CGEM-IT HV-LV DISTRIBUTION SYSTEM

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LNF-INFN

HV GEM- REQUIREMENTS

HV GEM – METHODS

THREE METHODS

1. Use of standard multi-channel HV power supply (i.e. independent voltages) through a high value protection resistor (typ 10 Meg)
2. Single Power supply with external resistive partition network for GEM and upper drift electrode (with protection resistor)
3. Floating stacked channels

Method 1 allows full independent control of drift and transfer field but a sustained spark can be developed in case of discharges then causing an irreversible GEM damaging (the effect is probably generated by a combination of the generator reaction time and the capability of both source/sink current then developing a temporary increase in GEM voltage).
→ STRONGLY DISCOURAGED *

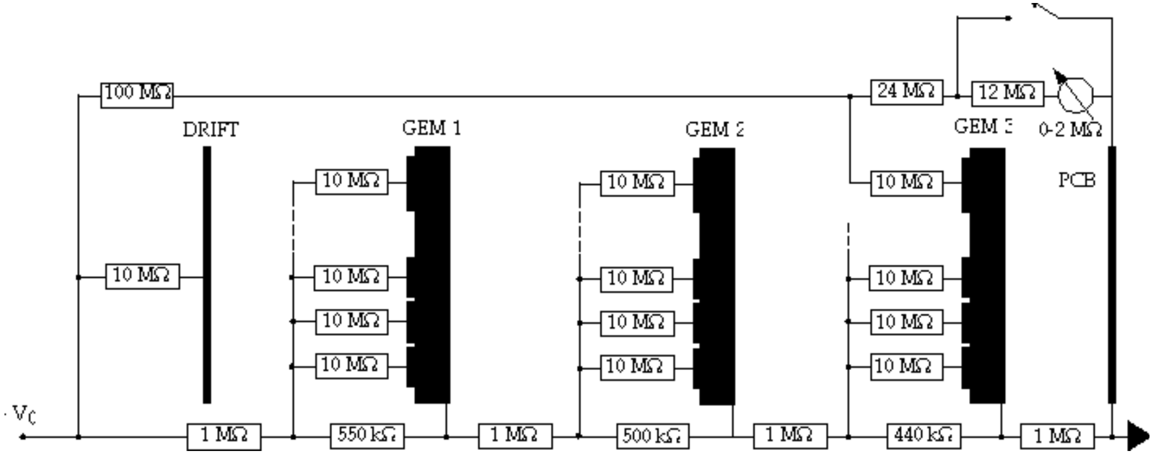
Method 2 avoid the problem at the cost of partition resistor power dissipation and loss of control flexibility in applied voltages. (the double network for cathode and GEM allows to mitigate the power dissipation)
→ LOW FLEXIBILITY, NO SINGLE GEM CURRENT MONITOR

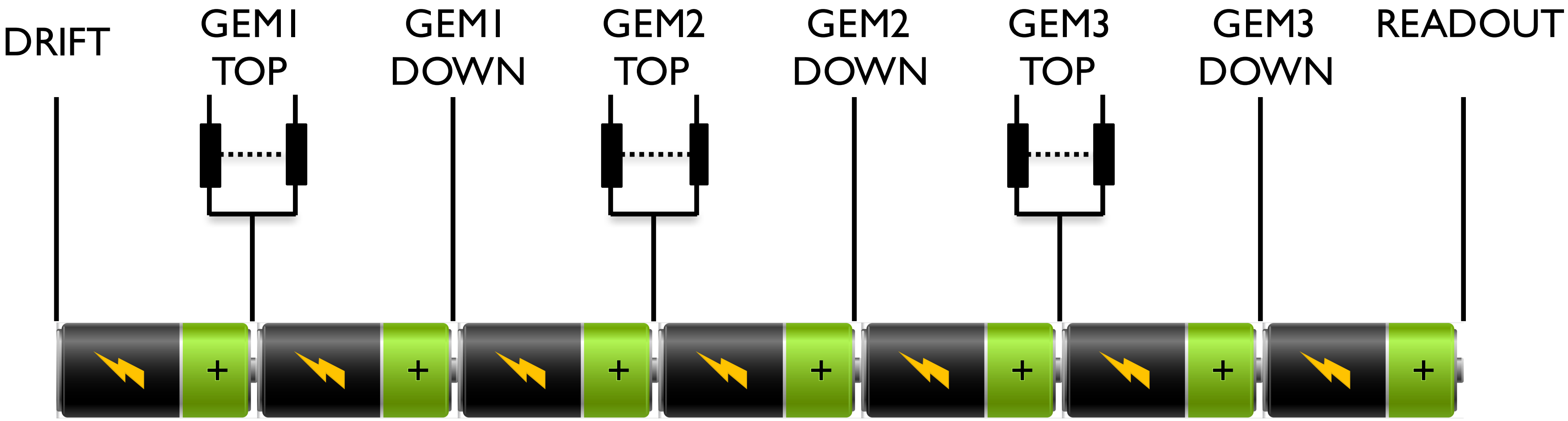
Method 3 each GEM layer has his own floating power supply with current monitoring (more in the next slides)
→ HIGH FLEXIBILITY, CURRENT MONITORING BUT MORE EXPENSIVE

* Construction, test and commissioning of the Triple-GEM tracking detector for COMPASS, Nucl. Instr. and Meth. A490(2002)177
* Charge amplification and transfer processes in the Gas Electron Multiplier, by S. Bachmann et al, Nucl. Instrum. Methods A438, 1999, 376

HV GEM – RESISTIVE PARTITION/FLOATING STACKED CHANNELS

The double network for cathode and GEM allows to mitigate the power dissipation)





1 kV MAX FLOTING UP TO 5 kV

FLOATING STAKED CHANNELS

ADVANTAGES

- Layer voltage can be set independently
- Current monitor for each layer (bipolar)
- No overvoltage in case of discharges (safe)
- The system can manage high rates

