Examinations of the US modules visually and with DAQ at KEK

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Two US modules, 20220040200018 (P011) and 20220040200043 (P031), that showed large instability in the S-curves of the noise occupancy scans were sent to KEK for cross-checking. Two examinations were carried out at KEK. Firstly, electrical measurement in a DAQ bench being used for the QA of module production at KEK immediately after reception of the modules, then visual examination according to the instruction of visual inspection of module production internal at KEK together with the metrology measurement. Below, the visual observations is reported first and then that of DAQ.

1. Visual examination

1.1. Observations in gluing of the hybrid feet

In the barrel module assembly, only two areas are involved in thermo-electrical adhesion: one is the gluing of the sensors to the TPG baseboard, and the other is gluing the hybrid to the ceramics facings via the feet of the hybrid. The former is hidden under the sensors and invisible after the completion of the modules while the latter is visible. Thermo-electrically the latter plays larger role because the most of the heat of the module is generated in the ASICs on the hybrid. With respect to the electrical stability, it is not understood how critical the thermal joint between the hybrid feet and the facings, however, the heat of ASICs will rise quickly from a stationary ~4.8W to a peak of ~6.4W as the noise occupancy scan passes the 0 fC threshold quickly. A heat of 1W at a foot will cause a temperature rise of about 1/4 deg.C for a glue thickness of 20 um, stationary. If the thickness is something like 160 um, the temperature rise will be 2 deg.C. This is worsened because the heat is concentrated in a narrower region of the foot about the width of ASIC because the carbon fibres in the carbon-carbon bridges are laid in one direction only. A transitional analysis may show much larger temperature changes that might worsen the electrical stability around 0 fC. We note that the instability is triggered first by the ASIC which is more susceptible to a pickup and that susceptibility could be worsened by the transional temperature change of the ASIC. Having this in mind, the area of hybrid feet must be fully filled up with thermal epoxy and the thickness be uniform and the minium, e.g., about 20 um. The thickness of the foot (from the bottom surface of the foot to the top surface of the hybrid flex) is about 1.05 mm. Then, the height of hybrid (i.e., from the surface of facing to the surface of the hybrid flex) will be about 1.07 mm, with a glue thickness of 20 um. The filling of epoxy and the thinness of the glue joint then form a smooth fillet around the feet, surrounding 100% of the edges ideally. The smooth fillet surrouding all edges and corners is also important for thermo-mechanical reason.

Out of the visual examination, observations of the gluing of the feet are summarized in Table 1 and 2 for the modules 018 and 043, respectively, together with Fig.1to Fig.15. The locations of the feet are, as in the standard view of the module (i.e., the pigtail of hybrid toward oneself),

f1: Top side, Near facing, Left side
f2: Top side, Near facing, Right side
f3: Top side, Far facing, Left side
f4: Top side, Far facing, Right side
b1: Bottom side, Near facing, Left side
b2: Bottom side, Near facing, Right side
b3: Bottom side, Far facing, Left side
b4: Bottom side, Far facing, Right side

After the visual examination, the modules were also gone through the metrology steps as same as the other KEK modules. The "Glue thickness" is deduced from the measured value of the hybrid heights subtracting 1.05 mm. From the point of view of KEK, we found several inadequacies where improvement can be made. Those are: Filling and Fillet of f2 and f4 of 018 where the deduced glue thickness is also large and exceeding 80 um; Filling and Fillet of b2 of 043 where the glue thickness of b1 and b2 are far exceeding 80 um. If there is any relation between the thermal performance and worsening the electrical instability in the bottom hybrid, the thermal joint of the bottom and near facing (i.e., b1 and b2) is most critical.

1.2. Other observation

We have noticed other out of the visual inspection: stains on the sensors on both of the modules. Fig.16 and Fig.17 show the stains in the module 018, and Fig.18 and Fig.19 in the module 043. They look like a remnant of silver and we wonder they are trans-print of conductive epoxy left on the jig or on the protective clean-room sheet for vacuum-chucking sensors.

2. DAQ examination

2.1. Result of Noise Occupancy Scans

After the default characterization sequence of the SCTDAQ, the Noise occupancy (NO) s-curves plot is generated by the SCTDAQ. Since the instability is severe or seen in the link1, the s-curves plots of only link1 are reproduced here. In the following figures, the US plots and then the KEK plots are shown in that sequence. The results were both measured at cold.

Fig.20 – Module 018 NO s-curves link1 (US)
Fig.21 – Module 018 NO s-curves llink1 (KEK)
Fig.22 – Module 043 NO s-curves link1 (US)
Fig.23 – Module 043 NO s-curves llink1 (KEK).

The results are very similar and no fundamental difference is found.

2.2. Difference in "Noise Occupancy" scan and "Noise" scan

There exist two ways to obtain s-curves: one is the default "Noise Occupancy scan" and the other is a standalone "Noise scan" that scans threshold with L1A triggers (with no CAL trigger). In using the standard trio of daq modules, CLOAC, MuSTARD, and SLOG, the fundamental difference of two methods is that the former is using the "burst mode" triggering and the hardware histogramming in MuSTARD, while the latter is using the "event-by-event" triggering and a software histogramming in the SCTDAQ. Because of this fundamental difference, the trigger repetition rate is much faster in the "Noise Occupancy scan" than in the "Noise scan".

In a note [1], we have reported a difference of the s-curves obtained by the "Noise Occupancy scan" and the "Noise scan". The "Noise scans" were repeated to the modules and the s-curves are shown in

Fig.24 – Module 018 Noise scan s-curves (KEK)
Fig.25 – Module 043 Noise scan s-curves (KEK).

By comparing between Fig.21 and Fig.24, and Fig.23 and Fig.25, the impression seems still valid, i.e.,

(1) S-curves are more aligned in channels in the Noise scan than in the NO scan
(2) The discontinuity at negative threshold seems more pronounced in the NO scan than in the Noise scan
(3) In detail, the S-curves are shifted toward lower thresholds in the NO scan than in the Noise scan

References

[1] Y. Ikegami, Y. Unno, " Comparison of S curves by a simple threshold scan with L1A triggers and the Noise Occupancy scan in the SCTDAQ(V3.38)", http://jsdhp1.kek.jp/~unno/notes/PRODUCTION/diffScurvesNSNO.pdf

Table 1. Visual examination of the module 20220040200018

Facing location	Photo	Filling	Fillet	Hybrid height (mm)	Glue thickness (um)
f1 (top, near, left)	Fig.1	Good	Good (a bit larger fillet is the standard of KEK)	1.118	68
f2 (top, near, right)	Fig.2	NG (unfilled gap)	NG	1.176	126
f3 (top, far, left)	Fig.3	Good	Good (a bit larger fillet and the fillet in the corners are desirable)	1.085	35
f4 (top, far, left)	Fig.4	NG (unfilled gap)	NG	1.156	106
b1 (bot'm, near, left)	Fig.5	Good	Good (a bit less fillet is desirable, missing fillet at the edge of the end of hybrid)	1.136	86
b2 (bot'm, near, right)	Fig.6	Pass (unfilled corner)	Pass (larger fillet desirable)	1.105	55
b3 (bot'm, far, left)				1.119	69
b4 (bot'm, far, right)	Fig.7	Good	Good (about ideal quantity)	1.103	53

Table 2. Visual examination of the module 20220040200043

Facing location	Photo	Filling	Fillet	Hybrid height (mm)	Glue thickness (um)
f1 (top, near, left)	Fig.8	Good	Good (ideal)	1.125	75
f2 (top, near, right)	Fig.9	Good	Good (more fillet at corner desirable)	1.140	90
f3 (top, far, left)	Fig.10	Good	Good (a bit larger fillet and the fillet in the corners are desirable)	1.093	43
f4 (top, far, left)	Fig.11	Good	NG	1.146	96
b1 (bot'm, near, left)	Fig.12	Good	Good	1.180	130
b2 (bot'm, near, right)	Fig.13 Fig.14	NG (unfilled gap)	NG	1.268	218
b3 (bot'm, far, left)				1.105	55
b4 (bot'm, far, right)	Fig.15	Good	Pass (more fillet desirable)	1.118	68

