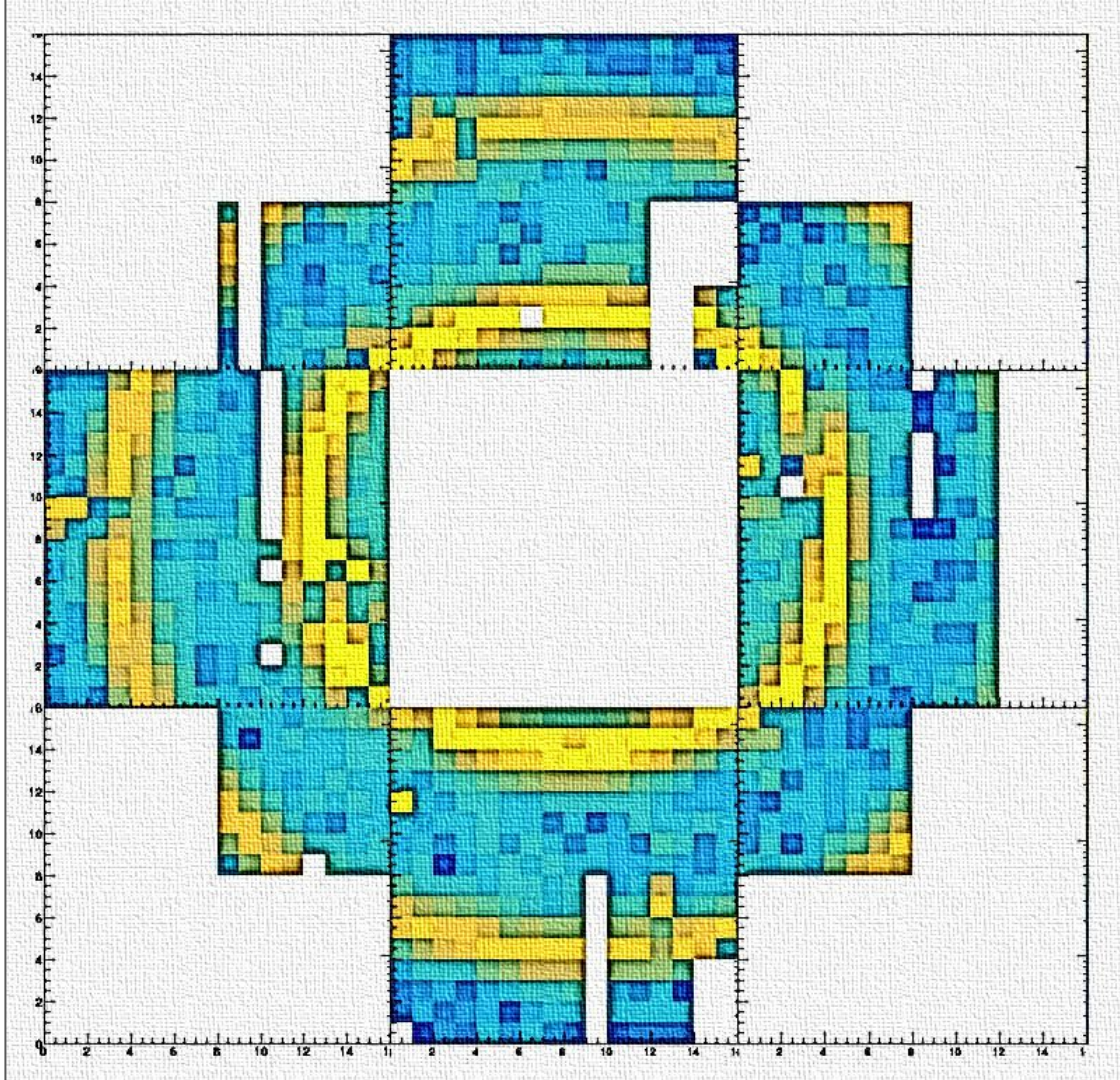
The ePIC-dRICH detector at the EIC

Roberto Preghenella
per il gruppo EIC Bologna

Assemblea di Sezione fine fine anno
22 December 2023, Bologna

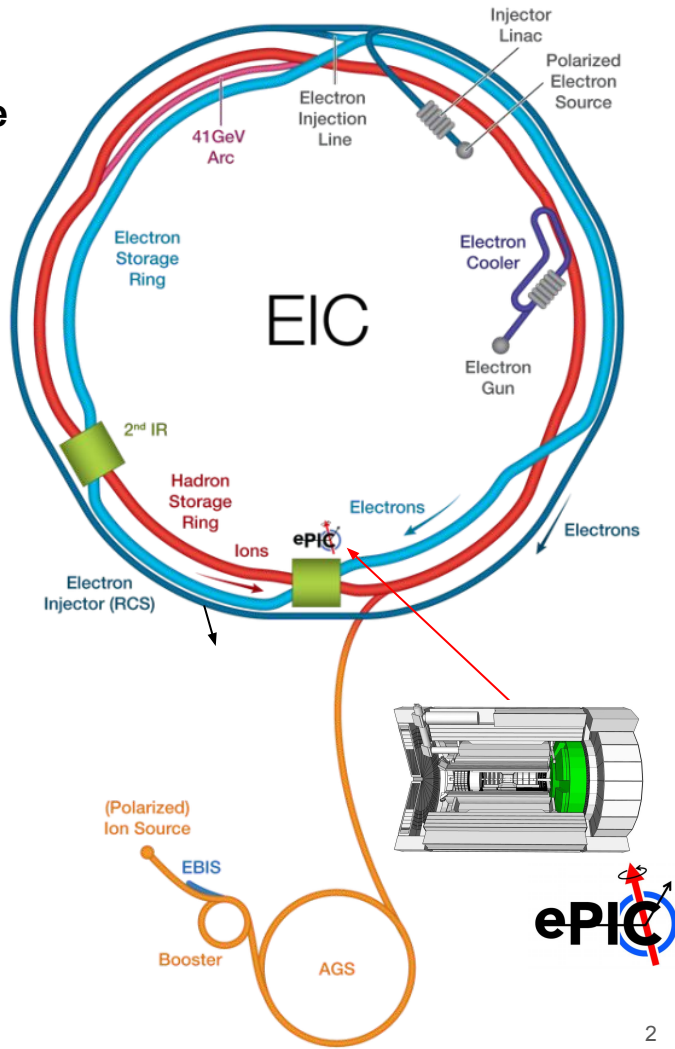
preghenella@bo.infn.it

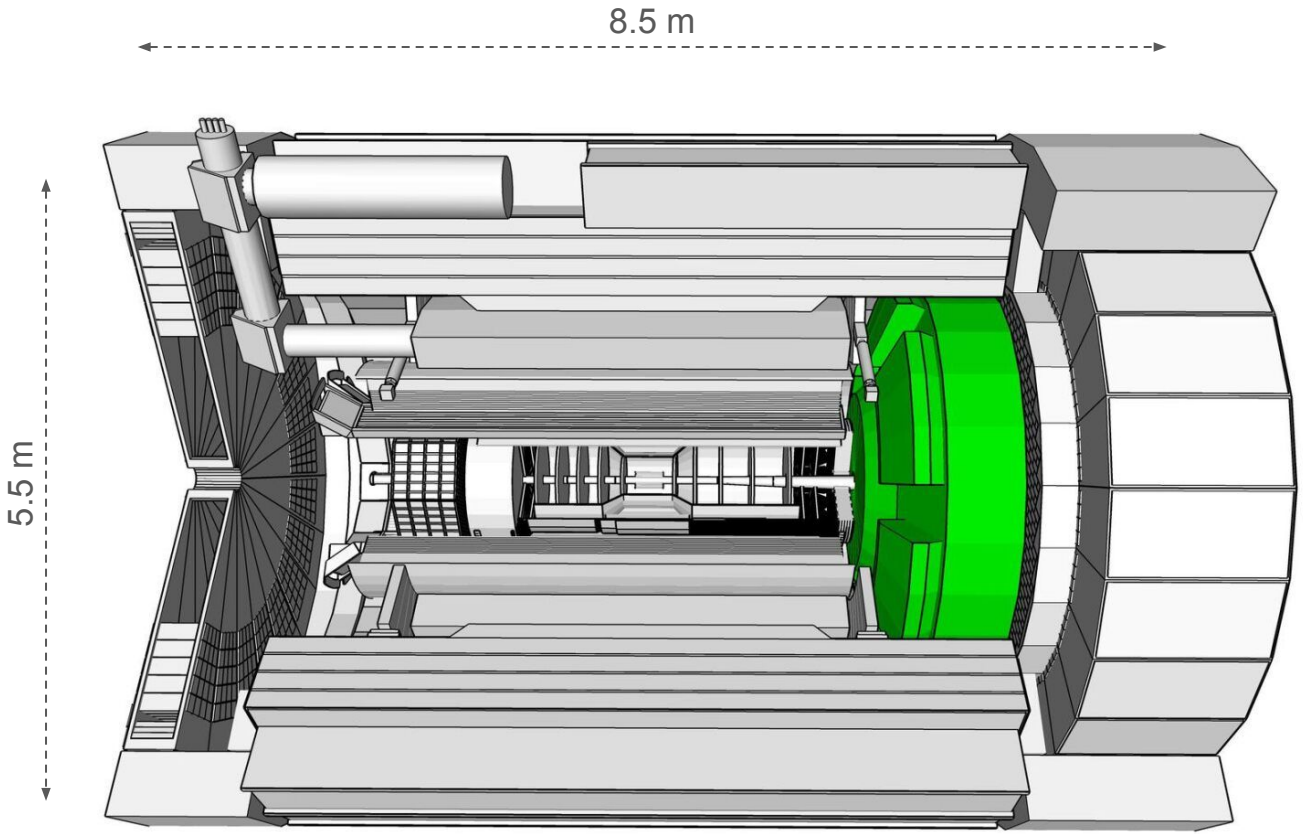


The Electron-Ion Collider

a machine that will unlock the secrets of the strongest force in Nature
is a future electron-proton and electron-ion collider at BNL (USA)
foreseen to start operation in early 2030's

- **the major US project in the field of nuclear physics**
  - one of the most important scientific facilities for the future of nuclear and subnuclear physics
- **the world's first collider for**
  - polarised electron-proton (and light ions)
  - electron-nucleus collisions
- **will allow to explore the secrets of QCD**
  - understand origin of mass & spin of the nucleons
  - extraordinary 3D images of the nuclear structure





dual RICH detector

INFN leadership

<u>strong BO responsibilities</u>

- Photodetector
- Readout & DAQ

<u>growing BO team</u> (> 3 FTE)

Agrawal, Antonioli, Bellini
Falchieri, Garbini, Giacalone,
Noferini, Paladino, Preghenella,
Rignanese, Rubini, Rath

<u>Responsabile Nazionale</u>

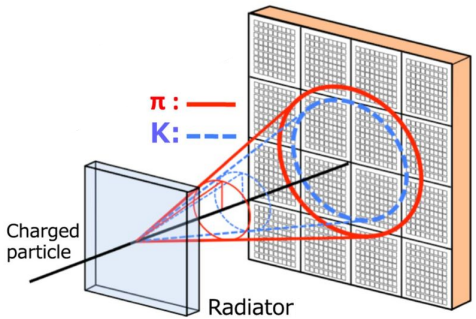
Antonioli

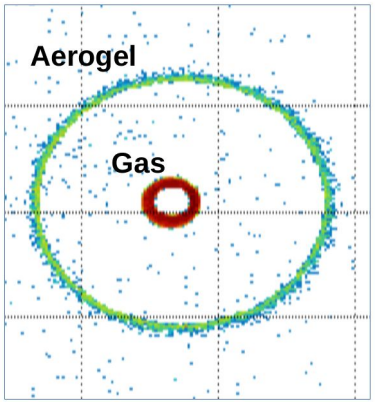
The dual-radiator (dRICH) for forward PID at EIC

compact and cost-effective solution for broad momentum coverage at forward rapidity

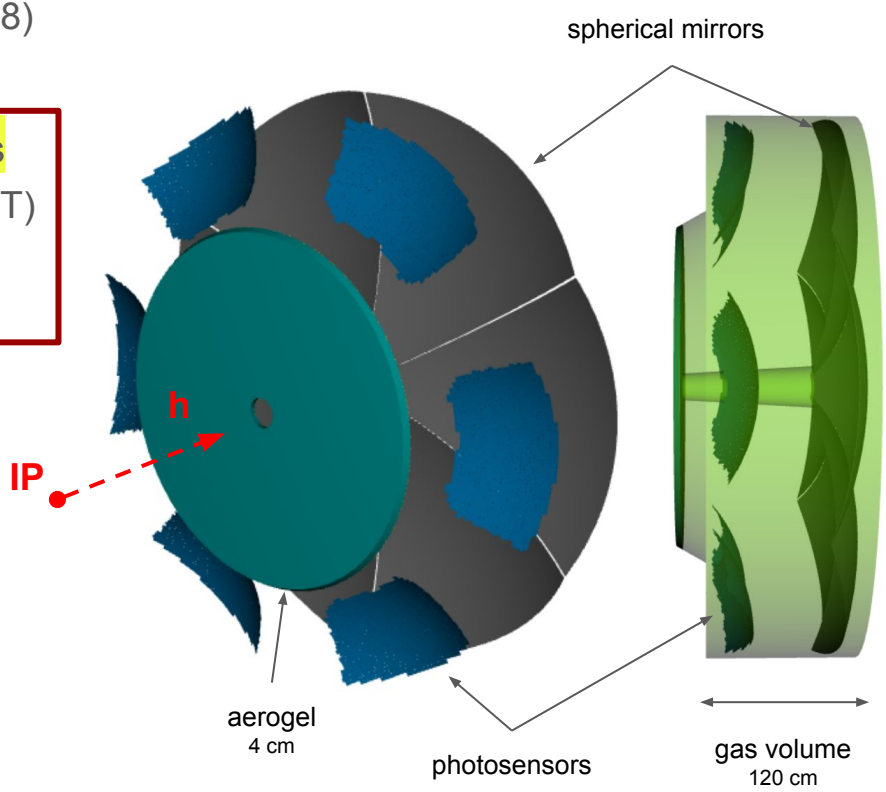
p = [3.0, 50] GeV/c
η = [1.5, 3.5]
e-ID up to 15 GeV/c

