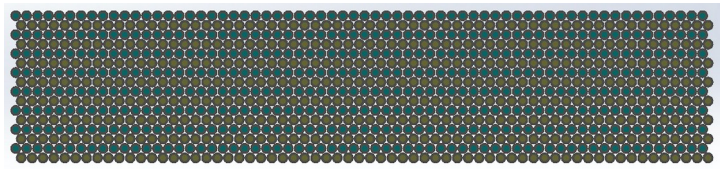
# IDEA dual-readout calorimeter

RD_FCC referee meeting
26.07.2024

Roberto

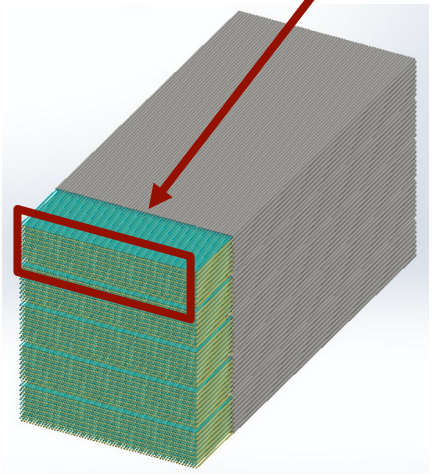
# Dual-Readout Calorimeter: Layout

Minimodule



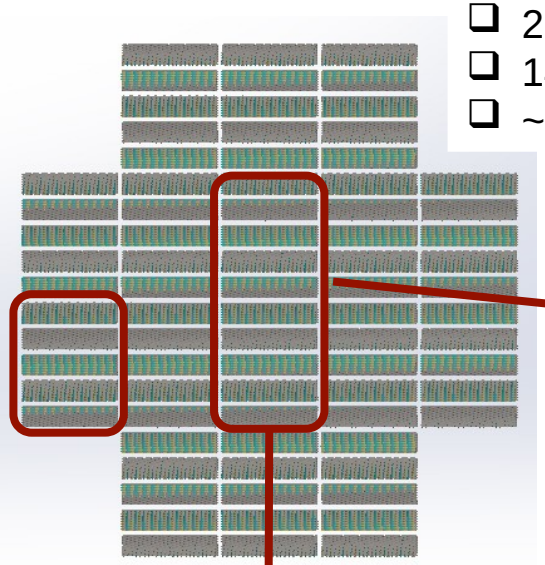
64 × 16 capillaries

Module



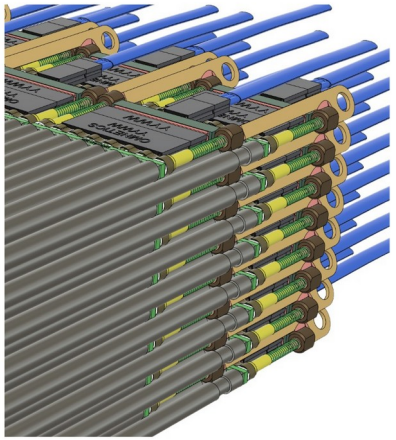
5 minimodules
~ 13 × 13 × 250 cm³

HiDRa



- 16 modules in total
- 2 central modules w/ SiPMs
- 14 modules w/ PMTs
- ~ 65 × 65 × 250 cm³

Highly granular modules

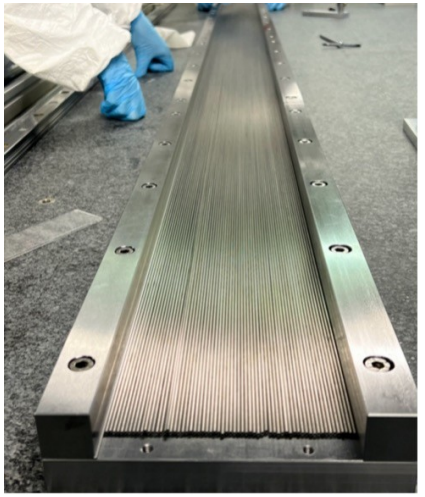


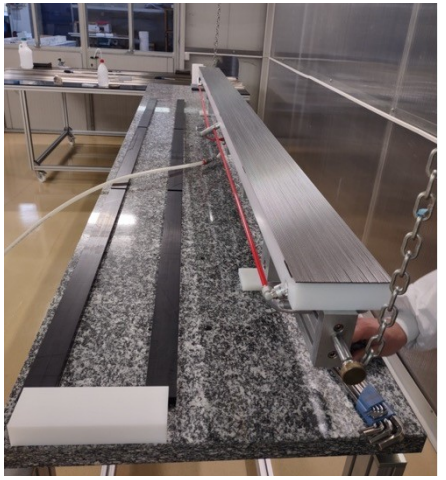
10240 SiPMs fitting detector back side

# Construction technique

**High quality tube selection:**
Accurate measurement of thickness, straightness, length, and internal diameter (pass/fail test with fibre insertion)

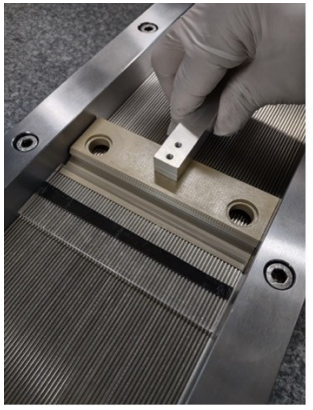
Structure anchored to granite table for stacking layers of tubes





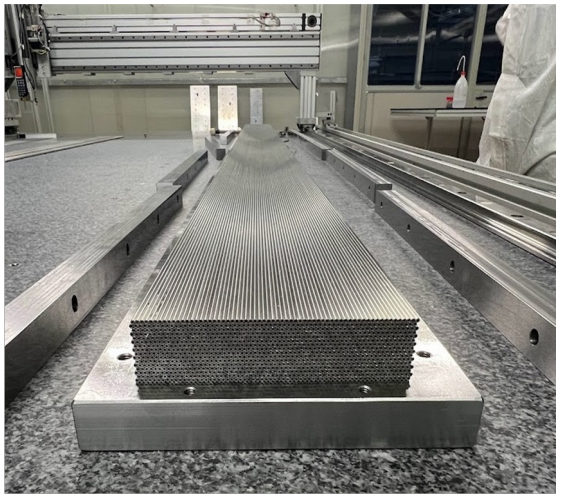
Vacuum + double-sided tape for tube handling

