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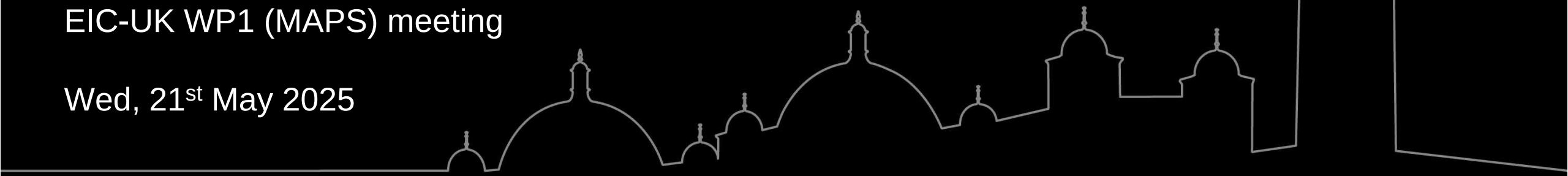
Wire bonding to LTU FPCs

James Glover

EIC-UK WP1 (MAPS) meeting

Wed, 21st May 2025

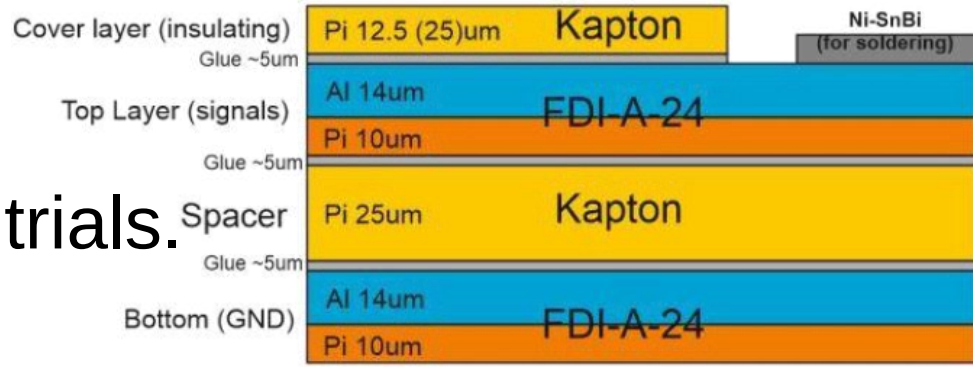


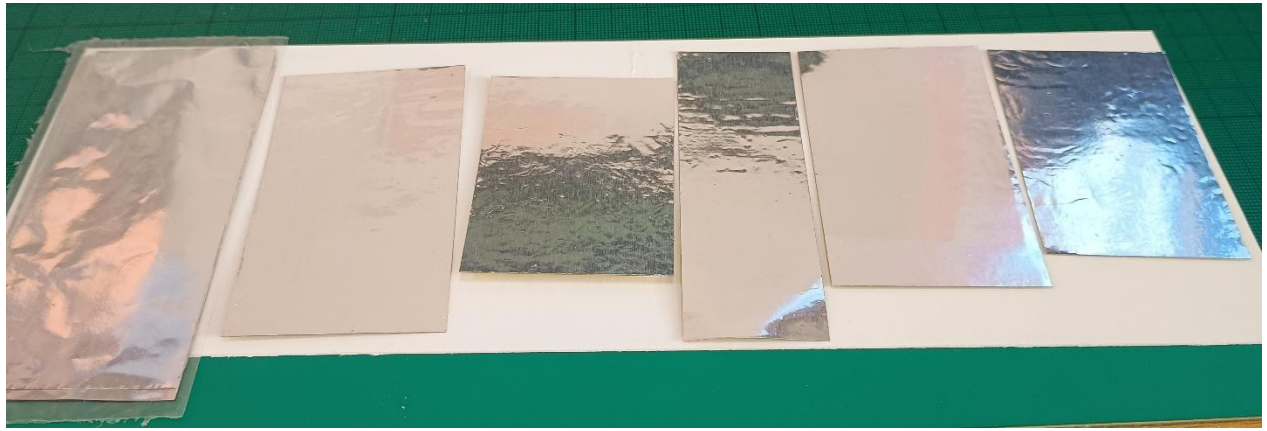
Wire bond samples

We received samples from LTU to trial wire wire bonding (and perform pull tests on).

