Readout electronics for TPC detector in the MPD/NICA project

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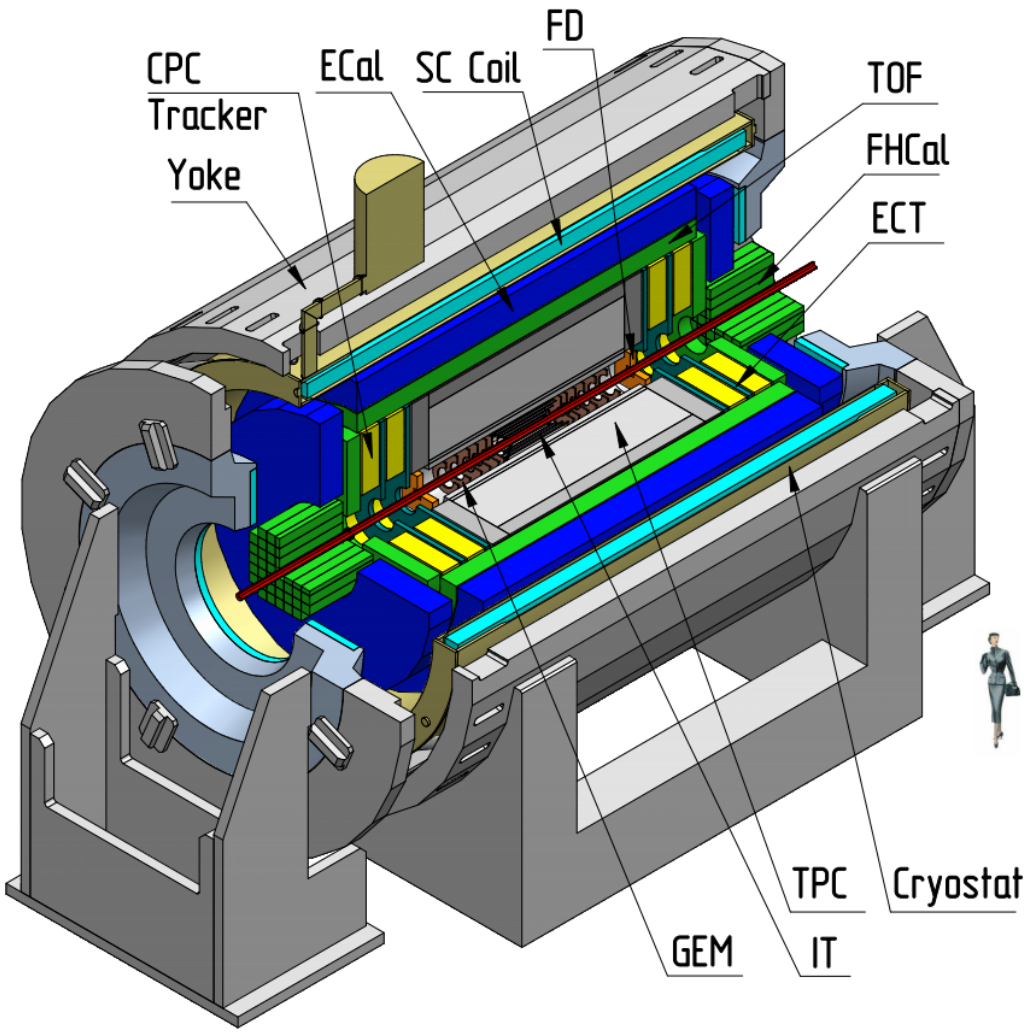
Outline

- Multi-Purpose Detector of NICA project
- TPC design overview and main parameters
- Requirements for the data readout system, design concept and status
- PASA + ALTRO chipset design
- SAMPA design
- Conclusion

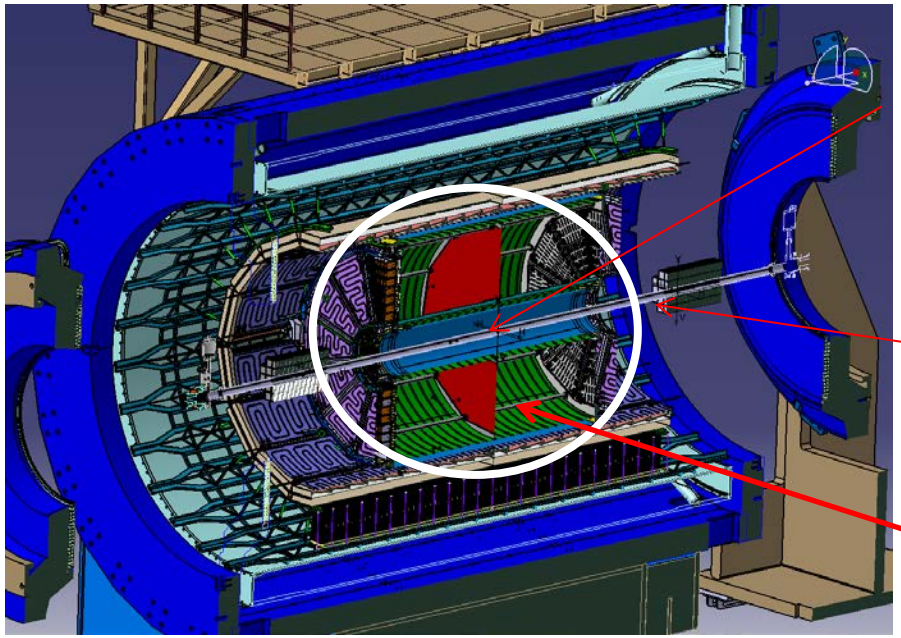
General view of the TPC in the MultiPurpose Detector (MPD) of NICA project



TPC - Time projection chamber
IT - Inner Tracker
TOF - Time of Flight
ECal - Electromagnetic calorimeter
ETC - Straw end-cap tracker
FHCal - Forward Hadron Calorimeter
FD - Forward Detector
CPC tracker - Cathode Pad Chamber

