13th Int. Particle Acc. Conf. IPAC2022, Bangkok, Thailand JACoW Publishing
ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOTK058

CERN's EAST EXPERIMENTAL AREA: A NEW MODERN PHYSICS FACILITY

S. Evrard†, D. Banerjee, J. Bernhard, F. Carvalho, S. Danzeca, M. Lazzaroni, B. Rae, G. Romagnoli, CERN, Geneva, Switzerland

Abstract

CERN's East Area has hosted a variety of fixed-target experiments since the 1950s, using four beamlines from the Proton Synchrotron (PS). Over the past 4 years, the experimental area – CERN's second largest – has undergone a complete makeover. New instrumentation and beamline configuration have improved the precision of data collection, and new magnets and power convertors have drastically reduced the area's energy consumption. This article will summarize the major challenges encountered for the design of the renovated beamlines and for the preparation and test of the components. The infrastructure was carefully fitted resulting in a very smooth beam commissioning, the details of which will also be presented along with the restart of physics in the second half of 2021. With the return of the beams in the accelerator complex, the East Area's experiments have taken physics measurements again and the facility's central role in the modern physics landscape has been restored.

INTRODUCTION

The East Hall, which hosts all the primary areas, the secondary beamlines, the Cosmic Leaving Outdoor Droplets (CLOUD) experiment [1], IRRAD and CHARM facilities, as well as the T09 and T10 test beam areas as shown in Fig. 1, has been renovated during the Long Shutdown 2 of the LHC (2019-2021).

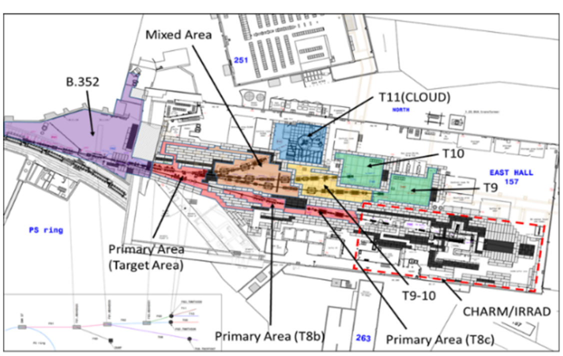

Figure 1: New facility layout.

To ensure the long-term operation of the PS East experimental area and to reduce the energy consumption of the facility by means of power converters with energy recovery option were the two main key drivers for the upgrade. Practically, this was achieved by implementing a new beamline layout, a new cycled powering scheme, and thoroughly refurbishing the associated infrastructure. To be able to change from a continuous to a pulsed power supply, the yokes of the magnets needed to be laminated. In addition, over the last years of operation, the maintainability of the magnets has been a critical issue, mainly because of long cooldown and repair times and the lack of spares for some magnet families. These two reasons drove the complete renovation of the magnets with laminated yokes and of fewer families.

† sebastien.evrard@cern.ch

INFRASTRUCTURE UPGRADE

To comply with the power consumption reduction, some services such as AC powering and the cooling network were downsized and renewed according to lower operation requirements [2]. Moreover, the shielding of the primary area was completely modified to satisfy radioprotection requirements, and to reduce the time needed to open it in case any equipment needs to be replaced. The access system was adapted to the new configuration and the size of the high activation areas was reduced to limit the exposure of workers during maintenance. The building envelope was completely refurbished to eliminate asbestos and improve greatly its thermal insulation.

Figure 2: New power converter farm.

Major refurbishment also took place in the neighbouring service buildings where the new power converters are located as shown in Fig. 2. They are now served by new systems such as demineralized water-cooling circuits and HVAC. With regards to the experimental areas (T09, T10, and T11), most of the services were upgraded and include new control rooms, gas distribution, and dedicated areas for detector/experiment set-up. Undoubtedly the upgrade turned out to be a unique opportunity to bring the facility up to the modern safety standards in terms of radioprotection by implementing dynamic air confinement in the primary area and separating the cooling circuits between activated and non-activated water. On the conventional safety

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOTK058

side, the safe operation of the new power converters, which include large energy storage capacitors, and the compliance to Atmosphere Explosible regulations for the design of the new gas distribution system prevail.

NEW BEAMLINES

The East Area is comprised of the irradiation facility IRRAD/CHARM that is served by the T08 beamline and the secondary beamlines T9-T11 as shown in Fig. 3. The renovated beamlines consist of 58 magnets of 12 different types powered by 61 power converters. Energy saving is obtained by using a pulsed magnet current, hence recovering, and storing in capacitors the magnet energy after each operation cycle. The primary lines can be operated within the 2.4 s extraction cycles of the PS. Due to limitations in the pulsed powering of large dipoles in the secondary beams, these beams can only be operated in 4.8 s cycles. However, alternating the primary beam on the targets every 2.4 s is still possible, as long as the same target destination is not programmed twice in a row.

