HGCAL DCDC modules

Taiwan Instrumentation and Detector Consortium

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bPOL12V for HGCAL

bPOL12V placement in HGCAL

HGCAL dedicated DCDC modules are based on bPOL12V:
an integrated buck converter designed at CERN
for the power distribution in High Energy Physics experiments.

HGCAL LD region radiation levels
min: 1Mrad, 2e14n/cm2 **max: 20Mrad, 2e15n/cm2**

HGCAL HD region radiation levels
min: 20Mrad, 2e15n/cm2 **max: 200Mrad, 8e15n/cm2**

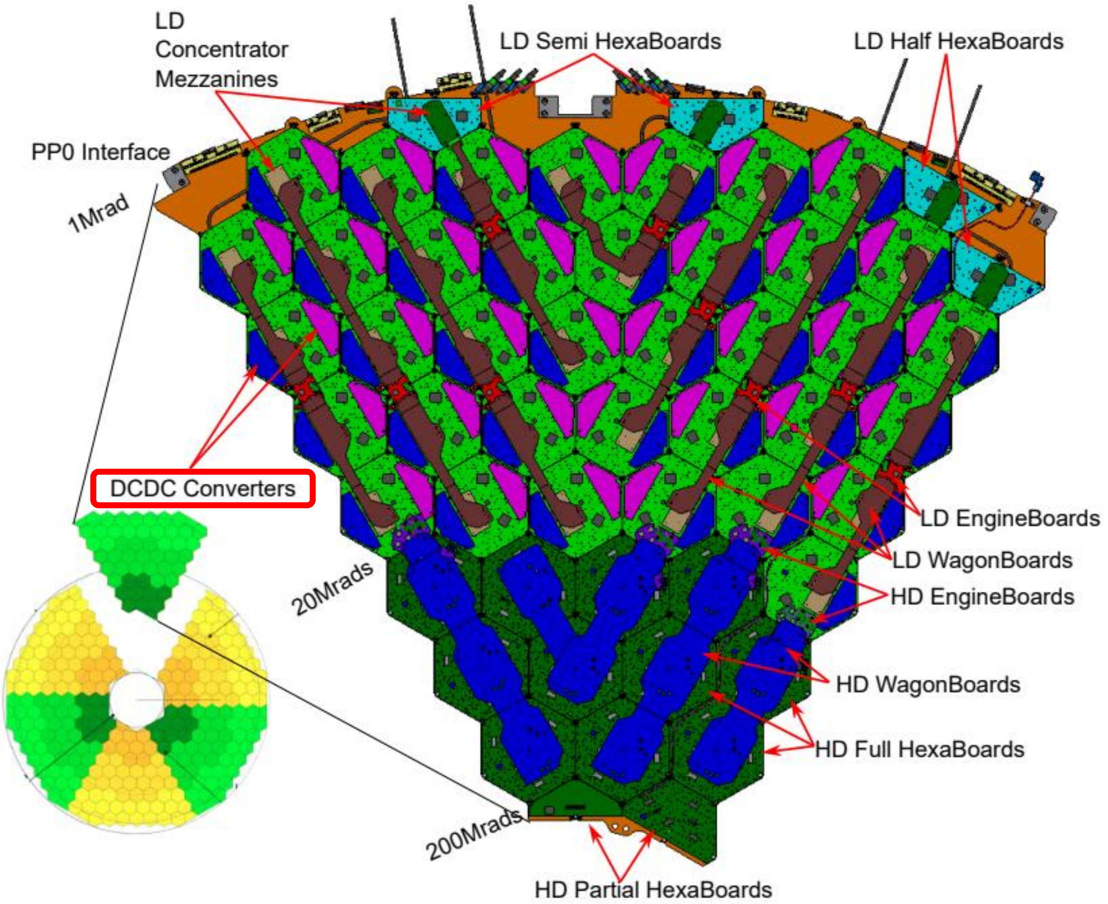
bPOL12V_V6 max specifications: **150Mrad, 7e15n/cm2**

bPOL12V use in HGCAL is limited to the LD region
due to the high radiation levels reached in the HD region.
Still, it is used to power both the LD and HD Hexaboards and Engines.

