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The development of a 128-channel ultra-low noise trans-impedance amplifier system

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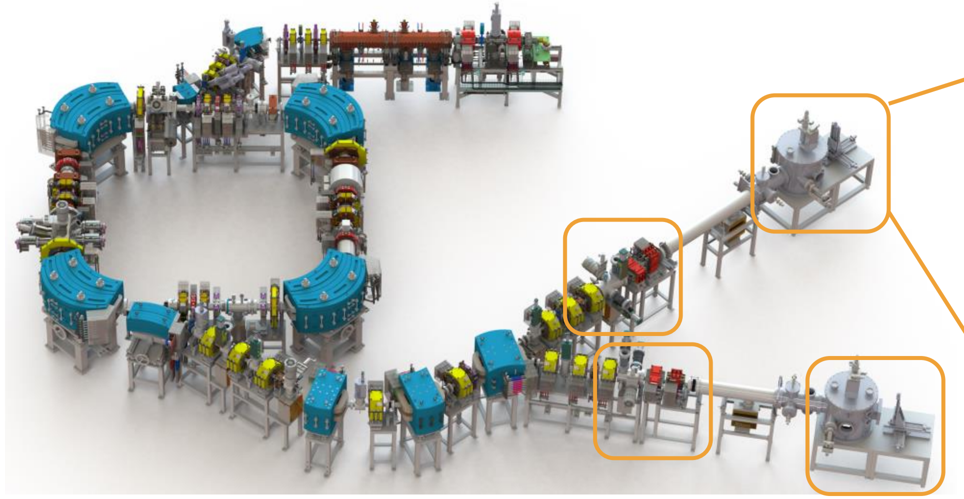
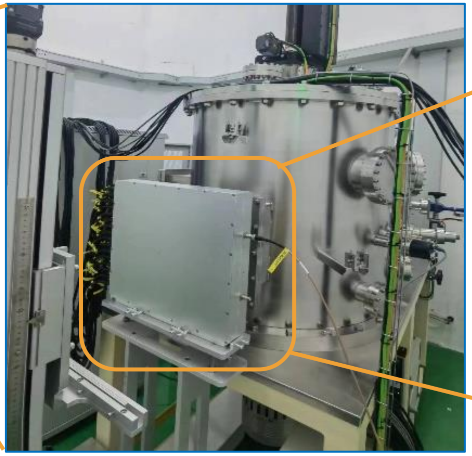
Background and Significance

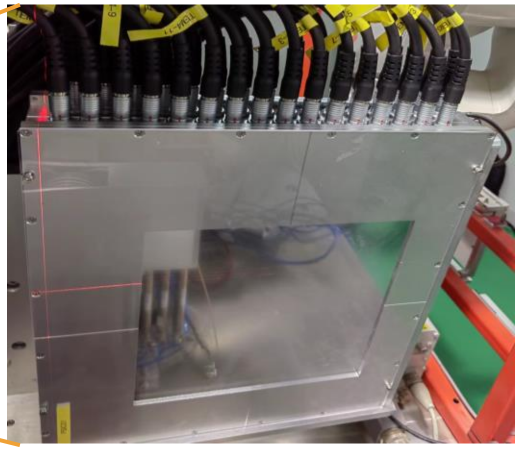
Proton Radiation Effects Facility



PREF's terminal



MSIC: Multi-strip Ionization Chamber

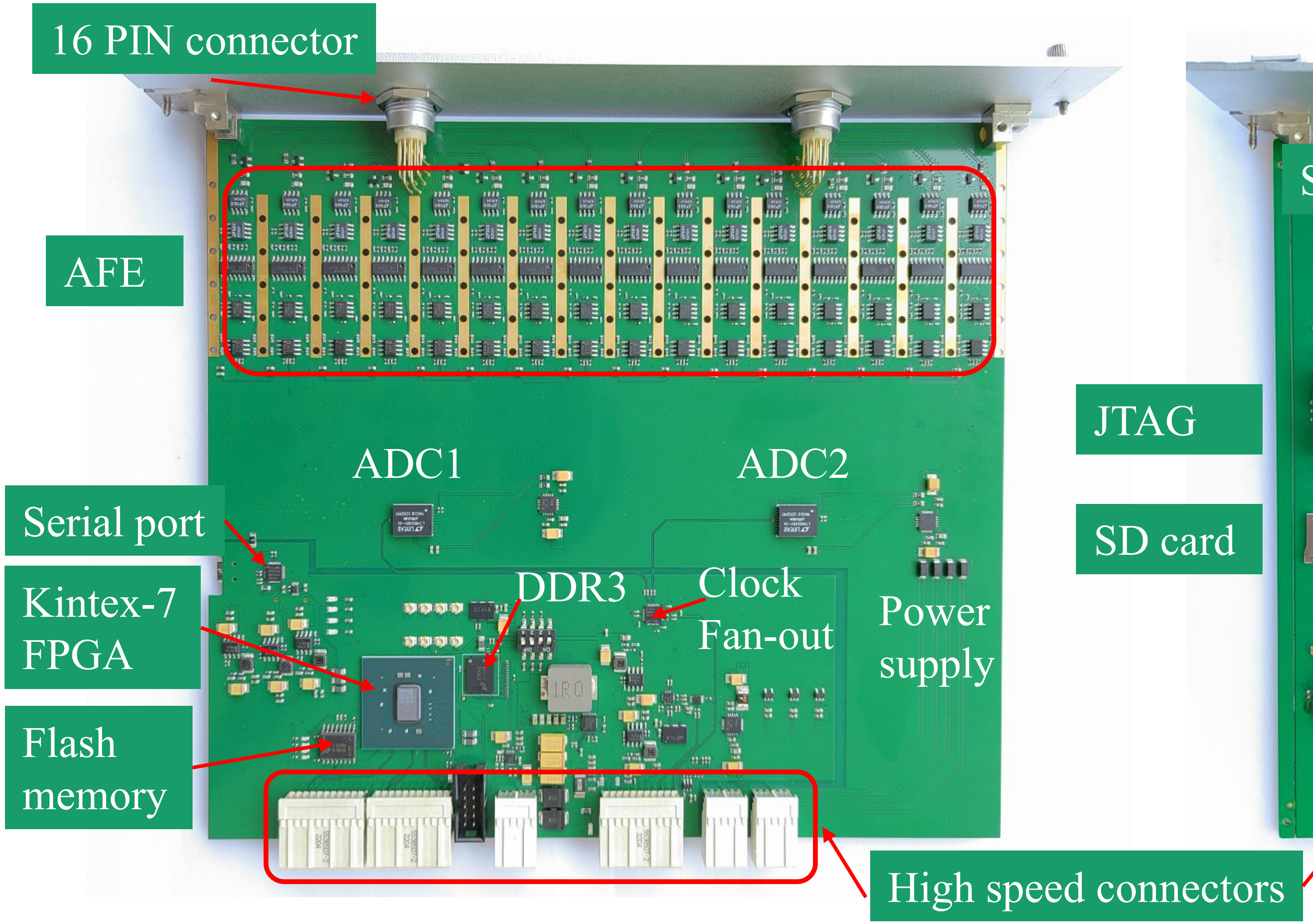


Parameter	Value
Number of channels	128 (16×8)
Measurement range	25 pA ~ 1.8 μA
Analog bandwidth	1 kHz
Sampling frequency	60 MHz

