorb transients related to power pulsing system.
    - Low currents before DC-DC due to converter ratio.
      - Low transients.

200V/12V



- Synergy with SLHC and new DC-DC hard-rad design conducted by CERN & RWTH Aachen)
  - ➢ Low High frequency noise
  - ➢ Radiation tolerant issues
  - ➢ **Very good DC-DC design**

3.1 Powering schemes: DC-DC-based Power System

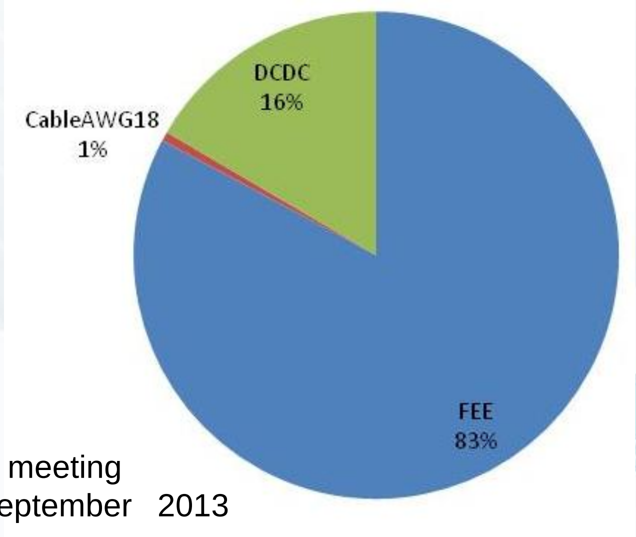
- Example (1/4 disk) : Power values per **group FTD 6+:**
  - FTD level – 4 petals:
    - **6 DC-DC converters**
      - 4 DC-DC (10V - 1.5V) – 2.1A / 0.4A
      - 2 DC- DC (10V - 2.5V) –2.5A / 0.5A
    - Short cabling – Low current (low transients) – **AWG18**
  - Outside FTD (**1cable per ¼ disk**)
    - Max out current per DC-DC less than 3 A (2.5A /0.5A)
      - Transients attenuated by the DC-DC
    - Primary power unit
      - Imax=3 A / V= 12V – **Power required > 36 W**
  - **TOTAL INSTALED POWER REQUIRED FOR FTD**
    - **1.4kW**
- A similar number of HV cable will be considered to keep the same granularity

3.1 Powering schemes: DC-DC-based Power System

- Power dissipation per ILC cycle (W/c): ***DC-DC converter efficiency : 80%**

Group	FTD 3+	FTD4+	FTD5+	FTD6+	FTD7+
FEE	4.6	5	5.4	5.6	3
CABLE	0.02	0.033	0.039	0.041	0.012
DCDC*	0.92	1	1.07	1.11	0.61
TOTAL (1/4)	5.55	6.04	6.48	6.74	3.69
TOTAL DISK	22	24.1	26	27	14.7
External cable (20m)	0.23	0.27	0.31	0.34	0.1

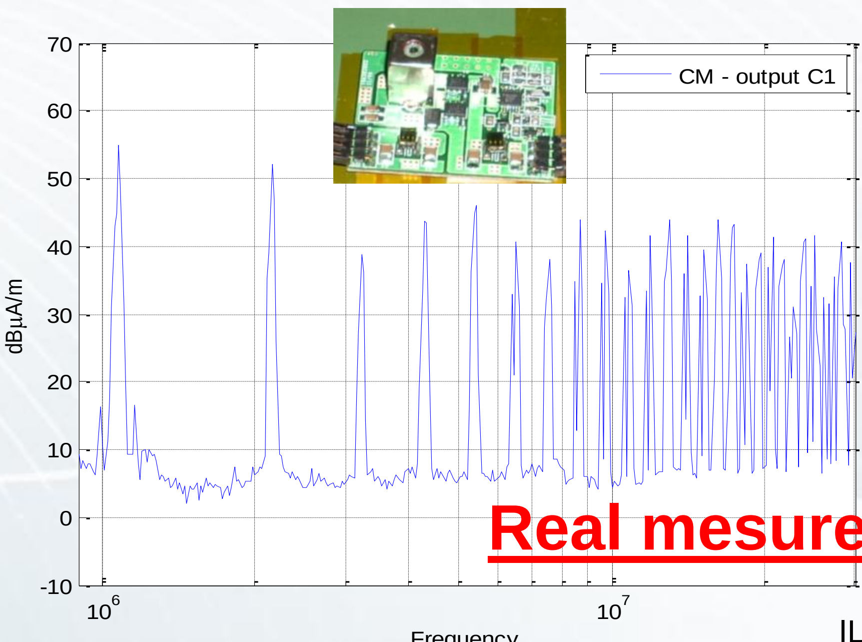
	POWER (W)
HALF SIDE	114 W
TOTAL FTD	228 W

