OMEGA ROC chips for photodetectors

Atelier nanosatellites
Montpellier

Christophe de LA TAILLE
OMEGA microelectronics group
Ecole Polytechnique & CNRS IN2P3
http://omega.in2p3.fr

Organization for Micro-Electronics desiGn and Applications

OMEGA group

- Mutualized ASIC design team
- 10 research engineers (1 IR0, 2 IR1, 6 IR2, 1CDD), 2 pHD students
- Importance of critical mass for more and more complex circuits
- Cross-fertilization between projects
- Technology transfer via startup WEEROC

OMEGA « ROC chips »

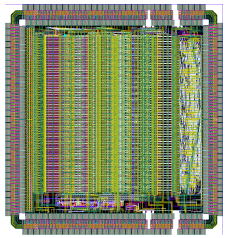
- Move to Silicon Germanium 0.35 µm BiCMOS technology in 2004
- Readout for MaPMT and SiPM for ILC calorimeters and other applications
- Very high level of integration : System on Chip (SoC)

http://omega.in2p3.fr

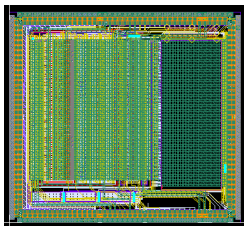
Chip	detector	ch	DR (C)
MAROC	PMT	64	-2f-50p
SPIROC	SiPM	36	+10f-200p
SKIROC	Si	64	+0.3f-10p
HARDROC	RPC	64	-2f-10p
PARISROC	PM	16	-5f-50p
SPACIROC	PMT	64	-5f-15p
MICROROC	µMegas	64	-0.2f-0.5p

PETIROC SiPm 16 50fC- 300pC

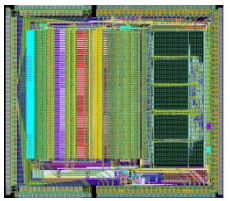
MAROC3



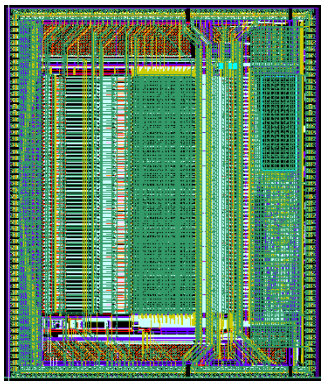
HARDROC2



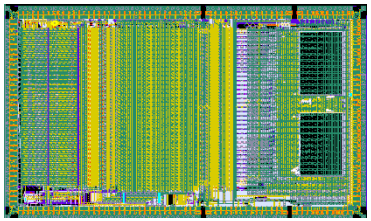
MICROROC1



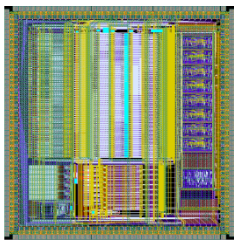
SKIROC2



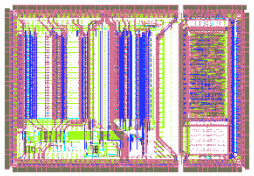
SPIROC2



SPACIROC

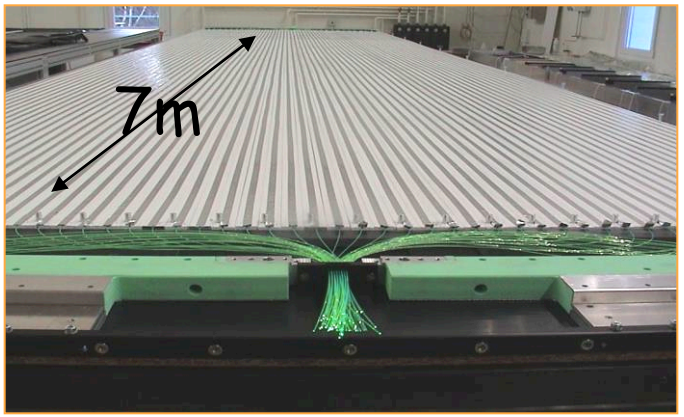


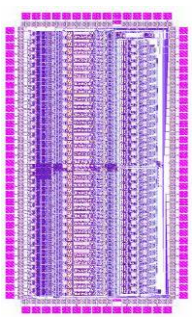
PARISROC2



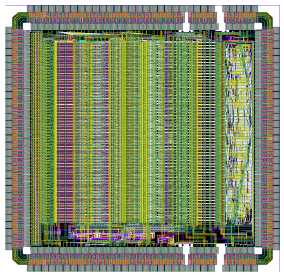
MAROC for MAPMT

- Started with OPERA_ROC (2001)
  - 32 Channels in BiCMOS 0.8 µm
  - 3000 chips produced in 2002
  - Readout OPERA Target tracker in Gran Sasso
- MAROC1 (2004)
  - First prototype with 64 channels
  - AMS SiGe 0.35 µm (12 mm^2, Pw=5 mW/ch)
- MAROC2 (2006)
  - 1000 chips produced and bonded on a compact PCB for ATLAS luminometer (ALFA)
- MAROC3 (2009)
  - Lower power dissipation
  - Wilkinson ADC added
  - 1000 chips produced in 2010



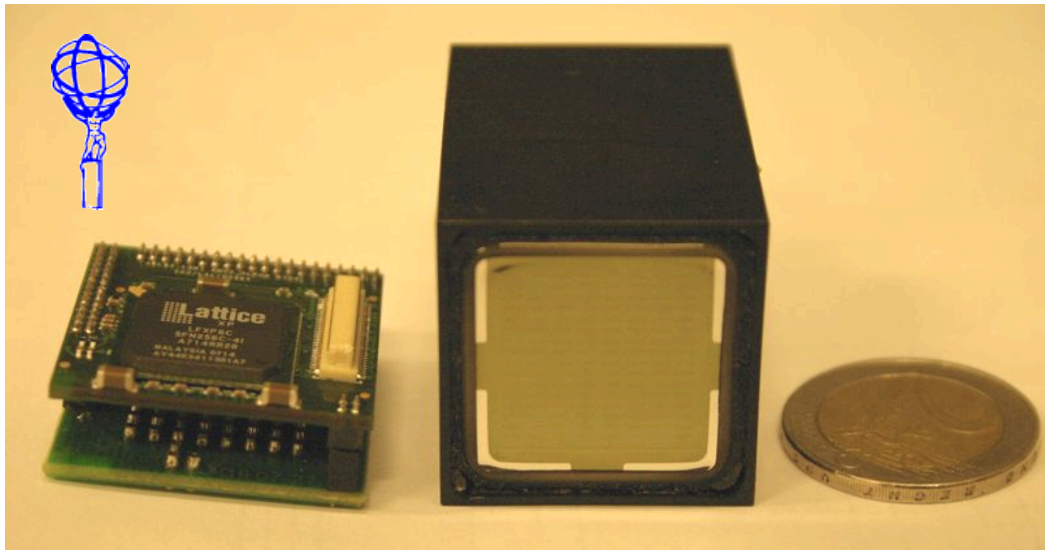


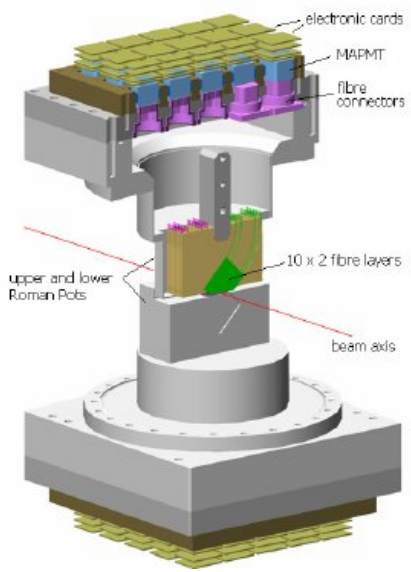
OPERA_ROC

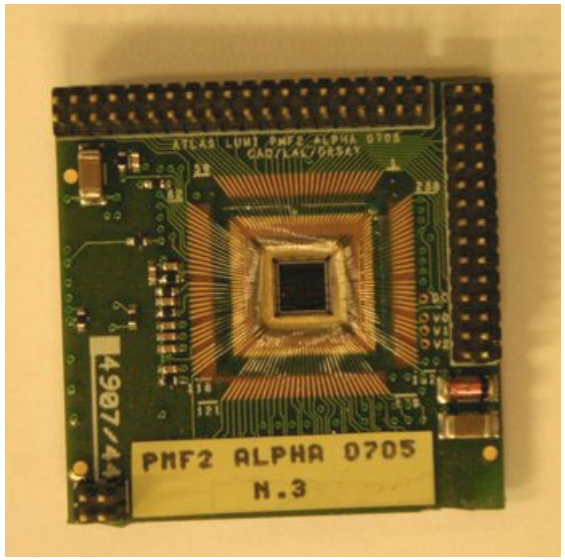


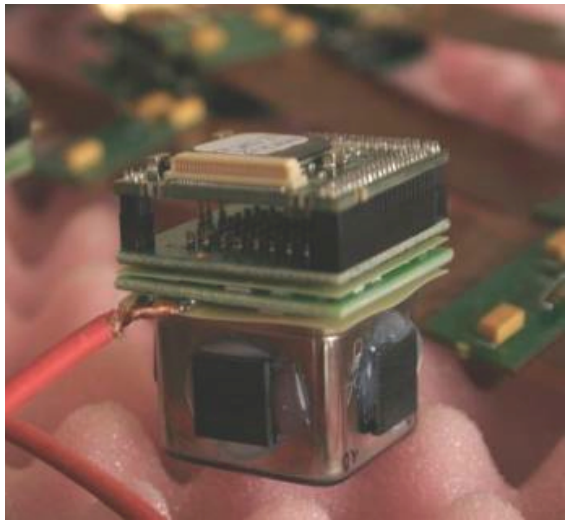
MAROC2

MAROC in ATLAS : ALFA



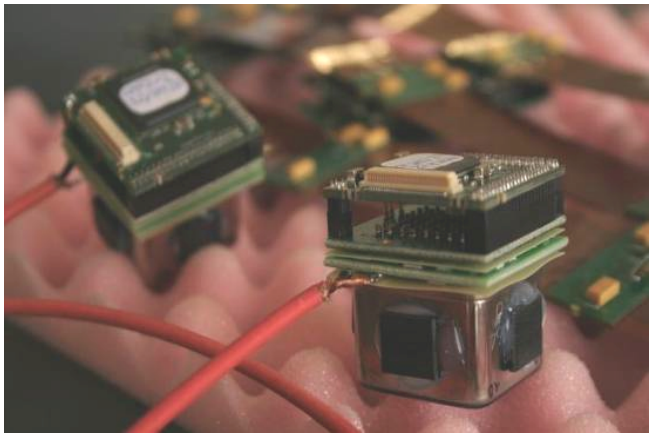


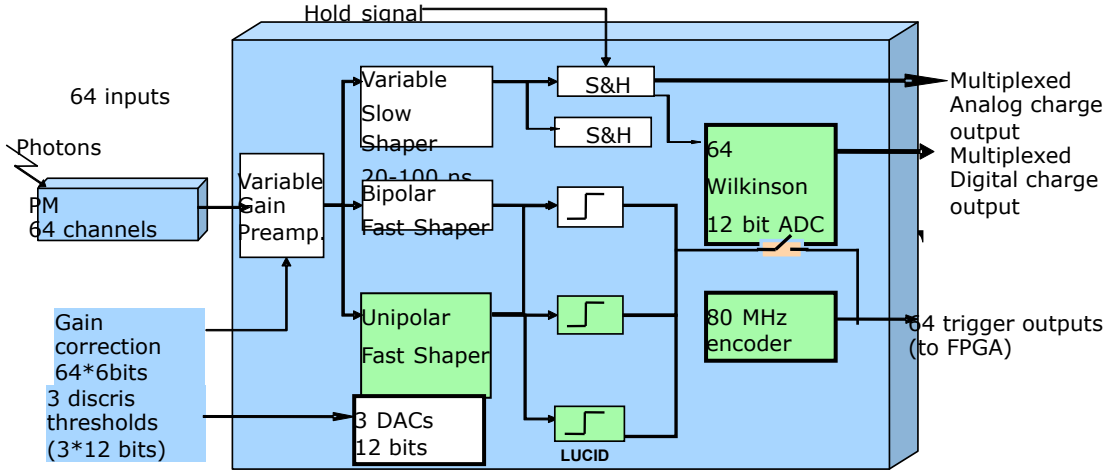


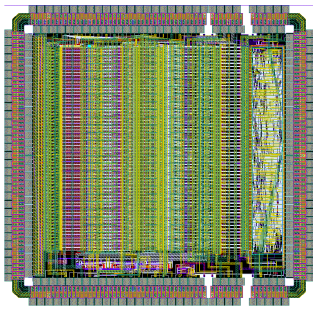


MAROC : MultiAnode Read-Out Chip

- Complete front-end chip for 64 channels multi-anode photomultipliers
  - 6bit-individual gain correction
  - Auto-trigger on 1/3 p.e. at 10 MHz
  - 12 bit charge output
  - SiGe 0.35 µm, 12 mm^2, Pd = 5 mW/ch
- Bonded on a compact PCB (PMF) for ATLAS luminometer (ALFA)
- Also equips Double-Chooz, medical imaging…
- 3000 chips produced





