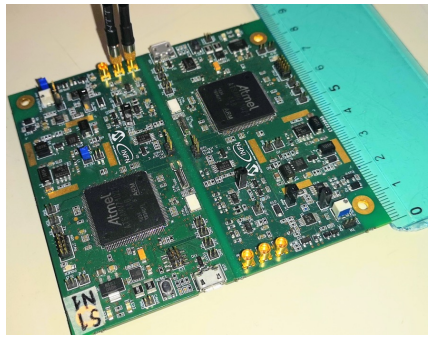
Frontier Detectors for
Frontier Physics

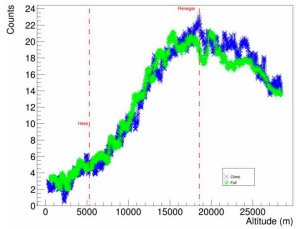
Compact and Light All-in-One Detectors for space application

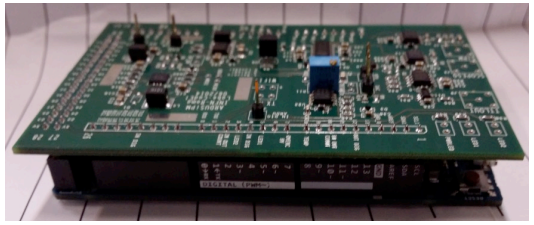
Valerio Bocci[(1)]

Babar Ali(3)(4), Davide Badoni (2), Valerio Bocci(1)
, Marco Casolino(2), Giacomo Chiodi(1), Francesco Iacoangeli(1), Dario Kubler (3), Laura Marcelli(2), Recchia,Luigi(1), Matteo Salvato(2)

(1) INFN Sezione di Roma
(2)INFN Sezione di Roma Tor Vergata
(3)Microchip Technology
(4) Sapienza University Rome







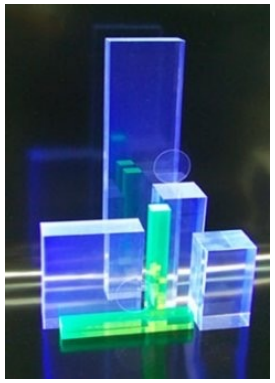
Frontier Detectors for Frontier Physics

ArduSiPM

In 2014 we realize and publish a new kind of detector using the new generation of SiPM and System on Chip (SoC)

V. Bocci, G. Chiodi, F. Iacoangeli, M. Nuccetelli and L. Recchia, "The ArduSiPM a compact trasportable Software/Hardware Data Acquisition system for SiPM detector," *2014 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)*, 2014, pp. 1-5, doi: 10.1109/NSSMIC.2014.7431252.

Valerio Bocci IEEE NSS/MIC 8-15 November Seattle



Scintillator

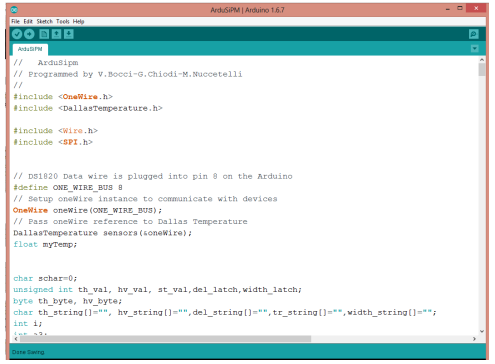
Photons Sensor (SiPM)

Main Feature

Custom Electronics (ArduSiPM Shield)

SAM3X8E SoC

Arduino DUE

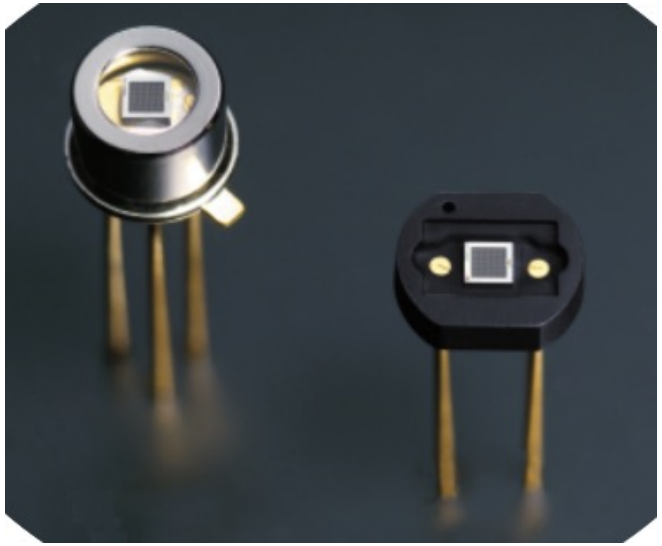


ArduSiPM Software

Particle Detector

ArduSiPM

SiPM (Silicon Photo Multiplier)



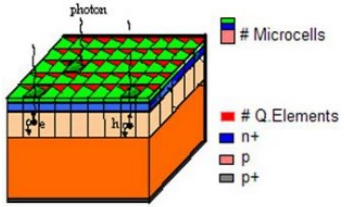
- The idea behind this device is the detection of single photon events in sequentially connected SiAPDs.

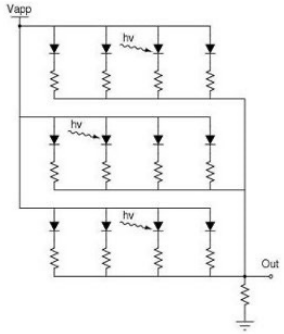
- The dimension of each single APD can vary from 20 to 100 micrometres, and their density can be up to 1000 per square millimeter.

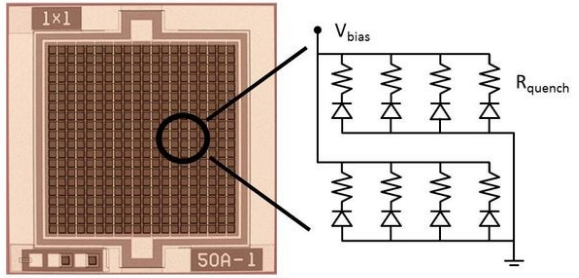
- Every APD in SiPM operates in Geiger-mode and is coupled with the others by a polysilicon quenching resistor.

- Although the device works in digital/switching mode, the SiPM is an analog device because all the microcells are read in parallel making it possible to generate signals within a dynamic range from a single photon to 1000 photons for just a single square millimeter area device.

- The supply voltage (Vb) depends on APD technology used, and typically varies between 20 V and 100 V, thus being from 15 to 75 times lower than the voltage required for a traditional photomultiplier tubes (PMTs) operation.

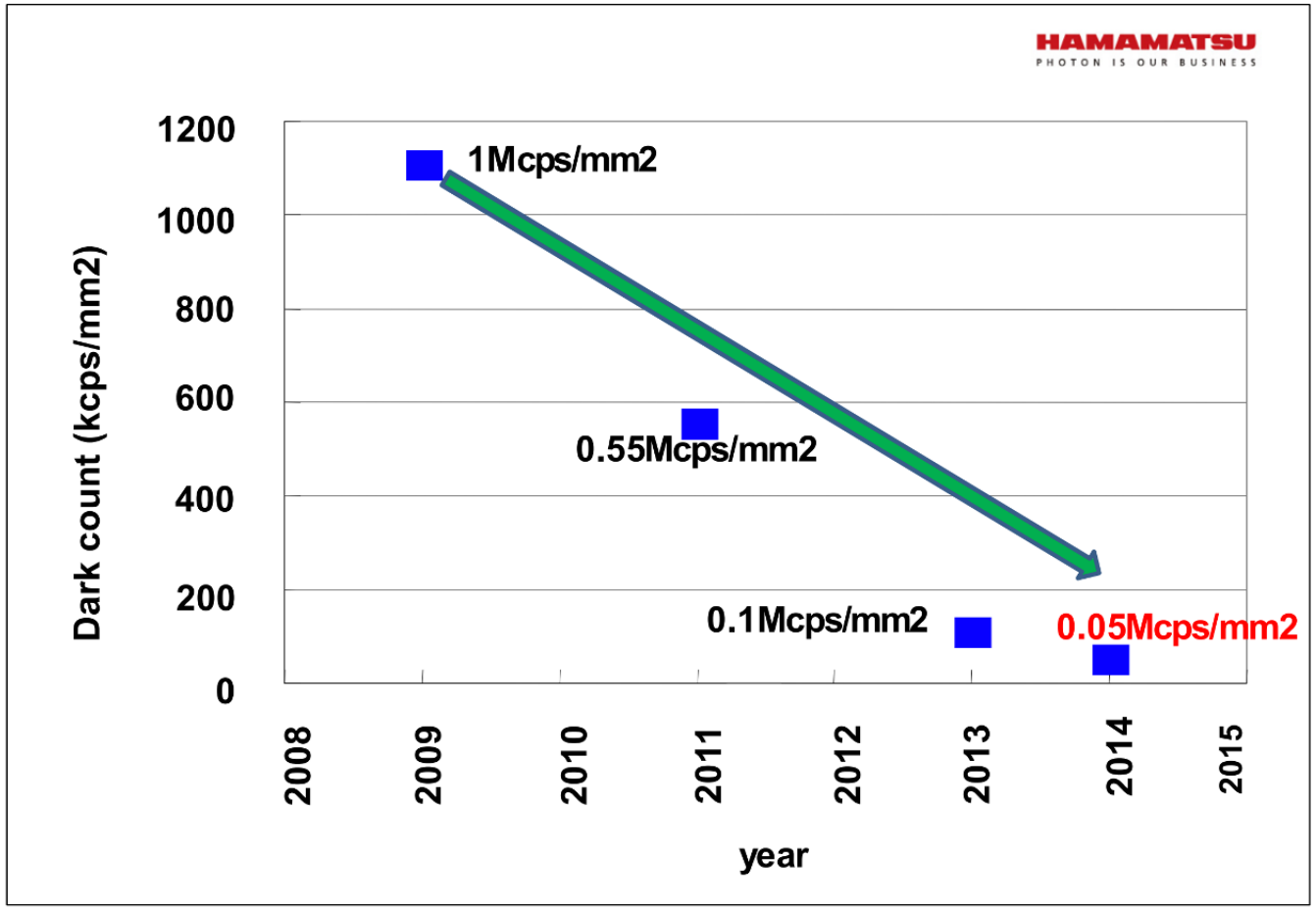


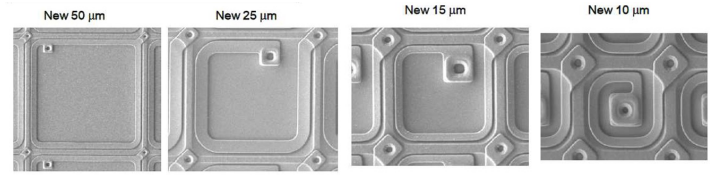




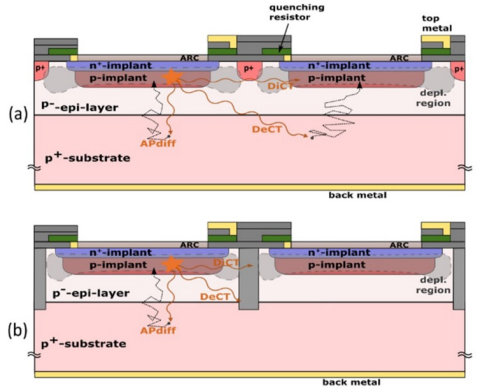
Improvements of SiPM technology from 2010-2015

Dark Counts reduction



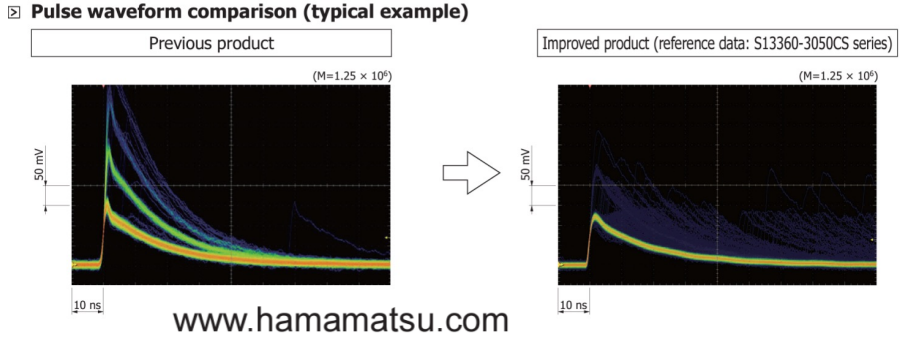


Metal resistor is less sensitive to temperature then polisilicon one



The Trench structure to decouple pixel

FBK Pub



www.hamamatsu.com

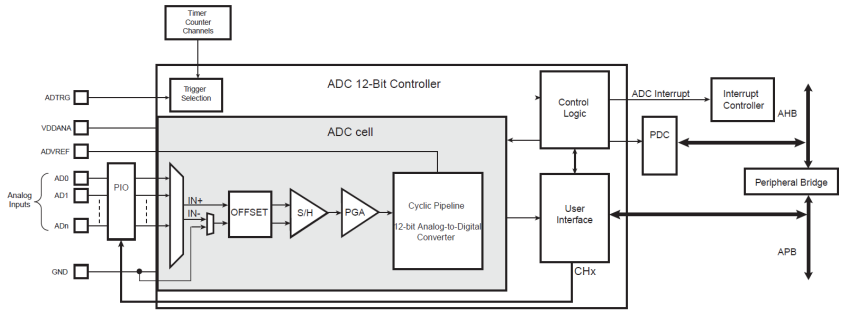
The SoC : Microchip SAM3X8E

Atmel now Microchip Technology

84 MHz 32 bits RISCH ARM® Cortex®-M3 Core

Analog Blocks

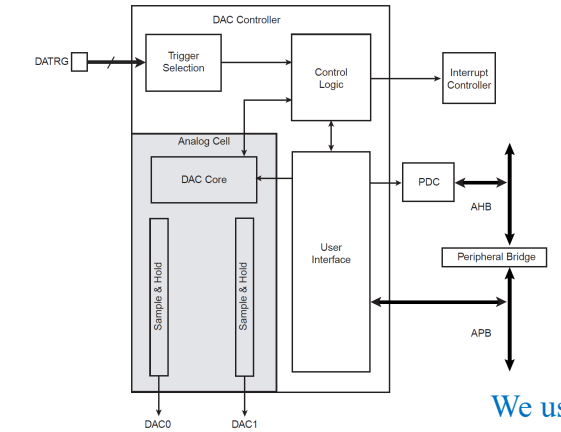
12 bit 1MSample ADC



We use as:

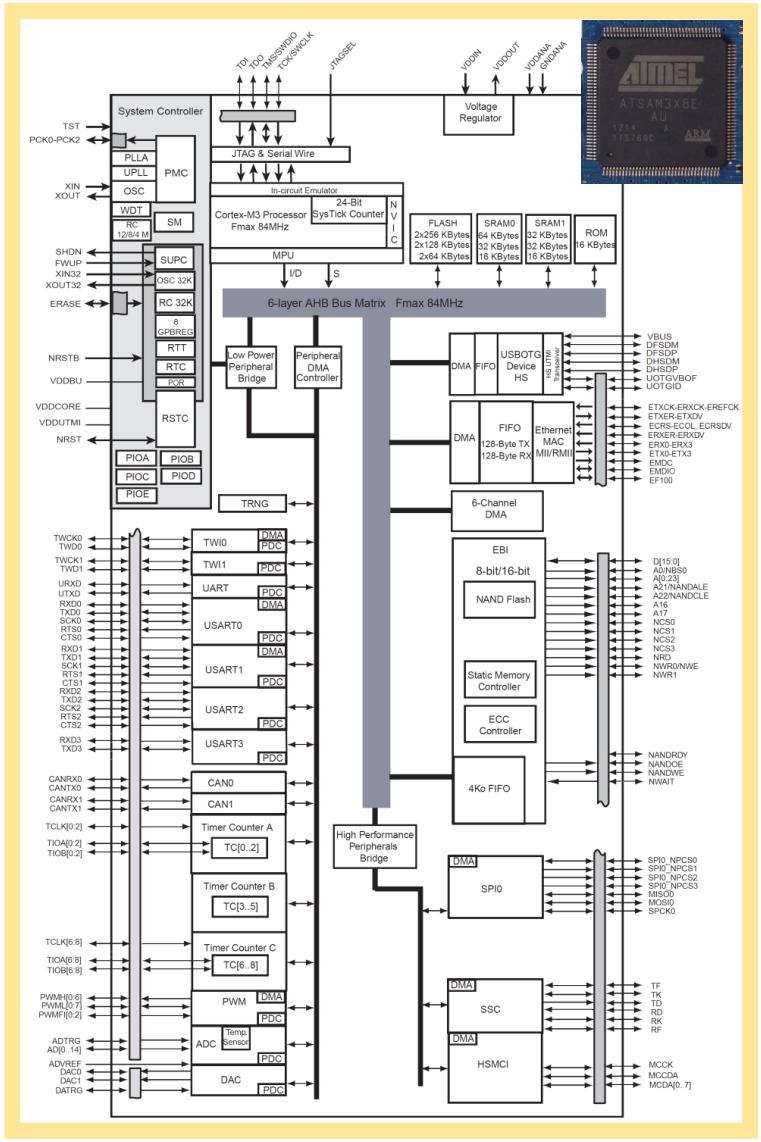
- Pulse Peak Measurements
- HV monitoring
- Threshold monitoring

