



**Dual-Readout Calorimetry
RD_FCC referee meeting**

Roberto

04.09.2023

Dual-readout calorimetry presentation

Fibre prototype → this talk

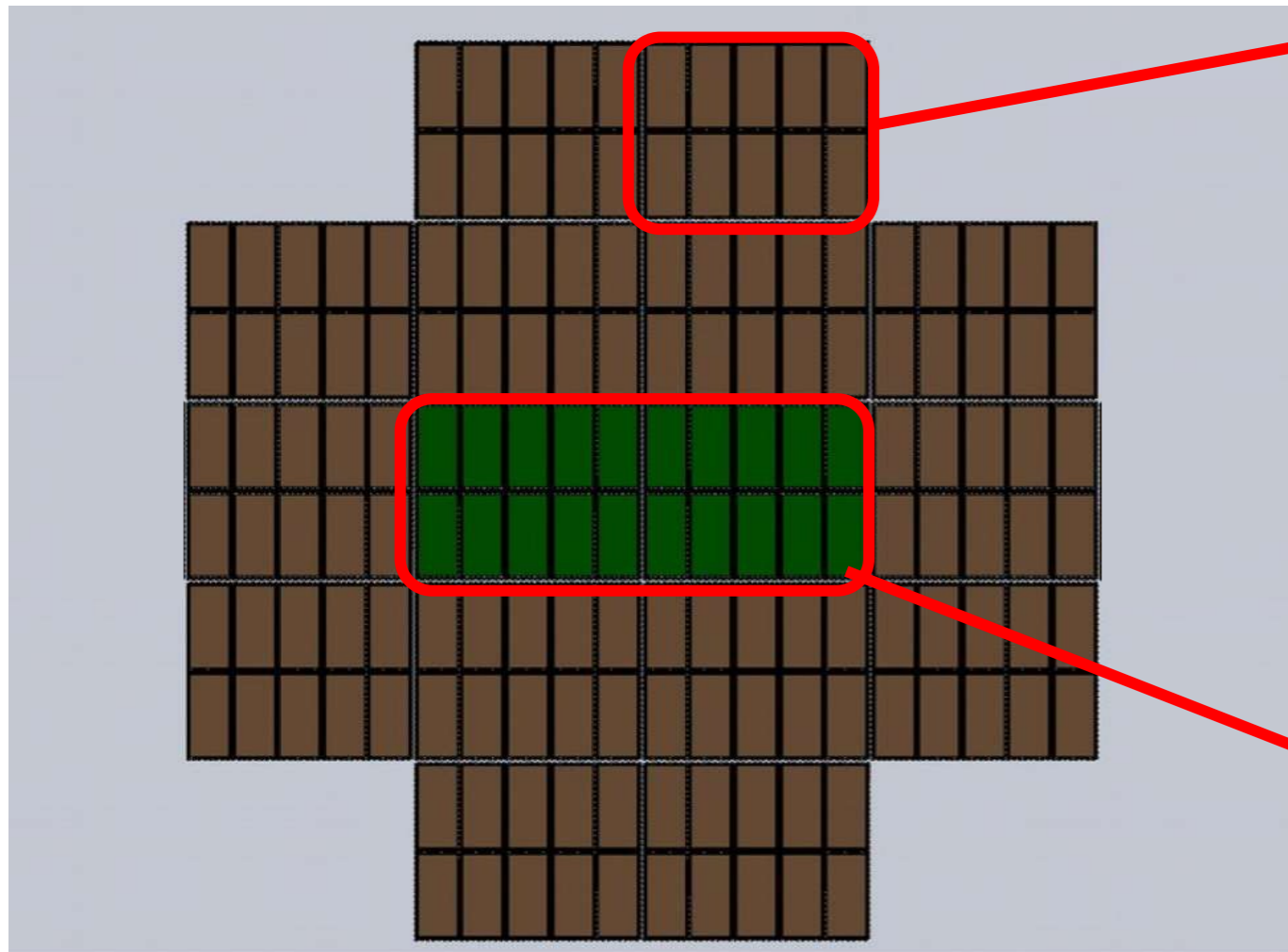
*** New proposals ***

1) Crystal em calorimeter option → Marco's talk

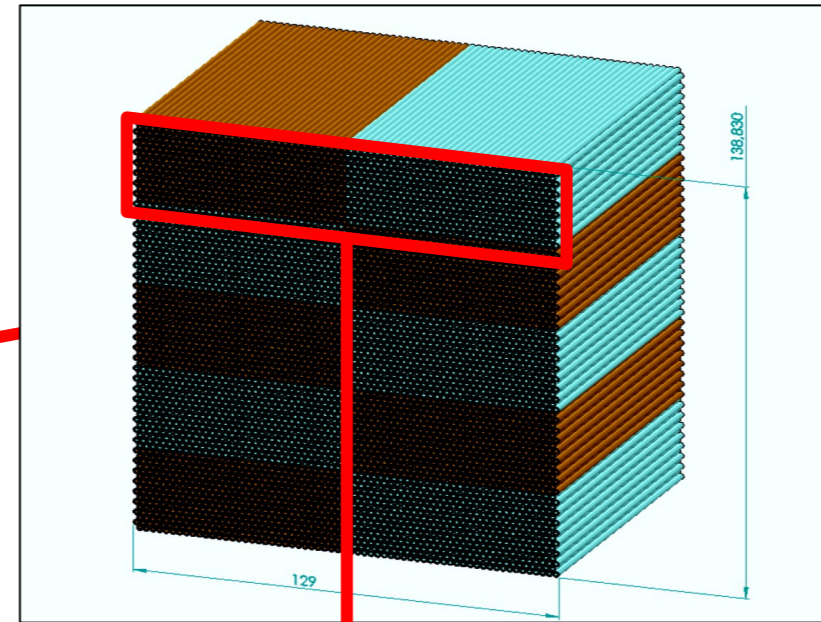
2) Digital SiPM R&D → Lodovico's talk

HiDRa: High-Resolution Highly Granular Dual-Readout Demonstrator

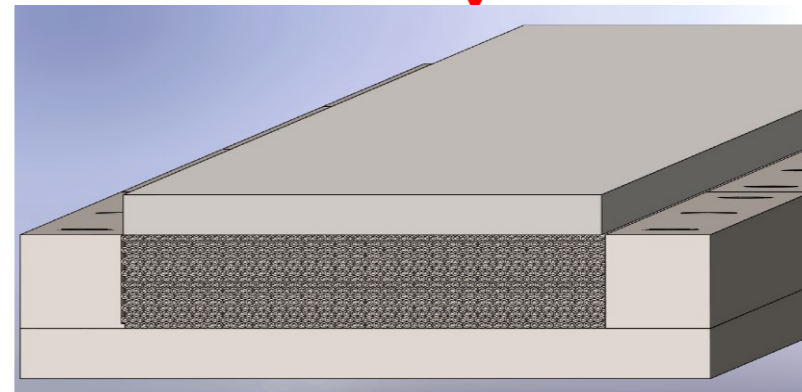
Hadronic-size prototype:
16 modules w/ highly granular core



~ 65 × 65 × 250 cm³



1 Module: 5 MMs
~ 13 × 13 cm²
5120 fibres



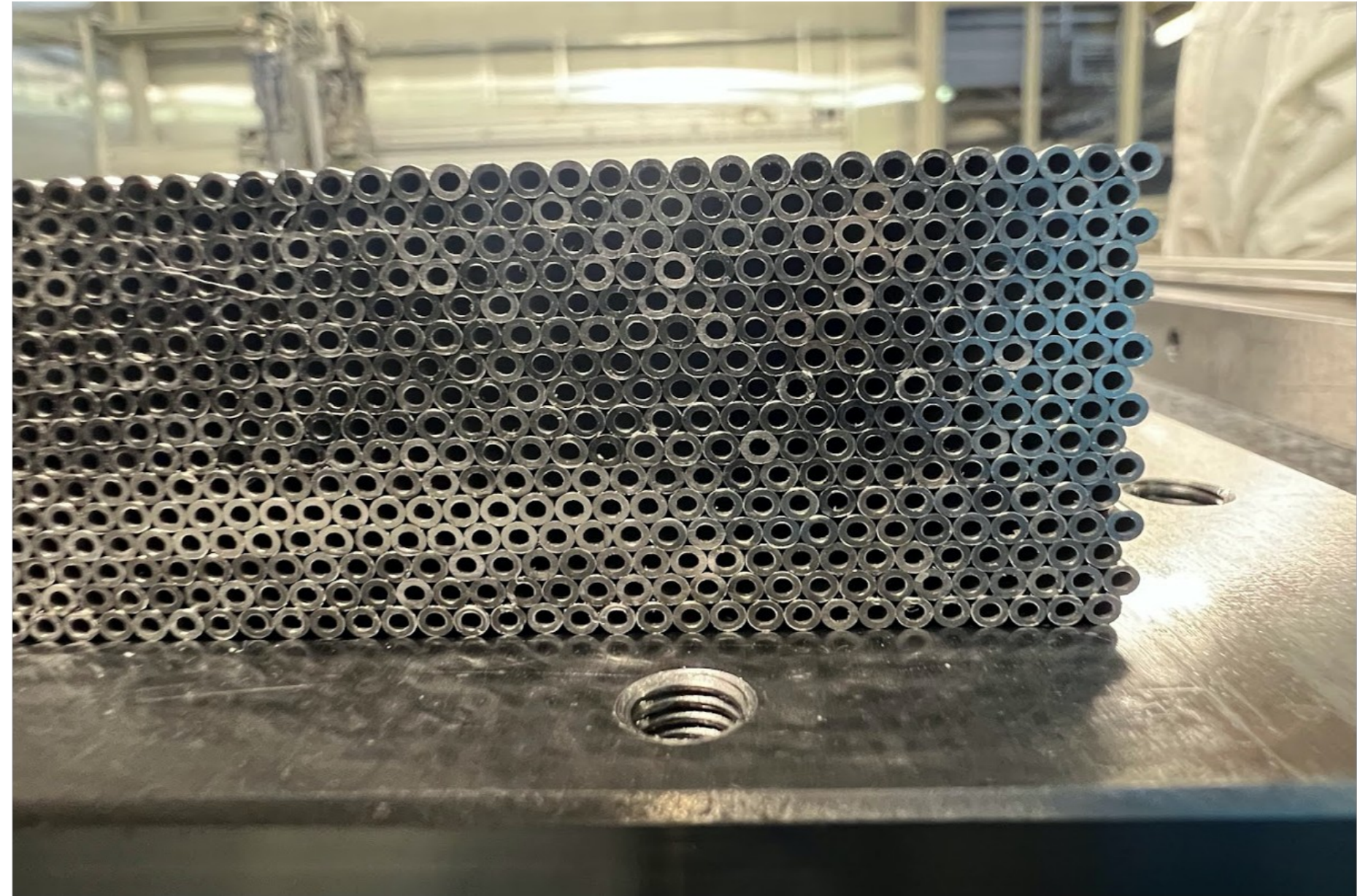
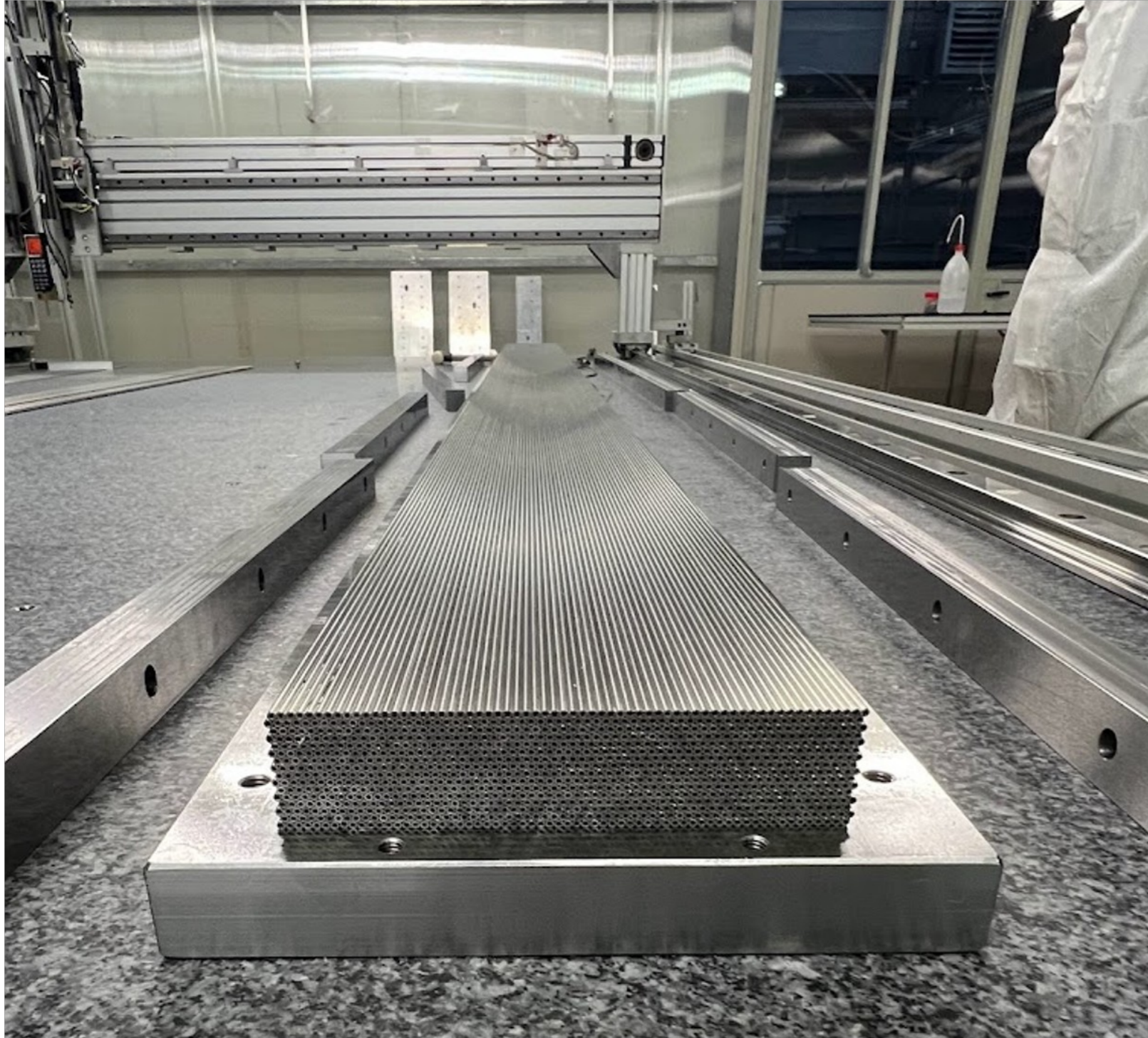
1 MiniModule:
64 × 16 = 1024 fibres in total
(512 S + 512 C)

highly granular core:
10240 fibres to read out with SiPMs

Credits: slides from Gabriella Gaudio (mechanics) and Romualdo Santoro (elx)