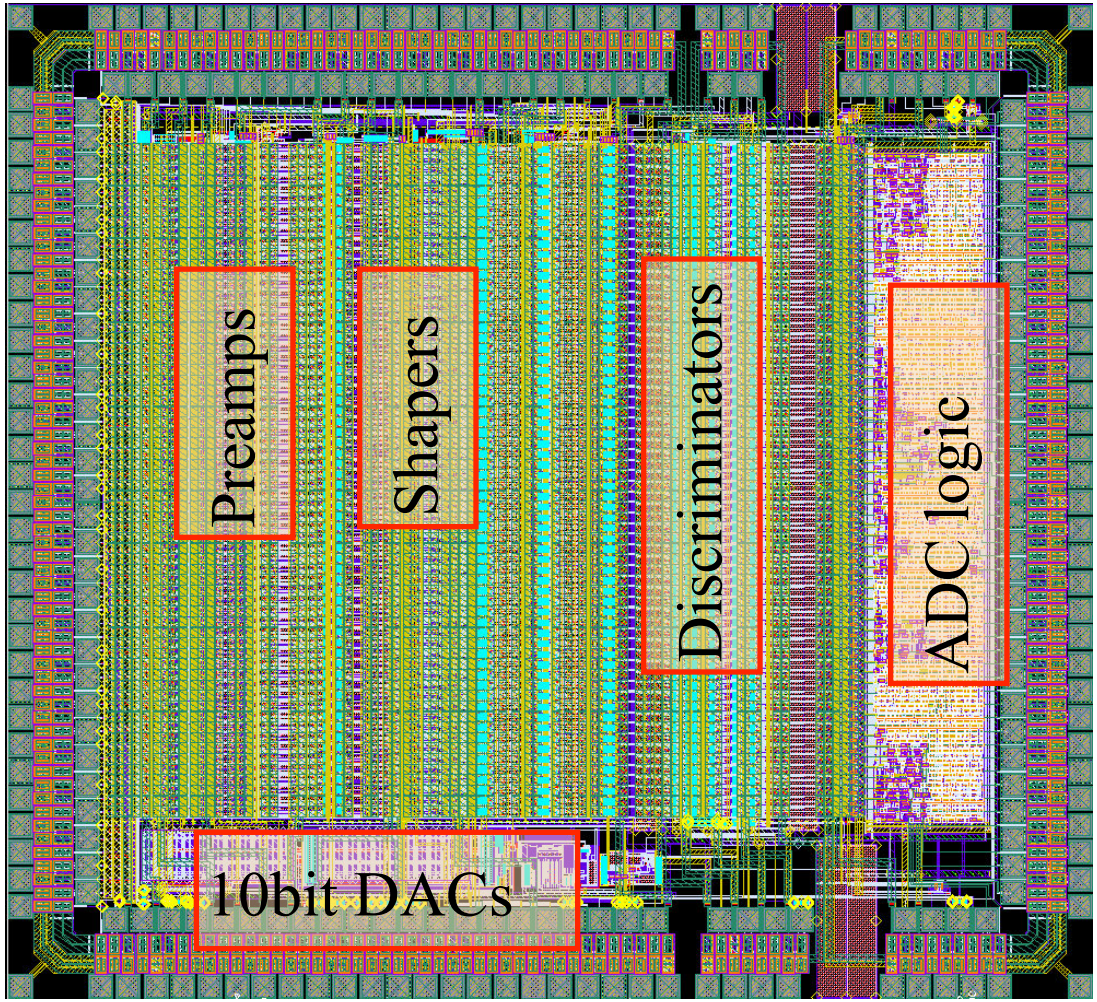


MAROC3 overview

1 MUX charge output

AMS SiGe 0.35µm
Package: CQFP240
Area: 16 mm2

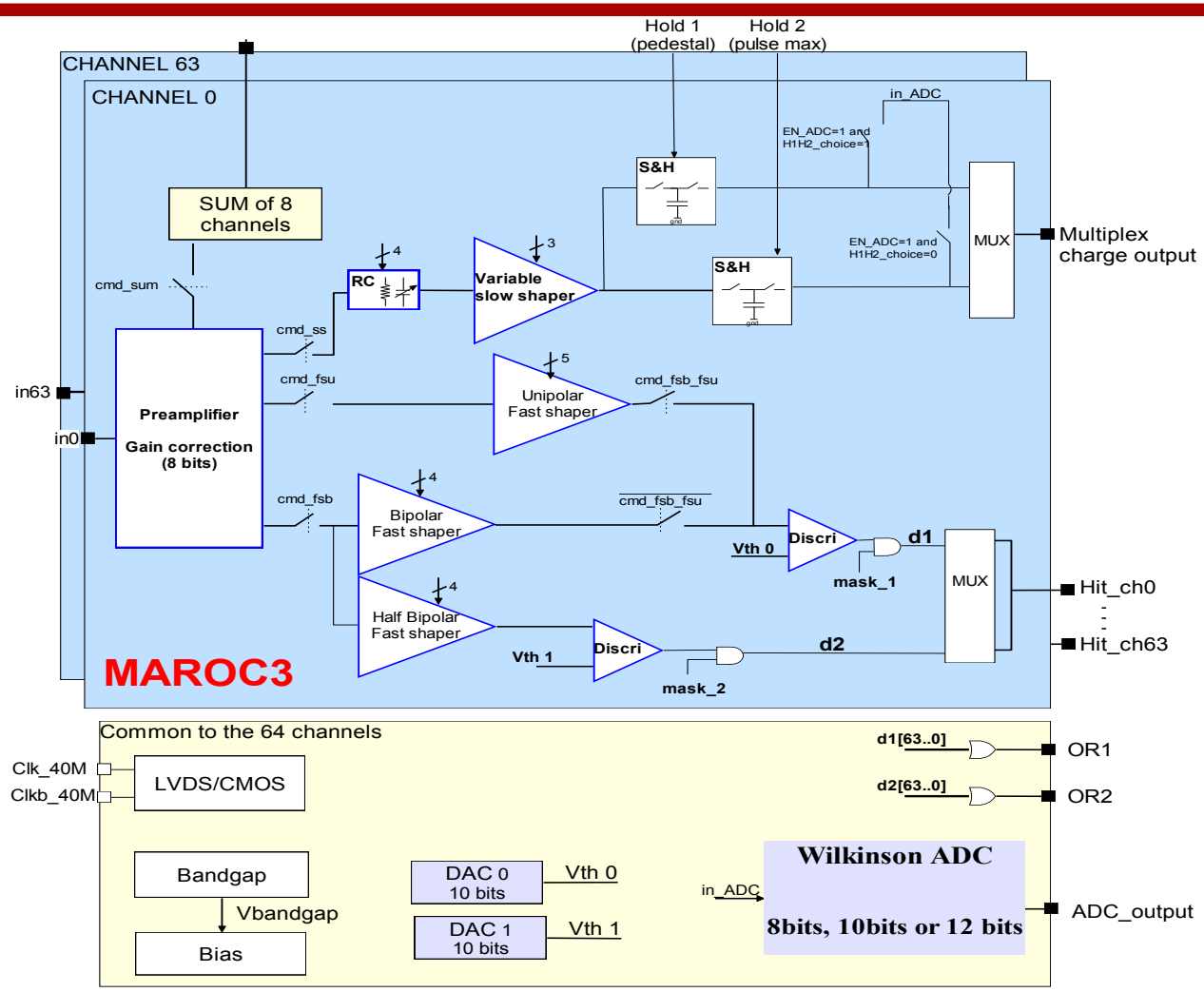
64 PM inputs



64 trigger outputs

2 Fast OR outputs

MAROC 3 – Main Features

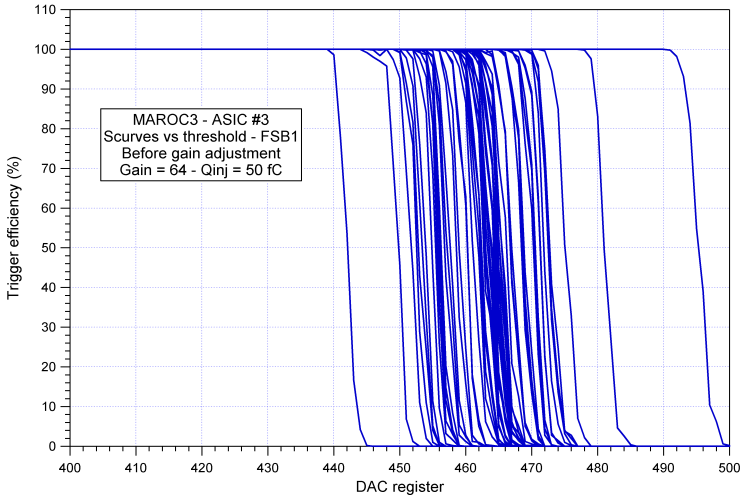


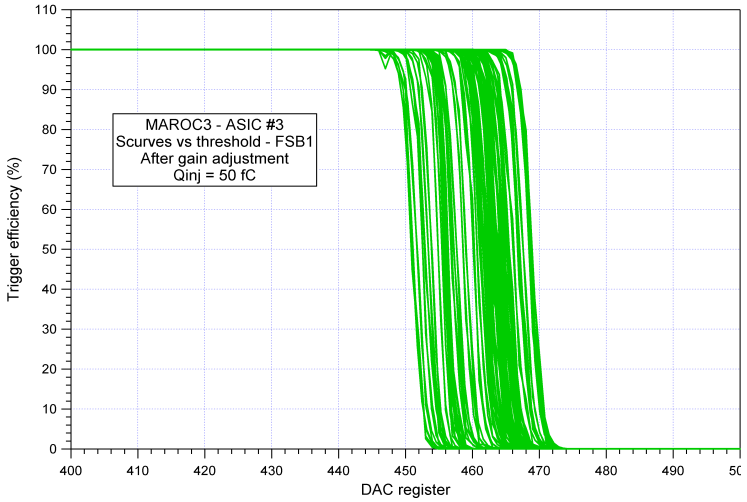
- **Almost pin/pin compatible**
- **Internal reference**
- **Gain adjustement:**
  - 8 bits (2,1,…,0.0156) instead of 6 bits (2,1,…, 0.0625)
- **Charge measurement**
  - Variable charge gain
  - Dynamic range increased
  - 8 or 10 or 12 bits wilkinson ADC
- **Trigger measurement**
  - Bipolar fast shaper: 2 thresholds
  - Only 2 DAC
  - Mux instead of an encoder
  - 2 OR outputs
  - New digital output levels: Vhigh and Vlow
  - Mask

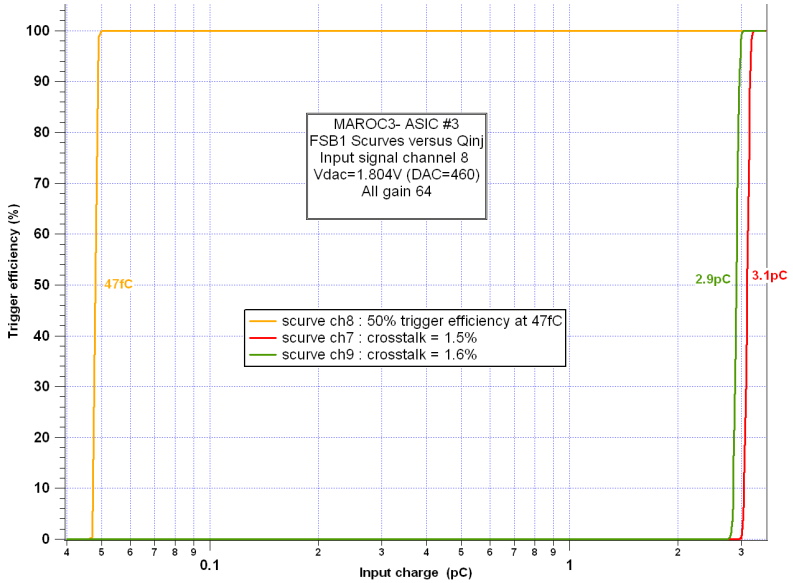
Technology: AMS SiGe 0.35 mm
Package: CQFP240
Area: 16 mm2
Power consumption: 220mW (➔ 3.5mW/channel)

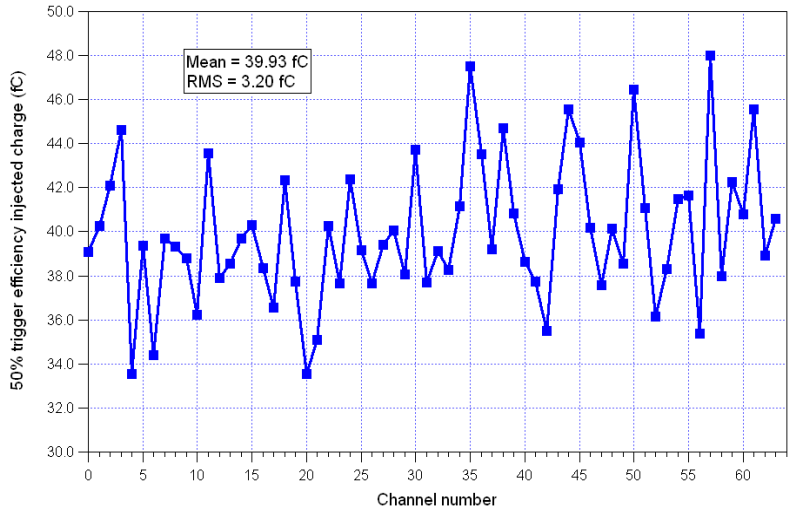
MAROC 3: Trigger performance

- 50% trigger efficiency:

