STATUS OF THE LINAC4 PROJECT AT CERN

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Abstract

Linac4 is a new 160 MeV, 40 mA H^- accelerator which will be the source of particles for all proton accelerators at CERN from 2013. Its construction has started in 2008, as part of a programme for the progressive replacement or upgrade of the LHC injectors during the next decade. Linac4 will initially inject into the PS Booster and at a later stage into a 4 GeV Superconducting Proton Linac (SPL), which could ultimately be upgraded to high duty cycle operation. For this reason accelerating structures, RF infrastructure and shielding of Linac4 are dimensioned for higher duty cycle from the initial phase.

Linac4 is normal-conducting, 80 m long and consists of an RF volume ion source, an RFQ, a beam chopping section and a cascade of three different types of 352 MHz accelerating structures. Its main design requirements are high reliability, high beam brightness and low beam loss. The accelerator will be housed in an underground tunnel on the CERN Meyrin site, which can eventually be extended to the SPL, with equipment installed in a surface building above.

The main parameters, the status of the main components, the planning, the project organisation and the civil engineering infrastructure are presented.

LINAC4 AND THE CERN INJECTOR UPGRADE

A programme for the progressive replacement or upgrade of the LHC injectors has been recently defined at CERN [1]. The first goal of this programme is to increase the LHC luminosity beyond nominal by improving beam brightness from the injector complex, which is now the main limiting factor towards higher luminosity. A second motivation is the replacement of the present cascade of injectors, which has been built between 1959 and 1978 and in the past few years has been giving rising concerns for its long-term reliability, with a more modern, reliable and easier to maintain system, where transfer energies and beam parameters are optimised for the LHC needs. Moreover, new low energy accelerators can be made compatible with operation at higher beam power that could be required by future physics needs.

The present sequence of accelerators used as LHC injectors is based on a proton linac of a relatively low final energy (Linac2, 50 MeV) followed by the 1.4 GeV PS Booster (PSB), by the 26 GeV Proton Synchrotron (PS) and finally by the 450 GeV Super Proton Synchrotron (SPS). The new injector sequence would use an H^- high-energy linear accelerator, the 4 GeV Low-Power Superconducting Proton Linac (LP-SPL), whose normal-conducting section of 160 MeV, to be built in a preliminary stage, is called Linac4 [2]. The LP-SPL can be eventually upgraded to a High-Power SPL (HP-SPL) operating at multi-MW beam power [3]. The SPL is followed by a new 50 GeV Proton Synchrotron (PS2). The last of the LHC injectors, the 450 GeV Super Proton Synchrotron (SPS), would be upgraded to cope with the higher brightness from its injectors. The scheme of old and new injection line is shown in Fig. 1.

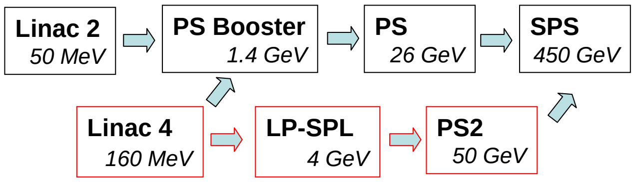

Figure 1: Scheme of the old and new LHC injectors.

A staged construction is possible because Linac4 can inject in a preliminary phase H^- ions into the existing PSB. The higher injection energy coupled with the benefits of H^- charge exchange injection are expected to increase brightness out of the PSB by a factor of 2, making possible a first increase in the LHC luminosity around 2013, when the nominal luminosity should have been attained in the LHC and a programme of upgrades to the ring and to the experiments aiming at higher luminosity could be implemented.

Linac4 will be housed in a 12 m deep underground tunnel, connected to the Linac2-PSB line. A surface equipment building will house klystrons and linac equipment. The Linac4 tunnel can be later on extended to the SPL. Figure 2 shows a view of the CERN Linac-PSB-PS complex, indicating the position of Linac4 and of the future extension to the SPL. Figure 3 presents the layout of the Linac4 infrastructure. Civil engineering works will start in October 2008 and are foreseen to be completed in November 2010.

