Toward Starting Up of the ALICE Dipole Magnet

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***Abstract*—The ALICE experiment is being installed in Point 2 of the CERN LHC, the former Point 2 of LEP. ALICE will have a single arm forward muon detector which requires a dipole magnet with a very large aperture that will be installed next to the solenoid used in the L3 experiment of LEP. A pre-assembly and pre-commissioning of the magnet appears essential before installation in its final position. Firstly, the permanent location will be very close to the large L3 solenoid and will lead to significant interference between both magnets. Secondly, the major components of the magnet have been realized in collaboration with several institutes and manufacturing companies in different countries. Finally, the assembly schedule and space in the final location of the magnet are very tight. The magnet is currently assembled in the experiment underground cavern in a location with convenient access conditions where it will be powered and tested during the last quarter of 2003. Subsequently, the magnet has to be completely dismounted and the components need to be lifted over the L3 solenoid to the final location where it will be re-assembled and fully commissioned. The different stages require special tooling and handling jigs to guarantee a controlled and repeatable assembly of the device. Some of the major handling tools which have been designed and manufactured for this process are described. Specific features of the assembly process are highlighted. Particular requirements are described and the results of the first magnet tests are discussed.**

The future assembly and test program is summarized in the conclusion.

***Index Terms*—Assembly, dipole, LHC, spectrometer.**

I. Introduction

ALICE[1] is the dedicated heavy ion physics experiment for LHC. The luminosity will range from $10^{27}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ for p-p collisions to $10^{31}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ for heavy ions. The installation in Point 2 of the LHC accelerator will be integrated in the existing infrastructure.

ALICE will be equipped with a range of different detectors. The detectors are for the majority located inside the L3 Solenoid (Barrel). The large single arm DiMuon forward detector occupies the experimental hall space to one side of the L3 solenoid. Some smaller forward detectors are located at the opposite side of L3 at distances up to about 100 m from IP.

The design of the large dipole magnet required for the forward muon arm spectrometer has been described in [1]. Table I summarizes the main parameters of the device. The final location of this magnet will be directly adjacent to the L3 solenoid magnet. The general concept of the dipole magnet is based on a window frame return yoke, fabricated from low carbon steel sheets. The flat vertical poles follow the defined acceptance angle of 9 degrees. The excitation coils are of saddle shape type (Fig. 1).

TABLE I
MAIN CHARACTERISTICS OF THE MAGNET

Parameter	Value	Unit
Max flux density	0.67	T
Bending strength	3.00	Tm
Avg. gap width	3.30	m
Ampere turns	1.97	MA
Operating current	5.86	kA
Coil voltage	590	V
Power	3.46	MW
Inductance	1.00	H
Stored energy	17	MJ
Diff. pressure	10.9	bar
Diff. temperature	30	˚C
Total weight	835	t
Overall dimensions (H×W×L)	9.0×6.7×5.0	m×m×m

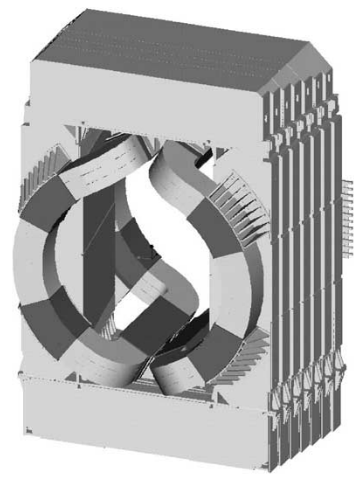

Fig. 1. General view of ALICE dipole magnet. The coils are wound from large hollow aluminum profiles.

They are cooled by pressurized demineralized water. The coil ends are located on both sides of the magnet yoke and determine the overall length of the magnet. The main flux direction in the gap is horizontal and perpendicular to the LHC beam axis.

The project is coordinated by CERN. A considerable part of design work has also been carried out by JINR/Russia.

Presently all large structures have been manufactured and delivery to the ALICE experimental site has started.

The flux return yoke has been designed and manufactured in Russia. The 28 steel modules of about 30 tons each were machined from laminated, press welded iron blocks which were available on site.

The two excitation coils are wound from large cross-section hollow Aluminum conductor. Each coil has 12 layers with 14 turns each assembled from 3 concentric sub-coils of 4 layers each. They were manufactured under CERN supervision by

Manuscript received October 20, 2003.

