Power supply requirements, maintenance service and test facilities at CERN

Outline

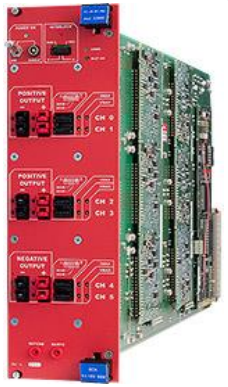
- Power supply and crate service
- Market survey context
- Technical description key elements
- Possible test qualification facilities at CERN

Power supply and crate service

Main activities

- PS and crate equipment for the LHC experiments
  - Procurement & maintenance frame-contracts
  - Repair, verification services and user support
  - Preventive maintenance campaigns
  - Equipment tracking from purchase through repairs and modifications
  - Qualification of new equipment
- Evaluation projects
  - Evaluation of commercial components (New shelves and power supplies)
  - Development of dedicated test tools
- Test systems and technical DB
  - Development and maintenance of automated LV and HV power supplies test rigs
  - Maintenance of dedicated technical DB for equipment tracking and follow up







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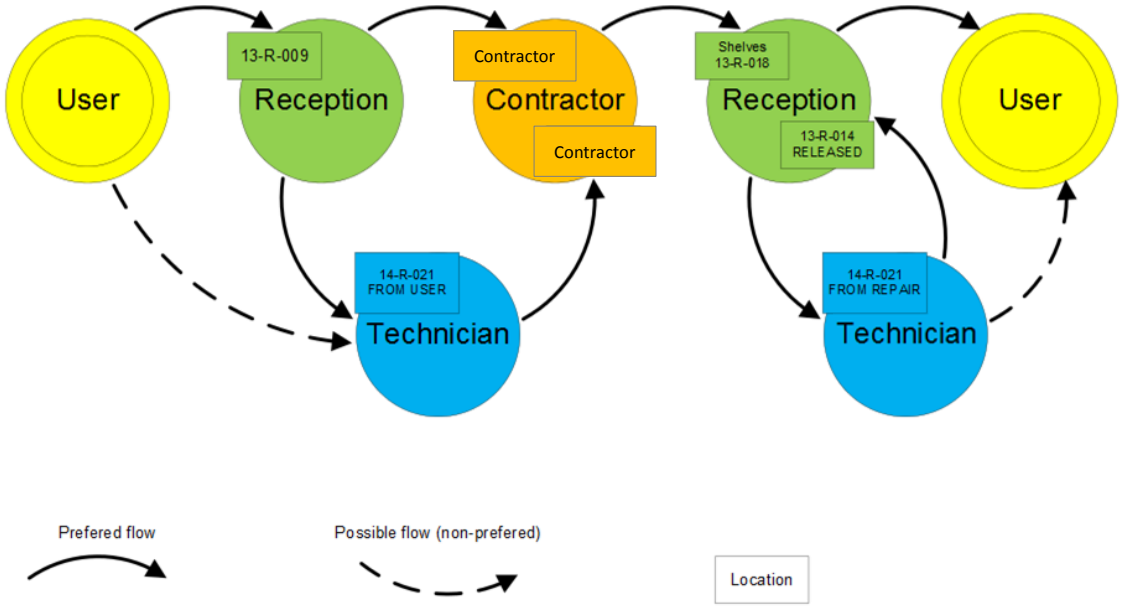
Power supply and crate service

Main activities

- PS and crate equipment – Procurement and maintenance contract operation
  - Grouped common procurement release orders (every quarter)
  - Centralised support for repairs (fixed repair prices)
  - Central service: Interactions point for users and vendors
  - Tracking and follow up process



