OMEGA presentation

IHEP visit

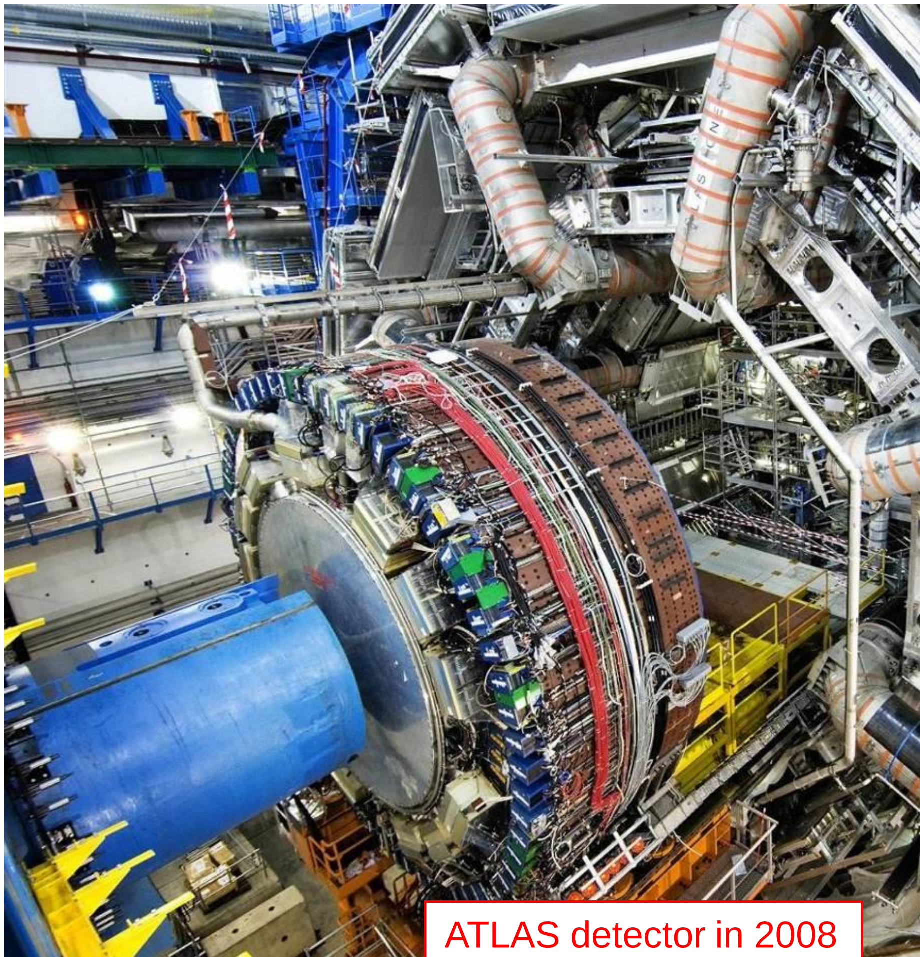
Salleh AHMAD, Sylvie BLIN, Stéphane CALLIER, Frederic DULUCQ, Julien FLEURY, Christophe de LA TAILLE,Gisèle MARTIN-CHASSARD, Ludovic RAUX Nathalie SEGUIN-MOREAU, Damien THIENPONT, Jeanne TONGBONG

OMEGA microelectronics group
Ecole Polytechnique & CNRS IN2P3
http://omega.in2p3.fr
& WEEROC SAS
http://weeroc.com

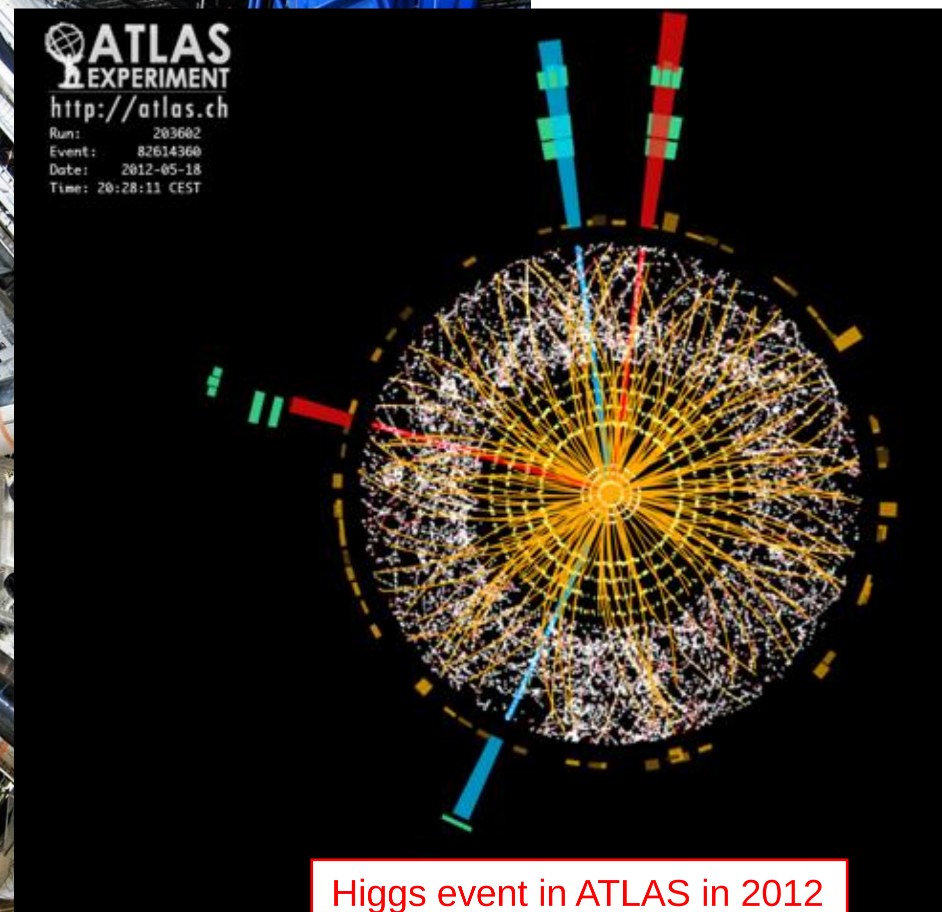
Organization for Micro-Electronics desiGn and Applications

Electronics in experiments

- A lot of electronics in the experiments…
  - The performance of electronics often impacts on the detectors
  - Analog electronics (V,A,A…) / Digital electronics (bits)



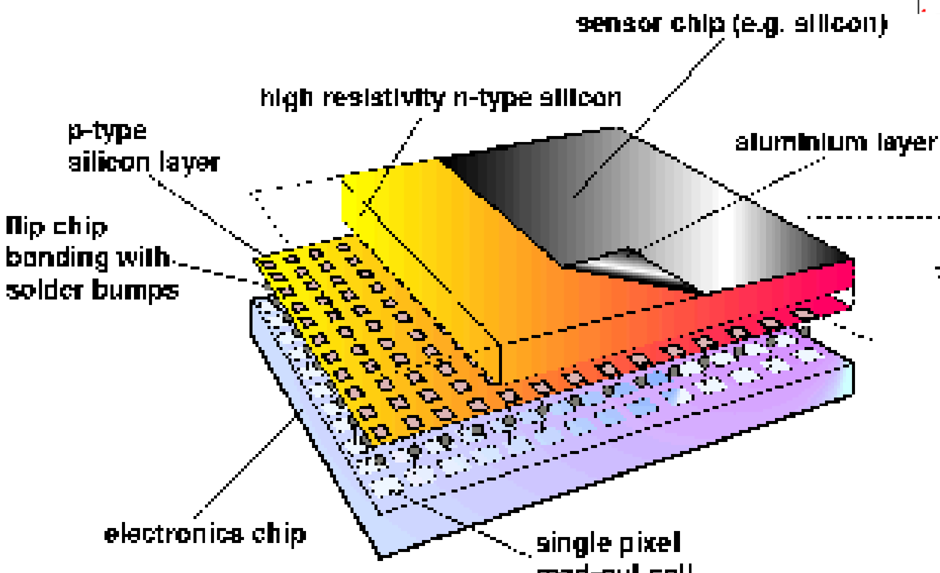
ATLAS detector in 2008



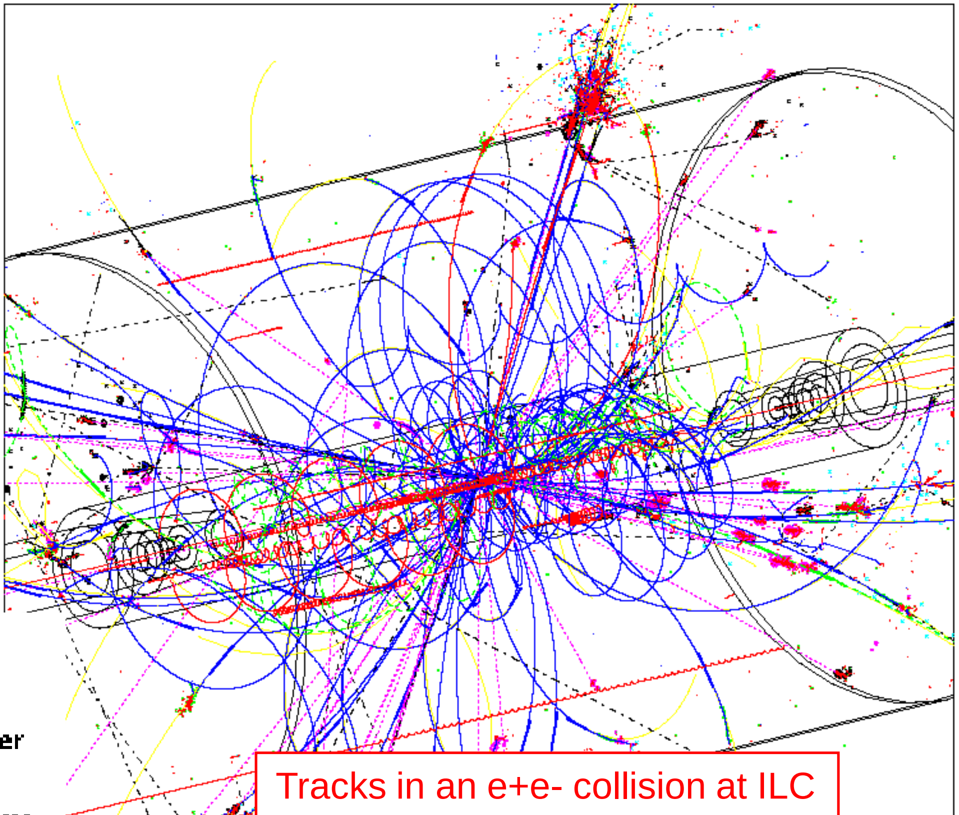
Higgs event in ATLAS in 2012

Electronics enabling new detectors : trackers

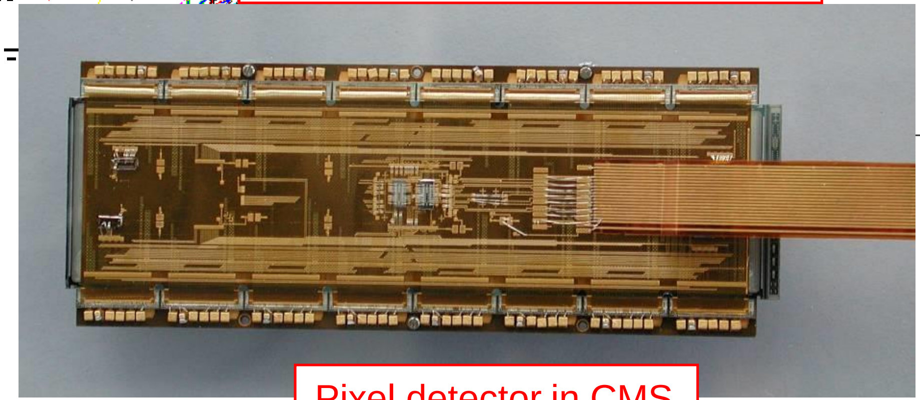
- Measurement of (charged) particle tracks
  - millions of pixels (~100 µm)
  - binary readout at 40 MHz
  - High radiation levels
  - Made possible by ASICs



Pixel detector and readout electronics



Tracks in an e+e- collision at ILC

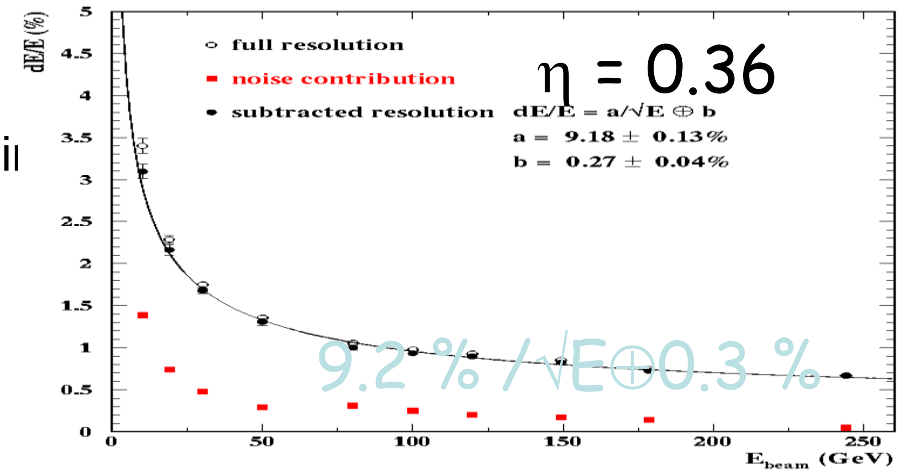


Pixel detector in CMS

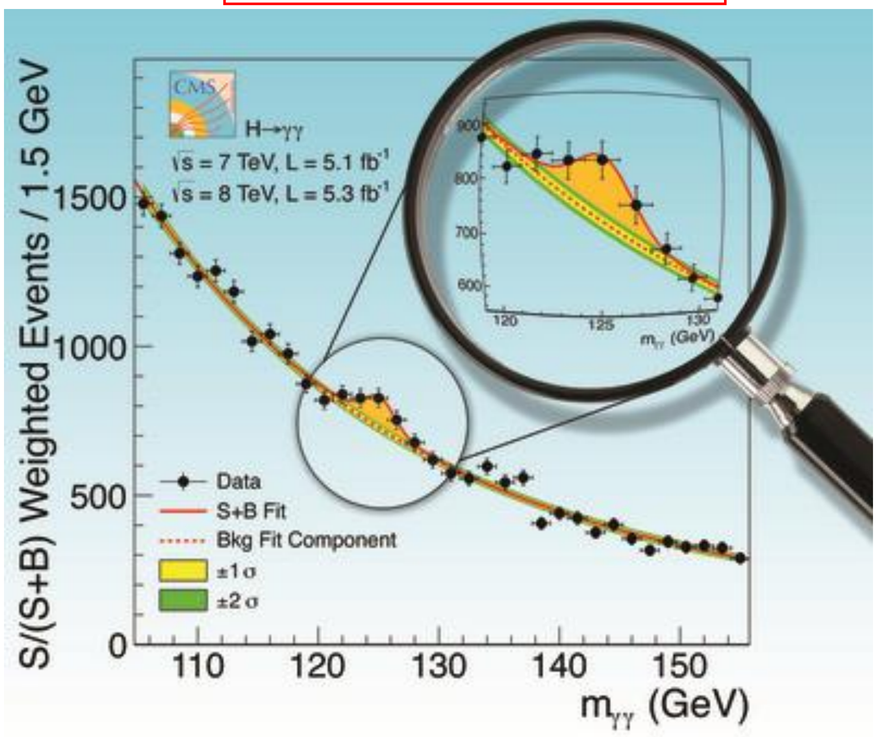
Importance of electronics : calorimeters

