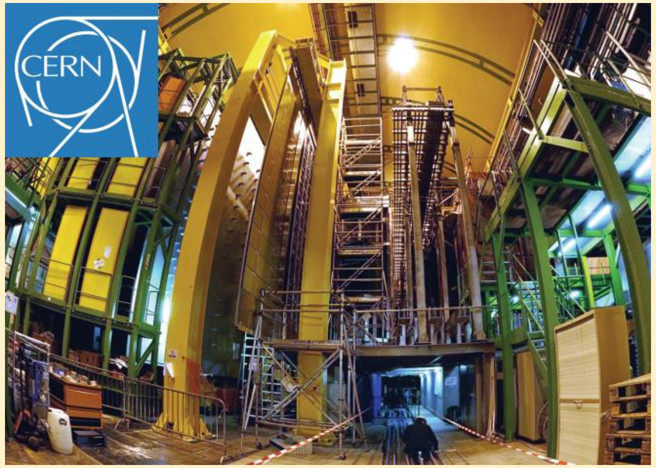
Options for alternate radiators for LHCb-RICH system

CERN: Mini-Workshop on gas transport parameters
for present and future generation of experiments



On behalf of LHCb-RICH group

S.Easo
22-04-2021

Science and
Technology
Facilities Council

Outline

- Studies done by Olav Ullaland
- Start of investigations to use CO_2 in RICH2
- Impact of potential usage of SiPM in the future
- Exploring non-gaseous radiators
- Summary

Investigations in the past

From O. Ullaland

Is there a future for the LHCb RICHes without perfluorocarbons?

Investigations in the past

From O. Ullaland

https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf
Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis.

Table 8.A.1 | Radiative efficiencies (REs), lifetimes/adjustment times, AGWP and GWP values for 20 and 100 years, and AGTP and GTP values for 20, 50 and 100 years. Climate–carbon feedbacks are included for CO2 while no climate feedbacks are included for the other components (see discussion in Sections 8.7.1.4 and 8.7.2.1, Supplementary Material and notes below the table; Supplementary Material Table 8.SM.16 gives analogous values including climate–carbon feedbacks for non-CO2 emissions).

Global Warming Potential (GWP) Absolute Global Warming Potential (AGWP)

Chemical Formula	GWP 20-year	Chemical Formula	GWP 20-year	Chemical Formula	GWP 20-year
CO2	1	**C3F8**	6640	CHF2OCF2CHF2	9710
CH4	84	CF3CF2CH3	6680	HCF2O(CF2CF2O)2CF2H	9910
N2O	264	CHF2CF2OCF2CF3	6720	CCl2F2	10800
CBrF2CBrF2	3440	SO2F2	6840	CHF3	10800
CCl4	3480	c-C3F6	6850	CClF3	10900
CHF2CF2CF2CF3	4510	**C4F10**	6870	HF2C-(OCF2)2-OCF2H	10900
E-C10F18	4720			CHF2OCF2OCHF2	11000
CF4	4880	CCl3F	6900	CHF2OCHF2	11600
CF3CF2CHF2	5080	CH3CF3	6940	CHF2OCF3	12400
CF3CHFCF3	5360	CF3CH2CF3	6940	NF3	12800
C10F18	5390	c-C4F8	7110	SF5CF3	13500
Z-C10F18	5430	CF3CFHCF2OCF3	7170	HF2C-(OCF2)3-OCF2H	15100
C8F18	5680	HCF2O(CF2CF2O)4CF2H	7320	SF6	17500
n-C7F16	5830	CF3OCF(CF3)CF2OCF2OCF3	7500		
CClF2CF3	5860	CClF2CClF2	7710		
n-C6F14	5890	CBrF3	7800		
(CF3)2CHOCHF2	5940	CF3CF2CF2OCHFCF3	7940		
CHF2CF3	6090	**C2F6**	8210		
n-C5F12	6350	CF3CHFOCF3	8900		
CCl2FCClF2	6490	HCF2O(CF2CF2O)3CF2H	9050		

Only molecules with an atmospheric lifetime longer than 20 years have been retained from this publication.

