EUROPEAN SPALLATION SOURCE

icBLM electronics

Clement Derrez

Test Engineer

www.europeanspallationsource.se

10 July, 2017

Outline

- Conceptual system design
- Detectors
- Electronics
  - High voltage unit
  - Signal acquisition unit
- Conclusion & Outlook

Conceptual system design

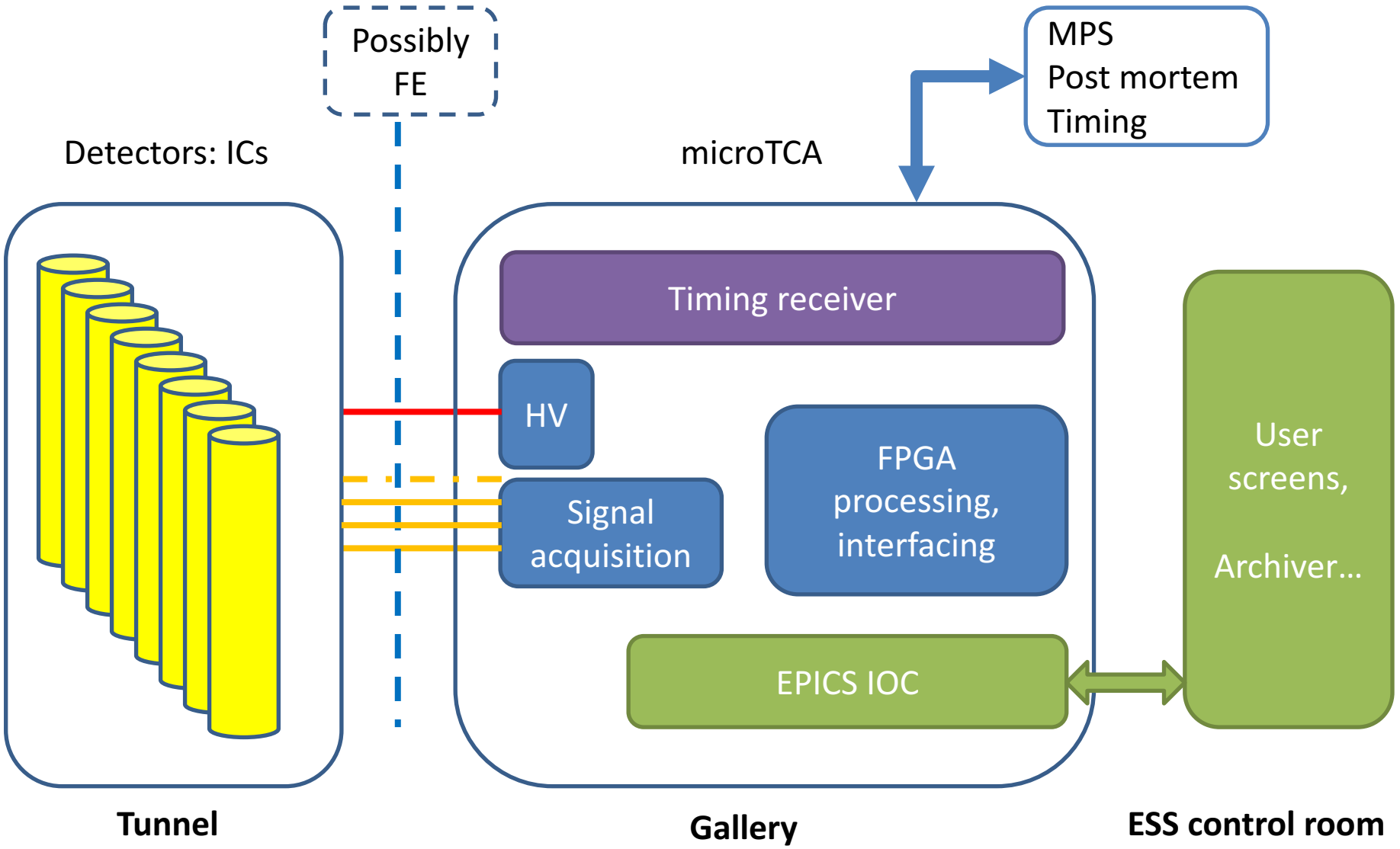
- BLM system: One of the most important diagnostic system of the ESS LINAC.
  - Keep the machine safe from beam-induced damage
  - Avoid excessive machine activation by providing critical input to the MPS

  → no blind spots & precise loss locations determination

- System designed for maximum reliability
  - Redundancy
  - low latency

- Challenges:
  - Complicated noise situation. Additionally, noise sources vary depending on the location within the accelerator.
  - Cabling: This will be covered by Edvard in the next talk

