# *Dual-Readout Calorimetry R&D Programme Status*

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*(on behalf of the IDEA proto-collaboration)*
*May 6th, 2020*

# Project breakdown

1) mechanics (absorber, structure, ...)

2) optical elements (fibre core, cladding, filters, ...)

3) light sensors

4) front-end electronics

5) data readout and processing

6) simulations and detector performance

# 1) Mechanics

- absorber choice (copper/brass, iron, lead, … ?)

- absorber structure (dimensions and production methods of basic elements)

- definition of procedure for “tower” assembly

- $4\pi$ projective geometry breakdown

# 1) Mechanics - objectives

1) refine possible absorber choices

2) select and validate a scalable tower-element production and assembly technique

→ tubelets, molding, rolling, extruding, … 3D printing

→ piling up / gluing

→ fibre deposition/insertion (fibres in metal tubes ?)

3) identify and validate mechanical self-supporting structure

4) identify and validate a $4\pi$ projective geometry solution

# 1) Mechanics - objectives

1) refine possible absorber choices

2) full-hadronic-containment module → validate both hadronic and em performance (resolution, particle id)

2) 4π projective geometry solution

# 2) Optics

- investigate fibre production

- fibre selection (attenuation length, numerical aperture, light mirroring)

- quality control and assurance

- matching with light-sensor PDE

# 2) Optics - objectives

- target light yields of ~ 100 Cpe/GeV and 400 Spe/GeV → O(10-30) attenuation of S signals

- obtain attenuation length of much longer than 2 m (scintillation-light yellow filtering)

- optimise matching to SiPM PDE spectrum

(interdependent)

- optical cross-talk: tackle S→C contamination ($10^{-4}$ ?)

# 3) Light sensors (SiPMs)

- dynamic range

- linearity

- cross-talk

- analog grouping

- digital SiPMs ?

# 3) Light sensors - objectives

- investigate standard vs. custom SiPM

- dynamic range: correctly handle 2-5 k photons over a single sensor

- validate (1-10) channel analog grouping (→linearity)

- investigate digital SiPMs ?

- Čerenkov-light sensing → UV sensitive SiPMs ?

- build/spread sensor qualification setups and expertise

# 4) FE electronics

- signal integration vs. sampling
- off-the-shelf vs. custom ASIC
- FPGA for information reduction (feature extraction)

Likely at present the most complex issue

# 4) FE electronics - objectives

- qualify commercial ASICs (Citiroc1A, MUSIC, ...)

- assess needed information (Q, Peak, ToA, ToT, ToP)

- assess time resolution requirements for longitudinal position reconstruction

- investigate feature extraction logic embedded on ASIC

# 5) Data readout and processing

1) Online:

- strongly depends on ASIC choice (FERS + data collector)

- sampling would require hard real-time digital processing

- neural networks for triggering purposes

2) Offline:

- exploit/validate neural networks for complex final-state identification and reconstruction

# 6) Detector performance

- Energy resolution (e/γ, single hadrons, jets, μ)

- Position (angular) resolution: resolve $\pi^0 \rightarrow 2\gamma$ decays

- Virtual longitudinal segmentation: exploit timing

- Isolated particle ID: e / γ / μ / single hadrons

- Complex particle ID: τ hadronic decays, e/γ within jets

- Identification and reconstruction of final states from $Z/W/H \rightarrow jj$, $H \rightarrow ZZ^*/WW^* \rightarrow 4j$, $H \rightarrow \gamma\gamma$, $Z/H \rightarrow \tau\tau$ decays

# Project schedule and funding

2020 (em) prototype with tubelers:

- work ongoing with delays of few months for COVID-19 crisis. The testbeam schedule needs to be reassessed

Full scale prototype(s):

- funding available in Korea for a 5-year R&D project to build and qualify a “full-hadronic-scale” projective prototype

- in Europe, no fund beyond 2020 is yet secured, preparing requests for a 3-year R&D project

