20231011
M.Borri

Science and Technology Facilities Council

Initial thoughts on the Flexible Printed Circuit (FPC) for ePIC-SVT Outer Barrels.

WP3: Electrical interfaces

SVT Outer barrels – material budget

- Considering the proposed new layout option;
- Material budget for L3 inspired by the ALICE ITS2 Inner Barrel (IB);
- LAS pwr consumption ~~20 W/cm2 i.e. 0.5 that of ALPIDE~~ 40mW/cm2

J.Schambach Epic Svt 20230928

Proposed new layout based on ITS3 ER2 Sensor

	Layer	r (mm)	l (mm)	X/X_0 (%)	Area (m^2)	theta (deg)	eta	n_rsu	T6	T5
IB	L0	37.4	260	0.05	0.06	16.04	1.96			
	L1	49.8	260	0.05	0.08	20.97	1.69			
	L2	124.5	260	0.05	0.20	43.77	0.91			
OB Opt 1	L3	260	520	0.25	0.85	45.00	0.88	24	4	
	L4	390	780	0.55	1.91	45.00	0.88	36	6	
OB Opt 2	L3	270	520	0.25	0.88	46.08	0.85	24	4	
	L4	420	780	0.55	2.06	47.12	0.83	36	6	
OB Opt 3	L3	271	542	0.25	0.92	45.00	0.88	25		5
	L4	422	845	0.55	2.24	45.00	0.88	39	4	3

B Abelev et al and The ALICE Collaboration 2014 J. Phys. G: Nucl. Part. Phys. 41 087002

Table 4.1: Estimated contributions of the Inner Layer Stave to the material budget.

Stave element	Component	Material	Thickness (μm)	X_0 (cm)	X_0 (%)
HIC	FPC Metal layers	Aluminium	50	8.896	0.056
	FPC Insulating layers	Polyimide	100	28.41	0.035
	Pixel Chip	Silicon	50	9.369	0.053
Cold Plate		Carbon fleece	40	106.80	0.004
		Carbon paper	30	26.56	0.011
	Cooling tube wall	Polyimide	25	28.41	0.003
	Cooling fluid	Water		35.76	0.032
	Carbon plate	Carbon fibre	70	26.08	0.027
	Glue	Eccobond 45	100	44.37	0.023
Space Frame		Carbon rowing			0.018
Total					0.262

ITS2 IB stave length ~270mm, width ~1.5cm, ALPIDE PWR <40m W/cm2

Science and Technology Facilities Council

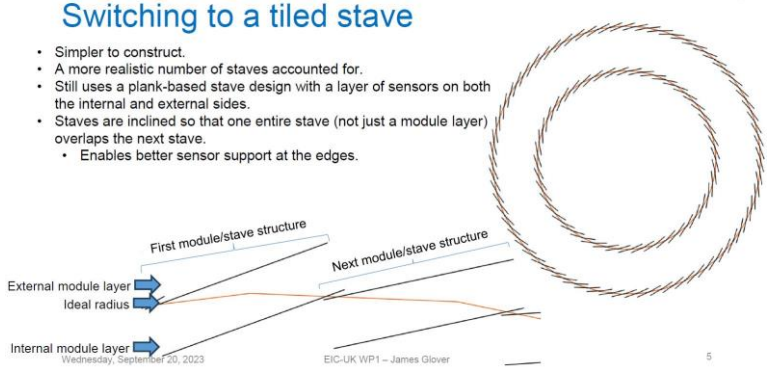
UNIVERSITY OF BIRMINGHAM

Birmingham Instrumentation Laboratory for Particle physics and Applications BILPA

ePIC

Switching to a tiled stave

- Simpler to construct.
- A more realistic number of staves accounted for.
- Still uses a plank-based stave design with a layer of sensors on both the internal and external sides.
- Staves are inclined so that one entire stave (not just a module layer) overlaps the next stave.
  - Enables better sensor support at the edges.