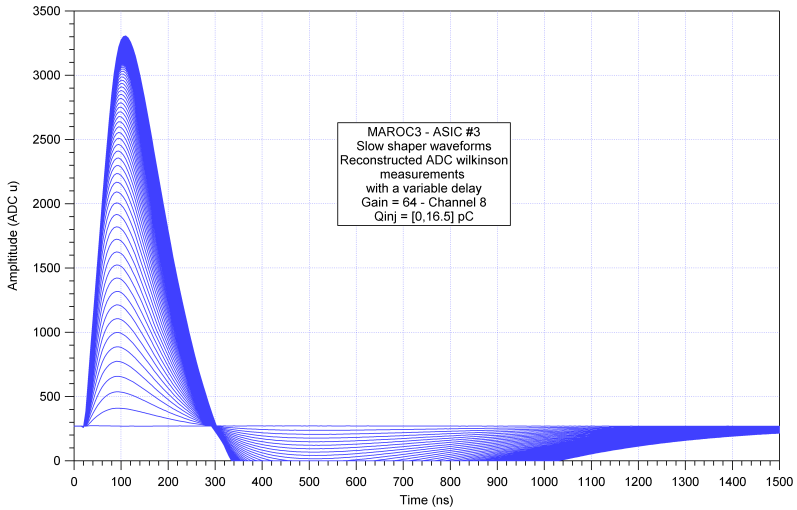


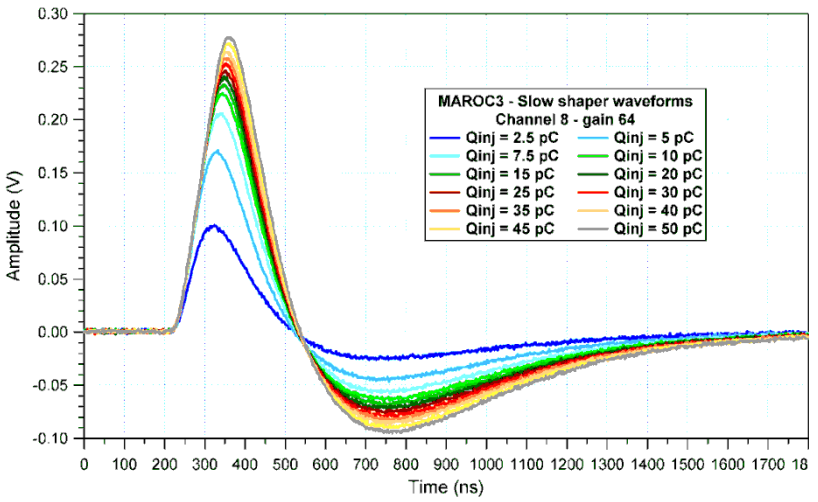


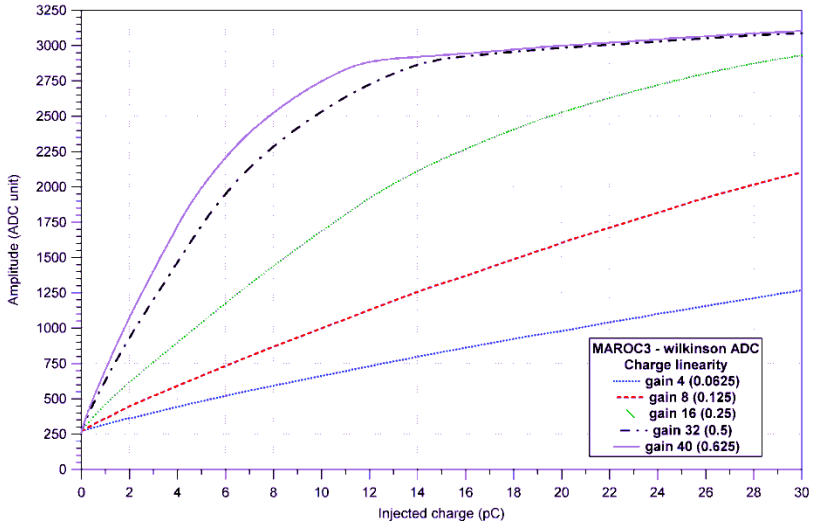


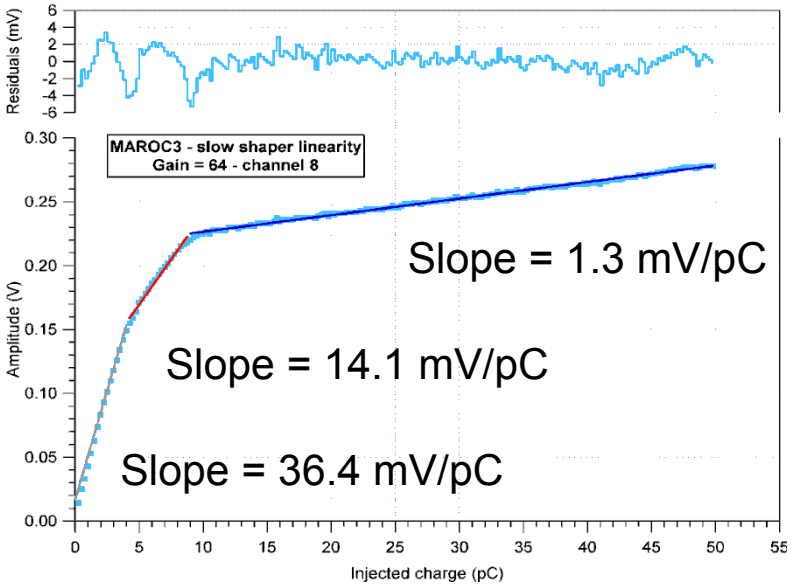


Charge measurements with wilkinson ADC





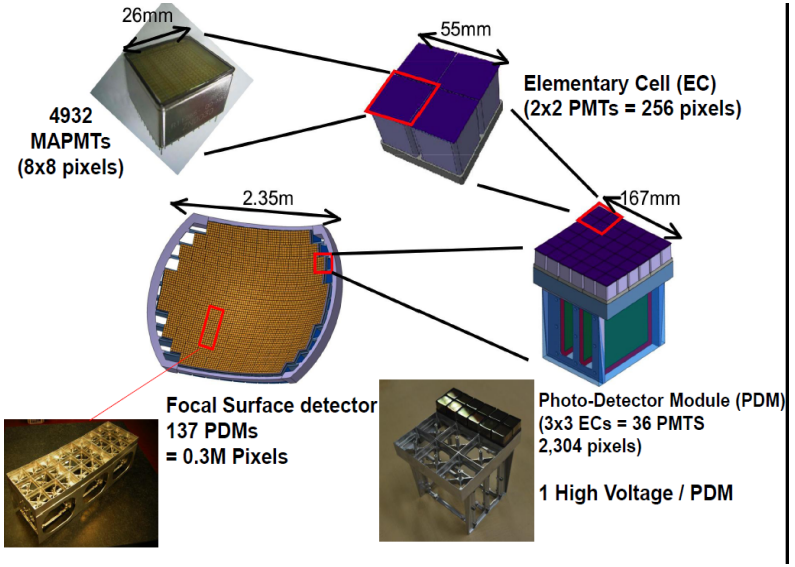




Variant: SPACIROC

SPACIROC - Spatial Photomultiplier Array Counting and Integrating ReadOut Chip

- Readout chip for 64 channels MAPMT
- Low-power(<1mW/ch) & radiation hardened
- Co-designed by LAL/JAXA/RIKEN

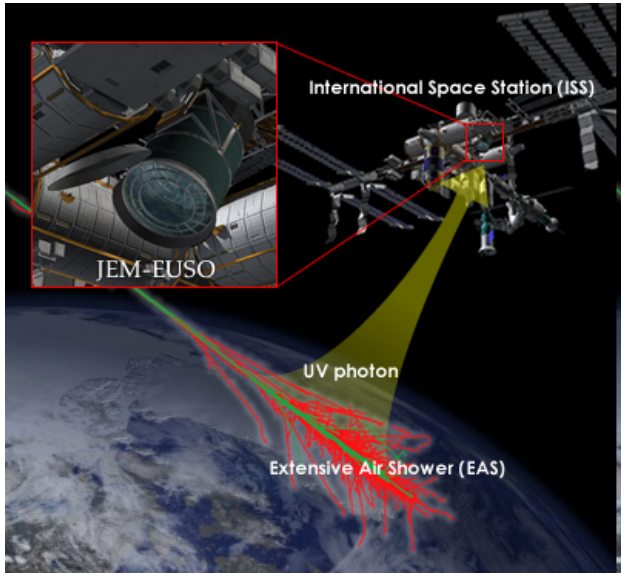


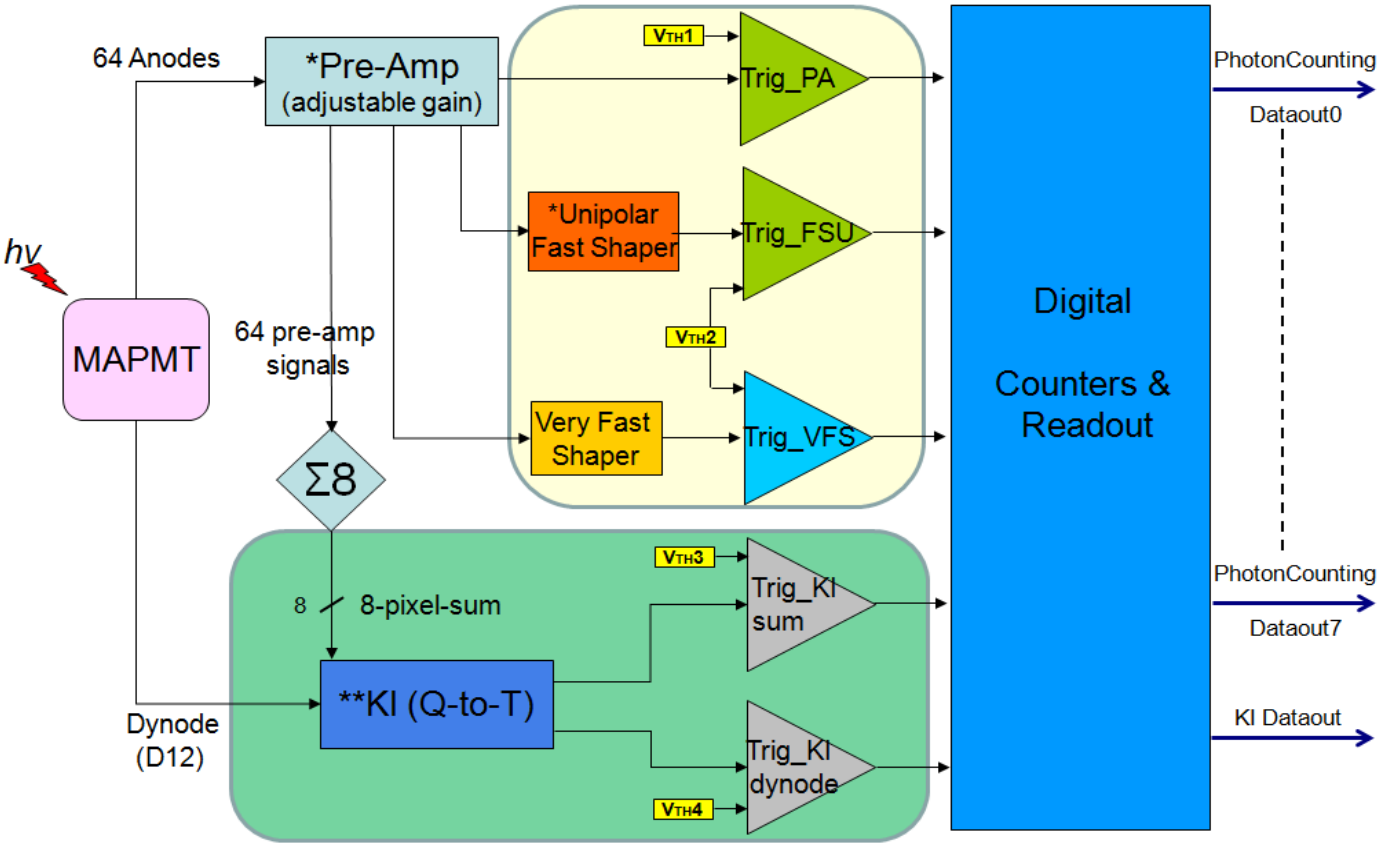
JEM-EUSO :

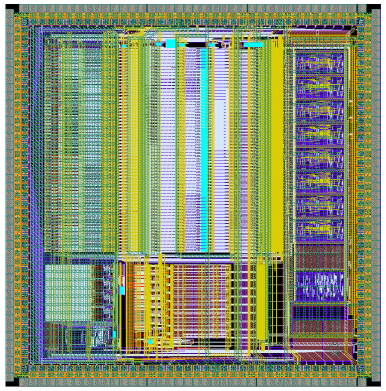
• Extremely High Energy Cosmic Ray(EECR) observer onboard of International Space Station
• Observing extensive air shower created by the EECRs

EUSO-BALLOON :

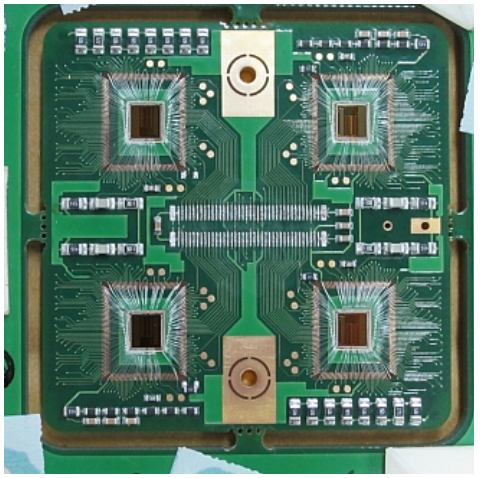
• A prototype (1 PDM) with electronics and mechanics as close as possible to the one of JEM-EUSO
• Project CNES + IRAP (Toulouse), APC and LAL supported by the whole JEM-EUSO collaboration
• Goal:
  - Launch in 2014
  - Technological demonstrator (PDM + software)
  - Study of the background
  - Tests of the DAQ and the algorithms (trigger et switch)
  - Detection of an atmospheric shower