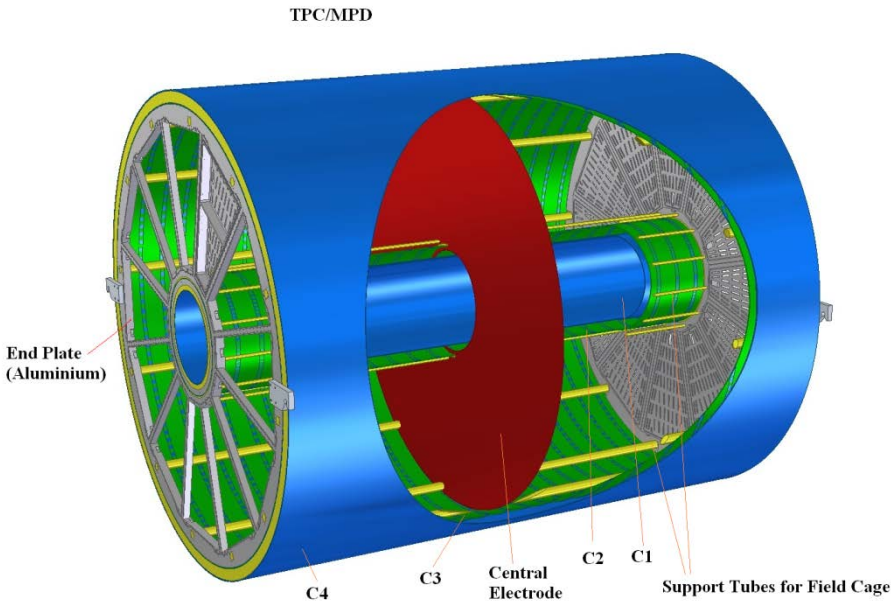
MPD tasks for TPC

The scientific program of the MPD includes the following topics:
> Particle yields and spectra (π, K, p, clusters, Λ, Ω)
> Event-by event fluctuation
> Femtoscopy with π, K, p, Λ
> Collective flow of identified hadron species
> In-medium modification of vector mesons



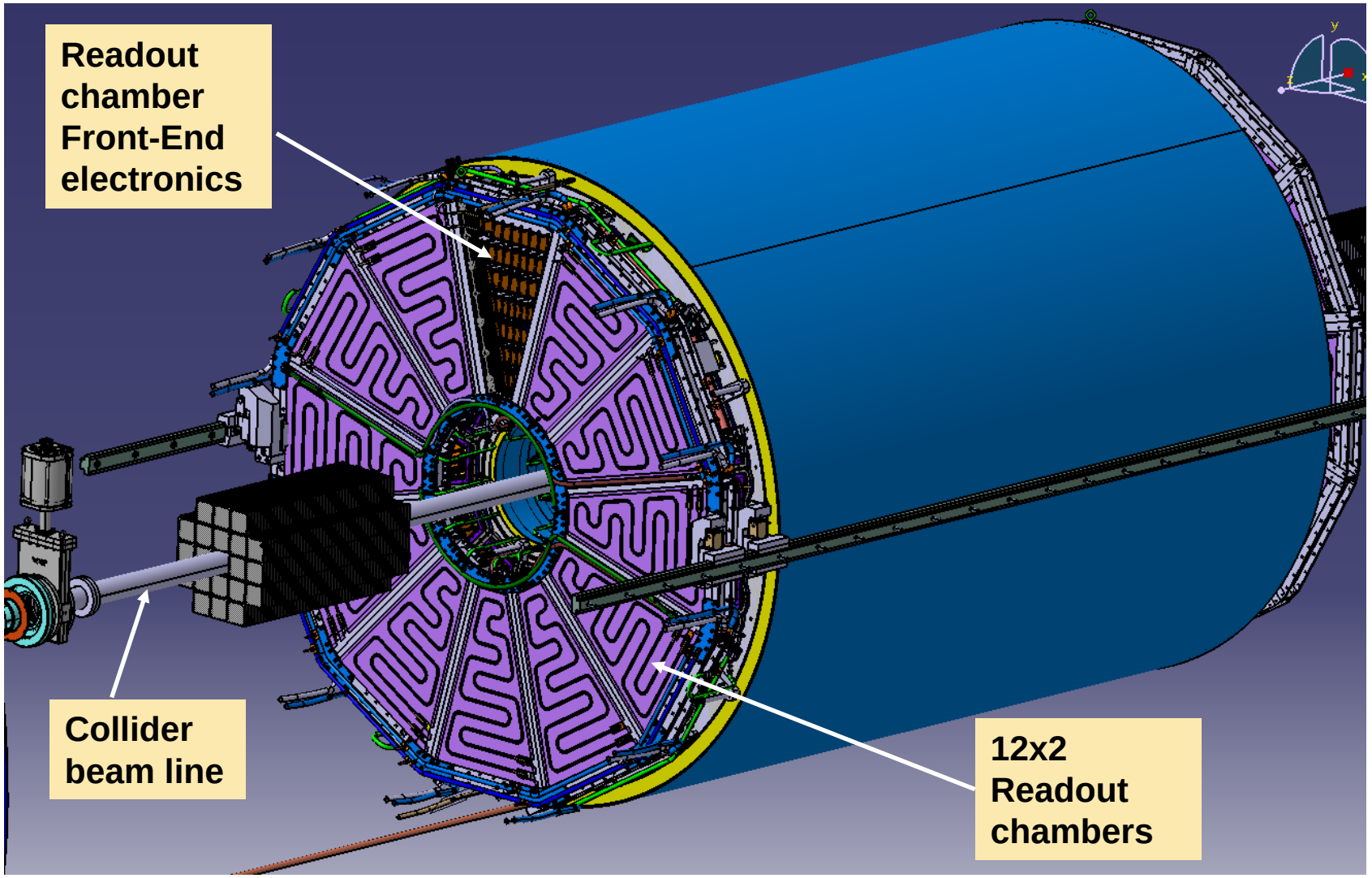
Observables	Detectors in use
Yields & spectra	TPC, ZDC, barrel TOF & ECAL end-cap tracker + end-cap TOF & ECAL
Di-leptons	TPC, barrel TOF & ECAL end-cap tracker + end-cap TOF & ECAL
Event-by-event fluctuations	ZDC, barrel TOF & ECAL end-cap tracker + end-cap TOF & ECAL
Flow	TPC,TOF, event plane detector (extended ZDC) end-cap tracker + end-cap TOF & ECAL
Hyperons, hyper-nuclei, charm	TPC, IT

