SiPM news

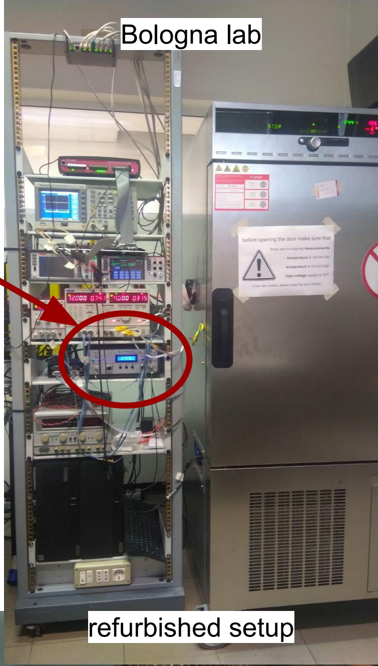
Roberto Preghenella

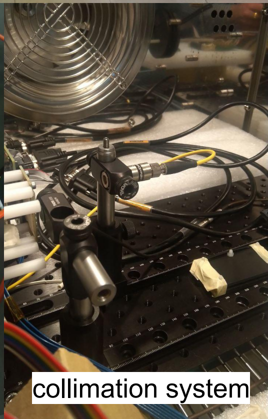
News

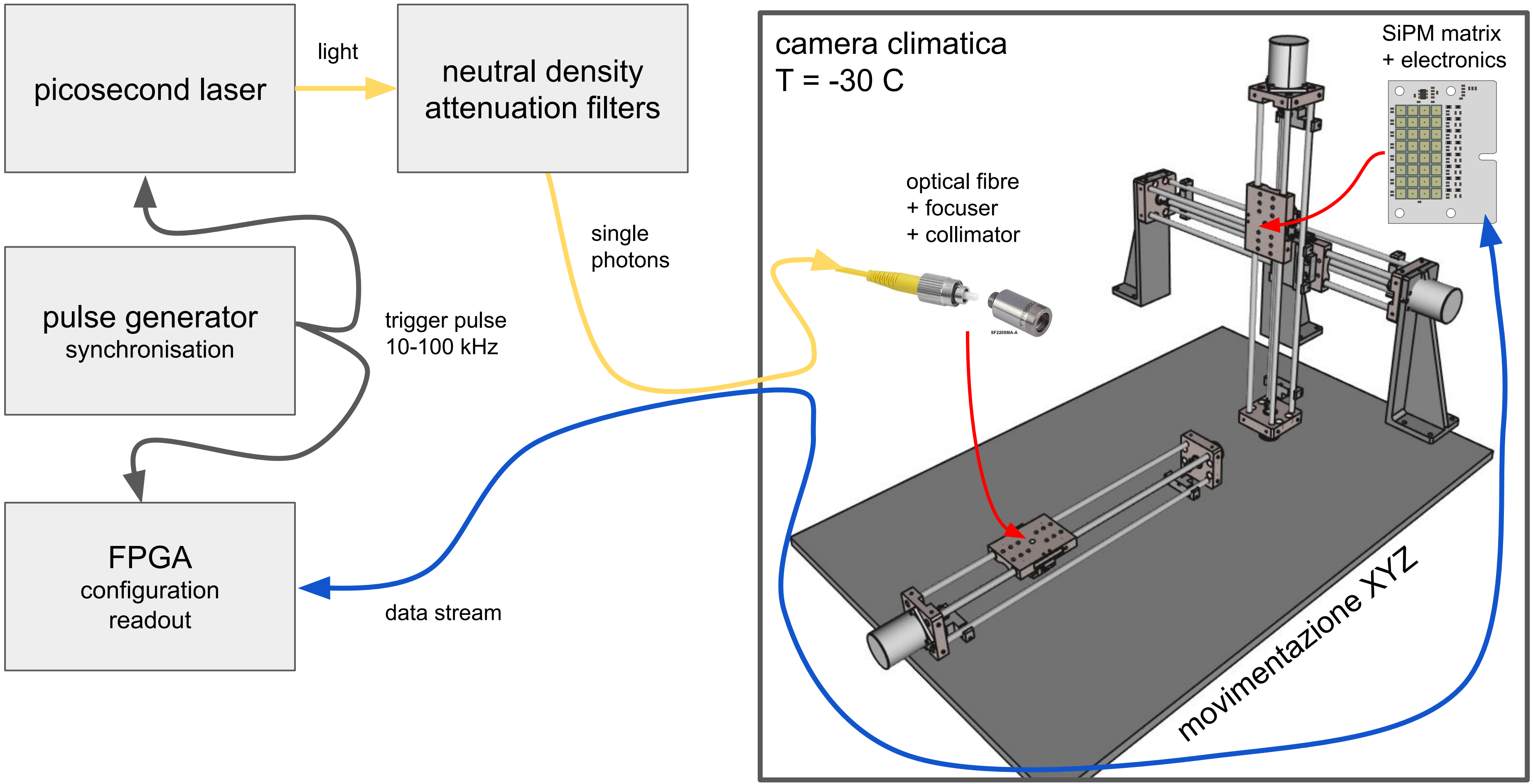
- we recently received the laser
- will receive soon XYZ linear stage for -30 C operations
- received today new SiPM carrier boards
- irradiation program with protons
- irradiation program with neutrons
- automatic annealing thermal camera
- air-cooled portable Peltier box
- new characterisation setup in Cosenza started
- plans to start next characterisation setup in Salerno

We recently received the new laser

- **goal is to measure time resolution of the complete chain**
  - before and after SiPM irradiation and annealing
- **will be able to measure relative variation of PDE**
  - plans also to measure relative variation of PDE vs. incident photon angle
  - we have a calibrated diode to try absolute PDE determination on single photon
    - not trivial need to measure absorption of absorbers
- **characteristics of the laser**
  - picosecond pulsed laser
  - 401.4 nm
  - 25 ps FWHM pulse width
  - < 4 ps synchronisation jitter
  - up to 20 MHz repetition rate
  - > 2 W peak power
- **system is being commissioned with climatic chamber**
  - optical components
    - absorption (<< 1 photon/pulse)
    - transport
    - collimation of light
  - synchronisation with ALCOR readout system
  - precision measurement of reference time

