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Status Report of Projects Activities at CERN

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Abstract
Besides the Long Shut-Down 1 (LS1), some projects are still progressing at CERN. Among them, it has to be mentioned LINAC4, a future essential part of the LHC injector chain, AWAKE, a project to verify the approach of using protons to drive a strong wakefield in a plasma, ELENA, a small compact ring for cooling and decelerating antiproton and HIE-Isolde, not to forget the long term studies for CLIC and FCC. This paper describes the status of these projects from the survey and alignment point of view.

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STATUS REPORT OF PROJECTS ACTIVITIES AT CERN

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Abstract

Besides the Long Shut-Down 1 (LS1), some projects are still progressing at CERN. The LINAC4, which will be the essential part of the injector chain in the future, is in the installation phase and will be connected to the existing accelerators in 2018. AWAKE, a project to verify the approach of using protons to drive a strong wakefield in a plasma which can then be harnessed to accelerate a witness bunch of electrons, will be using the proton beam of the CERN Neutrino to Gran Sasso, plus an electron and a laser beam. This facility will be installed in the CNGS target vicinity, as the experimentation with neutrino has been stopped at the end of 2012. ELENA, a small compact ring for cooling and further deceleration of 5.3 MeV antiprotons delivered by the CERN Antiproton Decelerator, is in the study phase. In the HIE-Isolde project, the preliminary survey works have started and the installation is going to take place in 2015.

The CLIC study is still on going and the new achievements will be presented. Moreover, since the beginning of the year CERN has launched a study of the feasibility of a circular collider of about 100km circumference, hosting either hadrons or leptons.

This paper gives an overview of the survey activities realised in the frame of the above mentioned projects and the challenges to be addressed.

INTRODUCTION

While the Large Hadron Collider (LHC), its injector complex and the experiments are heavily measured within the frame of the LS1 measurements campaign, there are still a range of new projects which are progressing.

The first part of the LINAC4, also called the 12 MEV section, has been installed and the fiducialisation of the others components is on-going. The AWAKE project is in the civil engineering and design phase while the ELENA machine, actually in the design phase, is going to be installed from middle of 2015. In the HIE-Isolde project, besides the development and the validation of monitoring system of the cryo-tanks of the linac, the metrological measurements during the assembly of the first module in a clean room and the preliminary works for the installation of the transfer lines have started.

From the CLIC side, after having intensively tested the alignment of the two beam test modules and its components in a dedicated lab, the module has now been transferred to the CLEX zone where it will be tested with beam. It will be the opportunity for the survey team to validate the alignment procedures which is part of the CLIC alignment strategy.

Last, but no least, as part of the European physics strategy, CERN has decided to study the feasibility of a big circular collider, which should be able to run leptons or hadrons. A conceptual Design Report should be produced by 2018 and, depending on the results found by the LHC, running at its maximum energy, the physics world will have to decide between CLIC and FCC.

LINAC4

As first step of the LHC luminosity upgrade program, CERN is building a new 160 MeV H^- linear accelerator (Figure 1), Linac4, to replace the 50 MeV Linac2 as injector to the PS Booster (PSB).

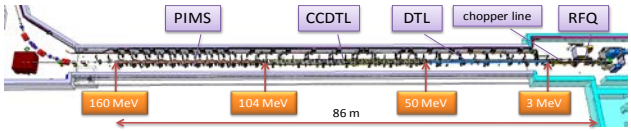

Figure 1: LINAC4 layout

Installation of the machine infrastructure has been progressing since the delivery by the civil engineering company of the Linac4 building and tunnel at end 2010. All equipment has been preliminarily integrated into an extensive 3-D computer model which allowed an early solution of interference problems.

In 2012 a new determination of the underground geodetic reference network along the main LINAC tunnel and the transfer line tunnel has been accomplished using AT401 and Gyromat3000 measurements.

In order to anticipate the heavy workload in the LHC during 2014, all the jacks in the straight line (before the L4 transfer line) have been pre-aligned during 2013: there are ready for the DTL, CCDTL and PIMS installation.

