ALICE 3 RICH: cooling and mechanics

ALICE Upgrade Week
7th-11th October, 2024

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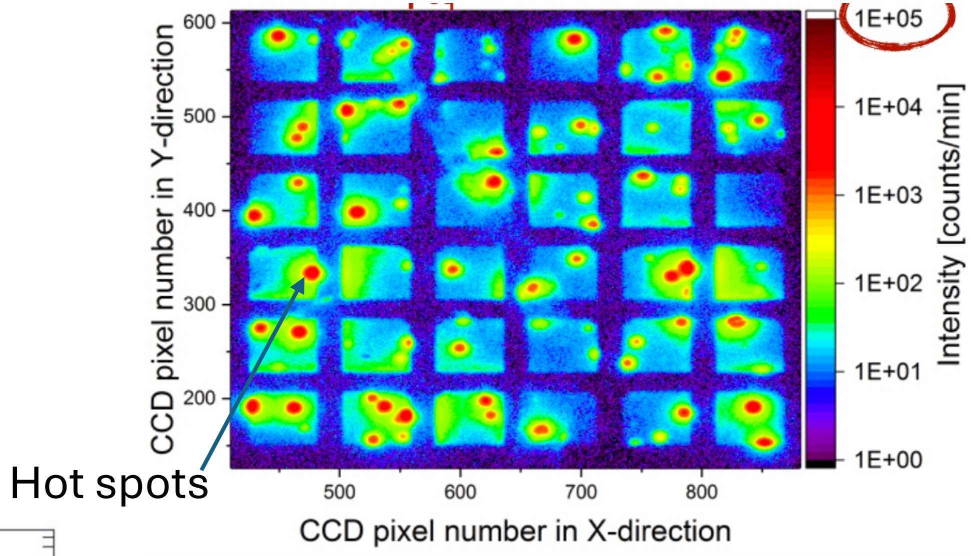
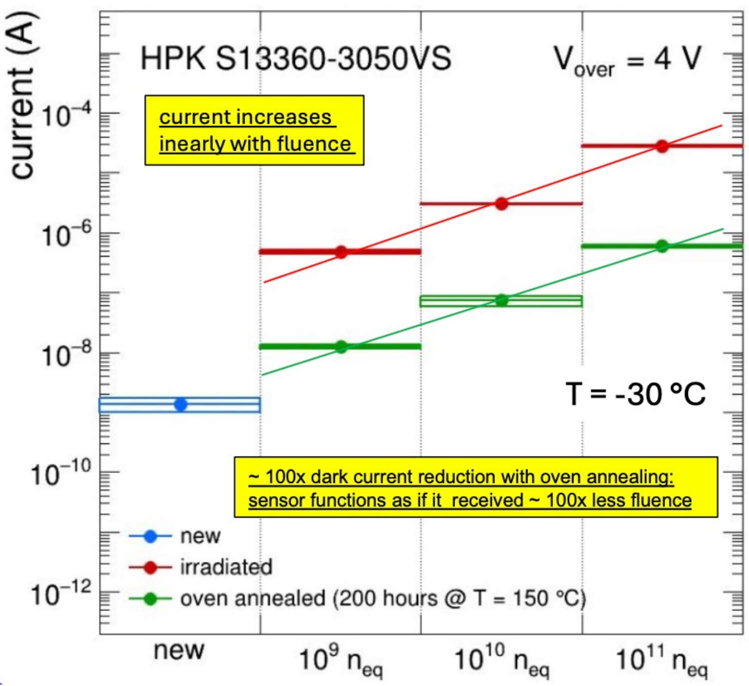
The barrel RICH challenges – Radiation Load

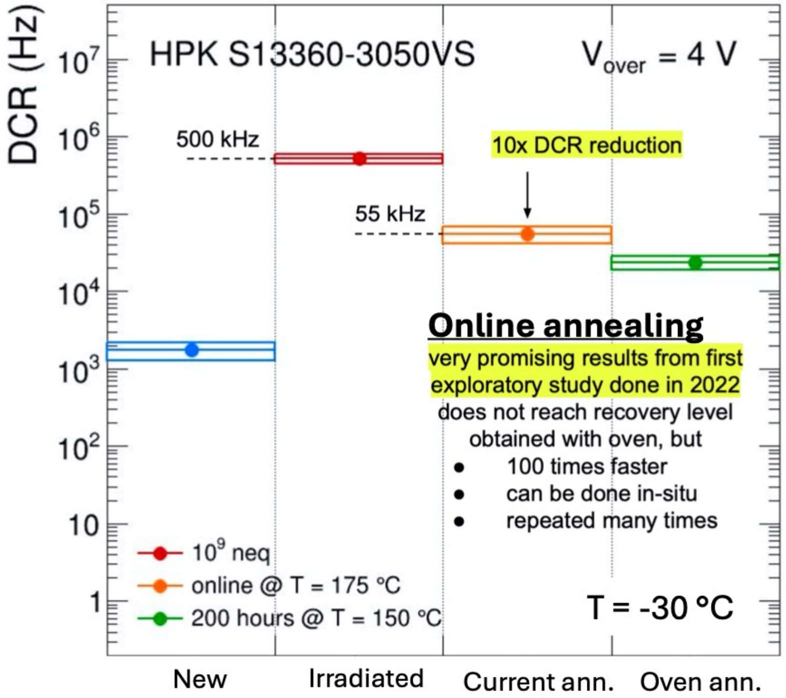
- High radiation load expected in the barrel (**NIEL ~ 8.4 x 10^{11} 1 MeV neq/cm^2**) → SiPM DCR increases to not tollerable values (> 1 MHz/mm^2)
    - Improve SiPM radiation hardness
    - ***Development of cooling/annealing strategy!***

