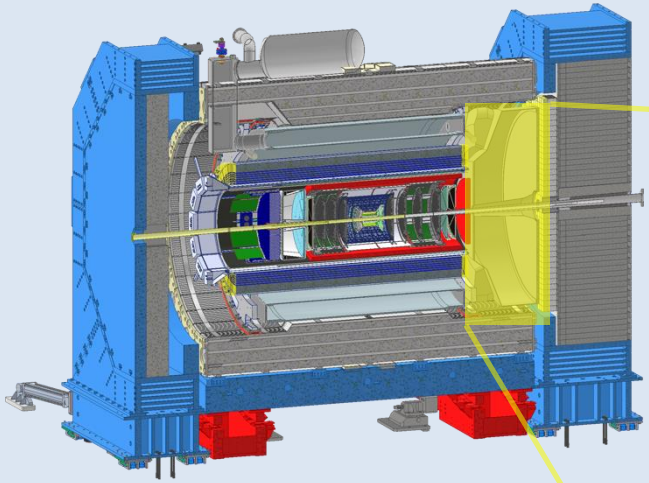
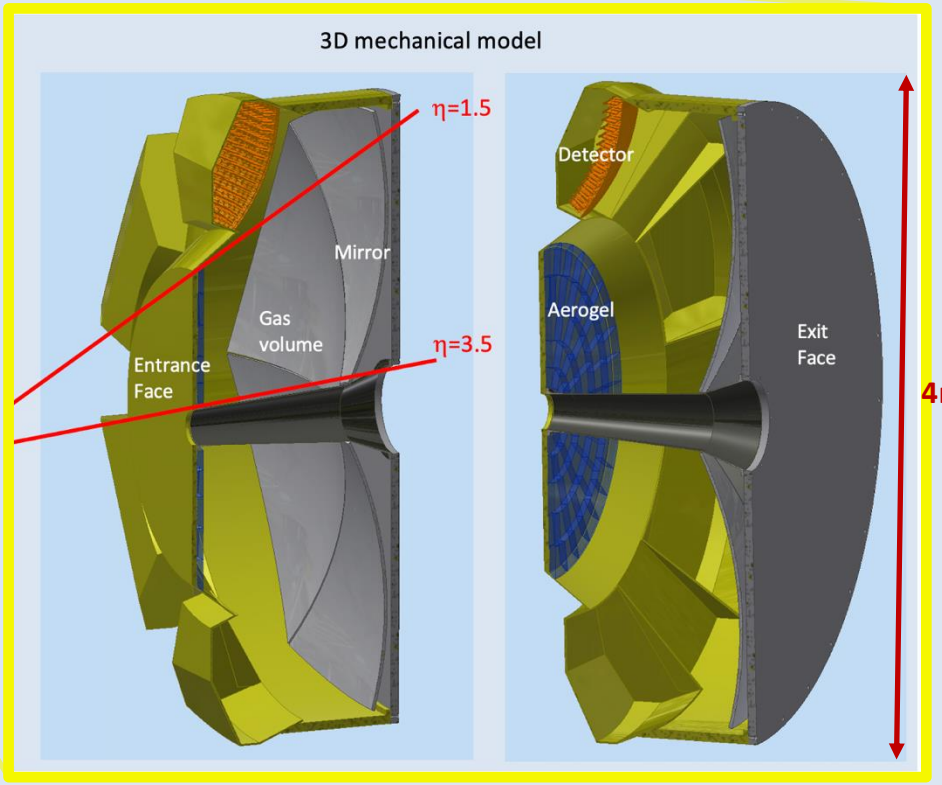


Dual-radiator Ring-imaging Cherenkov Detector (dRICH)

Essential to access flavor information



Goals:

- Hadron 3σ–separation between 3 - 50 GeV/c
- Complement electron ID below 15 GeV/c
- Cover forward pseudorapidity 1.5 (barrel) - 3.5 (b. pipe)

dRICH Features:

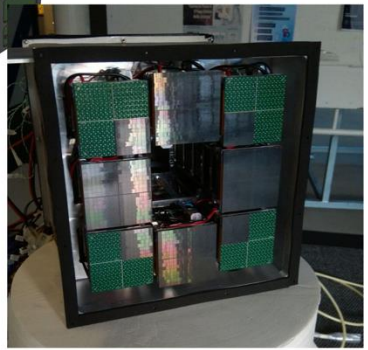
- Extended 3-50 GeV/c momentum range --> Dual radiator
- Single-photon detection in high Bfield --> SiPM
- Limited space --> Compact optics with curved detector