Di Mauro and o.b.o.t.A. Collaboration
Nuclear Inst. and Methods in Physics Research, A 936 (2019) 625–629

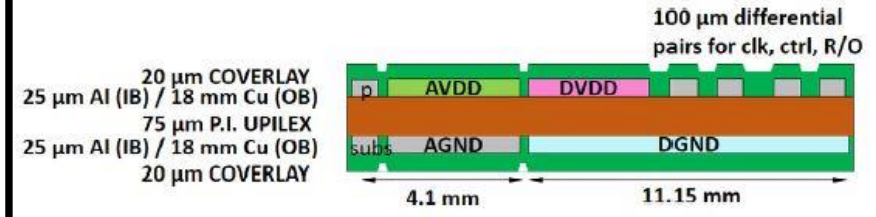
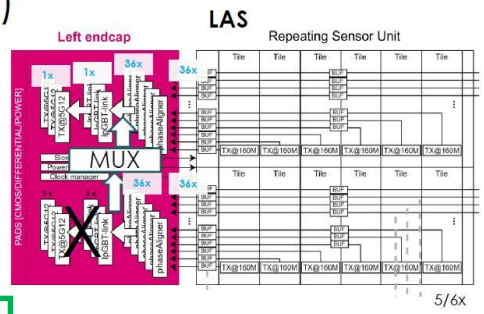


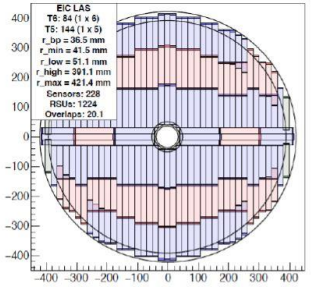
Fig. 4. Schematic cross section of the IB FPC (vias are not represented).

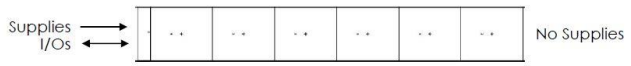
Large Area Sensor LAS

ePIC SVT: "Large Area Sensor" (LAS)

- **Inner Barrel** (Layers 0,1,2) will reuse ITS3-like sensors as is
  - **Layer 0:** 4 sensors in r-phi, 3 segments of 12 RSU
  - **Layer 1:** 4 sensors in r-phi, 4 segments of 12 RSU
  - **Layer 2:** 8 sensors in r-phi, 5 segments of 12 RSU
- EIC **variant** for the **Outer Barrel** (Layers 3,4) and **Endcap Disks**
  - "Large Area Sensor" (LAS)
  - Will be stitched, but not to wafer scale
  - Likely 1 Segment of 5 or 6 RSU (no need for right endcap)
  - Hope is to multiplex Domain data lines to 1 High-Speed output
  - More conventional carbon composite mechanical support with integrated cooling



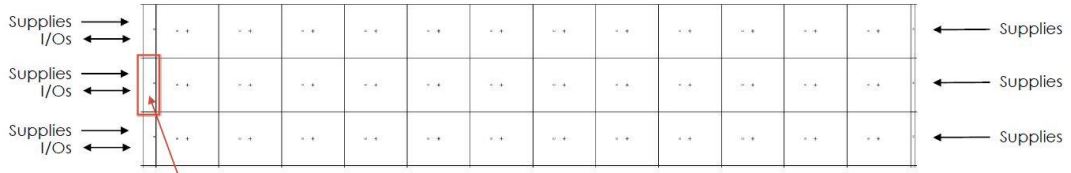


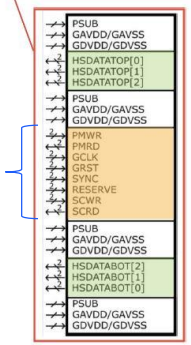


OAK RIDGE National Laboratory
J. Schambach

T6 only for SVT OB

Supplies and I/Os





7x diff cntrl lines
+ 1 diff clck

All I/Os are differential
6x 5.12 Gb/s data outputs ← w multiplexer only 1 data output per LAS
1x clock at 320 MHz
2x slow control at 2.5 Mbps

Global analog and digital supplies per *segment*
On-chip supply segmentation and control

Reverse biasing of substrate (PSUB)

OAK RIDGE National Laboratory
J. Schambach

UKRI Science and Technology Facilities Council

LAS w multiplexing – logical sketch of FPC

- FPC easier to design if LAS has data multiplexer:
  - x7 diff ctrl lines are on the high side…
  - .. but it should be OK to layout on a 2 layer FPC (19mm wide)
  - Design similar to existing ITS2 FPCs (15mm wide)

- FPC layout can be scaled to multiple segments per LAS.

