INFN BOLOGNA
Istituto Nazionale di Fisica Nucleare
Sezione di Bologna

IMAGING OF SCINTILLATION LIGHT WITH CODED APERTURE MASKS

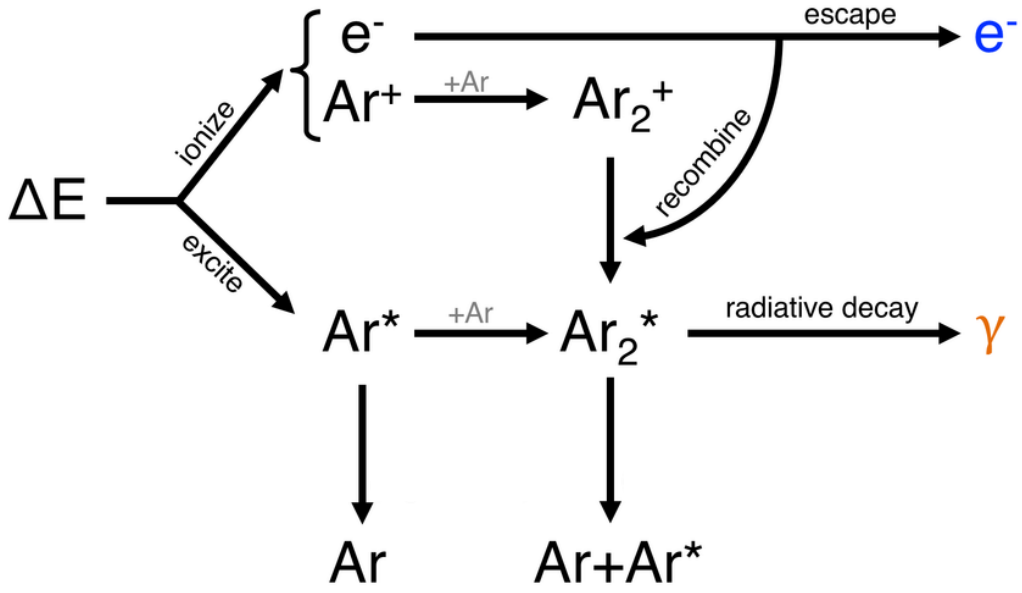
F. Mei

INFN Workshop on Future Detectors 2025

Sestri Levante, 18-3-2025

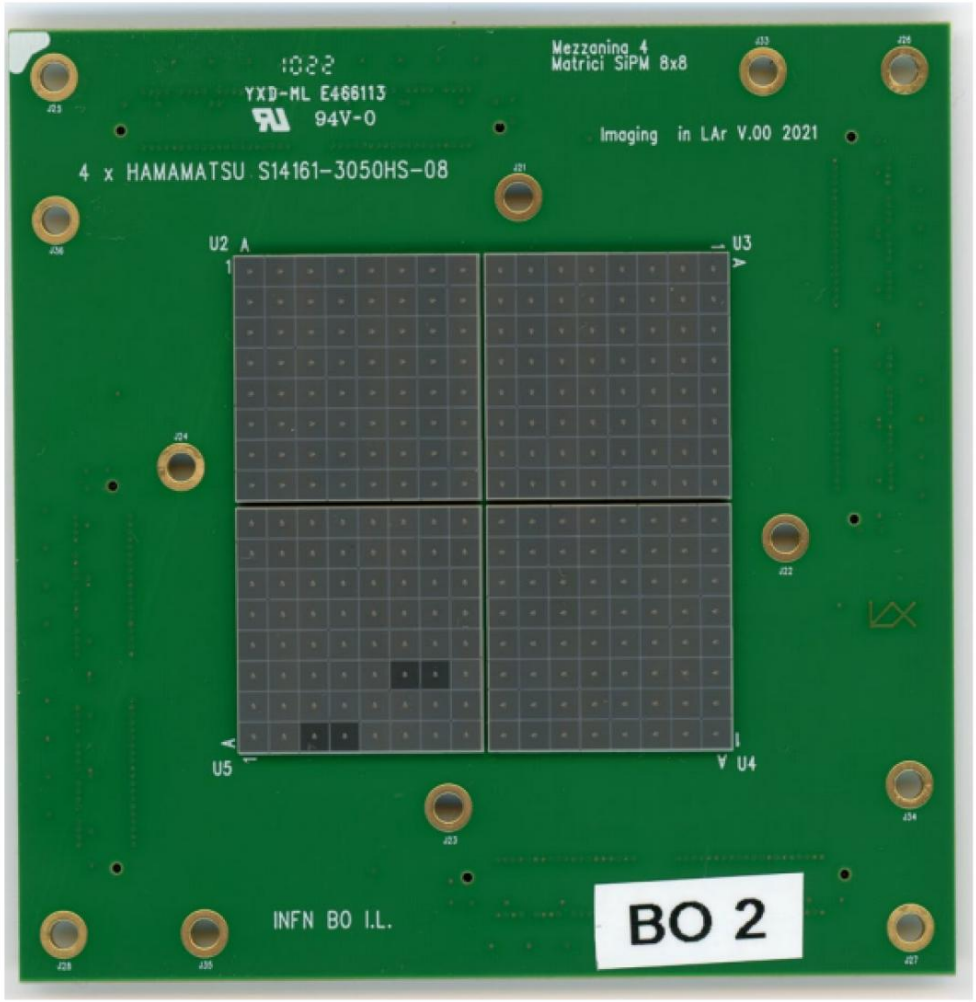
Scintillation Light in Nobel Liquid Detectors

- Noble liquid detectors have been used extensively in Dark Matter and neutrino physics, usually paired with a TPC collecting **ionization charge**.
- Due to the relatively **slow charge drift time**, this technique is not suitable in some high-rate environments such as accelerator-based neutrino experiments.
- Imaging of scintillation light with photographic cameras may offer a suitable alternative to charge collection. **Capturing images of the emitted light from multiple views** will allow the reconstruction of an event.
- Moreover, such a detector would not require an electric field or its associated hardware.



Charge drift time (Ar):	$> 1\ \mu s$
Scintillation light emission time (Ar):	~ 7 ns

