Summary of Mechanics and Integration Session

ePIC Brookhaven National Laboratory 2026 January

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(For TC Office)

Yale Wright Laboratory

One Session:

- Co-organized by Project Engineers and TIC
- Main Emphasis on Services and Cooling
- Large in-person and online Participation

All the slides are posted here:

https://indico.bnl.gov/event/30532/sessions/8774/#20260121

Contribution list | Timetable

Wed 21/01

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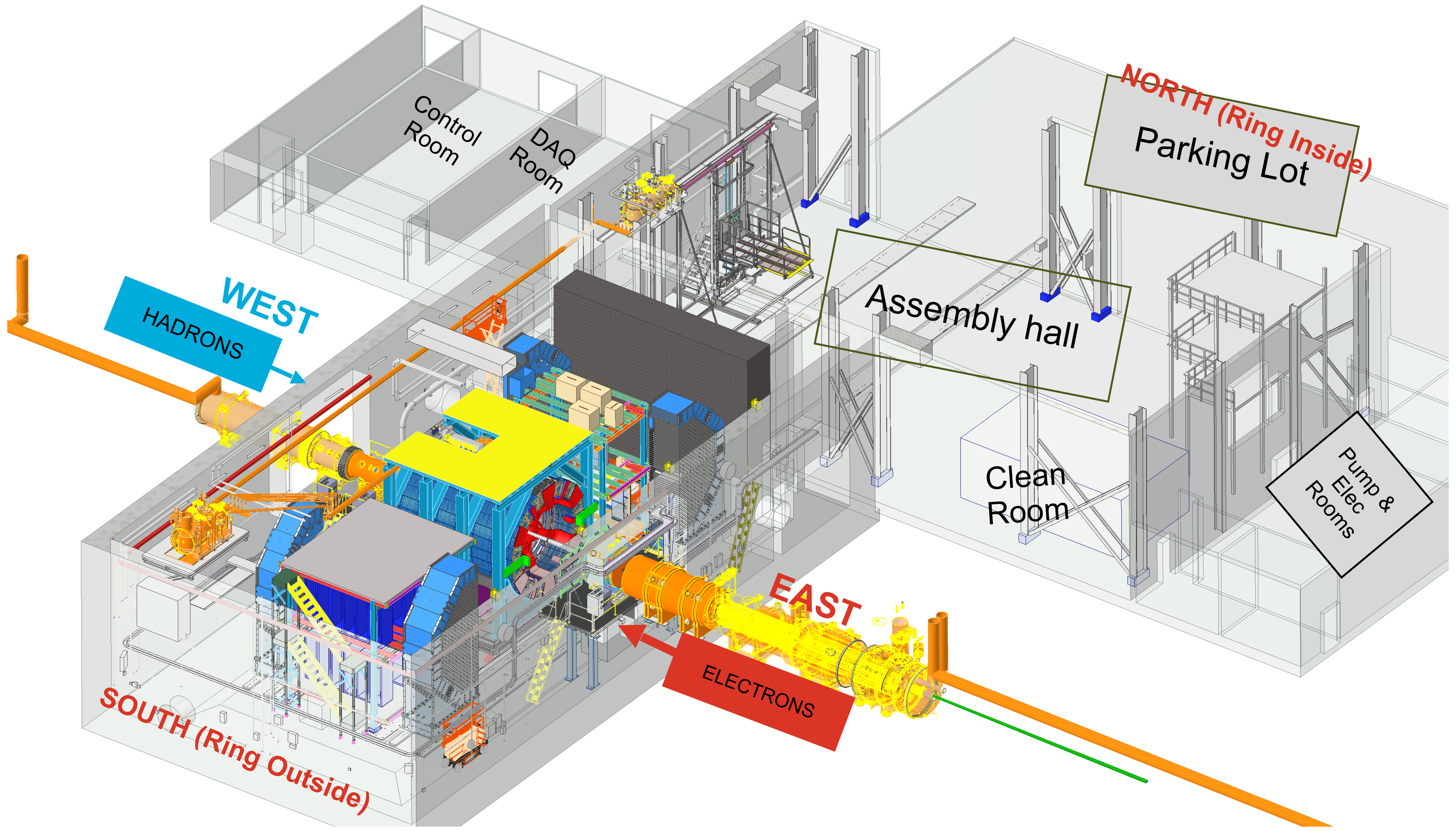
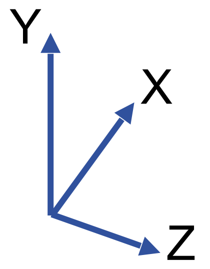
13:00	**Overview of ePIC Mechanical Design and Updates** *Brookhaven National Laboratory*	*Rahul Sharma* 13:00 - 13:20
	Status of global thermal model and cooling of ePIC *Brookhaven National Laboratory*	*Girish Gowda* 13:30 - 13:50
14:00	**BIC: Power Budget Estimation and Cooling Design Strategy** *Brookhaven National Laboratory*	*Dr Wouter Deconinck et al.* 14:00 - 14:15
	MPGDs: Power and cooling design *Brookhaven National Laboratory*	*Seung Joon Lee* 14:15 - 14:30
	B-ToF: Power Budget Estimation and Cooling Design Strategy *Brookhaven National Laboratory*	*Prof. Wei Li* 14:30 - 14:45
	SVT: Power Budget Estimation and Cooling Design Strategy *Brookhaven National Laboratory*	*Ernst Sichtermann* 14:45 - 15:00
15:00	**Far Backward Cooling Requirements** *Brookhaven National Laboratory*	*Stephen Kay* 15:00 - 15:15
	Far Forward Cooling Requirements *Brookhaven National Laboratory*	*Alexander Jentsch* 15:15 - 15:30
	dRICH Gas system Requirements for ePIC *Brookhaven National Laboratory*	*Silvia Dalla Torre* 15:30 - 15:45
	MPGD Gas system Requirements for ePIC *Brookhaven National Laboratory*	*Stefano Gramigna* 15:45 - 16:00
16:00		

Overview of the ePIC Installation, Integration and Infrastructure and Alignment (I^3 Group) by Rahul





- EPIC Detector Barrel will be assembled in the Assembly Hall and End Caps will be assembled in the Experimental Hall
- During maintenance shutdowns, detector barrel (central detector) can be rolled out from Experimental Hall to the Assembly Hall. Endcaps will always stay in the Experimental Hall.

