P2 / Ba$\overleftarrow{sk}$et readout system Integration

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Collaboration meeting
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Outlook

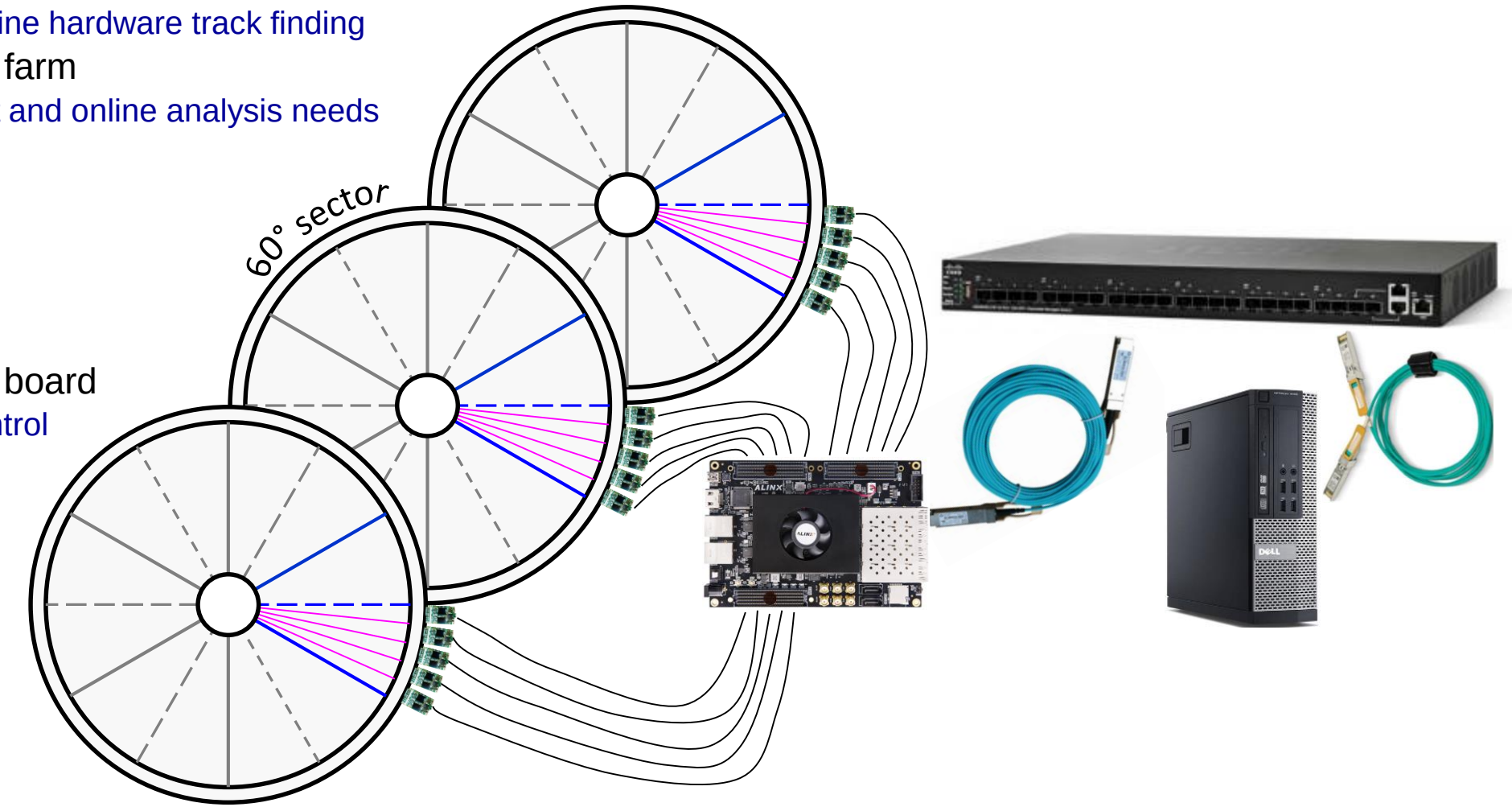
- Reminder of the readout architecture
- Integration
  - → Backend and services : near-detector versus remote
    - Data and LV power cables
  - → Radiation
  - → Network
- Next steps

- Last minute addition in train
  - → work in progress *en vrac*

Readout organization

- Three layer readout : frontend – backend – processing farm
  - → A 60° detector is read out by 10 frontend boards
  - → A backend reads projective 30° sectors in each plane
    - Possibility for on-line hardware track finding
  - → Scalable processing farm
    - As per throughout and online analysis needs

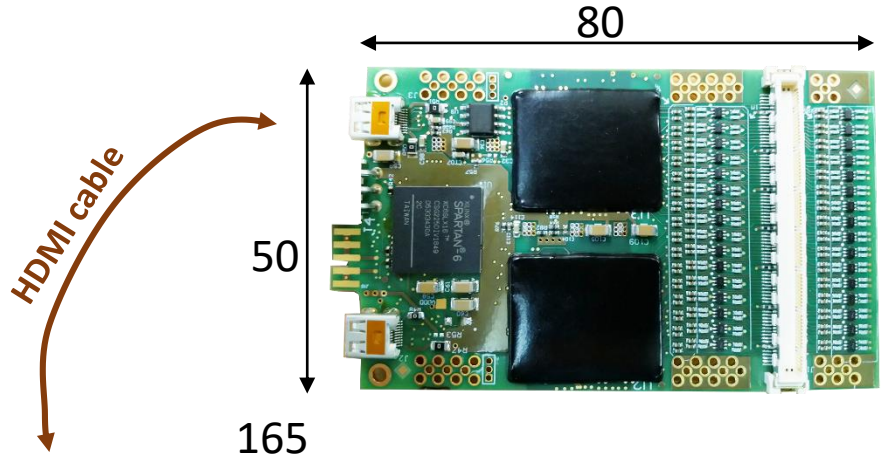
- Scale
  - → 180 frontend boards
  - → 12 backend boards
  - → A system supervisor board
    - Clock and run control
  - → A 10 / 40 GE switch
    - Data
  - → A 1 / 10 GE switch
    - Slow control