Imaging System

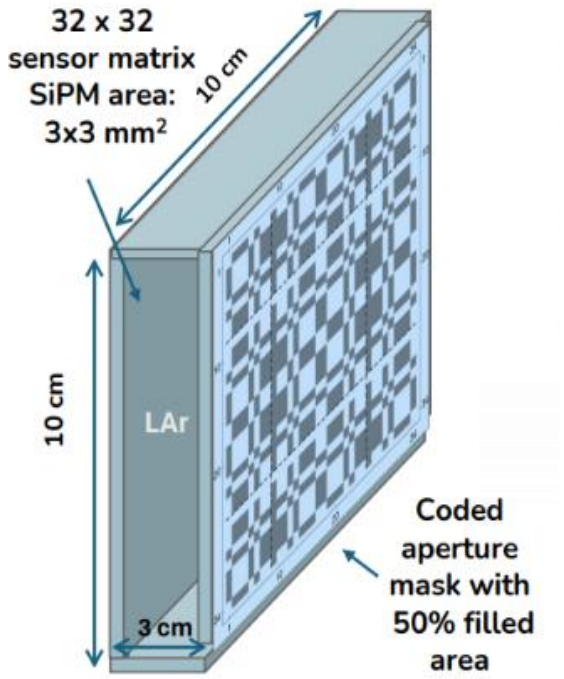


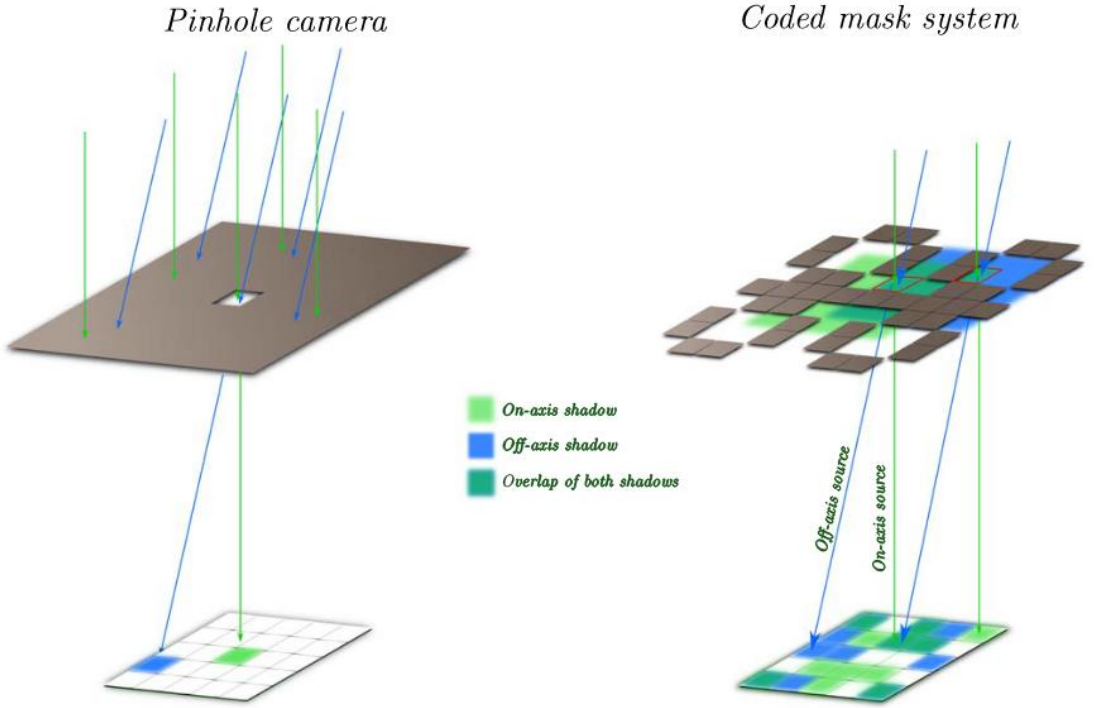
- Scintillation light in Argon or Xenon is emitted in the vacuum ultraviolet range. To achieve sufficient sensitivity, cameras are based on dense **SiPM matrices**, coated with a wavelength shifter.
- **Cryogenic operation** ensures very low noise.
- Most optical materials have low transmissivity at this wavelength. We are studying alternative techniques using **coded aperture masks** (array of opaque and transparent elements), already used in X-ray imaging and astrophysics.

