Dual-Readout Calorimetry Status of R&D Programme

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(on behalf of the IDEA proto-collaboration)
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Project breakdown

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

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

3) light sensors

4) front-end electronics

5) readout and processing

6) simulations and detector performance

Caveats

Hopefully, work distributed within more national-funded projects with different timelines

In case, harmonisation and coordination clear issues

Discussions on-going … not showing any firm plan

As parallel as possible developments depending on funding and manpower available

Take care: in schedules time counted from today

1) Mechanics – shopping list

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

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

- definition of procedure for “tower” assembly

- 4π projective geometry breakdown

1) Mechanics – objectives

1) refine possible absorber choices

2) select and validate scalable techniques for tower-element production and assembly

→ 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 4π projective geometry solution

1) Mechanics – tentative schedule

Possible plan(s):

~ 2-3 years for identifying and validate construction and assembly methods

~ 1-2 years for construction

2) Optics – shopping list

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

- quality control and assurance

- matching with light-sensor PDE

- investigate home-made fibre production (?)

2) Optics – objectives

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

- S signal: get attenuation length >> 2 m (yellow filtering)

- C signal: optimise matching w/ sensor PDE

(interdependent)

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

2) Optics – tentative schedule

- fibre selection: ~1-2 years

- quality assurance protocol and setup: ~2 years

- home-made fibre production: X years ?

→ need boarding of specific expertise

3) Sensors – shopping list

SiPMs:

- dynamic range

- linearity

- cross-talk

- analog grouping

- digital SiPMs ?

3) 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 (integrated digitalisation) ?

- Čerenkov-light sensing → UV enhanced SiPMs ?

- build/spread sensor qualification setups and expertise

3) Sensors – tentative schedule

- standard vs. custom SiPM: ~ 2 years
  (likely) continuous market survey anyway

- linearity and grouping: ~ 1-2 years

- quality assurance protocol and setup: ~2 years

- digital SiPMs: 3-4 years ?

- UV enhanced SiPMs: 3-4 years ?

4) FE elx – shopping list

- signal integration vs. sampling

- off-the-shelf vs. custom ASIC

- FPGA for information reduction (feature extraction)

Likely - at present - the most open issue

4) FE elx - objectives

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

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

- assess time resolution requirements for longitudinal position reconstruction

- investigate feature extraction logic embedded on ASIC

4) FE elx – tentative schedule

- commercial ASIC qualification: ~ 2 years

- establish performance requirements: ~ 1-2 years

- feature-extraction logic embedded on ASIC: 3 years (?)
need boarding of specific expertise

5) Readout and processing

1) Online:

- strongly depends on ASIC choice (initial choice: FERS + data collector) → move to waveform sampling ?

- sampling would require hard real-time digital processing → FPGA

- neural networks (on FPGA) for triggering purposes (?)

2) Offline:

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

5) Readout – tentative schedule

- exploit Citiroc1A / MUSIC → ~ 2 years

- (offline exploit) neural networks → ~ 1-2 years

- select ASIC → 2 years (?)

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 tubelets:

- work (slowly) ongoing with delays of few months due to COVID-19 crisis → testbeam schedule needs reassessment

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

Manpower and institutes

2021-2023

Type	Average FTE Expected
Faculty	4.2
Postdoc	2.2
Students	6.8
Engineers	1.3

INFN / Univ. Bologna, Milano/Como, Pavia, Pisa, Roma 1

Korea Consortium (Kyungpook National University, Korea University, University of Seoul, Yonsei University, includes also Iowa State University)

University of Sussex

RBI Zagreb

Conclusions

- many complex options (yet) to be resolved

- planning for full-hadronic-scale prototype to assess/validate over ~ 4 years:
  a) detector performance
  b) construction and assembly methods

- will hopefully require a non-trivial work of harmonisation and coordination of independent national grants (funding secured in Korea, not yet in Europe) → first news in a couple of months

- need to embark some additional expertise (i.e. groups)

