L'R&D per il Power System

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Presentazione alla Sezione delle attività di Upgrade di CMS per HL-LHC
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IT and OT power systems

- Overall more than 3 times the power delivered to the present TRK
  - order of 50 kW to IT
  - around 100 kW to OT
  - Keeping the actual cable channels
- Quite different powering schemes:
  - IT: serial powering
  - OT: parallel powering using DC/DC converters on detector, with high multiplicity of channels
- Synergies b/w the systems ?
  - desirable (ease of operations and maintenance)
  - same order of power required per group
  - Both system requiring some LV/HV interplay

Perché di nuovo i power supplies ?

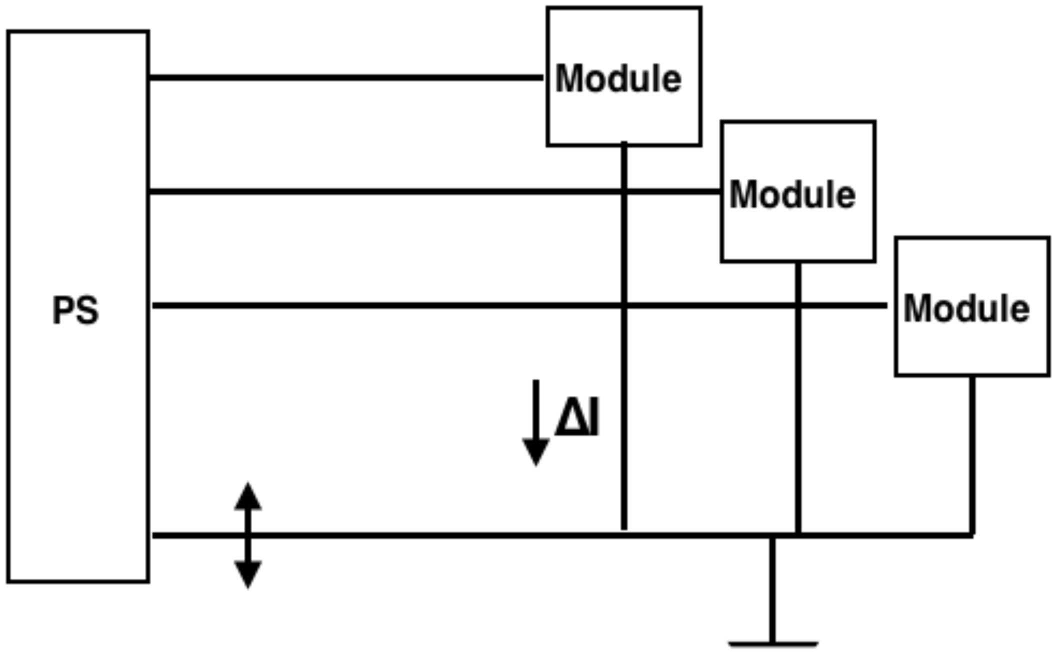
- Richiesta da parte dell’esperimento
  - Firenze ha mantenuto in questi anni un ruolo di riferimento per il sistema di alimentazione
- concomitanza di progetti regionali con CAEN

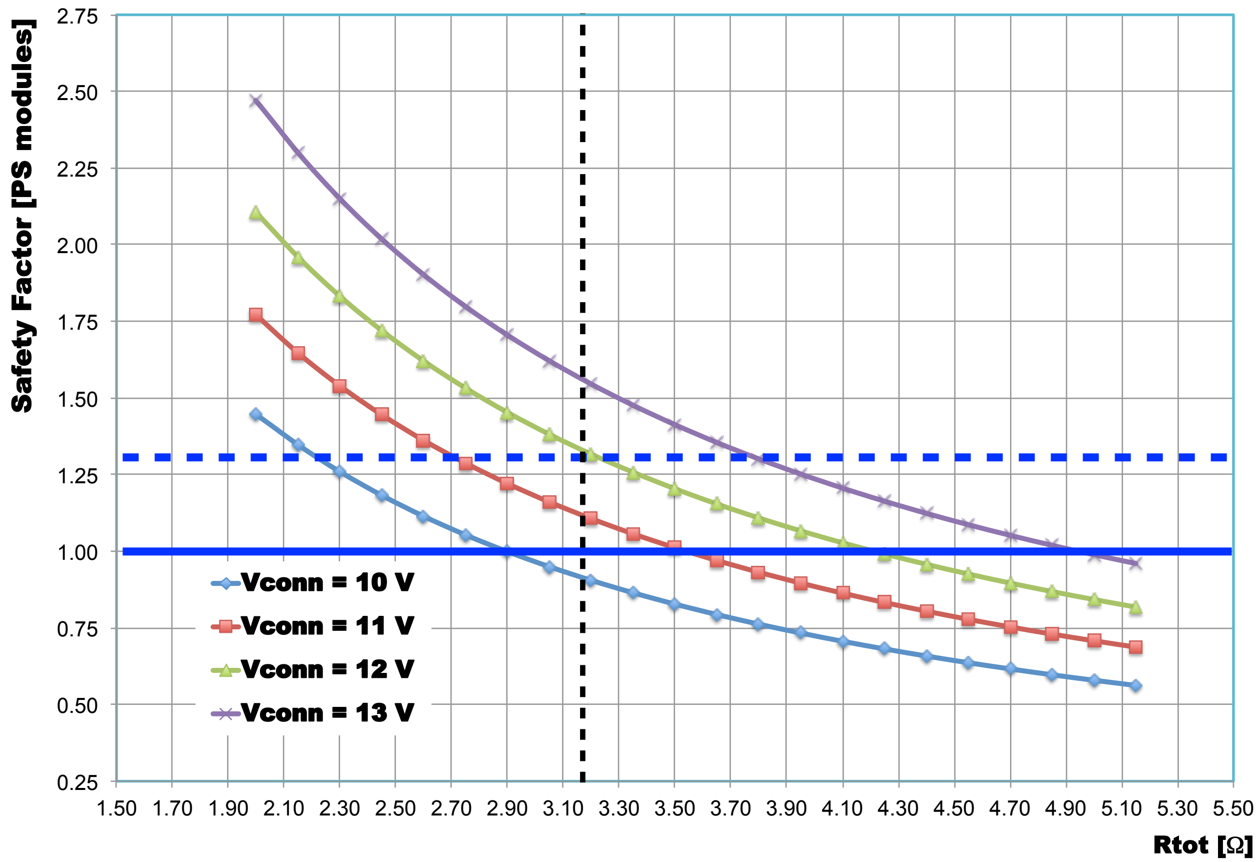
Sviluppi specifici: OT

- studio dello schema di alimentazione con DC/DC converters sul carico

- ottimizzazione del cavo di alimentazione: resistenza sulla linea è critica

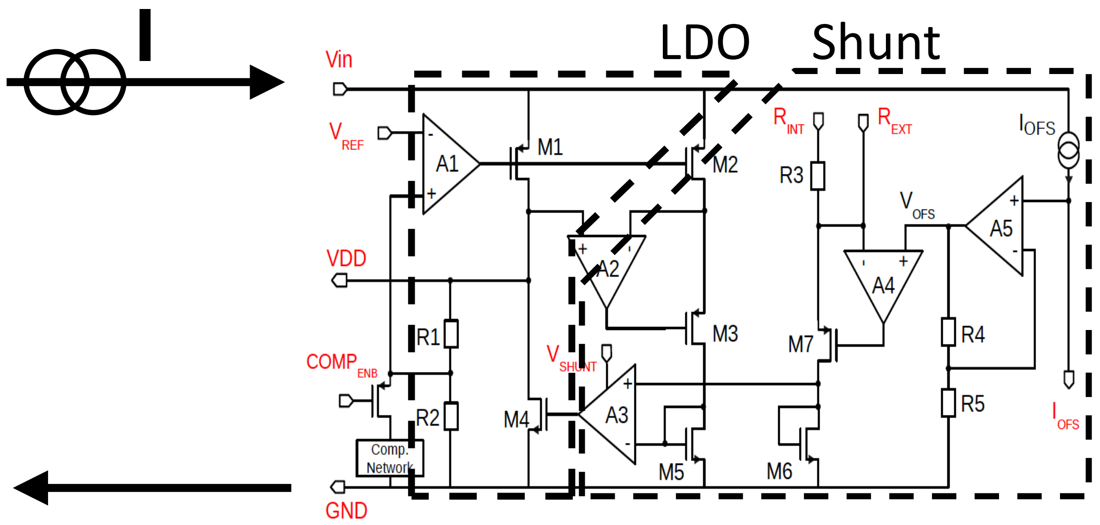
- grande quantità di canali da gestire → sviluppo di un nuovo sistema di comunicazione → interazione DCS/DAQ





