CMS Inner Tracker Power Systems

Simone Paoletti - INFN Firenze
for the Power System Working Group

15 OCT 2018

IT power overview

- ➡ 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.

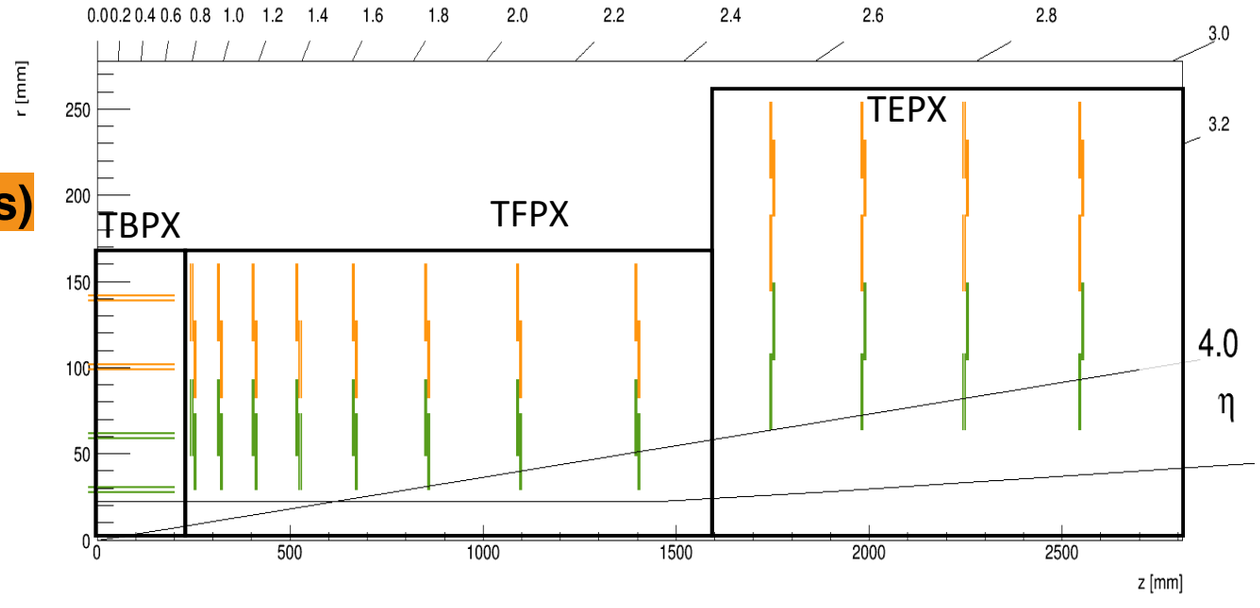
Two kinds of serial chains are formed:

- ➡ chains of modules with four readout chips (“8A” chains)
- ➡ chains of modules with two readout chips (“4A” chains)

LV power is distributed in parallel to r/o chips (analog and digital parts) within each module.

