# The New CERN Low-energy Facilities for Neutrino Detector Tests

**J. Bernhard∗, N. Charitonidis∗, D. Banerjee, M. Brugger, P. Chatzidaki, G.L. D' Alessandro, M. van Dijk, L. Gatignon, A. Gerbershagen, E. Montbarbon, B. Rae, M. Rosenthal, B. M. Veit**

CERN, EN-EA, Esplanade des Particules 1, 1211 Meyrin, Switzerland

E-mail: johannes.bernhard@cern.ch, nikolaos.charitonidis@cern.ch

**Abstract.** The beamlines at CERN's North and East Areas offer secondary beams in a wide range of momenta between 0.5 GeV/$c$ and 400 GeV/$c$ for fixed-target experiments as well as for test beam campaigns with a flexible configuration and variable beam composition and intensities. Recently, two new facilities for neutrino detectors tests have been established in an extension of the CERN North Area in context of the CERN Neutrino Platform project. These new tertiary beams extend the current capabilities of the H2 and H4 beamlines towards lower momenta in the range of 0.3 GeV/$c$ to 12 GeV/$c$, respectively 7 GeV/$c$, and currently serve the two ProtoDUNE prototype detectors. In addition, a complete overhaul of the CERN East Area is underway, which will provide secondary beams with momenta of up to 15 GeV/$c$ (T9 beam) and 12 GeV/$c$ (T10 beam). New beam optics and an optimised design will allow for electron, hadron and muon beams with high purity. We discuss the layout and performance of both North and East Area beamlines as well as the available infrastructure for the neutrino detector community.

## 1. Introduction to CERN Test Beam Facilities

The CERN secondary beam lines are serving both test beams and fixed-target experiments with particle beams of various momenta since the 1960s. The first experimental area constructed was the CERN East Area, extracting the 24 GeV/$c$ proton beam from the at the time newly commissioned Proton Synchrotron (PS). The produced hadrons or electrons are selected, transported and focused in the experimental areas. The East Area is currently under extensive renovation and will be able to host neutrino detectors and other users with particles in the momentum range of up to 15 GeV/$c$. The spot-size and the beam purity is flexible and controllable with the use of absorbers, collimators and magnetic elements.

In 1978, following the construction of the Super Proton Synchrotron (SPS) and the need of precision experiments at higher momenta, CERN's North Area was commissioned. The high-energy proton beam from SPS had an unprecedented energy of 450 GeV/$c$, while the machine is nowadays operated at 400 GeV/$c$. The beam is slowly extracted onto three Beryllium targets producing a wide spectrum of secondary particles. The secondary hadrons and leptons are then being directed to 6 different beam lines in total, each one offering unique characteristics and possibilities for physics experiments. The beam lines serve three different experimental areas (EHN1, EHN2 and ECN3).

∗Corresponding authors.

Journal of Physics: Conference Series **1468** (2020) 012127 doi:10.1088/1742-6596/1468/1/012127

Today, the North Area facilities host a number of permanent fixed target experiments, such as COMPASS, NA62, NA61 and NA64. In addition, many different test beams of all LHC experiments and various other users are served. In 2018, an extension of the EHN1 hall was constructed towards the hosting of the NP-02 and NP-04 detectors, prototypes for DUNE experiment, currently under construction in Fermilab and South Dakota [1].

## 2. The North Area VLE beam lines

The EHN1 H2 and H4 beam lines are two large precise magnetic spectrometers that can momentum-select and transport particles with momenta in the range of approximately 15 GeV/$c$ up to the primary SPS beam momentum of 400 GeV/$c$. However, for lower energy particles and for the interesting range of momenta below 10 GeV/$c$ for neutrino-products, the length of these beam lines becomes a limiting factor due to the unstable nature of pions and kaons. In order to satisfy the stringent beam requirements of the DUNE prototype detectors, two new, "very low energy" (VLE) beam lines were designed, optimised and commissioned in 2018, designated H2-VLE and H4-VLE [2]. The design principle of these new beam-lines is shown in Figure 1.

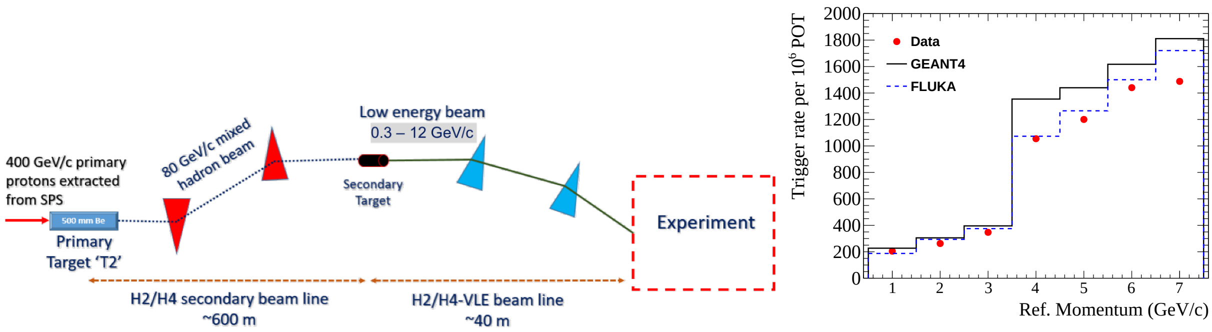


**Figure 1.** Left: Schematic principle of the new H2-VLE and H4-VLE beam lines, figure taken from [2]. Right: Trigger rates for H4-VLE(NP-04 experiment), figure taken from [3].

