20231120
M.Borri

Science and Technology Facilities Council

Flexible Printed Circuit (FPC) for ePIC-SVT: Towards specifications

WP3: Electrical interfaces

SVT configuration – an FPC prospective

Current and future

IB	r [mm]	l [mm]	X/X0 %
L0	36	270	0.05
L1	48	270	0.05
L2	120	270	0.05

LAS T5

BARREL	r [mm]	l [mm]	X/X0 %
Layer 3	270	540	0.25
Layer 4	420	840	0.55

LAS T5

DISKS	+z [mm]	-z [mm]	r_out [mm]	X/X0 %
Disk 0	250	-250	240	0.25
Disk 1	450	-450	420	0.25
Disk 2	700	-650	420	0.25
Disk 3	1000	-850	420	0.25
Disk 4	1350	-1050	420	0.25

J. Glover
Current and future tracking and vertexing detectors
7 Nov 2023

Science and Technology Facilities Council

- L0,L1,L2 only 50um Si:
  - No FPC overlapping sensor;

- L3 and all disks have the same material budget;
- This material budget is referenced to ITS2 Inner barrel:
  - Al FPC is overlapping the sensor;

- L4 allows for about x2 the material budget of layer 3 and disks:
  - To keep FPC constrains (e.g. material budget) as in L3 and disks;

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

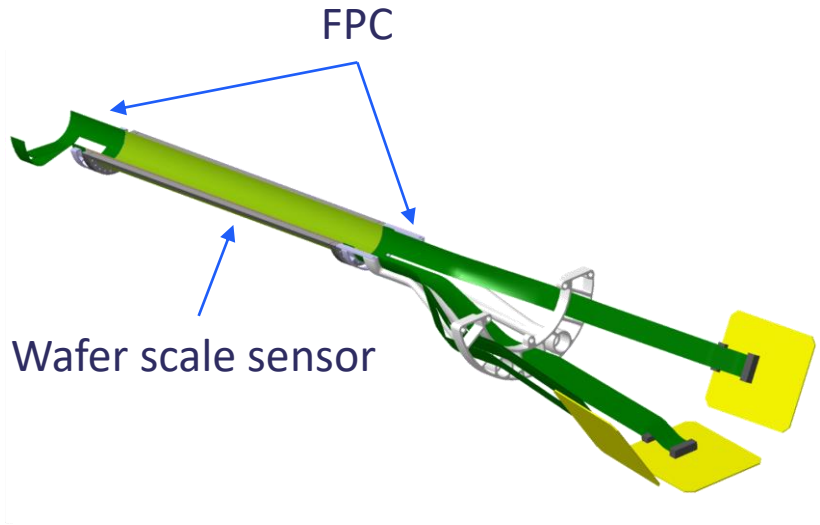
IB L0, L1, L2 - FPC

Images from several ALICE ITS3 contributions

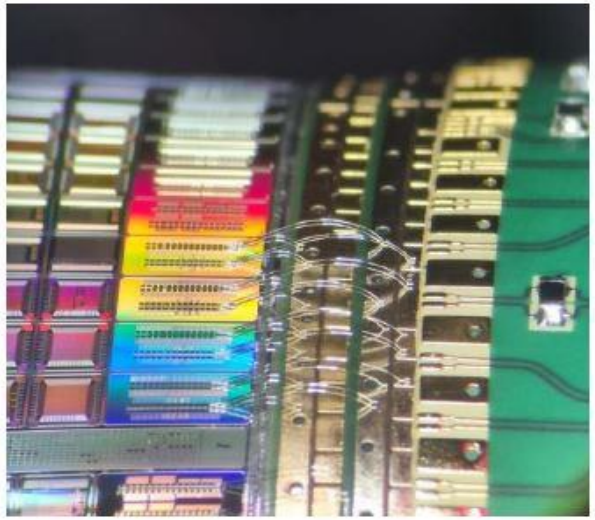
- L0,L1,L2 only 50um Si:
  - No FPC overlapping sensor;
    - No restrictions in no. of conductive layers in the FPC;

- FPC interconnected via wire-bonding to sensor end caps:
  - Left end cap: data, ctrl, clk, pwr, gnd;
  - Right end cap: pwr, gnd;

- Is the EIC Inner barrel an identical copy of ALICE ITS3?
- Can we power from the right and left end caps like in the EIC?



FPC wire bonded to curved sensors



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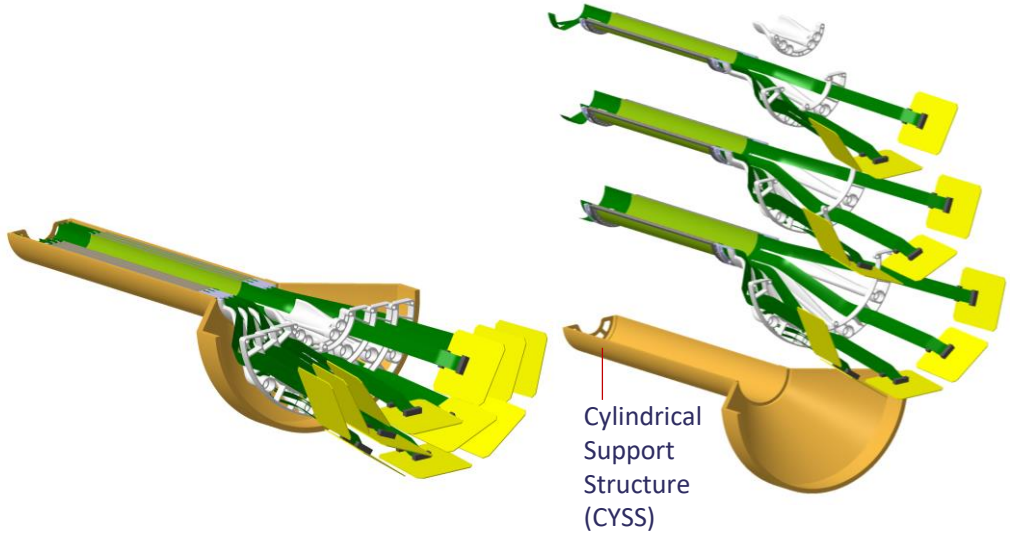
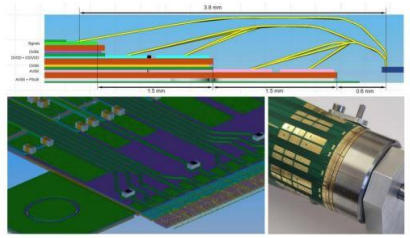
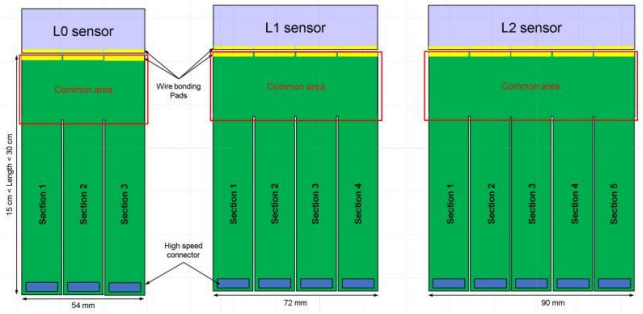
Half detector
(3 Half-layers)

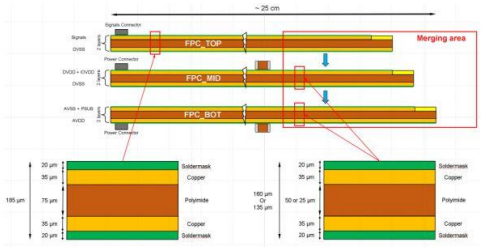


IB L0, L1, L2 – FPC update

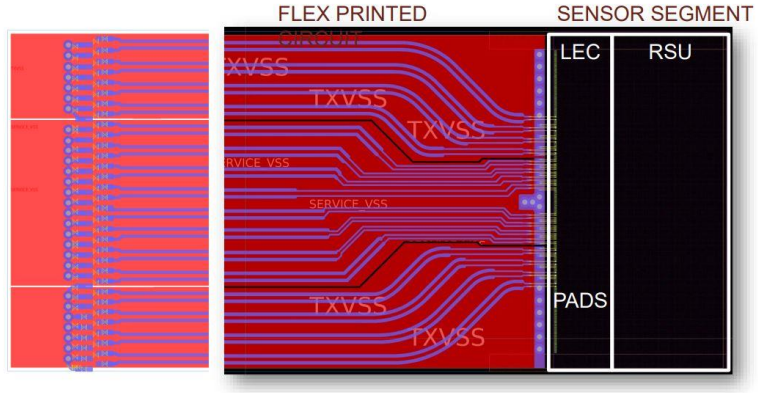
FPC







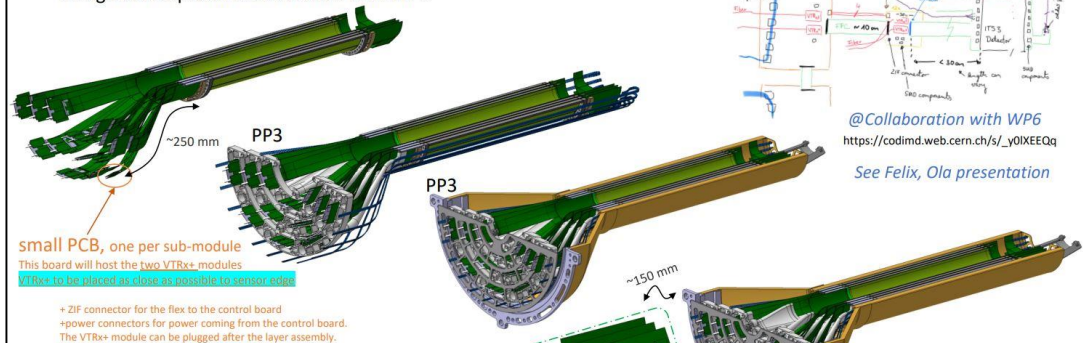
LEC Pad Ring and Flex



Layout updates: Front end electronics layout being evaluated (Preliminary)

ALICE ITS3 WP

- Design and position of the boards depend on available volume limited by the FoCAL acceptance cone.
- Design developed in collaboration with WP6



@Collaboration with WP6
https://codimd.web.cern.ch/s/_y0lXEEQq

See Felix, Ola presentation

small PCB, one per sub-module
This board will host the two VTRx+ modules
VTRx+ to be placed as close as possible to sensor edge

+ ZIF connector for the flex to the control board
+power connectors for power coming from the control board.
The VTRx+ module can be plugged after the layer assembly.
The approximate dimensions are 30 mm x 30 mm.

