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ITAINNOVA
INSTITUTO TECNOLÓGICO DE ARAGÓN

Hybrid power supply distribution system for high current detectors

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OUTLINE

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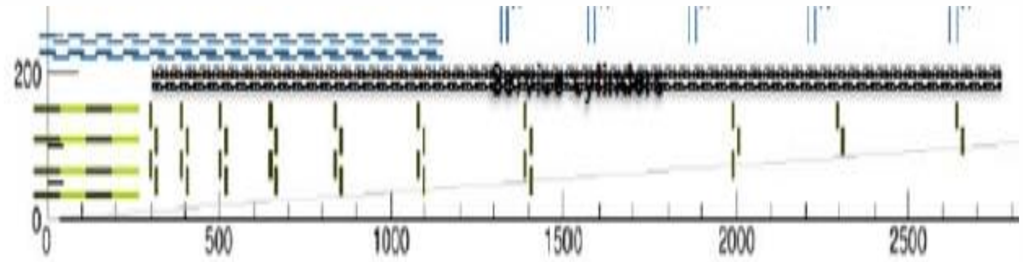
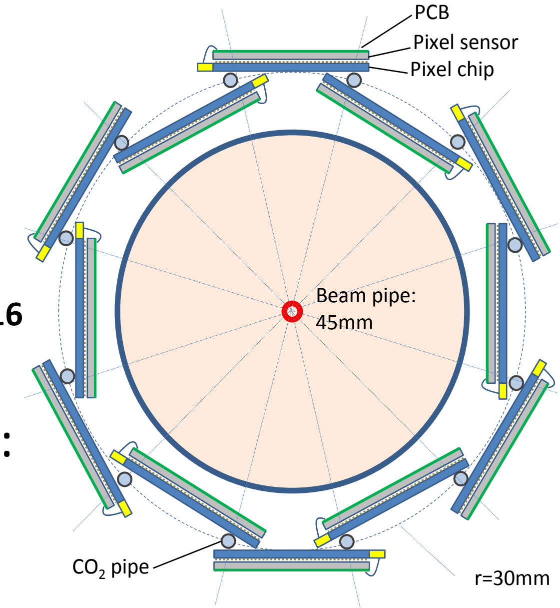
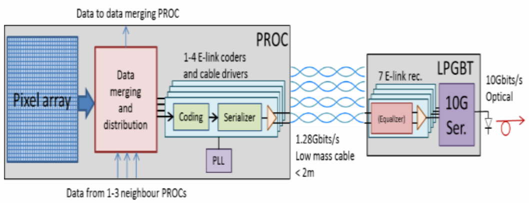
- 2. Power consumption
  - Topologies
- 3. Hybrid topology
  - Power requirements
  - Material budget
  - DC-DC
  - EMC
- 4. Conclusions

1. Introduction

- CMS pixel phase II
  - 4 barrel layers
  - 10 disks end-caps
- Two modules layout
  - 4 or 8 chips per module
- Pixel modules:
  - L1: **~10MGy (1Grad), ~10^{16} Neu/cm^2**
  - L2: ¼, L3: 1/8, L4: 1/16, ID: 1/5, OD: 1/10
- Services (r= ~16cm): **~100Mrad, ~10^{15} Neu/cm^2**

