MPGDs: Power and Cooling Design

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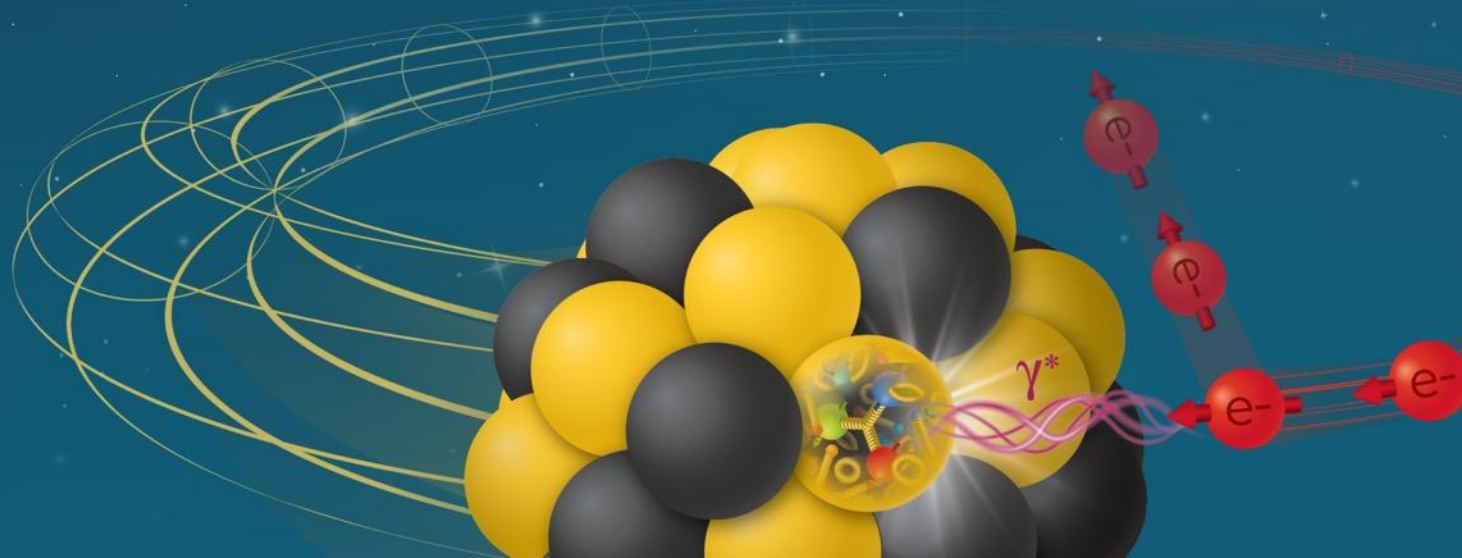
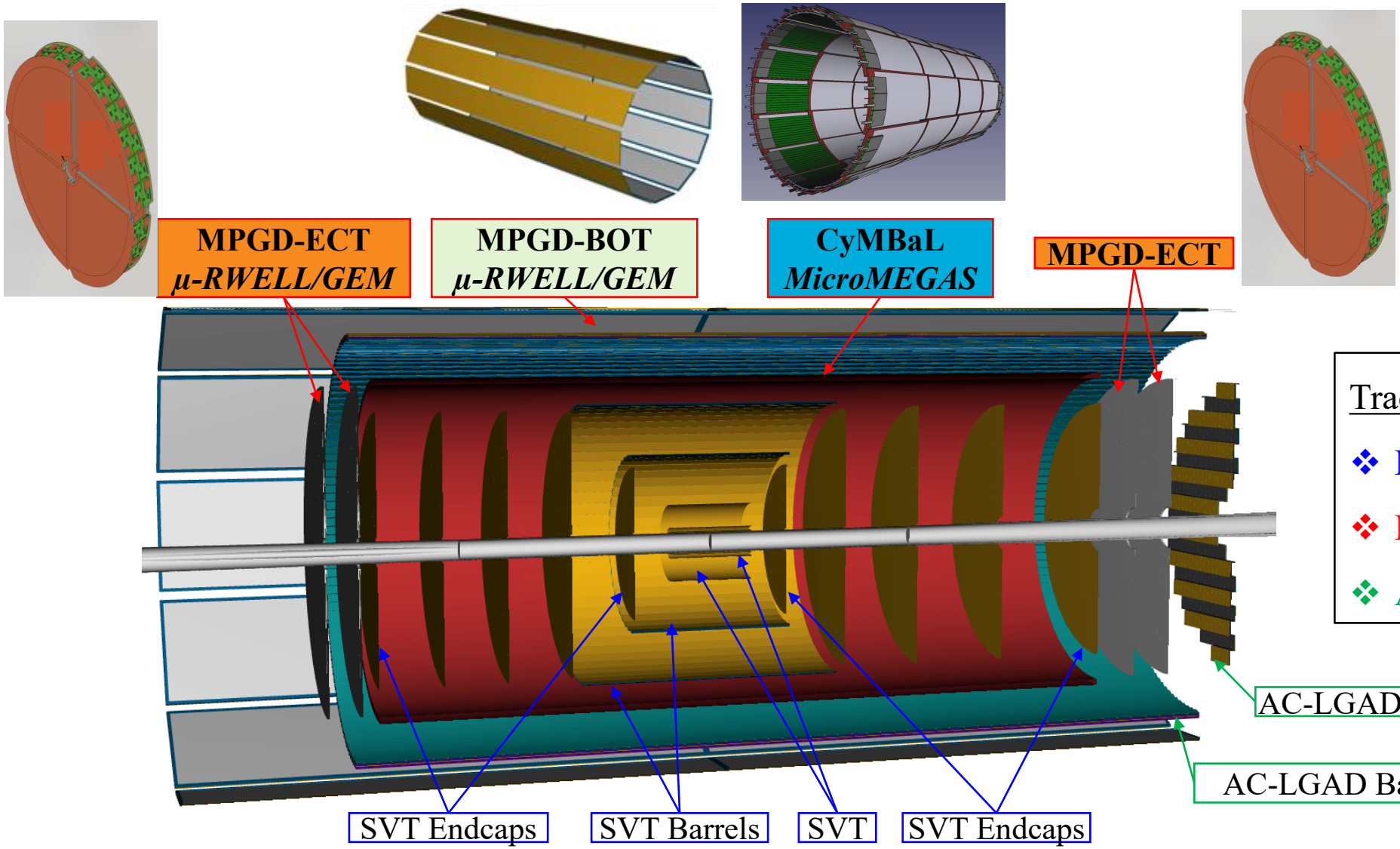


ePIC Collaboration Meeting
Brookhaven National Laboratory, US
Jan 20-23, 2026

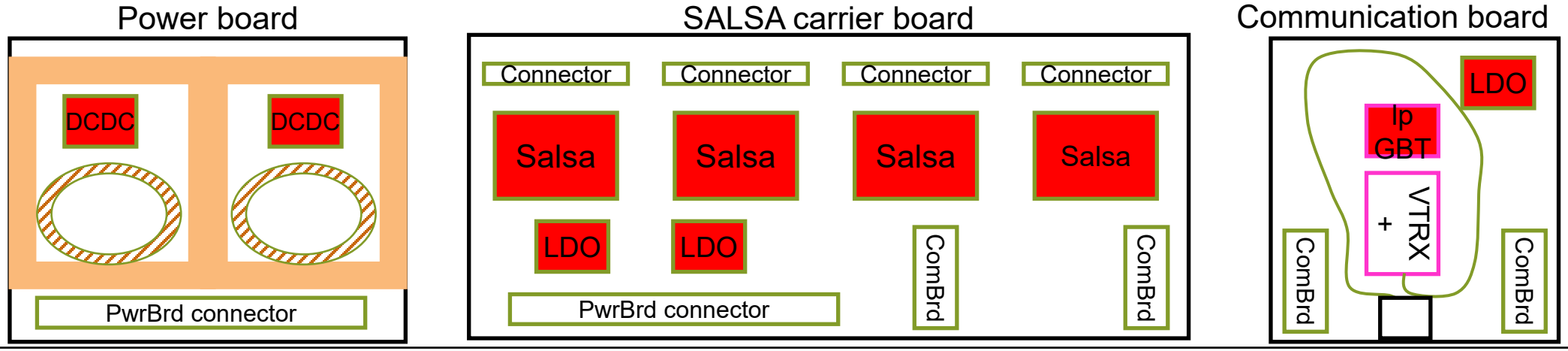
Electron-Ion Collider

Overview of MPGDs



MPGDs Readout Design

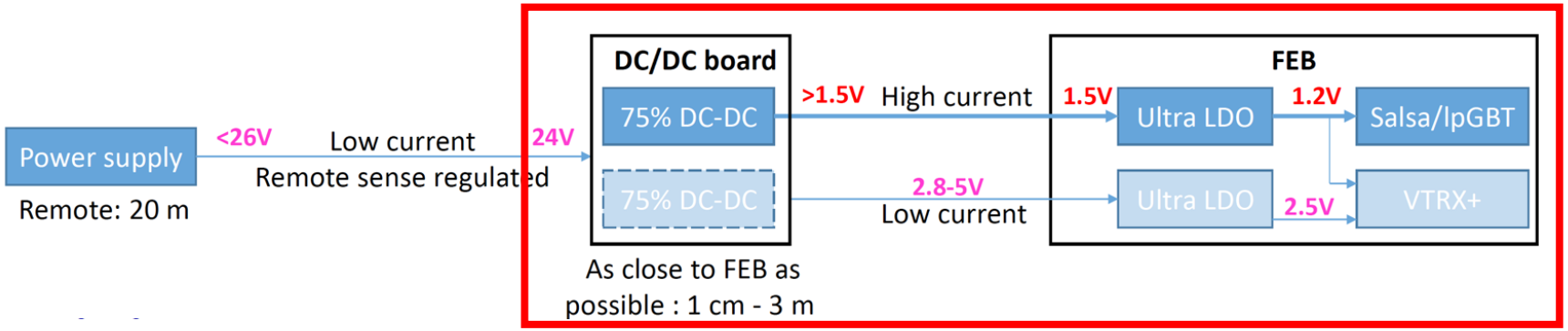
1. **Unified Readout Architecture:** All MPGD subsystems (**BOT, ECT, and CyMBaL**) utilize a standardized streaming data path based on the **SALSA ASIC**, coupled with **lpGBT** and **VTRx+** for high-speed data transmission.
2. **Subsystem Implementation Diversification:**
   CyMBaL: One common power board per tile (supporting 3 FEBs).
   MPGD-ECT: A sandwich-board design located on the module rims to minimize material budget.
   MPGD-BOT: A large spatial distribution of FEBs to cover long detector (7 FEB / 1.8 meter)
3. **Integrated Thermal Management:** High-density heat loads are managed through a **shared water-cooling infrastructure**, using embedded aluminum or copper heatsinks tailored to the mechanical constraints of each tracker.



