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Reducing background for Hyper-K's IWCD

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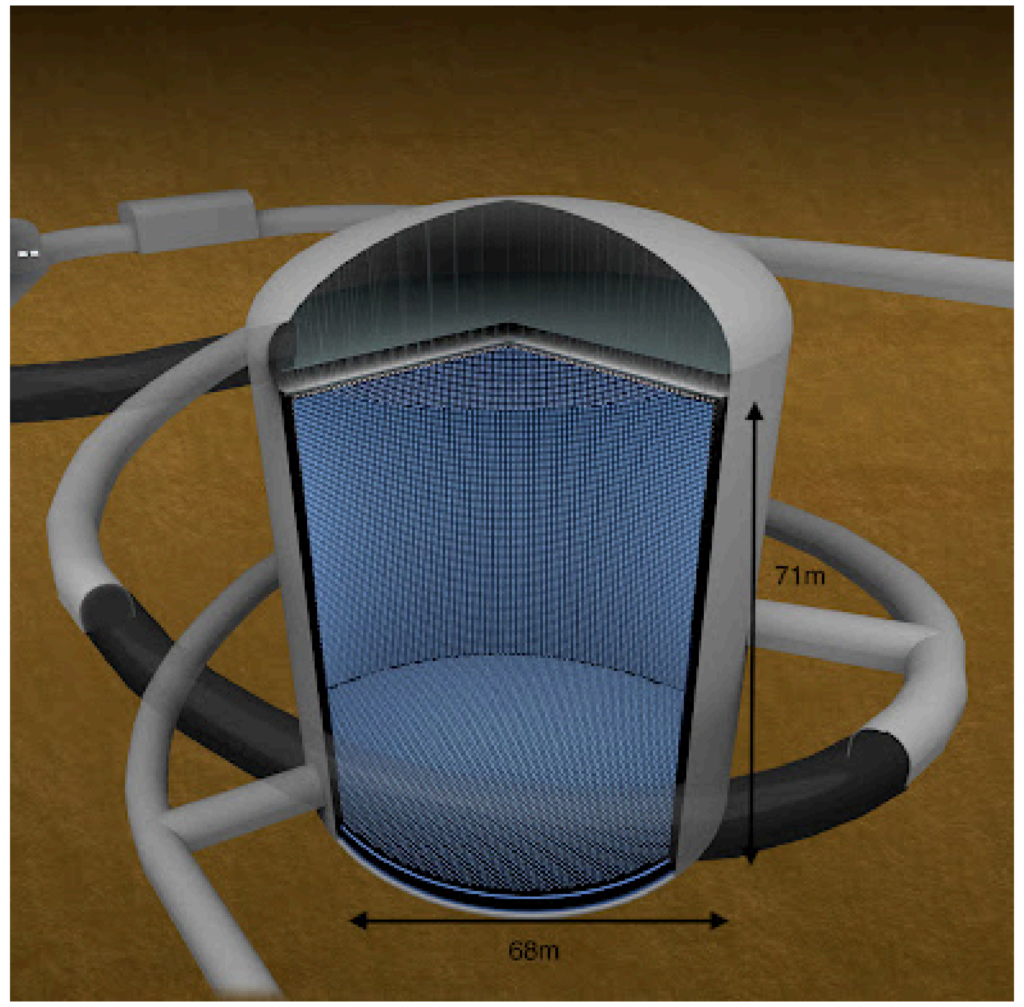
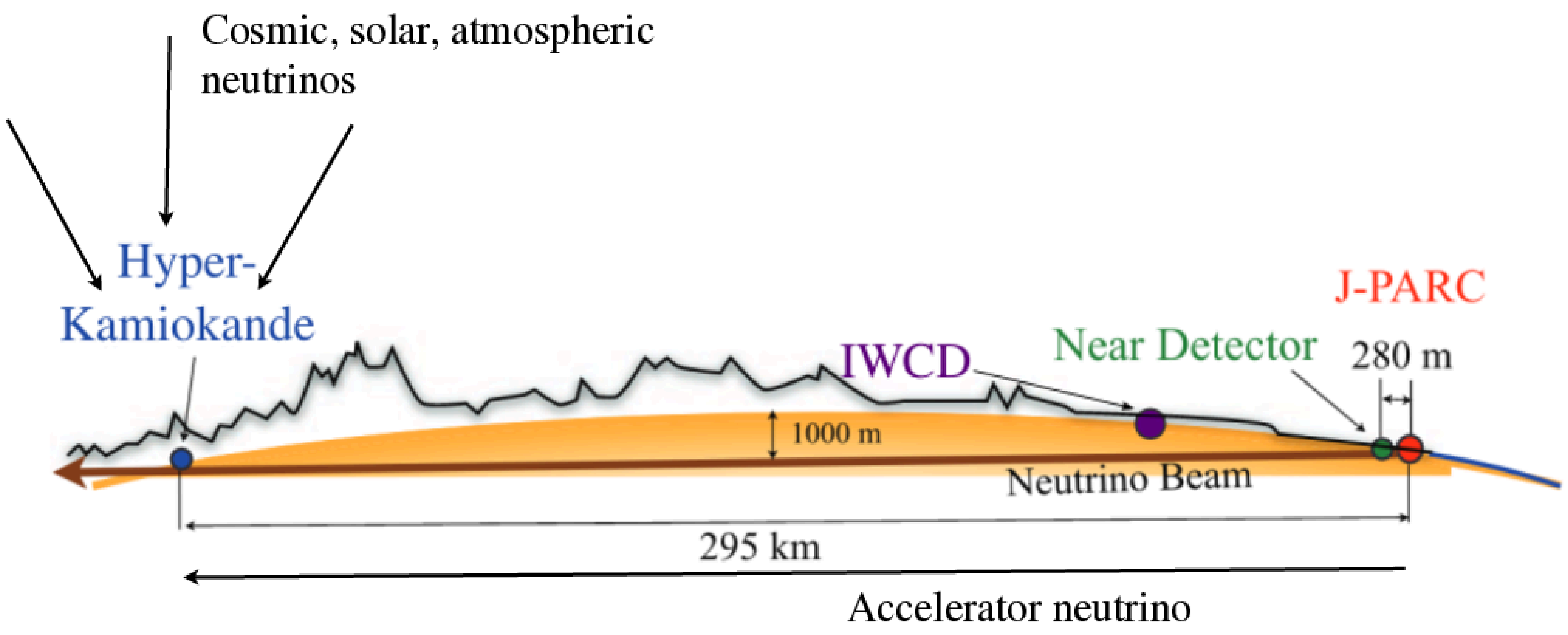
Hyper-Kamiokande

Introduction

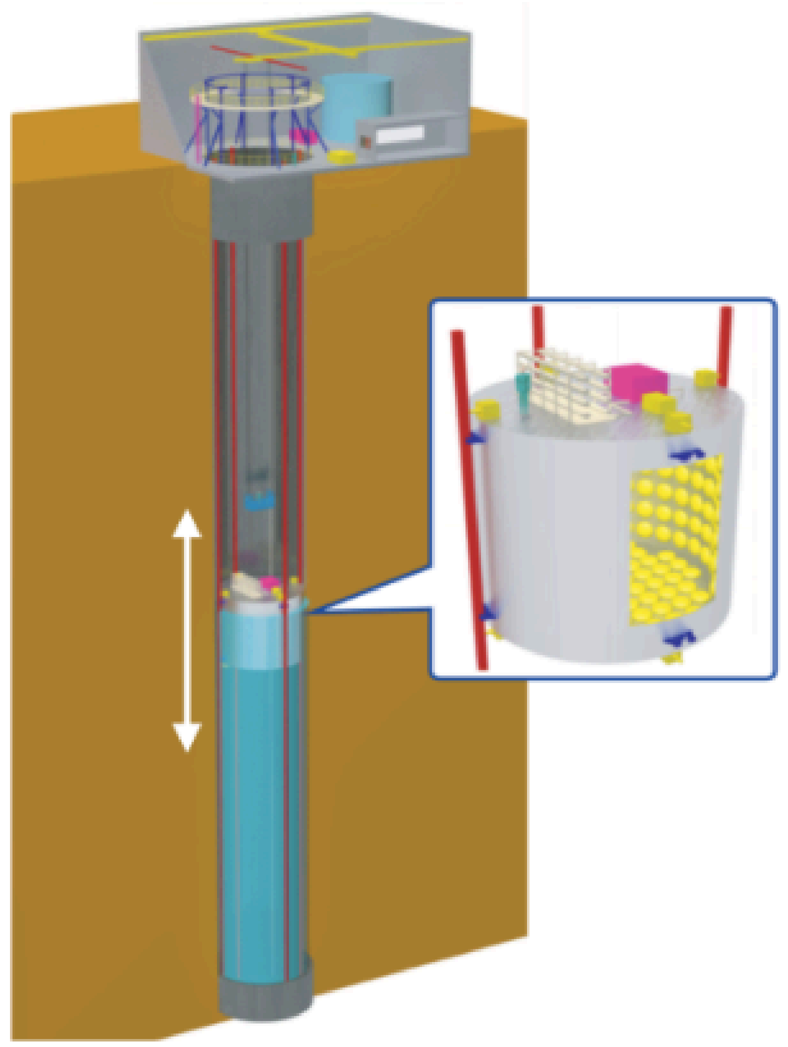
- **Neutrinos are leptons** created in many nuclear processes around us:
  - From p-p chain in Sun's core, to Potassium decay in bananas.
- **Detecting neutrinos is challenging:** Small mass and interact via weak force (low cross-section).
- To measure **neutrino oscillation,** we need a long baseline experiment, such as Hyper-K.
  - Compare neutrino beam at Hyper-K tank with **Intermediate Water-Cherenkov Detector (IWCD)**.

