SPACIROC

Spatial Photomultiplier Array Counting and Integrating ReadOut Chip

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Organization for Micro-Electronics desiGn and Applications

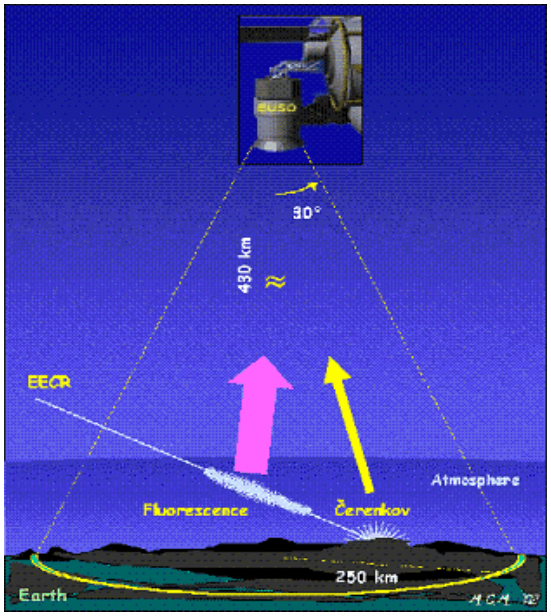
Outline

- The main application
- The requirements and the global architecture
- SPACIROC1 and SPACIROC2 summary
- SPACIROC3 measurements
- Conclusion

Main application: JEM-EUSO

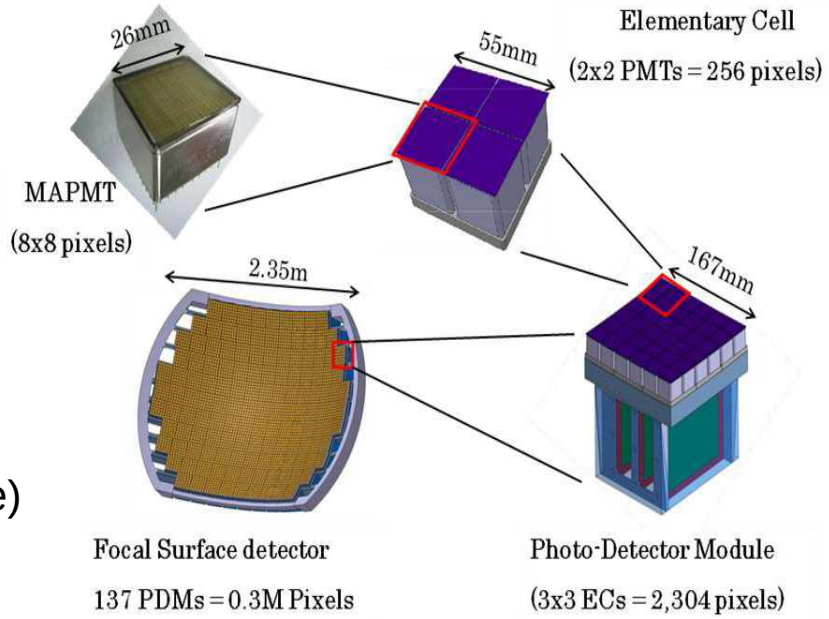
JEM-EUSO :

- Extremely High Energy Cosmic Ray (EECR) observer onboard of International Space Station
- Observing Extensive Air Shower created by the EECRs
- Total irradiation dose: 60 krad/5years



EUSO-BALLOON : Poster from Hiroko Miyamoto and talk from Valentina SCOTTI on Friday

- Project CNES + IRAP (Toulouse), APC and LAL supported by the whole JEM-EUSO collaboration
- 1 PDM with electronics and mechanics as close as possible to the one of JEM-EUSO
- SPACIROC : 64-channel MAPMT readout



Goals:

- ✓ Launch in August 2014
- ✓ Technological demonstrator (PDM + software)
- ✓ Study of the background

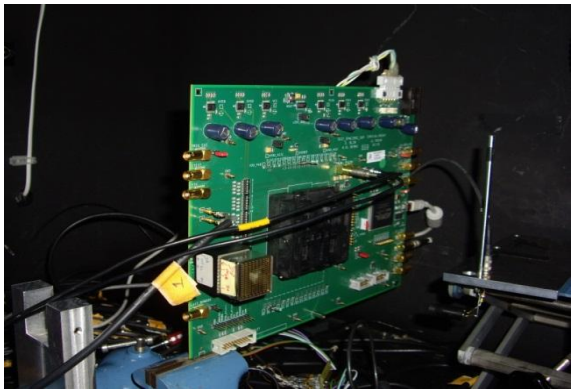
Front End ASIC requirements

- **64 channels photon counting**
  - Single photon counting 100% trigger efficiency: 1/3 pe (~50 fC when MaPMT gain=10^6)
  - MaPMT gain adjustment per pixel
  - Double pulse resolution : ~10 ns
- **Charge measurement (integration block)**
  - 8 channels: each for 8-pixel sum preamplifier signals
  - Dynamic range: from 1 pe to 100pe per pixel
- **Data acquisition & Readout to be done every 2.5 µs (GTU)**
  - Readout Clock : 40MHz
- **Radiation Hardness By Design** : TMR (Triple Module Redundancy)
- **Power budget** : <1 mW/channel

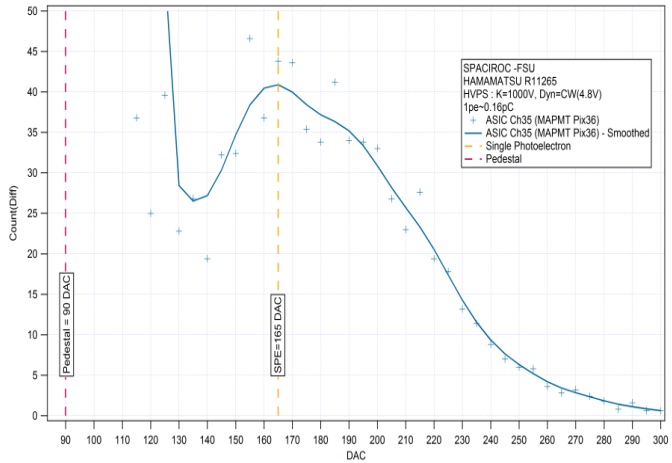
SPACIROC1 + MAPMT measurements

Test setup @APC:

HVPS: K=1000V & Cockroft Walton
MAPMT: Hamamatsu R11265-M64
MAPMT Gain: 1.10^6 (1p.e=0.16pC)
DC LED : λ=378nm

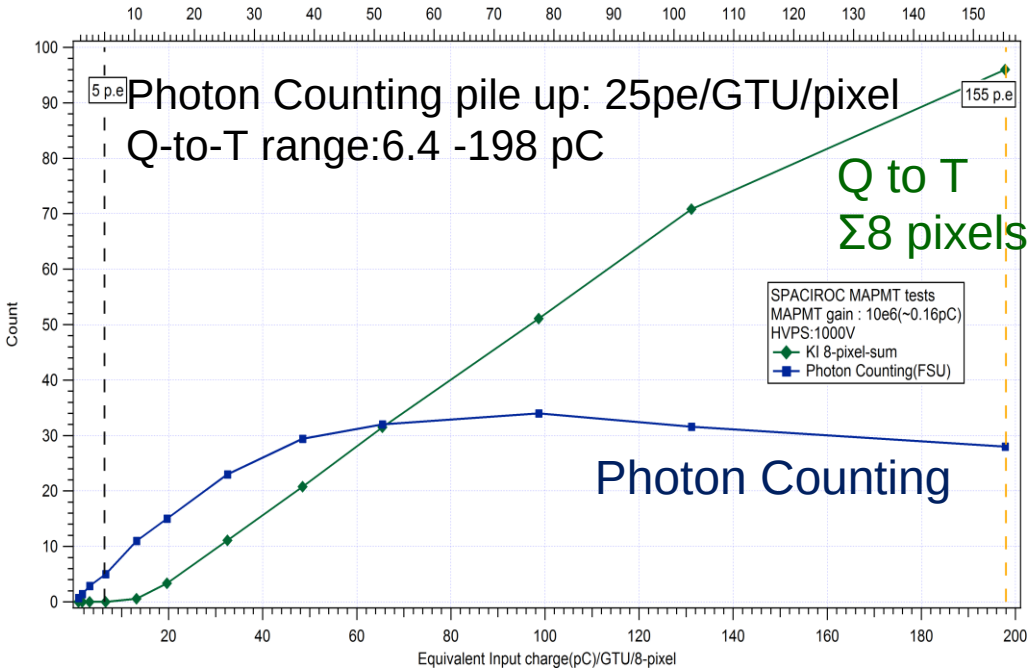


Photoelectron spectrum



→Photon counting saturation too early (25pe/GTU/pixel)
→Slope of the Q-to-T also depends on timing of input pulses inside a GTU.

