A state machine solution to control superconducting cavities

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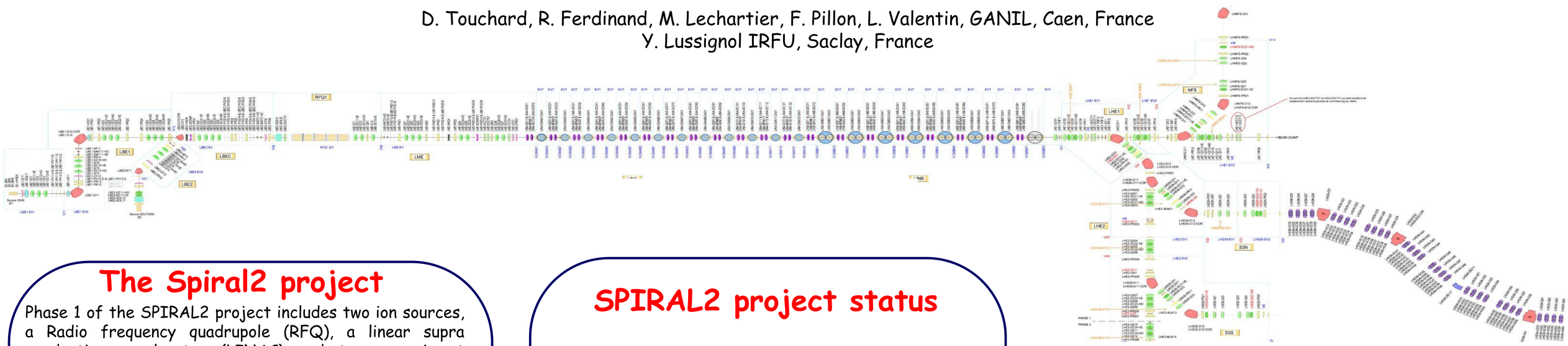
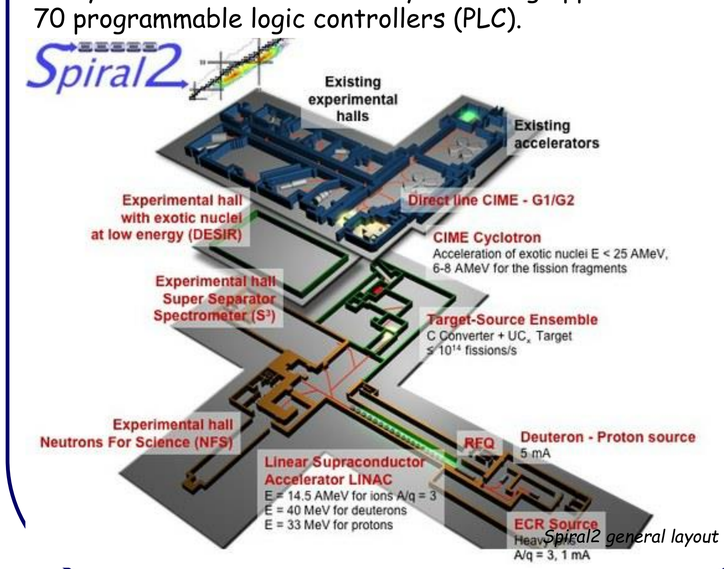