Sviluppi specifici: IT

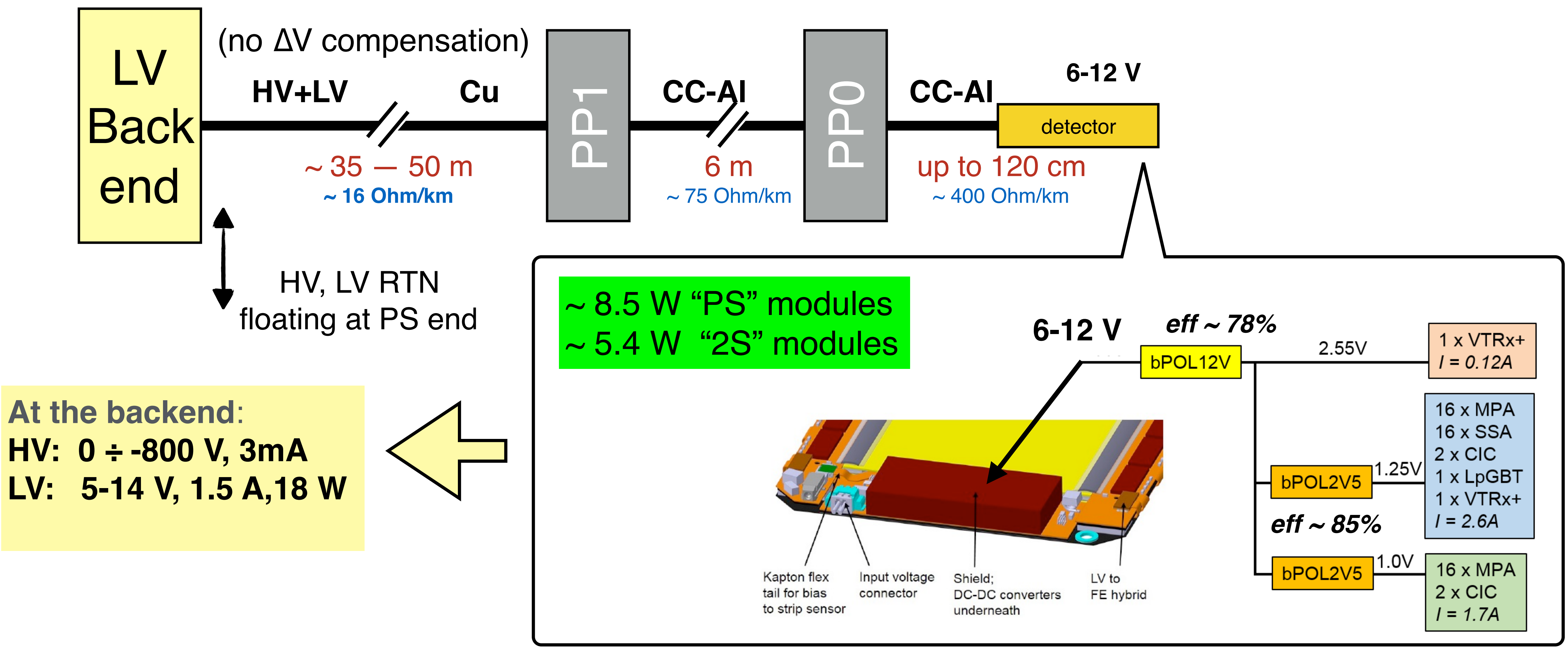
- Sistema seriale (alimentato in corrente) completamente da capire:
  - ✓sicurezze richieste
  - ✓procedure di accensione
  - ✓dinamica dei transienti
  - ✓grounding, distribuzione HV ….



Outer Tracker

The CMS OT Power

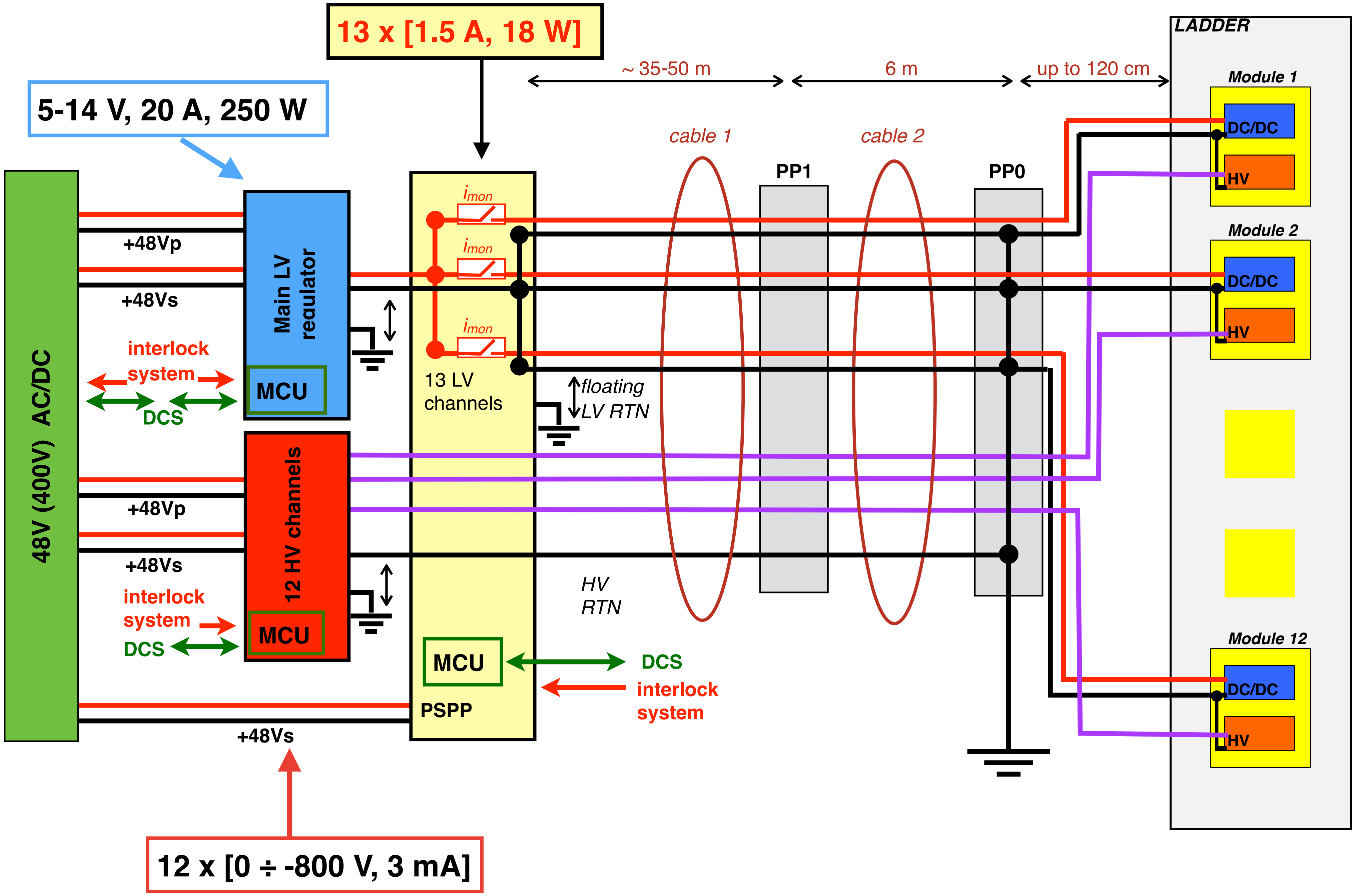
- **13296** modules (types: “PS” and “2S”) - individually operated **—> High number of channels**
- Common ground on detector side → RETURN (RTN) line floating at Power Supply end
  - specific isolation requirements (DC and in frequency) b/w HV, LV RTN lines and local ground/earth
- No Vdrop compensation: **—> Limited cable length**
  - order of 12V at Power Supply connector, 6-12 V at detector end.
- “Wired” safety to protect the detector’s FE: **—> HV and LV linked operation**
  - HV OFF when LV OFF on the same module



Power Units

Total of 1224 power cables connecting the OT to the power backend

- 12 HV lines per cable
- 13 LV pairs per cable (serving detector structures with up to 12 modules)
- LV provided by one regulator and distributed up to 13 LV channels
- HV provided by 12 regulators



System Constraints

- The **bpol12V** max input voltage sets the voltage limit at the PS connector
  - **assuming 12V as reference value**
- no option to implement voltage drop recovery:
  - fast sensing not compatible with the on-module DC/DC converters
  - lack of a “star” configuration at the detector’s side

