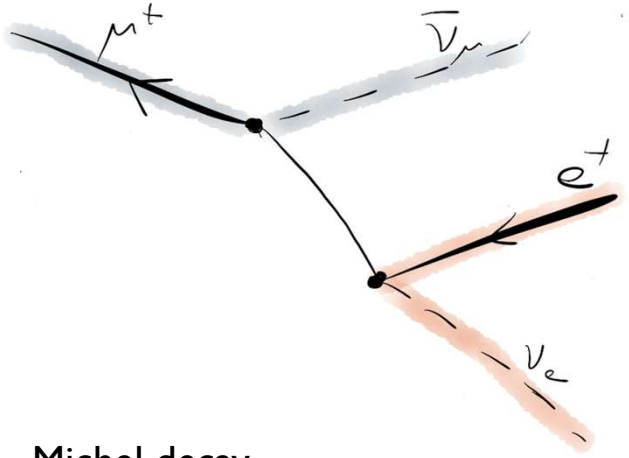
DEVELOPMENT OF A DC-DC CONVERTER FOR THE MU3E EXPERIMENT

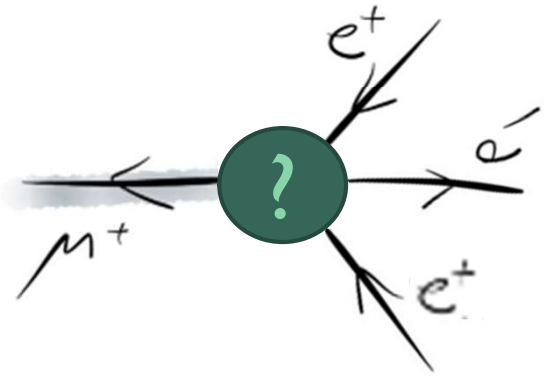
MOTIVATION



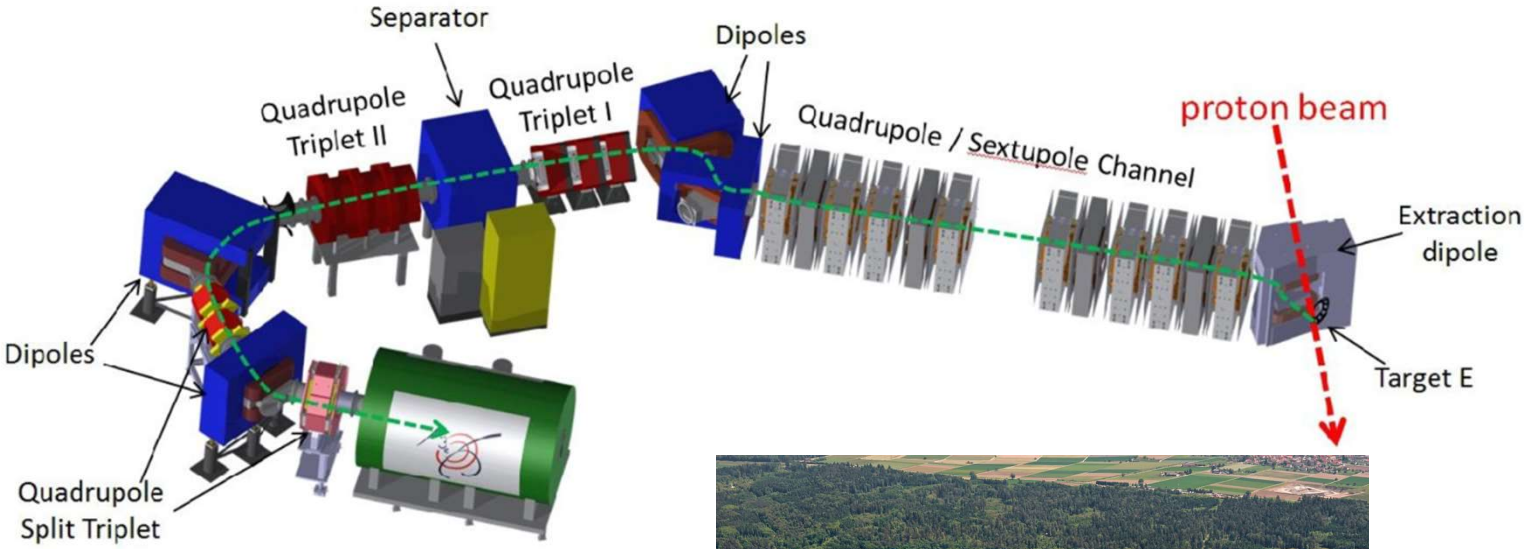
Michel decay

- Branching ratio nearly ~100%
- μ → eee suppressed in the standard model
  ⟹ lepton flavour violation