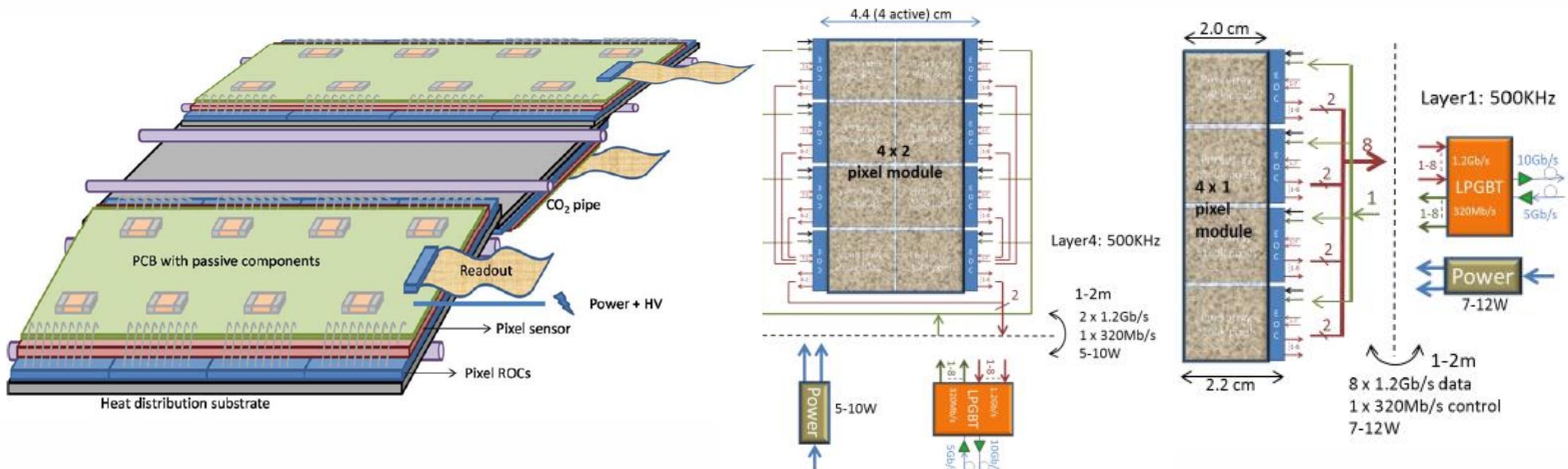






2. Power consumption

- New chip technology will force to design and develop a complex power supply distribution system for pixel phase II
  - Huge power / high current demanded by each power channel due to chip technology (250 nm → 65 nm)



* Based on Jorgen´s Christiansen doc.

2. Power consumption

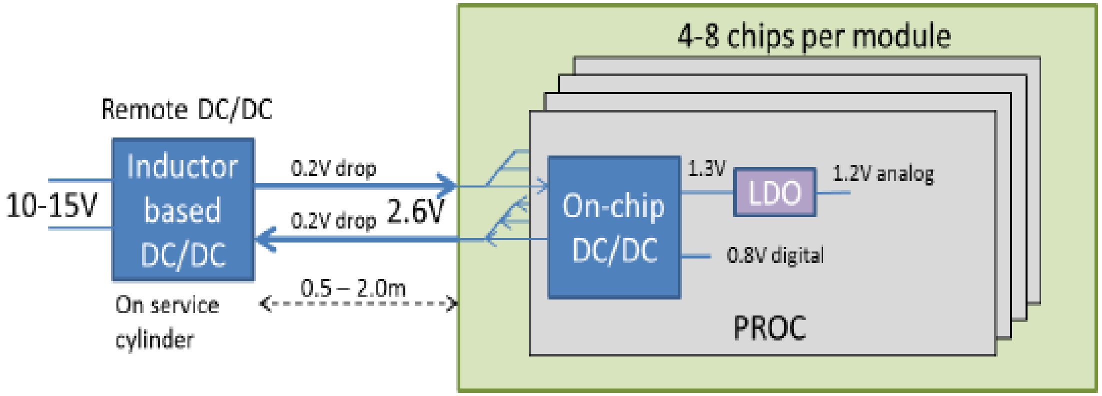
- Pixel electronics will operate at
  - 1.2V Analogue part
  - 0.8V Digital part
- The estimated current consumption per pixel chip
  - High rate regions
    - Analogue : 0.96A – 0.64A
    - Digital : 2.5A – 1.25A
  - Medium rate regions
    - Analogue : 0.96A – 0.64A
    - Digital : 1.25A – 0.6A
  - Low rate regions
    - Analogue : 0.4A – 0.24A
    - Digital : 1A – 0.5A

2. Power consumption

- New Pixel needs - **16 kW – 9 kW at 1.1V – 15 kA – 8kA**
- Power aspects and limitation:
  - Low mass & noise
  - Power dissipation aspects
  - Reliable systems (high granularity)
- Design aspects :
  - EMC/Grounding
  - Safety/protection aspects (HV and LV lines)
  - Power cabling & services (noise coupling & mass)
- Actually several options are under discussion:
  - DC-DC based power distribution
  - Serial powering
  - Hybrid powering