Steadly progress of photodetector towards integrated design completion in 2026

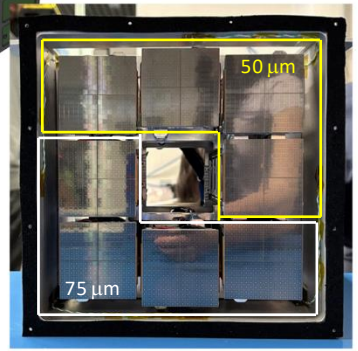
towards construction

2022
electronics v1

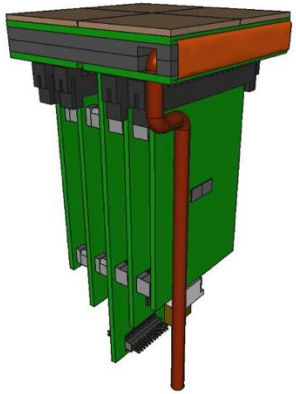
2023
electronics v2



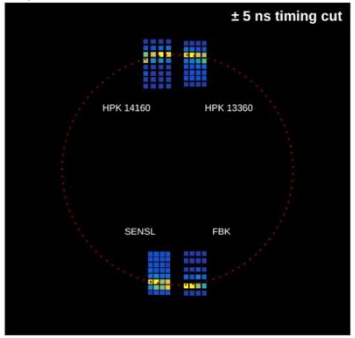
2024
electronics v2.1

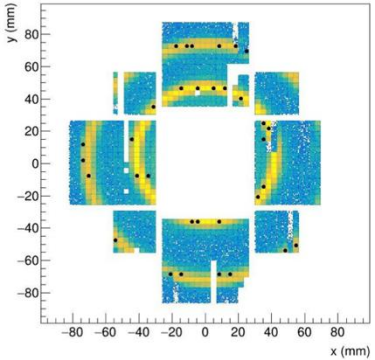


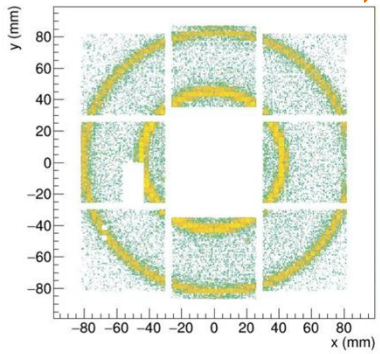
2025/26
electronics v3



ALCOR 32 ch







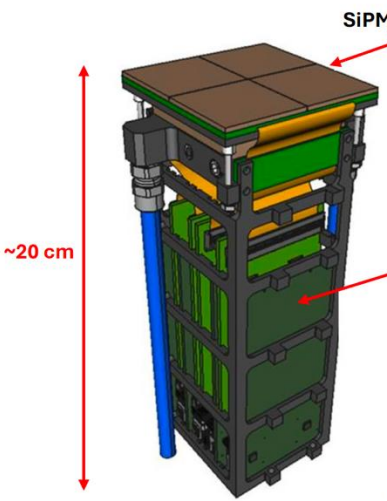
Full size engineering test article

2025 + SiPM carrierv3 + RDO

2026 + ALCOR 64ch + FEB 64

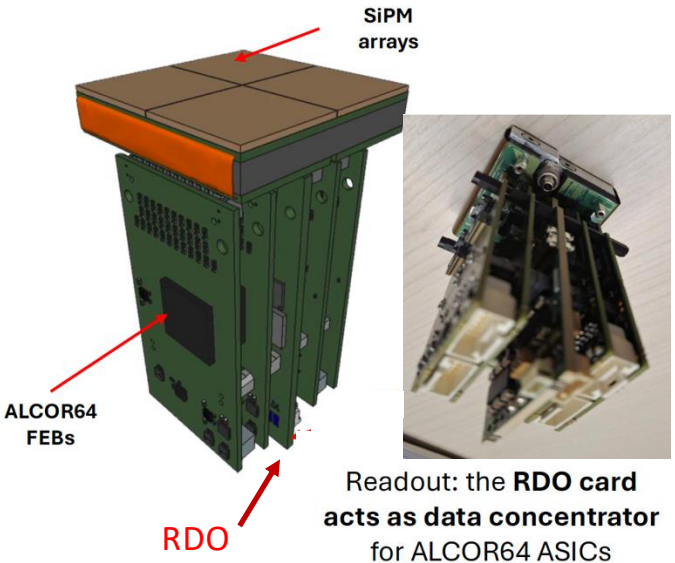
The dRICH detector box is segmented in **1248 PDUs** reading 256 SiPMs each:

dRICH-Prototype PDU



Readout: **commercial FPGA boards** using FireFly cables connected to ALCOR32 dual-FEBs

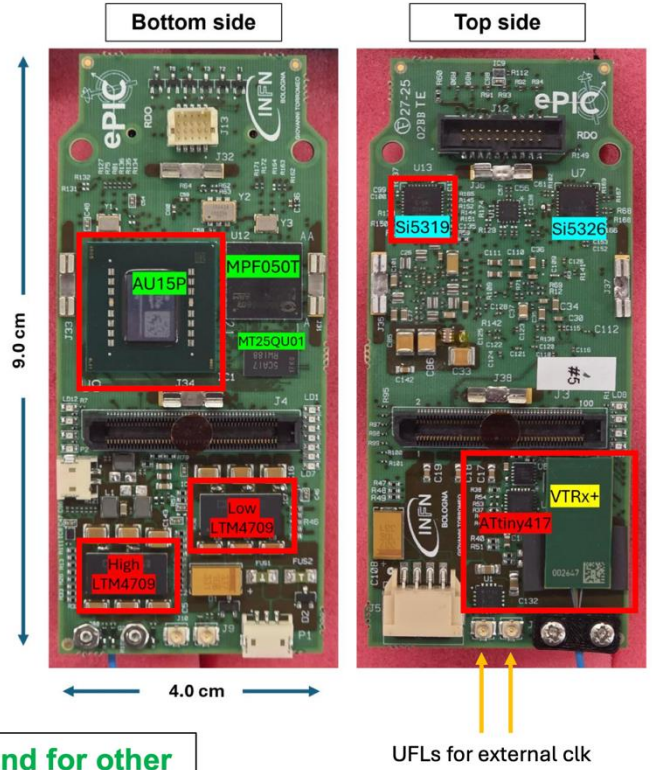
dRICH-PDU



Readout: the **RDO card acts as data concentrator** for ALCOR64 ASICs

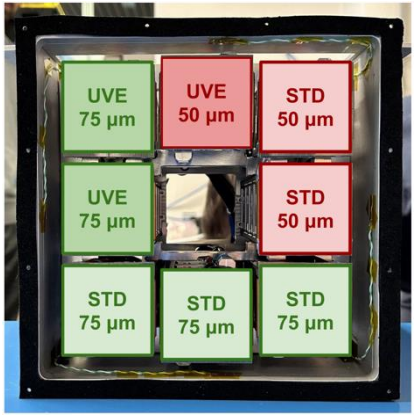
Concentrate the ePIC RDO functionalities inside the space of a credit card

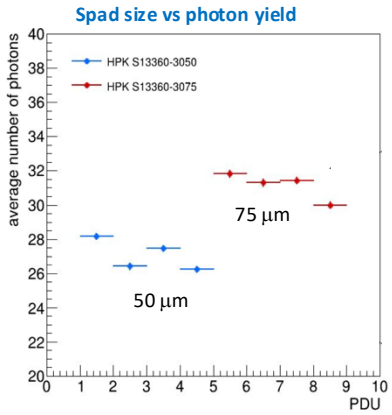
1. Mechanical pairing with Fake-FEBs ✓
2. **Power-up** checks before and after **ATtiny417** programming (check **LTM** Vouts) ✓
3. **Prg AU15P** via external connector ✓
4. **Prg MPF050T** via external connector ✓
5. Check UFL I/Os → For external signals (clock, trigger, spill ecc) ✓
6. **Prg Si5319** via AU15P at boot (programming 125 MHz clk of Si5319 for VTRX+ communication) ✓
7. Check consumptions ✓
8. **Fiber loop** through the **VTRx+**, for data transmission and reception checks. ✓
9. **Link IPBUS** via **VTRx+**, Ethernet protocol implementation and PING routine ✓
10. Turn on Fake-FEB via I2C from RDO ✓
11. **Prg ALCOR** via Fake-FEB (via IPBUS → **VTRX+**) ✓
12. **ALCOR readout** (via IPBUS → **VTRX+**) ✓



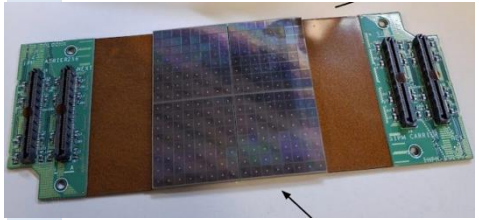
8th of September: no showstoppers found for other 8 RDOs production.

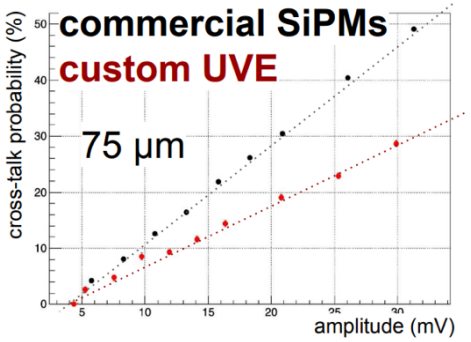
FInalization of the engineering of the SiPM optimized layout





Custom: lower cross-talk probability

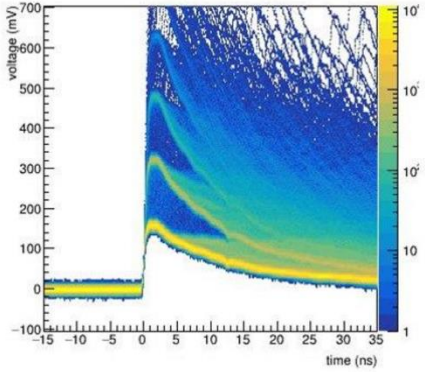




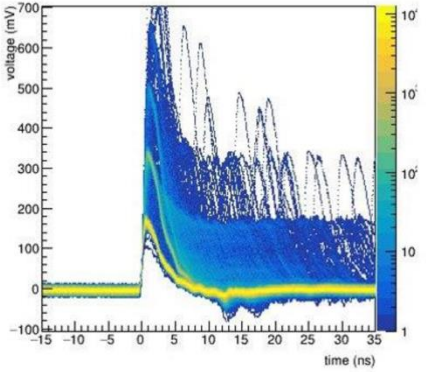
A manufacturer error prevented the use at the 2025 test-beam

