Chapter 2

Experimental area

2.1 Underground area and surface facilities

The ALICE detector and area facilities are located at Point 2 of the LHC accelerator tunnel in the commune of St. Genis-Pouilly, France. It is comprised of several surface buildings and a shaft which gives access to the underground installations, see figure 2.1. A large assembly hall, equipped with an overhead crane of 63 t capacity houses the ALICE main workshop and a 150 m^2 permanent clean room. The primary gas supply and services like electricity, cooling and ventilation are distributed from the dedicated service buildings at the surface.

The SX2 assembly hall, is built over the PX24 access shaft to the underground cavern, see figure 2.1. This large hall is equipped with an overhead crane with 65 t capacity which is used to transfer equipment between the surface and the UX25 cavern via the shaft PX24. The building contains also the power supply for the L3 solenoid and a 80 kW Uninteruptible Power Supply (UPS) for the experiment.

The beam line is situated 44 m underground as shown in figure 2.1. The floor of the UX25 cavern is 52 m underground and there is 28 m of overburden above the detector. The detector operations are controlled and supervised from the ALICE control room in the SX2 surface building. A large part of the electronics for the ALICE detector is housed in four floors of counting rooms, which are suspended inside the PX24 shaft. The counting rooms are separated from the underground cavern by a concrete shielding and therefore accessible during machine operation. Some of the gas systems for the detector are installed on top of this shielding.

Personnel access to the experimental cavern is through the PX24 shaft. Equipment for the experiment reaches the cavern through the PX24 shaft or alternatively through a machine access shaft. The cavern is equipped with an overhead crane using two hooks of 20 t capacity each. Two levels of gangways cover the full length of the UX25 cavern on both sides. Racks for trigger, electronics, gas systems and services are located on the cavern floor and along the cavern walls on the upper gangways.

Three distinct areas, the A side, centre, and C side, can be identified in the cavern. On the A side, the low-beta triplet is installed on a concrete platform. The space underneath this platform is used for racks and cooling systems installations. This part of the cavern also contains a magnet for compensation of the muon dipole field. This magnet is installed on a removable platform in order

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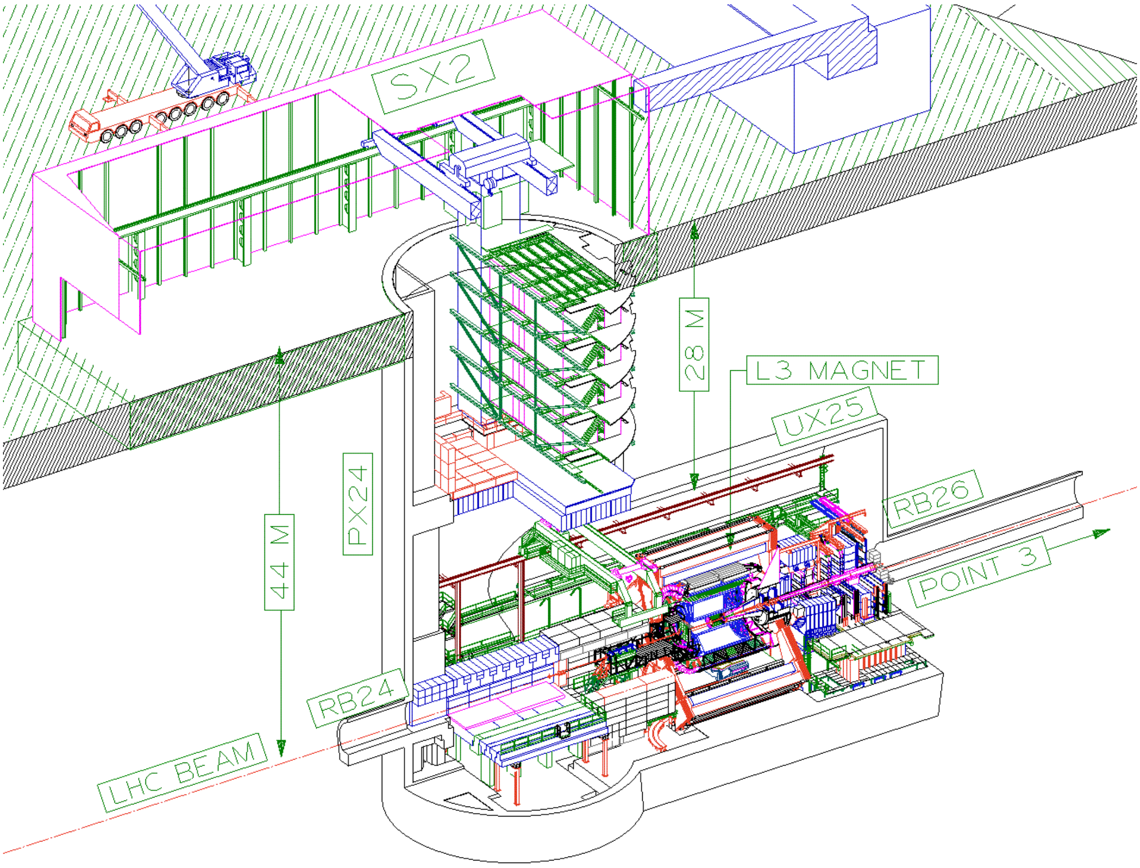