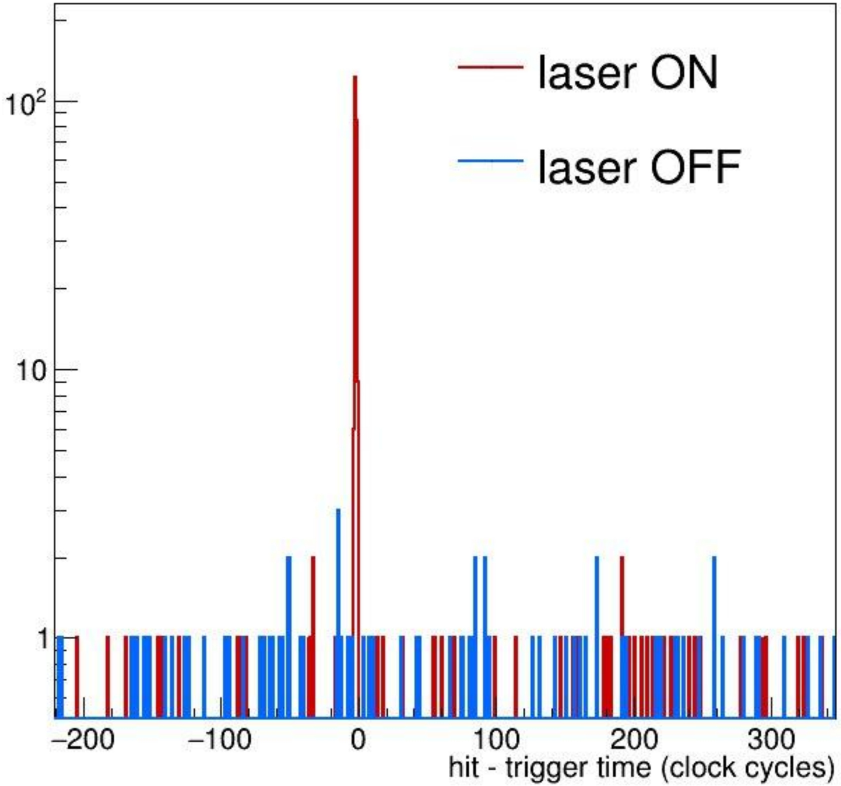


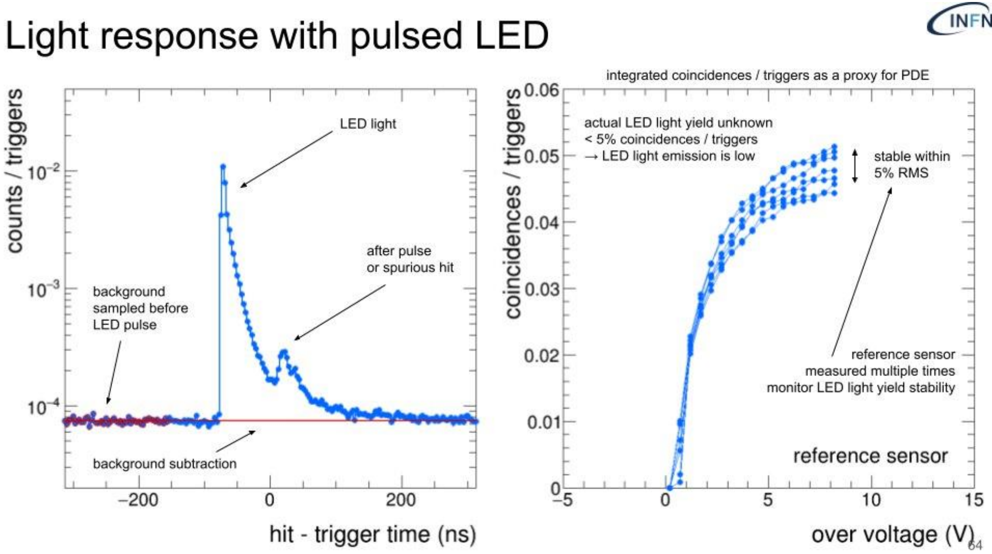



picosecond laser
light
neutral density attenuation filters
pulse generator
synchronisation
trigger pulse
10-100 kHz
single photons
FPGA
configuration
readout
data stream
camera climatica
T = -30 C
optical fibre
+ focuser
+ collimator
SiPM matrix
+ electronics
movimentazione XYZ

We recently received the new laser

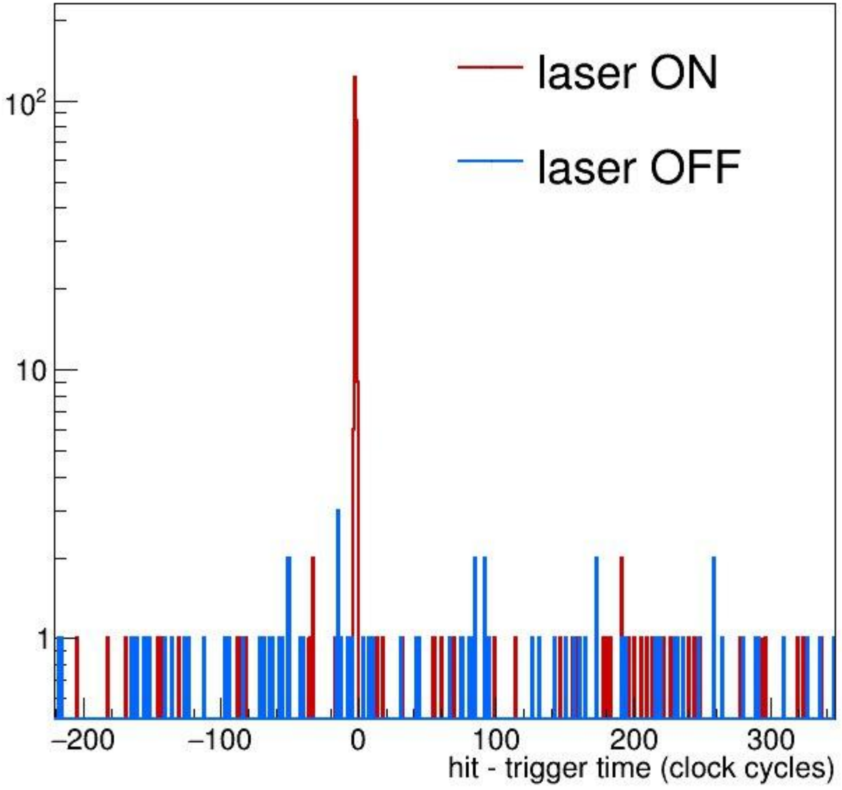
much nicer pulse response wrt. old LED-based system, need to work on sychronisation to fully exploit the laser

