The Power Distribution System for the Mu3e Experiment

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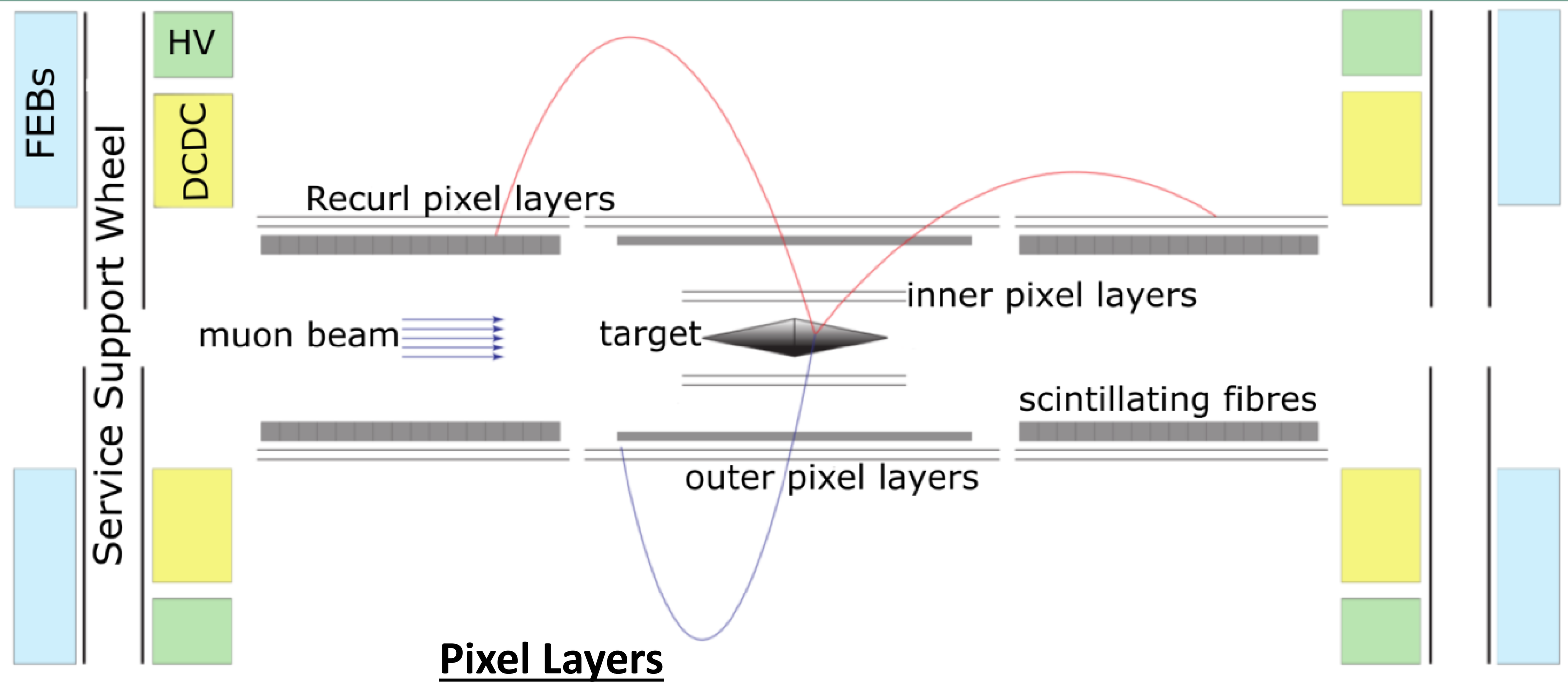
Summary

The Mu3e experiment under construction at the Paul Scherrer Institute, Switzerland, aims to search for the lepton flavour violating decay of a muon into one electron and two positrons with an ultimate sensitivity of one in 10^{16} muon decays. The detector for the Mu3e experiment consists of High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) combined with scintillating tiles and fibres for precise timing measurements. The entire detector and front-end electronics are located in the 1m diameter bore of a 1T superconducting magnet. A compact power distribution system based on custom DC-DC converters provide the detector ASICs and readout FPGAs with supply voltages of 1.1V to 3.3V with currents up to 30A per channel. 126 converters are placed as close as possible to the detector and provide 10kW of power in total. The final version is currently being designed and integrated into the experiment to be used during the upcoming commissioning runs. The poster presents the results of recent prototype tests and the path to the production of the full power system.

