The KLOE Calorimeter ADC and TDC

(E. Spiriti)

- **Calorimeter signal processing requirements**
- **KLOE data aquisition requirements**
- **ADC working principles and measured performance**
- **TDC working principles and measured performance**
- **ADC/TDC auxiliary (DAQ related) functions**
- **System test**
- **Conclusion**

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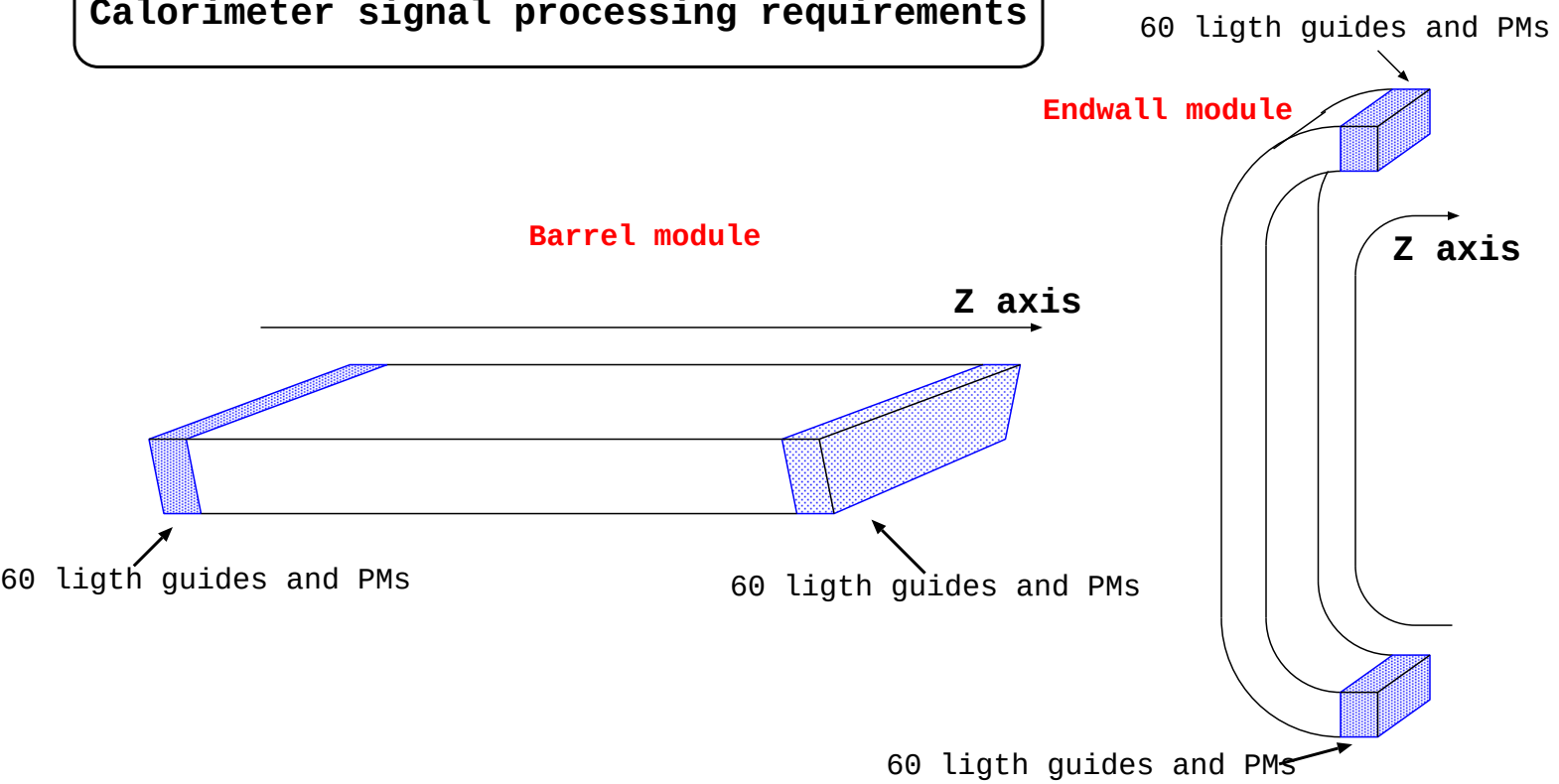
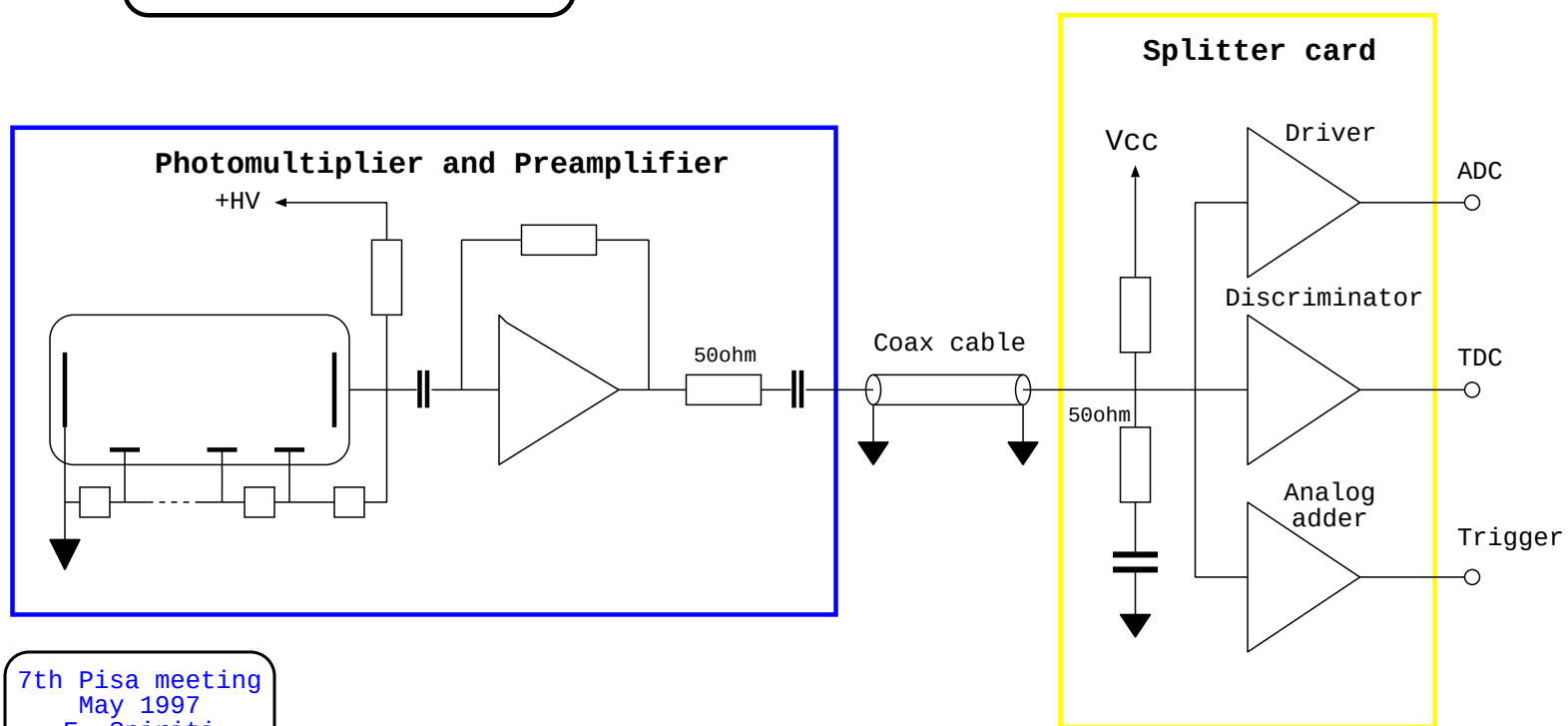
Calorimeter signal processing requirements



Shower reconstruction → Charge measurement (ADC)

Arrival time and Z coordinate → Time measurement (TDC)



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Calorimeter signal processing requirements

ADC

ADC dynamic range

Taking into account:
* Maximum energy released in one cell
* Attenuation lenght
* PM gain

Photoel. @ 510 MeV ~ 900

Dynamic range = 1~1000 photoelectrons

ADC resolution

Assuming:
1 adc count = 0.5 photoel.