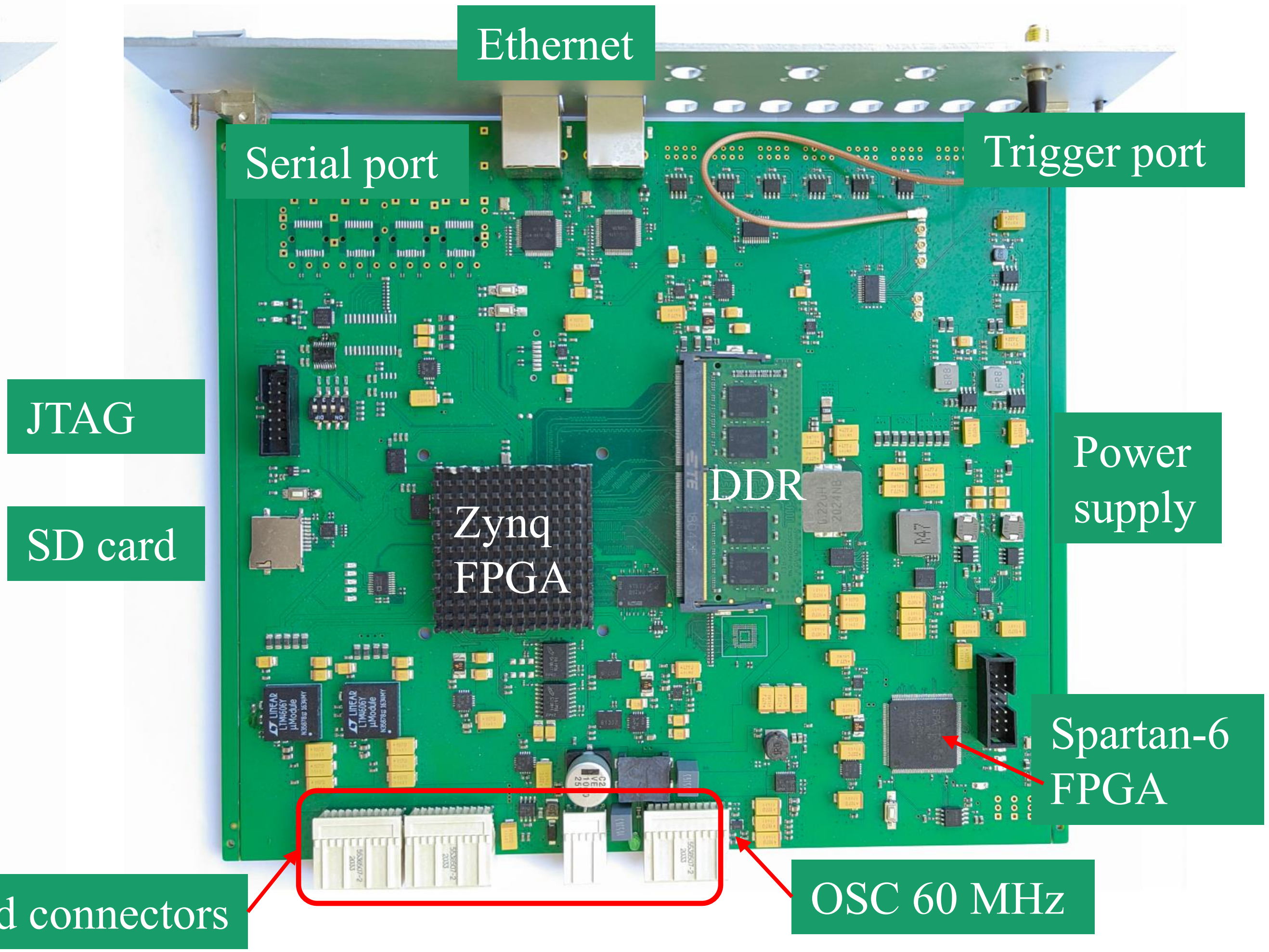
readout system

System Structure

Data acquisition board and AFE



Data processing board



System Structure

Data acquisition board and AFE* 8 **Data processing board**

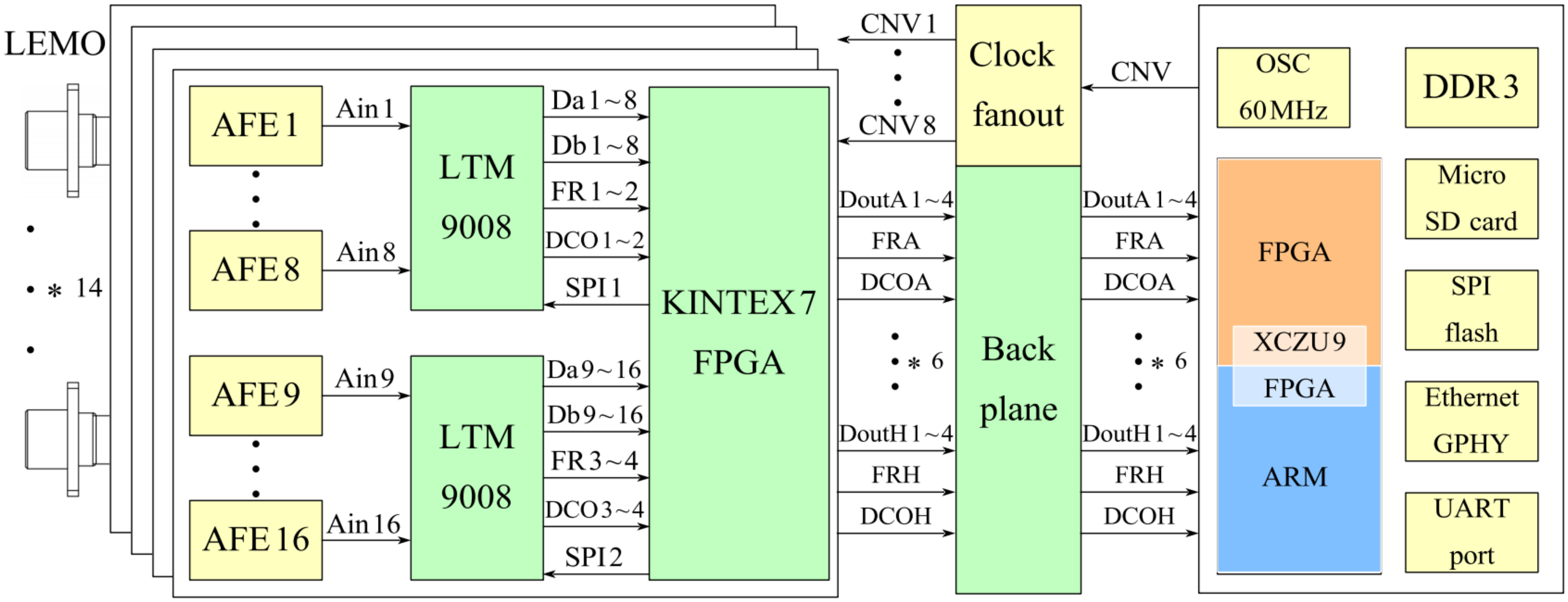
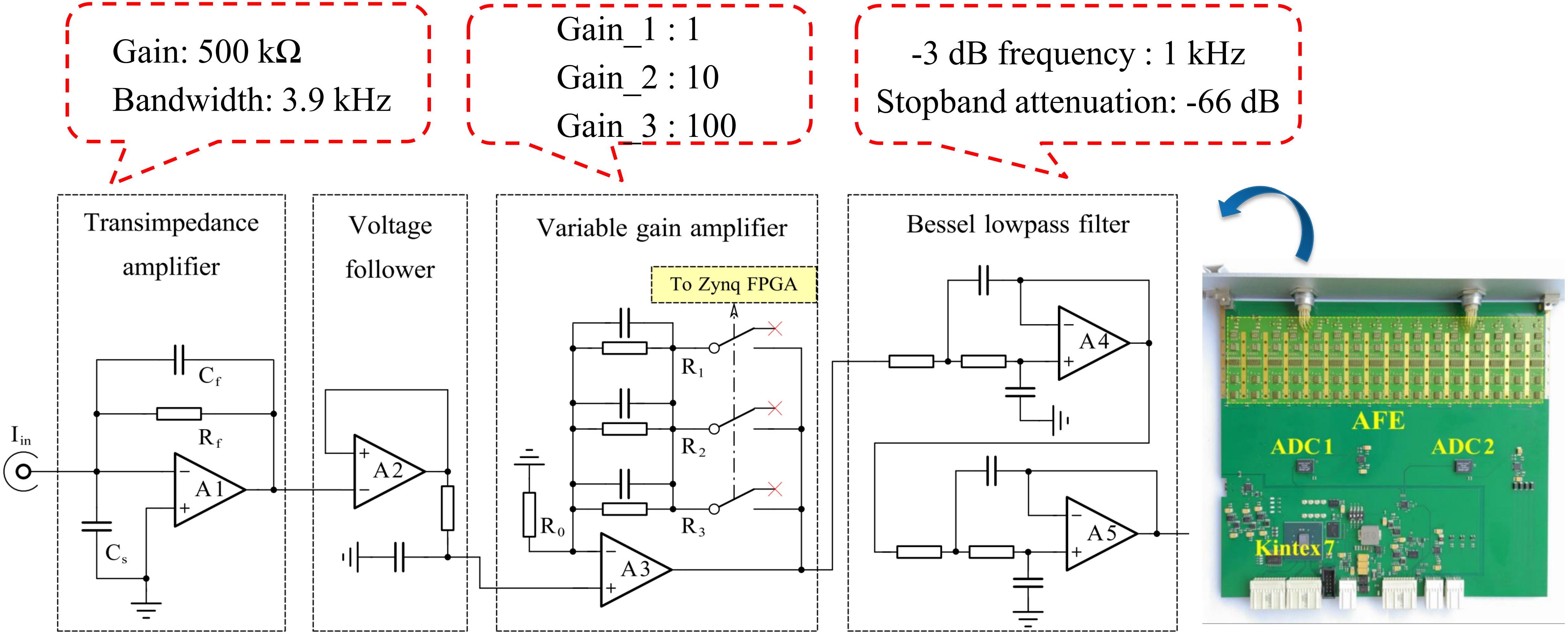


