The ARC compact RICH detector concept: design, simulations and prototype development

Serena Pezzulo

University and INFN Genova

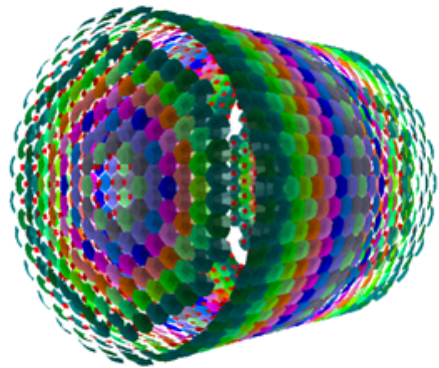
serena.pezzulo@ge.infn.it

March 18, 2025

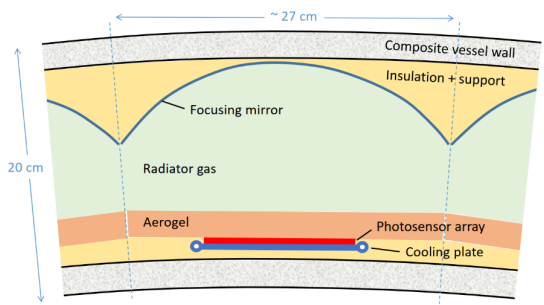
The ARC concept

ARC (**A**rray of **R**ich **C**ells) is a proposed RICH detector for the FCC (or another Higgs factory)

- First presented by R. Forty at FCC week 2021
- Lightweight and compact solution for PID
- Specifically adapted for the CLD experiment, occupying 10% of the tracker volume:
  - Dimensions: 20 cm radial depth, 2.1 m radius, 4.4 m length
  - Material budget targeted below $0.1X_0$
- Cellular in design, with each cell functioning as an independent RICH detector cell



ARC single cell geometry



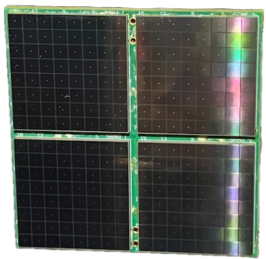
- Two radiators: $\mathbf{C_4F_{10}}$ (or a more eco-friendly alternative) + **Aerogel** (for low **p** tracks)
- Spherical focusing mirror
- Photosensor array: most suitable candidates are Silicon Photomultipliers (SiPMs) arrays with cooling plates
- Aerogel also as thermal insulator between SiPM array and gas radiator

Goal: Construct prototype of single cell in 3 years (fostered by DRD4 Collaboration)

Silicon Photomultipliers

SiPMs: compact, highly sensitive light detectors capable of detecting single photons

- SiPM array with 0.5 mm $\times$ 0.5 mm pixel
- PDE from FBK curve (at Overvoltage=10V) is considered



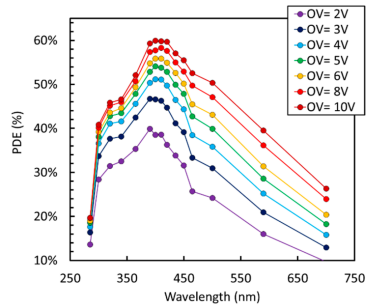
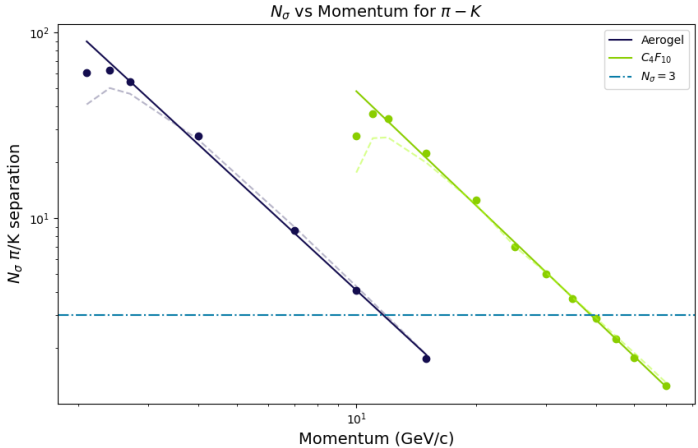


