OAK RIDGE National Laboratory

July 10, 2025, SVT Workshop

IB Readout

(Many thanks for many of the slides from our ITS3 colleagues from LPSC Grenoble)

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ORNL

U.S. DEPARTMENT OF ENERGY

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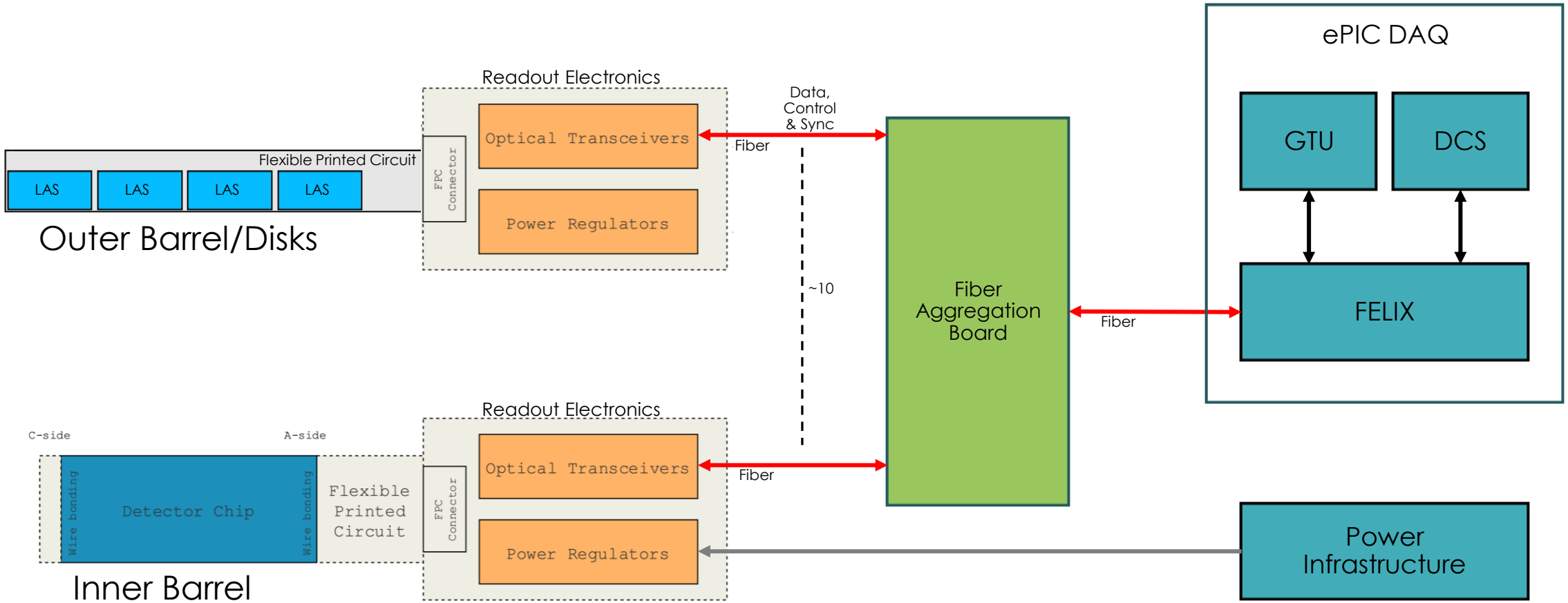
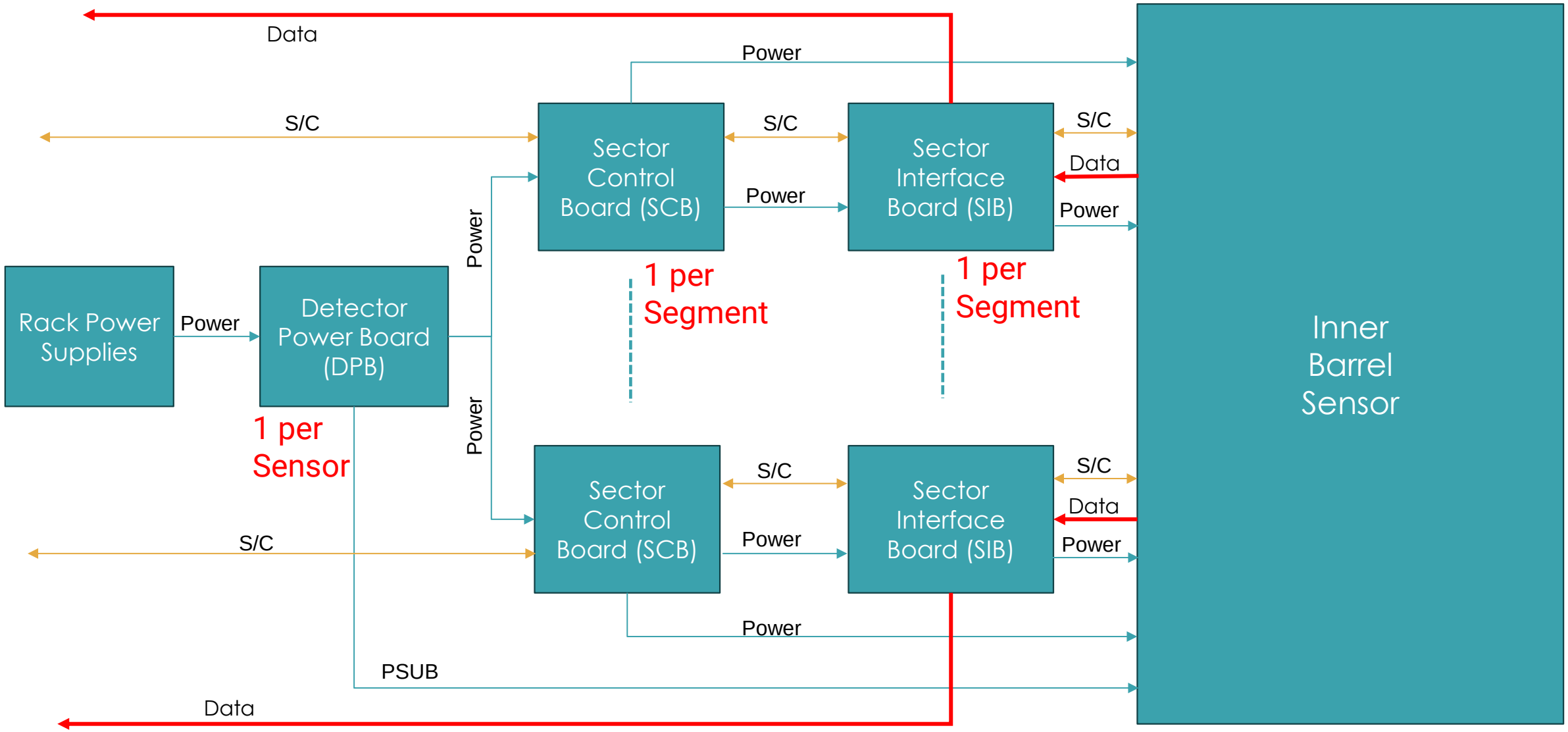
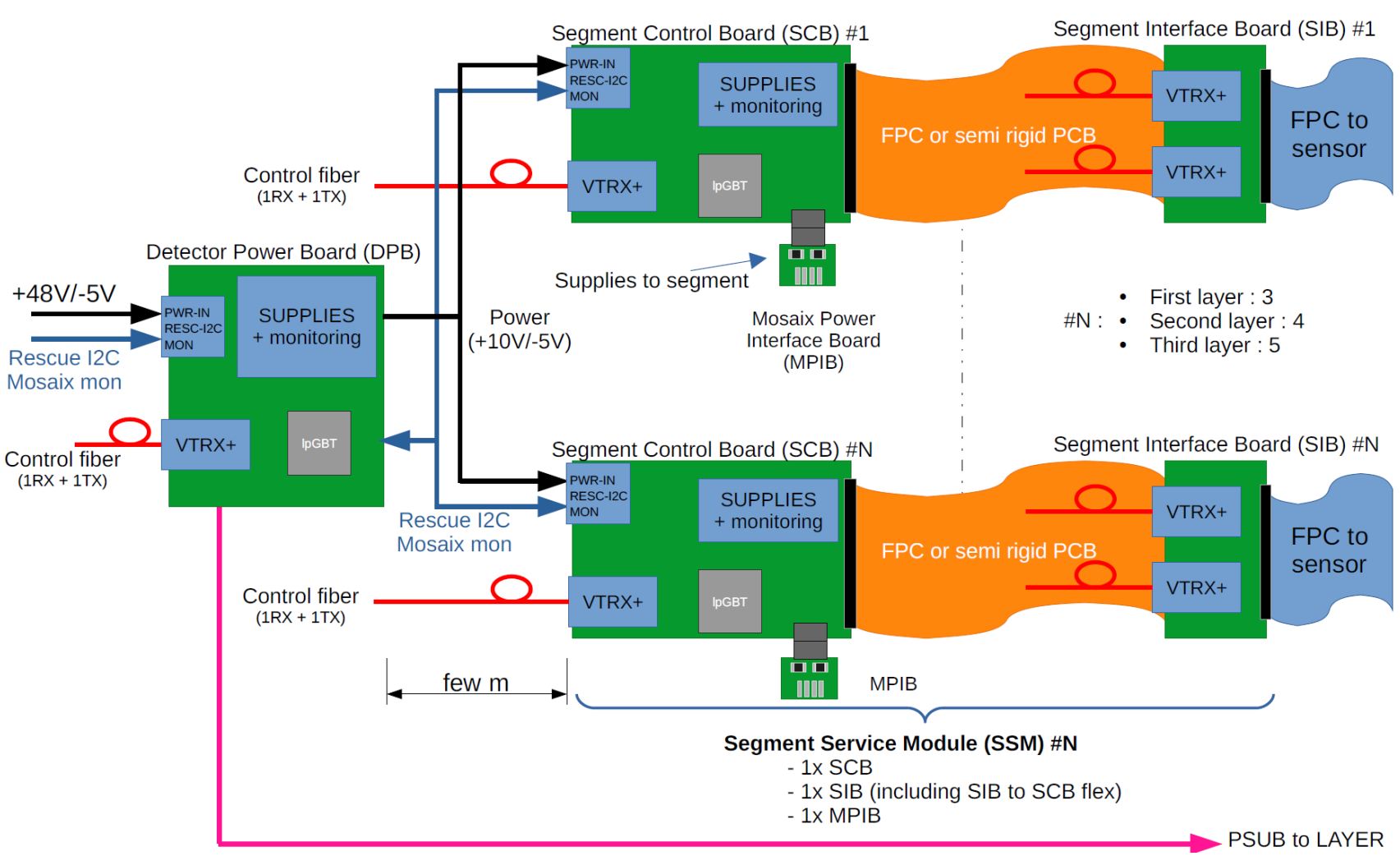
SVT Electronics – Simplified Overview



