Optics and reconstruction with lenses

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CSN1 Review of SAND

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DUNE

Lens-based optical readout for GRAIN

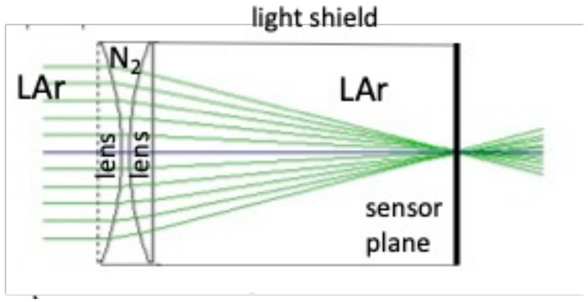
- Purpose of optical detectors:
  - Spatial reconstruction of the events
  - Time reference for triggering and selecting beam interactions against background
  - Calorimetric measurement of the energy deposited in GRAIN
- Lens-based optical readout – an innovative readout system:
  - Optical imaging cameras taking pictures of neutrino interactions
  - VUV light detection and low materials light transmittance in VUV

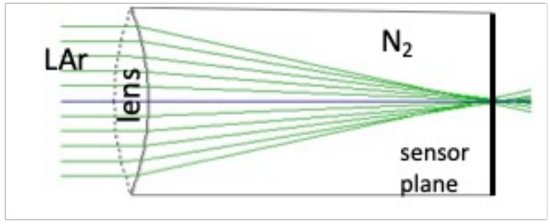
Materials and design

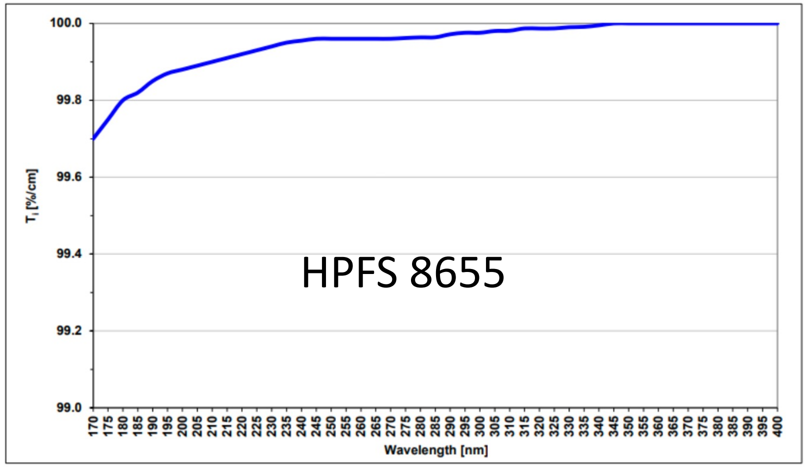
- Materials
  - Fused silica HPFS 8655 need of xenon doping of Argon
  - Alternative option: usage of MgF2 – no need for xenon doping

Both successfully tested in LN_2

- Design
  - Type A: Two plane-convex lenses → gas between the two lenses
  - Type B: Single bi-convex lens → gas between the lens and the sensor
- SiPMs:
  - Matrix with 32x32 SiPMs with different sizes:
  - (1mm, 2mm -> baseline, 3mm)







