RBI Proposal for Dual-Readout Calorimeter Constructed from Capillary Tubes

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IDEA collaboration meeting – Bologna, Italy
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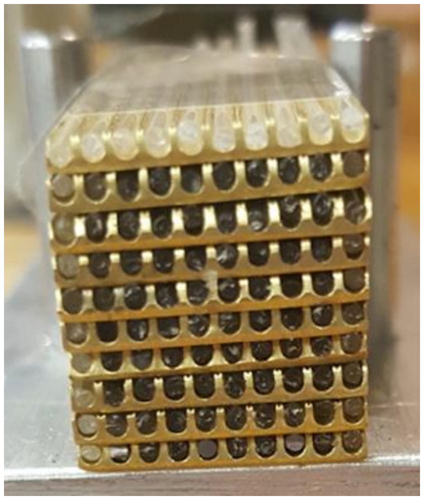
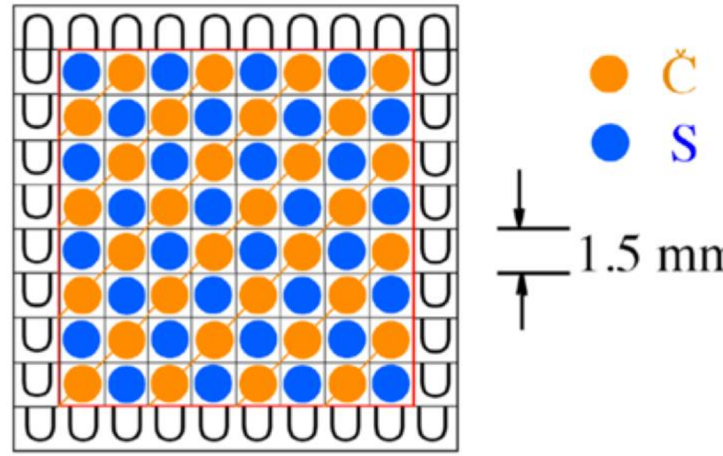
CDSE
Centar za detektore, senzore i elektroniku

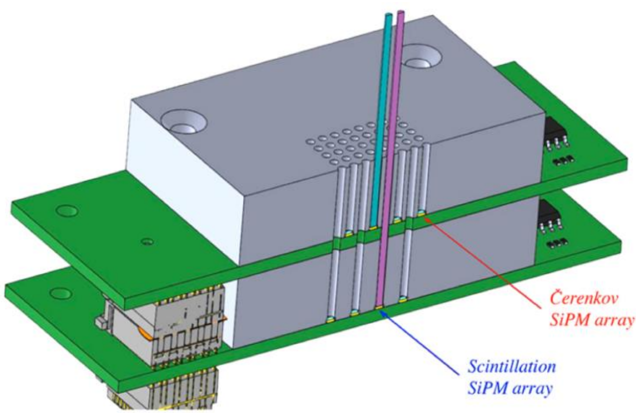
DREAM of a Calorimeter for the
International Detector for Electron-Positron Accelerator(s)

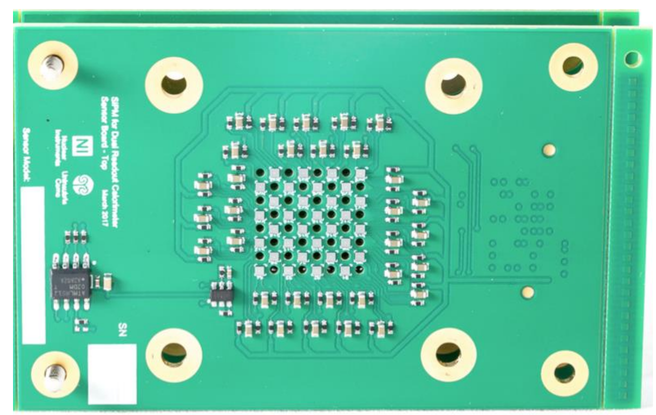


The module is built from stacked brass layers, housing 1 mm diameter clear & scintillating fibers with a pitch of 1.5 mm

The light propagated in each fiber is sensed by individual SiPMs

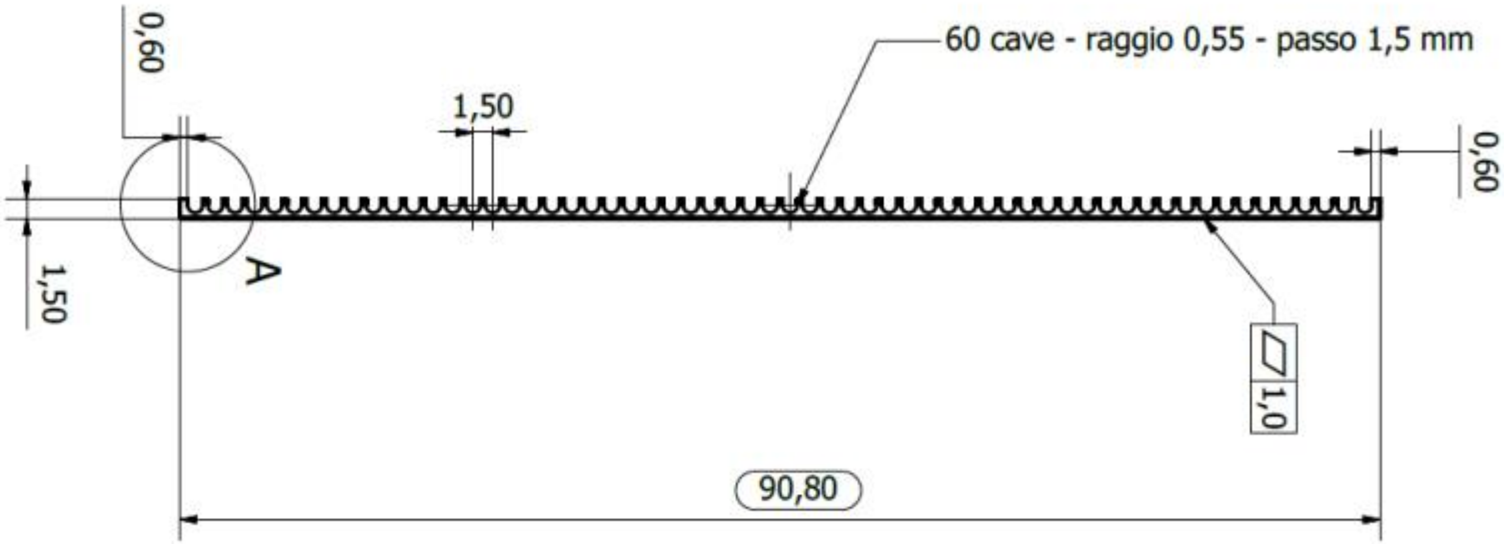


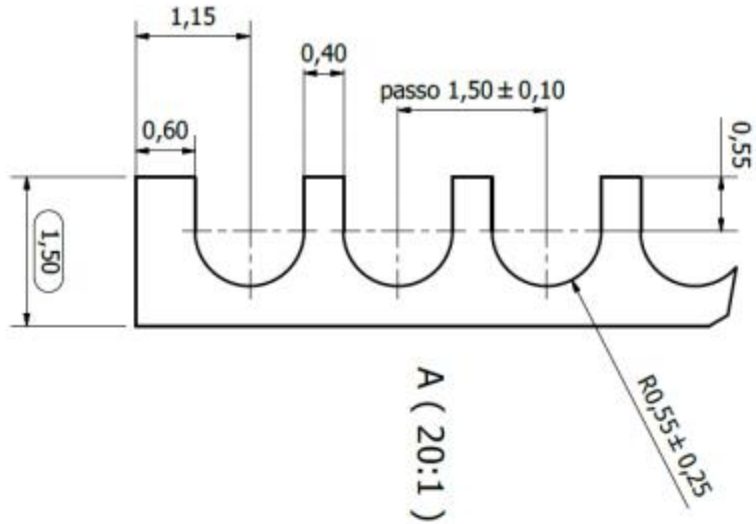




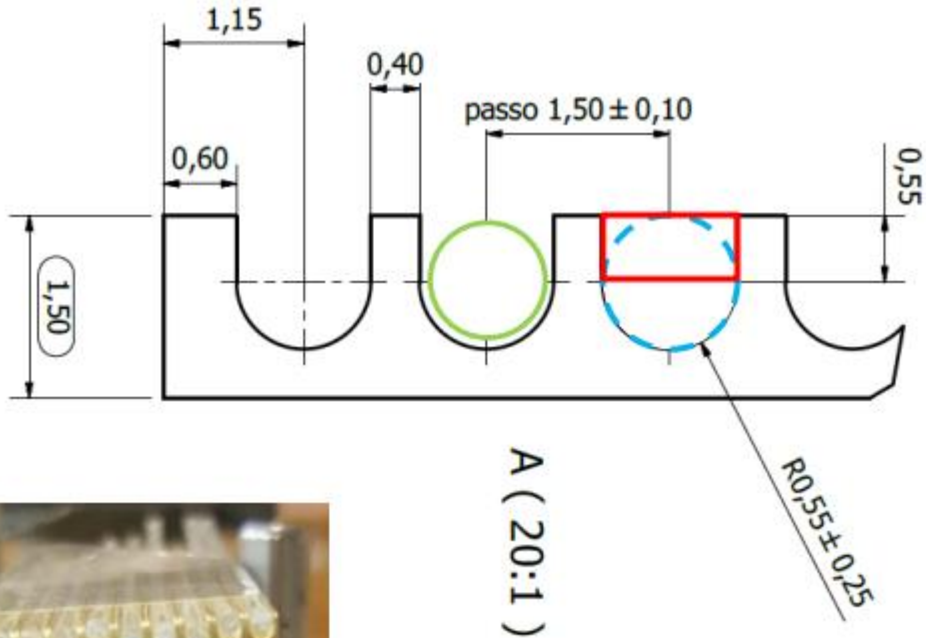
The SiPMs collecting Cerenkov / scintillating light are placed on separate boards to avoid that Cherenkov light is contaminated by scintillating light. The latter is expected to be ≈ 50 time more intense

Previous design





Open area calculation for the Previous design



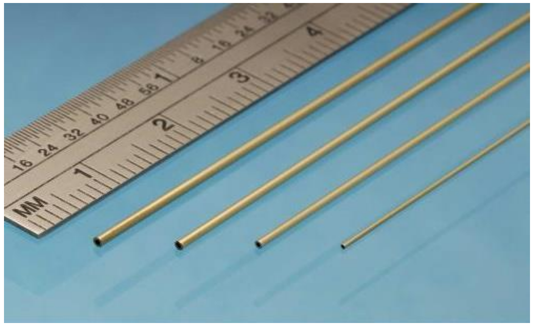
The total area of a single cell consist of 1.1 mm x 0.55 mm rectangle (A = 0.605 mm^2) and half circle with 0.55mm radius (A = 0.475 mm)
=> A = 1.08 mm^2

The total area of the fiber (0.5 mm radius) placed in this cell is A = 0.785 mm

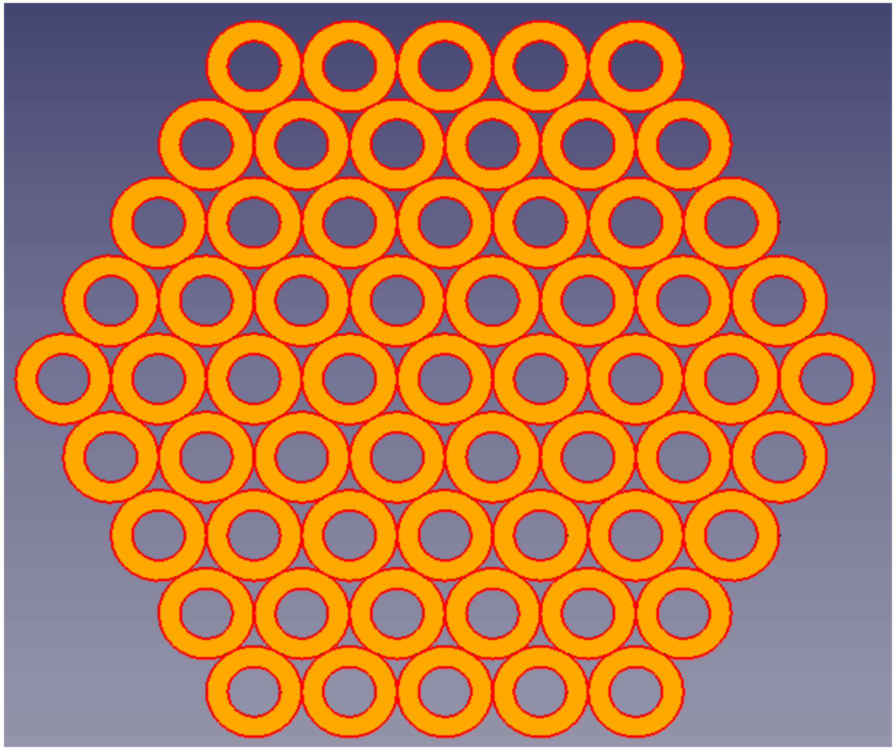
=> The open area between the fiber and the fiber's cell (0.785 / 1.08) => **27%**

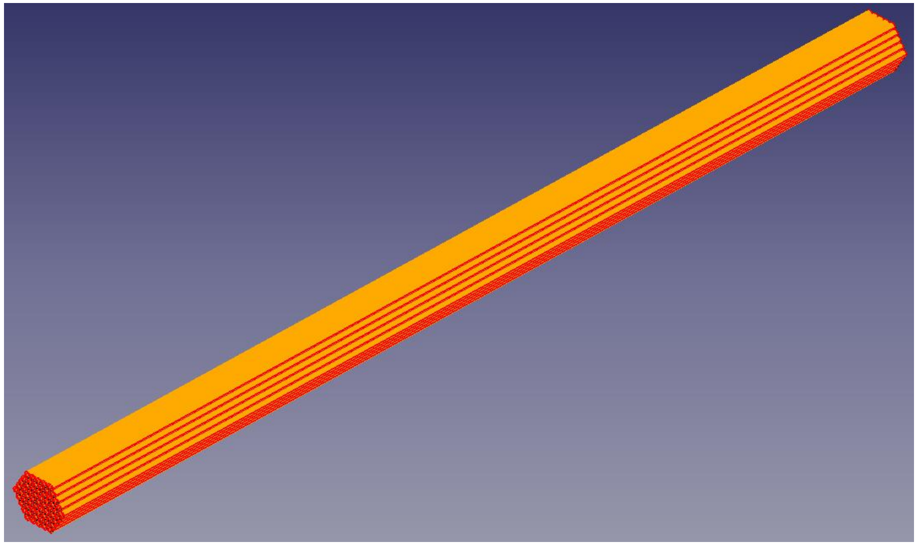
RBI Proposal

Several designs were presented during RBI-Como meeting in April. It was agreed that the hexagonal layout is of high interest and that two eventual prototypes could be constructed. One with Big Brass tubes (OD 2mm, ID 1.1mm) and one with Small Brass tubes (OD 1.3mm, ID 1.1mm)

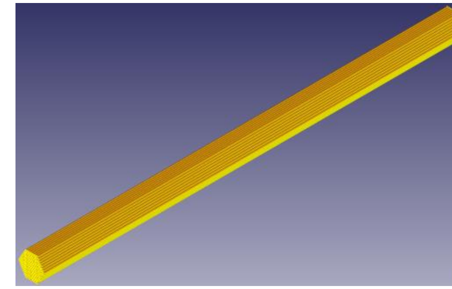


Different gluing alternatives are under investigation.





