

# Dual-Readout R&D Status and Plans



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*On behalf of the IDEA detector concept group*



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## Main objectives of the R&D plan for the next years

- ❖ Construction of an EM-size of a DR Calorimeter and evaluation of its performance
- ❖ Identifying and evaluating solutions at system level – Mechanics, Sensors, Readout scheme, Calibration
- ❖ Proof of concept of the dual-readout technique with respect to hadronic performance

## Execution in two steps

- ❖ Short-term plan – Construction and evaluation of a module with EM shower containment ( $10 \times 10 \times 100 \text{ cm}^3$ ) and a high-granularity core ( $3.5 \times 3.2 \times 100 \text{ cm}^3$ ) equipped with SiPMs
- ❖ Mid-term plan - design, construction and evaluation of a scalable system with hadronic shower containment, partially equipped with SiPM for cost/performance optimization

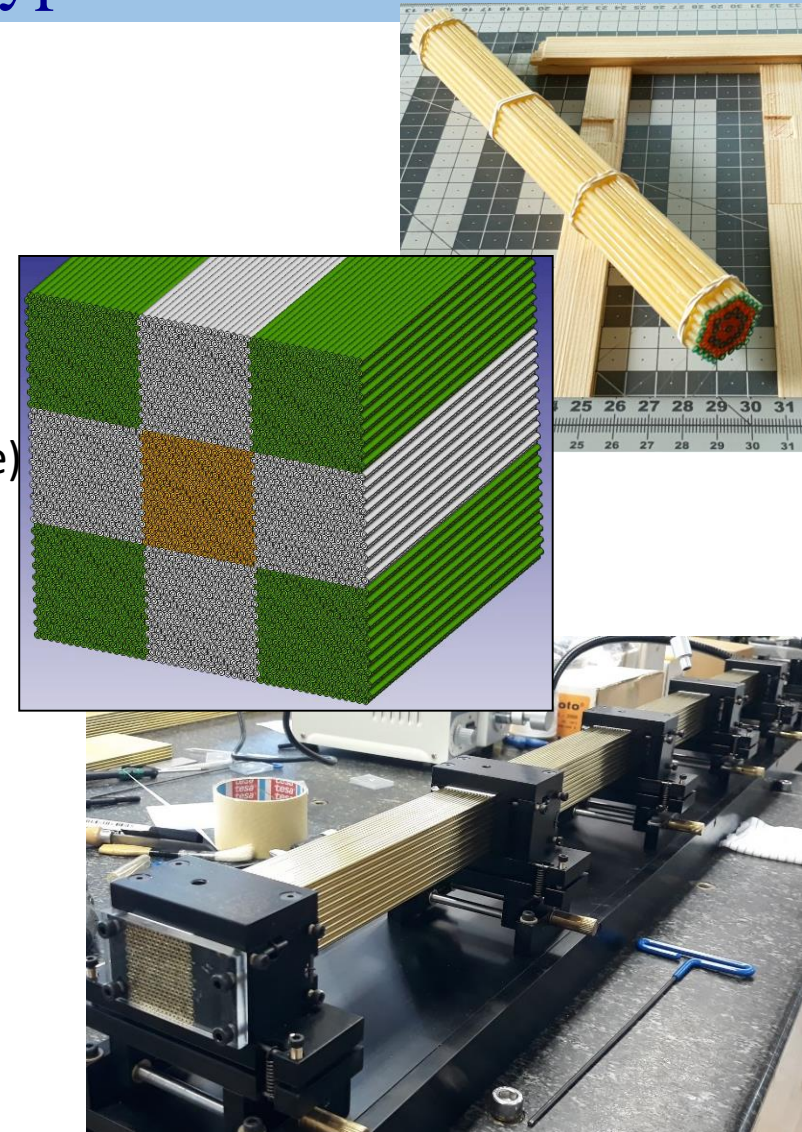
**The simulation input will be curtail to define the requirements and to guide the R&D process in the correct direction**

### Design requirements of EM prototype (10 x 10 x 100 cm<sup>3</sup>)

- ❖ Brass Capillaries with Outer diameter 2 mm and Inner diameter 1.1 mm
- ❖ 9 individual modules of 16 x 20 capillaries (160 Č & 160 Sc per module)
- ❖ Each capillary of the central module to be equipped with a SiPM (320 in total)
- ❖ The rests of the surrounding modules to be equipped with PMTs (2 per module)

### “Off the Shelf” capillaries

- ❖ Produced by Albion Alloys within the specifications OD 2.0 (+ 0.1 / - 0.0) mm, ID 1.1 (+ 0.1 / - 0.0) mm
- ❖ The requirement of the ID comes from the outer diameter of the fibers, while the OD can be tuned





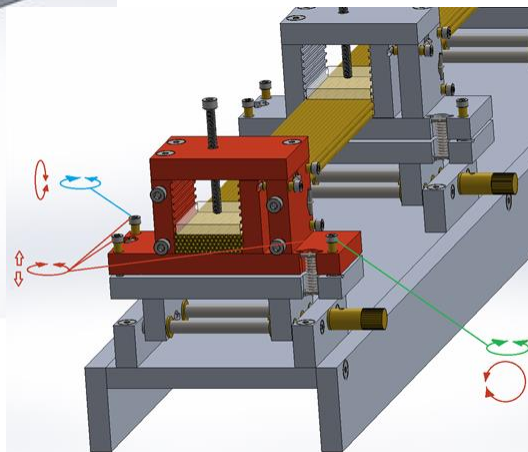
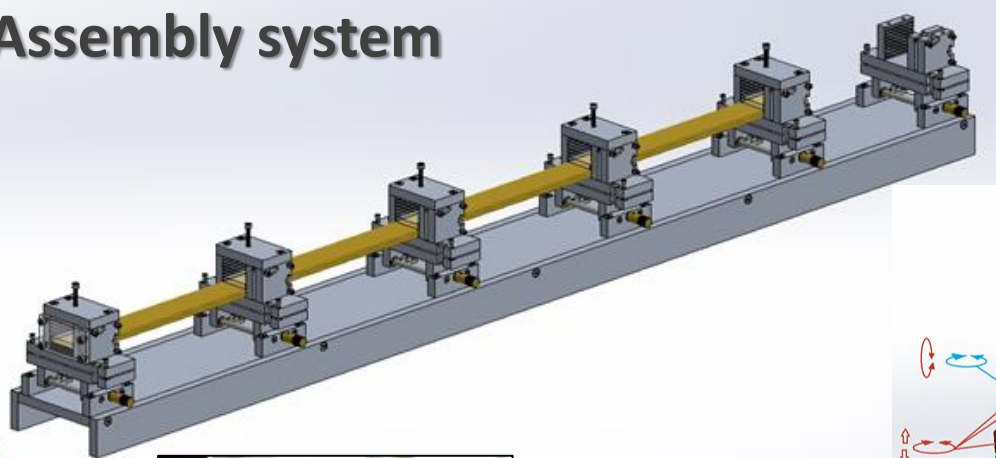
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# R&D strategy for the Dual-Readout Calorimeter

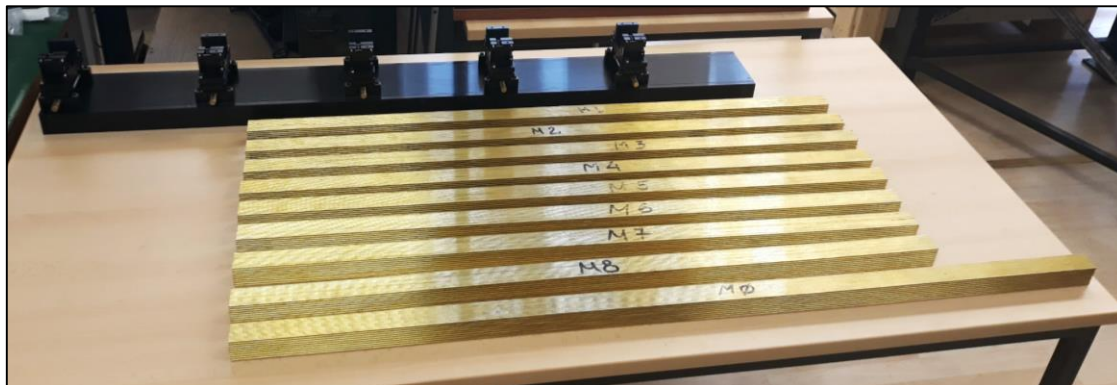
## From idea to prototype for IDEA



### Assembly system

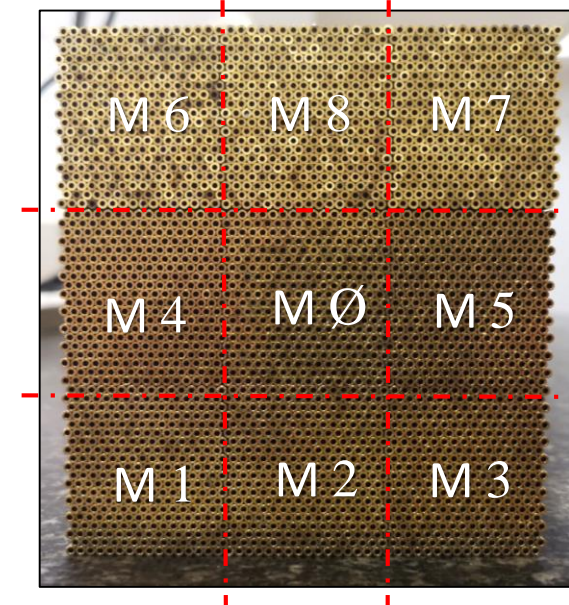


Aneliya Karadzhinova-Ferrer, 4th FCC Physics and Experiments workshop, Nov 12th 2020

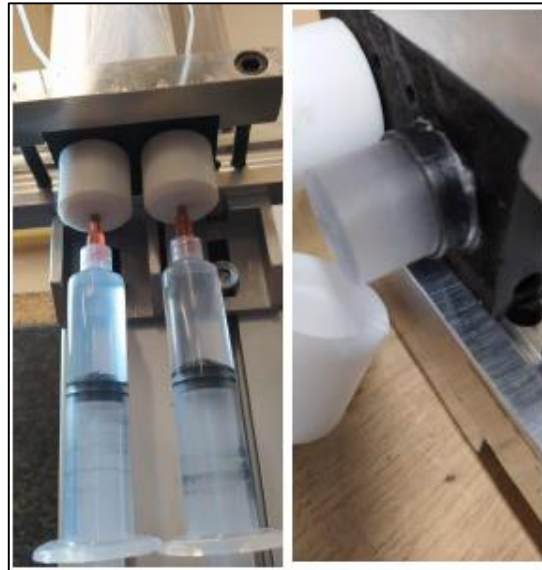
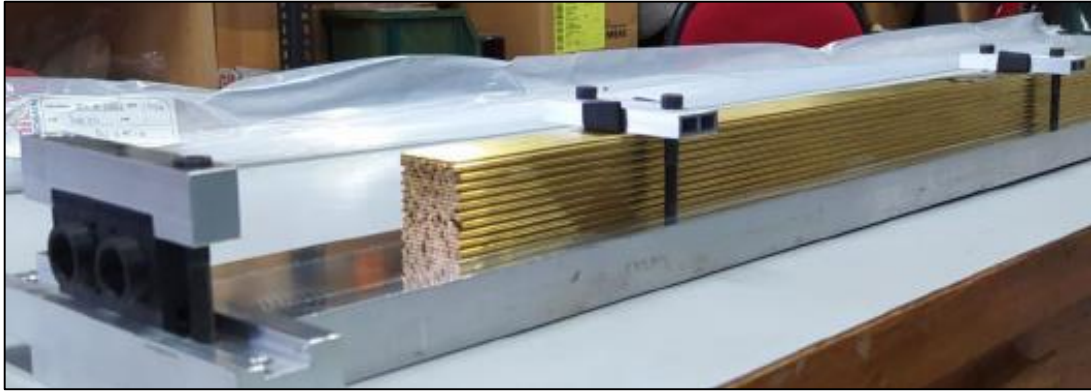


