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FADC Readout Option

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Introduction

ADC based DAQ system has been used in WASA at COSY detector.

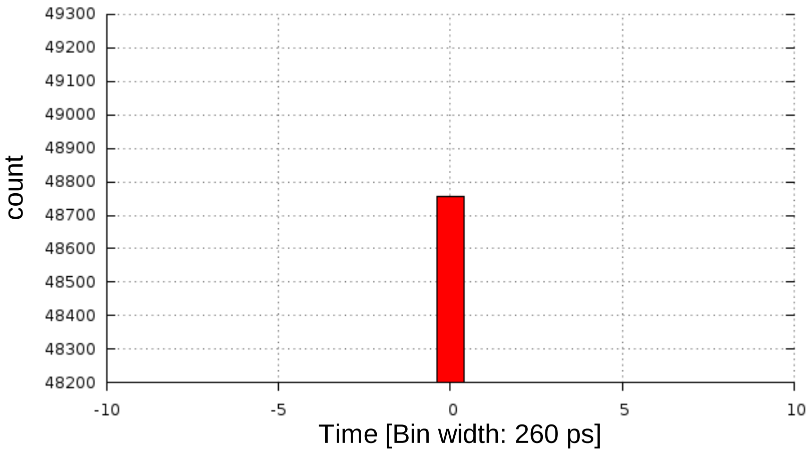
Our group exploits this experience.

This talk will

- propose an expansion of the existing system boundaries
- introduce the technique needed for that

The key feature for this expansion: Real time processing

Existing system
- 16 channels ADC-Board with sampling rate of 240 MHz
- Trigger initiated processing of buffered ADC data



Comparison of constant-fraction values, calculated offline and real-time

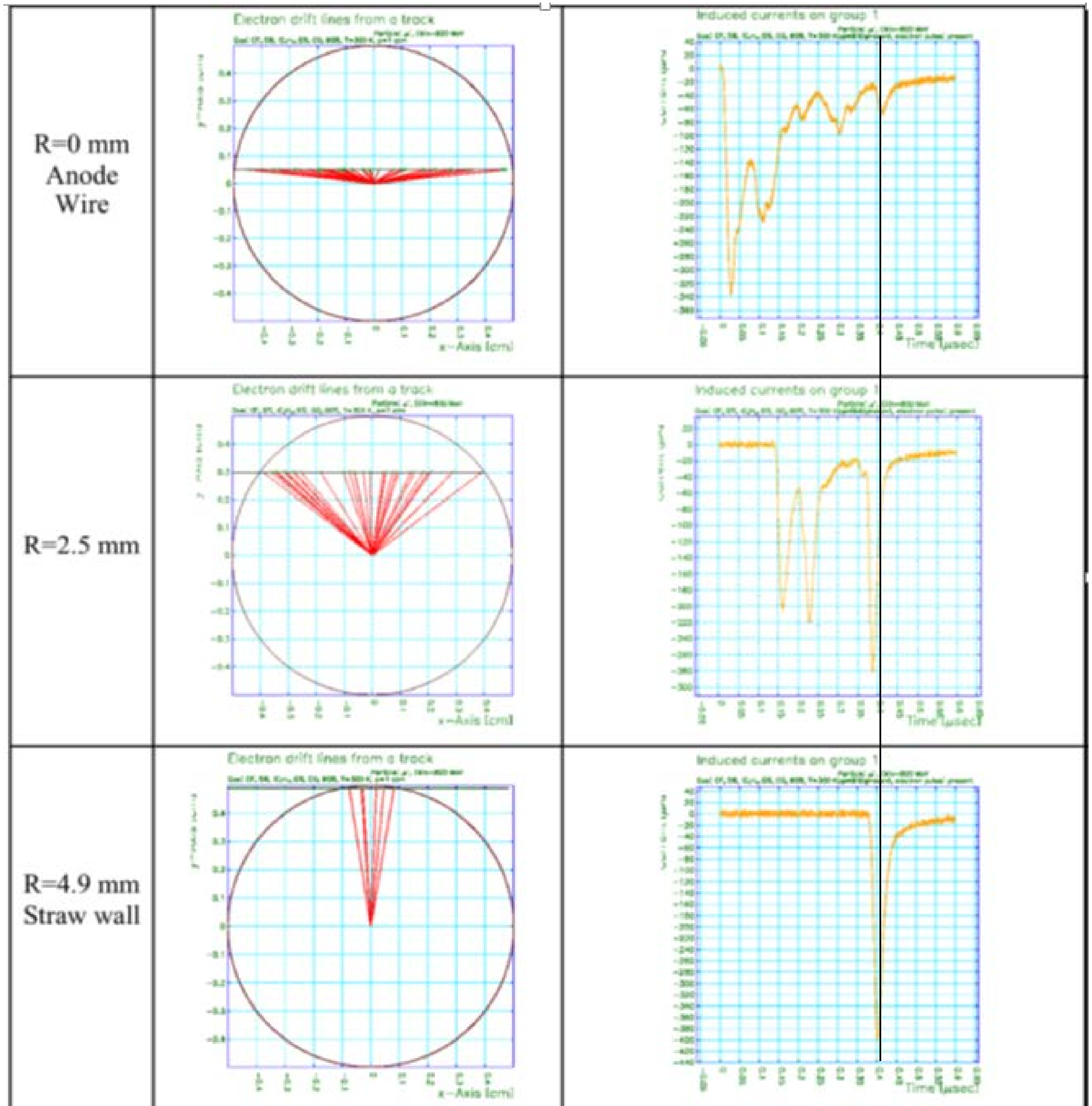
has been modified
- with real time processing

Tests with straw-pulses show equal results for both kinds of processing. This demonstrates the high reliability of the processing used so far and of the new one.

The modified system is used to carry out experiments and to develop new algorithms.