Power requirement (all MPGDs)

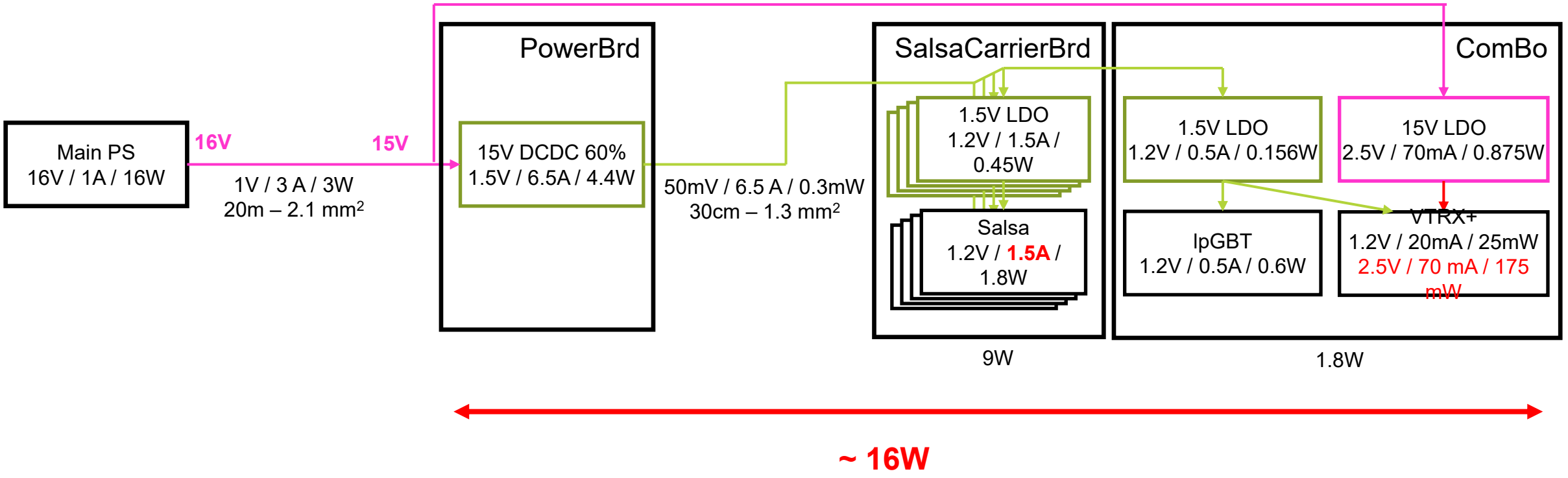
- Review of powering scenarios
  - Likely increase of expected power consumption of SALSA (important uncertainty at this stage of the development)
  - 3 options are considered (SALSA current of 1A, **1.5A** and 2 A)

- The power chain is as follows
  - LV power supply – cable plant – DCDC power board – Salsa carrier and communication boards
  - The last actors in the power chain are LDO regulators producing clean power for ASICs
    - Salsa, lpGBT, VTRX+
  - Salsa requires high current 1.2V
  - lpGBT requires low current 1.2V
  - VTRX+ requires low current 2.5V and 1.2V

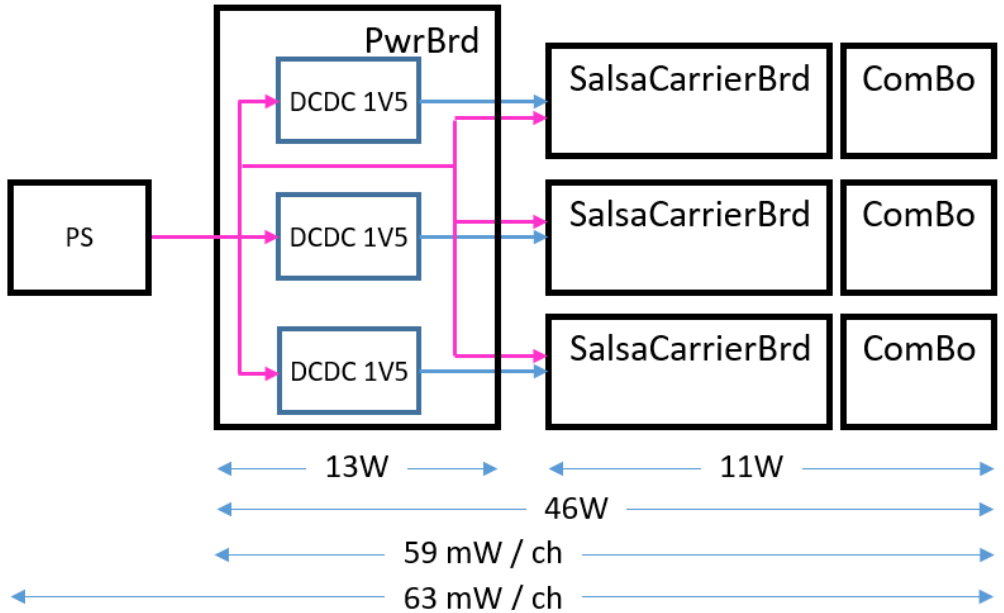


Power distribution : single power board (1.5A SALSA current)

- Single power board for each FEB
- Example for 1.5 A total SALSA current
- Adapted to MPGD-ECT and MPGD-BOT



Power distribution : shared power board (CyMBaL)

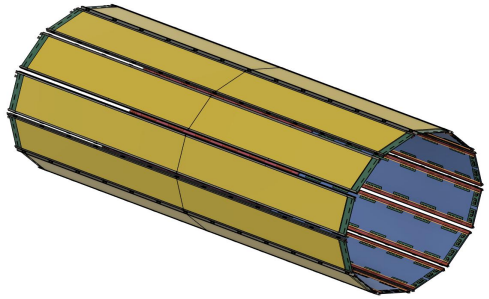


	Salsa 1.5A	
	Power	Pwr/ch
	W	mW
Salsa	1.8	28.1
Salsa carrier	9.0	35.2
Salsa carrier + ComBo	10.8	42.2
Power board	13.1	
3 x (Salsa carrier + ComBo) + PwrBrd	45.5	59.2
Power supply	48.5	63.1

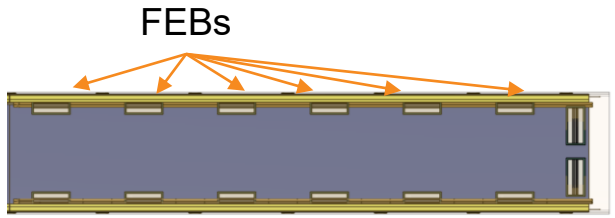
- An important uncertainty coming from the consumption of Salsa
- LV powering options laid – the power consumption and heat dissipation figures estimated
  - → Safety factor is not applied
  - → Varying the Salsa current gives the idea
- An Excel file exists that checks several hypotheses
  - → Several parameters can be changed such as Salsa current, DCDC efficiencies, voltage drops, etc.
- Total power dissipation for CyMBaL (current new baseline scenario) :

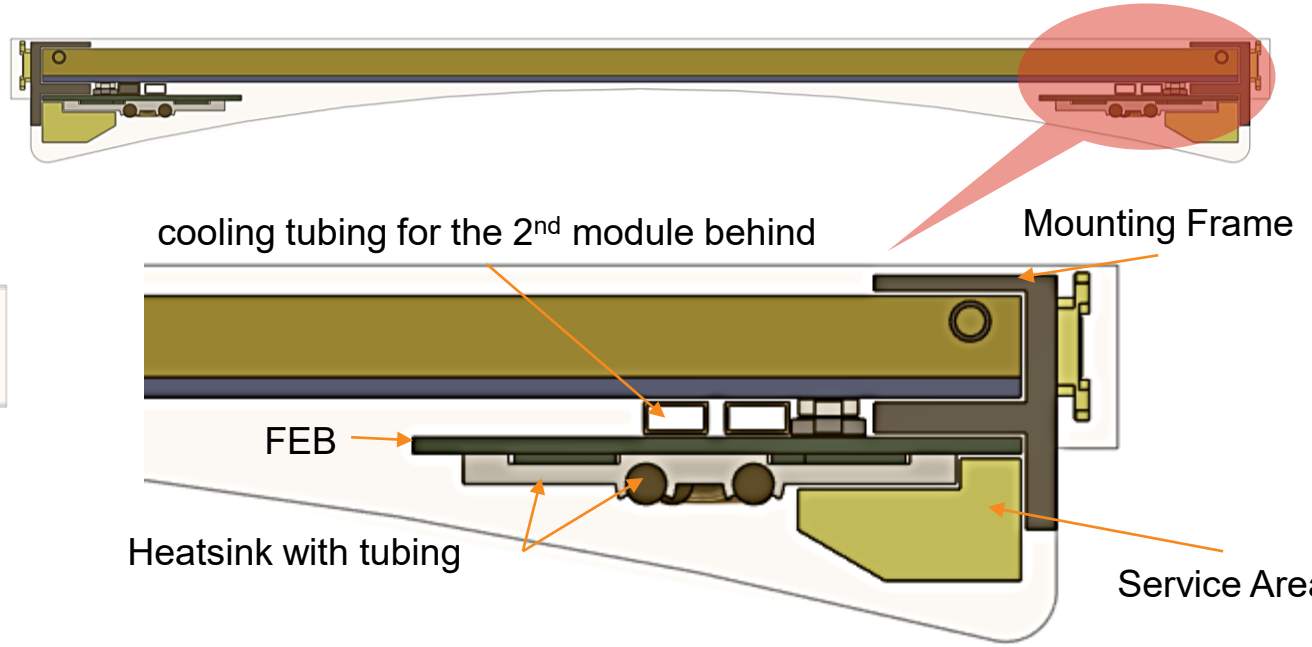
  59 mW/ch x 768 x 48 = **2.3 kW**

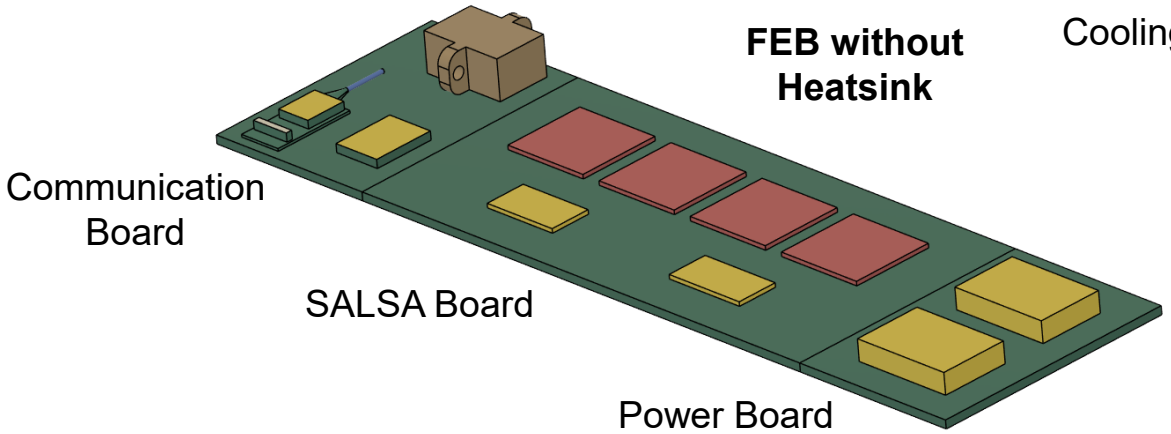
MPGD-BOT module: FEB with cooling

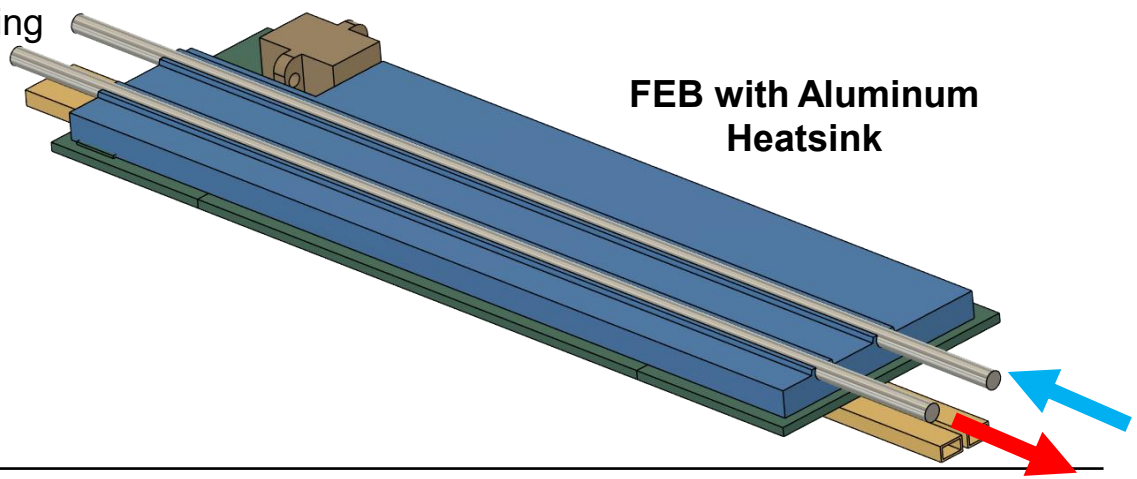


MPGD Barrel Outer Tracker (MPGD-BOT)