Glue dispensing and tube alignment and positioning

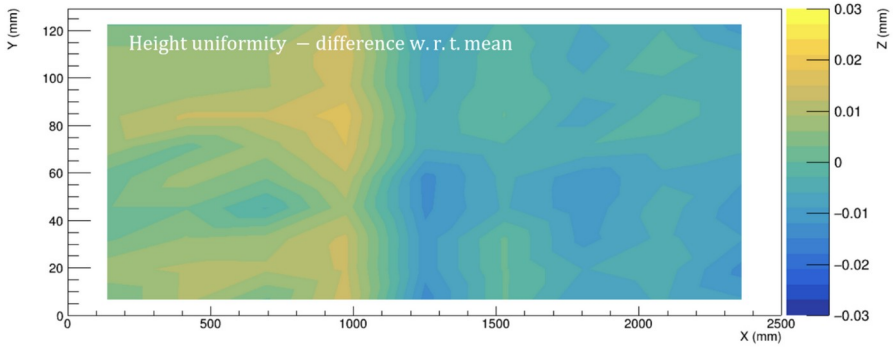


# Construction technique and mechanical precision

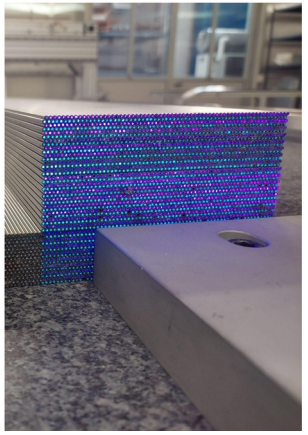
Semi-automatic system for planarity measurement: 90 measurements per minimodule



O(10 µm) precision on minimodule height (calor2024)



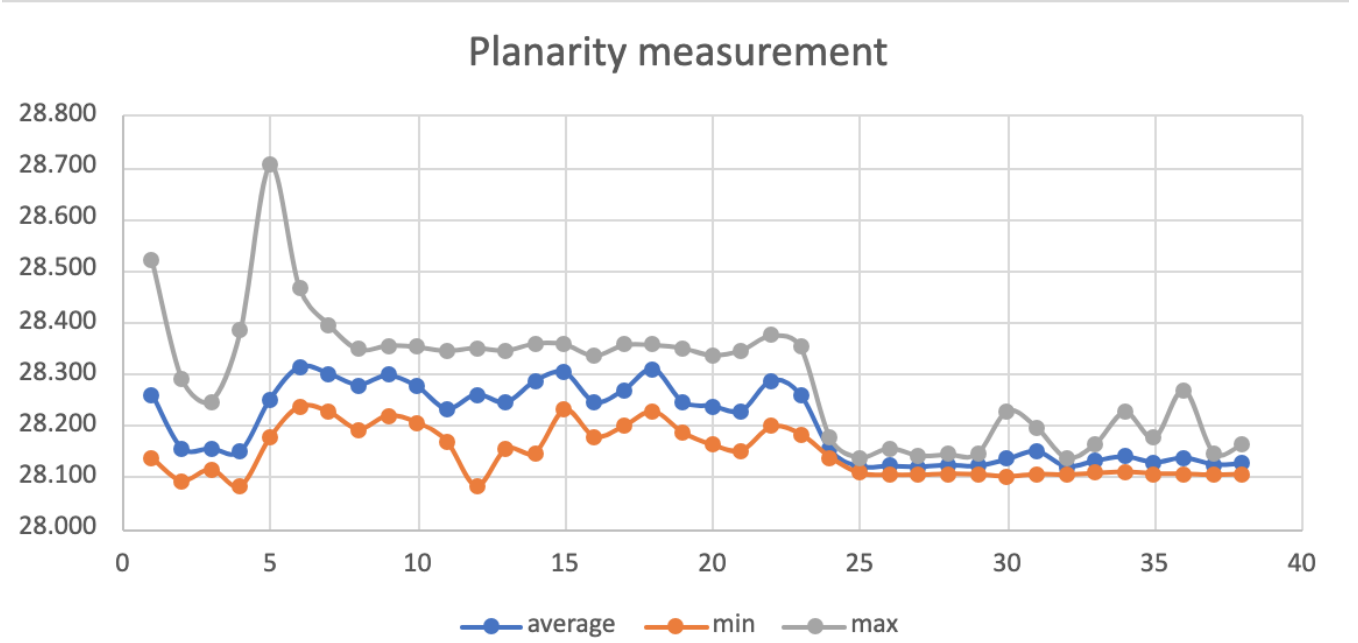

Production started in November 2023: 38/80 minimodules assembled
First test beam with 36 modules planned in August 2024 (PMT readout only)