Control Board
Contains all the remaining electronics
It is divided in several segments avoiding acceptance cone
Different layout under study
In terms of components the control PCB will host two VTRx+ modules, many SMD components (passive + active) as well as the DC-DC converters.

*VTRx+ (Versatile TransReceiver)= Optical Link Module for Data Transmission

@G.Ledey

UKRI Science and Technology Facilities Council

OB – FPC

- L3 material budget is referenced to ITS2 Inner barrel:
  - Al FPC is overlapping the sensor;
- L4 is ~x2 L3 material budget

- OB staves are populated by the same type of LAS
  - One option was also considering populating the staves with LAS with different multiplicities. Discard?

- Configuration A:
  - L3: **LAS T5** x5, length 540mm
  - L4: **LAS T5** x8, length 840mm

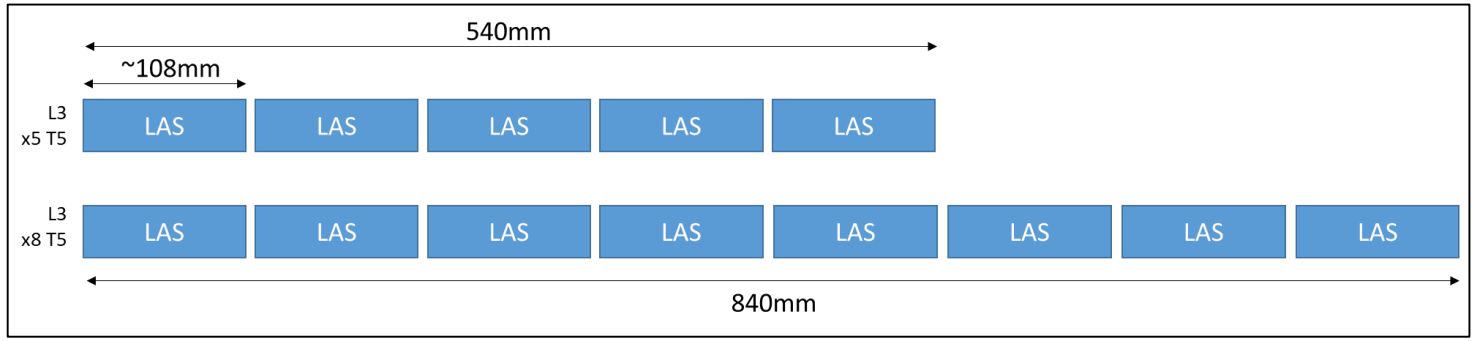
- Configuration B:
  - L3: **LAS T6** x4, length 520mm
  - L4: **LAS T6** x6, length 780mm

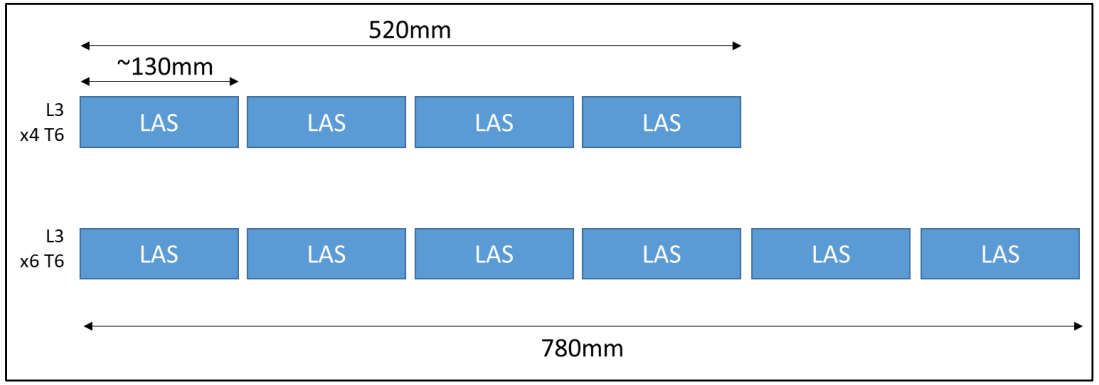
- Baseline design assumes that LAS are installed on the front and back plane of the stave

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





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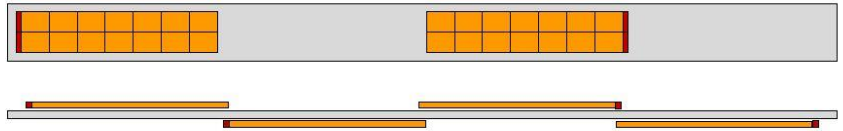
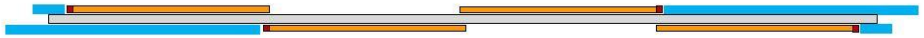
OB – Baseline options for module loading (1/2)

Possible architecture for barrel layers

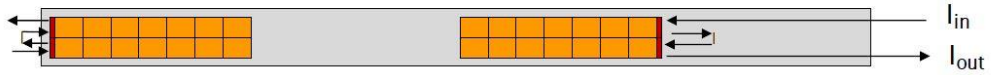
- Sensors will most likely be needed on two sides to provide overlap.
  - This has an impact on the stave design, i.e. a truss structure would not be possible.



- In this configuration services could run as shown in blue.



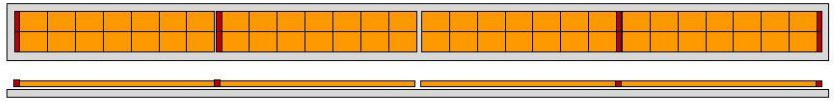
- If now serial powering is added, this would mean four chains of two sensors per stave → the total current to L4 scales of a factor 2



Similar on the bottom

Possible architecture for barrel layers

- The outermost sagitta layer, L4, is made of 1x7 sensors, it is two sensors wide and four sensor long (8 sensors per stave).
  - See baseline ePIC SVT configuration at https://indico.bnl.gov/event/17713/
- Top and side view of L4 (the stave is in grey).
  - Services would come in from the two sides.
  - The orientation of the periphery is to reduce the amount of services running on the stave.



- This simple configuration however leaves dead areas between sensors.
  - Periphery will need to be bonded to services flex/tape on stave, space not shown in this drawing.

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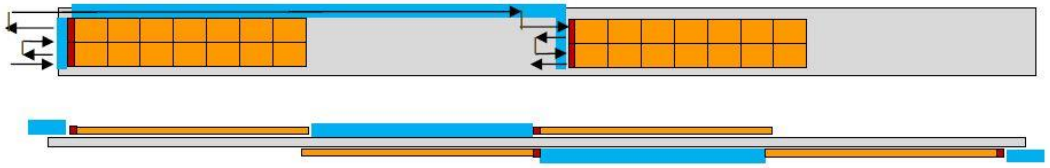
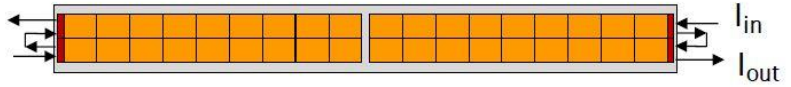
OB – Baseline options for module loading (2/2)

Possible architecture for barrel layers

- Another possibility would be as shown below, giving a reduction factor 4 in the total current to L4



- For the innermost sagitta layer (L3), we would have chains of two sensors, giving a reduction factor 2 in the total current to L3
  - Made of 1x9 sensors, it is two sensors wide and two sensor long (4 sensors per stave).
  - Services come in from the side and connect to periphery at end of stave to minimise material.



  - Note that most likely also in this case we might need sensors on two sides to avoid the gap in the middle.

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Disks – FPC & loading stave (or disk) from front & back sides

- Material budget for L3 and disks achieved by:
  - Al FPC w only 2 layers [it overlaps the sensor]
  - 50um thin and low pwr sensor
  - light support and cooling structure

- Issue to stay within material budget if:
  - access to sensors services only from 1 side of the support structure
  - there are more than 2 LAS in sequence

- Note:
  - Material budget non-uniform also w only 2 LAS
    - good or bad?