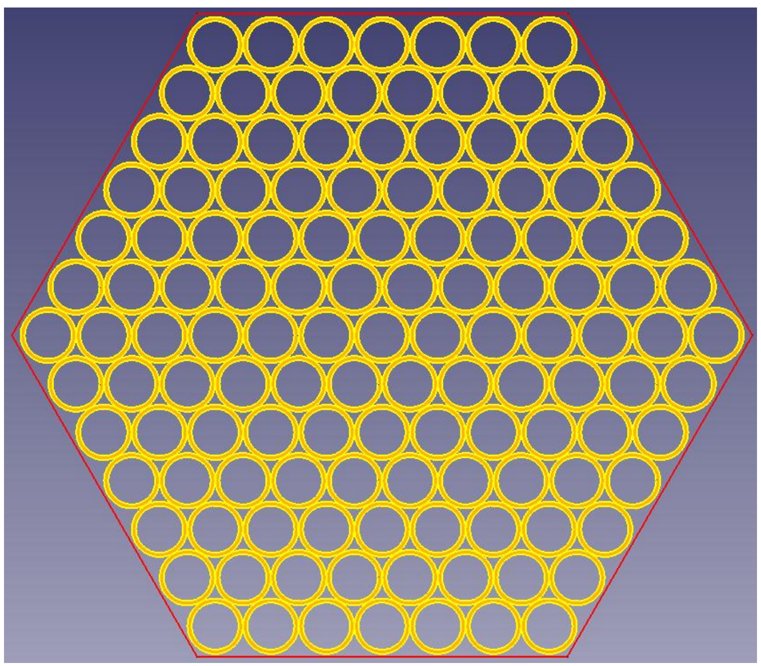
RBI Proposal



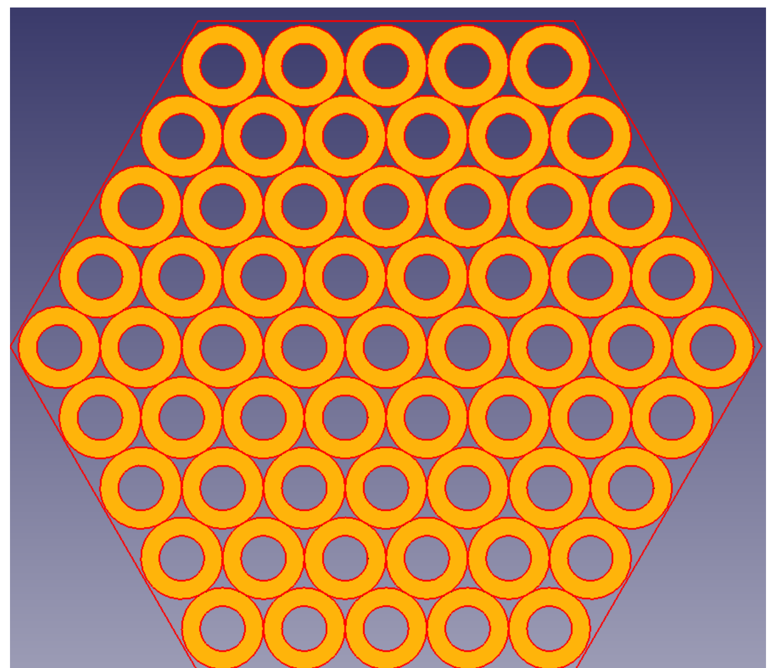
Less than 11 % open area between the tubes

Brass Tube – OD 1.3 mm & ID 1.1 mm

Total height ~15 mm



Brass Tube – OD 2mm & ID 1.1mm



Total height ~ 16 mm

The red line serves to demonstrate of the size of the hexagonal (8.65mm per side)

Let's talk numbers

Fibres details

Total number of fibres: ~*131 M* (130,729,608).

For each tower: ***different fibre lengths.***

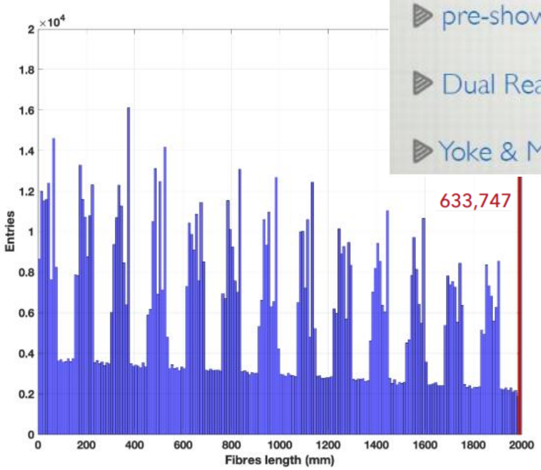
~35% are 2m long.

~38% are <1m long.

Mean length: *~1.3 m*

Total length: *~166,987 km*

This is an "ideal world" with a constant sampling fraction

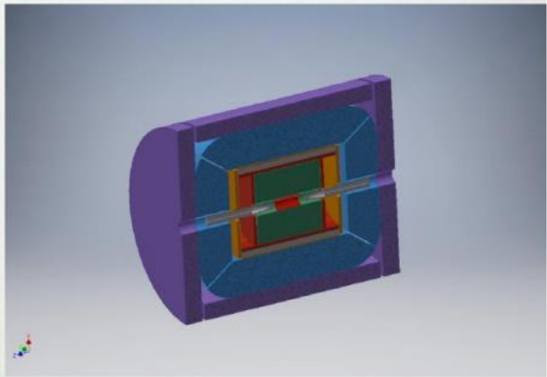


Detector Layout:

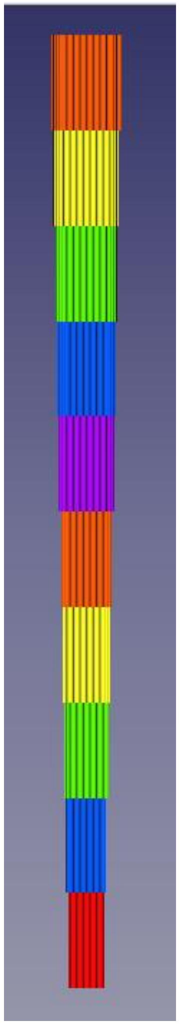
- Beam Pipe (≈1.5 cm radius)
- Vertex Detector (R ∈ [1.7; 34] cm)
- Drift Chamber (L = 400 cm, R ∈ [35; 200] cm)
- Outer Silicon Layer (strips)
- SC Coil (2T, ≈2.1m); THIN! 30 cm ($0.74 X_0$; 0.16 λ @90°)
- pre-shower (1-2 X_0)
- Dual Readout Calorimeter (2m, 7 λ)
- Yoke & Muon Chambers

