ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPRB086

# DESIGN & OPTIMIZATION OF THE ALIGNMENT SUPPORTS FOR THE NEW LAMINATED MAGNETS FOR THE CERN EAST AREA CONSOLIDATION PROJECT

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*Abstract*

The East Area is one of CERNs experimental area, running since its foundation in 1958. Extracting a 24GeV proton beam from the Proton Synchrotron accelerator, the primary beam is divided into different secondary beams, serving various experiments and user's facilities such as CLOUD, CHARM, IRRAD.

Due to improved optics and an energy saving scheme, the facility will go under a renovation [1] between 2019 and 2020, including the replacement of the magnets with new laminated ones to allow a cycled powering scheme. Those magnets need improved supports, and in some cases even a new design, to optimize the alignment operations in those areas. This article will mainly address the different proposed solutions for plug-in supports as well as for conventional ones.

## INTRODUCTION

### *Current Alignment in the East Area*

Built in 1958, the East Area still has some of its components just as old. Among those, most supports used for the alignment have not been modified since, or barely. In some cases, the alignment device is old but still operational, thus only need a refurbishment. In other cases, the support has to either be adapted or fully designed, according to the geometry of the laminated magnet. One recurring issue in the facility is the variety of alignment types used for a same magnet family.

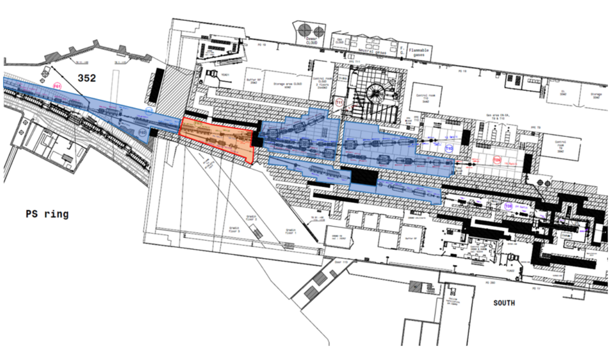


Figure 1: New East Area layout.

With the current layout, the operators tend to spend too much time in the most activated area of the East Hall: the Primary Area. Although its disposition will change for the renovation, its radiation level perceived will still be over 50μSv/h. The alignment is made once the magnet is fixed to its support, and only then the hydraulic & electrical circuits can be manually connected. All of those operations are highly time-consuming and optimized as outlined in the following sections, increasing also exposure to radiation. For illustration, the beam lines are divided into two main sections: the Primary Area (red) & the others (blue) in Fig. 1.

## PRIMARY AREA: PLUG-IN SUPPORTS

The Primary Area hosts the beam lines extracted from the PS accelerator. The main 24GeV beam is impinging on production targets, dividing the beam into three secondary beams T9, T10, T11 respectively of a maximum energy of 15GeV, 7GeV, 3.5GeV. At the same time, the T8 line conserves the Primary beam at 24GeV. Particle production at the target stations and losses along the beamline create particle showers activating surrounding materials and requiring the area to comply with radiation protection constraints.

Optimizing the latter, the new layout targets a reduction of the required number of operations in the area and of the time spent for any of those interventions.

The concept developed for those types of requirements is based on the plug-in philosophy, already used at CERN in the past for different applications. The system consists of a pre-aligned base support, where the laminated magnets can be laid on by the means of a guiding system for the crane operator, and fixed in its position on top of plug-in feet.

Once that the magnet is loaded on its pre-aligned support, its magnetic centre would theoretically match with a precision of 0.2mm with the beam calculated for the optics. This of course, will be verified by quick but required survey measurements, to confirm the expected alignment. Ideally, no additional adjustment is necessary afterwards.

Ultimately, this application can further improve the previous situation by allowing for (semi-) remote handling and installation of the magnets. It will further decrease time spent in alignment operations.

Figure 2 shows the various types of laminated magnets used in the area, according to their specific role on the lines:

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10th Int. Particle Accelerator Conf. IPAC2019, Melbourne, Australia JACoW Publishing
ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPRB086

4 corrector, 2 dipole and 3 quadrupole magnets. All the required supports have been completely re-designed to match with the specifications, but also with the space available around the beam equipment.

All of those supports will have the following characteristics:

- load requirements: magnets from 1.1 to 20.5 tons;
- a guiding system to allow for required positioning accuracy;
- material choice adopted to optimize radiation protection requirements (lowest possible activation) and ensuring the required mechanical resistance.

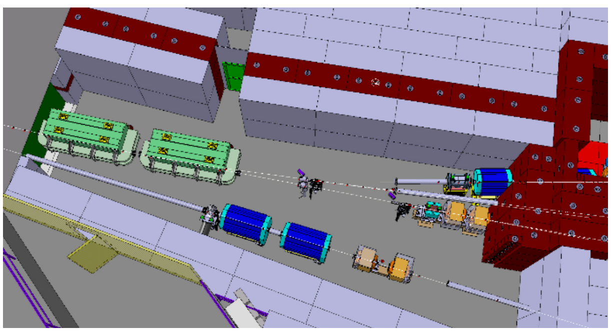

Figure 2: 3D Integration of magnets & their support.

In addition to the available space, the design also considered beam line heights. The corresponding layouts were optimised by means of Finite Element Analysis (FEA). For each magnet family, the various support structures have been standardised and different load simulations were achieved [2] in order to validate the geometry and the material selection. The following sections illustrate the case of the Long Focussing Quadrupole magnets (QFL).

### Plug-in Foot

To evaluate the layout of the plug-in-supports and corresponding load requirements, their geometry was adapted such that the three-foot system could sustain at least the weight of the QFL magnet (4.2T). Given challenging design constraints for the contact points, the FEA mesh had to be refined to ~0.5 million elements. Figure 3 shows the stress analysis to be conform for the chosen support material, in particular for yield stresses to maintain a required safety coefficient above 1.5 (preventing from eventual material defaults or from future increased load requirements).

