AIDAinnova WP8

Roberto

June 12th, 2020

WP8: Calorimeters and Particle Identification Detectors

Task 8.2. Towards next generation highly granular calorimeters

- 8.2.1 Integration aspects of highly granular calorimeters (DESY …)
- 8.2.2 Future Liquid Noble Gas Calorimeters (CERN, …)

Task 8.3. Innovative calorimeters with optical readout

- 8.3.1 Crystal detectors (CERN, FZU, VU, INFN-PG, INFN-LNF, INFN-TO)
- 8.3.2 Large area scintillator detectors (MPP-MPG, DESY, INFN-BO, JGU)

Task 8.4: Innovative solid-state light sensors and highly granular dual-readout fibre-sampling calorimetry

- 8.4.1 Innovative SiPMs and future applications in PID detectors (JSI, INFN-PD, CERN, FBK, UiB, FZU)
- 8.4.2 Development of highly granular dual-readout fibre-sampling calorimeters (INFN-PV, UoS, RBI, CAEN)

Task 8.3.1 Crystal detectors

Radiation-hard optical materials with ultrafast timing response

Innovative test suites required to be developed for the crystal characterisation and classification

Scalable and cost-effective production techniques to be explored with industrial partners.

8.3.1: Fast, radiation-hard crystals

Attività del subtask:

- Sviluppo di cristalli di prossima generazione, con σ_t < 30 ps, adatti all'uso a rate elevatissime in ambienti di radiazione intensa
- Test suite innovative per misurare le performance di cristalli ad alto rate, sia in laboratorio che con test beam; classifica dei cristalli
- Sviluppo di tecniche economiche di produzione a grande scala, in collaborazione con i partner industriali (GlassToPower, Crytur)

Sezioni INFN:

- Perugia (C. Cecchi), con NA (G. Di Nardo), collaborazione esterna da BINP Novosibirsk – collaborazione Belle II
- Frascati (M. Moulson), con FE (L. Bandiera), NA (M. Mirra), RM1 (M. Raggi), TO (C. Biino) – collaborazioni KLEVER e PADME

Altri partecipanti:

- CERN, FZU Prague, INP Minsk, U Vilnius, ICCUB Barcelona, UniMIB
- Partner industriali: GlassToPower, Crytur

8.3.1: Fast, radiation-hard crystals

Calendario e divisione dei subtask

M1-M24	Investigation of different materials	CERN, MIB, FZU, Vilnius, Minsk
M6-M48	Characterisation of optical, timing properties, radiation damage	CERN, MIB, FZU, Vilnius, Minsk, **PG**
M6-M36	Simulation	Minsk, ICCUB, CERN, **PG, LNF**
M18-M48	Production techniques	GlassToPower, Crytur
M18-M42	Prototype construction	**PG, LNF,** CERN, Minsk, ICCUB
M30-M48	Beam tests	**PG, LNF**, CERN, Minsk, ICCUB

8.3.1: Fast, radiation-hard crystals

Fondi assegnati: 10 k€ a LNF; 10 k€ a PG

Insufficienti per assegno di ricerca: attività da svolgere con risorse esistenti nel contesto di programmi esistenti (NA62/KLEVER, PADME, Belle II)

Attività focalizzata su item specifici:

- Caratterizzazione dei proprietà dei cristalli (M6-48)
  - in particolare, misure cristallografiche per correlare la qualità cristallina alla risposta ottica, presso il laboratorio di diffrattometria a raggi X a Ferrara
- Studi della prestazione di cristalli selezionati a rate elevatissime in test beam presso la BTF a Frascati (M30-48)

Sinergie:

- 8.3.4: «Scalable production procedures for highly granular scintllator calorimeters»
- 8.4.1 e 8.4.2: «Innovative solid-state light sensors»
- 12.3: Tecniche di simulazione per calorimetri

Task 8.3.2 Large area scintillator detectors

Organic scintillators in large tiles or strips

SiPM readout for high granularity and time measurement (~300 ps with tiles of ~300 cm^2)

Doping or coating for neutron detection

Test benches

Task 8.3 - Sub-task "Large area scintillator detectors" (MPP-MPG, DESY, INFN-BO, JGU):

"Organic scintillators offer a fast response and high light yield for moderate cost, making them a good choice for the application in large area detectors, like the muon detector of the SHiP experiment or the electromagnetic calorimeter of a Near Detector for the DUNE long-baseline neutrino experiment.

Direct readout with SiPMs, pioneered for application in hadron calorimeters for electron-positron colliders allows the building of compact calorimeters with high granularity and good time resolution. Several geometrical configurations of large tiles and strips will be studied to optimise their application in large area detectors. Enhanced test benches for the use with large detection units will be developed. The tests include studies to enhance the neutron detection capability for neutrino experiments by doping or coating of the scintillator material.

A prototype for a SHiP muon detector module will be built and tested in order to demonstrate a time resolution of about 300 ps using large tiles (200 cm^2) as building blocks

Sezioni coinvolte: INFN-Bologna (A. Montanari), INFN-Frascati (G. Lanfranchi):
Fondi richiesti: 120 k€ per finanziare:

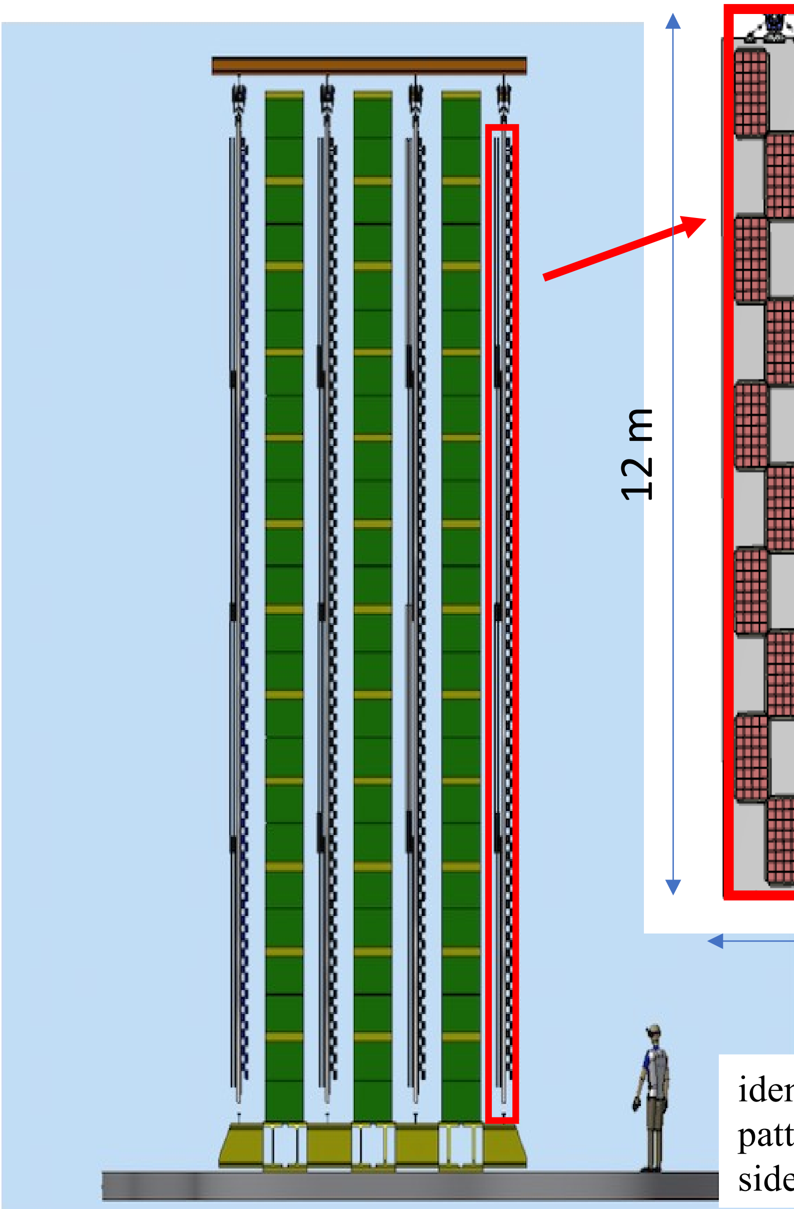
- un assegno di ricerca;
- costruzione e test di un modulo zero complete del sistema a muoni di SHiP [vedi slide dopo]
- sviluppo e test di SiPMs 6×6 mm^2 con FBK che potessero sostituire quelli attualmente in uso (Hamamatsu) in sinergia con lo sviluppo di SiPM per DUNE.

Fondi ottenuti: 20 k€

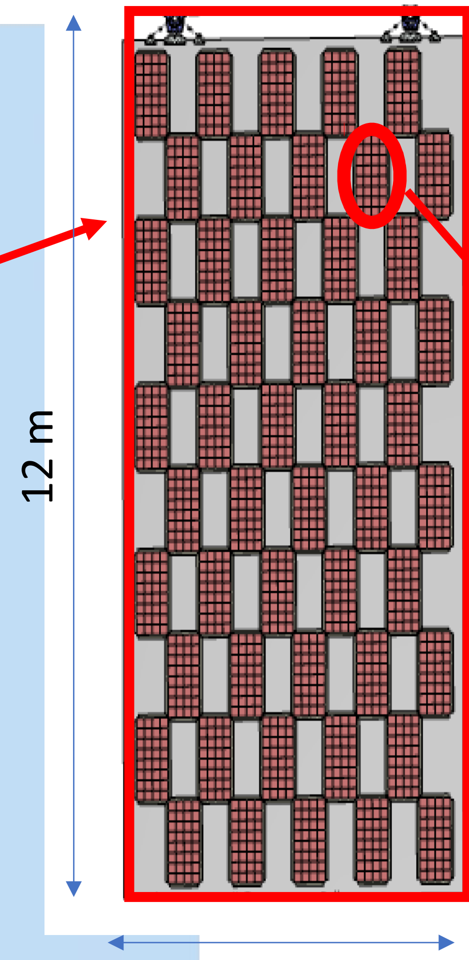
- andranno a finanziare meta' di un assegno di ricerca su LNF.
- sicuramente non possiamo garantire la costruzione del modulo 0 in queste condizioni.