HK tank



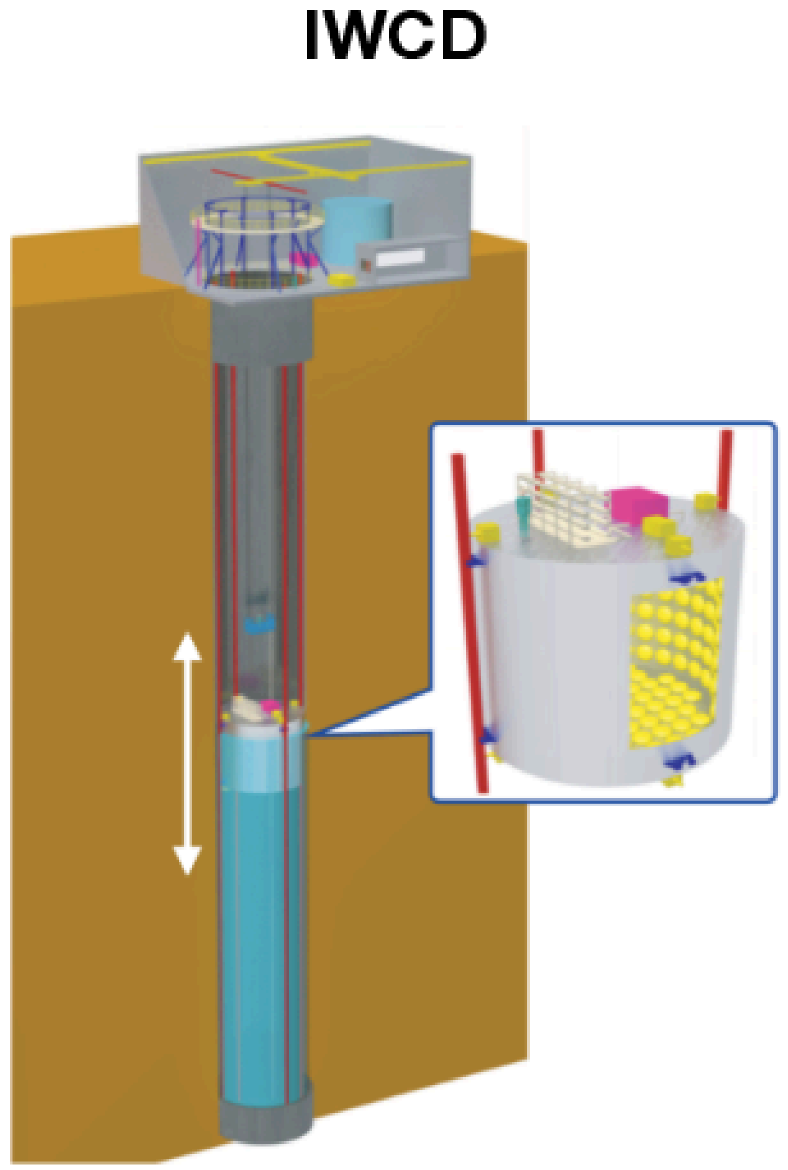


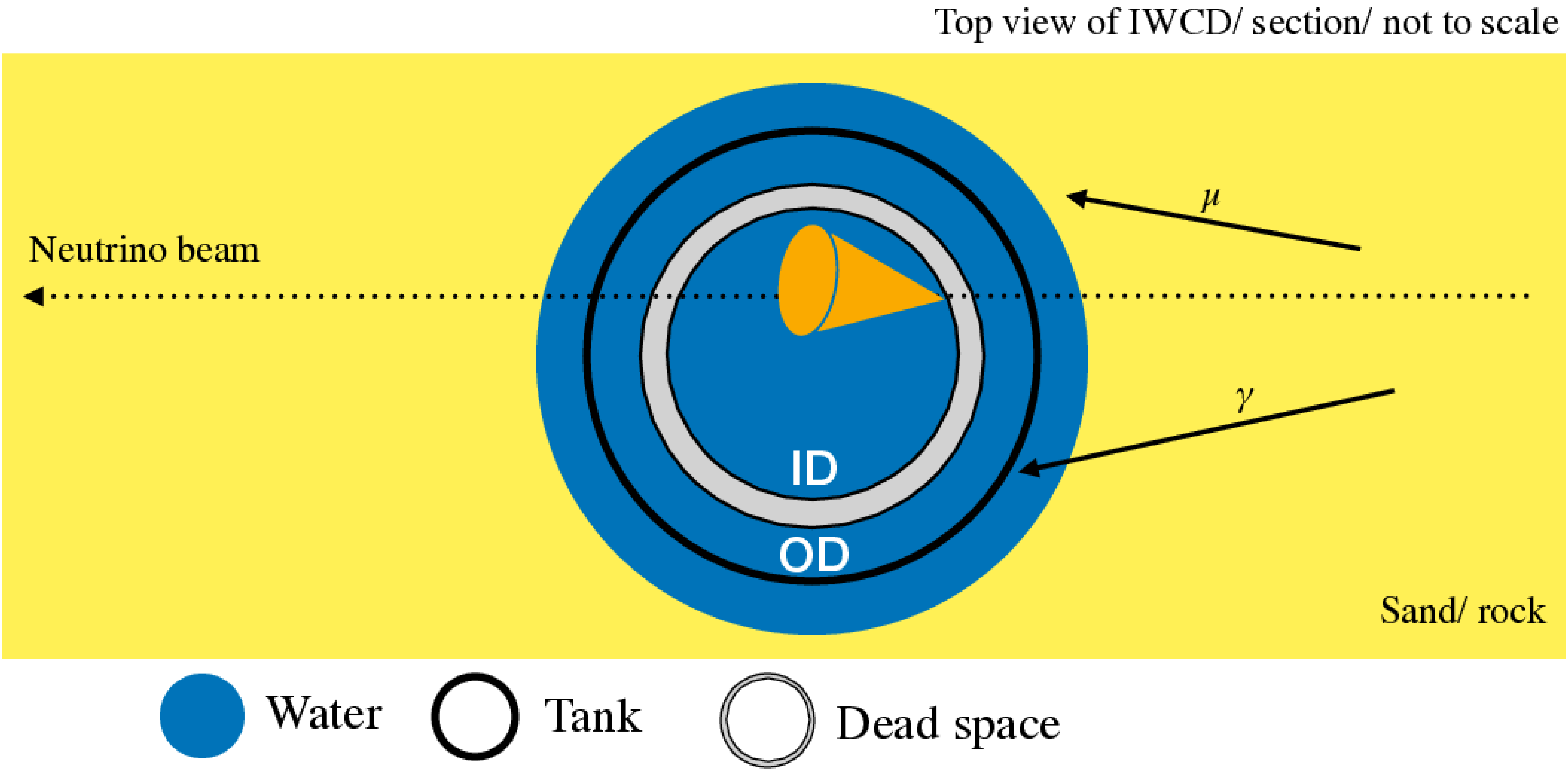
IWCD

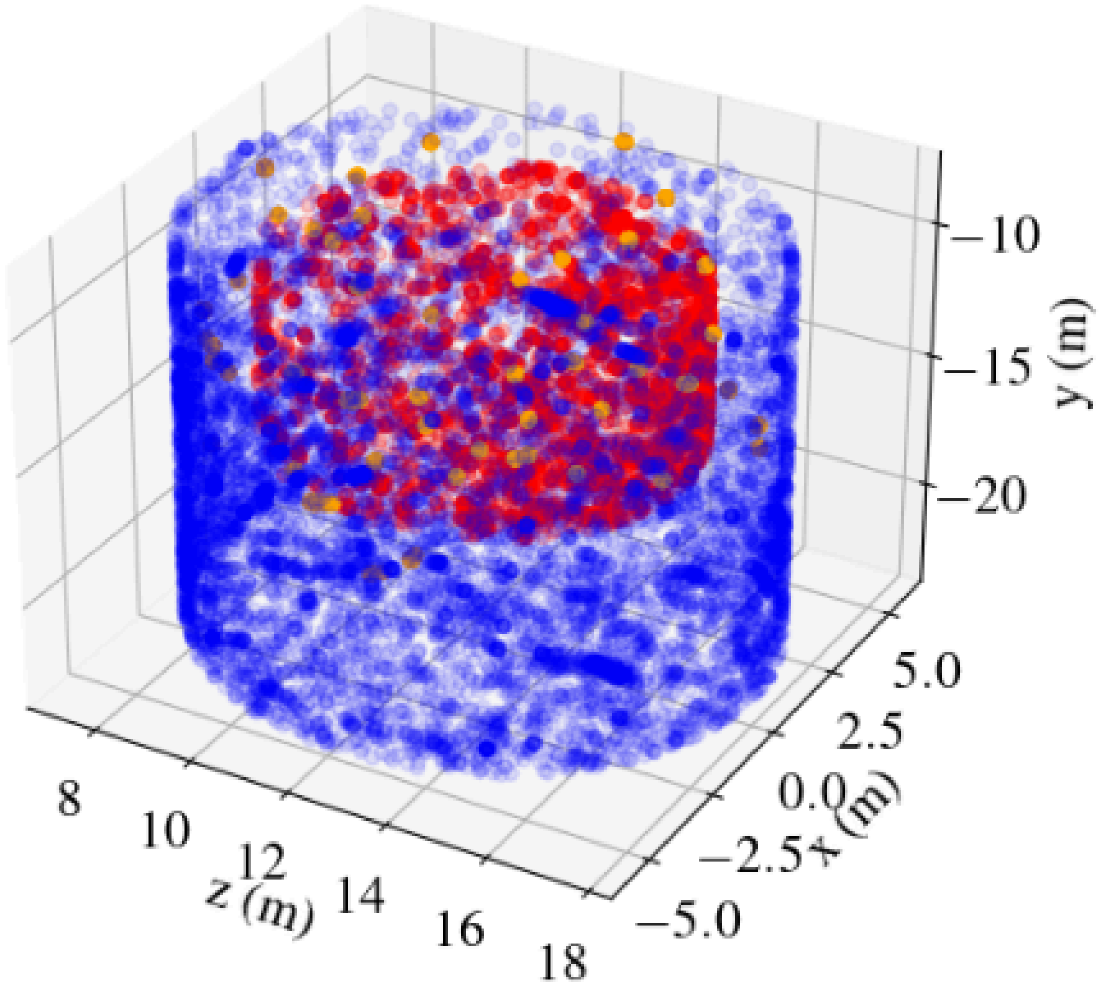


IWCD background

- Our beam is composed mostly of muon neutrinos, with a little of electron neutrinos, too.
- **We want to see Cherenkov rings in the inner detector (ID):** $\nu + H_2O \rightarrow \mu + H_2O$.
- Neutrinos will interact with sand and water in outer detector (OD):
  - **This creates an unwanted background:** ν + nuclei $\rightarrow \pi, \gamma, \mu, e$...

