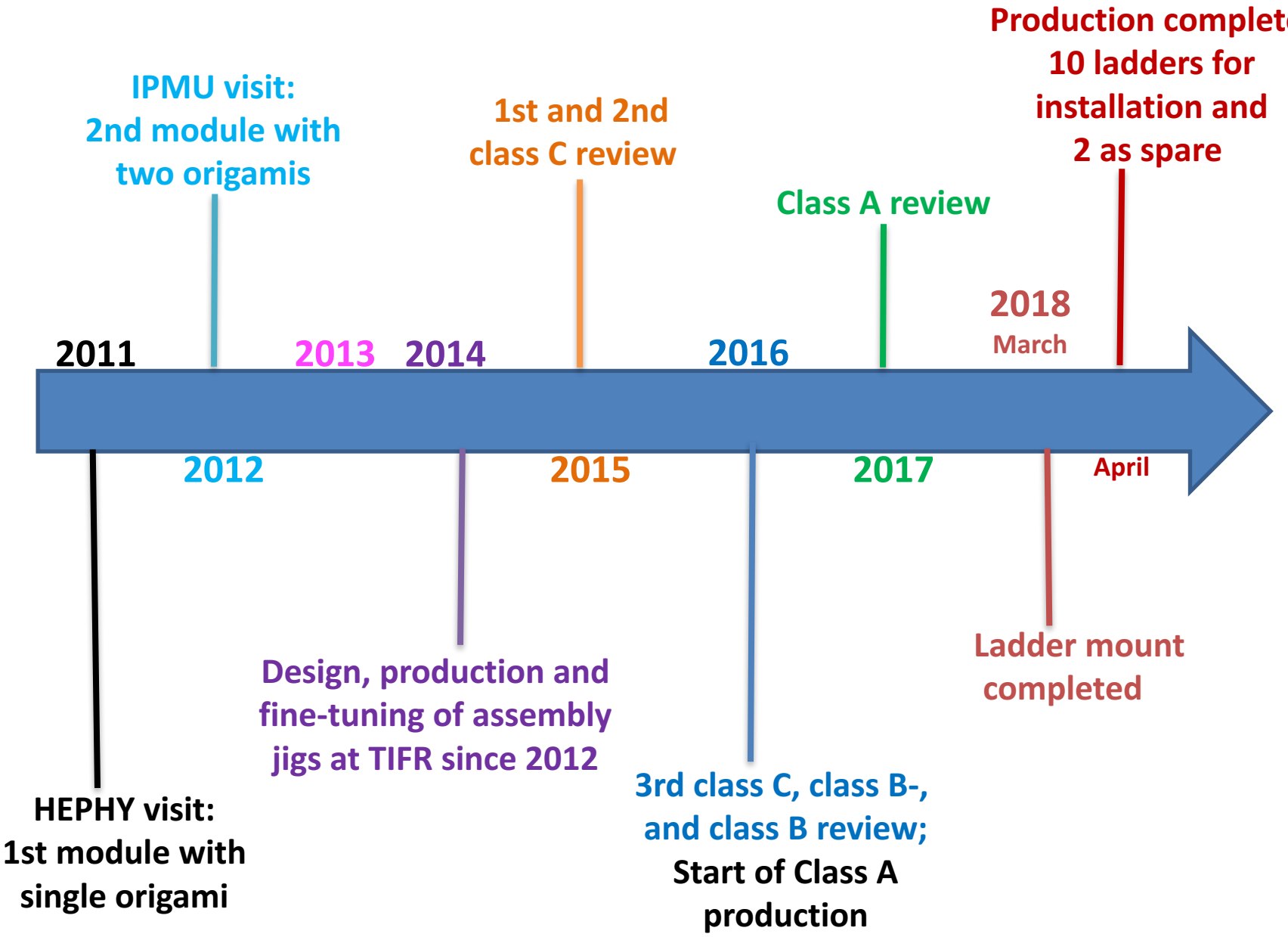
Building the Layer 4 of Belle II SVD

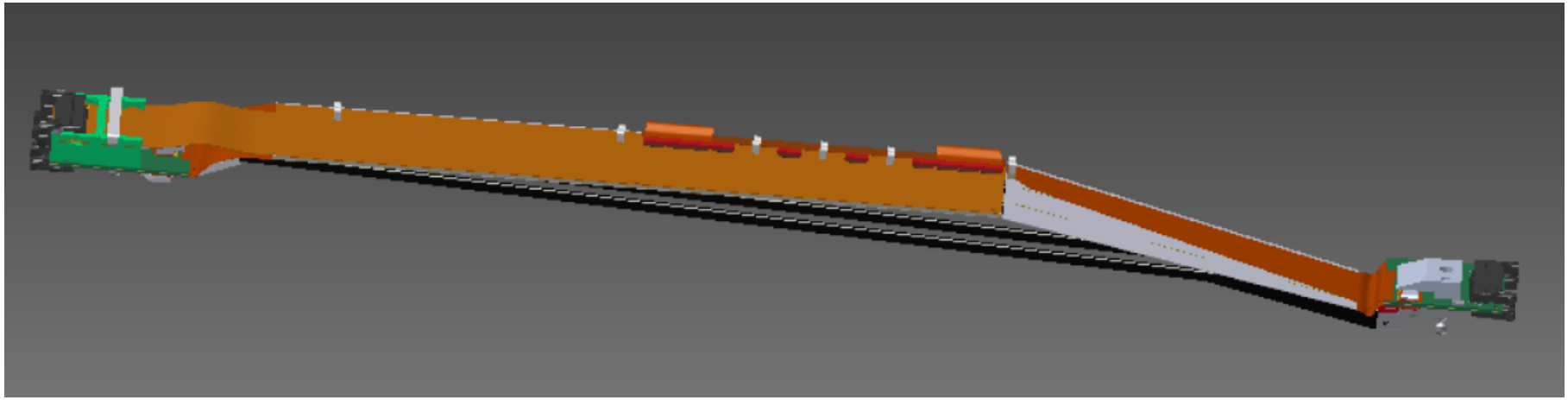
Kamesh and Team

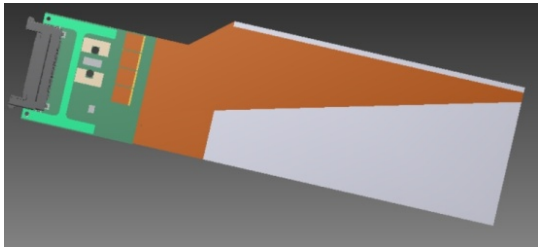
DHEP Annual Meeting
May 8-9, 2018

Milestones of L4 ladder production

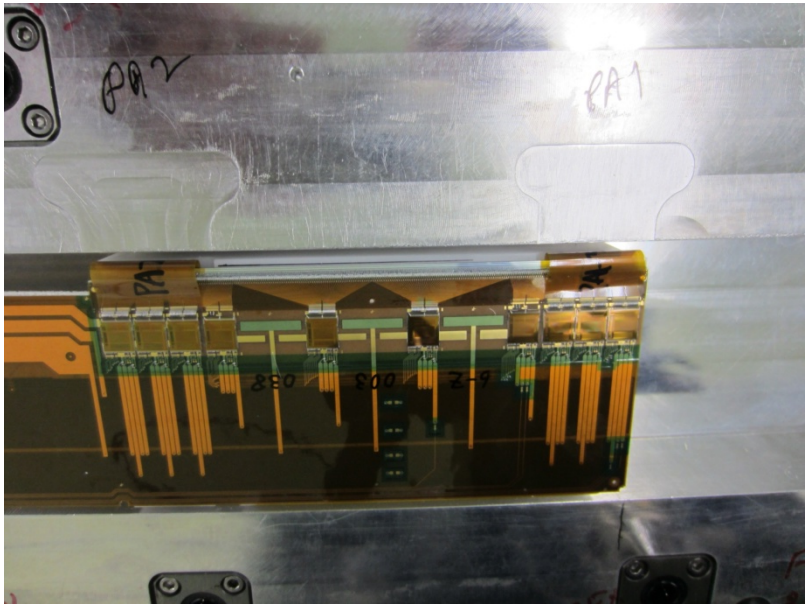


3D model and main parts of an L4 ladder

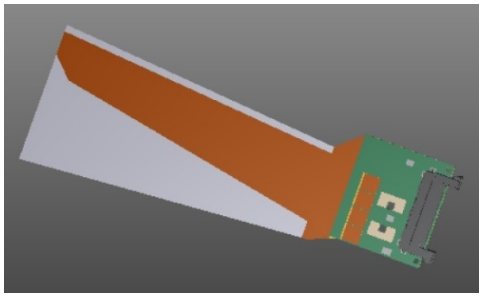




Backward sensor
(Rectangular DSSD)