2 x 12 bit 1MSample DAC



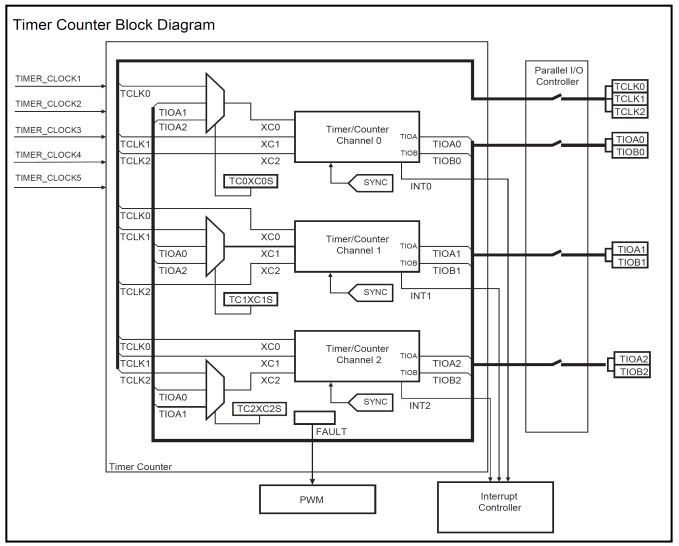
We use as:

- Threshold settings



Digital Blocks

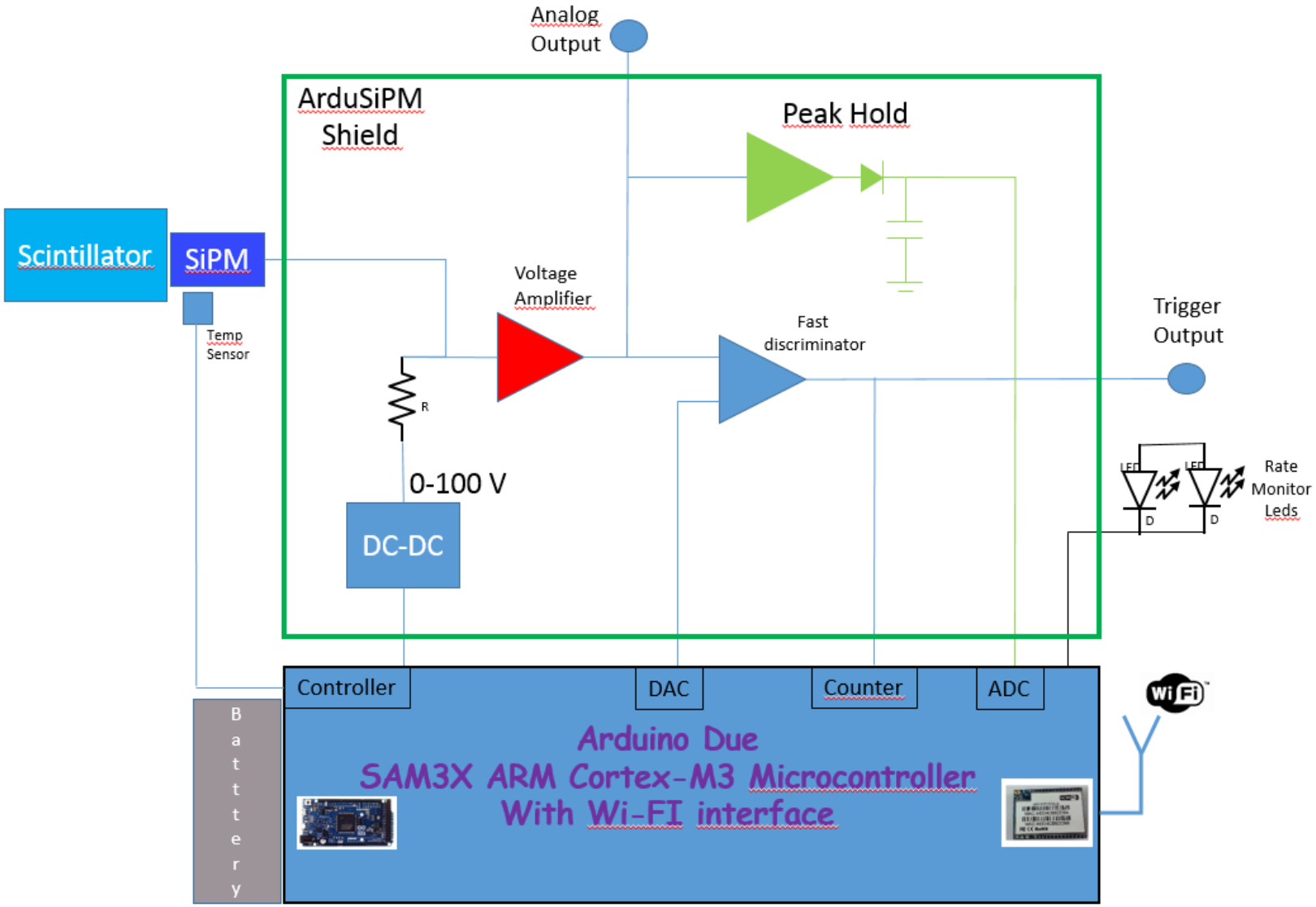
9 x 32 bits Digital Counters upto 42 MHz (24 ns)



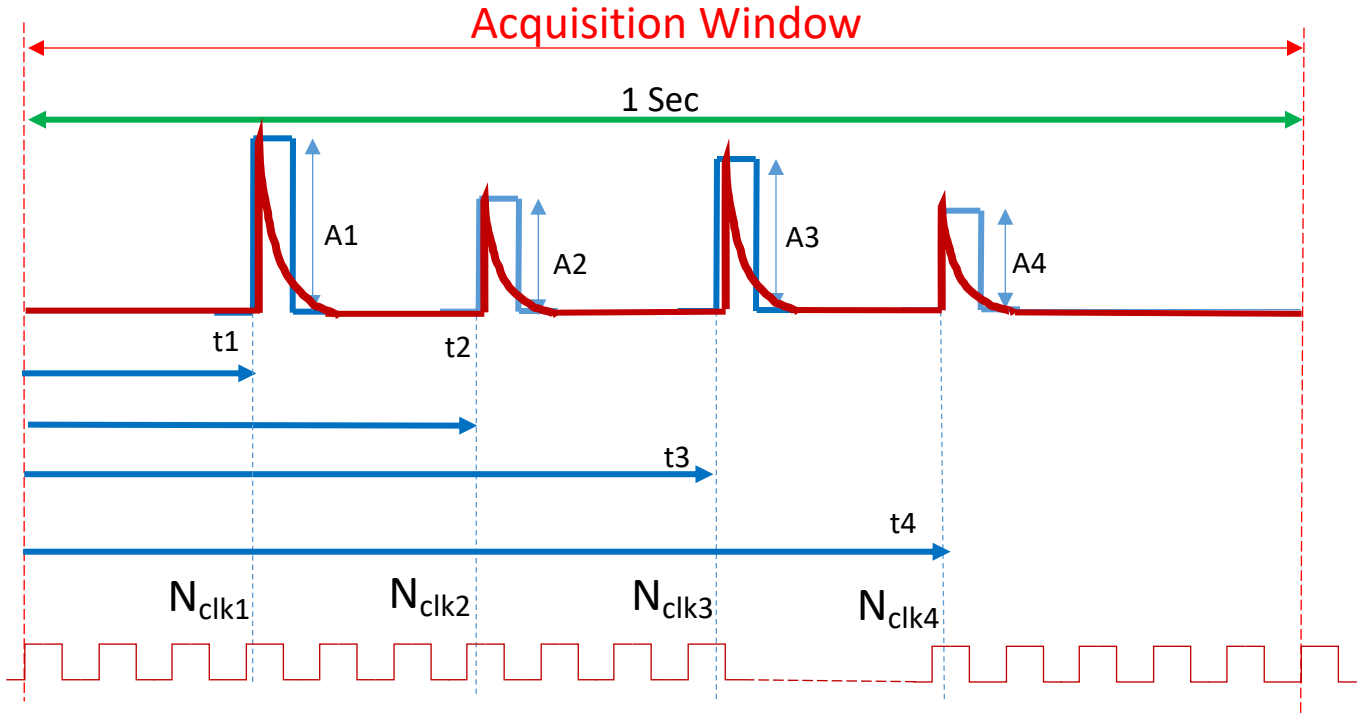
We use in Wide Range of Functions

- Time Measurement (TDC)
- Event Counting
- Pulse Generation
- Delay Timing
- Synchronization with an external signal

ArduSiPM Block Diagram



ArduSiPM measuraments



Data Stream example:

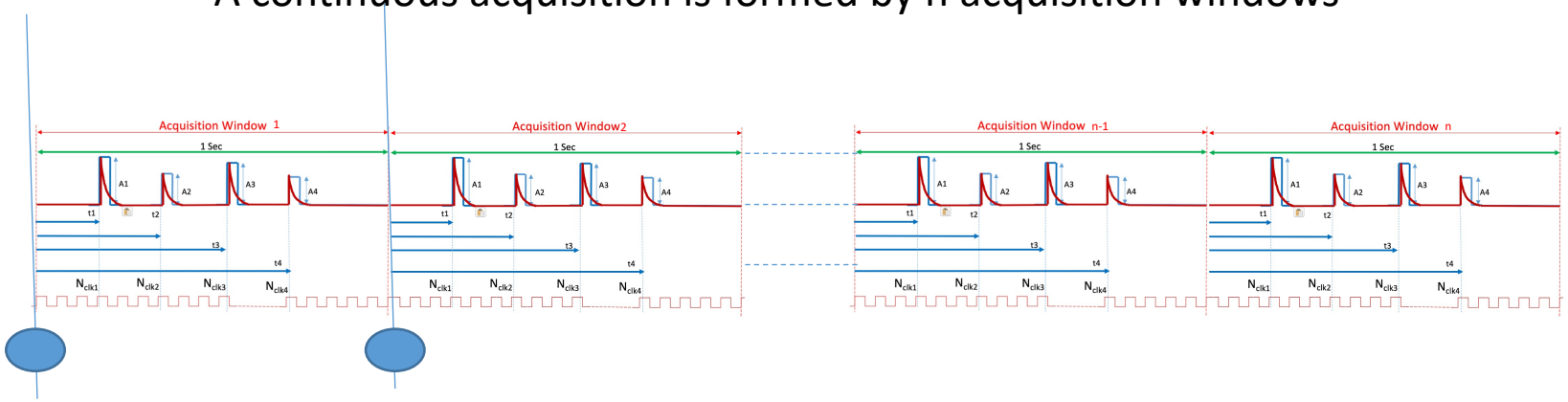
```
Only rate:
$10
$50
$244

ADC+Rate:
v1Fv1Dv22v27v1Dv19v20v23v20v1Cv19v1F$12
v18v1Ev1Ev1Bv19v1Bv29v19v1Av1Dv1Bv1Dv2Av18v1B$15
v15v20v21v21v1Dv1Fv1Av1Av1A$9
v19v17v1Bv18v1Cv1Dv1D$7

TDC+ADC+RATE:
taedvataf0v7tv9v3$3
```

Legend:
vXXX ADC Value in HEX MSB zero suppressed
tXXXXXXXX TDC value in HEX MSB zero suppressed
$XXX rate in Hz

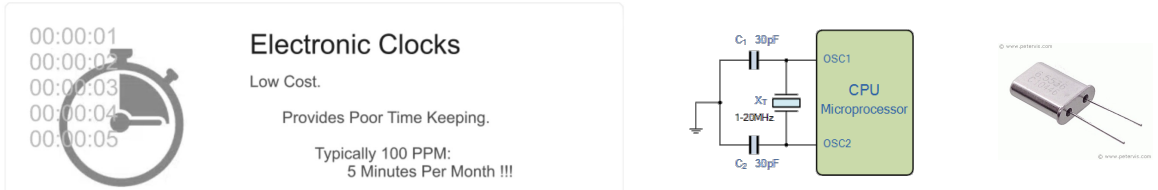
Using Hardware resources (ADC,DAC,Counters)

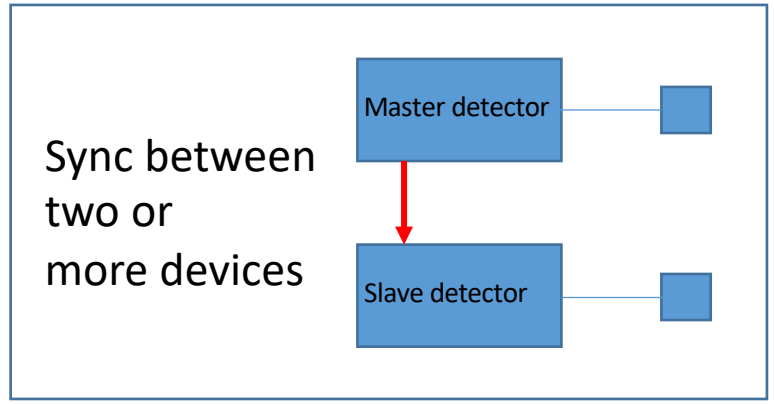
- Number of pulses in a time window
- Amplitude of each pulse
- Time in numbers of CPU clocks

A continuous acquisition is formed by n acquisition windows

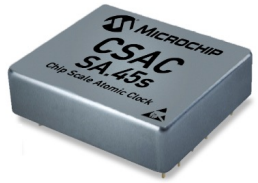


Any acquisition window can be synchronized and calibrated with an external time reference like:



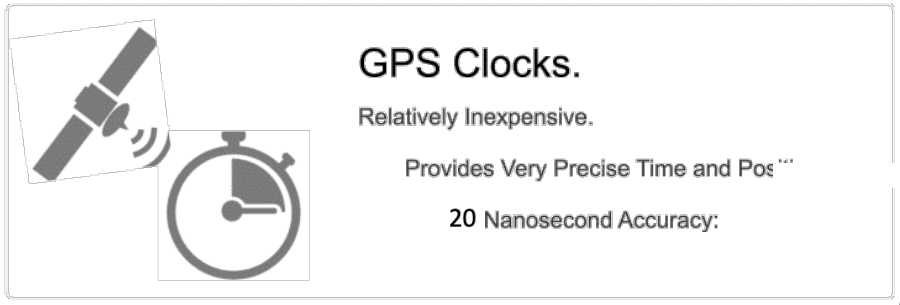


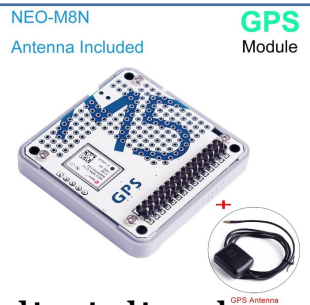
A **chip scale atomic clock** (CSAC) is a compact, low-power atomic clock fabricated using techniques of microelectromechanical systems (MEMS) and incorporating a low-power semiconductor laser as the light source.



