

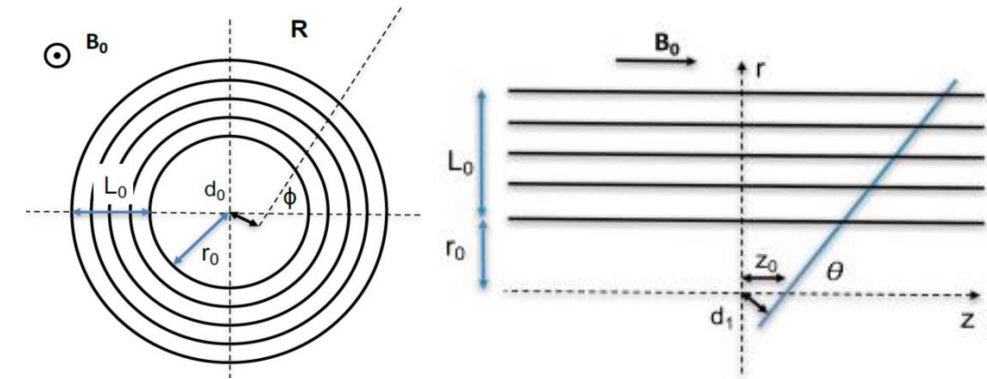
Vertex detectors for FCC-ee and the FCC-SEED concept



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IPHC (Strasbourg)

- In the context of FCC-ee, development of a vertex detector concept.
- General requirements :
 - Sustain/cope with the large beam backgrounds, high bunch-crossing rates,
 - Have a material budget as low as possible ($\lesssim 0.5\% x/X_0$) => **imply air cooling**, thin **MAPS** sensors ($\lesssim 50 \mu m$),
 - Have a single point resolution $\lesssim 3 \mu m$, with **low power dissipation** allowing for air colling ($\lesssim 50 mW/cm^2$),
 - Have the first measurement point as close as possible to the collision point => first layer slightly above the beam pipe radius => **curved sensors**.
 - Impact parameter resolutions depends as square root of material budget, but lineary on r_0 .
 - Reducing material budget is important, but full acceptance is even more.
- In this presentation, we will discuss various detector concepts, with a focus on FCC-SEED, and would not go into the details of other concepts, nor DRD3 developments.

Drasal, Riegler, <https://doi.org/10.1016/j.nima.2018.08.078>



$$\Delta d_0|_{res.} \approx \frac{3\sigma_{r\phi}}{\sqrt{N+5}} \sqrt{1 + \frac{8r_0}{L_0} + \frac{28r_0^2}{L_0^2} + \frac{40r_0^3}{L_0^3} + \frac{20r_0^4}{L_0^4}}$$

$$\Delta d_0|_{m.s.}^{opt} \approx \frac{0.0136 \text{ GeV}/c}{\beta p_T} r_0 \sqrt{\frac{d}{X_0 \sin \theta}} \sqrt{1 + \left(\frac{r_0}{L_0}\right) + \left(\frac{r_0}{L_0}\right)^2}$$

FCCee

$$\sigma_{d_0} = a \oplus \frac{b}{p \sin^{3/2} \theta}$$

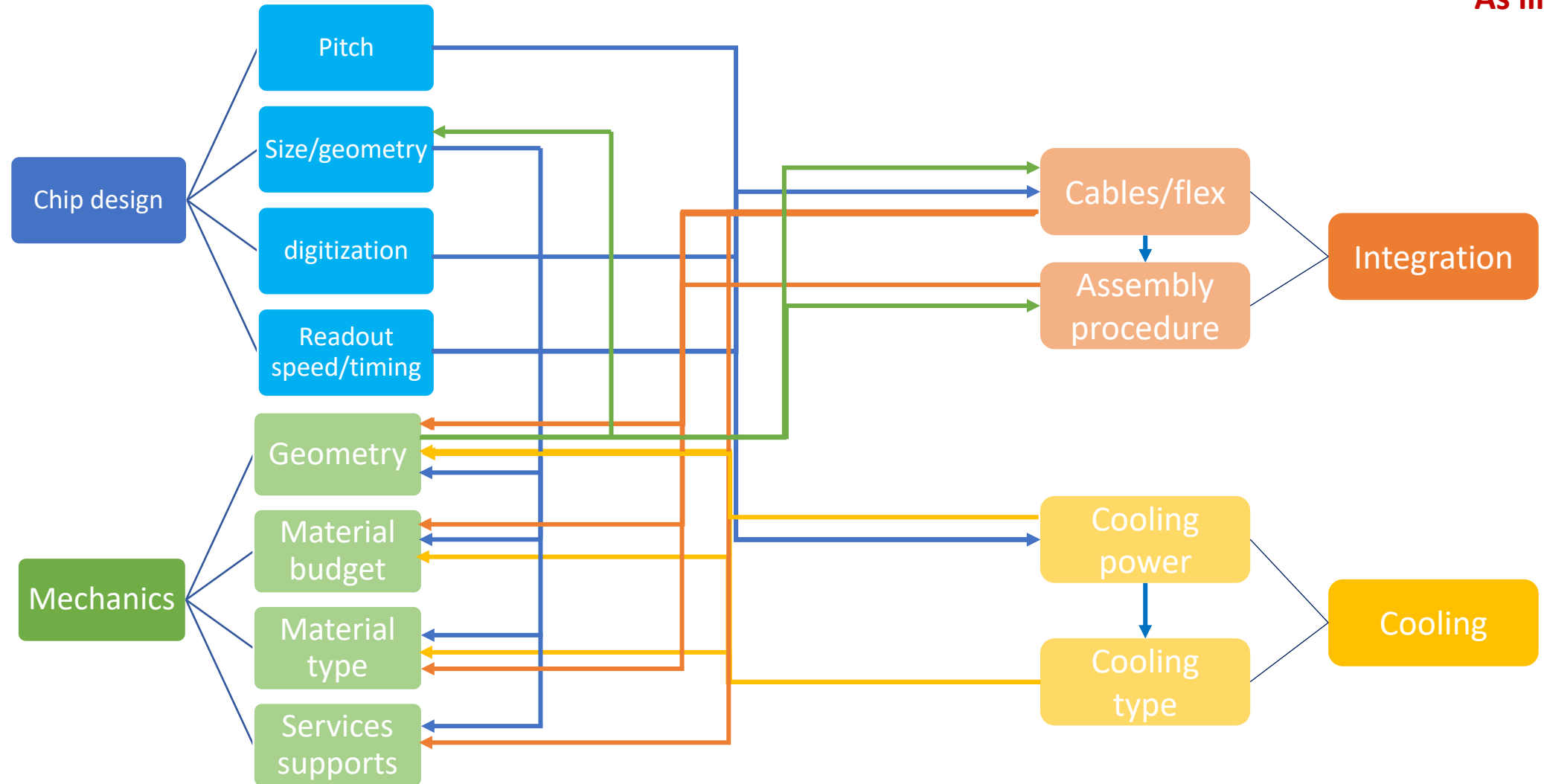
$$a \lesssim 3 \mu m \text{ (or better)}; \quad b \approx 15 \mu m$$

Vertex sensor specifications

			Depends on pitch, charge sharing and encoding
Spatial resolution per layer	$\simeq 3$	μm	Balance between power dissipation and particle rate
Pixel pitch	14-20	μm^1	
read-out time	$\simeq 500$	ns^2	To be compatible with air cooling
Power dissipation	$\simeq 20 - 50$	mW/cm^2	
Sensor thickness	40 – 50	μm^3	Reduced material budget, allows for bending
Safety factor on particle rate	3	4	
Maximum Hit rate	75 / 25	MHz/cm^2^5	Related to max particle rates at the Z energy
Maximum Hit rate	$22.5 \times 10^{-3} / 7.5 \times 10^{-3}$	$hits/mm^2/BX^5$	
Assumed cluster multiplicity	5		Expected max fluence per year
Fired pixel rate	375 / 125	MHz/cm^2^5	
Fired pixel rate	0.33 / 0.11	$fired\ pixels/mm^2/BX^5$	
Occupancy/pixel/read-out	$3.45 \times 10^{-3} / 1.15 \times 10^{-3}$	$/pixel/readout^5$	
Ionising radiation (1 st layer)	5	$MRad/year^5\ 6$	
Corresponding Fluence	6×10^{13}	$n_{eq}(1\ MeV)/year^5\ 7$	

Vertex detector design "spaghetti" diagram

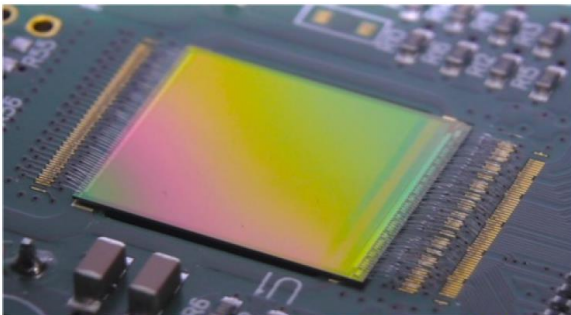
As illustration



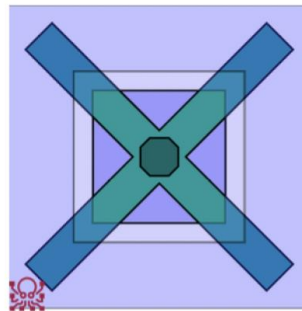
Technologies for Vertex detector

Light, low-power, small pixels, reasonable timing? → Monolithic active pixel sensors (MAPS)!

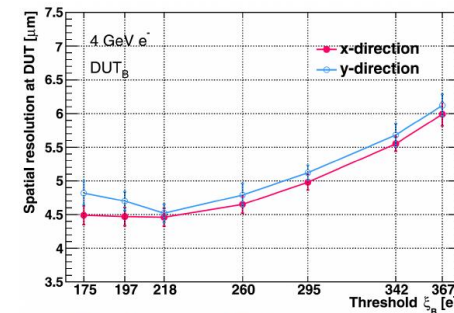
	ARCADIA [13] (M. Barbagiovanni)	OCTOPUS [14] (D. Dannheim)	TaichuPix [15]
Process	110 nm LFoundry	65 nm TPSCo	TJ 180 nm
Pitch [μm^2]	25×25	$\mathcal{O}(20 \times 20)$	25×25
σ_{xy} [μm]	Down to 4.6 [16]	Goal: 3	Down to 4.5 [17]
Timing	$\mathcal{O}(\text{ns})$ to $\mathcal{O}(10\text{'s of ps})$	5 ns time tag with ToT	$\sim 100 \text{ ns}$ time dispersion
Size [cm^2]	1.28×1.28 , side-abutable	$\approx 2 \times 3$	2.56×1.28
Thickness [μm]	< 50 to 500	≤ 50	150
Power [mW cm^{-2}]	< 30	≤ 500 (first prototype), ≤ 50 (goal)	< 200
Pixel hit rate [MHz cm^{-2}]	Up to 100	100, matrix readout with Asynchronous Priority Arbiter	Spec: 36 [18]
Project status	Full-scale proto.: MD3	Design phase	Full-scale proto.: TaichuPix3



ARCADIA MD3 chip [13]



N-opt sensor variation in OCTOPUS (A. Velyka @ 4th DRD3 week)

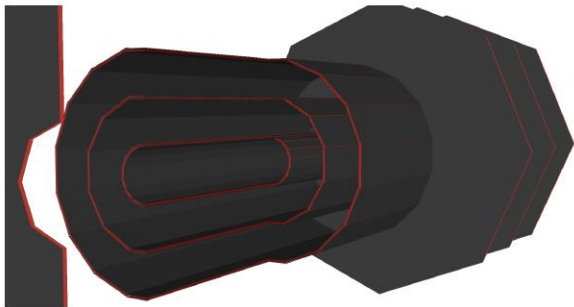


TaichuPix3 spatial resolution [15]

Vertex detector layouts for FCCee in DD4hep full simulation

CLD

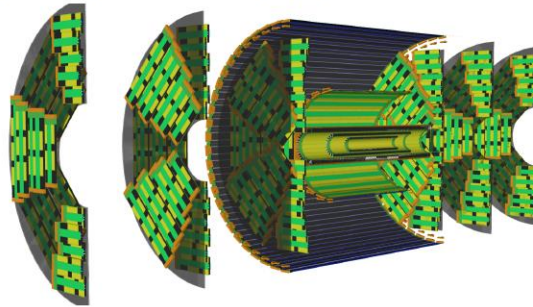
(CLD/ILD), [2]



- Adapted from CLIC design
- $r_{\min} = 13 \text{ mm}$
- Three double-layer barrel layers and disks, $0.6\text{--}0.7\% X_0$ per double layer
- No specific sensor chosen, assume $3 \mu\text{m}$ resolution

IDEA stave-based

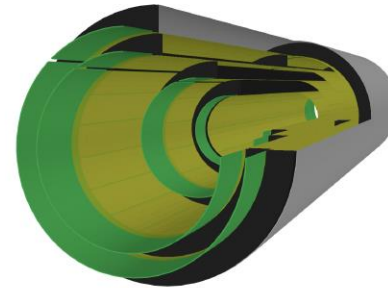
(IDEA/ALLEGRO), [3]



- $r_{\min} = 13.7 \text{ mm}$
- 3 inner barrel ($0.25\% X_0$), 2 outer barrel layers and 3 disks ($\sim 0.5\% X_0$)
- Engineered design (Pisa) integrated with machine (LNF [4])
- IDEA: ARCADIA [5] (inner barrel) and ATLASPix3 [6] (rest)
- ALLEGRO: OCTOPUS

Ultra-light inner VXD

(IDEA/ALLEGRO), [7]



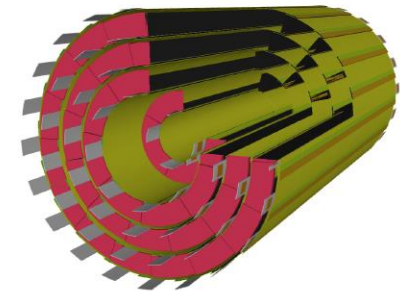
- Curved, 2D-stitched MAPS (ALICE ITS3-like [8])
- Four layers $0.075\% X_0$ per layer
- Sensitive sensor fraction of $\approx 95\%$
- Powering via metal layers, readout in silicon

ALFA det. concept: 5-layer curved inner VXD (long barrel)