Figure 2.1: The general implementation of the ALICE experiment at Point 2 of the LHC tunnel.

to allow access for installation and maintenance of the detectors. The central part of the cavern is occupied by the L3 solenoid magnet which houses the ALICE central detectors. The dipole magnet and the forward muon system are located on the C side of the cavern. Below the dipole magnet, a rack area for the time critical trigger detectors is installed.

2.1.1 Detector integration

The general layout of the ALICE experiment is shown in figure 2.2. The detector is composed of 18 sub-detectors and their associated systems for power supply, cooling, gas, detector control, detector safety, trigger and data acquisition.

The central part of ALICE is enclosed in the L3 solenoid, which has an internal length of 12.1 m and a radius of 5.75 m.

The ITS, TPC, TRD and TOF detectors are supported inside the L3 solenoid magnet by the so-called space-frame. The space-frame is a cylindrical, 7 m long and 8.5 m diameter stainless steel construction. This structure rests on two 12 m long rails, which span the length of the solenoid magnet. The rails are attached to the octagonal frame which supports the magnet ‘doors’ on each side of the magnet. There is a second pair of rails for the PHOS detector and a third pair for the EMCal detector. The HMPID is mounted on a cradle, which is attached to the space-frame. The

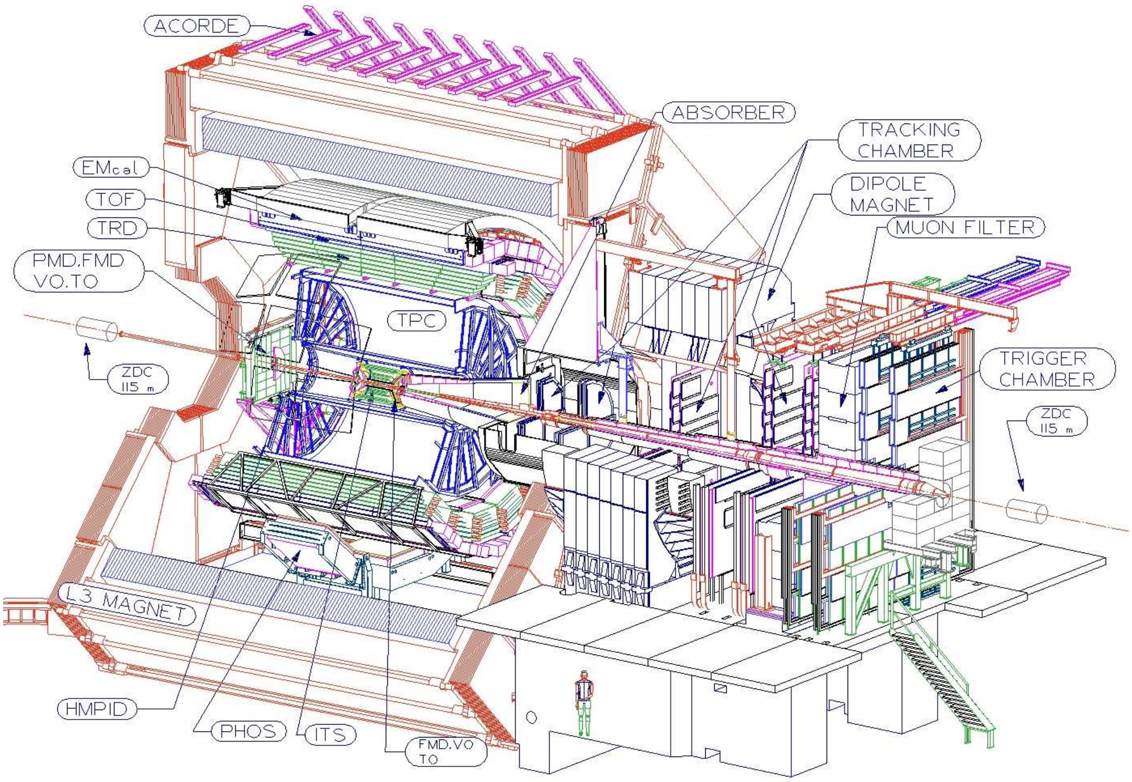

Figure 2.2: General view of the ALICE detector.

rails can connect to removable extensions on the A side in order to allow the displacement of the structures for installation or maintenance.

In addition there are large structures installed on both sides of the space-frame which serve as supports for services. The services on the C side of the experiment are leaving the solenoid through gaps in the permanently closed magnet door. The services on the A side of the experiment must be removable and are therefore fixed to a structure called the mini-frame which can be removed for maintenance of the ALICE detectors.

All support structures inside the solenoid field volume are made of non-magnetic materials. The layout of the support structures follows the 18 fold segmentation of the TPC. The structural beams are placed in the insensitive regions between the readout chambers of the TPC detector.

A concrete beam shield around the beamline dominates the space between the L3 solenoid and the A section of the LHC tunnel. The muon arm spectrometer is installed on the C side of the solenoid. It is comprised of a normal conducting dipole magnet and five stations of tracking chambers. Particles emitted in the direction of the muon arm are absorbed in the muon arm absorber (figure 2.2), which reaches into the L3 solenoid, and a 300 t iron filter wall.

2.1.2 Safety infrastructure