SHiP Muon System in a snapshot

Muon system = 4 stations

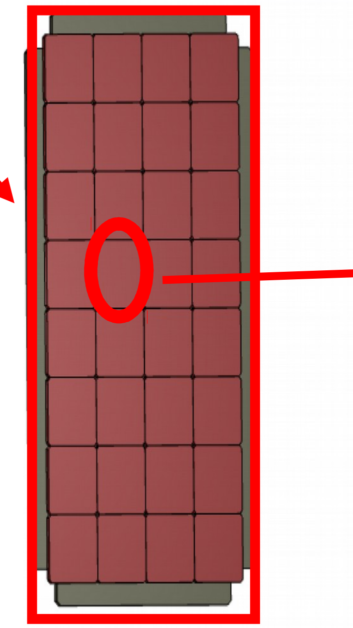


1 station = 100 modules

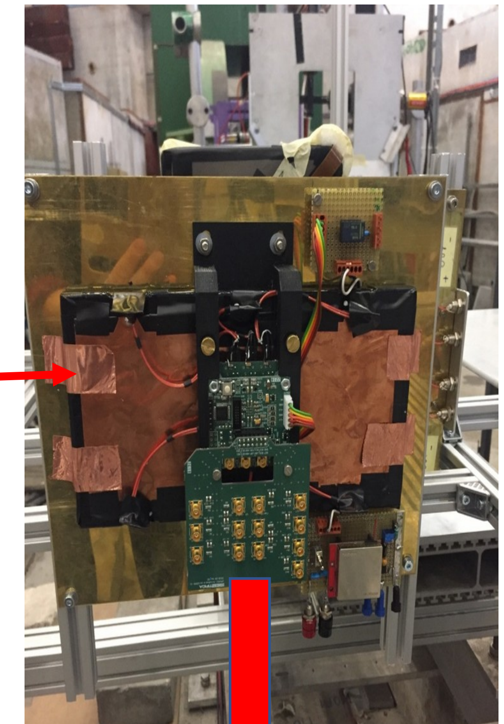


identical but staggered pattern on the opposite side of the supporting wall.

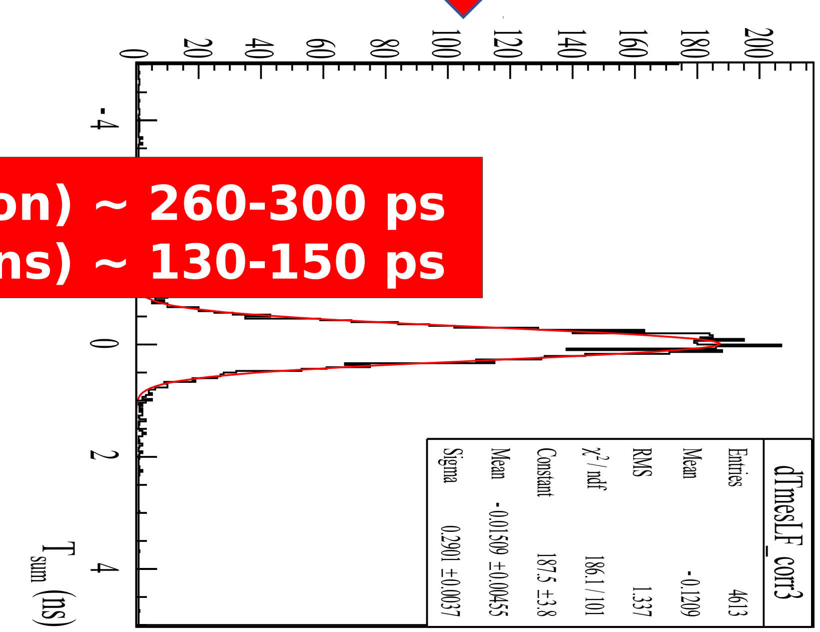
1 module = 32 tiles



1 tile ~ 200 cm²



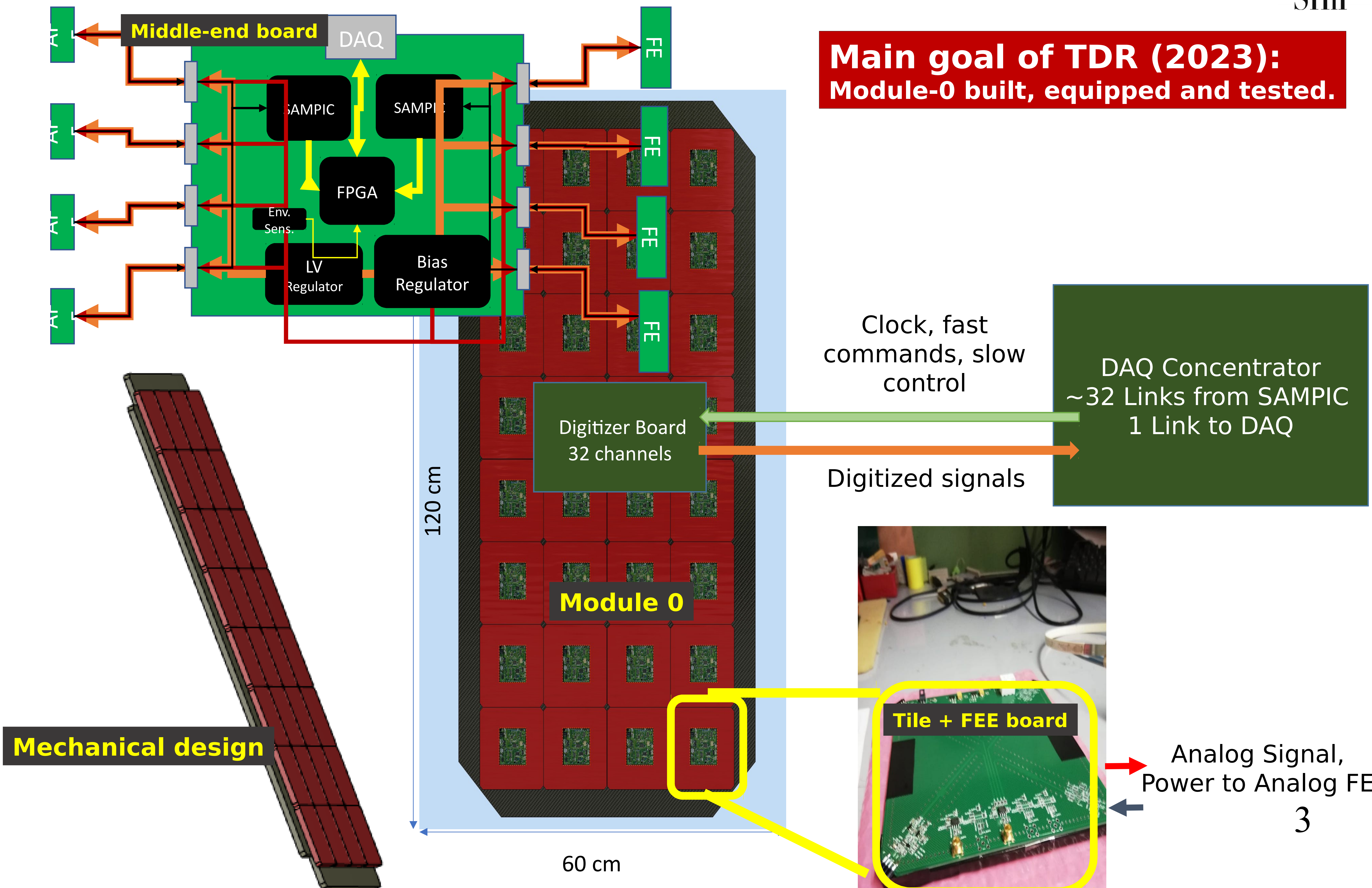
σ(t) (1 station) ~ 260-300 ps
σ(t) (4 stations) ~ 130-150 ps



