INFN
Istituto Nazionale
di Fisica Nucleare

Call HiDRa

CdS Pavia - 14 luglio 2020

Roberto

CSN 5 Call – HiDRa

High-Resolution Highly Granular Dual-Readout Demonstrator

Goals:

direct demonstration of hadronic resolution:

~ 30% / √E [em ~ 10% / √E]

→ need “hadronic size” → ~ 65×65×200 cm^3

identify and assess a scalable solution (in all aspects)

work out all critical issues for physics at future leptonic Higgs factories

CSN 5 Call – Ingredients

Mechanics:

identify and assess a scalable construction method
(material, assembly, QAQC)

Sensors (SiPMs):

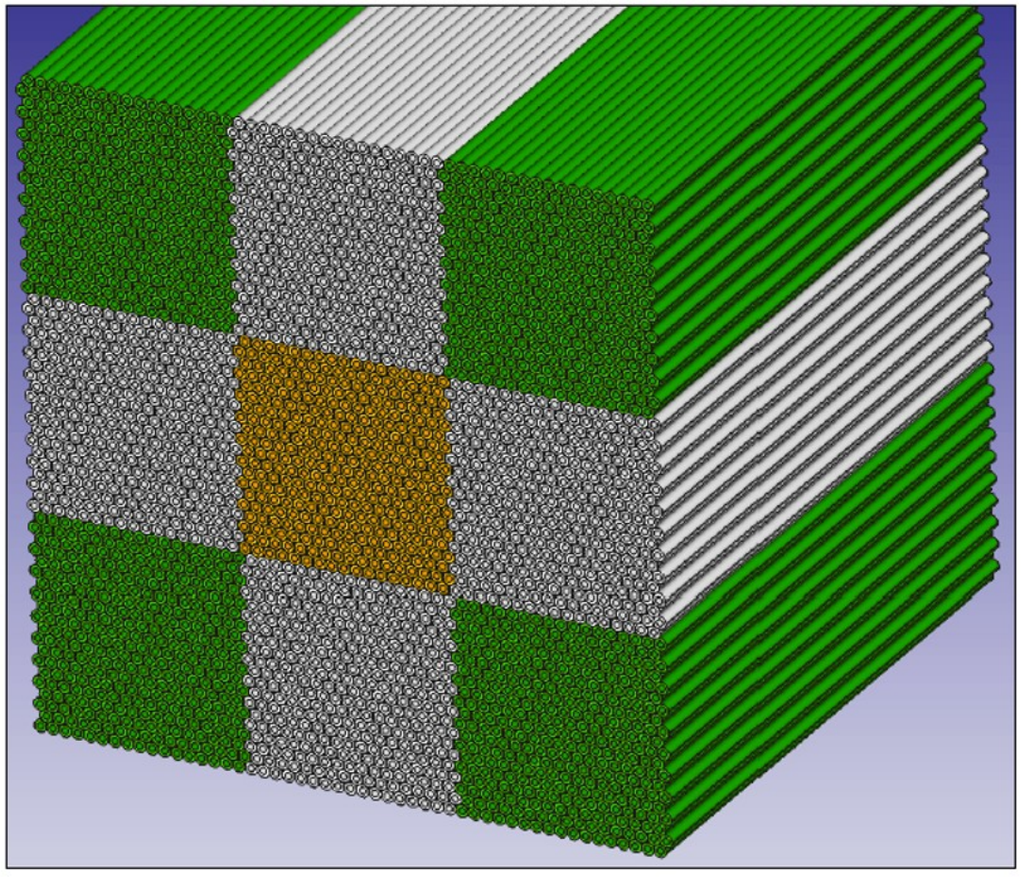
high transverse granularity O(2 mm)
timing information O(100 ps) → shower depth O(5 cm)

FEE: test/qualify commercial ASIC
→ Citiroc (QDC), SiREAD (sampler), MUSIC

digital SiPMs: highly prospective R&D

Simulations, data analysis … deep learning algorithms …
→ validate Geant4 simulations

