Lens based optical readout for GRAIN

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LAr Optical System Working Group (GE-BO-LE)

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Overview

- The lens design
- First simulation results
- Test set up
  - in water with CCD → first results
  - in LAr by using SiPM matrix → under design and construction
- Next steps

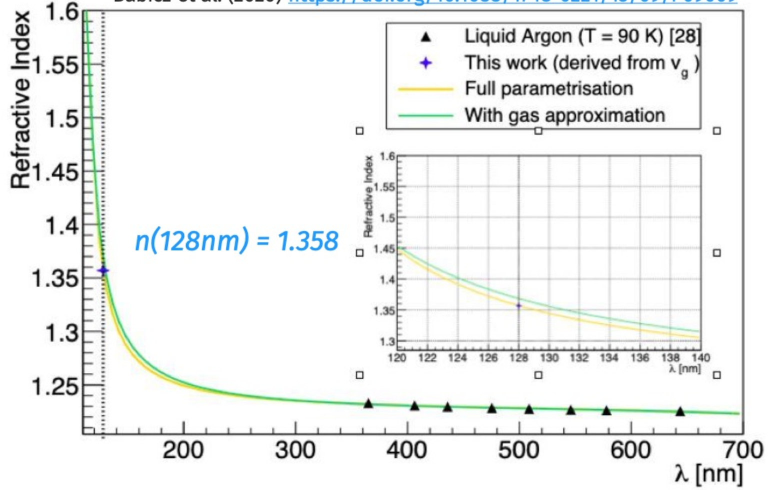
Problems and solutions

- Which material?
  - with high transmittance
  - with refractive index different from LAr refractive index (1.26-1.4, not known precisely)
  - suitable in cryogenic enviroment

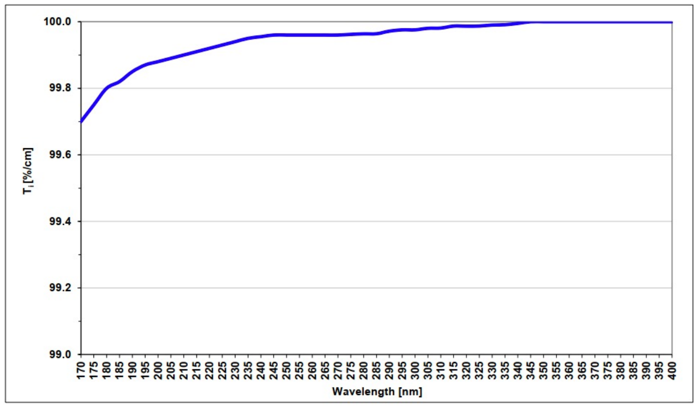
HPFS 8655 Fused Silica
extremely pure synthetic glass
n=1.57 at **178 nm**

→ we have to use Xe doped LAr

Babicz et al. (2020) https://doi.org/10.1088/1748-0221/15/09/P09009

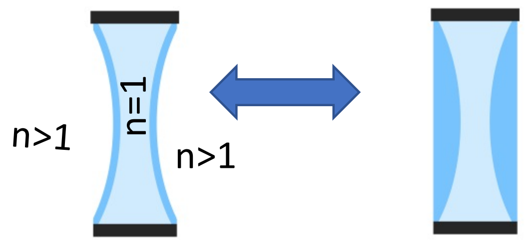


Internal Transmittance:



The focusing effect

Since the glass refractive index might be close to the LAr refractive index the focusing effect can be done by placing N_2 gas between the lens surfaces

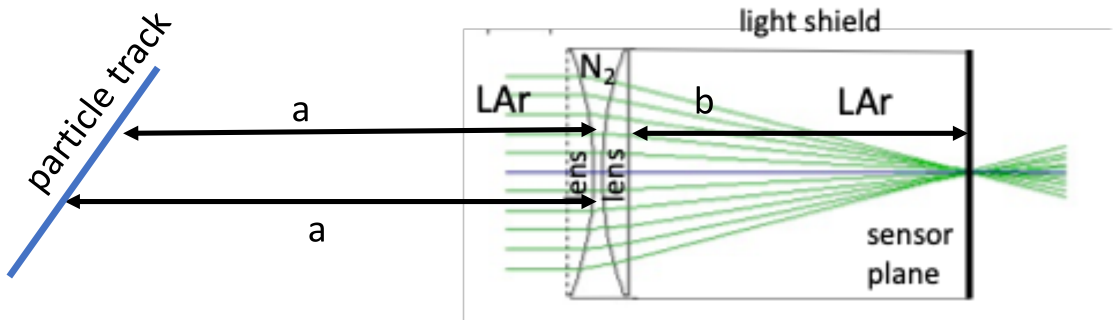


The focal lenght:

- is determined by the combination of the curvature and the material refractive index
- will be fixed, but it have to be optimized for covering a large field of view
- such that in the field of view tracks are imaged in the sensor plane in lines no more than 2-3 mm width

Field of view requirements:

- b smaller than 10 cm (fixed!)
- a between 0 -130 cm



Focal lenght

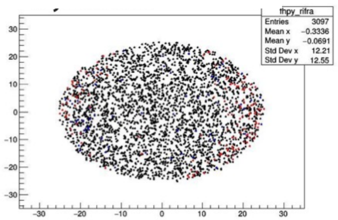
The radius of curvature, the sensor dimension, the material refractive index determine the focal lengh

