Form 8

Research Result Report
ICRR Inter-University Research Program 2024

Research Subject:

An auto-flashing sytem in Hyper-Kamiokande for monitoring the detector evolution with time

Principal Investigator:

Luis Labarga (University Autonoma Madrid)

Participating Researchers:

Pablo Fernández (also DIPC, San Sebastián, Spain)
Felipe Garay (PhD student, University Autonoma Madrid)
Nataly Ospina (University Autonoma Madrid)
Dustin Samudio (PhD student, University Autonoma Madrid)
Bryan Zaldivar (also IFIC, Valencia, Spain)

Summary of Research Result :

We have studied various auto-flashing system configurations: number of lights, their intensities, wavelength range/s, their position, the amount of daily data necessary from each light etc. The guiding design is that of Super-Kamiokande - one permanent light source located approximately at the middle of the detector -, that has been extremely useful for the running and understanding of the SK experiment.

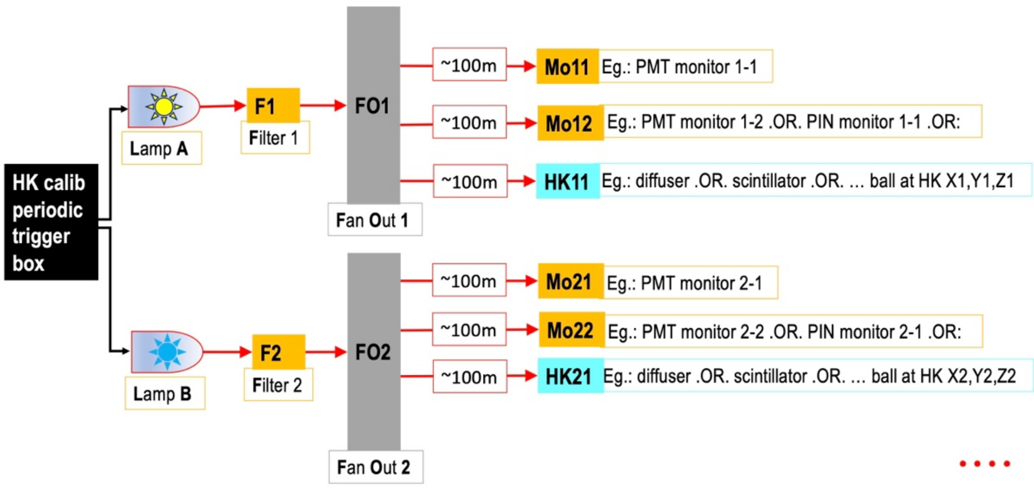
The need of several λ ranges in such a system became apparent in Super-Kamiokande after Gd loading. The light provided by the SK's auto-Xenon system is mostly $\lambda > 400$ nm, range along which light transmission is mostly affected by scattering effects. Clear different relative evolutions of the light transmission are observed with Nickel data in SK (mostly producing Cherenkov light, typically $\lambda <$ 400 nm). For $\lambda < 400$ nm it is absorption that dominates.

An important point of the investigation is whether the different λ ranges should be flashed from the same ball, or it is OK to have some of the balls flashing always on one λ range and other balls in another λ range. Unfortunately, not: isotropic light emission by a ball is much more difficult to achieve for low wavelengths.

The placing of emitters at different parts of the detector has been found to be important: they provide insight in the Z behavior in light transmission, also on how reflections, incidence angles, others, affect the estimates of any relevant variable.

In the following we discuss the current status of the above items.

The approach arrived to, is two sets of two light emitters: the first set will feature high reliability lamps providing light with λ >> 400 nm, that will be feed to diffuser + scintillator balls located in the central part of the ID, and that will emit scintillation light λ > 400 nm with large isotropy, mostly because of the scintillation process that is intrinsically isotropic. This set of lights is very much as the current system in Super-Kamiokande. The figure below sketches this first set.



The figure next presents the main characteristics of the diffuser + scintillator ball to be used (the same as in SK).