AGORA det. concept: 4-layer curved inner VXD (long barrel + 2 layers of ladders)

FCC-SEED

(soon available to any det. concept)

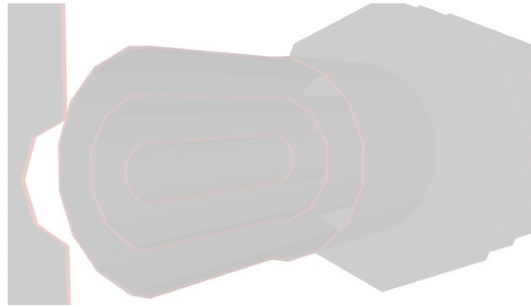


- Curved, 1D-stitched MAPS
- Five layers, $\approx 0.1\% X_0$ per layer
- Overlapping curved sensors to avoid gaps
- Powering and readout via

Vertex detector layouts for FCCee in DD4hep full simulation

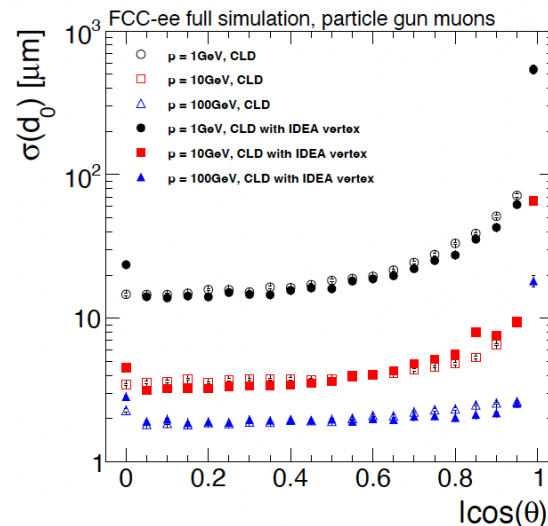
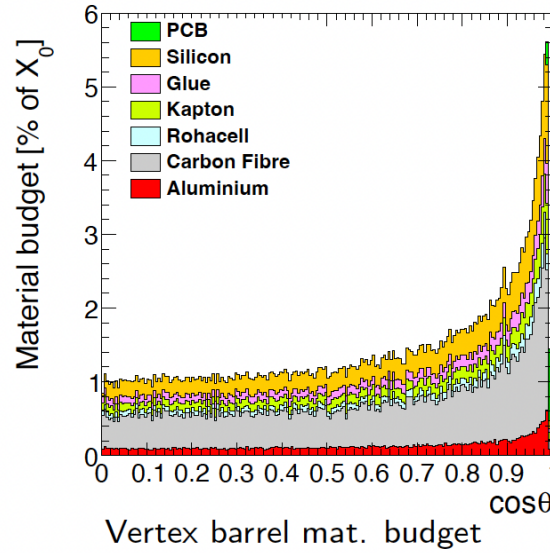
CLD

(CLD/ILD), [2]

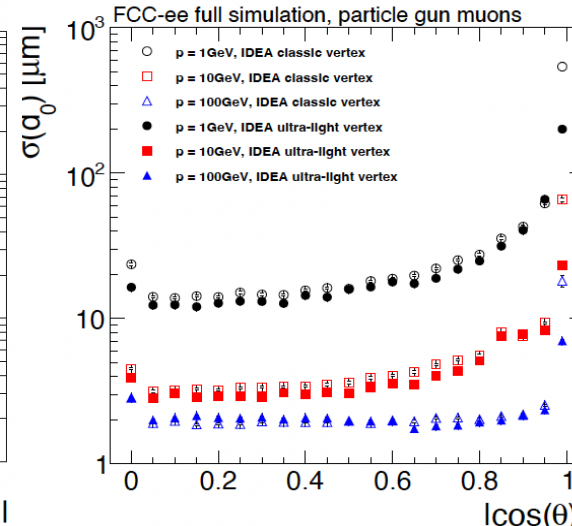
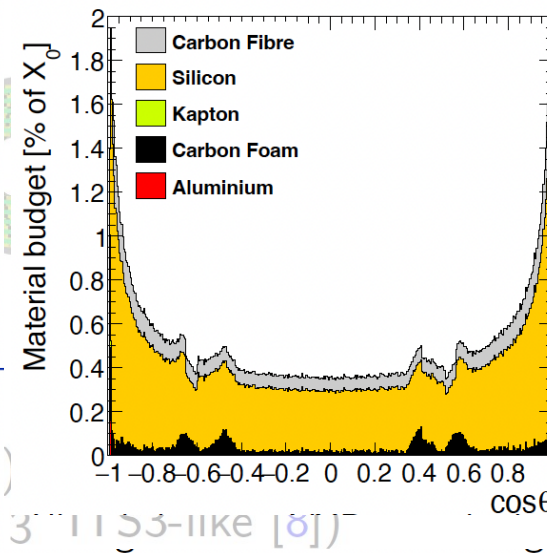


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- $r_{\min} = 13 \text{ mm}$
- Three double-layer barrel layers and disks, $0.6\text{--}0.7\%$ X_0 per double layer
- No specific sensor chosen, assume $3 \mu\text{m}$ resolution

IDEA stave-based

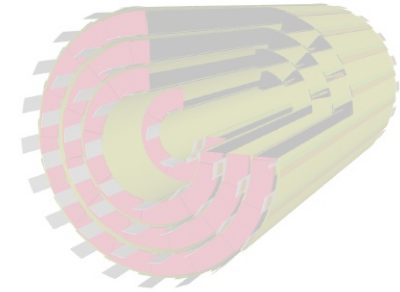


Ultra-light inner VXD



FCC-SEED

(soon available to any det. concept)

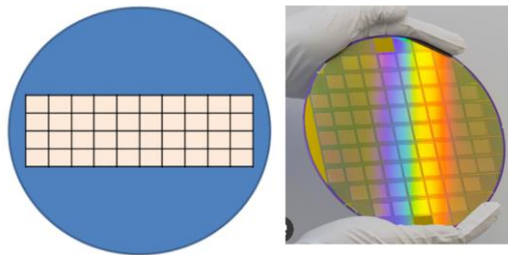


- Curved, 1D-stitched MAPS
- Five layers, $\approx 0.1\%$ X_0 per layer
- Overlapping curved sensors to avoid gaps
- Powering and readout via long flex cables

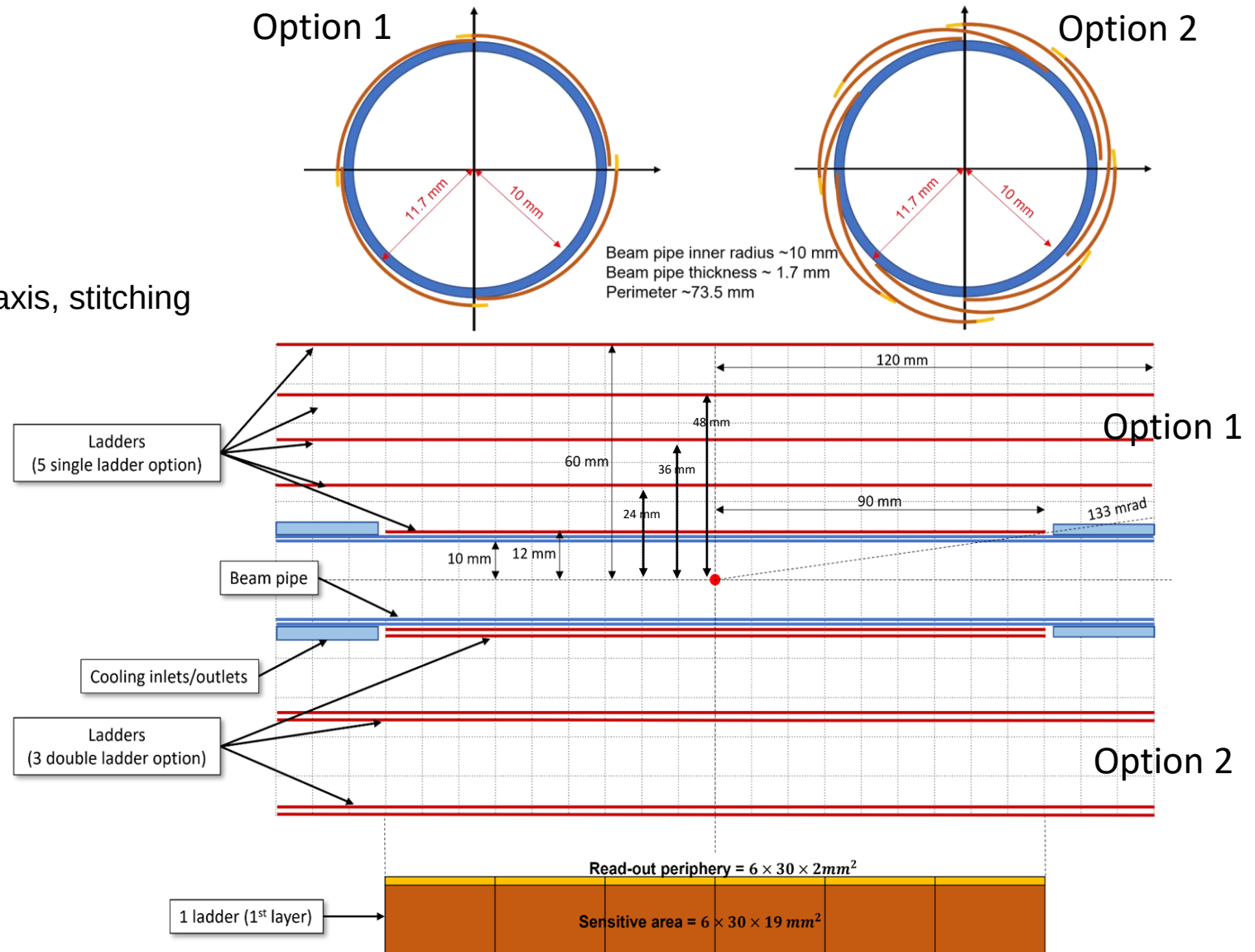
inner VXD (long barrel)
d inner VXD (long barrel + 2 layers of ladders)

FCC-SEED, general approach

- General approach : curved sensors, favour hermeticity.
- Main concept :
 - Have curved “ladders” (a la ALICE),
 - Have octopus-like sensors,
 - Bend wafer “slice”, have bonding along the Z-axis, stitching as an option,
 - Overlap to avoid holes in the acceptance,
 - Barrel+endcaps.

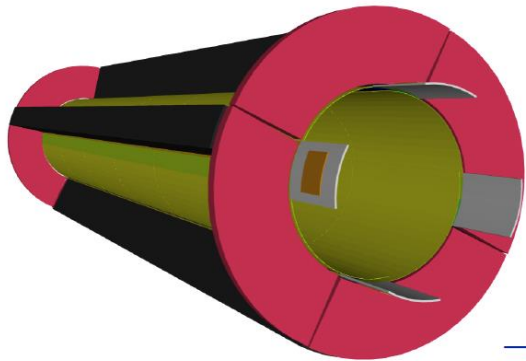
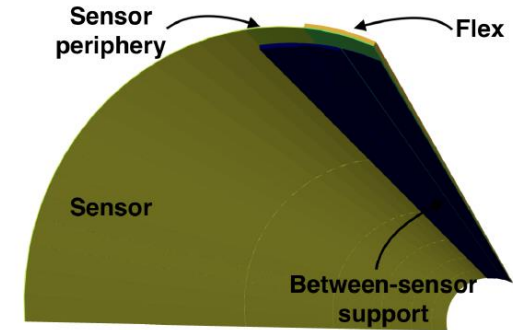


- Very first steps :
 - Mastering the techniques for bending sensor,
 - Learn “basics” for mechanics and integration (gluing, wire bonding),
 - Measure impact of the bending on the chip's properties.



Ladder properties

- $30 \times 23 \text{ mm}^2$ sensors, 3 mm periphery in ϕ and 0.1 mm in z
- $\sim 40 \mu\text{m}$ insensitive, and $10 \mu\text{m}$ sensitive thickness (TPSCo 65 nm)
- 3.6 mm wide flex next to periphery (properties as in IDEA VXD)
- 1 mm carbon fibre supports between sensors



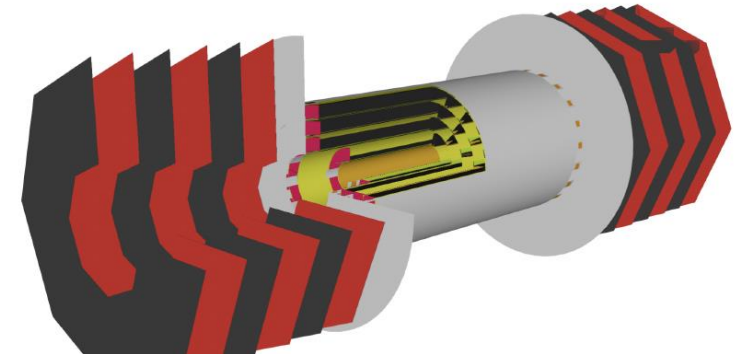
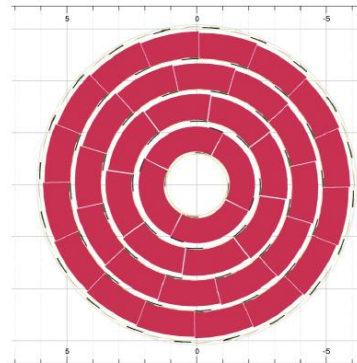
Complete first layer