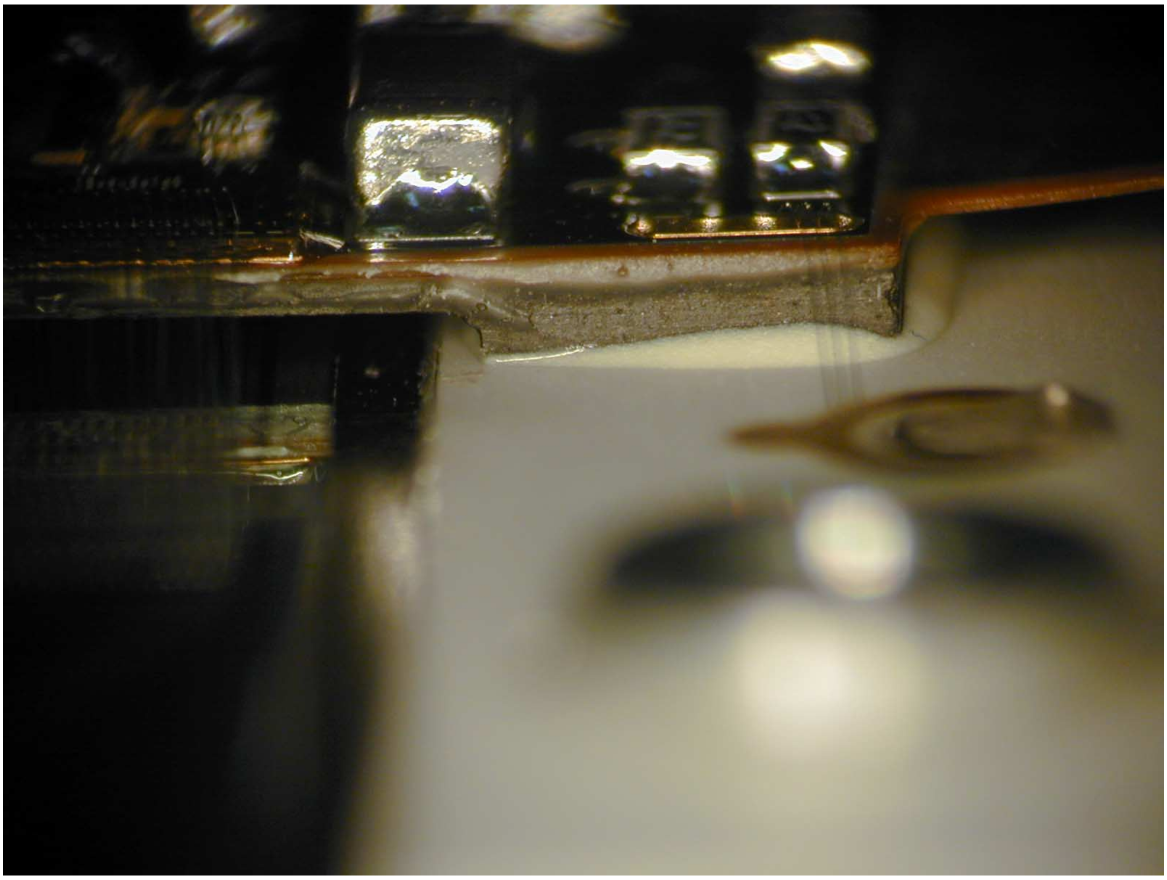

Fig.1. Gluing of hybrid foot f1 (top, near, left) of the module 20220170200018

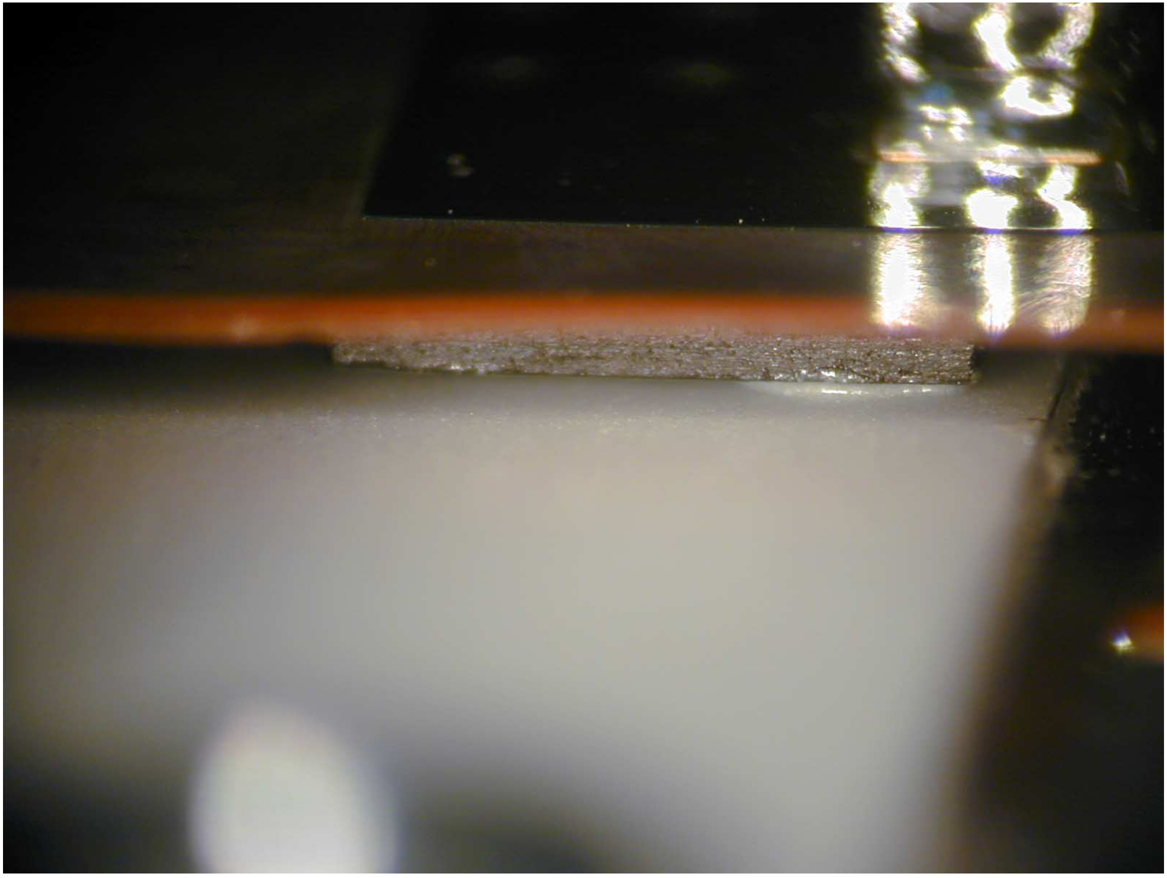

Fig.2. Gluing of hybrid foot f1 (top, near, left) of the module 20220170200018

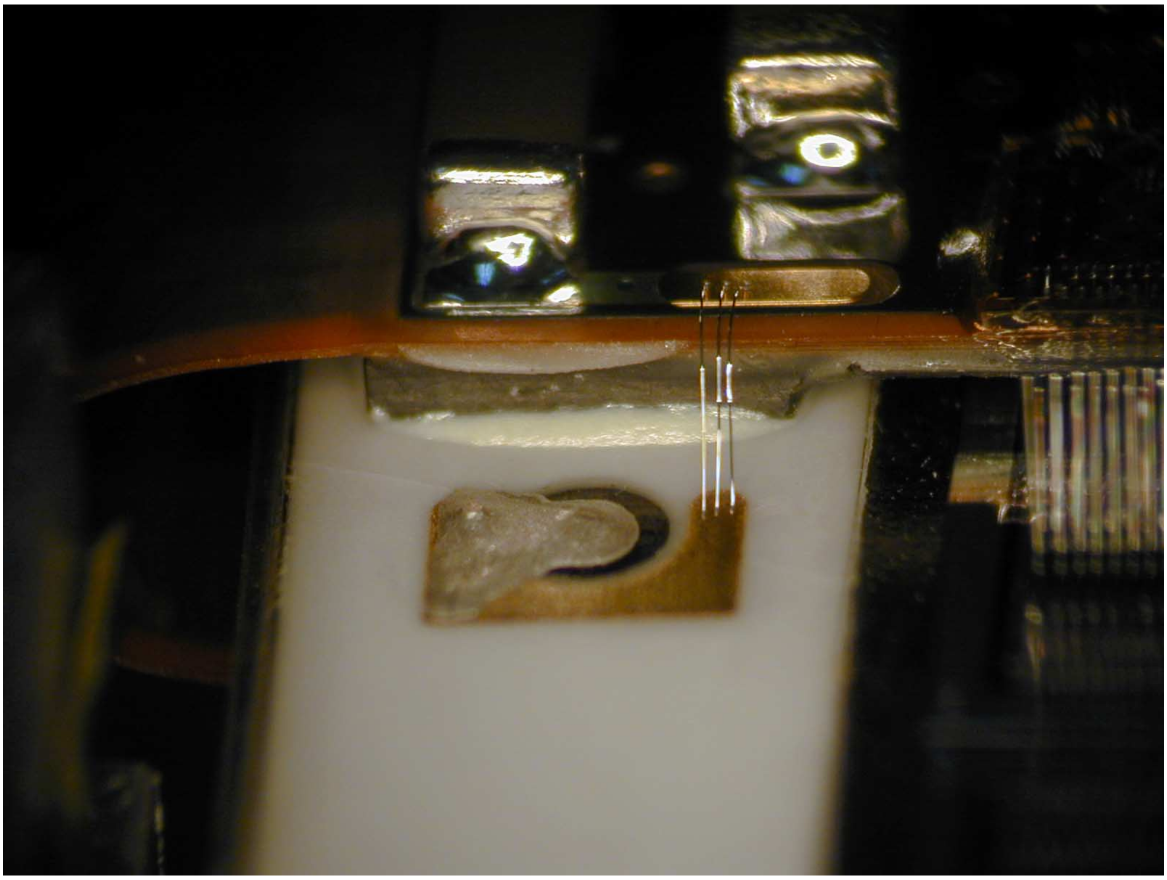

Fig.3. Gluing of hybrid foot f3 (top, far, left) of the module 20220170200018

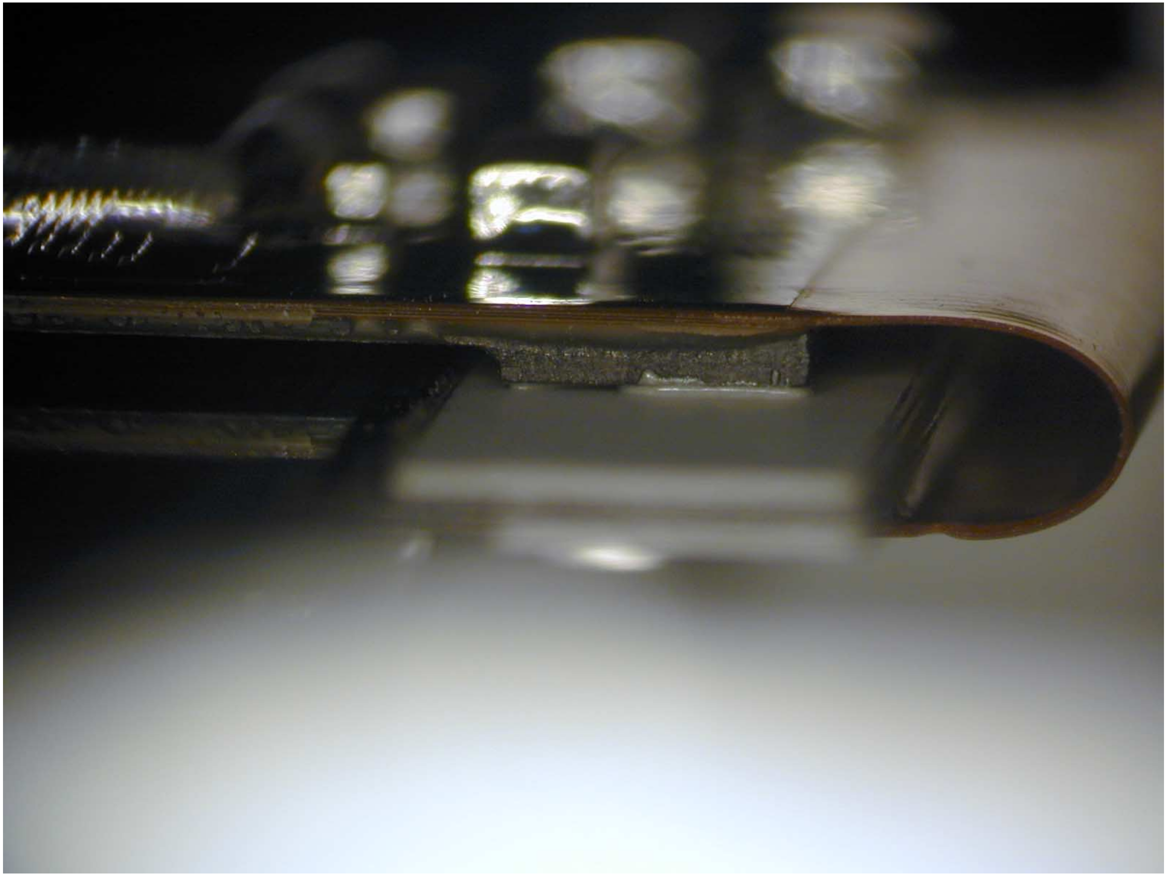