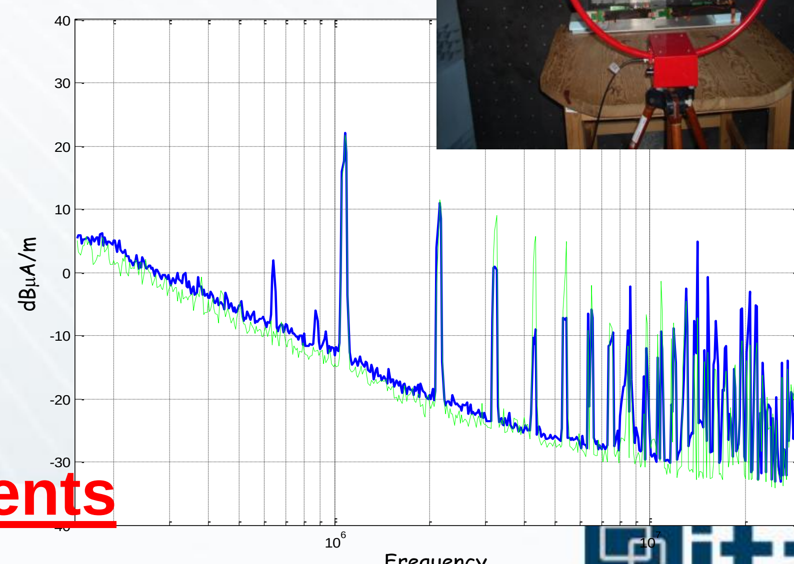


FTD6

3.1 Powering schemes: DC-DC-based Power System

- Important topics associated with DC-DC converters
  - Material
    - Shielding – Main inductor.
  - Dynamic
    - Dynamic behavior: Negative impedance & Transients
  - EMI phenomena (Noise)
    - Conducted & Radiated

