



**ISTITUTO NAZIONALE DI FISICA NUCLEARE**  
**Laboratori Nazionali del Sud, Sezione di Genova**

---

INFN-20-012/GE

24 Agosto 2020

**INFN INTERNAL NOTES**

**The “Automated Welding Machine” in the integration  
process of the Detection Units of the KM3Net  
experiment: general description**

Giorgio Cacopardo<sup>1</sup>, Giacomo Ottonello<sup>2</sup>, Stefano Ottonello<sup>2</sup>, Massimiliano Cresta<sup>2</sup>,  
Franco Parodi<sup>2</sup> Fabio Pratolongo<sup>2</sup>

<sup>1</sup>) INFN, Laboratori Nazionali del Sud, Via Santa Sofia, 62, 95123 Catania, Italy

<sup>2</sup>) INFN, Sezione di Genova, Via Dodecaneso, 33, 16146, Genova, Italy

**Abstract**

This note describes one of the tools used during Process-1 of the integration of the Detection Units (DUs) in the KM3NeT experiment. In particular, the device is designed to seal the Break-out-box (BOB). The BOB is a box interface between a Digital Optical Module (DOM) and the electro-optical cable (VEOC) for power and optical connection of each optical module (DOM) to the DU. The original manual version of the tool developed by NIKHEF was automatized by INFN-LNS in order to guarantee a reproducible operation in the recursive process of the DU integration and two samples have been realized for the integration sites at LNS and Genova respectively.



# INDEX

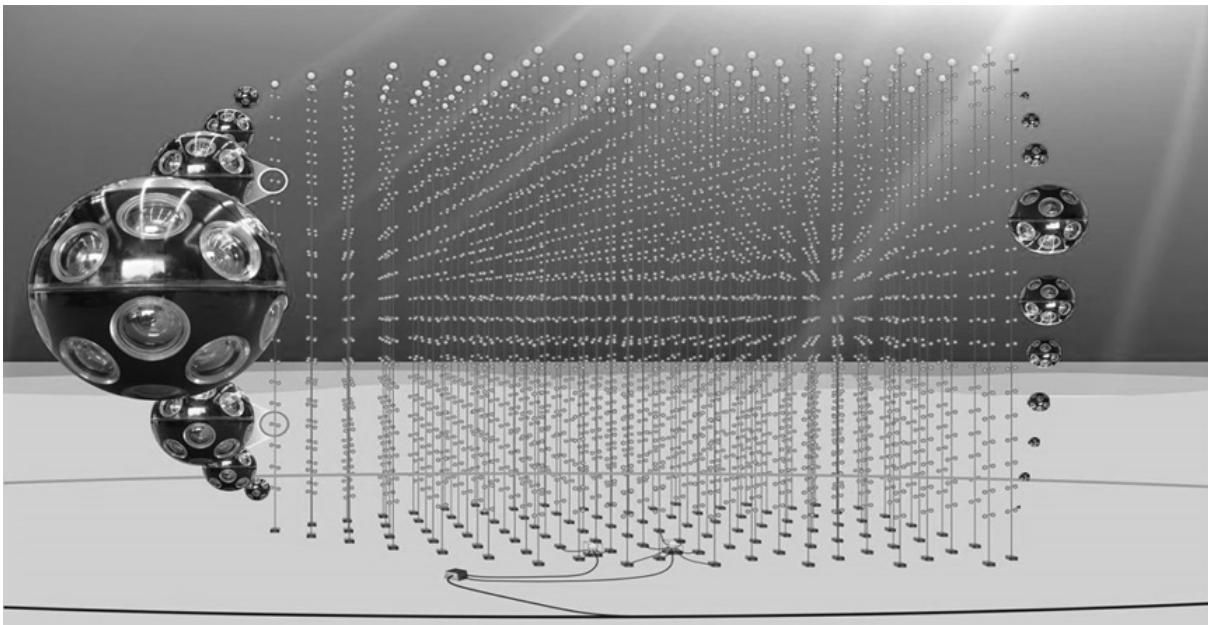
Abstract.....	1
1.Introduction.....	2
2.General layout.....	4
2.1 Machinery Directive Rules and guidelines	4
2.2 Short description.....	5
3.Qualification .....	7
4.Conclusion .....	8
References .....	8

