Introduction to GRAIN detector

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DUNE CSN1 Review

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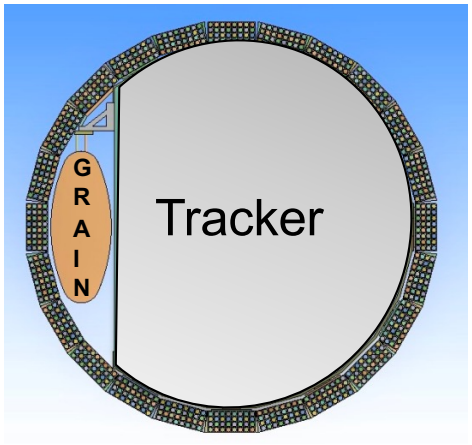
Why GRAIN in SAND?



- DUNE ND complex needs to constrain systematic uncertainties
- SAND is the unique detector permanently on axis

GOALS of SAND

- monitor for beam parameter changes on a weekly basis
- perform cross-section studies on different nuclear targets
- ν_μ , ν_e , $\bar{\nu}_\mu$, $\bar{\nu}_e$ on-axis sample

Interactions on ECAL

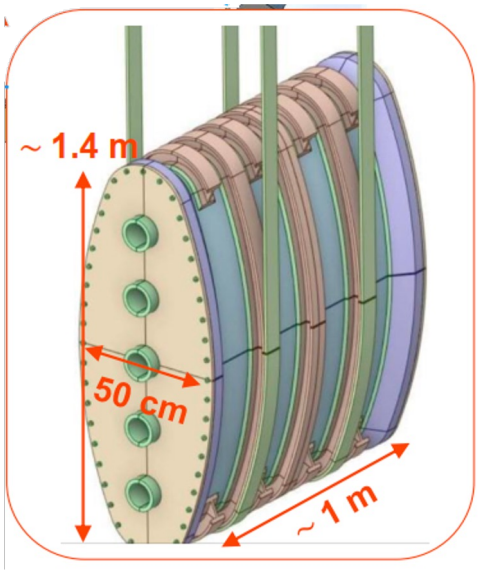
Interactions on Tracker

Interactions on GRAIN

for a robust LBL analysis in combination with ND-LAr+TMS

What is GRAIN?

GRanular Argon for Interactions of Neutrinos



It is a **passive** target:

- ~1 ton FV LAr in a magnetized volume
- compromise between mass (event statistics and thickness)
- to study of v-Ar interactions with downstream tracker/calorimeter

It is an **active** target:

it is instrumented with sensors:

for collecting UV scintillation light with arrays of SiPMs

for performing imaging of the event

for vertex location, event topology, time information

Events in GRAIN

Target	CP optimized FHC (1.2MW, 2y)				CP optimized RHC (1.2MW, 2y)			
	ν_μ CC	$\bar{\nu}_\mu$ CC	ν_e CC	$\bar{\nu}_e$ CC	ν_μ CC	$\bar{\nu}_\mu$ CC	ν_e CC	$\bar{\nu}_e$ CC
CH_2	13,010,337	624,330	192,118	31,902	2,035,973	4,870,562	91,004	69,278
H	1,222,576	111,574	18,396	5,557	194,216	906,130	8,712	12,434
C	1,547,011	67,294	22,799	3,458	241,710	520,287	10,800	7,460
Ar	3,114,331	121,506	46,384	6,503	480,862	936,489	21,932	13,867
Pb	62,127,600	2,507,940	923,012	130,680	10,375,400	18,222,200	437,284	265,304

0.1 neutrino interactions per spill

A good sample for:

- inclusive/exclusive CC sample with a magnetic spectrometer ← **ND-LAr+ TMS**
- cross-section constraints / tuning nuclear model
- a comparison with hydrogen interactions