UV enhanced with fast signal

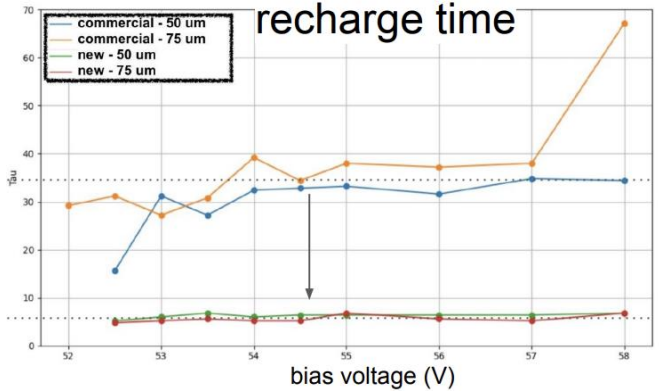
S13360 (50 µm)



Custom (50 µm) - UVE



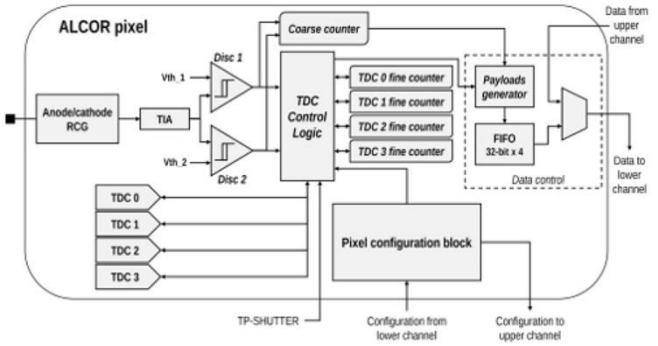
Custom: lower pile-up probability



First ALCORv64 test article produced in a MPW run, chip packaging is ongoing with interesting lesson learned

First samples being mouned on FEB

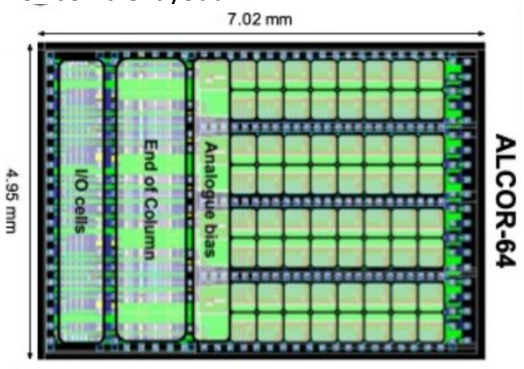
ALCOR block diagram



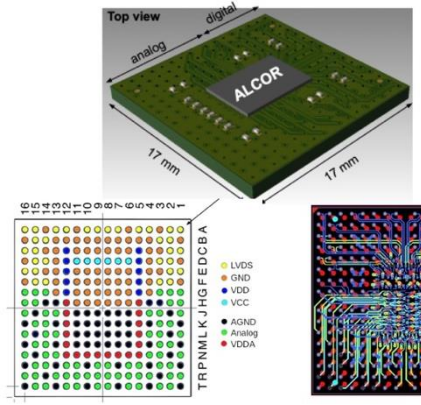
ALCOR key specifications

Function	Digitization from SiPMs with 1 p.e. sensitivity
Mode	Single-photon tagging or time and charge
Tech Node	110 nm CMOS
Channels	64 (8x8), dual polarity
Cdin	<1 nF
Digitization	20-40 ps TDCs, TOA + TOT; Timing <150 ps
Shutter	Width: 2–3 ns, programmable latency
Input Rate	<2.4 MHz (up to 5 MHz on single channel)
Clock	394.08 MHz operation from BX 98.5 MHz
Links	788 Mbps LVDS, SPI configuration
Power	12 mW/ch
Package	BGA
Rad Tolerance	Radiation hard

Silicon die layout

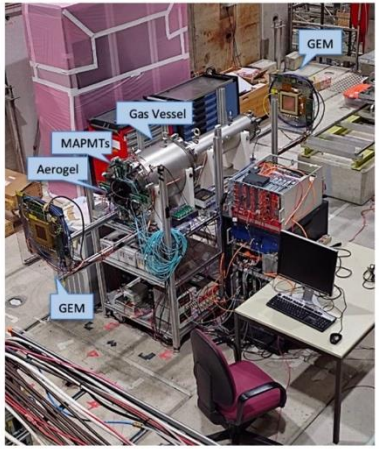


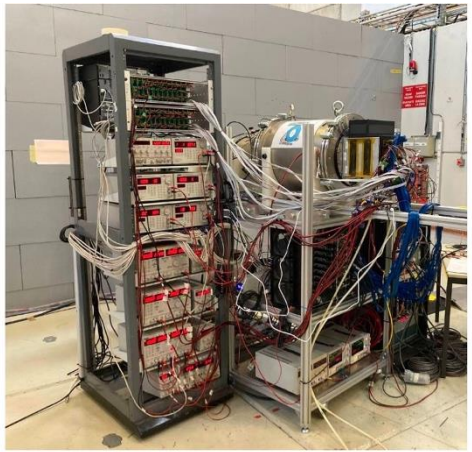
Compact ball-grid array (BGA) package with interposer

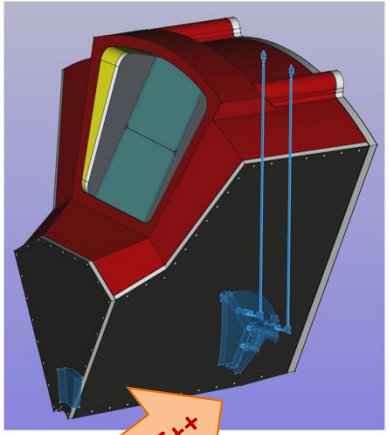


Previous validations w Basic Prototype:

- Dual-radiator concept
- C_2F_6 radiator gas performance
- Aerogel rafractive index
- SiPM-ALCOR readout chain
- EIC-driven readout plane
- Temperature gradients
- RDO data acquisition
- Alternate gases

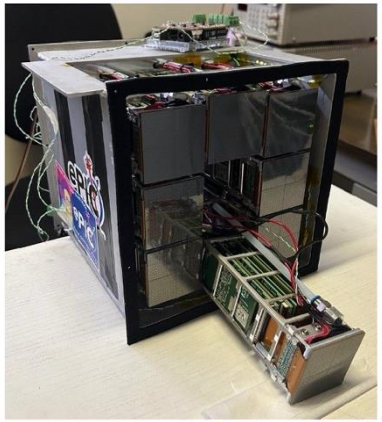


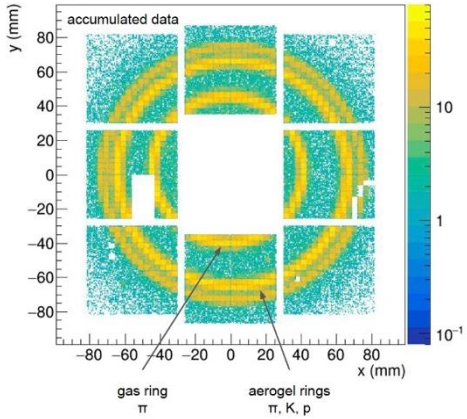


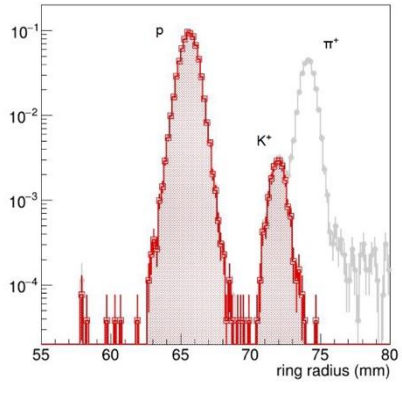


Real-Scale Prototype:

- Mechanical stability
- Gas & light thightness
- Temperature gradients
- Assembling scheme
- Inner components supports
- Optical septa
- ……..

