The Abdus Salam
International Centre
for Theoretical Physics

UNIVERSITÀ
DEGLI STUDI DI TRIESTE

ECAL2 MSADC readout

Status report and updates

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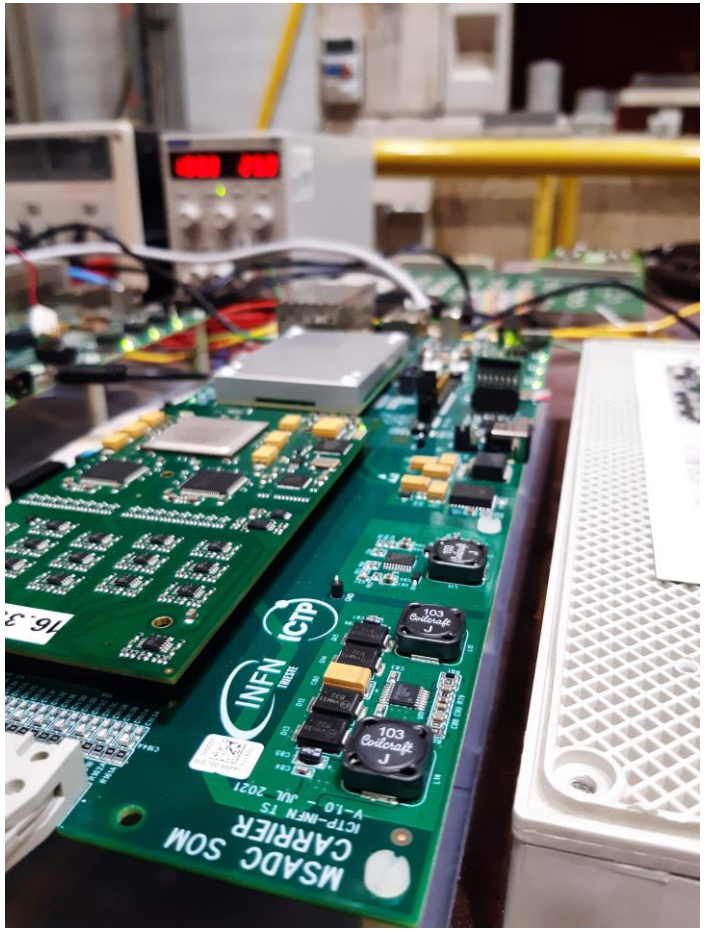
On behalf of the DSP-group

Outline

- Introduction
- Hardware developments and updates
- Setup during AMBER Pilot run 2021
- Data analysis and compression
- Updates on the setup at beam downstream
- Goals

COMPASS ECAL2 Data Acquisition Platform – MSADC SoM Carrier



- 100ch central part of ECAL2
- Based on the MSADC Board (currently operating with ECAL2 FE) + SoM (FPGA DSP)
- New :
  - Free-running mode, triggerless operation
  - Real-time online data features extraction for data reduction
  - Possible multipurpose free-running mode applications
- Full production of carriers : 24 Boards x 16 channels (384 ECAL2 Ch)

MSADC, Digitizer board

- 16 analog channels
- 12 bits @ 80 Msps
- **15.4 Gbps** raw data rate

System on Module and interfaces

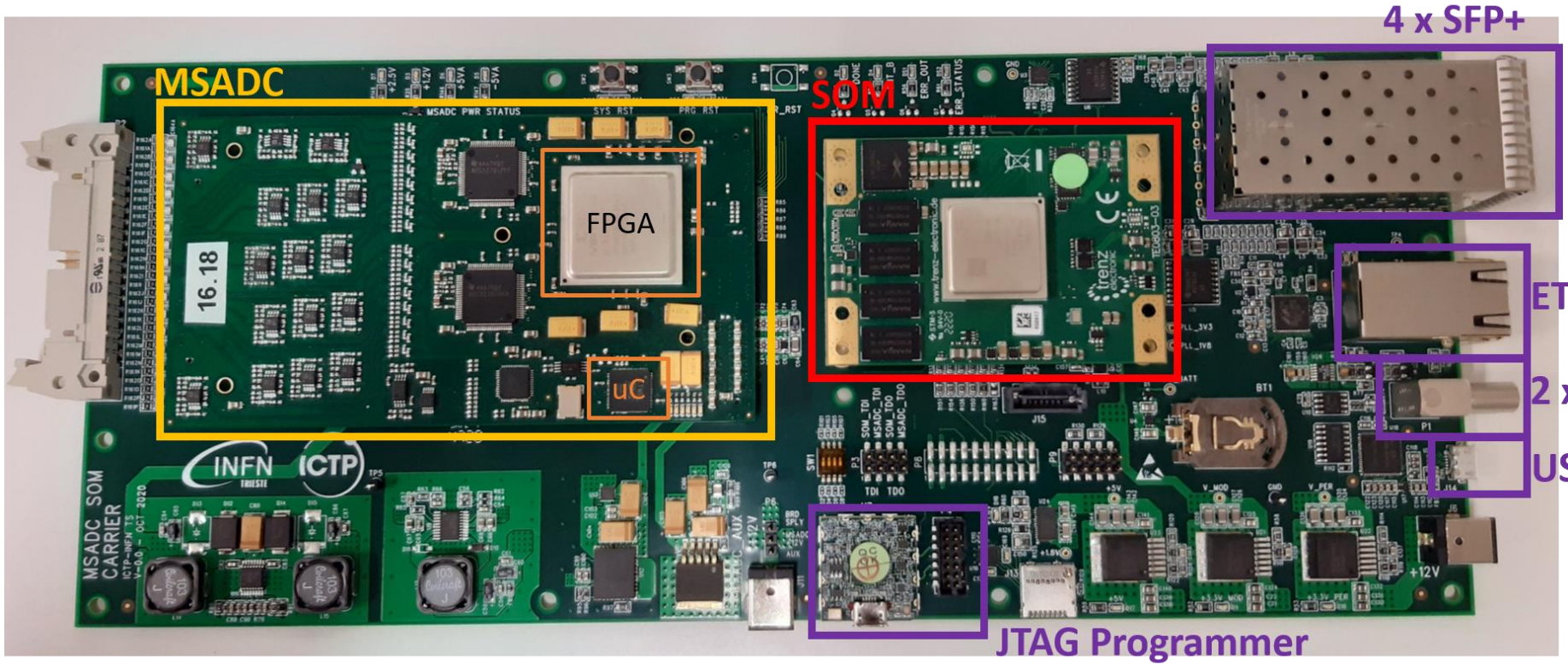
- Zynq Ultrascale+ SoC
- 2/4/8GB DDR4
- 4 High speed SFP+ interfaces
- GB Ethernet
- Serial UART USB
- SD Card
- SATA
- I2C

