The SARAF-LINAC Project for SARAF-PHASE 2

N. Pichoff, P. Bredy, G. Ferrand, P. Girardot, F. Gougnaud, M. Jacquemet, A. Mosnier, Pierre Bertrand, M. Di Giacomo, R. Ferdinand, et al.

THE SARAF-LINAC PROJECT FOR SARAF-PHASE 2

N. Pichoff, P. Bredy, G. Ferrand, P. Girardot, F. Gougnaud, M. Jacquemet, A. Mosnier, CEA/IRFU, Gif-sur-Yvette, France
P. Bertrand, M. Di Giacomo, R. Ferdinand, CEA/GANIL, Caen, France
D. Berkovits, J. Luner, J. Rodnizki, Soreq NRC, Yavne, Israel

Abstract

SNRC and CEA collaborate to the upgrade of the SARAF accelerator to 5 mA CW 40 MeV deuteron and proton beams (Phase 2). This paper presents the reference design of the SARAF-LINAC Project including a four-vane 176 MHz RFQ, a MEBT and a superconducting linac made of four five-meter cryomodules housing 26 superconducting HWR cavities and 20 superconducting solenoids. The first two identical cryomodules house low-beta (β_{opt} = 0.091), 280 mm long (flange to flange), 176 MHz HWR cavities, the two identical last cryomodules house high-beta (β_{opt} = 0.181), 410 mm long, 176 MHz, HWR cavities. The beam is focused with superconducting solenoids located between cavities housing steering coils. A BPM is placed upstream each solenoid.

INTRODUCTION

SARAF [1] is an Israeli national project, announced in 2001, managed by SNRC and aiming to deliver 5 mA beams at 40 MeV (deuteron) or 35 MeV (proton). Its phase 1 consisted of an ECR source, a low energy beam transport (LEBT), a 176 MHz four-rod radiofrequency quadrupole (RFQ) and a prototype superconducting (SC) module (PSM) containing 3 SC solenoids and 6 SC HWR cavities. Its phase 2 consists in increasing the energy to final one. In this context, SNRC solicited CEA (France) to contribute to this phase.

The present CEA proposal at 176 MHz is based on its experiences on the 88 MHz SPIRAL2 [2], the 175 MHz IFMIF [3] the 352 MHz IPHI [4], ESS [5] and LINAC4 [6] projects. Beginning of 2014, CEA presented a cost-optimized design to the SARAF International Steering Committee which concluded that no major risk was foreseen, but suggested to make the design more robust in order to compensate possible loss of performances during the machine life-time.

During 2014, a new linac design has been studied, discussed between SNRC and CEA and finally accepted by both parts (Fig. 1). This paper summarises this last design: the SARAF-LINAC reference design.

SARAF PHASE 2 PROJECT

CEA is in charge of studying, delivering, and commissioning the SARAF-LINAC made of:

- an optional 4-vane RFQ bunching and accelerating 5 mA-cw beams from 20 keV/u to 1.3 MeV/u,
- a MEBT measuring, cleaning and matching the beams,
- a superconducting linac accelerating the beams to final energies within the limited bean loss criterion for Hands-On maintenance,
- and the associated local control systems.

SNRC is in charge of providing:

- the source and LEBT,
- the HEBT,
- the building,
- the main control systems,
- the auxiliaries for the linac (RF power, electricity, water, liquid helium, compressed air…).

The final commissioning is planned for mid-2022.