Layout properties

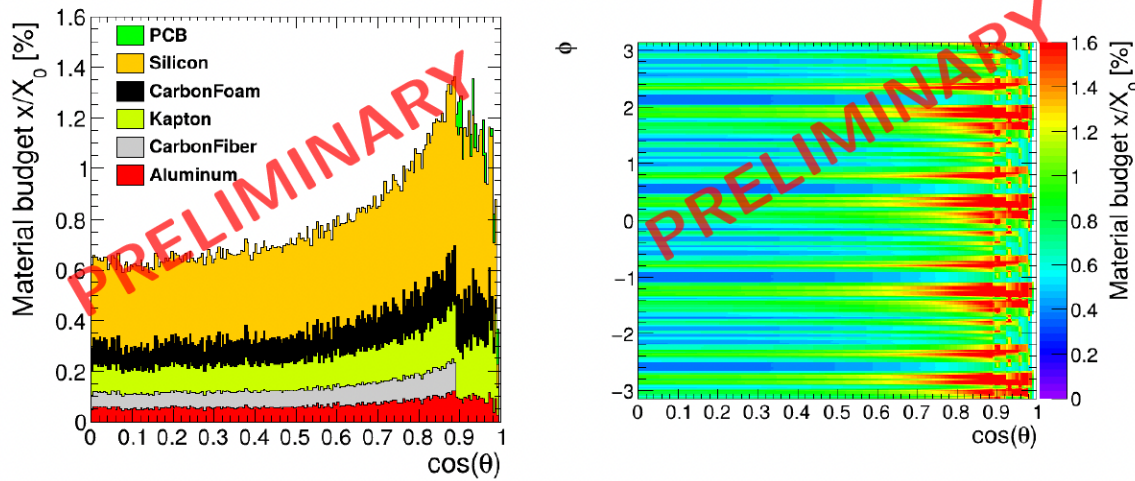
- $r_{\min} = 11.8 \text{ mm}$ after $100 \mu\text{m}$ Kapton layer for el. insulation from beam pipe
 - Sensor overlap of $\sim 0.5 \text{ mm}$ in ϕ to avoid gaps $\rightarrow$ Almost fully hermetic!
 - Layers rotated in ϕ to even out material budget
 - Disks: From CLD, but single-hit and increased acceptance limit of $\theta \geq 125 \text{ mrad}$
- $\rightarrow$ Need to revisit disk design and material budget assumptions there

Support and readout structures

- Carbon foam support rings and longerons
- Hybrid flex and opto-el. ASIC at end of stave
- Proxy for off-detector services



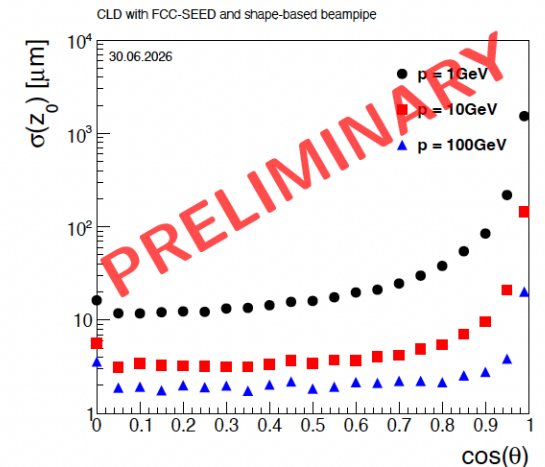
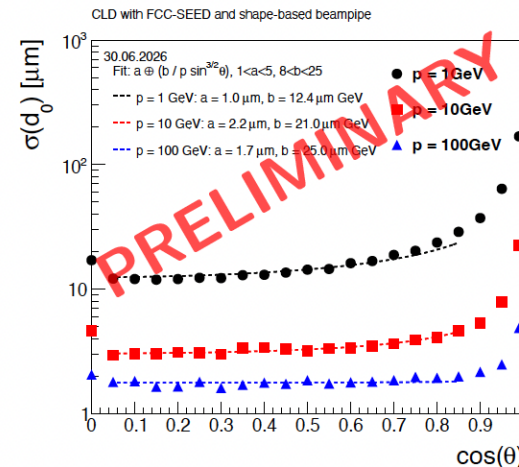
Air cooling tubes and fixations to be added !



FCC-SEED barrel material budget in 1D (left) and 2D (right)

- About 0.12% X_0 per layer in the barrel
- Silicon is about half of the total mat. budget
- Significant contributions from beam pipe kapton layer, flex (kapton + Al) and carbon fibre (support and outer tube)
- High mat. budget density in 2D plot from end-of-ladder hybrid with opto-el. proxy

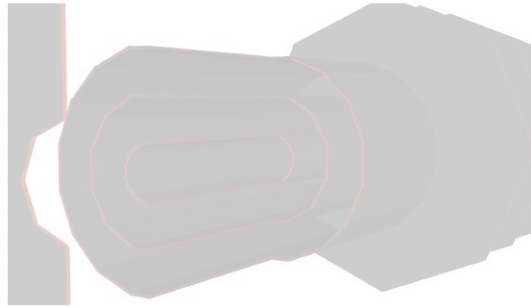
- FCC-SEED in CLD_o2_v08 using default [CLDConfig](#) and evaluating with [TrackerPerformanceScripts](#)
- Very good performance of FCC-SEED $\rightarrow a \approx 2 \mu\text{m}$, $b \approx 12.5 \mu\text{m GeV}$
 - $\rightarrow$ Thanks to almost full hermeticity per layer
- Previous study without 1 mm thick carbon fibre support between sensors was even better
 - $\rightarrow$ Important design parameter
- Similar performance observed also in ILD@FCC-ee



CLD_o2_v08 with FCC-SEED with $r_{\min} = 11.8 \text{ mm}$

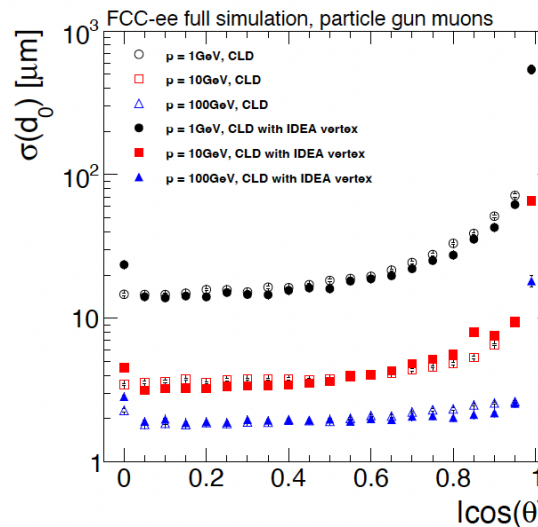
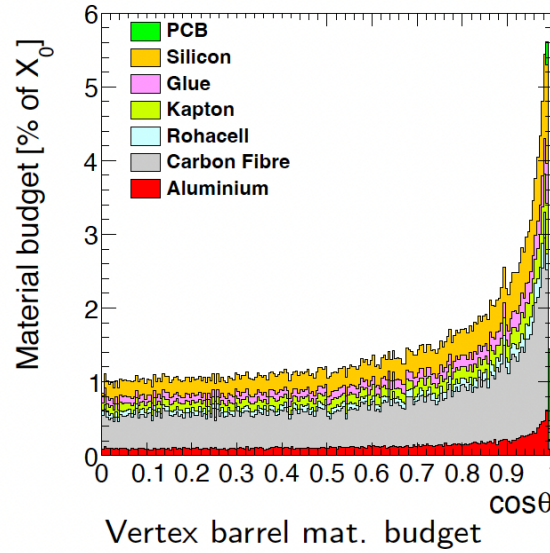
Vertex detector layouts for FCCee in DD4hep full simulation

CLD (CLD/ILD), [2]

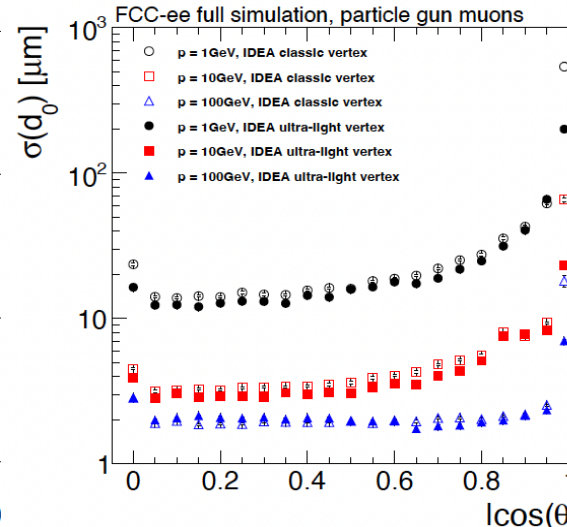
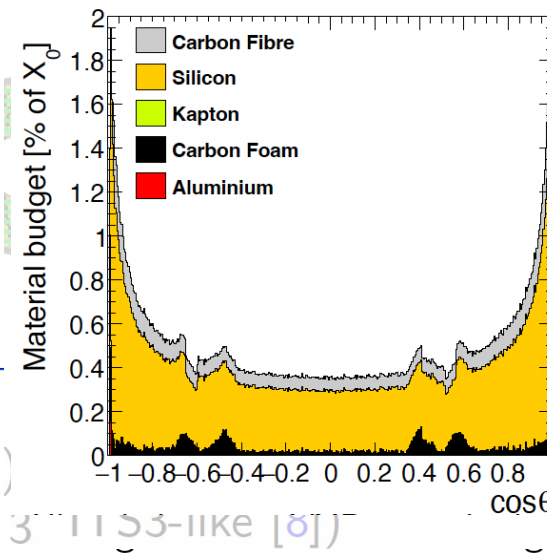


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IDEA stave-based

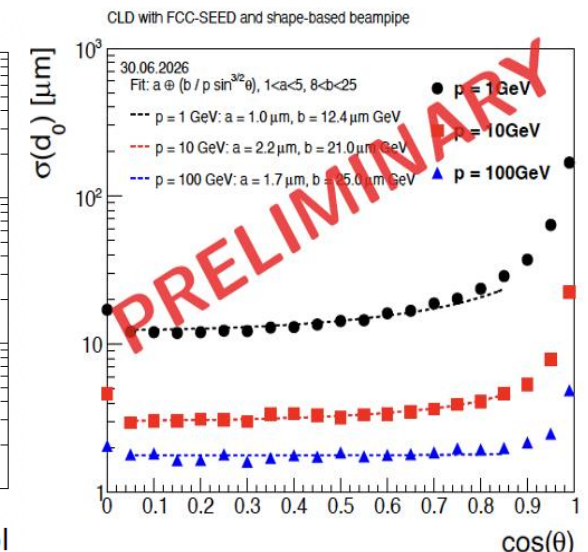
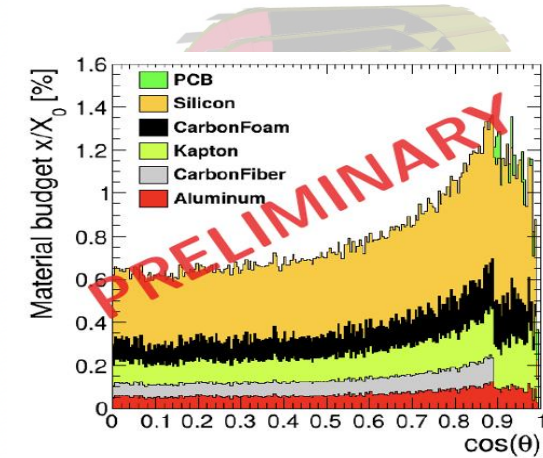


Ultra-light inner VXD



FCC-SEED

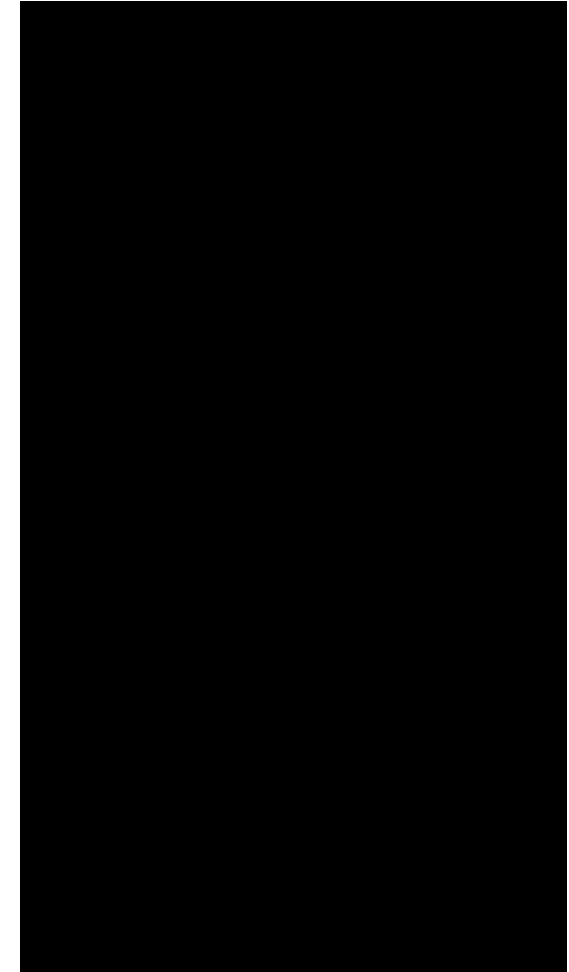
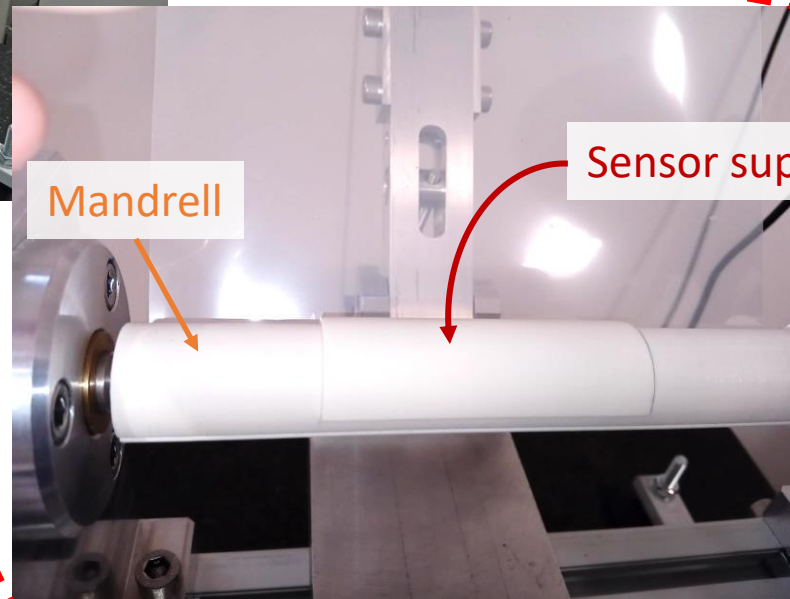
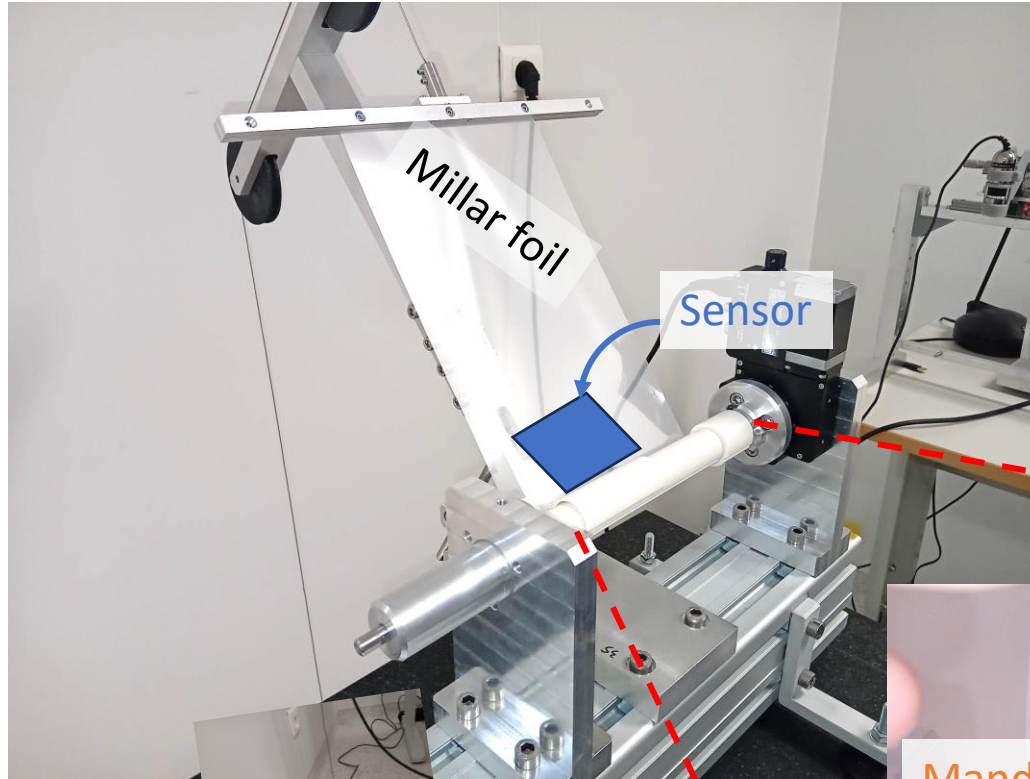
(soon available to any det. concept)