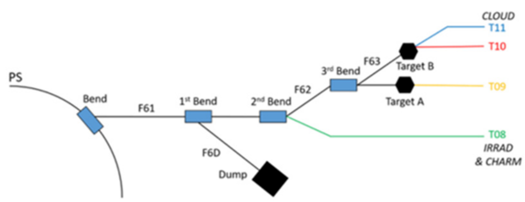

Figure 3: Synoptic of the new beamlines.

The secondary beams to the T09, T10 and T11 beamlines in the East Area are produced from the 24 GeV protons on target [3]. The T09 beam is produced from Target A and the T10/T11 beam is produced from Target B, both of which are arranged in a multitarget configuration as shown in Fig. 4 with five target heads. This ensures easy switching between the different targets for the required secondary beam (hadron enriched or electron enriched). The T09 and T10 beams are produced at a vertical production angle of 30 mrad and 35 mrad, respectively, which also prevents the primary protons from reaching the experimental areas. The T11 line accepts secondary particles at the same vertical production angle as T10, however with an additional horizontal production angle of 120 mrad.

Figure 4: Multitarget configuration for the Target A (T09) and Target B (T10).

In addition to new magnets and target heads, new beam stoppers and collimators have been installed in the beamlines. The beam instrumentation has also been updated with the scintillating fibre detectors used as beam profile monitors and new high pressure threshold Cherenkov detectors (XCET). The new XCETs can be filled up to 15 bars with the option of using refrigerant gases like R134A and R218 in addition to the standard CO2, N2 and He which improve the particle identification at these lower energies in the East Area.

COMMISSIONING

Hardware Commissioning

The commissioning of equipment/infrastructure can be split into 3 different phases: installation, the Individual System Tests (ISTs) and Hardware Commissioning (HWC). The main difference between ISTs and HWC is that in ISTs, the equipment is tested independently, whereas for the HWC, various components are tested as a whole (system). Both stages benefited from a careful and pondered approach to meet the expected deadlines.

The biggest constraint for commissioning was time. By the time the project entered the commissioning phase, the PS ring was closing for operation. Therefore, the project prioritized building 352 and performed a full commissioning cycle, and later did the same for the experimental hall (B.157), making it possible to align the project with the master schedule of the Organization. During this period, weekly meetings took place to plan the tasks ahead and to mitigate any possible blocking points. Not only that, a series of documents describing the tests, the risks and preventive measures were also prepared.

Beam Commissioning

The renovated East Area restarted its operation with beam in September 2021. After ISTs and HWC, controls for all devices and readout of the beam instrumentation were checked and the beam setting files were added to the beam control software, CESAR. A dedicated plan for ramping up the intensities and number of cycles per super cycle was also proposed by Radiation Protection that was followed during the commissioning. The first beams were observed right after switching on the power converters and magnets with the set-up beam files. The beams were checked first at the highest momenta of 15 GeV/c for T09 and initially 10.5 GeV/c for T10, which was increased to 12 GeV/c in 2022. Figure 5 shows the beam profile at T09 at the focal point for a 15 GeV/c beam with an observed rate ~ 10^6/spill.

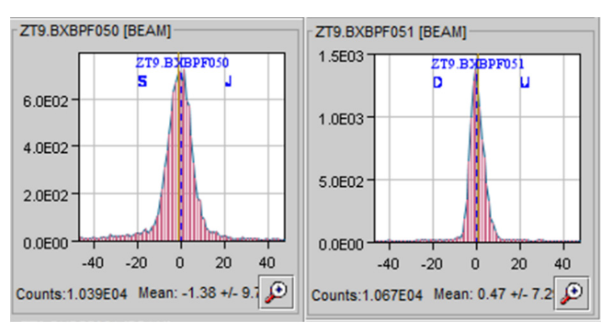

Figure 5: T09 beam profiles on the scintillating fibre detectors in the horizontal (left) and vertical (right) planes.

ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-THPOTK058

The T11 beam was commissioned successfully in 2021, up to the entrance of the CLOUD experimental area, as works on the experiment were still ongoing. After CLOUD became ready in the beginning of 2022, the large-sized, 3.5 GeV/c hadron beam was checked and set-up within a matter of hours to the satisfaction of the experiment.

In the T09 and T10 beamlines, different beam modes are available: 1) mixed hadron beam – a secondary beam derived from the primary protons impinging and interacting on the production target, which is then momentum selected with the help of 2 large dipoles and a collimator. There is the possibility to absorb the electrons in a movable absorber to increase the hadron purity; 2) pure electron/positron beam – the e^+ or e^- beam is selected from the conversion of the gammas that were produced in the target or from decays of neutral pions in a movable converter (few mm Pb), after deflecting all charged particles with two sweeper magnets. This mode is exclusive to T09; 3) pure muon beam – muons are selected from the pion decays absorbing the pions in closed collimators and/or the stopper dumps, either giving a wide-momentum band muon beam or a momentum-selected muon beam, depending on the location of the chosen absorber. After the initial tuning of the secondary beam, all beam modes were checked, and the performance of the beams were as expected. The radiation levels were also validated by RP for the nominal intensities.