## Table of figure:

Figure 1: km3 experiment.....	2
Figure 2: Schematic drawing .....	3
Figure 3: Schematic picture of a DOM BOB .....	4
Figure 4: General view .....	5
Figure 5: the spare BOBs after the sealing .....	7

## 1.Introduction

The KM3NeT experiment [1] for the detection of high energy cosmic neutrinos is being built in two sites of the Mediterranean Sea, Capo Passero in Sicily (ARCA) and Toulon in the French coast (ORCA). The full detection system includes 3 building blocks of DUs [2], each block of 115 DUs as shown in fig.1.



*Fig.1 General layout of 1 building block of the km3 detector*

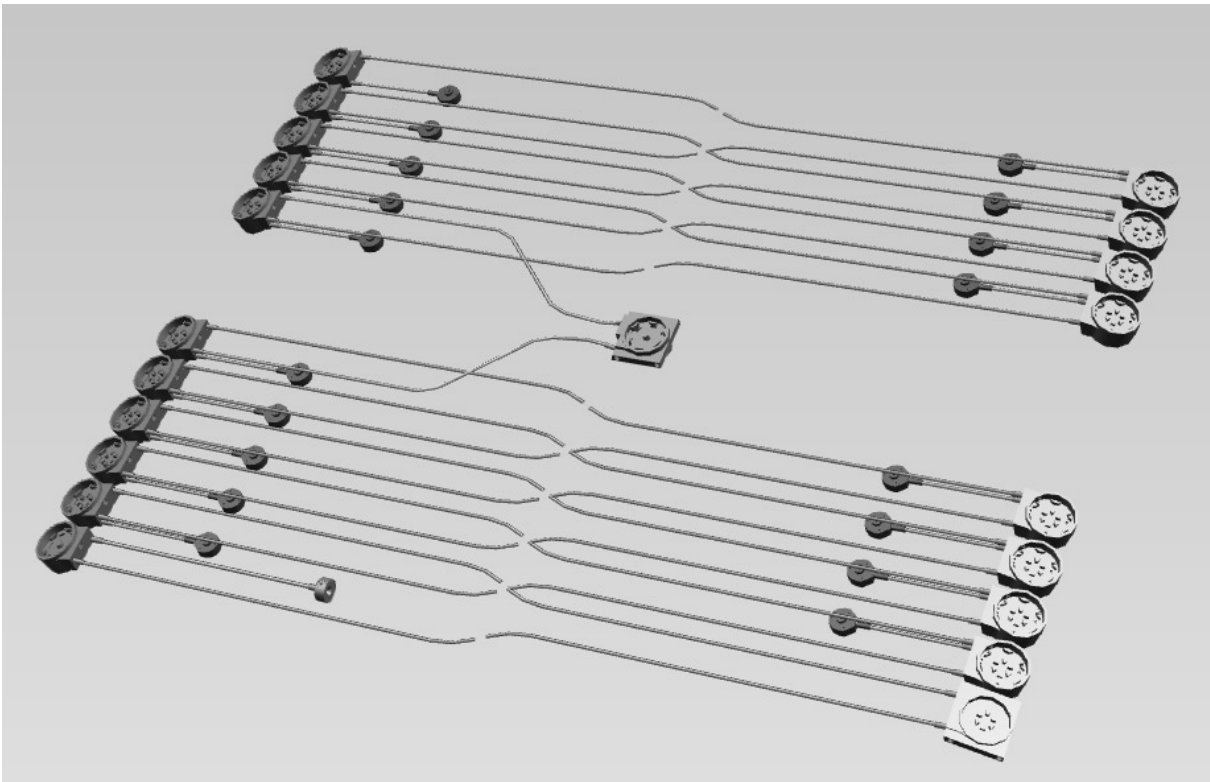
Each DU accommodates 18 DOMs [3], kept vertical by a top buoy and connected to the DU base via the VEOC. The DOMs are produced in various integration sites of the KM3NeT collaboration

while the VEOCs are provided by the Dutch MCAP company specialized in cable and glass fibers assemblies. The schematic of cable, filled with oil to be in equi-pressure during operation at the sea bottom, is reported in fig.2.