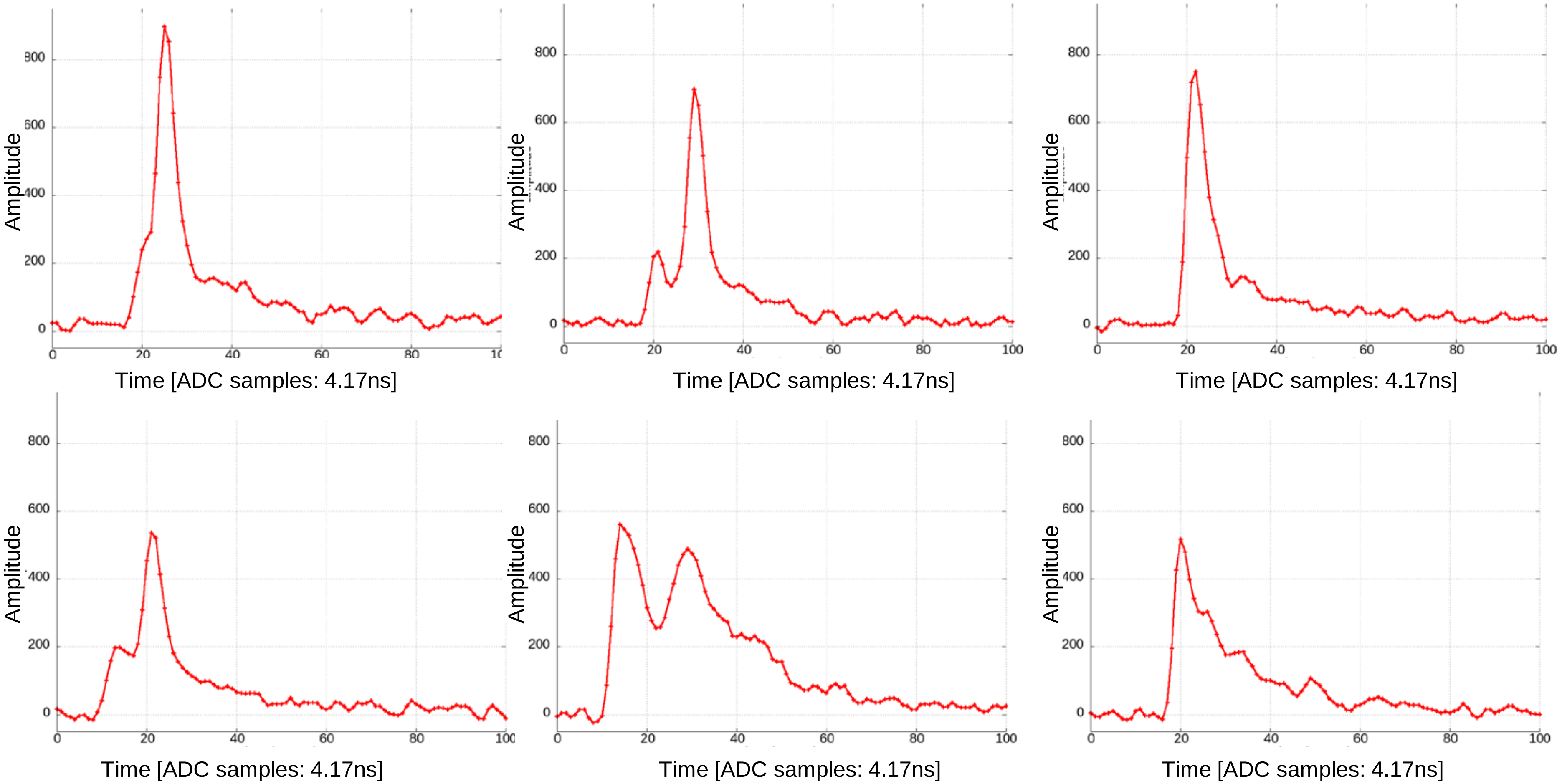
- **Which boundaries are to be expanded**
- **How it will be done**

Response depends on the distance from the track to the wire



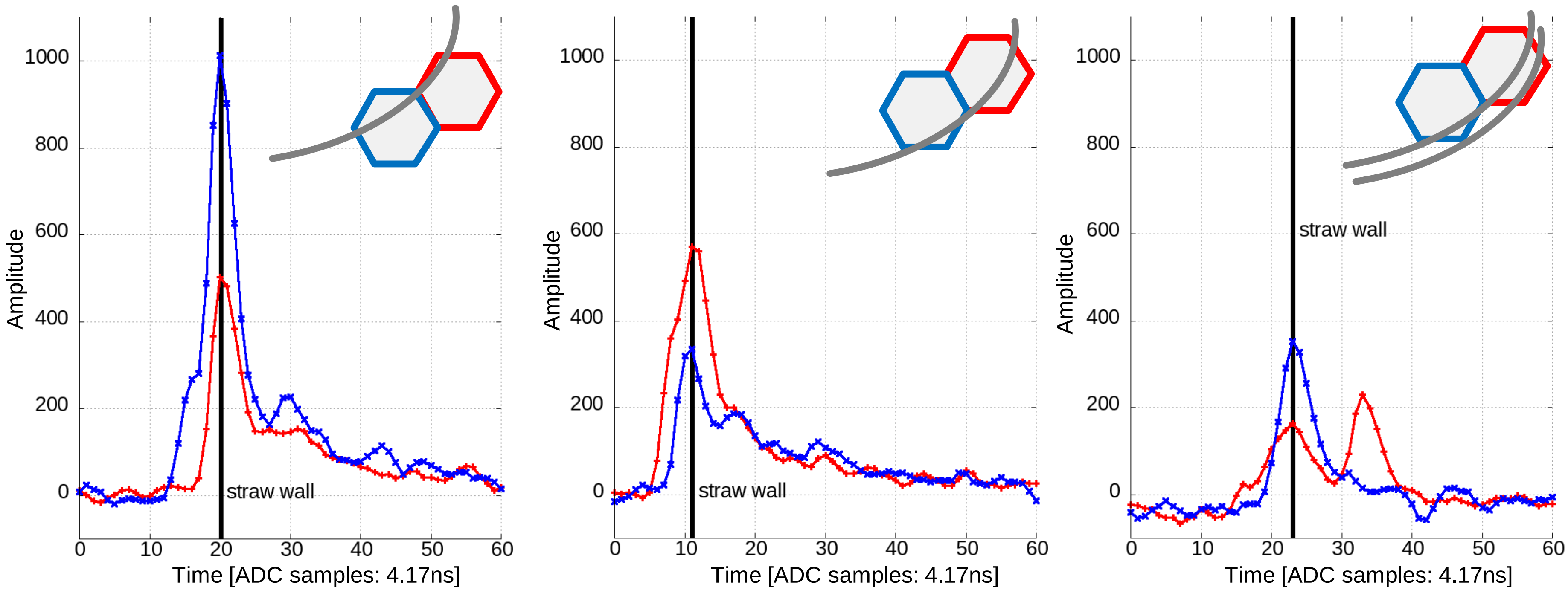
Figures from: Chapter Straw Tracker extract full doc, NA 62

Today we don‘t know what we see within 100.. 150 ns based on the single straw data. Possible multiple tracks and the amount of clusters belonging to the same track can not be detected.



Gas Ar/CO2 (90/10), Beam Momentum 2.7 GeV/C, HV 1800

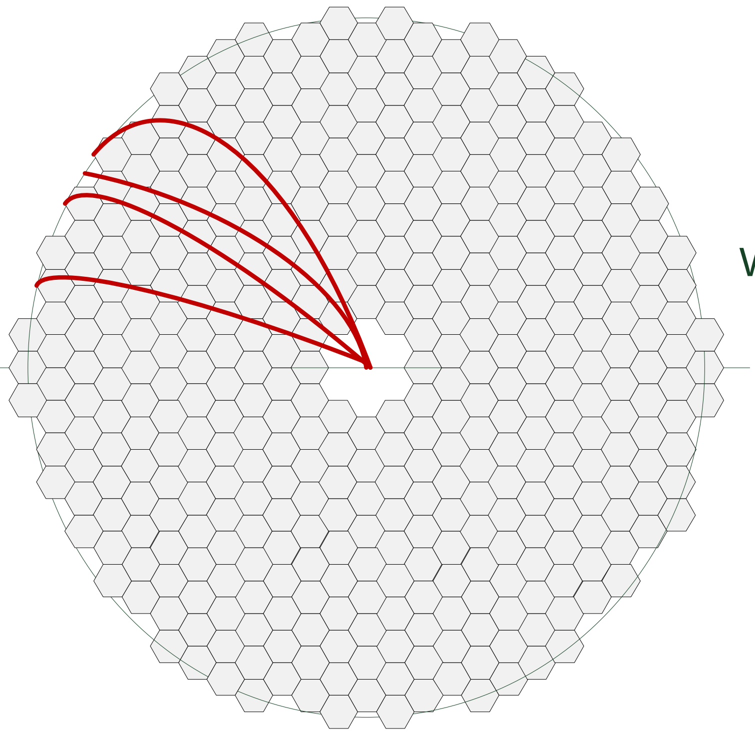
Interpretation of straw data dependent on the neighboring straw data