2.1 Power consumption: Topologies

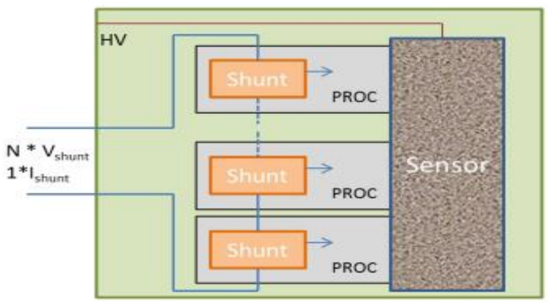
- DC-DC based power distribution (conversion limitation)
  - 2 Power conversion stages
    - On chip – stage 1 (2/3 ratio)
    - At 0.5 or 2 m distance - Stage 2 (4/6 ratio)

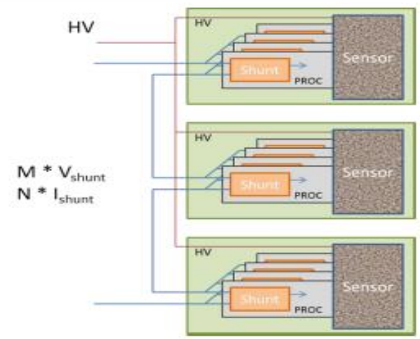


* Based on Jorgen´s Christiansen doc.

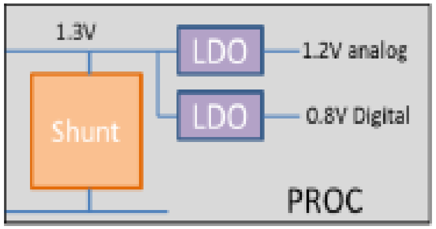
2.1 Power consumption: Topologies

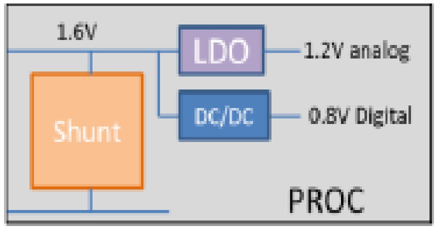
- Serial power distribution (big floating structures / shunt regulators)
  - Several options
    - In module (4/8 chips series) / Across module (8 modules series)

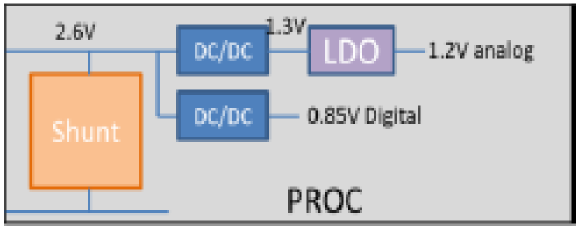




    - Finally voltage stage



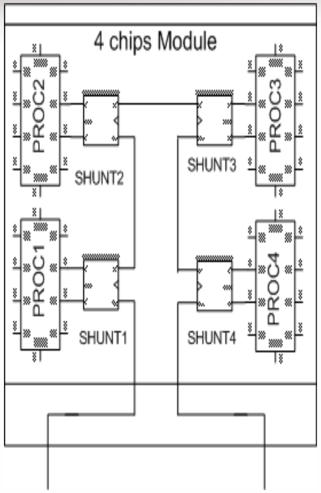


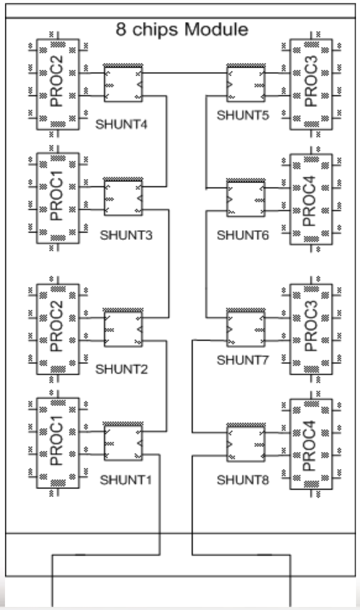


* Based on Jorgen´s Christiansen doc.

