

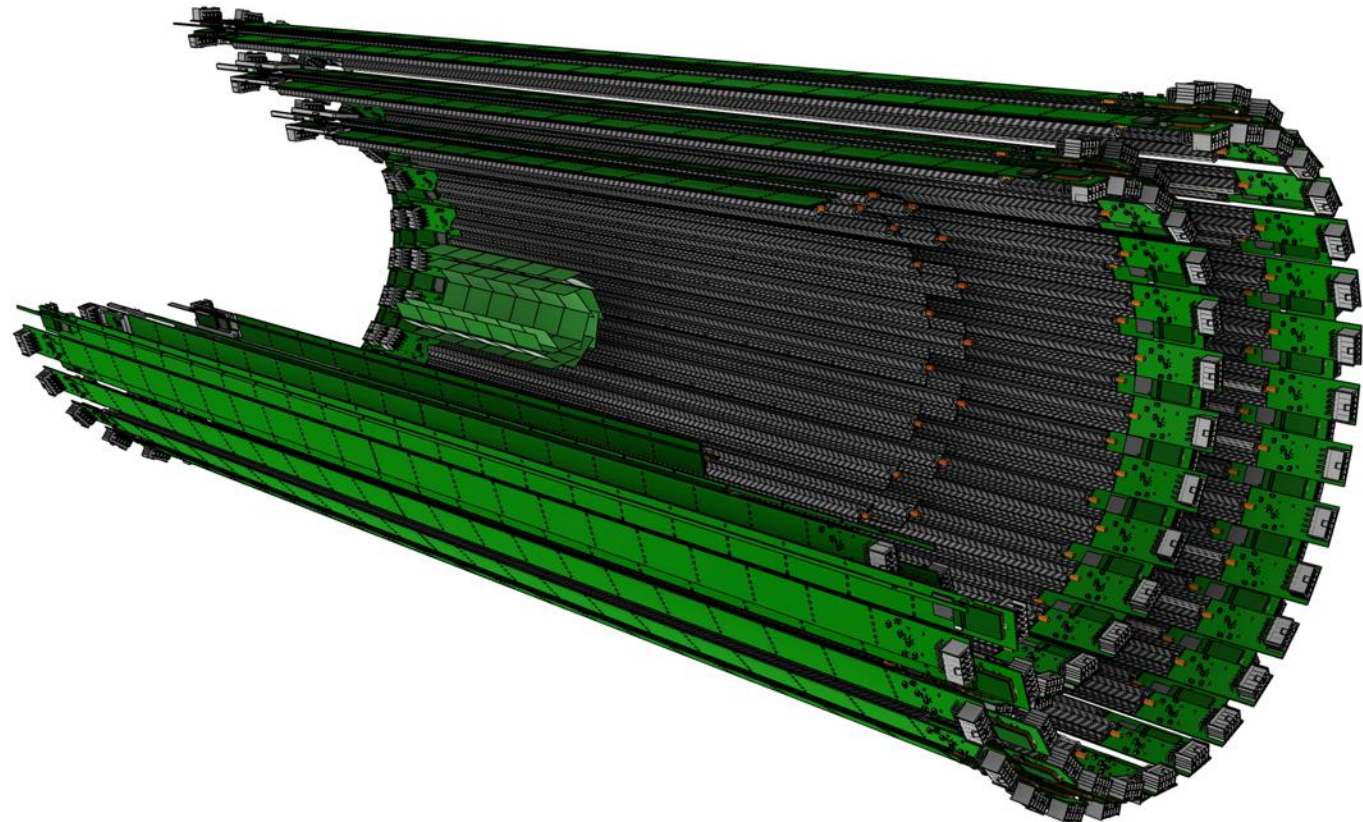
oVTX Module and Ladder Assembly overview: first considerations for the discussion

(... iVTX will follow as soon as
we have the 1st TPG prototype)

VTX Baseline	L1	L2	L4 A/B	L5 A/B	L6 A/B
Radius [mm]	14.1	22.1	82.5/89	108/114.5	133.5/140
#Ladders	6	10	18/18	24/24	30/30
Chip/Ladder	4	4	12/13	16/17	20/20

S. Bettarini

on behalf of the VTX WG 4



Outline

- **Items (definitions):**
 - Parts: Flex circuits (N_{flex} types), chip ($N_{\text{thick,vs}}$ thicknesses & Obelix-versions)
 - **Module** (electrical unit: N_{module} types): flex+chip assembly (7 Types)
 - Support Structure (mechanical/thermal: N_{omega}):
 Ω -beam with cold-plate containing cooling pipe, sliding ends and water tube connector(s)
 - **Ladder**: final unit to be mounted: $N_{\text{layer, AorB}}$ (6 Ladder Types) - “SVD-like” mounting concept
- **Specifications (according to “QA Group) and prototype development:**
 - Mechanical precisions (grade: A \rightarrow B, C prototypes)
 - Electrical (detector grade: A \rightarrow B)
- **Assembly Procedures (rework allowed? Production yield \leftrightarrow spares):**
 - Module: chip alignment, glue deposition on the flex and flex to chip gluing/bonding, electrical test, storing/shipping
 - Ladder: preparation of the Ω -beam, parylene deposition on the cold-plate, 1st/FWD & 2nd/BWD
Module alignment and gluing to the cold-plate, el. test, storing/shipping
- **Tools (chuck/jig) develop/design and production \leftrightarrow $N_{\text{module,ladder}}$ construction sites**
 - Needed “facilities”: CMM, gantry-like(?), u-bonding, Test-stand.
 - Site certification for Module/Ladder “production”
- **Shipping/Temporary Exp./Importation** of the parts/modules/ladders (parts customs clearance, construction DBase)
- **Schedule**: parts availability, tool/procedure development (optimizing=parallelizing), site dedicated facilities and engineer/technical person-power resources.

N_{flex} Flex circuit types

- According to the oVTX layout, increased complexity (and costs!) of the Al-flex circuit and so far $N_{flex} = 7$
- Still to demonstrate the feasibility: starting with Dummy Cu 4-chip prototype(*) → (CERN) Al 4-chip DUMMY flex → final (CERN) Al 12-chip flex (orders already set). After:

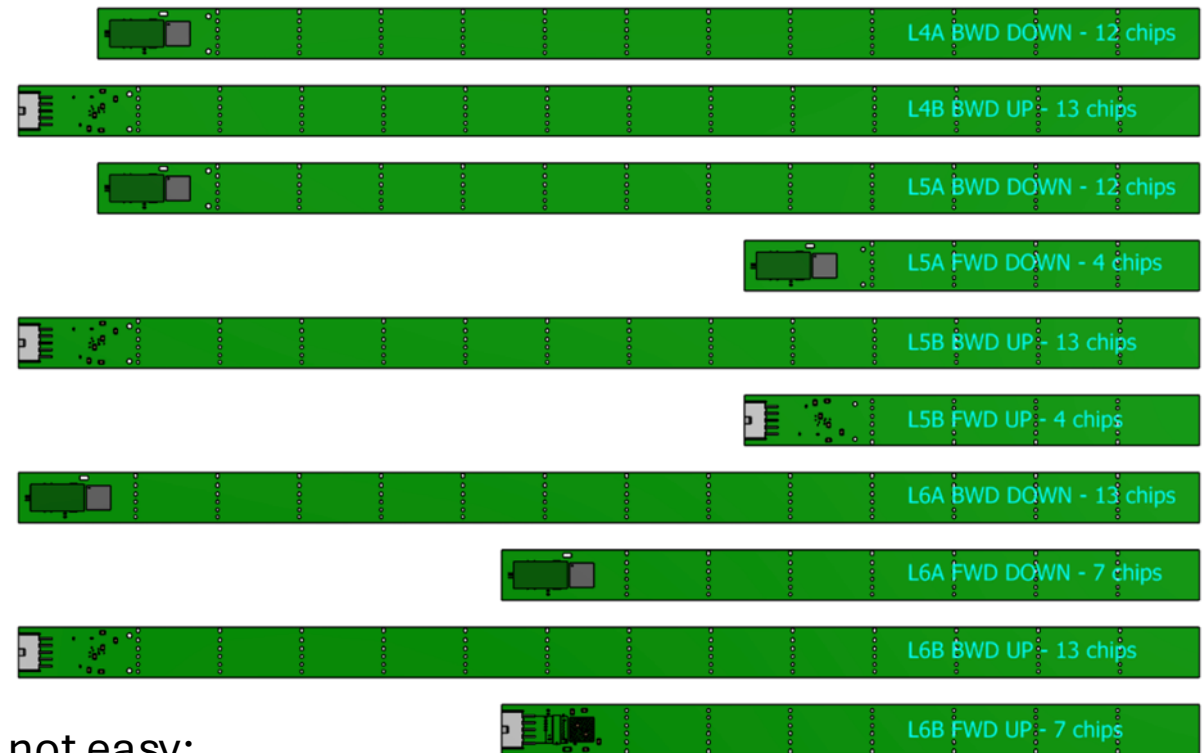
7 FLEX Types:

- Need discussing cost/req. time estimate with the CERN workshop for:

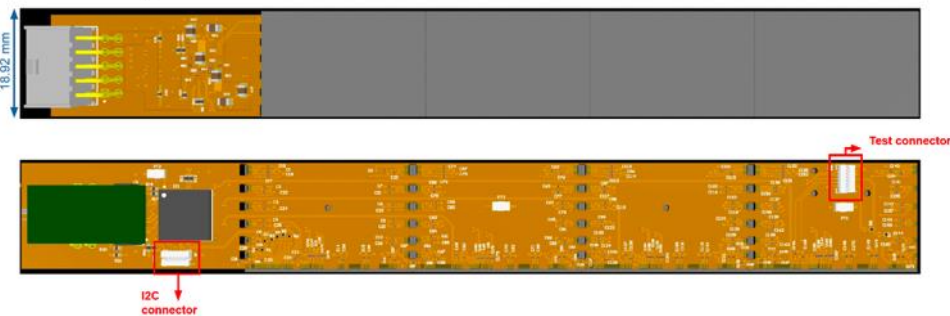
- Pre-production of each type:
 - allowing module/ladder electrically active prototypes
 - specify tests to ensure needed quality
- mass production of (tested) flex

- (*) will be used also in the 1st mini-ladders for test beam with lpGBT/VTRx+ DAQ
- Converged on the choice of the connectors on the ladder (and on the cables to the DOCK boxes).

12 BWD DOWN	13 BWD UP	4 FWD DOWN	4 FWD UP	13 BWD DOWN	7 FWD DOWN	7 FWD UP
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Dummy Flex



- Flex handling not easy:
 - 50 discrete components/chip
 - ~500 um thickness, planarity “unknown”

Obelix-chip ($N_{thick, vs}$ thicknesses, Obelix-versions)

- It's well known that the VTX overall schedule is “driven” by the chip ...
- Chip thinning (at wafer level):
 - Obelix-1 from pad wafers available with thickness 400 μm ? (for mechanical prototypes)
 - When will Obelix chips with final thickness (for oVTX: [50-100 μm]) be available?
 - Chip handling and assembly procedures may depend on chip thickness ...

• We can foresee:

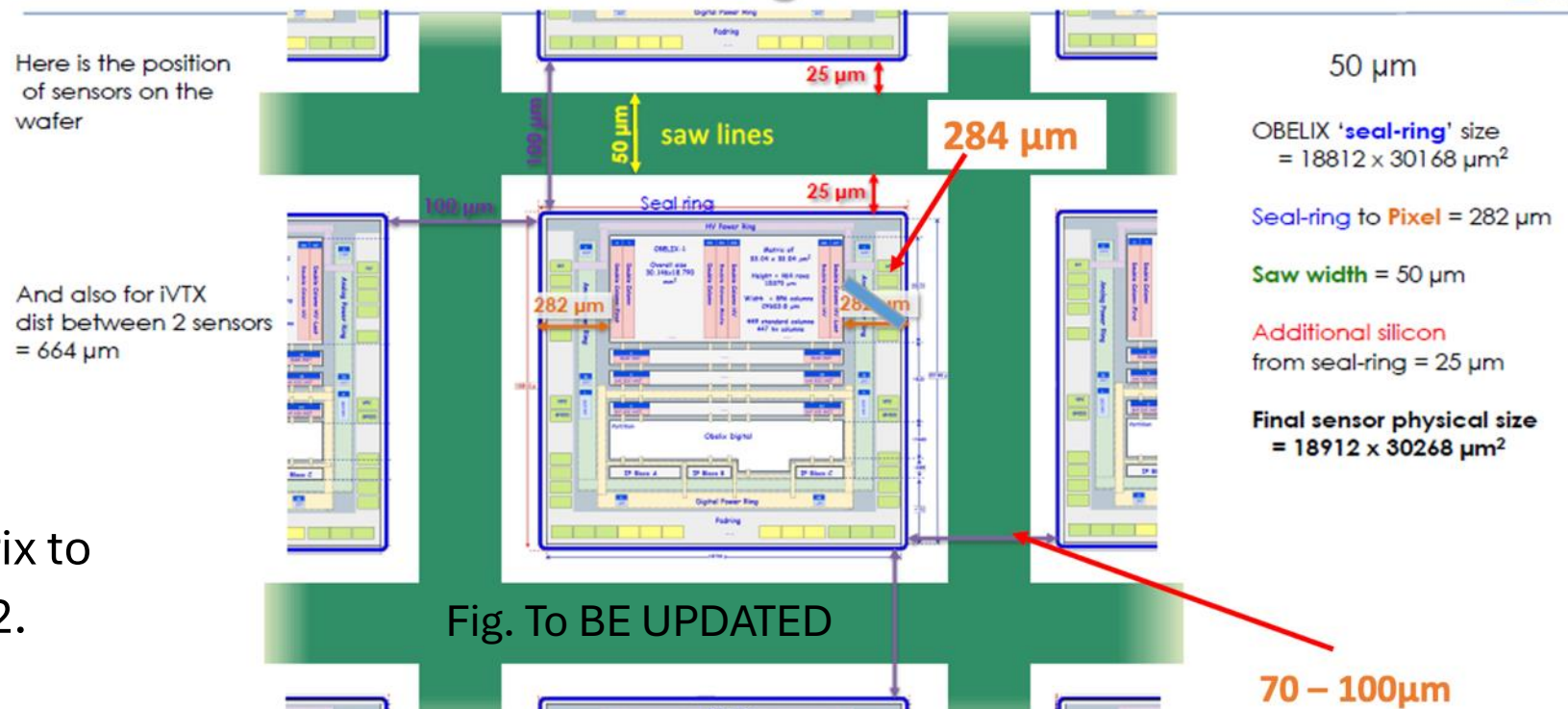
- $N_{thick} = 2$ (400 $\mu\text{m}/[50-100 \mu\text{m}]$)
- $N_{vs} = 3$