Irradiated SiPM

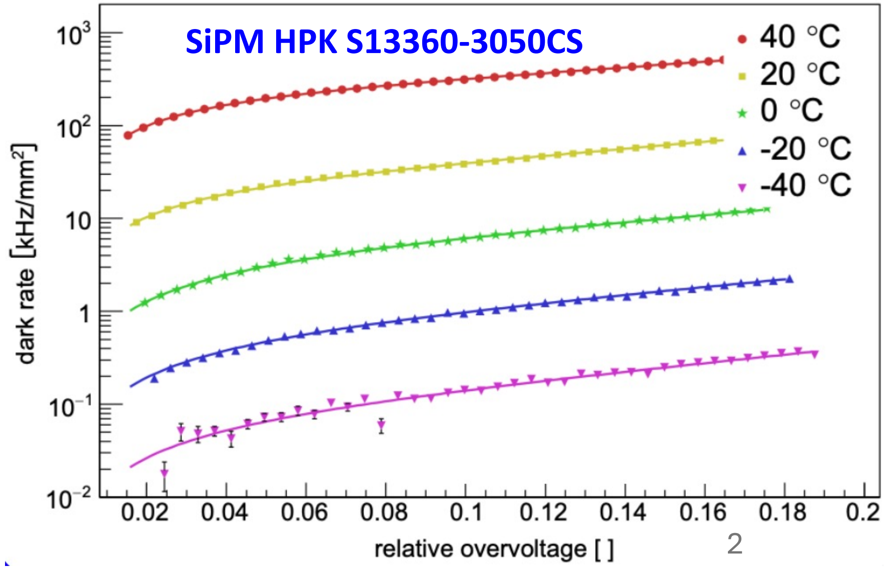


From R. Preghenella





NIMA 846 (2017) 106–125



SiPMs cooling concept

Dual-phase CO_2 cooling - A good choice for HEP applications

- advantages of dual-phase CO2 cooling for HEP applications:
  - **large latent heat transfer** due to the phase change energy for the transition of liquid to gas
  - operation with **low mass flow** of the coolant is possible
  - **low mass flow as well as a low liquid viscosity results in a low pressure drop along cooling pipe**
    - **a low pressure drop allows the use of small pipe diameters or technical solutions like micro-**
  - **channel cooling, which allows new detector design concepts**
  - high **heat transfer capability** (typical ~8000 W/Km) is possible despite small pipe diameters
  - practical **temperature range** of −40°C to 25°C for detector application
  - CO_2 is a **natural**, non-toxic, non-flammable, radiation resistant and non-magnetic gas

Micro-channel cooling on Si - A silicon-embedded Technologies

- micro-channel cooling in Si is a favourable technology
  - **optimized thermal contact with heat sources**
  - heavily simplified assemblies
  - reduction of material
  - **efficient for cooling “chip-like” heat densities**
- basic technological process: deep RIE + (anodic, eutectic, fusion) wafer bonding
- further integrations also possible!
  - example: metal Re-Distribution Layers (RDL) (*M. Ullán et al. (HSTD13, 2023)*)

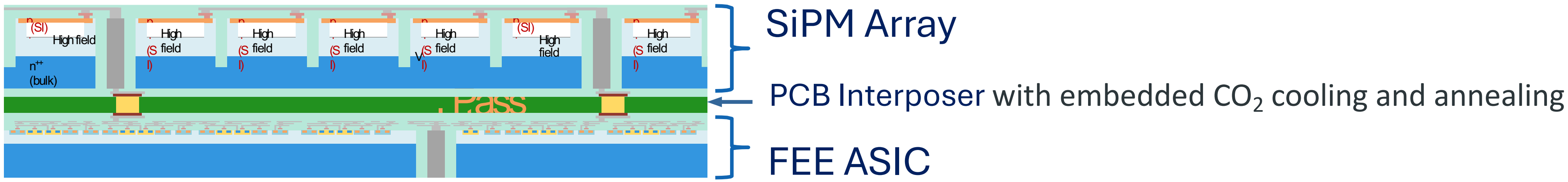
Hybrid pixel detector & micro-channel cooling plate

Monolithic CMOS detector

Monolithic CMOS detector with integrated micro-channels

SiPMs cooling concept

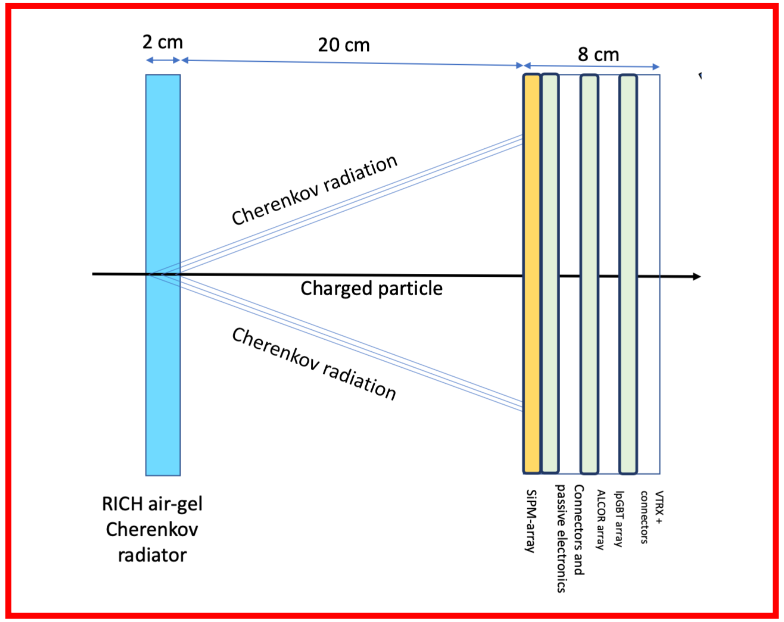
- Cool down the sensor to -40 °C
  - Dual-phase CO_2 micro-channels thorugh a special iterposer (between the sensor and the FEE ASIC)



- Isolate the detector from the external evironment
  - Thermal insulator vessel: -40 °C inside, 20 °C outside

Involvement of Politecnico of Bari!