R smaller → focal lenght smaller
but R>> lens radius

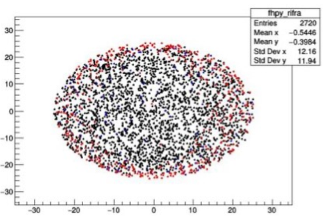
Lens radius 25-30 mm → R > 55 mm → focal lenght > 60 mm

Total reflection
Rifraction

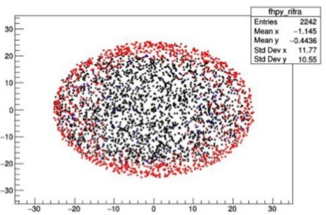
Lens diameter= 50 mm



f = 89 mm



f = 70mm

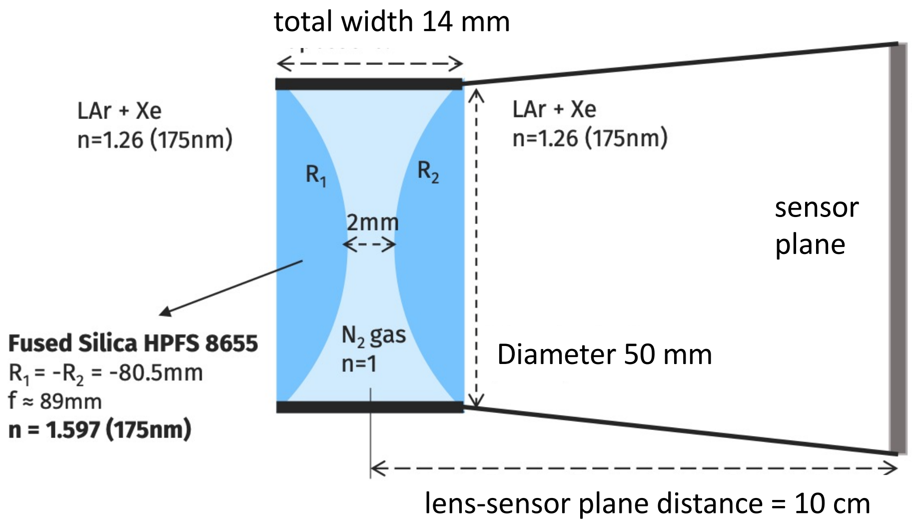


f = 61mm

Field of view requirement:

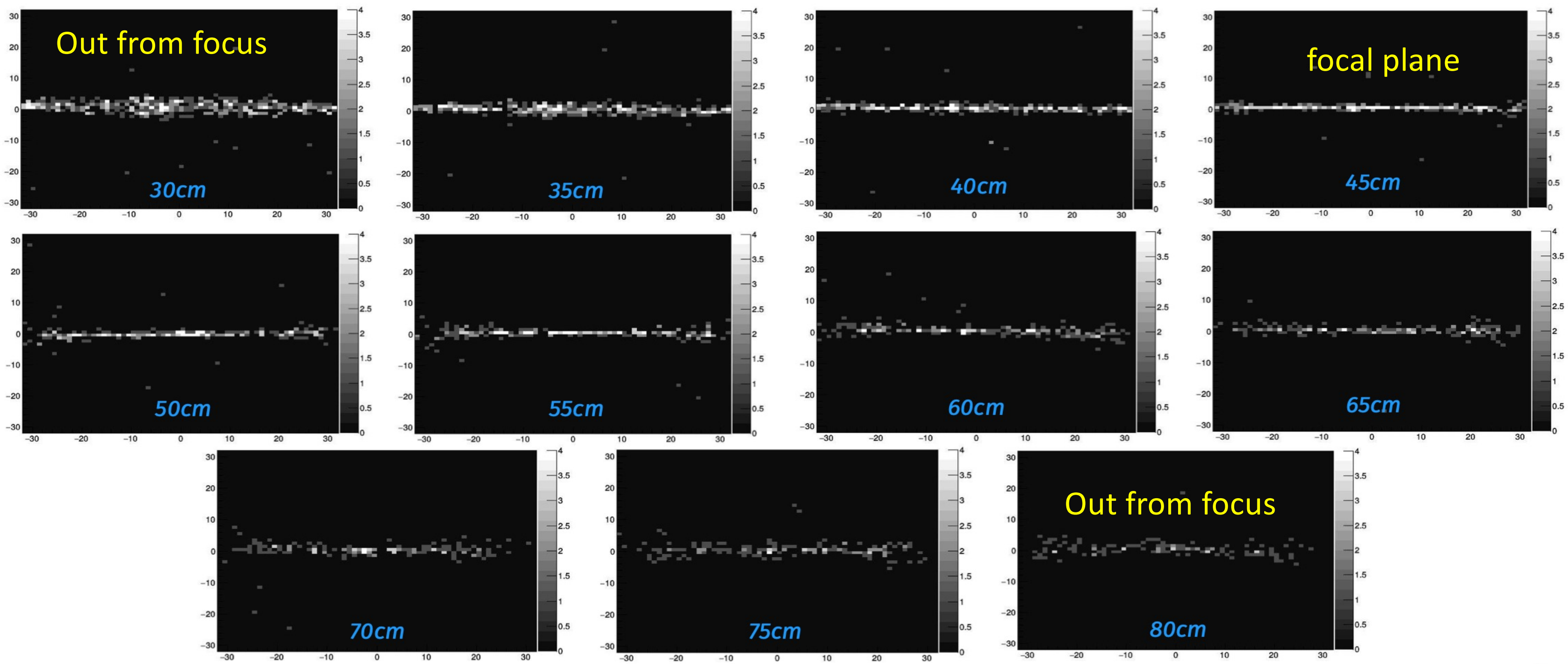
- a between 0 and 1.3 m
- b< 10 cm
- b must be chosen for maximize the field of view