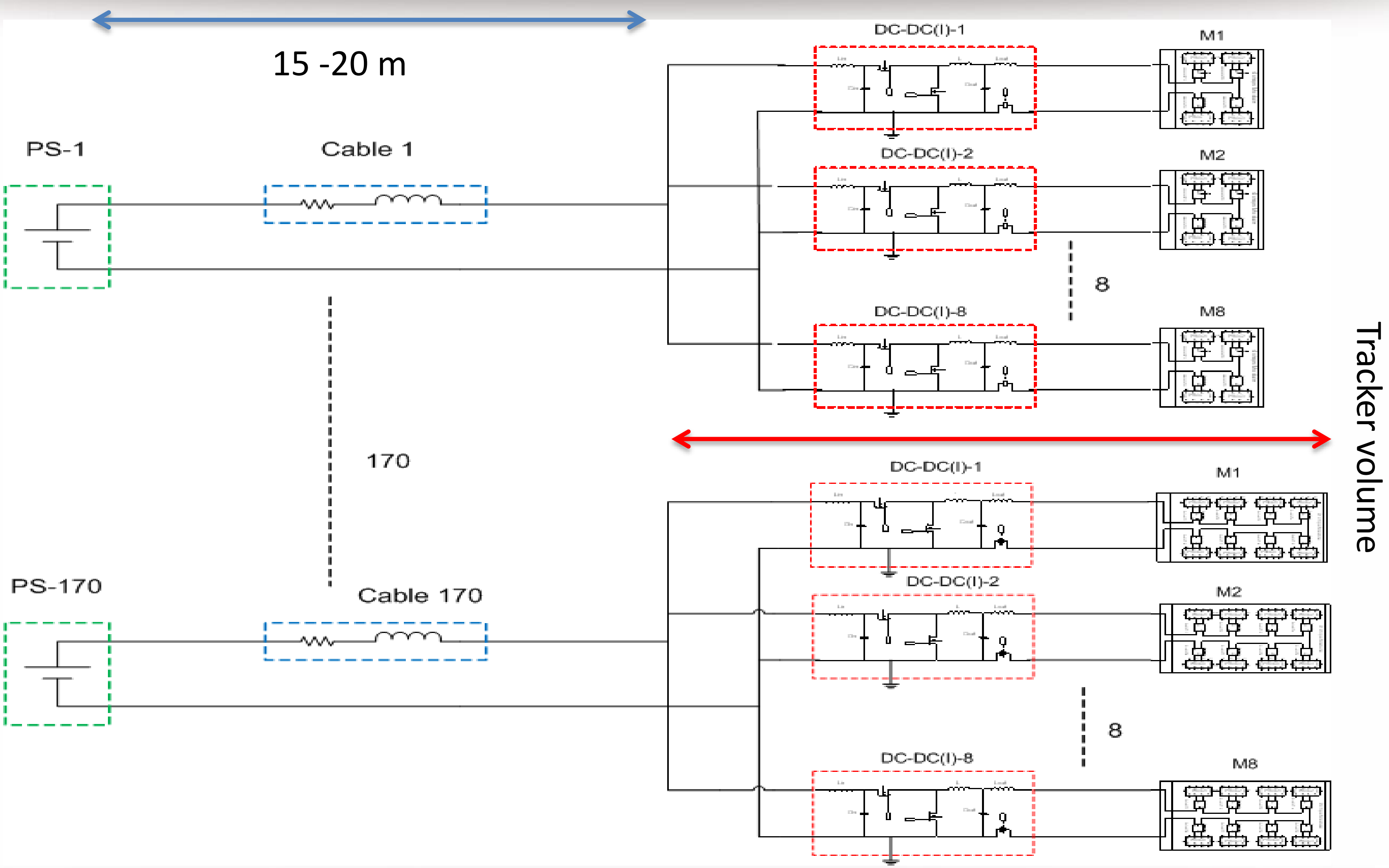
3. Hybrid topology

- Hybrid topologies are based on Serial & DC-DC
  - Common to serial (70%) and DC-DC option (30%)
- Serial connection at module level
  - 4 PROC & 8 PROC in serial (Adv & Disadv.)
  - 1356 modules
- One current-controlled DC-DC converter per module is located at service cylinder,
  - Grouping (1 power group per 8 modules)
  - Decouples the system – inside / outside
- Primary power units (standard one):
  - 170 units & power cable.





3. Hybrid topology



3. Hybrid topology: Power requirements

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- The power requirements are very similar to the in-module serial powering.