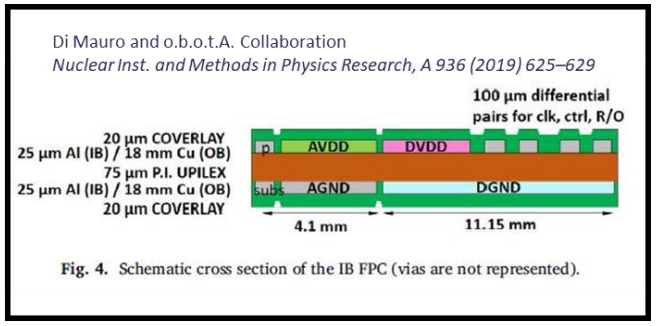
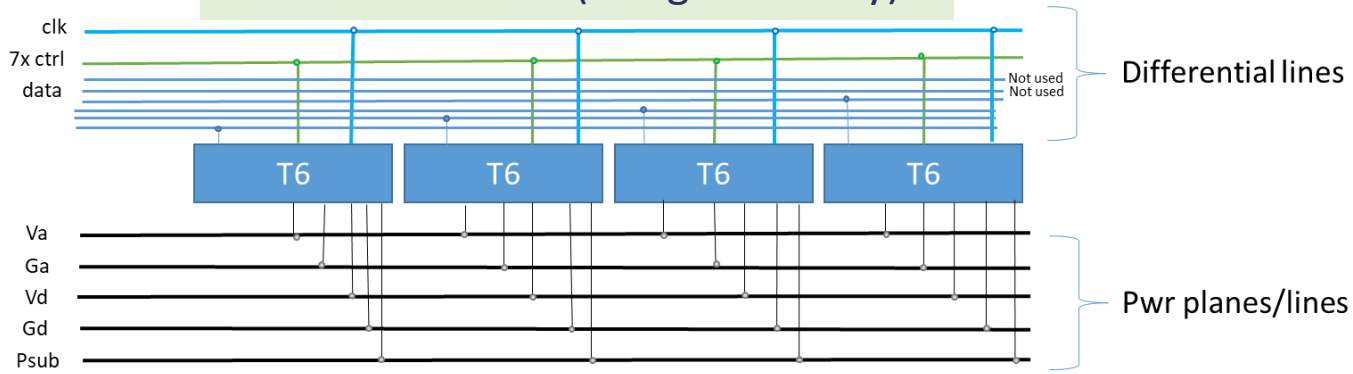
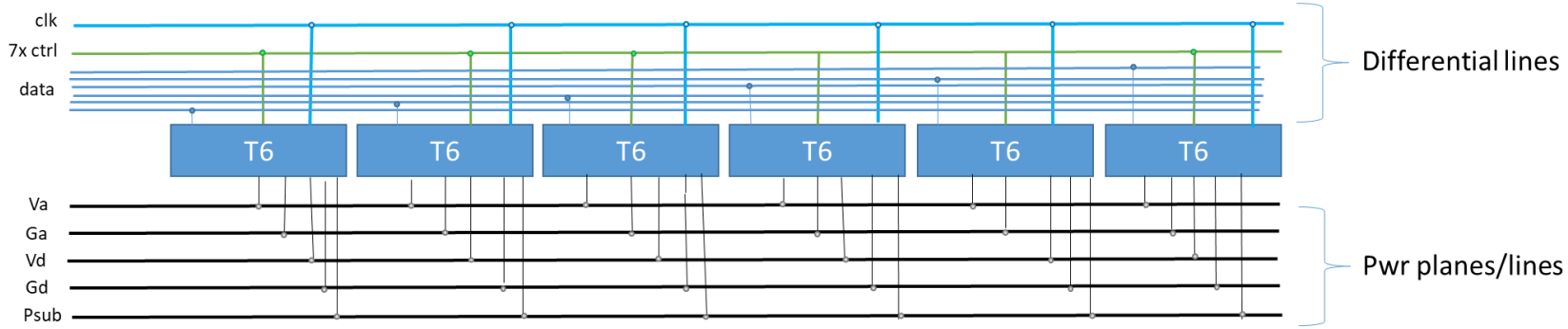


Fig. 4. Schematic cross section of the IB FPC (vias are not represented).

OB L3 – 4x T6 LAS (1 segment only)



OB L4 – 6x T6 LAS (1 segment only)