First prototype

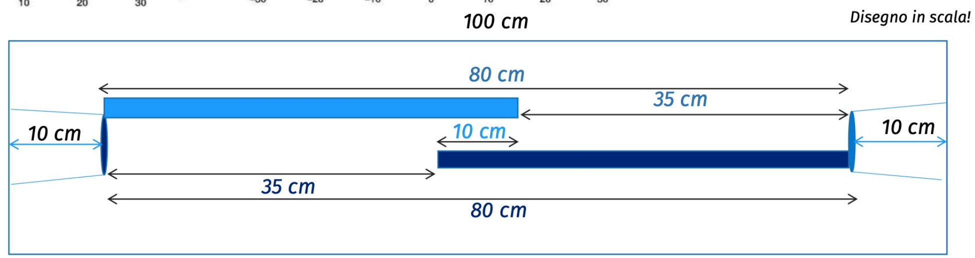


Focal lenght between 88 mm and 98 mm accordingly to LAr refractive index (1.26 or 1.4)

First simulation results

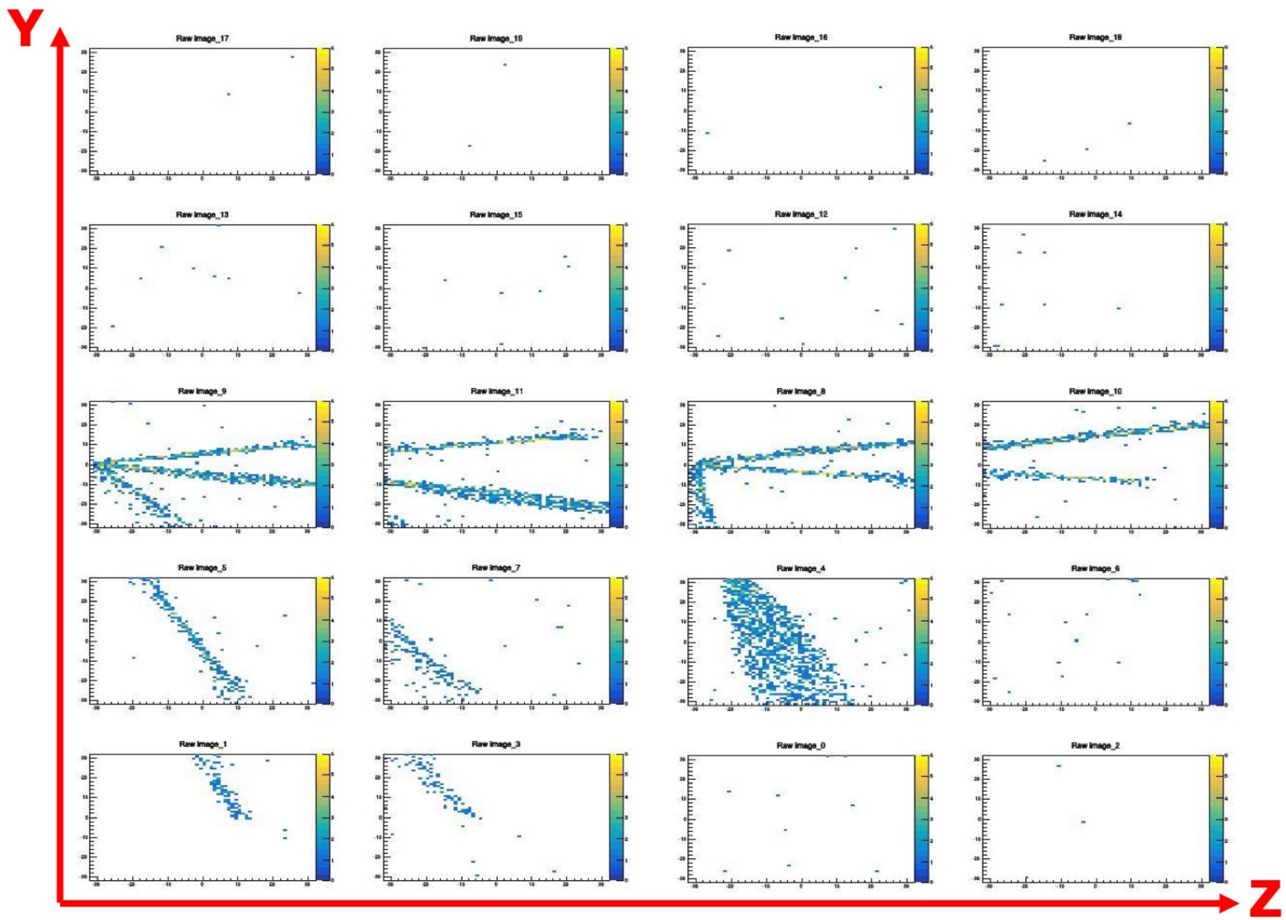


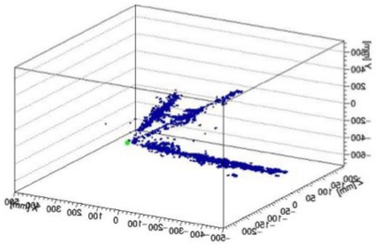
by using two sensors facing each other,
we can cover the whole distance,
each sensor will detect the farest part (a from 35 to 80 cm)