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

~ 4.2 k modules
~ 13.2 k r/o chips

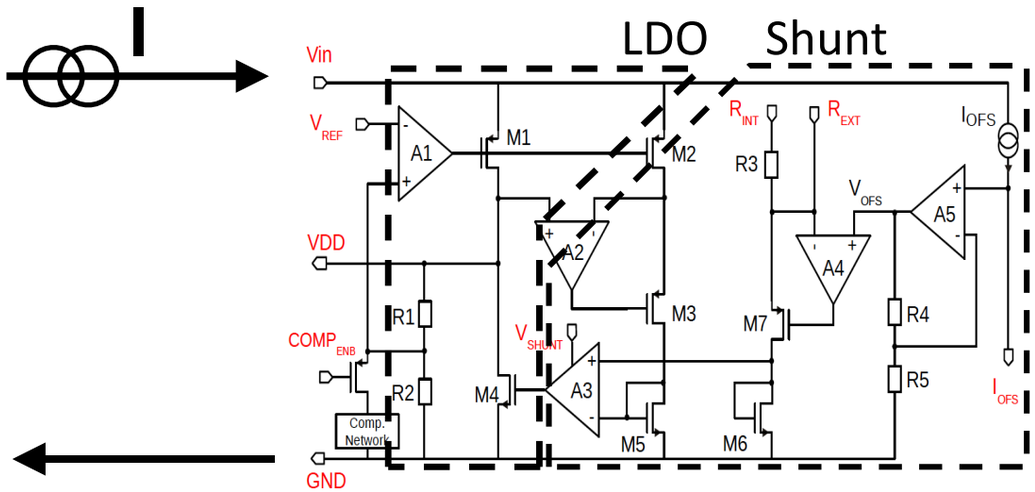


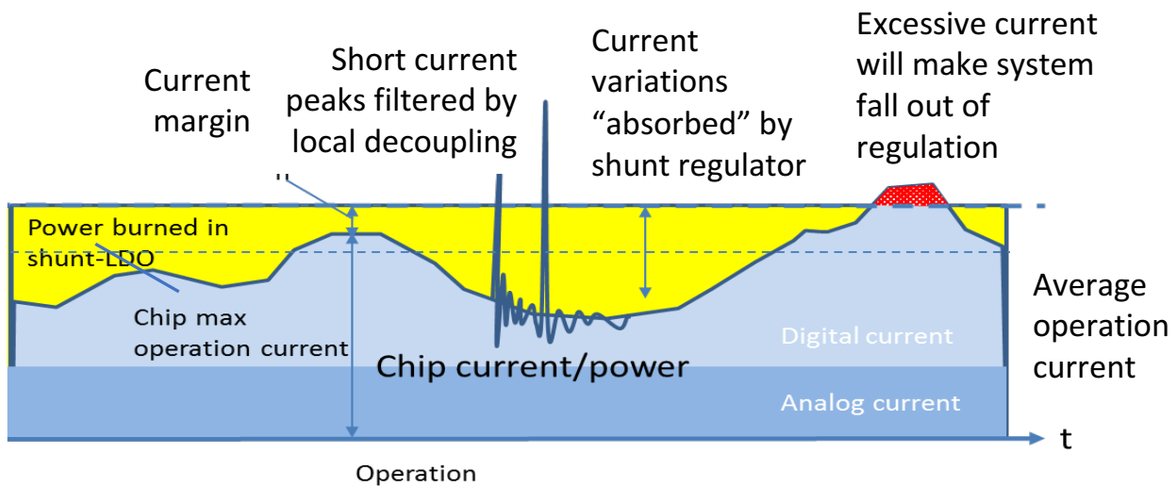
Power Consumption

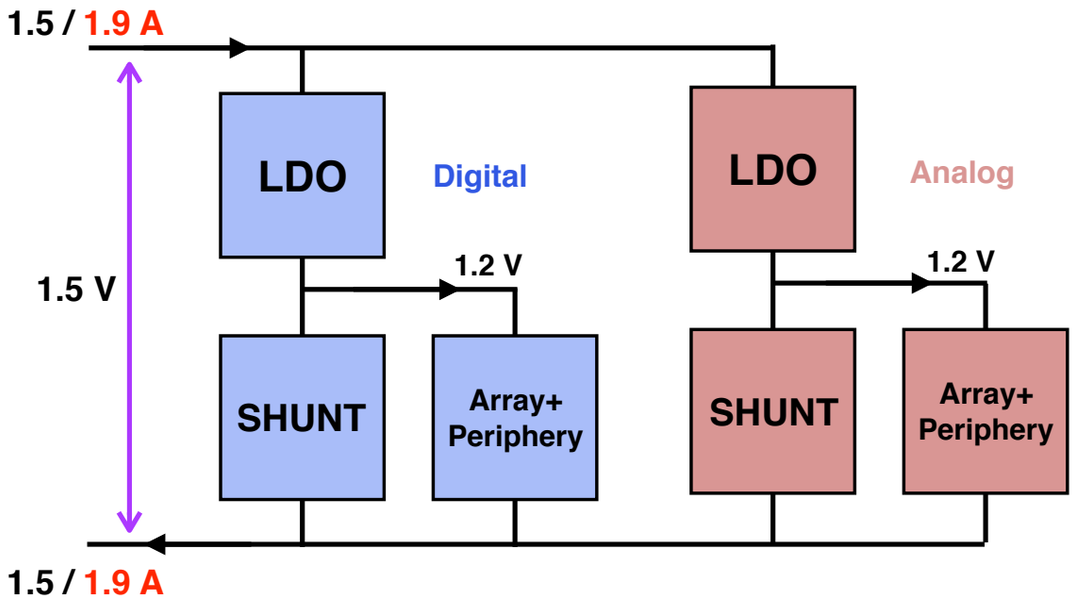
Considered “baseline”: 1.9A x 1.5 V per r/o chip