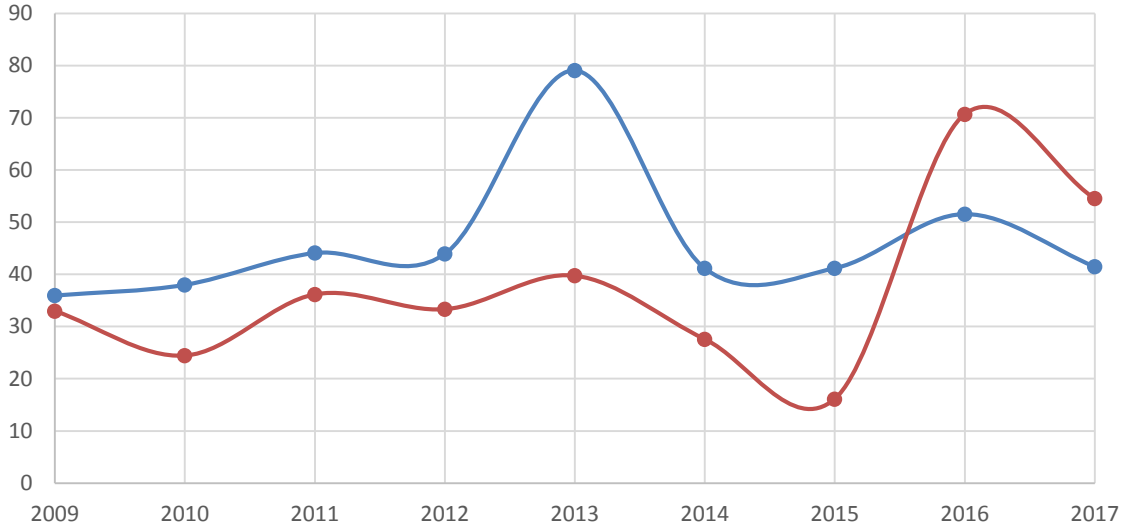
Power supply and crate service

LHC experiments power supply and crate equipment

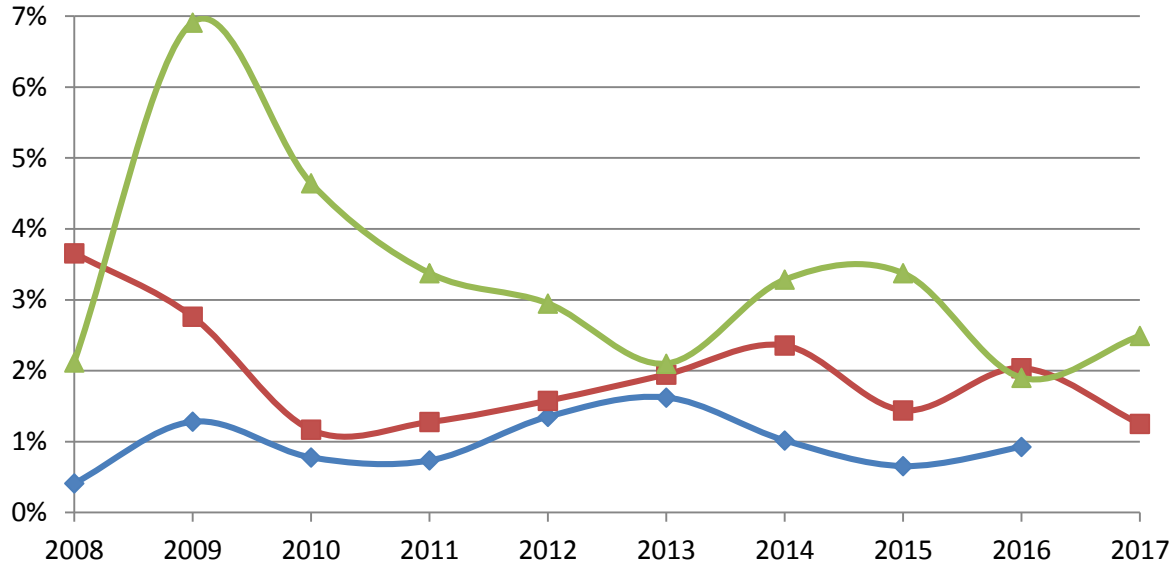
- Equipment quantity: Over 13’000 units (~ 25 MCHF)
- First equipment delivered in 2005
- 300 to 600 PS tests performed yearly
- Long shutdown 1 (2014) preventive maintenance campaign (mostly fan exchange): About 1000 devices

Technical DB: Equipment tracking

Average repair turnaround time (days)



Annual failure rate



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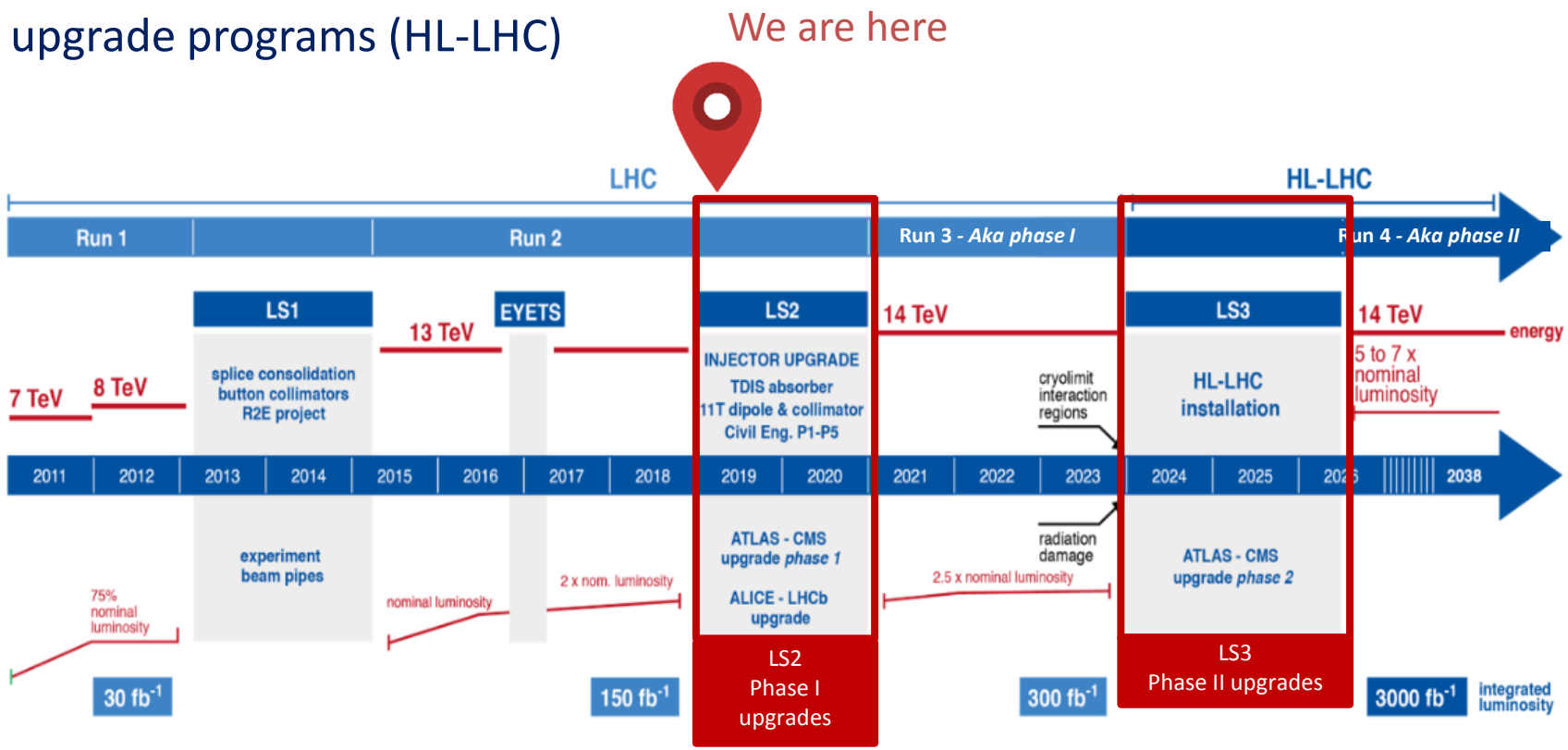
Market survey context

