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THE NEW CERN EAST AREA PRIMARY AND SECONDARY BEAMS

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Abstract

The East Area at the Proton Synchrotron is one of the intensely used facilities at CERN, serving for over 56 years beams nowadays to more than 20 user teams and experiments for about 200 days of running each year. Besides primary proton and ion beams for the irradiation facilities IRRAD and CHARM, mixed secondary beams of hadrons, electrons and muons within a range of 0.5 GeV/c to 12 GeV/c are provided. The CERN Management approved an upgrade and a renovation of the full facility to meet reliably future beam test and physics requirements. We present a new, flexible beam design that will assure better purity of the secondary beams, even with the new possibility of highly pure electron, hadron or muon beams. The upgrade also includes a pulsed powering scheme with energy recovering power supplies and new laminated magnets that will reduce both power and cooling requirements. The renovation phase has started already and first beams in the new facility will be delivered from 2021 on.

INTRODUCTION

Current Facility

The East Area is among the oldest CERN's facilities, in which beam tests, experiments and irradiations are hosted since the 60's. The primary beam is extracted from the Proton Synchrotron by a third-order resonance method. Usually around five extractions per overall PS super-cycle of typically 40 s take place; however, it depends both on users other than PS ones and on schedule constraints, respectively. The primary proton beam, whose momentum is 24 GeV/c, is commonly extracted within 2.4 s cycles during a 400 ms long flat top with a nearly constant rate. Particle beams are then transported by the F61 beam line towards the experimental hall. In order to serve either the North branch, leading to a production target feeding the secondary beams, or the irradiation facilities (namely CHARM and IRRAD), a dedicated magnet can switch the beam. If the whole CERN accelerators complex operates with ion beams, only these two irradiations facilities can be served. Finally, the North branch offers two secondary beam lines for R&D detector tests and calibrations (T9 and T10), and one secondary beam line dedicated to the CLOUD experiment (T11). Their momentum can reach 10 GeV/c, 6 GeV/c and 3.5 GeV/c respectively.

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Project Scope

During the last years, operation in the East Area has been slowed down because of technical issues, mainly related to failures and damages of magnets and power supplies. Replacing a magnet in the primary zone requires certain accessibility conditions, *e.g.* the opening of the primary area roof over a length of 6 m. Furthermore, magnets belong to more than 20 different types, *i.e.* having spares available in case of a breakdown would generate additional costs. In addition, the DC supplied magnets imply a high energy consumption in spite of a very low operational duty cycle.

The CERN Management has approved the East Area Renovation Project, for which the reshaping of the whole area is engaged, including beam optics and infrastructure. The redesign of the beam lines will reduce the various magnet families drastically and improve the radiation situation, especially in the primary zone. It will therefore contribute to better maintainability of this experimental area. Furthermore, a new, pulsed powering scheme with laminated magnets and energy recovering power supplies will considerably contribute to energy savings. Finally, the building will be modernised to fulfil the latest safety requirements. This whole study is documented in [1].

NEW BEAM LINE LAYOUT

The East Area renovation starts directly after the extraction from CERN's Proton Synchrotron. The main characteristics of the extraction remain the same as well as the optical elements. Renovation is focused on all beam lines, *i.e.* the transfer line to the secondary targets (now called F61, F62 and F63), the primary beam towards the irradiation facilities (T08), and finally the secondary beam lines (T09, T10 and T11). Optics have been calculated with the help of TRANSPORT [2].

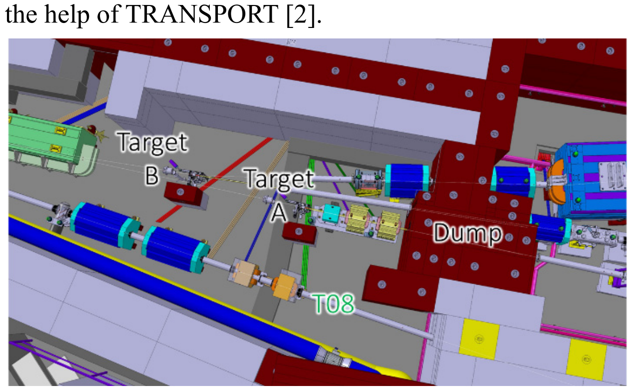

Figure 1: 3D layout of production targets and dump.