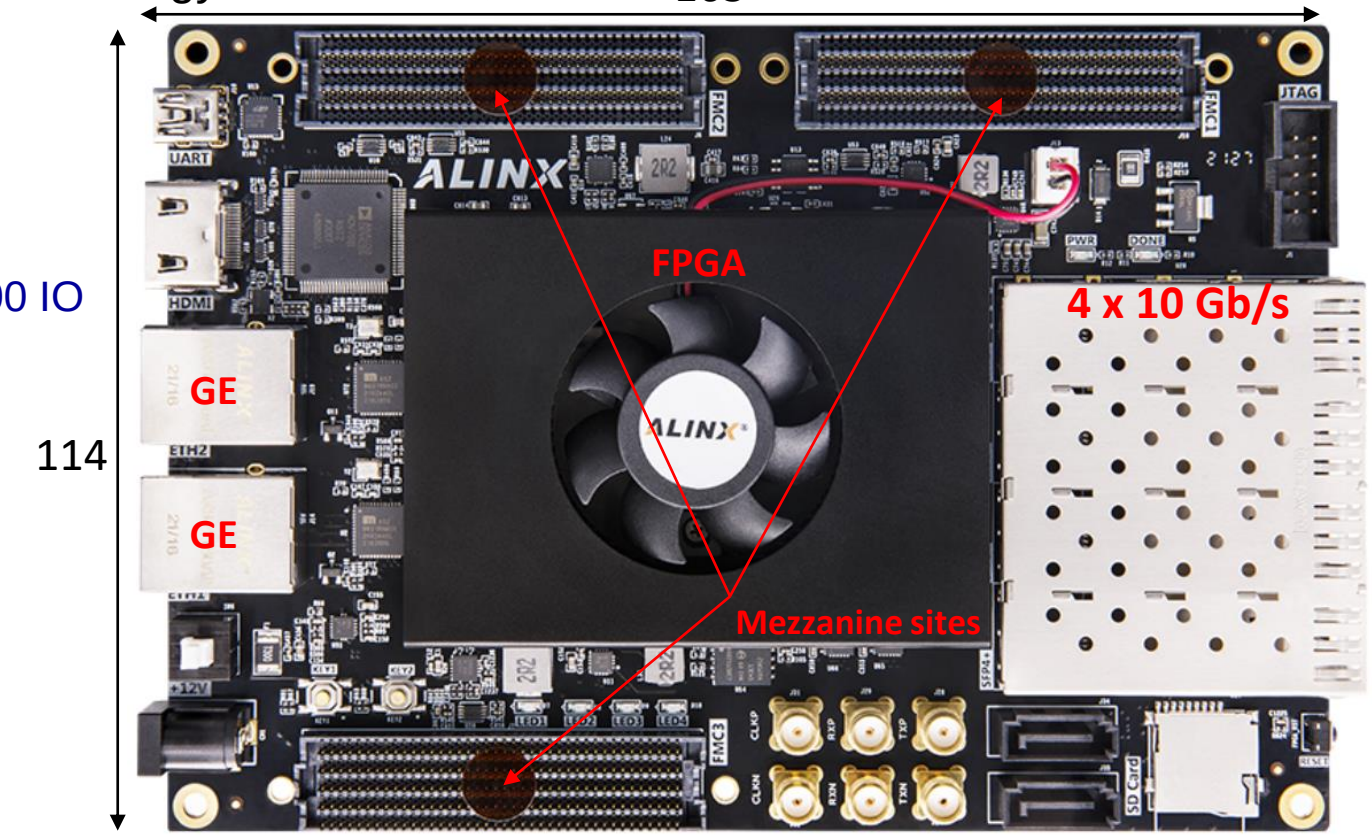


- Full validation possible in a pilot run populating only two 30° projective sectors (1/6)

