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AWAKE FROM RUN 2A TO RUN 2B

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Abstract

AWAKE is the first proof-of-concept proton-driven plasma wakefield acceleration experiment. AWAKE's first phase concluded in 2018, with controlled acceleration of electrons to energies of 2 GeV in a 10-m long plasma. AWAKE's second phase operates since 2021. It has been divided into four stages (Run 2a, 2b, 2c and 2d) to prove step-by-step that the required electron beam parameters can be obtained reliably and consistently. The transition from Run 2a to Run 2b, which is scheduled for the first semester of 2023, includes the decommissioning of the current vapor source as well as the installation of a new 10-meter-long step-density vapor source. After summarising the motivation for the AWAKE Run 2 programme, this paper describes the preparation works for such an installation, the challenges linked to the infrastructure and the implementation of scheduling tools for the coordination of the facility.

PRESENTATION AND TIMELINE

The Advance WAKEfield Experiment, AWAKE, aims to achieve high-energy acceleration of a high-charge electron bunch [1]. To accomplish this physics goal, Run 2 started in 2021 with a four-stage programme, as shown in Figure 1, to prove step by step the reliability, consistency and stability of electron beam parameters [2] [3]:

- Run 2a (2021-2022): demonstrate the electron seeding of the proton bunch self-modulation in the plasma source of the original set-up (Run 1). [4]
- Run 2b (2023-2024): demonstrate the stabilisation of micro-bunches with a density step plasma source.
- Run 2c (2026 and on): demonstrate electron acceleration and emittance control in the new set-up with two plasma sources.
- Run 2d (from 2028): demonstrate the scalability of the experiment either with the rubidium vapor source or the discharge plasma source.

This paper focuses specifically on the transition from Run 2a to Run 2b. Run 2a ended with its last proton run on December 7th, 2022. The first proton run of 2023 is foreseen for May 2023. However, it was known already from the beginning of 2022 that the new rubidium plasma source for Run 2b (Gen II) would not be ready for installation before the end of May 2023. Hence, it was decided to take advantage of this time without plasma cell in the tunnel to test a discharge plasma source (DPS) that could be used later in Awake Run 2c or Run 2d. The transition from Run 2a to Run 2b includes: the decommissioning of the plasma source from Run 1 (Gen I), the installation, testing and uninstallation of the DPS, and the installation of Gen II. All these works are carried out in a limited timeframe from December 2022 to July 2023, as shown in Figure 1.

PREPARATION WORKS

The very ambitious plan to transform Run 2a into Run 2b involves many different groups from CERN as well as from external companies. The decommissioning of Gen I and the design and installation of Gen II are handled by an external UK-based company with various interfaces with CERN services such as 3D integration, cabling, survey alignment, and as manufacturing of new pieces. In addition, the DPS research and installation is handled by CERN

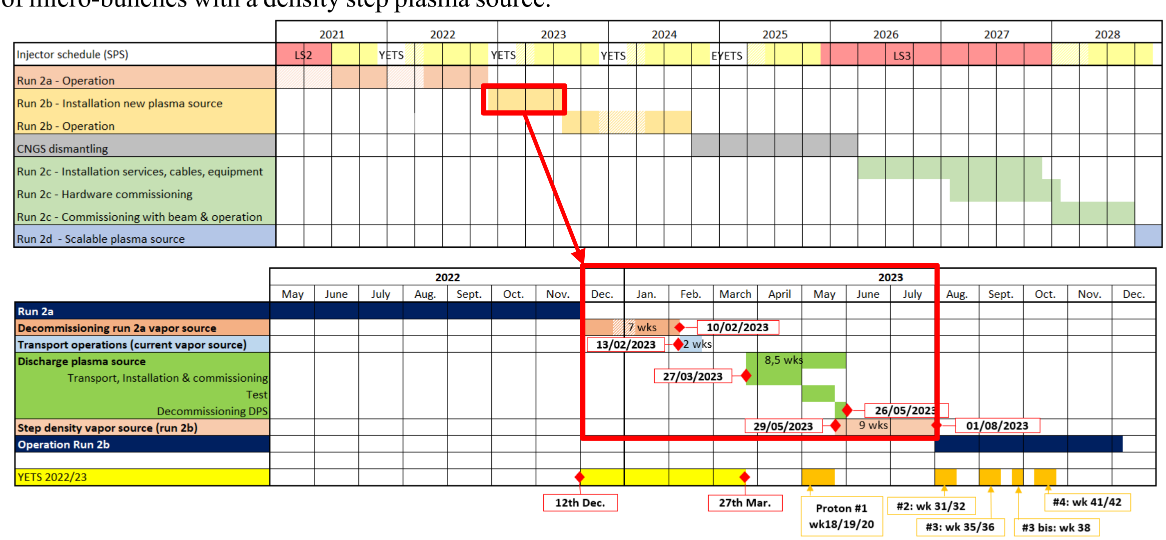

Figure 1: Proposed timeline for AWAKE Run 2.