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

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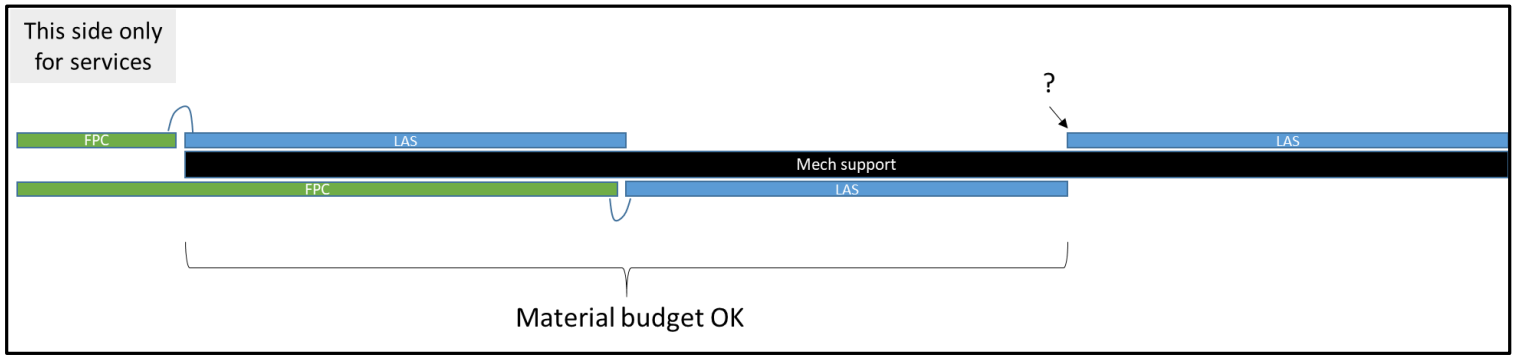
Total					0.262

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



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

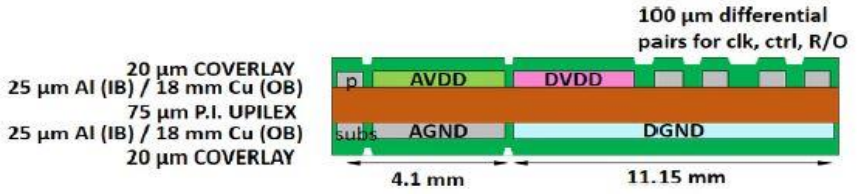


Fig. 4. Schematic cross section of the IB FPC (vias are not represented).

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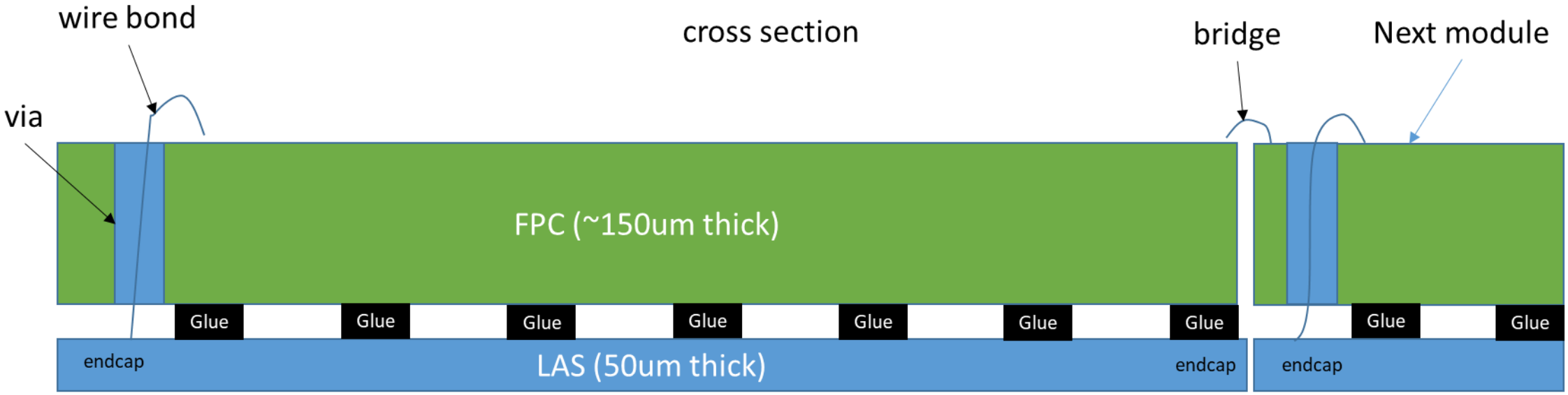
ALICE ITS2 approach

- Modularity is always welcome
- 1 FPC per 1 LAS;
- 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.



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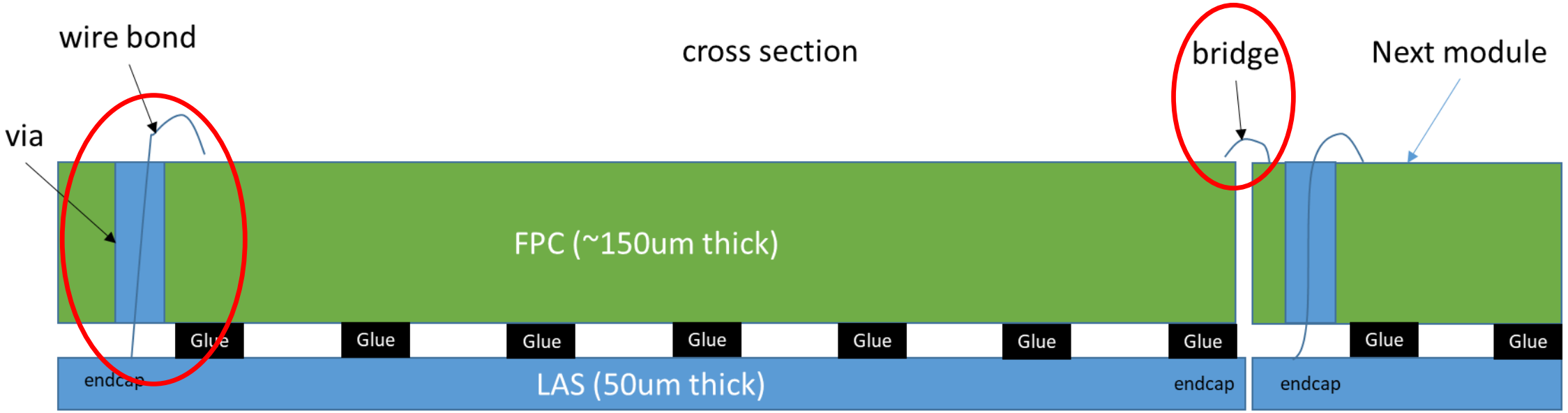
ALICE ITS2 - Feasibility considerations: pwr planes

- Bottlenecks for the cross section of the pwr planes:
  - Vias for the wire bonding;
  - Module to module bridges;

- Is the sLDO the solution to this problem?



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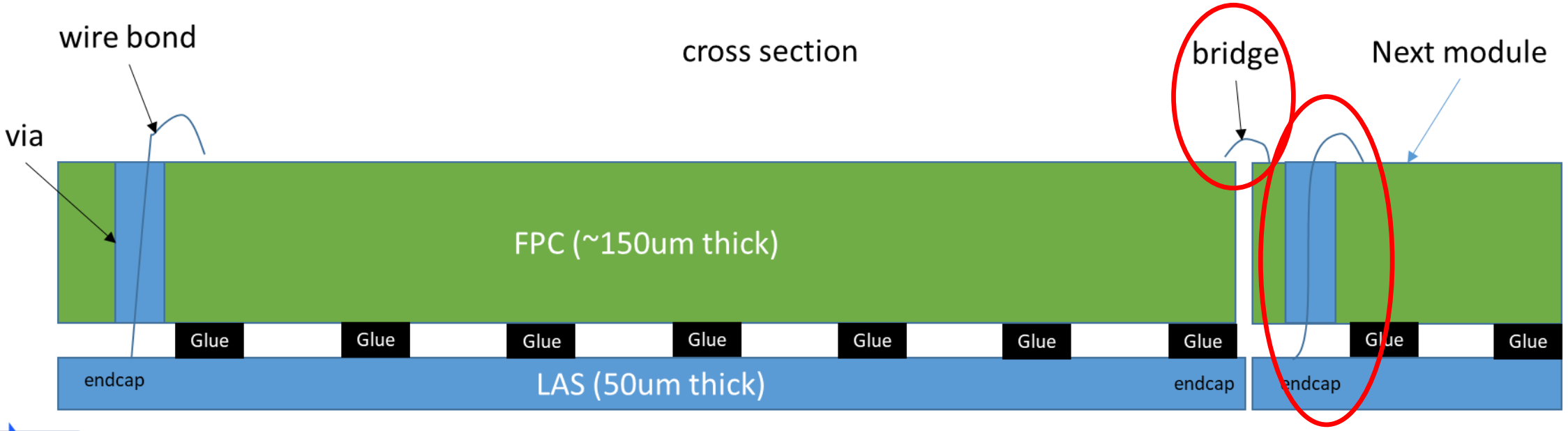
ALICE ITS2 - Feasibility considerations: wire-bonding

- The left encap of the LAS will be densely populated with wires:
  - to connect FPC to the sensor.
  - to connect bridge the FPCs.

- Is there sufficient space to do this? Could the pads be shifted on LAS design?