Fig.4. Gluing of hybrid foot f4 (top, far, right) of the module 20220170200018

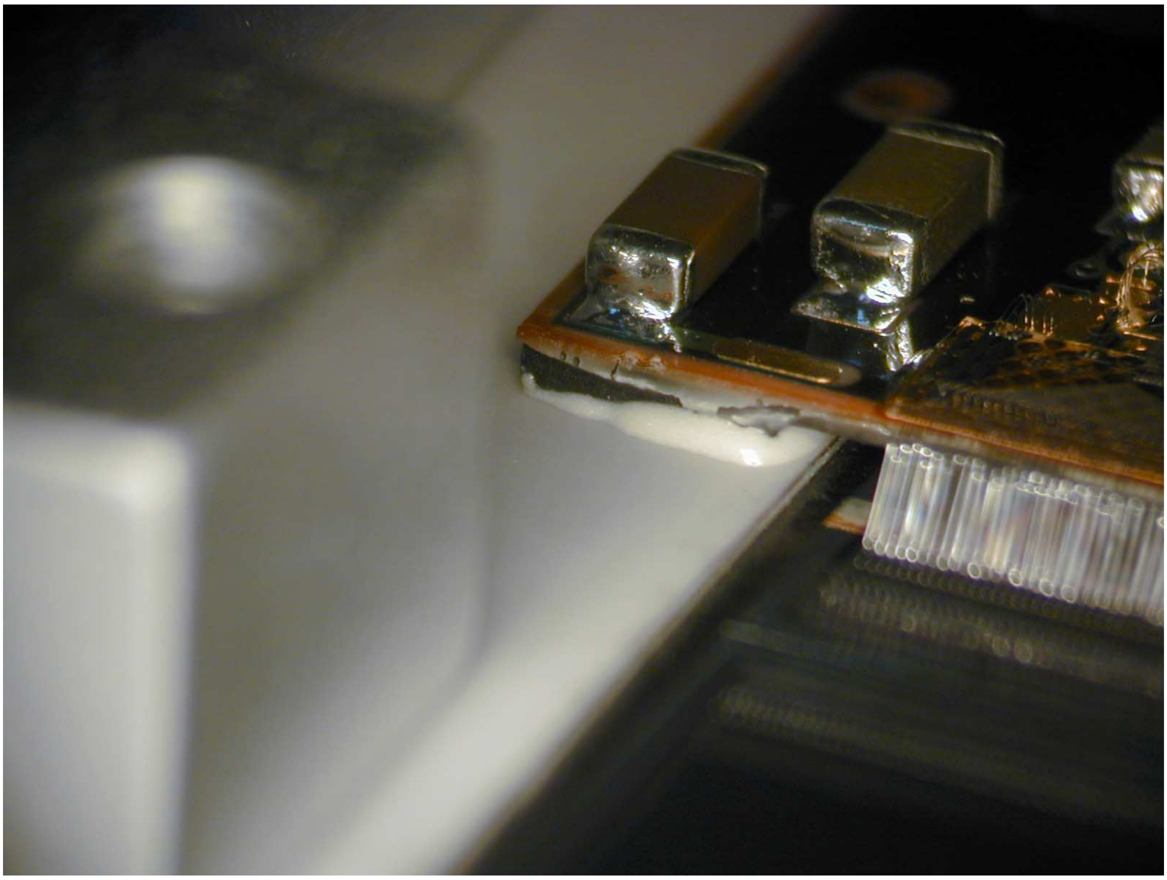

Fig.5. Gluing of hybrid foot b1 (bottom, near, left) of the module 20220170200018

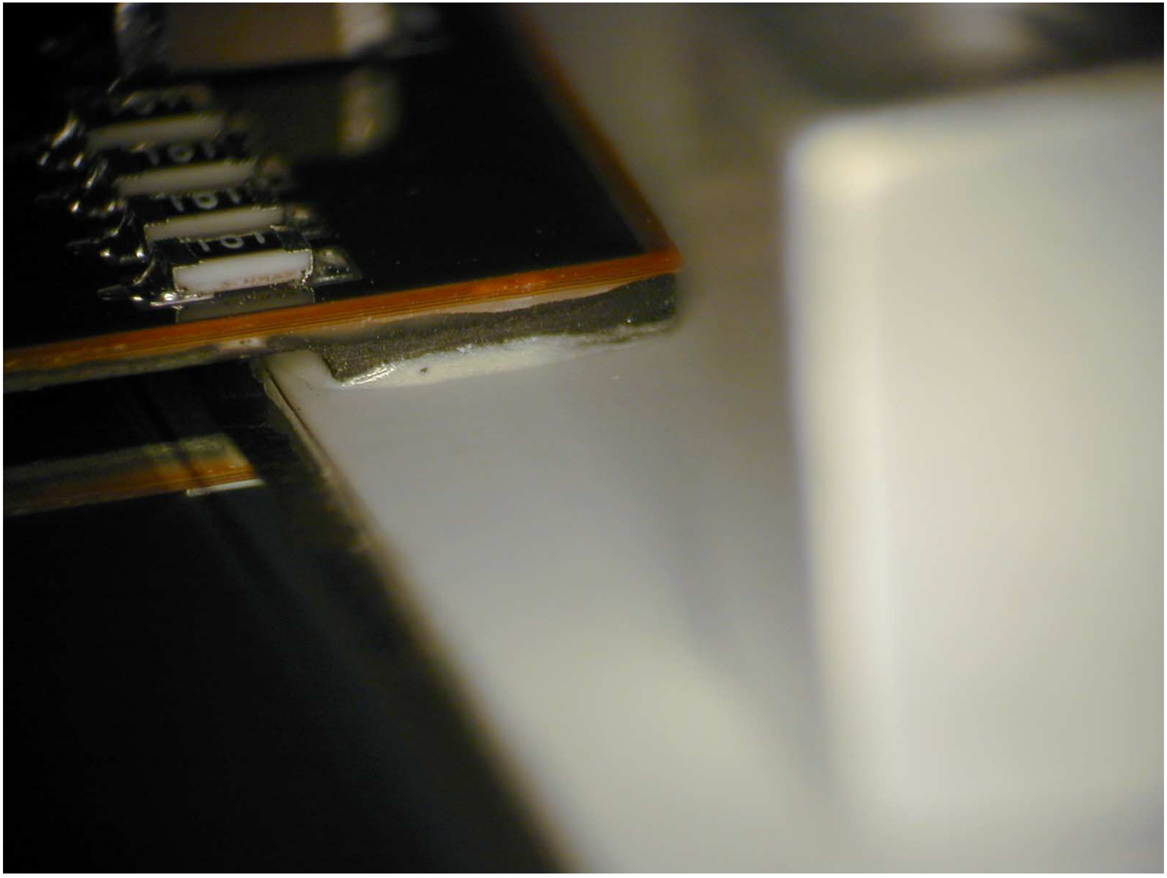

Fig.6. Gluing of hybrid foot b2 (bottom, near, right) of the module 20220170200018

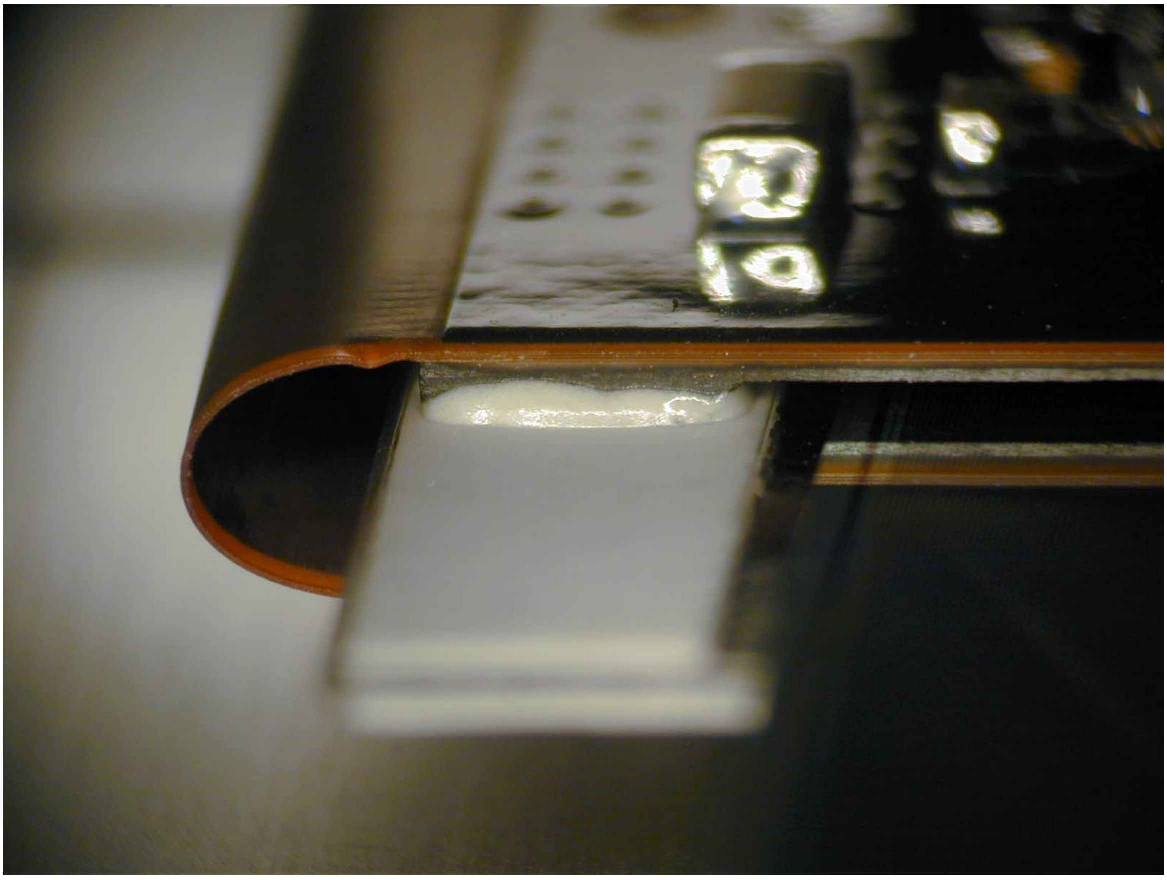

Fig.7. Gluing of hybrid foot b4 (bottom, far, right) of the module 20220170200018