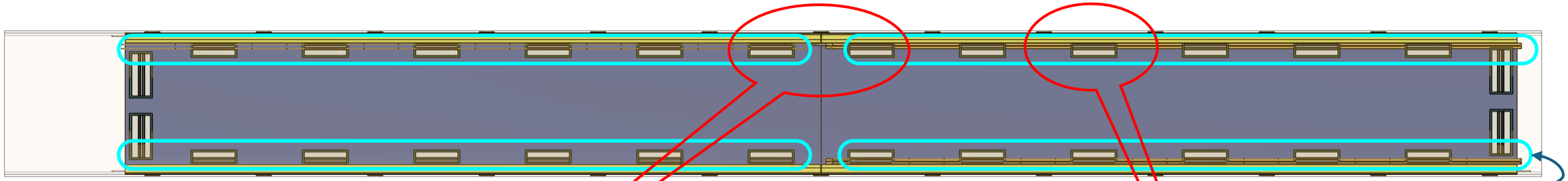






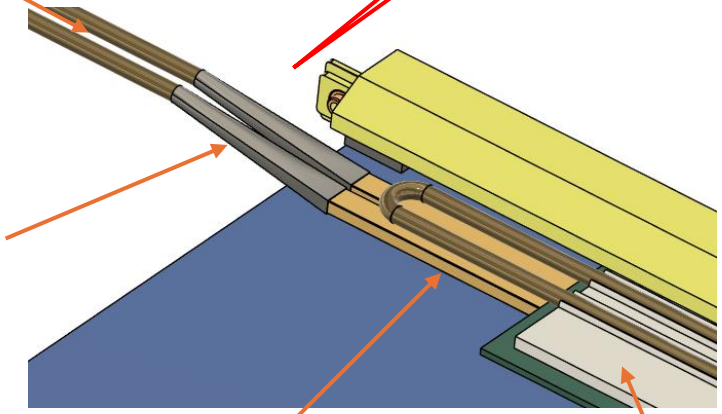


MPGD-BOT module: FEB cooling design



Service Area for
4 ×cooling loop

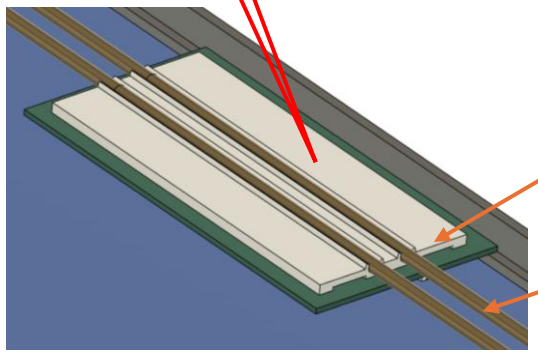
Cooling line
(left module)



Custom
adapter

Rectangular Tubing
under FEB (low profile)

Cooling line
(right module)



Aluminum
Heat Sink

Cooling Pipe

Expected Cooling Parameters

Total power: 112W = 16W × 7 FEB

Flow rate: 1.6 L/min

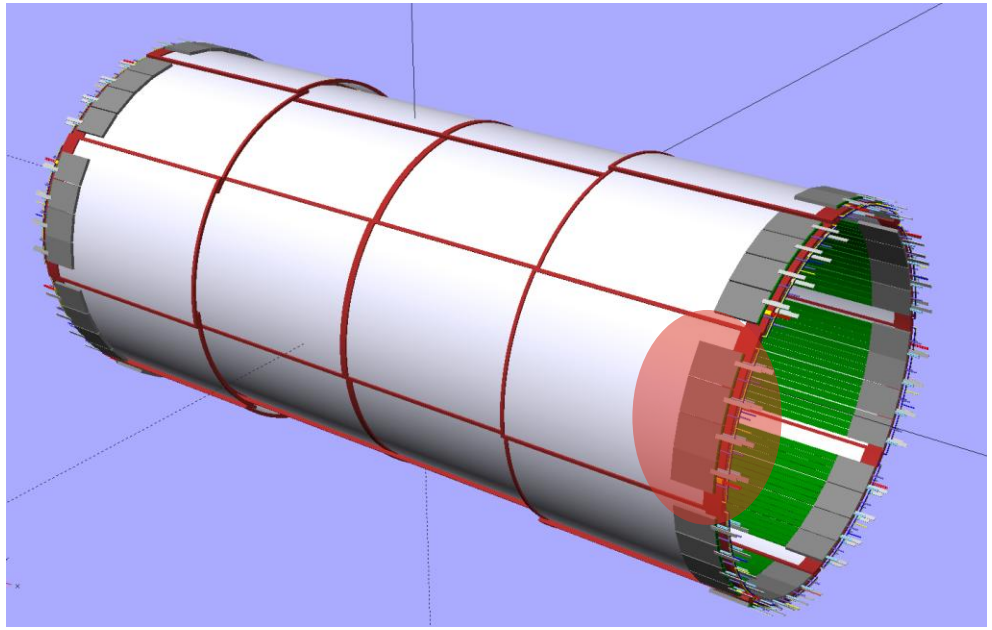
Flow speed: ~ 1.5 m/s (OK for 5 mm ID pipe)

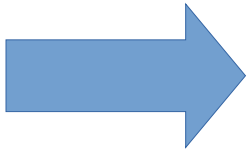
T_{in} = 22 °C, dT < 1 °C

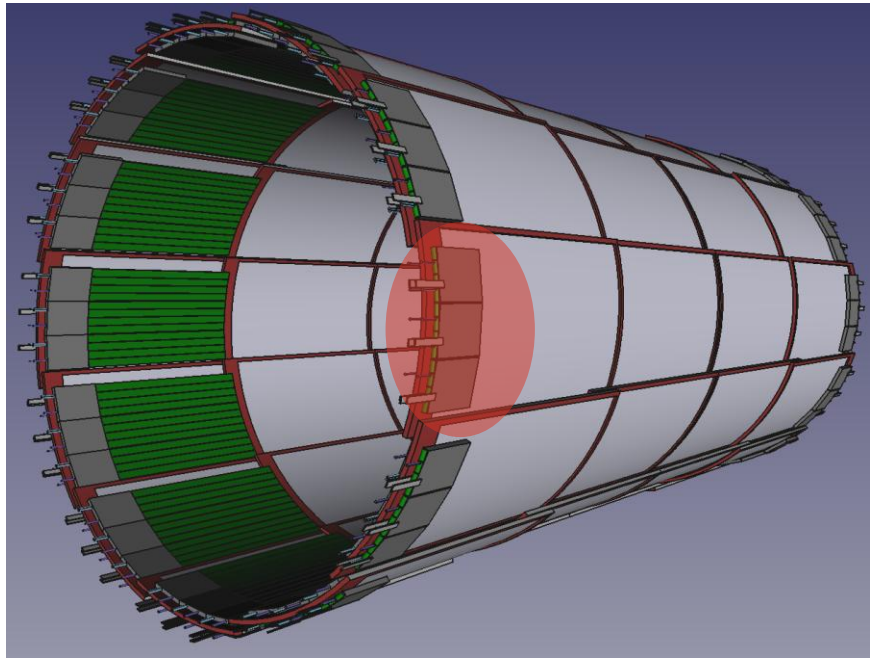
Requires more dedicated thermal simulation

CyMBaL – Updated design

In order to simplify installation and maintenance, the EIC Project proposed a change in design







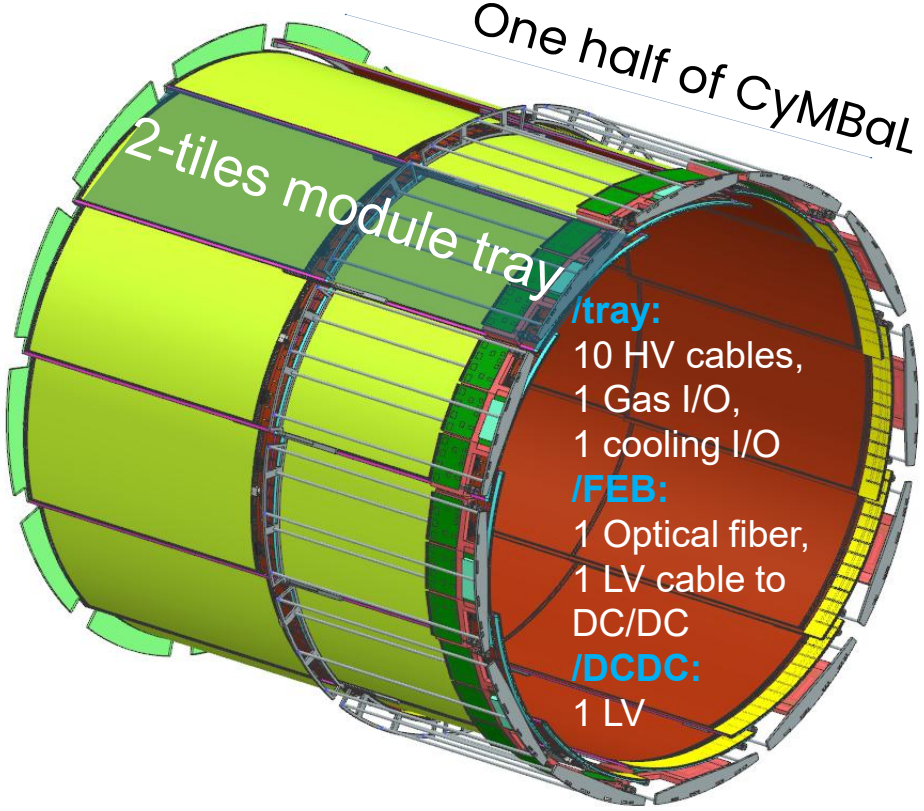
Old design

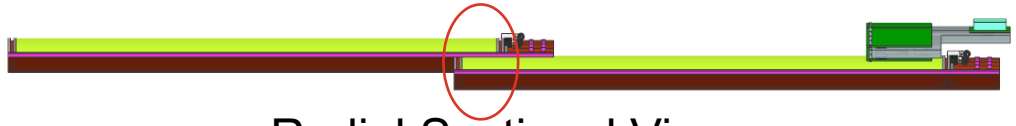
- **32 module: 8 modules in ϕ times 4 modules in z**
- Overlaps in ϕ and in z for hermeticity
- 1024 readout channels/module
- 4 FEB per module
- 32K readout channels

New design (2025)