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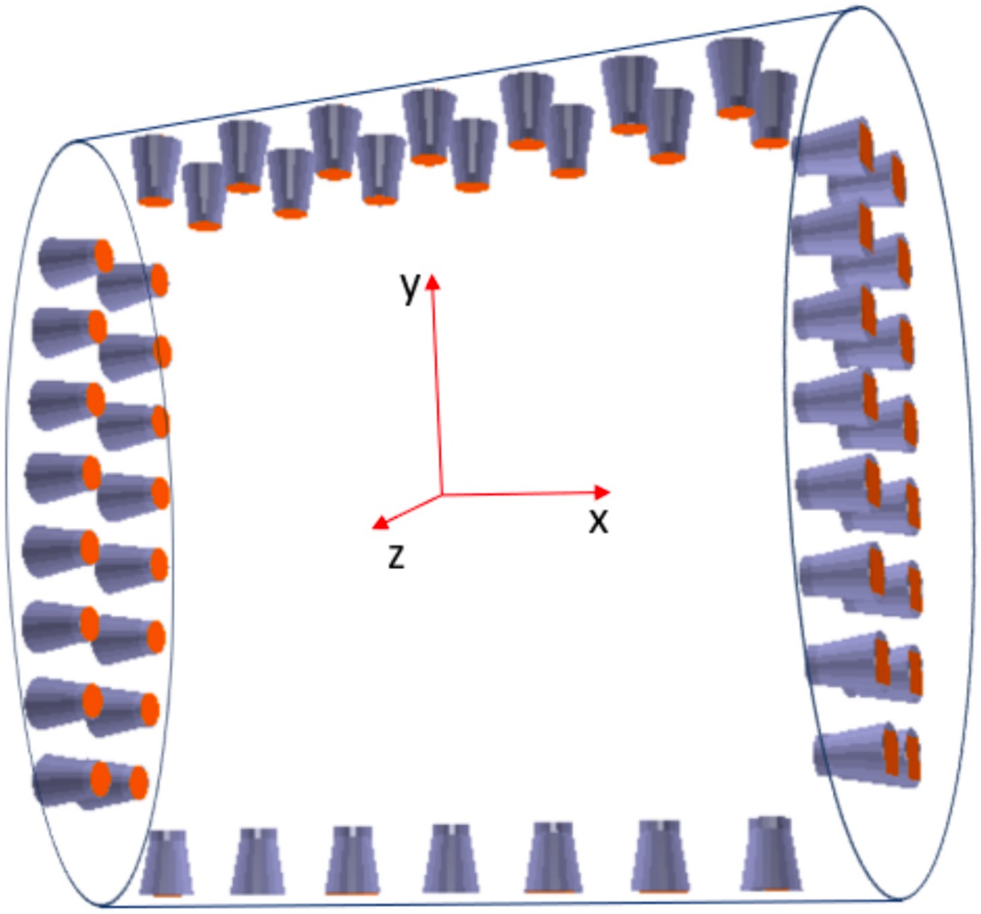
Lens-based configuration

- FoV: cone of semi-aperture 18°
- Track distinguishable distance > 40 cm from camera
- Distribution to ensure every point is visible by at least 1 camera
- 53 cameras: 16 on each side, 14 in the top, 7 in the bottom
- Matrices: 32x32
- SiPM dimension: 2x2 mm^2



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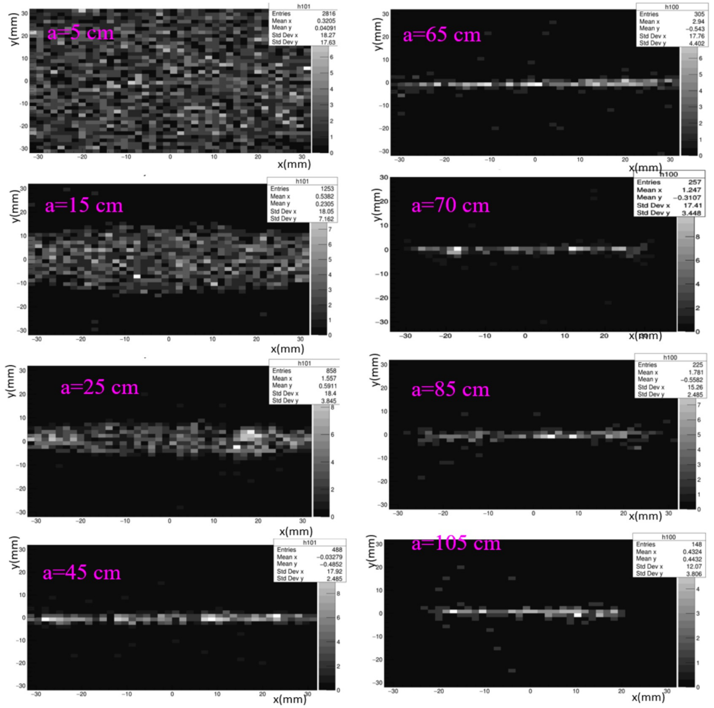
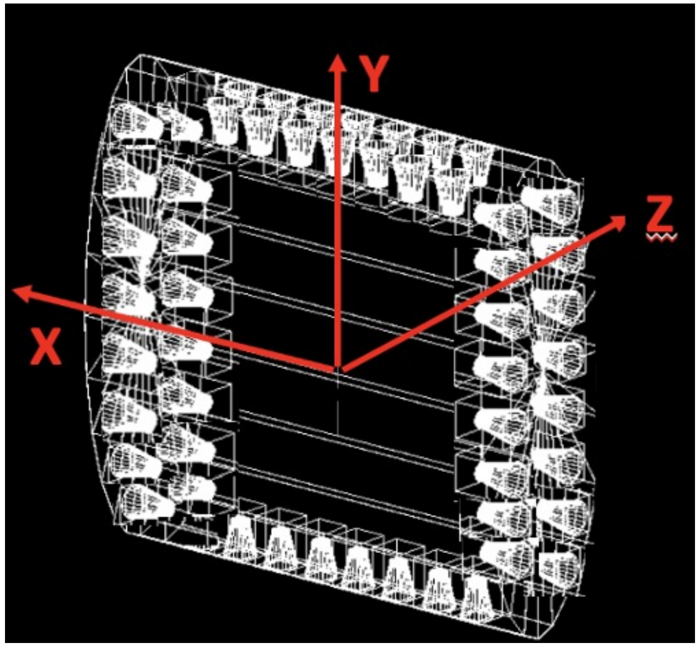
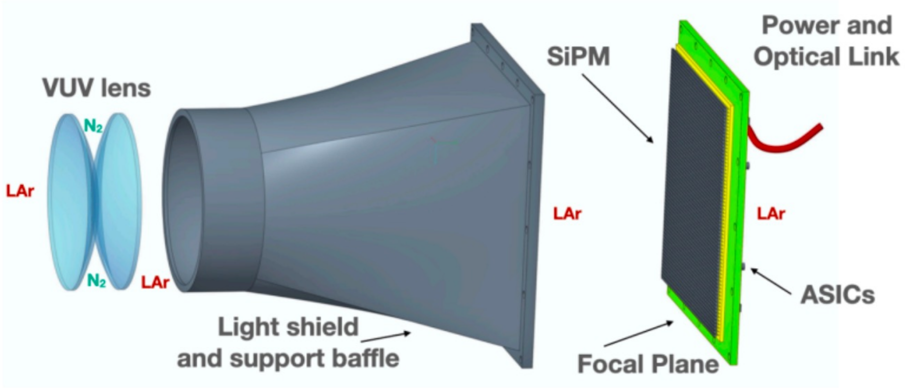
Example of the simulation results

