

# Omnidirectional Photon Projection Chamber

synergy of Scintillation Cherenkov and Tracking

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# Time Projection of Electrons

- Electrons are dragged by field towards the anode.
- The principle of time projection

$$\Delta z = v\Delta t.$$

Optical readout provides the  $t_0$  to  $\Delta t$  at single-phased DUNE.

- Ion time projection has the similar detection principle.

# Photons vs. electrons

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# Photons vs. electrons

- Photons cannot be at rest, always traveling.
- No drifting field is needed.
- Ease of engineering, but cannot control the direction of propagation

$$\vec{r} = \vec{v}\Delta t.$$

- ① cover the detector with photo-sensors  $4\pi$ .
- ② time projection becomes a 3D.

# Large liquid scintillation and Cherenkov detectors

- Traditionally as calorimeters.
- Time-of-flight methods have long been employed to reconstruct event vertices.

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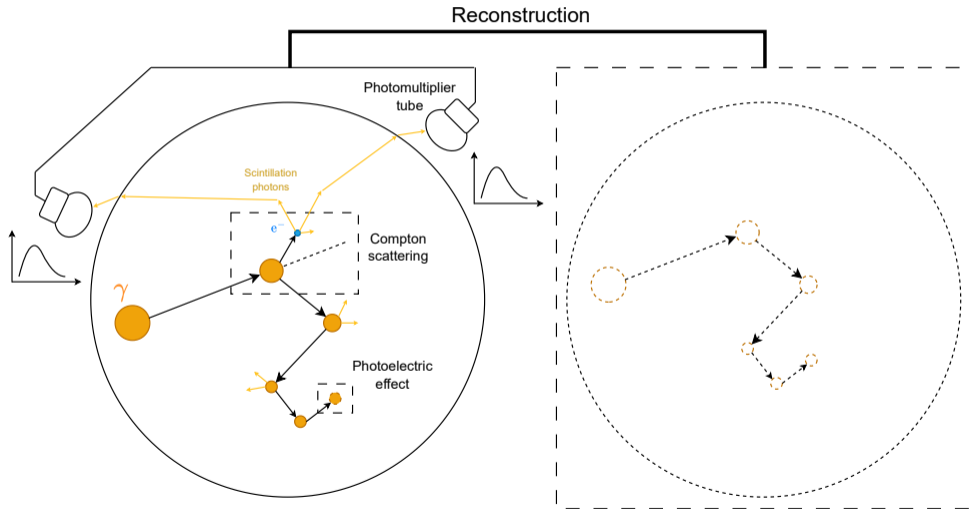
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## Photons travel much faster than drifting electrons

- ① 1 cm need ADC precision of 50 ps.
- ② Can be relaxed to 1 ns if  $\sim 400$  photons are detected.

# Dream of scintillation-Cherenkov-tracking detector



# Ambiguity of direction in 3D

$$\vec{r} = \vec{v}\Delta t.$$

- ① Hardware approach: measure the direction of incoming photon
  - ▶ development of lenses for liquid scintillation and Cherenkov detectors
- ② Solve the inverse problem with machine learning, in light of **computational imaging**.
  - ▶ extract particle interaction tracks from data analysis.
  - ▶ invertible full probabilistic modeling a.k.a. **probabilistic programming**

- ① A unified, fully probabilistic scintillation-Cherenkov reconstruction framework.
  - ▶ initially demonstrated by Borexino and SNO+.
- ② Reconstruction  $\gamma$  tracks at a series of light sources.
  - ▶ Demonstrated by Biller et al. and EXO-200, in terms of "multi-sited" events.
- ③ Incorporate energy and momentum conservation laws at each light source.
  - ▶ Kalman and particle filters needed, aka **sequential Monte Carlo**.

## Fully probabilistic detector optical response function

- A surrogate function by the theory inhomogeneous Poisson point process, [probe](#).
- Super-position of Poisson process provides natural modeling of scintillation-Cherenkov and multi-site events.
- → See Chuanhui Hao's tasks.

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## Inference of multiple light sources

- The number of light-sources are unknown.
- Changing number of parameters during inference.
- Reversible-jump Markov Chain Monte Carlo.
- → See Yiyang Wu's tasks.