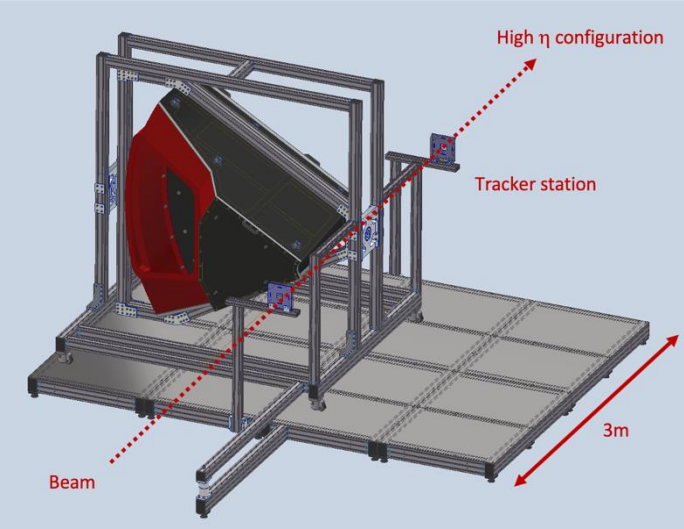


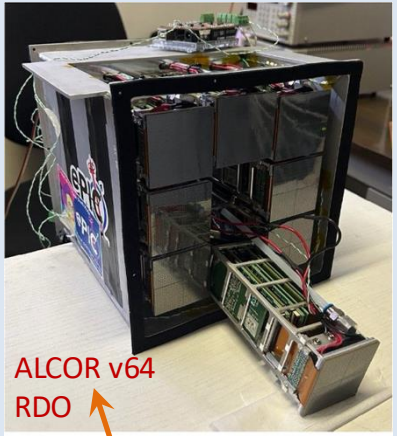


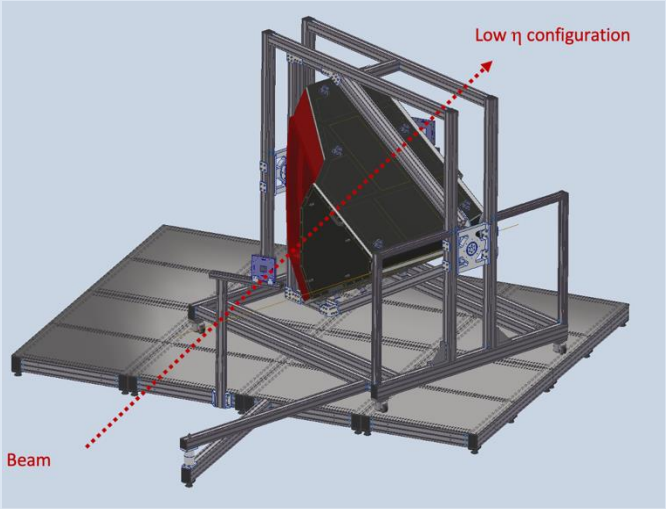


dRICH Schematic of Installation

Real-Scale Prototype (1 sector) with support saddle + platform for safe operations (ePIC pseudorapidity scan)