Current-driven serial Power chains:

- the Shunt-LDO configuration defines ΔV=f(I)
- aiming at ΔV~1.5 V
  - 1.2V required by electronics
  - 0.3V for LDO regulation and headroom
- the chain has to provide enough power for transients: considering ~ 25% headroom w.r.t. “typical” conditions. 1.5 A → 1.9 A





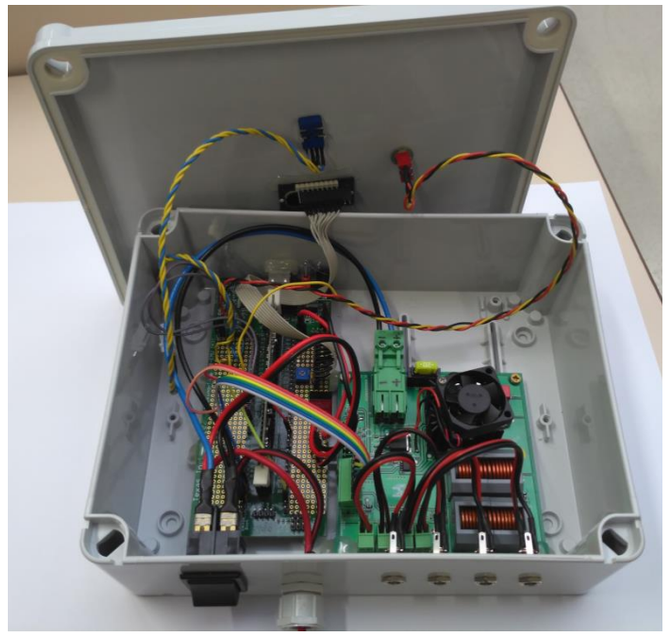


Serial Power current sources

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

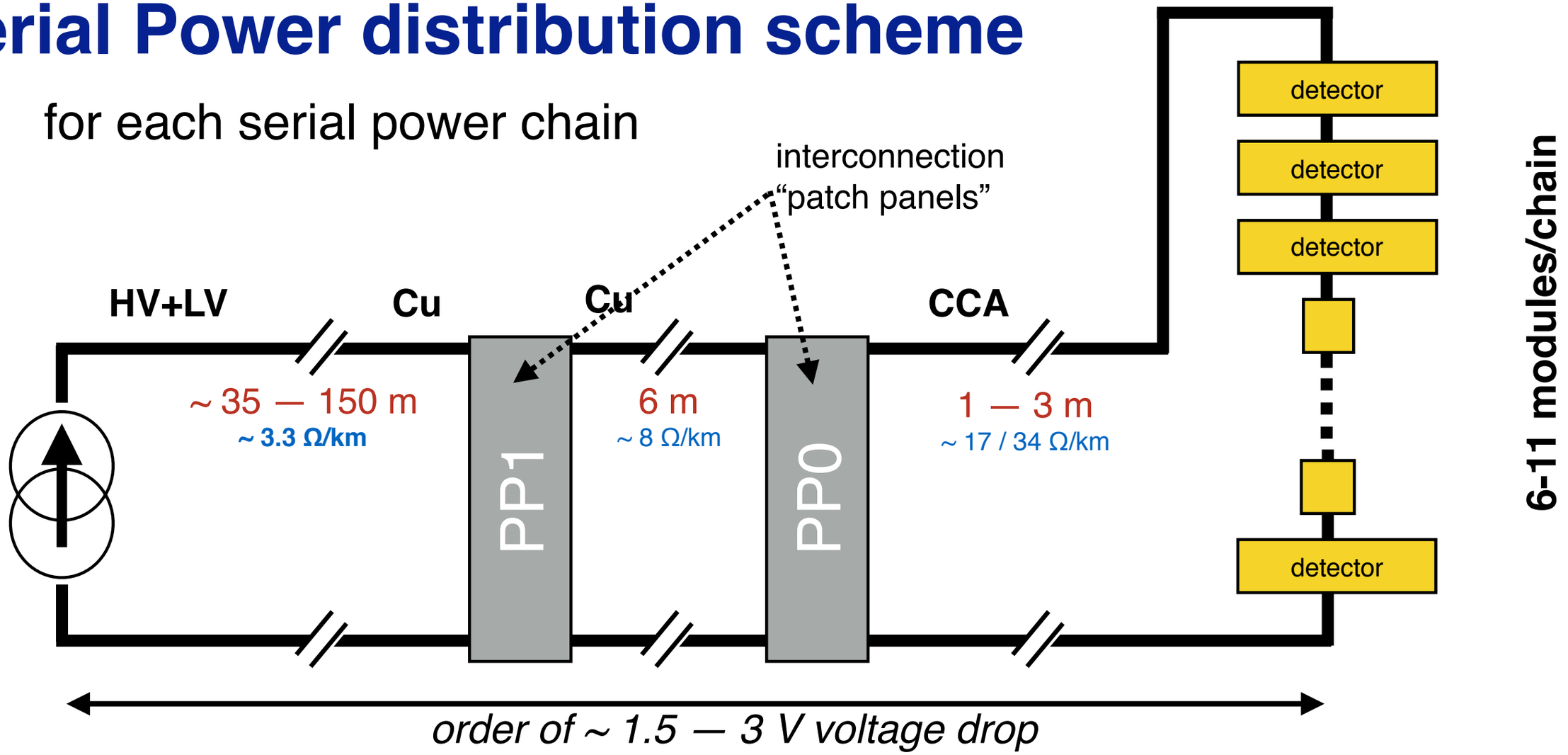
CAEN (NEOLITE regional project)
- both current and voltage regulation
- 10.5V/2.3 A max
- “sibling” board survived > 50Gy at CHARM

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