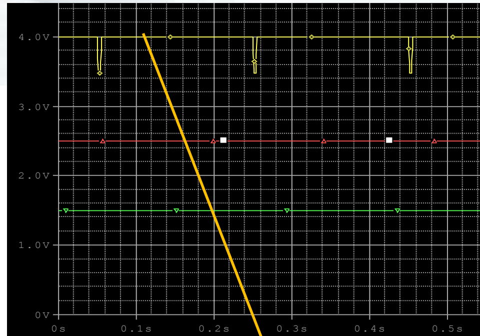


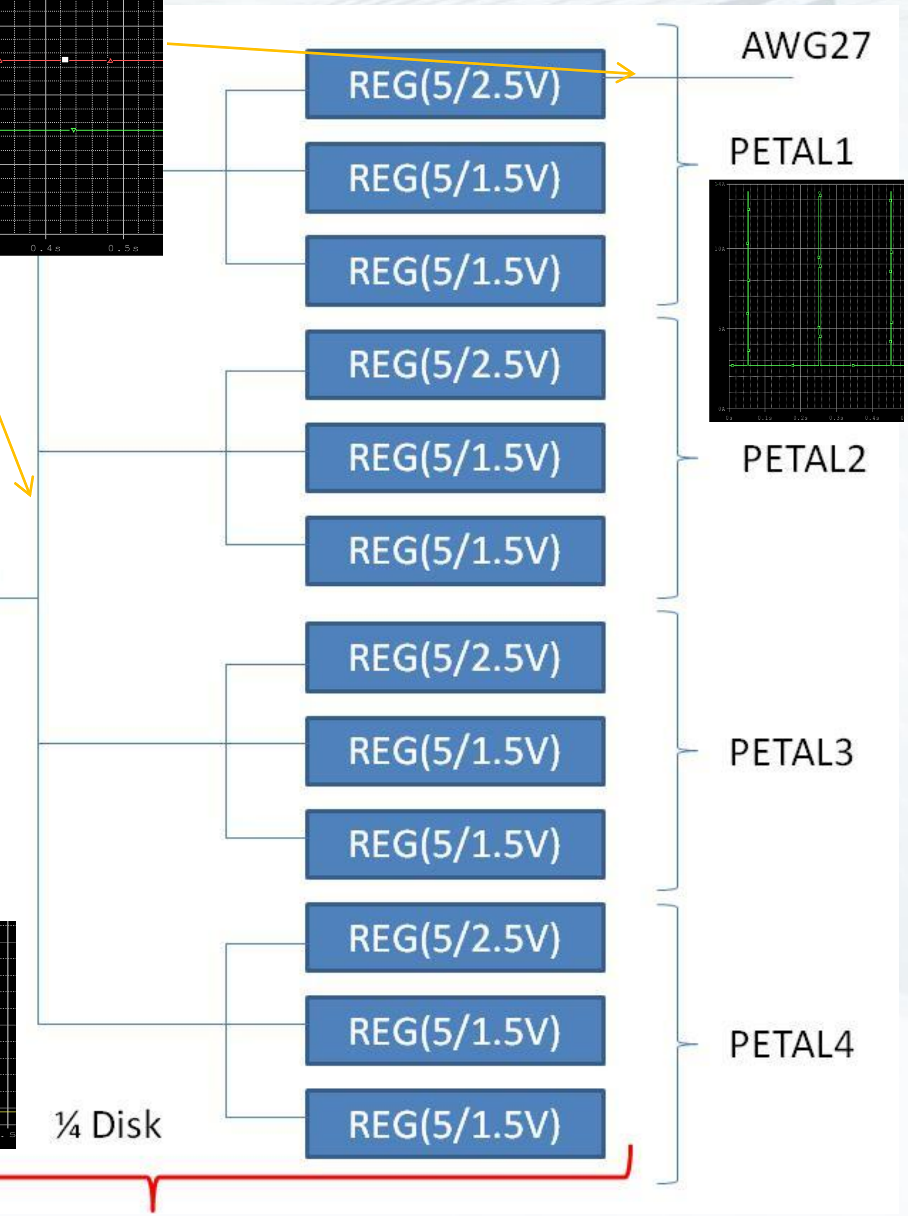


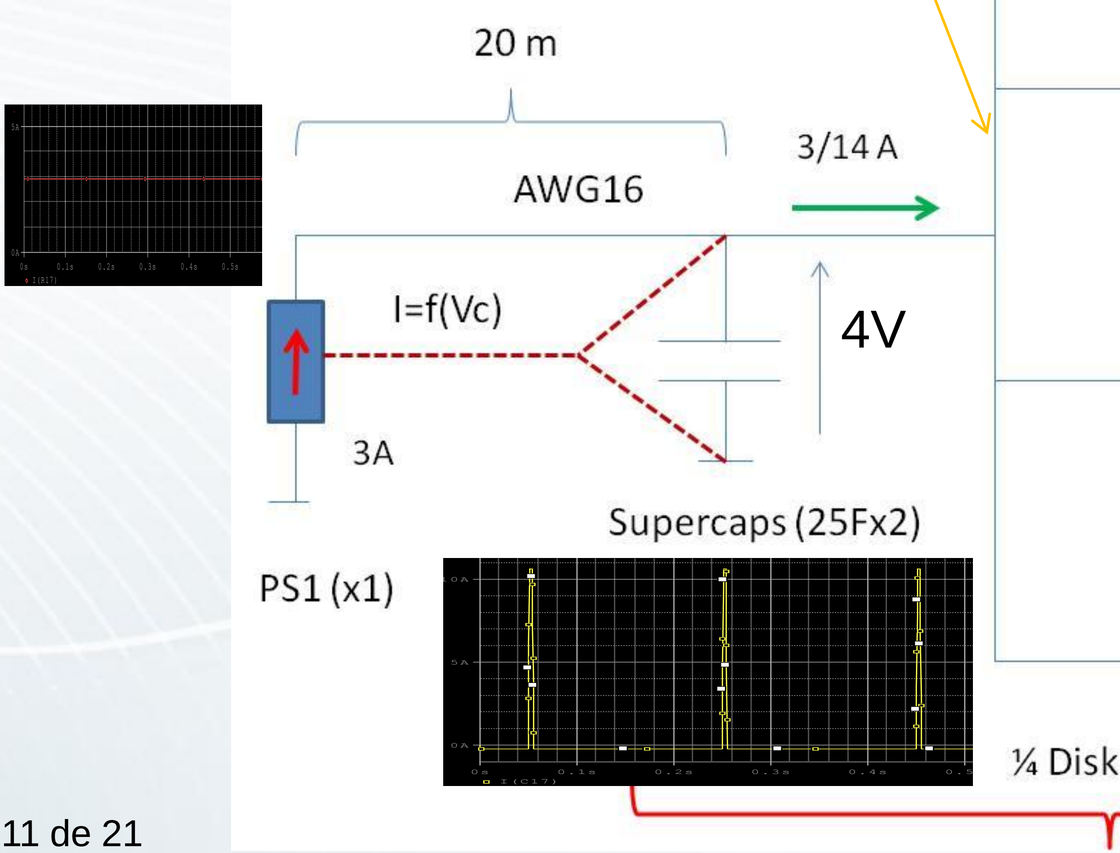
Real mesurements

3.2 Powering schemes: Super-capacitor based PS

- **Super-capacitors:**
  - Pulse power
- **LV regulators**:
  - Stabilize FEE voltage
- **Current source :**
  - Controls super-capacitor voltage