- Geant4-based simulation framework implemented
- Capability to simulate both single interactions and spills

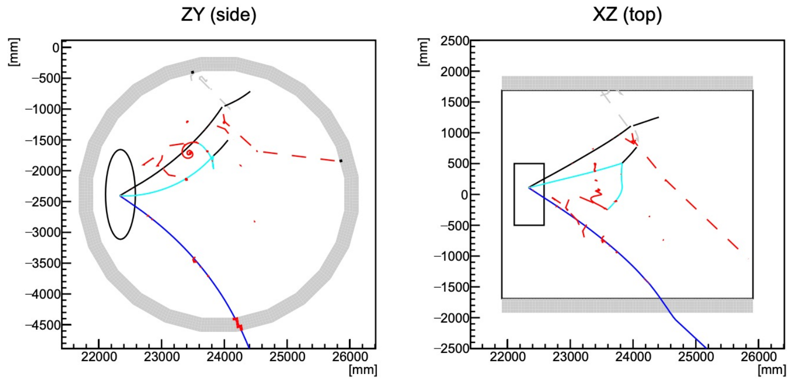


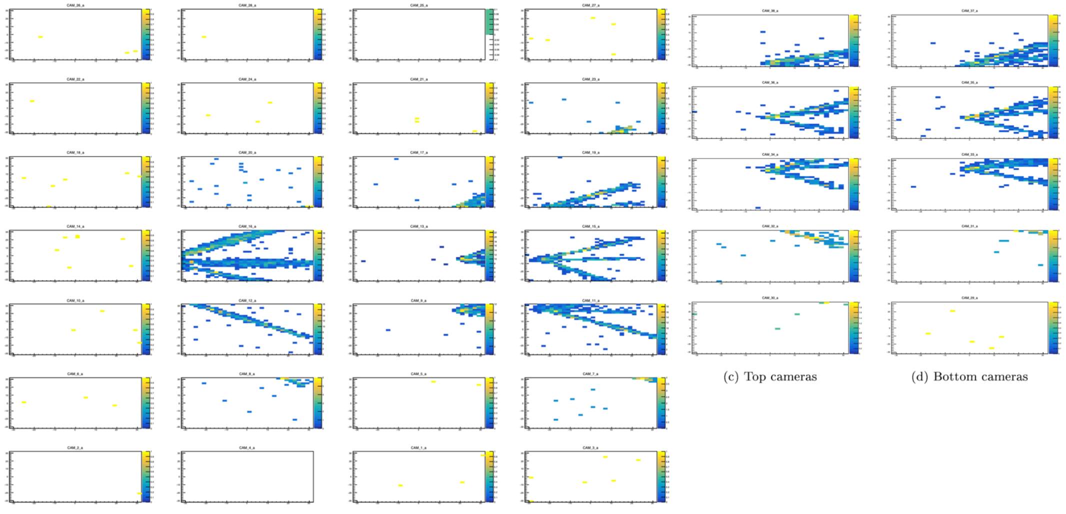
1 GeV muon parallel
to the lens central plane