Prototyping and test strategy

- Designs made on CAD and simulations need to be confronted to reality : can we build such detectors ? How to interface it properly with MDI ? How to mechanically support it ? How to cool it down efficiently? Where to pass cables ? Etc... etc...
- Prototyping and assembly tests are essential to ensure the detector concepts are making any sense.
- Vast campaigns of prototyping and test to be realised. FCC-SEED will benefit from the CBM chips developed at IPHC : **Mimosi**.
 - Mimosi has already specs close to what is needed at FCCee,
 - Existing Mimosi helped us already to practice sensor bending,
 - Sharing production with CBM can allow to have large quantities of sensors to tests,
 - Use Mimosi to understand performance changes with different bending radius,
 - Prepare a demonstrator, potentially with a fully functional layer 1.
- Simulations and realisation of FCC-SEED demonstrator, based on Mimosi, recently received support from French funding agency (ANR).

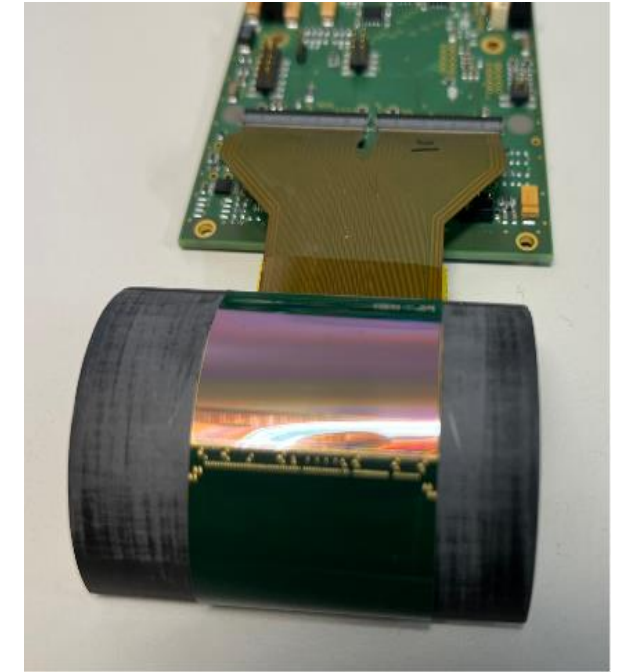
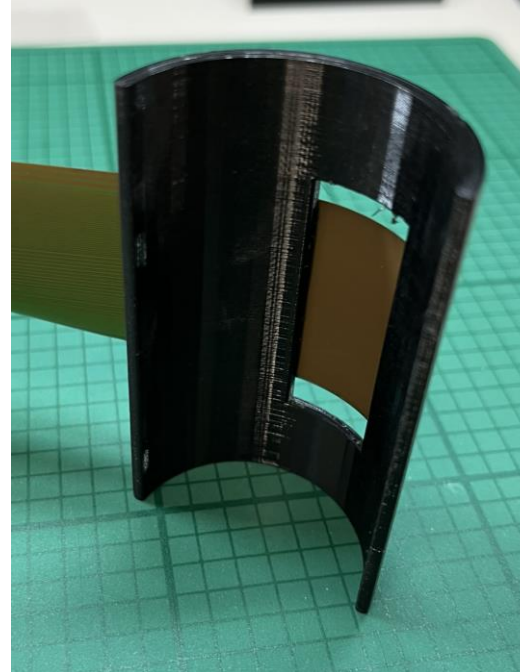
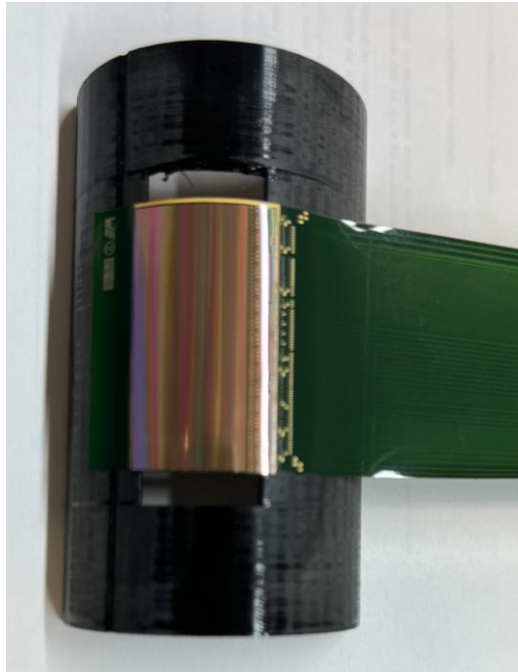
Sensor Bending setup (strongly inspired from ALICE)



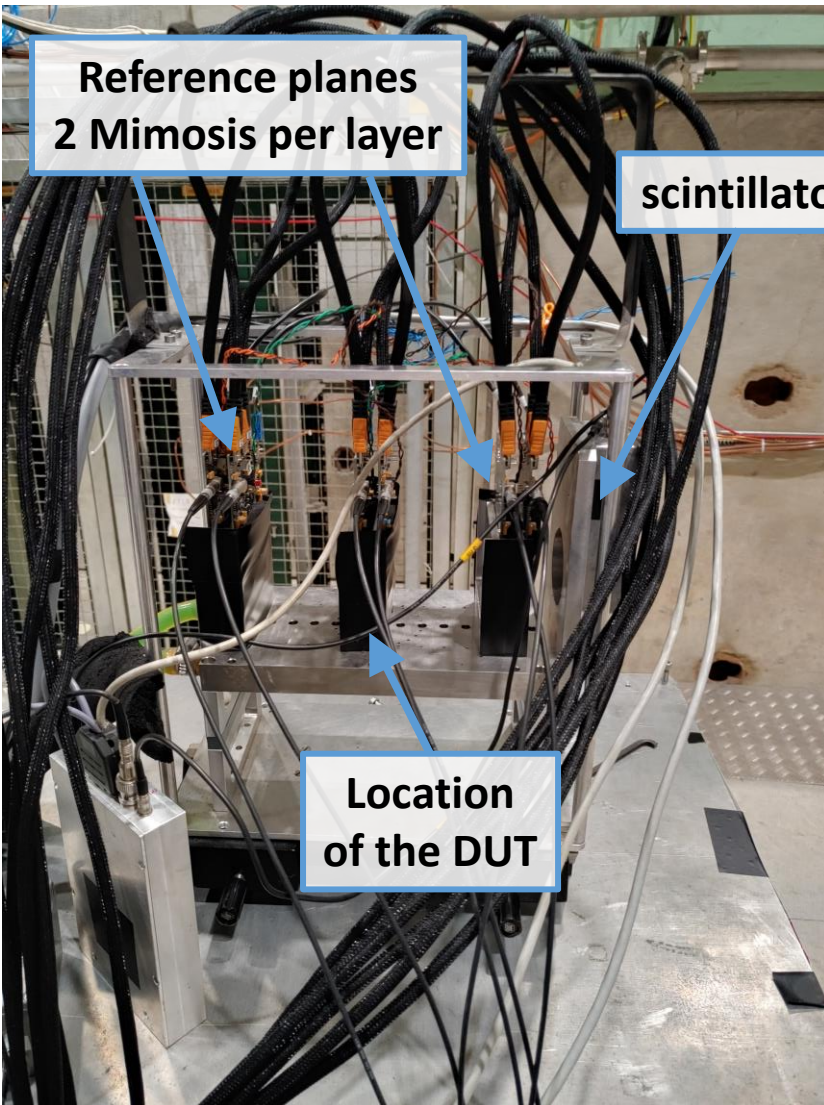
3D printed Mandrell and sensor support

Test beam preparation

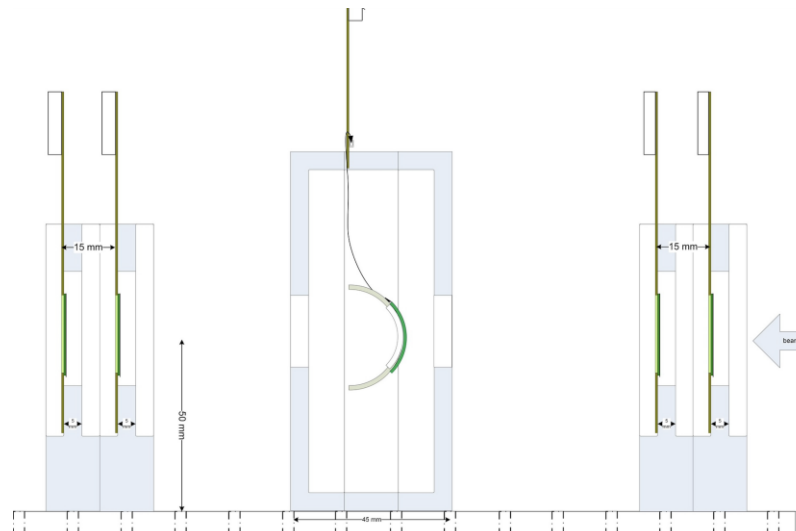
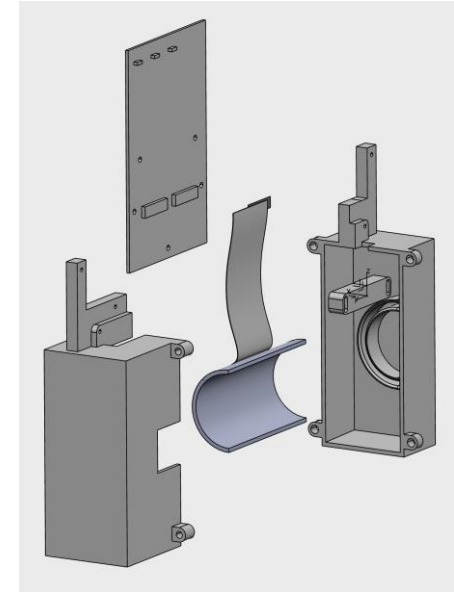
- A different version of half-shelf developed for test beam.
- Removable part.
 - allowing for a safe bending,
 - opening for the passage of the beam.
- Glue positioned only on the contact surfaces.



Beam test preparation



- Testing with beams to be performed with a [Mimosi-based telescope](#).
- [Two layers with two Mimosi sensors each](#), sandwiching the Detector Under Test (DUT).
- Synchronisation “for free”, uses same DAQ and software.
- Key point to address : alignment with bend sensors.



MIMOSIS-2.1 features	
Spatial resolution	~5 μm
Time resolution	< 5 μs
Sensor thickness	~50 μm
Power dissipation	< 100 - 200 mW/cm ²
Rate (average/50 μs peak)	20/80 MHz/cm ²

Summary and next steps

- FCC-ee puts very stringent requirements on vertex detectors, mainly driven by Z pole collision environment and high-precision physics program
- Multiple vertex detector layouts available. FCC-SEED soon available in Key4hep full simulation framework as well (**pull request made to FCC-SEED as option to ILD**)
 - Trend towards lower material budget and curved sensors,
 - Redundancy and hermeticity as antagonist to low material budget.
- Vertex detector that provide nice resolution “in simulation” is a starting point. A lot of effort has to be spent on ensuring the feasibility of these nice detectors :
 - Can it be constructed, integrated,
 - how to design cooling,
 - minimise mechanical support while maintaining rigidity,
 - how to interface with MDI and other detectors.
 - etc... etc...
- Realisation of prototypes and demonstrator will be of utmost importance.