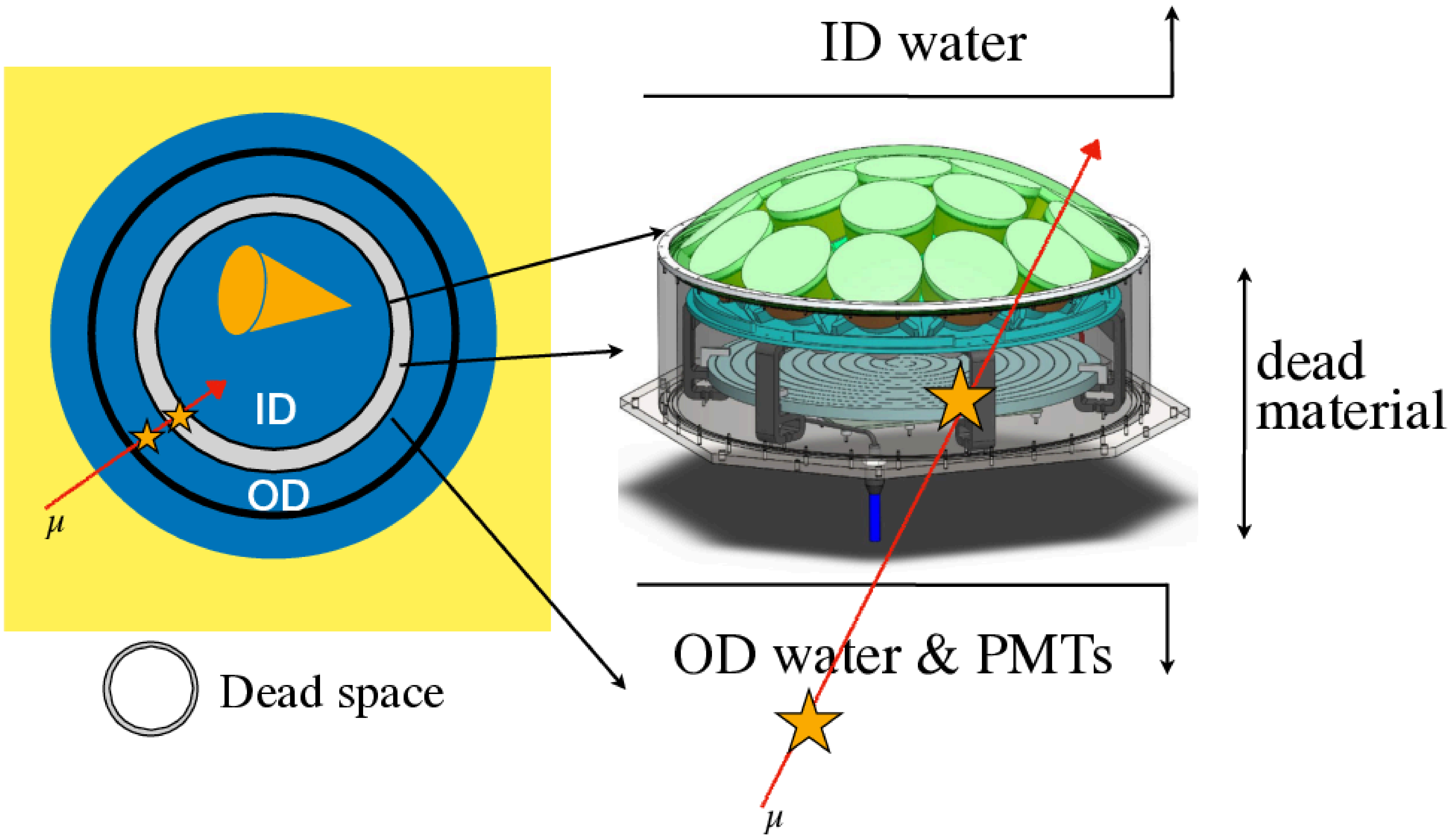


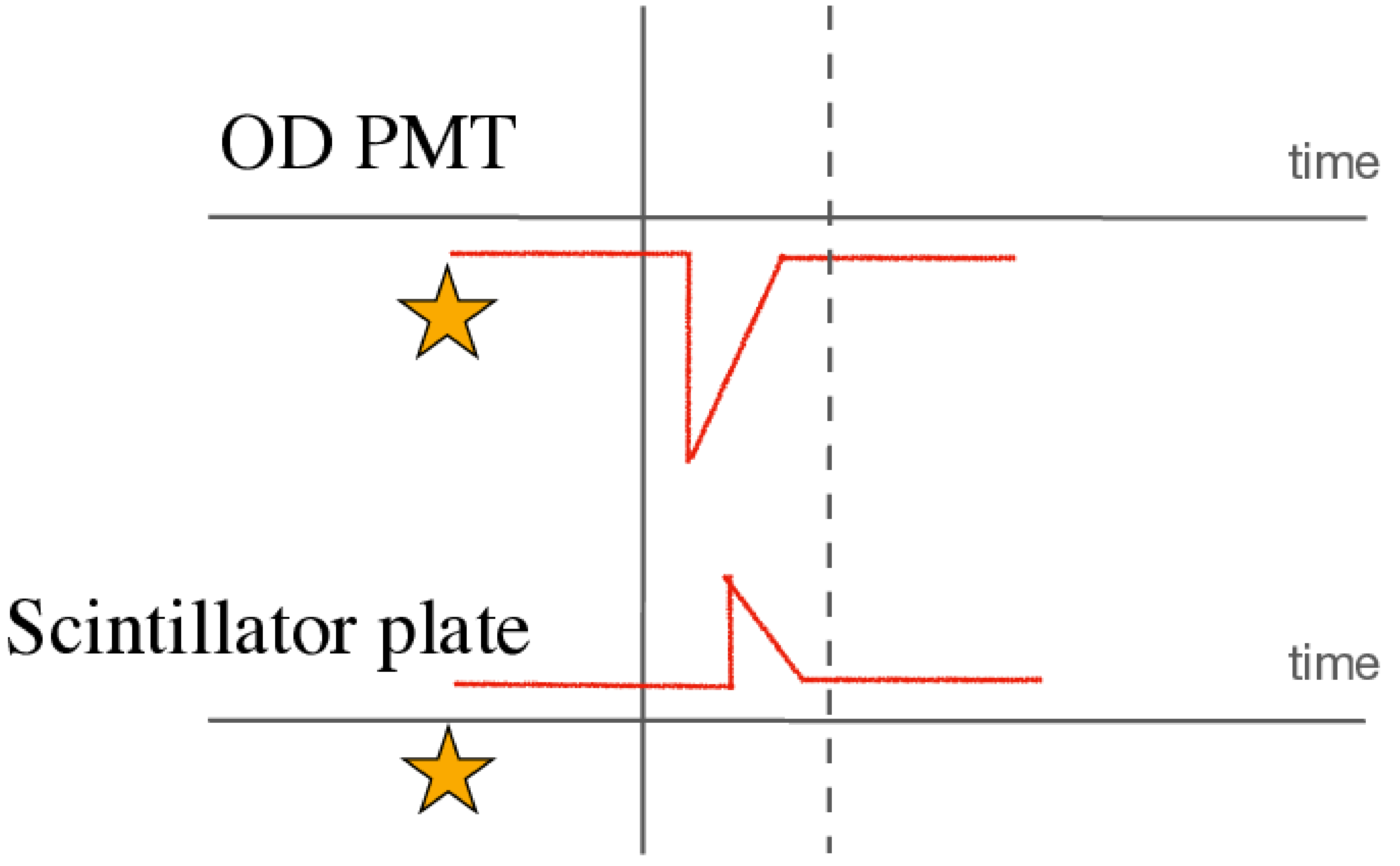




Vetoing mechanism

- 19 PMTs at the top of multi-Photomultiplier module (mPMT) will detect ID events (neutrinos).
- Vetoing relies in a time-coincidence circuit between auxiliary detectors around ID:
  - In the dead material: **scintillator plate** at the bottom of mPMT.
  - Around OD: PMTs facing outwards on the OD water.