(Obelix-1, -2 and for mass production)

All the Obelix-vs have the same die dimensions (?)

Note: we need to extend the matrix to allow enough phi overlap for L1&2.

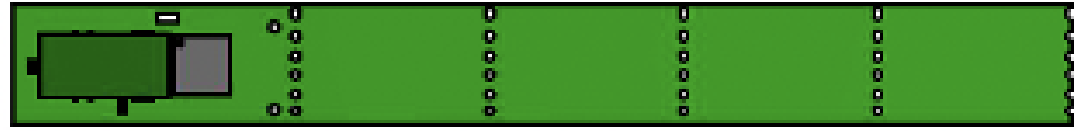
On OBELIX size and dicing



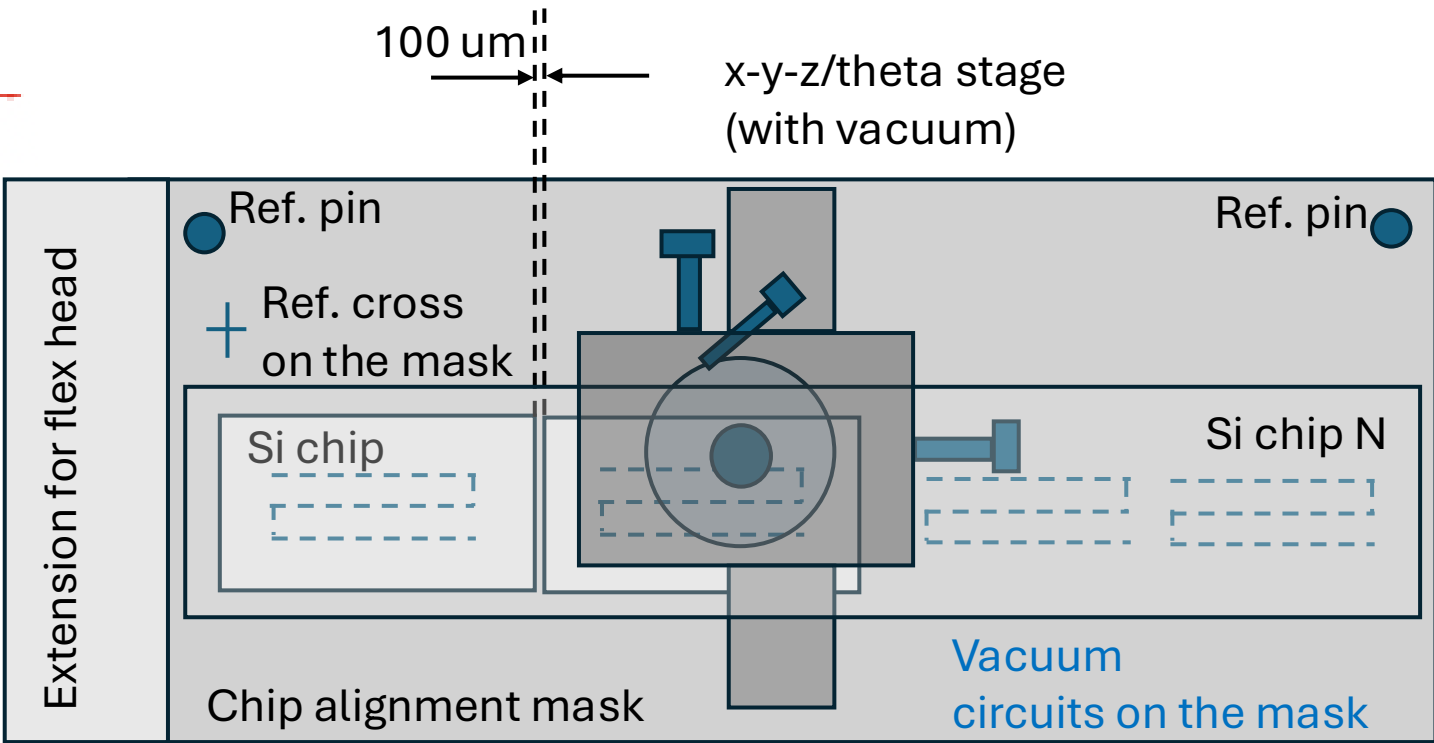
Module (electrical unit: N_{module} types): flex+chip assembly

- Modules (building blocks for Ladders) can be assembled in dedicated sites where they can be tested with the DAQ for lpGBT/VTRx+ w/o cooling: then to be eventually shipped to “Ladder” sites.
- We need for the final production $N_{\text{module}} = N_{\text{flex}}$ with the final vs/thickness of Obelix
- For the development of the tools/procedures we should use also different vs/thicknesses of Obelix.

• 1st prototype (same as L5A FWD) for sure we’ll have
Module with Cu 4-chip dummy flex and
Obelix-1 chip to test on beam



- Assembly concept:
(inspired by the Alice-IB ITS2 procedure)
 1. Align the chips
(4→13 depending on N_{module})
on a mask by vacuum chucks;
chip positioning made in sequence
one-by-one by a x-y-z/theta stage



Which is the precision required on the positioning of the chips? $\sigma_x \sim \sigma_y \sim 10 \text{ um}$.