<5.0E-11

0.05 ppb





GPS disciplined oscillator

ArduSiPM

Dissemination in fields other than those of high energy physics

example : analytical chemistry using chemiluminescence and bioluminescence

analytical chemistry
IF:6.986
pubs.acs.org/ac
Technical Note

Ultrasensitive On-Field Luminescence Detection Using a Low-Cost Silicon Photomultiplier Device

Maria Maddalena Calabretta,* Laura Montali,* Antonia Lopreside, Fabio Fragapane, Francesco Iacoangeli, Aldo Roda, Valerio Bocci, Marcello D'Elia,* and Elisa Michelini*

Cite This: *Anal. Chem.* 2021, 93, 7388–7393
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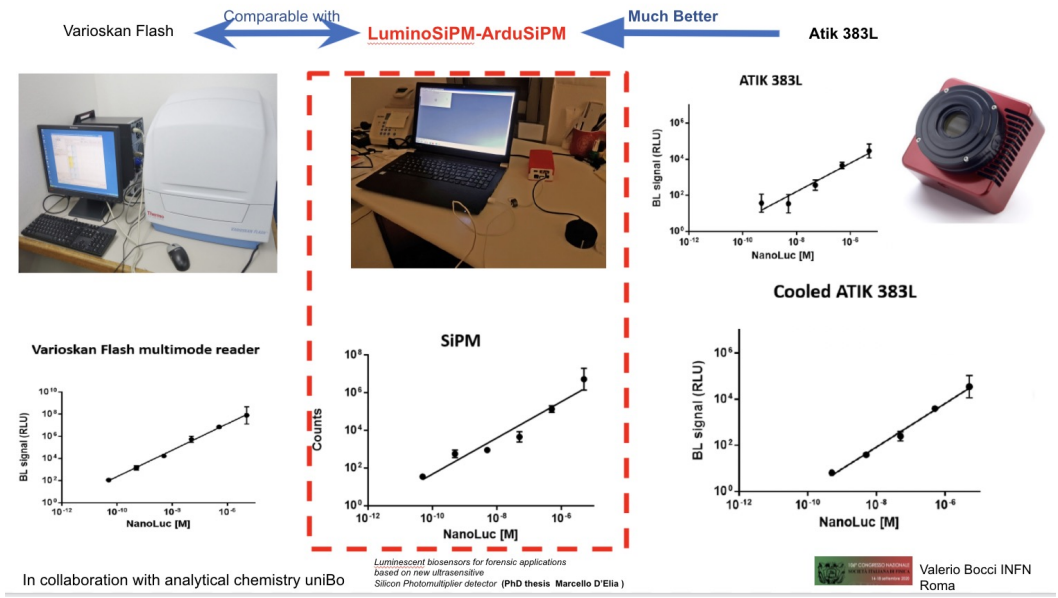
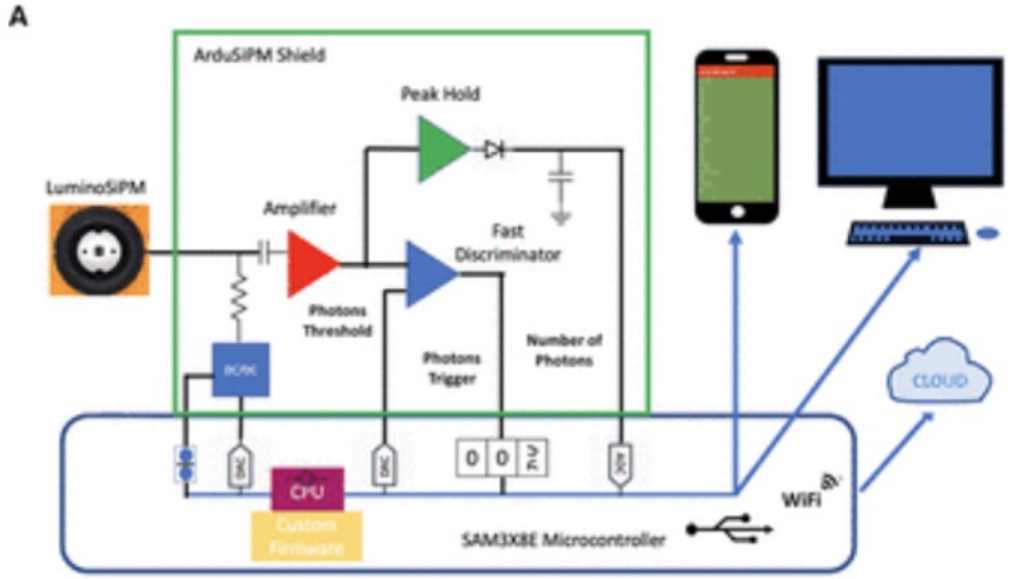
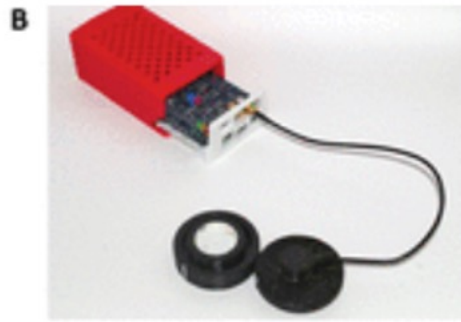
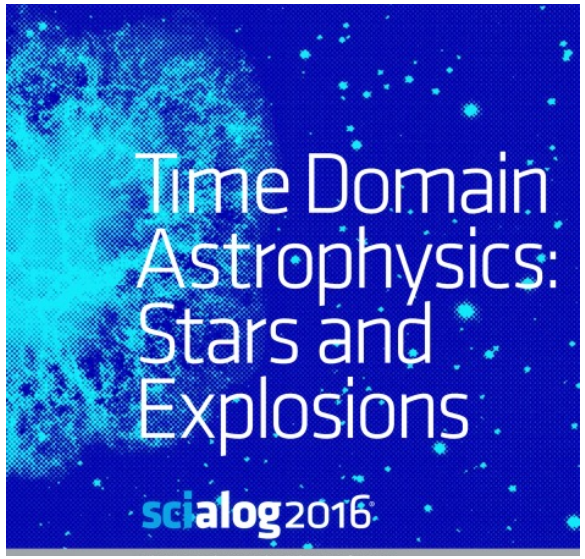
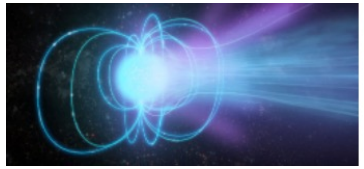






Time-domain astronomy





A POSSIBLE OPTICAL COUNTERPART TO A FAST RADIO BURST?

BY: AAS NOVA | MAY 5, 2022 | 1

THE ASTROPHYSICAL JOURNAL

OPEN ACCESS

AT2020hur: A Possible Optical Counterpart of FRB 180916B

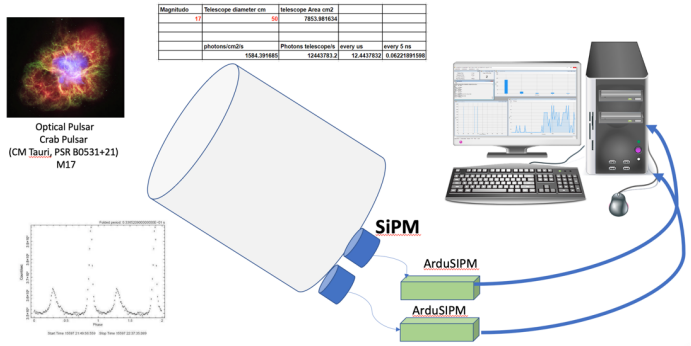
Long Li[1], Qiao-Chu Li[1], Shu-Qing Zhong[2], Jie Xia[3,4], Lang Xie[3,4], Fa-Yin Wang[1,5], and Zi-Gao Dai[1,6]

Published 2022 April 21 • © 2022. The Author(s). Published by the American Astronomical Society.

The Astrophysical Journal, Volume 929, Number 2

Citation Long Li *et al* 2022 *ApJ* **929** 139

Raw design of ArduSiPM as fast photometer



Triggers from
- GW detectors
- neutrino detectors (km^3)
- very high-energy astronomy (CTA)

Need for a fast optical (electromagnetic) follow-up

Acta Polytechnica Vol. 51 No. 6/2011

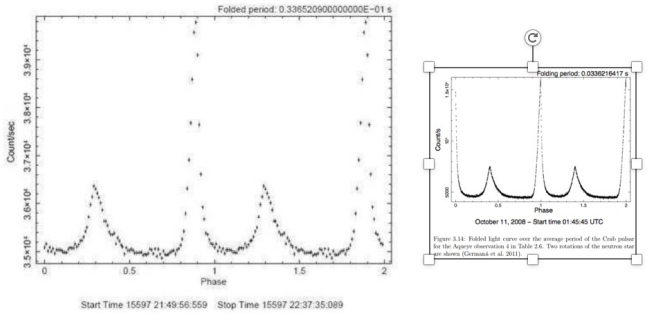
A New Fast Silicon Photomultiplier Photometer

F. Meddi, F. Ambrosino, C. Rossi, R. Nesci, S. Sclavi,
A. Ruggieri, S. Sestito, I. Bruni, R. Gualandi

Abstract

The Crab pulsar is one of the most intensively studied X-ray/optical objects, but up to now only a small n
research groups have based their photometers on SiPM technology. In early February 2011, the Crab pulsar signal was
observed with our photometer prototype. With low-cost instrumentation, the results of the analysis are very significant:
the processed data acquired on the Crab pulsar gave both a good light curve and a good power spectrum, in comparison
with the data analysis results of other more expensive photometer instrumentation.

Keywords: Silicon PhotoMultiplier detector (SiPM), photometer, fast variability, Pulsar.



Ultra-Fast InfraRed Detector for Astronomy

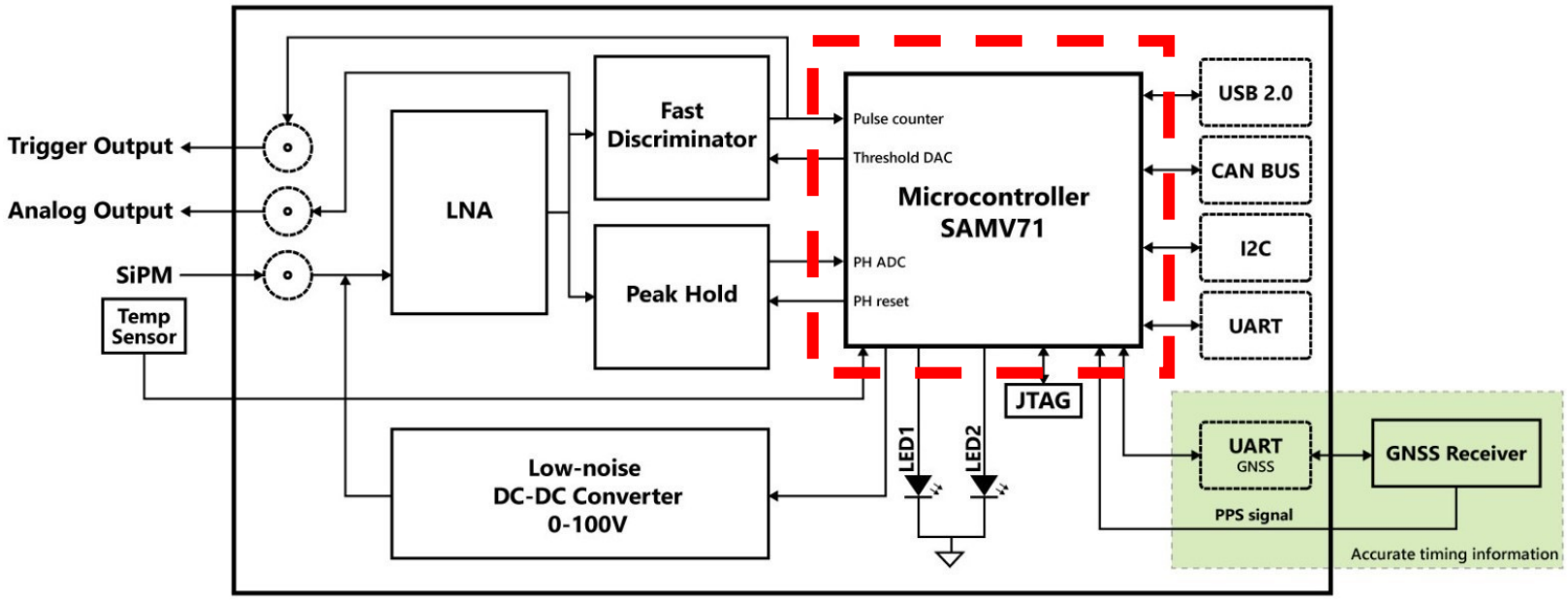
Alessandro Drago (a), Emanuele Pace (b), Simone Bini (c), Mariangela Cestelli Guidi (c),
Catalina Curceanu (c), Augusto Marcelli (c), Valerio Bocci (d)

(a) Università di Firenze & INFN/LNF, (b) Università di Firenze & OPC-Osservatorio Polifunzionale del Chianti, (c) INFN/LNF, (d) INFN/Roma1

Frontier Detector for Frontier Physics - 15th Pisa Meeting on Advanced Detectors, La Biodola, Isola d'Elba, 22-28 May 2022

The Cosmo ArduSiPM

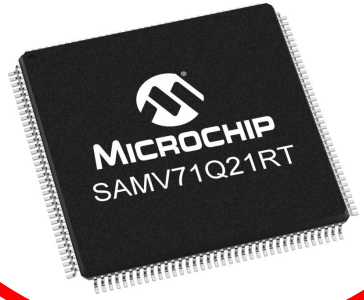
ArduSIPM analog + SAM3X8E --> ArduSIPM analog + SAMV71



- 32-bit ARM® Cortex®-M7 RISC (5.04 CoreMark/MHz)
- floating point unit (FPU)
- maximum speed of 300 MHz,
- 2048 Kbytes of Flash,
- dual 16Kbyte cache memory, up to 384 Kbytes of SRAM

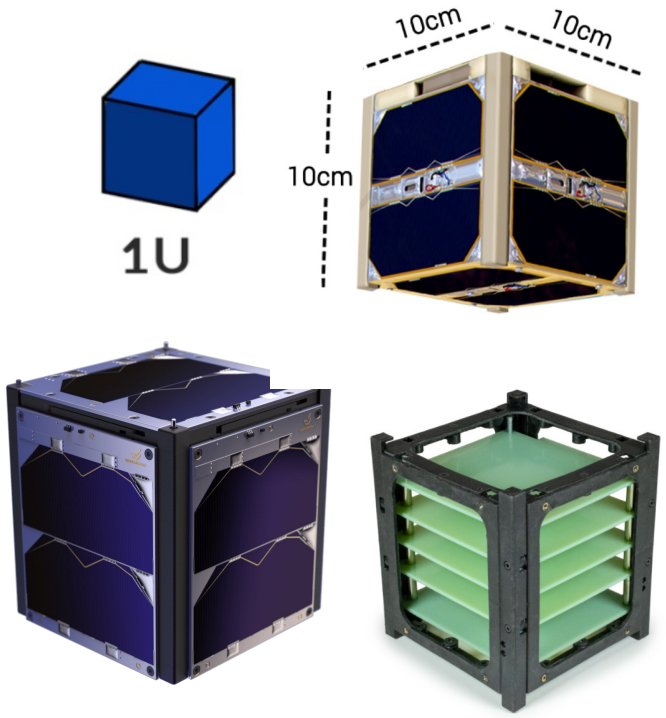
SAMV71Q21RT ☆

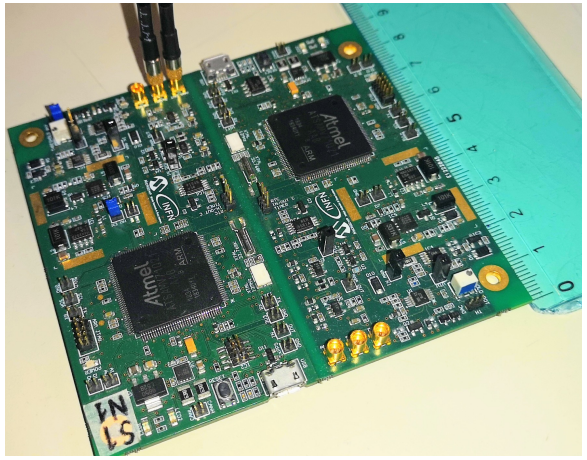
Radiation Tolerant Cortex M7 MCU

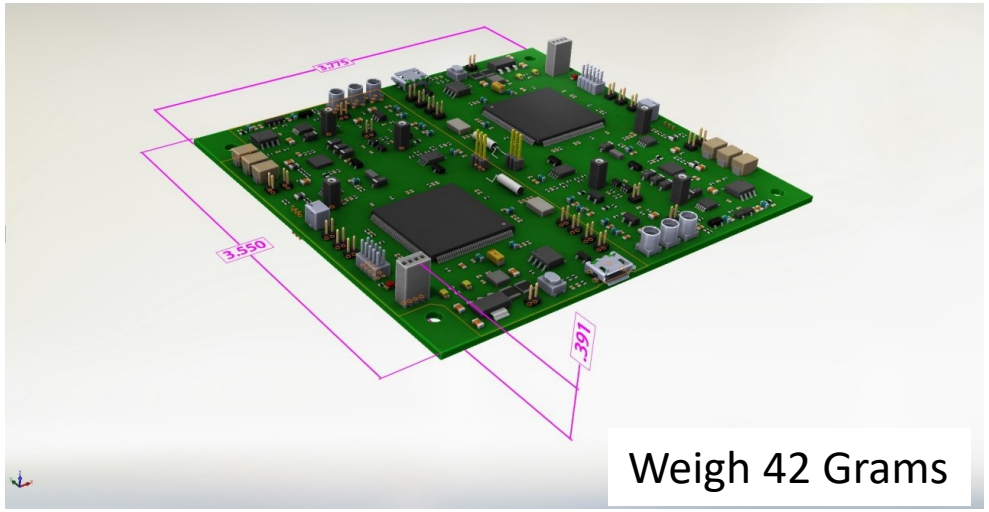


Cosmo ArduSiPM

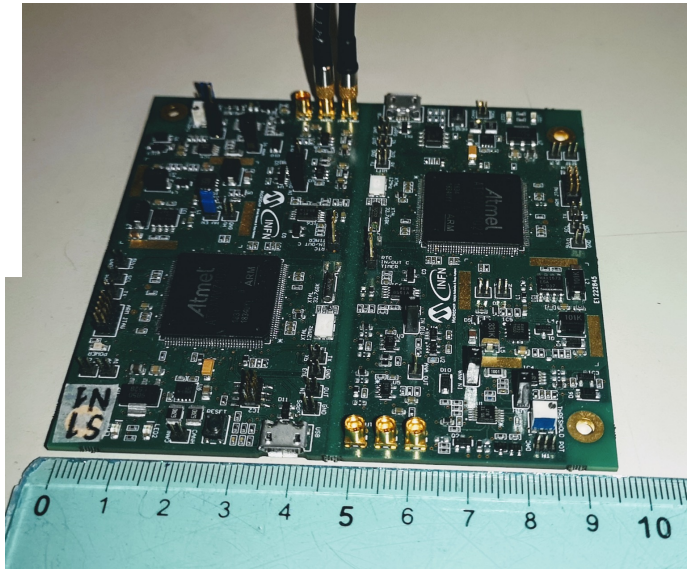
a double channel PC104 Board (0.1 U)