Theories of physics beyond the standard model



THE EXPERIMENT



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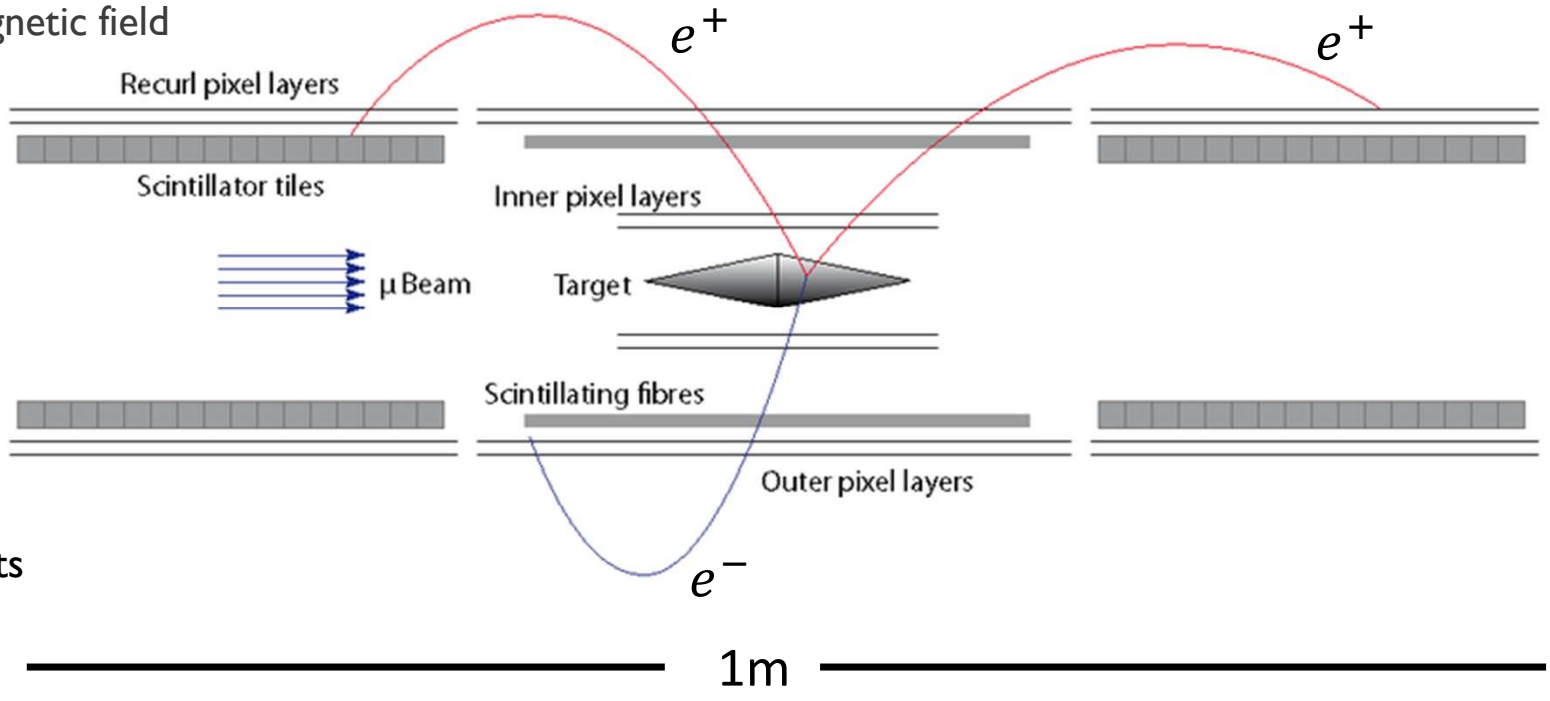
- High intensity muon beam
  - $10^7 - 10^8$ muons/seconds
- Sensitivity goal:
  B(μ→eee) ≤$2 \cdot 10^{-15}$

