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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ID[[1]](#footnote-2): | Title: Development of the electronics and time synchronization for Hyper-Kamiokande | | | | | | | | | | | | | |
| PIs: **Members:** | **French Group** | | | | | | | **Japanese Group** | | | | | | |
| Name (Family name, First name) | | | **Title** | | **Lab./Organis.[[2]](#footnote-3)** | | | **Name**  (Family name, First name) | | | **Title** | | **Lab/Organis.[[3]](#footnote-4)** |
| Russo Stefano  e-mail: srusso@lpnhe.in2p3.fr | | | Dr. (staff) | | LPNHE/IN2P3 | | | Hayato Yoshinari  e-mail: hayato@suketto.icrr.u-tokyo.ac.jp | | | Dr. (staff) | | ICRR, The Univ. of Tokyo |
| Alain Blondel | | | Dr. (staff) | | LPNHE/IN2P3 | | | Yusuke Kataoka | | | Dr. (staff) | | ICRR, The Univ. of Tokyo |
| Sara Bolognesi | | | Dr (staff) | | IRFU/CEA | | | Yasuhiro Takemoto | | | Dr.  (staff) | | ICRR, The Univ. of Tokyo |
| Stephane Callier | | | Dr (staff) | | OMEGA/IN2P3 | | |  | | |  | |  |
| Frederic Dulucq | | | Dr (staff) | | OMEGA/IN2P3 | | |  | | |  | |  |
| Jacques Dumarchez | | | Dr (staff) | | LPNHE/IN2P3 | | |  | | |  | |  |
| Sandrine Emery | | | Dr (staff) | | IRFU/CEA | | |  | | |  | |  |
| Samira Hassani | | | Dr (staff) | | IRFU/CEA | | |  | | |  | |  |
| Claudio Giganti | | | Dr (staff) | | LPNHE/IN2P3 | | |  | | |  | |  |
| Mathieu Guigue | | | Dr (staff) | | LPNHE/IN2P3 | | |  | | |  | |  |
| Lucille Mellet | | | PhD | | LPNHE/IN2P3 | | |  | | |  | |  |
| Michel Gonin | | | Dr (staff) | | LLR/IN2P3 | | |  | | |  | |  |
| Olivier Drapier | | | Dr (staff) | | LLR/IN2P3 | | |  | | |  | |  |
| Pascal Paganini | | | Dr (staff) | | LLR/IN2P3 | | |  | | |  | |  |
| Thomas Mueller | | | Dr (staff) | | LLR/IN2P3 | | |  | | |  | |  |
| Margherita Buizza-Avanzini | | | Dr (staff) | | LLR/IN2P3 | | |  | | |  | |  |
| Benjamin Quilain | | | Dr (staff) | | LLR/IN2P3 | | |  | | |  | |  |
| Boris Popov | | | Dr (staff) | | LPNHE/IN2P3 | | |  | | |  | |  |
| Marco Zito | | | Dr. (staff) | | LPNHE/IN2P3 | | |  | | |  | |  |
| Christophe de La Taille | | | Dr. (staff) | | OMEGA/IN2P3 | | |  | | |  | |  |
| Selma Conforti | | | Dr. (staff) | | OMEGA/IN2P3 | | |  | | |  | |  |
|  | | | | | | | | | | | | | | |
| **Funding Request from France** | | | | | | | | | | | | | | |
| **Description** | | | **€/unit** | | | | **Nb of units** | | | Total (€) | Requested to[[4]](#footnote-5): | | | |
| Visit to Japan | | | 100/day | | | | 30 days | | | 3000 | IN2P3 | | | |
| Travel | | | 1000 | | | | 2 travel | | | 2000 | IN2P3 | | | |
| Visit to Japan | | | 100/day | | | | 15 days | | | 1500 | CEA/IRFU | | | |
| Travel | | | 1000 | | | | 1 travel | | | 1000 | CEA/IRFU | | | |
|  | | |  | | | |  | | |  |  | | | |
| Total | | |  | | | |  | | | 7500 |  | | | |
| **Funding Request from KEK** | | | | | | | | | | | | | | |
| **Description** | | | **k¥/Unit** | | | | **Nb of units** | | | **Total (k¥)** | Requested to: | | | |
| Visit to France | | | 20/day | | | | 20 days | | | 400 | KEK | | | |
| Travel | | | 150 | | | | 3 travels | | | 450 | KEK | | | |
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|  | | |  | | | |  | | |  |  | | | |
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| Total | | |  | | | |  | | | 850 |  | | | |
|  | | |  | | | |  | | |  |  | | | |
| **Additional Funding from France** | | | | | | | **Additional Funding from Japan** | | | | | | | |
| **Provided by/Requested to[[5]](#footnote-6)** | | **Type** | | | **€** | | **Provided by/Requested to[[6]](#footnote-7)** | | | | **Type** | | **k¥** | |
| JENNIFER2-RISE IN2P3 | | travel | | | 5000 | | JSPS | | | | travel | | 450 | |
| JENNIFER2-RISE CEA | | travel | | | 1500 | |  | | | |  | |  | |
|  | |  | | |  | |  | | | |  | |  | |
| Total | |  | | | 6500 | | Total | | | |  | | 450 | |

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| **Summary**  **Of**  **2021**  **Project** | Hyper-Kamiokande (HK) will be the third generation of extremely successful long baseline neutrino program in Japan. It will open fascinating new windows on the universe, probing the leptonic CP violation with the highest precision, testing the three-flavor neutrino oscillation paradigm and having a unique capability to probe Grand Unified Theories through proton decay, in conjunction with a strong astrophysical program.  The HK detector will be the largest underground water Cherenkov detector with a 68 m diameter and 72 m height cylindrical tank, It will be equipped with up to 50,000 photo-sensors in the inner detector. This project aims to develop and ultimately produce the photosensor front-end electronics and synchronization system of the HK experiment.  