Civil Construction: Buildings and Supply Systems

The following is a description of the building complex for the new facility. It reflects the current status of the planning activities. The arrangement of the buildings is based on an extensive discussion about how to respond to the requirements of the accelerators and of the experiments. The aim was to minimize costs while observing radiation protection rules and ecological aspects. The experience gained ten to fifteen years ago during the construction of SIS/ESR served as a valuable basis. Alternative construction plans were then developed with the help of a renowned engineering consultancy, with special expertise in civil engineering and tunnel construction.

1 Location of the new facility

In view of the injection from SIS 18 into SIS 100/200, and the configuration of the beam lines to the experimental stations and to the other storage rings. the new buildings will be best located east of the current GSI area, as shown in Figure 1.1. The synchrotron SIS 100/200 is in the north, about 24 m below the surface. There will be three regions with access to ground level: an emergency exit in the north and, respectively, one access area at the injection region and one at the extraction region, where the components of the ring will be brought in. In these two areas, there will be additional underground structures containing the supply installations for the rings .

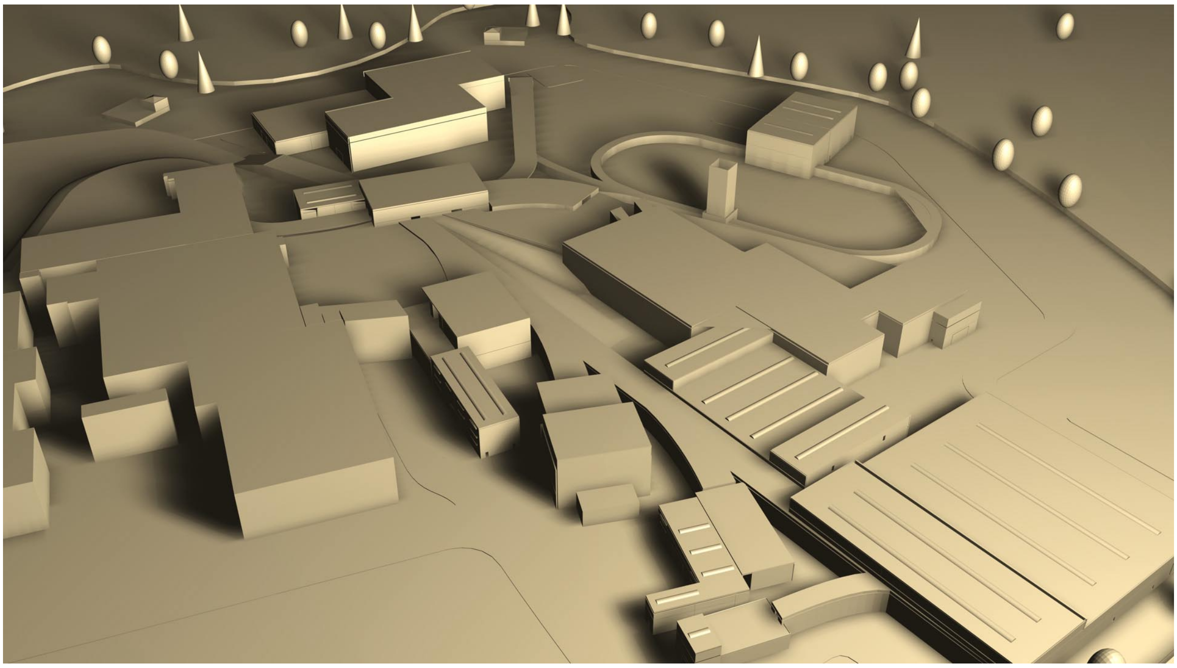

Figure 1.1: The solution proposed in this CDR is a cost-effective combination of deep underground and near-surface construction

The southern part of the ring is adjacent to the experimental installations. These are above ground installations and cover an area that corresponds approximately to that of the current facility (14 ha). Presently, this area is covered with woods and is owned by the Bundesland Hesse. The open fields south of the woods were not considered for the building project because of jagged plots and different owners. This should avoid the risk of losing much time due to prolonged purchase negotiations.

The experimental installations and the beam lines with their supply buildings will be set up above ground. After extraction, the beam will be split into a number of branches which will be guided towards the south, to the Plasma Physics (PP), the Nuclear Collisions (NC) and Atomic Physics (AP) experimental halls, the antiproton target (APT) and the superconducting fragment separator (Super-FRS). The plasma physics' experimental station will be assembled in such a way that beams from SIS 18 as well as from SIS 100/200 can collide with the laser beam. The high-energy storage ring (HESR), with its two halls for the electron cooler and the antiproton experiments, will be located in the east in order to guarantee a suitable connection to SIS 18 and to the new synchrotron. The halls for the collector ring (CR) and the NESR will be situated south of the super-fragment separator and the antiproton target.

The cryogenic system for the cooling of the SIS 100/200 magnets and the corresponding helium gas recovery installation, as well as the ventilation system, are planned for the area between the injection and extraction buildings. The operational buildings for the experimental installations will be placed near their appendant halls. The buildings under- and above ground will be connected with the present facility by suitable transport roads. In the north, the existing forest road will be improved and will thus provide a good connection between the northern and eastern buildings. In order to develop the buildings on the west side of the new area, a road connection is planned to the southern part of the current area.

For reasons of easy radiation protection and in view of ecological considerations a first approach in planning the new facility has to examine whether it would be feasible to locate all experimental installations underground at the level of SIS 100/200. The beam line would be approximately 24 m below ground level. The synchrotron, the HESR, and part of the transfer lines can be set up by means of a tunnel drill, without interfering with the trees above. For the construction of the underground buildings with larger dimensions, open building pits with multiply reanchored retaining walls would have to be set up due to the subsoil, which is basically composed of four layers:

- The first layer, between the surface and a depth of 5 m, consists of fine and medium sands.
- The second layer, at a depth of 5 to 10 m, is composed of argillaceous fine sand silts.
- The third layer, at a depth of 10 to 20 m, consists of a dense deposit of fine and medium sands

The fourth layer consists, in the upper part (20 to 35 m), of alternating layers of argillaceous silts, as well as fine and medium sands. In the lower part (35 to 50 m depth), there exists a substantial amount of silty clays.