- Assembly concept (continued):

2. Align the flex on a dedicated masks through pin-holes and hold by vacuum (flat surface up);

3. Glue dot deposition (*); ○●●●●○

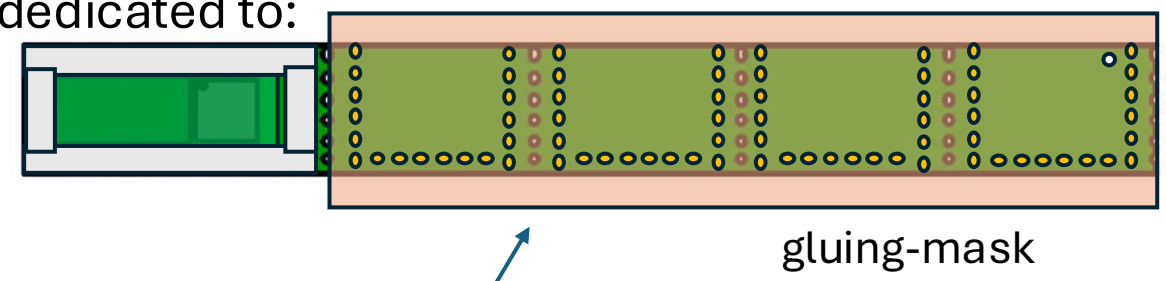
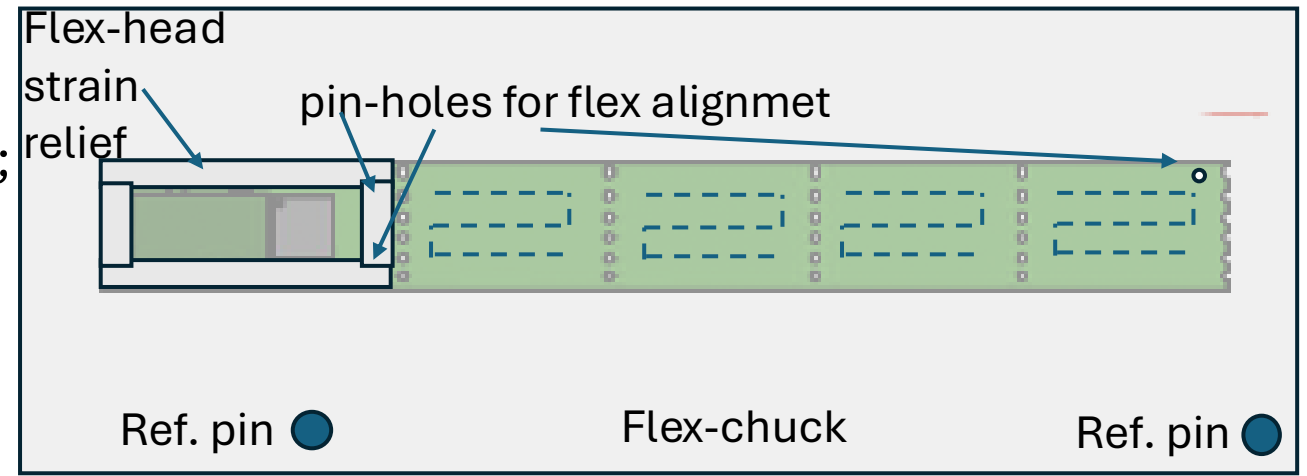
4. Lower and Overlap the Flex chuck on the chip alignment mask to squeeze the glue dot;

5. Let the glue cure (12→24 h);

6. Remove the Flex chuck and transfer the Assembly to a service chuck to perform the Chip ← → Flex bonding

7. After bonding, transfer the Module on a chuck dedicated to:

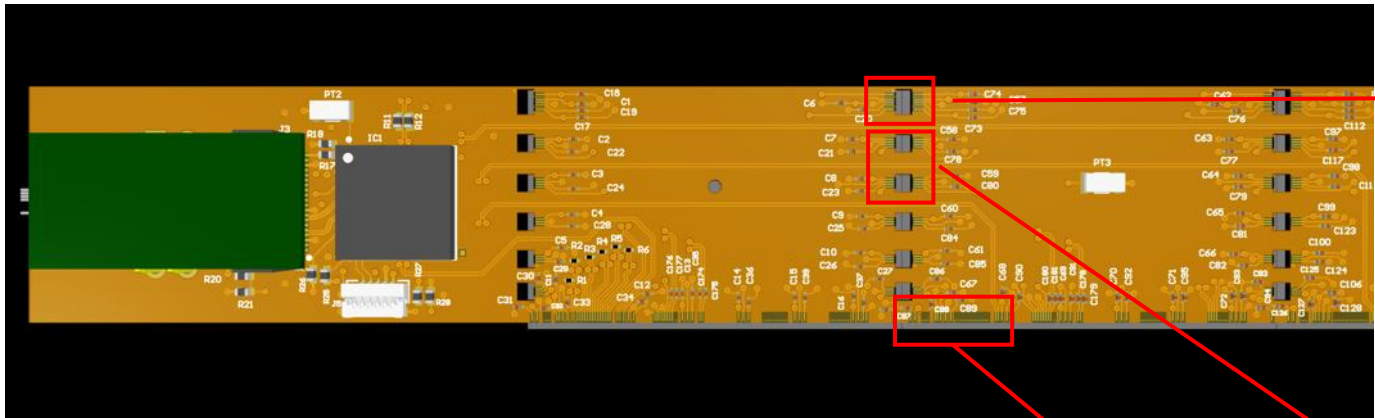
- a. the electrical test
- b. Boxing, eventually for the shipping to the ladder's site.



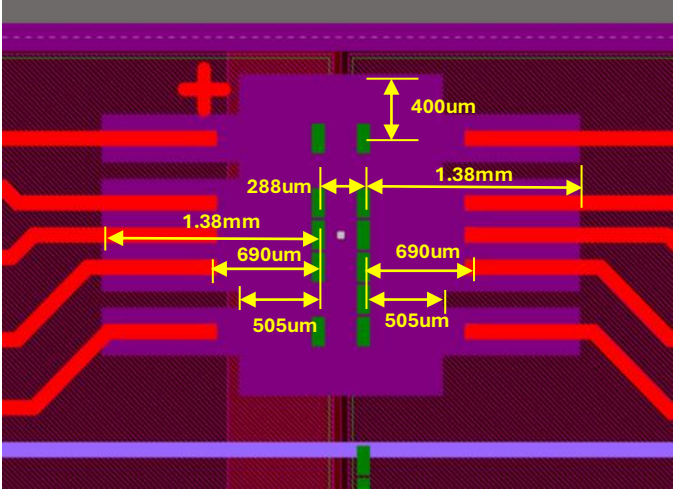
(*) This operation is the most critical one: we need to deposit the minimal amount of glue and ensure that glue is under the flex pads for bonding preventing vibration (on both the short and long chip's sides) but preventing also the squeezing/contamination on the chip pads! Possible use of an adhesive gluing mask with holes on flex flat face.

Starting with tested parts (flex and chips) **how to allow rework** in case the electrical test spots one not-functioning chip ?
By hot air we could detach the broken chip? Then put the new chip on the chip mask and go back?
Solving this issue in a proper way is crucial and it would improve the module production yield!