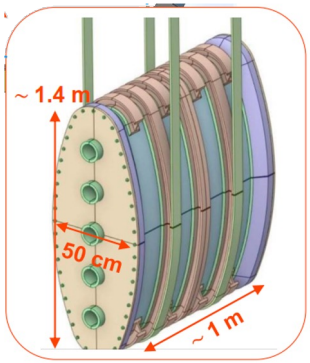
SAND multi-target

$$N_X(E_{rec}) = \int_{E_\nu} dE_\nu \; \Phi(E_\nu) \; P_{osc}(E_\nu) \; \sigma_X(E_\nu) \; R_{phys}(E_\nu, E_{vis}) \; R_{det}(E_{vis}, E_{rec})$$

at NEAR ~1

SAND LAr interactions

GRAIN requirements



As a **passive** target:

- thin volume (minimum number of X_0)
- thin cryostat

Impose limits on cryostat **size** and **material**

There is the needs of R&D for imaging

As an **active** target:

- contribute to the neutrino energy reconstruction, for **recovering the energy** lost in LAr
- identify the **interaction vertex** and **tracks** of contained particles (protons, pions)
- matching with back-propagated tracks from the tracker.
- select interactions in terms of exclusive final state particles

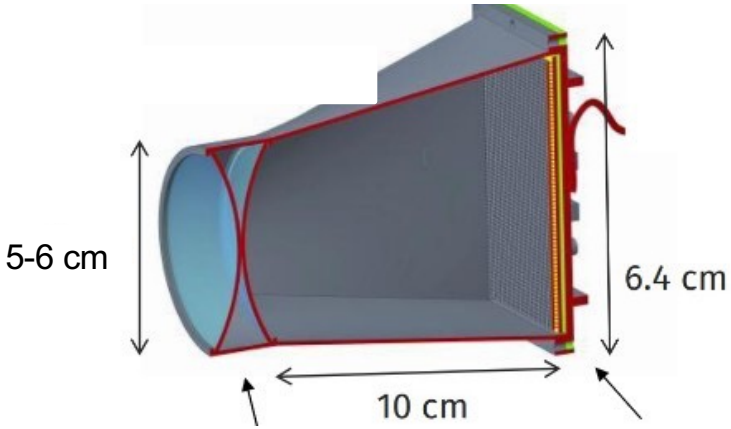
widens phase space (large angles w.r.t. beam axis, lower momentum + short particles not exiting).

- exploting the high resolution O(200 ps) **timing information**
  - SAND is the unique fast detector in the ND complex

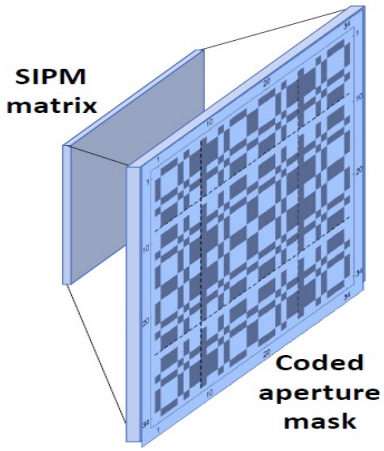
R&D for VUV cameras

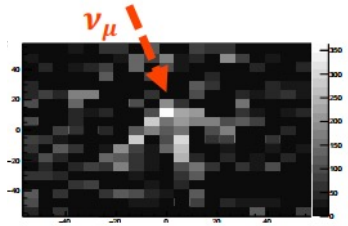
- **Two possibilities** for the optical system:

Lens-based optical detector



Coded mask-based optical detector





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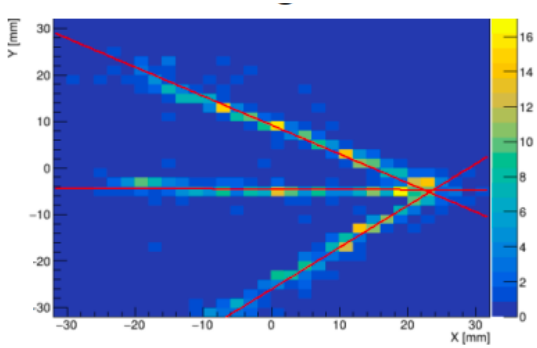
- **Similar** SiPM **32x32 matrixes**:
  - 2 mm x 2 mm for lenses or SiPM of 3 mm x 3 mm for masks
- A **unique ASIC** specifically designed for GRAIN