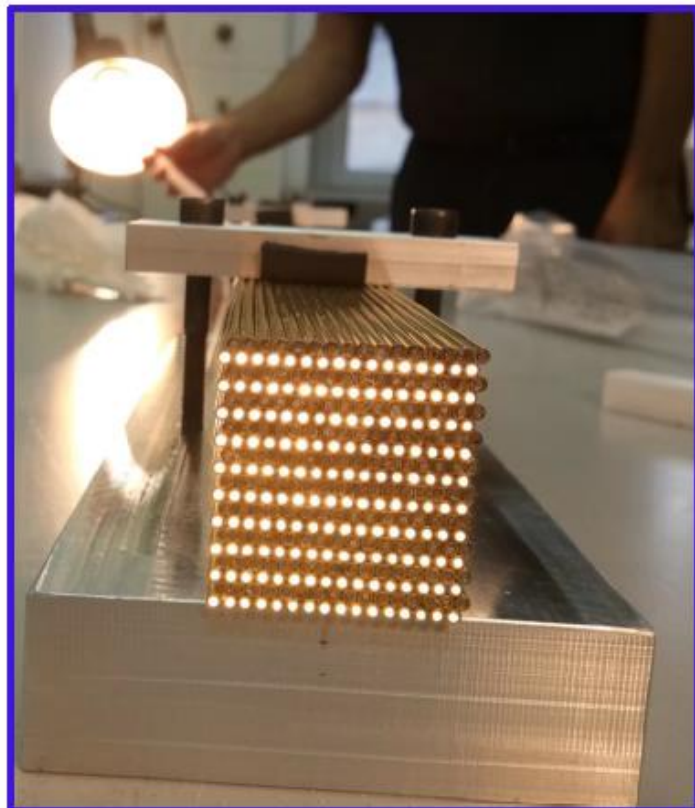
### EM tower prototype - Structure

- ❖ Time to produce a single module is  $\approx 1.5$  day
- ❖ The modules nicely fit close to each other
- ❖ The width and the height of the modules have a std of  $\sim 80 \mu\text{m}$  with a maximum difference  $< 200 \mu\text{m}$

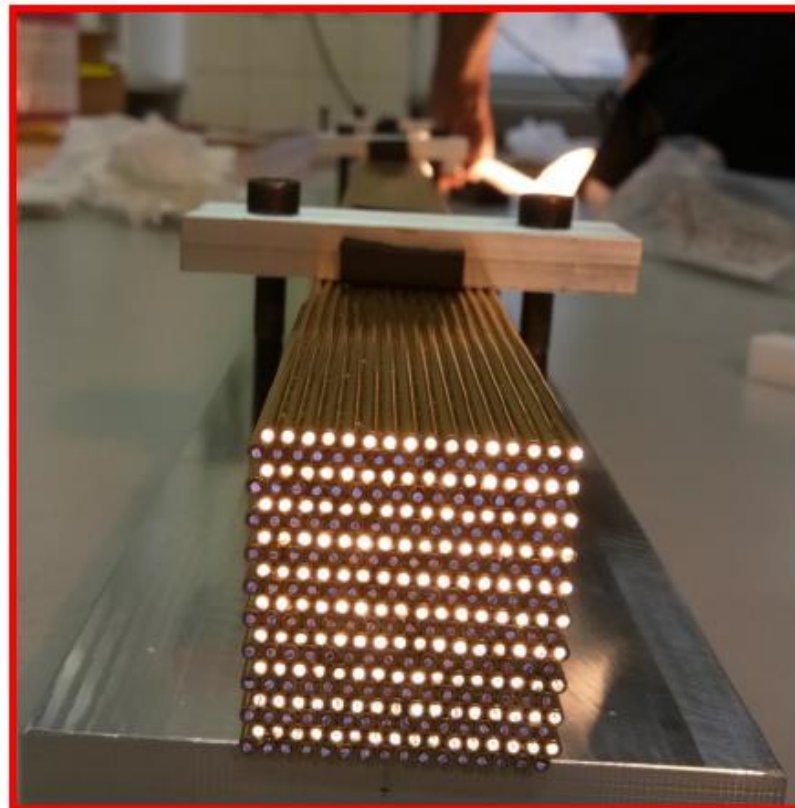


## From idea to prototype for IDEA





Scintillation fibers

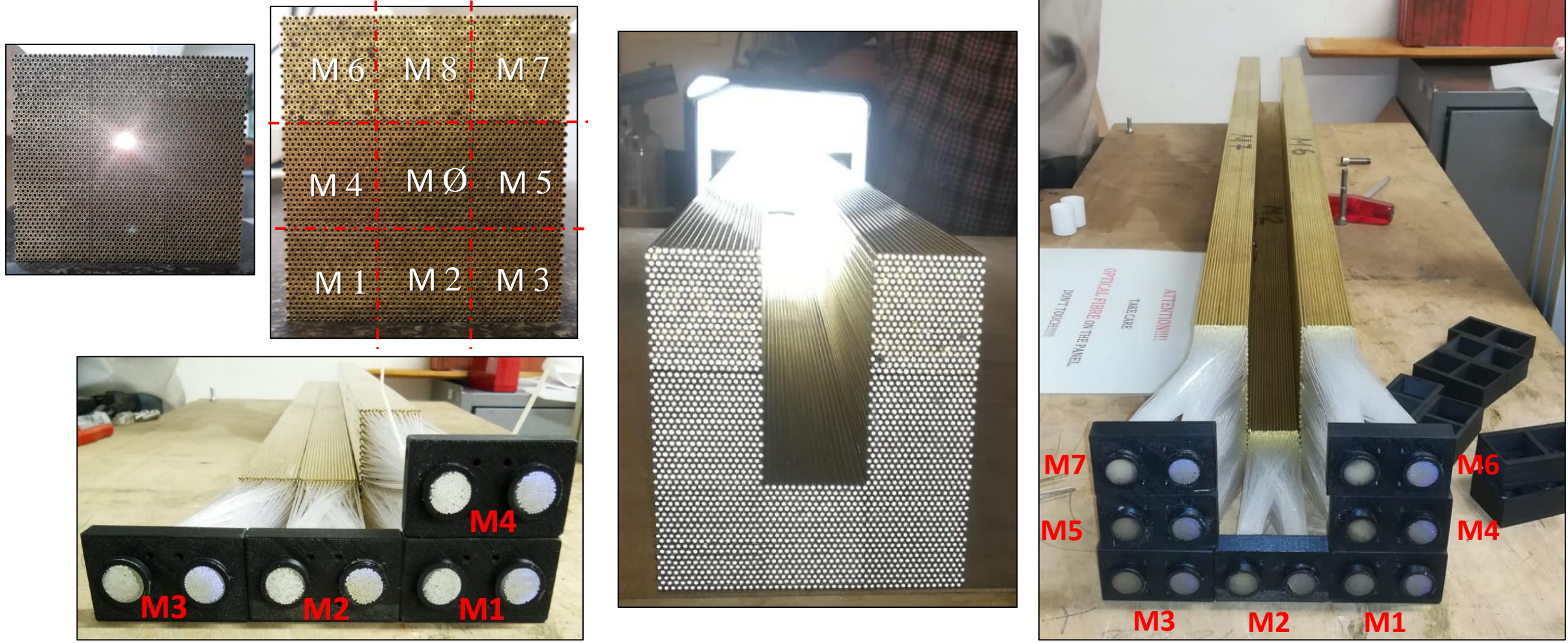


Cherenkov fibers

### EM tower prototype – Fiber insertion

- ❖ Time to insert and mount 160 Č & 160 Sc fibers into single module is  $\approx 1.5$  day, due to 24h epoxy curing time

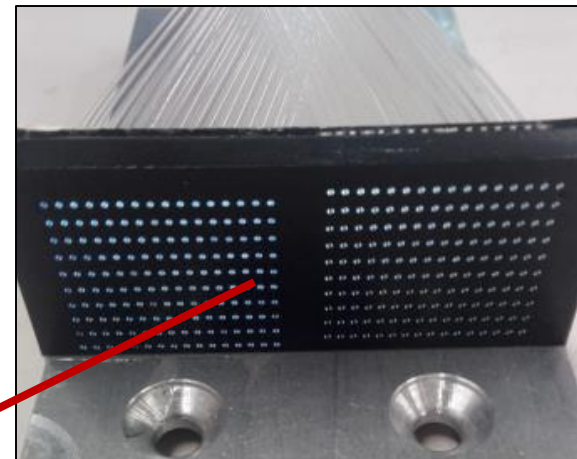
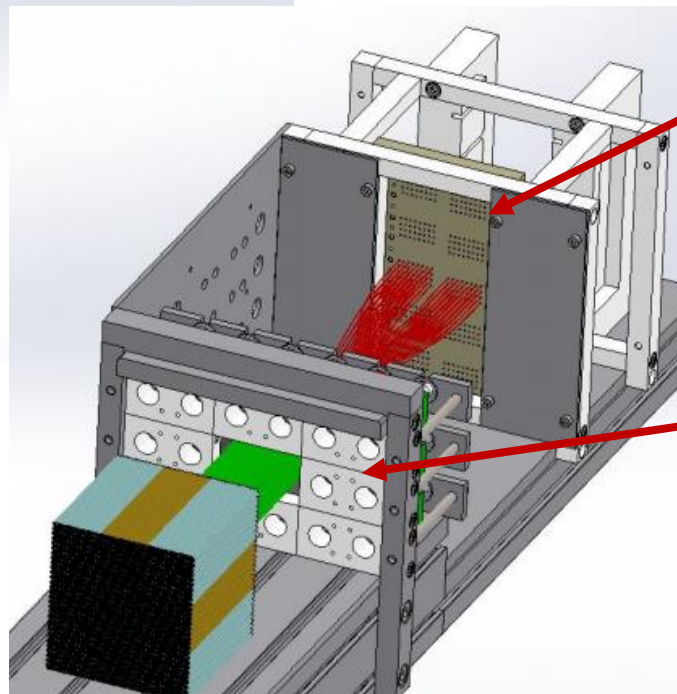
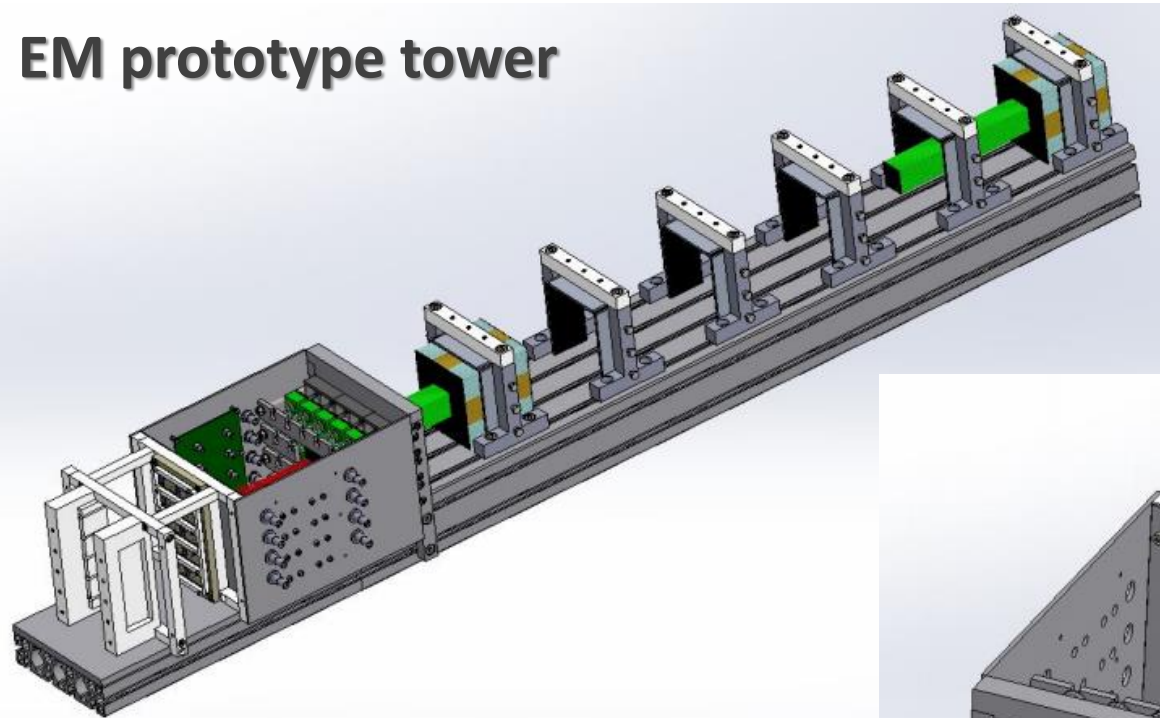
**Fibers illuminated from rear end**