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Primary Beam Transfer Lines

First, a primary dump beam line (F6D) is included in the future East Area layout: it will exclusively be used to set up the PS extraction. The transfer line layout has undergone minor changes. In fact, laminated magnets will replace solid yoke ones. In addition, two corrector magnets will be added in the F62 line, allowing steering of the beam in both horizontal and vertical planes. C-shaped switching dipoles will replace the obsolete splitter and lead the beam on one or the other production target. Indeed, two North primary targets will be installed to produce three secondary beam lines named T09, T10 and T11. As shown in Figure 1, a dump placed after both targets is designed to cleanly discard primary protons, thus reducing high level radiation doses in the primary area. The beam spot size at both targets has been evaluated using TURTLE simulations [3]. The currents of the two last quadrupoles of the F62 beam line will be tuned such that the beam spot size fits within the target diameter (specified in Table 1). This optics of F61 and F62 transfer lines is depicted in Figure 2. Finally, instrumentation along all these primary lines will be upgraded and a dedicated ventilation will be installed for the primary area.

Table 1: Specification of the Multi-target Heads

Head n°	Material	Length (mm)	Diameter (mm)	Comment
1	Be	200	10 + Al	Electron
	W	3	casing	enriched
2	Al	100	10	Electron
	Be	3		enriched
3	Al	200	10	Hadron
4	Air	200	10	Empty
5	Al	20	10	Hadron

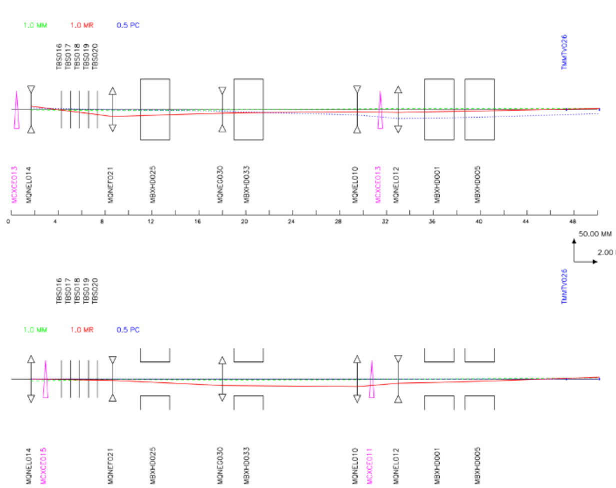

Figure 2: Optics layout of F61 and F62 beam transfer lines. The beam is focused in both planes at the A target (leading to T09 secondary beam line).

Primary Beam For The Irradiation Facilities

Like for the beam transfer lines, optics and modes of operation will be kept in the future East Area. Laminated magnets will be used instead of solid-yoke ones. In the IRRAD area, it will be possible to focus the beam in both planes on any of the three irradiation tables. Beam instrumentation will also be upgraded.