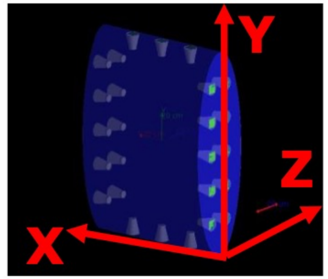


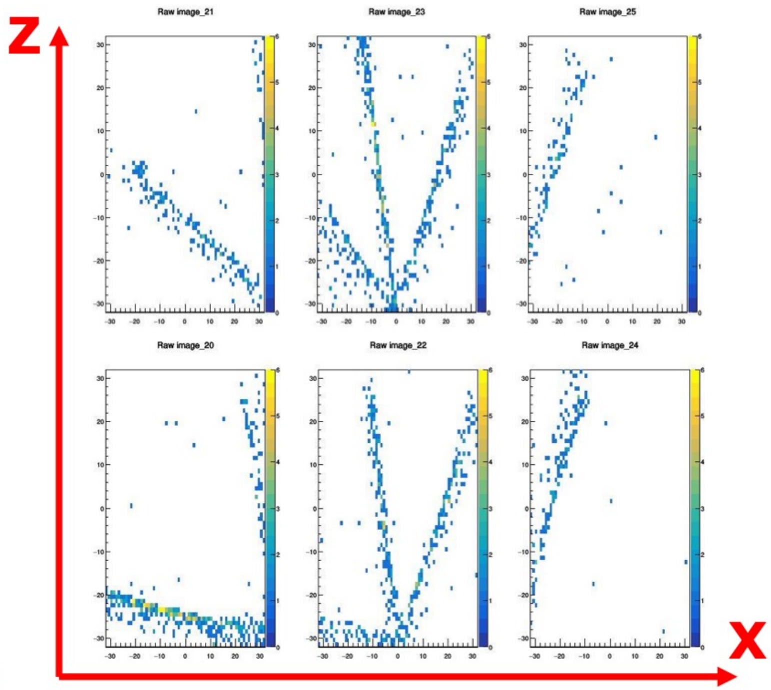
First simulation results in GRAIN

ν_μ CC in GRAIN



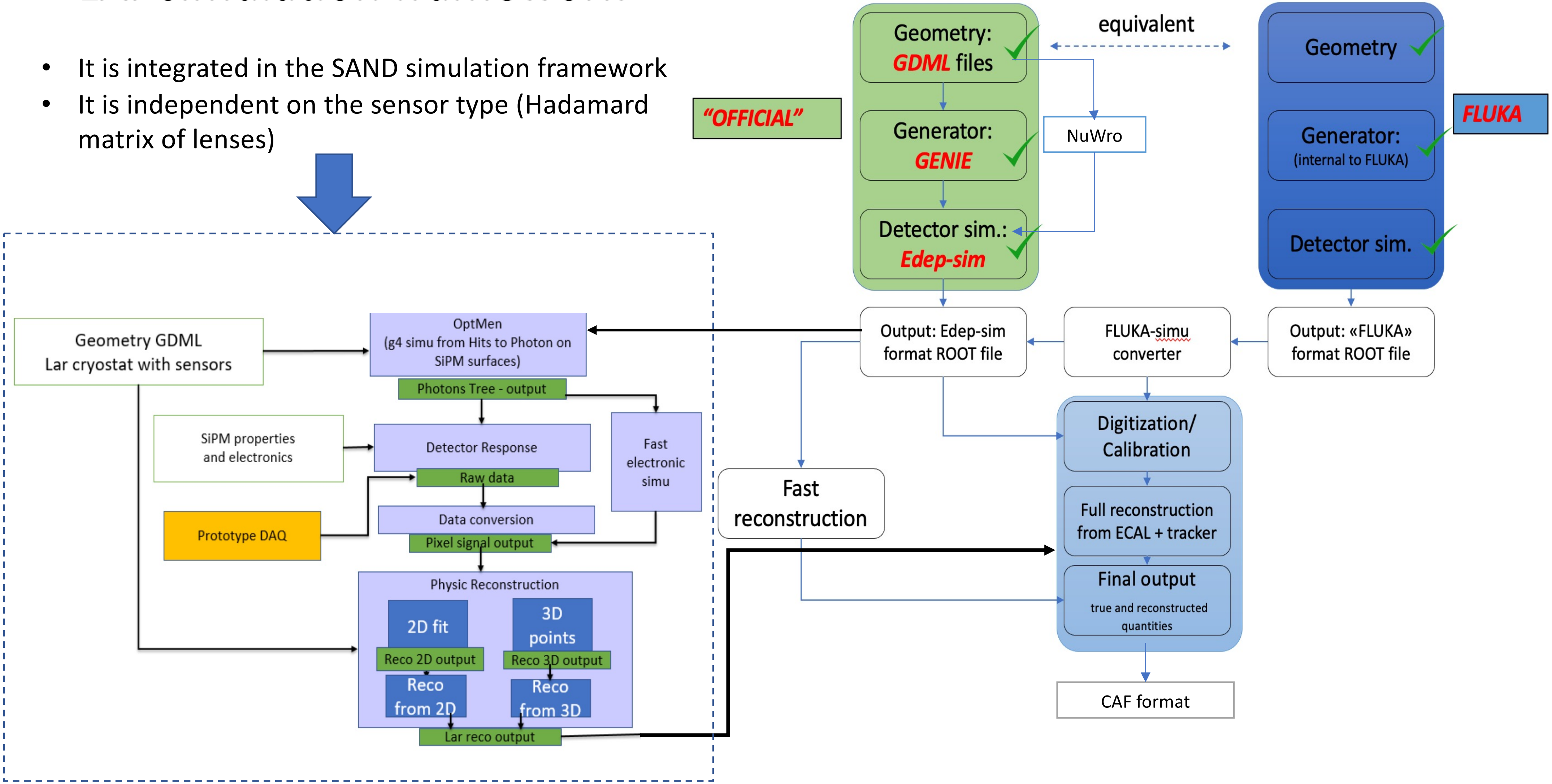






LAr simulation framework

- It is integrated in the SAND simulation framework
- It is independent on the sensor type (Hadamard matrix of lenses)

