

THE BEAMLINES OF THE CERN EAST AREA RENOVATION PROJECT

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Abstract

The East Area at the Proton Synchrotron is one of CERN's longest running facilities for experiments, beam tests, and irradiations with a successful history of over 55 years. The facility serves more than 20 user teams for about 200 days of running each year and offers mixed secondary hadron, electron and muon beams of 0.5 GeV/c to 10 GeV/c. In addition, the primary proton beam or ion beam is transported to the irradiation facilities CHARM and IRRAD. Due to the steadily high user demand, the CERN management approved an upgrade and renovation of the facility to meet future beam test and physics requirements. New beam optics will assure a better transmission and purity of the secondary beams, now also with the possibility of pure electron, hadron or muon beams. The upgrade includes a pulsed powering scheme with energy recovering power supplies and new laminated magnets, reducing both power and cooling requirements. Together with the building consolidation, this results in considerably lower energy consumption. The renovation phase is scheduled mostly during the technical stops between 2019 and 2020. We will give an overview of the project scope including upgrades and future beams.

CURRENT FACILITY

The East Area at CERN is an intensely used experimental area at the Proton Synchrotron that serves various users and facilities with primary proton and ion beams as well as secondary mixed beams that are derived from a production target. The primary beam is delivered by a third-order resonance extraction from the PS and transported via the F61 transfer line towards the experimental hall. The primary proton beam has a momentum of 24 GeV/c and is usually extracted within 2.4 s cycles during a 400 ms long flat top with a nearly constant instantaneous rate. The number of East Area extractions is usually around 5 extractions per overall PS super-cycle of typically 40 s and depends on other users and schedule constraints. The beam can be switched via a dedicated splitter magnet (no longer used as splitter) to either serve a production target for secondary beams ("North Branch") or the irradiation facilities IRRAD and CHARM ("South Branch"). During operation of primary ion beams, only the irradiation facilities can be operated. Following the production target, three beam lines offer secondary beams for detector tests and calibrations (T9, T10) and for the CLOUD experiment (T11). Presently, T9 can be operated with momenta up to 10 GeV/c, T10 up to 6 GeV/c, and T11 at 3.5 GeV/c.

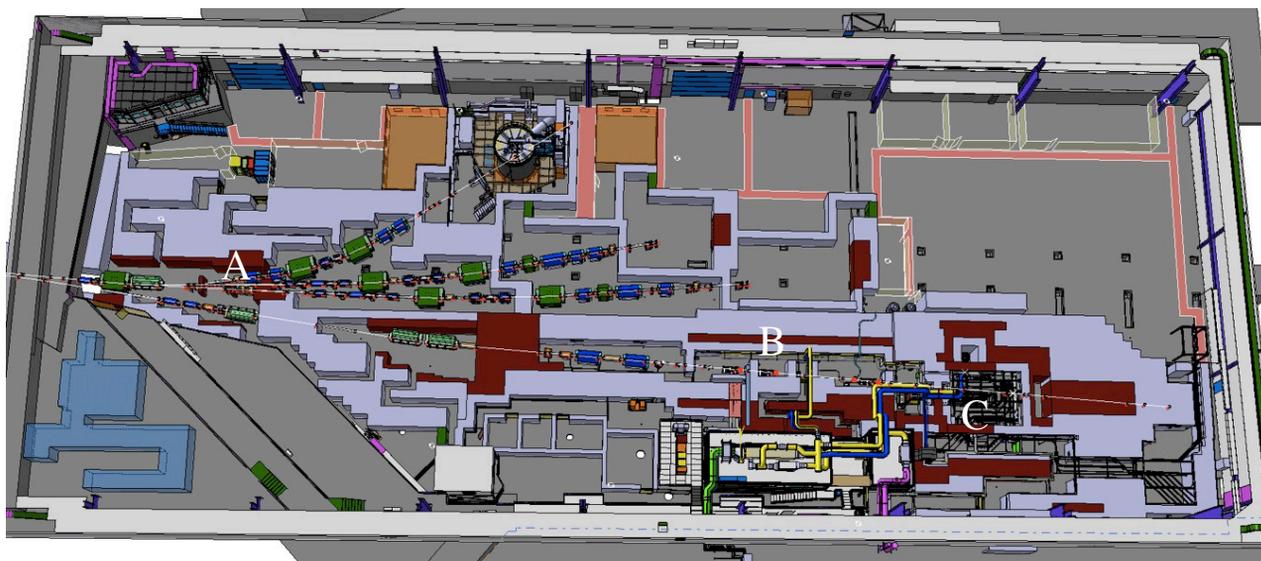


Figure 1: East Area Layout after the renovation. The primary beam is extracted from the PS and arrives from the left side. It can be directed either towards the two production targets (A) in order to create secondary beams or towards the two irradiation facilities IRRAD (B) and CHARM (C).

