Status of detection electronics for 11T protection including trim protection

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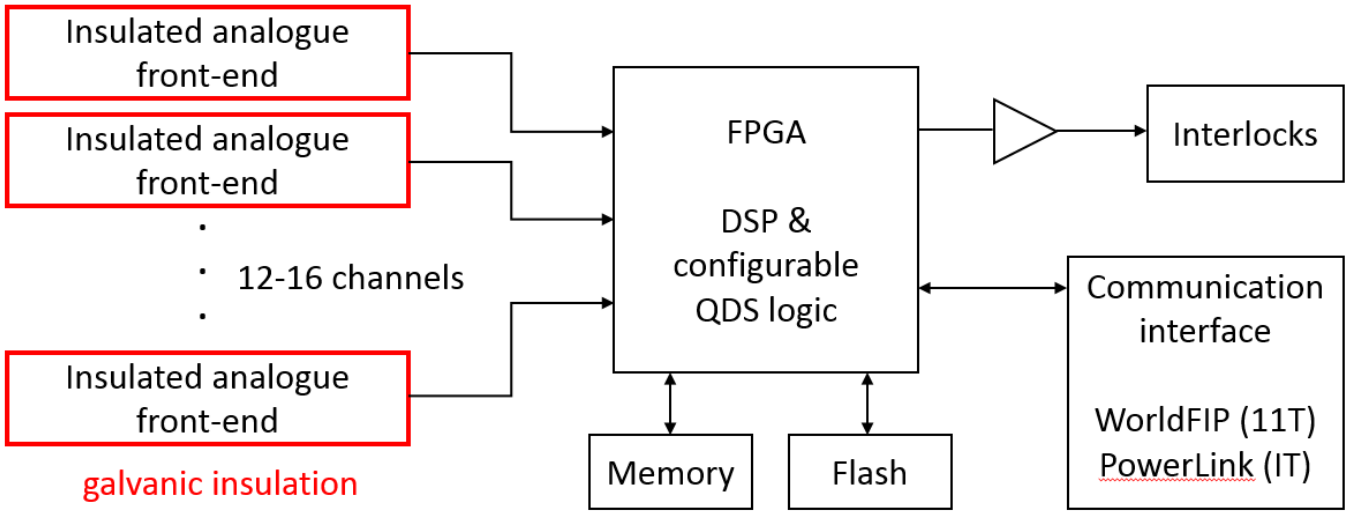
Topics