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Digital Object Identifier 10.1109/TASC.2004.829719

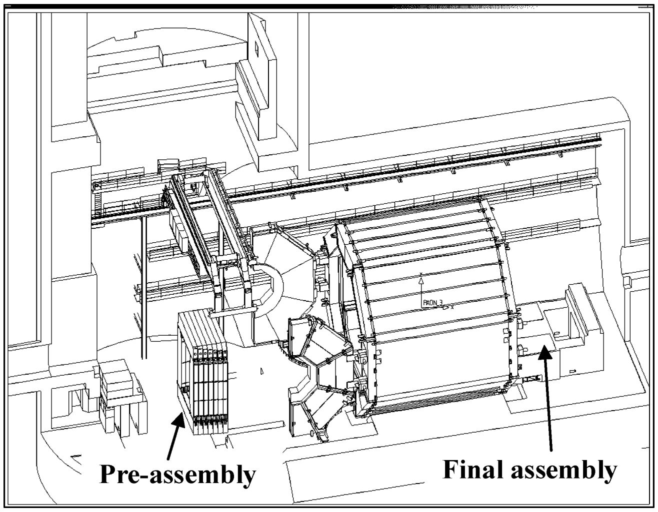

Fig. 2. ALICE experimental cavern.

French industry. The coils are supported in the yoke with stainless steel support structures which required extensive mechanical and magnetic calculations. These components have been produced in Spain.

In the final location the magnet will be fixed to a steel concrete foundation which is common to the whole muon detector. This construction is being coordinated by the CERN civil engineering group.

To validate the installation procedure and minimize the risk of unforeseen adaptations during final installation, a full assembly and pre-commissioning in a convenient location will precede the final assembly in the experimental cavern. This procedure appears essential to verify the conformity of the different components. One of the challenges of the pre-assembly which has started in October 2003 is therefore the correct fitting of the main components.

II. Assembly Constraints in Final Location

The ALICE magnet system consists of the large L3 solenoid and the adjacent dipole magnet. Both magnets have main flux directions orthogonal to each other. The proximity of the magnets leads to strong requirements for the mechanical rigidity of both magnets [2].

A. Space Restrictions

The ALICE dipole magnet will be erected on a 3 m high steel concrete platform behind the big solenoid in the ALICE experimental cavern (Fig. 2). The foundation occupies the major part of the available floor space in this location and does not provide any flat surface useable for manipulating the big magnet structures. In addition, the magnet yoke will be situated at less than 1 m from the rear face of the L3 solenoid leaving only several cm to both sides of the coil ends during the installation (Fig. 3).

B. Forces

The combination and closeness of the L3 solenoid and the dipole magnet create a complex field and EM force situation. When the dipole is operated in the pre-assembly position no net external forces will be present. However, in the final position

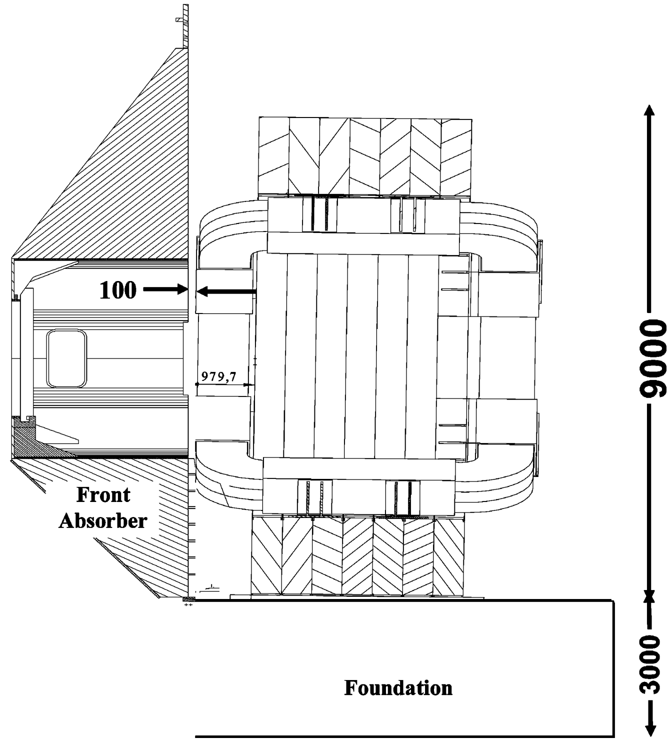

Fig. 3. Installation space constraints.