Mu3e Detector



Scintillating Fibres/Tiles
- Very good time resolution
- E.g. background suppression

Pixel Layers
- HV-MAPS
- Thin & high granularity sensors
- Combined with onboard signal processing → MuPix chips
- Very good spatial resolution

Frontend Boards
- Readout electronics
- Preprocessing & sorting of hits
- Send data to GPU farm

Power Requirements

Detector	# partitions	Vout [V]	Typical current [A]
Pixel layer 1	4	2.3-2.4	10.3
Pixel layer 2	4	2.3-2.4	10.3
Pixel layer 3	36	2.4-2.5	21.9
Pixel layer 4	42	2.4.-2.5	21.9
Fibres	12	2.2+	7
Tiles	28	2.2+/3.6+	39/.1

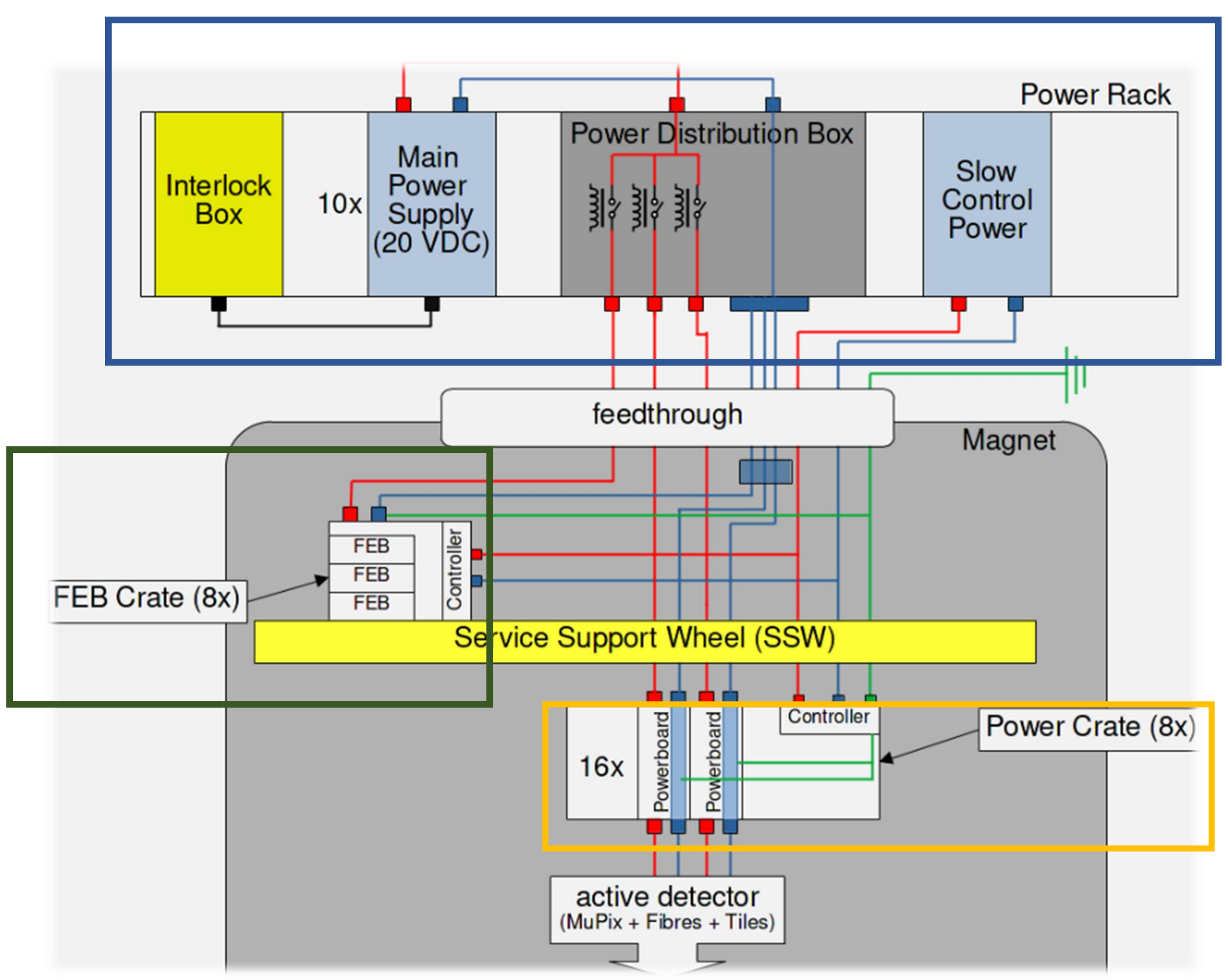
- Relatively low voltages required by the detector components (1-3.3V)
- Cables are very long → high losses through the cables
- Thicker cables are not possible due to space constrains
- Solution: DC-DC converters close to the detector parts step a 20V input voltage down to the required value
- Power distribution is segmented into power partitions