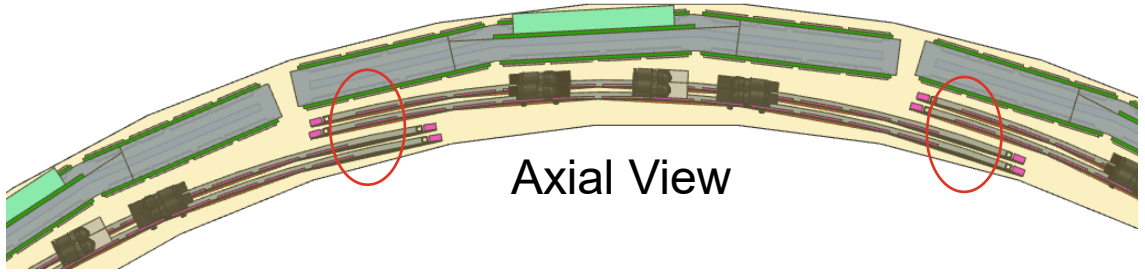
- **48 module: 12 modules in ϕ × 4 modules in z**
- Overlaps in ϕ and in z for hermeticity
- 768 readout channels/module
- 3 FEB per module
- **37k readout channels**

CyMBaL – Detector Design

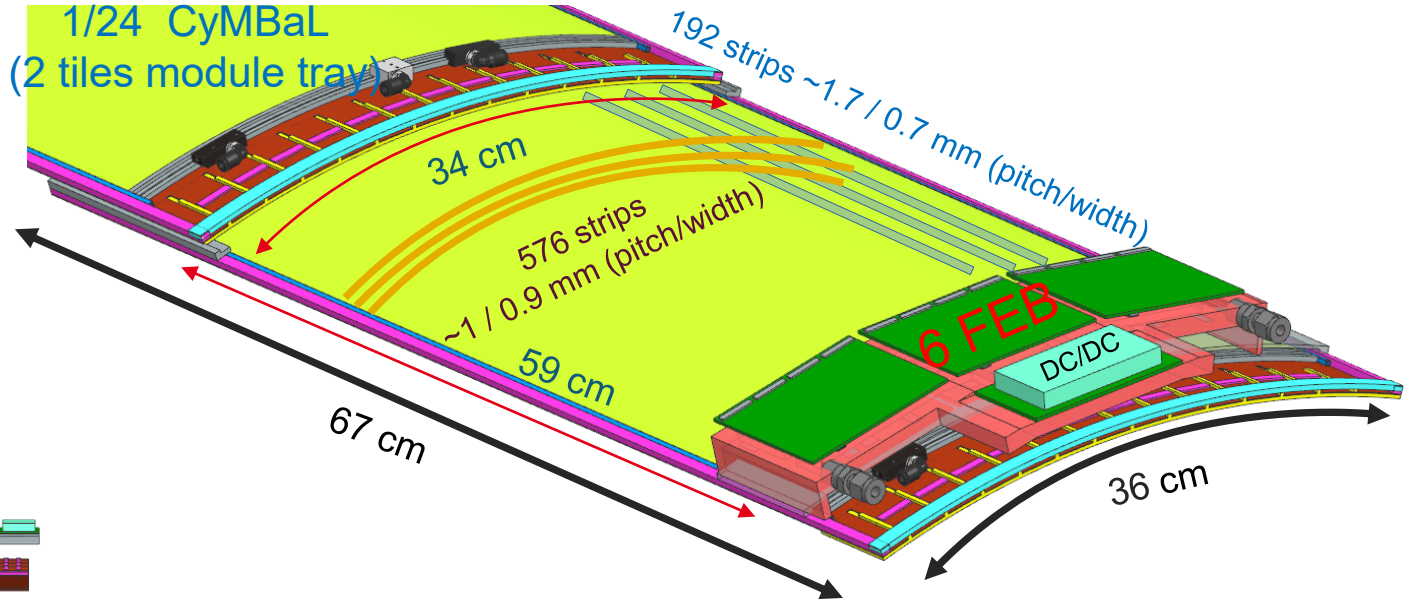




Radial Sectional View



Axial View

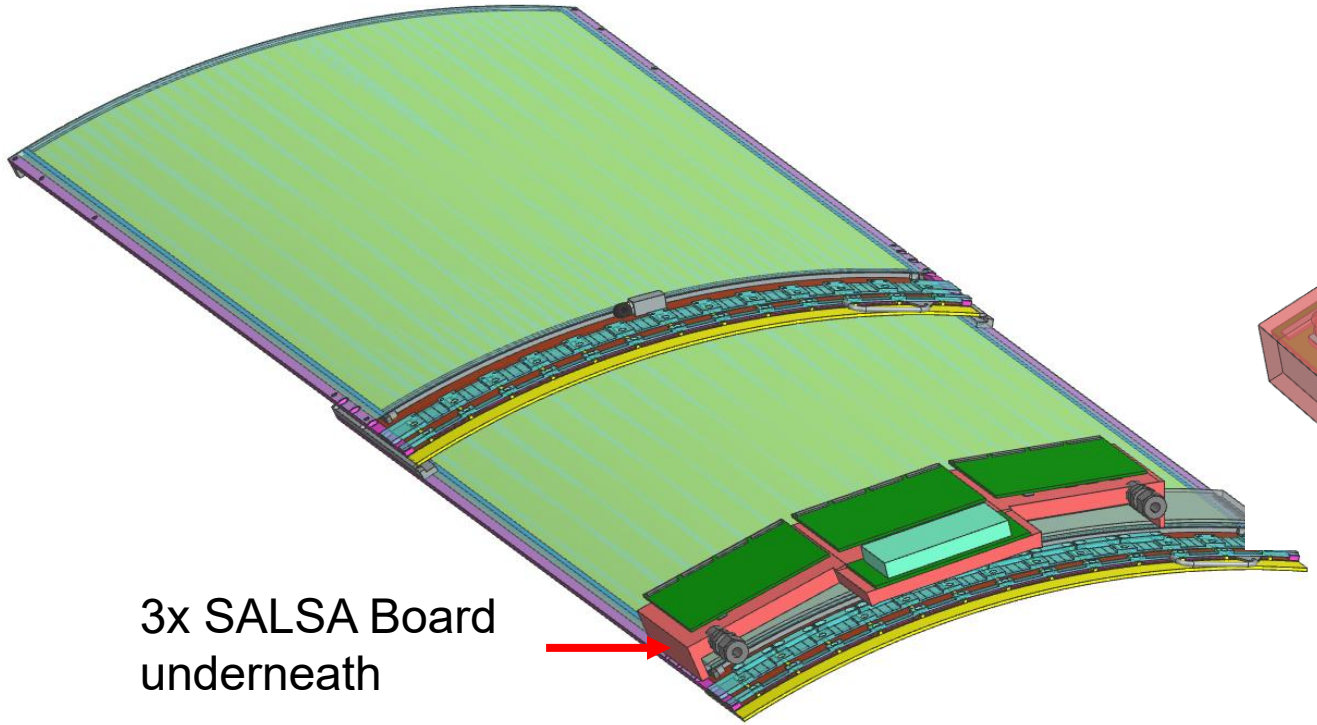


- Within the envelop, space only available for 3 FEBs per tile
- Each FEB will read (4 ASICs * 64 ch/chip) 256 channels
- Total number of channels per tile limited at 768

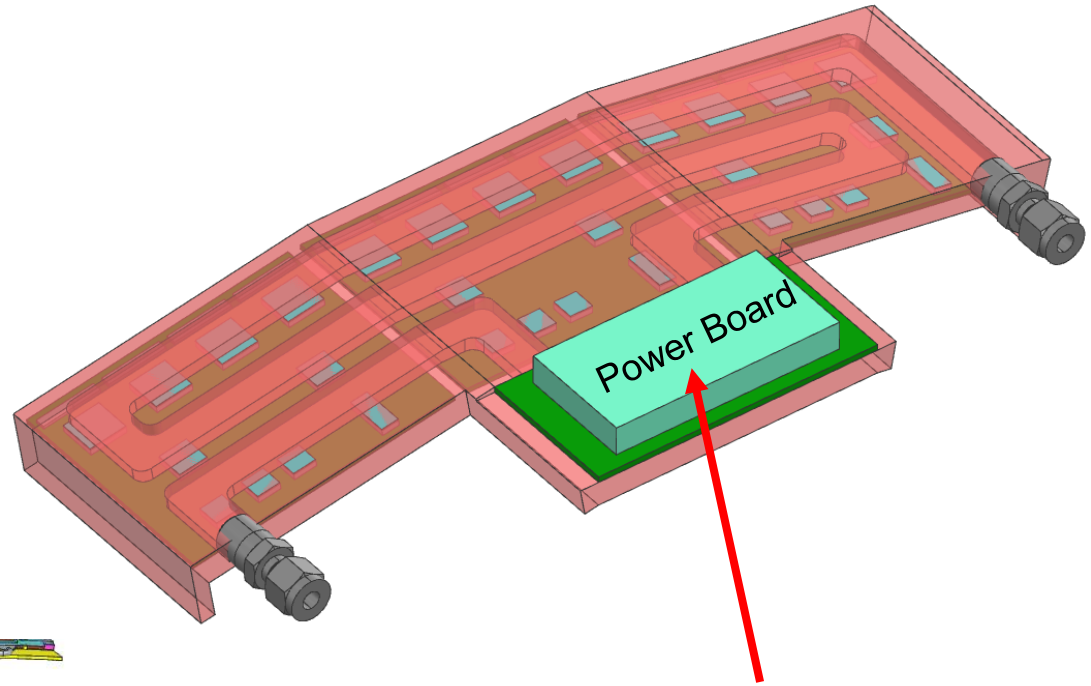
CyMBaL: Cooling Design

One Cooling Block per section →2 Tiles (6x SALSA Board + 1x Power Board)