TABLE II
FORCES Fz ON DIPOLE MAGNET [kN]

Op Mode	Force on Coil	Force on Yoke	Net Force
Stand alone	1456	-1419	37
L3 off	1023	-2675	-1652
L3 on	1028	-2813	-1795

TABLE III
EM FORCES ON COIL SUPPORTS

Location	Support sub assembly	Right coil		Left coil	
		Fx [kN]	F [kN]	Fx [kN]	F [kN]
L3	Top	-533	977	863	1258
	Bottom	-544	1018	875	1296
Center	Top	249	1378	-123	1302
	Bottom	280	1484	-148	1411
Downstream	Top	-553	940	295	725
	Bottom	-569	981	310	767

considerable attraction between both flux return yokes appears independently of the solenoid being operated or not (Table II). When the solenoid is switched on, the stray field will be coupled with the current in the dipole magnet coils and lead to noticeable Lorentz forces (Table III). These forces will be transmitted to the yoke by the coil supports and result in a considerable turning moment around the vertical axis of the dipole.

III. Pupose and Benefit of the Pre-Assembly

A. Magnet Yoke

The yoke modules have been assembled horizontally in the factory. This procedure is very different from the assembly in vertical position and does not allow the final machining of alignment dowels and adjustment of eventually necessary shims at the junction of horizontal and vertical modules. The restricted space in the final location however does not allow any major or precise machining. Removal of parts to be adjusted in surface work shops is equally impractical since all components need to be lifted above the L3 solenoid and then transferred to other cranes. It is therefore essential to validate the complete assembly procedure in detail prior to the final assembly.

B. Excitation Coils

The installation of the two excitation coils is a rather complex and delicate process. The coils are stored and transported in horizontal position. In order to be inserted in the yoke they need to be turned by 90 degree and then lowered onto the lower coil supports. The space between yoke and coil ends is just about 10 cm to both sides which requires a perfect control of the operation over the 6 m high vertical yoke modules. In addition both coils are located at a distance of 10 cm with respect to each other in the yoke. The handling jig needs therefore to be designed such as not to extend outside the coil footprint.

C. Magnet Parameters

In order to verify the proper electrical and magnetic parameters of the dipole magnet it is necessary to test the device at an adequate distance from L3 solenoid or other big metallic masses. The pre-assembly location at the RB 24 side of the ALICE experimental cavern provides this possibility (Fig. 2).

The same is true for the mechanical stresses in the magnet structures [3]. It is therefore planned to survey the structural stresses in critical locations in order to compare to the forces which will occur in the final location close to the L3 solenoid.

D. Installation Time Window

The final installation is tributary to the termination of the installation site and can therefore not be started before June 2004. However, the required time to complete the ALICE detector leaves a very restricted time window for assembly, commissioning and field mapping of the dipole magnet. Consequently, it is compulsory to respect the allocated time. This is however, only possible with a tested assembly procedure and a pre-installation of all magnet services and control system components. The geometry survey during pre-assembly guarantees a subsequent correct alignment of the structures.

IV. Assembly Procedure

The dipole magnet yoke is a self-supporting structure without machined contact surfaces with the magnet foundation [4]. The yoke base is therefore aligned with the means of shims, i.e. thin steel plates which are inserted between yoke base modules and foundation plate to level each module correctly. After the successful first assembly of the yoke and control of overall dimensions, holes for alignment dowels need to be machined at the interfaces between all yoke modules in order to avoid further alignment during the final installation. For this operation important scaffolding needs to be installed for the work at heights of up to 9 m from the foundation level.

A detailed assembly procedure has been edited. This document will be updated during the pre-assembly.

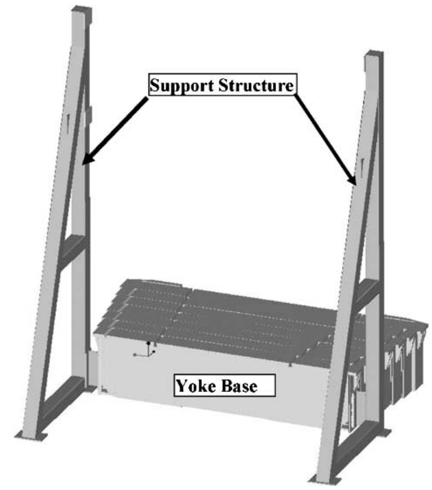

Fig. 4. Yoke module support jig.