➢ Photo Counting and Q to T counter data for input range of 1-180 p.e/GTU/pixel

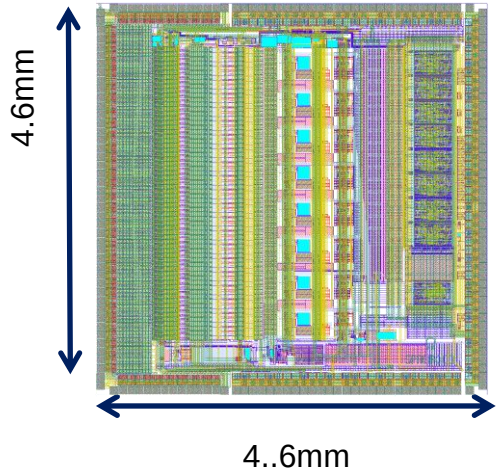


SPACIROC 1 and 2 measurements summary

SPACIROC1 / SPACIROC2	Consumption mW/ch		Min input charge (fC)		64 channel dispersion DAC unit		Double pulse separation (ns)	
Trig_fsu	1.07	0.87	30	20	2.5	2.3	36	27

SPACIROC3

- Reduce the power consumption: **0.7mW/ch**
- Double pulse resolution (can we reach 5 ns?)
- Improve charge integration measurement (better linearity, starts at 0, goes to 800 pe in a GTU)
- Improve the digital part



Technology: AMS 0.35µm SiGe

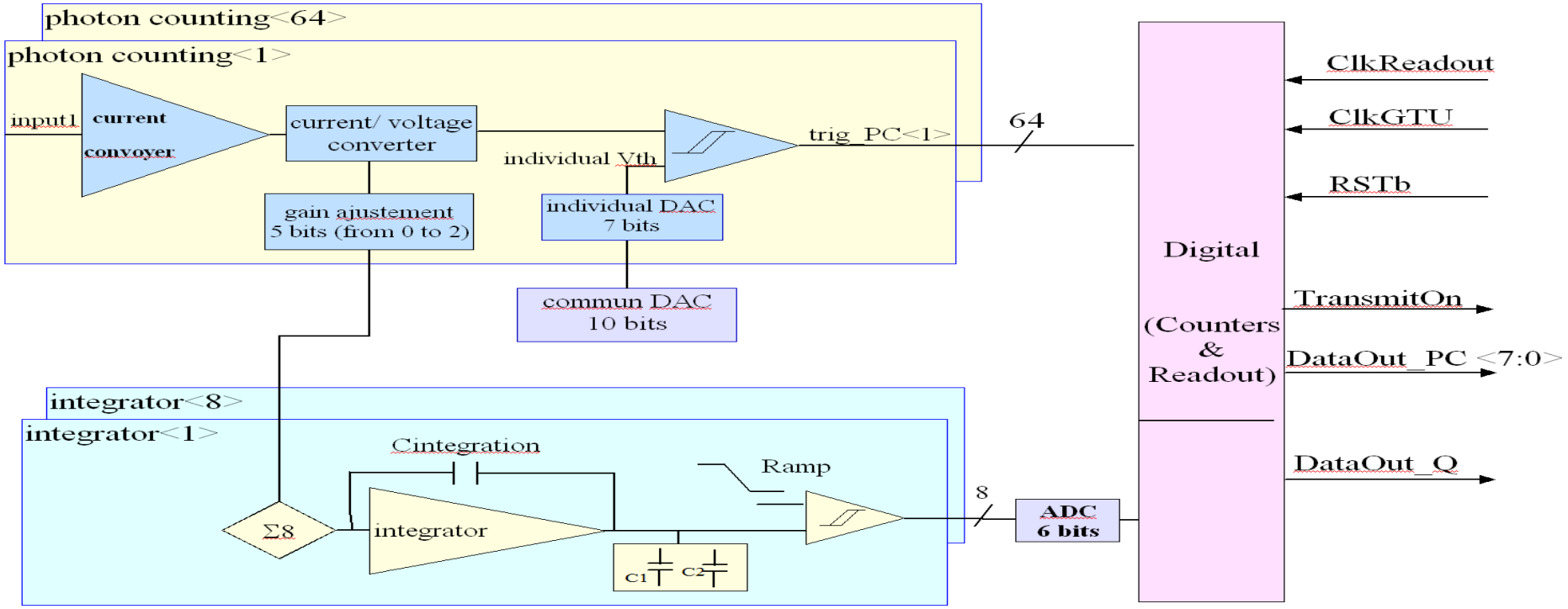
Submitted in November 2013

Delivered: March 2014

Power supply: 0-3V

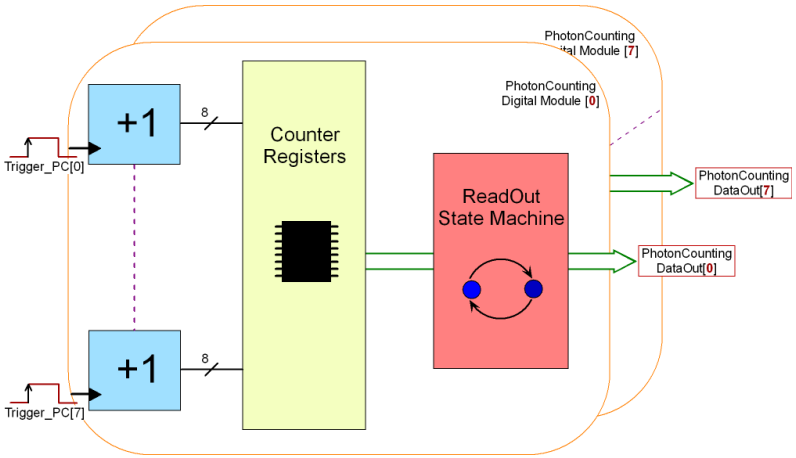
Packaging : CQFP208 (proto)

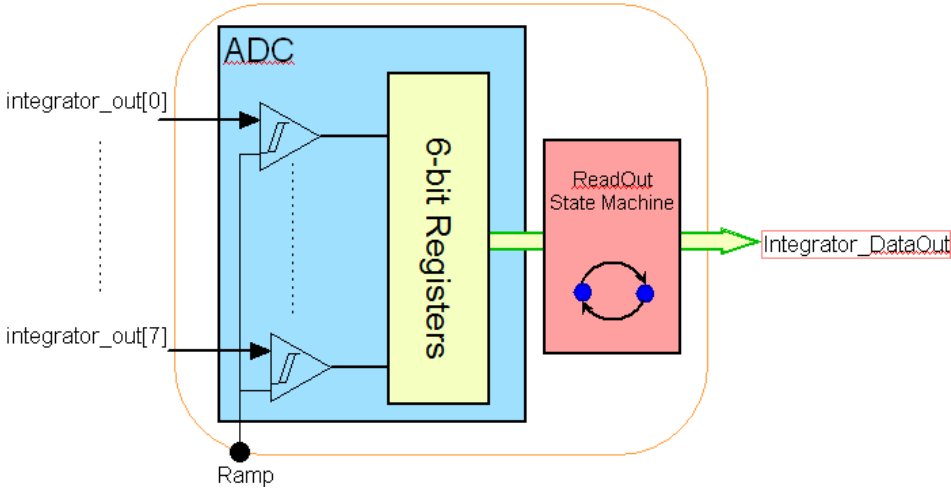
SPACIROC3 architecture



- **Photon counting: faster**
  - The gain adjustment of the previous versions has been removed (less consumption and faster)
  - The adjustment of individual offset for each channel will be done instead
- **Charge measurement: more linear**
  - Sum by 8 for integrated block
  - Adjustment gain before the sum (before flight)
  - Analog memory: 2 capacitors to remove dead time
  - Integration during 1 GTU and conversion by 6-bit ramp ADC