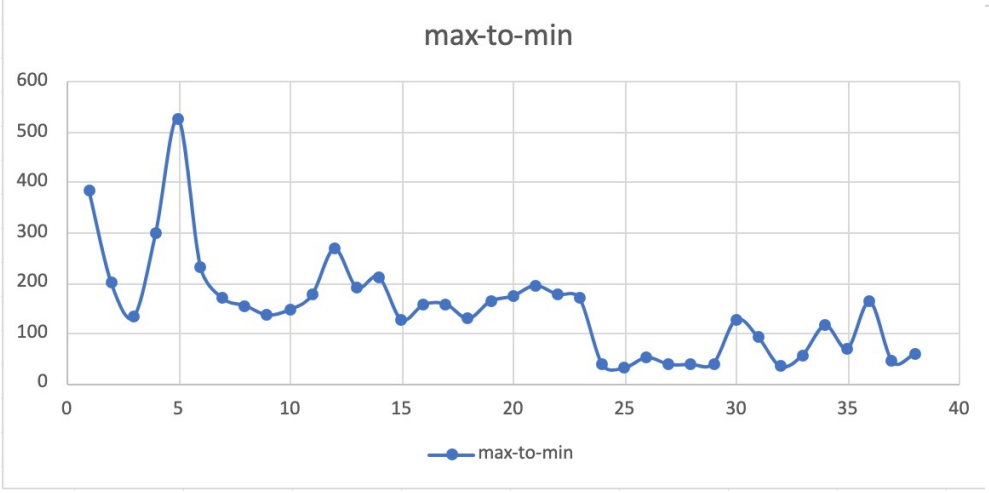


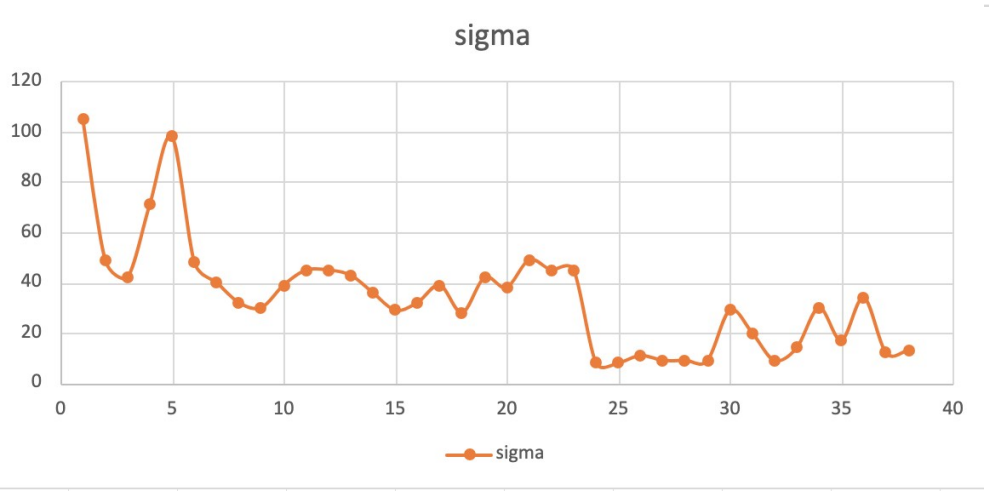
# Planarity measurements

Pretty stable results

Well within requirements



# Status

After some delay, production in steady state: rate ~ 8 minimodules / month

- Target: finish ~ end 2024 / beg. 2025

Tube and fibre quality quite good but rejection close to threshold (5%)

- Fibres → ok (replacement at no cost)
- Negotiations ongoing for tube “refurbishing”

Fibre: limiting factor in assembly procedure

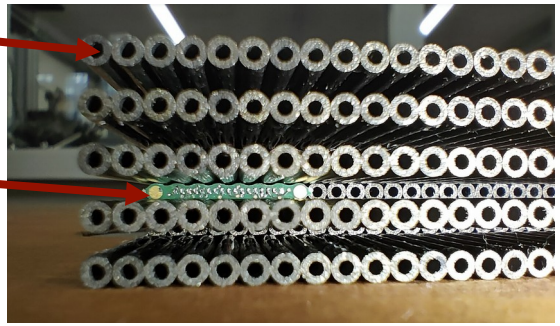
1) fibre cutting → automatic machine now in operation

2) fibre insertion (?) - at present 1 minimodule / 12-16 h

# Integration of highly granular modules

SiPMs for scintillating light

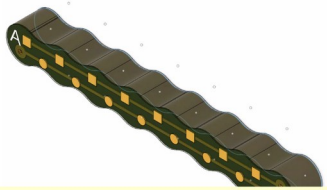
SiPMs for Cherenkov light



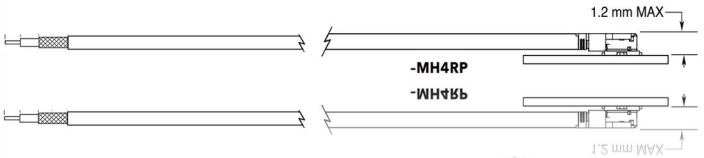
High precision required for SiPM alignment

PCB designed according to tube shape → self-alignment w/ fibres

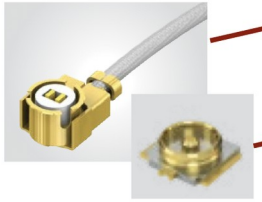
mini FE-board with integrated grouping (8 SiPMs)



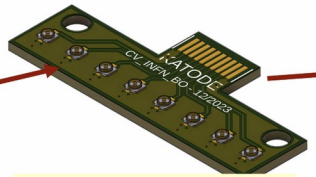
MH081: shielded micro-coax RF cables from Samtec



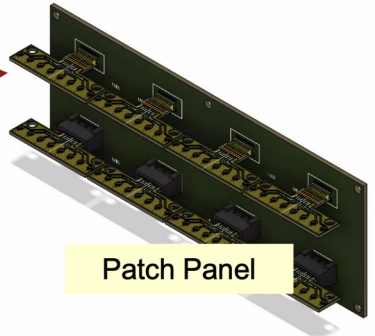

SiPM bar mounted on the front and two-pin cable on the back



connectors fitting into the PCB holes

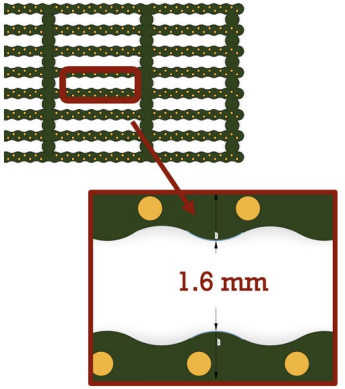



Bridge board: serves 8 SiPM-bars



Patch Panel

Large FE-board equipped with 16 SiPM-bars

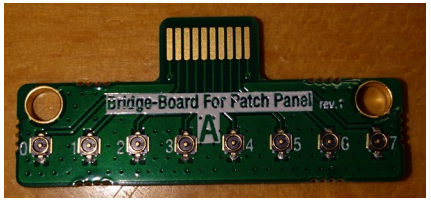



A5202-board: serves half mini-module

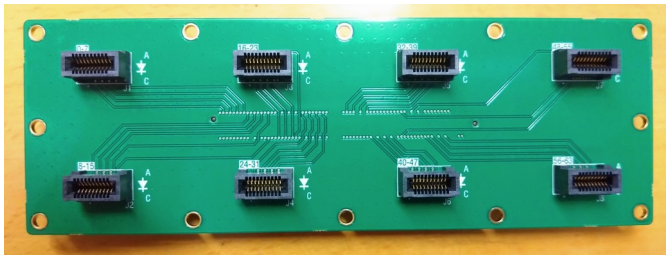
# Preproduction and first qualification

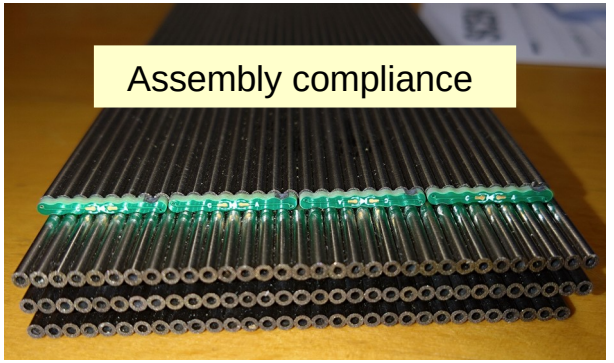
- Mini front-end board (40 prototypes )

