

dRICH electronics integration and SiPM

Roberto Preghenella

INFN Bologna

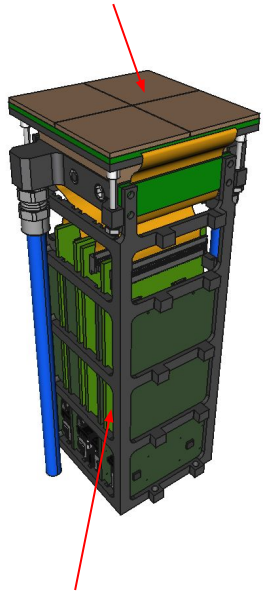
activities involving BO, CS, CT, FE, SA, TO, TS

2024 test beam at CERN-PS

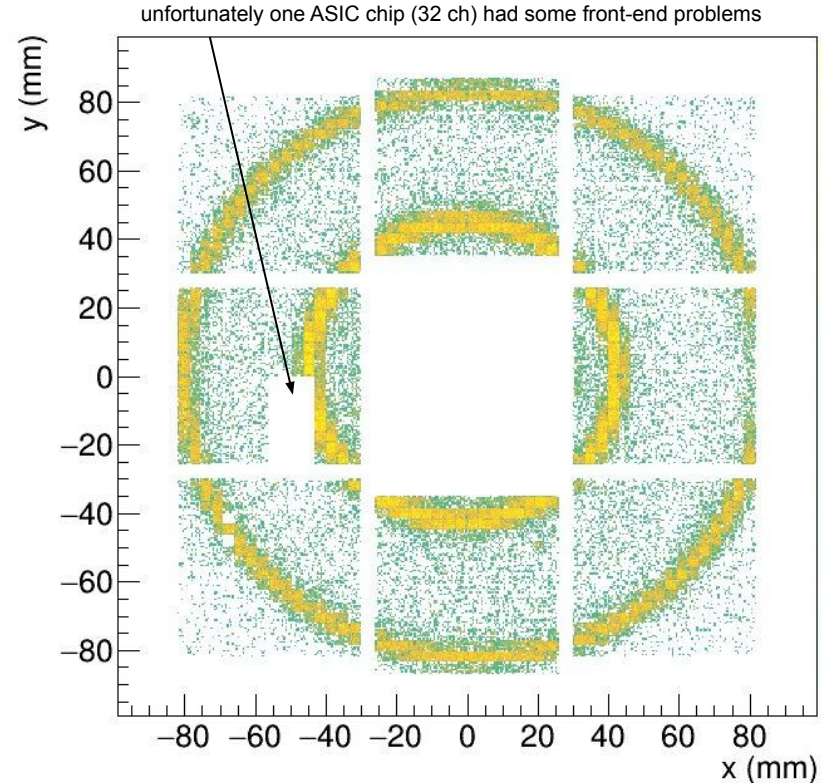
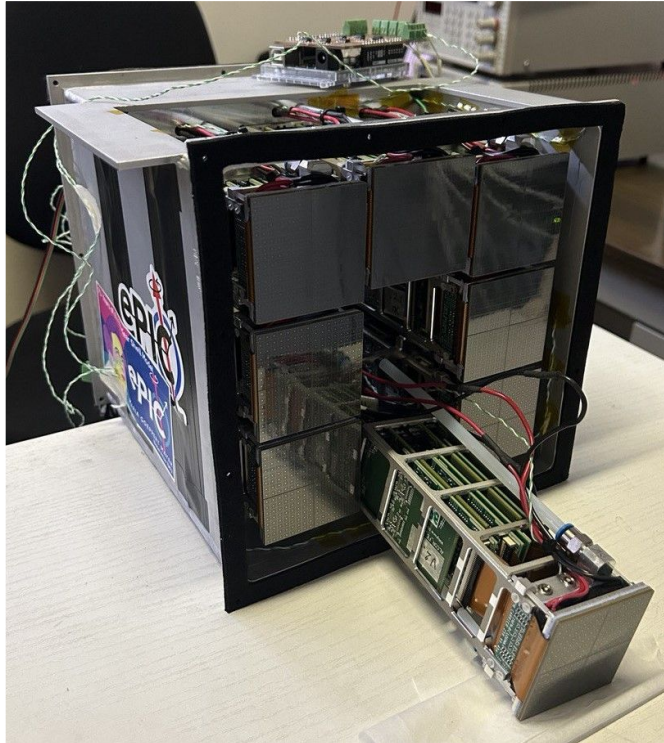
another successful beam test with prototype SiPM photodetector units (CERN-PS, ended on 5th June)

PDU

4x SiPM matrix arrays
(256 channels)



front-end electronics
(ALCOR ASIC inside)

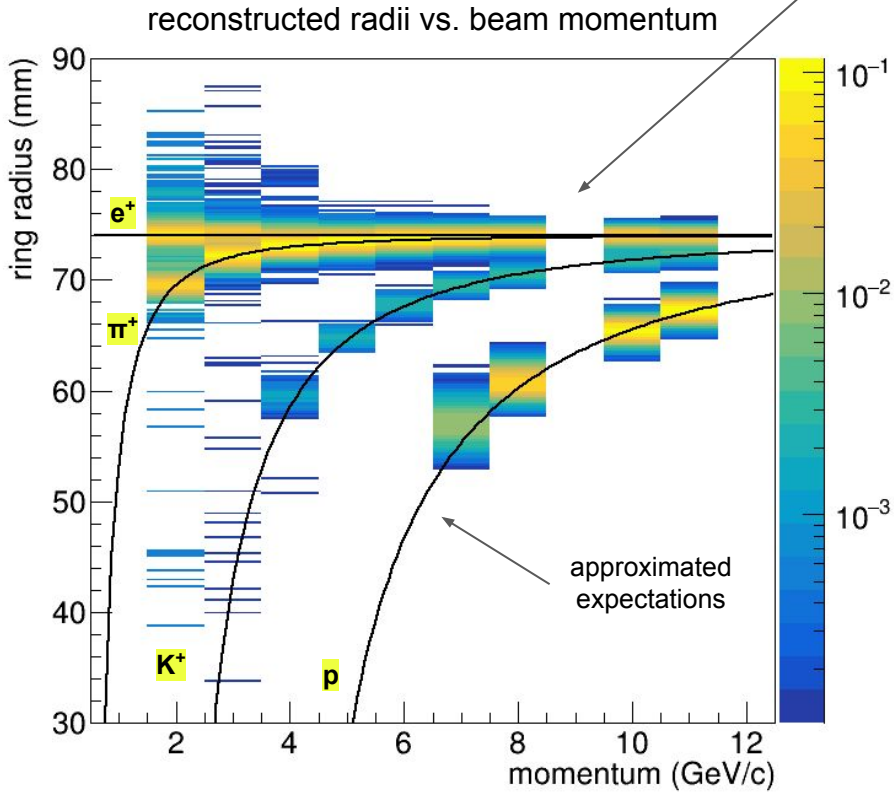


all the rest was rather full of photons
> 2000 SiPMs with TDC readout at work

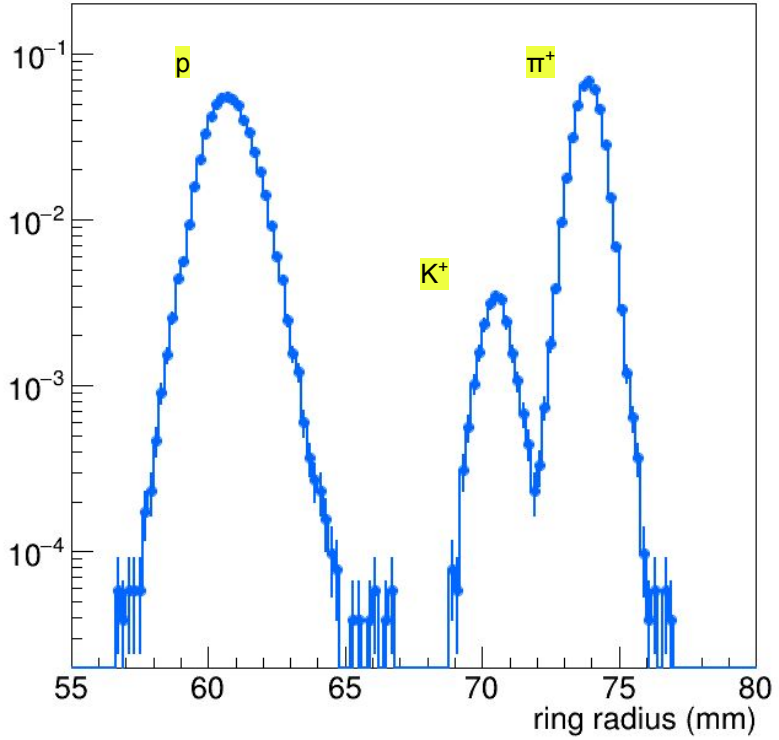
Beam momentum scan

positive particles, aerogel only

something went wrong with the beam configuration for 9 GeV (that's a pity, data seems not good)



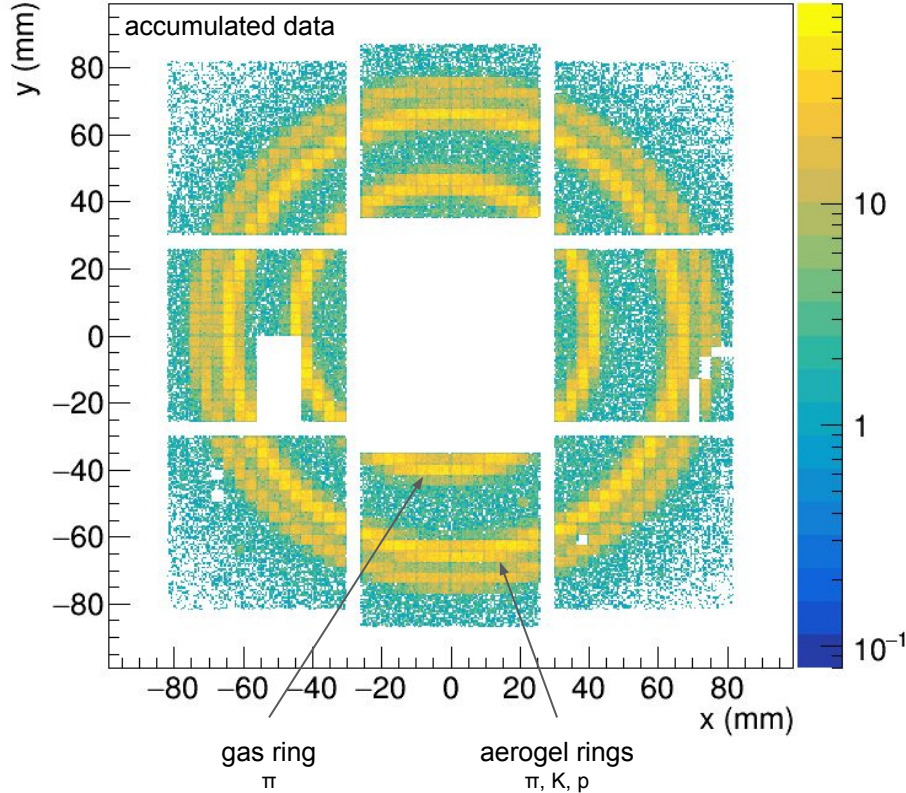
reconstructed ring radius at 8 GeV/c beam momentum