Pixel power = 15.8 / 8.8 kW

Power	Serial* (in –Mod)		Hybrid		Serial * (Across Mod)		DC-DC *	
	Cons.	Opt.	Cons.	Opt.	Cons.	Opt.	Cons	Opt
On chip LDO /DC-DC (kW)	6.1	3.1	6.1	3.1	5.9	3.0	2.4	1.4
Excessive power shunt (kW)	2.19	1.18	2.19	1.18	**2.1 ?**	**1.15 ?**	-	-
Mod Power (kW)	24.1	13.1	24.1	13.1	23.8	12,95	18.2	10.2
Cables Power	1.1	0.6	1.1	0.6	0.9	0.5		
Total (kW)	25.1	13.7	25.1	13.7	24.7	13.5	21	11.8
DC-DC (kW)	-	-	2.5	1.3	-	-	2.8	1.4

* Based on Jorgen´s doc.

3. Hybrid topology: Material Budget

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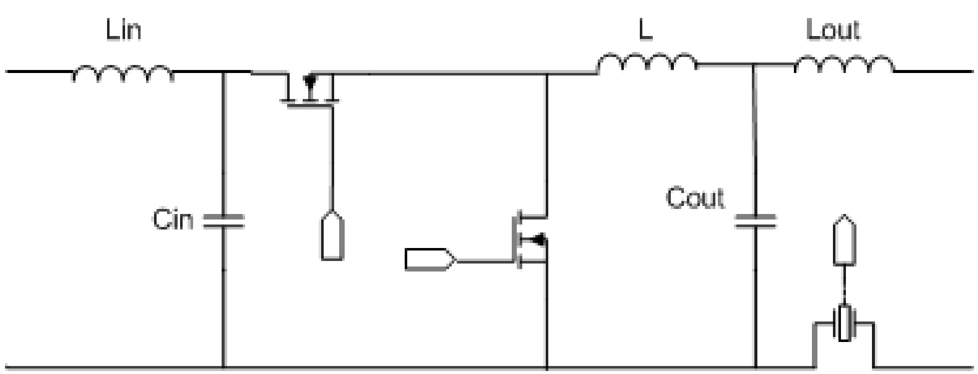
- Material budget & Volume

Power	Serial (in –Mod)		Hybrid		Serial (Across Mod)		DC-DC	
	Cons.	Opt.	Cons.	Opt.	Cons.	Opt.	Cons	Opt
Power cabling mass	2.08	1.14	2.08	1.14	1.79	0.97	5.33	2.99
DC-DC - Kg (number)	-	-	1.4 (1356)	1.4 (1356)	-	-	2.8 (2800)	1.4 (1356)
Cables outside (num)	1356	1356	170	170	168	168	334	170
Loop current (Avg)	2737 (2)	1491 (1.09)	1937 (11)	1052 (6)	2289 (13)	1244 (7.5)	1605** (4,8)	872** (5,1)
Cable section* (mm2)	87923	86283	13090	11925	13429	12054	22821	11688

- * Outside service cylinder – Based Tracker TIB cable Novacavi (10 A – 11mm external diameter)
  - Isolation, shield thickness, HV and sense are dominant (copper only 30% of section)
- Goups of 8 DC-DC

3. Hybrid topology: DC-DC

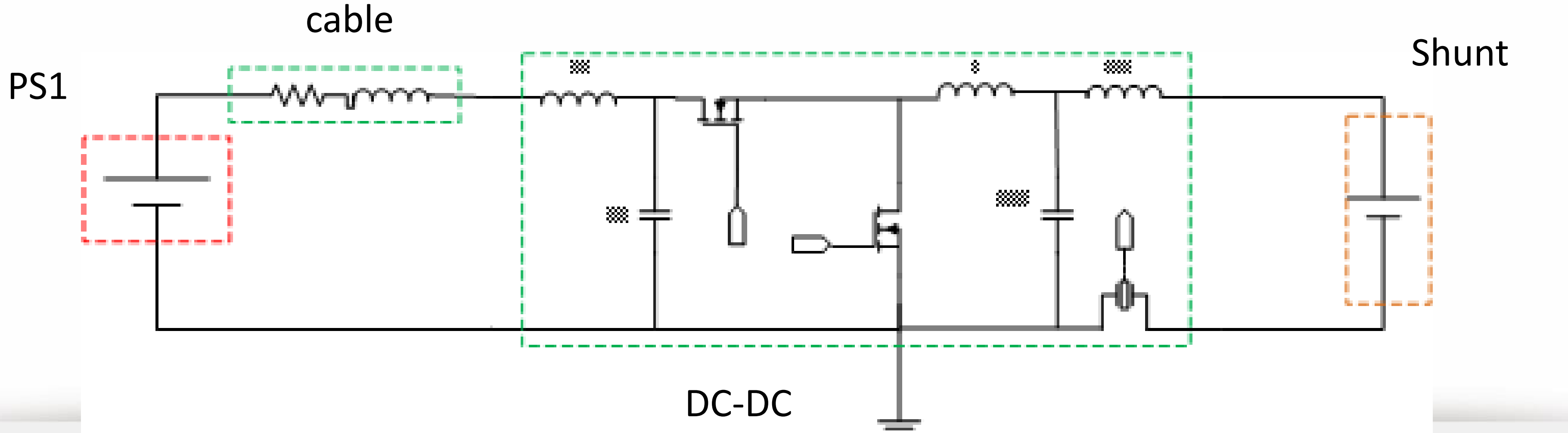
- The DC-DC converters will be placed on service cylinder (space / length required – 2 x 0.5 m*)
  - DC-DC Buck converter current controlled
- The main goals of the DC-DC are:
  - To create power groups (decouple the system in two parts)
  - To ground the system
  - It may help to decrease the amount of noise from outside.
  - Of course it will help to decrease currents