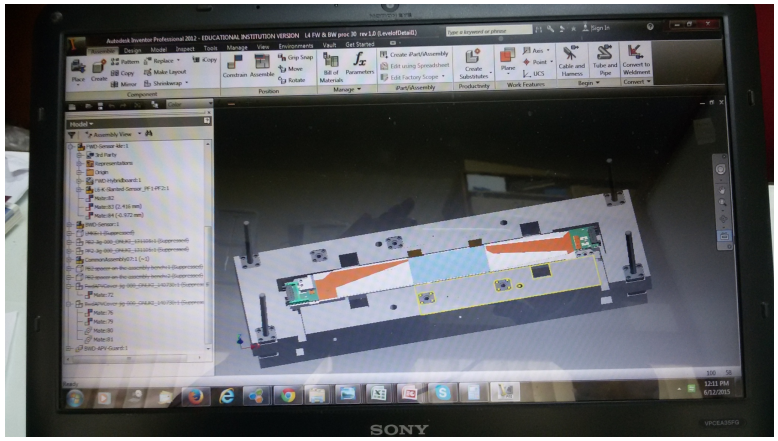


Central origami sensor
(Rectangular DSSD)



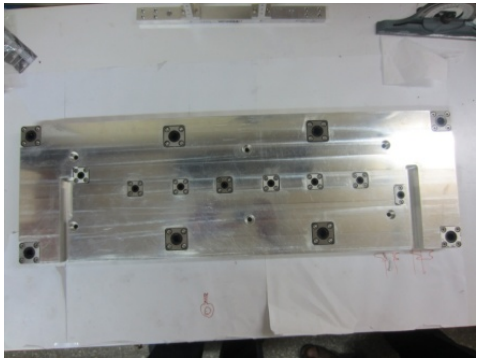
Forward sensor
(Trapezoidal DSSD)
Slant angle of 11.9°

Design and production of assembly jigs

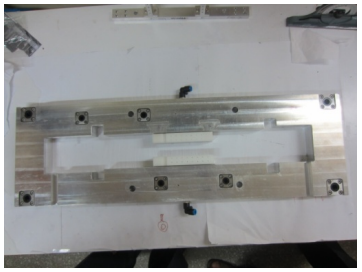


Design software: Autodesk Inventor Professional 2012

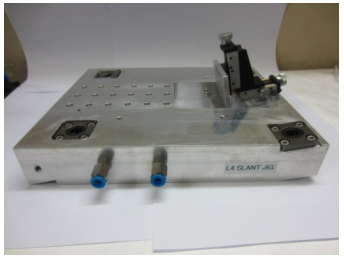
Number of jigs designed: ~50



Assembly base



Assembly bench



Slant jig (11.9°)

Tolerances Achieved:

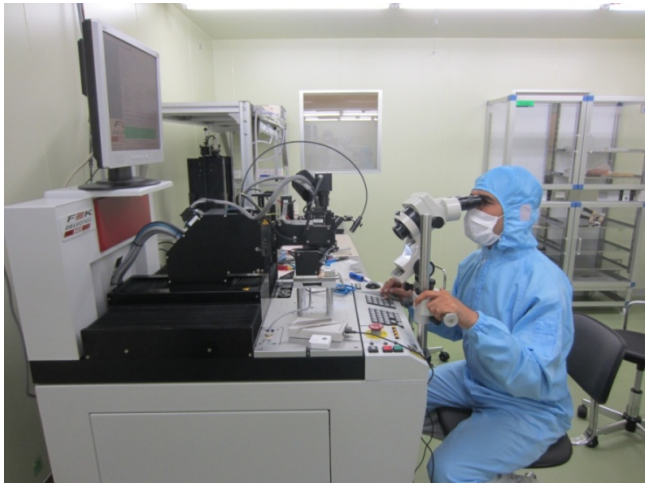
Length of rods tolerance : +/- 40 µm
Diameter of rods : +/-20 µm
Flatness of small jigs : less than 70 µm
Flatness of large jigs: less than 150 µm

Design, production and fine-tuning of the jigs and their CMM were all performed in-house

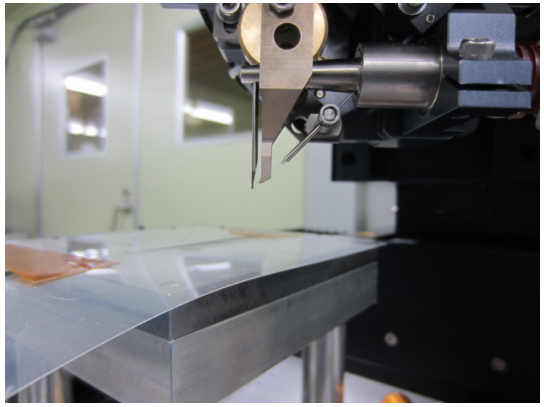
Purpose of jigs:

- Precise placing of the components (sensor always on polyacetal part)
- Starting from step# 1 they are used for each and every operation (never touch the components with hand)
- Picking up and placing components
- Alignment of the components
- Holding the hybrid boards
- Transfer of components with the help of vacuum

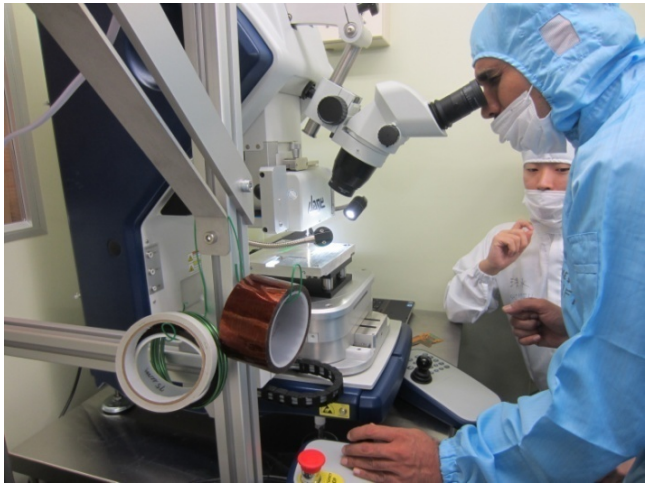
Instruments for ladder assembly at IPMU



Wire bonder (TIFR)



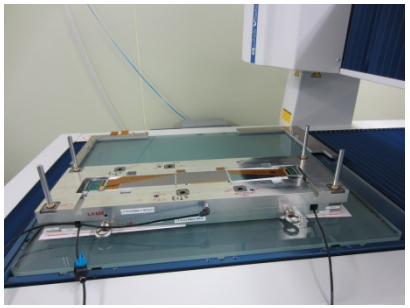
Wire: Al+Si (1%) 25 µm diameter



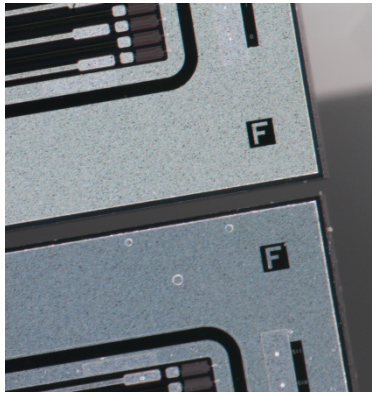
Pull tester

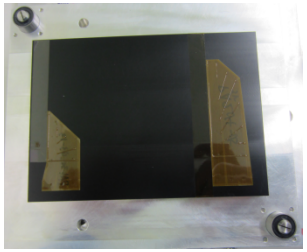
Microscope (TIFR)