THE DETECTOR

- Placed inside a 1T strong magnetic field
- Three detector subsystems

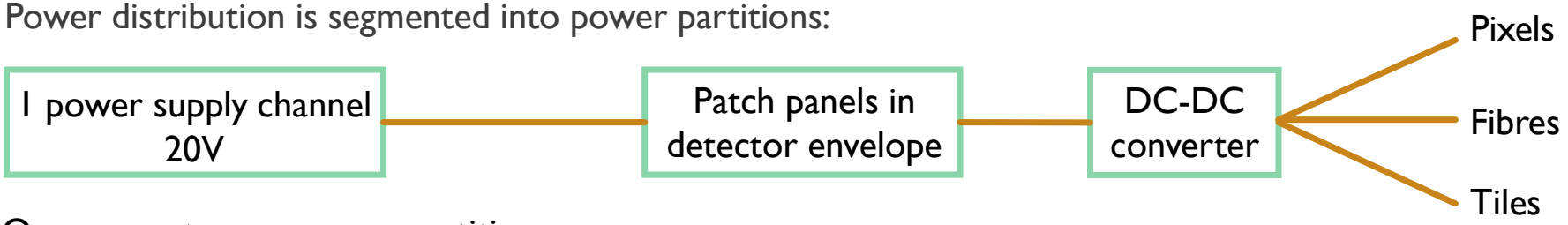


- Pixel detector (MuPix sensors)
  - Accurate track and vertex reconstruction
- Scintillating fibres
- Scintillating tiles

} Exact timing measurements

POWER REQUIREMENTS

- 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 according to size
- Solution: DC-DC converters close to the detector parts step a 20V input power down to the required value
- Power distribution is segmented into power partitions:

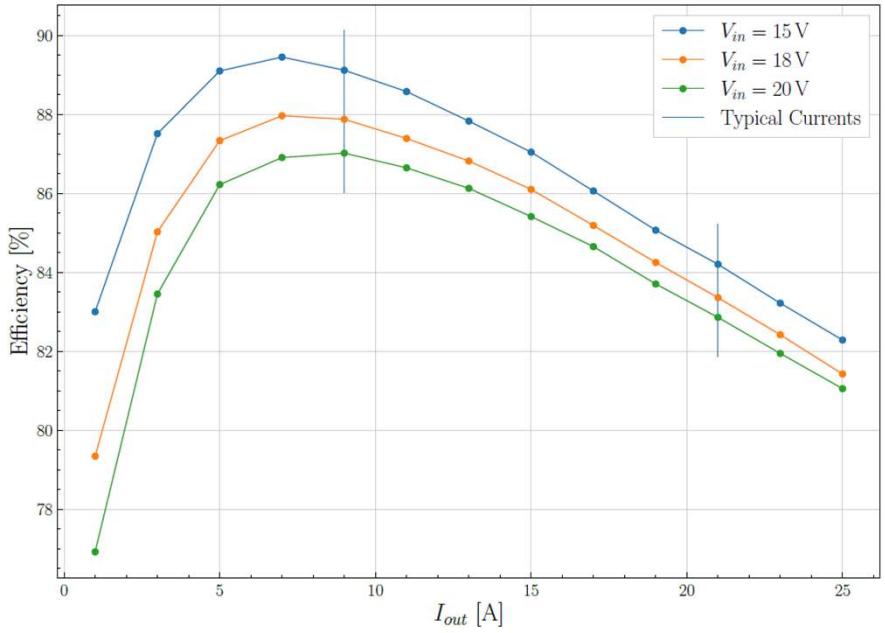


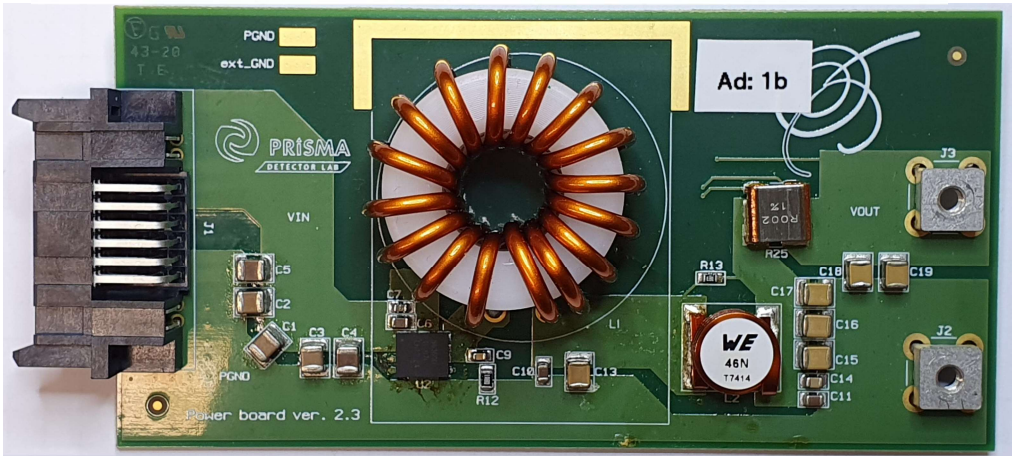
- One converter per power partition
- 126 in total

⟶ provide more then 9kW power in total!

THE MU3E DCDC CONVERTER

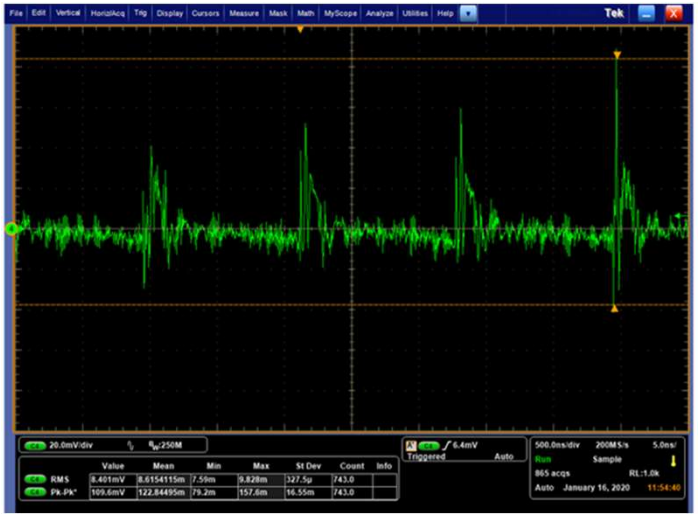
- Vin = 20V
- Vout = 2.1V
- Working in magnetic field
- L = 0.55µH
- C = 22µF
- fswitch = 1MHz
- Efficiency: 87.0% at 10A





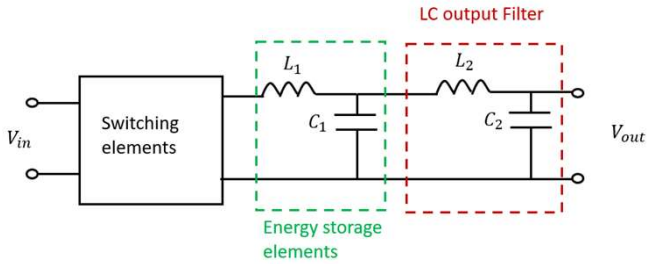
OUTPUT SIGNAL & FILTERING

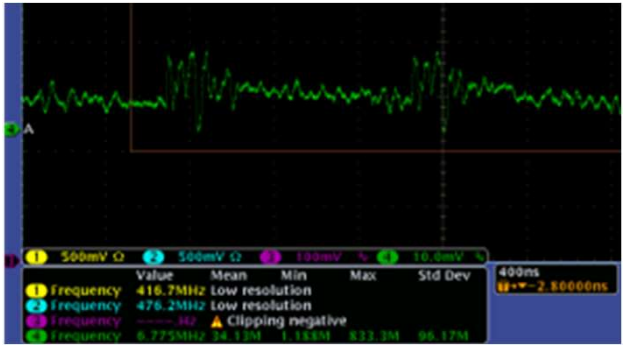
- V_{in} = 20V
- V_{out} = 2.1V
- I_{out} = 5A
- f_{sw} = 1MHz