Other topics:

- ePIC Detector Support Hierarchy View
- Envelopes Model and Drawing Package
- ePIC Central Detector Weight Summary
- Interaction Region and Alignment Requirement

Technical Summary

Subsystem / Area	Status	Key Notes
Barrel Systems (Cradle, Platforms, Support Rings, All subdetector Support structures and Installation Tooling)	**PDR Completed**	Integrated model under refinement. Subdetector installation tooling design and procedures also under refinement.
Endcap Structures (Flux Return Steel, Support Frames)	**FDR Complete**	Fabrication packages and drawings approved
Endcap and Barrel Motion & Control Systems	**PDR Completed**	Mechanisms and control integration validated in model
Services Integration (Cooling, Power, Signal Routing)	**PDR Completed**	Service envelopes defined; routing documented and verified
Cooling Systems	**In Progress**	Design maturing with detector designs; Facilities 18 °C water baseline. Air Cooling or Convection Cooling as a second preference. Special cooling like Glycol cooling system is only used for dRICH detector.
Building 1006 Modifications (Experimental & Assembly Halls)	**PDR Completed**	Reuse of existing STAR infrastructure provides major schedule and cost advantage

Alignment Challenges [central beryllium section of the beam pipe at the IP]

- **Tight requirement focused on the Be section**
  - Central beryllium section at the IP must stay within ±1 mm (X/Y) and ±5 mm (Z).
  - Surrounding detectors and supports can be looser as long as they can be surveyed.
- **Shared, tightly packed alignment budget**
  - Manufacturing tolerances, structural deflections, survey / transfer errors, and adjustment mechanism tolerances all draw from the same small budget.
  - Any single contributor getting "too large" reduces margin for the others and risks exceeding the overall ±1 mm(X/Y) / ±5 mm (Z) limits.
- **High support sensitivity of the thin Be pipe**
  - Thin, flexible Be pipe will react strongly to small motions or rotations at its supports.
  - Heavy detector installations such as EEMCAL can move/deflect GST/PST structure and in turn move the beam pipe. Kniematic mounts and pre adjustments to allow for deflection are being planned at the moment.
- **Interface constraints at ends and short bellows**
  - Beam-pipe ends and flanges must stay compatible with the rest of the beam line; short bellows can only accept a few mm of X/Y misalignment and limited angle.
  - Maintaining the IP position while also keeping end offsets and angles within bellow capacity is a coupled, multi-point constraint.
- **Thermal cycling and operational handling**
  - Pump-down / bake out to >100 °C introduces thermal expansion and contraction; the system must return to the same aligned state after cooling.
  - Repeated thermal and operational cycles (bake outs, interventions, motion of surrounding detectors) must not accumulate into permanent Be-pipe misalignment.
  - Vacuum Group evaluating titanium end sections (central section remains beryllium) in place of aluminum to improve behavior under bakeout thermal cycling; bellows at both ends will accommodate thermal expansion/contraction, and a mock-up with testing is being considered to validate the approach.

Status of developing a global thermal model and cooling of ePIC by Girish

Example for Calorimeters:

Detector	Cooling Method	Design Tasks	Description	Status
		Cooling system	Cooling requirements, Calculation of heat load, flow rate, pressure drop	In Progress
Forward Emcal	Water Cooling		dew point temperature for condensation, Tubing diameter, Insulation requirement	
		Modeling of Cooling system	CAD Model of the 1/4 inch copper tubing with heat sink integrated with board assembly	Completed
		Cooling of FEB	Thermal simulation of FEB's	Completed
		Active cooling of the SiPM's to be assesed	Design change with and without thermal pad downstream of SiPM board	Completed
		Optimisation of cooling system design	Reduce FEB temperatures to 3C above dew point	In Progress
Barrel Emcal	Water Cooling	Cooling system for Barrel Pb/Scifi	Cooling requirements, Calculation of heat load, flow rate, pressure drop	In Progress
		ESB Cooling of Astropix heat removal	Thermal simulation of Astropix through PbScifi to assese need for active cooling	Completed
		ESB Cooling for SiPM stability	Thermal simulation of cold plate design optimisation as per temperature specification	Completed
Forward Hcal	Convective Cooling	Cooling system	Cooling requirements, Calculation of heat load, flow rate, pressure drop	In Progress
		Cooling of PCB	Thermal Simulation of Insert Assembly	In Progress
Barrel Hcal	Convective Cooling	Assese the need for Active Cooling	Cooling requirements, Calculation of heat load, flow rate, pressure drop	In Progress
EEEMCAL	Water Cooling	Cooling system	Cooling requirements, Calculation of heat load, flow rate, pressure drop	In Progress
		Cooling of SiPM	Thermal Simulation of of SiPM in contact with crystals	Completed
		Cooling of FEB	Thermal Simulation of FEB	In Progress

Summary

- Existing MCW, ACW and Cooling circulator with number of CDUs is sufficient to cool the heat load of the various detector components which are liquid cooled.
- Convective Cooling is used to cool other detector components which are air cooled.
- Special Cooling systems such as Glycol is used to cool the dRICH detector.
- Global Thermal model development is in progress for various detectors.

Next Steps

- Refine cooling calculations
- Decide manifolding sizes and locations
- Work with detector groups to determine temperatures, tube sizes, flow rates
- Consider cooling interface details

Various Cooling types and heat loads:

Liquid Cooling System

		Units
Cooling media	Water	
Forward EMCAL	3,428	W
Barrel EMCAL	3,101	W
Cymbal	1,944	W
Outer MPGD	2,856	W
pfRICH	294	W
DIRC	310	W
EEMCAL	1,010	W
TOF	30,000	W
SVT Outer	301	W
SVT Disks	655	W
SVT Inner	412	W
MPGD Endcap Disks	1,296	W
Total Heat Load	45,564	W

- Barrel TOF and Forward TOF heat load needs update

Air Cooling System

,		Units
Cooling media	Air	
Barrel HCAL	1,280	W
Forward HCAL	1,656	W
SVT Inner	211	W
SVT Disks	5,819	W
SVT Outer	3,218	W
Total Heat Load	12,184	W

Special Cooling System

		Units
Cooling media	Glycol	
dRICH	19,968	W

Platform Electronics & Racks

		Units
Cooling media	Water	
Platform	80,000	W
DAQ Room	250,000	W
Total Heat Load	330,000	W

BIC: Power Budget Estimation and Cooling Design Strategy by Wouter

Significant Heat Sources and Power Estimates

Total Heat Load: The entire BIC (consisting of 48 sectors and 96 End-of-Sector Boxes) has a total estimated heat load of approximately 4.3 kW.