Samples also share with Liverpool for these trials.

- Single Al foil layer: LTU-15-10
- Dual Al foil layers: LTU-15-10 + 25µmKapton + LTU-15-10





Initial findings from Liverpool were reported at the last Electrical Interfaces Meeting.

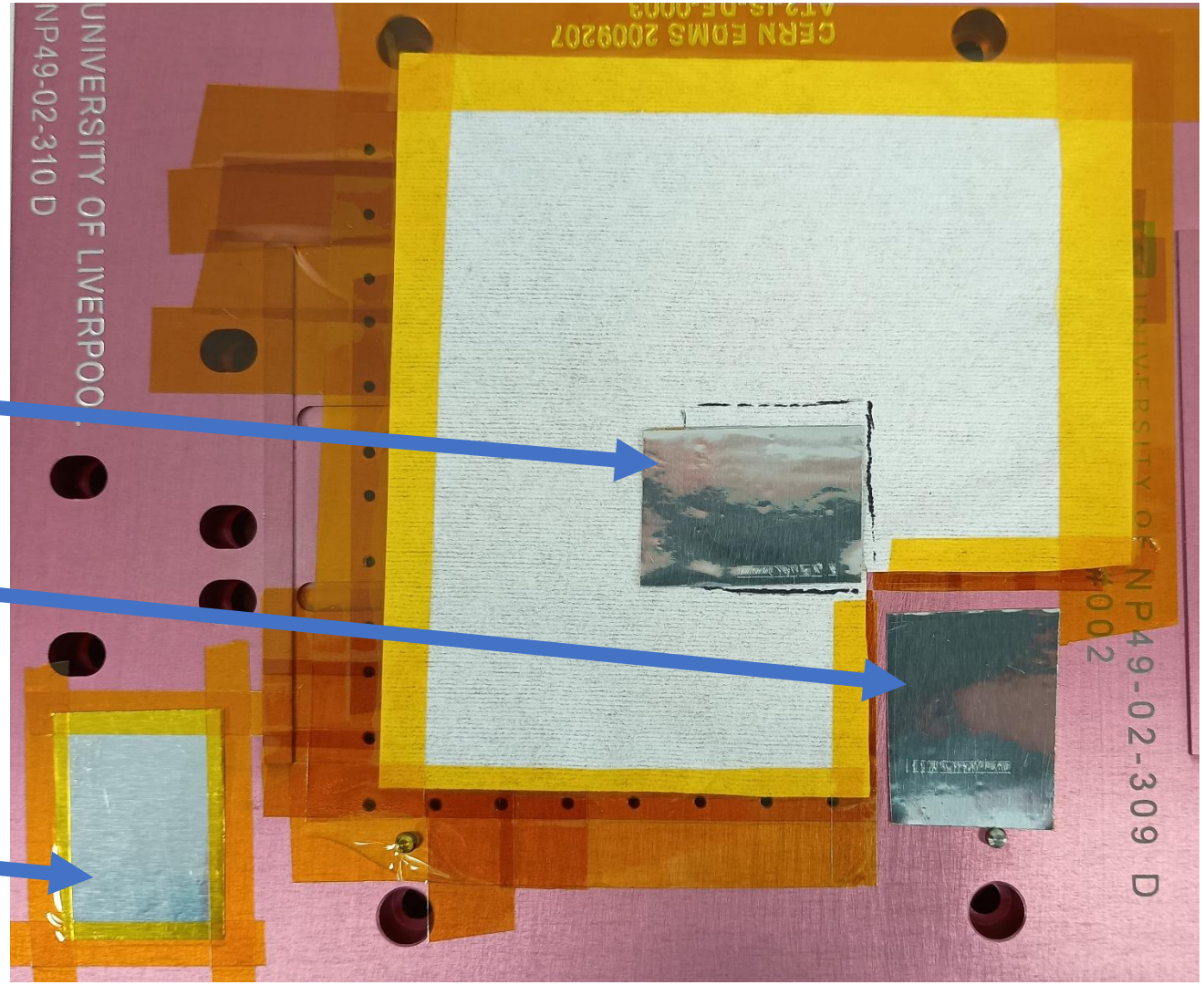
Mounting options

No samples have been cleaned for these tests

Focussed on Dual Al foil layers (LTU-15-10 + 25μmKapton + LTU-15-10) for 1st trials.

