Chapter 2 East Area renovation: Motivations and general description

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2.1 General description of the East Area before and after Long Shutdown 2 (LS2)

The East Area is one of the oldest experimental areas at CERN: the first implementation dates from the early 1960s. The experimental area itself is located in Building 157 on the Meyrin site and surrounded by a number of associated service buildings (Fig. 2-1), including Buildings 251 and 263, which house the power converters.

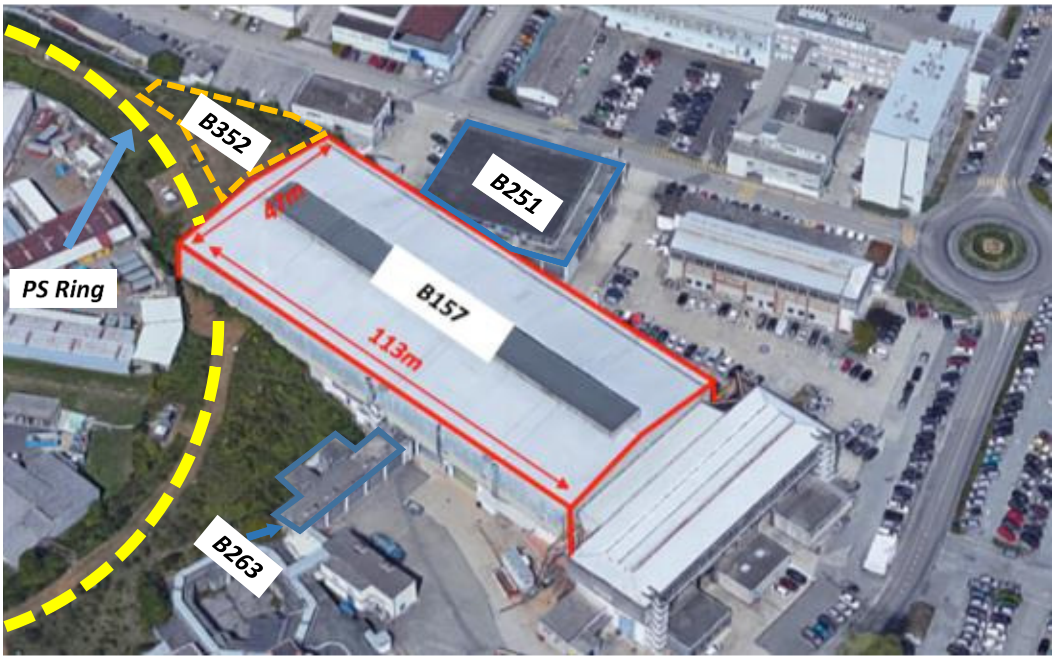

Fig. 2-1: Aerial view of the East Area buildings.

Already before renovation (Fig. 2-2), the proton synchrotron (PS) extraction (F61) located in Building 352 provided 24 GeV/c protons to the East Area. It provided slowly extracted primary proton beams to the so-called T8 proton IRRADiation facility (IRRAD [1]) and CERN High energy AcceleRator Mixed field facility (CHARM [2]). The last part of T08 together with IRRAD and CHARM was renovated during LS1. The second branch, F61N, allowed protons to be sent onto the so-called North target, from which three simultaneously running secondary beams were derived: T09, T10, and T11. The T09 and T10 beamlines were used as general-purpose test beams, which, due to their design and also due to technical restrictions, were limited to 10 and 6 GeV/c respectively. The T11 line had a maximum beam momentum of 3.6 GeV/c and was most of the time used by the Cosmic Leaving Outdoor Droplets (CLOUD [3]) experiment. A synoptic of all these beamlines is shown in Fig. 2-3 with indication of maximal momentum. The two primary proton branches were operated in alternation, and each had its own dedicated 2.4 seconds PS cycles. The beam intensities were of the order of 3–4 × 10^{11} protons per PS cycle for the primary beams and up to 10^6 particles per cycle for the secondary test beams.

