

CONSTRUCTION STATUS OF LINAC4

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Abstract

The civil engineering works for the Linac4 linear accelerator at CERN started in October 2008 and regular machine operation is foreseen for 2014. Linac4 will accelerate H^- ions to an energy of 160 MeV for injection into the PS Booster (PSB). It will thus replace the ageing Linac2, which presently injects at 50 MeV into the PSB, as the first step in the injector upgrade for the LHC aiming at increasing its luminosity. This paper reports on the status of the design and construction of the main machine elements, which will be installed in the linac tunnel from the beginning of 2012 onwards, on the progress of the civil engineering and on the ongoing activities at the Linac4 test stand.

INTRODUCTION

The present sequence of accelerators used as LHC injectors at CERN starts with a proton linac of a relatively low energy (Linac2, 50 MeV, commissioned in 1978), which is followed by the 1.4 GeV PS Booster (PSB, 1972), by the 26 GeV Proton Synchrotron (PS, 1959) and finally by the 450 GeV Super Proton Synchrotron (SPS, 1976). The performance of this cascade of accelerators in terms of beam brightness for the LHC is limited by several factors, the first bottleneck being the limited intensity that can be accumulated at injection into the PSB because of space charge induced tune shift at 50 MeV energy.

Upgrading the linac energy is therefore the logical start for a programme aimed at increasing the LHC luminosity beyond what is provided by the present injectors. This in turn implies replacing Linac2 with a new linear accelerator, because no space is available at the end of the Linac2 tunnel for a significant increase of the beam energy. The PSB and PS themselves being the next limiting elements after the linac, the upgrade programme can be organised in two stages, the first one consisting in the replacement of Linac2 with a new linac injecting into the PS Booster, and a second one where PS Booster and PS are in turn replaced by new accelerators. Moreover, the upgrade of the LHC injectors will allow replacing aging accelerators presenting increasing reliability and maintenance problems with modern machines with simplified operation and maintenance and less radiation concerns.

In the approved upgrading scheme the new linear accelerator replacing Linac2, called Linac4 because the 4th ion linac to be built at CERN (Linac3 being the heavy-ion injector), goes up to 160 MeV and is connected to the present Linac2 to PSB line. Its position is such that it can be extended at a later stage into a linear accelerator of higher energy, the 4 GeV Superconducting Proton Linac

(SPL) [1], which would eventually replace the PS Booster and inject into the successor of the PS, the 50 GeV PS2.

The construction of Linac4 has been approved by the CERN Council in its June 2007 session. The conversion of the PSB for Linac4 is foreseen for the 2013/2014 shutdown, and from the 2014 run onwards the PSB will operate with its new injector linac. At the same session, the Council has approved a detailed design of SPL and PS2, to be ready for a construction project starting in 2013.

LAYOUT AND CIVIL ENGINEERING

Linac4 is being built on the CERN Meyrin site (Fig. 1), at the location of an artificial hill made with the excavation spoil from the old PS. This site provides at the same time an easy access, a natural earth shielding, an easy connection to the existing Linac2-PSB transfer line, and finally a straightforward extension to the underground tunnel housing the SPL.

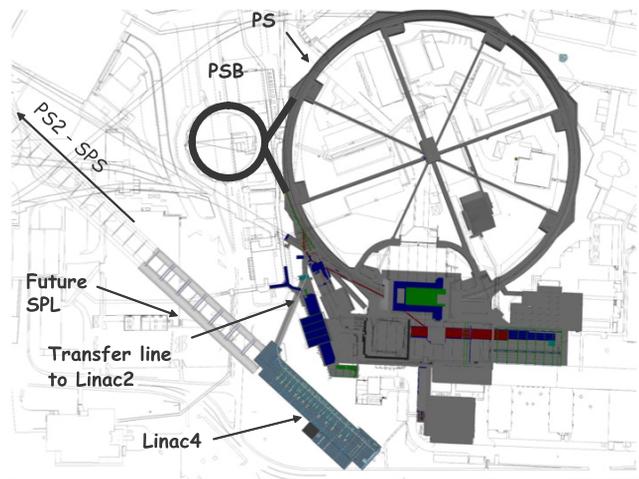


Figure 1: View of the PS Complex at CERN, showing the position of the new Linac4.