LHC Roadmap: Schedule beyond Long Shutdown 2 (LS2)

LS3 for the LHC experiments

- Atlas and CMS have important upgrade programs (HL-LHC)
- Implies new sub-detectors, new electronics
- New powering infrastructure required



Market survey context

Goal of the market survey

- Broad spectrum
  - Covering different needs
  - Experiments are large international collaborations
  - Lots of different detectors each with different powering needs
- Selection of candidate manufacturers before development, prototyping and call for tender
  - Prepare purchasing process for the users (detectors)
  - Make the development, prototyping and call for tender processes easier and faster for the users
- Include the long term availability and maintenance requirements
  - Purchase order to be accepted 15 years after completion of series production
  - On-site support and maintenance on-call or at regular interval for a period of 15 years after completion of series production
  - Corrective maintenance during the warranty period on the CERN site if so requested
  - Immediate technical support from within Europe during normal office hours during the entire lifetime of the equipment

Market survey context

On-site support – Working on the CERN site

Information relating to the applicable access and working conditions for contractor working on the CERN site can be found through the links below.

https://procurement.web.cern.ch/en/key-reference-documents
(«Working on the CERN-site» document)

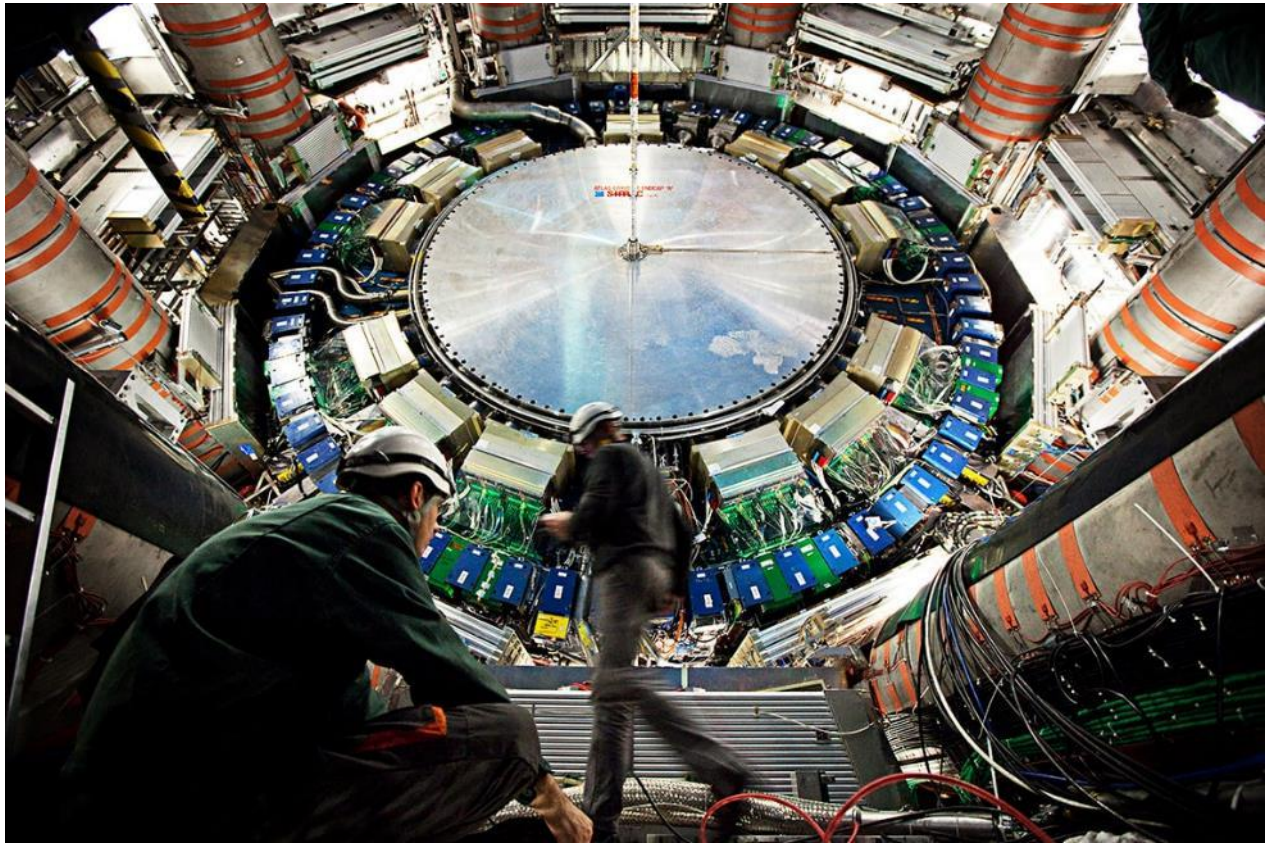
https://hse.cern/content/safety-rules
CERN health, safety and environemental protection unit

Bidders shall take this information into account when drawing up their bid working on the CERN site.