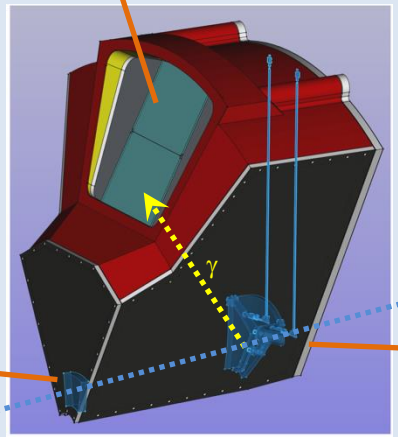




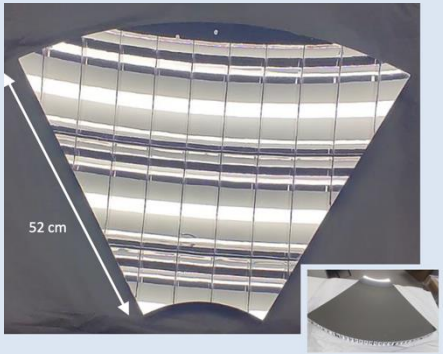


“Final” Photon Detector Units

Aerogel
Test Article

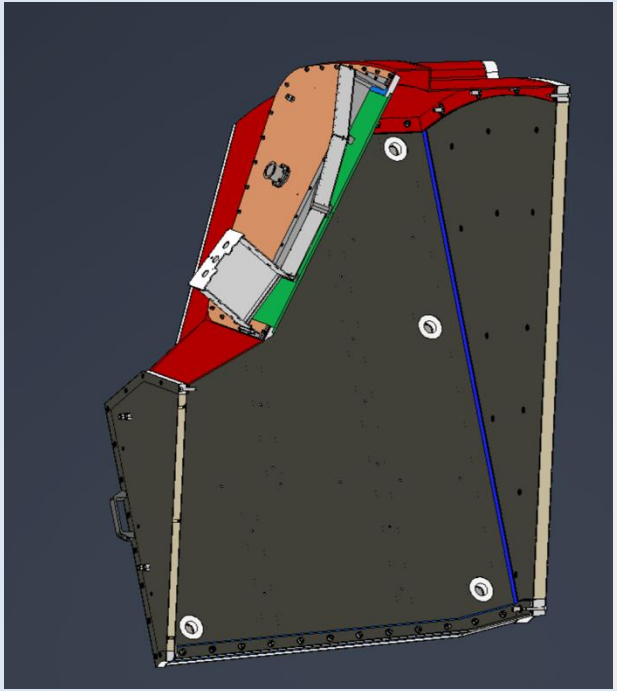


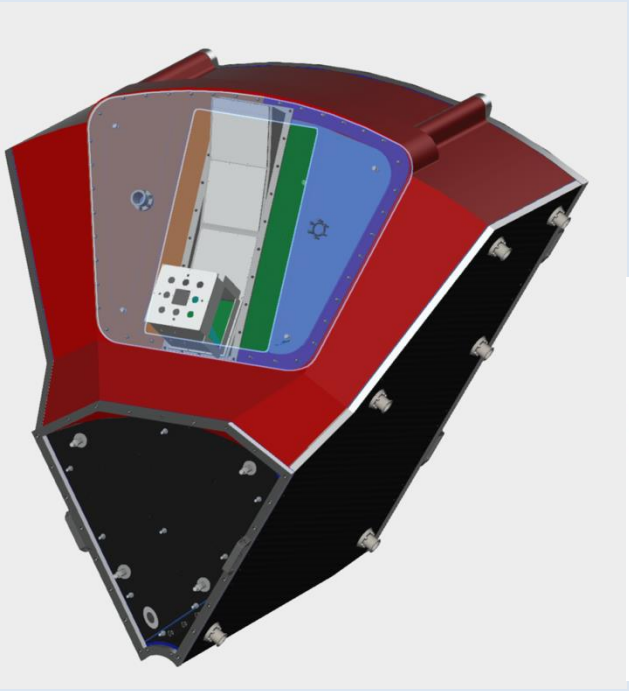
Mirror
Test Article

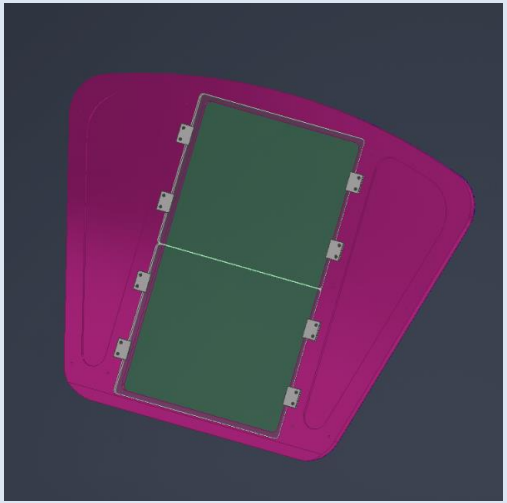


Detector Box

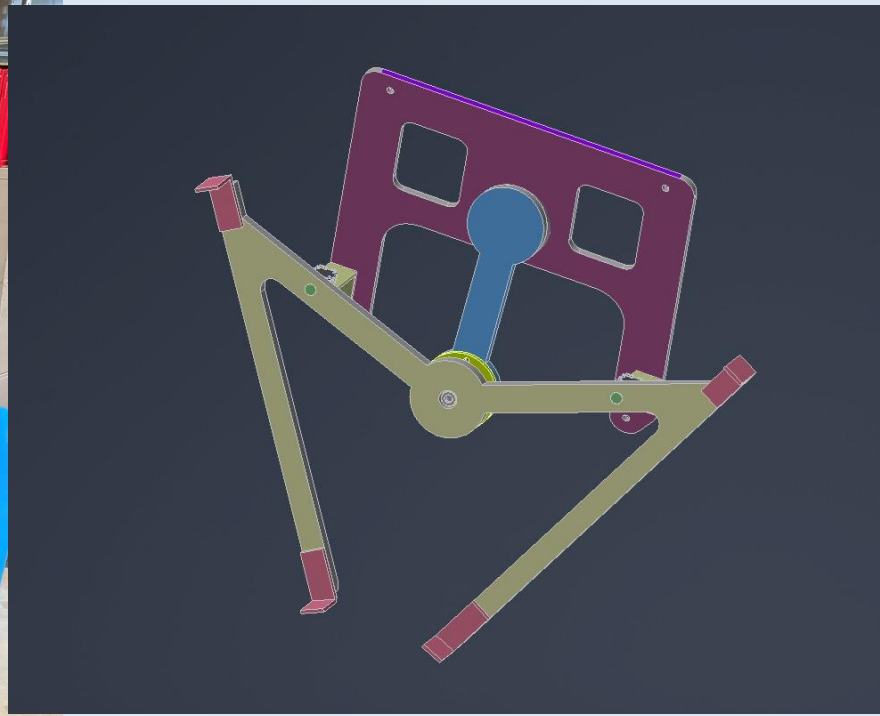
Gas volume sealed by a large-area quartz window
Several inlets/outlets for gas dynamics study
Compatible with the existing detector boxes
Different mounting point mimicking the curved surface at ePIC
Baseline for future detector box upgrades