- Total ripple height: ~30mV
- Requirement from MuPIx sensor: ≤ 10mV

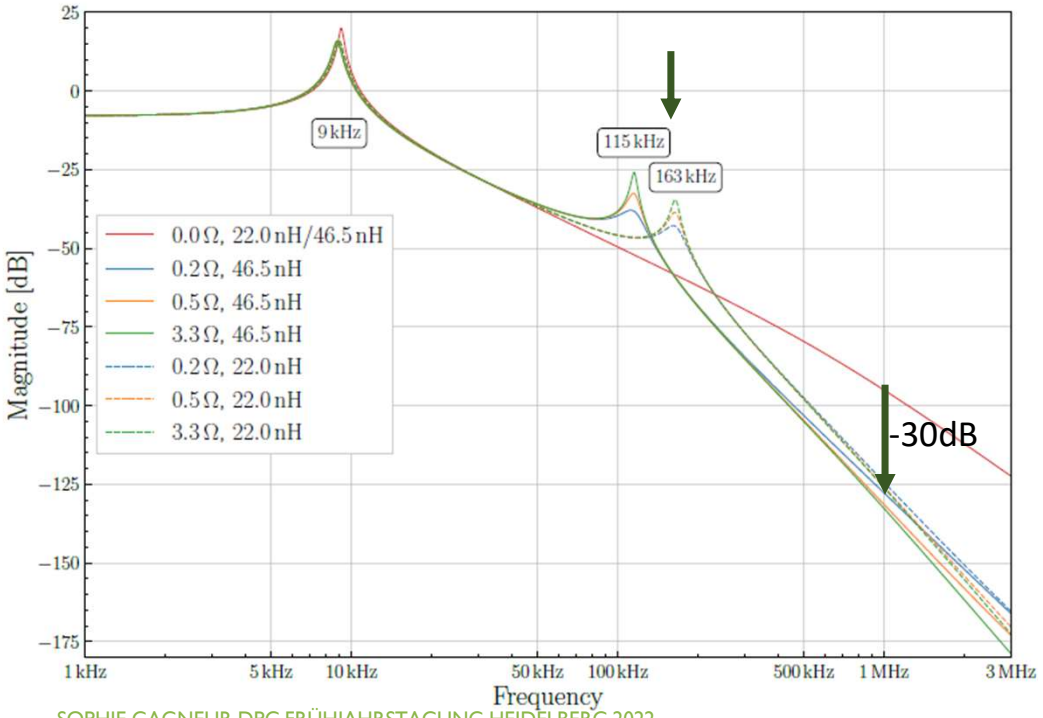
⟹ Output filter required