Very different algorithm reconstruction

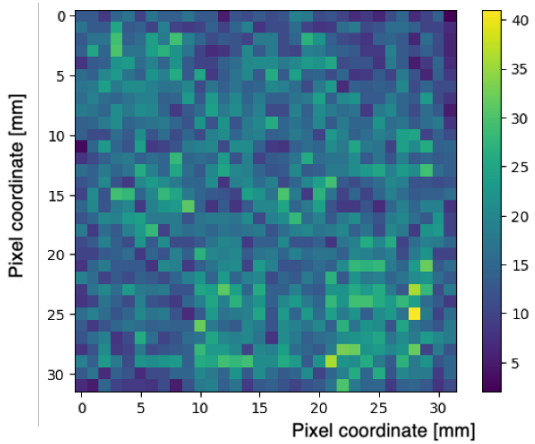
Lens reconstruction chain

- Identifying tracks and vertex in each image



- Combining the different cameras
- - by volumes intersection
  - Tested on a 100k interaction sample
  - by geometric projective algorithm
  - tested on single points and single tracks

Coded mask



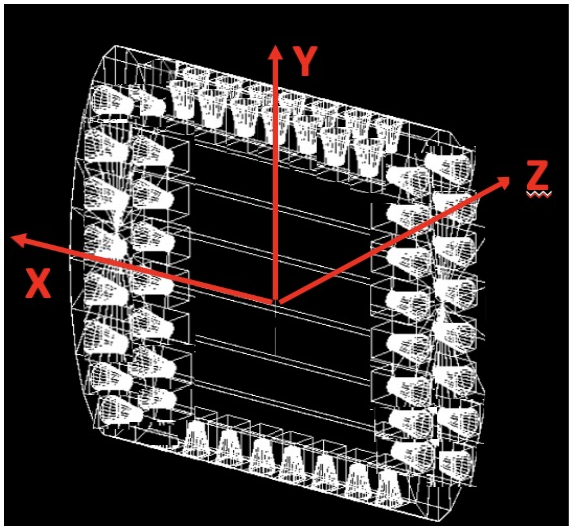
- by an iterative algorithm that needs GPU