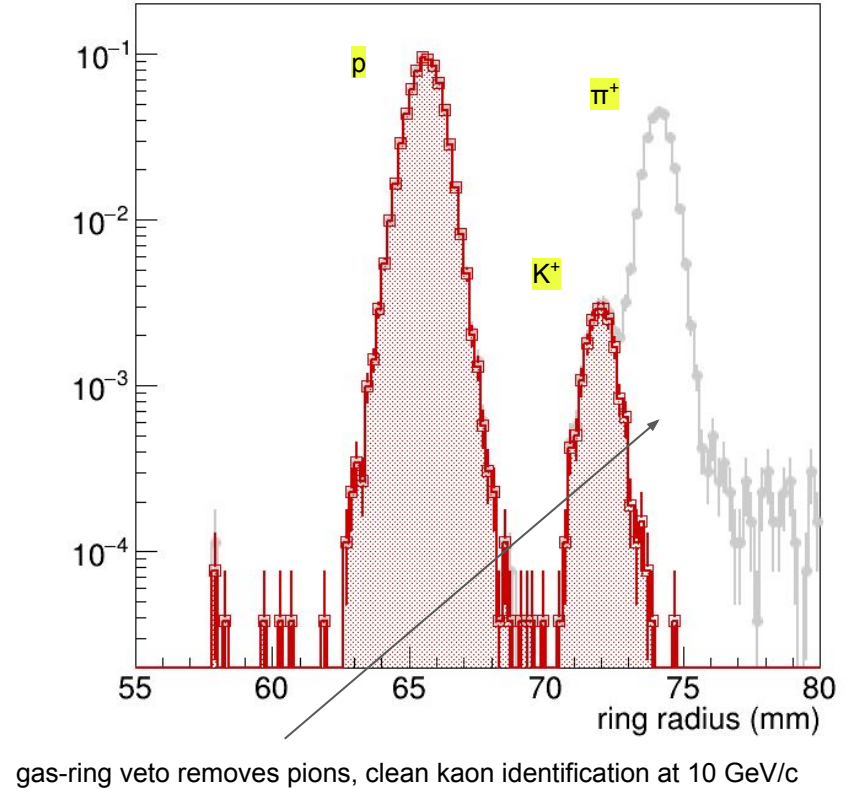
Interplay between aerogel and gas radiators

gas ring tags pions, at 10 GeV/c kaons and protons are below C_2F_6 gas threshold

10 GeV/c positive beam with no selection applied

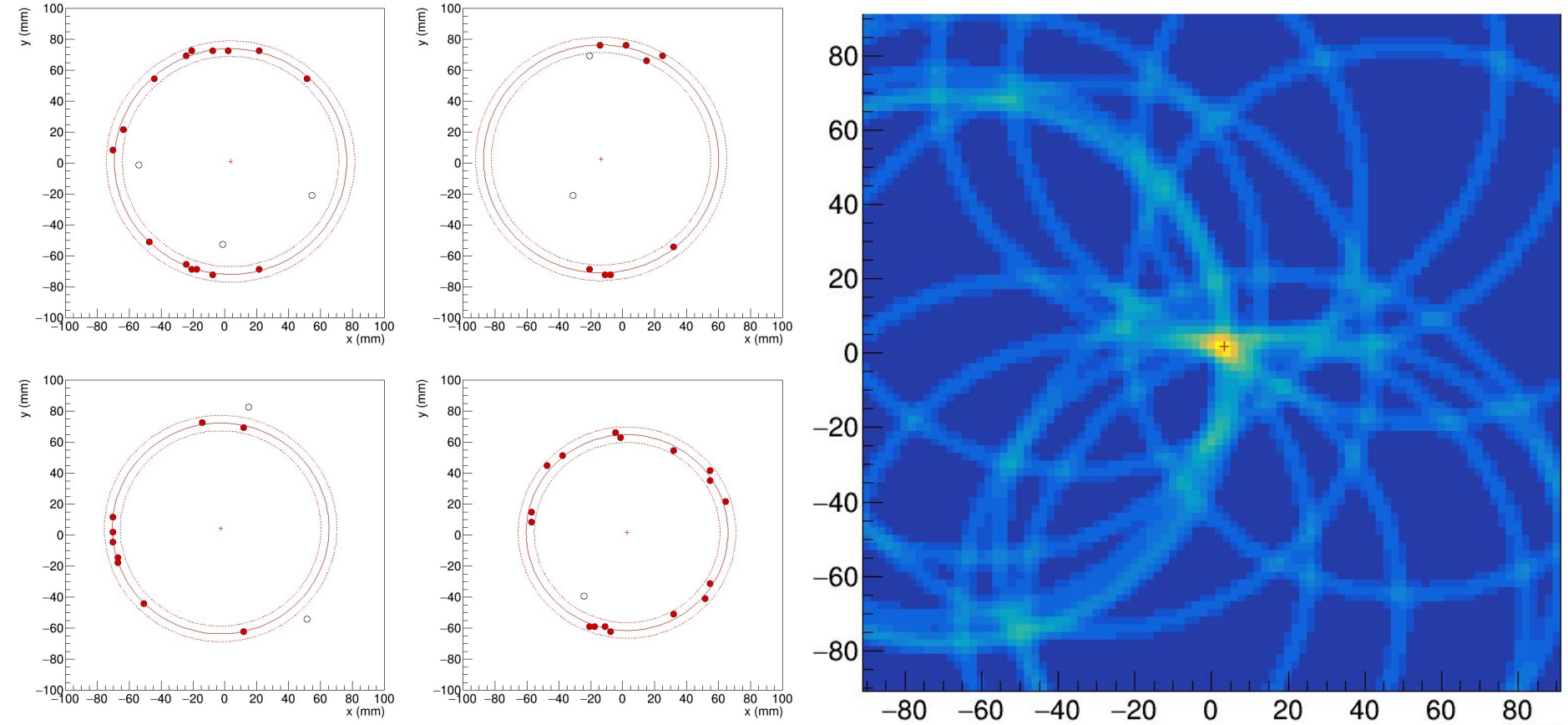


reconstructed ring radius at 10 GeV/c with gas veto



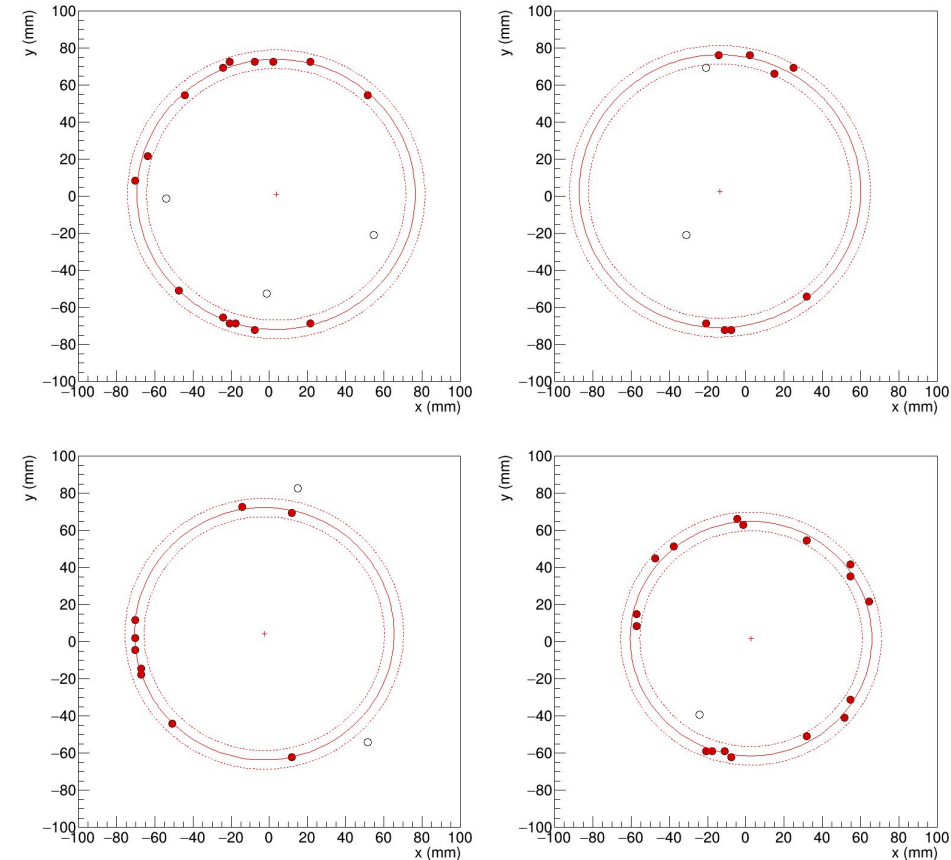
Test beam data analysis

event-by-event pattern recognition with Hough Transform Method



Test beam data analysis

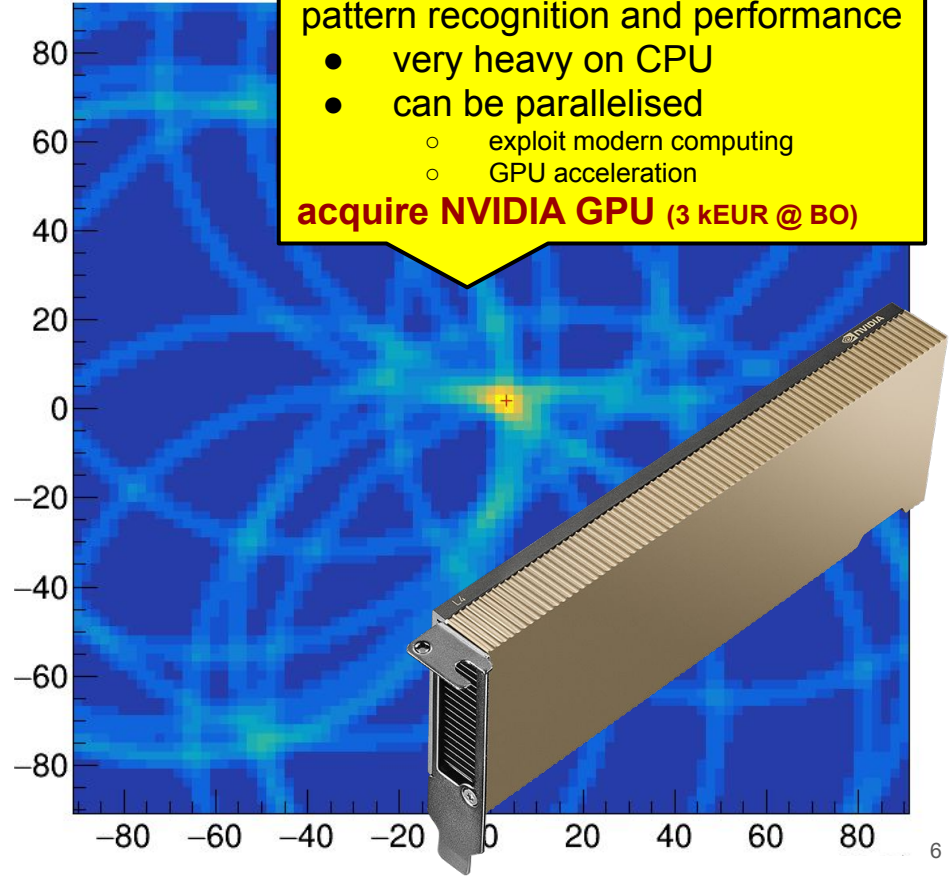
event-by-event pattern recognition with Hough Transform Method



push Hough Transformation method to fine 4D space (X, Y, R, and T) for best pattern recognition and performance

- very heavy on CPU
- can be parallelised
 - exploit modern computing
 - GPU acceleration

acquire NVIDIA GPU (3 KEUR @ BO)