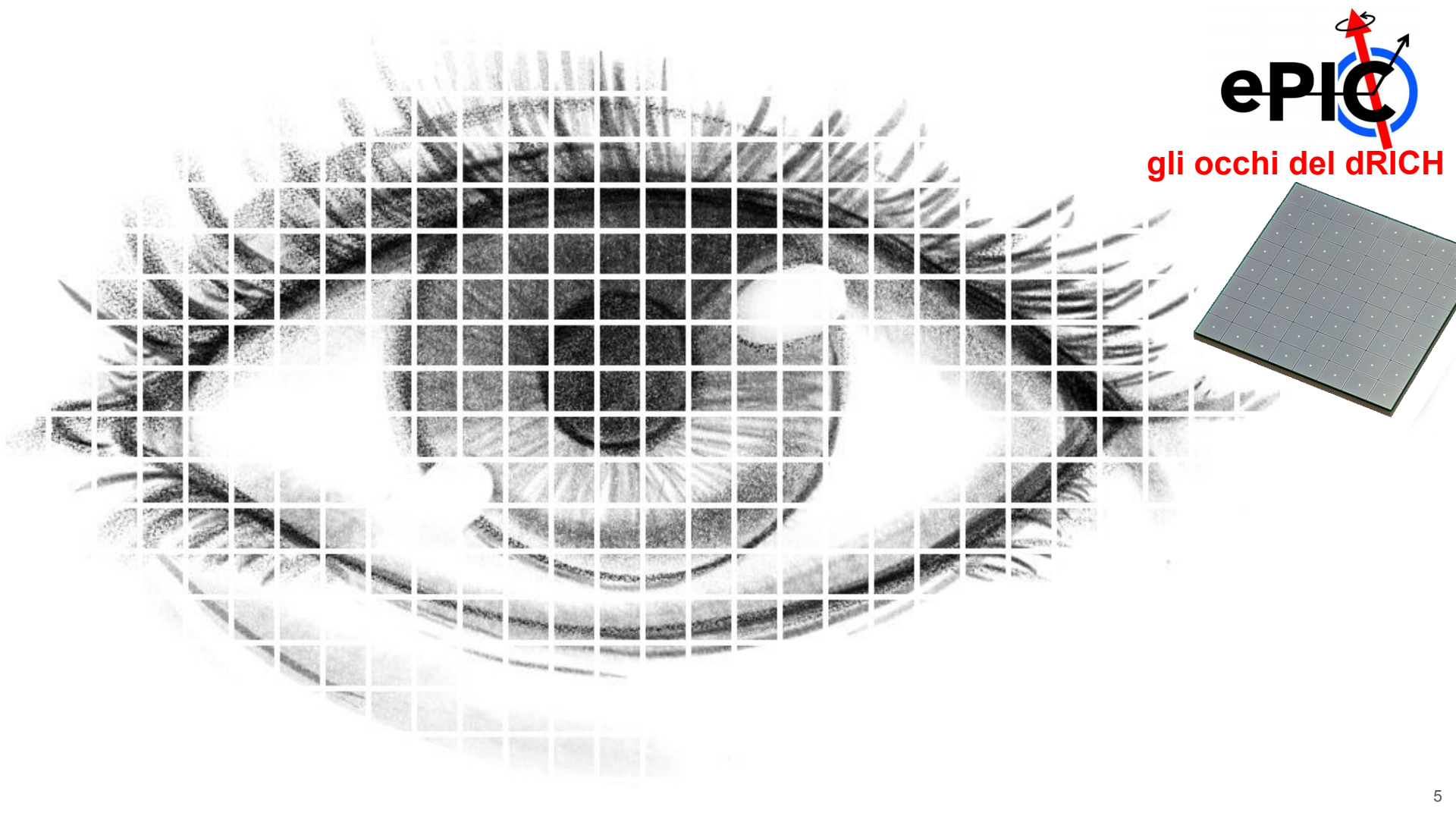
- **radiators:** aerogel (n ~ 1.02) and C_2F_6 (n ~ 1.0008)
- **mirrors:** large outward-reflecting, 6 open sectors
- **sensors:** 3x3 mm^2 pixel, ~ 3 m^2 of photodetectors
  - single-photon detection inside high B field (~ 1 T)
  - outside of acceptance, reduced constraints
  - SiPM optical readout



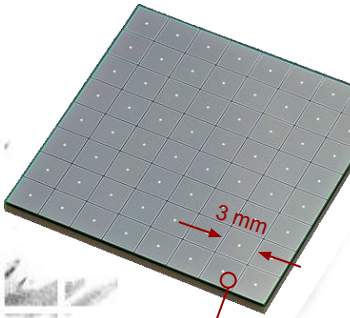


example event (accumulated hits)

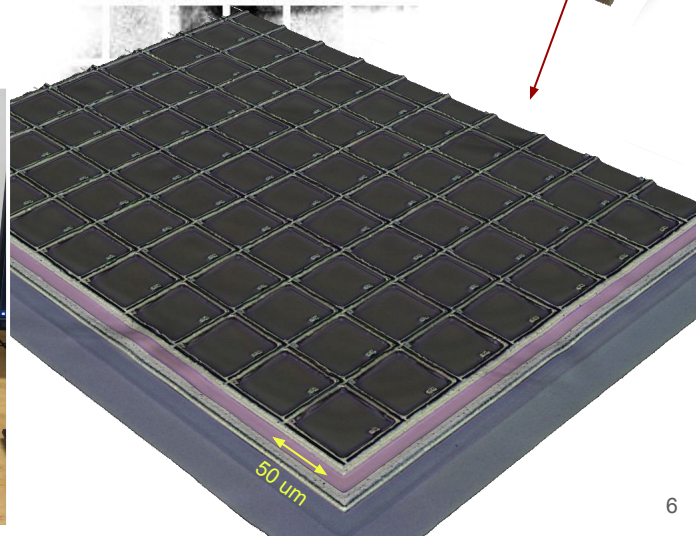



ePIC
gli occhi del dRICH

gli occhi del dRICH



gli occhi visti dal nuovo microscopio laser



SiPM Silicon Photomultipliers

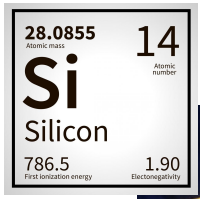
- **pros**
  - cheap
  - high photon efficiency
    requirement ☑️
  - excellent time resolution
    requirement ☑️
  - insensitive to magnetic field
    requirement ☑️

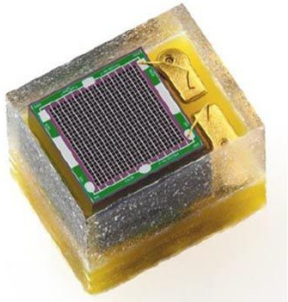
- **cons**

large dark count rates

not radiation tolerant

technical solutions and mitigation strategies
- 🐧 cooling
- ⏱️ timing
- 🔥 annealing





SiPM cooling for low-temperature operation (−30 °C or lower)

external chiller with fluid recirculation (ie. siliconic oil)

the chiller here one is just a commercial example

cooling and heating capacity

could use heating capability for annealing? must be demonstrated to be feasible

cooling capacity at -40 C is large (1.5 kW)

General & Temperature Control

huber

Temperature range	-55...250 °C
Temperature stability	±0,01 K

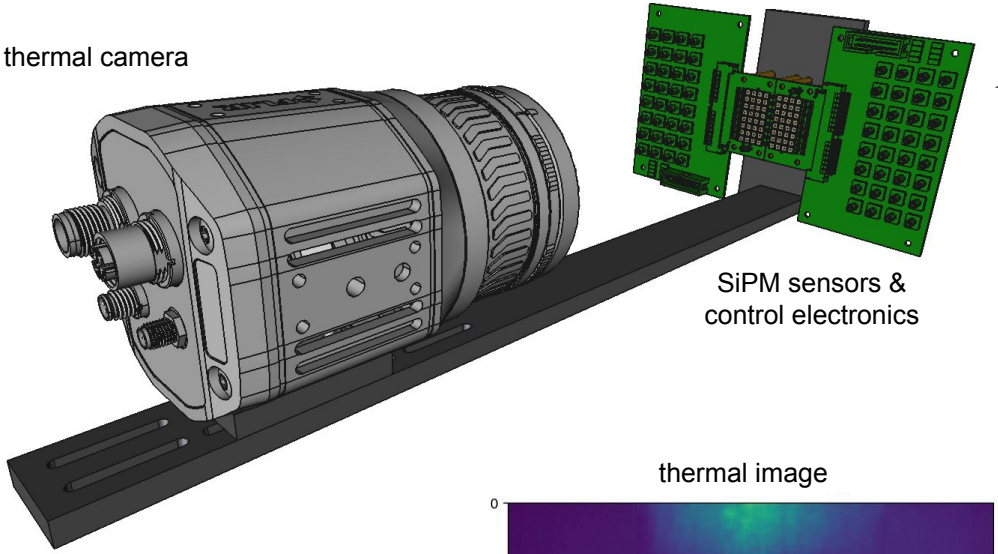
Heating / cooling capacity

Heating capacity	6 kW								
Cooling capacity	250	200	100	20	0	-20	-40	-50	°C
	6	6	6	6	6	4,2	1,5	0,65	kW

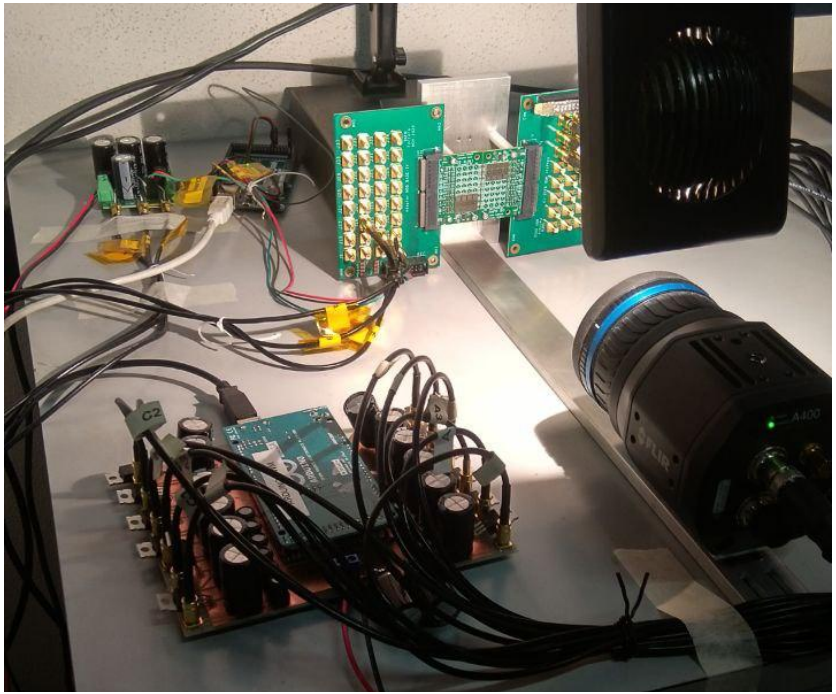
Automated multiple SiPM online self-annealing

system for online self-annealing with temperature monitor and control of each individual SiPM