→ Floating Stacked Channel power supply system is more expensive, but is flexible and safe

FLOATING STAKED POWER SUPPLY AVAILABLE ON THE MARKET

- HVG210 – LNF
  - First device available on the market (2013)
- A1515 – CAEN
  - Recently introduced on the market

HVG210

- ON/OFF button for enabling or disabling the HV power supply
- Control leds
- +/- 12 V Power Supply
- USB connector for diagnostic
- CAN bus connector (with internal termination)
- Voltage monitor capability
- Current monitor capability
- Trip control capability

The system can is able to safely fully power a Triple-GEM detector providing, besides voltage and current monitor features, trip control capability (very useful in case of GEM discharges)

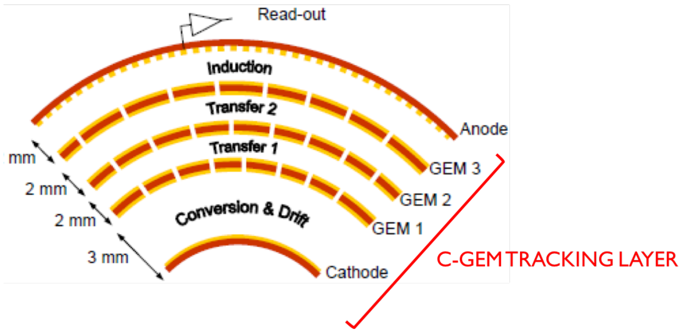
* G. Corradi, F. Murtas and D.Tagnani, A novel High Voltage System for a triple GEM detector. *Nuclear Inst. and Methods in Physics Research, A (NIM A46 128)*
* https://web2.infn.it/GEMINI/index.php/hvgem

CAEN A1515

TECHNICAL SPECIFICATIONS:

- 14/16 independently controllable High Voltage channels
- Individual Floating Channel (insulated up to 5 kV)
- Designed specifically for GEM detectors
- Output channels grouped into 2 Complex channels
- Radiall 52 pin or SHV connectors (??)
- 0÷1kV output voltage
- Dual range current:
  - High Power: 0 ÷ 1 mA, (1 nA Imon resolution)
  - High resolution: 0 ÷100 µA, (100 pA Imon resolution)
- Programmable TRIP parameter (Complex channel setting)
- Current generator operation in Overcurrent condition

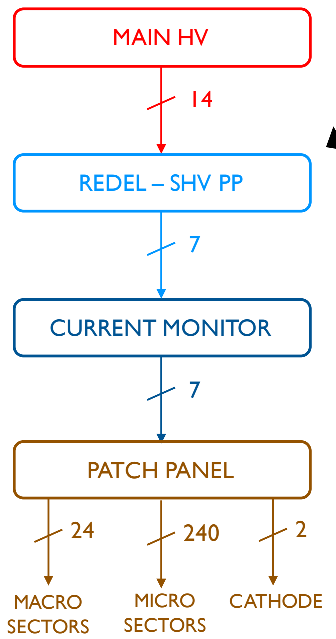
HV DISTRIBUTION CHAIN - I



CGEM LAYER	MACRO SECTORS	MICRO-SECTORS
1	12 [(2+2+2)/side]	120
2	24 [(4+4+4)/side]	240
3	27 [(5+5+5)/(4+4+4)]	270

C-GEM LAYER2:

- 4 HV connections/GEM [Gas IN side] + 4 HV connections/GEM [Gas OUT side → 8 Macro Sectors
- 3 GEMs → 24 Macro Sectors



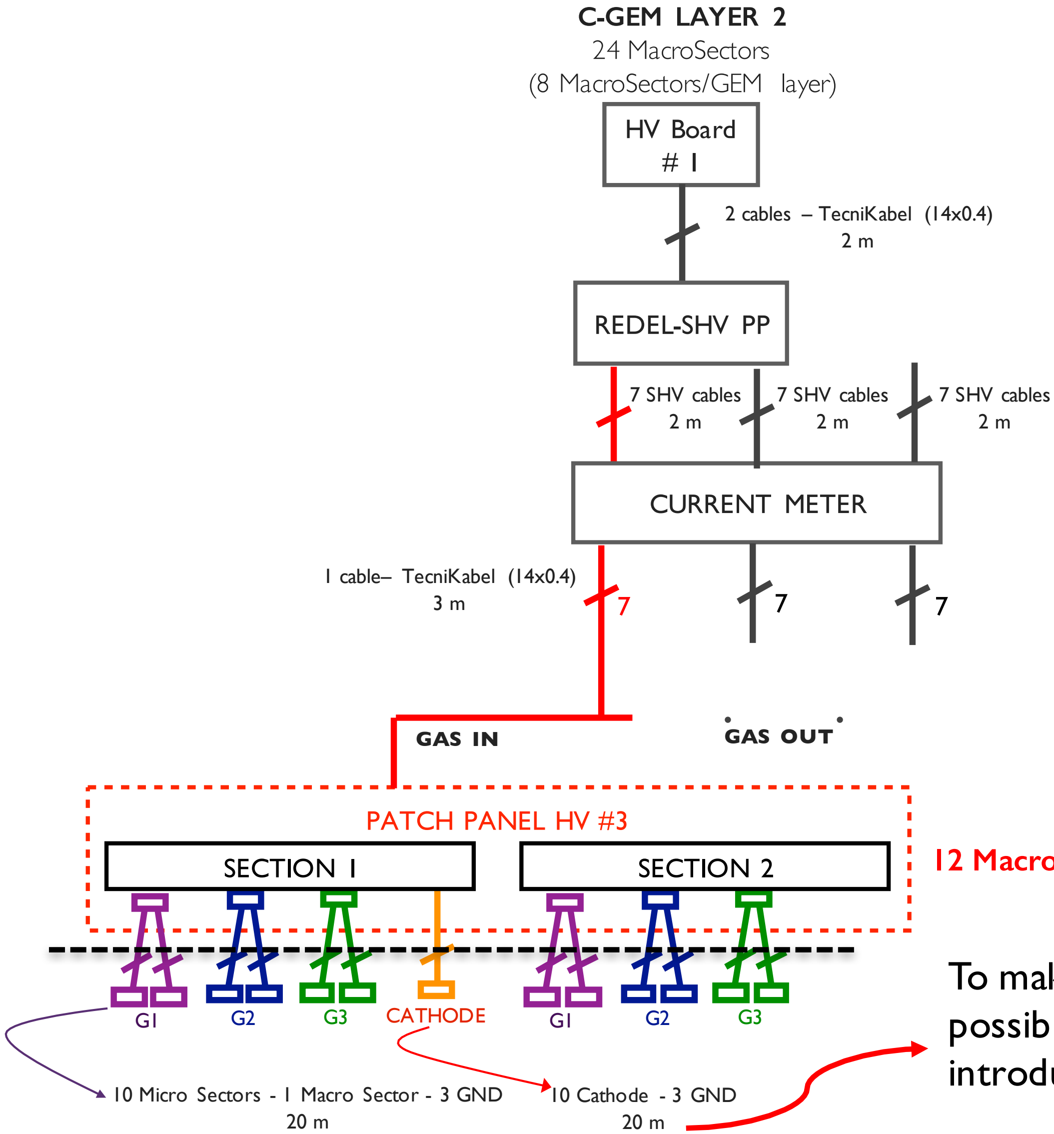
not required if MAIN HV is equipped with SHV connectors

