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# THE SARAF-LINAC PROJECT 2018 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 MEBT line and the superconducting linac (SARAF-LINAC Project). The prototypes of the 176 MHz NC rebuncher, SC cavities, RF coupler and SC Solenoid-Package are under construction and their test stands construction or adaptation is in progress at Saclay. Meanwhile, the cryomodules and the global system just passed their Critical Design Reviews. This paper presents the status of the SARAF-LINAC Project at April 2018.

## 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 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.

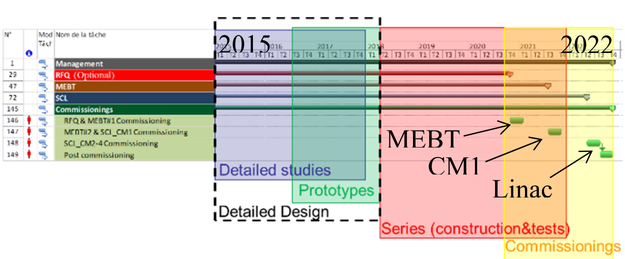


Figure 1: SARAF-LINAC major schedule.

Following the IPAC 2017 status [2], this paper presents the status of these developments after the third year of detailed design phase.

In March 2018, three Design Reviews (DR) took place at Saclay:

- System CDR2.
- MEBT DR.
- Cryomodule Critical DR (CDR).

## SYSTEM

The linac layout is given on Fig. 2.

A systematic engineering process is applied to derive and follow requirements, specifications, solutions and acceptance of each subsystems (from SARAF-LINAC to small components).

The proton or deuteron beam dynamics, from 40 µA to 5 mA, from 1.3 MeV/u to 40 MeV final energy have been calculated (including the error studies) with TraceWin code package [3]. The linac tuning strategy [4] and associated performances [5] have been studied, see Fig. 3.

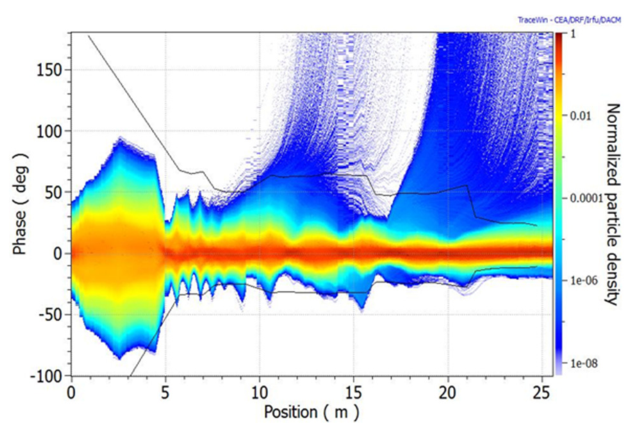


Figure 3: Beam statistical longitudinal distribution with errors. Blue tails represent unhooked particles with very low probability ($<10^{-7}$).

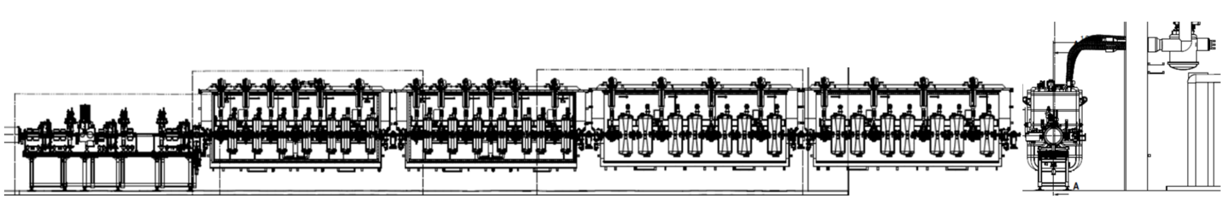

Figure 2: SARAF-LINAC layout, side view (left) and beam view (right).

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The field in the cavities will be tuned from phase measurement between downstream BPM. The correlation between errors on amplitude and phase has then been estimated from systematic of random errors on BPM phase measurement (using a Monte-Carlo process). Systematic errors have more influence on amplitude as random errors have more influence on phase (Fig. 4).