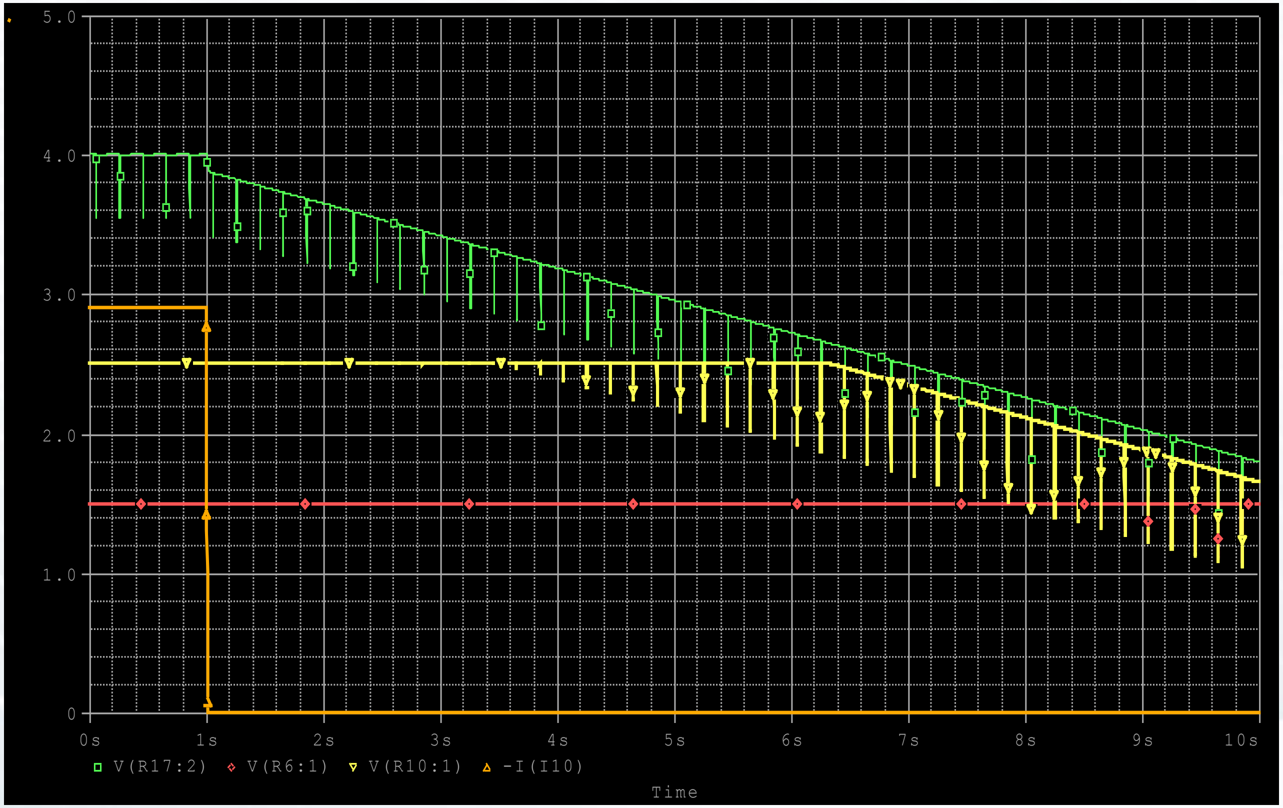






3.2 Powering schemes: Supercapacitor based PS

- The high capacitance has two advantages:
  - It will protects the system in case mains failure – Similar to UPS
    - It helps shutdown the system in a controlled way.
  - The dynamic response of primary power unit may be very slow
    - Remote regulation of the supercap voltage will be easy



- The duration of the shut-down capability will depend on :
  - Capacitance
  - Voltage

3.2 Powering schemes: Supercapacitor based PS

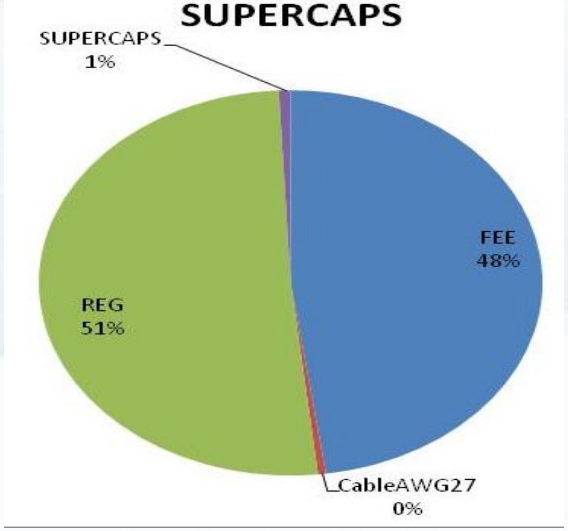
- Example (1/4 disk) : Power values per **group FTD 6+:**
  - Routing Inside each petal
    - **3 Regulators**
      - 2 REG (4V -1.5V) / 1. A Pk – 0.21A
      - 1 REG (4V- 2.5V) / 1.2 A Pk – 0.25A
    - Short cabling – Less than 0.2 meter (low voltage drop)
  - Per Group- ¼ disk (12 LV regulators)
    - **2 Super-capacitors** per (1/4 disk) – C=25 F / V=4 V / Imax=11 A /Imin≈0
    - **1 Cable per disk**
    - Max out current per cable around 2/3 A (defined by FEE stand-by)
  - Primary power unit
    - I max = 3 A / V ≈ 4V – **Power = 12W**
  - **TOTAL INSTALED POWER REQUIRED FOR FTD**
    - Power – **480 W**
- A similar number of HV cable will be considered to keep the same granularity