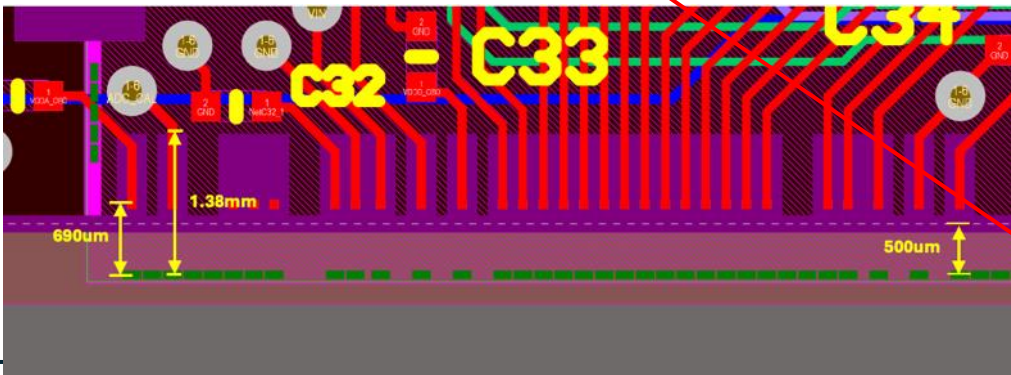
4 chip Cu Dummy Flex – rectangular slot opening (according to our u-bonding experience)



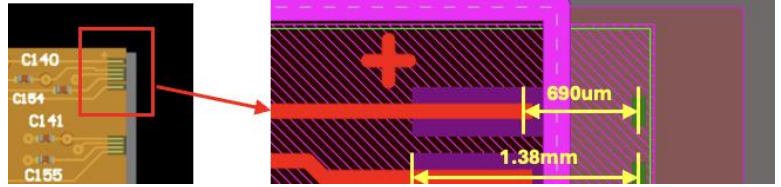
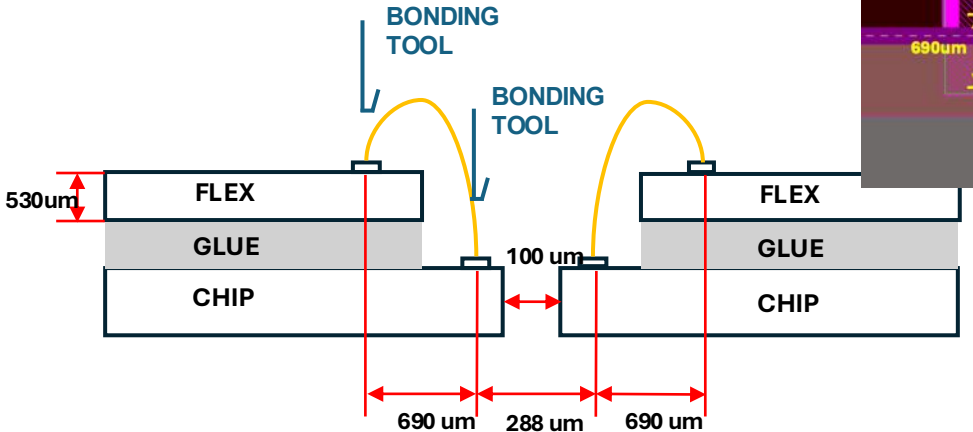
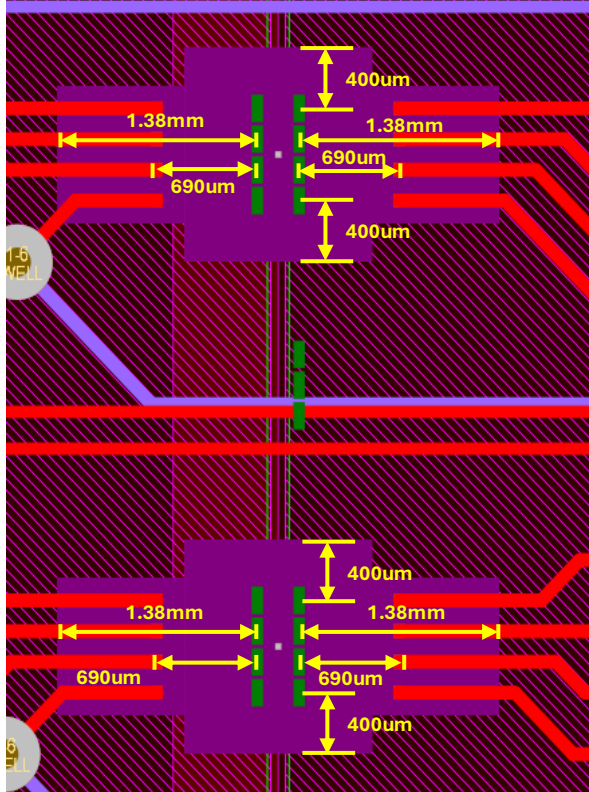
Slot size: 1.3mmx2mm



- Flex thickness: 530um
- Ni/Au plating on the bonding pads and component pads
- Chip pad: 88umx188um
- Flex pad: 88umx100um
- Slot size: 1.3mmx2mm/1.3mmx1.4mm

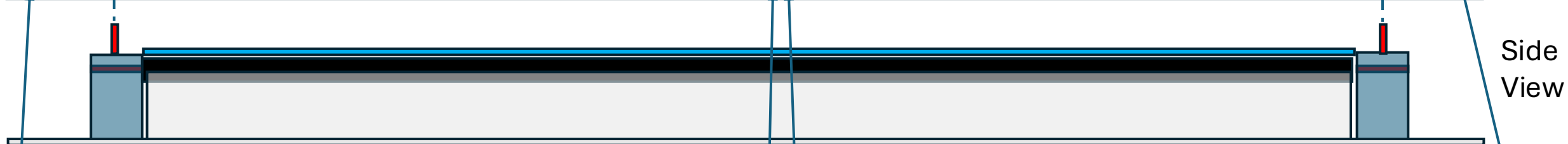
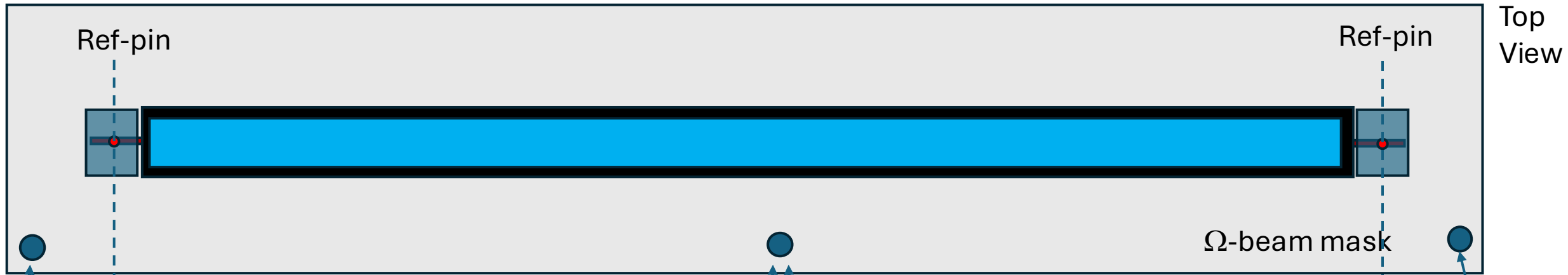


Slot size: 1.3mmx1.4mm



Ladder Assembly: concept (N_{layer} , AorB types)

