Study of new aerogel radiators for the LHCb RICH upgrade

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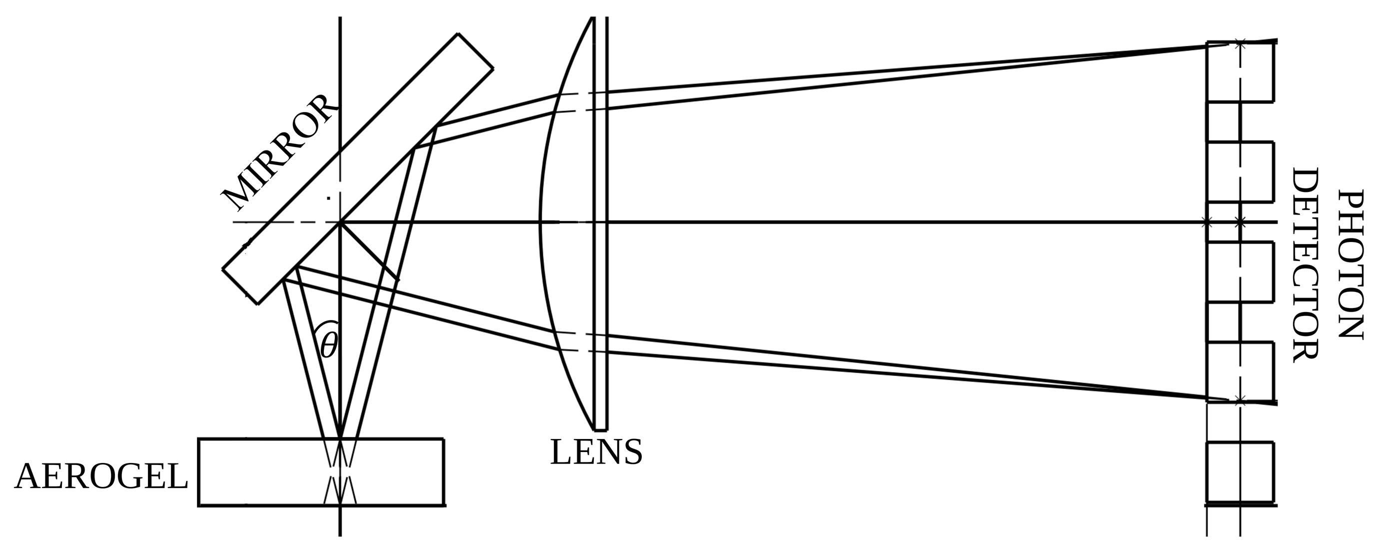
Motivation

The LHCb detector at the Large Hadron Collider in CERN uses a single-arm spectrometer, dedicated for precision studies of CP violation and rare decays of b and c quarks. The detector's performance is constantly being improved throughout upgrades during LHC's shutdowns. After the high luminosity LHC upgrade (Run 5), hadron identification will be extremely challenging due to higher detector occupancy. A number of different technologies are under study, including the use of aerogel as a Cherenkov radiator presented in this poster.

Particle identification using Ring Imaging Cherenkov (RICH) detectors:

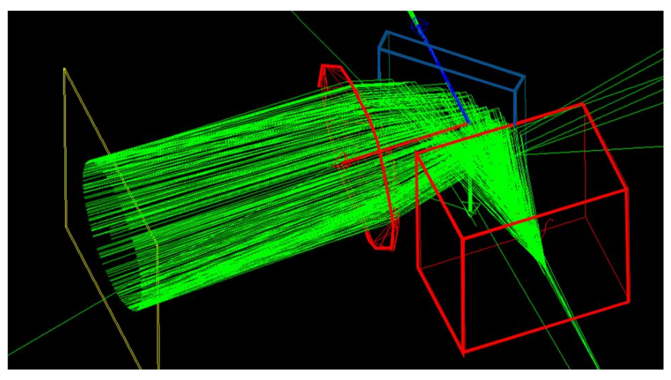
- Charged particle traveling through medium faster than the phase velocity of light, emits Cherenkov photons under the angle θ:

$$\cos\theta = 1/(n\beta)$$

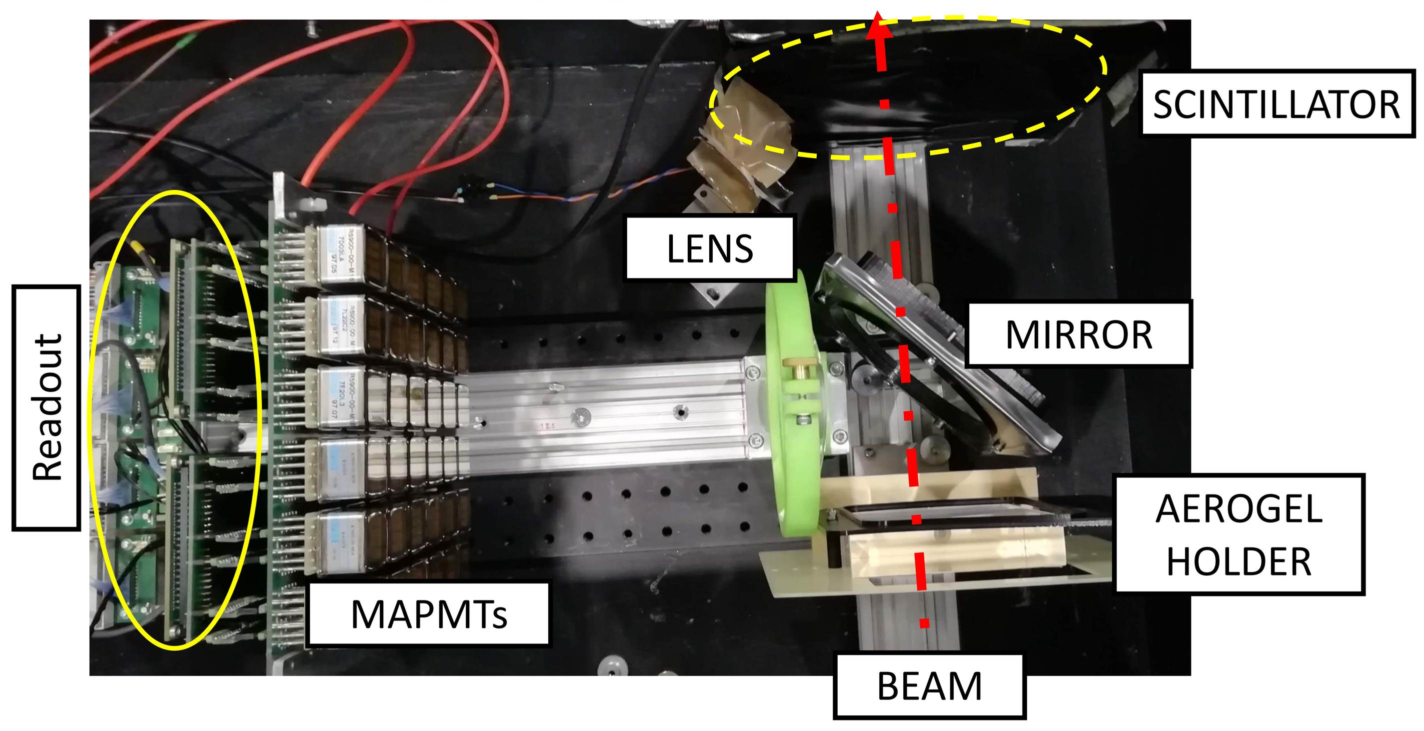


Experimental setup

Testbeam

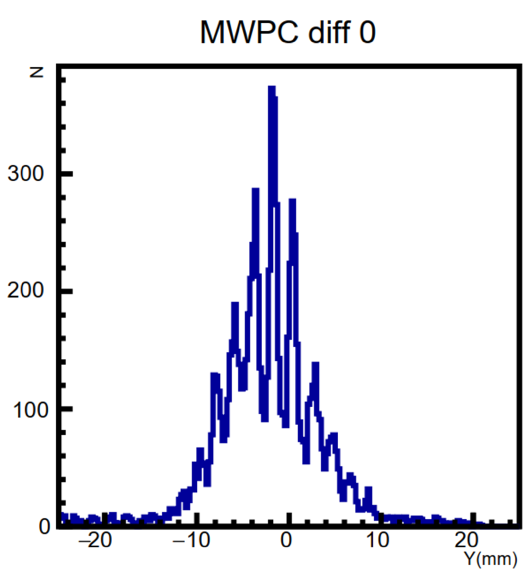


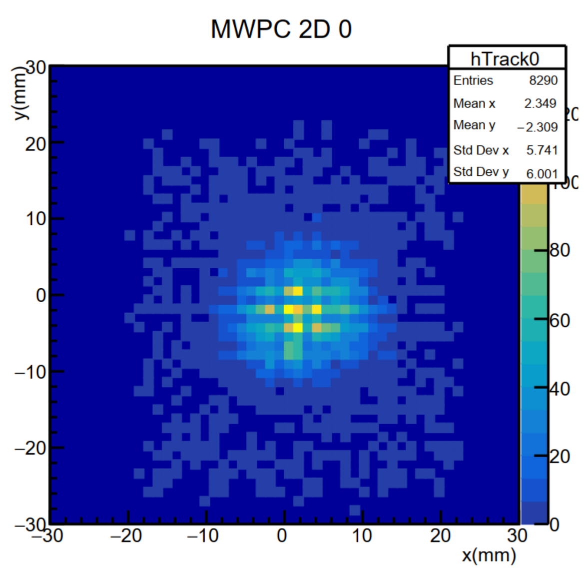
- SPS CERN beamline T4-H8, July, 2021
- 180 GeV/c protons and pions
- Beam spread: RMS ~ 6mm
- Beam intensity: 10^5-10^6 particles/spill
- Light-tight aluminium crate:
  1. Aerogel holder in the centre of the beamline
  2. Light reflected at 90° with UV-enhanced aluminium coated flat mirror
  3. Plano-convex borosilicate lens
  4. 6x6 Hamamatsu MAPMTs
  5. Plastic scintillator for triggering acquisition in coincidence with MWPCs