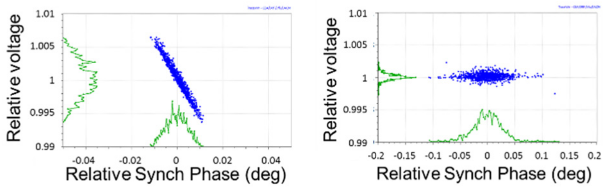


Figure 4: Influence of systematic (left) and random (right) errors on BPM phase measurement on the cavity tuned field phase (abscissa) and amplitude (ordinate).

The vacuum system and associated performances have been estimated (Fig. 5).

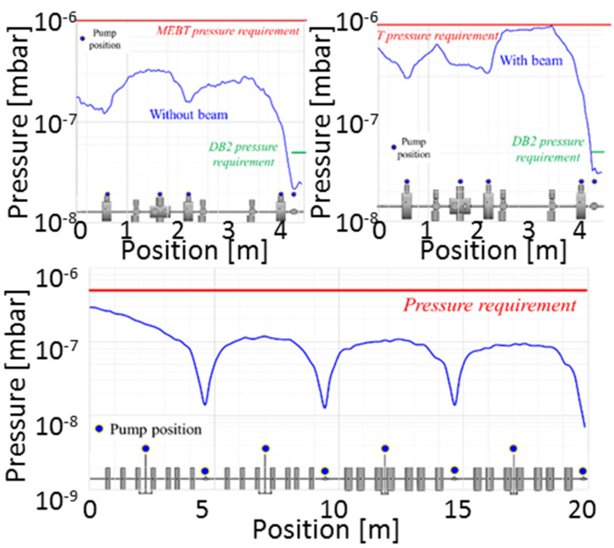


Figure 5: pressure distributions along MEBT (up) without (left) and with (right) beam and along SCL (down) before cool down.

## MAJOR COMPONENTS STATUS

The major components prototypes or first of series are being built:

- MEBT Rebunchers by SDMS [6],
- HWR cavities by RI [7],
- RF Couplers by TETD [8],
- Solenoid Packages by ELYTT [9] and CRIOTEC [10].

The associated test stands are getting prepared for acceptance tests in the second semester of 2018.

### *The MEBT Rebuncher*

The 105 kV CW, 5 kW, β=0.053 NC rebunchers are being built by SDMS Company. The first rebuncher will be tested in the second semester of 2018. The acceptance criteria are linked to vacuum performances, frequency tuning (geometry), power consumption (copper coating) and water cooling.

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

The low-beta (0.091) prototypes were built by RI Company. It was prepared (BCP, HPR) and tested by CEA. Multipactor at low and medium fields was observed and passed through. The surface resistance at low field was measured at about 16 nOhms. Results at high field (above 2 MV/m) are not exploitable for now. Some issues were observed at higher field in the vertical test cryostat, and we are investigating the causes.

The high-beta (0.181) prototypes are being built.

### *The SC Magnet*

The Final Design Review of SC magnets has just been done at the ELYTT Company's manufacturing site. Only small changes have been proposed compared to CEA design. The prototype of the Solenoid Package is expected to be tested in the last quarter of 2018. The Current Lead Clusters, designed by CEA, are being manufactured by CRIOTEC Company.

## TEST STANDS

The major components are tested at Saclay in dedicated test stands (TS) all in the same facility (Fig. 6):

- RBTS for Rebunchers.
- VCTS for Vertical Cavities,
- ECTS for Equipped Cavities (with coupler and tuner),
- SPTS for Solenoid Packages,
- CMTS for assembled Cryomodules.

