Contribution aux exercices de prospective nationale 2020-2030

Accélérateurs et instrumentation associée

PIP-II

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1. Informations générales

Titre : Proton Improvement Plan II

Acronyme : *PIP-II*

Résumé *(max. 600 caractères espaces compris)*

Fermi National Accelerator Laboratory (FNAL) is building a new superconducting linear accelerator and upgrading the existing synchrotron complex together designated The Proton Improvement Plan-II (PIPII) Project [1]. The central element of PIP-II is a new 800 MeV superconducting linac accelerating a CW 2-mA H- beam. The Accelerator divisions of IPNO and LAL are involved in the prototyping phase and are discussing a possible In-Kind contribution to the production phase and more specifically on the second Spoke section of the superconducting linac (SSR2).

Préciser le domaine de recherche *(plusieurs choix possibles)*

- *Physique des accélérateurs (nouveaux concepts machines, optique et dynamique des faisceaux…)*
- *Sources de particules (électrons, positrons, muons, protons, ions lourds stables, ions radioactifs…) et cibles associées*
- ***Supraconductivité accélérateur (aimants fort champ, cavités SRF…)***
- *Accélération plasma (électrons, ions…) et interaction lasers/faisceaux*
- *Technologies RF innovantes (structures haut gradients, alimentations RF…)*
- *Diagnostics faisceau, instrumentation et contrôle intelligent*
- *Développement durable de la discipline (infrastructures technologiques, efficacité énergétique, fiabilité…)*
- *Autre :*

Préciser la motivation principale visée par la contribution :

- *Accélérateurs pour la physique nucléaire*
- ***Accélérateurs pour la physique des particules***
- *Accélérateurs pour les sources de lumière ou de neutrons*
- *Accélérateurs pour les applications sociétales (santé, énergie, industrie…)*
- *Autre : (préciser)*

2. Description des objectifs scientifiques et techniques *(2 pages max incl. figures)*

The future In-Kind contribution of France to PIP-II project has been defined and agreed scientifically (but not yet approved by TGIR) with FNAL PIP-II project on procuring the following deliverables:

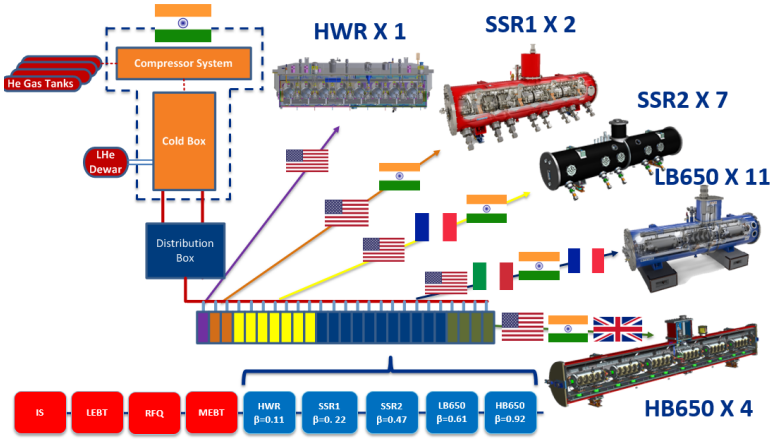
- 40 dressed SSR2 Single-Spoke Resonators (including Niobium),
- 37 Frequency Tuners
- 40 SSR High Power Couplers (HPC).

The 40 SSR2 cavities will be procured and validated in vertical cryostat with Low Power Coupler (LPC) at 2K prior to shipment to Fermilab. The 37 frequency tuners will be procured and installed on their cavities, and validated in vertical cryostat at 2K. Cavities will be shipped with their Frequency Tuner if they meet the ambitious PIP-II specifications (Accelerating gradient of 11.5 MV/m and an intrinsic quality factor of 9.8E9). The 40 HPC will be procured and shipped directly to Fermilab after visual inspection and low power validation. No cleaning, high power test or RF conditioning will be performed.