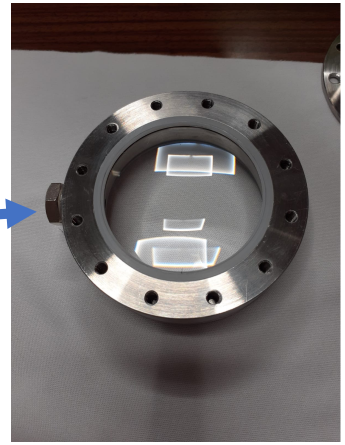


Tests of the first prototype in water

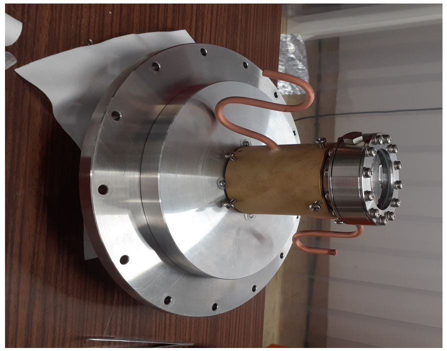
- Lens produced by **GestioneSILO.**
  - Materials: **Fused Silica HPFS 8655. (n=1.57)**
  - $R_1 = R_2 = -80.5$mm
  - f ≈ 89mm in LAr (n=1.26-1.4)
- Visible light source (650 nm)
  - trasported on fiber
  - Movable position inside the box volume
  - The distance between the lens system and CCD can be changed
- In water → (n_lens=1.45 n_water=1.33, bigger focal length f=118 mm)

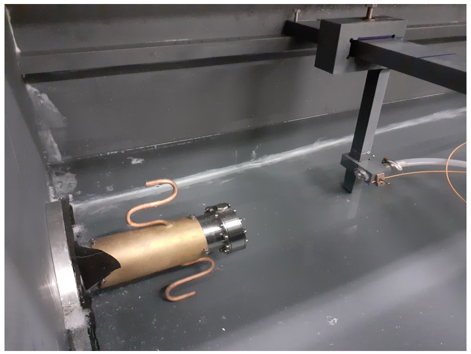
First lens prototype

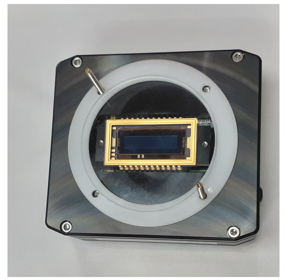
Valve for gas filling



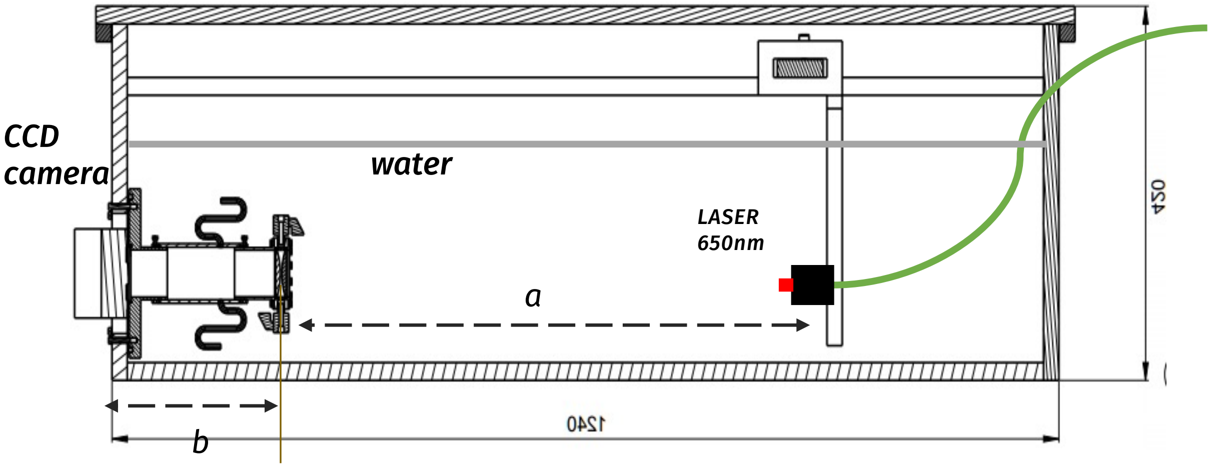
Lens support
by R. Cereseto
(INFN-GE)