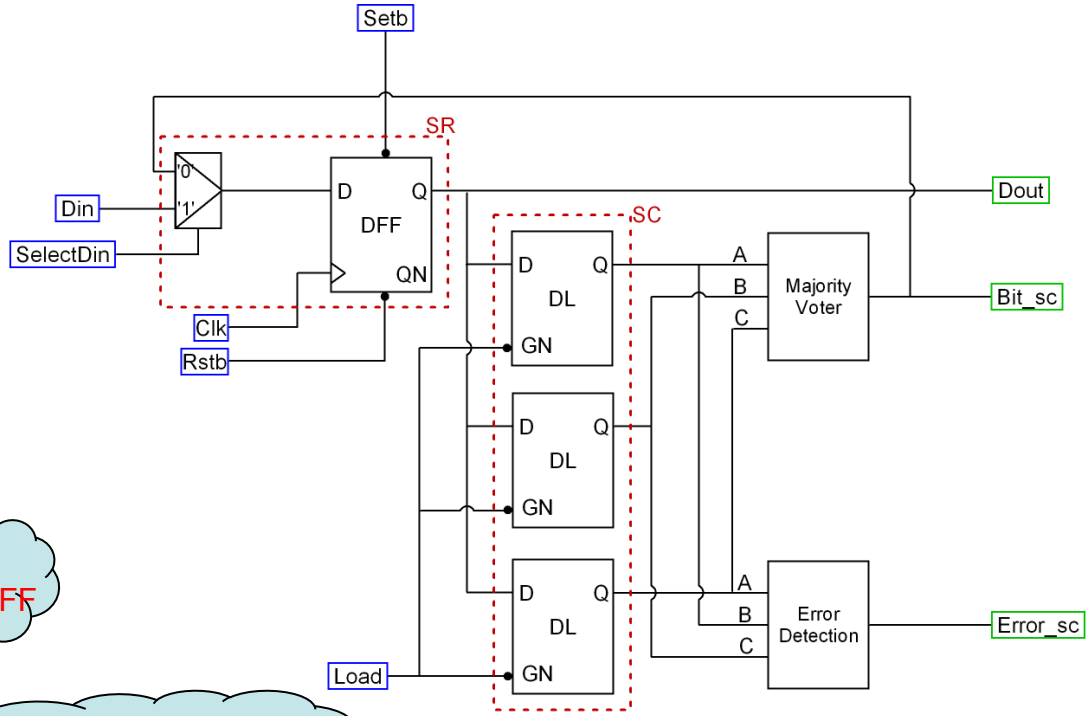
SPACIROC : 16mm²

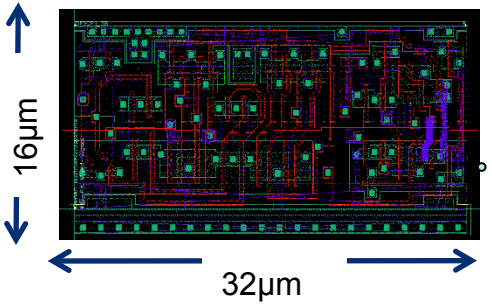


SPACIROC – Slow Control Cell

Slow control cell:

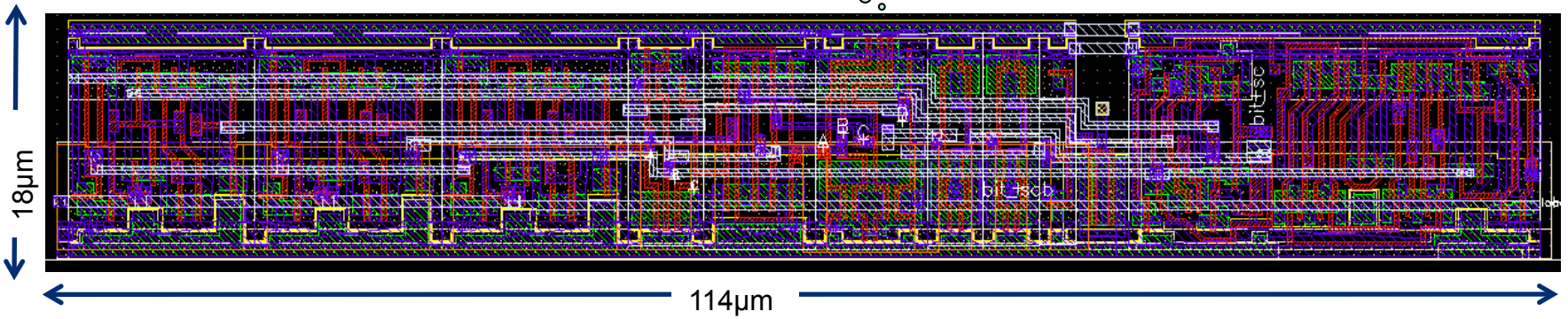
- 1 Scan DFF + triple Data latch
- Majority voter
- Bit error detection
- Non-destructive data readout
- Bigger layout : SEL protection,...