Diagram of this multi-channel readout system

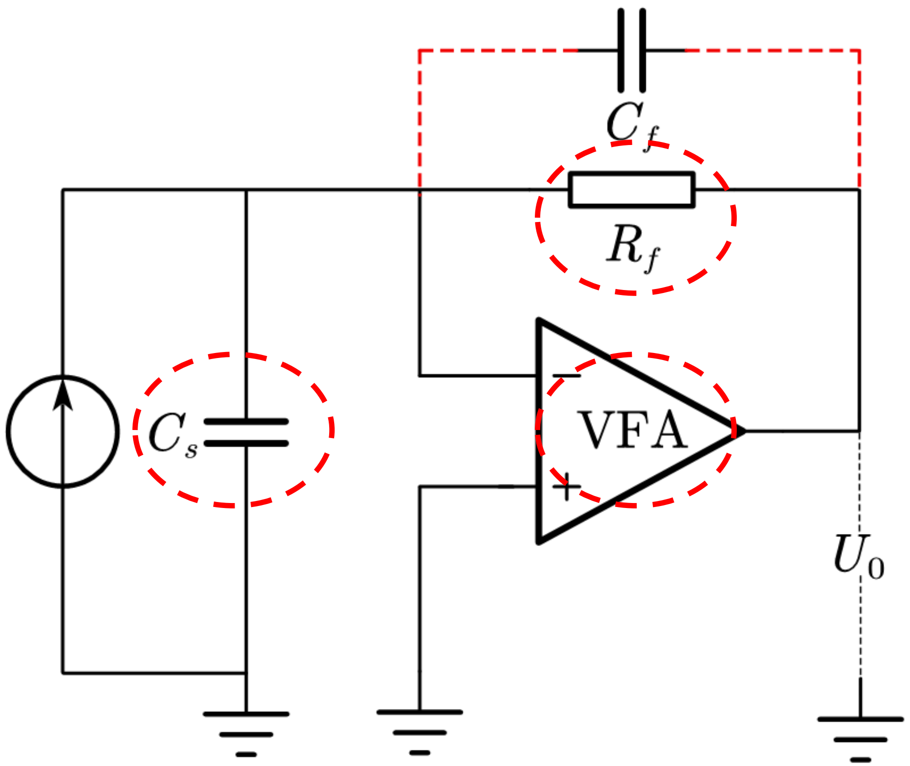
Analog Front-end Electronics

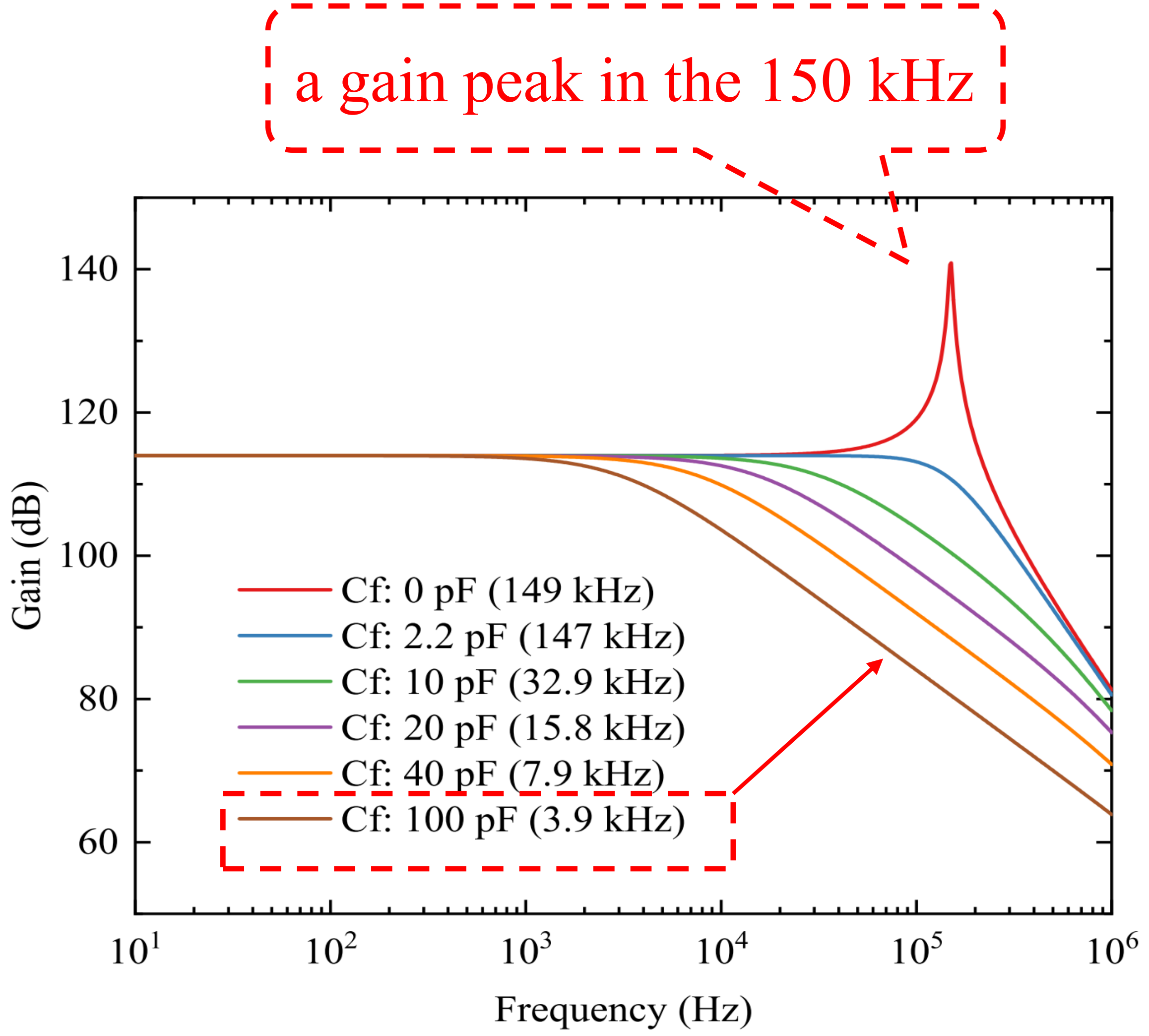


Block diagram and the PCB board diagram of the AFE

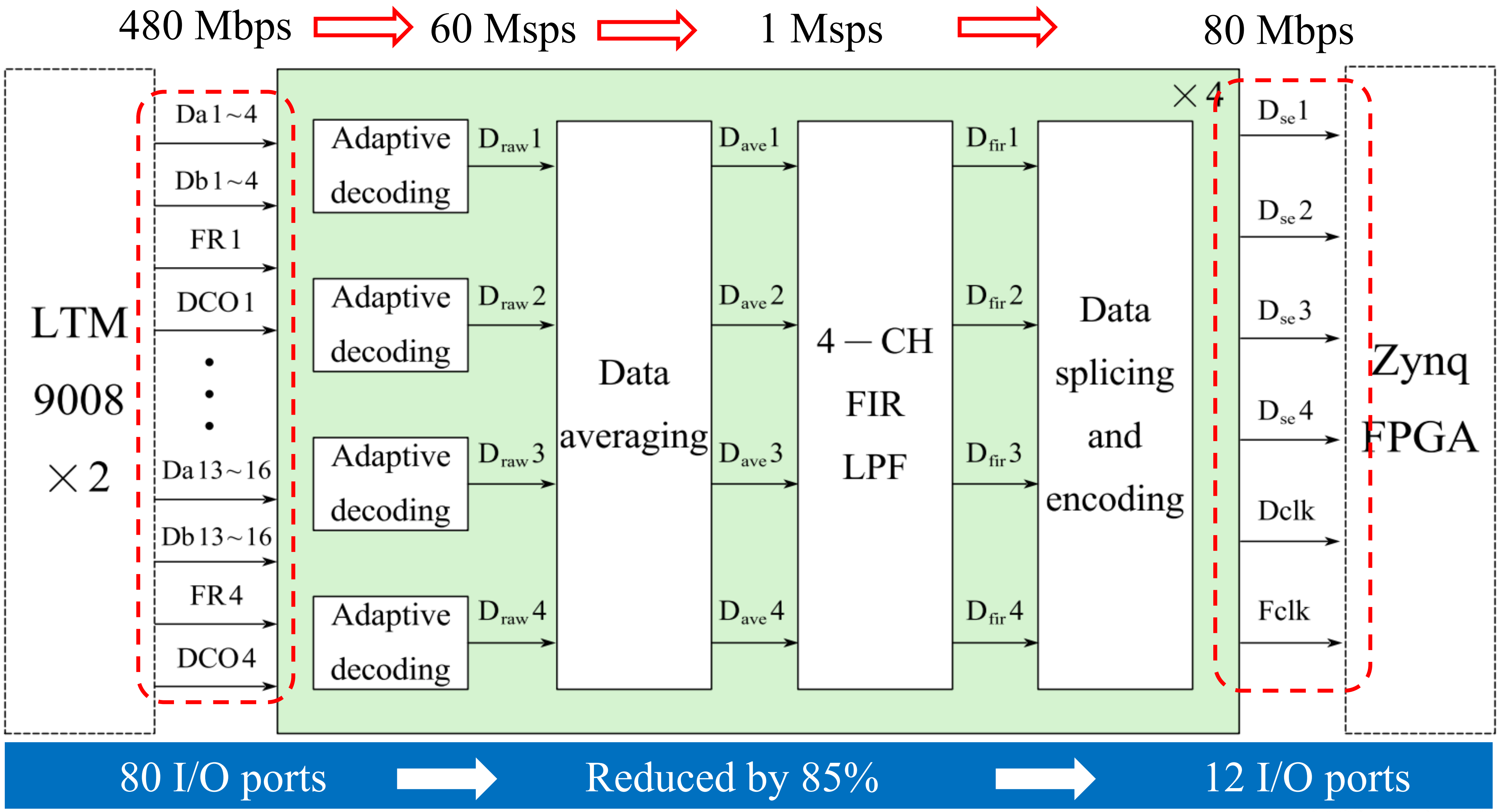
TIA Circuit with the feedback capacitor

$$C_f = \frac{1}{4\pi R_f f_{GBWP}}\left(1 + \sqrt{1 + 8\pi R_f C_s f_{GBWP}}\right)$$