C

VHDL

MSADC SoM Carrier V0_0-- Hardware developments

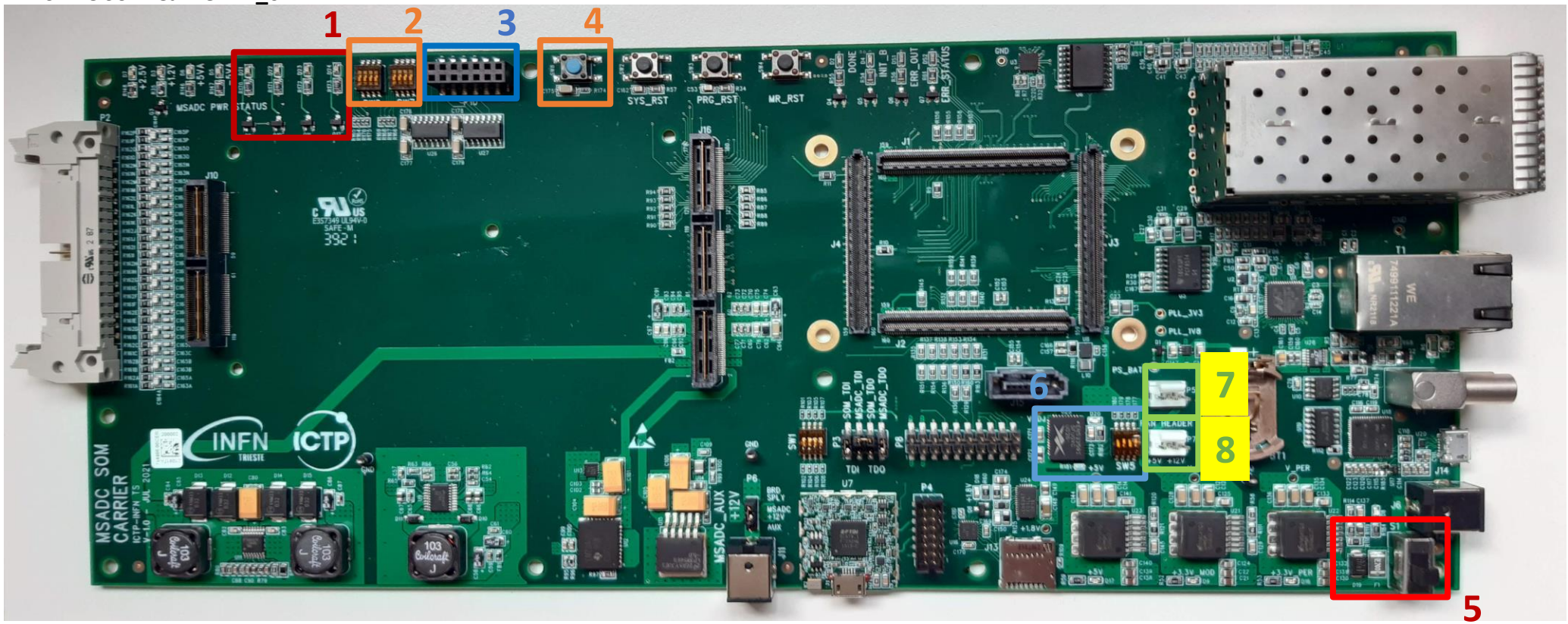
MSADC SoM Carrier V0_0



- Two versions of the carrier card
- 3 units of V0_0
- 3 units of V1_0
- Both designs were tested and validated
- Carrier cost under 3 k€ each (07/2021)