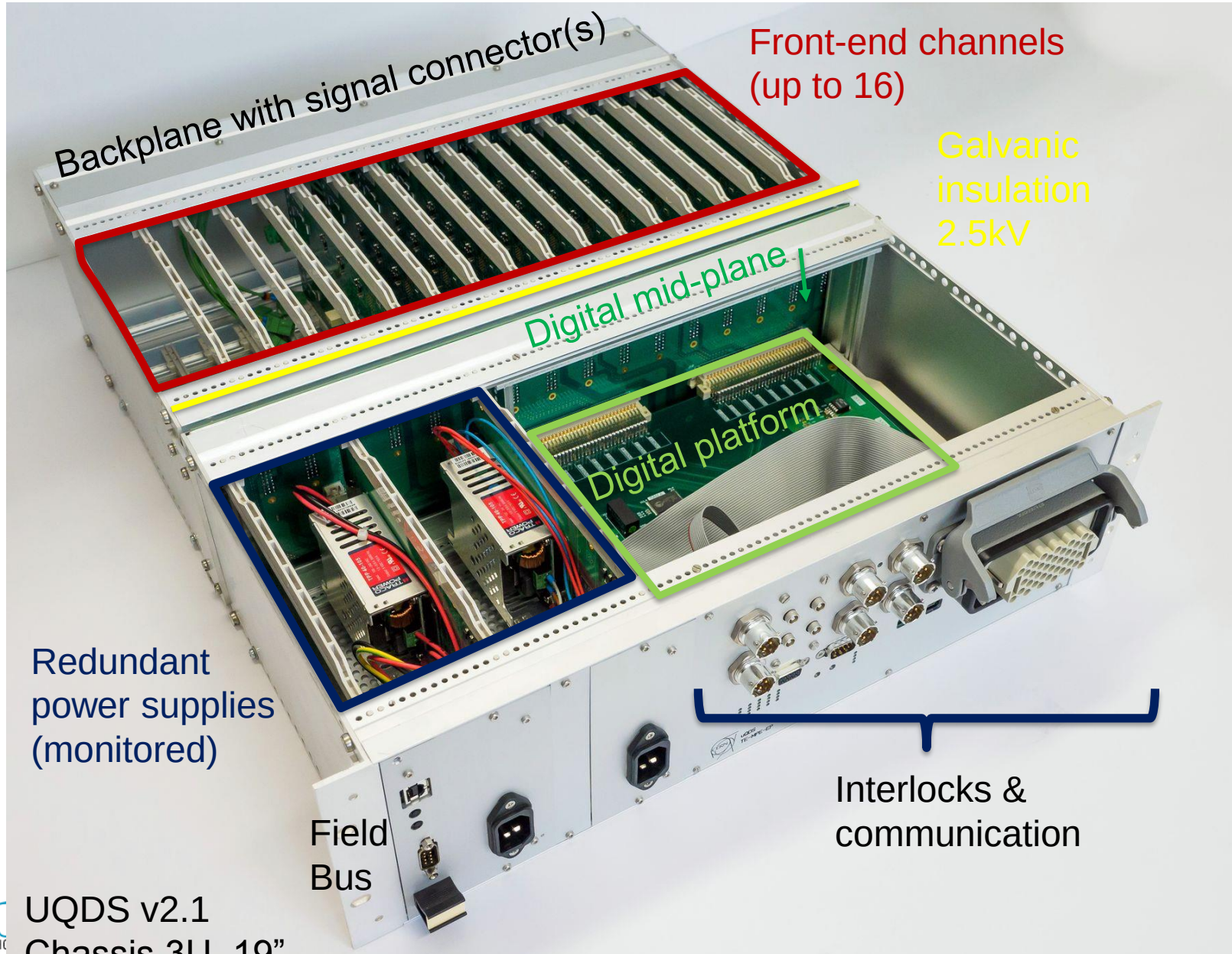
- UQDS concept
- UQDS components & specification
- Status of Digital Platform & Frontend
- 11T magnet protection system & integration
- Heater supervision unit
- Trim lead protection unit
- Testing strategy
- Conclusion

UQDS concept



- Multiple front-end channels connected to one logic device performing the QDS tasks
- QDS function defined by FPGA firmware
- Front-ends flexible enough to cope with all required input signals
- Modular concept, one platform for various tasks