A. Yoke Base

The base module B1 (narrow pole gap side) is used as geometric reference. Once it is aligned it is tack welded to the foundation plate in order to avoid any movement during subsequent assembly steps. The following module is positioned next to the previous one, leveled by shims and aligned horizontally by jacks. It is pulled against the previous module with the help of temporary tie rods and then secured against movement with external tie brackets since the temporary tie rods need to be retracted before installation of the next module. When all 7 base modules are installed and the alignment controlled they will be fully consolidated by the 11 permanent tie rods.

B. Yoke Frames

The vertical and top modules are assembled frame by frame starting at the upstream side of the magnet. In order to secure and align the 1st two vertical and the 1st top module in space temporary support structures need to be erected to both sides of the yoke base (Fig. 4). After alignment the first frame is fully tied to the yoke base with the bolted connections. The procedure to mount the following frames corresponds to that described for the yoke base.

Special jigs have been designed to turn the vertical modules into the upright position with the overhead crane.

C. Excitation Coils

To prepare the insertion of the two excitation coils it is necessary to disassemble the yoke top once the yoke has been fully assembled and commissioned and to install the lower parts of the coil supports.

The presence of the dowels will guarantee the alignment after loosening the bolted connections between vertical modules and yoke base which is necessary to create the play to disengage the yoke top modules.

The coil supports are attached with bolted connections to the yoke. The holes need to be machined before the insertion of the coils and the lower supports are positioned within a tolerance to allow final adjustments once the coils are in place and aligned

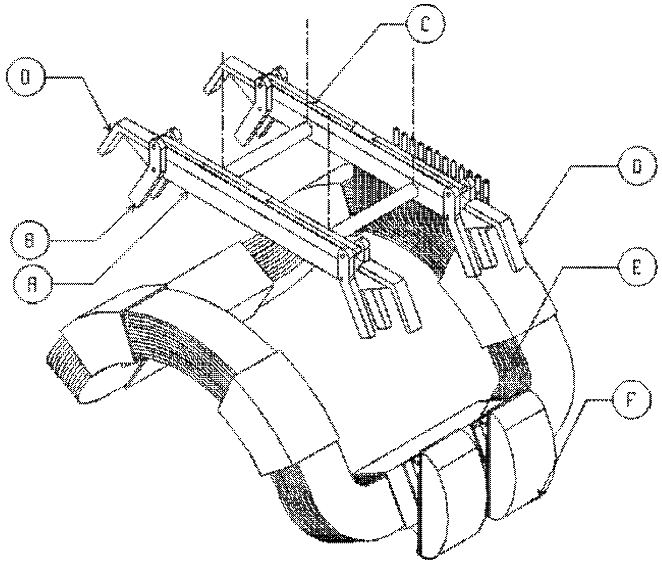

Fig. 5. Coil installation jig.

correctly. The final position of the coil supports will then be fixed with alignment dowels.

One of the main challenges is the turning of each coil by 90 degree and the subsequent lowering inside the yoke gap. A rather sophisticated handling jig has been designed for this purpose (Fig. 5).

The two main constraints are the restricted space to fix the coil and the necessity to be able to extract the device once the coil is inserted in the yoke. Only one overhead crane of 40 ton capacity is available for the operation.

The following procedure has been developed. A support girder (position A, Fig. 5) is placed inside the inner perimeter of the coil resting on the face (a) of the straight sections of the coil. Articulated brackets (position B) are connected to the girder and pulled against the inner coil face (b) by means of tie rods (position C). The outer clamps (position D) provide the structural stability of the assembly when the coil is turned on the rotating shoes (position F) to the upright position. The rotating shoes are connected to the inner lower coil support cradle (position E). When the coil is turned to the upright position and secured by the overhead crane, the turning shoes can be removed and the coil inserted in the open yoke. After disconnection of the tie rods from the brackets B these can be folded back in the plane of the support girder. The removal of the lower bracket D frees then the girder from the coil and the girder can be extracted from the yoke.

V. Conclusion

The pre-assembly work has started in October 2003. The magnet will be ready for 1st power tests at the end of February 2004. After the pre-commissioning it will be dis-assembled and installation in the permanent location will start in June 2004.

The pre-commissioning will include the verification of the overall dimensions of the magnet. All electrical and magnetic parameters will be checked. The temperature profile inside the detector volume will be established in order to check the necessity of additional insulation for the dipole coils.

Strain gauges will be positioned at the critical junctions between coil supports and magnet yoke. These parameters will be used during the final commissioning to detect weak elements [4].

The installation planning of the ALICE experiment at point 2 requires a strict and reliable scheduling of the installation. The dipole magnet will need to be fully commissioned and the magnetic field map measured within a tight time frame before the end of 2004.

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