Conceptual system design



Conceptual system design

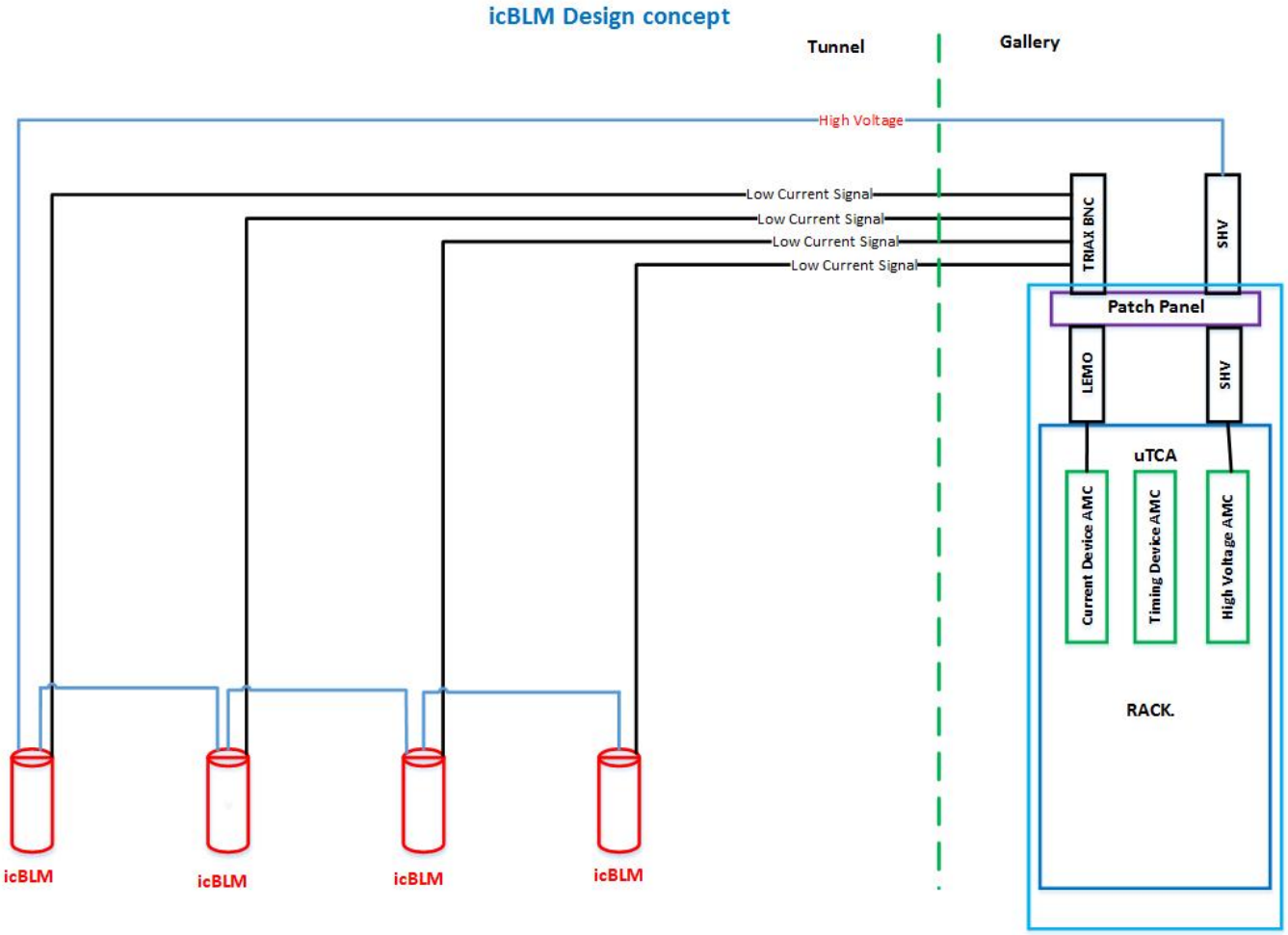
Units deployed in the support area fit in a 47U rack

- Specified by BI
- Provided by WP15.

Unit description	Installation area	Comment	Entity
Current readout	Support	FMC or custom acquisition crate	CAENels FMC-PICO or custom acquisition crate (CERN Solution)
High voltage supply	Support	1 is needed per mTCA chassis	CAENels HV-PANDA.
Timing Receiver	Support	Event receiver for triggers and clock	The unit is provided by ICS.
Power supply	Support	Power supply for mTCA chassis	The unit is provided by ICS.
Central Processing Unit	Support	CPU for mTCA chassis, Intel i7	The unit is provided by ICS.
Chassis	Support	The microTCA chassis	3U microTCA crate. The unit is provided by ICS.
MicroTCA Carrier Hub	Support	1 is needed per mTCA chassis	The unit is provided by ICS.
Rack	Support	Electronics rack	The unit is provided by WP15 and specified by BI.
Rack patch panel	Support	Installed on top of the rack	The patch panel will be designed by WUT
Sensor	Tunnel	Ionization chamber	
Beam Line Element Patch Panel	Tunnel		