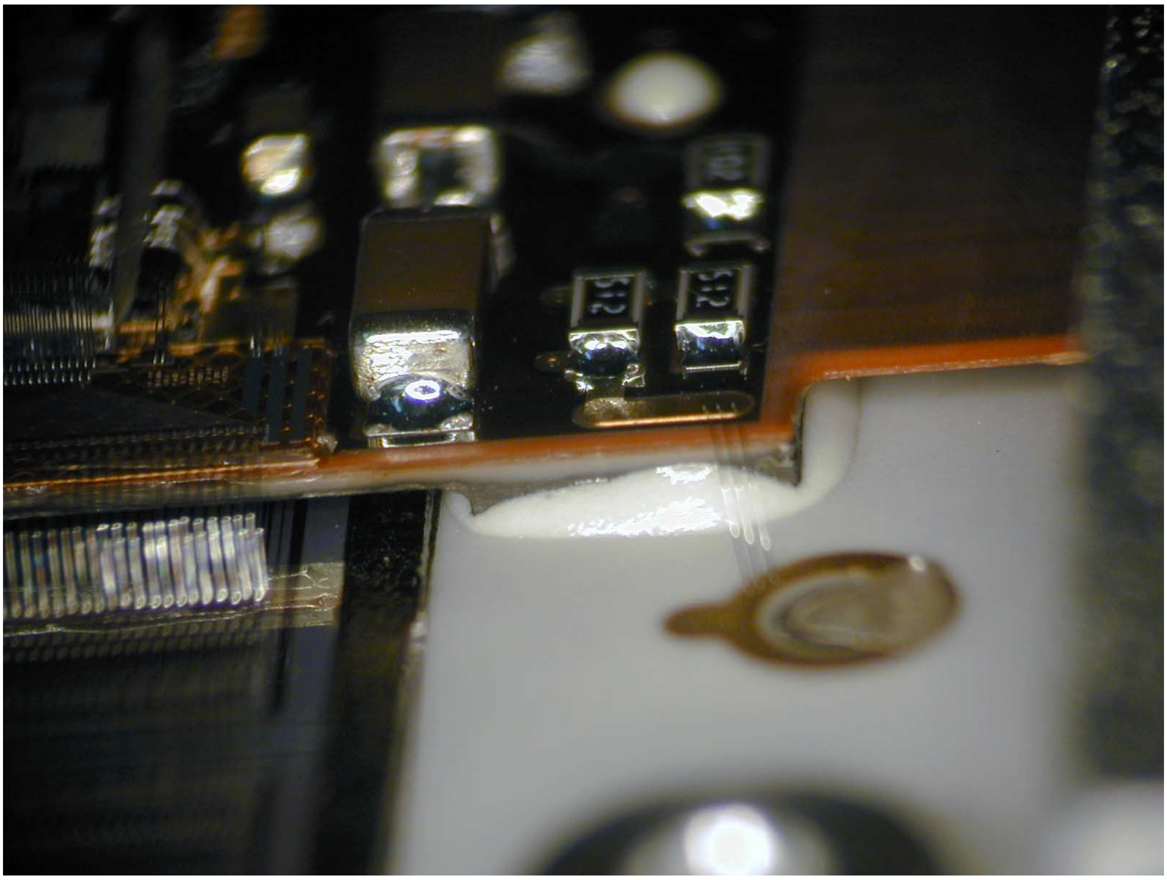

Fig.8. Gluing of hybrid foot f1 (top, near, left) of the module 20220170200043

Fig.9. Gluing of hybrid foot f2 (top, near, right) of the module 20220170200043

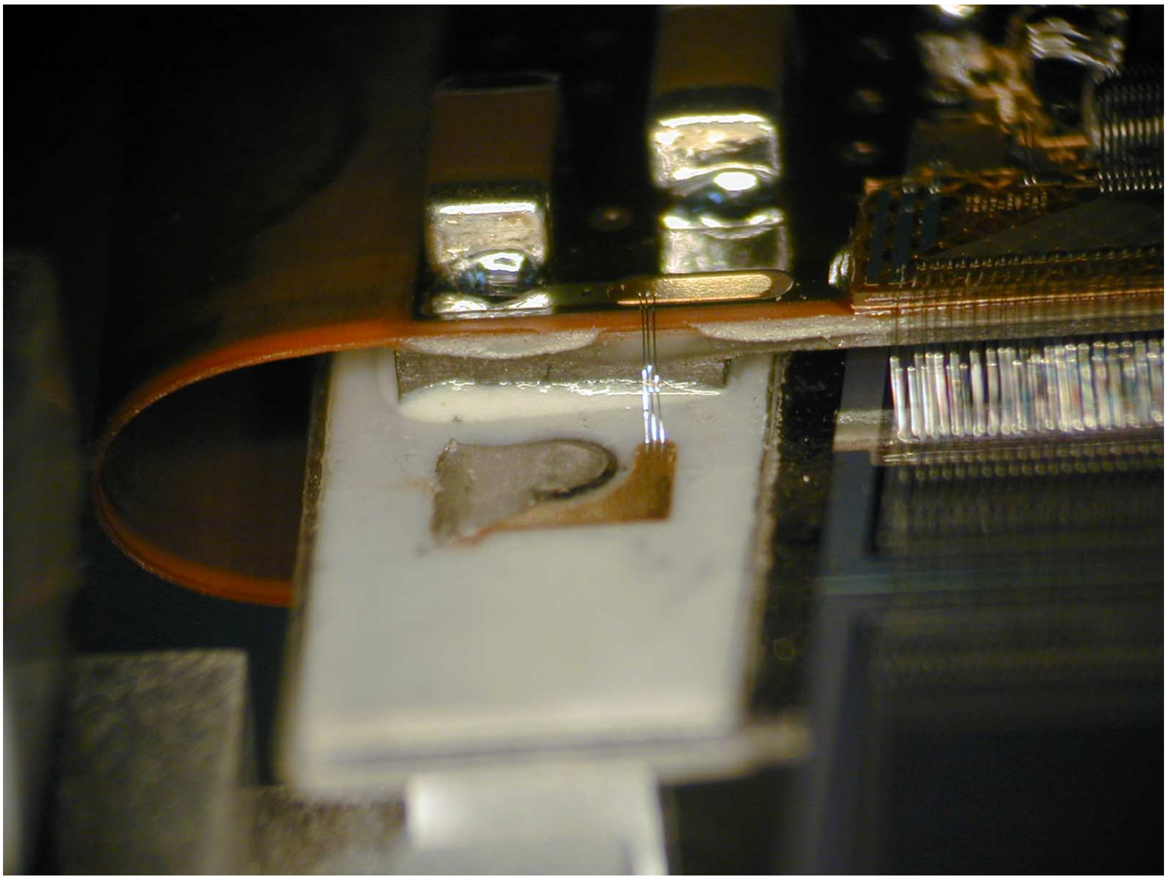

Fig.10. Gluing of hybrid foot f3 (top, far, left) of the module 20220170200043

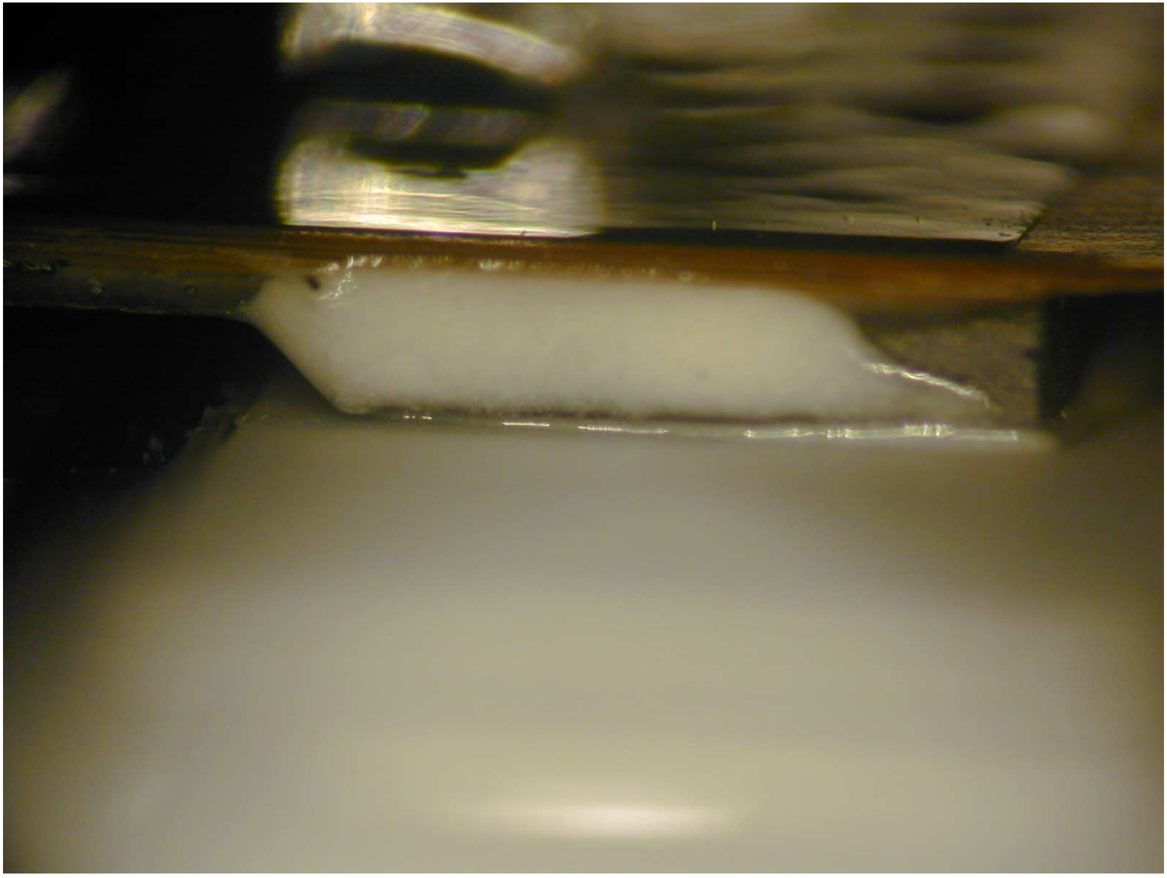

Fig.11. Gluing of hybrid foot f4 (top, far, right) of the module 20220170200043

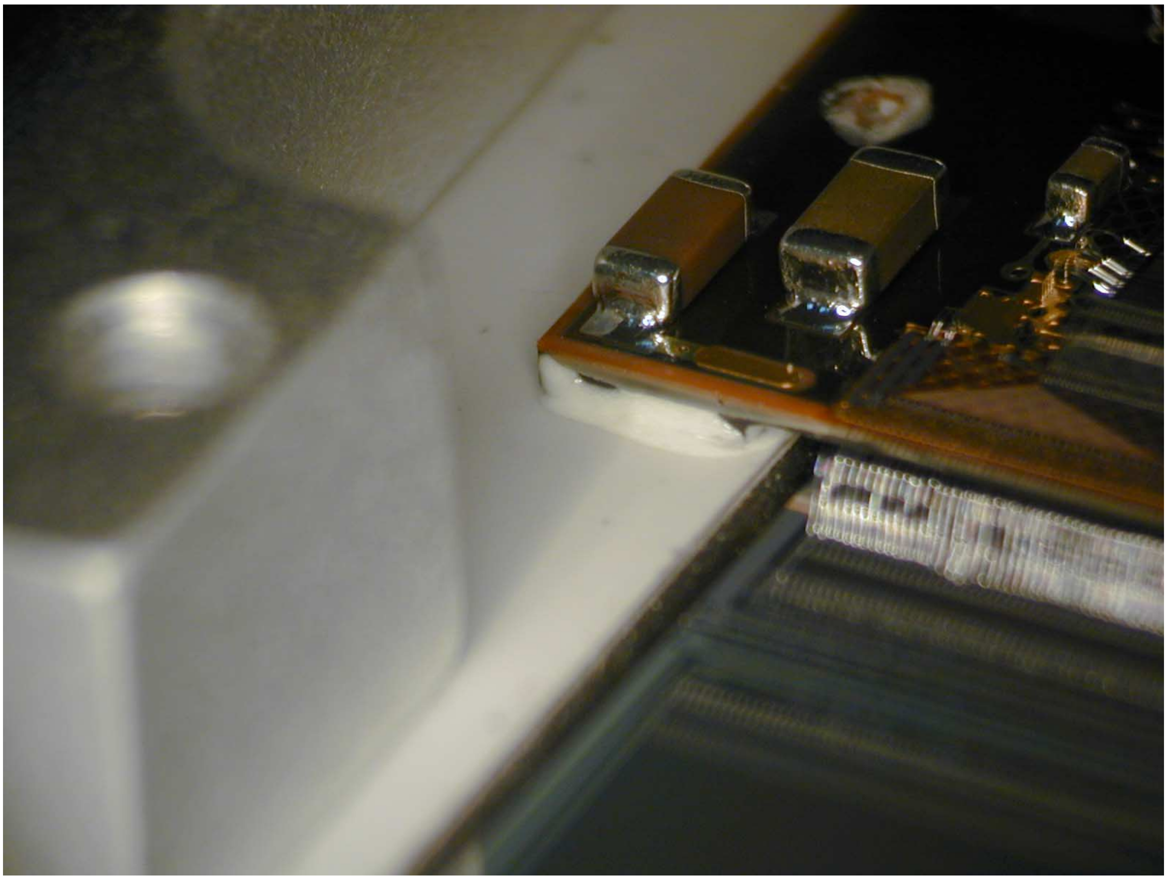

Fig.12. Gluing of hybrid foot b1 (bottom, near, left) of the module 20220170200043