WHATEVER HV POWER SUPPLY WILL BE USED IT WOULD BE USEFUL TO PROVIDE AN INDIPENDENT CURRENT MEASURE *

* e.g. CAEN A1515 board provides a single channel current measure (in/out) but it requires an on-site calibration that (in principle) could mask a current leakage in the HV distribution system or in the detector

HV DISTRIBUTION CHAIN - II

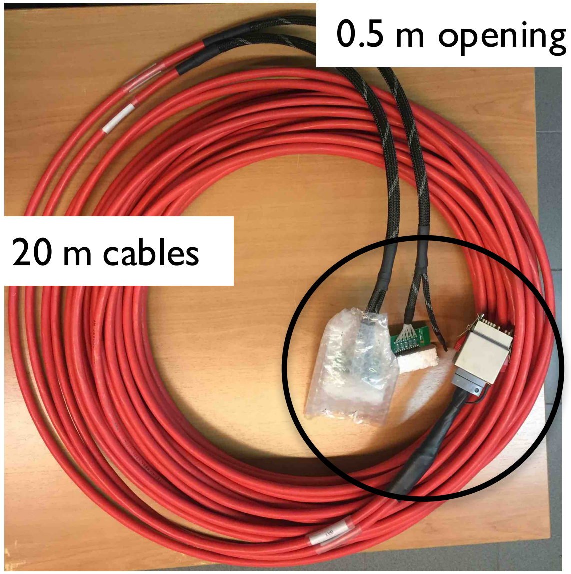
C-GEM LAYER2 HV DISTRIBUTION CHAIN

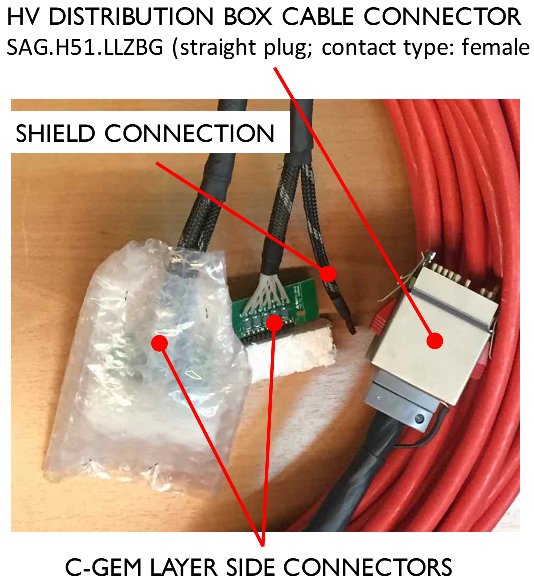


12 Macro Sectors/Side

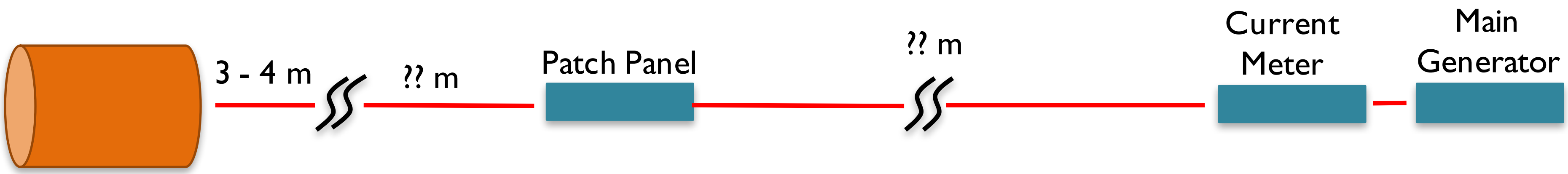
To make the insertion structure tool as light as possible we have to reduce the 20 m detector then introducing a further patch-panel near the detector