**The fiber insertion procedure for all 9 modules is almost completed**



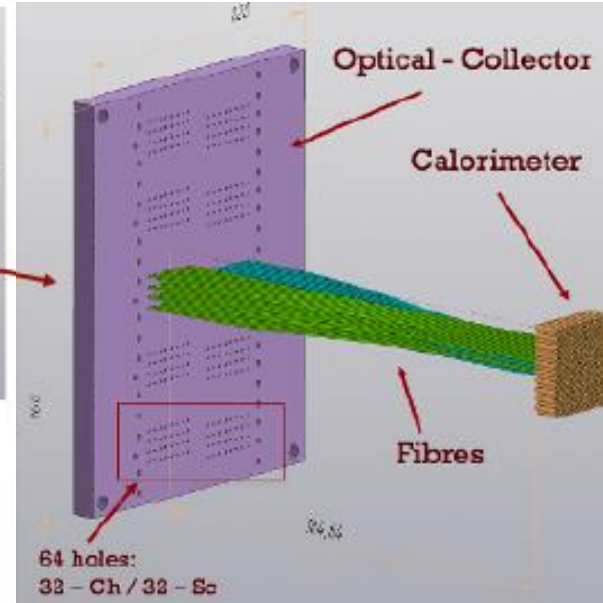
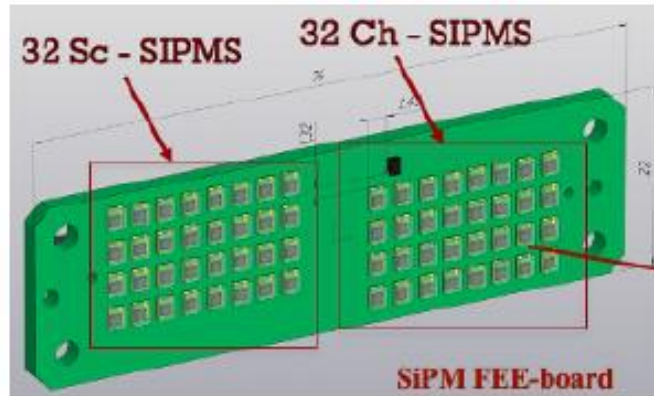
EM prototype tower



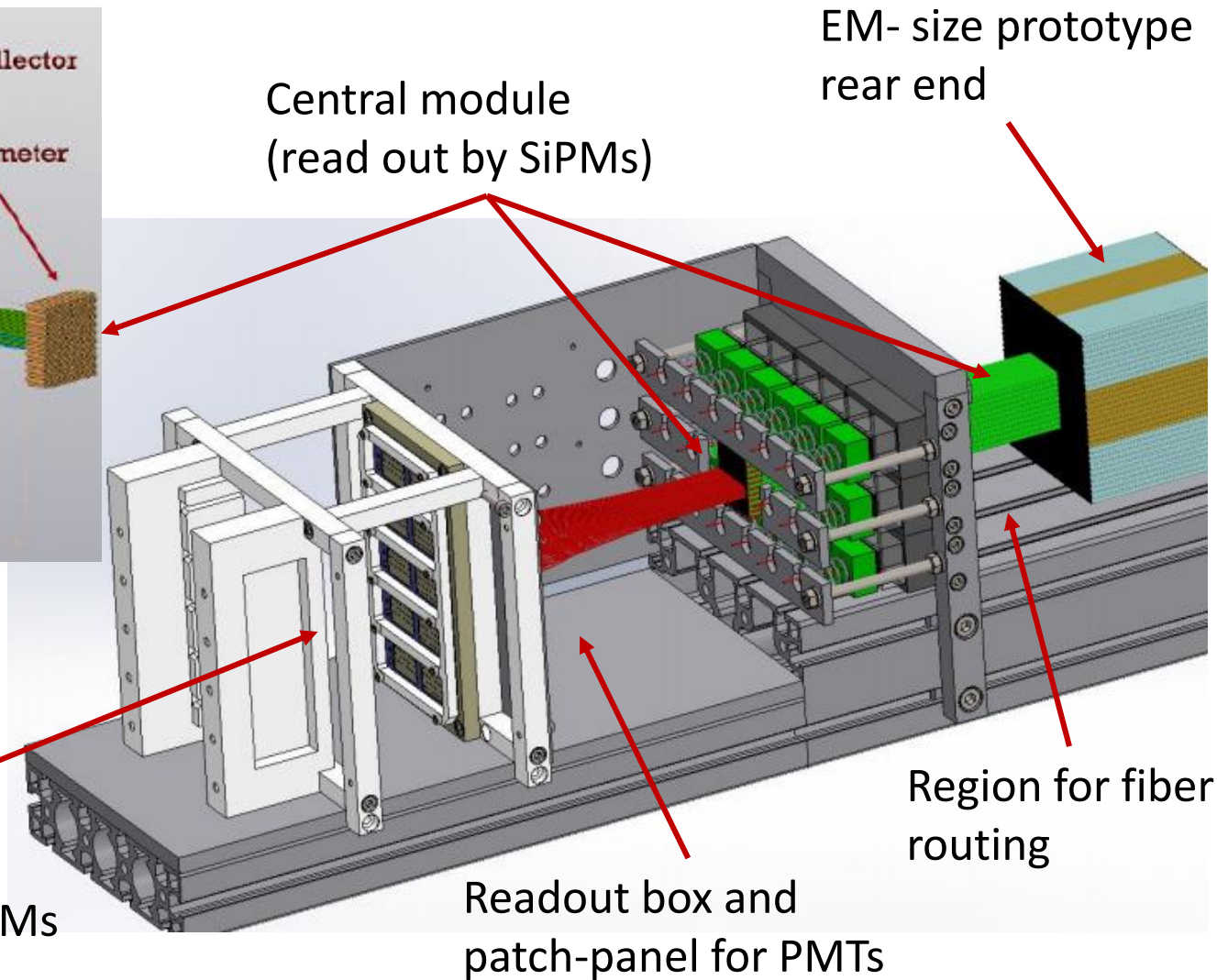
Fiber grouping for SiPMs



Fiber grouping for PMTs

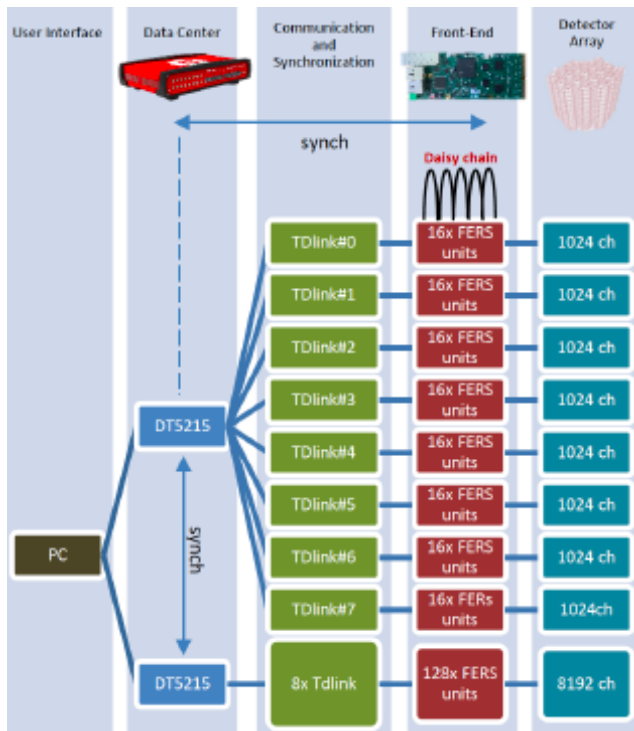


S14160-1315PS		
Effective Area	1.3x1.3	mm <sup>2</sup>
Cell pitch	15	μm
Number of cells	7296	
Geometrical factor	49	%
V <sub>bd</sub>	38+3	V
Gain	3.6*10 <sup>5</sup>	
PDE	32	%
Xtalk	<1	%
DCR (Typical)	120	kHz

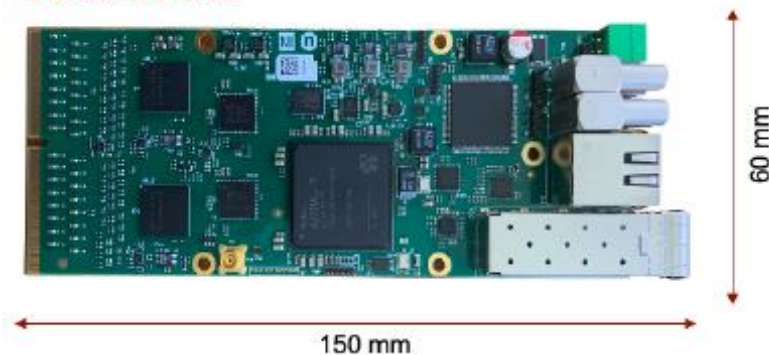


### Readout scheme for EM prototype (10 x 10 x 100 cm<sup>3</sup>)

- ❖ The readout of the PMTs will be based on Caen QDC (V862AC) and TDC (V775N) modules
- ❖ The readout of the highly granular module (320 SiPMs) will be based on the Caen FERS system (5200) using 5 readout boards (A5202)