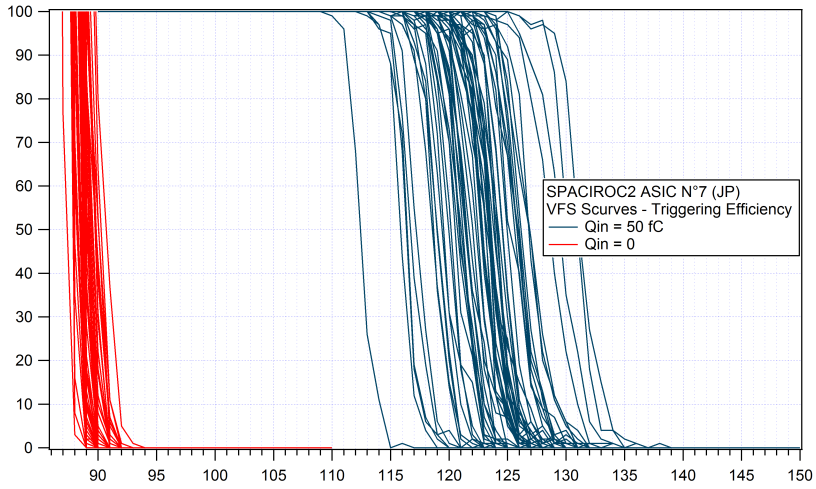


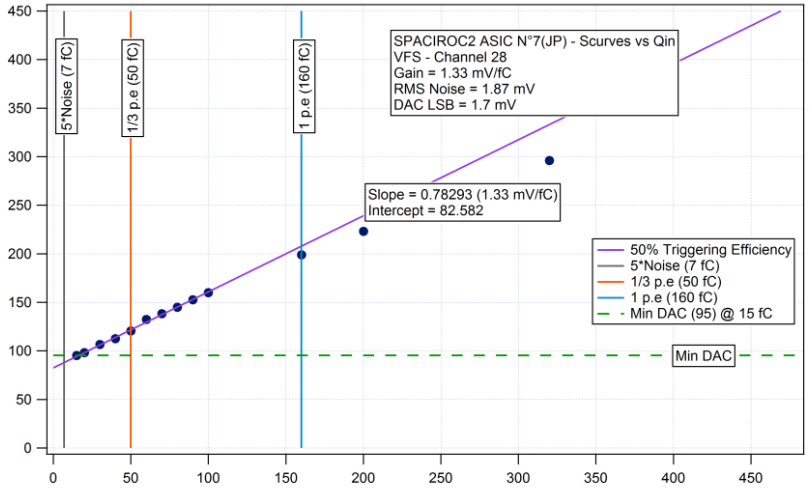
Layout Bascule DFF

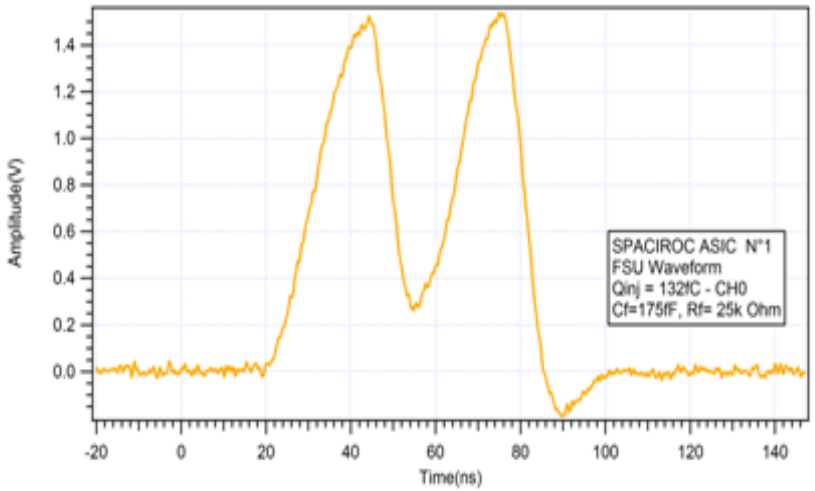
Layout Slow Control Cell Spaciroc

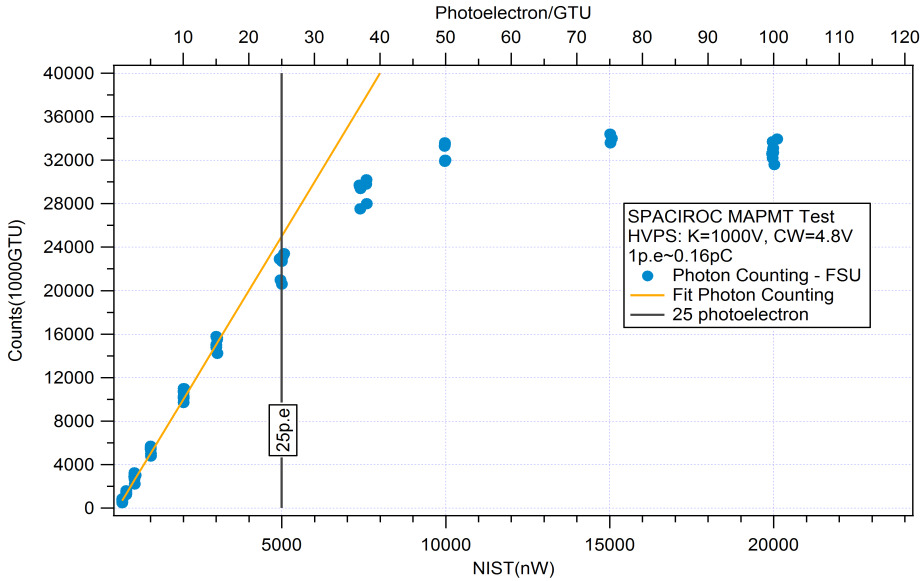


SPACIROC2 measurements



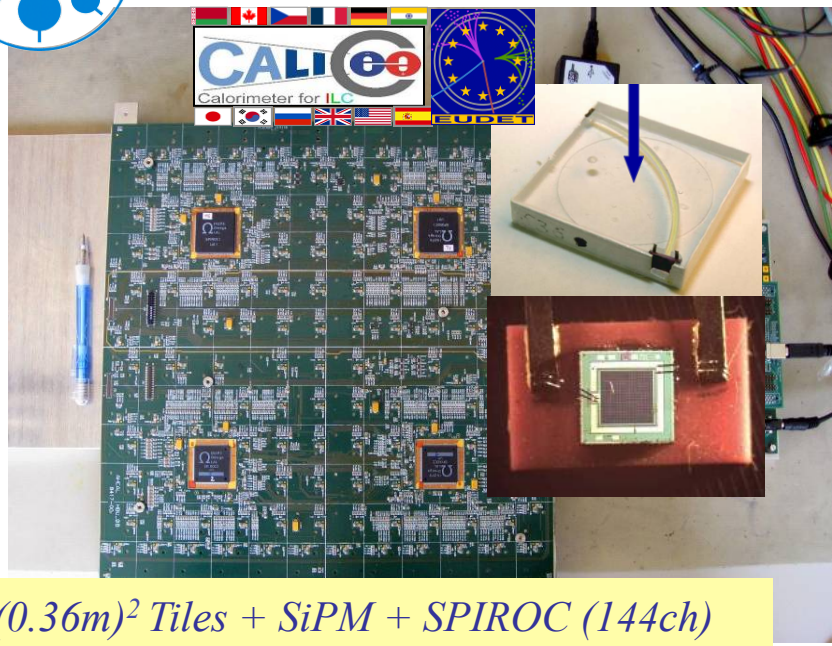






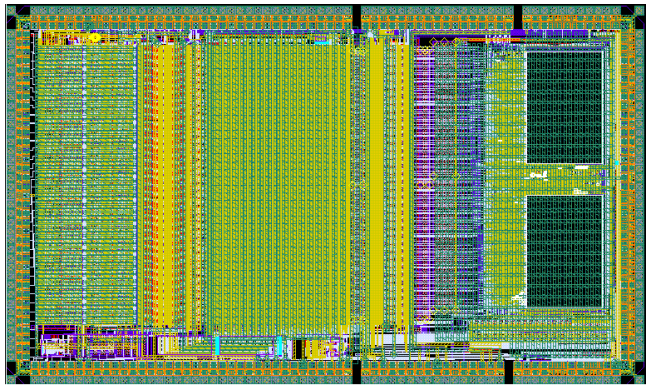
SPIROC for SiPM readout

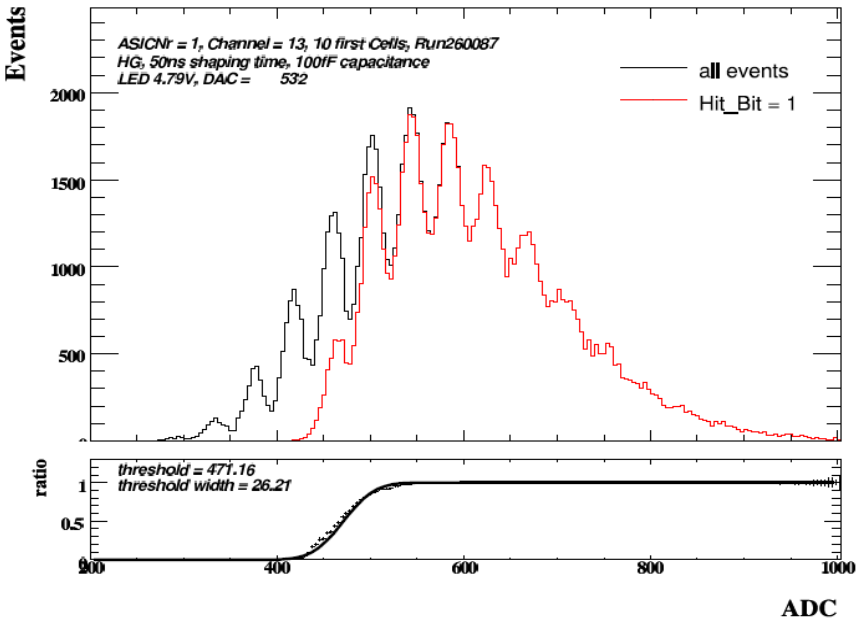
- SPIROC : Silicon Photomultiplier Integrated
- Readout Chip
  - Developed to read out the analog hadronic calorimeter for CALICE (ILC)
  - DESY collaboration (EUDET project)
  - Chip embedded in detector : low power !



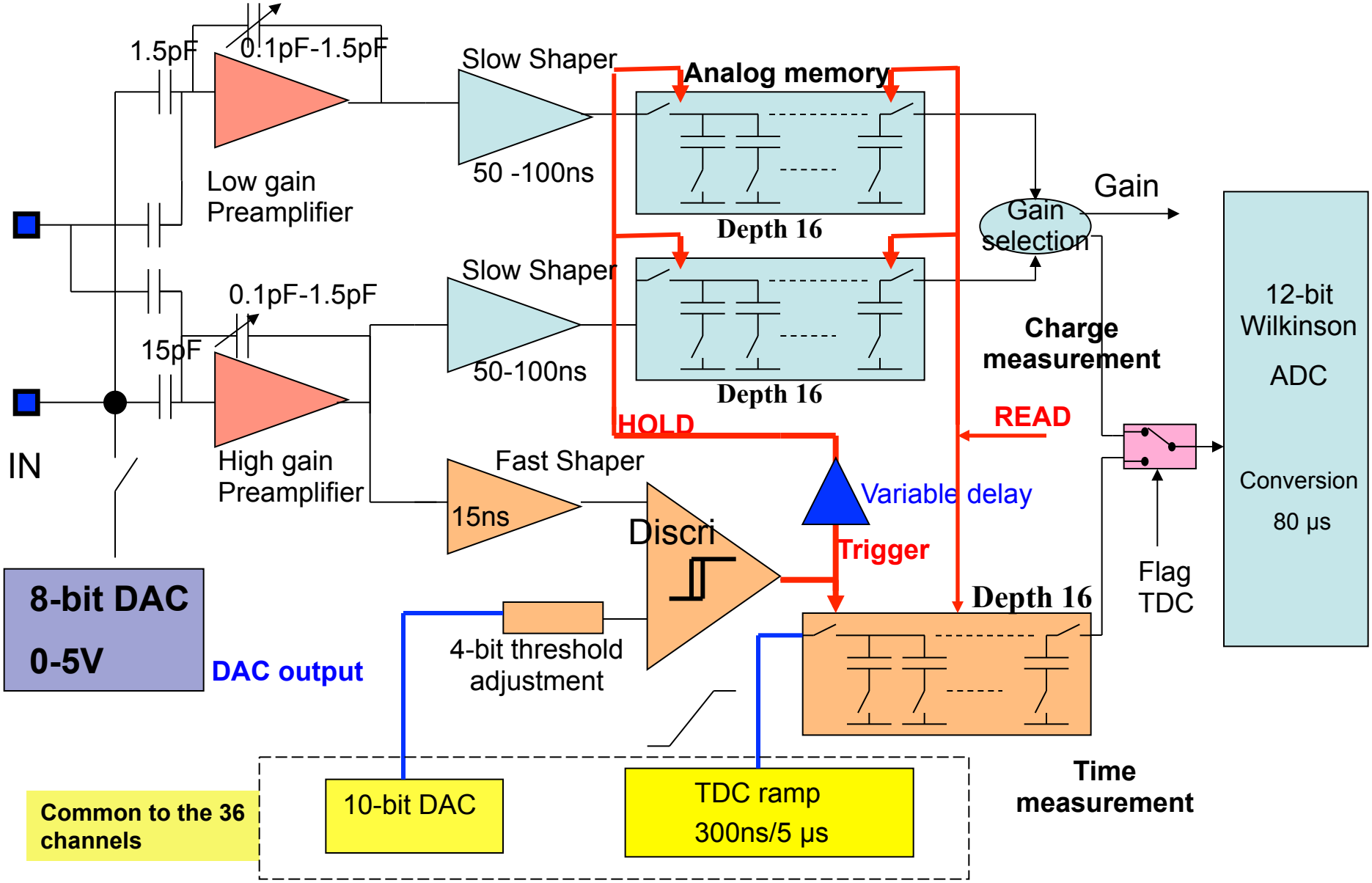
(0.36m)² Tiles + SiPM + SPIROC (144ch)

- 36 channels autotrigger 15bit readout
  - Energy measurement : 15 bits in 2 gains
  - Autotrigger down to ½ p.e.
  - Time measurement to ~1ns
  - Power dissipation : 25µW/ch (power pulsed



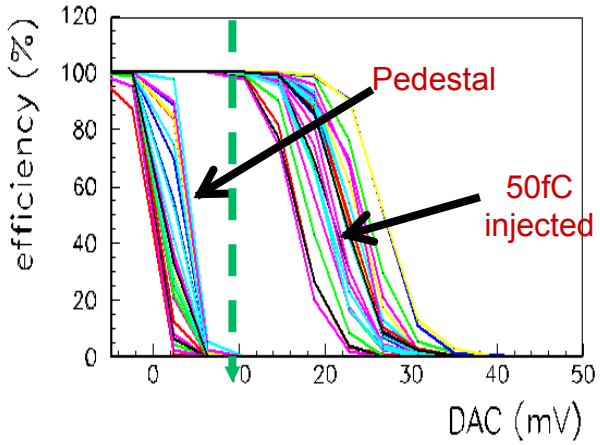


SPIROC : One channel schematic

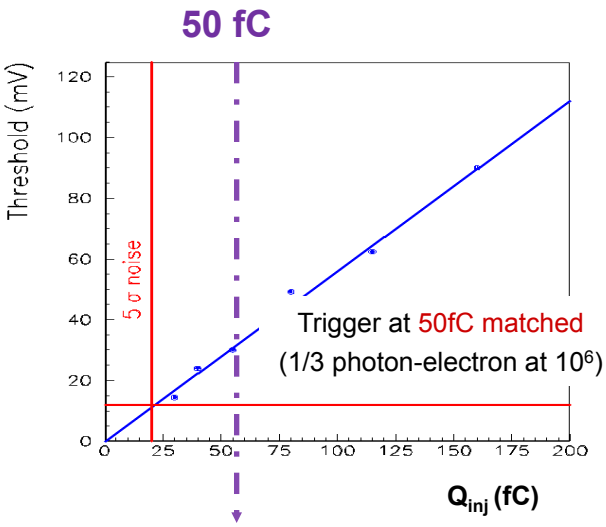


SPIROC measurments

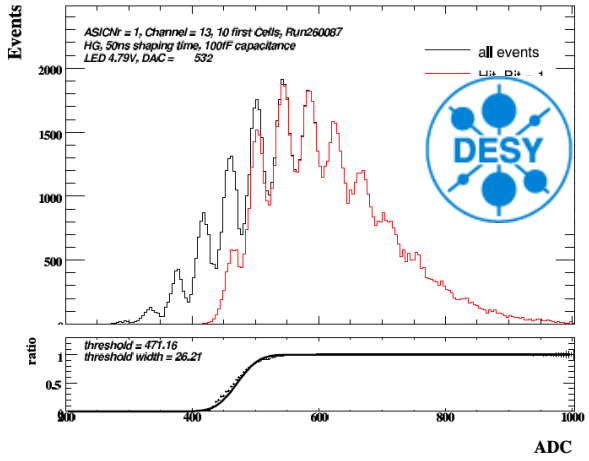
36-channel S-curves: trigger efficiency versus threshold (1 LSB = 2 mV)



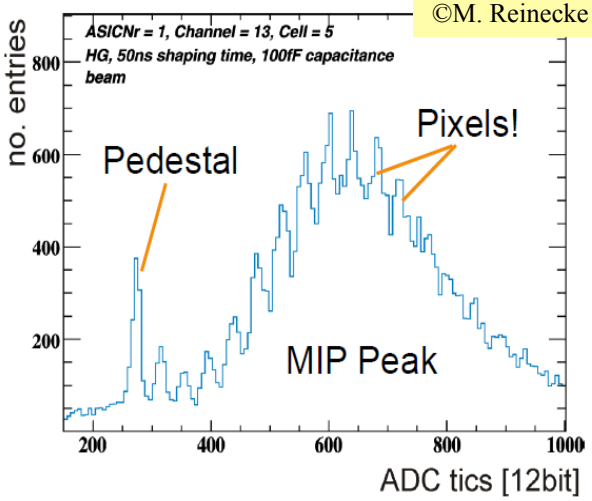
50 % Trigger efficiency point vs Q_{inj}



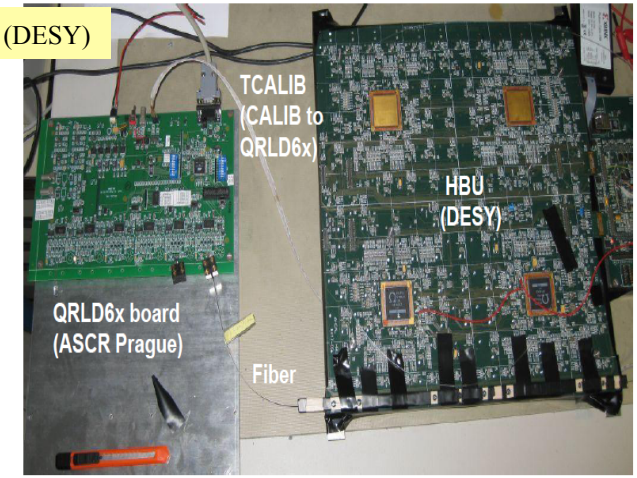
SiPM SPECTRUM with Autotrigger



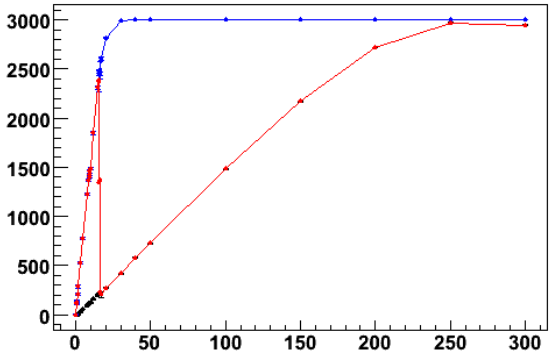
MIP response in DESY 6 GeV electron testbeam