IB Readout, Power & Controls Scheme



IB Readout Architecture

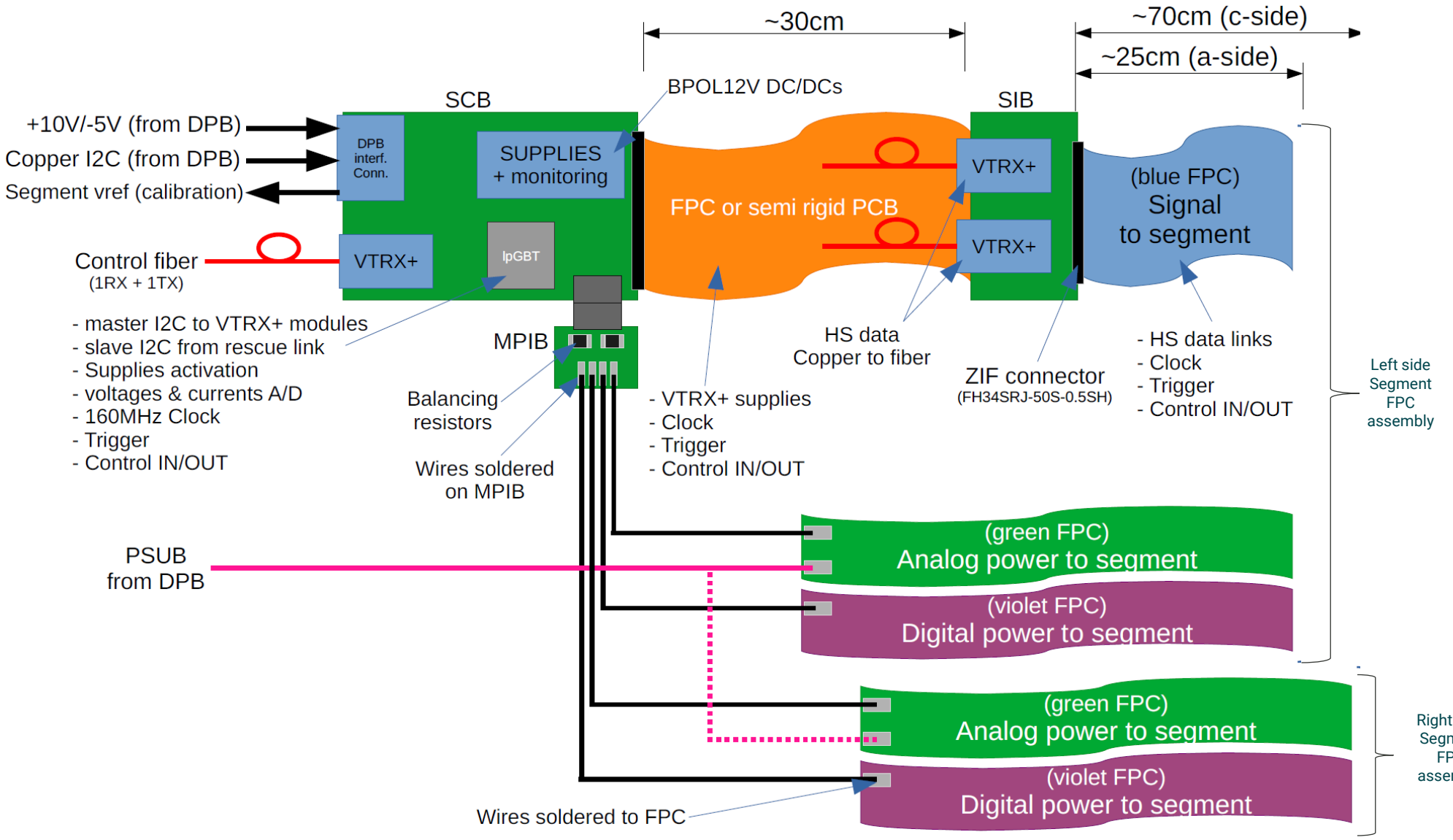


Detector Service Electronics

1 set per sensor

1 DPB
+
3 or 4 or 5 SSM

Segment Readout Architecture



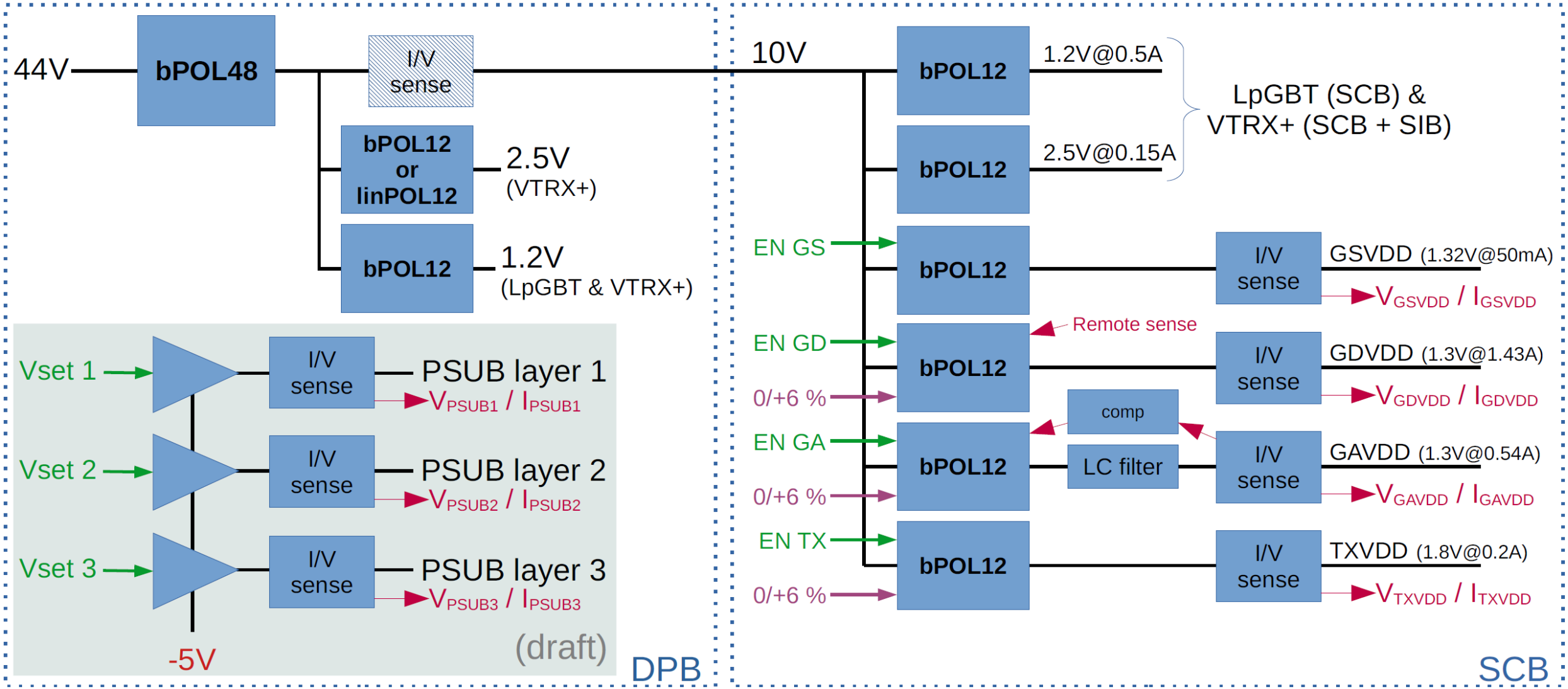
SCB Features:

- Power Supply Tree
- 1 lpGBT for
  - Clocking
  - Triggering
  - Slow Control
  - Monitoring

SIB Features:

- 2 VTRx+
- Transport ‘slow’ signals

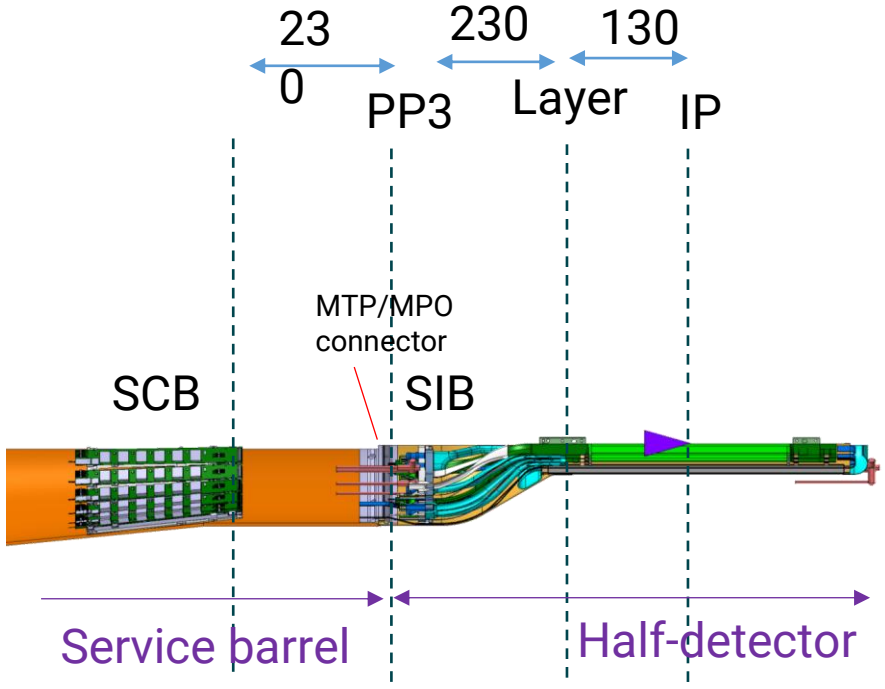
DPB – SCB Power Tree



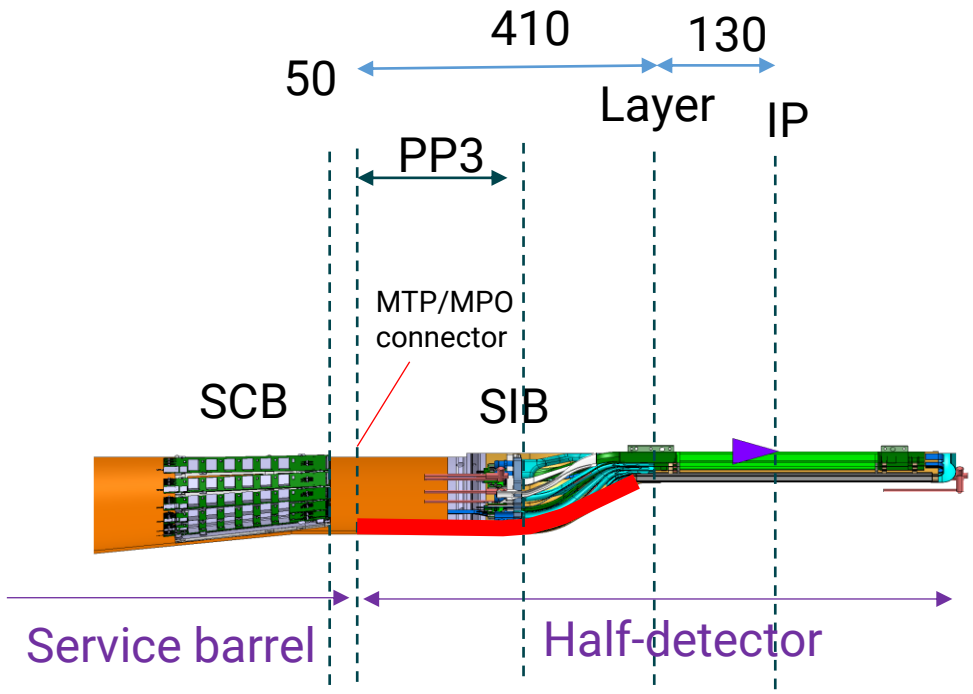
Readout Board Counts

- **Layer 0:** 4 sensors with 3 segments each
  - 4 sensors times 3 segments = 12 SIB
  - 4 sensors times 3 segments = 12 SCB
  - 4 sensors = 4 DPB
- **Layer 1:** 4 sensors with 4 segments each
  - 4 sensors times 4 segments = 16 SIB
  - 4 sensors times 4 segments = 16 SCB
  - 4 sensors = 4 DPB
- **Layer 2:** 8 sensors with 5 segments each
  - 8 sensors times 5 segments = 40 SIB
  - 8 sensors times 5 segments = 40 SCB
  - 8 sensors = 8 DPB
- **Total IB:** 68 SIB + 68 SCB + 16 DPB

Options for VTRx+ Pigtail Attachment



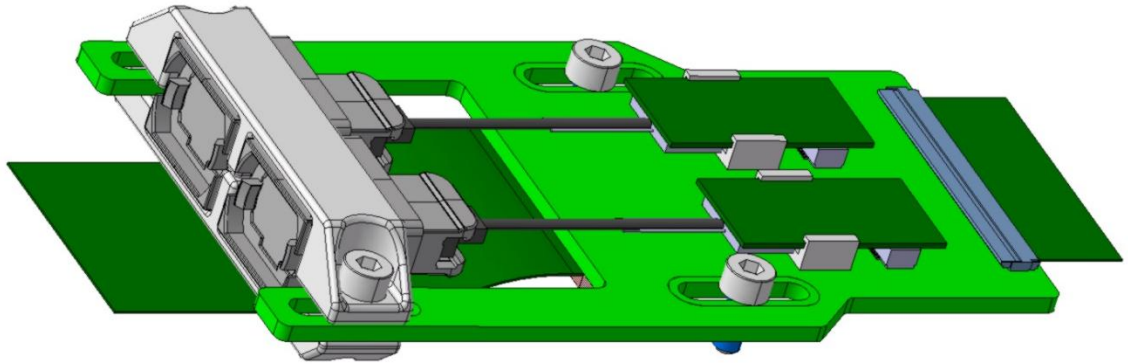
Option A:
Solution involving large SIB boards

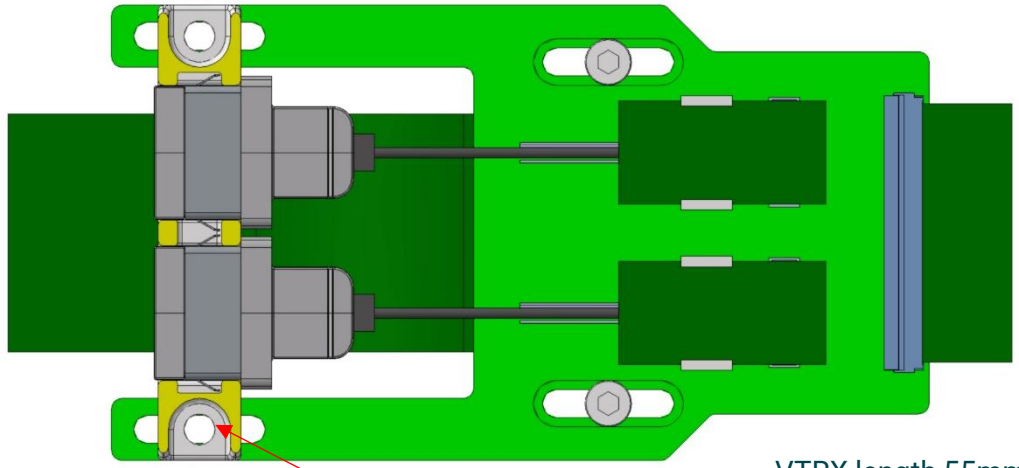


Option B:
Solution involving the enlargement of the PP3

ITS3 SIB Design

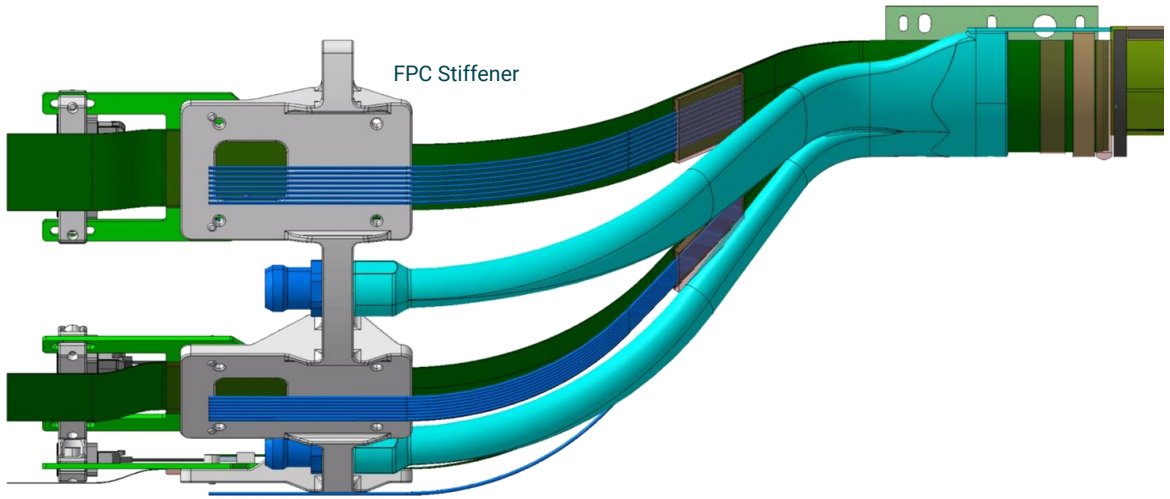
Option A: Solution with large SIB boards

