CLAS12 RICH front end electronics

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on behalf of CLAS12 RICH electronics group

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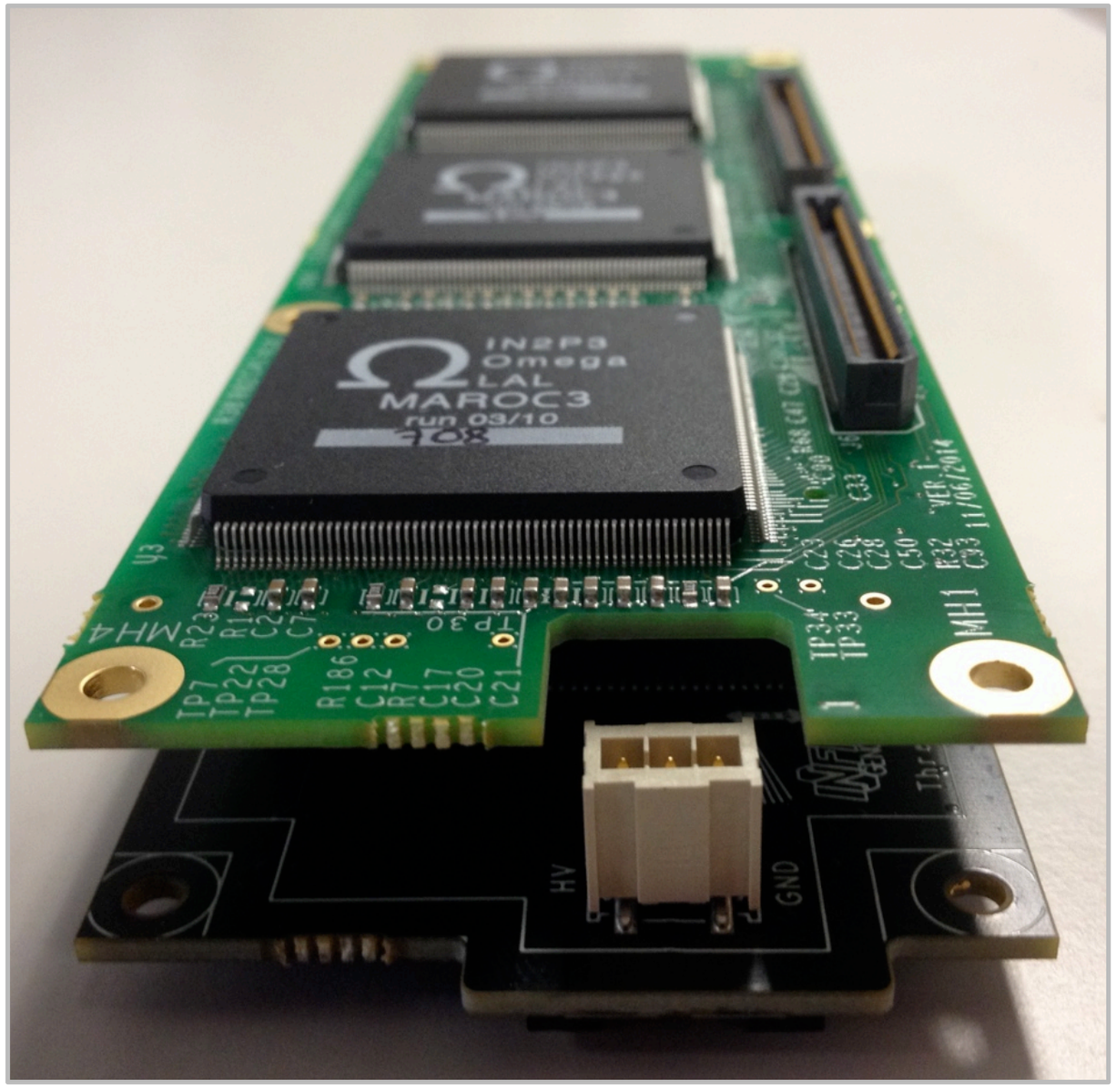
CEBAF Large Acceptance Spectrometer

Jefferson Lab

INFN Istituto Nazionale di Fisica Nucleare

Overview



CLAS12 RICH project

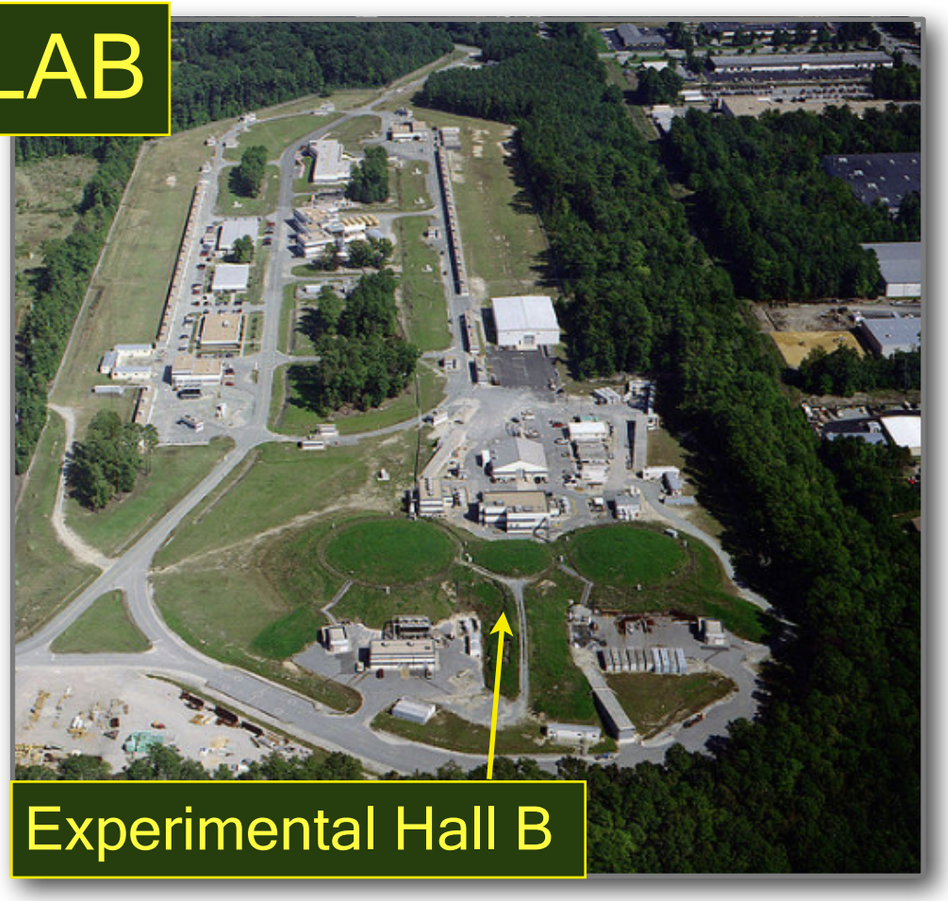
Electronics Requirements

Hardware design

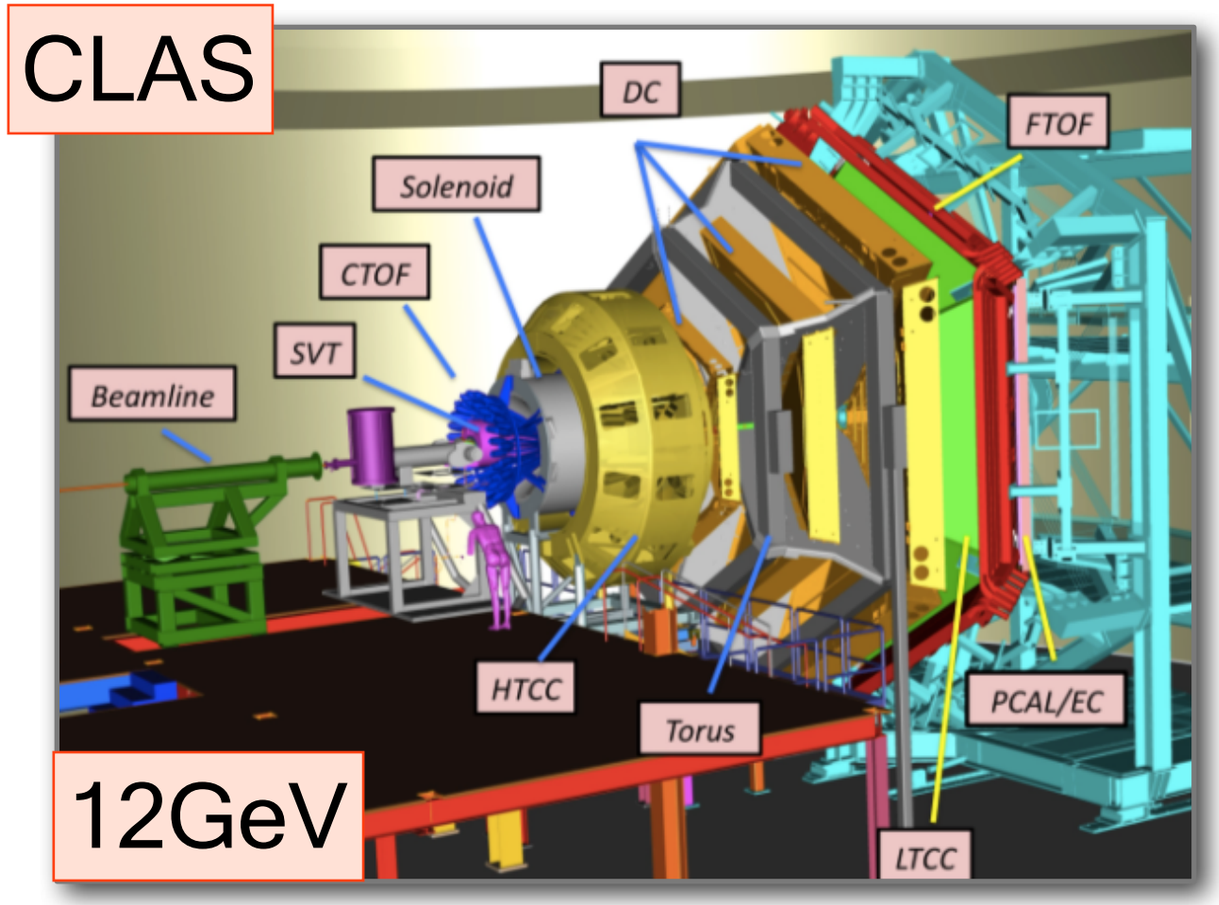
Performance

CLAS12

at Thomas Jefferson National Laboratory, Newport News, Virginia, USA



Continuos Electron Beam Accelerator Facility (CEBAF)



CEBAF Large Acceptance Spectrometer (CLAS)

RICH will be installed in the CLAS12 spectrometer in the Hall B of JLAB

RICH Project

Replace conventional Cherenkov (LTCC) to achieve excellent K/Pi separation

- First sector:

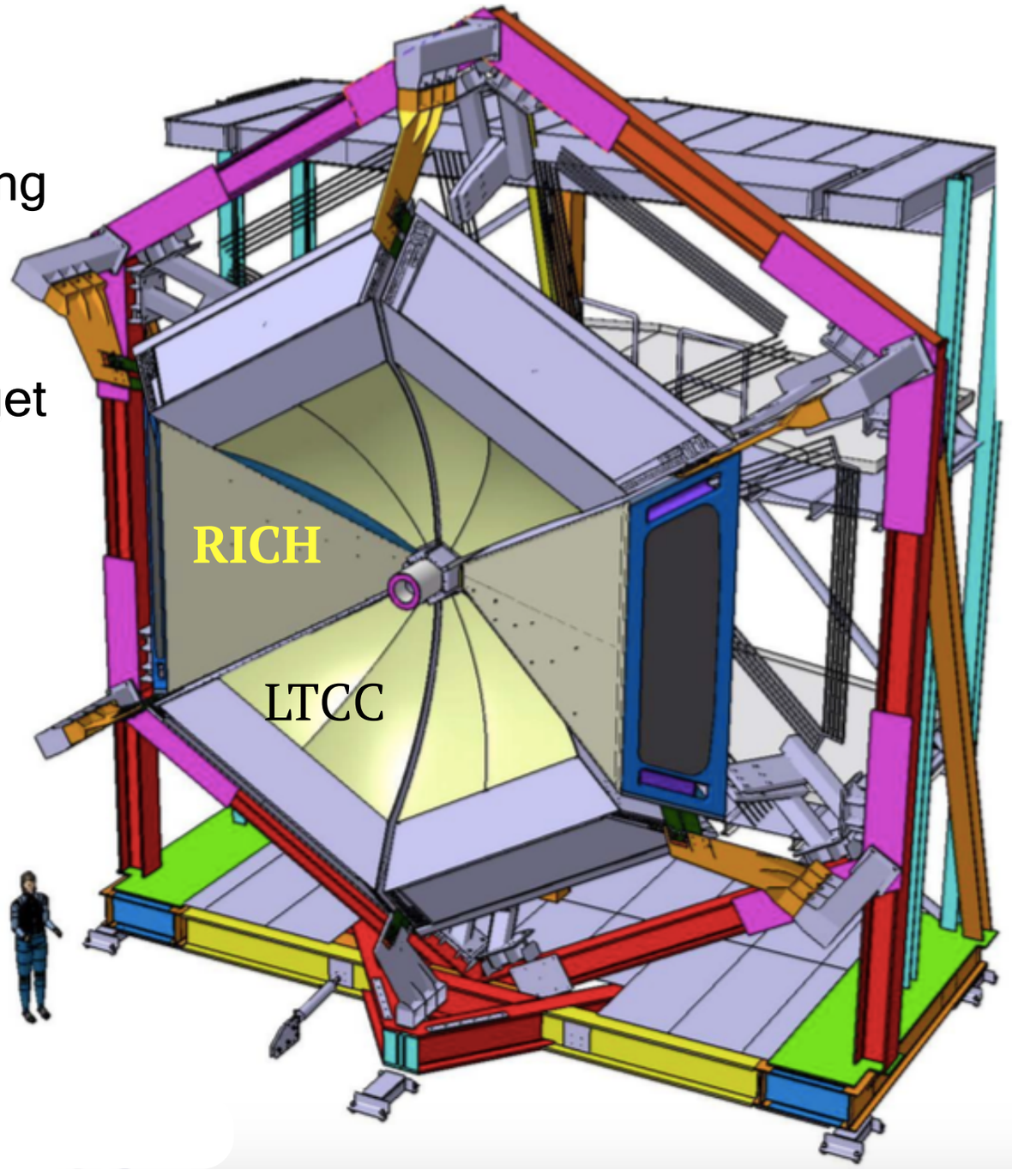
  ready for the beginning of CLAS12 data taking

