# THE SARAF-LINAC PROJECT 2017 STATUS

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*Abstract*

SNRC and CEA collaborate to the upgrade of the SARAF accelerator to 5 mA CW 40 MeV deuteron and proton beams (Phase 2). CEA is in charge of the design, construction and commissioning of the superconducting linac (SARAF-LINAC Project). This paper presents to the accelerator community the status at March 2017 of the SARAF-LINAC Project.

## INTRODUCTION

The SARAF-LINAC project, managed by CEA (France), integrated to the SARAF-Phase 2 project managed by SNRC (Israel) has been introduced in [1].

In 2014, a first System Design Report (on the base of which [1] was written) was presented and served of basis on an agreement between CEA and SNRC.

The < 8 year project can be simplified in 3 overlapping phases (Fig. 1):

- ~3 years of detailed design, including prototyping,
- ~4 years of construction, assembly and test at Saclay,
- ~2 years of installation and commissioning at Soreq.

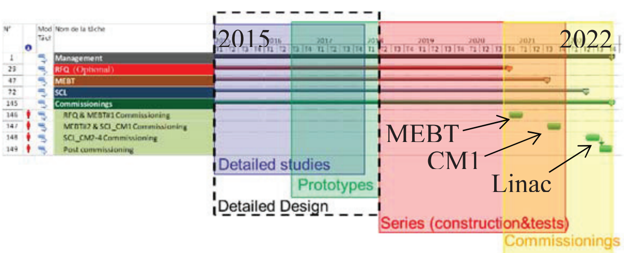


Figure 1: SARAF-LINAC major schedule.

In this paper, the status of these developments after the second year of detailed design phase is presented.

Last year, four Design Reviews (DR) took place at Saclay:

- June 2016: Critical DR (CDR) of major components.
- December 2016: CDR of system.
- December 2016: Preliminary DR (PDR) of Beam diagnostics.
- February 2017: PDR of Local Control Systems.

## SYSTEM

The linac layout is given in Fig. 2. Since [2], some small modifications have occurred:

- a new RFQ pole geometry (v2) has been designed by SNRC and implemented in the TraceWIN package code [3],
- the number of quadrupoles in the MEBT has been reduced from 9 to 8 leaving more room for vacuum valve and diagnostics,
- the cryomodules have been elongated by a few centimeters (PDR in May 2017).

The design of the major components have been finalized. The beam dynamics, including the error studies has been calculated including these changes. The linac tuning strategy [4] and associated performances [5], (see Fig. 3) have been studied.

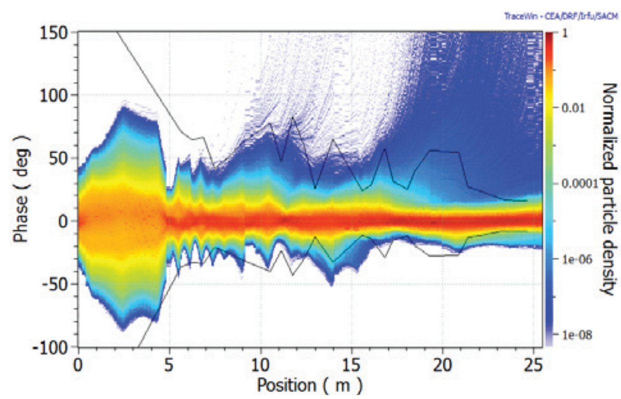


Figure 3: Beam statistical longitudinal distribution with errors. Blue tails represent unhooked particles with very low probability (<$10^{-7}$).

The vacuum system and associated performances have been estimated using 5 turbo-pumps in the MEBT and 8 in the SCL (4 in the downstream warm-sections and 4 on cryomodule central cavities, see the pressure distribution along SCL in Fig. 4).