Meccanica e fibre

Minimodule 0



Module handling and DQ



Same stiffback used for module handling by adding extra vacuum tool



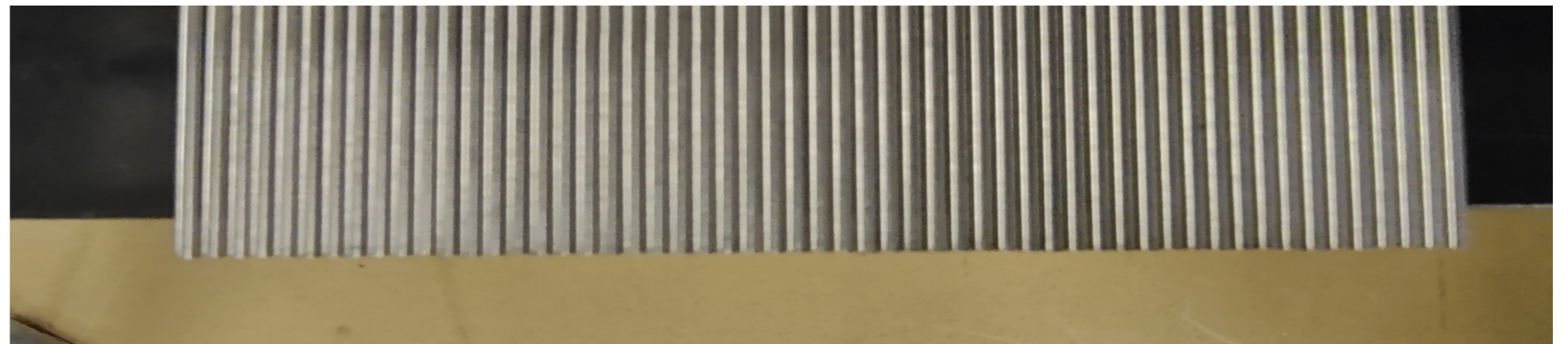
Semi-automatic system for planarity QAQC

Procurement

- Capillary Tube
 - Production completed
 - 1st batch on July 15th (6000 tubes) – arrived August 22nd
 - Very bad handling by SpedService (INFN National contract)
 - See later for first checks
 - 2nd batch (80000) ready on August 12th
 - Shipment (by sea) ongoing
- Scintillating fibres
 - First spool arrived at CERN on August 29th → enough to complete first minimodule
 - 10 MM/month expected assembly rate → 5120 fibre/month delivery rate schedule
- Clear fibres
 - Foreseen to arrive soon at CERN all together

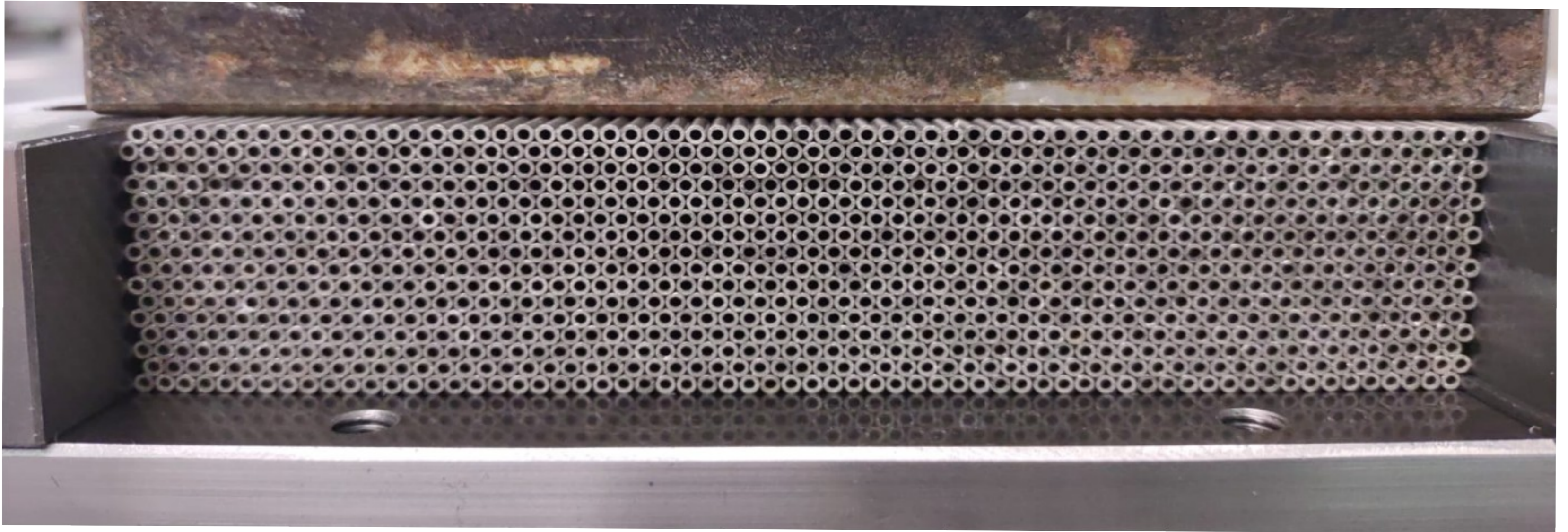
QAQC on first capillary tubes

- OD: 2.000 – 2.012 (a few tenths measured with micrometer – more systematic measurements in coming days)
- ID: pass/fail test with fibres: all ok and with clean edge (no scratch on fibres)
- Straightness: rolled on plain surface: discarded 6/1200 (5‰)
- Length: aligned on one side, check other: extremely good
- **Surface dirty: cleaning needed to grant gluing → cost estimate in next weeks**