3 mounting options considered:

- Vacuumed with a diffuser.
- Vacuumed directly to jig (naked).
- Taped flat.



Material considerations

Liverpool showed that wire bonding onto this Al foils behaves very differently that to a standard PCB/silicon chip.

- Had to adjust bond parameters just to get wire to weld.
- Even then results were inconsistent.
- However, did show that good welds can occur.

PCBs (typically) have thin metallisation on thick (FR4) substrate.
ASICs (typically) have thin metallisation on silicon substrate.

- The metallisation can be similar to that on these foils (~15 µm Al).
- The substrate are very rigid* compared to these foils (<50 µm Kapton).

* For silicon >100 µm thick.

Soft substrates

Had to rethink the bond parameters due to these more flexible substrates. Many parameters are optimised for rigid substrates(with soft wire):

- Touchdown force (cN) – how much resistance the tool receives to known it has made contact.
- Overtravel (µm) – how far the tool is pushed into the substrate after making contact.
- Bond force (cN) – how much extra the tool pushes while welding.
- Deformation (%) – how much the wire should change before welding is complete.

How much is one compacting the substrate, rather than the wire?

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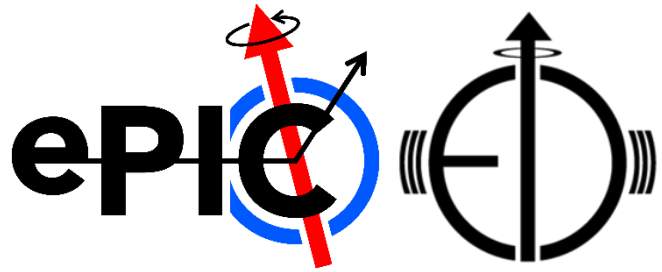
Wire bond trials

No samples have been cleaned for these tests



Initial settings (standard PCB) fail to get successful welds.

Lowering TF+BF, while increasing Def had little effect.

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
18	35	20	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	24	50	25	90	CCC	w. grain	Taped	9	6.99	1.80	0	0	0	5	4
									Vac'd (naked)	3	4.94	0.80	0	0	0	3	0
									Vac'd (diff)	4	5.48	0.98	0	0	0	4	0
14	50	16	24	50	25	90	CCC	w. grain	Taped	8	4.74	1.18	0	0	0	8	0
									Vac'd (naked)	3	6.44	0.86	0	0	0	3	0
									Vac'd (diff)	9	6.00	1.91	0	0	0	9	0
14	50	16	24	25	25	90	CCC	w. grain	Taped	9	13.30	1.38	0	0	0	6	3
									Vac'd (naked)	9	14.37	1.68	0	0	0	6	3
									Vac'd (diff)	10	13.12	1.76	0	0	0	3	7
14	50	16	24	25	25	45	Heraeus	w. grain	Taped	8	11.21	1.75	1	2	3	0	2
									Vac'd (naked)	9	13.22	1.37	2	2	3	0	2
									Vac'd (diff)	4	9.61	0.32	0	0	0	4	0
14	50	16	24	25	25	90	Heraeus	w. grain	Taped	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	7	13.45	0.87	3	0	2	2	0
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14	50	16	24	25	25	45	CCC	w. grain	Taped	10	9.65	1.37	9	0	0	0	1
									Vac'd (naked)	10	11.93	0.72	8	0	0	1	1
									Vac'd (diff)	9	10.70	1.82	8	0	1	0	0
14	50	16	24	15	15	45	CCC	w. grain	Taped	10	10.73	2.18	2	1	1	0	6
									Vac'd (naked)	10	11.57	1.74	9	1	0	0	0
									Vac'd (diff)	10	10.02	2.41	10	0	0	0	0
14	50	16	24	13	13	45	CCC	w. grain	Taped	10							
									Vac'd (naked)	9	10.40	1.88	8	1	0	0	0
									Vac'd (diff)	10	9.95	2.27	6	0	0	4	0

Full spreadsheet can be seen here.