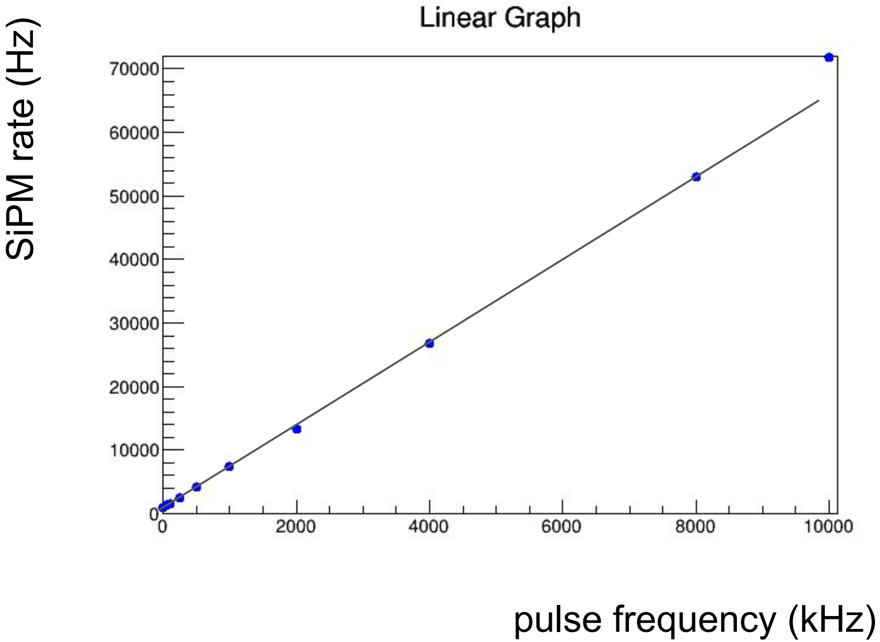




We recently received the new laser

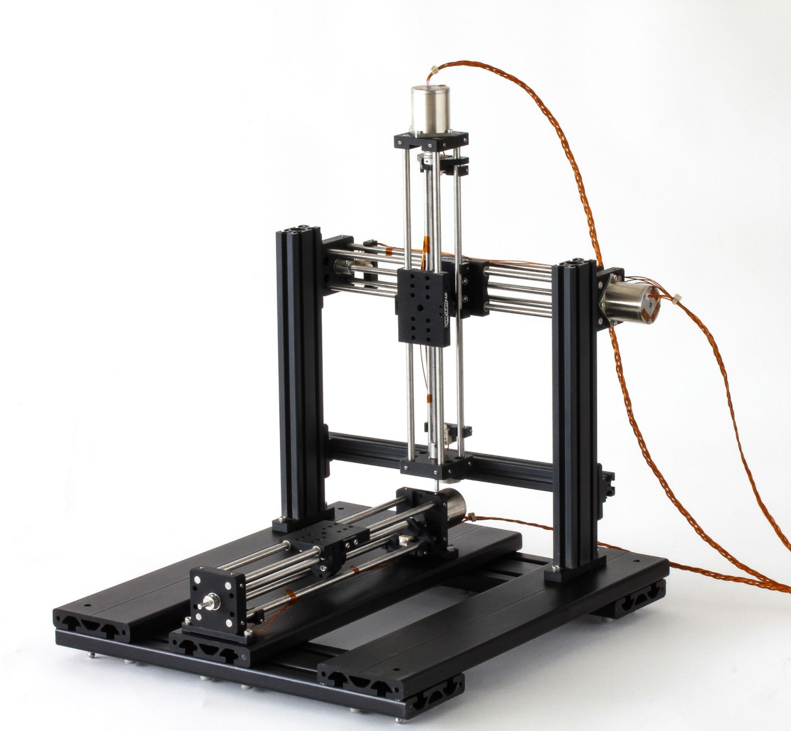
light yield at the SiPM is low (we can decrease more) → 70 kHz signal / 10 MHz laser → < 1% light signal per pulse





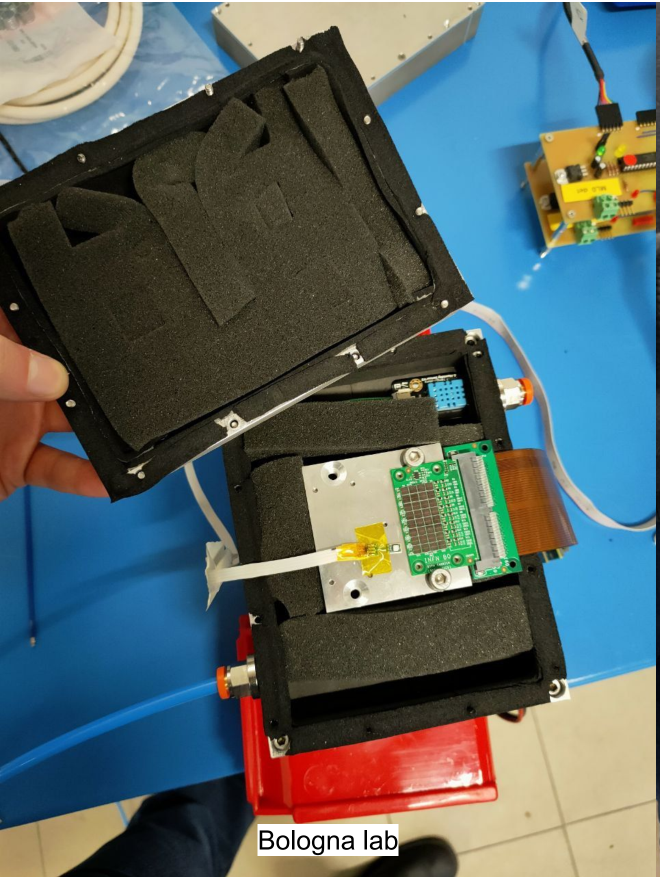
XYZ linear translation stage to arrive tomorrow

- **brand new linear translation stage**
  - 200 mm stroke on all axes
  - to be installed inside the climatic chamber
  - translate SiPM prototype matrices wrt. laser
    - or viceversa if more conveniente
- **compatible with low-temperature operation**
  - vacuum technology
  - designed to operate down to -40 C
- **automatic scan multiple SiPM performance**
  - time resolution of multiple SiPM
  - as a function of the position on the SiPM
    - can use focused light
  - relative single-photon PDE