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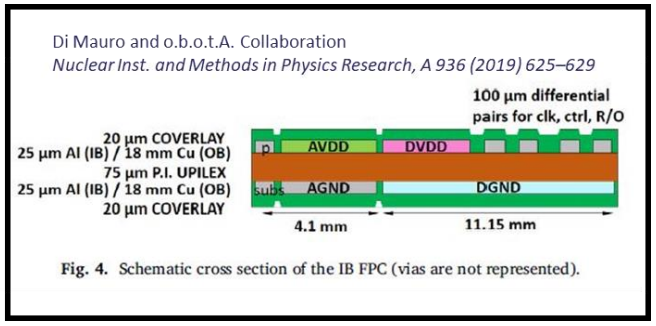
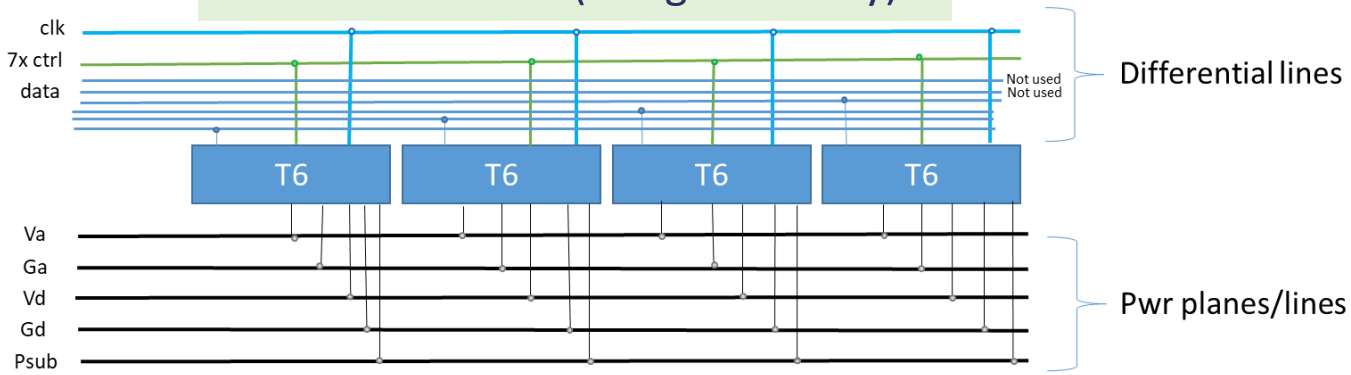
LAS w multiplexing – logical sketch of FPC

- 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)

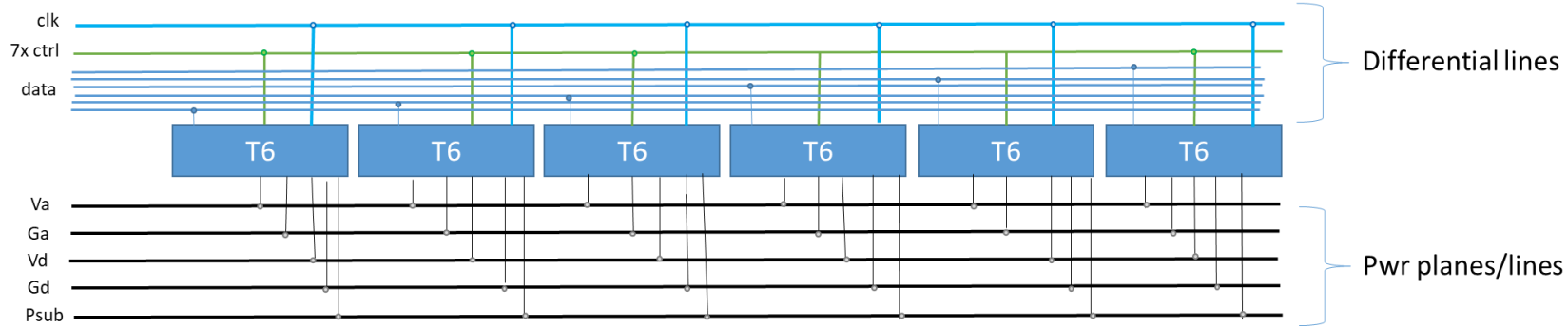
- FPC layout can be scaled to multiple segments per LAS.



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

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Disks - FPC

e-endcap Disk index	z (mm)	inner r (mm)	outer r (mm)
1	-250	36.76	240
2	-450	36.76	415
3	-650	36.76	421.4
4	-900	40.0614	421.4
5	-1150	46.3529	421.4
h-endcap Disk index			
1	250	36.76	240
2	450	36.76	415
3	700	38.52	421.4
4	1000	53.43	421.4
5	1350	70.14	421.4

- L3 and disks have the same material budget;
- This material budget is referenced to ITS2 Inner barrel:
  - Al FPC is overlapping the sensor;

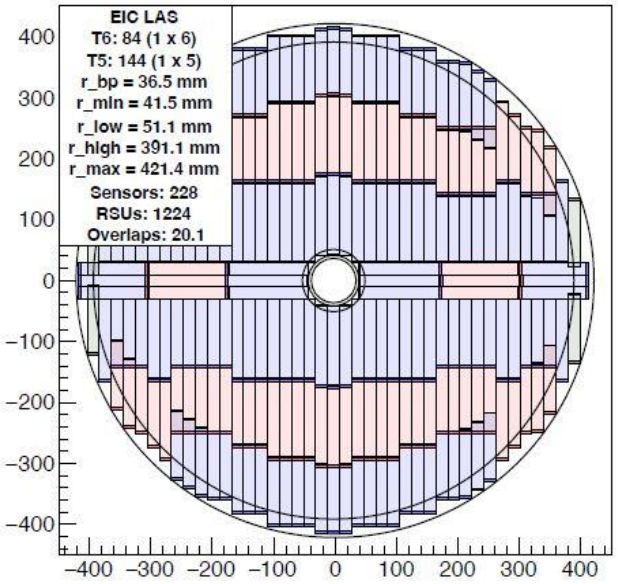
- Total of 10 disks of 8 different types;

- Different LAS variants will be installed in each disk;
- Currently LAS are installed on the front and back plane of the disks;
- Several layouts and LAS dimensions under consideration;

- Selected image for disks w combined LAS T5 and T6:
  - Representative of full disk coverage;

P.Jones – EIC SVT general meeting 20230822

ePIC-SVT ED4 z=-1050 cm



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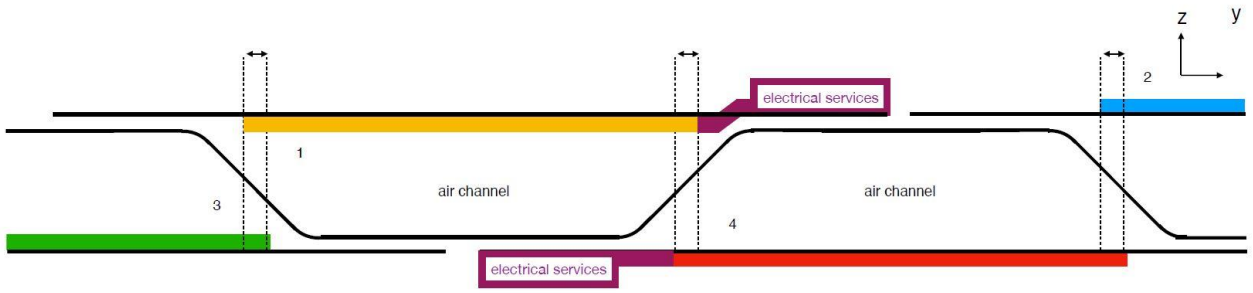
Disks - Baseline options for module loading (1/2)

Disk concept — Alternative

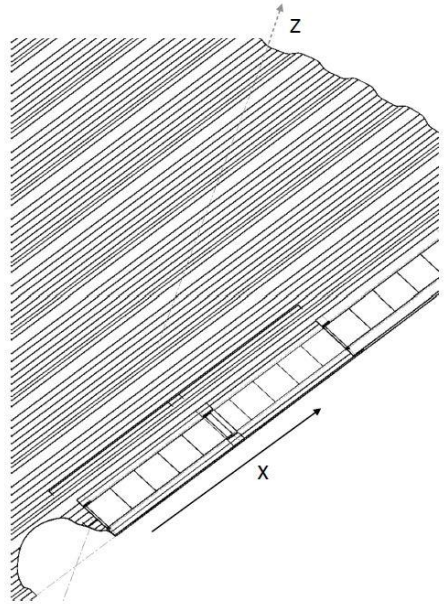
While the concept on the preceding slides "seems simple," we are investigating alternatives:

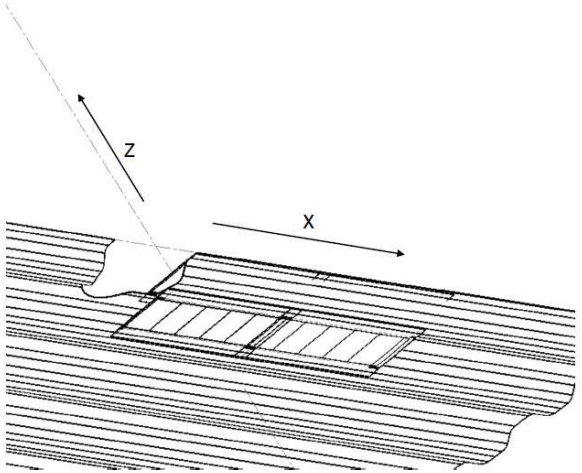


Having a sensor module part of the face-sheets — as shown here — would seem preferred,
Arguments include that services can be guided to areas with mechanical support

Two module sides or heights would thus result in *four* sensor planes on the disk — color coded above