- Bridge board (10 prototypes )

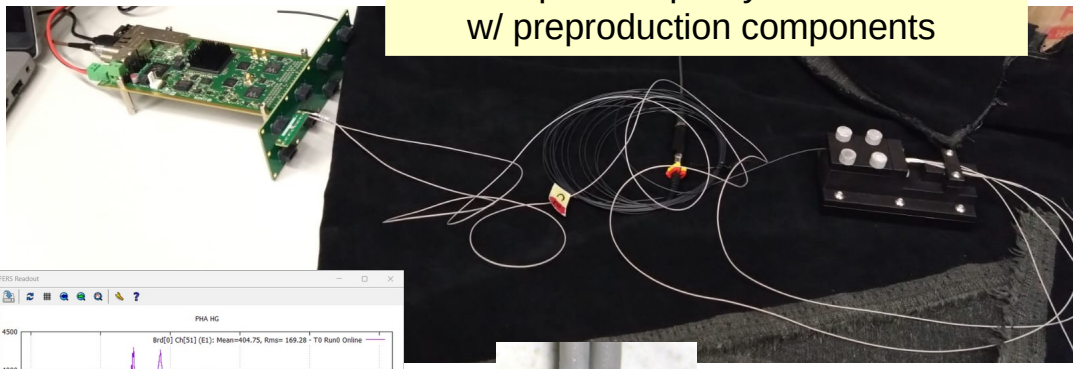


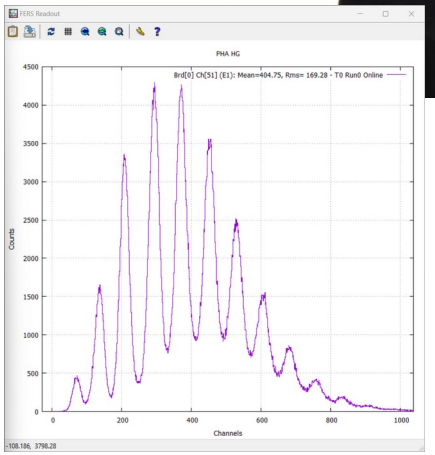

- Patch panel (4 prototypes)

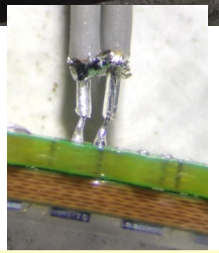





Multi-photon quality assessment
w/ preproduction components



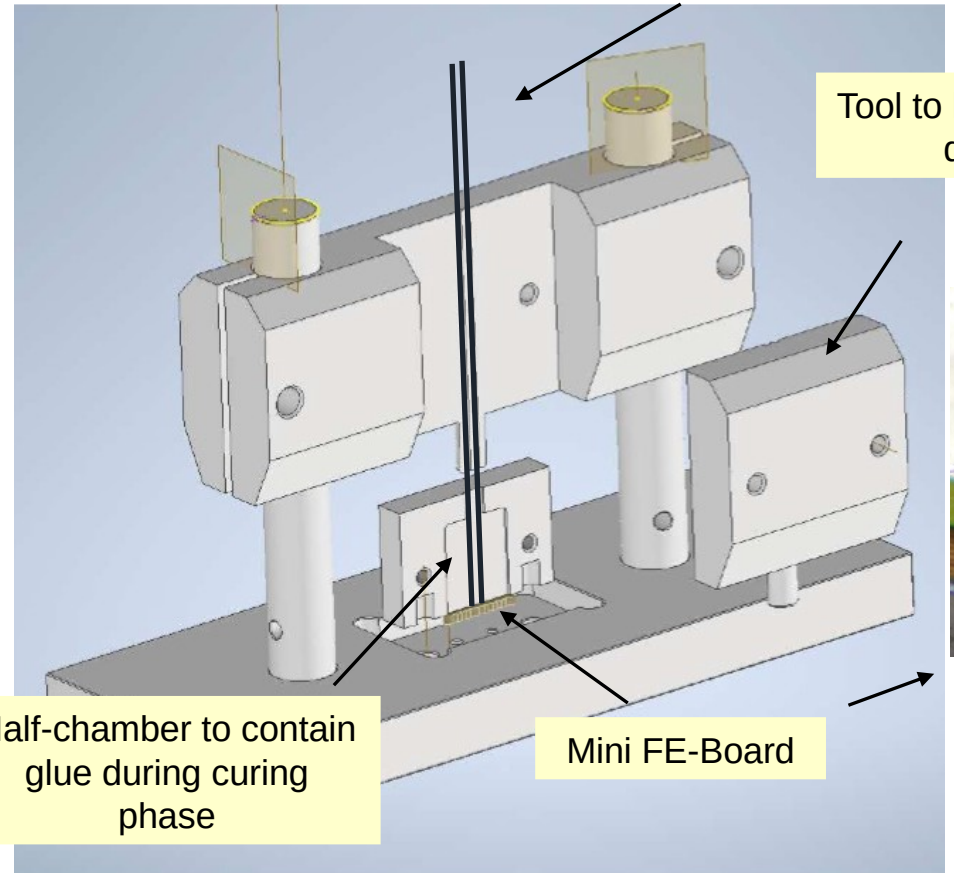


Ready for production!