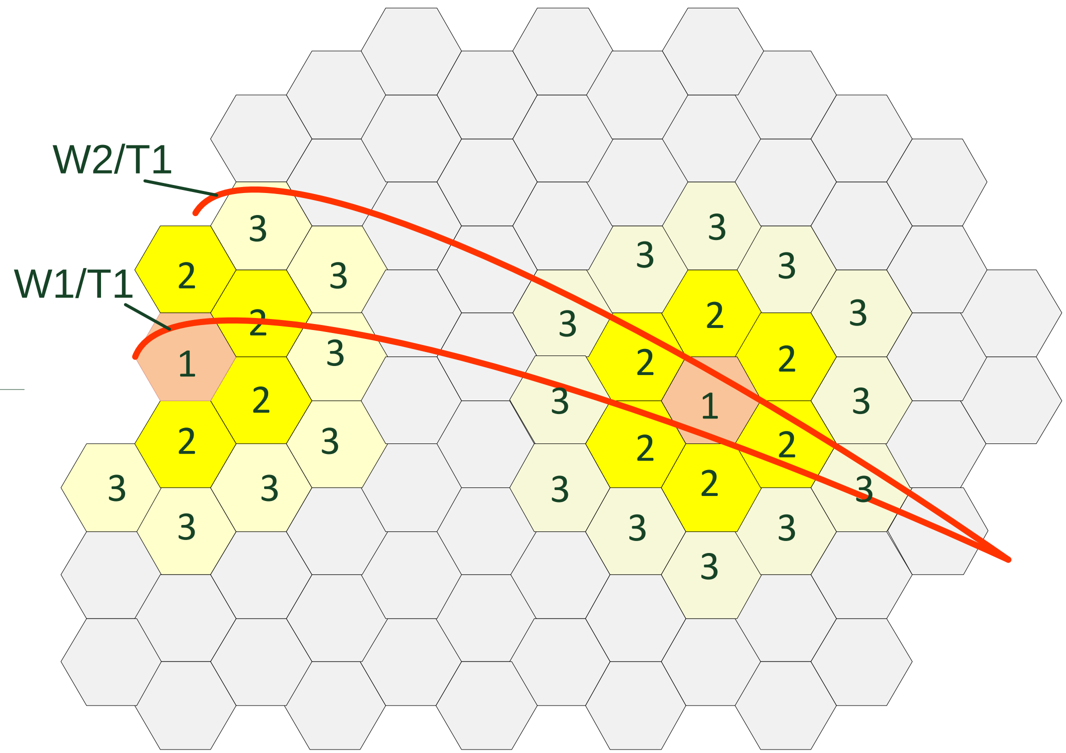


Gas Ar/CO2 (90/10), Beam Momentum 2.7 GeV/C, HV 1800

Event building

- Register trailing and leading edge parameters for all signal peaks
- Based on the trailing edge parameters, estimate the wall position/time starting with the most outside STT layer (1).
  →first wall (W1)→Track belonging to first wall (T1)





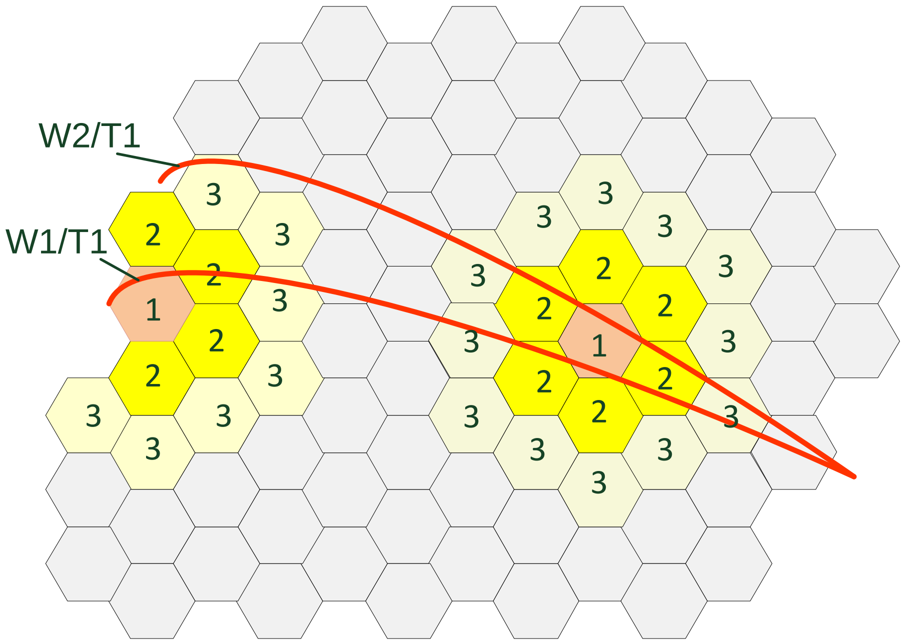
Note: Straw tubes have been shown as hexagonal pattern for simplicity

Event filtering

- Define coincidence window according to the propagation time and the electron spread
- Check coincidence (event) in the neighboring (2) and in the second order neighboring (3) straw
- If no event happened in the neighboring straw, the event should be lost. Each of new events corrects wall (trailing edge) position.

- If more than one event takes place, note for this straw all „walls“, for example W1 and W2, and leading edge parameters belonging to each of them

- A decision which of the leading edge parameters corresponds exactly to this wall/track should be done later by track reconstruction



Clustering: track by track

Proposed format for clustered data transfer

W_1	ST_nmb	le_1	le_2	ST_nmb	le_1	le_2	ST_nmb	le_1	le_2
W_2	ST_nmb	le_1	le_2	ST_nmb	le_1	le_2	ST_nmb	le_1	le_2
●									
●									
W_N	ST_nmb	le_1	le_2	ST_nmb	le_1	le_2	ST_nmb	le_1	le_2

Advantages

Real time processing dependent on neighboring straw data allows distinction of multiple tracks crossing the same tube and response of multiple clusters belonging to same track.

Efficiency and time resolution will be kept under high counting rates expected in the PANDA experiment.

In spite of the larger date volume involved into FPGA processing the data transfer will be sufficiently reduced comparing to existing method.
The required post processing and technique power will be also reduced.

Requirements

High density design requires data convolution of many straw data.
Any subdivision leads to additional overlap and increases the processing required.
→keep the number of FPGA channels as high as possible (reduce sampling rate), provide FPGA communication to the neighboring FPGAs.