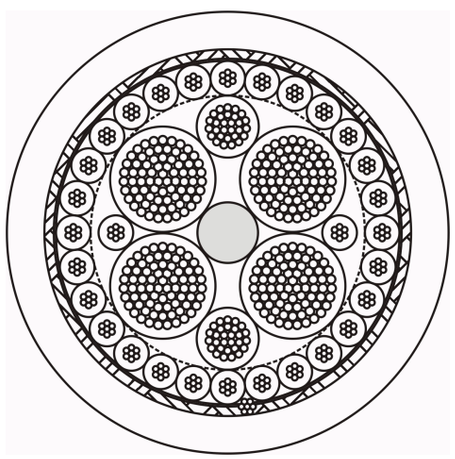
Serial Power distribution scheme

for each serial power chain

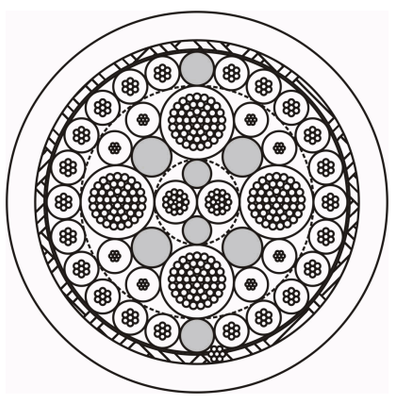


One cable → 2 power chains

Cable 1: ∅ = 15.3 mm



Cable 2: ∅ = 13.4 mm



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

Power to r/o chips

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

	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

n. r/o chips	13192
power to r/o chips	37 kW
power dissipated on cables and interconnections	18 kW (Assuming ~85m long cables)
Total power	**55 kW**

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.