Thermal shield



Mechanics

Cylindrical projective geometry

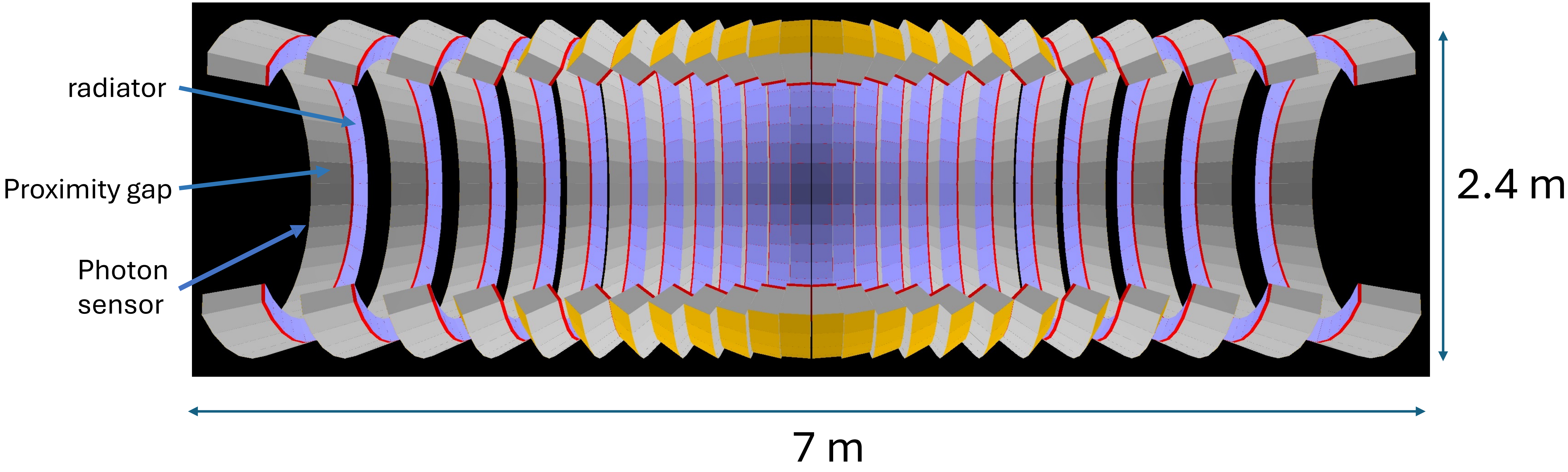
- All aerogel tiles oriented toward nominal interacion point
- Full coverage to charged particles without ovelaps
- Trapeizoidal tile profile to maximize the acceptance