170 000 km of fiber with average length of 1.3m

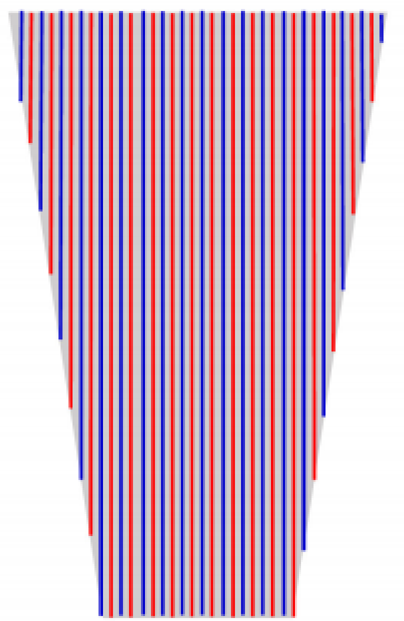
100 000 000 x 1m long brass tubes



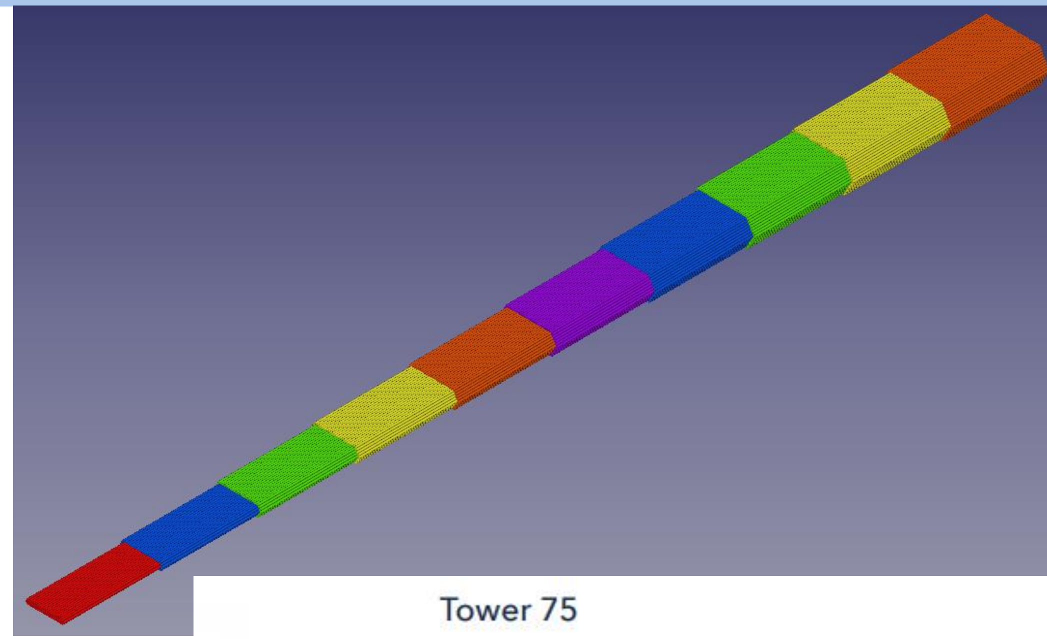
Tower 75 of Tubes



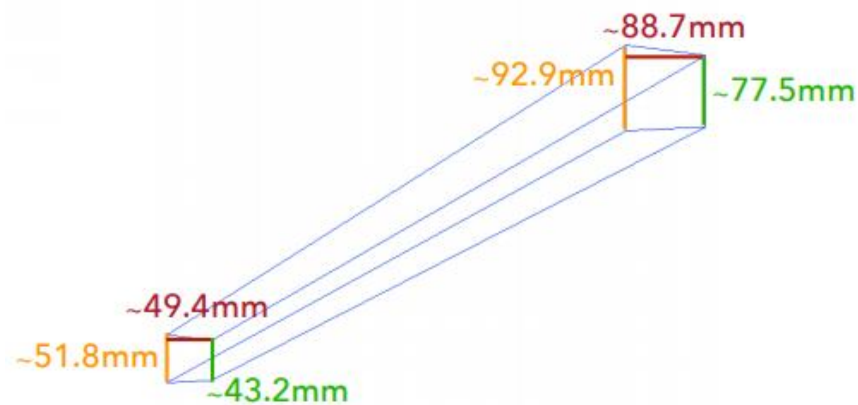
9 + 20 + 9 fibers



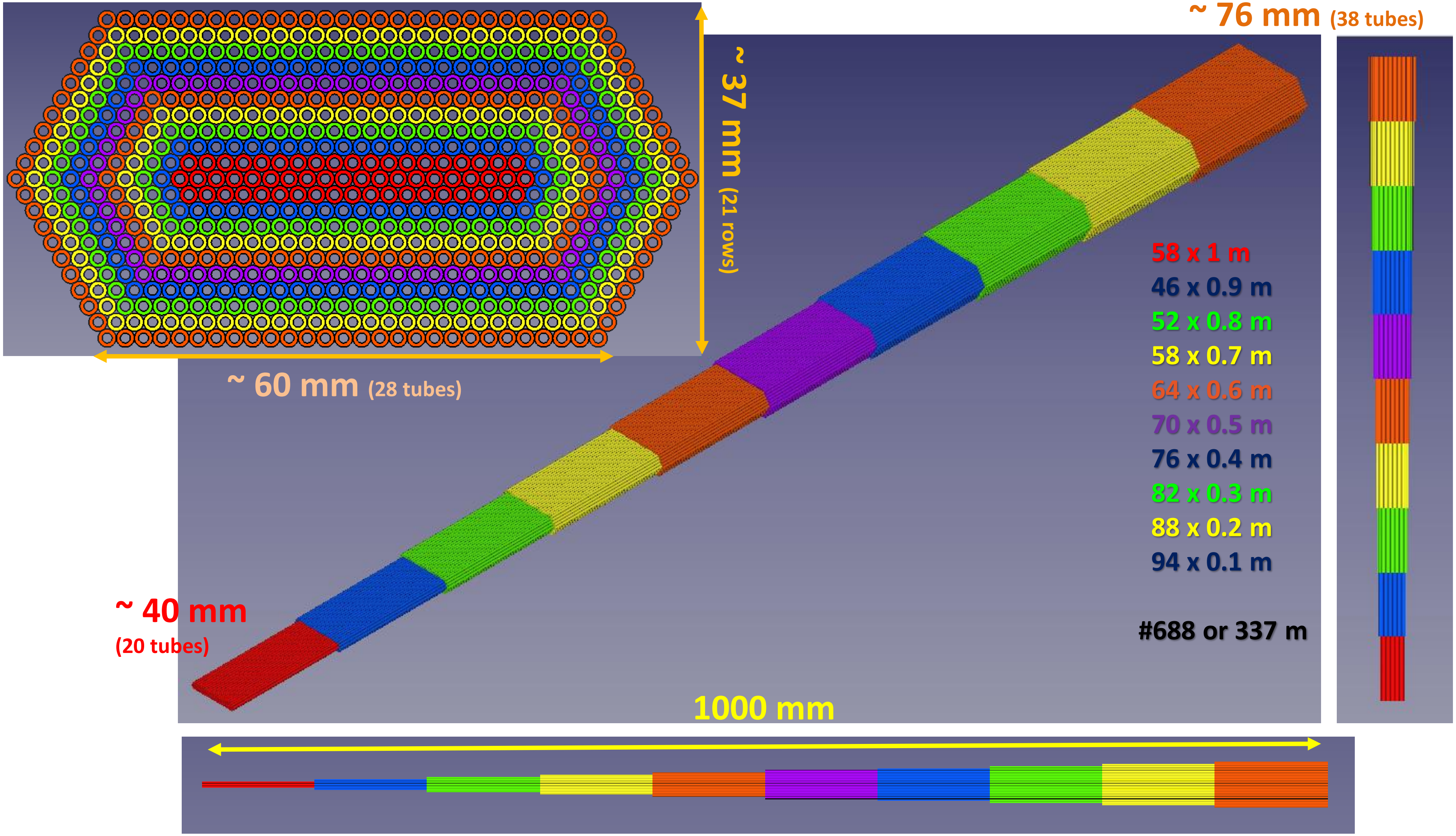
20 fibers



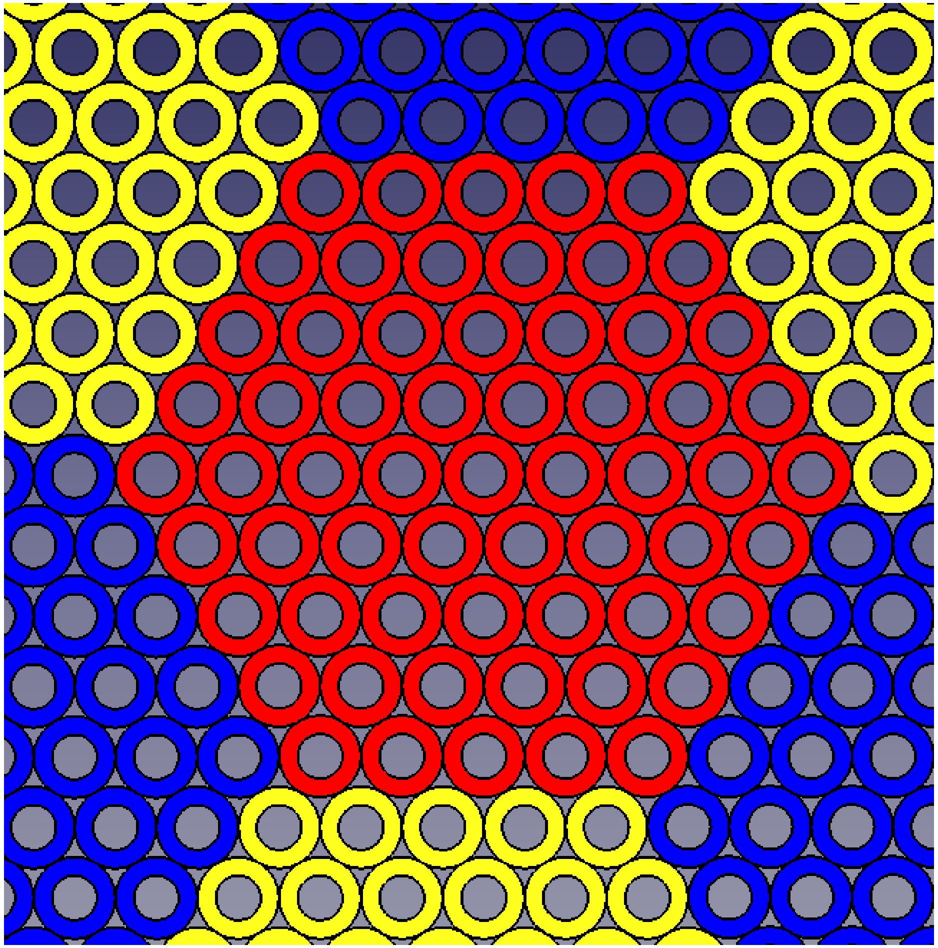
Tower 75

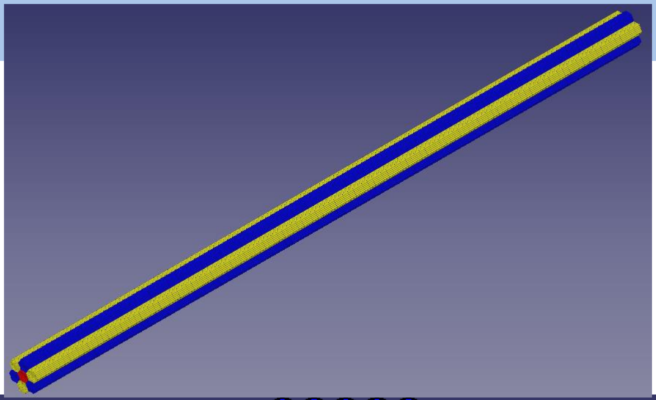


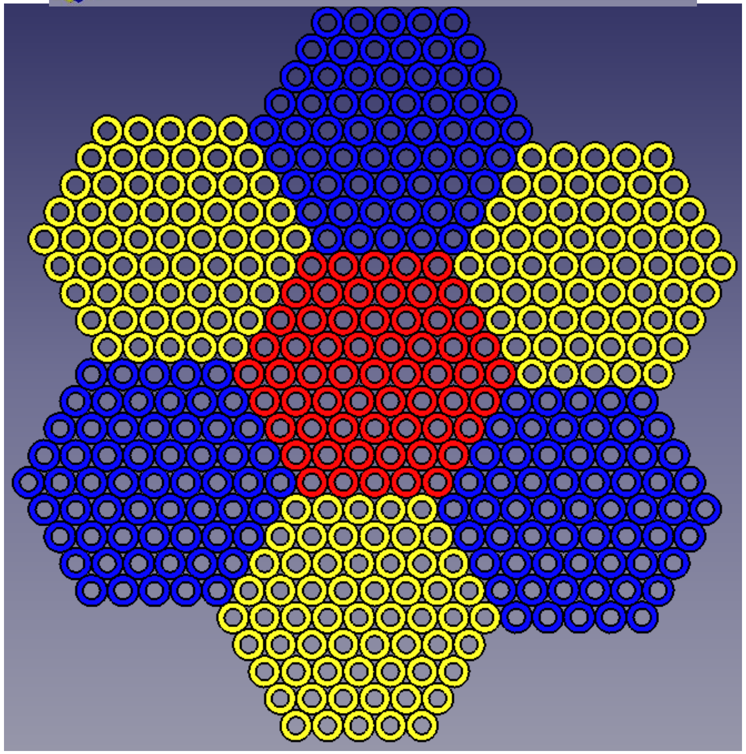
Tower 75 of Tubes



Hexs by Hexs



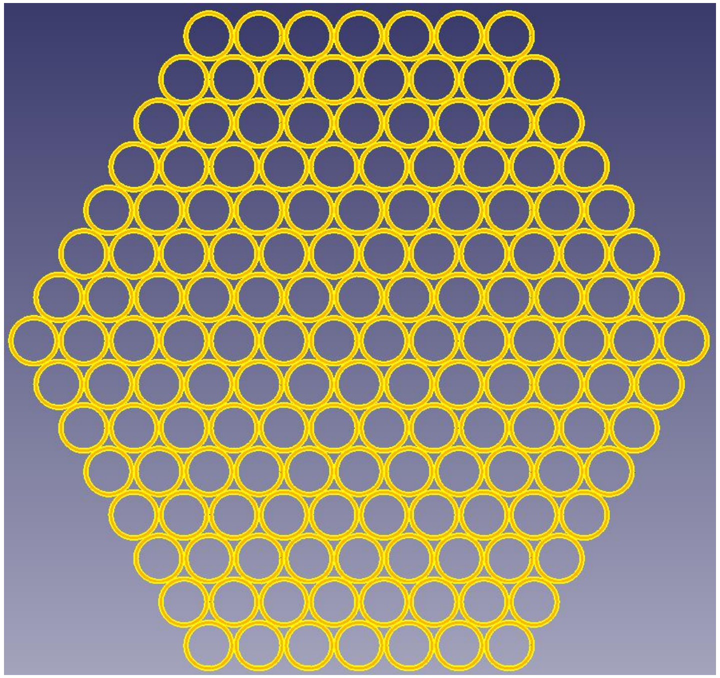




RBI proposal - Prototype

Less than 11 % open area between the tubes

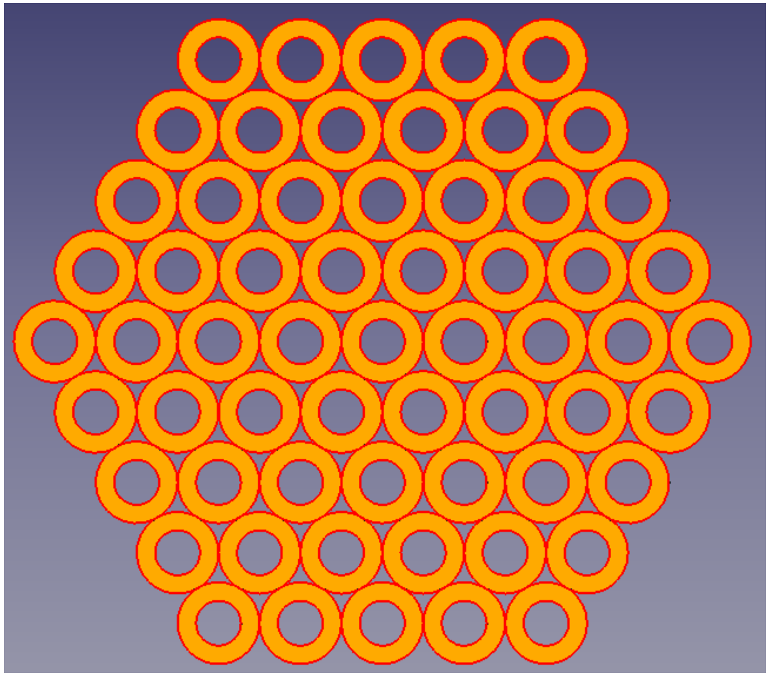
Brass Tube – OD 1.3 mm & ID 1.1 mm



127 + spears => 153

1.65 £ per **30cm** x 153
252.45 £ - 282.82 €

Brass Tube – OD 2mm & ID 1.1mm



61 + spears => 80

2.15 £ per **100 cm** x 80
172 £ - 192.68 €

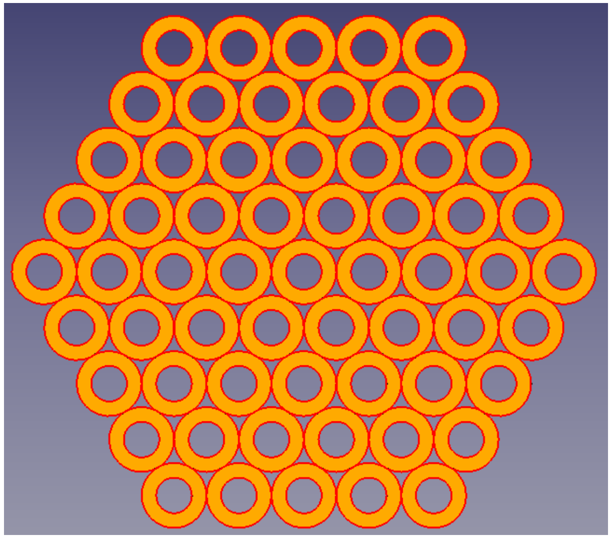
492.3 € (with delivery)

Parameters of the Brass Tubes

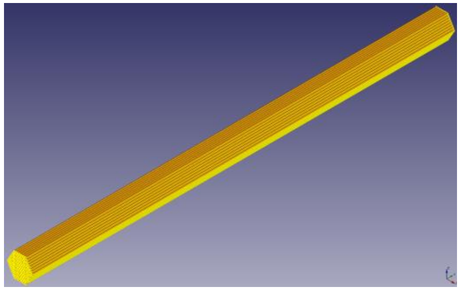
Tolerances on OD and ID are ± 0.05 mm
Tolerance on length is ± 0.5 mm