Gluing robot

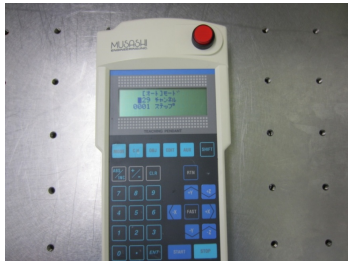


CMM



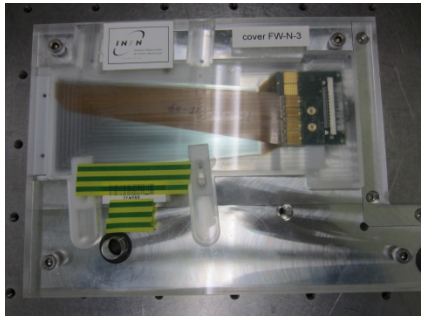


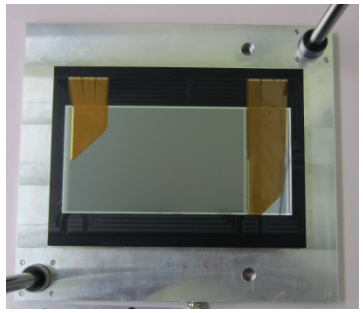
Glue pattern



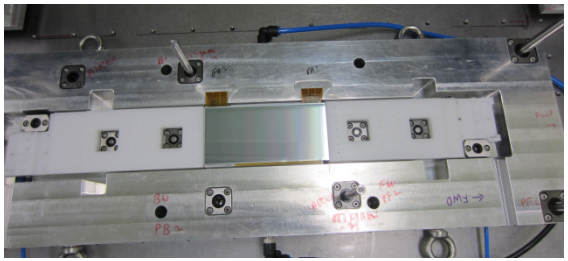
Teaching pendant

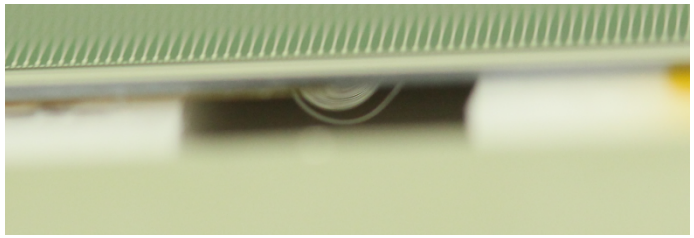
Key steps in ladder assembly

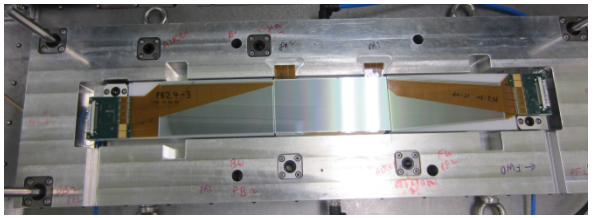


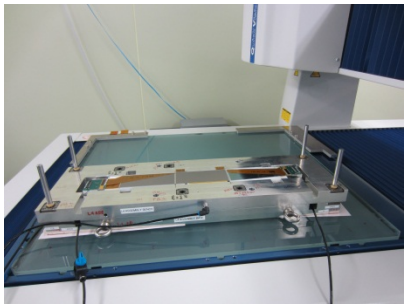


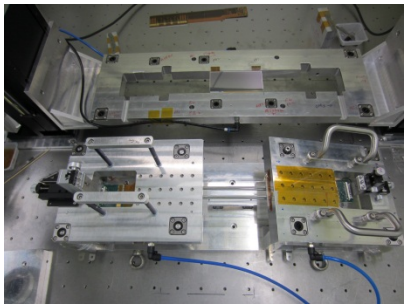
- Well defined protocols for assembly
- Checklist for each key step in database
- Electrical verification
- Photos @ each operation

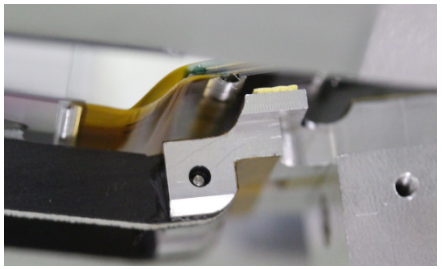


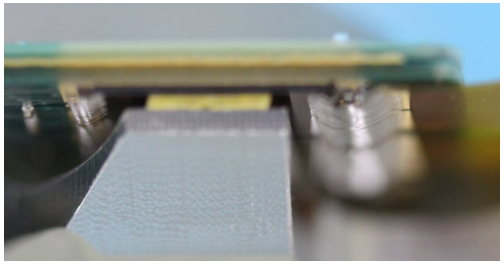


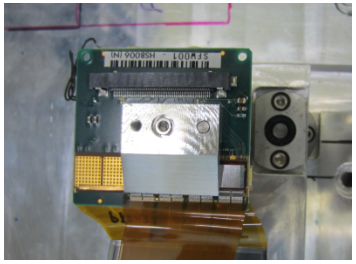




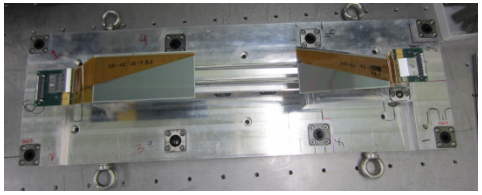




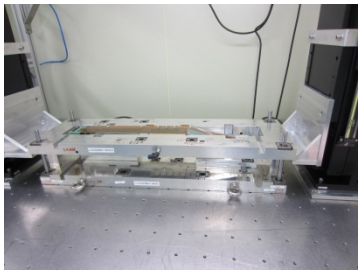




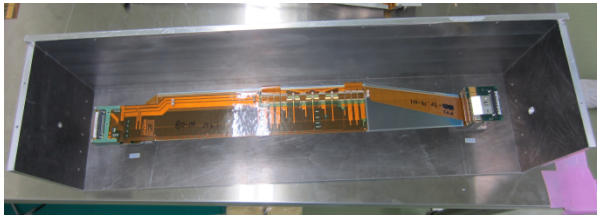
APV guard fixing



Half ladder

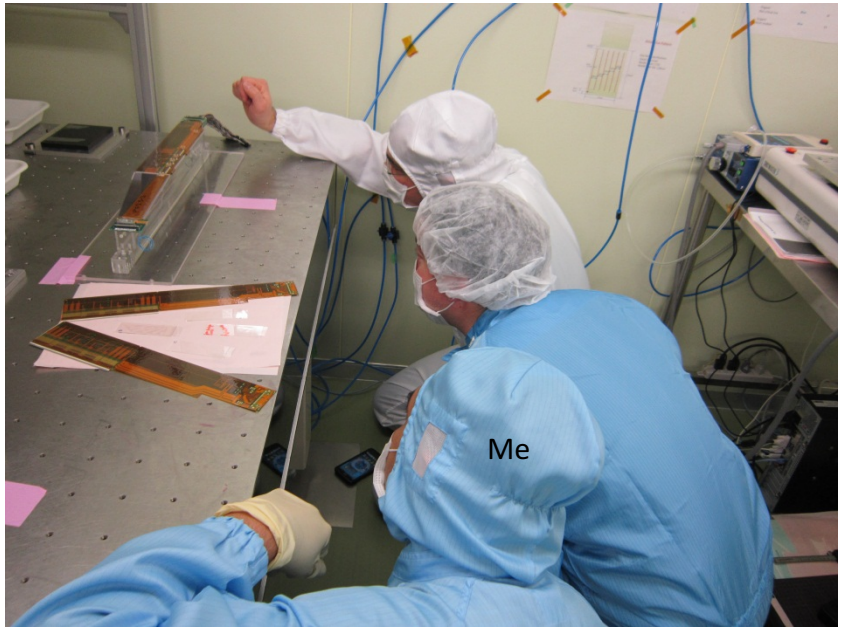


Final stage



Ladder in the container

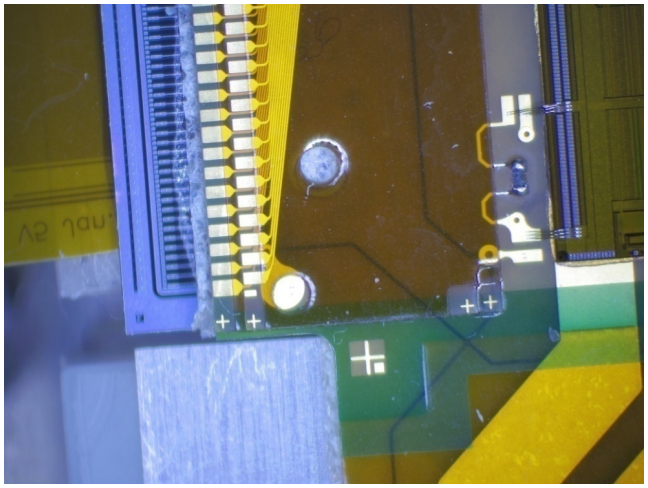
Class C review

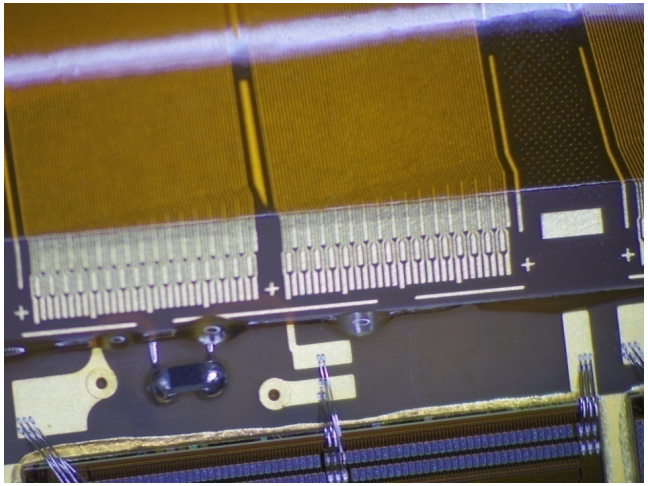


- All jigs and assembled ladder were critically monitored and verified by the experts from Austria, Italy, Australia and Japan