24 sectors in z

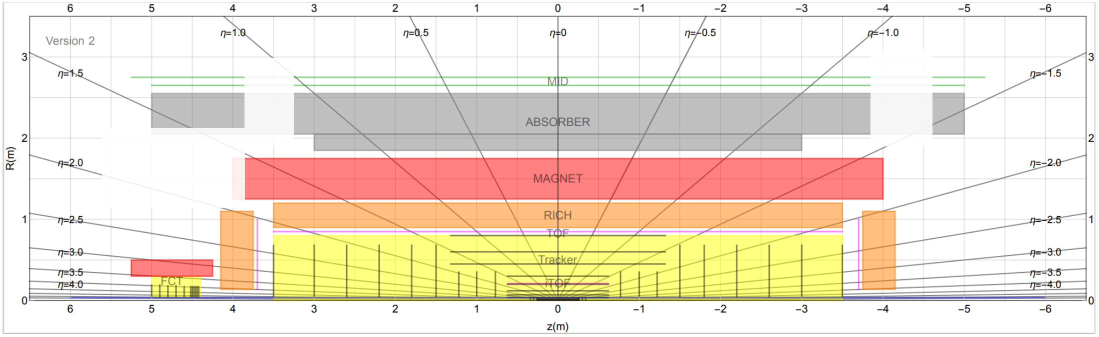
36 modules in $r\phi$ for each sector

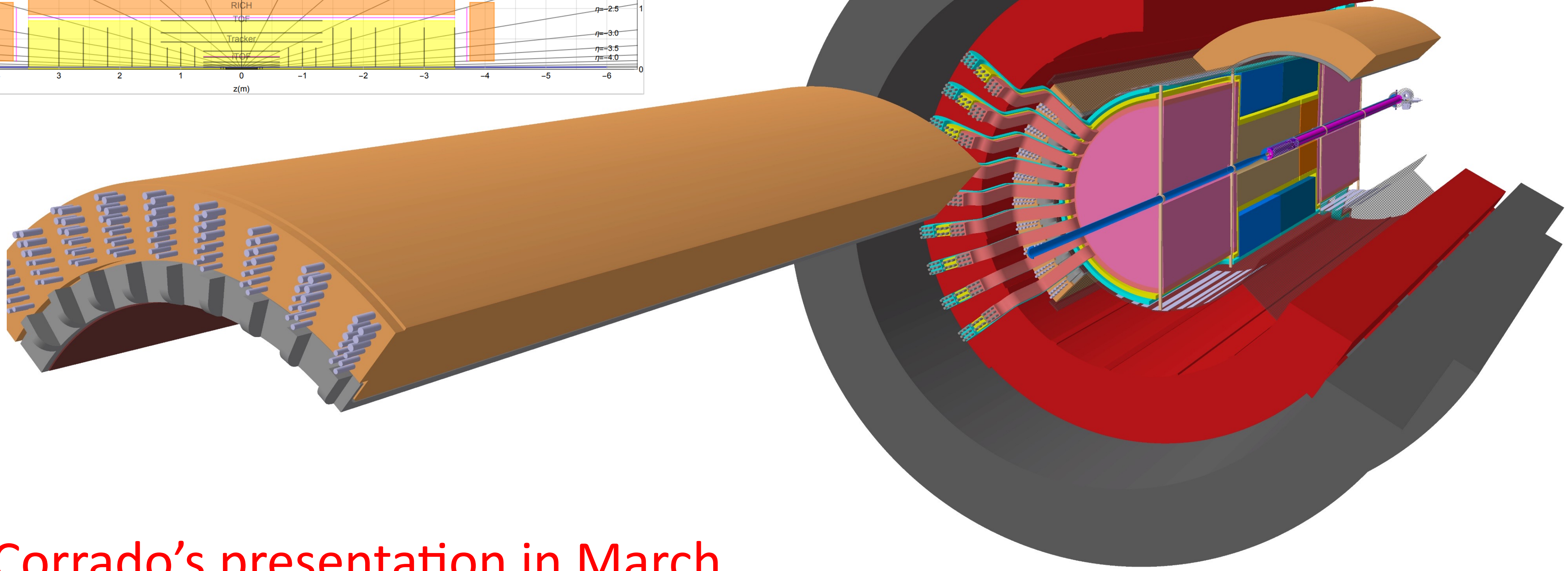
Sensor area $\cong$ 30.7 m^2

channels $\cong 7*10^6$

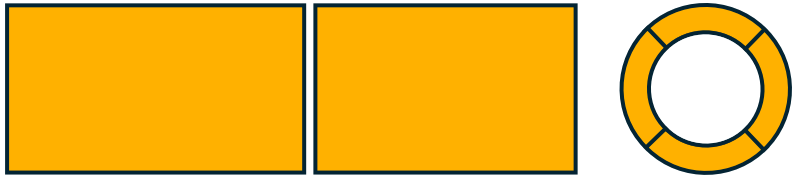