Fig.13. Gluing of hybrid foot b2 (bottom, near, right) of the module 20220170200043

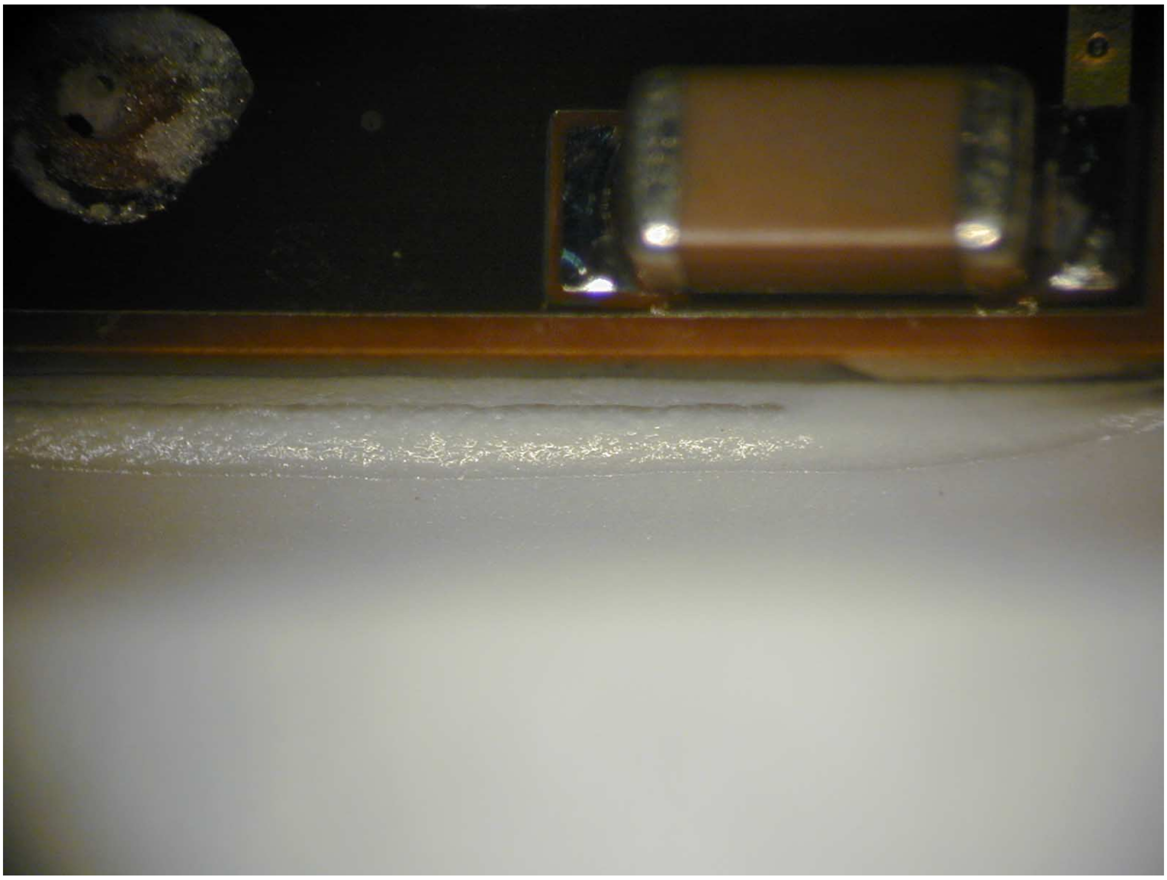

Fig.14. Gluing of hybrid foot b2 (bottom, near, along strips) of the module 20220170200043

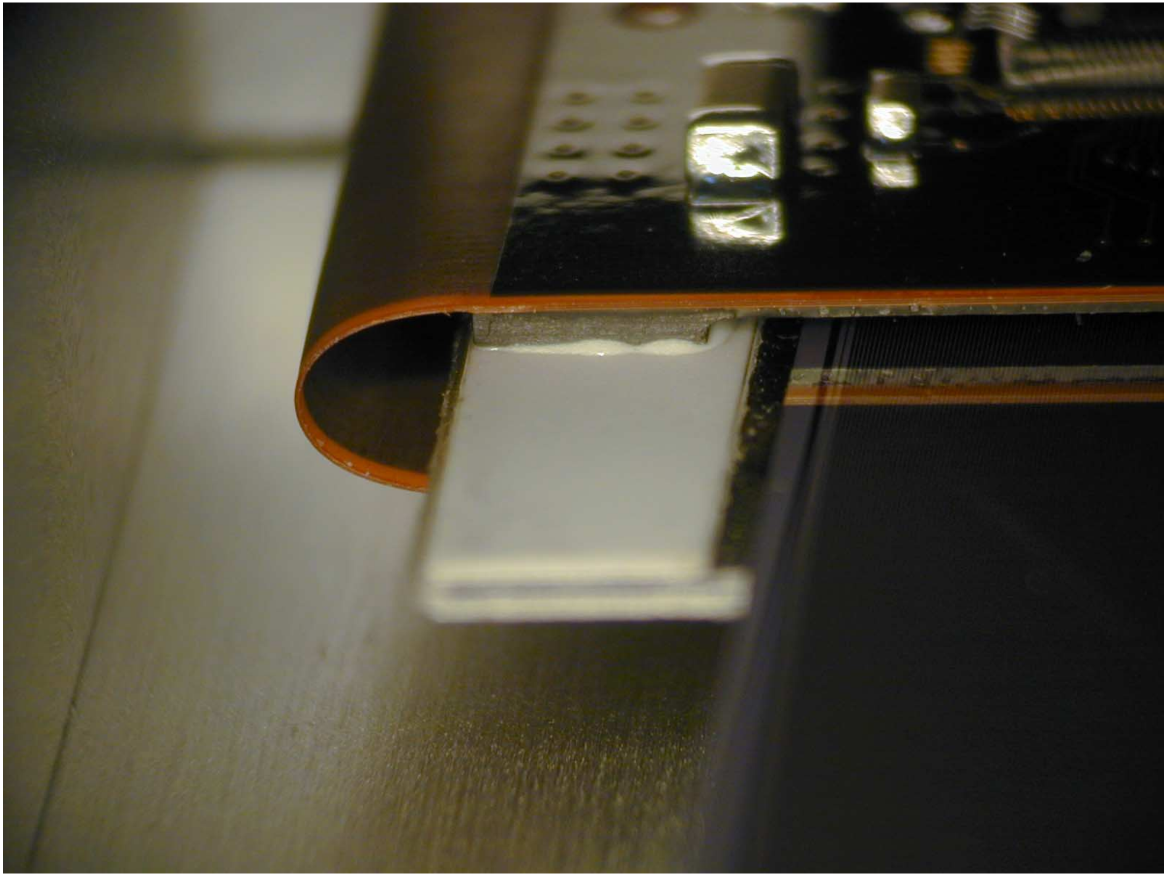

Fig.15. Gluing of hybrid foot b4 (bottom, far, right) of the module 20220170200043