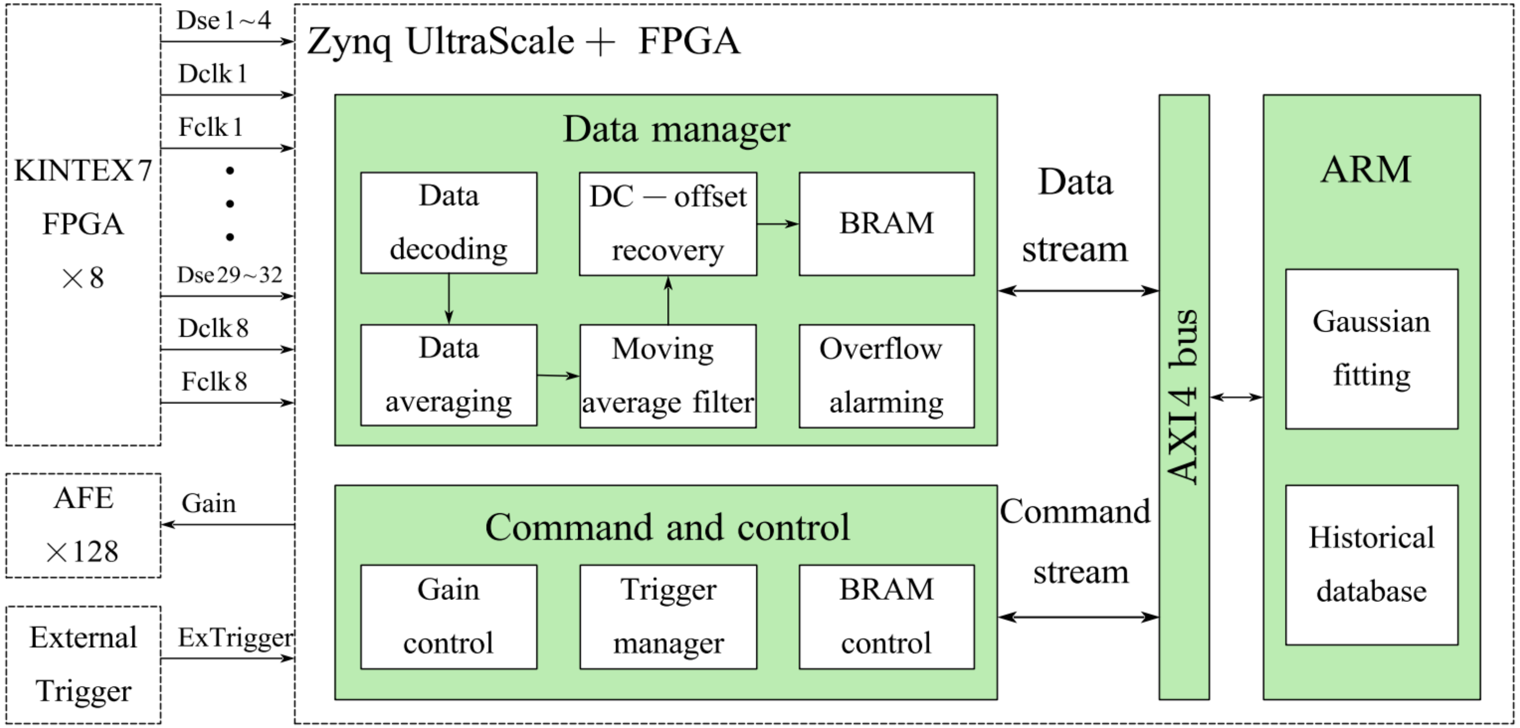


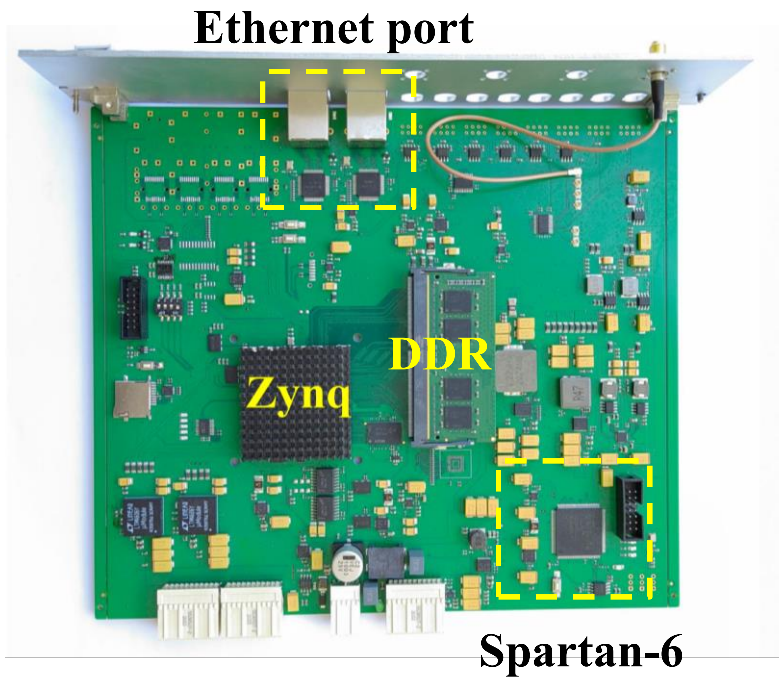


Firmware of the Kintex-7 FPGA



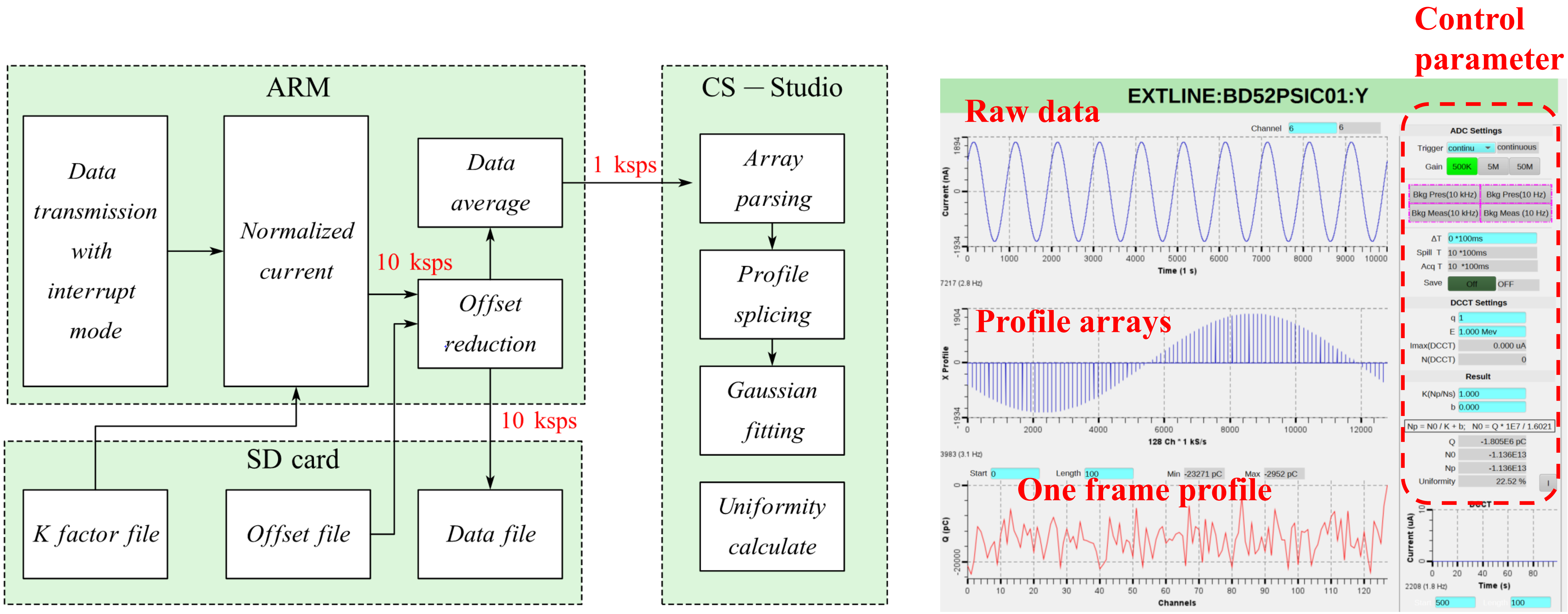
Zynq FPGA Firmware Design