Please note:
The Global Warming Potential is given relative to CO_2 which is set to be 1.
LHCb RICH friends are indicated in **red.**

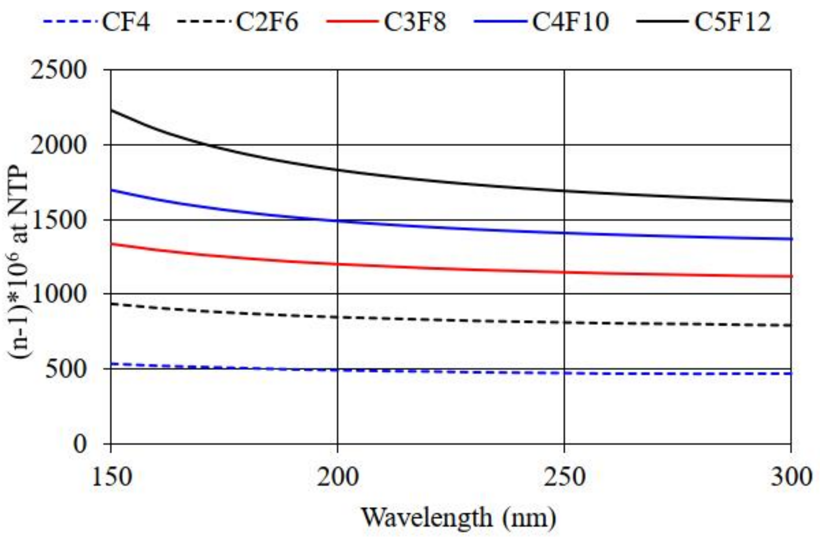
No uncertainties are given for these values in the publication. They should therefore be taken as indicative and not as absolute values.

C_4F_8O is also ruled out, since it has a large GWP 12000 (100-year time horizon).

Investigations in the past

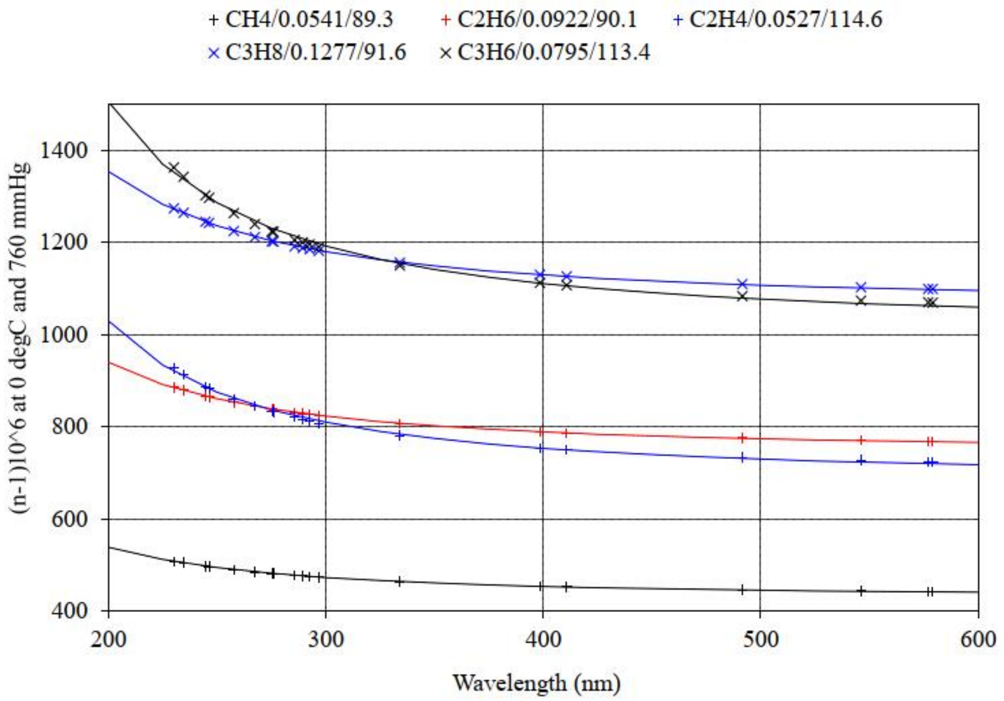
From O. Ullaland

Fluorocarbon gases : RICH1



Assuming that we are not looking for a reduction of a few percent in the Global Warming Potential, but rather a factor of 10 (or even better 100),

then we are not too far off from a correct working point with a C_3H_8 gas.