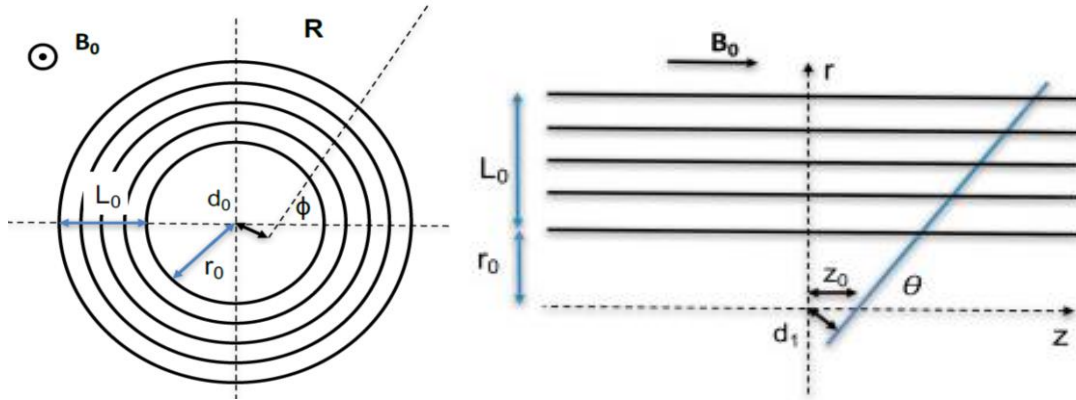
Backups

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- [2] N. Bacchetta, et al., *CLD – A Detector Concept for the FCC-ee*, [arXiv:1911.12230 \[physics.ins-det\]](#).
- [3] A. Ilg, *Design and Performance of the IDEA Vertex Detector at FCC-ee in Full Simulation*, in *Proceedings of The European Physical Society Conference on High Energy Physics — PoS(EPS-HEP2023)*, EPS-HEP2023, Sissa Medialab, Dec., 2023.
- [4] M. Boscolo, et al., *Progress in the design of the future circular collider FCC-ee interaction region*, [JACoW IPAC 2024 \(2024\) TUPC67](#).
- [5] C. Neubüser, T. Corradino, G.-F. Dalla Betta, and L. Panzeri, *ARCADIA FD-MAPS: Simulation, characterization and perspectives for high resolution timing applications*, [Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **1048** \(2023\) 167946](#).
- [6] I. Peric, et al., *High-Voltage CMOS Active Pixel Sensor*, [IEEE Journal of Solid-State Circuits **56** \(2021\) 2488–2502](#).
- [7] A. Ilg and F. Palla, *Design, performance and future prospects of vertex detectors at the FCC-ee*, [PoS ICHEP2024 \(2024\) 1062](#).
- [8] ALICE collaboration, *Technical Design report for the ALICE Inner Tracking System 3 - ITS3 ; A bent wafer-scale monolithic pixel detector*, tech. rep., CERN, Geneva, 2024.
<https://cds.cern.ch/record/2890181>.
Co-project Manager: Magnus Mager, magnus.mager@cern.ch.
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<http://cds.cern.ch/record/2928193>.
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- [11] X. Mo, G. Li, M.-Q. Ruan, and X.-C. Lou, *Physics cross sections and event generation of e^+e^- annihilations at the CEPC*, [Chinese Physics C **40** \(2016\) 033001](#), <https://doi.org/10.1088/1674-1137/40/3/033001>.

- [12] A. Ciarma, M. Boscolo, G. Ganis, and E. Perez, *Machine Induced Backgrounds in the FCC-ee MDI Region and Beamstrahlung Radiation*, *Proceedings of the 65th ICFA Advanced Beam Dynamics Workshop on High Luminosity Circular e⁺e⁻ Colliders eeFACT2022* (2022) Italy, <https://jacow.org/eefact2022/doi/JACoW-eeFACT2022-TUZAT0203.html>.
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- [18] Y. Zhang et al., *Development of a CMOS pixel sensor prototype for the high hit rate CEPC vertex detector*, *Nucl. Instrum. Meth. A* **1042** (2022) 167442.
- [19] R. Brenner, C. Dehos, and E. Locci, *Multi Gigabit Wireless Data Transfer in Detectors at Future Colliders*, *Frontiers in Physics* **10** (2022), <http://dx.doi.org/10.3389/fphy.2022.872691>.
- [20] IDEA Study Group Collaboration, M. Abbrescia et al., *The IDEA detector concept for FCC-ee*, [arXiv:2502.21223](https://arxiv.org/abs/2502.21223) [physics.ins-det].
- [21] M. Benedikt, et al., *Future Circular Collider Feasibility Study Report Volume 2: Accelerators, technical infrastructure and safety*, 2025. <http://cds.cern.ch/record/2928793>.
- [22] B. Humann, F. Cerutti, and R. Kersevan, *Synchrotron Radiation Impact on the FCC-ee Arcs*, <https://jacow.org/ipac2022/doi/JACoW-IPAC2022-WEPOST002.html>.

Main parameters of tracks resolution

Drasal, Riegler, <https://doi.org/10.1016/j.nima.2018.08.078>



• Relevant parameters for tracks resolution ($\Delta d_0, \Delta p_T/p_T$) :

- Single point resolution $\sigma_{r-\phi}$,
- Material budget (*m. s.*),
- Radius of the innermost measured point r_0 ,
- Level arm (L_0).

• Remarks,

- With existing single point resolution, performance strongly dependant on r_0 and material budget,
- Multiple scattering impact reduced with lower r_0 ,
- d_0 resolution improves with the number of layers N , $\Delta p_T/p_T$ proportional to $\sqrt{1/N}$,
- Strong dependence of $\Delta p_T/p_T$ to the level arm (L_0).

$$\Delta d_0|_{res.} \approx \frac{3\sigma_{r\phi}}{\sqrt{N+5}} \sqrt{1 + \frac{8r_0}{L_0} + \frac{28r_0^2}{L_0^2} + \frac{40r_0^3}{L_0^3} + \frac{20r_0^4}{L_0^4}}$$

$$\Delta d_0|_{m.s.}^{opt} \approx \frac{0.0136 \text{ GeV/c}}{\beta p_T} r_0 \sqrt{\frac{d}{X_0 \sin \theta}} \sqrt{1 + \left(\frac{r_0}{L_0}\right) + \left(\frac{r_0}{L_0}\right)^2}$$

$$d_{tot}/X_0 = (N+1)d/X_0.$$

$$\frac{\Delta p_T}{p_T}|_{res.} \approx \frac{12 \sigma_{r\phi} p_T}{0.3 B_0 L_0^2} \sqrt{\frac{5}{N+5}}$$

$$\frac{\Delta p_T}{p_T}|_{m.s.} \approx \frac{0.0136 \text{ GeV/c}}{0.3 \beta B_0 L_0} \sqrt{\frac{d_{tot}}{X_0 \sin \theta}}$$

FCCee

$$\sigma_{d_0} = a \oplus \frac{b}{p \sin^{3/2} \theta} \quad \begin{matrix} b \sim r_0 \sqrt{\text{material}} \\ a \sim \sqrt{r_0} \end{matrix}$$

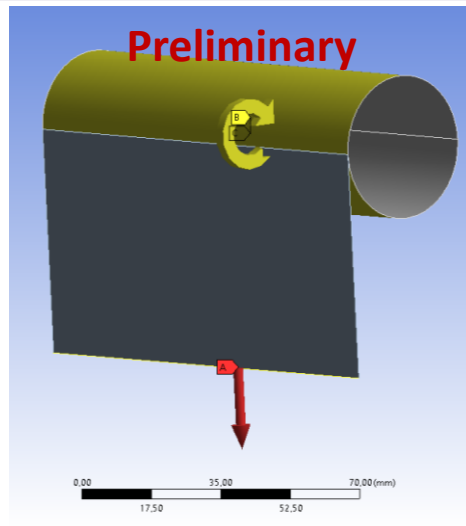
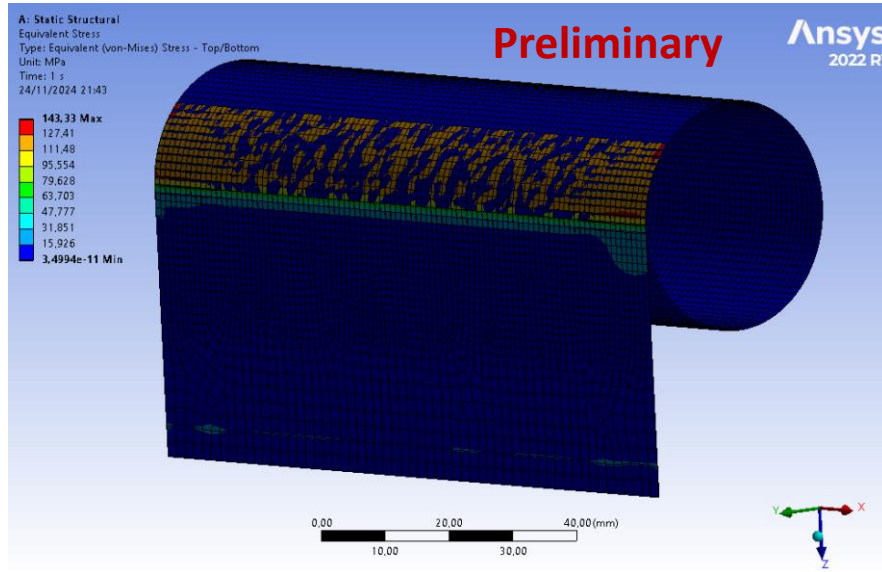
$a \approx 5 \mu\text{m}; \quad b \approx 15 \mu\text{m}$

ALICE ITS2

$$\Delta d_0|_{m.s.} = 22, 4.4, 2.2 \mu\text{m} \text{ for } p_T = 1, 5, 10 \text{ GeV/c}$$

Material budget is a key parameter !

M.Krauth, T.Sommen

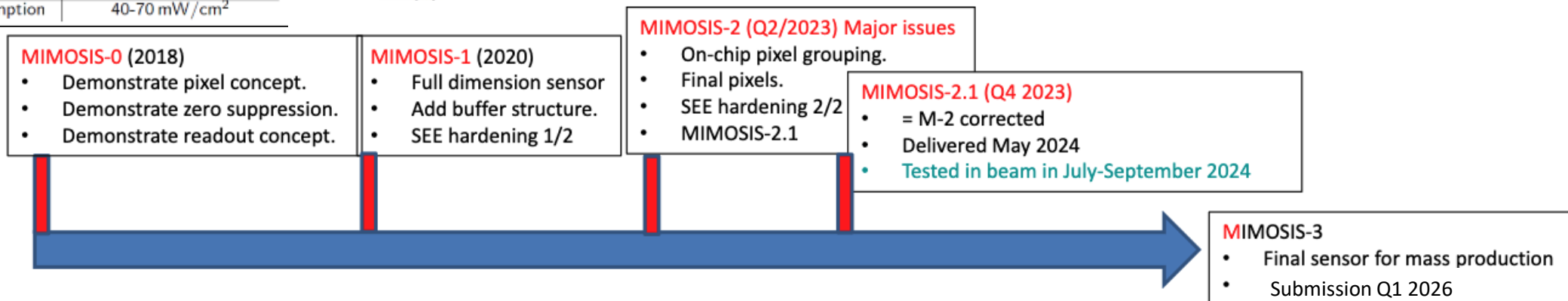


- Goal : simulate the bending of a silicon sensor, to determine the breaking points vs thickness and inner radius.
- Start with the modelling of a simple leaf of silicon, but mechanical characteristics of chips might be different :
 - Simulation of a complete chips might be difficult,
 - Considering measuring the mechanical characteristic of Mimosis and feed the simulation with the results.
- Preliminary studies with ANSYS being performed, but much more work is needed.
- More simulations (thermo-fluidic) related to thermal aspects are also required.

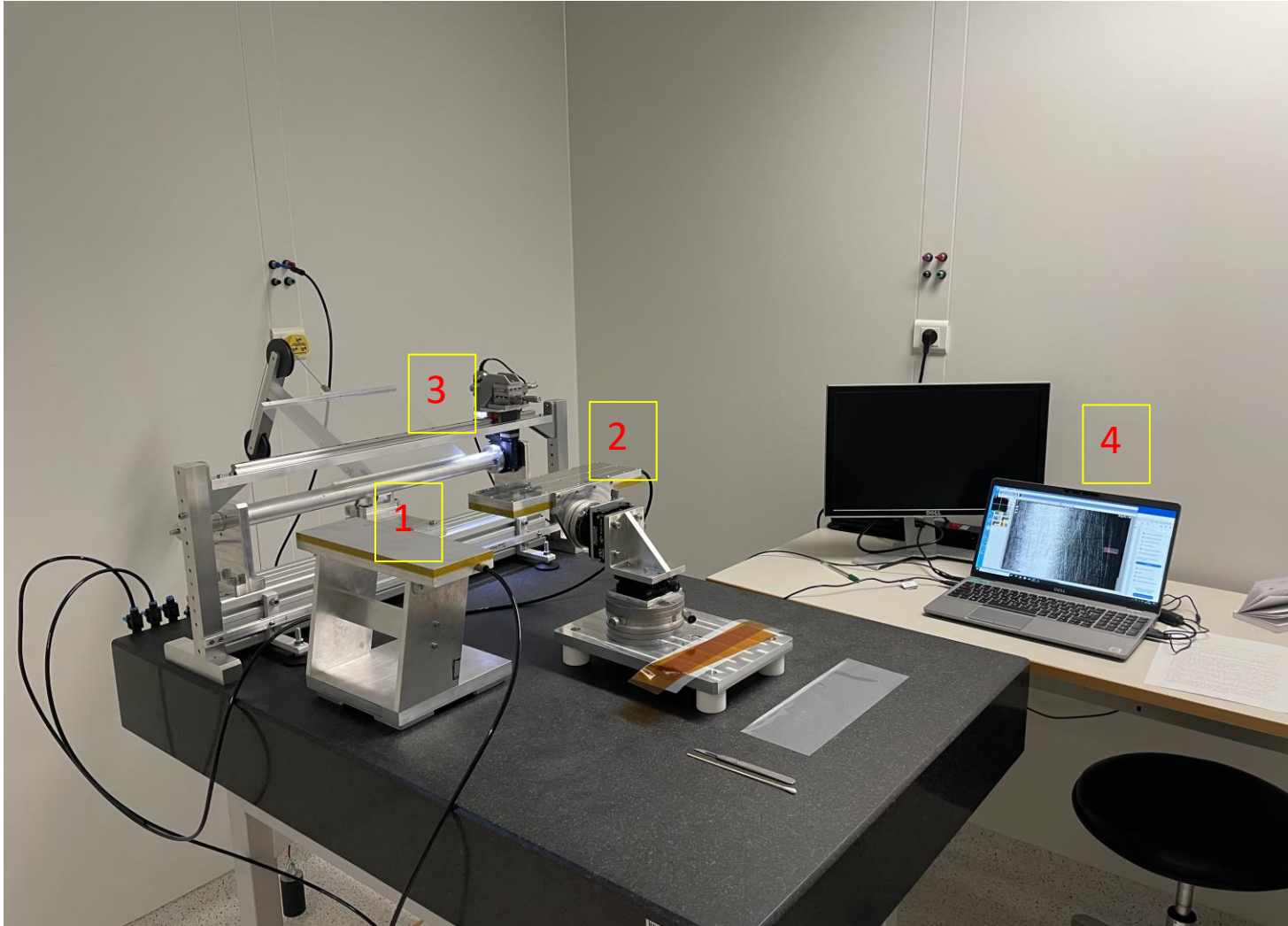
Physics parameter	Requirements
Spatial resolution	$\sim 5 \mu\text{m}$
Time resolution	$\sim 5 \text{ ns}$
Material budget	$0.05\% X_0$
Power consumption	$< 100 - 200 \text{ mW/cm}^2$
Operation temperature	-40°C to 30°C
Temp gradient on sensor	$< 5\text{K}$
Radiation tol* (non-ion)	$\sim 7 \times 10^{13} \text{ n}_{\text{eq}}/\text{cm}^2$
Radiation tol* (ionizing)	$\sim 5 \text{ MRad}$
Data flow (peak hit rate)	@ $7 \times 10^5 / (\text{mm}^2\text{s})$ $> 2 \text{ Gbit/s}$