SPACIROC – Digital Architecture





Photon counting: (no change)

- Edge Gray counter
- Data buffer: 8-bit per channel
- Readout latency: 1 GTU

Output format (MSB first)
→ 64 bits data (8 channels) + Parity Bit

TransmitOn_PC: width 1.625µs

8 serial outputs

Charge integration:

- Level Gray counter
- Data buffer: 6-bit depth per integration block
- Readout latency: 2GTU

Output format (MSB first)
→48 bits data + Parity Bit

1 serial output

SPACIROC3: integrator simulation

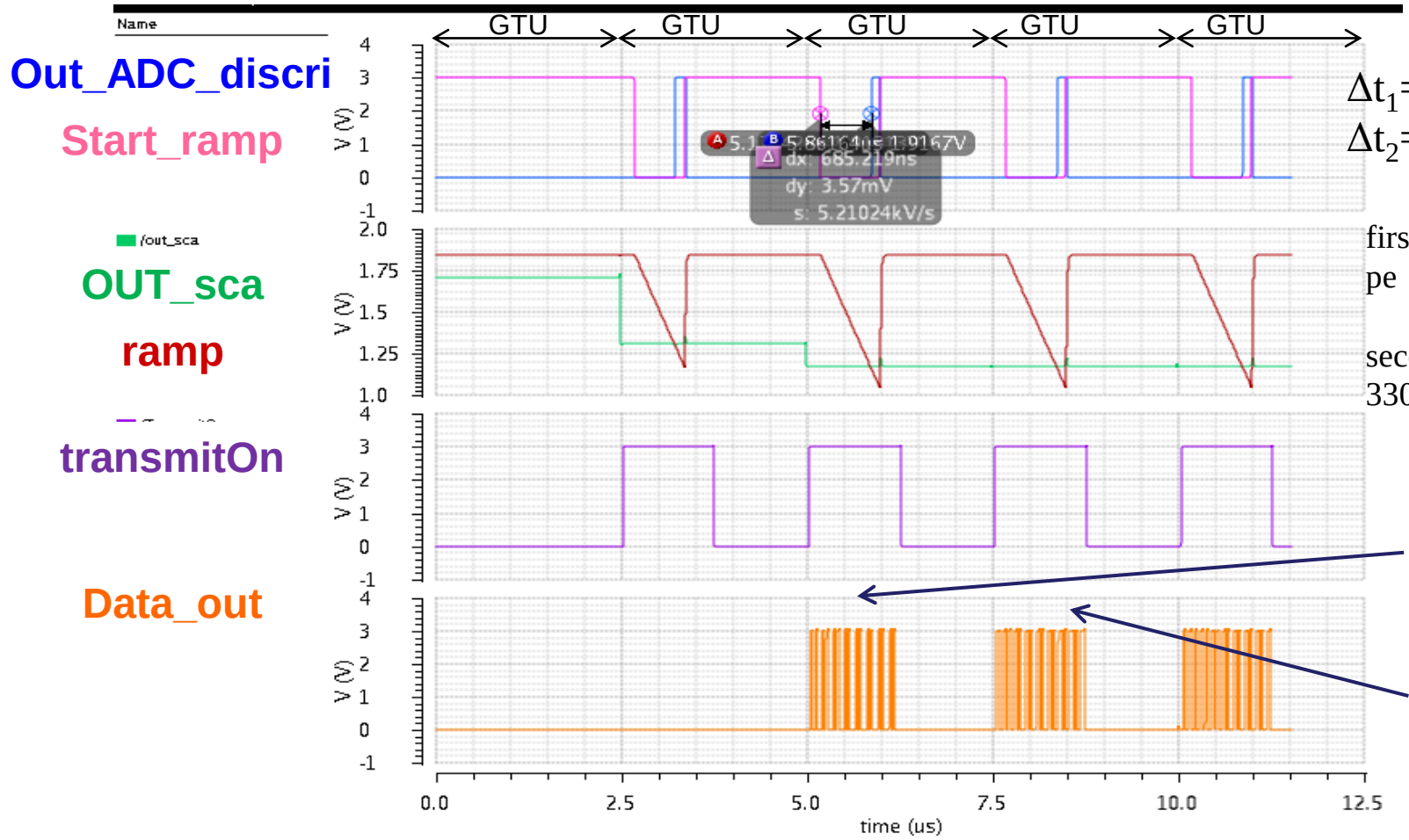
Charge measurement= integrator +SCA+6-bit ramp ADC

3 dynamic ranges: 1pe calibration
0pe to 30pe per pixel (plot below)
0pe to 100pe per pixel

6-bit ramp ADC @40HMz

Time conversion max=1,575µs <GTU (2,5µs)

LSB depends on the slope ramp



Δt_1= 551,6ns (22)
Δt_2= 685,1ns (27)

first input pulse: 250 pe (30 pe/channel)

second input pulse: 330 pe (40 pe/channel)