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PROJECT SCOPE

The users of the experimental area require high availability and reliability of the beams, which has been increasingly endangered due to the age and reduced reliability of the installed components. Recent failures include in most cases power supplies and magnets, for which the repair often requires time-consuming removals of the ~6 m thick roof shielding. In addition, the low operational duty cycle in combination with DC powered magnets results in very large energy consumption. A detailed study [1] was carried out that identified several objectives for a renovation of the East Area with its beam lines and infrastructures. A redesign of the beam lines will streamline the various magnet families used and improve the radiation situation and maintainability in general. The performance of the new beam lines will be improved in terms of maximum momentum and in free choice of particle type. Thanks to the cycled powering mode of the new magnets in combination with energy-recovering power supplies, considerable energy savings will be possible, *i.e.* a reduction from 11 GWh/a now to about 0.6 GWh/a in the future. In addition, the building infrastructure will be modernised to comply with latest safety requirements. Figure 1 depicts the new layout of the East Area after the renovation.

BEAM LINE UPGRADES

The principle of extraction by third-order resonance and the corresponding optical elements, such as the magnetic septum inside the PS will be kept for the new East Area operation. The renovation works will be concentrated on the primary beam transfer line to the secondary targets (F61), the primary line towards the irradiation facilities (T8), and the secondary beam lines.

Primary Beam Transfer Line

The renovation includes primarily replacement of solid-yoke magnets by laminated ones with additional correctors allowing a better steering towards the irradiation areas and the production targets. In addition, a C-shaped switching dipole will replace the increasingly unreliable and obsolete splitter for better reliability. The splitting option, more efficient for operation, was in fact no more used since 2005 for technical reasons hard to overcome in a reliable manner. A new primary dump (F6D) was included for setting-up the extraction. Additional C-shape dipoles will furthermore switch between the two new production targets for secondary beams. Moreover, the beam instrumentation will be completely upgraded and dedicated ventilation for the primary zone will be installed.

Primary Beams for Irradiation Facilities

The primary beam line for the irradiation facilities (T8) will mostly undergo infrastructure renovations as the irradiation facilities were newly installed and operated since LS1. While the optics and modes of operation will be basically kept, the solid-yoke magnets will be replaced

by laminated versions to allow for a pulsed operation. The number of magnet families will be furthermore reduced (*e.g.* only one type of corrector magnets) and the beam instrumentation will be upgraded.

Secondary Beams

The new secondary beam lines have been designed to better cope with present physics requirements, such as higher top momenta and better selectivity of particle types. Furthermore, lower dose rates to personnel and faster repair times by improving equipment accessibility are a priority. Unlike the old design, two primary targets will be used to produce secondary particles for T9 (Target A) and T10/T11 (Target B). Both targets will be again of the type “multi-target” due to the reliable operation of the last years. Each multi-target contains five different target heads (see Tab.1) that can be chosen depending on the requirements for the secondary beams (*e.g.* electron-enriched beams, hadron beams) by steering the primary beam on the selected target head. The two secondary beam lines T9 and T10 will follow mostly identical design considerations to ensure flexibility for choice of particle types of intensities up to 10^6 particles per extraction. The beams will have a vertical production angle of 30 mrad in order to safely dump the non-interacting primary protons and to make it inherently impossible to extract the primary beam towards the secondary zones. For T9 only, a fixed collimator (“TCX”) with a cylindrical aperture of 80 mm diameter will pre-define the beam and two sweeping magnets will provide the possibility of a photon beam that will be converted on demand into a tertiary electron or positron beam with the help of a lead foil. This is not possible for T10, because the target is shared with the T11 line. The front-end consists of a triplet of quadrupoles and a horizontally deflecting dipole magnet, which focus and deflect the useful beam onto a 4-jaw horizontal/vertical collimator that serves as a momentum slit. Just behind this collimator, a set of movable lead plates can be used if required to absorb electron contamination in the beam for high purity hadron beams.

Table 1: “Multi-target” Configurations.