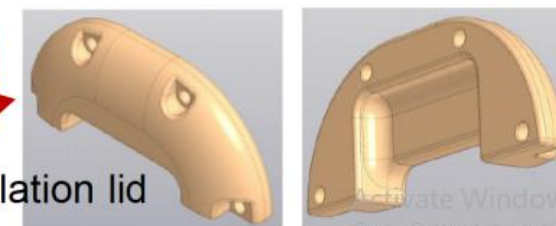
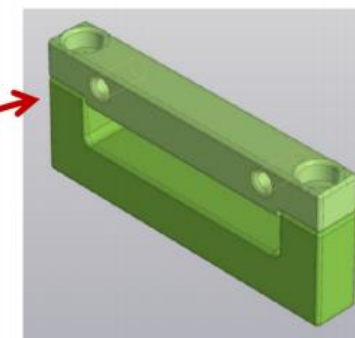
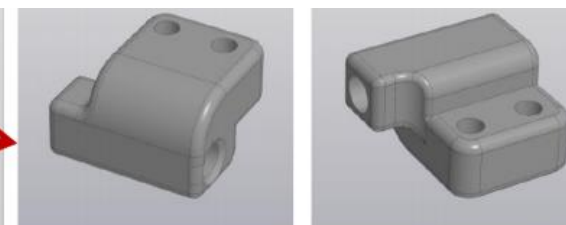
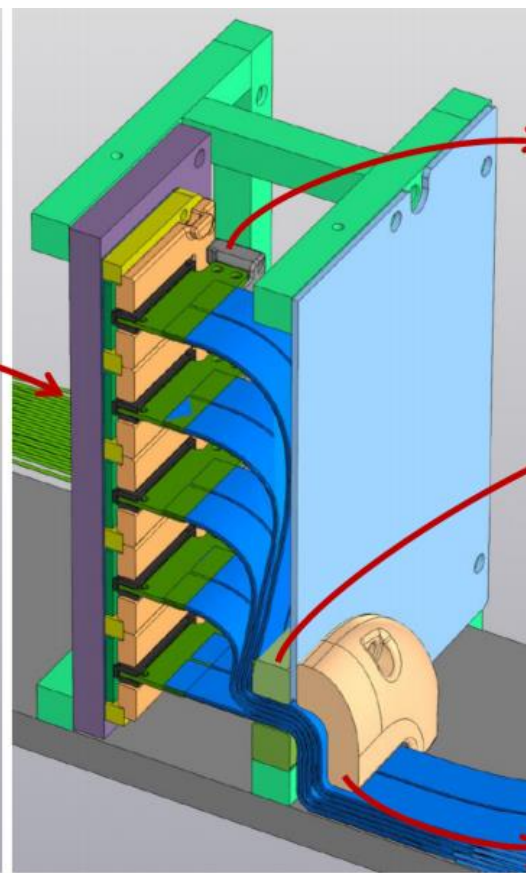
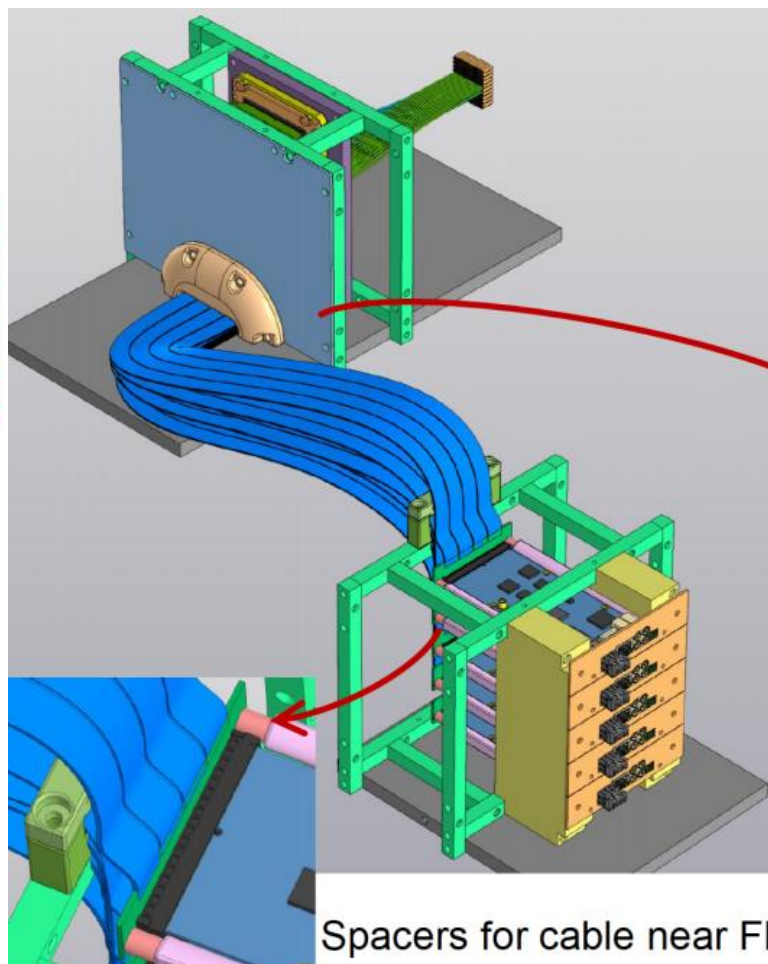
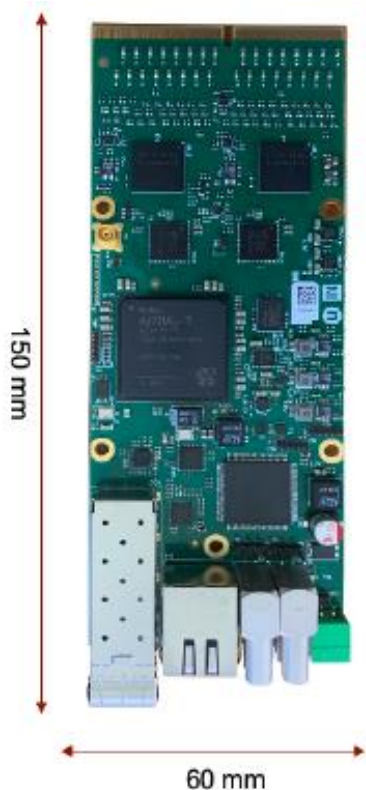


FERS: A5202



- Two Citiroc1A for reading out up to 64 SiPMs
- One (20 – 85V) HV power supply with temperature compensation
- Two 13-bit ADCs to measure the charge in all channels
- Timing measured with 64 TDCs implemented on FPGA (time resolution  $\approx 200$  ps)
- Optical link interface for readout (6.25 Gbit/s)

### Readout box and patch-panel for SiPMs for EM prototype (10 x 10 x 100 cm<sup>3</sup>)



### **Status of the EM-size DR prototype (10 x 10 x 100 cm<sup>3</sup>)**

- ❖ The absorber of all the modules has been assembled
  - ❖ All fibers have been delivered and the insertion process is close to its end
  - ❖ Frontend boards delivered (to be tested)
  - ❖ FERS system expected to be delivered at the beginning of December
  - ❖ System commissioning expected in January 2021
- 
- ❖ Beam time at DESY is scheduled for the last two weeks of February 2021

**Even if there are alternatives under study, the presented concept could be considered almost ready for large production**

## From EM- to hadronic-size DR prototype

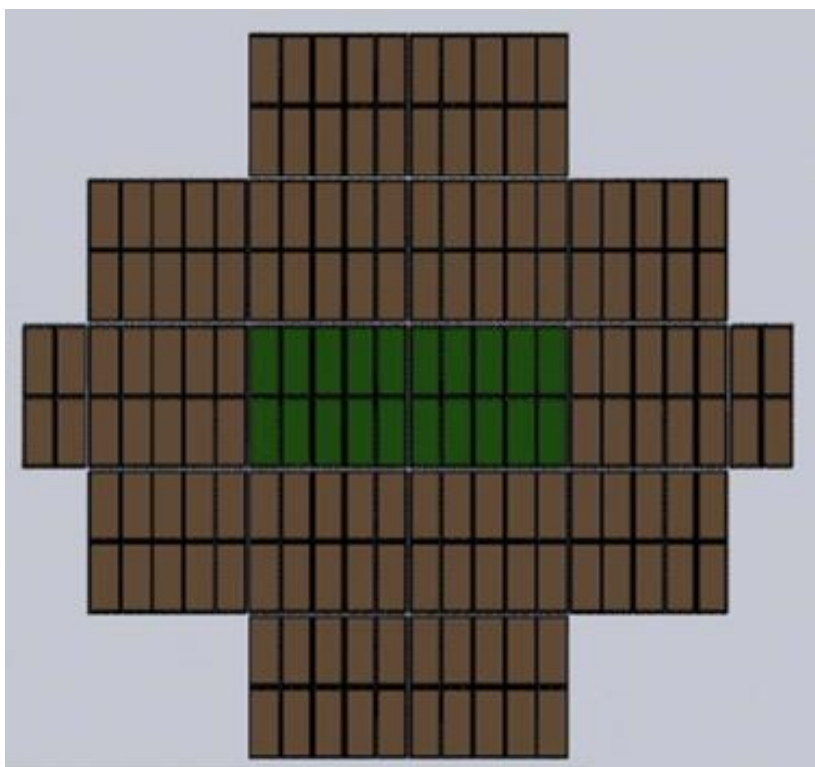
(10 x 10 x 100 cm<sup>3</sup>)



(65 x 65 x 200 cm<sup>3</sup>)

- New scalable design
- New readout scheme

- Alternative and scalable solution for the DR mechanical structure
- Alternative approach for the readout scheme
- Calibration of the DR calorimeter

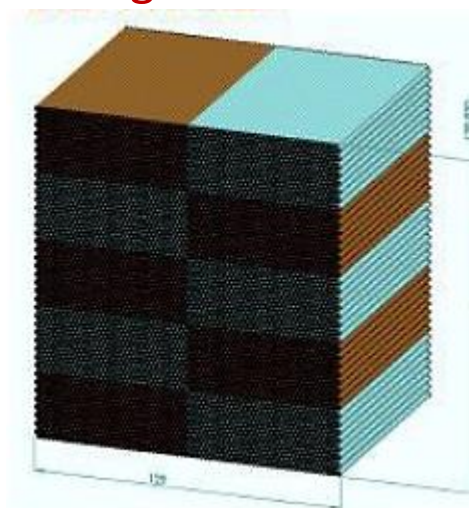


\* One possible design

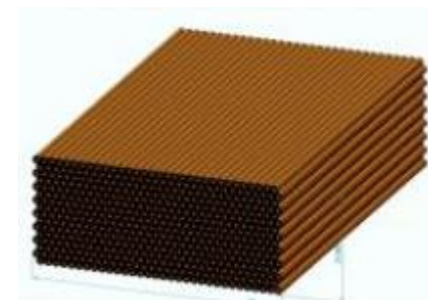
## Hadronic tower prototype (65 x 65 x 200 cm<sup>3</sup>)