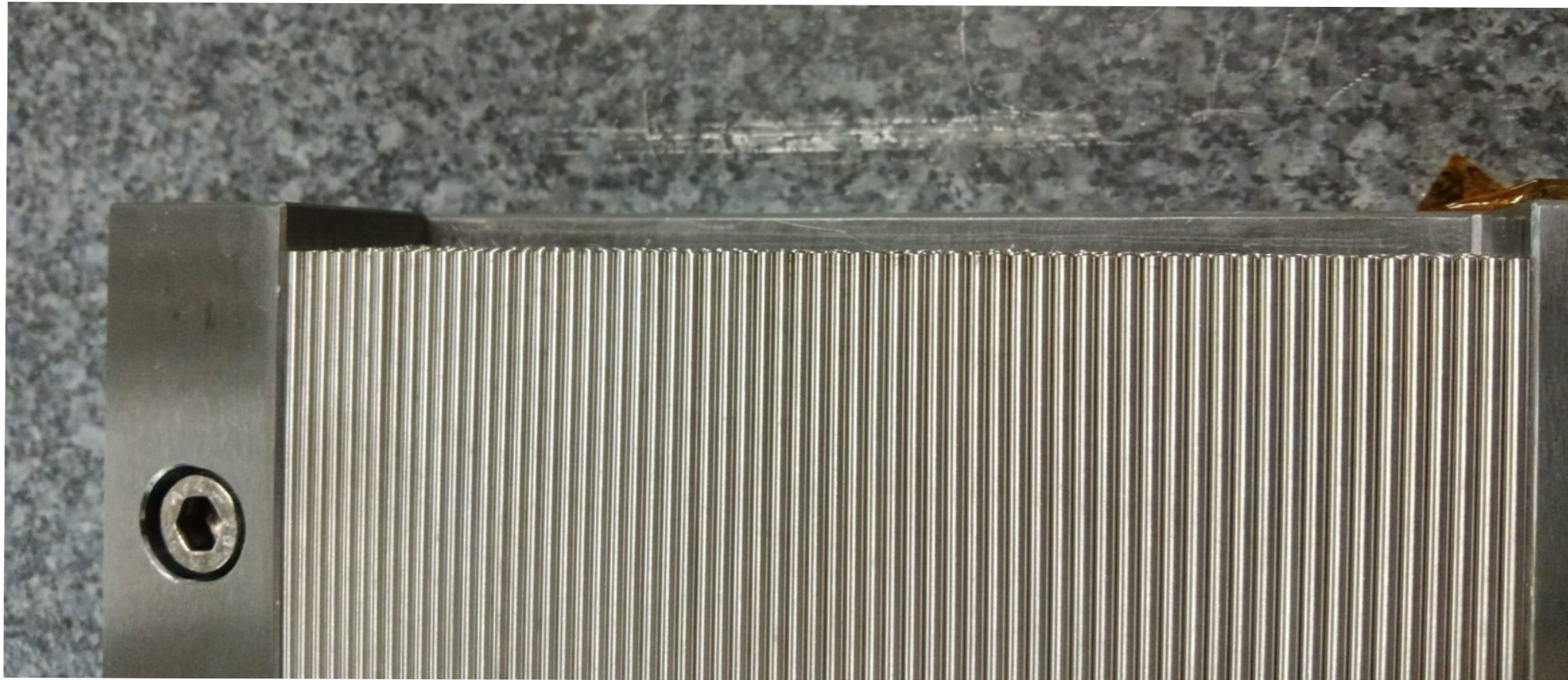
QAQC on first capillary tubes

Dry run performed to check tooling and tube piling-up



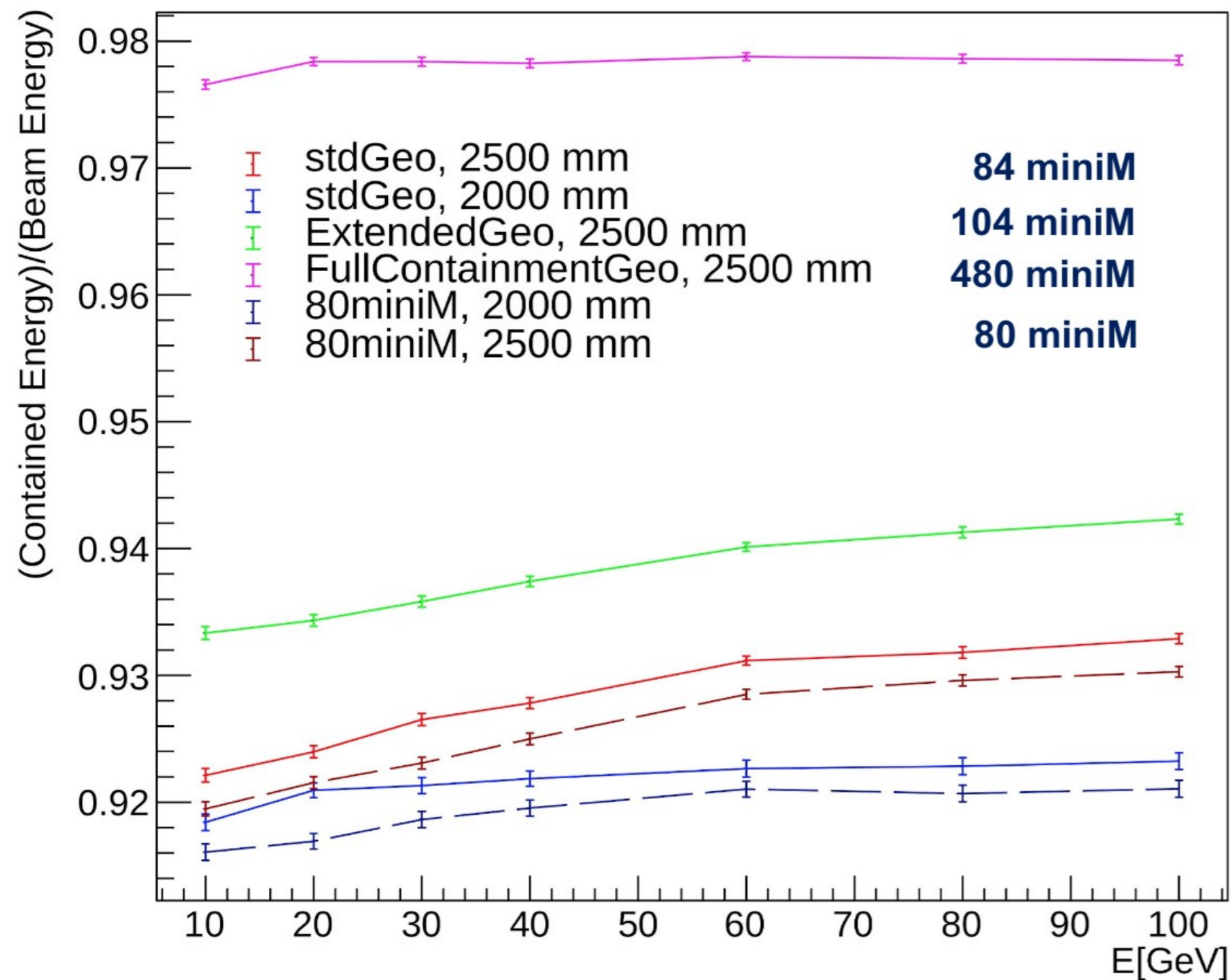
QAQC on first capillary tubes

Dry run performed to check tooling and tube piling-up

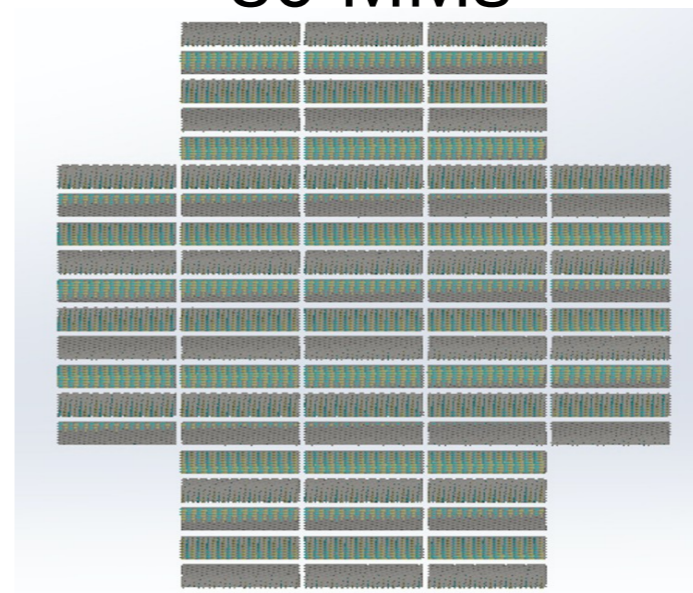


HiDRa containment++

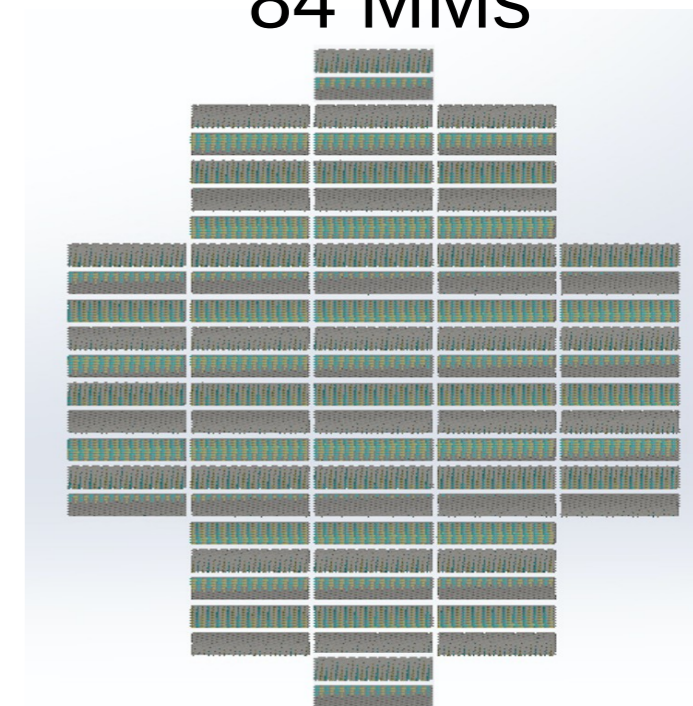
Pion Containment in [10, 100] GeV Range



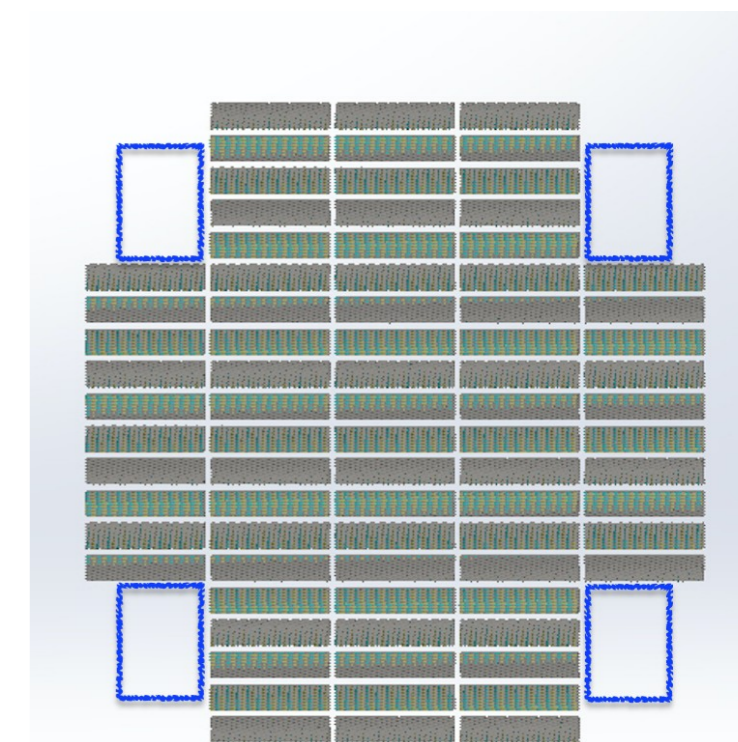
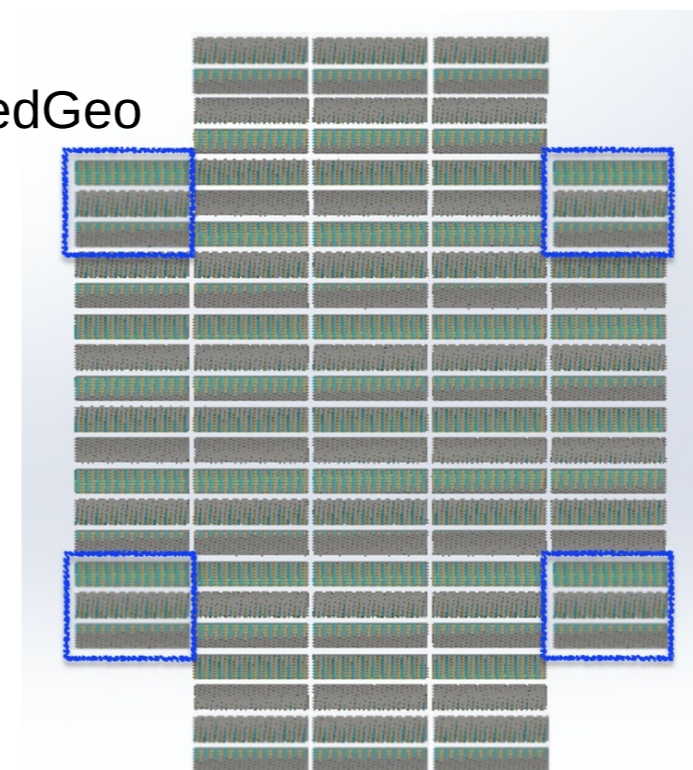
80 MMs



84 MMs

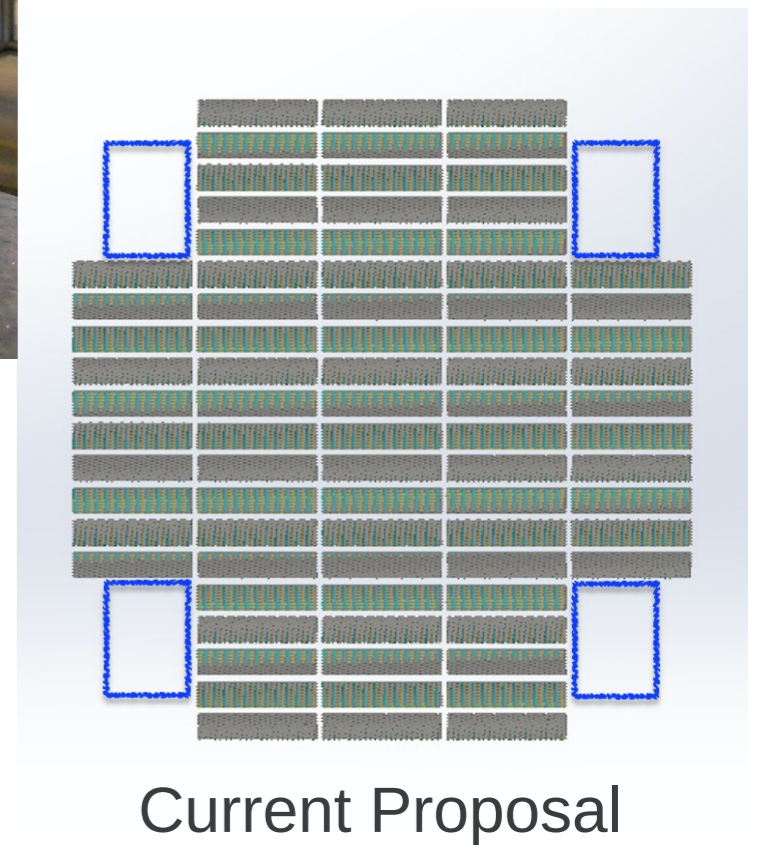
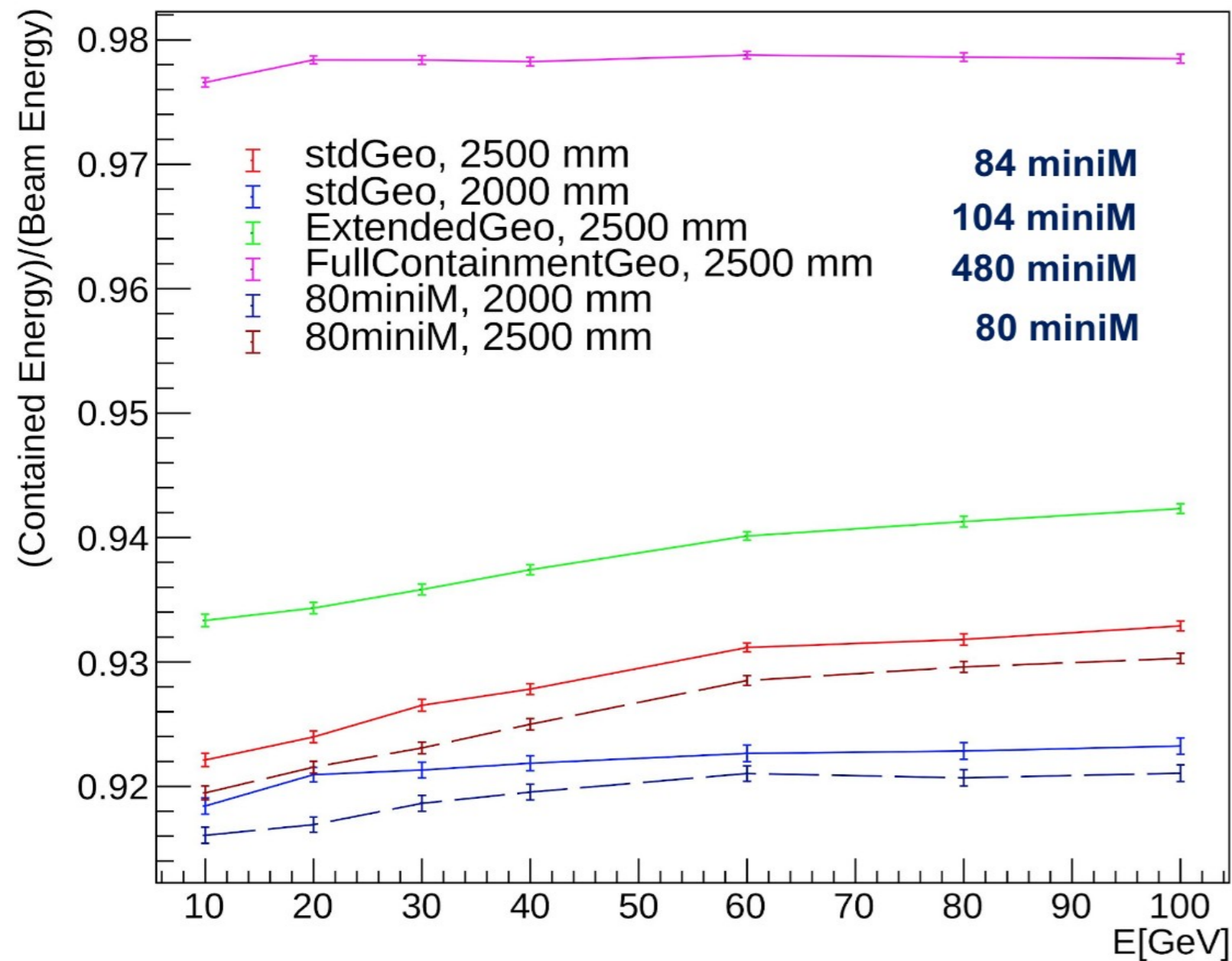


ExtendedGeo



HiDRa containment++

Pion Containment in [10, 100] GeV Range



HiDRa containment++

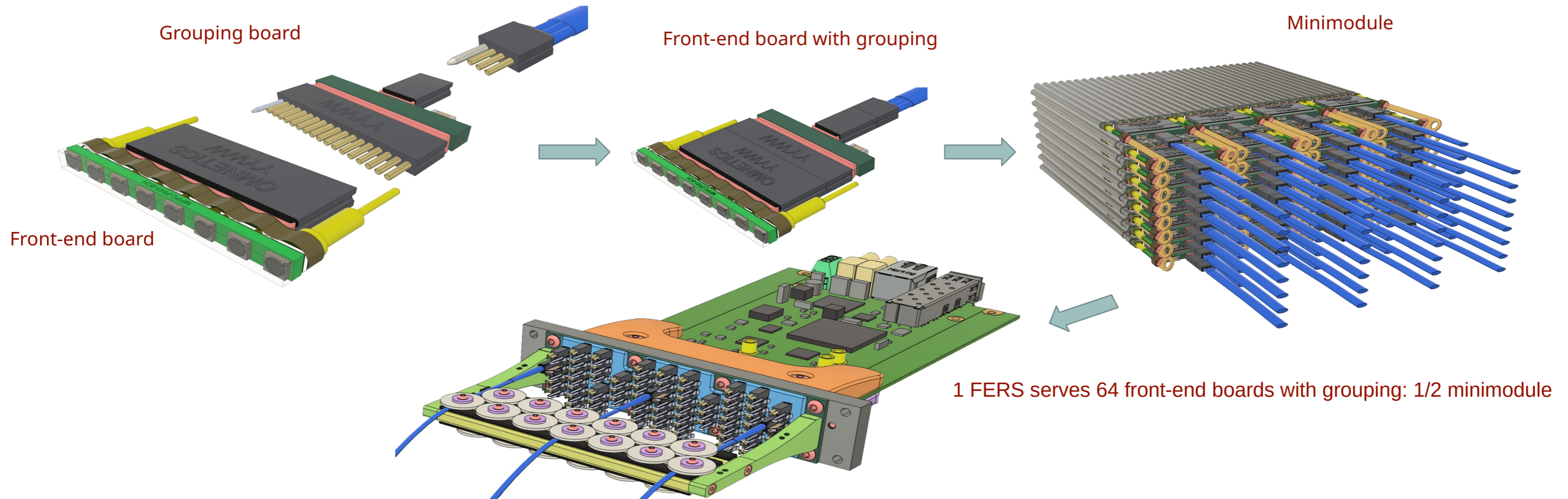
Additional funding request (on RD_FCC)

4 more (lead) modules, 4 readout towers each → 16 readout towers

1 PMT (scint) + 1 PMT (Cher) → 32 more PMTs → 45 k€

Elettronica SiPM

FEE-boards and cabling

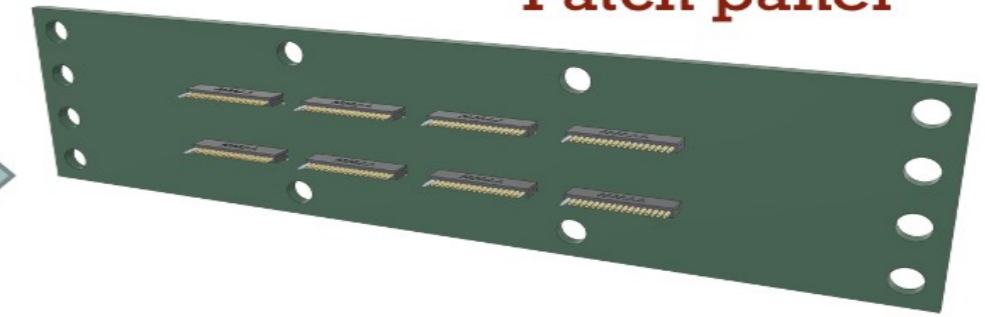
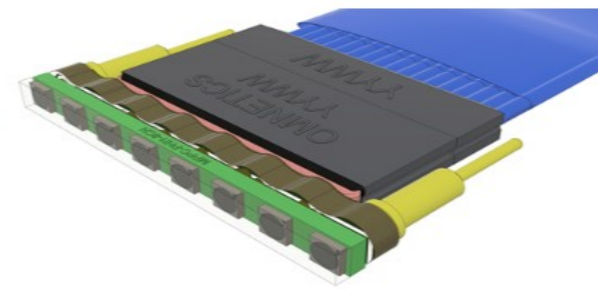
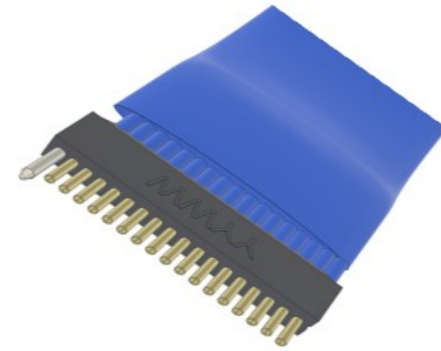
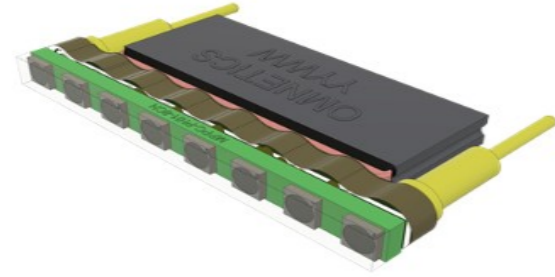