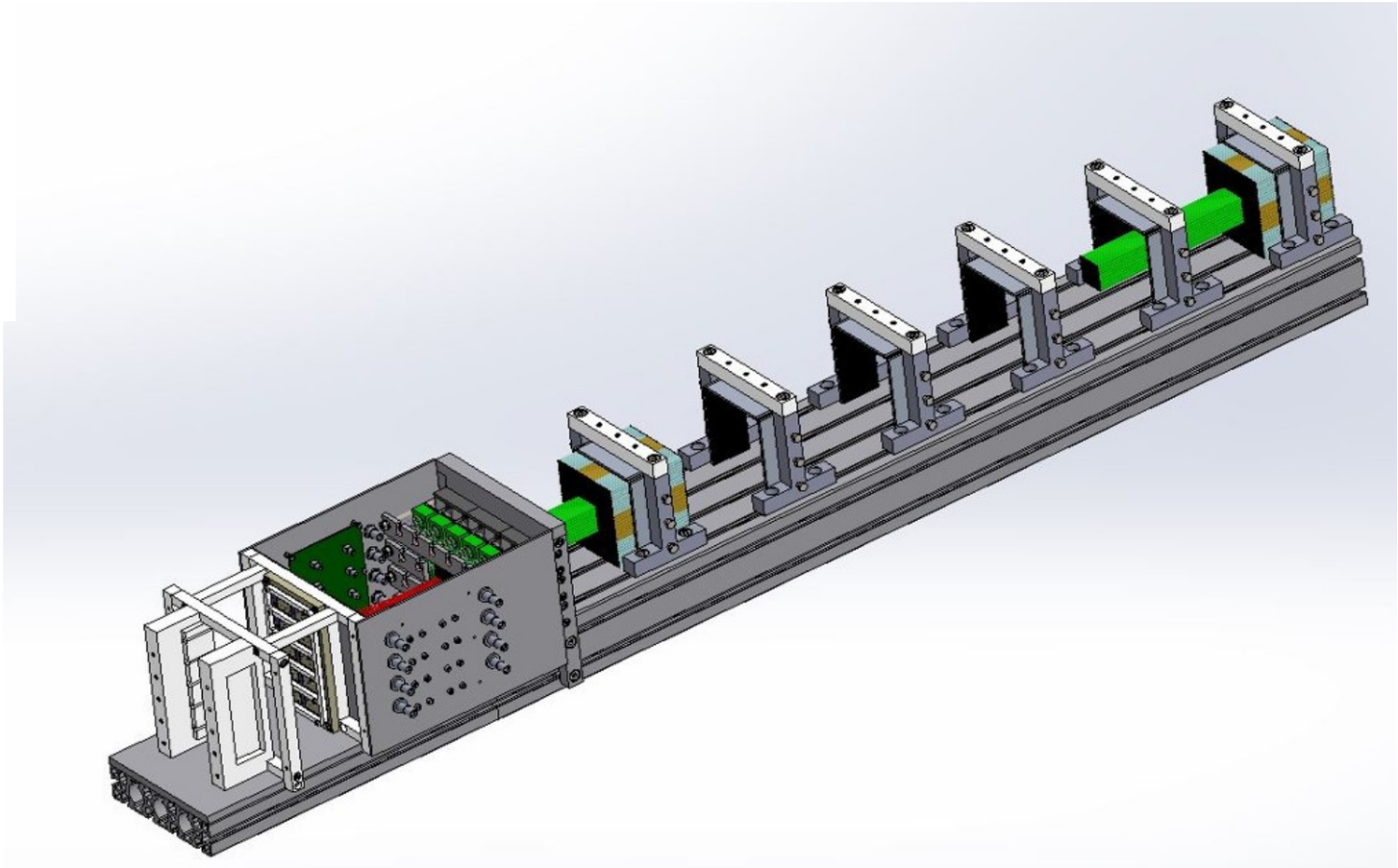
The 10×10 cm^2 2020 prototype



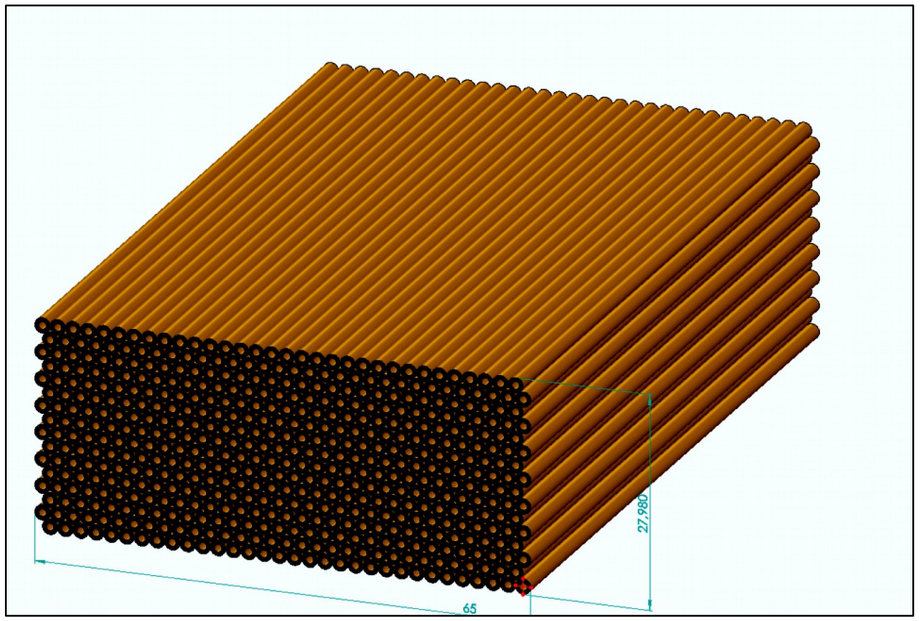
10×10 cm^2 divided in 9 (1m long) towers
16×20 capillary each (160 C + 160 S)

Tubelets:
- brass CuZn37
- 2 mm outer Ø, 1 mm inner Ø

Readout:
- central tower with SiPMs
- 8 surrounding towers with PMTs (à la RD_52)