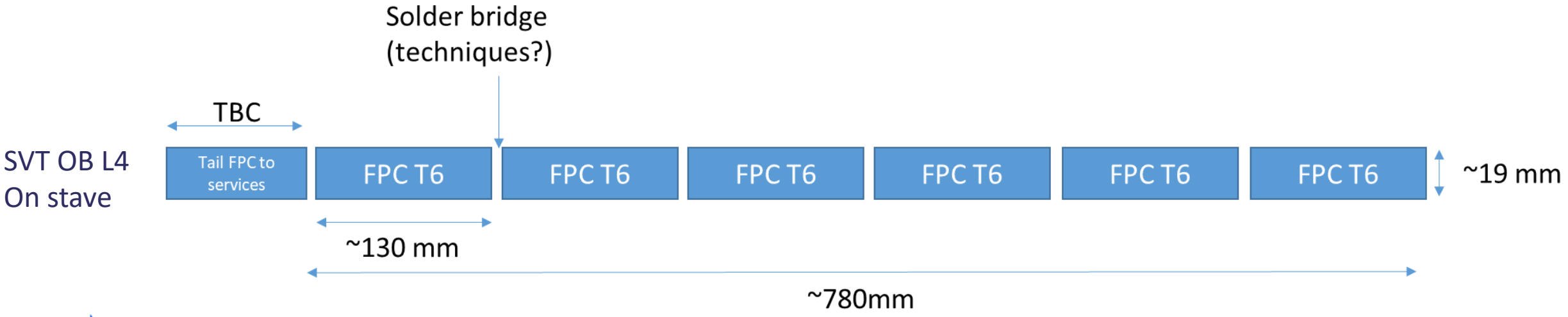


- ToDo: to check if LAS w/o multiplexing could fit in a 2 layer FPC
  - L4: 36 differential data lines (it seems a lot)
  - It needs preliminary design

Science and Technology Facilities Council

FCP modularity Vs limits on manufacturing dimensions

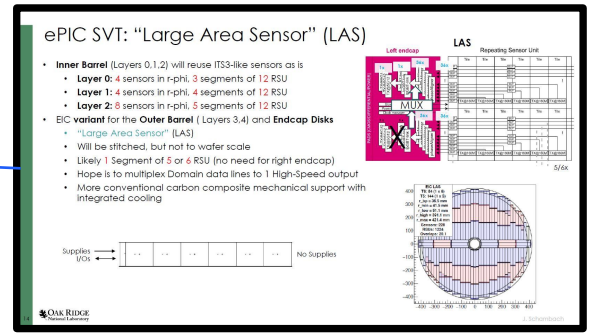
- Modularity is always welcome
- 1 FPC per 1 LAS or 1 FPC per 2 LAS seems achievable;
- FPCs bridged at stave loading;
- Tail FPC could contain IC for data transmission, length to be defined
  - Cooling might be required, see FPC w integrated micro-channels.



Science and Technology Facilities Council

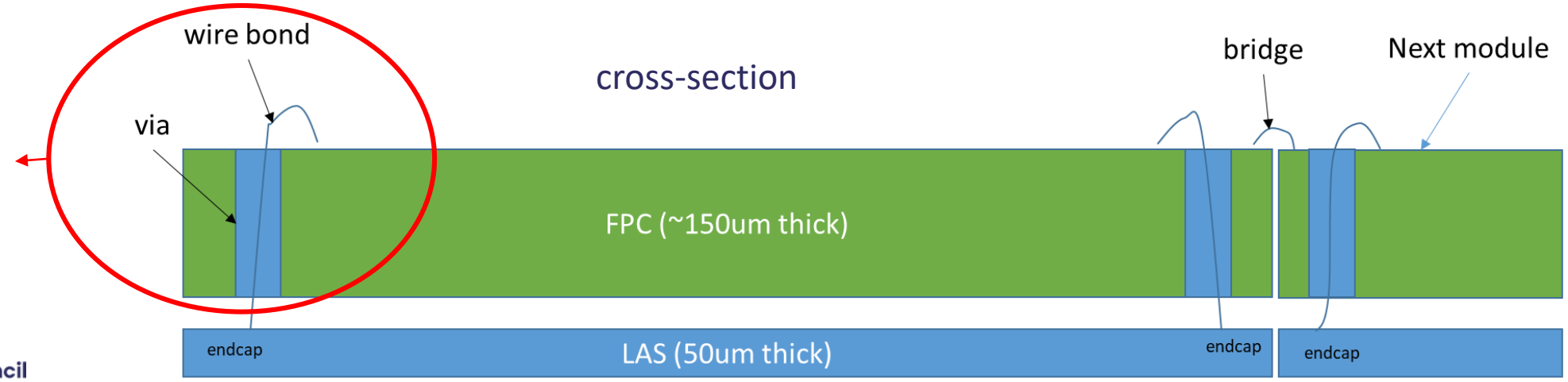
Doubt

- “likely 1 segment 5 or 6 RSU (no need for right endcap)”
- FPC will have 25um Al power planes:
  - It could provide pwr to both encaps form one end
    - “RI” drop calculated on FPC ? (ToDo)
  - FPC can provide power to both end caps:
    - Exploiting length of sensor
      - L3: 2 x T12 LAS = ~260 mm x 2 = ~520 mm; data lines: 6X2 =12 (reduction via multiplexing?)
      - L4: 3 x T12 LAS = ~260 mm x 3 = ~780mm; data lines: 6X3 =18 (reduction via multiplexing?)
    - In-chip multiplexing could data lines reduction:
      - data rate and pwr consumption.