TPC parameters



Item	Dimension
Length of the TPC	340cm
Outer radius of vessel	140cm
Inner radius of vessel	27 cm
Outer radius of the drift volume	133cm
Inner radius of the drift volume	34cm
Length of the drift volume	170cm (of each half)
HV electrode	Membrane at the center of the TPC
Electric field strength	~140V/cm;
Magnetic field strength	0.5 Tesla
Drift gas	90% Ar+10% Methane, Atmospheric pres. + 2 mbar
Gas amplification factor	~ 10^4
Drift velocity	5.45 cm/μs;
Drift time	< 30μs;
Temperature stability	< 0.5°C
Number of readout chambers	24 (12 per each end-plate)
Segmentation in φ	30°
Pad size	5x12mm^2 and 5x18mm^2
Number of pads	95232
Pad raw numbers	53
Pad numbers after zero suppression	< 10%
Maximal event rate	< 7 kHz (Lum. 10^{27})
Electronics shaping time	~180 ns (FWHM)
Signal-to-noise ratio	30:1
Signal dynamical range	10 bits
Sampling rate	10 MHz
Sampling depth	310 time buckets

TPC design


Readout chamber Front-End electronics
Collider beam line
12x2 Readout chambers

Requirements for the data readout system

- Total number of channels is: 95 232
- Trigger rate – 7 kHz, max tracks per event - 1000
- Mean data stream with zero suppression – 7 GB/s
- Mean data stream without zero suppression – 23 GB/s

- Requirement for TPC end-caps transparency (because of FEE is shading CPC Tracker, ECT, TOF)

Read out electronics design status

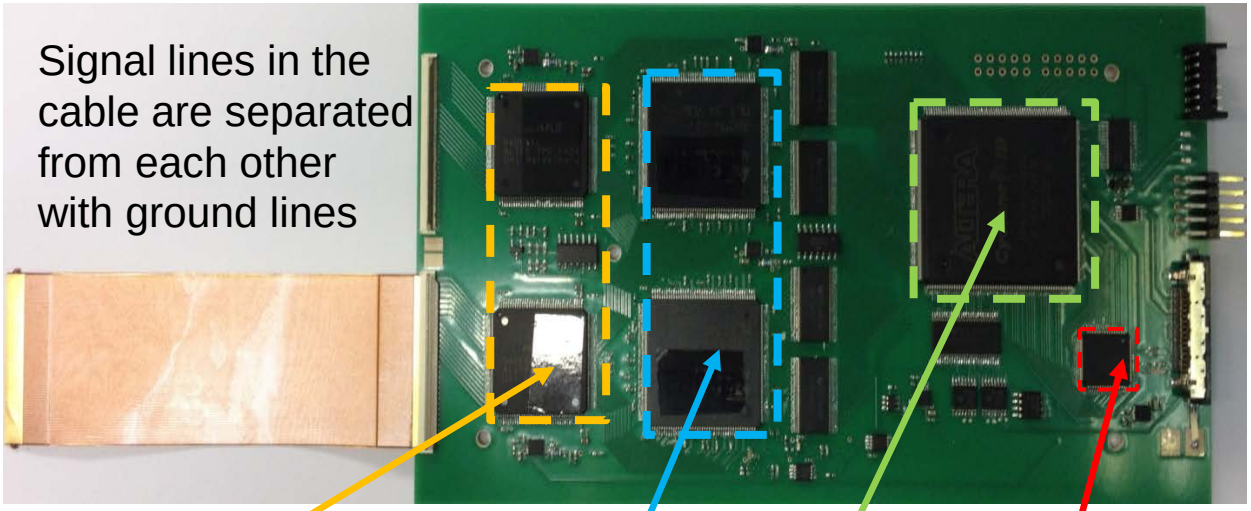
- Main components of FEE - FECs, RCUs and gigabit data links
- Design based on the ASICs (PASA +ALTRO or SAMPA) and FPGAs

- ALTRO+PASA option (FEC64S) – design was completed
- Pilot system (512 ch) – is under testing