Coded Aperture Masks

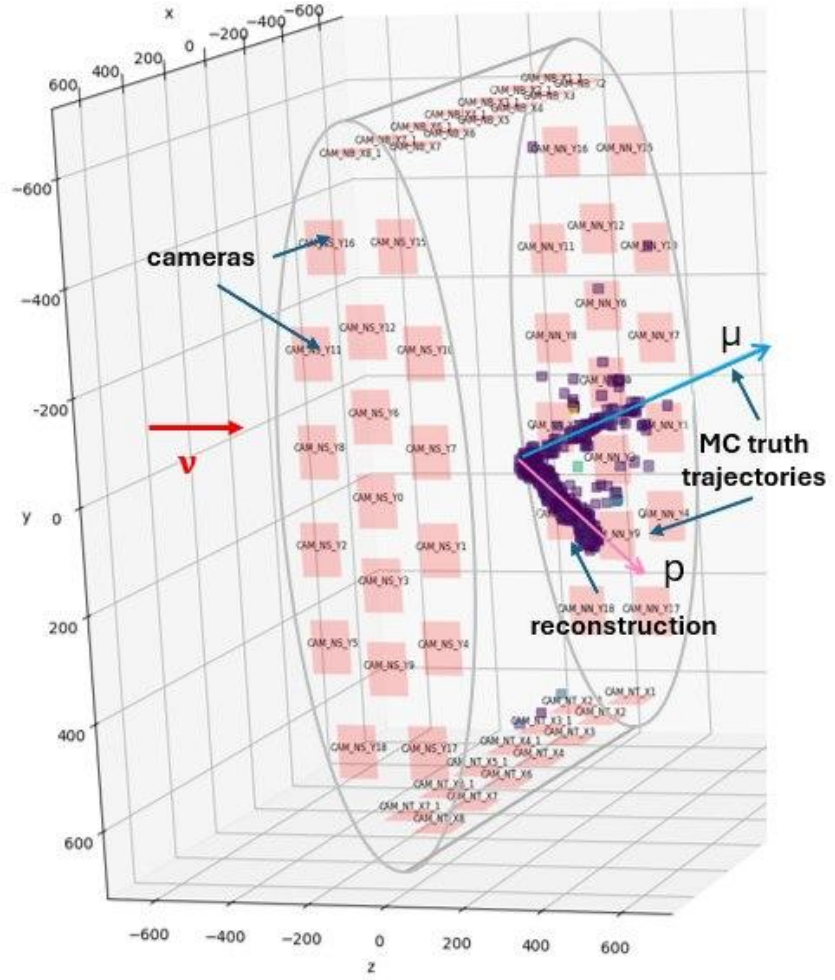
- A classic pinhole camera can deliver excellent angular resolution, but it is inefficient owing to count loss caused by the opaque material.

- A coded aperture mask camera registers an **overlapping set of multiple images**, each set associated with one point source, **preserving angular resolution while improving efficiency**.





Event Reconstruction



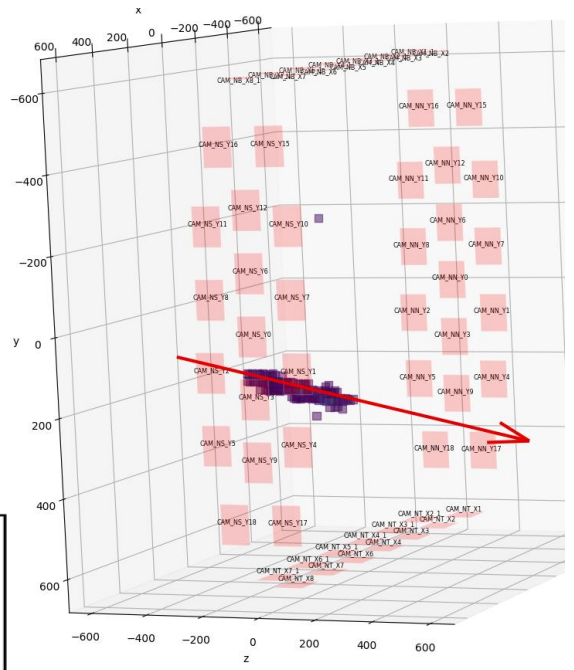
Display of a ν_μ charged current quasi-elastic interaction reconstructed with 60 cameras placed across the detector surface.

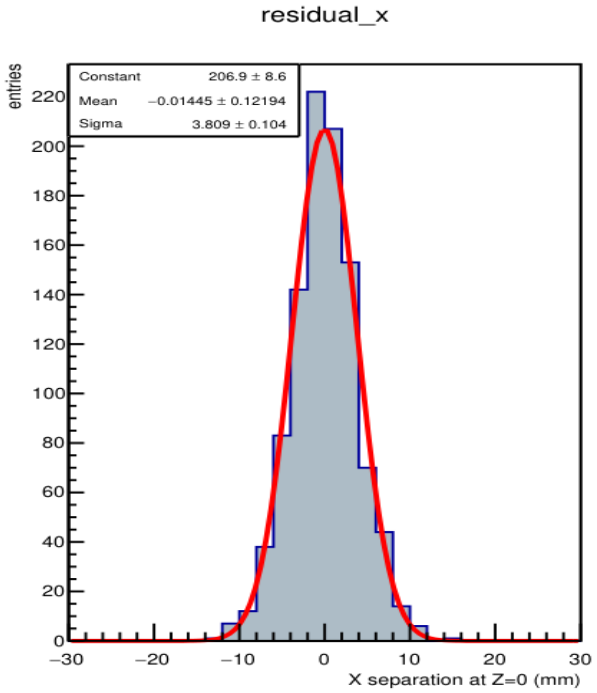
- The goal is to reconstruct the **3D distribution of the scintillation light source** recorded by the sensors, combining views from multiple cameras.
- This nontrivial task is performed using the **Maximum Likelihood Expectation Maximization** iterative algorithm. For this computation, the fiducial detector volume is divided into voxels.
- The computationally expensive reconstruction is implemented using OpenCL kernels running on **GPU(s)**.