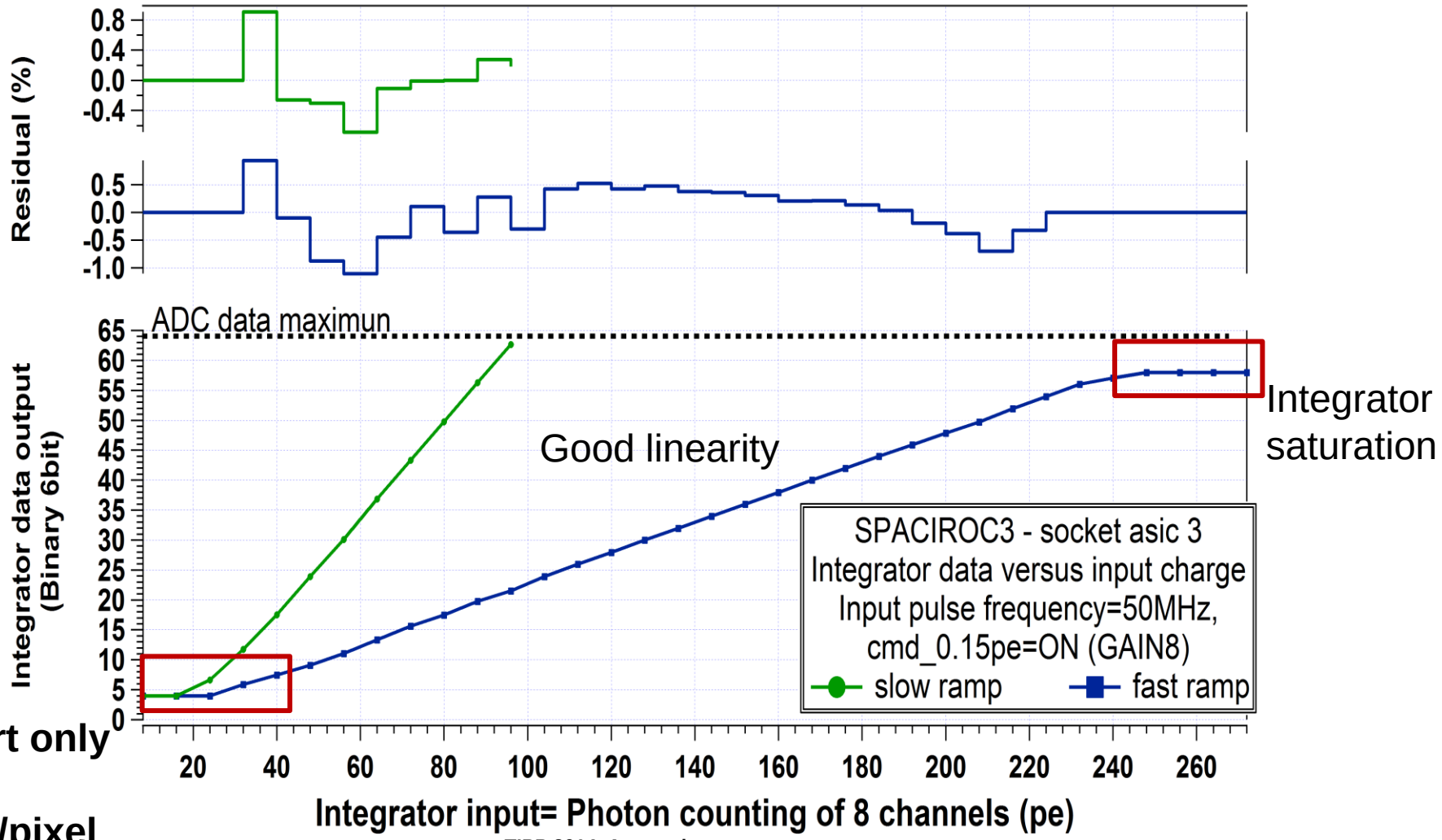
$Data\_out_1$ 24

$Data\_out_2$ 29

Integrator measurements

- dynamic range:
  - 0pe to 30pe per pixel (
- Ramp slope variable: slow (300mV/µs) and fast (900mV/µs)

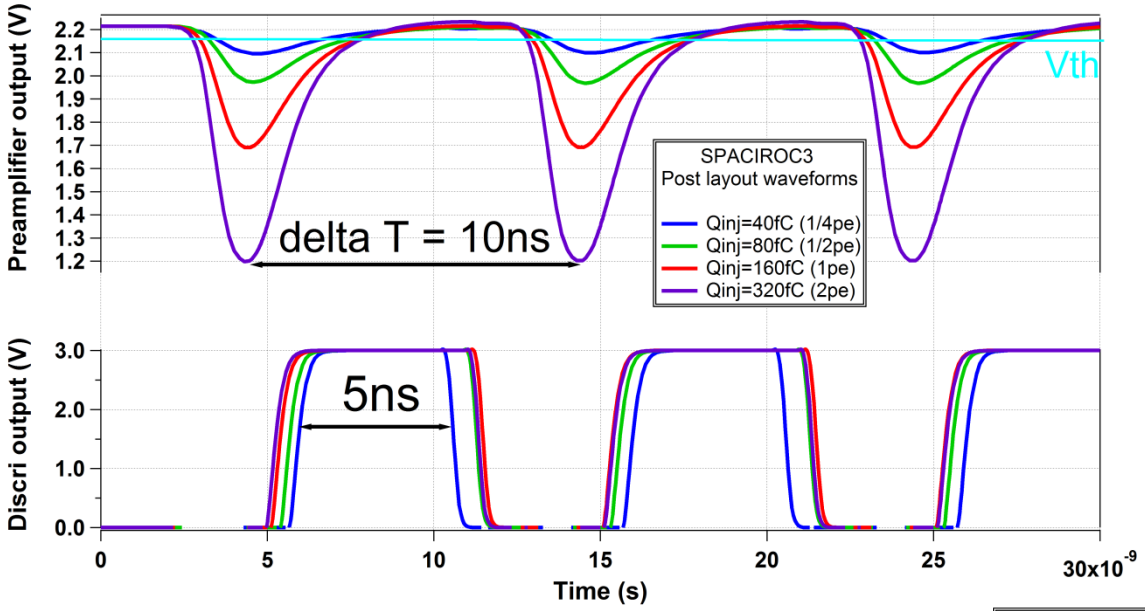
➢ **Measurements just starting**



Start only for 3pe/pixel

SPACIROC3: photon-counting simulations

- **New current conveyor output and trigger output**



Input pulse:

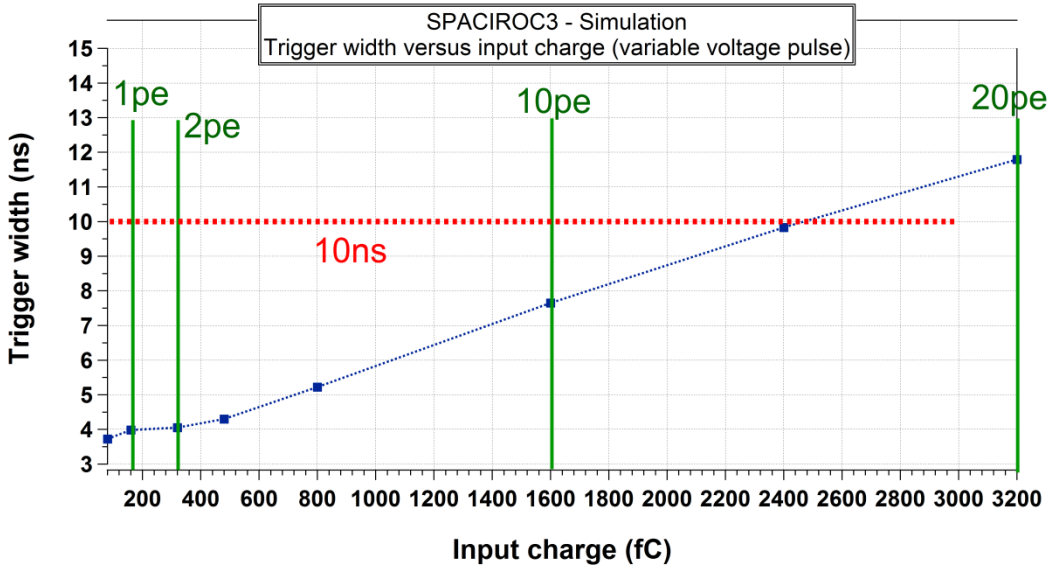
Period: 10 ns (100MHz)