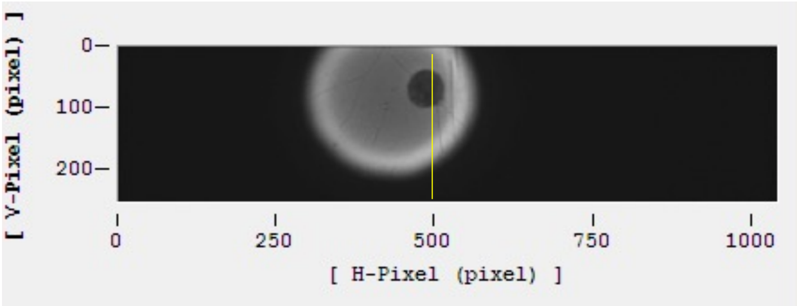


CCD (UV-visibile)
Dim: 24 mm x 12 mm

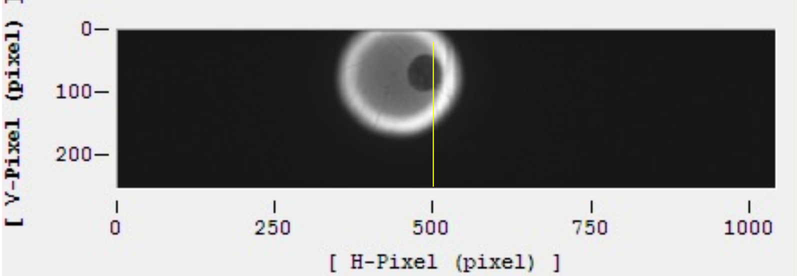


Tests in water b=117 mm

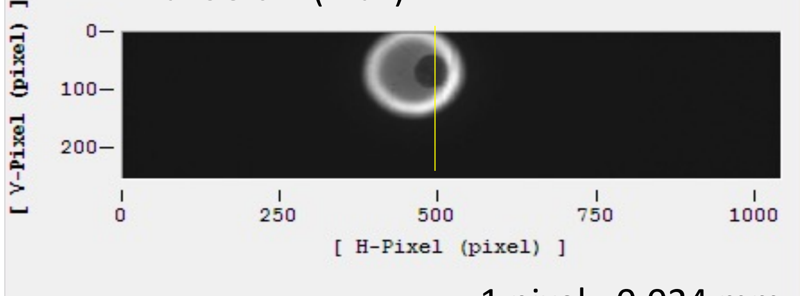
a=70 cm



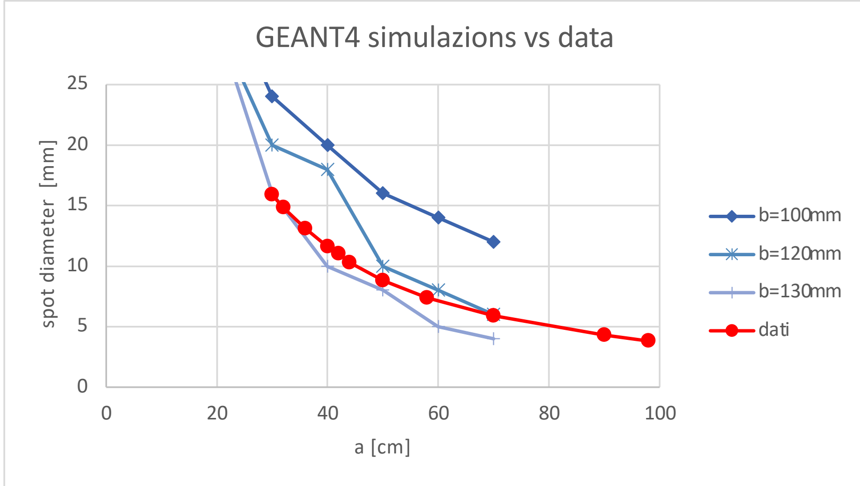
a=90 cm

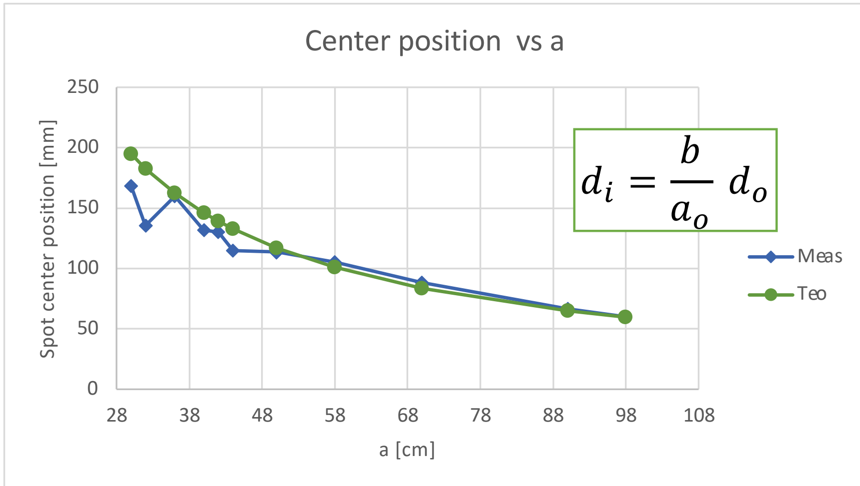


a=98 cm (max)