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Wire bond trials

No samples have been cleaned for these tests

Additionally increasing US stated to get somewhere.

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
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									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
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16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
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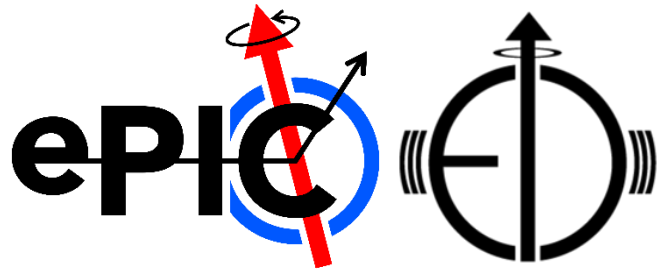

Bonds were done in small groups (of 10 wires).

# of successful wires bonded was a good initial indicator.

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
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									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
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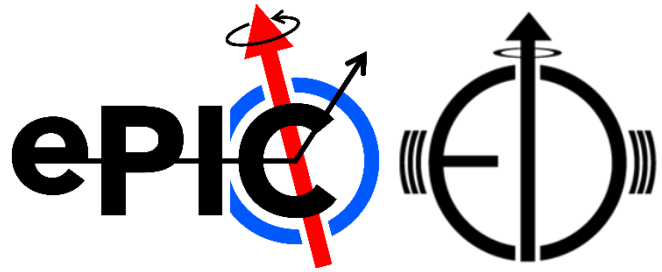

Reducing the (source) overtravel had a large effect!

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
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									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
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16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
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Full spreadsheet can be seen here.

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Wire bond trials

No samples have been cleaned for these tests

Turning overtravel down as far as the bon machine would allow (without bond errors), seemed to the way to go.

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
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									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
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Wire bond trials

No samples have been cleaned for these tests

In general, minimal difference between the mounting variations.

“Taped”, noticeably lifted during pull tests.

Full spreadsheet can be seen here.

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									Vac’d (diff)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac’d (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac’d (diff)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	24	50	25	90	CCC	w. grain	Taped	9	6.99	1.80	0	0	0	5	4
									Vac’d (naked)	3	4.94	0.80	0	0	0	3	0
									Vac’d (diff)	4	5.48	0.98	0	0	0	4	0
14	50	16	24	50	25	90	CCC	w. grain	Taped	8	4.74	1.18	0	0	0	8	0
									Vac’d (naked)	3	6.44	0.86	0	0	0	3	0
									Vac’d (diff)	9	6.00	1.91	0	0	0	9	0
14	50	16	24	25	25	90	CCC	w. grain	Taped	9	13.30	1.38	0	0	0	6	3
									Vac’d (naked)	9	14.37	1.68	0	0	0	6	3
									Vac’d (diff)	10	13.12	1.76	0	0	0	3	7
14	50	16	24	25	25	45	Heraeus	w. grain	Taped	8	11.21	1.75	1	2	3	0	2
									Vac’d (naked)	9	13.22	1.37	2	2	3	0	2
									Vac’d (diff)	4	9.61	0.32	0	0	0	4	0
14	50	16	24	25	25	90	Heraeus	w. grain	Taped	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac’d (naked)	7	13.45	0.87	3	0	2	2	0
									Vac’d (diff)	8	11.44	2.18	4	1	1	2	0
14	50	16	24	25	25	45	CCC	w. grain	Taped	10	9.65	1.37	9	0	0	0	1
									Vac’d (naked)	10	11.93	0.72	8	0	0	1	1
									Vac’d (diff)	9	10.70	1.82	8	0	1	0	0
14	50	16	24	15	15	45	CCC	w. grain	Taped	10	10.73	2.18	2	1	1	0	6
									Vac’d (naked)	10	11.57	1.74	9	1	0	0	0
									Vac’d (diff)	10	10.02	2.41	10	0	0	0	0
14	50	16	24	13	13	45	CCC	w. grain	Taped	10							
									Vac’d (naked)	9	10.40	1.88	8	1	0	0	0
									Vac’d (diff)	10	9.95	2.27	6	0	0	4	0