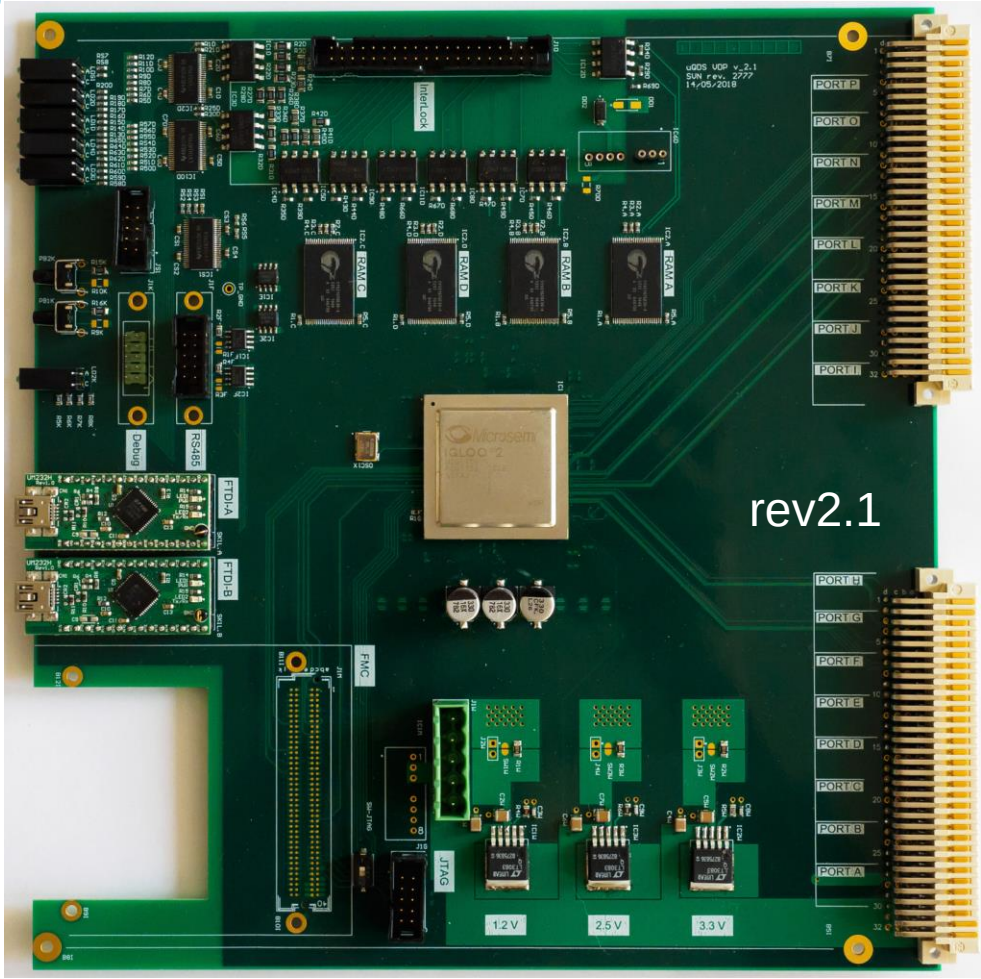
UQDS version 2.1, system overview



UQDS components

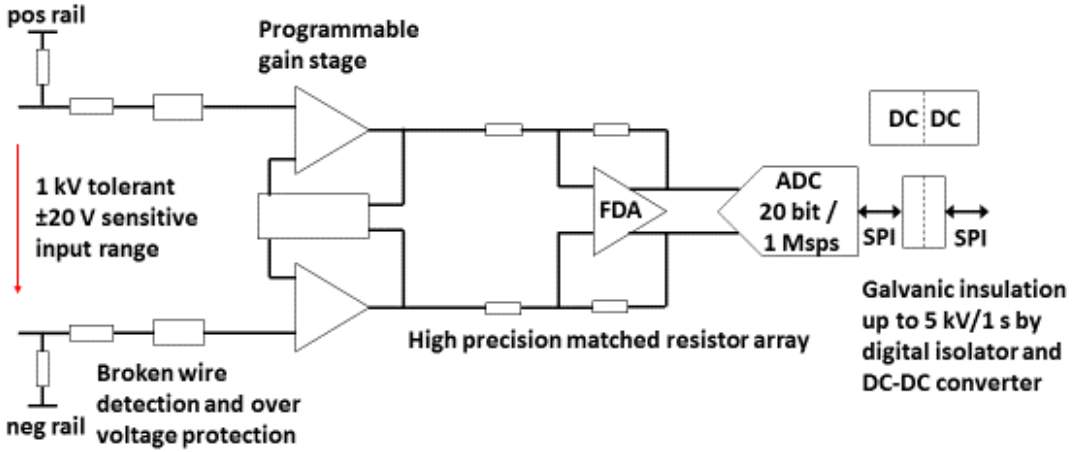
- **Digital platform** houses FPGA, interlocks and communication interface. Performs quench detection algorithms
- **Mid-plane** connects Front-end with Digital platform
- **Frontend** amplifies signal, digitizes and provides galvanic insulation
- **Power supplies** (redundant) including supervision
- **Auxiliary communications controller** to integrate system into controls infrastructure