Market survey context

Large variety of power supply types (and layouts)

- Each detector has different constraints …
  - Powering needs
  - Locations (related environmental constraints)
  - Physical/space limitations
  - Cooling requirements/constraints
  - Control granularity
  - Etc.
- … and different system choices
  - Dedicated radiation tolerant POL DC-DC converter
  - Own-custom developed AC-DC and/or bulk DC-DC
  - Dedicated shunt LDO chip for serial powering
  - Etc.



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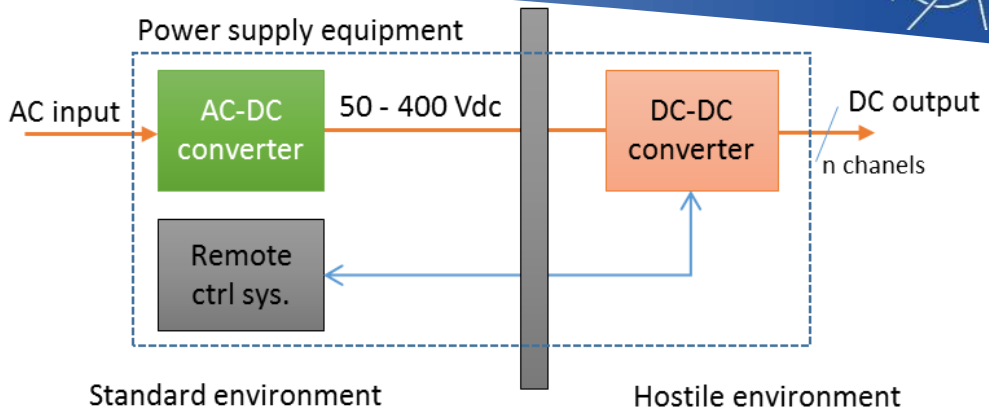
Technical description key elements

Power supply technical requirements

- Electrical input
  - 400/230V nominal, 50Hz three or single-phase supply
  - DC input telecom industry 48V to 400V typically
- Optional intermediate DC stage
  - In specific cases, distributed power supply systems (AC-DC separated from the DC-DC conversion stage) might be required
- DC output
  - Grouped in 7 main types, different voltage, current and channel count
  - Detailed requirements will likely be specific to each sub-detector
- Efficiency
  - Overall efficiency better than 85% above 40% of nominal load



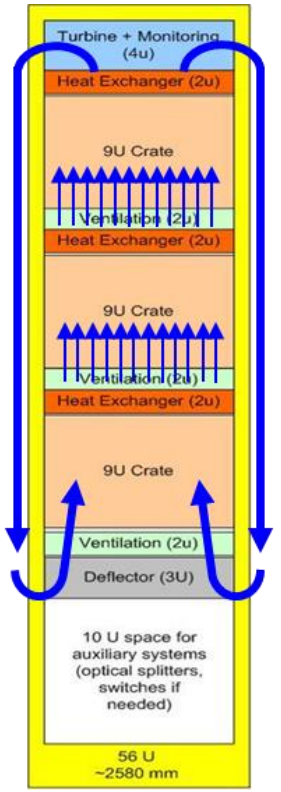
Implementation example

MS for LV and ELV power supplies							
Type	Category	Electrical charateristics				Environment	
		nominal DC output voltage [V]	output current per ch. [A]	channel number	Regulation	Standard	Hostile
A	ELV	up to 60	up to 20	up to 14	Regulated voltage source	x	x
B	ELV	up to 50	up to 20	up to 10	Regulated current source[1]	x	x
C	ELV	up to 25	up to 200	up to 17	Regulated voltage source	x	x
D	ELV	up to 60	up to 80	up to 2	Regulated voltage source with optional redundancy	x	
E	LV	up to 1500	up to 50 mA	up to 24	Regulated voltage source	x	x
F	HV	up to 4000	up to 1 mA	up to 8	Regulated voltage source	x	x
G	HV	up to 12000	up to 1 mA	up to 32	Regulated voltage source	x	x
1: Required for serial powering applications							

Technical description key elements

Power supply technical requirements

- Monitoring and control
  - OPC-UA compliant monitoring and control SW. See Ben Farnham's presentation after the coffee break
- Environment
  - Standard
    - No significant radiation or magnetic fields present – a "normal" industrial environment
  - Hostile (maximum numbers, specific to each sub-detector)
    - Radiation and/or magnetic fields present
    - Stray magnetic fields up to 5500 Gauss (550 mT)
    - Total ionising radiation up to 1 kGray
    - Neutrons fluence up to $6x10^{12}$ 1 MeV eq. neutrons/cm2
  - Underground area
    - CERN safety instructions - Halogen free cable isolation and PCB substrate
- Cooling
  - In most cases, equipment installed in ventilated racks (vertical bottom up recirculating airflow)
  - Where stray magnetic field is present fans with electric motors may not function. Other means of heat removal may be foreseen for PS equipment cooling