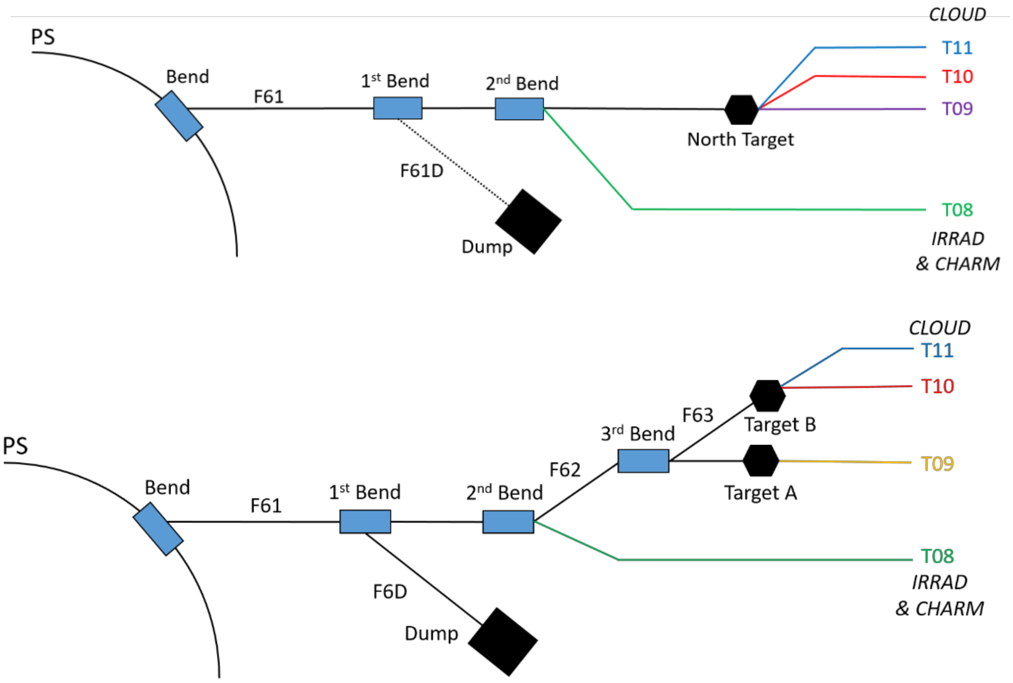

Fig. 2-2: Schematic view of the layout in the East Area before (top) and after (bottom) renovation.

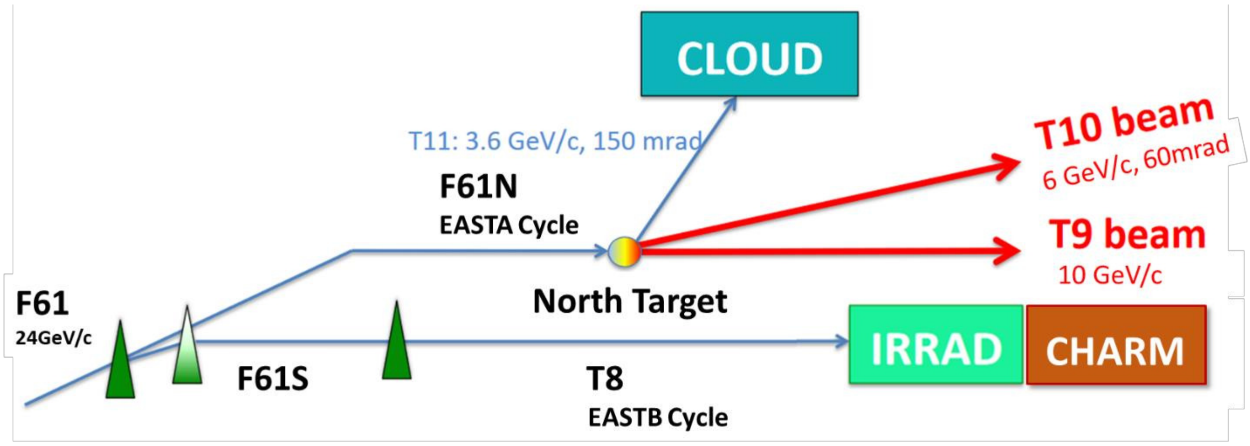

Fig. 2-3: Schematic view of the beam layout in the East Area before renovation with beam energies.