Tracking

- 2x MWPC: at the upstream and downstream ends of the crate
- Active area 5 x 5 cm^2
- Gas mixture: 90-10 Ar-CH_4
- CF discrimination and digitized with CAEN V673A TDC, time bin: 1 ns
- Acquisition trigger: coincidence of both MWPCs and the plastic scintillator

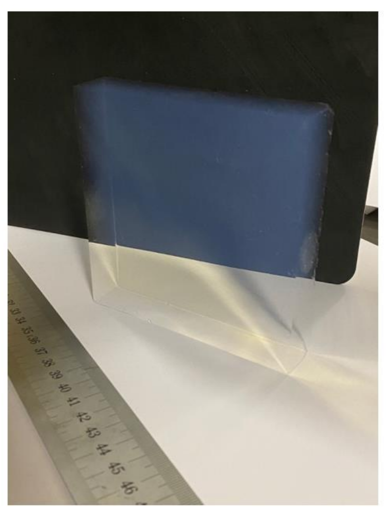


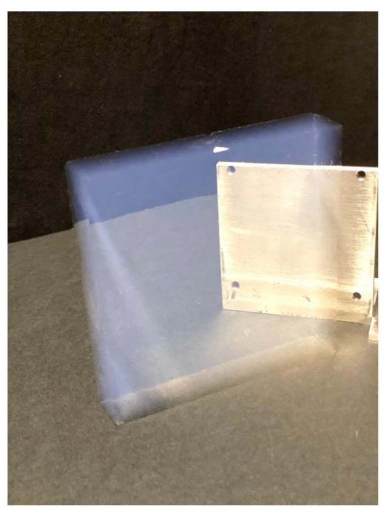


Aerogels

- Hydrophobic with improved transparency compared to Belle II aerogels
- Produced by Chiba University, Japan [3]
- Pinhole drying method
- Tile size: 12 x 12 x 2 cm^3
- Refractive index: 1.03, 1.04, 1.05
- Average transmission lengths:

Ref. ind.	L@400nm [mm]
1.03	63
1.04	56
1.05	37



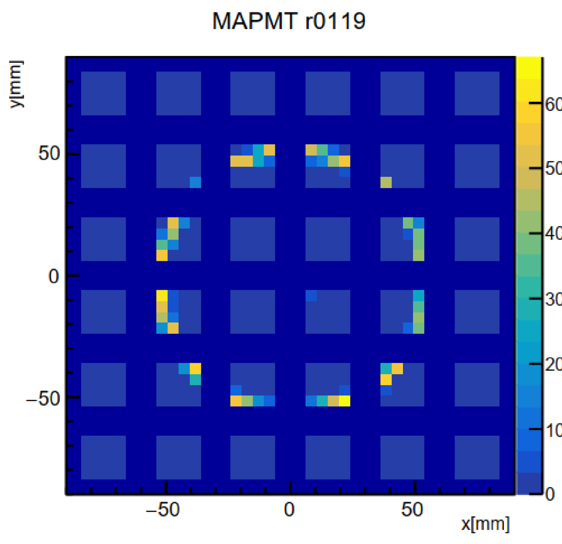


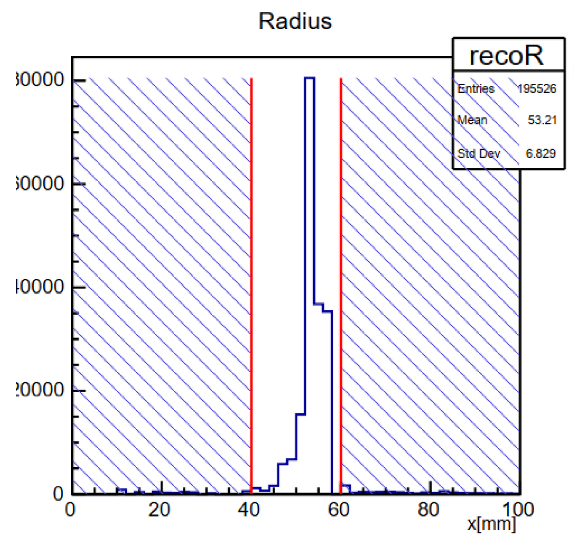
Photon detection

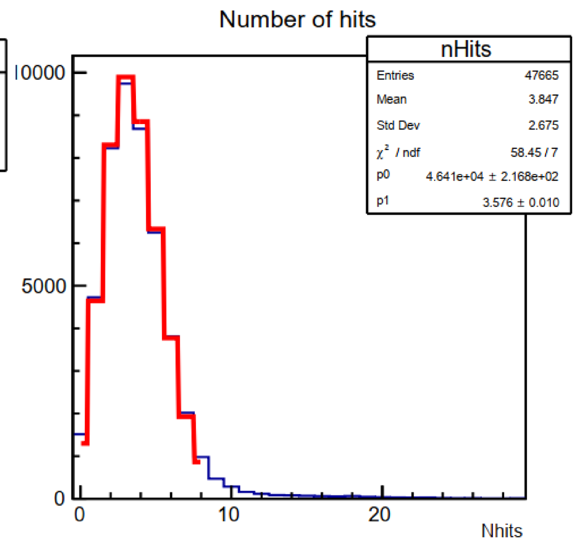
- 16 (4x4) channels MAPMT, Hamamatsu R5900-M16 [1]
- Pad size: 4.5 x 4.5 mm^2
- Array: 6 x 6
- Pitch: 30 mm
- Average QE: 11.9%
- Collection efficiency: 70%
- Signal readout: Belle II ARICH front-end electronics [2], time bin: 125 ns

Measurements

- All three refractive indices
- Stack of tiles: from 1 (2 cm) to 4 (8 cm) for 1.03
- Measure distribution of number of photons per track $N_{detected}$
  - Estimate radius for each hit
  - Apply radius cut
  - Fit Poisson distribution
- Compare with simulation in Geant4-based software (GEARS)







