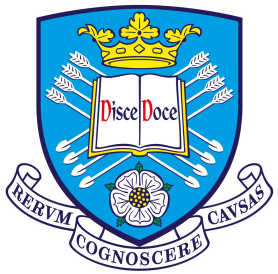


The University Of Sheffield.

Optical calibration design for the Hyper-Kamiokande Outer Detector

Celeste Pidcott

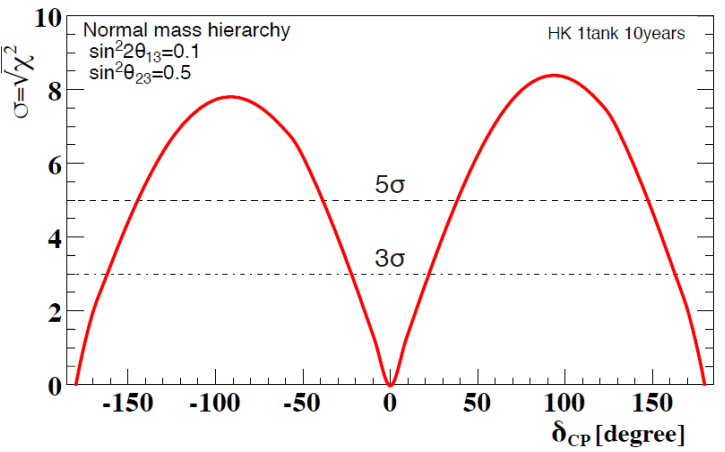
09/04/19

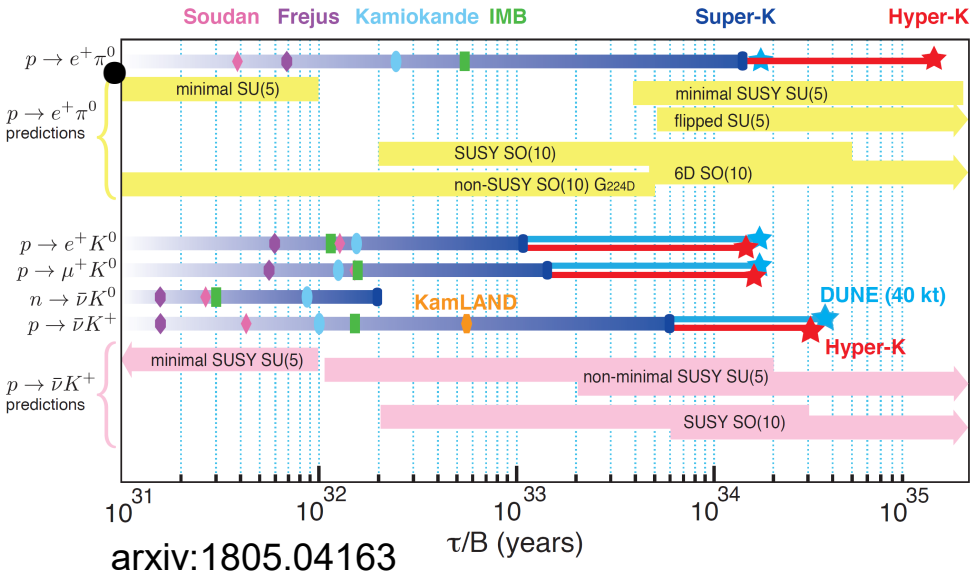
IoP HEPP/APP 2019

Hyper-Kamiokande

- Next generation water Cherenkov detector, will study neutrino interactions from astronomical sources, atmospherics neutrinos, and long baseline neutrino beams