MSADC SoM Carrier V1_0 -- New features

MSADC SoM Carrier V1_0

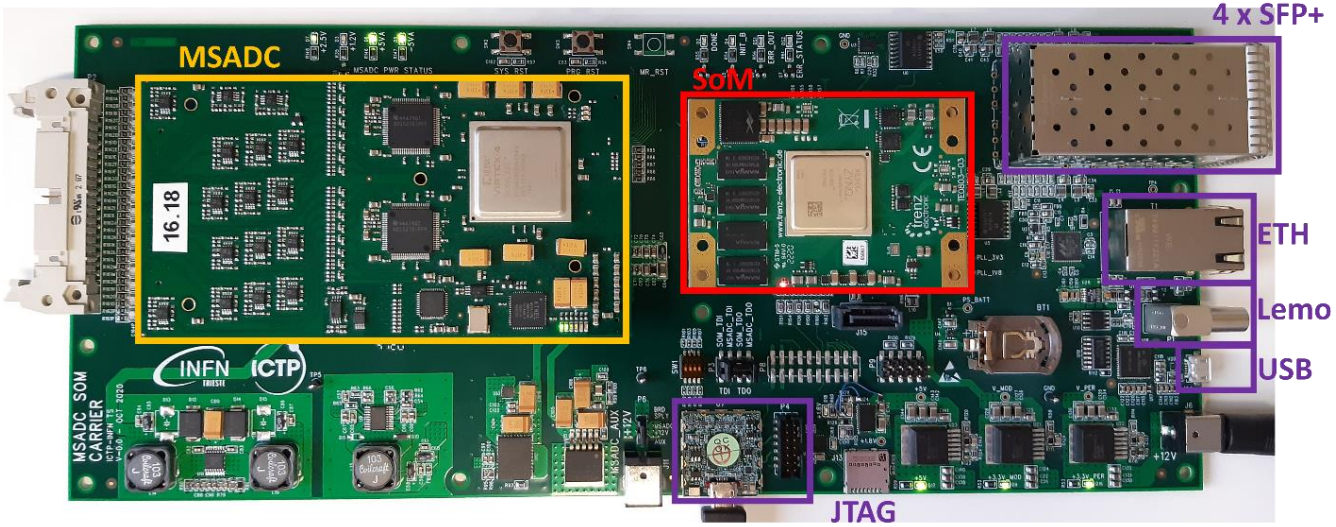


1_ User LEDS
2_ Slide switches
3_ 2 x PMOD
4_ Tact switch
5_ Power Switch
6_ Prog Vaux
7_ SATA Power
8_ Fan Power

AMBER Pilot Run 2021, Goals and Initial Setup

Main Goals

- Data taking of long data traces from a prototype ECAL2 detector, for developing a Digital Pulse Processor for data features extraction
- Study the noise distribution of the channels
- Study the ECAL2 response (pulse model)
- Integrate and test an ECAL2 HV power source control system
- Test and validate the MSADC-SoM Carrier card