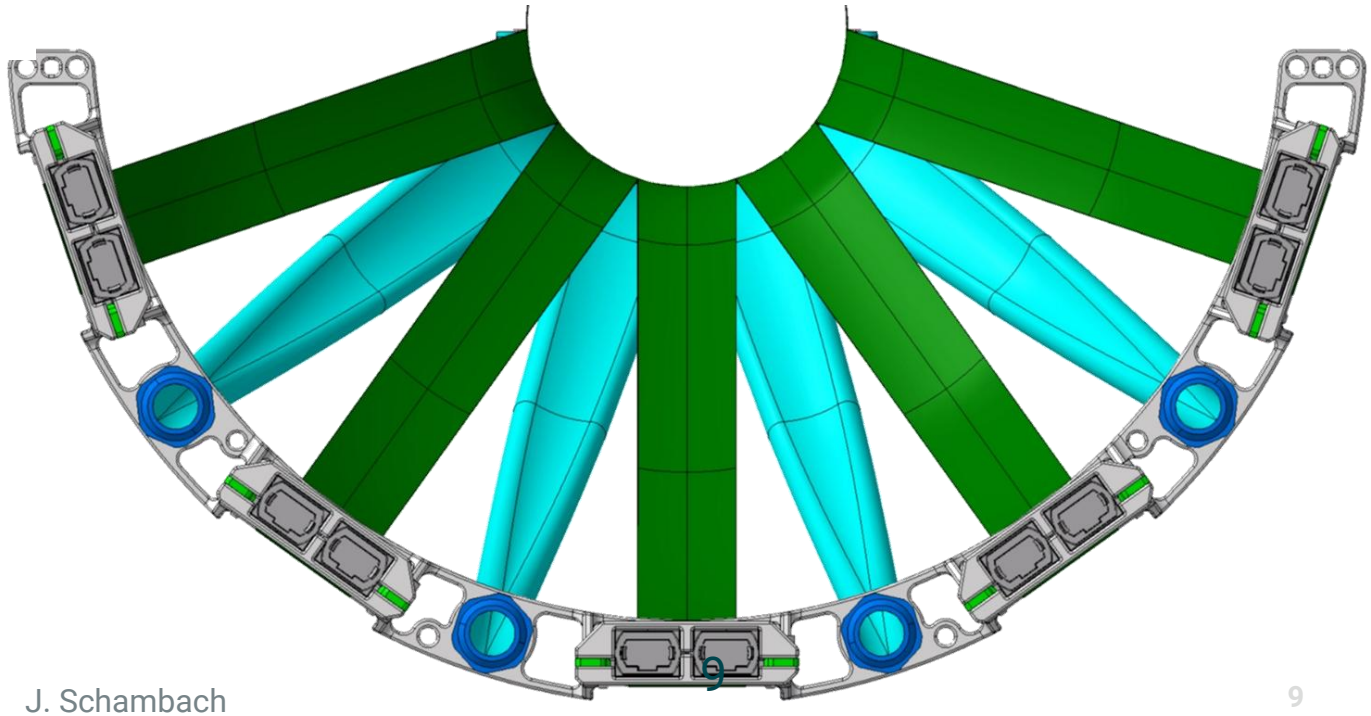


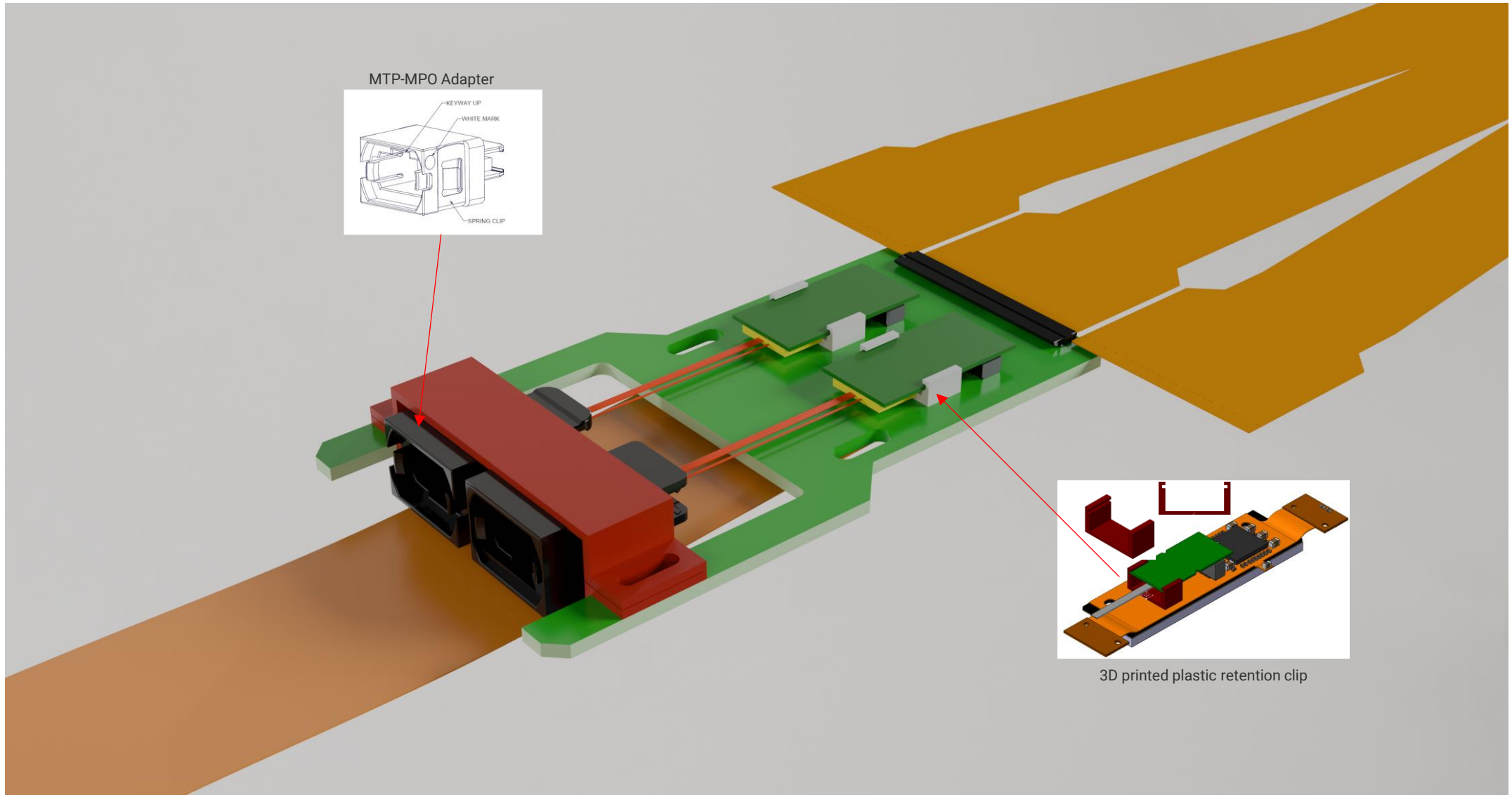


Adjustable

VTRX length 55mm
SIB length 79 mm

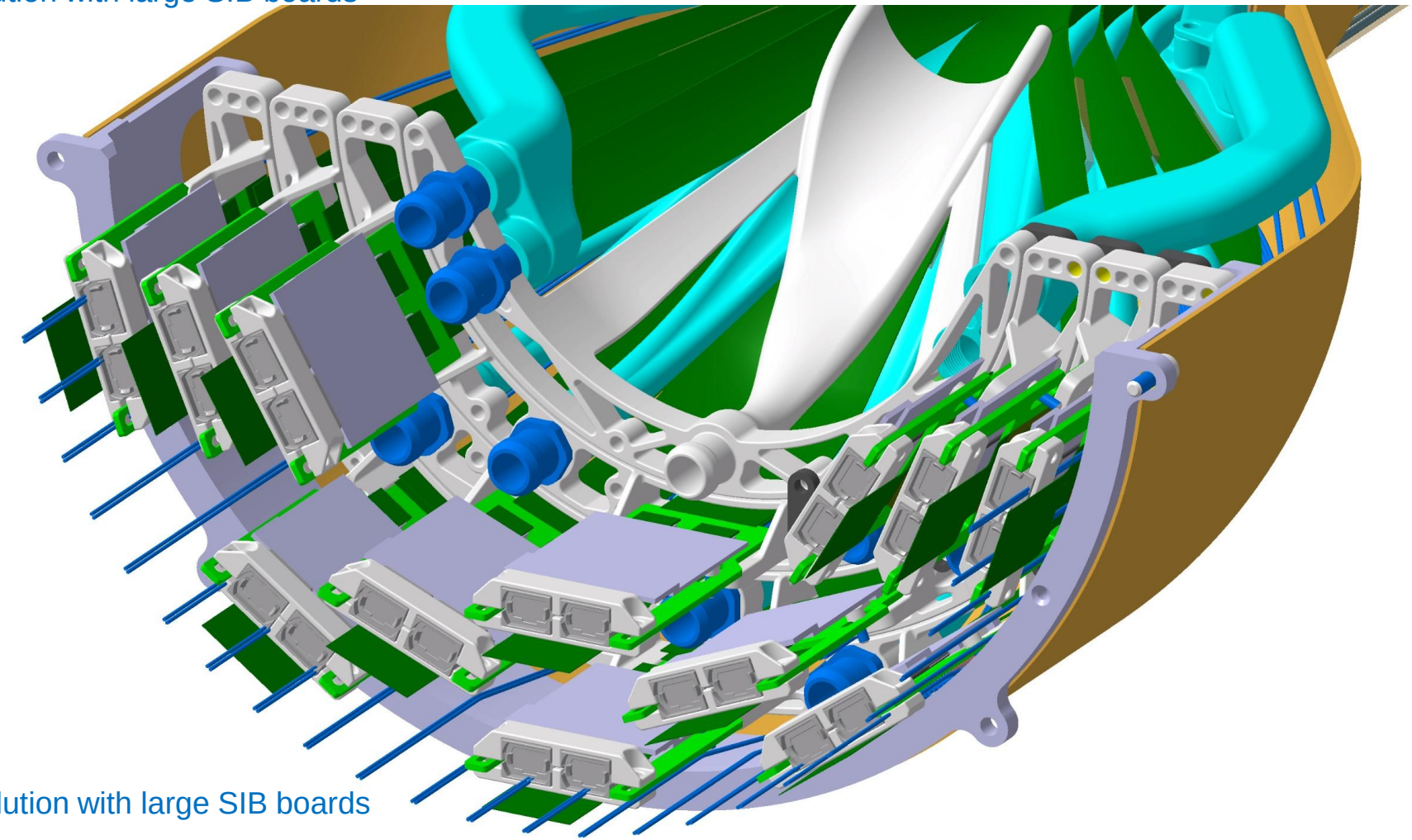





MTP-MPO Adapter
KEYWAY UP
WHITE MARK
SPRING CLIP
3D printed plastic retention clip