1. Preparation of the CF Ω -beam with parylene deposition on the cold-plate;
2. Insert/align the Ω -beam in a supporting mask to ensure the planarity of the cold-plate needed for the module gluing;
3. Install the sliding mechanism (on one end) and the fixing feature (to the cones) on the other; then the connectors for the cooling tube to serve the cooling pipe (tests mechanical and thermal);
4. The 1st Module is flex-up on its box: take a dedicated coupling chuck for the upside-down turn. Pay attention that the Module is completely u-bonded. Align the module (chip-up) on the chuck w.r.t. a hosting mask with some reference holes;
5. Dispense a calibrated amount of glue on the chips, away from the region of the chip boundaries, but ensure the maximal contact surface chip $\leftarrow \rightarrow$ cold-plate, which affect the cooling efficiency.
6. Using reference pins, lower the Module mask on the Ω -beam mask and let the glue cure.
7. Take away the Module hosting mask.
8. Fix by the screws the strain relief for the flex head.
9. Depending on the module type, if done for the BWD part, repeat the operation for the FWD part and fix by the screws the strain relief on that side. The clearance between BWD and FWD is (critical) 100 μm .
10. The ladder is taken by the two ends with a bar (mimicking the one to be used for the ladder mount) to be transferred into the testing/shipping box, for 1. electrical tests; 2. connection of the cooling circuit and thermal tests.
11. Store the ladder and ship to KEK for the ladder mounting.

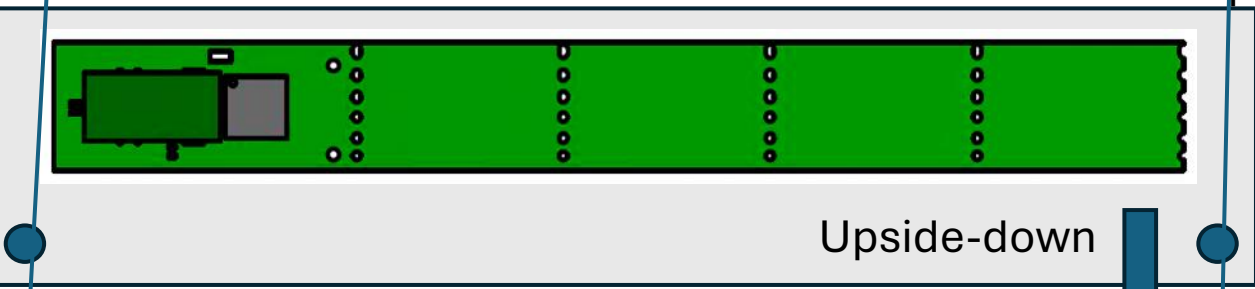


Sliding +
Cooling-connectors

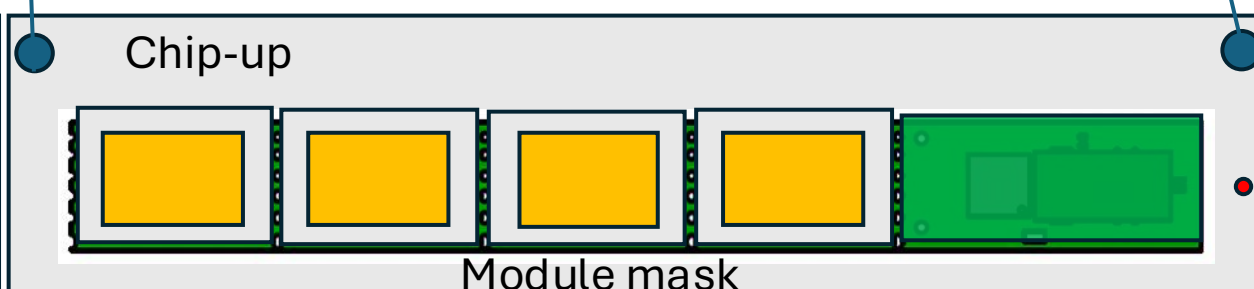
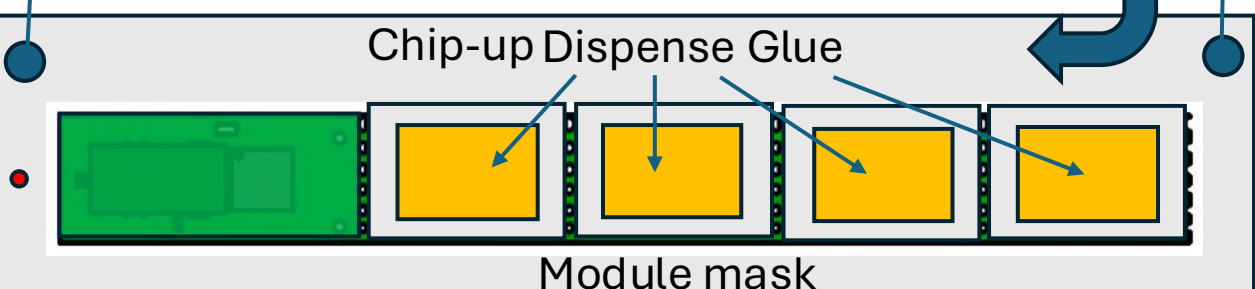
1st Module gluing to the cold-plate