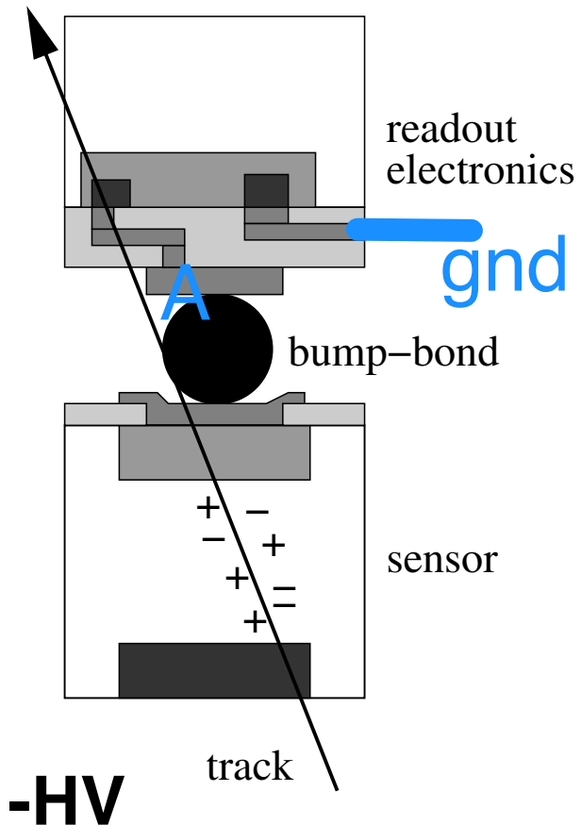
Total power budget ~ 6 kW (4 crates).

path to draft specifications document

- Granularity and amount of power per board ~ identified
- next steps:
  - turn ON and OFF procedures
  - LV ramp speed
    - ✓not too fast
    - ✓not too slow
  - Protection features requires (OVV, OVC etc.)
    - ✓anything special for serial powering ?
  - Behaviour during transients
  - Extra needs in case of failure scenarios
    - ✓all simulations and tests so far ok
  - HV/LV interplay

→ need to increase experience with real module chains

HV/LV interplay



Necessity to forbid HV ON when LV is OFF

- is there consensus on this ?
- want to have this safety implemented at hardware level
- implications of that to be understood