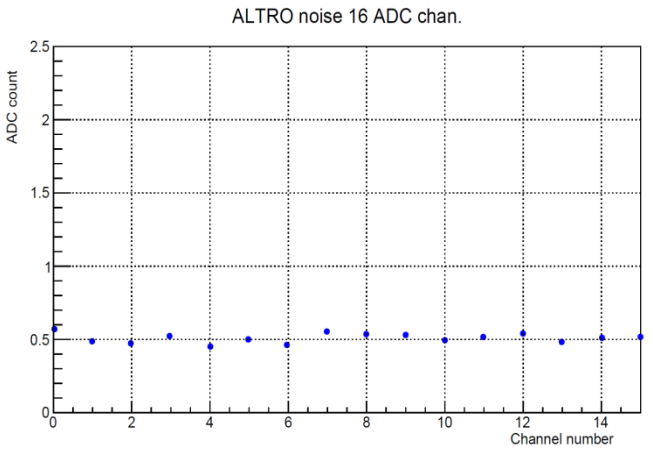
- SAMPA option – design is in progress

- Controller RCU - design was completed
- Controller manufacture – December 2017

FEC-64S (top side) with cable

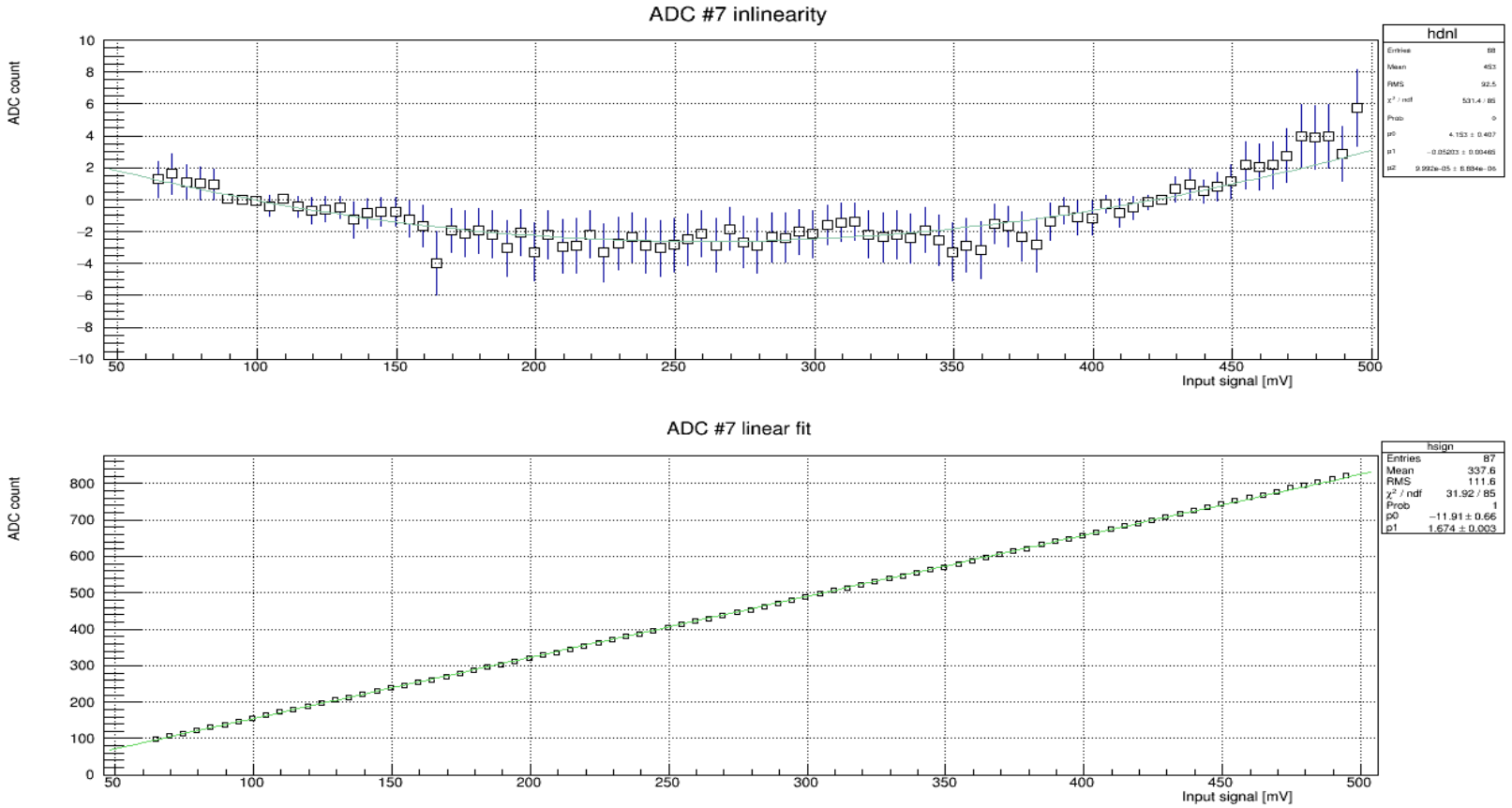


- Signal to noise ratio, S/N - 30
- σ_{NOISE} < 1000e$^-$ (C=10-20 pF)
- Dynamic Range – 1000
- Zero suppression
- Buffer (4 / 8 events



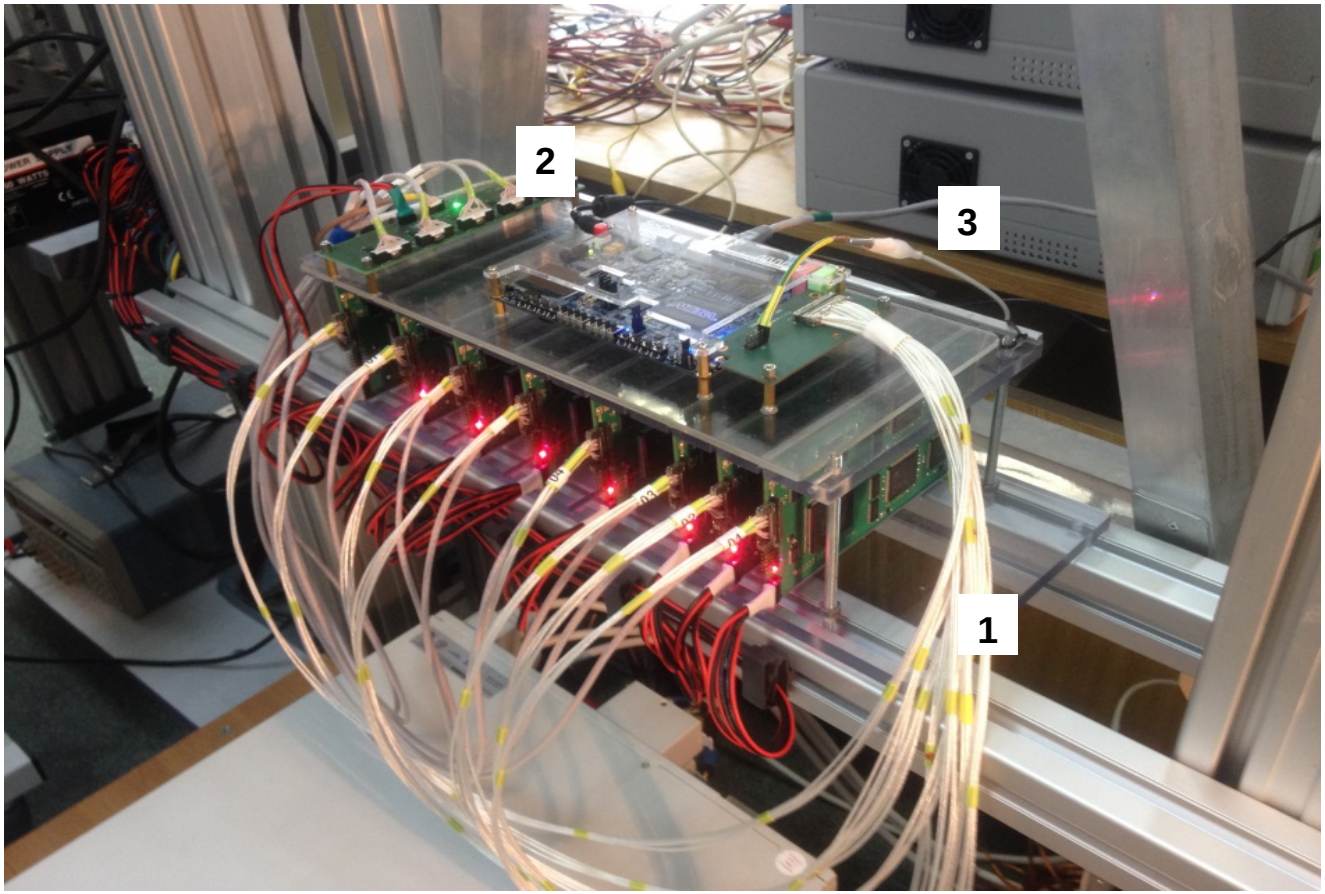
Noise value at 16 FECs channels (without cable)