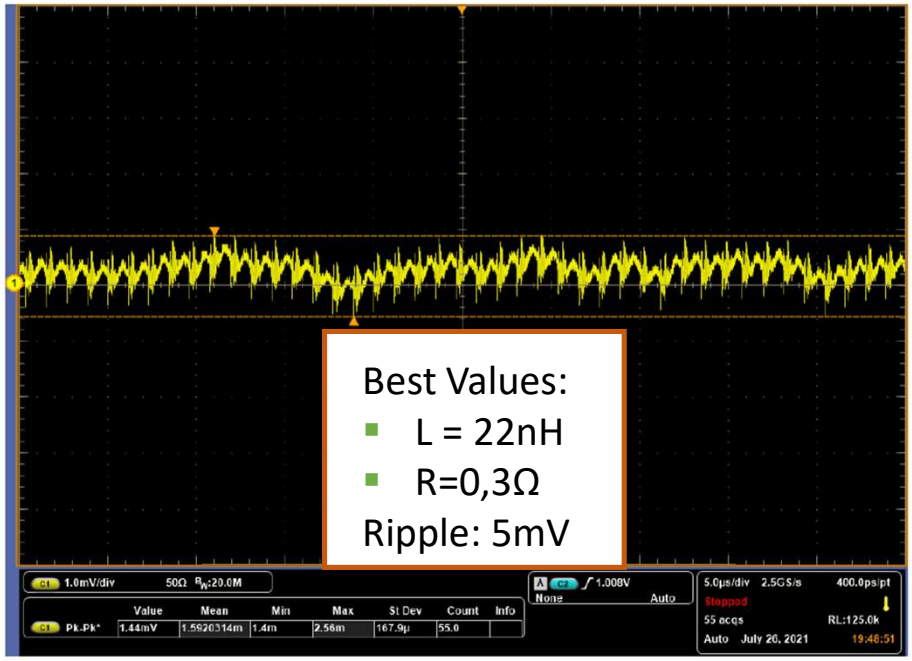




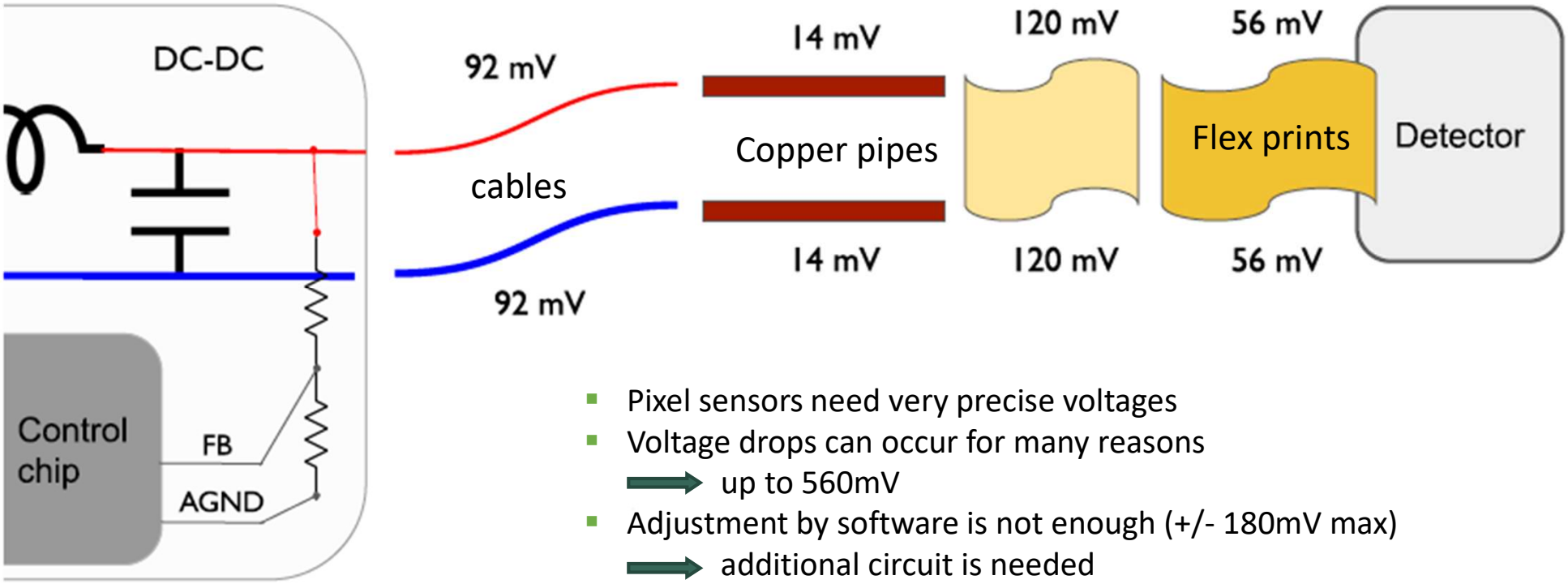
- Ripple hight: ~15mV
  ⟹ reduction of 50%
- Not below 10mV
- Rethink filter design