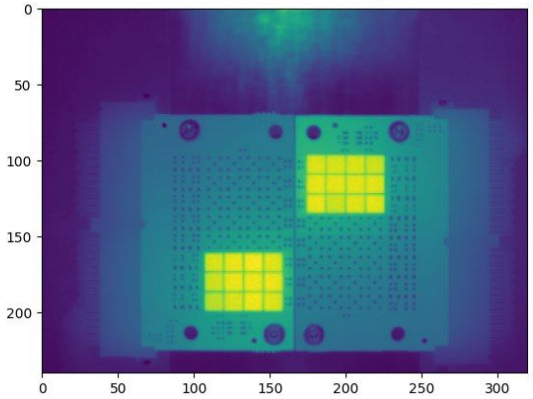
thermal camera



SiPM sensors & control electronics

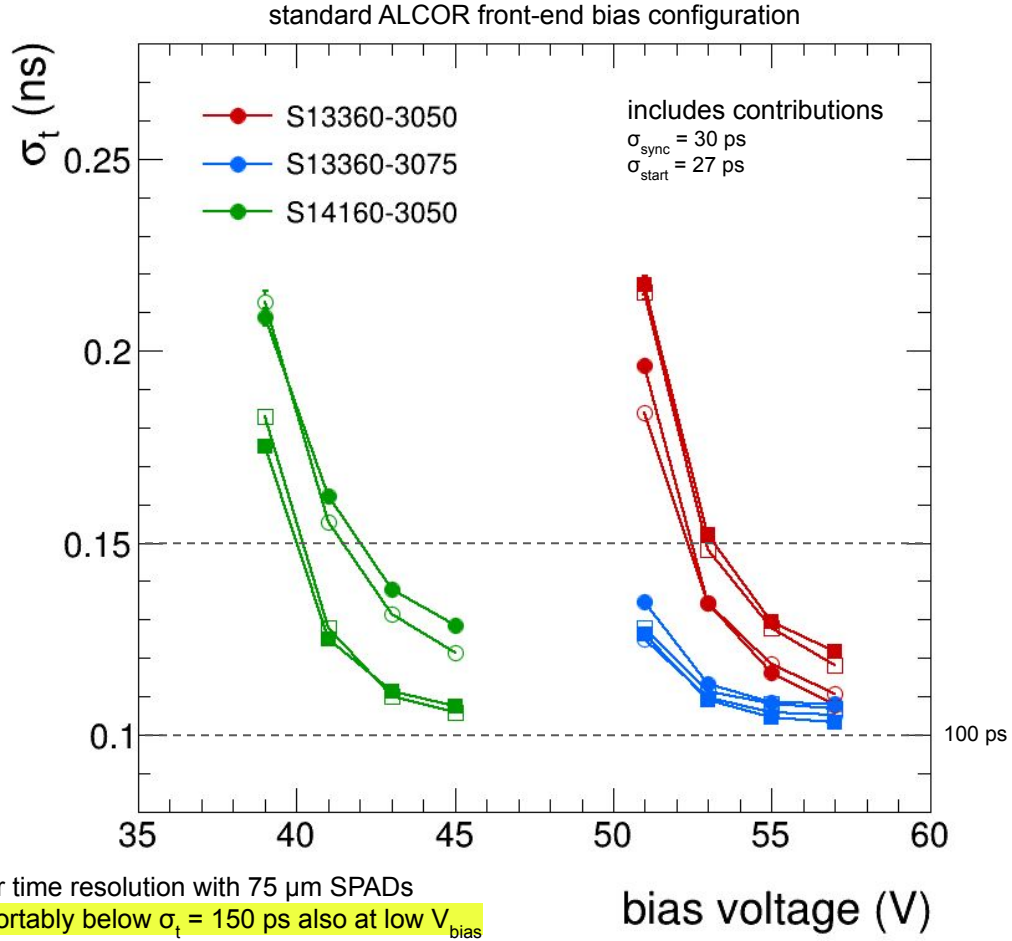


thermal image

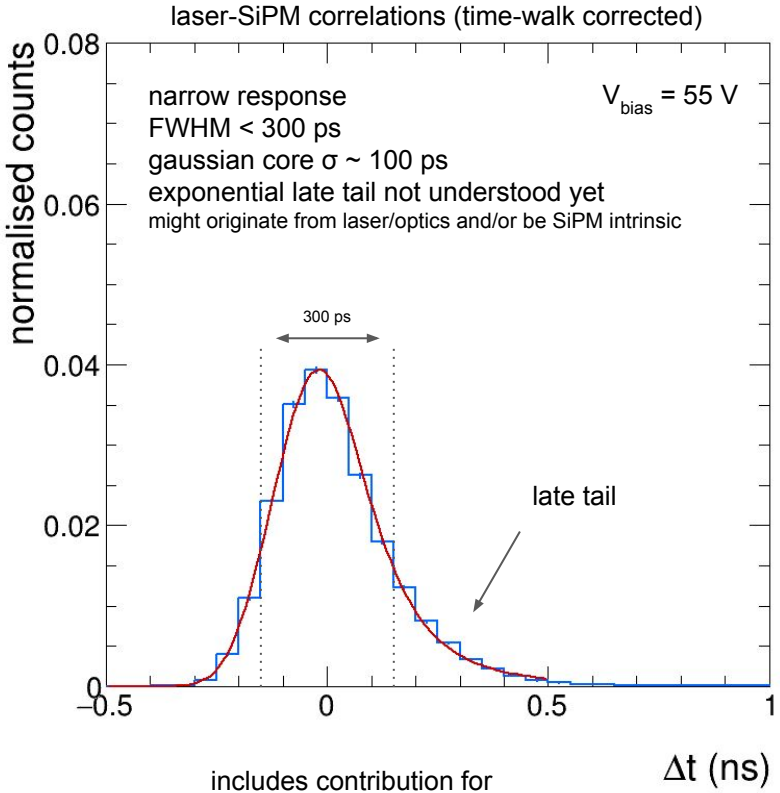


monitor and logging system

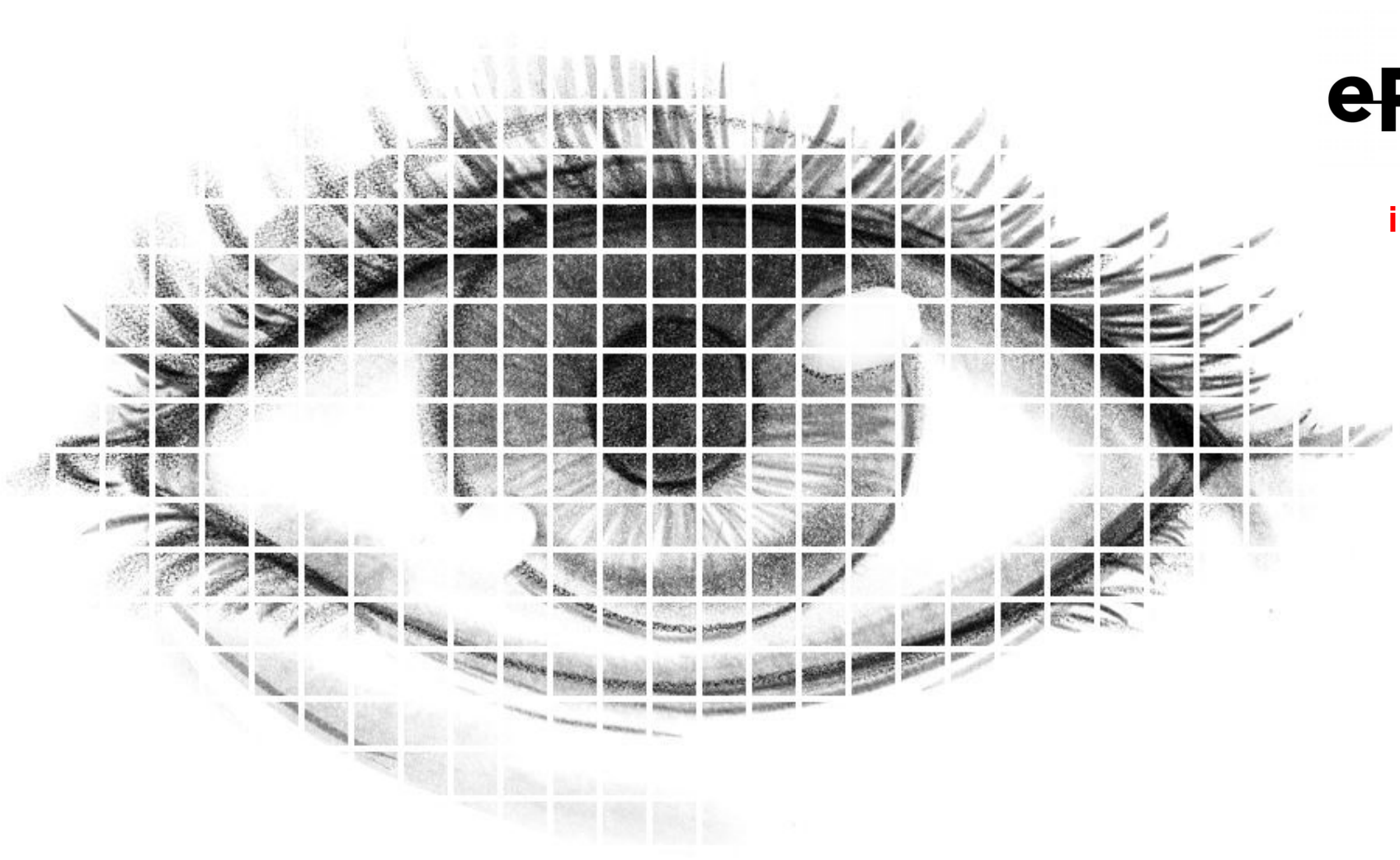
Timing performance measurements with full electronics



better time resolution with 75 μm SPADs
comfortably below σ_t = 150 ps also at low V_{bias}



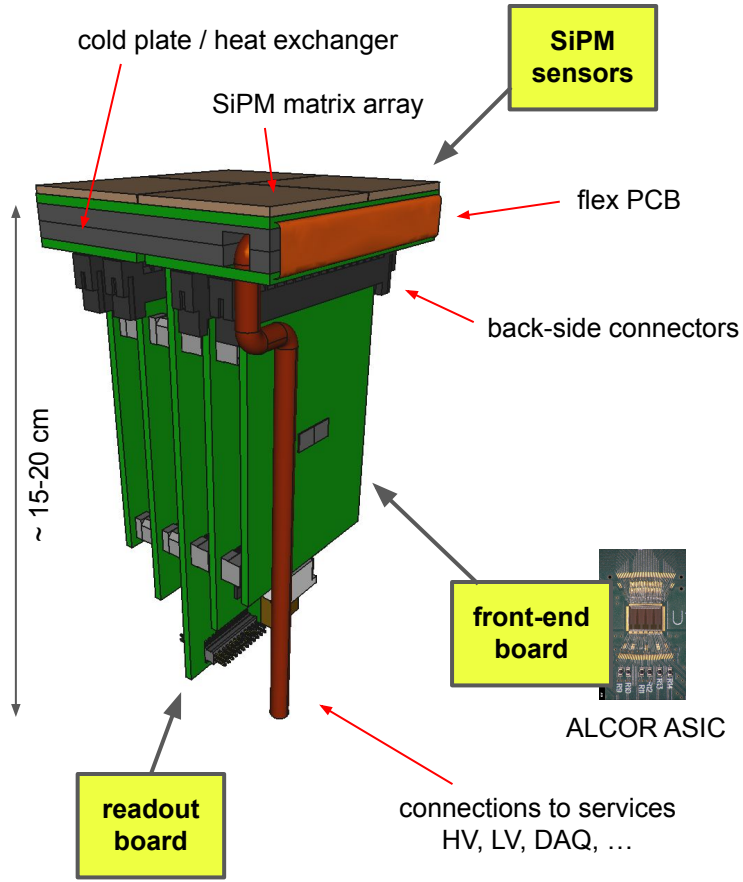
includes contribution for
laser-ALCOR synchronization
measured to be σ_{sync} = 30 ps
and reference time resolution
measured to be σ_{start} = 27 ps