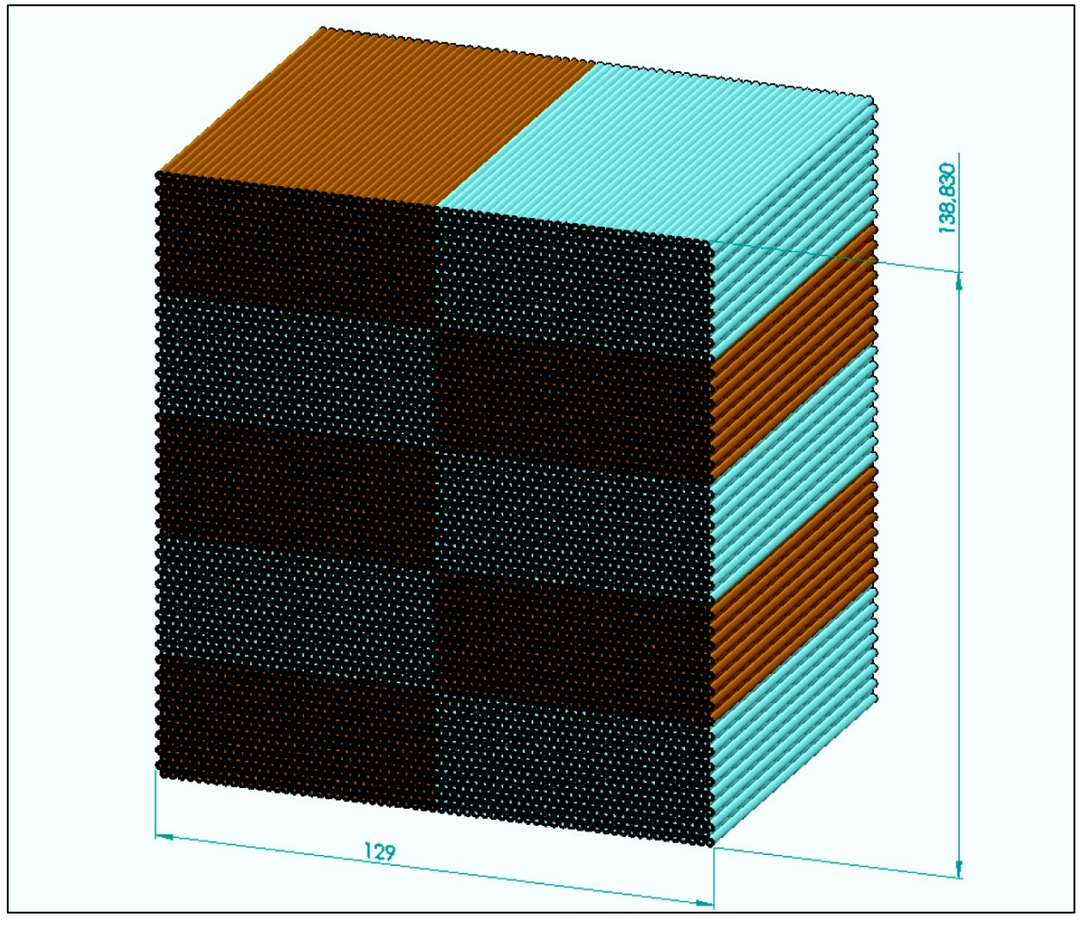


Detector design



1 Mini-Module (MM):

32 × 16 channel (512 ch)



1 Module:

2 × 5 MMs
→ 10 FEE boards
(8-channel grouping)

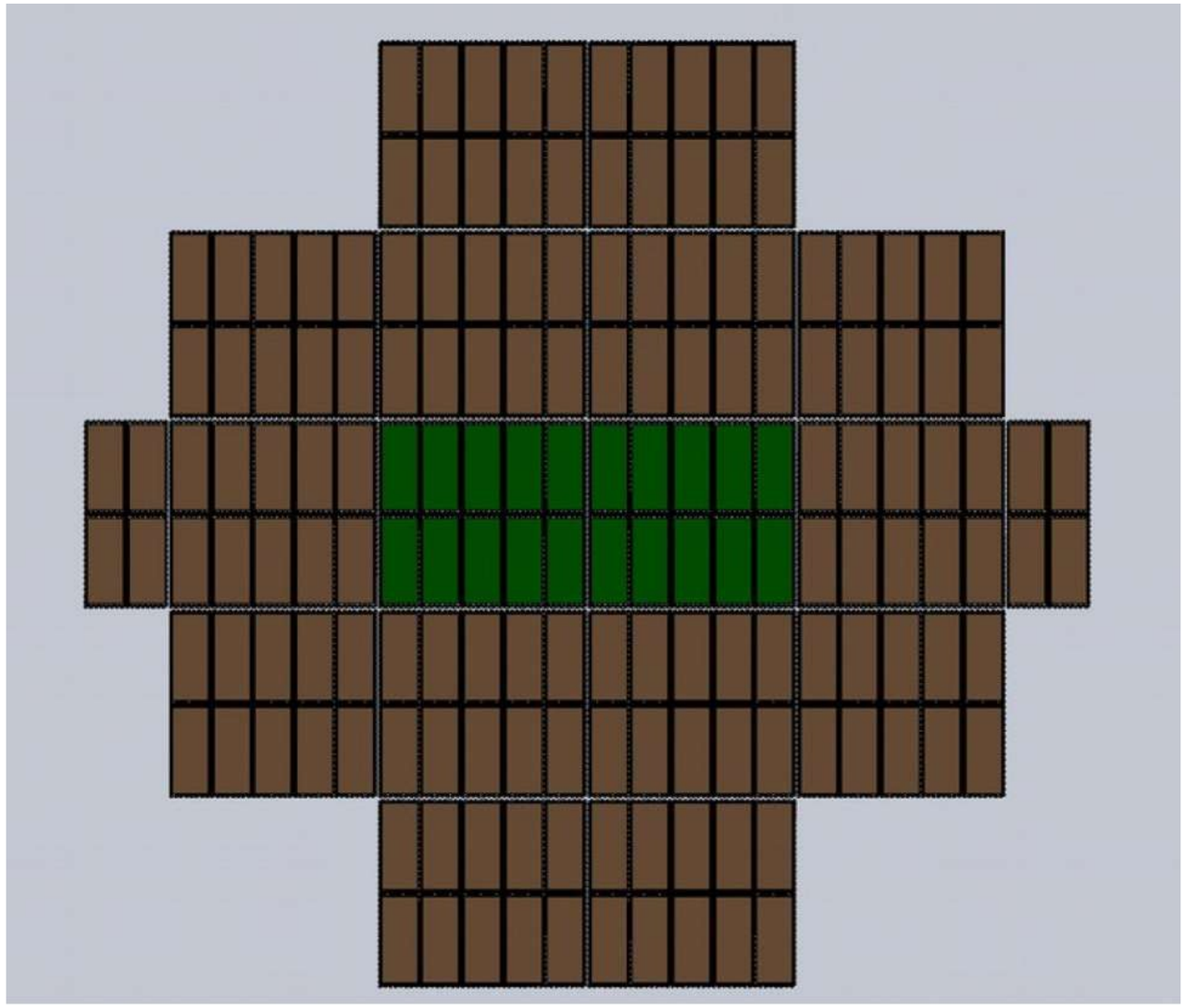
~ 13 × 13 × 200 cm^3

Main deliverables

17 modules:

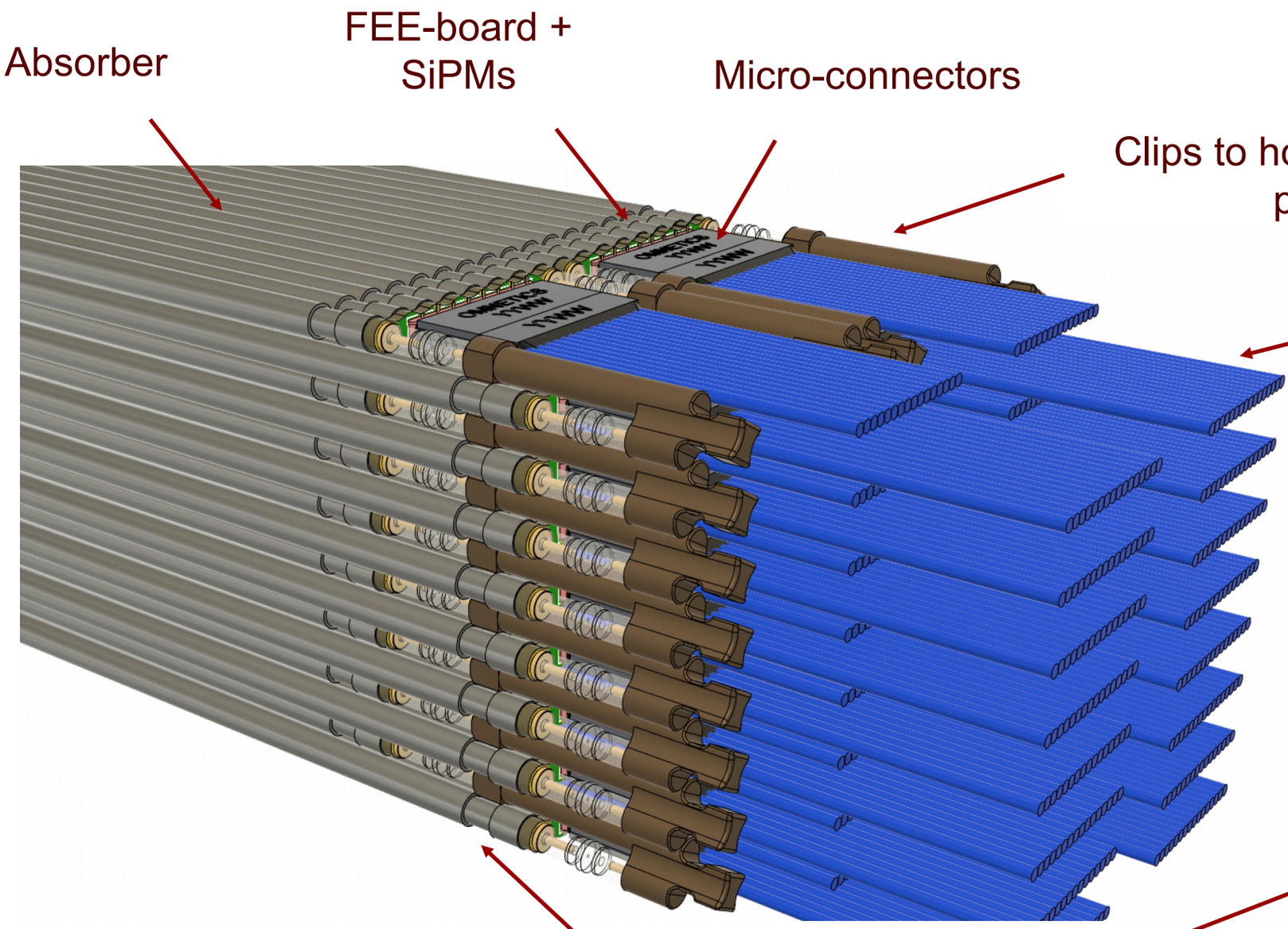
- 2 central ones with SiPMs
  → ~ 10 k SiPMs
  → ~ 20 FEE boards

- all others with PMTs
  → ~ 150 PMTs



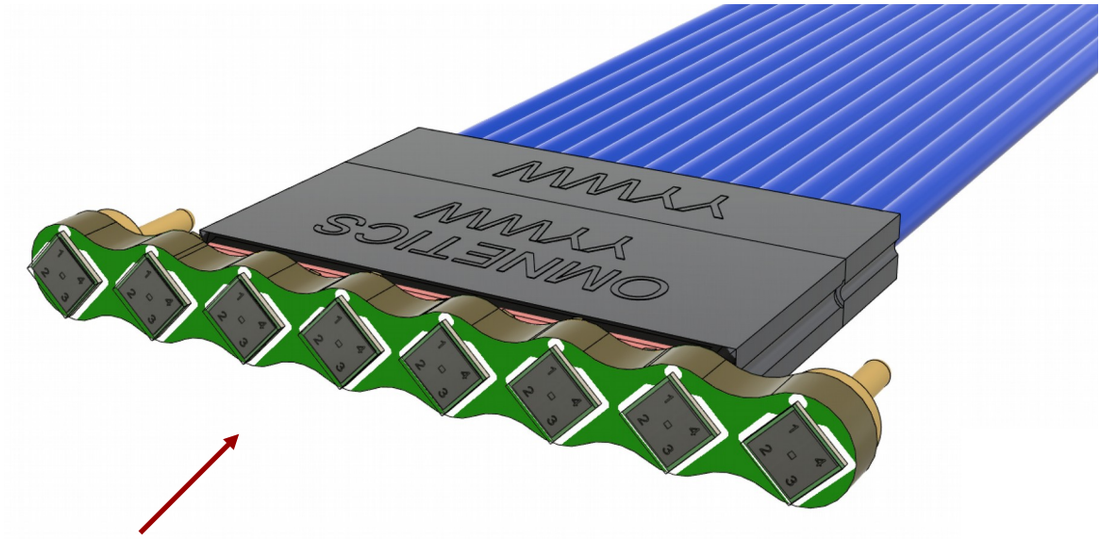
d-SiPMs: small 64-channel demonstrator
~ 1 × 1 × 100 cm^3

New concept for a true scalable module (I)