Weigh 42 Grams



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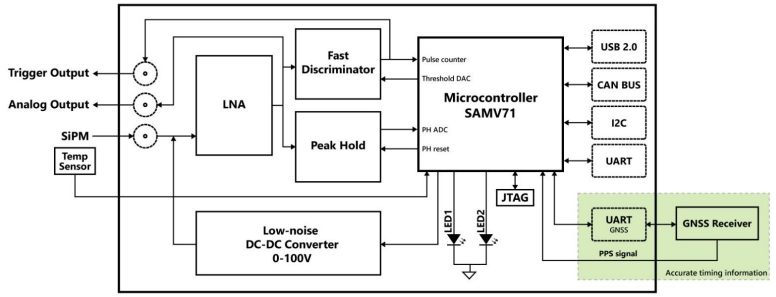
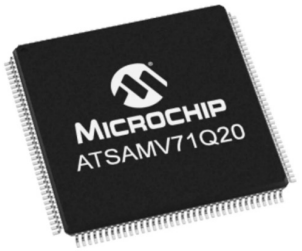


The ArduSiPM architecture can scale with SoC Growth

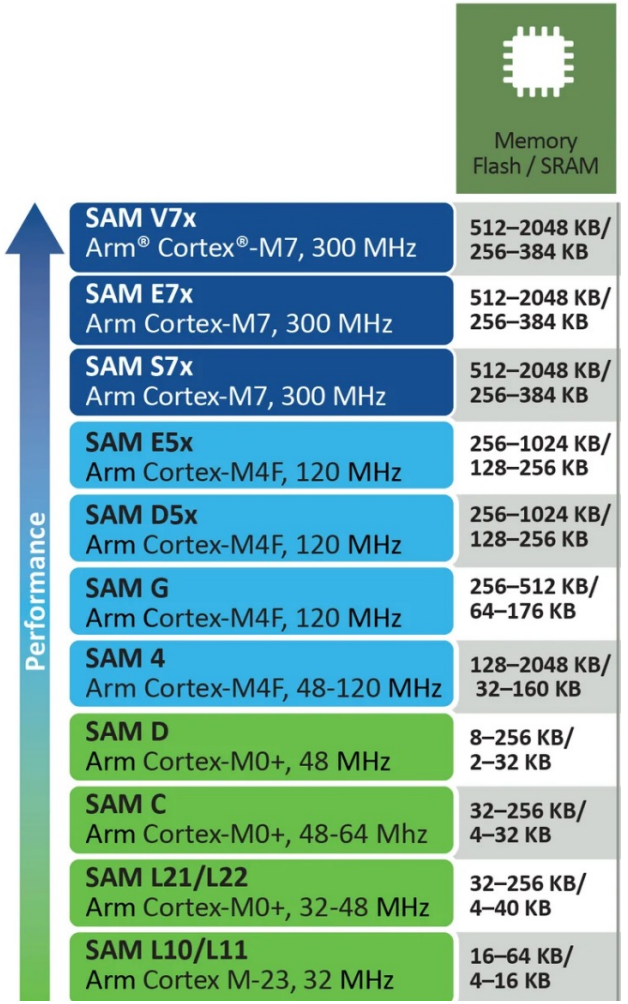


SAM3X8E

- 32-bit ARM ® Cortex®-M3 RISC
- 84 MHZ
- 12 bits 1 Msamples/s ADC
- SRAM 64 + 32 Kbytes
- Flash 2 x 256 Kbytes

SAMV71

- 32-bit ARM® Cortex®-M7 RISC
- 300 MHZ
- 12 bits 2 Msamples/s ADC
- Multi port SRAM 384 Kbytes
- Flash 2048 Kbytes
- Cache 16/16 Kbytes
- Two Analog Front-End Controllers (AFEC), allowing dual sample-and-hold at up to 1.7 Msps. Offset and gain error correction feature.



- ***Better time resolution.***
- ***More data processing capability***
- ***More firmware ad hoc solution***

Example More memory –> RT histogram

MICRO

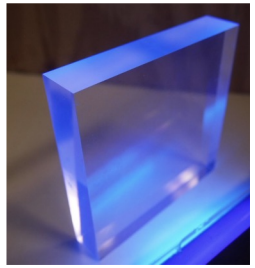
(co**M**pact-electron**I**cs so**C** pa**R**ticle-detectors and bi**O**luminesceNce)
INFN National Scientific Committee 5 (CSN5) experiment

CSN5 Technological research

Development of All-In-One detectors (detectors, electronics, daq), using latest generation commercial integrated circuit systems (SoC), for particle detection or measurement of bio (luminescence) fluxes.

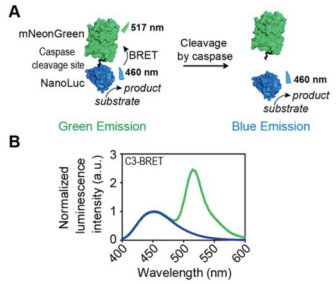
INFN Roma: Valerio Bocci (National manager),Giacomo Chiodi,Francesco Iacoangeli , Luigi Recchia,
INFN Roma2: Davide Badoni (Local Manager) , Marco Casolino, Matteo Salvato, Mattia Scagliotti

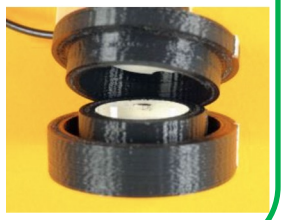
Scintillator or Cherenkov radiator



~3-100 photons in few ns

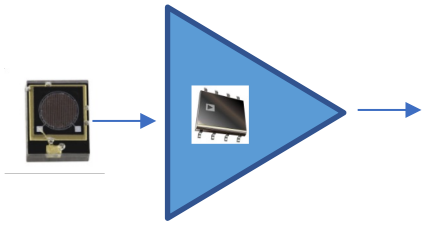
Bio(luminoscence) flux measurements

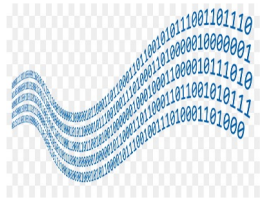




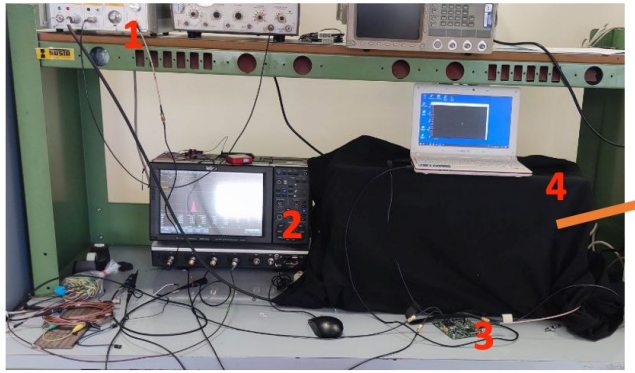
~10^5-10^6photons/s

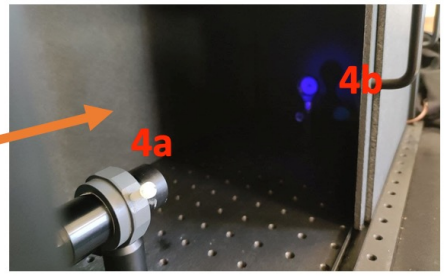
MICRO device



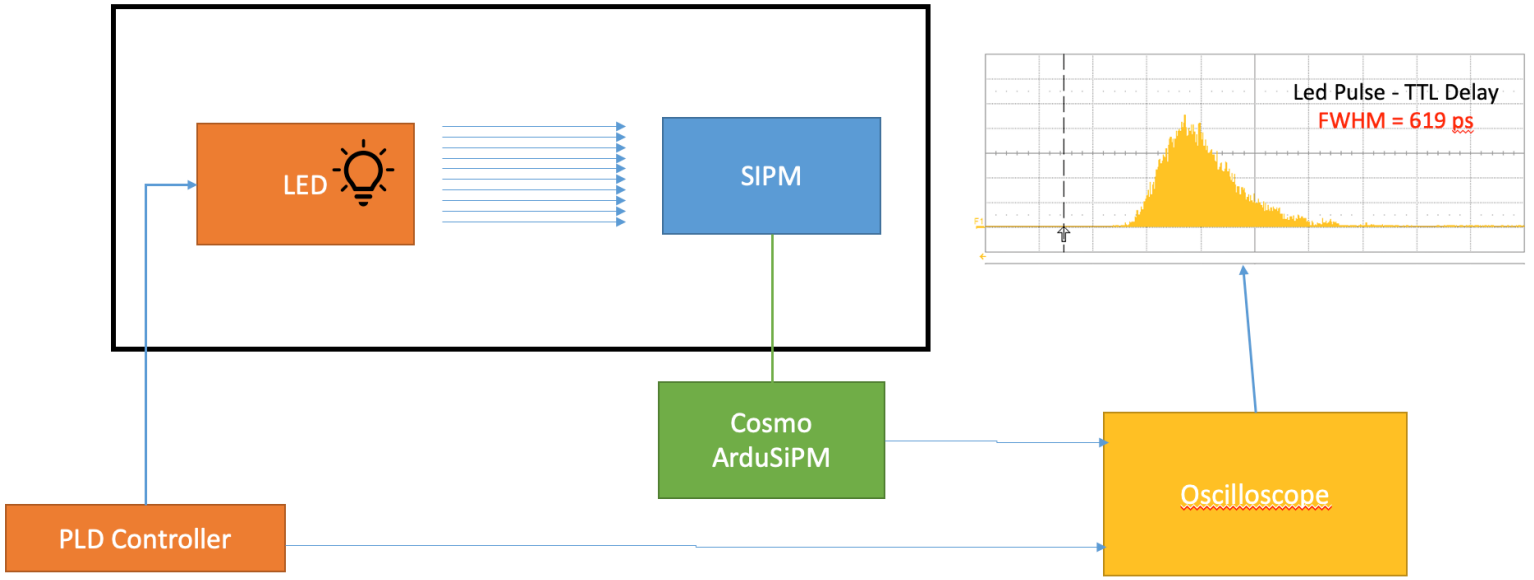


Optical test bench



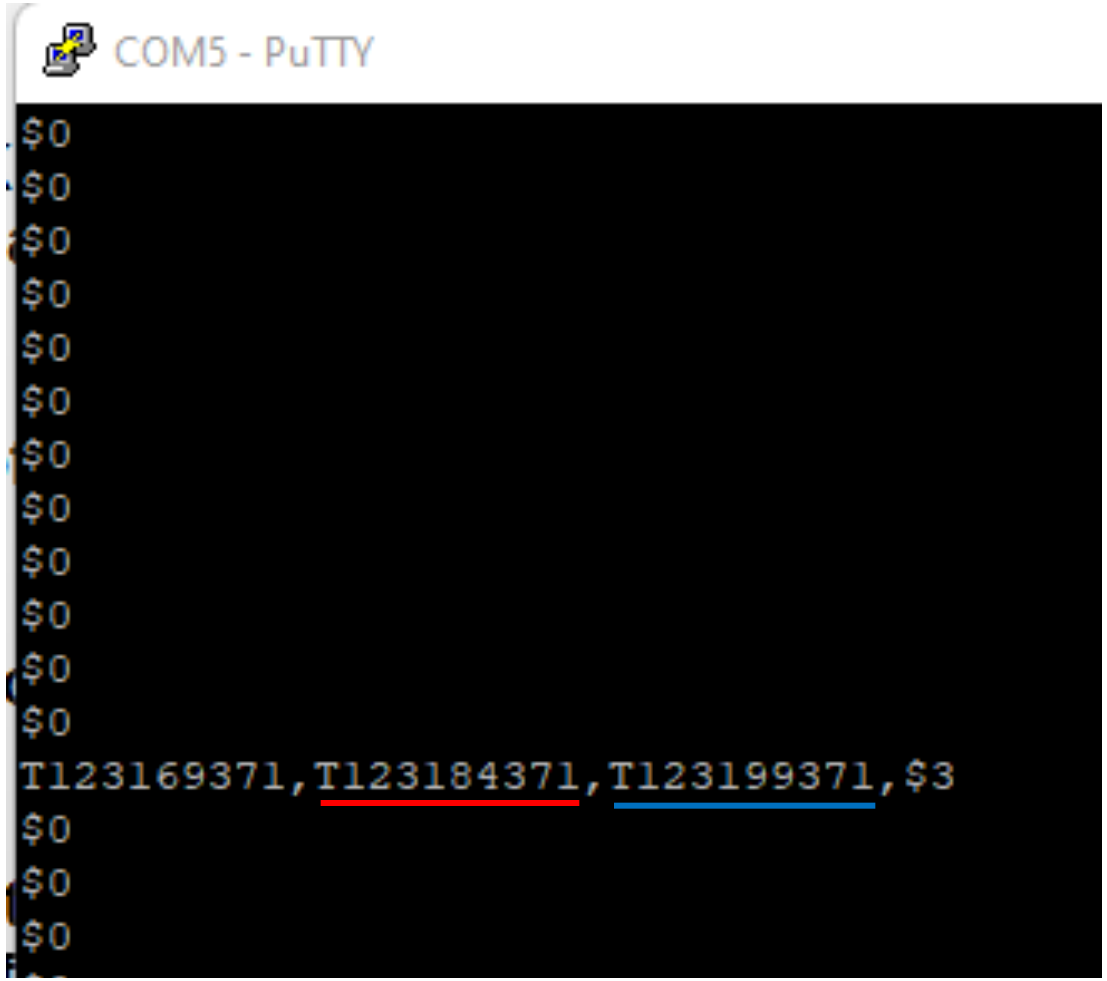


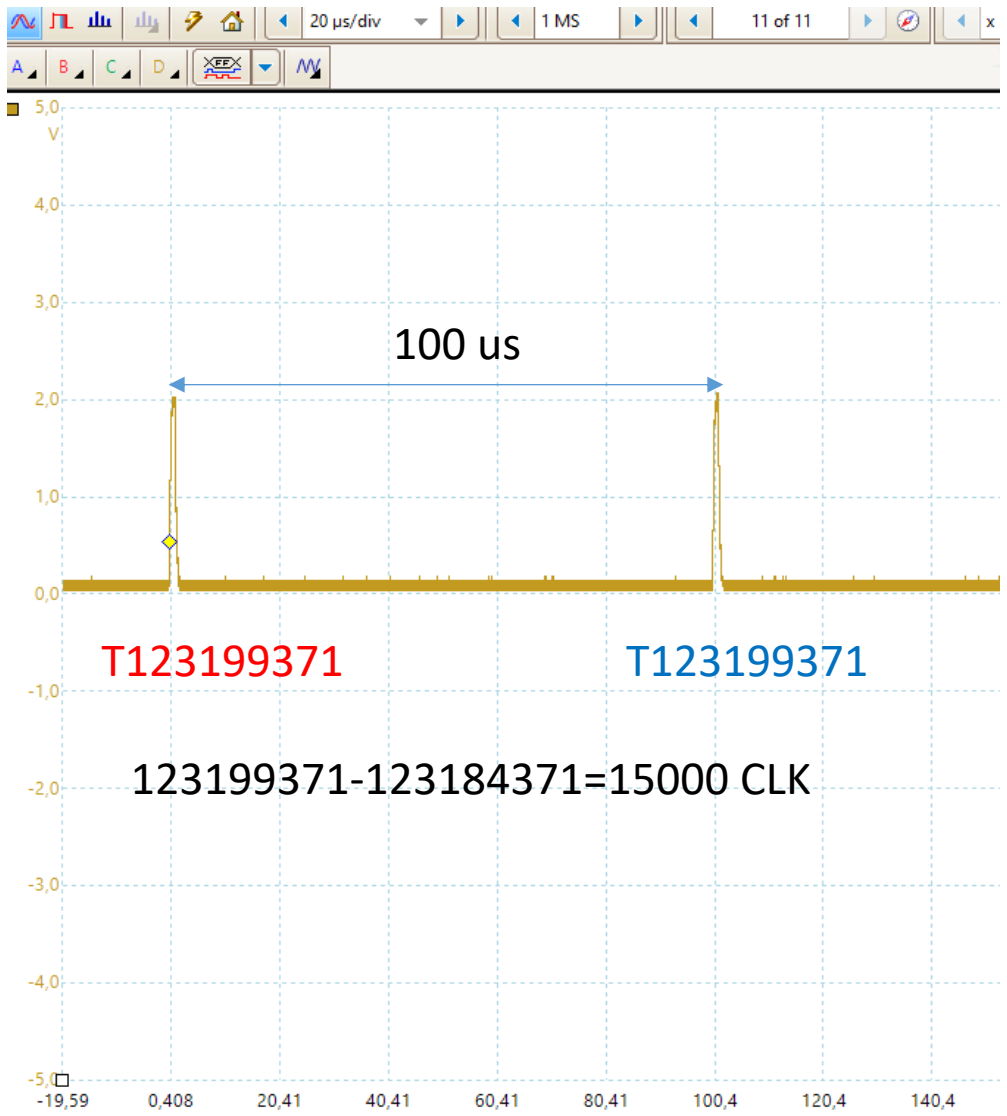
1 - Driver LED Picoquant PDL 800-B, pulse width as short as 800 ps (FWHM)
2 - Oscilloscope LECROY 12bit, 2Gsample/s, 4000Mhz Bandwidth
3 – Cosmo ArduSiPM
4 - Box
4a – Led heads 460nm
4b – SiPM 13360-1325CS Hamamatsu