Test beam data analysis

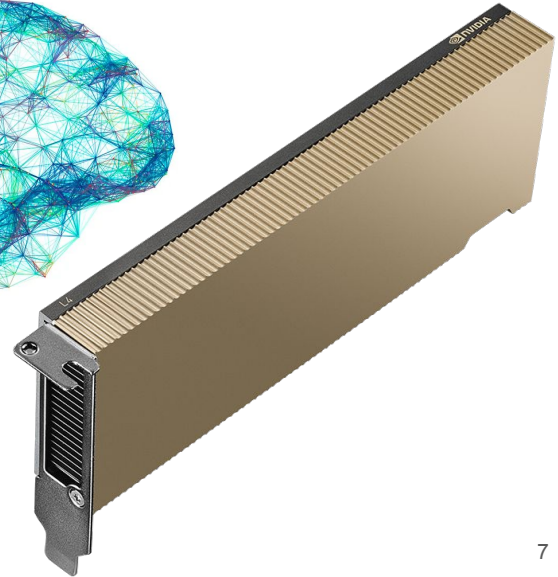
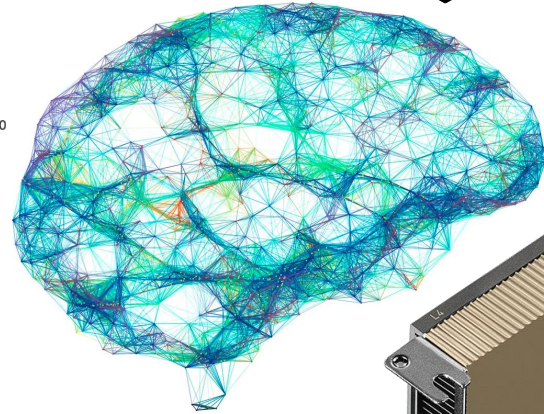
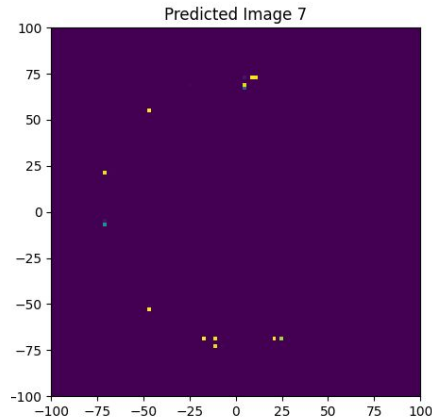
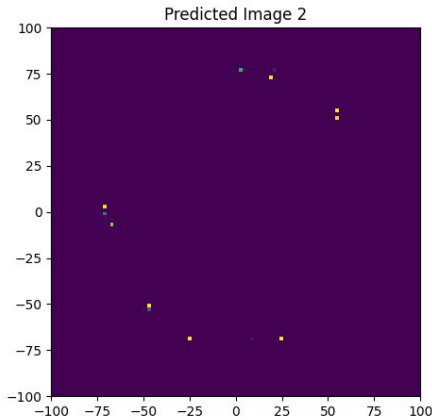
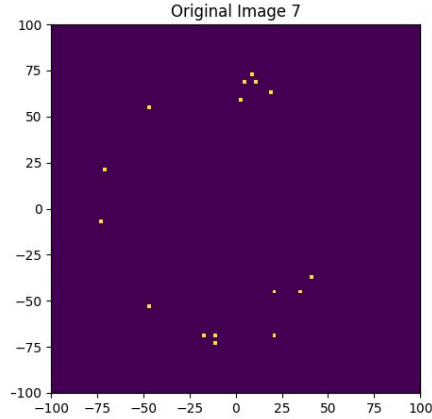
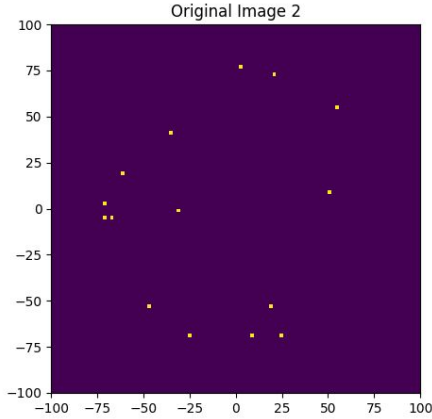
background identification with Machine Learning

started data analyses for dRICH ring reconstruction and background rejection based on Machine Learning approaches
acquire NVIDIA GPU (3 KEUR @ BO)

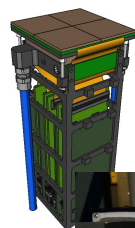
input image



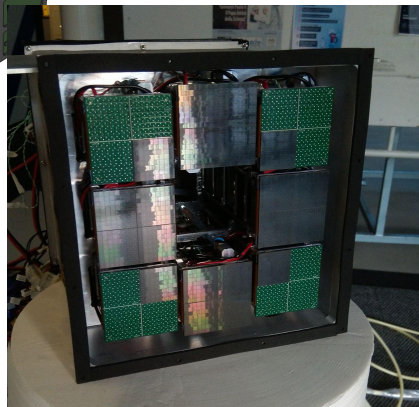
ML prediction



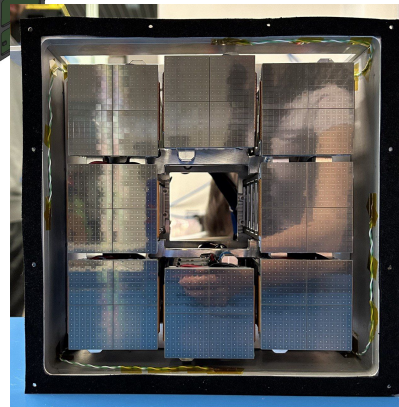
2022
electronics v1



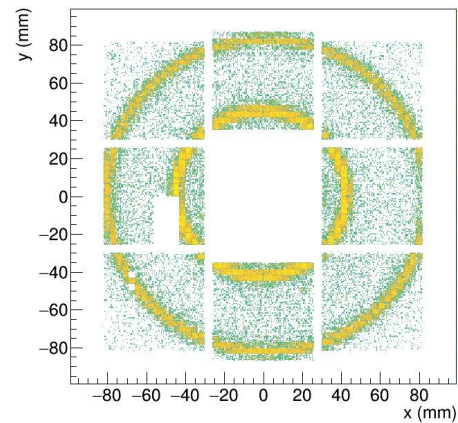
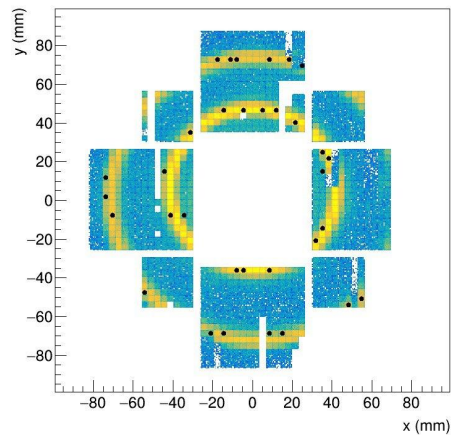
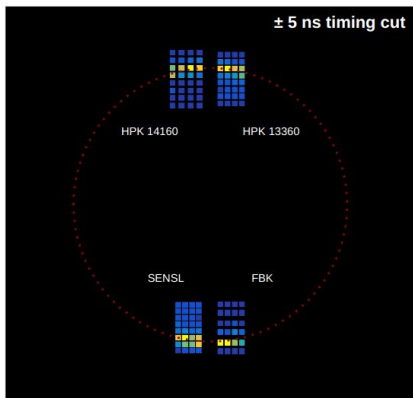
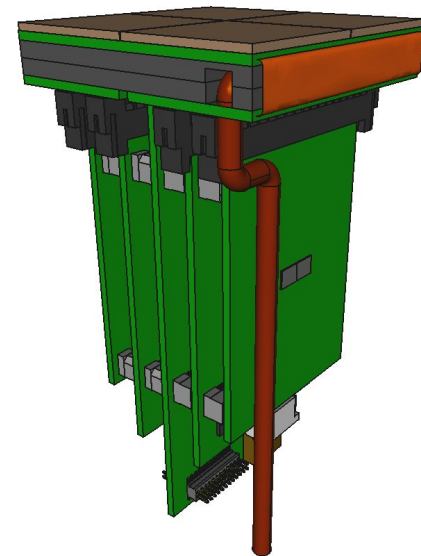
2023
electronics v2