detector integration

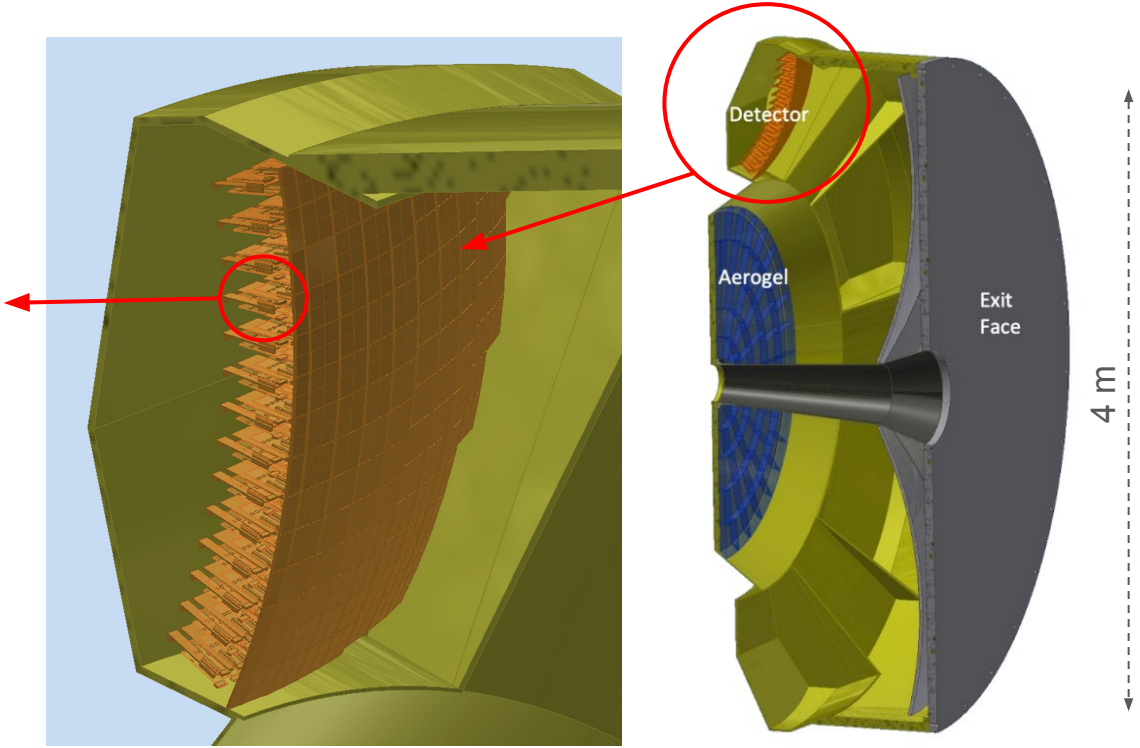
Photodetector unit

conceptual design of final layout

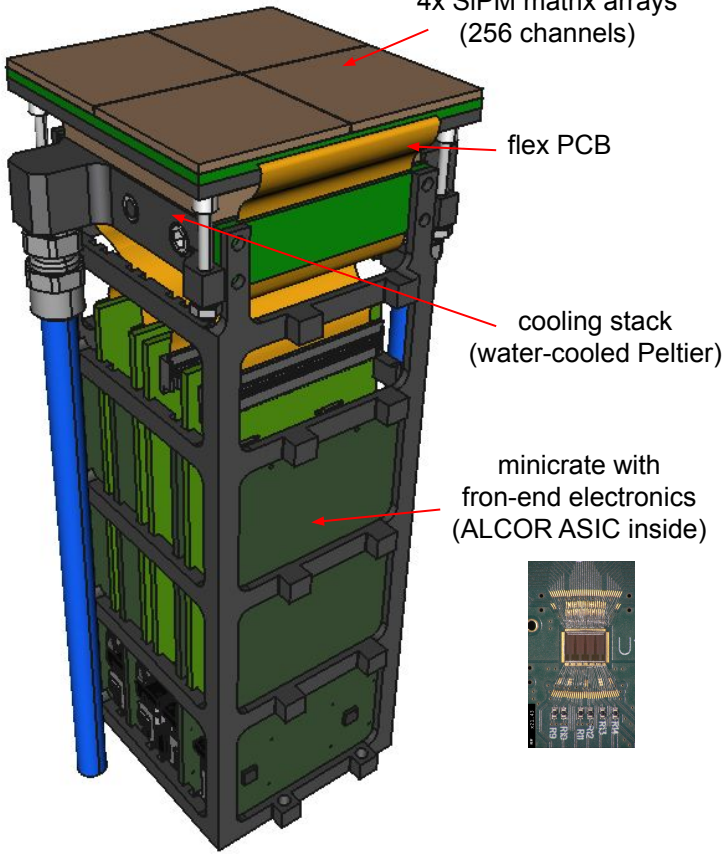


SiPM sensor matrices mounted on carrier PCB board

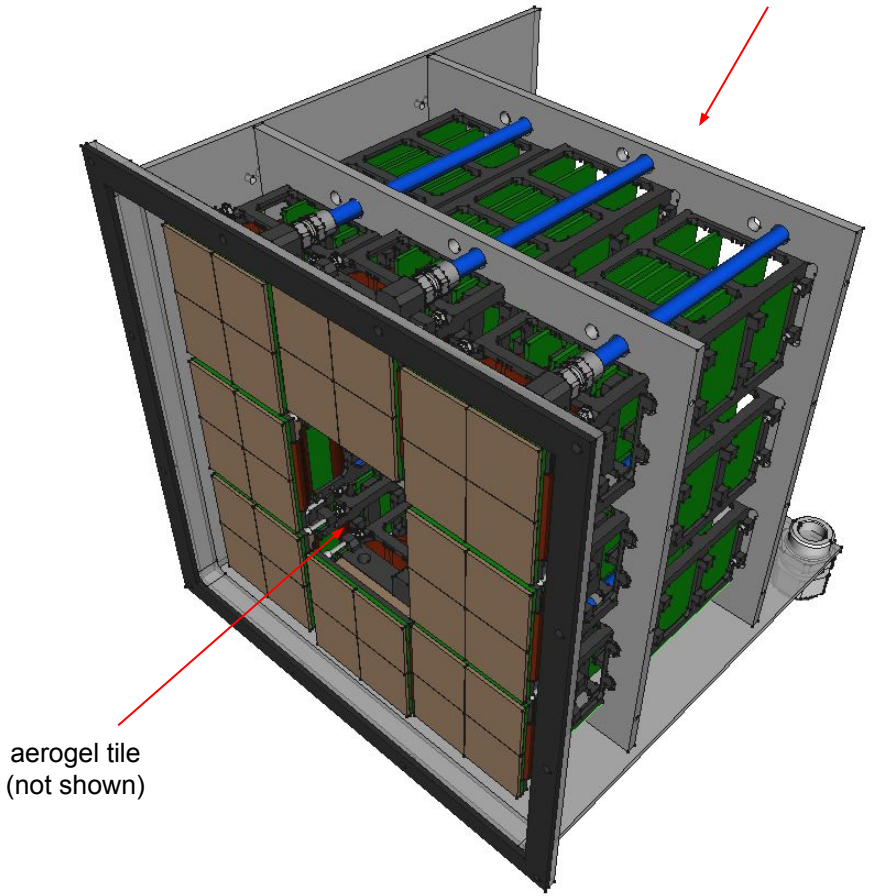
- 4x 64-channel SiPM array device (256 channels) for each unit
  - need modularity to realise curved readout surface
- 1248 photodetector units for full dRICH readout
  - 4992 SiPM matrix arrays (8x8)
  - 319488 readout channels



EIC ePIC-dRICH SiPM photodetector prototype



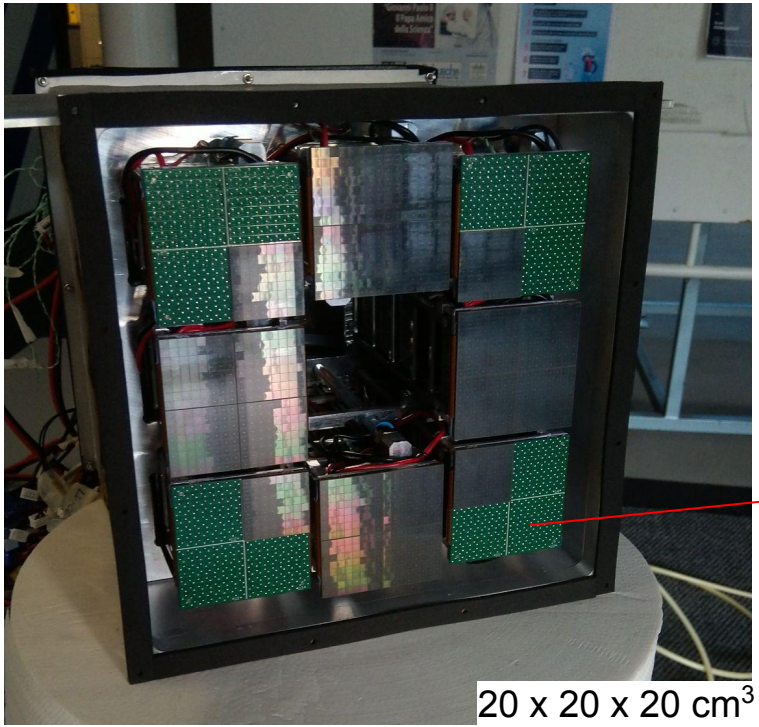
PhotoDetector Unit (PDU)



Readout Box

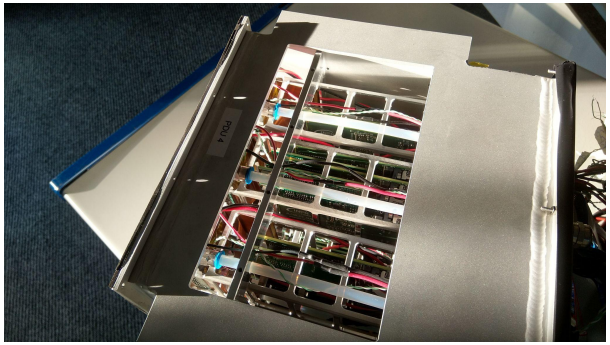
EIC ePIC-dRICH SiPM photodetector prototype

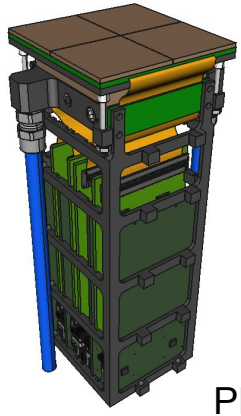
Readout Box (front)



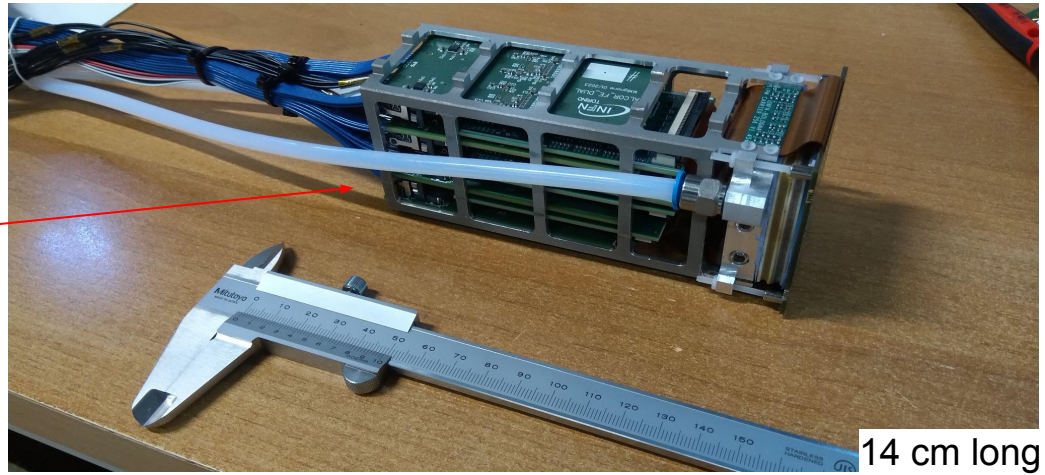
20 x 20 x 20 cm^3

(top)