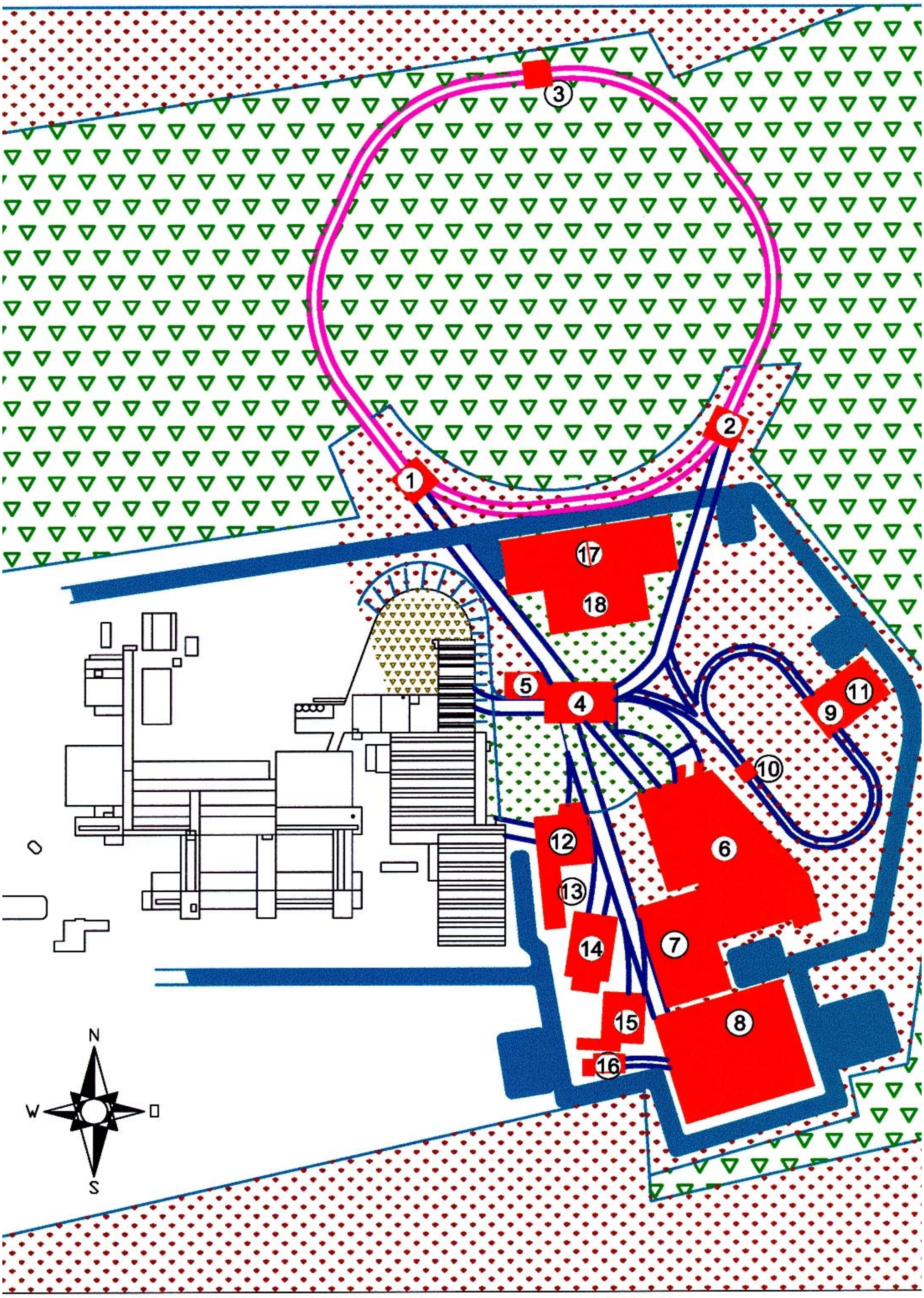

Figure 1.2 Plan view of the buildings of the new facility

2 Buildings

The above-ground part of the future facility consists of a complex of buildings listed in the following table and shown in Figure 1.2. The above-ground connections of these buildings, containing beam components, will be constructed as passages with concrete walls and ceilings.

	Structure	Floors	Plan Area (m²)	Gross vol. (m³)
1	Extraction building	3	1600	51400
2	Injection building	3	1600	51400
3	Emergency exit	3	400	11200
4	Transfer building	1	1643	31220
5	Transfer-operation	1	600	9000
6	Super-FRS and APT	1	10590	161610
7	CR	1	4000	58000
8	NESR	1	8465	122740
9	HESR-experiment	1	805	5230
10	HESR-cooler	1	245	2910
11	HESR-operation	1	1225	22900
12	PP	1	1740	26070
13	PP and NC-operation	3	720	10080
14	NC	1	1130	25390
15	AP high energy + operation	1/3	1425	14850
16	AP low energy	1	350	3250
17	Cryogenic system	2	5510	77115
18	Energy center	2	2500	34000

Altogether (excluding SIS 100/200) buildings with a gross volume of approximately 820,000 m^3 are needed. The surface area for these buildings amounts to approximately 60,000 m^2.

2.1 Underground Structures

SIS 100/200 is proposed to be constructed in a tunnel with circular cross section in the fourth ground stratum, at a depth of twenty to thirty meters below the ground surface. This is the most cost-effective solution and also preserves the forest north of the "Prinzenschneise" from above-ground building activities to the extent possible. Setting up a ring at the surface would demand enormous earth fills and barricading measures, on account of the required radiation protection.

With an exterior diameter of eight meters, the tunnel for the SIS 100/200 rings should best be constructed by means of an automatic tunnel drill. The costs will include the mounting of the tunnel drill, the excavation and building costs for the emergency exit, the two buildings at the extraction and at the injection, and the tunnel itself with a length of 1,080 m. This will amount to approximately DM 150 million. By way of a 100 m ramp, the extracted beam will be steered to the surface and then split into a number of branches. The ramp for the injection may be steeper. Its proposed length is 50 m. These ramps will be built according to open construction methods as shaft buildings. The estimated costs for the ramps amount to DM 8 million.