Grain performance
reco and track containment

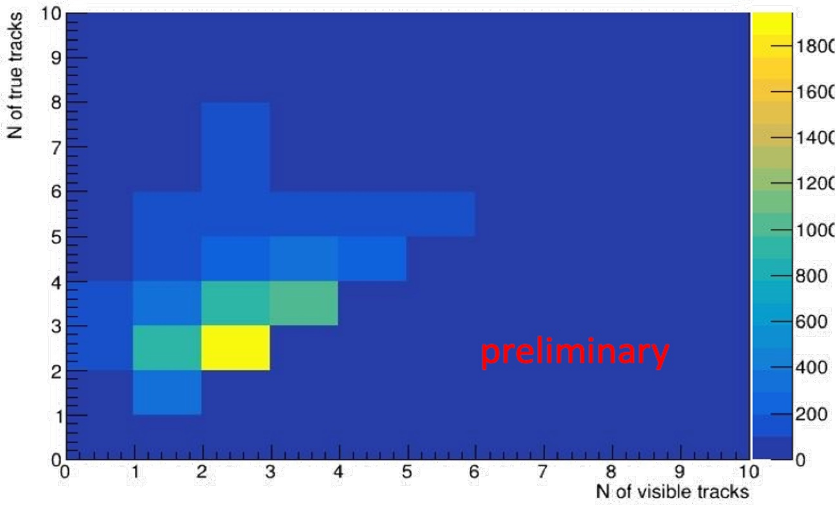




(a) Left cameras
(b) Right cameras
(c) Top cameras
(d) Bottom cameras

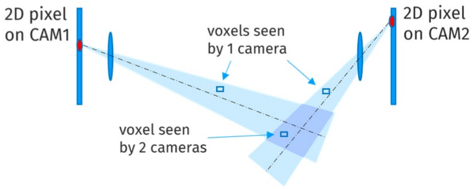
True \ Reco	Contained	Not contained
Not contained	247 (~ 3%)	8269 (~ 97%)
Contained	3301 (~ 74%)	1186 (~ 26%)

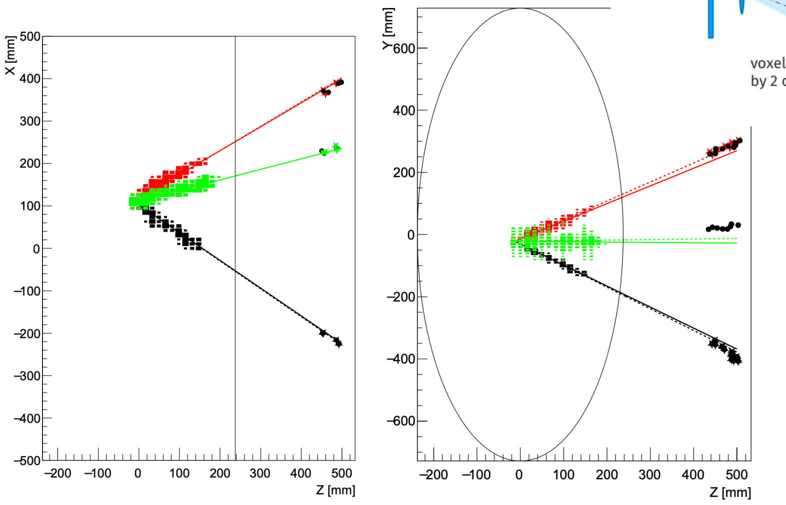
15k ν_μ CC sample and 5 cm FV cut from the cryostat walls
GRAIN+STT info used here



GRAIN performance -track reconstruction

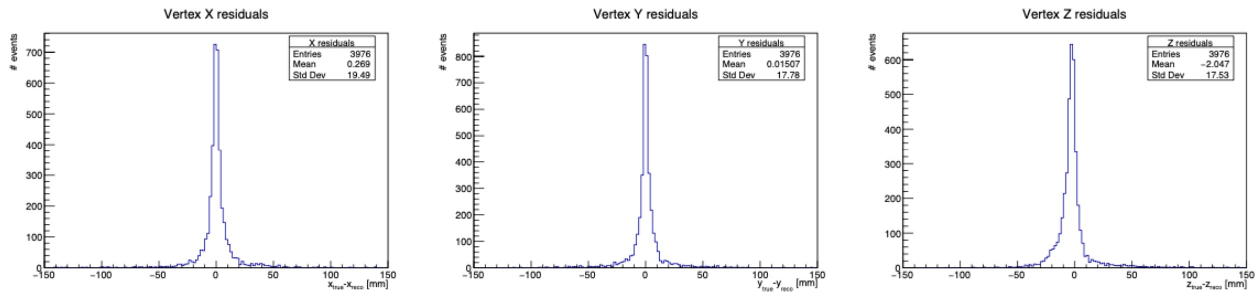
- Track reconstruction in 2 steps:
- 2D analysis of the camera images and fit of the tracks
- 3D matching of the different tracks based on projective geometry or voxelization