Ωmega

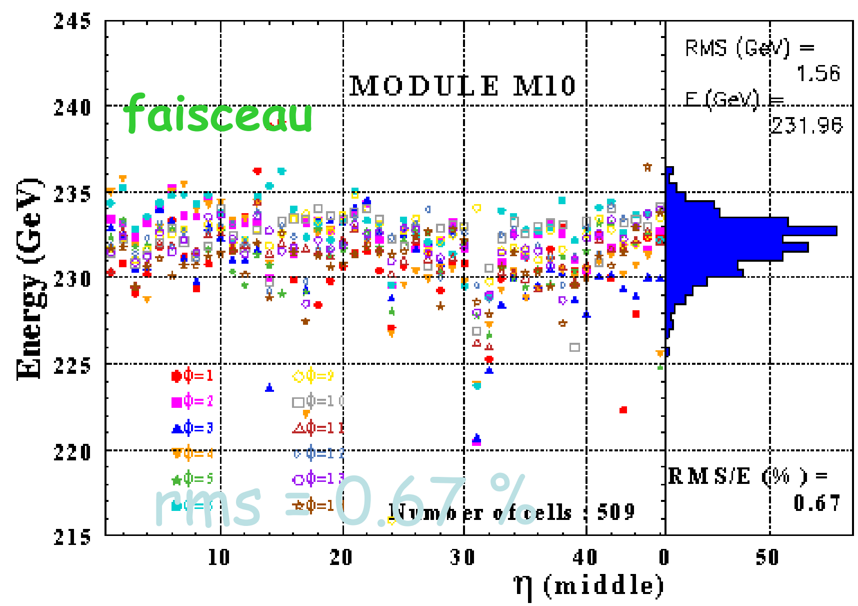
- Large dynamic range (10^4-10^5)
- High Precision ~1%
  - Importance of low noise, uniformity, li
  - Importance of calibration



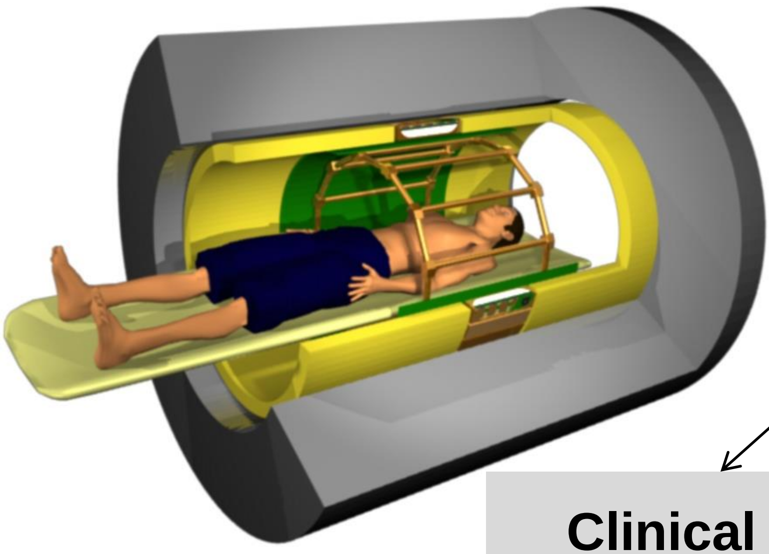
H -> γ γ in CMS calorimeter



Energy resolution and uniformity in ATLAS



Societal applications : PET



PET Ring / Scanner

Clinical PET
(Whole Body PET)

Preclinical PET
(Animal PET)

- For humans

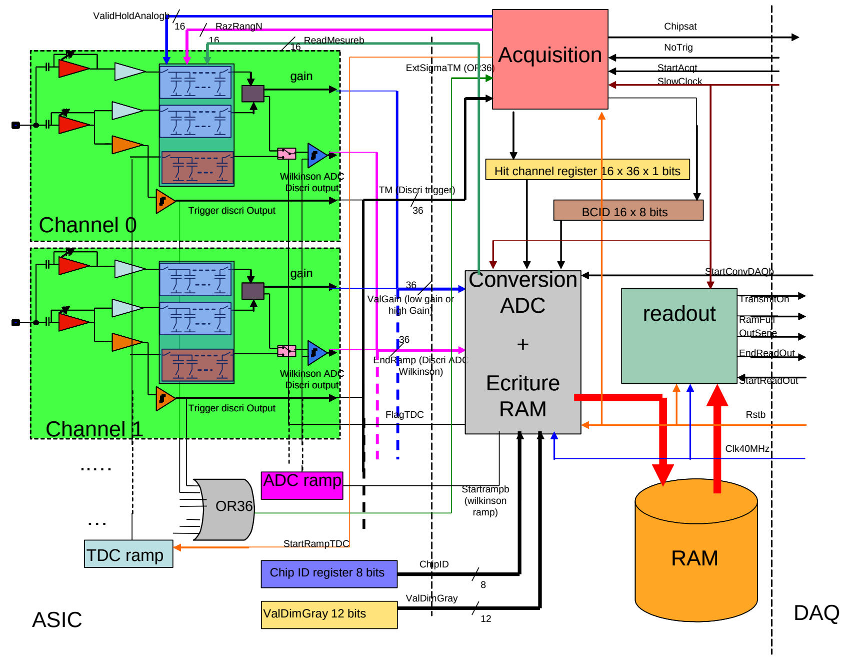
- large diameter FOV (>60 cm)
- spatial resolution: **few mm**
- time resolution CRT< **400 ps** for ToF
- high sensitivity (low dose) ➔ large area
- high total data rate

- For mice, rats, rabbits (& human brain)

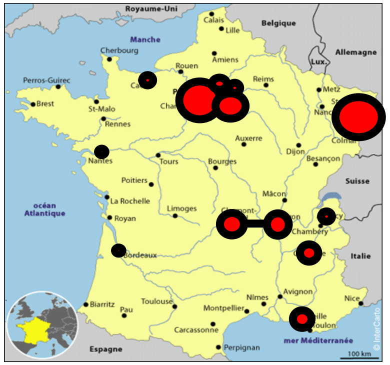
- Small diameter FOV (4-15 cm)
- spatial resolution: **< 1 mm**
- time resolution only for coinc. (few ns)
- medium sensitivity
- Depth - of - Interaction desirable to fight parallax effect

« Microelectronics poles »

- Motivation :
  - Continuous increase of chip complexity (SoC, 3D…)
  - Minimize interface problems
- Importance of critical mass
  - Daily contacts and discussions between designers
  - Sharing of well proven blocks
  - Cross fertilization of different projects

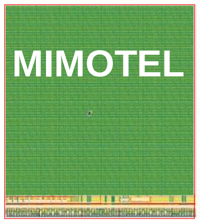


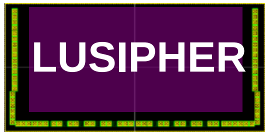
- Creation of poles with critical mass (~10 persons)
  - Orsay (OMEGA)
  - Clermont-Lyon (MICHRAU)
  - Strasbourg (IPHC)

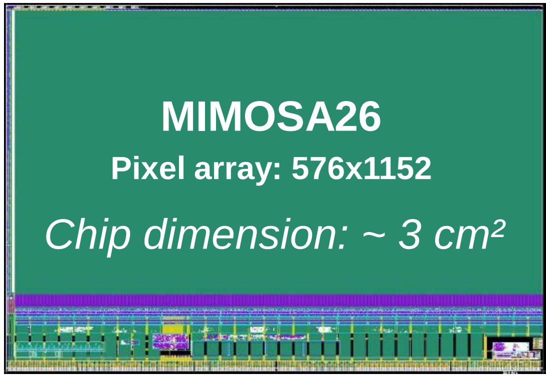


Examples of chips at IN2P3

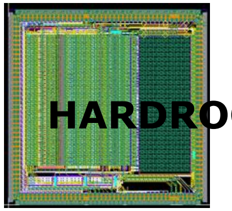
- MAPS sensors at IPHC (Strasbourg)

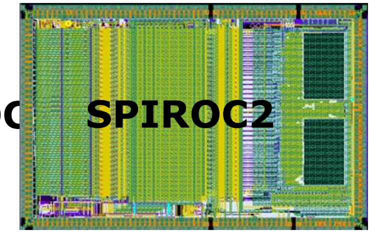


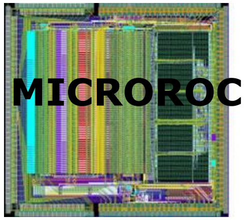


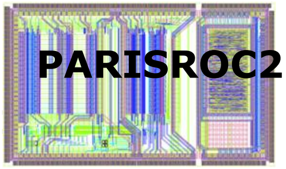


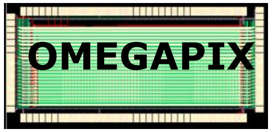
- ROC chips at OMEGA (Orsay)

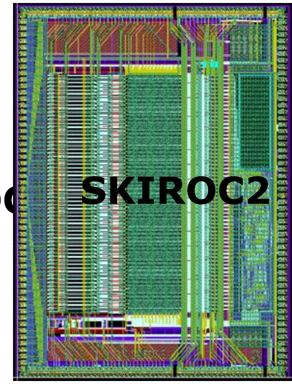




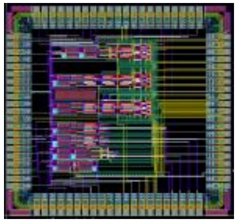


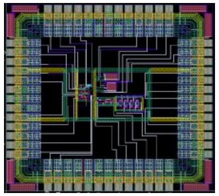


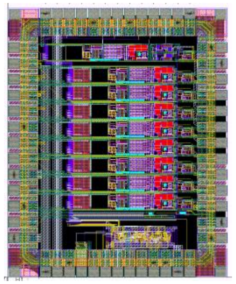


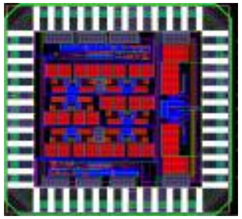


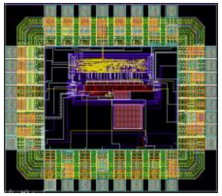
- Chips at MICHRAU (Lyon-Clermont)

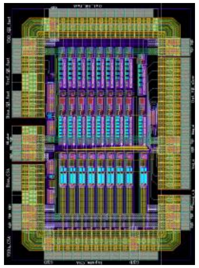


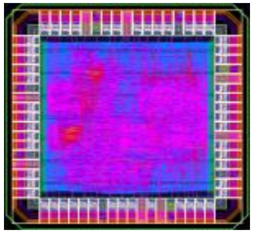

CHOCAPIC

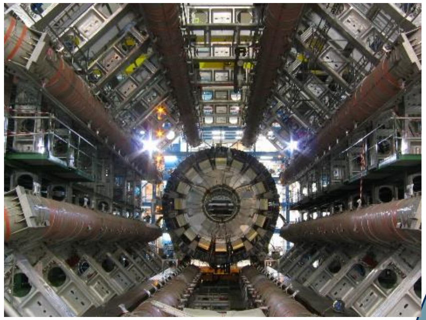

LARZIC


FATALIC


HOCTASIC

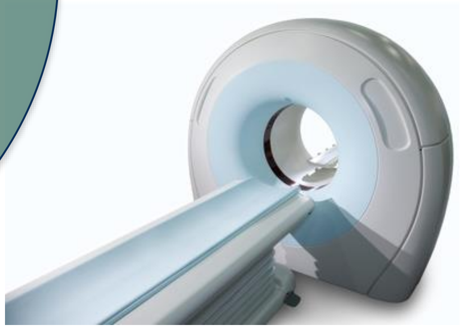

SICASIC


FEAFS (IC)



Research,
Institute

Education
School



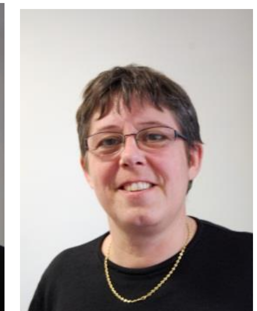
Industry, company

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

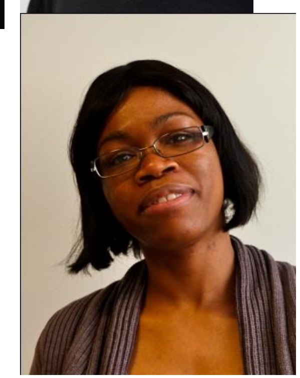










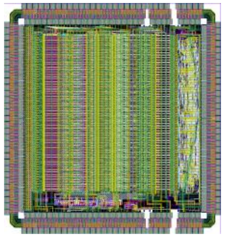
OMEGA ROC chips

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

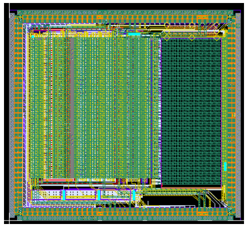
Chip	detector	ch	DR (C)
MAROC	PMT	64	-2f-50p
SPIROC	SiPM	36	+10f-200p
SKIROC	Si	64	+0.3f-10p
HARDROC	RPC	64	-2f-10p
PARISROC	PM	16	-5f-50p
SPACIROC	PMT	64	-5f-15p
MICROROC	µMegas	64	-0.2f-0.5p
PETIROC	SiPM	32	50fC-300pC

http://omega.in2p3.fr

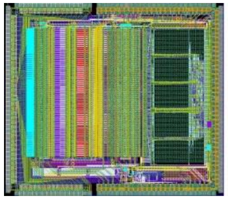
MAROC3



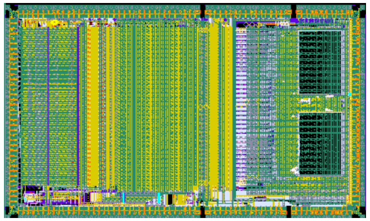
HARDROC2



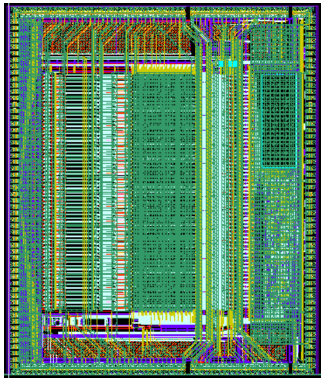
MICROROC1



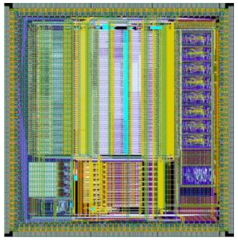
SPIROC2



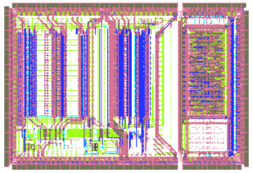
SKIROC2



SPACIROC



PARISROC2



MAROC for MAPMT

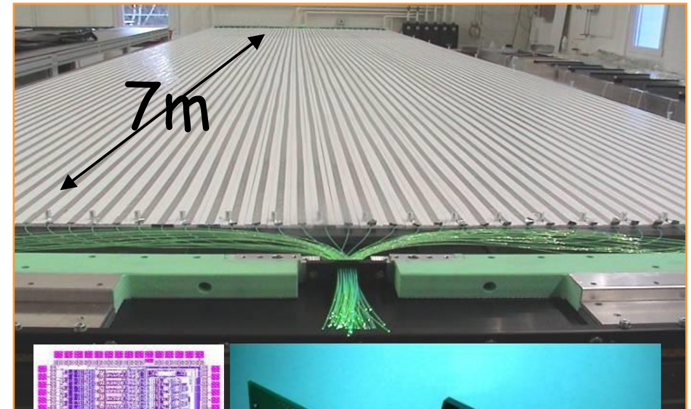
- Started with OPERA_ROC (2001)
  - 32 Channels in BiCMOS 0.8 µm
  - 3000 chips produced in 2002
  - Readout OPERA Target tracker in Gran Sasso