FEC64S linearity



Top graph shows the difference between the measured value and the linear fit. The bottom graph demonstrates FEC response to the input signal

Eight cards at the test setup



1) FECs array (512 ch. in total); 2) clocks and control signal distribution card; 3) RCU emulator

New ASIC for TPC electronics (SAMPA)

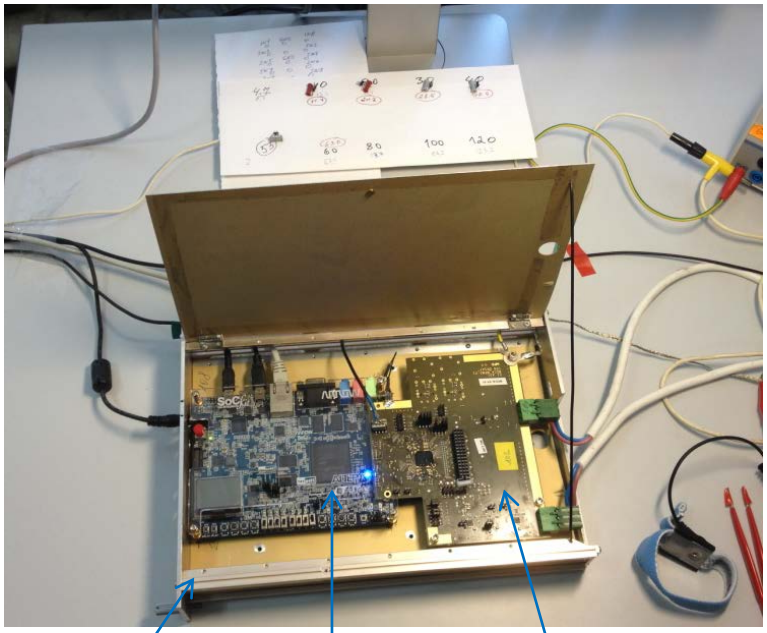
- New ASIC SAMPA [1,2] is under development. V2, V3 and V4 preproduction versions are exist.
- Few amount of pilot chips version V2 was tested and measurement results has showed us feasibility of design SAMPA-based FEC for the TPC MPD/NICA.
- Concept of usage SAMPA chip in the FEE was defined and design of the new FEC in progress.

[1] S.H.I. Barboza et al. SAMPA Chip: a New ASIC for the ALICE TPC and MCH Upgrades. // J. Instrum. 2016. V. 11. C02088.

[2] J. Adolfsson et al. SAMPA Chip: the New 32 Channels ASIC for the ALICE TPC and MCH Upgrades. // J. Instrum. 2017. V. 12. C04008.