arxiv:1805.04163

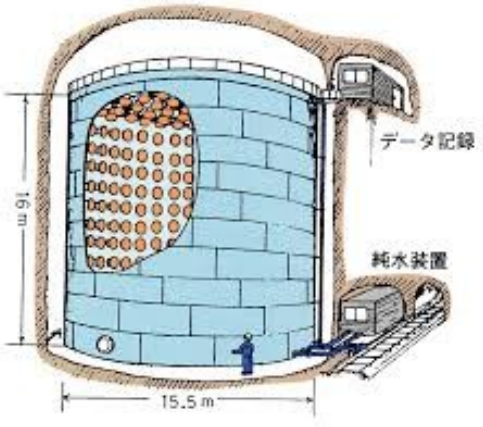


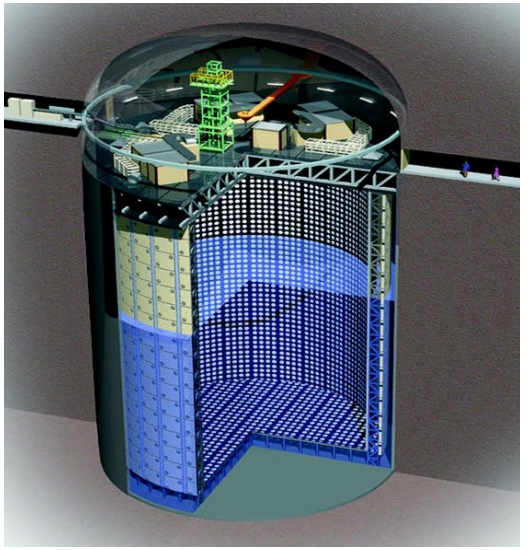


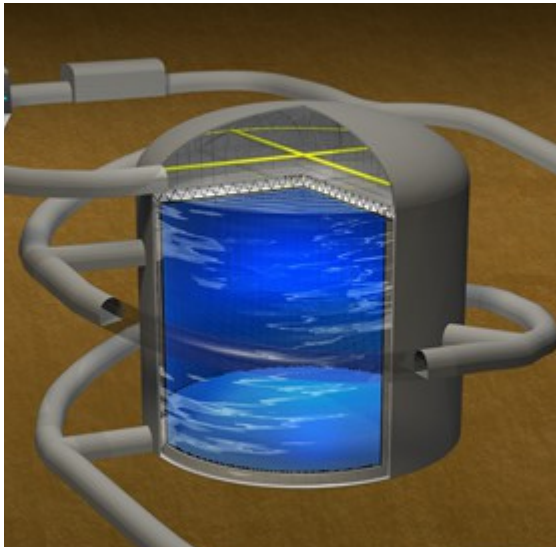
arxiv:1805.04163

- Also perform nucleon decay searches

Hyper-Kamiokande

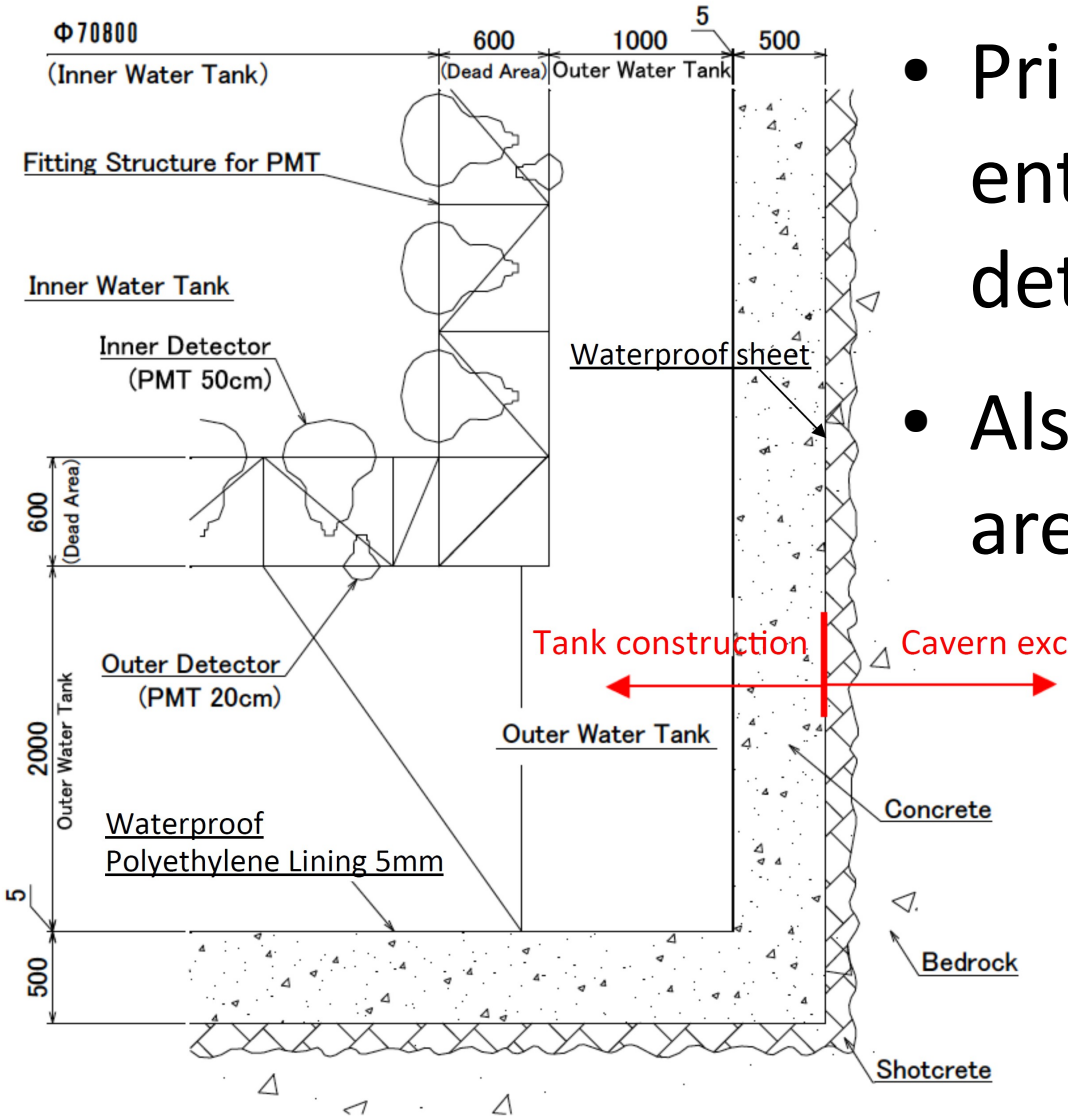






	Kamiokande 1983 - 1996	Super-Kamiokande 1996 -	Hyper-Kamiokande ~2026-
Mass (fid.)	4.5 (0.68) kton	50 (22.5) kton	258 (187) kton
OD thickness	~1.5m	~2m	1m (barrel), 2m (caps)
ID PMTs	948 (50cm ϕ)	11,129 (50cm ϕ)	40,000 (50cm ϕ)
OD PMTs	123 (50cm ϕ)	1,885 (20cm ϕ)	6,700 (20cm ϕ)