- *em*-scale prototype under construction
  testing in < ~ 1 year

Backup

2020 prototype

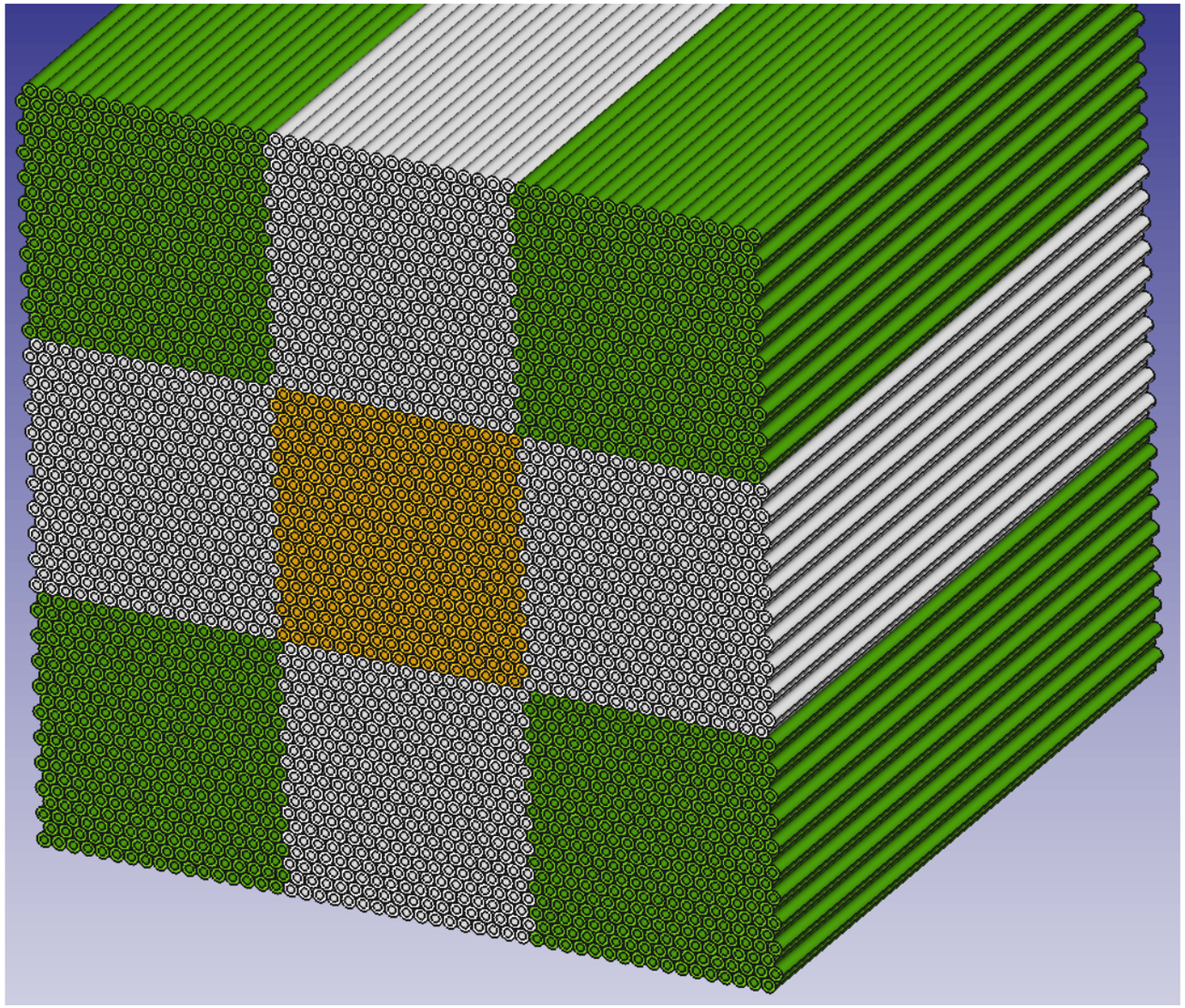
New idea: use tubelets (Zagreb RBI proposal)