Fire detection in large volumes such as surface halls and the underground cavern is ensured by roof-mounted permanently installed smoke detectors. Fire detection in parts of the detector is ensured by a sniffer system. This system can be modified according to the layout of the detector elements. Both systems can generate level 2 and 3 alarms. Alarm level 3 is sent directly to the fire brigade for intervention. Alarms level 2 from the sniffer can be handled by the Detector Control System (DCS) which would cut electrical power and flammable gas in the detector. The racks on the C side are equipped with individual smoke detectors and a CO_2 fire-extinguishing system.

Air is also sampled, by the sniffer system, for oxygen deficiency hazard in some restricted areas such as the L3 magnet and the rack area on the C side. In case of lack of oxygen during an access in the given area, the evacuation alarm will be triggered.

The closed volumes of the solenoid magnet are connected to a nitrogen-flushing system. In the event of a fire, nitrogen is channeled by the ventilation systems directly to these areas.

The surface gas building and the gas racks in UX25 are monitored by permanently-installed flammable-gas detectors. Flammable gas detection in the detector environment is ensured by the sniffer system.

The ALICE experiment fully complies with the CERN rules and regulations in matters of safety [23].

2.2 Radiation monitoring and shielding installations

Radiation monitors for the dose surveillance of material and equipment are installed in the solenoid magnet, on the A side of the experiment. Additional radiation monitors are installed in the cavern to monitor the induced activity and warn people entering during shut-downs. Monitors are also installed in the PX24 and SX2 to monitor the stray radiation during LHC operation. Fixed monitors survey the air and water release.

The radiation environment in the experimental cavern was simulated for the planned running scenario of the ALICE experiment. Running with pp, low- and high-mass ion-ion collisions over a ten year period was assumed. Beam-beam interactions, beam-gas interactions and miss-injected beams were considered as potential radiation sources. Table 2.1 shows doses and fluences for different central detectors [24]. The dose at the location of the inner layer of the ITS pixel detector is estimated to 2.7 kGy with a 1 MeV neutron equivalent fluency of $3.5 \times 10^{12}\,\mathrm{cm}^{-2}$ for the ten years operation scenario. The doses at the different rack locations inside the cavern are at most of the order of 5 Gy or substantially lower. The neutron fluencies are typically $10^3\,\mathrm{cm}^{-2}$ with a maximum at $10^8\,\mathrm{cm}^{-2}$ for one location.

The 2.4 m thick PX24 shielding plug is not sufficient to shield the produced radiation during nominal operation of LHC. A permanent shielding from 1.6 m thick concrete blocks is therefore put into place around the beam line as an extension of the machine tunnel over the length of the LHC elements.