Mechanics



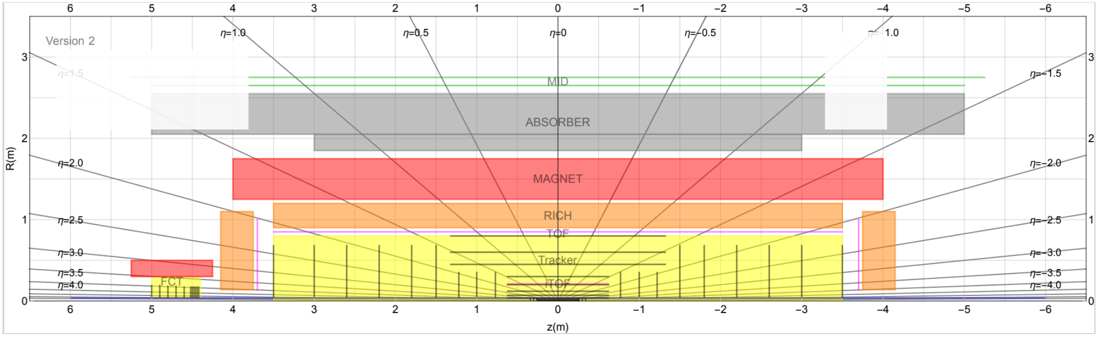


From Corrado's presentation in March

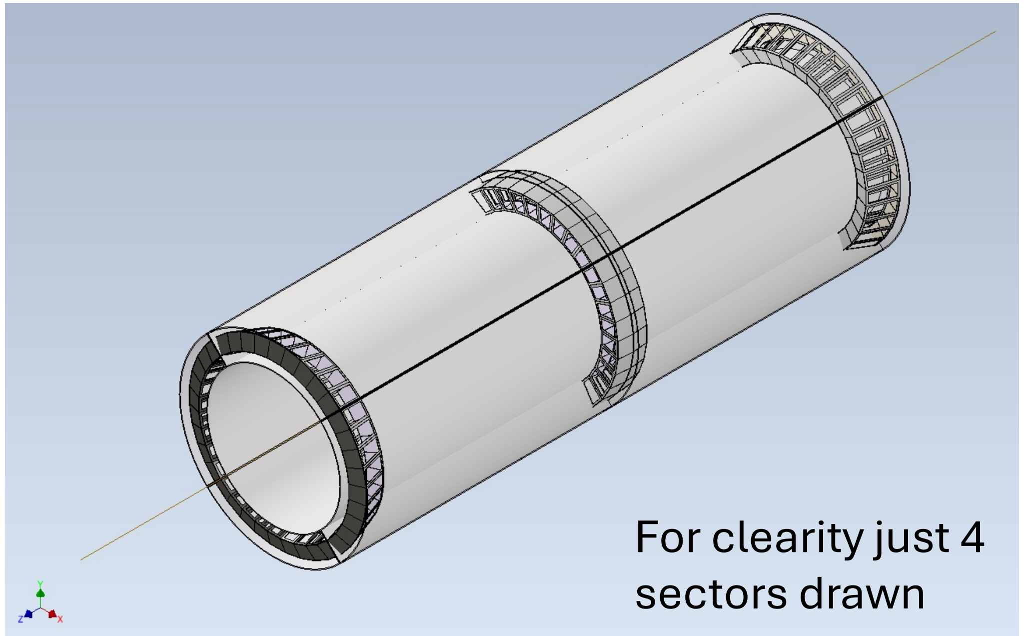


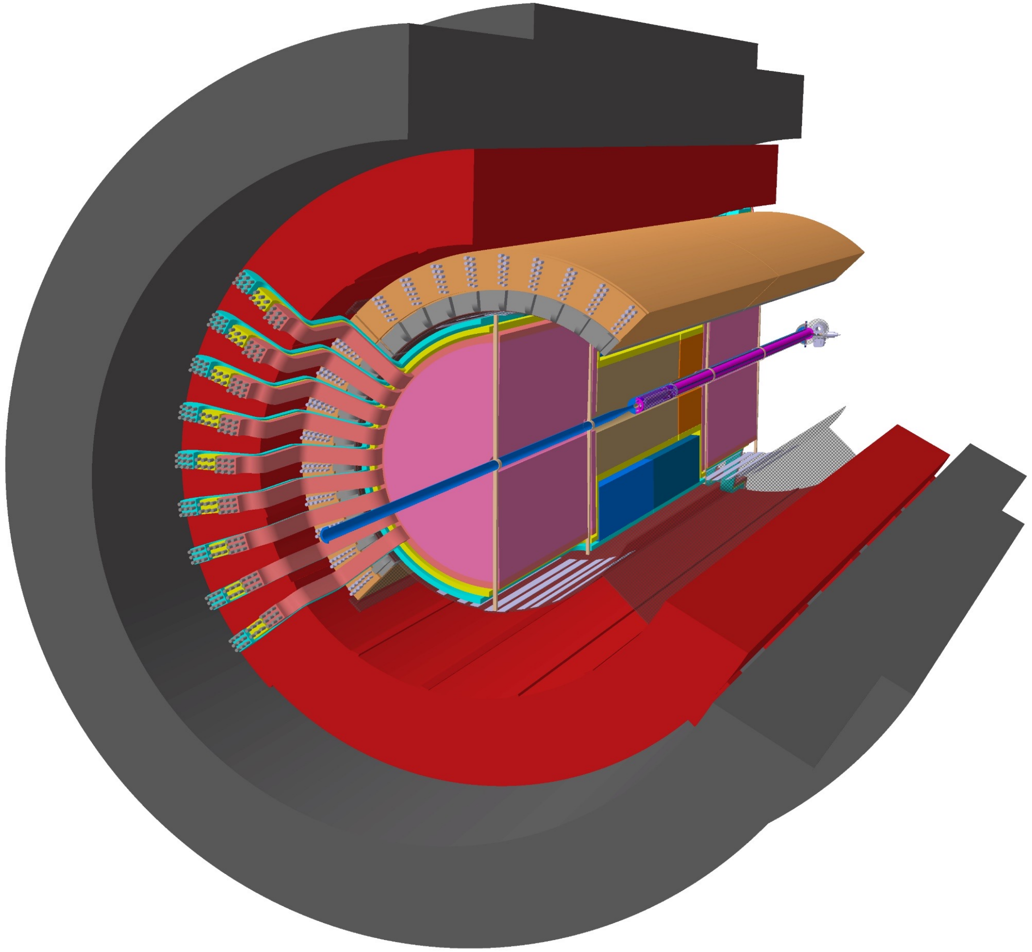
TOF+RICH (1/4) insertion from A-side