Baseline solution

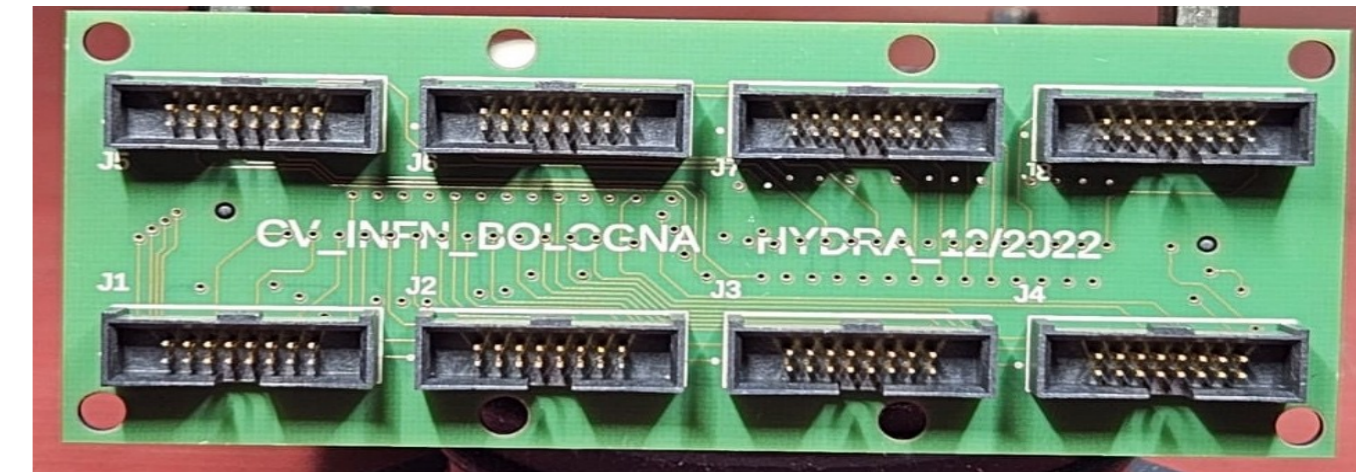
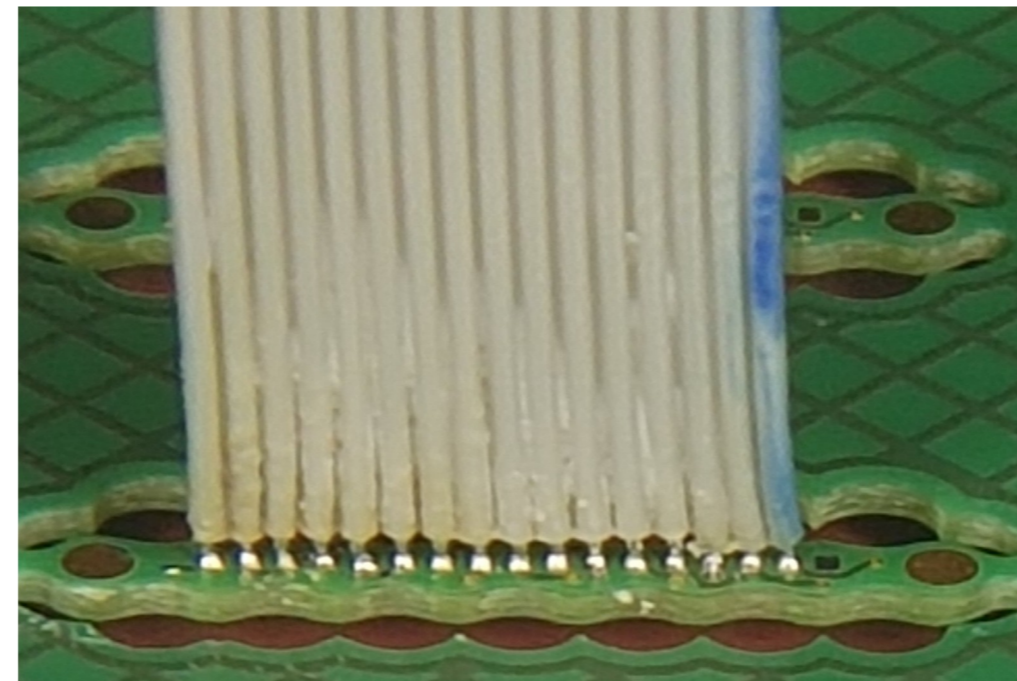
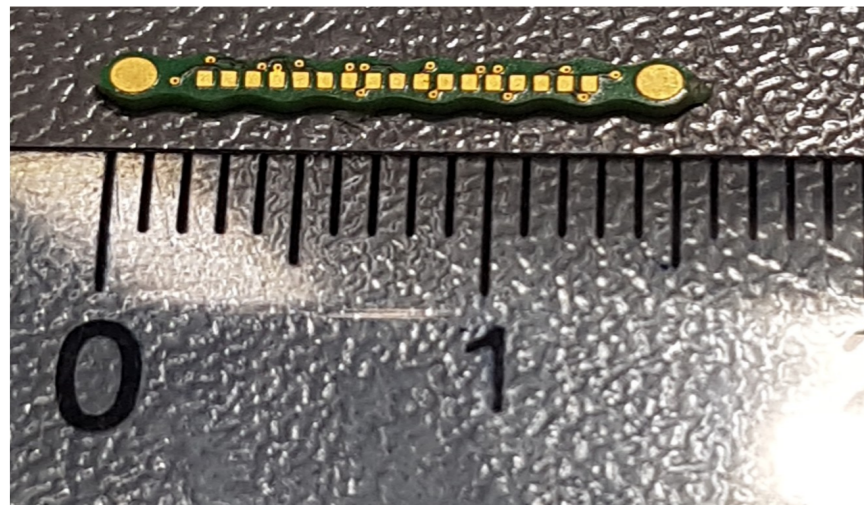
- ❑ Each bar of SiPMs operated at same voltage
- ❑ Signals from 8 SiPMs summed up grouping board
- ❑ 2 FERS operate 1 full minimodule
- ❑ 20 FERS operate high-granularity core of HiDRa prototype

From design to real components

The front-end board



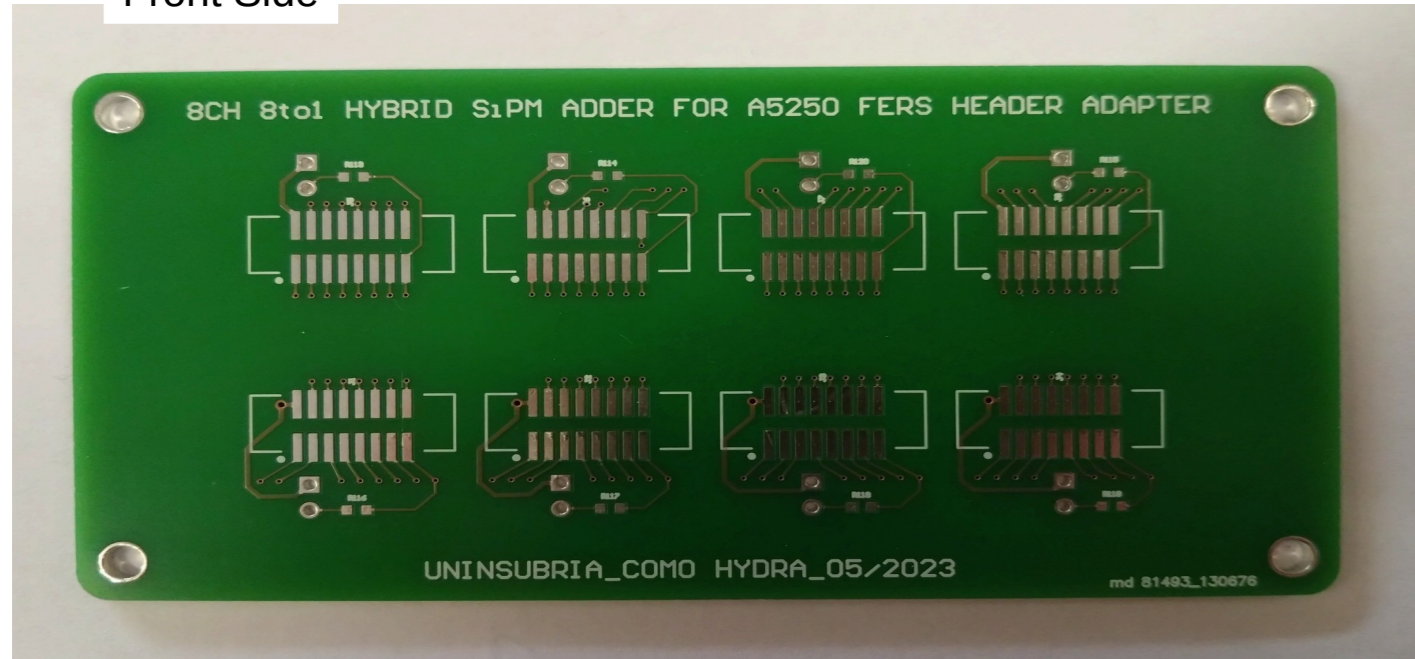
Patch panel



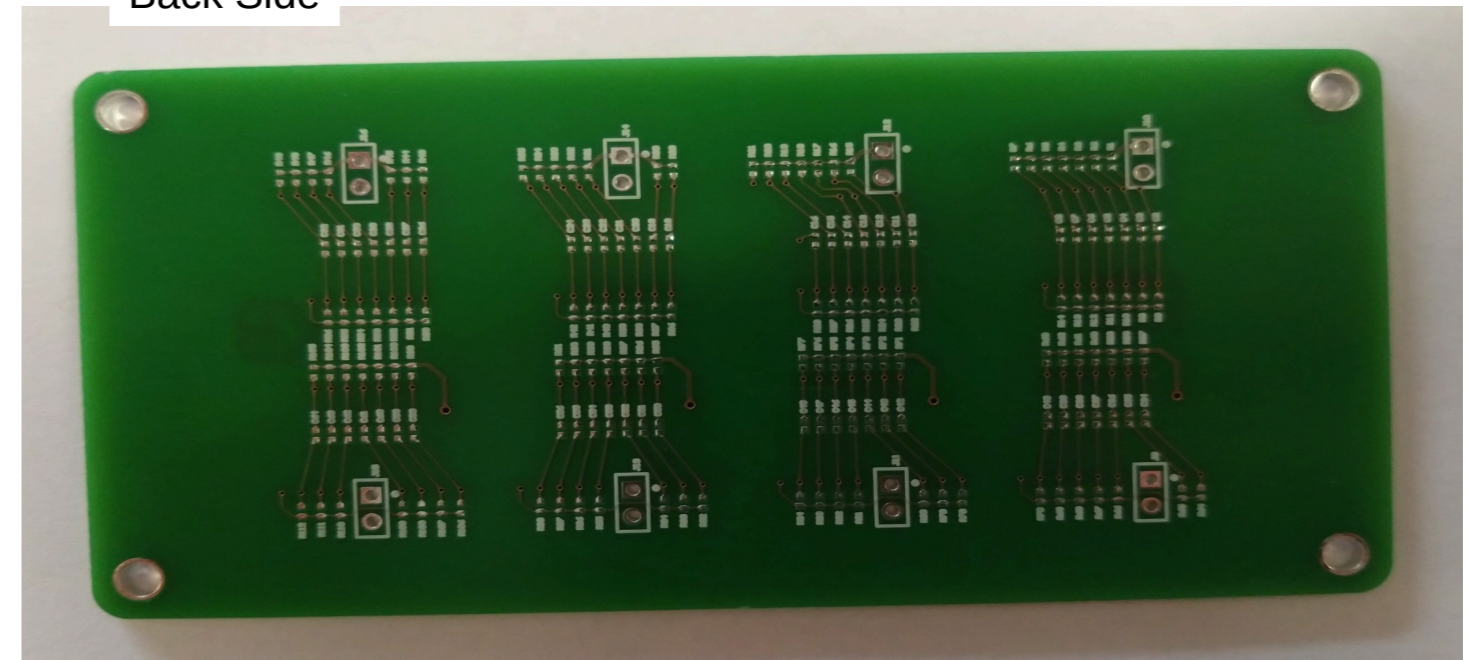
- ❑ 1 grouping board delivered (late) in July (2 designs to be compared)
- ❑ 17 front-end boards delivered (late) in July (3 missing used for tests)