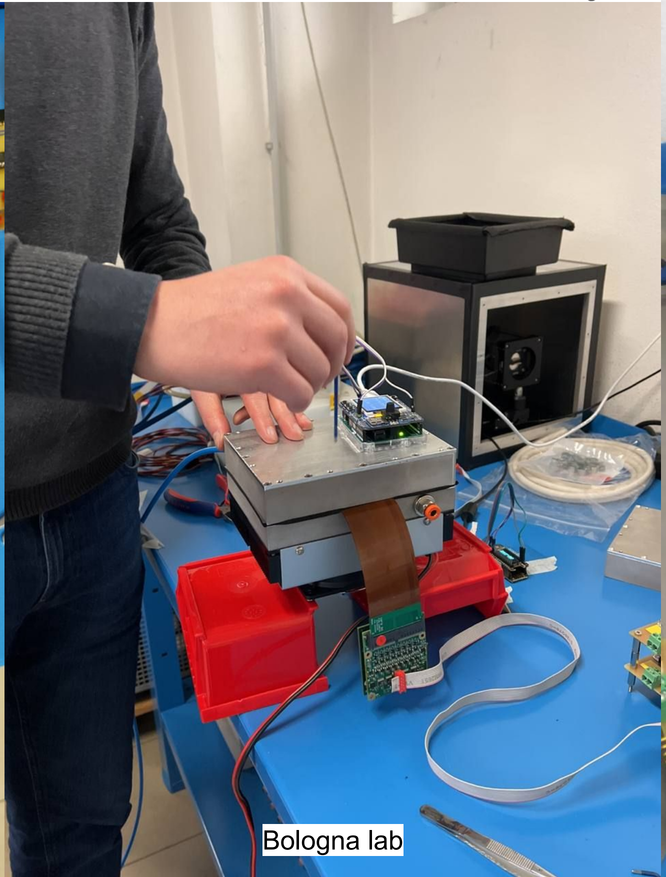


Air-cooled portable Peltier box

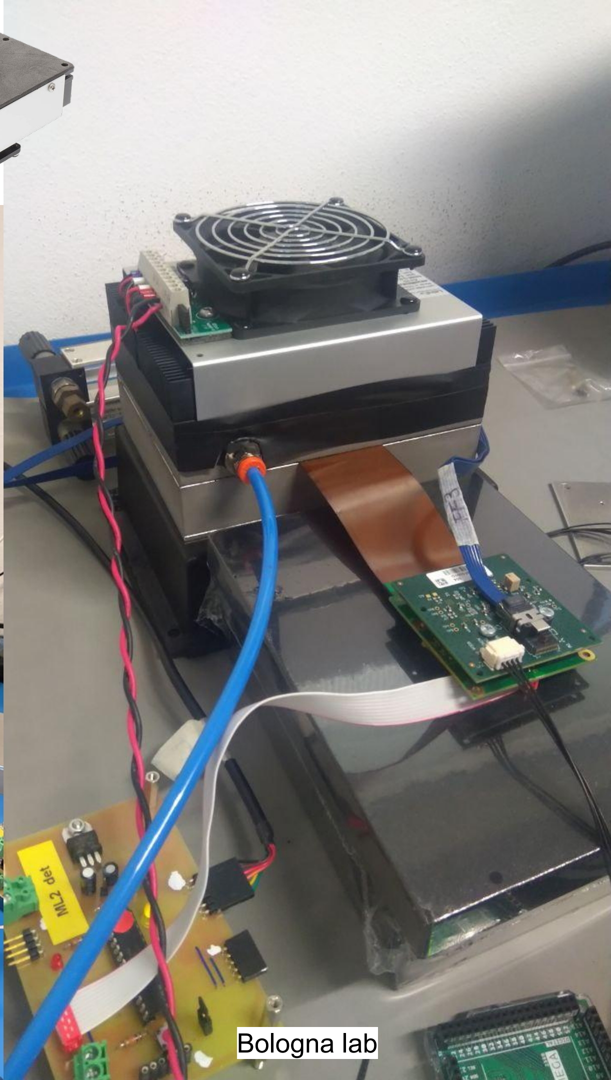
designed and realised by us based on Laird cooler assembly