Vias will produce a bottleneck on real estate for routing pwr planes.

Data multiplexing would help to reduce bottleneck



Science and Technology Facilities Council

To keep both end caps to achieve better pwr seems feasible?

FPC technology

- The technology of reference is an Aluminium tracks process.
  - Only few places can offer this technology
    - CERN -> ALICE ITS2 IB FPC
    - LTU -> ALICE ITS2 OB power bus
- To consider:
  - Select third supplier in UK
  - Develop capability with supplier -> apply for Innovation grants

Science and Technology Facilities Council

Daresbury & FPCs & ALPIDE

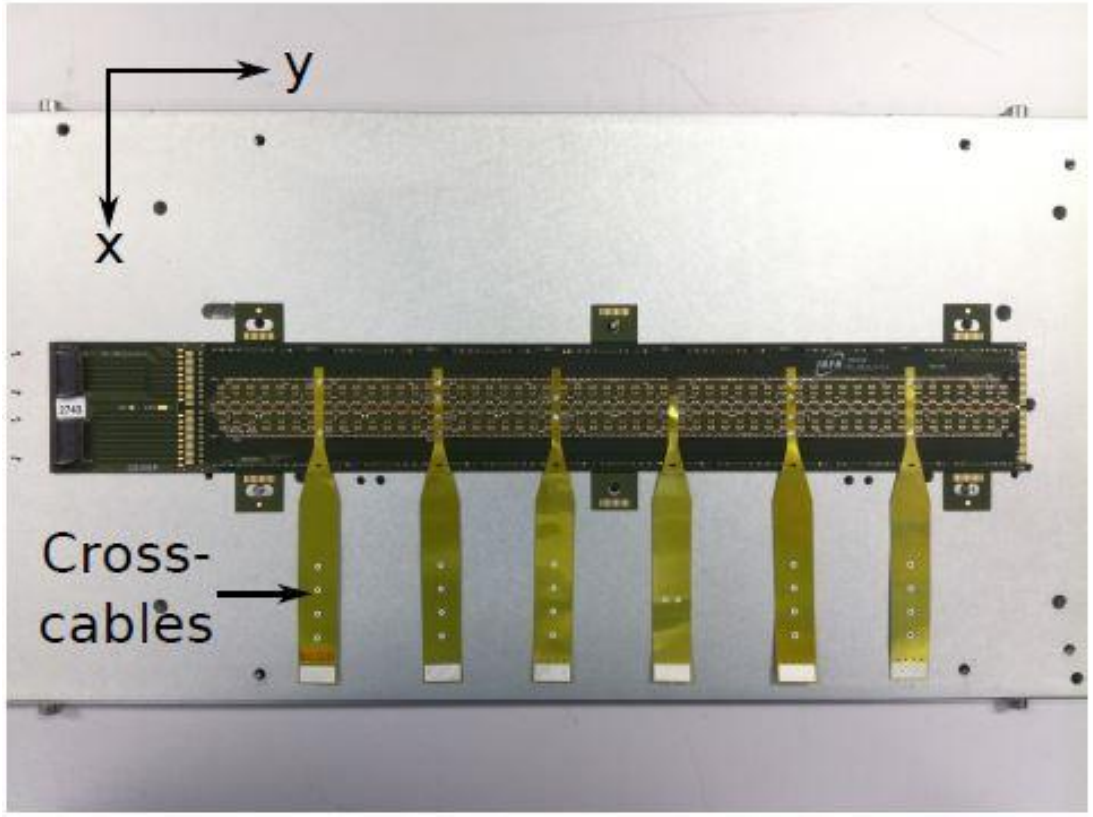
- ALICE ITS2 OB modules at the University of Liverpool
  [M.Buckland, M.Borri]
  [ALPIDE 100um thick]
  [Complete]

- Wire-bond less R&D on ALPIDE quad
  [A.Hill, M.Borri]
  [ALPIDE 100um thick]
  [Complete]

- R3B-Trt (FAIR) -> to produce 54 units (+ spares) ITS2 IB modules
  [M.Borri, M.Buckland, A.Hill]
  [ALPIDE 50um thick]
  [Started]