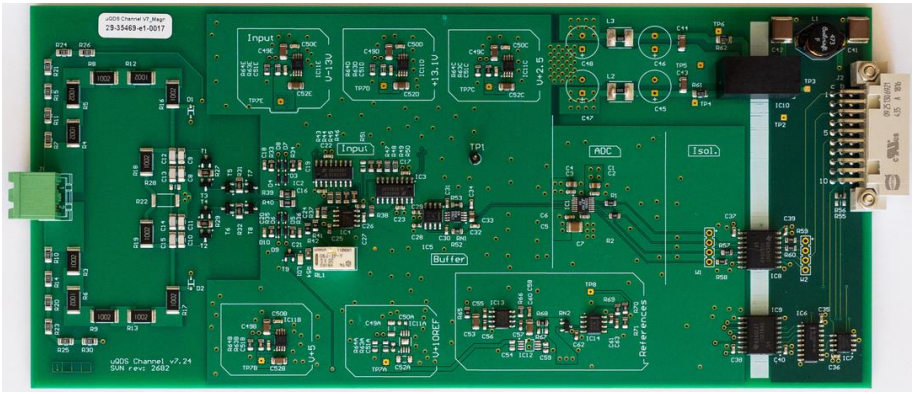
Status of the digital platform



- Based on IGLOO2 (M2GL150)
- Supports 16 front-end channels via mid-plane
- Communication via RS485, USB2.0, USB3.0 or WorldFIP
- 16 isolated Heater trigger outputs
- 2 isolated Interlock lines
- 2/2 sync lines
- New LDO (better rad tolerance)
- Rad-tol up to 100Gy (tested in CHARM)
- ➔ Baseline for 11T QDS

Front-end channel specifications/design



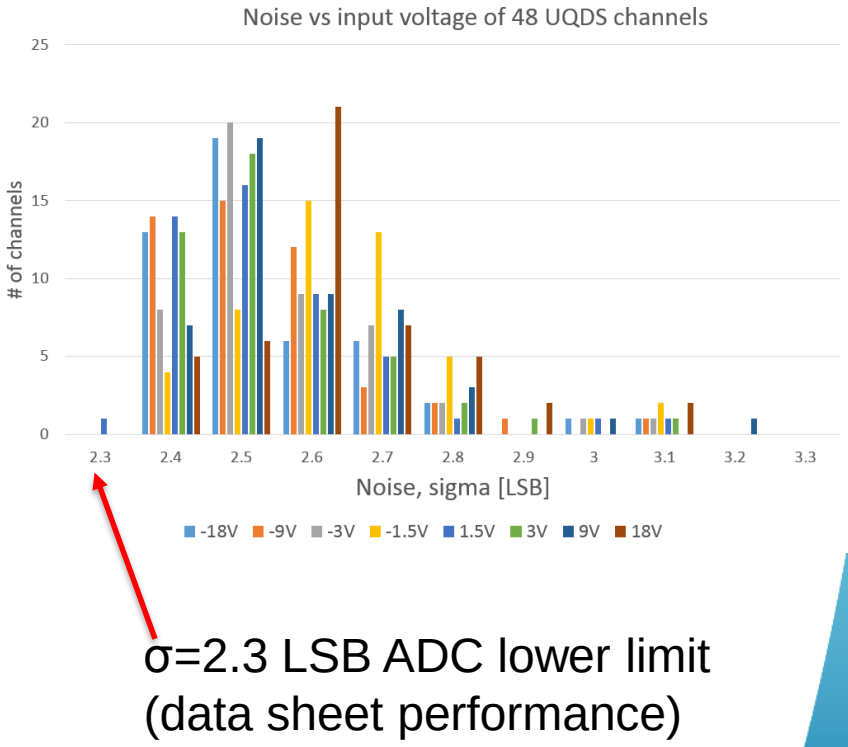


Front-end rev7.24 (UQDS 2.x compatible)

Parameter	Value
Resolution (20-bit ADC)	95nV/LSB .. 43uV/LSB
ADC speed	Up to 1Msp/s
Analogue bandwidth/ gain	125kHz @ G=1 90kHz @ G=9 50kHz @ G=45 7kHz @ G=450
Active input voltage range	+/-50mV .. 22.5V
Max differential input voltage	1kV/1s
Galvanic insulation	2.5kV/20min

Front-end channel status

- UQDS 2.1 compatible version since spring this year
- 50 channels produced v7.24 (mainly for FAIR test-bench)
- Characterization of production shows good reproducibility of noise etc.
- High range version with additional divider (up to +/-135V)
- Standard range version (+/-22.5V)
- Current version serves as baseline for 11T UQDS boxes

