Two-Year Interview

31st of January 2025, CERN, CH

Nikita Zena van Gils

Short Reminder:

- External PhD, based at CERN, CH
- In the Advanced Wakefield Experiment (AWAKE) at CERN
- Started April 1st 2023

PhD Topic:

- External Electron Injection for the Advanced Wakefield Experiment (AWAKE) Run 2b

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Goal for AWAKE Run 2b (2023 – 2025):

stabilisation, i.e. maintaining large wakefield amplitudes over long plasma distances by introducing a step in the plasma density.

External electron injection of electron bunches:

allows to probe the wakefield amplitude (by measuring the energy gained by the electron bunch in plasma)

→ *this provides a direct measurement of the effect of the plasma density step on the wakefields*

Recall (mentioned during the 9-months interview 06-02-2024):

Describe your research plans for the next period. What do you anticipate to be the most important milestones? Are there any risky aspects, and do you have a 'plan B' in case complications arise?

- International Particle Accelerator Conference (IPAC2024) abstract submitted=> proceedings paper (**not** peer reviewed) regarding optics setup of the electron beam line to be written (to be submitted by May~15th)
- Preparatory tests in March 2024 to establish injection setup for experimental measuring campaigns during 2024 (April-September for ~10weeks) and clarify possible shortcomings (methods to tackle these)
- Initial further controlled injection during the April 2024 experimental measurement campaign (Run). This will require me to:
  - to establish reliable injection setups and clarify possible shortcomings (methods to tackle these) **operational**
  - study the relevant physics of beam transfer lines and wakefields **theoretical**
  - understand and define the injection scheme to evaluate wakefield amplitudes **experimental**
- All in work towards => physics results as well as technical results for upcoming papers
- Risks:
  - experimental schedule delays outside my control (further adaptations to the experimental setup are planned between two measuring campaigns=> will require adaptability to new setup)
  - electron losses during acceleration due to density step

What were your main achievements in the preceding period? To what extent have earlier plans been realized? Give a brief overview of your activities over the last 1 year. Include information on new techniques/methods learned, data collected, analyses completed and manuscripts written (if any).

- Proceedings paper for the 6th European Advanced Accelerator Concepts workshop (EAAC2023)

Was submitted for review March 15th 2024→ peer reviewed and accepted December 2024 ☑

External electron injection setup for the advanced wakefield experiment (AWAKE) run 2b

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Abstract. AWAKE is a plasma wakefield acceleration R&D experiment at CERN, where wakefields are driven by relativistic and self-modulated proton bunches. The goal of AWAKE Run 2b is to demonstrate that a correctly placed plasma density step stabilises the wakefield amplitude (after saturation of self-modulation) at a higher value than without the step. This can be demonstrated by accelerating witness particles. It is therefore planned to externally side-inject 19 MeV test electrons into the wakefields. In this manuscript, the injection setup for the AWAKE Run 2b experiments is summarised. Challenges on beam transport due to the Earth's magnetic field upstream of the vapour source entrance are highlighted and uncertainties on the injection location are estimated. Additionally, a new plasma-light-based diagnostic to verify that electrons cross the plasma column is introduced.

What were your main achievements in the preceding period? To what extent have earlier plans been realized? Give a brief overview of your activities over the last 1 year. Include information on new techniques/methods learned, data collected, analyses completed and manuscripts written (if any).

- International Particle Accelerator Conference (IPAC2024) abstract submitted=> proceedings paper (**not** peer reviewed) regarding optics setup of the electron beam line to be written (to be submitted by May~15th)

  → **Poster and paper submitted May 15th 2024 and published July 1st 2024 :** 10.18429/JACoW-IPAC2024-MOPR42

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PREPARATION FOR REALISATION OF EXTERNAL ELECTRON INJECTION FOR AWAKE RUN 2B

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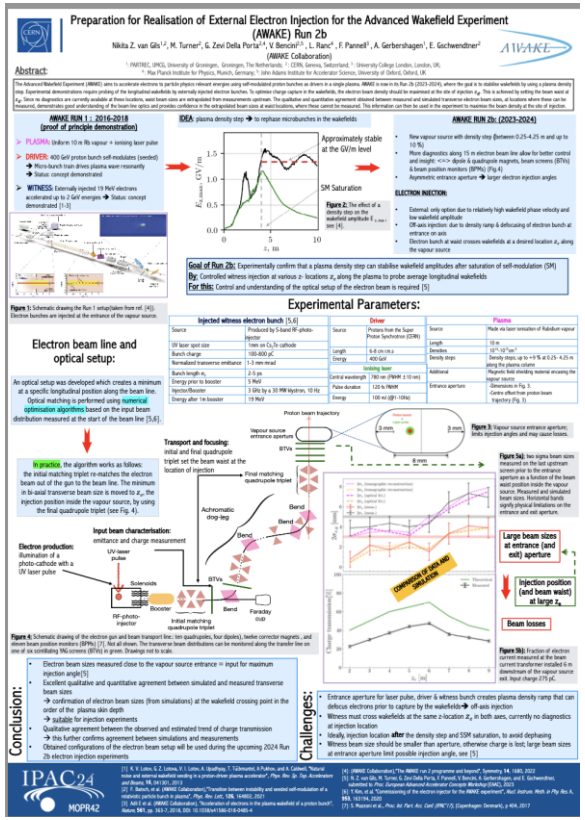
Abstract

