A RF driven H⁺ Source for LINAC4

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Abstract

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 RFQ alternatives (with different injection energies) and a pressing linac schedule made it necessary to develop a flexible two-source-design.

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A RF driven $\text{H}^-$ Source for LINAC4

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I. INTRODUCTION

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

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

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

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. $\text{H}^-$ 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 [7], some months ago a discussion about a replacement of the IHPI (In-

II. $\text{H}^-$ SOURCE AT 95 KV

A first goal was to develop a RF $\text{H}^-$ 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 $\text{H}^-$ ions are post-accelerated with a diode gap (see FIG. 4).

Further features of the source are summarized below:

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FIG. 2: 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 [8], HV PS: HV power supply).

FIG. 3: Source alignment with respect to the vacuum tank (see FIG. 2).

FIG. 4: Extraction and deflection of the electrons by a set of permanent magnets the $\text{H}^-$ ions are post-accelerated with a diode gap (see FIG. 4).
FIG. 3: Rear view of the 95 kV source ensemble: vacuum tank, main ceramic and Faraday box with the plasma chamber inside.

FIG. 4: 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 (incl. spectrometer, Faraday box) floats on 60 kV.

- with 2 pumping groups (\(~500 \text{l/s}\)) on ground and better conductances pressures of \(~10^{-5}\) mbar are feasible,
- emittance growth reduced due to achieved proximity to the first solenoidal field,
- enhanced lifetime due to external antenna,
- a dynamical compensation system \(\Delta E/E \sim 0\) will replace the passive compensation system (see FIG. 2) after the commissioning phase [4],
- \(2\pm0.2\) MHz, 100 kW peak power, pulsed up to 1 ms, max. repetition rate 50 Hz, pulse-to-pulse stability \(~1\%\), pulse stability (during pulse) \(~1\%\), single frequency operation

III. SOURCE AT 45 KV

The possible use of a RFQ with a lower injection energy (45 keV), optimized for Linac4, 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 post-acceleration could not be adapted for a 45 kV solution, because the beam explodes. Therefore a single stage extraction concept has been thought of. The main ceramic will be replaced by a standard stainless steel shell and the post-acceleration will be omitted. The gain of space allows to shift the source closer to the first LEBT solenoid. The electrons are dumped on ground potential.

Firstly we will commission the CERN source at 35 kV and re-measure its emittance. Then the high voltage will be changed to its nominal level. Adaptations of the source in 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. FIG. 5 shows the inside of the 45 kV H\(^-\) source.

IV. LOW ENERGY BEAM TRANSFER

The emittance of the LEBT is optimized with a short distance between PAS (PAS: post-acceleration system) and solenoid. 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 space show a minimum emittance growth about 20%. This total emittance growth has two contributions: \\
\\n\[
\epsilon_{\text{total growth}} = \epsilon_{\text{PAS}} + \epsilon_{\text{LEBT}} = 13\% + 7\% [9].
\]

In the case of an omission of the PAS the emittance growth can be reduced, however the higher extraction voltage may increase the beam divergence and the emittance, if the DESY extraction configurations are kept. Emittance measurements are foreseen to study this increase and develop if necessary a new extraction system and optimum solenoid configuration.

V. 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 autumn; afterwards the RF equipment (Generator, RF transformer) will be installed. 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 spring 2008.

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