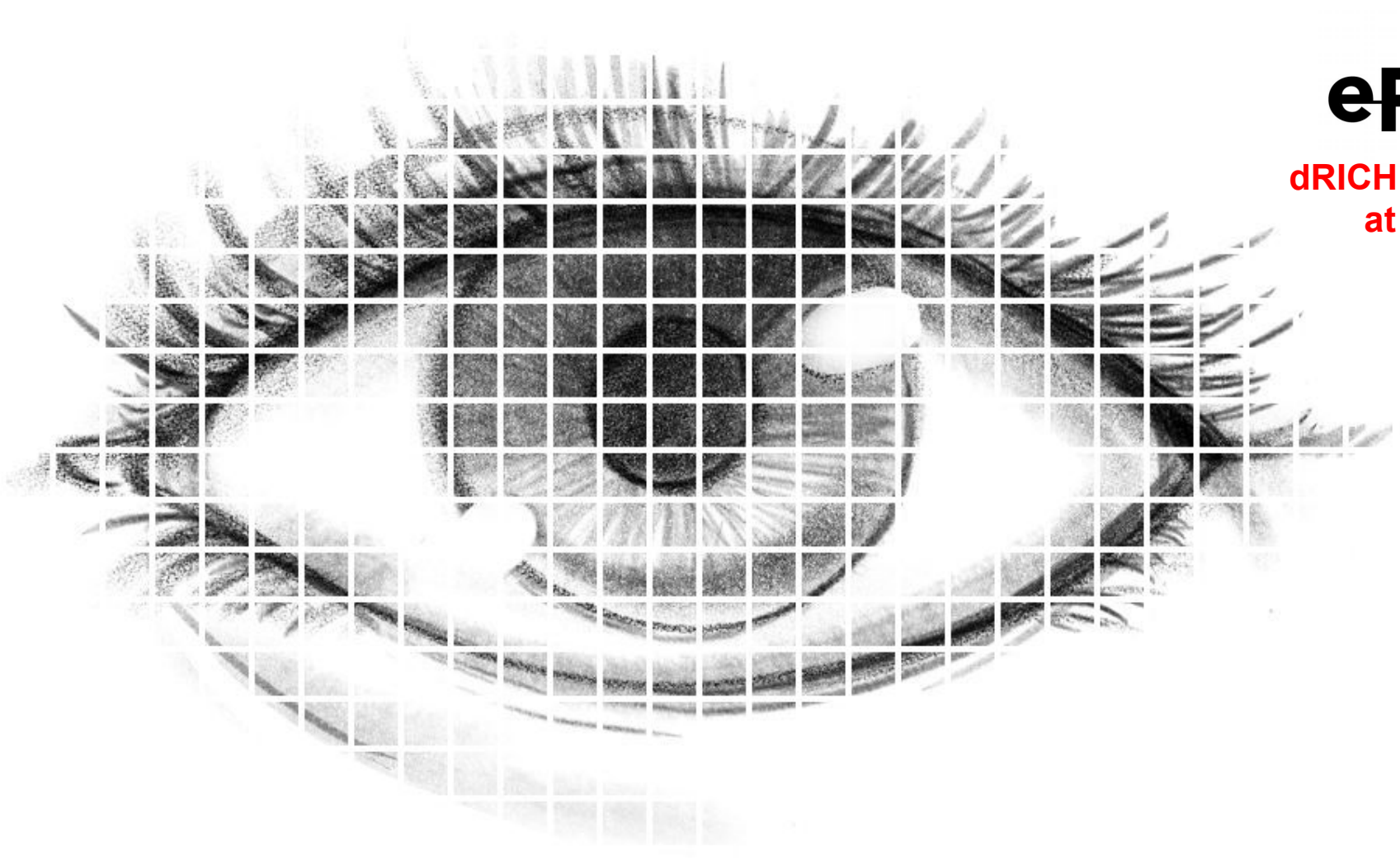


PDU

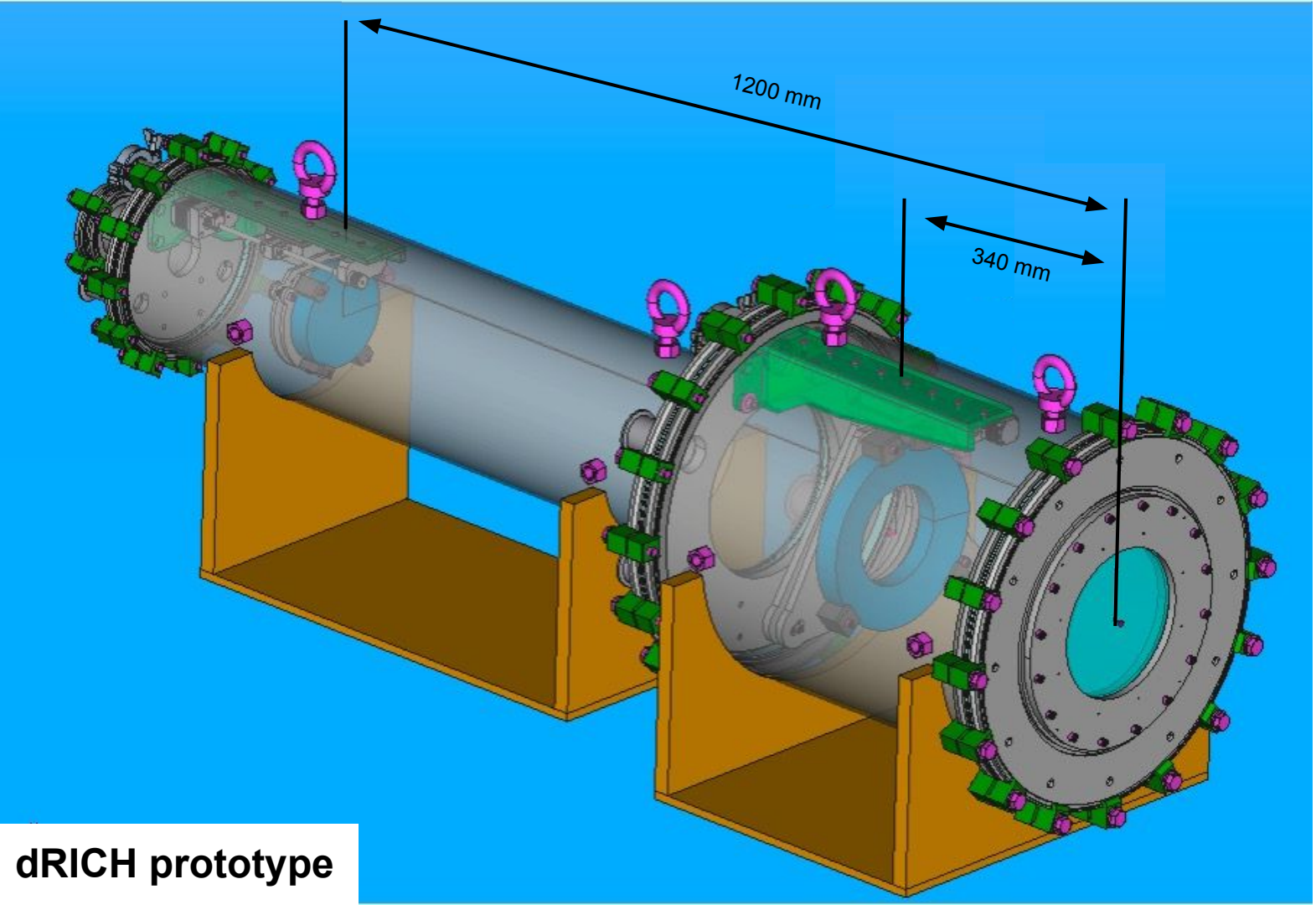


14 cm long

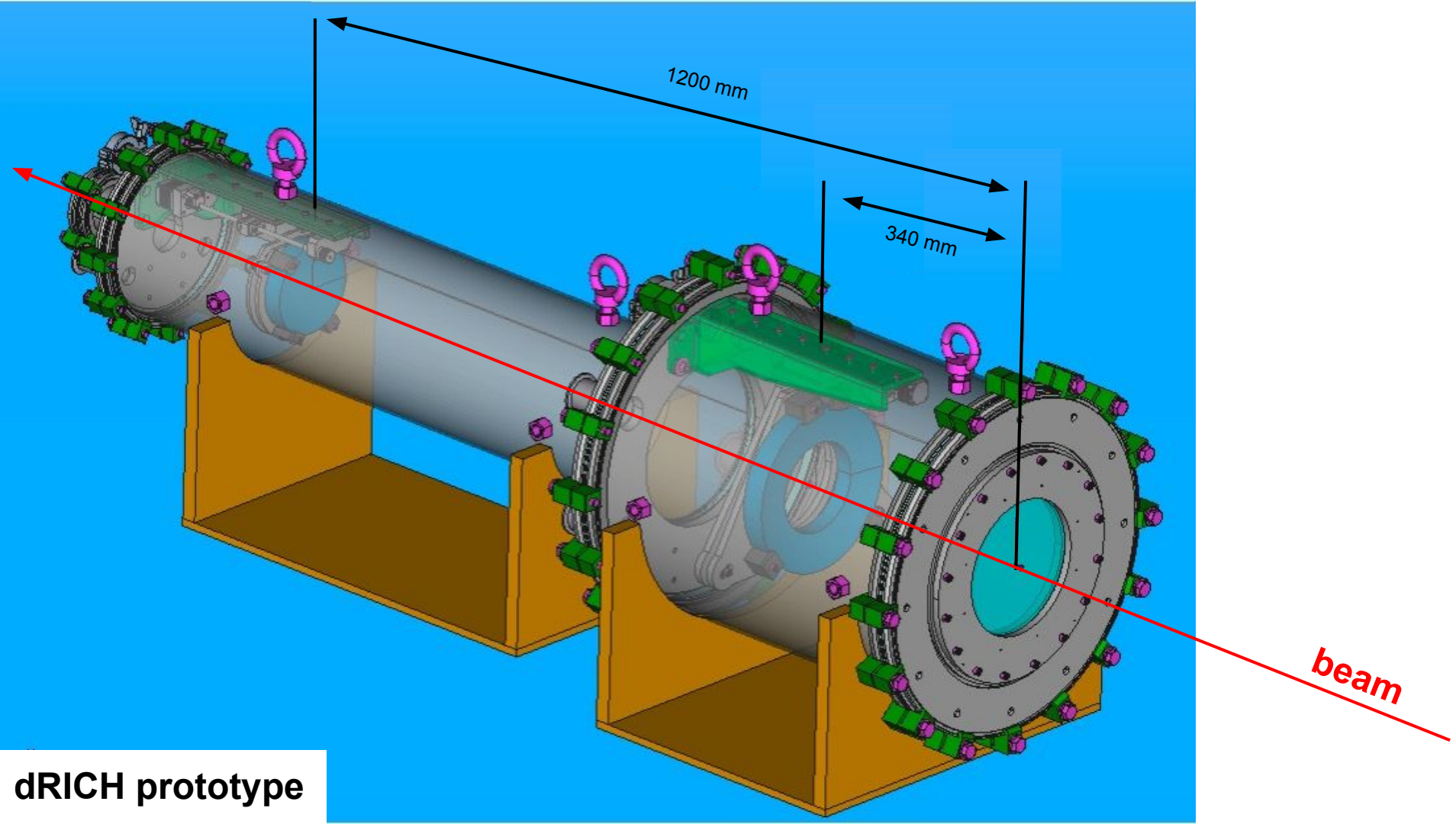
fully-equipped 1280-channels SiPM readout surface