- Second sector:

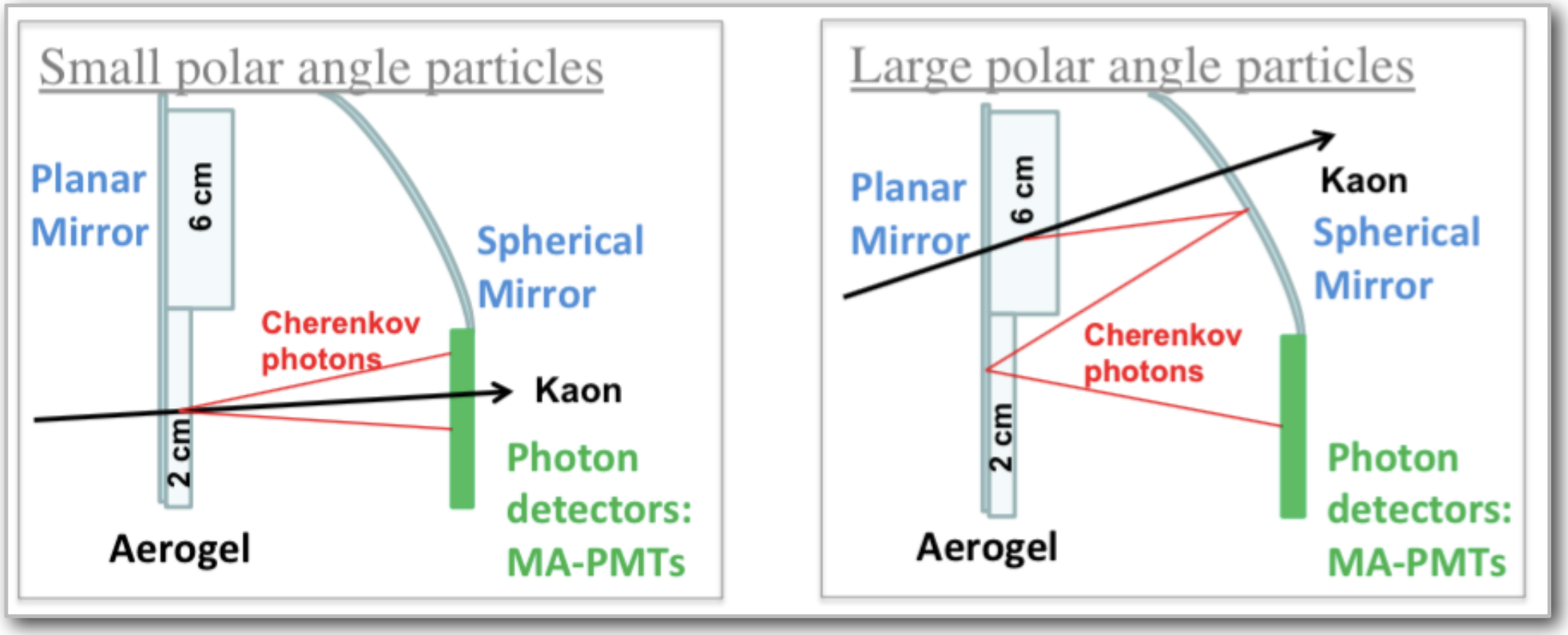
  Simmetric setup for transverse polarized target

International collaboration

(Italy, USA, Korea, Germany, Chile, UK)

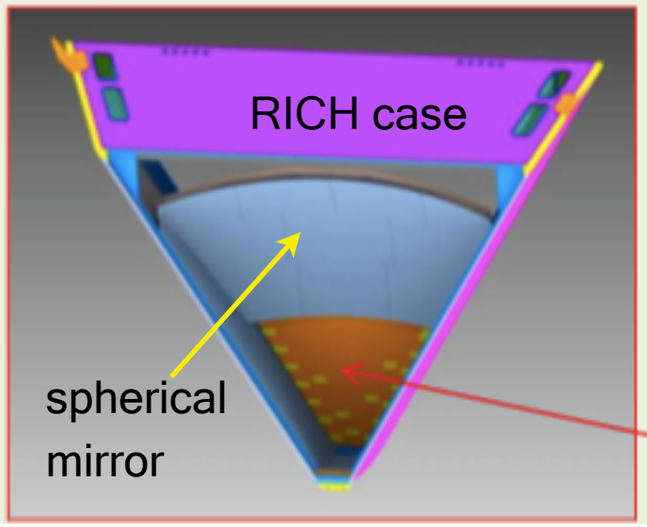


RICH Design



- Hybrid geometry reduces instrumented area (1 m^2, 25k channels, MA-PMTs)
- Detector concepts validated at CERN T9 (December 2012) NIM A766 (2014) 22
- Aerogel radiator to cover the momentum range 3-8 GeV (optical photons)
- Isolated N_2 volume to avoid moisture

RICH Electronics Panel

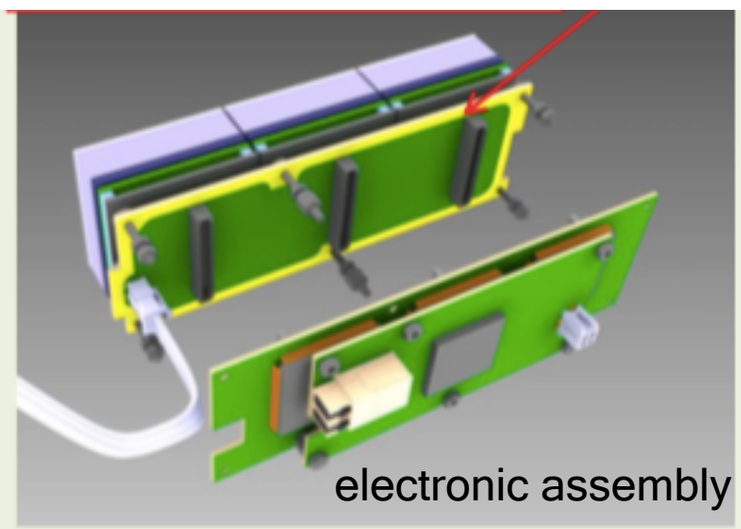


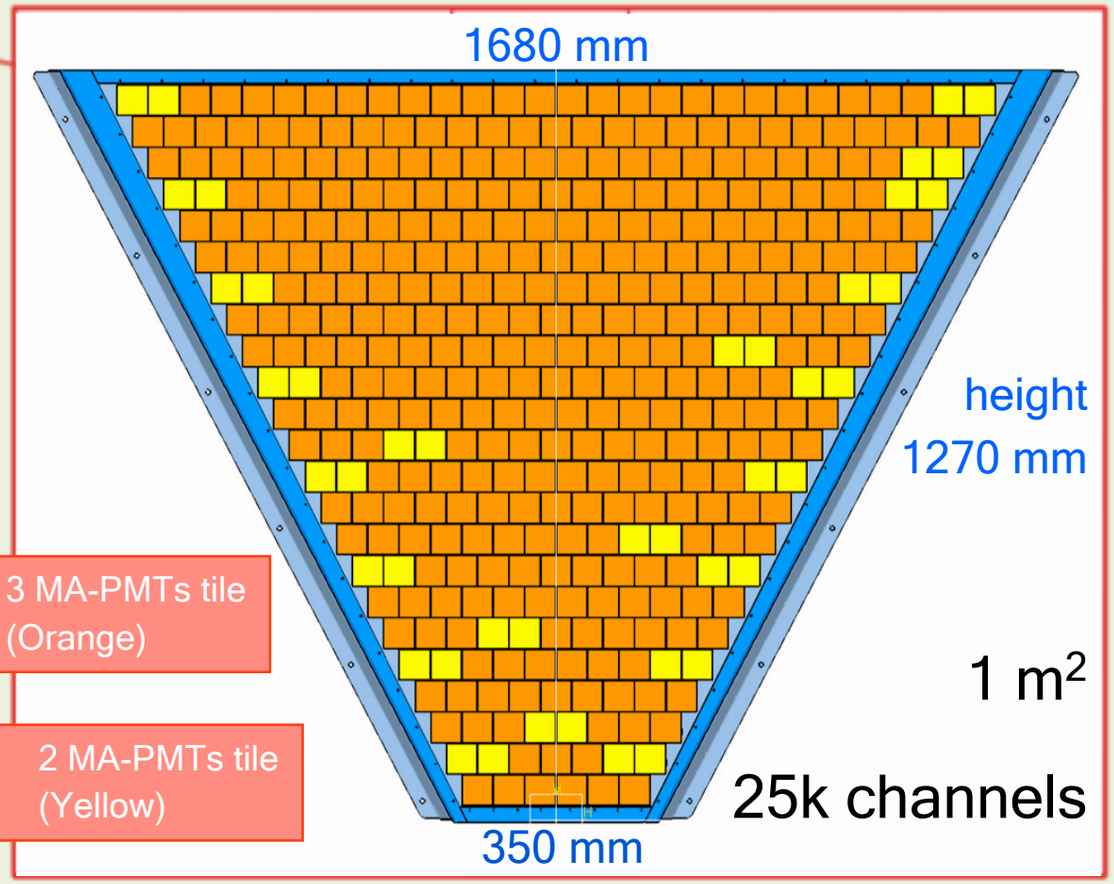
Tessellation approach: 2 or 3 MA-PMT tiles

Services out of acceptance (lateral loglines)