Resolution = 11 bits

TDC

TDC dynamic range

Taking into account:
* Maximum spread in particle time arrival on the calorimeter
* Fibers light propagation time

Dynamic range = 220 nS

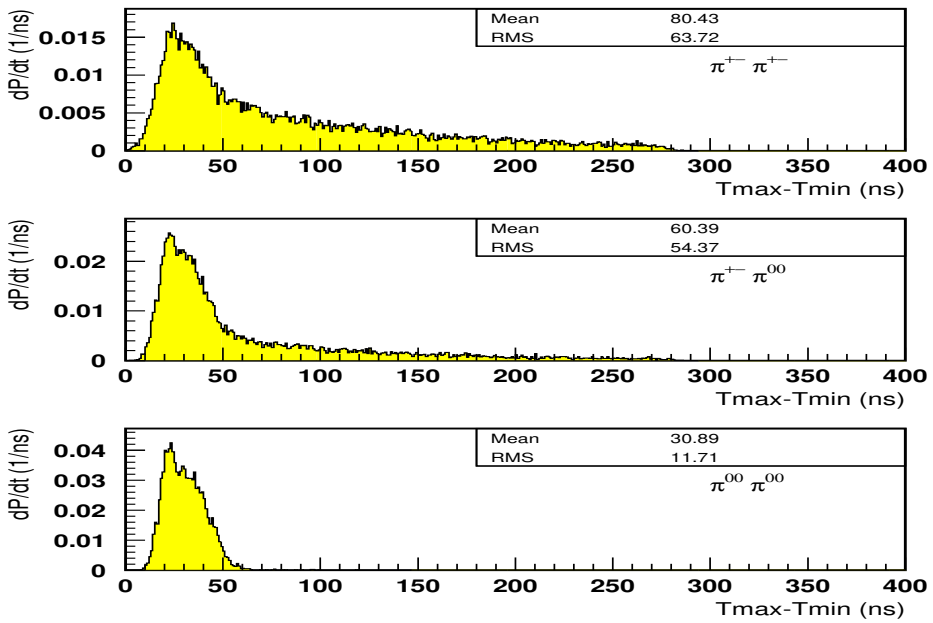
TDC resolution

Assuming:
1 adc count = 55 pS

Resolution = 12 bits

Calorimeter signal processing requirements

- **Particle arrival time not fixed in time**



- **Signals time arrival versus trigger**

  * no lumped delay linees

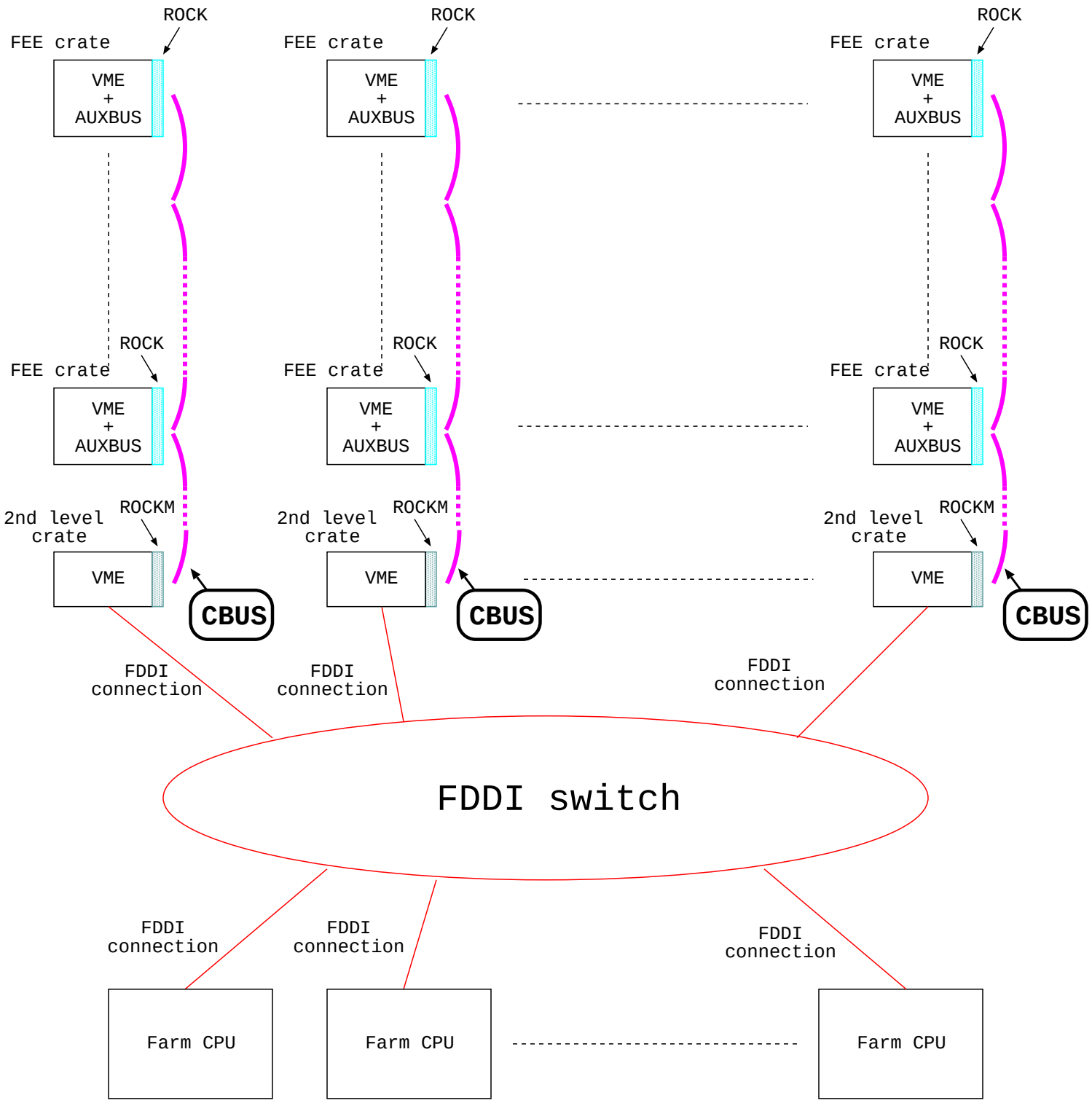
  * no long signal cables

Signals arrives before trigger

TDC
Delay with monostable

ADC
Double baseline subtraction

KLOE data acquisition requirements



Data flow = 10 KHz * 5 KBy = 50 MBy/Sec

- 2 ADC chains (6 FEE crates each)
- 2 Calorimeter TDC chains (6 FEE crates each)
- 4 Chamber TDC chains (3 FEE crates each)
- 2 Trigger chains

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KLOE data acquisition requirements