-Tested on a first v-Ar interaction sample

Parallel studies

For each option the optimized layout in GRAIN is under study

Lens-based optical detector

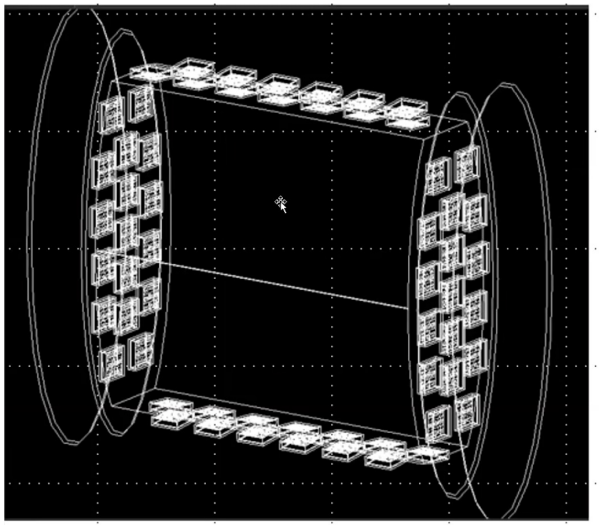


58 cameras

Matrices: 32x32

SiPM dimension: 2 mm x 2 mm

Coded mask-based optical detector



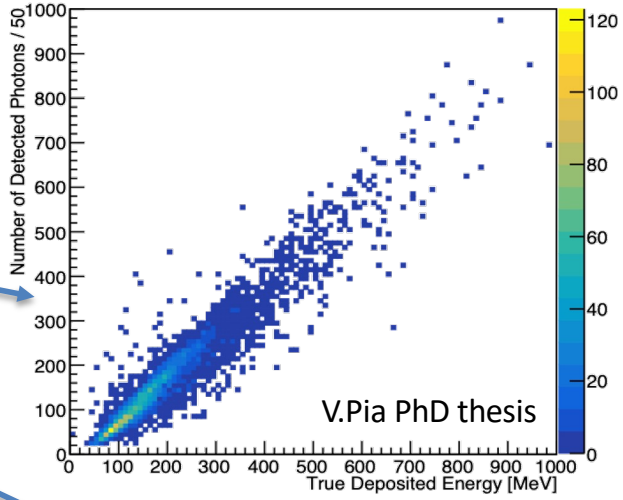
60 cameras

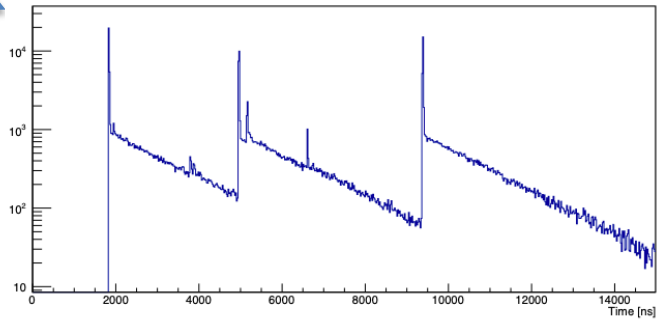
Matrices: 32x32

SiPM dimension: 3 mm x 3 mm

Expected performances

- Goals:
  - **Calorimetrical** reconstruction
  - **Event identification** within a spill
  - **Track** reconstruction