2024
electronics v2.1



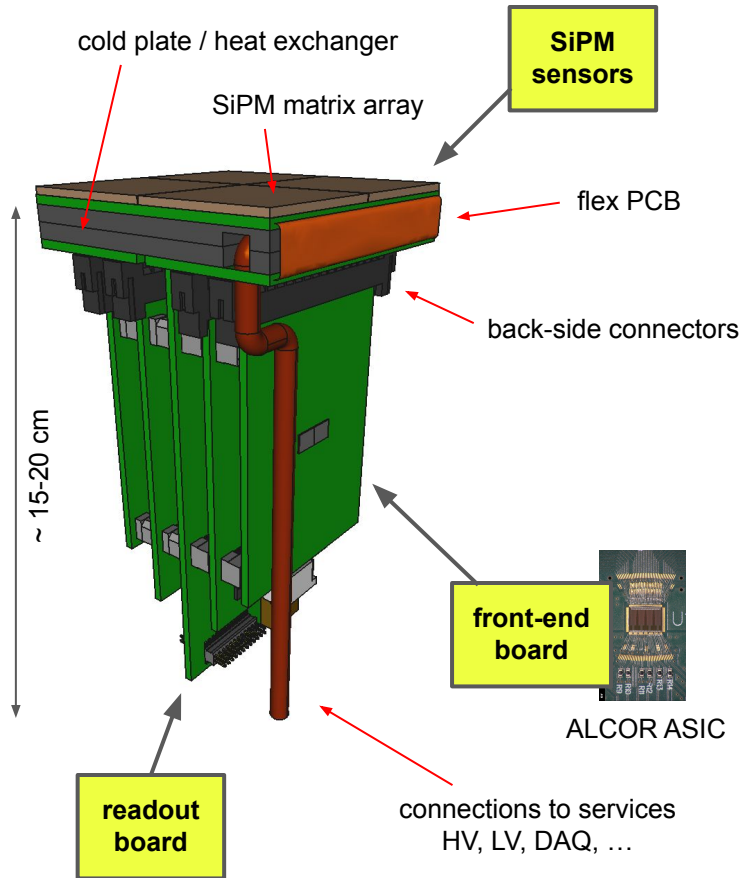
2025
electronics v3
final prototype



PDU and integration

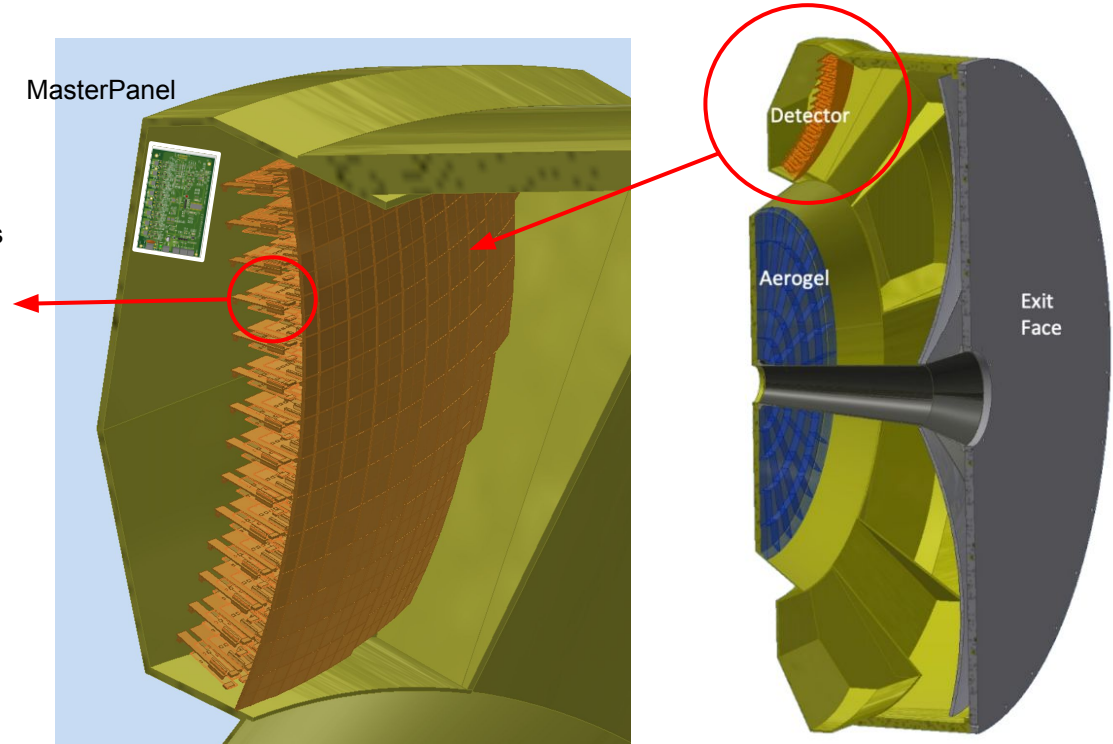
Photodetector unit

conceptual design of PDU layout



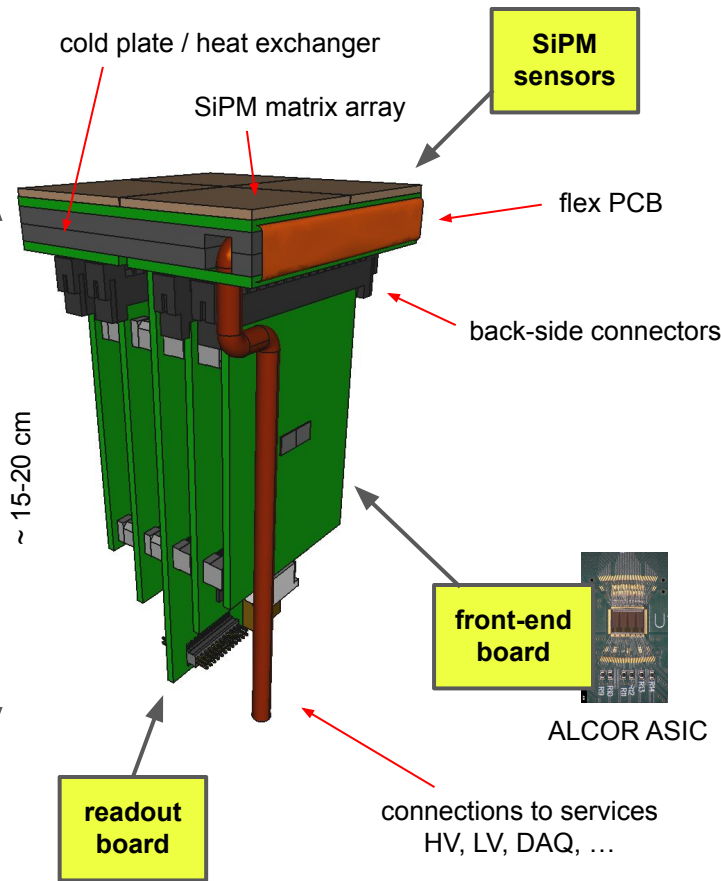
SiPM sensor matrices mounted on carrier PCB board

- 4x 64-channel SiPM array device (256 channels) for each unit
 - need modularity to realise curved readout surface
- 1248 photodetector units for full dRICH readout
 - 4992 SiPM matrix arrays (8x8)
 - 319488 readout channels



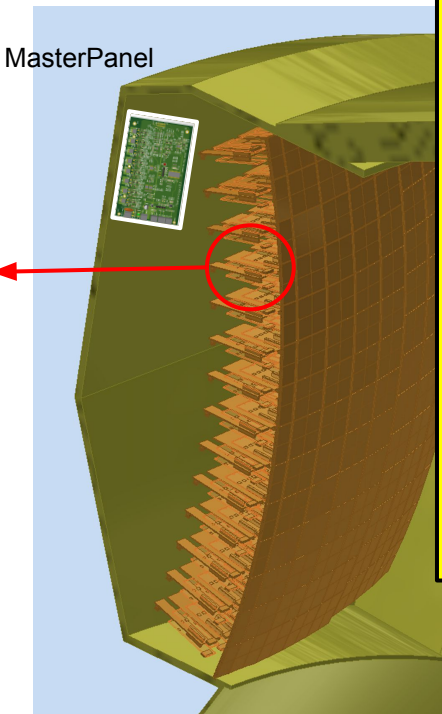
Photodetector unit

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SiPM sensor matrices

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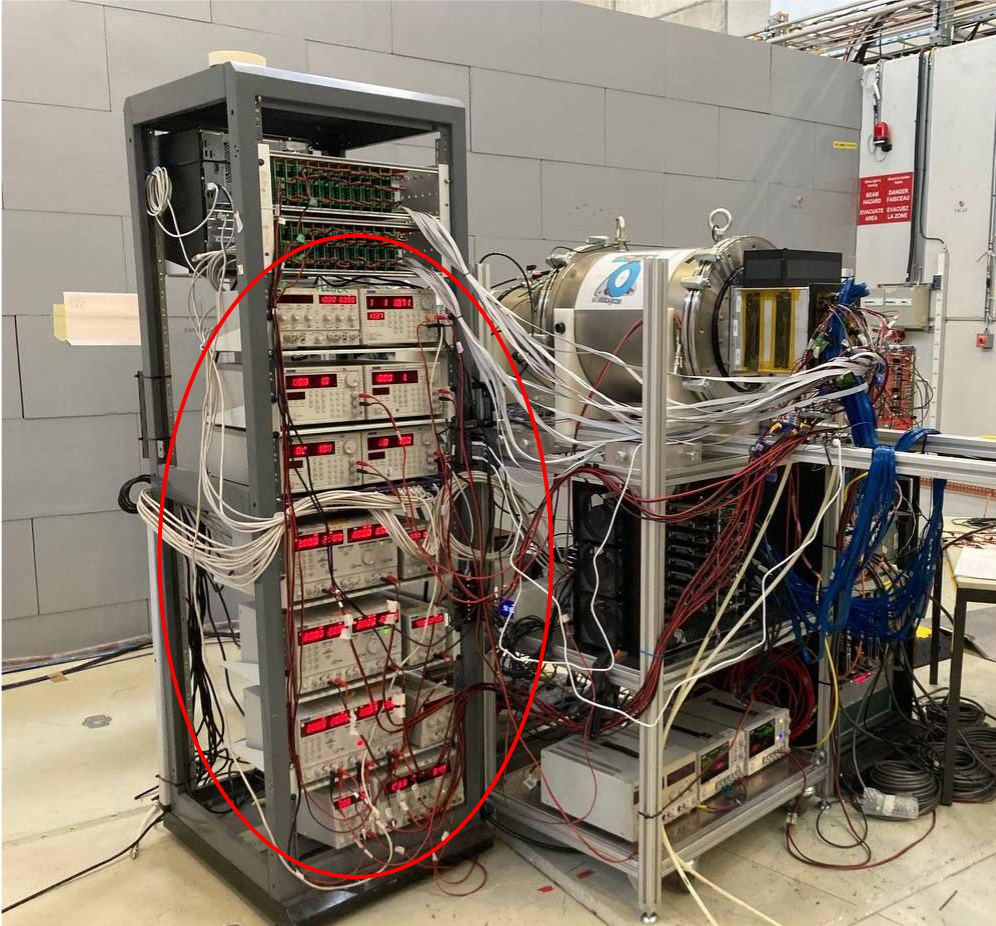


conceptual design of ePIC-dRICH PDU should become a **real design** with **realisation of few prototypes** in 2025

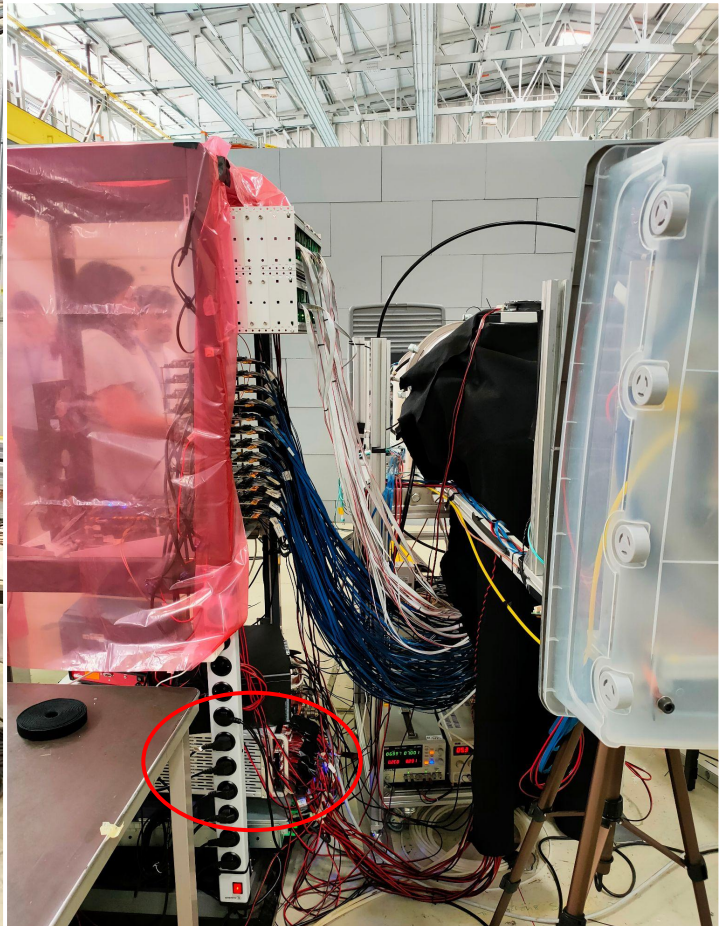
- RDOs will be available
- FEB design in progress
- SiPM carrier design in progress
- working on cooling as well

acquire SiPM matrices (20 kEUR @ BO)
SiPM carrier boards (7.5 kEUR @ BO)
FEB boards and ALCOR (see M. Ruspa)
RDO boards (see following slides)
annealing test boards (5 kEUR @ BO)
MasterPanel boards (5 kEUR @ FE)
chiller available
cooling plates made in BO W-shop
cables, and other components (requested as part of "RS budget")

Power supply system



many table-top power supplies in 2023



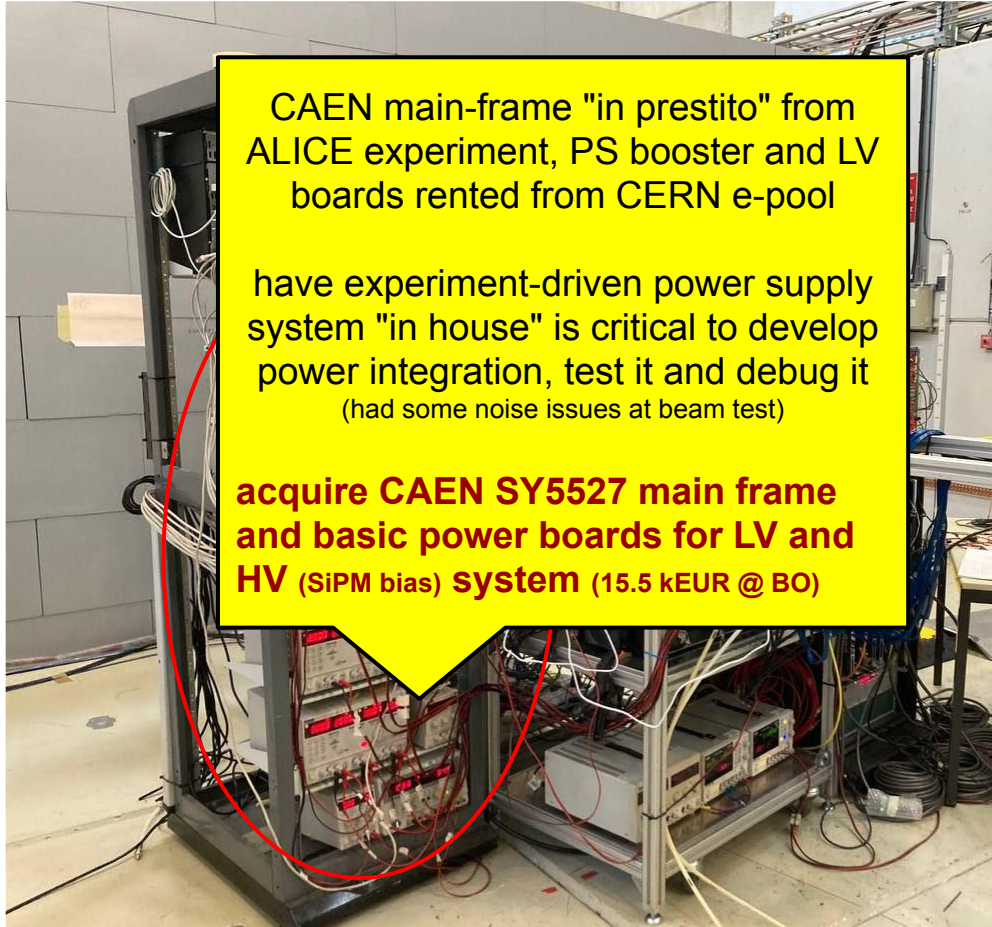
first test with rented CAEN power-supply units in 2024