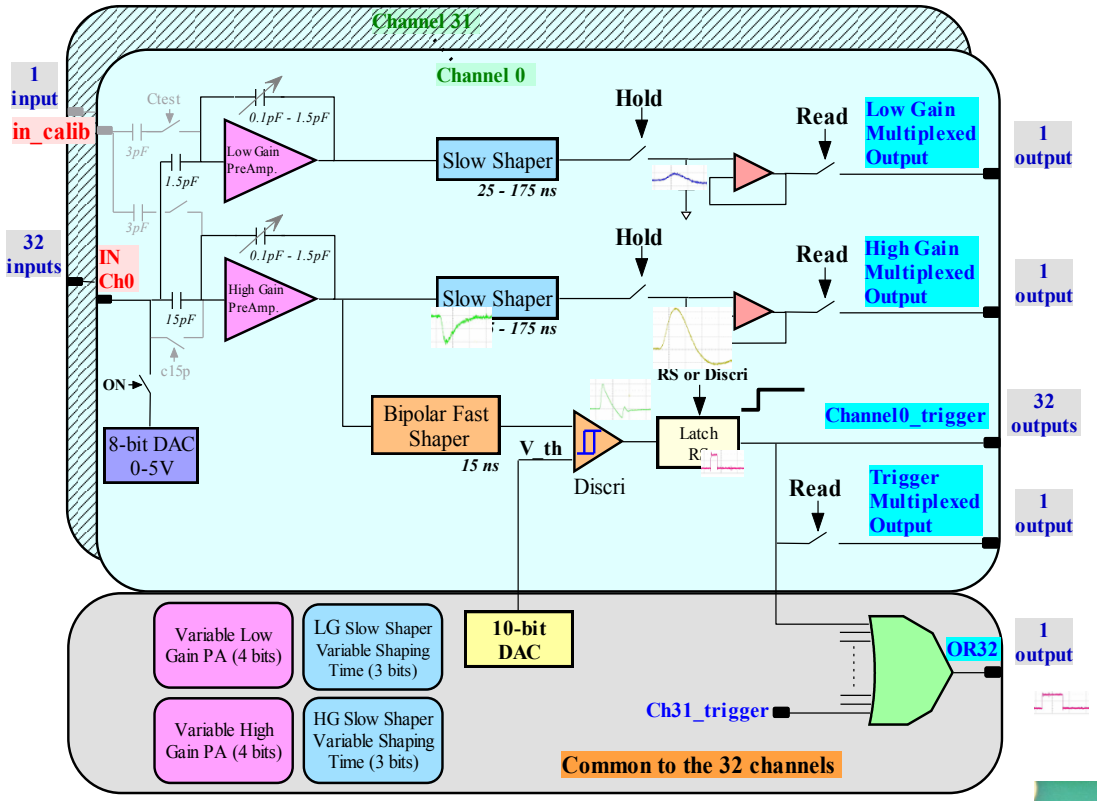
©M. Reinecke (DESY)



linearity using the auto gain mode and internal ADC

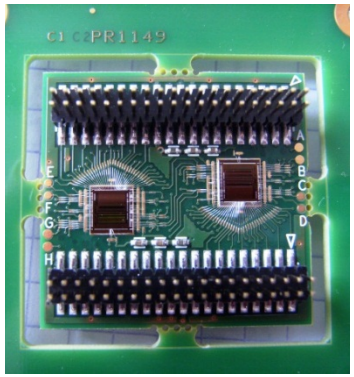


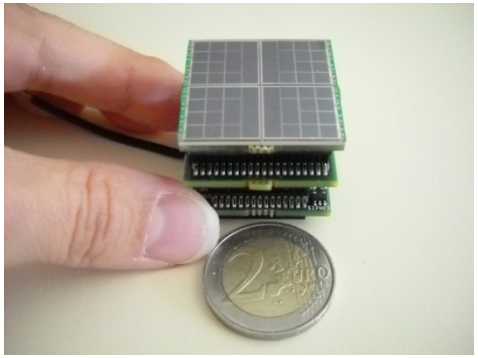
EASIROC: SIMPLER VERSION OF SPIROC



- 32-channel front-end readout (analogue part of SPIROC)
  - 2 multiplexed analog outputs (high gain, low gain) [tri state outputs]
- Trigger output
  - 32 Trigger outputs
  - OR32 output
  - Trigger multiplexed output (latch included) [Tri state output]
- Low power : 4.84 mW/channel, 155 mW/chip

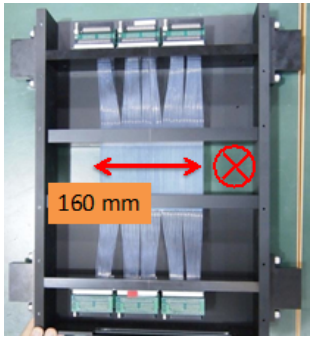
SipMed, IMNC, LAL, OMEGA





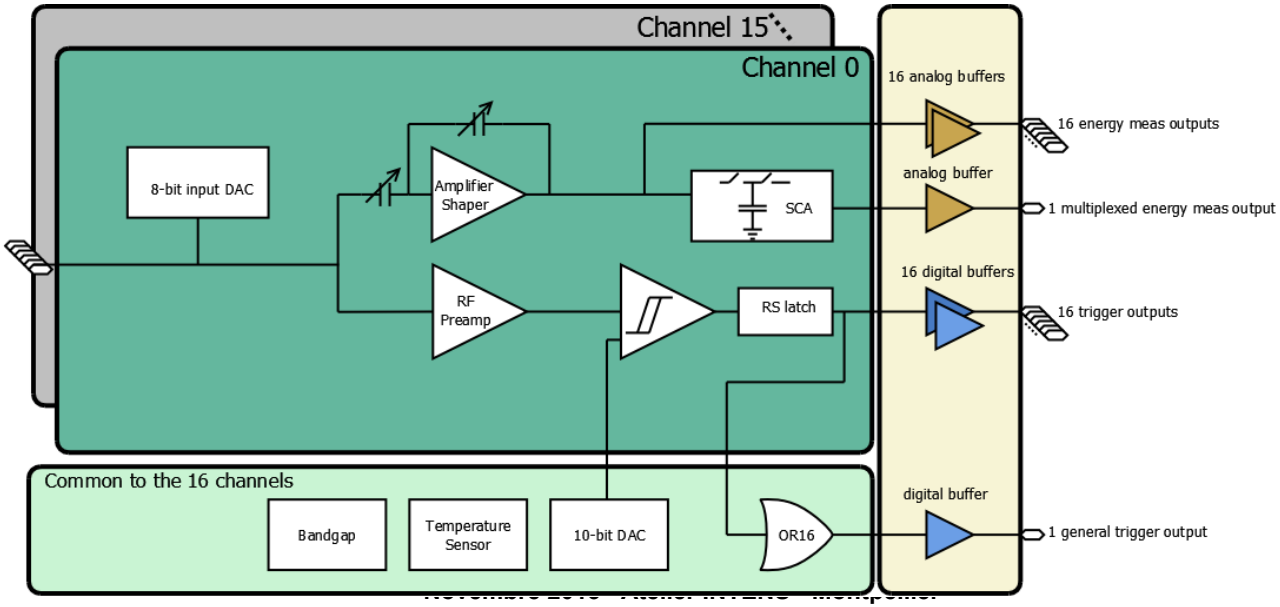
Many applications:

- Astrophysics (CTA Palermo),
- Nuclear physics (KEK, Tohoku),
- PET (Roma, Pisa, Valencia),
- Vulcanology (Napoli, IPN Lyon)

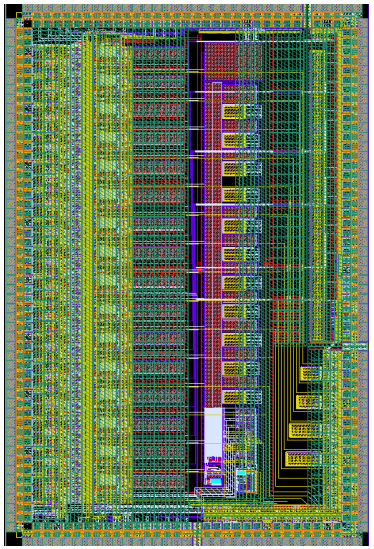


JPARC

- 16 channels, prototyping ASIC
- 16 discriminator output, 16 charge output, MUX charge output, Trigger OR
- Power consumption 3.5mW/ch
- RF, common emitter SiGe fast amplifier, DC coupled to detector, GBWP 10GHz@1mW
- Fast SiGe discriminator, BW 1GHz @ 1.5mW
- Low noise amp+shaper for charge measurement
  - Adjustable peaking time (25ns, 50ns, 75ns, 100ns)
  - Low gain for high swing (up to 3000pe) : 360uV/pe

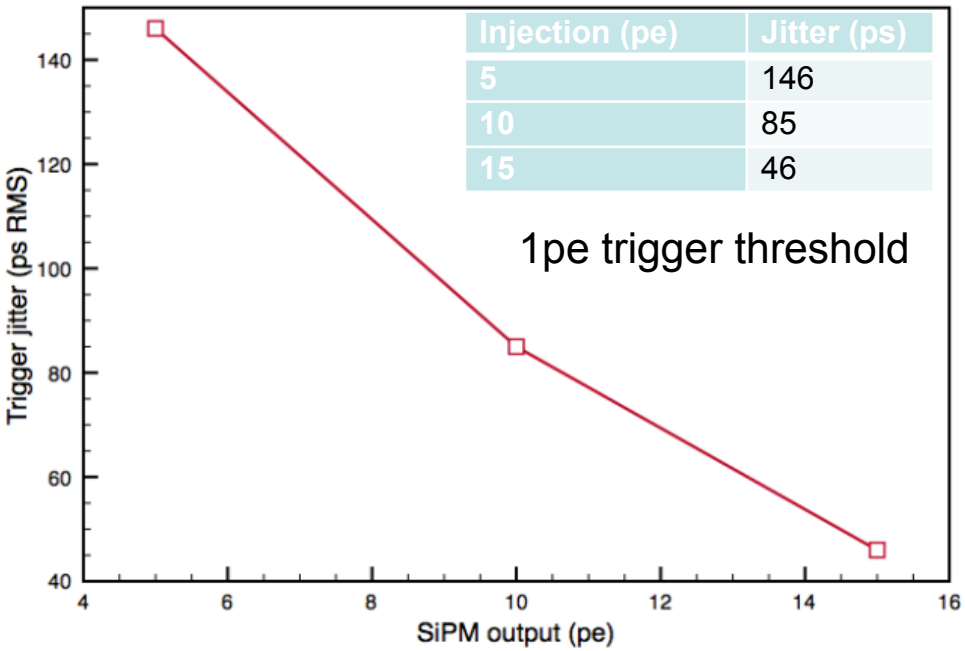


weeroc



PETIROC measurements with SiPM

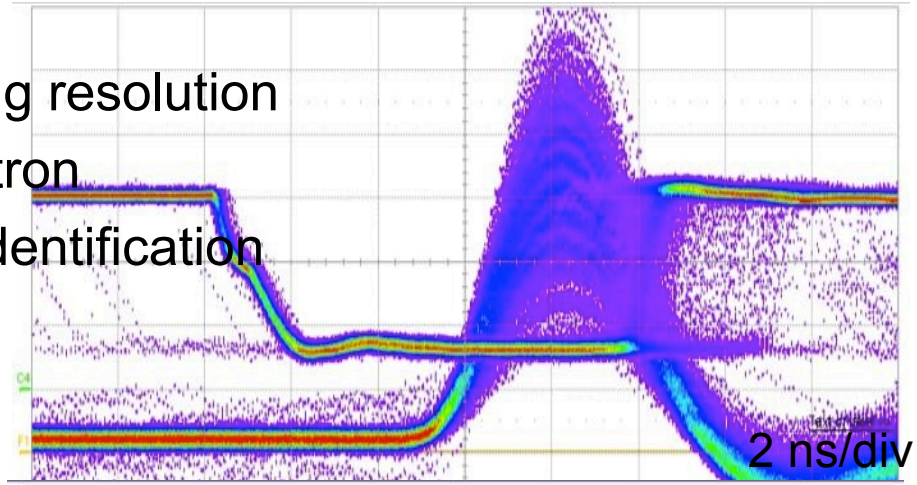
- 1x1mm SiPM Hamamatsu,
- Laser for low light injection
  - 405nm, Jitter : 28 ps FWMH
- Low trigger mandatory for good timing resolution
- Petiroc can trigger on first photoelectron
- Petiroc is low noise : single photon identification



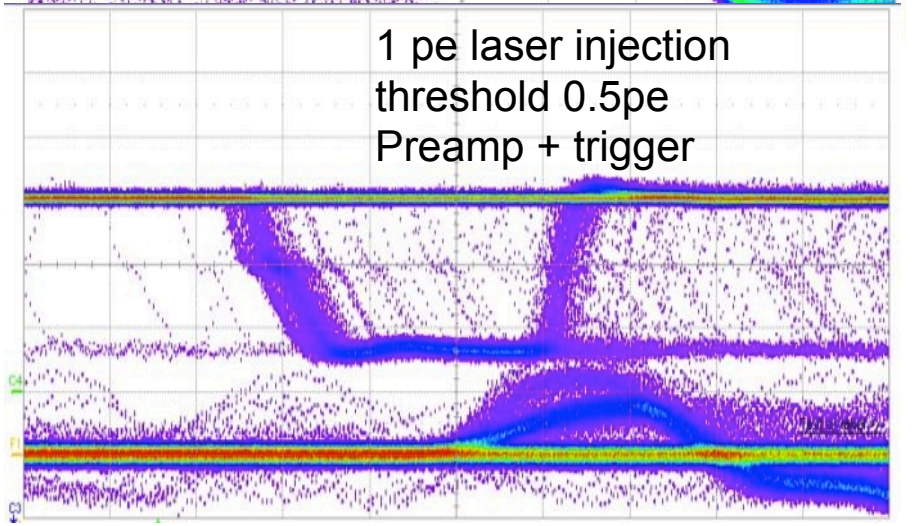
Injection (pe)	Jitter (ps)
5	146
10	85
15	46

1pe trigger threshold

10 pe laser injection
preamp out



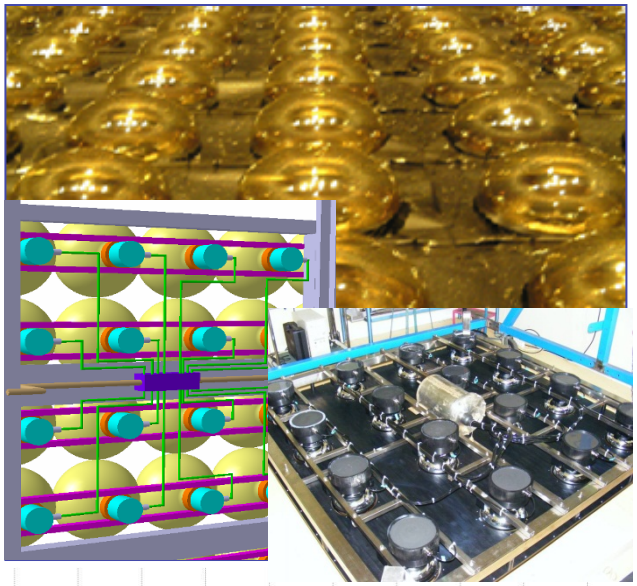
1 pe laser injection
threshold 0.5pe
Preamp + trigger



