A radio frequency driven H⁻ source for Linac4[a)]

D. Küchler and Th. Meinschad[b)]
CERN, Geneva 1211, Switzerland

J. Peters
DESY, Hamburg D-22607, Germany

R. Scrivens
CERN, Geneva 1211, Switzerland

(Received 28 August 2007; presented 28 August 2007; accepted 10 September 2007; published online 17 January 2008)

Future requirements on higher beam intensity and brightness will need an upgrade of the present CERN accelerator chain. Linac4 will be an essential part of the upgrade of the proton accelerator facility. The source for this H^- linac will be based on a copy of the DESY rf driven H^- source. New possible radio frequency quadrupole alternatives (with different injection energies) and a pressing linac schedule made it necessary to develop a flexible two-source design. *© 2008 American Institute of Physics.* [DOI: 10.1063/1.2801382]

I. INTRODUCTION

In the context of a renewal of the large hadron collider (LHC) injector chain and a possible LHC luminosity upgrade,[1,2] a new H^- linear accelerator (Linac4) has been approved. Linac4 (Ref. 3) will replace Linac2 and will inject around 2012 H^- ions into the PS Booster at an energy of 160 MeV.

The linac project requires a high performance and high reliability H^- ion source. A collaboration with DESY allows CERN to construct a modified version of the DESY-HERA source.[4] In this way a preliminary H^- beam should be available beginning 2008. The source parameters for the different CERN H^- linac design phases and the conceptional design are published in Ref. 5.

The 2 MHz DESY rf volume source, proving its high reliability and high current capability over the past years, comes close to the requirements and shows a promising potential for improving its performance. H^- currents up to 70 mA without cesium have been reached.[6]

The installation of CERN's 3 MeV test stand, the front end of Linac4, has already started (see Fig. 1). However, as outlined and motivated in Ref. 7, some months ago a discussion about a replacement of the IHPI (Injecteur de Protons de Haute Intensité) radio frequency quadrupole (RFQ) started. From the source point of view this leads to a change of the extraction energy from 95 to 45 kV. That is why after the original 95 kV design (introduced in Ref. 5) also a 45 kV prototype has to be designed. But finally only the 45 kV option will be realized.

[a)]Contributed paper, published as part of the Proceedings of the 12th International Conference on Ion Sources, Jeju, Korea, August 2007.

[b)]Author to whom correspondence should be addressed. Electronic mail: thomas.meinschad@cern.ch.

II. H^- SOURCE AT 95 kV

A first goal was to develop a rf H^- source at an extraction voltage of 95 kV. The basic idea was, that the entire source infrastructure, which is kept at ground potential at DESY, floats on an intermediate 60 kV HV platform (see Fig. 2). The beam is extracted from the source with 35 kV, this gives then together the needed beam energy of 95 keV. The 2 MHz rf generator and the vacuum pumps stay also at ground potential. The entire extraction electrode system is coupled to the source body, which is suspended onto the vacuum tank by a ceramic insulator. The source is aligned with respect to the vacuum tank (see Fig. 3).

After the extraction and the deflection of the electrons by a set of permanent magnets, the H^- ions are postaccelerated with a diode gap (see Fig. 4).

Further features of the source are summarized as follows: (1) with two pumping groups (~500 l/s) on ground and better conductances pressures of $\sim 10^{-5}$ mbar are fea-

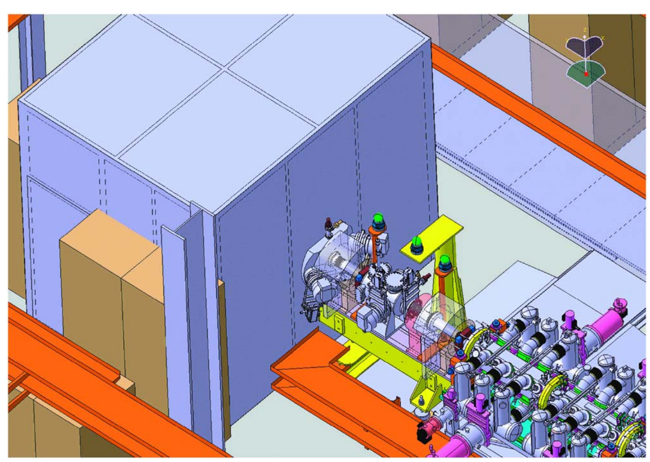

FIG. 1. (Color online) Linac4 front-end (status August 2007) with the IPHI RFQ (95 keV injection energy).