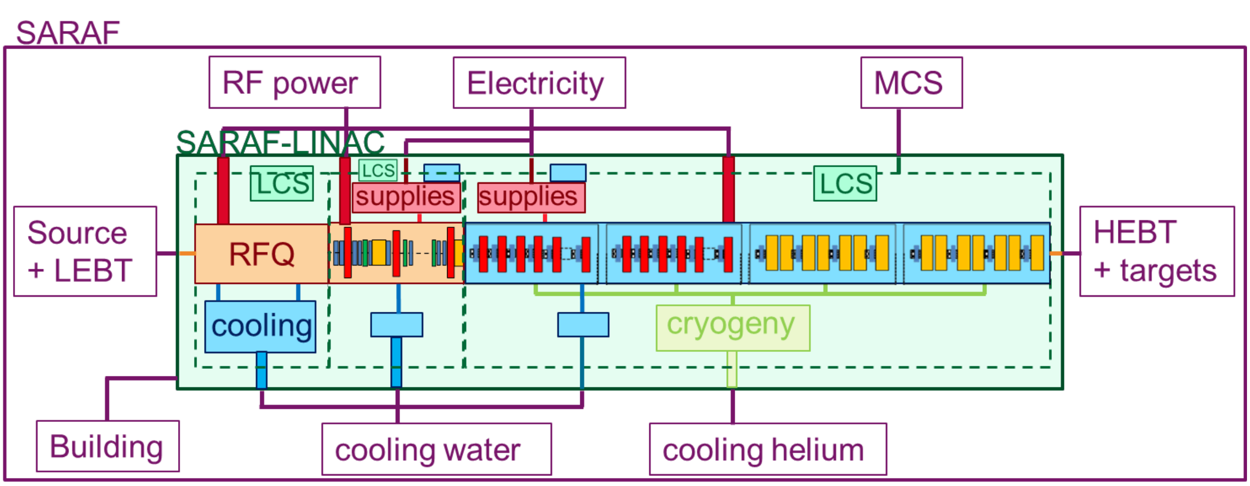

Figure 1: SARAF Phase 2 Project. In purples are SNRC deliverables, in other colours are the CEA deliverables.

ISBN 978-3-95450-168-7

The RFQ

The Radio-Frequency Quadrupole (RFQ):

- bunches the beam at 176 MHz,
- sets the beam longitudinal distribution,
- accelerates the beam to 1.3 MeV/u.

SNRC is studying a new pole profile for its 4-rod RFQ, reducing the exit energy from 1.5 MeV/u to 1.3 MeV/u. The goal is to reduce the necessary RF power in the cavity, relaxing its heating.

In parallel, based on its experience on IPHI (Fig. 2) or SPIRAL2, CEA studies a four vane RFQ whose technology enables to reduce the power density deposition and the associated cooling difficulties, allowing a cleaner beam dynamics. The choice between both RFQ will be done in 2016.

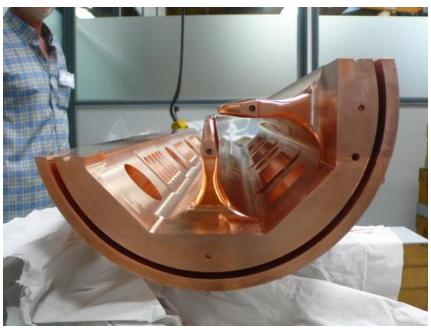

Figure 2: IPHI half-RFQ.

The MEBT

The Medium Energy Beam Transport line (MEBT) is the transition line between RFQ and SCL structures. It plays no acceleration goal, but has other important roles:

- to match the beam from the RFQ to the SCL,
- to steer the beam on the accelerator axis,
- to measure the beam current and the transverse and longitudinal beam distributions,
- to clean the beam if necessary (elimination of halo)
- to stop the pulsed beam (low power) during tuning process of the injector alone,
- to cope with the high vacuum gradient between RFQ and downstream SC structure,
- to leave room for a future fast chopper system.

The 4.73 m MEBT (Fig. 3) contains:

- nine quadrupoles (Q1-9) of SPIRAL2-type (Fig. 4),
- three 176 MHz 3-gap rebunchers (RB1-3, Fig. 5),
- three H/V slit boxes (SB1-3),
- two diagnostics boxes (DB1-2).
- Drifts of future fast chopper and associated deviated beam stop.

The LINAC4 [7] or SPIRAL2-like [8] electrodes of the fast chopper would be placed in Q5 and Q6 and DB1. SPIRAL2-like beam stop would be placed between Q7 and SB3.