Two trigger levels

1st level

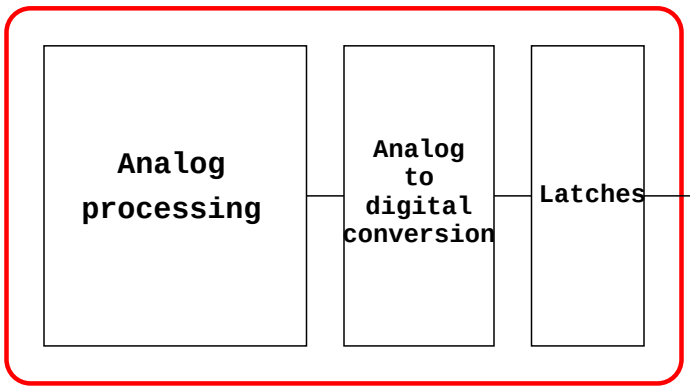
- Arrival time < 200 nS after signal → TDC
- Arrival time >150 nS and <350 nS after signal → ADC
- Starts digitization
- 2 µS Conversion time

2nd level

- (1.5 µS - 2.0 µS) after T1
- Starts data buffering on FEE boards
- Event counting on FEE boards, ROCK, ROCKM and Trigger Supervisor
- Starts data readout from ROCK and ROCKM

Calorimeter ADC/TDC logical structure

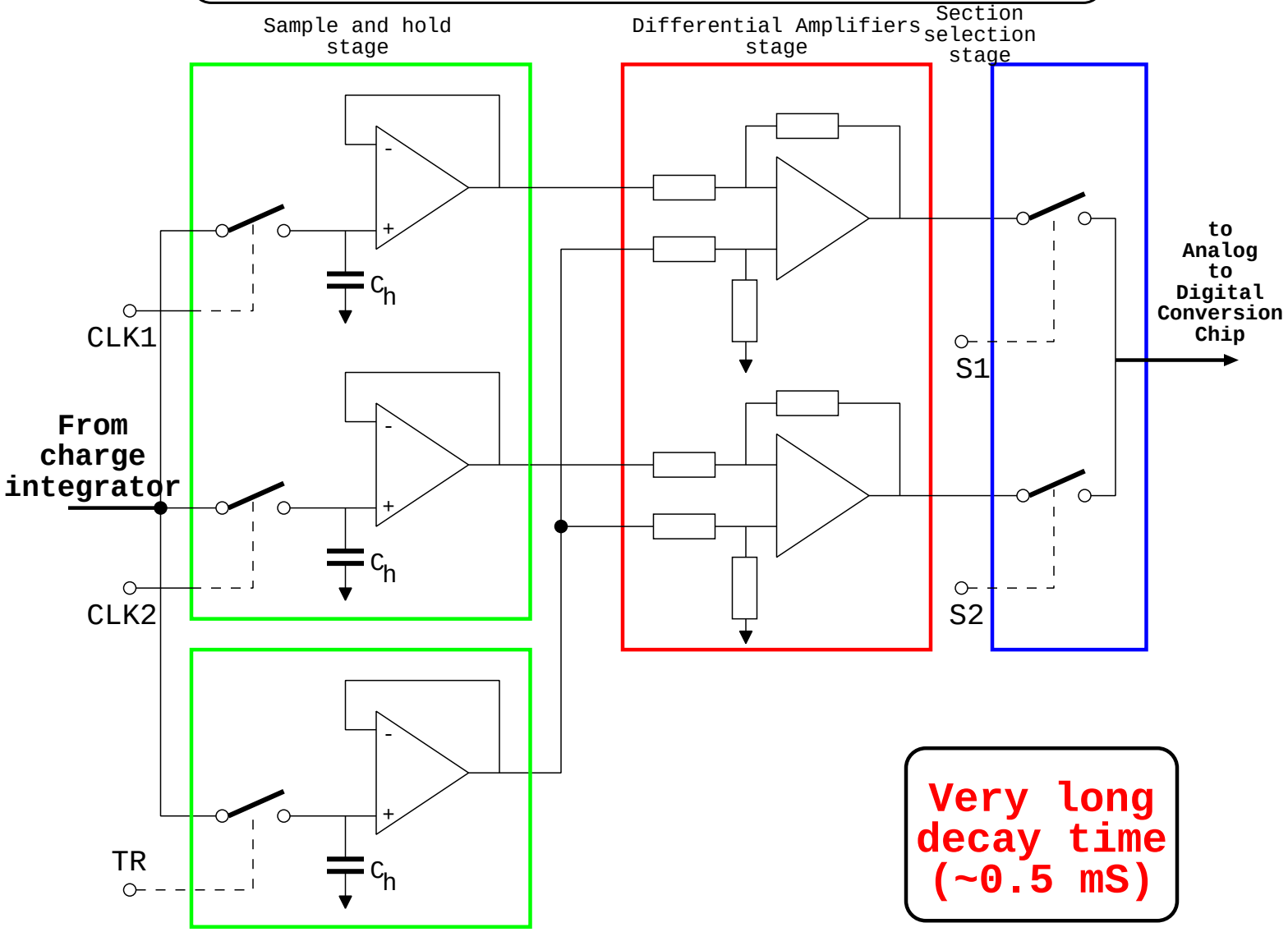
Digitization (T1 driven)



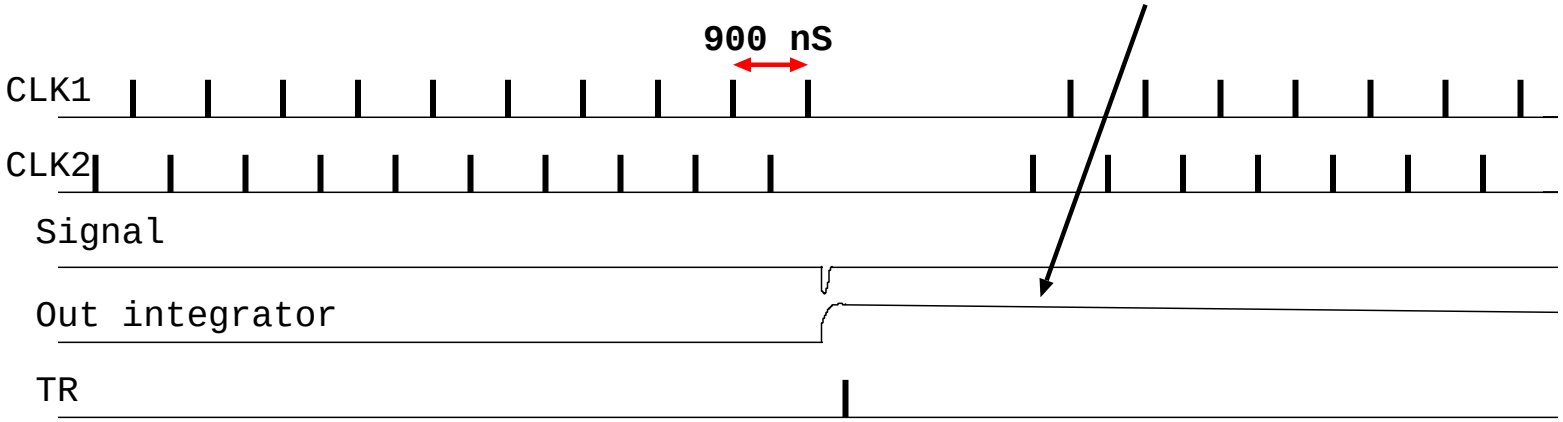
Data processing (T2 driven)

- **Zero suppression**
- **Pedestal subtraction**
- **Trigger counting**
- **Data buffering**

ADC working principle and measured performance



Very long decay time (~0.5 mS)



$$\text{Occupancy} = \frac{50 \text{ hits/event} * 10 \text{ KHz}}{5000 \text{ ch}} = 100 \text{ Hz/ch}$$