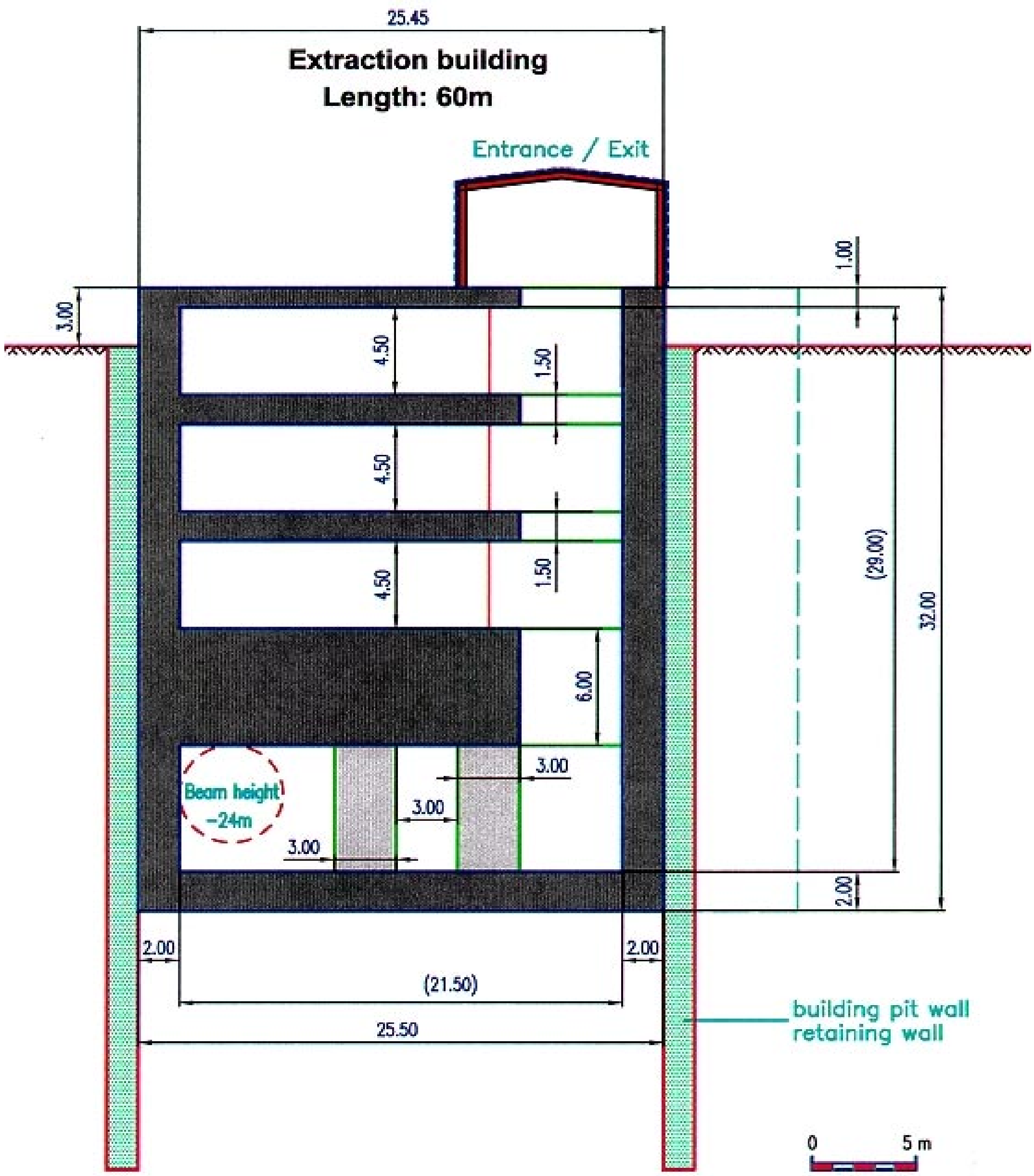

Figure 2.1: Sectional view of the extraction building

The extraction and the injection buildings will be implemented underground with above-ground access as shown in Figure 2.1. They will be constructed in an open foundation pit surrounded by a multiply anchored wall, which - during construction - will take up the horizontal soil and water pressures. The pits will serve as start and destination points for the tunnel-drilling machine. The two buildings are to host the necessary support installations of SIS 100/200.