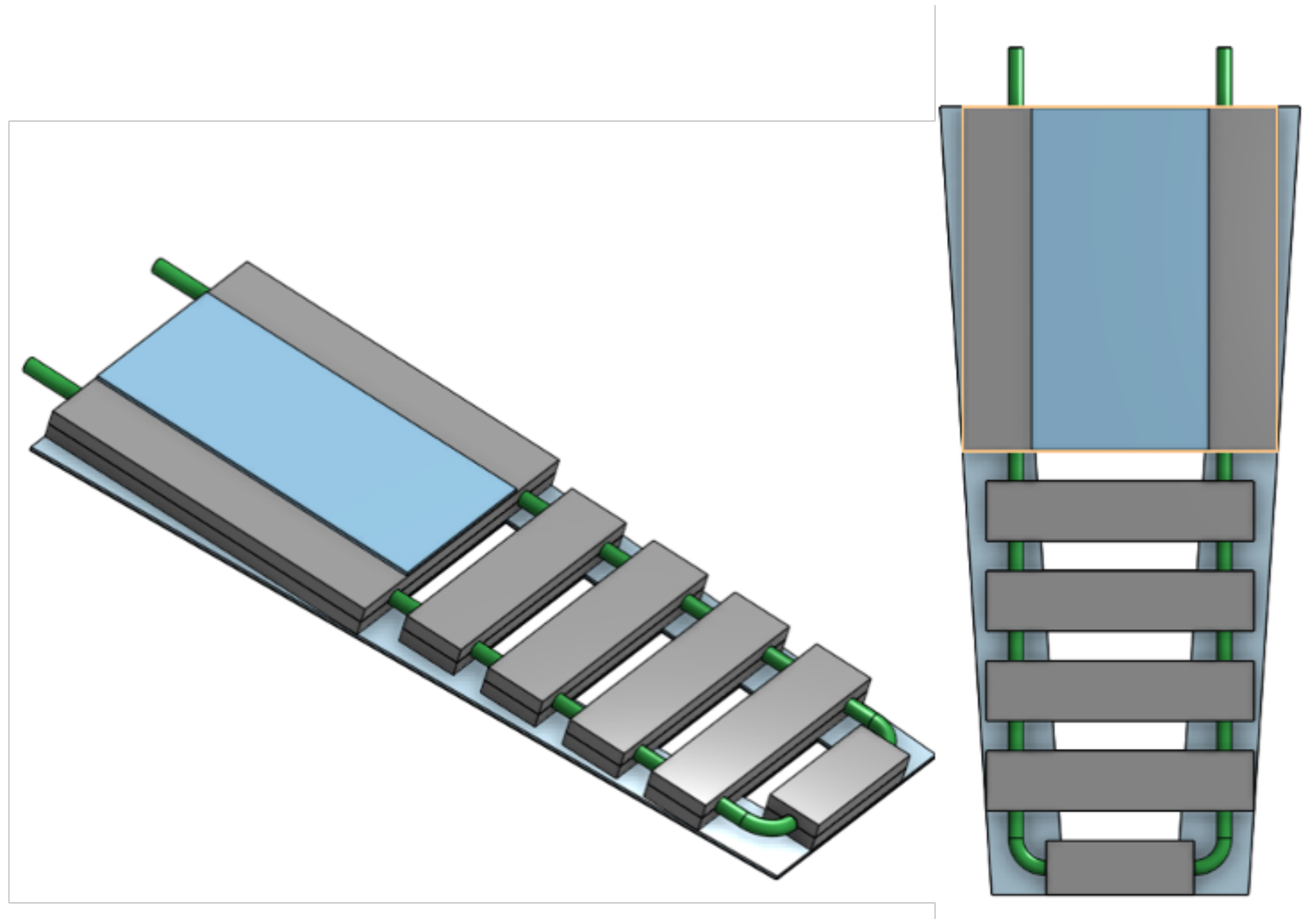
AstroPix Sensors: These contribute 2 kW total (42 W per sector).

End-of-Sector Boxes (ESB): The 96 ESBs account for 2.3 kW total (24 W per ESB). Individual components within each ESB include SiPM services (12 W), CALOROC boards (8 W), and AstroPix End-of-Tray Cards (4 W) .

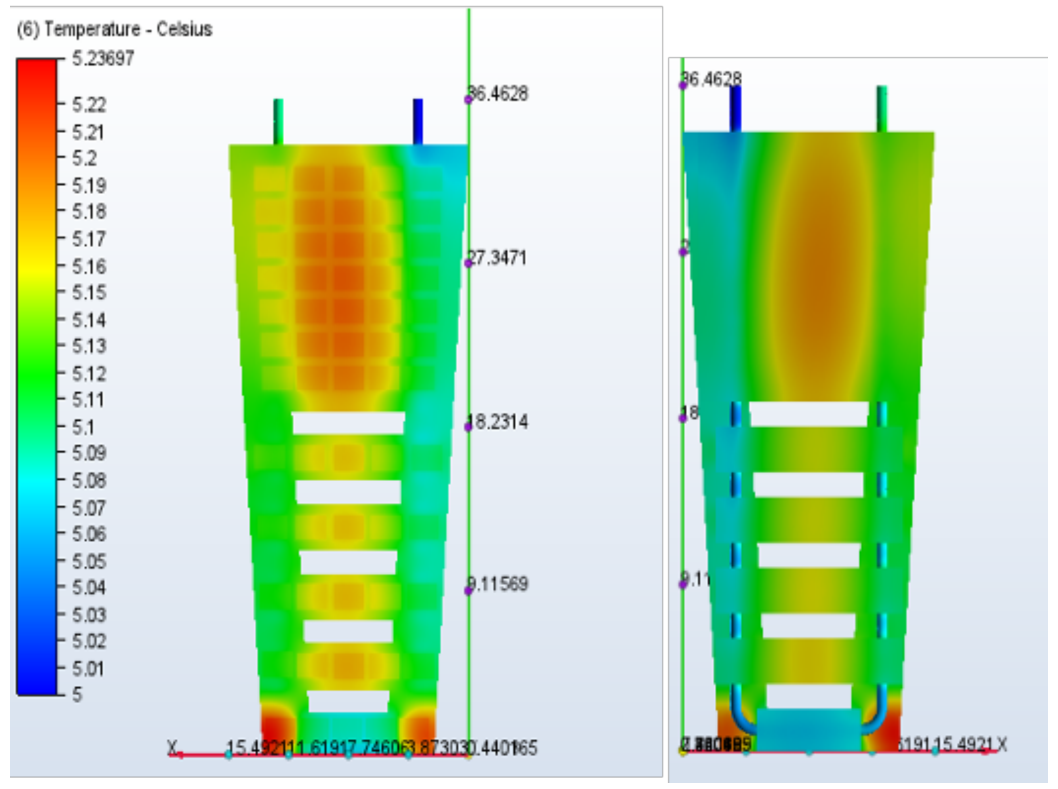
Cooling Strategy Overview

- **Passive Cooling (AstroPix):** Despite a high total heat load, AstroPix sensors have a low heat density. Heat is evacuated radially outwards through carbon fiber tray walls to a 1-inch thick aluminum plate, which is then cooled by room-temperature water.
- **Active Cooling (ESB):** Due to higher heat density, the ESBs require an active chilled water loop to stabilize SiPM temperatures at approximately 7°C.
- **Environmental Control:** ESBs and AstroPix layers will be slow-flushed with nitrogen to prevent condensation during cooling.

Aluminum cold plate, PCBs on both sides:



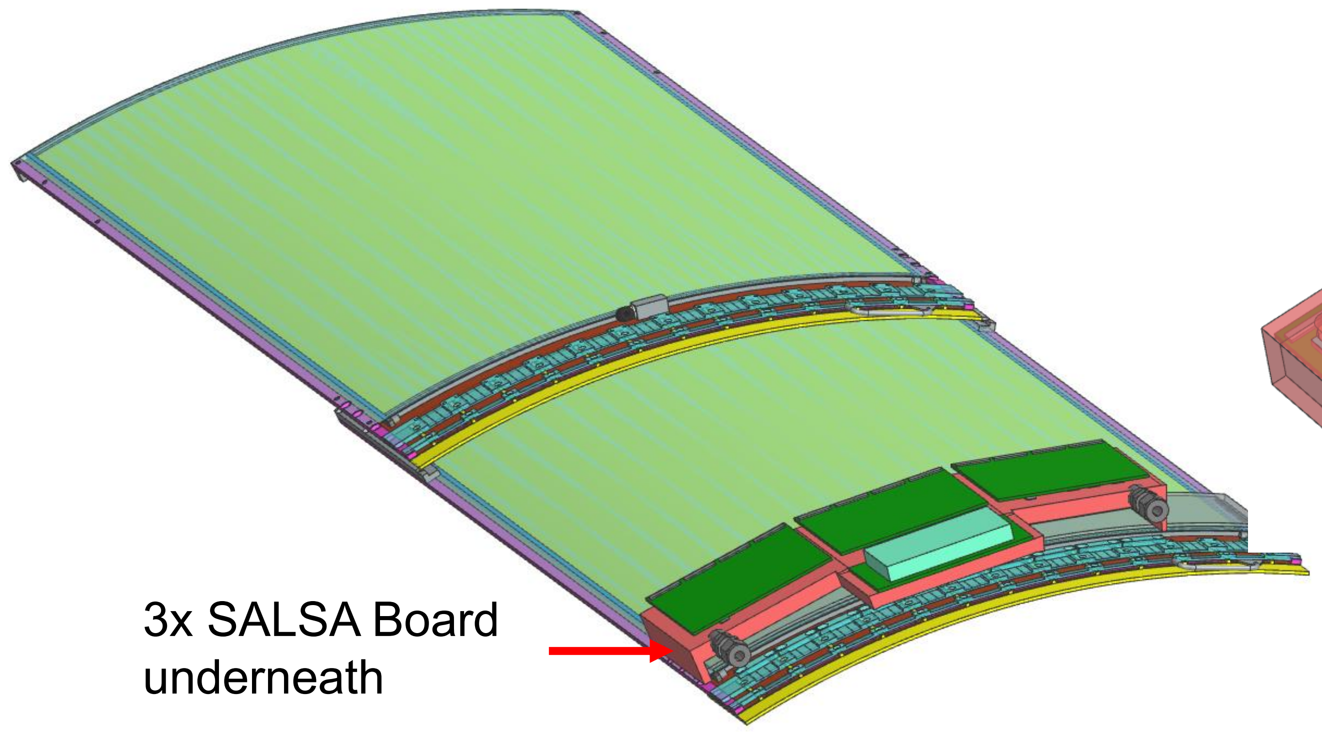
•CALOROC board: FR4 PCB → **metal-core** PCB under consideration

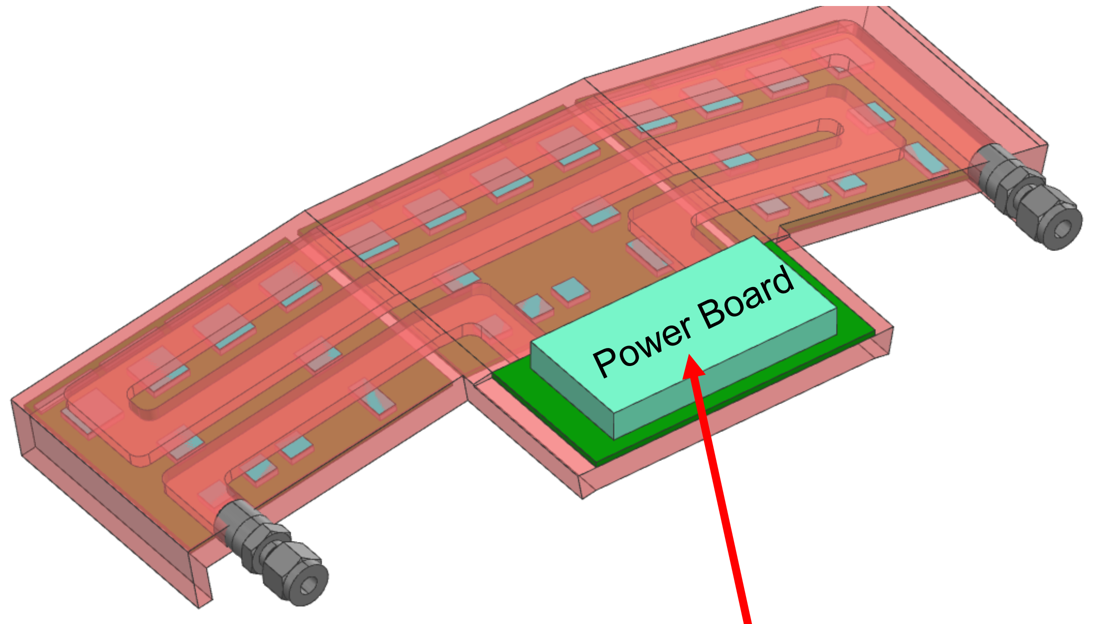


Mechanical Design and Engineering Ongoing Work:

Development and construction of thermal test articles are underway to validate these CFD calculations using resistive element arrays and thermal diodes.

MPGDs: Power and Cooling Design by Seungjoon Lee





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 of Challenges

- **Space Constraints:** Fitting cooling manifolds and power cables in the congested "gap" areas between detectors.
- **Material Budget:** Balancing the need for effective heat sinks (which are usually dense metals) with the requirement to keep tracking detectors at low material budget.