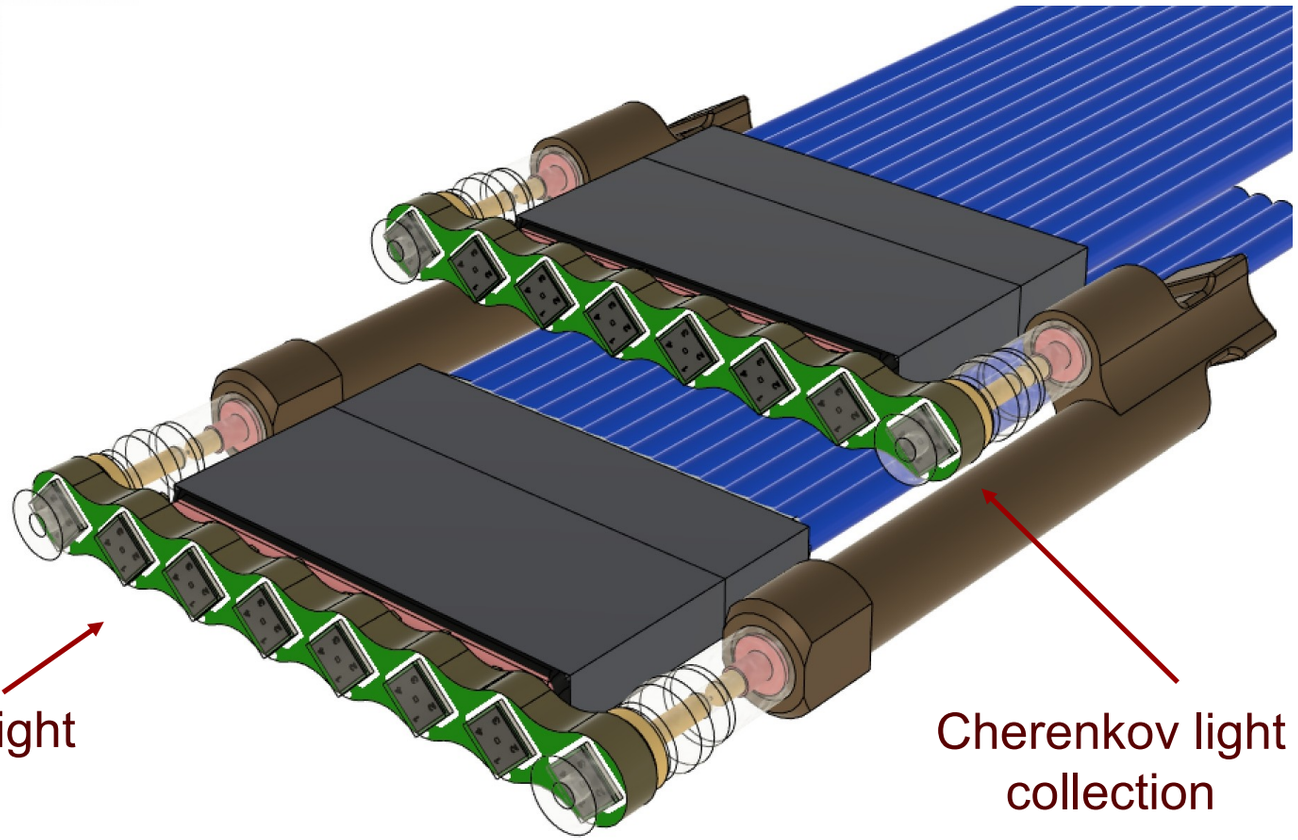
preliminary test

New concept for a true scalable module (II)



FEE-board + SiPMs
Segmentation optimised to exploit grouping

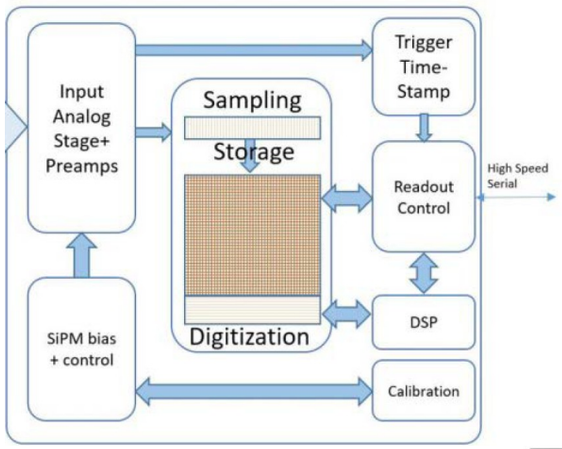
Pair of FEE-boards joint together with clips



Scintillating light collection

Cherenkov light collection

SiREAD waveform sampler (alternative readout ASIC)

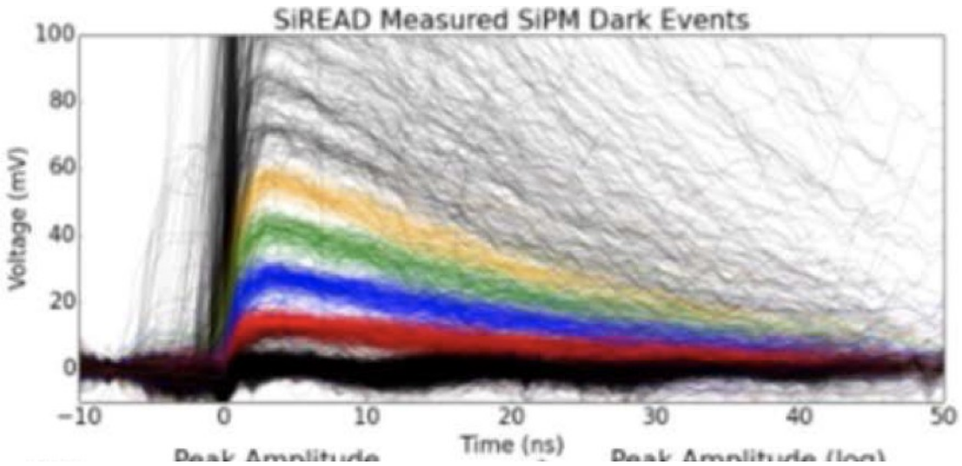


System-on-Chip with

a) built-in SiPM biasing, calibration and digitisation control (analog side)

b) feature extraction and digital signal processing (digital side)