- ❖ 17 modules in total
- ❖ 2 central modules read out with SiPMs
- ❖ 15 modules read out with PMTs

Single module constructed from 10 mini-modules  
~ 13 x 30 x 200 cm<sup>3</sup>

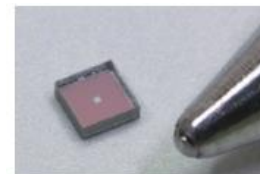
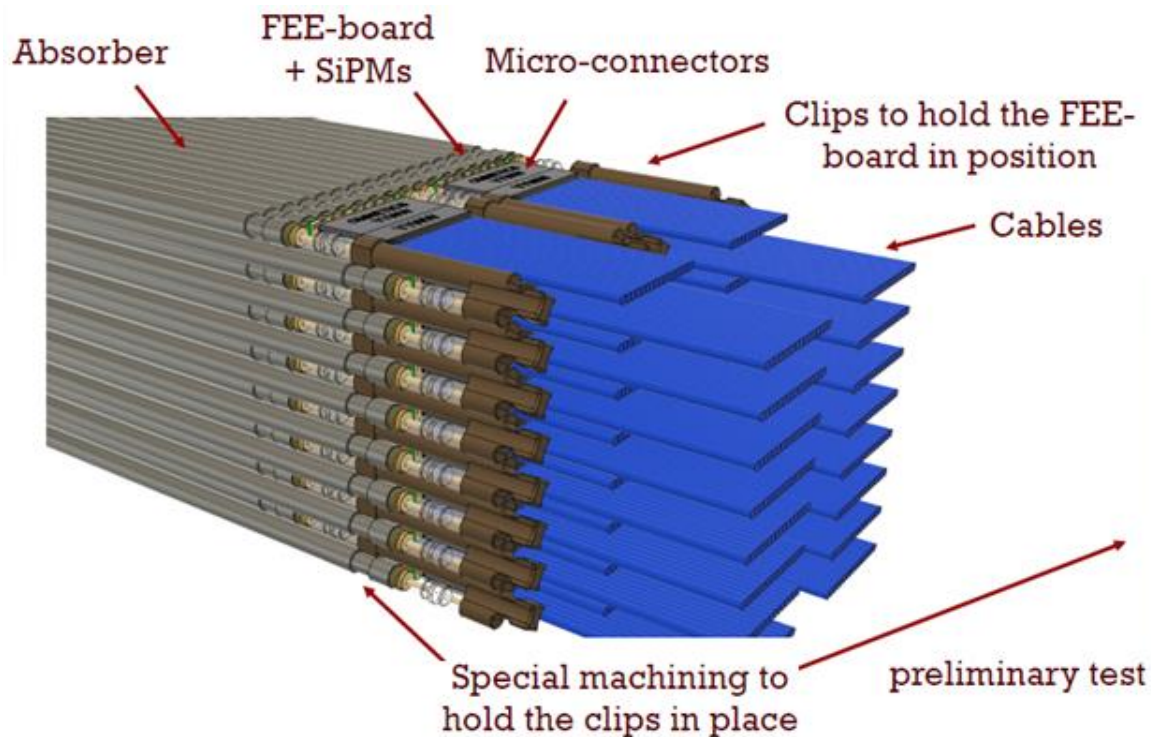


Mini-module constructed from  
32 x 16 capillaries

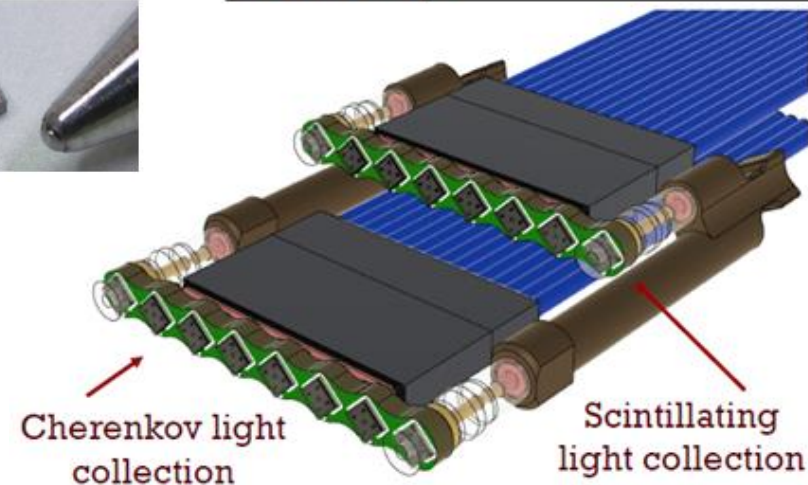


## Option based on capillaries

For the new design we are investigating scalable options which could allow to build large and projective modules.



Pair of FEE-boards joint together with the clips

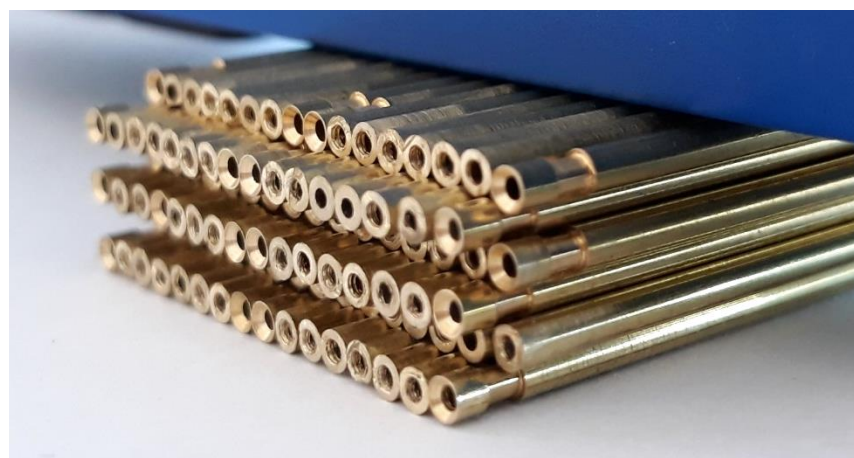


The SiPMs will be directly connected to the fibers and fixed to the absorber. This option will allow to group signals from 8 SiPMs to reduce the number of channels to be read out.