The 10 m long gap between this permanently installed shielding and the front of the L3 solenoid is covered by 1.6 m thick concrete shielding blocks which are removable over a length of 7.5 m in order to open the solenoid doors and to gain access to the central detectors for installation and removal of modules.

The radiation from the LHC machine towards the experiment is shielded by combined steel (0.8 m) and concrete (1.0 m) walls in the LHC tunnel to either side of the UX25 cavern. These plugs fill the tunnel cross-section around the machine magnets and the Cryogenic-Ring Line (QRL).

Table 2.1: Doses and neutron fluences in central detectors [24].

System	Radius (cm)	Dose (Gy)	h-Φ (cm^{-2}) 1 MeV n-equ
SPD1	3.9	2.7×10^{3}	3.5×10^{12}
SPD2	7.6	6.8×10^{2}	1.3×10^{12}
SDD1	14	2.5×10^{2}	5.5×10^{11}
SDD2	24	1.2×10^{2}	3.2×10^{11}
SSD1	40	5.0×10^{1}	2.3×10^{11}
SSD2	45	3.0×10^{1}	2.0×10^{11}
TPC(in)	78	1.6×10^{1}	1.5×10^{11}
TPC(out)	278	2.2×10^{0}	4.5×10^{10}
TRD	320	1.8×10^{0}	2.6×10^{10}
TOF	350	1.2×10^{0}	2.0×10^{10}
PHOS	460	5.0×10^{-1}	1.7×10^{10}
HMPID	460	5.0×10^{-1}	1.7×10^{10}

2.3 Magnets

The experiment includes a solenoid magnet previously used in the L3 experiment of LEP which houses the central detectors and a dipole magnet situated next to the solenoid which is part of the forward muon spectrometer.

A dipole magnet with resistive coils and a horizontal field perpendicular to the beam axis is an integral part of the muon spectrometer arm. The required field integral in the forward direction is 3 Tm. The tracking stations are located up to 14 m from the IP.

2.3.1 Solenoid

The L3 solenoid magnet is a room temperature solenoid with an octagonal aluminium coil cooled by demineralised water via external cooling circuits. The octagonal steel flux return yoke is closed by pole cap ‘doors’. The magnet was put into operation in 1988 for the L3 LEP Experiment [25].

The elevation of the LHC beam axis by 300 mm with respect to LEP results in an eccentric position of the L3 solenoid, which was centered on the LEP interation point. As an improvement measure additional steel elements (the so-called ‘plug’) were inserted to reduce the diameter of the hole in the L3 doors and compensate the off axis effect. The field variations in the volume of the detectors, up to 2.5 m in radius and ± 2.5 m along the axis from IP, are below 2% of the nominal field value. This is a reduction by a factor of two as compared to the original L3 field quality.

The main characteristics of the L3 solenoid are given in table 2.2

2.3.2 Dipole

The dipole magnet [26] is placed 7 m from the interaction vertex, at some 10 cm distance from the L3 solenoid.

Table 2.2: L3 solenoid magnet characteristics.

Parameter	Value	Unit
Nom. flux density	0.50	T
Ampere turns	5.04	MA
Operating current	30.00	kA
Stored energy	150	MJ
Power	4.20	MW
Number of turns	168	
Inner radius of coil	5930	mm
Avg. radius of coil	6375	mm
Total weight	7800	t
Overall dimensions (D×L)	15.8×14.1	m

The size (free gap between poles 3.5 m, height of the yoke 9 m, total weight about 900 t) is defined by the requirements on the angular acceptance of the spectrometer. The magnetic flux density (B_{nom}= 0.67 T, 3 Tm field integral between IP and muon filter) is defined by the requirements on the mass resolution.

The magnet yoke is constructed from 28 low-carbon steel modules made for cost reasons from existing steel stacks which consist of 3 cm thick steel sheets welded to each other. The vertical poles are oriented at an angle of 9° with respect to the vertical symmetry plane leaving a free gap between the poles of 2.972–3.956 m.

The two Saddle type coils have semi-cylindrical coil ends. They are constructed from hollow aluminium conductor with square cross-section of 25.5 cm^2 and an internal hole for cooling with demineralised water at a rate of some 130 m^3/hr. Each coil is assembled from 3 sub-coils with 4 layers of 14 turns each. They delimit the overall length of the magnet to 5 m. The distance of the centre of the dipole yoke from the IP is 9.87 m. The main characteristics of the ALICE dipole are shown in table 2.3

The magnet was installed in its final position on a 3 m high reinforced concrete platform. The close distance between the solenoid magnet and the dipole leads to a strong magnetic force (estimated at 120 t) between the two magnets. Measurements, at full power, do not indicate any displacement of the magnet structures. The stray field in the vicinity of the magnet attenuates rather rapidly to less than 50 Gauss at the level of the gangways.