Frontend and backend components

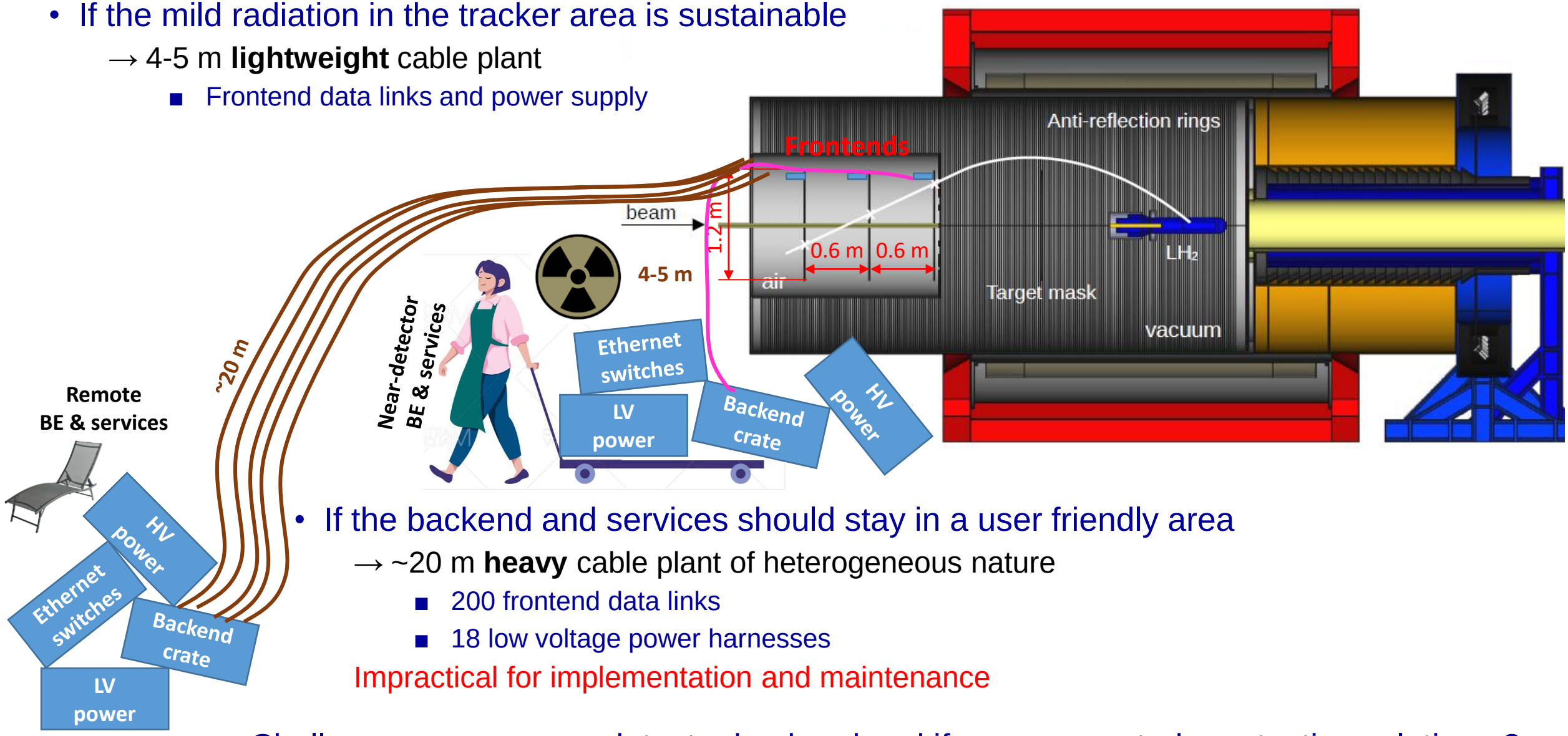
- Frontend: SRS 128-channel VMM-based hybrid
  - → 2 VMM3a ASICs (Atlas NSW)
  - → Spartan 7 FPGA from Xilinx
  - → Proprietary communication link over a HDMI cable
  - → Production of 200 hybrids ongoing by SRS Technology
    - Expected by end 2024
- Backend: AXKU040 development board
  - → Xilinx Kintex UltraScale FPGA - XCKU040
    - ~0.5M flip-flops; 21 Mbit RAM; 2k DSPs; ~500 IO
  - → 4 Gbyte DDR4 memory
  - → 10 Gbit/s and 1 GE interfaces
  - → 3 mezzanine connectors
    - Possibility to aggregate up to 16 frontends
  - → 3 units acquired
  - → Offer received for 15 units
    - Acquire in 2025





Spread of the readout system

- If the mild radiation in the tracker area is sustainable
  - → 4-5 m **lightweight** cable plant
    - Frontend data links and power supply



- If the backend and services should stay in a user friendly area
  - → ~20 m **heavy** cable plant of heterogeneous nature
    - 200 frontend data links
    - 18 low voltage power harnesses

Impractical for implementation and maintenance

Shall we agree on near-detector backend and if necessary study protective solutions ?

Consider HDMI data cables

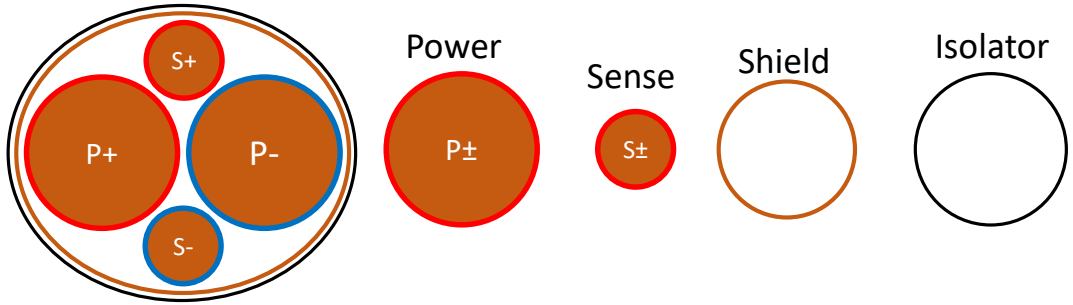
- There is a HDMI cable assembly per Hybrid : 180 assemblies in total
- An assembly is composed of
  - → A long large cross-section HDMI – HDMI cable
    - One of the HDMI connectors connected to backend
    - Placed outside of the cap
    - Ø8 mm
  - → A small HDMI-HDMI jumper
  - → A short low cross-section HDMI – micro-HDMI cable
    - micro-HDMI is connected to frontend
    - Placed within the cap and should be supported by detector structure
    - Ø6 mm

- Expected weights
  - → 10 m HDMI-HDMI : 0.62 kg — 180 units : ~110 kg
  - → 15 m HDMI-HDMI : 1.06 kg — 180 units : ~190 kg
  - → 20 m HDMI-HDMI : 1.43 kg — 180 units : ~260 kg
  - → 3 m HDMI-µHDMI : 0.12 kg — 180 units : 21 kg
- Maintenance with remote backend is not handy : requires 180 reconnection cycles