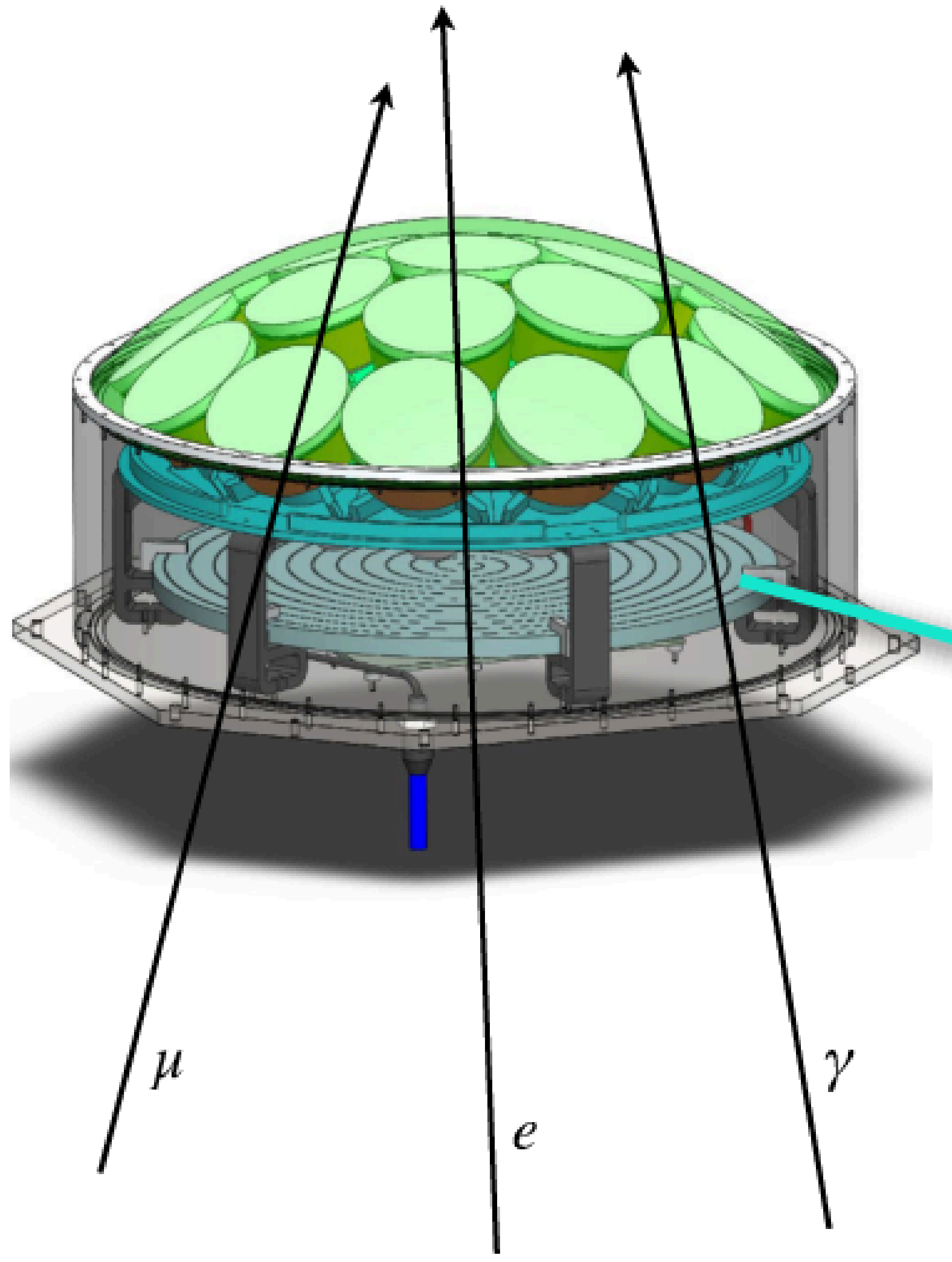


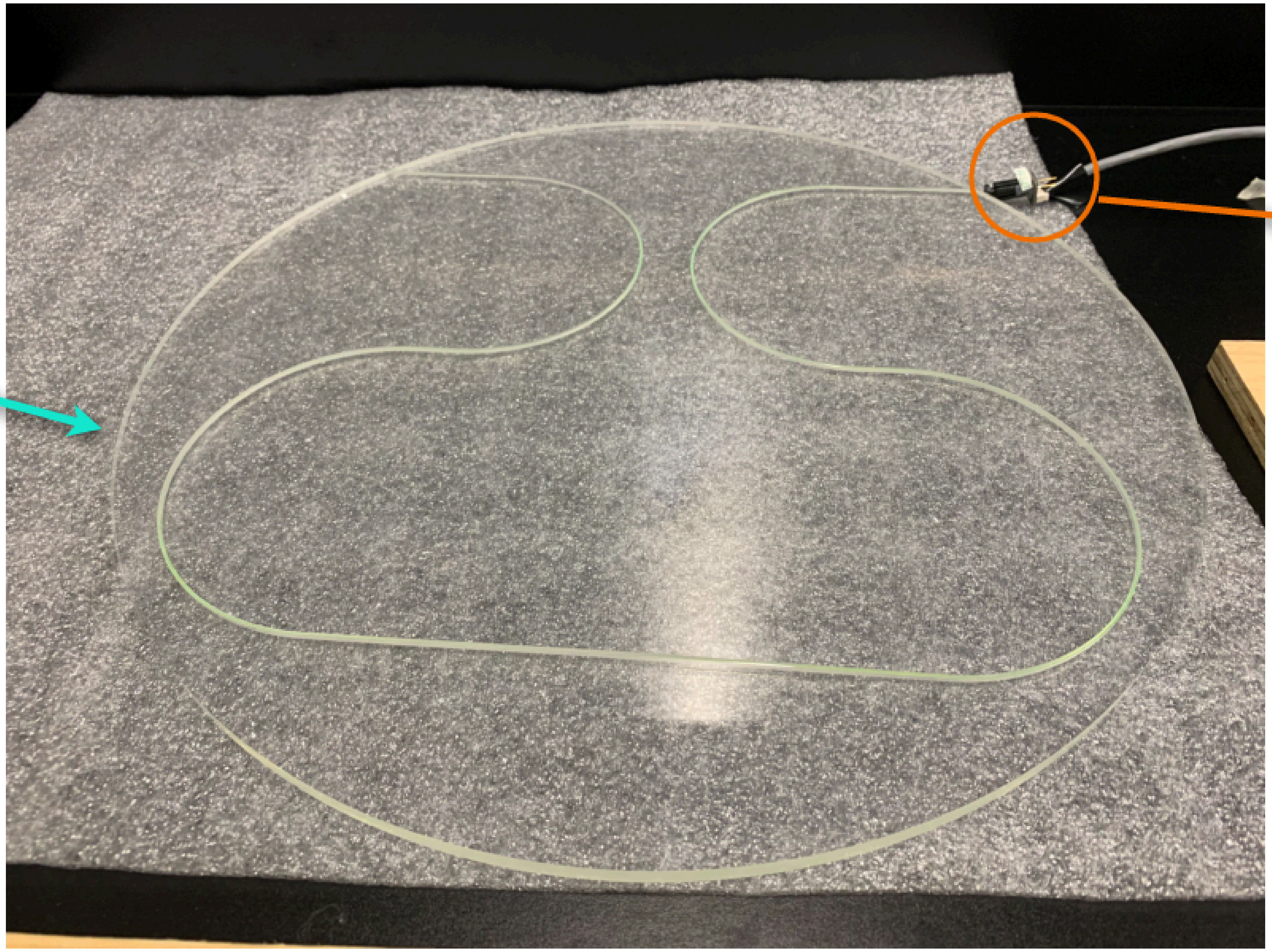


Same time window = coincidence = veto

Scintillator plate

- **Background particles**
  - Charged, photons
  - Deposit energy
- **Scintillator: EJ204**
  - Excited by energy
  - Generate photons
- **WLS fibre: Y11(200)**
  - Capture scintillation photons
  - Guide them out photo-sensor
- **MPPC: 1350CS**
  - Generate electric pulse
  - Count photons