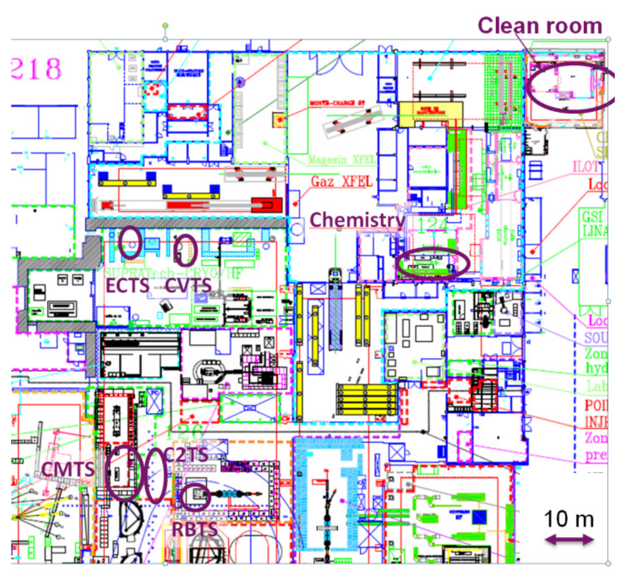


Figure 6: SARAF-LINAC components Test Stand in the Saclay facility.

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## CRYOMODULES

The cryomodule [11] (Fig. 7) CDR has been passed in March 2018. The review focused on the following aspects:

- Requirement and interfaces with the system.
- Mechanical performances: support frame, top plate, vacuum vessel, support…
- Electromagnetic performances: magnetic shield, RF supplies…
- Cryogenics performances: thermal distribution, thermal shield, insulation vacuum, valves boxes…
- Performances control: instrumentation…
- Life Cycle: transport, installation, cool-down, safety, maintenance…

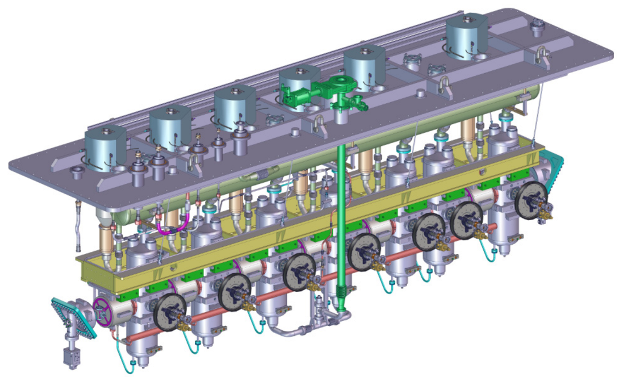

Figure 7: 3D view of the low beta cryomodule.

The tendering documents are being prepared. The building of the cryomodule components should start in 2019.

## BEAM DIAGNOSTICS

A set of diagnostics have been identified to fulfil the system 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 (2 in MEBT and 4 in SCL,
- 1 fast FC in MEBT,
- 1 H/V emittance-meter in MEBT,
- 12 neutron beam loss monitors (nBLM).

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

## LOCAL CONTROL SYSTEMS

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

EPICS standard platforms are developed at Irfu, based on VME64X, Industrial PCs and PLCs (Fig. 8). EPICS IOCs are running on VMEs (semi-fast acquisition) 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).

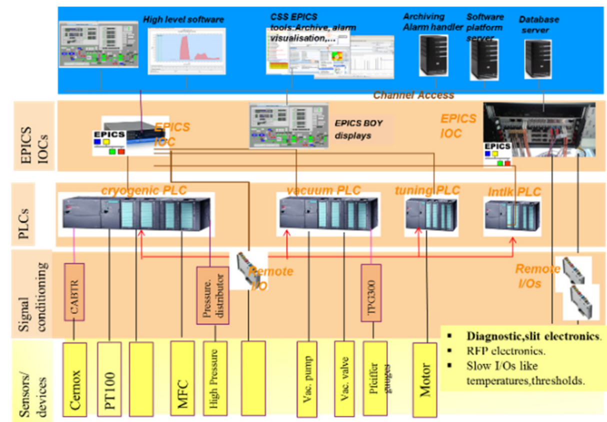


Figure 8: breakdown of a LCS template.

The first cabinets containing all the equipment for the test stands have been or are built. They will be tested with test stands as "prototypes" for the final machine.

## CONCLUSION

The SARAF-LINAC prototypes of major components are now being built. They should be tested at the end of 2018. Cryomodule design is completed and they are entering the call for tender process. Their construction should start in 2019.

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