400 Hamamatsu MA-PMTs

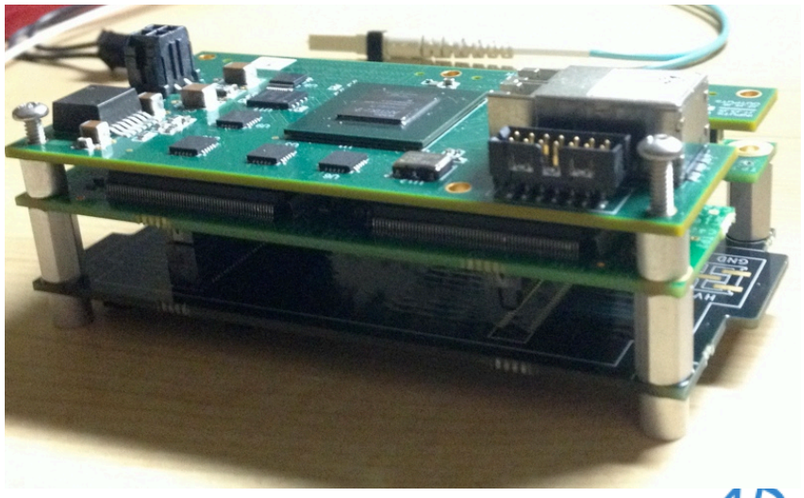
H8500 and H12700

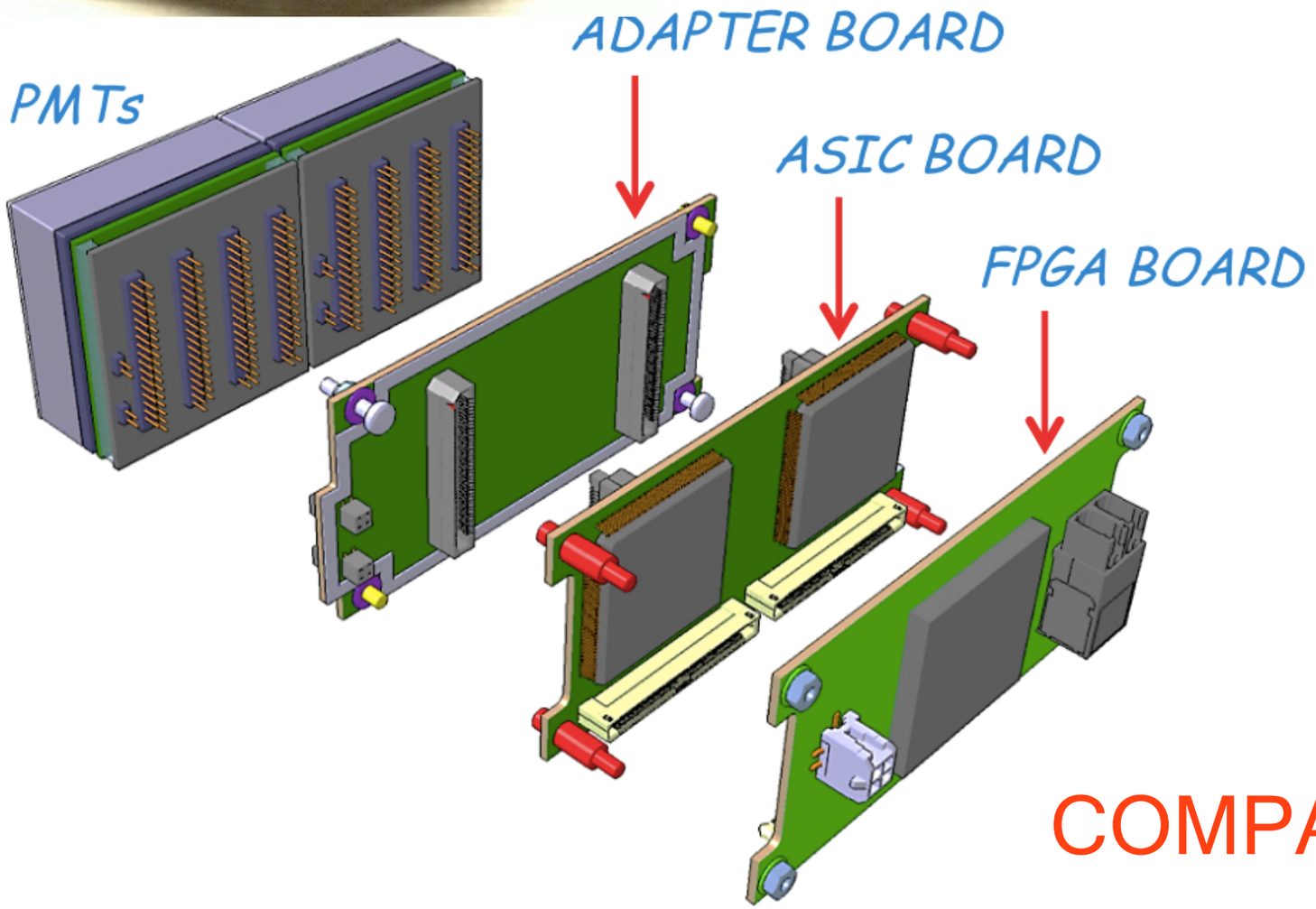




single photon sensitive surface

RICH Electronics Module





CLAS12-RICH Requirements

Single photoelectron capability

Adjustable gain 1:4

Time resolution 1 ns

Trigger rate 20kHz

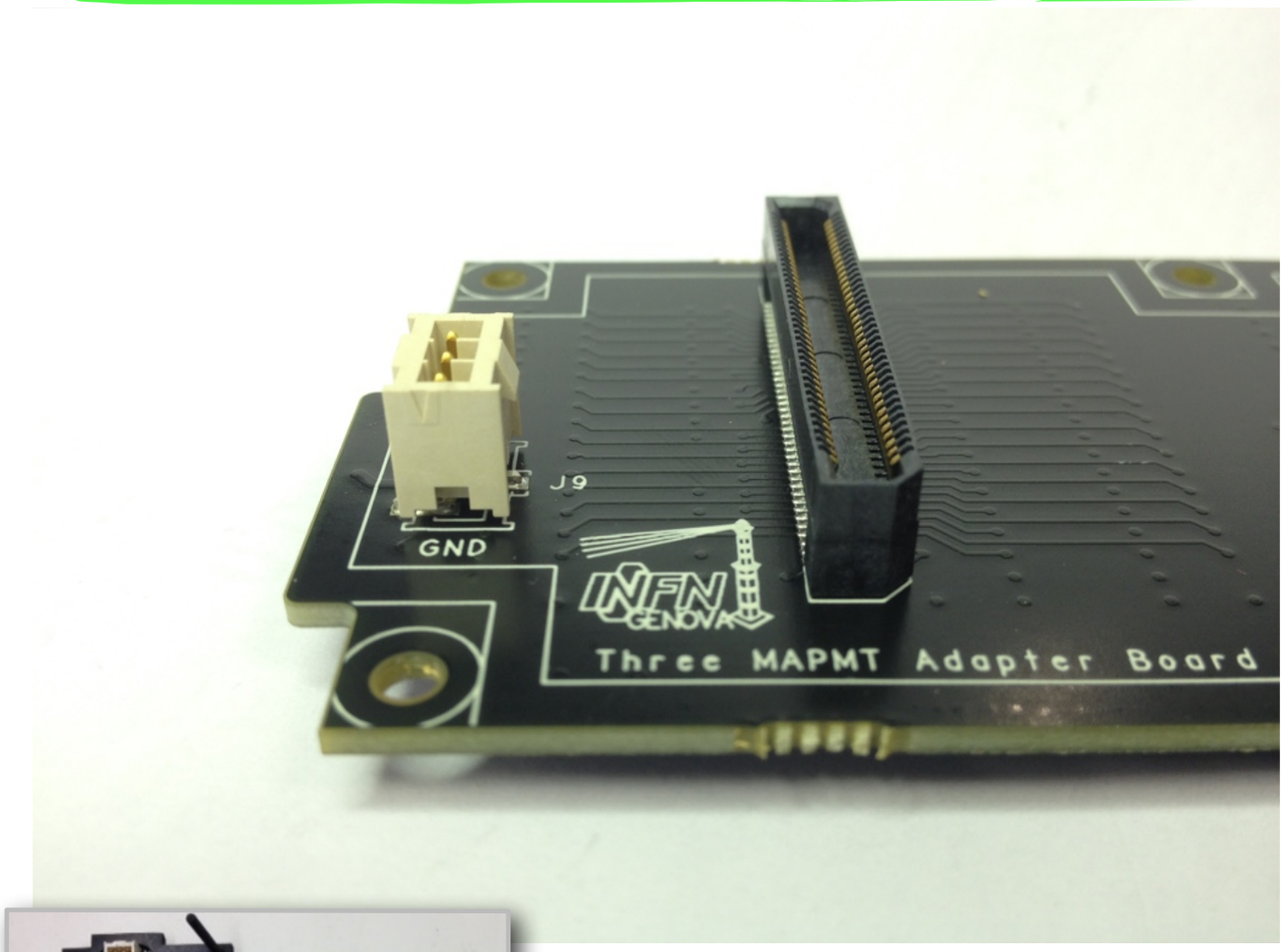
Trigger latency 8 μs

<4 Watts/module

Radiation tolerance adequate for CLAS12 environment

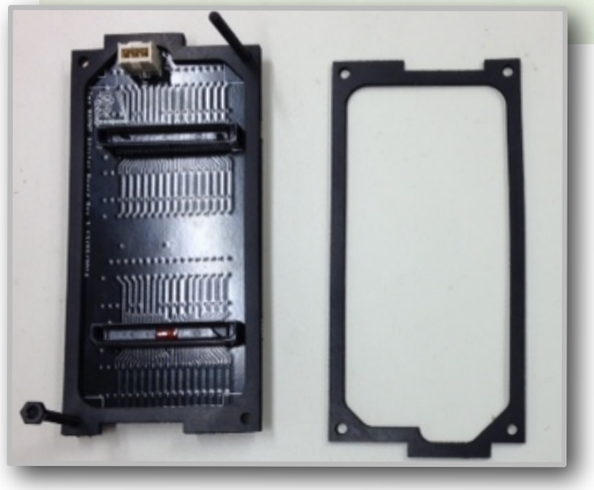
COMPACT! ON DETECTOR!!

Adapter Board



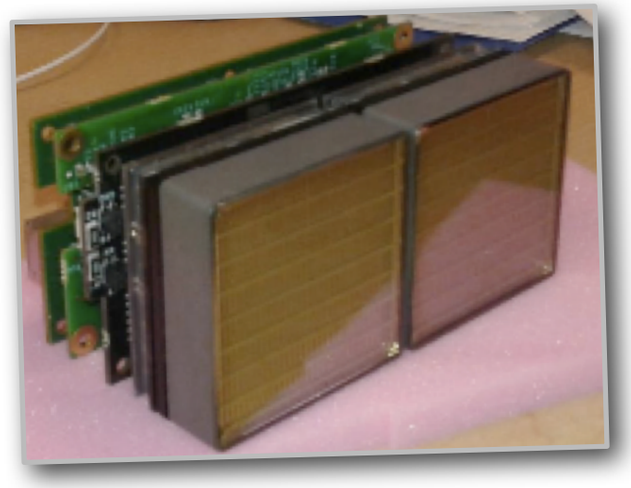
Feed through passive board:

- Distribute HV power to MA-PMTs
- Light & gas tight
- Low capacitance electrical connectivity with front end chip



Design to achieve 96% packaging factor

(1 mm gap between MA-PMTs)



ASIC Board

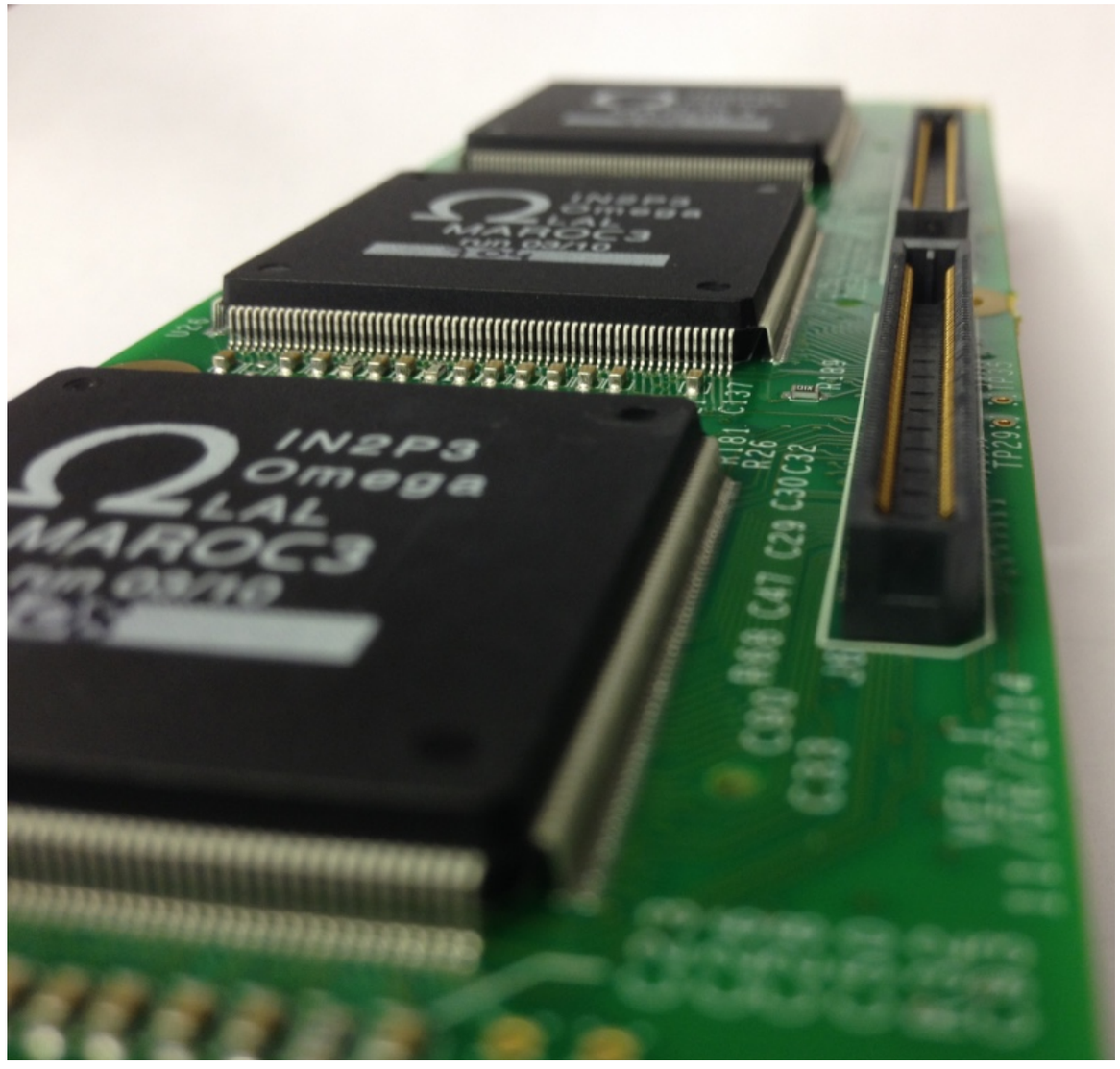
Application Specific Integrated Circuit (ASIC) board features:

Multi Anode Read Out Chip (MAROC)

- 64 inputs
- 64 outputs (binary)
- Common **THRESHOLD** (10 bits)
- Individual Preamplifier **GAIN** 0 to 4 (8 bits)
- Charge output (12bit ADC, serial)
- Highly Configurable shaping sections
- Total 829 bits for slow control