Full system: 4 stations, 3 filters

(288 m²) active area, ~ 13000 tiles, 2 tons of scintillator, > 50000 SiPMs

Goal of the EoI: Construction and test of a module-0 (32-tiles) equipped with the final front-end and middle-end electronics



Task 8.4.1 Innovative SiPMs and future applications in PID detectors

- Multi-channel detectors with improved radiation hardness (FBK)
- Time resolution O(50-100 ps)
- Characterisation of dark-count noise performance as function of temperature
- Adaptive power supply (with Czech company FOTON)

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sub-task 8.4.1 "Innovative SiPMs and future applications in PID detectors"

Finanziamenti richiesti nel progetto:

Beneficiary short name	Person-months	Monthly personnel cost	Personnel costs	Travel	Equipment and consumables	Other direct costs	Sub-contracting	Material direct costs	Total direct costs	EC requested funding (without overheads)	EC requested funding (including overheads)	
Task 4.1	Innovative SiPMs and future applications in PID detectors									175 000.00	218 750.00	
CERN			0.00					0.00	0.00	10 000.00	12 500.00	
INFN	11.0	5 800.00	63 800.00	0.00	0.00	0.00	0.00	0.00	63 800.00	20 000.00	25 000.00	PD
JSI			0.00					0.00	0.00	40 000.00	50 000.00	
FBK			0.00					0.00	0.00	50 000.00	62 500.00	
Bergen			0.00					0.00	0.00	30 000.00	37 500.00	
CAS/FZU			0.00					0.00	0.00	10 000.00	12 500.00	
CAS/FZU			0.00					0.00	0.00	15 000.00	18 750.00	FOTON

Sezioni INFN coinvolte: Padova, Torino

Sinergie:

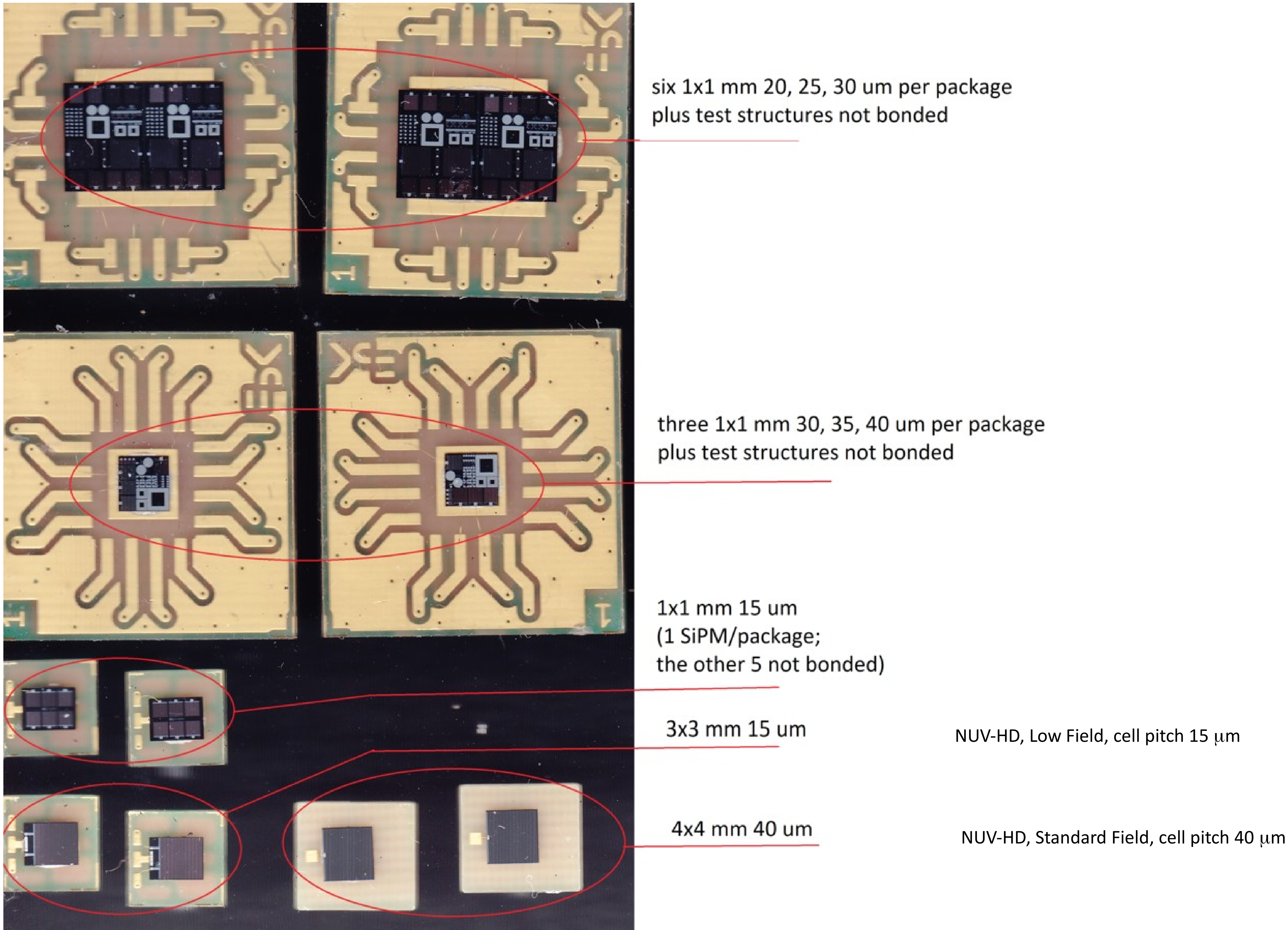
- L'upgrade del rivelatore TOP di Belle II con utilizzo di SiPM ha sinergie con l'upgrade del rivelatore ARICH di Belle II (parte della sub-task 8.4.1)