Flex-up

Cone Fixing +
Cooling-connectors

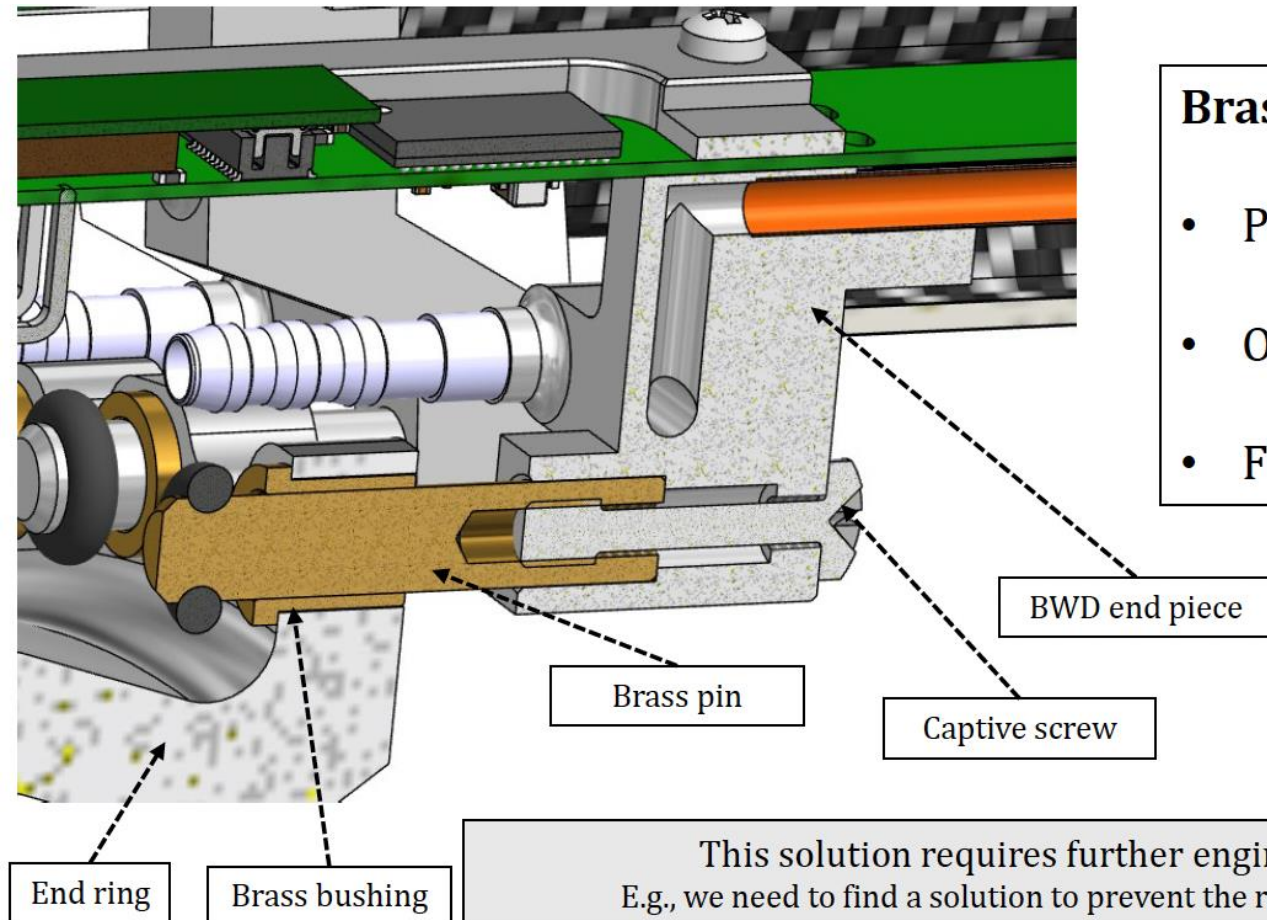
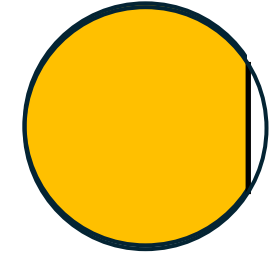


2nd Module gluing to the cold-plate



oVTX ladder sliding mechanism

- Linear (not magnetic) stage required a dedicated production (too expensive)
- Change the cross-section to avoid ladder rotation
- Compliant with “SVD” ladder mounting



Brass-brass linear bushing system

- Pin pre-positioned in brass bushing glued to end-ring
- O-ring prevents pin drop onto detector
- Final positioning: pin inserted and locked by captive screw

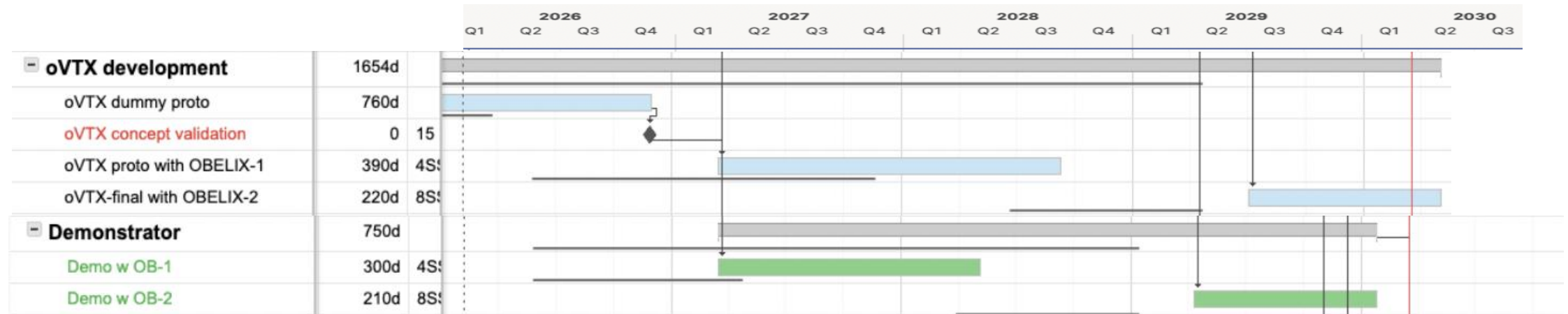
This solution requires further engineering development considering the ladder mounting procedure
E.g., we need to find a solution to prevent the rotation of the pin (hex shape on the head of the pin or an imprint for an Allen key)

Specifications (“QA Group”) and prototype development:

- According to our Belle2 –SVD experience it’s mandatory to establish a “QA Group” in charge of dictate the specifications, review the (written!) procedures and the tools developed by the construction sites and certify their ability to assemble “class A” Modules or Ladders before starting the production.
- Each Module construction site must be able to make the (optical) survey of the parts before starting the Module assembly and certify that the built Module is electrically working before shipping that to the Ladder sites or continue with Ladder assembly (grounding, temp. monitoring, electrical test OK).
- All the sites must have a (class “100 000”-ISO 8) clean room with CMM. Gluing robot and u-bonding machine (and dedicated technicians) . “Gantry”-like facilities are not mandatory but certainly useful for speed-up assembly and improve quality.
- Each Ladder construction site must be able to certify that the received Module is electrically working (incoming test) before starting the Ladder assembly, and that finally the built Ladder is ok (perform mechanical/thermal/electrical test ok) before shipping to KEK (grounding, temp. monitoring, el. tested).
- Mechanical precisions (educated guess to be obtained on mechanical prototypes):
 - chip alignment precision on the mask: $o(10\text{ }\mu\text{m})$?
 - difference between the nominal chip positions and the current ones on the Module: $o(50\text{ }\mu\text{m})$?
 - flex misalignment w.r.t. its nominal position for the chips such to allow the (following) Ladder assembly: $o(100\text{ }\mu\text{m})$? Final precision for Ladders to allow mounting: $o(200\text{ }\mu\text{m})$?
- (Electrical) ladder grade:
 - A (to be installed: defects < 5% ?) → B (electrically active/mechanically montable but lower quality)
- Number of (final)spare ladders: 15→20% for each type.

oVTX Demonstrator(s) for TDR and schedule

- The assembly of (first) mechanical and then electrically working prototypes (the so called “demonstrators”) allows to realize which are the critical issues to face, how difficult is to design/produce/use the needed tools and to make a reliable estimation of the oVTX construction schedule.
- The assembly tools and the procedures need to be developed with dummy mechanical parts (Si chips w./w.o pads, dummy flex, cold-plate, ...): part’s planarities might be critical for gluing (i.e. spread)! Adhesive tape investigations?



- In the WS in December we discussed the list of oVTX “demonstrators” for TDR
 - New proposal, according to part availability.