The mixed hadron secondary beam from the T2 primary target with a momentum of 80 GeV/$c$ is directed on a secondary target where tertiary particles are produced at a lower energy. Subsequently, the wanted particles are selected with the use of magnetic elements and collimators, and are focused on the cryostat. The tertiary beam line branches are equipped with tailor-made instrumentation, towards an event-by-event reconstruction of each particle's species and momentum. Scintillating fibre detectors are used for beam profile and intensity [3] measurements, while Time-of-Flight(ToF) and Cherenkov detectors are used for the particle identification in the low energy range. The particle trigger rates for H4-VLE is shown in Figure 1. The performance of H2-VLE is very similar.

## 3. The East Area

The East Area is one of CERN's longest running facilities for experiments, beam tests, and irradiations. It serves usually more than 20 test beam teams and experiments for about 200 days of running each year. Due to its high demand, an upgrade and renovation of the facility is currently being undertaken to reliably meet future requirements. New beam optics [4, 5] will provide better transmission and purity of the secondary beams including highly pure electron, hadron or muon beams, which was so far not possible. The upgrade features a new powering scheme with energy recovering power supplies and new magnets, which are only pulsed during the 400 ms extraction from the PS typically happening about 4-6 times in a normal supercycle of 40 s. In addition, the building and its infrastructure are also being consolidated resulting in a considerably lower energy consumption, e.g. a reduction from 11 GWh/year to around 0.6

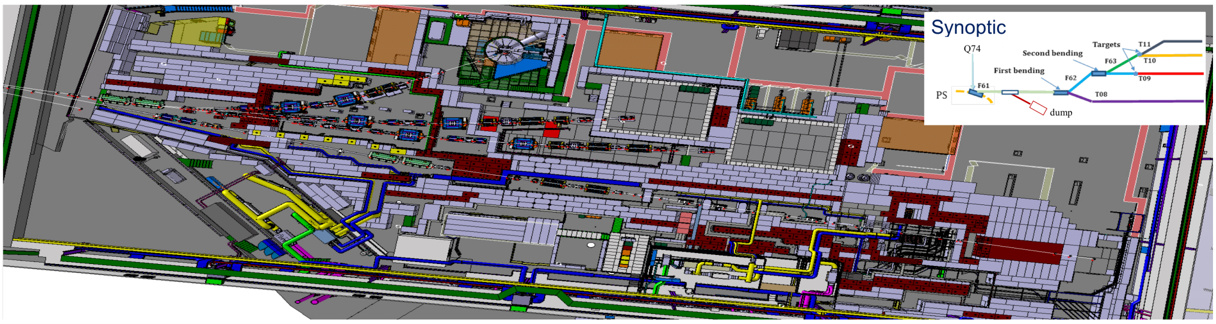


**Figure 2.** Top view of the CERN East Area after completion of the renovation project.

GWh/year only in electricity. The renovation phase is currently going on during the technical stop between 2018 and 2020.

For test beam users, the three beam lines T09, T10 and T11 and their attached experimental areas will provide secondary beams of up to 15 GeV/$c$, see Fig. 2 for a top view of the facility. The beam lines will be equipped with scintillating fibre detectors and Cherenkov threshold detectors with the same characteristics as the ones used in the North Area. Prominent examples of already tested neutrino detectors and prototypes are for instance the BabyMIND detector [6], the ARIADNE prototype [7] and P355, an optically read-out high-pressure gas TPC [8].

## 4. Conclusions

CERN offers a wide range of test beam facilities that are well fit for the requirements for testing modern neutrino detectors and concepts. Both East and North Area are providing experimental areas with infrastructure to test and operate table-top detectors up to the massive ProtoDUNE prototypes with dedicated beam lines in a momentum range well fit for state-of-the-art neutrino experiments. Dedicated beam time for 2021 and beyond can be already requested with the relevant CERN committees, while potential users are invited to discuss any possible technical aspects with the corresponding authors.

## Acknowledgments

We are thankful for the important input from technical experts at CERN, especially those involved in the successful design, installation and commissioning of the VLE beam lines in the North Areas as well as the East Area Renovation project team that is currently completing the renovation efforts.

## References

[1] Acciarri R *et al.* (DUNE) 2016 (*Preprint* `1601.05471`)
[2] Charitonidis N and Efthymiopoulos I 2017 *Phys. Rev. Accel. and Beams* **20** 111001
[3] Booth A *et al.* 2017 *Phys. Rev. Accel. and Beams* **22** 061003
[4] Bernhard J *et al.* 2018 (*International Particle Accelerator Conference* no 9) (Geneva, Switzerland: JACoW Publishing) pp 717–719 ISBN 978-3-95450-184-7 https://doi.org/10.18429/JACoW-IPAC2018-TUPAF023 URL `http://jacow.org/ipac2018/papers/tupaf023.pdf`
[5] Montbarbon E, Bernhard J *et al.* 2019 (*International Particle Accelerator Conference* no 10) (Geneva, Switzerland: JACoW Publishing) pp 3730–3733 ISBN 978-3-95450-208-0 https://doi.org/10.18429/JACoW-IPAC2019-THPGW062 URL `http://jacow.org/ipac2019/papers/thpgw062.pdf`
[6] Antonova M *et al.* 2017 Baby MIND: A magnetised spectrometer for the WAGASCI experiment Tech. Rep. NUPHYS2016-HALLSJO URL `https://cds.cern.ch/record/2261621`
[7] Hollywood D *et al.* 2019 (*Preprint* `1910.03406`)
[8] Andreopoulos C *et al.* (HPTPC Collaboration) 2017 Proposal to Measure Hadron Scattering with a Gaseous High Pressure TPC for Neutrino Oscillation Measurements Tech. Rep. CERN-SPSC-2017-030. SPSC-P-355 CERN Geneva URL `https://cds.cern.ch/record/2284748`