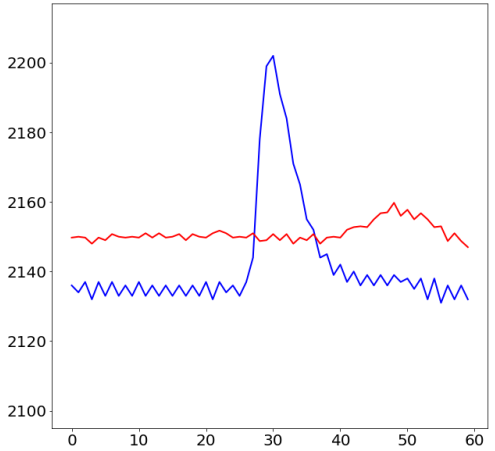


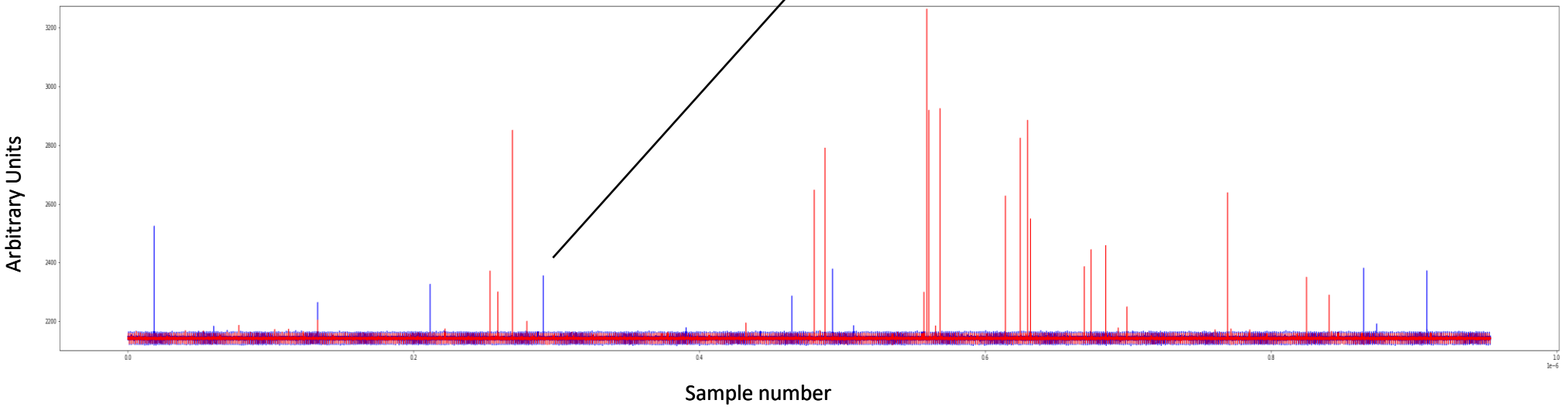
Initial Setup

- Located at end of beam downstream
- ECAL2 prototype 5x5 elements + Shaper
- MSADC-SoM Carrier
- High Voltage Power supply control
- PC for remote data taking, programming and control

Results

- Validated design, data taking with beam
- Read 16 channels in parallel (two at a time), free running
- 1,5 TB of data for analysis and noise optimization
- Develop compression algorithm for efficiently transmit the data from the MSADC to the SoM card





Compression

MSADC, data generation
- 16 Channels
- 12bit x 80 Mbps= 960 Mb/s per channel
- 16 * 960 Mb/s = 15360 Mb/s (15.4 Gbps)

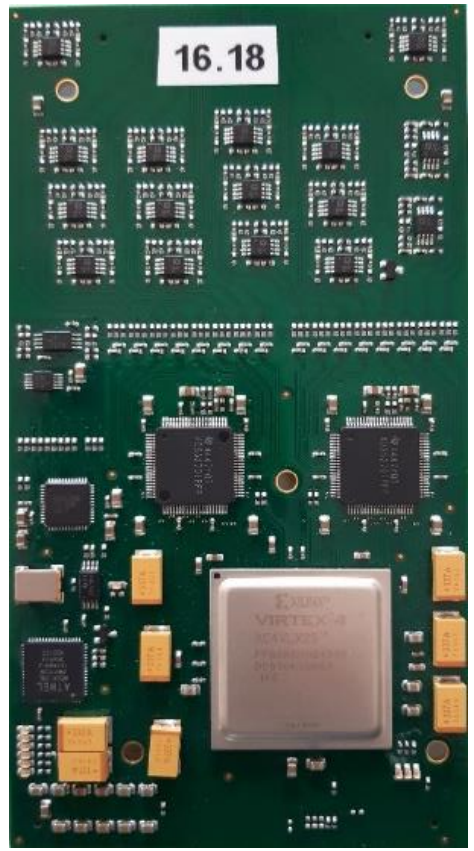
MSADC, actual data Tx capabilities per channel
- Max theoretical data rate = 800 Mb/s
- Achievable data rate = 400 Mb/s

Current data rate per channel vs Raw data rate
- 16 Channels
- Link bandwith = 400 Mb/s
- Raw data rate = 960 Mb/s