*Based on Jorgen doc – fill factor 0.8

3. Hybrid topology: DC-DC

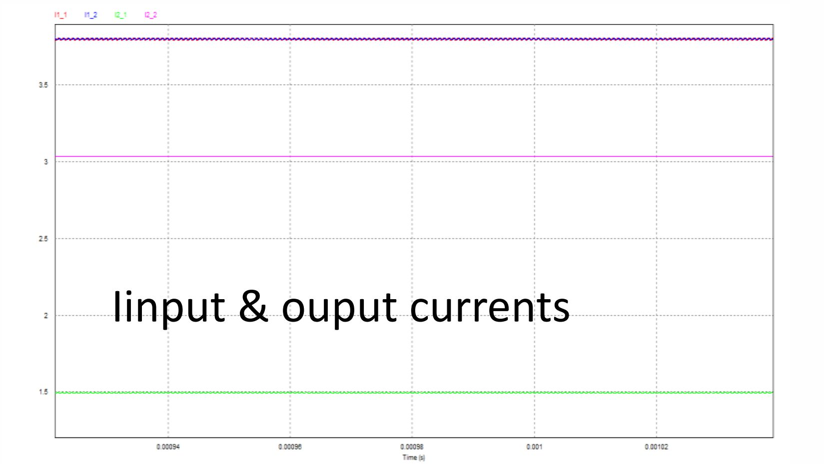
- In order to analyze the requirements of the DC-DC converter, a simulation has been performed.
  - Lin = Lout= 60nH
  - L= 600nH
  - Cin=Cout= 47 uF
  - Fsw = 1.4 MHz.
  - VFEE = (1.3 x4 / 1.3 x 8) / IPROC = 3.8 A