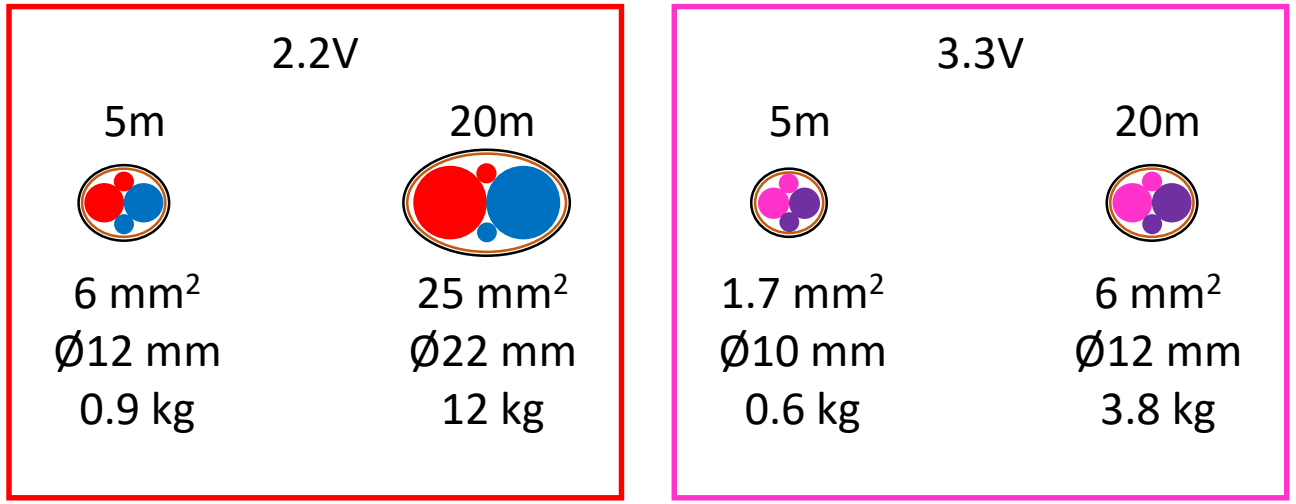
Consider power supply cables

- VMM frontend power consumption with ~20% safety margin
  - → 3.3V – 0.2A
  - → 2.2V – 2A
- Chosen low voltage power supply granularity
  - → 2.2V : 1 PS module per detector : 20 A
    - 10 VMM frontends
  - → 3.3V : 1 PS module per half plane : 6A
    - 30 VMM frontends
- Number of LV harnesses
  - → 2.2V : 18 – one per detector
  - → 3.3V : 6 – one per half plane

Harness composition



Scale 1:1



- Total weight

2.2V 5m	2.2V 20m	3.3V 5m	3.3V 20m
~18 kg	~220 kg	~5 kg	~25 kg

- Maintenance with remote backend is not handy : requires reconnection of all harnesses

Under study : option based on TDK / Lambda Z10-40/LAN

- Module from 0 V to 10V 40 A / 400 W
  - → Interlock
  - → USB / LAN

- 6 units can be aggregated in a 19” shelf

H 83 x D 350 x W 434 12kg

~50kg

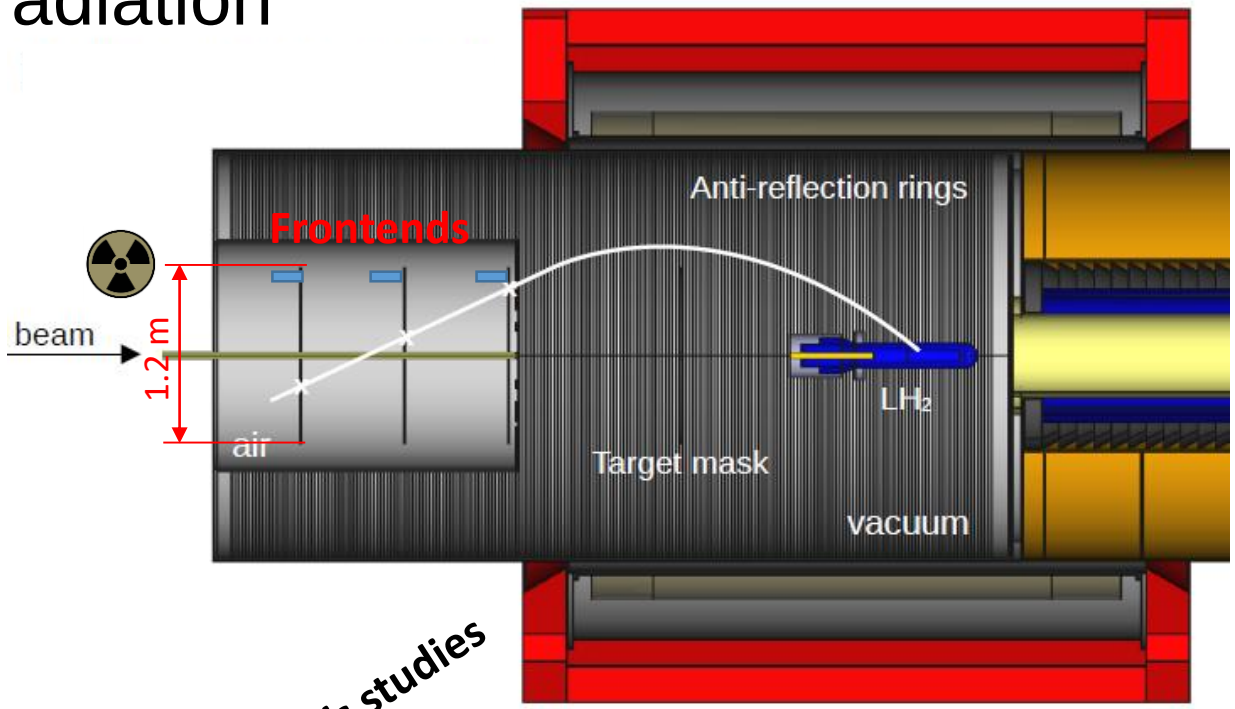
- Handy to maintain : modules can be replaced separately

- 2 units purchased, setup prepared to evaluate noise and remote regulation performance
  - → Backup solution : Wiener PL506 power supply with that same granularity but less handy to maintain