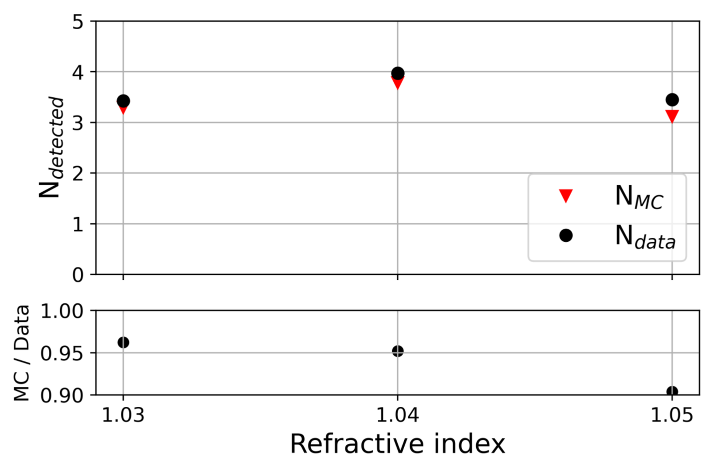
Results

Refractive index

	$N_{detected}$	N_{mean}	$N_{detected}$	N_{mean}	Geo. eff.
Ref. ind.	Data		Simulation		
1.03	3.6	3.9±3.2	3.3	3.3±2.0	49%
1.04	4.0	4.2±2.8	3.8	3.8±2.2	50%
1.05	3.5	3.7±2.6	3.1	3.2±2.0	40%

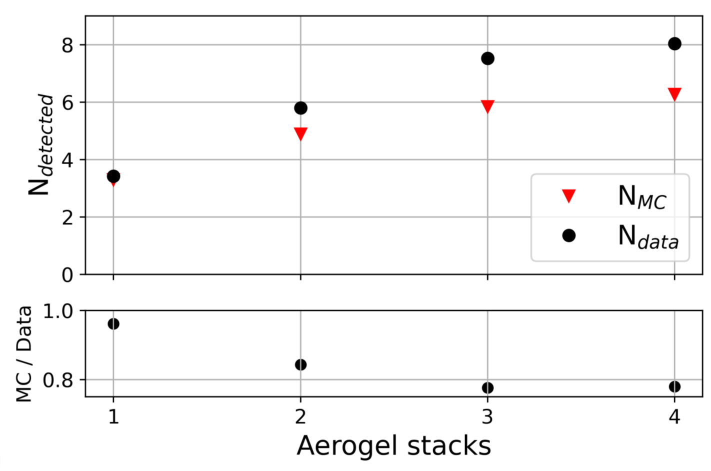
$N_{detected}$ – Detected photons extracted from Poisson fit

N_{mean} – Arithmetic mean ± std dev



Aerogel stacks

	$N_{detected}$	N_{mean}	$N_{detected}$	N_{mean}
# tiles	Data		Simulation	
1	3.6	3.9±3.2	3.3	3.3±2.0
2	5.8	6.1±3.1	4.9	4.9±2.5
3	7.5	9.0±4.9	5.8	5.9±2.7
4	8.0	8.3±3.4	6.3	6.3±2.8



- Approximate linear scale – high clarity of the aero

Estimation of the yields

- **Geometrical** efficiency: ~50%
- **Photon detection** efficiency: QE (~12%) and collection efficiency (70%): ~8%
- **Losses** in the optical components: 10-20%
- With total efficiency ~3.5% and 3.6 photons detected we estimate ~ 50 photons / cm

Conclusion

Focus on the radiator studies: novel aerogels from Japan

- Refractive index: 1.03, 1.04, 1.05
- Stacks: 2 cm – 8 cm

Comparison with the MC data from simulation

- 10% agreement – single tile
- 20% agreement – 4 tile stack

Next testbeam in October: measure detectors with fast timing readout

References

[1] "Hamamatsu Data Sheets for R5900-M16."

[2] R. Pestotnik et al., "Front-end electronics of the Belle II aerogel ring imaging detector," Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip., vol. 952, p. 161711, Feb. 2020, doi: 10.1016/j.nima.2018.12.026.

[3] M. Tabata, I. Adachi, H. Kawai, T. Sumiyoshi, and H. Yokogawa, "Hydrophobic silica aerogel production at KEK," Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip., vol. 668, pp. 64–70, 2012, doi: 10.1016/j.nima.2011.12.017.

This work was carried out within the framework of the LHCb RICH collaboration.