Disk concept — module placement





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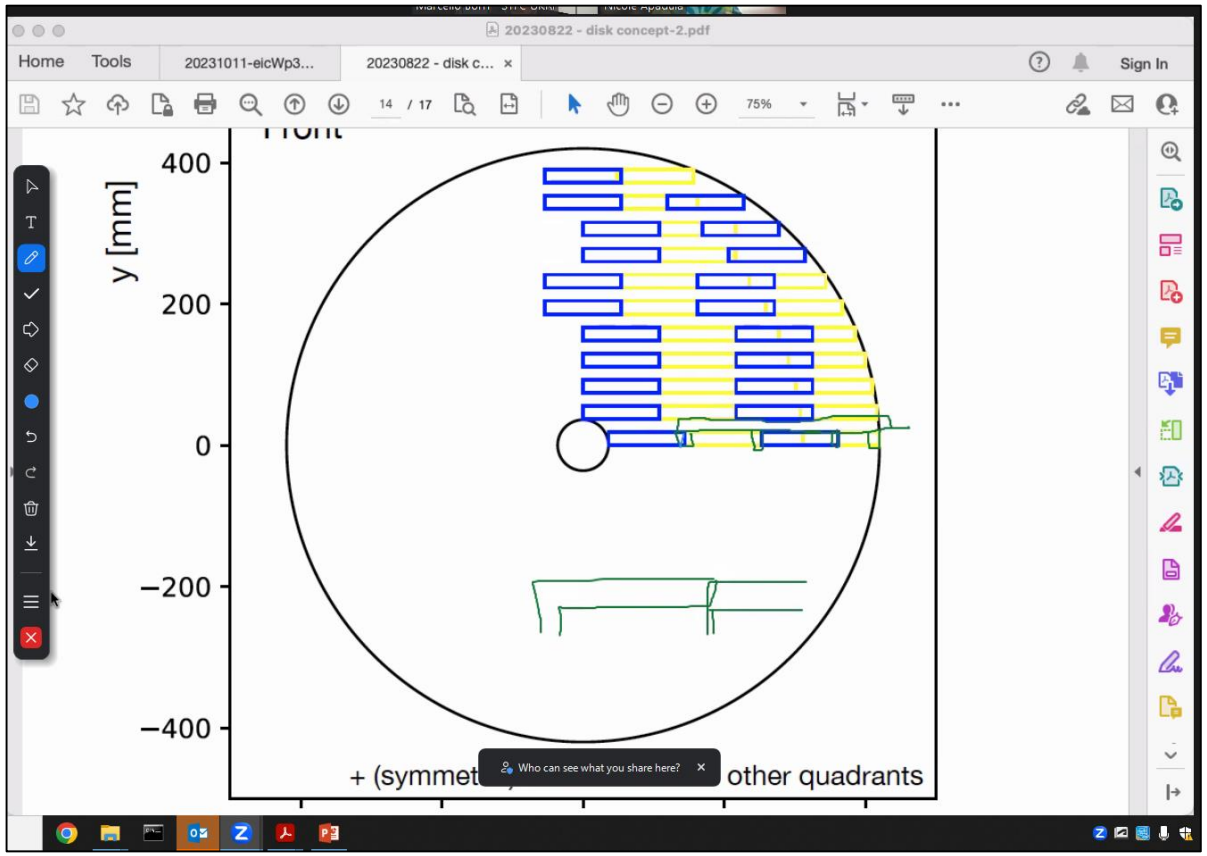
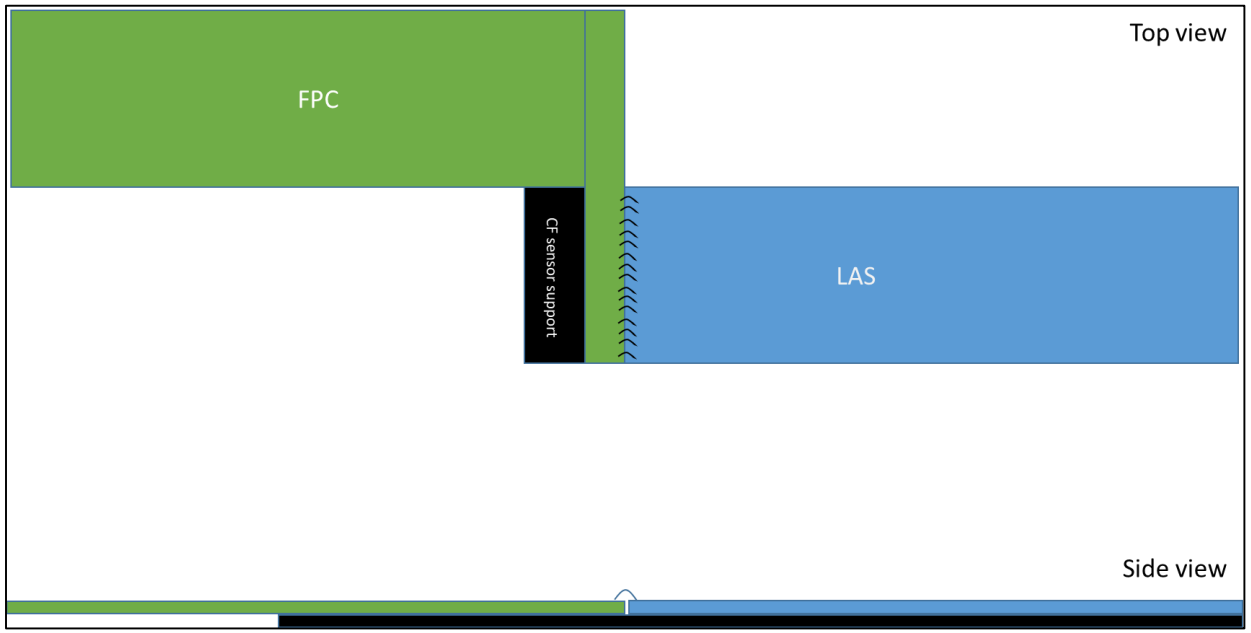
Air cooling

Disks - Baseline options for module loading (2/2)





- L-shaped FPC;
- The short-side of the L-shaped FPC overlaps the long-side of L-shaped FPC of the module in the next/next/neighbouring row;
  - Potential localised excess of material budget
  - … this could still be within the material budget because of air cooling (instead of water)

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Material from 1:1 meeting N.Apadula M.Borri

Disks – air cooling considerations

Potentially lower material budget w air cooling

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

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FPC – desing considerations SVT OB (and disk)

- Passives: caps, resistors etc.
- IC: sLDO; ctrl distribution ASIC;

- Features: module address hard wired via configurable resistors on FPC?

- Al tracks;
- Polyimide substrate;

- Two layers FPC;

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Conclusion

- sLDO:
  - No need for power bus, correct?
- Wire-bonding pads on LAS:
  - fixed position? Can be moved around periphery?
- Configuration of modules on stave:
  - Only loading from one side due to mechanical requirements for stiffness; Agreed?
- Air cooling:
  - feasible for stave? (and disk?)
- Low material budget achievable by interplay of different design parts
- To start preliminary design referenced to MOSS or MOSAIX
  - Need to add detail/inform discussion

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Thank you

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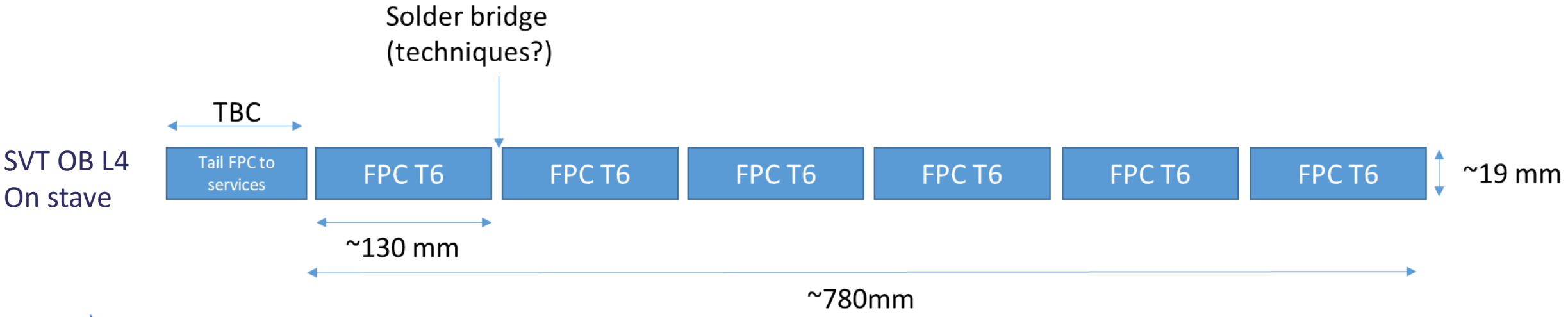
	width (mm)	length (mm)	# pixels per reticle								
RSU size	19.564	21.666	894,240								
Pixel size	0.0200	0.0225									
Barrel					Sensor						
Layer Index	**radius (mm)**	**z (mm)**	**Area (mm^2)**	**RSUs in width**	**RSUs in length**	**# of sensors in r-phi**	**# of sensors in z**	**# pixels**	**# sensors**	**Notes**	**# Readout Links**
0	36	270	61,073	3	12	4	1	128,770,560	4	bent ITS3	72
1	48	270	81,430	4	12	4	1	171,694,080	4	bent ITS3	96
2	120	270	203,575	5	12	8	1	429,235,200	8	bent ITS3	240
3	270	540	916,088	1	5	87	5	1,944,972,000	435	1x5 LAS	435
4	420	840	2,216,706	1	5	135	8	4,828,896,000	1080	1x5 LAS	1080
e-endcap											
Disk index	**z (mm)**	**inner r (mm)**	**outer r (mm)**								
1	-250	36.76	240	176,710	1	5		375,580,800	84	1x5 LAS	84
2	-450	36.76	415	536,815	1	5		1,135,684,800	254	1x5 LAS	254
3	-650	36.76	421.4	553,632	1	5		1,171,454,400	262	1x5 LAS	262
4	-900	40.0614	421.4	552,835	1	5		1,166,983,200	261	1x5 LAS	261
5	-1150	46.3529	421.4	551,127	1	5		1,166,983,200	261	1x5 LAS	261
h-endcap											
Disk index											
1	250	36.76	240	176,710	1	5		375,580,800	84	1x5 LAS	84
2	450	36.76	415	536,815	1	5		1,135,684,800	254	1x5 LAS	254
3	700	38.52	421.4	553,216	1	5		1,171,454,400	262	1x5 LAS	262
4	1000	53.43	421.4	548,909	1	5		1,158,040,800	259	1x5 LAS	259
5	1350	70.14	421.4	542,422	1	5		1,144,627,200	256	1x5 LAS	256
TOTAL			**8,208,062**					**17,505,642,240**	**3768**		**4160**

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.