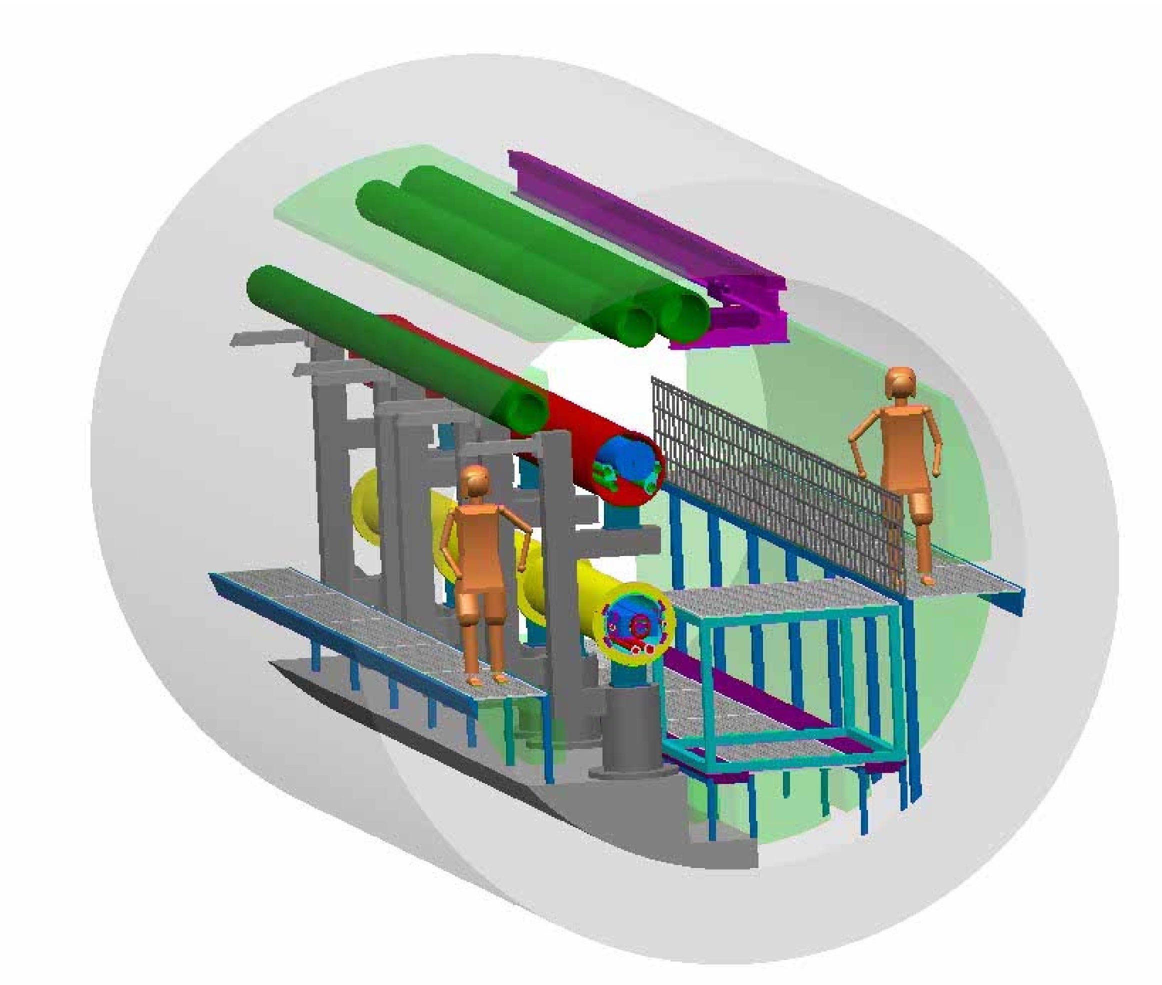

Figure 2.2: Arrangement and Accessibility of SIS 100/200 components

The effective inner tunnel diameter is 5 m. Figure 2.2 shows the general layout of the tunnel. It will contain the two accelerator rings, one above the other, with the necessary support and adjustment hardware, especially the liquid-helium transfer system. Multifunctional platforms allow accessibility of all components.

2.2 Above-ground Structures

Above-ground halls with substantial shielding needs – nuclear collisions station, plasma physics station, AP high and low energy stations, antiproton and Super-FRS target, Super-FRS- experimental station and transfer building – will be constructed as framed structures and made of reinforced concrete. These structures will contain the necessary headroom for an overhead crane. Exterior weather protection (e.g. made of trapezoidal sheet-metal) will be provided. On account of the hall sizes and the load concentration by the walls, a pile foundation will be implemented. By that the construction of substantially thinner ground plates of the buildings is more cost effective, saving a lot of reinforced concrete. Examples for this type of construction are shown in *Figure 2.3* and *Figure 2.4*.

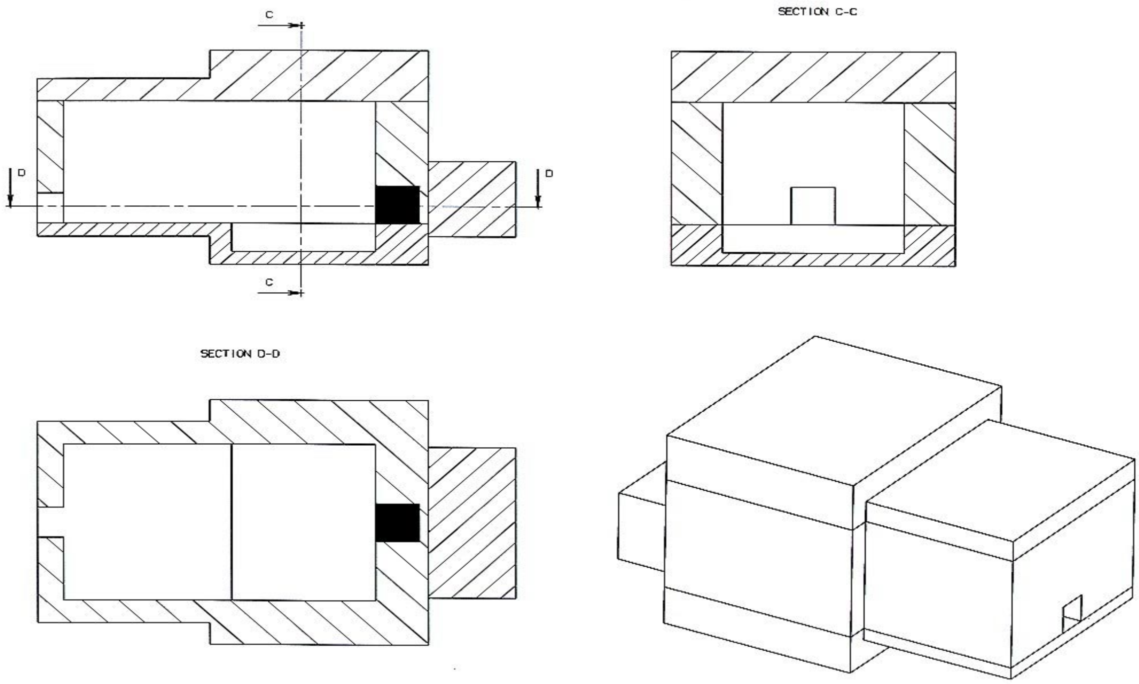

Figure 2.3: The shielding of the NC-Cave is integrated in the construction of reinforced concrete