Test Pulse (12 bit DAC, 0 to 5pC)*

Voltage regulators (High SpeedTransceiver Logic optimized)*



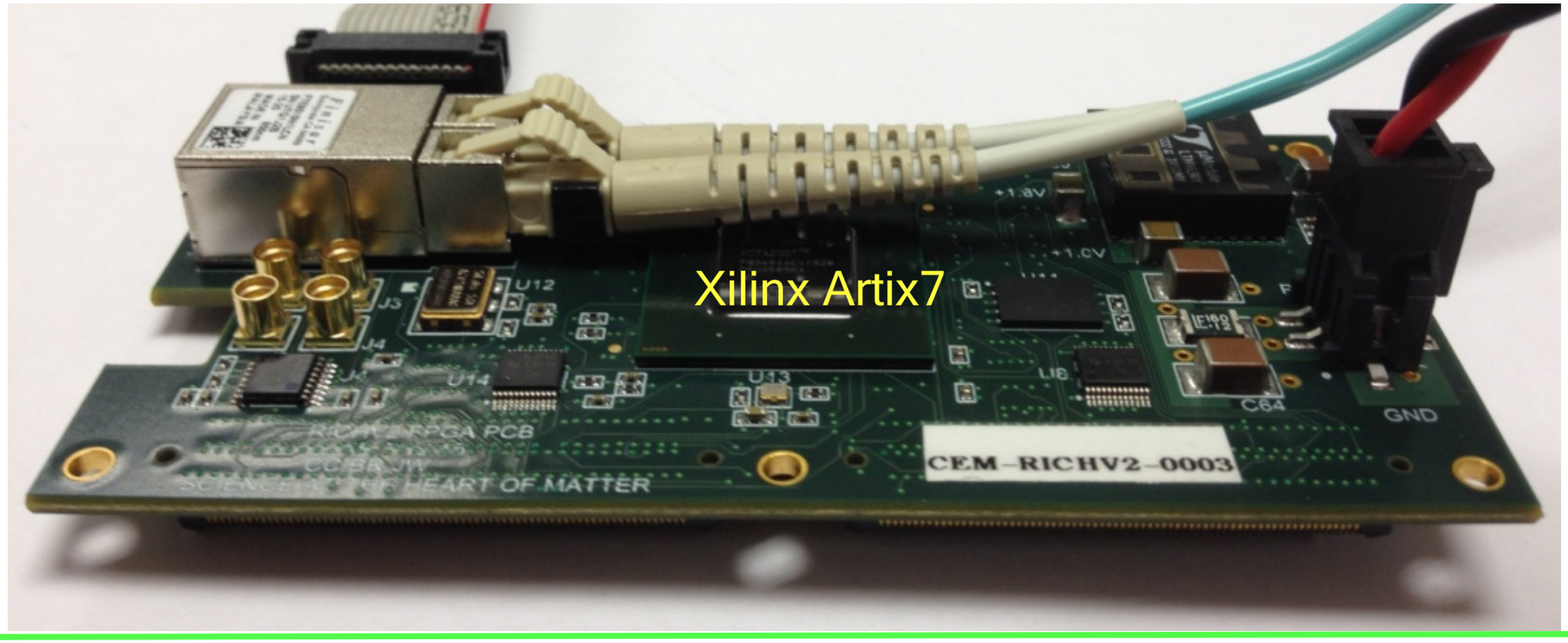
3 ASIC variant

* pre production run Dec 2015

FPGA Board

Field Programmable Gate Array (FPGA)Board

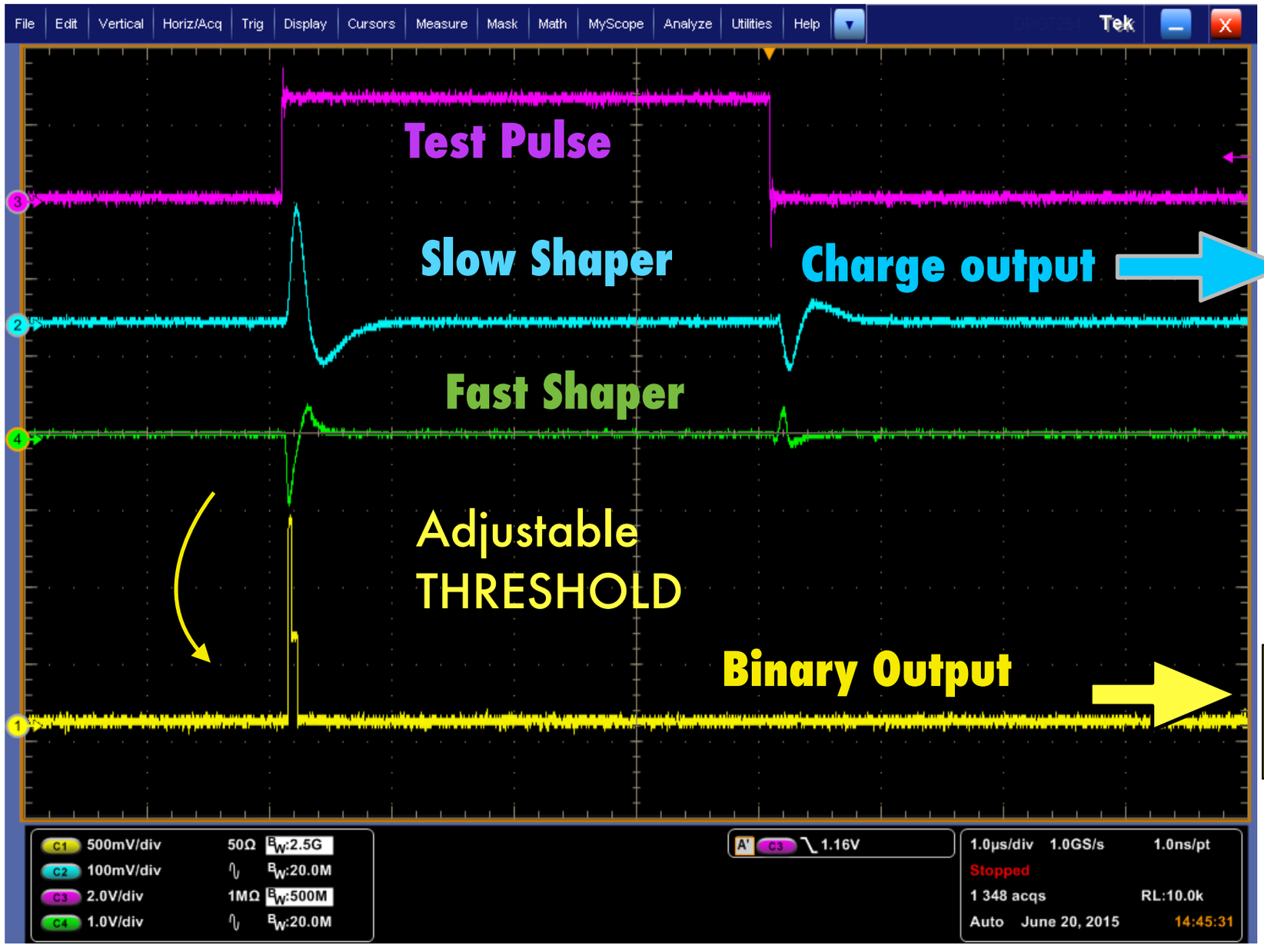
- TDC reference clock (1 ns)
- Fixed Latency Trigger (up to 8 µs)
- MAROC slow controls,
- Stream triggered data to event builder
- Scalers
- FIRMWARE support 192 or 128 channels
- OPTICAL ETHERNET: up to 2.5 Gbps
- TRIGGER MODES: External, Internal, Self (on MAROC binary ouputs)



MAROC Signals

example of MAROC signal processing

INPUT
On Board
Test Pulse
1pC



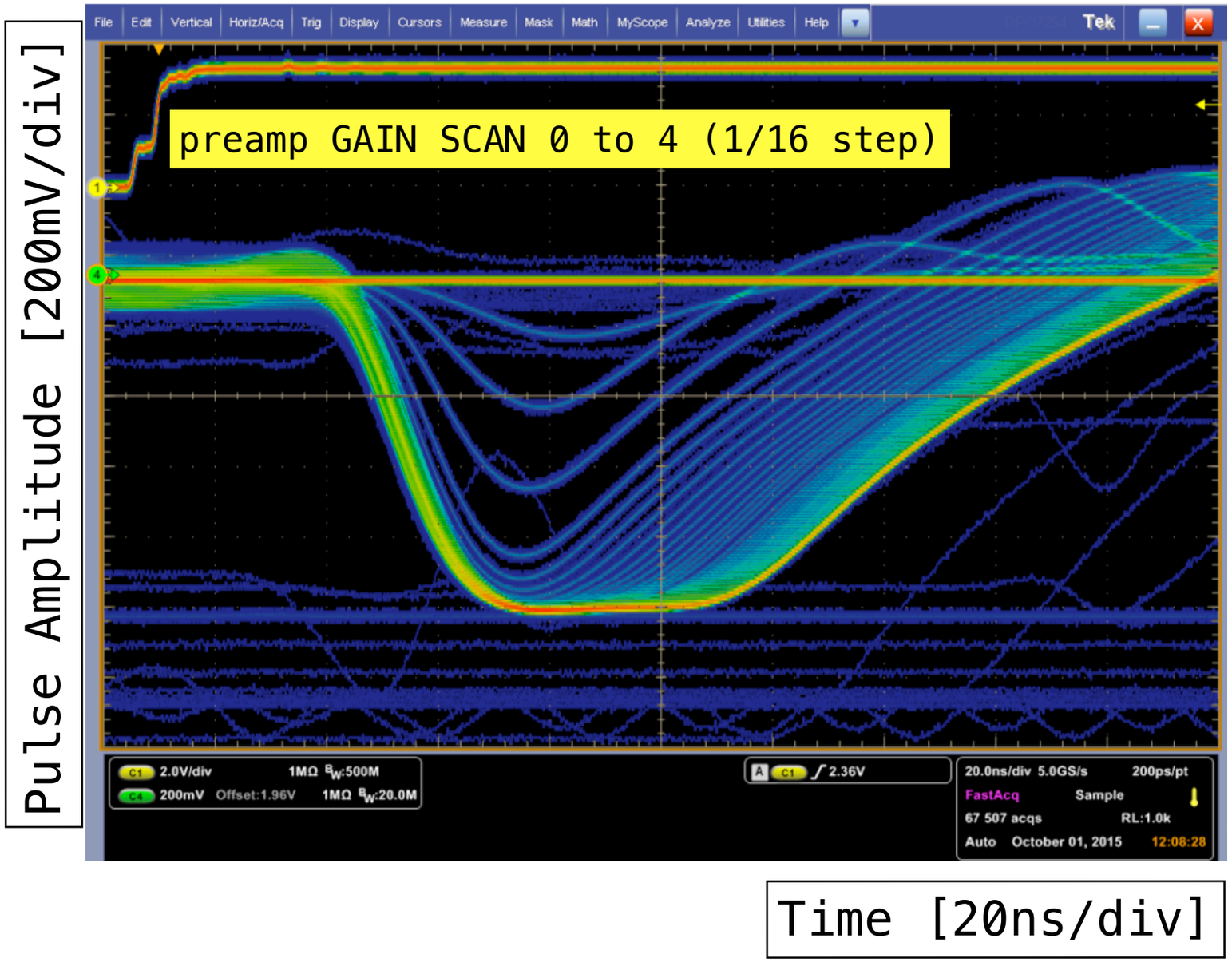
ADC
(MAROC)
calibration only
more on backup slide

SCALER/TDC
(FPGA)

TDC used for physics runs!