- Sinergie con altre attività per quanto riguarda l'elettronica di lettura. Si prevede l'utilizzo del front-end AISC (preamplificatore e discriminatore) "FastIC" e del convertitore "picoTDC", sviluppati da CERN, Università di Barcellona, KU Leuven che vedono interessati anche LHCb RICH e LHCb TORCH.

Richiesti 10 chip FastIC con evaluation board, consegna prevista per fine 2020

Attività in corso:

- FBK ha fornito a titolo gratuito alcuni campioni degli ultimi sviluppi di SiPM fuori catalogo
- In fase di test SiPM 4×4 mm^2 NUV-HD, Standard Field, cell pitch 40 μm
  e SiPM 3×3 mm^2 NUV-HD, Low Field, cell pitch 15 μm
- In fase di progettazione box per test parallelo di 8 SiPM



Task 8.4.2 Development of highly granular dual-readout fibre-sampling calorimeters

Modular construction/assembly of 10×10 cm^2, 2 m long prototypes

SiPM readout with time resolution O(100-200 ps)

Analog signal grouping (linearity!)

Compact modular readout elx (CAEN)

Objectives

small (1 m long) prototype to be built and tested in next months → mechanical assembly of 10×10 cm^2 modules

qualify commercial ASICs (Citiroc1A, MUSIC, … SiREAD)

assess needed information (Q, ToA, ToT, Peak, ToP) for particle ID/separation

assess time resolution requirements for longitudinal position reconstruction

investigate feature-extraction logic embedded on ASIC

test/qualify digital SiPM performance (FBK) - **NEW**

INFN : PV, MI, BO, PI, RM1, CT, TIFPA

Others:

University of Sussex, RBI Zagreb

+ cluster of Korean Universities (w/ 2 M$ grant over 5 years)

+ CAEN & FBK

Submitted call proposal (HiDRa) to INFN CSN 5

funding request of almost 1 M€

Backup

2020 prototype

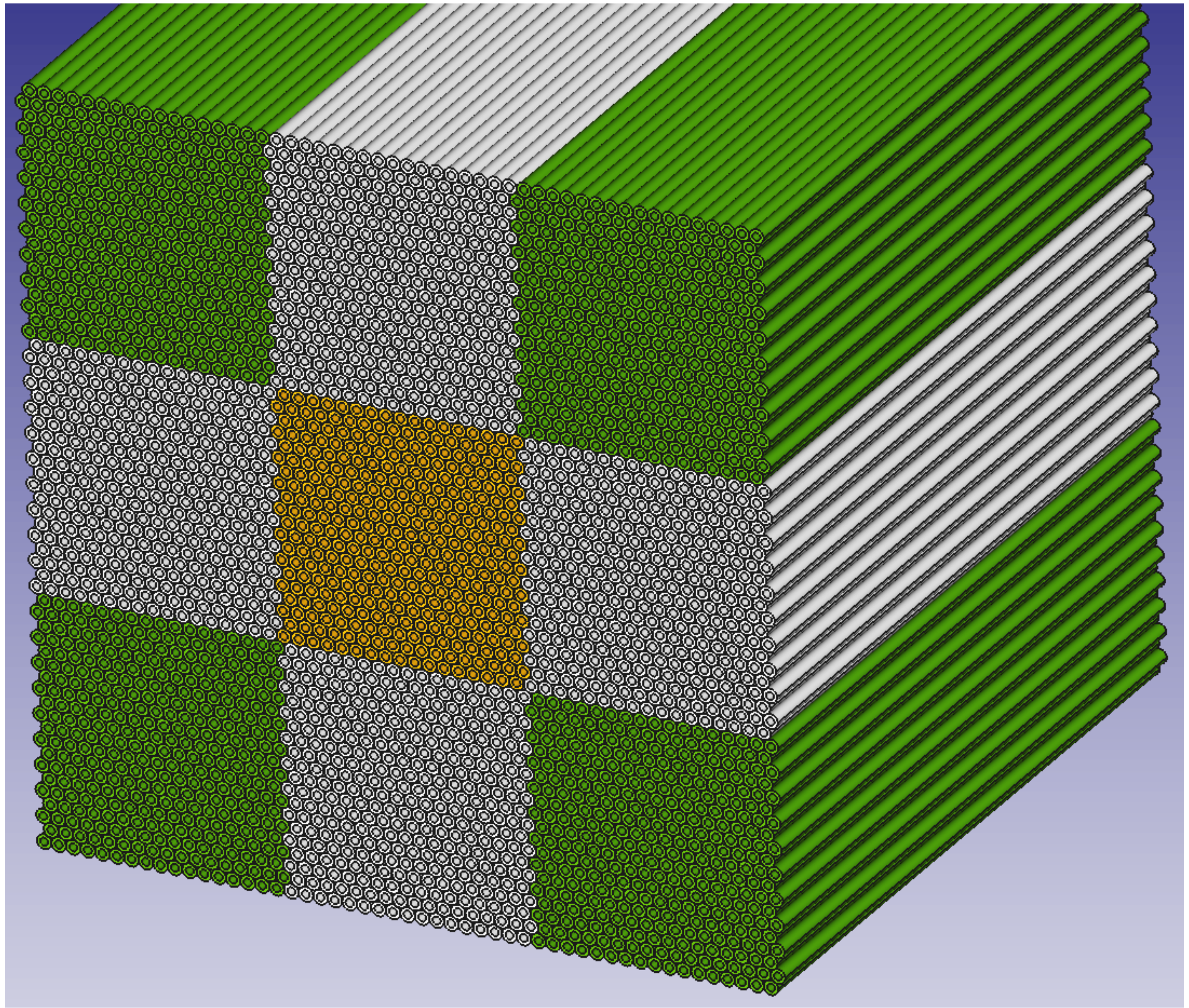
New idea: use tubelets (Zagreb RBI proposal)