Figure 2 : Linac4 jacks ready for installation

The 3Mev and 12 MeV test stand

The section up to 3 MeV has been transferred from a test area to the tunnel during 2013: the LEBT, the RFQ and the MEBT and the diagnostic line have been aligned in order to allow the 3 MeV beam tests.

After the final fiducialisation on surface, the DTL01 with its Electro-Magnetic Quadrupoles (EMQ) have been aligned during the second trimester of 2014 inside the Linac4 tunnel. The 12 MeV beam tests are now in progress.

First CCDTL alignments

All the Permanent Magnet Quadrupoles (PMQ) and EMQ magnets have been aligned on the CCDTL structures with respect to the drift-tubes axis defined during the previous measurements.

The CCDTL04 and CCDTL05 have been installed and aligned in the L4 tunnel.

DTL and PIMS Metrology

The PIMS M has been measured with the laser tracker in order to check its geometry after the complex welding process. All the drift-tube centres well aligned and are inside the range of +/- 0.1 mm.

Figure 3 : PIMS M (August 2014)

A complete metrology of the DTL03 with the 4 segments assembled has been performed : the axis defined by the drift-tubes axis is “perfect” (+/- 0.08 mm). The different segments of the DTL02 will be measured in a few months before the final measurement after assembly.

To be continued …..

The dump alignment design is in progress and a dry test will be performed this year.

The five bending magnets will be soon ready at CERN for the magnetic measurements. The survey challenge will be to align the vacuum chambers inside the magnets before their installation on the beam in the tunnel.

The 12 MeV beam commissioning will be finished in December. The next beam tests will be the 50 MeV (DTL02 and DTL03), the 100 MeV (all the CCDTL will be installed + PIMS1) and the 160 MeV (all the PIMS will be installed).

All these elements will need a geometry validation and fiducialisation before going down and aligned in the L4 tunnel.

THE AWAKE PROJECT

The Advance WAKefield Experiment (AWAKE) Collaboration in an international group of physicists who are proposing to use the LHC's penultimate synchrotron, the SPS, to drive plasma wakefield acceleration and accelerate a GeV scale electron beam [1].

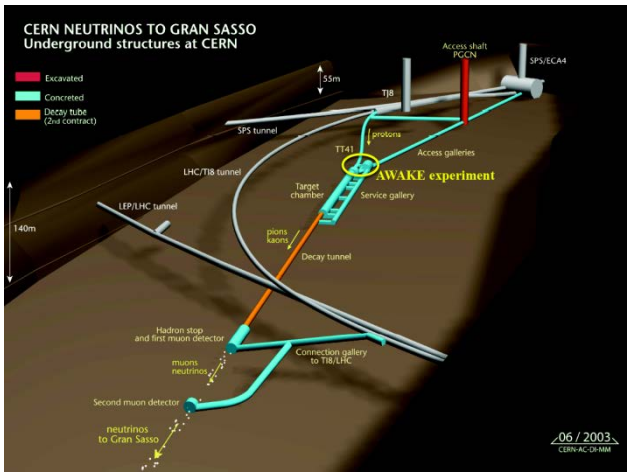

Figure 4 : the AWAKE location at CERN

AWAKE will use proton beams from the Super Proton Synchrotron (SPS) in the CERN Neutrinos to Gran Sasso (Figure 4) facility, which has been stopped at the end of 2012. These protons will be injected into a 10-metre plasma cell to initiate strong wakefields. A second beam – the “witness” electron beam – would then be accelerated by the wakefields, gaining up to several gigavolts of energy (Figure 5).