Potentially: 3D printed in copper



3x SALSA Board underneath



2x of Shared Power board to support 6 FEBs

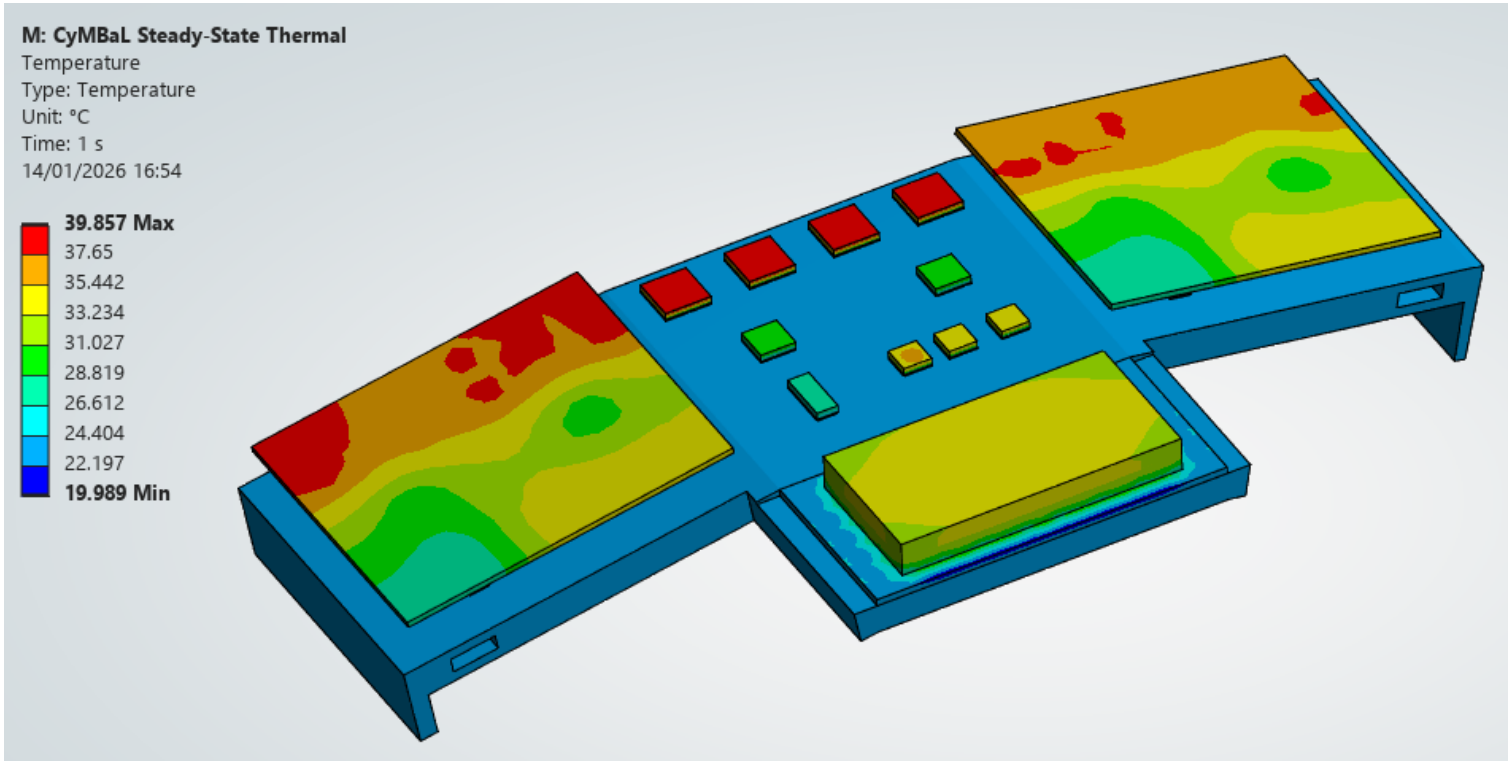
CyMBaL: Thermal Simulation

SALSA current of 1.5 A:

Flow rate: 3 L/min

Temperature: T_{in} = 22°C, T_{out} = 22.66 °C

Pressure: ΔP 0.03 bar

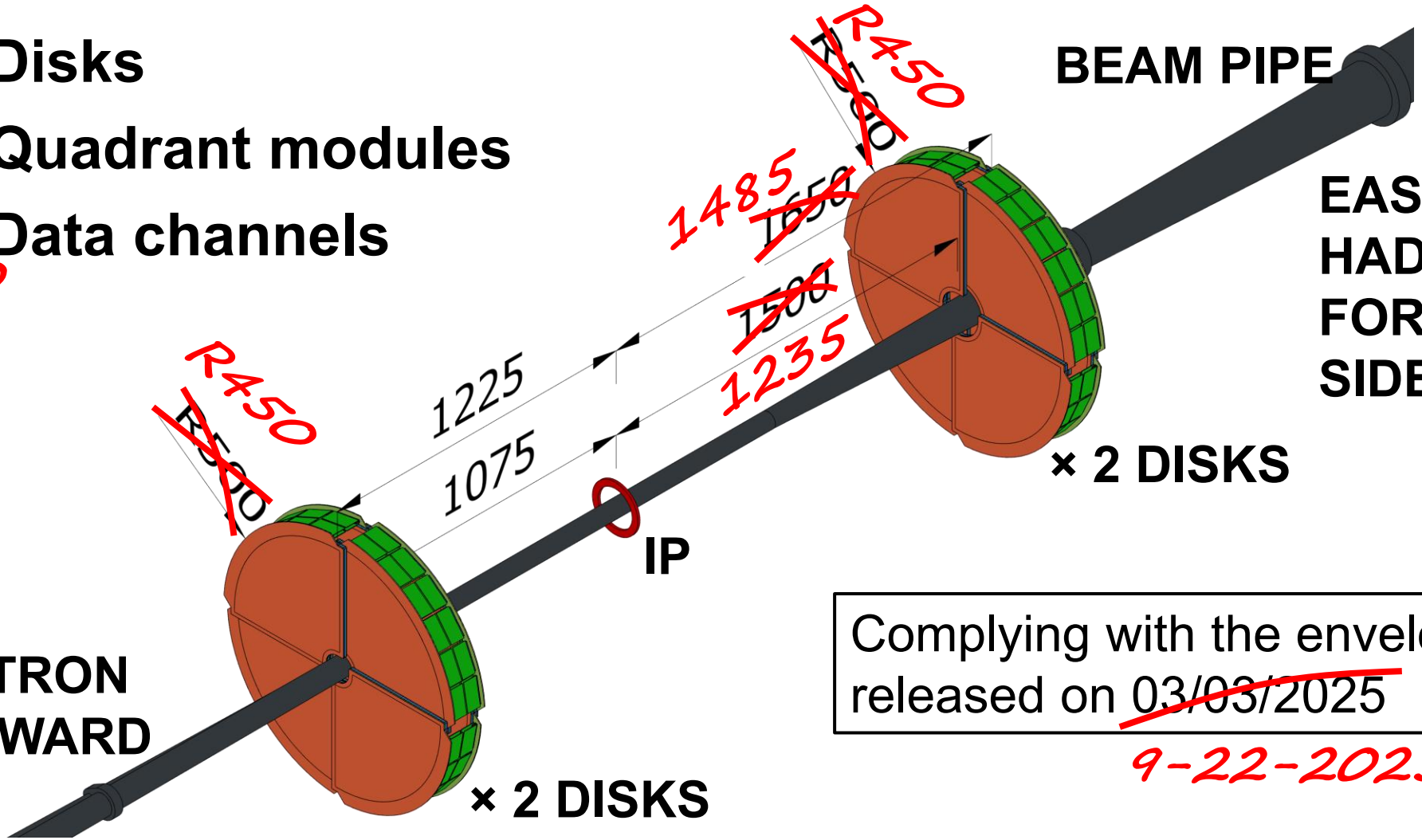


MPGD-ECT Overview

4 Disks

16 Quadrant modules

~~24576~~ 20480 Data channels



Complying with the envelope released on ~~03/03/2025~~ 9-22-2025

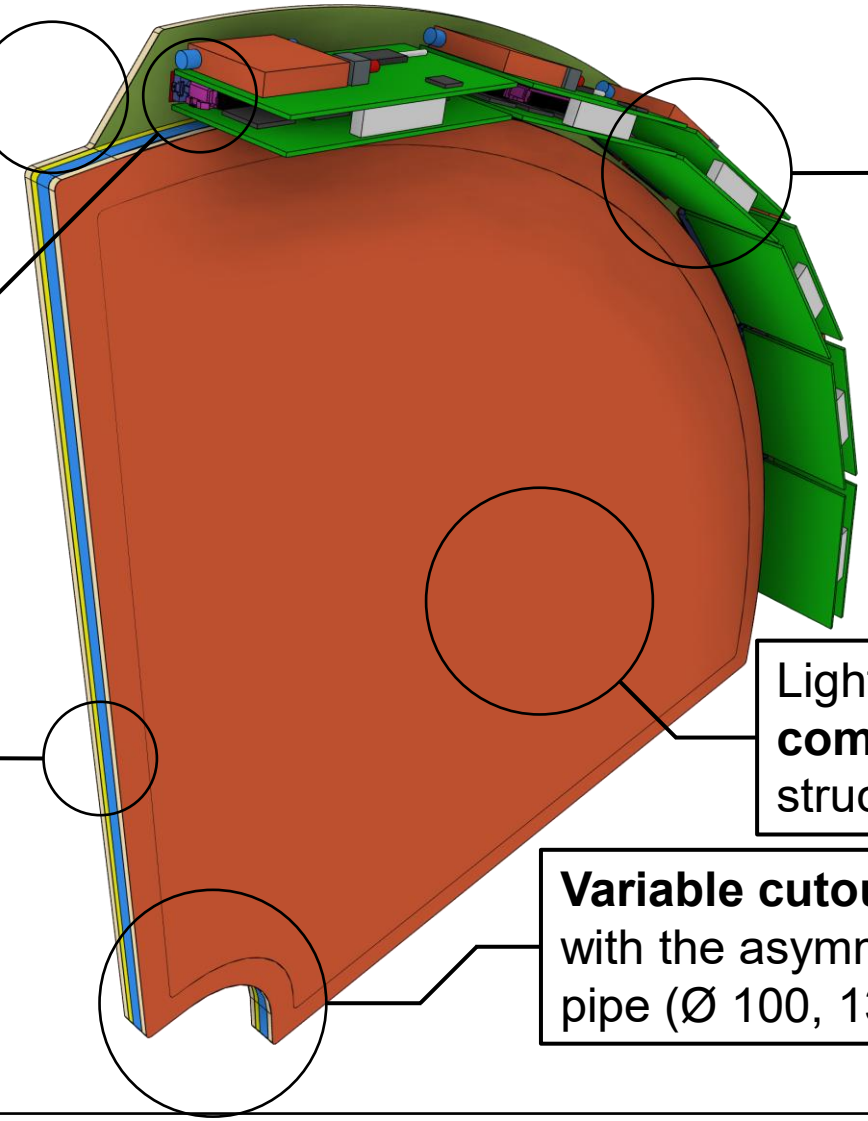
Quadrant Concept

Cutouts for services
At 0°, 90°, 180°, and 270°

4x **SALSA** ASICs per FEB

2x **Hirose FX20-140P** Connectors per FEB

Fiber-reinforced epoxy frames define the gap and reinforce the outer support panels