2 ns/div

PARiSROC for PMm²

- Photomultiplier ARray Integrated SiGe Read-Out Chip
  - Replace large PMTs by arrays of smaller ones (PMm2 project)
  - Centralized ASIC 16 independent channels
  - Auto-trigger at 1/3 p.e.
  - Charge and time measurement (10-12 bits)
  - Water tight, common high voltage
  - Data driven : « One wire out »



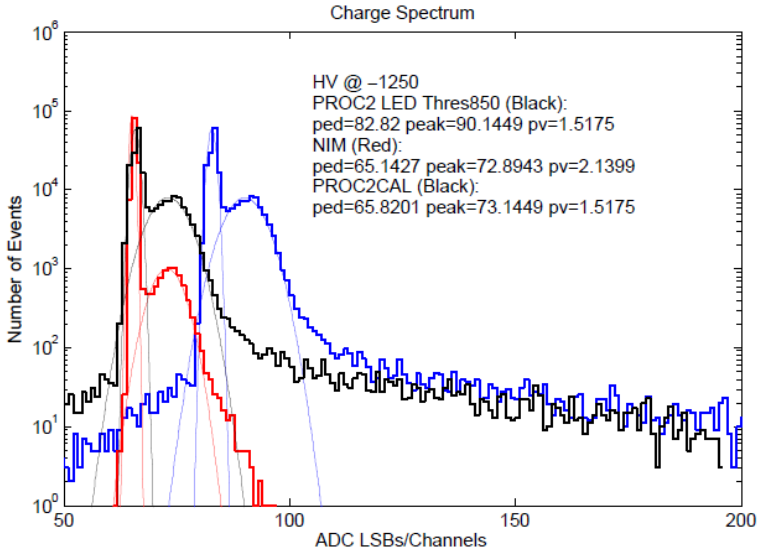
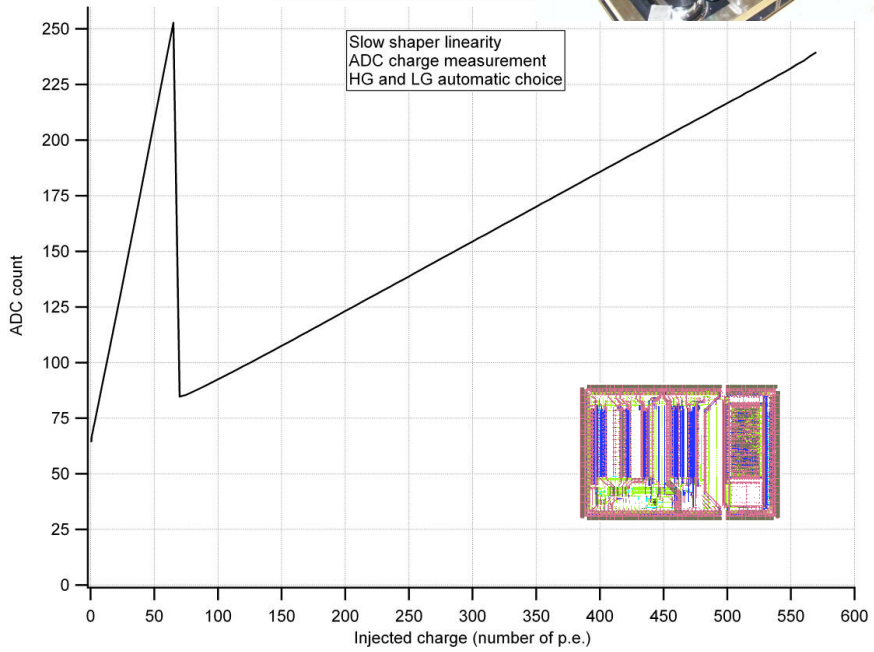
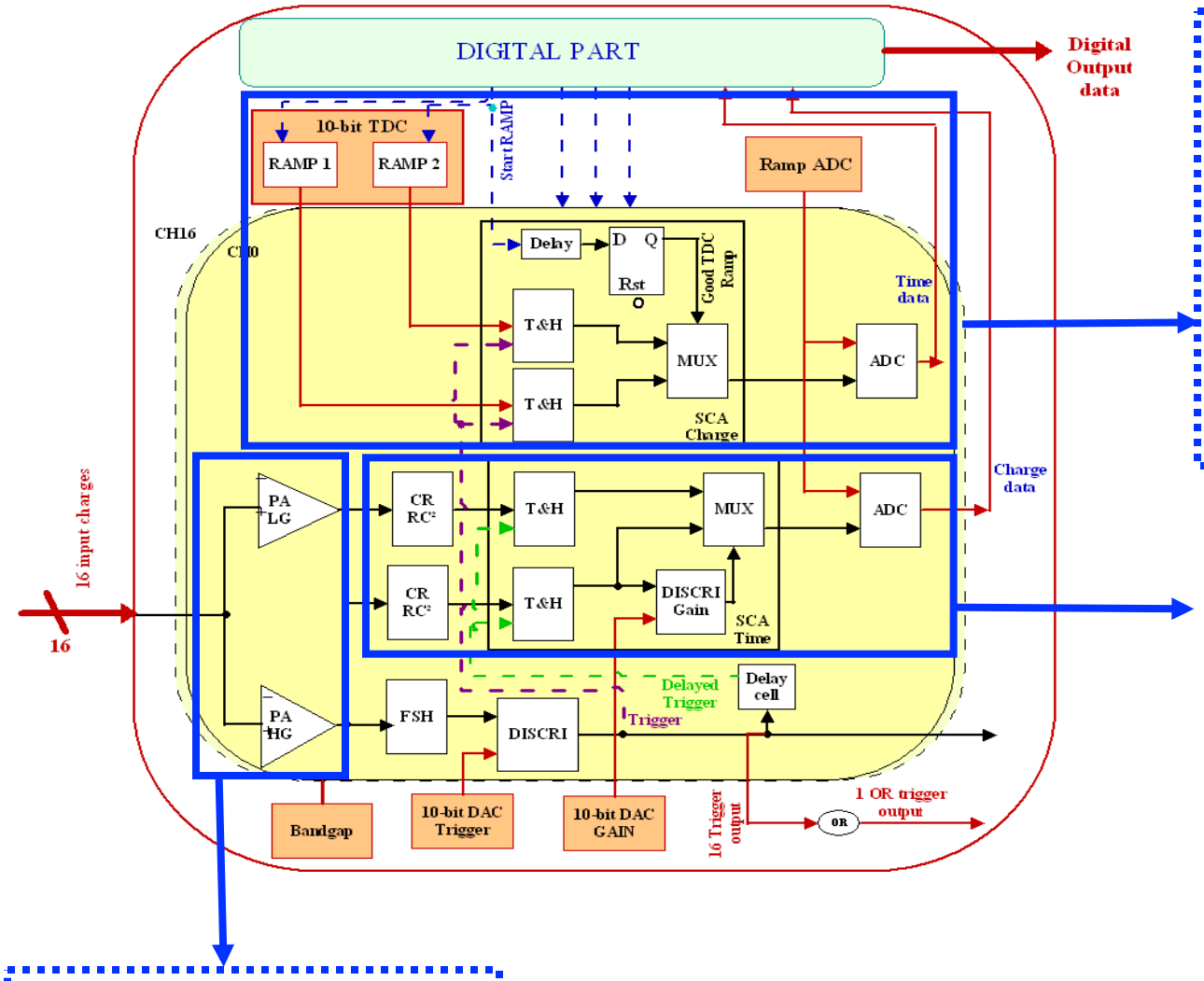


Figure 3.3.4: The calibrated of diff[illegible]



PARISROC: System On Chip



Time measurements

2 systems:

1. Coarse time by 24-bit gray counter (Digital part)
   - working at 10 MHz
   - with 1.67 s of dynamic
   - 100 ns steps
2. Fine time by analog TDC
   - ✓ 100 ns dynamic range
   - ✓ Time resolution: 220 ps
   - ✓ Non linearity: +/- 1ns

Charge measurements

- ✓ Two gain channels to cover the large input dynamic range
- ✓ 2 input preamplifier with adjustable gains (on 8 bits)
- ✓ Shaper with variable shaping time (form 25 ns to 100 ns) and gain
- ✓ Charge resolution: max 0.2 p.e. (32 fC) for 10-bit ADC
- ✓ Dynamic range from 1/3 pe to 600 pe (~ from 50 fC to 100 pC)

Input stage

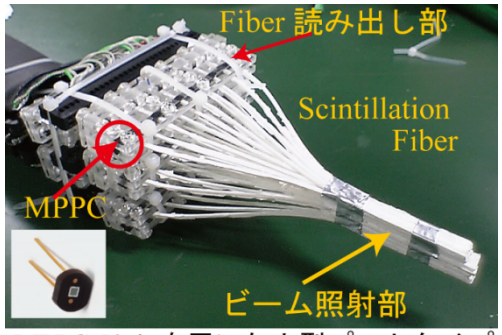
2 input preamplifiers with adjustable gains (on 8 bits)

Conclusion http://omega.in2p3.fr/ and http://weeroc.com/

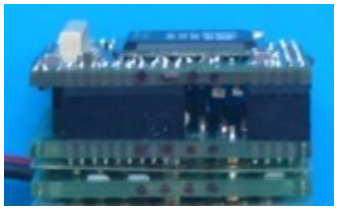
MAROC, SPACIROC , PARISROC : for PMTs

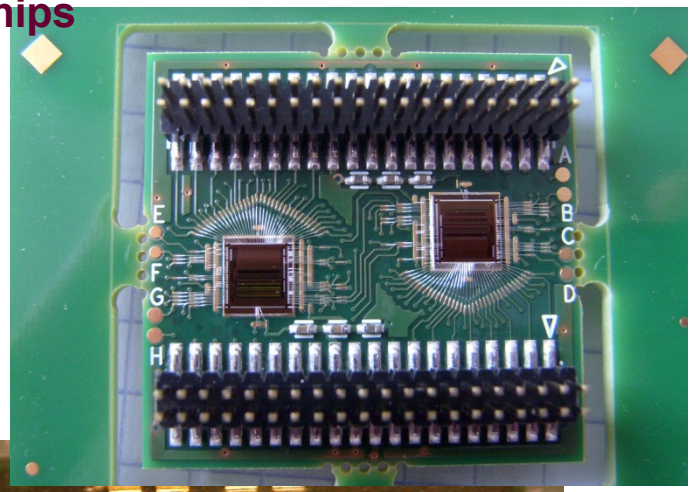
SPIROC, EASIROC for SiPM

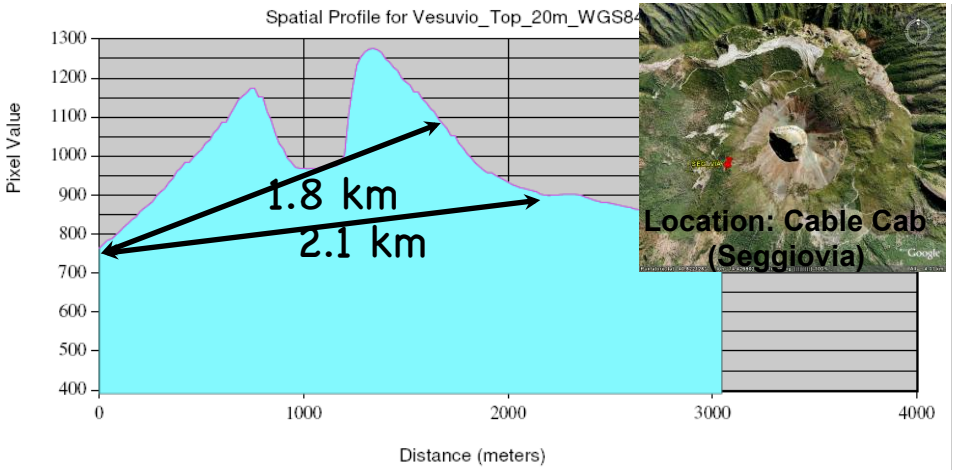
- ✓ **Low power multichannel System on Chips, smart detectors**
- ✓ **Versatility allows these chips to be used in various applications**
- ✓ **Space applications also considered for some of the chips**