Gluing and wire-bonding

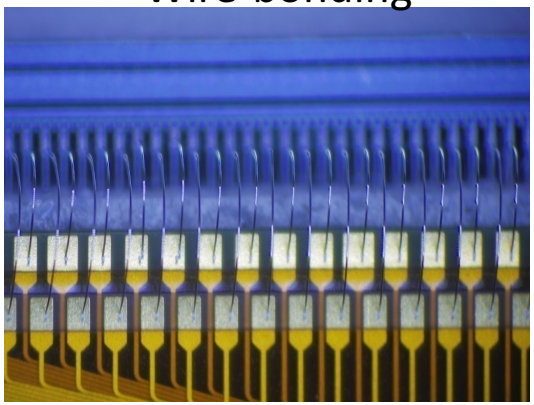
Gluing





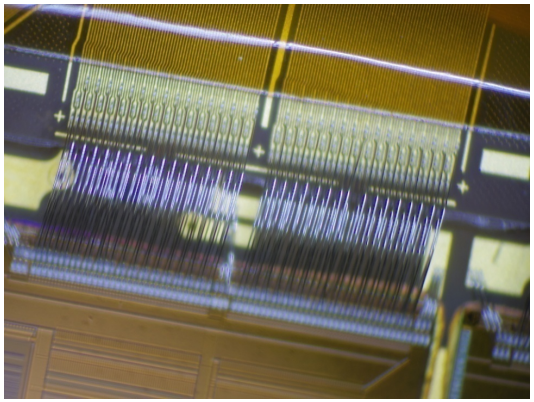
- Monitor glue spread at each step
- Else, we risk WB performance

Wire-bonding



- Bond pull strength ~10 gf (destructive test on samples)
- Total wirebonds per ladder ~ 8000

Pitch adapter to sensor



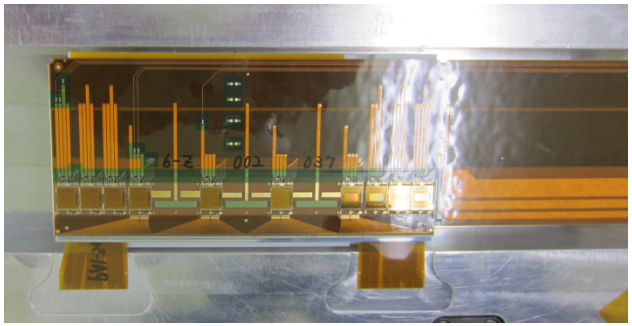
Pitch adapter to APV chips (three rows)

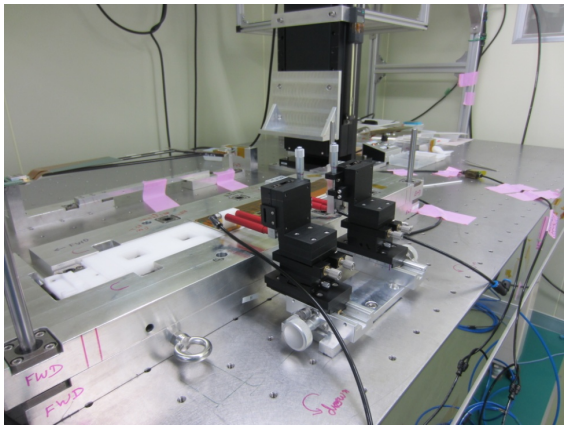
Key challenges:

- Proper selection of pads while programing the bonder
- Removal of tiny wire-bond pieces from the pads (left over due to unbonding during auto-operation)
- Rebonding due to the limited bondable space on pad, particularly for APV chip bond pads
- Adjustment of shorted wire-bonds (pitch: 88 µm)
- Continuous monitoring with microscope