3.2 Powering schemes: Super-capacitor based PS

- Power dissipated per ILC cycle (W/cycle):

Group	FTD 3+	FTD4+	FTD5+	FTD6+	FTD7+
FEE	4.6	5	5.4	5.6	3
CABLE AWG 27	0.04	0.04	0.05	0.06	0.02
LV REG	4.9	5.41	5.74	5.96	3.24
SUPERCAPS	0.06	0.072	0.083	0.089	0.027
TOTAL (1/4)	9.63	10.6	11.3	11.7	6.4
TOTAL DISK	38.5	42.1	45	46.5	25.5
External cable (20m) – AWG 16	2.92	3.515	4	4.4	1.26

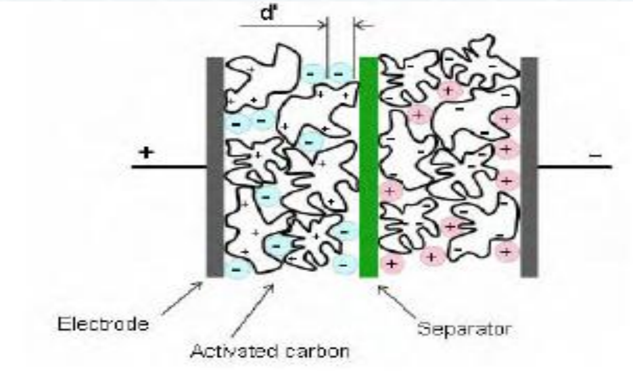
	POWER (W)
HALF SIDE	197 W
TOTAL FTD	**395 W**



FTD6

4 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
- Super-capacitors are electrochemical capacitors with very high capacitance (x1000) – Most common EDL
- Most of the material of the capacitor is carbon
- Main characteristics
  - It operates at low voltage – Vmax = 2.7 V
  - Large number of cycles & High efficiency (Low ESR))
  - Temperature range - 35ºC up to 65 ºC



4 Super-capacitors

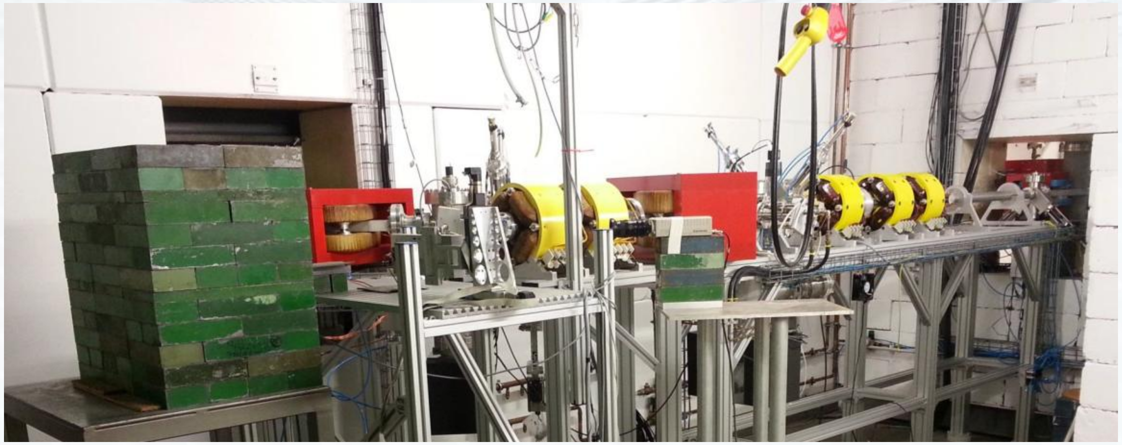
- There are two elements that have to be analyzed in detail for HEP applications
  - Cycling issues
  - Radiation issues
- Cycling issues (Reliability).
  - Super-capacitor should be able to operate more that 10 million of cycles per year (DC-DC too)
- Radiation issues
  - Type of radiation:
    - Gammas & electrons
  - Total dose:
    - 1 or 2 Mrad.