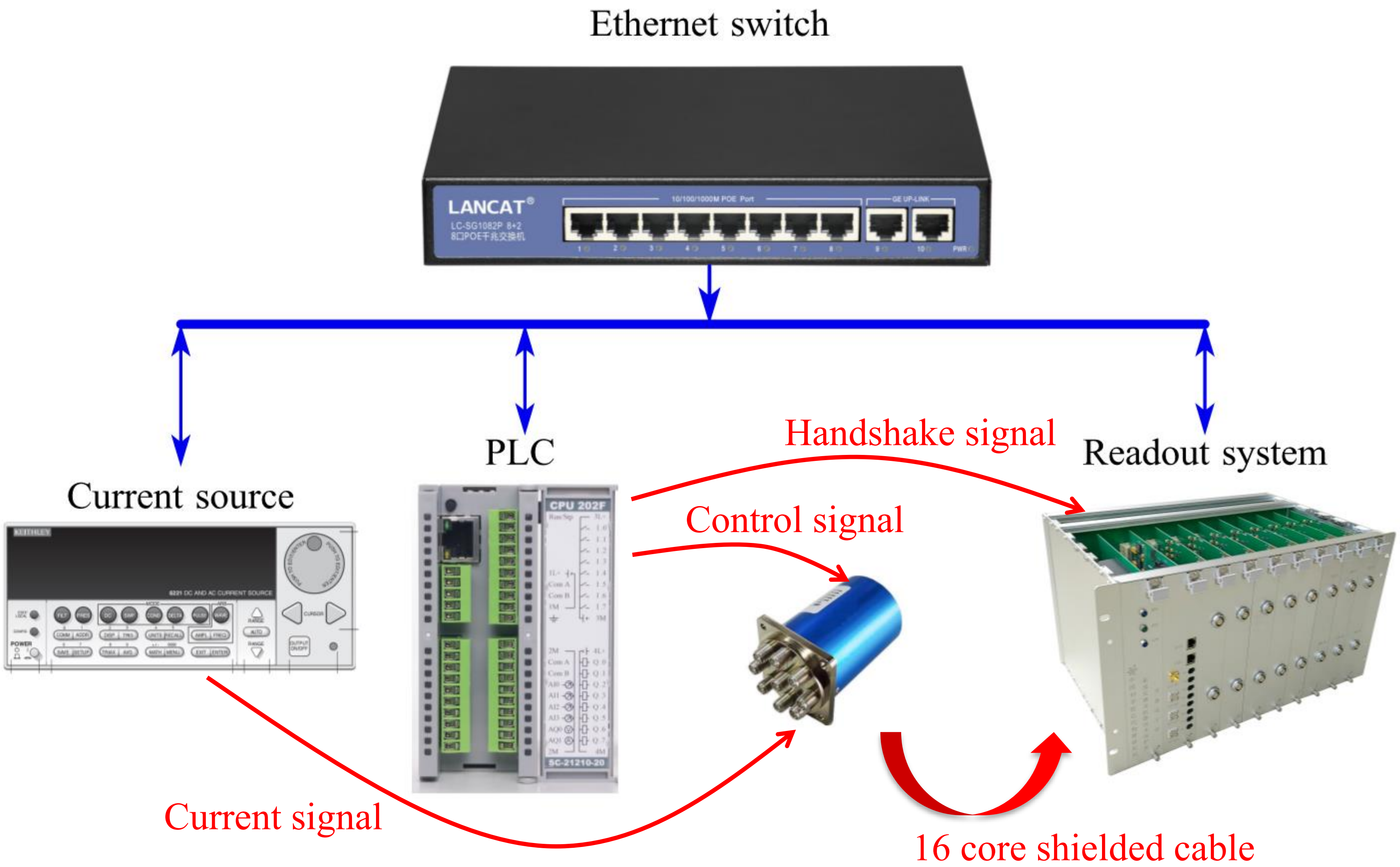
Schematic of the Zynq FPGA firmware and the PCB board diagram.

ARM Embedded Design



Schematic of the ARM embedded design and the graphical user interface.