	Material	Length	Diameter	Comment
1	Be	200 mm	10 mm plus	Electron enriched
	W	3 mm	Al. casing	
2	Al	100 mm	10 mm	Electron enriched
	Be	3 mm		
3	Al	200 mm	10 mm	Hadron
4	Air			Empty
5	Al	20 mm	10 mm	Hadron

In between the second and third quadrupoles, another 4-jaw horizontal/vertical collimator defines the vertical and horizontal acceptance. Furthermore, a new beam stopper/dump can be electronically inserted to allow access to the experimental zone, but also to create low intensity muon beams. With the help of a doublet of quadrupoles and a second horizontal dipole, the dispersion is

recombined and the beam is deflected towards the user zone. Another triplet is then used to flexibly focus the beam. A vertical dipole compensates the vertical production angle, *i.e.* deflects the beam parallel to the floor. This magnet can also be used for vertical steering. A horizontal corrector allows then steering the beam horizontally on the experimental set-up. The intrinsic momentum resolution is about 0.7%, the momentum band $\pm 15\%$, and the acceptance about 4 mrad (hor.) x 2.8 mrad (vert.) for T9 and 5 mrad (hor.) x 3 mrad (vert.) for T10. The beam instrumentation includes scintillating counters as intensity monitors and small MWPCs as profile monitors with an option to move to XBPF scintillating fibre profile monitors in the future. In each beam line, two threshold Cherenkov counters provide particle identification.

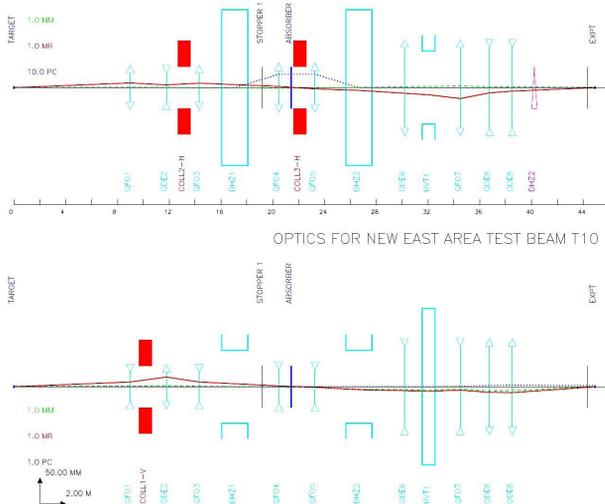


Figure 2: Optics for the T10 beam line. The red line corresponds to the sine-like ray, the green line represents the magnification term and the dotted-blue line is the dispersive term. Calculations with TRANSPORT [2].

Figure 2 shows the optics for T10 as an example. The T11 beam for the CLOUD experiment is a reduced version of the T10 design due to space restrictions. The main difference is the last doublet of quadrupoles, which are used to over-focus the beam in order to provide the very large beam size of 1.3 m x 1.3 m that is required by CLOUD [3].

MAGNETS AND POWER SUPPLIES

The new powering scheme is based on pulsed operation of laminated magnets and energy-recovering power supplies with the aim to reduce both RMS power and total energy consumption at the same time. The number of magnet families used was reduced significantly, which allows for more flexibility for spare magnets and easier maintenance. The new SIRIUS power supplies are modular and feature energy recovery by capacitor banks after each cycle as depicted for e.g. a SIRIUS 4P converter in Fig. 3.

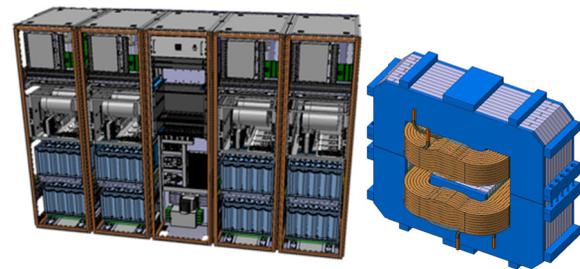


Figure 3: left: Layout of new SIRIUS 4P power converter with centrally located energy recovery module (Courtesy: TE-EPC). Right: New laminated CR200 corrector magnet (Courtesy: TE-MSA).

INFRASTRUCTURE RENOVATION

The civil engineering works will focus on asbestos removal and renovation of the building façade with considerably better thermal insulation properties. During the renovation, the outside façade of the building will be replaced by better insulating sandwich-panels. This will be the main factor for the expected reduction of heating costs and other infrastructure-related energy consumptions of currently 3.5 GWh/a to only 1.2 GWh/a after the upgrade. Further infrastructure works will be performed on the electrical network including extensive re-cabling campaigns, on the gas distribution to the experiments, and on cooling and ventilation of both equipment and the experimental area itself, respectively. Safety-related improvements such as better radiation protection and improved access control are a priority of the project.

CONCLUSION AND OUTLOOK

The study phase for the East Area Renovation has been successfully completed. By commencing the renovation of the building façade, the implementation phase was recently started and will continue through LS2 up to 2021, when the commissioning phase will be reached and first beams are scheduled. Future users will profit from better selectivity of secondary beams with an energy range that overlaps now with the CERN North Area beams.

ACKNOWLEDGEMENTS

The authors acknowledge the continuing help and support of all involved groups at CERN and the involved companies.

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