HV DISTRIBUTION - CABLES

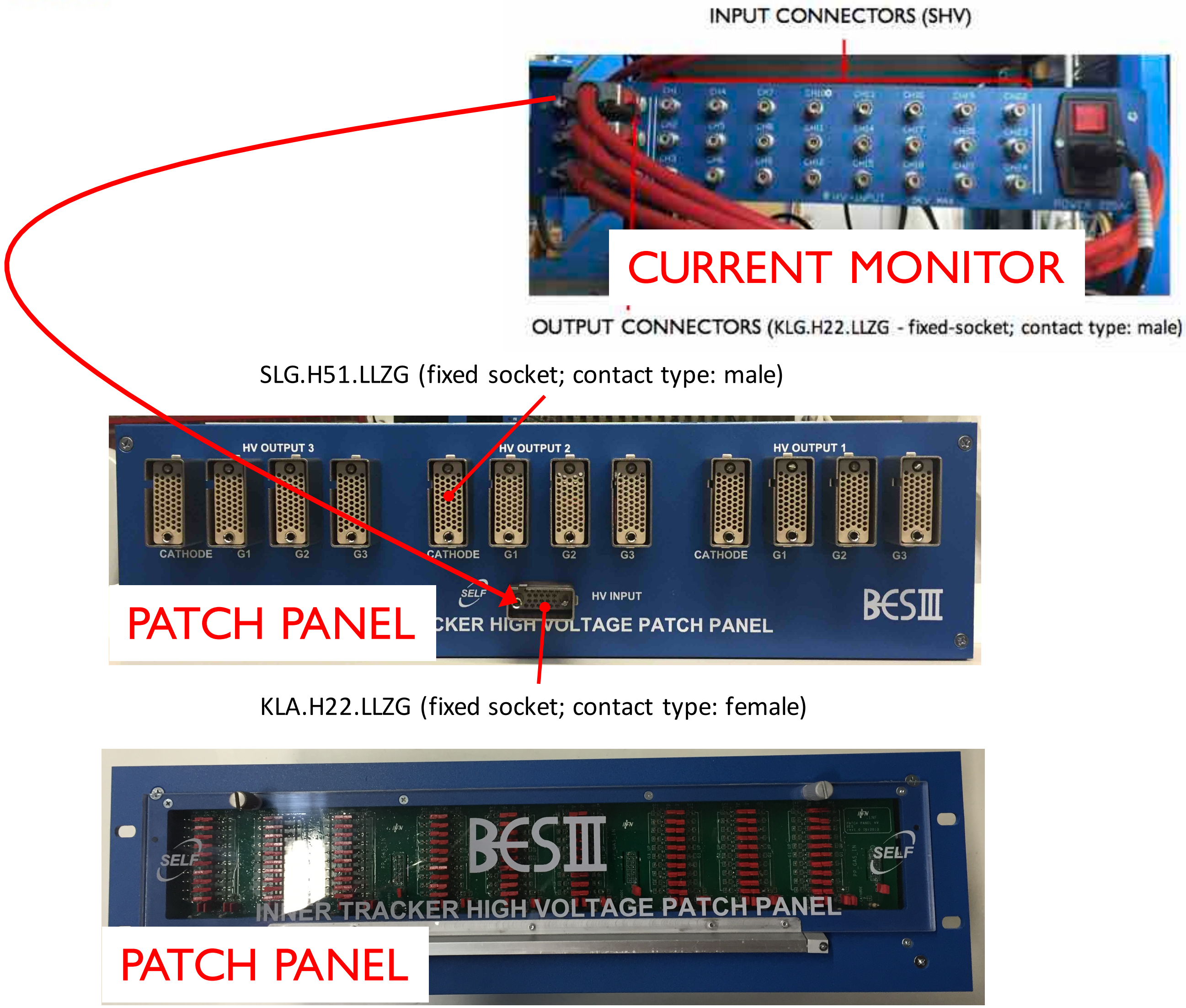


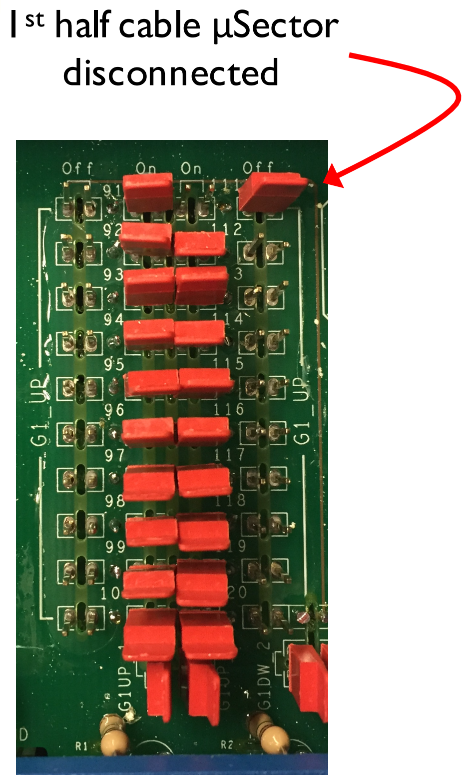


- At the moment we have 12 GEM cables and 1 Cathode cables (enough to fully instrument C-GEM layer 2 prototype)
- Cable reworking required to reduce the length of cable connected to GEMs (the length of cable connected to C-GEM Tracker must be as short as possible to minimize system weight)



HV DISTRIBUTION – CURRENT MONITOR & PATCH-PANELS





- PP #1 & 2 completed

HV DISTRIBUTION - SUMMARIZING

- A safe C-GEM Tracker power supply system must use a network resistor or floating stacked channels main generator
- Floating stacked channels provides more flexibility both in C-GEM field setting and current monitoring
- Redundancy in current monitoring (i.e. independent GEM layer current monitoring) could be useful

The system has been fully designed and we already have produced all components/cables to supply C-GEM layer 2 prototype

ON-DETECTOR LVPS REQUIREMENTS

- Each ASIC boards will host 2 chips. Voltage/Current requirements are:
  - Analog section: 1.5 V – 1,7 A
  - Digital section: 2.5 V - 100 mA
- Local (low drop) voltage regulators must be used for voltage stabilization.