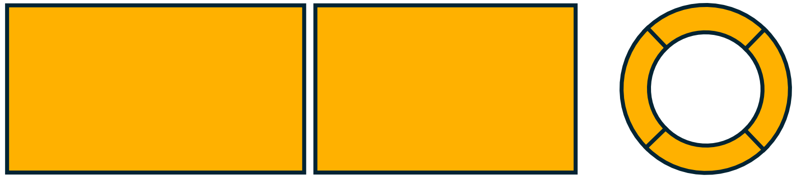
Mechanics



Full cylinder divided in 8 modules

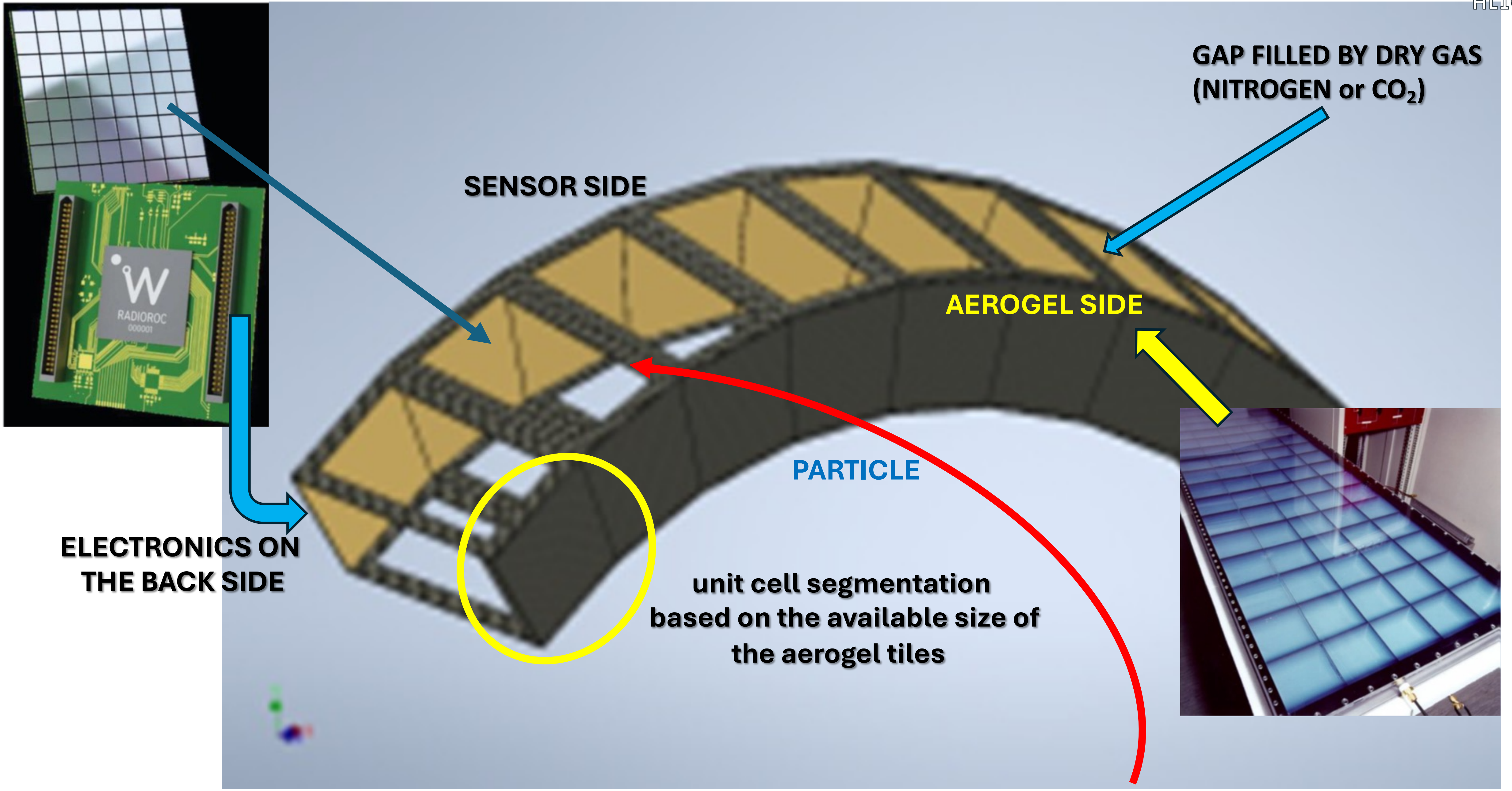




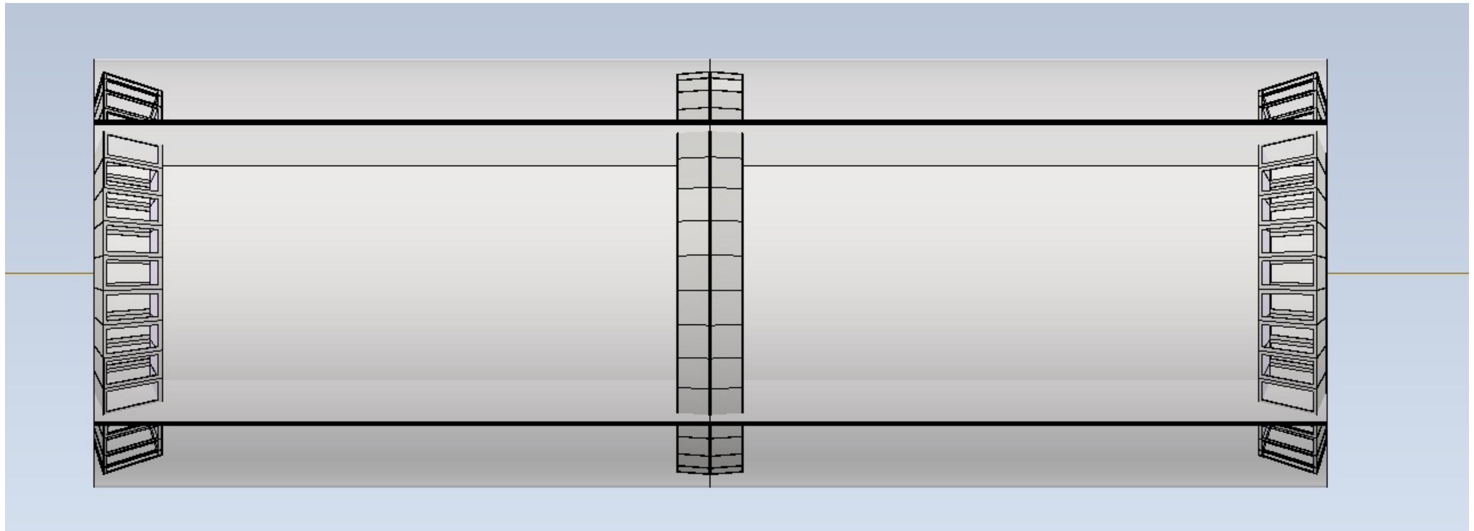


TOF+RICH (1/4) insertion from A-side