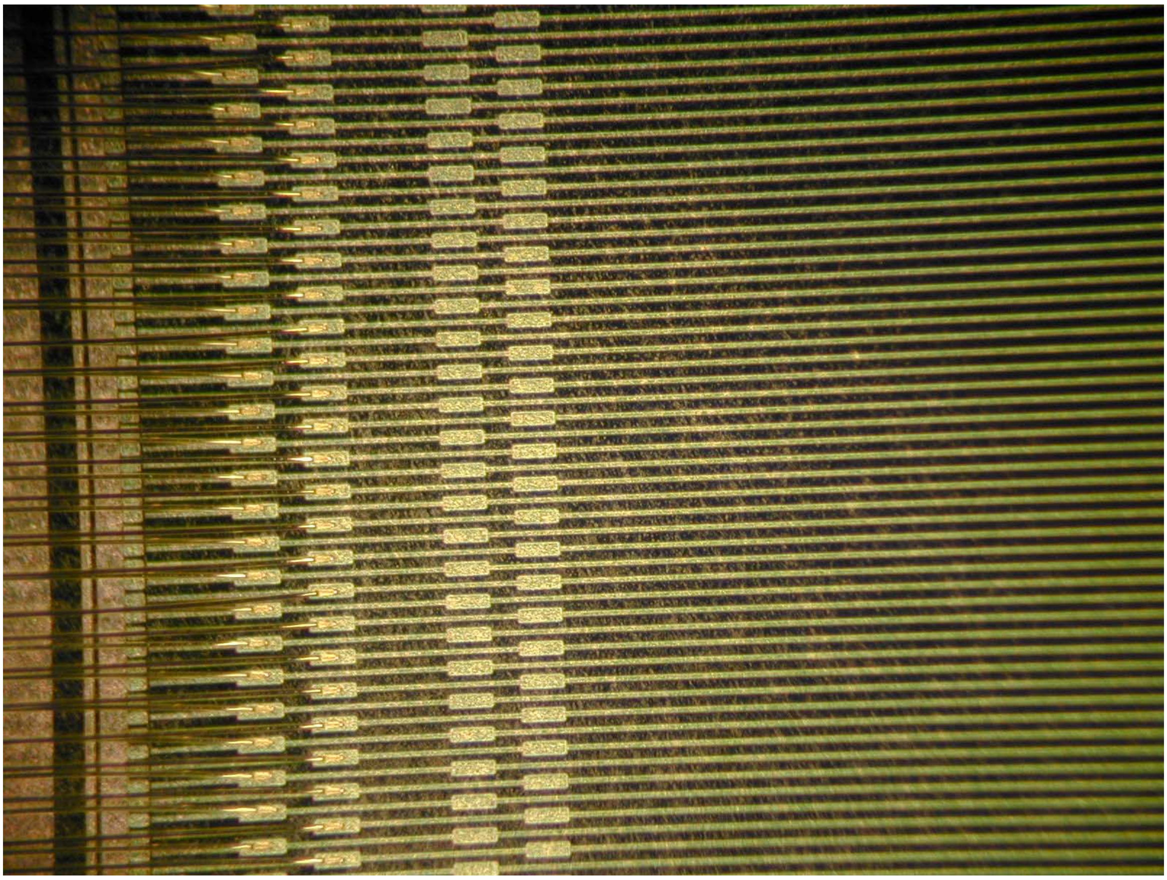

Fig.16. Stains in the module 018

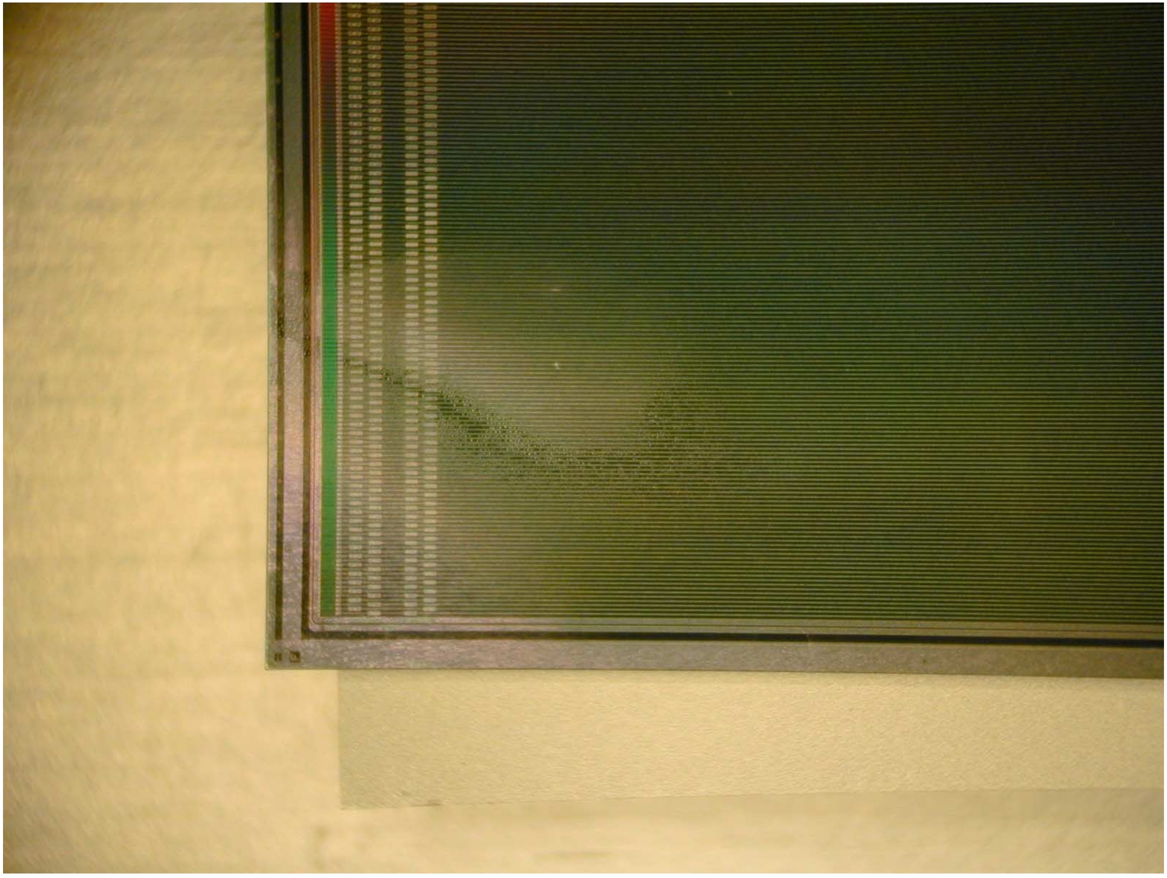

Fig.17. Other stains in the module 018

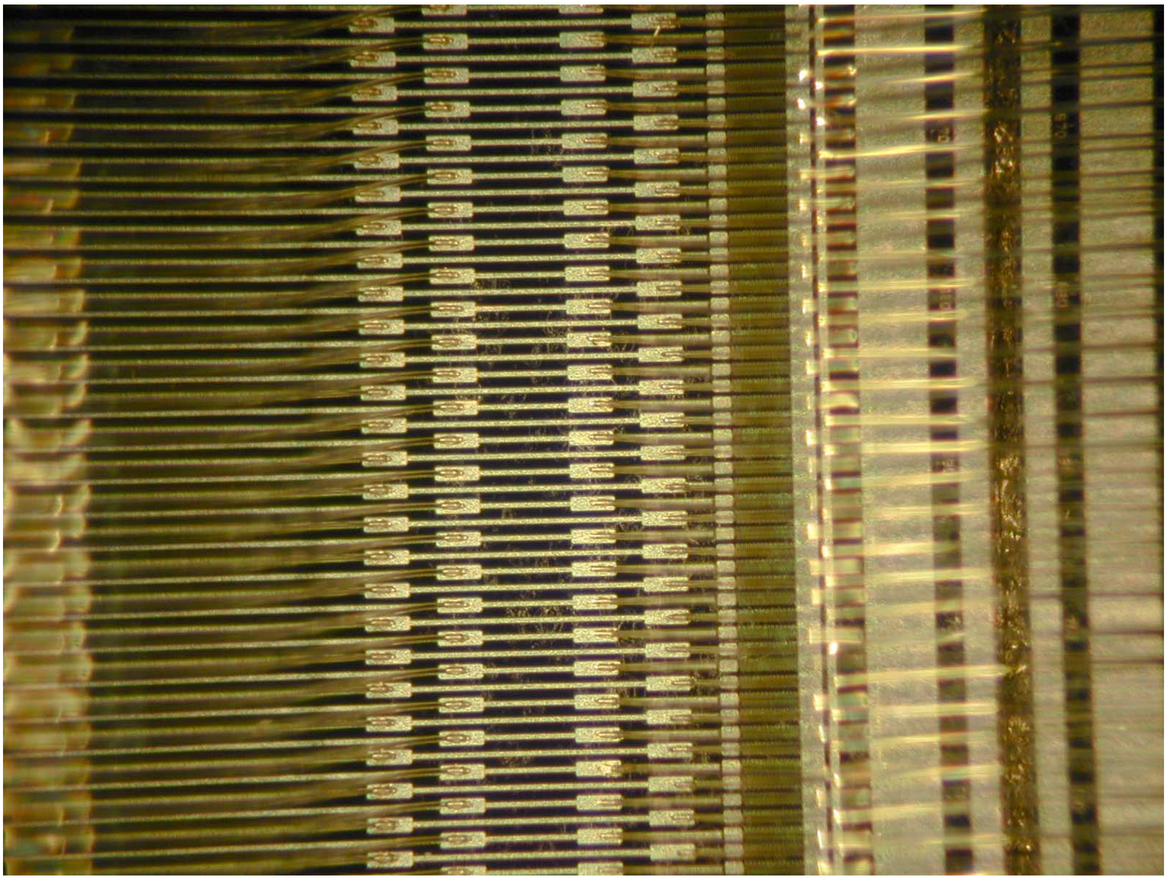

Fig.18. Stains in the module 043

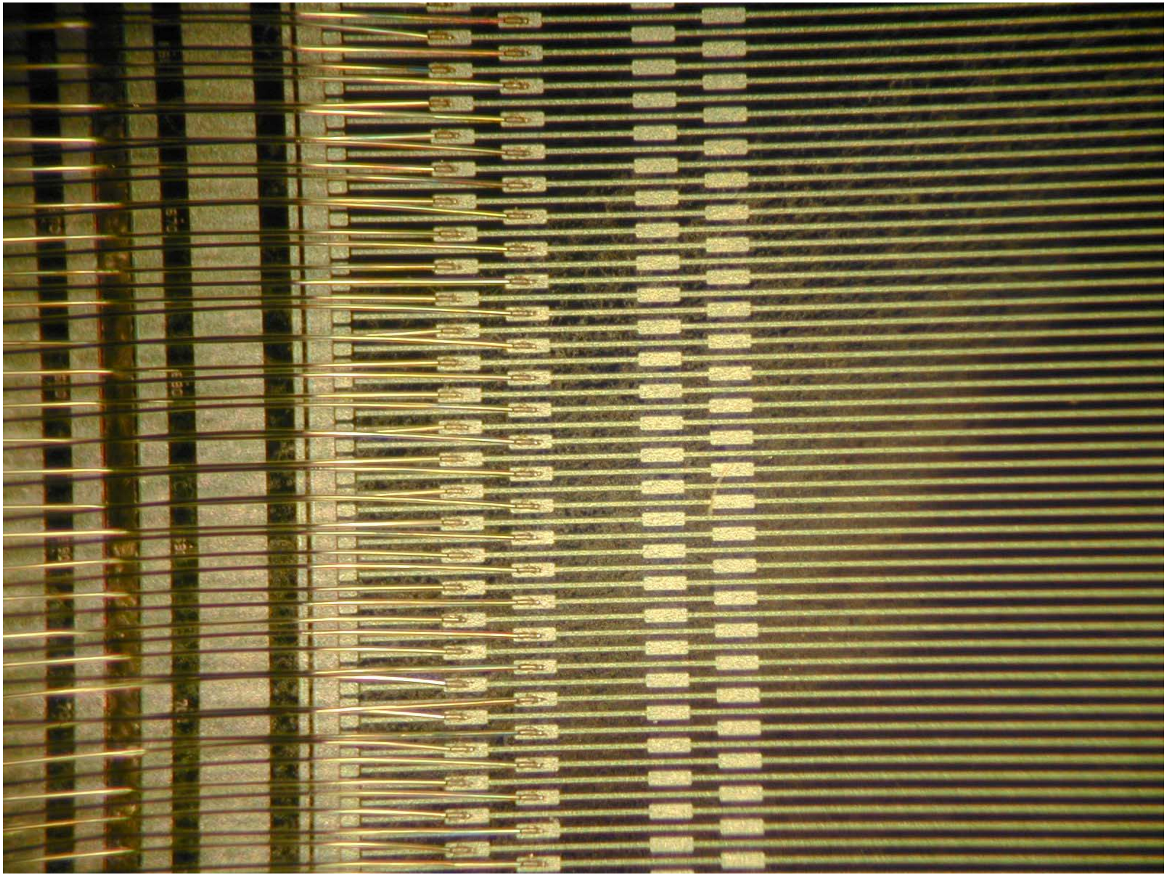