ITS3 Services – Ongoing design

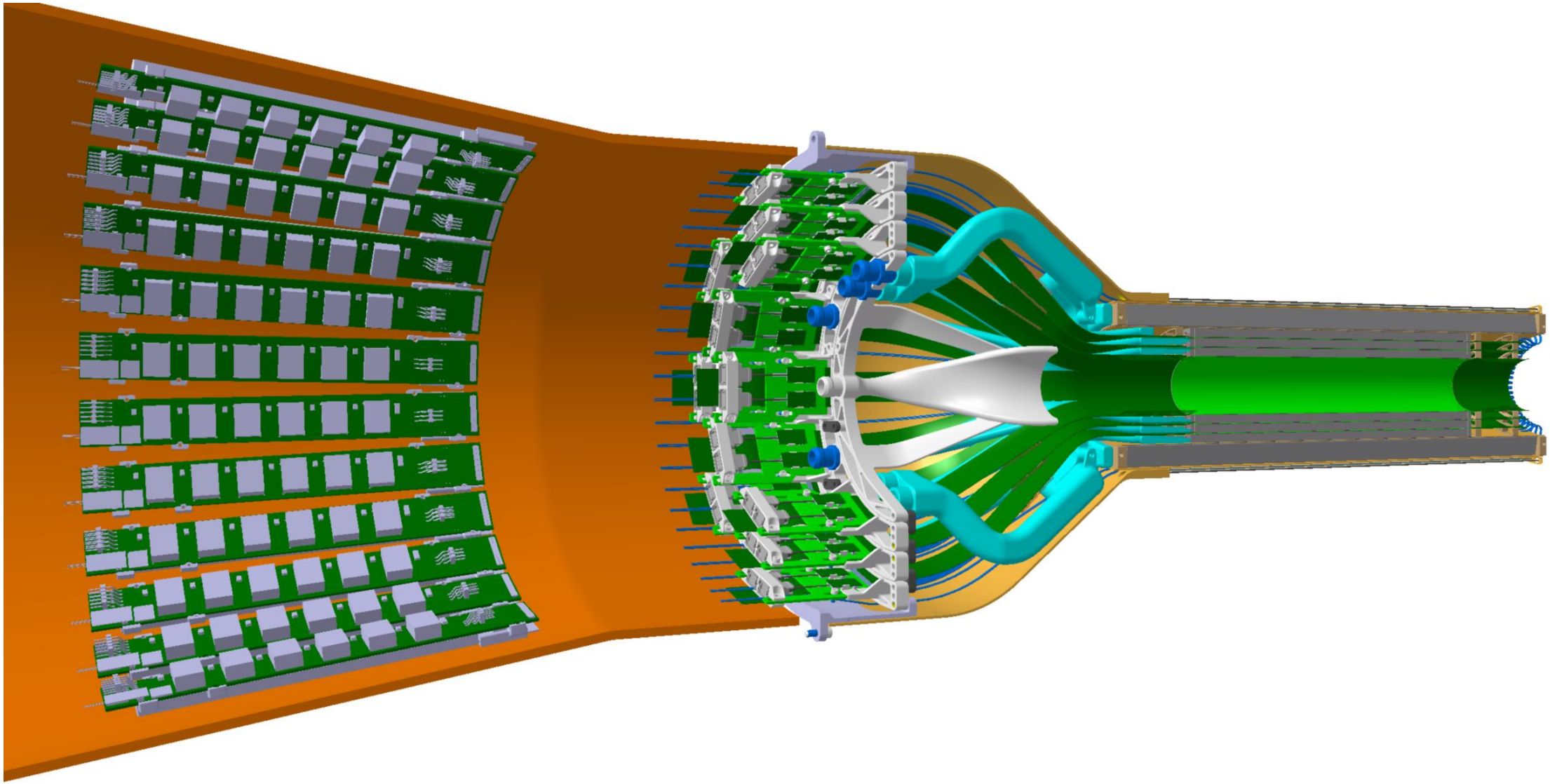
Option A: Solution with large SIB boards