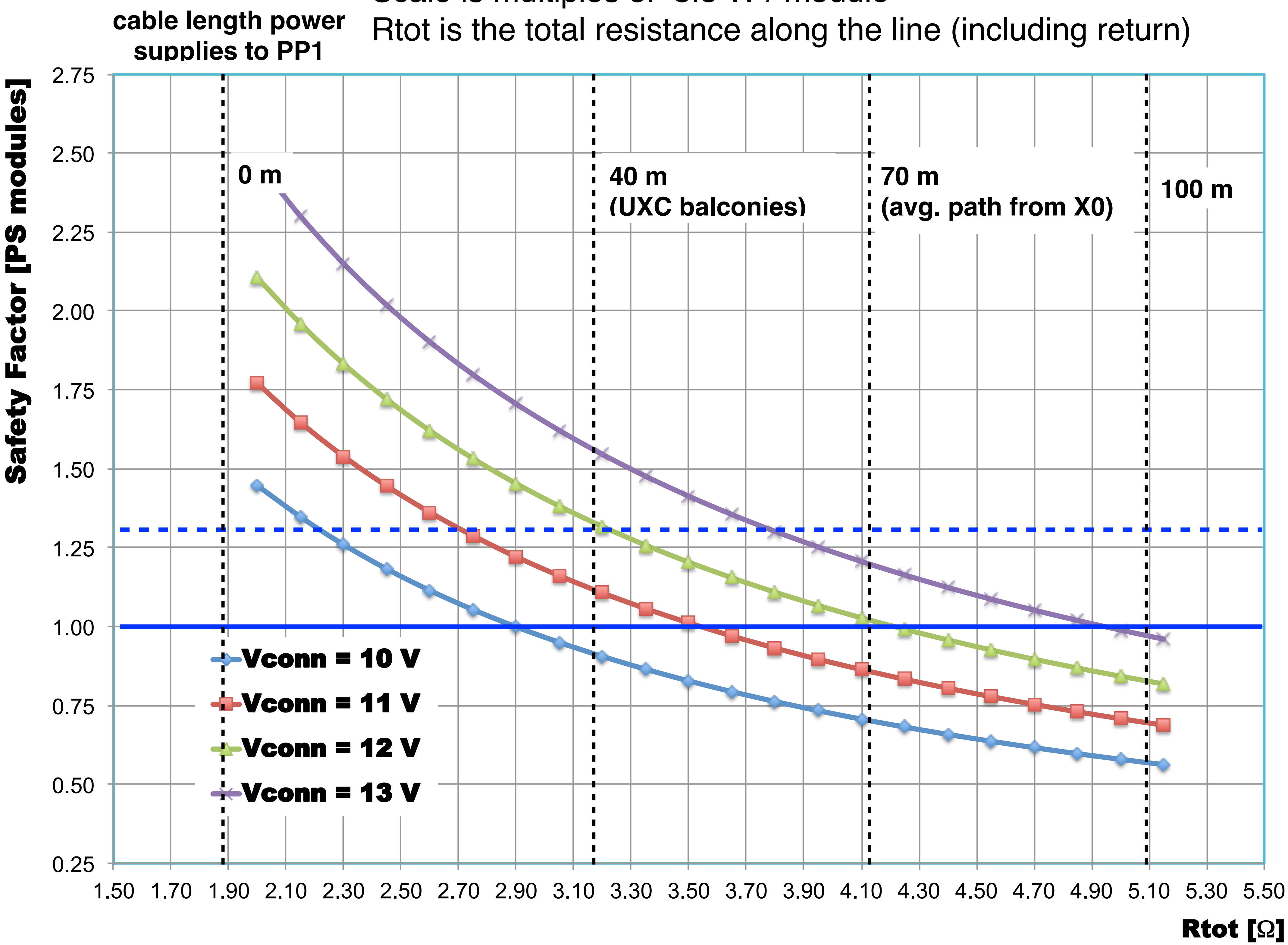
- The maximum power which can be delivered to the detector modules is limited by the line resistance:
  - cable cross section limited by space in the cable channels
    - ✓ **Cable length is a discriminating factor**

LV backend system to be located on balconies in UXC

- LV cables length ~40m → limits the voltage drop
- B ~ 25-50 mT
- order 1-10 Gy radiation and 1-10E9/cm2 HEH(20MeV) in 10y HL-LHC

Cable resistance and maximum power

Maximum power that the system can provide to each module.
Scale is multiples of 8.5 W / module
Rtot is the total resistance along the line (including return)



System dimension

	Groups	LV power/ group	48 V power per crate	crates	n AC/DC	n racks UXC
56U racks with: 5 crates + 3 AC/DC	1224	250 W	2 kW	204	102	**41**

40 m cable @ 12V Vout

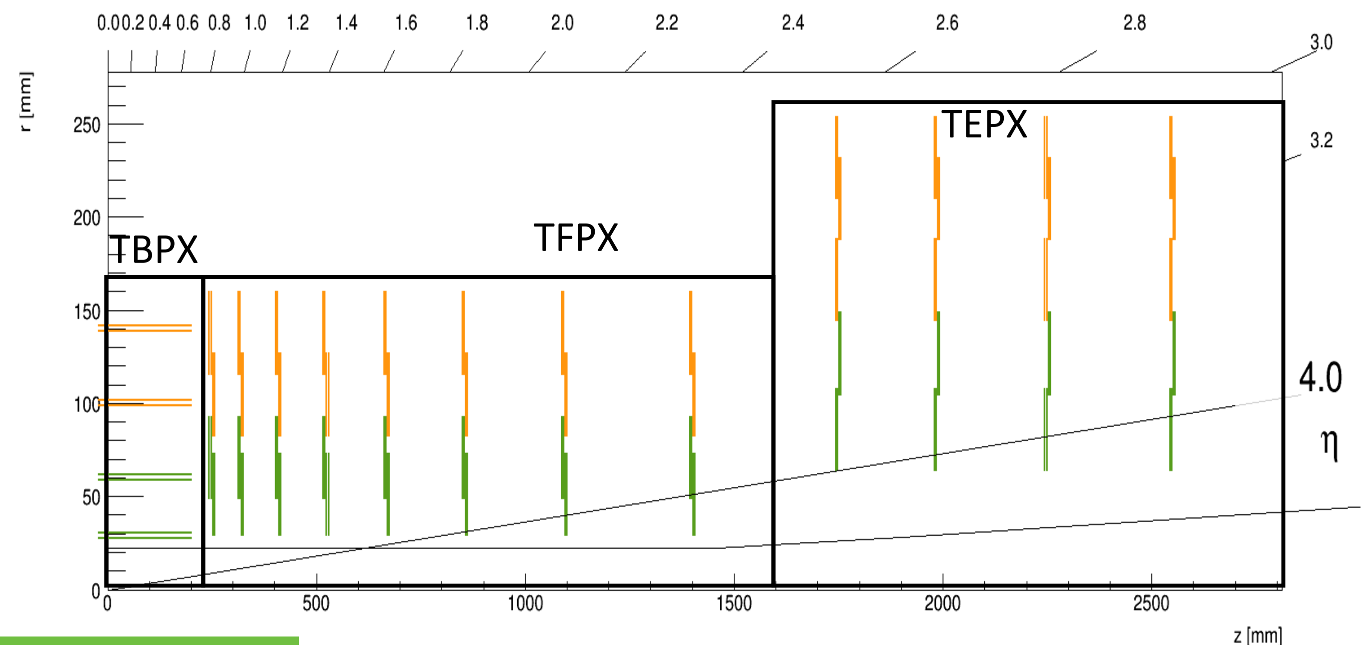
	PSU POWER OUT [W]	POWER DISSIPATED [%]	safety factor	TOT POWER [W]	applying 80% PSU effic. [W]	Applying 85% AC/DC eff [W]
5616 PS modules	11.37	49.80%	1.00	63854	79817	93903
7680 2S modules	6.28	44.27%	1.00	48230	60288	70927
1032 pre-heaters	11.00	100.00%		11352	14190	16694
HV power				12400	15500	18235
				135836	**169795**	**199759**

with safety factor (25%) → 300 kVA evelope

Inner Tracker

Radiation levels and space constraints prevent from using on-module DC/DC converters in the Inner Tracker:

- ➡ LV power is distributed to IT modules according to a serial powering scheme, forming **576** chains of up to 11 modules
- ➡ HV bias is distributed in parallel to modules in each serial chain
- ➡ Optoelectronic services (lpGBT and Versatile Link+) are detached from the modules and hosted on dedicated boards (“portcards”) positioned around the IT support tube and powered making use of on-board DC/DC converters, following a parallel powering scheme similar to the one used for OT modules.