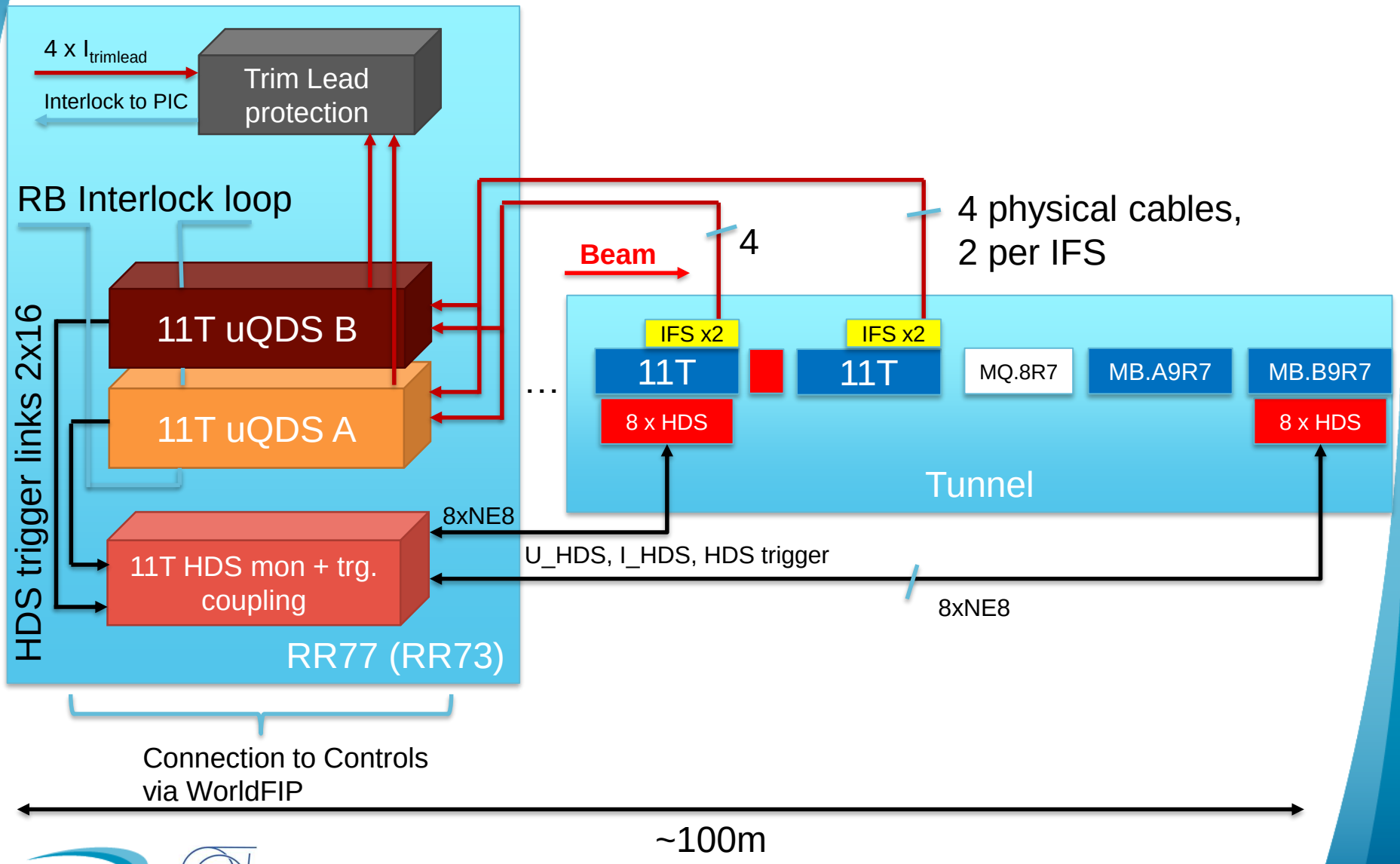


σ=2.3 LSB ADC lower limit (data sheet performance)