Prior to the production phase, a very complete and fruitful prototyping phase has been initiated since beginning of 2018 and will finish in end of 2021. This phase consists in:

- Joint design of the SSR2 spoke cavity and its helium tank, the HPC and frequency tuners.
- Procure 4 HPC prototypes and 4 frequency tuners
- Test in vertical cryostat and proceed with surface treatment optimization of 3 SSR2 cavities prototypes
- Test specific heat treatments (Nitrogen infusion or doping, 120°C baking) to measure their positive and negative impacts on SSR2 Spoke cavity performances and decide which could be integrated in the surface preparation procedure of the prototype and series cavities. This R&D will be performed at IPNO on 352 MHz Single Spoke Resonator from MYRRHA project.
- Analysis of the sensitivity to magnetic trapped flux of SSR2 cavities. Calculations will be performed and compared to experimental data measured during vertical tests at IPNO.
- Transportation study: aims at addressing cavity performances before and after shipment of the cavity and/or power coupler. This will also help to optimize transportation box and procedure. This study could be done on a SSR1 and/or SSR2 cavity.
- Aging test on SSR1 tuner cartridge in the dedicated nitrogen cooled test bench at IPNO. This test would simulate several years of pulsed operation of the cold motor and piezo actuator. The performances of both motor and piezo actuator will be monitored thanks to specific sensors (deformation gages, resolver, …).
- Issue a report on the optimized recipe for cavity surface preparation (Q_0 optimization) and how to reach frequency target of the dressed cavity (cavity + tuner + HPC) at 2K.

3D view of the jointly designed SSR2 Spoke resonator



PIP-II SRF Linac and future possible In-Kind contributions from France, Italy, India and UK

3. Développements associés, calendrier et budget indicatifs *(1 page max. incl. figures)*

IN2P3 contribution is phased accordingly to PIP-II project management:

- The Preliminary Design Phase (2018 – 2021) is the preliminary engineering design phase of the in-kind deliverables. It culminates in the completion of the system and component Preliminary Design Reviews (PDR). This also integrates specific R&D studies on cavities (heat treatments, magnetic sensitivity) and tuners (aging test). A support of about 100k€ over 4 years is required covering cryogenic tests and travel expenses.
- The Final Design Phase (2019 – 2022) aims at closing the design, procuring some components, testing prototypes (3 cavities, 4 HPC and 4 tuners) and addressing their performances thanks to existing facilities at IPNO and FNAL. No significant investment is required for this phase. A support of about 400k€ over 4 years is however required to procure prototypes and perform cryogenic tests.
- The Procurement/Assembly/Fabrication Phase (2021 – 2024). IN2P3's contribution in Phase 3 is the production, assembly and tests of the deliverables described previously for the PIP-II Project. The final In-Kind contribution will depend on the final decision of the Ministère de l'Enseignement Secondaire, de la Recherche et de l'Innovation (MESRI) represented by the High Council TGIR (Très Grande

Infrastructure de Recherche). The total cost of the In-kind contribution for this phase has been roughly estimated at 20M€.

- The Delivery and Acceptance Phase (2022-2024) will, after full qualification of all deliverables and if authorized by PIP-II project, consists in:
    - Organizing and perform the Transportation Readiness Review
    - Delivering to FNAL and proceed with Site Acceptance Review of each batch composed of:
        - Cavities equipped with their tuner
        - High power RF couplers
    - Any non-conformity to follow mutually agreed remedial protocols
    - Transfering ownership of each batch of cavities and RF couplers to Fermilab

4. Impact
(0.5 page max.)

The opportunity to work in close collaboration with world-leading accelerator laboratory Fermilab is of first interest for IN2P3 and for all technical people that will be involved on PIP-II Project. The joint-design activities, R&D and prototyping programs have been defined accordingly to IN2P3 labs interests and expertise. Moreover, this contribution to PIP-II will serve the international DUNE experiment [2] dedicated to neutrino science in which many scientists from France will be involved.

Références

[1] : https://pip2.fnal.gov/

[2] : https://www.dunescience.org/