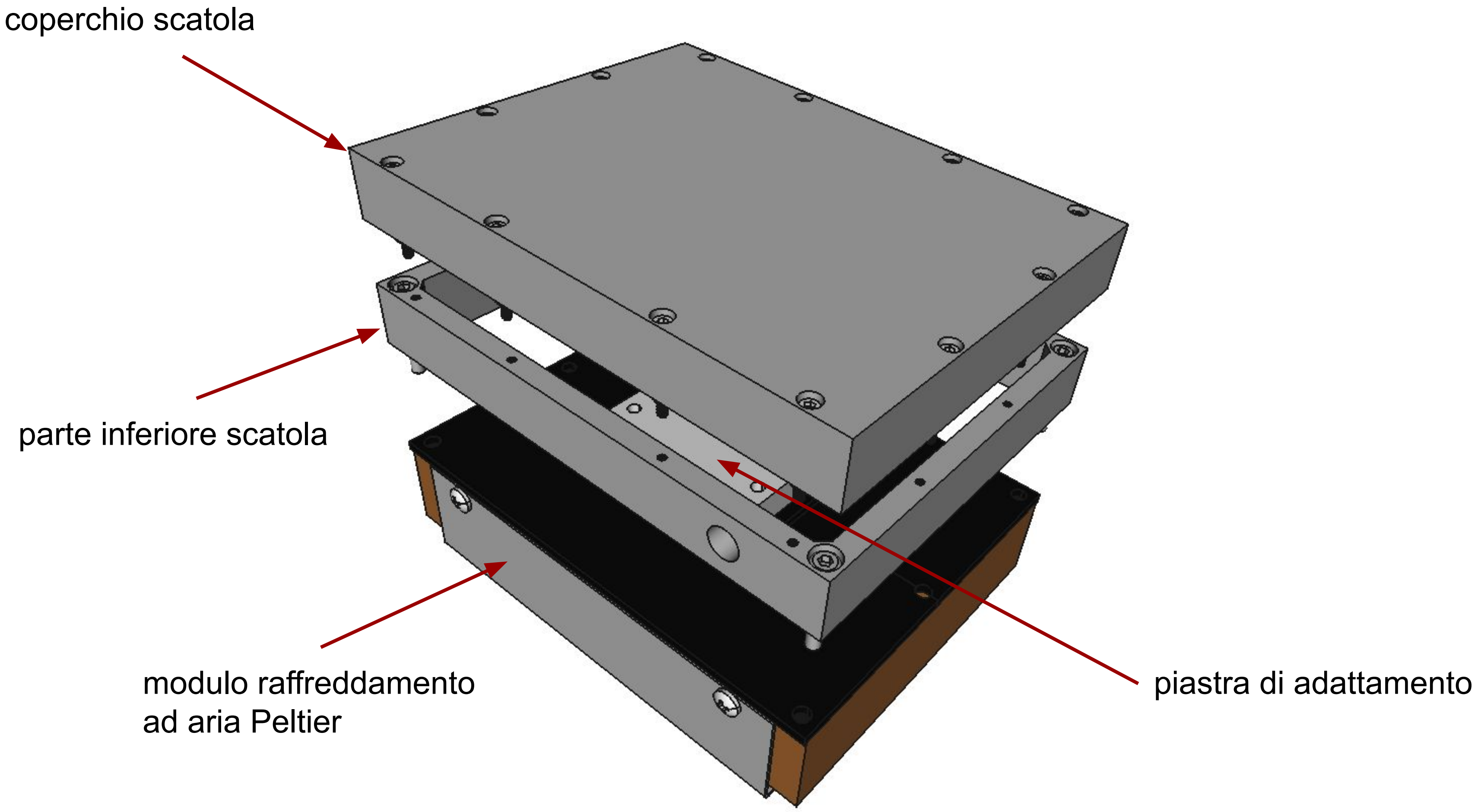
Bologna lab



Bologna lab

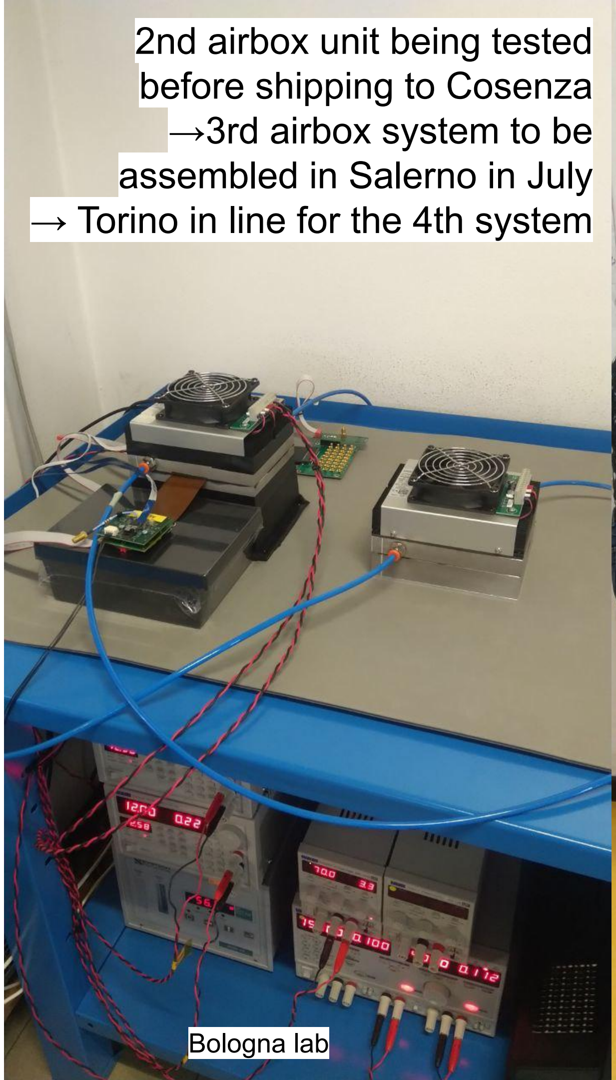


Bologna lab


coperchio scatola
parte inferiore scatola
modulo raffreddamento
ad aria Peltier
piastra di adattamento

airbox in Cosenza

- **airbox installed in Cosenza**
  - after tests in Bologna
  - shipped to Cosenza
  - system installed on 13-14 April
  - good teamwork
    - Bologna
    - Cosenza
    - Salerno
- **Cosenza ready to contribute**
  - to SiPM characterisation
  - in charge of proton-energy scan
- **3rd airbox to Salerno**
  - system will be installed in July
  - increase SiPM test capacity
- **Torino in line for 4th system**
  - for tests of ALCOR chip with SiPM at low T



Bologna lab

Cosenza lab

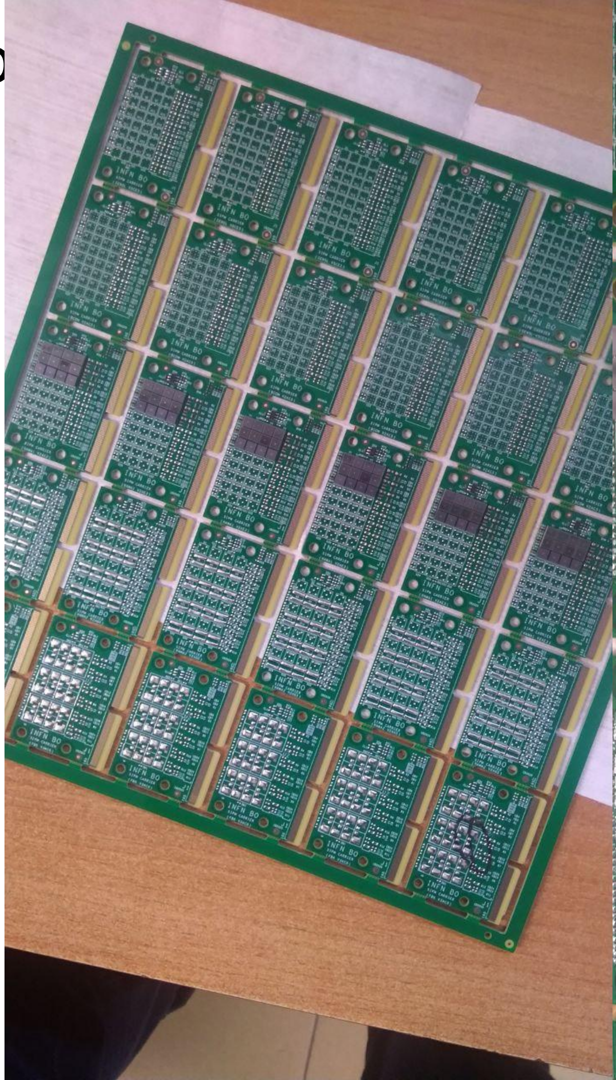
SiPM irradiation plans 2023

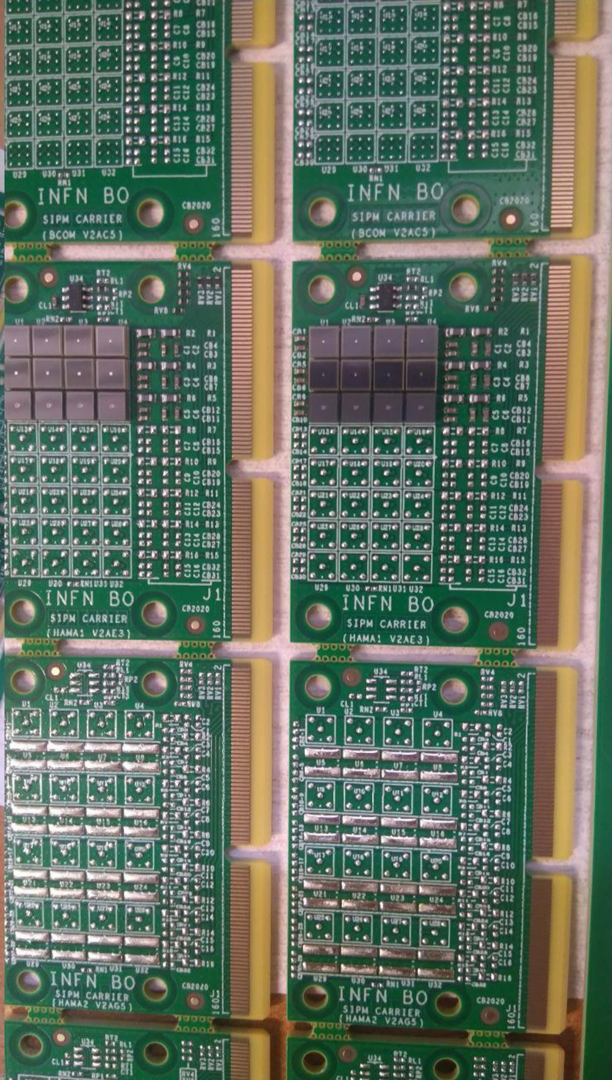
SiPM custom boards for ongoing R&D

35 new boards have been produced arrived today

- **new SiPM carriers**
  - keep same boards designed in 2020
  - populate 3 rows
    - 4 sensors / row
  - sensors from Hamamatsu
    - 4x S13360-3050
    - 4x S14160-3050
    - 4x S13360-3075
- **perform different type of irradiation/annealing studies**
  - one carrier board for each study
- **keep a minimal statistical sample for each study**
  - 4 sensors / type