TID max	150Mrad
SEE max	45 MeV/(mg/cm²)
DD max	7e15n/cm2 1.2e15p/cm2 (27MeV) 2.34e15p/cm2(230MeV) 4.71e15p/cm2(24GeV) 4e14p/cm2 (27MeV) + 6e14 n/cm2

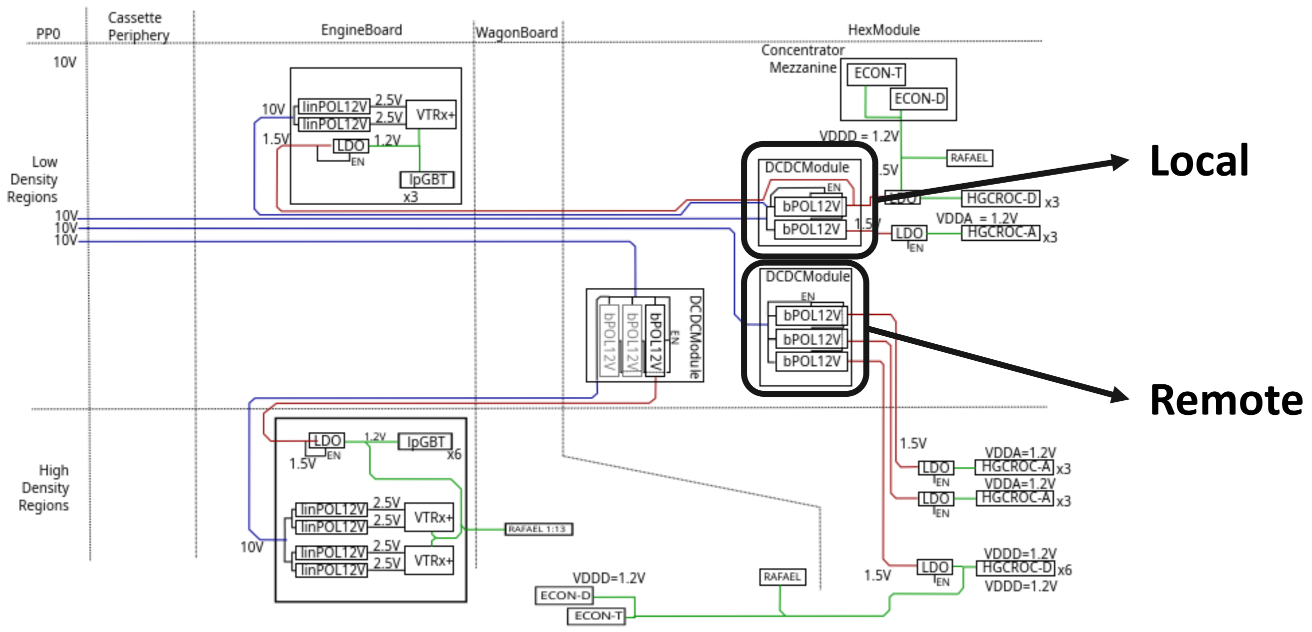
DCDC project - Home (cern.ch)

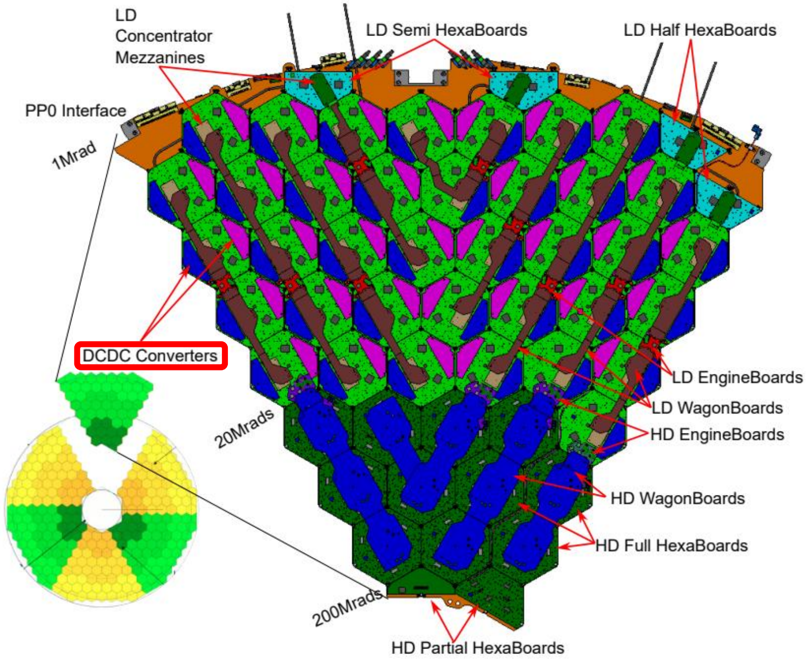
Courtesy of Matthew Noy



Local and Remote bPOL12V DCDC modules

Courtesy of Matthew Noy





The most common variants of DCDC mezzanines across HGCAL will be the Local and Remote:

- **The Local hosts 2xbPOL12V powering the LD Hexaboard on which it is mounted**
  LD Hexaboard (full) current requirement : Analog: ~1.95A Digital: ~1.65A
  (up to ~2.92A when powering also the LD Engine)

- **The Remote hosts 3xbPOL12V powering an HD Hexaboard, further inside the cassette**
  HD Hexaboard (full) current requirement: Analog1: ~1.95A Analog2: ~1.95A Digital: ~2.12A

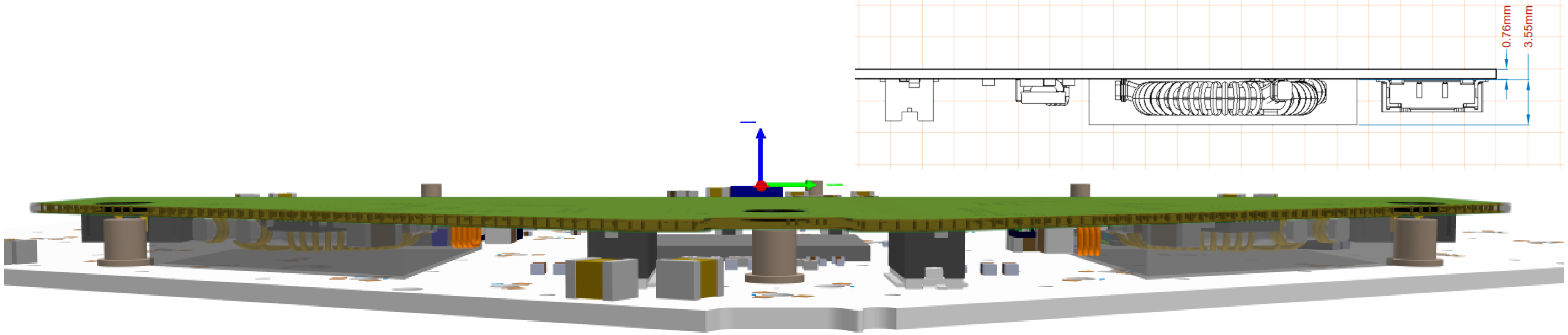
Integration & Design

Integration of the Local and Remote bPOL12V

The available space above the LD Hexaboard in which the Local and Remote fit is 5.1mm.

The Local is connected to the Hexaboard through a 4mm high connector,
three countersunk screws fix the PCB to SMT tapped spacer mounted on the Hexaboard, **the DCDC PCB thickness is ~0.76mm**.
HGCAL custom toroidal coil height is 3mm, **the custom shields height is 3.55mm**,
the air gap between the shield and the Hexaboard is filled with a 0.5mm thick thermal pad.

The Remote board integration is similar,
in this case there is no SMT electrical connector between the DCDC mezzanine and the Hexaboard,
the Remote shields will be sitting on the gap pads and fixed similarly through 3 countersunk screws to SMT tapped spacers.