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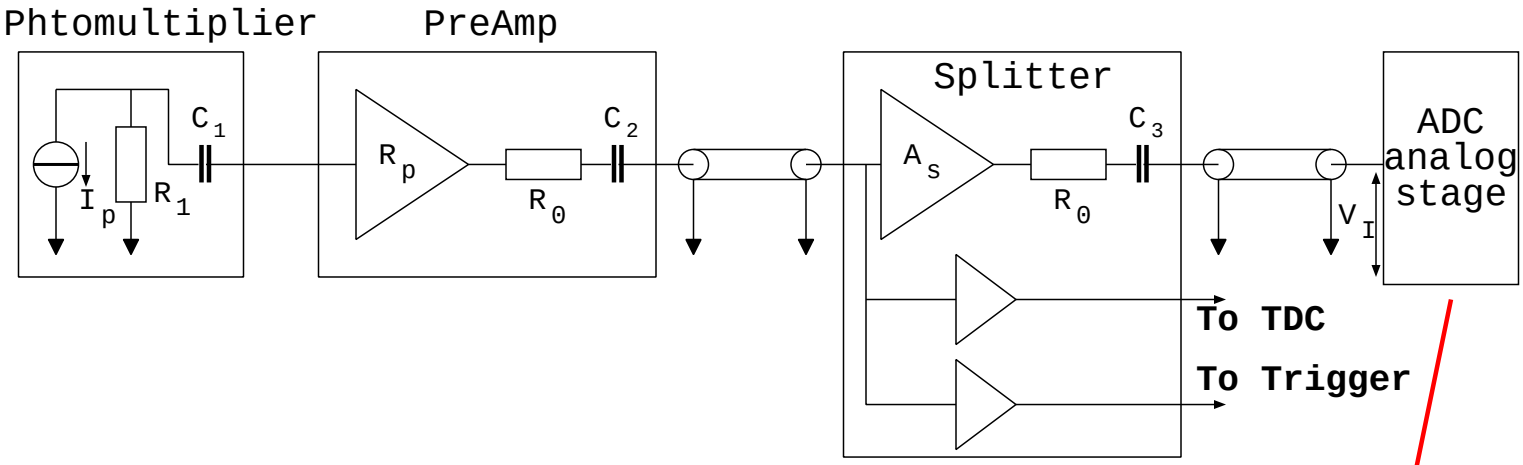
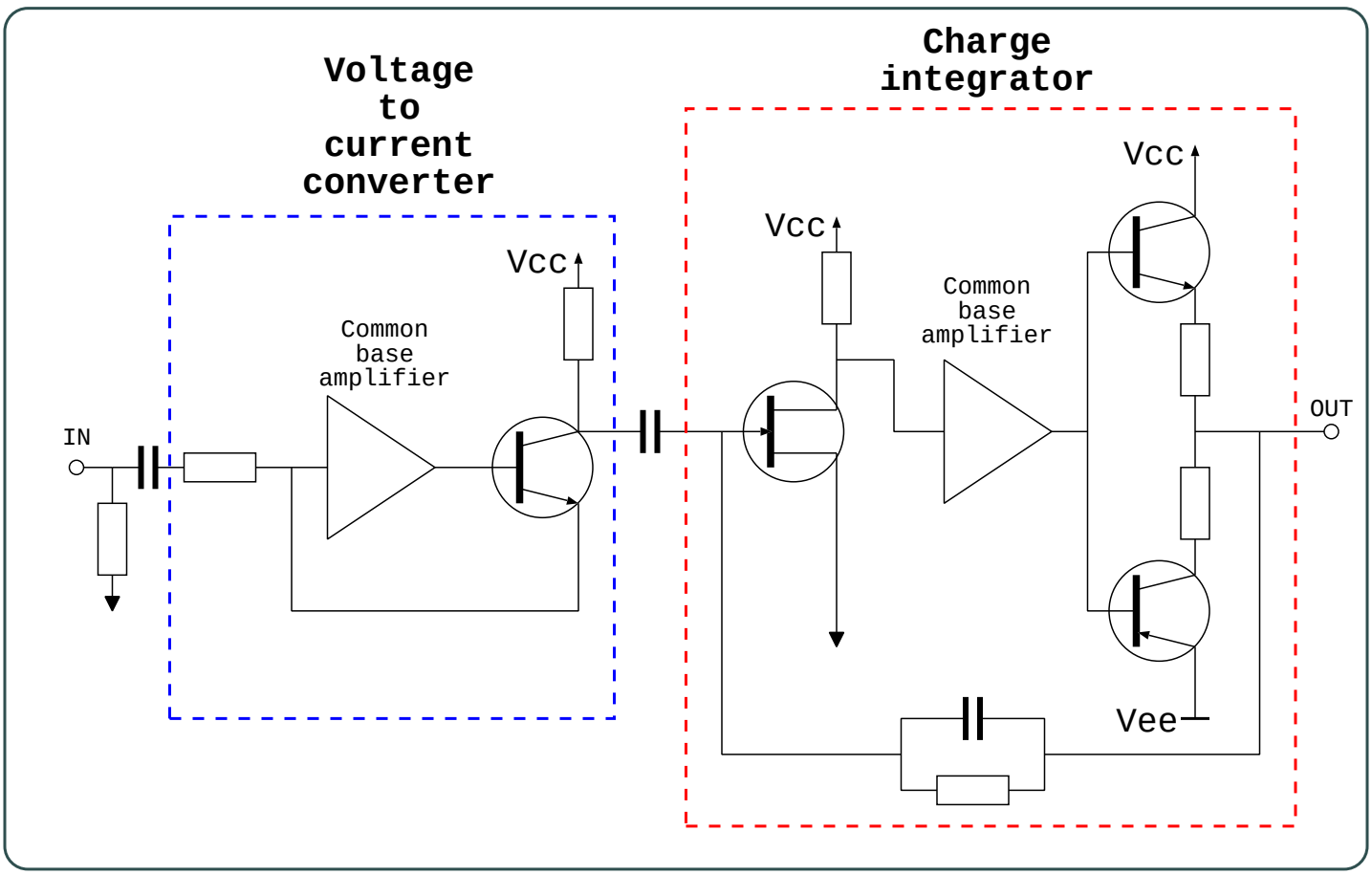
* **Developed in collaboration with CAEN.**