Looking at a HV+LV integrated system

HV distribution and grounding options

Several options → to be tested on real module chains

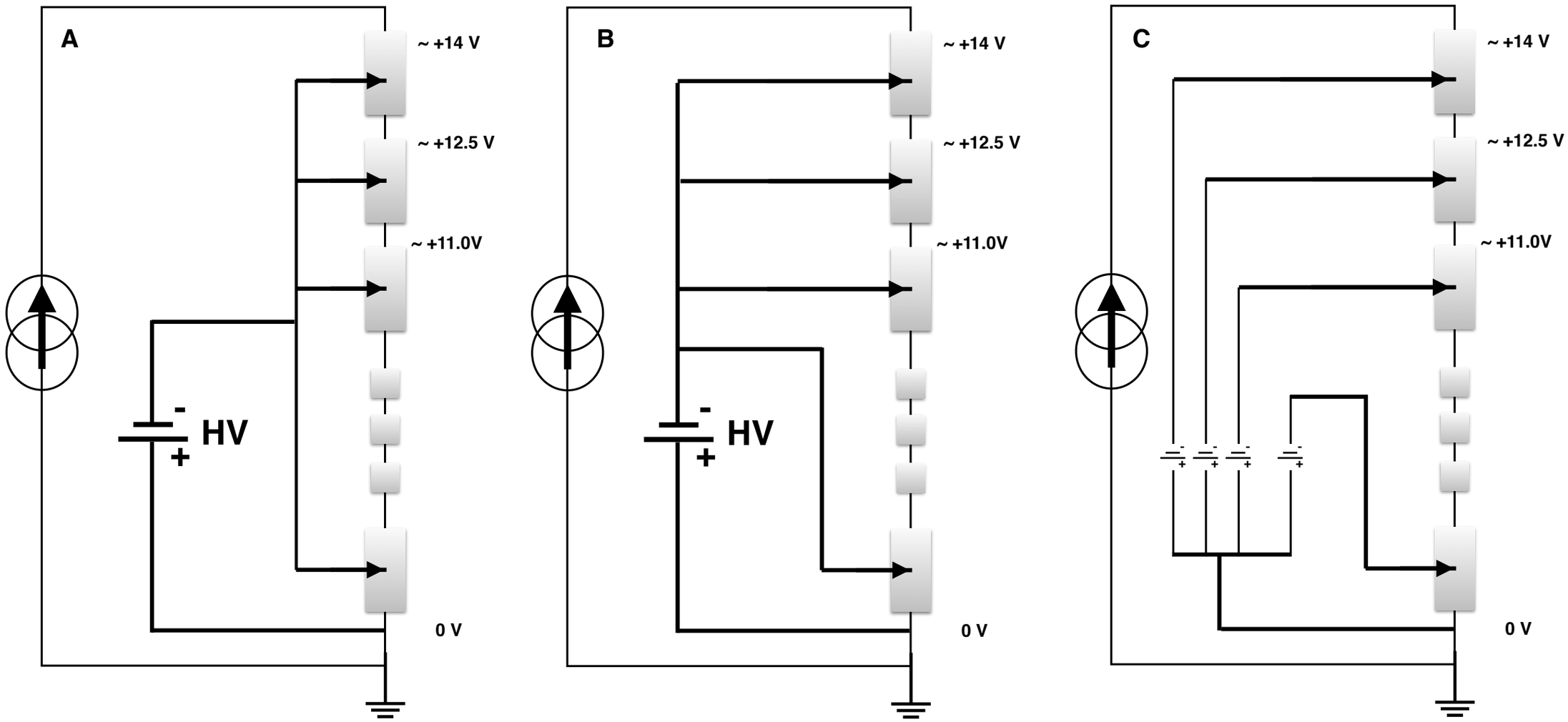
- Only one HV RTN line needed (i_HV through r/o chips)
- One “ground point” at detector side → floating power supply

HV wiring choices:

A) less material budget

B) can disconnect single modules via jumpers at power supply end

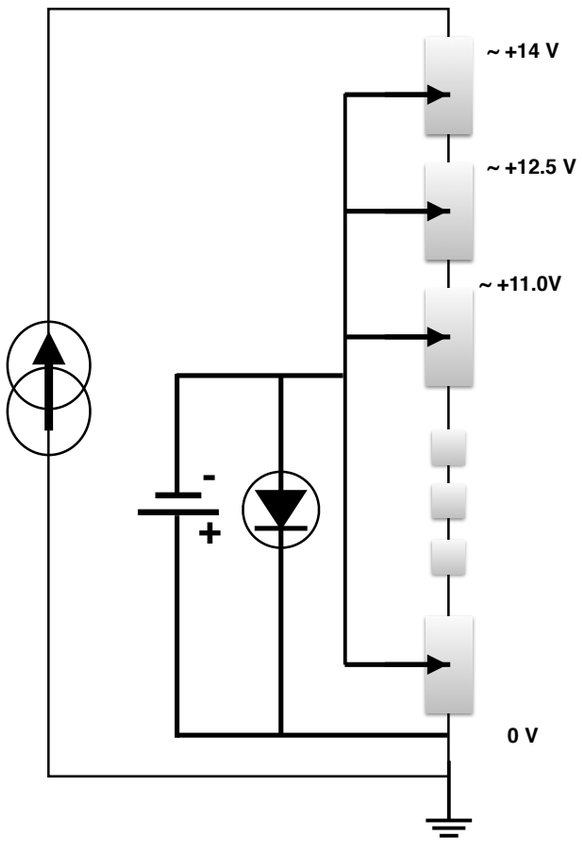
C) can regulate individual modules (could be useful for 3D sensors)