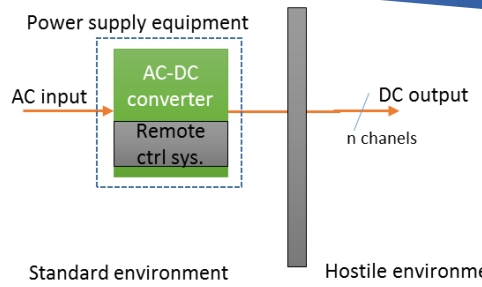
Front view of most LHC experiments electronics rack

Technical description key elements

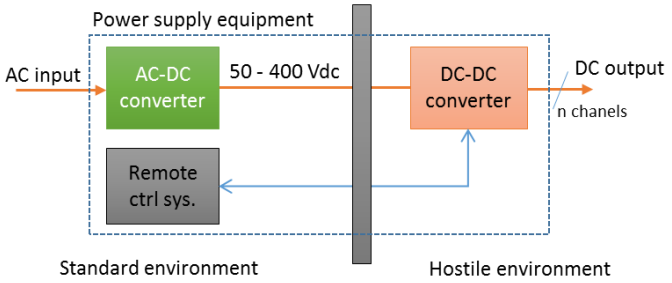
Various possible implementations of PS systems

- Illustration cases given here are not exhaustive
- Combinations of systems possible in certain applications (e.g. HV - LV combinations)
- In some cases, the required power supply will only be a sub-part of the entire powering system (e.g. DC-DC only or first stage AC-DC only)

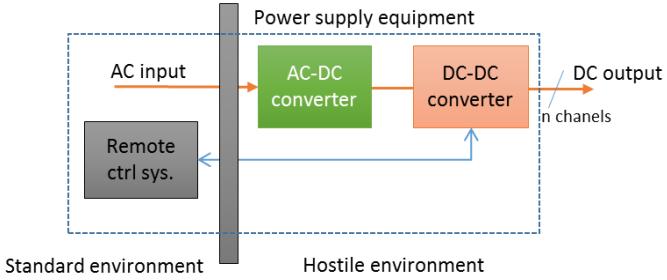
Case 1
- AC-DC PS in standard environment
- Integrated control and monitoring



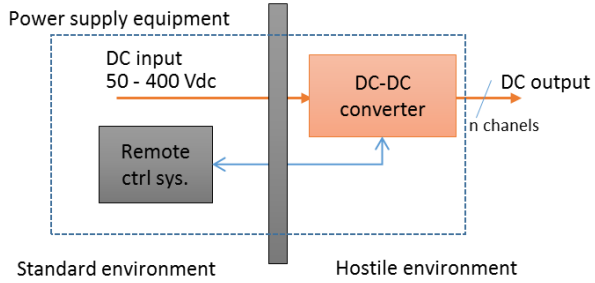
Case 2
- AC-DC in standard environment
- Rad+Mag tolerant DC-DC
- Remote control and monitoring



Case 3
- Rad+Mag tolerant AC-DC and DC-DC in hostile env.
- Remote control and monitoring



Case 4
- Rad+Mag tolerant DC-DC
- Remote control and monitoring
- DC supply from an external source



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Technical description key elements

Example 1

Use case: CMS Outer Tracker - Implementation considerations

LV backend system located on balconies in UXC

- LV cables length < ~50m in order to limit Vdrop
- Bfield ~ 25 mT and 1-10 Gy in 10y HL-LHC

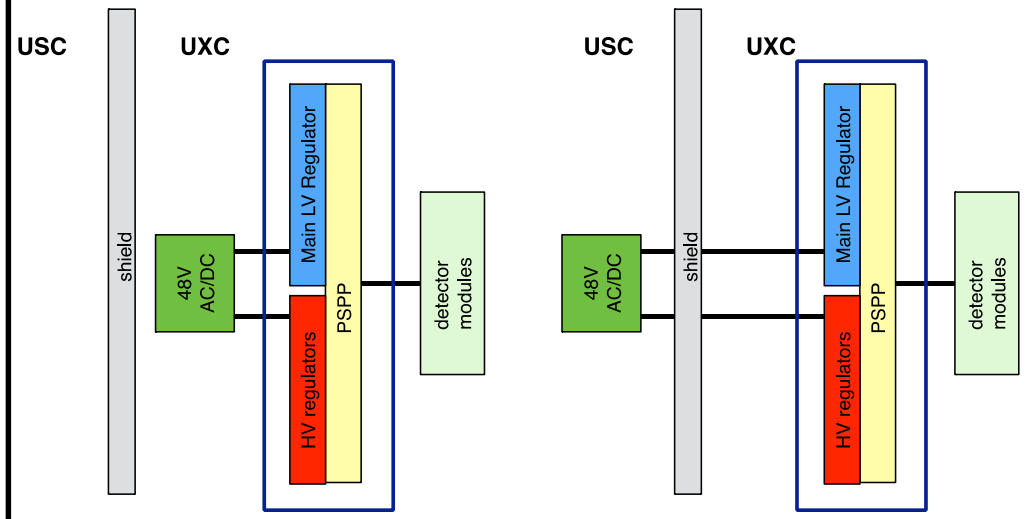
Specific constraint: Interlocking of individual LV-HV channels