Micrograph of the fabricated prototype SiREAD and chip on the evaluation PCB



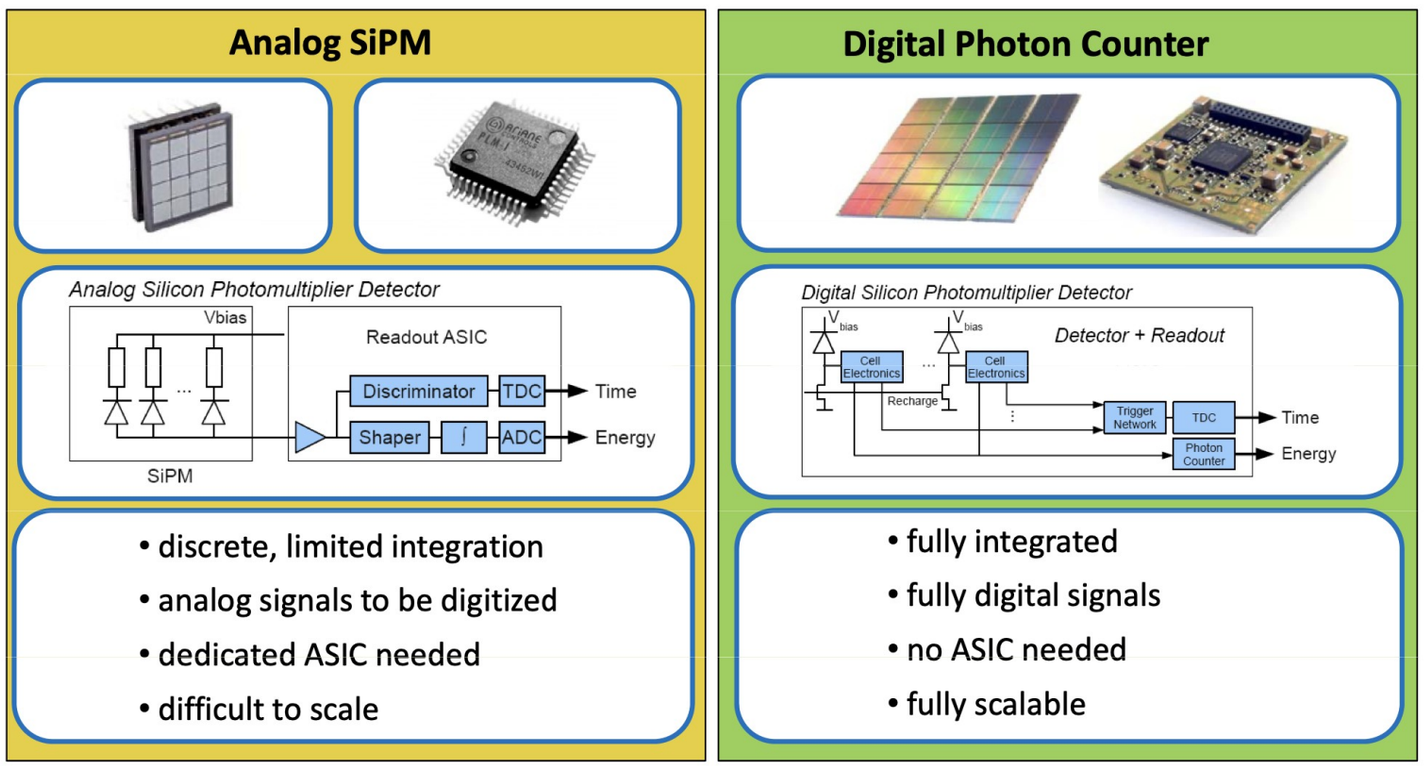
https://indico.bnl.gov/event/6351/contributions/29462/attachments/23682/34356/190709_Nalu_Scientific_-_Electronics_Update_for_EIC-PID_workshop_for_web.pdf

Produced by Nalu Scientific

Plans for integration into the FERS readout system (CAEN)

Next year, demo board likely available for preliminary tests and qualification

Do we really want to be Analogue ?



https://indico.cern.ch/event/192695/contributions/353376/attachments/277251/387863/TIPP2014_Amsterdam_lecture_Philips_Haemisch_pub.pdf

- Not yet consolidated technology but strategic R&D in terms of cost production and system complexity
- Performance not yet at SiPM level but rapidly improving
- Good expertise, in simulation and design, at FBK and in few INFN groups
- Non-linearity corrected before summing information
- Timing performance more straightforward

Interesting review-paper: NIM-A, 809 (2016), 31-52

SW and performance

Lot of work in progress for:

a) integration in FCCSW (DD4HEP, EDM, digitisation, …)

b) integration with other detectors (drift chamber and preshower)

c) development of calibration and correction procedures for single particles (e, γ, μ, single hadrons, jets)

d) exploiting timing information

e) developing deep learning algorithms for event selection and reconstruction

f) crystal option for em measurements (U.S. colleagues) ××× NEWS ×××

g) last but not least: clearing inconsistencies between EU and SK results

Many people contributing (INFN, U.K., Croatia, S. Korea, … U.S.)