Power supply system

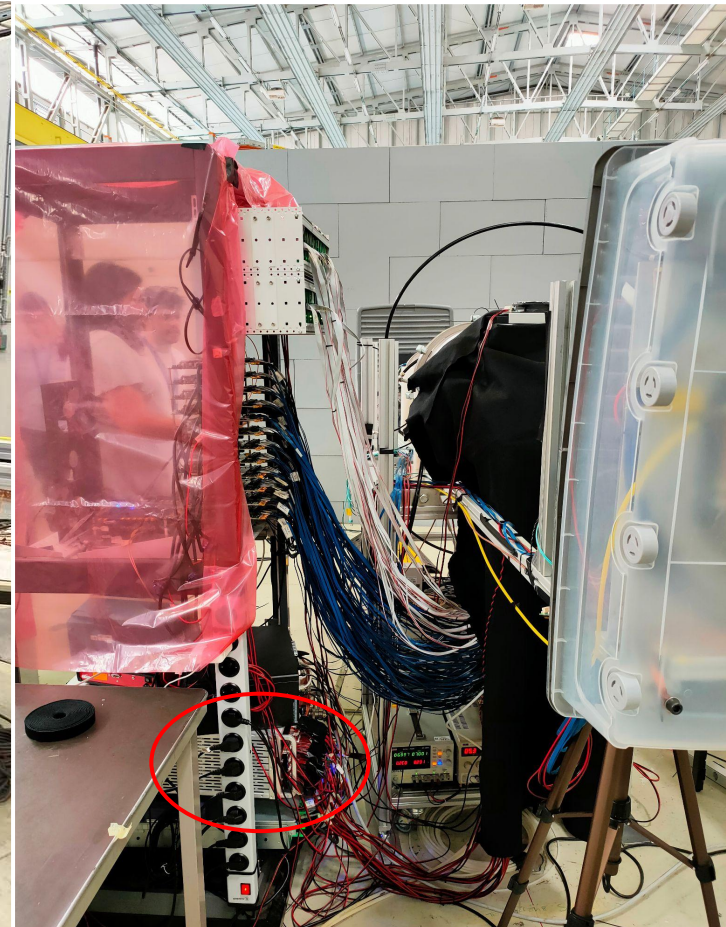
CAEN main-frame "in prestito" from ALICE experiment, PS booster and LV boards rented from CERN e-pool

have experiment-driven power supply system "in house" is critical to develop power integration, test it and debug it
(had some noise issues at beam test)

acquire CAEN SY5527 main frame and basic power boards for LV and HV (SiPM bias) system (15.5 kEUR @ BO)



many table-top power supplies in 2023

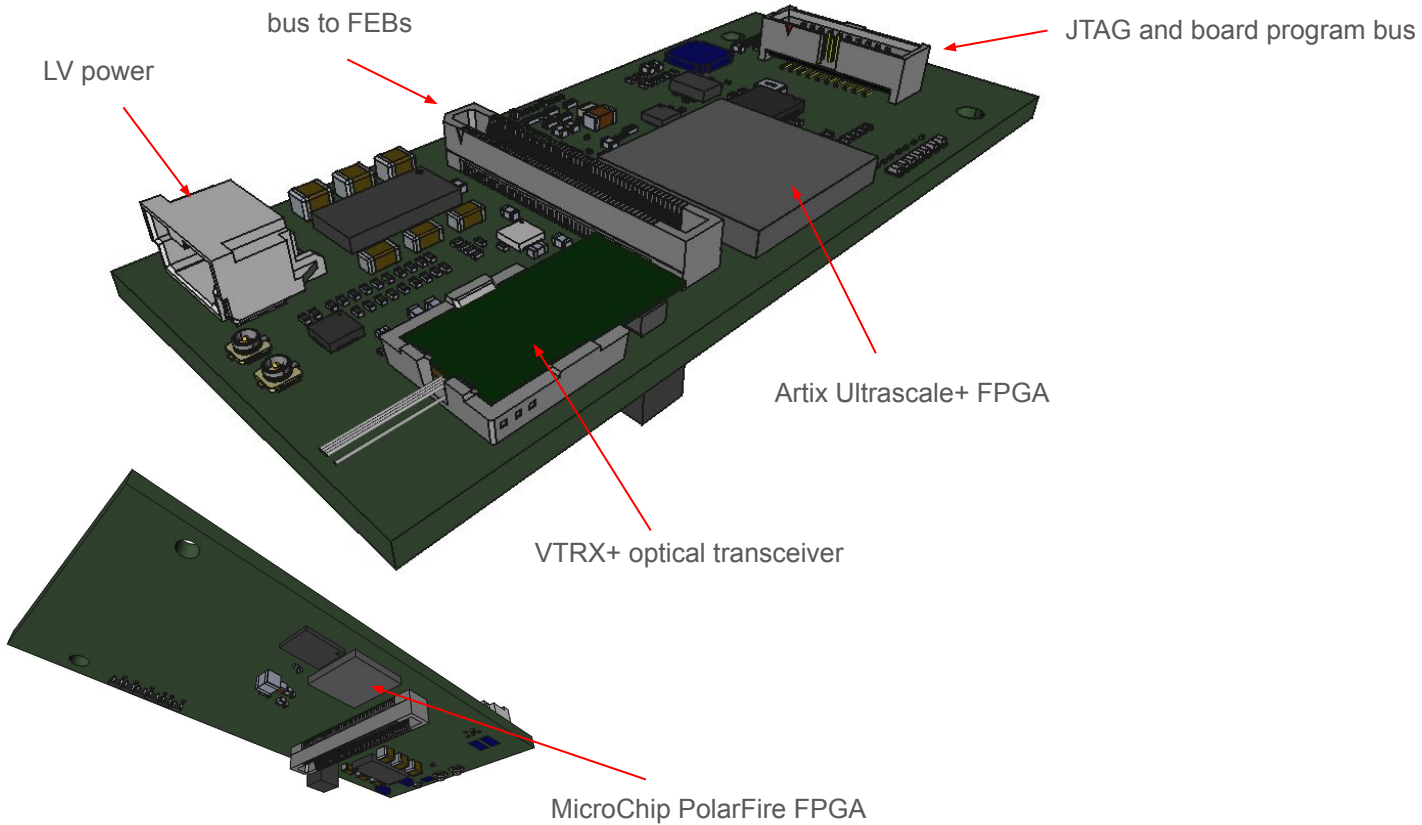


first test with rented CAEN power-supply units in 2024

RDO

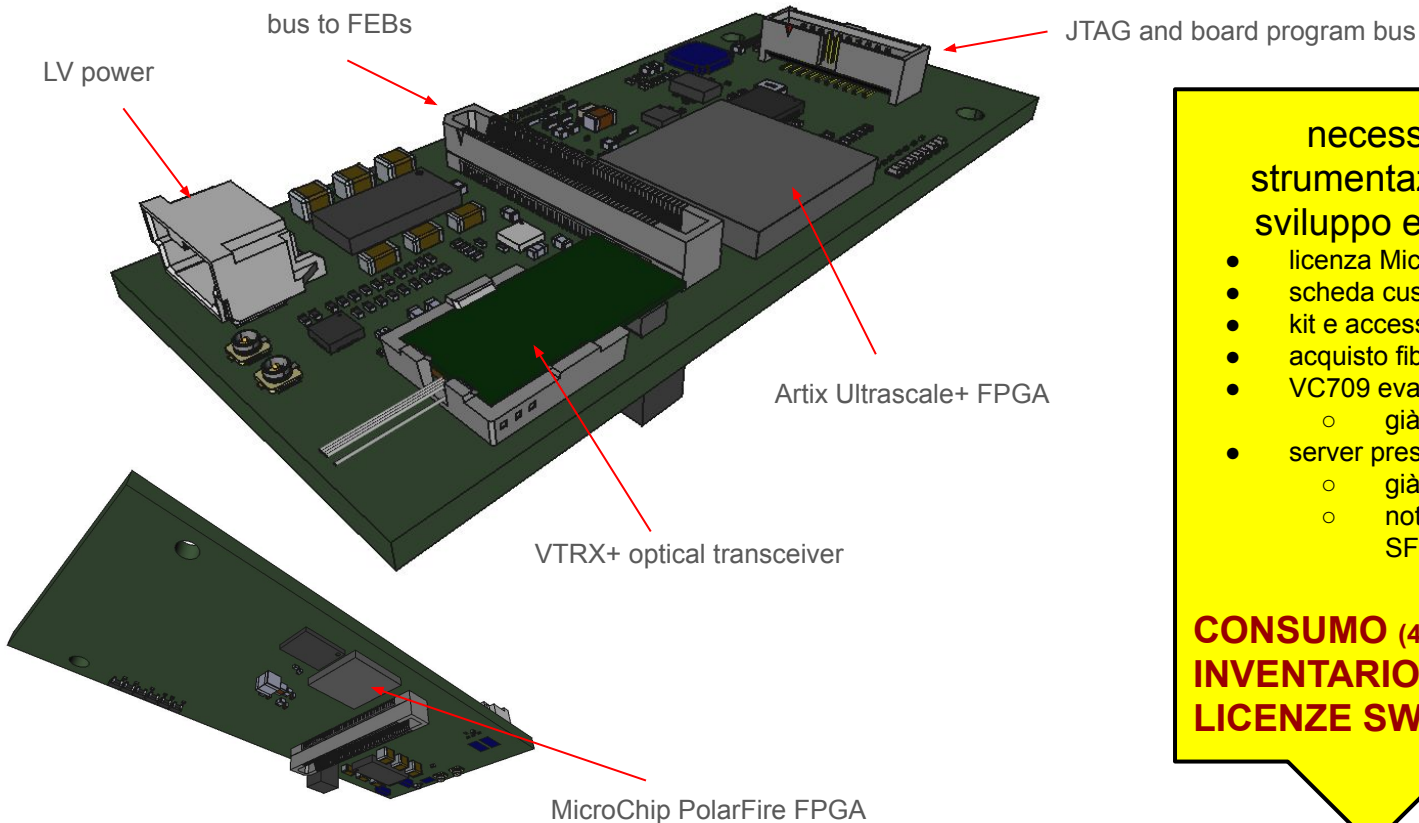
RDO is in advanced design stage

project will be soon sent for board layout by external company and production of first prototypes



RDO is in advanced design stage

project will be soon sent for board layout by external company and production of first prototypes



necessità acquisizione di strumentazione per test, debug, sviluppo e utilizzo su test beam

- licenza Microchip sviluppo FW
- scheda custom per programmazione scheda
- kit e accessori commerciali programmazione
- acquisto fibre ottiche
- VC709 evaluation board
 - già richiesta preventivi 2024 (NDB)
- server prestazionale con SFP
 - già richiesta preventivi 2024 (NDB)
 - nota: erano stati dimenticati costi SFP, processore aggiuntivo e UPS

CONSUMO (4 KEUR @ BO)

INVENTARIO (17.5 KEUR @ BO)

LICENZE SW (1 KEUR @ BO)

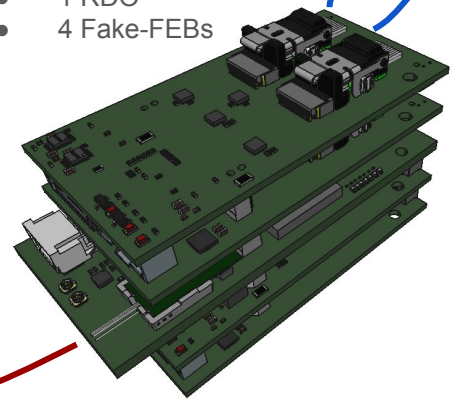
Beam-test 2025 RDO readout architecture

use IPbus protocol (already used) via Ethernet (SFP) to access RDO FPGA and readout ALCOR data on a **high-performance computer system**