Frontend radiation

- Dose estimates for ±0.5m around the beam
  → 20 rad / h

Time	TID (krad)	Grade
Hour	0.02	Commercial
Day	0.5	
Month	14	
1 000 h	20	Rad tolerant (space)
3 months	43	
6 months	86	
9 months	130	
Year	173	
10 000 h	200	Rad hard



Derived from Malte's studies

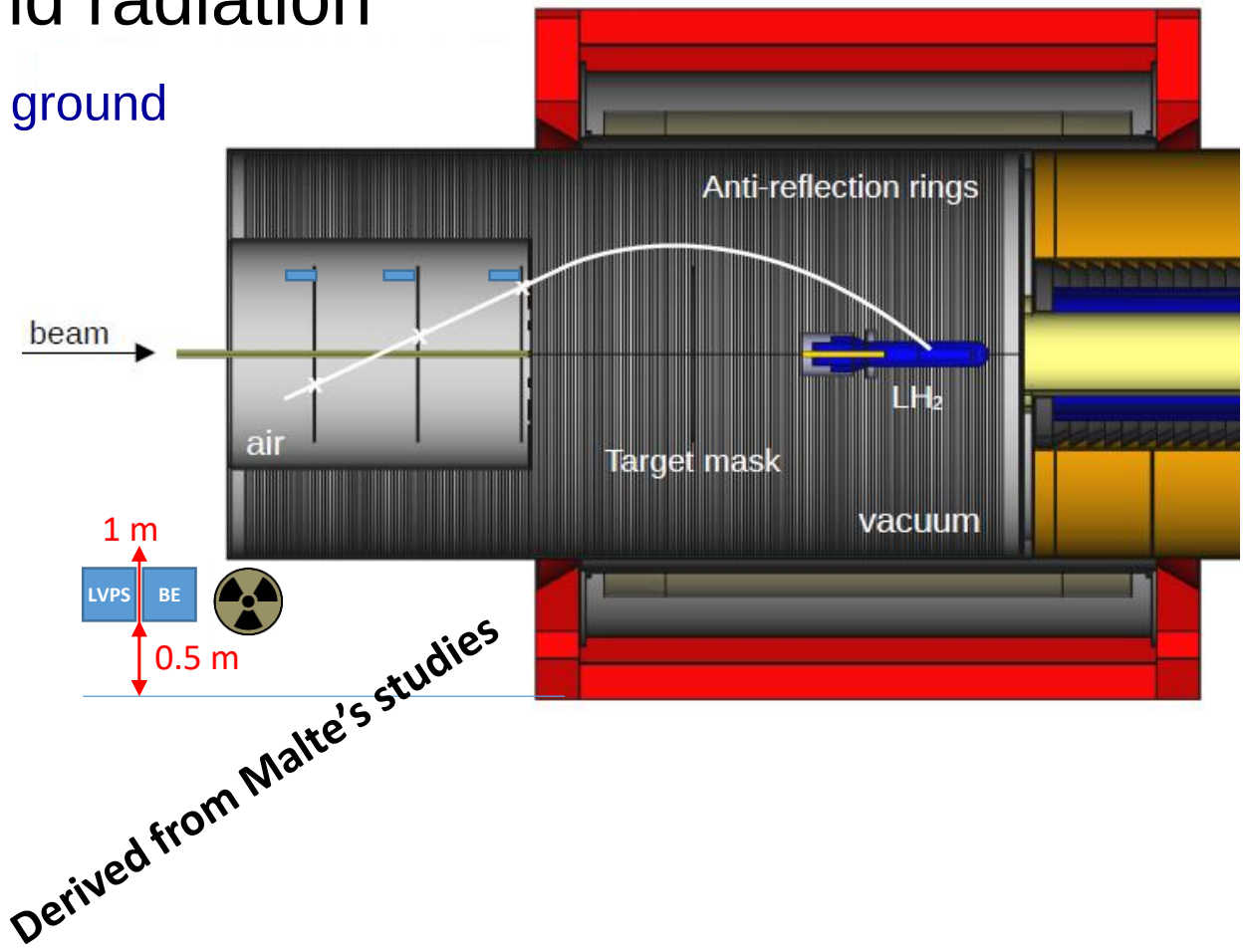
- NIEL : flux needs to be normalized to 1 MeV neutron equivalent to calculate fluence
  → Risks start from fluences > 10^{11} – 10^{12} 1 MeV neq / cm^2

- SEE effects : need to evaluate > 20 MeV proton flux
  → Xilinx gives some data to estimate SEE rates for flip-flops and memories : Spartan7

Near-backend radiation

- Dose estimates for area between 50 cm to 1m from ground
  → 2 rad / h

Time	TID (krad)	Grade
Hour	0	Commercial
Day	0.1	
Month	1.4	
1 000 h	2	
3 months	4	
6 months	9	
9 months	13	
Year	17	
10 000 h	20	Rad tolerant