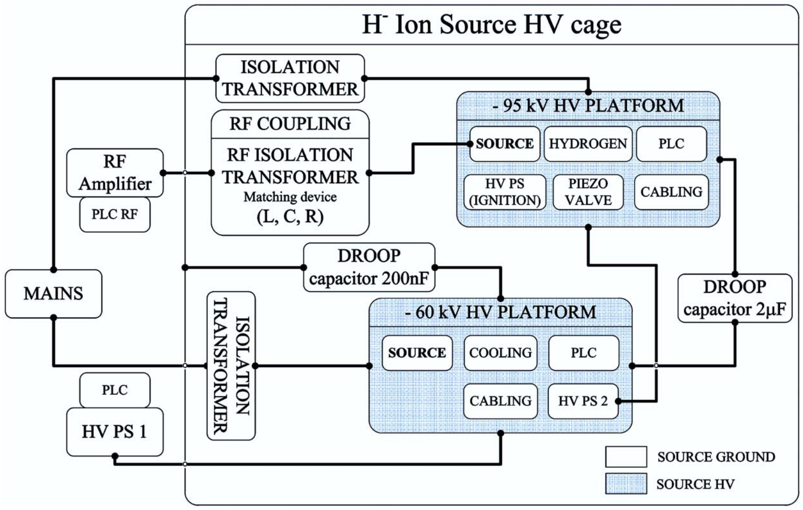

FIG. 2. (Color online) Source schema for the 95 kV option (passive droop compensation): the source is operated on two HV platforms and the rf power is brought up to the 95 kV one by a rf transformer (PLC: see Ref. 8, HV PS: HV power supply).

sible; (2) emittance growth reduced due to achieved proximity to the first solendoidal field; (3) enhanced lifetime due to external antenna; (4) a dynamical compensation system $\Delta E/E \sim 0$ will replace the passive compensation system (see Fig. 2) after the commissioning phase;[5] (5) 2 ± 0.2 MHz, 100 kW peak power, pulsed up to 1 ms, maximum repetition rate of 50 Hz, pulse-to-pulse stability of $\sim 1\%$, pulse stability (during pulse) of $\sim 1\%$, single frequency operation

III. SOURCE AT 45 kV

The possible use of a for Linac4 purposes optimized RFQ with a lower injection energy (45 keV) made it necessary to design a 45 kV H^- source. Based on the actual schedule a source with an extraction voltage of 45 kV should be ready beginning 2008. Simulations indicated that the postacceleration could not be adapted for a 45 kV solution because the beam explodes. Due to this a single stage extraction concept has been thought of. The main ceramic will be replaced by a standard stainless steel shell and the postacceleration will be omitted. The gain of space allows us to shift the source closer to the first low energy beam transport (LEBT) solenoid. The electrons are dumped on ground potential.

Firstly we will commission the CERN source at 35 kV and remeasure its emittance. Then the high voltage will be changed to its nominal level. Adaptations of the source in the case of voltage holding problems are feasible. The distance between ground electrode and the plasma electrode can be modified by changing the spacers that hold the entire electrode system. Figure 5 shows the inside of the 45 kV H^- source.