Option A: Solution with large SIB boards

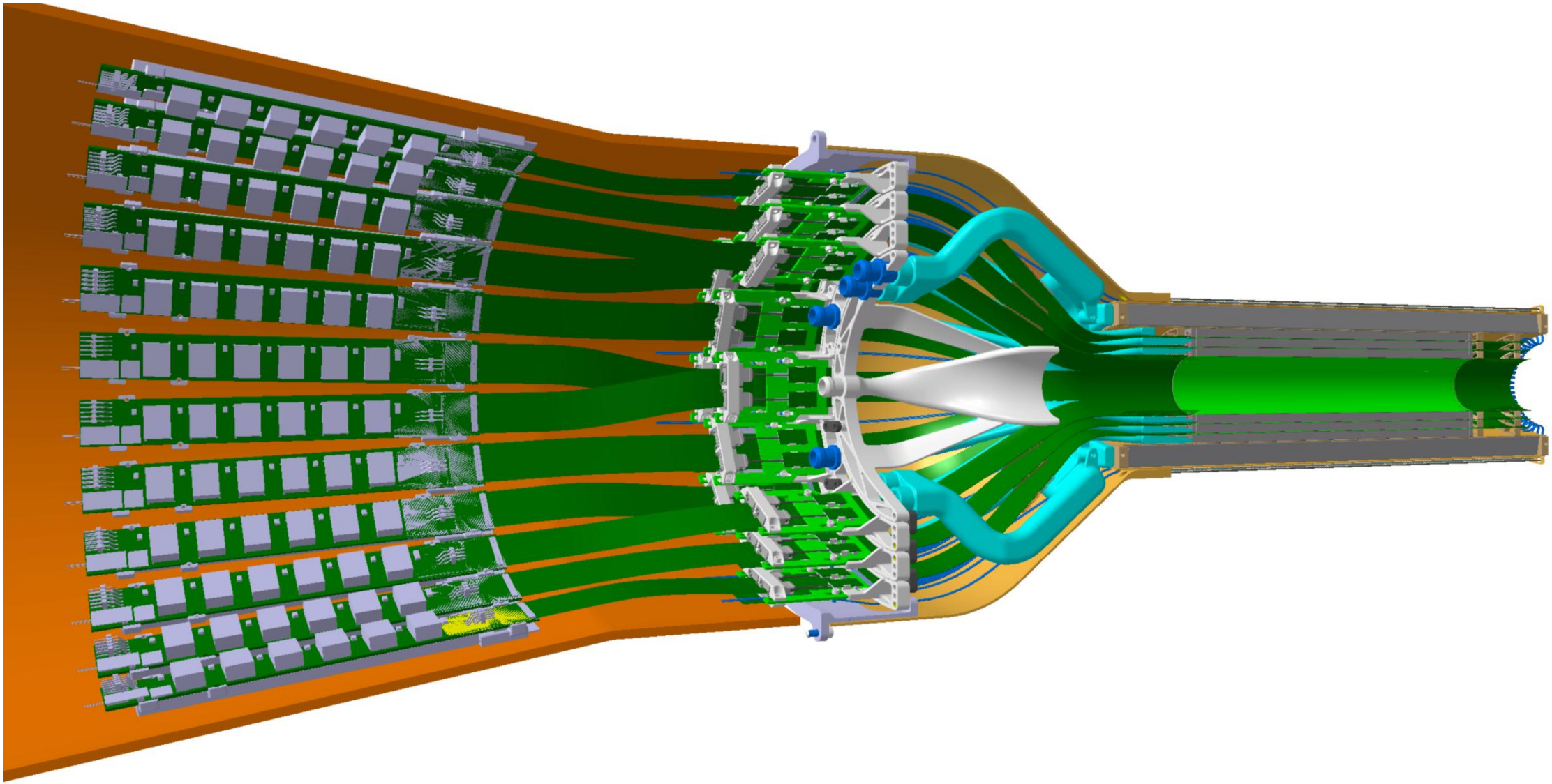
ITS3 Services – Ongoing design

Option A: Solution with large SIB boards



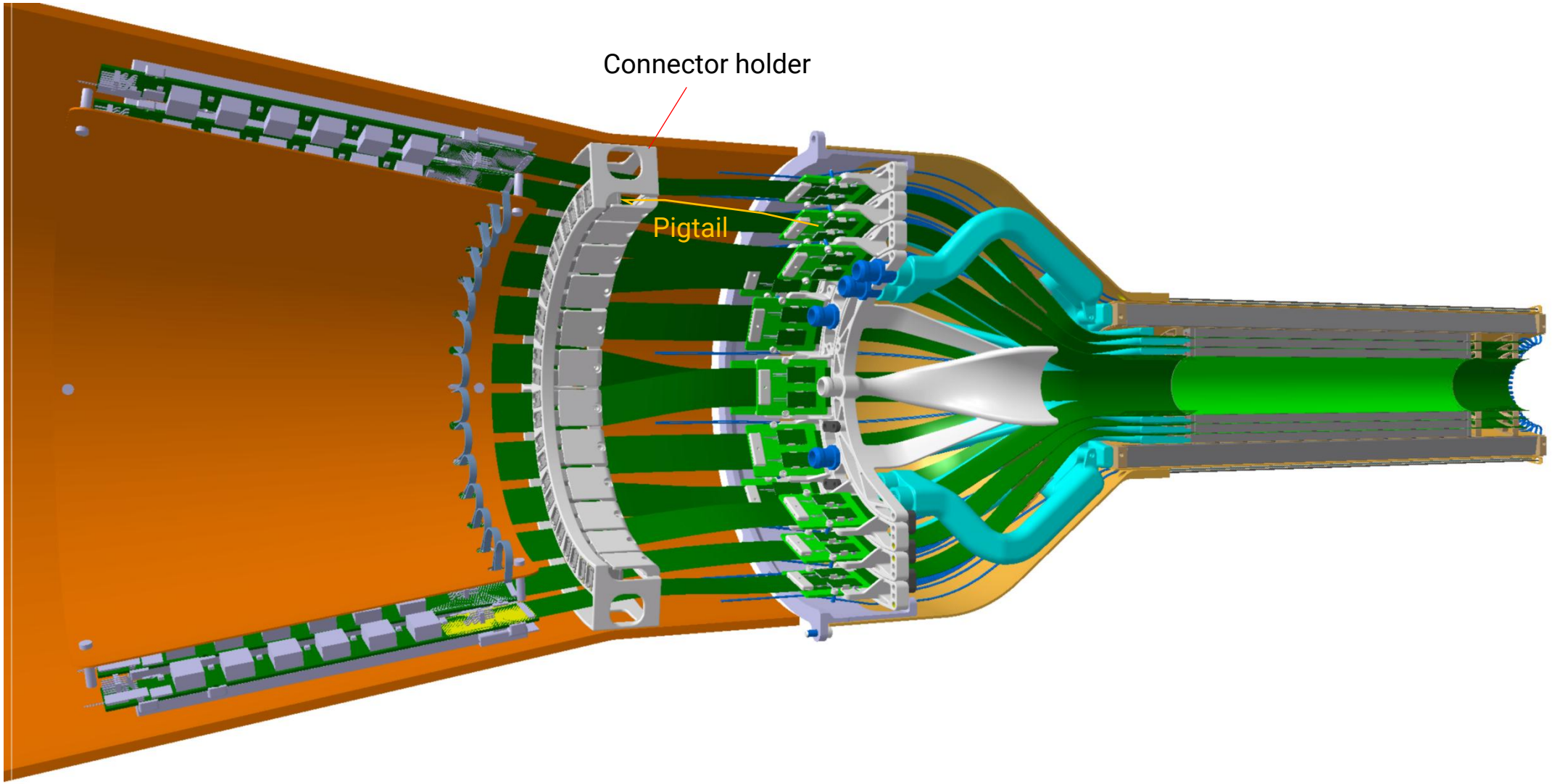
ITS3 Services – Ongoing design

Option A: Solution with large SIB boards



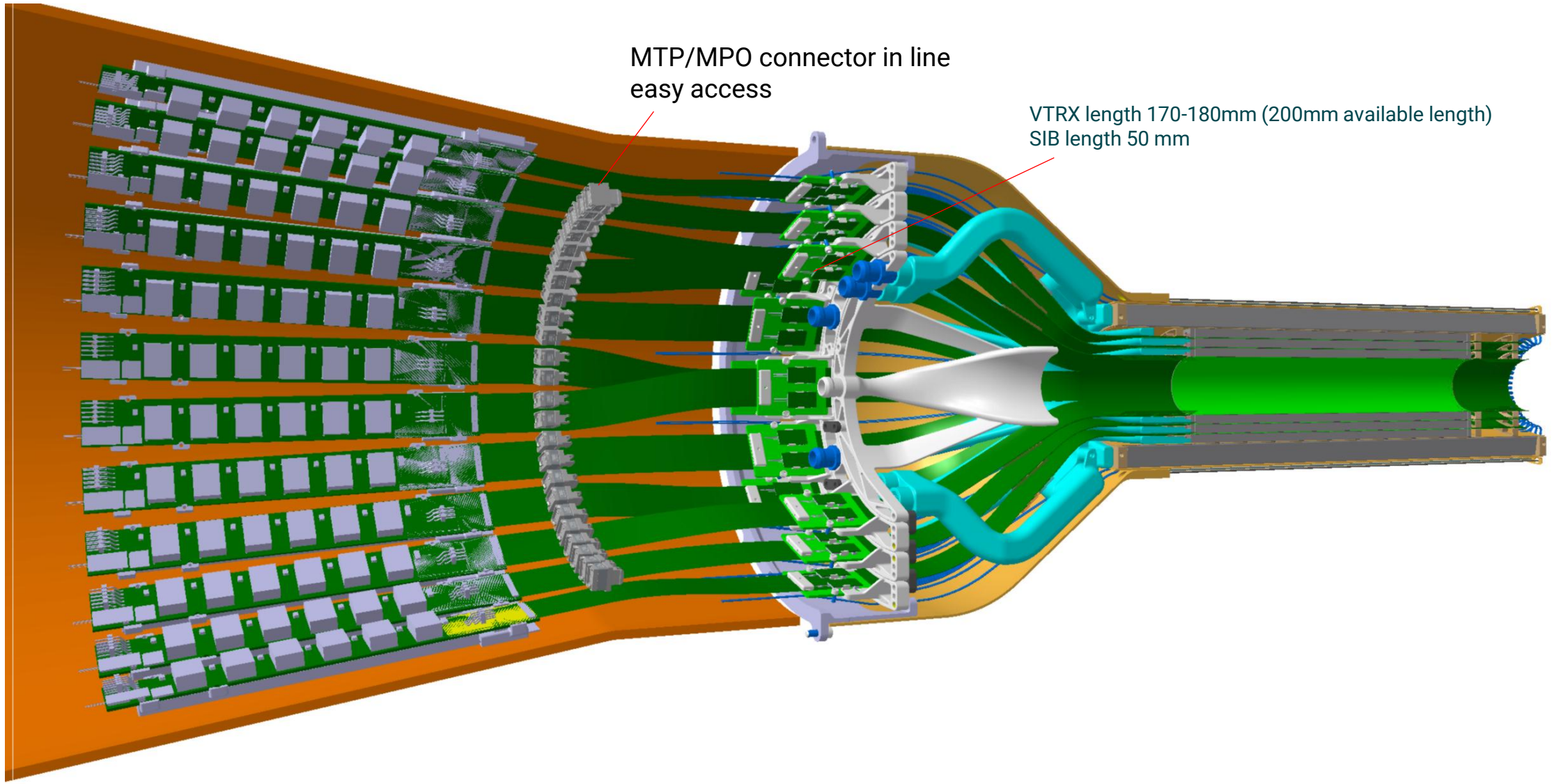
ITS3 Services – Ongoing design

Option B: Solution with enlargement of the PP3

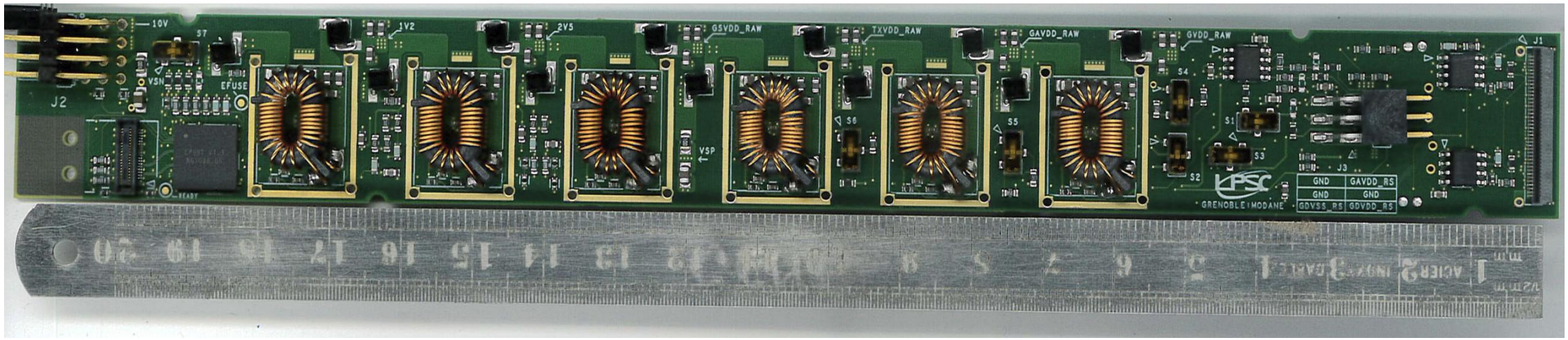


ITS3 Services – Ongoing design

Option B: Solution with enlargement of the PP3

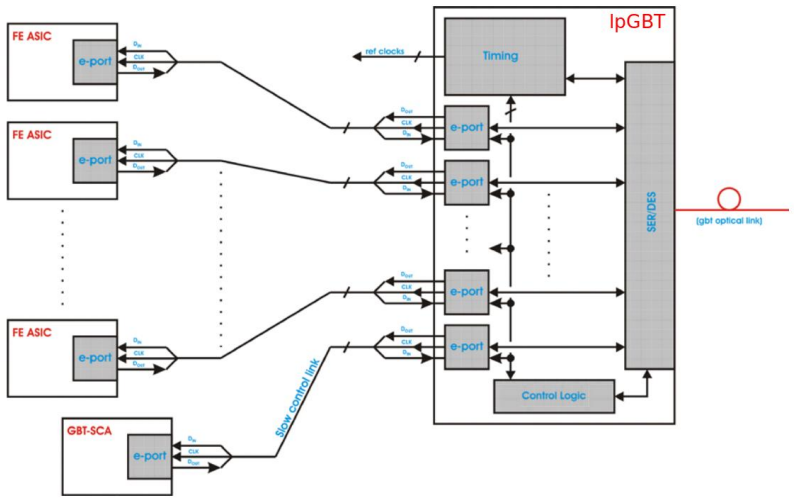


ITS3 SCB Design with bPOLs

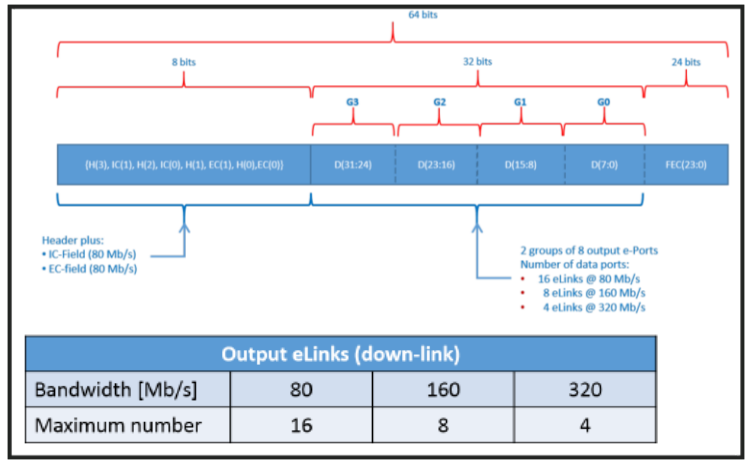


From Yesterday: Data Rates

lpGBT Protocol



- Front Ends connect to “e-links”
- The fiber protocol includes “Forward Error Correction”
- Downlink runs at 2.56 Gbps
  - Downlink frame is 64bit wide, of which 32 bits are payload
  - 1.28 Gbps payload
  - Up to 16 e-links @ 80 Mbps
- Uplink runs at either 10.24 Gbps or 5.12 Gbps
  - Uplink frame is either 128bit or 256bit
  - 256bit frame contains 192bits of payload (7.68 Gbps)
  - Up to 24 e-links at either 160 Mbps or 320 Gbps



Output eLinks (down-link)			
Bandwidth [Mb/s]	80	160	320
Maximum number	16	8	4

Downlink

Line Rate: **2.56 Gbps**