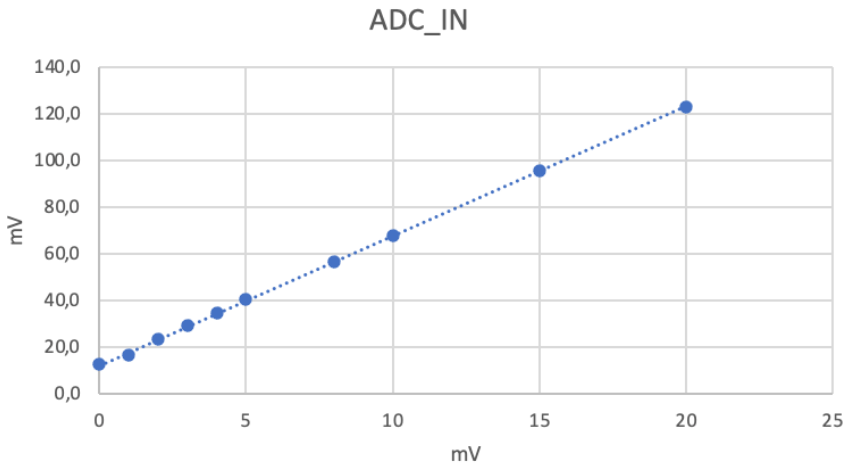
Time Measuraments between Pulses

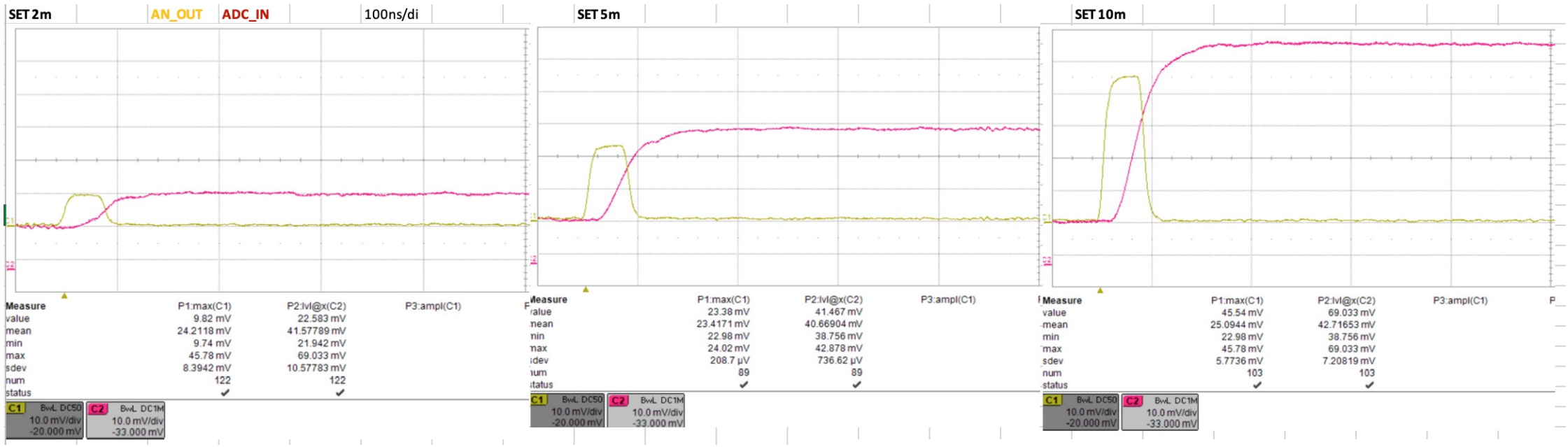
TDC_CLK=CPU_CLK/2=150 MHz -> 6.6 ns





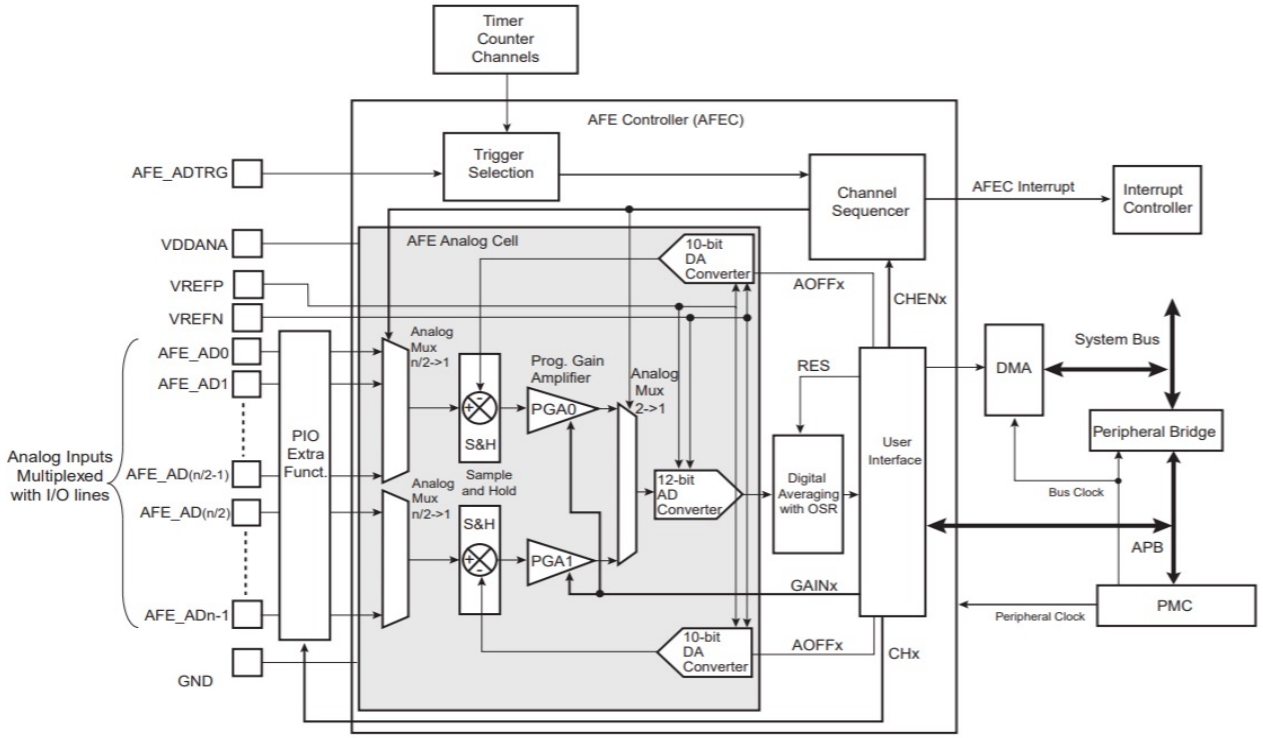
Peak Hold Circuits



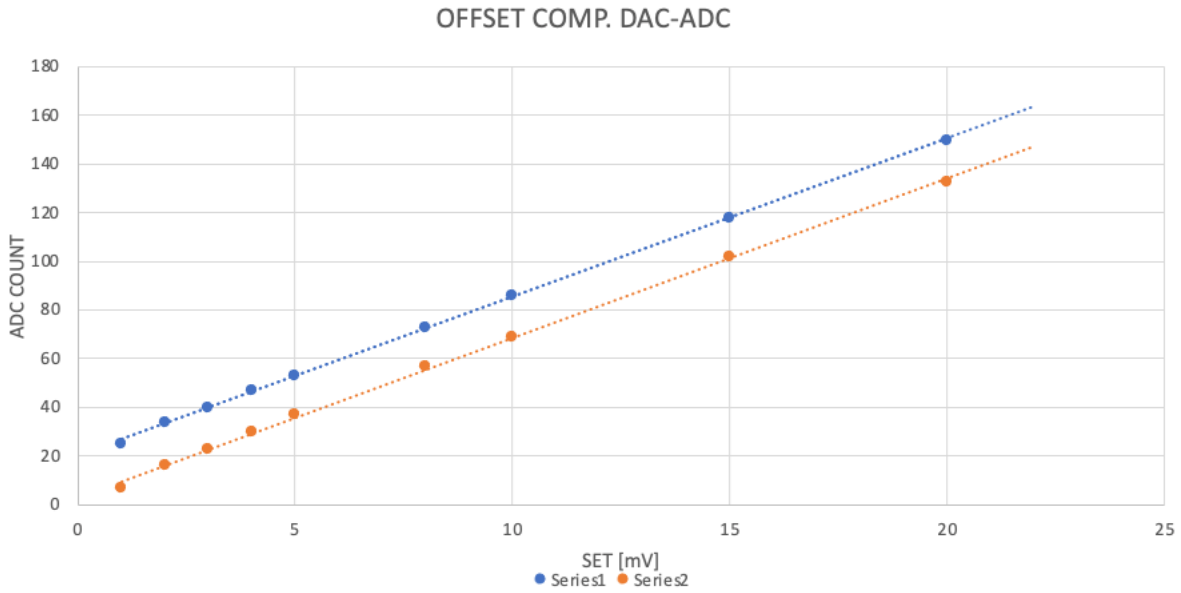


ADC internal offset compensation

Figure 52-1. Analog Front-End Controller Block Diagram



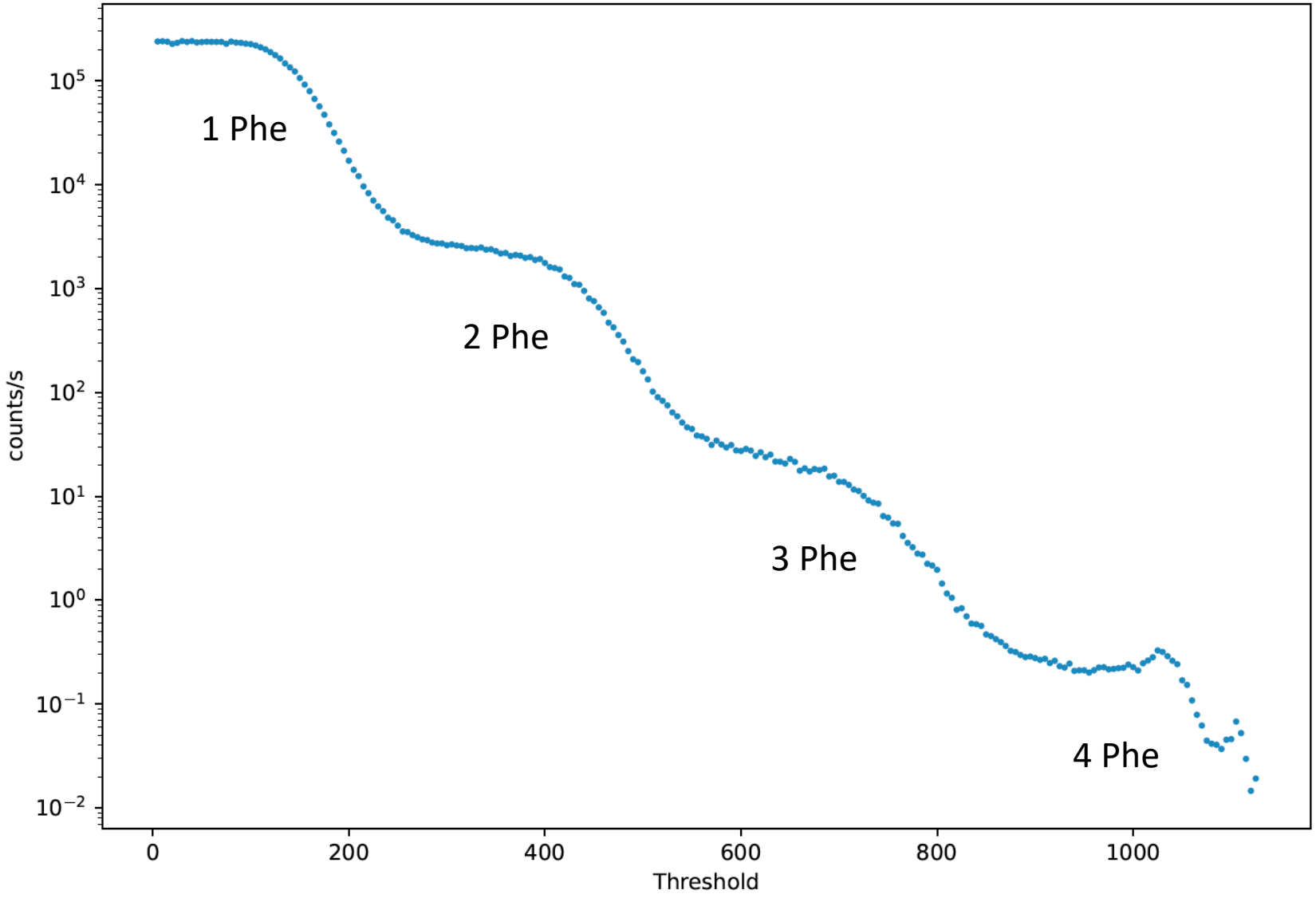
The analog offset of the AFE is configured in the AOFF field in the Channel Offset Compensation register (AFEC_COCR). The offset is only available in Single-ended mode. The field AOFF must be configured to 512 (mid scale of the DAC) when there is no offset error to compensate.To compensate for an offset error of n LSB (positive or negative), the field AOFF must be configured to 512 + n.



Cosmo ArduSiPM :

SiPM Automatic Characterization

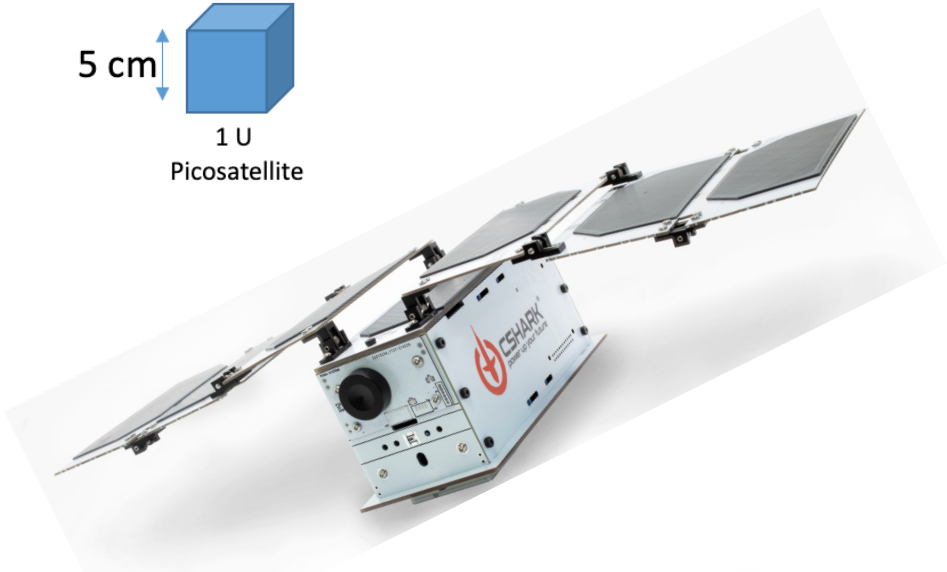
Count vs Threshold

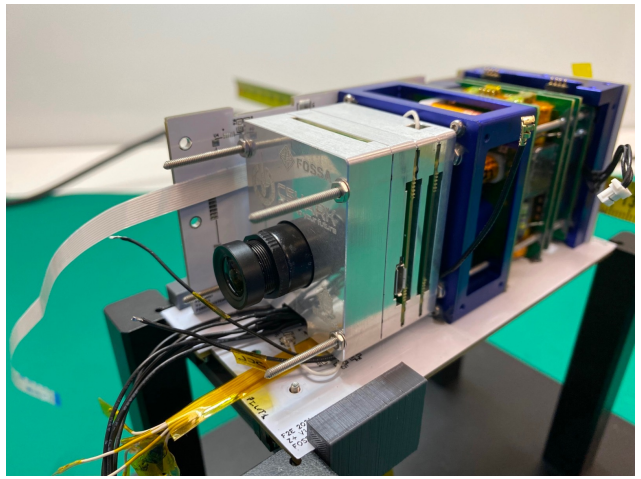


Next STEP picosatellite

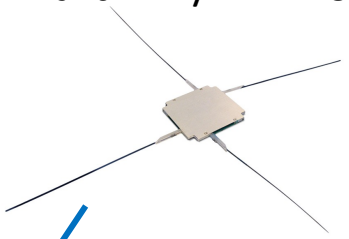
5 cm

1 U
Picosatellite



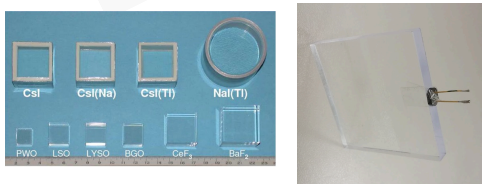


Earth TX/RX Module



Camera Module

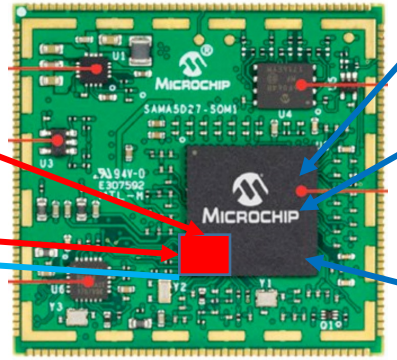
Scintillator



Photons sensibility to
Visible or IR

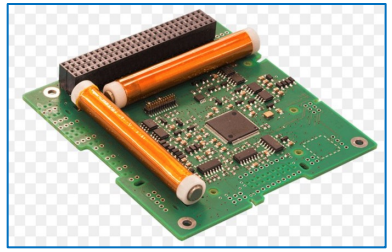
INFN TechTransfer
Istituto Nazionale di Fisica Nucleare