Outer Detector



- Primary role is to veto particles entering from outside of detector (e.g. cosmic ray muons)
- Also determine if events in ID are fully/partially contained
  - Shielding from gamma particles
  - 1 metre wide on barrel, 2 metres at top and bottom caps

Outer Detector

- Nominal design report configuration: 6,700 outward facing 20cm (8”) PMTs, approximately 1% photocoverage
- New design: 3” PMTs, 0.42% photocoverage
- Reflective sheeting and addition of wavelength shifting plates to PMTs enhances light collection

Outer Detector Calibration

- Timing:
  - To veto events during ID trigger, determine ID-OD timing offset, and know relative offsets between OD PMTs
- Linear charge response
  - Response for single pe events, measure gain drift
- PMT non-linearity
  - High energy events can saturate charge response
- Use LED light delivered by optical fibres to illuminate PMTs; same concept used in SK-IV

LED Calibration System

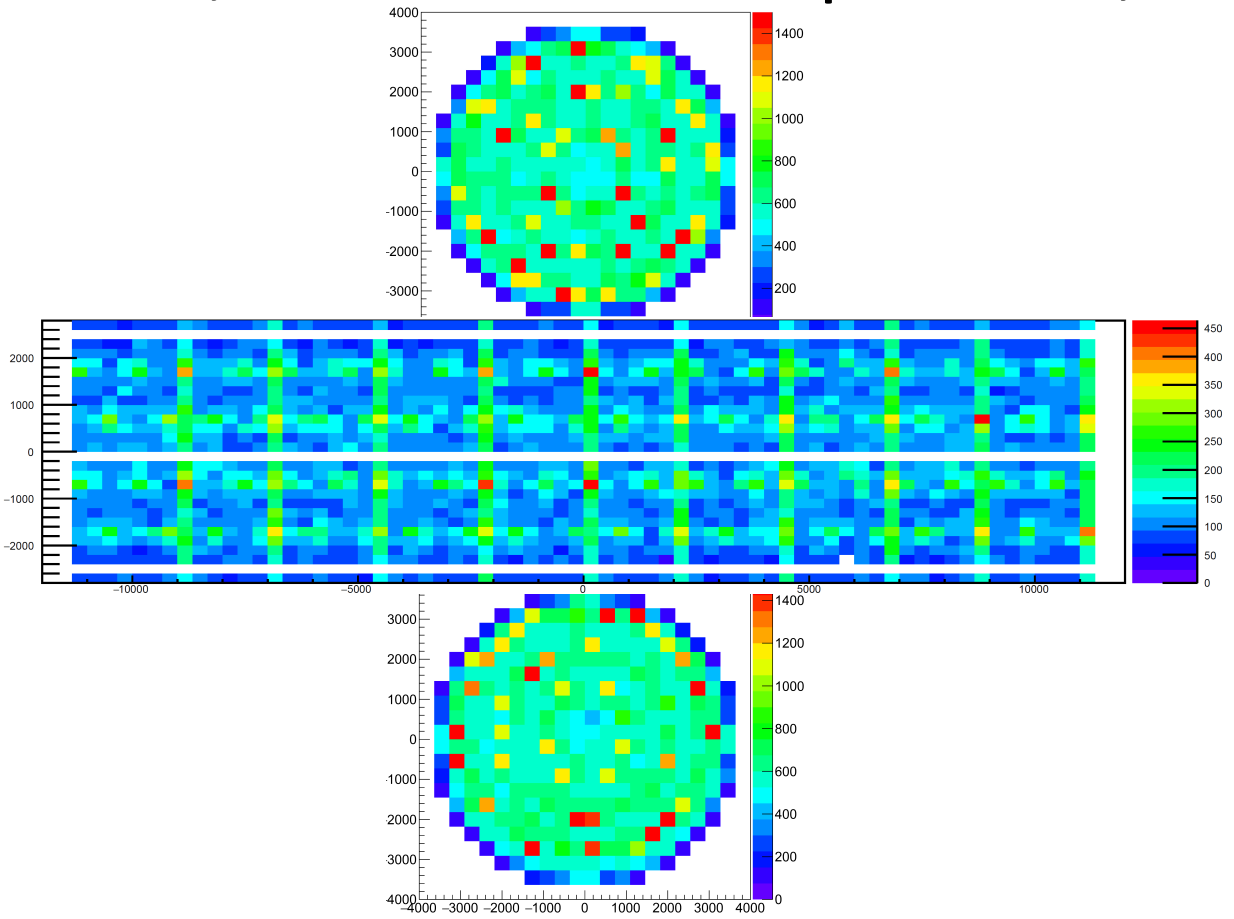
- LED calibration system already designed for use in ID
  - Developed by Liverpool, Warwick, Sheffield, Imperial
- Uses wide angle and collimated light to measure PMT response and water properties
  - Main interest for OD is PMT response – use wide angle light source