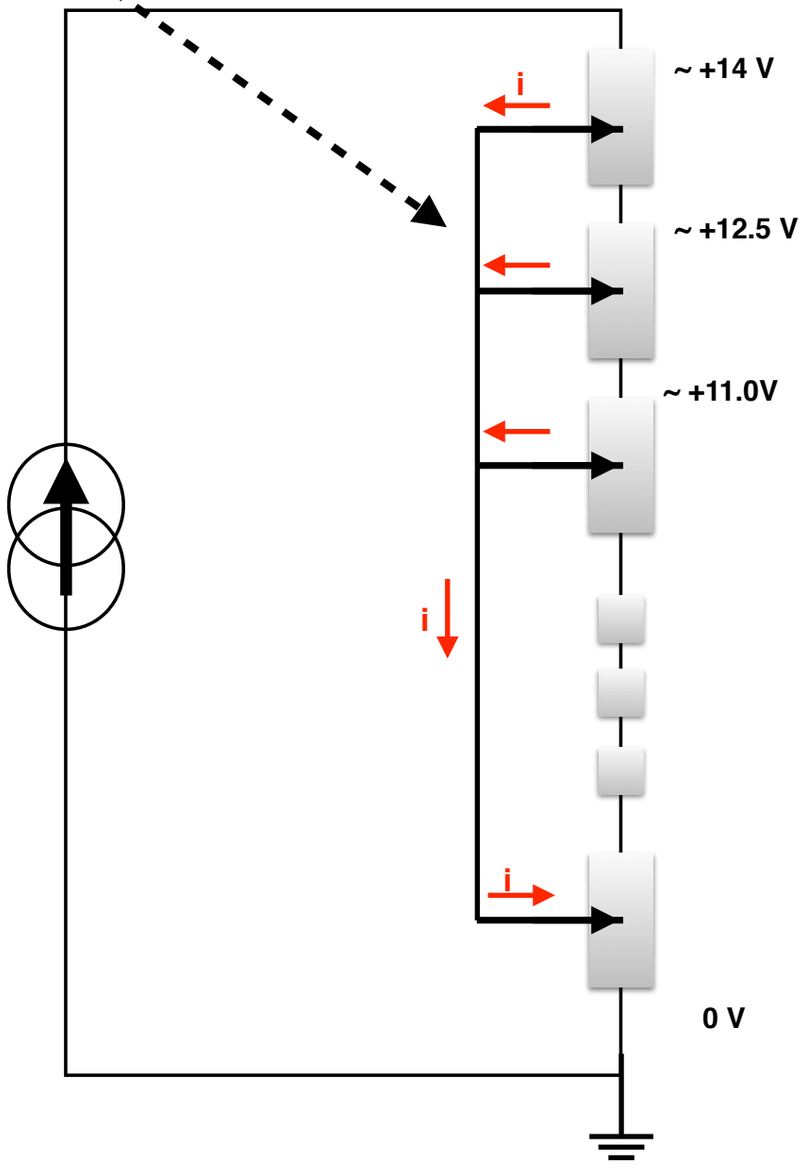


HV/LV interplay (2)

When HV OFF(or if disconnected to HV power supplies) this branch has high impedance to ground
- Voltage is “undefined”
- bias current from some sensors will flow through other sensors in the chain.

Several counter measures can be proposed/tested:
- Regulate HV to 0 V
- crowbar circuit shorting to ground when HV OFF
- diode to ground at power supply
- ….





Power Supply Market Survey

Market Survey is being prepared for Outer Trackers (CMS, ATLAS)

Can we consider inserting some very inclusive specs for Inner Trackers as well ?

Should agree on some (very inclusive) broad brush specs … ?

LV:

- output current per channel: regulated between 0 and XX A
- output voltage range: up to XX V
- number of channels/board: up to XX.
- etc.

HV:

- multi (xx) channels 0V to -XXXX V