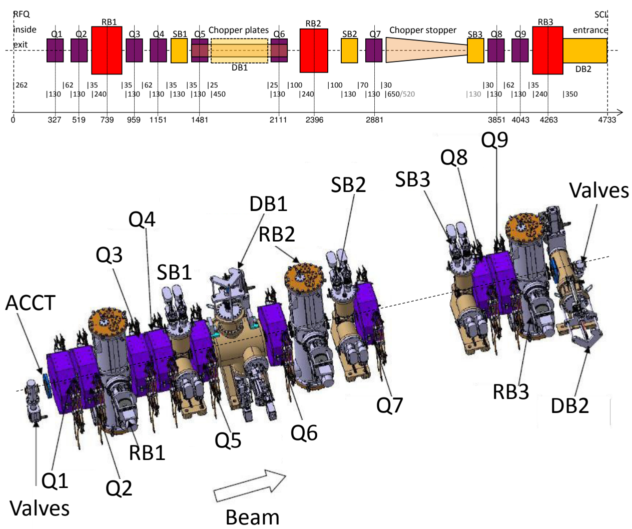

Figure 3: MEBT design.

Figure 4: SPIRAL2 quadrupole used in SARAF MEBT.

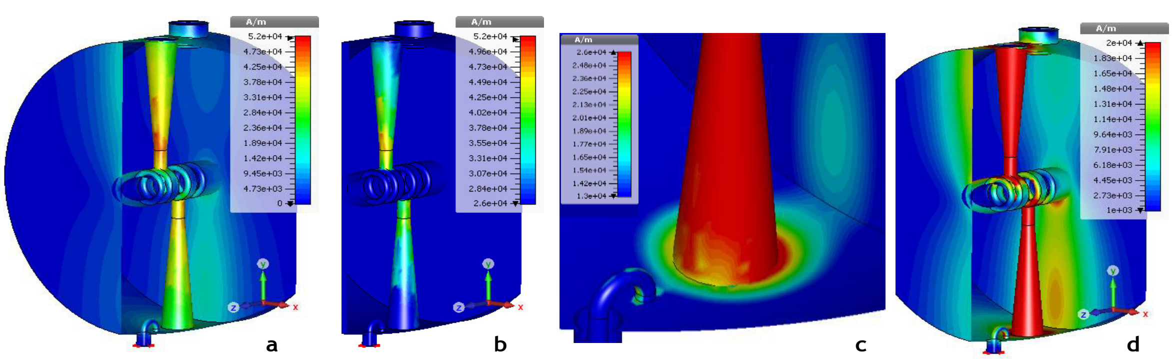

Figure 5: Critical current density (power deposition) on various scale in MEBT rebunchers for 120 kV.

The SCL

The Super-Conducting Linac (SCL) is in charge of accelerating the beams to their final energy.

It is made of 4 cryomodules (Fig. 6). The first two are identical (CM1&2) and house low-beta (β_{opt} = 0.091), 28 cm, 176 MHz HWR cavities (Fig. 7), the last two are identical (CM3&4) and house high-beta (β_{opt} = 0.181), 41 cm, 176 MHz HWR cavities (Table 1). The beam is focused with superconducting solenoids (Fig. 8) housing steering coils. The maximum simulated required on-axis peak field is 5.8 T [9]. A BPM is placed upstream each solenoid. Each solenoid package, including the BPM, solenoids (and associated steerers), end bellows and flanges, is 34 cm long.

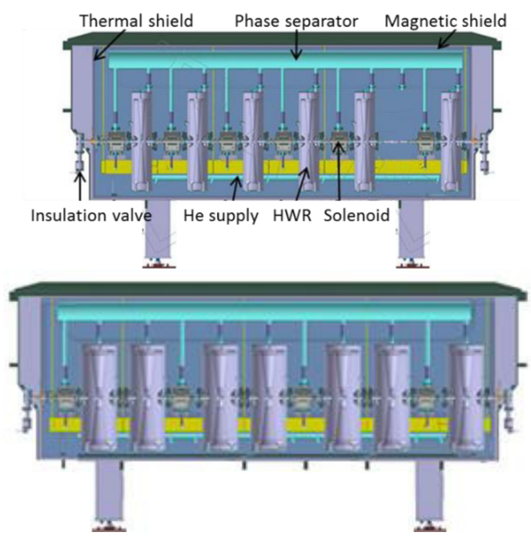

Figure 6: SARAF-LINAC cryomodules (up-CM1&2; down-CM3&4).