Single channel response, 1 microsecond/div

Gain Scan



Single channel fast shaper response,

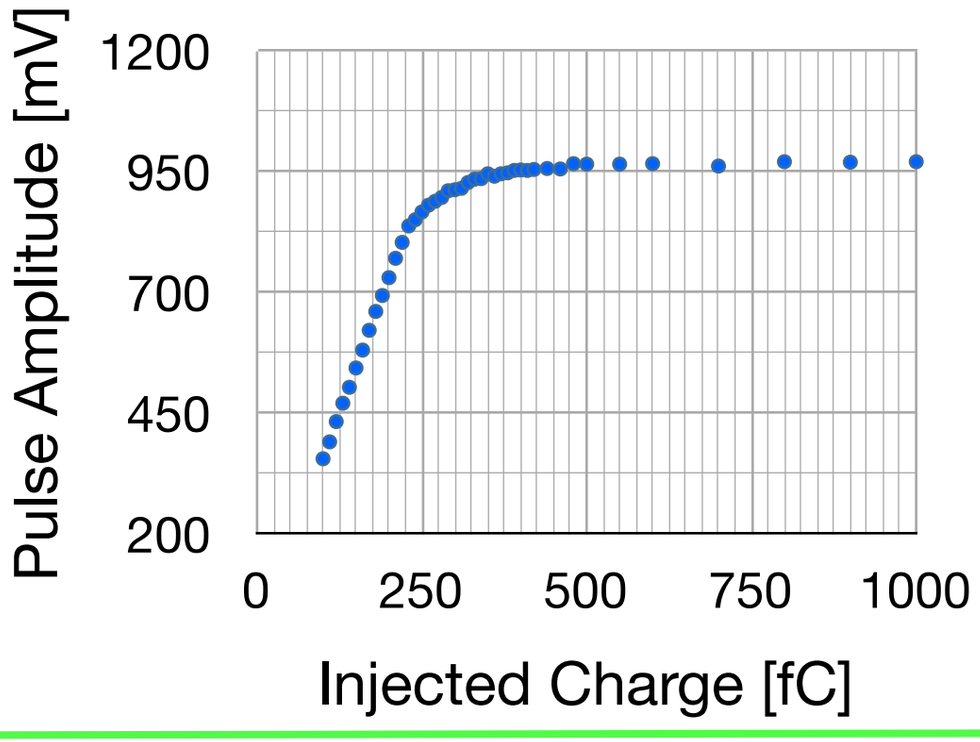
High gain shaper

precedes the discriminator

3.75 Volt/pC in the linear region

20-25 ns rise time

Fast Shaper Gain



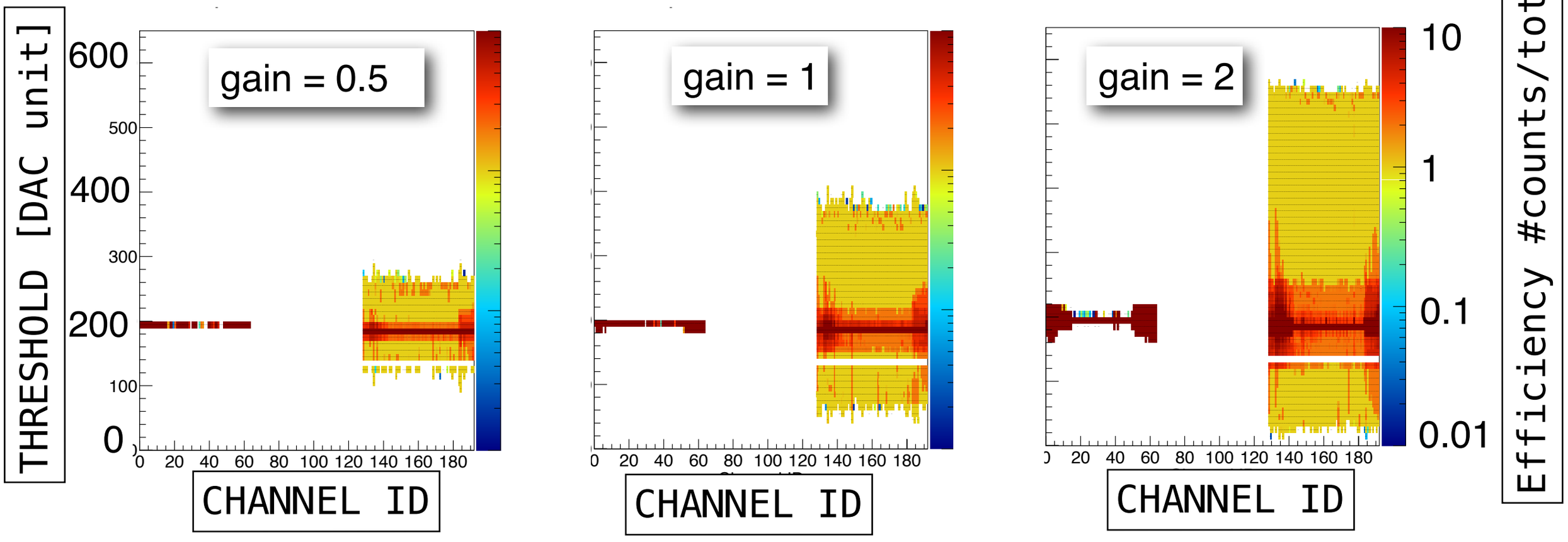
Counting Efficiency Test Pulse

Single photoelectron level (160 fC) 100kHz external pulse generator

128 channels (64 injected, 64 for baseline) X axis

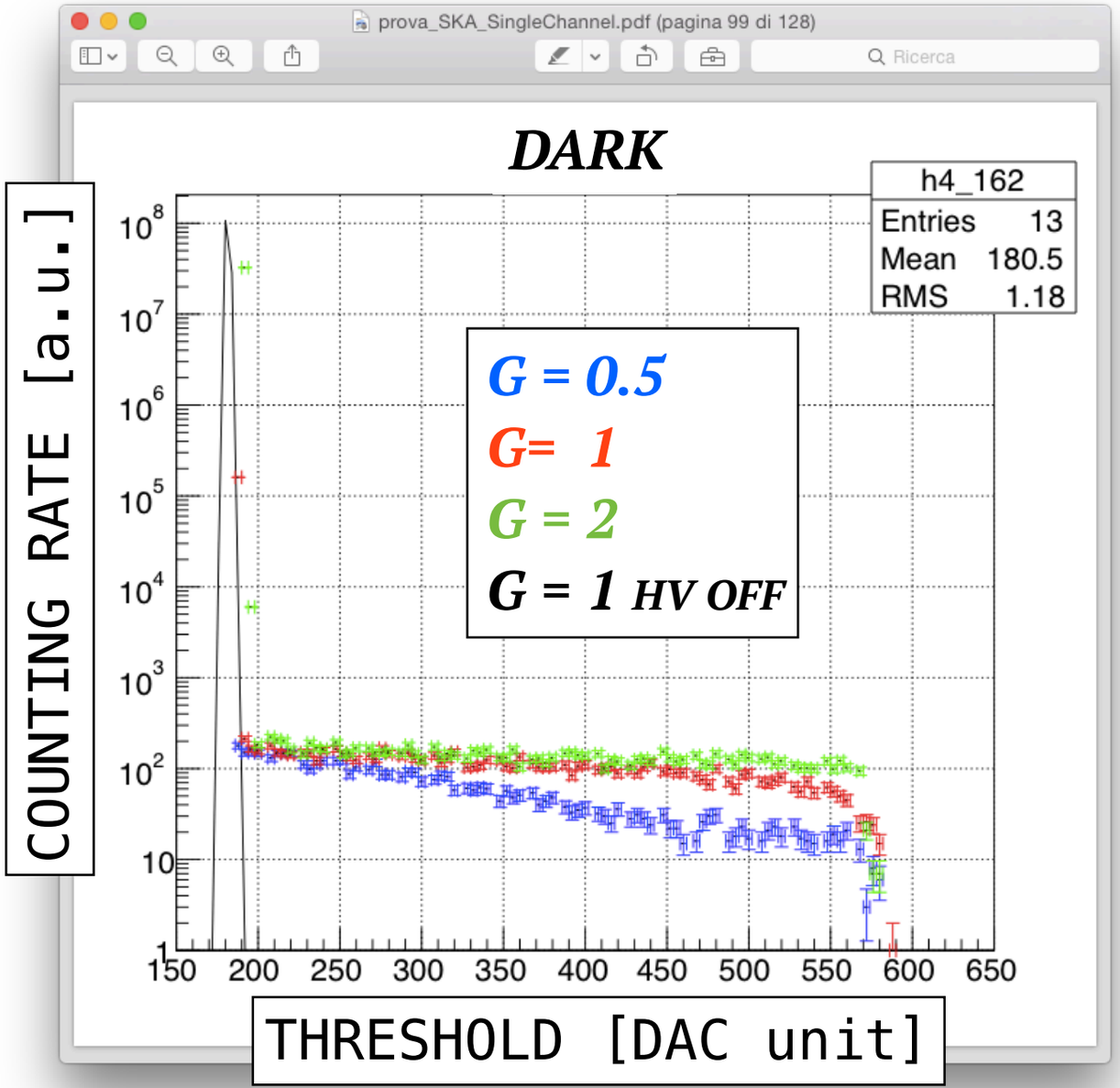
Threshold scan for different preamp gains Y axis

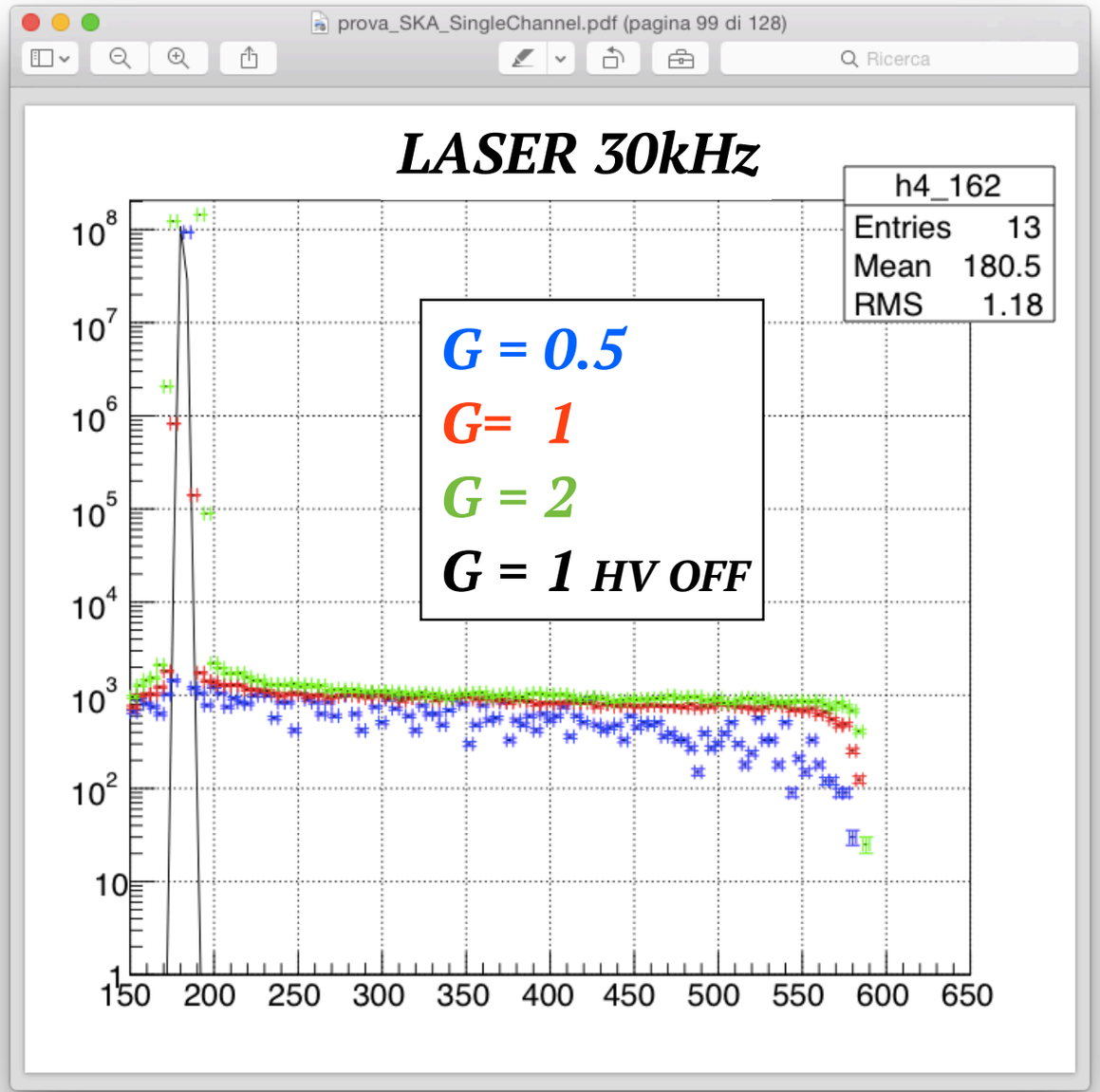
Scaler firmware counting **efficiency** (100% inside yellow regions) Z axis



Counting Efficiency Dark & Laser

Preamp can push low gain pixels to saturation (plateau) allowing an excellent efficiency