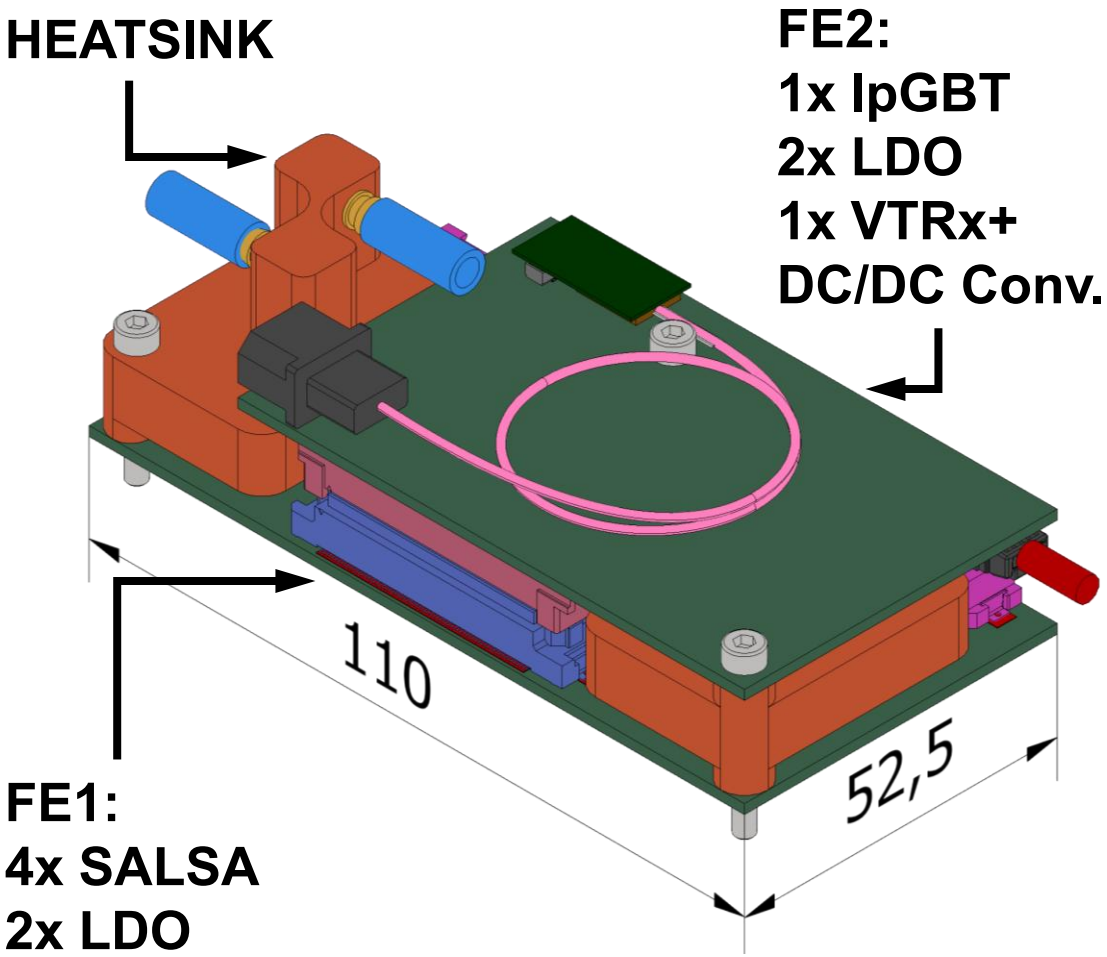


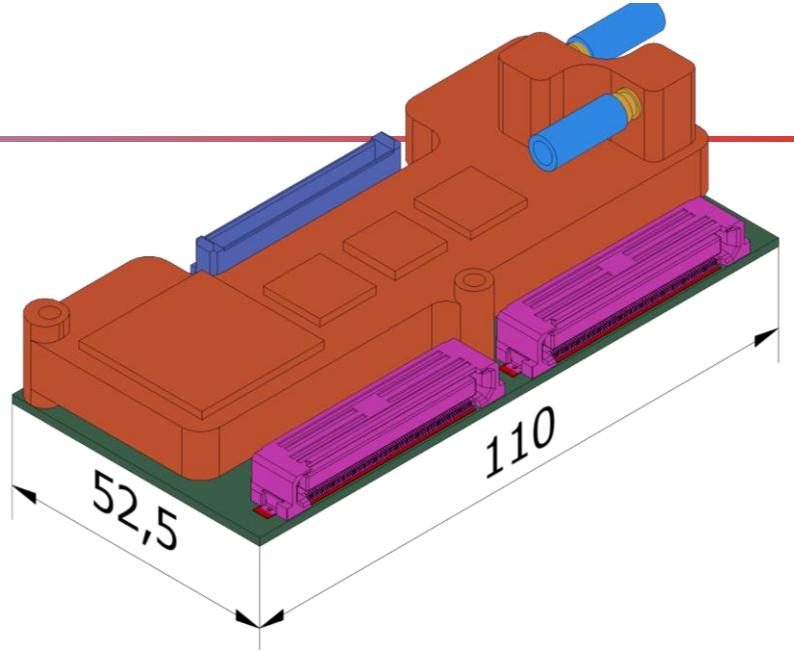
6 **FEBs** per quadrant located in the service rim

Lightweight **sandwich-structured composites** for anodes/cathodes' structural supports

Variable cutout to cope with the asymmetric beam pipe (Ø 100, 130, and 180)

New FEB Model



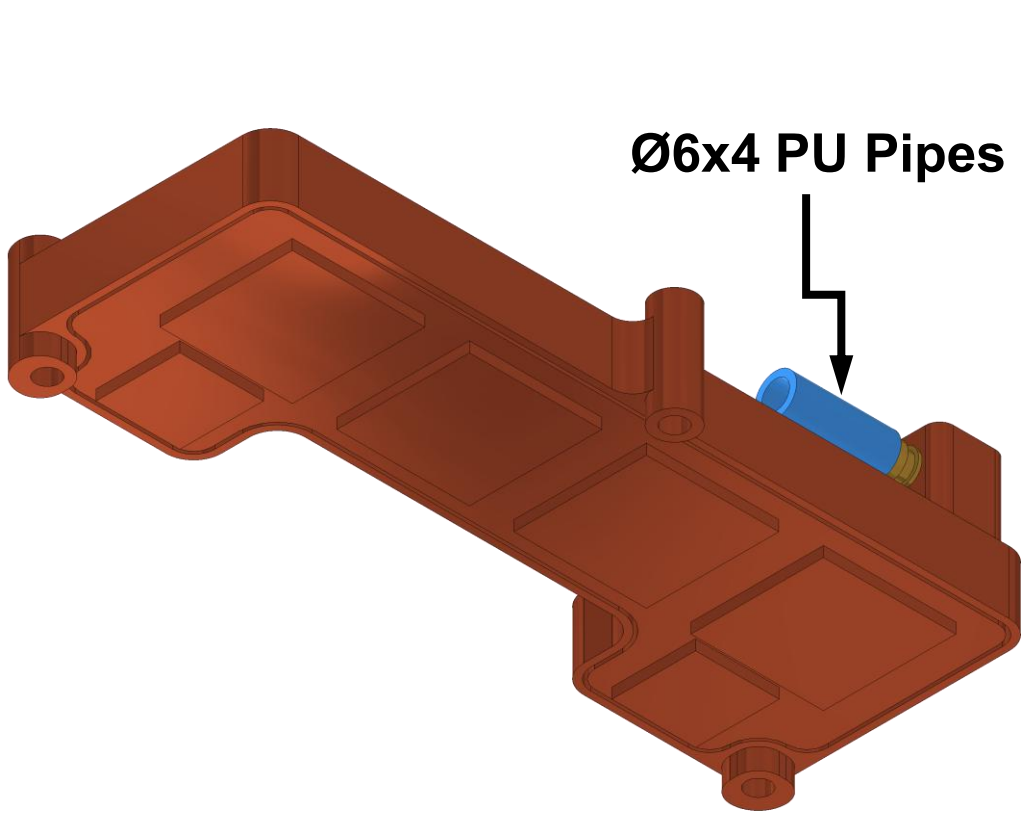


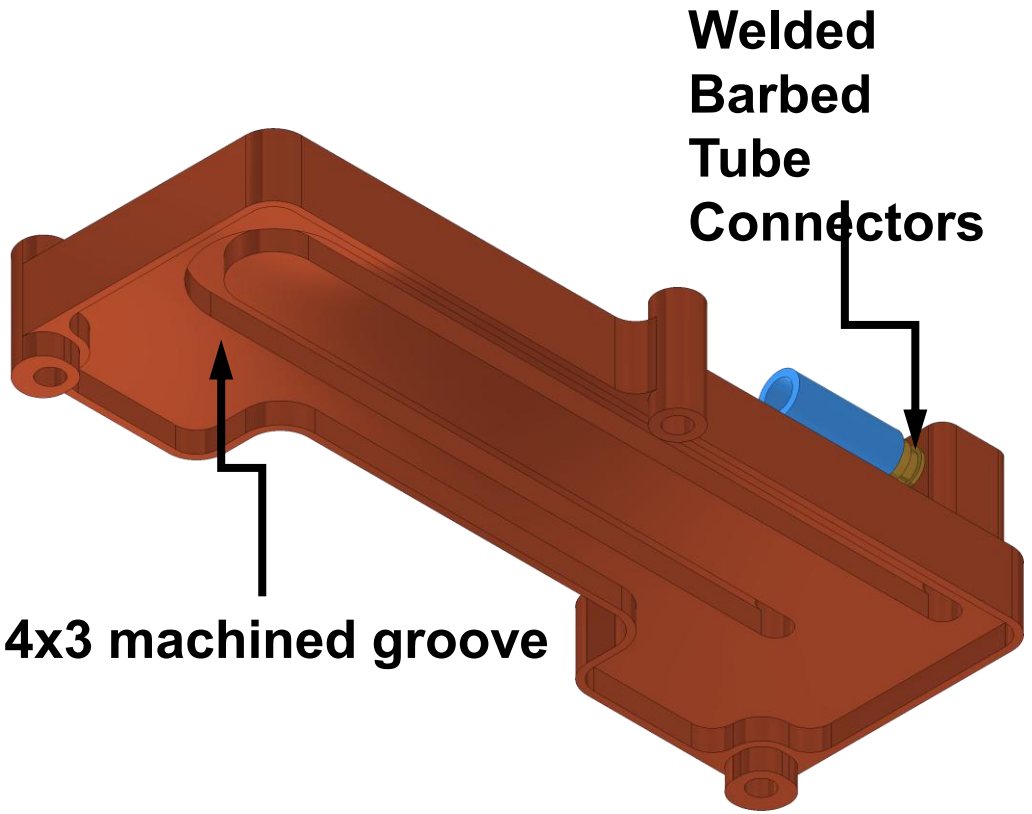
All 5 **heatsinks** in a module **connected in series** with pipes running close to the outer rim

No. **2 Ø6x4 PU pipe per module** as inlet/outlet for the cooling chain

All major heat sources are mounted on the top/bottom face of FE1/FE2 to face the heatsink

Heatsink Design





Preliminary proposal, no simulation has been run yet

Quite **bulky and difficult to manufacture** →

We will be working on **alternative cooling solutions** including 3D printed heatsink

Summary of Power and Cooling Requirement

Assumption: **1.5A** current for SALSA chip => **16W per FEB**

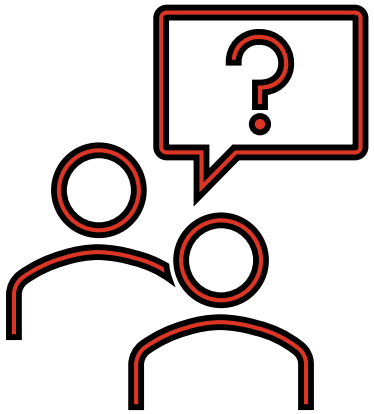
	CyMBaL	MPGD-ECT	MPGD-BOT
Detector Module	48	16	24
FEBs per Module	3	5	14
Total FEBs	144	80	336
Total Power Req.	2.3 kW	1.28 kW	5.38 kW
Supply from	Both sides	Both sides	**East side**

Assumption: Water cooling, Heatsink with metal/plastic tubing, dT< 1 °C, ~ 3 L/min

	CyMBaL	MPGD-ECT	MPGD-BOT
#FEB per cooling line	6	5	7
Cooling line per module	0.5	1	2
Total cooling line	24	16	48
Supply from	Both sides	Both sides	**East side**

Summary

1. There has been major design change for ECT and CymBaL.
2. Each subsystem has their own power/service/cooling design based on SALSA board which is still under development.
3. Preliminary water-cooled heatsink designs provide a baseline for heat dissipation across all MPGDs.
4. Critical Dependencies: Final cooling validation is pending the SALSA ASIC power specifications (1A vs. 2A uncertainty) and the application of appropriate safety margins.
5. Each subsystem will need more dedicated thermal simulation for the cooling design validation



Questions?