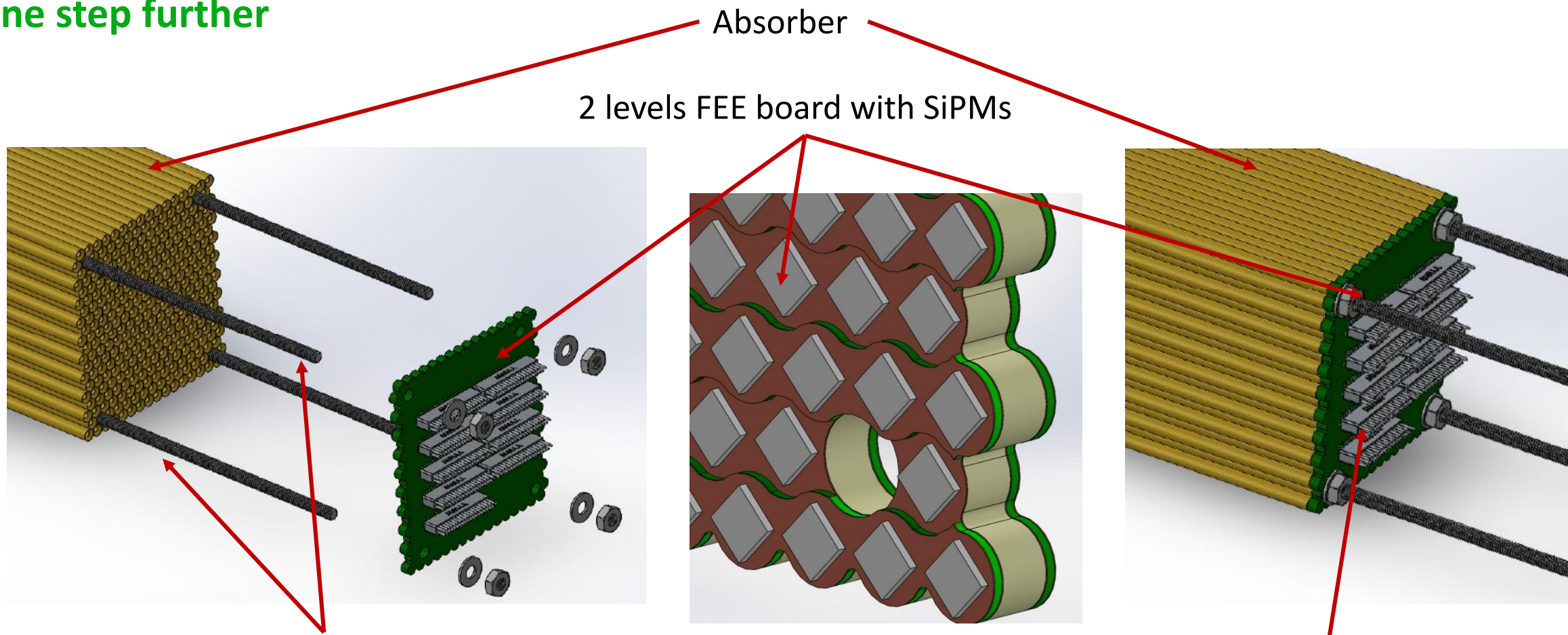




## Mockup with PCB and capillaries



## One step further



Absorber

2 levels FEE board with SiPMs

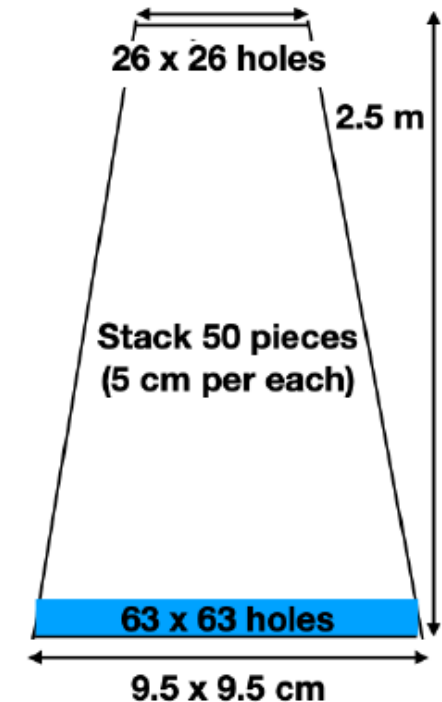
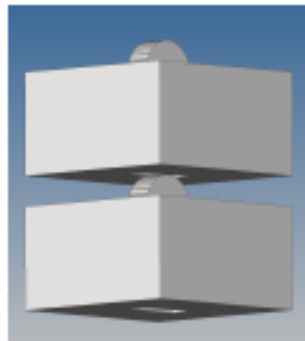
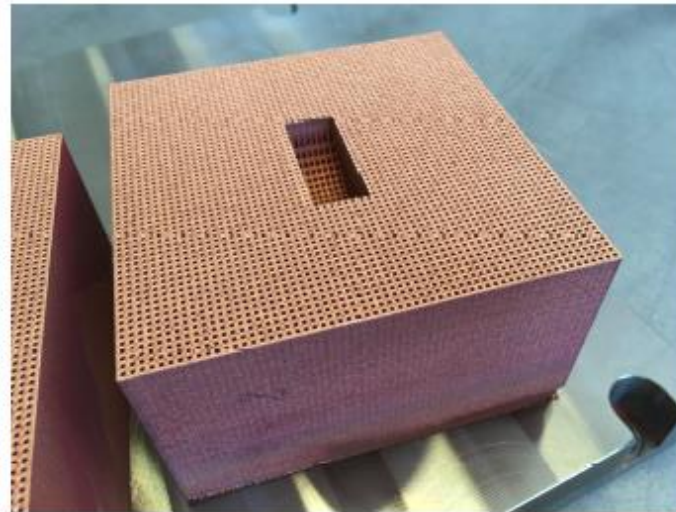
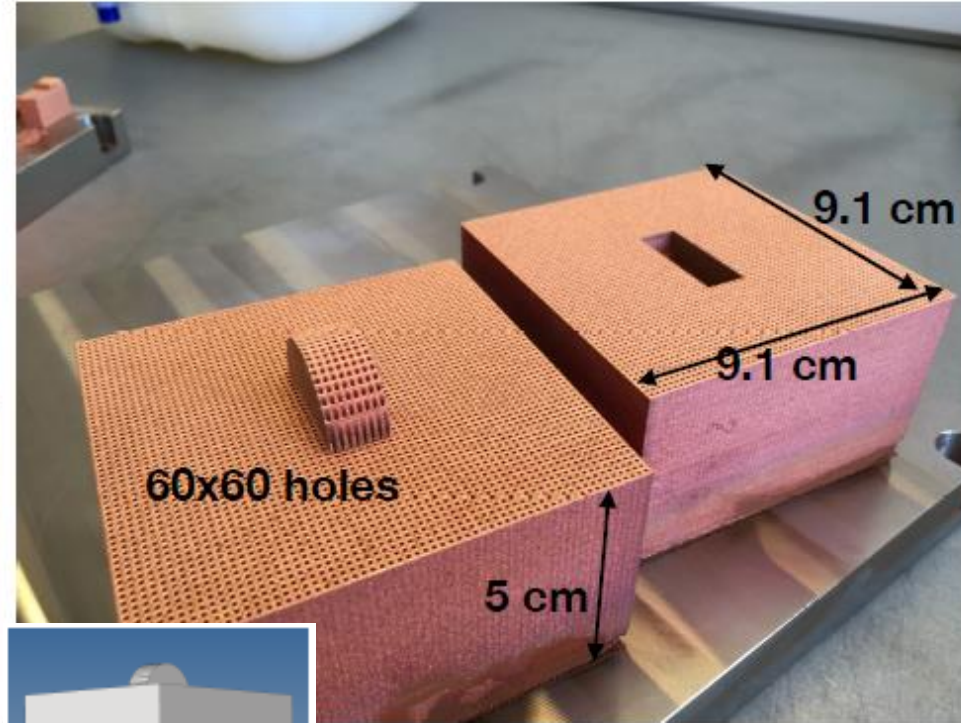
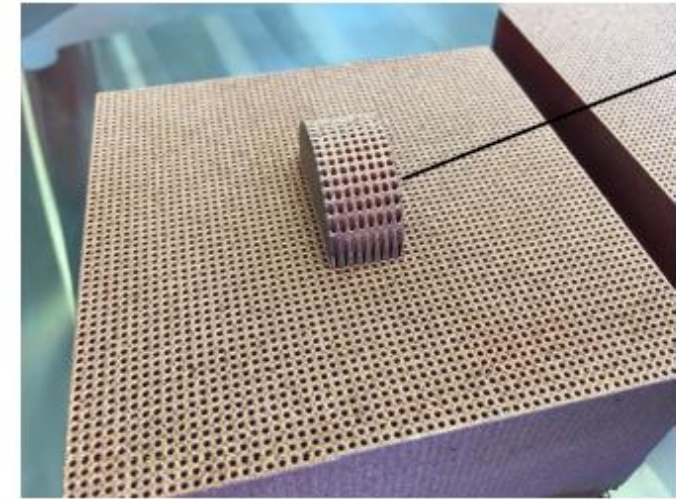
Rods for FEE board mounting and joining together adjacent towers

Micro-connectors

# Alternative solution for the DR mechanical structure

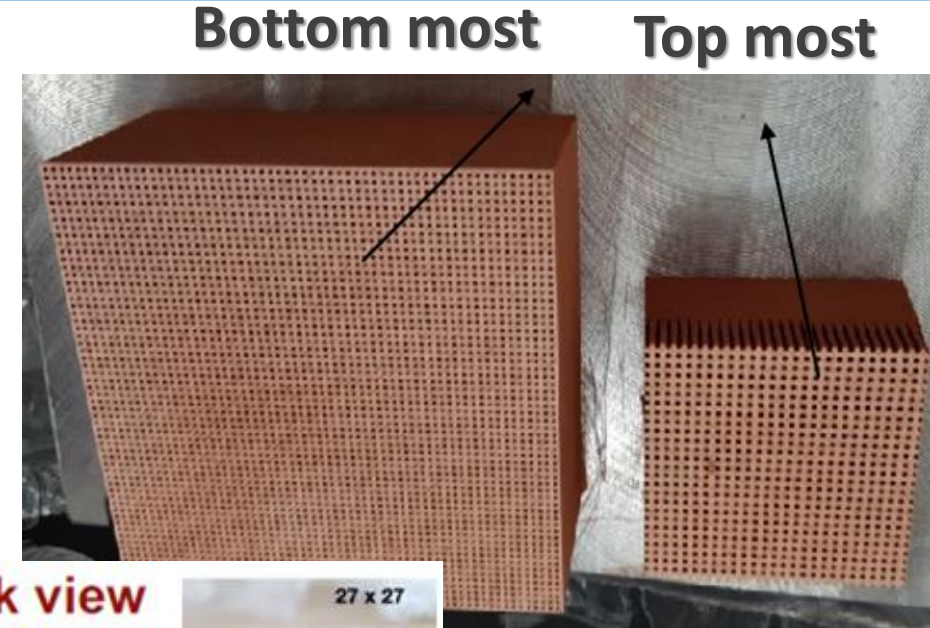
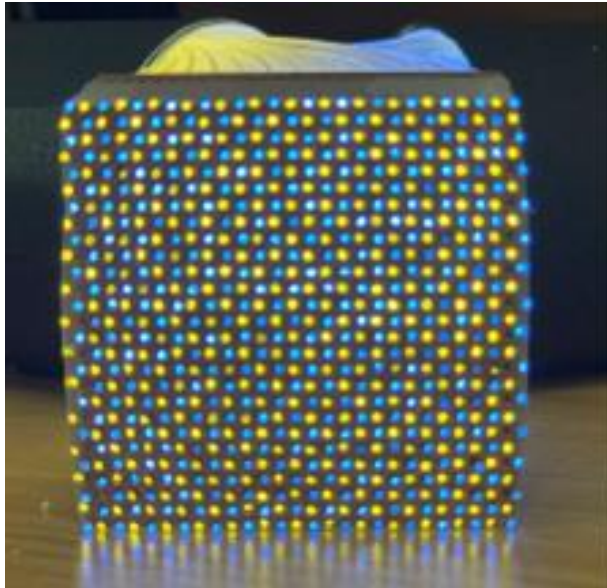
## 3D printing techniques are under study

- ❖ Cu density: from 95 to 99.5%
- ❖ 1.3 mm diameter for a hole for fibers
- ❖ 0.7 mm pitch between two holes
- ❖ 60 x 60 holes with precise alignment in 9.2 x 9.2 cm (height 5 cm)



# Alternative solution for the DR mechanical structure

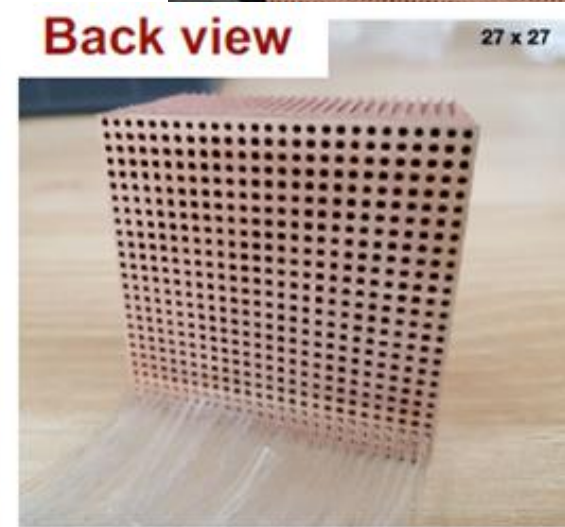
Alternatives based on 3D printing techniques are under study



Front view



Back view



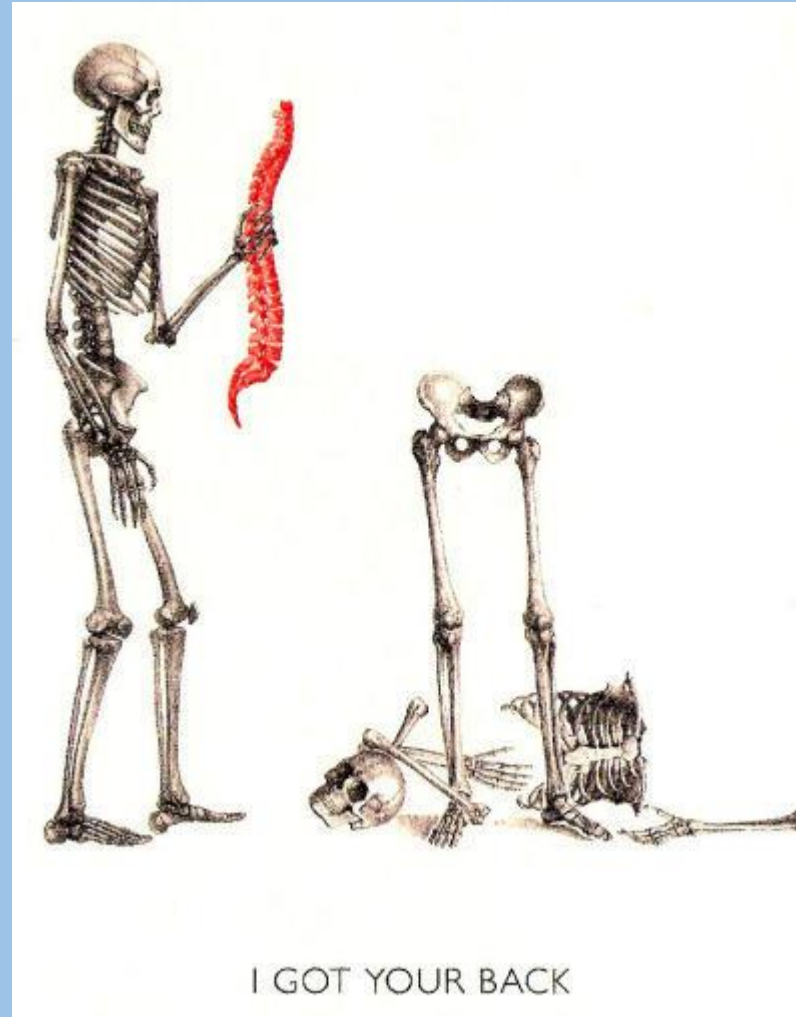
- ❖ The preparation of the proof of concept test beam at DESY, scheduled for mid-Feb. 2021, is well advanced
- ❖ The design of a scalable tower-like module is progressing well: different options have been identified and discussed
- ❖ The mid-term goal is to build a demonstrator with hadronic containment, partially equipped with SiPMs, to evaluate the hadronic performance
- ❖ Calibration of the DR calorimeter