Science and Technology Facilities Council

ALICE ITS2 OB

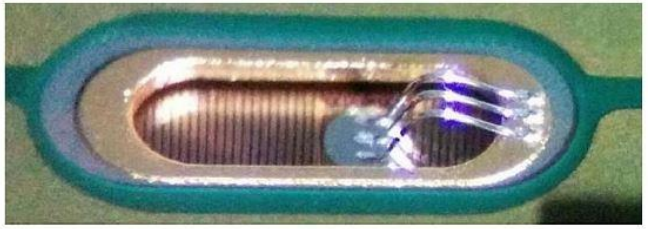


Cu tracks [☹]

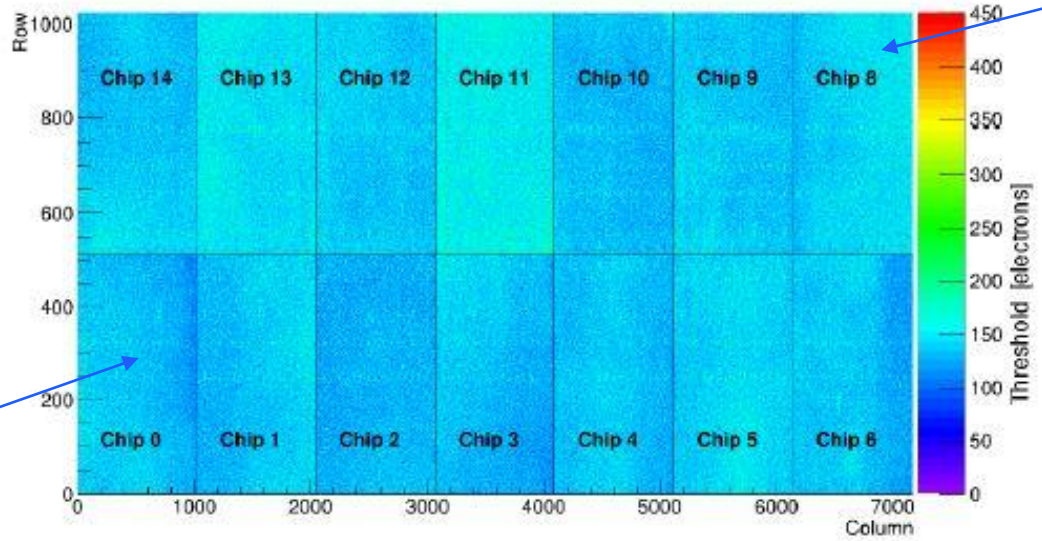
2 rows of 7 ALPIDE per FPC

-> similar to T6 LAS w 2 segments [☺]

->layout could still be a good reference for SVT OB



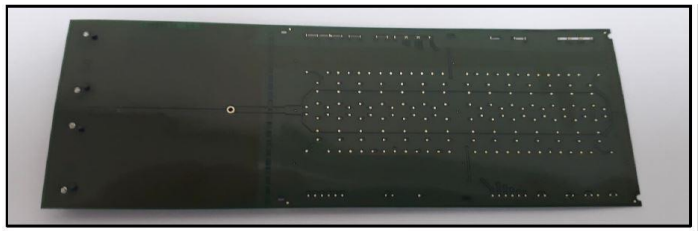
Threshold scan on representative module:

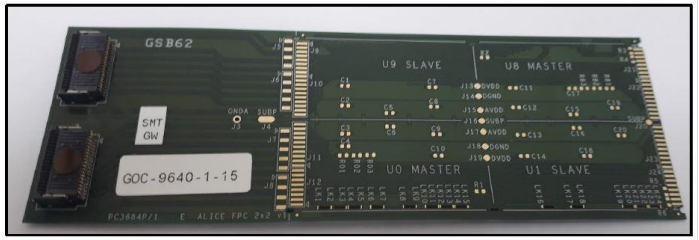


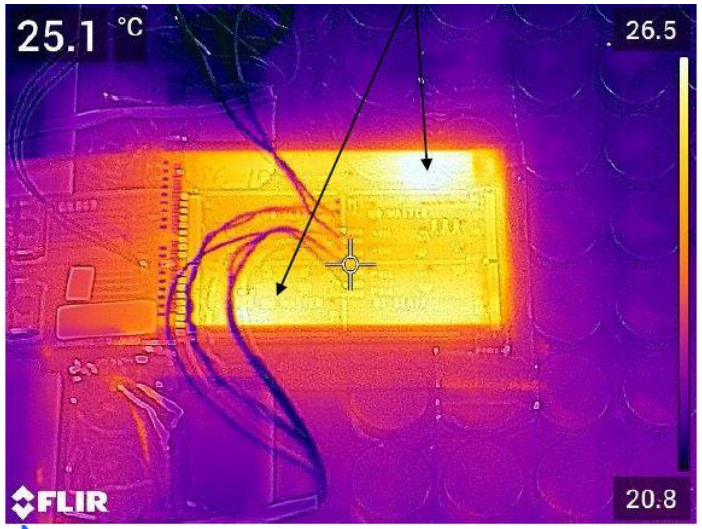
Series Production and Test of Hybrid Modules for the ALICE ITS Upgrade
M.Buckland

Science and Technology Facilities Council

ALPIDE QUAD w/o wire-bonds







Science and Technology Facilities Council

- ALICE was supposed to use laser soldering as interconnection technique…
- .. But it did not converge.