The users controlled their test beams themselves from a common local control room, the East Beam Control Room (EBCR), inside Building 157. PS operators controlled the primary beams from the CERN Central Control room. Certain equipment, e.g. collimators and vacuum, were only controllable locally from the EBCR. The layout of the East Hall in its pre-LS2 configuration is shown in Fig. 2-4.

Over the years the East Area has served, in addition to the CLOUD experiment and the irradiation facilities IRRAD and CHARM, a multitude of test beam users. Recently, T10 was mostly used by the ALICE [4] collaboration, whereas T09 served many different users, from the Super Proton Synchrotron (SPS) or Large Hadron Collider (LHC) experiments but also linear collider, space experiments, and R&D projects from all over the world. Due to serious over-booking of the Experimental Hall North 1 (EHN1) test beams in the SPS North Area, the East Area is getting increasingly popular.

The new layout after renovation (Fig. 2-2) presents a similar layout: the F61 line provides protons from the extraction of the PS to the East Area. The first bend in the F61 line sends the protons to the F6D line with a dump placed at the end used for PS extraction test beams. The protons will be deviated after the second bend to T08 and the irradiation facilities CHARM and IRRAD; or they will be deviated through F62 to the other lines. T09 will be still used as general-purpose test beam and will receive the beam after target A. If not present in T08 and T09, the beam will go through F63 to target B and will serve the T10 and T11 lines. T10 will be used like T09 as a general-purpose test beamline, however, T11 will always host the CLOUD experiment. A general detailed description of the line with physics calculation is available in Section 2.3.

2.2 Problems in the East Area

Over the last decade the exploitation of the East Area has been hampered by a number of technical problems and restrictions, mostly (but not only) related to magnet failures. Many of the 63 magnets installed in the East Area are very old (up to 50 years) and belong to 22 different families, in many cases without spare magnets being available.

Many of the critical magnets are located in a heavily shielded 'primary area', for which no ventilation system is available. The production of ozone due to the passage of the beam through air has certainly contributed to the degradation of the magnets, in combination with the high radiation levels. Whenever a magnet in that area fails, the East Area must be stopped for a period of several weeks (one week to open the 6 metre thick roof and at least one week to fix the magnet itself).

Some critical magnets in the F61 and F61S branches are located in the PS ring zone. Their accessibility is very difficult as well, so that an intervention takes at least a week during which the PS (and hence also the SPS and LHC!) must be stopped.

One important incident occurred in 2004, when the MNP23 magnet in F61S failed after 30 years of service, due to erosion induced blockage of its water circuits. During the 2006–2007 annual stop, the septum magnet was replaced by a C-shaped bending magnet (MCB [5]), which is pulsed between EASTA and EASTB cycles (Fig. 2-3). This allows all beamlines to be operated, but the option of running the irradiation facilities and the test beams simultaneously on the same PS cycle was lost. This, aggravated at the same time by root-mean-square power restrictions on the aging PS main power supply and thereby on the maximum number of East Area cycles, has led to reduced cycle efficiency for the East Area exploitation with, in particular, a severely reduced duty cycle for the test beams.

In 2010, the start-up of the East Area was delayed by more than two weeks because the MNP23 magnet in T09 had to be replaced by a spare magnet, which has been modified to hopefully reduce the risk of short circuits. As the new magnet showed some water leaks from the start, it was decided to lower the top momentum of the T09 beam from 15 to 10 GeV/c. In 2011, the T10 beam had to be stopped 10 days before the end of the proton run due to a failure of its first bending magnet.