Fig.19. Similar but other stains in the module 043

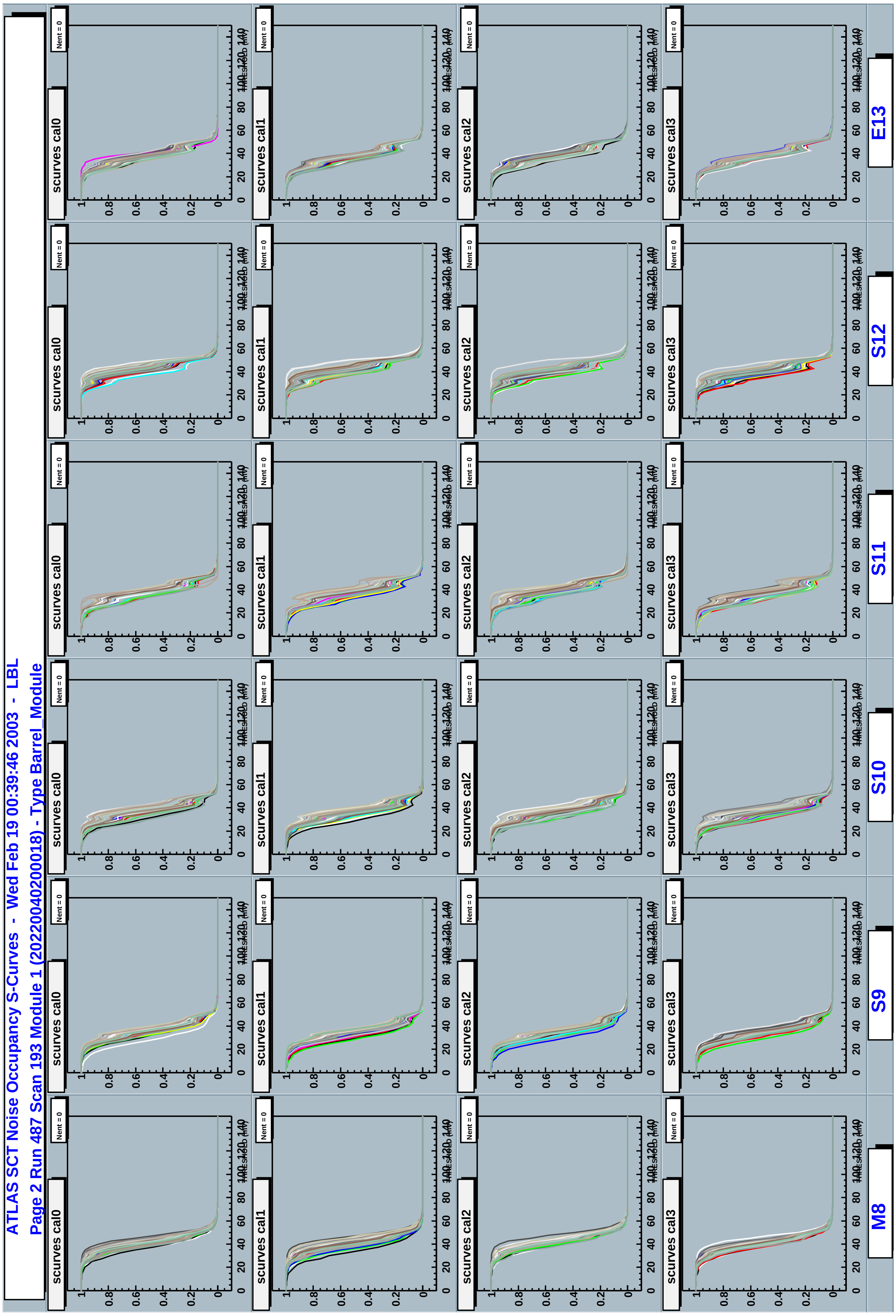

Fig.20. Module 018 NO s-curves link1 (US)

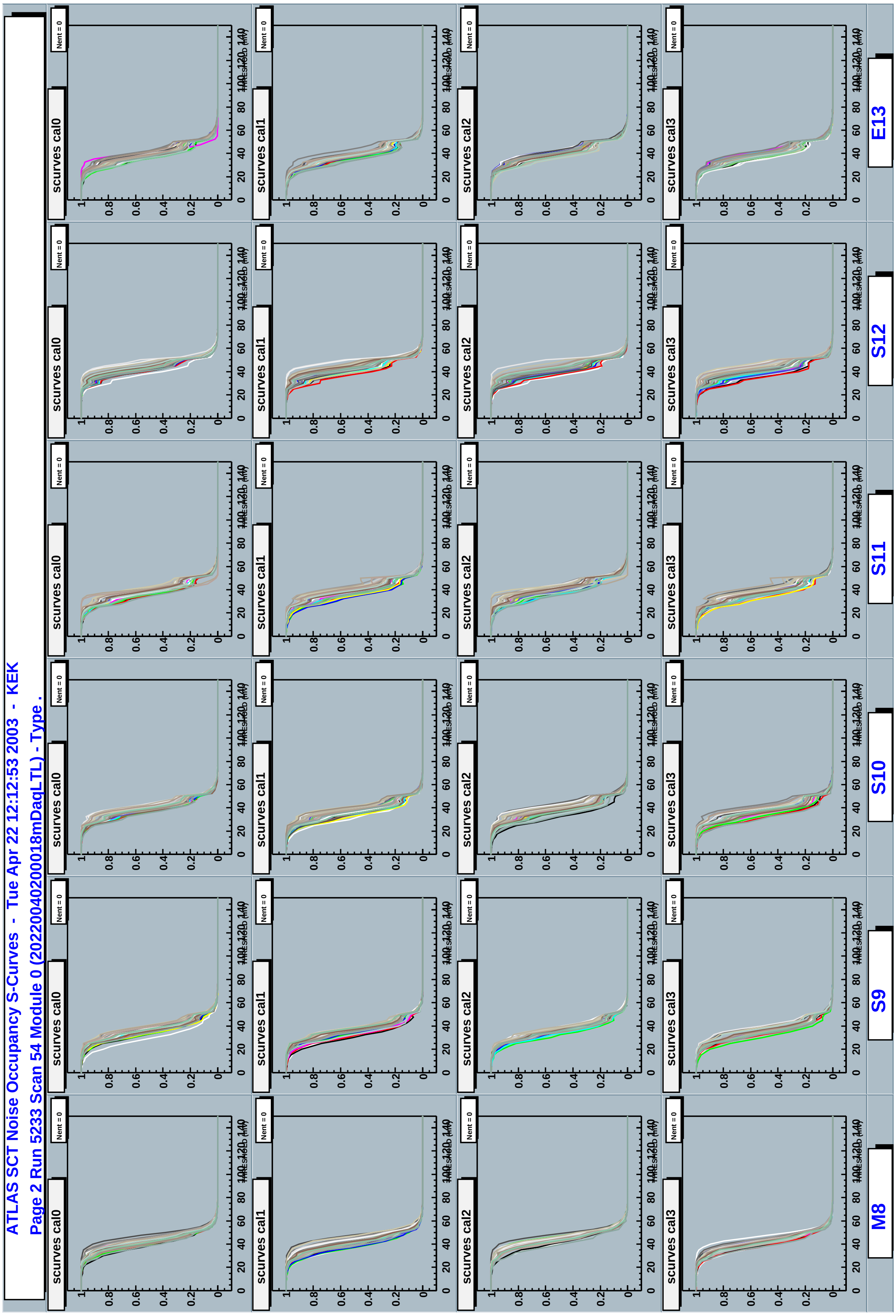

Fig.21.   Module 018 NO s-curves llink1 (KEK)

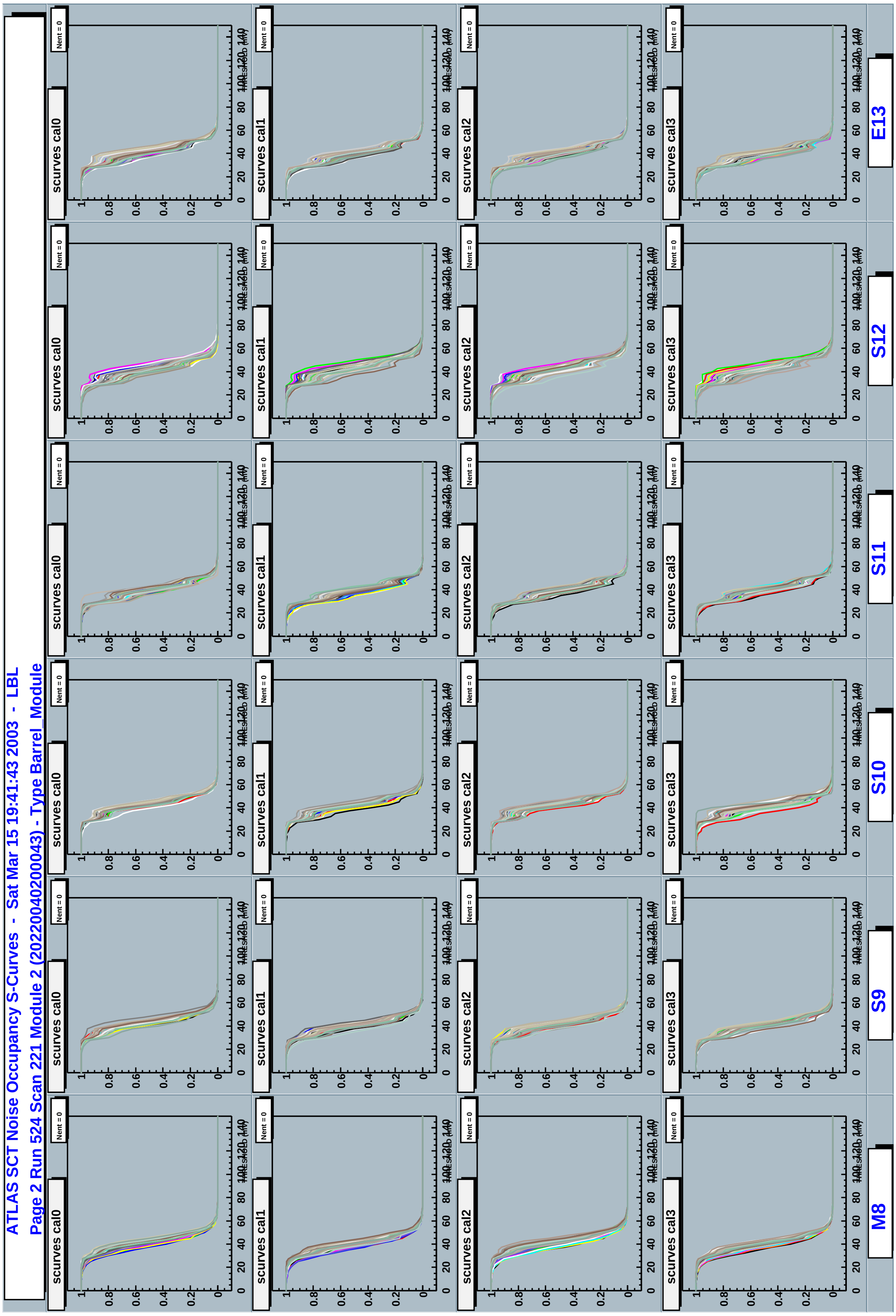

Fig.22. Module 043 NO s-curves link1 (US)