falling edge=rising edge=1ns

Charge=0.25 pe, 0.5 pe, 1 pe and 2 pe

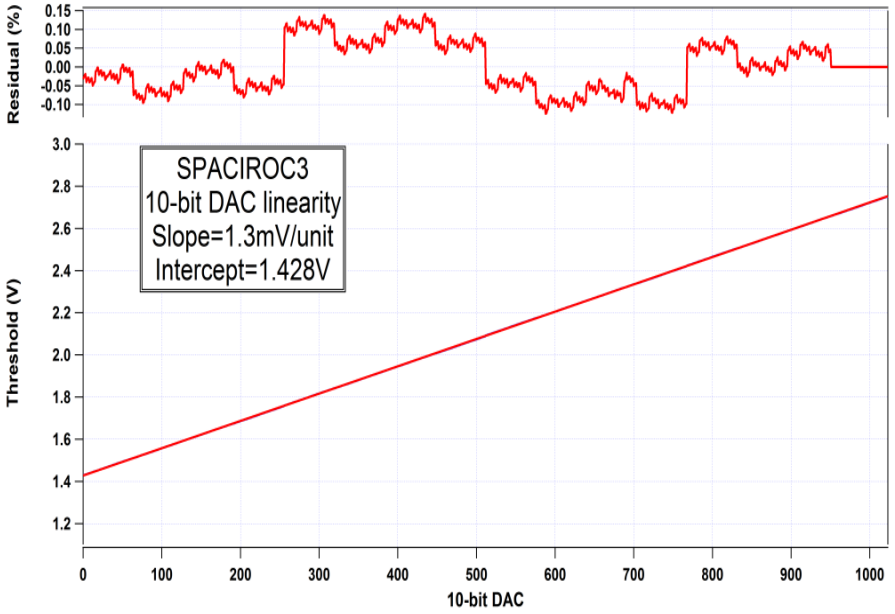
- **Trigger width versus input charge**

width less than 10 ns up to 15 pe



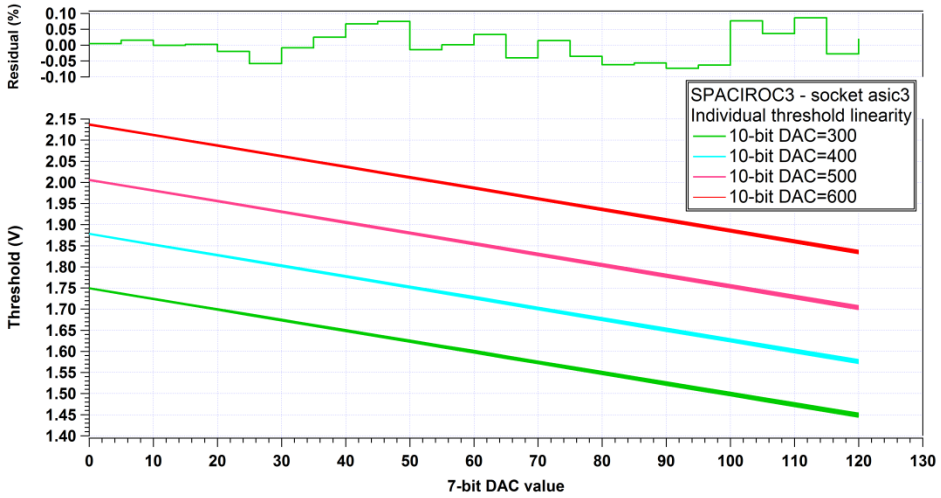
DACs Measurements

Commun DAC

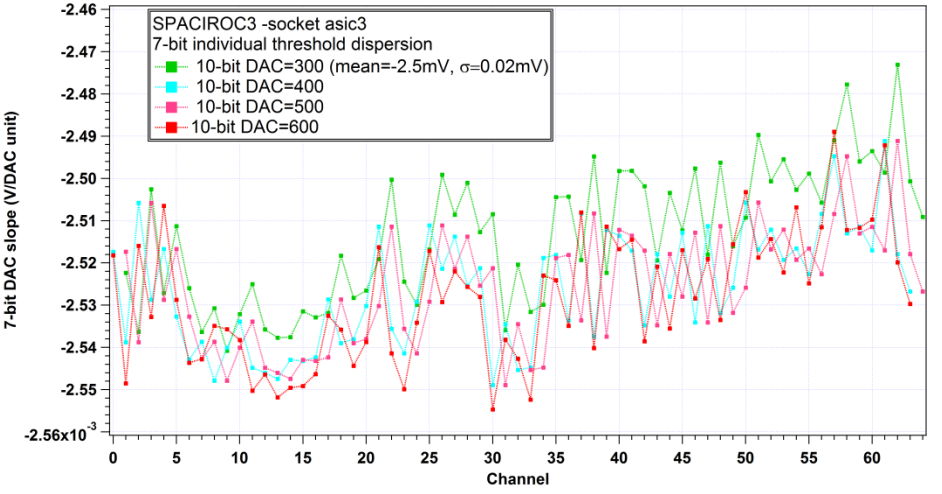


10-bit DAC. Range : 1.4 – 2.8V.
Linearity: ±0.15%. LSB:~1.3mV

Individual threshold linearity



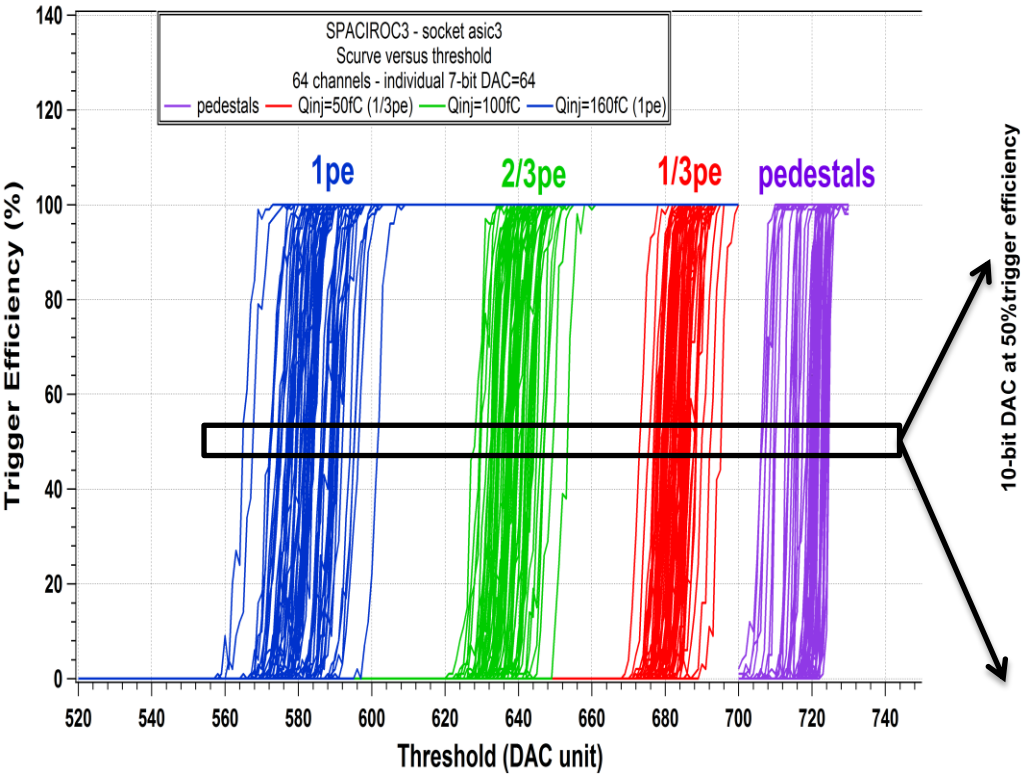
7-bit DAC. Range : 300mV
Linearity: ±0.08%. LSB:~2.5mV



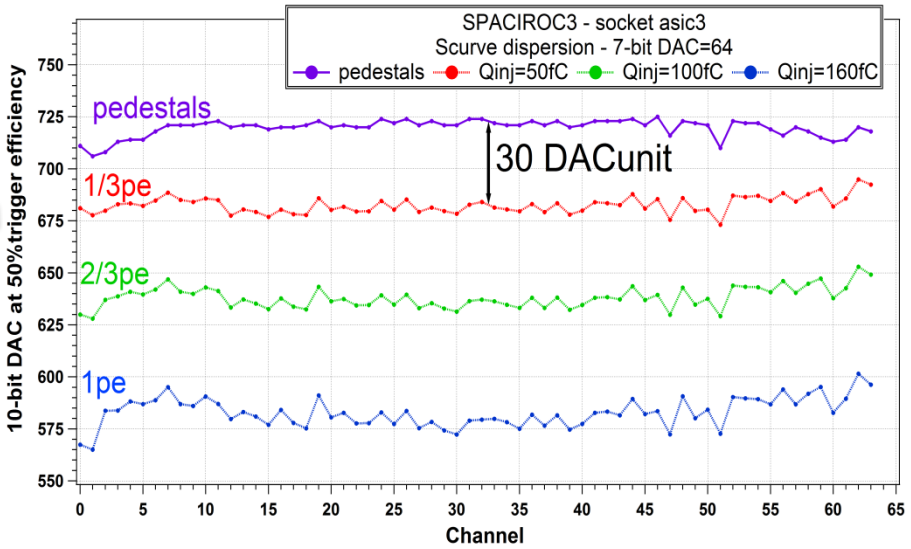
- **Good linearity**
- **Low dispersion between channel**