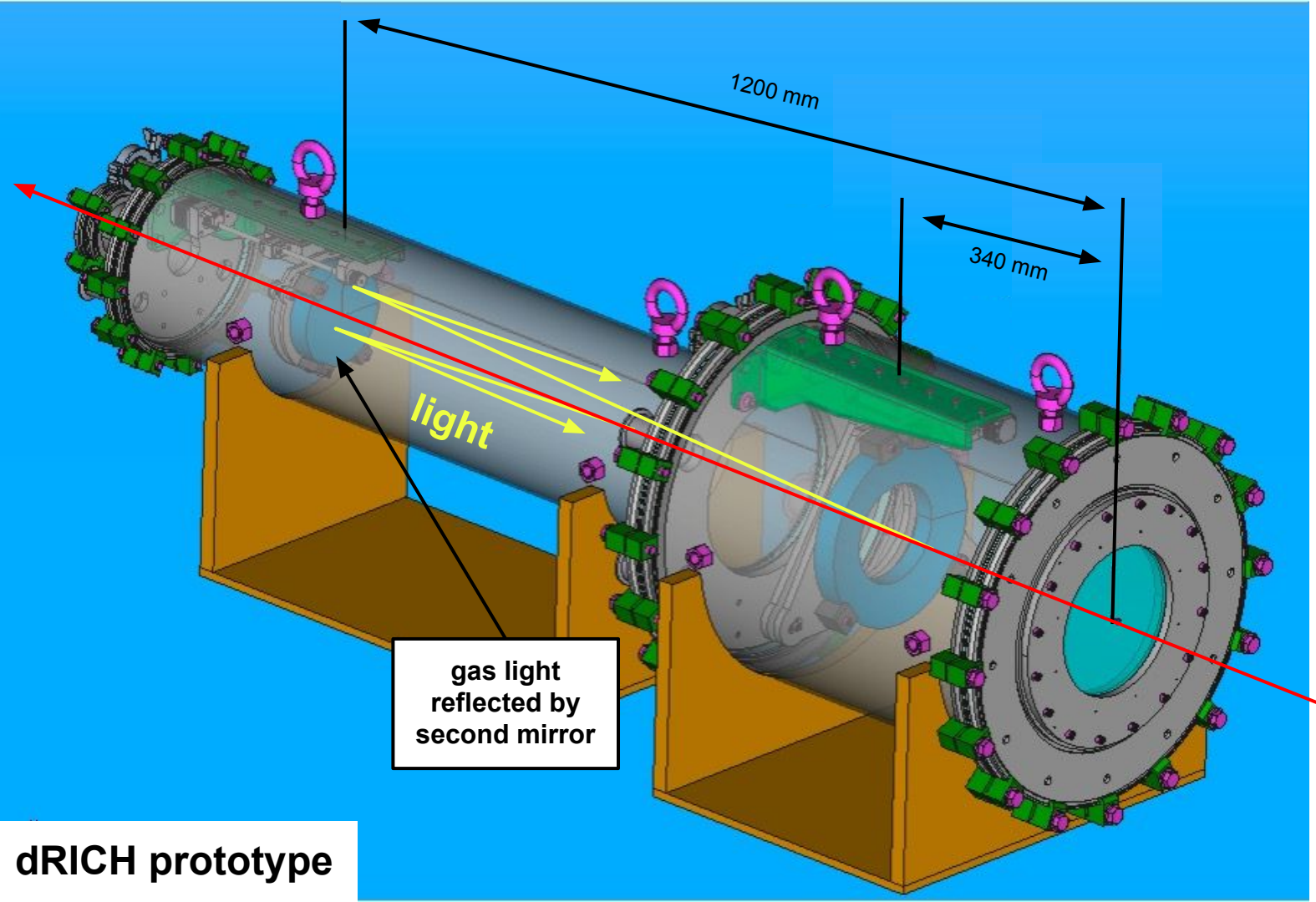
dRICH prototype at beam test



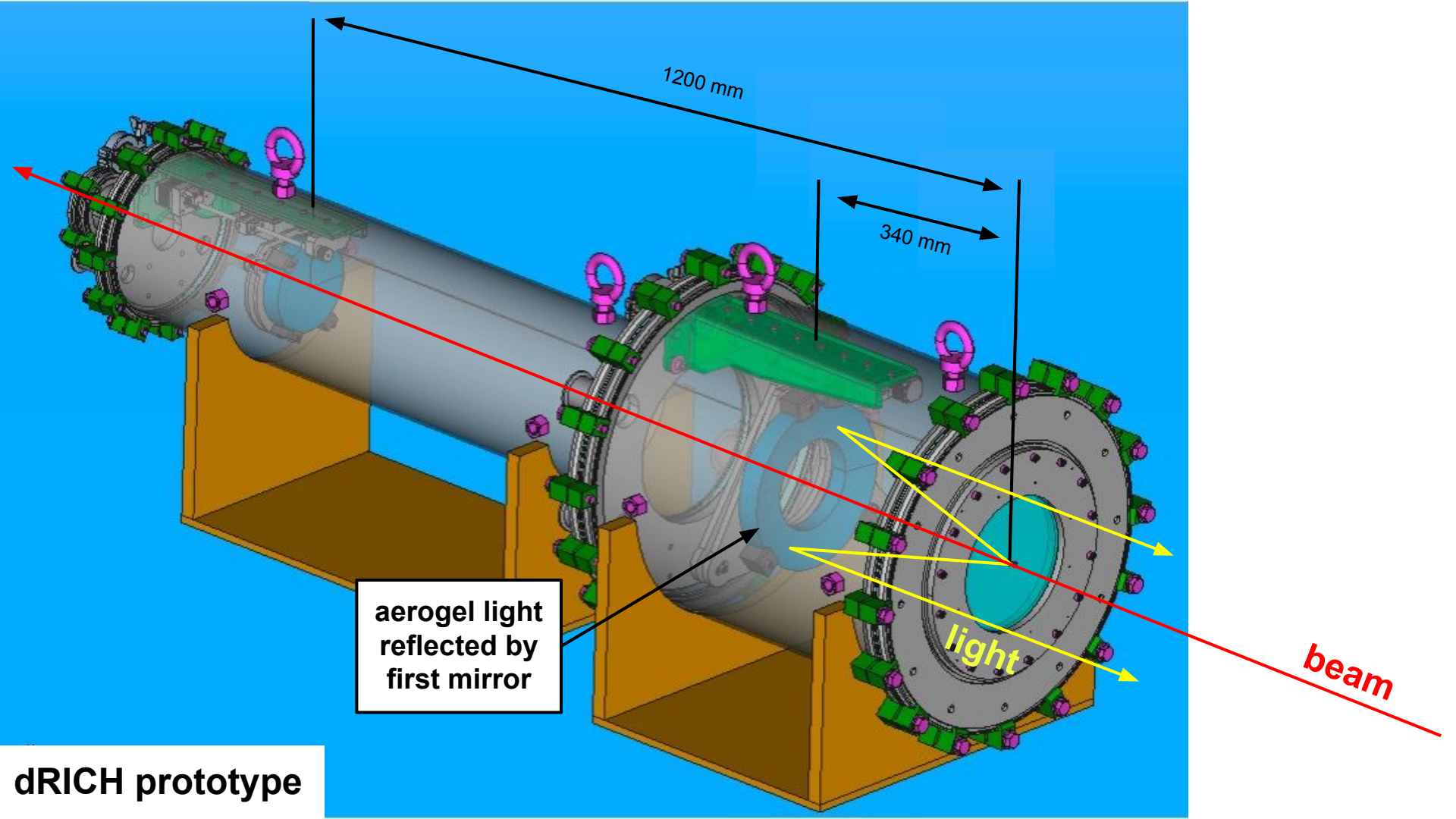
dRICH prototype



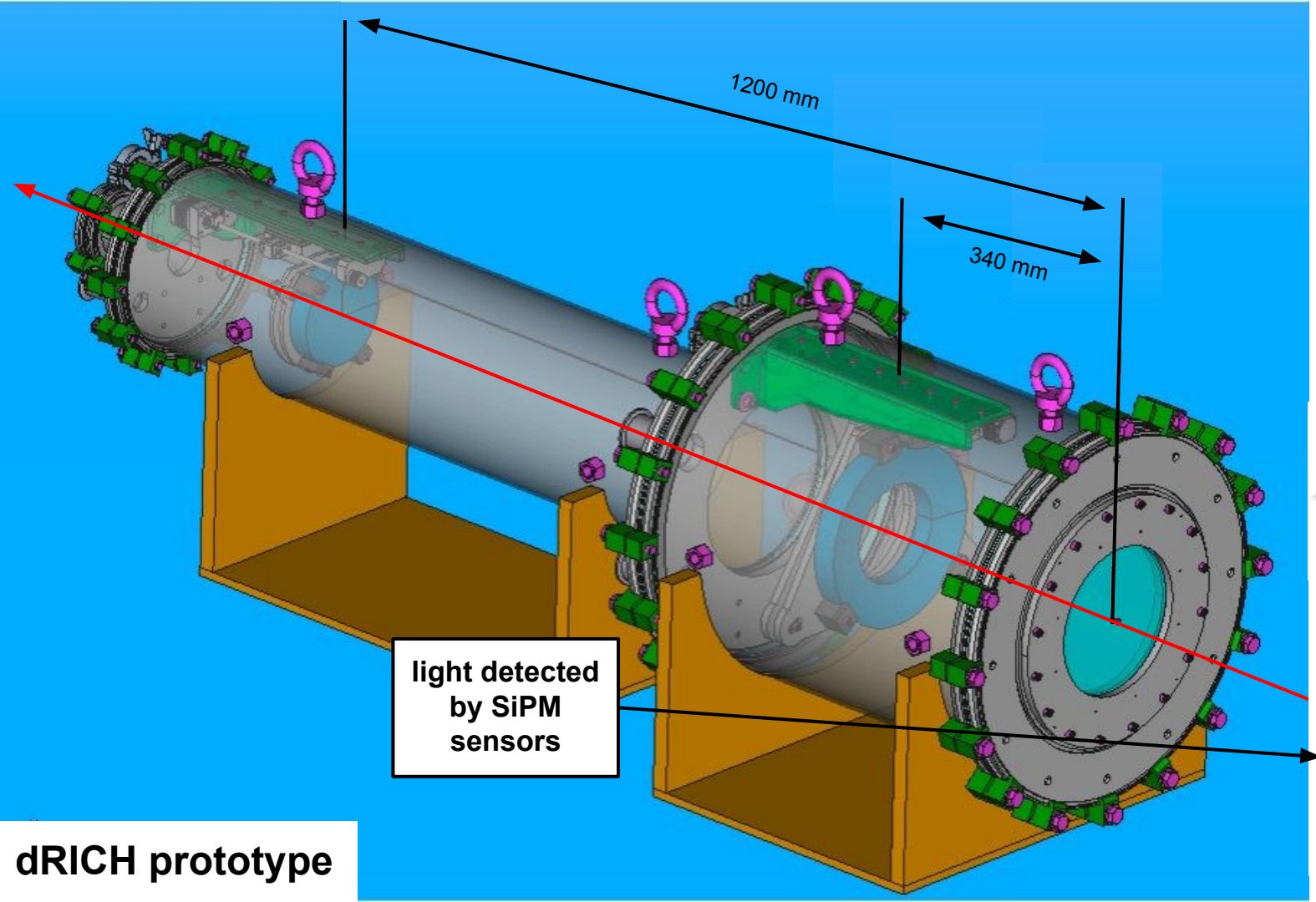
dRICH prototype

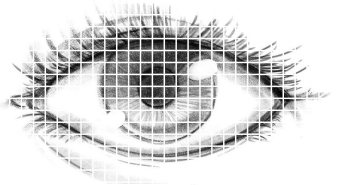


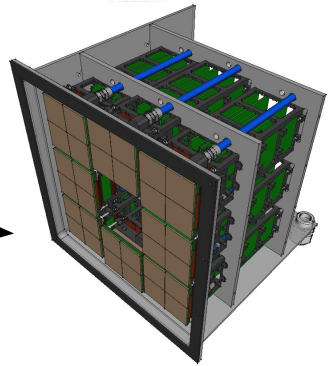
dRICH prototype



dRICH prototype







dRICH prototype

dRICH prototype on the T10 beam line at CERN-SPS

DAQ and DCS computers

auxiliary control electronics crates

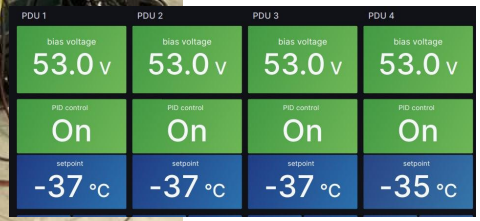
gigabit ETH switch for DAQ and DCS

low voltage and high voltage power supplies

dRICH prototype

SiPM photodetector readout box

DAQ FPGAs and clock distribution



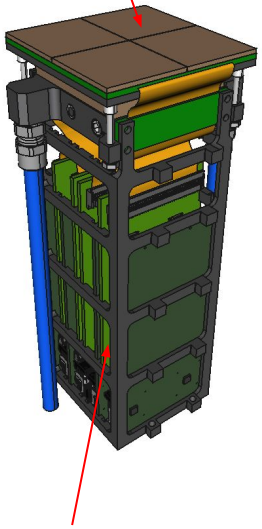
SiPM at low temperature

2023 test beam at CERN-PS

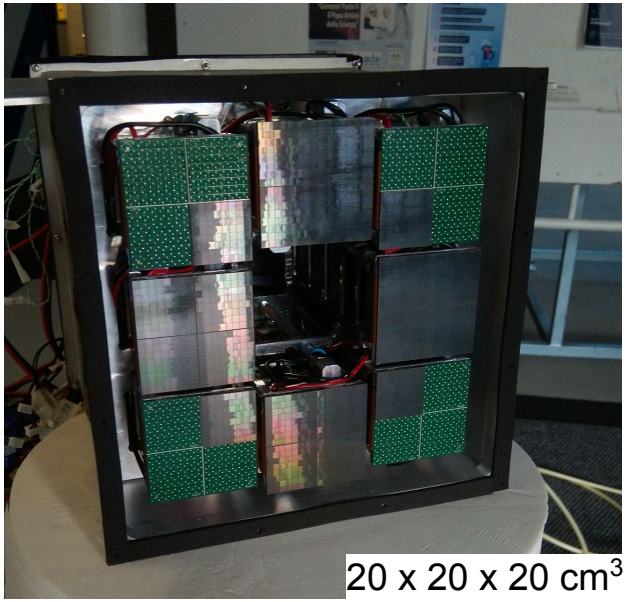
successful beam test with prototype SiPM photodetector units (CERN-PS, ended on 18th October)

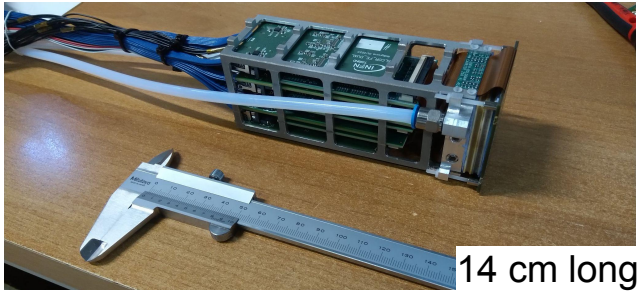
PDU

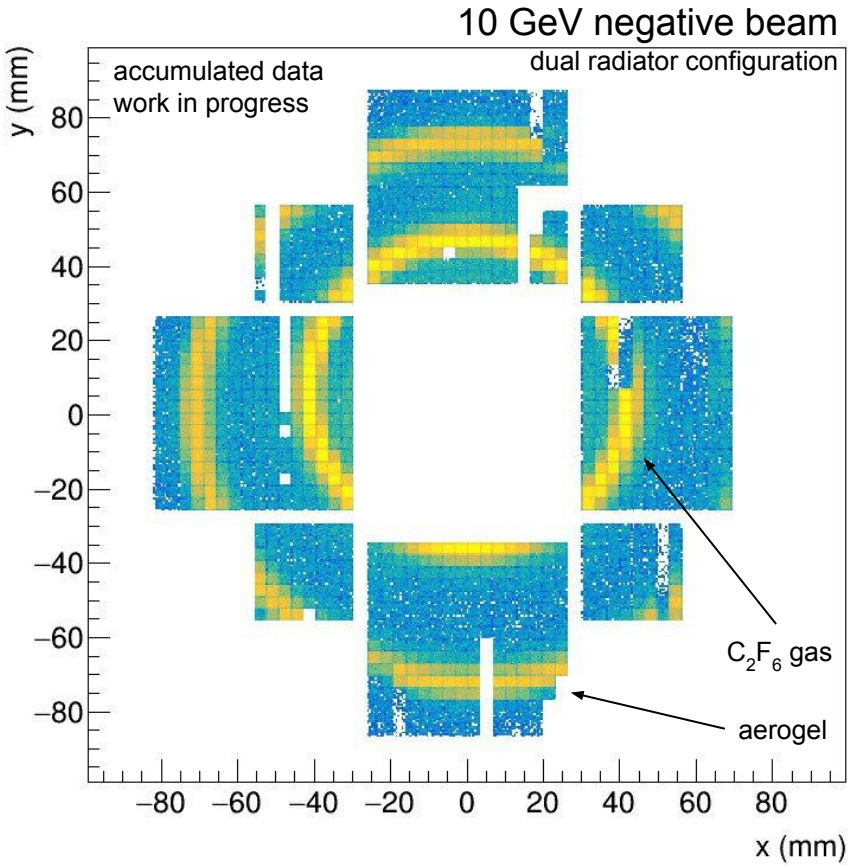
4x SiPM matrix arrays
(256 channels)



front-end electronics
(ALCOR ASIC inside)