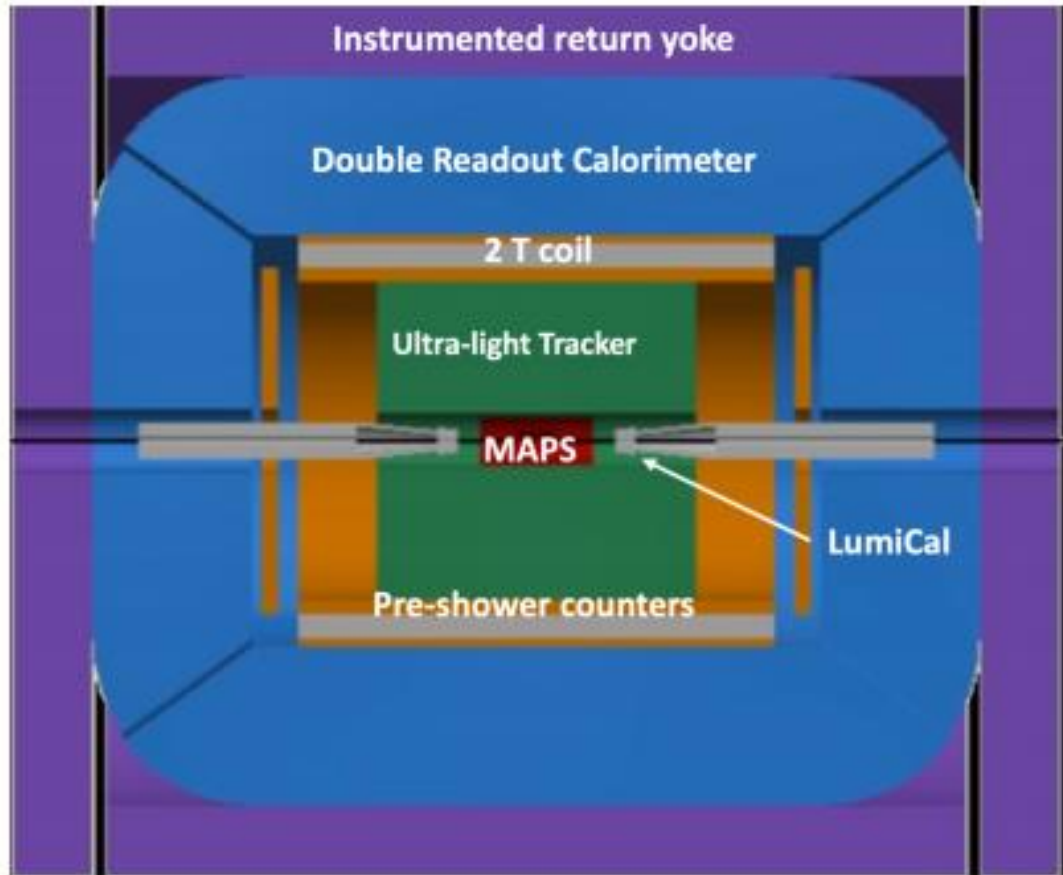


# Thank you for your attention!



# Backup slides





\* See FCC-ee: The Experimental Challenge – M. Dam

## IDEA

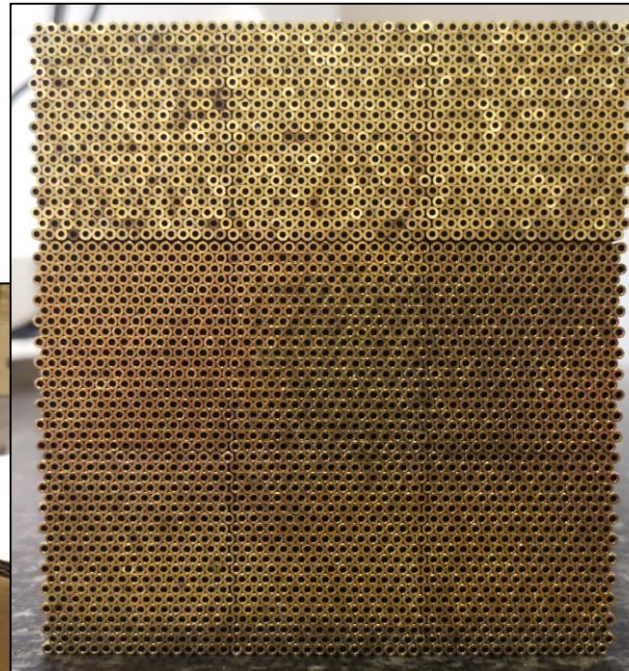
New, innovative, possibly more cost-effective design

- ❑ Silicon vertex detector
- ❑ Short-drift, ultra-light wire chamber
- ❑ Dual-readout calorimeter
- ❑ Thin and light solenoid coil inside calorimeter system



# The Bucatini Calorimeter: EM-size prototype

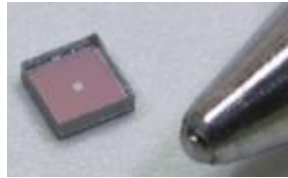
*The Bucatini Calorimeter*



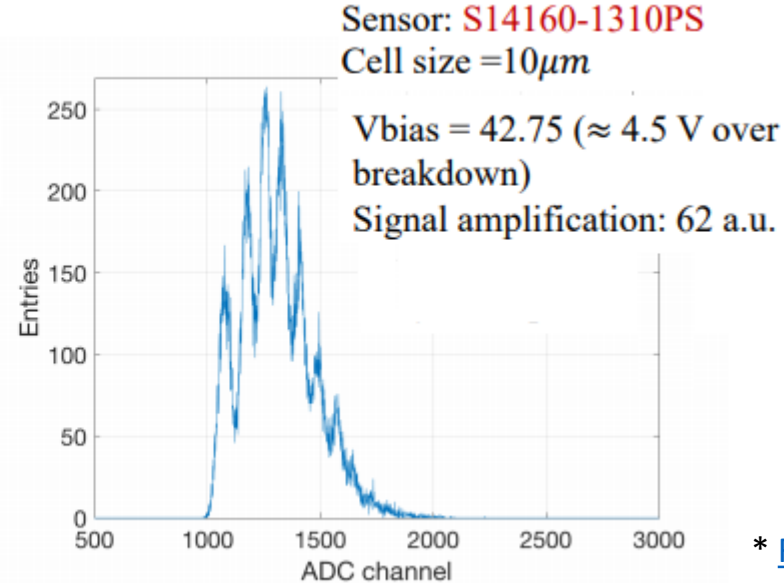
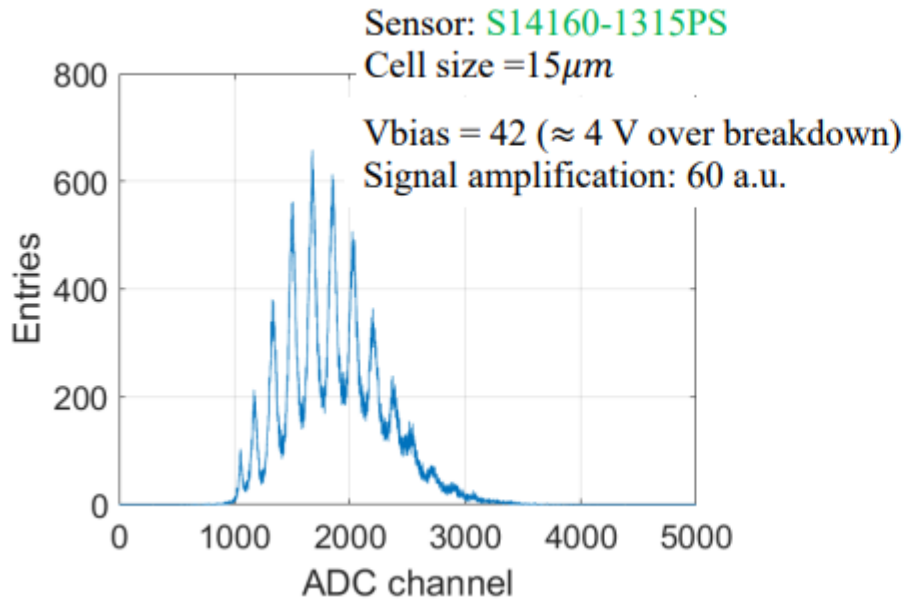
**Face of the tower**



**Rear end of the tower**



SiPM	Pixel pitch ( $\mu\text{m}$ )	Sensitive area ( $\text{mm}^2$ )	Dyn-range	Package ( $\text{mm}^2$ )	Eff (%)	DCR (kHz)	Cross talk (%)	After pulse (%)
S13615-1025	25	1x1	$\approx 1600$	1,13x1,13	25	50	1-3	$\approx 1$
S14160-1315PS	15	1.3x1.3	$\approx 7300$	2.6x1.3	32	120 - 360	$\approx 1$	$\approx 1$
S14160-1310PS	10	1.3x1.3	$\approx 16700$	2.6x1.3	18	120 - 360	$\approx 1$	$\approx 1$



The quality of the multi-photon, obtained with the same ASIC (Citiroc1A) that will be use at the Feb 2021 test beam.