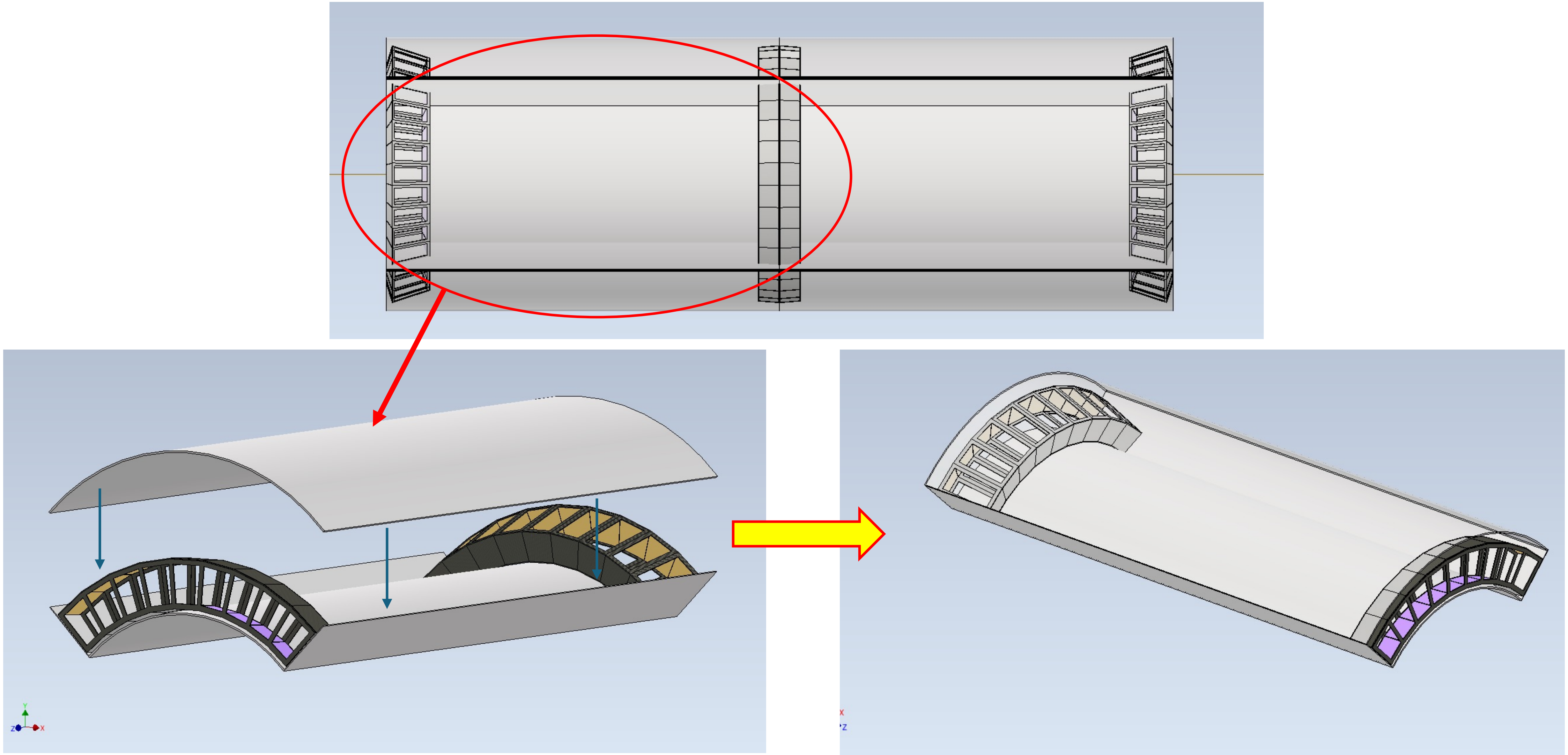
Mechanics


RADIOROC
000001
SENSOR SIDE
GAP FILLED BY DRY GAS
(NITROGEN or CO_2)
AEROGEL SIDE
PARTICLE
ELECTRONICS ON
THE BACK SIDE
unit cell segmentation
based on the available size of
the aerogel tiles