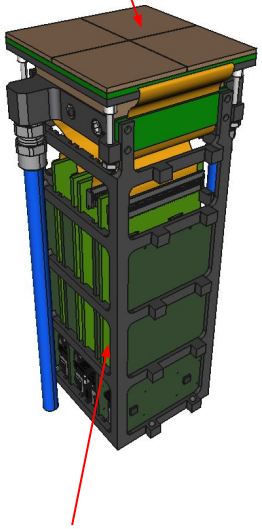


2023 test beam at CERN-PS

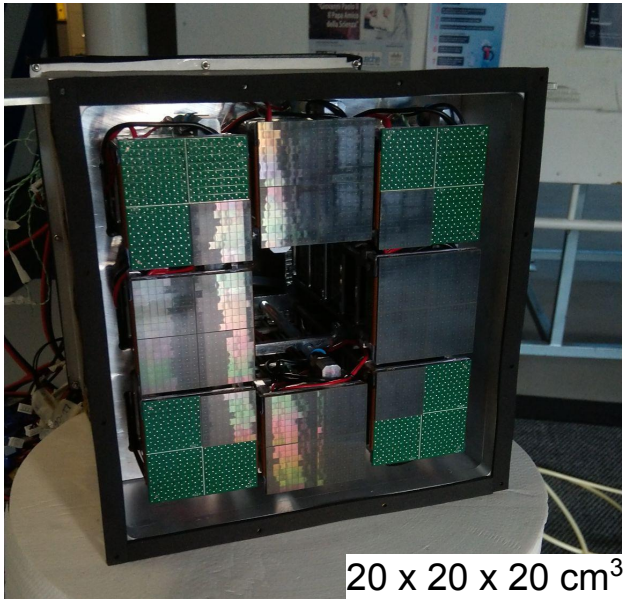
successful beam test with prototype SiPM photodetector units (CERN-PS, ended on 18th October)

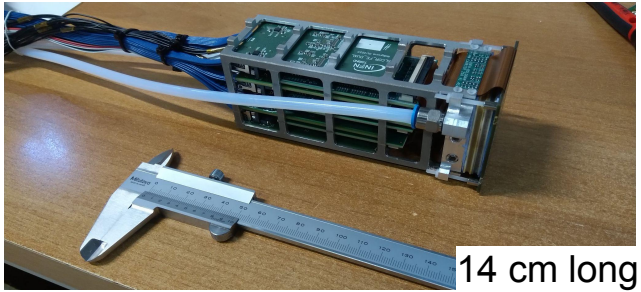
PDU

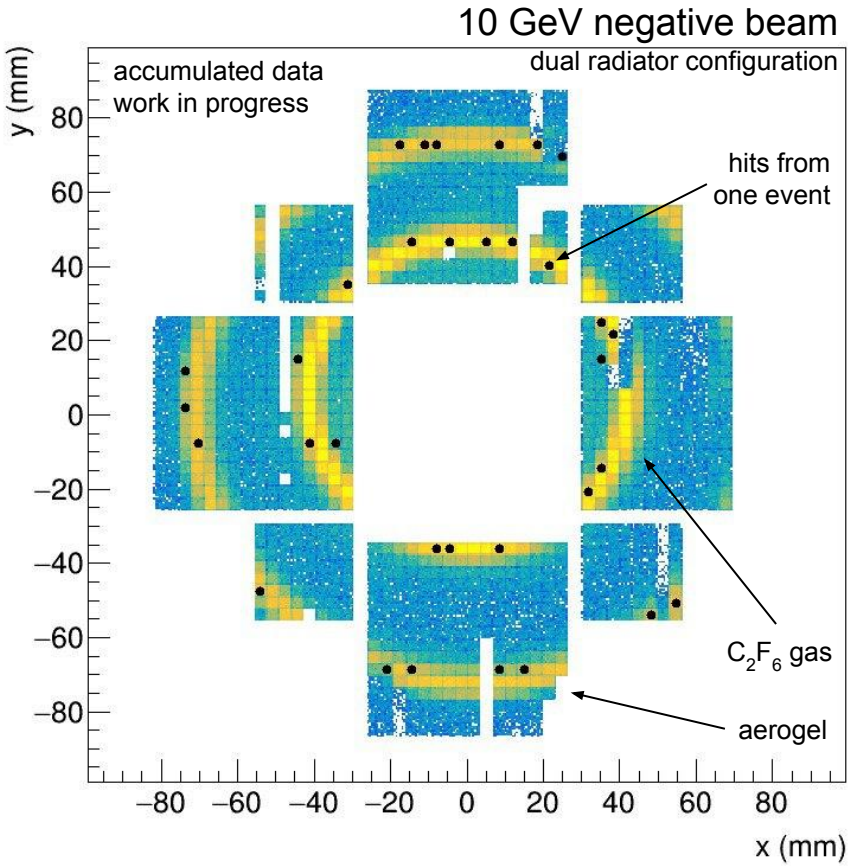
4x SiPM matrix arrays
(256 channels)



front-end electronics
(ALCOR ASIC inside)

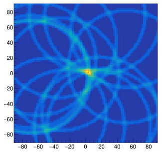






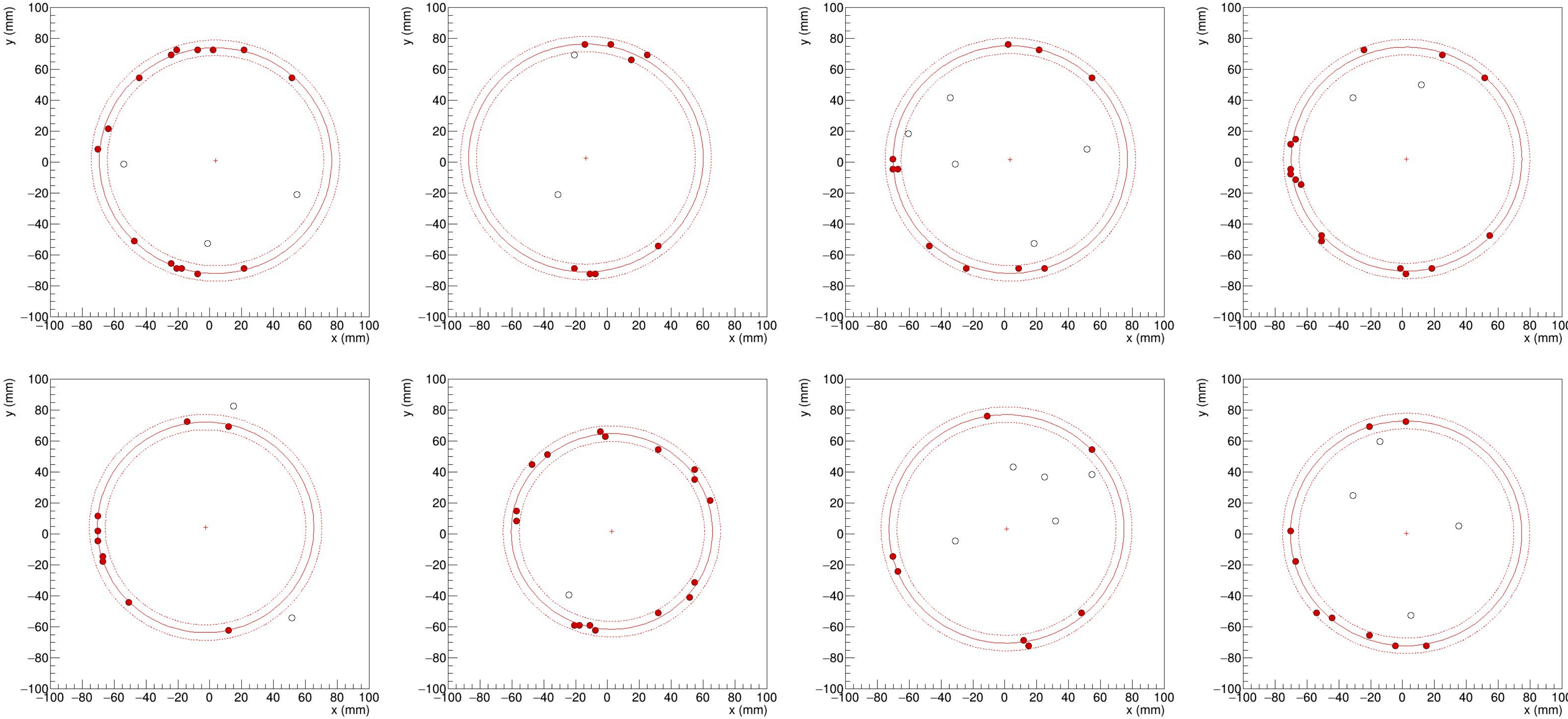
2023 test beam data analysis ongoing

event-by-event ring reconstruction: Hough Transform Method



10 GeV negative beam

only aerogel radiator

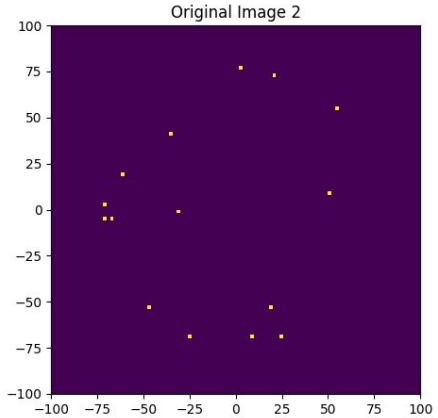


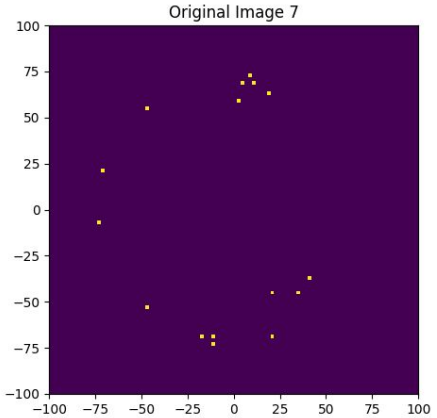
2023 test beam data analysis ongoing

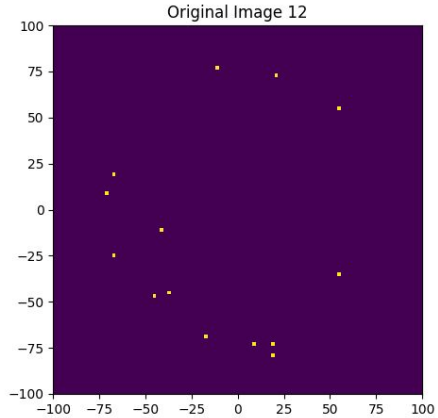
event-by-event ring reconstruction: Machine Learning

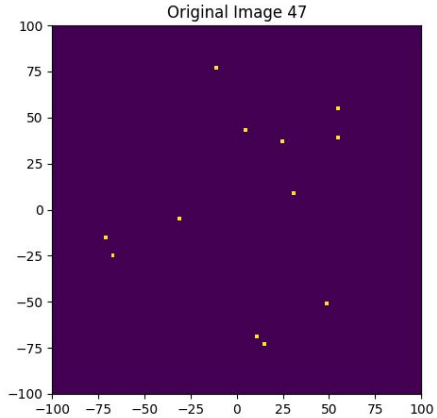
10 GeV negative beam
only aerogel radiator