The Advanced Wakefield Experiment (AWAKE) aims to accelerate electrons to particle physics relevant energies using self-modulated proton bunches as drivers in a single plasma. AWAKE is now in its Run 2b (2023-2024), where the goal is to stabilise wakefields by using a plasma density step. Experimental demonstrations require probing of the longitudinal wakefields by externally injected electron bunches. To optimise charge capture in the wakefields, the electron beam density should be maximised at the site of injection z_e. This is achieved by setting the beam waist at z_e. Since no diagnostics are currently available at these locations, waist beam sizes are extrapolated from measurements upstream. The qualitative and quantitative agreement obtained between measured and simulated transverse elec-

wavelength: 800 nm) of rubidium vapour [3, 4]. It is 10 m long, with a radius >∼1 mm.

Seeded proton bunch self-modulation and subsequent wakefield growth, as well as the acceleration of externally injected witness electrons was demonstrated in AWAKE Run 1 [5–7].

Numerical simulation studies show that the use of a plasma density step (during the development of self-modulation) allows for stabilisation of the field amplitudes after saturation of self-modulation [8, 9]. The purpose of the ongoing experimental campaign (Run 2b [8]) is to demonstrate the effectiveness of a density step. One method to achieve this goal consists in measuring increased energy gain of accelerated witness particles. AWAKE requires external injection as wakefields are of relatively low amplitude (∼0.5 GV/m) and high phase velocity (relativistic



What were your main achievements in the preceding period? To what extent have earlier plans been realized? Give a brief overview of your activities over the last 1 year. Include information on new techniques/methods learned, data collected, analyses completed and manuscripts written (if any).

- Preparatory test in March to establish electron beam setup for experimental measuring campaigns during 2024 (April-September for ~10weeks) and clarify possible shortcomings (and methods to tackle these)

→Experimental upgrade allowed for better diagnostics at the crossing location (of all three beams)

→Started August 2024 ~5 weeks +2 weeks of data taking at the end of the year

→Dedicated studies resulted in the submission of a peer reviewed technical paper (NIM-A) which has been <u>accepted and published</u>

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Verification of electron beam alignment and optics for external off-axis injection in AWAKE Run 2b

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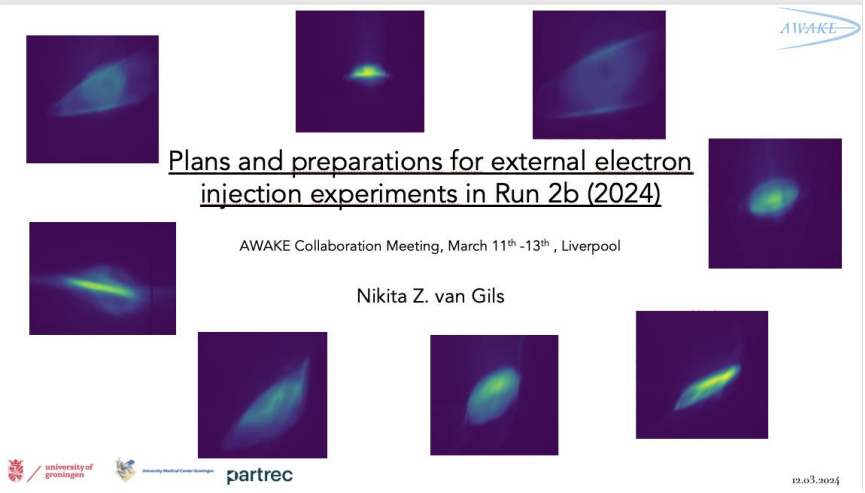
Abstract