Reasons for the changes

If the tool pushes too hard, it risks piercing the foil or damaging the Kapton insulating the aluminium layers, therefore:

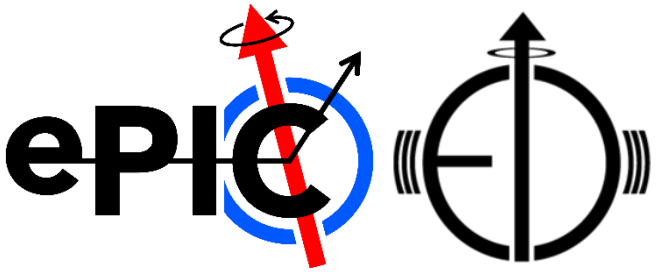
- Minimise touchdown force (TF).
- Minimise bond force (BF).
- Minimise overtravel (OT).

The foil (~15 µm) is thinner than the wire diameter (25 µm), it could melt at a similar point to (or before) the wire, so:

- Increase deformation (Def), to account for deformation of the foil (and not just the wire).

Summary

No samples have been cleaned for these tests



- Further studies on wire bonding to the aluminium foils from LTU have occurred.
- We are seeing some good indications and are determining parameters to focus on for optimising the welds.
- Parameters are not there yet but should be a good starting point.
  - Expecting that the support structure will also play a big part (bonding on a thick aluminium vacuum jig).
  - Noticed some difference with the bonds on the diffused vacuum sample. The clean room paper gave some cushioning and needed more overtravel (14 µm) than the others (13 µm) when very low.

Added bonus – spTAB update

- We have an additional jig from Oxford (thanks)!
  - This version is designed to be James-proof (FPC only fits in the correct orientation).
- We also have the updated PCBs from Andy (thanks)!
  - Now with the the solder resist removed under the FPC to minimise the height different between the aluminium layers of the FPC and the pads of the PCB.

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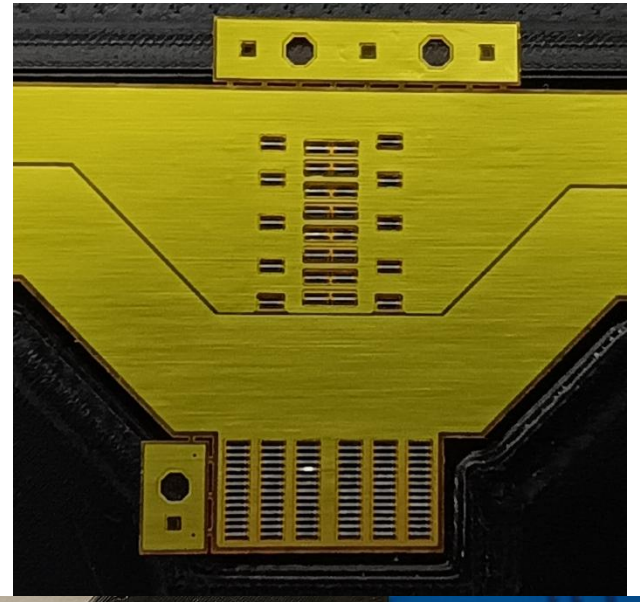
Oxford jig

- Upon inspection, this jig does not have the cut-outs for the B-FPC alignment tabs.
  - Can be solved by cutting off tabs (can only used for FPC for the M-FPC data transmission tests).
- PCB (for the wider, Power/Data IN side) sits too far out and bond pads do not align with the FPC's traces.



Summary – 2

The Oxford jig (in its current form) is not suitable.

- We are looking to modify the designs.
- Fallback would be to return to the previous Birmingham jig.

Considerations for mounting and bond the 2nd version of the M-FPC is ongoing. Considerations between:

- Bonding while FPC is held by a weight only (and holding with a bead of glue, around edges, after bonding).
- Holding FPC with glue dots for bonding (and adding more glue afterwards).