Simulation of OD

- Hyper-K simulations performed using WCSim
- Outer detector simulated with nominal 8” PMTs, 1% coverage and also 3” PMT, 0.42% coverage configurations
- Using Geant4 particle gun, insert light sources into OD to assess light coverage
  - 80 around barrel, 56 in both top and bottom caps
  - Considered sources mounted on inner and outer walls
  - Study coverage with 50% of sources (assess redundancy)

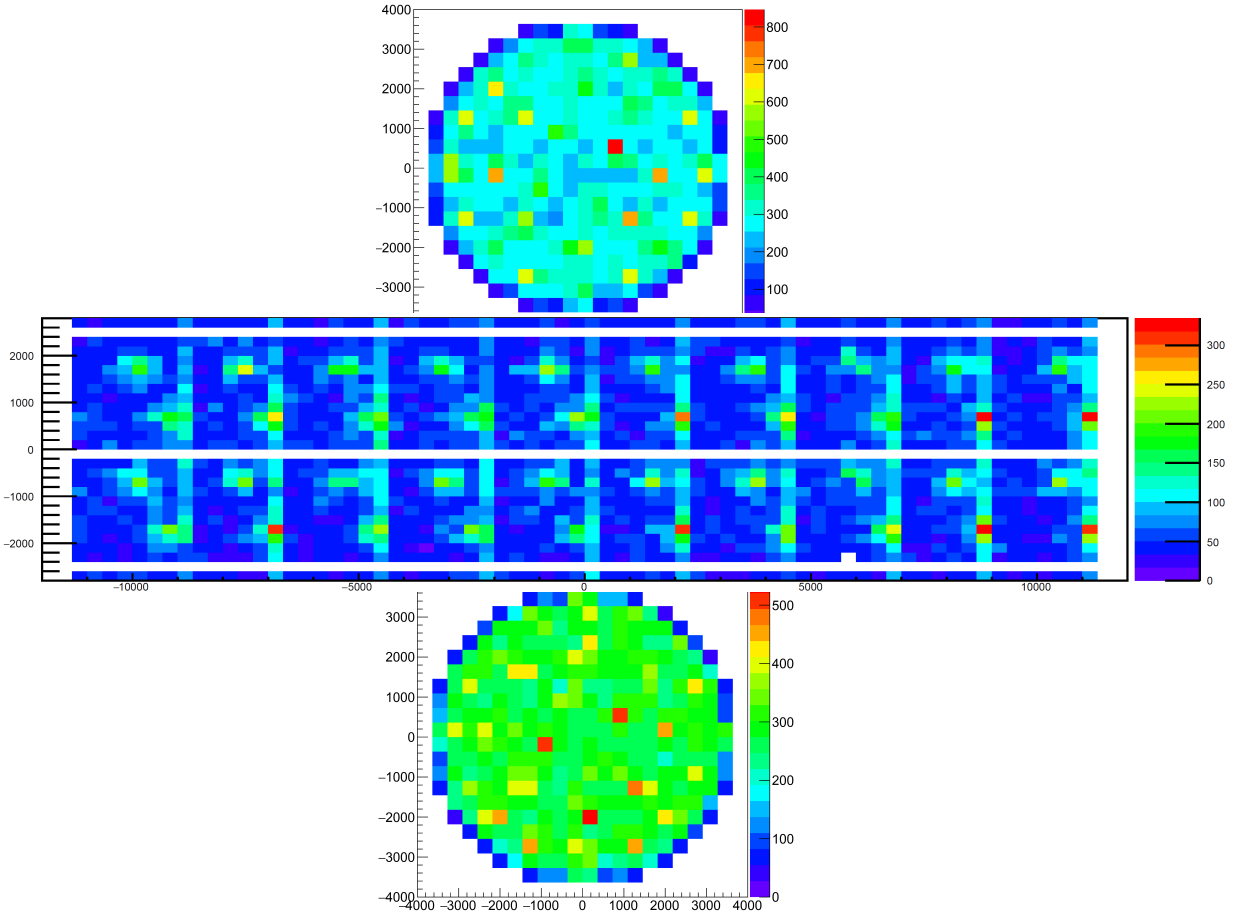
8” PMTs, all fibres, outer wall

- 192 sources mounted on outer wall facing inwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