- MAROC1 (2004)
  - First prototype with 64 channels
  - AMS SiGe 0.35 µm (12 mm^2, Pw=5 mW/ch)

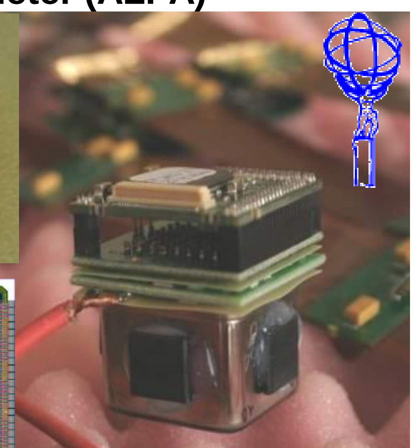
- MAROC2 (2006)
  - **1000 chips produced and bonded on a compact PCB for ATLAS luminometer (ALFA)**

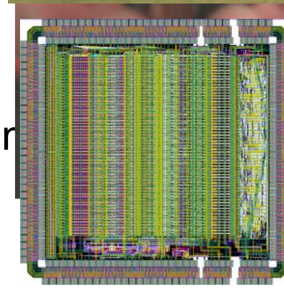
- MAROC3 (2009)
  - Lower power dissipation
  - Wilkinson ADC added
  - 1000 chips produced in 2010

- Many applications: Double-Chooz, Menphyno, medical ir



OPERA_ROC

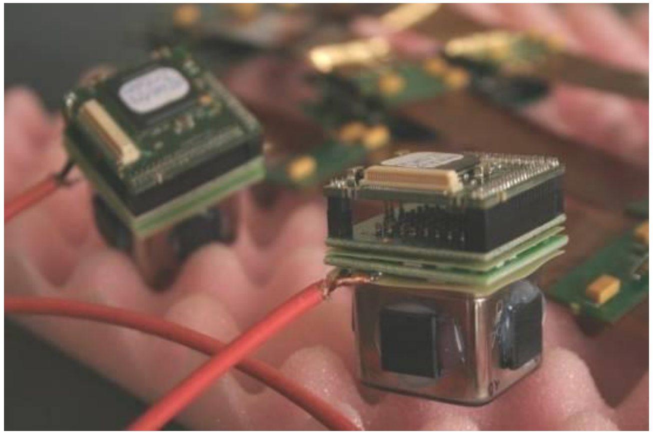


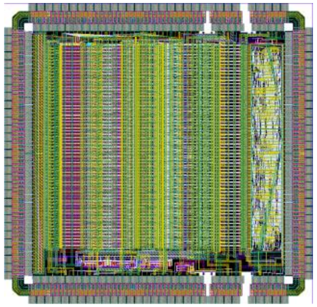


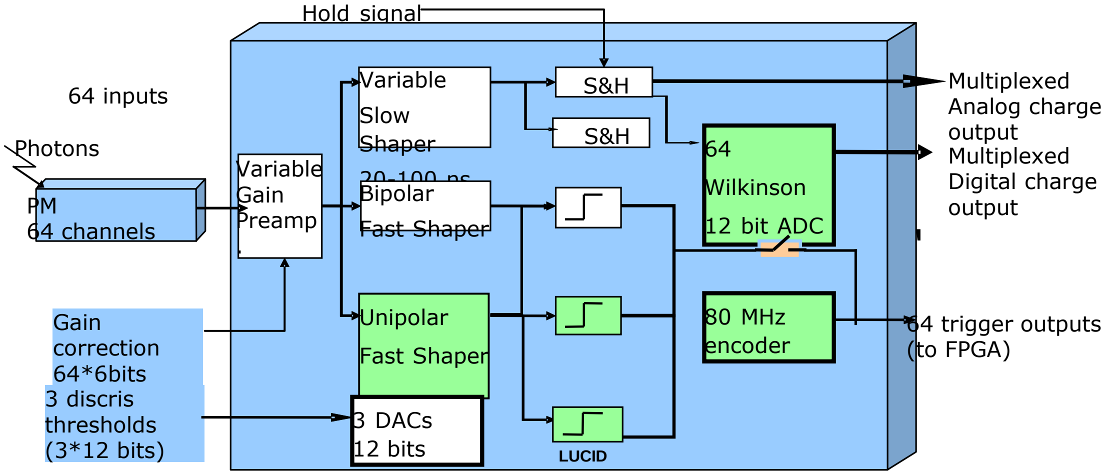
MAROC2

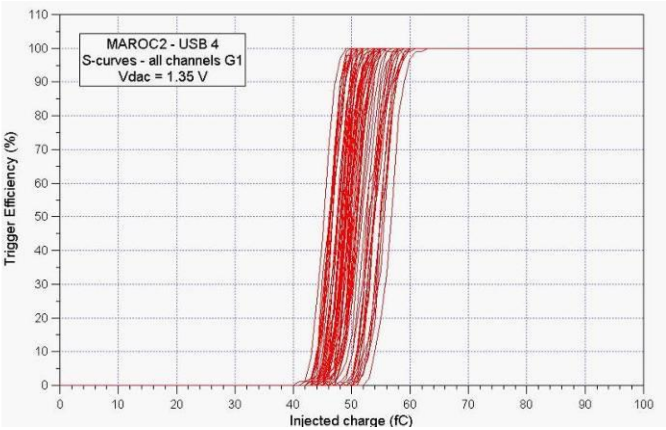
MAROC : MultiAnode Read-Out Chip

- 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

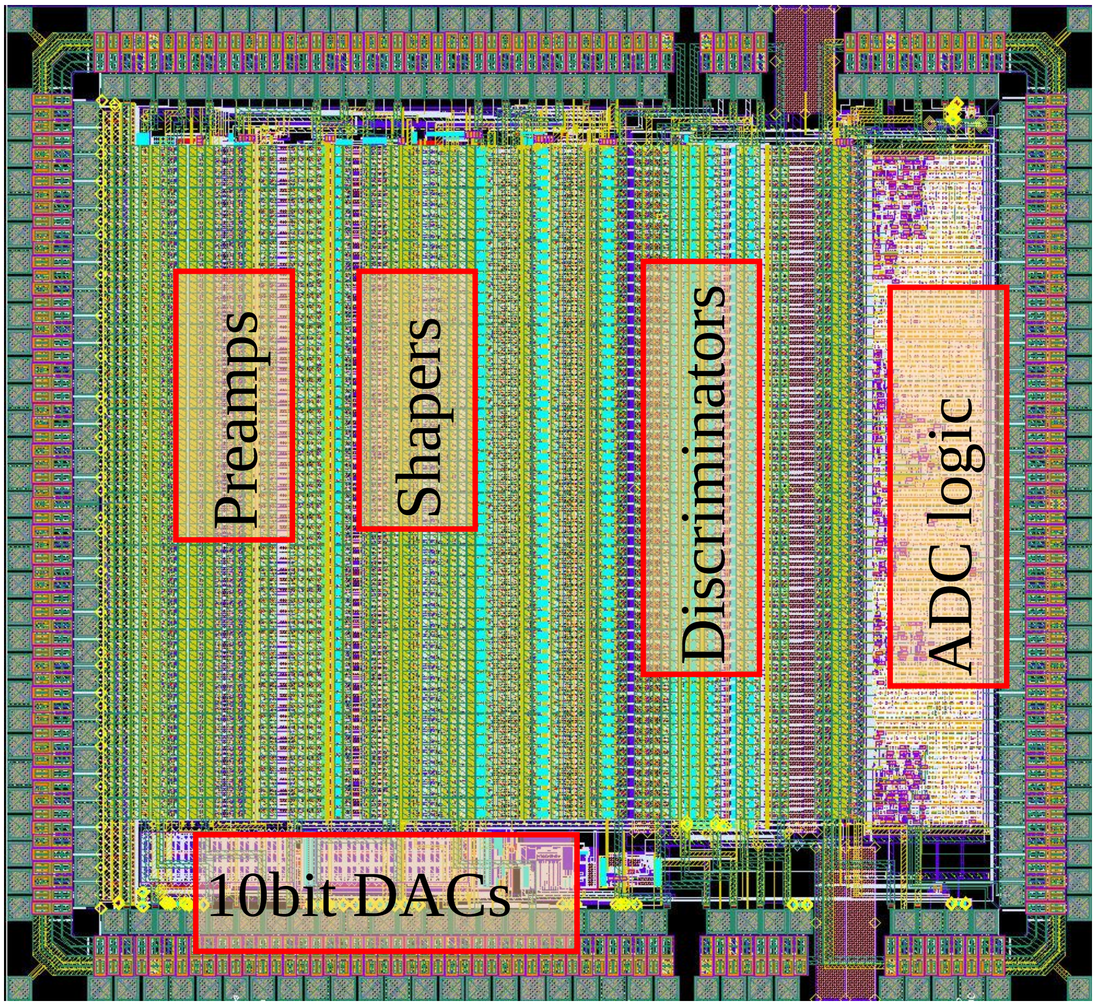




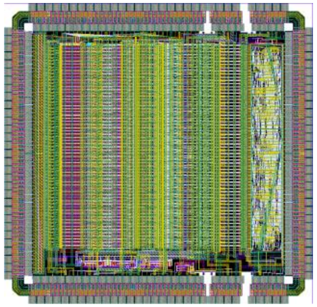


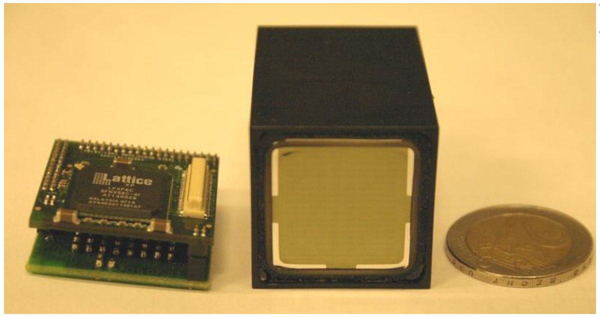


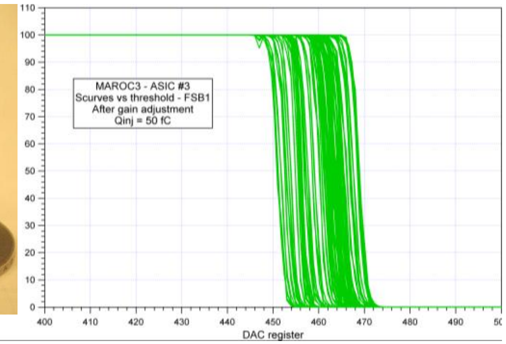
AMS SiGe 0.35µm
Package: CQFP240
Area: 16 mm2



MAROC3 users







2012-2013	
Ralf ENGELS	Allemagne/Juelich
Vladimir SOLOVOV	Portugal/ Coimbra
Scott Lumsden	UK/Glasgow
JJ Velthuis	UK/Bristol
Piero Giorgio FALLICA/ ST micro	Italie/ Catania
Vincent TATISCHEFF	France/Orsay
Alexander Nadeev	Russie
Domenico Lo Pesti	Italy/Catania
E.L. Rizzini	Suisse/Genève
D. Lo Presti	Italie/ Catania
P. Rodrigues	Portugal/Lisboa
Stephen Wotton	Suisse/Genève
JJ Velthuis	UK/Bristol
Riccardo Faccini	Italie/Roma
Patrizia Rossi	Italie/Frascati
Sima Cristina	Roumanie/Magurele
Patrizia Rossi	Italie/Frascati
D.Cussans/P.Baesso	UK/Bristol
Paolo Baesso	UK/Bristol

Alain Blondel	Suisse/Genève
Pedro Rodriguez	Portugal / Lisboa
William Brooks	Chili / Valparaiso
Stephane Colonges	France / Paris
Evandro Lodi Rizzini	Suisse / Genève
Günter Kemmerling	Allemagne/Juelich
Thomas Schweizer	Allemagne/Munich
Jason Legere	USA / Durham
Evandro Lodi Rizzini	Suisse / Genève
Ronan Oger	France / Paris
Erik Vallazza	Suisse / Genève
Daniel Bertrand	Belgique / Bruxelles
Ronan Oger	France / Paris
Jason Legere	USA / Durham
Tanushyam Bhattcharjee	Kolkota/Inde
Vincent Tatischef	France / Orsay

Gabriela Llosa	Espagne / Valence
Pierre Salin	Sofia Antipolis/France
Prof. A.A.Petrukhin	Russie/Moscou
Erik Vallazza	Suisse / Genève
Riccardo Faccini	Roma/Italie
Pierre Salin	Sofia Antipolis/France
John Parsons	USA
Bernard Genolini	France / Orsay
Nicoleta Dinu	France / Orsay
JJ Jaeger	France / Paris
Vincent Tatischef	France / Orsay

ATLAS lumi : 500chips (LAL)
Double Chooz : 1000 (Nevis)

CLAS12 RICH (INFN)
LHCb RICH ? (CERN)
JUNO ? (IPHC)