ADC working principle and measured performance

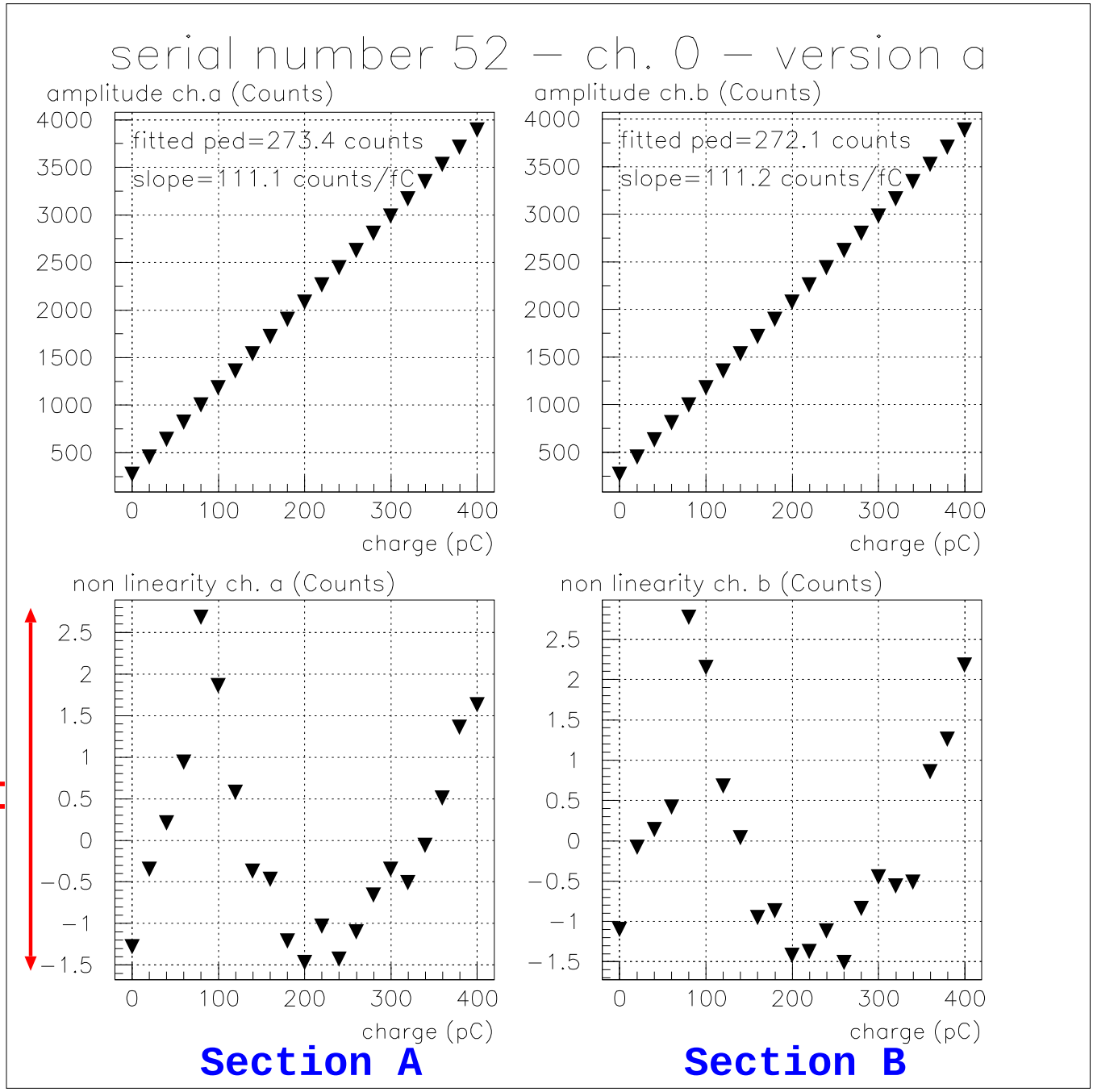


$$\frac{V_0(s)}{I_P(s)} = K \frac{s^3}{(1+\tau_1 s)(1+\tau_2 s)(1+\tau_3 s)} \frac{A}{(1+\tau_f s)}$$



ADC working principle and measured performance

Linearity plot for one channel



NLI = 4 counts = 0.1% of full scale

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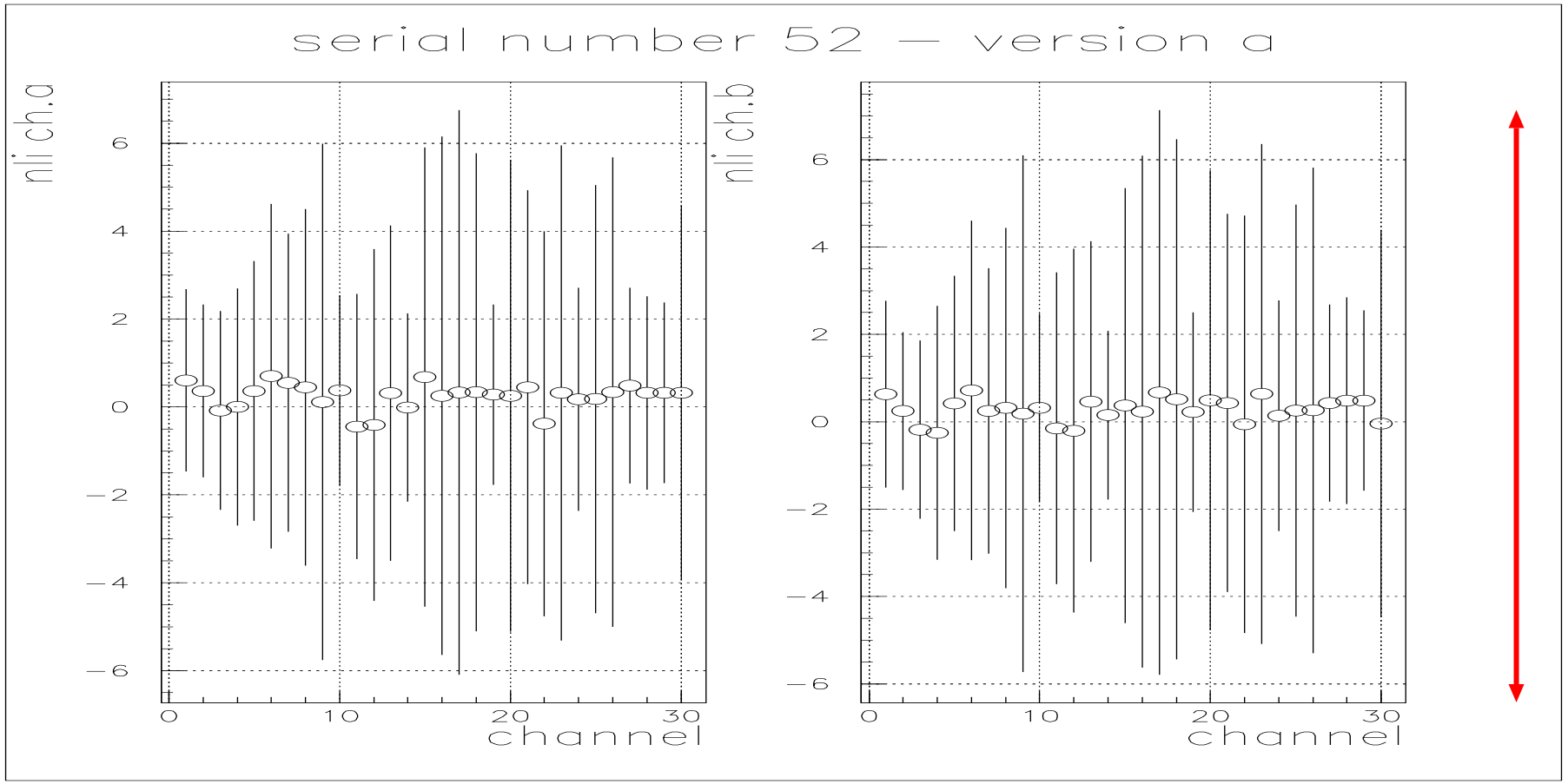
ADC working principle and measured performance

