

Table 1: Summary of the Main Parameters Required in the Technical Specification and the Results Achieved [4]

| Requirement | Technical Specification Required | Technical Specification Reached |
|--|--|--|
| Electron energy | 250 MeV | 152 MeV |
| Beam production in Recovery Mode | 180 MeV in RF failure mode | No |
| Beam macrobunch repetition rate | 1 Hz | 1 Hz |
| Modulator/klystron repetition rate | 10 Hz | 10 Hz |
| RF frequency | 500.04 ± 0.005 MHz | 500.04 ± 0.005 MHz |
| | 3000.24 ± 0.030 MHz | 3000.24 ± 0.030 MHz |
| Beam charge Multibunch per 500 MHz bunch | >0.08 nC (distributed in one or two 3 GHz bunches) | Yes |
| Multibunch train length | 1 to 70 bunches at 500 MHz with 2 ns spacing (2 to 140 ns) | 1 to 70 bunches at 500 MHz with 2 ns spacing - Operating with 35 bunches |
| Center energy stability pulse to pulse | <0.1% rms | <0.1% rms |
| Energy spread | <0.5% rms | 0.15% rms |
| Normalized emittance | <50πμm rad (1σ in x/y) | 52.5/55.5πμm rad (in x/y) |
| Pulse to pulse beam position variation | 0.2 mm rms | <0.1% rms |
| Pulse to pulse beam angle variation | 0.05 mrad rms | Not tested |
| Beam charge Single Bunch per 500 MHz bunch | >1.5 nC (distributed in one or two 3 GHz bunches) | Not tested |
| Single Bunch bunch length | 1 ns | Not tested |

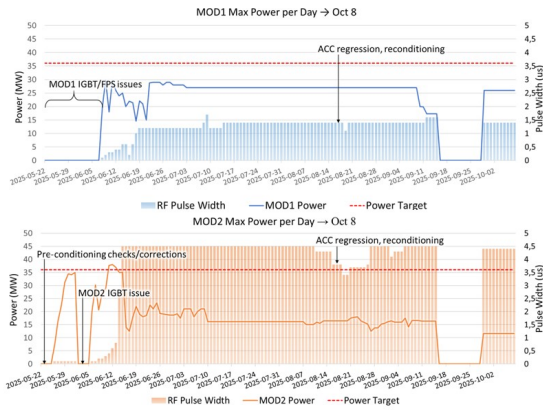


Figure 4: Klystron power output into the RF structures (FBU, ACC1, ACC2 and ACC3, with or without SLED until September 2025 [4].

2025 was lost for user operation, Fig. 5, and the injector energy operating setpoint was reduced from 180 MeV to 152 MeV. The new operating point allowed high reliability of the LINAC for a scientific availability of ~95%, if we discount the first month of planned operation (Aug 2025), Fig. 5. Out of this uptime, 97.5% of the beam was delivered in top-up mode. Operation in early 2026 started relatively well, until the facility and the machine suffered from a cryoplant failure, a significant unplanned power outage, and a water to vacuum leak in one of our SR dipole chambers. The degraded performances are displayed in Fig. 6. The facility nevertheless delivered the beam in top-up mode 99.7% of the time until our spring shutdown. Top-up mode requires both the injector and the booster ring to be highly operational.

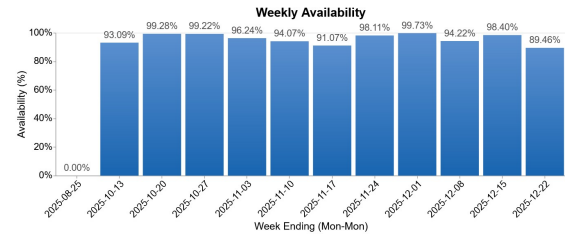


Figure 5: Weekly operational performances from October to December 2025.

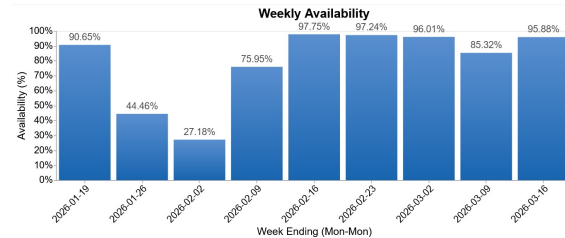


Figure 6: Weekly operational performances from January to March 2026.

FUTURE OPERATION

Although scientific operation appears stable, the turn-key injector project did not reach the required specification, Table 1. Pushing the RF power in the ACC accelerating structures is part of the RF processing. One conclusion of our RF conditioning campaign is that the RF design of those structures is, with good confidence, adequate for the level required [4]. RI has nevertheless produced a backup structure, following its current RF and mechanical designs, in the event one of the RF structures needs replacement due to potential arcing that could affect beam for scientific use. Obviously a dedicated RF power test-stand would be very beneficial to test not only the new ACC, but also RF

components that were exchanged as they had failed to hold the required E field during the commissioning phase [4]. In absence of such a test-stand, the push of RF power to higher RF voltage and longer pulse length will have to be planned, and will require extended downtime. We expect 8-10 weeks shutdown for a few years, based on discussions with colleagues in other facilities. While most of the time may be dedicated to repair or maintenance of the facility, including the LINAC; it is expected to operate our injector during most of this downtime. This time will be used to progress the RF conditioning to reach accelerating fields in the accelerating structures that are compatible with a 180 MeV electron beam production as a first milestone and towards a 250 MeV beam production equivalent, to complete the technical specification.

Extended downtime to RF conditioning and commissioning of the injector with beam will create new operating parameters for its operation. However, the scientific operation allocated time will have to be decreased to allow for proper RF conditioning. CLS typically plans to deliver around 4200 hours of beam for science. Given the long dark time CLS has suffered, a strategic decision, to sacrifice science for technical specification within the warranty time of our injector, must be balanced in regards to the benefit of forfeiting warranty and accepting many years of RF conditioning to reach full tech spec. By accepting to push the injector towards its designed specification, during the warranty period, and should there be a necessity to purchase a replacement RF structure, CLS will not have to strain its budget. However, if one decides to push slowly over years to reach the technical specifications, one preserves the user time and trades a potential purchase should something go wrong while reaching the required performances.

SUMMARY

The overall timeline summary of the commissioning with attempt to operate since September 2024 to September 2025 has been provided, and since October 2025 the facility delivers reliable beam to science in top-up mode. The per-

formances of the injector are however, below the specified performance. The delay in restarting scientific operation certainly affected our relationship to our users. Today, the facility must consider whether to continue operating the injector with the parameters achieved, or to gradually RF condition the three accelerating structures to full performance - either within or outside the warranty period provided by the vendor, and either in situ or, if funding is available, on a dedicated test-stand.

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