4-chip module mechanical prototype



1/14

xTool F2 Ultra 60W MOPA & 40W Diode Dual Laser Engraver

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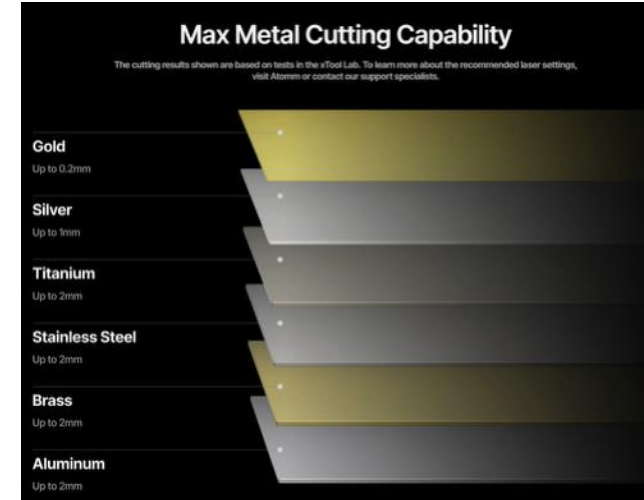
- Vibrant Color Marking: 60W MOPA unlocks 100+ consistent colors on metals.
- 48MP Dual Cameras: Precise alignment and fine detail, even on tiny items.
- All-Metal Capability: Color engraving, emboss, and cut brass, stainless steel, and more.
- Efficient Batch Engraving: 220 × 220 mm area & 15,000mm/s speed for pro-level output.
- Safety-Assured: Enclosed cover. Eye-protection cover. Fire safety stop.

• We should start NOW in Pisa with the development of the tools for a 4 chip **Module**, using:

- **dummy bare Si chips** (Laser cut recently installed @INFN-Pisa)
- **old Cu-Flex(es)** (w/o discrete components)
- (2 pipes) cold plate(s)(old production)

Autumn
2026

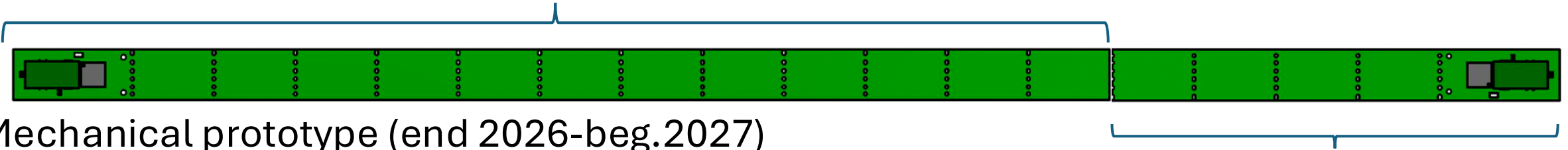
- **Si chip from pad wafers**
- **dummy Cu-flex with discrete comp.**
- **u-bonding**
- **old cold-plate (glued with Ω -beam?)**



MBI-Institute has the
Same machine

After validating the concept, build new tools to produce:

- 12-chip extended Module → (12+4) = 16-chip (L5A) Ladder



Mechanical prototype (end 2026-beg.2027)

- 12-chip long kapton heater + 1 Cu Dummy 4-chip Flex (+ 4-chip kapton heater?)
- 12 dummy Si chip + 4 Obelix-1 pad chips
- Ω -beam + cold-plate with cooling circuit

Electrical 4-chip prototype for test-beam (beg. 2027-mid.2027):

- 4 Obelix-1 chips
- 1 Cu Dummy 4-chip Flex
- Old production cold CF plate providing cooling



Electrical prototype L5A (mid. 2027-end 2027): final demonstrator (*)

- Al-12-chip Flex + Al-Dummy 4-chip Flex
- Obelix-1 chips
- Ω -beam + cold-plate with cooling circuit
- Sliding mechanism and fixing to the CF cone rings

Chips/Flex/Cold-plate availability for prototypes

- To start the design/production/test of the mechanical tools for Module and Ladder assembly at each candidate construction sites, the parts are needed:

- Chips:

- Easy to obtain by laser cut naked (w/o pads) Si dies ~300-400 um thickness. For 50-100 um-thick Si chips thinned wafer must be ordered.
- Obelix-1 pad chips (400 um-thick) available one month before Obelix-1 delivery ?
- Target (50-100 um)-thick pad and electrically working chip ?



- Flex prototypes: their thickness (500 um)/flatness can impact the flex-to-chip gluing procedures

- We can start from (naked) flex obtained from cutting Kapton foils (previously glued to obtain 500 um-thick stacks); absence of discrete components on the surface and the lpGBT/VTRx+/Connector on the head
- Need to produce mechanical Kapton prototypes with pads mimicking the right thickness for Module gluing and bonding
- Verify with the 1st Al-prototypes (4-chips and 12 chips) with the real flatness if the gluing procedures are working
- High costs will not allow to have Al-pre-production samples for all (7 so far) the types before project approval...

- Cold-plates & Ω -beams (for Ladder):

- We can start with flat (Al or CF ?) flat plates of the right dimensions to tune the tools/procedures for ladder assembly
- We must concentrate on only 1-type (proposed L5A) ladder type for CF Cold-plate(with cooling pipe) + Ω -beam + sliding fixtures to verify the Ladder prototype feasibility (first mechanically with sliding, then electrically working with cooling)
- Having finalized the CF prototypes (and production/lamination methods), high costs will allow only a very few samples for each Ladder type and more than a single company must be chosen to realize the prototypes to be sent to the Ladder production sites.

Snapshots of (old: 2 pipes / new: 1 pipe) cold plate/ Ω -beam prototypes



Snapshots of the new kapton heaters:



A look after the TDR, toward construction (to be detailed)

- In 2027 (TDR) final decision on the “sharing” of oVTX Module/Ladder construction within the sites.
 - After VTX project approval refurbish the site labs. with the needed facilities (operating clean room, CMM, u-bonder, ...)
- Then the identified oVTX Module/Ladder construction sites, knowing which Module/Ladder type(s) to assemble, will start the design of their tools (facility-dependent), specifically developed for Obelix-2.
- The mechanical prototype parts (Si chips + flex + Ω -beam with cold-plate) will be produced to allow the use/tuning of the assembly tools and the realization of each Module/Ladder type: mechanical prototype (in 2027), final electrical demonstrator with Obelix-2 (in 2029)
- As Maximum: 7 Module’ sites/ 6 Ladder’s oVTX sites.
- Qualification of the site(s) for production: 2029-mid 2030
- 2029→2030: final Al-Flex production; Ω -beam with cold-plate production
- In 2030 start oVTX production Module(s)/Ladder(s): 1.5 → 2 year.

oVTX Baseline	L4 A/B	L5 A/B	L6 A/B
Radius [mm]	82.5/89	108/114.5	133.5/140
#Ladders	18/18	24/24	30/30
Chip/Ladder	12/13	16/17	20/20
# Modules	1/1	2/2	2/2