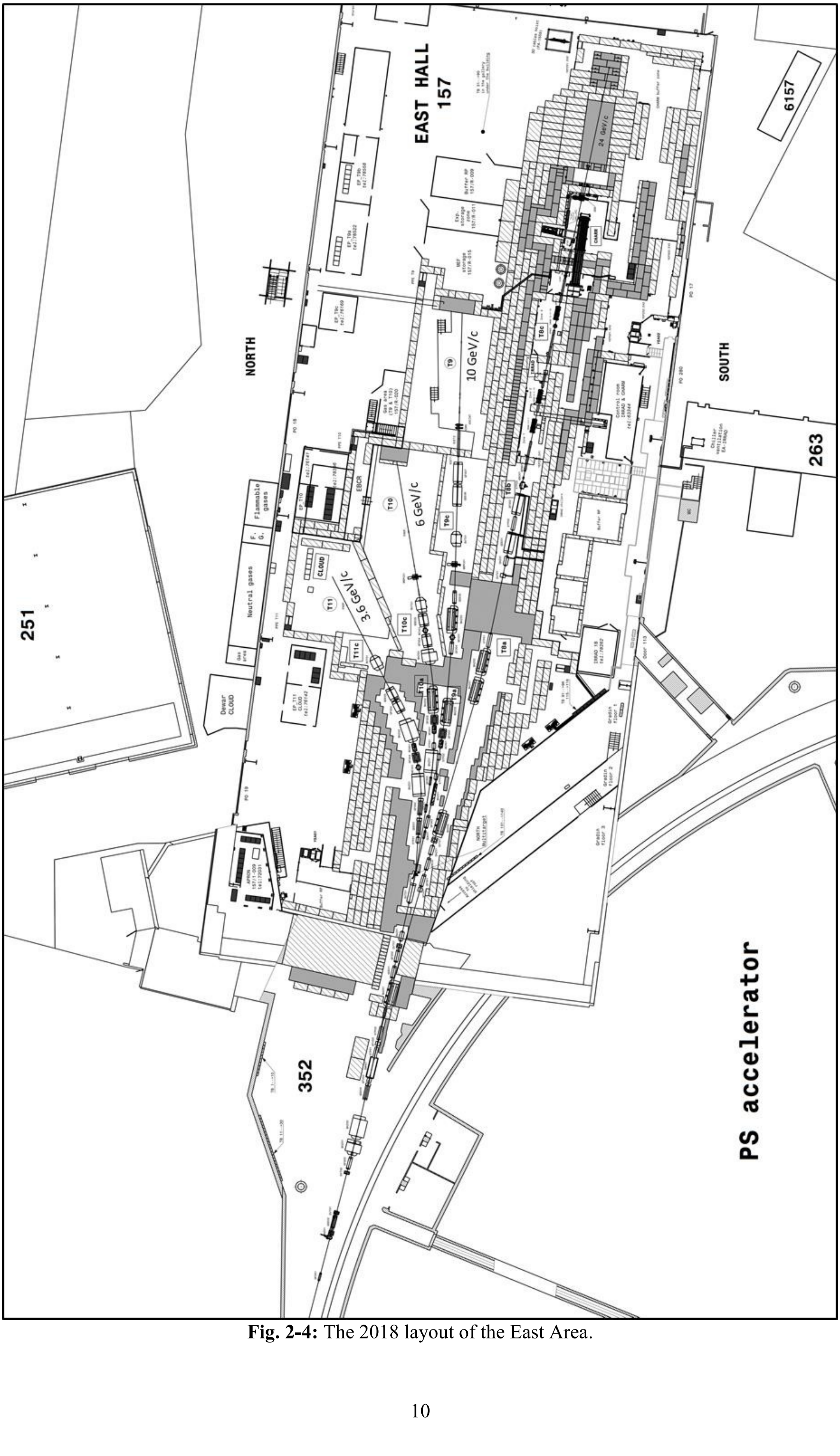

Fig. 2-4: The 2018 layout of the East Area.

Also, a number of quadrupoles were causing worries. Three Q120 type quadrupoles had to be replaced in the 2008/2009 shutdown. Two Q800 type quadrupoles could no longer operate at their nominal current since the inlet temperature of the cooling water had been increased by a few degrees. The top momentum of the T10 beamline had correspondingly to be decreased from 7 to 6 GeV/c.

A number of magnets are quite radioactive. This concerns, in particular, the quadrupoles at the beginning of the secondary beamlines and T09 first bending magnet and its surroundings. In fact, the protons that traverse the North target without interacting are lost inside the magnet itself or just downstream of it, in uncontrolled conditions. The whole environment has therefore high radiation levels. At this point it should be pointed out that this magnet is the most critical magnet in the whole East Area.

2.3 Physics justification

The research and development activities pursued at the East Area are articulated along three main themes: fundamental physics experiments, beam tests for detector R&D and experiments (like NP), and proton and mixed field irradiation activities.