SiPM custom boards fo





Boards to irradiate at TIFPA in June 2023

- **proton energy scan [5 boards]**
  - proton energy: 145, 75, 45, 25, 18 MeV
    - will scan 5 values of the hardness factor K
    - K = 1.1, 1.5, 2.0, 2.5, 3.0
  - fluence to be defined
    - fixed proton fluence → damage scales with K
- **online annealing [2 boards]**
  - 145 MeV standard energy
  - split 10^9 n_{eq} fluence in 10x repeated irradiation-annealing cycles
    - 10^8 shots
    - 30-minutes long online annealing
  - forward and reverse current bias
- **offline annealing [7 boards]**
  - 145 MeV standard energy
  - 10^9 neutron equivalent fluence
  - study annealing in the laboratory
    - standard oven (150 h - 150 C)
    - forward current
    - reverse current
    - infrared lamp annealing
    - else
  - study impact of preventive-annealing
    - standard oven (150 h - 150 C)
    - multiple standard cycles (4x cycles)

will do 10^9 fluence in June
10^{10} fluence later this year
delivered on the same boards

slot on 9-10 July

TIFPA characterisation running programme

Day	May Holy	May BO	May CS	Jun Holy	Jun BO	Jun CS	Jul Holy	Jul BO	Jul CS	Aug Holy	Aug BO	Aug CS
1	Holy				ANN		Sat					
2				Holy	ANN		Sun				Legnaro	
3				Sat	ANN						Legnaro	
4				Sun	ANN						Legnaro	
5					ANN					Sat		
6	Sat				ANN					Sun		
7	Sun				ANN							MEAS
8		MEAS					Sat					MEAS
9		MEAS			TIFPA		Sun					MEAS
10		MEAS		Sat	TIFPA			Salerno				MEAS
11		ANN		Sun				Salerno				MEAS
12		ANN						ANN		Sat		
13	Sat	ANN						ANN		Sun		
14	Sun	ANN						ANN				
15		ANN	MEAS				Sat	ANN		Holy		
16		ANN	MEAS				Sun	ANN				
17		ANN	MEAS	Sat				ANN				
18		ANN	MEAS	Sun				ANN				
19		ANN	MEAS		MEAS			MEAS		Sat		
20	Sat	ANN			MEAS			MEAS		Sun		
21	Sun	ANN			MEAS			MEAS				
22		ANN			EIC_NET		Sat					
23		ANN			EIC_NET		Sun	Varsavia				
24		ANN		Sat				Varsavia				
25		ANN		Sun				Varsavia				
26		ANN				MEAS		Varsavia		Sat		
27	Sat	ANN				MEAS		Varsavia		Sun		
28	Sun	ANN				MEAS		Varsavia				
29		ANN				MEAS	Sat	Varsavia				
30		ANN				MEAS	Sun					
31		ANN										

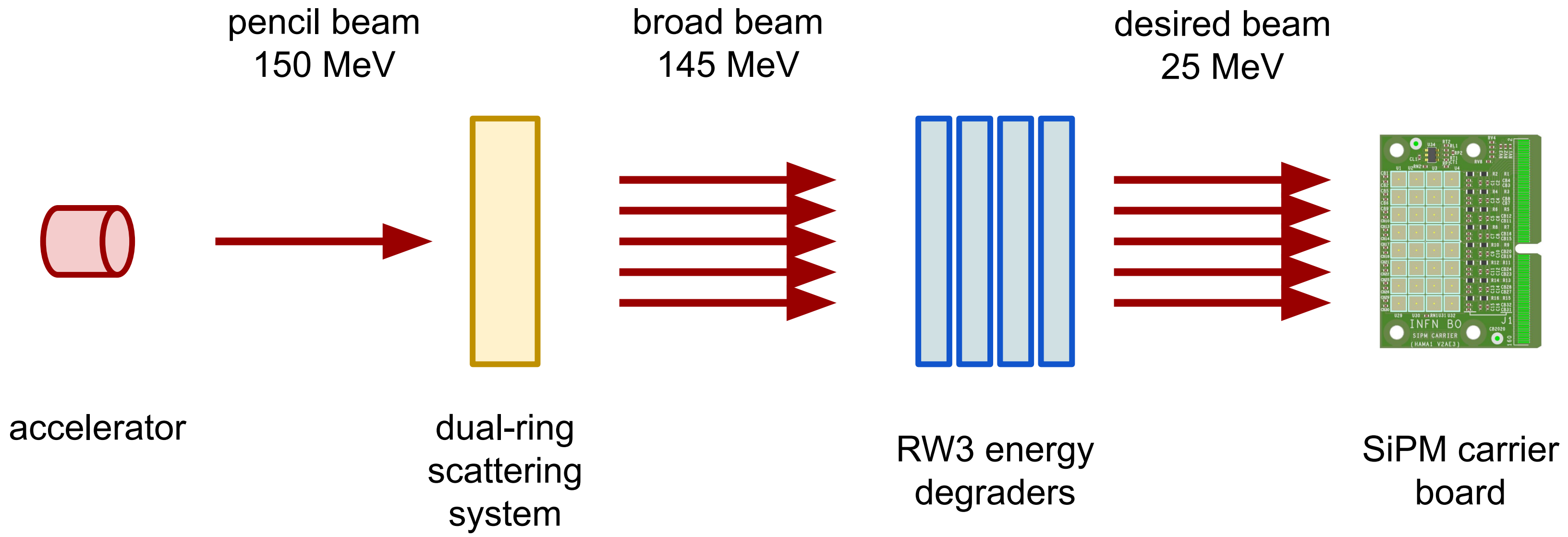
May:
- boards arrive in Bologna
- preliminary characterisation in Bologna
- 5 PES boards shipped to Cosenza
- characterisation in Cosenza
- pre-irradiation annealing in Bologna

Jun:
- irradiation at TIFPA
- boards recovered from TIFPA
- characterisation in Bologna
- PES boards exchange in Corigliano
- characterisation in Cosenza

Jul:
- PES boards exchange in Salerno
- post-irradiation annealing in Bolona
- characterisation in Bologna
- PES boards exchange in Varsavia