Photon counting measurements: Scurves

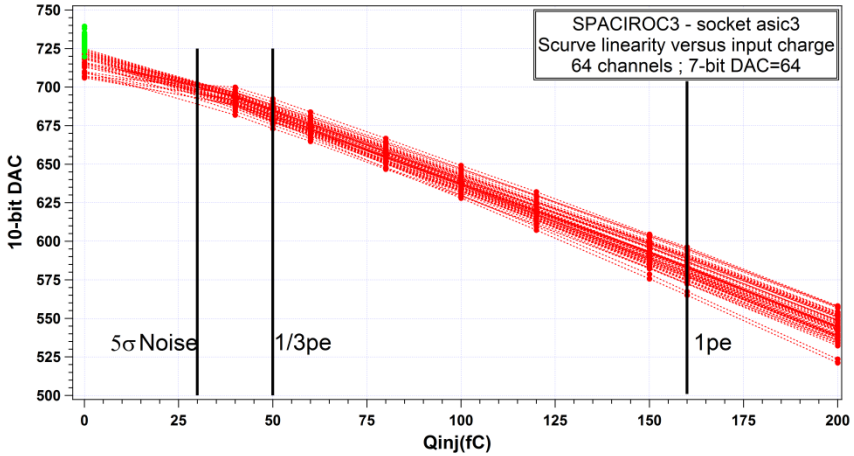
- 64 scurves for different input charge



- DAC value at 50% trigger efficiency versus channels



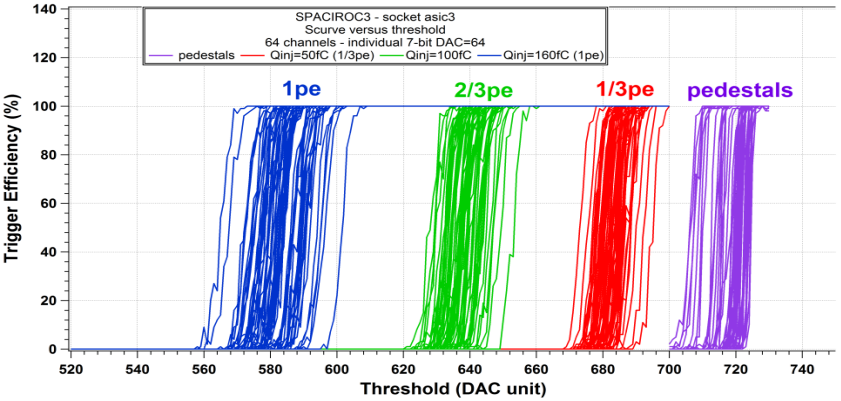
- DAC value at 50% trigger efficiency versus input charge

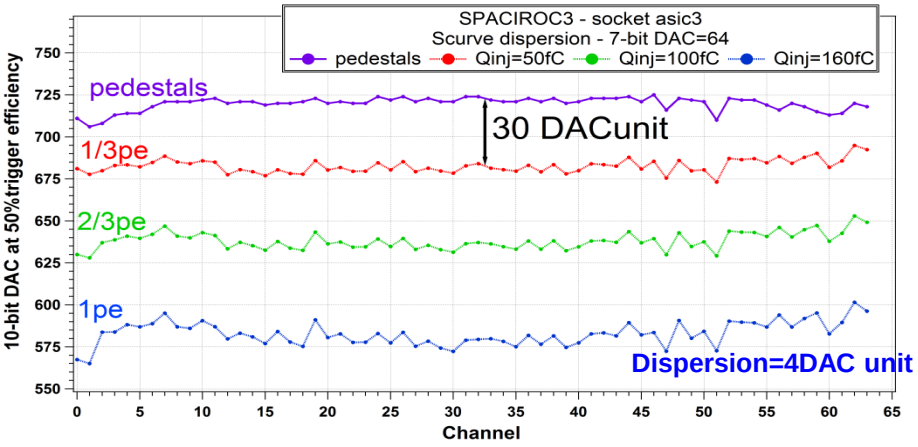


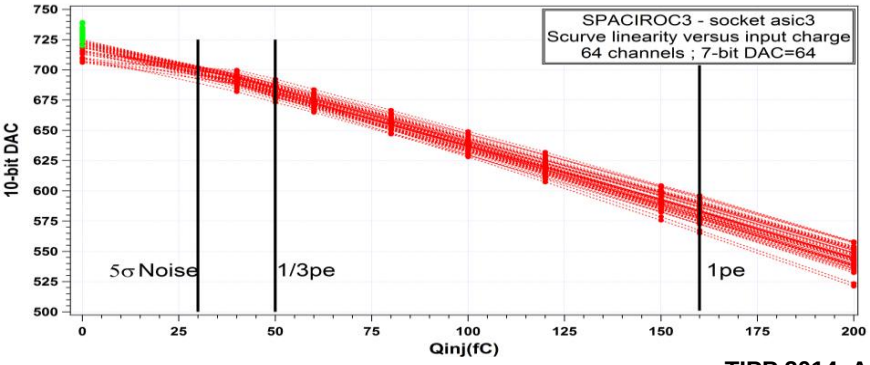
- **Good separation between the pedestals and 50fC scurves= 30 DAC unit**
- **Dispersion between channel=4 DAC unit**
- **Dispersion of the trigger linearity correlated to the 7-bit DAC dispersion**