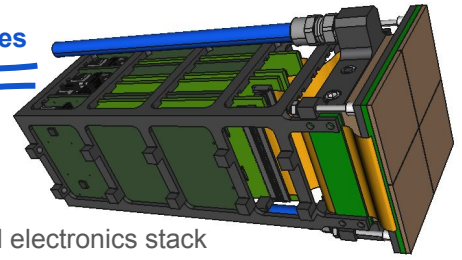
the simplest (and likely also cheapest) way to readout RDO and 2K ALCOR SiPM channels in 2025

8x front-end electronics stacks each with

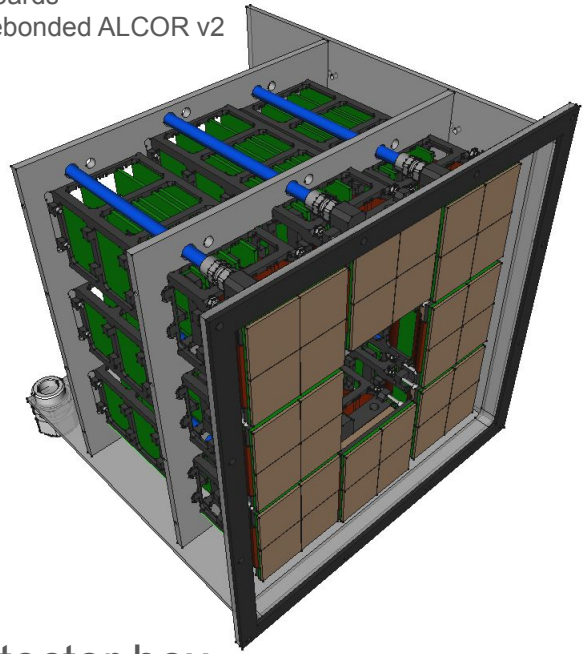
- 1 RDO
- 4 Fake-FEBs



8x FireFly cables



existing front-end electronics stack
4 ALCOR-dual boards
each with 2x wirebonded ALCOR v2



VTRX+ optical link to SFP



server bi-processore prestazionale con 8 link ottici SFP

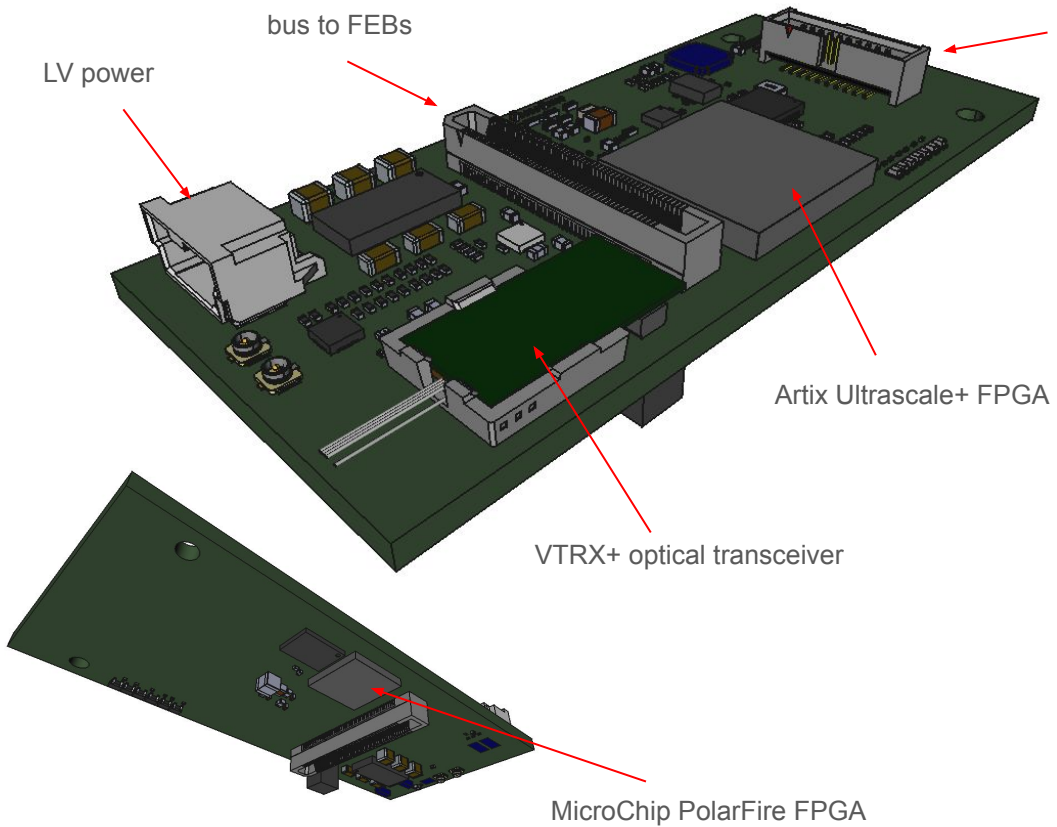
outside

inside detector box

Full-fledged RDO development, test and debug in 2025

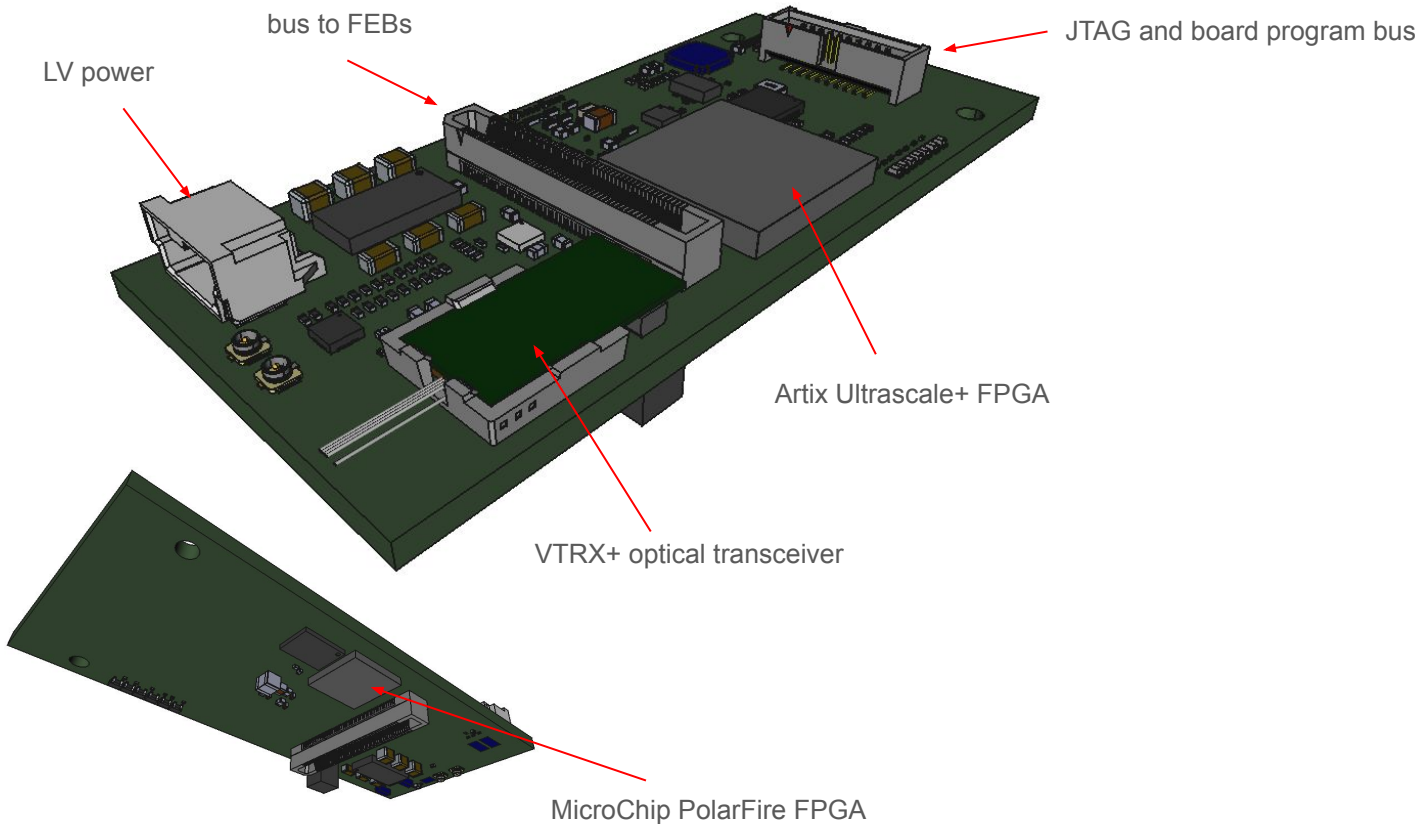
needs an FPGA development board (VC709) to simulate the ePIC DAQ (FELIX)

Xilinx Virtex7 VC709 evaluation board is also critically needed in 2025 to be able to advance the development of RDO firmware and test critical features of the board and DAQ communication protocol over VTRX+ optical transceiver



Radiation hardness of RDO components

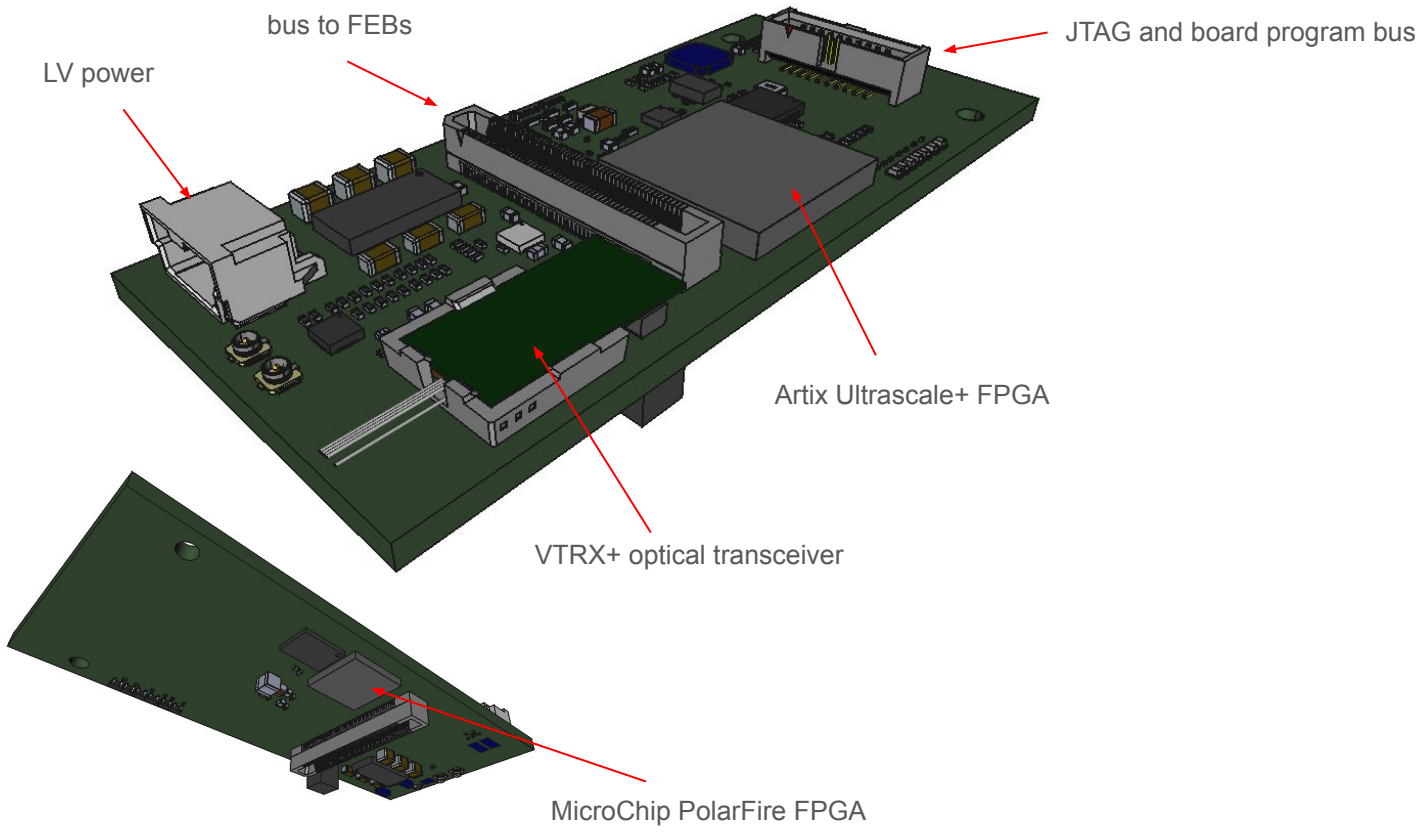
should be tested as well, important to do it soon and replace in case



see following slides on irradiations, which will cover also these aspects
 plan to also test the overall functionality of the board and its electronics (faults, SEU rates, ...) at CERN-CHARM irradiation facility with 1-week long continuous mixed-hadron flux