Figure: PDE vs Wavelength for FBK SiPMs
doi.org/10.3390/s19020308

π/K particle separation – C_4F_{10} + aerogel



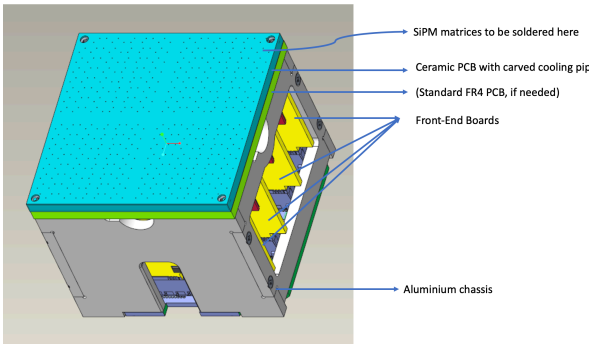
Separation above the threshold ($N_\sigma = 3$) up to 13 GeV/c for aerogel and 40 GeV for C_4F_{10}

Localized Cooling for SiPM Sensors

Active Cooling: A new housing board design integrates a ceramic PCB with fluid coolant circulation, in order to achieve sensor temperatures of -60°C to -80°C

Compact and High-Performance Design:

- SiPMs directly soldered onto metalized pads on the ceramic surface
- Hollow PCB structure enables coolant flow
- Optimized signal routing through PCB vias minimizes analog signal length, preserving integrity and timing performance



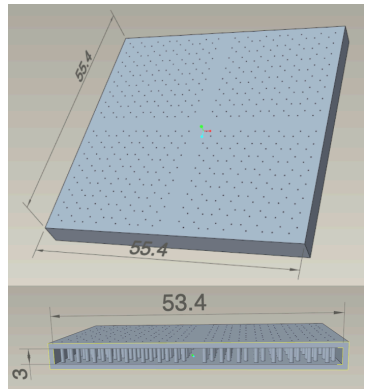
Synergies with **LHCb/RICH** upgrade II, **ALADDIN**, **DRD4** WP 3 and 4

Localized Cooling for SiPM Sensors

Active Cooling: A new housing board design integrates a ceramic PCB with fluid coolant circulation, in order to achieve sensor temperatures of -60°C to -80°C

Compact and High-Performance Design:

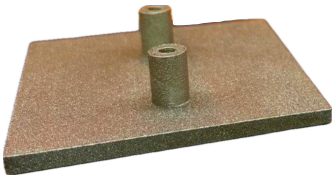
- SiPMs directly soldered onto metalized pads on the ceramic surface
- Hollow PCB structure enables coolant flow
- Optimized signal routing through PCB vias minimizes analog signal length, preserving integrity and timing performance



Synergies with **LHCb/RICH** upgrade II, **ALADDIN**, **DRD4** WP 3 and 4

Prototype development

We have multiple contacts for the ceramic cooling PCB, with prototypes expected in the coming months. Meanwhile, we are testing 3D-printed plastic and **metal prototypes**, using hot water to test the thermal properties of the cooling plate



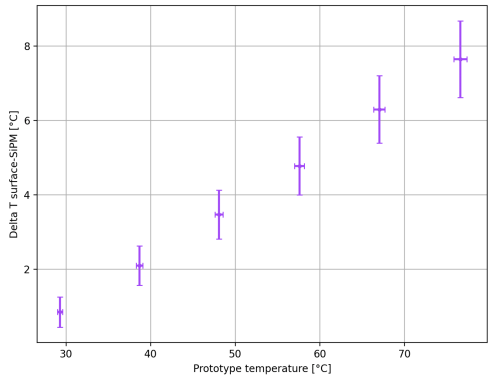


Figure: Temperature gap between the surface of the prototype and a glued SiPM.

Conclusions

- Particle separation power was studied for C_4F_{10} and aerogel, showing good performance in the 2-40 GeV/c range for $\pi - K$ separation
- Alternative **environmentally friendly** radiators have been explored [ECFA '24]
- **SiPMs** are promising photosensors due to their high sensitivity and compact design. A **new cooling prototype** is under development, with initial tests on 3D-printed plastic and metal models
- **Next Steps**:
  - Extend simulations to the entire ARC detector, include the **magnetic field**, develop a global **PID likelihood approach**
  - Evaluate prototype thermal behavior at low temperatures (-60°C to -80°C) using silicon oil
  - Plan to conduct a **test beam** in autumn for a photodetector module with integrated active cooling
- More details on the simulations in the **supporting note**: [10.17181/6g0gs-7kw30]

Università di Genova

INFN

CERN

Thank you for the attention!

Serena Pezzulo

University and INFN Genova

serena.pezzulo@ge.infn.it

March 18, 2025