(slide: courtesy of Simone Paoletti, CMS)

LV and HV systems on same racks in UXC:

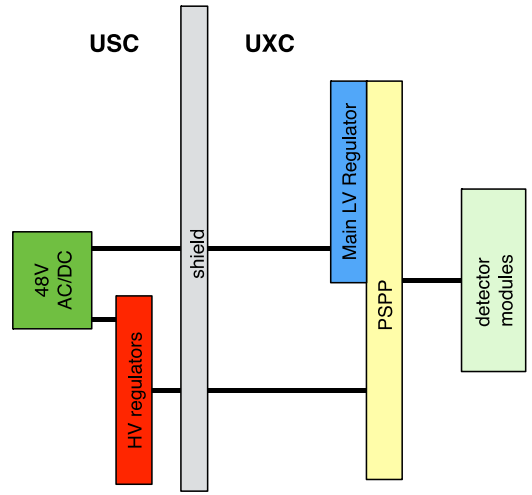
- easier implementation of LV/HV interoperation
- sharing interface to interlocks and DCS

48V can be either inside or outside UXC



HV and 48V system in USC

- non-hostile area
- can look to commonality with other sub-detectors
- LV main regulator, LV channels (PSPP), HV channels implemented as separate pieces



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Technical description key elements

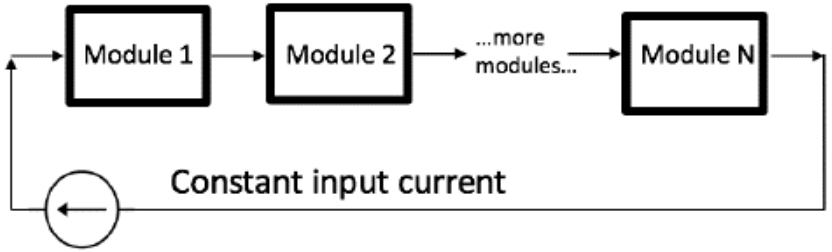
Example 2

Use case: Pixels - Serial powering

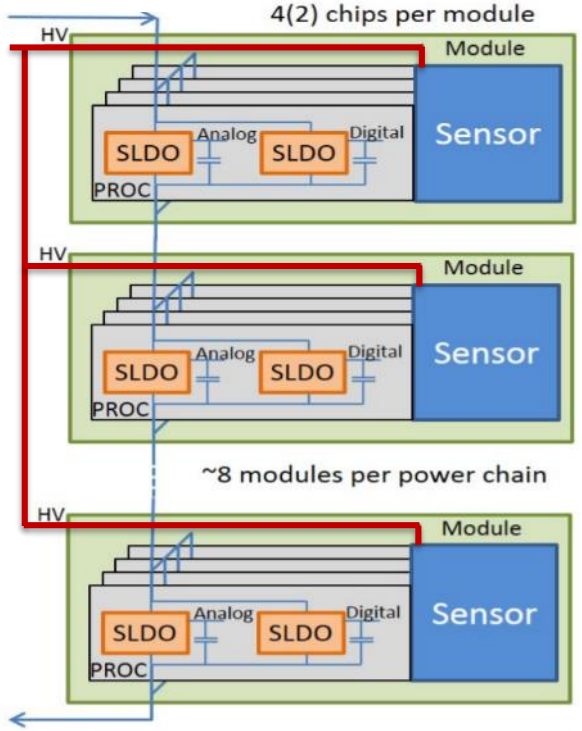
Serial powering identified as the baseline choice for powering the CMS and ATLAS HL-LHC pixel detectors.

Based on a shunt-Low Drop Out regulator design:

- ✓ **Low mass**
  - ✓ power cabling reduction length of chain
- ✓ **On-chip integrated solution**
- ✓ **Radiation hard**
- ✓ **Not sensitive to voltage drops**
  - ✓ Could reduce even more the cabling material budget
- ✓ **Smooth Operation with low noise**
  - ✓ Not sensitive to dynamic load changes



8A (4A), 12V



Across-module serial powering:

- Pixel detector modules serially powered.
- Up to four chips per module powered in parallel.
- Modules/ sensors grounds differ inside a chain.

- **A power supply current (Iin)** "re-used" among multiple loads connected in series.
- Enough current injected in the power loop to satisfy the highest possible load current.
- Total current constant- **independent of the actual current consumed in the load**.

(slide: courtesy of Stella Orfanelli, CMS)

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Possible test qualification facilities at CERN