PA wrapping setup

Origami module





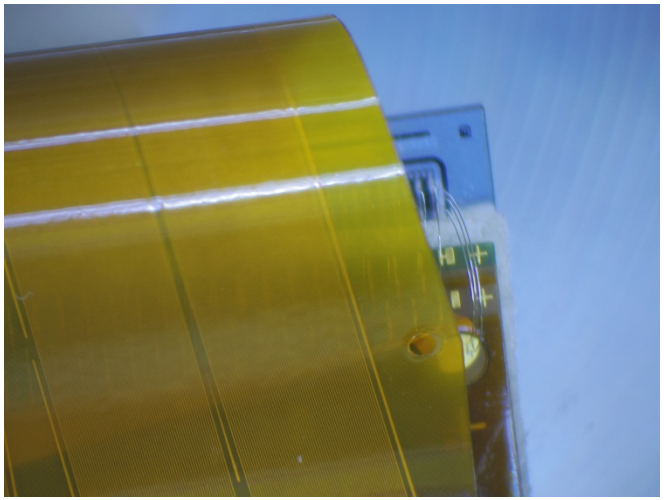


fig 2

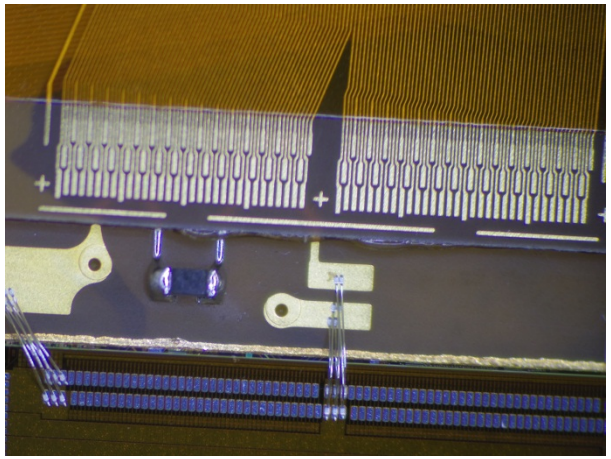


fig 1

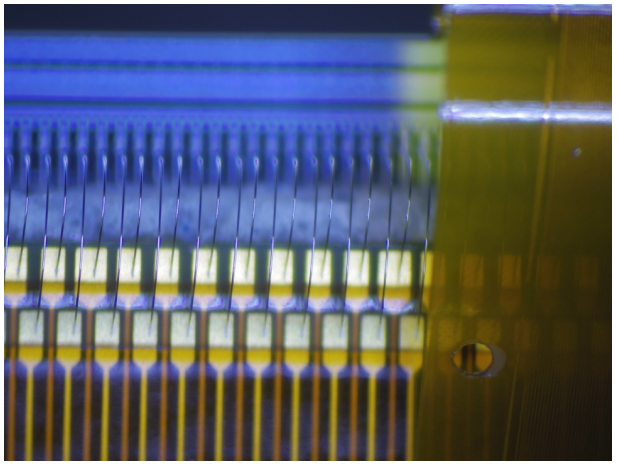


fig 3

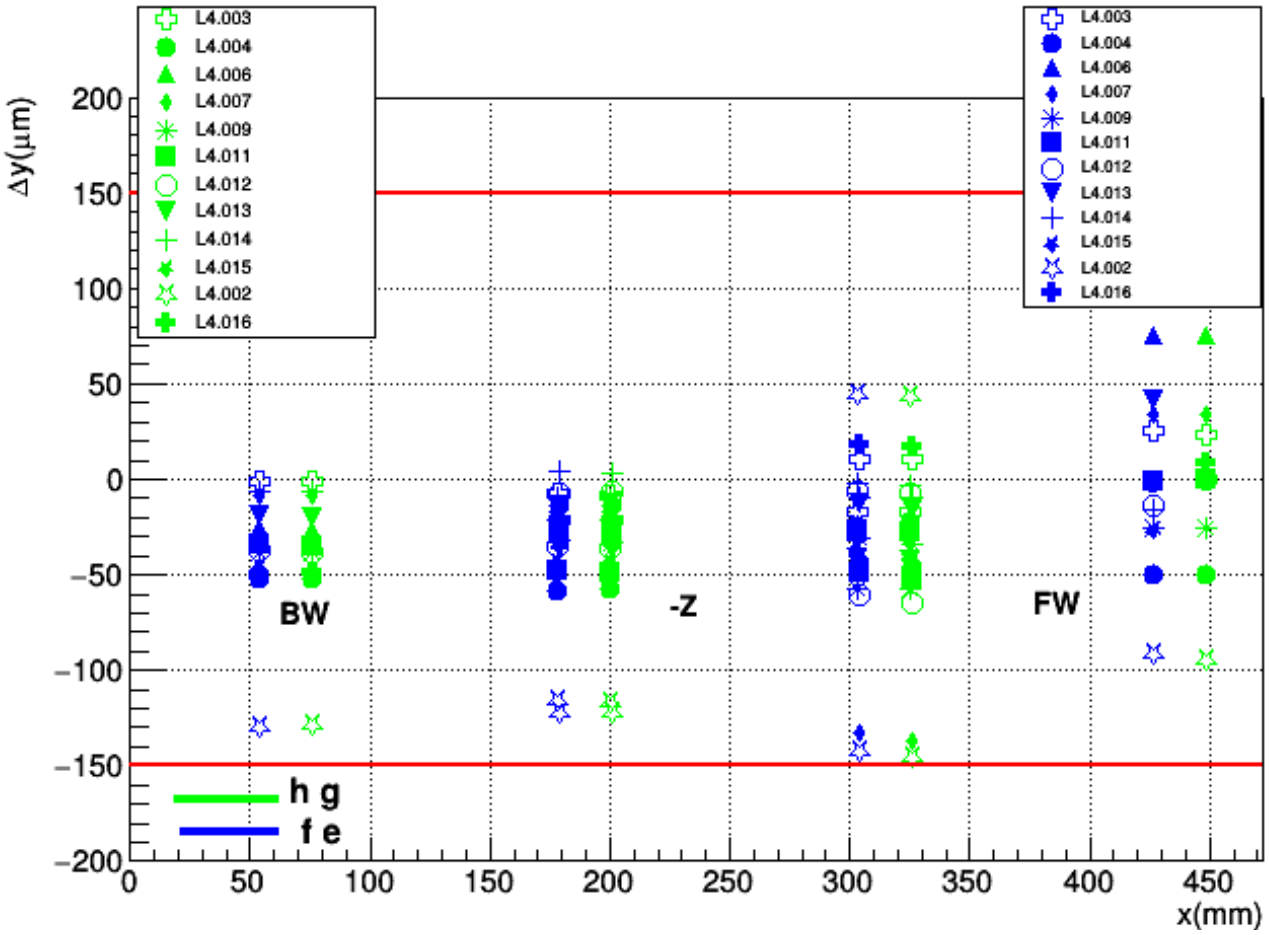
Key challenges:

- Perform the operation very slowly under microscope
- Not too much pressing from the top, but ensure to have proper gluing between the parts, else bonding issues fig 1
- Take care of bias bonds on the N side of sensor fig 2
- Take care of delicate bonds as shown in fig 3

CMM and EQA results of assembled ladders

Mechanical Quality:

- Deviations from the design value along three axes are within the specification: ±150 μm in x, y and ±250 μm along the z-axis



Electrical Quality Assurance:

P-side

number of defects = 2 / 768 (0.26%)
p_Noisy = 0 (0.00%)
p_Open = 0 (0.00%)
p_Short = 0 (0.00%)
p_Pinhole = 2 (0.26%)
p_Particle_Resp = 0 (0.00%)

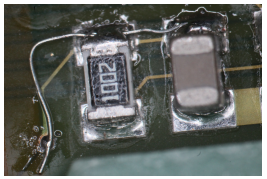
N-side

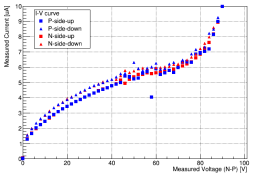
number of defects = 2 / 512 (0.39%)
n_Noisy = 1 (0.20%)
n_Open = 1 (0.20%)
n_Short = 0 (0.00%)
n_Pinhole = 0 (0.00%)
n_Particle_Resp = 0 (0.00%)

- On average, 1-2 electrical defects introduced during assembly

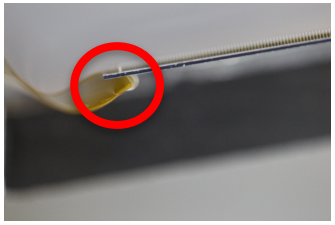
Challenges faced during production

1st challenge: In the 1st ladder, found open in the origami PCB due to which the sensor was drawing no current ➡ fixed the open

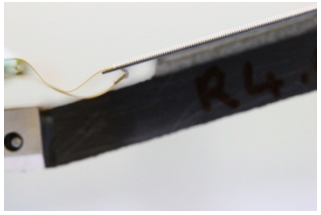




2nd challenge: Sensor breakdown early due to a suspicious pinhole ➡ removed the wire-bond of the bonded pinhole strip

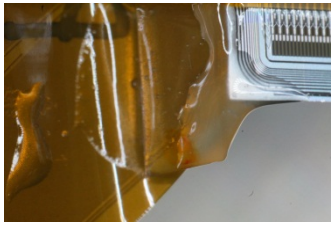


3rd challenge: PA partially peeled off from the FW sensor (this time only happened to L4)

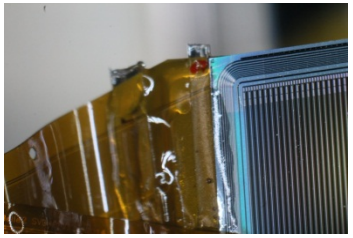


4th Challenge: PA fully peeled off from the FW sensor both for L4 and L6 on the half as well as full ladders

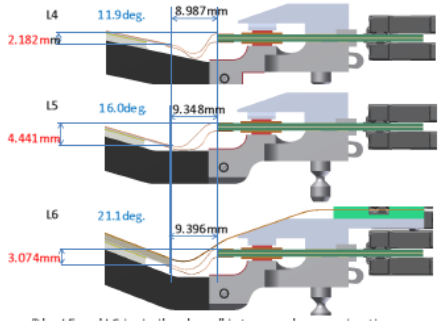
Initial solution: Type 2 glue reinforcement (left)



Challenge contd.: Peel-off reappeared in L4 ladder
Final solution: Type 3 glue reinforcement (right)



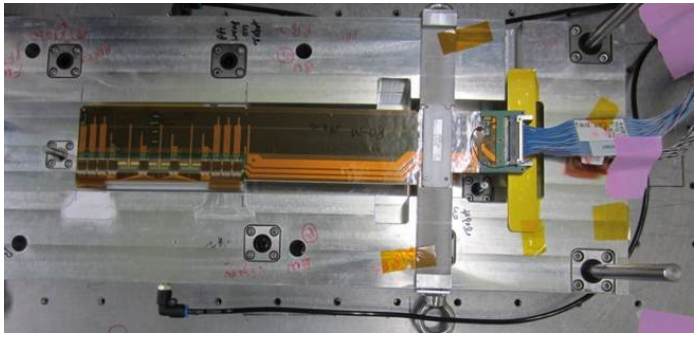
Reason: L4 has more constraint between the FW sensor and PA compared to L5 and L6

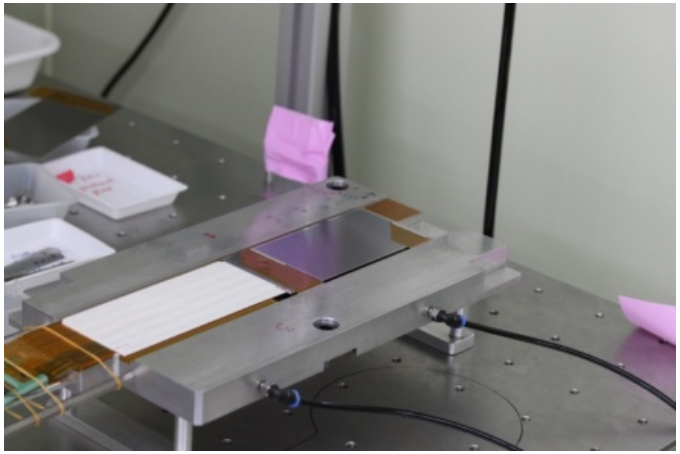


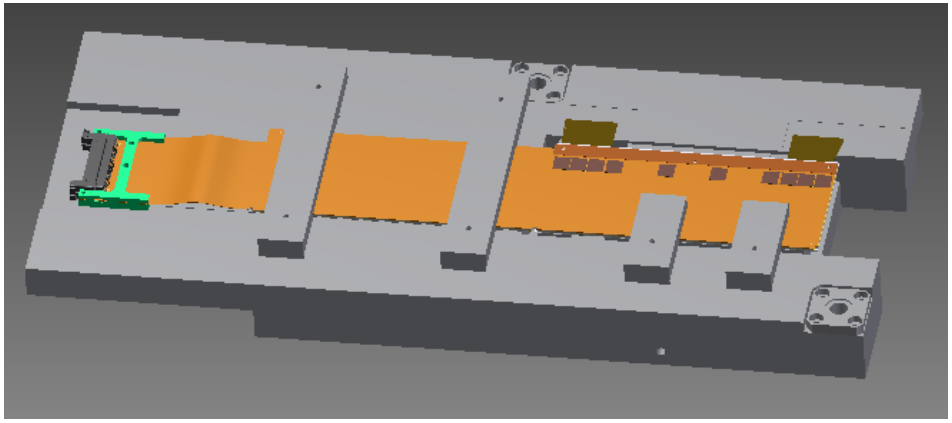
5th challenge: One of the assembled origamis has more noise channels so we needed to keep it aside