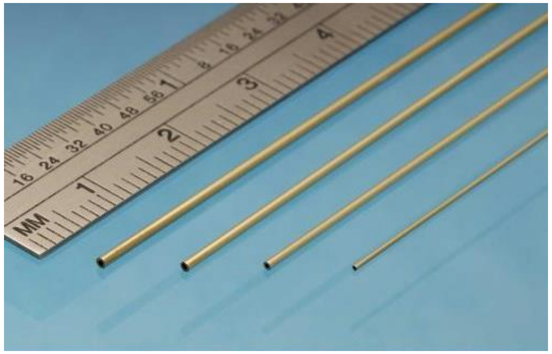
The tubes have hardness value of 170 HV (545 Mpa, 162 HB, 85 HRB)

The tubes are straight, the company can provide sample pieces of both sizes for quality checks



Common and Leaded Brass Tubes (also other metals)
Outer Diameter: 0.3 mm > 60 mm
Wall Thickness: 0.05 mm > 3.5 mm wall
Inner Diameter: 0.05 > 56 mm
Length: 3 mm to 6 metres
Different shapes available





Aneliya Karadzhinova-Ferrer, CDSE, RBI

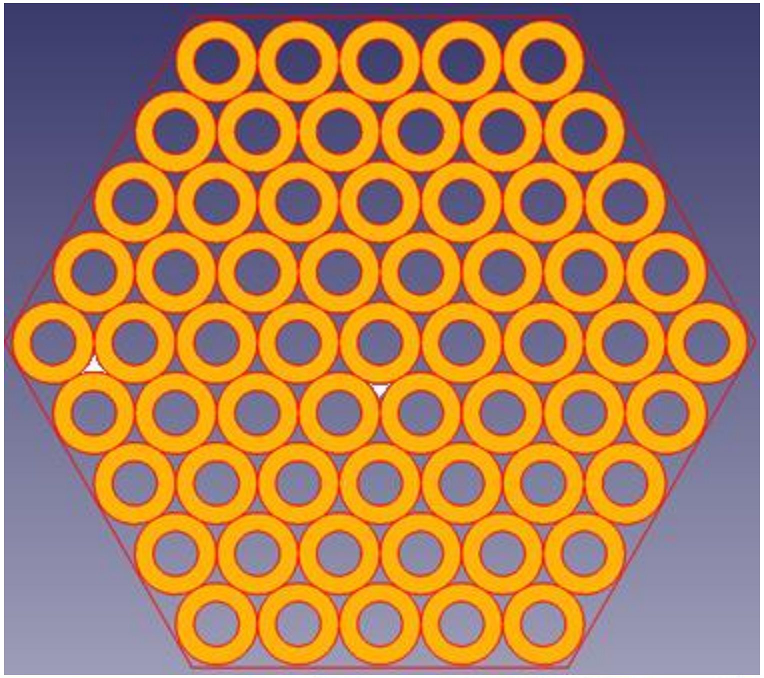
Parameters of the adhesive

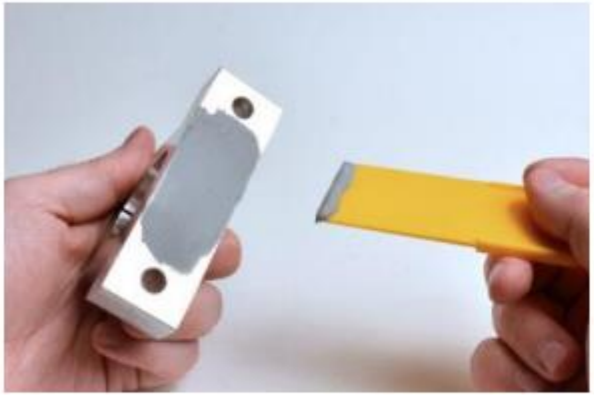
Radiation hard

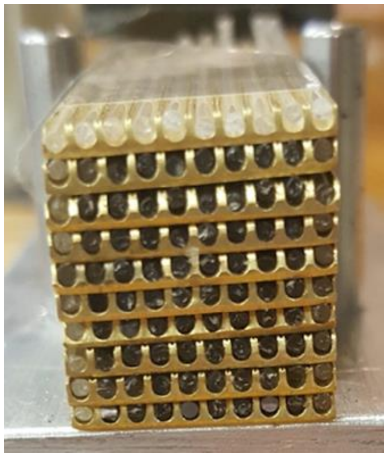
Medium curing speed: 12-24 h -> flexibility during assembly

With or without metal filling -> under consideration

Several different adhesives are available on the market -> in gel and spray form

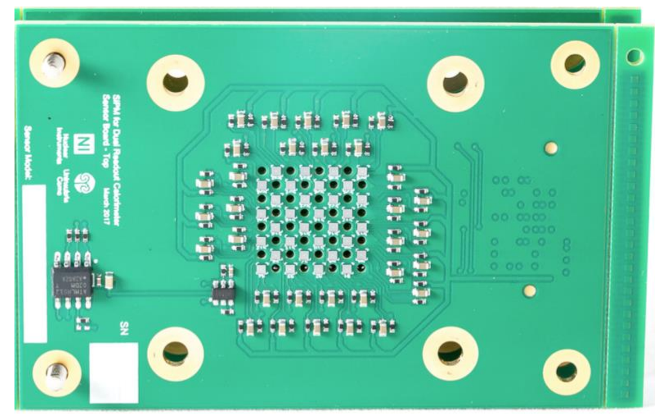






Fibers

- Clear & Scintillating fibers with diameter of 1 mm
- Filling up half of the tubes with Scintillator and placing Clear fibers in the other half of the tubes



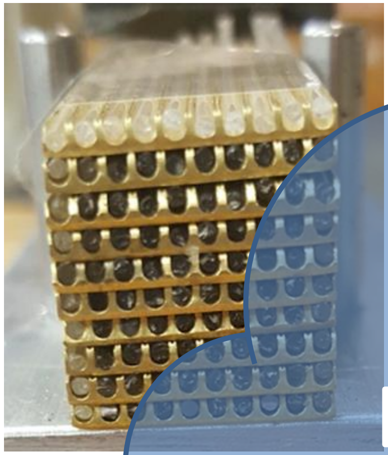
Read-out Electronics

- CAEN SiPM kit for testing is to arrive soon in Zagreb

Testing

- 10 GeV electron beam – all slots are full for this year in Europe, BUT this gives us time to focus on the construction of the prototype

DREAM of a Calorimeter for the
International Detector for Electron-Positron Accelerator(s)



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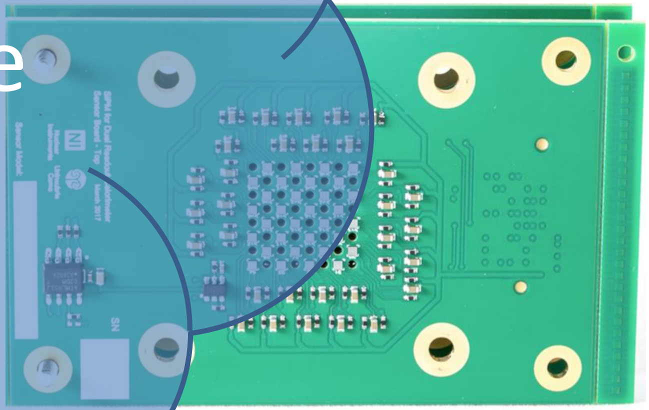
DREAMs come true Prototype!



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Institut Ruđer Bošković

RBI is the largest Croatian research institute in the fields of the natural sciences and technology

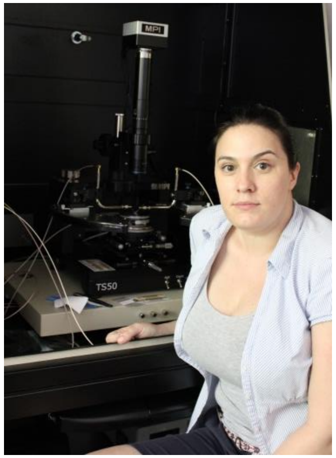
- ✓ RBI employs 800 academics and students
- ✓ Fields of research : Experimental and Theoretical Physics, Chemistry and Materials Physics, Organic and Physical Chemistry, Biochemistry, Molecular Biology and Medicine, Environmental and Marine research and Computer Science and Electronics
- ✓ Main site is located in Zagreb, the capital of Croatia.

European Research Area – PaRaDeSEC project

PaRaDeSEC => ***Pa**rticle and **Ra**diation **De**tectors, **S**ensors and **E**lectronics in **C**roatia*

Aims to establish a Centre for Detectors, Sensors and Electronics at RBI, as part of the Horizon 2020 Framework Program

Dr. Jaakko Härkönen
ERA Chair project leader



Dr. Aneliya Karadzhinova-Ferrer

Dr. Andrey Starodumov

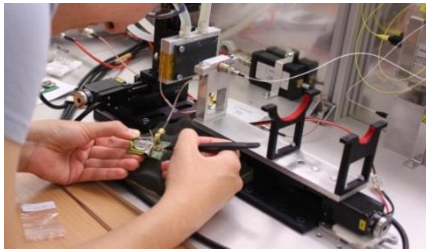
Dr. Matti Kalliokoski

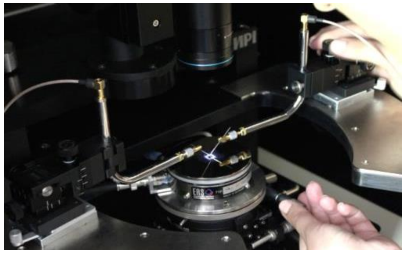
Dr. Valery Chmill

http://lnr.irb.hr/PaRaDeSEC/main.html

European Research Area – PaRaDeSEC project

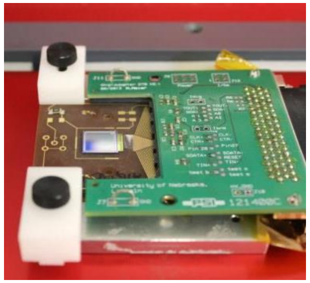
We are focusing to develop future generation ultra-fine pixel detector for particle tracking and implementing HEP community developments into gamma / X-ray / neutron detection