Backup Slides

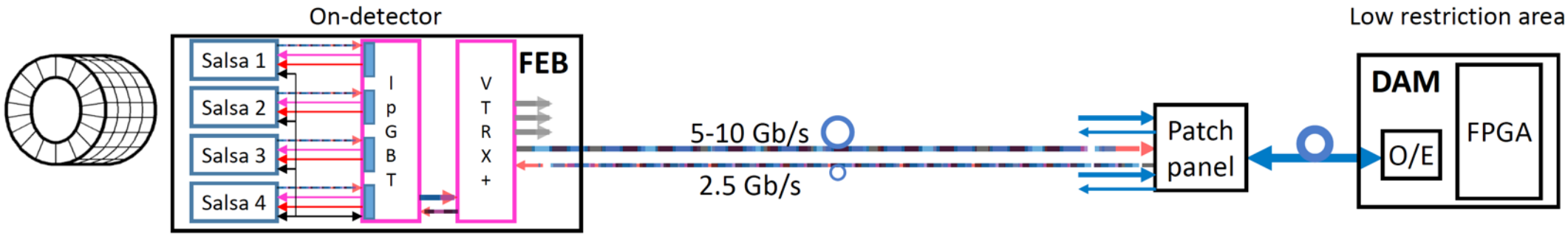
PLACEHOLDER

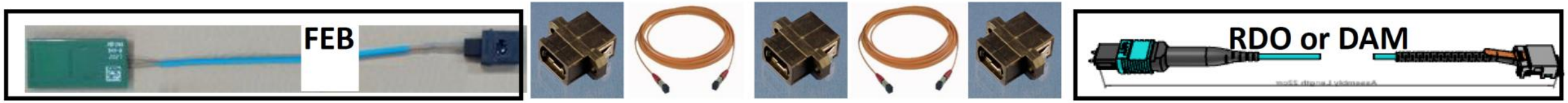
Services Estimates (MPGD-ECT)

Far from the detector (Before the manifolds/splitters)						
Service	**# lines**	**Flow**	**Material**	**Fittings**	**Dimensions**	**Comment**
Gas	4	IN	SS316/Cu	SS316/Brass	Ø8	1 per disk, 1 manifold per disk
	4	OUT	SS316/Cu	SS316/Brass	Ø8	1 per disk, 1 manifold per disk
Cooling	4	IN	PU	SS316	Ø12	1 per disk, 1 manifold per disk
	4	OUT	PU	SS316	Ø12	1 per disk, 1 manifold per disk
Dry air	4	IN	PU	SS316/Brass	Ø8	1 per disk, 1 manifold per disk (if humidity not controlled otherwise)
Data	96/80		Fiber optics		Ø2(?)	1 per FEB, 24/20 FEBs per disk in the 6/5 feb per module hypothesis
LV	96/80		Cable		Ø8(?)	1 per FEB, 24/20 FEBs per disk in the 6/5 feb per module hypothesis
HV	16		Multi-channelCable		Ø10(?)	1 per module (4 HV channels per module, 16 per disk), 4/5 kV highest voltage channel
GND	2		Copper braid		70 mm2	1 per side, if not provided otherwise
ENV	8		Cable + sensor		Ø8(?)	4 per side, 2 temperature + 2 humidity

Close to the detector (after the manifolds/splitters)						
Service	**# lines**	**Flow**	**Material**	**Fittings**	**Dimensions**	**Comment**
Gas	24	IN	PA11	SS316/Brass	Ø6	2 per module (8 per disk), modules could be connected in series to reduce # of ingoing/outgoing pipes
	24	OUT	PA11	SS316/Brass	Ø6	2 per module (8 per disk), modules could be connected in series to reduce # of ingoing/outgoing pipes
Cooling	16	IN	PU	SS316	Ø12	1 per module (4 per disk), All FEBs in each module are connected in series
	16	OUT	PU	SS316	Ø12	1 per module (4 per disk), All FEBs in each module are connected in series
Dry air	16	IN	PU	SS316/Brass	Ø6	1 per module (4 per disk)
Data	96/80		Fiber optics		Ø2(?)	1 per FEB, 24/20 FEBs per disk in the 6/5 feb per module hypothesis
LV	96/80		Cable		Ø8(?)	1 per FEB, 24/20 FEBs per disk in the 6/5 feb per module hypothesis
HV	16		Multi-channelCable		Ø10(?)	1 per module (4 HV channels per module, 16 per disk), 4/5 kV highest voltage channel
GND	2		Copper braid		70 mm2	1 per side, if not provided otherwise
ENV	8		Cable + sensor		Ø8(?)	4 per side, 2 temperature + 2 humidity

CyMBaL – Readout electronics



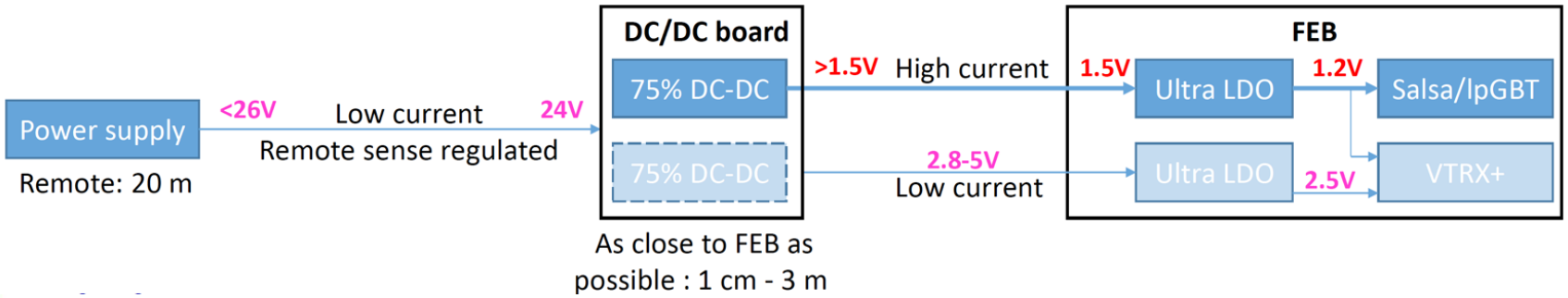


Short pigtail / on board

Fibers of adapted length between patch panels

Short pigtail / on board

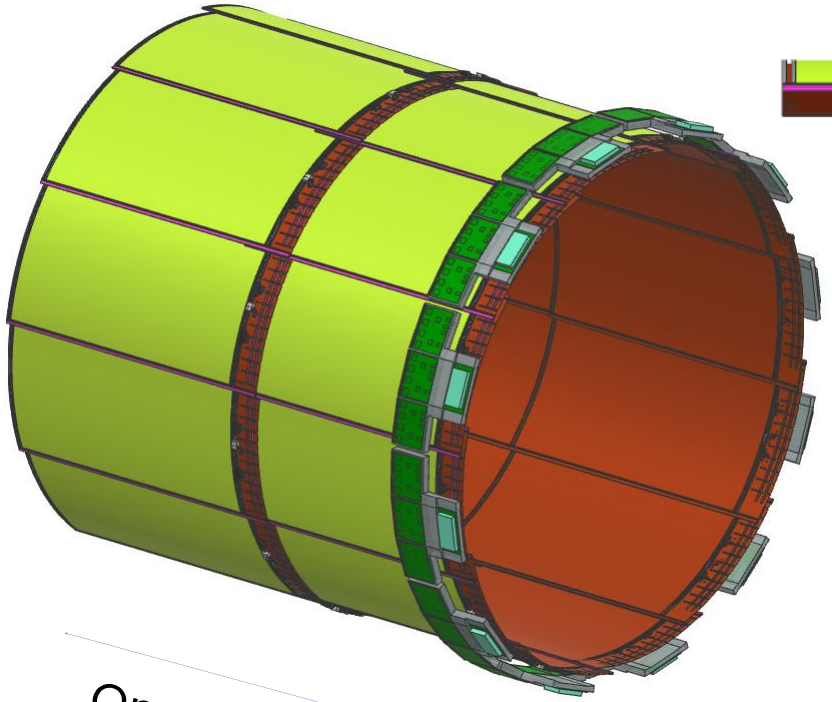
FEB LV Powering scheme



Cooling

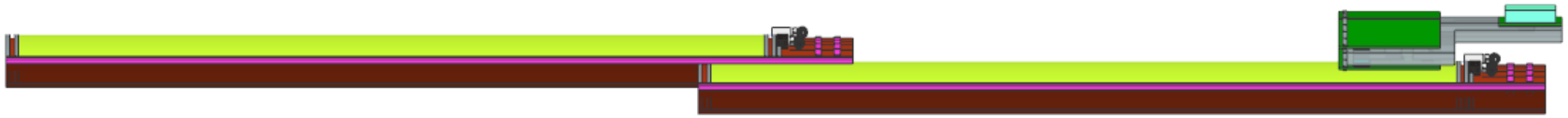
Current estimates: 18 deg water loop to cool each module, i.e. 3 (FEBs) x 2 (tiles) + DCDC is sufficient

CyMBaL – Layout

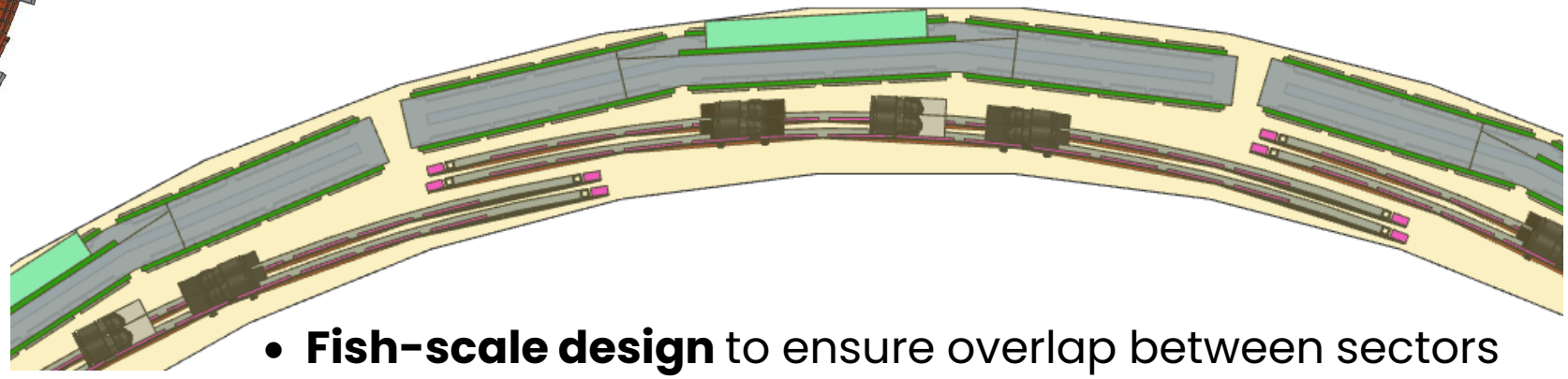


One half of CyMBaL

Micro-coaxial flat cables will bring signals from the inner tiles to the FEBs

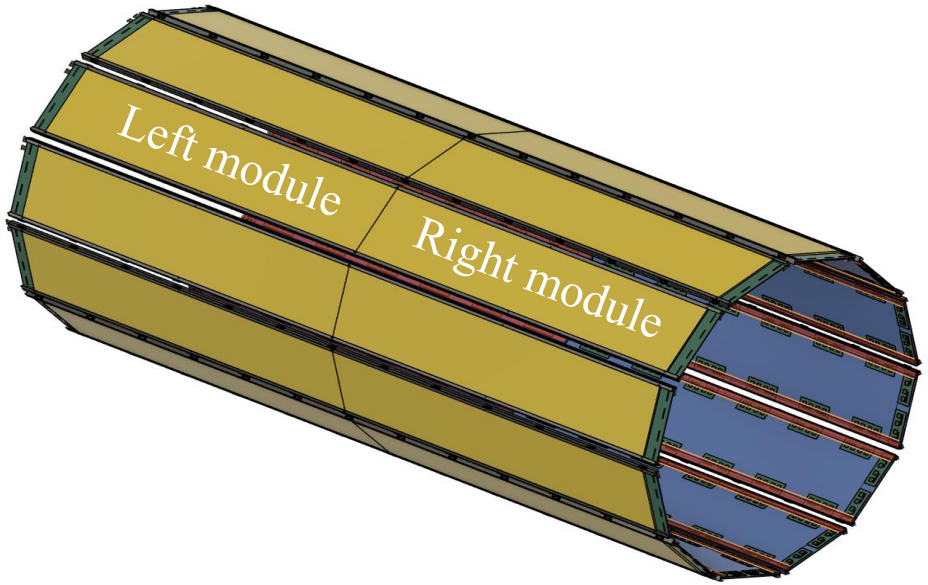


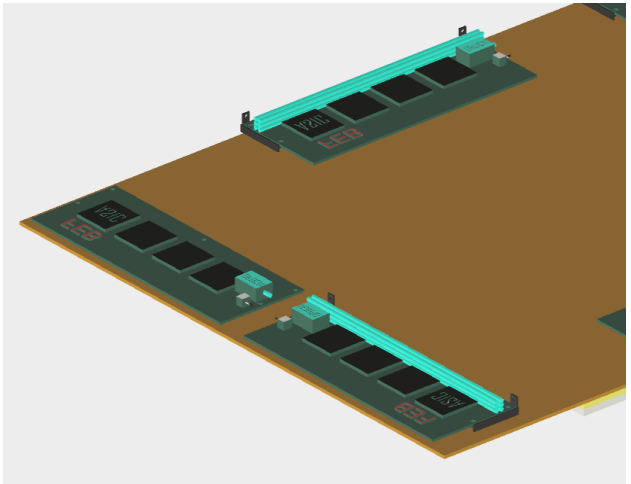
The two tiles in each module overlap in Z of about 4 cm