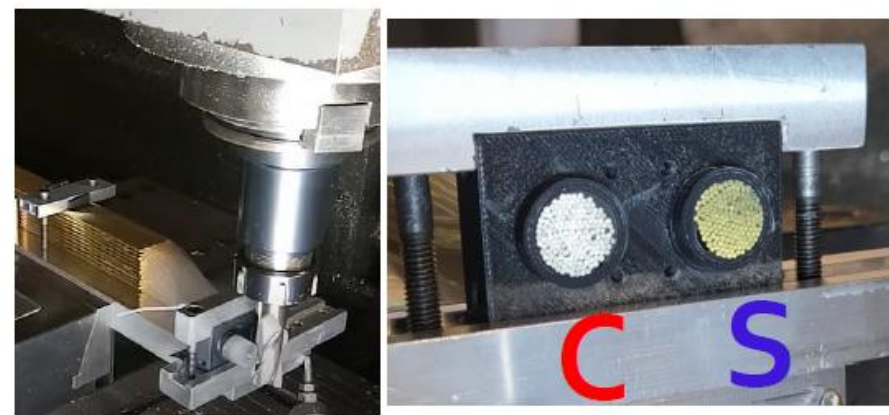
\* [R. Santoro talk](#) at CECP Oct 26-28, 2020



Syringe removed

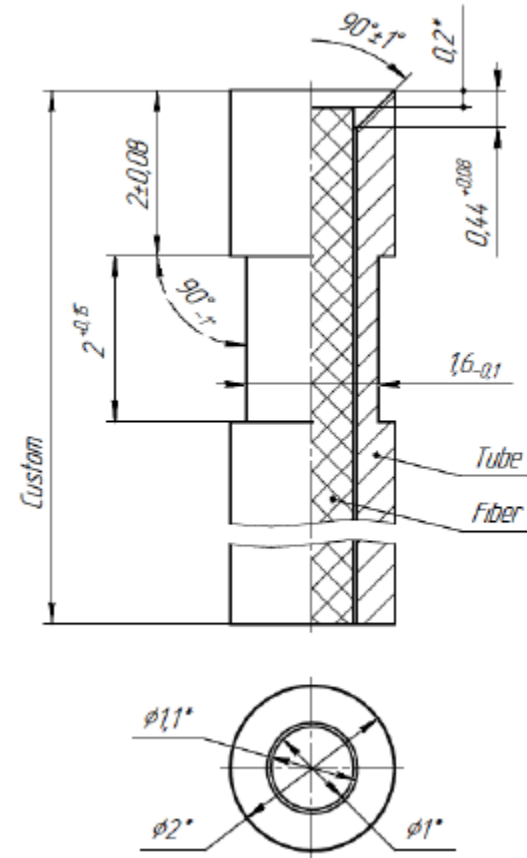
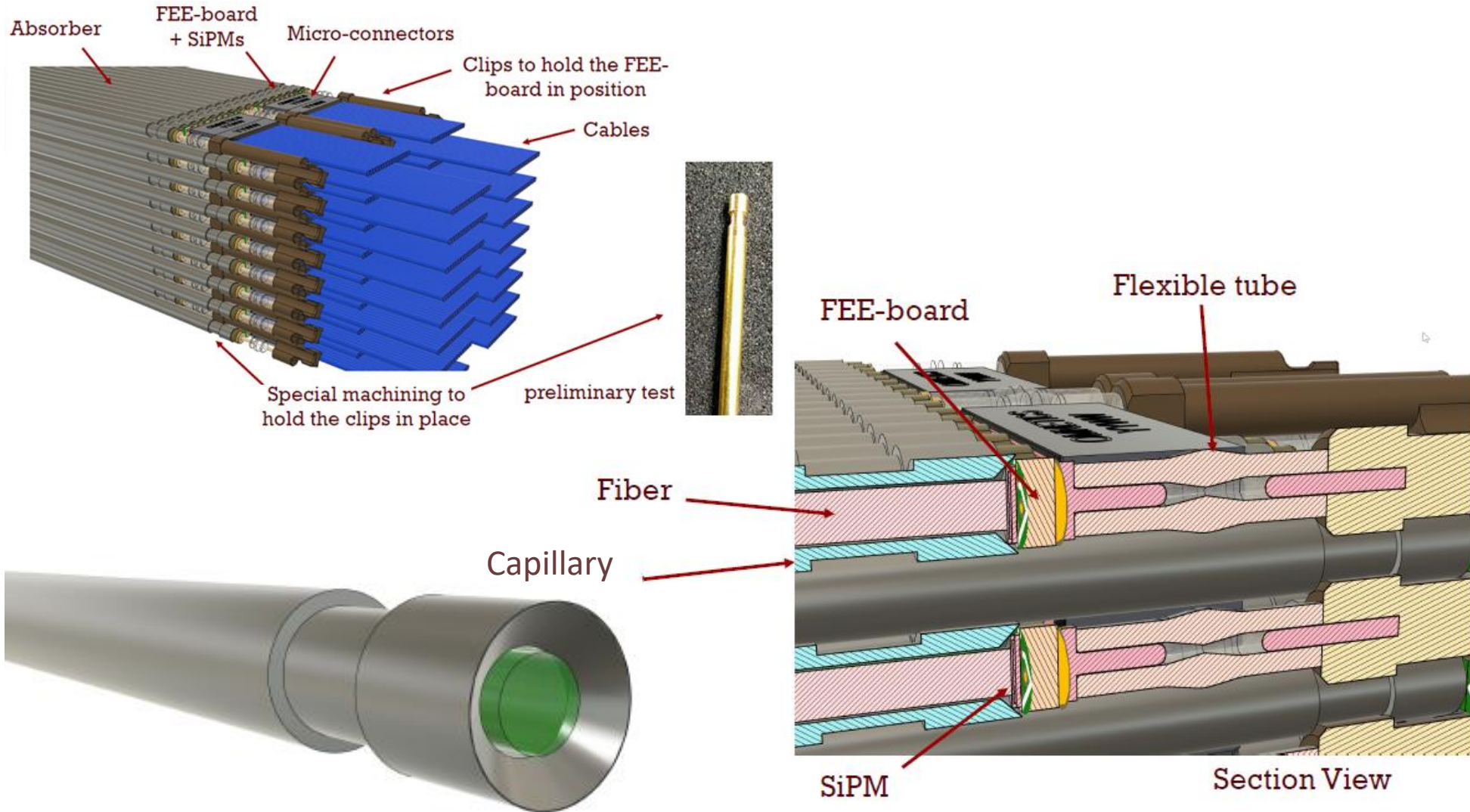


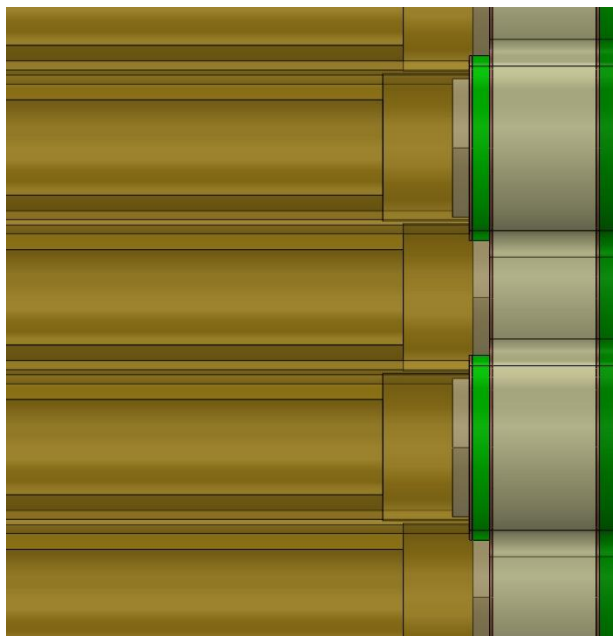
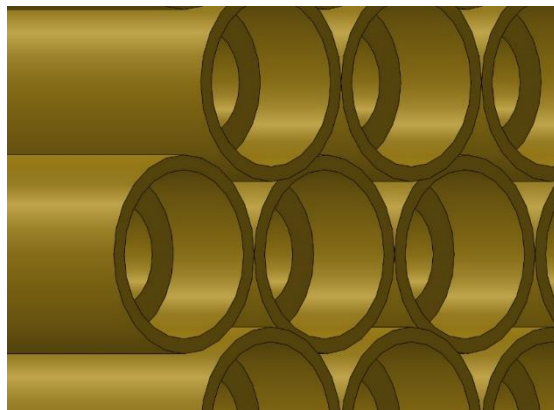
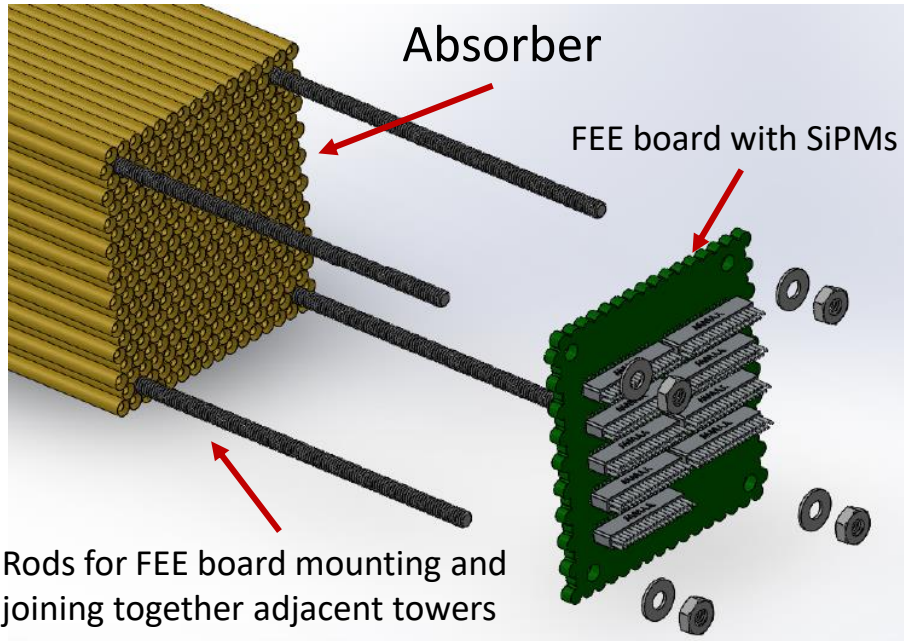
Teflon containers removed



Grouped glued fibers outside 3d printed holder are cut off by milling machine

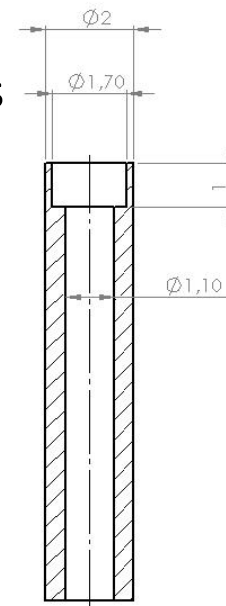
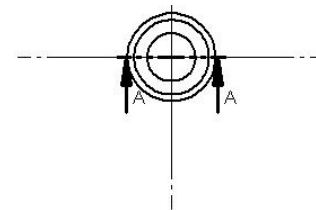
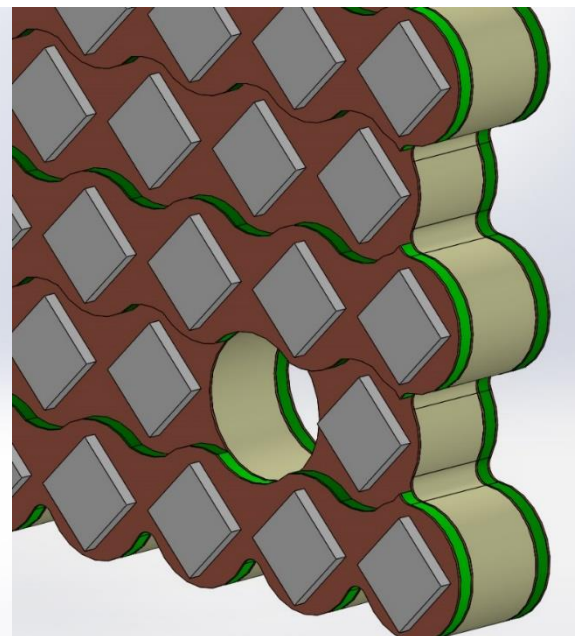
# Idea of readout scheme 2.0 (hadronic-size prototype)





Another consideration regarding the inner profile of the capillaries

2 levels FEE board with SiPMs



SECTION A-A  
SCALE 10 : 1