Production of 10 more RDO in 2025

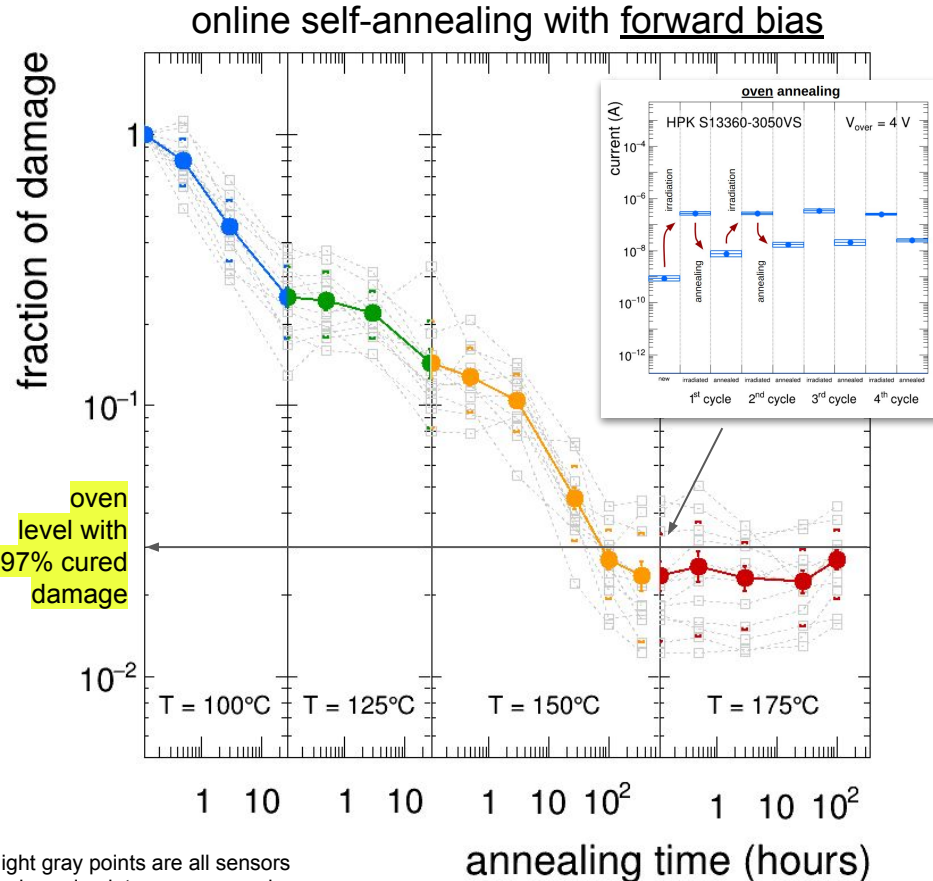
sub judice necessità di revisione della scheda e/o necessità di più RDO



CONSUMO
(10 kEUR @ BO)

irraggiamenti

Detailed studies of SiPM online self-annealing



**test on a large number SiPM sensors
how much damage is cured as a
function of temperature and time**

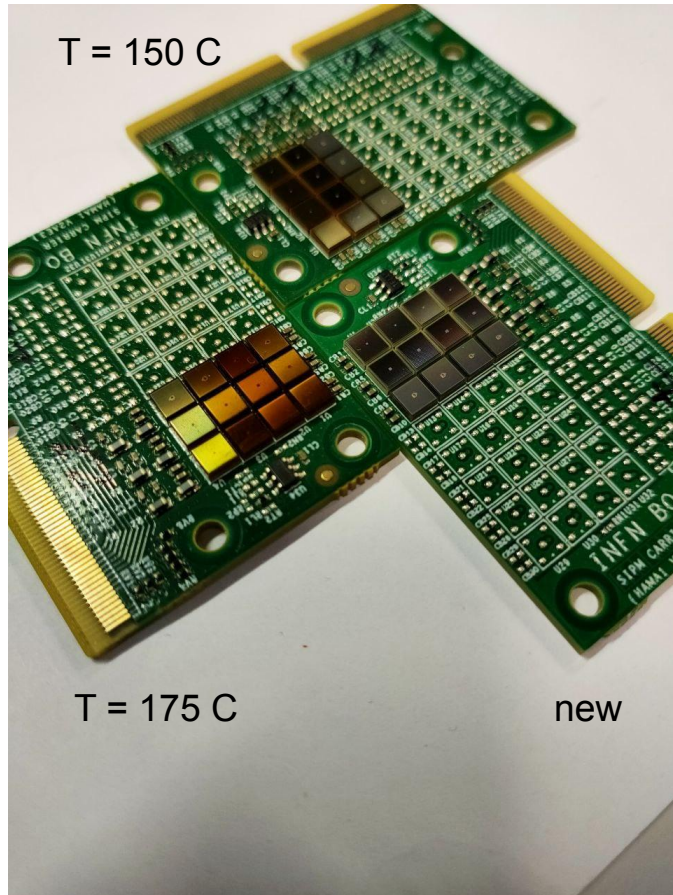
the same sensors have undergone self-annealing
increasing temperature steps
increasing integrated time steps

- started with T = 100 C annealing
 - performed 4 steps up to 30 hours integrated
- followed by T = 125, 150 and 175 C

**fraction of residual damage
seems to saturate at 2-3%
after ~ 300 hours at T = 150 C**
continuing at higher T = 175 C seems
not to cure more than that

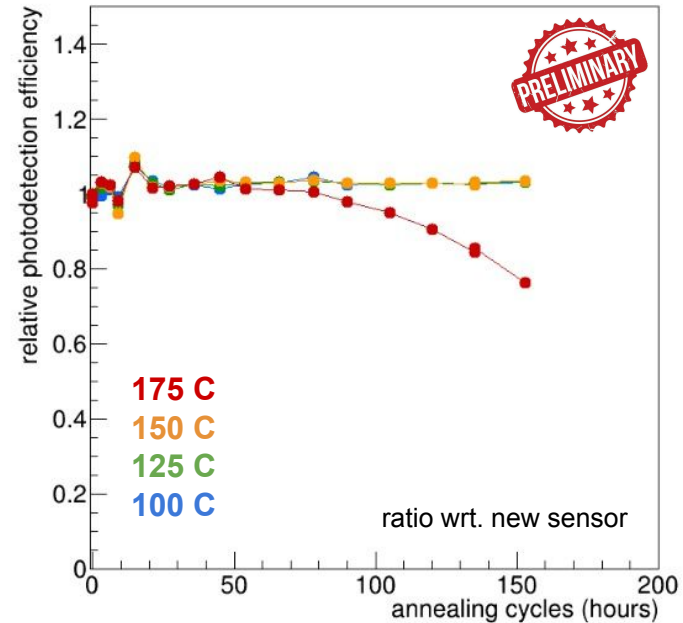
light gray points are all sensors
coloured points are averaged over sensors
coloured brackets is the RMS

Detailed studies of SiPM online self-annealing



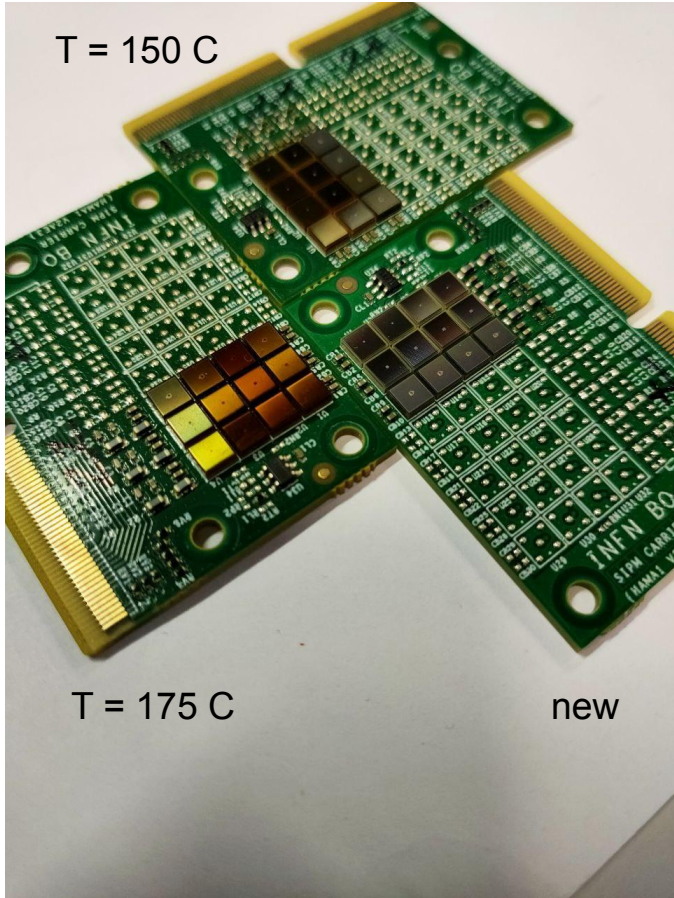
after many hours of online annealing

we noticed alterations on the SiPM windows
 in particular in one board that underwent
 500 hours of online annealing at $T = 175\text{ C}$
 the sensors appear "yellowish" when compared to new



detailed studies are ongoing, preliminary results indicate efficiency loss after 100 hours of annealing at $T = 175\text{ C}$. **lower temperatures unaffected up to 150 hours**

Detailed studies of SiPM online self-annealing

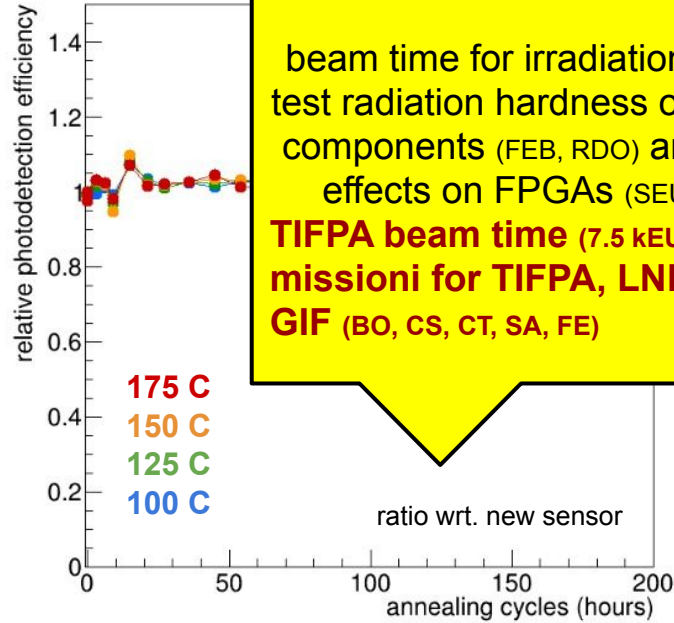


after many hours we noticed alterations in particular in 500 hours of online the sensors appear