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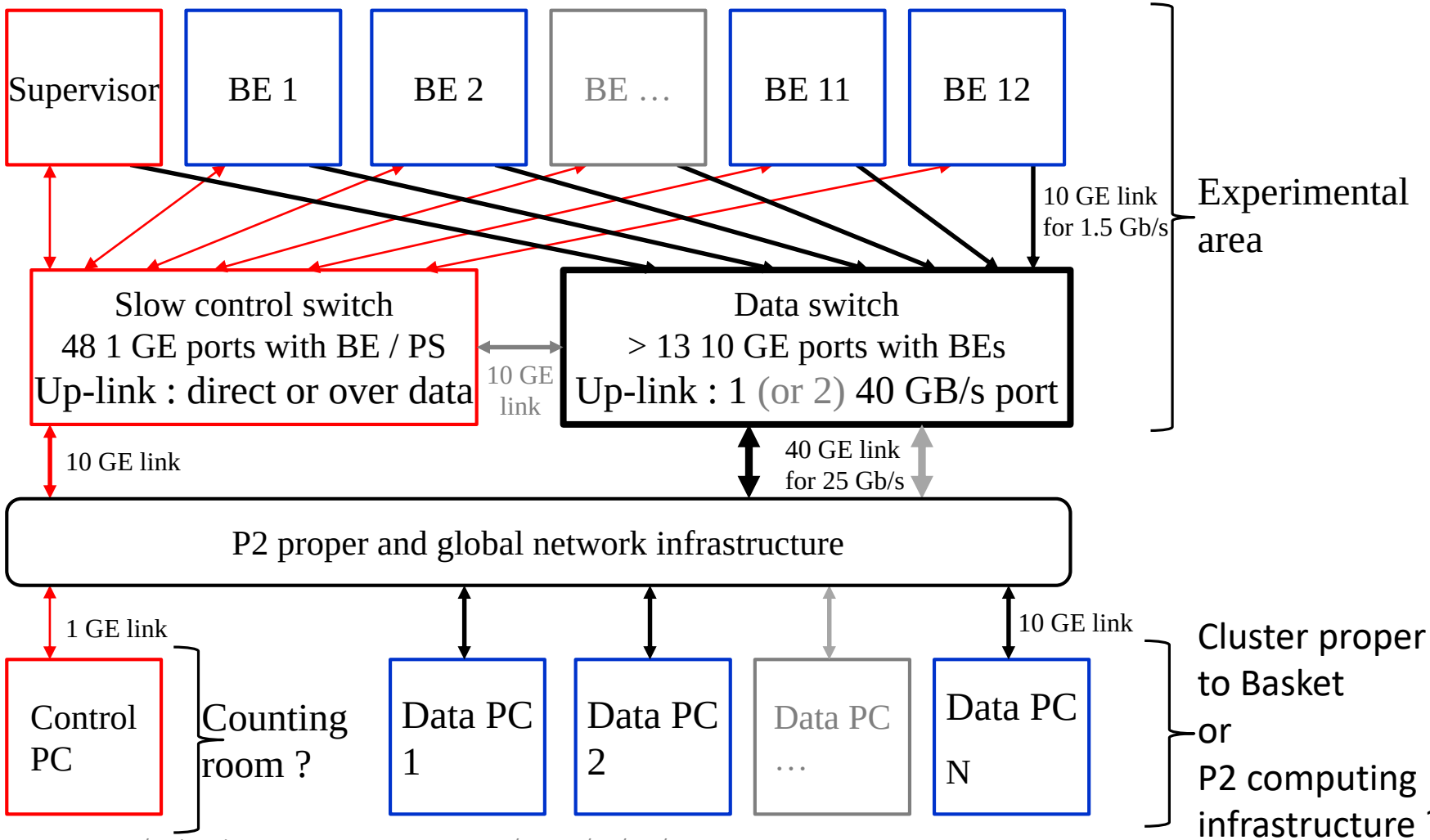
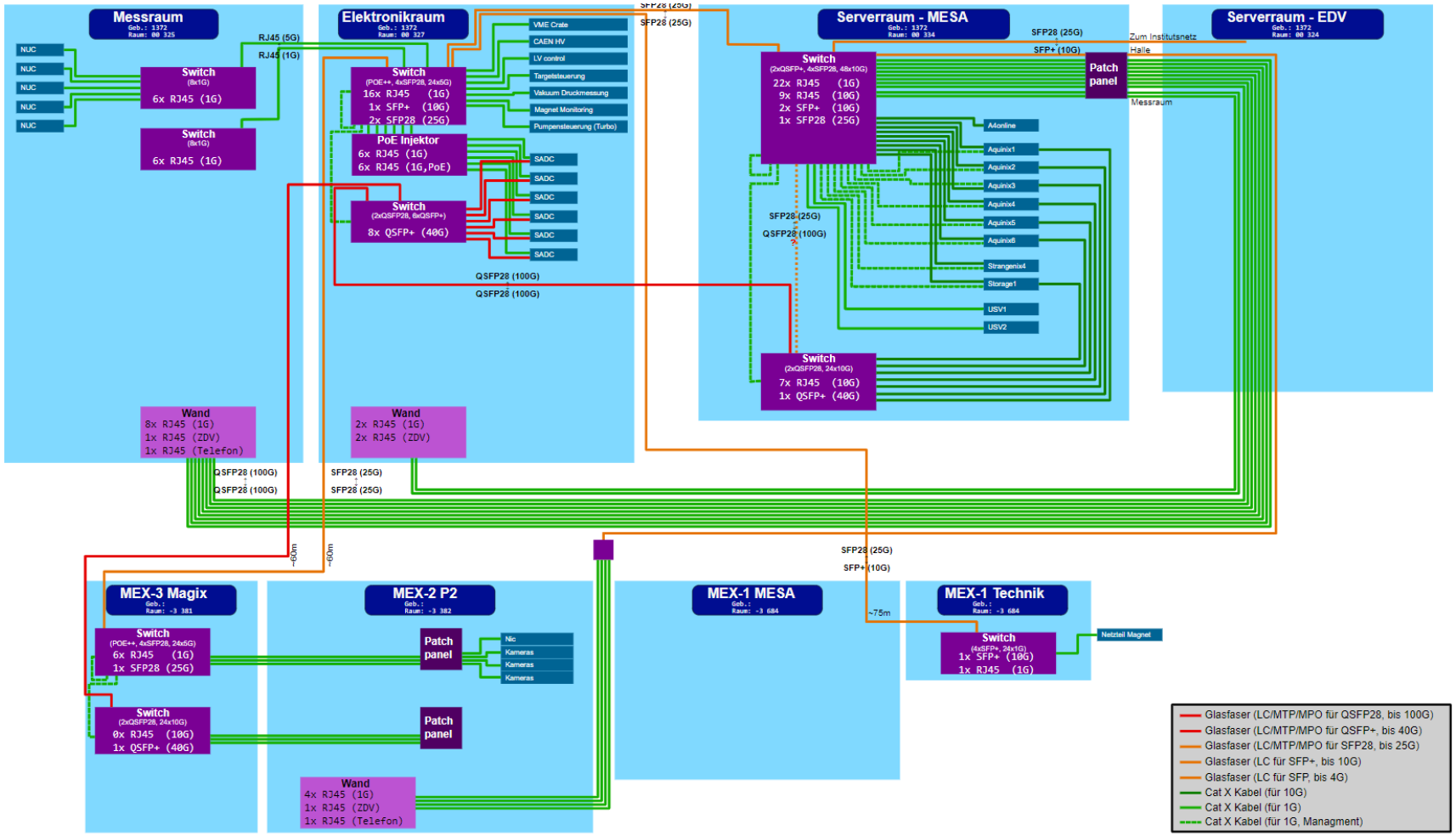
Network infrastructure