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TE-VSC (Vacuum Surface and Coating) group with the same miscellaneous interfaces. This work distribution, shown in Figure 2, requires efficient coordination and anticipation of the works.

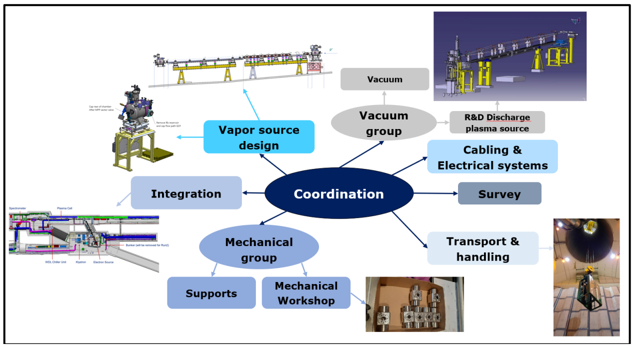

Figure 2: Diagram of the various work packages involved in the Run 2a to Run 2b transformation.

INFRASTRUCTURE CHALLENGES

While Run 2a was using the infrastructure installed for Run 1, major works are planned to reconfigure the area to make room both for the DPS and Gen II. AWAKE has a very particular topography that needs to be considered for any installation. Indeed, to access the area, it is necessary to go through a 60-meter-deep pit shaft (diameter of 8 meters), then an 800-meter-long downhill-sloping access tunnel, after which the narrow and intricate space of the experimental area is reached. Due to travel and space limitations, transport vehicles must be carefully chosen and activities carefully planned.

Run 1 Vapor Source Decommissioning

When planning for the removal of the Run 1 vapor source, it appeared quickly that the main challenge would be the transport. Indeed, when Gen I was transported in, the tunnels were empty. Figure 3 shows the transport path simulation: at the cavern end, on the left, heavy supports need to be removed to make room for the plasma source manoeuvres, in the middle, shielding blocks standing in the transport path, and in general, the space is quite narrow, making the procedure quite long and intricate. In addition, on-site visits revealed that it was also necessary to dismantle the Material Access Doors (MAD) for the duration of the works. (Fig 4)

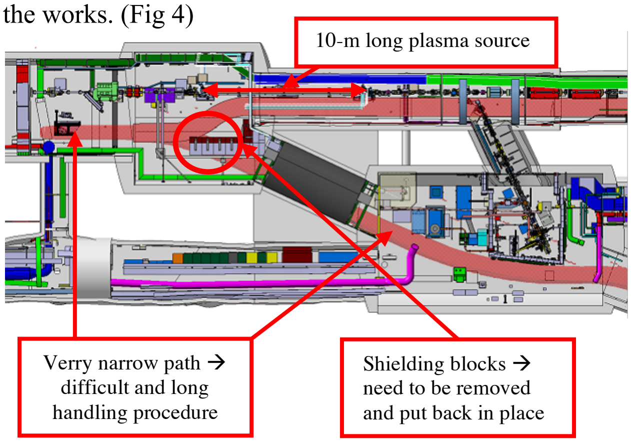

Figure 3: Transport path of the vapor source (~150kg).

The decommissioning procedure started in December 2022 with the disconnection and rubidium cleaning of Gen I. Accounting for resources availability, there was a limited time window to carry out the transport (i.e., in February 2023) and carefully coordinate the MAD removal.

Figure 4: On the left, the MAD, removed, on the right, the access point without MAD.

While the worst-case scenario was planned, the transport went flawlessly: with careful manoeuvres due to a 5 centimetres margin, it was possible to remove Gen I while leaving the shielding blocks in place, as shown in Figure 5.

Figure 5: Left, Gen I is lifted from its supports. Middle, Gen I is rolled along the shielding wall. Right, Gen I is taken out through the access point.

Discharge Plasma Source

While the DPS project is also challenging in terms of transport due to the nature of the area, it has additional constraints in terms of integration. Indeed, the two control racks need to be positioned within 30 meters of the source. The only viable position found is right behind the shielding wall, as shown in Figure 6. This required an additional small shielding wall [5] to protect the electronics present in the racks against stray radiation from the proton beam (see Figure 6).

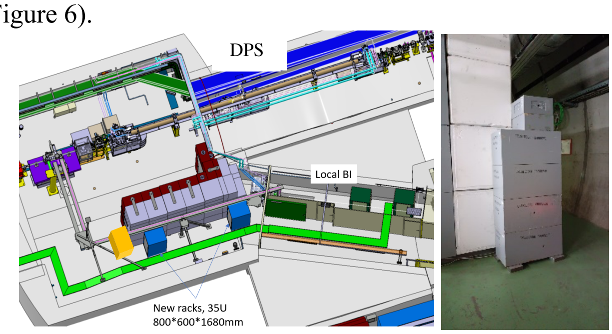

Figure 6: Left, integration of the racks and in orange the position of the new shielding wall. Right, the new shielding wall mounted.