Additional jigs to mitigate challenges

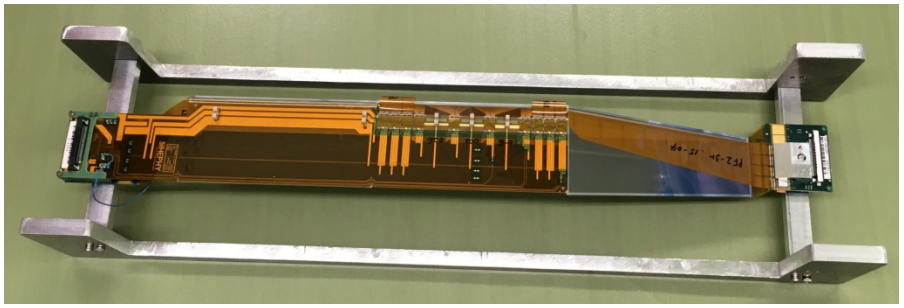
- Designed and produced an Origami pickup jig to pickup the OS4 from the assembly bench to make a way for aligning FW and BW sensors on the assembly bench and gluing onto the ribs







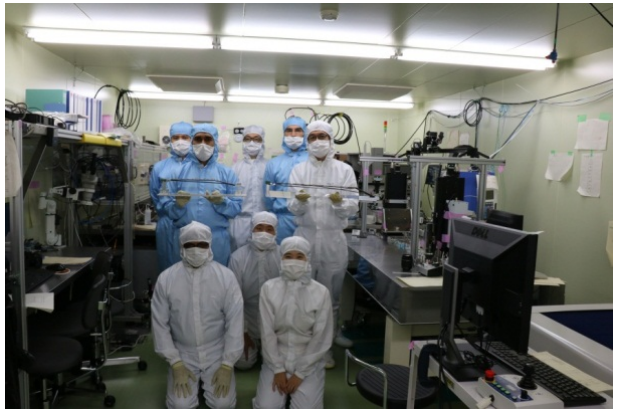
Holding the OS4 jig with holders as shown in the figure



Flip Jig

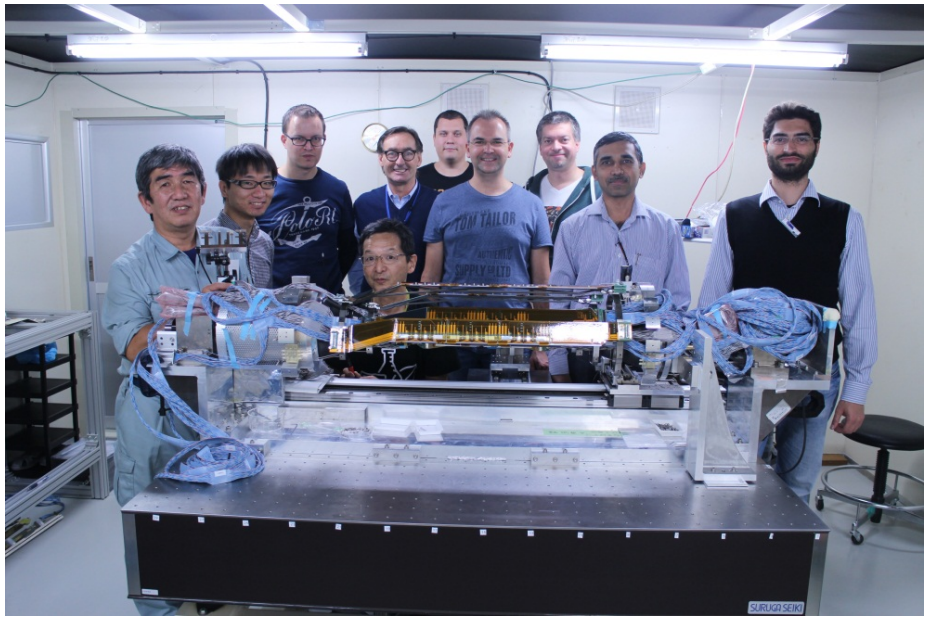
Summary

3pm tea time discussion at IPMU

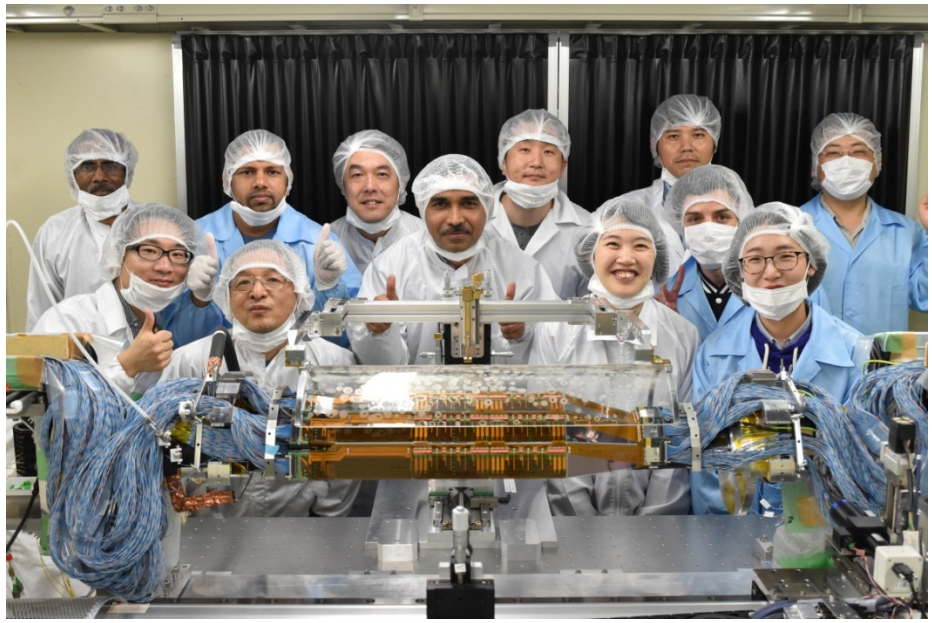


L4 and L6 teams at IPMU

- Visual inspection and photos at IPMU
- Transport ladders to KEK
- Incoming inspection and EQA at KEK
- Keratharm attachment
- Visual Inspection (photos)
- Ladder mount one per day due to complex and laborious inspection procedures