- Reminder
  - → Frontend data : ~120 Mbit/s – 20% of link bandwidth
  - → Backend raw data : 1.5 Gbit/s – 20% of a 10 GE link
- Baseline : 2 distinct networks
  - → Slow control : 1 GE
  - → Data : **10 GE**



Mapping to planned network / computing infrastructure for P2

- Assume a near-detector backed, shell we consider near-detector Ethernet switches too ?
  - → At most 2 10 GE cables and 2 40 GE Ethernet fibers to depart
  - → Versus 48 GE cables and 13 10 GE fibers in case of remote data and slow control switches

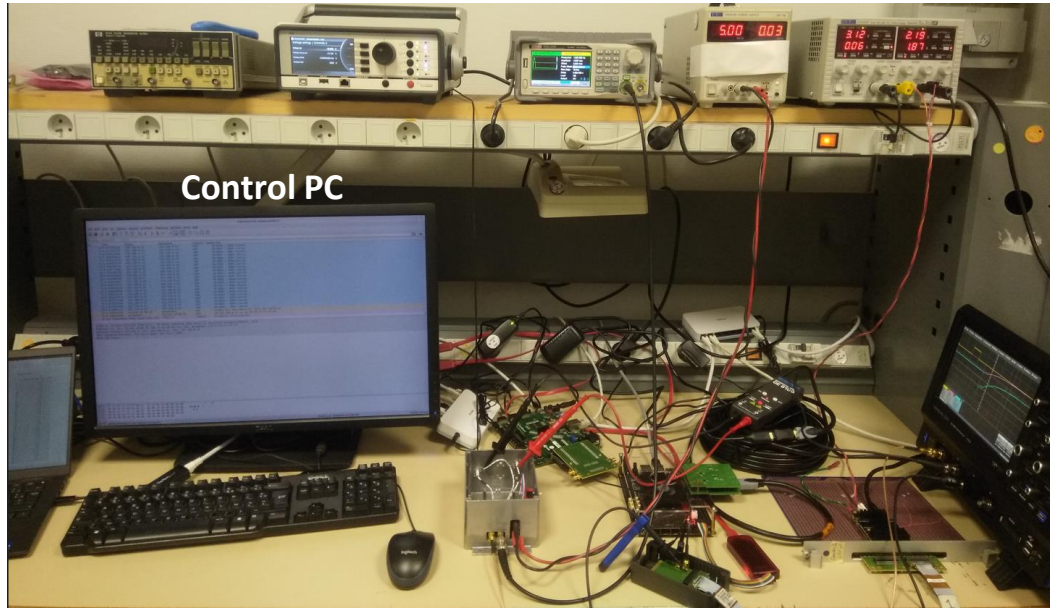


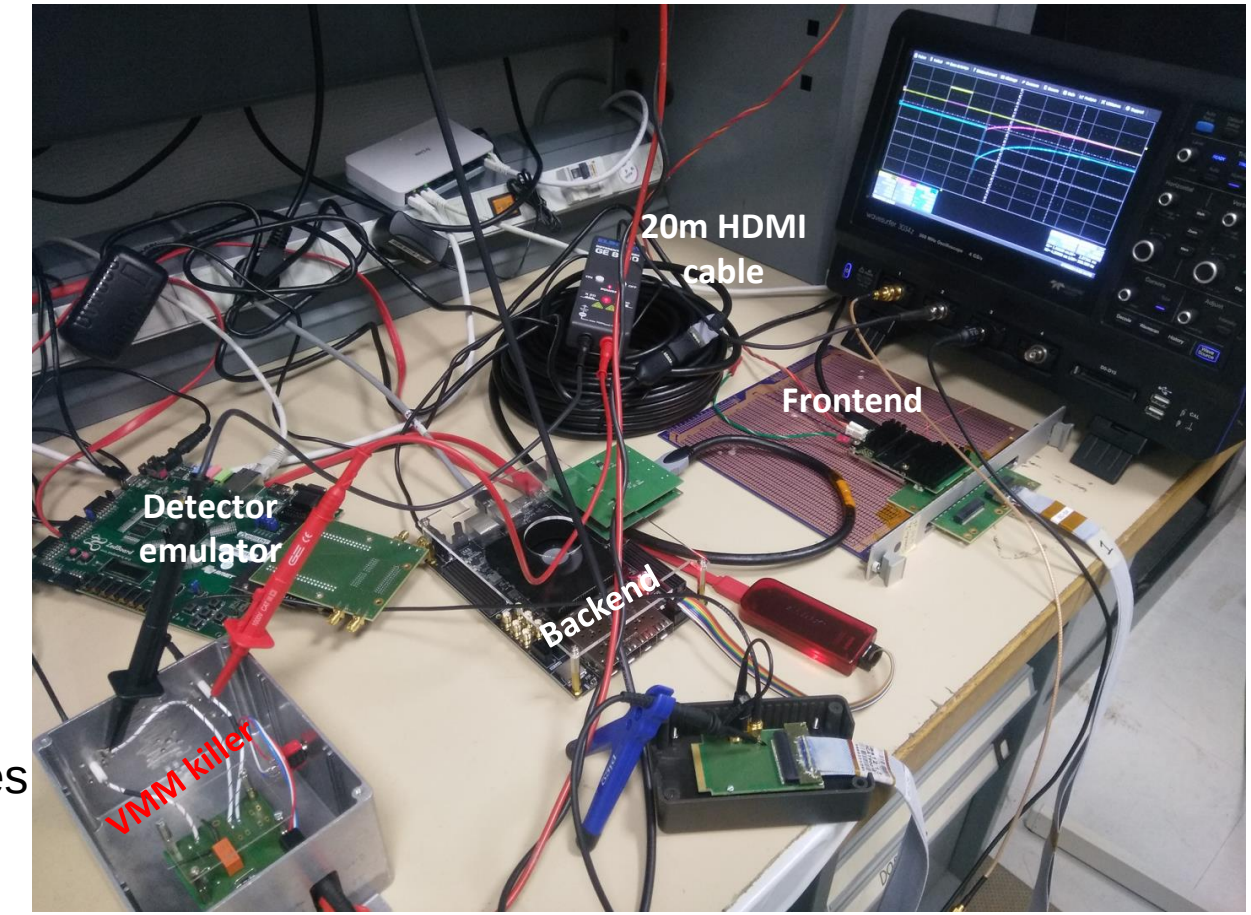
Next steps

- Finalize radiation environment studies for frontends
  - → Evaluate 1 MeV neq fluence and > 20 MeV proton flux
  - → Decide if irradiation campaigns need to be scheduled
    - →
- Make choice for the place of the backend and services
  - → Evaluate 1 MeV neq fluence and > 20 MeV proton flux
  - → Decide for near-detector or remote backend and services
    - Near-detector backend : devise proper shielding if necessary
    - Remote backend : validate 20 m long data link robustness
      - Work ongoing with encouraging preliminary results
- Make choice for LV power supply
  - → Validate noise and remote regulation capability for 5 m and 20 m power cables
    - Work ongoing
  - → Decide among TDK Lambda and Wiener options
    - Asses volume and weight
- Make choice for network infrastructure
  - → Near-detector or remote switches
  - → Evaluate performance for expected data throughput
  - → Decide for physical interfaces between switches
    - Optical vs electrical
    - 25 GE vs 4 GE
    - Redundancy
- Longer term decisions to be taken on the nature and performance of the processor cluster

Ongoing activities *en vrac*

- 2nd electronics test bench assembled for system-level developments
  → In addition to the setup dedicated to backend firmware development

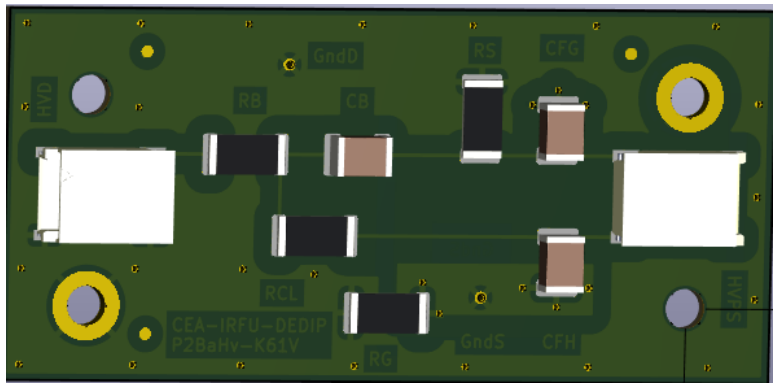