1 pixel =0.024 mm

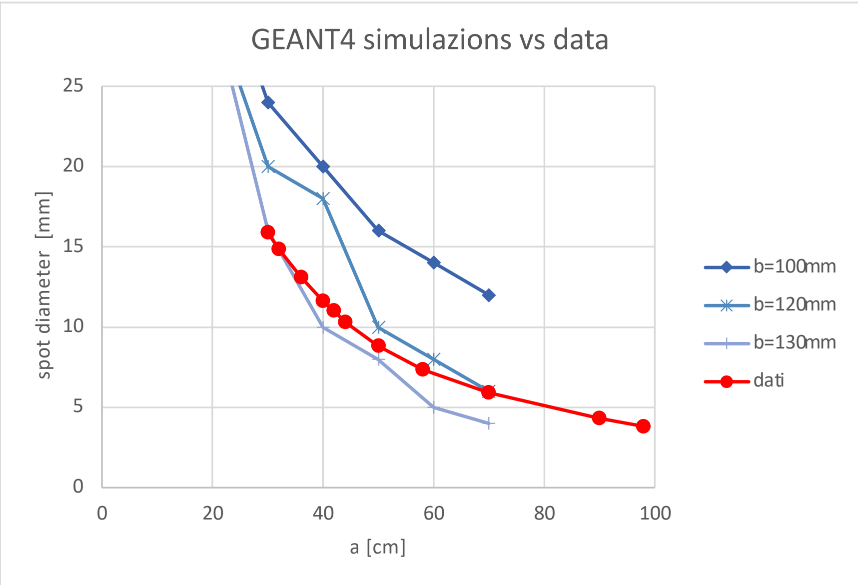




Field of view and focal plane

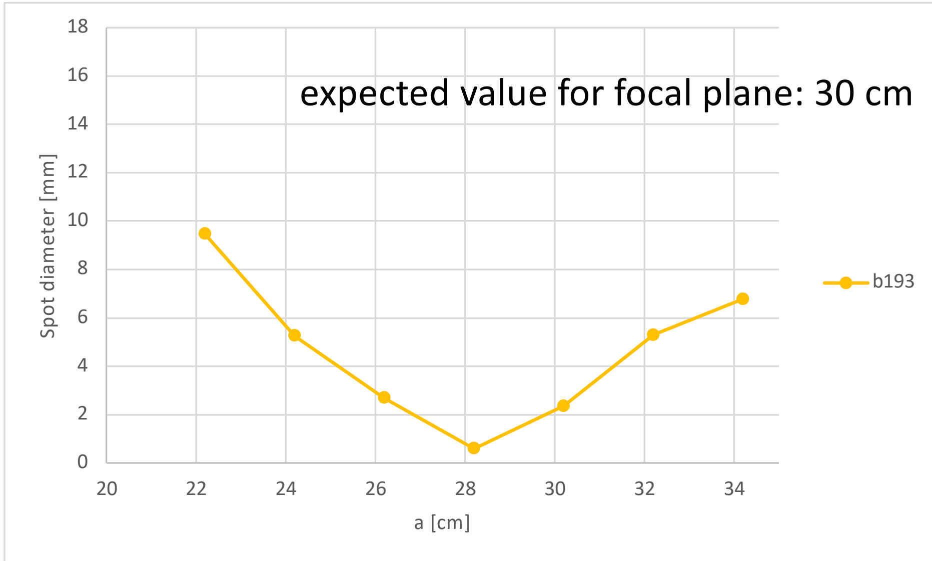
Focal plane: distance between lens and object, where the focusing is maximum

b=117 mm



In this case the focal plane is outside the box

b=193 mm



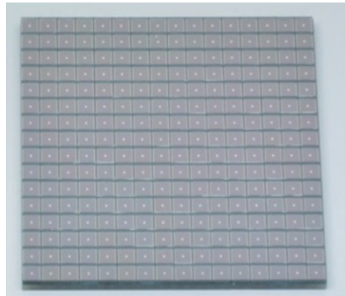
by increasing the b value (with the same lens) the focal plane position decreases

Observed differences with respect to simulations in:
- spot dimensions
- focal plane position (more precise measurements)

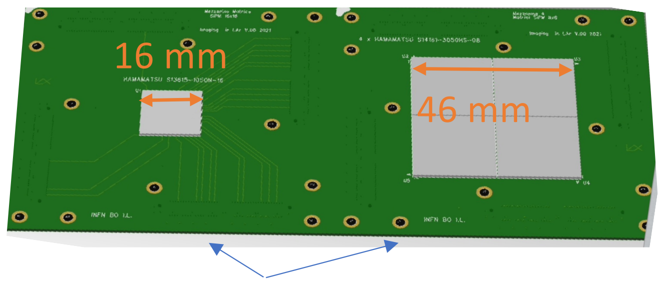
The general behaviour are in agreement
- scaling of the image
- focal plane shift

Future tests with SiPM in LAr

- VUV lens system coupled with 16x16 SiPM matrix
  - → 1 mm pixel side Hamamatsu S13615
  - → 3 mm pixel side Hamamatsu S14161