The emittance of the LEBT is optimized with a short distance between postacceleration system (PAS) and solenoid (Fig. 6). The space charge compensation will be optimized with gas injection. Simulations (linear beam compensation model, compensation fraction of 90%) assuming a uniform beam density in horizontal and vertical spaces show

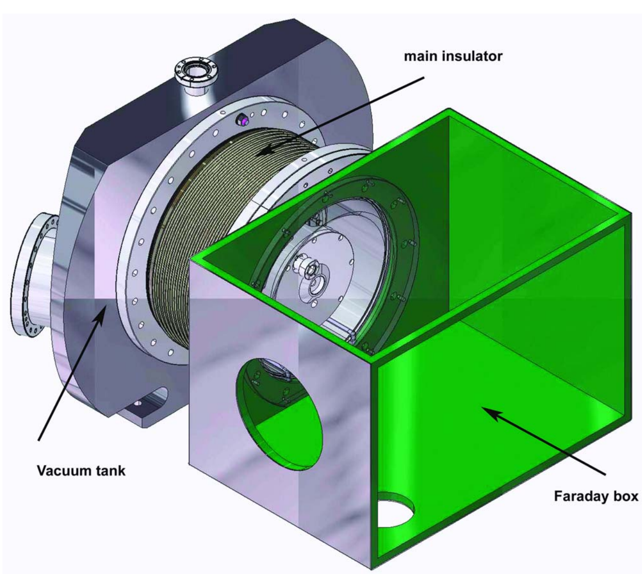

FIG. 3. (Color online) Rear view of the 95 kV source ensemble: vacuum tank, main ceramic, and Faraday box with the plasma chamber inside.

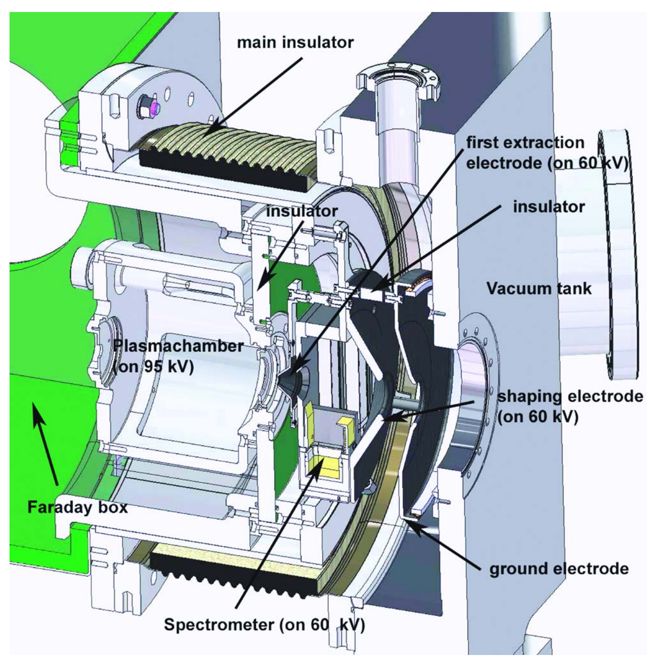

FIG. 4. (Color online) Sectional view of the 95 kV CERN rf source: the vacuum tank is kept at ground potential outside the HV cage, the plasma chamber operates at 95 kV, the rest of the source body (including spectrometer, Faraday box) floats on 60 kV.

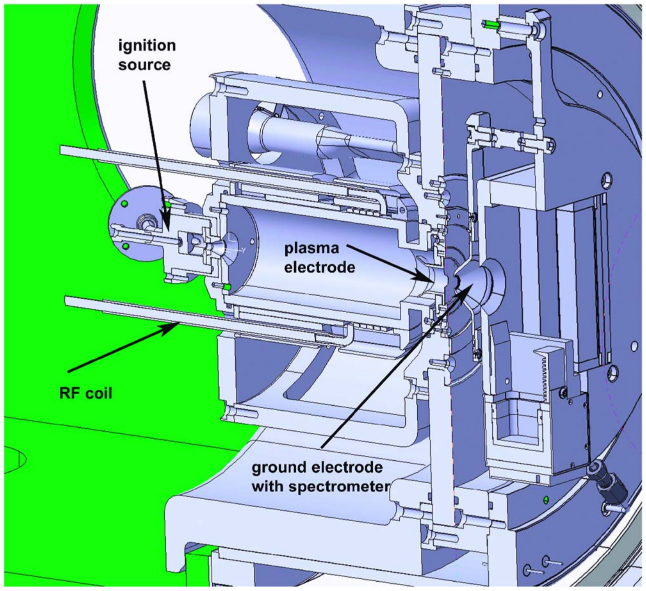

FIG. 5. (Color online) Sectional view of the 45 kV CERN source: ignition source, rf coil, plasma electrode, and spectrometer.