~ 4.2 k modules
~ 13.2 k r/o chips

2-chip modules: TBPX L1, L2 & R1, R2 (4A chains)
4-chip modules: TBPX L3, L4 & R3, R4, R5 (8A chains)

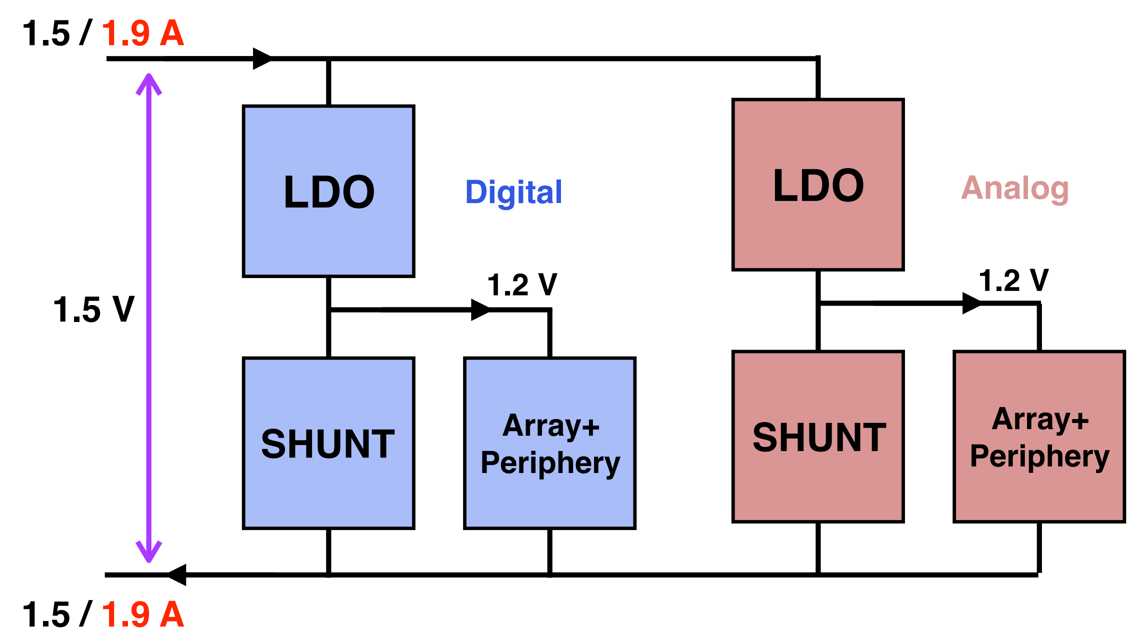
Shunt-LDOs within the r/o chip provide:

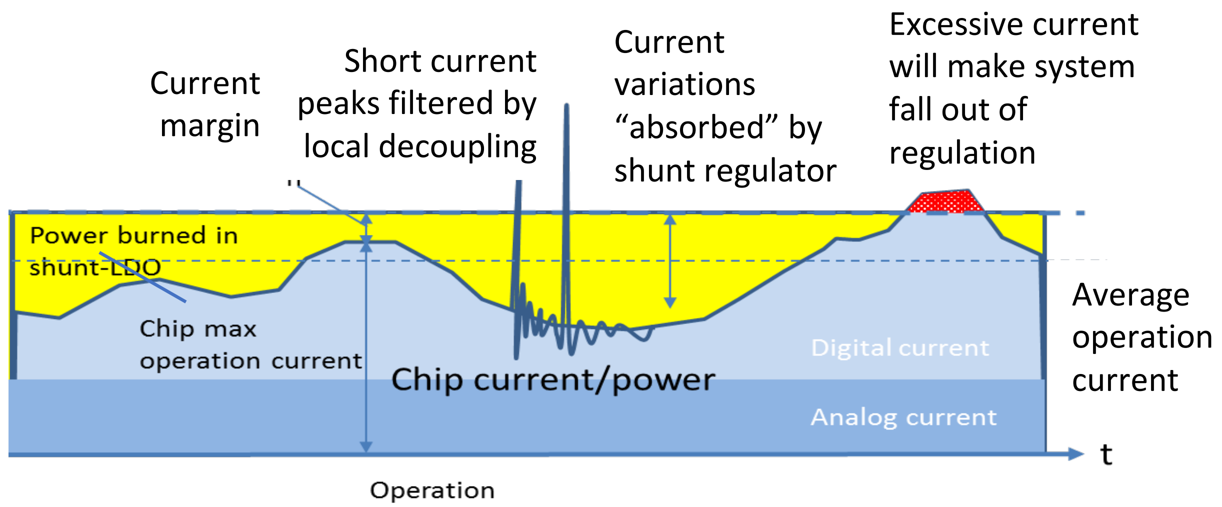
➡ shunt functionality: needed to implement the serial scheme
➡ LDO regulation: ensure correct voltage (~1.2V) to the electronics

Serial Power chains are current driven:

- the Shunt-LDO configuration defines ΔV=f(I)
- aiming at ΔV~1.5 V (1.2V + 0.3V for LDO)
- the chain has to provide enough power for transients:

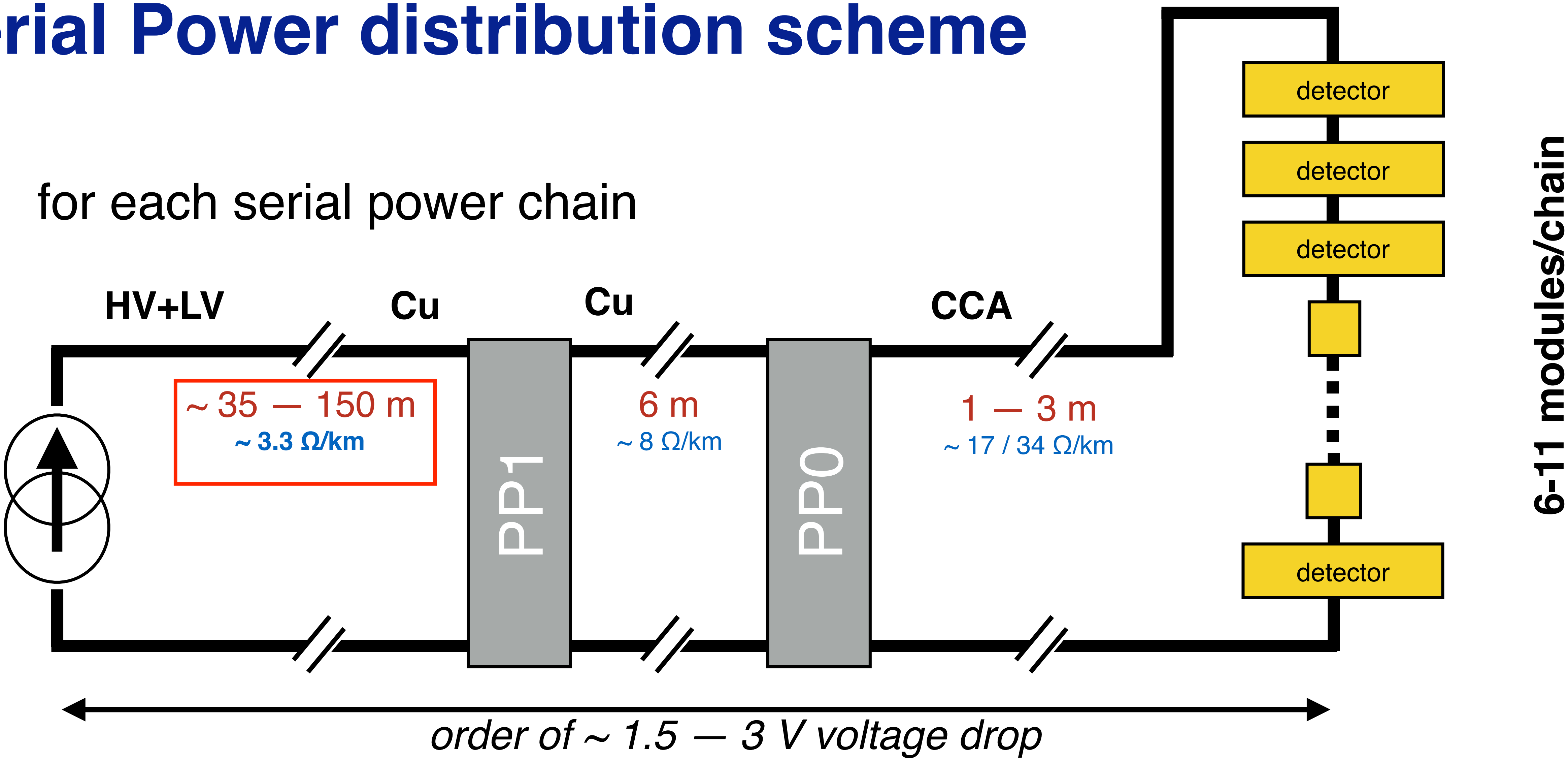
  considering ~ 25% current headroom w.r.t. "typical" conditions