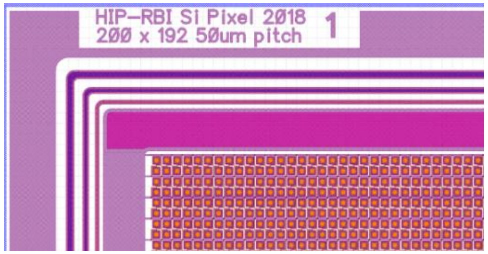

Scanning TCT setup


Probe station

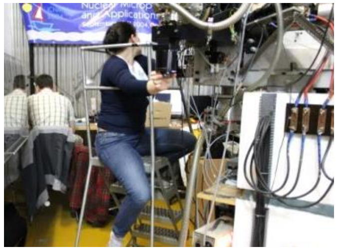

Wire bonder


CMS pixel detector module testing setup & DAQ


CMS Pixel Detector

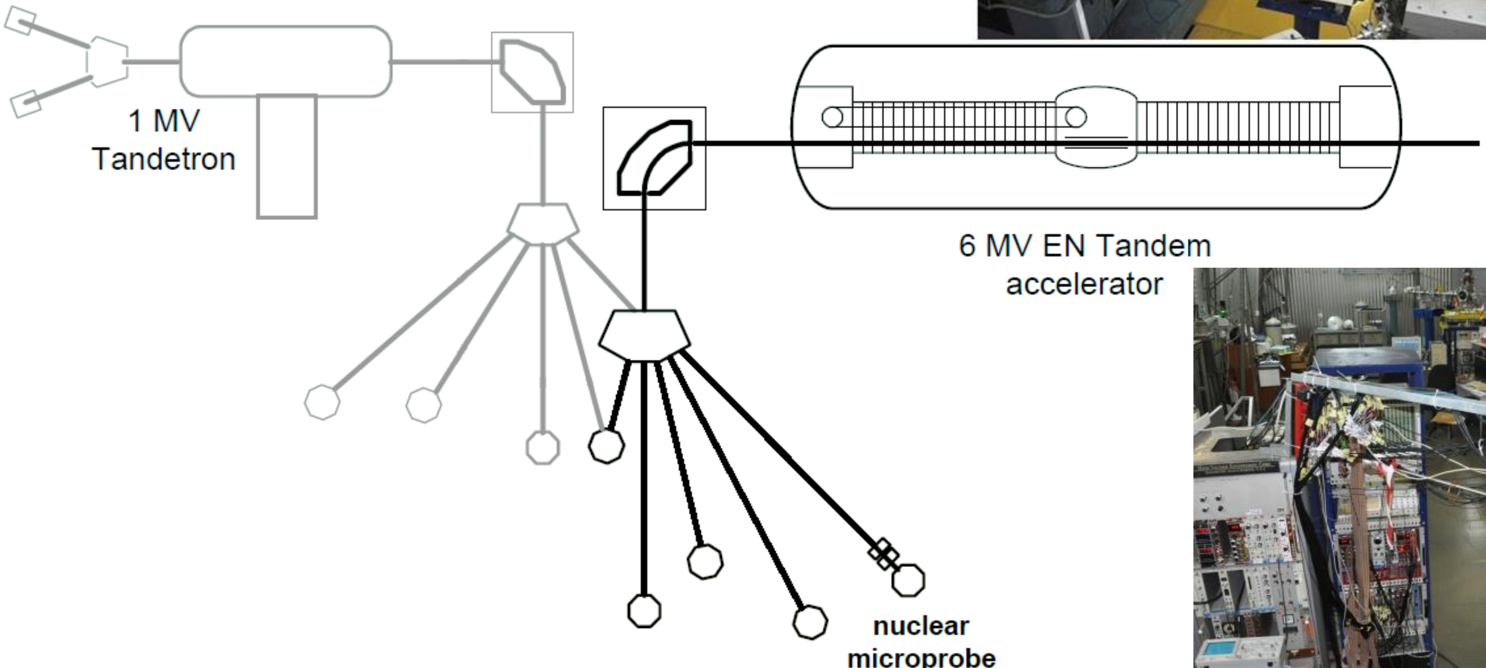


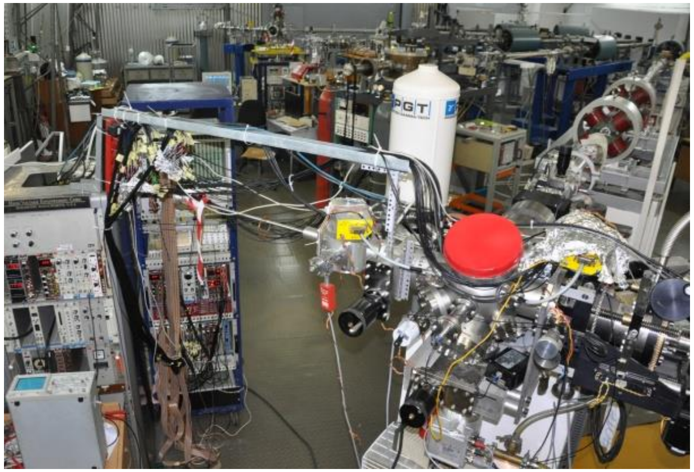
RD53 Pixel sensor layout


MicroProbe @ Ion Beam Facility

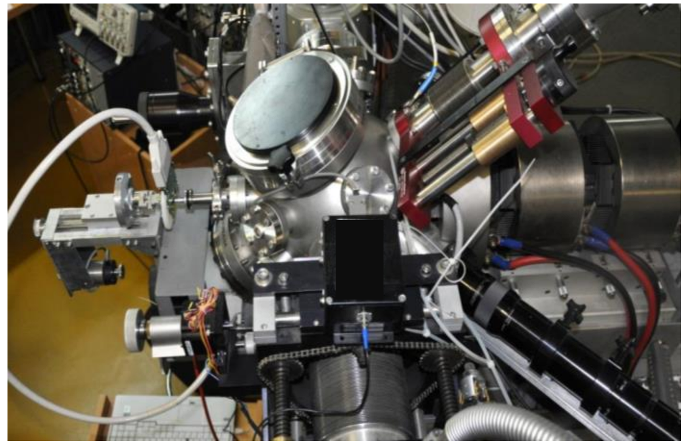

Co60 Gamma irradiation Facility

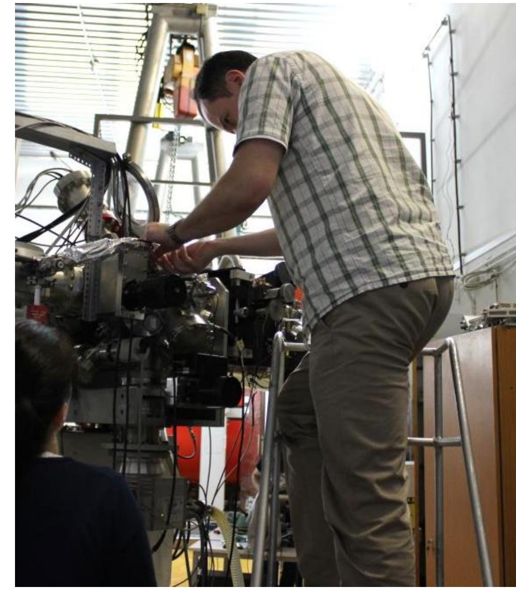
Laboratory for ion beam interactions
Ruđer Bošković Institute, Croatia

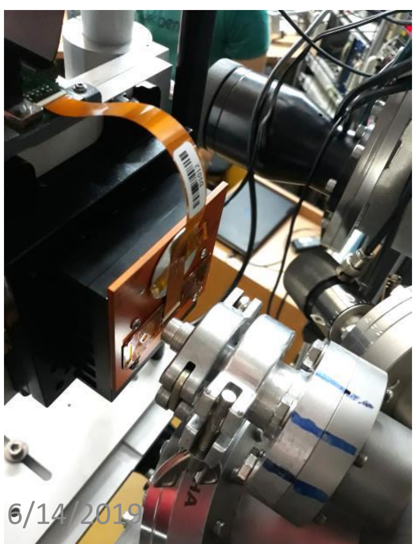


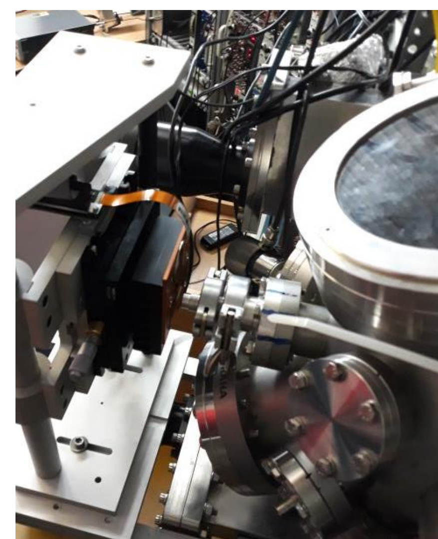


IBIC Measurements



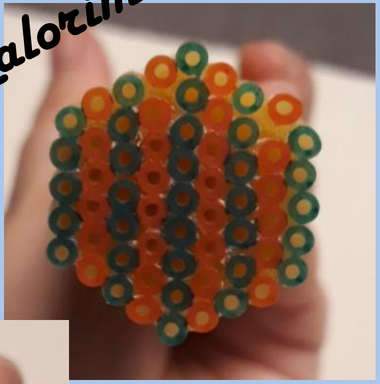






Summary

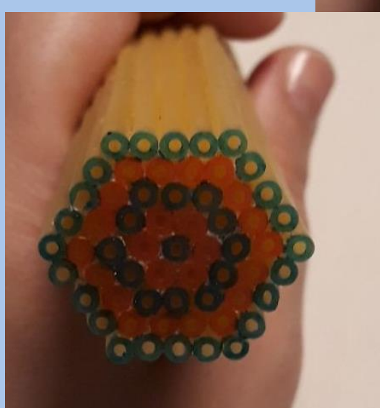
The Bucatini Calorimeter



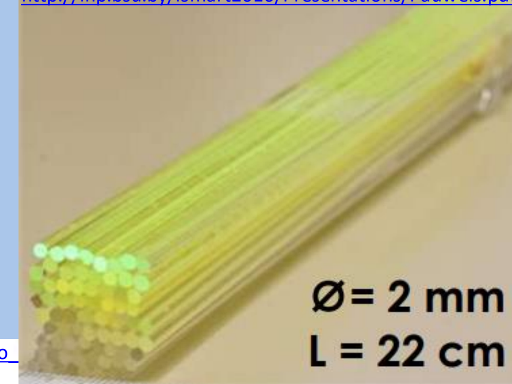
- ✓ Flexible design
- ✓ Easy construction of a single module
- ✓ High packaging factor – the remaining open area between the tubes can be filled with metal powder
- ✓ Different shapes, sizes and material type of the tubes are available
- ✓ Low cost of the absorber
- ✓ Better and tighter alignment between the individual modules/ towers
- ✓ The tubes can be filed with fibers and/or scintillator

Thank you for your attention!

The Bucatini Calorimeter

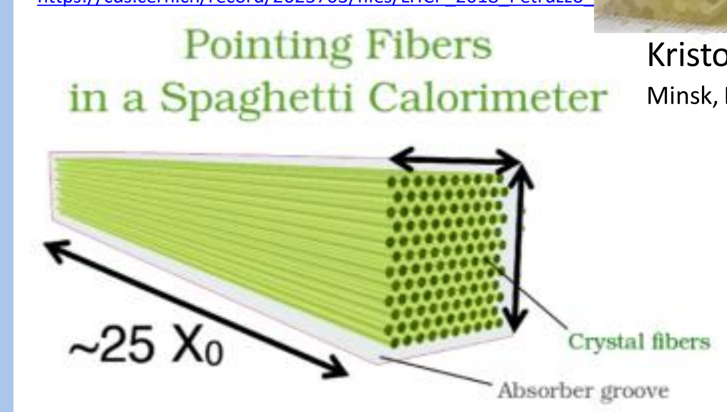


http://inp.bsu.by/ismart2016/Presentations/Pauwels.pdf



Kristof Pauwels - I S M A R T 2 0 1 6, Minsk, Belarus 28 September 2016

https://cds.cern.ch/record/2623703/files/LHCP_2018_Petruzzo_



Marco Petruzzo - LHCP 2018 Sixth Annual Conference on Large Hadron Collider Physics, Bologna, Italy 4-9 June 2018

Backup slides

RBI proposal – Small Brass tubes
Active area – 195 mm x 300 mm

Brass Tube – OD 1.3 mm & ID 1.1 mm; Length 300 mm

2 rows x 7 tubes + 2 rows x 8 tubes + 2 rows x 9 tubes + 2 rows x 10 tubes + 2 rows x 11 tubes + 2 rows x 12 tubes + 1 rows x 13 tubes = 127 + spears => 180

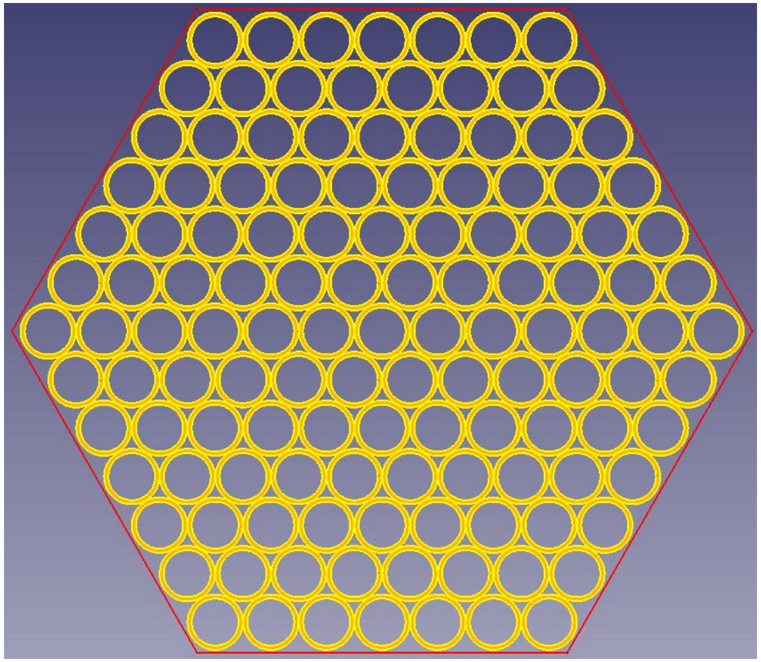
$$A = \pi r^2 = \pi * 0.65^2 = 1.327$$

$$A = \frac{3\sqrt{3}\,s^2}{2} = \frac{3\sqrt{3}\,8.65^2}{2} = 194.39\text{mm}^2$$

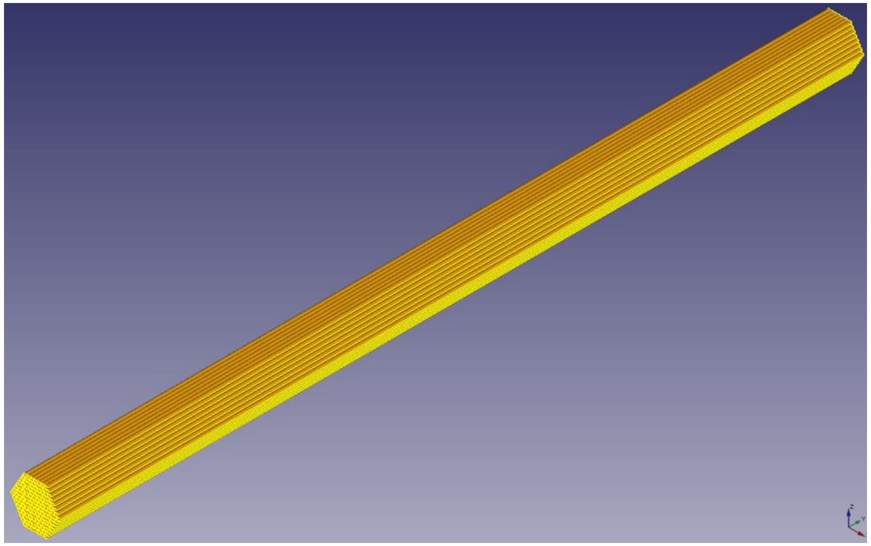
Less than 11 % open area between the tubes

The red line serves to demonstrate of the size of the hexagonal (8.65mm per side)

Total height ~15 mm



Each side ~9 mm



300 mm

RBI proposal – Big Brass tubes
Active area – 220 mm x 1000 mm

Brass Tube – OD 2mm & ID 1.1mm; Length 1000mm

2 rows x 5 tubes + 2 rows x 6 tubes + 2 rows x 7 tubes + 2 rows x 8 tubes + 1 rows x 9 tubes = 61 + spears => 80