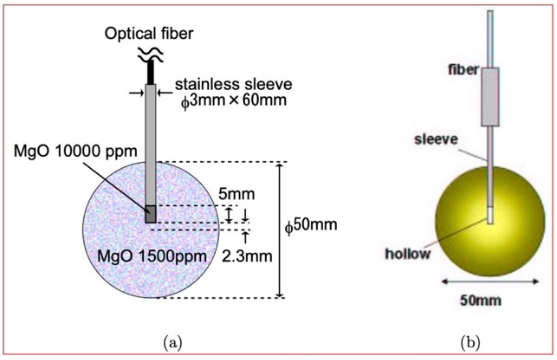


Figure 12: Schematic view of diffuser ball (a) and scintillator ball (b)

diffuser ball: angular variation of the photon emission time was measured to be less than 0.2 nsec.

scintillator ball: 5cm Ø diameter acrylic ball including 2000 ppm of MgO (diffuser) and 15ppm of POPOP (wavelength sifter).

Both made by CI Kogyo (04-2948-1811; Saitama, JP).

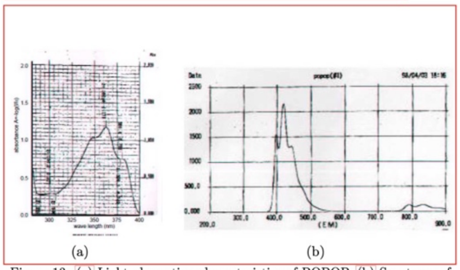
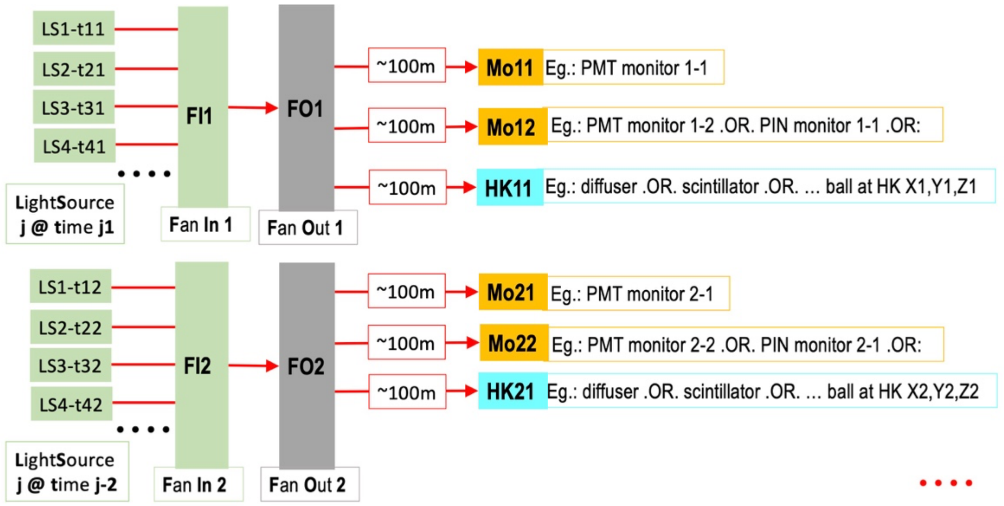
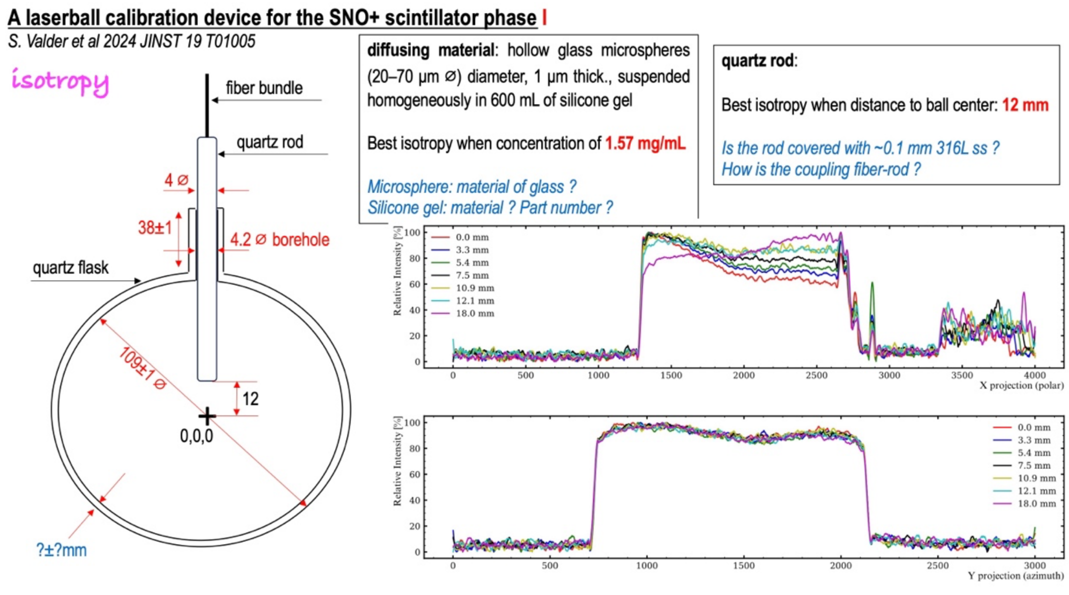