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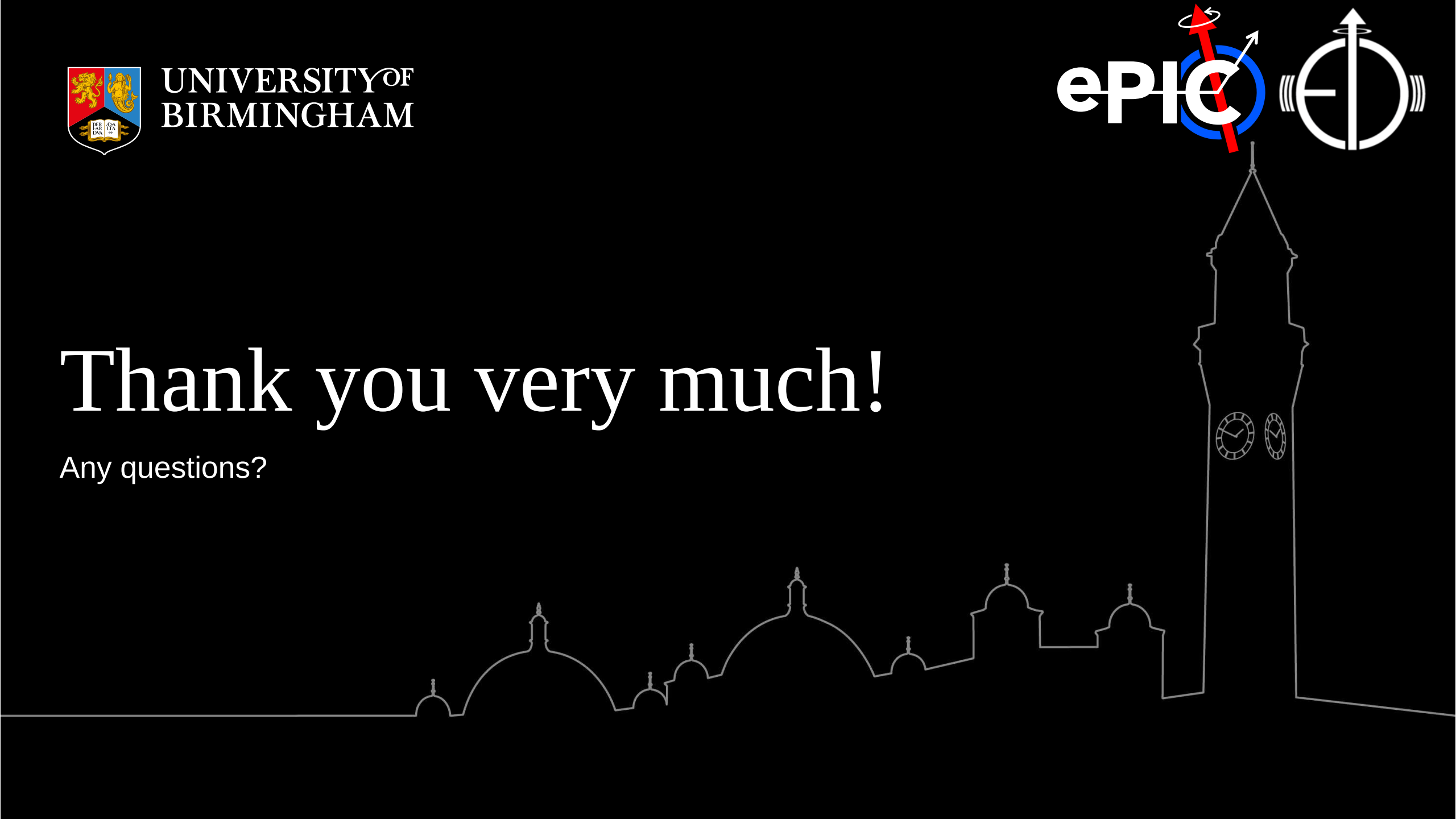
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ePIC
Thank you very much!
Any questions?