Next topic: Sampling rate 240 MHz → 120 MHz

Contribution of drift-time binning into tracker resolution

Example for ATLAS Transition Radiation Tracker:

- The gasses in the TRT have a characteristic energy of about 2 eV. Thus we have for the coordinate perpendicular to the wires a spread of 0.114mm:

$$\sigma_x = \sqrt{\frac{2 \times 2eV \times 0.1cm}{1530V/0.2eV/cm}}$$

- For an average of 10 primary ion pairs, the distance of the closest electron to the wire has a spread of about 0.012mm
- **The drift-time binning in 3.125ns contributes 0.043mm**
- Noise and gain variations gives 0.035mm
- Uncertainties in wire position and time=0 gives 0.036mm
- All together this gives a coordinate resolution of about 0.132mm, in excellent agreement with detailed calculations – and with data.

Peter Hansen, Lecture on gaseous tracking detectors

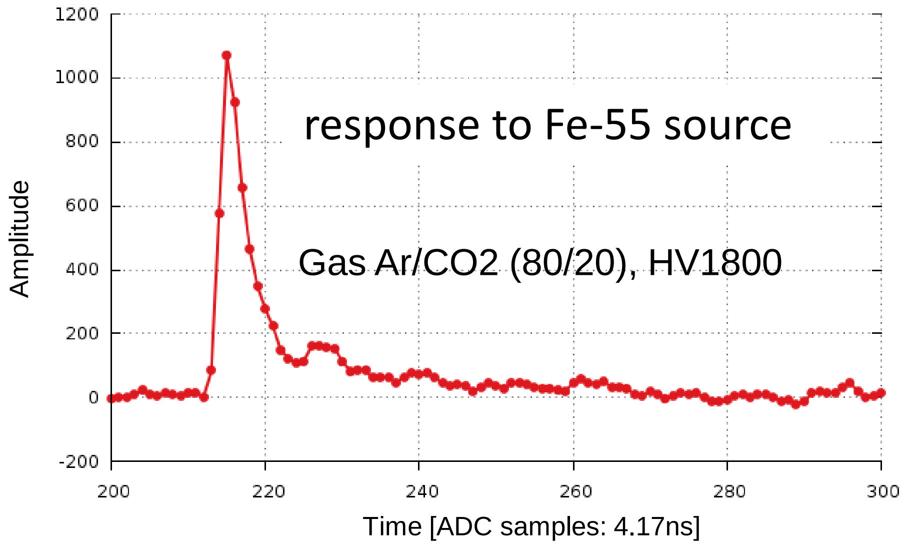
Sampling rate

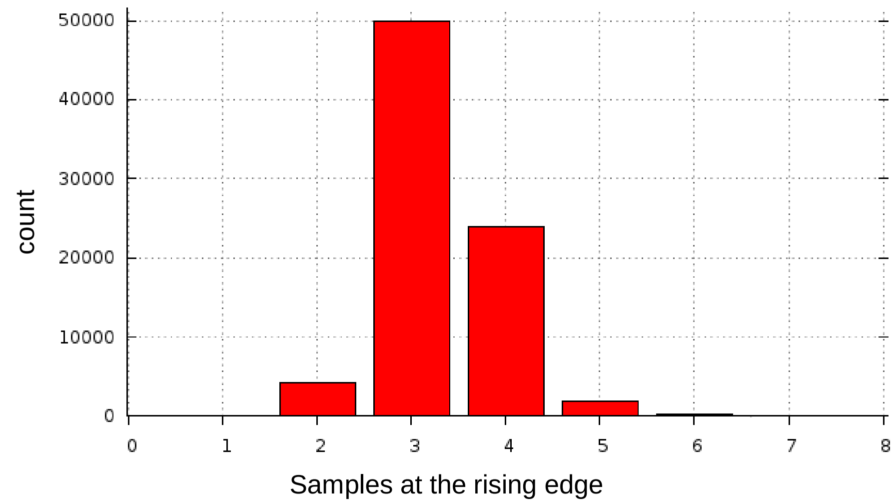
The actual 240 MHz QDC module provides a timing resolution (binning) of 260 ps, if subsampling used.

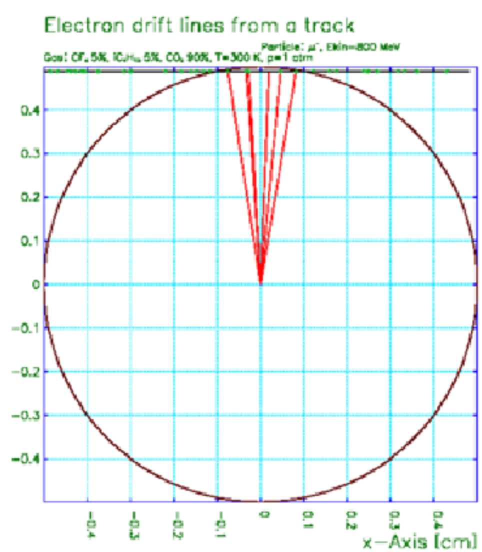
The drift-time binning in 3.125 ns contributes 0.043 mm
Binning in 260 ps contributes **0.003 mm.** **Do we need it?**

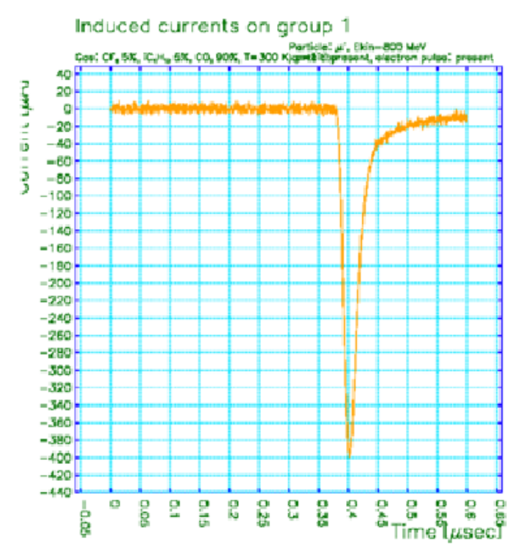
To answer → define the shortest pulse (response to Fe-source) and investigate proton beam response→ adjust shaping time.

Expected: The system response to Fe-55 source and to proton hitting the straw wall are comparable.