The East Area commissioning went fairly smoothly thanks to the excellent work and support of all teams involved, with just minor challenges to be faced. The secondary beamlines have been operational with the users taking physics data since October 18th, 2021, as scheduled. The beam performance is mostly as expected, however it was possible to outperform design parameters in some cases, for instance being able to provide 16 GeV/c beams in the T09 zone despite aiming for 15 GeV/c maximum momentum. All spot sizes, focal points, and the performance of the beam particle identification are as expected.

CHALLENGES

Ground Loading Plan

The East facility is the only surface experimental area at CERN receiving the full primary proton beam; in this case 5.10^{11} protons/spill with a beam momentum of 24 GeV/c, requiring the construction of a large radiation shield made of concrete/cast-iron blocks and beams as shown in Fig. 6.

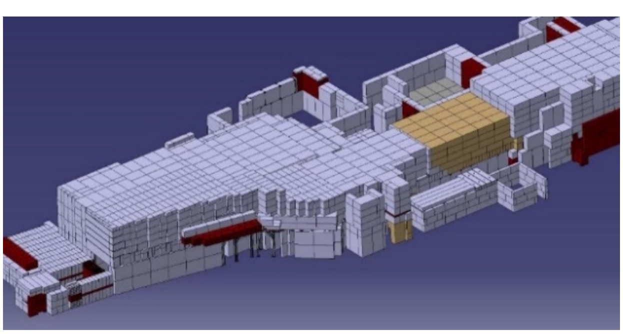

Figure 6: 3D model of the new radiation shield (10.000 t).

The new loading scheme far exceeded the floor working loads limited to 30 t/m^2. Where standard safety approaches are impossible, a bespoke safety approach must be followed with a view to ensuring an equivalent level of safety. A back analysis [4] of the new layout confirmed some residual risks of material damage to the structure of the building but no risk to personnel. In addition, a monitoring campaign (survey measurements) and visual inspection of the structure were conducted during the construction stage, allowing defects to be detected early and mitigation measures to be defined. As an outcome, the deformations under load were found to be less important (max. 2.5 mm) than predicted by the simulations (max. 9 mm as shown in Fig. 7): no significant differential sagging was identified.

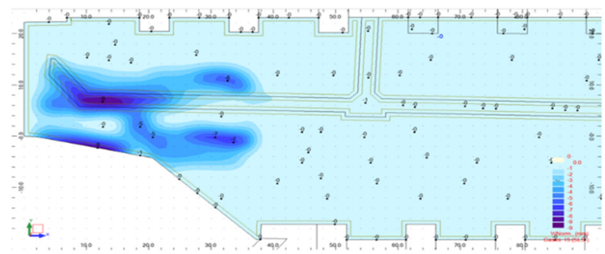

Figure 7: Simulation of the slab deformations (mm).

COVID Pandemic Consequences

Since CERN experienced a 3-month full lockdown (March-June 2020) due to the COVID pandemic, almost all contractors and CERN staff were not allowed to work on-site. Moreover, work methods had been adapted to mitigate risk or to cope with unavailability of personnel due to preventive quarantines. Some suppliers outside CERN were also affected, resulting in a late delivery of equipment or the repatriation of critical activities to CERN. All in all, the project suffered from a delay of 3 months.

CONCLUSION

With the return of the beams in the CERN accelerator complex in 2021, the East Area's experiments have taken physics measurements again and the facility's central role in the modern physics landscape has been restored.

ACKNOWLEDGEMENTS

The authors would like to thank all involved CERN equipment/service groups for the help & support provided.

REFERENCES

[1] J. Kirby *et al.*, CERN Proposal SPSC/P317; the CLOUD Experiment, CERN-SPSC-2004-023; SPSC-M-721.

[2] J. Bernhard *et al.*, "CERN Proton Synchrotron East Area Facility: Upgrades and renovation during Long Shutdown 2", CERN Yellow Reports: Monographs, CERN-2021-004, Geneva, 2021, vii, doi:10.23731/CYRM-2021-004

[3] E. Montbarbon *et al.*, "The CERN East Area Renovation", *Nucl. Instrum. Methods Phys. Res., Sect. B*, vol. 461, pp. 98-101, 2019. doi:10.1016/j.nimb.2019.08.028

[4] R. Fernandez, B.157 load analysis, CERN EDMS # 2349640, 10.05.2020. https://edms.cern.ch/