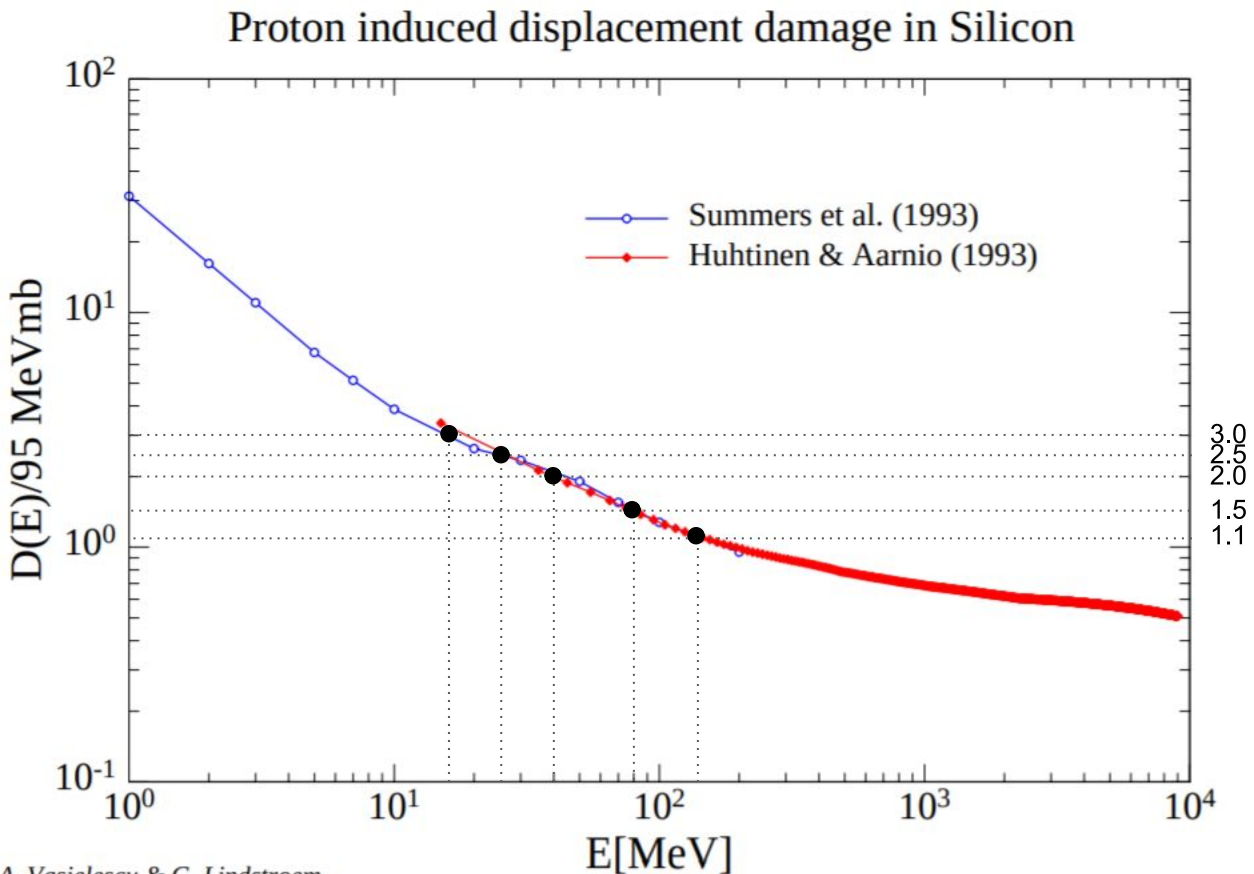
Aug:
- characterisation in Cosenza

Proton Energy Scan



change the number of energy degrader to achieve the desired beam
need to study material / thickness and pieces available at TIFPA

Proton Energy Scan

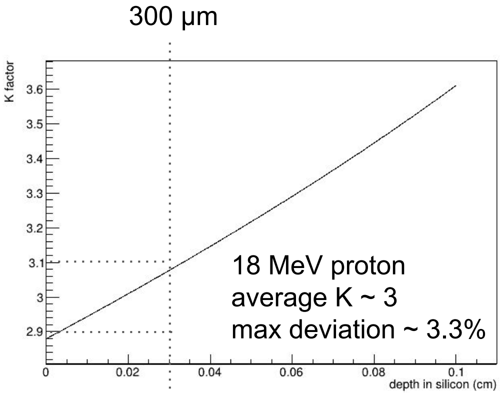


A. Vasielescu & G. Lindstroem

measure 5 points on the hardness factor (K) curve

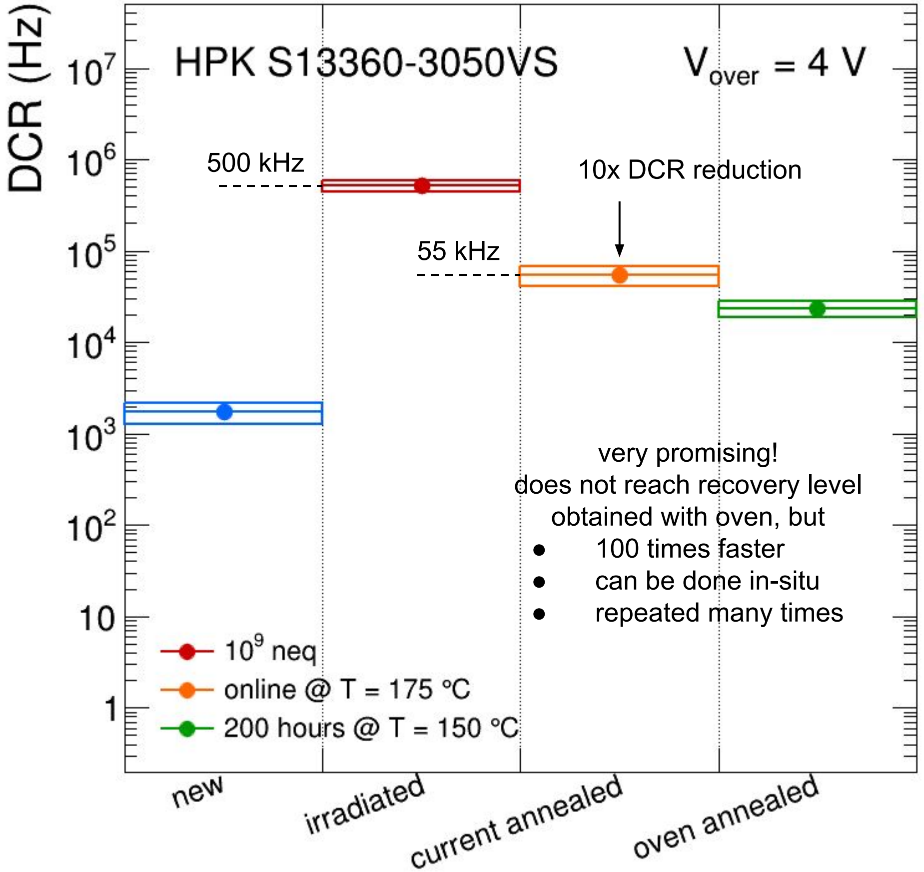
K < 1.1 cannot be achieved
max 150 MeV with broad beam

energy loss in silicon too large at low proton energy
→ will cause variation of K while crossing the sensor