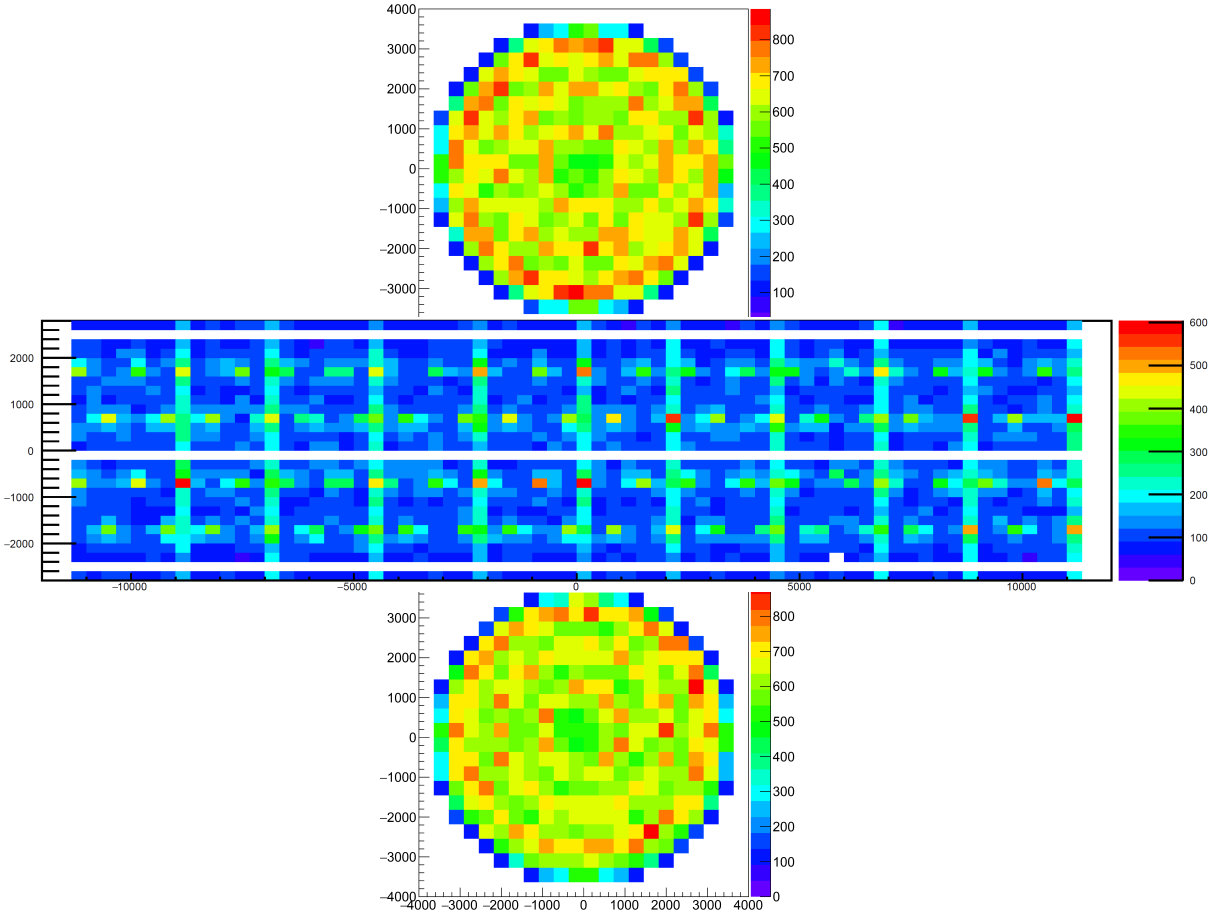
8” PMTs, 50% fibres, outer wall

- 96 sources mounted on outer wall facing inwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