2.3.1 Fundamental physics experiments

Over the last 20 years, the East Area housed fours physics experiments: HARP [6], DIRAC [7], CLOUD, and P349 [8]. HARP (PS214) was studying the hadron production of protons on a number of nuclear targets, to constrain predictions of the neutrino fluxes at experiments such as MiniBooNe and K2K, performed from 2000 to 2002. The DIRAC experiment (PS212) aimed at measuring the lifetime of pionic atoms, to observe Kaon atoms and to measure their lifetime. DIRAC took data over many years and was completed in 2012. The CLOUD (PS215) experiment uses a special cloud chamber to study the possible link between galactic cosmic rays and cloud formation. This is the first time a high-energy physics accelerator has been used to study atmospheric and climate science. The results are contributing much to our fundamental understanding of aerosols and clouds, and their effect on climate. CLOUD is in full swing and will continue for many years. P349 took data in 2014 and 2015, to study polarization in the anti-proton production process, in view of applications in the production of polarized anti-proton beams. The East Hall is the only location where new experiments can be proposed at the PS.

2.3.2 Test beam for detector R&D

The test-beam program in the East Area covers all aspects of detector R&D in the high-energy physics field: from collider and fixed target experiments (detector R&D for LHC, linear colliders, North Area, GSI, etc. experiments), through cosmic ray detectors to be flown on balloons or satellites (PAMELA [9], AMS [10], GLAST [11], PEBS [12], etc.), to emulsions and detectors to be used in neutrino or dark matter searches (MINOS [13], OPERA [14], SHiP [15], baby-MIND [16], etc.). Throughout the conception cycle of new particle detectors, the needs for test-beam campaigns are numerous, from the tests of new concepts, the characterization of first prototypes, the validation of final designs, and the calibration and performance assessments of the production modules.

The test beams in the East Area are as popular as ever, in spite of the low duty cycle for their operation. This is illustrated in Fig. 2-5. Over time, less beamlines have been available for test beams as the irradiations and experiments have been using more of the beam time on their dedicated beamlines.

The test-beamlines in the East Area are complementary to the test-beamlines at the SPS North Area, as they allow significant flux in the energy range not or hardly covered in the North Area (typically limited to ≧ 10 GeV/c). Some experiments prepare their set-up in the East Area before running in the North Area. In addition, some users that prefer the North Area beams accept running in the East Area, as the North Area beamlines are increasingly over-booked.

Recently, users are more willing to come to the East Area since some minimal beam instrumentation has been added (a scintillator and a delay wire chamber) at the end of each beam. This has further improved with the introduction of a modern beam control system.