2.4 Beam pipe

The beam vacuum system represents the main interface between the experiment and the LHC machine. It must therefore fulfil a dual set of requirements.

The ALICE experimental requirements include maximum transparency to particles, limited beam-gas backgrounds and conformity with the environmental and installation constraints.

The accelerator requirements include safe operation of the machine, adequate beam aperture and dynamic vacuum conditions compatible with ultimate LHC performance.

Table 2.3: Dipole magnet characteristics.

Parameter	Meas. Value	Unit
Ampere turns	/	MA
Operating current	6.00	kA
Coil voltage	597	V
Power	3.58	MW
Inductance	1.00	H
Stored energy	18	MJ
Diff. pressure	12	Bar
Flow rate	130	m^3/h
Diff. temperature	24	C
Mag. field B_x (center of coils)	0.666	T
Field integral B_x (-13.8 m $< z < -6$ m)	3.04	Tm

The vacuum system is a fully in-situ baked UHV system, pumped by a combination of lumped sputter-ion and distributed Non-Evaporable Getter (NEG) pumps. The NEG system consists of a thin sputtered coating along the whole internal surface of the vacuum chambers. The average vacuum pressure has been estimated to be 10^{-8} Pa for pp run and 10^{-9} Pa for Pb-ion run with nominal parameters.

The ALICE beam pipes, ranging from 19 m of either side of the IP consist of 3 sections (figure 2.3). The Central section (CS) beryllium beam pipe is a 4 m long beryllium section with internal diameter 58 mm and 0.8 mm thick wall. This part is protected by a polyimide wrapping about 80 μm thick and extends along the beam from -3585 mm$< z <$ 365 mm. The C side section in the absorber consists of 3 chambers of conical stainless steel tubes which are up to 450 mm in diameter. The A side section uses standard LHC machine components and consists of 4 copper tubes. The main parameters of the beampipe are summarized in table 2.4

To simplify the assembly procedure, an all-metal valve with RF-bridge is located between the CS and A sections. Each vacuum chamber has its fixed point towards the A-side, and towards the C-side a bellows or compensator module allowing for thermal expansions and relative beam pipe movements.

The main pump used to eliminate gases in the system is the NEG pump. After activation by heating under vacuum to above 200°C, the NEG film gives a high distributed pumping speed for most gases. Gases not pumped by the NEG system are removed by sputter-ion pumps.

The vacuum chambers are designed to resist stress induced by vacuum and the weight of the mechanical components. However, especially the Beryllium is not able to support stresses induced by offsets during detector opening and closing procedures. The chambers will therefore be vented to neon gas at atmospheric pressure, purified to the ppb level by a special developed gas purifying system. Neon is not pumped by the NEG system, so the beam vacuum system can be made operational at the end of a short intervention by simply re-pumping the neon gas.

All chambers are permanently equipped with bake-out heaters for periodic re-activation of the NEG coating, with the exception of the central section.

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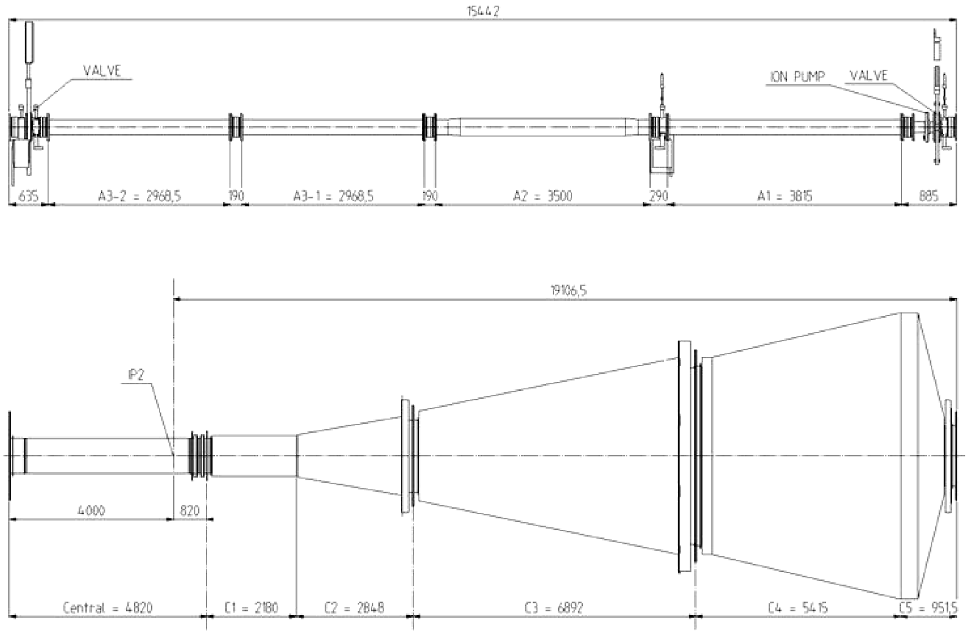