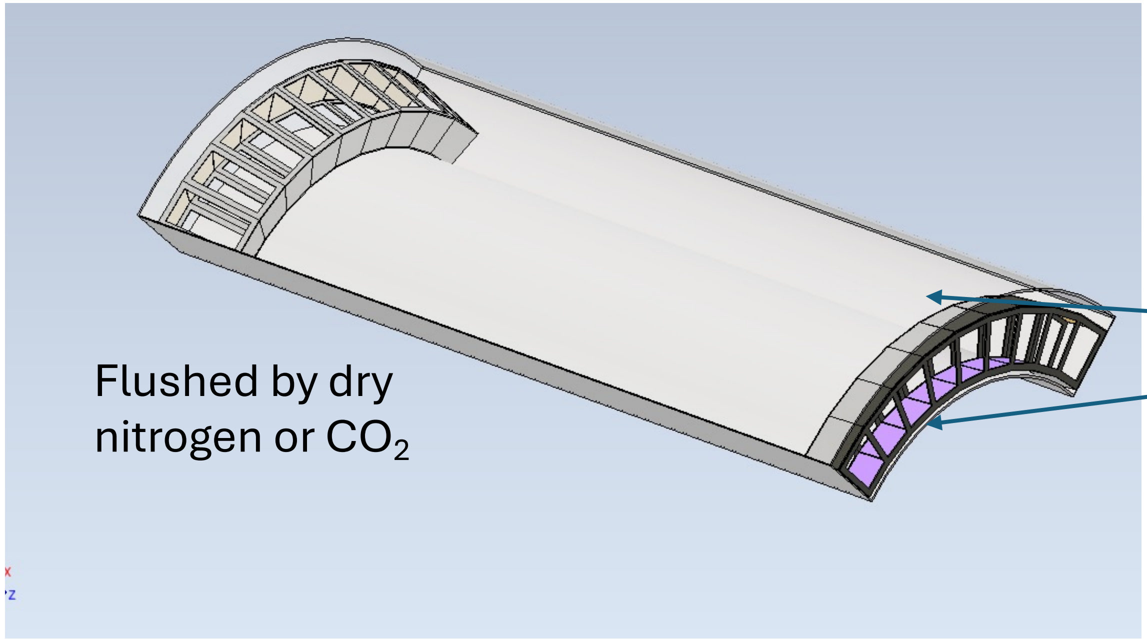
Mechanics



Mechanics

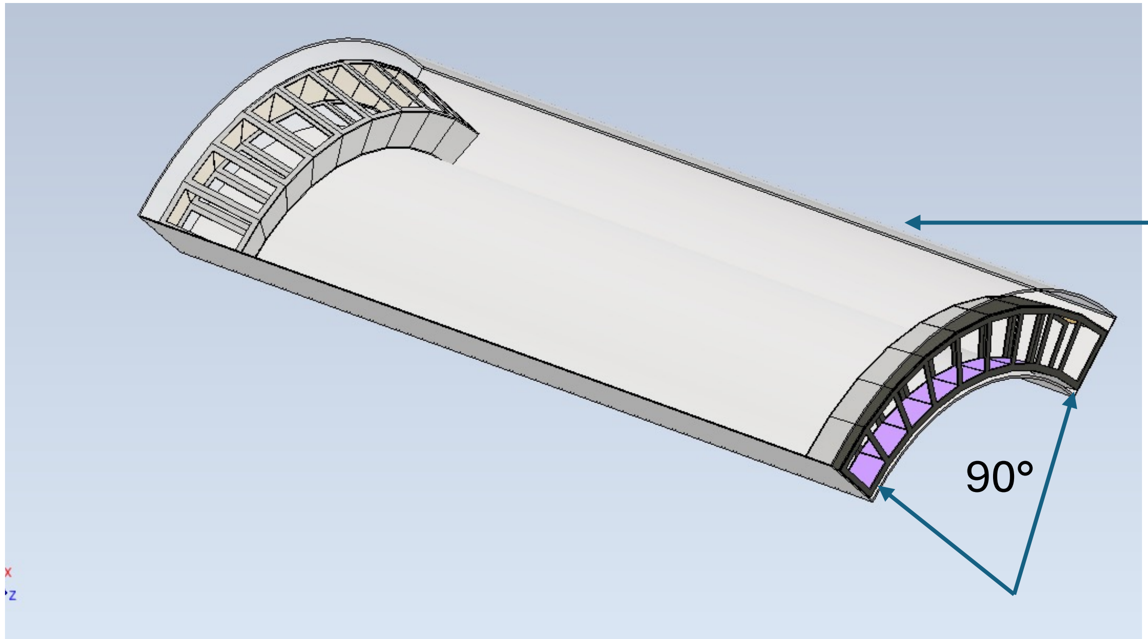


Mechanics



THERMAL SHIELD (due to space constraints no more than few centimeters of thickness)

Inner temperature = - 40 ° C
Outer temperature = 20 °C



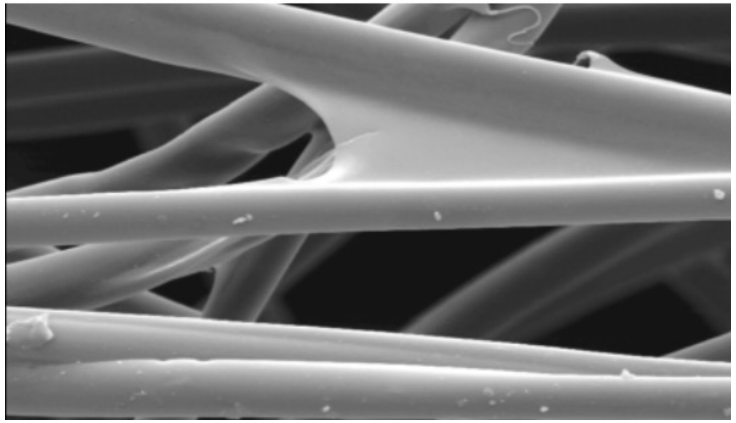
Full cylinder divided in 2 cylinders, each of them divided in 4 slices (90° each)

Thermal shield

Aerogel as thermal insulator!!

Thermal Wrap Aerogel Blankets (CABOT)

Made of aerogel granules embedded in non-woven fibers, which produces a flexible, compressible, and highly efficient insulation material.



Flexible aerogel blanket (Cryogel® Z)

Composed of a flexible aerogel blanket laminated to a vapor retarder.

Conclusion & outlook

- Cooling the SiPM sensors is crucial for reducing the dark count rate (DCR) to acceptable levels for single-photon detection.
- We have begun exploring the possibility of using dual-phase CO_2 micro-channels within the interposer.
- Dedicated studies on the interposer will commence soon.
- A thermal shield will be required to isolate the detector from external environmental factors.
  - Specific heat exchange simulations will be carried out to determine the materials and thickness needed.
- Initial CAD drawings of the detector structure have been completed.

Backup

Thermal shield

Aerogel as thermal insulator!!

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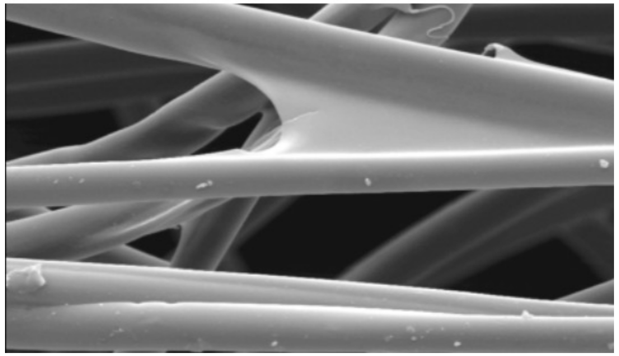

Thermal Wrap™ blanket - Thermal conductivity with temperature

Mean Temp °C	Thermal Conductivity (mW/mK)	Mean Temp °F	Thermal Conductivity (BTU/hr*ft*°F)
-129	13	-200	0.0075
-73.3	17	-100	0.0098
-17.8	20	0	0.0116
23.9	23	75	0.0133
37.8	25	100	0.0144
93.3	32	200	0.0185

Thermal shield

Aerogel as thermal insulator!!

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THERMAL CONDUCTIVITY †

Tested in accordance with ASTM C177

Mean Temp. °F / °C	***k*** BTU-in/hr-ft²-°F / mW/m-K
-200 / -129	0.096 / 14
-100 / -73.3	0.10 / 15
0 / -17.8	0.11 / 16
75 / 23.9	0.12 / 17
100 / 37.8	0.12 / 17
200 / 93.3	0.13 / 19

†Thermal conductivity measured at a compressive load of 2 psi.