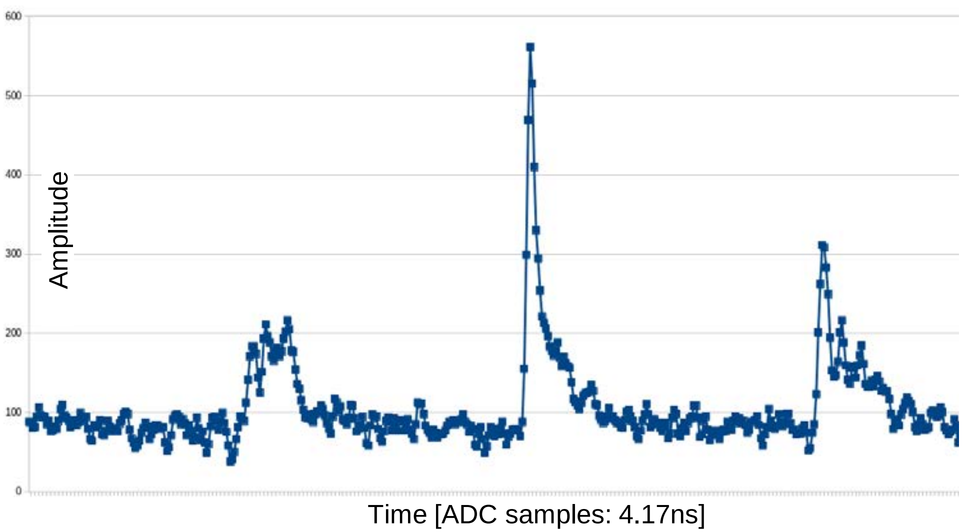




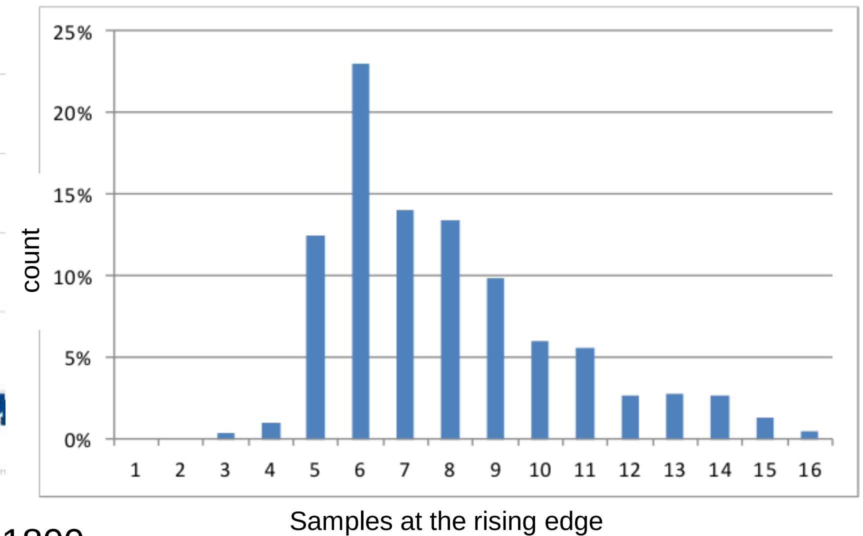




However for proton radiation, we almost don’t see pulses with 3-4 sampling points on the leading edge



Gas Ar/CO2 (90/10), Beam Momentum 2.7 GeV/C, HV 1800



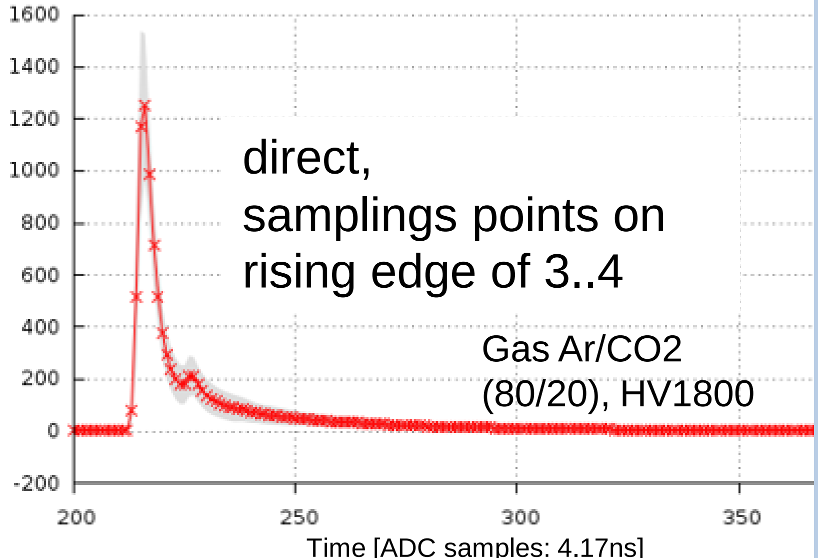
Reason:

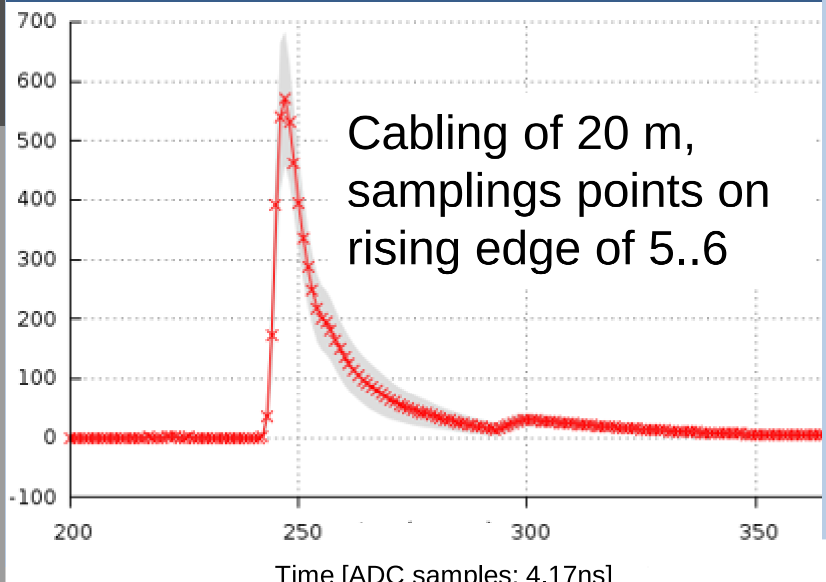
The ionization in the second case is mostly smaller than in the first case and these small single clusters are invisible for electronics under noise, reducing the spatial resolution and causing near straw wall dead zone.

By reducing the system noise, detecting of small single clusters can be achieved.

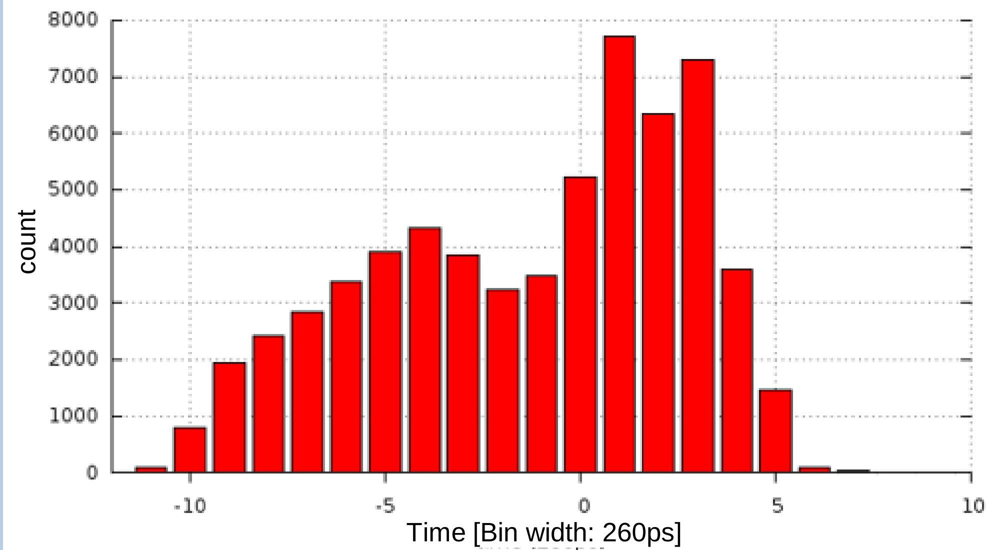
Shaping time adjustment - Test with cable length