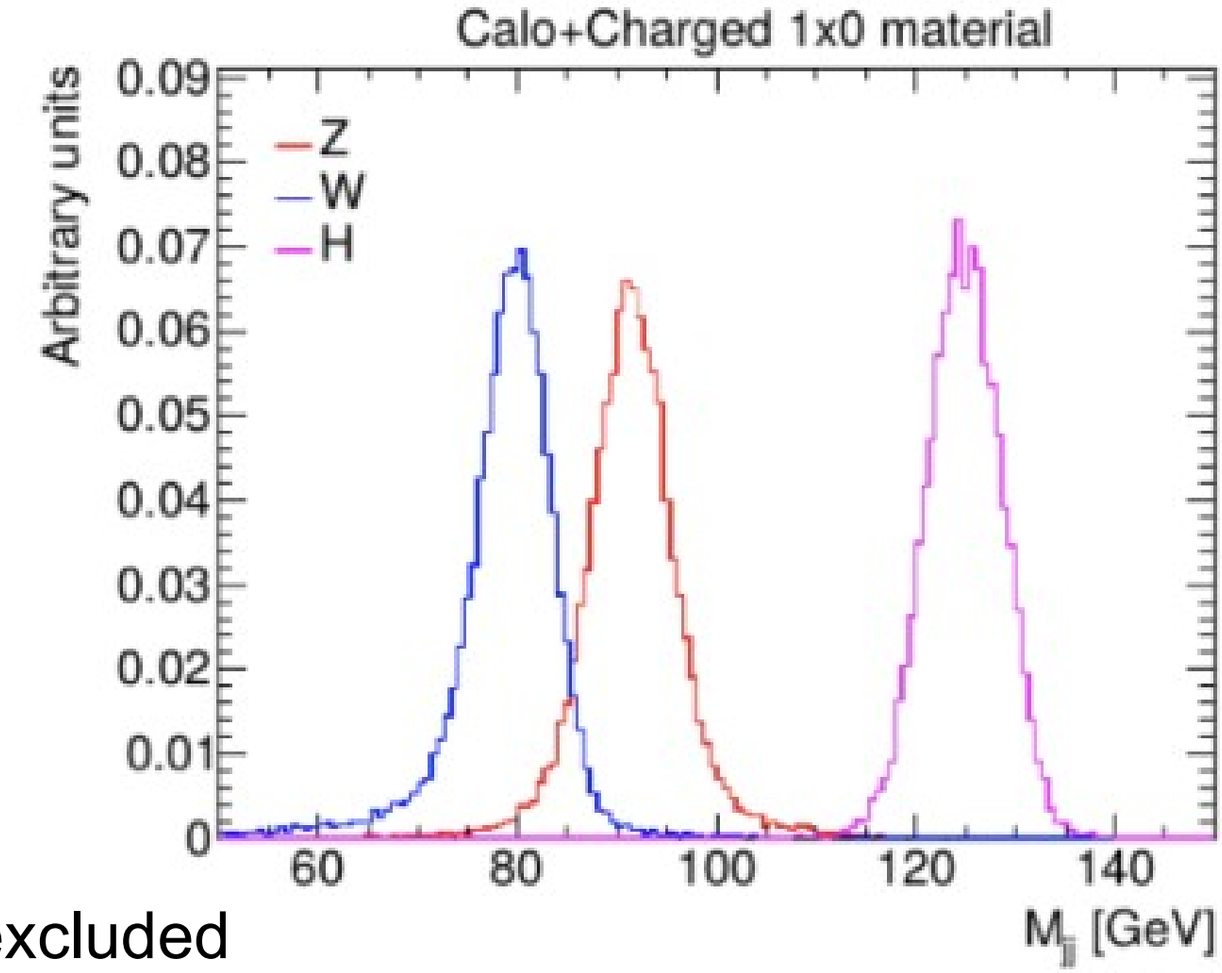
Commercial information

Physics benchmarks: 2-jet final states

$$e^+e^- \to HZ \to \tilde{\chi}^0\tilde{\chi}^0 jj$$

$$e^+e^- \to WW \to \nu_\mu \mu jj$$

$$e^+e^- \to HZ \to bb\nu\nu$$



semi-leptonic decays of heavy quarks excluded

Project organisation

P.I.: Roberto Ferrari (PV)

WP 1: Mechanics and fibre characterisation (MI, PI, PV)
Responsible: G. Gaudio (PV)

WP 2: Light sensors (analog and digital SiPMs) (BO, CT, MI, TIFPA)
Responsible: M. Caccia (MI)

WP 3: FEE and DAQ development (BO, CT, MI, PV, TIFPA)
Responsible: R. Santoro (MI)

WP 4: Performance assessment (MI, PV, RM1)
Responsible: G. Polesello (PV)

Groups and personpower

7 INFN departments (BO, CT, MI, PI, PV, RM1, TIFPA)

External firms: CAEN, FBK

International collaborators: RBI (HR), Un. Sussex (UK), Kyungpook National Univ., Seoul National Univ, Univ. of Seoul,
Yonsei Univ. (S. Korea)

RU	FTE and Numer of people (without AdR requests)						FTE and Numer of people (with AdR requests)					
	2021		2022		2023		2021		2022		2023	
	FTE	People	FTE	People	FTE	People	FTE	People	FTE	People	FTE	People
Bologna	0,7	2	0,7	2	0,7	2	1,7	3	1,7	3	0,7	2
Catania	0,6	3	0,6	3	0,6	3	0,6	3	1,6	4	0,6	3
Milano	1	3	1	3	1	3	1	3	2	4	2	4
Pavia	1,8	7	1,8	7	1,8	7	2,3	7,5	2,8	8	2,3	7,5
Pisa	0,8	4	0,8	4	0,8	4	0,8	4	1,8	5	1,8	5
Roma 1	0,2	1	0,2	1	0,2	1	1,2	2	1,2	2	0,2	1
TIFPA	1,2	3	1,2	3	1,2	3	1,2	3	1,2	3	1,2	3
Total	6,3	23	6,3	23	6,3	23	8,8	25,5	12,3	29	8,8	25,5