# Backup

# 2020 prototype

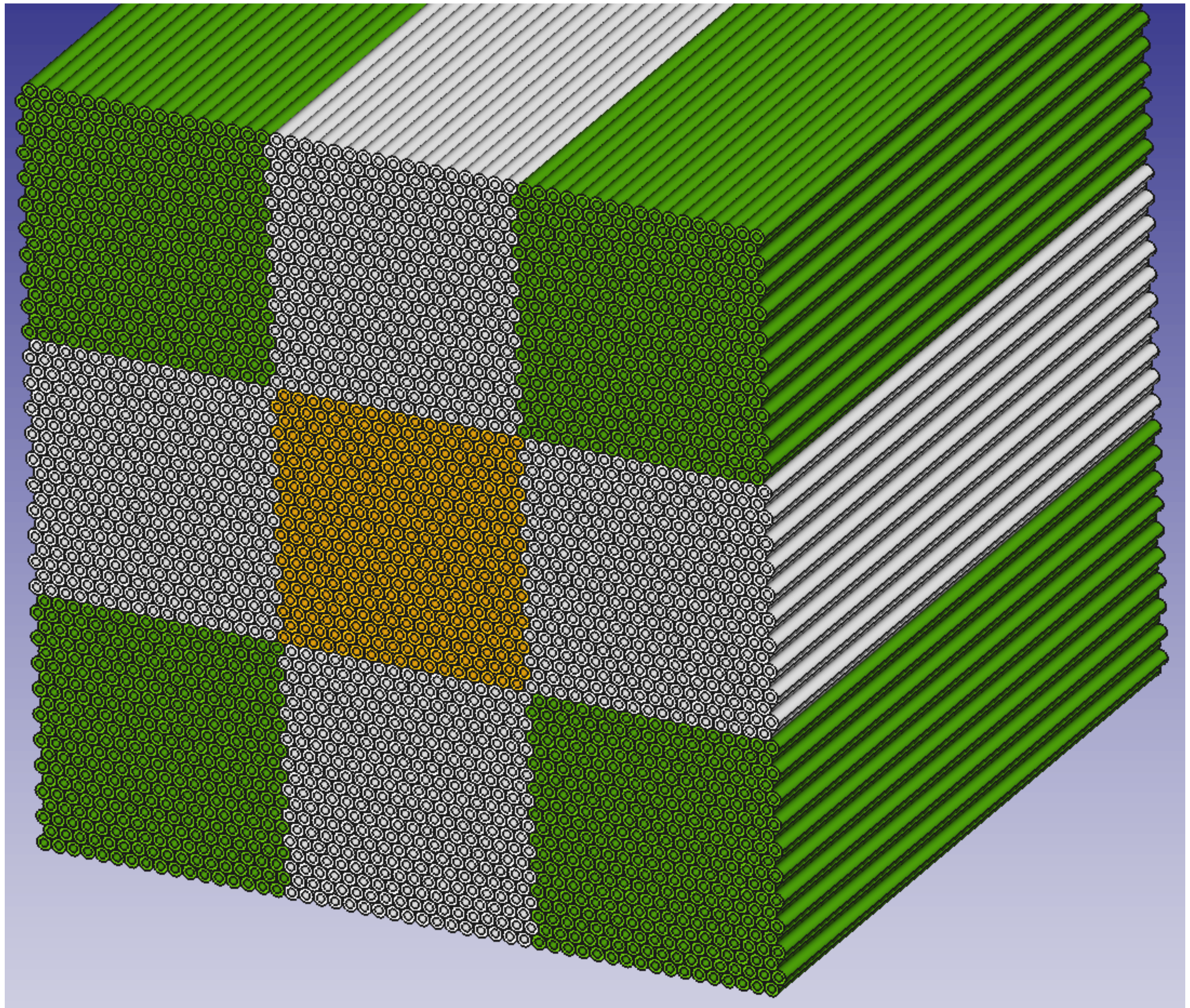
## New idea: use tubelets (Zagreb RBI proposal)