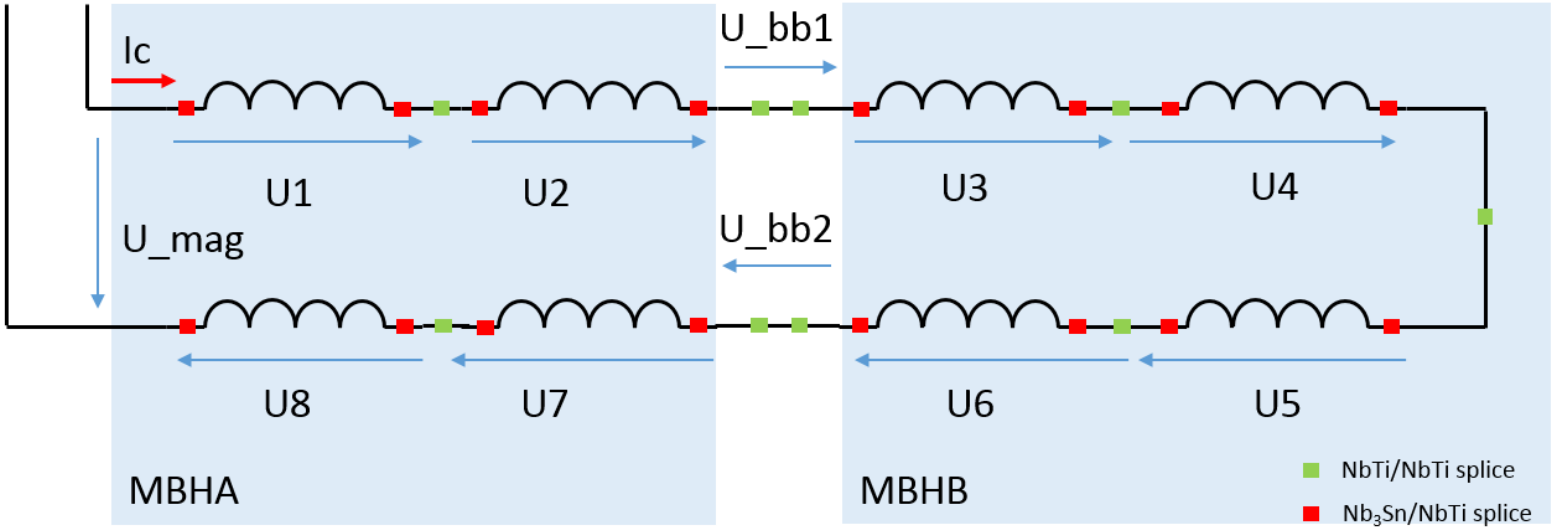
11T magnet protection system

- **UQDS** will serve as quench detection system
  - Detect asymmetric and symmetric quenches
  - Detect quenches of the interconnection bus-bar
  - Cover all bus-bars in the magnet assembly
- **11T HDS controller** will provide HDS trigger coupling and supervision
- **Trim lead protection unit** will supervise and protect the trim power supply leads

11T circuit protection: integration



11T instrumentation/channel distribution



- 8x pole voltages for asymmetric and symmetric quench detection (pole voltages include adjacent short bus-bars)
- 2x interconnection bus-bar voltage for bus-bar protection
- 1x total magnet voltage (for diagnostics)
- 1x circuit current (for current dependent settings)

➔ 12 isolated channels per QDS box

➔ Fully redundant scheme, all splices covered (vtaps, cables, QDS boxes)

11T Quench detection

- Comparisons between pole voltages used for quench detection
  - Fast detection between neighbouring poles (good common mode rejection)
  - Detection of symmetric quenches by comparing pole voltages further apart

  ➔ Exact algorithms to be defined (instrumentation permits a wide range of detection schemes)
- Settings of time discrimination filter (and / or) threshold can be defined as a function of the circuit current

  ➔ Loosen detection setting at lower currents to avoid tripping on flux-jumps

11T HDS controller

- Trigger coupling of 2x 16 HDS trigger lines form UQDS (fully passive, no fan-out required)
- Monitor quench heater voltage & current (uses 4x existing DQHSU card)
- HDS trigger monitoring (measure current driving into DQHDS trigger relay coil)
- Connected directly to the 16 DQHDS
- Supervision of Heater-to-IFS box cable

➔ currently in implementation phase

Trim lead protection unit

- The resistive leads of the 11T trim circuit require active protection
- Lead voltage will be measured redundantly, triggers on 100mV threshold (2x4 voltages)
- Current sharing will be monitored and optionally interlocked (1x4 currents)
- Unit will be composed of existing quench detection boards (DQQDC & DQAMG)

➔ Conceptual design completed

SM18 measurements

- In 2018 we followed the Nb3Sn magnet testing in SM18 with UQDS boxes acquiring data
- Data acquired allows studies flux-jumps, quench precursors, oscillations etc.
- Estimate what level of filtering is necessary
- However due to noisy Power converters (Thyristor spikes), picture is not representative for LHC tunnel

➔ Details given in the talk of Ernesto

Conclusion/Outlook

- Development is progressing well
- Design of 11T QDS defined
- Instrumentation and integration of 11T defined
- Version 2.1 of UQDS ready,
  pre-series produced (5 pieces)
- Final version for 11T QDS next year
- 11T HDS controller: implementation phase
- Trim lead protection: conceptual design completed