Parameter	Value
Technology	TowerJazz 180 nm
Epi layer	$\sim 25 \mu\text{m}$
Epi layer resistivity	$> 1 \text{ k}\Omega\text{cm}$
Sensor thickness	$60 \mu\text{m}$
Pixel size	$26.88 \mu\text{m} \times 30.24 \mu\text{m}$
Matrix size	1024×504 (516096 pix)
Matrix area	$\approx 4.2 \text{ cm}^2$
Matrix readout time	$5 \mu\text{s}$ (event driven)
Power consumption	$40-70 \text{ mW/cm}^2$

- **Designing of a new chip is a long process.** To move forward, we are bending/testing already existing sensors : **MIMOSIS** (CBM experiment @ FAIR), IPHC (PICSEL, C4PI platform).
- MIMOSIS : based on ALPIDE architecture.
- **Fulfil already a significant amount of specs** : milestone toward e^+e^- colliders.
- **Functional versions Mimosis 1 or 2.1 are good candidates for bend sensor testing.** Mimosis 2.0 are good candidates for bending tests.



Bending bench setup



Inspired from ALICE technique.

1. Fixed suction table,
 - preparation of the sensor,
2. Mobile suction table,
 - Linear displacement in xyz,
Angular displacement in $\theta - \varphi$,
 - Pickup the sensor on 1, and precise positioning on the cylinder
3. Bending of silicon, motor for mandrel rotation, camera for alignment,
4. PC for camera display and other measurements.

Test bench for Mimosis testing

- Le slow control & DAQ
 - NI PXIe crate
 - CPU + DAQ board FlexRio (FPGA)
 - SW under Windows 7 Pro
 - DAQ : GUI executable (C++ Builder)
 - SC : GUI Python Q

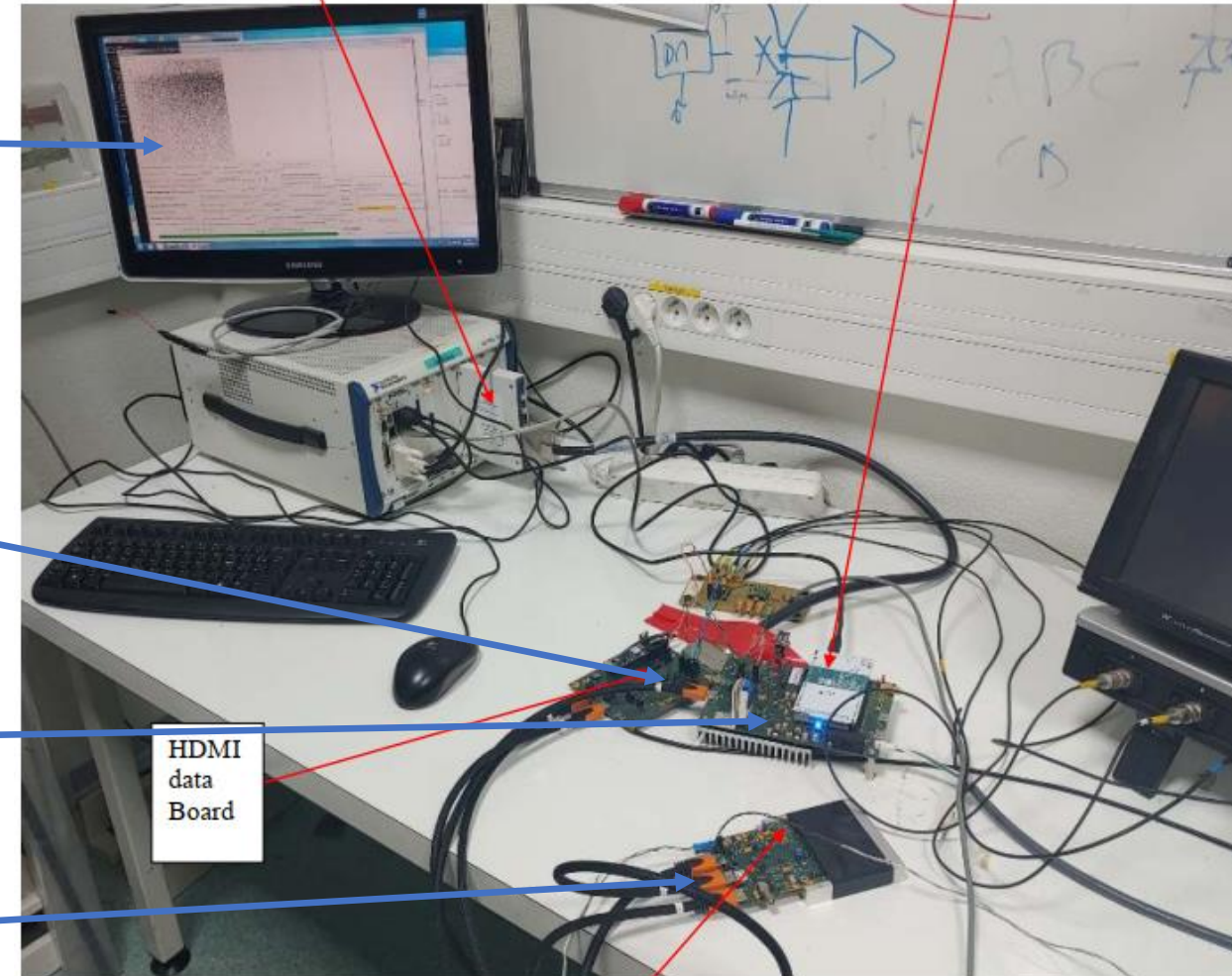
DATA board transmission links to Mimosis / DAQ, 8 links at 320 Mb/s.

S3 board (Slow control Steering Synchro) provides slow control I2C and clock to Mimosis

Mimosis is mounted on a “**Proximity board**”

PXIe crate with Flex-Rio card & 6587 Gigabit front-end

S3 Board

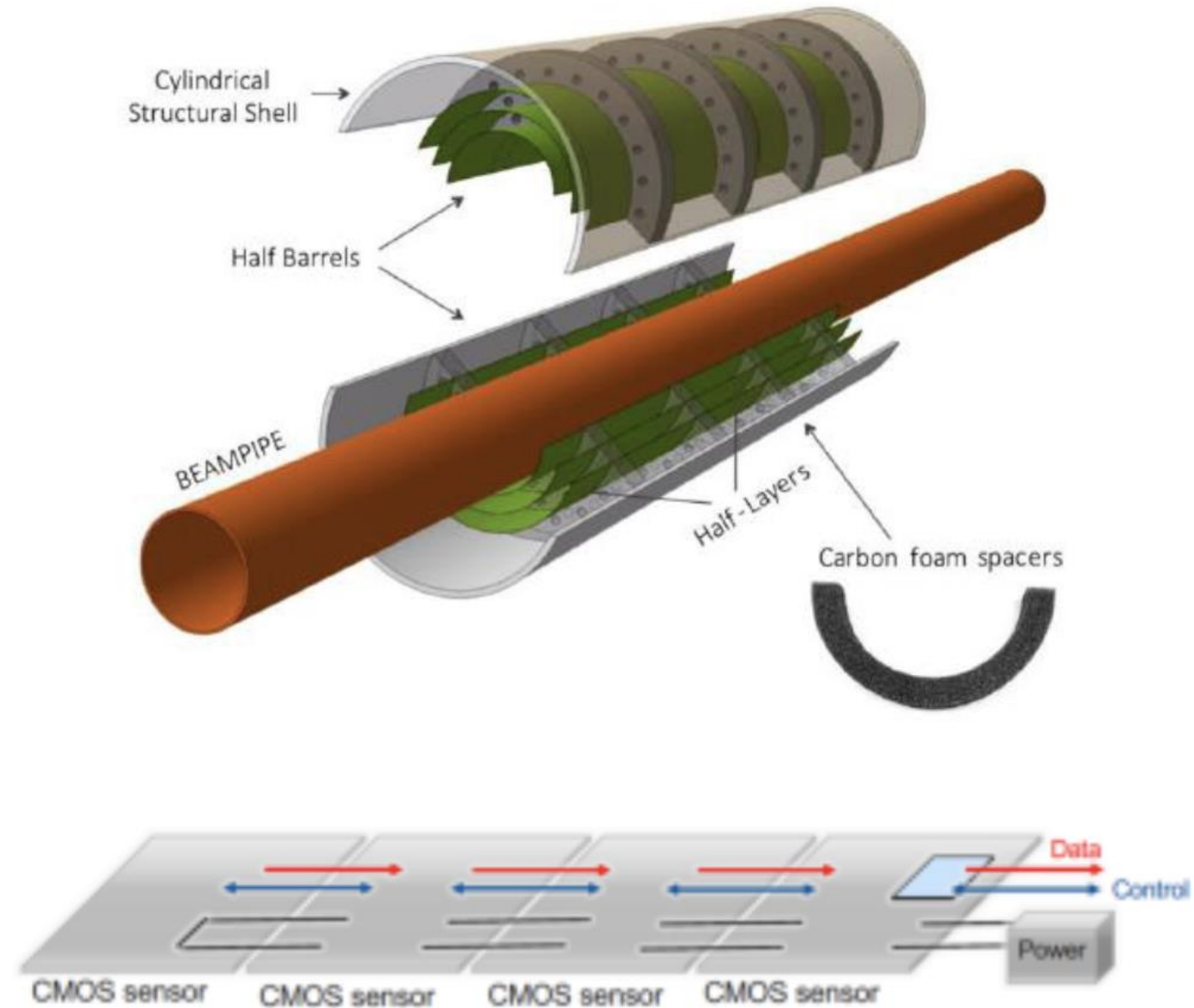


HDMI data Board

Proximity board with Mimosis_1 sensor on support

Effort started (LPNHE) to develop a FPGA-based DAQ system for Mimosis.

Alice ITS3

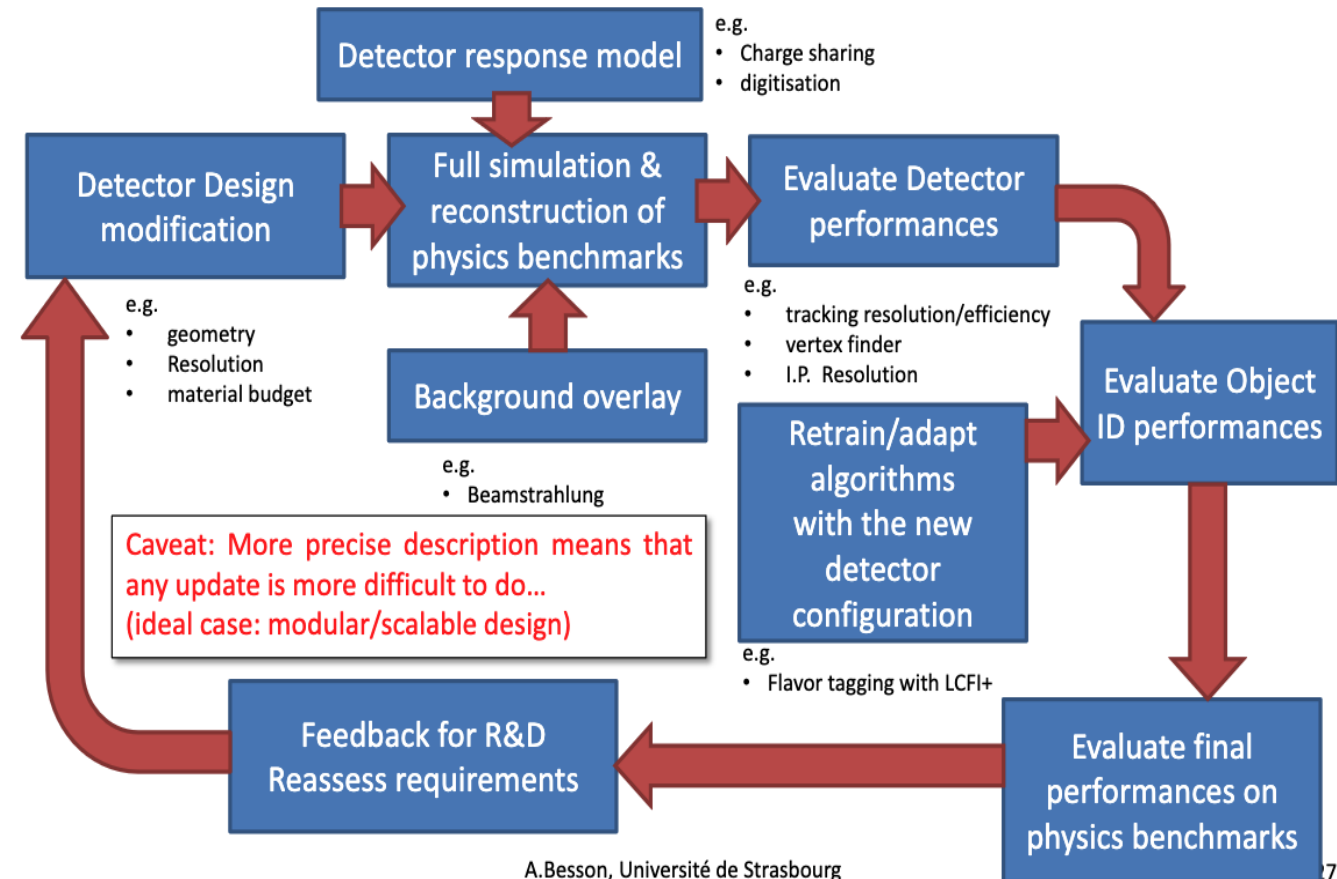


- Goals for mechanics and integration:
work toward a robust vertex concepts
for FCCee in the coming years.