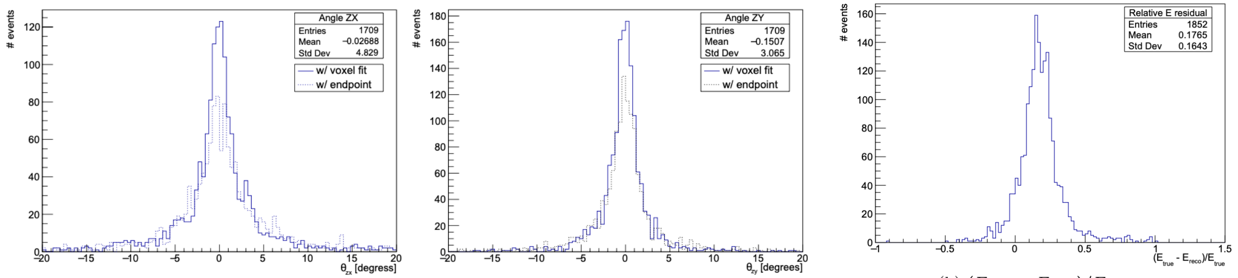
(a) ZX (top) (b) ZY (side)

- Vertex detection performance



(a) (b) (c)

- Angular resolution, energy resolution

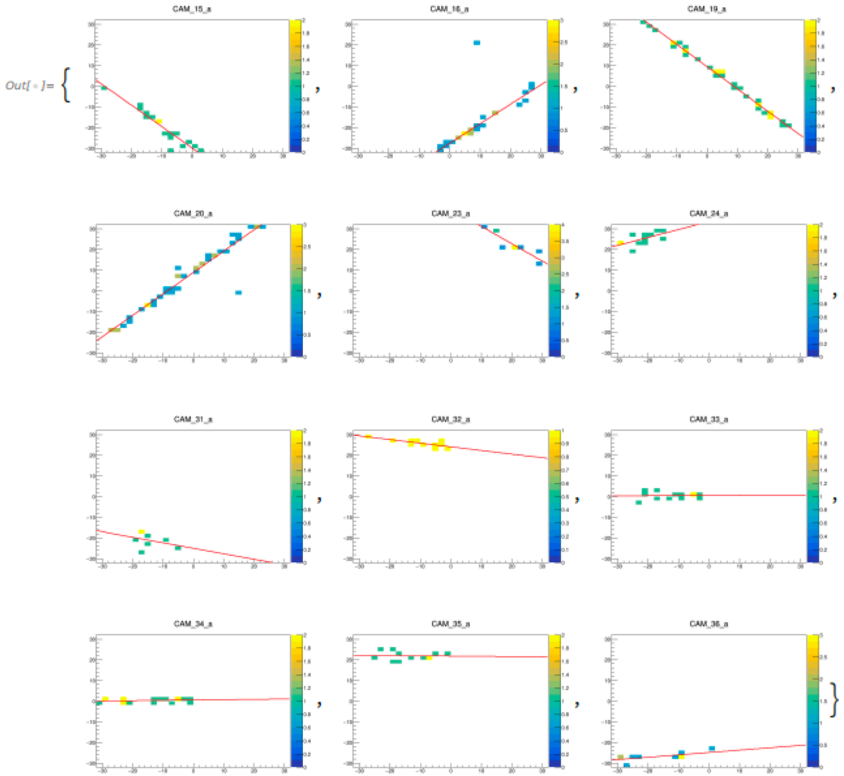


(a) Angle ZX (b) Angle ZY (b) $(E_{reco} - E_{true})/E_{true}$

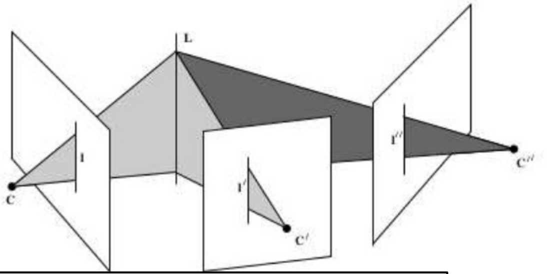
More details here

Projective geometry

- Algorithm for track reconstruction under development by Lecce group



- Single track: tested
- Test with 2 tracks from neutrino interaction: in progress