Specific test facilities available at CERN

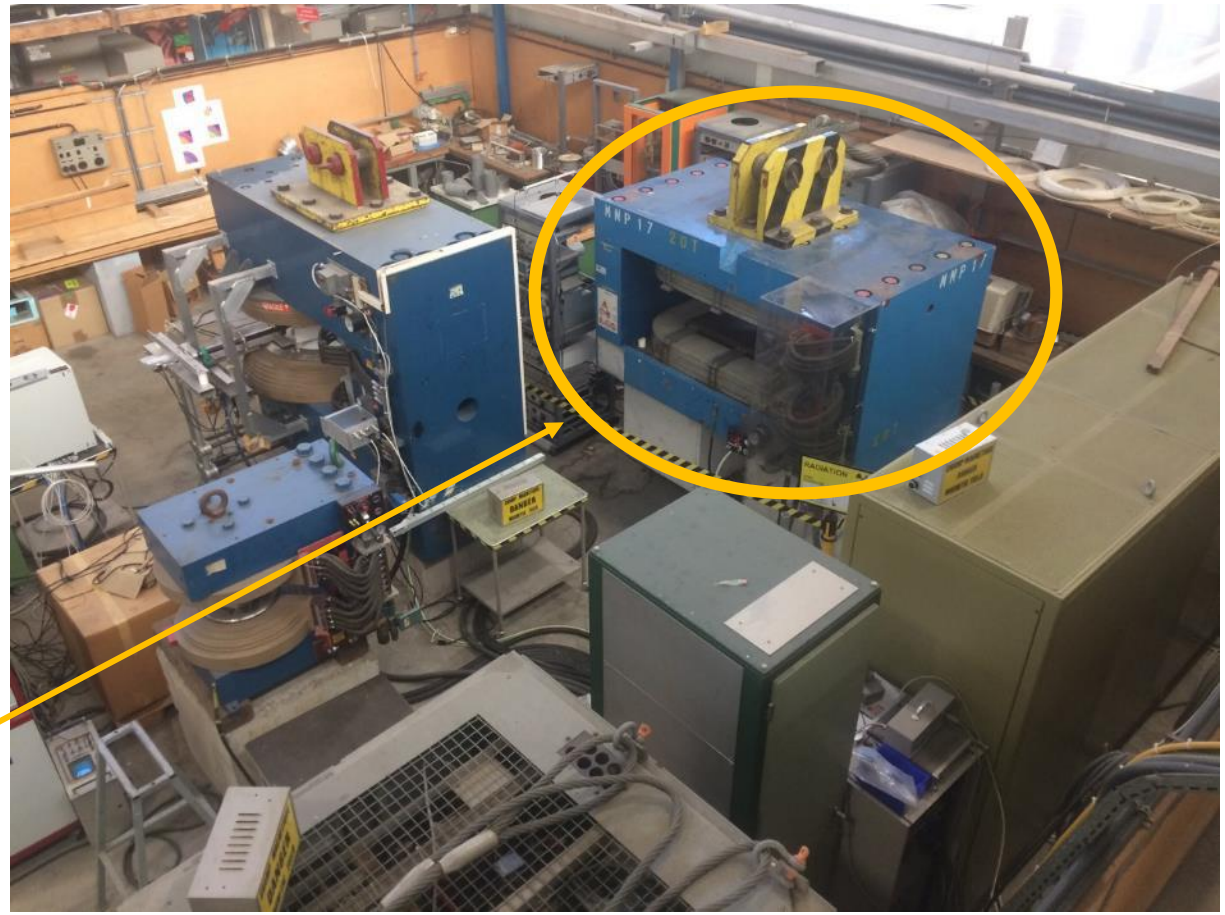
- Beam facility (e.g. IRRAD proton facility) to perform radiation tolerance tests
  - See the next presentation

- Large magnets for magnetic stray field tests of power supplies

Possible test qualification facilities at CERN

Magnet Test Facility at CERN

- Located on the main CERN site (Meyrin)
- Access to building convenient (i.e. not restricted providing one has access to CERN site)
- Access to enclosure requires prior scheduling & arrangement with facility supervisor
- Assistance for interfacing with facility supervisor & operating the magnet will be available
- Facility contains several large magnets, all capable of fields in excess of 2 Tesla, well more than expected in the target environment
- Highest fields request for DC power supplies is 5500 Gauss (550 mT)



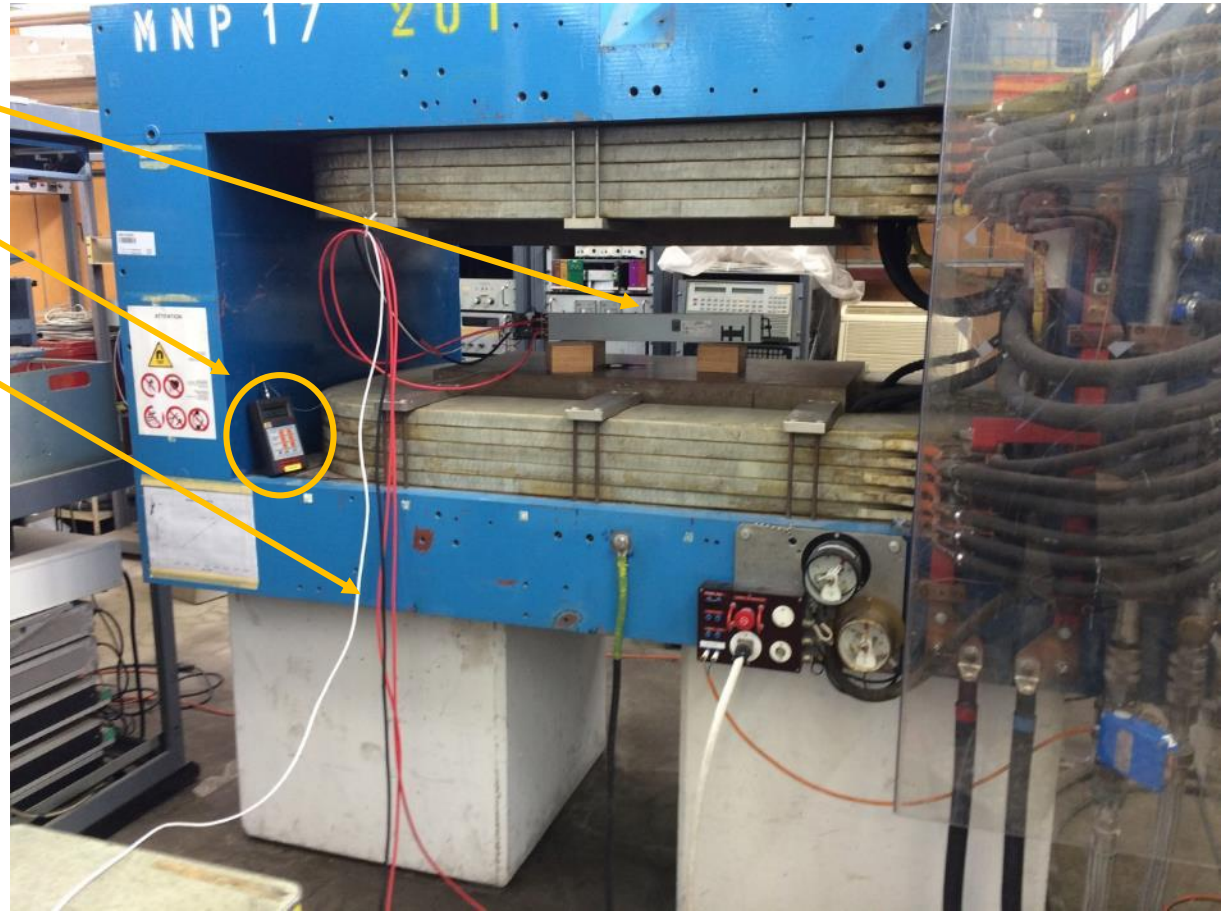
Most convenient general-purpose magnet is MNP17, which has pole pieces of 100 x 50 cm, with 30 cm separation