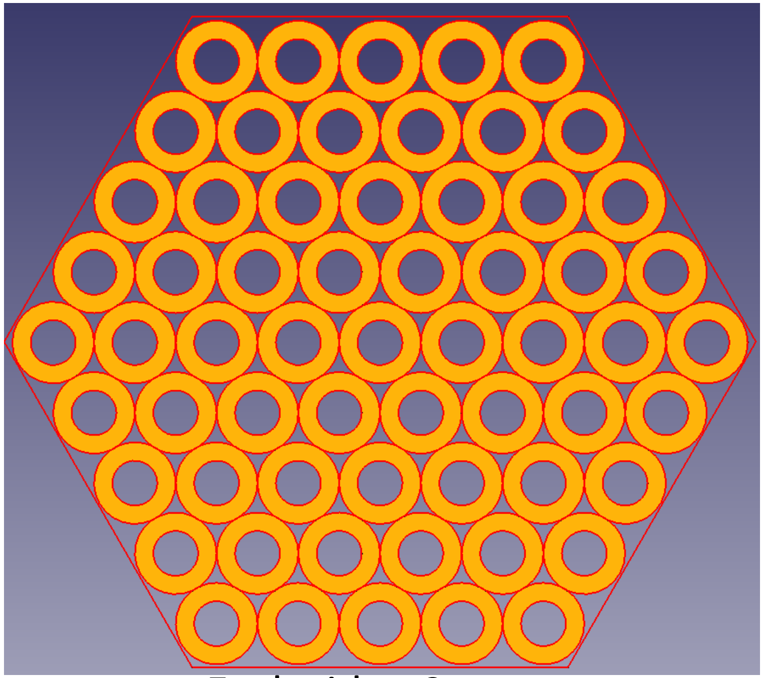
$A = \pi r^2 = \pi * 1^2 = 3.1416$ => 61 * 3.1416 = 191.64 mm

$$A = \frac{3\sqrt{3}\, s^2}{2} = \frac{3\sqrt{3}\, 9.2^2}{2} = 219.9\text{mm}^2$$

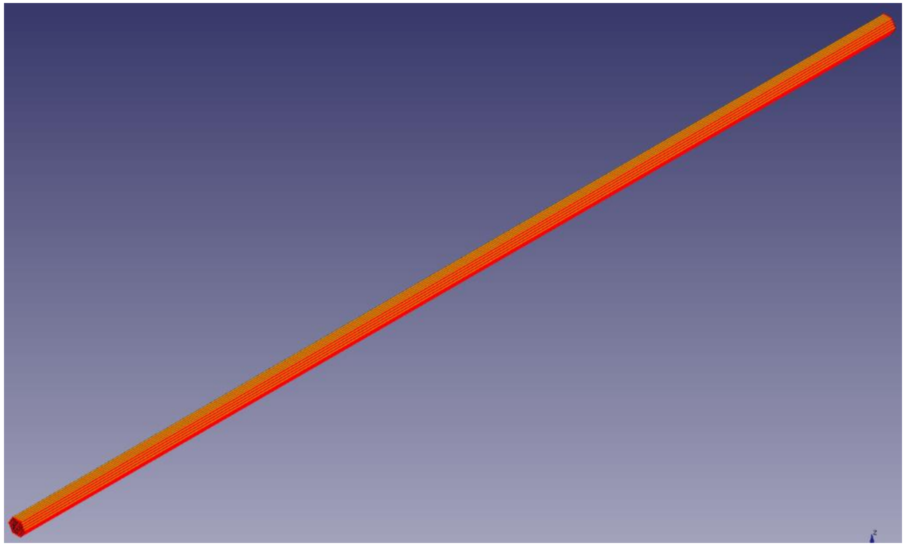
Less than 11 % open area between the tubes

The red line serves to demonstrate of the size of the hexagonal (9.2mm per side)

Total height ~ 16 mm



Each side ~9 mm



1000 mm

RBI proposal – Small Brass tubes
Active area – 195 mm x 300 mm

Brass Tube – OD 1.3 mm & ID 1.1 mm; Length 300 mm

Initial calculation

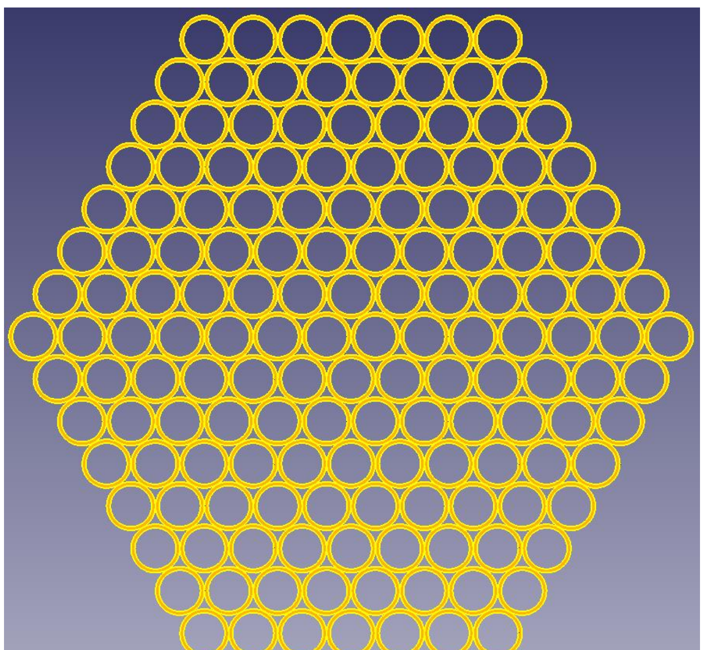
2 rows x 7 tubes + 2 rows x 8 tubes + 2 rows x 9 tubes + 2 rows x 10 tubes + 2 rows x 11 tubes + 2 rows x 12 tubes + 1 rows x 13 tubes = 127 + spears => 153

3 x Brass Tube in package – 7.27Euros
153 tubes = 51 packages => ~ 370 Euros

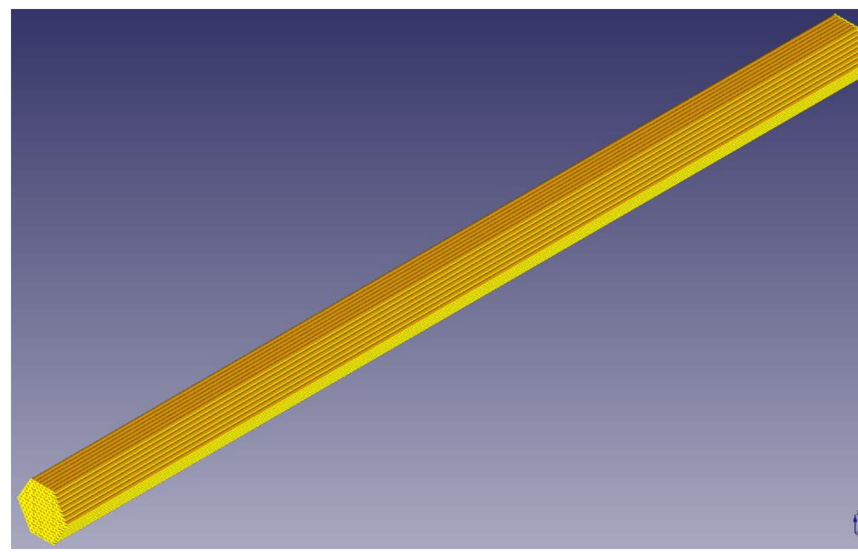
Less than 11 % open area between the tubes

The red line serves to demonstrate of the size of the hexagonal (8.65mm per side)

Total height ~15 mm



Each side ~9 mm



300 mm

RBI proposal – Big Brass tubes
Active area – 220 mm x 1000 mm

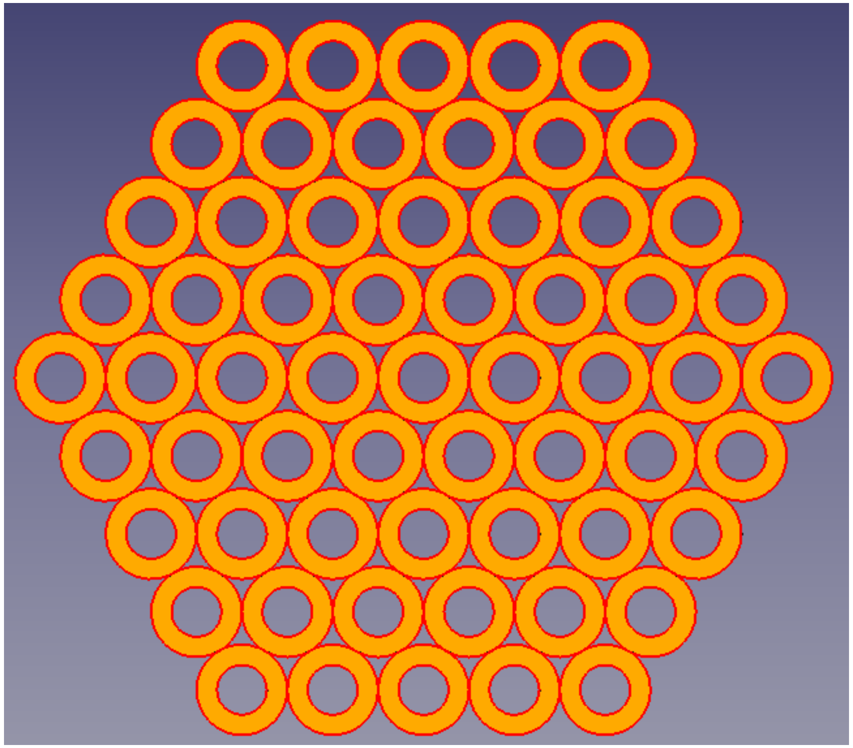
Brass Tube – OD 2mm & ID 1.1mm; Length 1000mm

Initial calculation

2 rows x 5 tubes + 2 rows x 6 tubes + 2 rows x 7 tubes + 2 rows x 8 tubes + 1 rows x 9 tubes = 61 + spears => 80

2 x Brass Tube 10 package – 6.57Euros
80 tubes = 40 packages => ~ 263 Euros

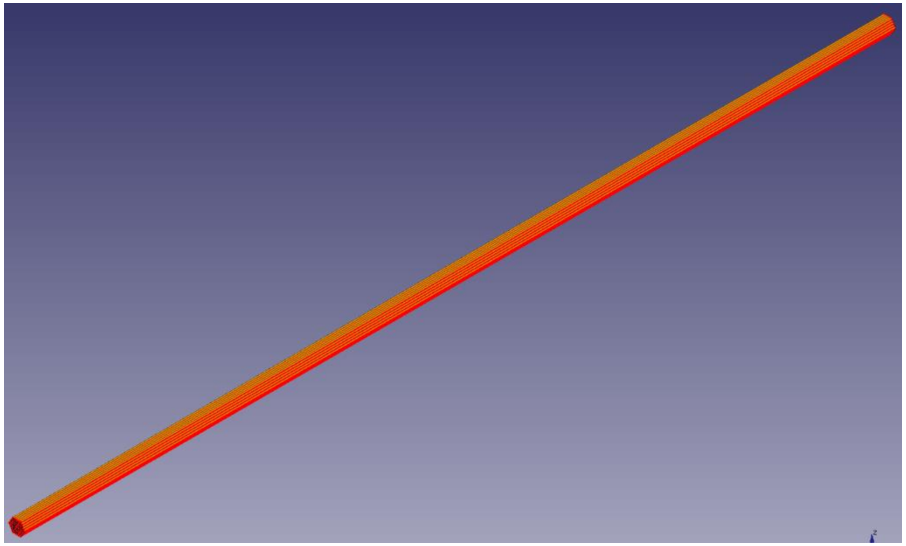
Total height ~ 16 mm



Each side ~9 mm

Less than 11 % open area between the tubes

The red line serves to demonstrate of the size of the hexagonal (9.2mm per side)