SAMPA testing in Dubna

Using SAMPA test board in Dudna

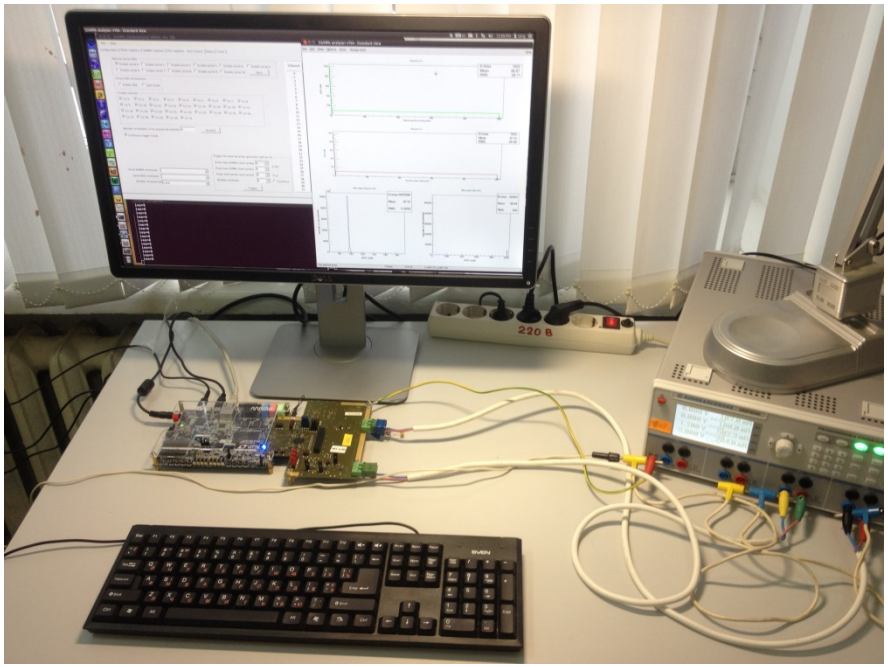


Shielding box

FPGA development board

SAMPA test board

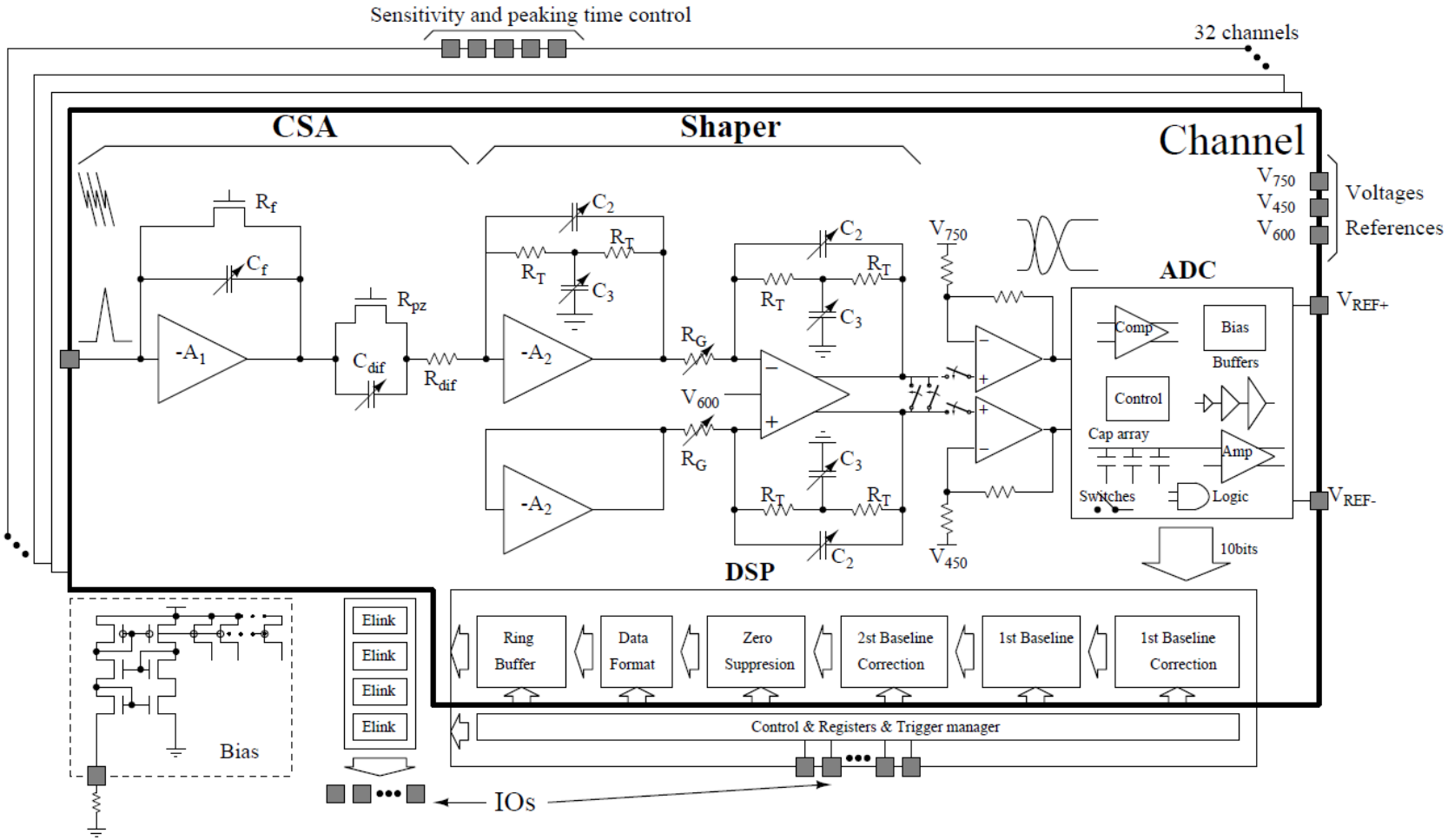
General view of test setup



SAMPA chip parameters:

- Cross-talks < **0.5%**
- Noise ~ **500e$^-$**
- ADC ENOB = **9.2 bit**
- e-links (**350 MHz each**)