Laser at single photoelectron level Hamamatsu H12700 @ 1000 Volts

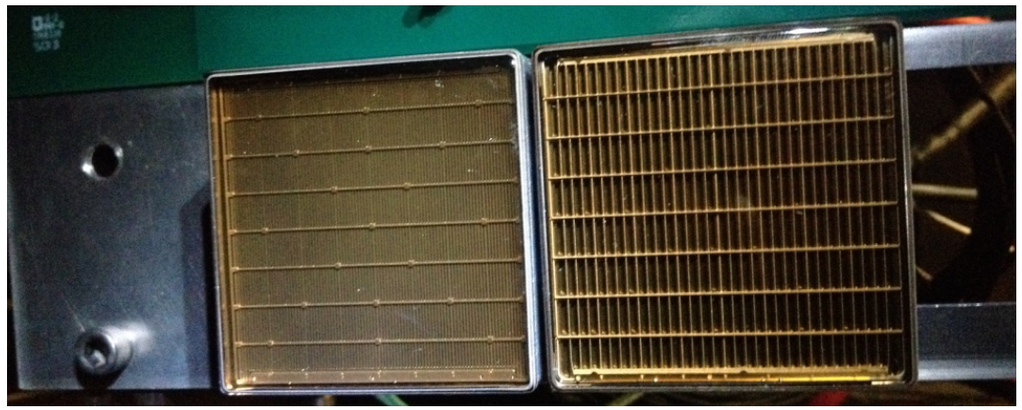
Scaler measurements 30 seconds

MA-PMT Dark Rate

30 seconds scaler measurement

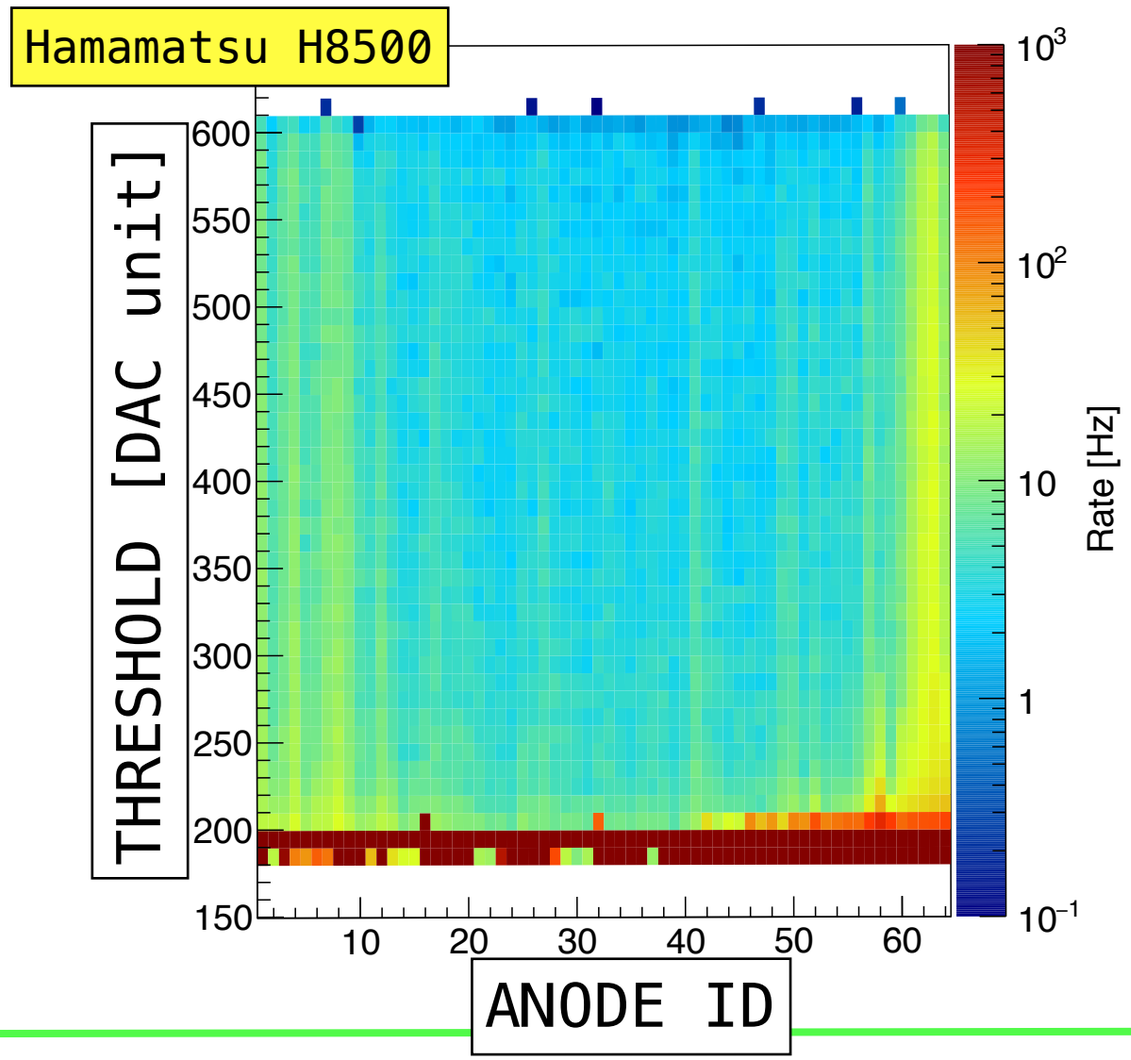
Typical rate

10 Hz/pixel

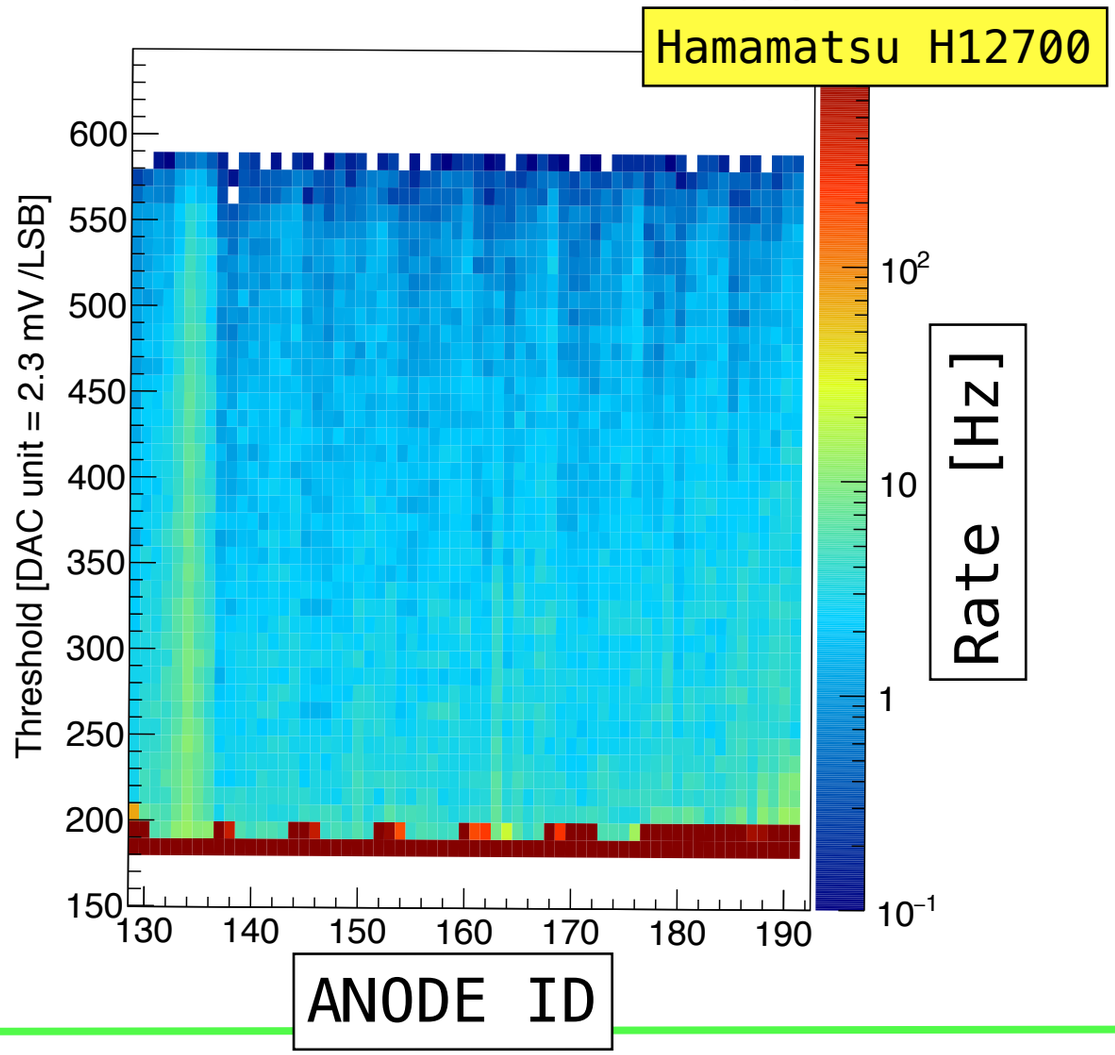


Compatible with Hamamatsu specification

Dark Rate CA7482 HV 1000



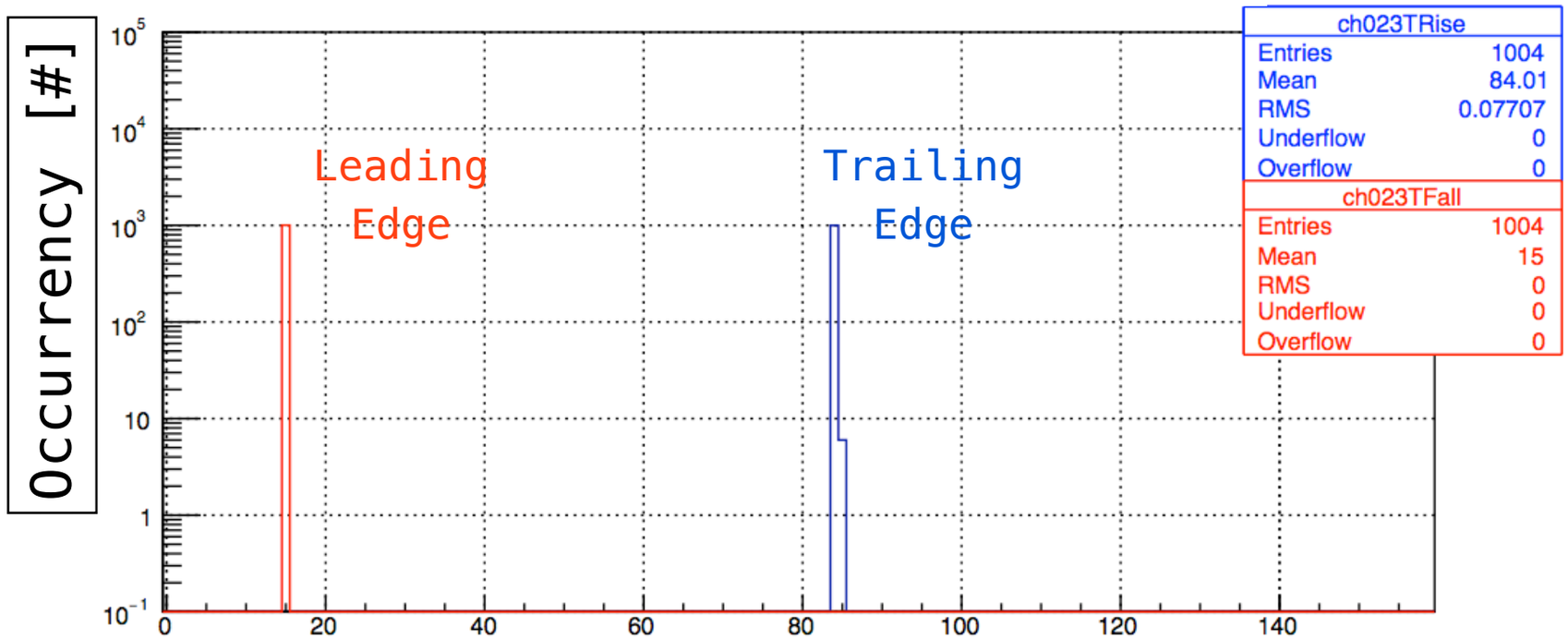
Dark Rate GA0507 HV 1000



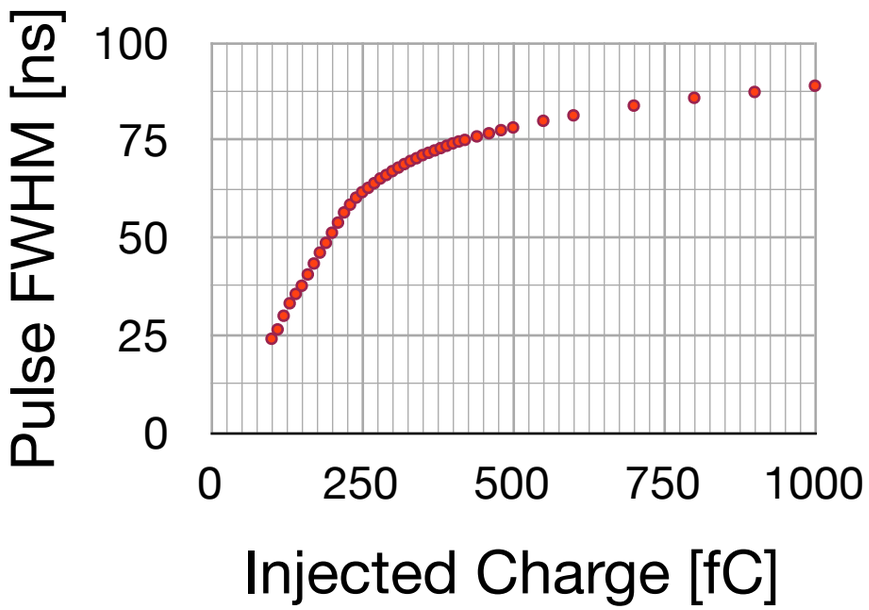
TDC Response Test Pulse

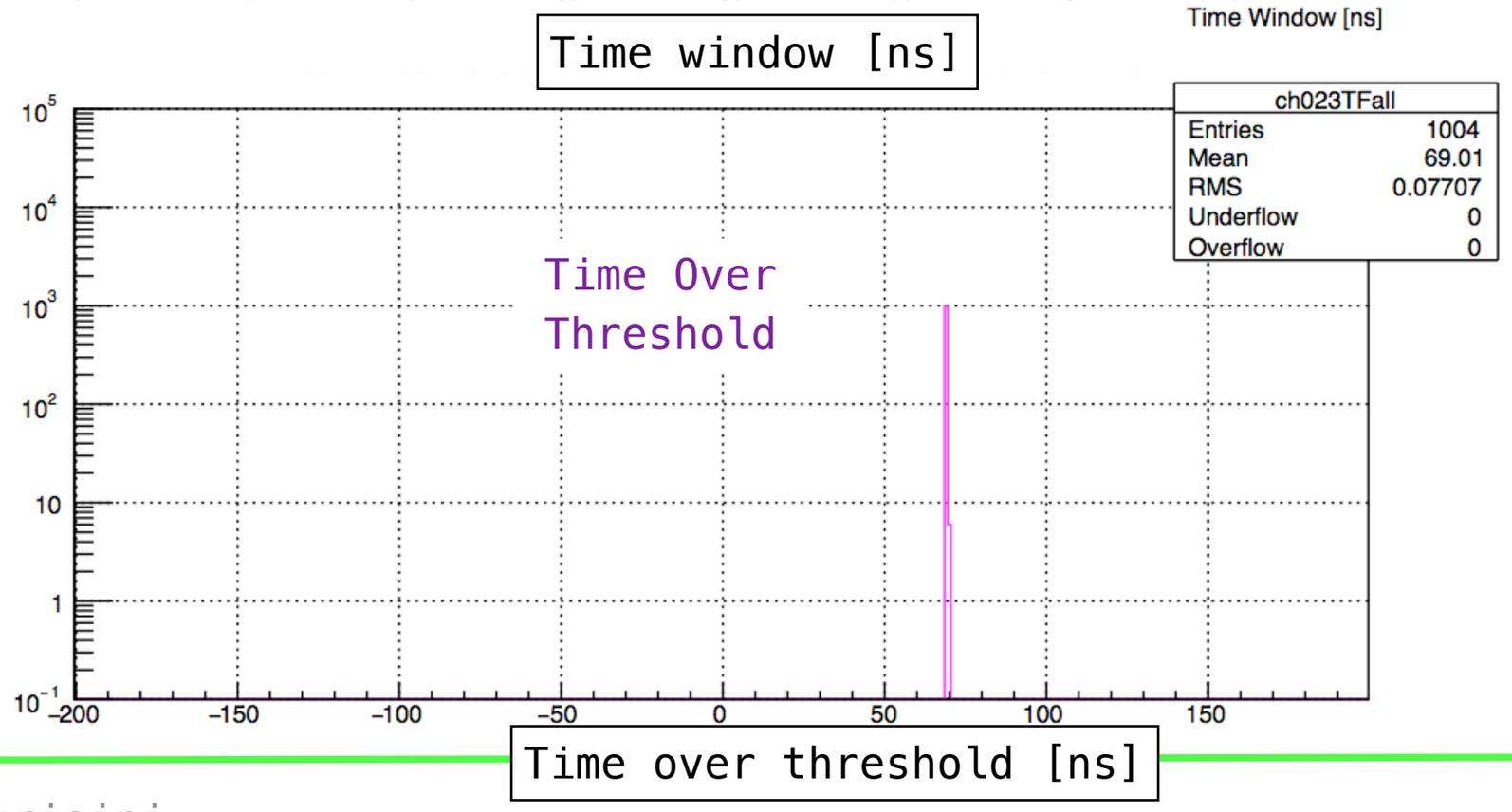
Main acquired data are MAROC binary ouputs time information