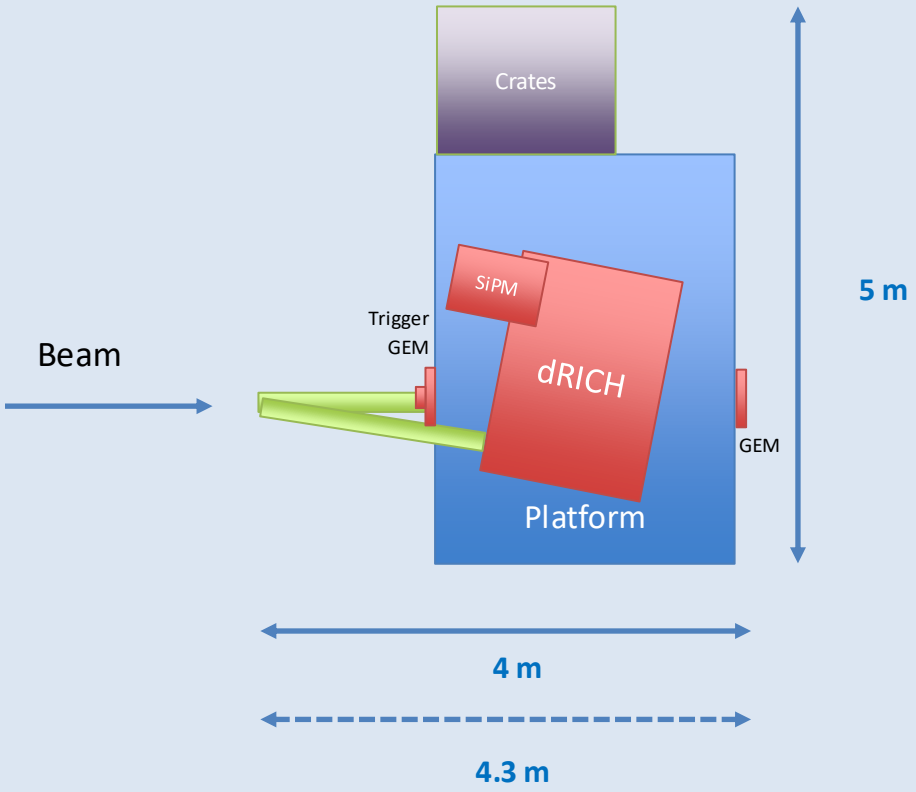


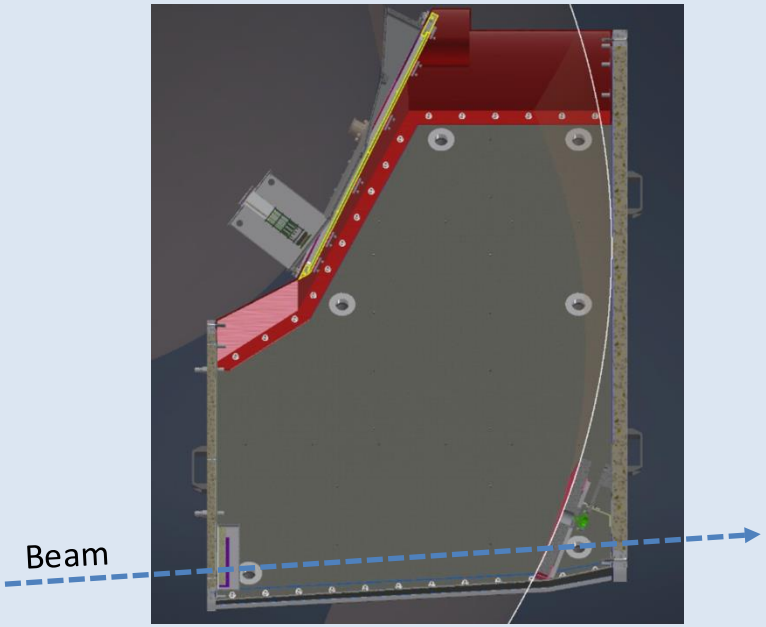
Quartz Window



Real Scale Prototype

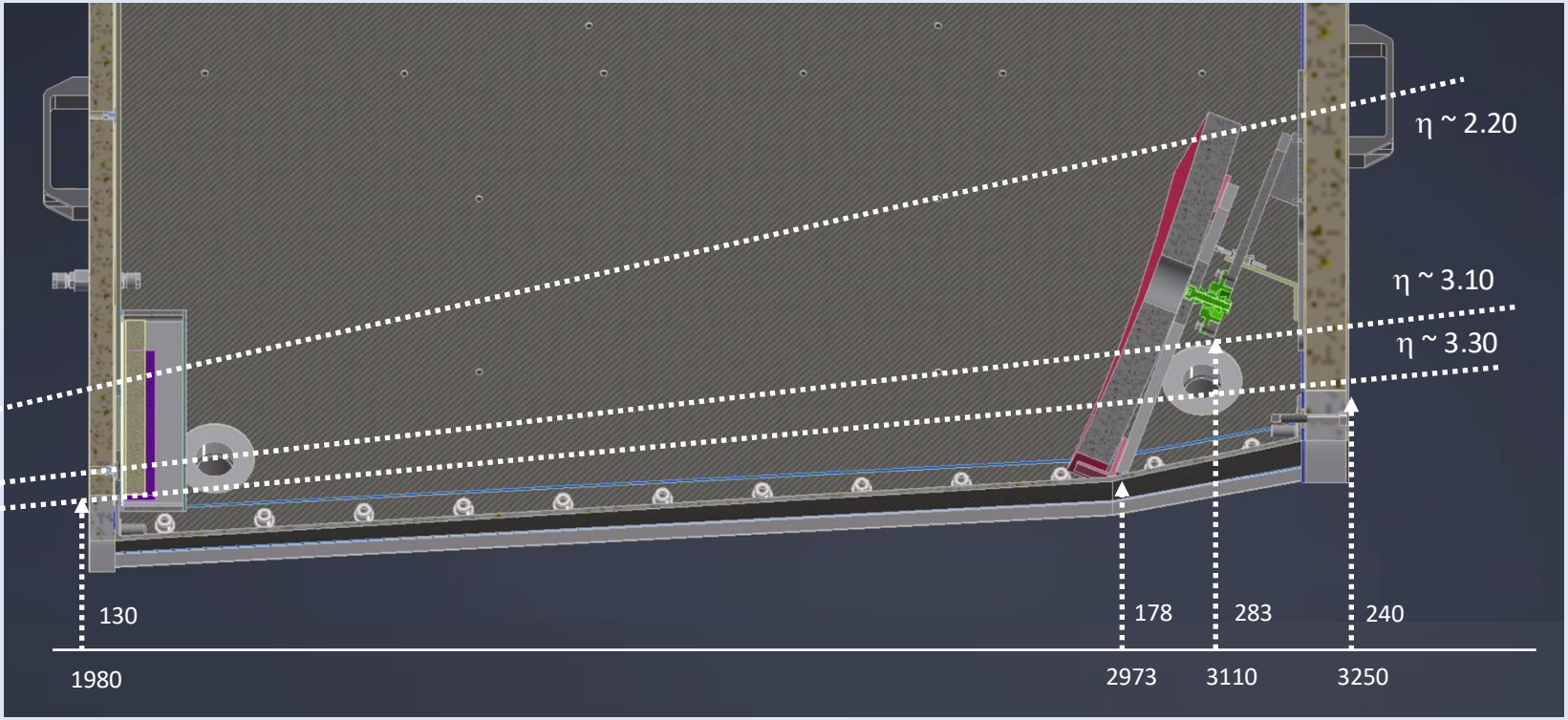
Setup Schematic



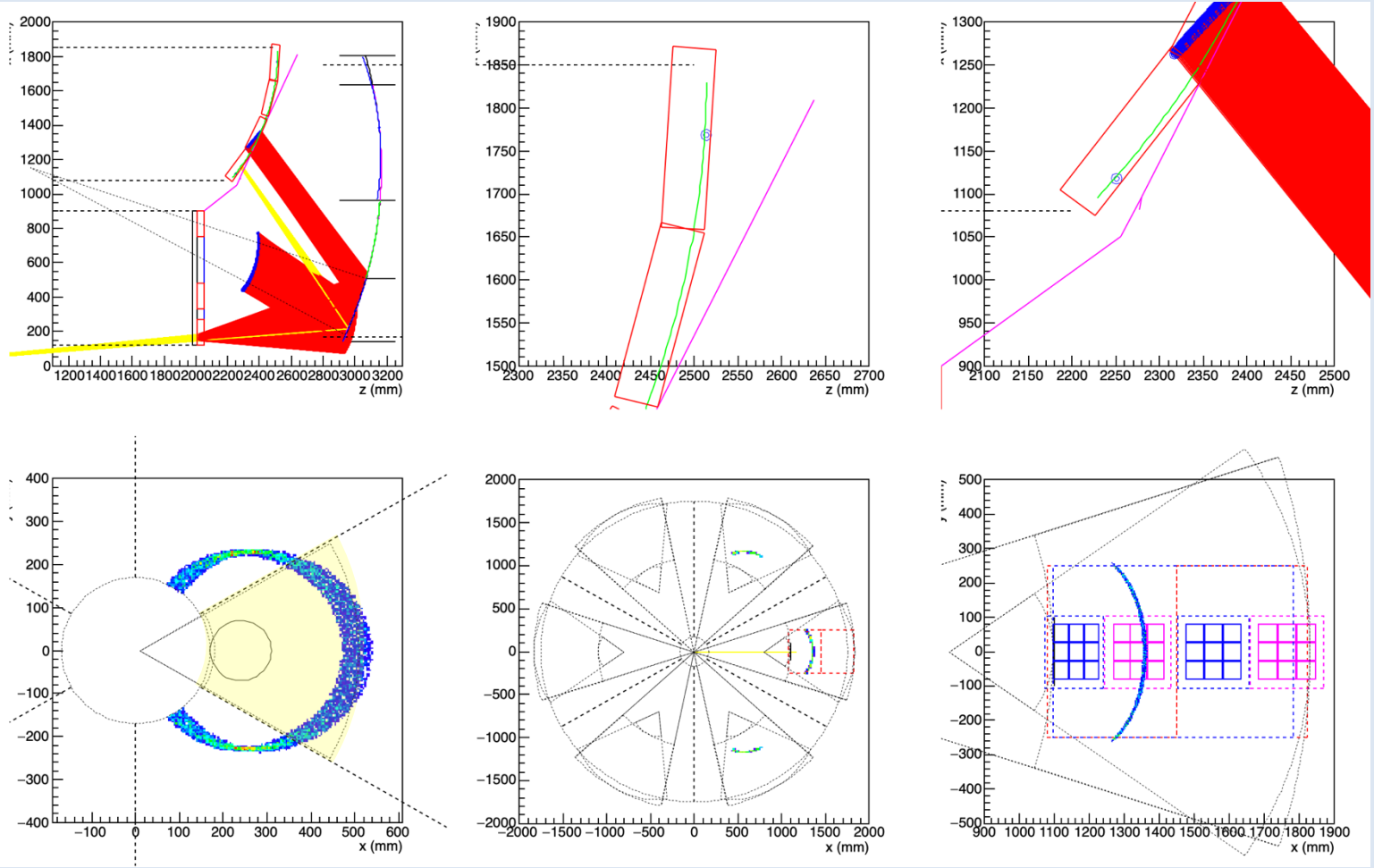


Carbon fiber skins + honeycomb (4-5% X_0)
Aerogel (3-4% X_0)
Plastic scintillators (trigger) (2% X_0)