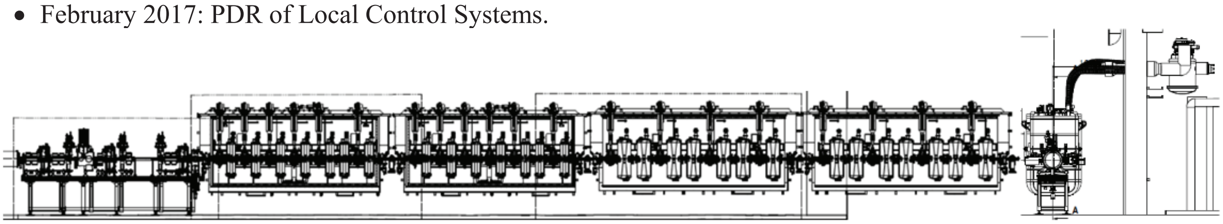

Figure 2: SARAF-LINAC layout.

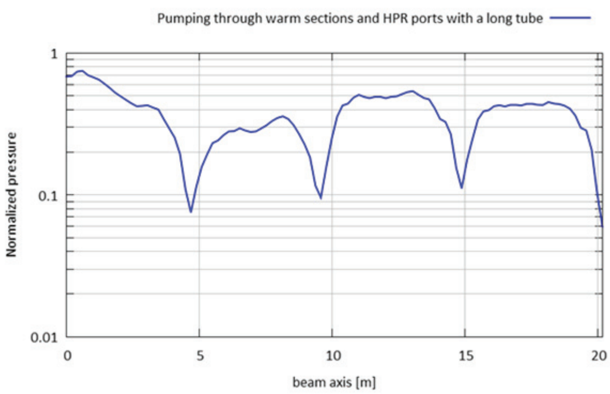


Figure 4: Pressure distribution along SCL.

## MAJOR COMPONENTS

The CDR of major elements (with prototypes because they are exhibiting the highest technological risks) took place at Saclay in June 2016:

- the MEBT rebunchers,
- the low- and high-beta SC HWR cavities,
- the cold RF couplers,
- the SC magnets.

### *The MEBT Rebuncher*

176 MHz rebunchers with split spoke geometry (Fig. 5) will be built as MEBT rebunchers.

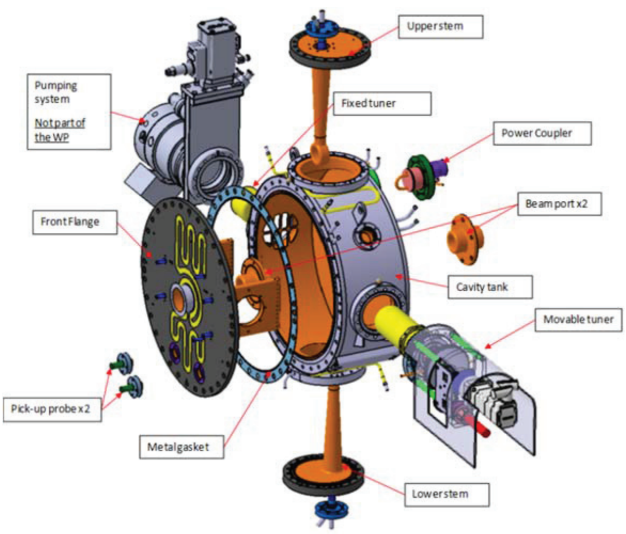


Figure 5: Rebuncher exploded view.

Beam dynamics required to operate the rebunchers at maximum 105 kV effective voltage in nominal operation (cw or pulsed) and longitudinal emittance measurement could lead to operate one rebuncher at 160 kV only in pulsed mode. The rebuncher has been specified for 120 kV cw operation. 30% margin on surface resistance and 20% on thermal conductance have been used to design its cooling. The maximal temperature is kept below 100 °C.

### *The SC HWR Cavities and RF Coupler*

12 low-beta (0.091) and 14 high-beta (0.181) 176 MHz HWR cavities will be used. Their maximal accelerating fields are respectively 6.5 MV/m and 7.5 MV/m. Their designs are now completed (Fig. 6). The maximal power delivered by the RF couplers to the beam are 4.8 kW and 11.4 kW respectively.