input image

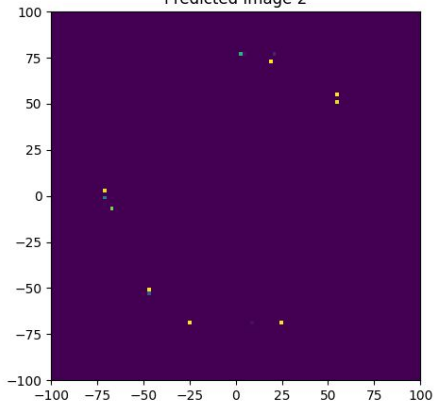


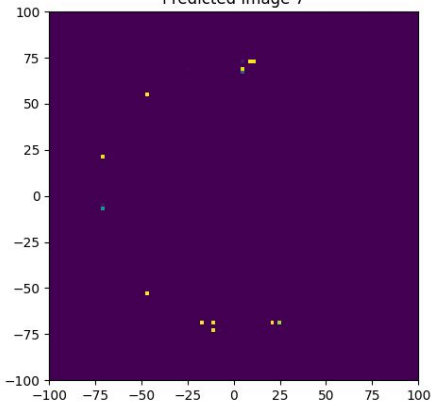


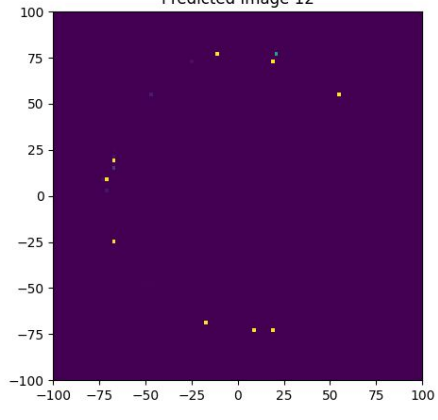


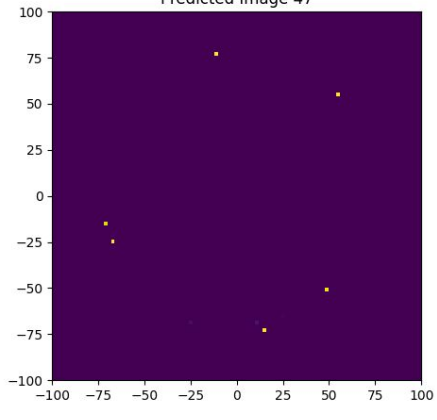


ML prediction









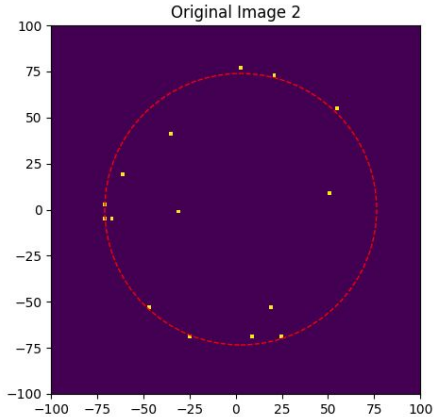
2023 test beam data analysis ongoing

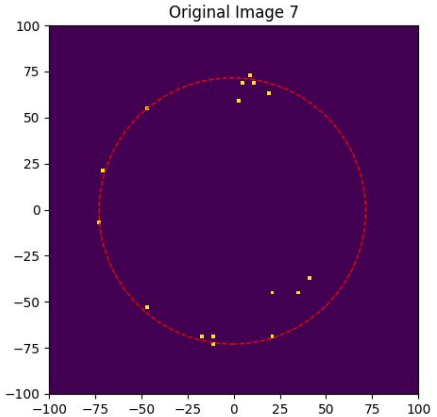
event-by-event ring reconstruction: Machine Learning

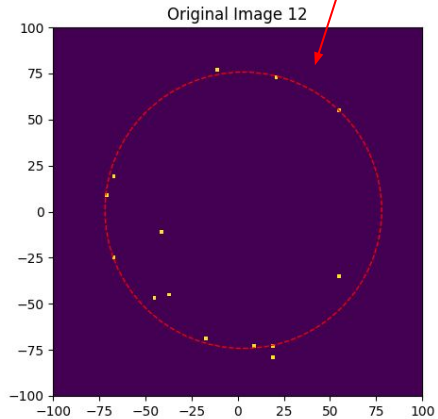
circle fit on ML prediction

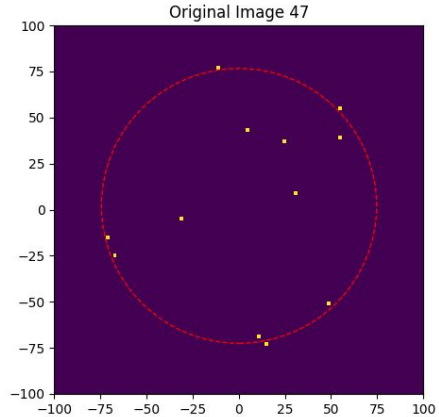
10 GeV negative beam
only aerogel radiator

input image

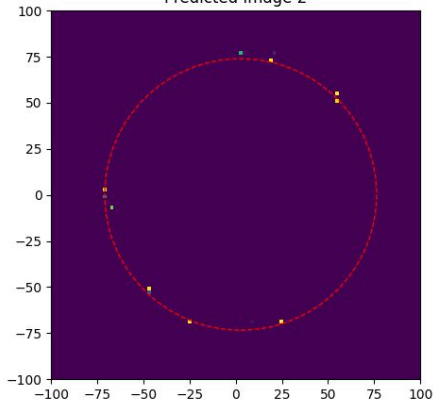


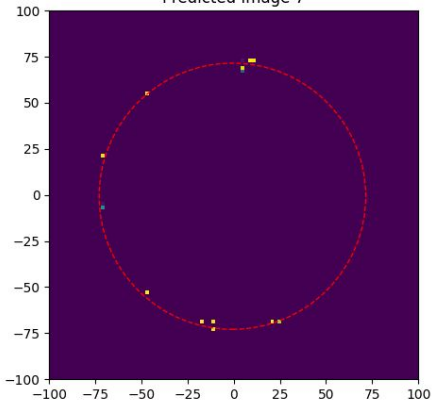


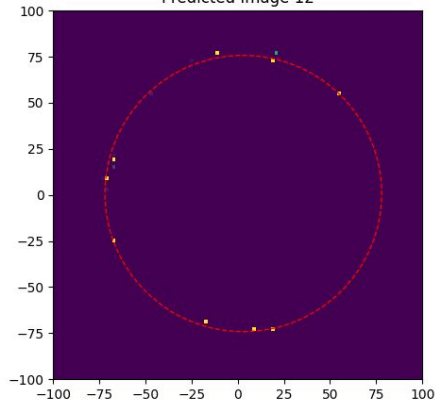


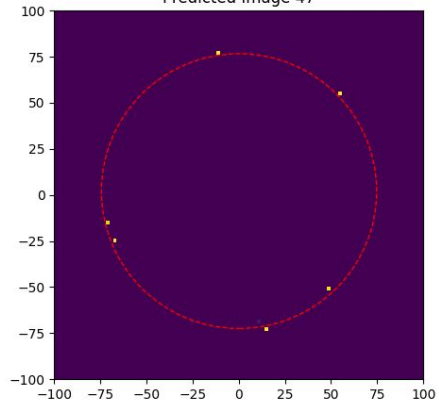


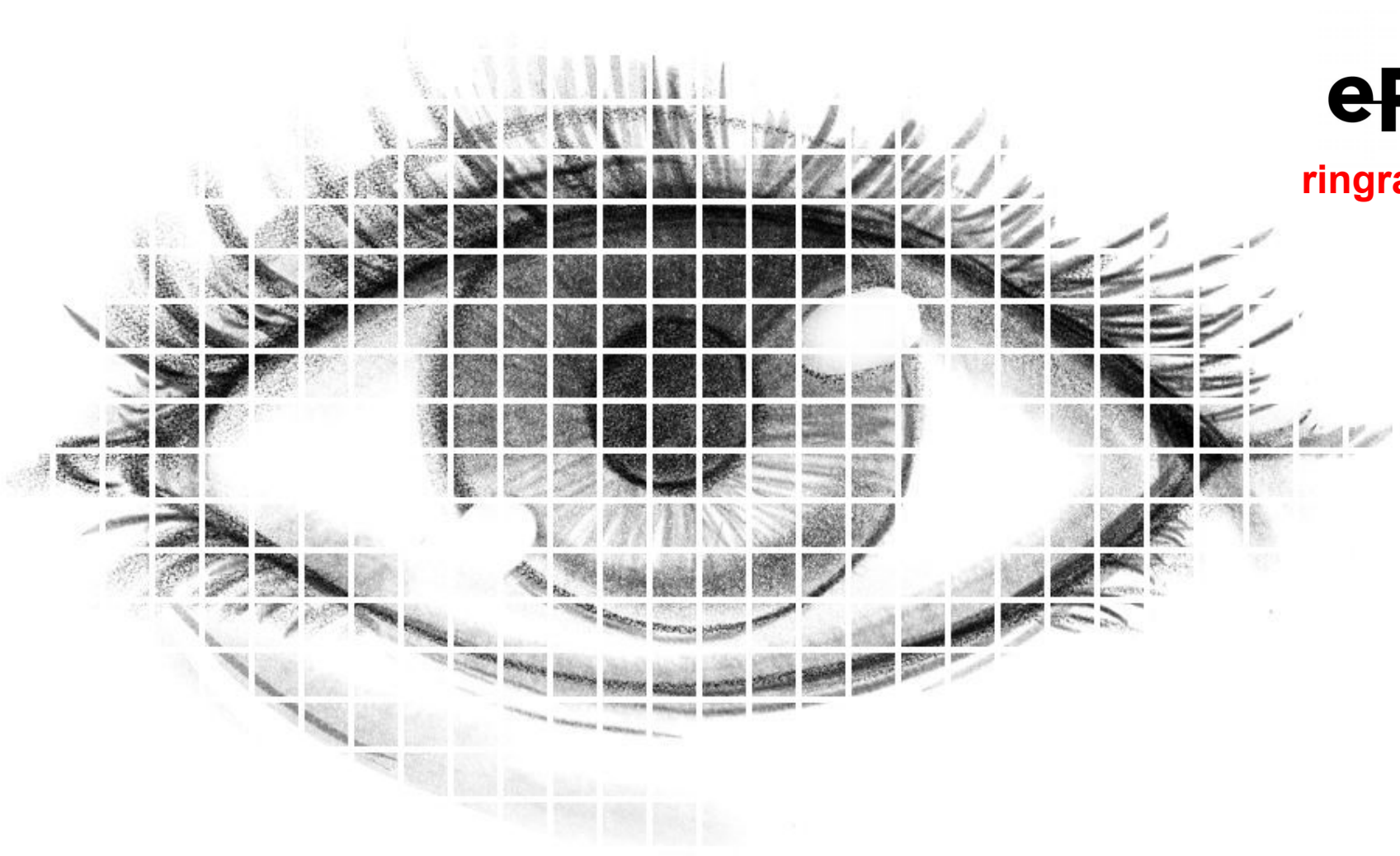
ML prediction





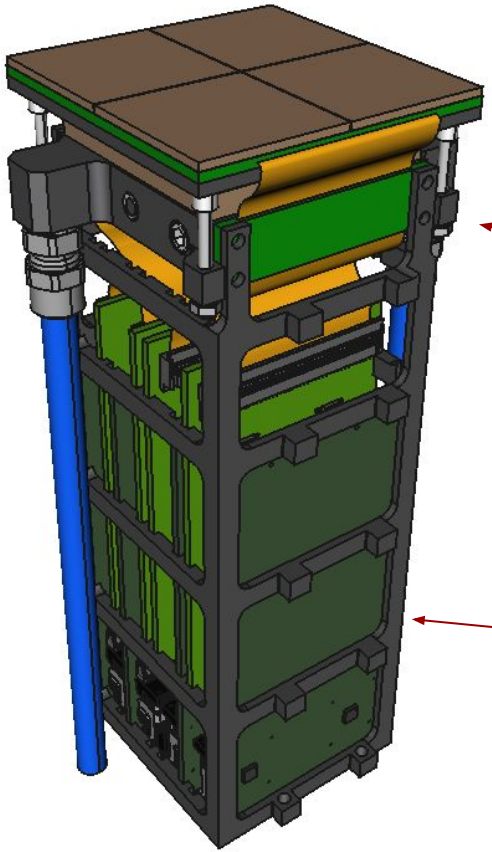






ringraziamenti

Contributi fondamentali alla realizzazione del prototipo



PhotoDetector Unit (PDU)

circuito stampato SiPM con flex PCB

Casimiro Baldanza
laboratorio elettronica

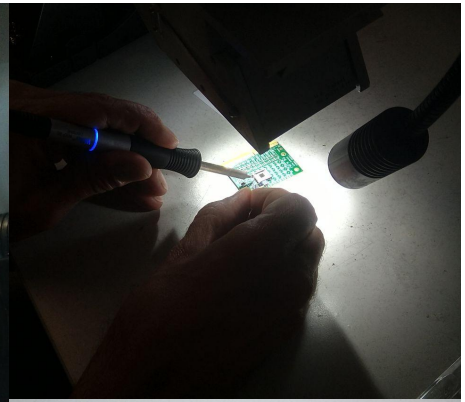
piastre per sistema di raffreddamento
assemblaggio moduli Peltier

Tommaso Fadanni
Giulio Pancaldi
officina meccanica
Daniele Cavazza
tecnologie avanzate

realizzazione meccanica mini-crates
disegno tecnico mini-crate

Michele Furini
officina meccanica
Roberto Michinelli
progettazione meccanica

Tanti contributi fondamentali al successo del progetto

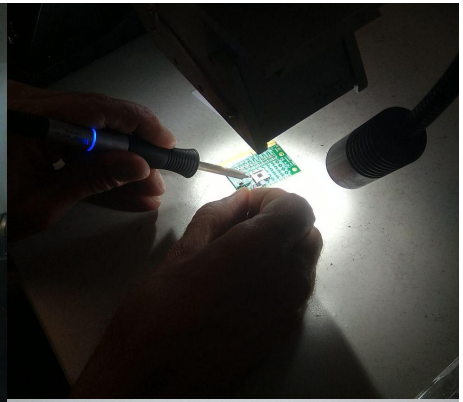


S13360-3050UVE

molte le persone in Sezione grazie alla quali
questo progetto esiste e prosegue

Amministrazione e Direzione
Responsabili Servizi
RUP
Ricercatori e Tecnologi del gruppo EIC

Te uti fondamentali al successo del progetto



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molte le persone in Sezione grazie alla quali questo progetto esiste e prosegue

Amministrazione e Direzione
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RUP
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buone feste a tutti