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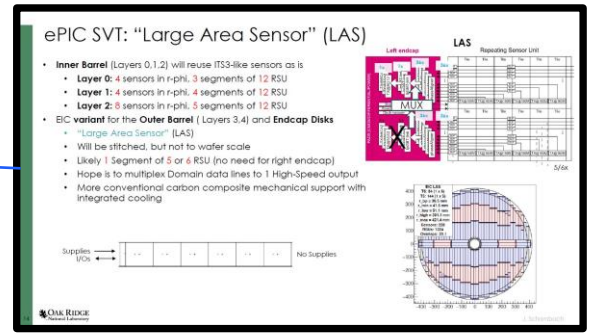
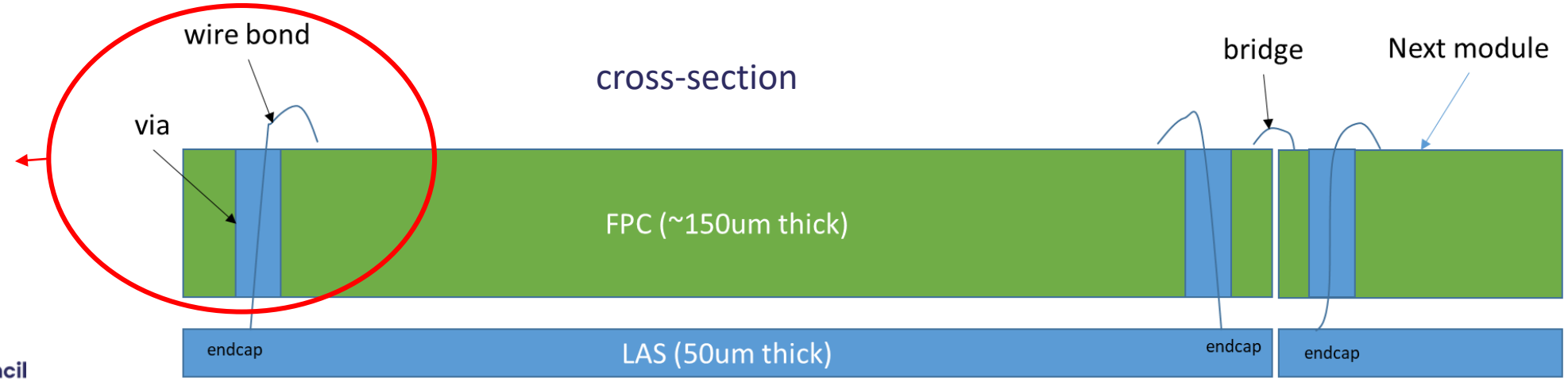
Doubt

- “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



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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

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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]

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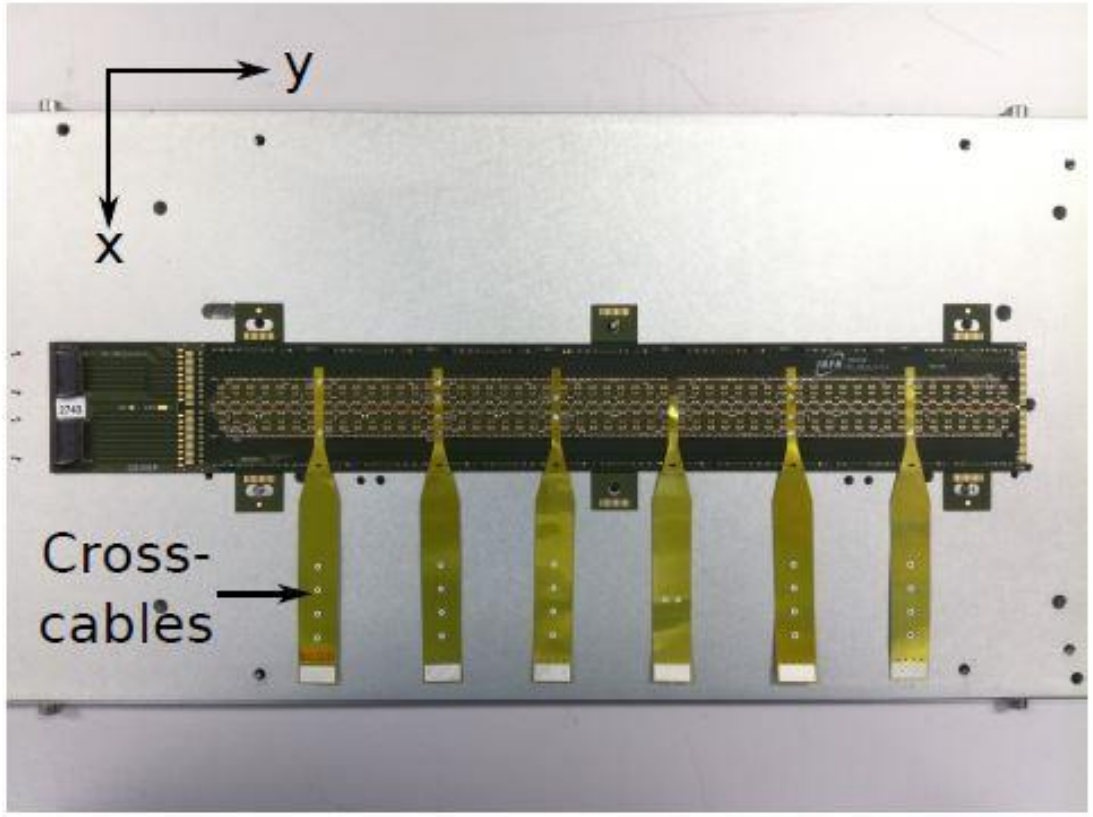
ALICE ITS2 OB

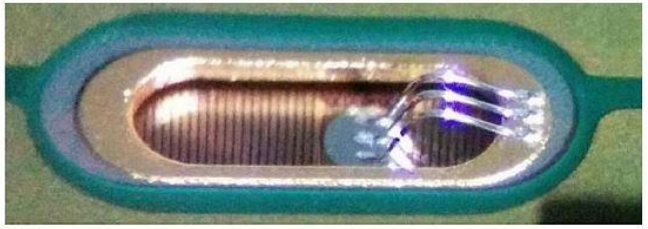


Cu tracks [☹]