Off-line test platform



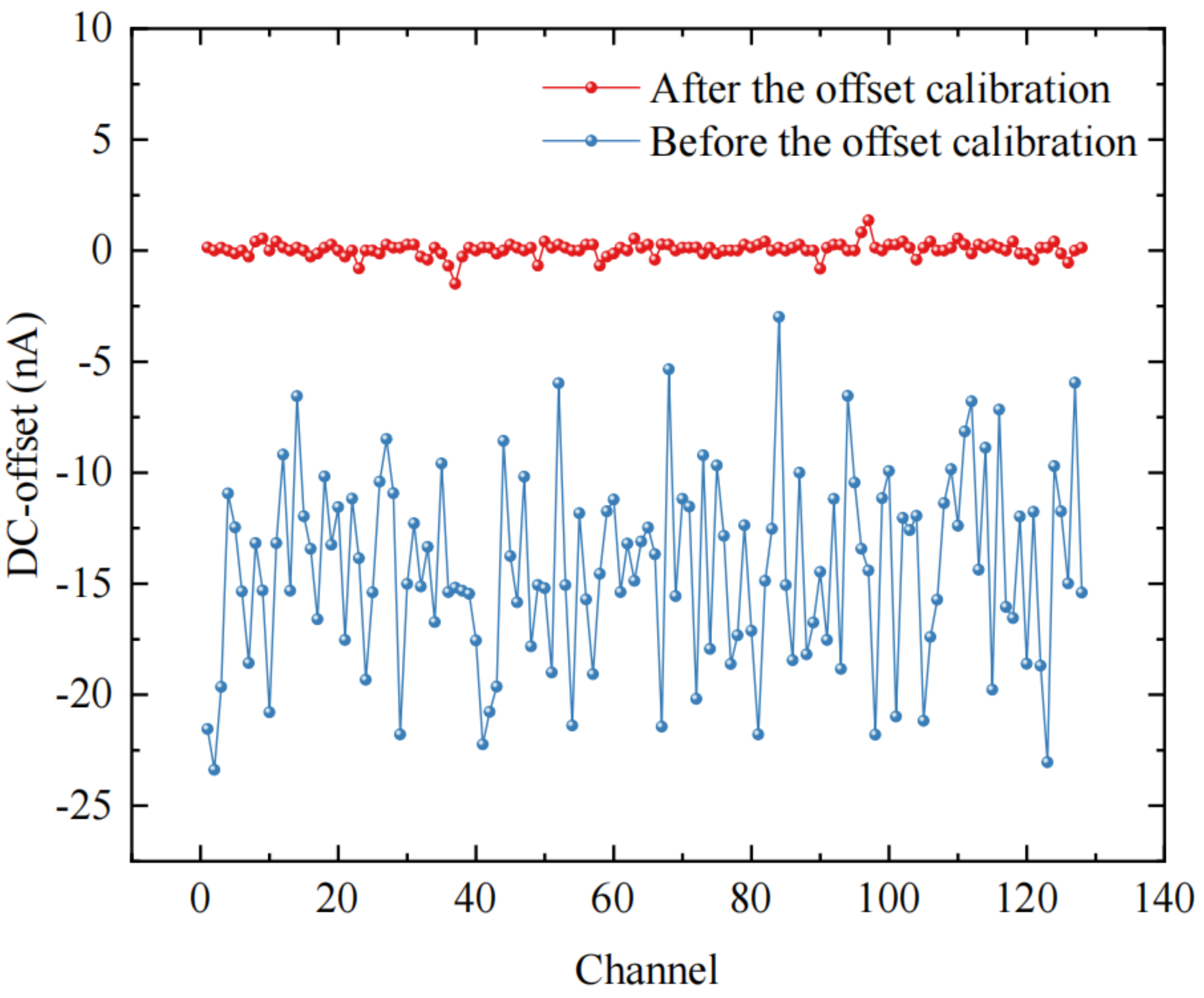
Baseline Calibration Test

- **Mean offset :**

  -14.34 nA to 0.05 nA

- **FWHM:**

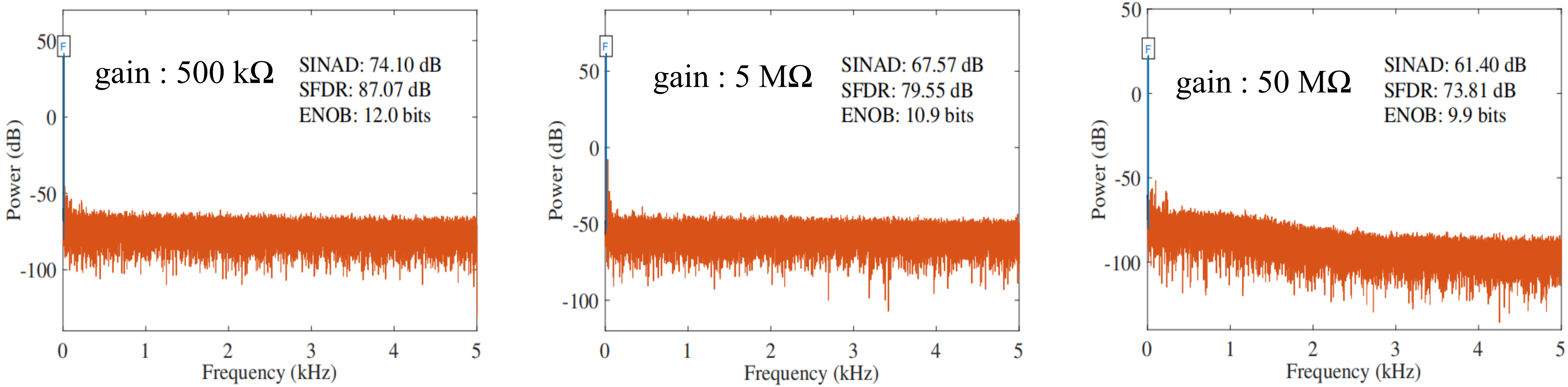
  10.01 nA to 0.75 nA.



The 128 channels' DC-offsets before and after the offset calibration.

Effective Number of Bits Test

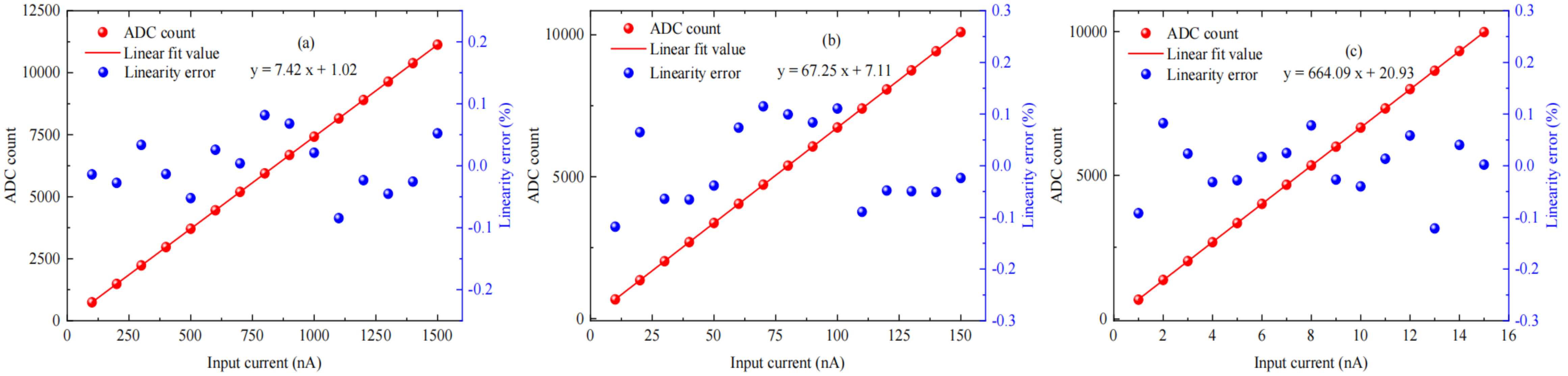
Gain	Bin width	SINAD	SFDR	ENOB
500 kΩ	0.1 Hz	74.10 dB	87.07 dB	12.0 bits
5 MΩ	0.1 Hz	65.57 dB	79.55 dB	10.9 bits
50 MΩ	0.1 Hz	61.40 dB	73.81 dB	9.9 bits



Noise spectral density of the readout electronics.

Amplitude Linearity Test

Gain	Min amplitude	Max amplitude	Step	Nonlinearity
500 kΩ	0.1 μA	1.5 μA	0.1 μA	< 0.09 %
5 MΩ	10 nA	150 nA	10 nA	< 0.11 %
50 MΩ	1 nA	15 nA	1 nA	< 0.12 %



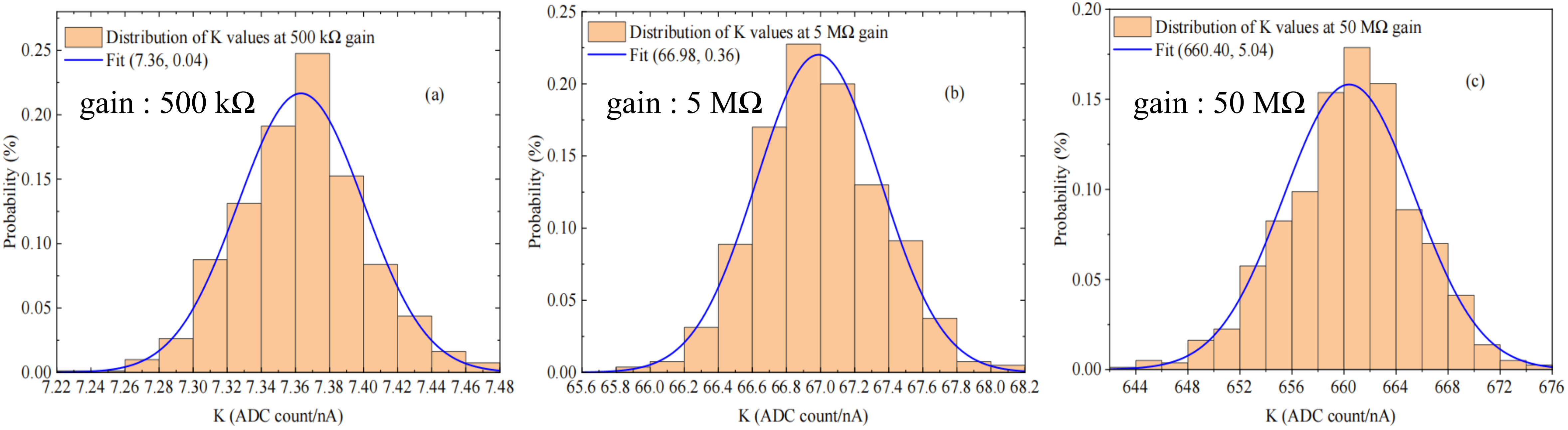
Output amplitude linearity of the readout electronics.