Mockup Assembly @ KEK



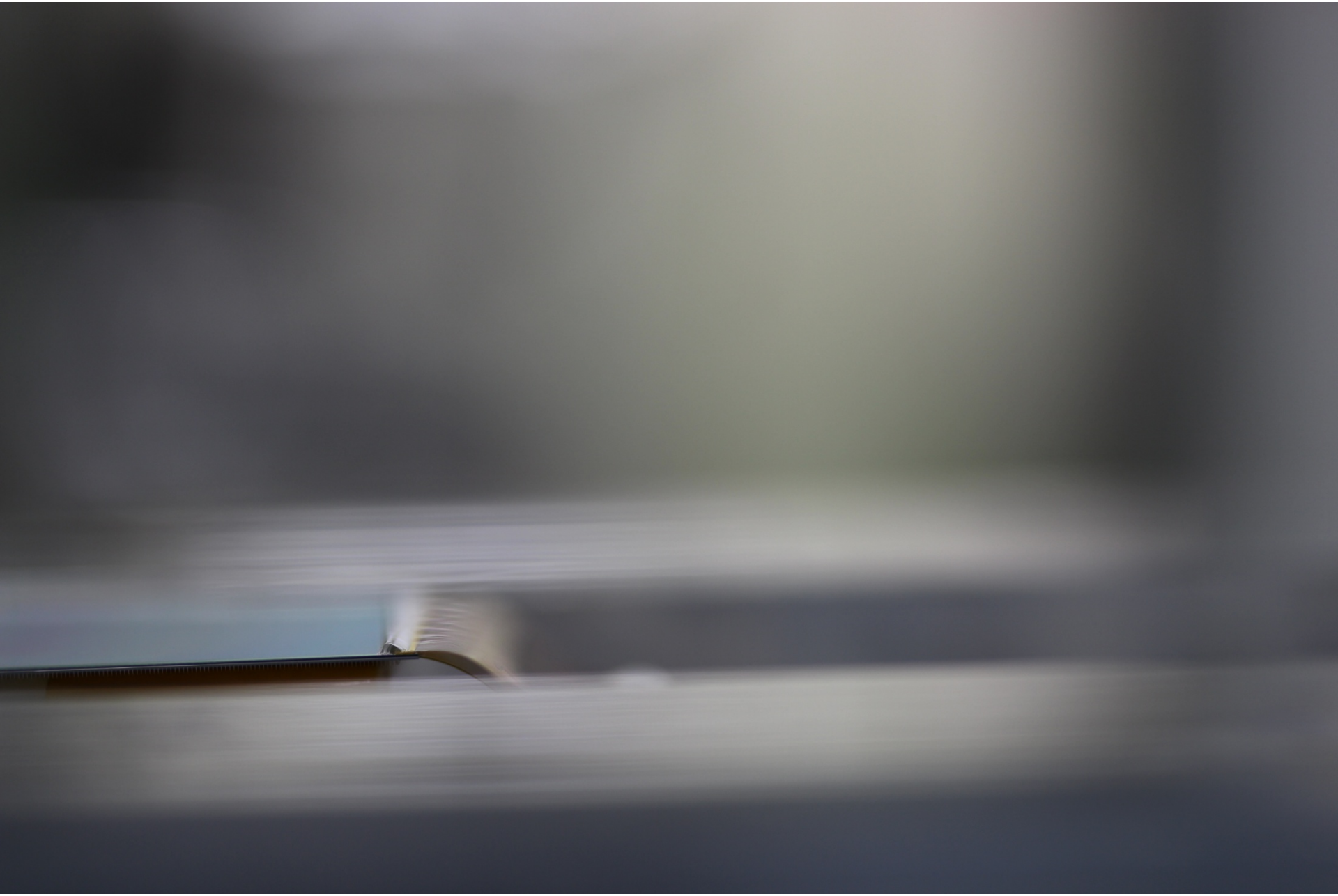
Production completed - April 18, 2018

Thank You

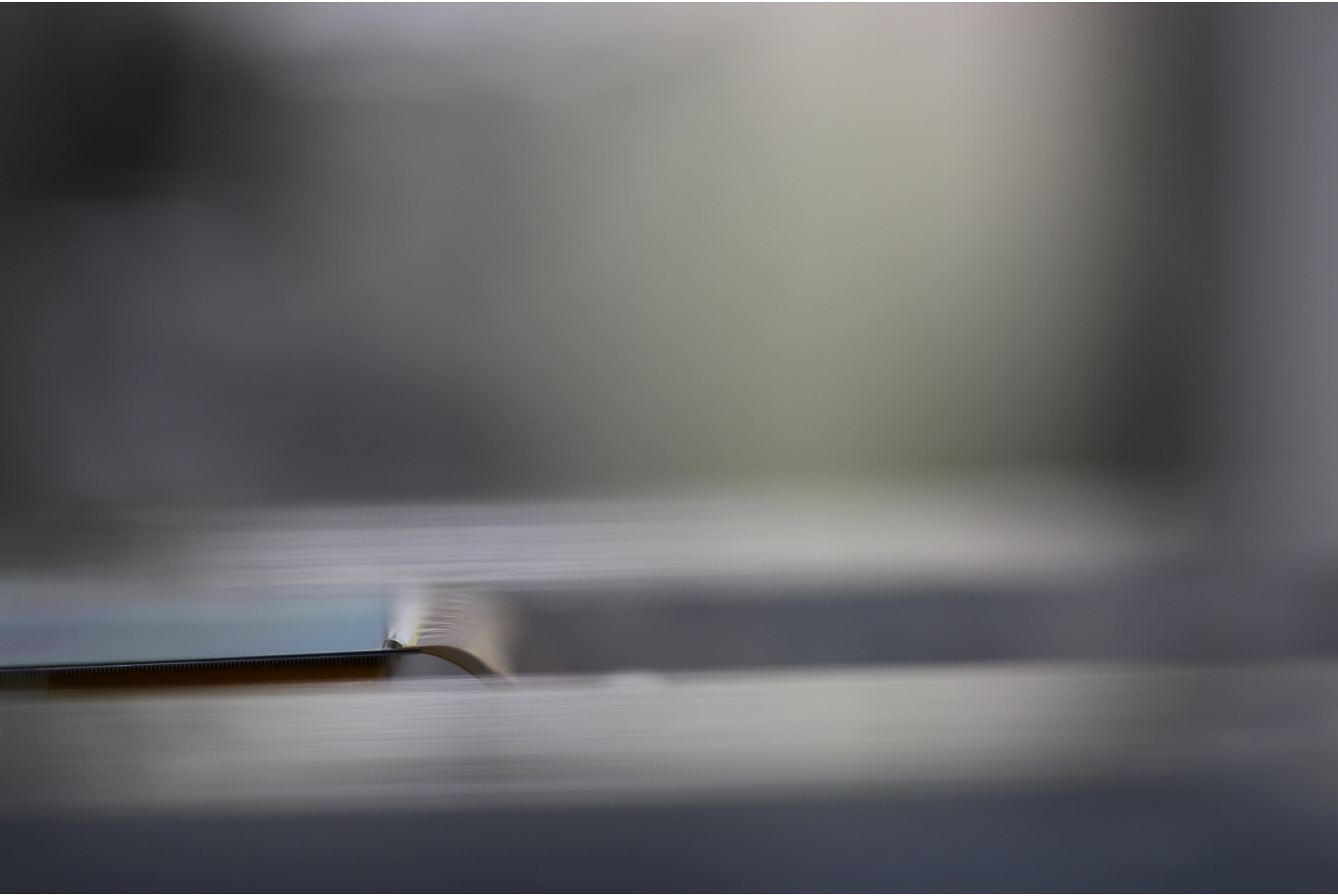
Backup slides

SFW study before gluing

Effect on sensor while adjusting the Hybrid board in x direction

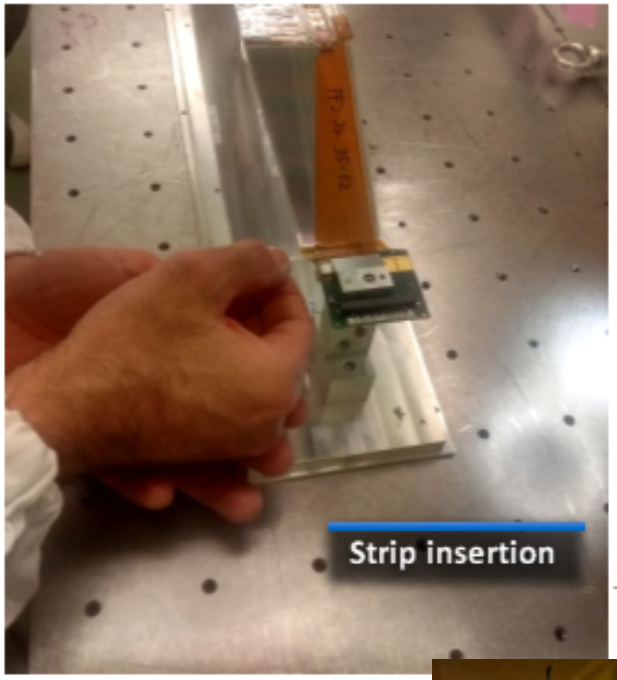


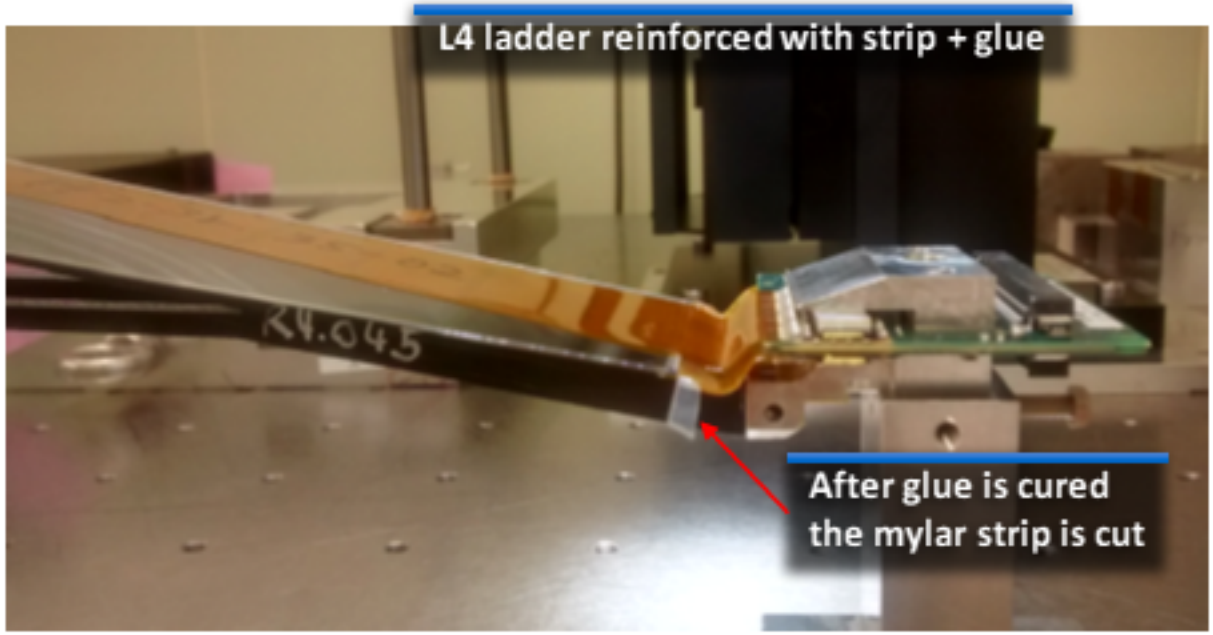
Effect on sensor while adjusting the Hybrid board in x direction