### Supporting Structure

As the main structure has to sustain the entire load once the magnet is on top, the chosen material and shape should allow the system to keep its precision within 0.2mm between the calculated optics and the magnetic centre. The deviation at the surfaces in contact has a direct impact on the precision, as underlined in Fig. 4.

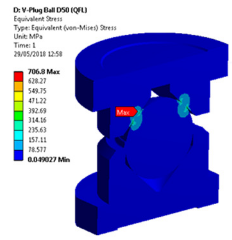

Figure 3: Stress on plug-in foot.

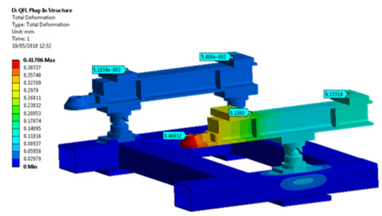

Figure 4: Deformation on support structure.

### Analysis of Incident Cases

When the overhead crane lifts the magnet down, the operator will have to use a visible mark to guide the system onto its plug-in feet. As it is slowly being driven (0.1m/min), a few impacts might occur on this guiding system, as presented in Fig. 5. The force for such an impact was typically estimated around 2kN, for a maximum stress constraint of 185MPa. The selected type of aluminium (ENAW-6082) is compatible with this application range.

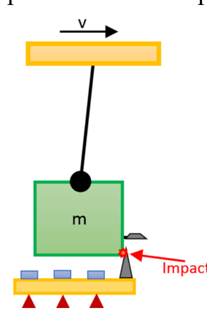


Figure 5: Impact analysis.

The finally chosen design structure is shown in Fig. 6. This system will be also used for the Short Focussing Quadrupole magnets (QFS) on the T11 beam line [3]. It allows for having a compact layout compatible with space constraints, while still leaving space for the surveyors to access the alignment system. In order to have a fixed measure between the magnetic center of the magnet and a reference surface, machinable wedges will also be integrated.

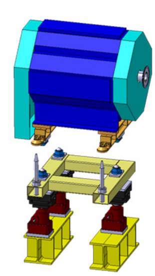

Figure 6: QFS plug-in structure.

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## OTHER STANDARDIZED SUPPORTS

All other areas in the East Hall will host the beam lines as well, but are less subject to radiation hazards. Are concerned the PS extraction area, the Mixed area, the Secondary area, and the T8 area. While classic supports can be used in these areas, a normalized type of support for one magnet family is of advantage, aiming to re-use existing supports as much as possible for cost optimization [4]. This is studied in detail, especially as twelve different magnet families are concerned.

Typically, the measurements of the recycled supports were taken, in order to check on the new geometry of the laminated magnets, and their compatibility. If needed, the geometry of the magnet or the support was adapted. In some cases, as the magnet was previously already laminated, the recycled support could be used directly. The supports used in other particular cases did not comply with the operator's requirements, and have to be completely renewed. Furthermore, all recycled supports will have to go through refurbishment, especially concerning their integrated system of alignment.

Figure 7 shows a typical example of one laminated magnet and its support, which will be used for the East Area renovation.

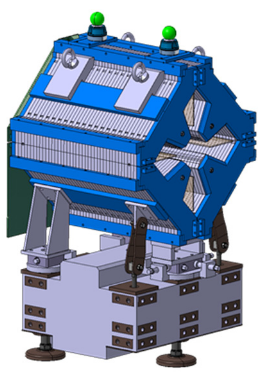

Figure 7: Q100L magnet and support.

## WEPLATE ALIGNMENT PLATFORM

In the framework of the High Luminosity LHC project, a new alignment table has been recently developed at CERN [5] as shown in Fig. 8. It is based on a simple manual adjustment system using regulating screws and wedges. The innovation lies in the location of all adjusting knobs on the front part of the table allowing for the safe and easy alignment of components located in radioactive areas, where access is often very tricky.

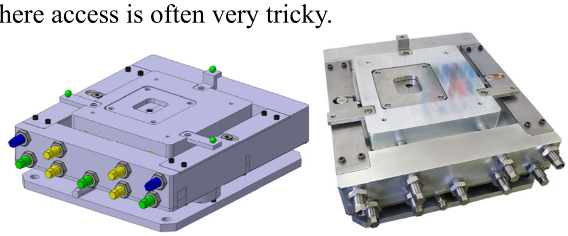

Figure 8: WePlatE alignment platform.

This six degrees of freedom, manually operated table is fitted with independent axis movements. Its main features are the following:

- Service load 500kg;
- Radiation compliant (no lubrication, mainly aluminium construction);
- Locking mechanisms for the actuators and the table;
- Repeatability ≤0.2mm;
- Displacement range:
  - Beam (X): +/-10mm, 0.4mm p/turn
  - Radial (Z): +/-25mm, 1.5mm p/turn
  - Vertical (Y): +/-6mm, 0.28mm, p/turn
  - Roll, Pitch and Yaw: >>14mrad

## CONCLUSION AND OUTLOOK

The new laminated magnet plug-in structures needed for the East Area renovation were validated through structural FEA analysis. Few minor modifications are still required in some cases, but the main concept was demonstrated and will allow to (semi-) remotely handle critical components, reducing so significantly the time spent in the area for the alignment. In this spirit, CERN developed a WePlatE alignment table which could also be used in the East Area Primary zone for certain light beam line components. In parallel, existing supports will be re-used in less critical areas whenever possible.

## ACKNOWLEDGEMENTS

The authors would like to thank all involved CERN equipment/service groups and are grateful for the continuous help and support provided.

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