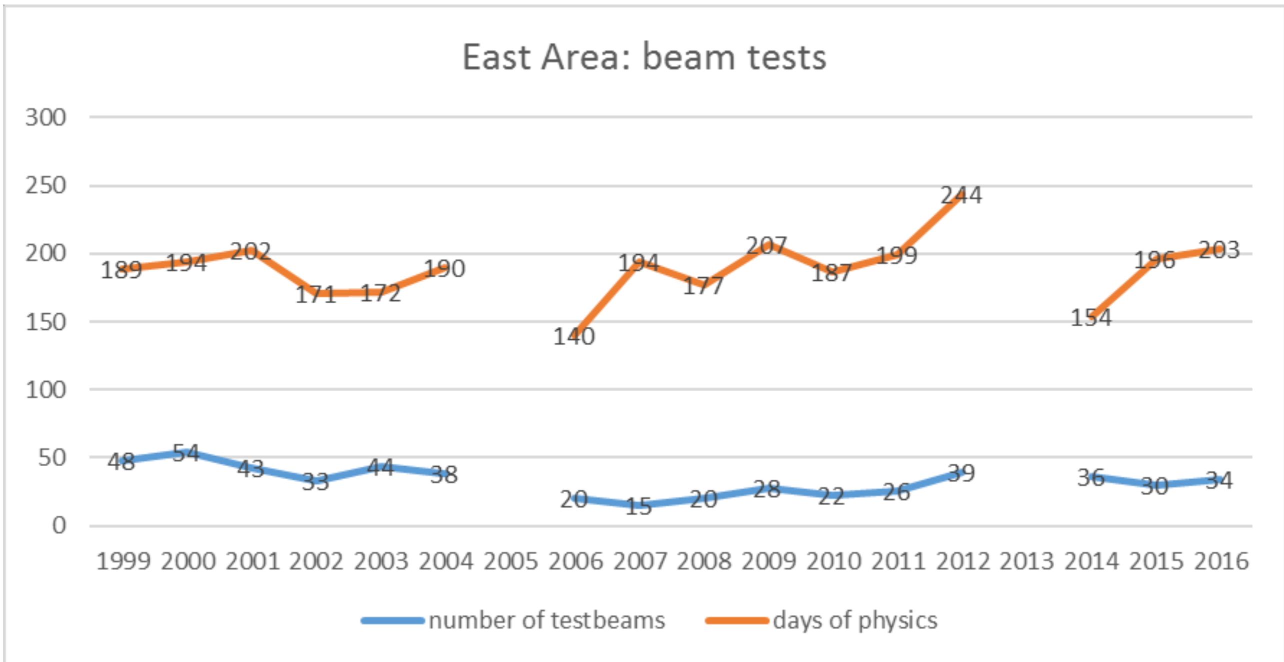

Fig. 2-5: Number of tests beam in the East Area and number of days of test beam operation.

The East Area is thus indispensable, both for the users with needs for the lower energy test beams (such as ALICE, CBM [17], PANDA [18], etc.) and to cope with the overbooking of the EHN1 beams. However, some users consider the East Area beamlines unsuitable, because there is no energy overlap with the beamlines in the North Area. For them, the beamlines would be more usable only if the top momentum were well above 10 GeV/c and if there were more selectivity in particle type (electrons, hadrons, muons) as with the North Area beamlines.

An important advantage of the East Area is also the short distance between control rooms and the test beam areas, therefore allowing short cable lengths. The access to the test areas is much faster (< 15 seconds for the movement of the beam stoppers) than in many of the EHN1 beams where the movement of the beam dumps may take up to 6 minutes!

2.3.3 Irradiation facilities

Next to the test beams, the East Hall hosts the EA-Irradiation facility addressing the needs of the community for proton irradiations and for mixed field irradiation (Radiation To Electronics (R2E) project).

The proton irradiation facility was designed and built driven by the need to qualify detectors and materials for the increasingly harsh environments of the experiments at the LHC, which had to cope with the doses induced by the design luminosity of 300 fb^{-1}, and will have to develop detectors resisting the doses induced by 3000 fb^{-1} proton–proton collisions, as illustrated in Fig. 2-6.

Up to 2012 proton irradiations were performed in the T7 beamline, alternating beam time with test beams, until 2009, and this was the unique use from then on as the needs for irradiations grew. R2E had been served by several parasitic facilities, such as a location behind the T6 target in TCC2, CNRAD, and H4IRRAD. These facilities suffered from difficult access conditions and/or lack of flux. During Long Shutdown 1, a dedicated facility in the East Area was thus build, with support from the EU AIDA funding, to satisfy the needs of the proton irradiation and R2E project.