Additional (support) slides

Spreadsheet definitions

TF= Touchdown Force (cN)
Def= Deformation (%)
BF= Bond Force (cN)
US= Ultrasonic Power (%)
S_OT= Source Overtravel (µm)
D_OT= Destination Overtravel (µm)
LeaveAng= Leave Angle (°), 90° = perpendicular to surface
Heraeus= Hersaeus AlSi-M, Aluminiun+1%Silicon wire (medium strength), 25 µm, >1% elongation, 15-17cN Breaking Load (installed to the Right-hand wire bonder in BILPA)
CCC= Custom Chip Connections CC-250, Aluminiun+1%Silicon wire (medium strength), 25 µm, 1-4% elongation, 15-18g Tear Strength (installed to the Left-hand wire bonder in BILPA)
w. grain= With the grain of the Al foil
a. grain= Against the grain of the Al foil
Taped= Foil taped down (all 4 sides) to chuck.
Vac'd (naked)= Foil vacuumed to chuck, nothing in between chuck and foil.
Vac'd (diff)= Foil vacuumed to chuck, with clean room paper as a diffuser between chuck and foil.
#/10= # of pullable wires, out of a maximum of 10 wire attempts
# of S_b(1)= # of Source heel breaks (failure mode: "1")
# of D_b(2)= # of Destination heel breaks (failure mode: "2")
# of Span(3)= # of Span breaks, centre of wire snaps (failure mode: "3")
# of S_p(4)= # of Source peels (failure mode: "4")
# of D_p(5)= # of Destination peels (failure mode: "5")

Wire bond trials

The standard deviation is still higher than preferred.

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
18	35	20	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	24	50	25	90	CCC	w. grain	Taped	9	6.99	1.80	0	0	0	5	4
									Vac'd (naked)	3	4.94	0.80	0	0	0	3	0
									Vac'd (diff)	4	5.48	0.98	0	0	0	4	0
14	50	16	24	50	25	90	CCC	w. grain	Taped	8	4.74	1.18	0	0	0	8	0
									Vac'd (naked)	3	6.44	0.86	0	0	0	3	0
									Vac'd (diff)	9	6.00	1.91	0	0	0	9	0
14	50	16	24	25	25	90	CCC	w. grain	Taped	9	13.30	1.38	0	0	0	6	3
									Vac'd (naked)	9	14.37	1.68	0	0	0	6	3
									Vac'd (diff)	10	13.12	1.76	0	0	0	3	7
14	50	16	24	25	25	45	Heraeus	w. grain	Taped	8	11.21	1.75	1	2	3	0	2
									Vac'd (naked)	9	13.22	1.37	2	2	3	0	2
									Vac'd (diff)	4	9.61	0.32	0	0	0	4	0
14	50	16	24	25	25	90	Heraeus	w. grain	Taped	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	7	13.45	0.87	3	0	2	2	0
									Vac'd (diff)	8	11.44	2.18	4	1	1	2	0
14	50	16	24	25	25	45	CCC	w. grain	Taped	10	9.65	1.37	9	0	0	0	1
									Vac'd (naked)	10	11.93	0.72	8	0	0	1	1
									Vac'd (diff)	9	10.70	1.82	8	0	1	0	0
14	50	16	24	15	15	45	CCC	w. grain	Taped	10	10.73	2.18	2	1	1	0	6
									Vac'd (naked)	10	11.57	1.74	9	1	0	0	0
									Vac'd (diff)	10	10.02	2.41	10	0	0	0	0
14	50	16	24	13	13	45	CCC	w. grain	Taped	10							
									Vac'd (naked)	9	10.40	1.88	8	1	0	0	0
									Vac'd (diff)	10	9.95	2.27	6	0	0	4	0

Full spreadsheet can be seen here.

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Wire bond trials

Some trials performed on a different bond machine, with different wire for comparison.