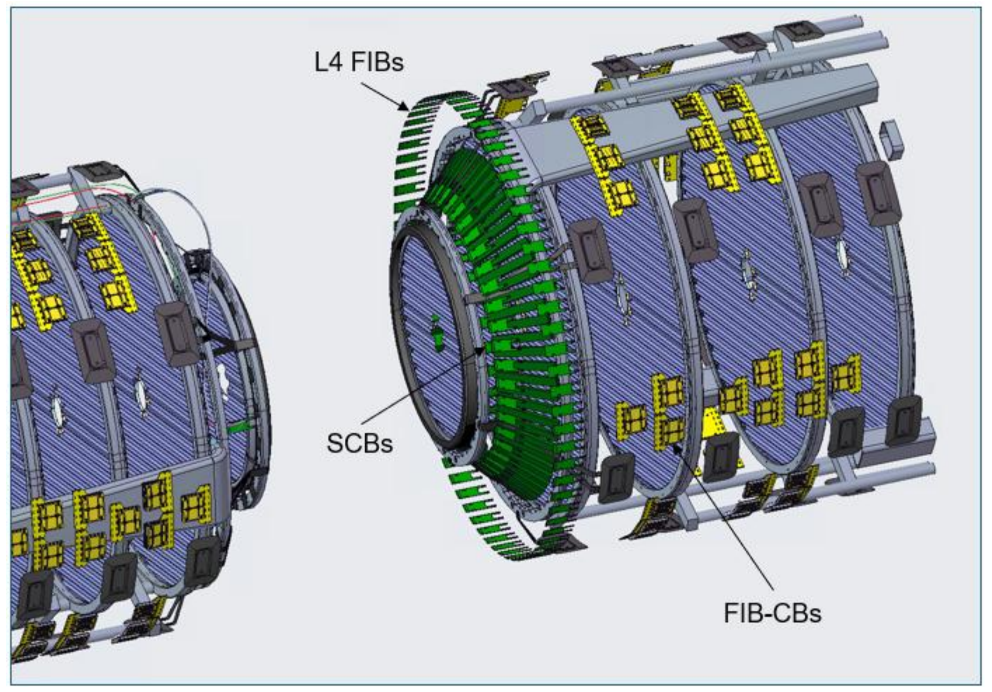
Summary

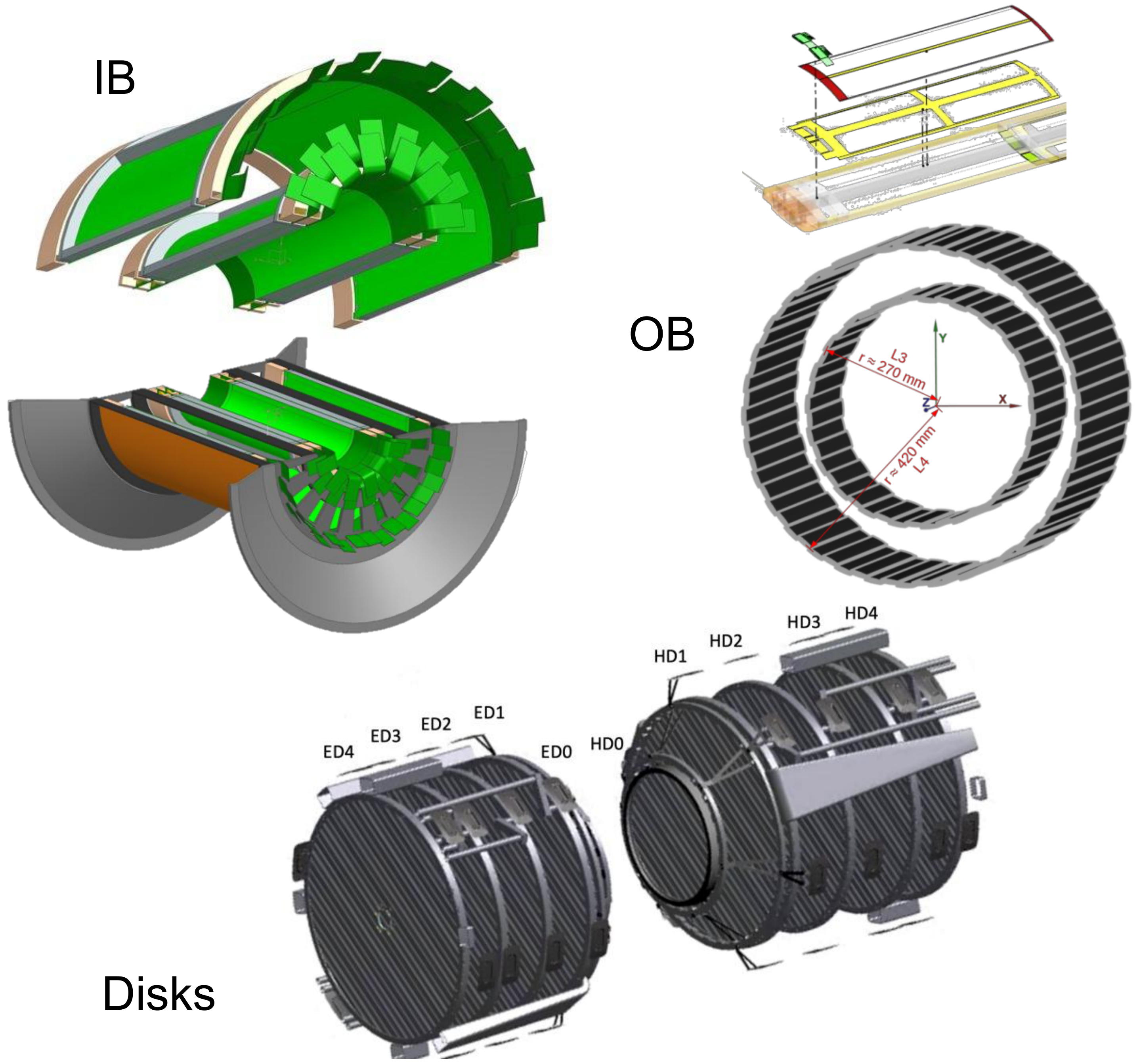
1. There has been major design change for ECT and CymBaL.
2. Each subsystem has their own power/service/cooling design based on SALSA board which is still under development.
3. Preliminary water-cooled heatsink designs provide a baseline for heat dissipation across all MPGDs.
4. Critical Dependencies: 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

SVT Power Estimates and Cooling Design by Ernst

SVT Power & Cooling Strategy

- Power Dissipation:
  - **Total Air-Cooled Power:** Estimated at **5.9 kW (typical)** to **9.3 kW (maximum)**, driven primarily by sensors, ancillary ASICs, and flexible printed circuits (FPCs).
  - **Liquid-Cooled Power:** Approximately **1.2 kW** dissipated by Readout Electronics (RDOs), specifically control boards.
- Cooling Systems:
  - **Air Cooling:** Targets the sensitive innermost barrel and disk layers to maintain required resolutions. It uses 34 independent air pipes to feed specific interior interstitial volumes .
  - **Liquid Cooling:** Uses "**modified chilled water**" for RDOs to minimize mass within the SVT envelope.
- Requirements & Safety:
  - **Temperature Limits:** Maximum allowable temperatures are **40°C** for the sensor units (RSU) and **65°C** for the electronics (LEC).
  - **Humidity Management:** Cooling air must be dried (Class 3 ISO 8573-1:2010 or better) to prevent condensation, as operating temperatures may fall below the ambient dew point.





SVT Summary

- based on up-to-date knowledge of continuing sensor and ancillary ASIC development,
- system design incorporates heat transfer tests and analyses of layers, staves, and disks,
- plant design and specifications developed, including humidity management,
- to be done:
  - CFD analyses of the SVT internal volume in its entirety,
  - moisture effusion at close-outs as services are finalized,
  - adjustments, as needed, towards final sensor and ancillary ASIC designs,
  - complete layout in CAD of liquid cooling loops for RDOs (mainly control boards)
  - (incorporate external heat in-/out-flux)

ePIC Luminosity Systems - Cooling Requirements by Stephen

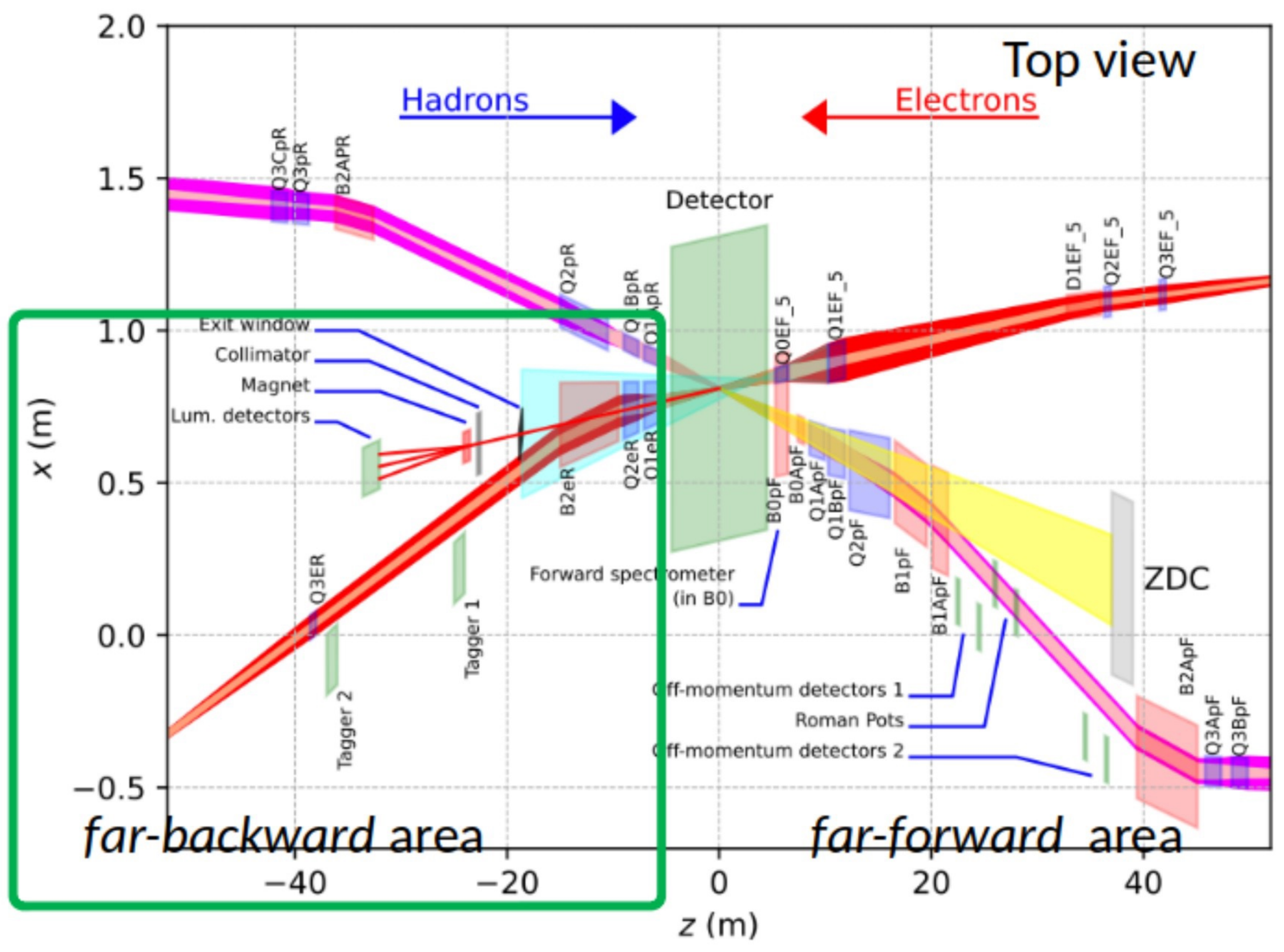
Mainly:
Pair spectrometer calorimeters and Pair spectrometer trackers