a minimum emittance growth about 20%. This total emittance growth has two conributions: $\varepsilon_{\text{total growth}} = \varepsilon_{\text{PAS}} + \varepsilon_{\text{LEBT}} = 13\% + 7\%$.[9] In the case of an omission of the PAS, the emittance growth can be reduced, however, the higher extraction voltage will enhance the beam divergence, if the DESY settings are kept. Emittance measurements are foreseen to study this increase and develop if necessary a new extraction system.

IV. CONCLUSION AND FUTURE PLANS

Both source solutions are followed in parallel, in order to be flexible for the final RFQ decision. The installation of the source infrastructure has started. The HV circuitry will be finished end of August; the rf equipment (generator, rf transformer) will be installed in September. The last fabrication drawings are going to be finished middle of November. The production of certain source parts started already and according to the latest planning the last source parts will arrive at CERN in February 2008.

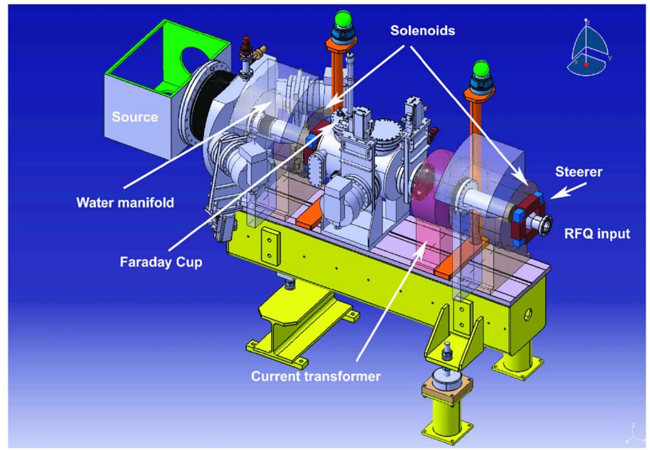

FIG. 6. (Color online) (Color online) 1.8 m long LEBT consisting of two solenoids and a diagnostic box in between for beam analysis and an injection valve for space charge compensation.

ACKNOWLEDGMENTS

The authors would like to thank C. Mastrostefano and M. O'Neil for the support in mechanical and electrical issues. Thanks, also to M. Paoluzzi for his commitment in the rf hardware and B. Riffaud and F. Luiz for their assistance in design questions.

[1] M. Benedikt, K. Cornelis, R. Garoby, E. Metral, F. Ruggiero, and M. Vretenar, Report No. CERN-AB-2004-022 OP/RF, 2004 (unpublished).
[2] M. Benedikt, R. Garoby, F. Ruggiero, R. Ostojic, W. Scandale, E. Shaposhnikova, and J. Wenninger, CERN-AB-2006-018-PAF, 2006 (unpublished).
[3] Linac4 Technical Design Report No. CERN-AB-2006–084 ABP/RF, 2006 (unpublished).
[4] J. Peters, PAC05 Conference Proceedings, 2005 (unpublished).
[5] D. Küchler, Th. Meinschad, J. Peters, and R. Scrivens, *Proceedings of the 11th International Symposium on Production and Neutralization of Negative Ions and Beams* (AIP, Melville, 2006), Vol. 925, p. 121.
[6] J. Peters, *Proceedings of the 11th International Symposium on Production and Neutralization of Negative Ions and Beams* (AIP, Melville, 2006), Vol. 925, p. 79.
[7] A. M. Lombardi, C. Rossi, and M. Vretenar, Report No. CERN-AB-2007-0027-RF, 2007 (unpublished).
[8] Programmable Logical Controller, Siemens S7/300.
[9] M. Jensen, D. Küchler, Th. Meinschad, R. Scrivens, and F. Wenander, Linac06 Conference Proceedings Knoxville, Tennesee, 2006 (unpublished).