Channel Consistency Test

Mean : 7.36
σ : 0.04

Mean : 66.98
σ : 0.36

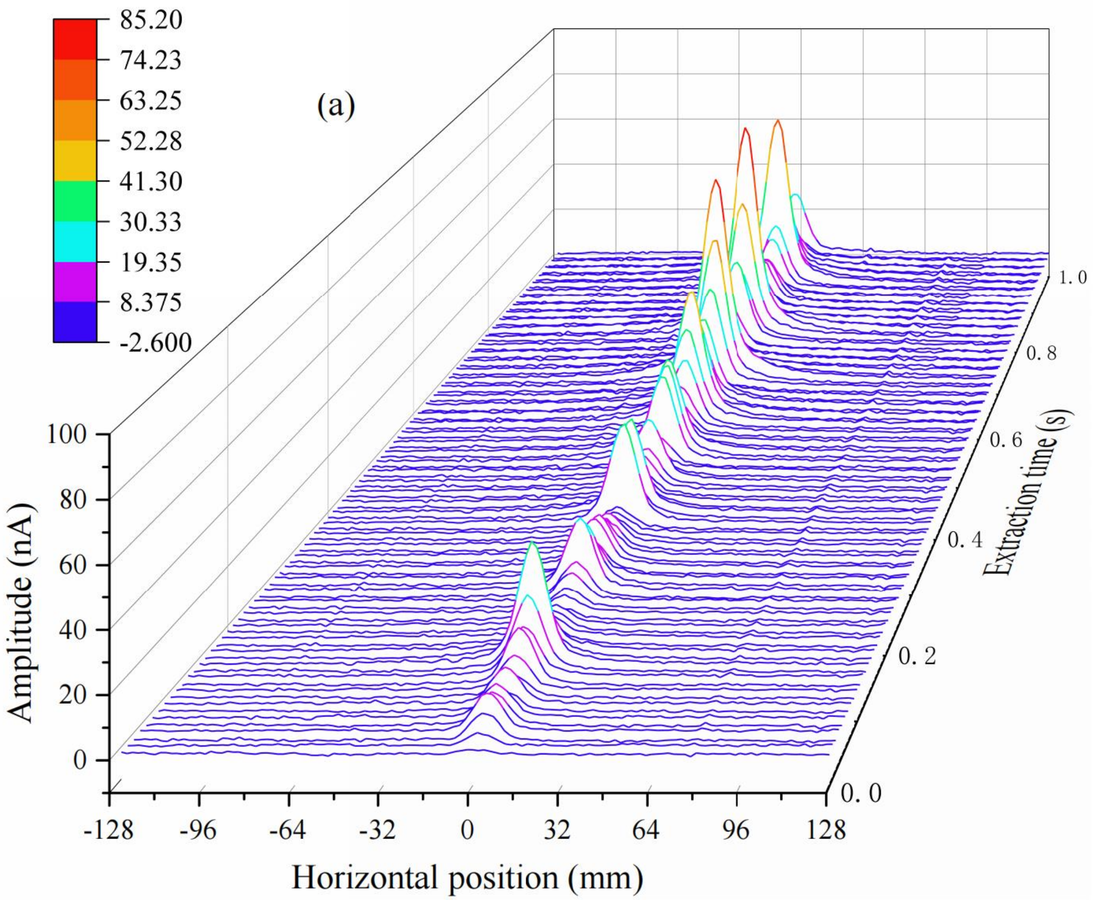
It is Compensable!

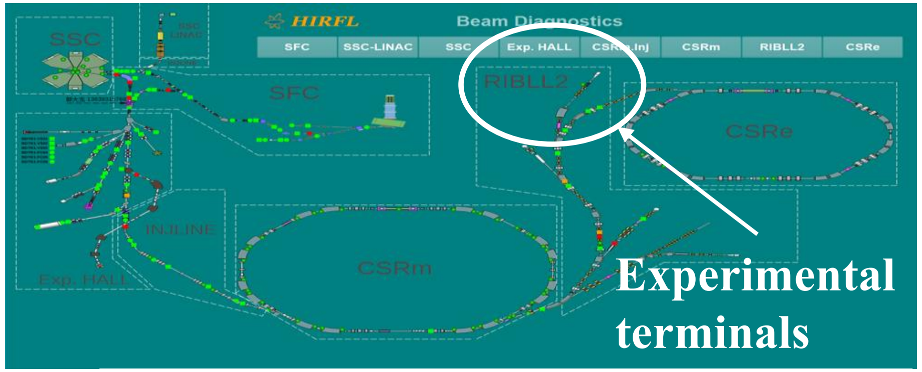


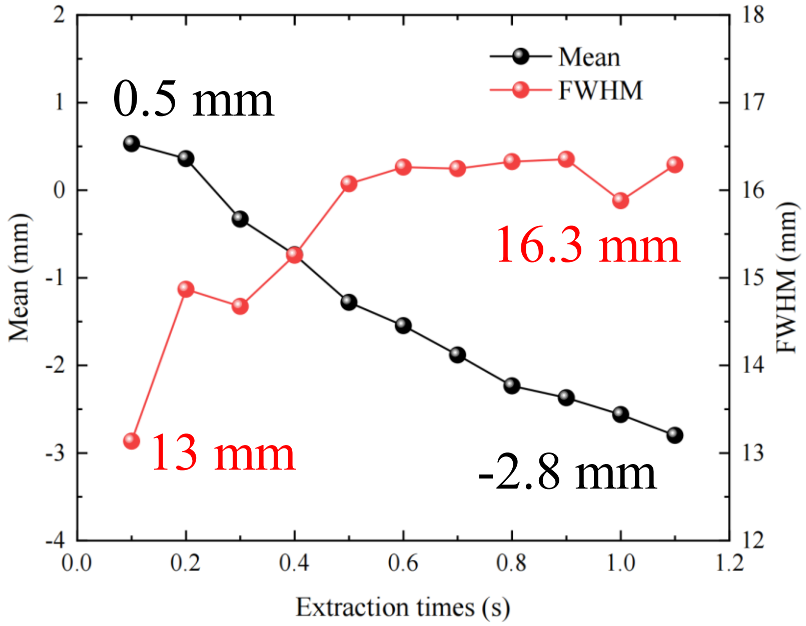
Statistical distribution of the K value in different gains.

Beam Test with MSIC in HIRFL-CSR

Beam: O6+, 60 MeV/u







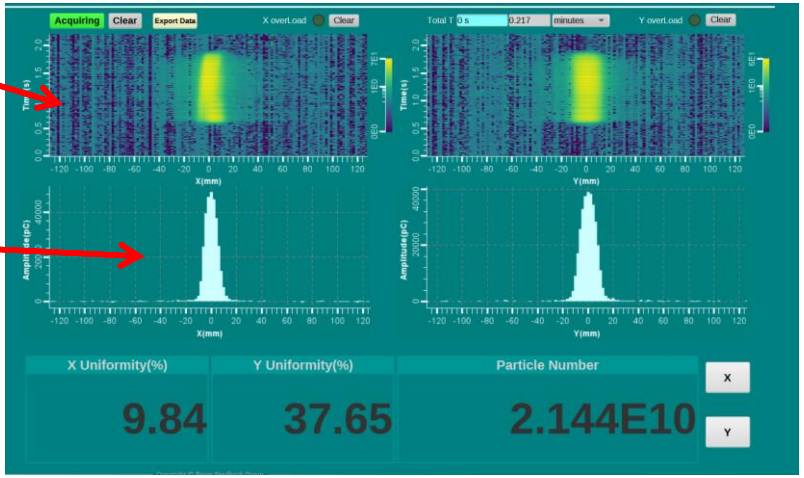
Beam profiles of the slow extraction in HIRFL-CSR.