- Jitter introduced by MAROC is below the sensitivity of the TDC (1ns)
- Time over Threshold measurement is feasible



Time over Threshold





TDC Response Laser + MAPMT

Correlation between leading time and time over threshold (proportional to the charge) allows for time walk correction

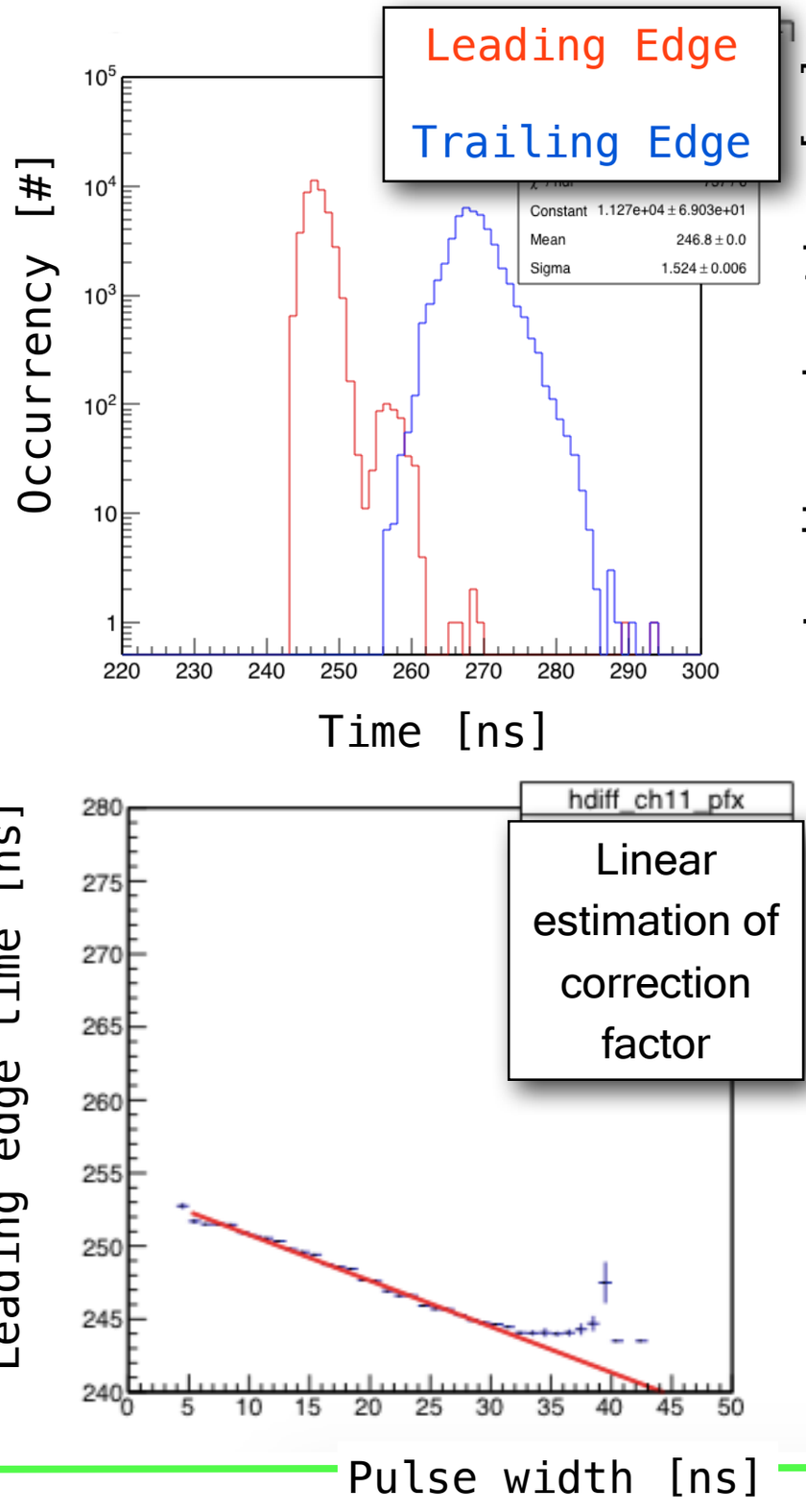
before (top left)

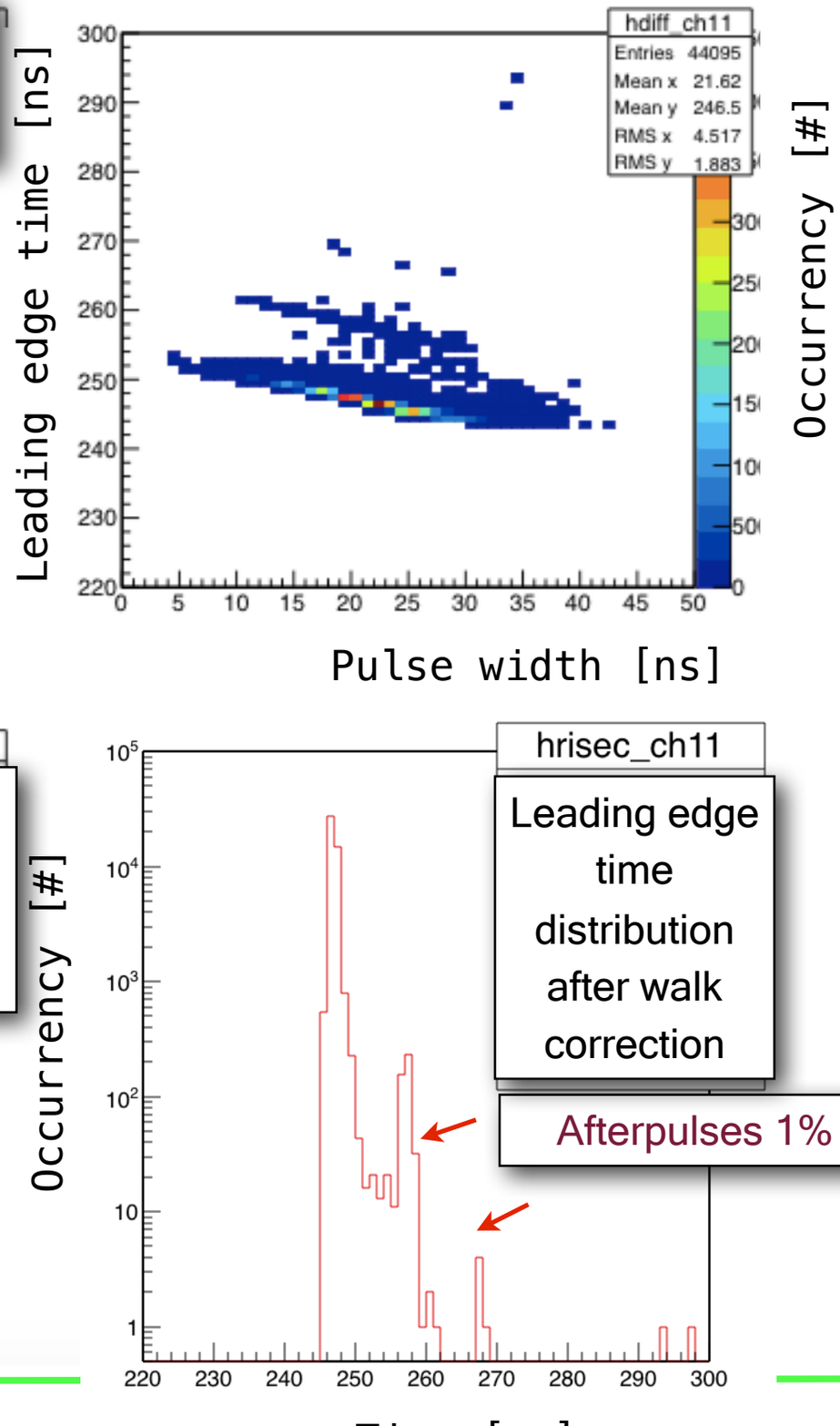
$\sigma = 1.524$ ns

after (bottom right)

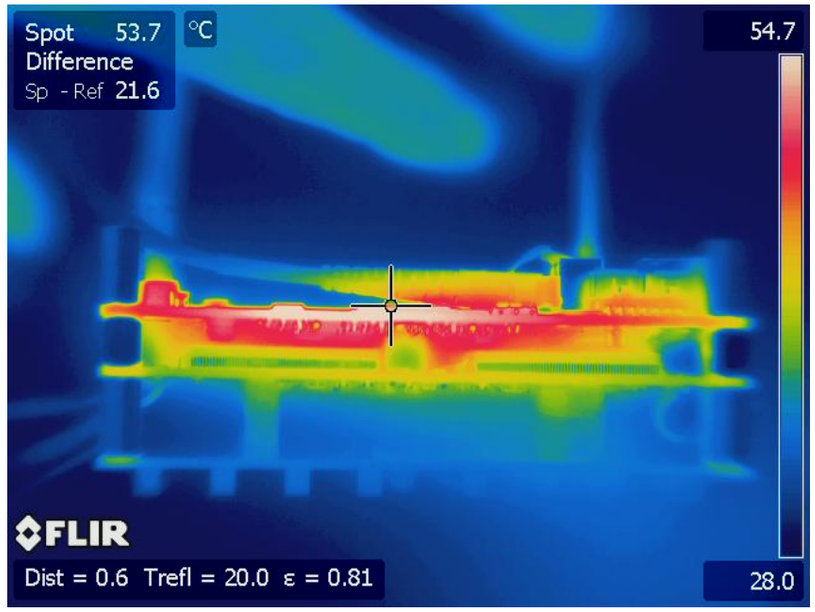
$\sigma = 0.480$ ns

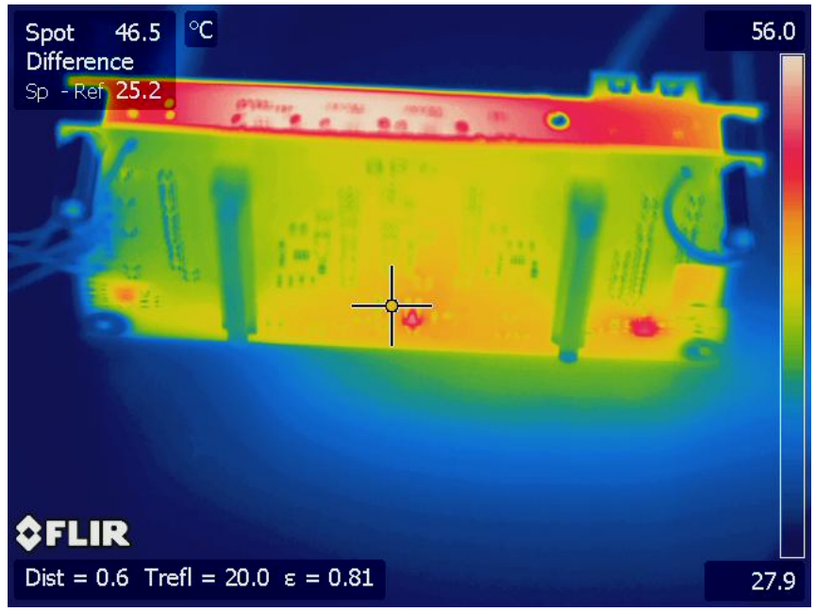
PRELIMINARY

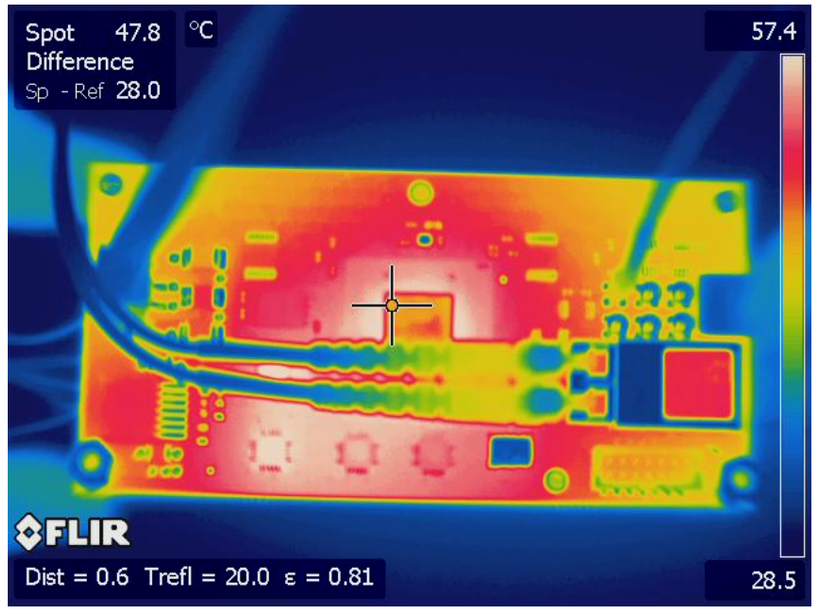




Heat production







Thermografic camera images of a RICH electronic module

- Power Consumption @ 5Volt:

  760 mA (3.80 Watts) 3MA-PMTs variant

  670 mA (3.35 Watts) 2MA-PMTs variant

Compatible with temperature requirements of CLAS12

Conclusion

CLAS12 RICH will be installed in the JLab Hall B in spring 2017

A compact front end electronics has been developed and tested:

Prototyping (640 channels)

Design validated with test pulse and MA-PMT measurements (Dark and Laser)