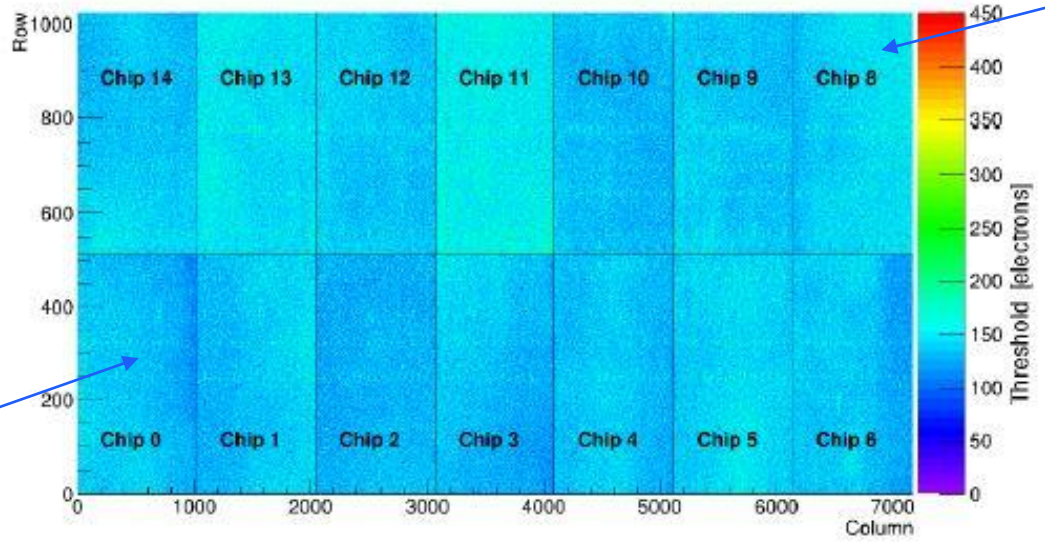
2 rows of 7 ALPIDE per FPC

-> 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

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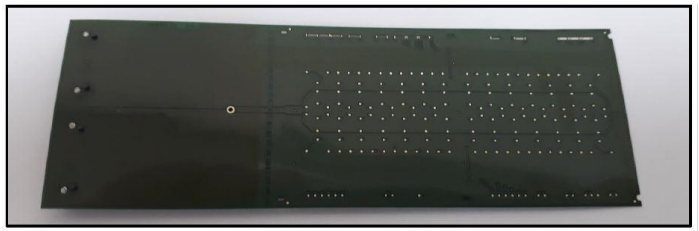
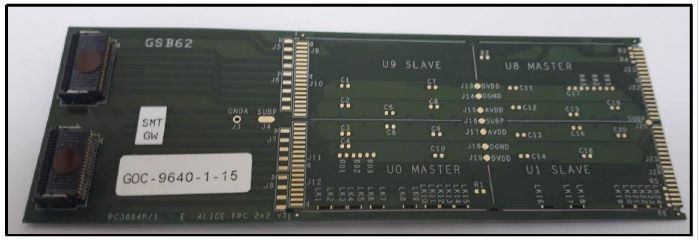
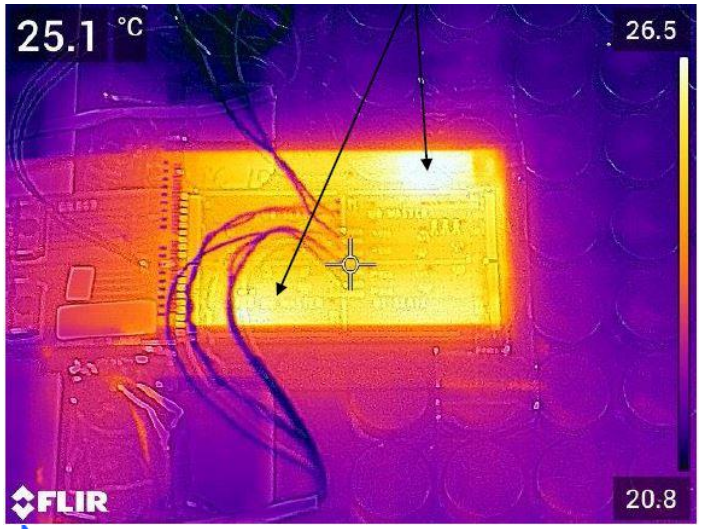
ALPIDE QUAD w/o wire-bonds







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- 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

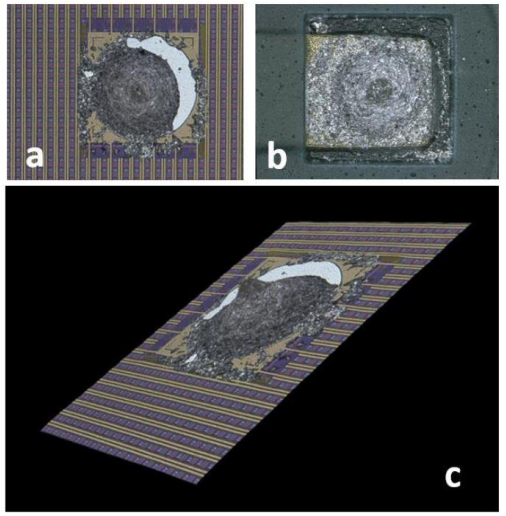


Fig. 7. Microscope images of contact pads after intentional separation of sensor and FPC: a) sensor contact pad, b) matching pad on FPC, and c) 3D rendering of sensor contact pad.

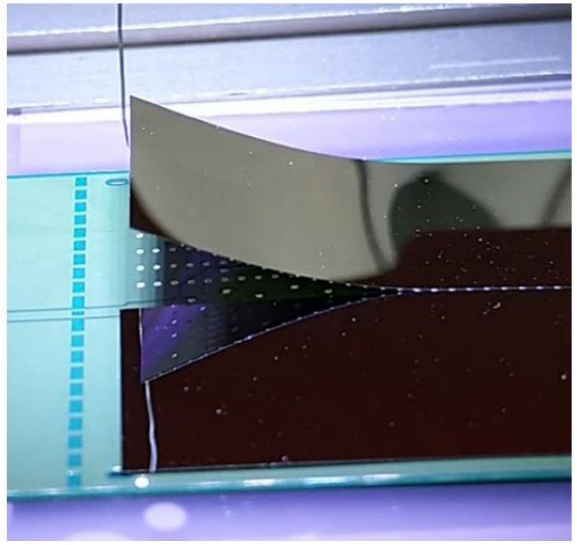
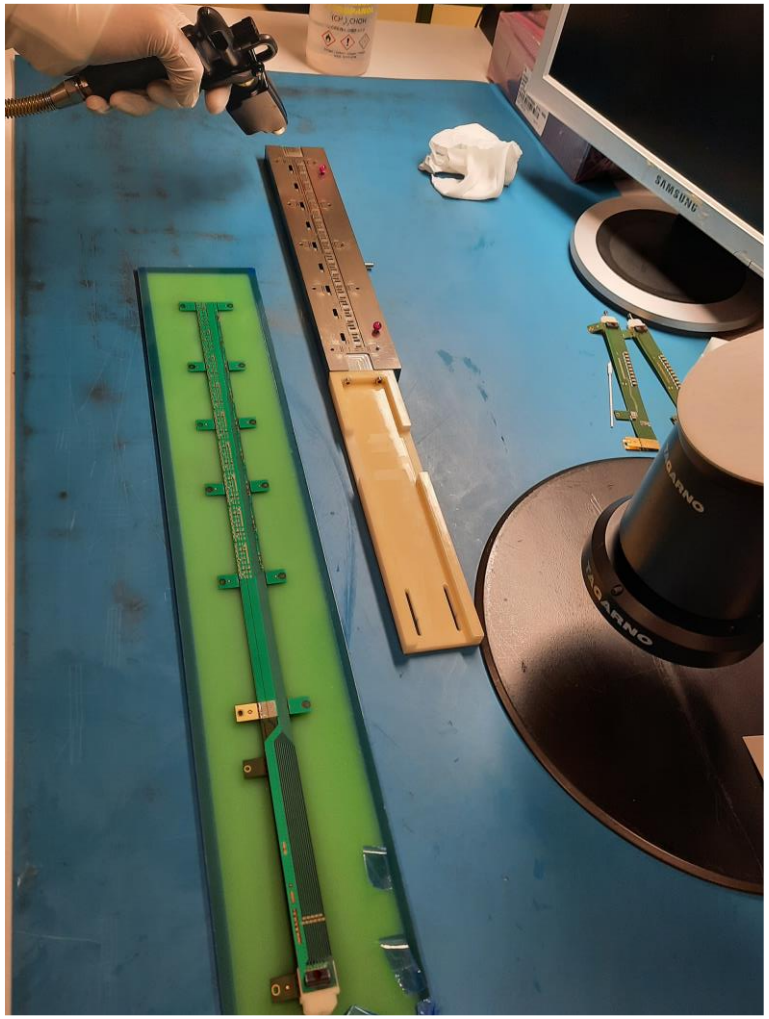


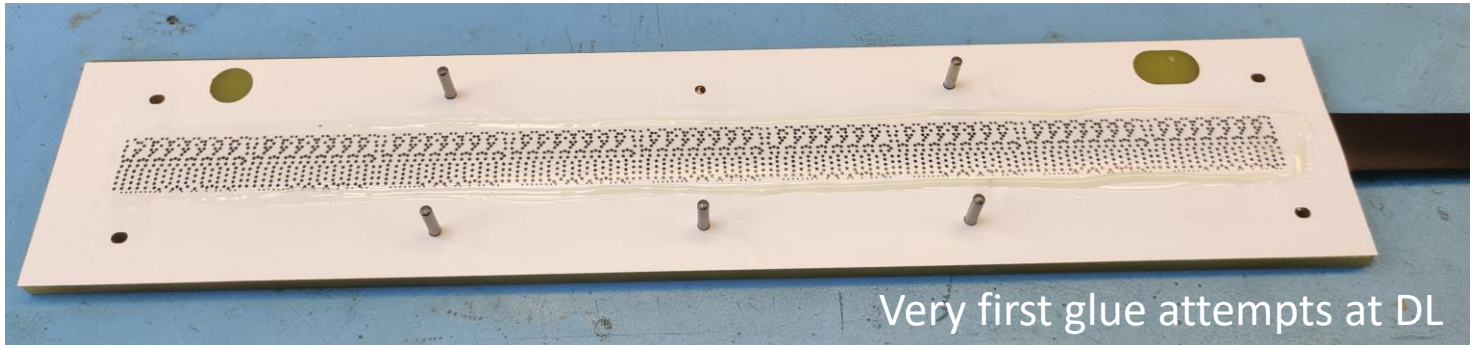
Fig. 6. Pull test on a chip attached to a FPC.

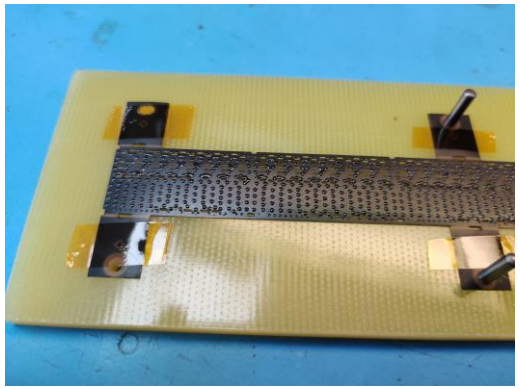
R3B Trt - ITS2 Inner barrel modules



- 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.