- **Fish-scale design** to ensure overlap between sectors
- Sectors overlap in phi of about 4 cm
- The 3 FEBs of the inner modules stacked on top of the 3 FEBs of the outer modules

MPGD-BOT: Services



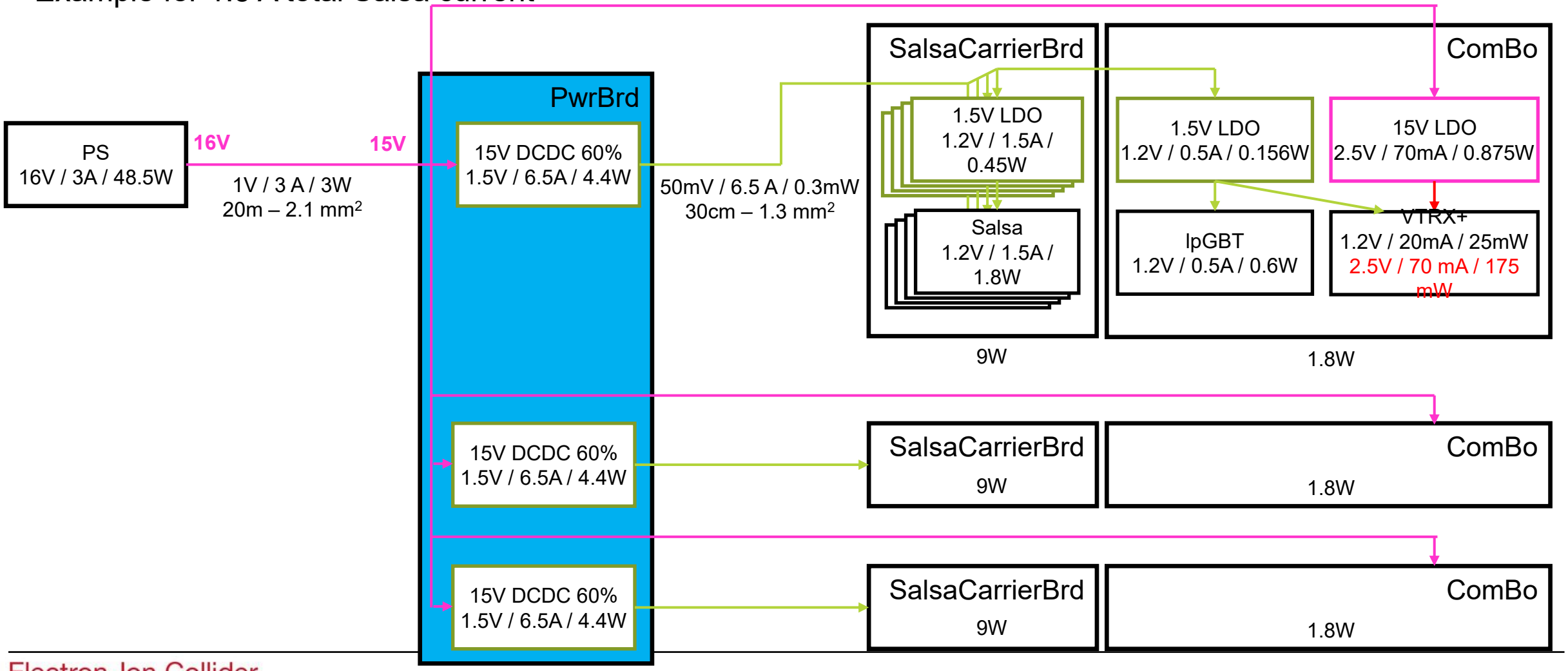


Service/Parts	Per Module	Total	Parameter
Frontend Boards (FEBs)	14	336	256 Channel / FEB
High Voltage	1 (through divider)	24	3.2 mm OD
Low Voltage	14	336	6 mm OD
Gas lines	2	48	3 mm ID, 4 mm OD
Cooling	4	96	6 mm ID, 8 mm OD
Data Cable	14	336	Optical Fiber
Environment Sensor	2	48	Temp. & Humidity
Ground			Depends on grounding plan
Power	225W	5400W	Based on 16W/board

- ❖ Parameters of service line are subject to change as FEB design progresses.
- ❖ The cooling requirement has not yet been finalized.
- ❖ The current cooling approach utilizes water cooling with a heatsink.

CyMBaL Power distribution : Shared power board

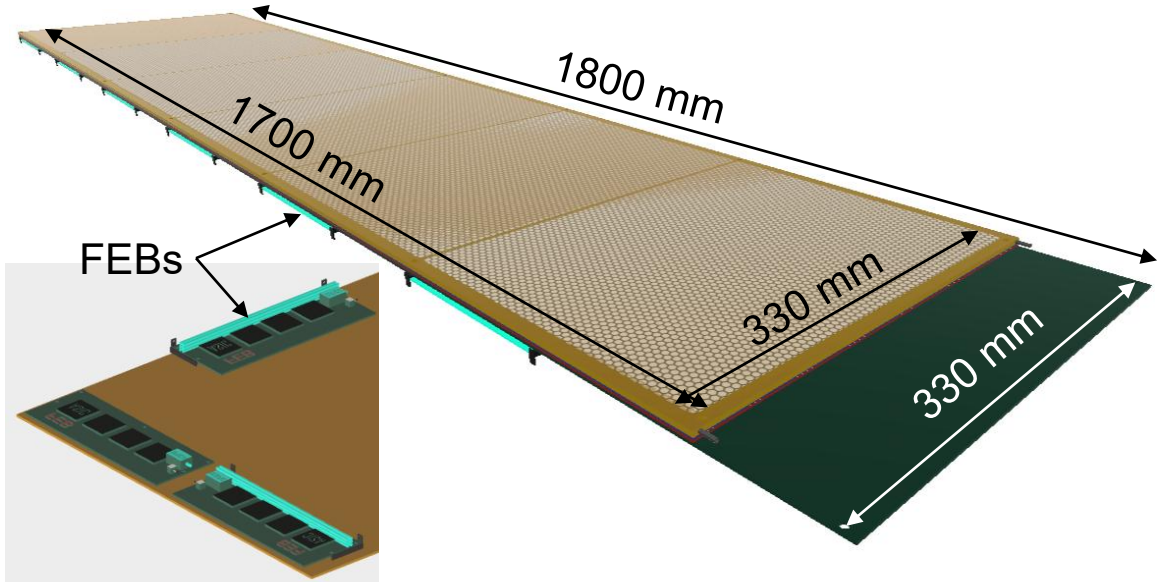
- Shared power board for the 3 FEBs of a tile
- Example for 1.5 A total Salsa current



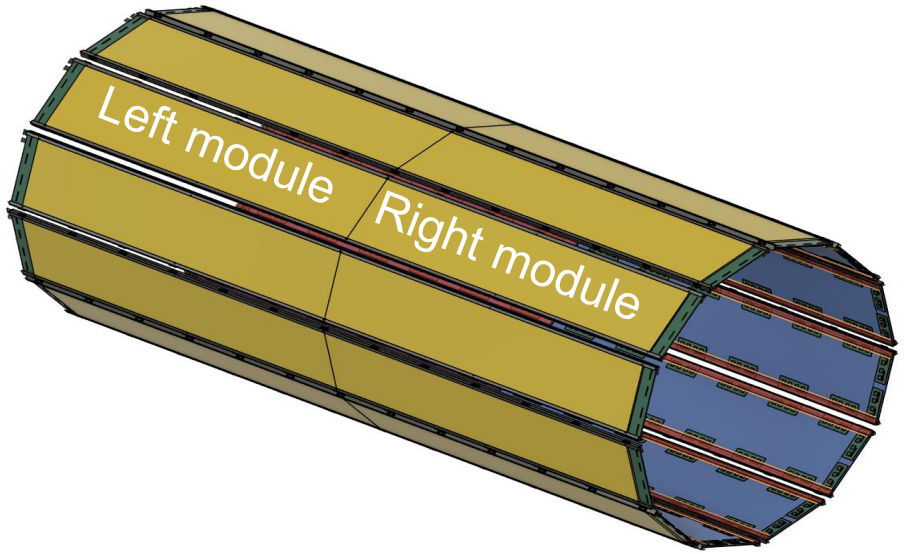
MPGD-BOT Design

24 planar detector modules

- 2 sectors in z made of left and right planar modules
- 12 modules in (r × φ) arranged in dodecagon geometry
- Total readout electronic channels ~80K

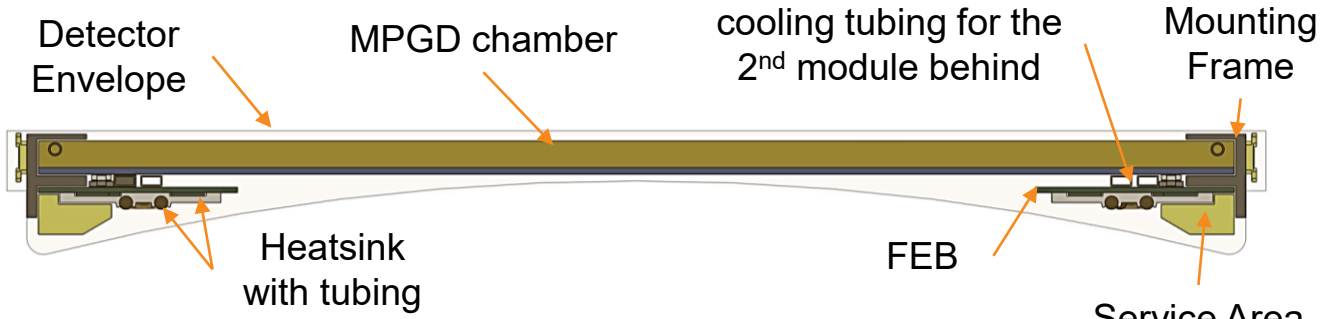


MPGD-BOT module



MPGD Barrel Outer Tracker (MPGD-BOT)

https://eic.jlab.org/Geometry/Detector/Detector-20240515102931.html



MPGD-BOT module cross sectional view