Beam Test in PREF - 60MeV proton beam

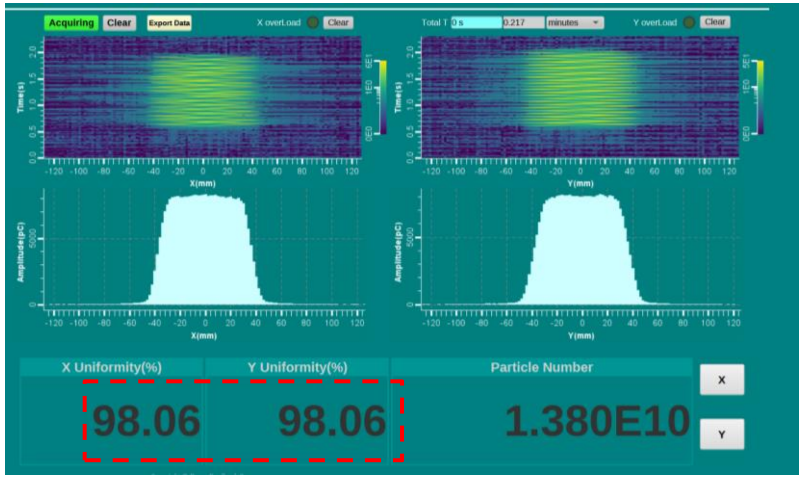
Unscanned beam

Waterfall

Profile



Scanning area:50 * 50 mm^2

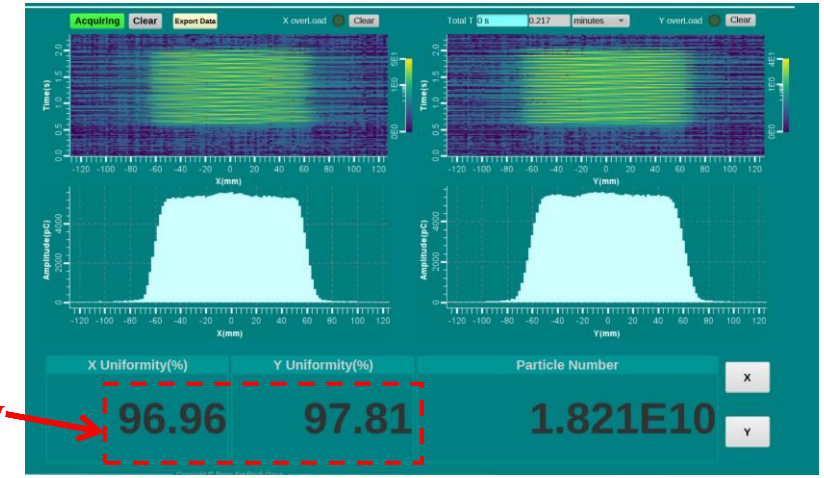


Beam current 32.3 pA

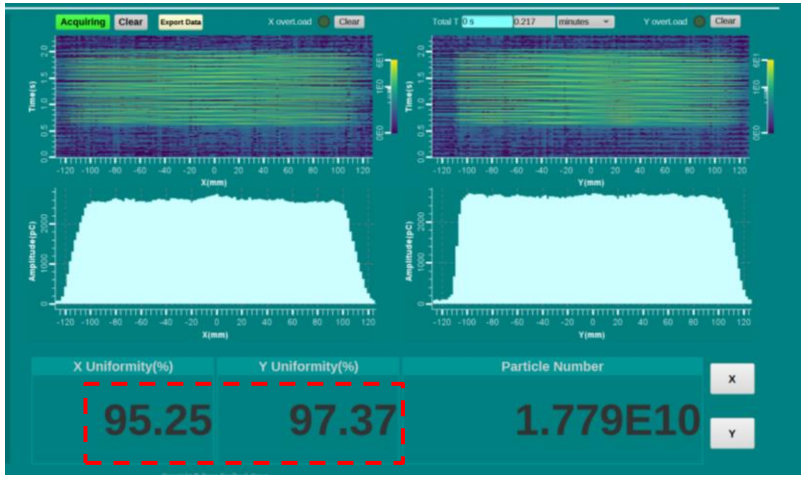
Scanning area:100 * 100 mm^2

Beam current 19.4 pA

Uniformity



Scanning area:200 * 200 mm^2

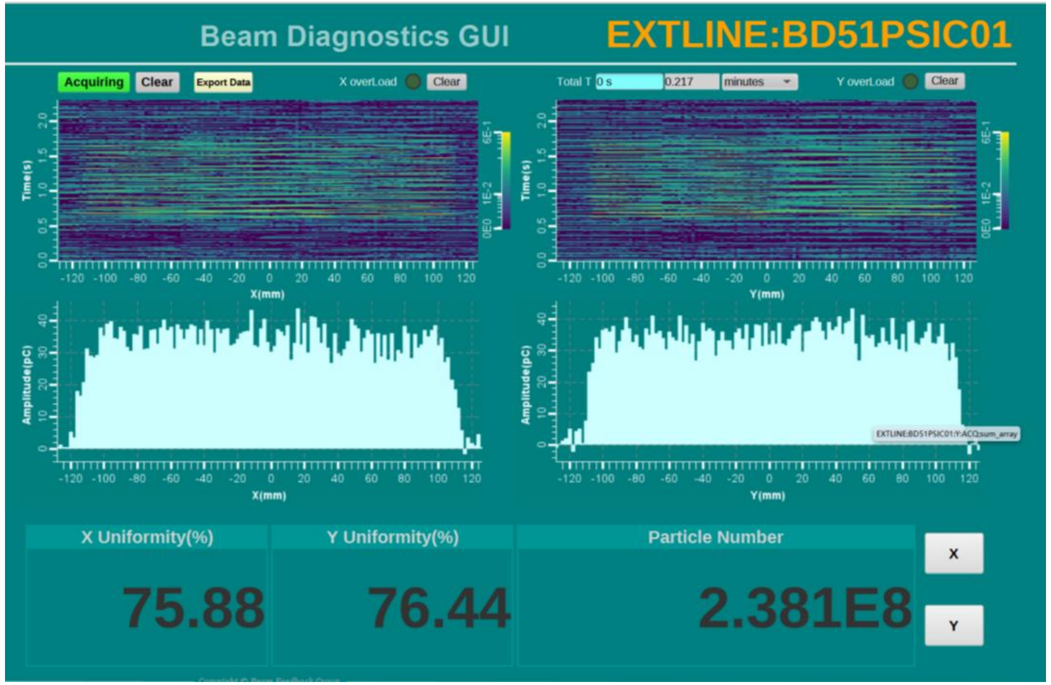


Beam current 9.3 pA

Beam Test in PREF – weak beams

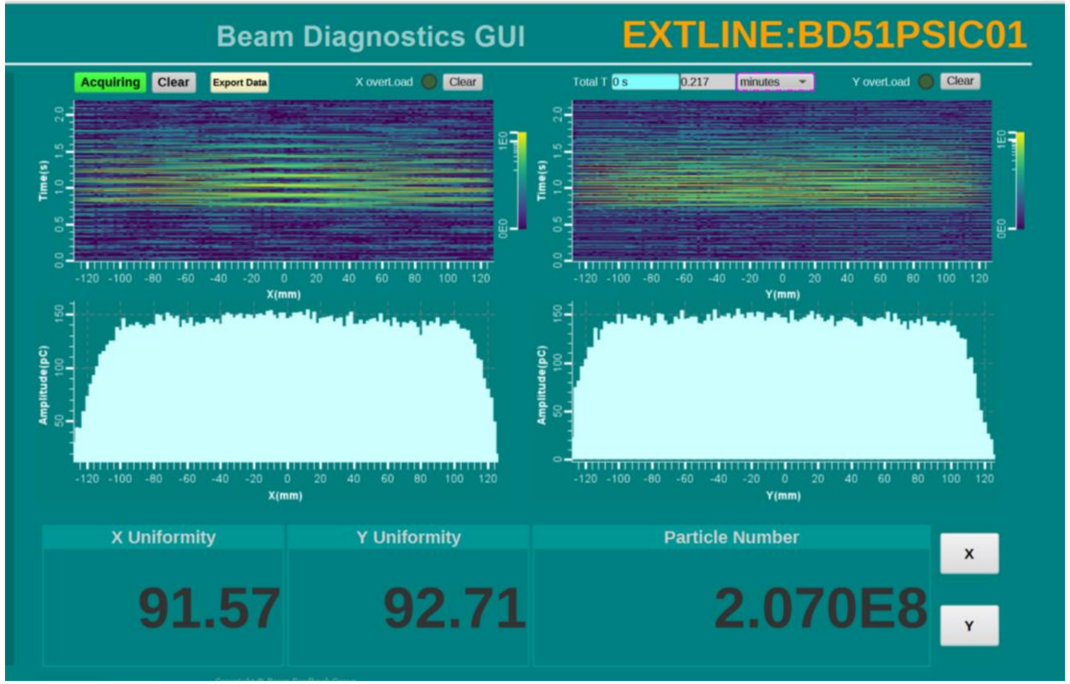
60MeV proton beam

Beam current： 0.14 pA



10MeV proton beam

Beam current： 0.11 pA



Beam profiles of the slow extraction in PREF.

Conclusion

1. A 128-channel readout system with 60 Msps.
2. A new I-V converter with a high dynamic of 25 pA–1.8 µA.
3. An adaptive decoding module to decode the 480 Mbps serial data.
4. An automatic calibration device.
5. Extend to other fast profile monitors.

DAQ board

Analog board × 8

Thank you for your attention!