Figure 2.3: Layout of the ALICE vacuum chamber.

Table 2.4: Dimensions and materials of the ALICE vacuum chamber.

Name	Length mm	min. ID mm	max. ID mm	Angle deg	Material
A/1	3815	80	80	0	Copper
A/2	3500	60	96	0	Copper oval chamber
A/3-1	2968.5	80	80	0	Copper
A/3-2	2968.5	80	80	0	Copper
Central	4800	58	58	0	Beryllium, Stainless steel
C/1	2180	58	58	0	Stainless steel
C/2	2848	58	120	0.7	Stainless steel
C/3	6892	120	300	0.8	Stainless steel
C/4	5415	300	450	0.9	Stainless steel
C/5	951.5	100	450	15	Stainless steel

2.5 Survey and alignment

The survey and alignment requirements for the ALICE detector elements can be separated into two categories. First, all sub-detectors and the beam pipe must be placed at the nominal position within a specified tolerance, typically of the order of mm, which is verified by standard survey techniques during installation and monitored with dedicated equipment during operation. The second category consists of requirements concerning the relative alignment of detector elements and the stability of their position during operation, typically of the order of $< 50\,\mu$m for the muon system, which is monitored by optical alignment devices, and $< 10\,\mu$m for the ITS, which is ensured by a rigid carbon-fibre structure.

The alignment strategy of the central detectors in the L3 magnet is determined by the mechanical interconnections of the subdetectors. The ITS detector, consisting of the Silicon Pixel Detector (SPD) at inner radius, the Silicon Drift Detector (SDD) at intermediate radius and Silicon Strip Detector (SSD) at outer radius, has a nominal clearance of 5 mm to the central beampipe. The SPD, SDD and SSD detector elements are positioned on a rigid carbon-fibre structure with an accuracy of better than $100\,\mu$m. The relative position of these elements is not monitored by external devices and all alignment questions are studied with particle tracks. The beam pipe is fixed to this ITS barrel structure on both sides with 4 steel wires at a tension of 50 N. This guaranties a stable relative position of the beam pipe and the ITS detector.

The ITS barrel itself is held by two fixation points on the inner TPC cylinder, which together with a third point on the bottom of the barrel fix the relative position of the ITS and the TPC. The weight of the ITS causes a sag of about 0.7 mm of the inner TPC drum. The relative position of the ITS and the TPC is monitored by an optical alignment system with a precision of $< 20, \mu$ m. The TPC is supported by two rails which are fixed inside the space-frame, while the space-frame itself is standing on rails which are fixed on each end of the L3 magnet.

The positioning of the ITS-TPC inside the L3 solenoid is determined by the requirement that the central beam pipe must be placed within ± 5 mm of the nominal beam axis and that the angle between the ITS-TPC axis and the magnetic field axis is less than 1 mrad. The installation of the TOF and the TRD modules on the space-frame causes a deformation of the space-frame of up to 5 mm and a sag of the rails supporting the space-frame of up to 10 mm. In order to monitor the beam-pipe position and space-frame deformation during detector installation and operation, an optical monitoring system is installed. The used BCAM [27] system has a relative angular resolution of $5\,\mu$rad. In case the 5 mm tolerance is violated, the entire space-frame is moved to place the beam pipe back in the nominal position.

In the muon spectrometer the particle momentum is measured by 5 tracking stations which are not mechanically conneted. The relative position of these stations is monitored to $< 50\,\mu$m with a dedicated system of BCAMs.