Outside the Magnet

Power Distribution Box
- Power supply outputs multiplied via relay bank
- Each power partition can be switched separately
- 112 power partitions for active detector (MuPix, Fibres, Tiles) (6A @ 20V)
- 8 power partitions for FEBs (20A @ 20V)
- In total : 120 power lines + 120 return lines are going into the magnet

Slow Control Power
- E.g. environment sensors, crate controllers, alignment systems
- Operate independent from main power

Mu3e Power Distribution System

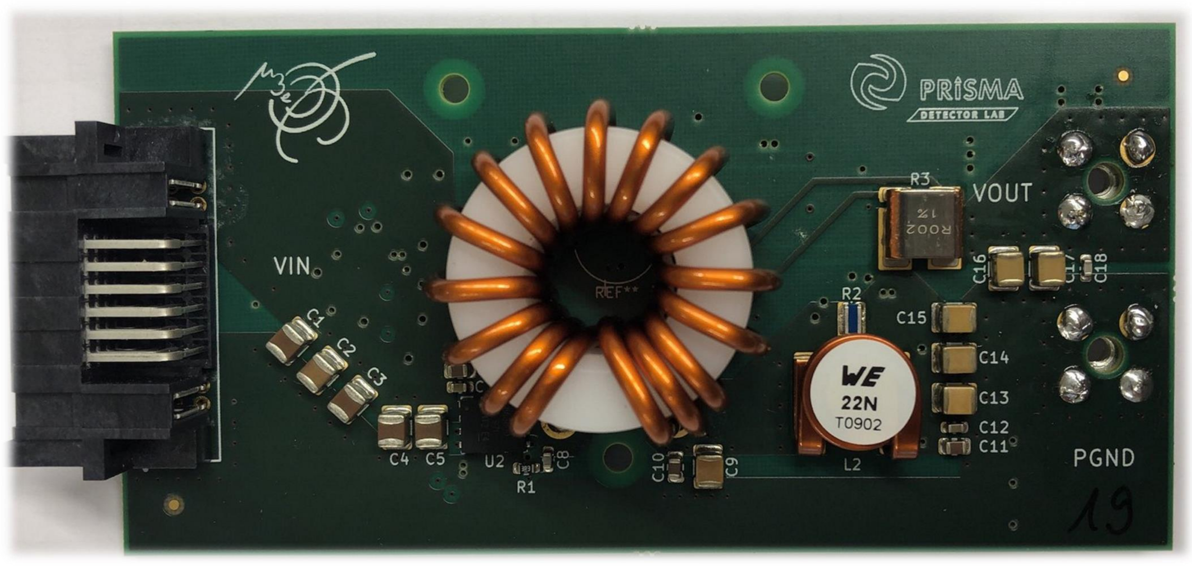


FEBs

Frontend Boards
- Located in FEB crates with a crate controller
- Each crate has its own power partition (8 in total)
- 3 buck converters embedded on each FEB
  → Stepping down 20V to 1.1V, 2.5V and 3.3V