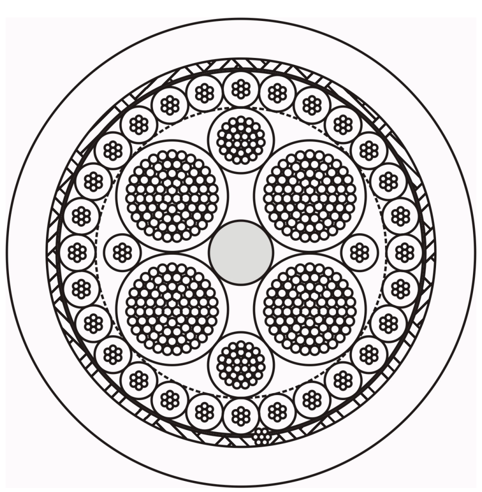
Serial Power distribution scheme

for each serial power chain

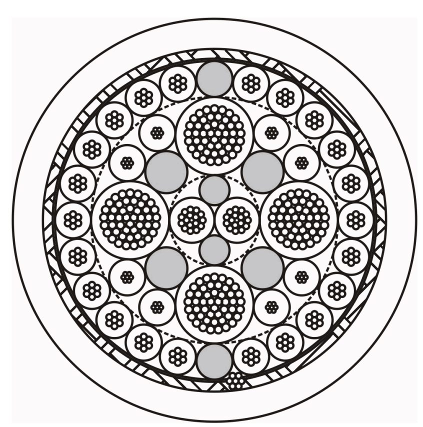


One cable → 2 power chains

Cable 1: ∅ = 15.3 mm



Cable 2: ∅ = 13.4 mm



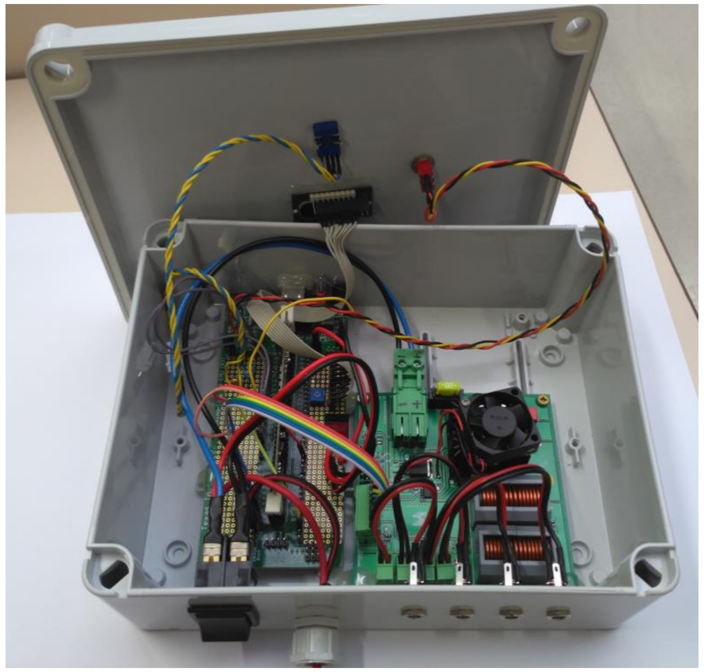
- Prototype cables available:
  - 4 LV conductors
  - 22 HV wires
  - 8 env. wires (T,H)

Serial Power current sources

- Two serial power sources were experimented in small laboratory setups:

CAEN (NEOLITE regional project)
- both current and voltage regulation
- 10.5V/2.3 A max
- “sibling” board survived > 50Gy at CHARM

ITAINNOVA current source prototype:
- 16V/16A rating (for a total of up to 8 modules)
- very configurable for serial powering tests:
  - start-up profile
  - switching freq.
  - dynamic responce, protections
- Can be used to study the dynamic behaviour at serial powering start-up



Power to r/o chips

Assuming power needed per chip is: **1.9A x 1.5V** (analog + digital)

n. r/o chips	13192
power to r/o chips	37 kW
power dissipated on cables and interconnections	18 kW
Total power	**55 kW**

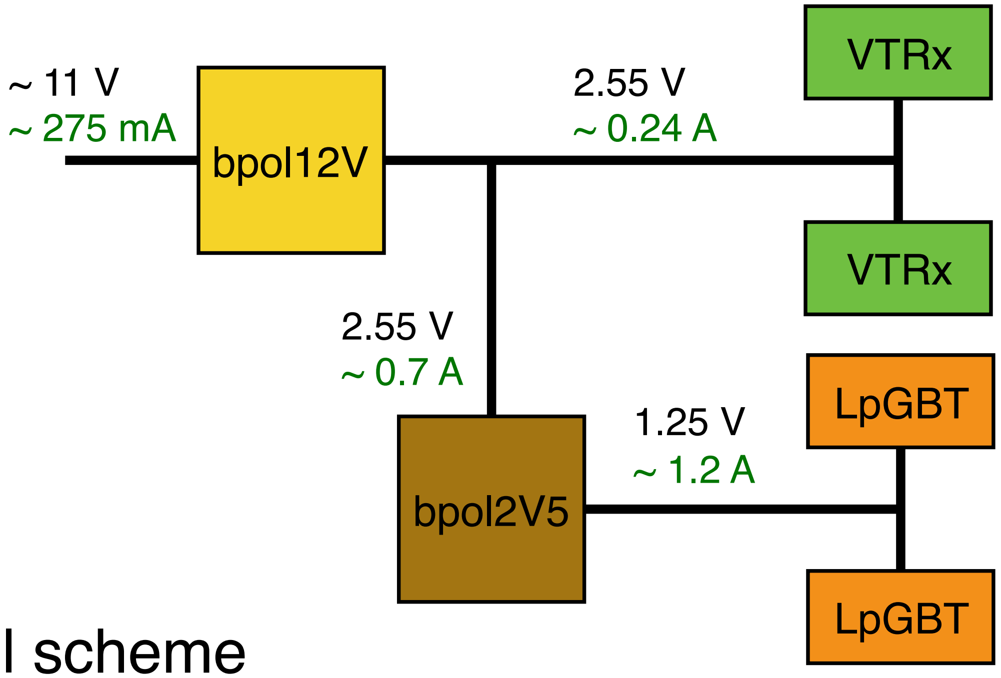
The power request details for serial powering (needed headroom, operating voltage, failure scenarios, turn ON/turn OFF procedures …) will get more defined as further tests with RD53A modules in larger chains are realised

	n. chains	n. cables	Max power/ chain
8A	312	156	180 W
4A	264	132	80 W
	576	**288**	

576 chains
292 Power Supply modules
~ 350 W per Power Supply module

Power to optical services

Optical services (LpGBT and Versatile Link+) are hosted on ~700 “port cards” distributed along the “support cylinder” (TBPX) and on the “Dee” structures (TFPX, TEPX)



Each port card is hosting:

- 2 LpGBT
- 2 VTRx
- 1 bpol11V5 DC/DC converter,
- 1 bpol2V5 DC/DC converter

Power is distributed according to a parallel scheme using the same kind of cables and power supply units of the OT. The total power required is ~2.3 kW

The same backend system powers also ~350 pre-heaters needed by the IT cooling system (tot power ~3.7 kW)

In total the backend system has to provide ~ 6kW of “parallel powering”