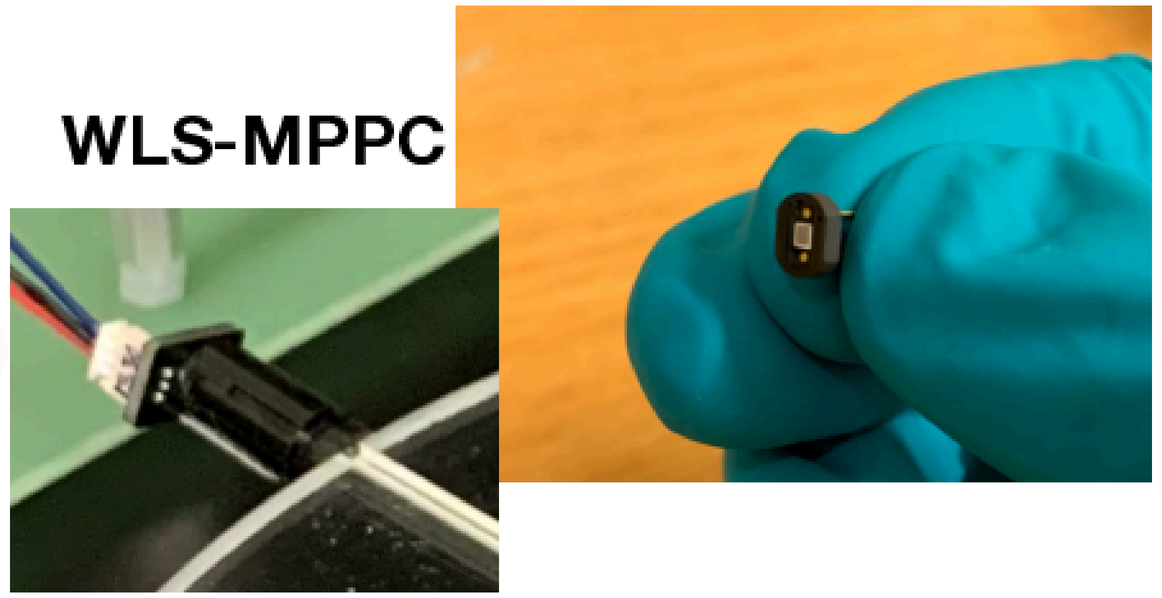




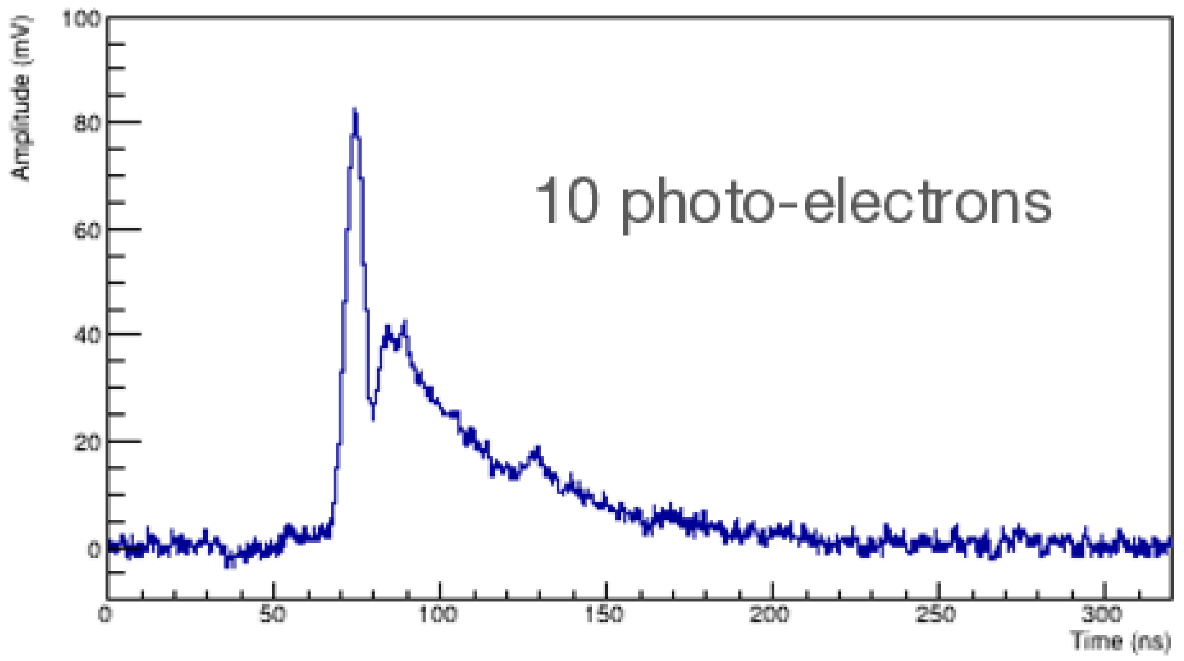
Our latest scintillator plate design

MPPC

WLS-MPPC

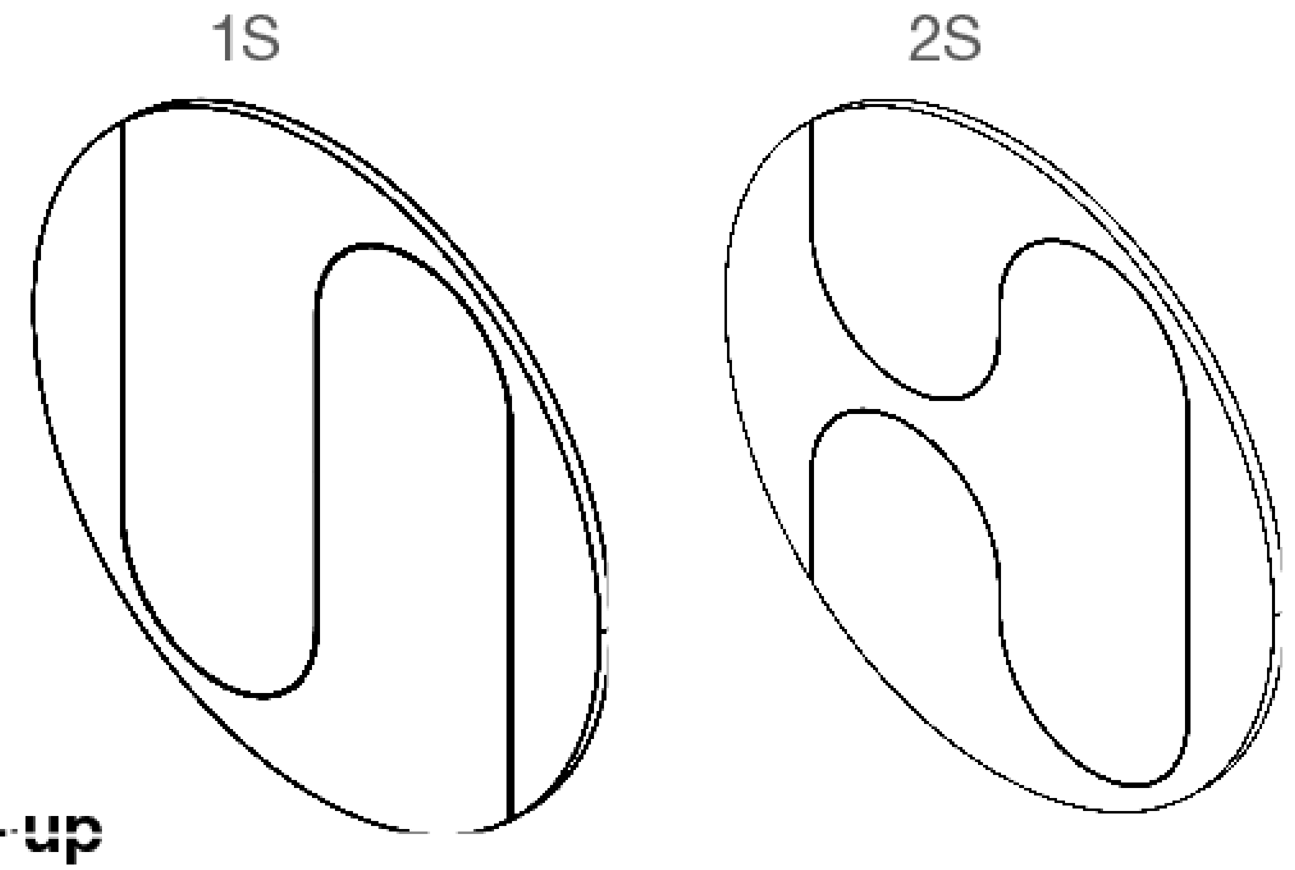


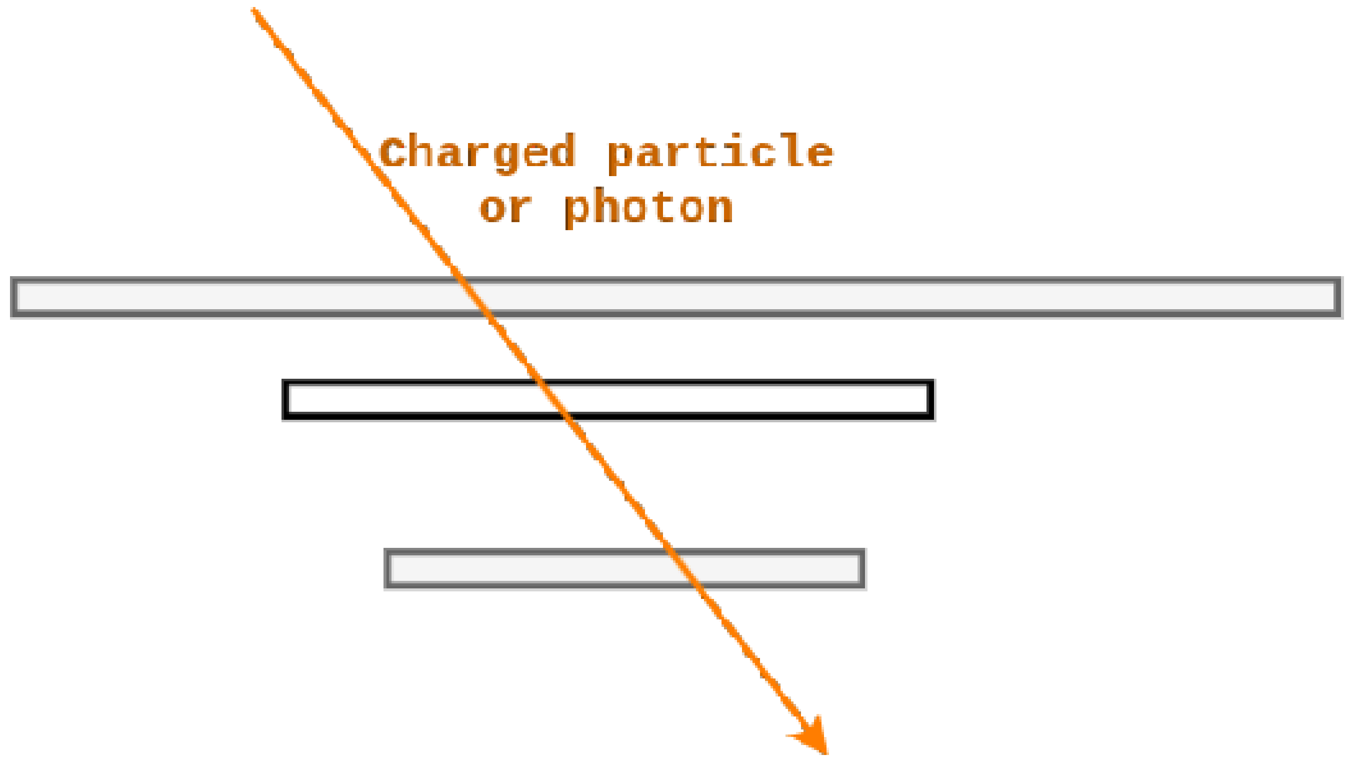
Electric pulse



Measurements: cosmic set-up

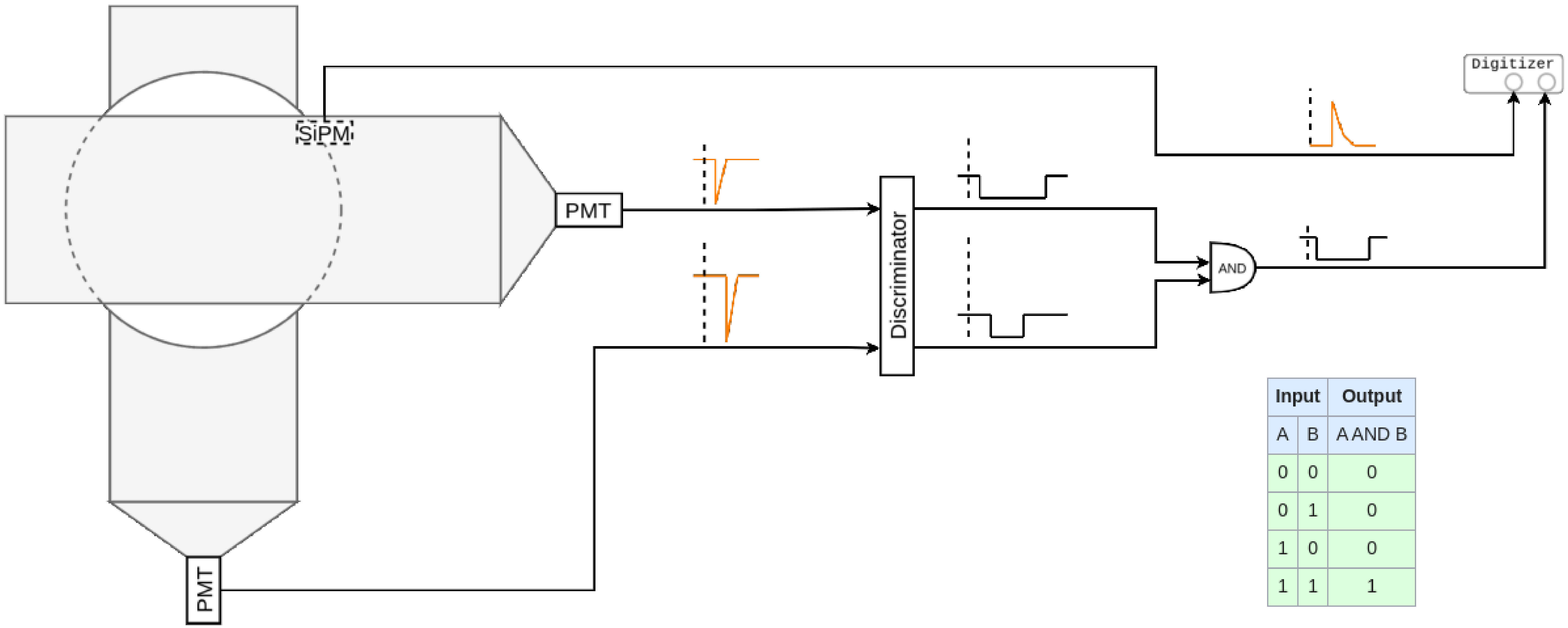
- **Time coincidence:** two big scintillator paddles with large area coverage.
- **Objectives:**