- Mains topics to worked on :

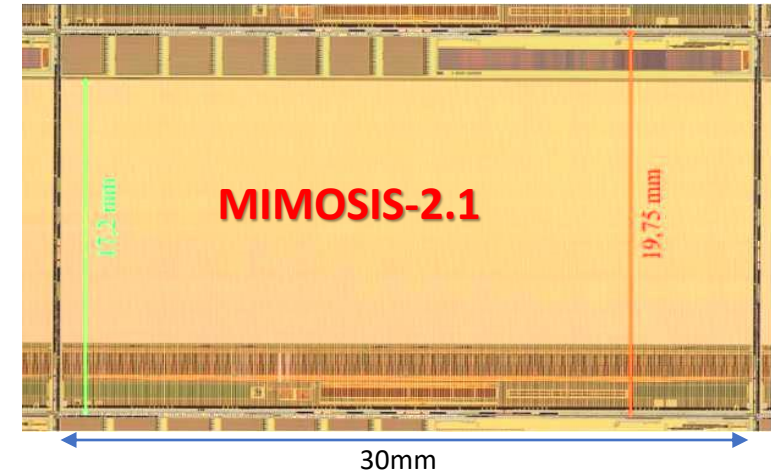
- Master curved sensor fabrication and testing,
- Explore mechanical options, type of material, stress and cooling, etc...
- Design a full mechanical geometry, to be tested in full simulation,

- Iterative process !

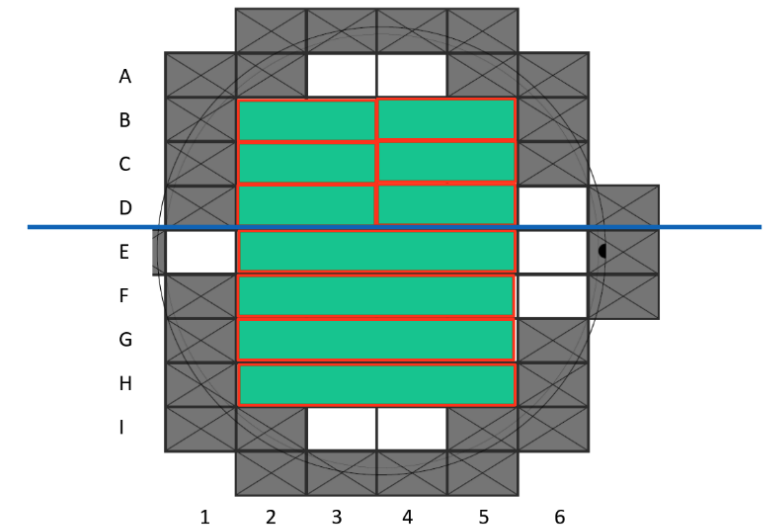


Toward curved Mimosis ladder

- Design of FCC-SEED requires a gain of expertise in curved sensors.
Many aspects to investigate, questions to answer.
 - To what minimal inner radius can we bend sensors ?
 - And for what sensors thickness ?
 - Does the bending change the chip performances ? Silicon properties ?
 - How to curve the sensors, and maintain the curvature ?
 - How to glue sensors on mechanical structure ?
 - How to make the bonding with curved sensors?
 - Etc... etc...
- Strategy/working plan.
 - Waiting for final chips to come (in many years), use existing and available chips : **Mimosis (CBM) prototype versions**,
 - Setup and practice sensors bending (different radii and different thicknesses), using sacrificial sensors,
 - Bend single functional Mimosis, and tests them (lab+source, beam). Requires flex and running DAQ,
 - Bend a Mimosis ladder, integrated on simplified mechanical structure, tests,
 - Design and realise a demonstrator/mock-up for the first FCC-SEED layer. Require mechanical designs work.



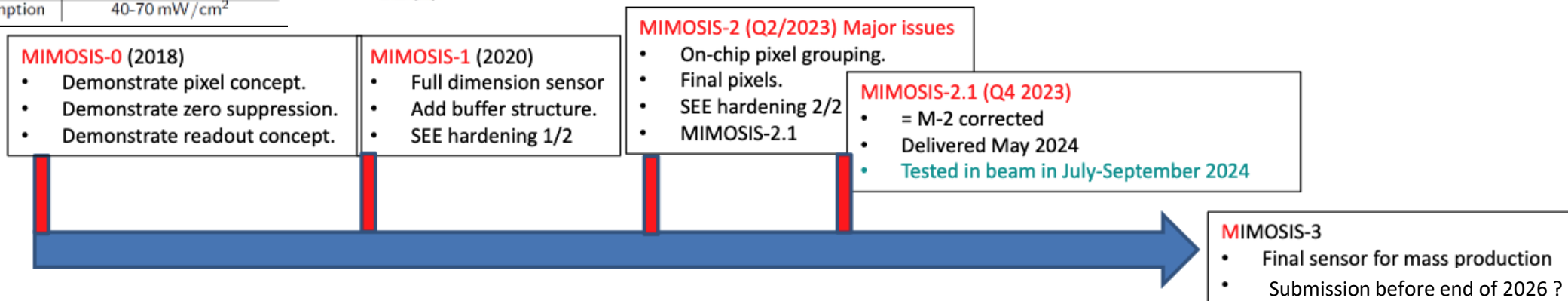
Cutting of Mimosis wafer



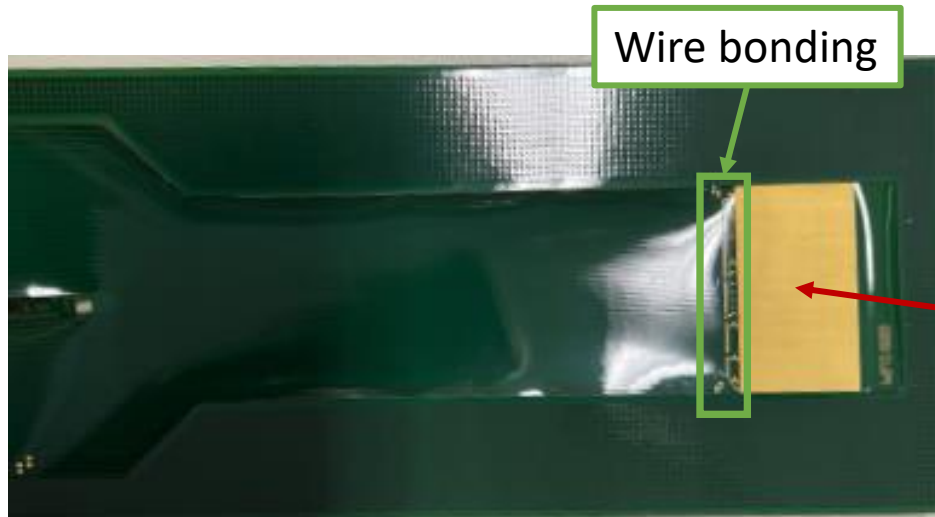
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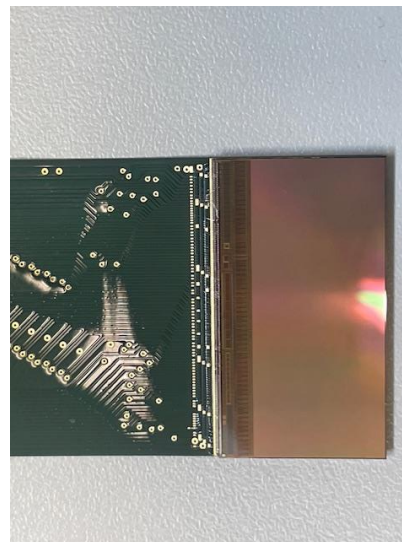
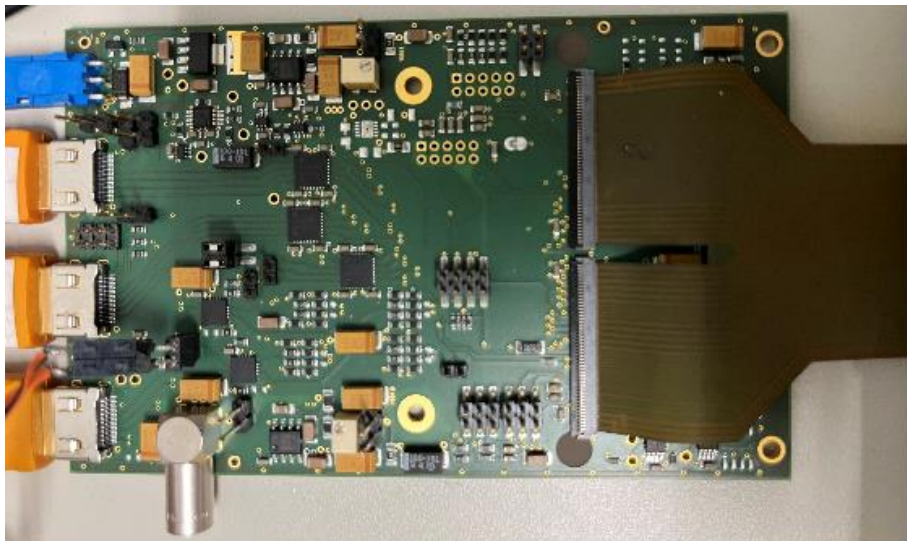
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Design of a flex cable and board for curved Mimosis testing



- Test board and flex for tests :
 - Developed for testing purpose only,
 - After first iteration, new flex and proximity board designed and produced (bug-fix + improved connectivity).
- First tests performed on MIMOSIS vs curved-MIMOSIS

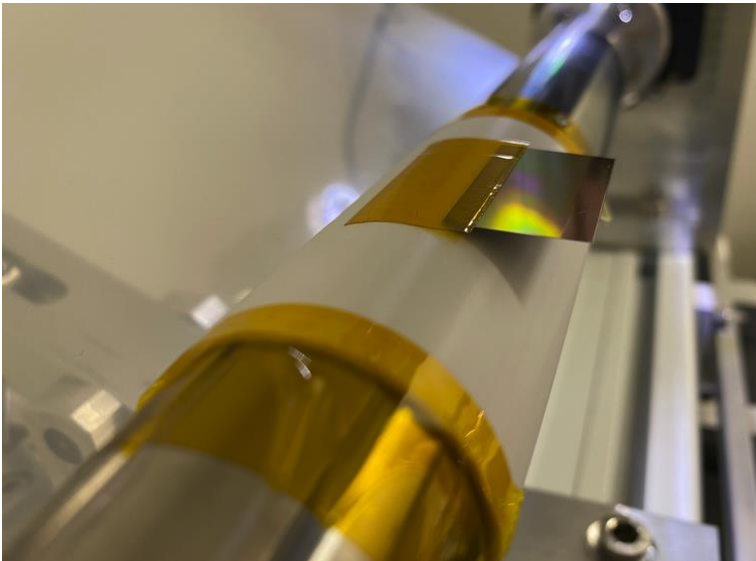


- For the final detector, the flex design is a key element.
 - Should allow for a robust and easy bonding,
 - Should be well integrated within the mechanics,
 - Should be as small and as light as possible.

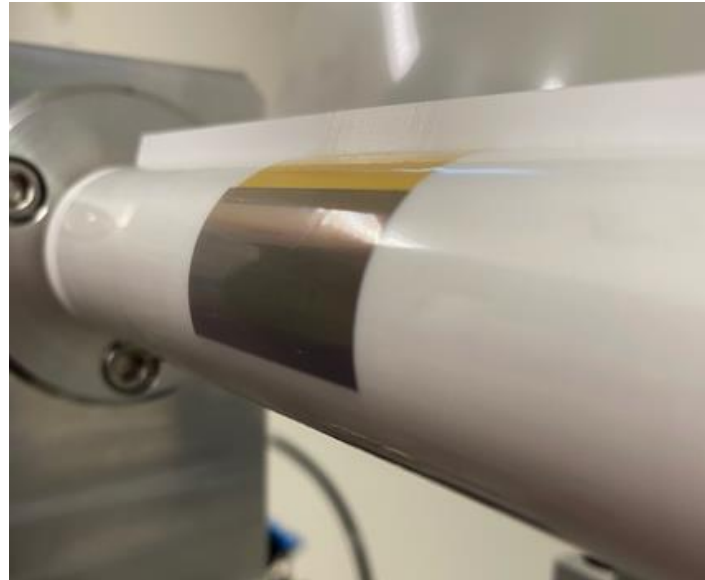
Toward functional bend Mimosis

- Observed difficulties while performing bonding.
- Glue was flowing out of the silicon back surface : contamination of the bonding pads, went on the Millar leaf.
- Several tests were performed, with different glue viscosities and glue doses.