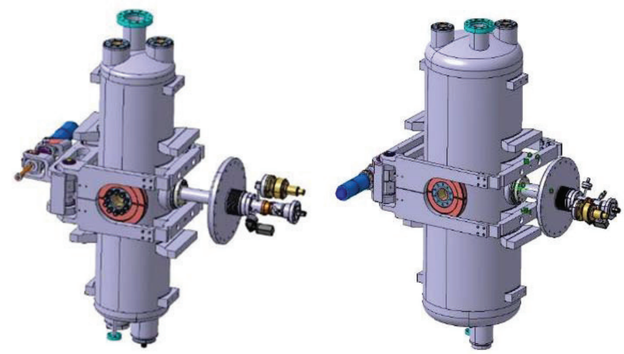

Figure 6: low-beta (left) and high-beta (right) equipped cavities.

### *The SC Magnet*

The SC magnet design is completed. A 3D cut is plotted in Fig. 7. Beam dynamics required operation at 2.9 T.m$^2$ and the magnet is designed to work at 3.5 T.m$^2$. The fringe field on cavity is kept below 20 mT. The steering coils designed to operate up to 8 mT.m are placed between the fringe field compensation solenoids. The component can be completely disassembled if necessary.

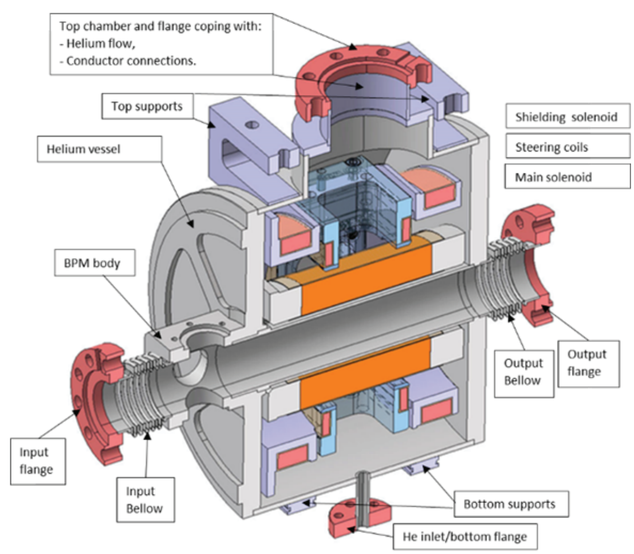


Figure 7: SC magnet 3D view.

## CRYOMODULES

The cryomodule PDR is planned in May 2017. However, its setting interfaces with the major elements are set. The component string is top-loaded. The cryomodule is designed to limit the string misalignment below +/- 1 mm. Titanium frame supporting the cavities strain is placed over the beam line in order to facilitate the assembly of the cryomodule (in yellow in Fig. 8).




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8 vertical and 4 horizontal tie rods maintain the frame at the designed position. Large access hatches are placed in front of tuner motors. Further details are given in [6].

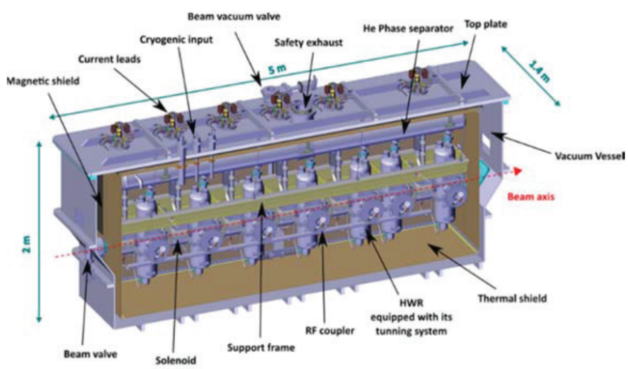


Figure 8: 3D view of the low beta cryomodule (the 6th cavity is optional).

## BEAM DIAGNOSTICS

The beam diagnostics PDR took place at Saclay in December 2016. The measurement requirements, given by the beam dynamics have been given (see [3]). A set of diagnostics have been identified to fulfil these requirements. They are:

- 3 ACCT (RFQ, MEBT and SCL exits),
- 1 Faraday Cup at MEBT exit,
- 4 "warm" and 20 "cold" BPMs,
- 6 H/V profile monitors (see Fig. 9): 2 in MEBT and 4 in SCL,
- 1 fast FC or Beam Extension Monitor [7] in MEBT,
- 1 H/V emittance-meter in MEBT,
- 12 neutron beam loss monitors (nBLM).