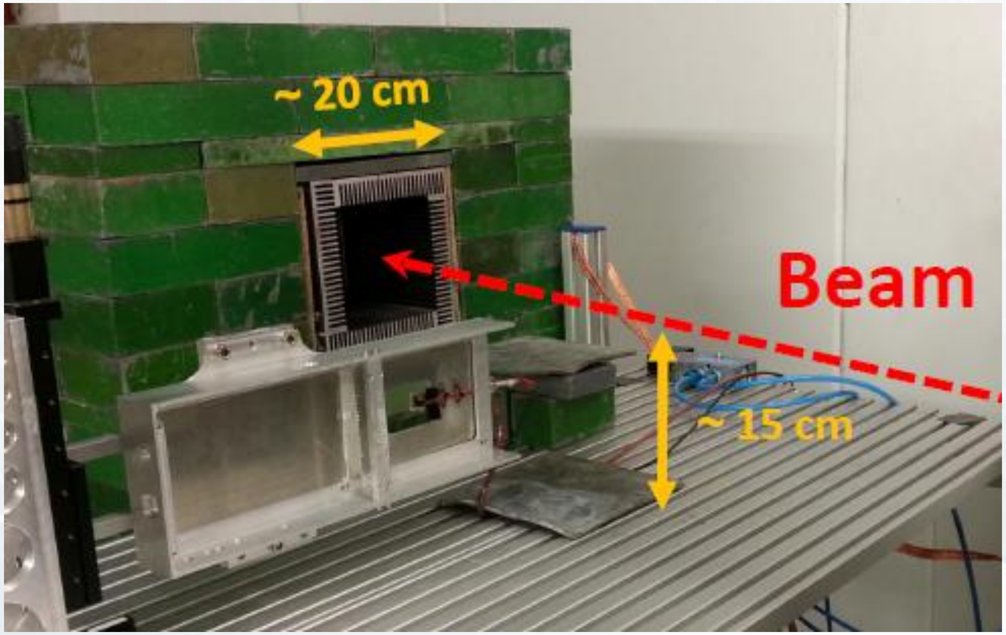
4.1 Radiation test for Super-capacitors

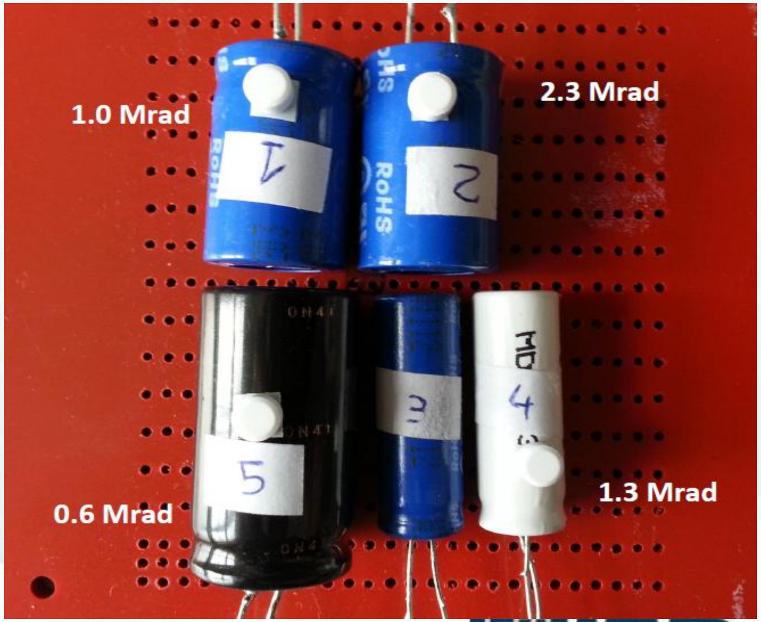
- A radiation test has been carried out in order to start the super-capacitor validation for FTD-ILD
- 5 super-capacitors have been tested – ESR(T) & C(T)
  - Different rates
    - 3 x 10 F & 2 x 25 F
  - Different companies
- They have been tested before and after radiation at 4 different current rates
- Radiation parameters:
  - Electrons at 20 MEV
  - Beam spot – 3x3 cm2
  - 4 hours of irradiation.
  - Total dose :
    - 0.6 Mrad -2.3 Mrad (3%)