- We tried an alternative wire-bondless idea using STFC technology. [Thank you STFC Interconnect]

- Au studding of pads + Ag epoxy

- Potential advantages: **cost effective**
  - 1 site/supplier Au studs the chips
  - All other sites are enabled module production (inc interconnection) by using stencils and conductive glues.

- VERY LOW TRL

Thin Si Sensors on Flexible Printed Circuits – Study of Two Bond Methods
A.Schneider

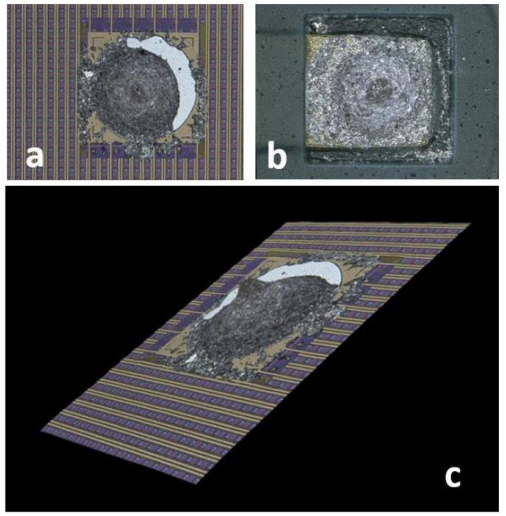


Fig. 7. Microscope images of contact pads after intentional separation of sensor and FPC: a) sensor contact pad, b) matching pad on FPC, and c) 3D rendering of sensor contact pad.