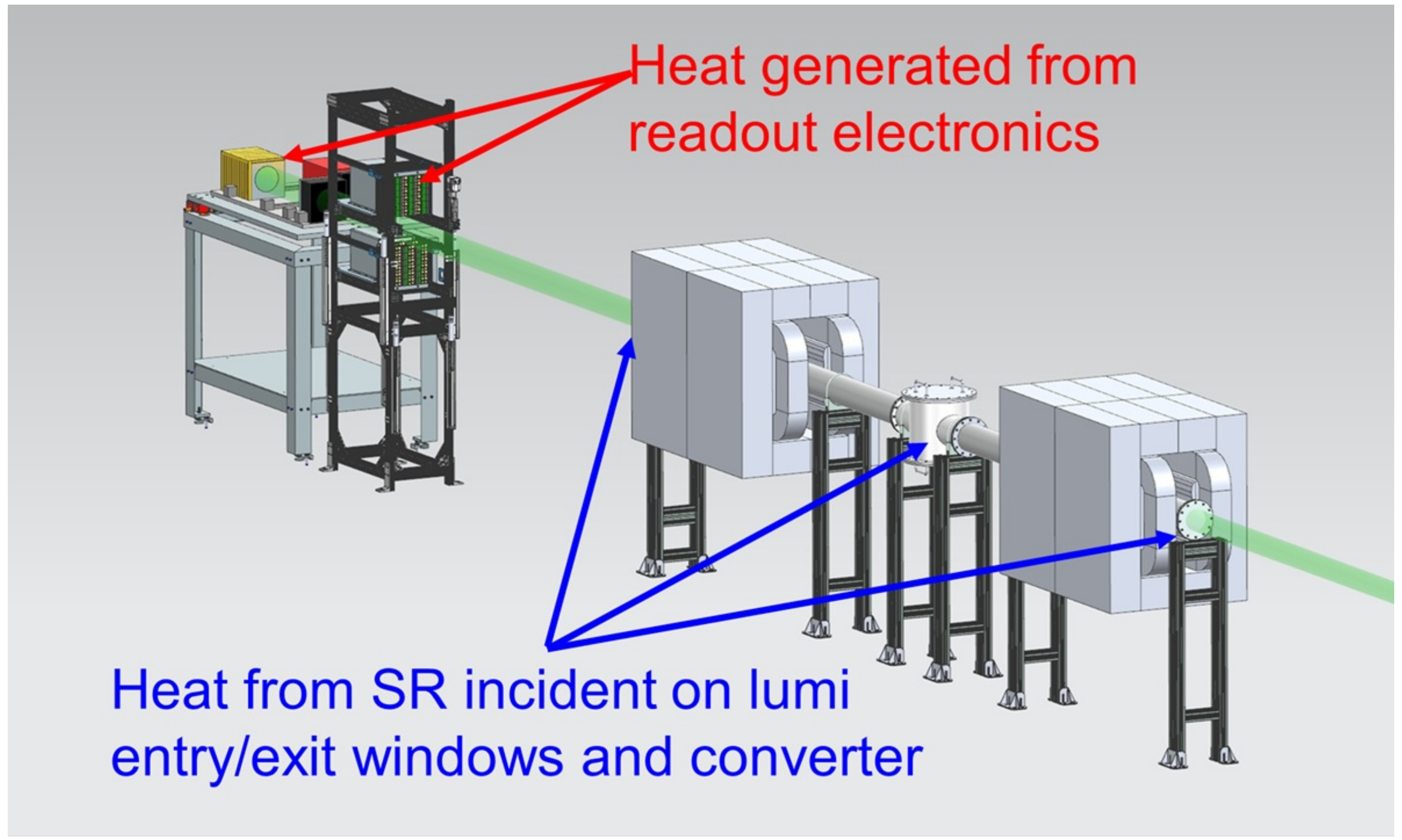
1. Heat Sources in the Luminosity Region
- **Synchrotron Radiation (SR):** Incident radiation from the beam results in a heat load on the vacuum system. While typically low, certain configurations are more problematic and require monitoring.
- **Readout Electronics:** Heat is generated by the trackers and calorimeters used to monitor luminosity.

2. Subsystem Power Estimates
- **PS Calorimeters:** Heat generation is considered low and tolerable.
- **PS Trackers:** Estimated heat generation is significantly higher. Whether current numbers are realistic and suggests the possibility of reducing the number of channels to manage the thermal load?
- Further support is needed to finalize estimates for the tracker electronics.

3. Cooling Strategy and Infrastructure
- **Proposed Method:** Due to the relatively large space available in the Far Backward (FB) luminosity region, **air cooling** is the primary candidate for the entire region.
- **Design Needs:** Work is ongoing to assess the exact volume of air required

4. Key Challenges & Next Steps
- Confirming the power consumption of the tracker systems is a top priority to ensure cooling designs are not undersized.
- Identifying the specific air cooling plant or infrastructure needed to handle the localized heat without interfering with the vacuum system or beamline components.
- Coordinating with the broader ePIC I^3 group to ensure luminosity cooling is compatible with the overall detector facility.





Far-Forward Cooling needs by Alex

- **Roman pots and OMD** cooling design is well-underway – simulations already performed.