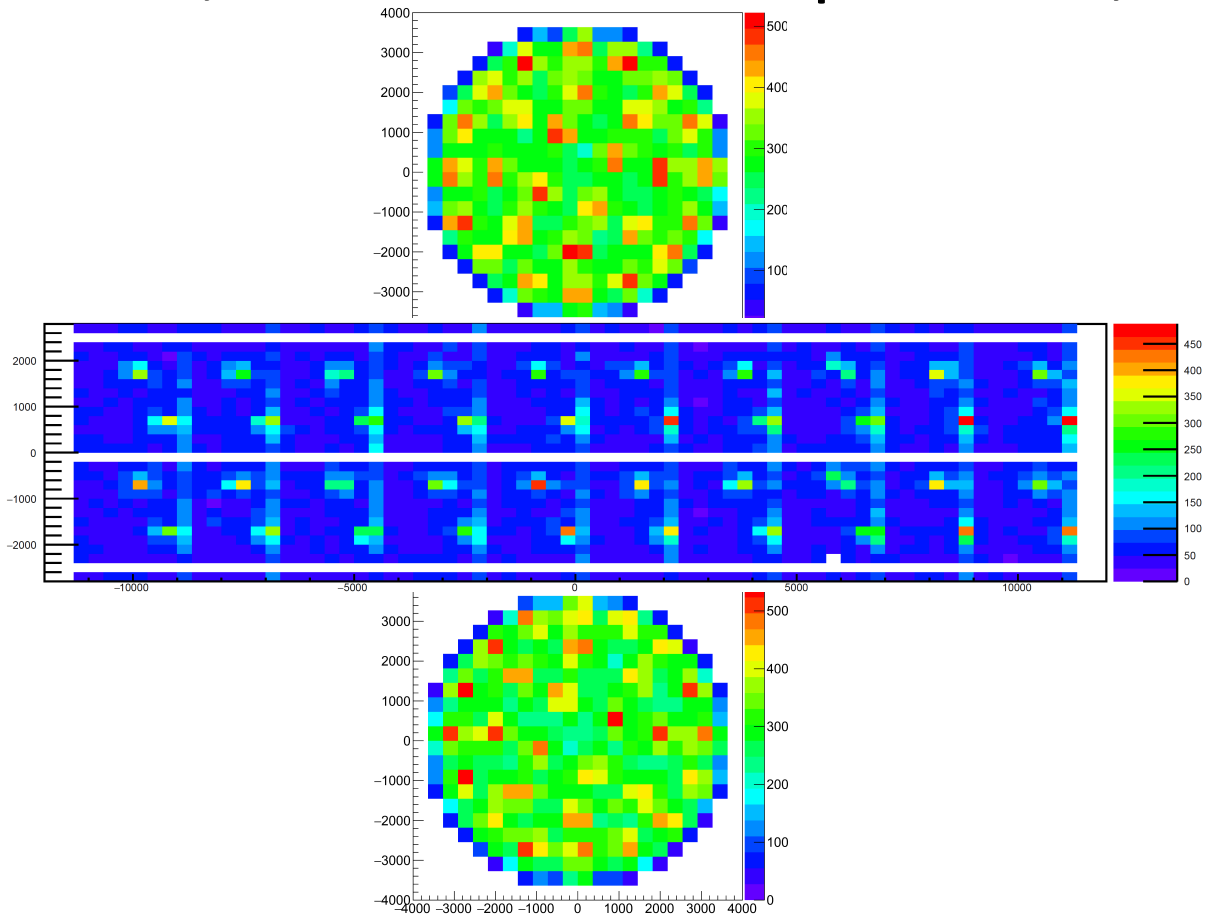
8” PMTs, all fibres, inner wall

- 192 sources mounted on inner wall facing outwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



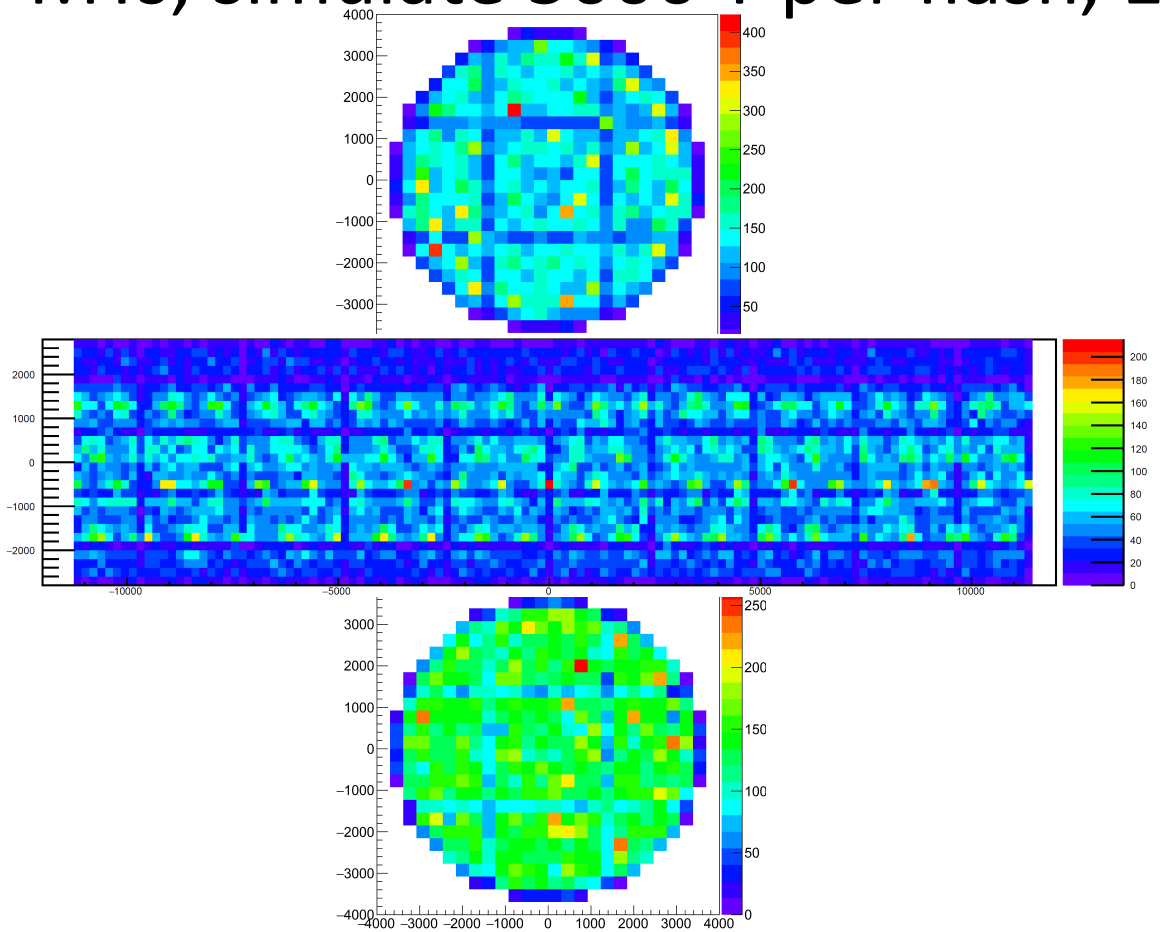
8” PMTs, 50% fibres, inner wall

- 192 sources mounted on inner wall facing outwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