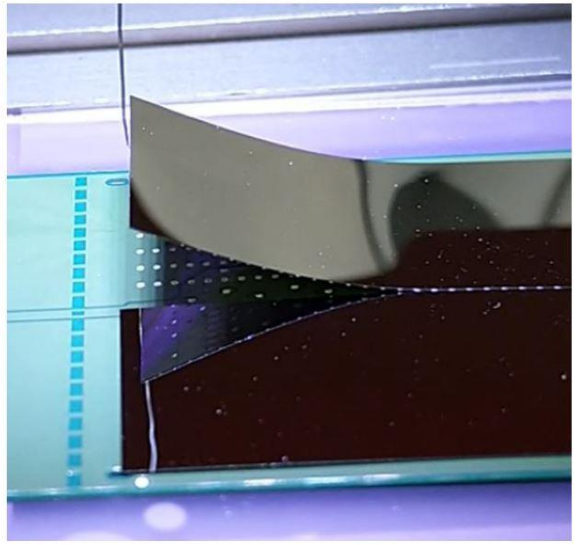
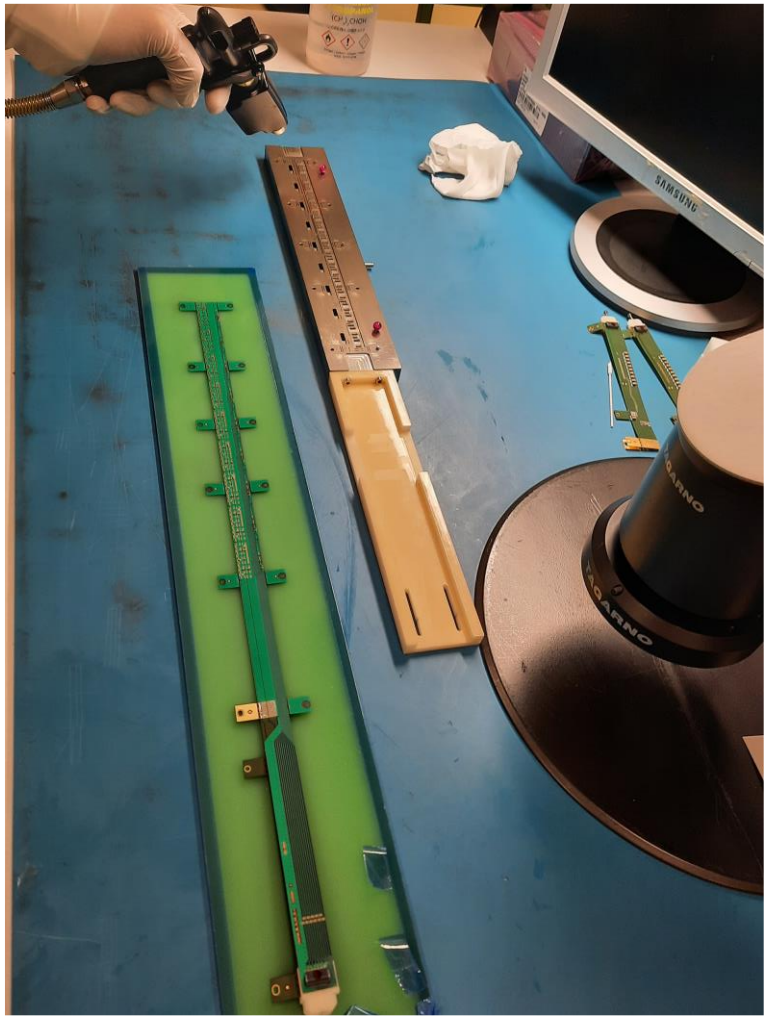
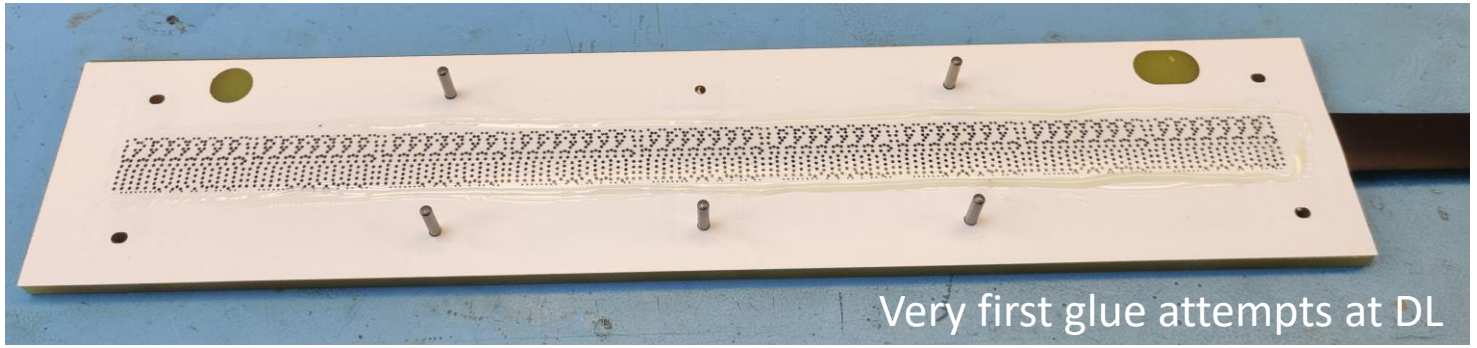


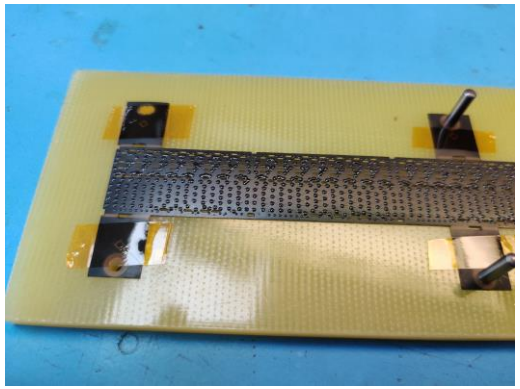
Fig. 6. Pull test on a chip attached to a FPC.

R3B Trt - ITS2 Inner barrel modules



- 9 ALPIDE in single row (all maters)
- Handling of 50um ALPIDE
- Selection of glue masks suppliers
- Design optimisation of jigs
- Buying from CERN Aluminium FPCs
  - FPC is made by a combination of 3 suppliers on 3 different countries
  - Lead time and supply rate was not easy to handle.





Science and Technology Facilities Council

Conclusion

- This slides capture initial thoughts on FPC for SVT OB modules
- Feedback is always welcome, already at this stage.
- More work is needed to further shape the design.

Science and Technology Facilities Council

Science and Technology Facilities Council

Thank you

Facebook: Science and Technology Facilities Council

Twitter:@STFC_matters

YouTube: Science and Technology Facilities Council