Raw data rate > Interface Tx capabilities

Compression factor $C > \frac{Data_{Raw}}{\mathrm{BW}_{link}} = 2.4$

MSADC

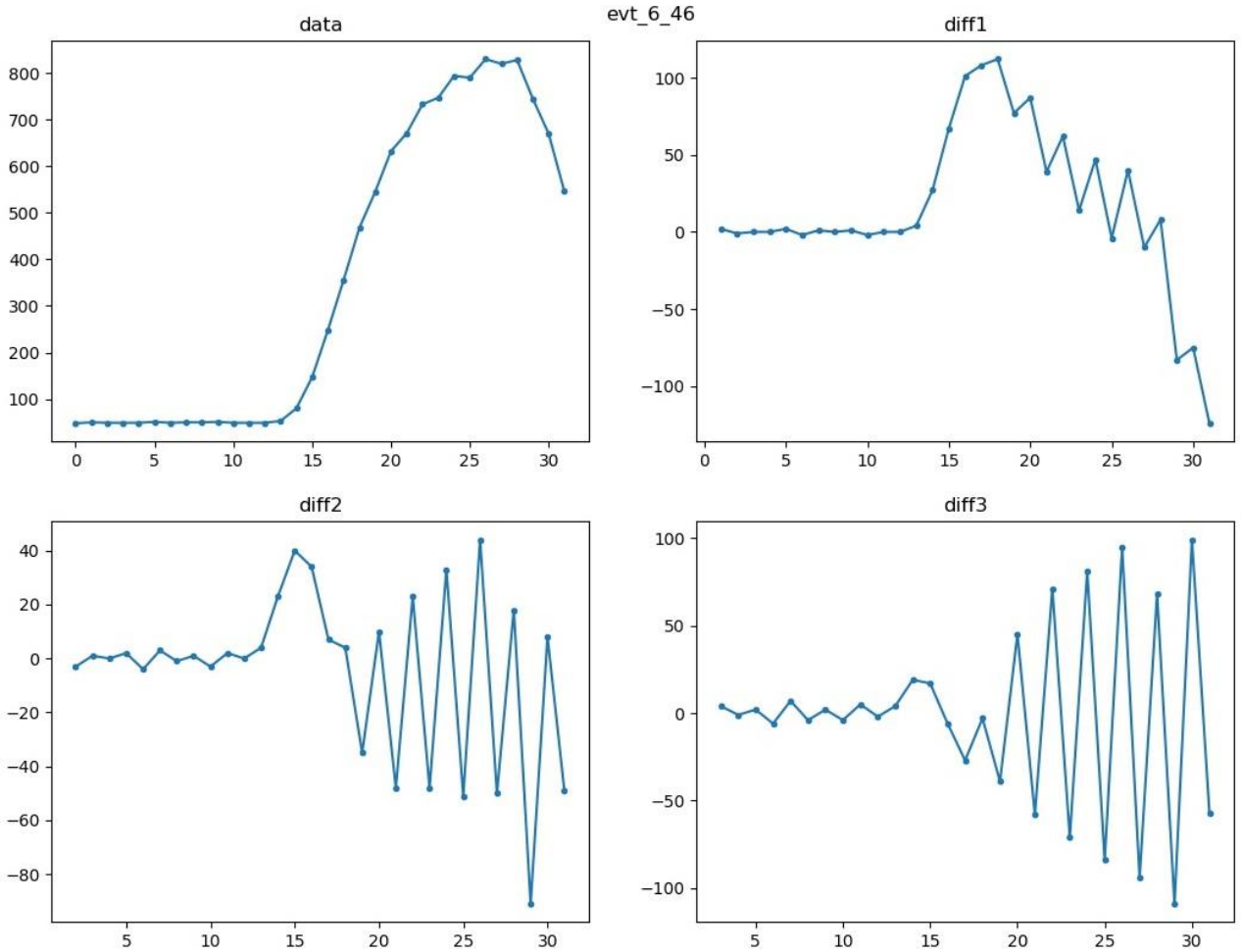


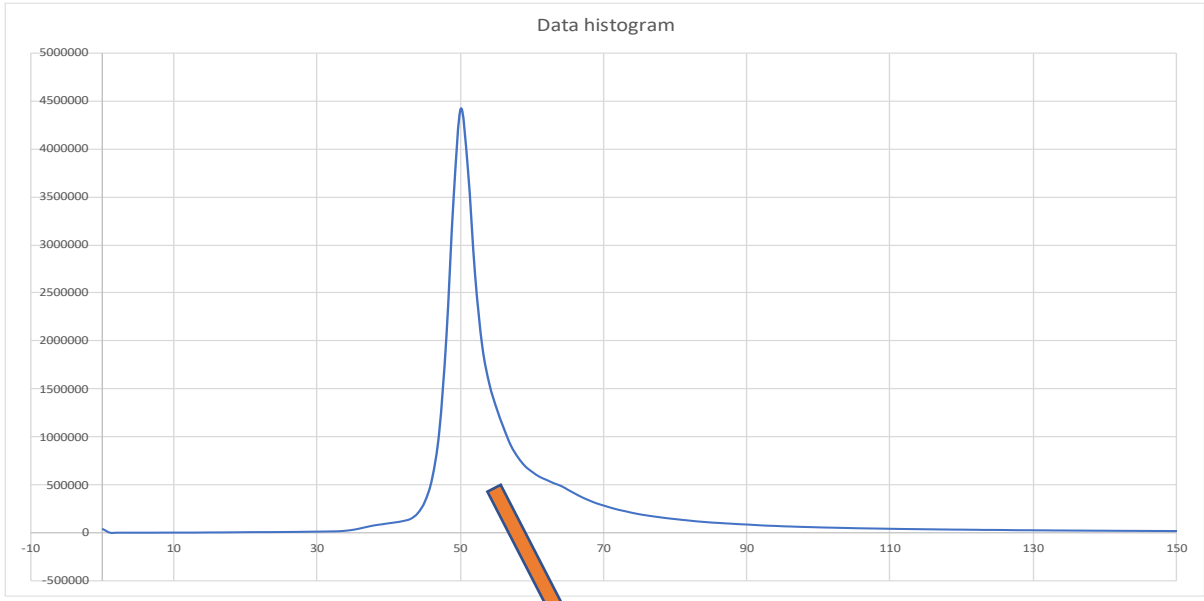
Prediction

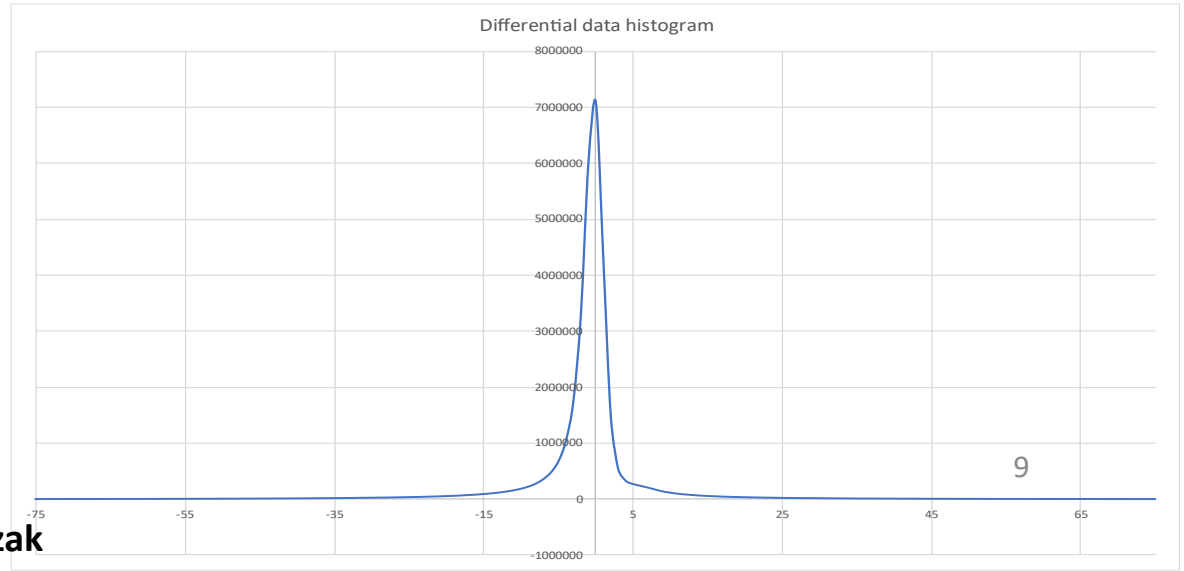
Different polynomial predictions:

- diff0: signal: x[i]
- diff1: x[i] - x[i-1]
- diff2: x[i] - 2*x[i-1] + x[i-2]
- diff3: x[i] - 3*x[i-1] + 3*x[i-2] - x[i-3]

Differential coding allows more concentrated distributions and lower bit rates







Huffman Codes

- Different code lengths
  - Most probable values assigned to shortest codewords, each code uniquely identified
- Start code (Trigger)
  - 26 bits
- SKIP code
  - When no samples at the encoder input
- Less probable values are coded with OUT-RANGE codes
  - Small deterioration

value	codewords
TRIGER/START	x3FFF FFE
SKIP	1111111111110
OUT-RANGE	1010+12bits

value	codewords	value	codewords	value	codewords	value	codewords
-32	1111101010	-16	111101110	0	00	16	111110011
-31	1111101011	-15	11101010	1	100	17	111110100
-30	1111101100	-14	11101011	2	11001	18	1111110100
-29	1111101101	-13	11101100	3	110110	19	1111110101
-28	1111101110	-12	11101101	4	1110001	20	1111110110
-27	1111101111	-11	11101110	5	1110010	21	1111110111
-26	1111110000	-10	11101111	6	1110011	22	1111111000
-25	1111110001	-9	1101110	7	1110100	23	1111111001
-24	1111110010	-8	1101111	8	11110000	24	1111111010
-23	1111110011	-7	1110000	9	11110001	25	1111111011
-22	111101000	-6	110100	10	11110010	26	1111111100
-21	111101001	-5	110101	11	11110011	27	1111111101
-20	111101010	-4	11000	12	111101111	28	11111111100
-19	111101011	-3	1011	13	111110000	29	11111111101
-18	111101100	-2	010	14	111110001	30	11111111110
-17	111101101	-1	011	15	111110010	31	11111111110