  - Obtain the spectrum generated by bare scintillator plates for cosmic rays.
  - Determine the average light yield.





Particle excites the three scintillators.

Cosmic set-up

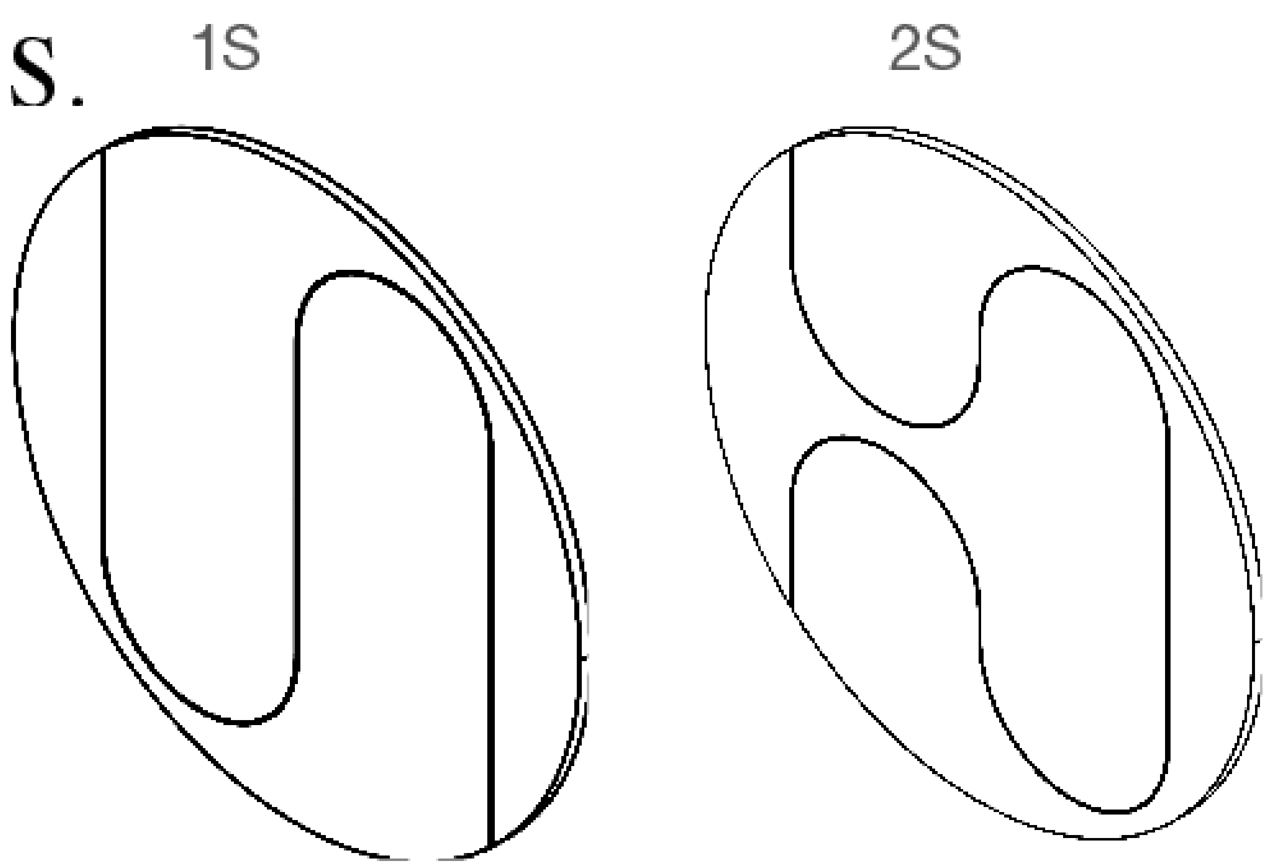


Input		Output
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

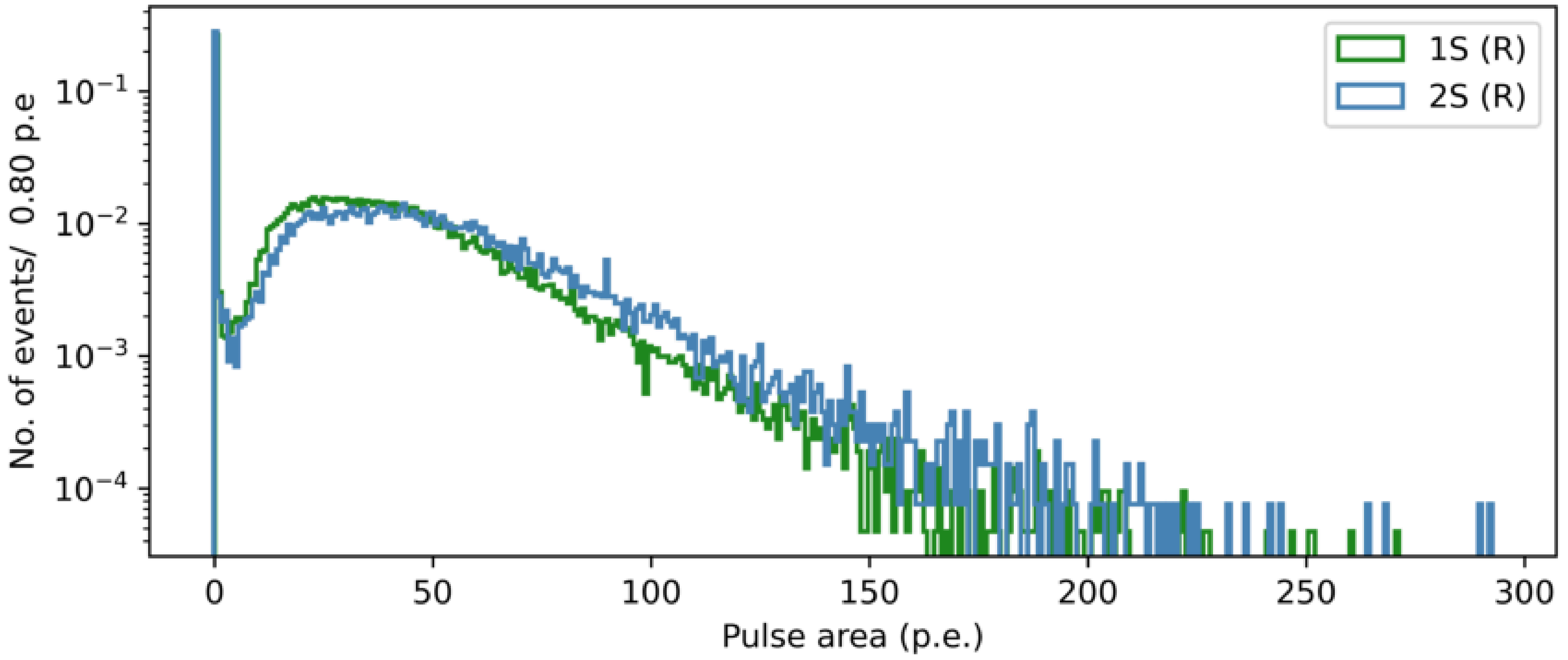
Coincidence between top and bottom paddles is used as trigger.