The Spiral2 project

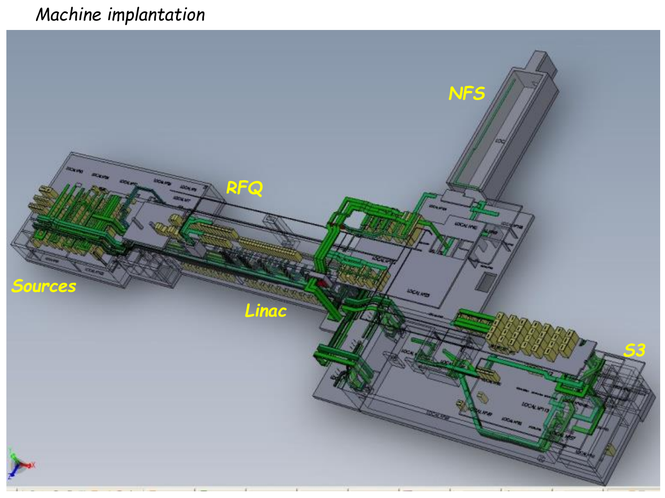
Phase 1 of the SPIRAL2 project includes two ion sources, a Radio frequency quadrupole (RFQ), a linear supra conducting accelerator (LINAC) and two experiment rooms. SPIRAL2's LINAC is capable of accelerating particles such as protons, deuterons, or ions from helium to nickel. The control command system is made up of 40 RF systems and is controlled by 70 tuning applications and 70 programmable logic controllers (PLC).



Spiral2 general layout

SPIRAL2 project status

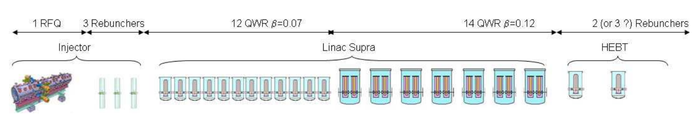
Machine implantation



In July 2019, the French Nuclear Safety Authority authorized to start the LINAC and beam commissioning.

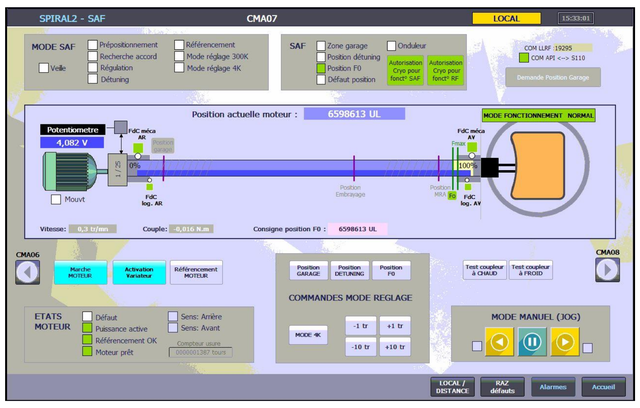
Radio frequency cavities

The driver accelerator facility composed by sources, followed by a Radio Frequency Quadrupole (RFQ), 3 bunchers, and a superconducting linear accelerator (LINAC) will be able to accelerate also proton, deuteron or heavy ion beams. The LINAC will be composed of 26 quarter wave superconducting resonators closed into 19 cryo modules. All cavities will be driven by independently power amplifiers at 88.0525 MHz.