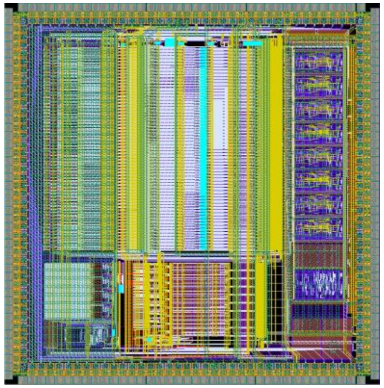
Variant: SPACIROC

JEM EUSO experiment
Analog Front End similar to MAROC
64 channels
Photoelectron counting (<50MHz)
Time Over Threshold
(collab.JAXA/Riken/Konan University)
Digital part :Digitization,memorization

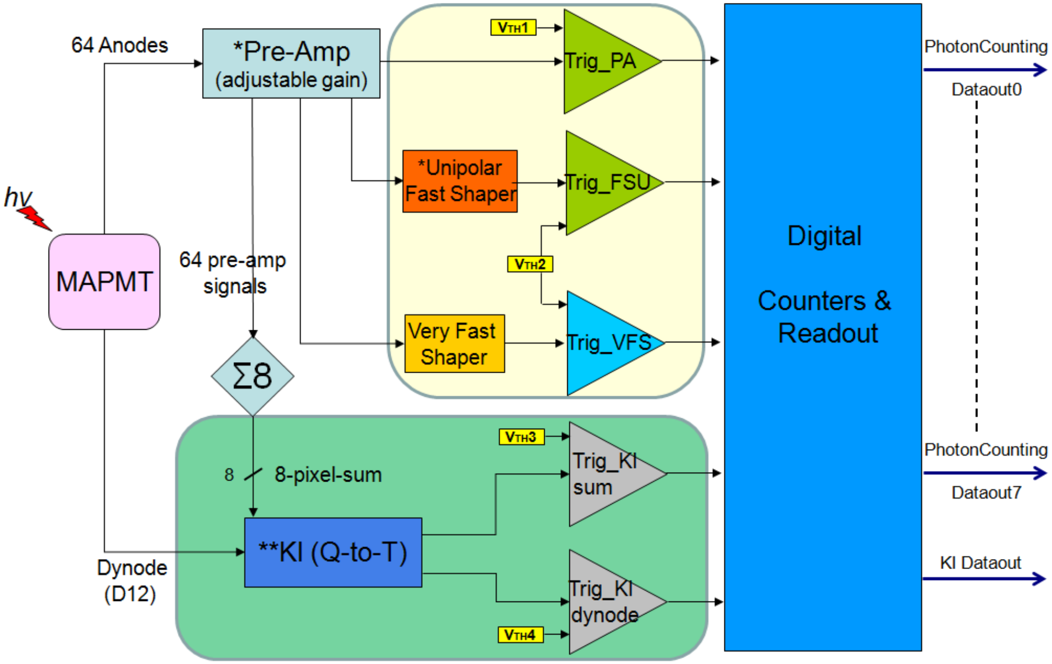
Power consumption < 1 mW/ch

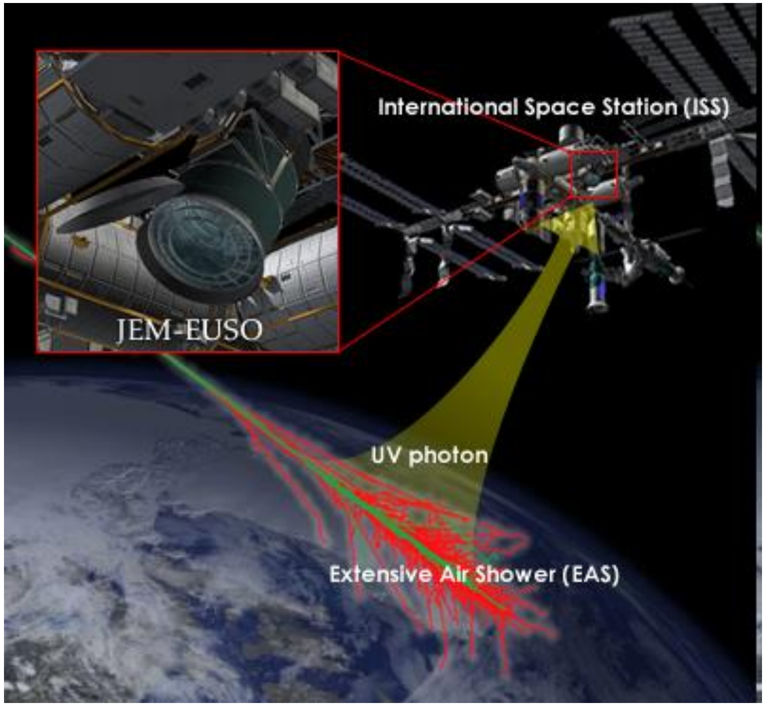
data flow ~ 384 bits / 2.5 µs

Radiation tolerance : triple voting



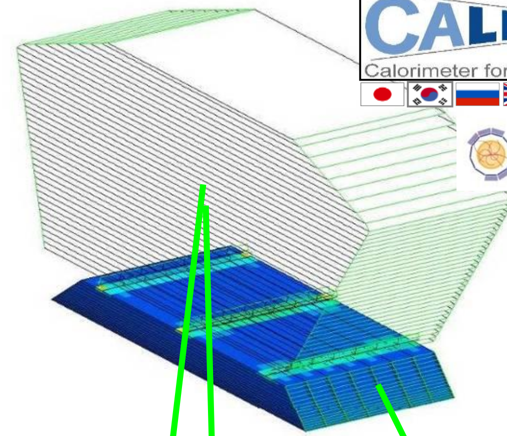
SPACIROC : 16mm^2



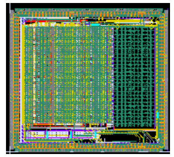


CALICE ASICs

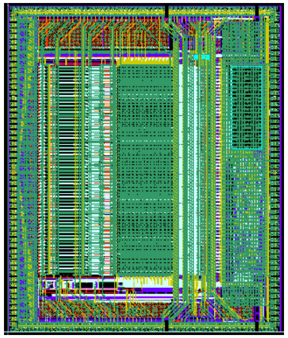
- Calorimeter readout: auto-trigger, analog storage, digitization and token-ring readout…
- power pulsing : <1 % duty cycle
- Optimized commonalities within EUDET/AIDA
- Dedicated run produced in march 2010 & nov 2014
  - 25 wafers = 200 k€ = 20 000 chips



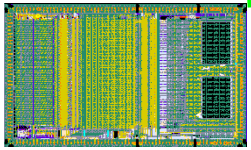
HARDROC2
SDHCAL RPC
64 ch 16 mm^2



SKIROC2
ECAL Si
64 ch. 70 mm^2



SPIROC2
AHCAL SiPM
36 ch 30 mm^2

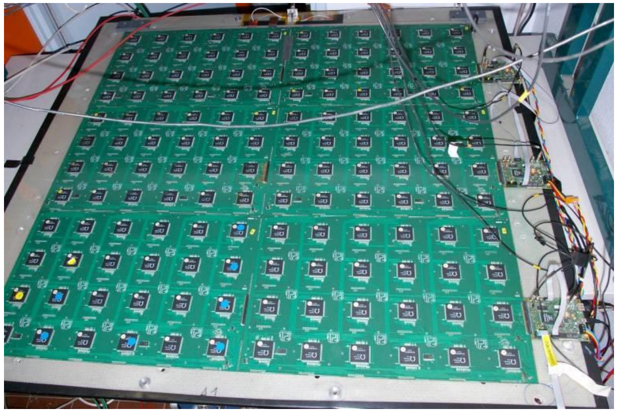


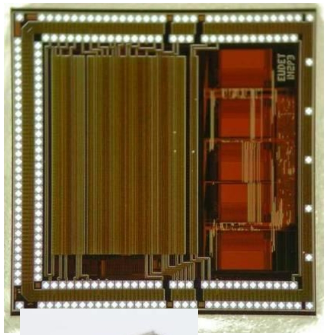
FLC_PHY3 (2003)

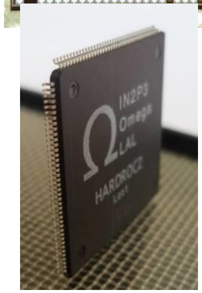
HARDROC2 for RPC readout

- **HARDROC2: 64 channels (RPC DHCAL)**
  - preamp + shaper+ 3 discris (semi digital readout)
  - Auto trigger on 10fC up to 20 pC
  - 5 0.5 Kbytes memories to store 127 events
  - Full power pulsing => 7.5 µW/ch
  - Fully integrated ILC sequential readout
  - 10 000 chips produced to equip 400 000 ch
  - SDHCAL technological proto with 40 layers (5760 HR2 chips
    - Successful TB in 2012 : 40 layers with Power Pulsing mode

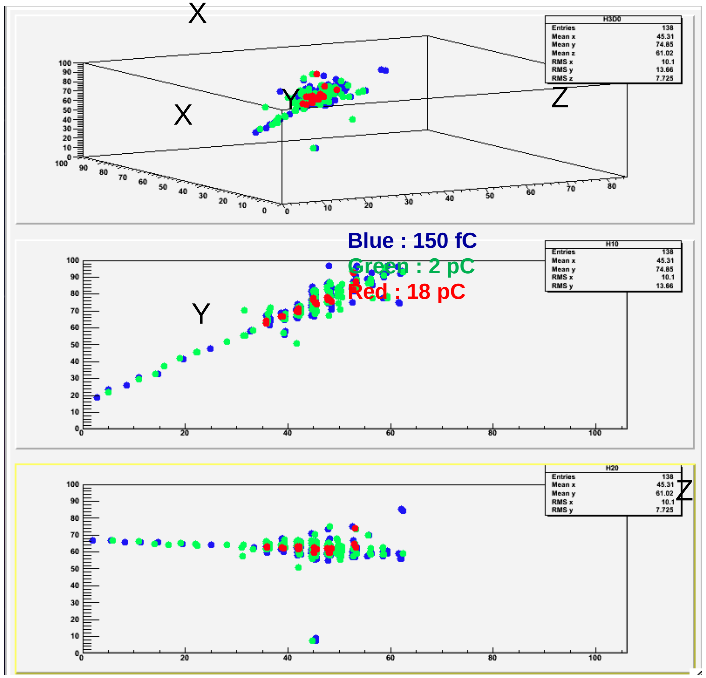
Cosmic hadronic shower





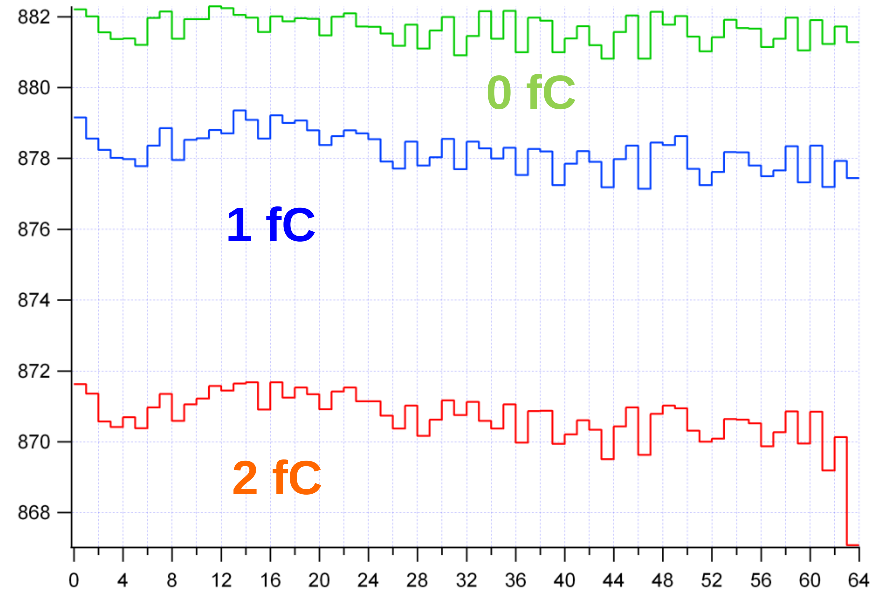


CdLT IHEP visit



MICROROC: 64 channels for µMegas (DHCAL ILC)

- ❑ Very similar to HARDROC except for the input preamp (collaboration with LAPP Annecy) and shapers (100-150 ns)
- ❑ Noise**: 0.2fC Cd=80 pF => Auto trigger on 1fC** up to 500fC
- ❑ Pulsed power: **10 µW/ch** (0.5 % duty cycle)
- ❑ **HV sparks protection**
- ❑ 1 m2 in TB in August and October 2011. Very good performance of the electronics and detector (Threshold set to 1fC).
- ❑ 2012: 4 m2 in TB

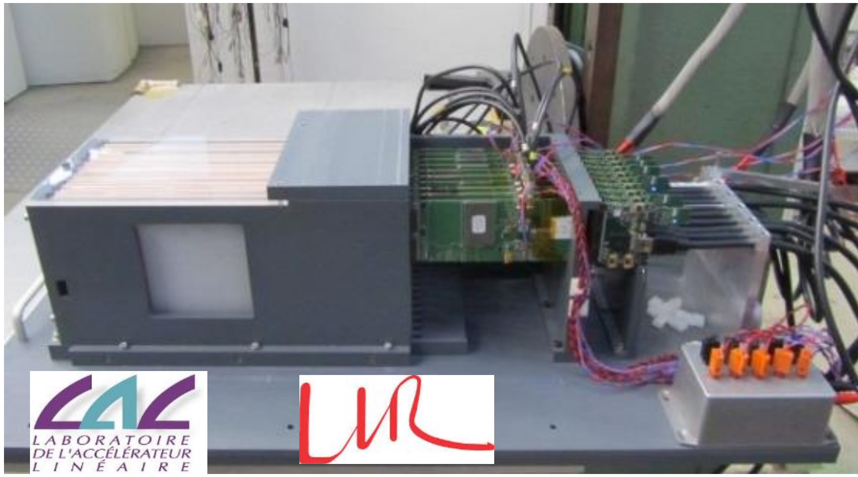


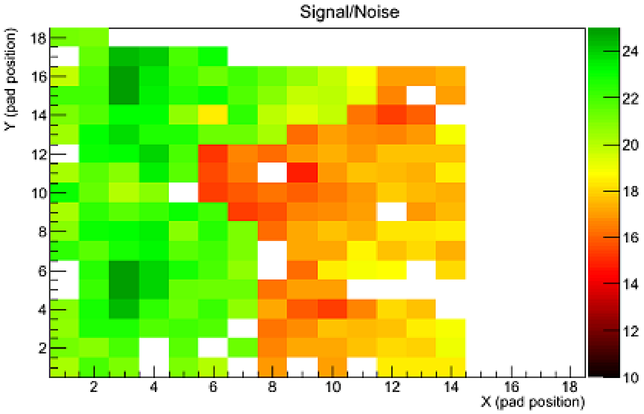
@LAPP Annecy

1m2 equipped with 144 MICROROC

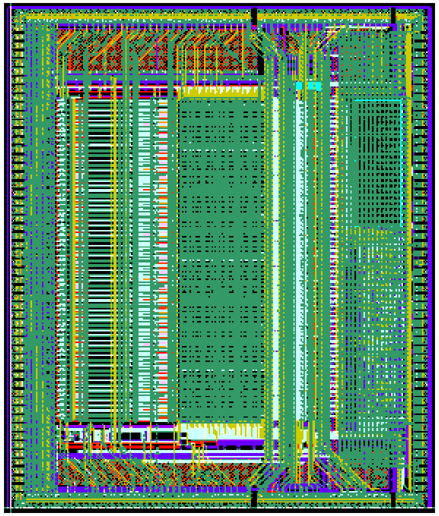
SKIROC : SiECAL chip

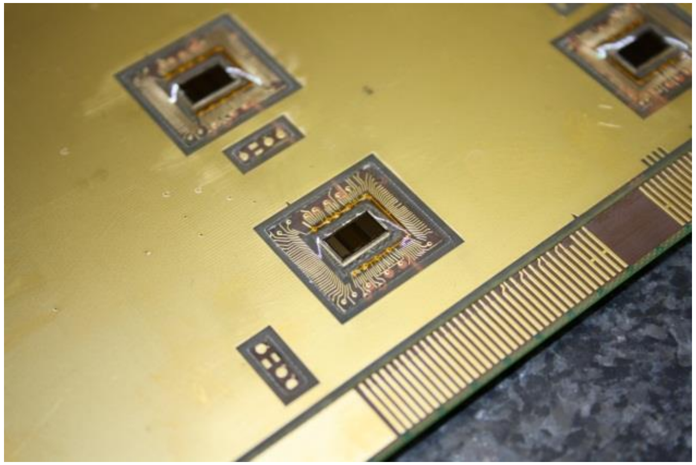
- 64 ch Si readout chip
  - Autotrigger @ ½ MIP = 2 fC
  - Charge measurement 15 bits
  - Time measurement