Firmware TDC fulfills requirements

Analog MAROC information (internal ADC) will be used for monitoring and debugging

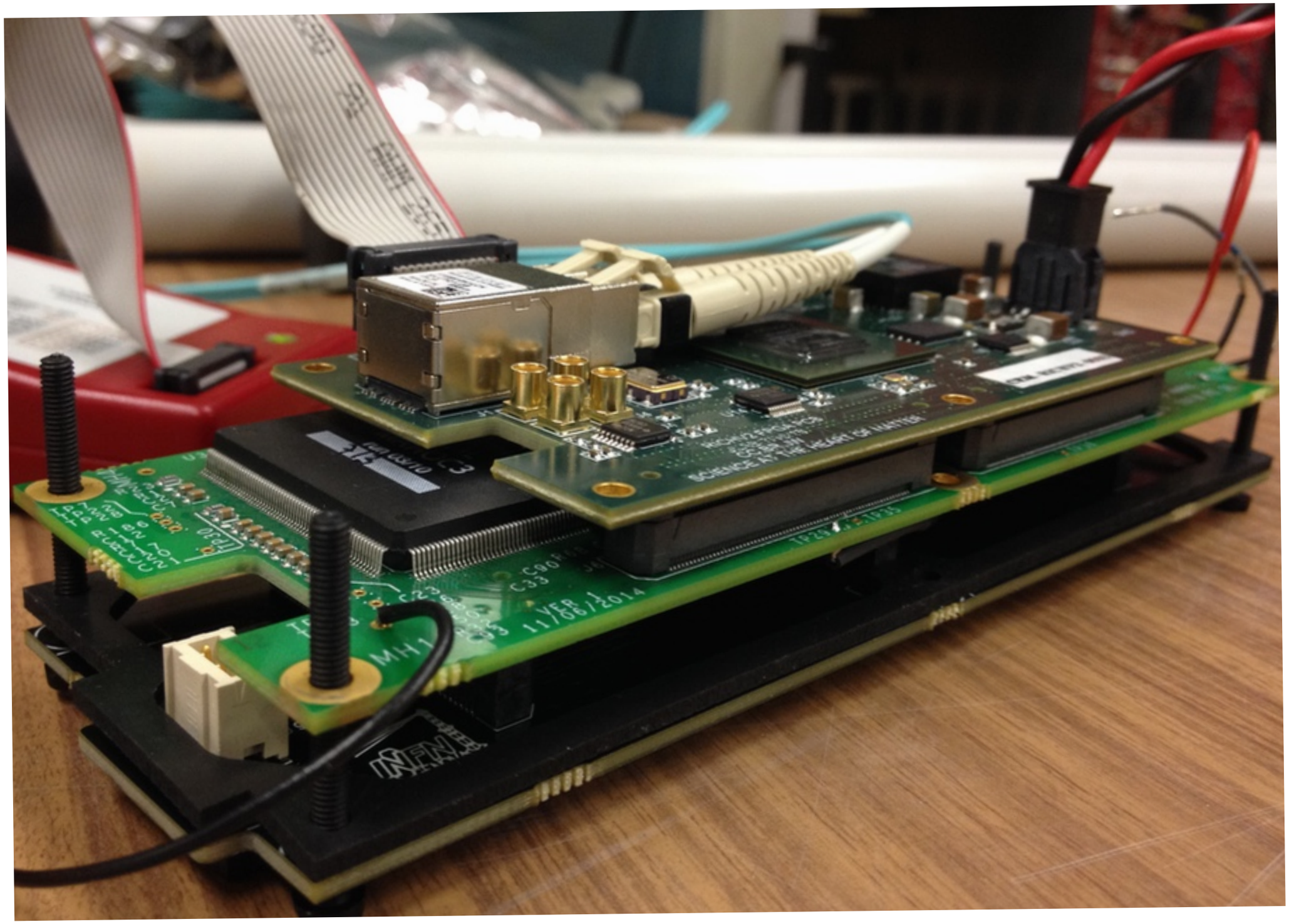
Calibration protocol on study

Production (25000 channels):

Small preproduction (2000 channels) with final optimization introduced during prototyping

Going to full production in 2016

RICH-MAROC Electronics



MAROC internal ADC

BACKUP SLIDE

Plots: reconstructed waveform using MAROC internal ADC for one channel and different MAROC slow control configurations

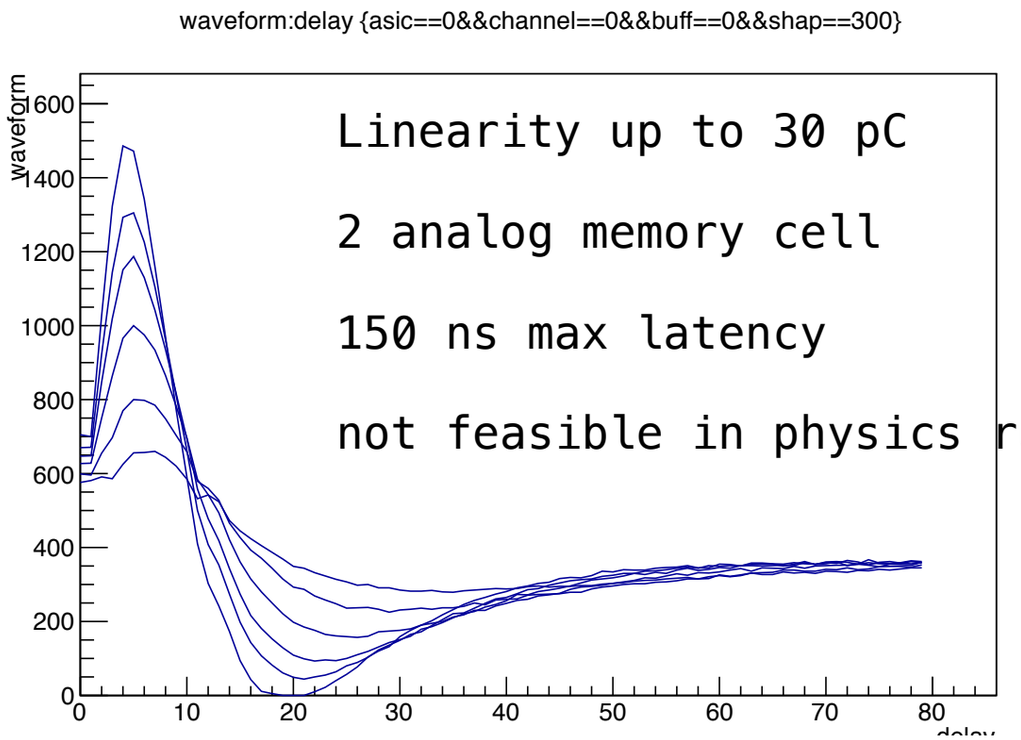
A = RCBuffer scan;

B = Pream Gain scan;

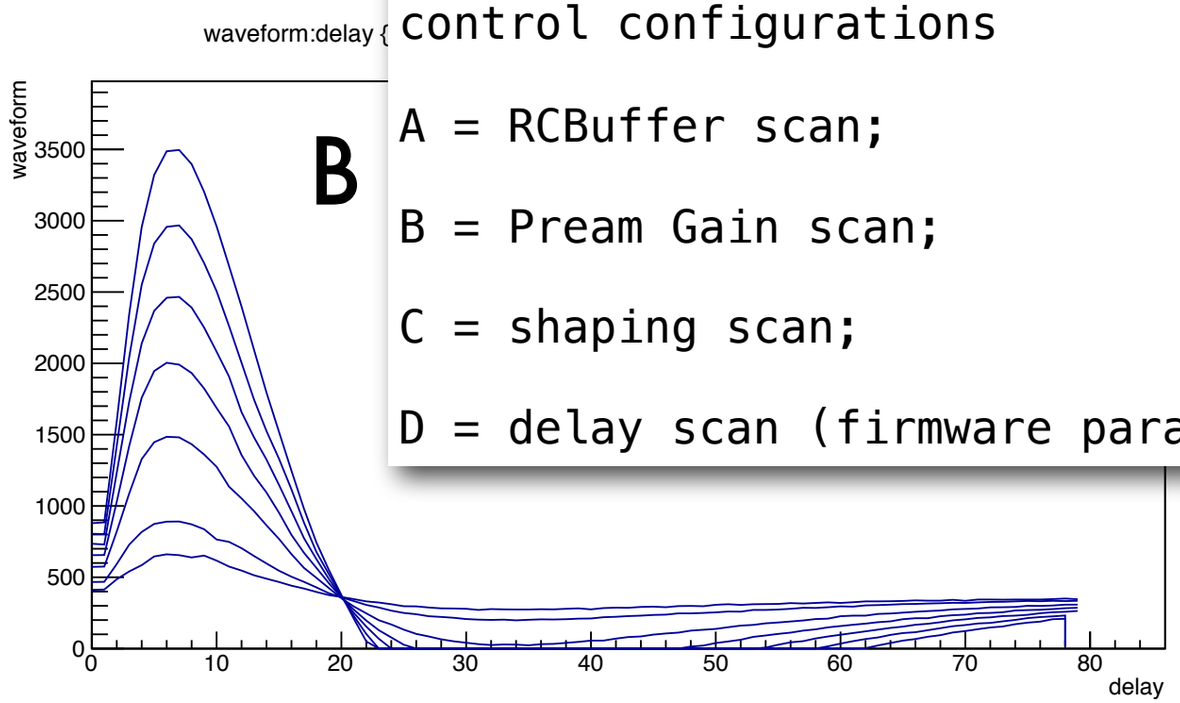
C = shaping scan;

D = delay scan (firmware param)

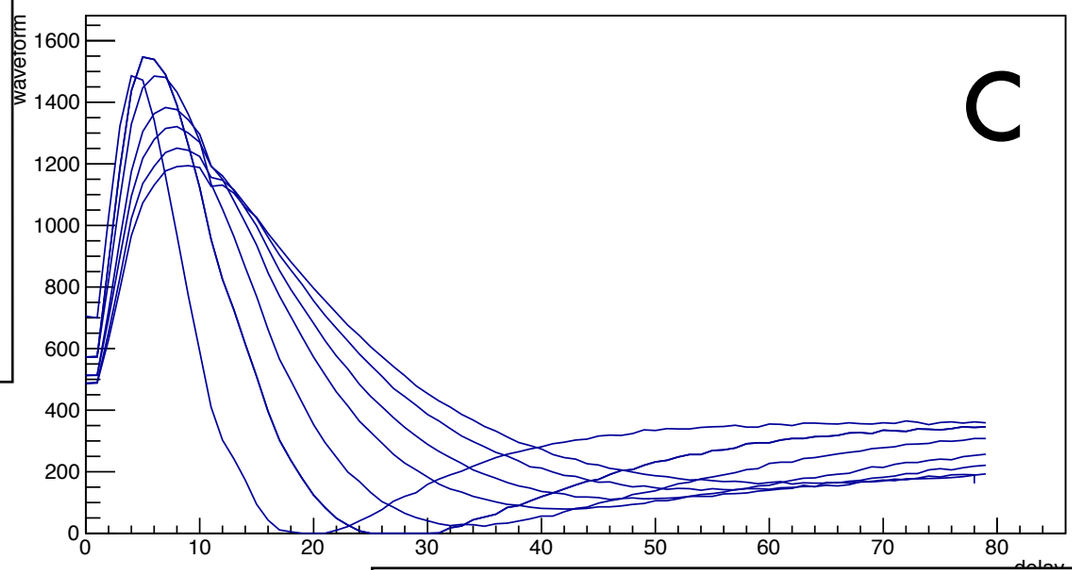
A



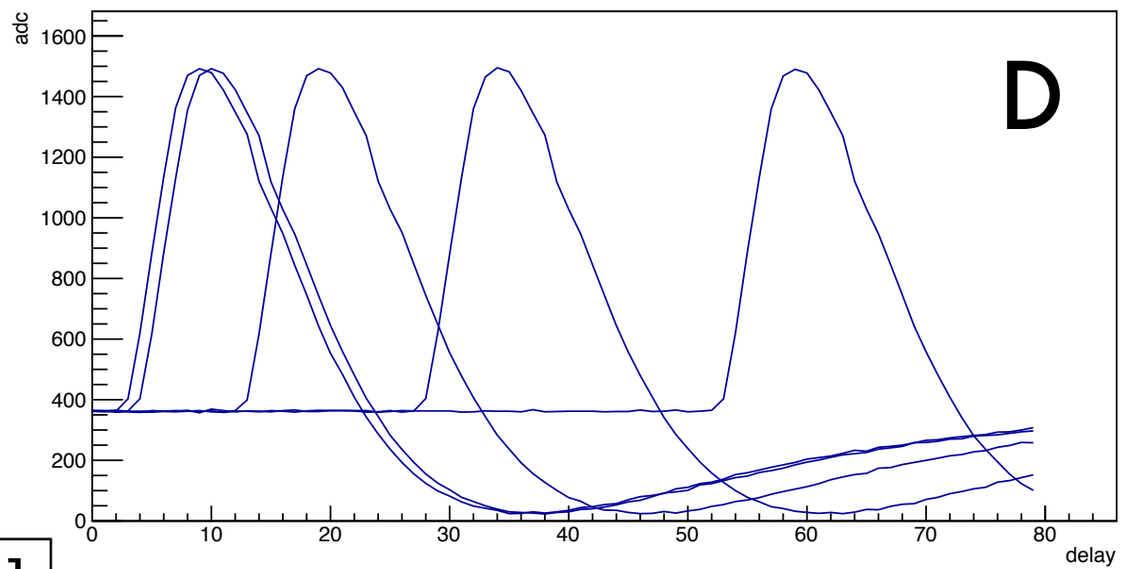
B



C



D



Amplitude [ADC units]

Time [8 ns clock ticks]