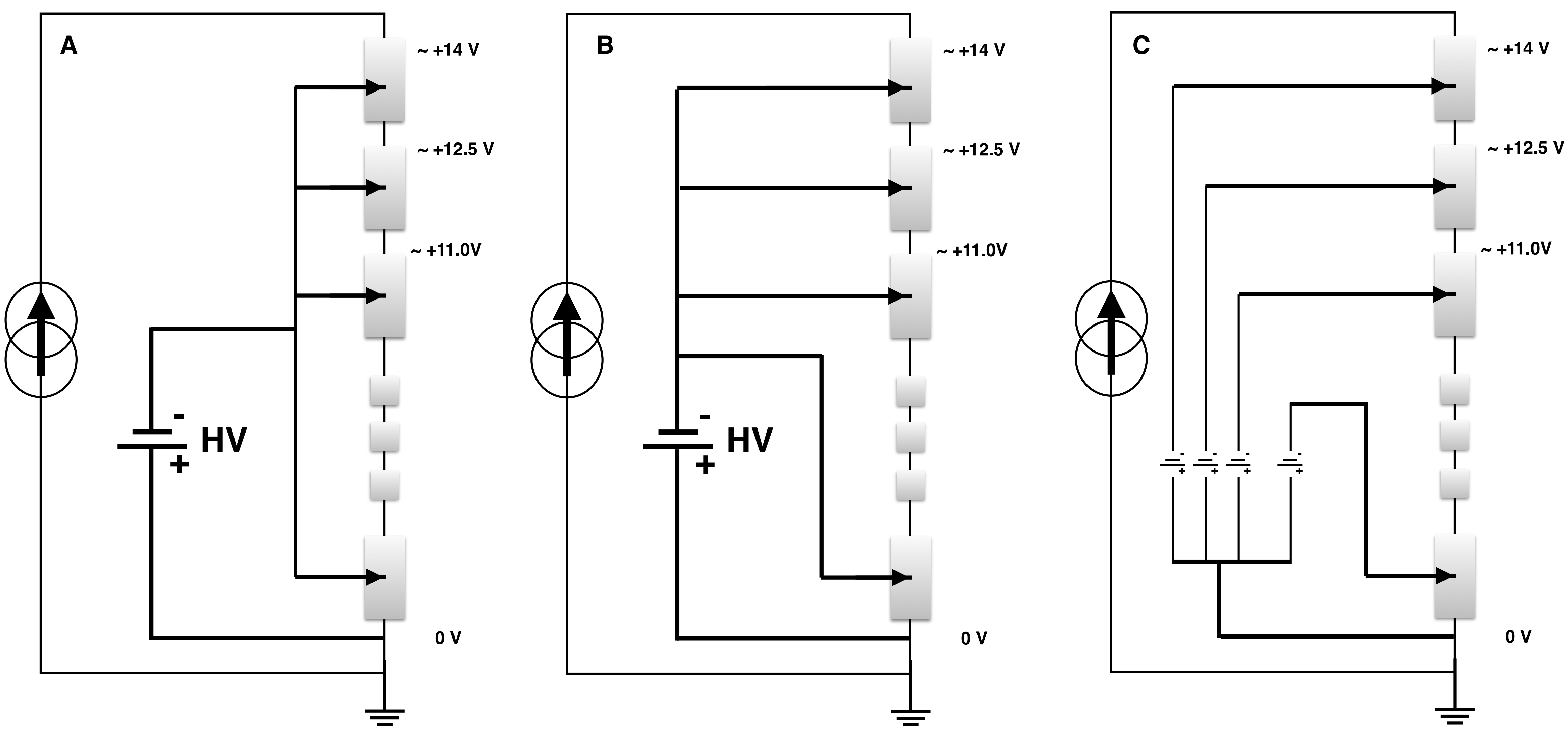
HV distribution and grounding options

Several options → to be tested on real module chains

- Only one HV RTN line needed (i_HV through r/o chips)
- One "ground point" at detector side → floating power supply

HV wiring choices:

A) less material budget
B) can disconnect single modules via jumpers at power supply end
C) can regulate individual modules (could be useful for 3D sensors)



projection: size of power system (IT)

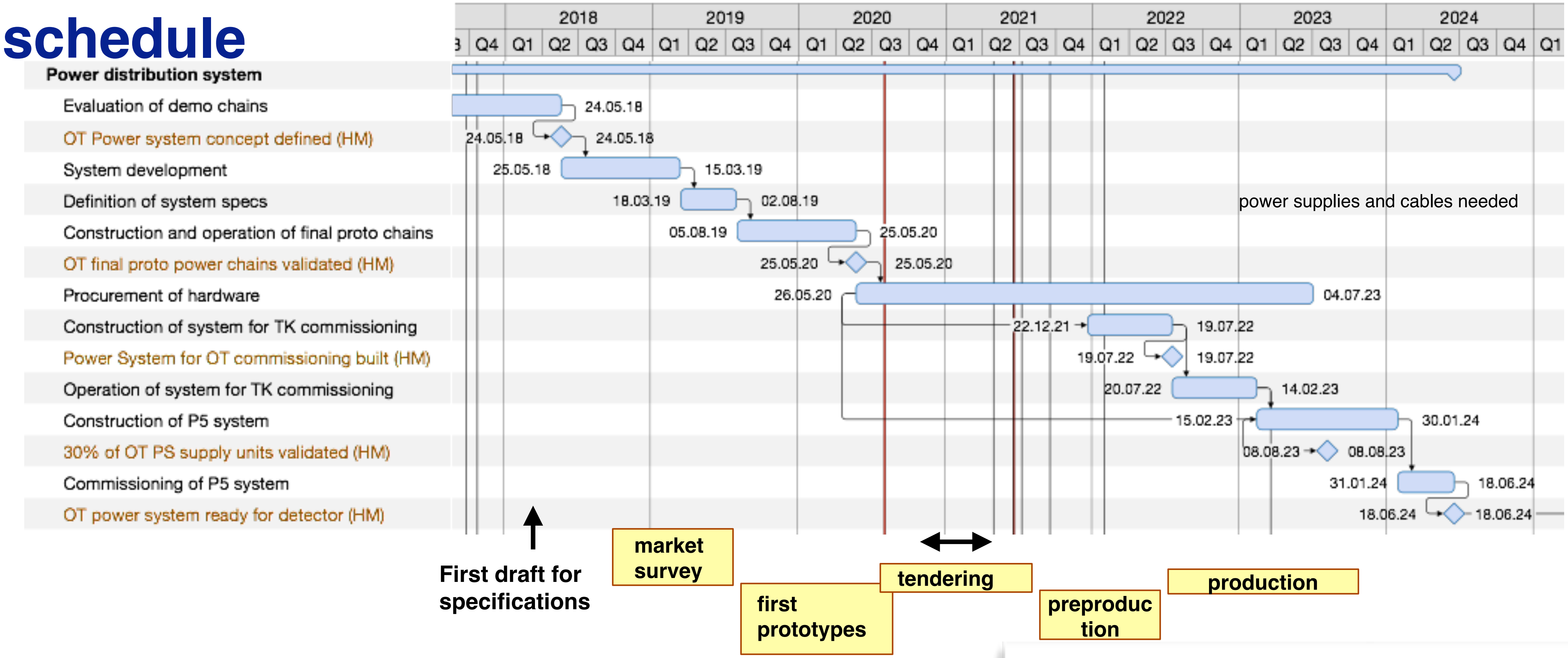
	power supply power [kW]	AC/DC power [kW]	380 power [kW]
Serial Power	55.00	68.75	80.88
HV power	2.50	3.13	3.68
Optoelectronics	2.30	2.88	3.38
pre-heaters	3.70	4.63	5.44
TOTAL	**63.50**	**79.38**	**93.38**

First exercise (~ guess)
Assuming boards powering 1 cable → 2 complex channels (LV+HV) per board
Assuming 56U high racks with 5 crates + 3 AC/DC

	n. chains	n. boards	LV power/ board	48V power/ crate	n crates	n Racks
8A	312	156	360 W	2 kW	33	
4A	264	136	160 W	2 kW	14	
	576	**292**			**47**	**10**

In addition: LpGBT-based opto conversion system and pre-heaters for IT.
Back end power based on OT power system.
Total power budget ~ 6 kW (4 crates).

