Work Package 7

Text taken from "description of work" (Annex 1 of the proposal)

The quality of the proton beam circulating in the LHC which determines its performance, is established in the lowest energy accelerators and can, at best, be preserved in the higher energy accelerators. It is true in particular for the superconducting proton linac (SPL), which must meet demanding requirements in terms of beam characteristics and reliability. Two technical subjects are especially critical for reliably reaching the required density of particles in all planes, the H^- ion source and the stability of the energy from the linac.

The emittances of the beam from the H^- ion source must be small and stable, the reliability has to exceed 99% and the lifetime 2000 hours. In the case of Linac4, which cycles at 2 Hz, existing solutions are expected to be applicable with only limited research and development. This is not the case with the SPL which cycles at up to 50 Hz with a duty factor of 4%, and an adequate solution remains to be found and demonstrated. Development and tests are critically needed to demonstrate that the characteristics required for the SPL can potentially be achieved and to guide the design of the operational source.

The stability and reproducibility of the field in the accelerating structures determines the stability in energy and phase of the beam delivered by the linac. Superconducting cavities are very efficient accelerating devices because of their very high gradient capability and because of the excellent power efficiency. However, they are very sensitive to mechanical vibrations, and the Lorentz forces resulting from pulsed operation at high gradient are an unavoidable source of excitation. The work done in the JRA "HIPPI" (part of the "CARE" I3 in the FP6) is already starting to address these issues by supporting the study of low beta superconducting cavities operating in pulsed mode, the development of a fast tuner and the realization of a high power 700 MHz test place in the CEA-Saclay. From that basis, there is the need to elaborate the architecture of an RF system that will achieve an adequate stabilization of the accelerating field and to specify its components. This "real" system has to use a single klystron to drive a large number of cavities, each cavity being fed through a high power amplitude/phase modulator. The complete linac beam dynamics has to be simulated to correctly analyse the consequences for the beam. The 700 MHz test place will be repeatedly used during this task to refine the characterization of the cavities and their tuner, to test corrective actions and finally to validate a system solution using prototype electronics

Objectives

- To develop a test bed for a high duty factor for the plasma generator of an H- RF ion source; to guide the design of the operational source.
- To elaborate the architecture, to specify the components and to demonstrate the performance of an RF system that will properly stabilize the accelerating field in the SPL and achieve the characteristics required for LHC in the following synchrotron ("PS2").

Description of work

Task 7.1 Development towards an H- source for the SPL

Development is required towards a negative hydrogen ion source that can fulfil the duty factor, intensity, emittance and reliability requirements of the SPL. One candidate for the plasma production method is the RF (2 MHz) driven plasma source. DESY has developed an ion source design where the RF antenna is separated from the vacuum system by a ceramic plasma chamber, which has allowed DESY to demonstrate a very high reliability source for low duty factors for the production of negative hydrogen ions with high intensities.

Increasing the duty factor of the source will result in increased thermal load on the elements of the plasma generation region, which will require cooling. The initial challenge is to manage the thermal load into the source.

The thermal distribution will be calculated with finite element modelling of the heat loads into the plasma generation system. Such modelling has already been shown to be fruitful for the Penning Ion Source design at ISIS.

Furthermore, the increased duty cycle will require increased hydrogen gas flow into the plasma region. Simulations will be performed to improve the geometry of the vacuum pumping system in order to reduce the pressure downstream of the plasma generation system (to avoid discharges in the high electric field region of the ion extraction region).

Construction of a plasma generation system and its sub systems (100kW 2MHz RF generator for up to 4% duty cycle, vacuum system and hydrogen delivery) will allow comparison with the thermal model, and with the efficiency of the vacuum pumping.

The resulting plasma generation system (and in particular its sub systems) will be available to serve for future testing, and as the basis of a future RF ion source for high duty factor operation.

The steps to design and build this generator are:

- Finite element thermal study of the Linac4 design source at the final duty factor.
- Design of the plasma generator to operate at 4% duty cycle.
- Construction of plasma generator and sub-systems (e.g. RF generator, hydrogen gas injection and pumping).
- Infrastructure preparation and system installation
- Plasma generation and study of the thermal conditions.

CERN will be the leading institute and will co-ordinate the other efforts. STFC will be involved in the ion source thermal modelling, and DESY will contribute to the modelling and design of the plasma generator.

Task 7. 2: Field stabilisation in pulsed superconducting low beta (v/c) accelerating structures

The goal is to elaborate the architecture of an RF system that will achieve an adequate stabilization of the accelerating field and to specify its components. First a detailed characterisation of the tuner/SC-cavity ensemble will be necessary to compare the two existing RF cavity/tuner ensembles and provide accurate data for the RF system design, using the test stand and high power RF source in CEA-Saclay and the results from the "HIPPI" JRA. In parallel the modelling of the different RF components, the cavity/tuner, the power amplifier, etc. will be done. As the component models are completed, the design architecture of the complete RF system will start. This architecture will address the complication introduced by the powering of several cavities from one RF source. Simulations to predict, understand and optimise the behaviour of the system will be combined with a simulation of the beam dynamics of the full Linac to ensure the beam quality at the exit of the accelerator. When optimized, the RF system will be fully specified, including items such as the high power modulator, the Low Level RF system and the algorithms controlling them.

Subsequently the preparation of the demonstration to validate the design can start. Prototype electronics and other necessary interfaces will be built. All components will be assembled in the test stand. The system validation tests will follow. It is expected that re-optimisation of the architecture will occur.
Finally a report will be produced summarising the results and describing the architecture and specifications of the complete Linac RF system.
The CEA-Saclay team will provide, operate and manage the test stand for superconducting cavities, with its 700 MHz high power RF system and one cavity/tuner ensemble. They will also contribute to the simulation of the RF system and of the Linac beam dynamics.
The INFN team will provide the other cavity/tuner ensemble and will participate in the in-depth testing of these components and the preparation of the data for the RF system design.
CERN will provide overall co-ordination and will participate in the design of the system architecture, the beam dynamics simulations and the preparation of the demonstration. All beneficiaries will be present at and participate in the tests and will also contribute to the final report, though CERN will have the main responsibility for it.