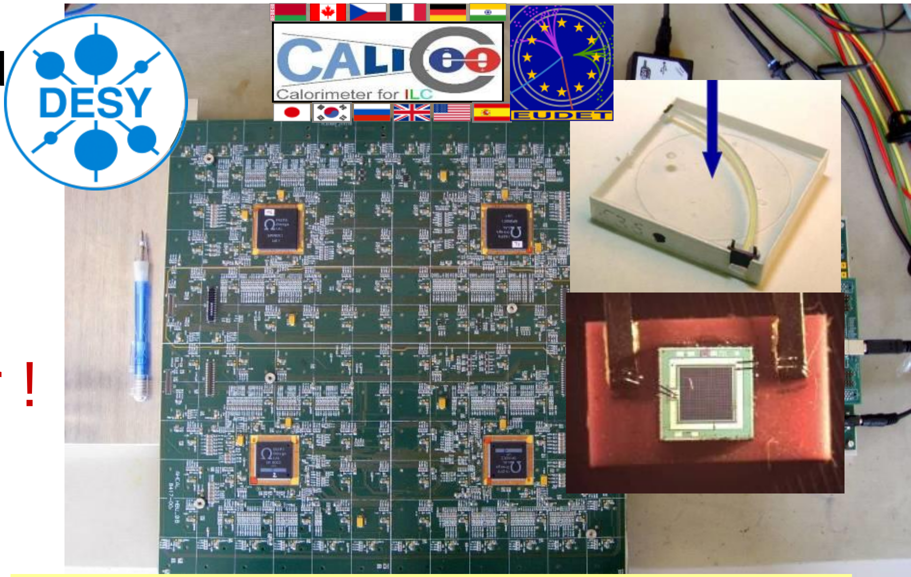
S/N > 10



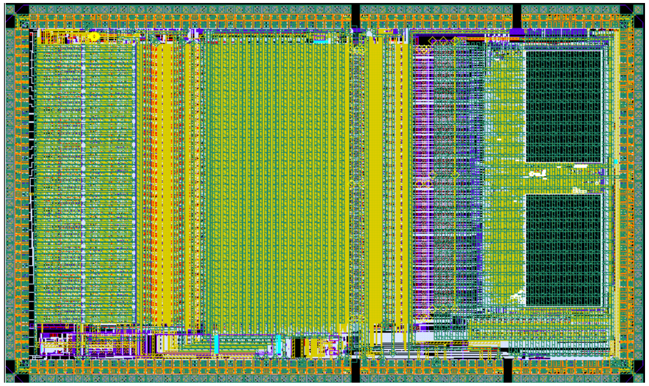


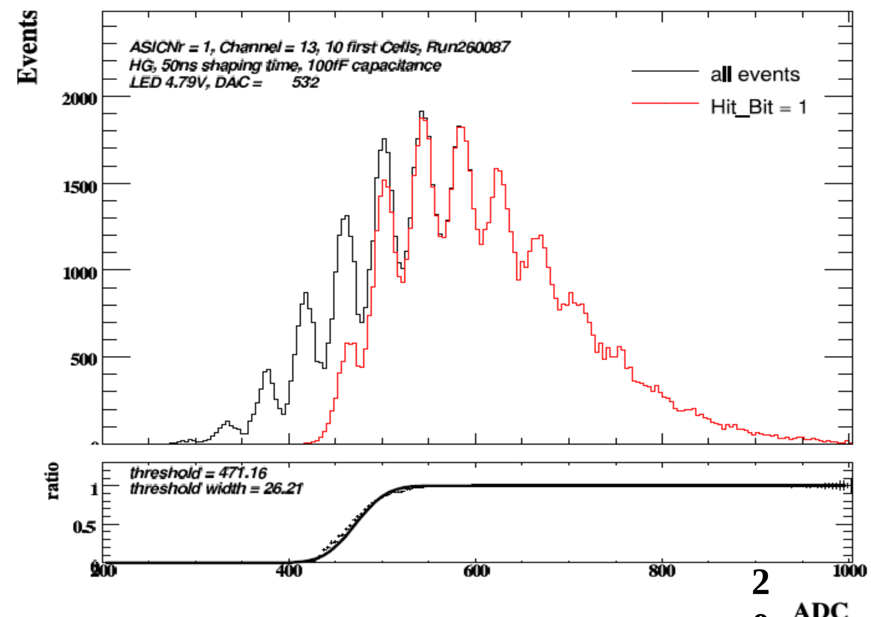
SPIROC for SiPM readout

- 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 !
- 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)

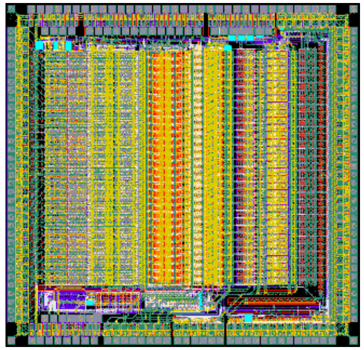


$(0.36m)^2$ Tiles + SiPM + SPIROC (144ch)





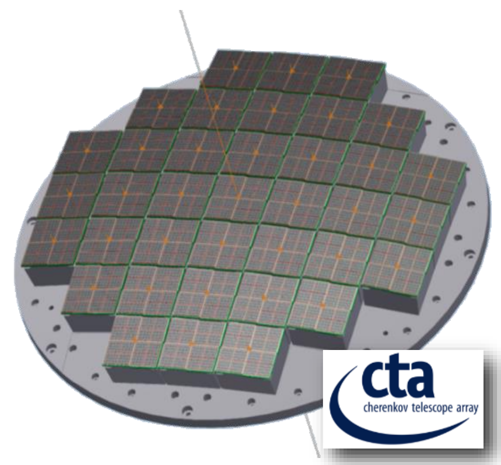
EASIROC/CITIROC : variants of SPIROC



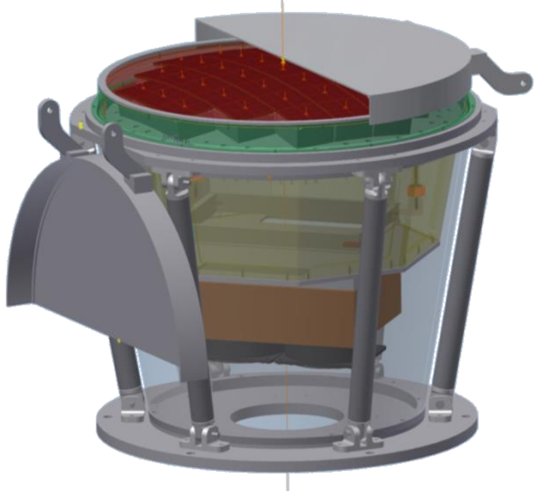
- J TECH / PUSAN UNIV / KOREA
- TOKYO UNIVERSITY / JAPAN
- IFC - INAF / PALERMO / ITALIA
- IMNC / ORSAY / France
- LLR / PALAISEAU / France
- UNIVERSITY ROMA / Italy
- INFN BARI / ITALY
- IMNC / ORSAY / France
- EHWA / KOREA
- INL / LYON / France
- TOULOUSE / France
- CERN / SWITZERLAND
- RWTH / AACHEN / GERMANY
- INFN ROMA / ITALY
- CERN / SWITZERLAND
- UNIV. DIJON
- KETEK / GERMANY

Users of EASIROC Modules

Name	Institute	Usage
A. Ishikawa	Tohoku	Fiber tracker (Silicon Test)
K. Ueno	KEK	Fiber tracker (COMET Test)
A. Sato	Osaka	Fiber tracker (COMET Test)
J. Tojo	Kyushu	Fiber tracker (COMET Test)
T. Kin	Kyushu	Fibertracker (Muon Radiography)
W. Ootani	Tokyo	MEG
M. Yokoyama	Tokyo	T2K upgrade
A. Minamino	Kyoto	T2K upgrade
H. Kawai	Chiba	Fiber tracker J-PARC E36
K. Kotera	Shinshu	PET/SPECT
K. Kojima	KEK	Muon detector (Material Science)
H. Nakayama	KEK	Radiation Monitor (Belle2)
A. Sakaguchi	Osaka	Fiber tracker (Nuclear Phys J-PARC)
H. Fujioka	Kyoto	Fiber counter (Nuclear Phys, GSI)
T. Murakami	Kyoto	Trigger counter (RIBF, heavy ion)
K. Hanagaki	Osaka	Fiber tracker (Silicon Test)
O. Jinnouchi	Tokyo Tech	Education
K. Yorita	Waseda	Education
T. Mibe	KEK	muon g-2

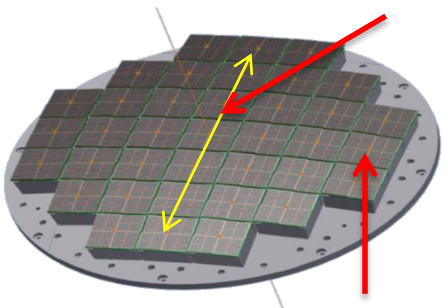


PDM Electronics



FOV = 9.6°

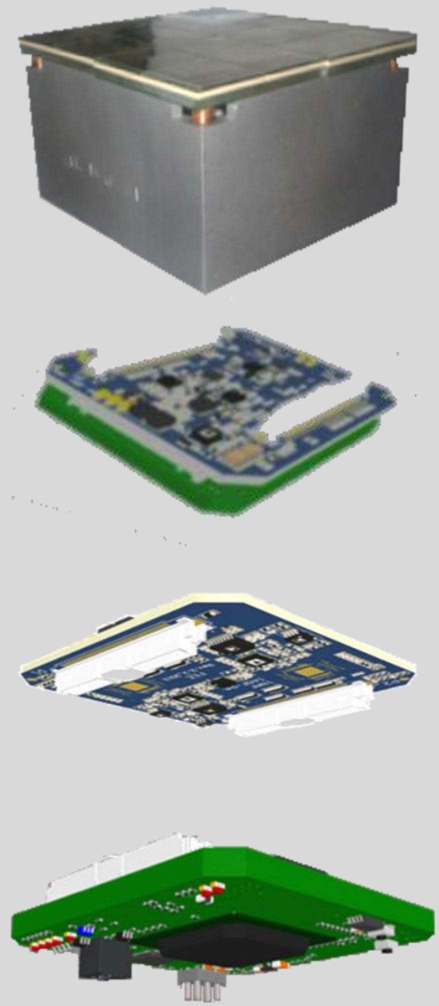
Ø = 350mm

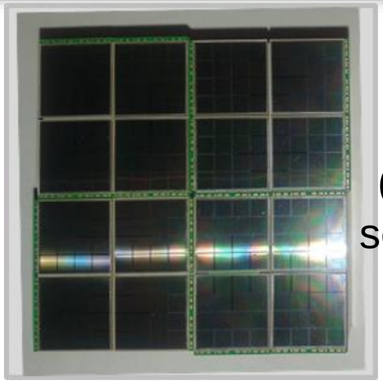


Photon Detection Module (PDM)

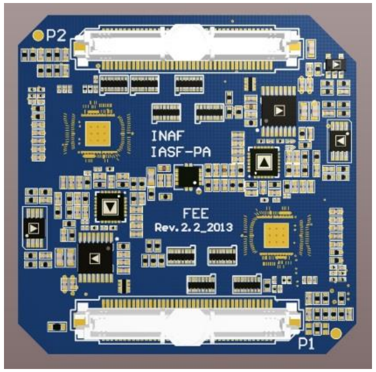
Pixel = 0.17° → 6.2 x 6.2 mm

ASSEMBLING

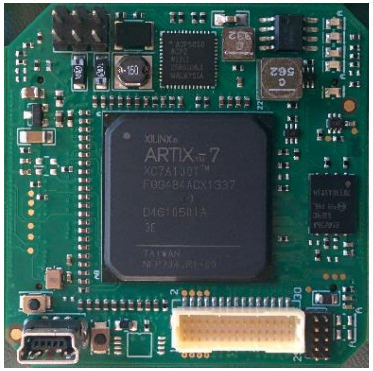




SiPM board
(9 +1 temperature
sensors embedde

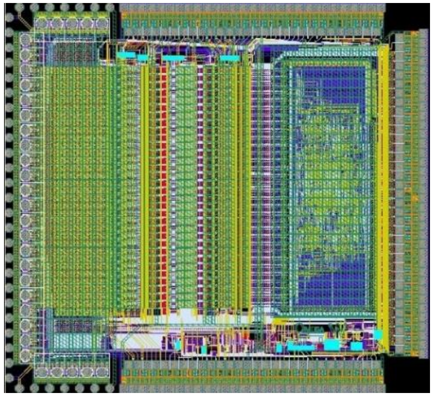


Front-End board
(2 CITIROC
ASIC)



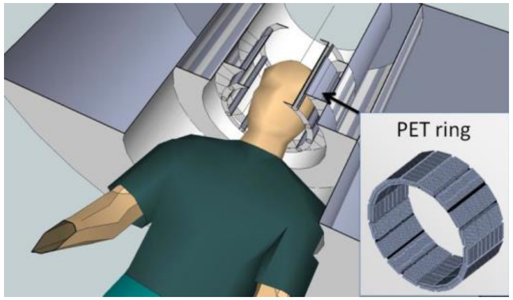
PDM FPGA Board
(XILINX ARTIX 7)