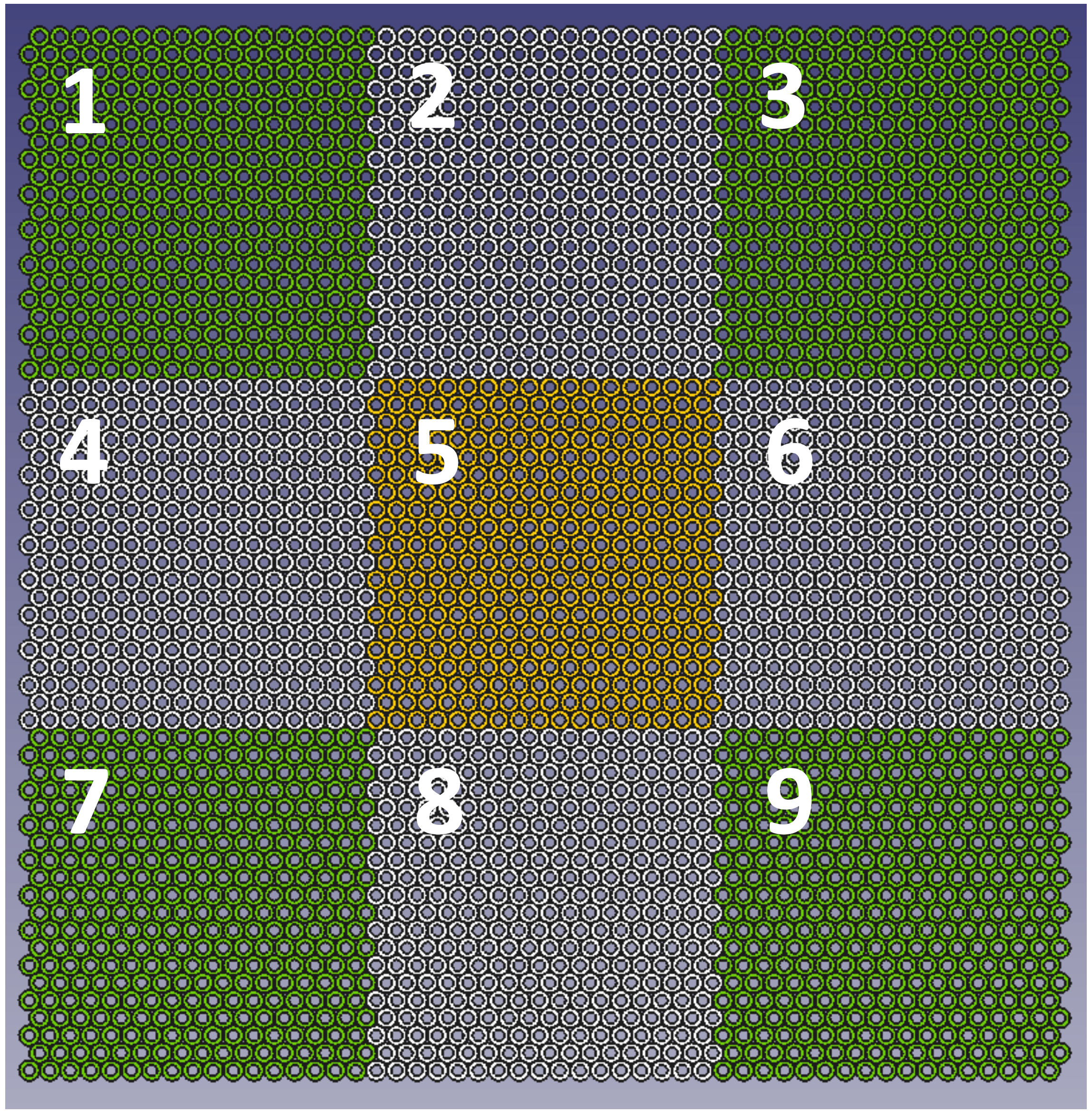
2020: build a ~10×10×100 cm^3 prototype
w/ 2 mm diameter tubelets

→ 60 horizontal layers of 51 tubes
→ 9 readout towers of 17×20 tubes each

central tower → SiPM readout
8 surrouding towers → PMT readout

Geometry





Tubelets

2.0 mm OD, 1.1 mm ID and 1000 mm Length

ID tolerance: + 0.1 mm and - 0.0 mm

Material: CuZn37, 170 VPN Hardness

→ independently build each 17×20 tower
→ two possible stacking strategies
→ gluing with Araldite 2011-A/B