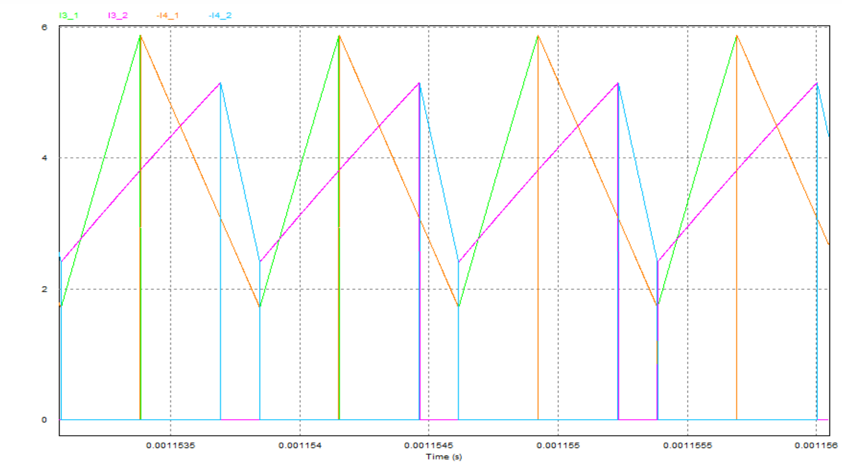


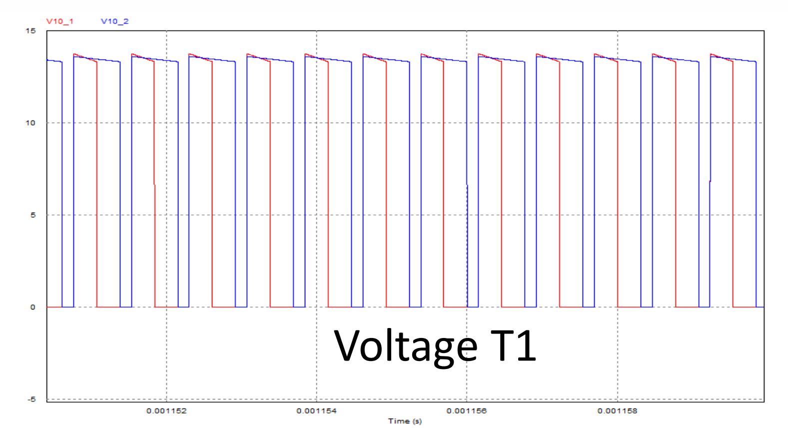
3. Hybrid topology: DC-DC

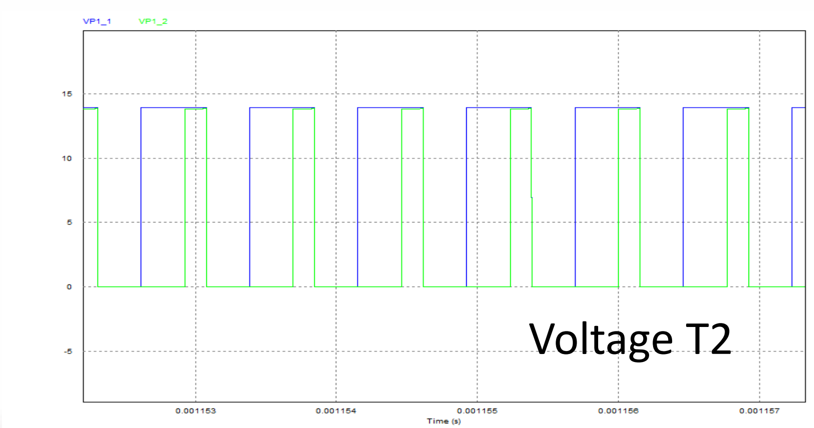
- Two cases have been studied (4 PROC / 8 PROC).
  - V=5.4V & V=10.8V