Figure 13: (a) Light absorption characteristics of POPOP. (b) Spectrum of POPOP light emission.

The second set of emitters will feature several λ,s in the range 300 < λ < 400 nm. For the initial light sources, we plan to use the LED multiwavelength system that our UK-HK colleagues are preparing for HK-OD calibrations. Those lights will be feed to highly isotropic diffuser balls located in the central part of the ID, that will emit the light without basically no change in its λ. The figure below sketches this second set of emitters. The specifications of the UK devices have to be written and agreed upon within months.

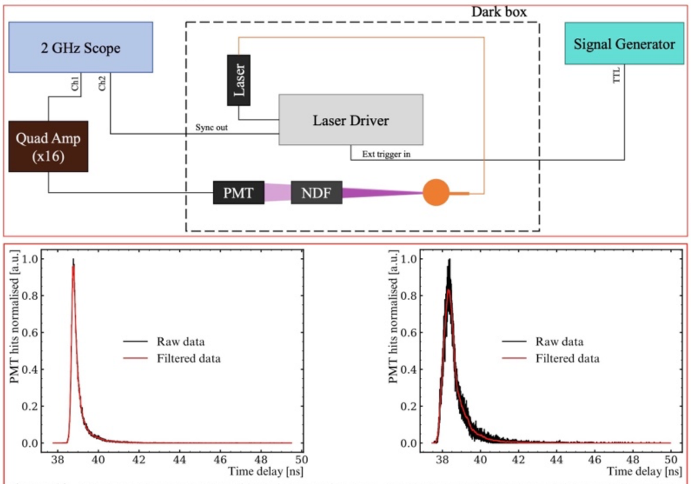


Diffuser balls with high isotropy (and very fast timing response, not mentioned up to now) are, probably, the main challenge of this project. We are closely following the R&D works by our colleagues of SNO+ (scintillator phase) in that direction. The two figures below summarize that work (in terms of isotropy and timing). We will soon contact SNO+ for prototypes to be tested by us.