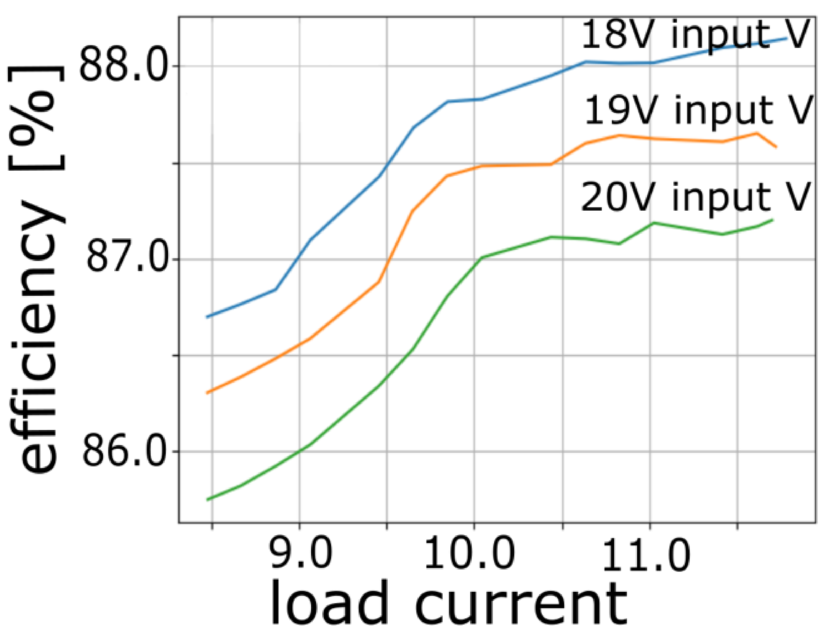
DCDC-Converters

Currently under test: Version V3

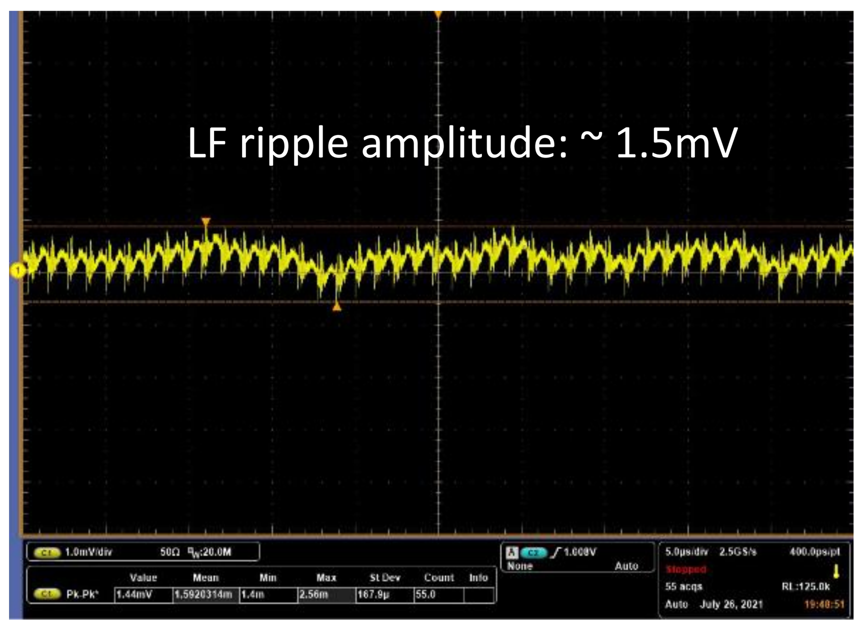


- Custom air coils needed
  → magnetic field
- Vin = 20V
- Vout = 2.1V
- L = 0.55uH
- C = 22uF
- Fswitch = 1MHz