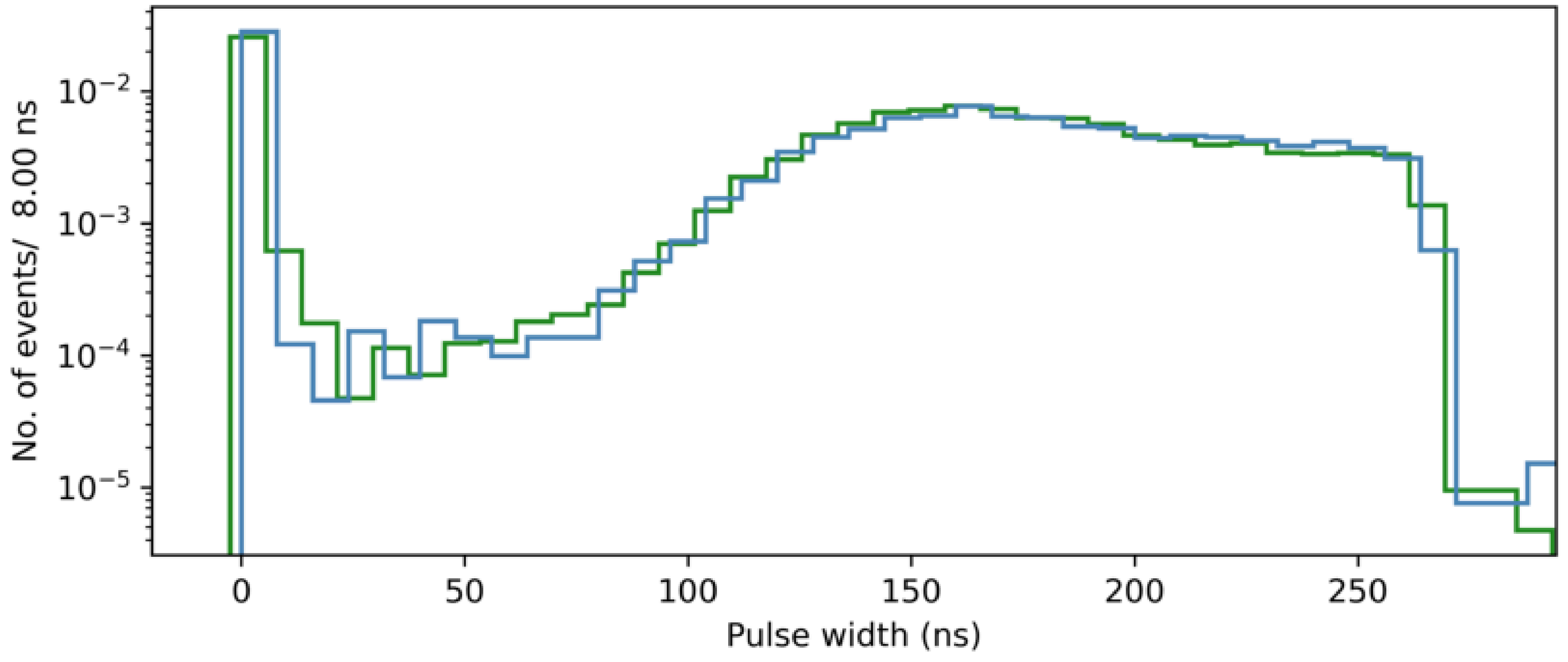
Measurements: cosmic set-up

- 2S configuration provided a slightly higher average photo-electron count than 1S.
- 2S spectrum is slightly shifted to the right.



	1S	**2S**
Area (p.e.)	42.572 ± 0.08	50.45 ± 0.03
Width (ns)	176.754 ± 0.005	180.19 ± 0.07
No. of events	26321	16432

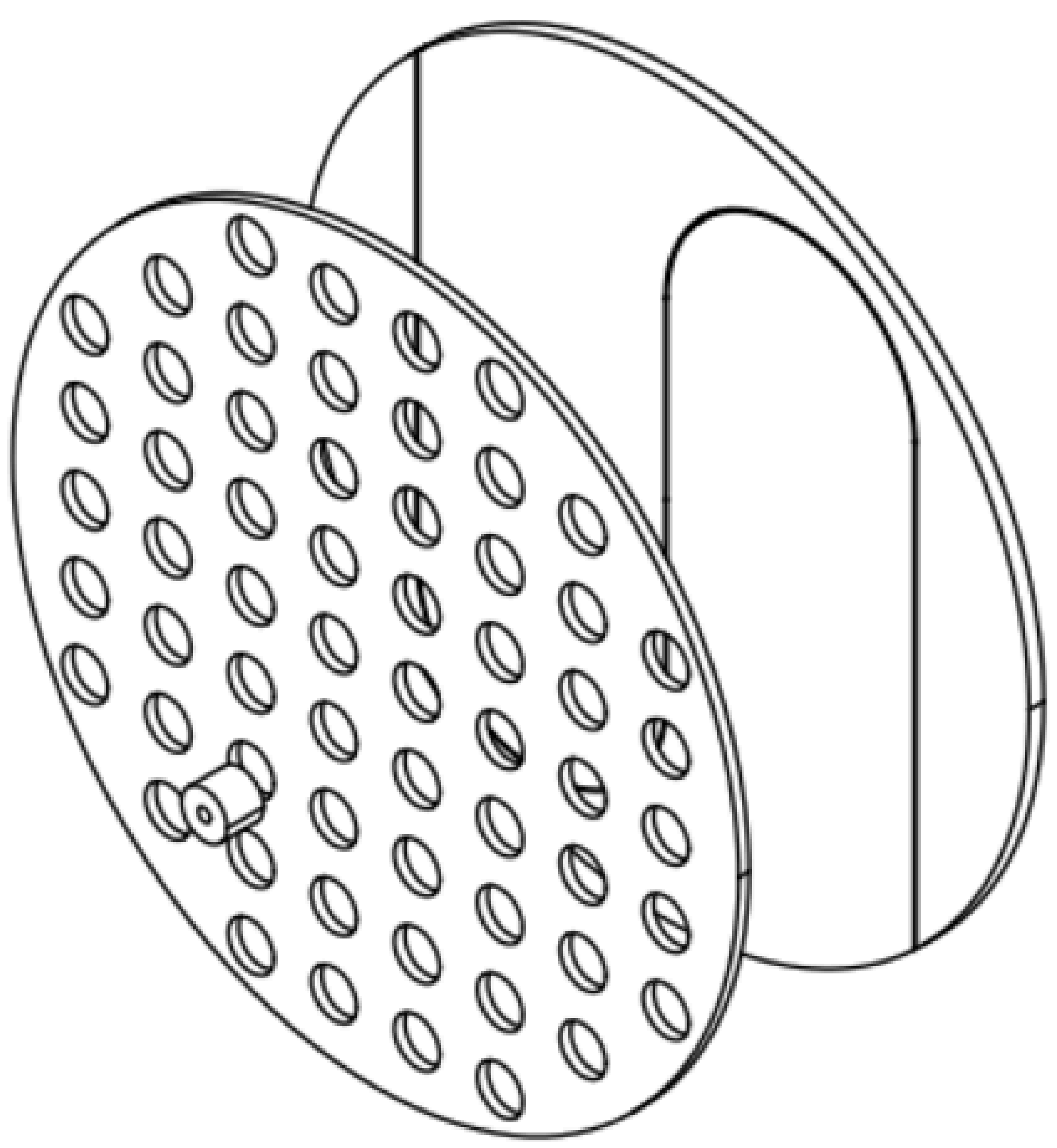




Measurements: mapping

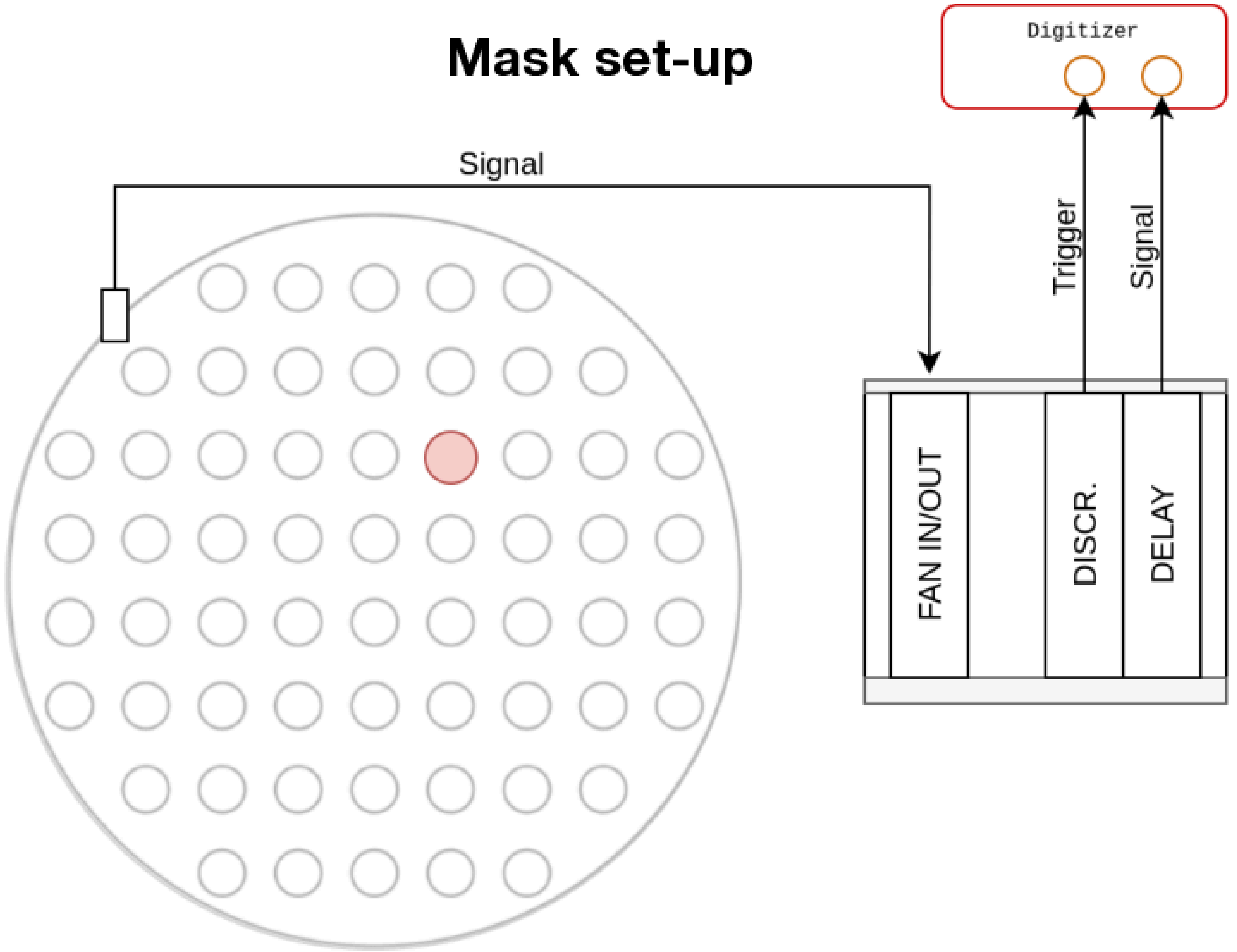
- **Mask set-up:** mask clamped onto scintillator; Sr-90 radioactive source to create a map.
- **Objective:** Understand changes in spectra and average pulse size by distance from MPPC.