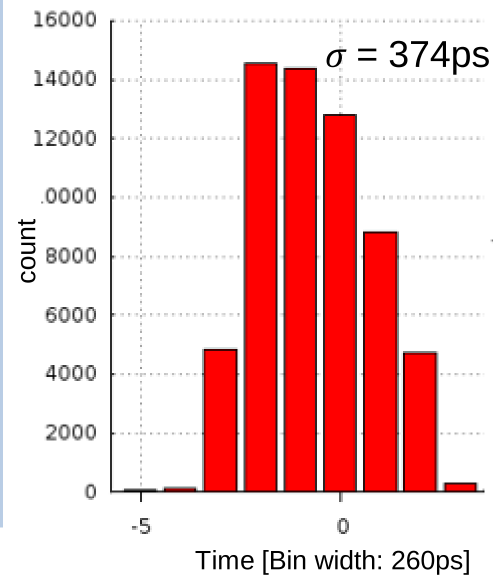
Fe-55 response (average)

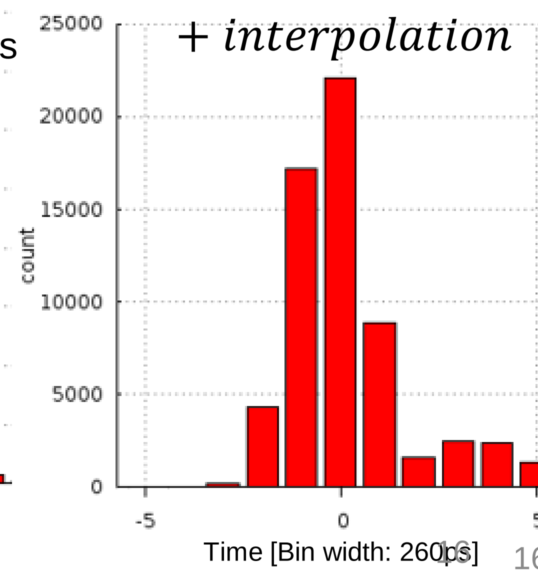




time difference 120 MHz vs. 240 MHz

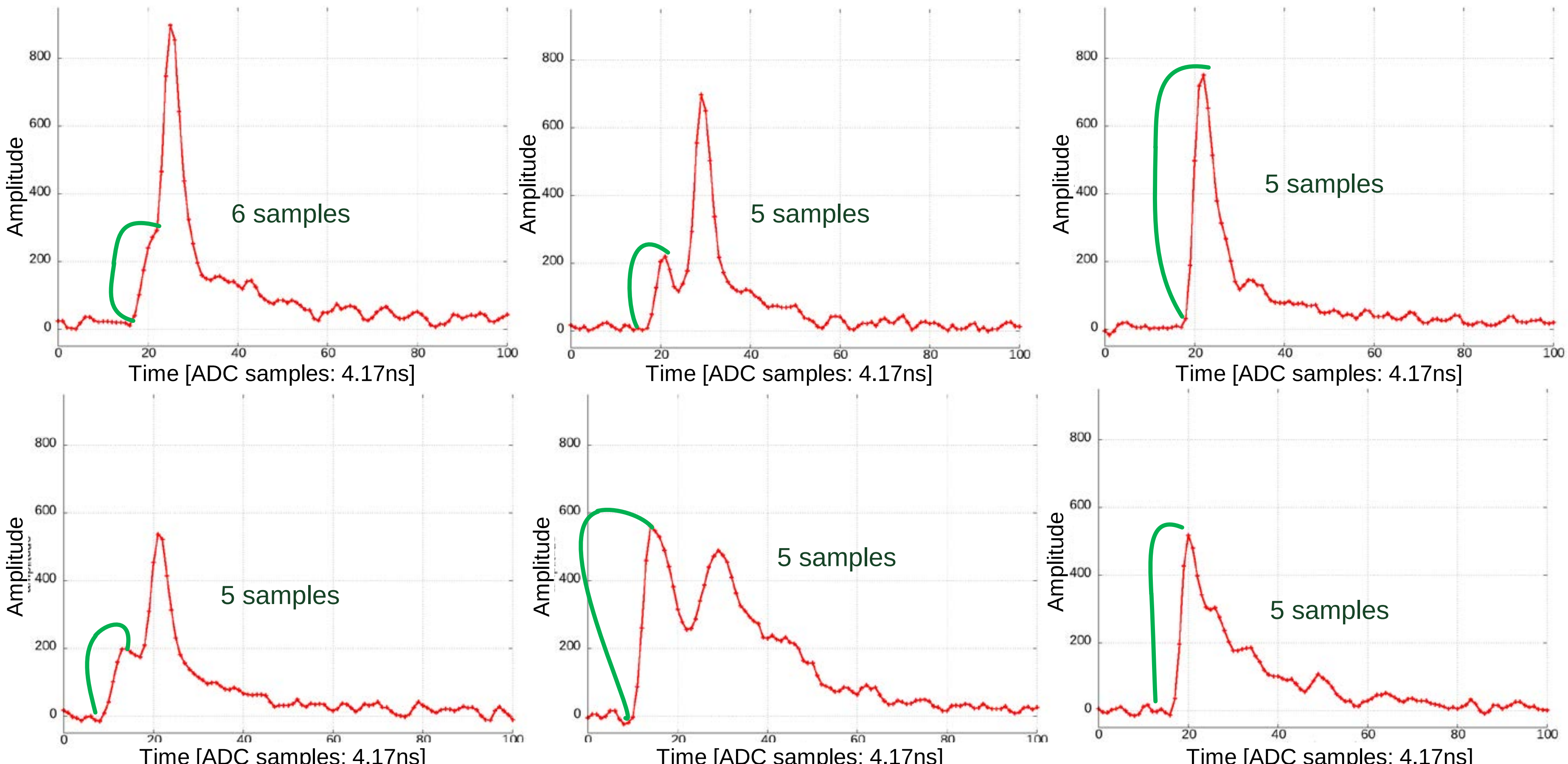






Advanced processing

- According to shaping time, check number of samples on rising edge response to FE-55 →N_le (note the gas mixture).
- By radiation response select the leading edge parameters (constant fraction, zero crossing..) based only on N_le points for fixed gas mixture.
- The figure below shows this for N_le =5.



Shaping time/sampling rate

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Estimated, that the actual system has shaping time of ca. 8 ns. Introducing this one of 12 ns (see experiment with cable) makes it possible to reduce sampling rate to 120 MHz (enough for shortest pulse response).