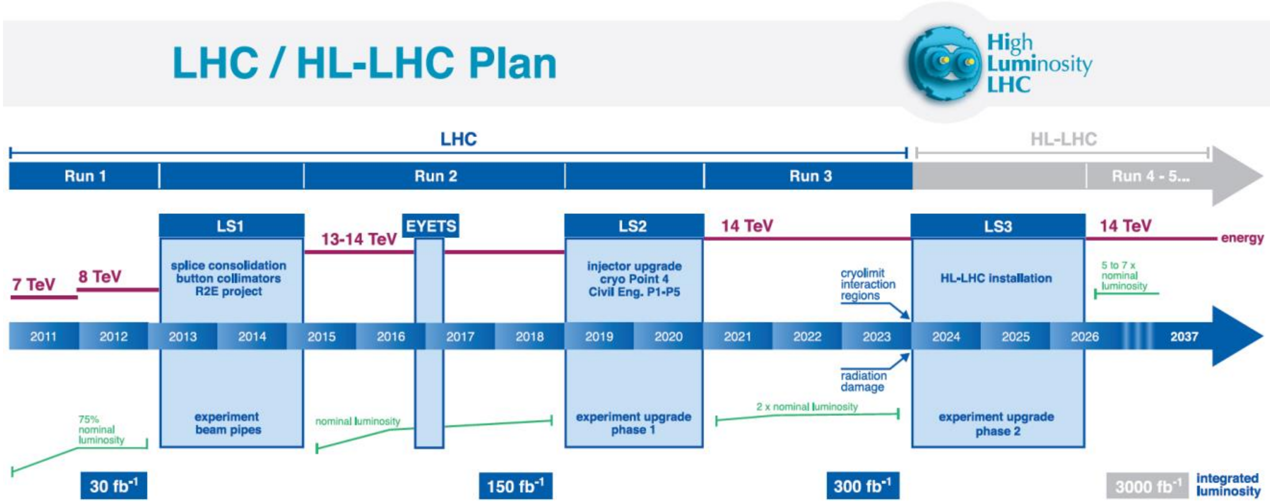

Fig. 2-6: Planned luminosity increase for the LHC accelerator.

This combined facility is installed in the zone once occupied by DIRAC, and profits from a number of important advantages with respect to its precursor in the T7 line, as listed below.

i) There is significantly more space and infrastructure available, allowing for the housing of large objects connected to power and cooling water.

ii) The shielding allows for higher integrated fluxes for the irradiations.

iii) The infrastructure is adapted properly to the needs of an irradiation facility.

iv) The access is a lot easier and, most importantly, no longer requires a long stop of the whole East Area. Also, in the new layout, access exposes the personnel to much lower doses.

v) The same proton cycles serve at the same time the proton irradiation facility, formerly installed in T7, and the mixed field facility in T8 previously behind DIRAC.

vi) There is more freedom in optimizing beam conditions for the proton irradiations than in T7 (the presence of several quadrupoles in the T8 line gives flexibility in focusing).

With the LHC program running well into the next decades, the needs for the EA-irradiation facilities have been established for many years to come. The needs of test beams, both for the LHC experiment upgrade programs, and also for all the larger high-energy physics community, for instance, the development of detectors for neutrino physics or dark matter searches, and the current physics experiment conducted in the East Hall require the East Hall to remain functional. Finally, the East Hall is the only location to host new experiments to be proposed at the PS.

2.4 Motivations and guiding principles for the new design of the East Area

This project is justified by:

1. The unique importance of the East Area for physics and test beams:

   – optimize the general layout of Building 157 to provide all the services needed for the experiments and allocate sufficient space for set-up in the test beam area itself and for storage purposes;

   – improve the performance of the beamlines with increased control over beam particle type and higher maximum beam momenta for T09 and T10 (15 and 12 GeV/c respectively, to be compared with 10 and 7 GeV/c now), allowing overlap with the momentum range of the EHN1 beamlines.

2. The extremely poor state of equipment, in particular magnets and power converters. On top of that, repairs are extremely costly in terms of manpower, radiation dose, and beam time (impacting also the PS, SPS, and LHC in some cases). The new design will:

   – use fewer types of magnets with sufficient spares and considered reliable by the magnet group. In particular, splitter magnets and delicate septum magnets must be eradicated;

   – optimize access to the beamline elements by restricting the primary area to the minimum size possible, reducing the time needed to open the shielded areas and the equipment density in all the areas;

   – replace the beamline components by standard systems (vacuum, collimators, beam stoppers, interlocks, etc.) to ease their maintenance and ensure their long-term operation.

3. The non-conformity of the area to modern safety standards (e.g. electrical, presence of asbestos, etc.) and to radioprotection requirements. The new design will:

   – bring the area up to modern standards from a radiation protection, safety, and instrumentation point of view;

   – restrict high radiation levels to those locations where they cannot be avoided. Dump the unused primary protons cleanly and as soon as possible after the two targets in a re-entrant dump;

   – refurbish the building envelope to eliminate the presence of asbestos and improve the thermal insulation of the building.

4. The reduction of the energy consumption of the facility. The new design will:

   – implement a cycled powering mode of the magnets instead of a steady state one allowing considerable energy savings in terms of electricity. Therefore, new generation SIRIUS power converters will be used and fitted with capacity banks for energy recovery between the various magnet cycles;

   – size the general services (cooling, ventilation, and electrical infrastructure) to optimize the energy consumption of the facility.

