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STATUS OF THE LINAC4 PROJECT AT CERN

K. Hanke, C. Carli, R. Garoby, F. Gerigk, A. Lombardi, S. Maury, C. Rossi, M. Vretenar

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INTRODUCTION

The present sequence of CERN's LHC injectors starts with a proton linac of relatively low energy (Linac2, 50 MeV protons, commissioned in 1978), followed by the 1.4 GeV PS Booster (PSB, 1972), 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 LHC-type beams is limited by several factors, the first bottleneck being the limited intensity that can be accumulated at injection into the PSB due to the space charge induced tune shift at 50 MeV energy.

Increasing the linac energy is therefore the first step of a programme aiming at increasing the LHC luminosity beyond of what is provided by the present injectors. This is accomplished by replacing Linac2 by a new linear accelerator, because no space is available in the Linac2 tunnel for a significant increase in beam energy. As the downstream synchrotrons are the next limiting elements after the linac, the upgrade programme is twofold and consists in the replacement of Linac2 by a new linac injecting into the PS Booster, and in an upgrade of the subsequent synchrotrons in order to remove bottlenecks.

In the approved upgrade scheme the new linear accelerator goes up to 160 MeV and is connected to the present Linac2 to PSB line.

The construction of Linac4 has been approved by the CERN Council in its June 2007 session. The conversion of the PSB for operation with Linac4 is foreseen for the 2014/2015 shut-down, and from the 2015 run onwards the PSB will operate with its new injector linac.

LINAC4 LAYOUT

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 easy access, natural earth shielding, easy connection to the existing Linac2-PSB transfer line, and finally the potential for extension towards possible future new facilities.

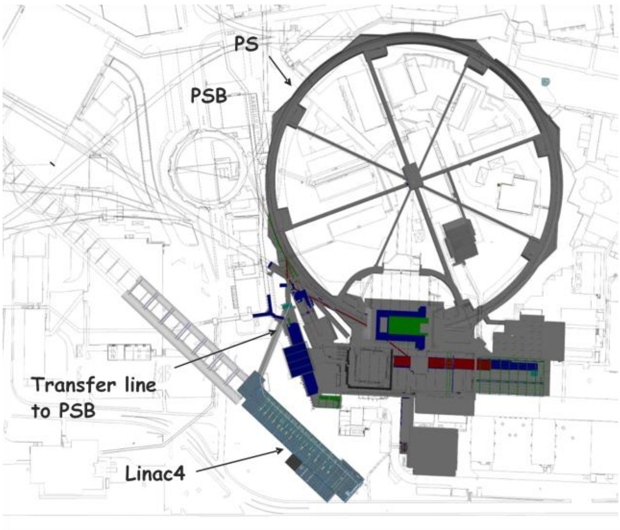

Figure 1: View of the PS Complex at CERN, showing the position of the new Linac4.

The linac will be housed in a 101 meter long tunnel located about 12 meters underground and connected by a 70 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 work has started in October 2008, with the removal of 40'000 m^3 of earth from the area. The linac tunnel has been now completed, and construction of the surface building has started in February 2010. Delivery of building and tunnel is foreseen for end 2010.

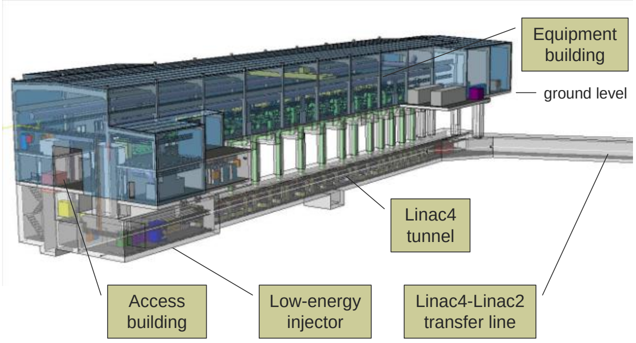

Figure 2: The Linac4 installations.

LINAC DESIGN AND CONSTRUCTION STATUS

The main Linac4 design parameters for operation as PSB injector are summarised in Table 1.

Table 1: Main Linac4 design parameters

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

Three different accelerating structures will be used in Linac4 after the radio-frequency quadrupole (RFQ), all at 352 MHz frequency. In particular, the Side Coupled Linac (SCL) at 704 MHz foreseen in previous designs has been replaced by a Pi-Mode Structure (PIMS) operating at the basic linac frequency [1, 2]. The Linac4 scheme with the transition energies is sketched in Fig. 3.