INNER TRACKER ON-DETECTOR LV REQUIREMENTS

VOLTAGE\CURRENT REQUIREMENTS PER BOARD	
1,2 V	1,7 A
2,5 V	0,1 A

LAYER	BOARDS	I [1,2V]		I[2,5V]		PD
1	16	27,2	A	1,6	A	35 W
2	28	47,6	A	2,8	A	62 W
3	36	61,2	A	3,6	A	80 W
TOT	80	136	A	8	A	176,8 W

CDC READOUT LV REQUIREMENTS

VOLTAGE\CURRENT REQUIREMENTS PER BOARD (2 board/cell (both sides readout) - 48 cells/layer - 4 layers)

6 V	5 mA

CELLS/LAYER	BOARDS/ LAYER	N of LAYERS	I [6 V]		PD	
48	96	4	1,92	A	11,52	W

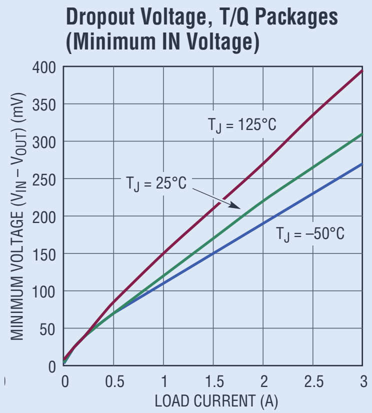
DO WE REALLY NEED HARD-RAD REGULATOR ??

LC4913 HARD-RAD REGULATOR

REG DROPOUT - LHC4913
1,5 V @ 3A
0,5 V @ 1A

→ DROPOUT @ 2A = 1V → 136 W PD due to $V_{REG\ DROP}$

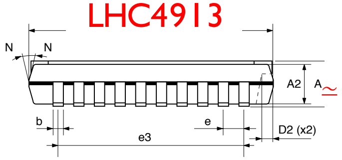
LINEAR LT3083 VOLTAGE REGULATOR



→ DROPOUT @ 2A = 0.225 V → 30 W PD due to $V_{REG\ DROP}$

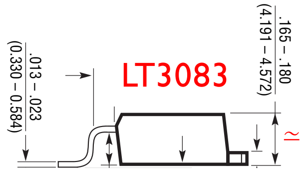
REGULATOR PAKAGING

LHC4913



≃ 3.5 mm

LT3083



≃ 5 mm

→ **TRANSITION-BOARD←→PREAMP BOARD CONNECTOR HEIGHT MUST MATCH REGULATOR TICKNESS AND HEAT DISSIPATION REQUIREMENTS.** ←

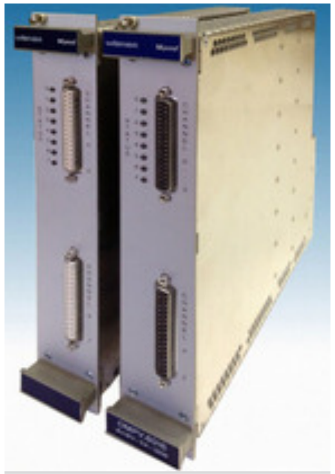
LV MAIN GENERATOR

A2517

8 Channel 5 V/15 A (50 W) Individual Floating Channel Boards

8 independently controllable Low Voltage channels
Individual Floating Channel
Individual remote sense lines
Full Digital PID Control Loop
8 pin D-Sub connectors
1÷5 V output voltage with 1 mV set resolution
15 A current full scale with 10 mA set resolution
50 W Max channel output power
1 mV Voltage Monitor resolution
1 mA Current Monitor resolution

Ripple < 10 mV_{PP}



- Low Voltage floating modules with 8 channels of 50W max. with 0-8V, 0-16V, 0-30V, 0-60V and 0-120V ranges
- 6U height, 220mm deep fully shielded mechanics
- All DC outputs with individual return lines, individually sensed, floating channel to
- channel and channel to chassis ground (125V, 500V tested)
- Extremely low noise and ripple: <3mVpp (0-20MHz)
- Voltage and current settings / monitoring for each channel, 15 bit resolution, accuracy
- +/-0.1% of full scale value
- Current monitoring and limiting for each channel, 15 bit resolution, accuracy +/-0.05%
- of full scale value
- high stability, 0.2%/10k
- Programmable channel parameters:
  - Terminal and load voltage, under voltage / over voltage trip points
  - current limit (current or voltage controlled mode)

LV DISTRIBUTION - SUMMARY

- Two system topologies:
  - On-detector voltage regulation
    - pros:
      - Can easily manage load current variations
      - Acts as a filter (voltage ripple & cable noise pickup reduction)
      - Do not require precise input voltage (not valid in our application)
    - cons:
      - Increase system power dissipation
  - Off-detector voltage regulation
    - pros:
      - Minimize power dissipation
    - cons:
      - Requires 4 cables/board (power + sensing)
      - Must be carefully designed (low power-path impedance, supply output capacitance splitting, high-frequency capacitors etc.)

On-Detector LVPS system must be floating, with remote sensing and low-ripple. On board voltage regulators, despite the power dissipation due to the voltage drops is probably the safest solution for our application.