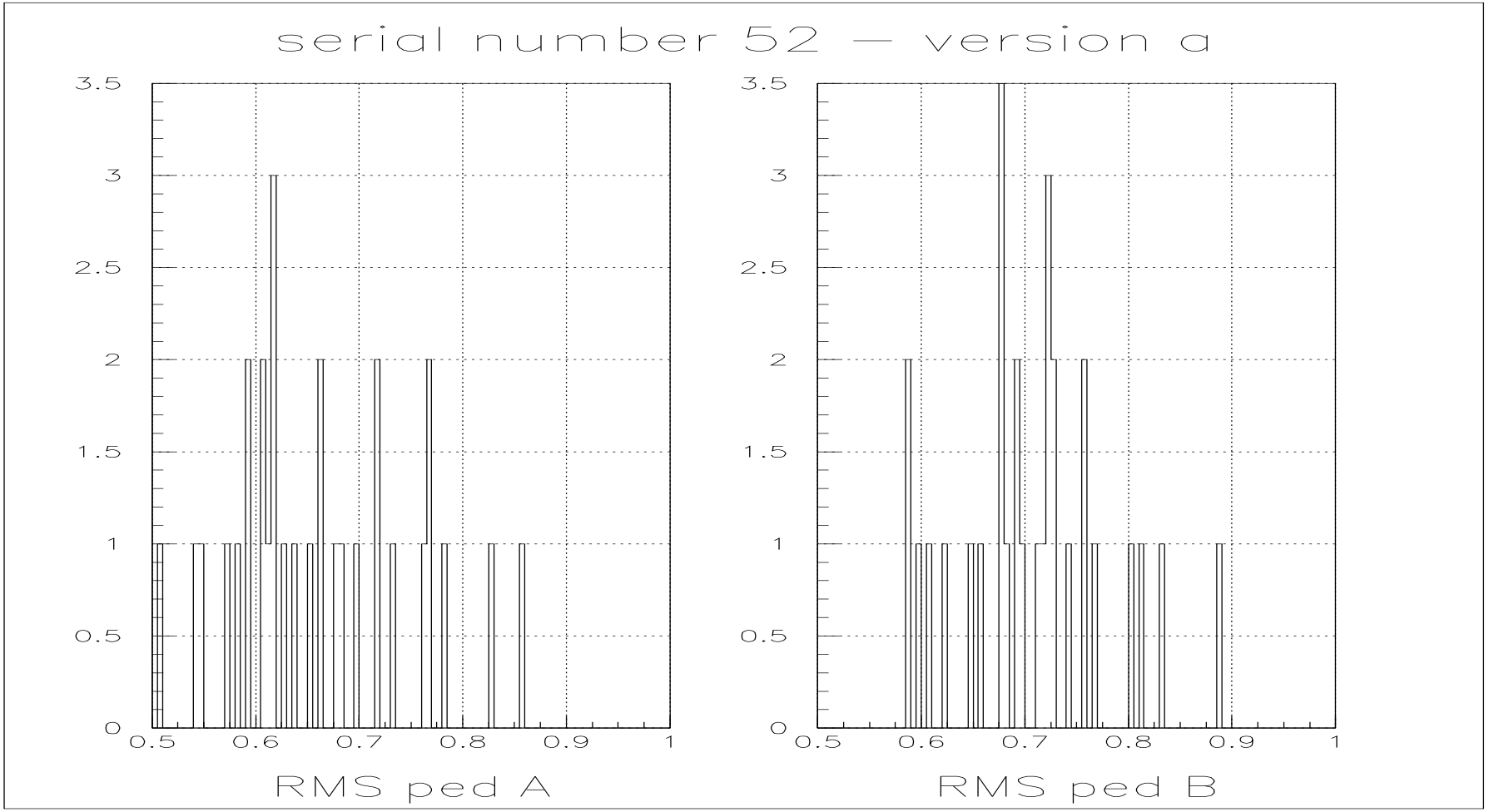
ADC integral non linearity for one board



NLI = 12 counts = 0.3% of full scale

ADC working principle and measured performance

Pedestal RMS (resolution) distribution for 1 board



RMS < 1 count

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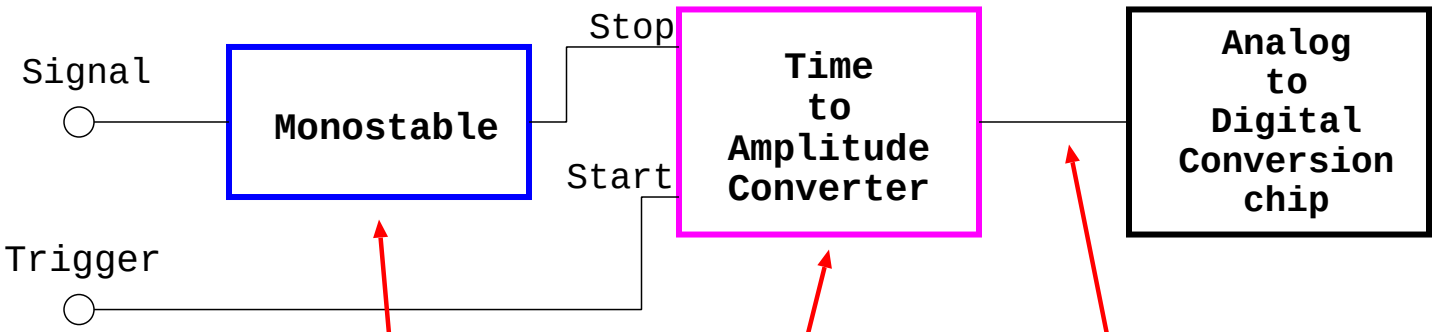
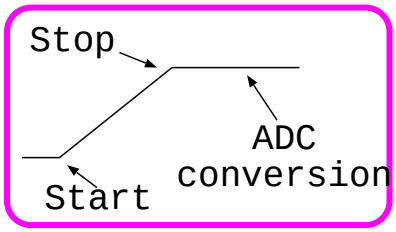
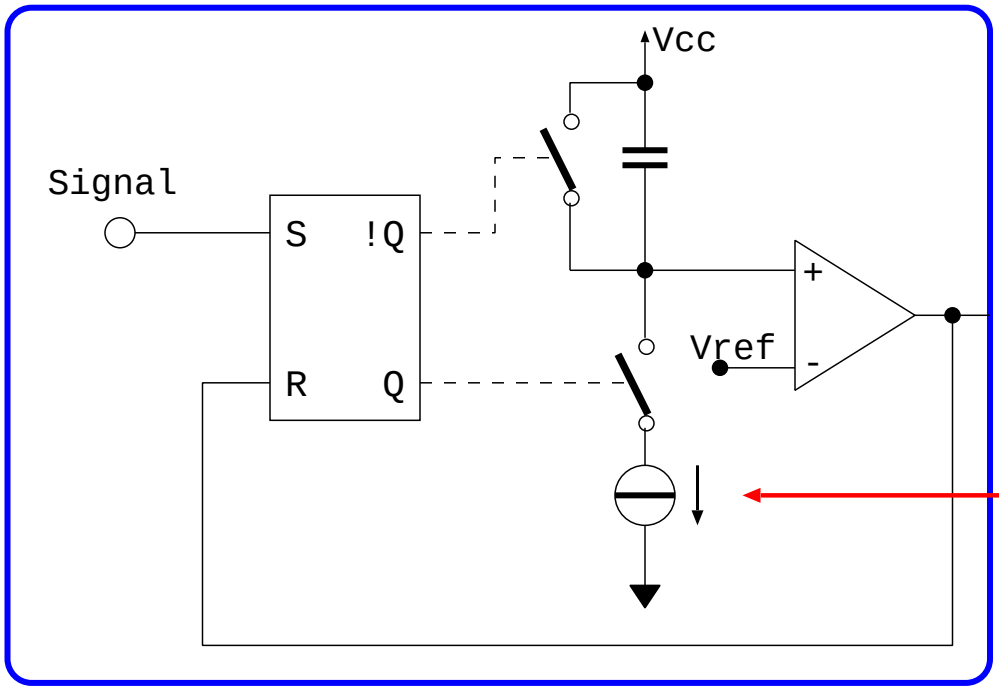
TDC working principle and measured performance