Global Multiple View Reconstruction of a Track

- The track is detected/seen by N cameras
- There are $M = \frac{N!}{2!(N-2)!}$ possible double-view reconstructions for the track
- We perform M reconstructions
- We take the mean value of the M possible reconstructions for each line parameter (director cosines (l, m, n))

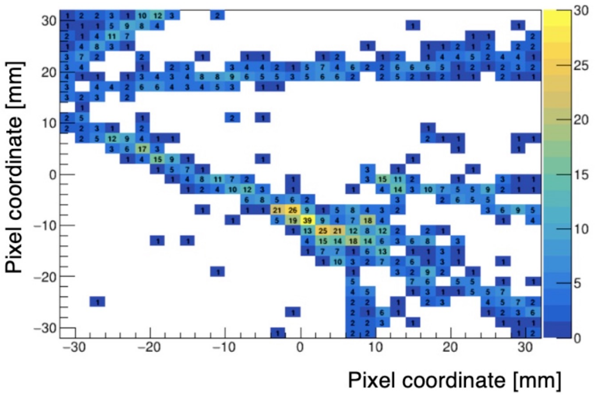
$$l = \frac{\sum_{i<j}^{N} l_{ij}}{M} \quad m = \frac{\sum_{i<j}^{N} m_{ij}}{M} \quad n = \frac{\sum_{i<j}^{N} n_{ij}}{M} \qquad (21)$$

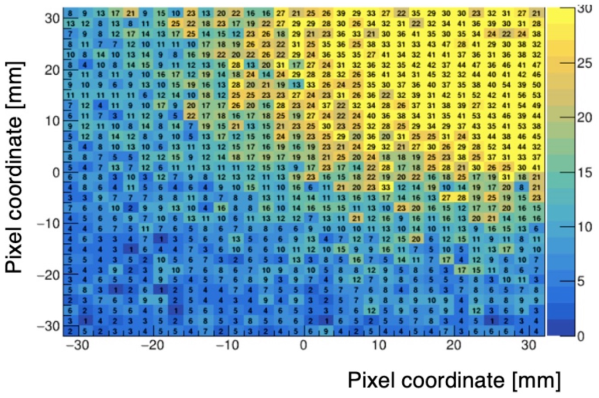
i, j camera indices

- Analysis of intercepts of the M reconstructions

ASIC requirements for GRAIN

- The simulation output is used for studying a dedicated ASIC architectural design
- Basic framework considerations
- A dedicated requirements document has been released





Document with ASIC requirements

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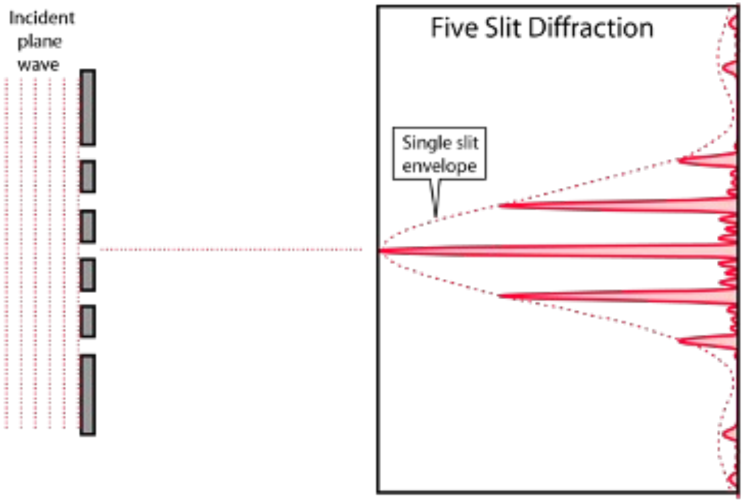
LArRI:

A new setup to measure **L**iquid **Ar**gon **R**efractive **I**ndex

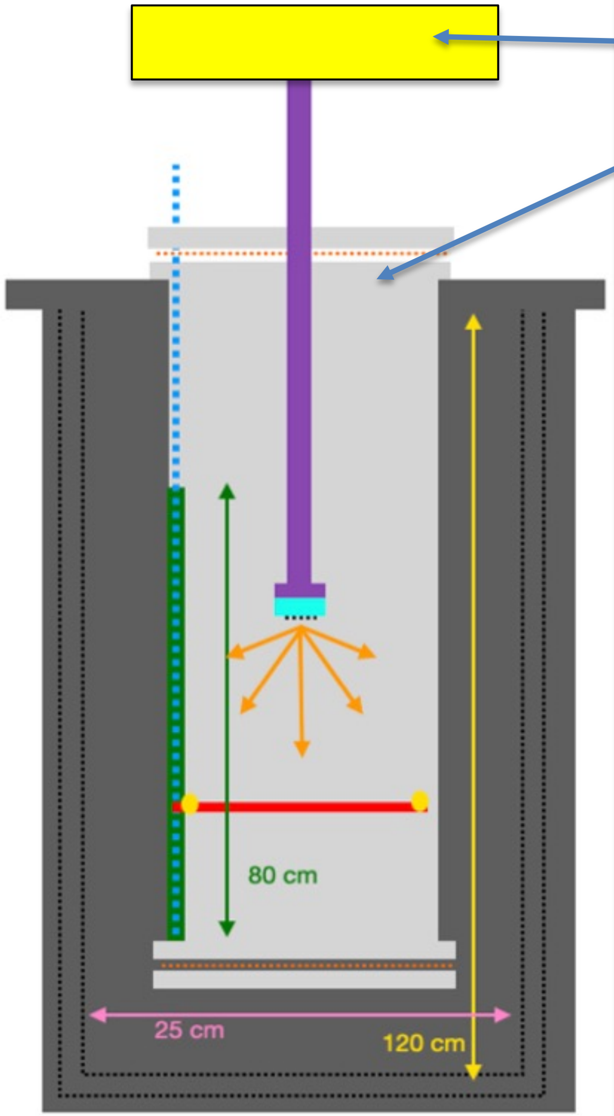
- LAr: most widely used scintillator, excellent properties at low cost
- Xe-doping shifts s. peak to λ_s=175 nm: increased uniformity, simplified detection
- **Main goal**: direct measurement of LAr refractive index crucial for imaging systems
- Further goals:
  - Characterize optical properties of LAr
    - Measure dispersion relation
    - Measure the attenuation length
  - Extend to other liquified noble gases



- A diffraction grating is used and when immersed in liquid the diffraction peaks position depends on $\lambda_L = \lambda_0/n$
- We need a light source:
  - Peak @λ_s, coherent and monochromatic