The DPS consists of the source itself, composed of eight glass tubes, copper cables, 3D-printed supports, components for alignment and aluminium windows, two

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aluminium 5-meter-long supports, two electronics racks, the gas injection system, and the shielding blocks. Due to the topography of the experimental area and to the very delicate nature of most elements, the transport sequence had to be thoroughly prepared.

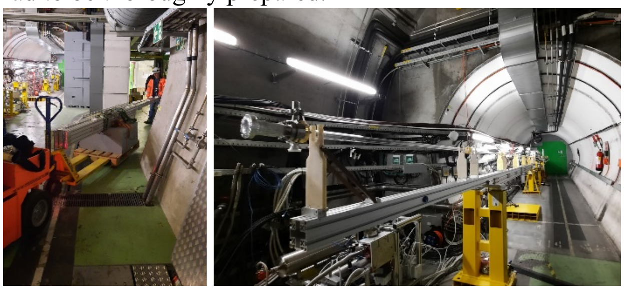

Figure 7: Left, transport of the supports. Right, DPS installed.

The carefully thought-out transport sequence is as follows: first come all sensitive elements of the DPS and its supports, then the additional shielding, and finally, after all transport vehicles have left the area, the two racks. Thanks to excellent coordination between the surface team with the transport truck and the underground handling team, the DPS was transported and installed in the tunnels within one day.

Once the DPS proton period will be over, dismantling the source and organising the transport out of the AWAKE area within a few days will be the next challenge. All elements will be activated due to proton irradiation. Hence, the DPS surface test lab needs to become a supervised radiation area, and the transport of all equipment as radioactive must be planned.

Step-Density Vapor Source Installation

One of the first challenges for this installation is cabling. When the planning was established, it appeared that the AWAKE area would be occupied by other activities from February 2023 on. In addition, the installation of Gen II must be finished before the second proton period in August 2023. Hence, it was decided to anticipate the cabling activity to October 2022.

Gen II consists of two 5-meter-long pieces with two cylindrical expansion volumes, as well as two girders and four supports, as shown in Figure 8.

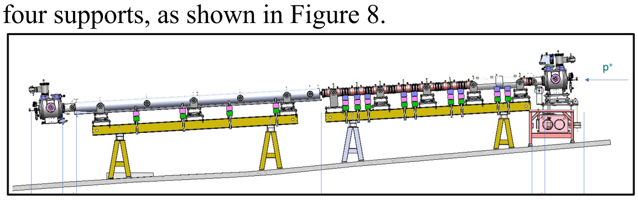

Figure 8: 3D model of Gen II. *

The three main installation phases are:

- Surface works: pre-assembly of the plasma source in a clean room in CERN, as well as pre-alignment of the two 5-meters long plasma tubes.
- Transport: this includes the 5-kilometer surface transport and the underground transport of the pre-aligned elements to AWAKE.
- Underground works: assembly of the plasma source in a narrow environment and final alignment of the tubes.

To limit time-consuming activities in the tunnel an efficient alignment procedure on the surface and the ability of the transport team to bring the plasma tubes to the tunnel without impacting the alignment done before transport are instrumental. Transport measures to ensure preserving the alignment, will include vibrations-dampening foam, slow driving, and careful underground handling.

COORDINATION OF THE FACILITY

Since 2022, the AWAKE project implements the methodology used at CERN for the coordination of major accelerators, such as LHC and SPS [6]. This methodology includes:

- Production of a master schedule timeline showing the major types of activities scheduled in the area.
- Setting-up of a Microsoft® Project schedule, and the publication via an online Gantt viewer for easier accessibility for the rest of the team.
- Production of a linear planning, showing specific areas of AWAKE where activities take place, with a planning update every time an activity is added, removed or re-scheduled.
- Bi-weekly coordination meetings to announce upcoming activities and access constraints, thus ensuring the safety of all teams working underground and minimising co-activities.
- Day-to-day coordination and on-site visits to follow up both planned and last-minute interventions.

AWAKE operation is specific: it is possible to do physics with electrons and laser, even when the rest of the CERN accelerator complex is shutdown. However, the electron and laser activities restrict access to the experimental area. Even though the DPS installation was priority during the Run 2a to Run 2b transition period, it was still possible to organise physics with electron beam thanks to an efficient communication between the experiment and technical coordination teams.

CONCLUSION

After AWAKE's Run 2a ended in November 2022, an ambitious installation and testing plan was implemented for the transition to Run 2b. This plan includes the decommissioning of the Run 1 vapor source, the installation, testing, dismantling and removal of a Discharge Plasma Source, and the installation of the next step density vapor source needed for Run 2b. While there were numerous transport and integration challenges, the decommissioning of Gen I and the installation of the DPS went well. The remaining activities are adequately prepared, with an experienced team in place, and a solid project management organisation to implement this programme.

* Courtesy of GWA Ltd

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