32 out of 64 bits are data:
Payload = **1.280 Gbps**

Data Uplink

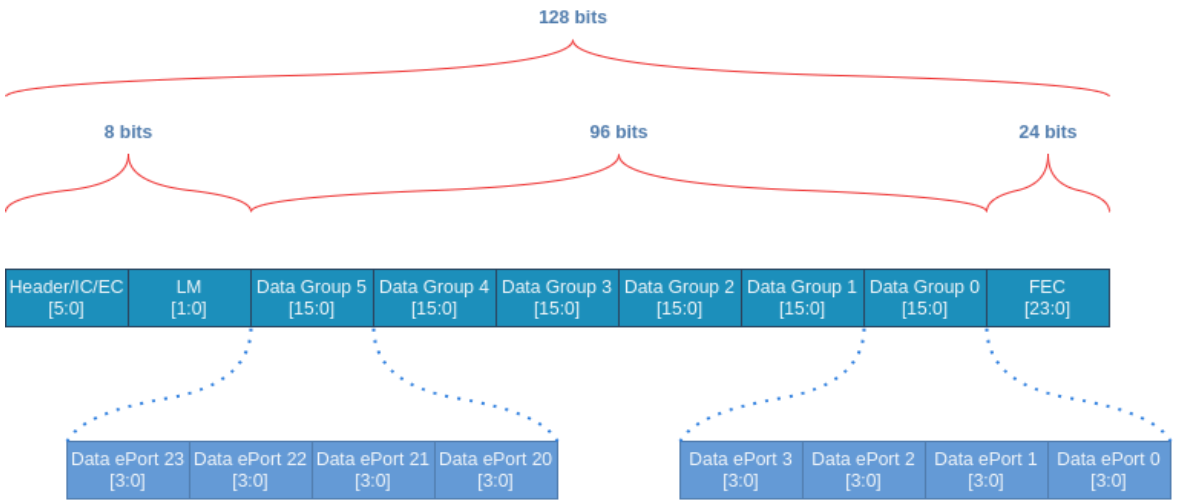
192 out of 256 bits are data:
Payload = **7.680 Gbps**

Input eLinks (up-link)												
Up-link bandwidth [Gb/s]	5.12						10.24					
FEC coding	FEC5			FEC12			FEC5			FEC12		
Bandwidth [Mb/s]	160	320	640	160	320	640	320	640	1280	320	640	1280
Maximum number	28	14	7	24	12	6	28	14	7	24	12	6

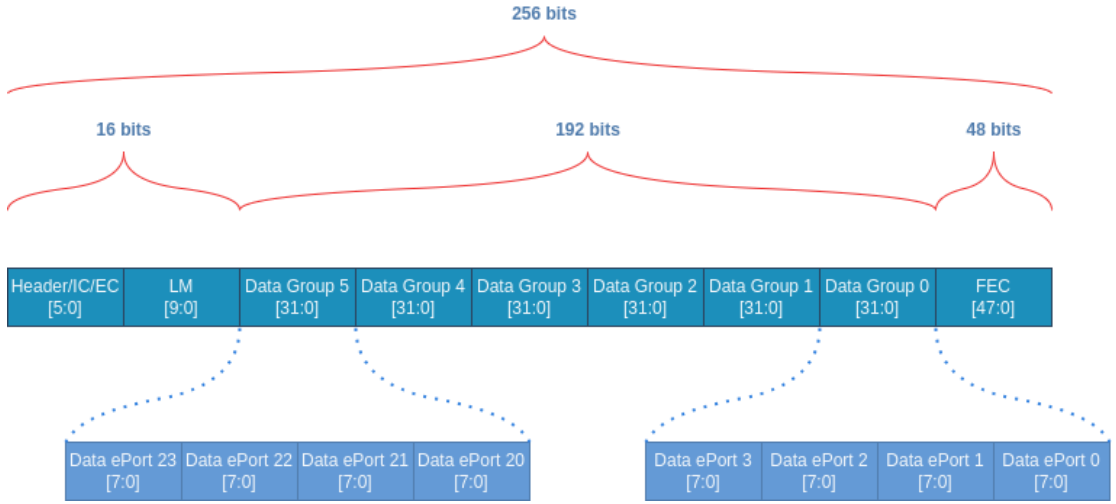
Field	5.12 Gbps FEC5	5.12 Gbps FEC12	10.24 Gbps FEC5	10.24 Gbps FEC12
Frame [bits]	128		256	
Header [bits]	2		2	
IC [bits]	2		2	
EC [bits]	2		2	
D [bits]	112	96	224	192
FEC [bits]	10	24	20	48
LM [bits]	0	2	6	10
Correction [bits]	5	12	10	24
# of eLink groups	7	6	7	6

lpGBT ePort Routing

5.12Gbps



10.24Gbps



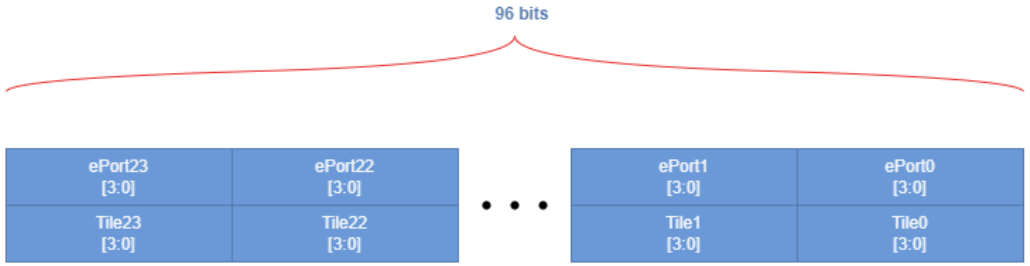
MOSAIX uplink						
Uplink bandwidth (Gbps)	5.12			10.24		
FEC Coding	FEC12			FEC12		
Tile bandwidth (Mbps)	40	80	160	40	80	160
Tiles per uplink [1]	48	48	24	48	48	48
Bits per tile	1	2	4	1	2	4
Tiles per ePort	2	2	1	2	2	2
Bits per ePort	4	4	4	8	8	8
Used bits per ePort	2	4	4	2	4	8
Bandwidth efficiency	50%	100%	100%	25%	50%	100%

1. To simplify routing scheme, 48 tiles are connected in instances where there are bandwidth enough to support a higher number of tiles.