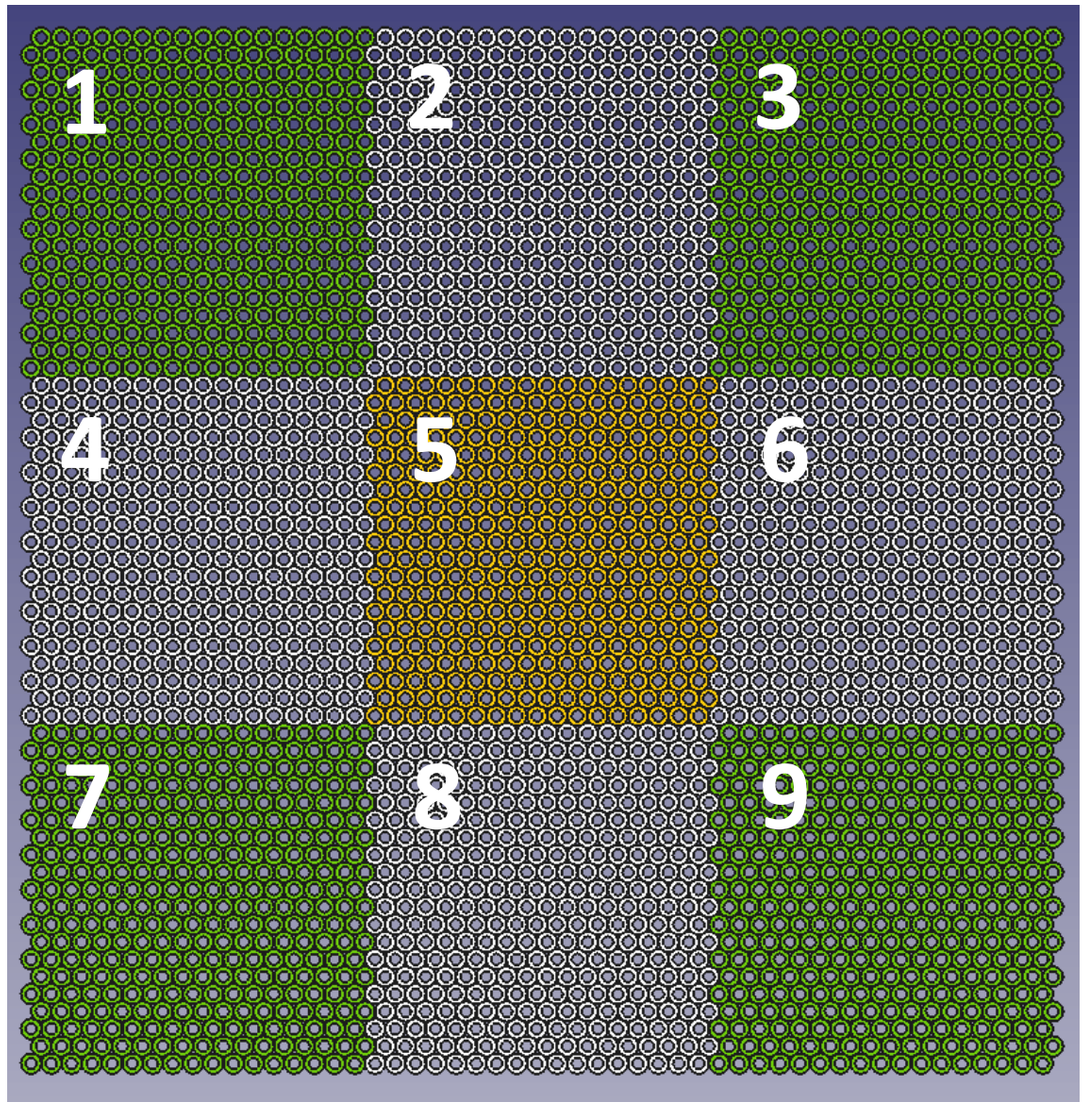
2020: build a ~10×10×100 cm^3 prototype
w/ 2 mm diameter tubelets