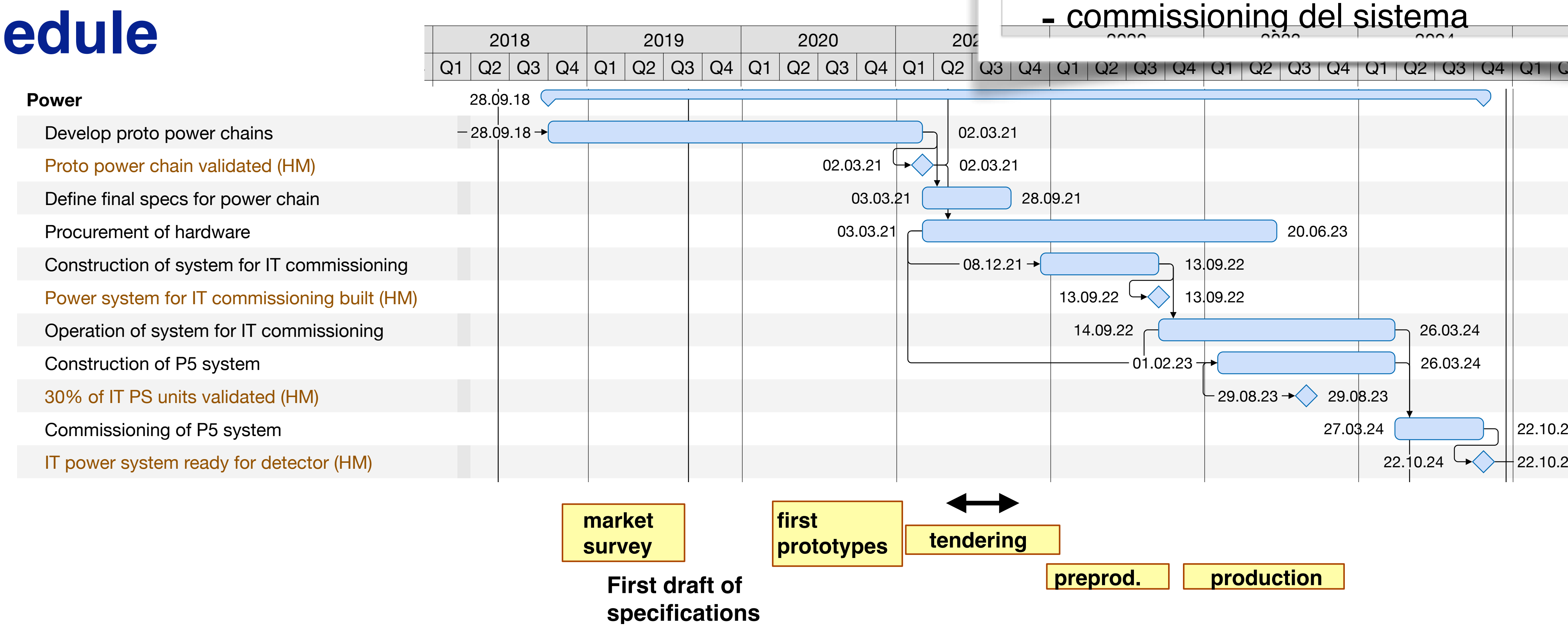
OT schedule



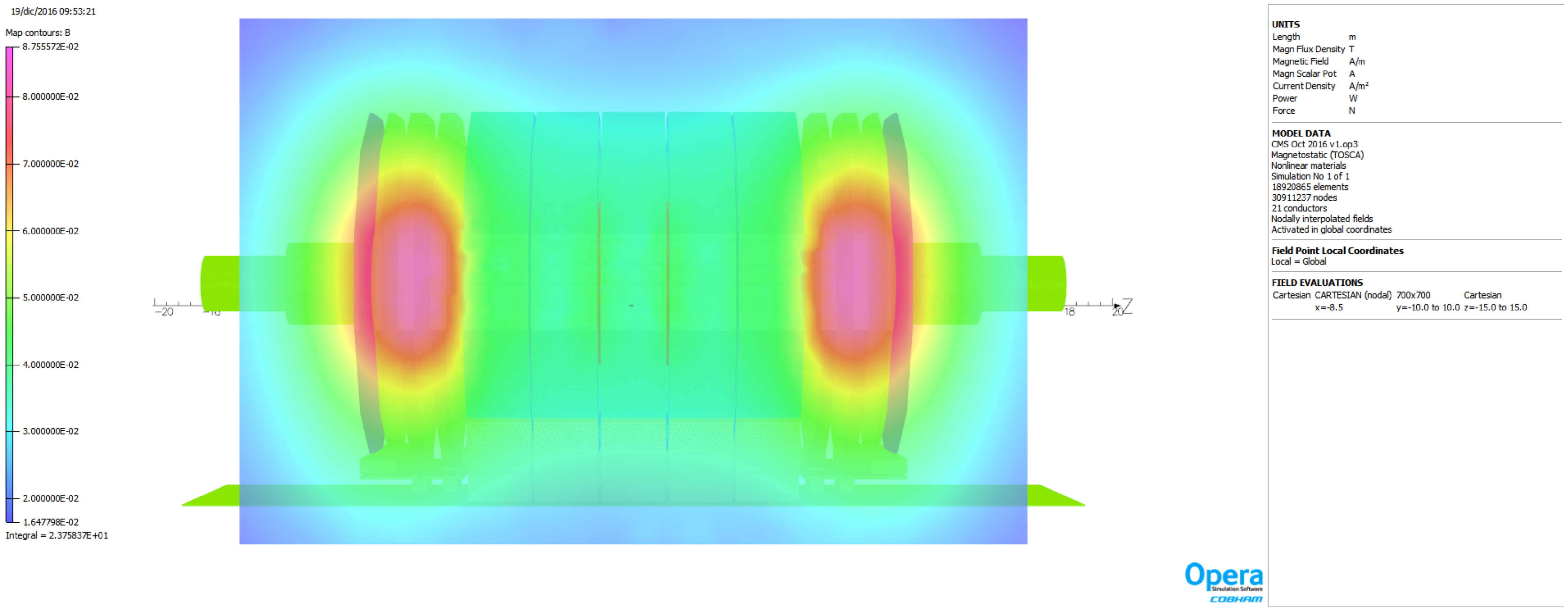
Studio dei prototipi
Setups per test vari

Periodo intenso di test al CERN
- Ricezione componenti (PS e CAVI)
- BURNIN
- commissioning del sistema