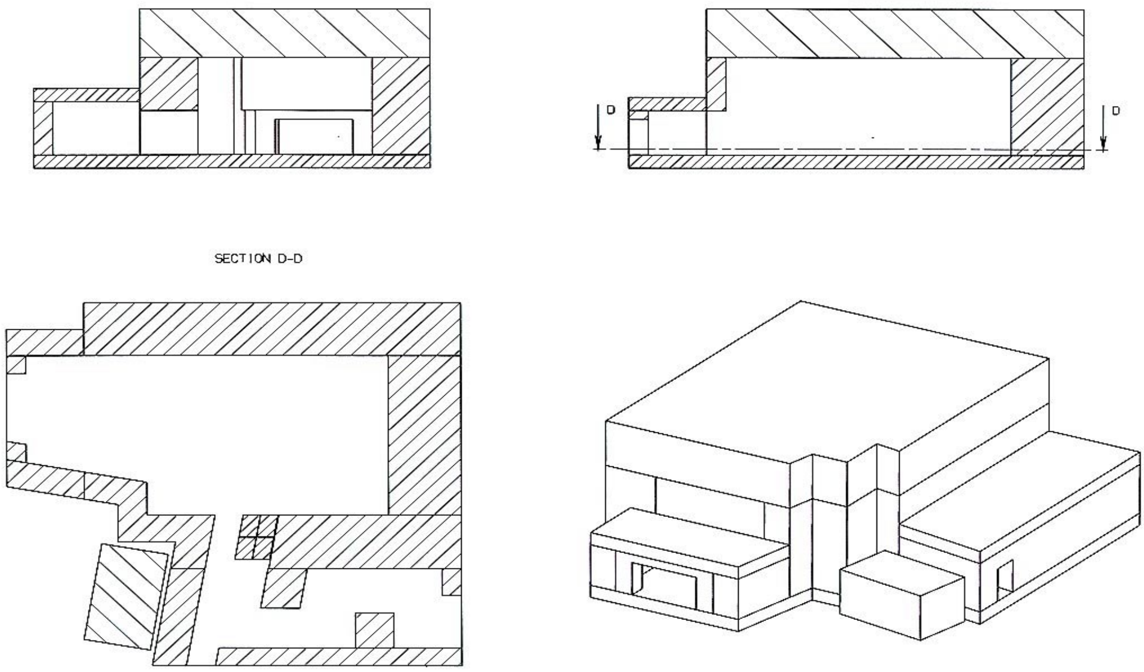

Figure 2.4: The plasma physics experimental station is another example for a concrete-building

There is a second type of halls, (Figure 2.5 and Figure 2.6), housing the collector ring, the NESR, the cooler and the experimental station of the HESR. These buildings, with a span of up to 100 m, will be set up as framed structures consisting of steel framework with inserted supports. The planned support grid will amount to 7.5 m. The shielding for the rings and experiment stations will be constructed by mobile concrete blocks. The roofs are to be assembled by a girder system as steel frame constructions. In sections with a high floor load (shielding), the base plate will be supported through underground piles.

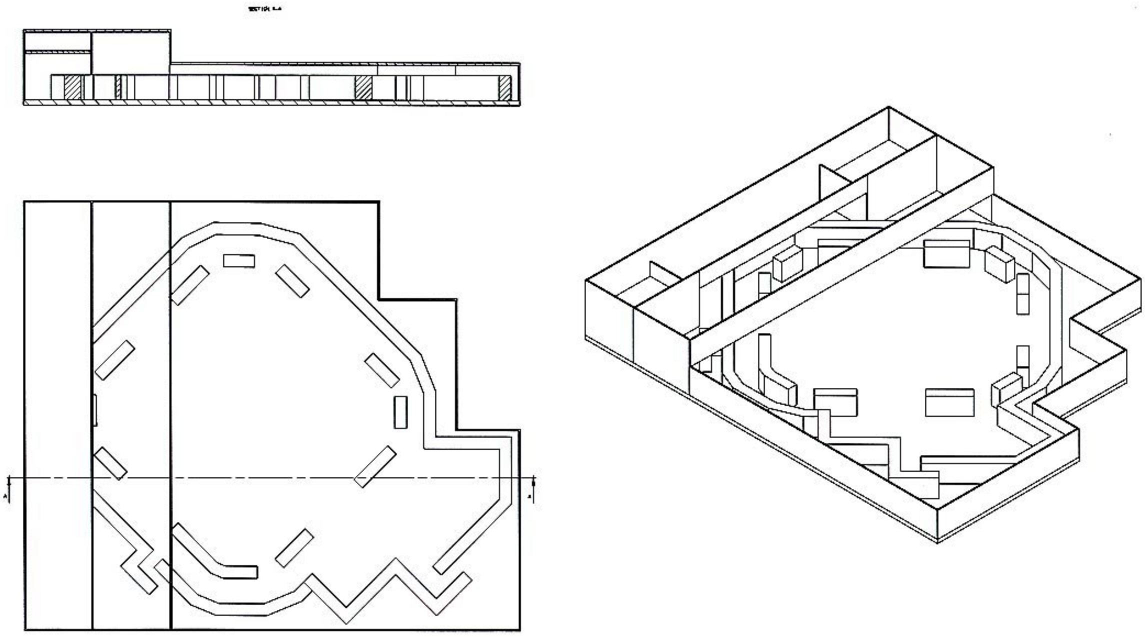

Figure 2.5: The NESR hall enveloping the storage ring and the appropriate shielding

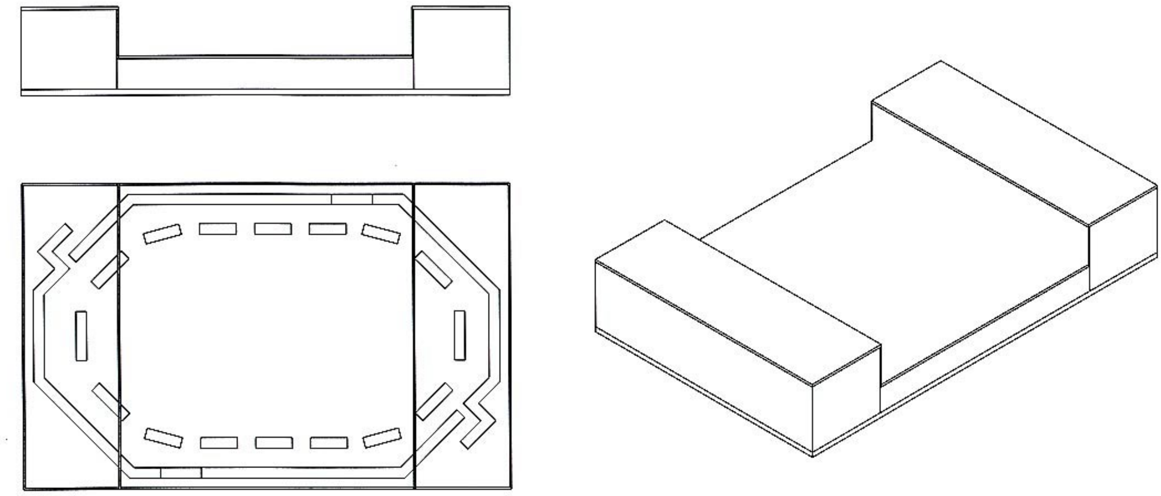

Figure 2.6: The CR-hall including crane and operations area

The operations buildings are planned as reinforced concrete structures which – for construction time reduction - might be set up as precast concrete units.