Photon counting measurements threshold adjustement

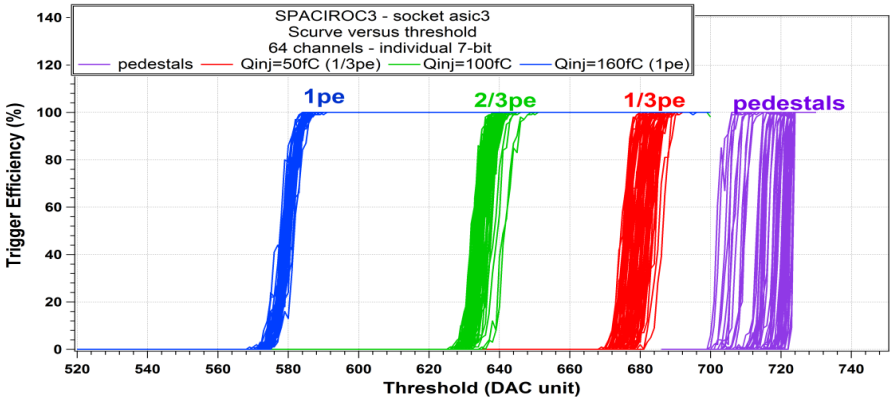
Without correction: 7-bit DAC=64

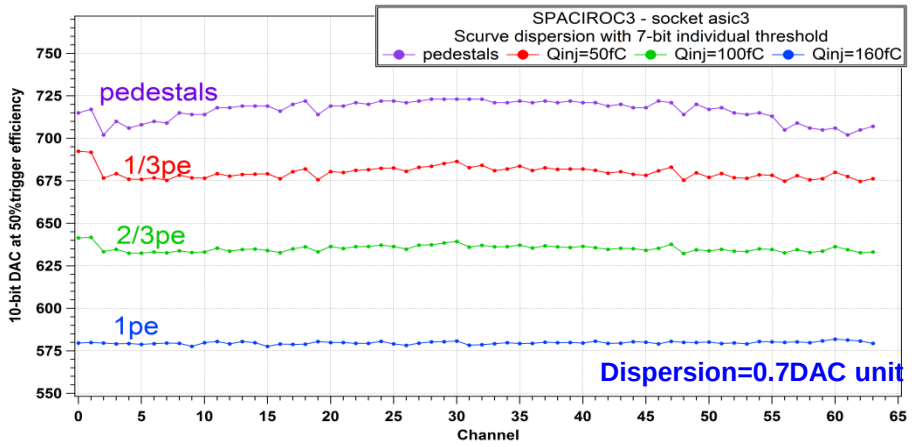


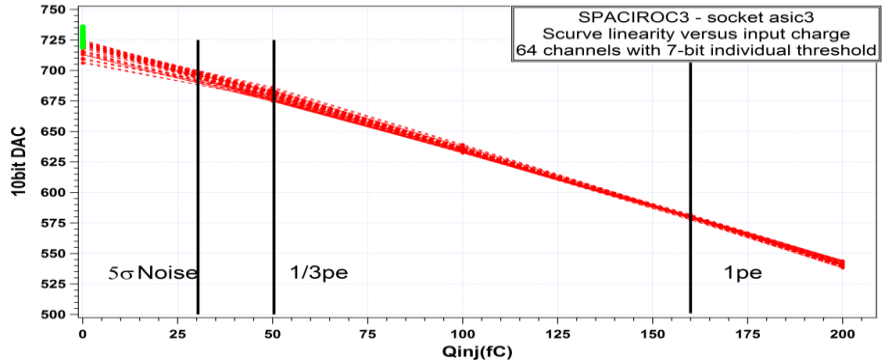




With correction: 7-bit DAC=individual value



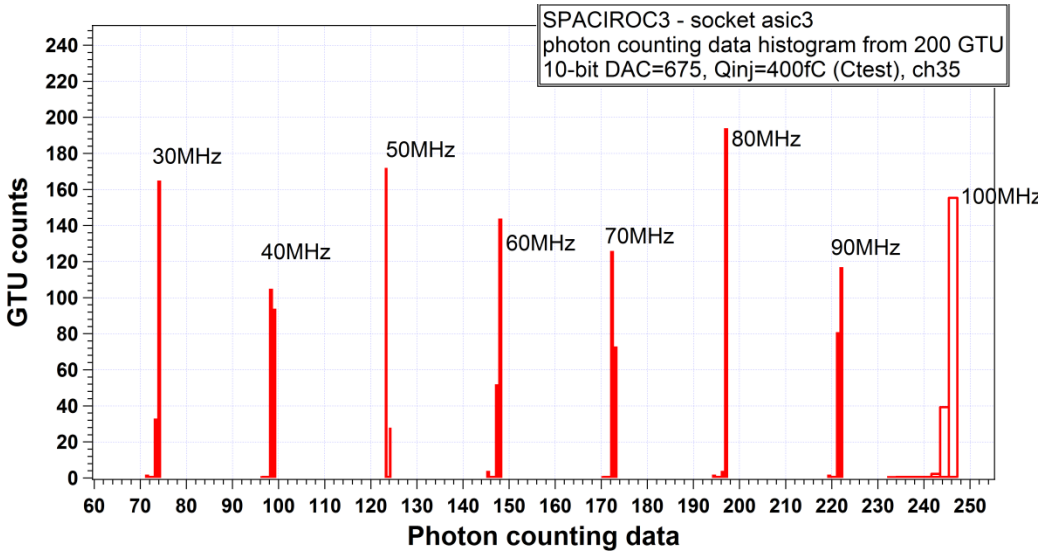


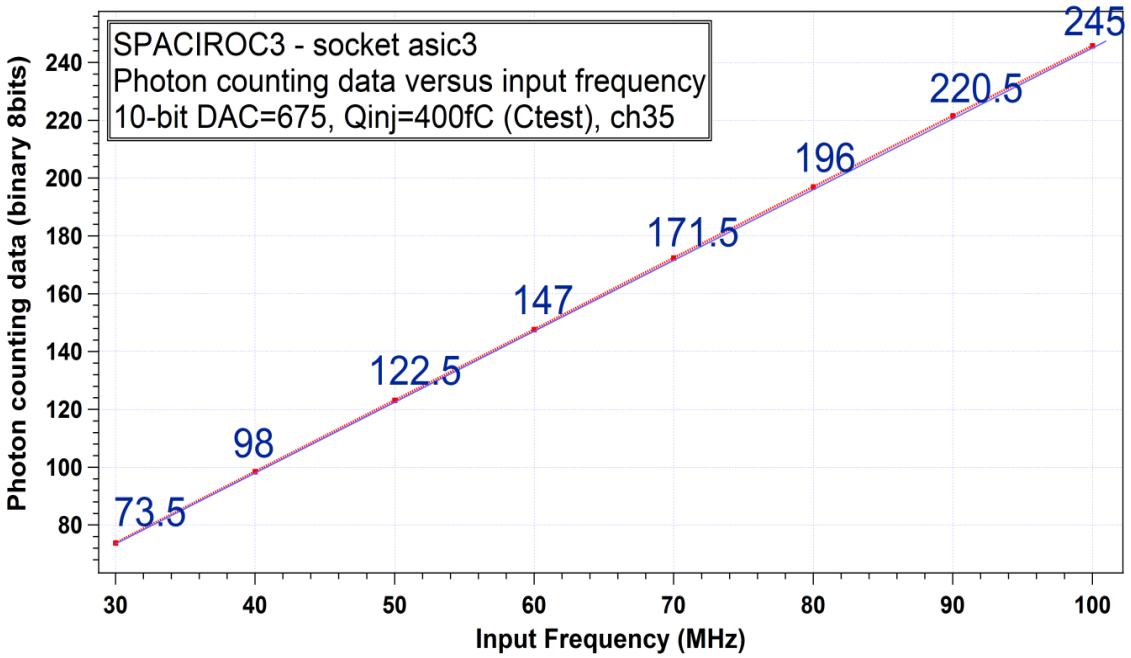


Double pulse separation

Setup: free running input pulses at different frequency

Histogram of photon counting data for 200GTU





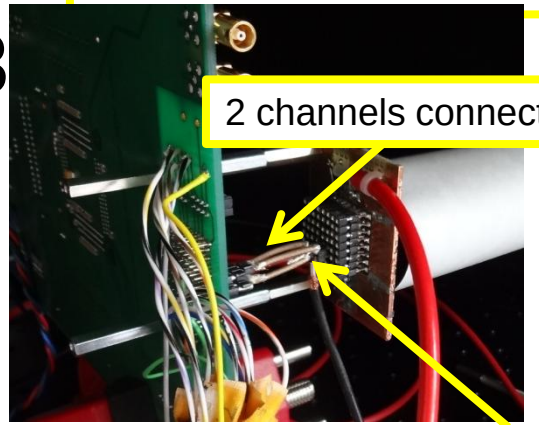
- **Data from photon counting are consistent and coherent with the GTU (2.5µs) *frequency.**
- **All pulses are detected at 100MHz**