GROUNDING - PRELIMINARY

GROUNDING:

- Front-End electronics is, generally, designed to amplify and record very small signals (few thousands of electrons)
- Detectors (and front-end electronics) are exposed to environment electromagnetic fields; induced signals (currents) can have frequencies components comparable with the signal to detect
- HV or LV large networks can contribute to inject noise in the signal path
- Safety rules require to earth the system
  - NB: grounding is not an active component of the system, then no operational currents must flow through the earth path
- Because detector dimension a ground mesh is often a forced choice

A good grounding scheme should prevent noise injection into sensitive circuits

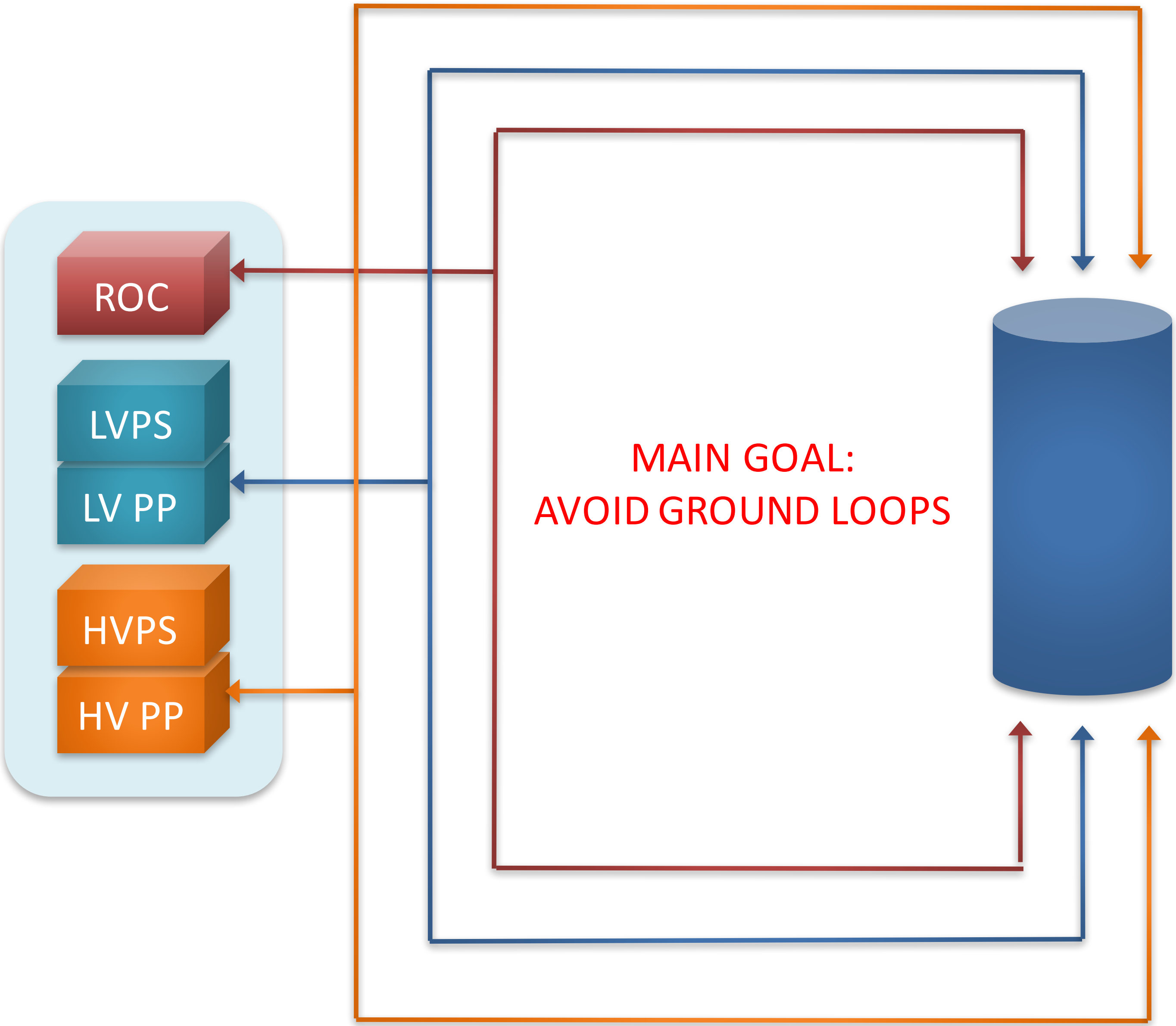
⬇

Signal path must not be a part of a large surface area ground loop

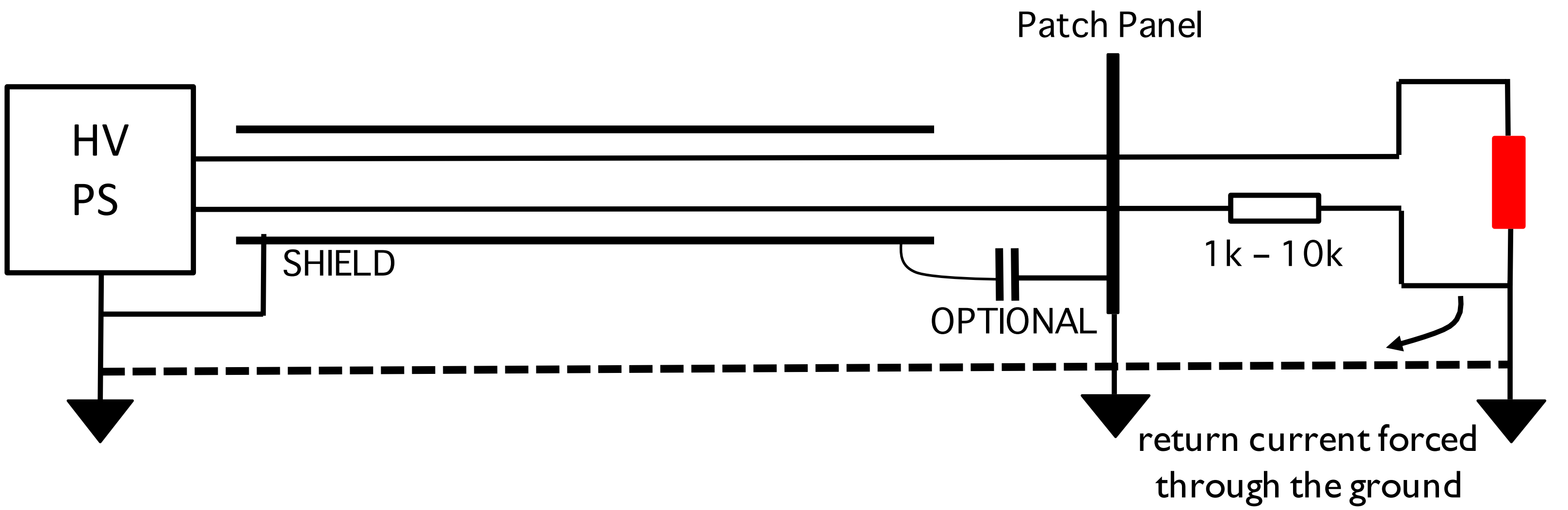
IT COMPONENTS LOCATIONS

- IT detector: 3 interconnected cylindrical layers. They are the innermost section of the BESIII apparatus.
- Very Front End electronics: Transition Boards (containing signal protecion networks and voltage regulators) and Preamplifier Boards. They are located on layer service flanges.
- Patch-Panel: passive interconnection system to limit signal and HV/LV cables length and weight (IT must be fully cabled before insertion). It is located as close as possible to the IT.