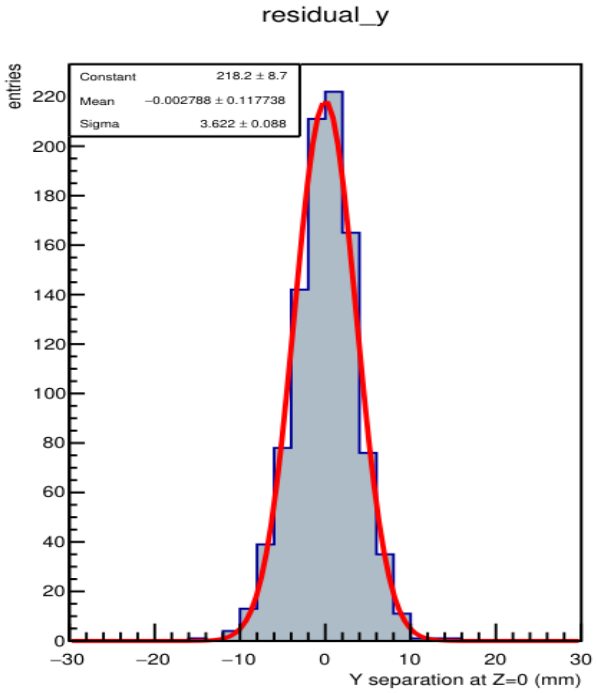
Performance from Simulations

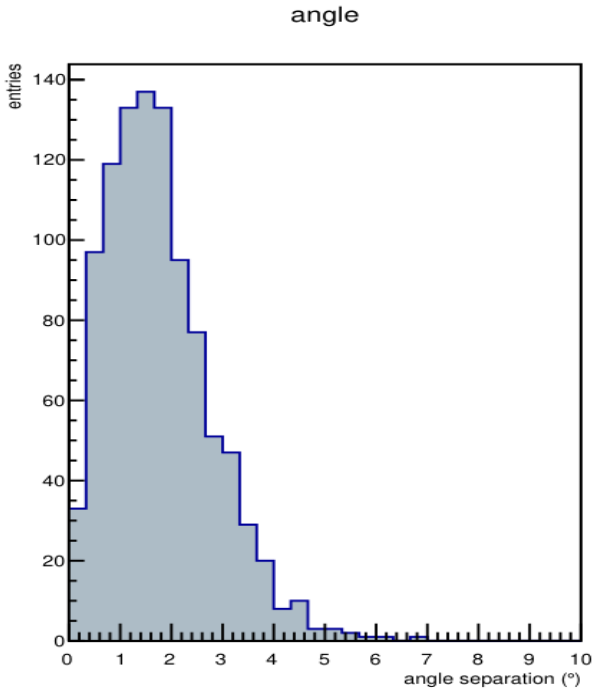
- Tracking is performed using a **weighted linear fit of voxel positions**, considering voxels with a score above threshold.

- The performance is evaluated with a simulated sample of 1 GeV muons, resulting in **few degrees of angular separation** and a resolution of 4 mm in residuals.









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THANK YOU FOR YOUR ATTENTION

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