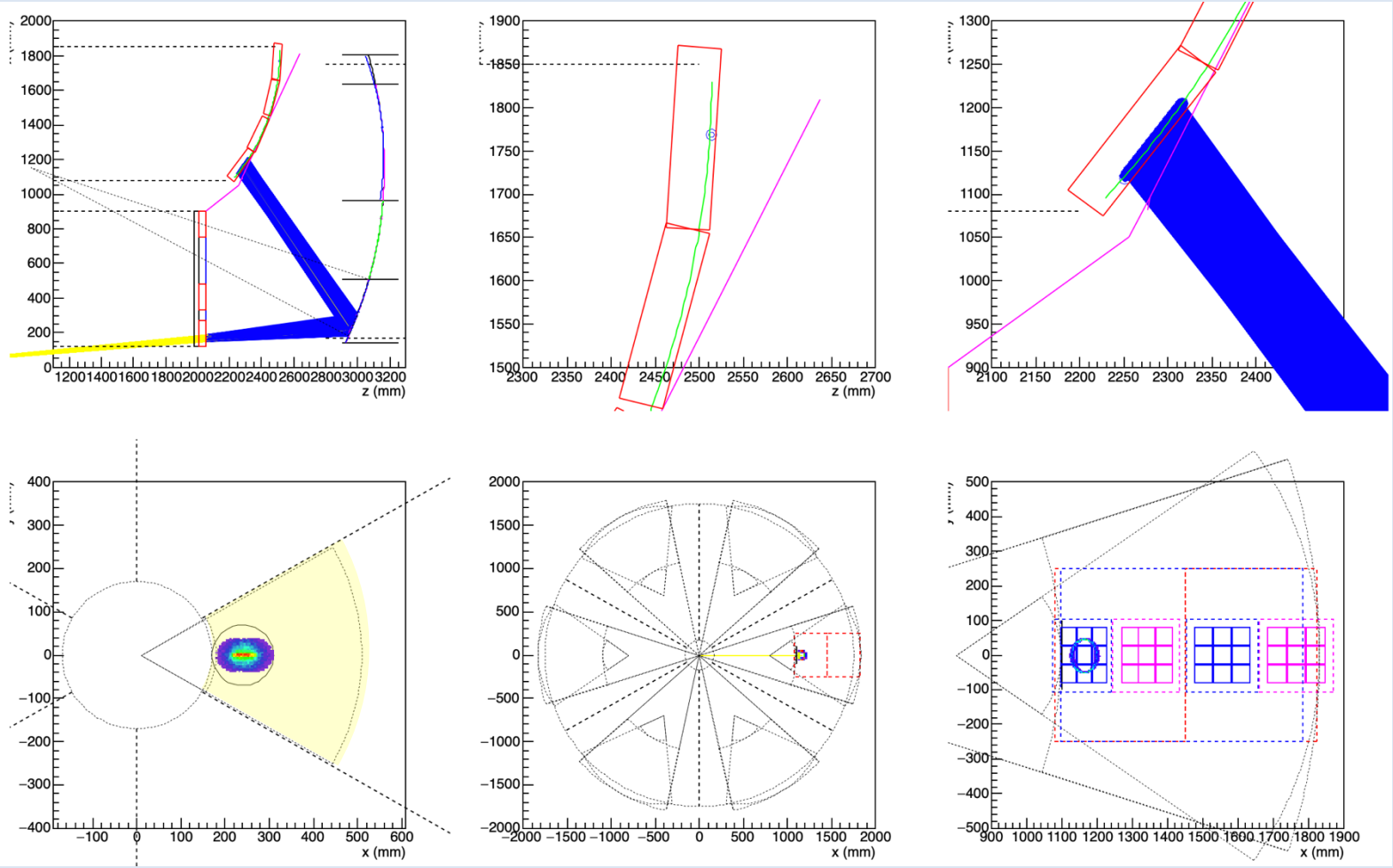
Real Scale DImensions



Aerogel Imaging

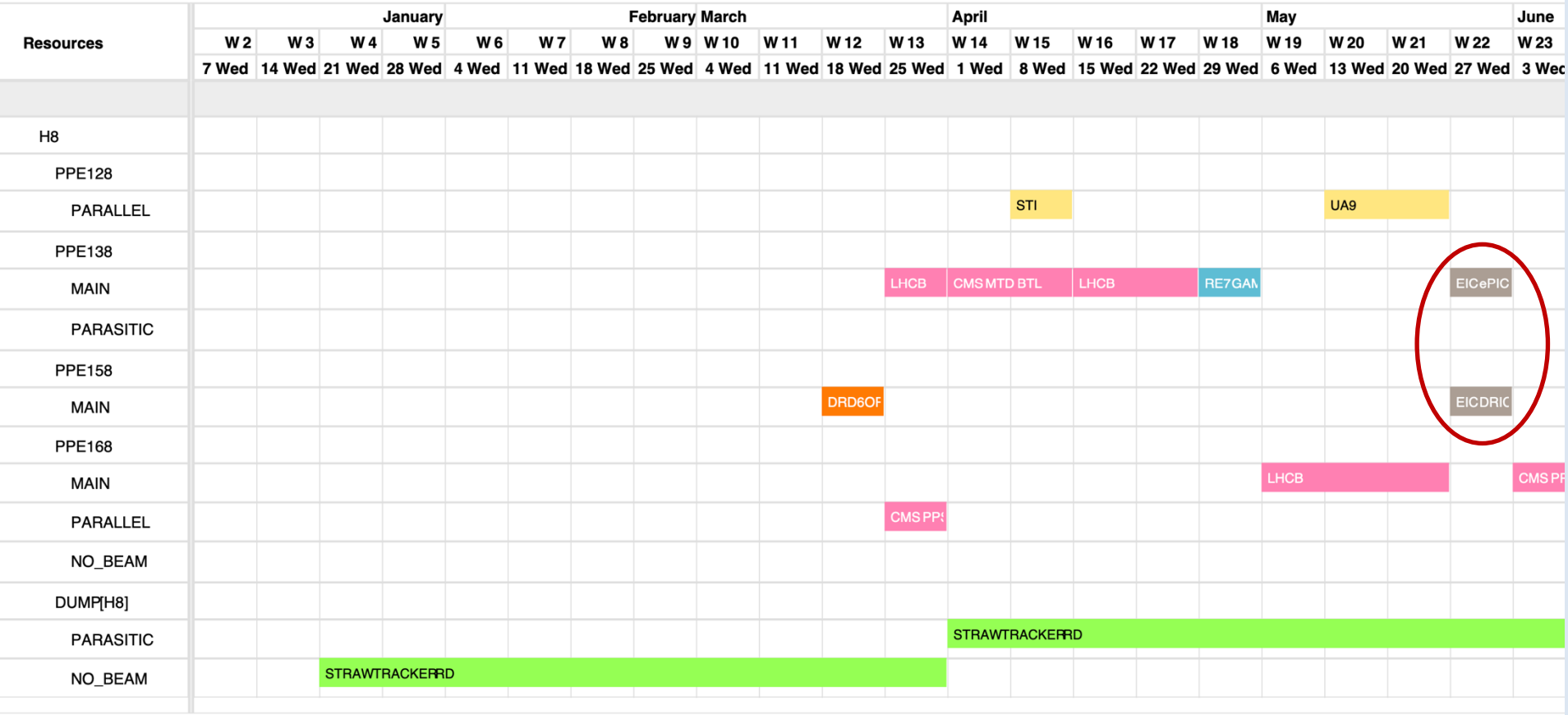


Gas Imaging



SPS H8 Schedule

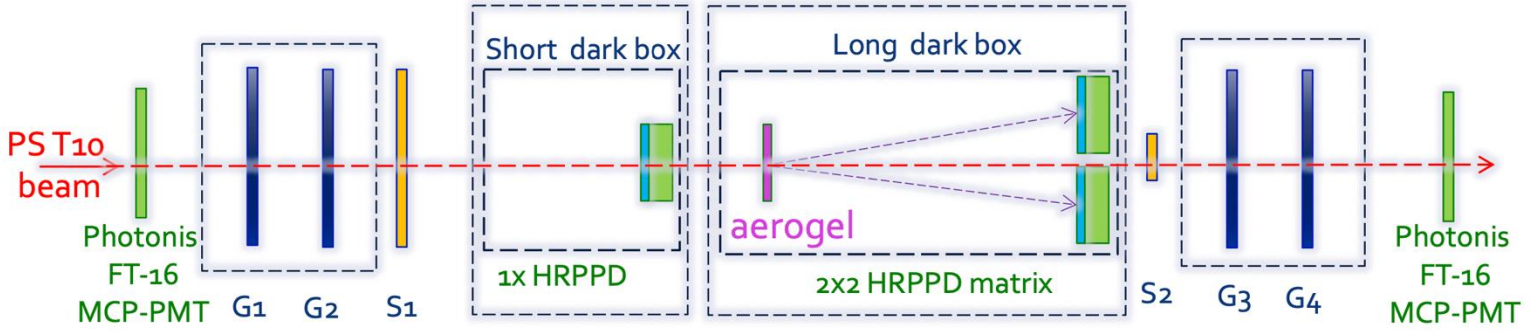
One weeks from 27th of May till 3rd of June in parallel with pfRICH



pfRICH has a not-negligible material budget and one may consider to move it downstream.

A setup to evaluate ePIC pfRICH prototype π/K and e/π separation capability at momenta below 10 GeV/c and timing resolution for both imaging (aerogel) Cherenkov photons and multi-photon flashes in HRPPD window

Schematic of the experiment



G1 .. G4 are GEM trackers; S1 & S2 are trigger scintillators; all equipment mounted on a single 8020 frame

Total length : <2 m
Total width : 0.6 m
Total height: 0.6 m
Height of beam : TBD

Systematic study on performance with saturated Cherenkov signal
(background vs beam intensity and profile, sensor temperature, radiator gas conditions)

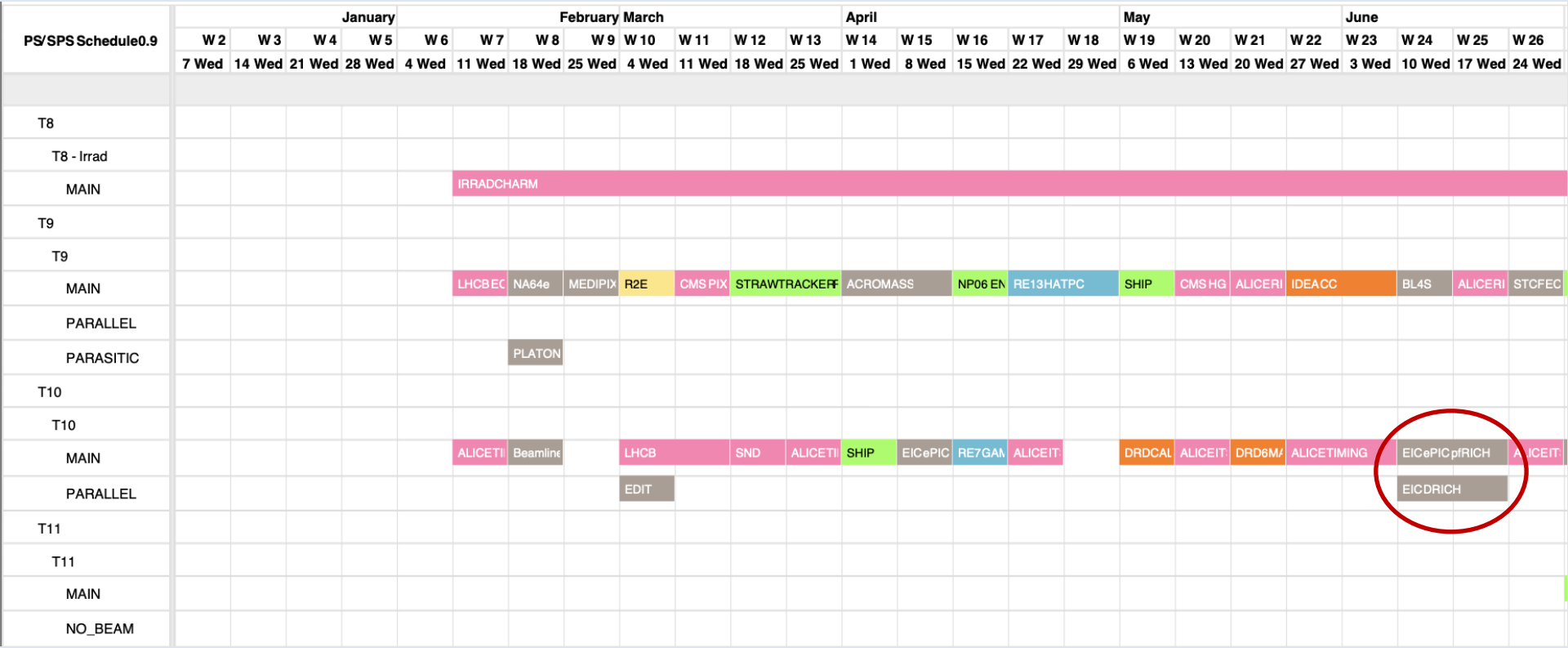
Scan the ePIC high-momentum region (gas working range)
Study ID performance vs beam Cherenkov tagging

(Change pseudo-rapidity layout by inner-components reconfiguration)

Particle	Polarity	Energy (0.1 to 15 GeV/c (T09)	High purity	Intensity	Beam size (Ømm)	Run number (if applicable
Mix Hadron	Positive	180	NO	$\leq$ 5e3	10 & 40	Several for commissioning & systematics
Mix Hadron	Positive	20	NO	$\leq$ 5e3	40	few
Mix Hadron	Positive	40	NO	$\leq$ 5e3	40	few