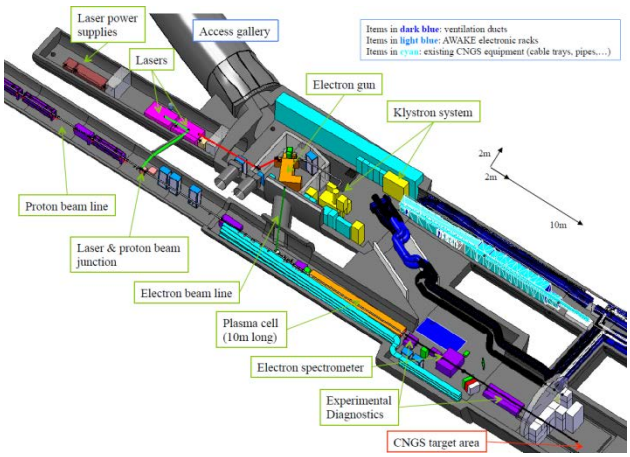

Figure 5 : the AWAKE facility

Even if the AWAKE project is still in the civil engineering stage, the survey team already did many tasks in 2013 and 2014.

Before CNGS dismantling, the survey team installed more reference points in the vicinity to keep the old CNGS magnets as reference for the future installation of AWAKE. The survey team used wire offsets and laser tracker AT401 to measure the whole TT41 proton beam transfer line from the SPS to CNGS area. A complete levelling of TT41 beam components and reference points was also realised as well as a complete laser scanning of CNGS area to give a complete as-built model for the AWAKE design and integration office.

Upon a request of the civil engineering team, the marking of the axis of the new electron transfer line and of laser core tunnels has been realised. Actually the civil engineering work is almost finished and the area is ready for the beginning of AWAKE installation. A laser scanning of the new electron line has been realised after boring to check the tunnel position.

In 2015, the first proton beam to the AWAKE experiment will be send. In 2016 the installation of electron source and beam line is schedule. So many survey works are scheduled for the upcoming 2 years.

ELENA

ELENA is a compact ring for cooling and further deceleration of 5.3 MeV antiprotons delivered by the CERN Antiproton Decelerator (AD). The AD physics program is focused on trapping antiprotons in Penning traps where anti-hydrogen is formed after recombination with positrons. The ultimate physics goal is to perform spectroscopy on anti-hydrogen atoms at rest and to investigate the effect of the gravitational force on matter and antimatter [2].

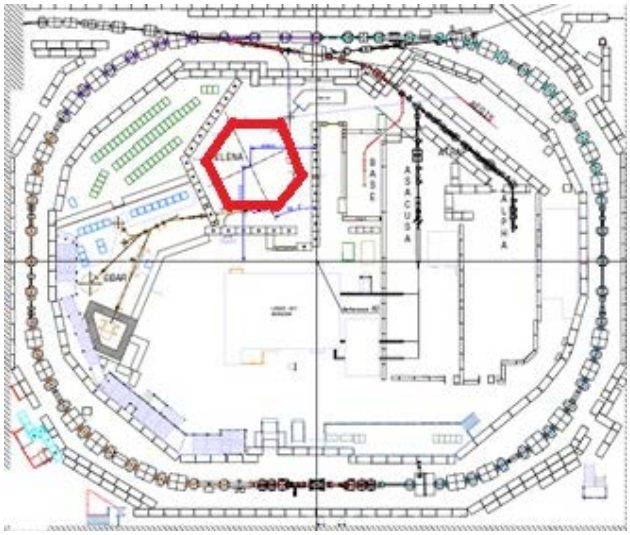

Figure 6: Elena and the AD complex

In a first step, ELENA will consist in a ring and a transfer line from AD to the new facility; in a second step, in 2017, several transfer lines will be constructed, starting from ELENA to the existing and new experimental areas as Base, ASACUSA, ALPHA, ATRAP, and GBAR. This will allow the almost simultaneous delivery of beam to these zones.

During the actual design phase, in 2014, the survey activities are mainly to give advice to the design office, and, in collaboration with the responsible for the magnets, to define the position of the survey targets, the supports, and the design of the moving tables.