Transistors currents









3. Hybrid topology: DC-DC

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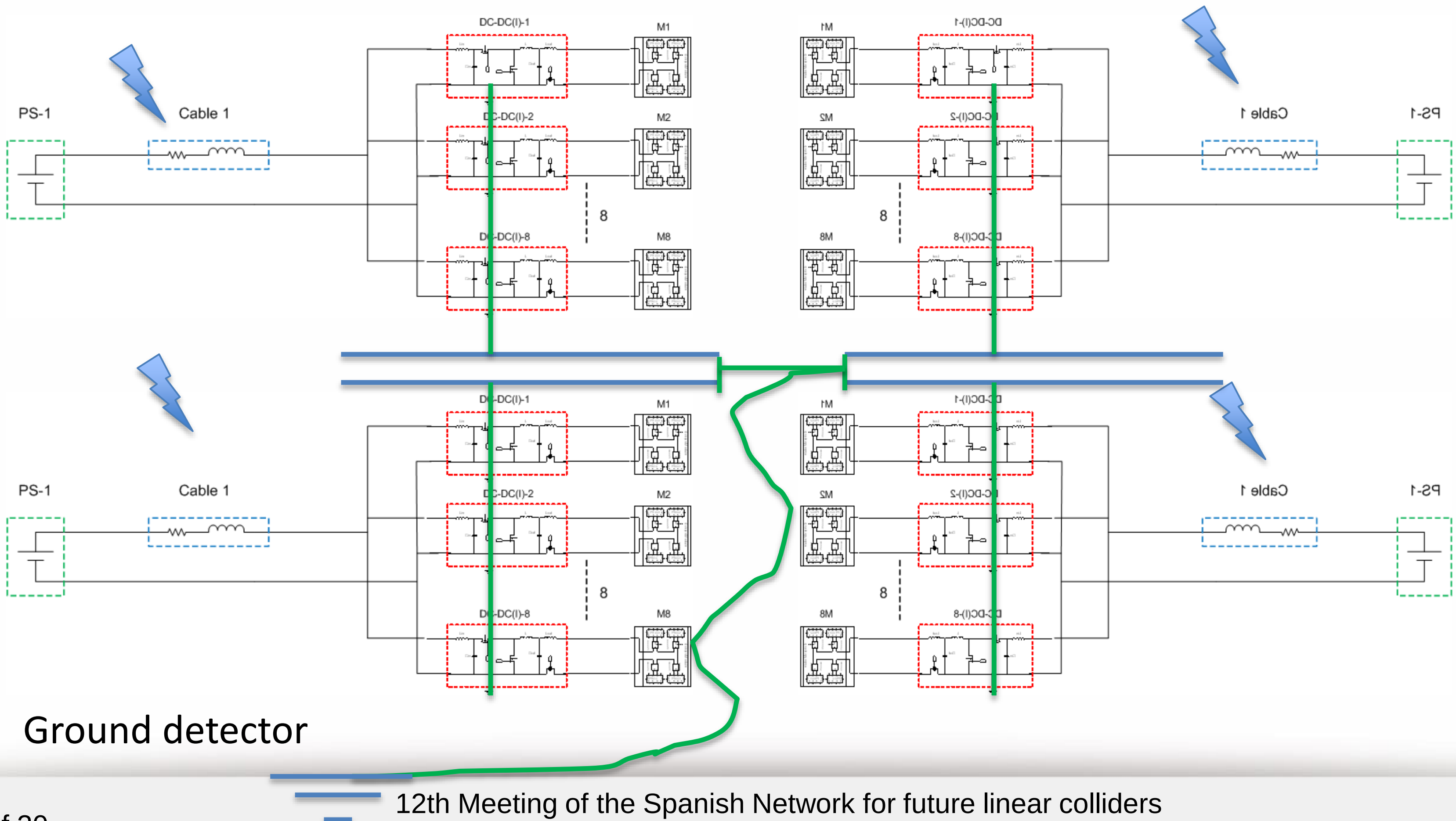
- The DC-DC voltage is kept bellow 15V.
  - 4 PROC – 5.4V & 8 PROC – 10.8 V
- The power requirements of DC-DC converter

	Power (W)		Current (A)	
	Conserv.	Optim.	Conserv.	Optim.
L1	21,3	11,6	3,8	2,0
L2	26,2	14,7	2,4	1,3
L3	26,2	14,7	2,4	1,3
L4	16,6	8,8	1,5	0,8
Inner disks	13,6	7,6	2,4	1,3
Outer disks	16,6	8,8	1,5	0,8

- Radiation levels
  - Services (r= ~16cm): ~100Mrad, ~10^15 Neu/cm2

3. Hybrid topology: EMC

- Hybrid topology can be grounded in a similar way to any HEP detector



3. Hybrid topology: EMC

- Each module may be grounded at service cylinder (locally)
  - Typical grounding topology in HEP
- All modules equally grounded
- A high frequency ground may be designed per module.
  - Small structure (Design per module – it can be tested)
- Noise coming from outside may be filtered
- It can keep the noise generated by pixel system inside tracker volume.
- Mid-scale prototype may be easily tested inside a laboratory
  - It is very simple to scale in order to estimate performance of the system at bigger scale.

3. Hybrid topology: EMC

- Hybrid topology – EMC aspects

	Serial (in Mod)	Hybrid	Serial (Across Mod)	DC-DC
Grounding	Extra connection (local all mod, 3 or 7 requires HF ground)	Local all modules (3 or 7 only requires HF ground)	Only 1 module per group (8xn requires HF ground)	Local all modules (all chips ground)
External noise Filtering	Complex	OK (all frequencies)	Complex	Local all modules
FEE noise injection	Yes	Filtered	Yes	Filtered
DC-DC Noise emissions	No	Yes	No	Yes
External Transients	Remotely	Local	Remotely	Local

4. Conclusions

- Several options to power high current detector have been presented
- The talk has been focused on hybrid power topology
  - It is not very different from other options
    - Similar technology (FEE need to adapted)
  - It has some advantages and some disadvantages
    - It helps to decrease the current and transients levels (local)
    - Special attention should be paid to grounding topology
  - No technical limitation due to radiation (ILC)