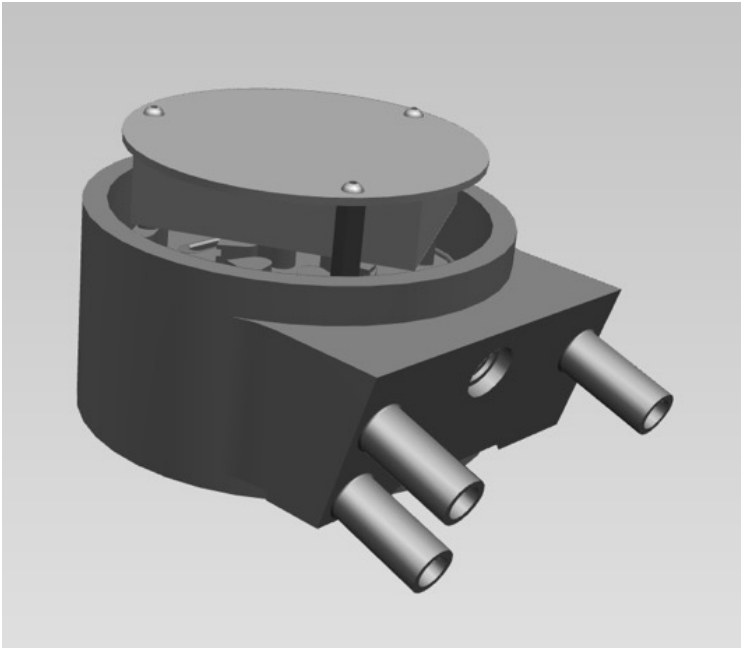
Every 9m in ORCA or 36m in ARCA, the VEOC has a break out box (BOB) made in black SIMONA® PP-EL-S polymer to allow connection to the corresponding DOM. The box has two separated compartments as shown in fig.3. The first is already sealed and includes a 375/12V DC-DC converter. The two conductors and one fibre of the VEOC are addressed to the second compartment which is open and oil free to allow the connection to the DOM via the splicing of the optic fibre and the clamp of the electrical wires

This operation is described in detail in the Integration procedure manual on Google Drive. As a result, the DOM is electrically and optically connected to the VEOC but in order to guarantee water tightness and equi-pressure during operation, the second compartment of the box must be finally sealed, and oil filled.

In each DU this operation must be repeated 18 times, one for each DOM, and hundreds of times when all the DUs of the building blocks of the detector are considered.



**Fig.2:** Schematic drawing of a completed ARCA VEOC.



***Fig. 3: Schematic picture of a DOM BOB showing the VEOC compartment with the mounted DC/DC converter board on top (before closing off the compartment with a PE cover).***

The automation of this process via the so called “automated welding machine” (AWM) can have a great impact during the DU integration process not only with respect to time optimization but also to improve the reliability of the process.

The design of the AWM was developed by one of us (G. Cacopardo) while the realization of all the mechanical structure was performed both at INFN-LNS and INFN-Genova.

In this note we focus on the general description and requirements of the machine while details on the mechanical structure, the electronic components and the software will be given in separate reports. The qualification of the device based on the check of the welding procedure repeated in a relevant number of spare BPBs is also discussed.