CAD design



Mask for LED and source collimators

Mask set-up



Red circle: Sr-90 source. Trigger provided by discriminator.

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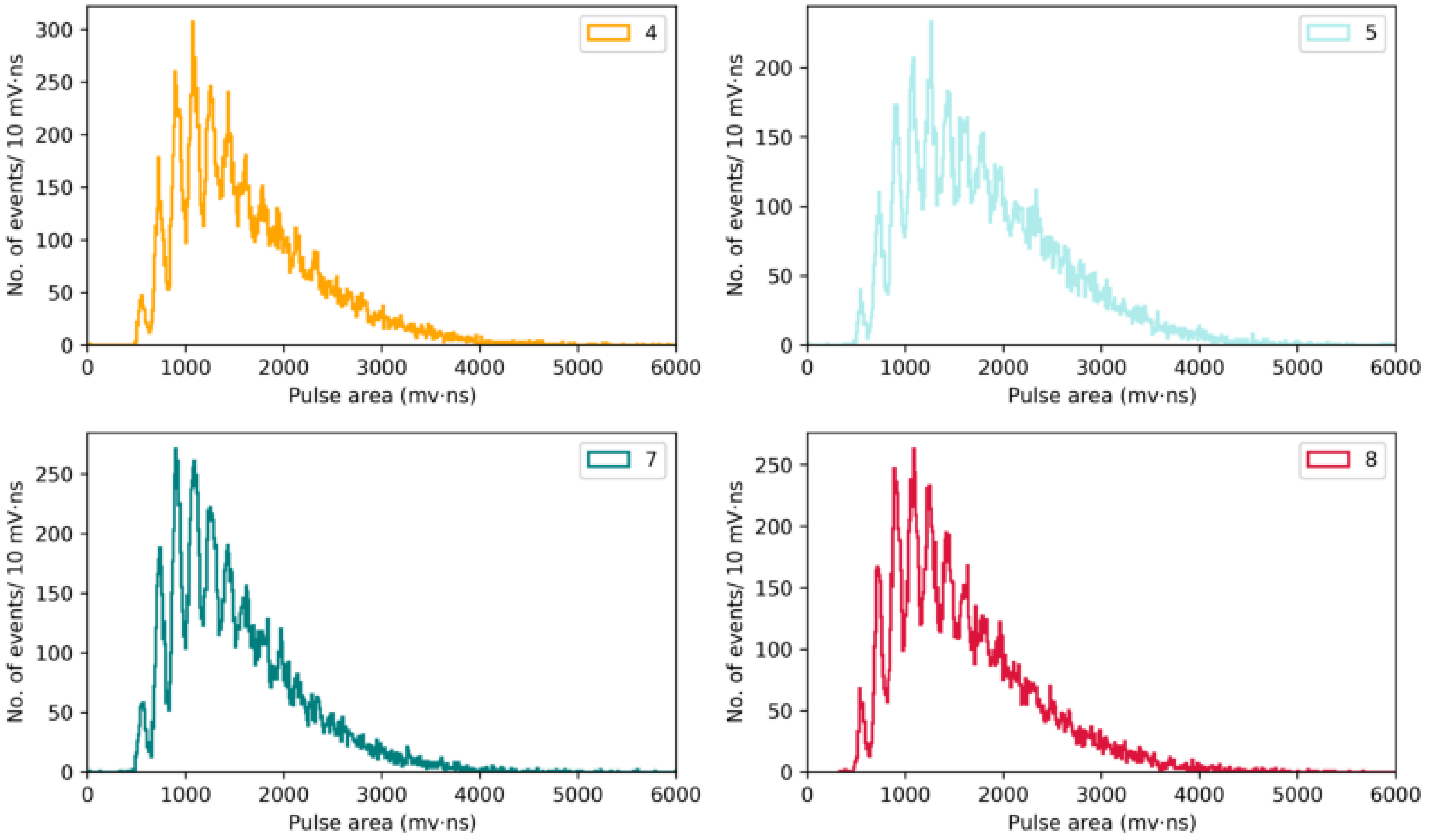
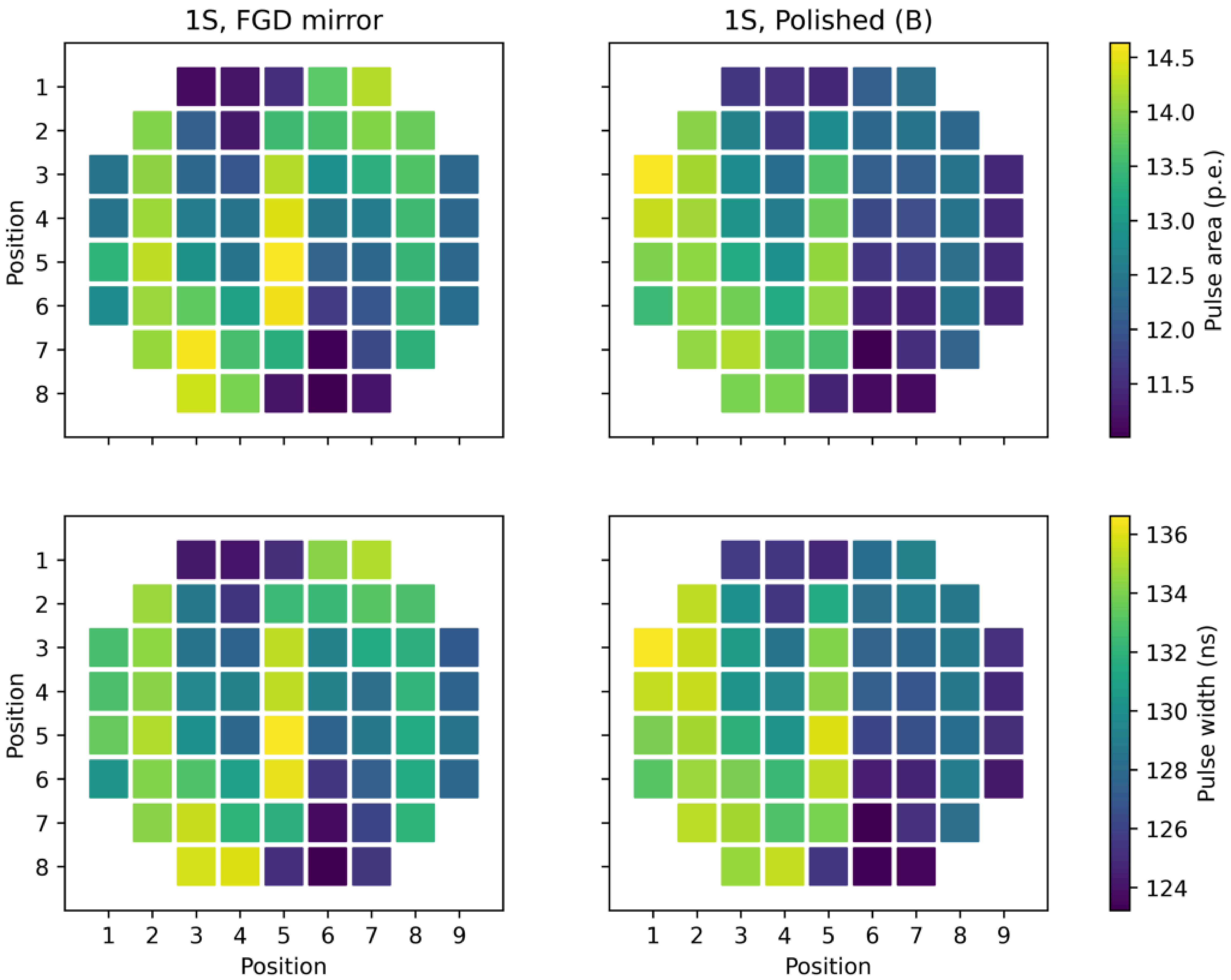
Measurements: mapping

- FGD-mirrored fibre and black-paint fibre were used each at a time in 1S plate.
- Average area and width are calculated for each position.
- Using a mirrored-end fibre will increase light yield when far away from the MPPC.

Pulse area distribution: row 4, cols 4, 5, 7, 8





Conclusions

- IWCD will rely on a time-coincidence circuit to reduce background effect.
- Scintillator plate will play an important role in IWCD's background-vetoing mechanism.
- We are close to determining the final configuration of the plate.
  - Learned a lot about spectrum generated by the 1S and 2S plate and how to improve light yield.

- Next steps:
  - Make a mapping of the 2S configuration and see how the sensitivity areas change.
  - Test new plate prototype arriving soon: 2S configuration with a coat of reflective material.
  - Continue to improve the background simulations with dead material in ID/OD boundary.