It has some (minor) drawbacks:

C_3H_8

Flash point	−104 °C (169 K)
Autoignition temperature	470 °C (743 K)
Explosive limits	2.37–9.5%

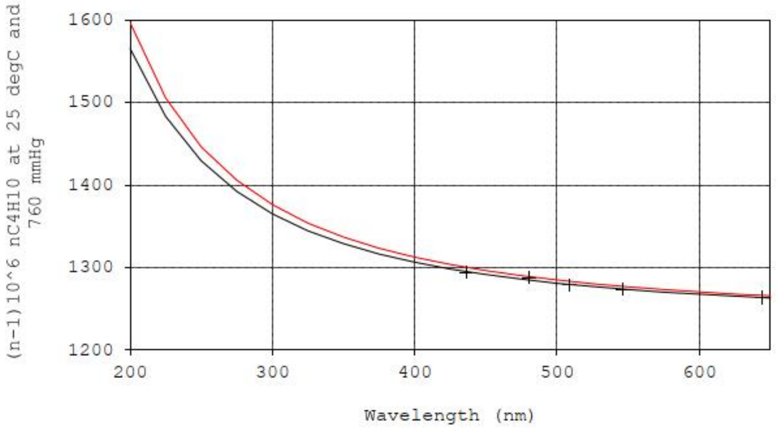
Propane: cooking gas

Hydrocarbon gases : RICH1

Investigations in the past

From O. Ullaland

C_4F_{10} vs C_4H_{10} :   RICH1



C_4H_{10} :

Depending on where you want to be, you get a little higher n-1 with Isobutane.

C_4H_{10}:

- Isobutane : GWP = 3.3
- Used as a refrigerant

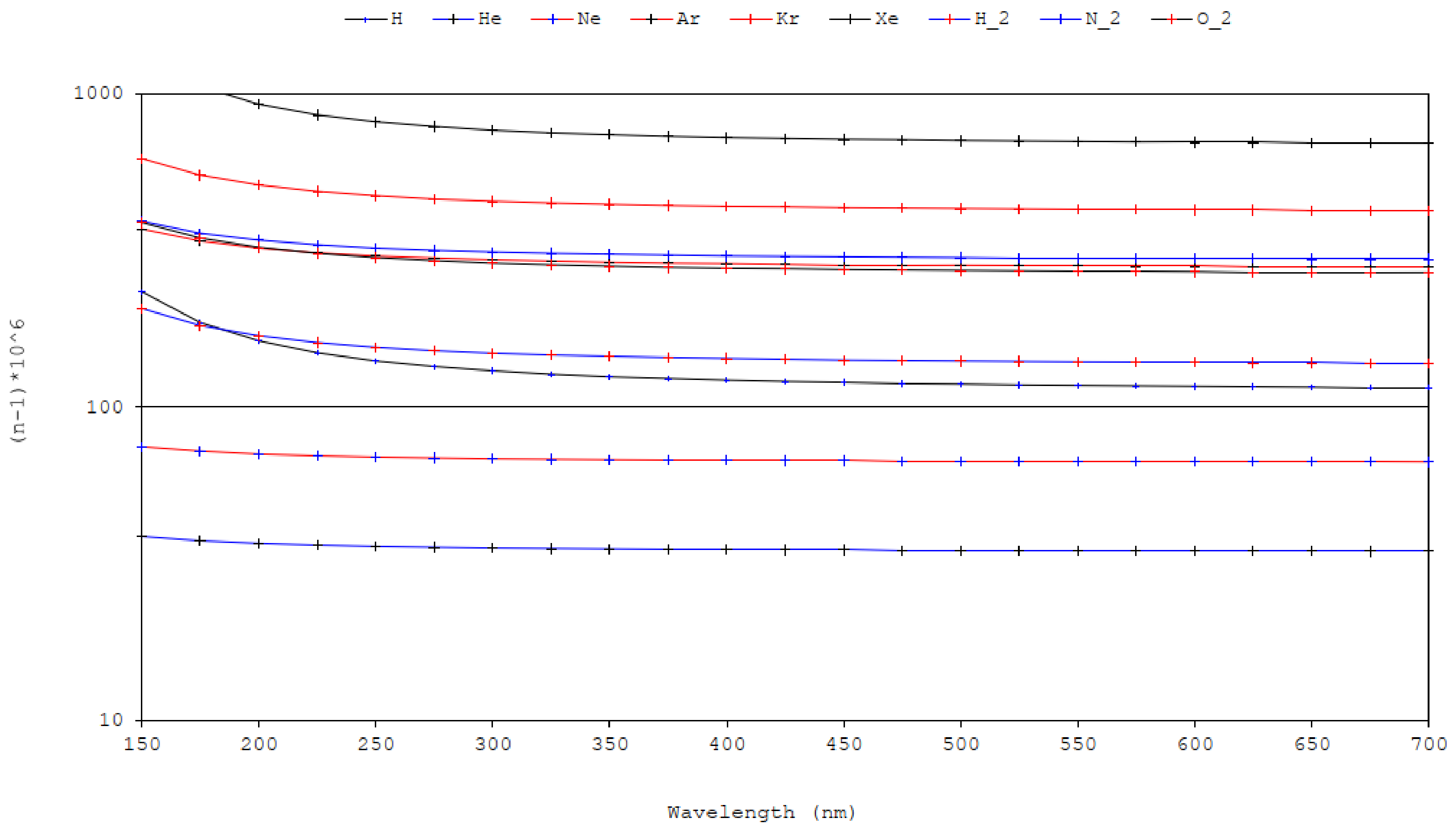
Risk of explosion

But you might still find that the CERN Safety Commission is blocking your goal.

Investigations in the past

Gases without Carbon

From O. Ullaland



These gases would require a pressurized container which is somewhat sub-optimal. (for RICH1)

$$(n\text{-}1) \propto \frac{P}{T}$$

For RICH2, it would be a very low pressure container, which is also not a good idea.

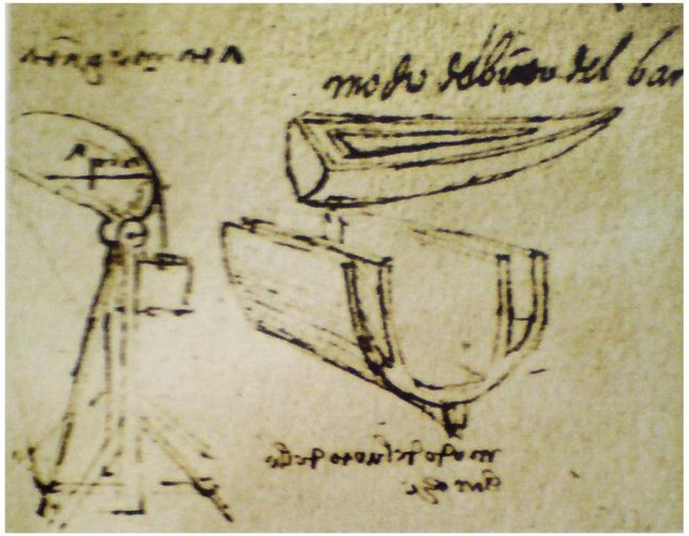
Investigations in the past

From O. Ullaland

A workable solution, with Isobutane, would require a new RICH 1 vessel.
It must, I think, be a double hull structure.
It must be designed with simplicity/gas tightness /safety in mind.

On second thought
- perhaps not.

If you do all that, and in addition manufacture the required new gas system, you have a perfectly safe and leak-tight detector which could work perfectly well with C_4F_{10} (or similar) without any spillage to the environment.