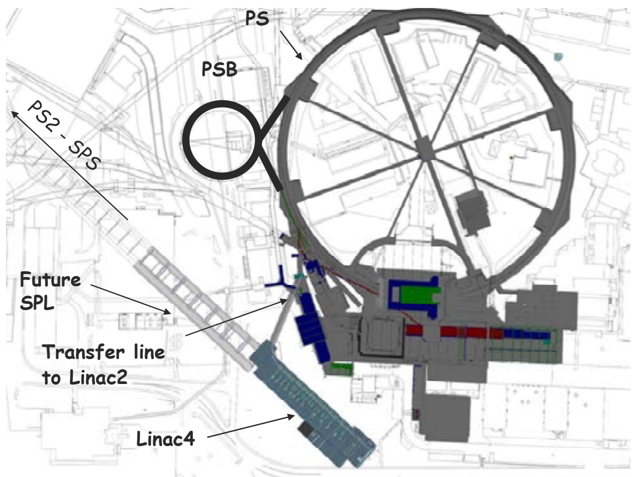

Figure 2: View of the PS Complex at CERN, showing the position of Linac4.

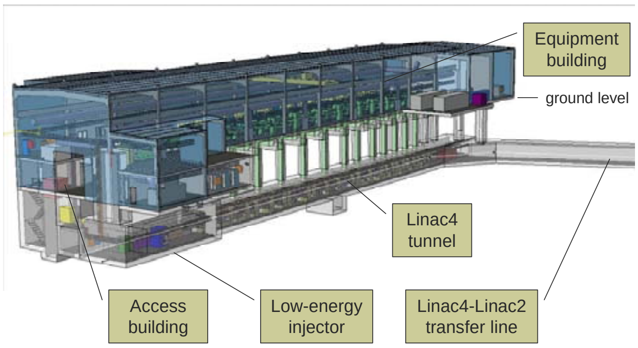

Figure 3: The Linac4 installations.

In June 2007, the CERN Council has approved the construction of Linac4 as a high-priority project for the period 2008-2013. At the same time, it has approved the detailed design of SPL and PS2, whose construction could start in 2012 and be terminated between 2015 and 2017.

LINAC4 DESIGN

The design of Linac4 is dictated by the requirement to operate in three different modes during its lifetime, depending on the characteristics (repetition frequency, pulse current and pulse duration) of the machine that it has to supply with beam:

1. PSB injector, 2013-2017: 1.1 Hz, 40 mA, 400 µs.
2. LP-SPL injector, from 2017: 2 Hz, 20 mA, 1.2 ms.
3. HP-SPL injector, after 2020: 50 Hz, 40 mA, 400 µs.

After a first phase as PSB injector the Linac4 beam pulse length will increase to 1.2 ms, whereas its current will go down by a factor 2. At a later stage, if the high-power programme is approved, Linac4 would operate at 50 Hz with a beam current going up again to 40 mA.

The main consequence on the Linac4 design is that civil engineering and in particular radiation shielding have to be dimensioned from the beginning for high-power operation. Accelerating structures and klystrons will be specified as well for high duty operation, whereas power supplies, electronics, and all electrical and cooling infrastructures will be dimensioned only for low beam power operation and will be replaced or upgraded when required for the HP-SPL. Additional space has been foreseen in the surface building for larger power supplies and for the additional SPL equipment.

In the design of machine and infrastructure particular care has been given to solutions providing the high reliability required for the first accelerator in the injection chain. Fault rate should be comparable to that of Linac2, ~1.5% of scheduled beam time. Particular attention has been given to the control of transverse and longitudinal emittance growth, for clean PSB and SPL injection, and of losses along the machine, to limit activation for the full-SPL mode of operation [4]. The main Linac4 design parameters are reported in Table 2.

Table 2: Main Linac4 design parameters

Output Energy	160	MeV
Bunch Frequency	352.2	MHz
Max. Rep. Rate	2	Hz
Max. Beam Pulse Length	1.2	ms
Max. Beam Duty Cycle	0.24	%
Chopper Beam-on Factor	65	%
Linac pulse current	40	mA
N. particles per pulse	1.0	$\times 10^{14}$
Transverse emittance	0.4	π mm mrad

Three different accelerating structures will be used in Linac4 after the RFQ, all the frequency of 352 MHz [5]. In particular, the Side Coupled Linac (SCL) at 704 MHz foreseen in a previous design has been replaced with a Pi-Mode Structure (PIMS) operating at the basic linac frequency [6]. The basic scheme with the transition energies is reported in Fig. 4.

Figure 4: Linac4 layout.

Some 352 MHz klystrons and other equipment from the old LEP accelerator will be re-used for Linac4. In the first stage (Fig. 5, top), 13 old LEP klystrons at 1.3 MW and 6 new pulsed klystrons at 2.6 MW will feed the accelerating structures. Most of the LEP klystrons will be connected in pairs to a single modulator, allowing for the progressive replacement of pairs of LEP klystrons with one klystron of the new type. In the final configuration (Fig. 5, bottom) 9 new klystrons will feed two RF cavities each.