- Front End Electronics: ROC and CONCENTRATORS. They are located on the platforms
- Power Supply: LVPS and HVPS. They are located on the platforms
- HV Patch Panels: IT bias voltage distribution. They are located on the platform (or somewhere between the platform and the detector. NB: we must access the Patch Panels for IT maintenance)

IT CONNECTIONS



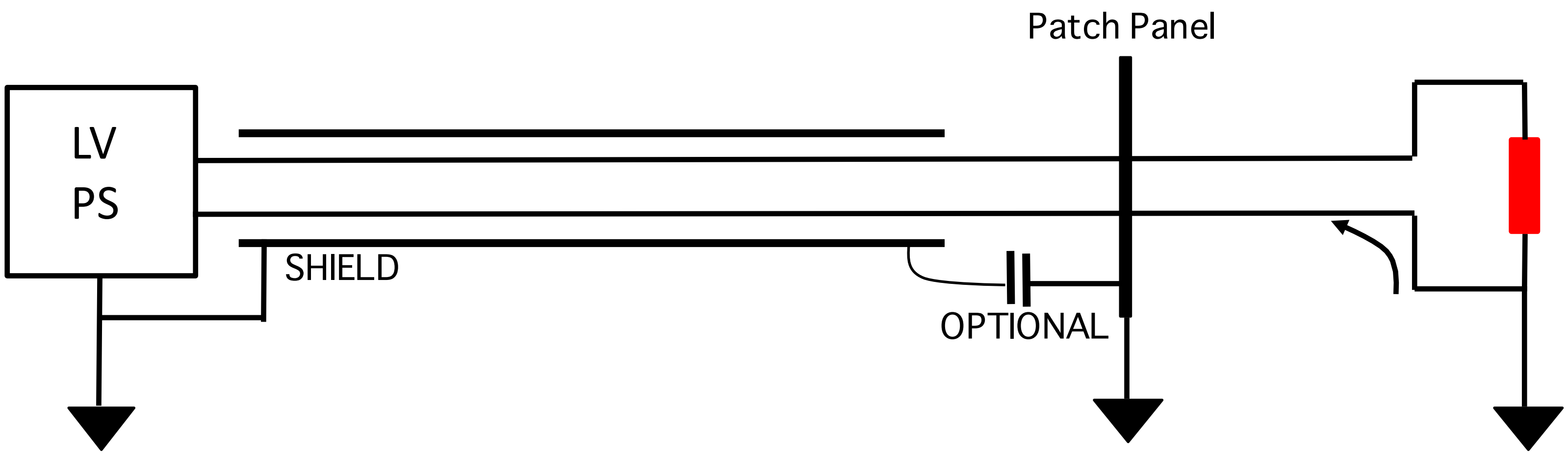
HV CONNECTION



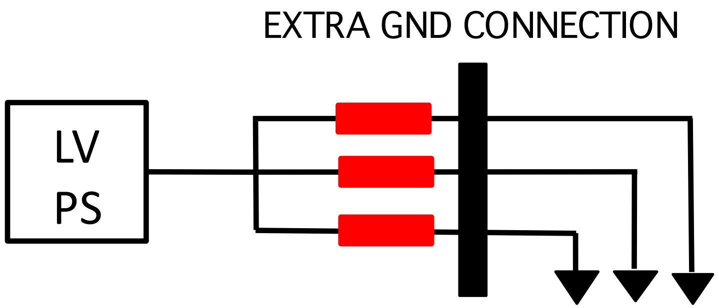
- HV is generally connected (one terminal) to GND on the detector side
- If non floating generators are used one of the HVPS terminals is connected to GND. In this case a low impedance ground loop is generated.
- To break the loop a 1k-10k resistor is used. As bias currents are generally low the voltage drop is not a problem, but the return current is routed to ground (grounding should not be used as power return)

DEPENDING ON THE PATCH PANEL LOCATION WE COULD USE SHIELDED CABLE ALSO AFTER IT

LV CONNECTIONS



- Power supply outputs must be insulated and connected to ground only at the load
- Individual loads should have individual Power Supply. If Power Supply partitioning is required it must be carefully designed. Anyway, current return between loads through local grounding network is unavoidable.
- Assuming the distances between the loads are short to minimize the Power Supply partitioning effects a low impedance ground connections between loads can be implemented