## **2.The general layout**

### **2.1 Machinery Directive Rules and guidelines**

The AWM is not realized to be market to outside companies: it will be used during the DU integration process 1 by trained people, only inside the INFN laboratories. However, the design is compliant to the EU's Machinery Directive which defines the essential health and safety requirements for a wide range of products, including machinery conformity with respect to the essential health and safety requirements (in Italian RES, Requisiti Essenziali di Sicurezza). This is accomplished by

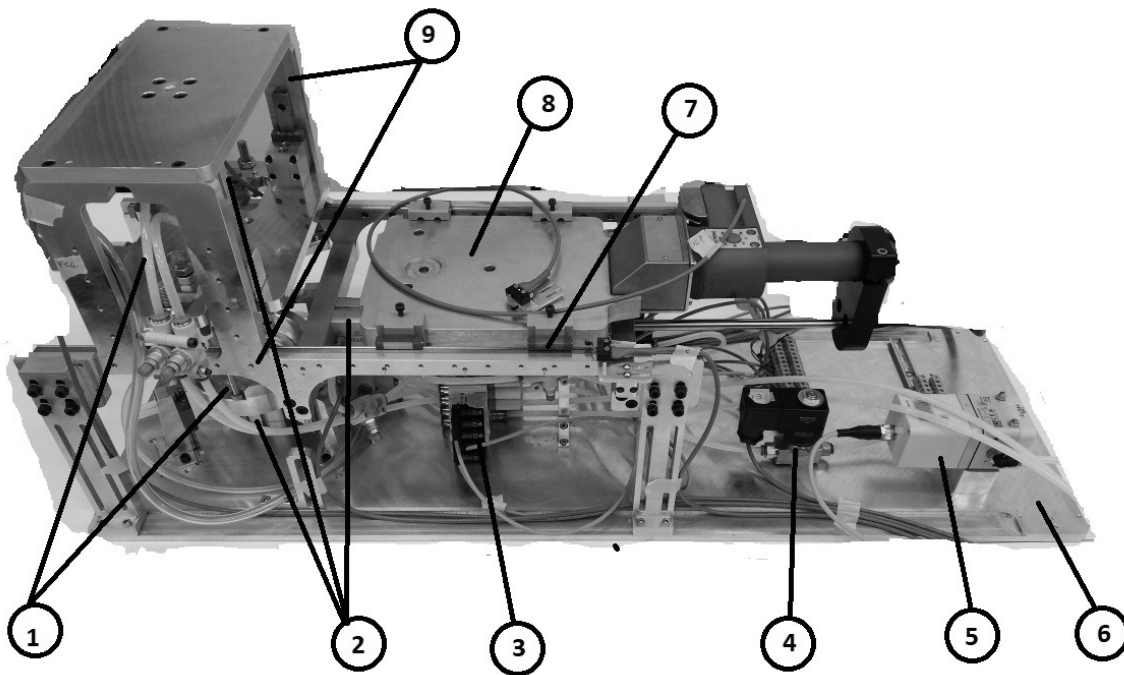
- a detailed risk analysis which includes the application of technical standards already during the design phase, the implementation of safety devices and guards, highlighting, in the instruction manual, the residual risks that cannot be eliminated,
- the technical documentation file to collect all the documents produced during the design phase, the construction and the test of the machine,
- the operation and maintenance manual,
- a manufacturer plate for identification

The AWM was designed following the guideline of the technical code DVS 2207-1 that applies to the welding of pipes, fittings and tapping tees made from PE-HD including types PE 63, PE 80 and PE 100. In this approach the quality of welded joints depends on the qualification of the welder as well as on compliance with the welding standards.

The welded joint can be tested by means of non-destructive methods: in our application this is accomplished using pressurized air inside the welded volume and checking for leaks. Within the framework of the quality assurance it is recommended to produce and test samples of joints before and during welding. This was done various times on spare BOBs as described in next chapter.