3 Supply Installations

3.1 Electric Power Supply

Presently, GSI is supplied by the 110/20 kV transformer station about 500 m off the laboratory. The power company "Hessische Elektrizitäts AG" (Heag) supplies GSI via three separate 20 kV lines (Figure 3.1). Downstream of the 110 kV bus bars, the pulse power consumption of the magnets of SIS/ESR is provided by one of these lines with a total of 30 MVA (Heag 1+2 parallel). In addition, there are lines for the Unilac area (Heag 3) and for SIS/ESR area (Heag 4) again totalling to 30 MVA. The two latter ones are run in a ring mode in order to avoid overloads.

In the future power supply the existing and the future pulse power need should be supplied directly from a 380 kV incoming line, as shown in Figure 3.1 on the right-hand side. The 20 kV control system will be set up centrally and will be separated into pulse power and remaining consumption. The cast resin dry type transformers will be installed in the load center.

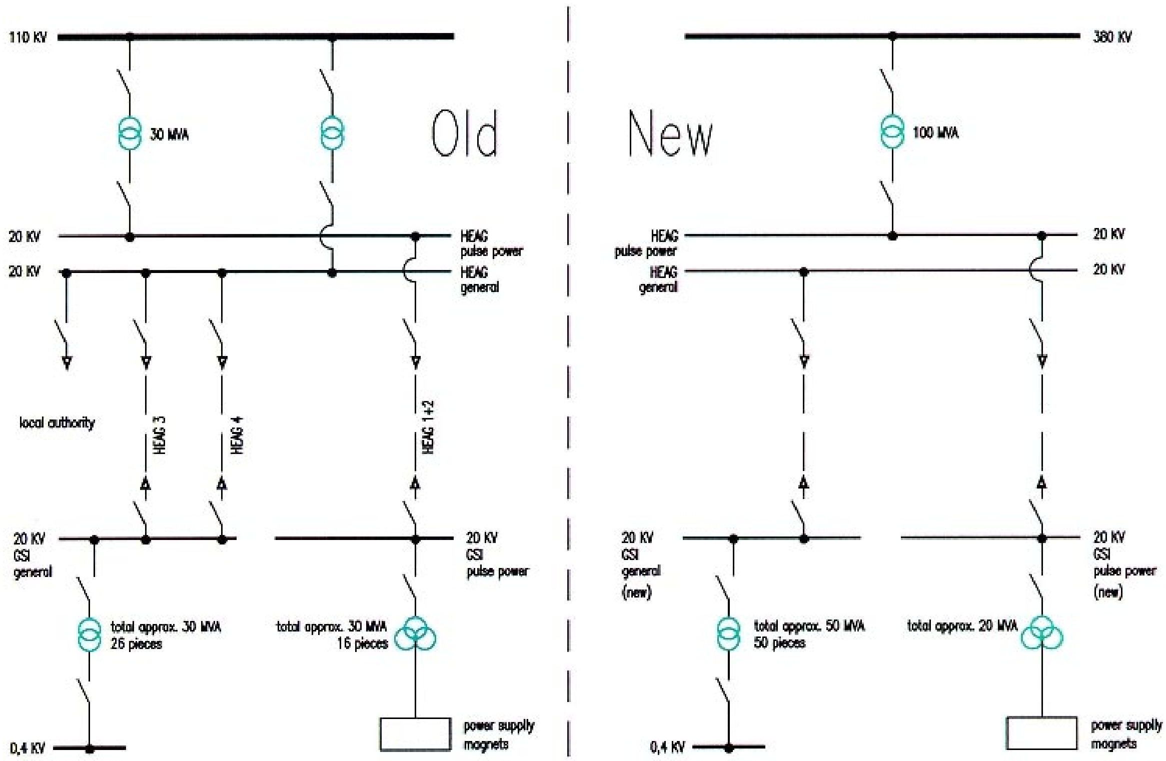

Figure 3.1: Planned modification of the electrical power network

For computer, measurement, diagnosis, and control systems, a decentralized net with an interruption-safe power supply will be installed. Basically, a structured power supply will be set up, mapping the structure of the accelerator complex. Parallel incoming lines and auxiliary incoming lines will guarantee power availability and flexibility during maintenance services.

The estimated costs for high voltage switchgears, transformers, distribution frames, interruption-safe power supply, and the cable network will total about DM 6 million.

3.2 Cooling facilities

The existing water cooling systems for the UNILAC and the SIS/ESR are working at full capacity. Therefore, the proposed new accelerator demands the design and installation of new cooling systems.
The experience gained from the operation of the current cooling units will influence the conception and the implementation of the new system. By using tested technology, in combination with new energy-saving methods, a relatively small increase of costs will produce a considerable increase in efficiency. As a result , we expect to get an optimum solution for the ecology and reduced operation costs. at the same time In order to avoid long pipe systems with correspondingly high transmission losses, it is recommended to produce the necessary cooling capacity of approximately 55 MW in two strategically located buildings.