Integration of a Local DCDC board on top of the LD Hexaboard

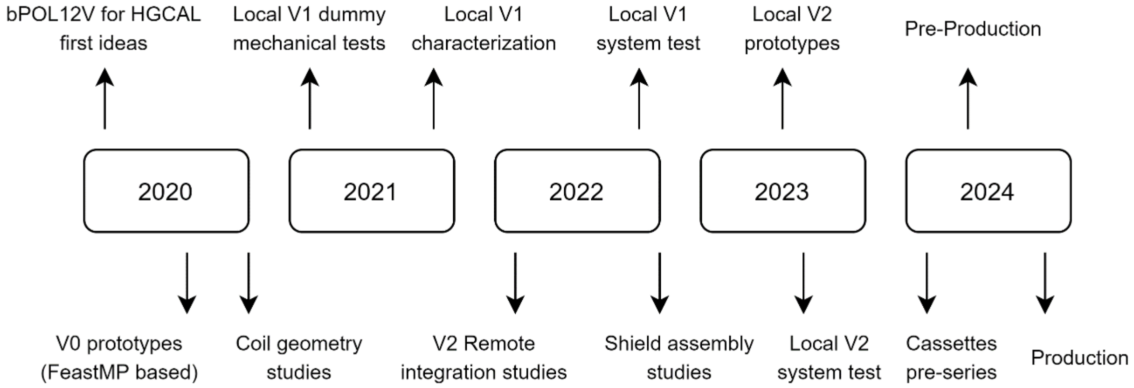
Design development: V1 and V2

The Local V1 PCB design was reviewed with focus on:

- Mechanical aspects:
  coil, shield, gap pad thickness,
  integration on the LD Hexaboard

- Electrical aspects:
  schematic and component choice,
  layout and stackup,
  main parasitics extraction

[DC-DC Mezzanine Review (20 May 2021) · Indico (cern.ch)]

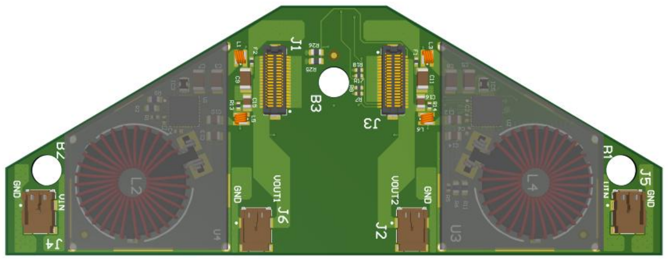


With many thanks to all the people involved in the development so far:
Boyuan Peng, Zhen Lin, (Zhejiang University),
Matthew Noy, Karol Rapacz, João Pedro Almeida, Pablo Antoszczuk (CERN)

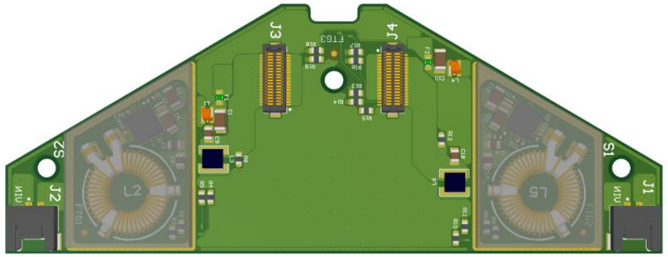
V2 PCB design main improvements:

- Continuous shield footprint for improved soldering:
  reduces the noise level on the LD module