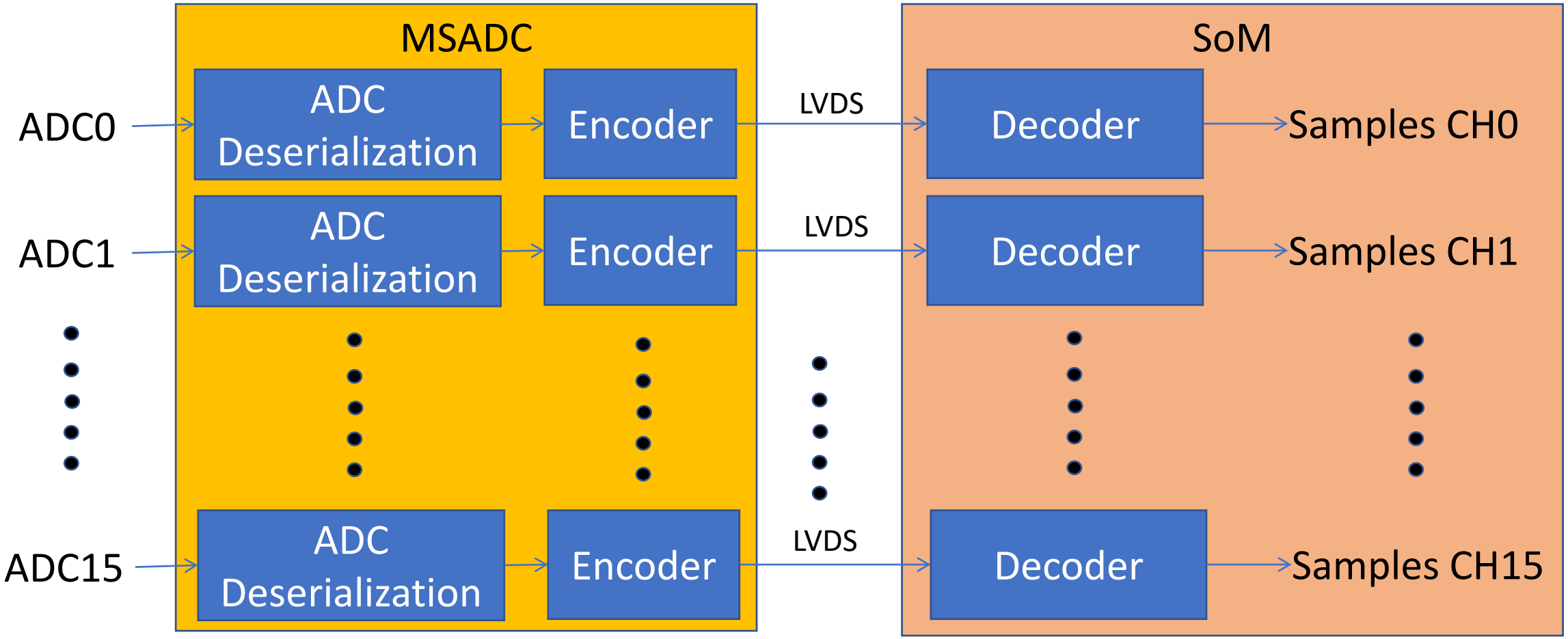
Implementation and Bit-rates

- Diff1 predictor selected due to its simplicity:
  - difference between the current and previous samples is coded
- The estimation neglects SKIP and START/TRIGGER codewords
- Huffman coding introduces negligible losses in compression efficiency
  - About 0.04 bps
- Simplified Huffman Coding introduces small losses in compression efficiency
  - Samples out of the range of [-32, 31] are coded on 12 bits with the preceding 4-bit prefix
  - About 0.18 bps

value	Bit-rate [bps]	Compression Rate
Entropy	4.3123	2.783
Huffman Coding	4.3508	2.758
Huffman Coding + simplifications	4.5290	2.649

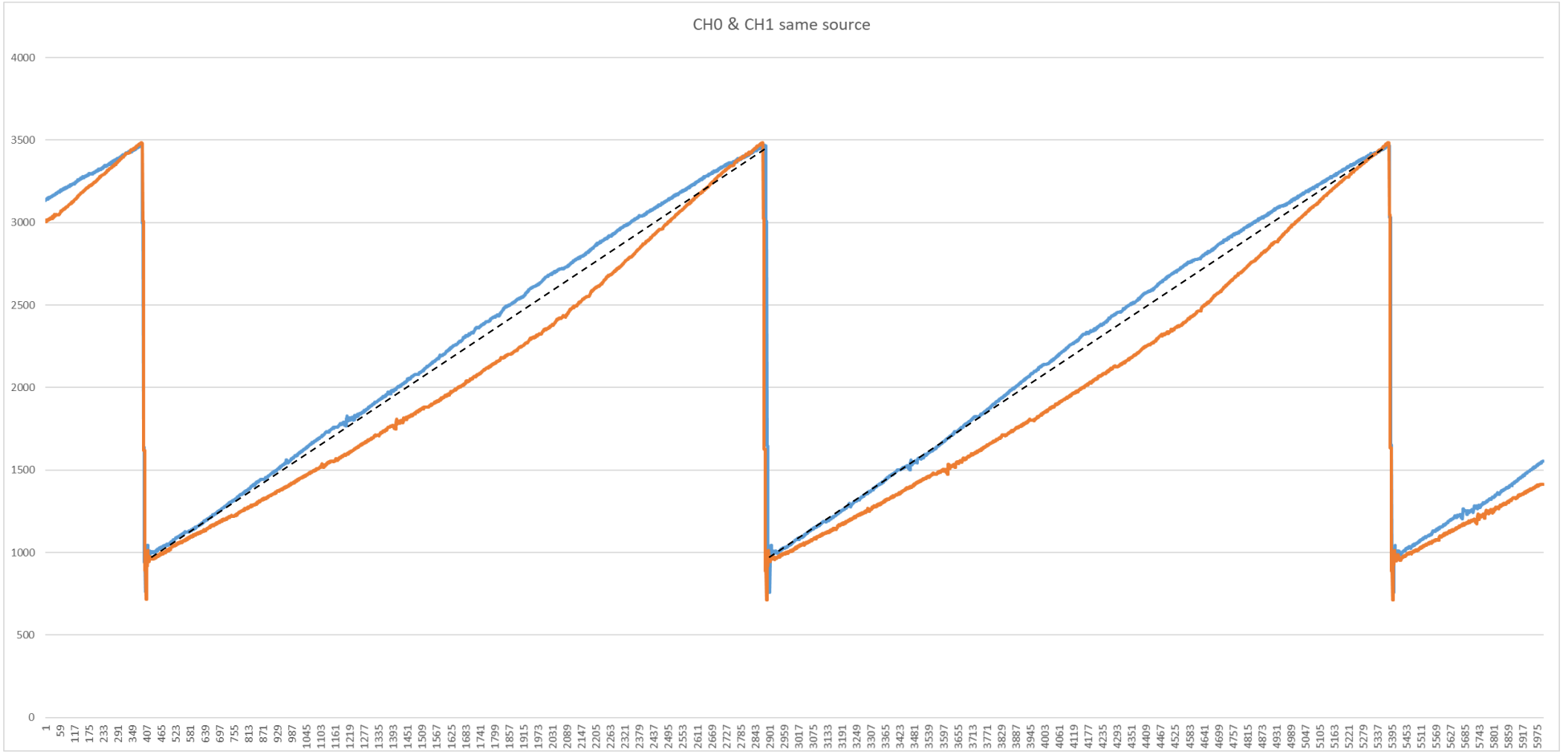
(2.4)