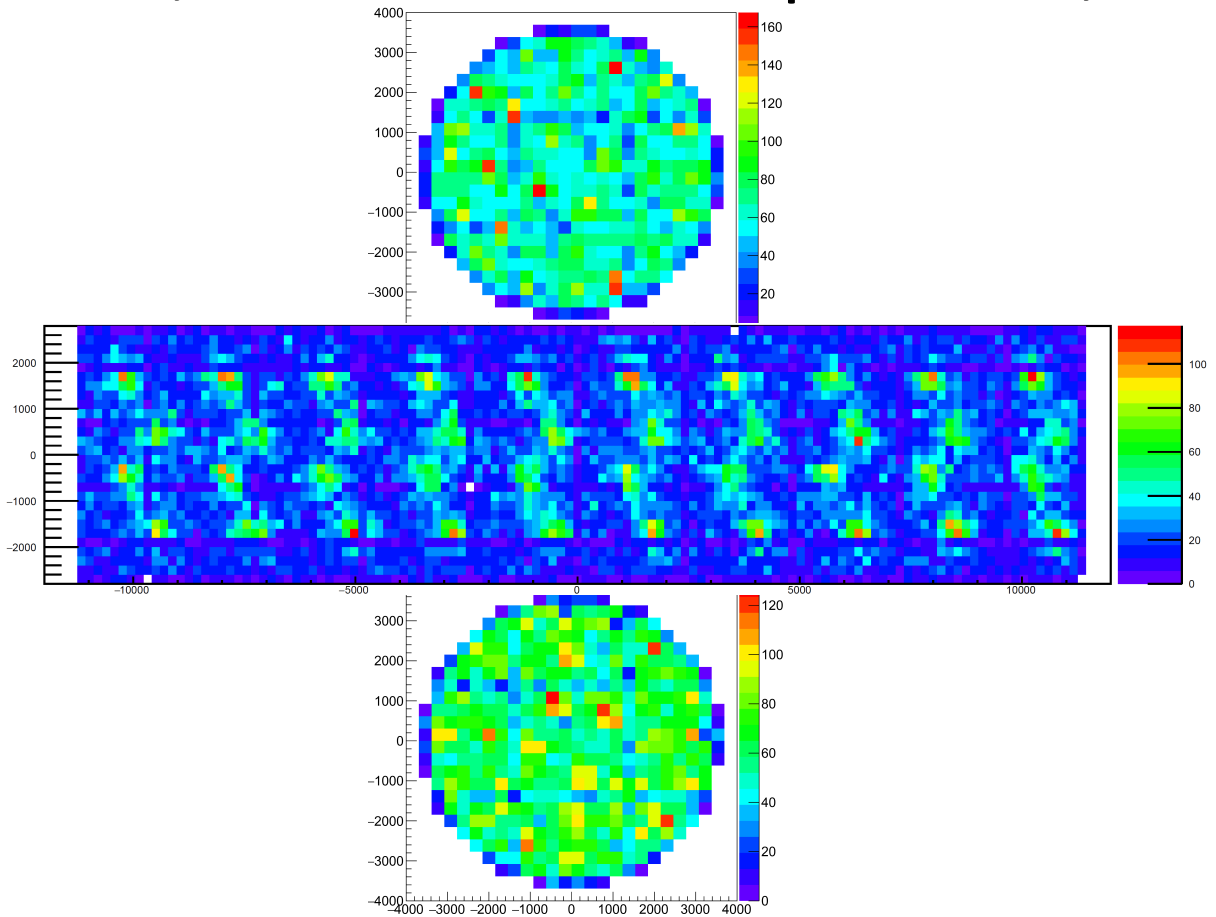
3” PMTs, all fibres, outer wall

- 192 sources mounted on outer wall facing inwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