- Optimized shield size:
  allows to integrate three bPOL12V in the Remote



V1 Local



V2 Local

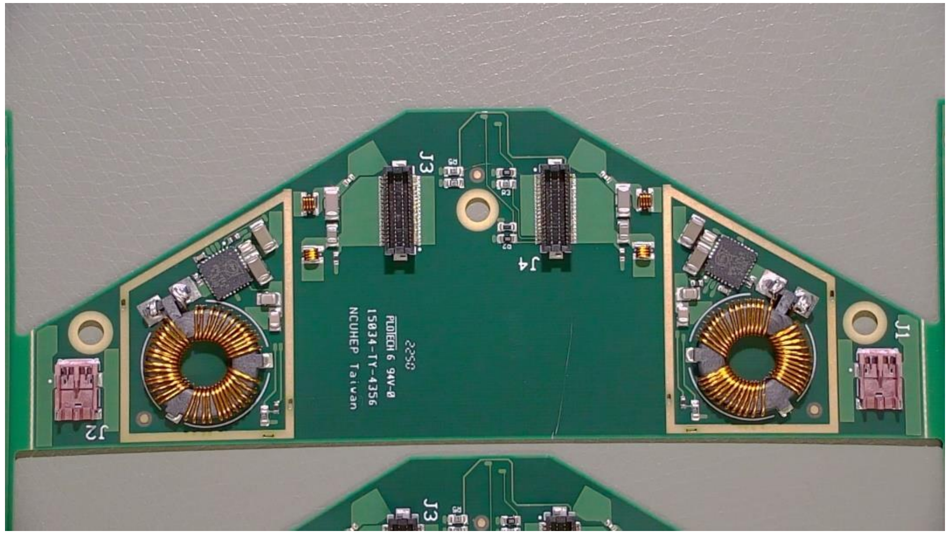
Custom toroidal coils

Custom toroidal coils

L = 220nH
fswitch = 2.5MHz
DCR = 35mΩ
Diameter = 12mm
Supplier 1

L = 460nH
fswitch = 1.7MHz
DCR = 60mΩ
Diameter = 16mm
Supplier 1

L = 460nH
fswitch = 1.7MHz
DCR = 60mΩ
Diameter = 16mm
Supplier 2



bPOL12V buck converter works featuring an inductance $460nH < L < 220nH$

An air core inductor must be used due to the high magnetic field present in CMS-HGCAL the toroidal geometry has been chosen to minimize the radiated magnetic field.

There are no commercial products that satisfy our needs in terms of: geometry, materials and electrical properties.

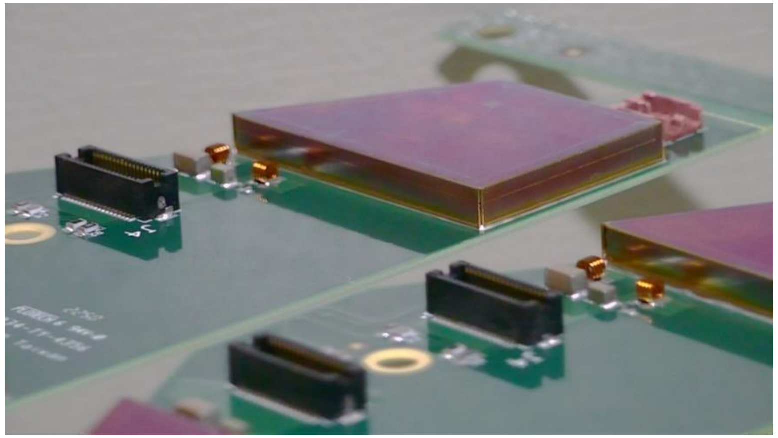
The custom 460nH coils proposed by two different suppliers guarantee similar results, both are compatible with pick and place machines for automated assembly and reflow soldering, to be assembled as a standard SMT part.

Custom EMI shields

Custom EMI shields

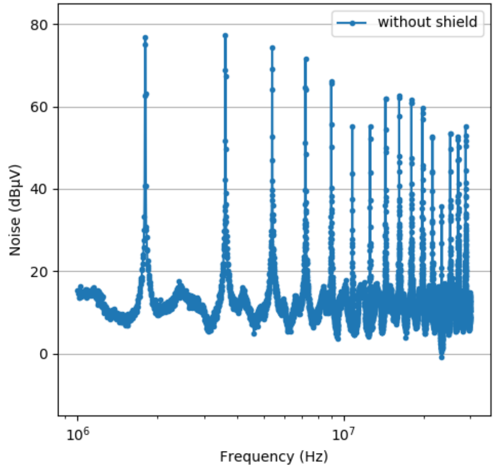
Shields prototyped by bending CuNi18Zn20 (a standard material used by EMI shield suppliers) and pure copper were compared using V1 DCDC boards.
EMC tests show how the higher electrical conductivity of pure copper improves the shielding.

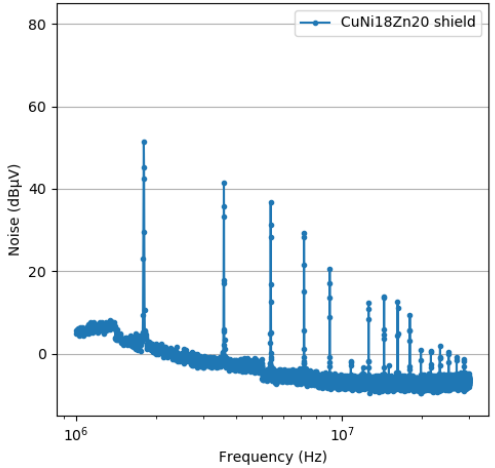
The on-board shielding is realized using a fully SMT 0.2mm thick copper shield (designed in three different variants) with matte tin plating over nickel for improved solderability.
The first samples should be prototyped and assembled on V2 boards before the end of 2023.