Common start TDC



Monolitic chip
Design: Prof. Poux
ISN Grenoble
Production: Thompson





Temperature coefficient compensation

* **Developed in collaboration with CAEN.**

Temperature stability

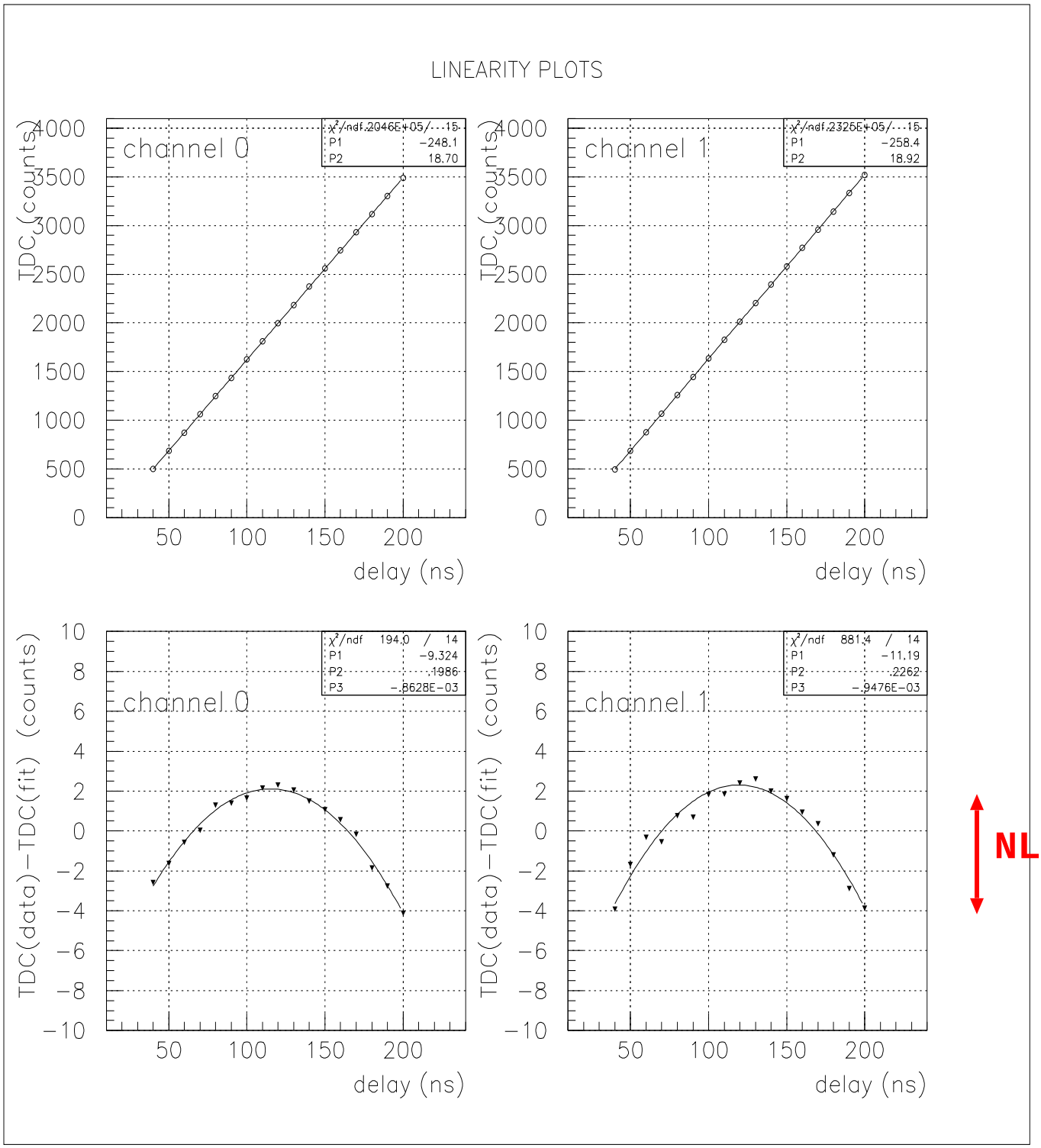
Different components (monostable, TAC, ADC) contributes to temperature stability

A temperature stability coefficient trimmering system is introduced at board level (common for 30 channels)

At production stage each board temperature coefficient is trimmered to:

+/- 0.3 count/C

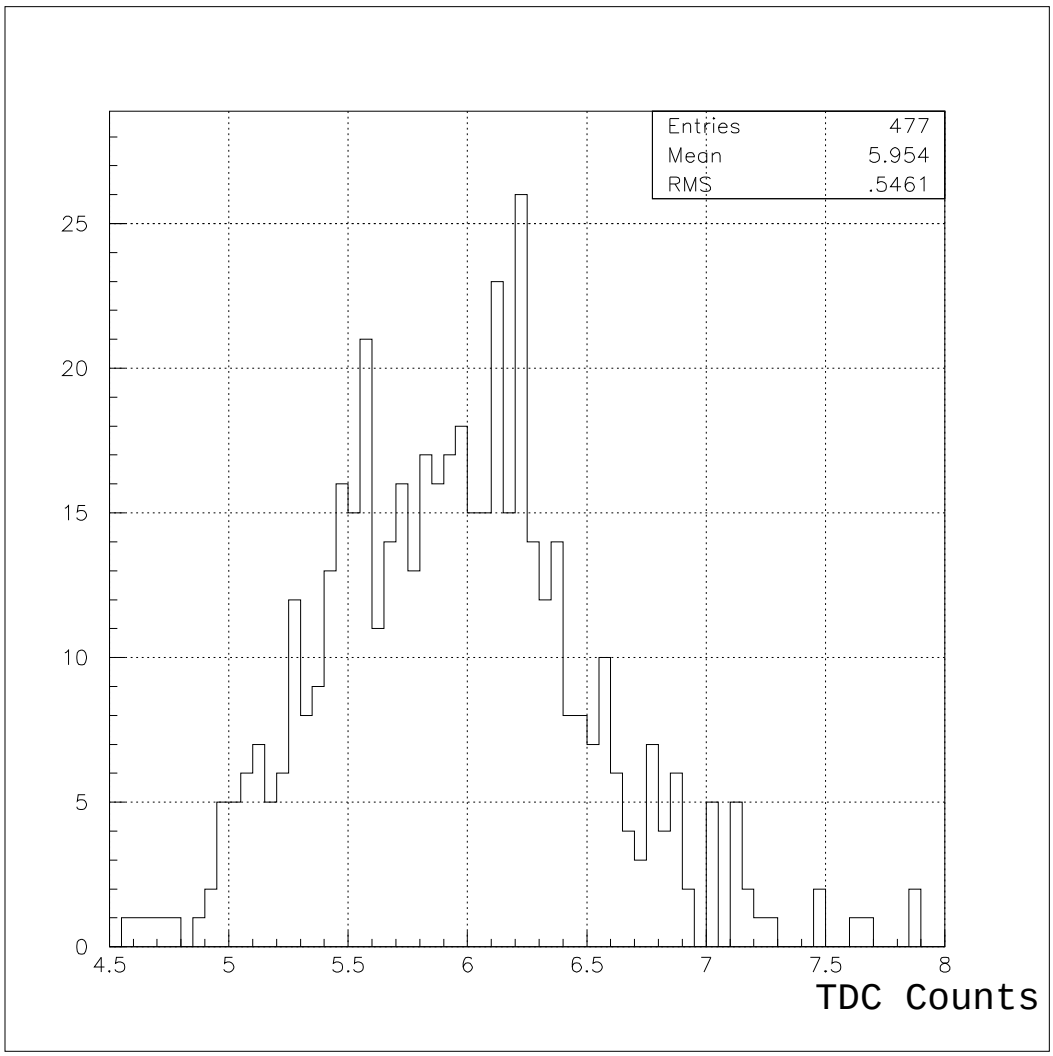
TDC working principle and measured performance