The distance between cryomodule ends and first solenoid is 25 cm (including valves and bellows). The distance between cryomodule ends and first or last cavity is 27 cm (including valves and bellows). The distance between two adjacent cavities, containing a bellow, is 8 cm.

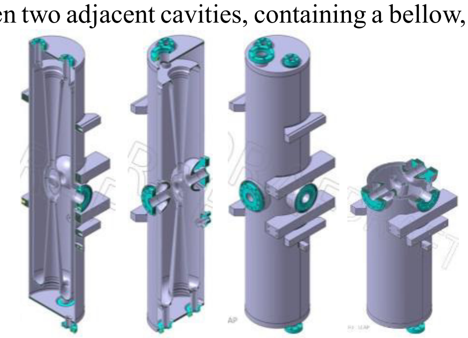

Figure 7: Low-beta cavity (β_{opt}=0.091) views.

The distance between consecutive cryomodules is set to 31 cm. It will be filled by a diagnostic box containing beam profile and bunch length monitors and a vacuum pump. The need and the type of diagnostics will be studied during the project.

Table 1: Cavity Main Properties

Property	Low-beta	High-beta
Optimal beta	0.091	0.181
Bore diameter [mm]	36	40
E_{acc} max. [MV/m]	6.5	7.5
E_{pk} max. [MV/m]	34	32
B_{pk} max. [T]	49	58
R/Q [Ω]	217	244
G [Ω]	31.7	50.5

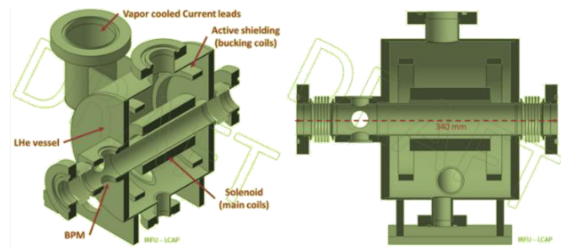

Figure 8: Solenoid package view (except steerers).

CONCLUSION

The detailed study phase, including prototypes for rebuncher, cavities, solenoid and couplers is planned for 3 years. The series construction and test is planned for 3.5 years partially in parallel with a 3-step installation and commissioning period of 2 years.

REFERENCES

[1] A. Kreisel et al., "SARAF Phase-I proton/deuteron linac beam operation status",WEIOB02, LINAC'14, Geneva, Switzerland (2014).

[2] P. Bertrand, R. Ferdinand, "SPIRAL2 accelerator construction progress", LINAC'12, Tel-Aviv, Israel (2012).

[3] A. Mosnier et al, "Present Status and Developments of the Linear IFMIF Prototype Accelerator (LIPAc)", THPPP075, IPAC'12, New Orleans, USA (2012).

[4] B. Pottin et al., "Status report on the French High-Intensity Proton Injector project at Saclay (IPHI)", LINAC'12, Tel-Aviv, Israel (2012).

[5] M. Eshraqi, "The ESS Linac", IPAC'14, Dresden, Germany (2014).

[6] A. M. Lombardi, "Commissioning of the low-energy part of Linac4", LINAC'14, Geneva, Switzerland.

[7] F. Caspers et al., "The CERN-SPL Chopper Concept and Final Layout", EPAC'04, Luzern, Switzerland (2004).

[8] G. Le Dem et al, "A single bunch selector for the next low beta continuous wave ion beam", PAC'07, Albuquerque - June 2007 MOPAN008 p. 158.

[9] N. Pichoff et al., "The SARAF-LINAC beam dynamics", MOPWA007, these proceedings, IPAC'15, Richmond VA, (2015).

ISBN 978-3-95450-168-7