Stage1 – LTU FPC, Aluminium


Very first glue attempts at DL



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1:1 meeting Nikki Marcello

20230822 - disk concept-2.pdf

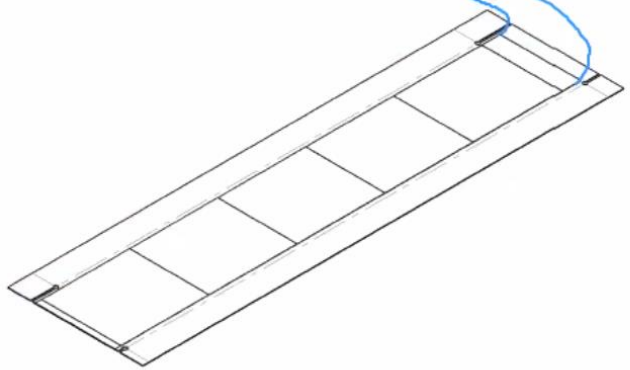
Home Tools 20231011-eicWp3... 20230822 - disk c... × Sign In

11 / 17 37.5%

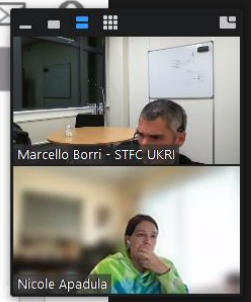
Module concept

A “module” could have one or more sensors on either or both sides,

In its most rudimentary form, with one EIC LAS only, it might look something like this:



Note that the EIC LAS sensor here as five RSUs and peripheries on both sides. Its support extends slightly beyond the main periphery (likely needed for bonding) and the slots would allow for overlap along the length axis (provided the materials are all thin enough or the structure is not entirely flat).



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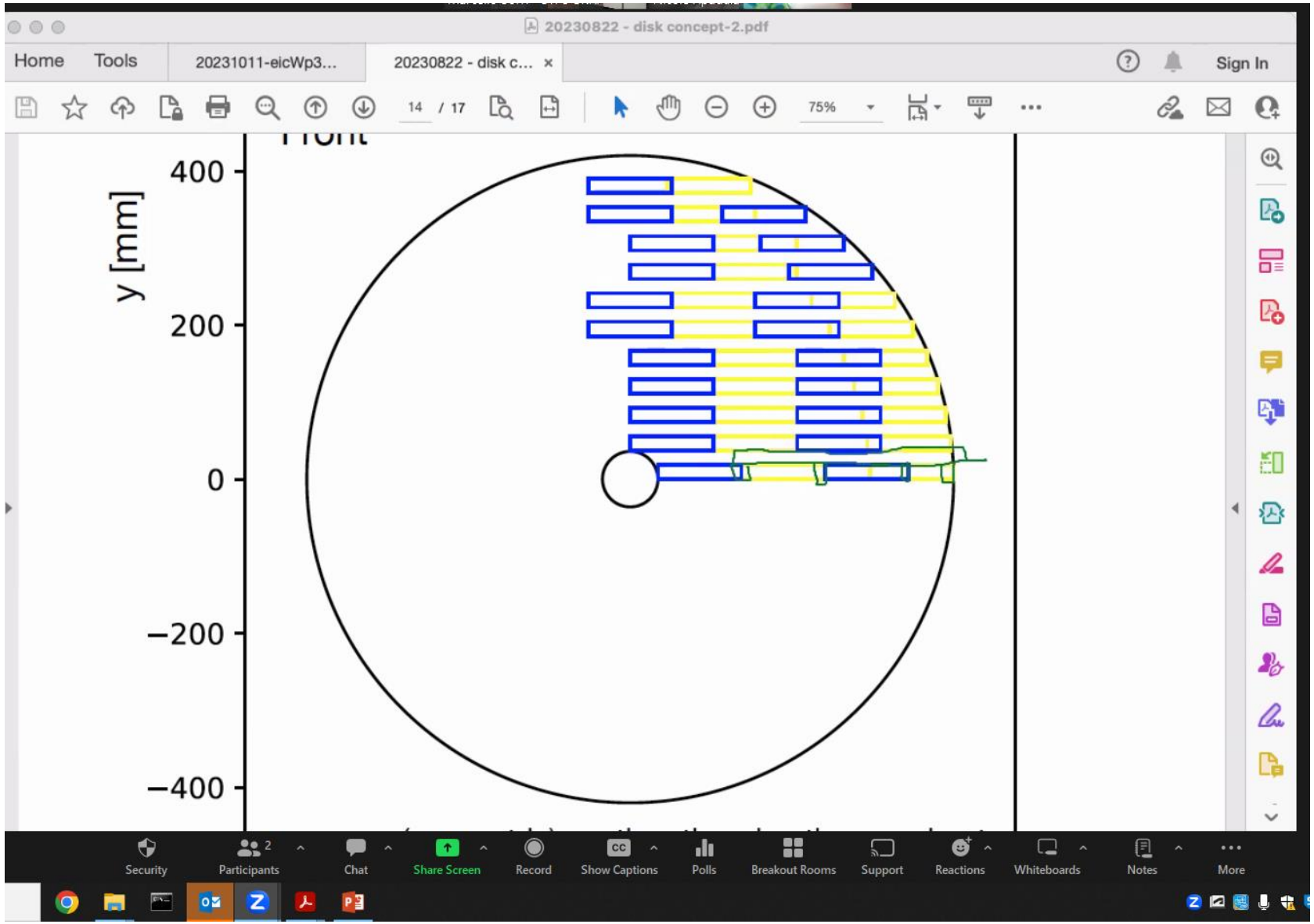
1:1 meeting Nikki Marcello



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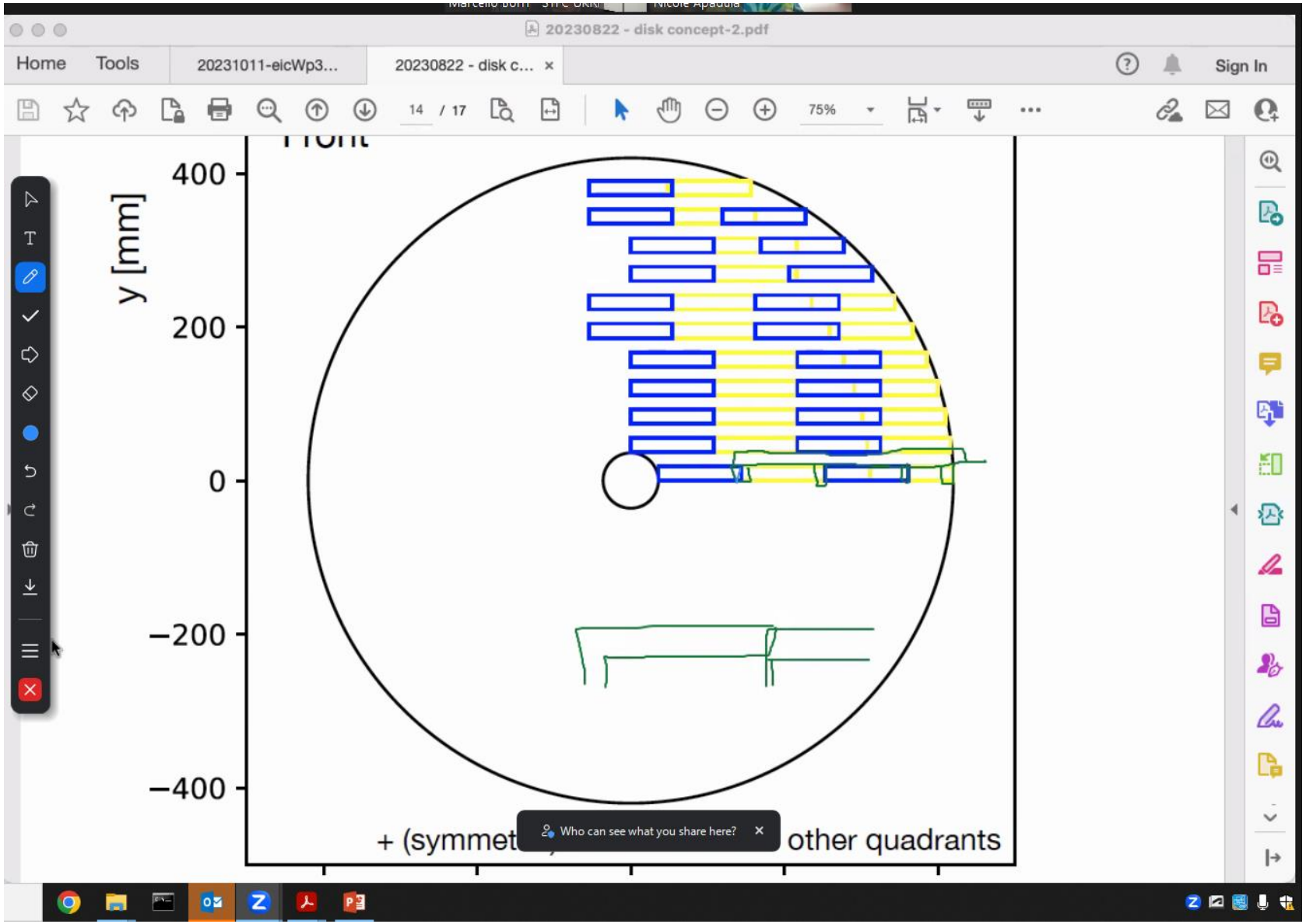
1:1 meeting Nikki Marcello



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1:1 meeting Georg Marcello

- GV Not sure if disks w air cooling will work
- Sensors to be mounted all on 1 side on stave, no staggering
- Cooling for stave currently undefined, most likely liquid cooling, but gas is also attractive due to uniformity
- Kapton is one of the dominant components of material budget, see below
- GV thinking of multipurpose parts:
  - Al foam for support and cooling, plus use it as power bus;
  - To bend Si LAS to increase structural approach
- Interplay between components to reach optimal design: sensor design, cooling, FPC;