NLI = 6 counts = 0.15% of full scale

TDC working principle and measured performance

NLI distribution for 16 boards

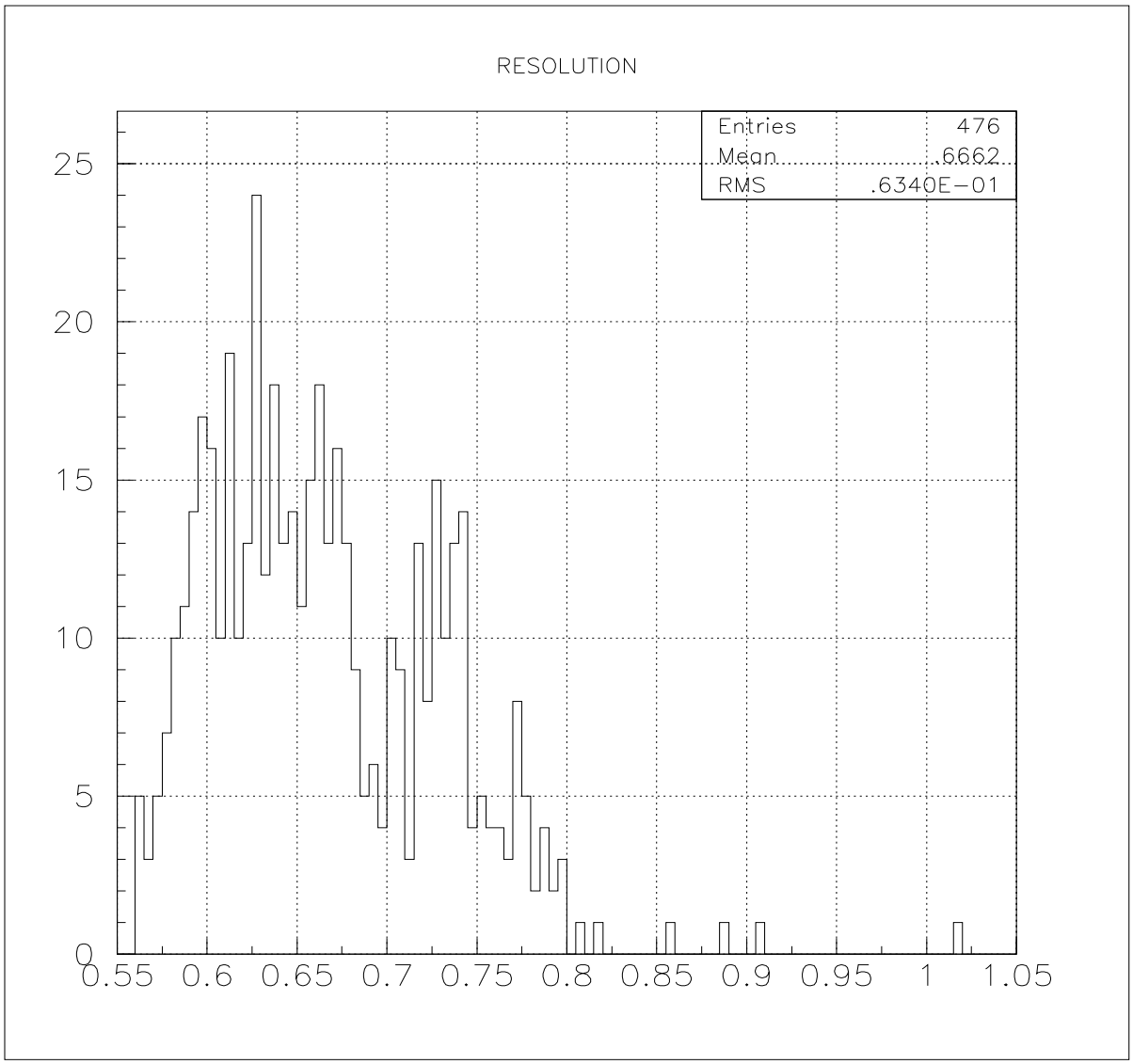


Max NLI = 8 counts = 0.2% of full scale

Boards ser. num.: 14,20,26,33,47,71,92,100,101,
109,110,115,116,119,120,121

TDC working principle and measured performance

Pedestal RMS (resolution) distribution for 16 board



RMS < 1 count

Boards ser. num.: 14,20,26,33,47,71,92,100,101,
109,110,115,116,119,120,121

ADC/TDC auxiliary (DAQ related) functions

ZERO SUPPRESSION

- Any rejection window (twice per channel for the ADC) can be programmed to reject pedestals values

PEDESTAL SUBTRACTION

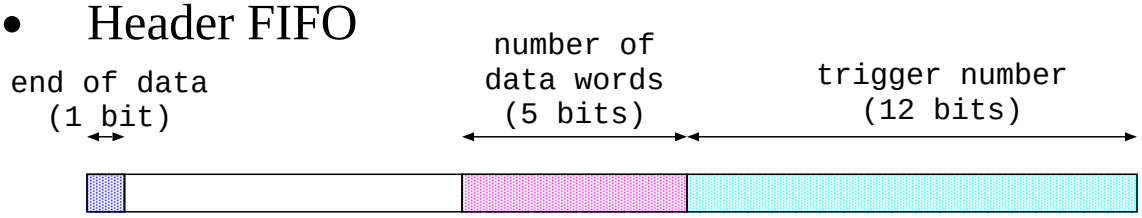
- Pedestal values subtracted hardware (twice per channel for the ADC)

TRIGGER COUNTING

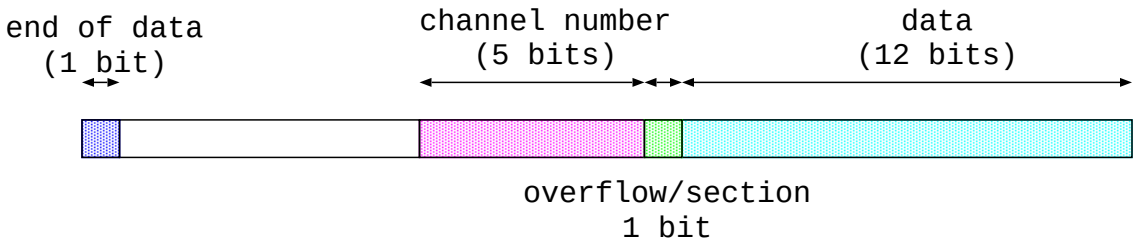
- Each second level trigger is counted on board (12 bit counter)

DATA BUFFERING

- Header FIFO



- Data FIFO



ADC/TDC auxiliary (DAQ related) functions

AUX BUS+ROCK

- Fast readout syncronous bus
- Sparse data scan
- Trigger number check event by event.
  (Header FIFO contain header also if no data)
- Golden number check.
  (Trigger counter value checked
  on each FE board)

VME BUS

- Initialization
- Error revovering
- Debug

System test

- **A complete (small chain) integration test has been set up**
  - **4 calorimeter modules = 480 channels**
  - **1 crate of splitter cards = 16 cards**
  - **1 crate of ADC boards = 16 boards**
  - **1 crate of TDC boards = 16 boards**
  - **2 ROCKs, 1 ROCKM, 1 CPU**

- **Items to test**
  - **Noise behavior**
  - **Performance verification**
  - **Stability**

Conclusions

- 70% of the ~5000 needed channel for Kloe calorimeter ADC/TDC have been produced

- All production has been locally tested and matches the specifications in terms of:

  - Linearity:
    - ADC: 0.3% of full scale
    - TDC: 0.2% of full scale
  - Resolution:
    - ADC: RMS<1 count
    - TDC: RMS<1 count
  - Stability
    - TDC: +/-0.3 count/C

- Integration and time stability tests are under way without relevant problems.