Key idea: compare the diffraction patterns produced by light in LAr and vacuum

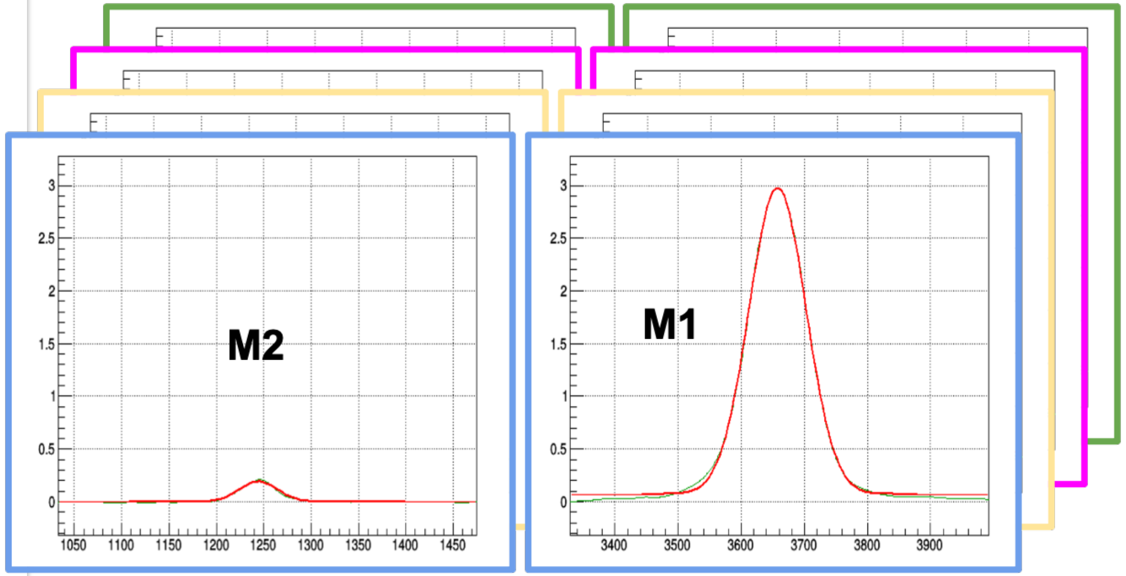
LArRI: setup and measurement strategy

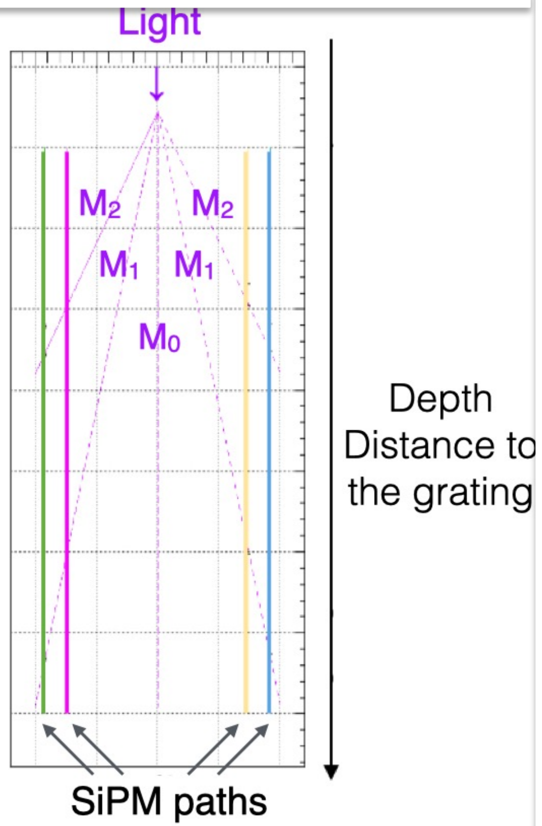


Warm part: low-pressure mercury lamp (@184.9 nm) + optical setup

Cold part: chamber & cryostat + diffraction grating + moving system to scan on the vertical axis (more compact) + light detectors (SiPMs)

Analysis strategy: simultaneous fit of the position of the $M_{1,2}$ diffraction peaks in vacuum and liquid to measure n(LAr)





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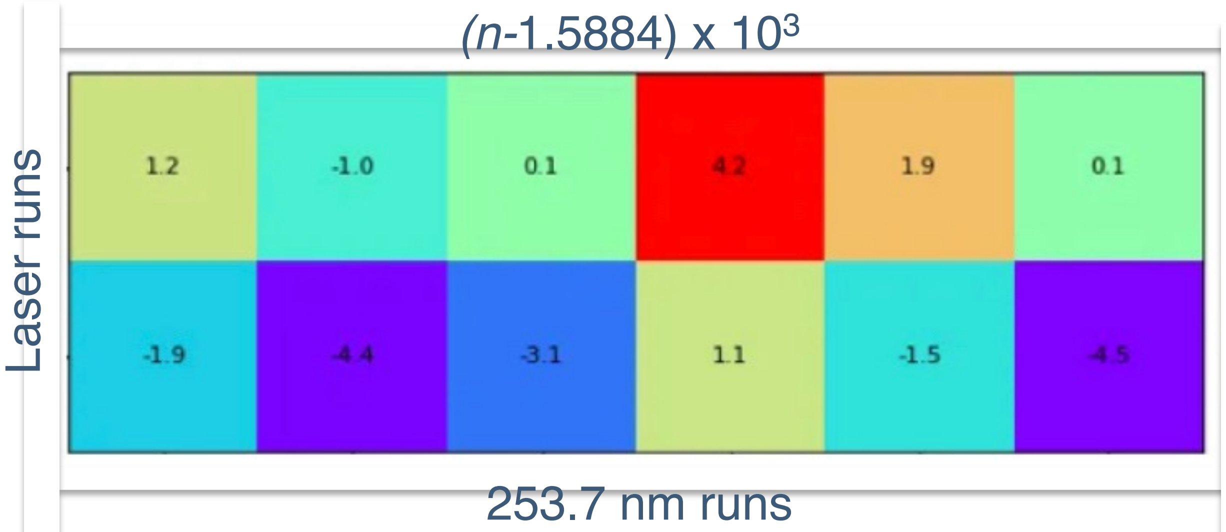
LArRI: results and next steps

- Consistency check measurements:
  - Same medium (vacuum), 2 wavelengths
  - Scans @402.9 nm vs scans @253.7 nm
  - Results shown as deviations x 10^3



- Compatibility of few parts per thousand!

- Preliminary results in liquid argon:
  - Refractive index @402.9 nm nLAr = 1.24(1)
  - Refractive index @253.7 nm nLAr = 1.24(1)
  - Refractive index @184.9 nm nLAr = 1.29(5)
- Conclusions:
  - System fully operational in vacuum and liquid
  - Analysis strategy validated
- Steps moving forward:
  - Evaluation of the systematics
  - Improve measurements @185 nm
  - Take runs in LAr to achieve the target