Nano ArduSiPM



Picosatellite OBC
On Board Computer

Magnetorquer Module



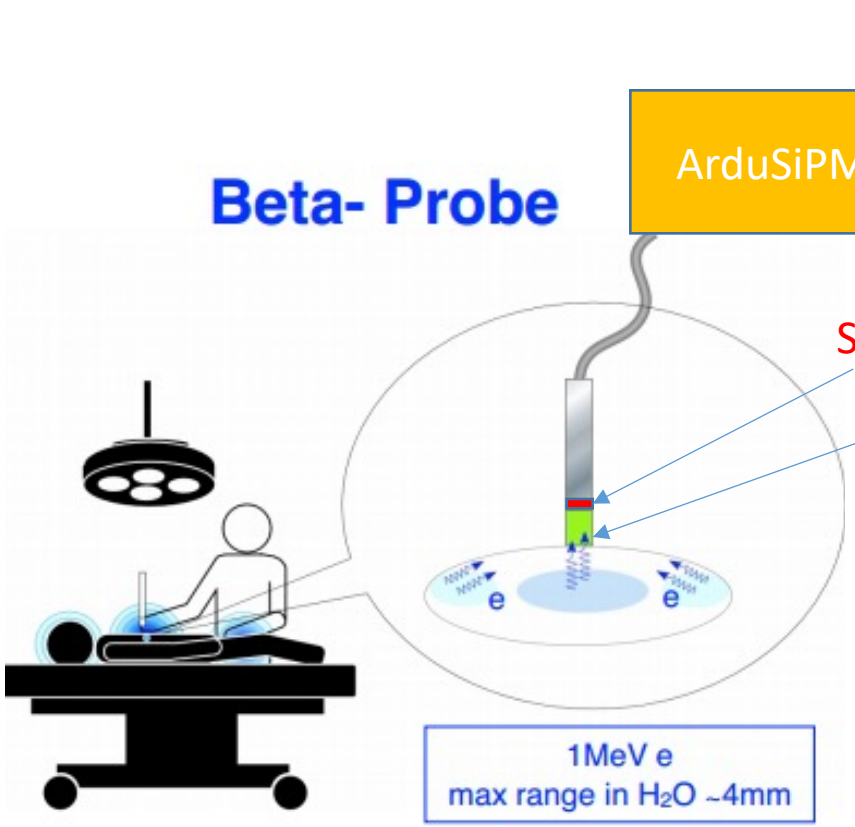
GPS Module

Conclusion

- The new MCU SoC chip have intersting CPU power and integrate many Peripheral.
- The presence of Counters ,ADC and DAC as internal peripheral strongly reduce the need for external components.
- The Counters speed increase with CPU Clock and can be used for
  TDC measuraments (absolute Time,Time over threshold)
- With an appropriate **FIRMWARE** we create Light All-in-one detector
  (sensor,FE electronics, Trigger, ADC,TDC, Scaler,DAQ elaboration)
- The performance grow of SoC MCU is faster than ASIC development
- New generation of MPU Soc can integrate multiple function a single chip (radiation detector,satellite controls)

Spare slides

Intraoperative β- Detecting Probe



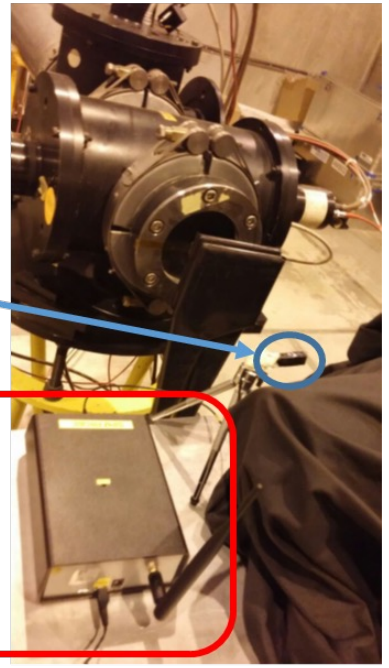
Monitoring Tablet app

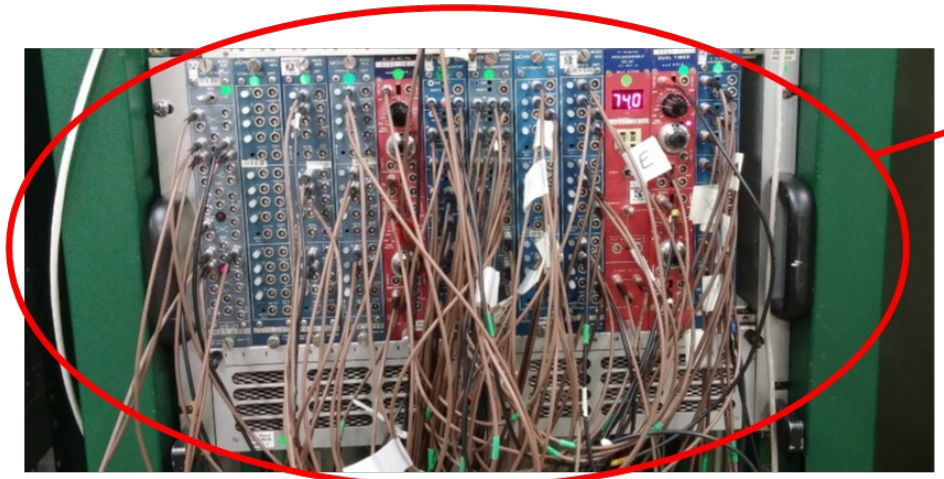
Radioguided surgery beta probe,
With para-Therphenil scintillator
coupled with SiPM detector.

Para-Therphenil Light Yeld 30 000 photons/MeV
Trasparent to gamma due to low density of para-Therphenil

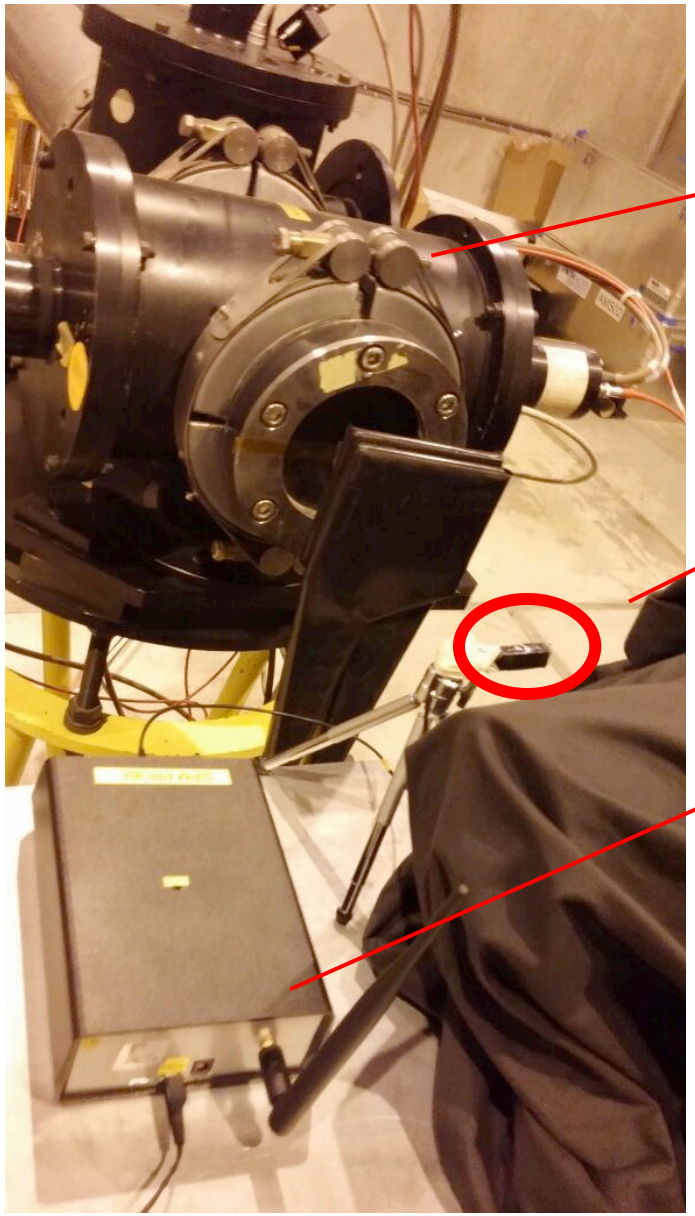
Use of ArduSiPM in the CERN UA9 Beam

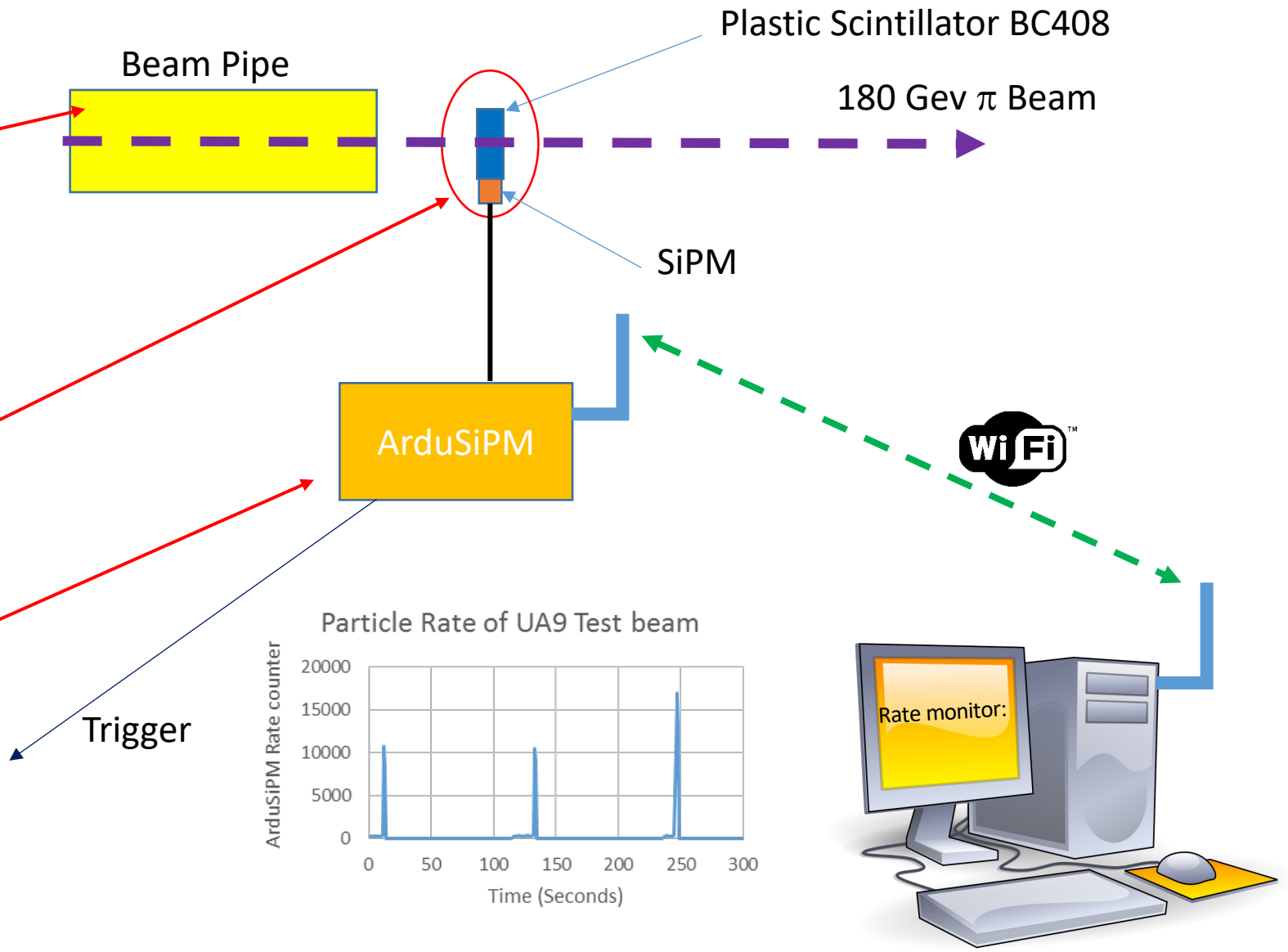
(substitute old Scintillator and electronics for PM)