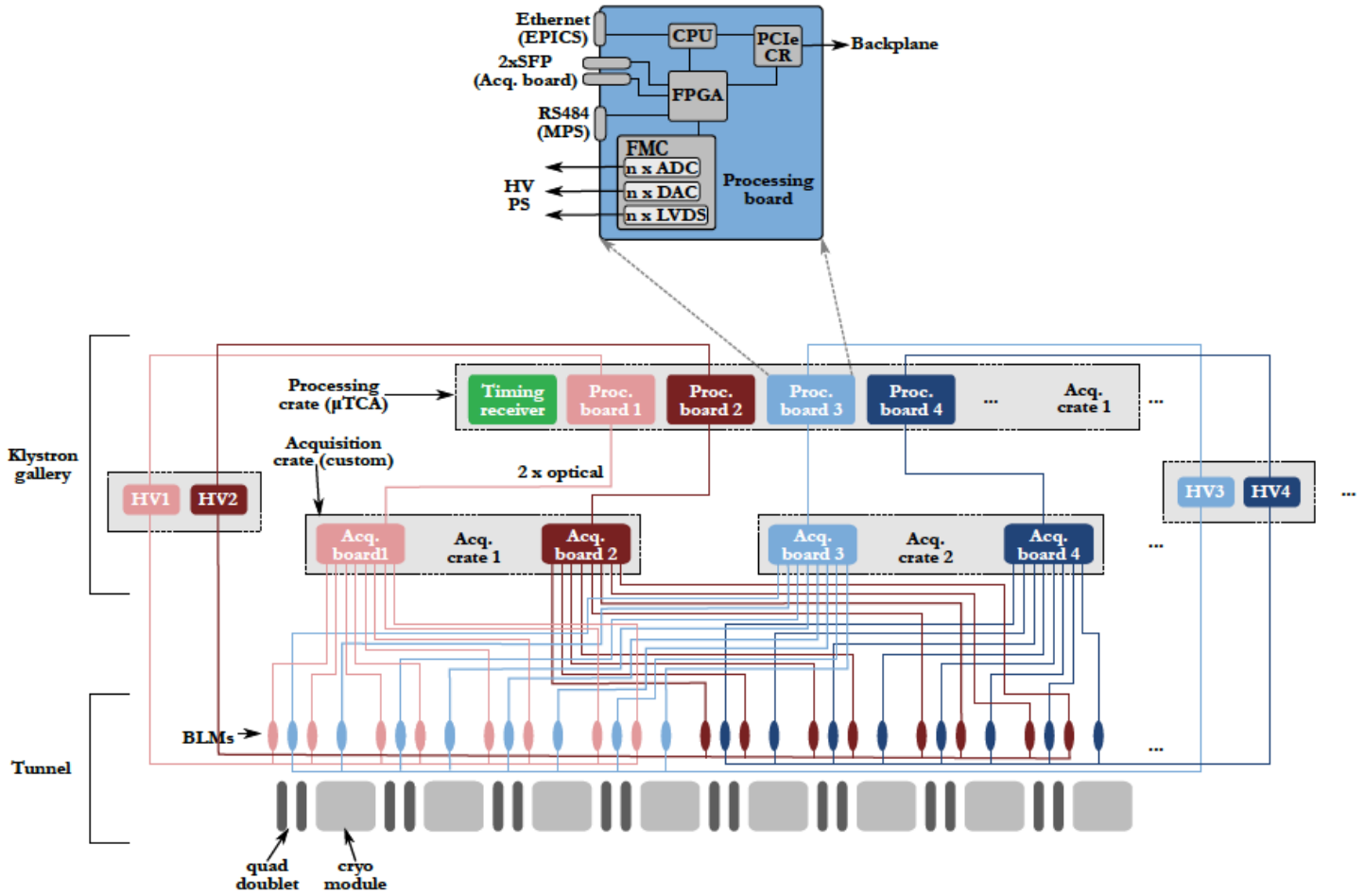
Conceptual system design

- Baseline solution, being evaluated:



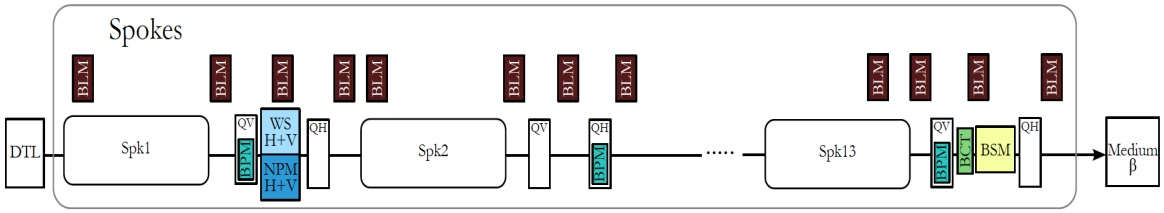
Conceptual system design

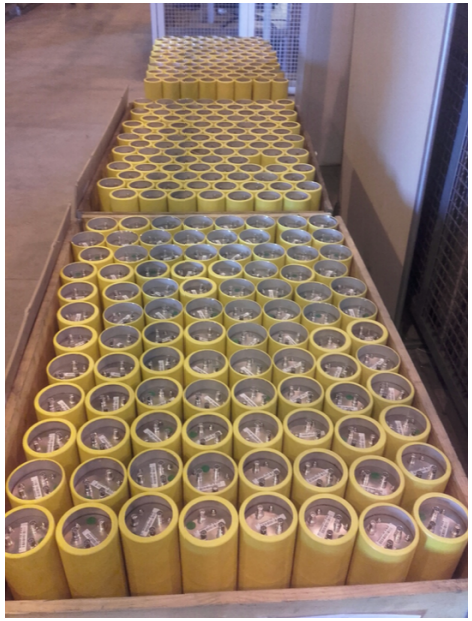
- Alternative solution: custom acquisition crate



Detectors

- Details have been covered in the icBLM detectors talk:
  - LHC-type
  - Design criteria: signal speed & robustness against ageing
  - Operated at 1.5 kV
  - Low pass filter at HV input
  - 285 ionization chambers received at ESS in Jul. 2017