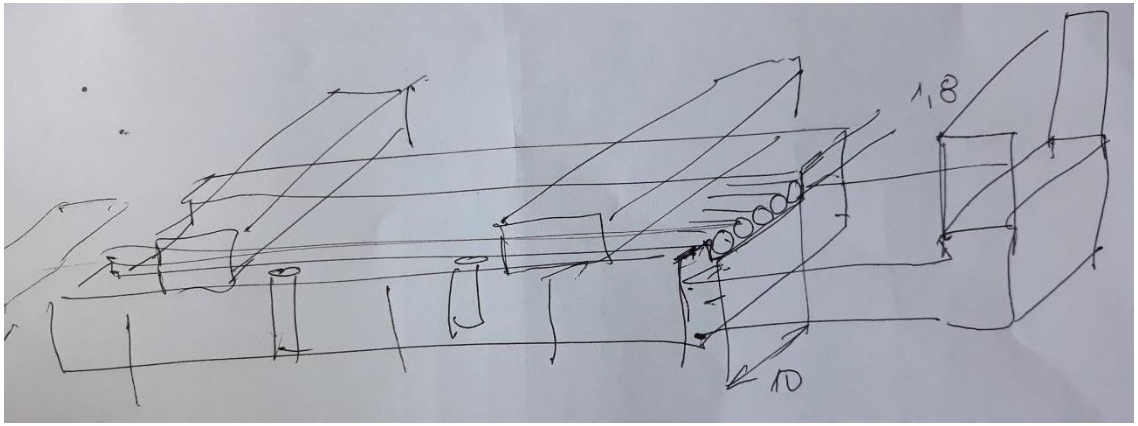


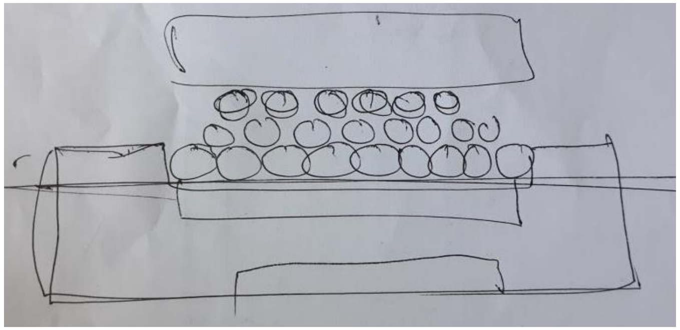
1000 mm

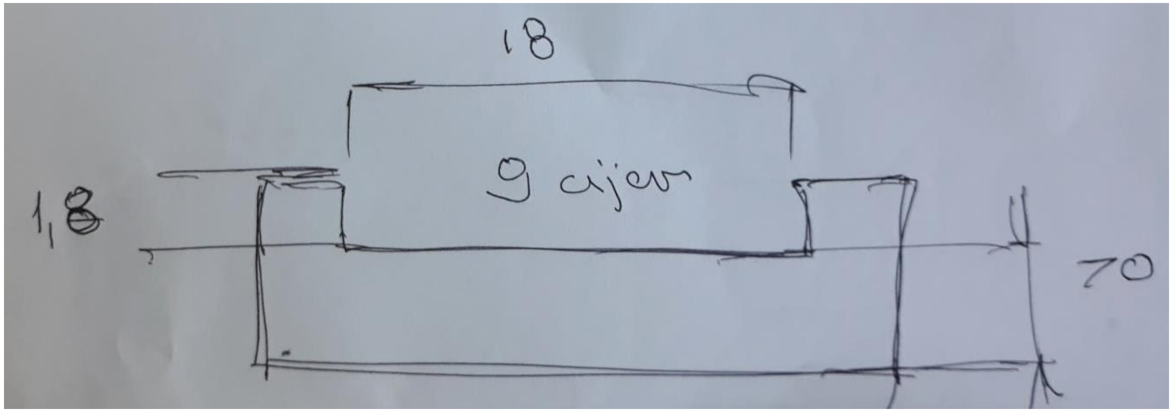
Prototype - RBI workshop

We have the support of the RBI workshop for the creation of a mold structure that will support and hold the tubes during gluing.

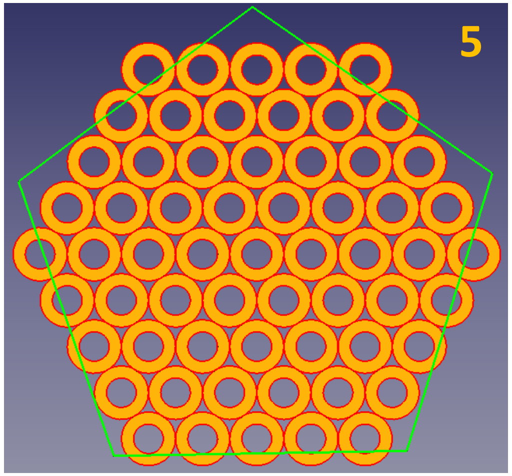
A structure made of Teflon is currently under construction

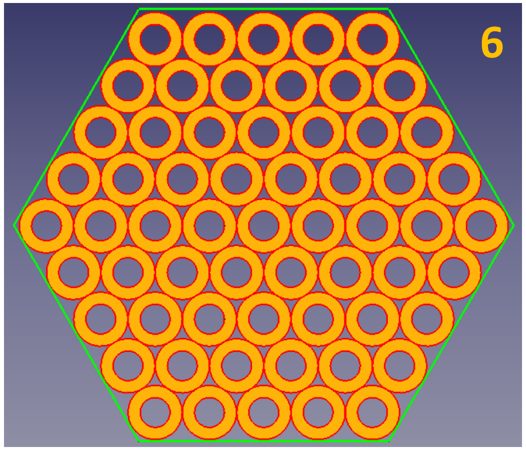


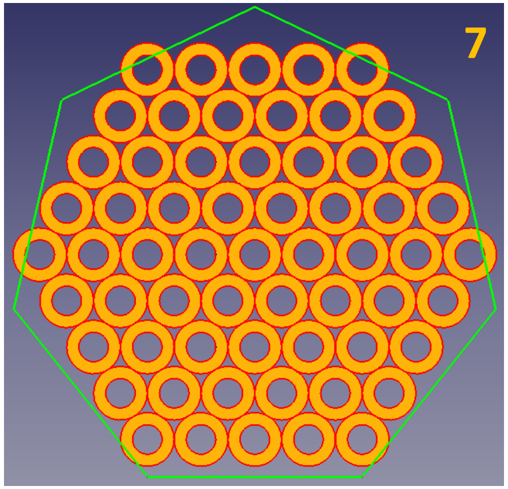


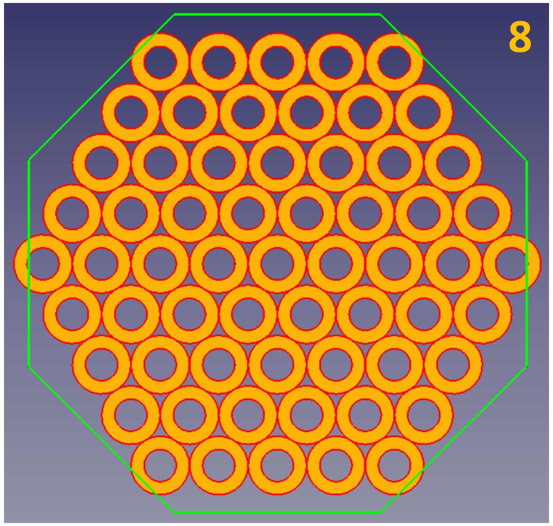


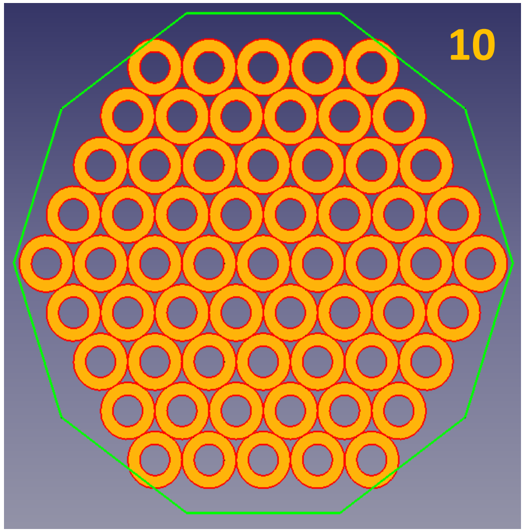
Polygons

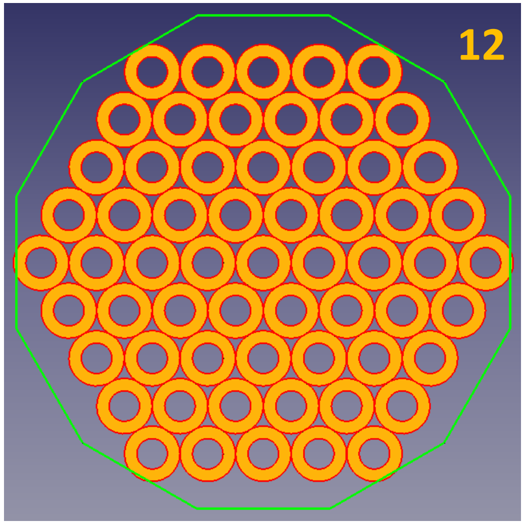








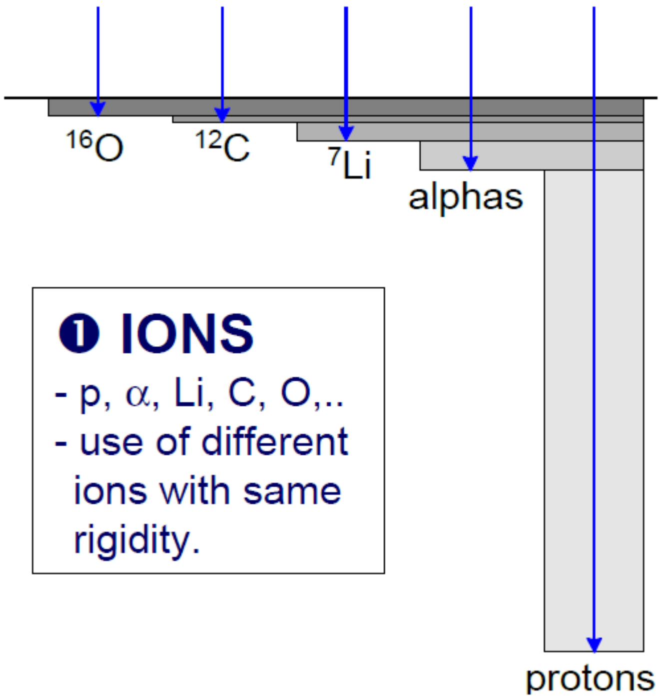




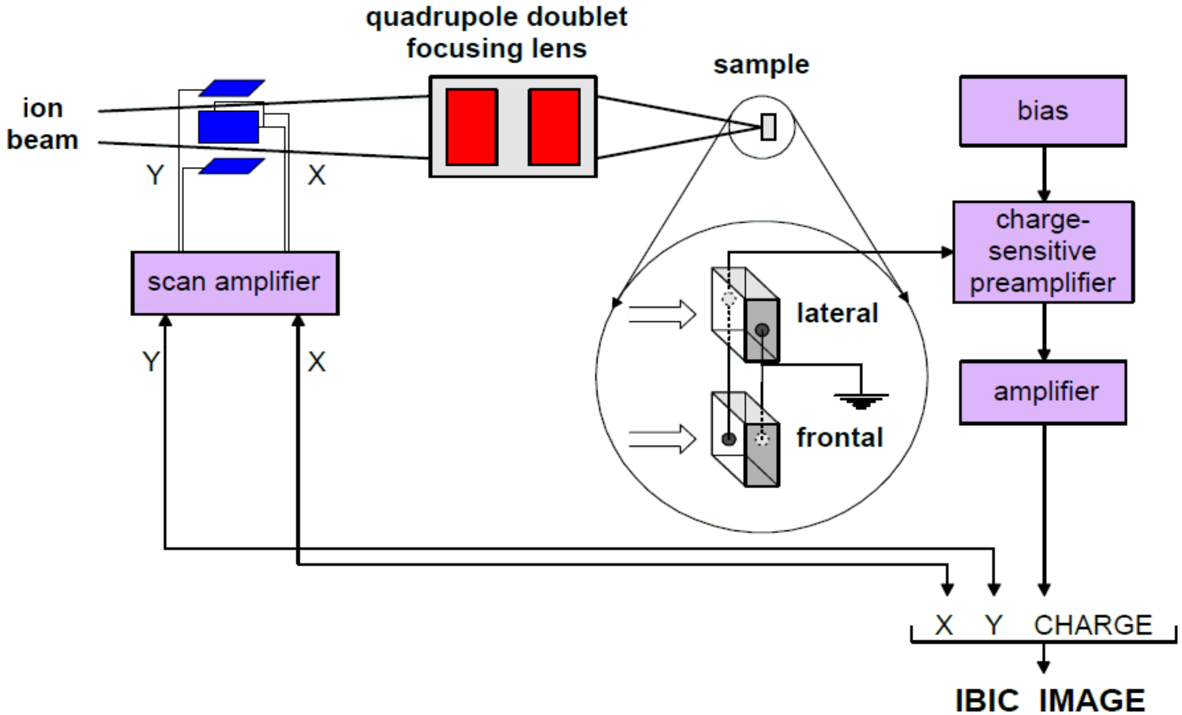
Nuclear microprobe

- Two accelerators, 6.0 MV Tandem Van de Graaff and 1.0 MV Tandetron
- Protons (0.4 to 8 MeV), ions up to ME/q^2 ratio of 15 MeV
- Beam spot size can be as low as 250 nm, in normal use ~few μm
- Scanning area from 1.5 mm down to tens of μm

Ion Beam Induce Current
Ideal radiation source for detector testing



❶ IONS
- p, α, Li, C, O,..
- use of different ions with same rigidity.