→ 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

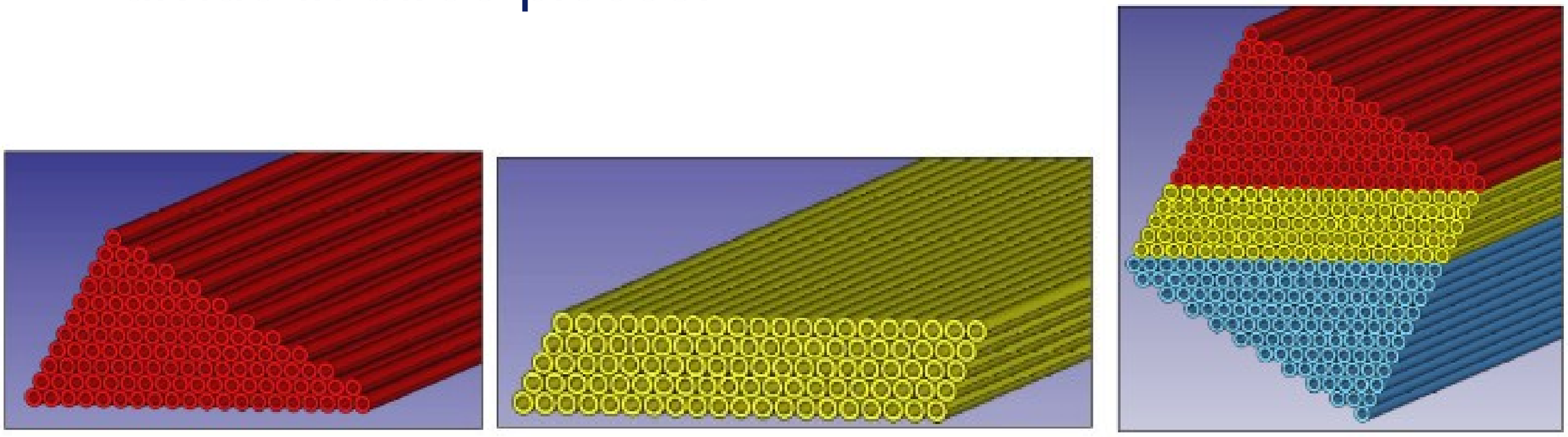
Stacking strategies

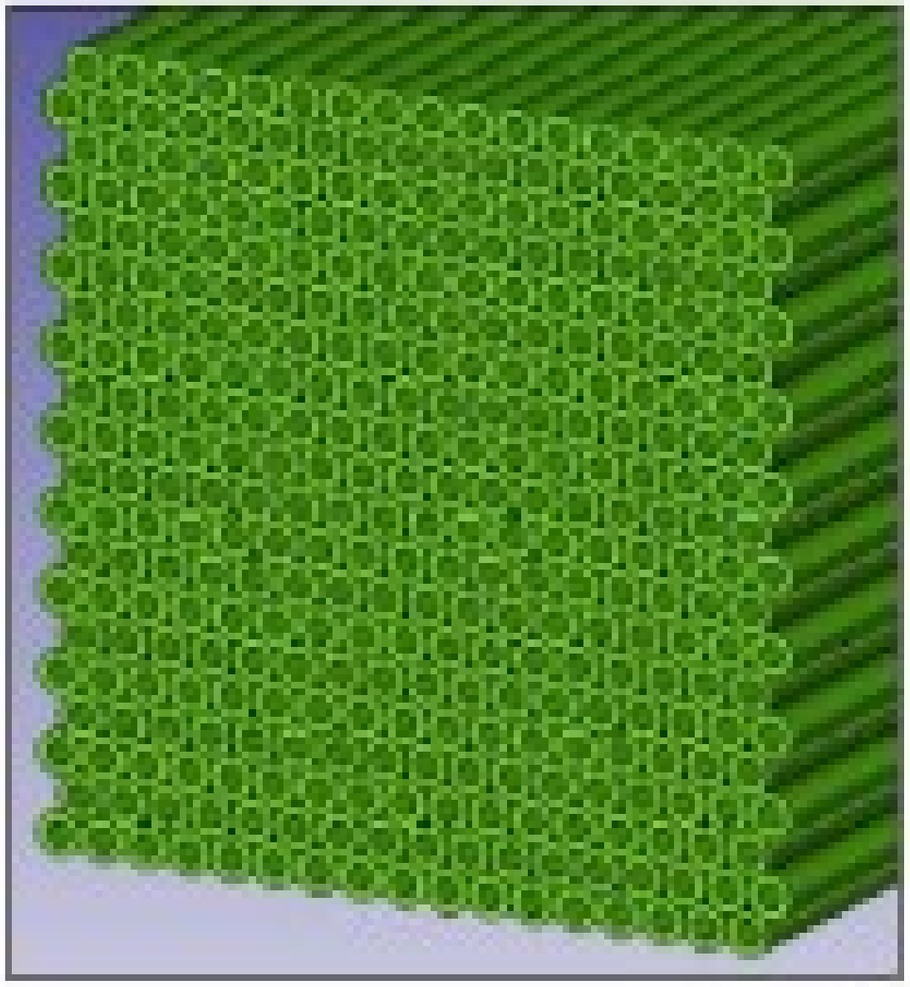
3 options under consideration:

- gluing one layer by one layer

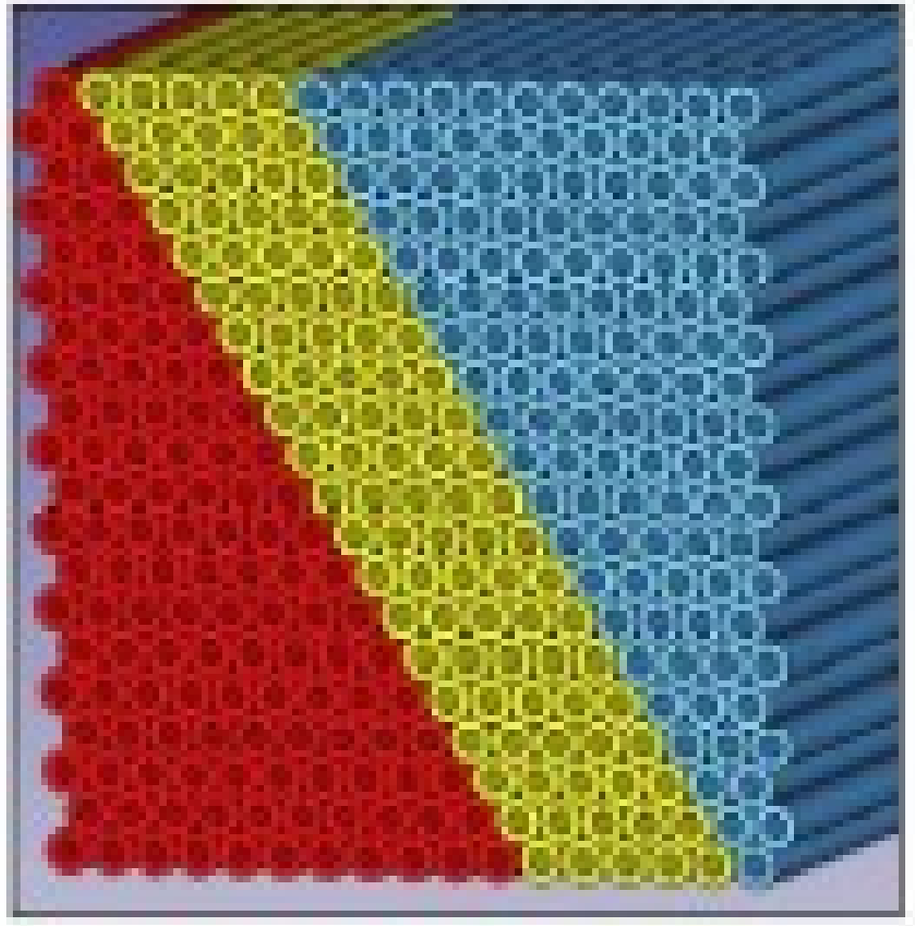
- gluing two layers at once

- 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 τ 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