# Conclusions

The project, the implementation, and the tests of timing calibration system for mini-tower of NEMO phase 1 have been performed in this thesis work. The NEMO phase 1 mini-tower is successfully deployed at the end of 2006. All the systems are working, in particular the timing calibration system and clock station have shown complete functionality.

The task of time calibration system is to determine the offsets matrix or displacement of the arrival times for all the different optical modules. The pointing of astrophysical sources are directly affected by accuracy of the time measurements, a simulation study shows that if the offsets accuracy is less or equal to 1 ns that does not affect the pointing resolution, then accuracy required is from timing calibration system is $\sigma \leq 1$ ns.

The timing calibration system of NEMO phase 1 is based on the distribution of optical signals at known time from common optical pulsers by a network of optical fibres. To reach this objective, optical pulsers and optical network have been projected, implemented and verified.

The offsets are calculated from:

$$offset_i = t_{peack,i} - corr_i$$

where $t_{peak,i}$ is the mean of the times where the signal pulses overcome a given threshold and $corr_i$ is the correction due to the propagation time of the pulses due to the fibres. To measure $corr_i$ a facility station was implemented and results have been presented.

This thesis work include also the projecting, the implementation and test of a clock shore station for whole apparatus. Assignments of the clock shore station are:

- Clock Fan-out toward FCMs onshore
- UTC data flow sent to FCMs onshore in synchronous protocol
- Recovery clock, UTC data and time from GPS receiver
- Go-and-Back time measurements FCM onshore/offshore by TDC

- NTP server
- Managing of timing calibration commands and procedures

In the timing shore station works the offset interface software, a MatLab application, which performs the retrieving and analysis of data calibration from acquisition system and produce the offset matrix. A mass analysis campaign is needed to analyze all the data stored so far from the detector, but some preliminary results have been presented.

The standard deviation of $t_{peak,i}$ calculated, include a TTS contribute, then to evaluate only the accuracy of timing calibration system is needed to know the TTSs of PMTs at intensity levels of calibration signals. This evaluation is ongoing. Nerveless, from preliminary results it is possible to confidently presume that the accuracy required will be reached.

Tests have been performed to assure that environmental parameters do not affect the correction values and the work conditions of the system. A partial onshore timing calibration was executed, the results confirm those ones obtained from onshore timing calibration. Moreover, pulser lifetime tests were performed for some optical pulsers. The results show that the tested pulsers do not derive for a period comparable to 14 years of mini-tower lifetime.

Some hints of a new timing calibration system for full NEMO tower have been presented. The system has ridden over the prototyping and now is in the mass production phase. It will be integrated in the tower for the deployment foreseen at the end of this year at KM4 site.

In all mentioned aspects of the time calibration system, my contribute has been essential from basic ideas to the final tests. Moreover, I had the opportunity to participate on the programmatic specification work as planning, interfacing and integration with other systems and persons involved.