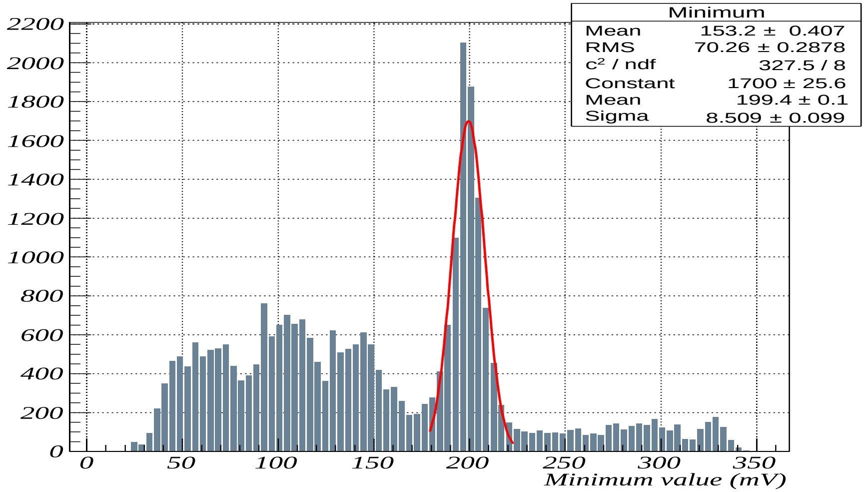
Chips for PET SiPM

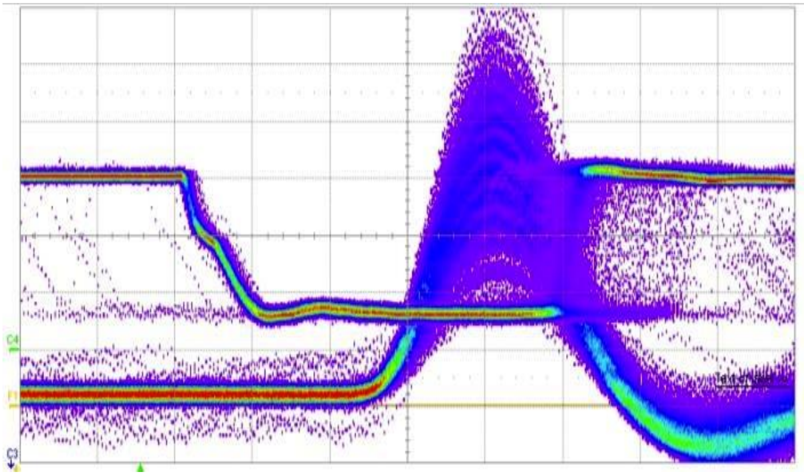


- PETIROC (nov 13)
  - 32 channels,
  - 1 GHz SiGe amplifiers/discriminators
  - Internal ADC/TDC 50ps

- TRIROC EU Project (feb14)
  - 64 channels
  - Dual polarity
  - Internal ADC/TDC 50ps

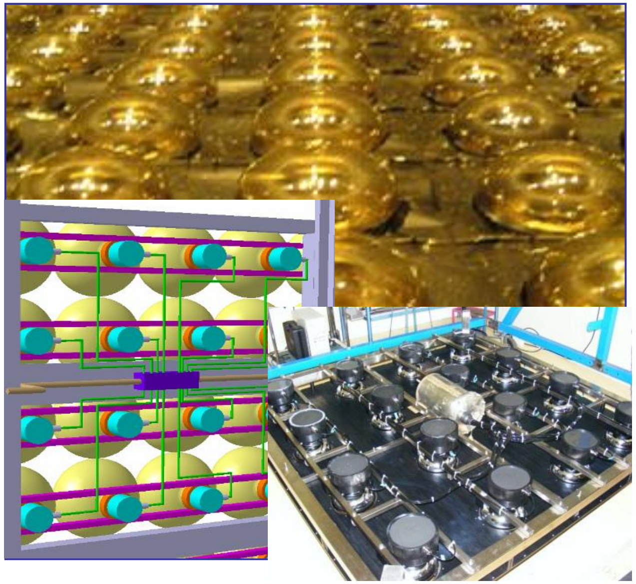






PARiSROC for PMm^2

- 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 »



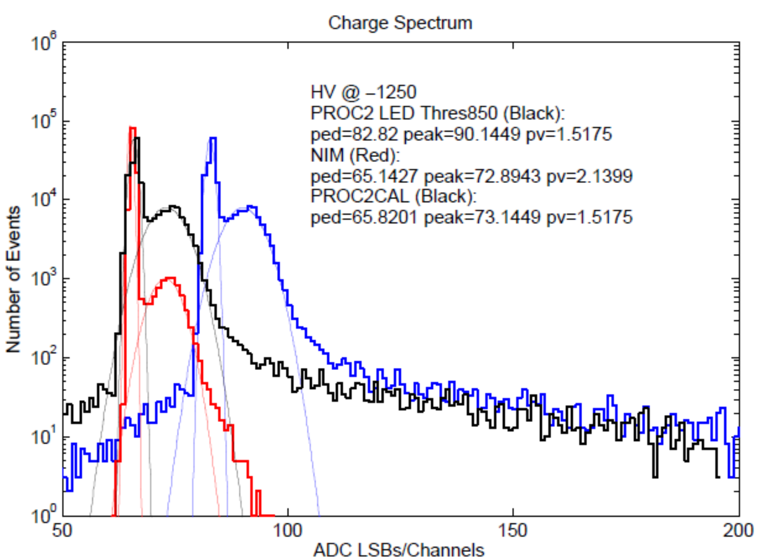
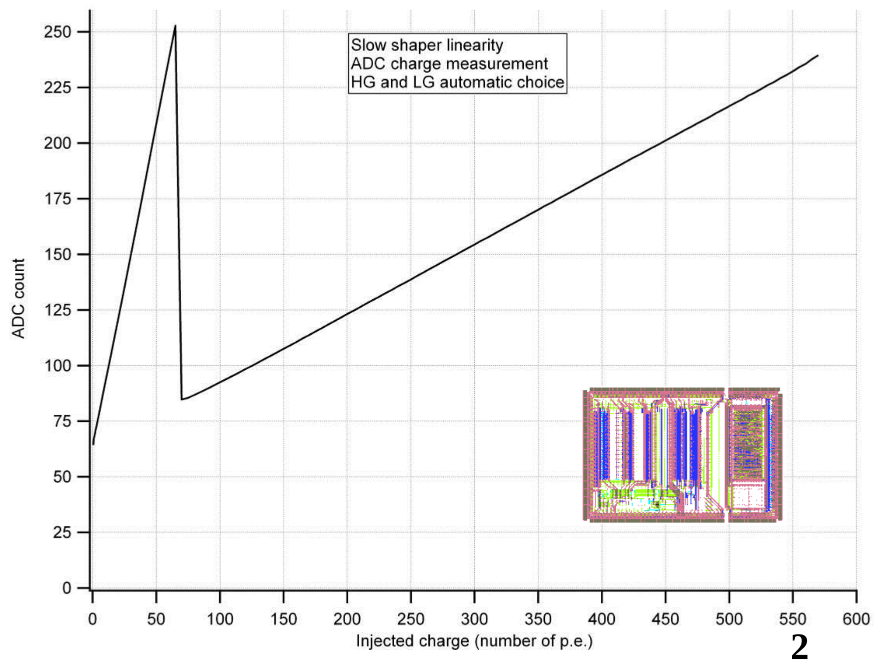
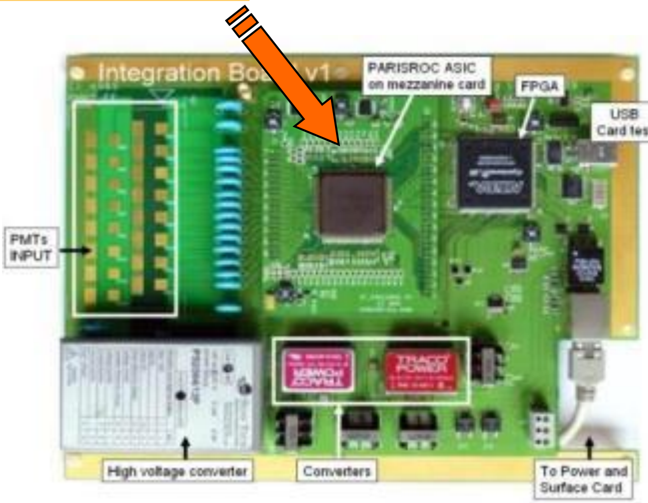


Figure 3.3.4: The calibrated of different acquisition sys



PMm² demonstrator

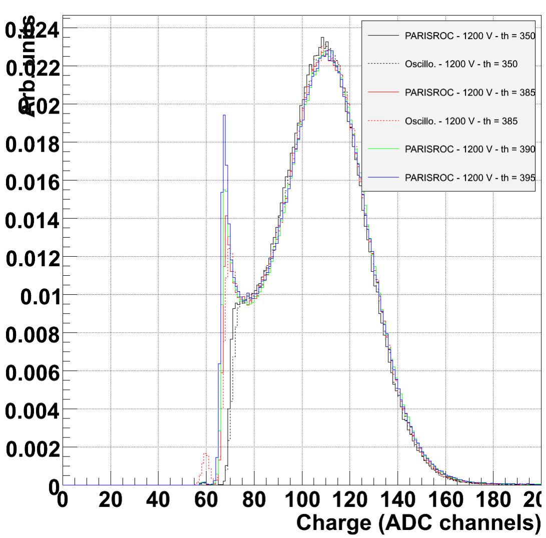
PARISROC2 chip



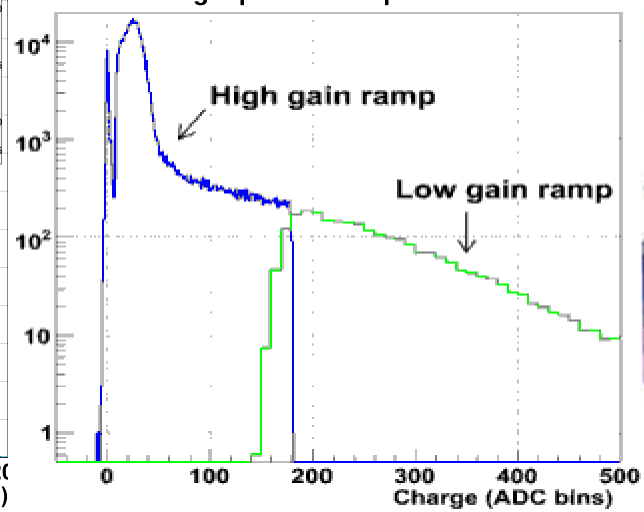
Watertight box

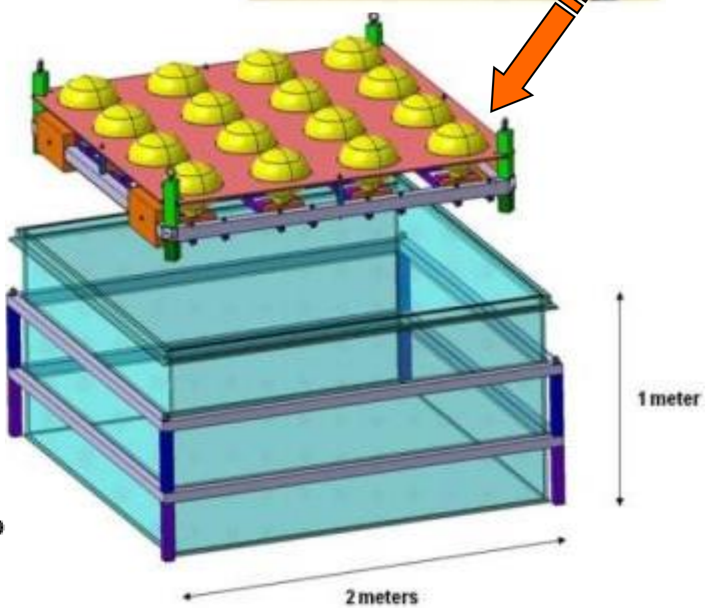
2m x 2m array

1-in (XP3102) single p.e. noise spectrum.



8-in (Hamamatsu R5912)
Single p.e. noise spectrum.





PARISROC for WFCTA

Property	WFCTA Specifications	Support or not
Signal polarity	*Negative (Anode) or Positive (Dynode)*	✓
Dynamic range	*160fC to 240pC,（10pe to 15000pe @ Gain = 10^5）*	✗ *(need combine two channels into one*
Resolution	*< 20% @ 10pe and < 5% @ 15000pe*	✓
Nonlinearity	*< 2% or <±1%*	✗ *(need combine two channels into one*
Time resolution	*20ns (RMS)*	✓
The adjustable threshold	*5pe to 100pe*	✓
Single channel event rate	*10kHz per channel*	✗ *(limited by USB interface and FPGA*
Width of the signal	*6ns to 50ns (FWHM) for Cherenkov light*	✓
Pedestal monitoring	*Background of electronics and sky*	
Channels	*1024 channels per*	
Power consumption	*260W per telescope*	

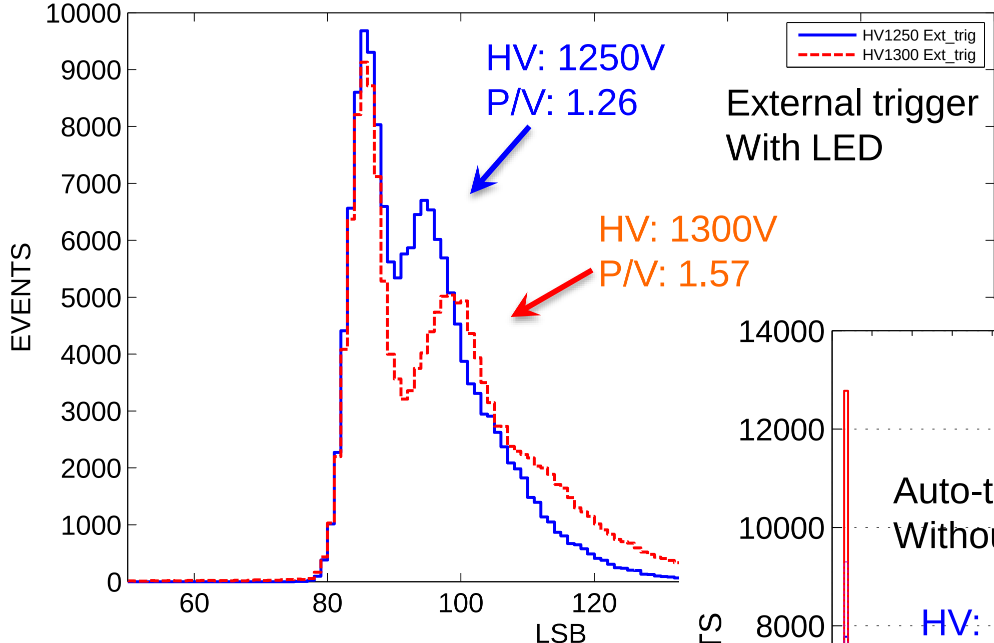
Performance limitations
- FPGA (Altera Cyclone III)
- USB Interface (FTDI FT245X)
- Specific ports (External trigger)