L4 requirements

Type	Description
XXX beam loss measurement	The beam loss shall be measured in the XXX section.
XXX beam loss measurement	A beam current loss of 10 mW/m shall be detected.
XXX PBI peak current range	Proton beam instrumentation in the XXX section shall function over a peak beam current range of 3 mA to 65 mA.
XXX PBI pulse length range	Proton beam instrumentation in the XXX section shall function over a proton beam pulse length range of 5 µs to 2.980 ms.
XXX PBI pulse-by-pulse measurement update rate	Unless specifically stated, all instrumentation shall be able to perform the measurements and report the relevant PV data at a repetition rate of 14 Hz.
XXX PBI damaging beam detection and mitigation	Beam conditions that are potentially damaging to machine components shall be detected by the instrumentation and reported fast enough so that the conditions can be mitigated before damage occurs.

Electronics: HV unit specifications

High Voltage Supply: Modulation	Self-testing the ion chamber channels by modulating HV bias voltage shall be possible	A pulse or a continuous modulation could be used. This produces a signal by coupling through the capacitance of the ion chamber.
High Voltage Supply: output voltage rating	Positive voltage of at least 3 kV	the use of “positive polarity” will minimize saturation effects under high dose rates
High Voltage Supply: output power	Maximum output power of at least 5 W	
High Voltage Supply: output voltage ripple	Output voltage ripple below 4 ppm pk-pk/FS	
High Voltage Supply: noise figure	Noise figure shall be compatible with that of the signal acquisition board. This includes temperature induced noise	

Electronics: HV unit

COTS solution: CAENels HV-PANDA will be evaluated

- Double-width AMC with MTCA.4 Rear I/O
- 4 channels rated at 4kV at 7W
- Configurable ramp rate
- Nominal voltage accuracy better than 0.05% FS and a ppm-level peak-to-peak output voltage ripple
- SHV type connectors

Electronics: Signal acquisition unit specifications

Signal acquisition: Dynamic range	Input current dynamic range: 10 nA to 10 mA.	Two separate ranges shall be used: the low end set by the condition that the operators must be able to tune on beam loss measurements down to 10 mW/m, while the high end shall allow recording of total beam loss during faults and machine studies	BLM is required to be able to measure at least 1% of 1W/m loss during normal operation and up to 1% of the total beam loss.
Signal acquisition: Response time	NC LINAC: Calculated melting time values of 3-4 us SC LINAC: 10 us The signal acquisition card shall therefore feature a bandwidth of at least 300 KHz and a minimum sampling rate of 1MSPS	"Particle time" - PT: time between the onset of beam loss (the primary is lost) and the moment particle (primary or secondary) hits the detector. Detection time: time needed for the detector signal to develop and to collect enough hits/current Processing time: from the output of the detector to the BIS output on the FPGA	
Signal acquisition: resolution	The signal acquisition card shall have a resolution of at least 20 bits		
Signal acquisition: noise figure	The signal acquisition card shall have a typical noise better than 10 nA in its lowest range, including temperature induced noise		