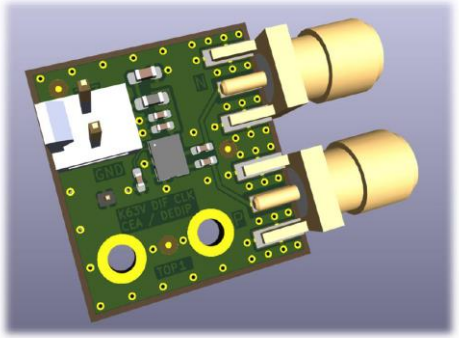
- Work in progress in several directions …
  → Spark protection
  → High rate operation
  → Backend – fronted connectivity over lengthy cables
  → …

Work in progress …

- High rate operation with detector emulator
  - → Negative exponential hit arrival at programmable rate on 64 channels – VMM chip
    - Extendable to 128 channels – to cover complete frontend
  - → So far, channel hit rate of 100 kHz validated on single VMM of a Hybrid
    - 20 kHz rate expected
- Fronted-backend link length
  - → Encouraging results for HDMI cables of up to 20 m
    - Synchronization established and data acquired
  - → More studies needed
- Protection circuitry to reduce dead time due to sparks
  - → Controversial results with some channels dead under heavy discharges from VMM Killer
    - Investigating with simulations and comparative measurements
- Transfer function studies
  - → Known charge injection scan at various dynamic ranges
- High voltage filtering and ballast board
  - → Up to 10 nA leakage current sensible to humidity
    - To be improved



Work in progress …



- Clean 156.25 MHz clock reference source piggyback card for 10 GE on backend
  - → 3.4 ps RMS jitter with 0.5 fs deterministic jitter
- Backend firmware development
  - → CERN SRS firmware ported on the ALINX Kintex UltraScale board
  - → Working to support from current 8 frontends to final 15 frontends
  - → Working on 10 GE data link implementation
  - → Embedded MicroBlase processor environment with Linux support
    - To be decided if to be used in final system
- Acquisition software
  - → Restructuring SRS software for P2 Basket application
- Low voltage power supply
  - → Validate TDK Lambda LV power modules
    - Remote regulation over various length harnesses
      - Using active electronics load
    - LAN based slow control
- Adaptation boards
  - → Detector – Frontend
  - → Detector – FEU/Dream electronics