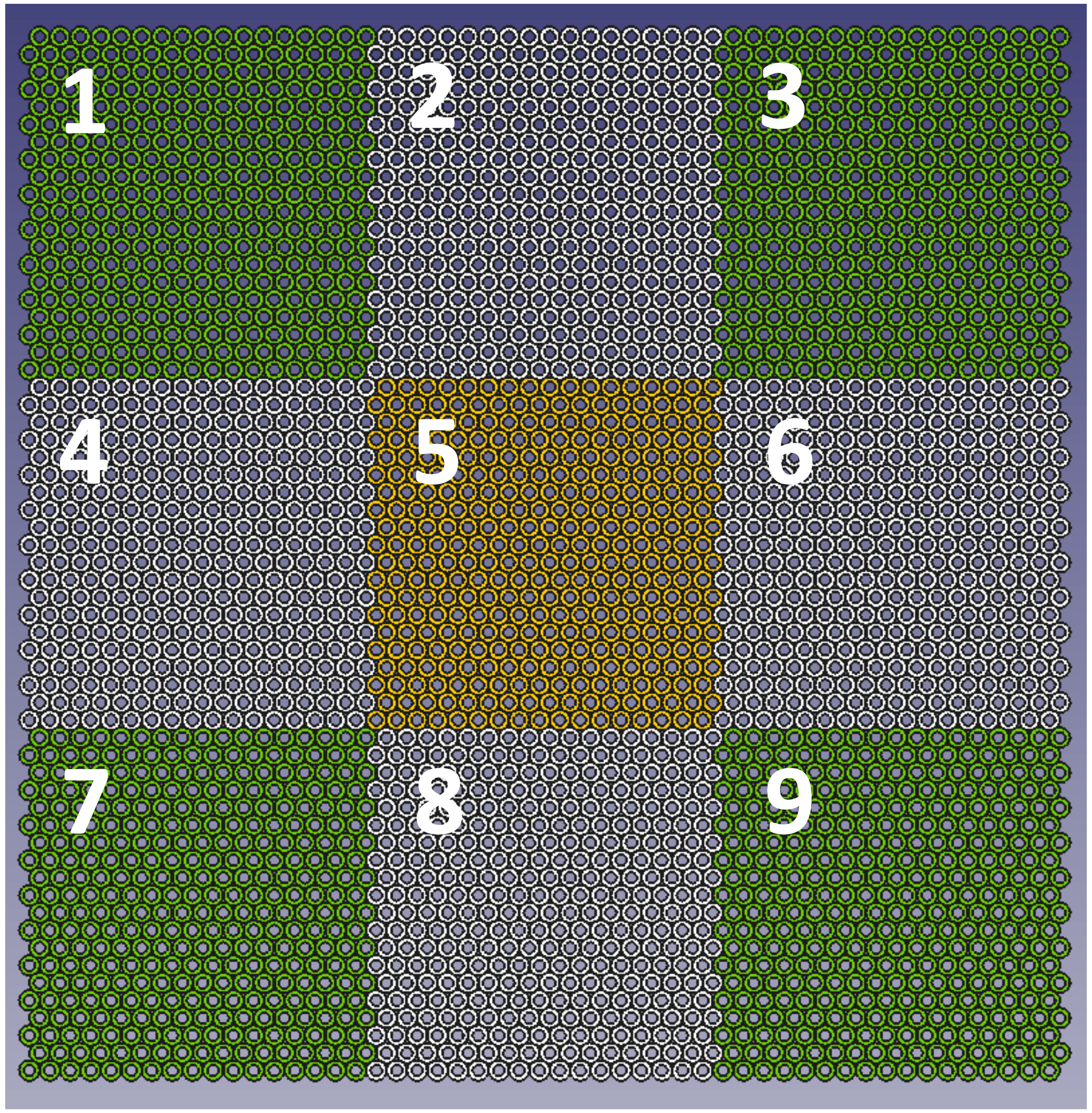
2020: build a ~10×10×100 $cm^3$ prototype
w/ 2 mm diameter tubelets

→ 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

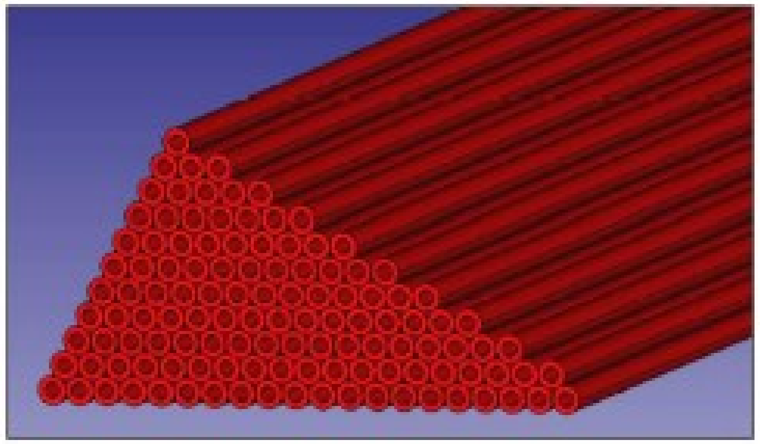
# Stacking strategies

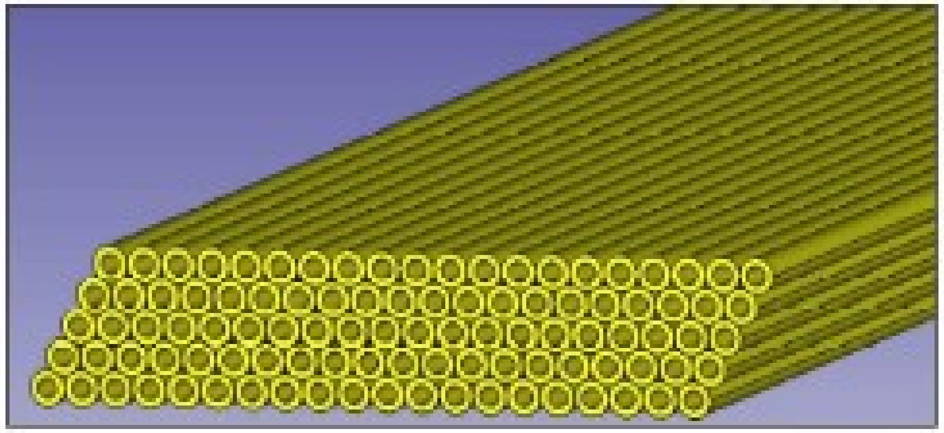
3 options under consideration:

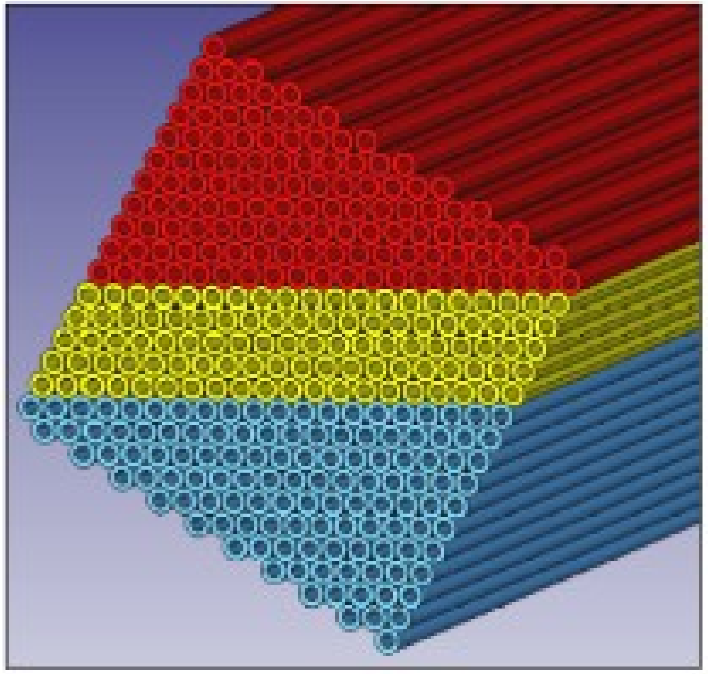
- gluing one layer by one layer

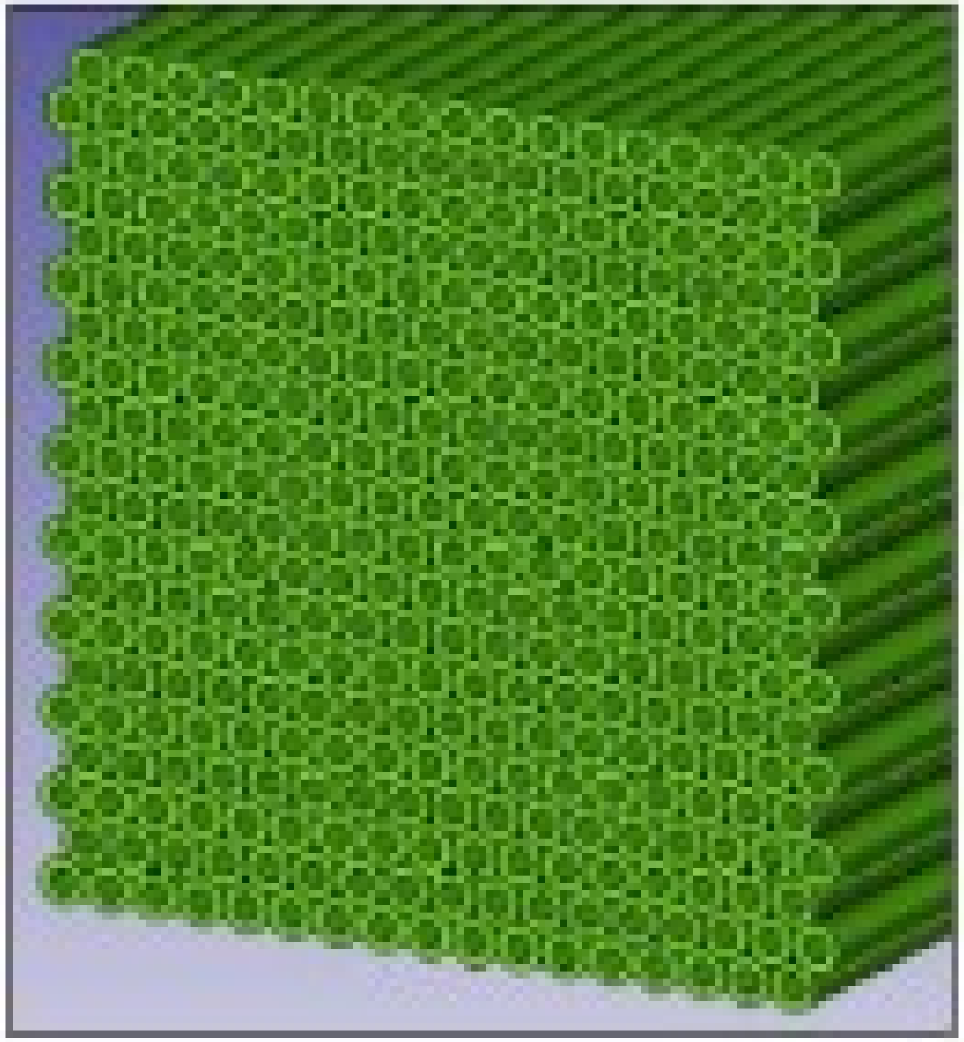
- gluing two layers at once

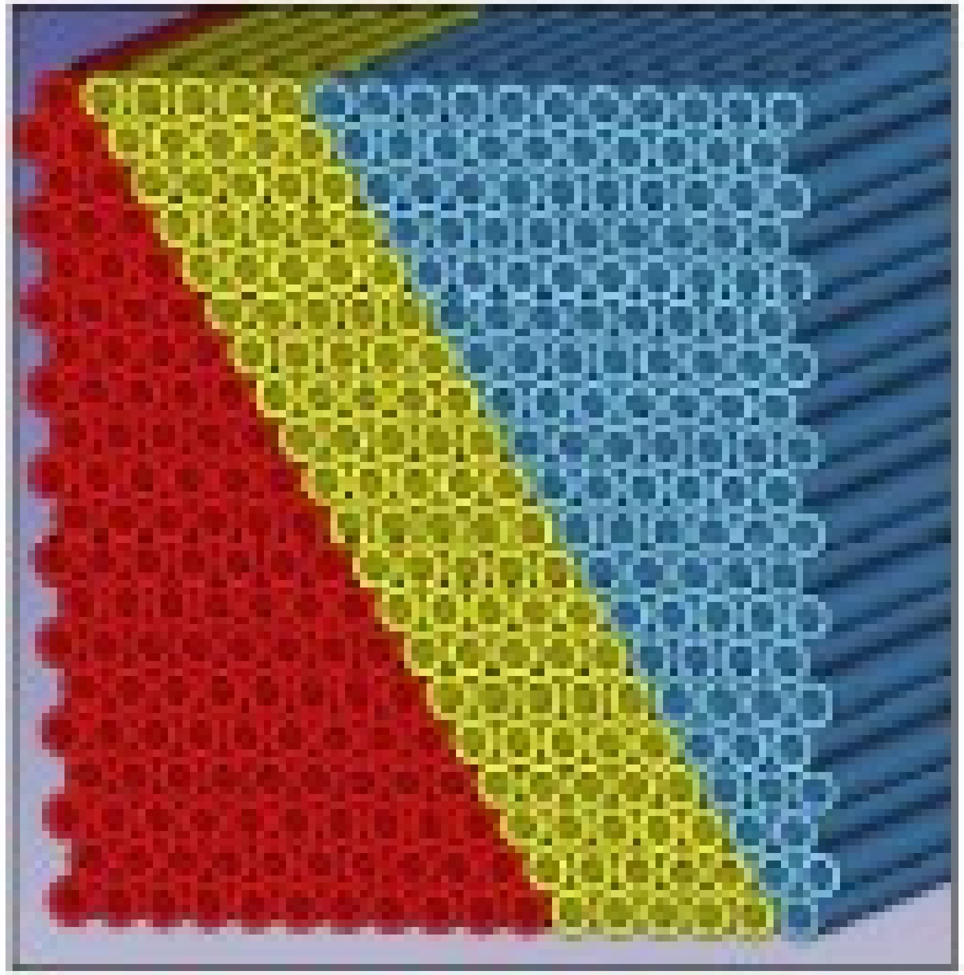
- divide in three pieces:











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
  see Romualdo’s slides

# Constraints & TB

RBI funding require a working prototype by end 2020

Beam tests at Desy in fall 2020 (to be reallocated)

# AoB

Simulations in progress (first preliminary results on $\tau$ hadronic decays expected soon) → timing capabilities the key

Physics analisys → exploiting excellent DR angular resolution for $\gamma\gamma$ final state reconstruction (axion-like particle searches)

Funding requests within AIDAinnova in progress