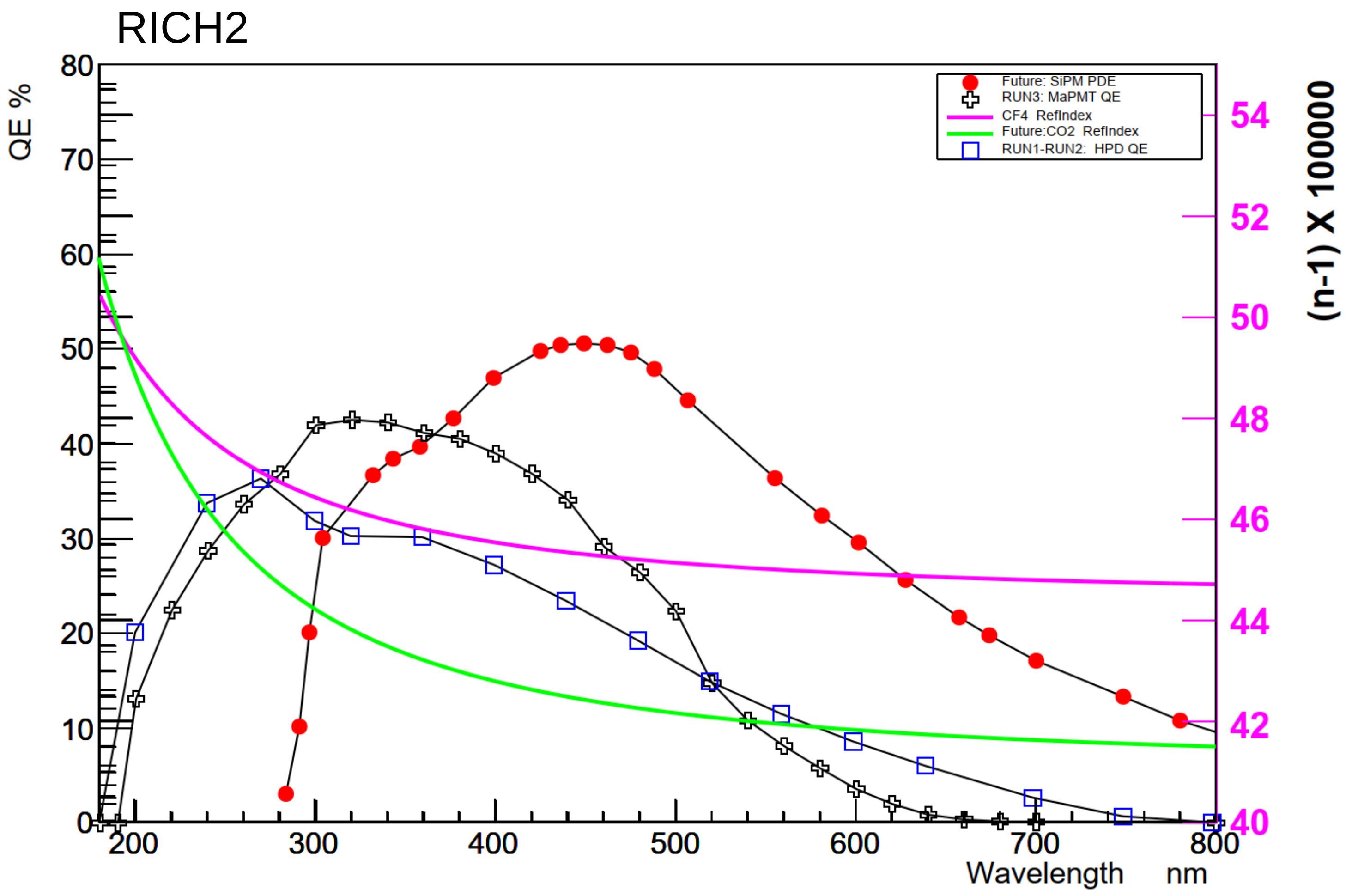


Inventions and ideas:
Leonardo da Vinci conceived of the ***Double Hull*** concept

Perhaps, after all, seen the other volumes, one could let the RICHes work with the gases they have successfully used to work with.

- In the future, the gas tightness of the enclosures will be further improved.
- In such a system, the gas loss is negligible; it may happen only during gas purification.