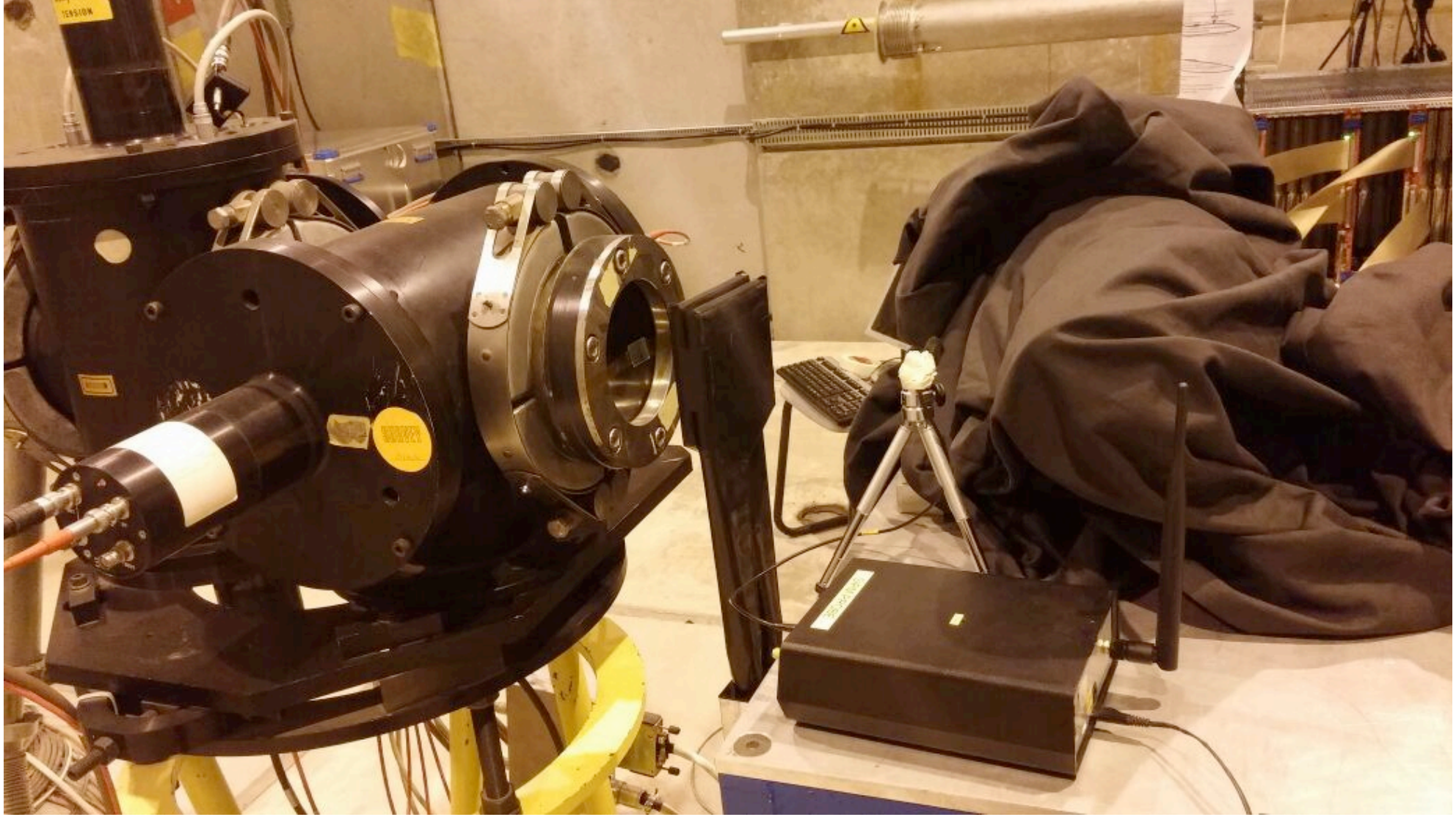




CERN UA9 Beam monitor



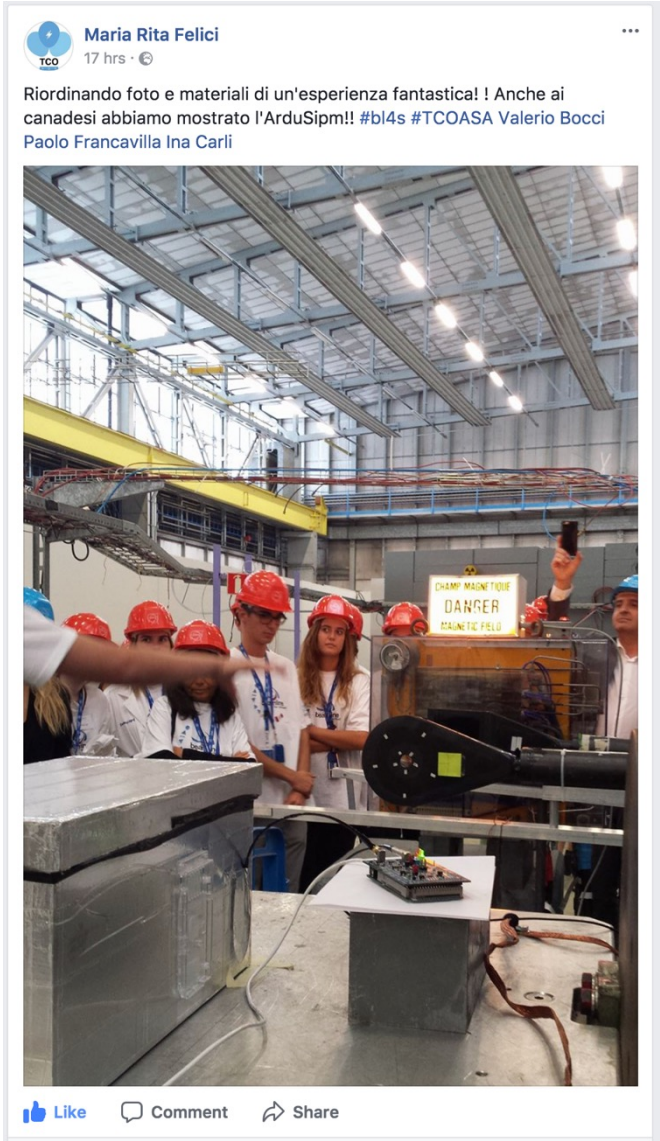


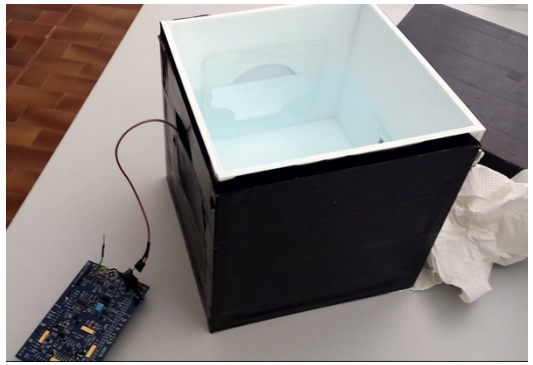


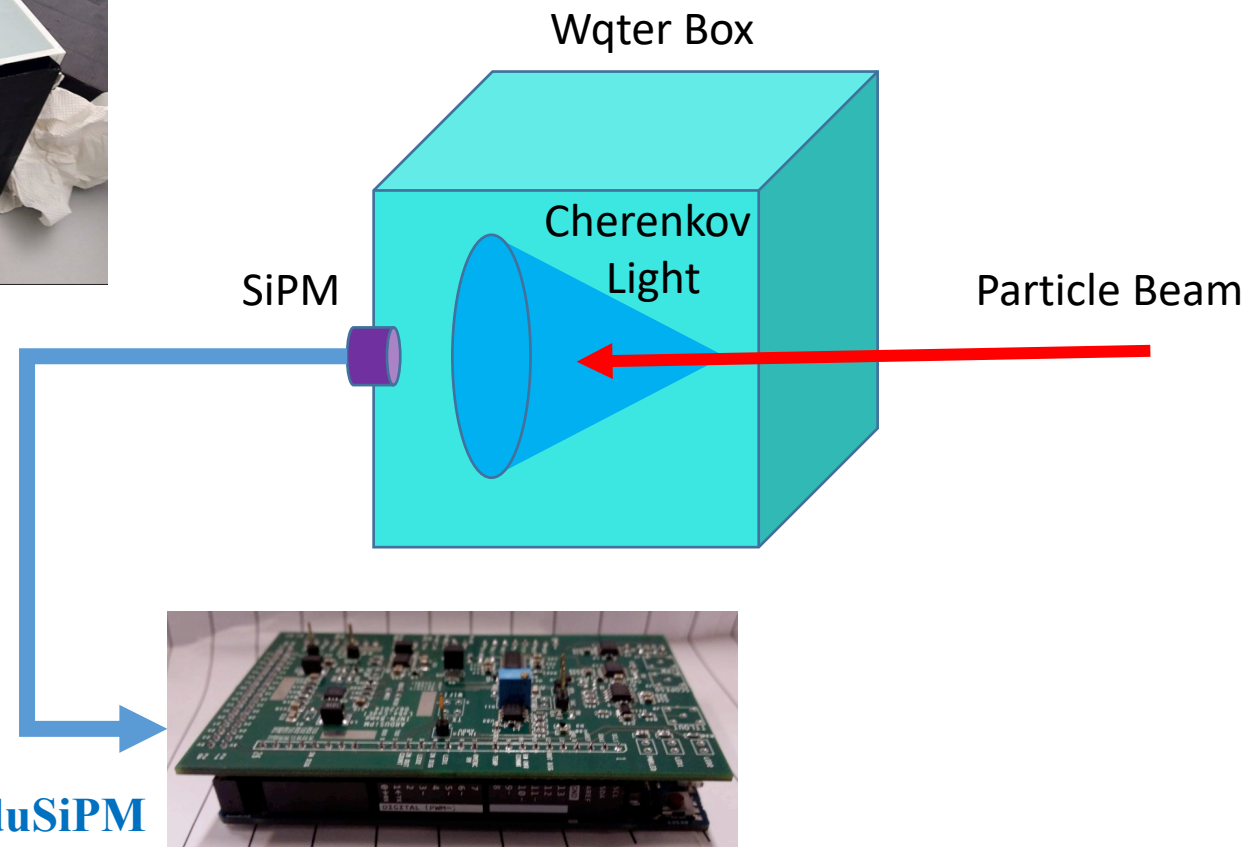
A School made Cherenkov light detector

(Winner of CERN “A beamline for schools”2017)

LICEO SCIENTIFICO STATALE T. C. ONESTI (prof Maria Rita Felici)







Dr. Valerio Bocci INFN Roma

2019

Anche l'INFN è in questi giorni allo Square Meeting Centre di Bruxelles, per la #Makerstown, un'occasione di confronto tra i protagonisti della tradizione manifatturiera europea, promossa dalla Commissione Europea e da Maker Faire Rome, di cui l'INFN è partner dal 2015. Primo evento del suo genere a Bruxelles, #Makerstown riunisce esperti del Do-It-Yourself, imprenditori e decisori politici europei, allo scopo di mostrare, condividere e creare occasioni di impresa in settori che vanno dalla stampa 3D, alla robotica, dalla tecnologia indossabile alle nuove Tecnologie dell'Informazione e della Comunicazione (TIC), dal cibo alla moda, anche grazie alla condivisione di idee e strumenti Web 3.0, tecnologie e metodologie per il crowdfunding. Selezionati lo scorso anno tra i primi 50 migliori maker della Maker Faire Rome 2015, i ricercatori dell'INFN Valerio Bocci e Francesco Iacoangeli hanno presentato a #Makerstown un rivelatore di raggi cosmici e uno scanner per fasci di particelle accelerate, realizzati con software e scheda Arduino Shield "ArduSipm" e sviluppati a scopo di ricerca dalla sezione di Roma1 dell'INFN. "Il rivelatore di particelle home-made non ha nulla da invidiare ai suoi fratelli maggiori, utilizzati ad esempio nell'acceleratore LHC, al CERN, per lo studio delle collisioni tra particelle ad altissima energia", spiega Valerio Bocci, "mentre il bassissimo costo di realizzazione lo rende adatto a numerose applicazioni di tipo didattico." I maker dell'INFN sono stati inoltre selezionati tra gli 8 (sui 45 presenti) che nell'ambito di #Makerstown presenteranno il loro progetto il 31 maggio al Parlamento Europeo. L'iniziativa #Makerstown è organizzata dal Wilfried Martens Centre for European Studies e da Think Young, organismo per la promozione della cultura di impresa in Europa. http://europeanmakerweek.eu/eu-maker-faire/

EOS Space project 30 Giugno 2018
ITI A. Russo Nicotera, AB Project, INFN Sezione di Roma

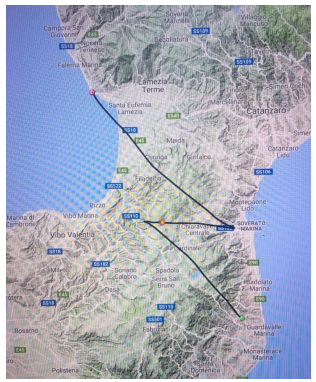
Dr. Valerio Bocci INFN Roma

2019

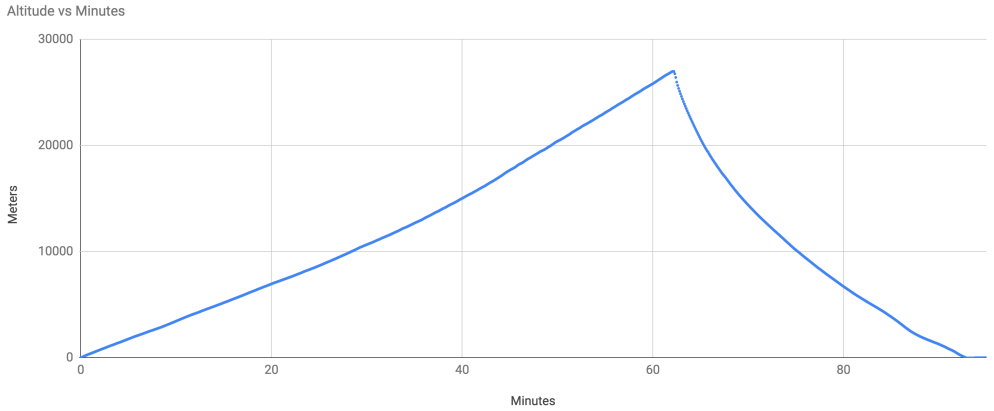
EOS Space project 30 Giugno 2018

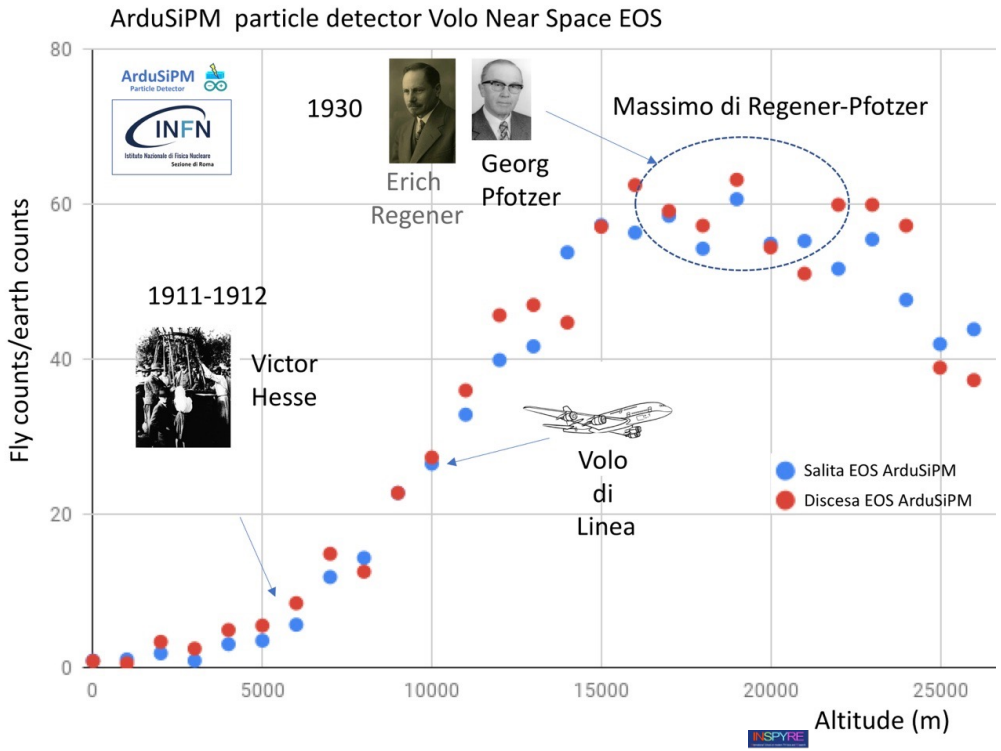
ITI A. Russo Nicotera, AB Project, INFN Sezione di Roma

EOS Space project 30 Giugno 2018
ITI A. Russo Nicotera, AB Project, INFN Sezione di Roma