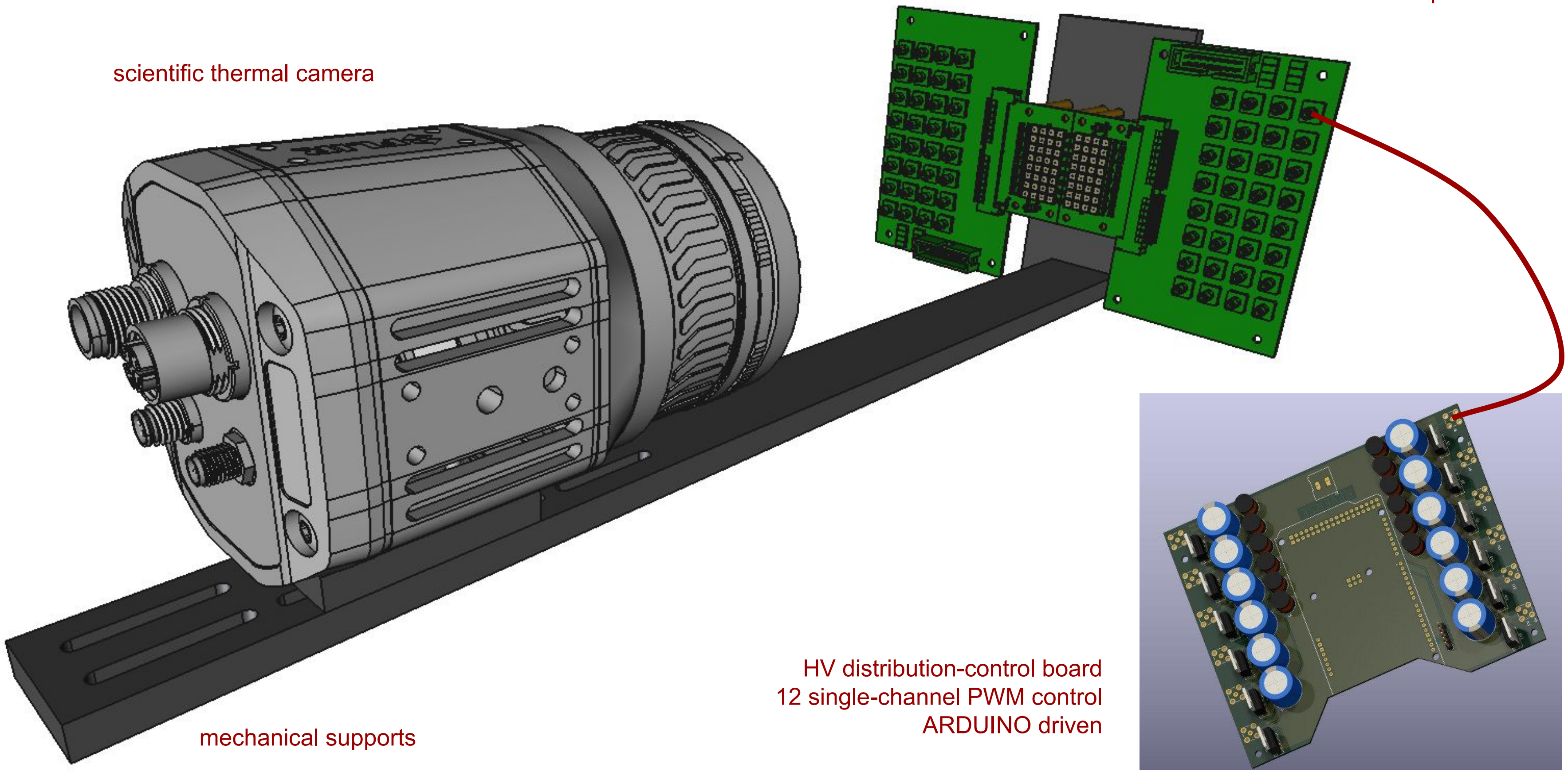


Online annealing

explore solutions for in-situ annealing



Automated multiple SiPM online annealing

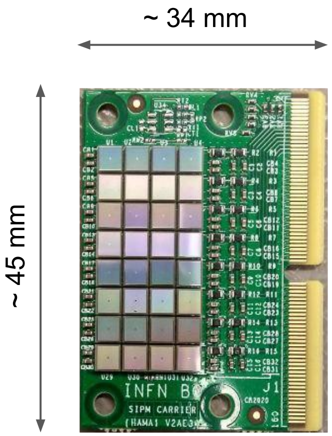


Boards to irradiate at LNL in August 2023

- **online annealing [2 boards]**
  - we have 3 days, we can do many rounds
  - split 10^9 n_{eq} fluence in 10x repeated irradiation-annealing cycles
    - 10^8 shots
    - 30-minutes long online annealing
  - forward and reverse current bias
- **offline annealing [9 boards]**
  - we have only one access in 2023
  - increasing neutron equivalent fluence with standard oven [3 boards]
    - fluence 10^9 10^{10} 10^{11}
    - standard oven (150 h - 150 C)
  - study annealing in the laboratory [4 boards]
    - fluence 10^9
    - forward current
    - reverse current
    - infrared lamp annealing
    - else
  - study impact of preventive-annealing [2 boards]
    - fluence 10^9
    - standard oven (150 h - 150 C)
    - multiple standard cycles (4x cycles)

slot on 2-3-4 August

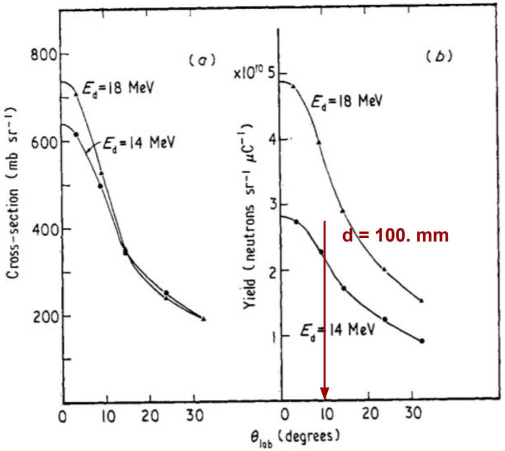
SiPM irradiation at CN-LNL



SiPM boards are “large”
need ~ uniform neutron flux within ~ 30x30 mm²

neutrons with
ϑ_{lab} < 5-10 degrees

boards placed at least at 100 mm from the target



estimate of neutron flux at 100 mm

more accurate estimates to be done

- **beryllium target** ⚠️
  - <u>will use an existing target at LNL</u>
- **4 MeV deuteron beam**
  - 100 nA current on target

~ 6.5 10^5 n cm^{-s} s^{-1}

irradiation time estimates

- 👍 30 minutes to reach 10^9 n cm^{-2}
- 👍 4.5 hours to reach 10^{10} n cm^{-2}
- ⚠️ 43 hours to reach 10^{11} n cm^{-2}
  - too much to be done in 3 days
  - need higher current and/or stay closer (50-70 mm)
  - or integrate in more days

SiPM plans for FY 2023

we have not been originally funded and eventually only partially, but we'll keep the milestones alive as much as possible

Milestones FY 2023

critical results for pre-TDR

- Timing measurement of irradiated (and annealed) sensors (6/2023)
- Comparison of the results achieved with proton and neutron irradiation sources (8/2023)
- Study of annealing in-situ technique with a proposed model selected as baseline for the pre-TDR (9/2023)

- **single-photon time resolution**
  - of full SiPM-ALCOR readout chain
    - no capacity to measure it so far
  - critical to set performance simulation
- **alternative annealing solutions**
  - so far done with industrial oven (days)
  - address ideas for faster / in-situ recovery
    - exploration started, promising
    - critical to become structured R&D
- **irradiation campaigns**
  - so far only with 150 MeV protons
  - critical to collect data on neutron damage
    - might be topologically different
    - effectiveness of annealing
    - test NIEL damage hypothesis
  - irradiation needed to test new annealings
- **operation at low temperature**
  - so far characterisation in climatic chamber
    - compare results with TEC (Peltier) cooling
  - explore alternative solution to TEC
    - liquid, hybrid (liquid + TEC) approaches
- **development of new sensors**
  - within INFN-FBK collaboration agreement
    - critical for procurement risk mitigation
  - reduction of DCR
    - field / thickness optimisation
    - exploration of advanced microlensing
  - development of "monolithic" SiPM sensor array
    - wire bonded, cost reduction