The shaping time should be short in order to get a response from the first primary cluster and thus better time resolution, but should be also sufficiently long to integrate further clusters so that there is only a single output pulse per particle crossing straw. Assuming 0.3 mm average spacing between primary clusters, the shaping time should be much longer then 15 ns for slow gas and 6 ns for fast gas. (NA62 TD Document).

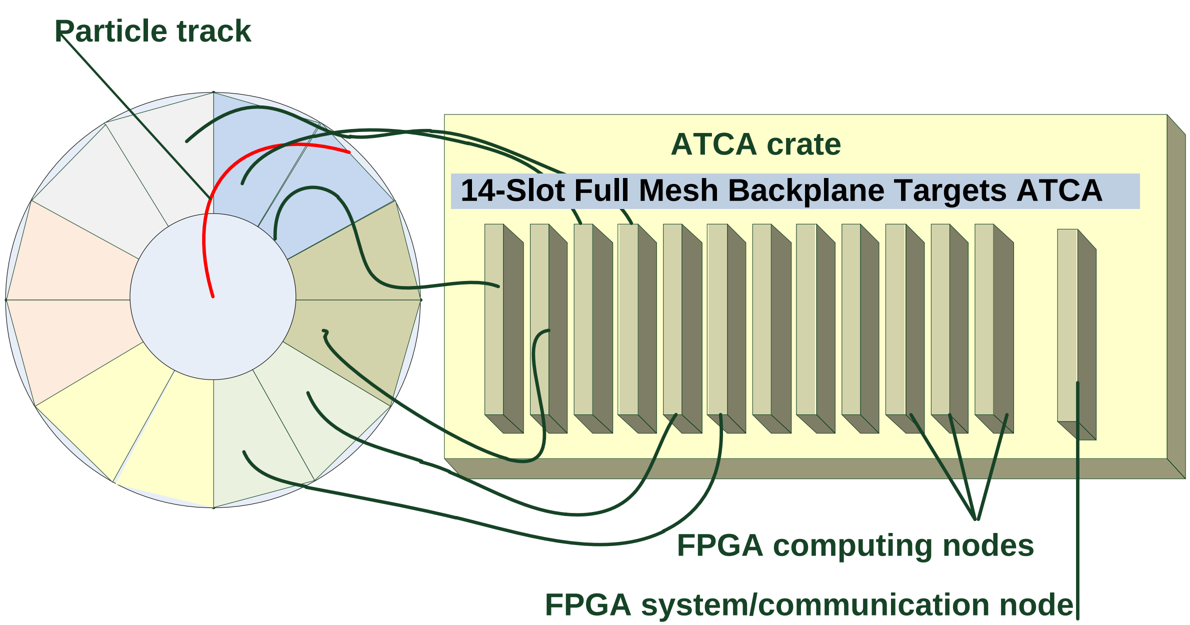
NOTE

- our approach doesn’t require shaping time increasing for slow gas thus keeping better time resolution for any gas mixture
- the introduced advanced processing will lead to further increasing time resolution compared to existing solution

HW Implementation: single ATCA crate system

System requirements:

- High number of channels should be processed on the same FPGA
- High number of FPGA should be integrated on the same FPGA-board
- Large FPGA-board dimensions are of choice
- Point-to-Point connections between boards are needed
- Using one of hardware standards is preferred



Single ATCA crate system: is it possible?

ATCA crate → 14 boards:
12 computing boards +1 communication board +1 expanded testing board

Straw number → ~4800
4800/12 boards= **400 channels/board**

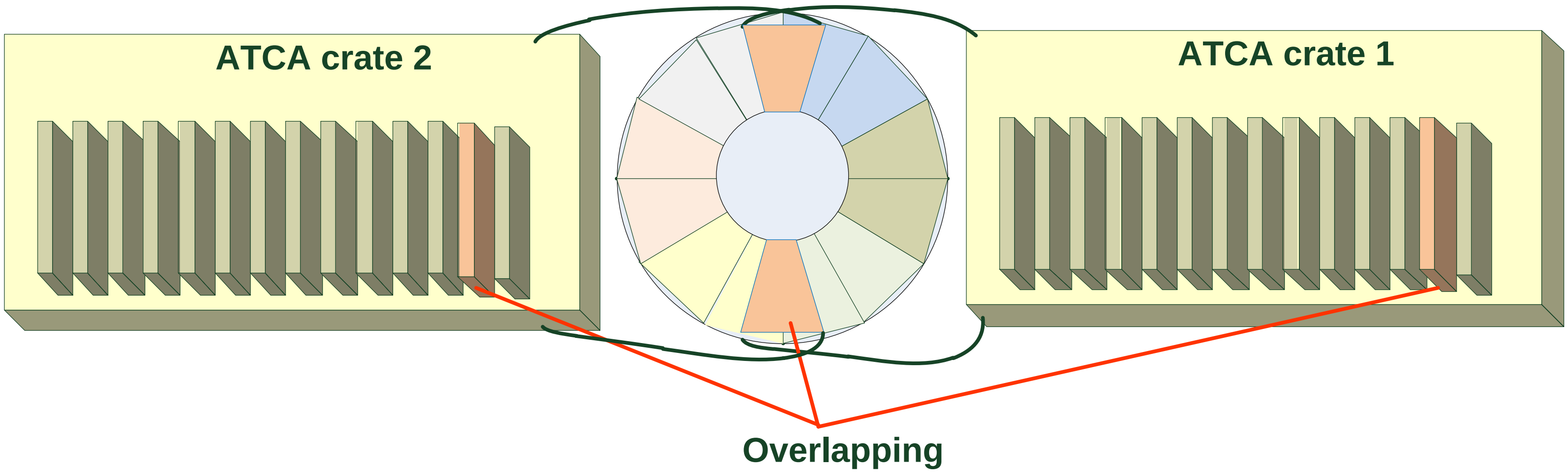
1 ADC channel output→2 LVDS pairs→4 user I/O FPGA pins
10 FPGA/board→ 40 channels/ FPGA→ min. 4x40=160 I/O FPGA pins