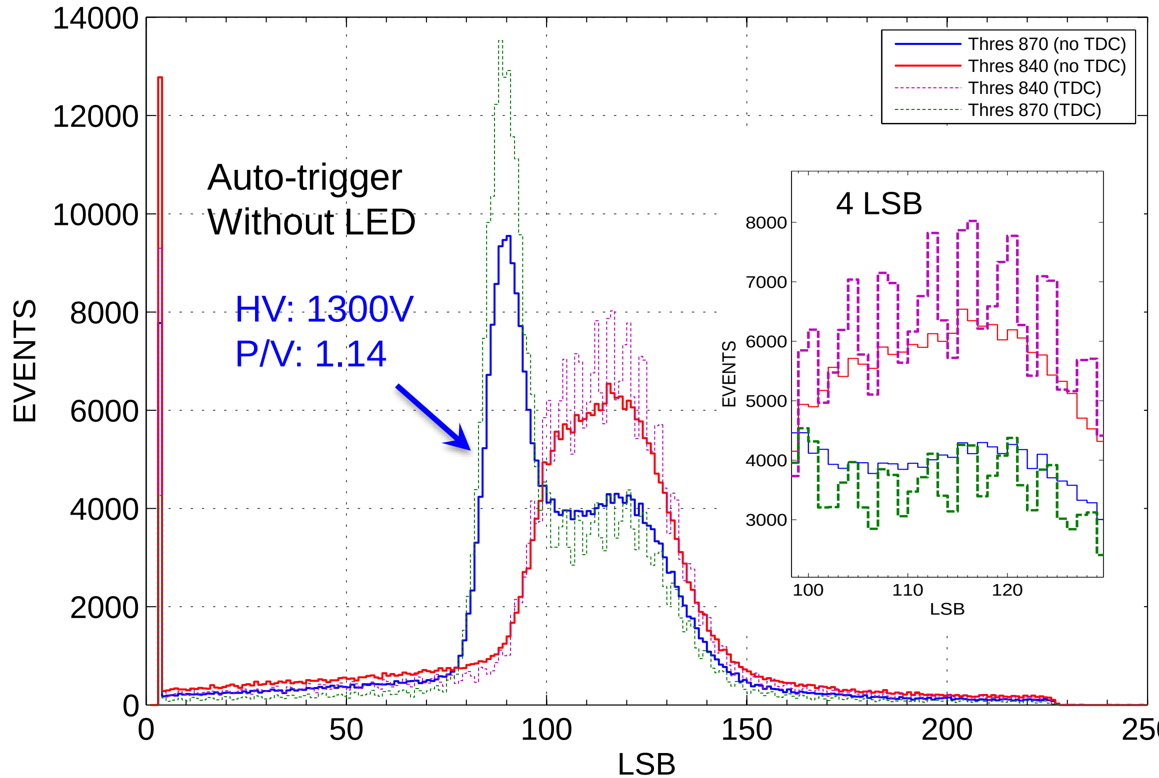
Telescope first prototype installed in Tibet

Single photoelectron spectrum

By using external trigger, the SPE spectrum can be easily extracted with good P/V ratio.

© Tiina Suomijarvi,
Yingtao Chen
IPN, Orsay, France





The periodical crosstalk from TDC unit will affect the accuracy of charge measurement when the internal trigger is used.

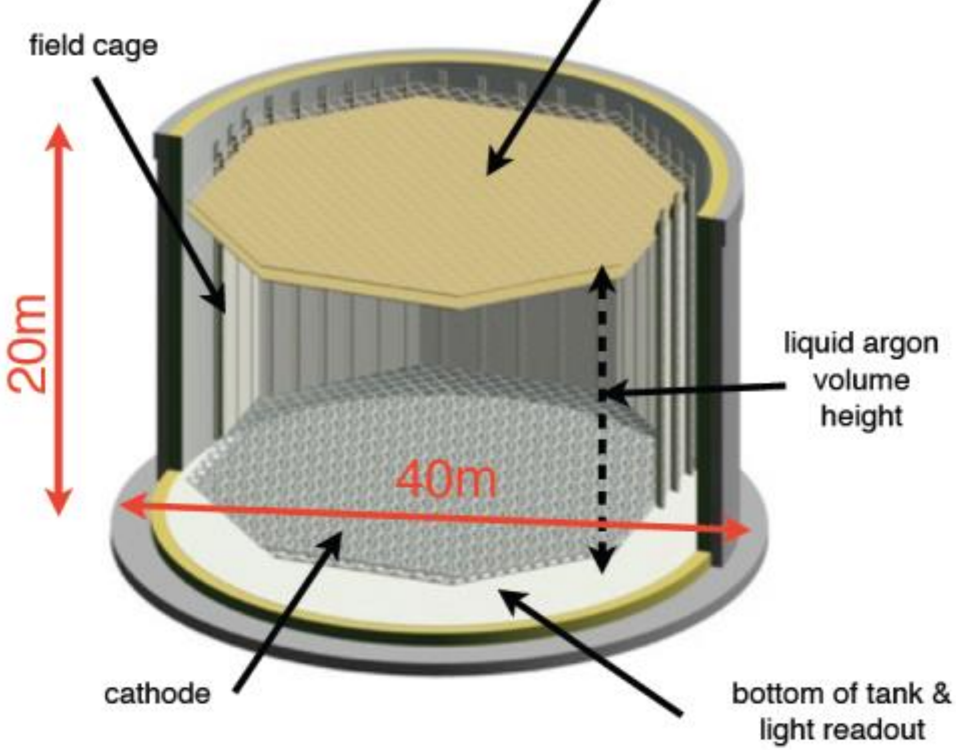
However, the threshold will not affect the location of the pedestal and the SPE peak.

LAGUNA-LBNO

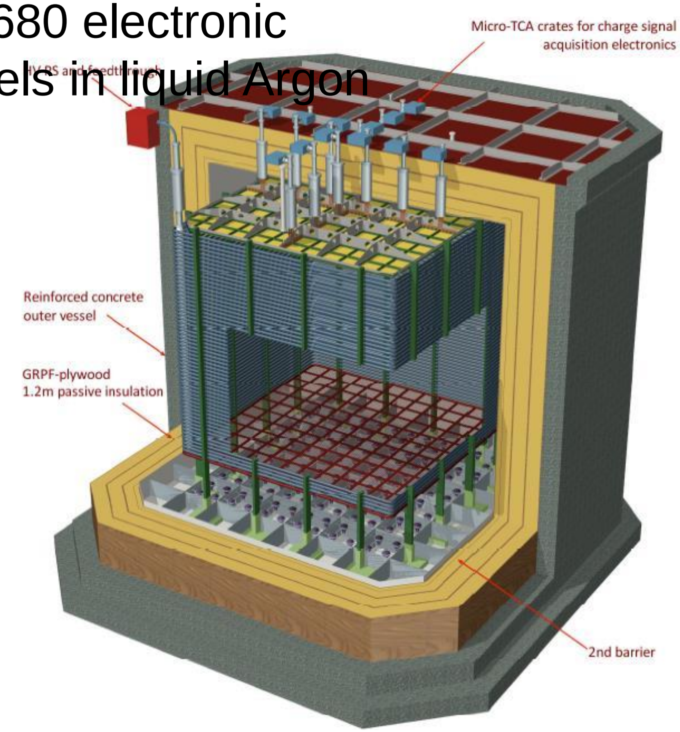
LAGUNA-LBNO : **L**arge **A**pparatus for **G**rand **U**nification and **N**eutrino **A**strophysics - **L**ong **B**aseline **N**eutrino **O**scillations.

© Tomas Patzak,
Margherita Buizza
APC, Paris, France

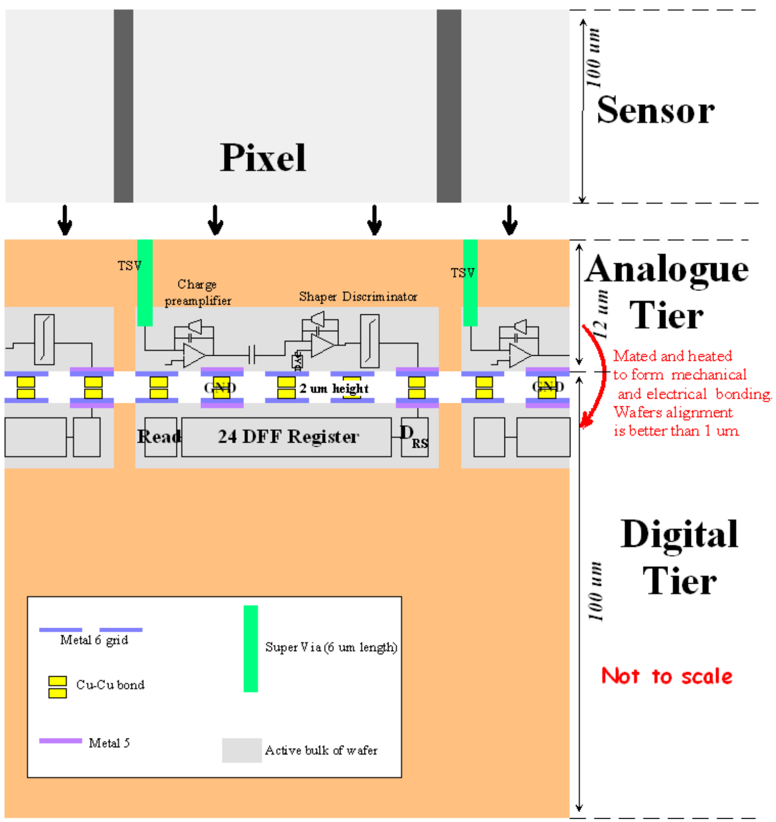
20KT Lar detector

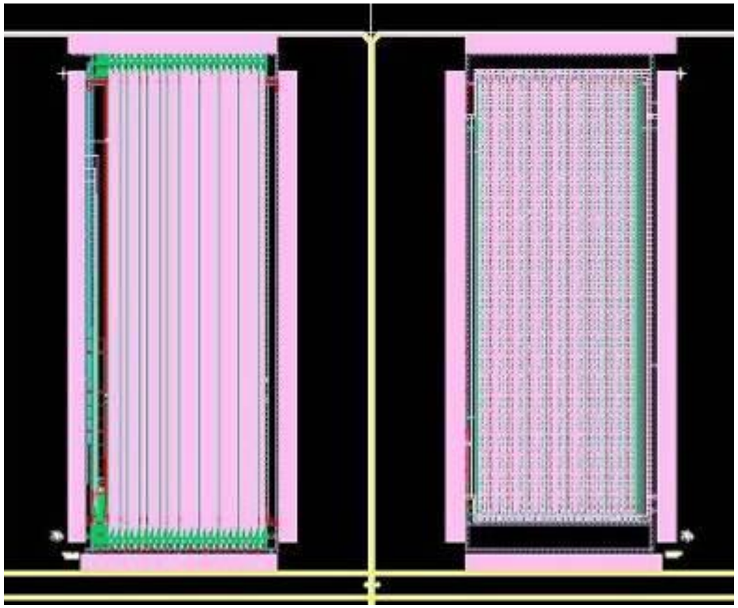


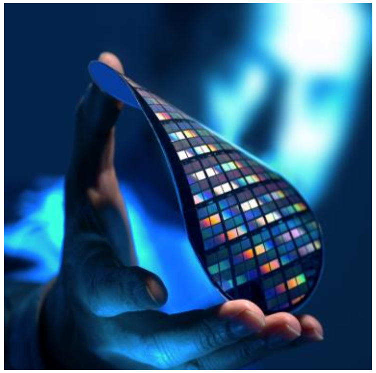
Large scale demonstrator with 7680 electronic channels in liquid Argon



- Double tier pixel readout for ATLAS sLHC
  - 50x50x50 µm pixels
  - Low power 3 µW/ch, low threshold 1000e-
  - Chartered/Tezzaron run may 2009
  - Collab with CPPM and LPNHE







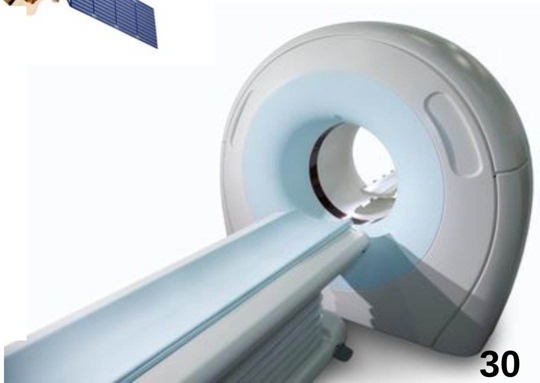
Technology transfer : Weeroc

- Startup company created in 2012 for industrial applications
- Cadence tools for industry (price !!)