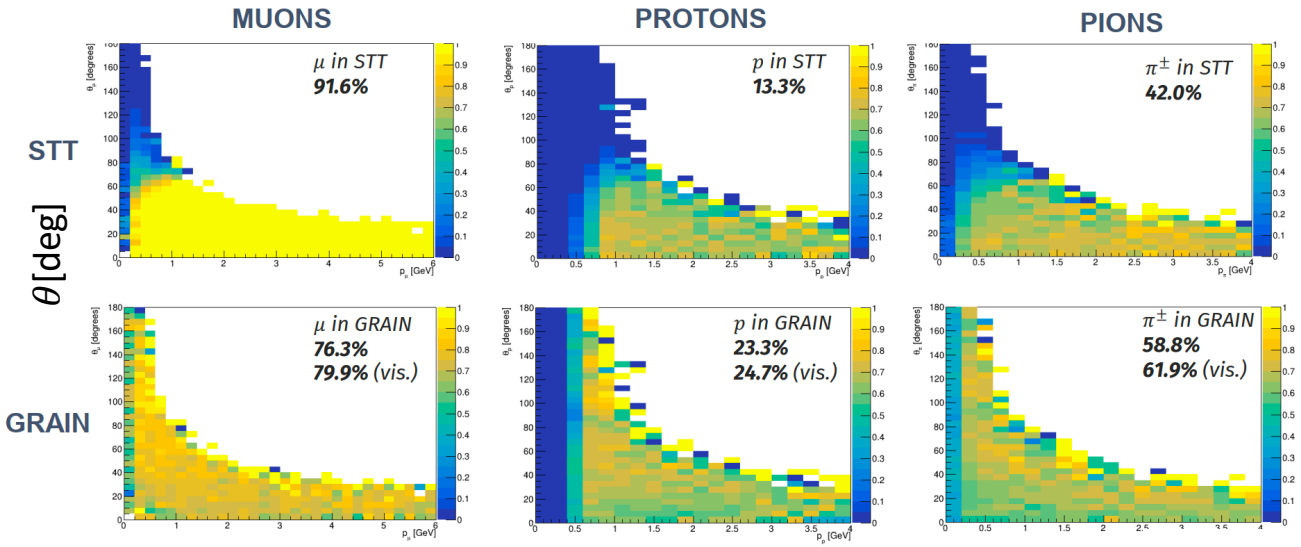




Photon distribution in a spill time

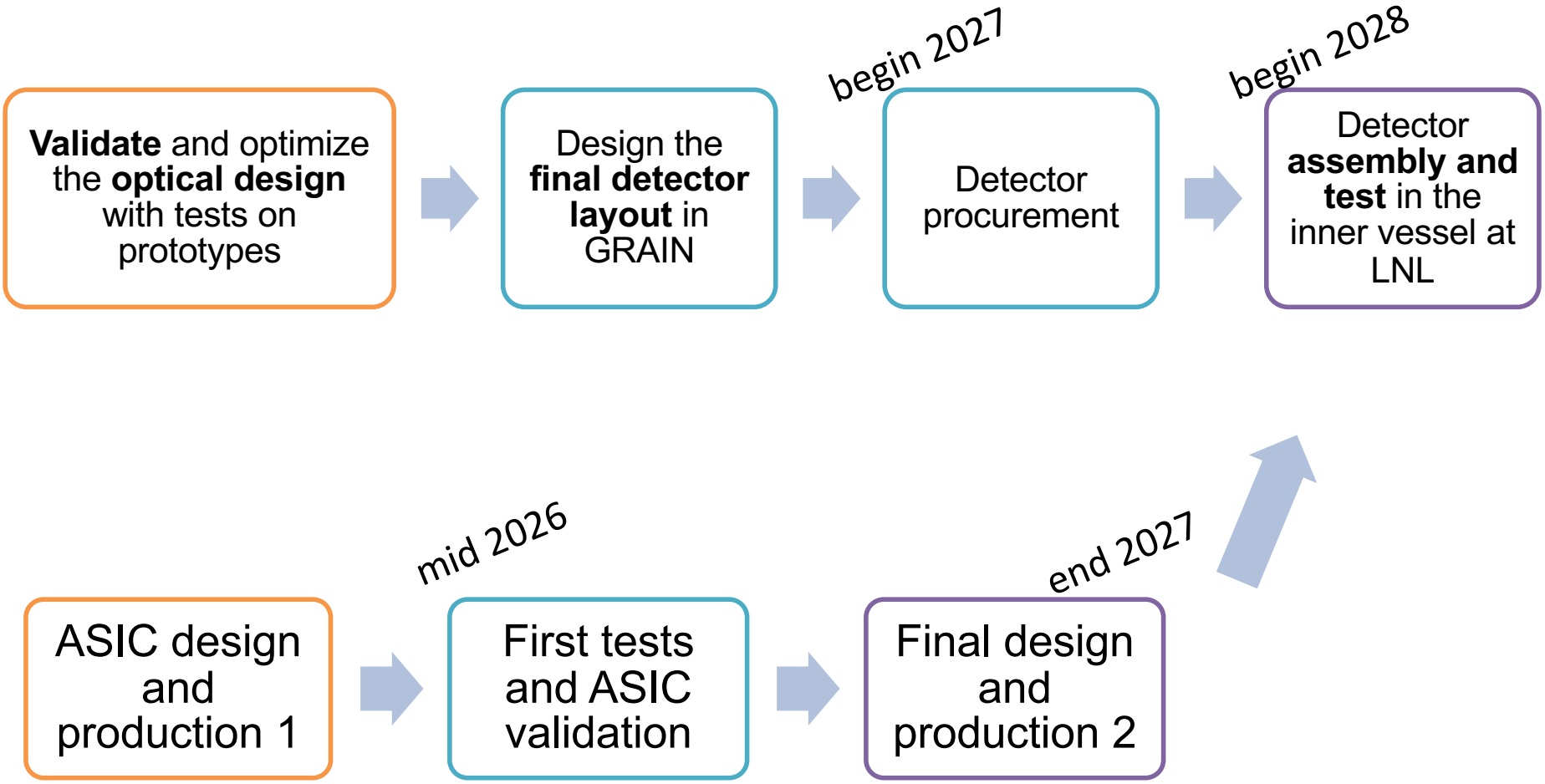
Acceptance

for particles produced in GRAIN (FHC sample)



M.Vicenzi PhD thesis

Roadmap and milestones



Conclusions

- GRAIN is an important detector for enhancing SAND capabilities
- The R&D on the optical detectors has just started the testing phase
- The path toward GRAIN assembly and construction is well-defined