SAMPA block diagram

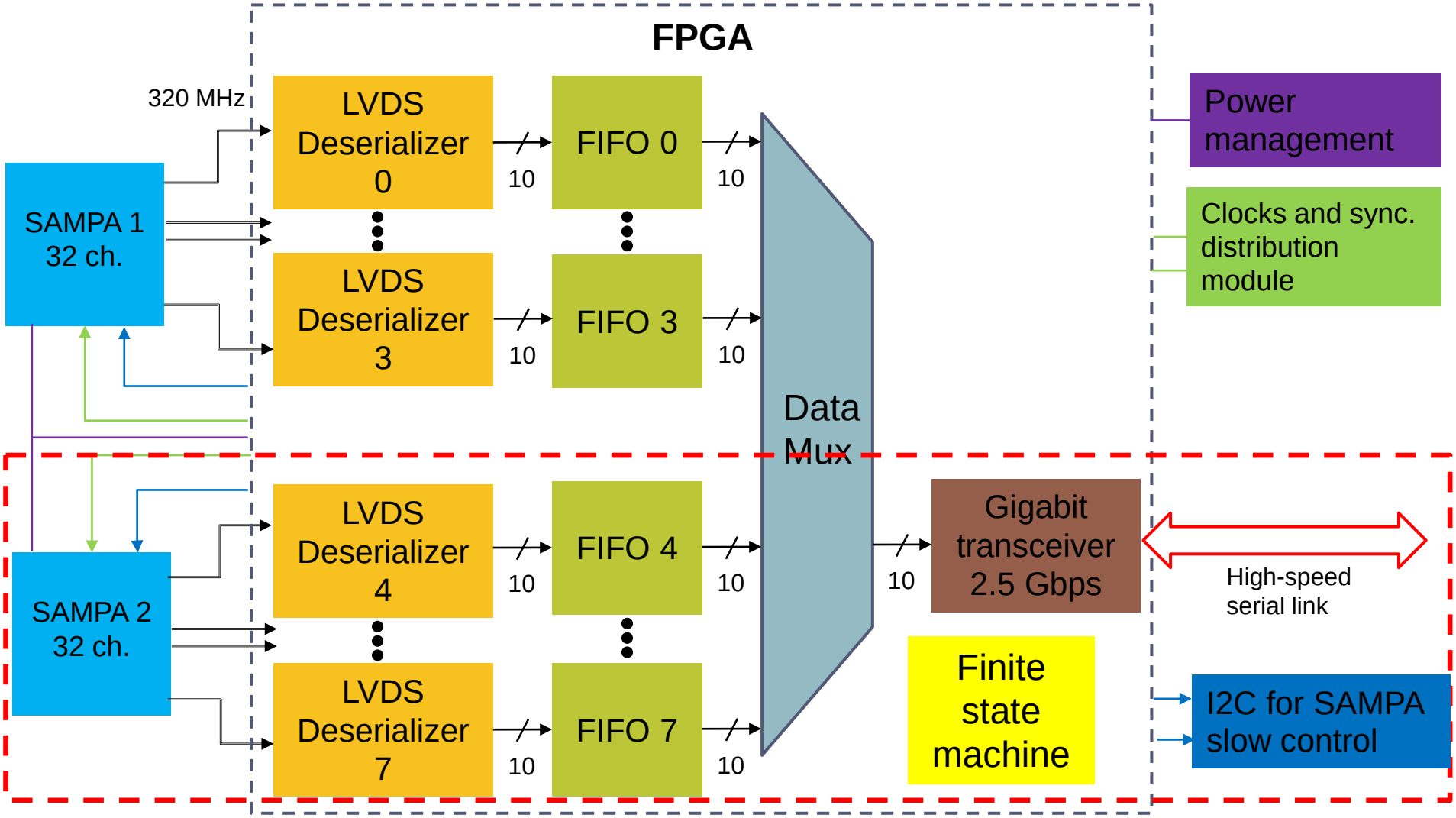


SAMPA based design issues

Main advantages of the SAMPA chip:

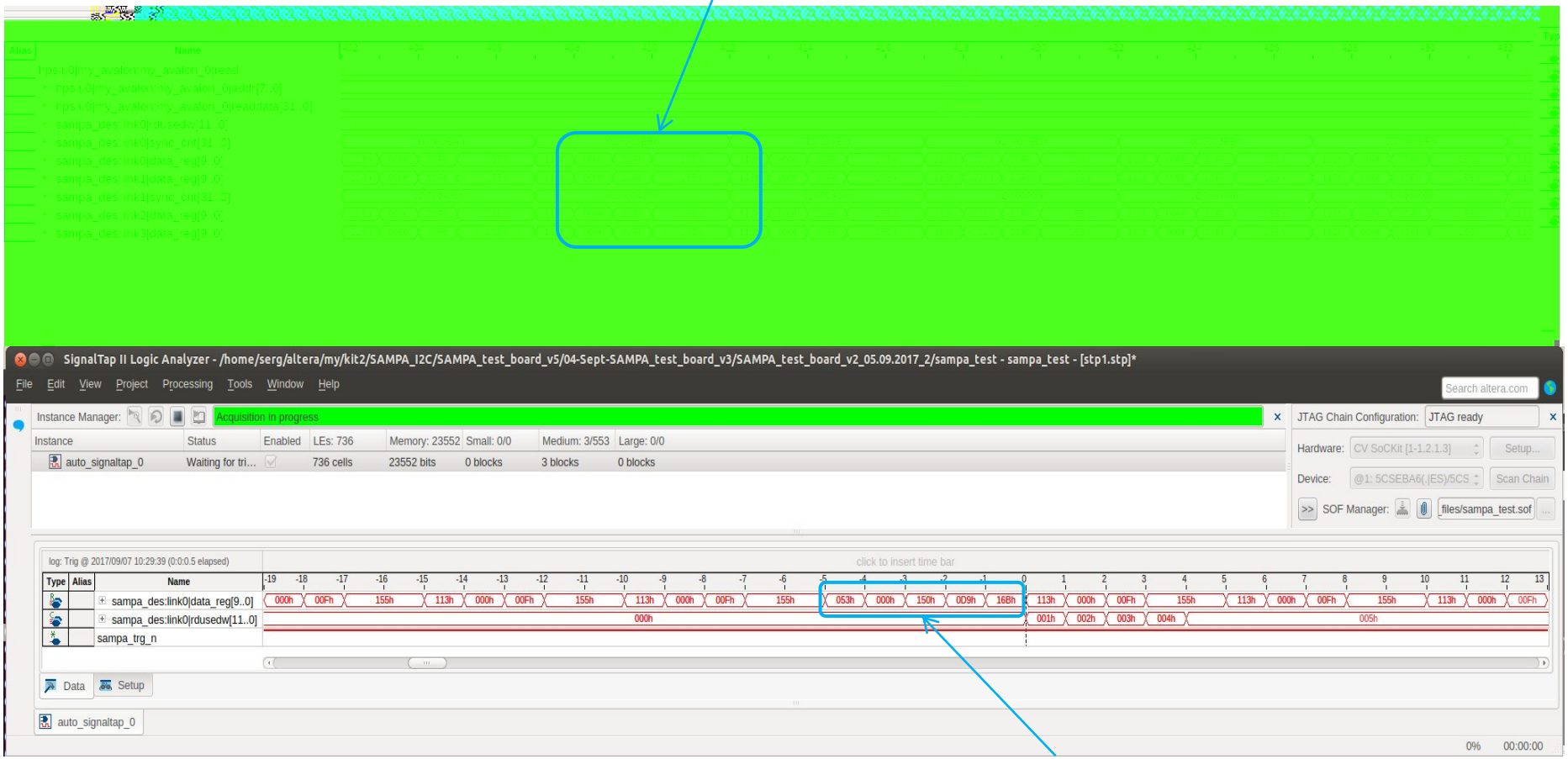
- SAMPA chip is more integrated then PASA and ALTRO chip set. Its square is only 225 mm^2 per 32 channels while squares of PASA and ALTRO are 484 mm^2 and 708 mm^2 respectively per 16 channels. Estimates show that the size of the FEC PCB can be reduced by a factor of 3.
- SAMPA chip can operating with multi-wire proportional chambers as well as with GEM chambers that is necessary for a future TPC upgrade.