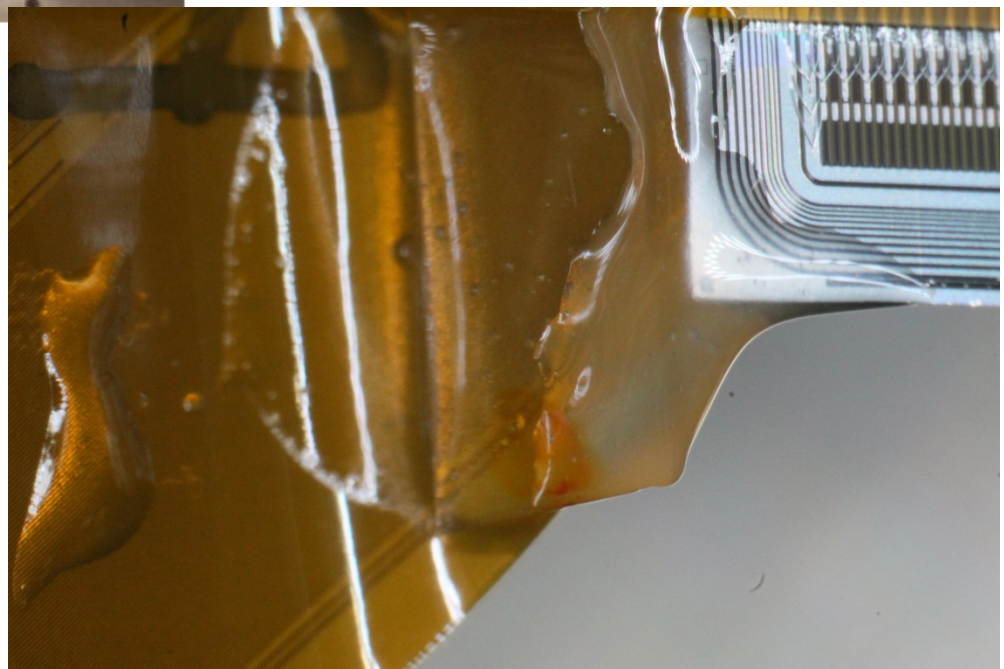


Effect on sensor while adjusting the Hybrid board in x direction

Solution for Peel-off issue from next Ladder

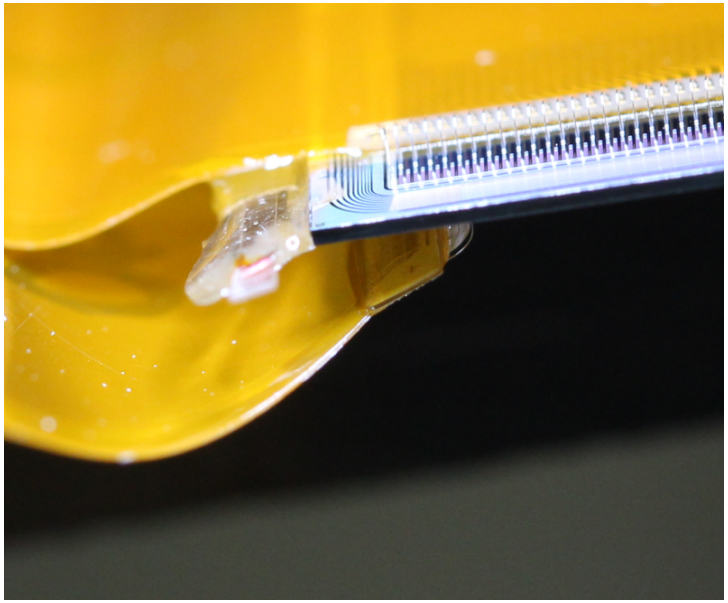


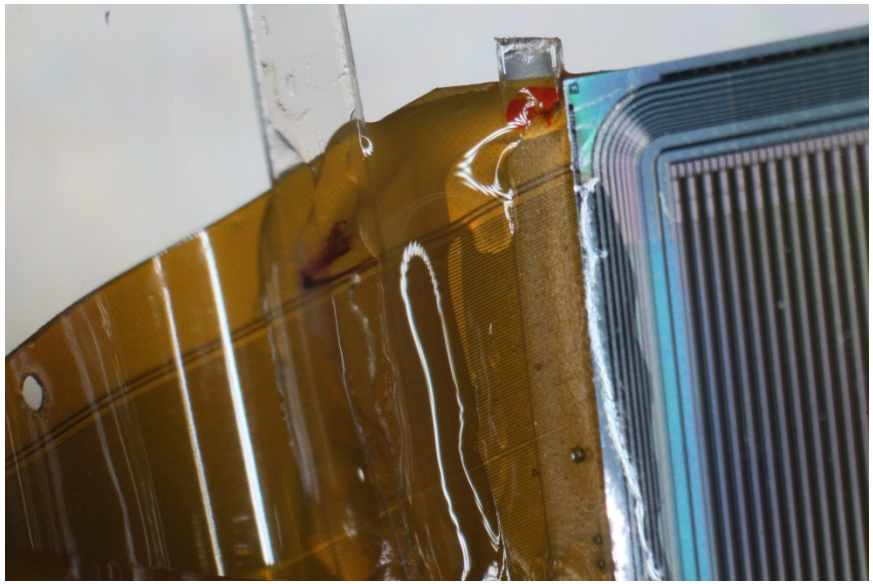




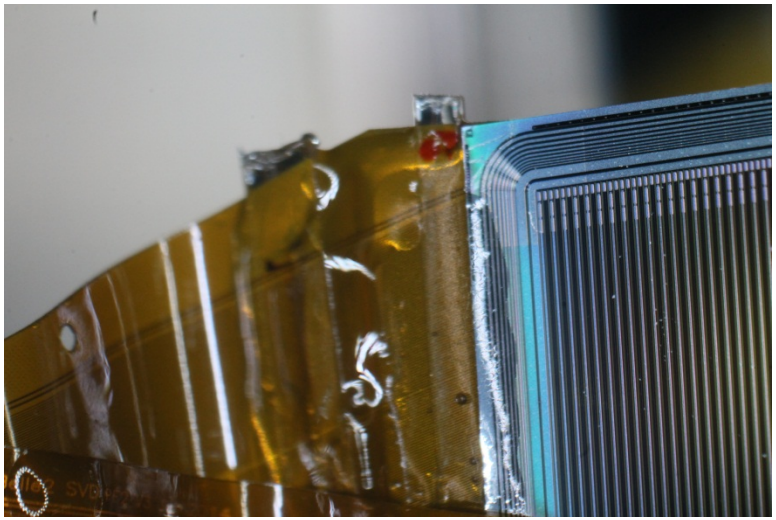
Type 2 glue reinforcement

Peel-off reappeared on L4.010





Type 3 Glue reinforcement



After Type 3 Glue reinforcement – No more Peel-offs