- Contracts with space industry, nuclear industry, medical imaging
- 5 people + support from OMEGA

WeeROC
High-end analogue & mixed microelectronics design

- http://weeroc.com/
- contact person: Julien Fleury



Summary

- Main activity : Analog and mixed-signal ASIC design

- Research topics :
  - multi-channel ASICs for particle physics and astrophysics detectors
  - BiCMOS SiGe and deep submicron CMOS technologies
  - ultra-low noise, low power and high speed design
  - radiation tolerance, reliability and space applications
  - integration with sensors and System on Chip (SoC)
  - chips for photodetectors, semiconductors or gaseous detectors

- Specific Applications :
  - medical imaging
  - low light "single photon" imaging
  - utilization in space

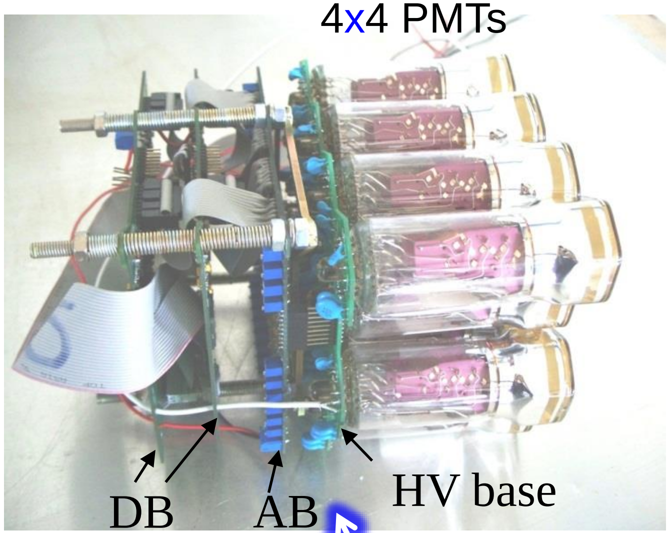
ROC family

	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

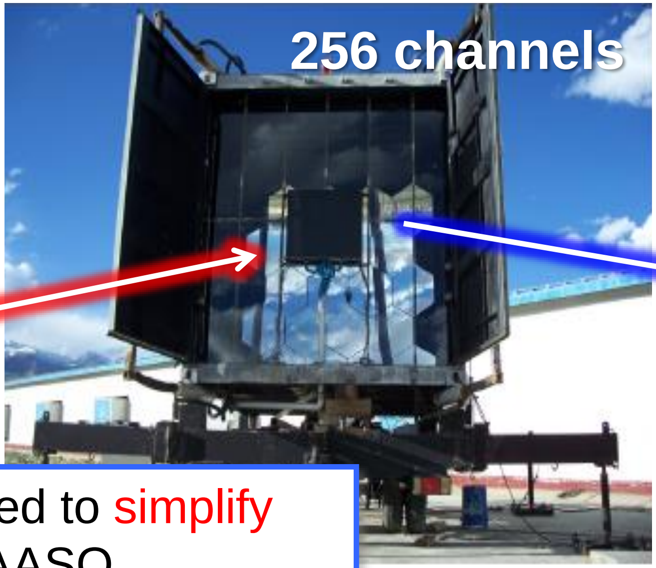
Backup slides

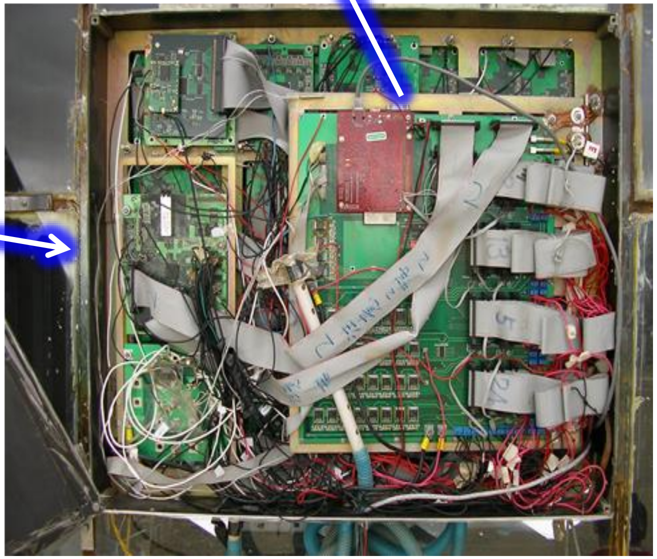
Challenges for electronics

- ✧ High altitude and low air pressure ➔ *decreased heat dissipation*
- ✧ Large number of channels ➔ *increased density, complexity and power consumption*
- ✧ Harsh environment and remote location ➔ *require stability, reliability and maintainability*
- ✧ Design based on IC ➔ *simplified design, decreased power consumption, increased reliability*



- Compact design
- High stability
- High reliability
- Easy to maintain





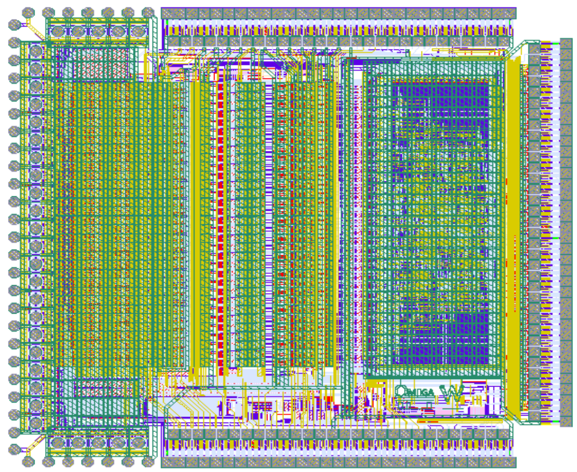
Prototypes in YBJ, Tibet

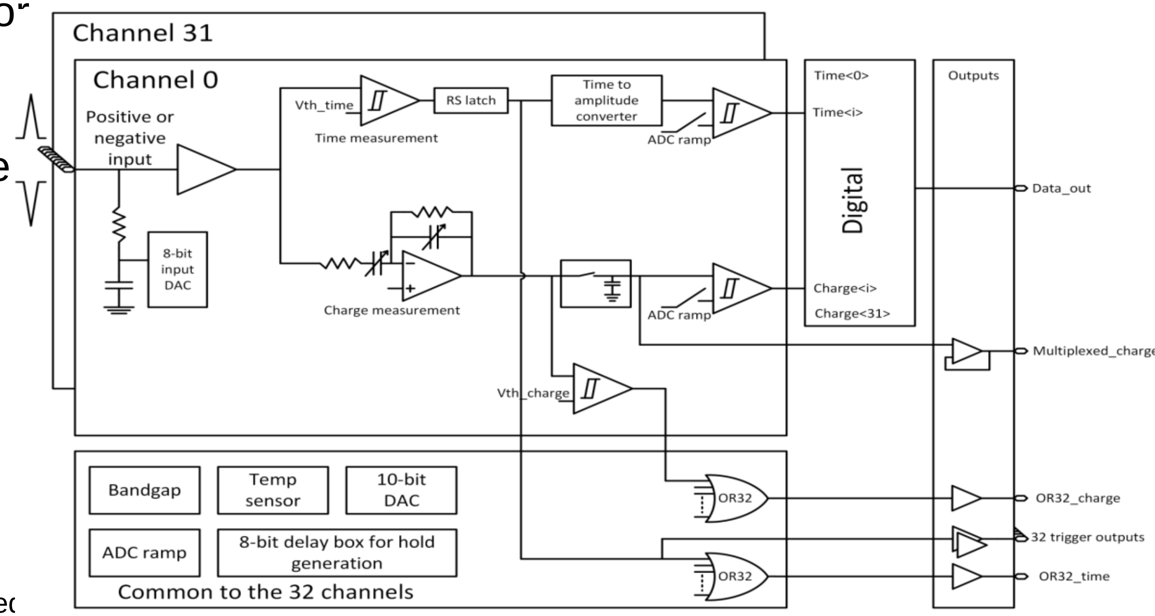
We focused on WFCTA at first

The ASICs can be used to simplify the electronics of LHAASO

PETIROC2

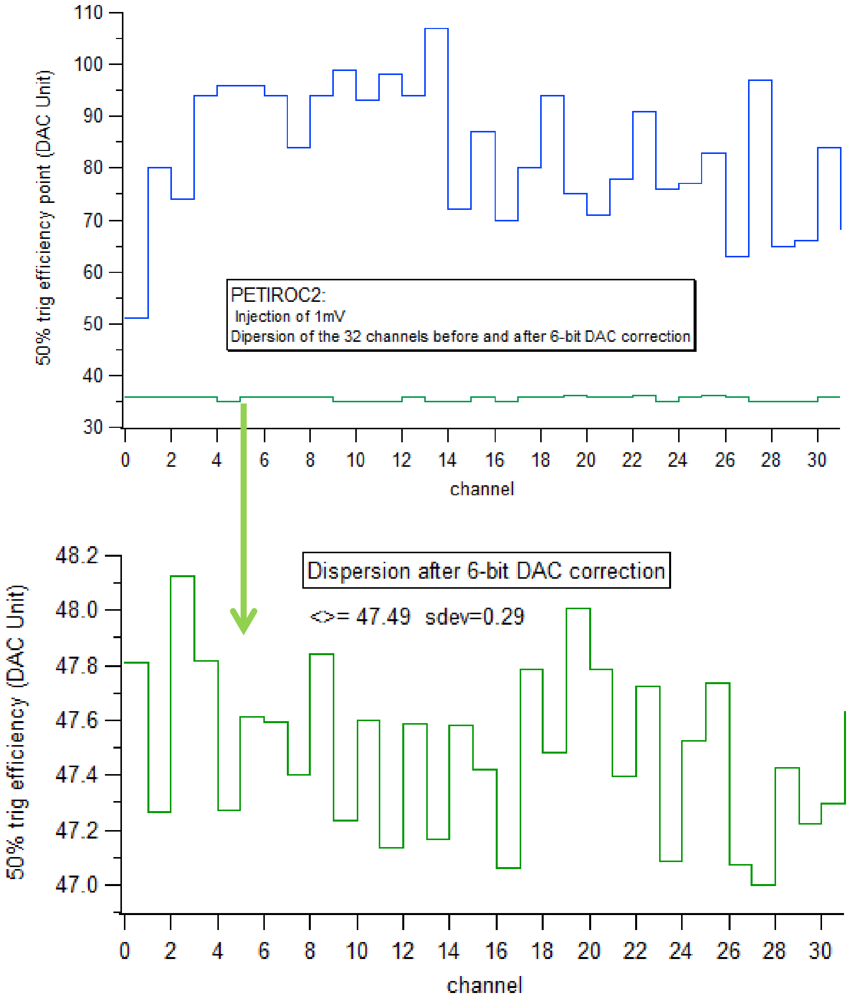
- Time of Flight read-out chip with embedded TDC (25 ps bin) and ADC
- Dynamic range: 160 fC up to 400 pC
- 32 channels (negative input)
  - 32 trigger outputs
  - NOR32_chrage
  - NOR32 time
  - Charge measurement over 10 bits
  - Time measurement over 10 bits
  - One multiplexed charge output
- Common trigger threshold adjustment and 6bit-dac/channel for individual adjustment
- Variable shaping time of the charge shaper
- 32 8bit-input dac for SiPM HV adjustment
- Power consumption 6 mW/ch
- Front-end
  - common emitter SiGe fast amplifier, DC couplec to detector
  - Fast SiGe discriminator

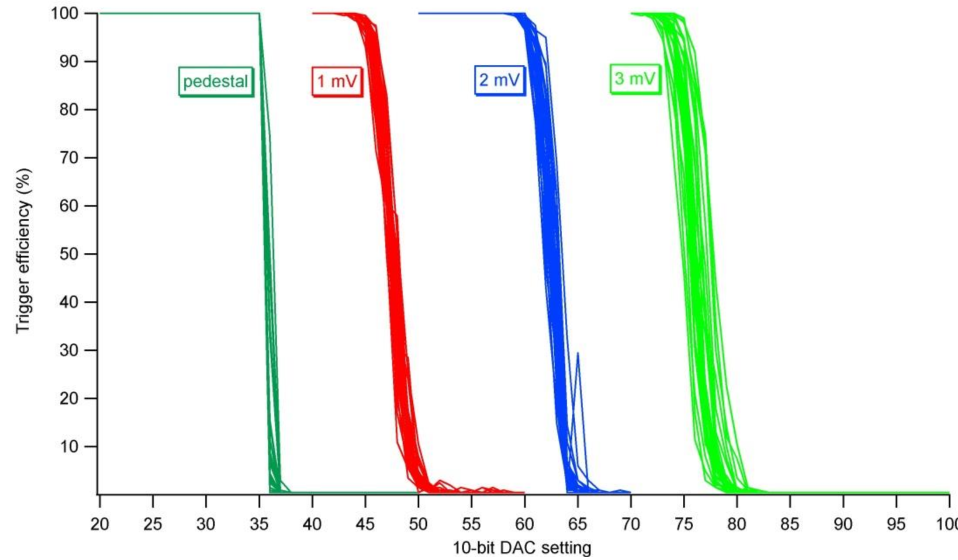


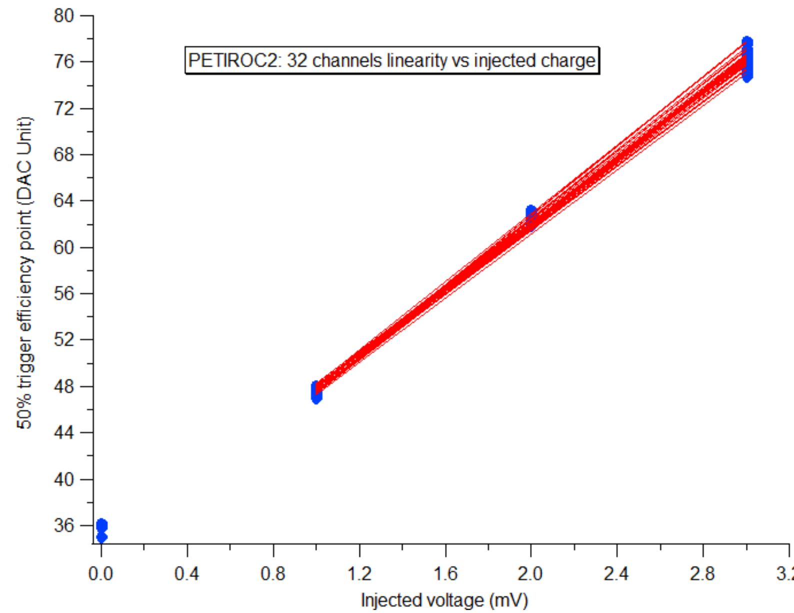


PETIROC2: « S-curves »

- Trigger efficiency measurements:







SUMMARY

Ωmega

- PETIROC is a versatile high speed readout chip for SiPMs
- A 64 channel version (TRIROC) has just been produced (see talk by Salleh AHMAD)
- Engineering run (0.35µm SiGe AMS) foreseen at the end of this year

http://omega.in2p3.fr/

http://www.weeroc.com/

Chip	Detector	Ch	Polarity	Dyn Range	Specificities
MAROC	PM	64	<0	5 fC - 5 pC	64 trig outputs, internal 8/10/12-bit ADC (for charge measurment)
SPACIROC	PM	64	<0	2 pC- 220 pC	Fast photon counting (50MHz)
PARISROC	PM	16	<0	50 fC - 100 pC	Internal TDC (<1ns), 16 trig outputs
HARDROC	RPC	64	<0	2 fC - 10 pC	3 discriminators, 128 deep digital memory to store 2x64 discriminator encoded data
MICROROC	µMEGAS/GEM	64	<0	0.2 fC - 500 fC	3 discriminators, 128 deep digital memory to store 2x64 discriminator encoded data
SKIROC	Si pin diodes	64	>0	0.3 f C - 10 pC	Internal 12-bit ADC for charge measurement
SPIROC	SiPM	36	>0	10 fC - 300 pC	36 HV SiPM tuning (8 bits), Internal 12-bit ADC for charge and time measurement
EASIROC	SiPM	32	>0	10 fC - 300 pC	32 HV SiPM tuning (8 bits), 32 trigger outputs
CITIROC	SiPM	32	>0	10 fC - 300 pC	32 HV SiPM tuning (8 bits), 32 trigger outputs
PETIROC	SiPM	32	<0	100fC – 300 pC	32 HV SiPM tuning (8 bits), 32 trigger outputs, Internal 10-bit ADC for charge and time measurement (25 ps)
TRIROC	SiPM	64	Both	100 fC- 300 pC	64 HV SiPM tuning (8 bits), 64 trigger outputs, Internal 10-bit ADC for charge and time measurement (25 ps)