SAMPA-based FEC block diagram



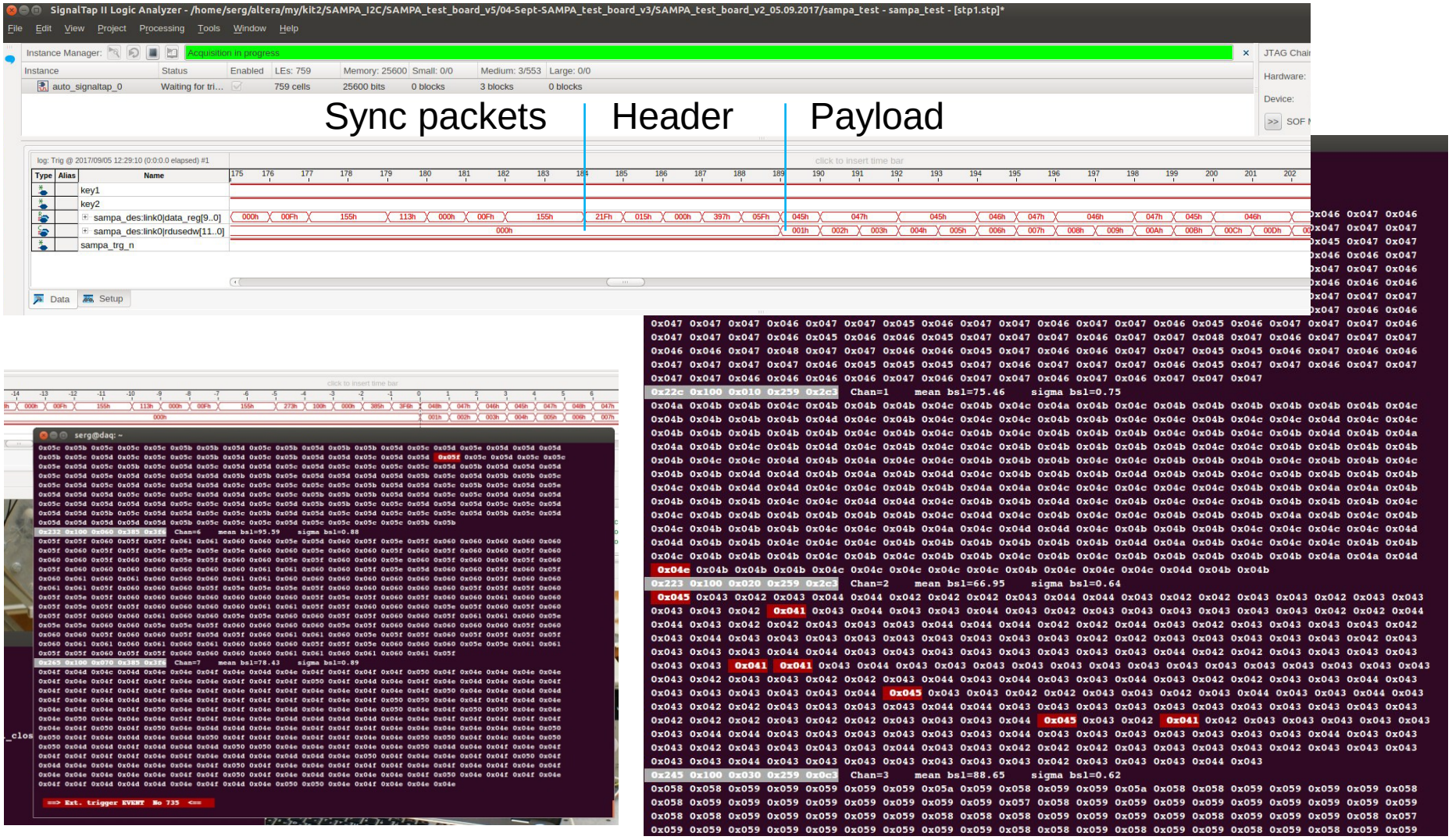
Firmware operation monitoring

Synchronization packets from 4 SAMPA links



Heartbeat packet

SAMPA data monitoring in test setup



SAMPA-based pilot system status

- The same concept as for ALTRO pilot system was proposed
- Target – 8 card system (512 ch.) for beam test (17/18 year).
- Firmware was developed and tested with SAMPA test board as model of FEC. Firmware works without any faults.
- FEC schematic was finished.
- PCB layout is in progress.

Conclusion

- FEE TPC for MPD/NICA project is designing.
- FEC testing including analog and digital parts was performed. RCU firmware was developed and verified.
- ALTRO-based FEC design was completed and trial lot of FECs was fabricated.
- RCU prototype is under verification.
- Schematics and firmware for SAMPA based FEC was designed. PCB layout is in progress.
- Preparation of beam test in progress.

On behalf TPC/MPD electronics group
allow me to express gratitude for the help to:

Luciano Musa (CERN)
Cristian Lippman (CERN,GSI)
Alex Kluge (CERN)
Marco Bregant (USP, Brazil)

Thank you for your attention!