# Mini FE-board: assembly station

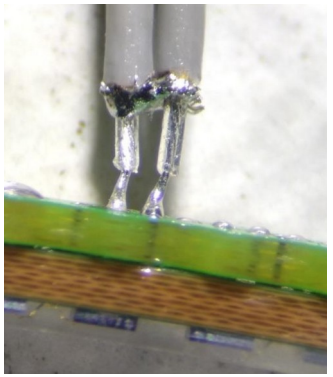
Two coaxial cables



Tool to hold cables in position during soldering

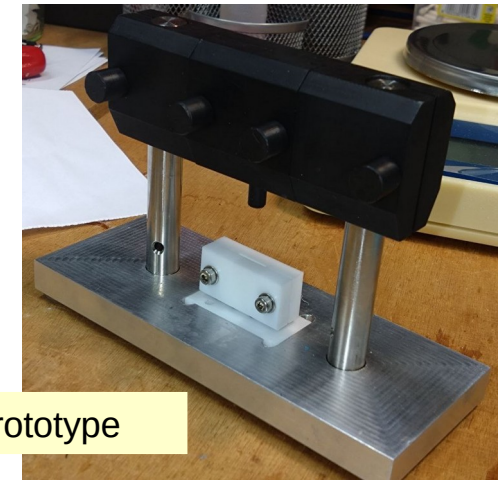
Half-chamber to contain glue during curing phase

Mini FE-Board



Different tests performed using different glue types and different approaches

Current results based on BC-600 optical cement

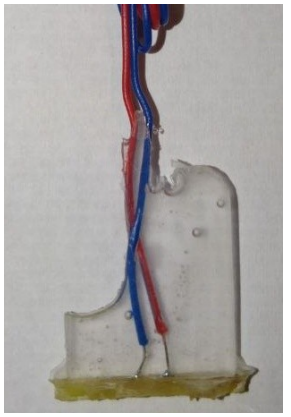


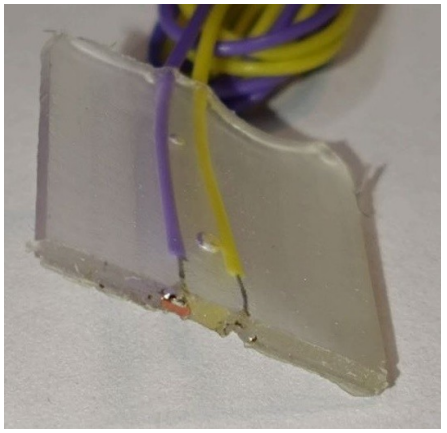
Prototype

# Different strategies tested with dummy components

- Strategy 1
  - Glue-chamber manufactured in Teflon
  - Glue filled with syringe
  - Tests w/ waiting time (from glue mix to displacement) up to 3 h
  - Glue curing time 24h

Final consideration: very difficult to fully control leakage and guarantee proper reference plane





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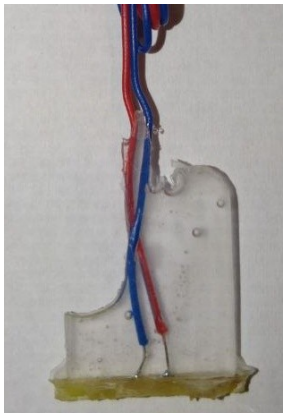
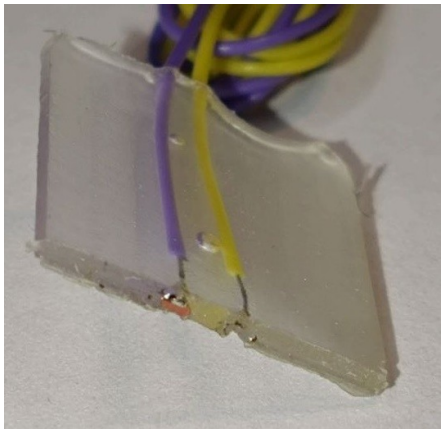
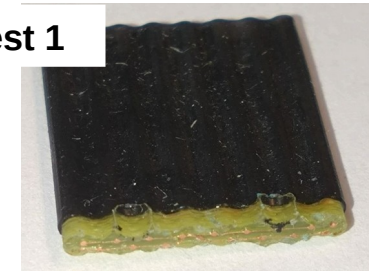


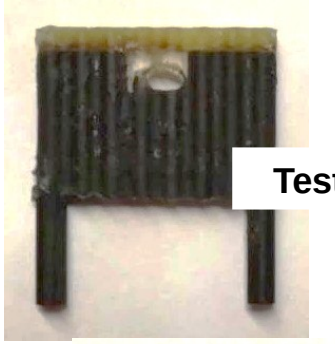


- Strategy 2
  - 3D-printed components to obtain good reference plane
  - Optimise 3D-component design and material
  - Optimise gluing technique

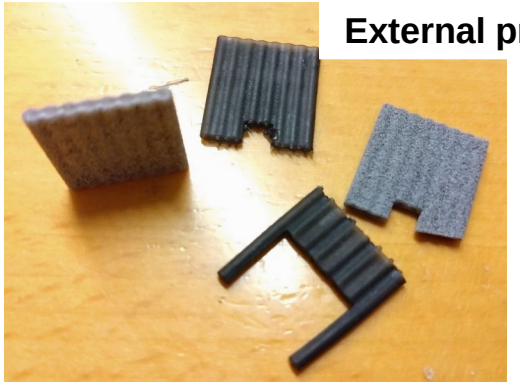
  Final consideration: way to go

Test 1

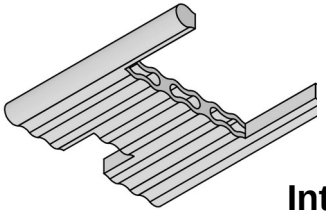


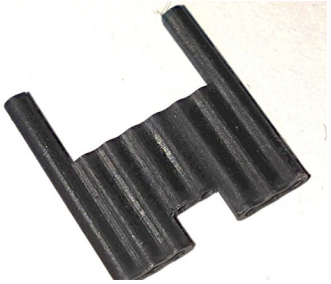


Test 2

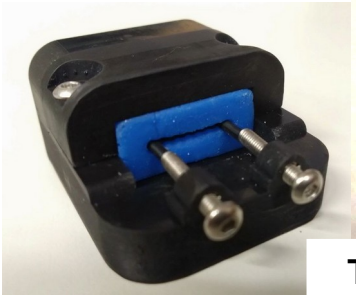


External production





Internal production



Test 3

# Schedule (high-granularity modules)

Procurement ongoing after some delay

SiPM delivery scheduled for week 36 (September 2)