Electronics: PICO-8 evaluation

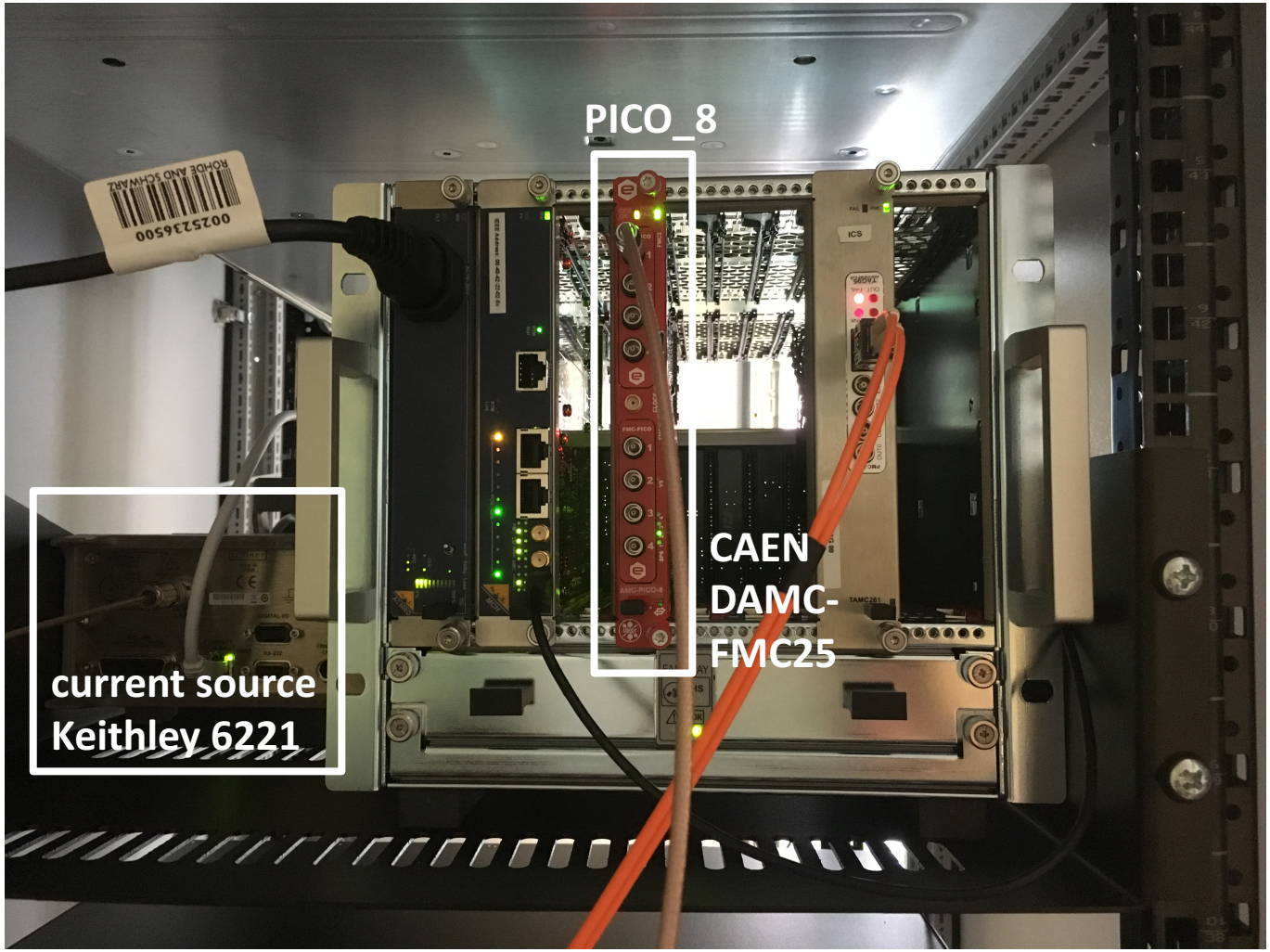
COTS solution: CAENels PICO-8

- 8-channel 20 bit Bipolar Floating Picoammeter with MTCA.4 REAR I/O

- “standard” AMC PICO-8 specs: http://www.caenels.com/products/amc-pico-8/
  - Full-scale ranges of 1mA and 1 uA
  - Input bandwidth: 10KHz

- ESS custom AMC PICO-8: (different input op-amp)
  - full-scale ranges of 10 mA and 500 uA
  - input bandwidth: 300 kHz

Electronics: PICO-8 evaluation



Electronics: PICO-8 evaluation

- Noise levels, as measured by manufacturer vs measured at ESS:

  (1 σ,10000 points @ 1MSPS)

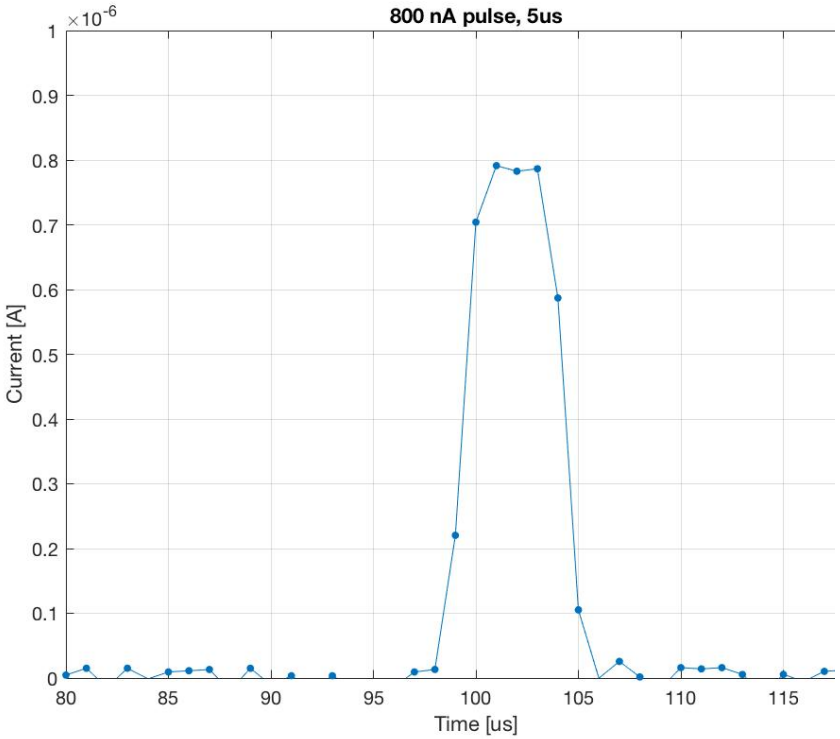
	CAENels	ESS testbench
10 mA range	190 nA	195 nA
500uA range	10 nA	10 nA