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
18	35	20	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	24	50	25	90	CCC	w. grain	Taped	9	6.99	1.80	0	0	0	5	4
									Vac'd (naked)	3	4.94	0.80	0	0	0	3	0
									Vac'd (diff)	4	5.48	0.98	0	0	0	4	0
14	50	16	24	50	25	90	CCC	w. grain	Taped	8	4.74	1.18	0	0	0	8	0
									Vac'd (naked)	3	6.44	0.86	0	0	0	3	0
									Vac'd (diff)	9	6.00	1.91	0	0	0	9	0
14	50	16	24	25	25	90	CCC	w. grain	Taped	9	13.30	1.38	0	0	0	6	3
									Vac'd (naked)	9	14.37	1.68	0	0	0	6	3
									Vac'd (diff)	10	13.12	1.76	0	0	0	3	7
14	50	16	24	25	25	45	Heraeus	w. grain	Taped	8	11.21	1.75	1	2	3	0	2
									Vac'd (naked)	9	13.22	1.37	2	2	3	0	2
									Vac'd (diff)	4	9.61	0.32	0	0	0	4	0
14	50	16	24	25	25	90	Heraeus	w. grain	Taped	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	7	13.45	0.87	3	0	2	2	0
									Vac'd (diff)	8	11.44	2.18	4	1	1	2	0
14	50	16	24	25	25	45	CCC	w. grain	Taped	10	9.65	1.37	9	0	0	0	1
									Vac'd (naked)	10	11.93	0.72	8	0	0	1	1
									Vac'd (diff)	9	10.70	1.82	8	0	1	0	0
14	50	16	24	15	15	45	CCC	w. grain	Taped	10	10.73	2.18	2	1	1	0	6
									Vac'd (naked)	10	11.57	1.74	9	1	0	0	0
									Vac'd (diff)	10	10.02	2.41	10	0	0	0	0
14	50	16	24	13	13	45	CCC	w. grain	Taped	10							
									Vac'd (naked)	9	10.40	1.88	8	1	0	0	0
									Vac'd (diff)	10	9.95	2.27	6	0	0	4	0

Full spreadsheet can be seen here.

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Wire bond trials

Seeing any wire span breaks is impressive.

TF (cN)	Def (%)	BF (cN)	US (%)	S_OT (µm)	D_OT (µm)	LeaveAng (°)	Wire	Direction	Mounting	#/10	Mean (g)	SD (g)	# of S_b(1)	# of D_b(2)	# of Span(3)	# of S_p(4)	# of D_p(5)
18	35	20	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	20	50	25	90	CCC	w. grain	Taped	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (diff)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	50	18	24	50	25	90	CCC	w. grain	Taped	9	6.99	1.80	0	0	0	5	4
									Vac'd (naked)	3	4.94	0.80	0	0	0	3	0
									Vac'd (diff)	4	5.48	0.98	0	0	0	4	0
14	50	16	24	50	25	90	CCC	w. grain	Taped	8	4.74	1.18	0	0	0	8	0
									Vac'd (naked)	3	6.44	0.86	0	0	0	3	0
									Vac'd (diff)	9	6.00	1.91	0	0	0	9	0
14	50	16	24	25	25	90	CCC	w. grain	Taped	9	13.30	1.38	0	0	0	6	3
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									Vac'd (diff)	4	9.61	0.32	0	0	0	4	0
14	50	16	24	25	25	90	Heraeus	w. grain	Taped	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
									Vac'd (naked)	7	13.45	0.87	3	0	2	2	0
									Vac'd (diff)	8	11.44	2.18	4	1	1	2	0
14	50	16	24	25	25	45	CCC	w. grain	Taped	10	9.65	1.37	9	0	0	0	1
									Vac'd (naked)	10	11.93	0.72	8	0	0	1	1
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14	50	16	24	15	15	45	CCC	w. grain	Taped	10	10.73	2.18	2	1	1	0	6
									Vac'd (naked)	10	11.57	1.74	9	1	0	0	0
									Vac'd (diff)	10	10.02	2.41	10	0	0	0	0
14	50	16	24	13	13	45	CCC	w. grain	Taped	10							
									Vac'd (naked)	9	10.40	1.88	8	1	0	0	0
									Vac'd (diff)	10	9.95	2.27	6	0	0	4	0

Full spreadsheet can be seen here.

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Prior to cutting B-FPC tabs