Grouping board

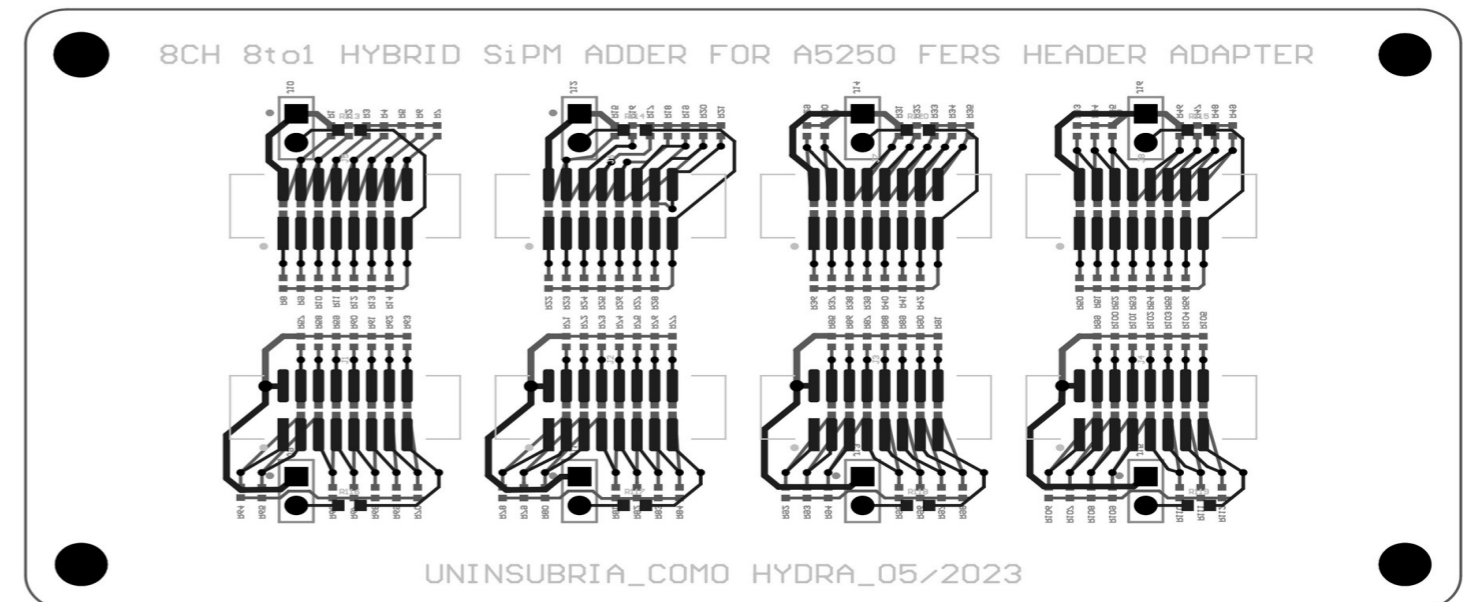
Front Side



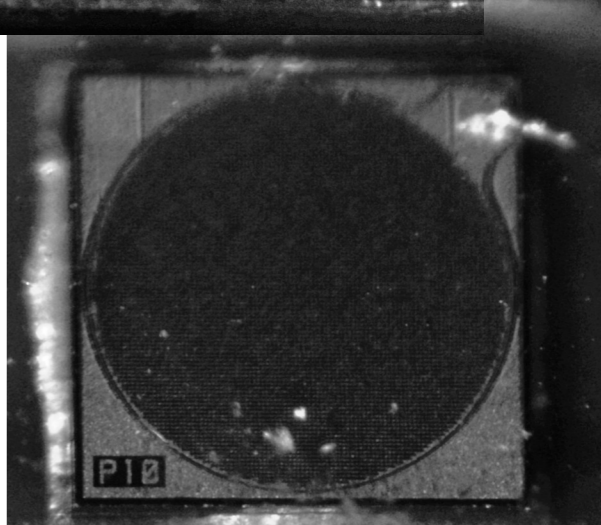
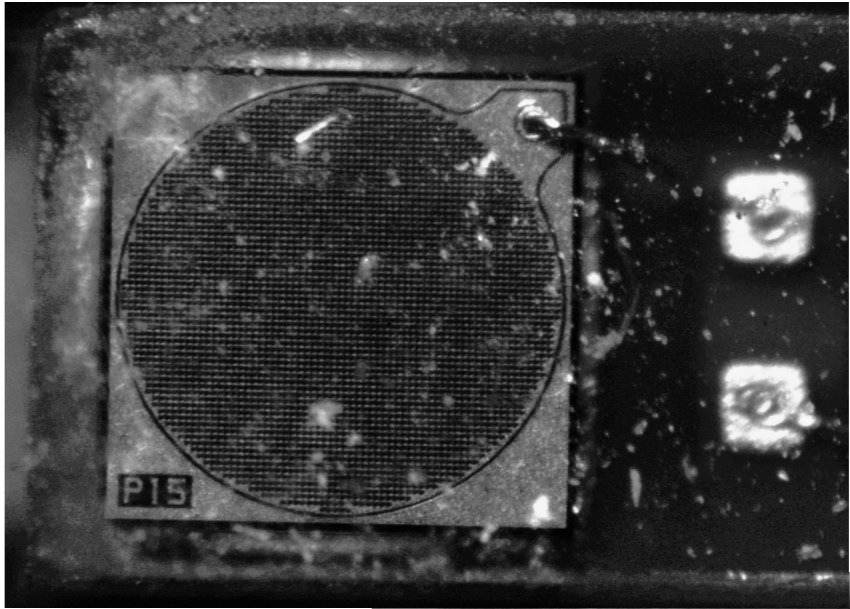
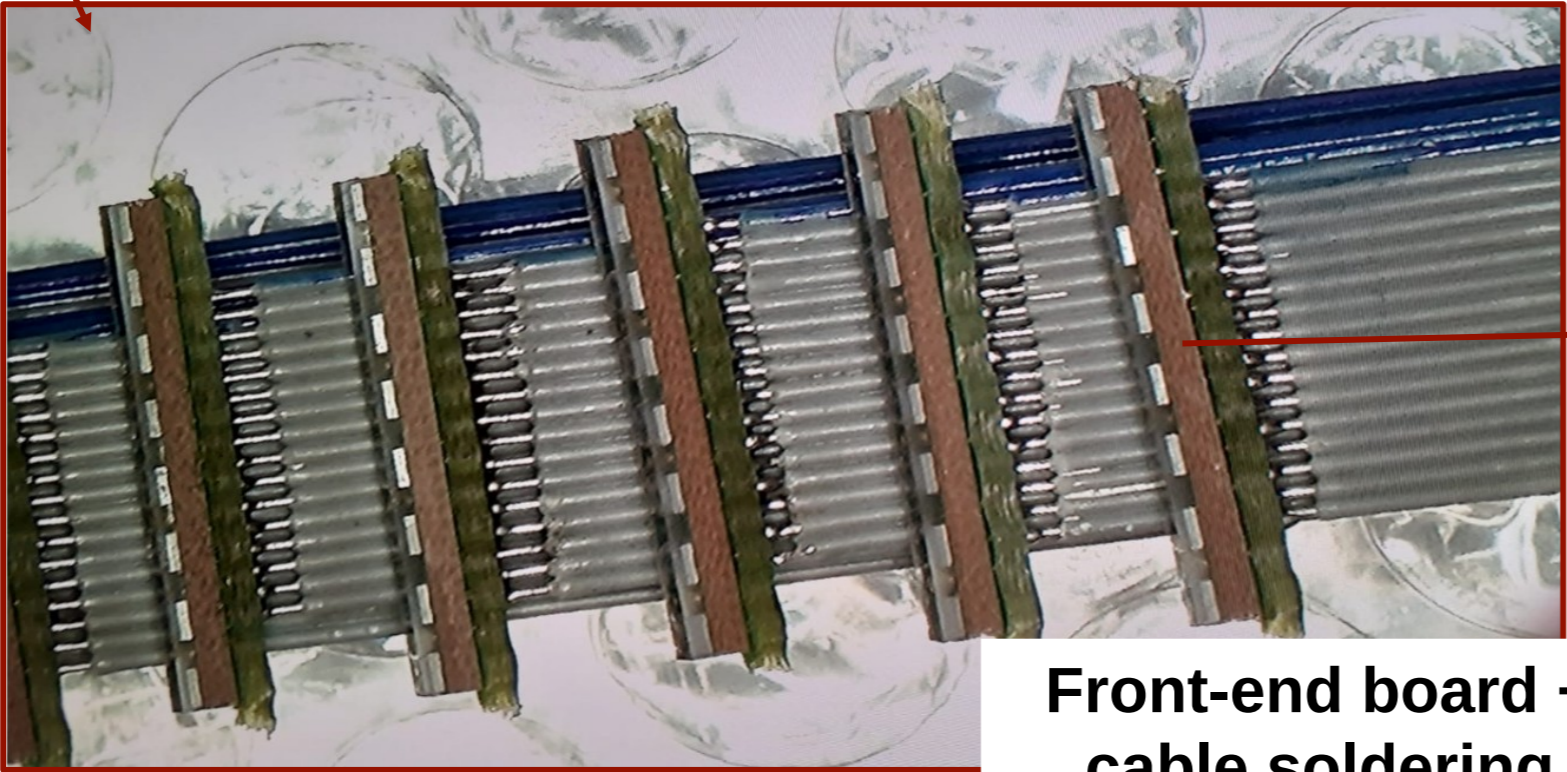
Back Side



- ❑ Grouping board only for test purposes. Once design frozen, it will be fully integrated
- ❑ Supports up to 8 front-end boards and is connected to FERS A5202 with patch-panel A5250
- ❑ Two grouping schema will be tested and compared
- ❑ Passive components will be mounted in lab to have maximum flexibility



Front-end boards



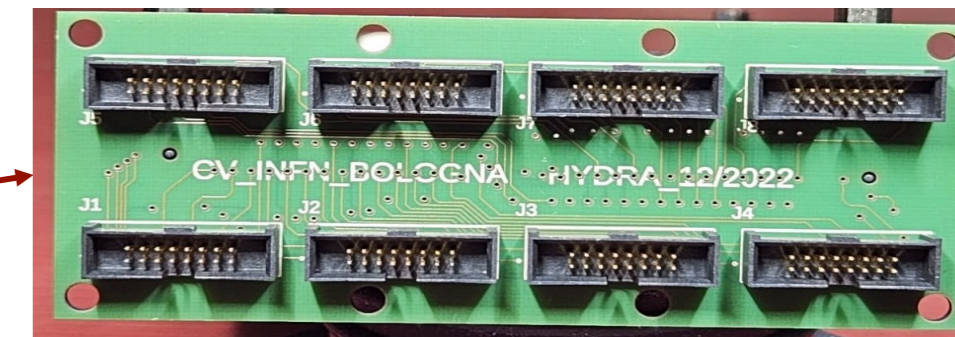
□ Same package equipped with SiPMs of different micro-cell sizes (10 μm and 15 μm)

Front-end boards (electrical tests)

Custom test board



Front-end board + cable



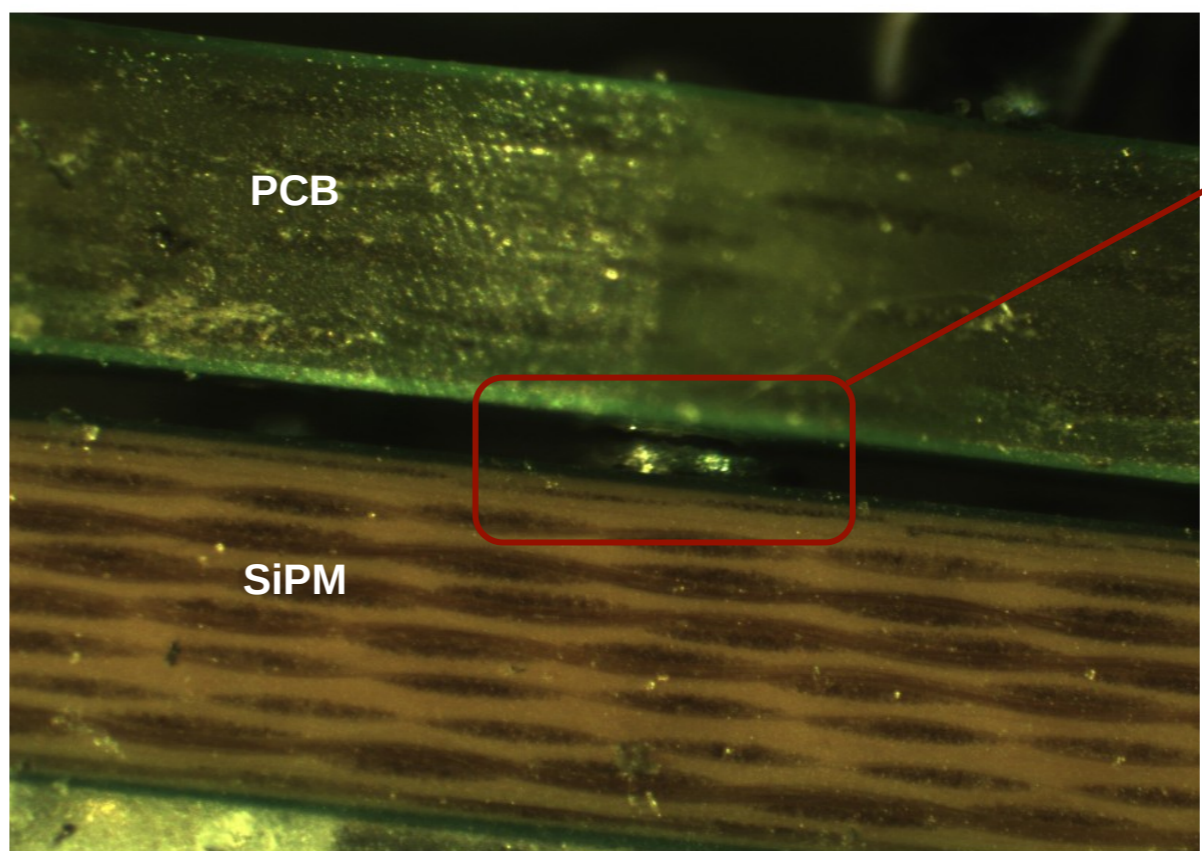
Patch panel

- ❑ Electrical test performed with multimeter, probing anode and cathode of each SiPM
- ❑ Identify shorts and opening in chain (i.e. bad SiPM soldering, cable damaged, bad front-end-board-to-cable soldering or bad connector crimping)
- ❑ Visual inspection to identify where defect is located
- ❑ Test needed also to qualify collaboration with company used for assembly

Electrical test report

Number	Sell size	Status	OK mark
P10-0	10	1ch NC(PCB)	
P10-1	10	OK	+
P10-2	10	OK	+
P10-3	10	OK	+
P10-4	10	OK	+
P10-5	10	2ch NC(PCB)	
P10-6	10	1ch NC(PCB)	
P10-7	10	OK	+
P15-0	15	bad crimping	
P15-1	15	OK	+
P15-2	15	OK	+
P15-3	15	2ch NC(PCB)	
P15-4	15	3ch NC(PCB)	
P15-5	15	OK	+
P15-6	15	1ch NC/1ch SC	
P15-7	15	OK	+
P15-8	15	OK	+

PCB-to-SiPM connection (side view at microscope)



Tiny air gap (visible at microscope) responsible for missing connection (NC)

Discussion with company needed to identify problem source and possible solution

Costi assemblaggio (su HiDRa2)

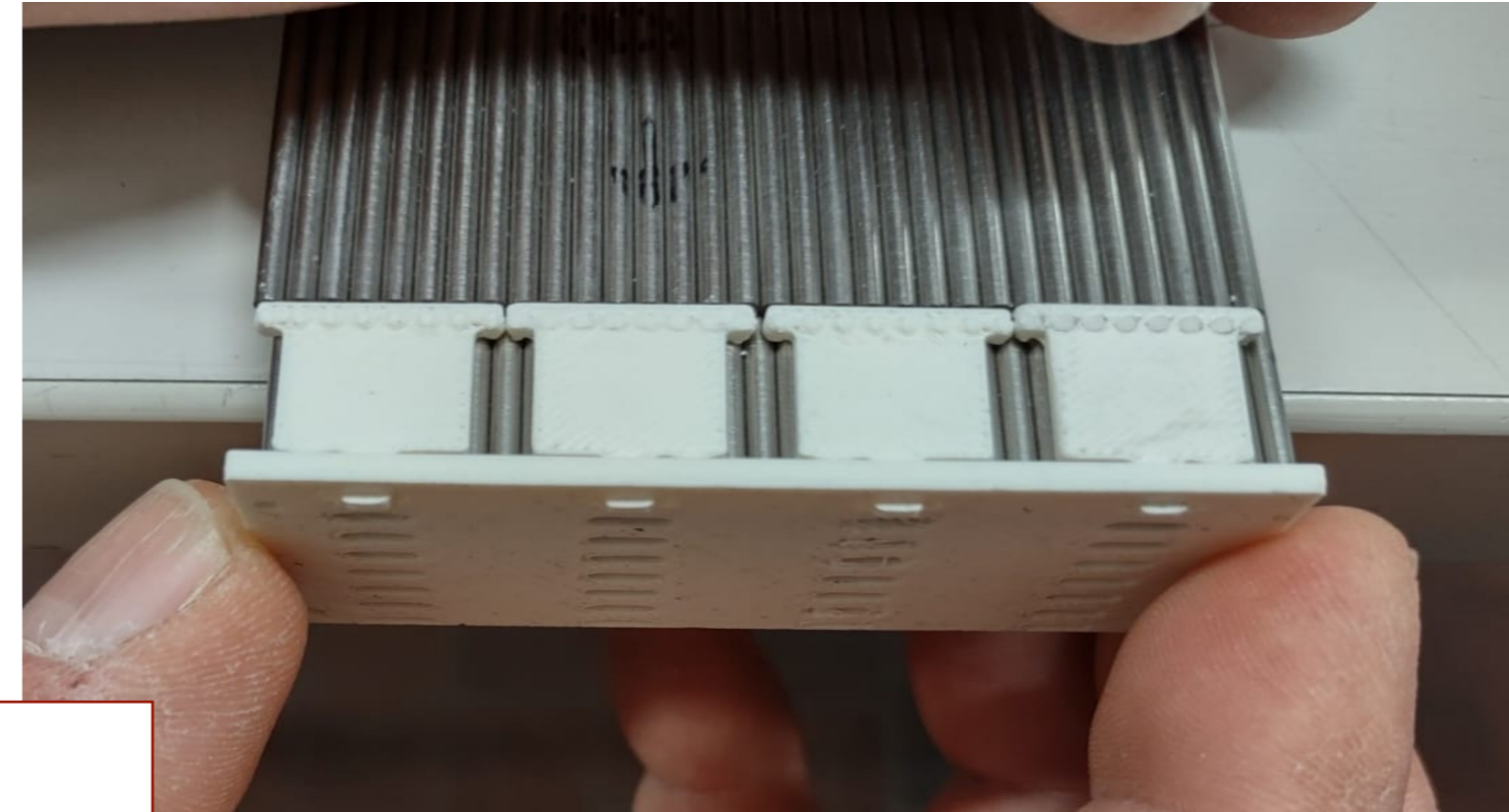
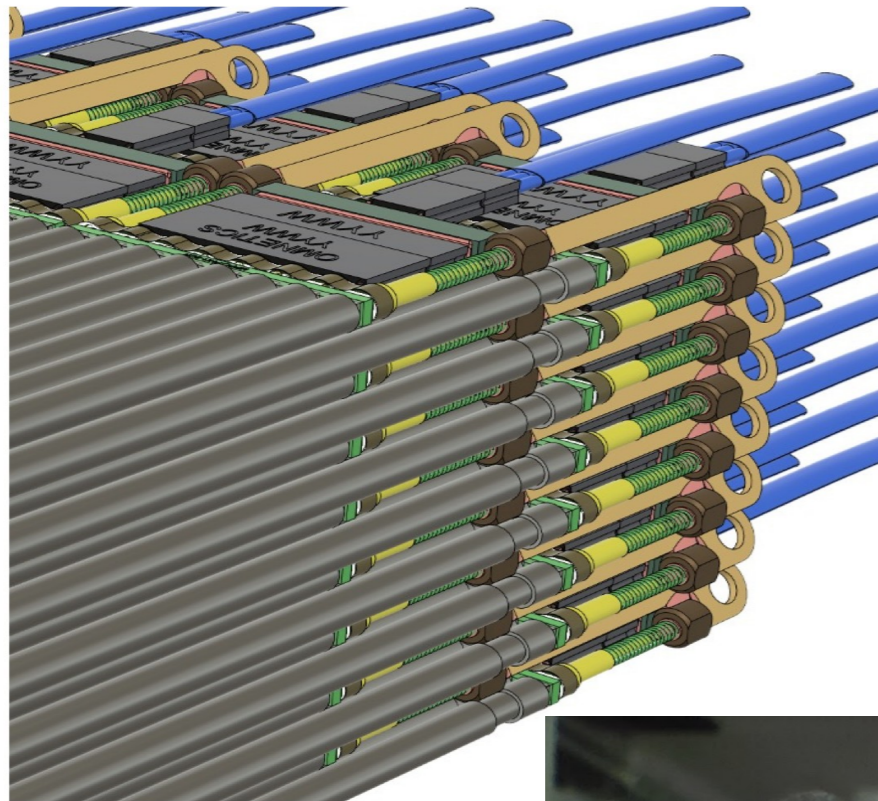
- 1344 front-end board da assemblare