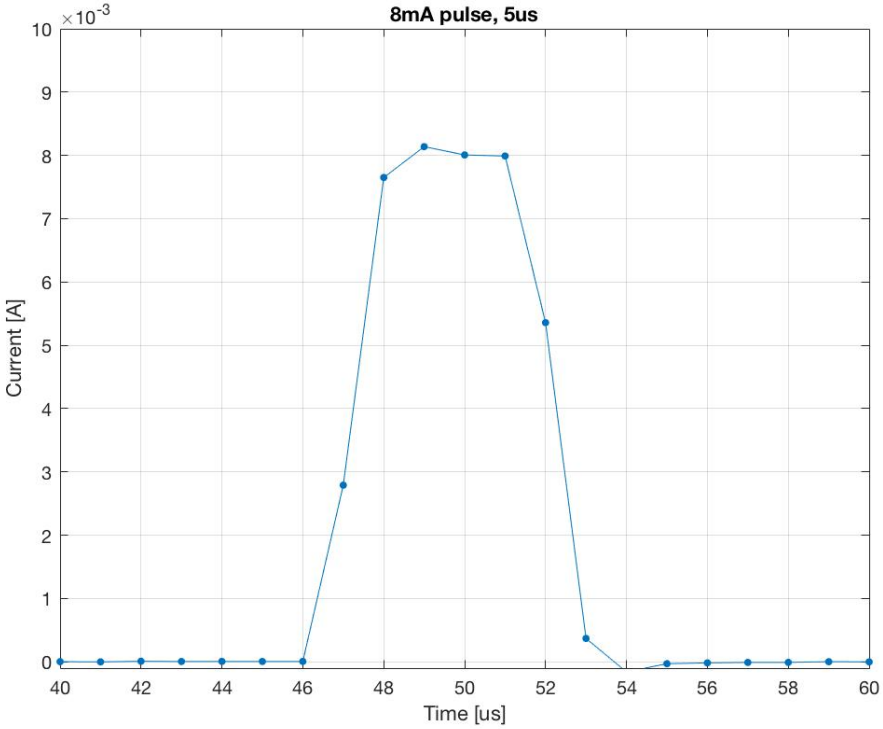
- Bandwidth, as measured by manufacturer:

	CAENels, 10mA range	CAENels, 500uA range
Ch 0	301 kHz	300 kHz
Ch 1	294 kHz	292 kHz
Ch 2	299 kHz	299 kHz
Ch 3	303 kHz	391 kHz

Electronics: PICO-8 evaluation

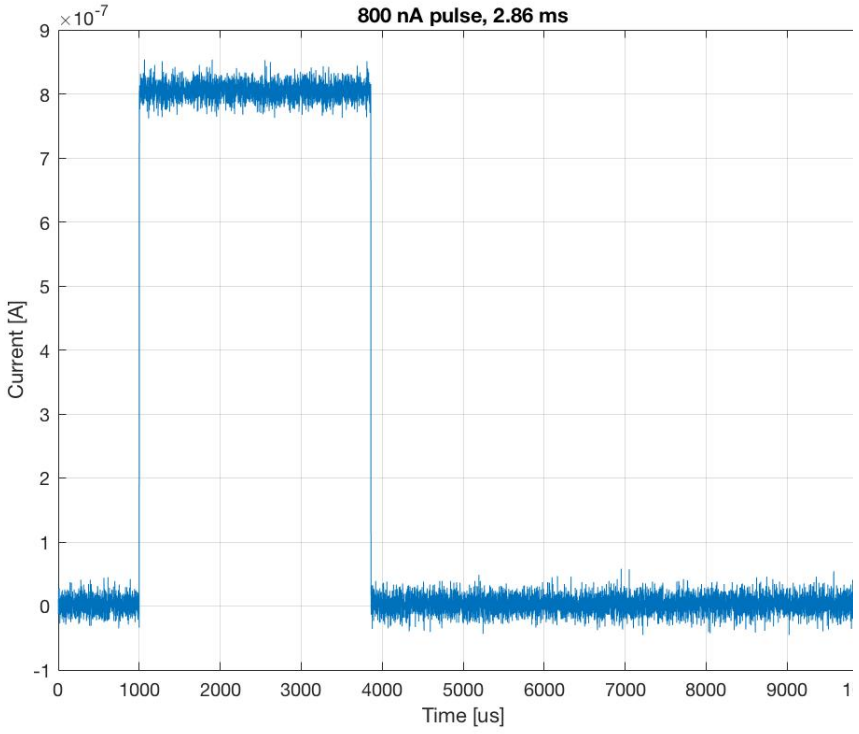
- Shortest pulse:

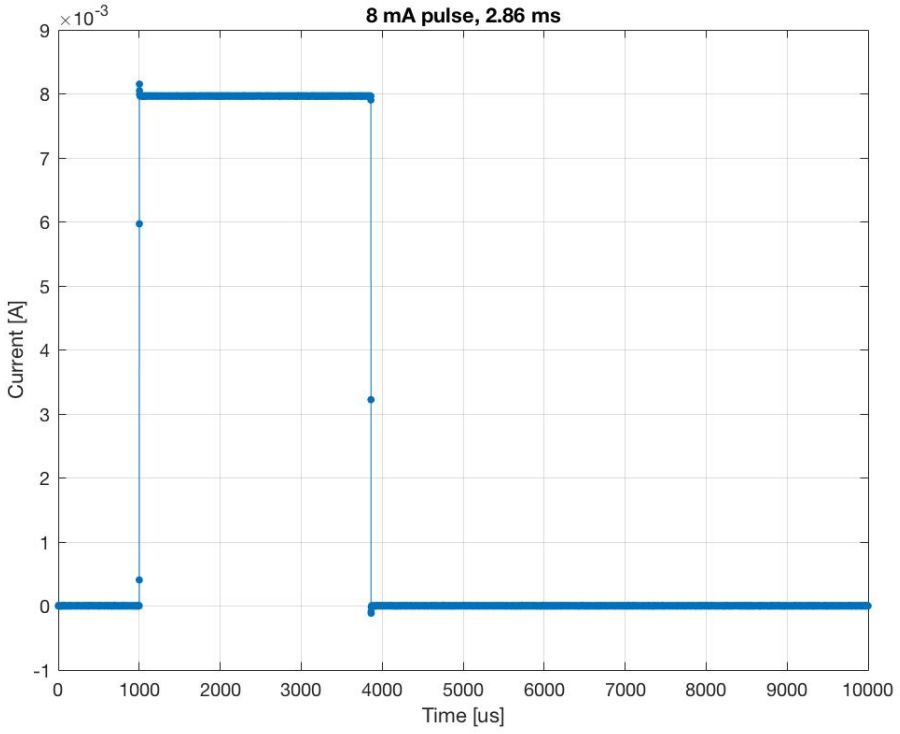




Electronics: PICO-8 evaluation

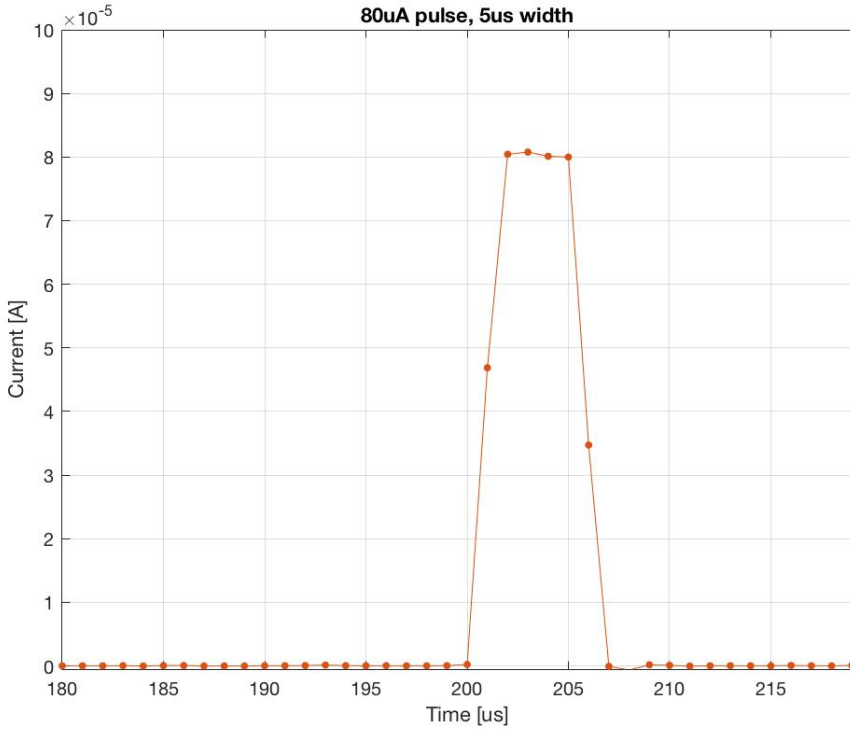
- Longest pulse:

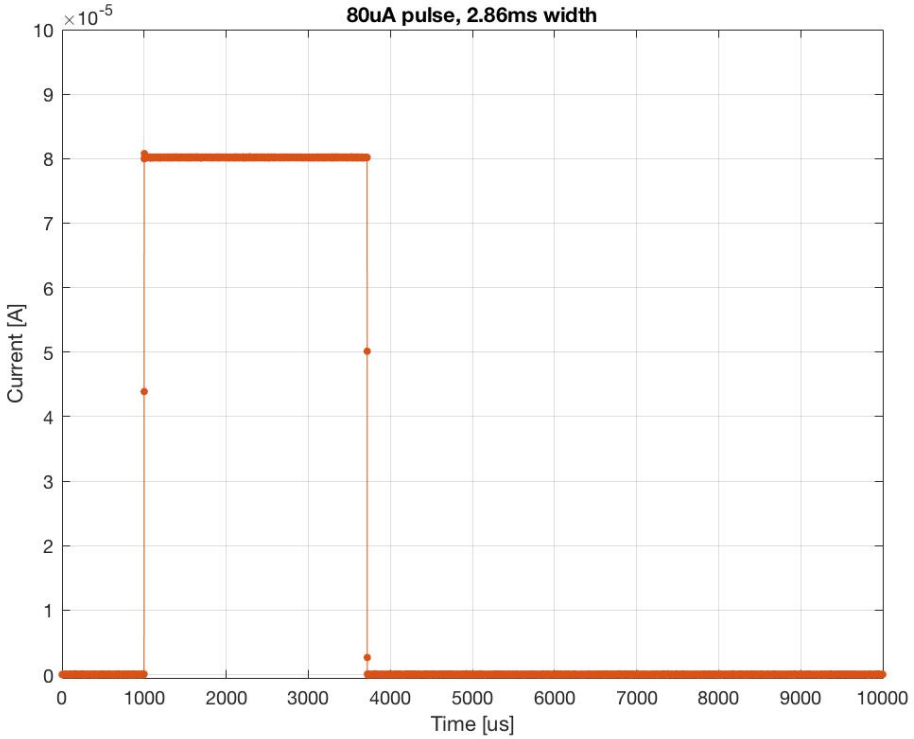




Electronics: PICO-8 evaluation

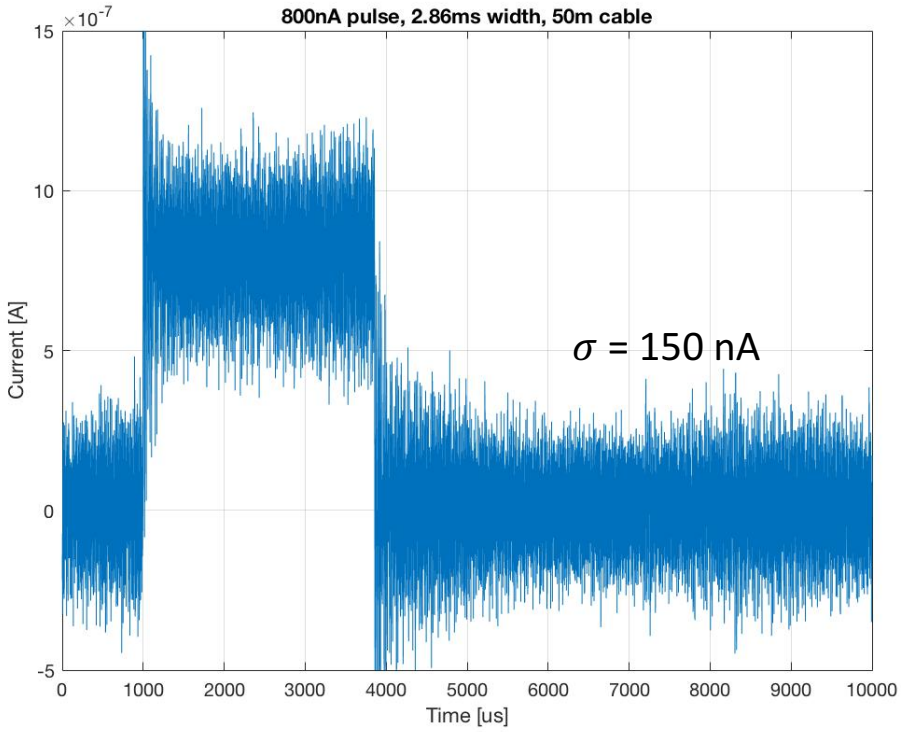
- 80 uA pulse amplitude: 1W/m loss during normal operation

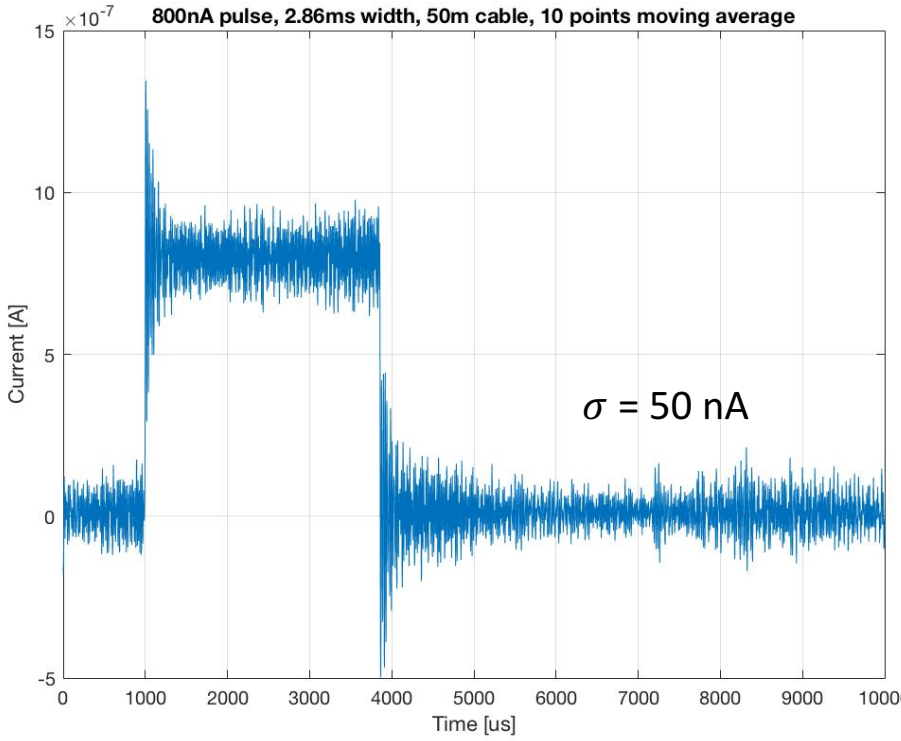




Electronics: PICO-8 evaluation

- Worst case: long off the shelf coax cable, moving average:





Electronics: signal acquisition unit

Alternative solution: Custom acquisition crate

- CERN BLEDP + processing mezzanine
- Current to frequency converter, fully differential front end
- Measurement of the current input is performed by two different techniques:
  - Advanced Current to Frequency Converter (ACFC) used in the range **10pA to 30mA**
  - Direct ADC acquisition (DADC) used in the range **20.3µA to 200mA**
  - **Transition between ranges managed by an FPGA**
  - **Optical output to post processing unit**

Conclusions & Outlook

- System design is moving forward quickly. 285 ICs received last week

- FRU tests:
  - Perform a “long-term” measurement to check for possible drift, on HV and signal acquisition units
  - Compare CERN solution evaluation with PICO-8

- Software and Firmware