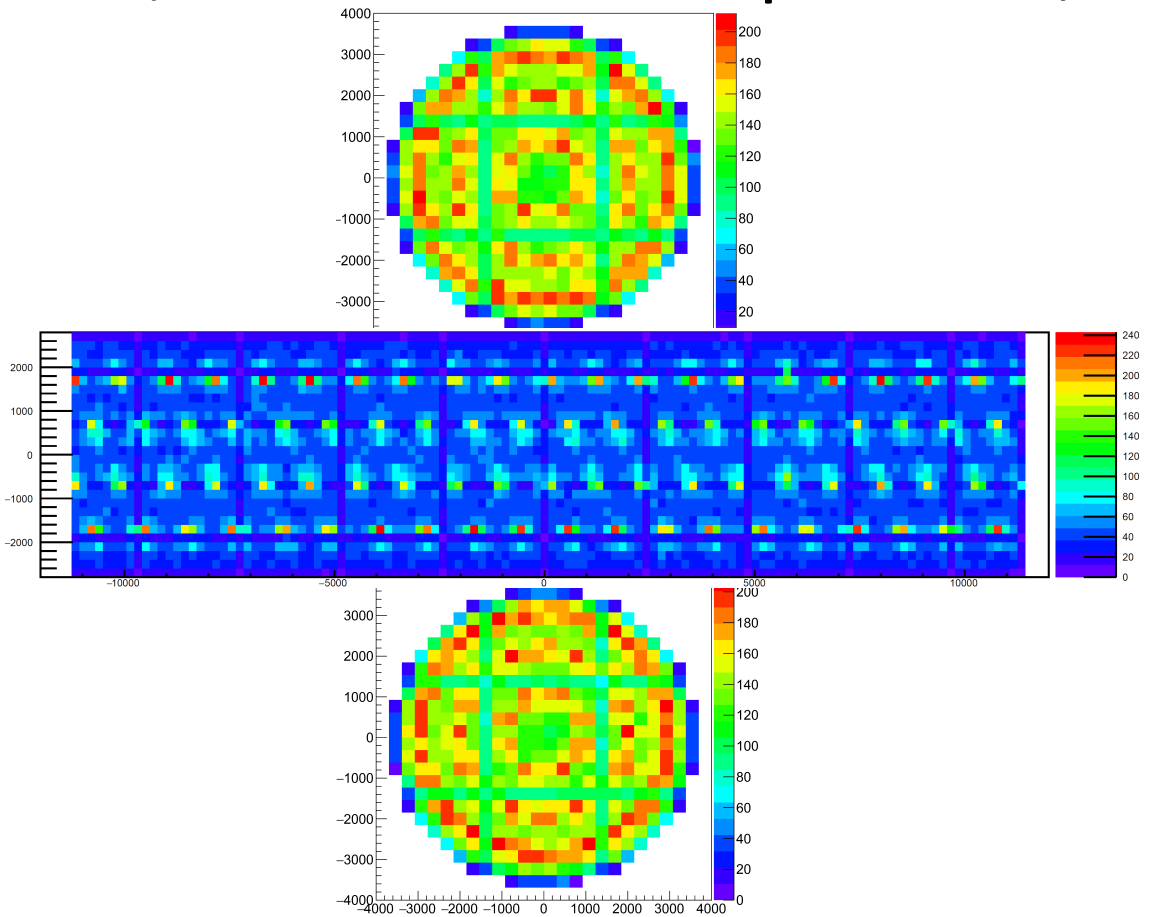
3” PMTs, 50% fibres, outer wall

- 96 sources mounted on outer wall facing inwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



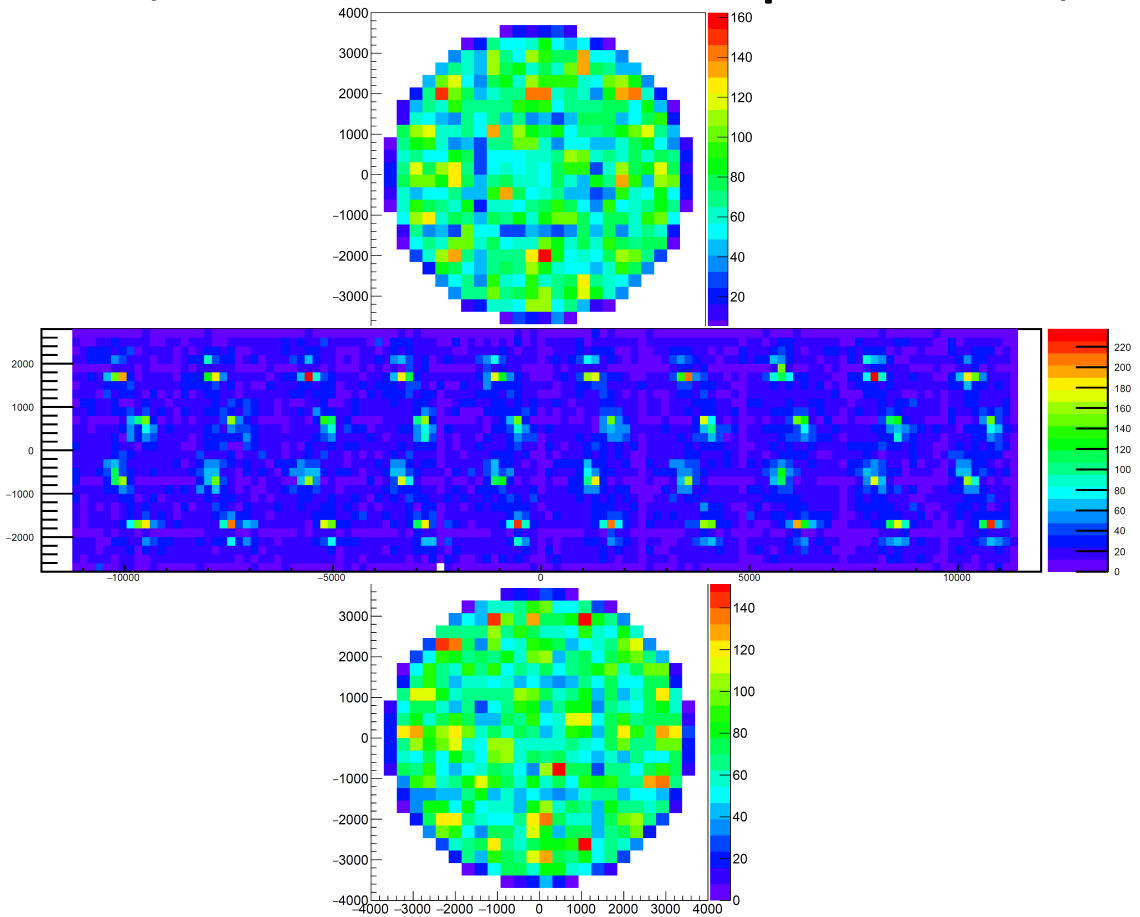
3” PMTs, all fibres, inner wall

- 192 sources mounted on inner wall facing outwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



3” PMTs, 50% fibres, inner wall

- 192 sources mounted on inner wall facing outwards towards PMTs; simulate 5000 ϒ per flash, 100 flashes



Summary and next steps

- Hyper-K outer detector is important for vetoing backgrounds and containment of ID events
- LED calibration system can be applied to calibrate PMTs in-situ, design of light source distribution ongoing
- Next step is to apply photoelectron fit code used for studies done at QM PMT test rig to simulated PMT responses for further assessment of light source requirements