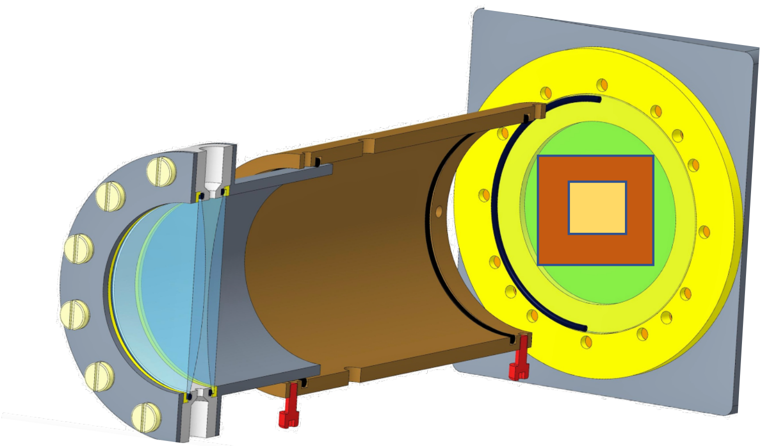
- 16x16 SiPM matrix



- mezzanine boards

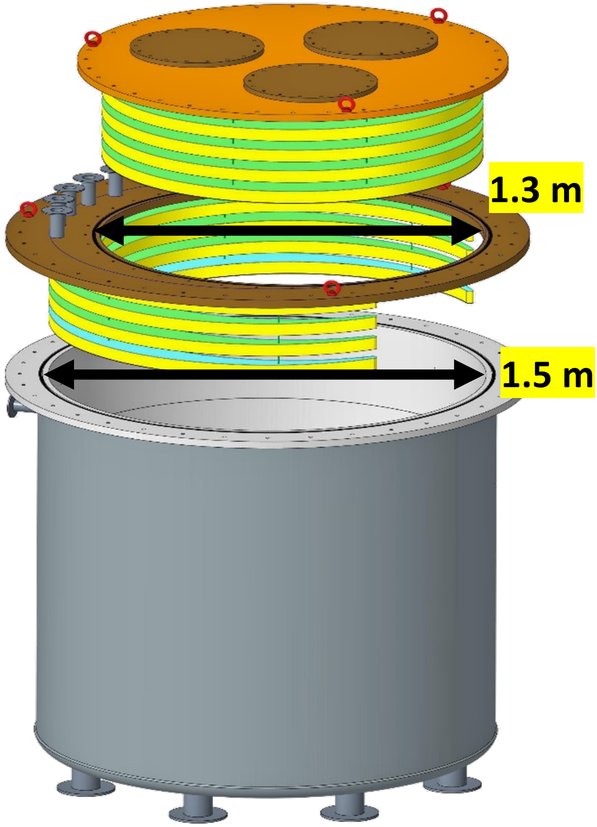
- ALCOR board with 8 ASICs for each matrix directly attached to the mezzanin board

- Xilinx FPGA board (outside the cryostat)



Same readout system developed by **Bologna group** for Hadamard matrix based detector

ARTIC - Argon Test InfrastruCture

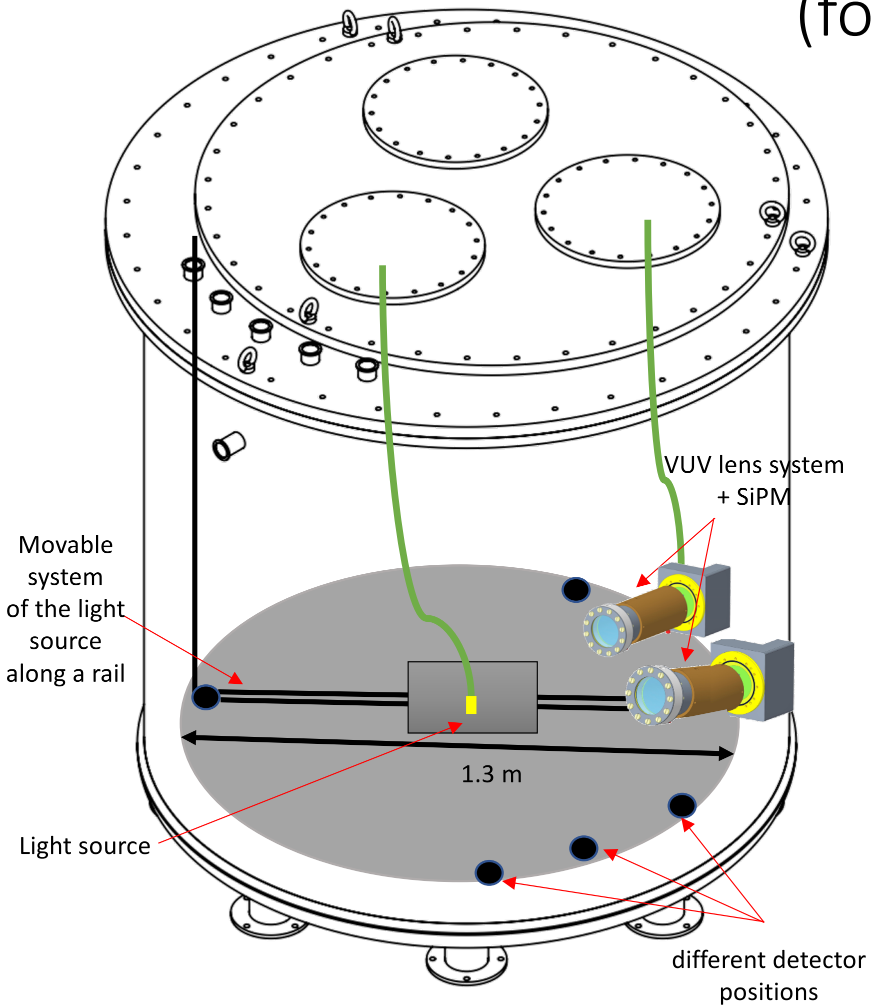


Evaporation rate
→ 0.7 l/h if the N2 level is at 10 cm
→ 2 l/h if the N2 level is at 1 m

Installed since 2020 and already used for other cryogenic tests!!

Future tests in ARTIC

(for lens or Hadamard matrix)



New elements:

- UV light source transported on fiber to the desired position (Hg lamp + monochromator + fiber)
- Movable support for the light source along a rail
- Sensor support
- 200 l of LAr

Next steps

- Precise simulations in GRAIN

- TESTS :
  - With new set of lenses
    - bigger dimension (try to cover the 1300 distance in GRAIN)
    - different focal lenght

  - in water (now)
  - in LAr with external source light (mid 2022)
  - in Xe doped Lar for detecting cosmics (end 2022)