SIMULATION & LAB MEASUREMENTS



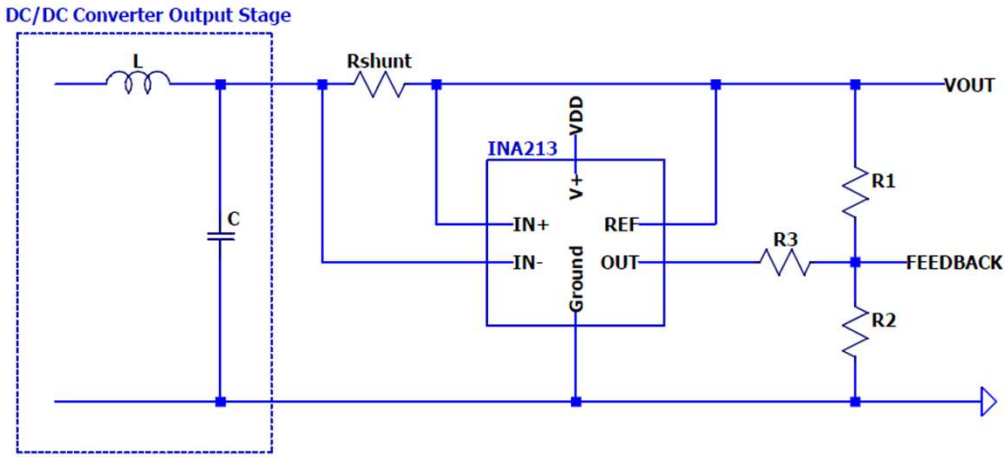


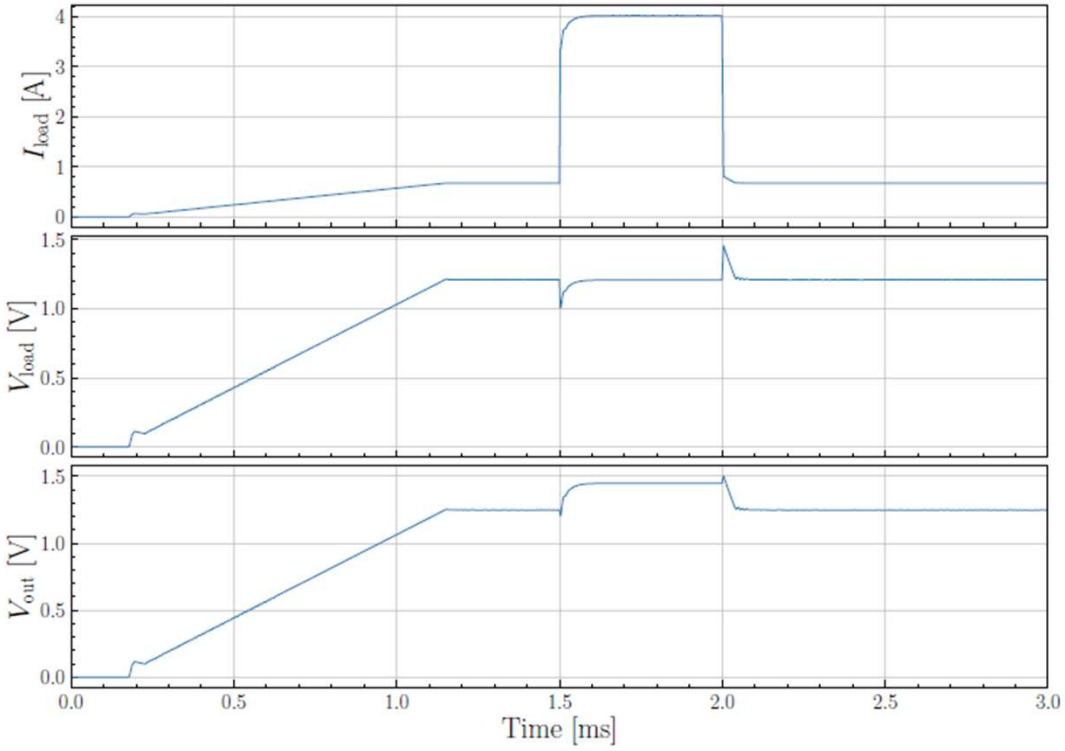
VOLTAGE DROPS



- Pixel sensors need very precise voltages
- Voltage drops can occur for many reasons
  → up to 560mV
- Adjustment by software is not enough (+/- 180mV max)
  → additional circuit is needed