Secondary Beam Lines

The secondary beam lines (T09, T10 and T11) have been re-designed to cope better with present physics requirements. In fact, the top momenta of both test beams T09 and T10 will increase from 10 to 15 GeV/c and from 6 to 12 GeV/c respectively. This will provide a useful energy overlap to CERN's North Area beam lines. Two North production targets instead of one will enable an enhanced flexibility for users. These targets will be again of the type "multi-target" because of the reliable operation over the last years. Each multi-target contains five different target heads (*cf.* Table 1) that can be selected depending on the requirements on the secondary beams moving the chosen target head in the beam. In this way, secondary beams can be made of electrons or hadrons. The T09 and T10 beams will have a vertical production angle of 30 and 35 mrad, respectively, in order to dump safely the non-interacting protons of the primary beam. In this way, it will be impossible to extract primary protons to the secondary zones. The maximum particle rate per extraction in both test beams is foreseen to be 1-2.10^6. In T09, a fixed collimator will pre-define the beam and two sweeping magnets will provide the ability to have a neutral beam. A 5 mm lead foil located just after the dump will convert the photons into electrons and positrons. T10 will not have this possibility to produce such tertiary electron or positron beams because of space constraints related to T11. Despite this difference, T09 and T10 both display a similar optics layout. The front-end consists of three quadrupoles and a 4-jaw collimator that allows selecting the beam acceptance in both horizontal and vertical planes. Then, a beam stopper (TBS017) can be remotely inserted onto the beam line to allow access to the experimental zone, but also to produce a low intensity muon beam. A second 4-jaw collimator is used to select the beam momentum thanks to a beam deflection in the horizontal plane ensured by a M200 dipole. Dispersion is then recombined by another dipole associated with a quadrupole. Finally, a last triplet of quadrupoles focusses the beam and a vertical dipole compensates the vertical production angle and makes the beam parallel to the floor. At last, a horizontal corrector magnet can steer the beam on the experimental set-up. Figure 3 displays the optics layout of T09. Its intrinsic momentum resolution is about 0.7 %, the momentum band ±15 %. For T09, the acceptance is about 4 mrad in the horizontal plane and 3.8 mrad in the vertical one. For T10, it is about 5 mrad (horizontal) and 3 mrad (vertical). Finally, both test beams are planned to have the same beam height, such that users can easily move their detectors from one beam to the other.

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The T11 beam line optics is equivalent to the one of T10 but with reduced lengths due to space restrictions. The last two quadrupoles of T11 are set to over-focus the beam in order to irradiate fully the CLOUD chamber [4]. Therefore, the beam spot size at CLOUD is 1.3 x 1.3 m^2.

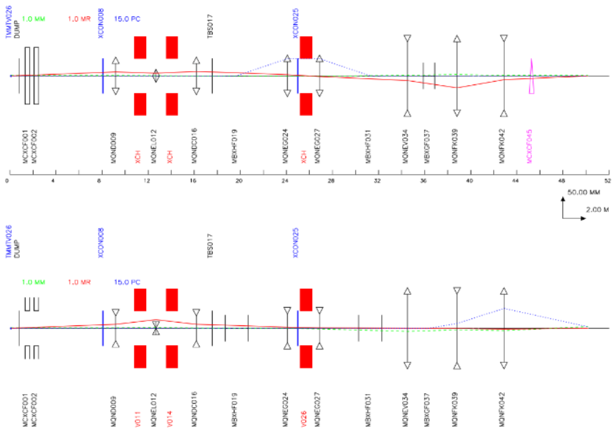

Figure 3: Optics layout of T09 beam line. The red line corresponds to the sine-like ray, the green like represents the magnification and the dotted-blue line is the dispersive term.

MAGNETS AND POWER SUPPLIES

The new powering scheme is based on pulsed operation of laminated magnets and energy-recovering power supplies. The number of magnet types is drastically decreased in order to get more flexibility for spare magnets as well as for easier and faster maintenance. The alignment supports of the magnets will also be improved [5]. The new SIRIUS power supplies are modular and allow for energy recovery by capacitor banks after each cycle. The annual power consumption will then be reduced from 7 to 1.1 GWh.

INFRASTRUCTURE RENOVATION

Infrastructure renovation concentrates on thermal insulation and on safety aspects that are considered as a priority in this project. The asbestos removal and the renovation of the building façade will allow decreasing the annual power consumption from 3 to 1 GWh [6]. Furthermore, works will be performed on the electrical network, the gas distribution to the experiments, and the cooling and ventilation of equipment and experimental zones.