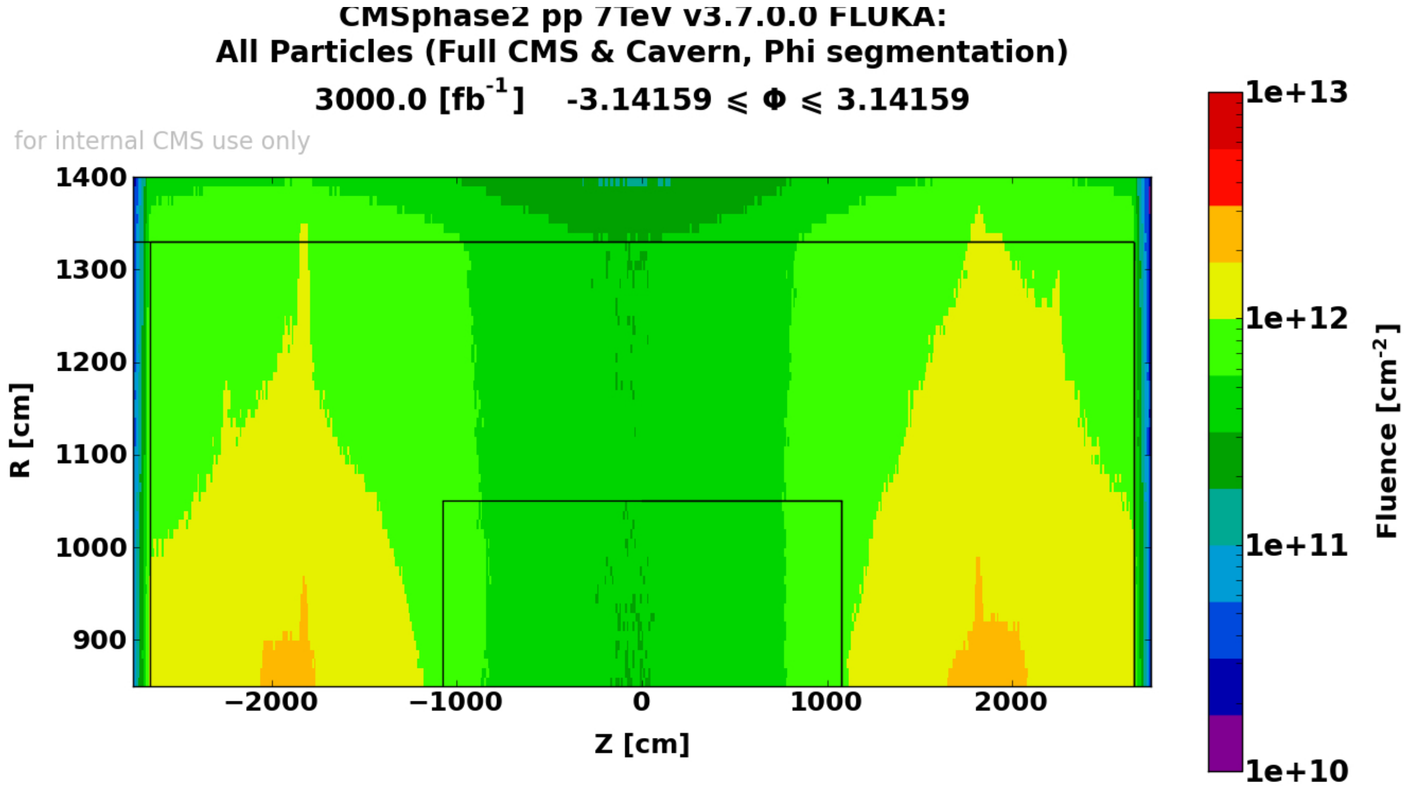
IT schedule

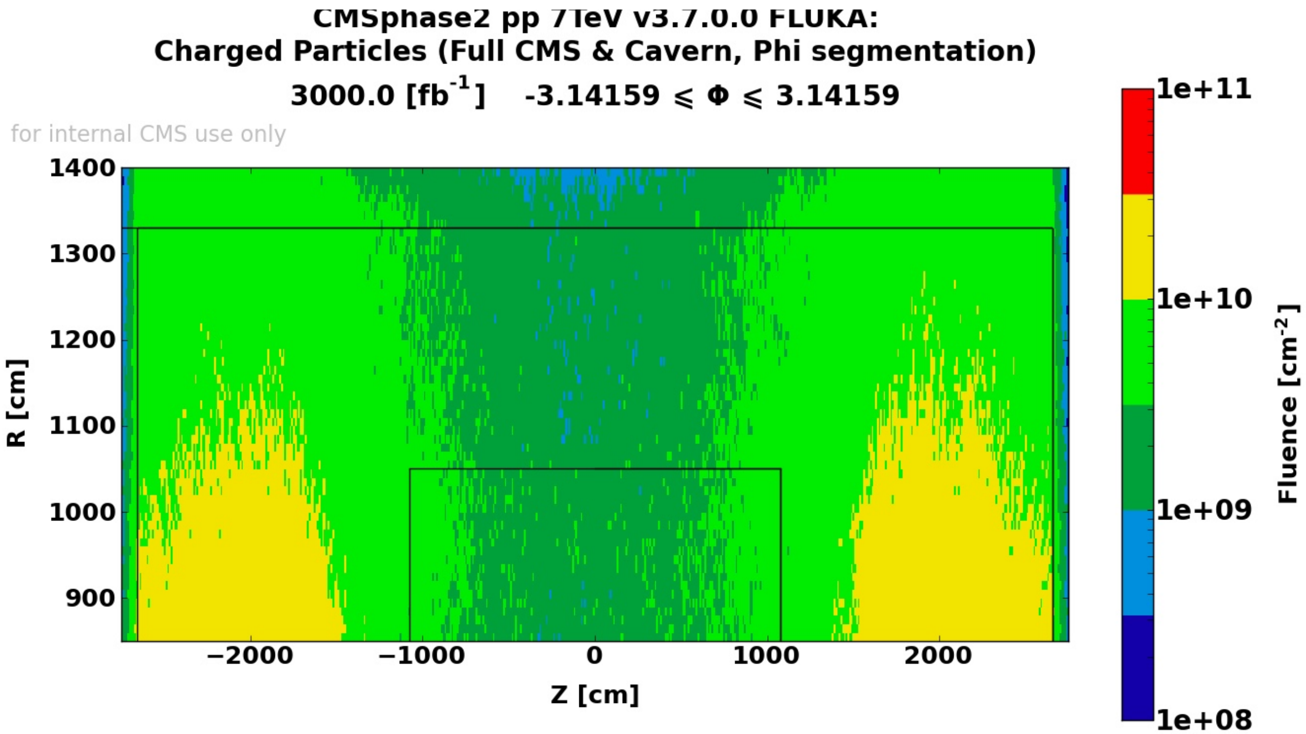


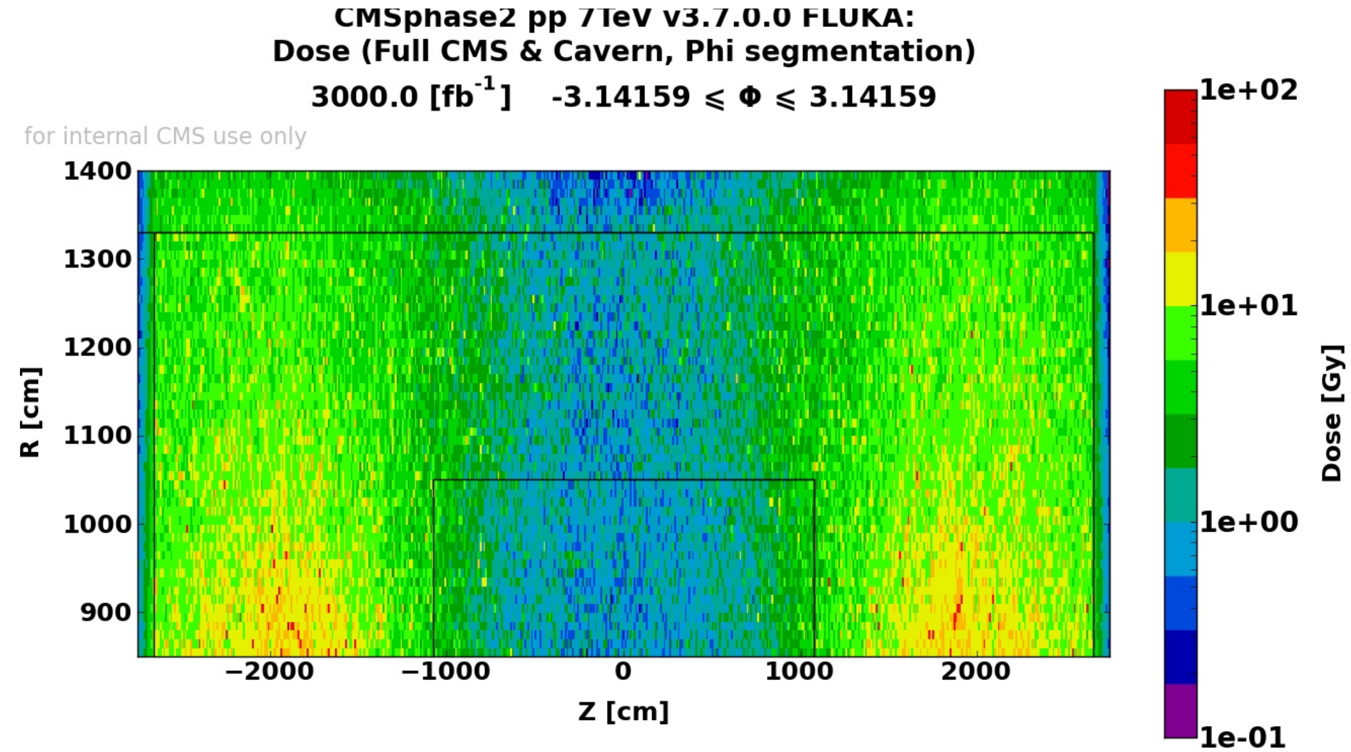
END



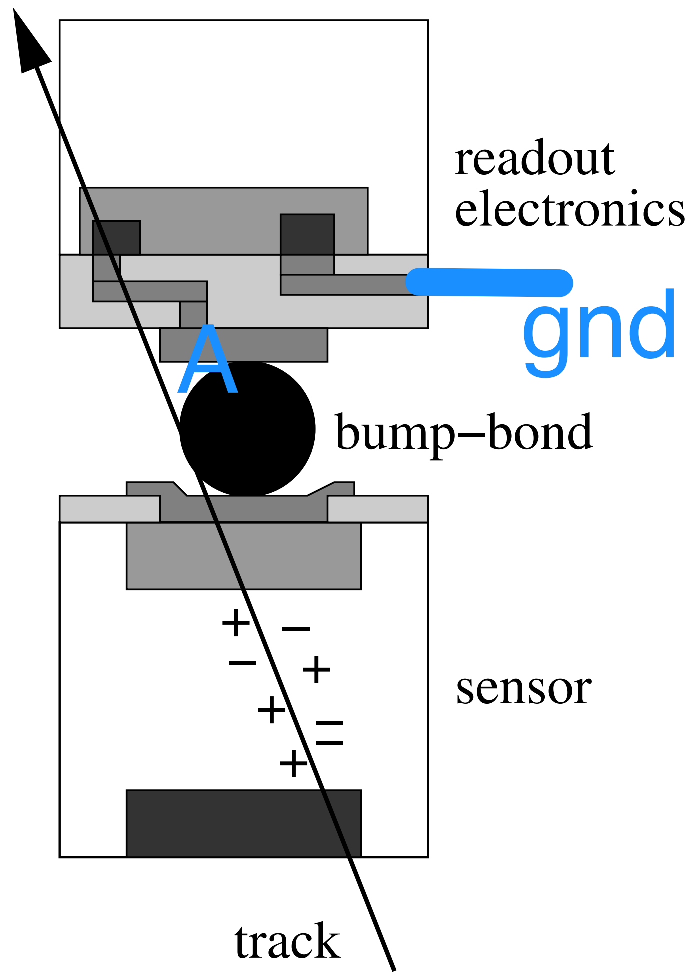
courtesy: Valerio Calvelli - University of Genova


CMSphase2 pp 7TeV v3.7.0.0 FLUKA:
All Particles (Full CMS & Cavern, Phi segmentation)
3000.0 [fb^{-1}] -3.14159 ≤ Φ ≤ 3.14159
for internal CMS use only
R [cm]
Z [cm]
Fluence [cm^{-2}]


CMSphase2 pp 7TeV v3.7.0.0 FLUKA:
Charged Particles (Full CMS & Cavern, Phi segmentation)
3000.0 [fb^{-1}] -3.14159 ≤ Φ ≤ 3.14159
for internal CMS use only
R [cm]
Z [cm]
Fluence [cm^{-2}]


CMSphase2 pp 7TeV v3.7.0.0 FLUKA:
Dose (Full CMS & Cavern, Phi segmentation)
3000.0 [fb^{-1}] -3.14159 ≤ Φ ≤ 3.14159
for internal CMS use only
R [cm]
Z [cm]
Dose [Gy]

Forbid HV ON when LV OFF



pixels (IT)
macro pixels (OT)