- Assemblaggio (offerta azienda):
 - Connessione SiPM – front-end board (SMD connection): 7.5 €/pz (10 k€)
 - Saldatura cavo – front-end board: 26.5 €/pz (36 k€)
 - Clipping connettore: semplice, da fare in casa (0 k€)

- Considerazioni:
 - Vista la difficoltà della procedure, crediamo valga la pena contattare qualche azienda più grande per la connessione SMD + verifica saldature → sono operazioni standard e pensiamo sia possibile ottenere una riduzione dei costi
 - Saldatura cavo, potrebbe essere fatta in casa se ci fosse disponibilità nelle sedi (tutt'altro che ovvia)

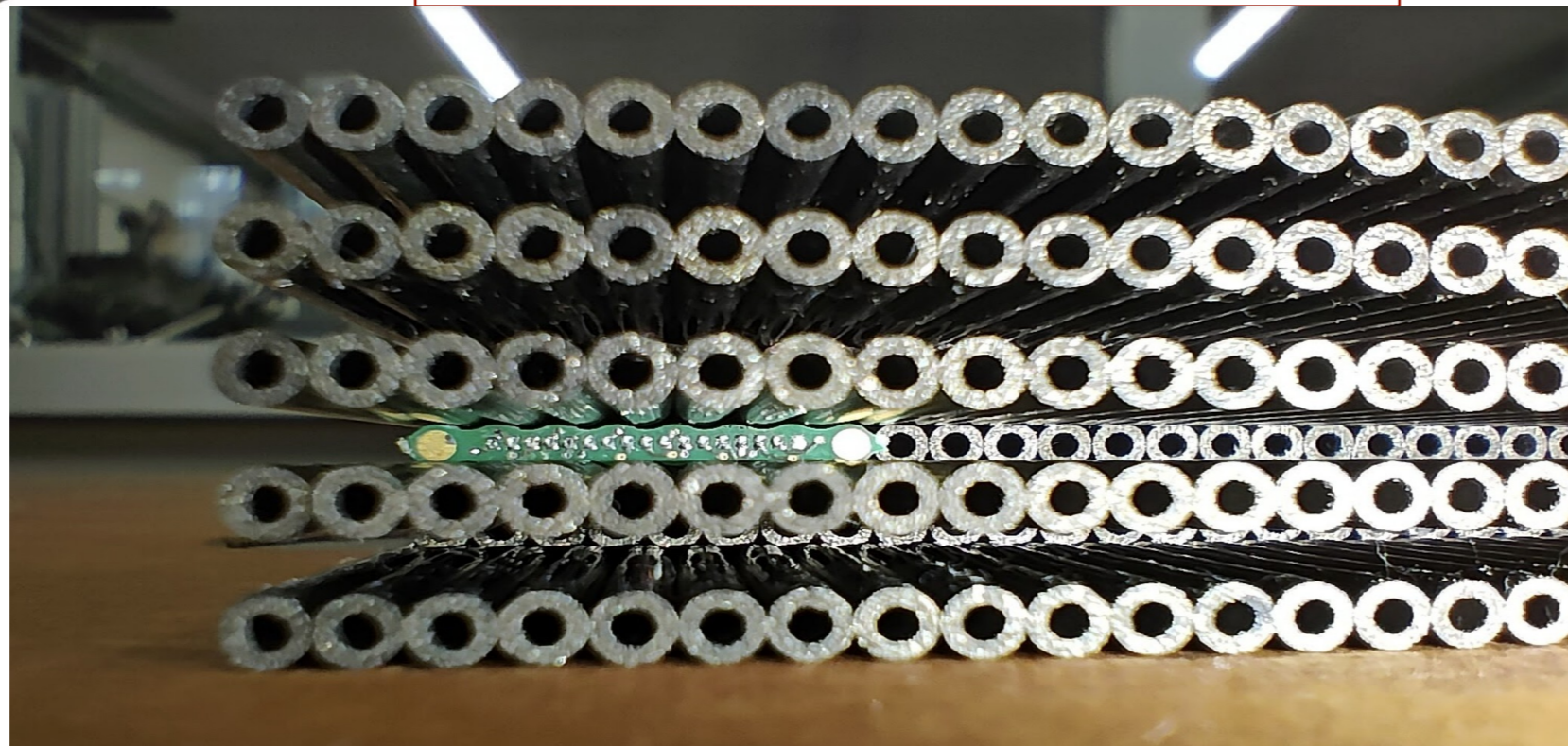
HiDRa R&D: mechanical integration

Very preliminary!



Board Integration Test

First tests with dummy components



FCC mid-term review

Sottomesse 5 note + 1 pending

- Dual-Readout Calorimetry for Future Experiments Probing Fundamental Physics
- Exposing a fibre-based dual-readout calorimeter to a positron beam
- Particle flow with a hybrid segmented crystal and fiber dual-readout calorimeter
- New perspectives on segmented crystal calorimeters for future colliders
- Preliminary cost estimate of the IDEA dual-readout calorimeter system

In corso di sottomissione:

- Performance of the IDEA dual-readout calorimetry in the identification and reconstruction of complex final states from tau hadronic decays with DNN

Conclusioni

- ❑ Consegna materiale iniziata → warming up faticoso ma speriamo sia servito a oliare le procedure
 - Ci sono ritardi ma ancora non pregiudicano il piano triennale della Call

- ❑ Un paio di extra-costi (su HiDRa2) da quantificare → contiamo/speriamo di riuscire a contenerli

- ❑ Miglioramento del contenimento possibile ma servono 32 PMT extra → richiesta su RD_FCC

- ❑ Due nuovi piani di sviluppo:
 - Calorimetria EM con cristalli dual-readout → Marco
 - Digital SiPM (era nel progetto iniziale della Call) → Lodovico

Tutte attività che rientrano nella roadmap ECFA per detector R&D (DRD 6 + DRD 4)

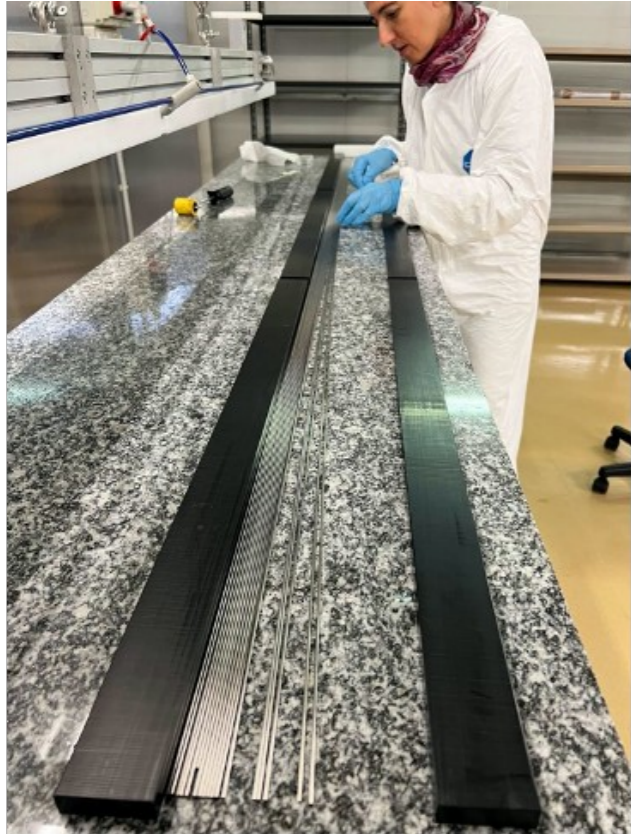
→ **R&D considerati strategici per future EWK/Higgs factory**

→ **sinergie internazionali molto forti ...**

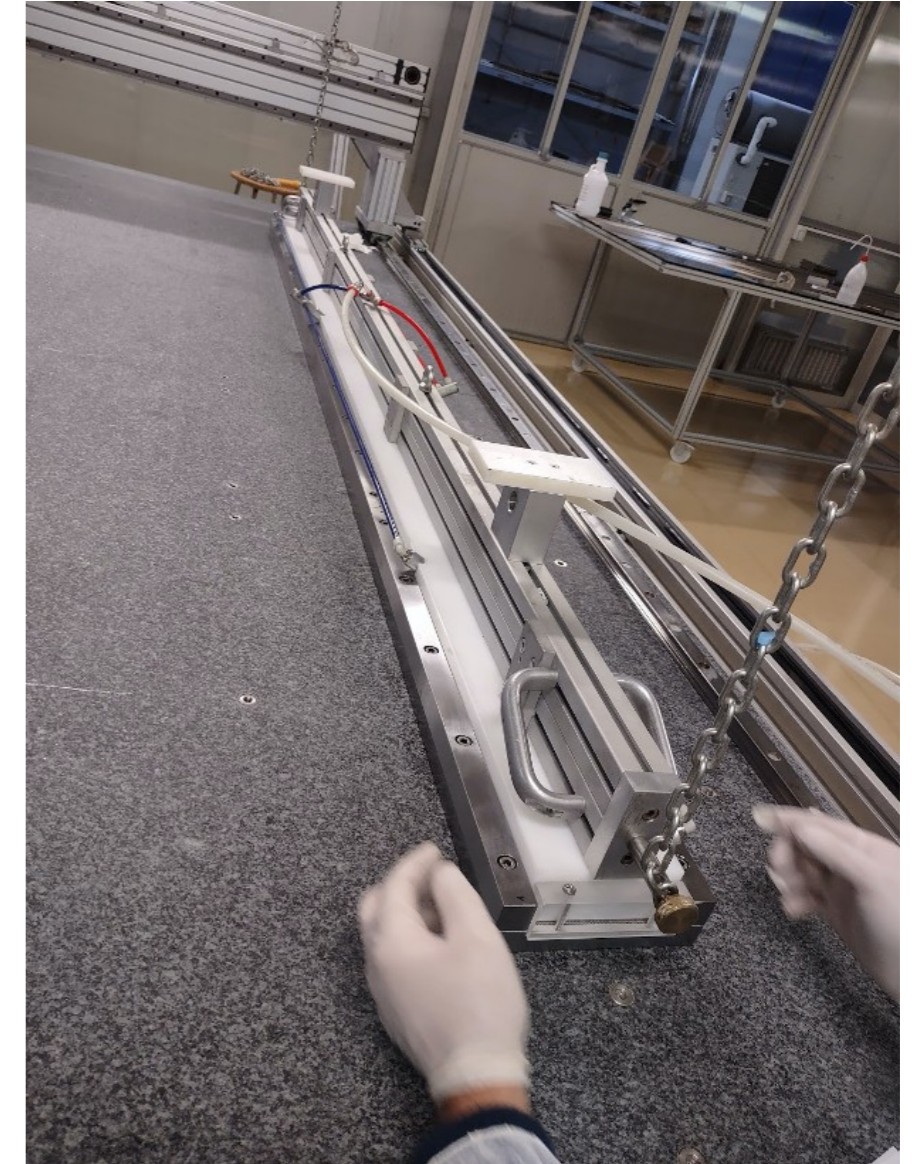
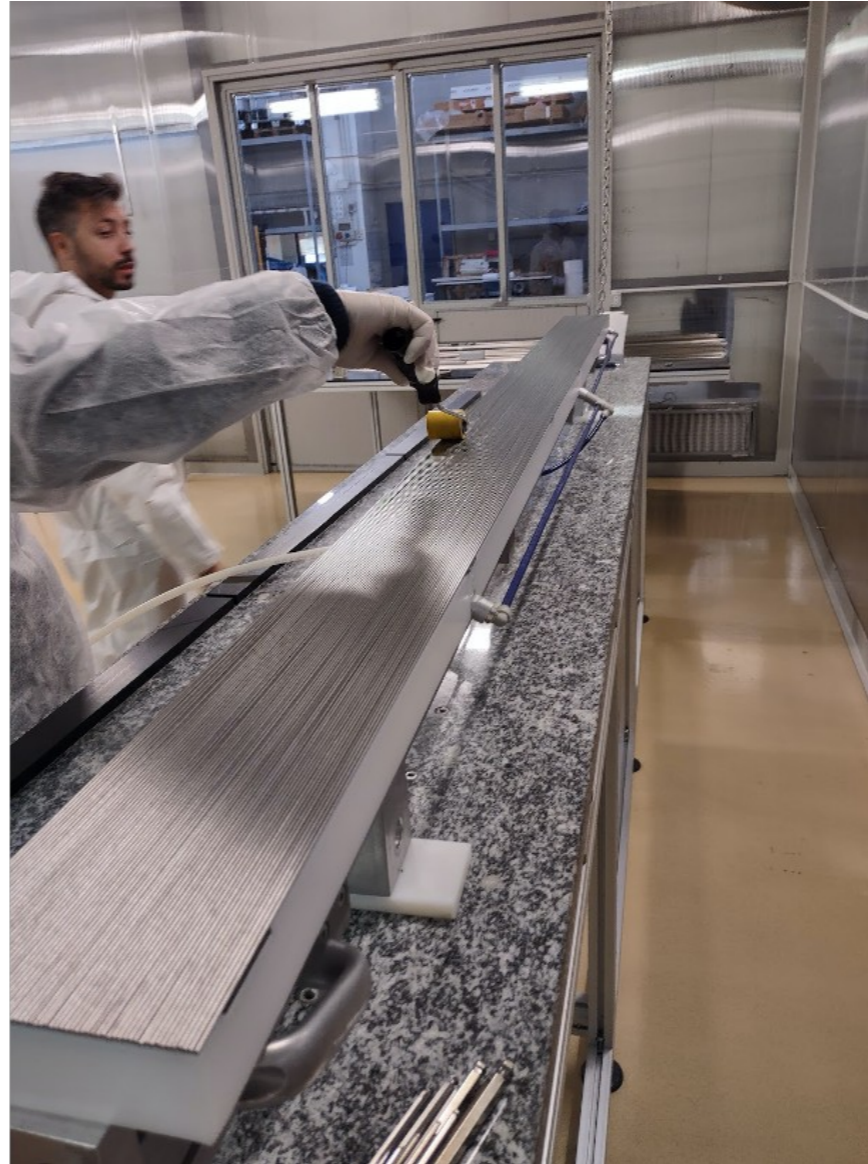
- ❑ Last but not least: testbeam con prototipo 2020 a H8 (28 giugno – 5 luglio) → condizioni fascio molto migliorate