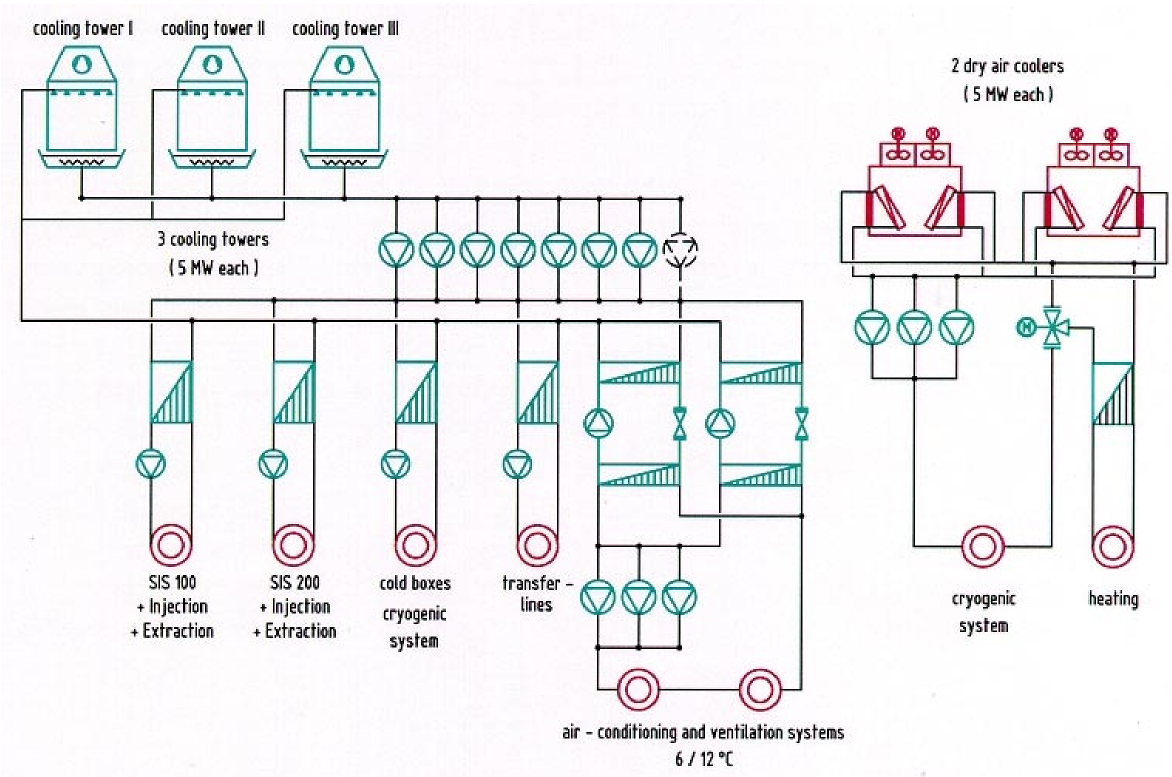

Figure 3.2: Diagram of the cooling facilities in „SIS cooling hall"

Located next to the cryogenic system, a cooling with a capacity of approx. 25 MW will be installed (Figure 3.2) consisting of

- a dry air cooler for cooling of the cryogenic system,
- a heat exchanger to meet the heat requirements in the buildings during operation periods,
- a cooling tower unit with five separate secondary cycles and
- a cooling unit to supply the air conditioning and ventilation systems.

The secondary cycles will work with an inlet temperature of approx. 25°C. They will cool the SIS 100/200, including injection and extraction, the transfer lines, the cold boxes of the cryogenic system, and the capacitors of the cold water units.

The second building is designed as an energy center. In this building, a cooling power of approx. 30 MW will be installed (Figure 3.3). The unit will consist of a cooling tower unit with eight separate secondary cycles, a second cooling unit, an additional heating unit to meet the heat requirements when the accelerator facilities are not in operation, a water purification unit for the production of demineralized water, and an air compressor. The secondary cycles are also to work with an inlet temperature of approx. 25°C. They will cool the experiments, the Super-FRS, the HESR, the NESR, the CR and the capacitors of the cold water units. This building will also host the process control center for the whole complex as well as a sufficiently large general hall/workshop.

During accelerator operation, the recovery cooled heat from the oil recovery cooler of the cryogenic system will be used to heat the buildings. When the accelerator is not in operation, An auxiliary heating unit is necessary running in accelerator shut down periods.

Experience gained with the operation of the existing cooling systems shows that water cooling towers offer the best capital to operation costs ratio. In the secondary cycle a inlet temperature of 25°C can be attained all year round. This enables cooling magnets and power supply units without using cooling facilities, which would require much higher capital costs and operation costs.

For operating cooling tower systems optimally, additional water is introduced through the demineralization facility and the cycle is equipped with an ozone dosage unit.

The secondary cycles for magnets and power supply units will be operated with varying volume flow pump stations, set up with redundancy to save energy. In large flow loops pumps are set up in steps and operated in combination of frequency controlled and normal pumps. A considerable amount of energy will be saved will by serial connection of consumers at the accelerator. By increasing the difference in temperature the rate of flow in the loop can be reduced, then requiring pumps of smaller dimensions.