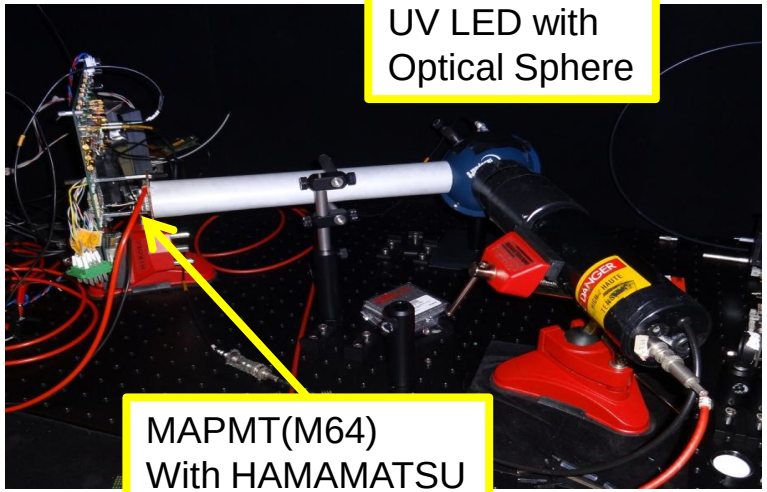
MAPMT first test

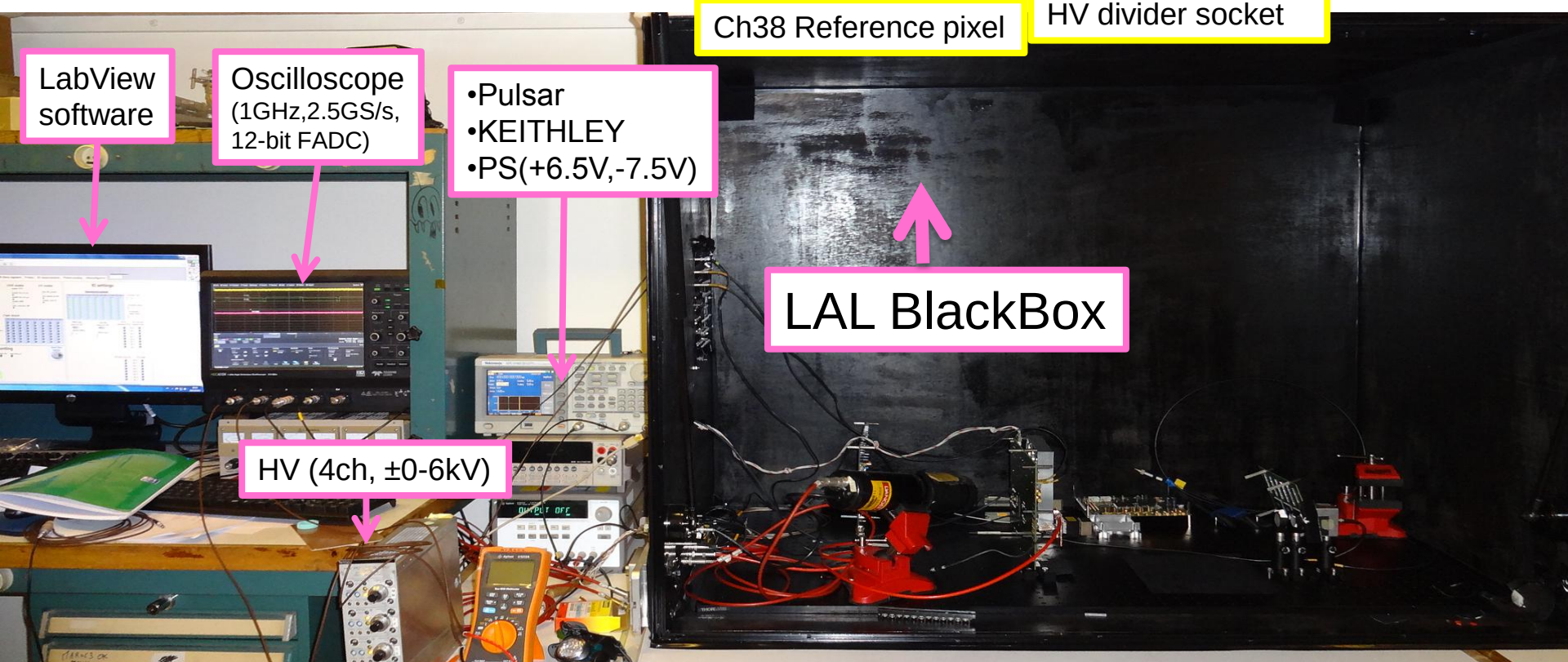
Omega

SPACIROC3 Testbench @LAL

(Hiroko Miyamoto)

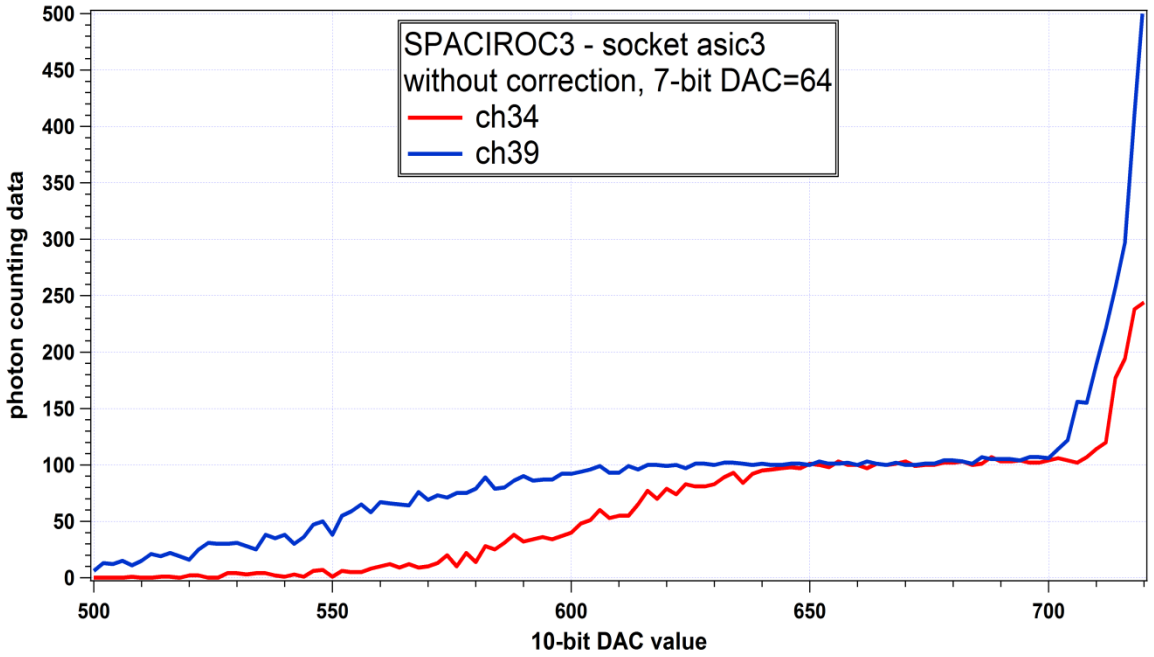






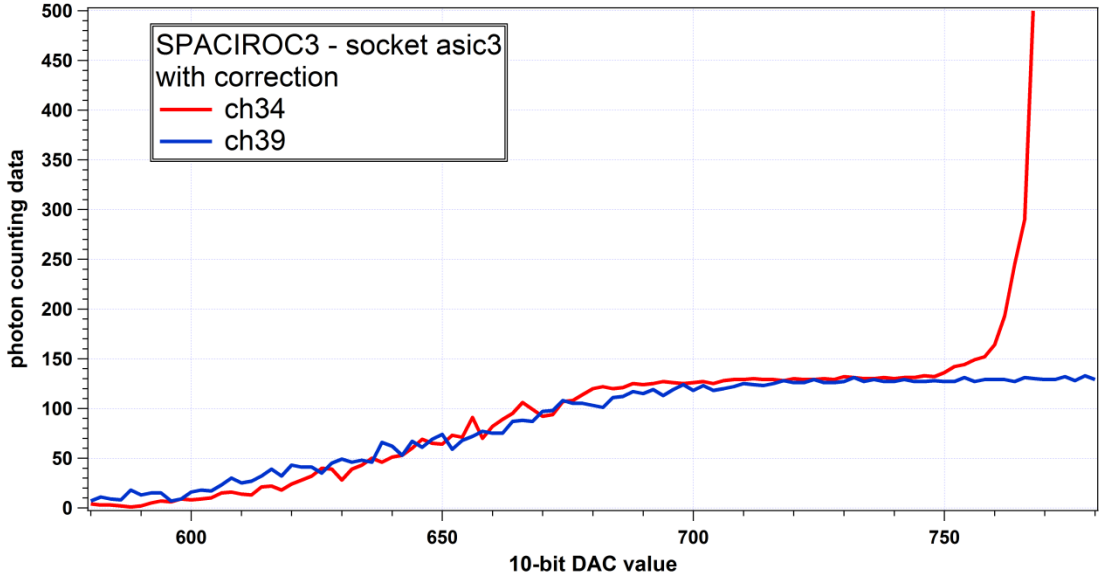
MAPMT first test

Setup:
2 channels connected
HV750V
Pulsed LED: amplitude ~20mV
in output of PMT reference pixel



➢ **No correction**:
100 GTU/DAC
All individual 7-bit Dac=64

➢ **Offset adjustement**:
200 GTU/DAC
CH34: 7-bit Dac=88
CH39: 7-bit Dac=127



❖ **Adjustement working well**

Conclusion

– **SPACIROC 1**: EUSO-Balloon

  • Detector with 36 asics in CQFP160

  • The photon counting works until 30pe per GTU

  • Q to T data to protect the Mapmt (decrease HV)

– **SPACIROC2** : conservative design

  • Fulfills photon counting JEM-EUSO requirements

  Minimize all power consumption problems

  Improve double pulse separation (but still not good enough)

– **SPACIROC3**:

  • the best solution for JEM-EUSO

  Photon counting: only one design to reach 100MHz

  New better charge measurement

SPACIROC3 exhibits good behavior

- **Improved power consumption**
- **Better double pulse separation resolution**
- **Better linearity for charge measurement**