The construction and installation phase is planned for 2015, where the survey team will perform the following tasks:

- Installation of reference points in the area, measure the network with respect to AD: transfer of the vertical plane by direct levelling and angles and distances measured with the absolute tracker AT401
- Marking on the floor of the beam lines (ELENA and transfer lines), as well as the girders and jacks, with respect to the network.
- Determination of target points w.r.t. the beam line (fiducialisation) of magnetic elements
- Alignment of about 30 components with respect to the network and smoothing.

For this project, it is foreseen to use the AT 401 as main instrument for the alignment, taking into account the good configuration of the ELENA ring.

HIE-ISOLDE

The HIE ISOLDE project is a major upgrade of the ISOLDE REX facility. The beams will be accelerated in a superconducting linac made of 6 cryo-modules (Figure 7) containing superconductive RF cavities and solenoids.

Figure 7: HIE-ISOLDE Linac and HEBT

To run the linac in the optimum conditions, the Monitoring and Alignment Tracking for HIE-IsoLDE (MATHILDE) system [3], based on HBCAM opto-electronic sensors, optics and precise mechanical elements, has been developed to guaranty radial positioning and monitoring of the superconducting RF cavities and the solenoids with precision of respectively 0.3 mm and 0.15 mm at one sigma level.

In the meantime the infrastructure installation in the HIE-ISOLDE accelerator area is going on as well as the machine elements procurement and assembly.

Most of the geodetic network is installed in the hall and measured. It will be upgraded according to the status of the infrastructure completion. The linac and HEBT transfer line supports are being aligned. Delivery of the first magnets started and the fiducialisation work will begin soon after acceptance tests. The diagnostic boxes arrived at CERN and a metrology comprising fiducial marks will be performed in the coming weeks.

The first Cryo-module assembly started in a class 100 clean room. Survey procedures have been adapted to the constraints of the clean environment. Special tooling has been designed to allow the adjustment and the geometrical follow up of the assembly from the adjacent class 10000 area whilst minimising the survey related work in the class 100 area.

Figure 8: Assembly work started in the clean room

CLIC

The study of modules, a key assembly for the project is one of the technical priorities. One complete module has been installed in a dedicated test area, allowing the successful validation the strategy of short range pre-alignment of the CLIC components [4]. The test area has been equipped with an air conditioning and ventilation system allowing temperatures from 20°C and 40°C and reproducing a longitudinal air flow from 0.3 to 0.8 m/s. Then the misalignments of the components and their supports have been measured and analysed during different steps of assembly: while linking the Drive Beam side to the Main Beam side by waveguides, putting vacuum inside the components, or modifying the environmental conditions (increase of temperature or air flow). The micrometric accuracy of sensors coupled with AT401 measurements has permitted a better knowledge of the impact of such constraints on the alignment of components. A new series of tests has started: the reproduction of machine operating scenarios on the module and their impact on the alignment of the components and their supports. The methods of measurements proposed and the results obtained are shown in [5]. In parallel, a module fully equipped with cWPS sensors for the monitoring of its alignment and supported by actuators has been installed in the CLIC Experimental (CLEX) facility, e.g. in an accelerator environment, with radiations, magnetic fields. The behaviour of sensors and actuators will be analysed.

Dedicated studies to improve the fiducialisation process of components have started. First, the tests have been performed on the Drive Beam (DB) quadrupoles, with a combination of AT401, CMM and cWPS measurements [6]. It has been demonstrated that a budget of error below 5 µm can be considered to determine the position of a magnetic axis, materialized by a stretched wire, with respect to external alignment fiducials.

The PACMAN project is an extrapolation of such a study. PACMAN stands for Particle Accelerator Components' Metrology and Alignment to the Nanometre scale. It is a Marie Curie Initial Training Network program, offering 10 PhD subjects in fields as beam instrumentation, magnetic measurements, survey and alignment [7], metrology, nano-positioning and high precision engineering. The program has started on the 1st September 2013, with duration of 4 years. Its aim is to develop very high accuracy metrology and alignment tools for the fiducialisation.