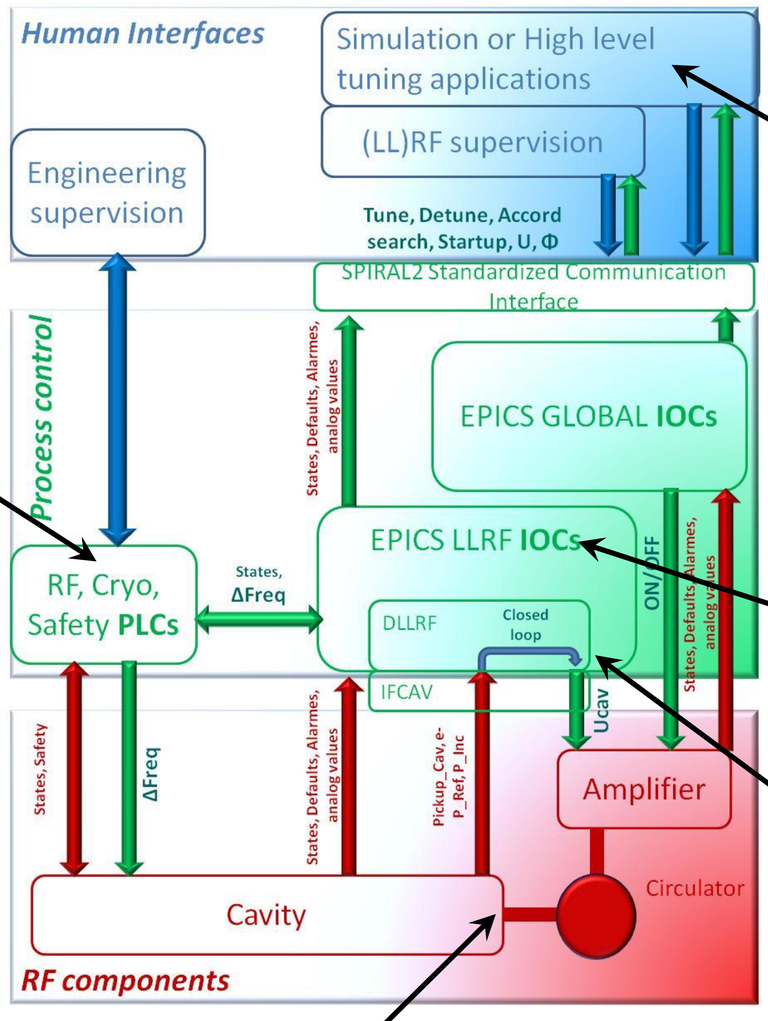


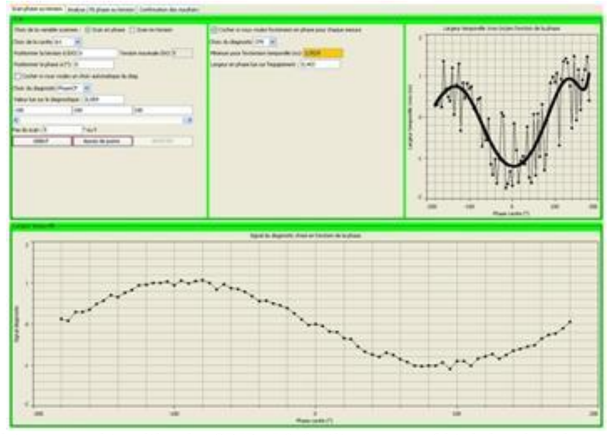
State Machine for the Radiofrequency command control system

For the command control room, and control process associated, EPICS was early chosen to ease development and integration of software components developed by all laboratories involved in the SPIRAL2 collaboration. Industrial PC Linux or VME Vxworks crates will host EPICS input output controllers (IOCs) To control Radio Frequency (RF) equipment, a dedicated command control (CC) sub system is identified. The main piece of this sub system is a low level radio frequency (LLRF) control process