They will be as close as possible as already existing diagnostics (SARAF Phase 1, Spiral 2, ESS…) and, if possible, off-the-shelf.

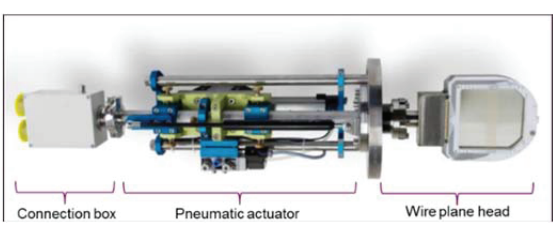


Figure 9: Spiral 2 Harp profiler [8].

## LOCAL CONTROL SYSTEMS

The PDR of the Local Control Systems for SARAF-LINAC components (called CCD = CEA Control Domain) took place at Soreq in February 2017.

Hardware and EPICS software standard platforms are developed at Irfu, based on VME64X, Industrial PCs and PLCs (Fig. 10). EPICS IOCs are running on VMEs and Industrial PCs that are more dedicated to slow control and communication with PLCs. About 40 cabinets are expected to host the electronics controlling:

- the cavity LLRF and LCS (including tuning motors),
- the magnetic element power-supplies,
- the cooling systems (water, helium, air),
- the vacuum systems (pumps, valves),
- the beam diagnostics electronics,
- the linac monitoring probes,
- the protection systems (local, global).

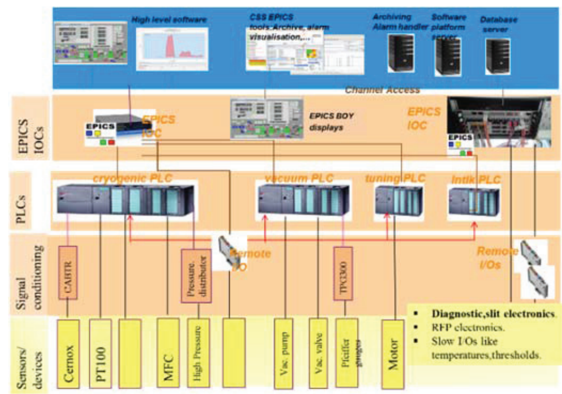


Figure 10: Breakdown of a LCS template.

## CONCLUSION

The SARAF-LINAC prototypes of major components are now at call for tender stages. They should be tested on dedicated test-stand at Saclay from the end of 2017 to the beginning of 2018. In the same time, cryomodule design should be completed.

## REFERENCES

[1] N. Pichoff *et al.*, "The SARAF-LINAC Project for SARAF-Phase 2", in *Proc. IPAC'15*, Richmond, VA, USA, 2015, paper THPF005.

[2] N. Pichoff *et al.*, "The SARAF-LINAC project status", in *Proc. IPAC'16*, Busan, Korean, 2016, paper MOPOY053.

[3] D. Uriot *et al.*, "Status of TraceWIN code", in *Proc. IPAC'15*, Richmond, VA, USA, 2015, paper MOPWA008.

[4] P.A.P. Nghiem *et al.*, "Strategy of Beam tuning implementation for the SARAF MEBT and SC Linac", presented at IPAC'17, Copenhagen, Denmark, May 2017, paper MOPIK057, this conference.

[5] J. Dumas *et al.*, "Beam dynamic studies for the SARAF MEBT and SCL", presented at IPAC'17, Copenhagen, Denmark, May 2017, paper MOPIK058, this conference.

[6] R. Cubizolles *et al.*, "Preliminary Design of the Cryomodules for the SCL for SARAF-Phase 2", presented at IPAC'17, Copenhagen, Denmark, May 2017, paper MOPVA042, this conference.

[7] J-L. Vignet, R. Revenko, "A Bunch Extension Monitor for the Siral2 Linac", in *Proc. IBIC'14*, Monterey, CA, USA, 2014.

[8] J-L. Vignet *et al.*, "A New Low-Intensity Beam Profiler for SPIRAL2", in *Proc. IBIC'13*, Oxford, UK, 2013.



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