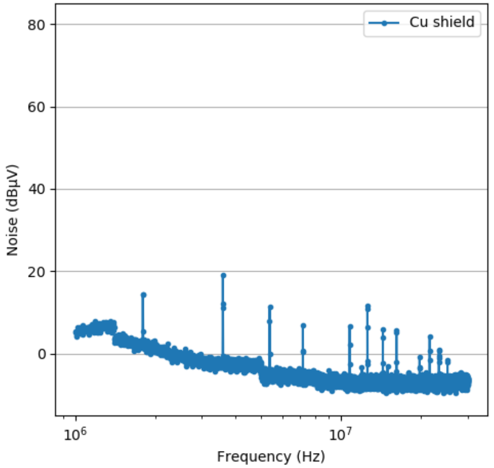


Prototype shield: pure copper foil 0.2mm thick

EMC tests: radiated noise (H)







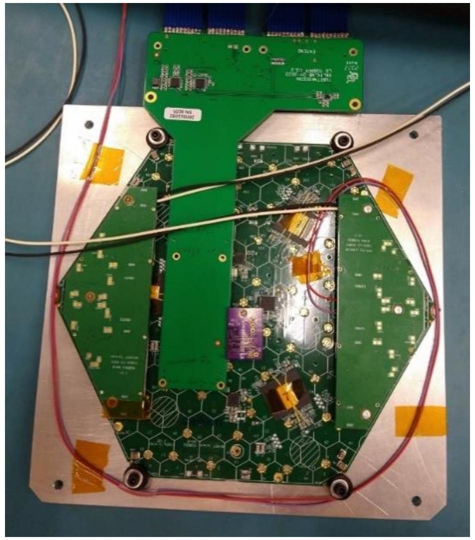
Performance at system level

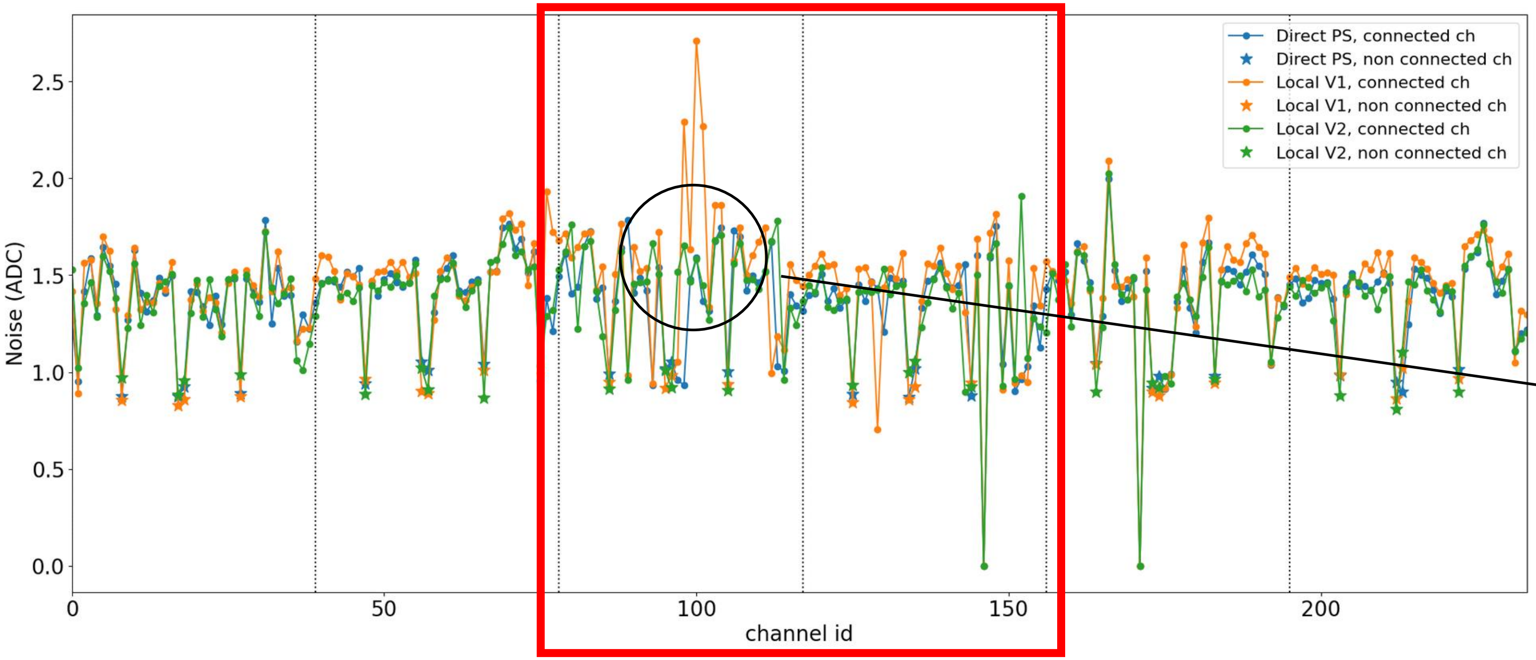
V1 and V2 Local impact on the Hexamodule noise