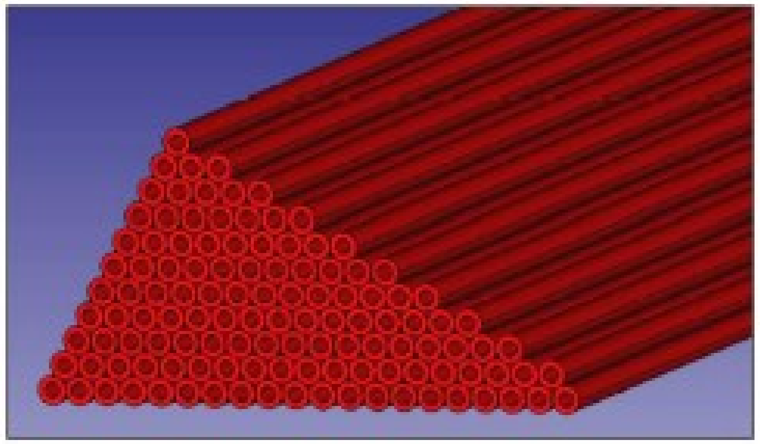
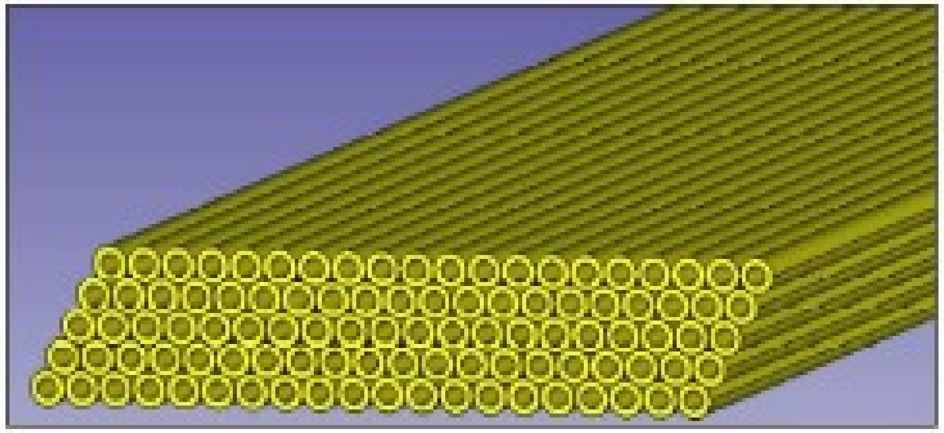
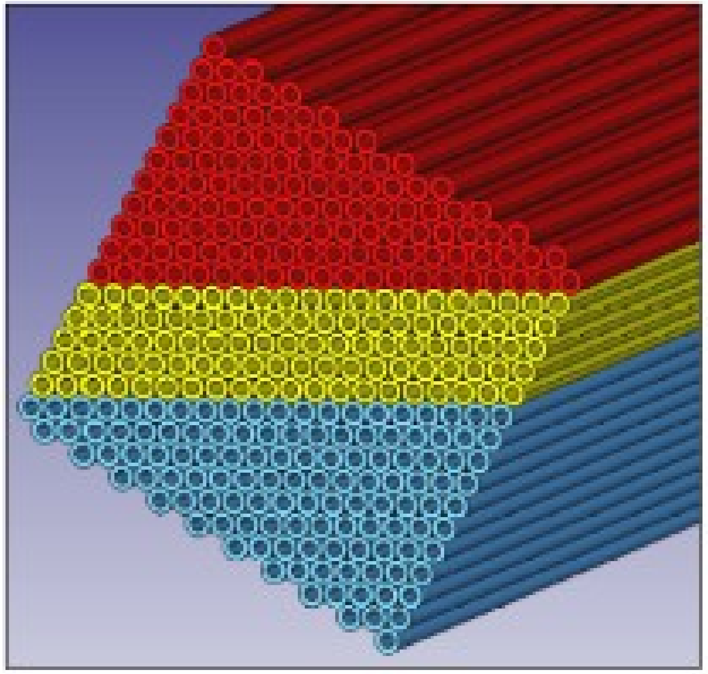
Stacking strategies