The linac will be housed in a 101 meter long tunnel located about 12 meters underground and connected by a 56 m transfer line to the present Linac2-PSB line (Fig. 2). A surface building above the linac tunnel will house klystrons and other equipment. An access building at low-energy side connects the two levels and provides access to the underground installations.

The civil engineering works have started in October 2008, with the removal of 40'000 m³ of earth from the area. The linac trench has been now completely excavated, and concrete works are starting. Once the linac gallery has been completed, it will be covered with earth and the surface hall will be built on top. Delivery of building and tunnel is foreseen for end 2010.

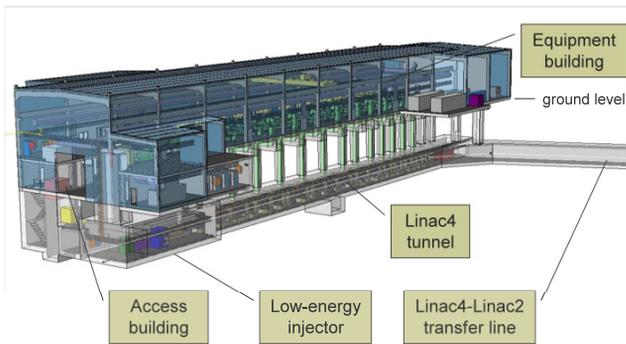


Figure 2: The Linac4 installations.

DESIGN FEATURES AND STATUS OF MACHINE COMPONENTS

The main Linac4 design parameters, for initial operation with the PSB and future operation for SPL and PS2, are reported in Table 1.

Table 1: Main Linac4 design parameters (PSB / PS2)

Output Energy	160	MeV
Bunch Frequency	352.2	MHz
Repetition Rate	1.1 / 2	Hz
Beam Pulse Length	0.4 / 1.2	ms
Beam Duty Cycle	0.08 / 0.24	%
Chopper Beam-on Rate	62	%
Linac pulse current	40 / 20	mA
N.of particles per pulse	1.0 / 1.5	$\times 10^{14}$
Transverse emittance	0.4	π mm mrad

Three different accelerating structures will be used in Linac4 after the RFQ, all at 352 MHz frequency. In particular, the Side Coupled Linac (SCL) at 704 MHz foreseen in previous designs has been replaced with a Pi-Mode Structure (PIMS) operating at the basic linac frequency [2, 3]. The Linac4 scheme with the transition energies is sketched in Fig. 3.

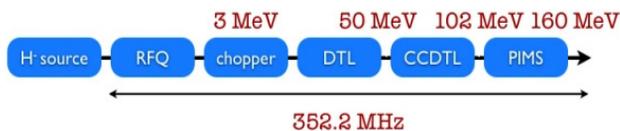


Figure 3: Linac4 layout.

After the 3 MeV Radio Frequency Quadrupole (RFQ) [4] a 3.6 m line equipped with two fast choppers and a collimator-dump can remove selected bunches from the linac pulse, in order to reduce beam loss at capture into the PSB.

Starting from 3 MeV, a Drift Tube Linac (DTL) accelerates the beam to 50 MeV energy. A novel DTL design has been developed for Linac4, whose main features are the positioning of the drift tubes inside the tanks relying on precise mechanical tolerances, without adjustments after assembly, and the exclusive use of metallic vacuum joints. As in similar designs, focusing is provided by Permanent Magnet Quadrupoles inside the

vacuum envelope. A prototype DTL (Fig. 4) has been successfully tested for alignment and RF field distribution and will be soon tested at high RF power [5].



Figure 4: DTL prototype.

A Cell-Coupled Drift Tube Linac (CCDTL) will accelerate the beam from 50 to 100 MeV [6]. This new type of structure is a DTL made of short 3-gap tanks connected by coupling cells. The quadrupoles are electromagnetic, and placed between the tanks. In this structure the drift tube alignment tolerances are considerably relaxed, and the quadrupoles are easily accessible for maintenance. The CCDTL design is now completed, and construction will start in 2009 in the frame of a collaboration project with BINP, Novosibirsk and VNIITF, Snezhinsk.