CONCLUSION AND OUTLOOK

This paper presents the full redesign of the CERN's East Area, which is depicted in Figure 4. This implies a new flexible beam optics, a significant reduction of power consumption and safety improvements.

The renovation already started since the end of 2018 by civil engineering works. It will continue through the Long Shutdown 2 and will finish in 2021, when the first beams will be sent to users after a beam commissioning phase.

ACKNOWLEDGEMENTS

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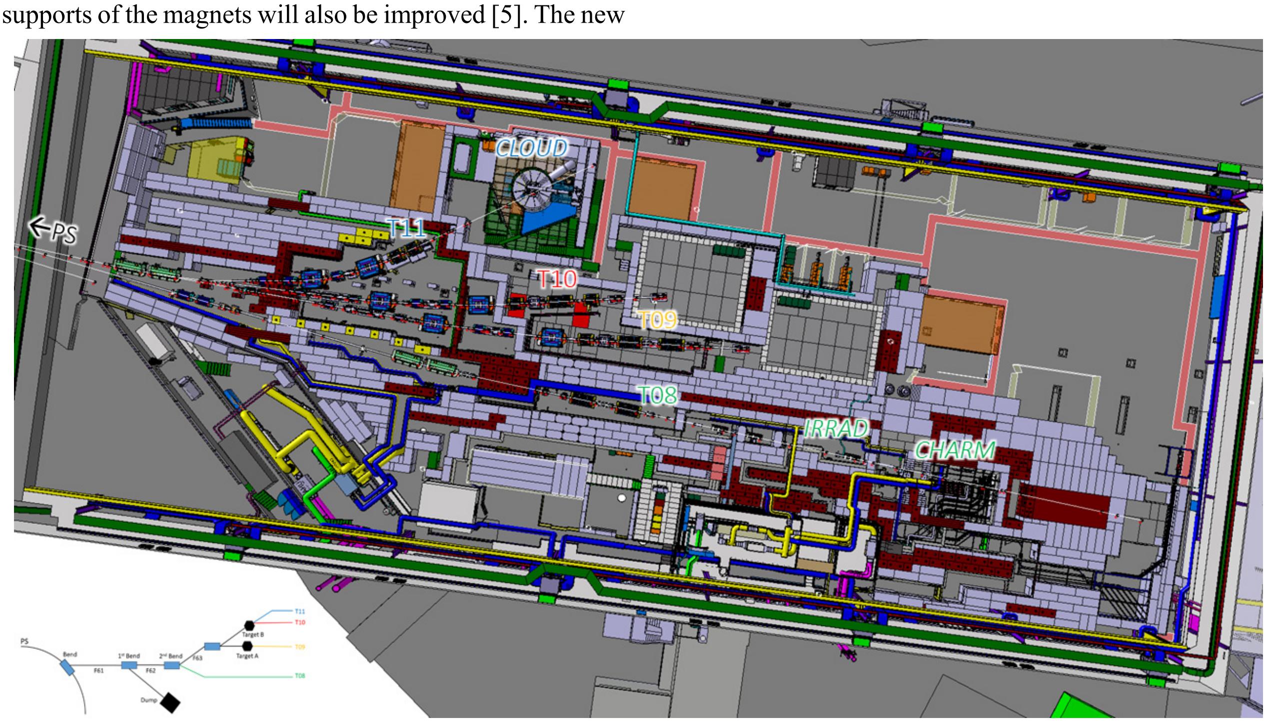

Figure 4: 3D layout of the future East Area, associated with a synoptic of the beam lines. The primary proton beam is extracted from the CERN PS (coming from the left side). It is then transferred thanks to the transfer beam lines either towards the two irradiation facilities IRRAD and CHARM (via the T08 beam line) or towards the production targets that are followed by the T09, T10 and T11 beam lines.

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