Backup

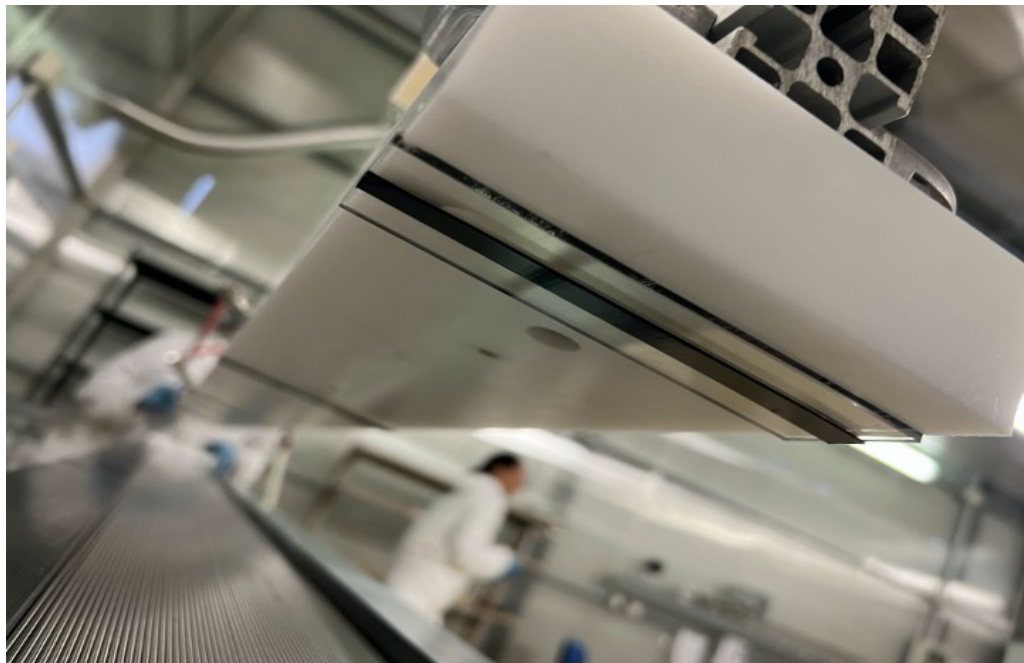
Module Construction Technique



tube aligned
in the reference
tool



Stiffback-like technique for tube handling,
glueing and positioning in the assembly tool



Vacuum + double-sided
tape for tube handling

Schema di produzione

- Day 0:
 - Preparazione tubi e tool
- Day 1:
 - Incollaggio Minimodulo N (~3h)
 - Preparazione fibre per Minimodulo N

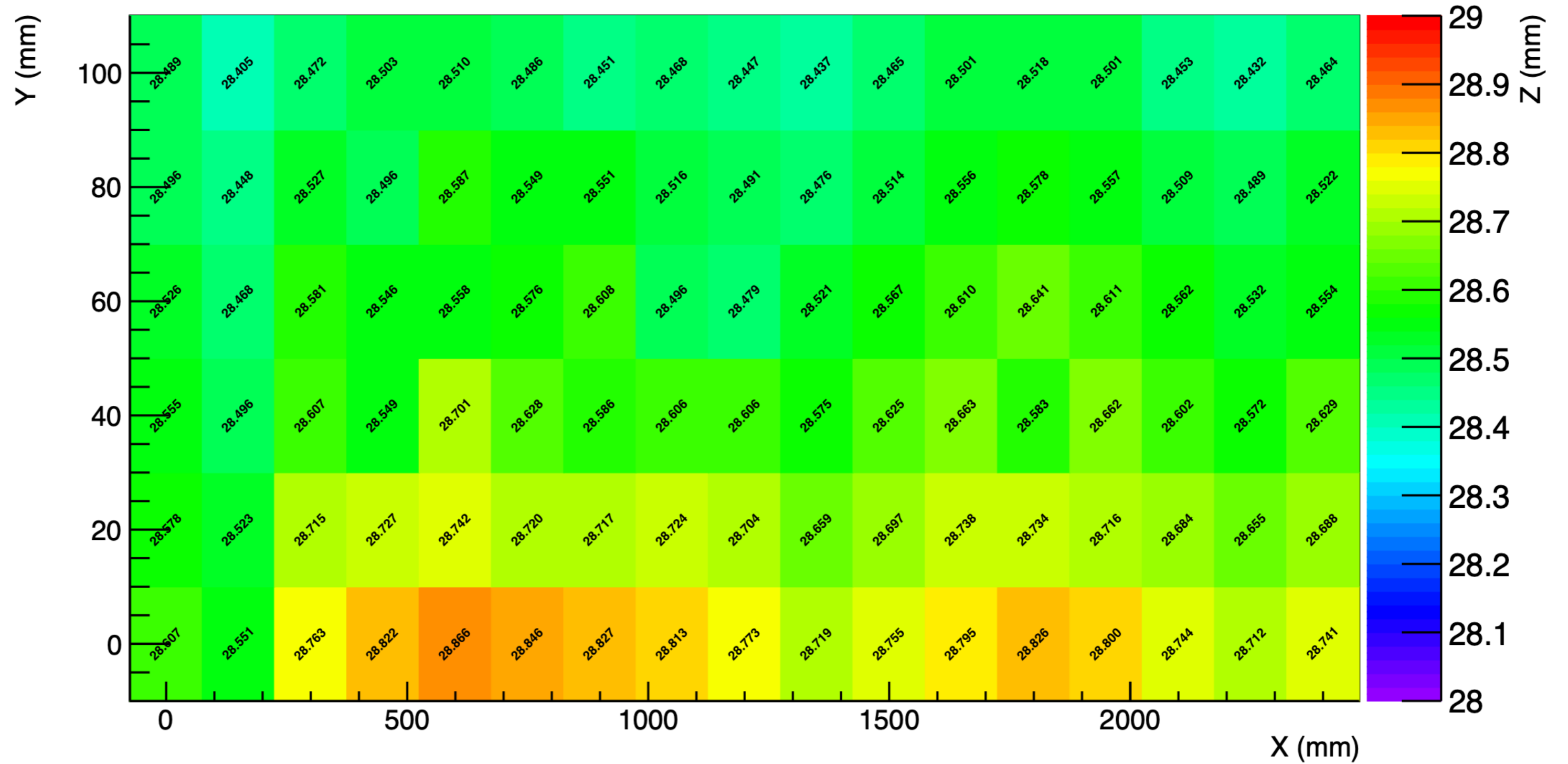
1 FTE fisico
+ 1 FTE tecnico meccanico

Preparazione progetto per PCTO
- Day 2:
 - Preparazione tubi per Minimodulo N+1
 - Apertura tool e spostamento Minimodulo N
 - QAQC Minimodulo N
- Day 3:
 - Incollaggio Minimodulo N+1
 - Fibre inserite nel Minimodulo N
 - Preparazione fibre per Minimodulo N+1

Minimodule-0 QAQC

tube OD:
2.026 mm

h_nom:
28.351 mm



Scintillating fibres

Totale capillari: $80 \times 1024 = 81920 + 5\% \text{ spare} = 86000$

Totale fibre (per tipo) = $(86000)/2 \times 2.9 \text{ m} = 125 \text{ km}$

Costi (best estimate): $24125 \text{ ¥} = \sim 170 \text{ k€} + \text{oneri (30\%)} = \sim 220 \text{ k€}$ [consegna al CERN $\sim 180 \text{ k€}$]

Fondi a disposizione: $120+51 = 171 \text{ k€}$ (CSN 5)



Quotation

Quotation Date 2022/10/26

Updated Date

Quotation Number KT22-1026-01

Methacrylic Products Department, Methacrylic Products Division

KURARAY TRADING CO., LTD.

TOKIYABASHI TOWER 21F, 2-6-4, Ottemachi, Chiyoda-ku, Tokyo, 100-0004, Japan

TEL: (+81) 3-6701-2032 FAX: (+81) 3-6701-2143

Email: Shota.Moriyama@kuraray.com

Dear Dr. Franco Bedeschi,

INFN

Italy

Terms : FCA Japan

Country of origin : Japan

Currency : Japanese Yen

Payment : Advanced Payment in T/T remittance

Quotation Valid : Until December 31st 2022

Description	Quantity (m)	Unit price(¥/m)	Total Amount	Delivery date	Others
[Plastic Scintillating Fiber]					
① SCSF-78, 1.0mmD 62,500m BJ	62,500	¥193	¥12,062,500	To be adjusted	SCSF-78 is subject to Japan's export regulations, so you will need to go through procedures such as reviewing your export license after placing your order.
② SCSF-78, 1.0mmD 62,500m BJ	62,500	¥193	¥12,062,500		
					Shipment date ① Before factory shutdown 2023 ② Before August 2024
Total	125,000		¥24,125,000		

Thank you for your request for a quotation of our products. We are pleased to quote as follows.

Clear fibres

Totale capillari: $80 \times 1024 = 81920 + 5\% \text{ spare} = 86000$

Totale fibre (per tipo) = $(86000)/2 \times 2.9 \text{ m} = 125 \text{ km}$

Costi (best estimate): ~ 40 k€ (consegna al CERN)

Fondi a disposizione: 49 k€ (CSN 1)

From: FRANK ALDINGER (IEU) <frank.aldinger@ivic-t.com>

Sent: Tuesday, February 14, 2023 10:08 AM

To: Franco Bedeschi <bed@fnal.gov>

Subject: ESKA / SK-40 / CERN CH

Dear Franco,

Please check and find our quote in below details :

ESKA	SK40-1500
Quantity	84 spools x 1.500 m = 126.000 m
Price	EUR 0.30/m as per sea freight consignment from Japan EUR 0.32/m as per air freight consignment from Japan
Delivery	DDP, delivered duty paid, CERN CH

Capillary tubes

- Got free sample of good quality
- Among lowest prices
- Proactive in looking for Italian PA compliant contract
 - contact with Daxel Italy (+10%, 40:60 customer:producer)
 - defining details in these days



Eastern Metal (HK) Industrial Co., Ltd.

To: Istituto Nazionale Fisica Nucleare
 Gabriella Gaudio,
Attn: PhD
From: Cynthia

Ref. No. : EMHK0903
Date: Sep,03rd,2022
Page: 1

Item	Product	Matirials	Dimensions	Unit Weight	Qty	T.weight	Unit Rate	Sum
				kgs/pcs	pcs	kgs	usd/pcs	usd
1	Capillary Tubing	304	2.0mm*0.45mm*2500m m	0.0434	87,000.00	3,779.00	0.364	31,710.03
Remark: external diameter 2mm (+- 0.050 mm) • internal diameter 1.1 mm (-0 + 0.1 mm) • length 2.5 m								

Price term: FOB China port
Payment term: TT,30% advance , Balance before shipping .
Documents: Manufacturer Test Certificate, Hydraulic test report, BL, CI, PL,COO
Technical Spec.: As above requirements.
3rd Party audit: As buyer specified.
Surface: Smooth surface, free from dirt, crack, pit, moisture, etc.
Package: Wooden Box
Deliver time 30 days
Validation 7 days
Origin: China.

Capillary tubes

Costi stimati:

- Materiale 31.7 k\$ (30 k€)
- +4% per mediazione Daxel (6% pagato da produttore) = 1.2 k€
- Trasporto (da valutare)
- IVA (22%) = 6.6 k€ → stiamo valutando consegna al CERN
- Dazi (25%) = 7.5 k€ → azzerati se acquisto rientrasse in contingenza UE

Totale (best estimate): ~ 31.2-45.3 k€ + trasporto

Fondi: 12 k€ (CSN 5)

→ mancano 25-40 k€ per poter lanciare ordine

Schedula

- Ordine ~ 3 week
- Consegna ~ 4 w produzione + 2 w importazione
- QAQC + pulizia in ultrasuoni ~ 4 w
 - **almeno 3 mesi da disponibilità fondi**
- Rate di produzione previsto
 - 5 minimoduli in 2 settimane → 80 minimoduli in 8 mesi
 - Include:
 - incollaggio assorbitore
 - inserimento fibre
 - incollaggio fibre e fresatura (per accoppiamento PMT)