(slide: courtesy of Sergei Lusin, CMS)

Possible test qualification facilities at CERN

Device Under Test in MNP17 Magnet (example)

- Commercial server power supplies were tested for magnetic-field tolerance using this magnet
- Device under test, mounted on phenolic blocks
- Calibrated field strength meter (available from facility coordinator)
- Power & control cabling connecting device under test to external equipment outside magnetic field zone (~3m length)
- This particular test demonstrated normal power supply operation up to 650 Gauss (65 mT) in one particular orientation. Magnetic-field tolerance levels in other orientations were significantly lower than that

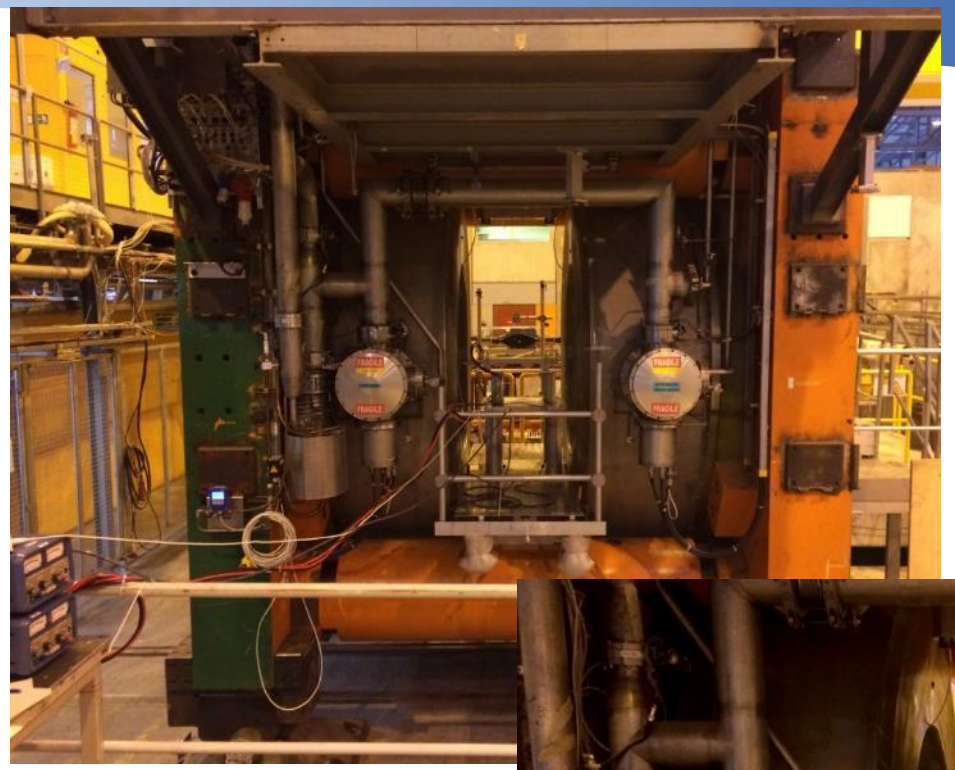


(slide: courtesy of Sergei Lusin, CMS)

Possible test qualification facilities at CERN

Alternate Facility: Superconducting Helmholtz Coil

- Useful for testing magnetic field tolerance along long axis of device for objects longer than 30 cm
- Again, capable of fields far higher than expected during operation in experimental environment
- Not as convenient as previous magnet. Sits in a restricted zone requiring special access & dosimeter



(slide: courtesy of Sergei Lusin, CMS)

Thanks for your attention

Questions ?