Efficiency



Output Voltage Ripples



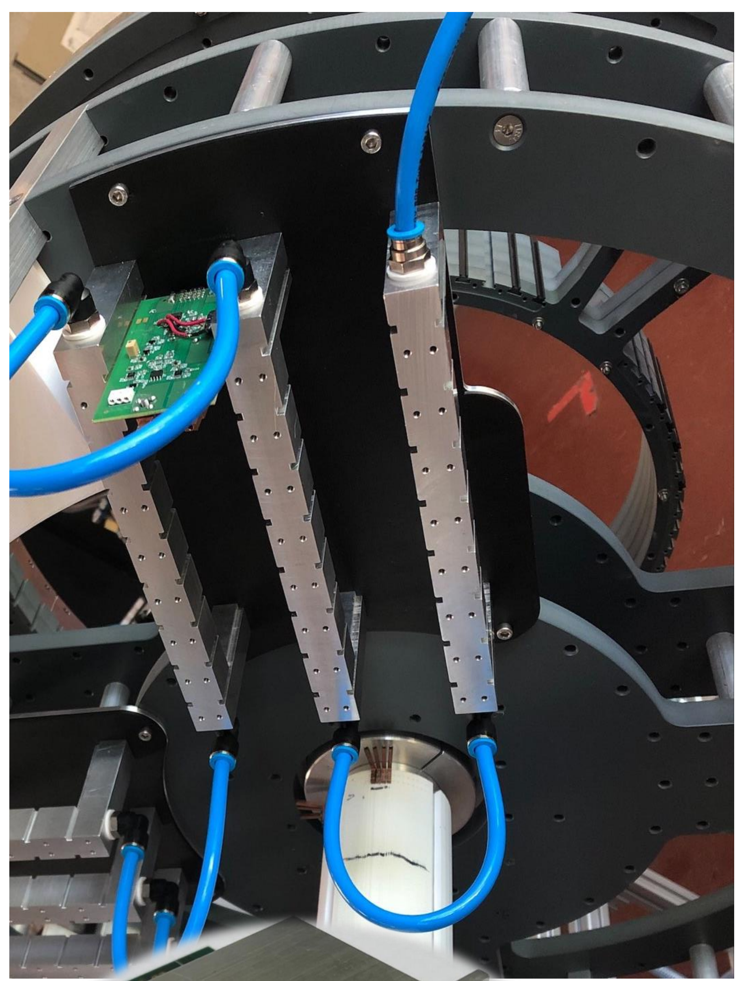
Special Features

Current Sense Measurement
- Monitoring the output current of the converter

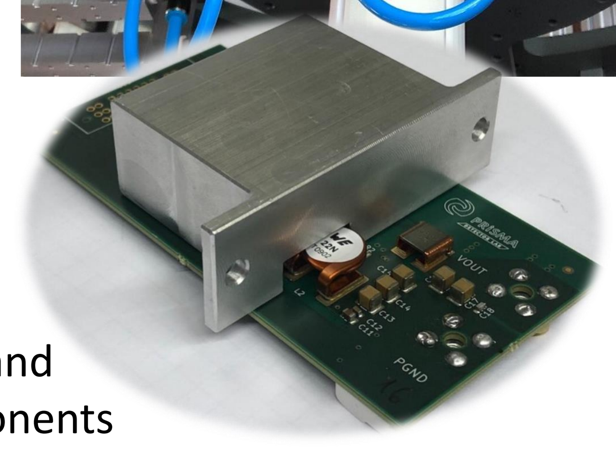
Voltage Drop Compensation
- Voltage drop in the cables to the load need to be compensated in the feedback loop

Temperature Interlock System
- System to prevent the detectors from overheating

Cooling Setup



The converters are water cooled



Aluminium block for electromagnetic shielding and colling of the critical components