A new layout is proposed, as illustrated in Fig. 2-7 which addresses most of the issues related to the existing layout. The beam design related options have been based on discussions with a number of physics coordinators, with the technical groups and representatives of the East Area experiments, and with representatives of the main East Area test beam users.

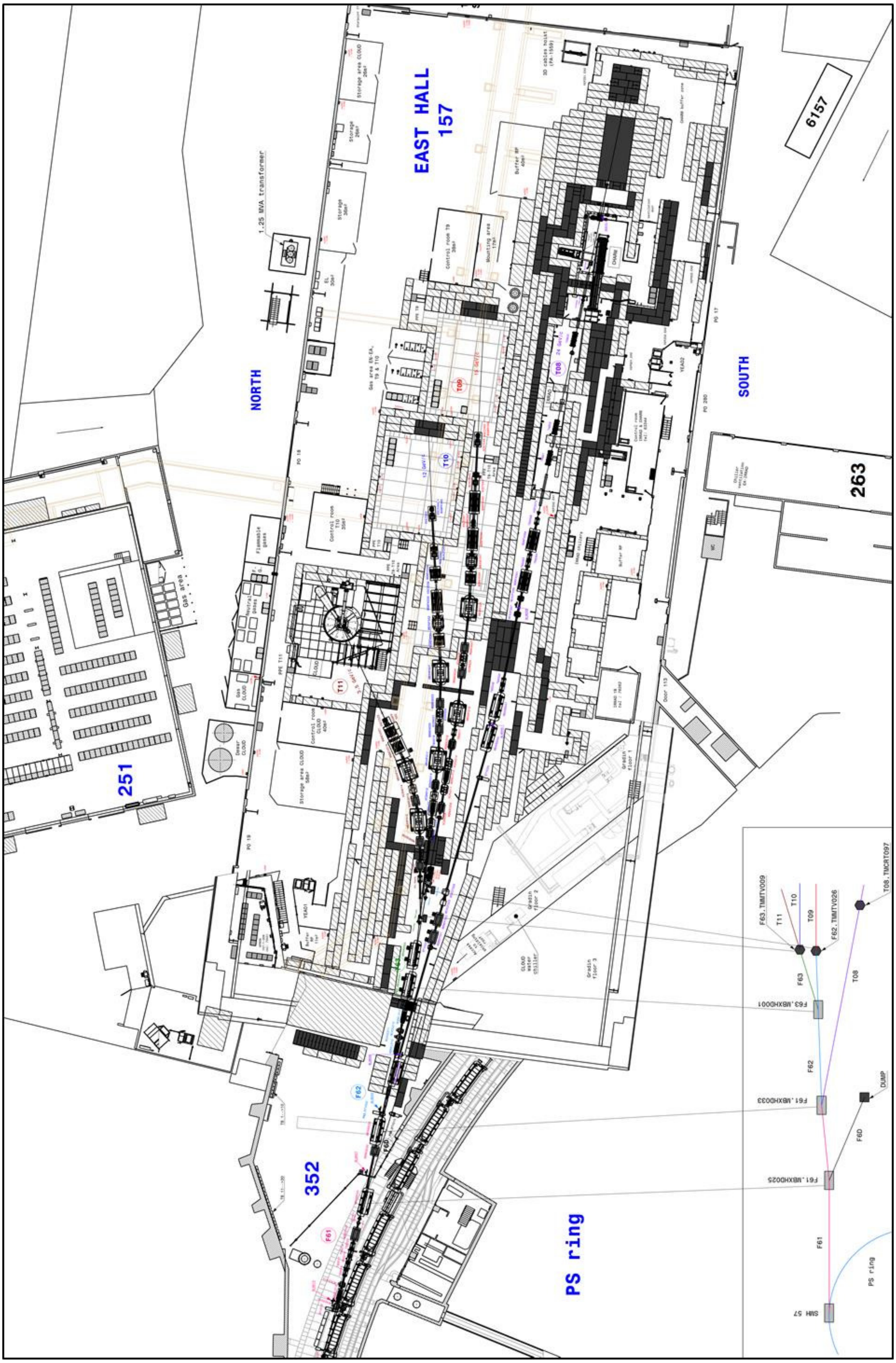

Fig. 2-7: Proposed new layout of the East Area.

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