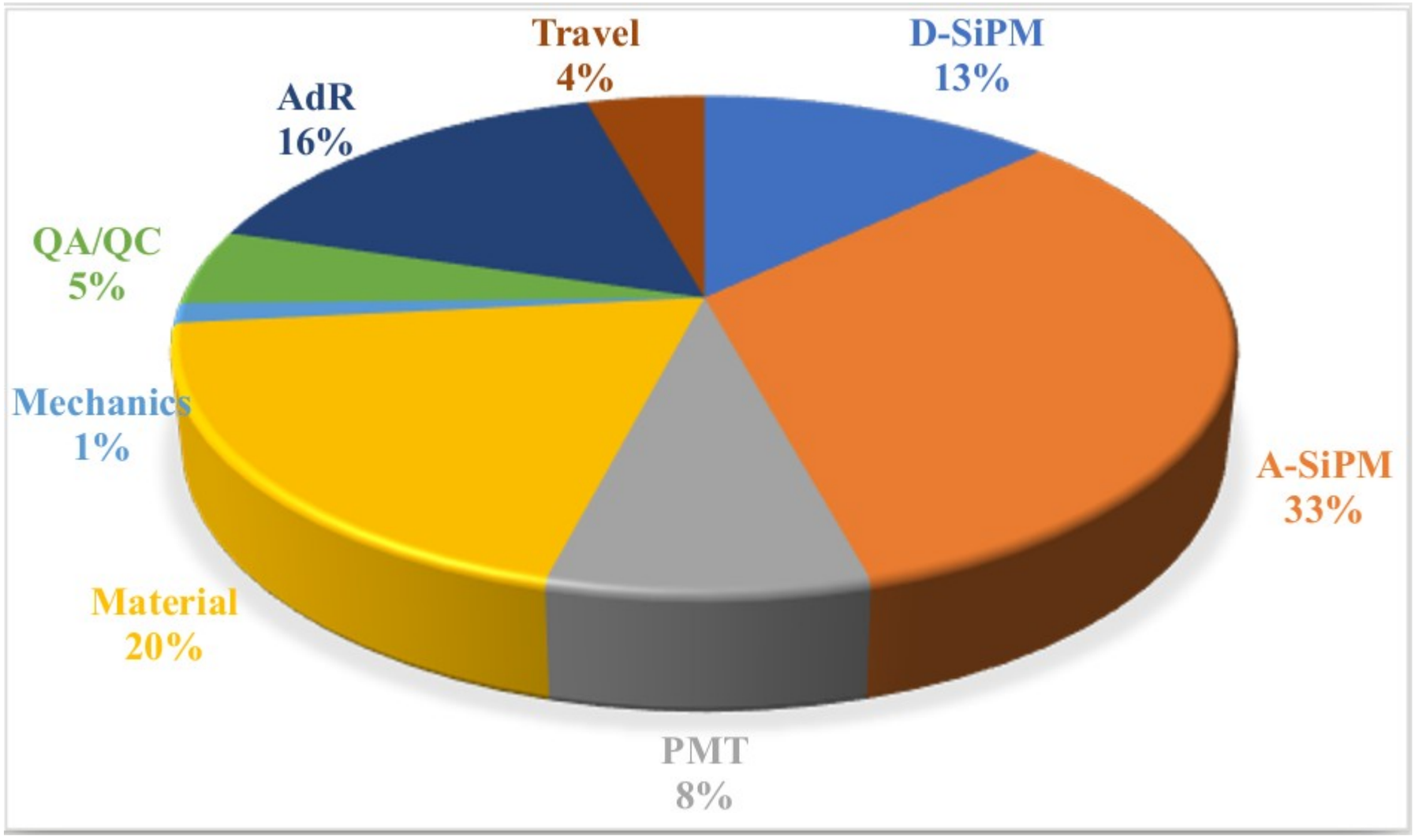
Table 1.3.1. Summary of FTE per each RU during the 3 years of the project.

Pavia group

G. Gaudio	20
J. Agarwala	30
R. Ferrari	50
A. Negri	10
L. Pezzotti	30
G. Polesello	20
S. Sottocornola	20
AdR (50% on project funds)	67
FTE	2.5

Funding requests

Total request: 858 k € (dominated by M&S)



Funding requests

Total request: 858 k € (dominated by M&S)

		BO	CT	MI	PV	PI	RM1	TIFPA	TOTALI
2021	M&S	40	15	115.3	16.2	24.4	0	15	**225.9**
	AdR	12.5	0	0	6	0	12.5	0	**31**
	Travel	1	1	1	4.4	1.1	0.4	1.6	**10.5**
2022	M&S	55	0	95	78	85	0	0	**313**
	AdR	12.5	12.5	12.5	12.5	12.5	12.5	0	**75**
	Travel	1	1	1.5	4	1.1	0.4	1.6	**10.6**
2023	M&S	50	0	5	39.2	45	0	0	**139.2**
	AdR	0	0	12.5	6.5	12.5	0	0	**31.5**
	Travel	2.2	1.6	3.5	7.2	2.6	0.4	4	**21.5**
Totali	M&S	145	15	215.3	133.4	154.4	0	15	**678.1**
	AdR	25	12.5	25	25	25	25	0	**137.5**
	Travel	4.2	3.6	6	15.6	4.8	1.2	7.2	**42.6**
Complessivo		174.2	31.1	246.3	174	184.2	26.2	22.2	**858.2**

External funding

AIDAinnova proposal

40 k€ → PV
30 k€ → CAEN
40 k€ → Sussex Un.
20 k€ → RBI

mainly for hiring people (AdR)

S. Korea: large funding for a 5-year project (projective hadronic prototype)

Requests to be submitted by our E.U. collaborators (U.K. and Croatia)

New potential collaborators showing up:

U.S. – Sarah Eno (Maryland), Chris Tully, Marco Lucchini (Princeton)
→ crystal option

FCC France – Gregorio Bernardi, Susan Gascon (CNRS)

Very rough time profile

Y 1 : R&D → identify solutions

Y 2 & 3 : prototype construction and (finally) qualification with beam

Richieste servizi (Pavia)

Officina meccanica: 5 m.u. / anno

Elettronica: 5 m.u. / anno

Summary

R&D still needed to assess DR performance and reach a "production level" maturity

3 years to build and test a hadronic-containment prototype

Main technical issues:
- mechanical construction
- readout complexity

Highly prospective R&D on digital SiPMs

Collaboration growing (crystal option likely coming) …

Plan B: continue R&D within RD_FCC at reduced speed