The third accelerating structure, the Pi-Mode Structure (PIMS) brings the beam to the final energy of 160 MeV. The PIMS resonators are made of 7 coupled cells operating in pi-mode. The tuning and coupling characteristics have been verified on a cold model [3] and a hot model is under construction at CERN for high-power testing in 2010.

The definition and specification of the RF equipment is well advanced. In the initial stage, thirteen 1.3 MW klystrons recuperated from the LEP accelerator will be used to feed the Linac4 accelerating structures, together with 6 new 2.8 MW pulsed klystrons. In a later stage, pairs of LEP klystrons will be progressively replaced by these new and more powerful devices. A large fraction of the high-power RF equipment will also come from the old LEP inventory. A prototype modulator for the LEP klystrons is operating reliably in the Linac4 test stand, whereas a new prototype for the higher power klystrons is being assembled.

The upgrades required by the PSB injection region for H^- injection at higher energy have been analysed in detail [7]. A prototype distributor magnet will be tested in 2009 and other critical components are being ordered for an early testing and optimisation.

THE LINAC4 TEST STAND

The Linac4 Front-end, consisting of ion source, RFQ and of the 3 MeV chopper line, is being progressively installed and tested in a dedicated Test Stand (Fig. 5). Together with commissioning of the first accelerating components, particularly critical for beam performance, the Test Stand allows early testing and characterisation of the RF infrastructure (LEP klystron operating in pulsed mode, Low-Level RF, etc.), of the modulators, of the beam instrumentation and of timing, control and interlock electronics. The Test Stand will be equipped with a movable beam diagnostics line, which will progressively analyse the different Front-end sections.



Figure 5: The Linac4 Test Stand.

The Test Stand infrastructure has been completed in 2007. At the end of 2008, the klystron modulator has been commissioned with a LEP klystron in pulsed mode. At the same time, the complete chopper line (3.6 m) has been assembled and vacuum tested (Fig. 6). Installation and vacuum tests of the ion source are presently completed. The measurement programme for 2009 includes the characterization of the H^- beam at the source output (45 keV) and a dry run of the chopper line to commission the equipment and all sub-systems. The next step will be commissioning of the LEPT, whereas beam commissioning of the RFQ and of the chopper line will start after the delivery of the RFQ from the CERN workshop, foreseen for October 2010.



Figure 6: The chopper line assembled at the Linac4 Test Stand.

PROJECT SCHEDULE

The duration of the project has been recently extended by one year, to compensate for a slower start due to the larger than foreseen amount of resources required at CERN in 2008/09 for LHC commissioning and repair. In the present schedule (Fig. 7), the first injection from Linac4 to PSB is foreseen in January 2014 and the start of the first physics run of the PSB with its new injector will take place in April 2014.

Construction and procurement of the main linac components start in 2009 and last approximately until the end of 2012. Tunnel and building will be delivered at the end of 2010, and installation of the general infrastructure will go on during 2011. Installation of accelerator components will take place in 2012. Beam re-commissioning of the Front-end in the linac building is foreseen to start in September 2012. The progressive commissioning of the accelerator sections and of the transfer line is scheduled during approximately 10 months, from end 2012 until October 2013. After the linac commissioning, three months are required for the modifications to the PSB injection region for the H^- injection at higher energy.

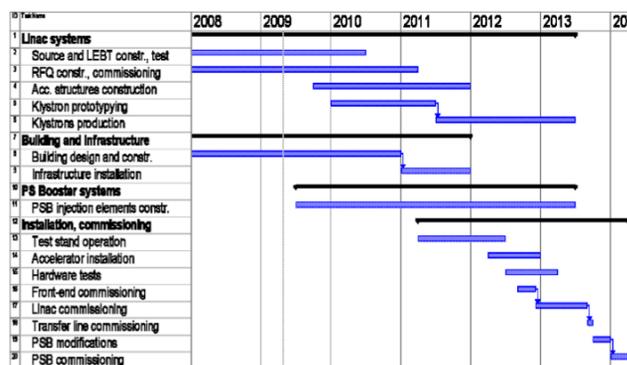


Figure 7: Linac4 Masterplan.

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