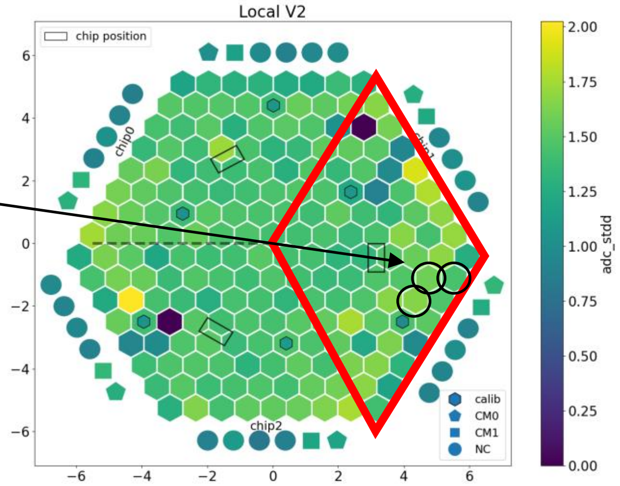
Both V1 and V2 Local DCDC boards have been tested with a full LD Hexaboard module.

While the V1 Local induced a spike in the noise measured on the LD Hexamodule,
V2 Local DCDC has no major impact on the noise level.

Local 2xbPOL12V module supplying a full LD V3 Hexa-module + Remote 2xbPOL12V

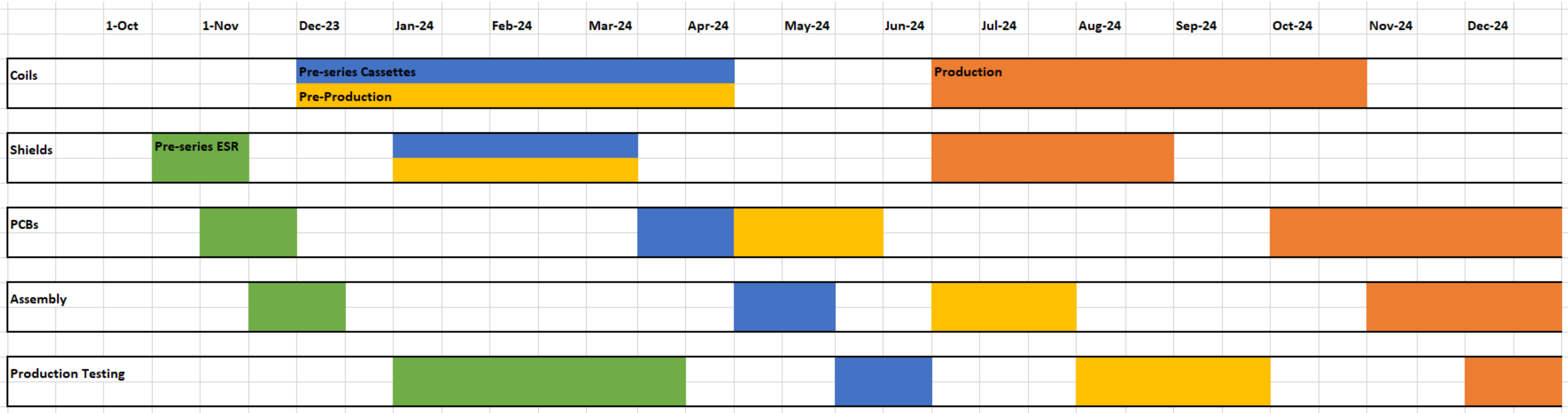






Planning

Planning



Quantities involved:

Pre-series ESR	200 bPOL12Vs	80 modules
Pre-series Cassettes	~500 bPOL12Vs	~200 modules
Pre-Production (5%)	~3k bPOL12Vs	~1.5k modules
Production	~60k bPOL12Vs	~25k modules