LEC Data Routing

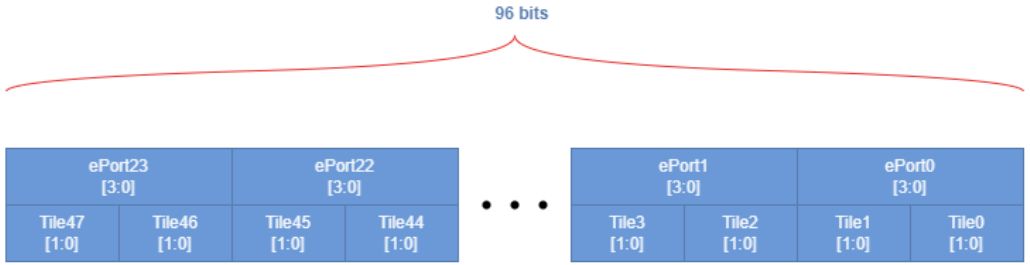
5 Gbps / 160 MHz

(6 links)



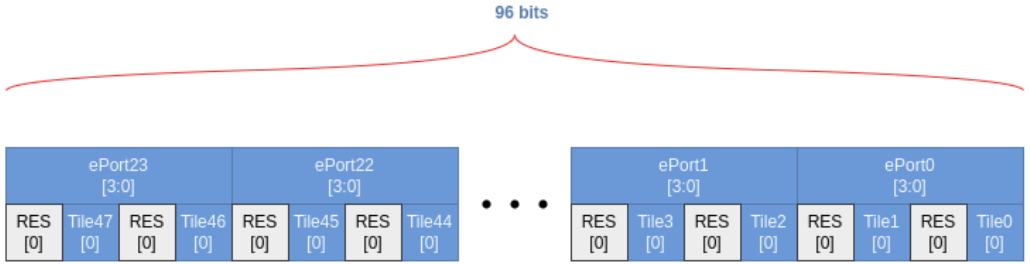
4 frames to reconstruct tile word

5 Gbps / 80 MHz



8 frames to reconstruct tile word

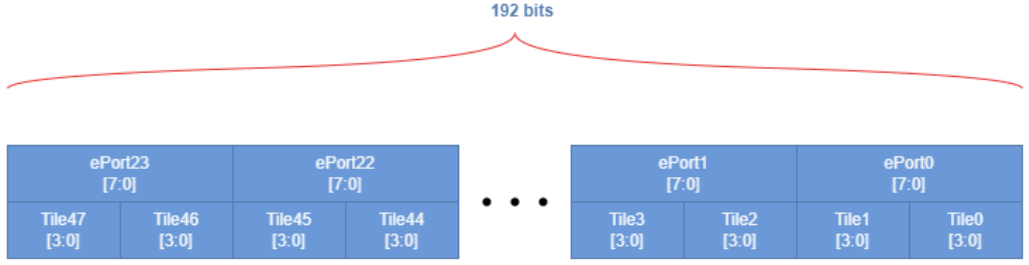
5 Gbps / 40 MHz



16 frames to reconstruct tile word

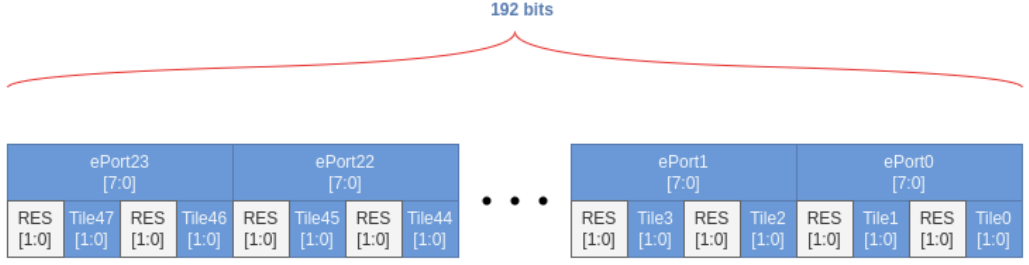
10 Gbps / 160 MHz

(3 links)



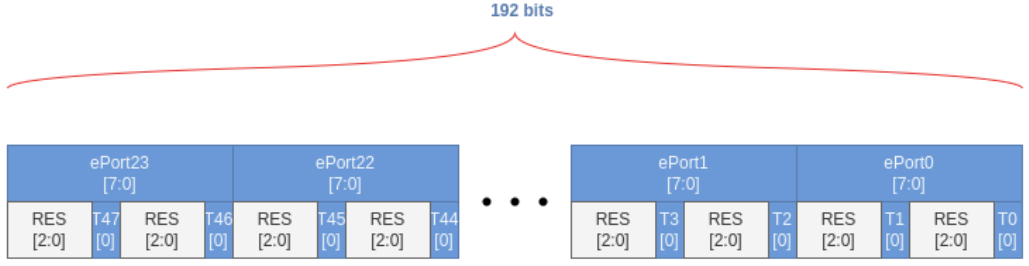
4 frames to reconstruct tile word

10 Gbps / 80 MHz



8 frames to reconstruct tile word

10 Gbps / 40 MHz



16 frames to reconstruct tile word

SVT Counts

	width (mm)	length (mm)		# pixels per RSU																				
																		Average						
Reticle size	19.564	21.666		**831,168**														Cluster size	4					
Pixel size	0.0208	0.0228																						
Barrel					Sensor												10x100GeV		10x275GeV					
Layer Index	**radius (mm)**	**z (mm)**		**Area (mm^2)**	**RSU in width**	**RSU in length**	**# of sensors in r-phi**	**# of sensors in z**	**# tiles**	**# pixels**	**# sensors**	**Notes**	**# Readout Links**	**# Staves**	**# Data VTRx+**	**# SC lpGBTs**	**Hit Rate / s**	**Hits/pixel/2 us frame**	**Hit Rate / s**	**Hits/pixel/2us frame**	**Data Rate (Mbps)**	**Data Rate / Link (Mbps)**	**Epty Rate (Gbps)**	**Epty Rate / Link (Mbps)**
L0	36	260		58,811	3	12	4	1	1,728	119,688,192	4	bent ITS3	96		24	6	4.50E+06	6.99E-08	1.22E+07	1.90E-07	1492.71	41.46	12.875	366.211
L1	48	260		78,414	4	12	4	1	2,304	159,584,256	4	bent ITS3	128		32	8	4.85E+06	5.65E-08	1.32E+07	1.54E-07	1608.81	33.52	17.166	366.211
L2	120	260		196,035	5	12	8	1	5,760	398,960,640	8	bent ITS3	320		80	20	1.41E+06	6.57E-09	3.83E+06	1.79E-08	467.72	3.90	42.915	366.211
L3	270	520		882,158	1	6	96	4	27,648	1,915,011,072	384	6 -RSU LAS	384	48	96	12	8.55E+05	8.30E-10	2.32E+06	2.26E-09	283.61	0.74	205.994	549.316
L4	420	840		2,216,706	1	5	148	8	71,040	4,920,514,560	1184	5-RSU LAS	1184	74	296	37	8.89E+05	3.36E-10	2.42E+06	9.13E-10	294.89	0.25	529.289	457.764
e-endcap																								
Disk index	**z (mm)**	**inner r (mm)**	**outer r (mm)**			**5-RSU LAS**	**6-RSU LAS**							**Readout Modules**					0.00E+00					
ED0	-250	36.76	240	176,710		96	0		5,760	398,960,640	96	5-RSU LAS	96	26	26	4	3.66E+06	1.71E-08	9.95E+06	4.64E-08	1214.07	12.65	42.915	457.764
ED1	-450	36.76	415	536,815		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	4.00E+06	5.36E-09	1.09E+07	1.46E-08	1326.85	3.97	149.310	457.764
ED2	-650	36.76	421.4	553,632		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	3.97E+06	5.32E-09	1.08E+07	1.45E-08	1316.90	3.94	149.310	457.764
ED3	-850	40.0614	421.4	552,835		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	3.74E+06	5.01E-09	1.02E+07	1.36E-08	1240.61	3.71	149.310	457.764
ED4	-1050	46.3529	421.4	551,127		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	3.35E+06	4.49E-09	9.10E+06	1.22E-08	1111.24	3.33	149.310	457.764
h-endcap																								
Disk index																								
HD0	250	36.76	240	176,710		96	0		5,760	398,960,640	96	5-RSU LAS	96	26	26	4	3.92E+06	1.83E-08	1.07E+07	4.97E-08	1300.31	13.54	42.915	457.764
HD1	450	36.76	415	536,815		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	4.45E+06	5.96E-09	1.21E+07	1.62E-08	1476.12	4.42	149.310	457.764
HD2	700	38.52	421.4	553,216		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	4.48E+06	6.00E-09	1.22E+07	1.63E-08	1486.07	4.45	149.310	457.764
HD3	1000	53.43	421.4	548,909		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	3.83E+06	5.13E-09	1.04E+07	1.39E-08	1270.46	3.80	149.310	457.764
HD4	1350	70.14	421.4	542,422		334	0		20,040	1,388,050,560	334	5-RSU LAS	334	96	96	12	3.25E+06	4.36E-09	8.83E+06	1.18E-08	1078.07	3.23	149.310	457.764
TOTAL				**8,161,315**					**280,320**	**19,416,084,480**	**4448**		**4976**		**1348**	**187**	**5.12E+07**	hits/s	**1.39E+08**	hits/s				
																	6.10	Gbps	**16.57**	Gbps		**Empty Rate:**	**2088.5**	**Gbps**
										# of segments:	**4500**													
																	Noise Rate		1.00E-08	(1/pixel/10us)				
																	Total Noise Pixels/s		1.94E+07	pixel/s				
																	Total Noise Rate		**1.16**	Gbps				

64bit/pixel

32bit/pixel

48bit/tile

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Max Rates

DATA RATES

Data from Stephen

- **Max Data Rate per Readout Link** HD0: **13.54 Mbps**
- 13.54 Mbps / 5 RSU/LAS / 12 tiles/RSU = **226 kbps**

Data from Shujie

- **Max Hit Rate per RSU: < 100 hits per RSU per ms**
- 100 hits/ms/RSU * 1000ms/s * 4 pixels per hit * 32 bits/pixel / 12 tiles per RSU = **1.02 Mbps**

NOISE RATES

- **10E-8 per pixel per 10us timeframe** * 100,000 * 69,264 pixels/tile * 64bits/pixel = **4.33 kbps**
- **10E-6 per pixel per 10us timeframe** * 100,000 * 69,264 pixels/tile * 64bits/pixel = **433 kbps**

TOTAL

1.02 Mbps + 433 kbps = **1.5 Mbps**