❷ RANGE
- 2 to 200 μm
- advantage over OBIC and EBIC
- large range - insensitive to surface
- depth profiling

❸ ION RATE
- beam current is reduced by decrease in object and collimator slits

❹ ION POSITION
- determined by scanning coils
- scanning pattern - arbitrary area, line, point

https://www.irb.hr/Laboratory-for-ion-beam-interactions

Ion sources of tandem accelerators

- Tandetron up to 1.0 MV
- Duoplasmatron (p, O)
- Sputtering

Voltages from 0.1 to 1.0 MV

Ions / max. currents (μA)

H	30
D	15
^{16}O	0.5-1.0

Ion sources of tandem accelerators

EN tandem up to 6.0 MV
- Alphatross NEC
- Sputtering - homemade,

/ to be exchanged (in 2007) by new NEC

Voltages 0.4 to 6.0 MV

<u>Sputtering source</u>

Ions / source currents (μA)

H	10
D	1
^{6}Li	0.5
^{7}Li	1.0
^{10,11}B	1.0
C ,O	20
F, Si	20
Cl, I	20

<u>Alphatross source</u>

Ions / source currents (μA)

H	1
D	0.5
^{3}He	0.5
^{4}He	1.0

Laboratory for ion beams - activities

Basic Research

- Inner shell ionization, chemical effects, data base
- Elastic scattering data base (p, He beams) for ion beam analysis

Material science applications

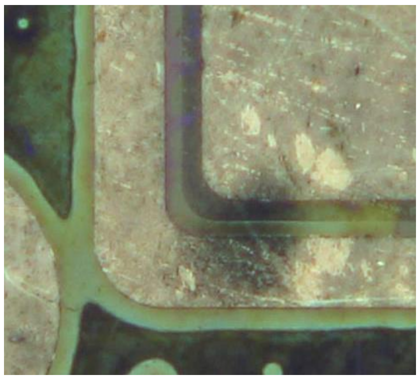
- Charge transport in semiconductors
- Development and application of depth profiling techniques (ERDA)
- Ion microprobe modification of materials (ion tracks, damage structuring, implantation)

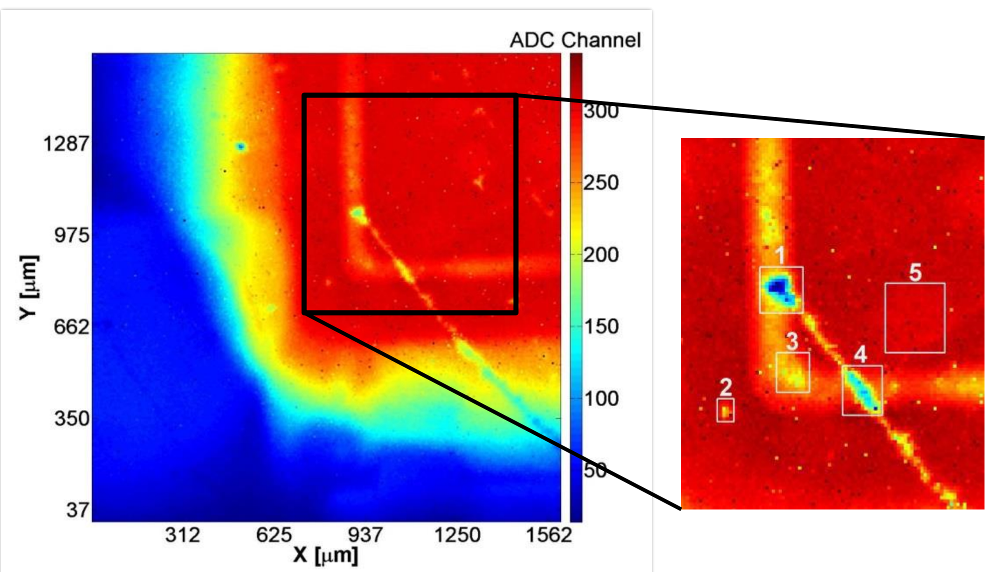
Other applications

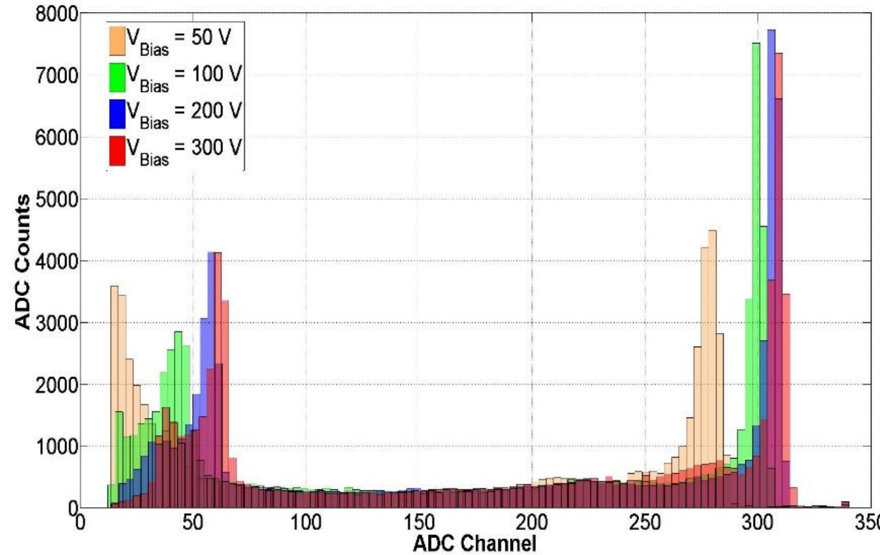
- Cultural heritage μPIXE analysis
- Technological projects (cement, glass, solar cells)
- Analytical services and irradiation services

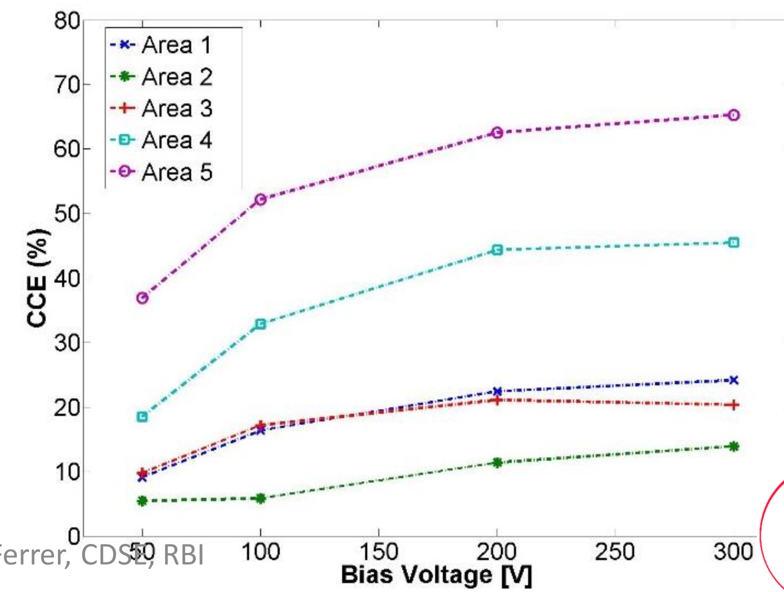
CdTe IBIC measurements

CdTe with AlN



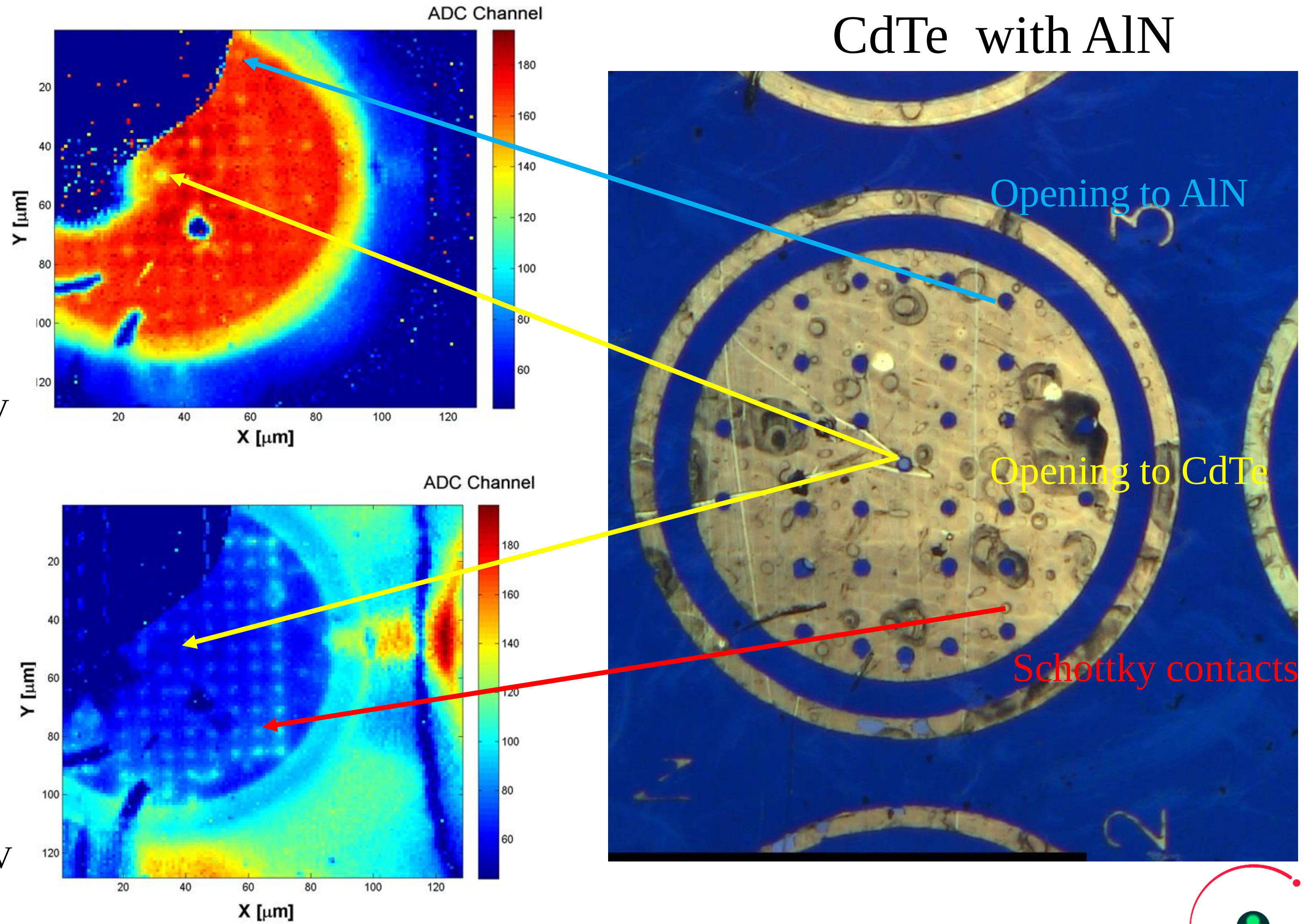






CdTe IBIC measurements

CdTe with AlN

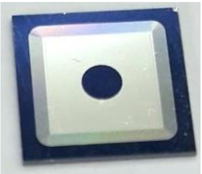


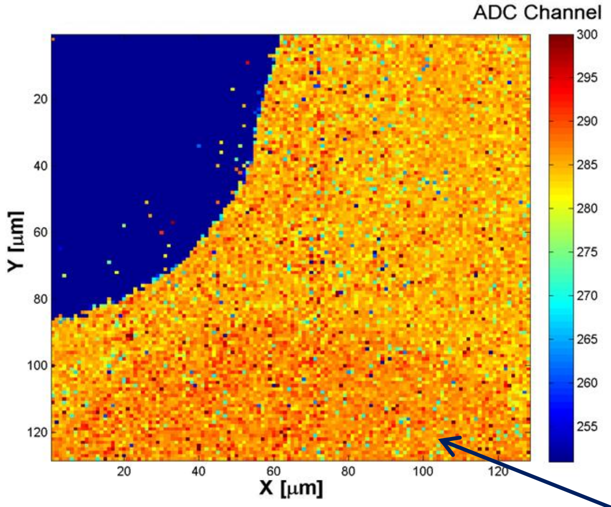
V_{bias} = +50 V

Reverse V_{bias} = -50 V

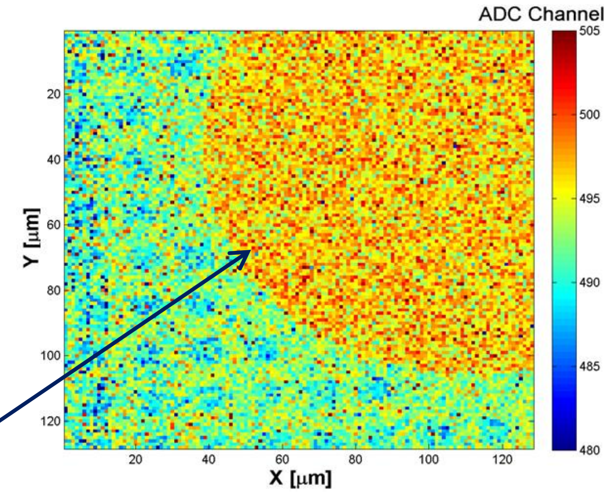
Si IBIC measurements

Si nFz





V_{bias}=+100V

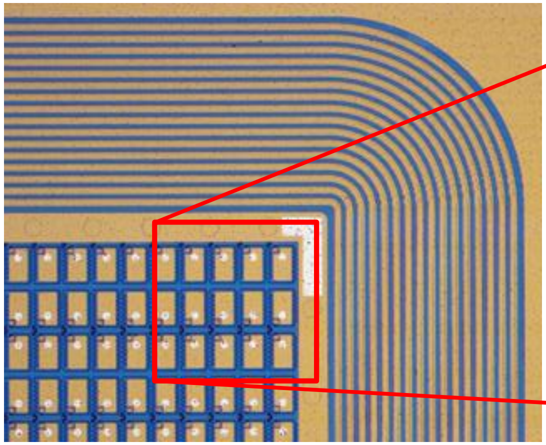


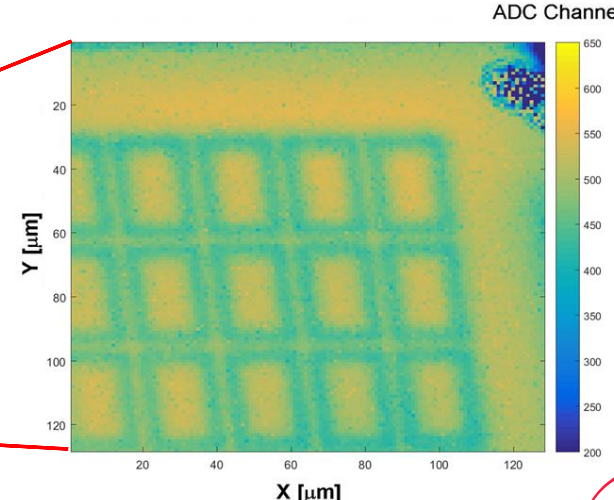
Si pFz

V_{bias}=-50V

Optical opening

n^{+}-in-p AC-coupled
pixel detector on p-type MCz Si





V_{bias}=-100V

For more details see:
Jennifer Ott, "Processing of pixel detectors …" on Wednesday @ 10:10