LINAC4 STATUS

The pre-integration of machine components required for the definition of the building has started in 2007 and has allowed tendering of the civil engineering works in

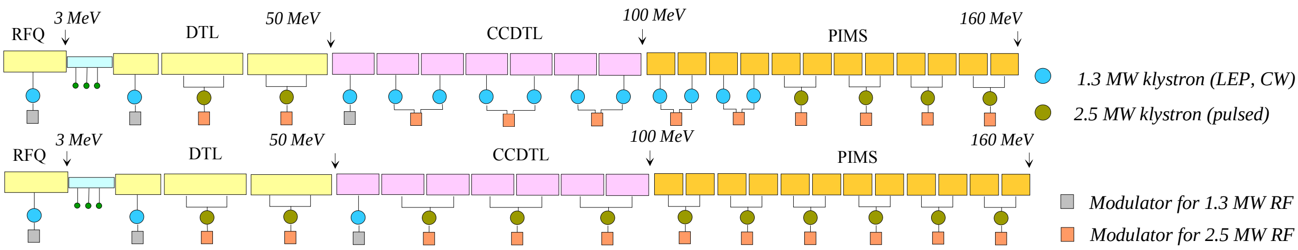

Figure 5: RF power distribution at installation (top) and after the end of the stock of LEP klystrons (bottom).

April 2008. Construction work is foreseen to start in October 2008 and building and tunnel should be delivered at end 2010. In parallel, safety requirements have been addressed, and a Safety File has been submitted in June 2008 to the CERN Safety Authorities.

Construction of the ion source, RFQ [7] and chopper line is progressing; they will be progressively installed in the Linac4 Test Stand (Fig. 6). First beam measurements with the RF volume ion source are foreseen for the end of 2008. The chopper line has been built and is presently being assembled. First beam tests at 3 MeV are foreseen after installation of the RFQ in March 2010. The prototype modulator and a LEP klystron operating in pulsed mode have been already successfully tested in the Test Stand.

Figure 6: The Test Stand with klystron and modulator (right) and ion source cage (bottom).

The mechanical design of the Drift Tube Linac (DTL) is now completed. The DTL will use Permanent Magnet Quadrupoles mounted in drift tubes precisely aligned inside the tanks, without adjustments after assembly [8]. Construction of a DTL prototype is well advanced and first high-power tests are foreseen for the beginning of 2009. Construction of the first DTL tank will start immediately afterwards. Two prototypes of the first Cell-Coupled DTL (CCDTL) module have been successfully tested at high power and the construction of the complete CCDTL is being organised [9]. The design of the PIMS structure has been completed, and construction of a full prototype of the first module is presently starting in the CERN Workshops [6].

PROJECT STRUCTURE AND SCHEDULE

The Linac4 project has been divided into 30 Workpackages, each under the responsibility of a Workpackage Holder. The Project Management, with the support of a Technical Coordinator and of a core team coordinates the different Workpackages.

The planning of the project (Fig. 7) depends on the schedule of the civil engineering works. After delivery of the building at end 2010, parallel installation of infrastructure and machine components will take place in 2011. In 2012 the different linac sections will be progressively commissioned. The connection of the transfer line and the modifications to the PSB for H^- injection will take place during the 2012/13 CERN machine shut-down. It is foreseen that Linac4 will provide particles to all CERN users from June 2013.

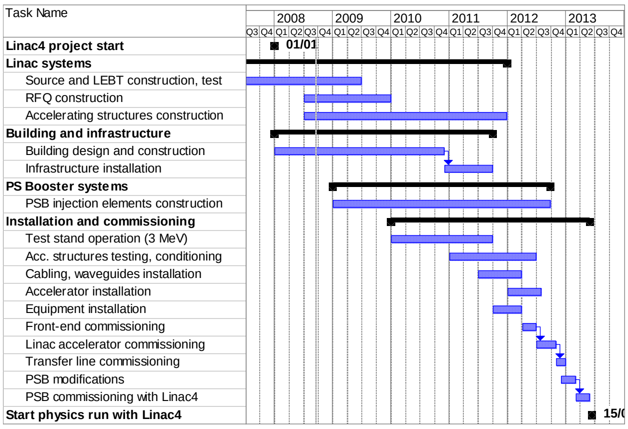

Figure 7: Linac4 Masterplan.

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