Possible? Kintex 7 offers up to 400 user I/O pins

Bottleneck

Cabling problem: connection of 400 channels to each ATCA board

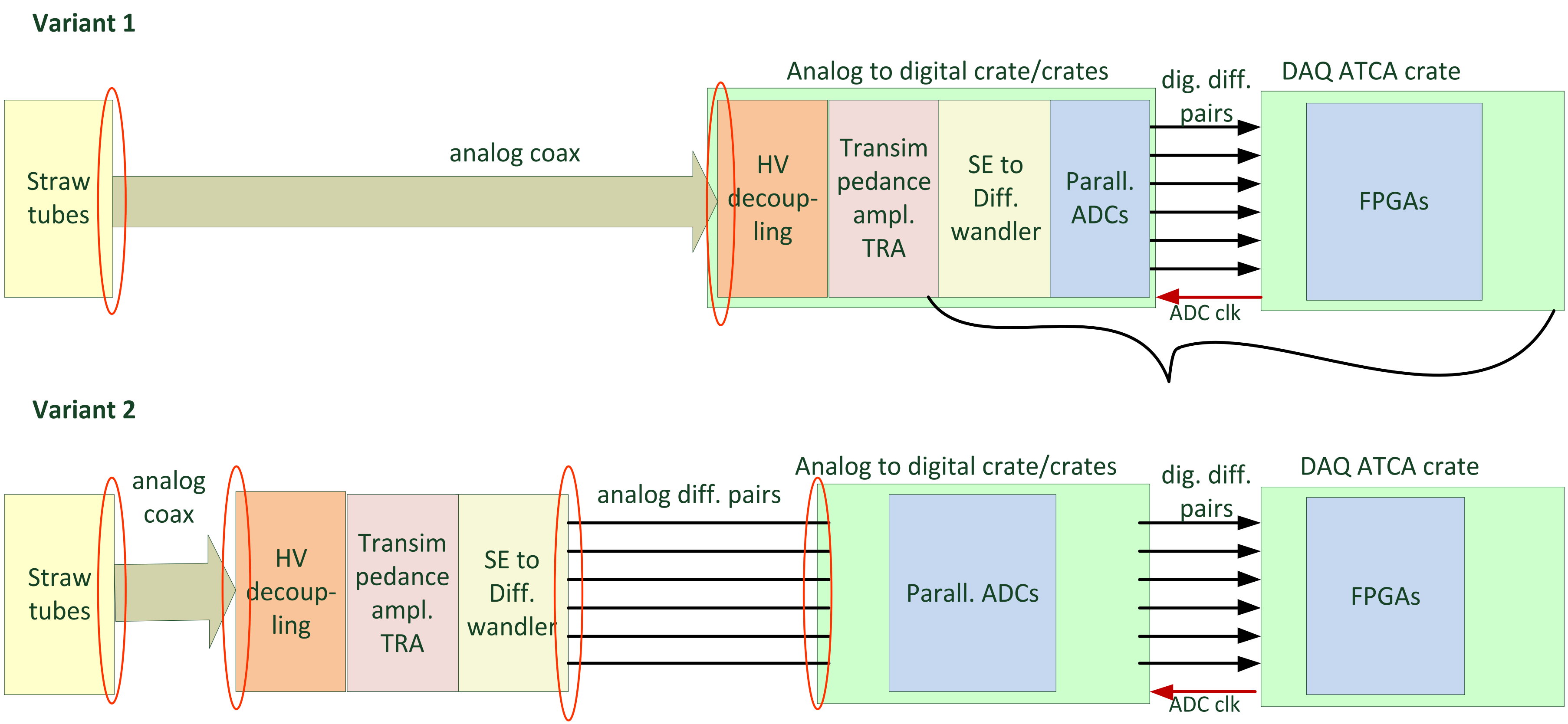
Alternative: if 400ch/board are not feasible
→ 2 ATCA-crate system



Options 1:
- ADCs and FPGA implementation at the same ATCA crate
- System consisting of ATCA FPGA crate and ADC unit

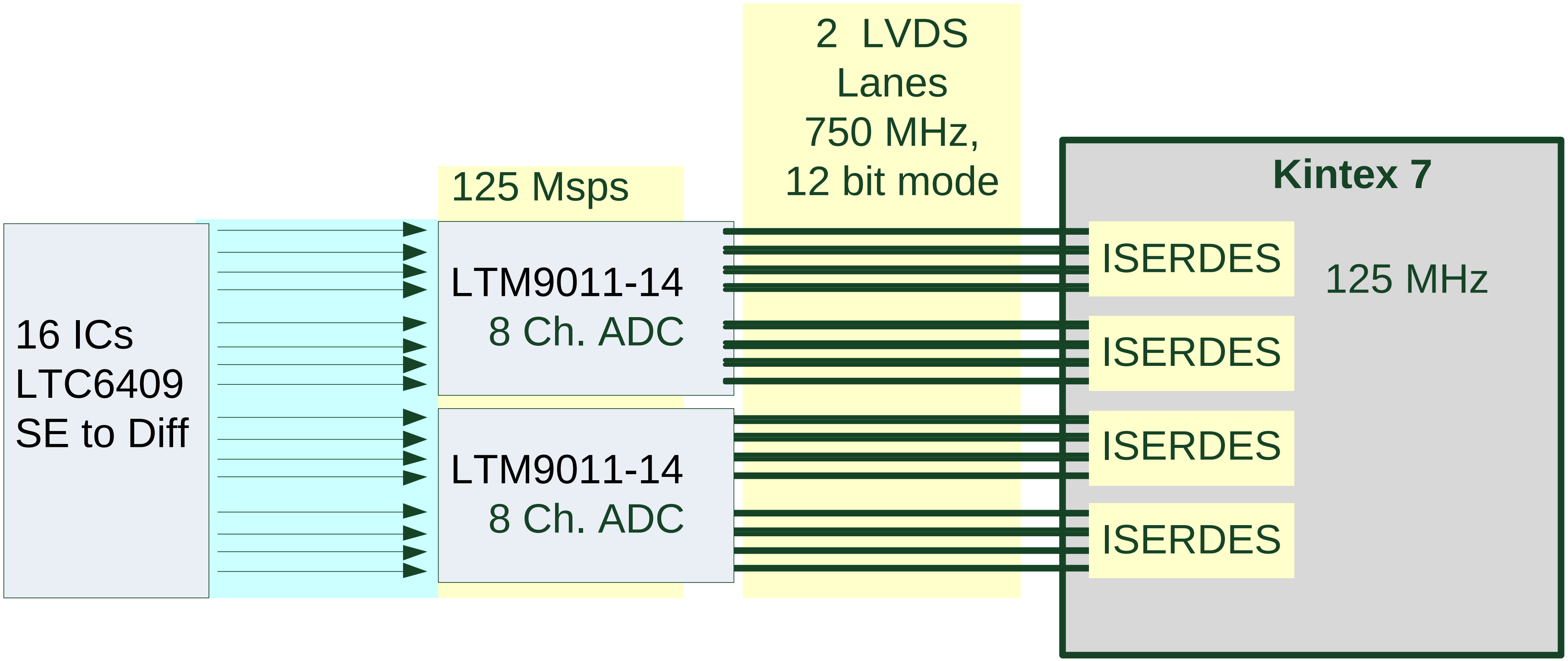
Options 2:
- Preamplifier on the STT site
- Preamplifier on the ADC site

Electronic chain



1. reduce number of interfaces and units
2. keep the same cable length/route length (same integration constant, same sampling time for real time processing of all convolved channels data)
3. get separation of analog and digital circuits

Under development: ADC/ FPGA test unit



Prototype: FMC board with ADCs used on Avnet Kintex evaluation board

Conclusion

Main property of introduced system:

- Real time processing dependent on neighboring straw data

System

- keeps efficiency and time resolution under higher hit rate
- gets higher resolution using advanced processing and uses the same small shaping time for slow and for fast gas
- reduces required post processing

and can be very compact implemented: inside of one rack

Outlook

There are some variants of the system architecture.

Available time will be used to make a choice.

We do it

- **by carrying out our experiments on straws and analysis of measured data**
- **by adapting of processing algorithms**
- **by developing and testing all new HW components, which should be integrated into the new system**

Note

Keep open the possibility to run the system with 120 MHz and with 240 MHz or 480 MHz with the reduced number of channels.

Some channels in system should always be running with a high frequency for advanced investigation.

References

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