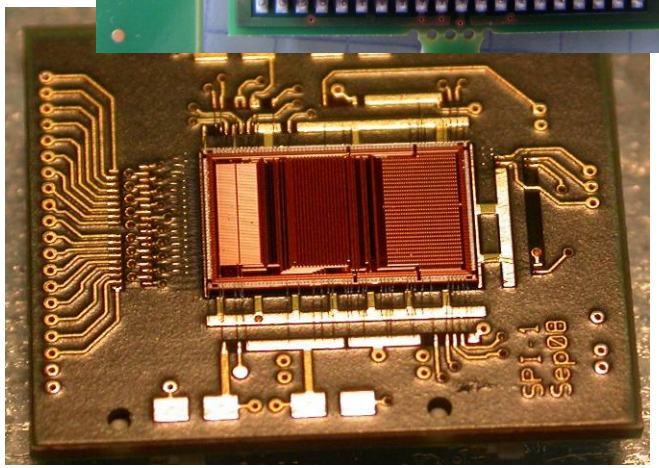


MPPC 50ch を用いた小型プロトタイプ





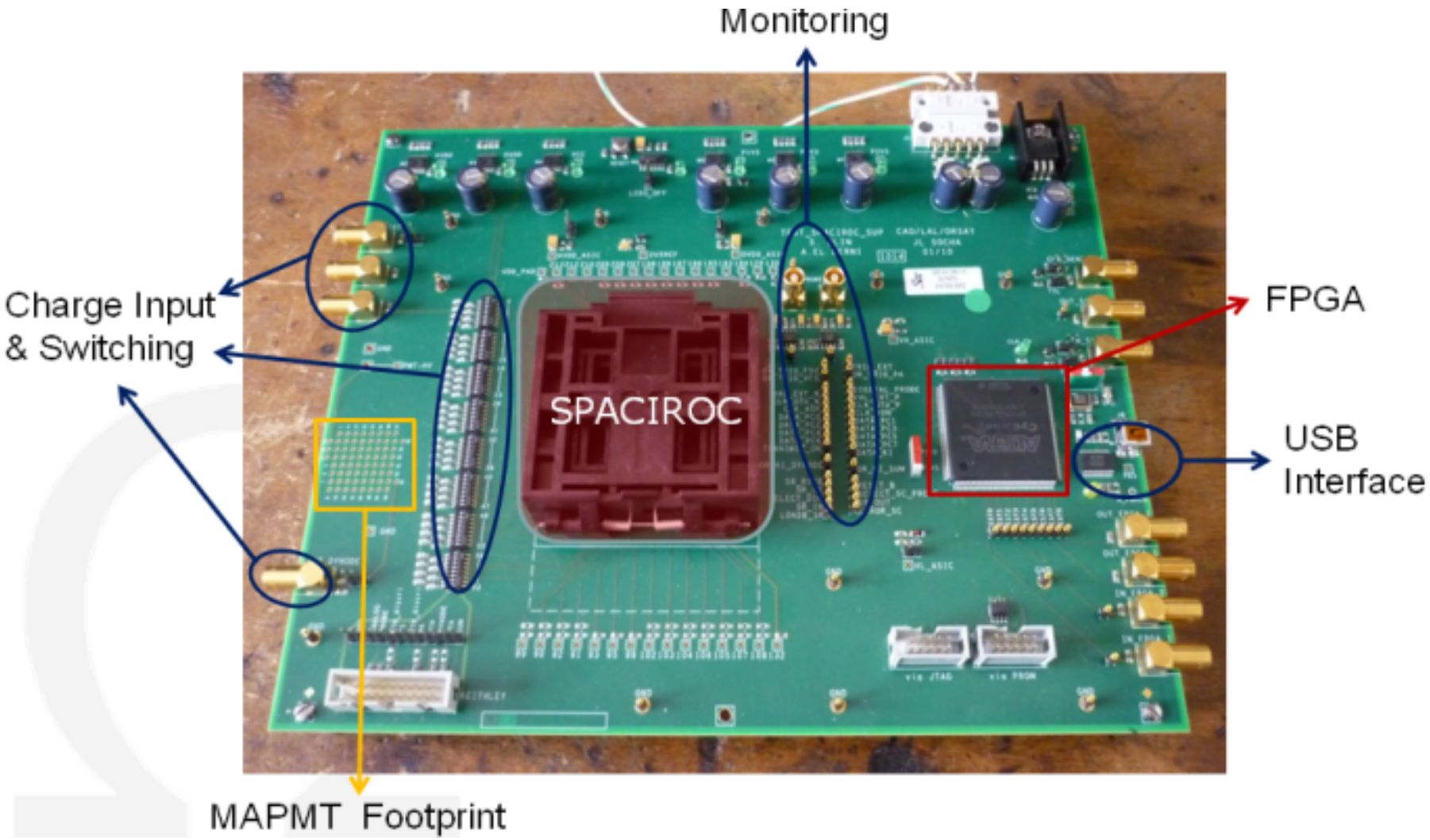




ROC family

	MAROC	SPIROC	EASIROC	HARDROC	MICROROC	SKIROC	PARISROC	SPACIROC
Technology	0.35µ SiGe	0.35µ SiGe	0.35µ SiGe	0.35µ SiGe	0.35µ SiGe	0.35µ SiGe	0.35µ SiGe	0.35µ SiGe
Packages available	•Naked •QFP240	•Naked •TQFP208	•Naked •TQFP160	•Naked •TQFP160	•Naked •QFP160	•Naked •QFP240	•Naked •QFP160	•Naked •CQFP240
Detector compliant	PMT, MAPMT, SiPM, µmegas, RPC	PMT, MAPMT, SiPM, µmegas, RPC, GEM, PIN	PMT, MAPMT, SiPM, µmegas, RPC, GEM, PIN	PMT, MAPMT, SiPM, µmegas, RPC	µmegas	RPC, GEM, PIN	PM matrix	MAPMT
Optimized for	MAPMT	SiPM	SiPM	RPC	µmegas	PIN	PM matrix	MAPMT
Nmber of channels	64	36	32	64	64	64	16	64
Kind of measurement	•Threshold •Charge	•Threshold •Charge •Time	•Threshold •Charge	•Threshold •Charge	•Threshold •Charge	•Threshold •Charge	•Threshold •Charge •Time	•Threshold •Charge
Outputs	64 triggers, 1 mux charge (analogue), 1 mux charge digitized	1 digital formatted output, 1 mux charge (analogue)	32 triggers, 2 mux charge (anlogue), 1 mux trigger	1 digital formatted output, 1 mux charge (analogue)	1 digital formatted output, 1 mux charge (analogue)	1 digital formatted output, 1 mux charge (analogue)	16 triggers, 1 digital formatted output, 1 mux trigger	64 triggers, 9 mux charge
Input Polarity	Negative	Positive	Positive	Negative	Negative	Positive	Negative	Negative

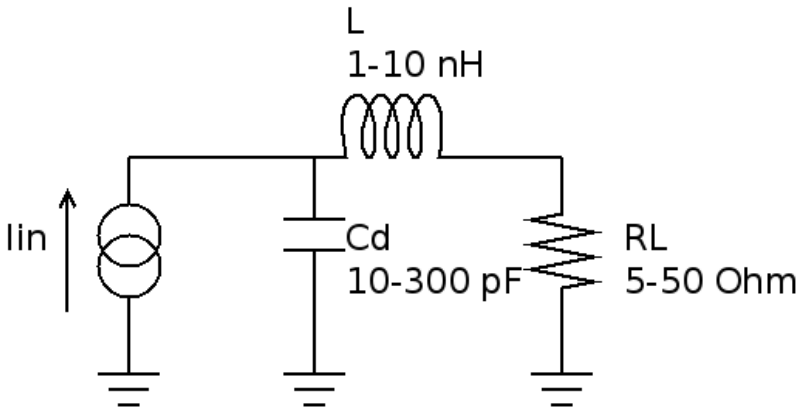
Standard testboard

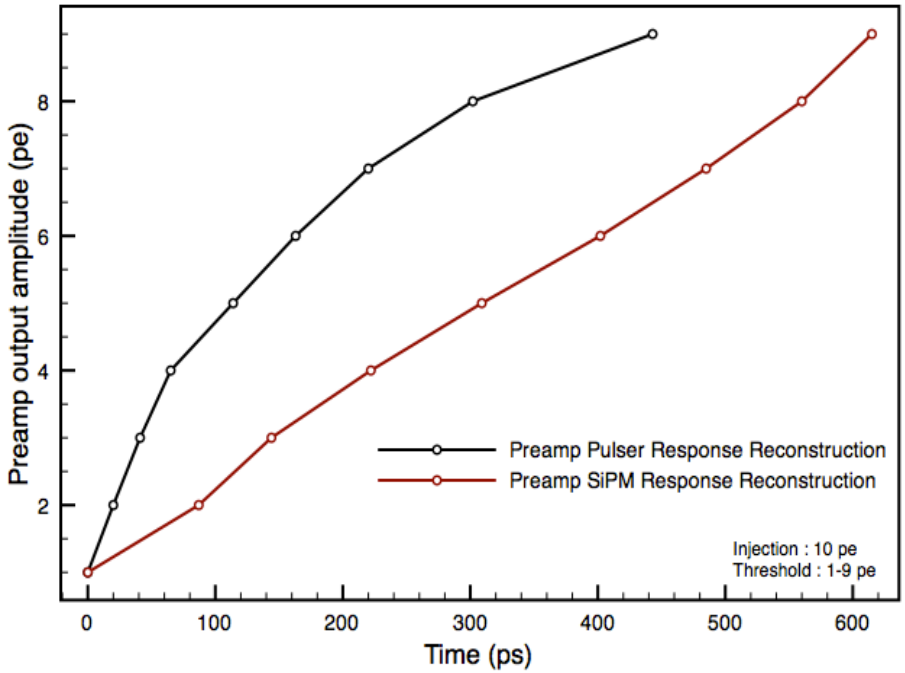


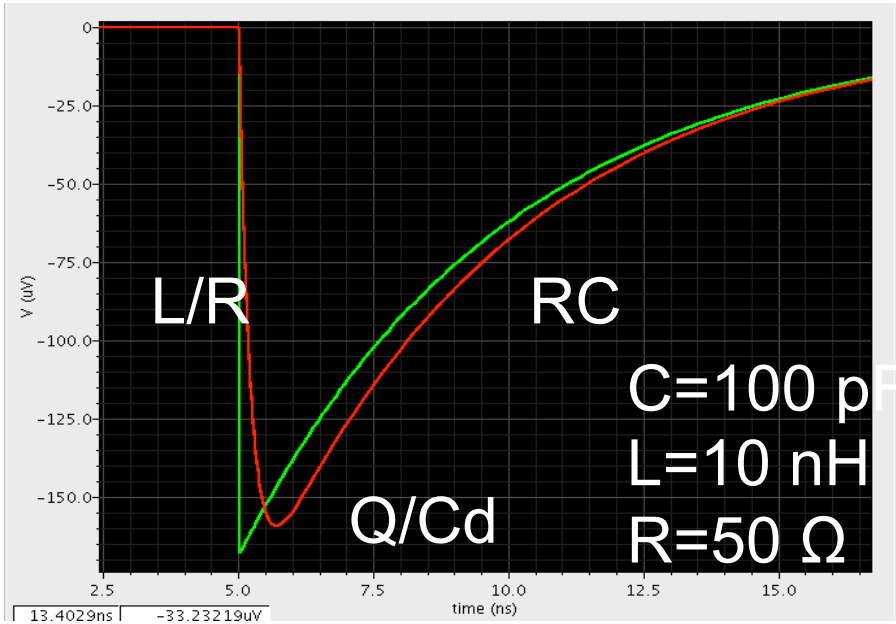
Backup slides

.

- Pulser vs SiPM comparison
- SiPM is significantly slower than Petiroc
  - Pulser with 100pF injection capacitance, 10pe injected
  - SiPM illuminated with laser pulse, 10pe measured
  - Threshold from 1pe to 9pe
- Petiroc bandwidth meas. : 877MHz with

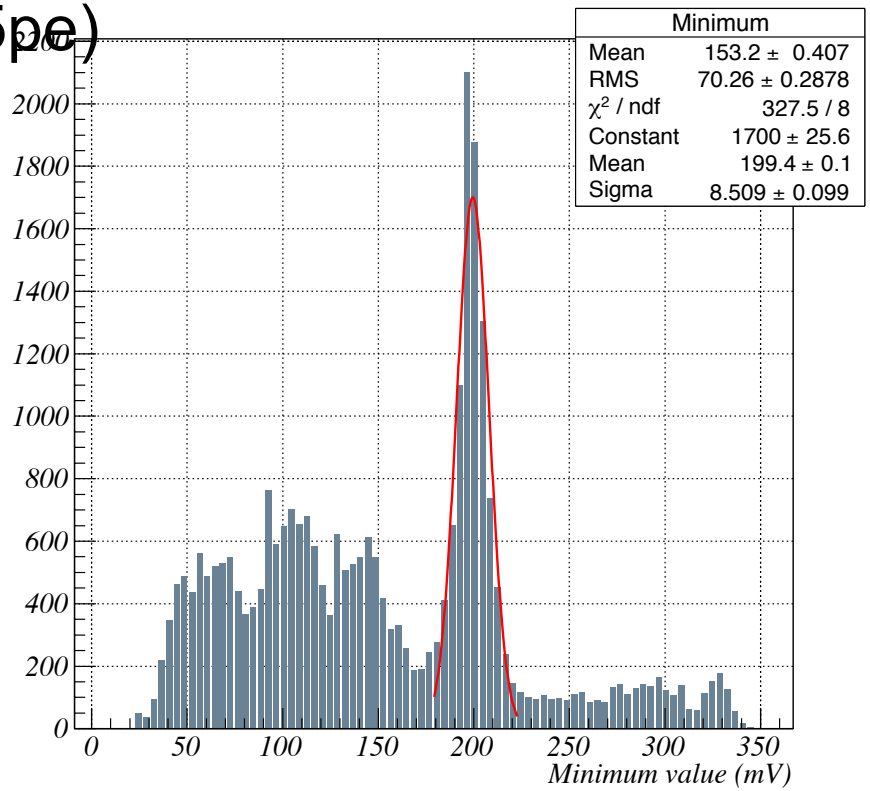






Energy resolution

- Preliminary meas, raw data, no correction for non linearities
- Using 3x3x5mm LYSO:Ce crystal & 3x3mm Ketek SiPM
- Na22 source
- Petiroc self-triggered (threshold 5pe)
- Energy resolution: 9.5% FWMH



MAROC3 trigger timing resolution

- Testpulse measurement
- Threshold : 50 fC (1.3 pe)