Preproduction:

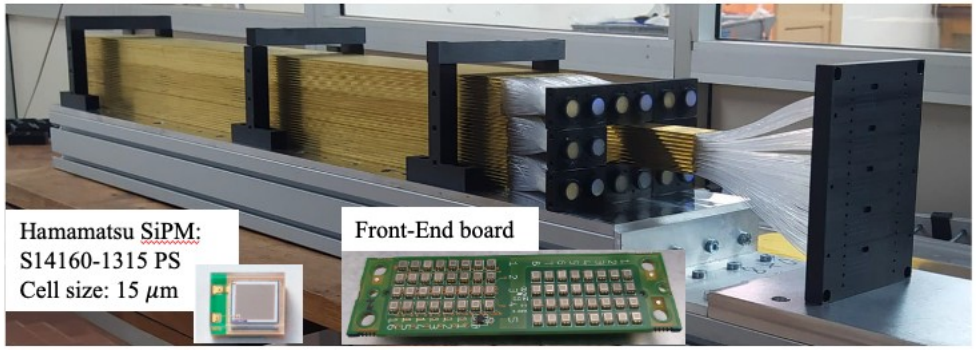
Mounting on PCBs within ~ end of October

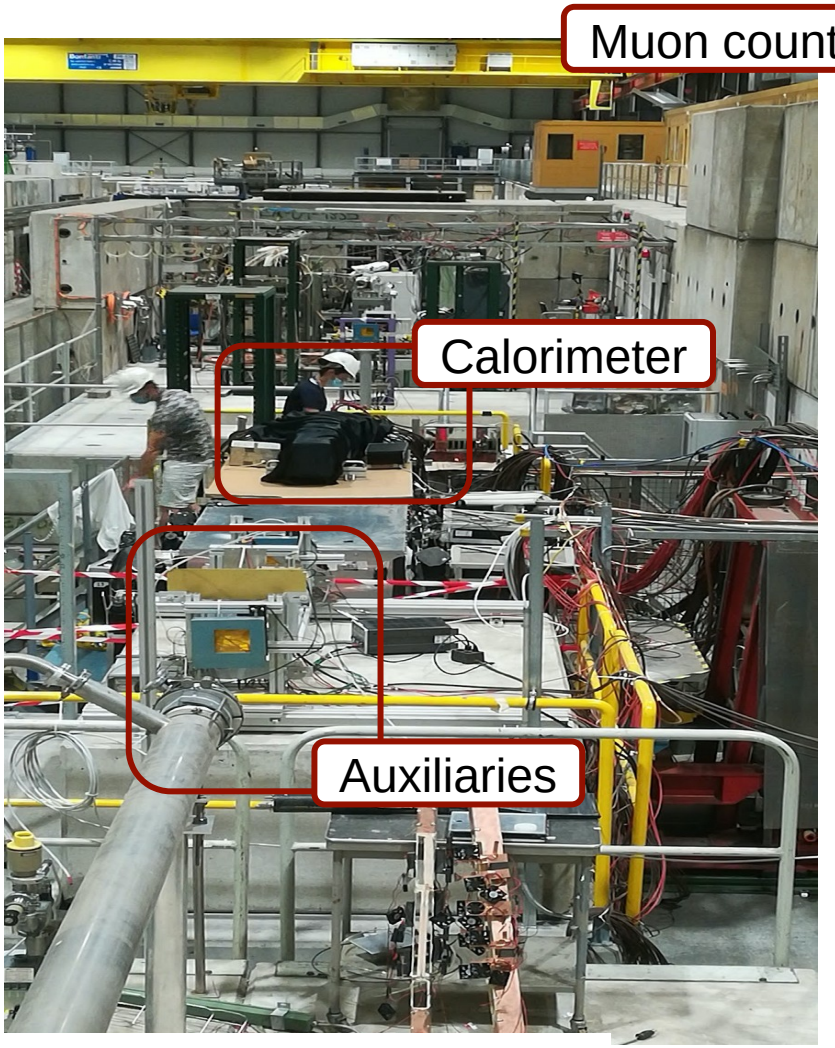
Fully qualified within ~ winter 2025

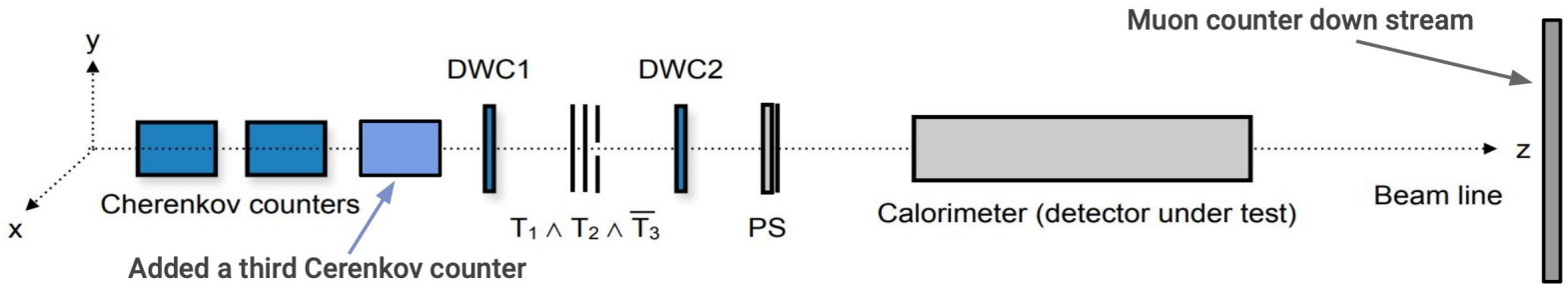
# Beam tests in 2021 and 2023

## CERN-SPS H8 beam line

- $e^+$ beam in energy range of 10-100 GeV
- Energy and position scan
- Purity issues (critical in 2021)