Exploring usage of CO_2 in RICH2



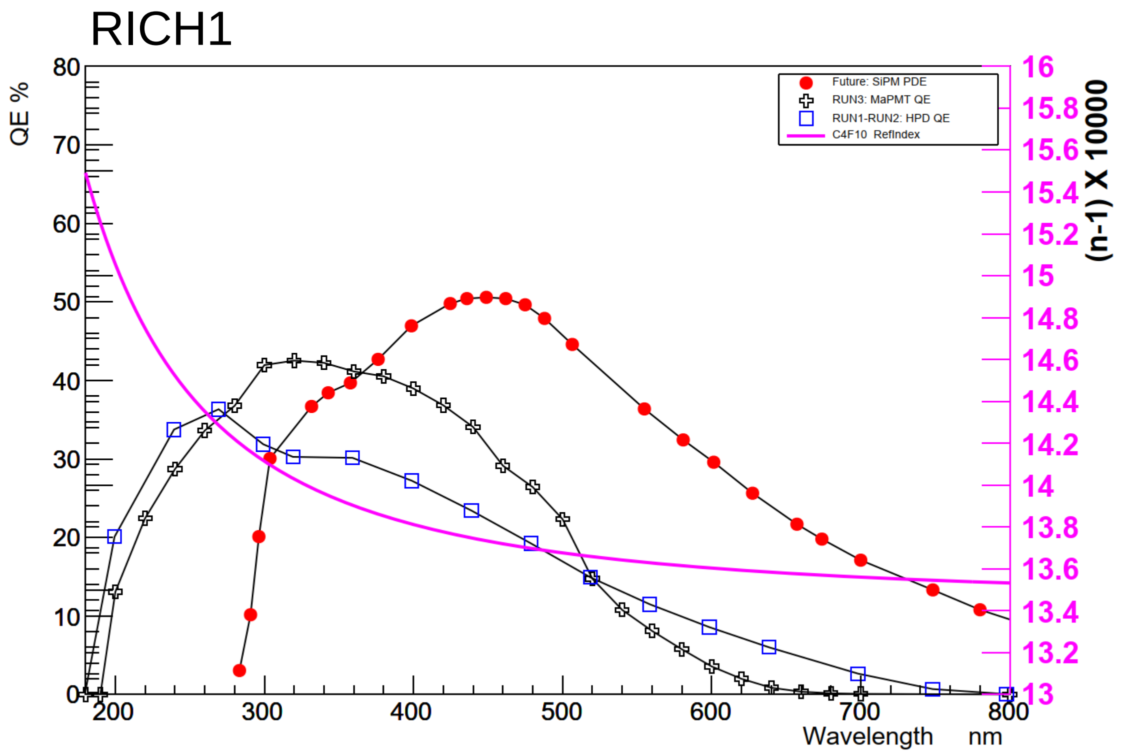
RICH2: RUN3

Preliminary

Nominal single photon resolution (in mrad)	MaPMT; CF_4	MaPMT: CO_2
Chromatic	0.34	0.53
Overall	0.50	0.66
Yield	34	33

- CO_2 expected to have a worse chromatic error contribution than CF_4
- Simulation studies expected to be performed to evaluate the effect, from CO_2.

Usage of SiPM in the future



- SiPM can reduce the chromatic error and increase the yield. This is expected for LS4.
- We hope that the gains obtained from using SiPMs are not lost with a change of the gas radiator.
- For single photon detection, dark counts are to be kept at the level of 100 kHz/mm^2
- This requires SiPM to be operated near -100 ^{0}C.
  One needs to ensure that radiator gas does not liquefy when using SiPM.
  (*The gas radiator is separated from SiPM region by a thin quartz window*)

Non-gaseous radiators in the future

Aerogel:

- It is planned to test improved versions of aerogel.
- However with n ~ 1.03, this is for the momentum range below 10 GeV/c.
- This may also require modification of the optics.

Novel materials:

- R & D starting in designing thin radiators made of photonic crystals (or meta-materials) , with desired n.
- There are many challenges involved in producing such materials with low chromatic error and high yield.

Ref: Nature Physics 14, 816-821 (2018).

SUMMARY

- Many options for replacing the current radiators with eco-friendly gases were investigated by Olav Ullaland.
- One of those options is to have a pressurized, leak tight container to use isobutane for RICH1.
- His general conclusion was to keep the current gases, unless a fantastic new option comes up in the future.
- In the future we plan to further improve the gas tightness of the gas enclosures.
- Usage of CO_2 in RICH2 is being investigated
- We plan to continue the search for eco-friendly gases which can be used as radiators in the RICH detectors. Any information related to this topic is quite welcome.
- In the future, new photon detectors like SiPM can reduce the chromatic error.
- In parallel , usage of non-gaseous radiators are also being explored