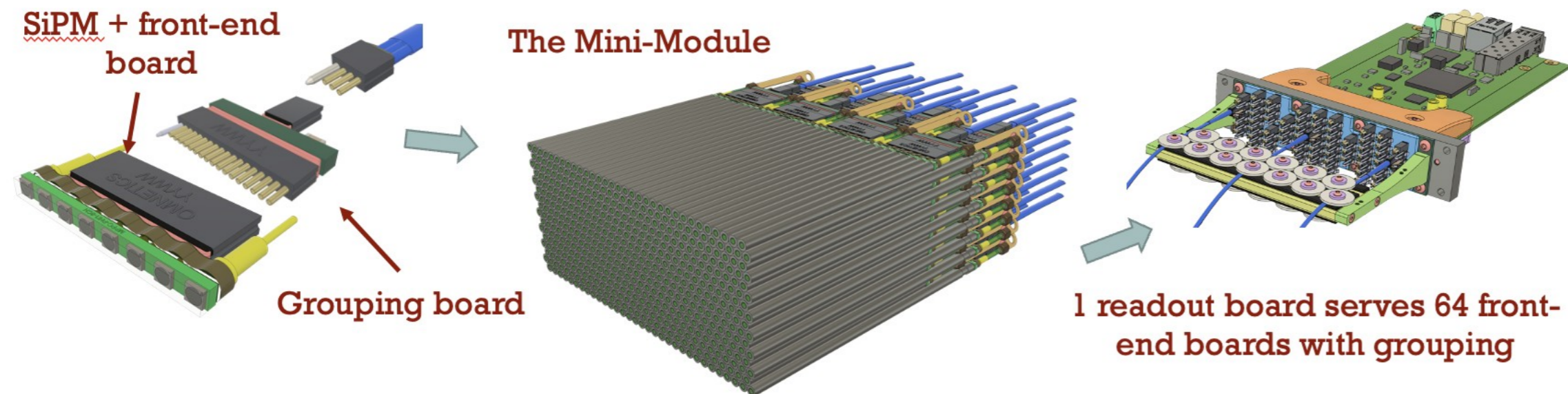
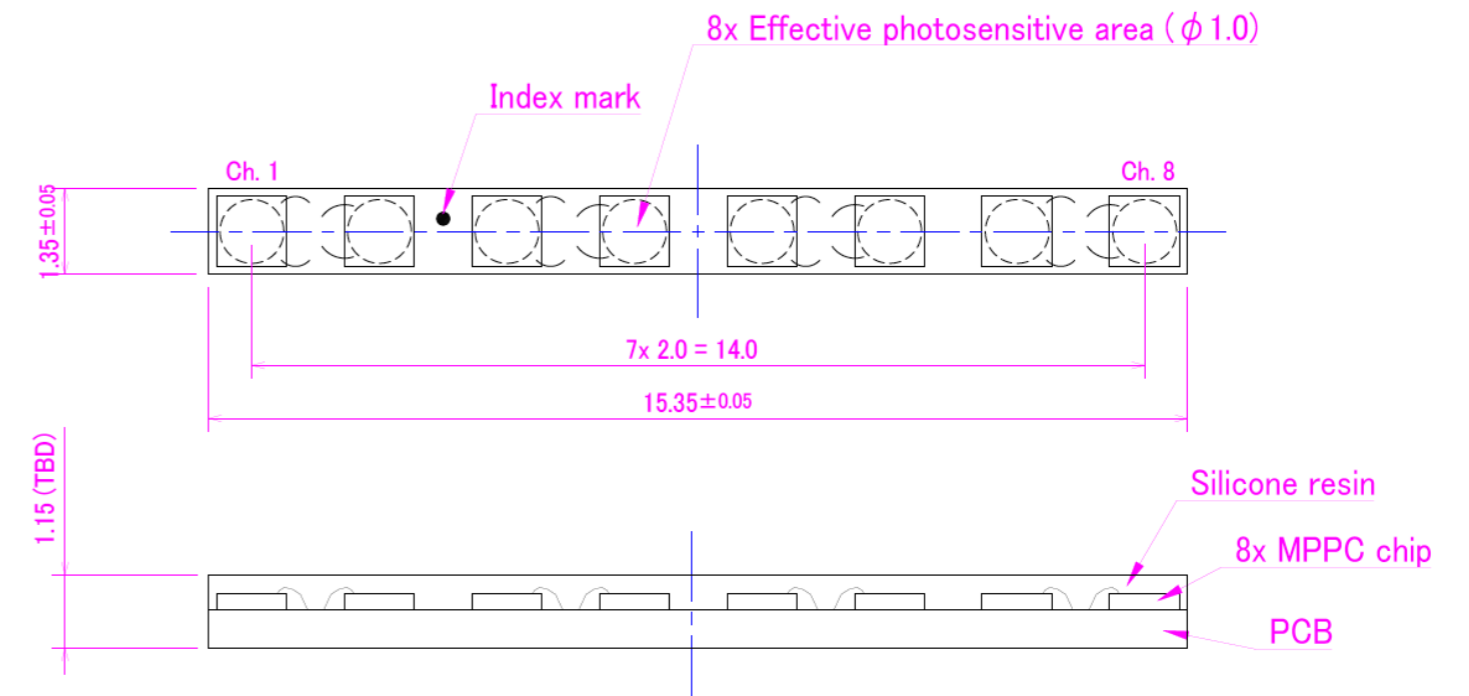
→ **complessivamente, un anno da disponibilità fondi**

Readout moduli alta granularità

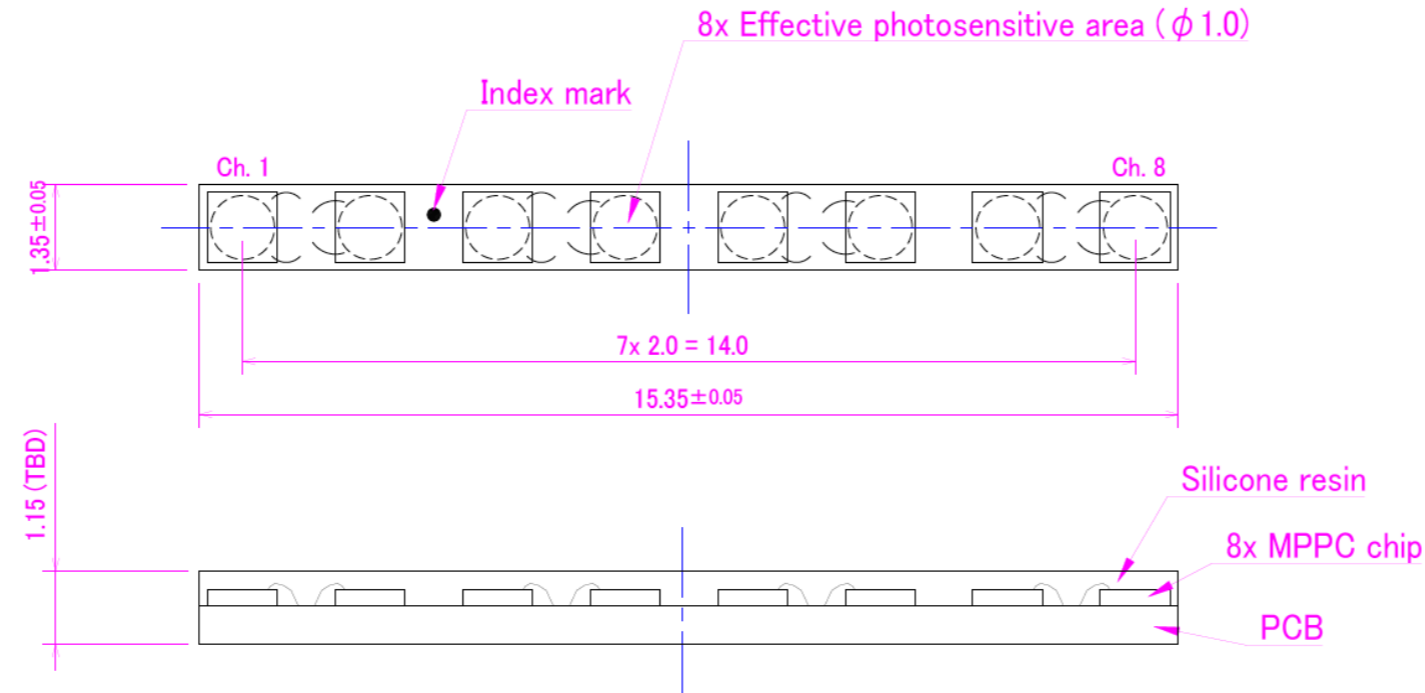
	Pezzi necessari	Già Disponibili	spare	Costo unitario	Costo totale	+ IVA	Assegnato 2023	Richieste 2024	commenti
Strip SiPM	1280	-	5%	48	64512	79 k	45 k		25 k restituiti nel 2022 e non riassegnati
A5202	20	9	-	5533	60863	75 k	35 k	40 k	6 acquistate su altri fondi
Data concentrator	1	1	1	-	-	-	-	-	acquistati su altri fondi

Moduli ad alta granularità

- SiPM necessari: 10240 → 1280 moduli (8 SiPM = 1 Modulo) + 5% spare = 1344 moduli
- Front-end board: 1344
- Grouping board + cavi: 1344
- Patch panel: 22
- Readout board (A5202): 20-22
- Data concentrator: 2



SiPM



- 20 moduli campione consegnati
- montaggio e qualifica a breve
 - 10 moduli con SiPM da $10 \mu\text{m}$
 - 10 moduli con SiPM da $15 \mu\text{m}$
- Mass production: 6/7 mesi con consegna di 2000 moduli /mese
 - consegna (presumibilmente) in unico batch salvo diversa richiesta da parte nostra

SiPM

Totale (best estimate): 65 k€
Fondi: 45 k€ (CSN 5)

→ mancano 20 k€ per poter lanciare gara
restituiti 25 k€ nel 2022 non riassegnati

Mail Hamamatsu:

...

Ti confermo che il prezzo della board con gli 8 SiPM per la quantità totale 1344 pezzi è 40 €/pz sia che scegliate di procedere con il pixel pitch da 10 μm sia da 15 μm .

Nel caso invece prendeste metà sensori con pixel pitch da 10 μm e metà da 15 μm il costo è 48 €/pezzo. Purtroppo non possiamo considerare la quantità totale.

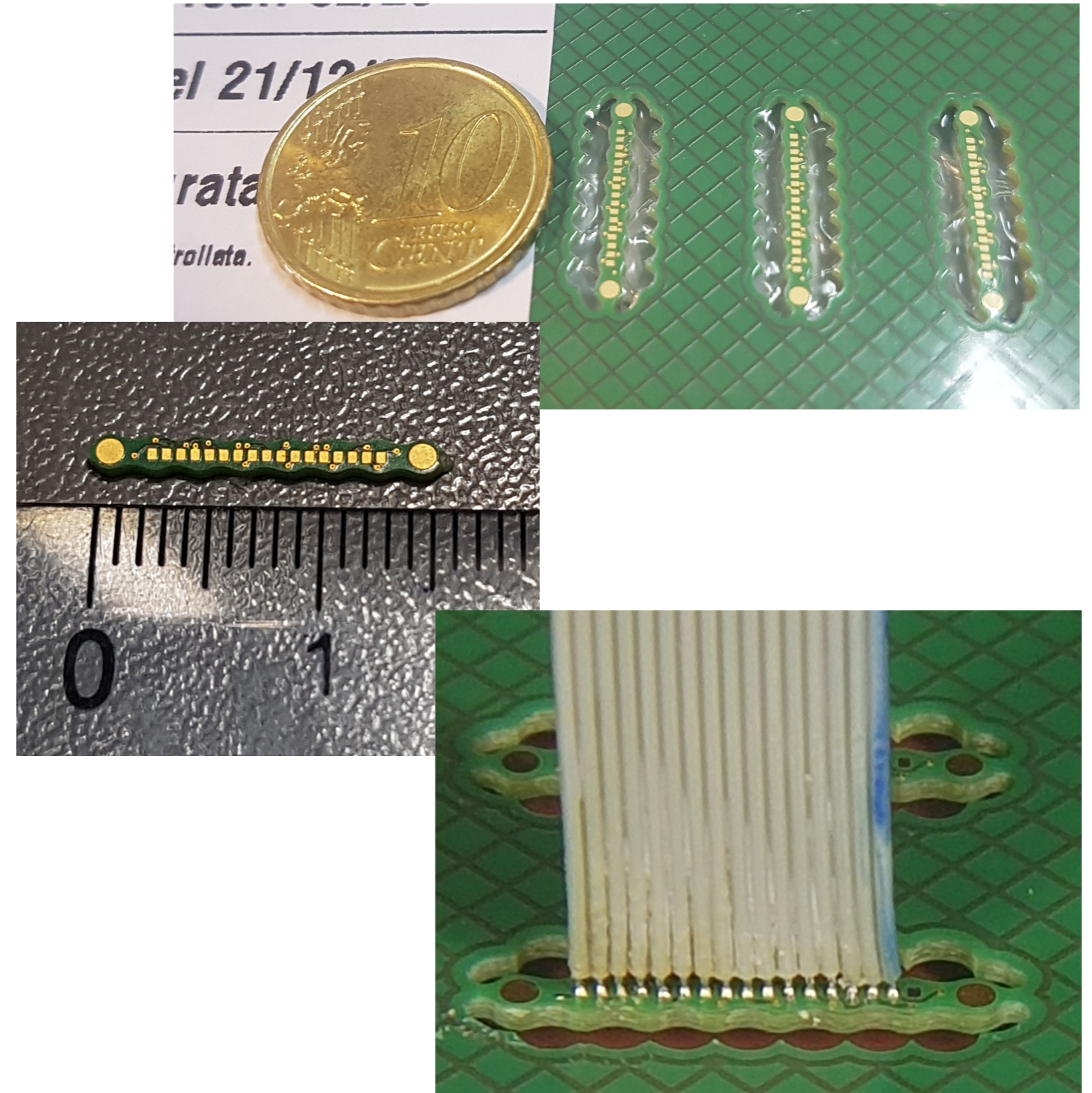
...

Ing. Simona Ferrulli

Sales Engineer

Front-end board

- prodotte front-end board per prototipi
- in attesa montaggio componenti
- sostituito connettore con saldatura diretta cavo + colla epossidica di rinforzo (soluzione ora ritenuta più robusta)
- identificata l'azienda per montaggio SiPM + saldatura cavo (ordine in finalizzazione)
 - tempi di produzione prototipo ~2 settimane
 - pronti per qualifica



Patch panel

- design completo e ordine fatto
- consegna prototipo attesa nei prossimi giorni

Schedula moduli alta granularità

- setup per qualifica catena di readout del modulo ad alta granularità verso primi di maggio
- apertura gara non appena fondi sufficienti disponibili
- tempi di consegna dominati dai 6/7 mesi per consegna SiPM
- qualifica dei SiPM su 2 sedi (Milano + Catania)
- tempi di qualifica full-speed:
 - 640 moduli per sede
 - 64 moduli connessi a una FERS e qualificati contemporaneamente
 - 1 settimana per qualifica gruppo (misura di V breakdown + equalizzazione guadagni)
 - 10 settimane full-time

FERS

Servono 20 schede FERS più un paio di spare, ne abbiamo 9

Totale per schede mancanti (best estimate): 75 k€

Fondi: 35 k€ (CSN 5)

PMT

In casa 96 × Hamamatsu R8900 (eredità RD52), ne servono altri 44 → nuovo modello R11265

Totale (best estimate): 65 k€ (consegna al CERN)

Fondi: 65 k€ (CSN 5)

Pos.	Codice prodotto Descrizione	Quantità (pcs)	Prezzo unit. EUR	Importo netto EUR
1.1	R11265-200 PHOTOMULTIPLIER TUBE ROHS:C	20	1.160,00	23.200,00
2.1	E11807 D-TYPE SOCKET ASSEMBLY ROHS:C	44	240,00	10.560,00
3.1	R11265-203 PHOTOMULTIPLIER TUBE TEMPI DI CONSEGNA: R11265-200: 2,5mesi DRO per 10pz/mese;R11265-203: 3,5mesi DRO per 4-10pz/mese; E11807: 1,5 mese per 20pz/mes 5mesi per 21-44pz/mese ROHS:C	24	1.300,00	31.200,00
			Totale IVA esclusa	64.960,00

Stima costi CORE e finanziamenti

	stima iniziale	stima attuale max.	stima attuale min.	assegnato csn 5 2022 + 2023	assegnato csn 1	deficit max.	deficit min.
fibre chiare	65	49	40		49	0	-9
fibre scintillanti	148	220	180	171		49	9
SiPM	75	79	65	45		34	20
FEE + cavi + montaggio	8	8	8	8		0	0
Readout	90	90	90	50		40	40
PMT	72	79	65	65		14	0
capillari	120	55	35	12		43	23
totale	578	580	483	351	49	180	83
CSN 5	578	531	443	351	0	180	92
CSN 1	0	49	40	0	49	0	-9

Totale fondi CORE assegnati a oggi: 400 k€

finanziamento mancante > ~90 (50) k€ → può andare al 2024 ma necessari storni su voci critiche

Criticità

***** Mancano almeno 50-60 k€ per: capillari (25 k€), SiPM (20 k€), fibre scintillanti (10 k€) *****

mentre non sono urgenti acquisti di PMT (65 k€) e FERS (35 k€)

Senza aspettare finanziamenti aggiuntivi:

**proponiamo di rimandare acquisto PMT al 2024
e usare quei fondi per coprire criticità**

per poter iniziare quanto prima possibile procedure per ordini di capillari e SiPM

Timescale

Deadline limitata dai tempi di costruzione e assemblaggio meccanico capillari + fibre

→ **complessivamente, un anno da disponibilità fondi**

Last but not least

Risorse umane (elemento qualificante del meccanismo delle call):

progetto prevedeva 6 posizioni, ne abbiamo avute 2 (Bologna e Milano)

no way to (at least partially) recover?