Mix Hadron	Positive	60	NO	$\leq$ 5e3	40	few

PS T10 Schedule

Two weeks from 10th till 24th of June in parallel with pfRICH



Scan in the momentum transient region in between radiators (aerogel and gas) working range
Study ID performance vs beam Cherenkov tagging
Systematics studies on beam focalization (emittance) and intensity
Change pseudo-rapidity layout (inner-components reconfiguration)

Particle	Polarity	Energy (0.1 to 15 GeV/c (T09)	High purity	Intensity	Beam size (Ømm)	Run number (if applicable
Mix Hadron	Positive + Negative	2	NO	≤ 5e3	10 & 40	few
Mix Hadron	Positive + Negative	4	NO	≤ 5e3	10 & 40	few
Mix Hadron	Positive + Negative	6	NO	≤ 5e3	10 & 40	few
Mix Hadron	Positive + Negative	8	NO	≤ 5e3	10 & 40	few
Mix Hadron	Positive + Negative	10	NO	≤ 5e3	10 & 40	few
Mix Hadron	Positive + Negative	11.5	NO	≤ 5e3	10 & 40	few
Electron enhanced	Negative	Any	NO	≤ 5e3	10 & 40	few

Conclusions

The test beams have been a driving force in the dRICH development

Test-beam campaign in 2025:

Implementation of RDO in the dRICH readout chain
successful commissioning in different experimental conditions

Deploiment of a eco-friendly station for gas performance validation
successful test of alternate gases at various pressure

Test-beam campaign in 2026:

Realization of PDU in the final layout
ALCOR 64
UVE SiPM
FEB+RDO stack

Real-scale prototype
off-axis optics
layout conformed to ePIC

Crucial effort prior of CERN 2 years shut down