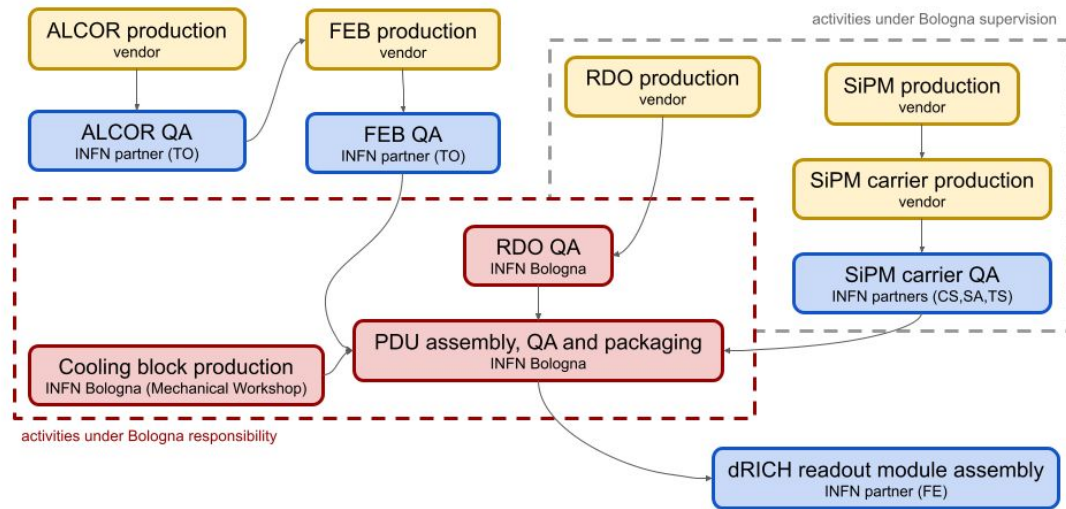
tail of irradiations linked to annealing studies, also critically needed to evaluate and clarify possible interplay between radiation and annealing damage to the SiPM resin

beam time for irradiation needed to test radiation hardness of electronics components (FEB, RDO) and measure effects on FPGAs (SEU, scrubbing)

TIFPA beam time (7.5 keUR @ BO)
missioni for TIFPA, LNL, CHARM, GIF (BO, CS, CT, SA, FE)



detailed studies are ongoing, preliminary results indicate efficiency loss after 100 hours of annealing at T = 175 C. lower temperatures unaffected up to 150 hours



SiPM QA labs

Richiesta Gruppi Salerno/Cosenza

Setup to test SiPMs at SA

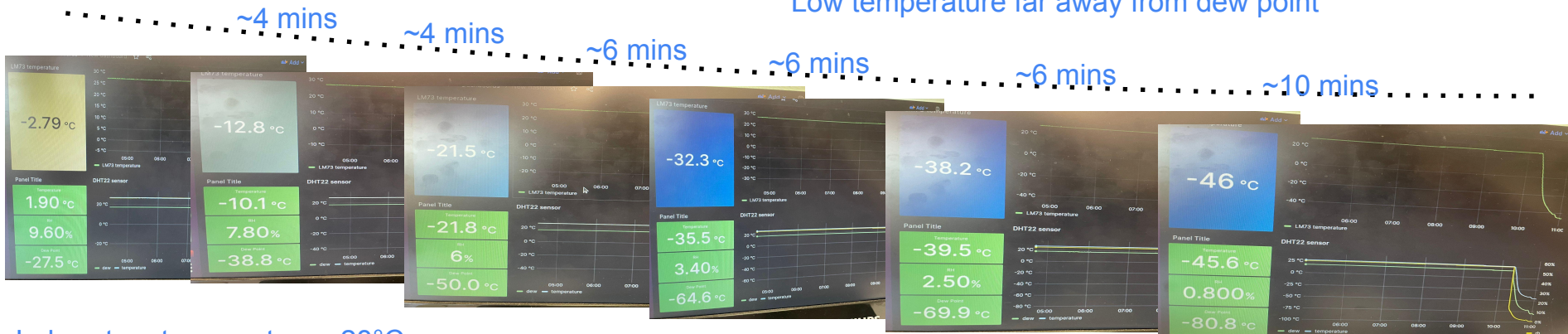


Dewar (temporarily provided by another group at UNISA)

- Idea to build a larger AirBox and use a dewar to go down in temperature
- Support from INFN section technicians



AirBox + Peltier + dewar (SiPM HV on)
Low temperature far away from dew point



Laboratory temperature ~28°C

Request from SA to buy Multiplexer and Keithly DAQ6510 to be uniform with CS setup and perform IV measurements

Richiesta Gruppi Salerno/Cosenza

Setup to test SiPMs at SA



Dewar (temporarily provided)

- Idea to build a larger AirBox and use a dewar to go to low temperature
- Support from INFN section technicians

AirBox + Peltier + dewar
Low temperature far away

acquisto dewar e materiale per realizzazione sistema raffreddamento
SJ alla verifica della fattibilità del progetto con il dewar attualmente in prestito

INVENTARIO (6 KEUR @ SA)

INVENTARIO (6 KEUR @ CS)

acquisto sistema DAQ con multiplexer per acquisizione IV

INVENTARIO (6 KEUR @ SA)

~4 mins ~4 mins ~6 mins ~6 mins ~6 mins



Laboratory temperature ~28°C

Request from SA to buy Multiplexer and Keithly DAQ6510 to be uniform with CS setup and perform IV measurements

Group background based on

- **30 y's of single photon detection experience**
 - COMPASS/AMBER RICH: MWPC & CsI; MAPMTs; MPGDs & CsI
 - Blue-sky R&D: nanodiamond photocathodes
 - ePIC dRICH : LAPPD (risk mitigation for dRICH)
 - **New, starting in 2025: SiPMs**

LAPPD

Done:

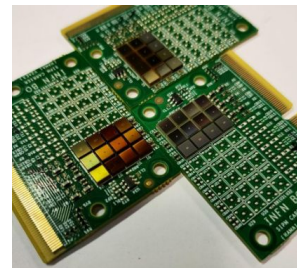
- General LAPPD characterization
- Time resolution measured with Cherenkov light in a test beam (published)
- Performance in magnetic field (publication being written)

Under completion:

- ageing studies of HRPPD, setup ready and under test
 - A tail of measurements in 2025 due to delayed availability of an HRPPD sample

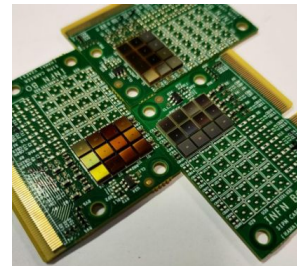


SiPM, starting from 2025



- **Equipping the lab**
 - The large majority of the equipment available (past activity)
 - **New procurements:**
 - Power supply, preamplifier specific for SiPMs
 - Peltier cell and chiller to study SiPMs at low T ($\sim -30^{\circ}\text{C}$)
- **Goals**
 - **Contribute to specific SiPM studies** (refinement of the detailed characterization also as support to more and more refined simulation)
 - **An example:** SiPM efficiency versus the photon impinging angle
 - **Preparing for future QA of the SiPM batches** (job in sharing with other INFN sites)

SiPM, starting from 2025



- **Equipping the lab**

- The large majority of the equipment available (past)
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- **Goals**

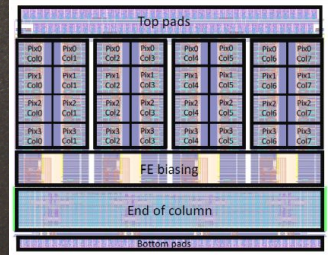
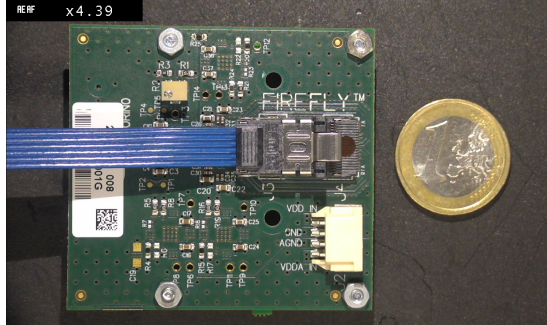
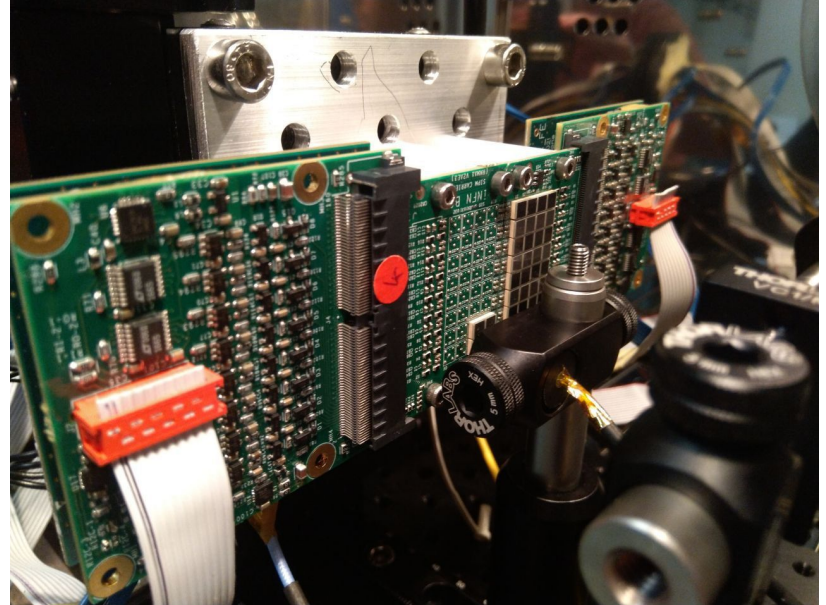
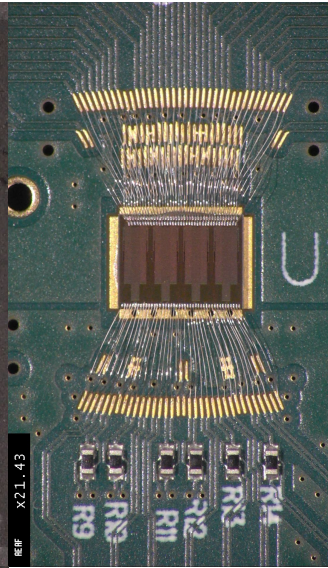
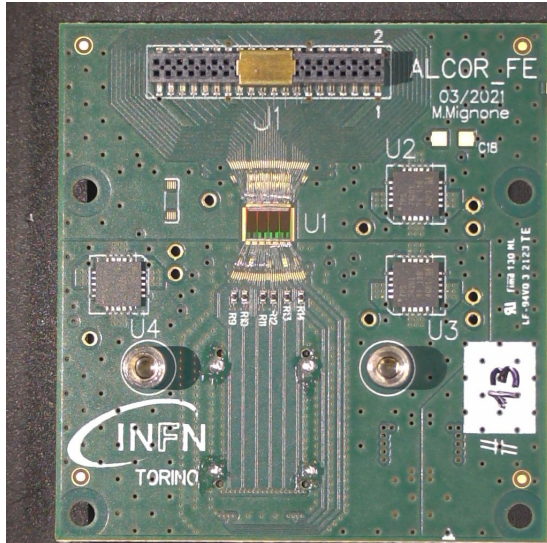
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richieste / metabolismo
realizzazione sistema per test
SiPM, acquisto amplificatori e
realizzazione sistema
raffreddamento

CONSUMO (10 KEUR @ TS)
INVENTARIO (3 KEUR @ TS)

ALCOR support for Genova activities on tagger

using same electronics chain developed for SiPM tests



produzione schede di elettronica
per attività GE e TS
CONSUMO (10 KEUR @ BO)