A laserball calibration device for the SNO+ scintillator phase II TIMING

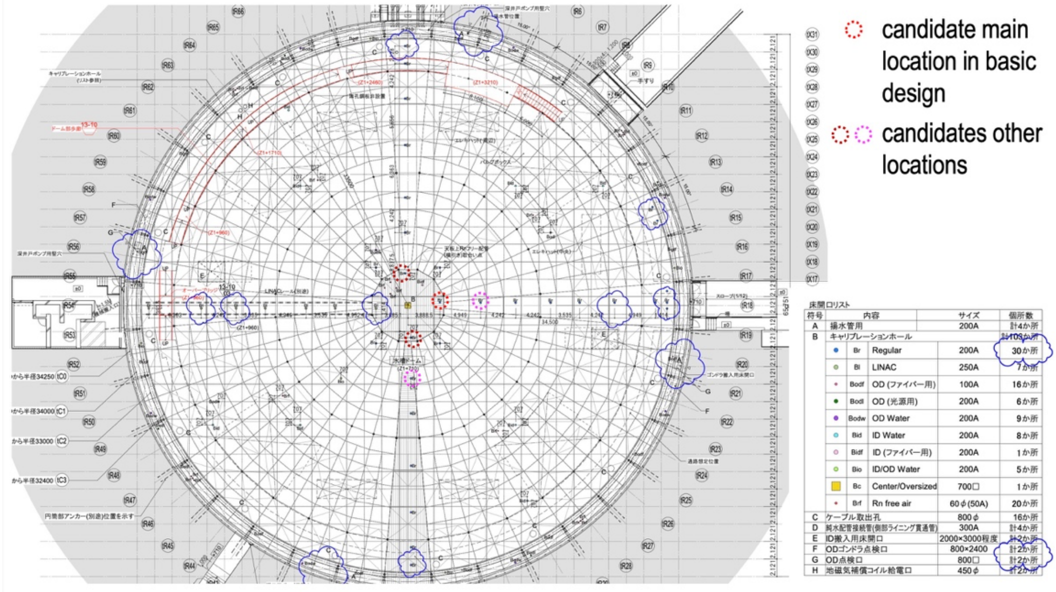
S. Valder et al 2024 JINST 19 T01005



Glass microsphere concentration [mg/mL]	Timing spread (FWHM) [ns]	
	MC	Data
0.51	0.04	–
1.05	0.22	0.28
1.57	0.51	0.64
4.84	1.61	–

Figure 13. The on-axis temporal profiles of the 1.05 mg/mL laserball over 100,000 acquisitions (left), and the 1.57 mg/mL laserball taken over 20,000 acquisitions (right). The measurement shown is the time delay between the synchronised output trigger from the laser and the PMT trigger.

The precise location of the emitters is driven by the location of the calibration ports at the top of the tank. The candidate positions in the (X,Y) plane are shown in the figure below (any Z coordinate different than 0.0 is yet to be decided).



We are studying the market for the different components and, when funding allows, acquire those necessary for the basic system. All components currently considered are reasonably standard except the diffuser balls for 300 < λ < 400 nm. We must make sure of our ability for acquiring them.

We list below the material we have up to now:

- 1x Power Supply C9727-01 for PMT Hamamatsu H2431-50

- 1x CCS200 spectrophotometer
  - 1 x Trigger input cable SMB - BNC
  - 1 x SMA-905 output
  - 1 x opt Fiber, SMA-SMA, 50 µm / 0.22NA, 1m
- 1x GEEKOM Mini PC IT13, NUC 13 i9-13900H for controlling CCS200
- 2x mating Sleeve/connector, FC/PC – PC/PC, narrow Precision Key 2.0mm, D-hole [Thorlabs ADAFCPM3]
- 2x 35m + 2 x 19.2m optical Fibers, 200µm / 0.22NA [Thorlabs FG200UCC] Ends A, B: FC/PC with Stainless Steel Ferrule, Furcation Tubing: FT030-BK
- 2x BF42HS01 1 – 4 fan-out, SMA– SMA, 200µm/0.39NA
- 2x BFYL1LS01 OG Y-Bundle, MM, SMA to Ø1.25 mm Ferrule, 200µm, 0.22NA ,1m, High OH
- 8x mating Sleeve / connector, FC/PC – SMA (905) , wide Key 2.2mm, [Thorlabs ADAFCSMA1]
- 6x mating Sleeve/connector, FC/PC – PC/PC, narrow Precision Key 2.0mm, D-hole [Thorlabs ADAFCPM3]

The last 4 items have been purchased with the funds of this research project.

We have requested to a major Spanish funding agency:

- 8x units of fiber-Connector _ 70m fiber _ SSsleave [by Fujikura c.o.]
- 2x 5cm diameter acrylic diffuser + wave-length-shifter ball [by CI Kogyo JP]
- 4x PMT Hamamatsu H2431-50
- 4x Power Supply C9727-01
- 2x Xenon lamp + filters + intensity regulators etc.
- 1x miscellaneous equipment for optical setup

The decision is expected by before August 2025.

Plan for fiscal 2025 and onwards

The plan for this FY2025 is to establish the final design of the system, in particular the way for providing the different wavelength ranges, to purchase most of the remaining key components.

In FY2026 we expect to build the system in the bench and to operate it. We are considering embedding it in the SK auto-calibration system (upon agreement by the SK Collaboration).

FY2027 should see the installation, commissioning and first data taken running of the HK auto-flashing system in the Hyper-Kamiokande detector.