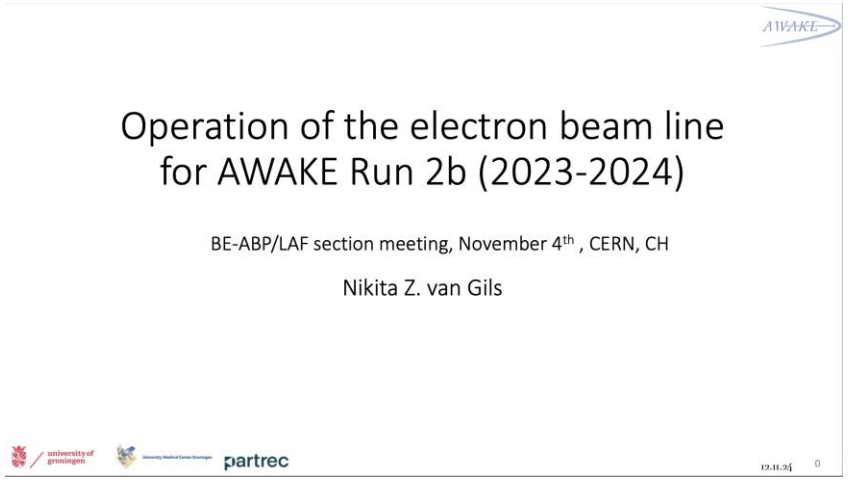
The Advanced Wakefield Experiment (AWAKE) has the long term goal to accelerate electrons to particle physics relevant energies using self-modulated proton bunches as drivers in plasma. AWAKE is currently in its Run 2b (2023-2025), where the goal is to stabilise the wakefield amplitude after the saturation of the self-modulation process by introducing a plasma density step. To optimise witness electron injection, retractable YAG screens have been installed inside the vapour source. These screens enable, for the first time, direct measurements of electron bunch sizes at the injection location and estimates of the spatial overlap with the wakefields. This manuscript presents an overview of the upgraded experimental setup and measurements of the transverse distribution of the electron bunches, crucial for improved control over the injection process. Additionally, results show agreement between simulated and measured transverse bunch sizes and positions, and the influence of various factors (e.g., plasma density, electron bunch charge, and witness bunch timing) on the electron charge overlapping with the wakefields. Furthermore, alignment challenges as well as potential solutions are discussed.

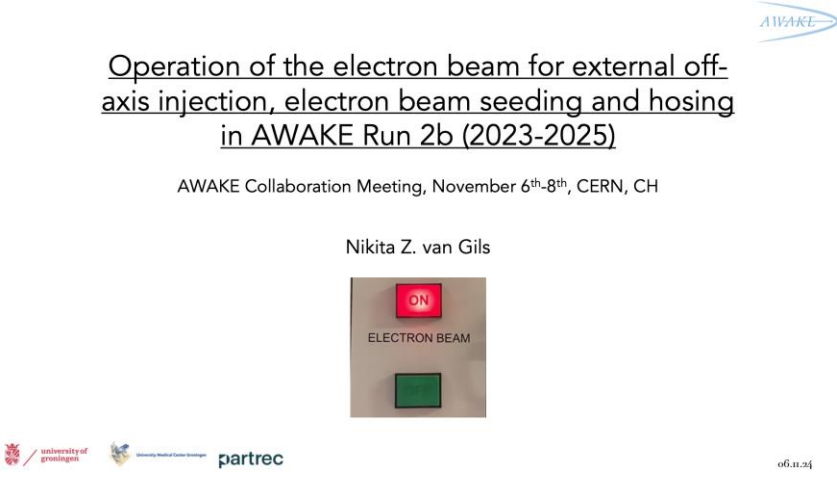
Keywords: Beam driven plasma wakefield acceleration, External electron injection, Beam optics

In addition..

- Presentation at an AWAKE Collaboration meeting in Liverpool (March) and at CERN (November)
- Presentation in the BE/ABP-LAF Section meeting at CERN (November)
- Recurring presentations at the Experimental meeting for AWAKE
- First introduction and use of MADX and XSuite beamline modelling
- Understanding analysis of further diagnostics in the AWAKE experiment → relating these to problems encountered during the experiment and initial ideas on solving these (by dedicated electron beam time studies).
- Understanding of development of diagnostics by operating the electron line during development of beam position monitor (BPM) studies for the Beam instrumentation (SY/BI) group







In addition..

- Course on Ethics in research (one zoom meeting every three weeks, for 6 months)
- Resilience course (online + a two hour session with a personal resilience coach)
- UMCG resilience course (online)
- UMCG fear of failure course (online)

→ 8.5 (+2.65) ECTs / 15 ECTs completed

Upcoming…

Describe your research plans for the next period/year. What do you anticipate to be the most important milestones? Are there any risky aspects, and do you have a 'plan B' in case complications arise?

- International Particle Accelerator Conference (IPAC2025) abstract and student grant submitted

→ proceedings paper (light-peer reviewed additional (or plan B) contribution to the planned thesis course) regarding the experimental investigation of electron beam scattering in rubidium vapour → of significance for AWAKE run 2c

→ to be submitted beginning of April 2025 (measurements to be taken February/March → tight deadline)

- Preparatory tests in February/March 2025 to establish alignment and setup for experimental measuring campaigns during 2025 (April-May for ~5weeks) and clarify possible shortcomings (methods to tackle these)
- Initial further understanding of the beam parameters needed for seeding of the self-modulation process (via optics simulations in MADX and XSuite) → closely working together with ABT (beam transfer section) to establish a working setup
- All in work towards => physics results as well as technical results for upcoming papers (e.g. a collaborative paper with initial data sets taken in 2024)
- Risks:
  - experimental schedule delays outside my control (further adaptations to the experimental setup are planned between two measuring campaigns=> will require adaptability to new setup)
  - technical problems or delays
  - dependence on timeline of other individuals

A big thank you to all who actively support my academic advancements !