Compression scheme in AMBER-ECAL2 data acquisition

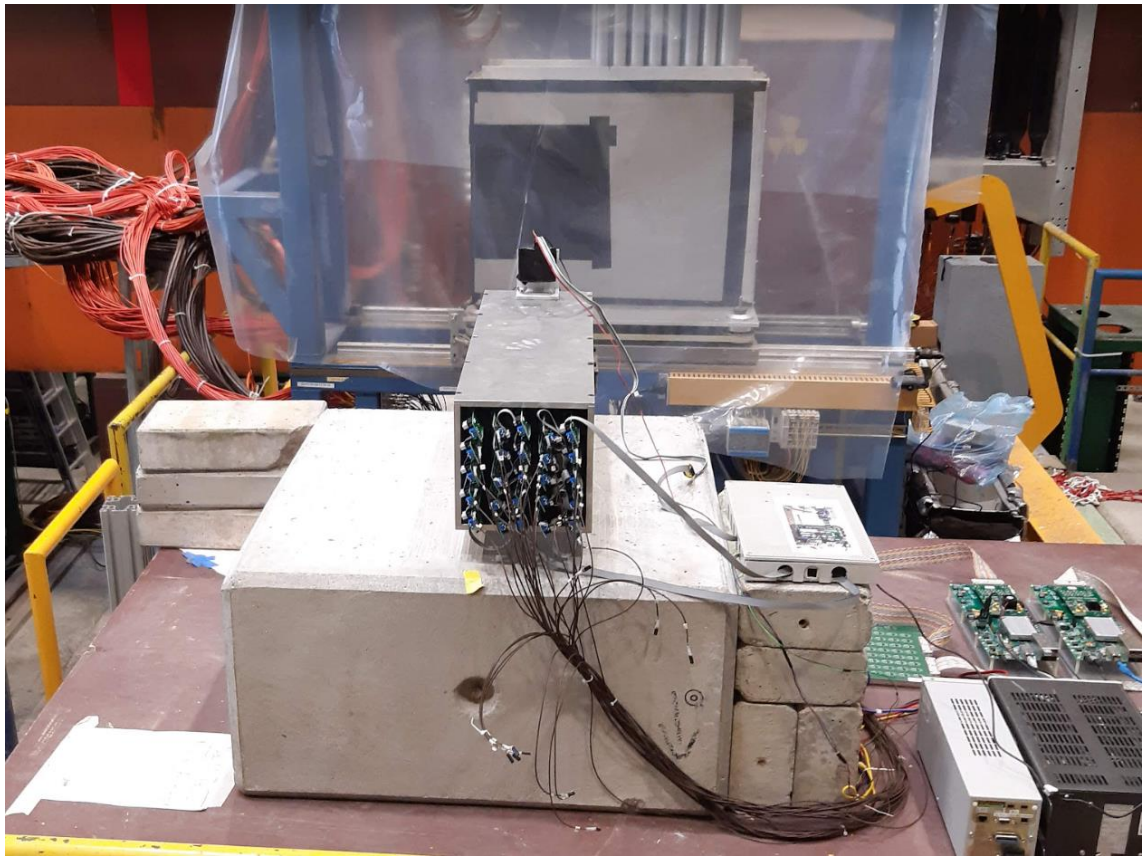


- One/separate encoder-decoder pair for each ADC channel
- Need for serialization/deserialization -> need for bit-level synchronization at the decoder
- Lossless compression

Current status of encoding system – debugging state



Setup in beam area -- updates



- 100V Power Supply for PMT polarization, can be controlled over IP
- Update Hardware for control of the PMT HVPS
- Update led pulser driver (operative testing)
- Re-installed some software tools for programming MSADC and SoM
- Added a NIM to TTL converter for BOS signal

Firmware Status

- Compression debugging
- Full implementation
  - Amplitude and time extraction
- Simplified implementation
  - Signal detection => 32 samples
- SFP+ Communication
- Amber protocol
- Completion of work packages to be defined

Hardware Status

- Carriers production
  - 3 units V0_0
  - 3 units V1_0
  - 24 Carrier under quotation process (last week)
- Carriers testing
- System on Modules (Xilinx Zynq Ultrascale+)
  - 5 acquired and using
  - Remaining ones under quotation process (availability)
- HV Control board fully implemented and working
- MSADC cards from current ECAL2 Front-End electronics

Thanks!

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