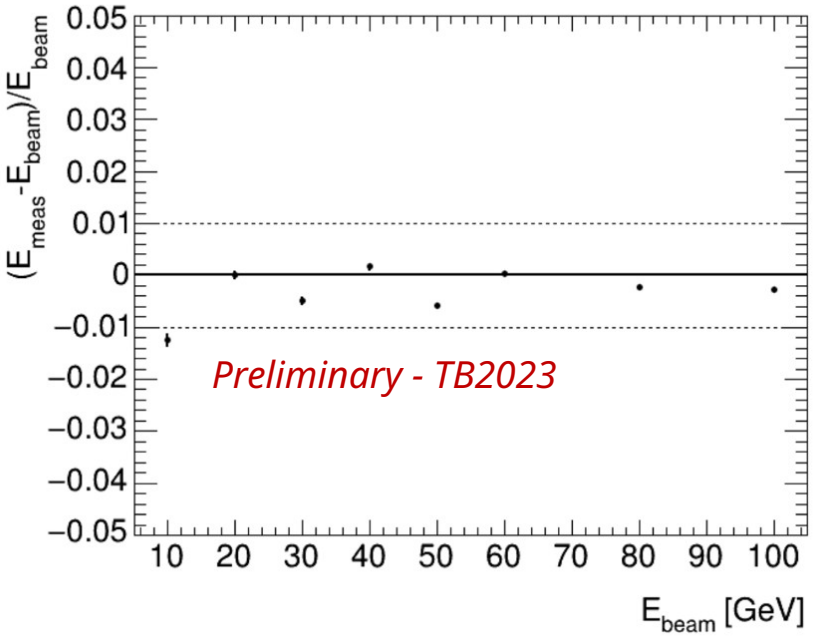


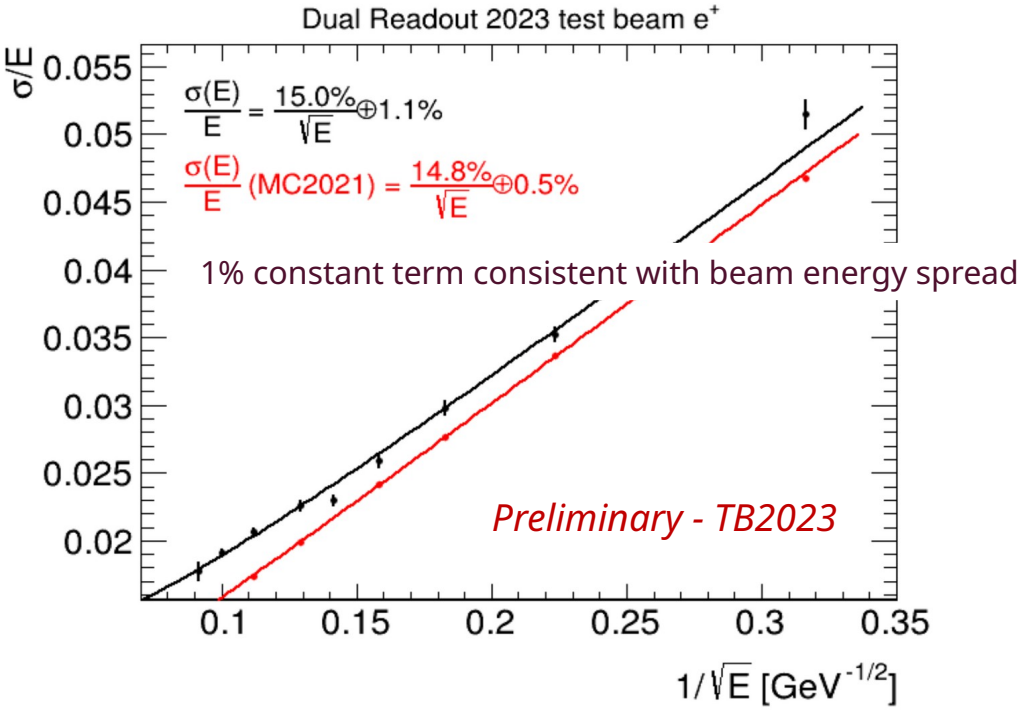



# Final results

Linearity




Energy resolution



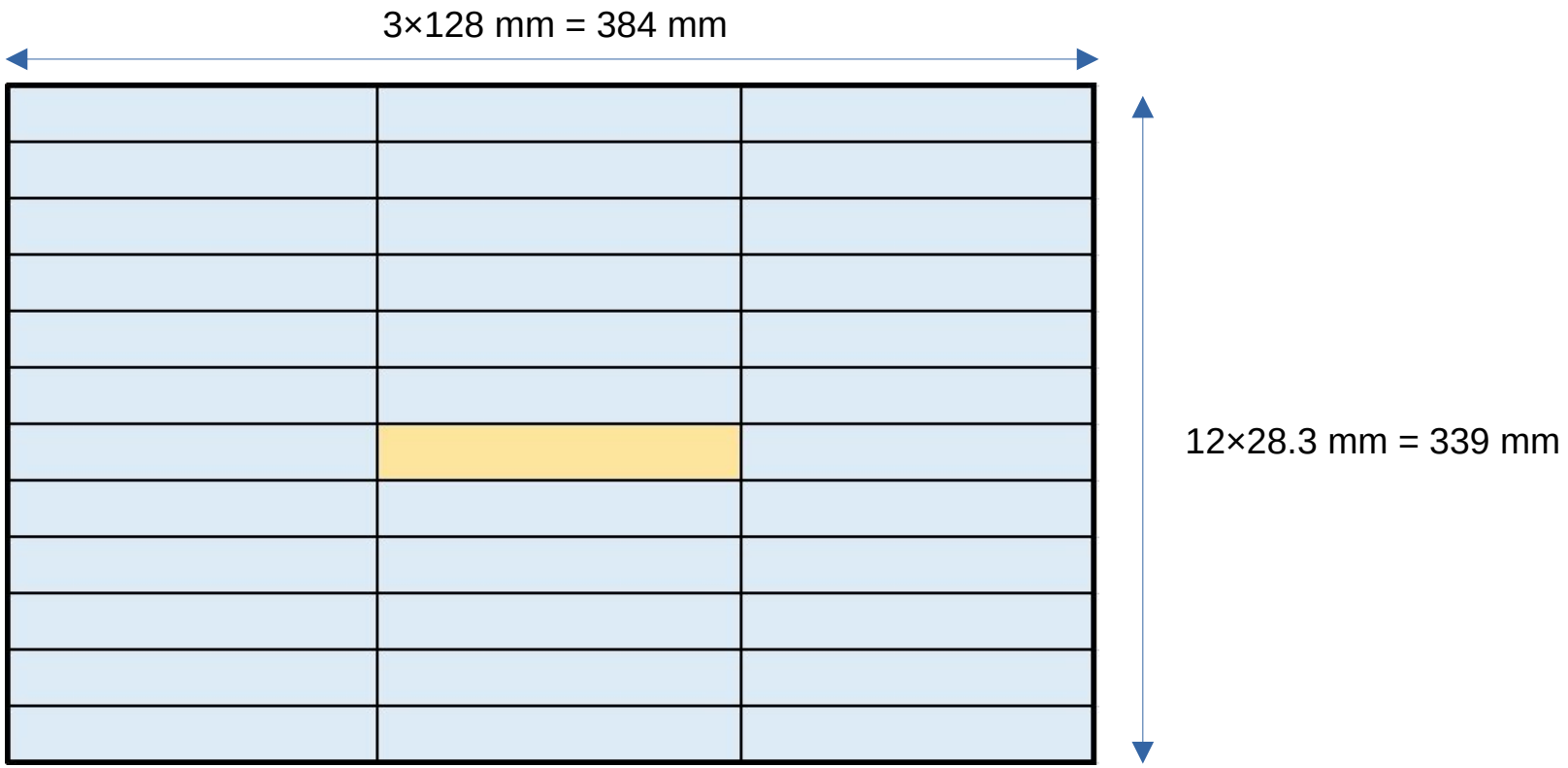

Results well in agreement with G4 simulations

# Testbeam 2024

36 minimodules in 3×12 arrangement (+ integrate position measurement w/ ATLAS_PIX3 sensors)

PMT-only: 36 + 36 PMT signals to read out

Focus on: understand/assess calibration procedure, operation and G4 validation



# Testbeam 2024 - timeline

~10 of 12 layers already piled up

35/36 modules ready, 1 more to be finalised with fibre loading

Mechanics to be finalised

Module will arrive at CERN on August 5th / 6th

1st week (August 7th →):
- Daq setup
- Elx checks

Last week (August 28th →):
- Physics measurements

# Personnel

New people (part of ATLAS LAr Milano group) joining Milano group:

Leonardo Carminati
Laura Nasella
Ruggero Turra

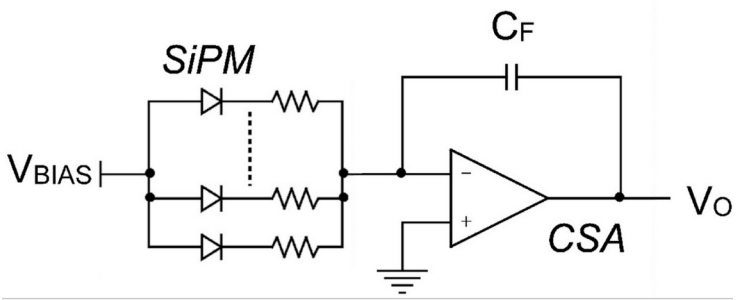
# Synergy

New proposal in CSN 5 for digital SiPM development (ASPIDES)
informal feedback: well received

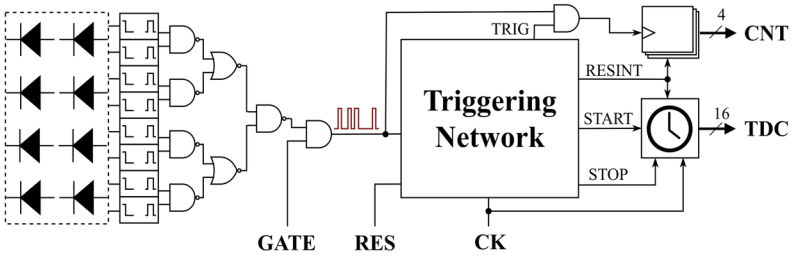
National coordinator: Lodovico Ratti
Collaboration: BA-BO-MI-NA-PD-PV-TIFP-TO
36 people, ~8 FTE

# About dSiPMs

SiPMs: analogue signal proportional to number of fired cells, readout performed externally




Digital (CMOS) SiPMs: readout functionalities implemented in sensor substrate (e.g. binary counters, SPAD masking, TDCs …)




M. Perenzoni et al. 2017 – IEEE JSSC

- CMOS SPAD arrays may offer different benefits:
  - Monolithic structure simplifies assembly for large area detectors
  - Front-end optimised to preserve signal integrity (especially useful for timing)