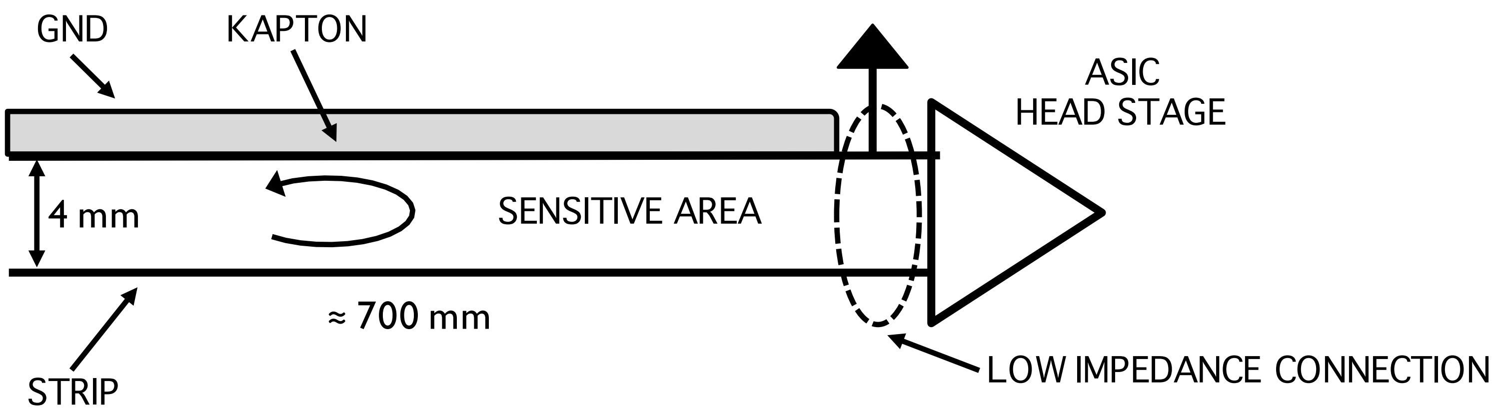


- Commercial available solutions do not fully match our requirements because the low modularity
- Power supply partitioning and/or other solution must be evaluated

FRONT-END ELECTRONICS – HEAD STAGE

- If preamplifiers has single ended inputs → No common mode noise rejection
- Preamplifier-Detector connections are the most critic section of the system → grounding scheme and Preamplifier PCB must be carefully designed:
  - Besides the standard design rules in mixed-signal PCB design (the ground plane acts also as local power return → return current from a noisy digital circuit should not affect sensitive analog circuits, if separate ground planes are used be aware of layers capacitive coupling, use different power power distribution for analog and digital circuits etc. etc.) the asic-detector coupling is a very delicate item.
    - Detector ground and preamplifier analog ground reference connection must be a low impedance connection
    - Signal wire/trace and ground wire/trace/layer must be as possible to minimize both noise pickup and connection inductance → the use of grounding plane is better as it acts also as a shielding.

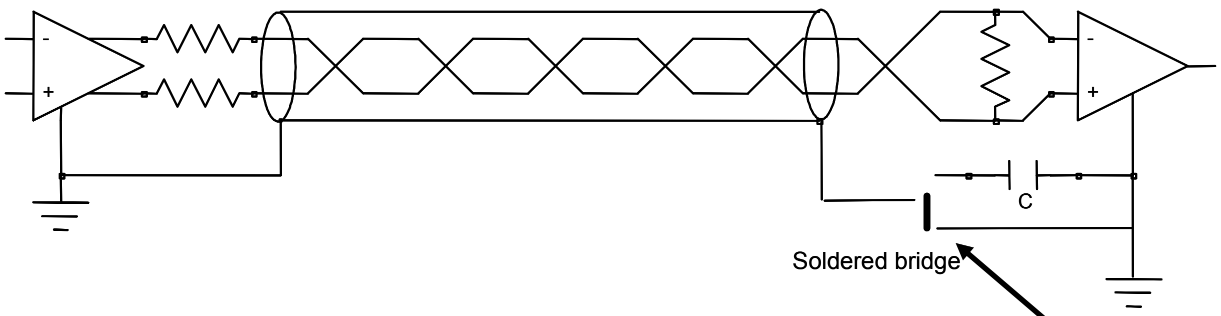
sensitive area should be minimized as much as possible to reduce noise pickup



FRONT-END ELECTRONICS – DATA TRANSMISSION

- No optical links → problem with inductive and capacitive noise coupling
- LVDS output stage → good immunity to common mode noise (but it would be better to have galvanic isolation of copper based signal links).
- Cable shield can be a source of ground loops but connecting just one side of the shield to ground has some disadvantages:
  - The shield effect is reduced
  - The dynamic common mode levels at near and far end are different

SOLUTION: ground the far end shield by means of a capacitor (short circuit at high frequency). Optionally both configurations can be foreseen



STRIP

FRONT-END ELECTRONICS – SHIELDING

- Shielding protects detector and readout electronics against:
  - capacitive coupling (stray or parasitic capacitances)
  - Inductive coupling (magnetic flux lines from external sources → current loops → voltages)
    - We ha no control on external sources, but we can reduce as much as possible the receiver area (picked-up signal amplitude is a function of both area and orientation)
  - RF
    - RF interference is a function of of the signal wavelength and the system dimension (potentially each wire and/or connection are receiving antennas)
    - Time-varying fields induce current in the shielding → a cable shield connected to the ground of an electronic circuit is a source of noise → <u>cable shield must be connected to FC</u> (NB: the use of a wire to connect the cable shield to the FC reduces the shielding effect)

Because the amount of input/output cables and the lack of space we can not implement a FC

↓

To minimize picked up noise we can only work on signal path optimization

CONCLUSIONS

- HV distribution system has been already defined and all the stuff required to instrument Layer 2 is already available
- LV distribution system needs further investigation (a reliable system requires to supply each board independently minimizing on-board regulator voltage drop).
- It is not possible implement a FC around the detector, so detector-preamplifier connection must be optimized and sensitive area reduced as much as possible (front-end electronics bandwidth optimized to cover correct frequency range could help a lot)
- Detector is connected to L/HV PS and ROC boards on both sides then system layout must be carefully investigated to avoid ground loops.