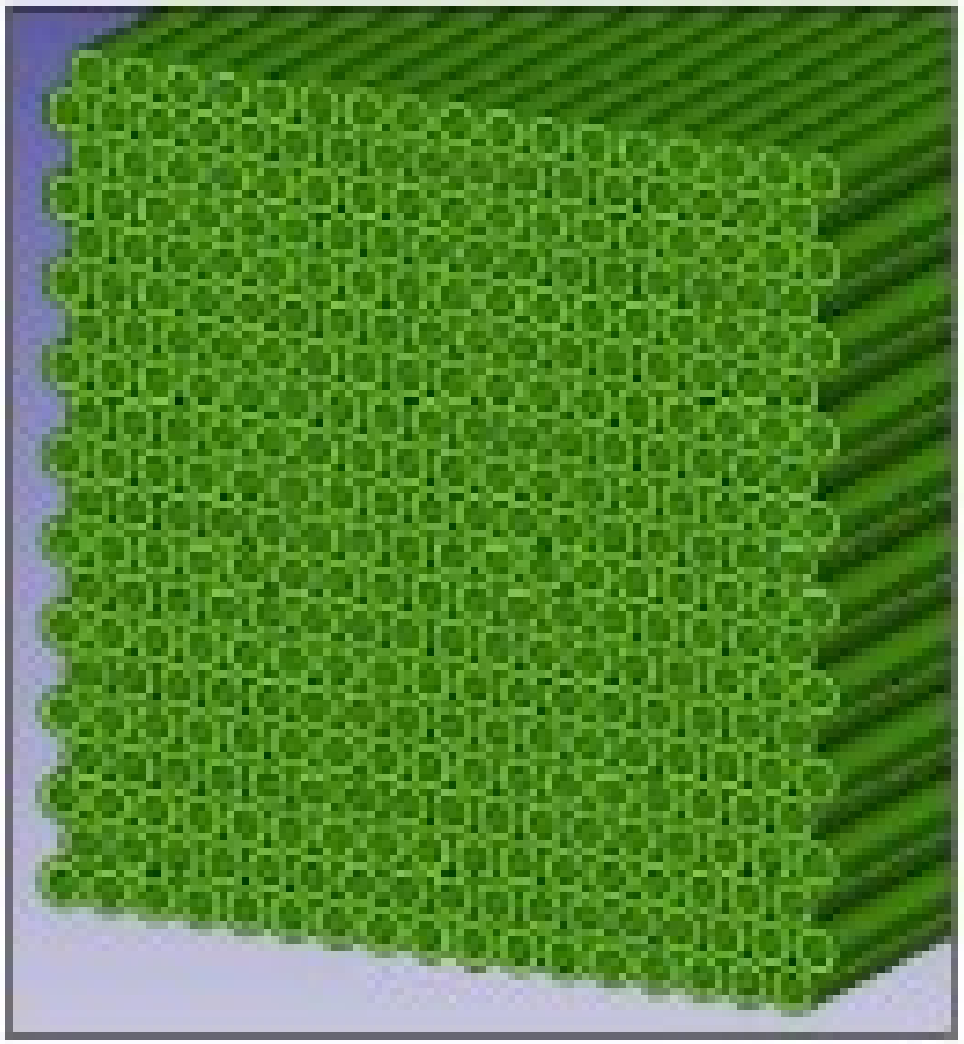
3 options under consideration:

- gluing one layer by one layer

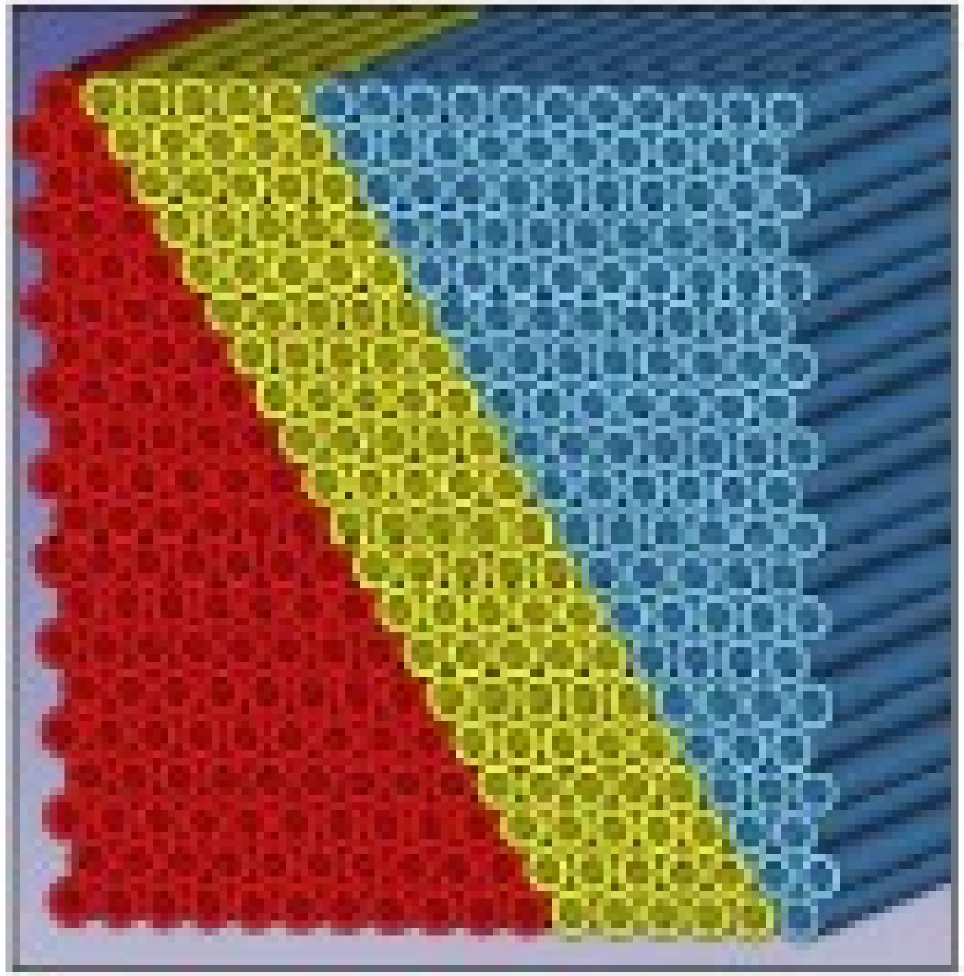
- gluing two layers at once

- divide in three pieces:



Longer time and higher glue consumption but better repeatability



Faster assembly time and lower glue consumption but worse repeatability

Preliminary tests seem to show that :

- horizontal alignment looks “easy”

- vertical alignment looks not that “easy”

→ impact of mechanical tolerances more critical wrt vertical alignment

- tolerances on straightness and external diameter ?
  → waiting for first bunch of tubes

Other big open issue:
fibre insertion ? To be studied at both RBI and Pavia

Process breakdown

- RBI : select, test and assembly tubelets
  study fibre insertion

- INFN Pavia : study and produce mechanics for fibre gathering and distribution
  study fibre insertion

- U. of Sussex : select and qualify S and Č fibres
  attenuation length, light yield, numerical aperture

- INFN Milano (Insubria) : SiPM selection and readout chain