Timing synchronization of each PMT signal is crucial for a precise reconstruction of the particle tracks due to the trigger-less nature of the detector. In HK, timing resolution of the photo-sensor is expected to be sub-nanosecond and the jitter less than 100ps RMS and, the association between the local time base and the Coordinated Universal Time (UTC) is also crucial to synchronize the data acquisition with the beam sent from the J-PARC particles accelerator in Tokai and to correlate the astronomical events detected by other detectors around the world.  After the great results achieved during the first round of tests performed to evaluate the different time distribution technologies selected, the attention is now shifting on testing it on front-end prototypes. In 2021 the time distribution concepts and technologies will be integrated with the front-end boards that are under design. Multiple solutions are under studies and as much as 4 different FE prototypes are expected to be ready by the end of 2021. The goal of this group is to realize a joint test campaign with a time distributor that feeds the clock to the front-end board that, in turn, reads the signal from a PMT. This scheme will allow to establish not only the feasibility of the clock delivery concept on a realistic testbench but also to evaluate how charge measure would be affected by the time distribution.  On the time base generation aspects, this group will focus its attention on the characterization of the GNSS (Global Navigation Satellite System) receiver, purchased at the end of 2020, against a so-called group 1 UTC lab, the SYRTE institute part of the Paris Observatory. This will allow to precisely measure the internal delay of the GNSS unit at level of less than 3 ns allowing a very high accuracy on the UTC time definition in the final detector. If the pandemic situation will allow travels this group is planning to deploy the GNSS receiver on the Super-Kamiokande site to test its performances on a site that is very similar to the HK one.  The photo-sensors and its front-end electronics are the two pillars of the detector. In order to comply with the vast HK physics, this electronics should combine a very low deadtime, to always keep an eye on potential near Supernovae, to an extremely wide charge dynamic range to be able to tackle both the low and high energy sectors of HK with an unprecedented precision. This project aims to develop a chip and its host front-end board in France combining the performances of the existing Super-Kamiokande chip, the QTC, and the cutting-edge technology of the chip (HGCROC) developed for the future CMS upgrade, the high-granularity calorimeter. This unique project relies on the strong expertise of the ICRR group, who has developed the QTC, and the OMEGA, LLR and CEA groups who are collaborating to develop the HGCROC. The chip development for HK has started in the OMEGA group from 2020, and 2021 will be a unique year where we aim to:  1. Produce the schematic and first version of the HK chip (HKROC) led by the OMEGA and the CEA-IRFU groups.  2. Prepare a first test board at LLR in collaboration with ICRR to validate the chip performances complies and surpass the HK requirements. The contribution of the ICRR group will be especially crucial to make sure the board allows to validate all requirements, as well as to avoid potential issues based on many years of QTC running for Super-K.  3. Prepare PMT test benches at LLR and ICRR to validate and compare the HKROC and QTC electronics using both generators and actual HK 20-inch PMTs.  This front-end project is supported by Ecole polytechnique which granted a 400 keuros budget for R&D development in France only. Based on this strong asset, the project -which involves very same groups contributing to the timing system - also requires an intense collaboration between the French and Japanese groups to grow up to next level and be successful. As hardware development requires face-to-face meetings and close work, we are planning to organize a direct meeting in Japan, to present the QTC solution and its clock-distribution system, and one in France, to present its French equivalent based on HKROC and the clock presented earlier in this document. |
| **Workshop / satellite session at annual workshop**  **(if applicable)** |  |
| **Common Articles Expected (if applicable)** |  |
| **Seconded / Jointly Supervised Students**  **(if applicable)** |  |

1. ID: identification, if program continuation, use previous ID; if new project, ID will be set by the TYL directors; [↑](#footnote-ref-2)
2. e.g. LAPP/IN2P3 or Irfu/CEA [↑](#footnote-ref-3)
3. e.g. IPNS/KEK or … [↑](#footnote-ref-4)
4. e.g. IN2P3, Irfu [↑](#footnote-ref-5)
5. e.g. French Embassy, other CNRS or CEA programs, PICS, European grants… [↑](#footnote-ref-6)
6. e.g. JSPS, RIKEN, Universities,….; [↑](#footnote-ref-7)