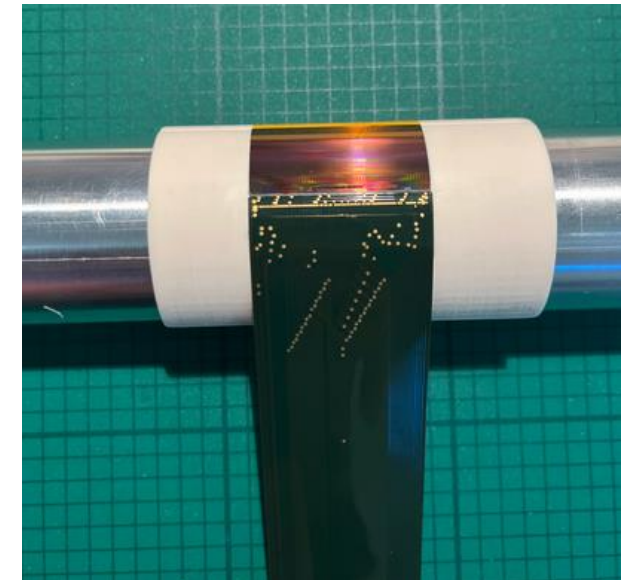
Sensor taping on the mandrel



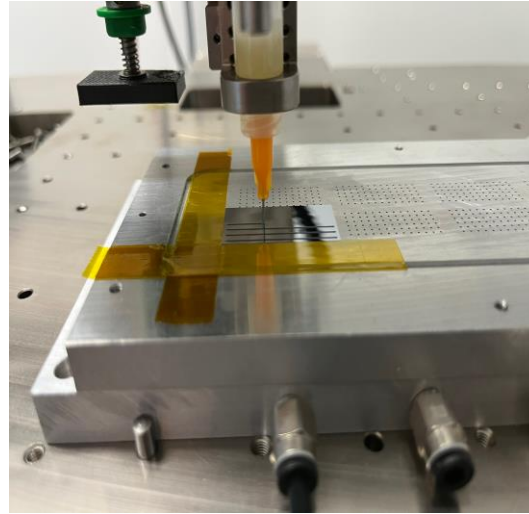
Sensor covered with Kapton foil,
after rolling the Millar foil



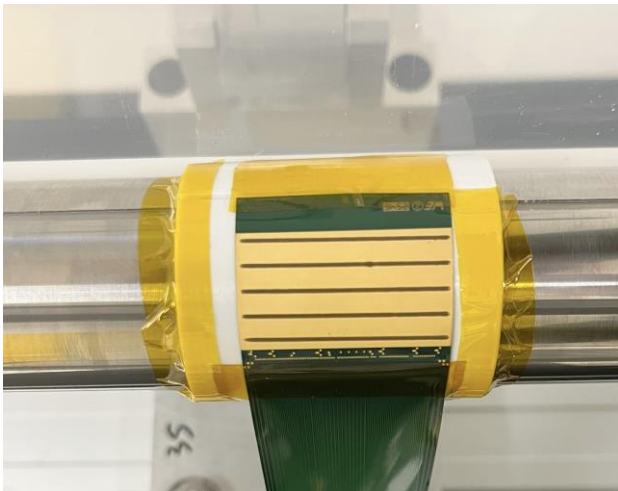
Curved sensor glued on it
support, ready for bonding



Toward functional bend Mimosis

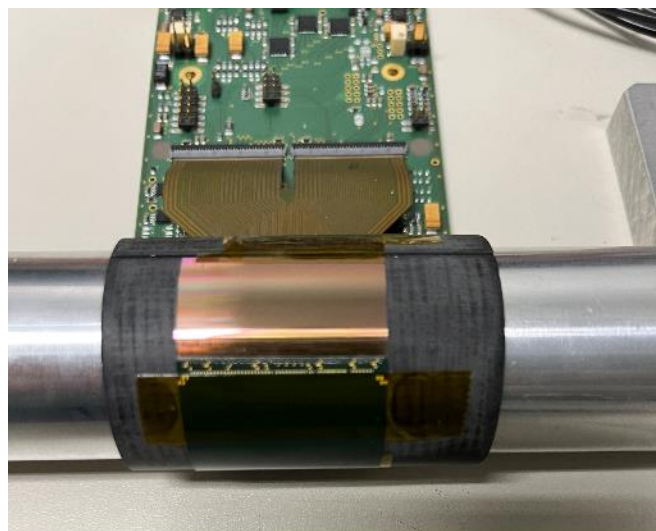
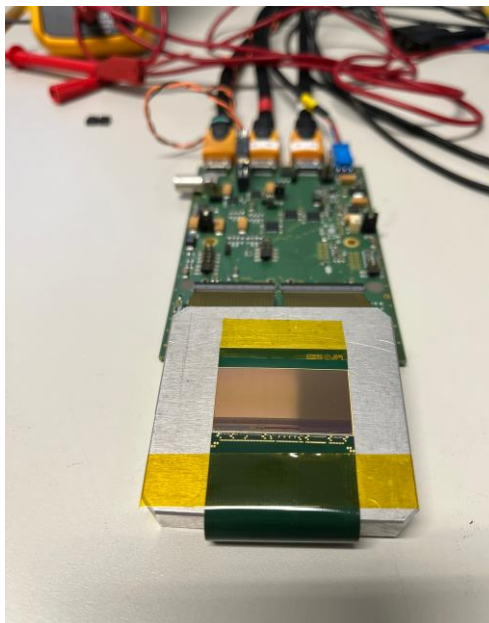


- Optimisation of glue deposition.
- New approach found to be working well
 - Glue deposited with an automated dispenser machine, perfect control of the glue quantity and glued surface,
 - Glue deposited on the flex,
 - Then gluing and bending of the ship performed.
- Found to be conclusive, and allowed us to move on.
 - But not suitable for the final detector (no flex wanted in the back of the sensor).



Firsts comparisons of flat and bent Mimosis 2.0

Different sensors

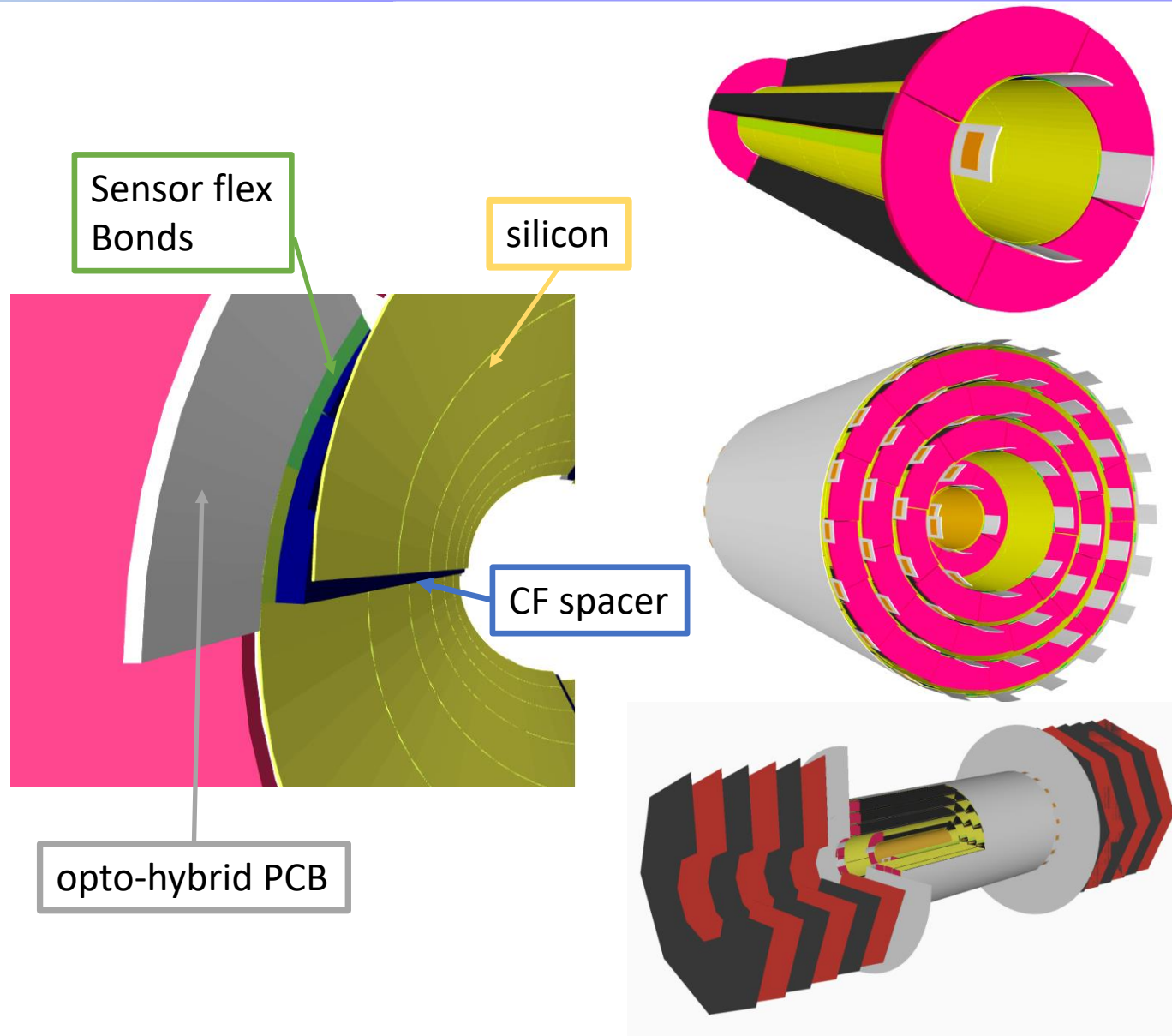


	IDigital	IAnalog
Reset ON	39mA	12mA
Reset OFF	119mA	9,2mA

	IDigital	IAnalog
Reset ON	39,9mA	11mA
Reset OFF	116,6mA	8,4mA

- Several tests of bending+bonding+electrical tests performed.
 - Bonding performed while the sensor is on the mandrel.
- Conclusive results with power consumption similar to flat sensors.
- Validation of the process, lead to the bending of 3 Mimosis 1.0.
 - 2 Mimosis bent and connected with success, partially functional (some bad bonding pads, nothing to do with curving),
 - 3rd Mimosis bent, connected, but does not provide correct data. Currently investigated by it is believed the chip had an issue before bending.
- Next step (ongoing):
 - bend more sensors after passing probe station, test the same sensors before and after bending.
 - Get ready for test beam mid-agust at DESY

DD4HEP Implementation of the FCC-SEED geometry



- Current geometry being tested in full simulation
 - In between overlapping sensor regions : 0.5 mm CF + 250 μ m Flex (200 μ m Kapton, 50 μ m Al).
 - Carbon foam longerons along Z direction, support the edges,
 - 5 layers,
 - 6 single side disks, extended down to $\theta = 135$ mrad (7.7°).
 - a hybrid flex at the end of the ladders (250 μ m), with a 5×5 mm opto-el. ASIC on top (orange, 100 μ m of Si)
- Very significant design work needed, but **requires mechanical realisations : simulation and prototyping !**

Design will surely evolve as we progress !

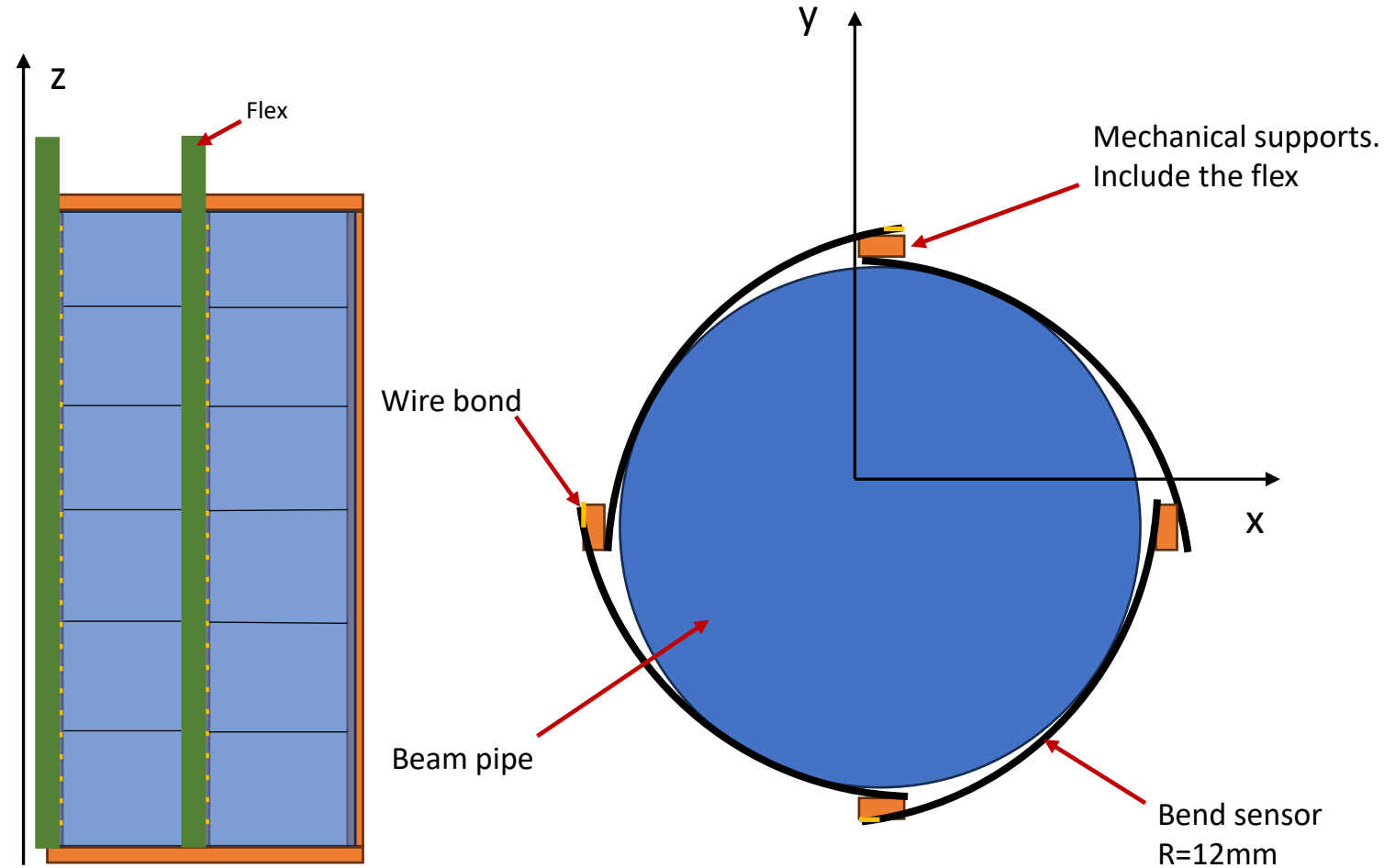
Not at scale !

Pros :

- Bonding on a “flat” surface,
- Improved acceptance,
- Options without stitching possible.

Cons:

- Extra material budget in bands along Z,
- Design of the mechanical structure challenging,
- Assembly and integration procedure challenging.



Assembly of quarters (hemi) of cylinders : assemble individual frames together around the beam pipe