VOLTAGE DROP COMPENSATION

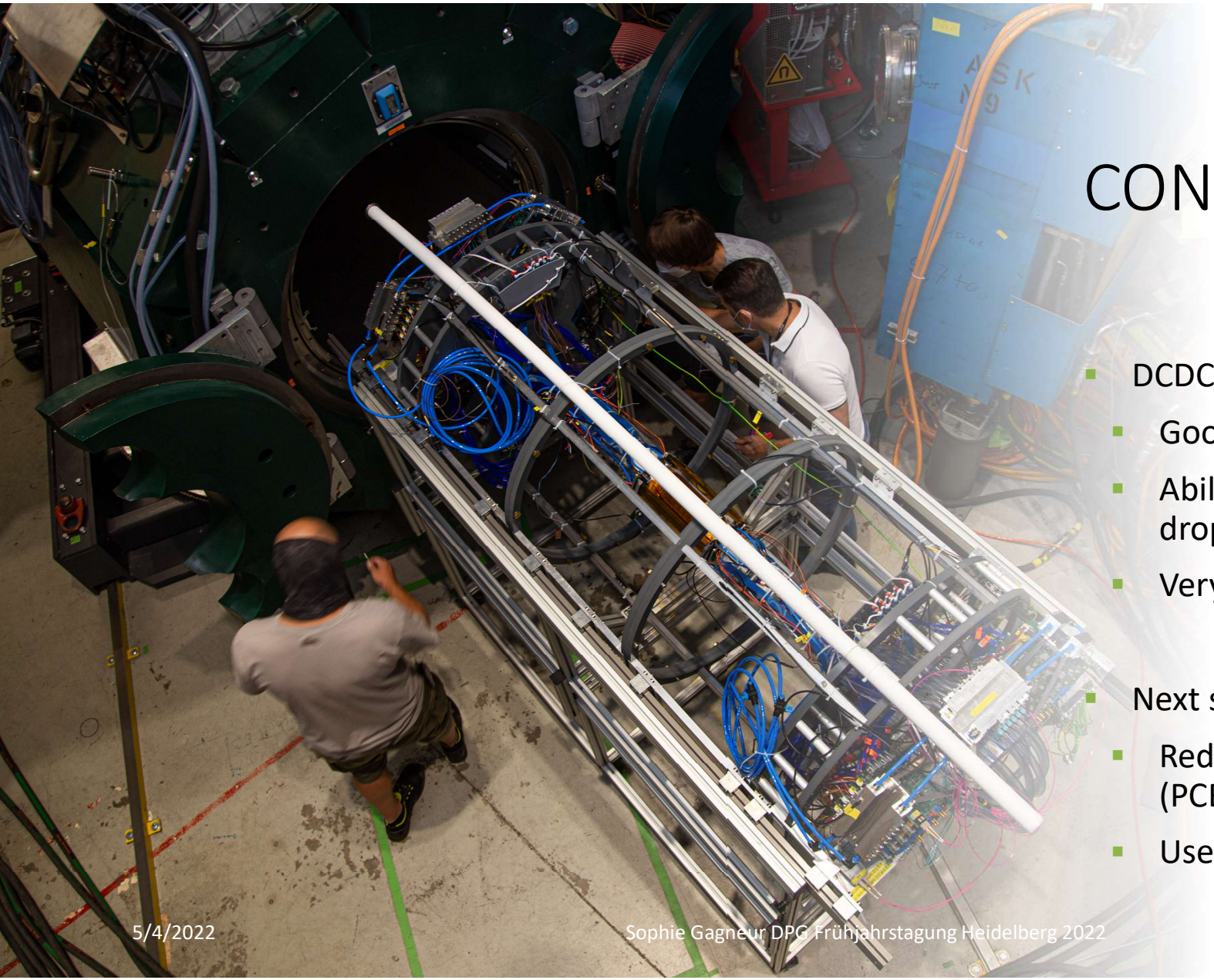




- Output voltage increases linearly with the output current

But:

- FB circuit is very sensitive to noise
- Resistance of cables must be well known



CONCLUSION

- DCDC converter with
  - Good efficiency
  - Ability to react to voltage drops
  - Very low output ripples
- Next steps
  - Reduce high frequency noise (PCB design)
  - Use converters in a test beam