  - Easier linearisation and calibration – direct digital output
  - Simplified DAQ → lower costs (at least for designs based on standard processes)

ASPIDES – proposta di sigla in CSN 5

# Requests for 2025 (material only)

RD_FCC:

BO: Cavi, minuteria e materiale test elettronica dual readout 5 k€

MI: acquisto 2 schede readout spare per il dimostratore Hidra 15 k€

PV: schede di readout per moduli aggiuntivi 3 k€

PI: acquisto PMT con basi per integrazione prototipo con moduli di RD52 44 k€ → s.j.

HiDRa2:

BO: integrazione elettronica di front-end 15 k€

PV: allestimento stazione per incollaggio e saldatura cavi e connettori 15 k€

PI: acquisto PMT con basi per integrazione prototipo con moduli di RD52 44 k€ → s.j.

# Summary

After some delay, production in steady state: rate ~ 8 minimodules / month

- Target: finish ~ end 2024 / beg. 2025
- Bottleneck: fibre loading

High-granularity modules

- SiPMs expected early September
- Mounting strategy tuned
- Preproduction qualification expected within 1Q 2024

HiDRa2 asked for one year program extension

Beam test with a (PMT-only) 36 minimodule setup → tune calibration procedure

# Backup

# AtlasPix3

## ATLASPix3 - Features

- **ATLASPix3 general features**
  - Depleted Monolithic Active Pixel Sensor (**DMAPS**)
  - **HVCMOS** technology
  - full-reticle size **20×21 mm²** monolithic pixel sensor
  - **TSI 180 nm process** on 200 Ωcm substrate
  - **132 columns of 372 pixels**
  - **pixel size 50×150 µm²**
  - **breakdown voltage ∼-60 V**
  - up to **1.28 Gbps downlink**
  - **25 ns timestamping**
  - designed by I. Peric at KIT
- **INFN**, **KIT**, **China, UK** collaboration