Ultima simulazione
Prima del lancio

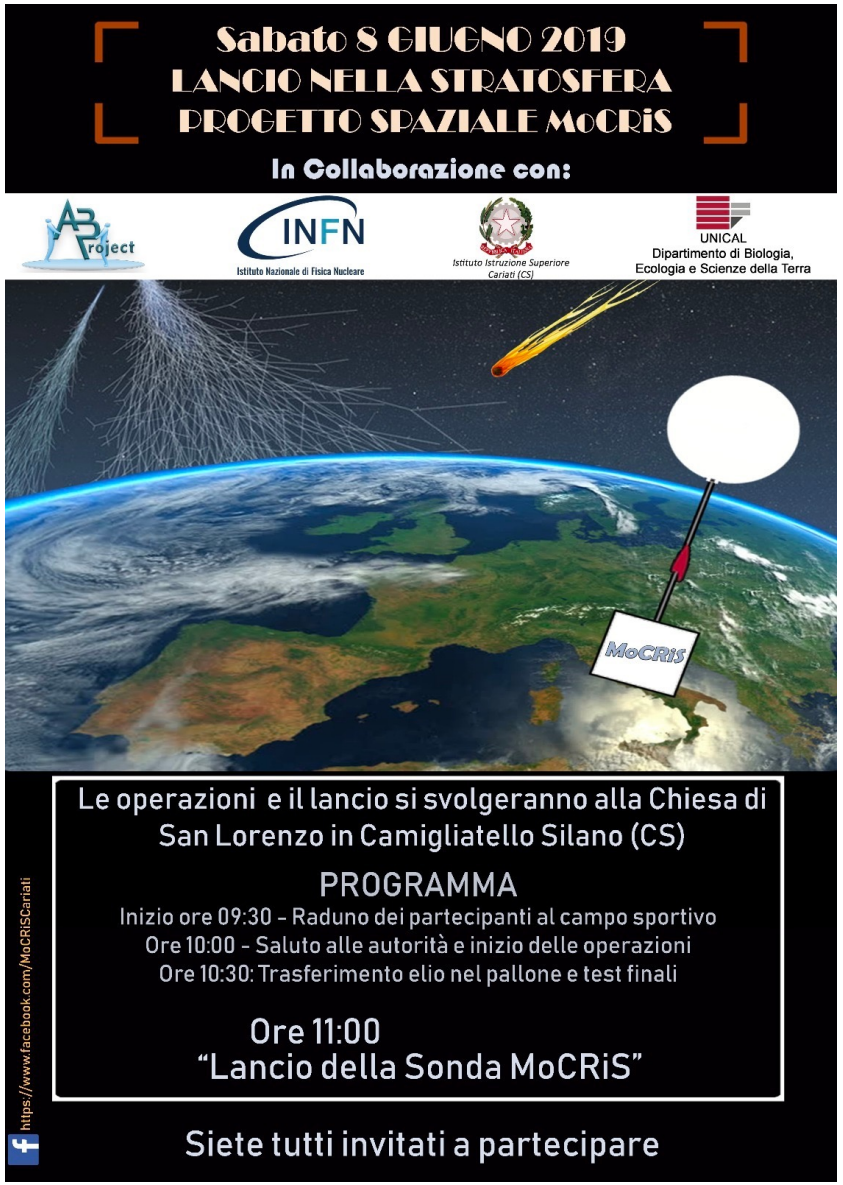


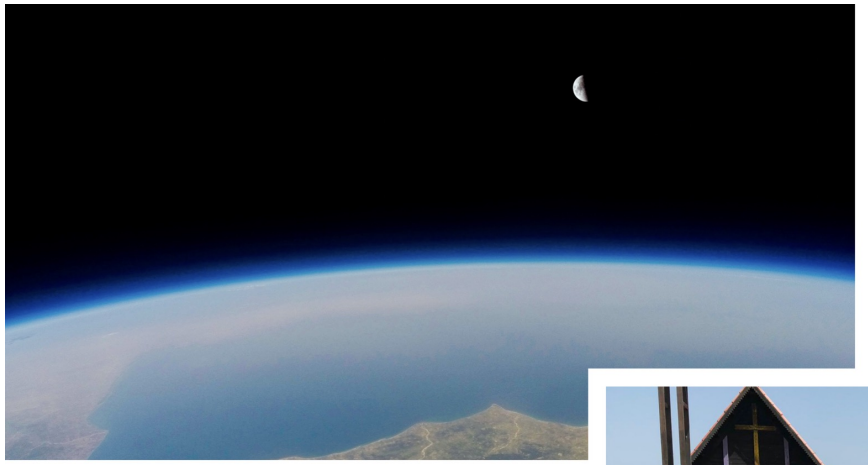


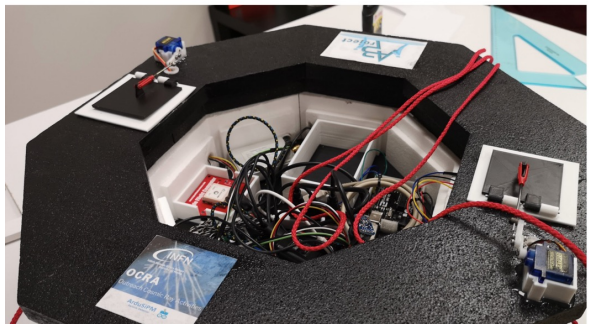
Dr. Valerio Bocci INFN Roma

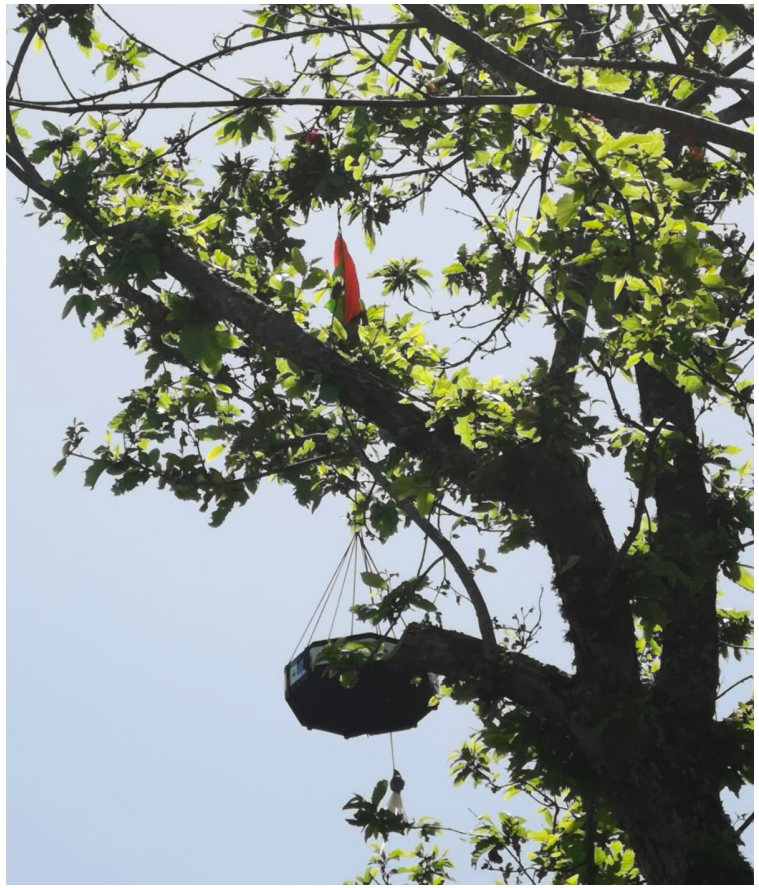
2019

Lancio Mocris 2019









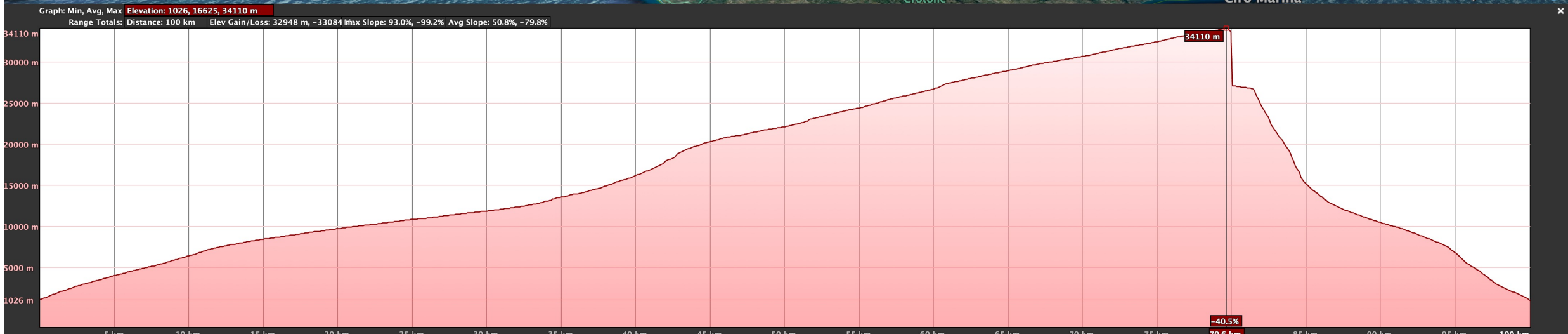
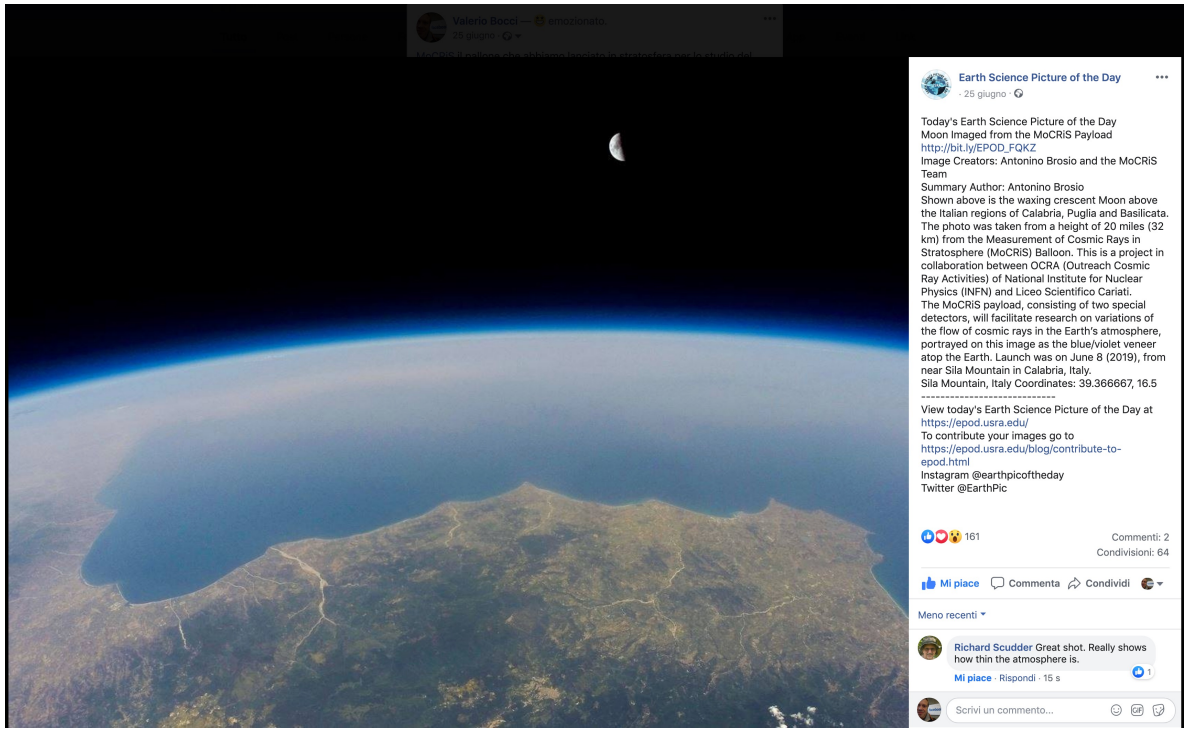


Figura 4.2. Misure di conteggi in fase di salita ottenute dai due rivelatori ArduSiPM in funzione della quota. Il massimo di ionizzazione è evidente intorno ai 20km.



EARTH SCIENCE PICTURE OF THE DAY

A SERVICE OF UNIVERSITIES SPACE RESEARCH ASSOCIATION

Moon Imaged from the MoCRiS Payload

June 25, 2019

« Previous | Today's | Next »

Image Creators: Antonino Brosio and the MoCRiS Team
Summary Author: Antonino Brosio

Shown above is the waxing crescent Moon above the Italian regions of Calabria, Puglia and Basilicata. The photo was taken from a height of 20 miles (32 km) from the Measurement of Cosmic Rays in Stratosphere (MoCRiS) Balloon. This is a project in collaboration between OCRA (Outreach Cosmic Ray Activities) of National Institute for Nuclear Physics (INFN) and Liceo Scientifico Cariati.

The MoCRiS payload, consisting of two special detectors, will facilitate research on variations of the flow of cosmic rays in the Earth's atmosphere, portrayed on this image as the blue/violet veneer atop the Earth. Launch was on June 8 (2019), from near Sila Mountain in Calabria, Italy.

Sila Mountain, Italy Coordinates: 39.366667, 16.5

Related Links
High Altitude Balloon Flight Over Mt. Olympus, Greece

Student Links
How to detect cosmic rays
Composition of Earth's Atmosphere

Earth Observatory
Probing the Electric Space Around Earth

Categories: | Satellites |
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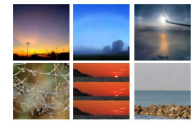


More...

Atmospheric Effects Links

- Atmospheric Optics
- Color and Light in Nature
- The Colors of Twillight and Sunset
- Refraction Index
- Image Gallery: Atmospheric Effects
- What is a Rainbow?

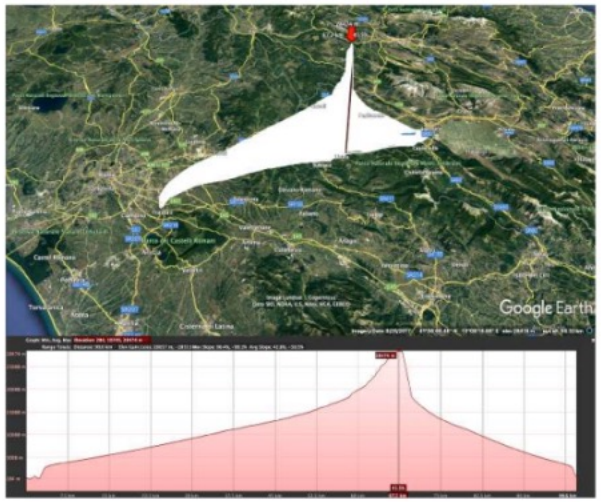
LANCIO

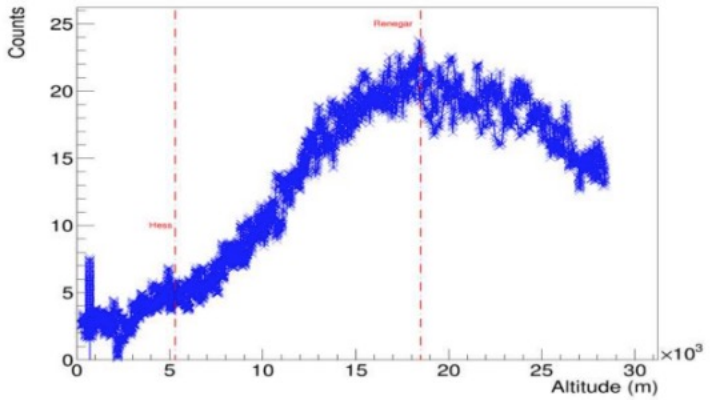
(volo strumentato da OCRA INFN Roma+ABProject)

Il cuore dello stage è stato il lancio del pallone stratosferico, equipaggiato con 2 rivelatori di tipo ArduSiPM, organizzato dalla sezione di Roma e dalla ditta ABproject. Il lancio è stato effettuato con successo e ha raccolto l'attenzione di tutti i presenti. La strumentazione ha raggiunto l'altezza di 28000 metri , per poi atterrare "comodamente" in un prato (simulazioni piana del Fucino atterrato vicino a Capistrello).

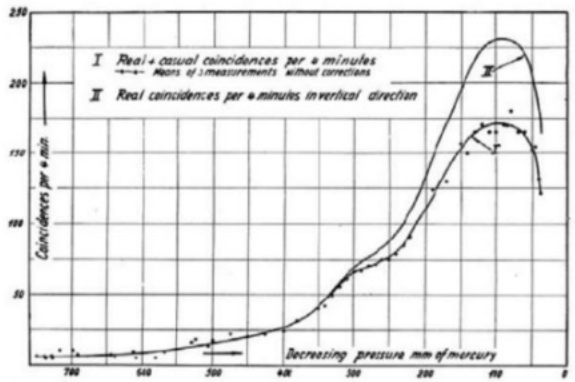
Massimo dello sciame a 15-20 Km

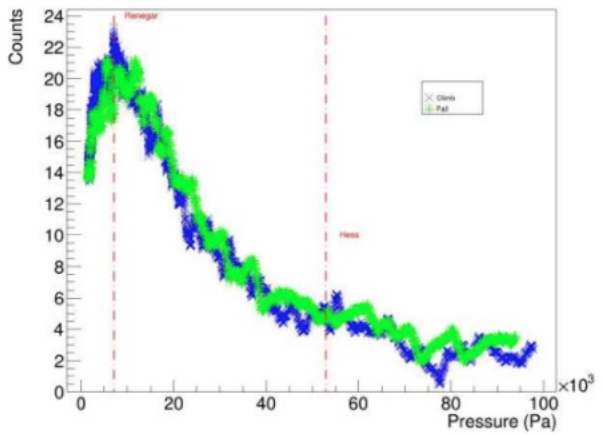
Il volo del pallone ha permesso di raccogliere dati sulla radiazione cosmica in quota, ripetendo le misure di Hesse (5300m 1910) e ritrovando il massimo di Regener Pfotzer (1935).



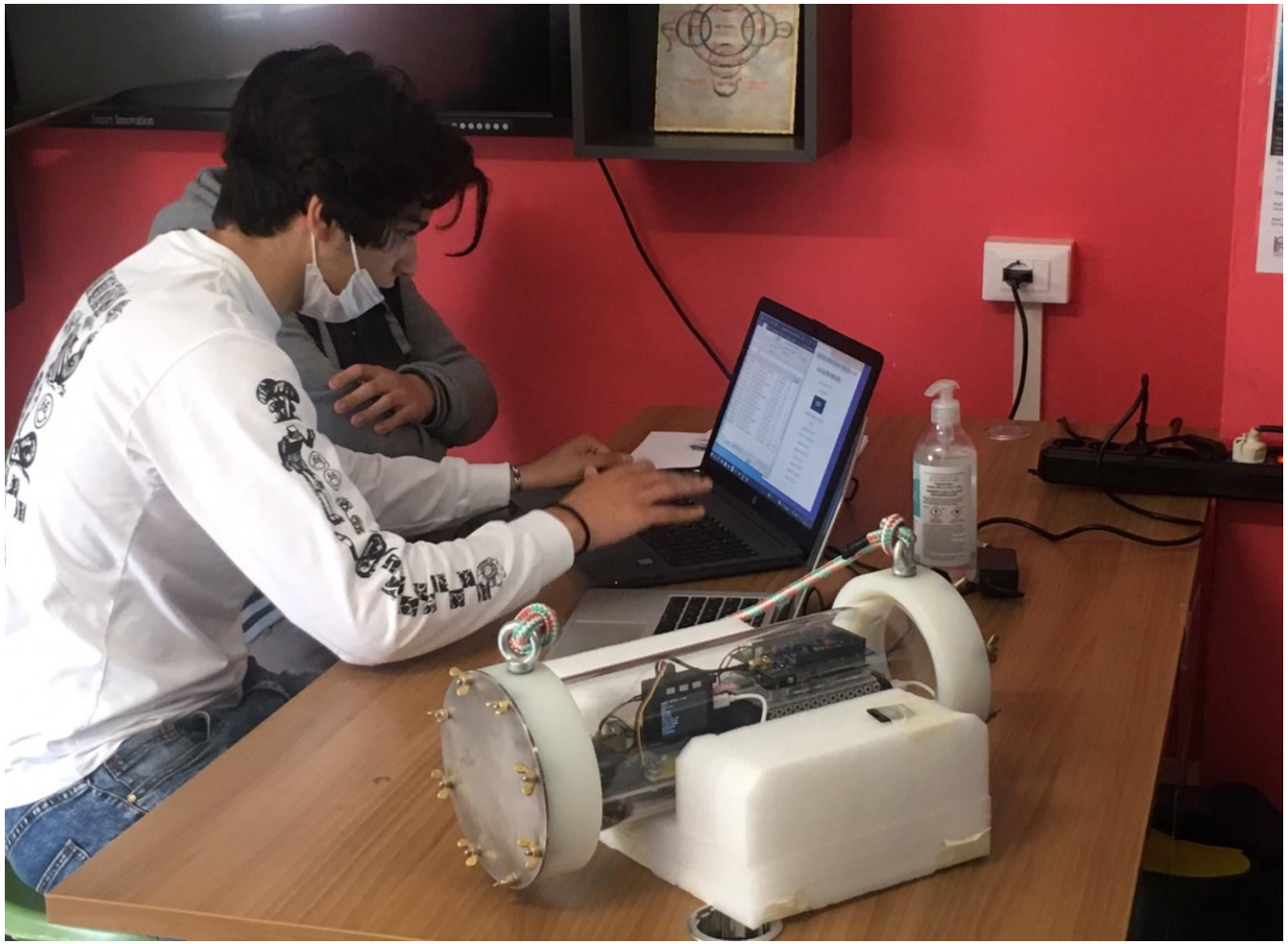


ArduSiPM Counts





ArduSiPM Mesasuraments in water



STAGE Outreach Cosmic Ray Activity OCRA 2022

Misura del flusso di particelle in funzione della quota con pallone stratosferico.

4-6 Maggio 2022 si è tenuto lo stage OCRA ai Laboratori Nazionali di Frascati . Vi hanno partecipato 28 studenti e studentesse selezionati tra i partecipanti all'International Cosmic Day (due per ogni sezione INFN OCRA).
Durante lo stage è stato lanciato un pallone stratosferico scientifico-didattico (il terzo realizzato dal gruppo OCRA di Roma), con lo scopo di misurare il flusso di radiazioni cosmica fino alla stratosfera (Abbiamo raggiunto 28 400 m).

Moon Imaged from the MoCRiS Payload

June 25, 2019