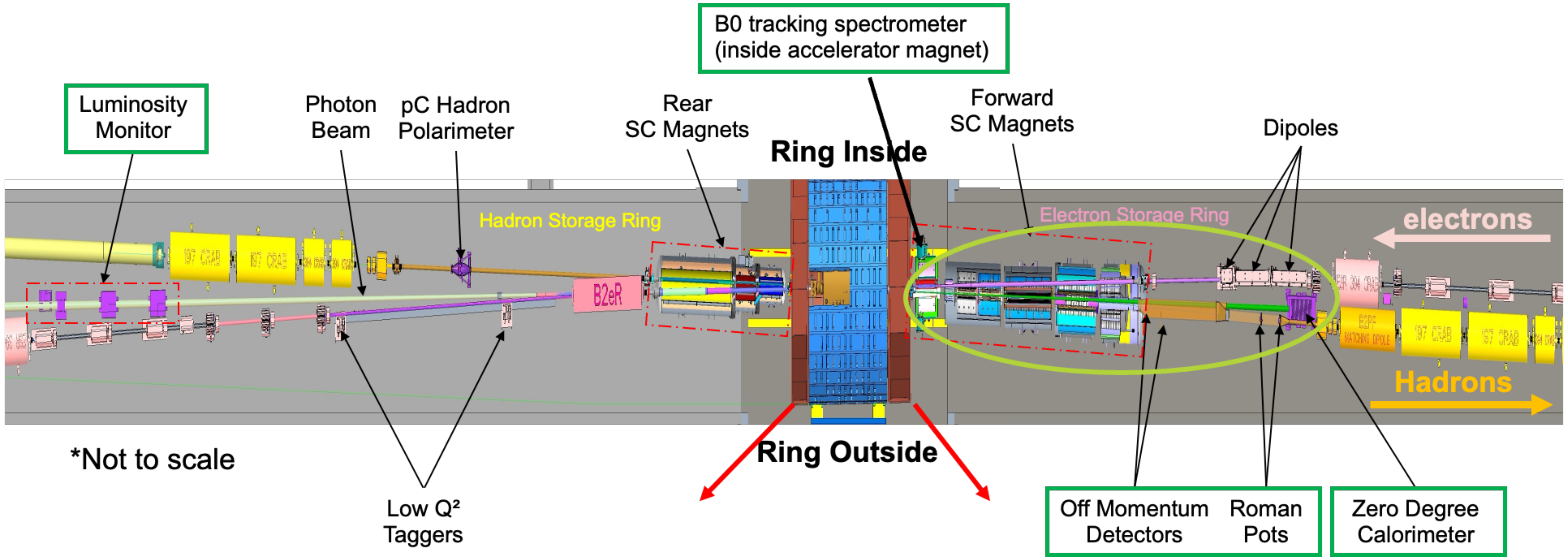
•Need to understand Peltier long-term functionality (e.g. radiation hardness).

•Need to asses full power consumption of modules as new ASICs become available.

- **B0 tracking and EMCAL** at very preliminary stage of cooling design.

• Less restrictive than RP/OMD (which are in-vacuum), but Peltier concept may not work at all here due to high dose/ neutron fluence.

- **ZDC** does not have strict requirements defined, but cooling will be easy given the location of the ZDC.



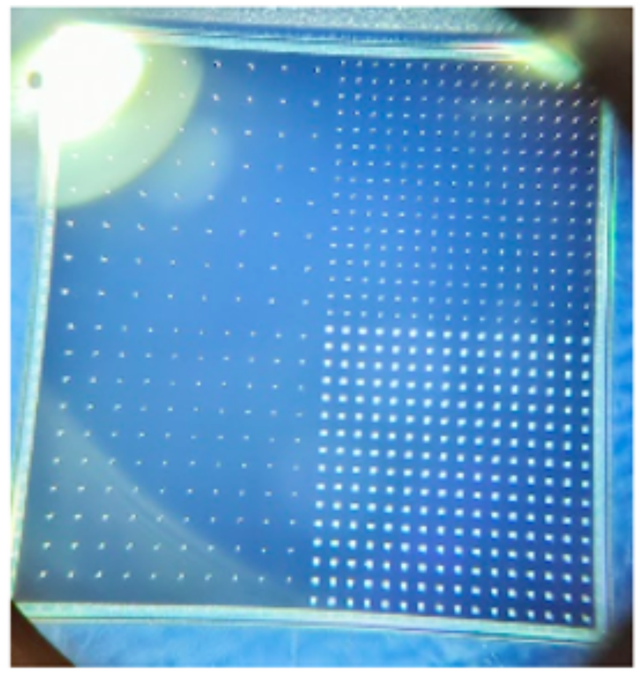
- 2 AC-LGAD tracking detectors **in vacuum** (Roman pots & off-momentum).
- 1 AC-LGAD tracking detector in **air** (embedded in B0 accelerator magnet).
- Zero-degree calorimeter in air (on a table between the beam pipes).

- Strong synergy with TOF: front-end + power board will be the same as FTOF.
  - **Only difference is sensor stave/module, and the separation of the FEB for flexibility for FF detector needs.**
- **Presently optimizing choice of readout board "flavor" which works best for auxiliary detector needs.**

Far-forward sensor "staves"

- (3) 1.6cm x 1.6cm AC-LGADs with 500um pixel pitch
- bump-bonded to EICROC1/2 ASICs
- staggered on a two-sided PCB to provide full active-area coverage.
- These sensors have 32x32 channels, matching the EICROC1/2.
  - Currently have 32x32 channel sensors from HPK which are under test.

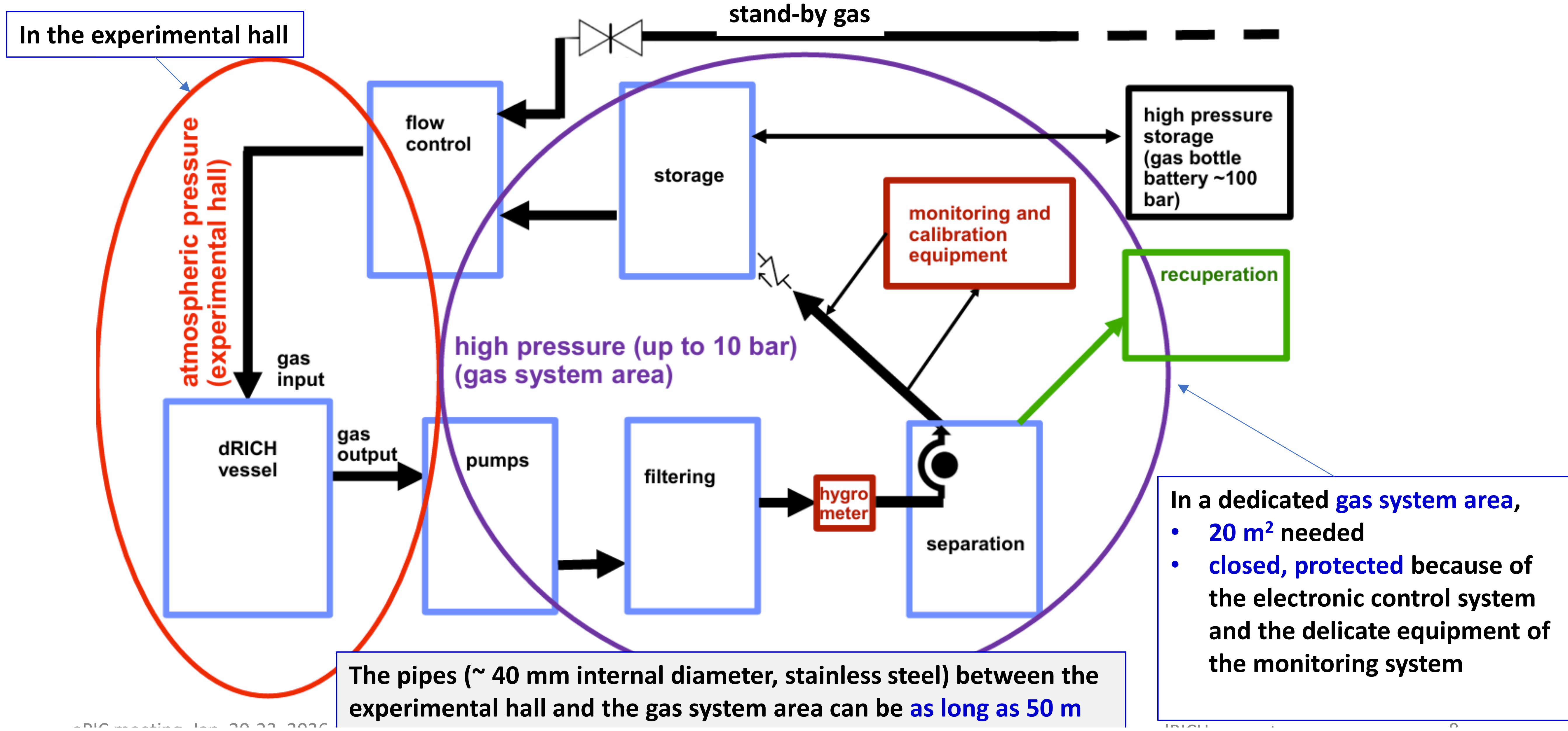
ePIC full size pixel detector: 1.6x1.6cm