## 2.2 Short description

The general layout of our AWM is illustrated in fig.4



*Fig.4: General view of the automated welding machine and its numbered parts*

The following major components can be identified:

- An electronic control panel powered by an electric cable with industrial plug,
- a cable with 76 electrical pins connectors on both sides to drive the commands from the control board to the machine,
- an electric cable between the control panel and for the 220V power supply,
- the mechanical structure where the welding operation takes place,

This part includes:

- An aluminium frame,
- A pneumatics actuator,
- Various pneumatics valves,
- A polywelder,

In addition, some emergency buttons like “start cycle”, “vacuum ON/OFF “, are located onboard to allow emergency stops and flexibility during manual operation.

This tool is able to grab and host the cap of VEOC portion of the BOB on the lower piston, utilizing vacuum. In the upper piston a BEOC cap is hosted in a similar way.

Two micro-switches are used as positioning sensors, in order to give to the control electronic board, the feed-back on the position of the two objects in the tool. After the positioning of the BOB and the cap, the polywelder moves to the heating position.

The polywelder is a standard tool for butt-welding of polyethylene pipes. It reaches temperatures between 180°C - 230°C. Also, in this case micro-switches give to the control board input regarding the right positioning of the polywelder. When the polywelder reaches its position, the lower and upper pistons act by pushing the BOB and the cap towards the polywelder, with a 0.14 N/mm<sup>2</sup> force as prescribed by the technical code DVS 2207 part 1, regulated by air pressure. The system then remains 60 seconds in this position until a bead will form both in the BOB and in the cap. At the end of bead-up time, the system, by regulating the air pressure, decreases the force applied on the BOB and on the cap down to 0.015 N/mm<sup>2</sup>, and maintains their respective positions for additional 60 seconds.

Then the pistons detach the cap and the BOB from the polywelder, that returns at its parking position. Finally, the upper piston is activated to push the cap on the BOB, with a force of 0.14 N/mm<sup>2</sup>. The system remains 300 seconds in this position until the complete cooling of the object.

This procedure guarantee alignment between the BOB and the cap, full compliance with technical code DVS 2207 part 1, increased reliability, and a safer procedure than in the past.

The description of the mechanical/pneumatic components and of the electronic/command/software will be detailed in successive reports.

### **3. Qualification**

The preliminary qualification of the automated welding machine was performed in the DU integration room at INFN in Genova.

This preliminary qualification was performed using 5 couples of spare empty BOBs together with the corresponding sealing caps. Before starting the automated welding cycle, the BOB and the cap are kept in place in their metallic support by the pneumatic system which has to be activated beforehand.

The cycle is the started and after 10', once it has reached the operating temperature, the polywelder is moved between the BOB and the cap which are then pushed simultaneously toward the hot surface of the polywelder. This configuration is then maintained for 55" sufficient to heat the BOB and cap contact surfaces. The two parts are then separated by the two pneumatic actuators, the polywelder, as previously described, moved into its parking position and the upper pneumatic actuator activated to push the cap in contact to the BOB. The automated procedure keeps this configuration for 5' to allow the welding of the two parts. The cycle is then terminated, the BOB released from its metallic support, ready to be used.

The circular welded part appears, at a visual inspection, very uniform without any evident imperfection. As a final and more effective leak test, the closed BOB was pressurized at 2 atm and immersed in a water tank. No evidence was found for all the 5 samples. In figure 5 there are the spare BOBs after the sealing performed with the AWM.



*Fig.5: the spare BOBs after the sealing performed with the AWM. The contact region between the BOB and the cap are well visible in the upper part of the BOBs and look uniform*

#### **4.Conclusions**

The automated welding machine to seal the BOBs of the Detection Units of the km3net detector will be used during the integration of the KM3net Detection Units in Genova. This system, designed by LNS, was realized in Genova and the preliminary qualification performed on 5 samples show that the device is suitable to be used during mass production.

#### **References**

- [1] arXiv:1601.07459 [astro-ph.IM].
- [2] Adrián-Martínez, S., Ageron, M., Aharonian, F. et al. Eur. Phys. J. C (2016) 76: 54.
- [3] EPJ Web of Conferences 116, 01002 (2016).
- [4] I. Sgura. VEOC to DOMs and base container integration procedure, internal note KM3NeT\_INT\_2016\_004.