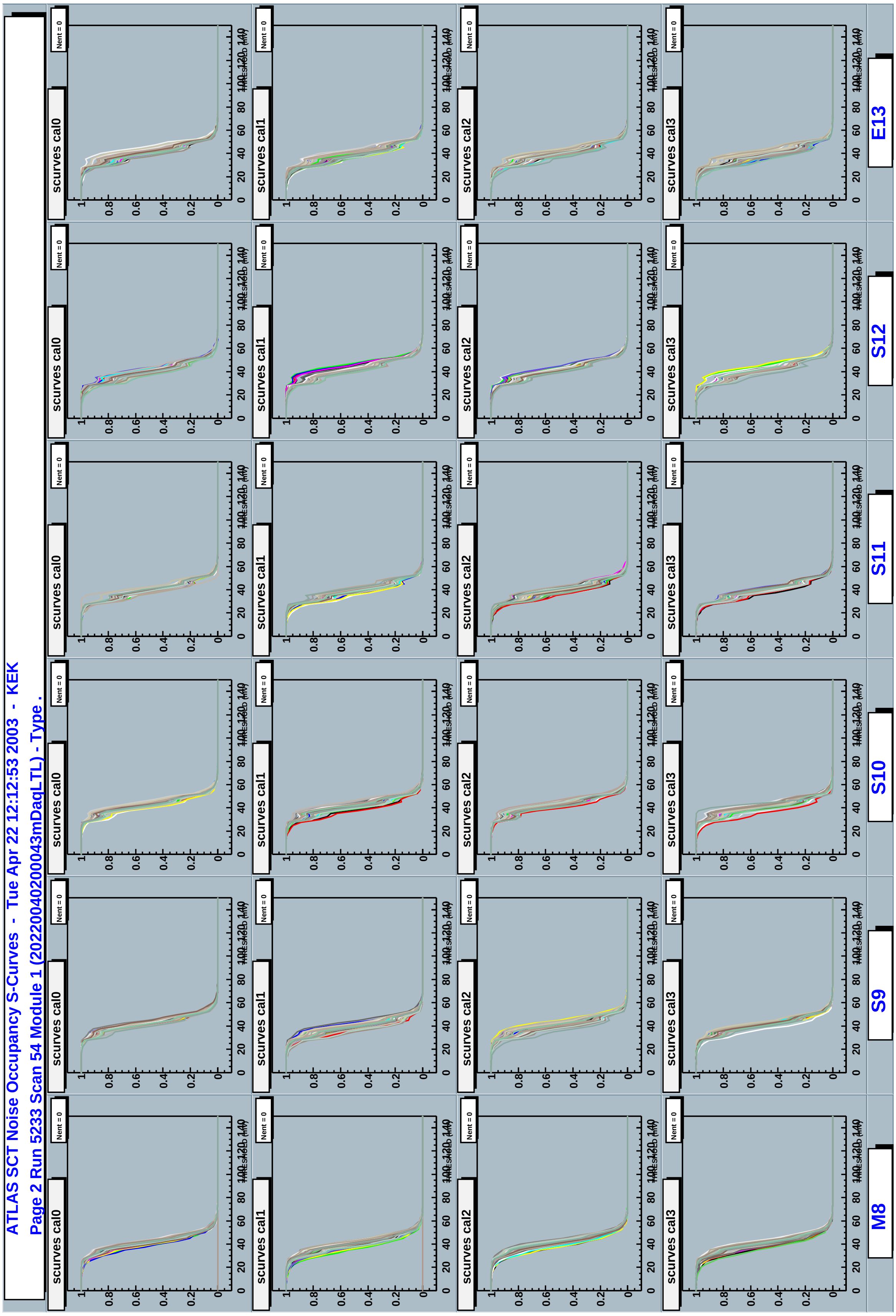

Fig.23. Module 043 NO s-curves llink1 (KEK).

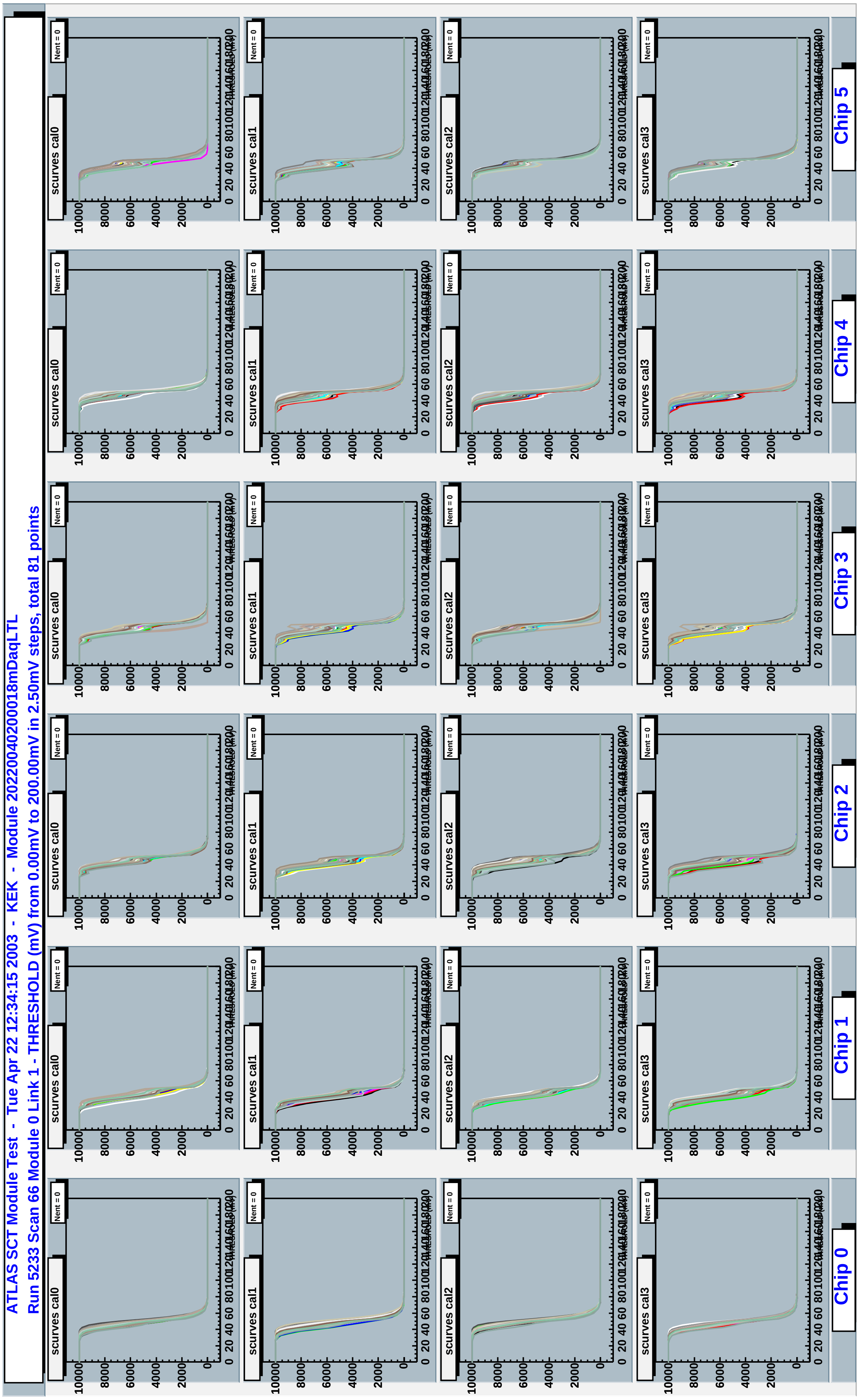

Fig.24. Module 018 Noise scan s-curves (KEK). Note the full scale is 200 mV in horizontal axis

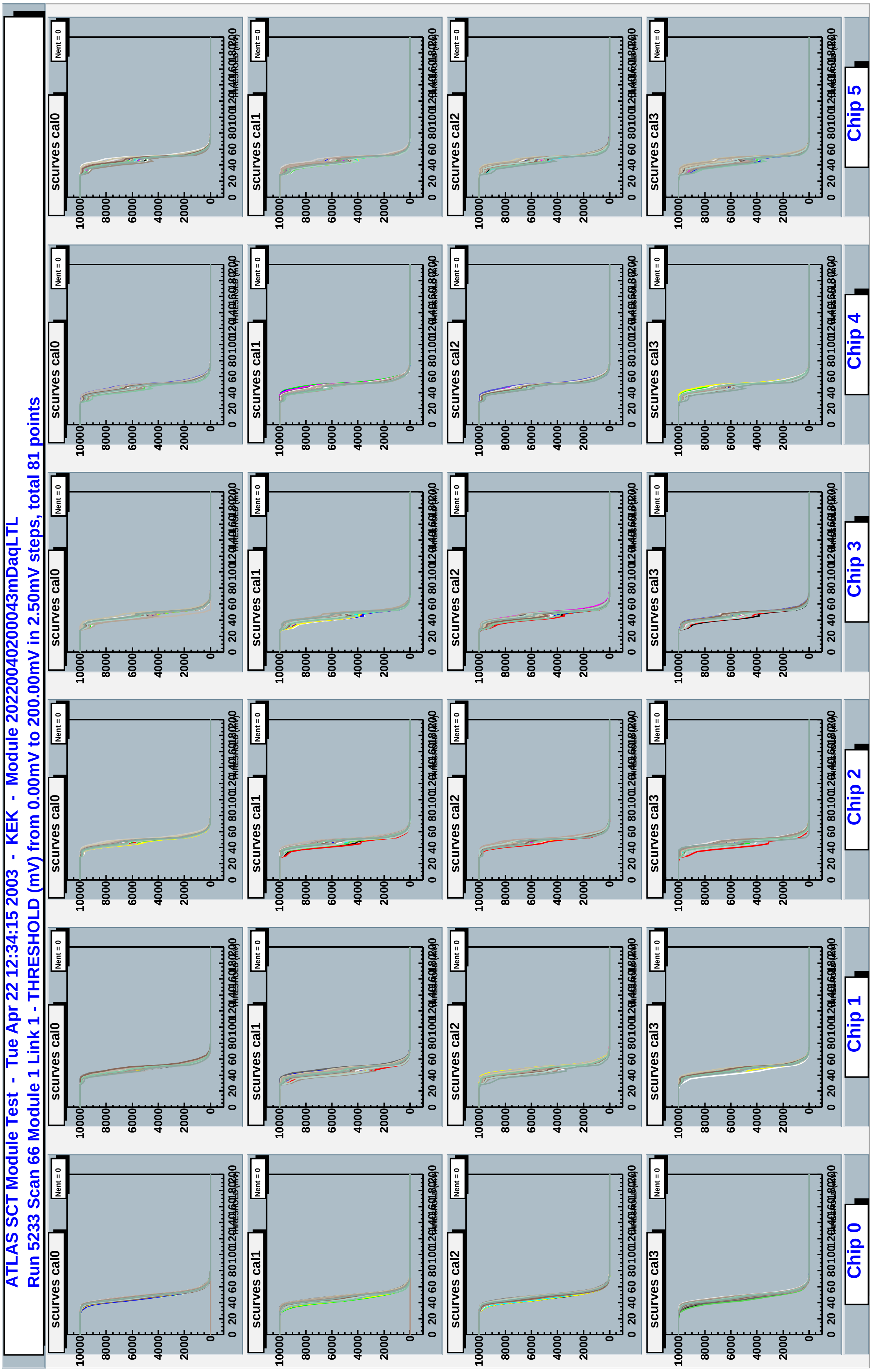

Fig.25. Module 043 Noise scan s-curves (KEK). Note the full scale is 200 mV in horizontal axis