dRICH gas system, principle and technical needs by Silvia

Baseline Gas: C2 F6 (Hexafluoroethane) is the selected radiator due to its high molecular weight and low chromaticity.

- **Key Challenges:**
  - C2F6 is expensive and a potent greenhouse gas, necessitating a **closed-loop circulation** and recovery system to minimize losses.
  - It has a low condensation temperature at atmospheric pressure, requiring careful thermal management.
  - Potential scintillation properties are under study to determine if quenching (similar to CF4 usage in LHCb) is required.



1. **Gas circulation system**
   - **Remaining principle studies (separator, recovery system)**
   - **Principle design of the system**
   - **Engineering test article**

   } **INFN Trieste**

   - **Executive drawings/realization compliant with BNL safety regulation - Project Engineer Team**

2. **System Control (electronics and programming) – most likely, BNL-INFN shared effort**

3. **Monitoring equipment – INFN Trieste**

MPGD Gas System Requirements by Stefano

All three subdetectors will operate with the **same gas mixture:**

$Ar:CO_2:iC_4H_{10}$ (93:2:5) is the main candidate

To be validated in the coming 2026 test beam campaigns

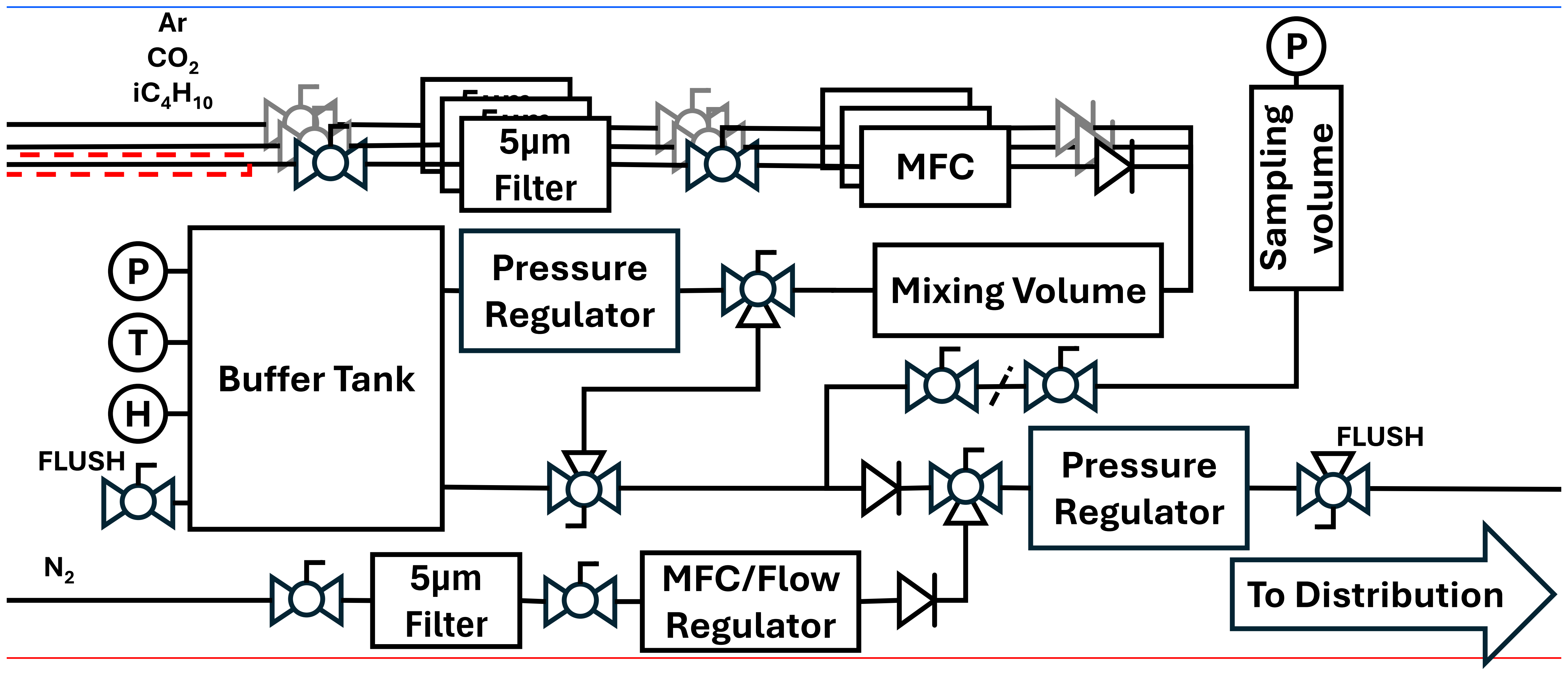
Flushing with nitrogen will be required whenever the operating gas mixture is not circulating to **prevent humidity** from entering the detectors

The **operating mixture** should be **as pure as realistically possible** to achieve consistent gas gains and reduce aging:

- **Ar → Grade 6.0 (99.999%)**
- **CO_2 → Grade 4.5 or better (99.995%)**
- **iC_4H_{10} → 99.5% or better**

Grade 5.0 (99.999%) N_2 is sufficient for flushing

Isobutane requires **warm storage** and/or **pre-heating** to avoid transition to liquid phase in the colder months



- The MPGD gas system has to **supply both a three-gas mixture and nitrogen**
- **Design and manufacturing should be entrusted to Project**, as it requires integration with onsite facilities
- Ample **support by the experts of all involved subsystems will be provided** to ensure maximum compatibility
- **Block diagrams** of the system main components have been provided as an example to **illustrate expected operation requirements**
- **Hazards to people, environment and the subdetectors** have been **laid out** to the best of current knowledge

No summary, for a summary talk.

Comment: A lot of exchange between DSCs and Egg., hope it gives momentum towards final design