Figure 9 : the CLIC test module

FCC

CERN is undertaking the study for post-LHC particle accelerator options in a global context [8]. The main emphasis of the conceptual design study is a hadron collider with a centre-of-mass energy of the order of 100 TeV in a new 80-100 km circumference tunnel for the study of physics at the highest energies as shown on Figure 9. This, along with its detectors, will determine the basic requirements for the tunnel, surface and technical infrastructures. Such a machine would in principle have the ability to reach 26 to 33 TeV. The conceptual design study will also include a lepton collider with a centre-of mass energy of the order of 90 to 350 GeV and its detectors, as a potential intermediate step towards realization of the hadron facility.

The work will involve an assessment of: the current reference systems and surfaces used at CERN for the accelerator alignment; the suitability of these reference systems for a project of this scale throughout the construction, installation and operation of the collider; and the integration with the reference systems used by the host states (France and Switzerland).

It will also include an analysis of, and input into, the relative and global position accuracies required for the beam line elements, taking into account the accuracies of the underlying reference systems, geodetic survey instruments, and metrological and other instruments to provide a breakdown of the alignment accuracy budget for all aspects of the necessary geodetic and metrological work (surface, tunnel and transfer networks, and civil engineering). This will require the identification of any additional data required (existing sources or additional measurements) and preliminary work on the design of measurement networks and simulation calculations for those networks.

The initial implication in the project has been through controls and input into a graphical tool being developed to determine the best location and orientation of the FCC in the local geology, and in providing coordinates for possible machine layouts to incorporate into the same application.

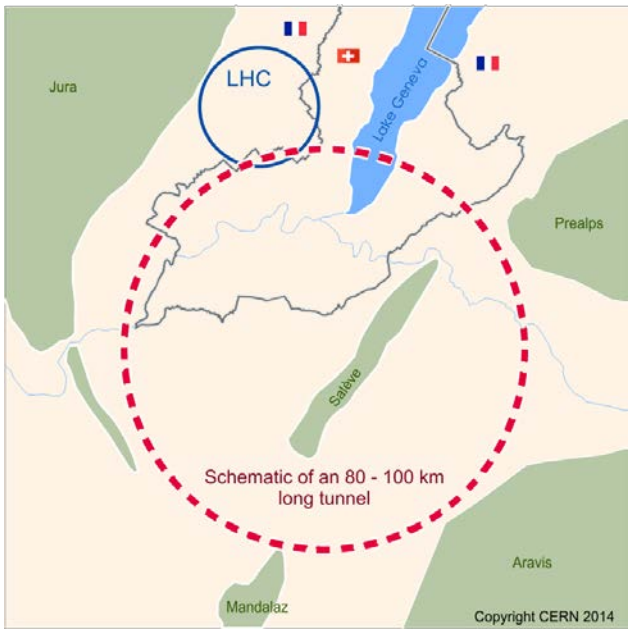

Figure 10 : the FCC location in the Geneva basin

CONCLUSIONS

Despite the fact that the LS1 has occupied most of the survey staff during the last two years, the others projects and studies have continued or some others have started.

The assembly of the LINAC4 components and their installation is progressing even tough this activity has been slightly reduced due to LS1 reasons, the ELENA and AWAKE projects have started recently but the installation of components is going to take place in 2015 and the installation of the transfer lines of the HIE-Isolde project is on good tracks.

On the R&D side, in the CLIC test Facility, a Two Beam Test Stand module has been installed and pre-aligned. It has been equipped with positioning sensors (HLS and WPS) developed since years allowing a permanent micrometric monitoring. A remote realignment, during operation with particles beam, will be possible based on these sensors and beam-based data.

The FCC study has started at the beginning of the 2014, the shape and location of the future collider in the Geneva area have to be decided by March 2015, a GIS tool developed in cooperation with the survey team will be used for this purpose. The challenge for the future years will be the definition of a new reference system and the extension of the actual Geoid in an area which covers the whole size of the collider.

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