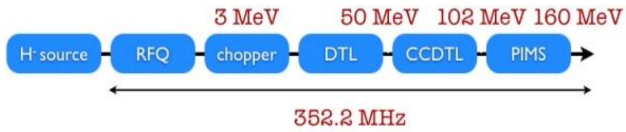

Figure 3: Linac4 layout.

A 3 MeV Radio Frequency Quadrupole (RFQ) is being constructed in the CERN Workshops and will be commissioned with beam in a dedicated test stand in the first months of 2011 [3]. The RFQ will be followed by a 3.6 m line equipped with two fast choppers (2 ns rise and fall times) and a collimator-dump which can remove selected bunches from the linac pulse, in order to reduce beam loss at capture into the PSB. The line has been already completed and will be commissioned together with the RFQ.

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 unit, corresponding to about half of the first tank (Fig. 4) has been built in order to investigate alignment and RF field distribution [4] and was recently successfully tested at nominal RF power, up to a duty cycle of 7.5%.

A Cell-Coupled Drift Tube Linac (CCDTL) will accelerate the beam from 50 to 100 MeV [5]. 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 started in 2010 in the frame of a collaboration project with BINP, Novosibirsk and VNIITF, Snezhinsk.

Figure 4: DTL prototype.

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 the CERN workshop. First low-level measurement on the clamped structure show excellent agreement with the predicted cell frequencies and the structure will be high-power tested in summer 2010.

Contracts for the construction of the DTL and PIMS are presently being negotiated and it is expected that the DTL construction starts in summer 2010, while the start of the PIMS construction is foreseen for January 2011.

The 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 [6]. A prototype distributor magnet has been tested in 2009 and other critical components are being ordered for an early testing and optimisation.

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, 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 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 have been completed, and commissioning of the H^- source has started in July 2009. Commissioning of the RFQ and of the chopper line will start after the delivery of the RFQ from the CERN workshop, presently foreseen for October 2010.

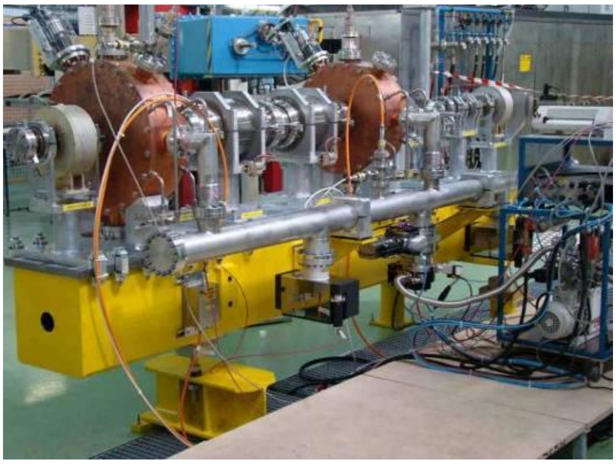

Figure 6: The chopper line assembled at the Linac4 Test Stand.

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 2015.

Construction and procurement of the main linac components started in 2009 and will last approximately until the end of 2012. Tunnel and building will be delivered by the end of 2010, and installation of the general infrastructure will go on during 2011. The installation of the accelerator components will take place in 2012. Beam re-commissioning of the front-end in the linac tunnel 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 H^- injection and other three months for setting up the PSB with the new linac beam.

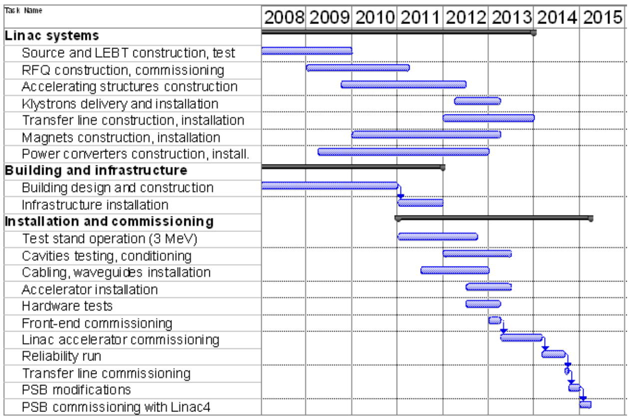

Figure 7: Linac4 Project Schedule.

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