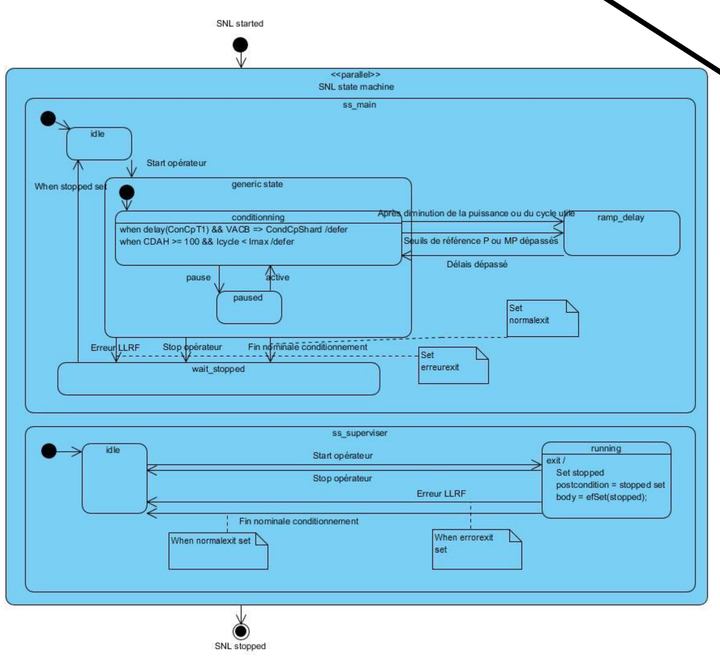


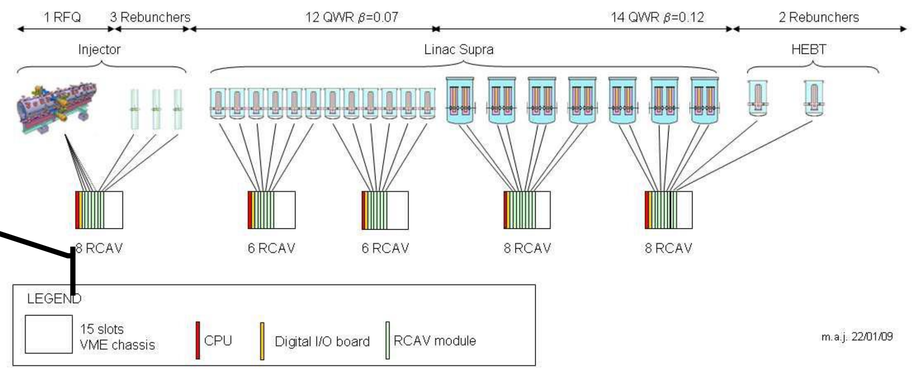
Siemens S7 programmable logic controllers (PLCs) will be dedicated to slow control material protection, safety and local engineering applications. In addition to general functions described above, PLCs take a particular place for RF command control. Amplifiers will be interfaced via dedicated PLCs solution. In the same way, a well tuned and regulated cavity which drifts in frequency should be adjusted by mechanical or thermal constraint. For the special case of mechanical according cavity delta frequency, dedicated brushless motors driven by PLC are implemented. ***The frequency tuning research <u>state machine</u> procedure is needed to set the cavities at the nominal 88,05MHz frequency.***





To drive a machine like the SPIRAL2 facility, a set of high level and supervision applications are going to be developed. After configuring equipment, conditioning dedicated sub systems like RF equipment, and setting theoretical beam values, RF equipment can be tuned and optimized for different kind of beams. ***Cavity automatic actions <u>state machine</u> procedure is the high level process given to operators to easily control cavities before applying tuning parameters from high level tuning applications.***





The LLRF will mainly provide the control analogue signal to each cavity's amplifier and regulate the accelerating field of each cavity with a fast automatic closed loop . Among others, it will also control the frequency, the start-up in an automated way, and will monitor the electric arc phenomenon. In order to fulfil these functionalities, the first digital subsystem (DLLRF) will acquire and process data from the second subsystem (IFCAV) which will host RF components to interface cavities. ***For cavity conditioning and field increase <u>state machine</u> procedure, the field rise was coupled to the conditioning function. The idea is to intelligently monitor cavity sparks. Indeed, from one start-up to the next, conditions may differ if maintenance operations have disrupted the quality of the internal surfaces of the cavities.***

The power coupler conditioning state machine procedure *consists in starting the high frequency with a very low power before increasing useful cycles, with a progressive increase in power over each cycle until a maximum power is obtained in continuous mode (100\% cycle). The procedure switches to the next cycle when the maximum power is reached. It is carried out with a return to minimum power without any other precaution. When the maximum amplitude of the last useful cycle (100\%) is reached, a progressive decrease in power is performed. The thresholds parameters and useful cycles to be processed can be set at any time. The degradation of the vacuum or a current induced on the coupler beyond the set thresholds induce both a power rise freeze, waiting for a nominal situation. If these degradation exceed the material tolerance limits, the LLRF safety device stops the procedure.*