4.1 Radiation test for Super-capacitors

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





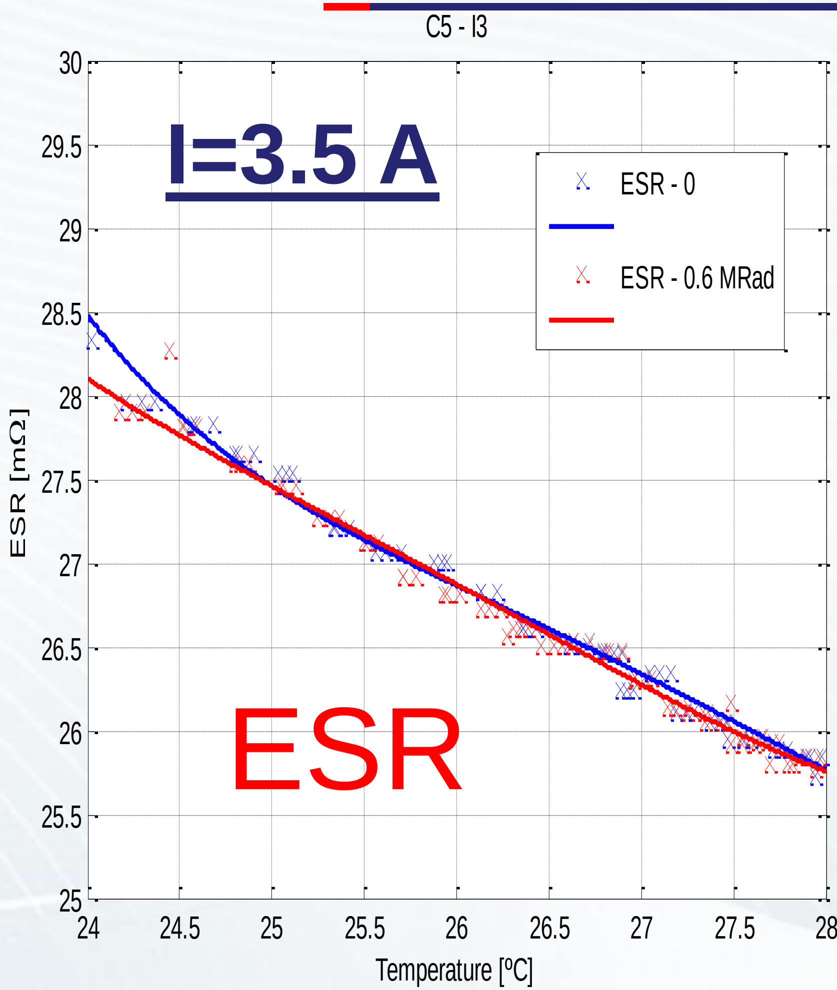


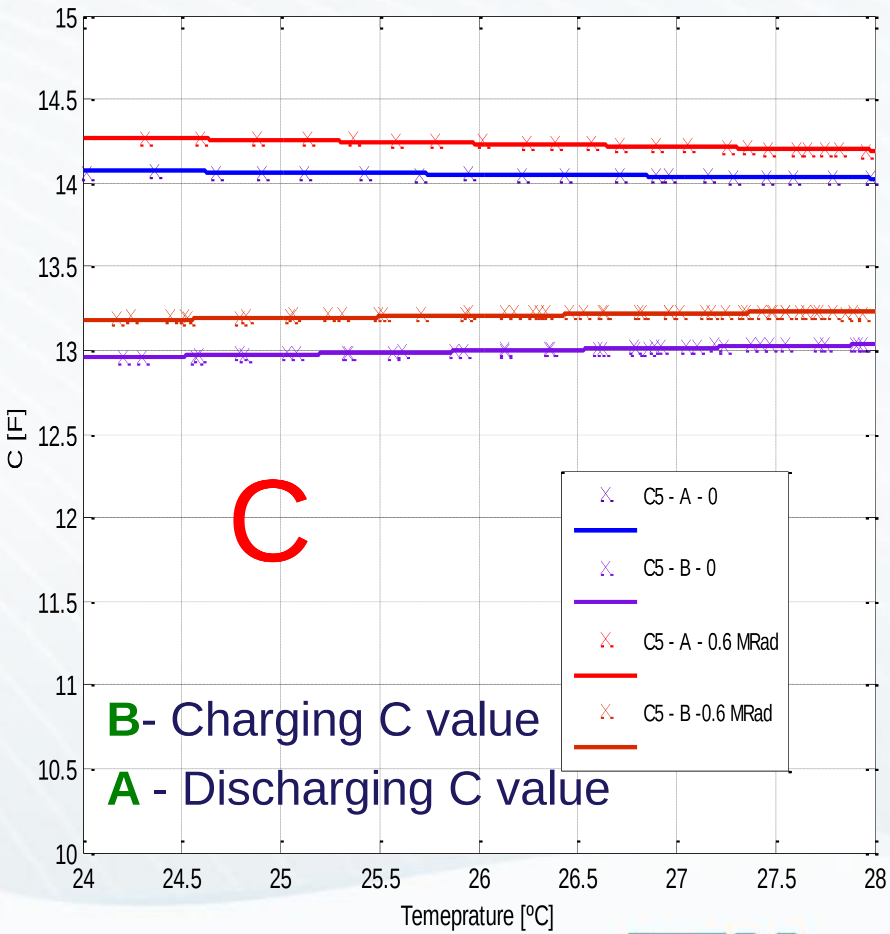
4.1 Radiation test for Super-capacitors

C = 10 F – Panasonic - 0.6 Mrad

Blue – Before radiation / Red – After radiation

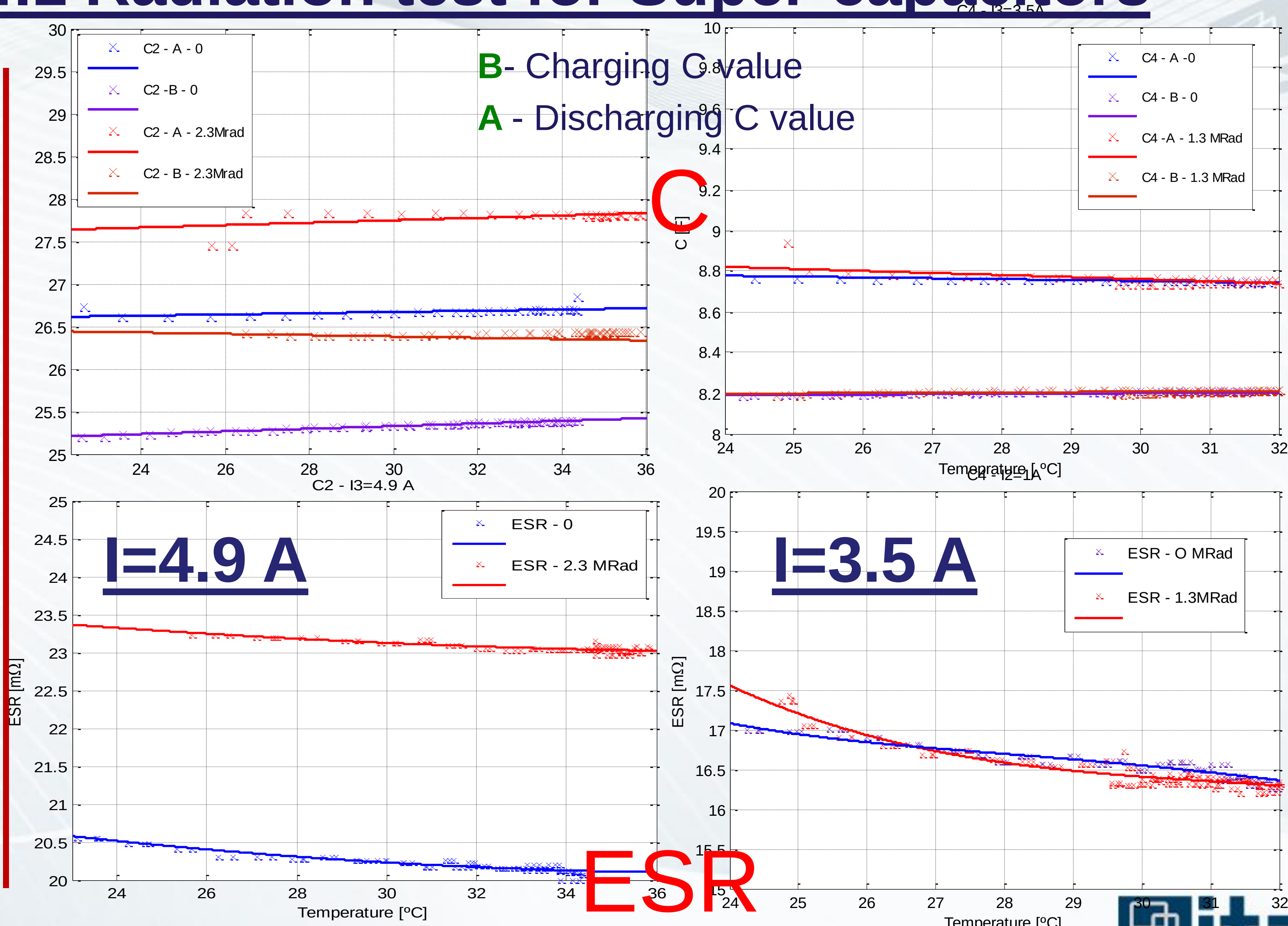
X Measured values / - Fitted values





4.1 Radiation test for Super-capacitors

C = 25 F – Maxwell- 2.3 MRad



C = 10 F – Nesscap- 1.3 MRad

5. Conclusions

- A general overview of the two power supply distribution system for FTD has been presented
  - Each of them has some advantages and disadvantages

	DC-DC	Super-caps
Power dissipation	228 W	395 W
EMI phenomena	Yes	No*
RAD tolerant	Yes	**? (First test OK)**
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