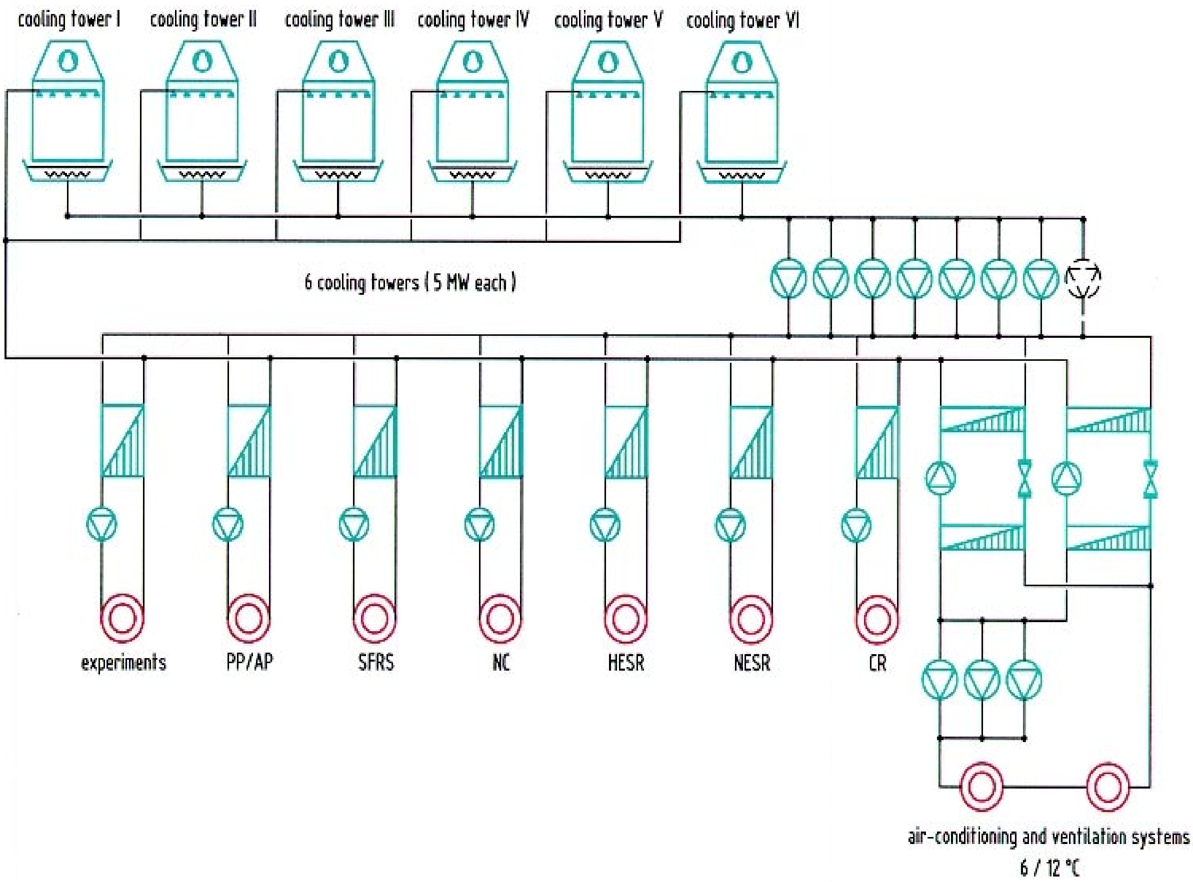

Figure 3.3: Diagram of the cooling facilities in the energy center hall

The cooling facilities consist of various cold water units, operating with an inlet/outlet temperature ratio of 6°C/12°C. The air conditioning and ventilation systems within the respective sections of the buildings are supplied by the cooling unit via buffer store and distribution systems.

The cooling facilities consist of various cold water units, operating with an inlet/outlet temperature ratio of 6°C/12°C. The air conditioning and ventilation systems within the respective sections of the buildings are supplied by the cooling unit via buffer store and distribution systems.

3.3 Air-conditioning and ventilation technologies

The criteria for the air conditioning and ventilation technologies are defined by the respective use of the buildings. Areas with activation, as e.g. the ring tunnel, require an air exchange once per hour and zones accessible to people every two hours . In zones with a high heat load , the air exchange is determined by the cooling capacity. For the specified buildings the following air volumes are determined:

Buildings	Cooling Criteria	air volume (m^3/h)
SIS 100/200	Activation; air exchange (once per hour)	36,000
Injection	Cooling 100 kW at 8 K	70,000
Extraction	Cooling 100 kW at 8 K	70,000
Transfer lines	Cooling 100 kW at 8 K	72,400
Plasma physics	Zones accessible to people, air exchange 0,5 times	18,000
AP	Activation; air exchange once per hour	13,000
Super-FRS	Zones hosting people, air exchange 0,5 times	11,000
Super-FRS	Air volume because of radiation protection	32,000
NC	Zones accessible to people, air exchange 0,5 times	25,000
HESR cave	Temperature constancy +/- 1,5°C	75,000
HESR cooler	Activation; air exchange once per hour	60,000
HESR	Activation; air exchange once per hour	15,000
NESR	Activation; air exchange once per hour	150,000
CR	Activation; air exchange once per hour	80,000
Vacuum assembly	clean room class 100.000	150,000
Exhaust air vacuum	Divided in 4 sections	30,000

For reasons of operation security and maintenance it is recommended that, from the air conditioning point of view, all units relevant for the accelerator and the experiments will be set up with some redundancy. After a certain number of operating hours and in case of malfunction the control system assigned to the respective unit turns on the redundancy unit. On a higher, manually operated level an emergency operation of the unit is allowed in case of a breakdown of the control unit.

The underground ring tunnel for SIS 100/200 is supplied with air streaming in from the injection building. The outgoing air is exhausted from the extraction area, and, depending on the operation method, can be fed in again as circulating air or can be exhausted to the exterior via a chimney. There are different operation modes for the accelerator tunnel: with pure circulating air, with 100 % outside air, or with an outside air percentage of 10% when the ring is accessed by maintenance personnel. Due to very limited space in the tunnel pipe, it is not possible to install additional circulating air coolers or heaters. For this reason air temperatures of 35 – 40°C have to be expected inside the tunnel during accelerator operation.

All ventilation units will be set up as combined circulating-air and mixed-air handling units ensuring an energy-optimized operation that is adapted to the exterior conditions and supplies.

The *vacuum exhaust-air* facility draws the possibly oil-polluted exhaust air in from the vacuum pumps, filters out polluted particles via copular filter cells and blows it out through a chimney. In order to avoid long pipeline sections and respectively substantial pressure loss this system will be divided into four locally separated sections.

3.4 Crane facilities

For assembly and maintenance of the accelerator and experiment components as well as of mobile shielding units, cranes will be necessary in the halls and experimental stations. The capacity and also the size of the crane bridge as well as the necessary transportation height influence the utilizable height of the hall and consequently the building costs. The plans propose nine large cranes with crane bridges between 20 and 75 meters and capacities of 10 to 25 tons in the halls for CR, HESR-cooler, HESR-Experiment, NESR, NC, PP, Super-FRS-low energy, Super-FRS-high energy and energy center.

The planned crane facilities will be set up in accordance with the industrial standard. They will be equipped with frequency-controlled drives in order to meet the demands on precise positioning. through a wireless crane control. The crane facilities will be set up in such a way that the crane bridge can also be used for assembling and servicing the hall ceilings – if this is technically possible.

4 Survey and Alignment of the Accelerator Components

4.1 Introduction

The buildings and their foundation, the magnets and their supports are all interrelated and need to be aligned within small tolerances on a geometrical precision grid. For a successful installation, the alignment possibility of each component and mechanical part has to be considered with great care from the early design phase on. Exact positioning of all elements with respect to the neighbouring components within the new facility is essential for a high beam quality, low losses and an easy commissioning of the machine.

Some considerations regarding the survey and alignment of the new accelerator facility will be conveyed in the following.

4.2 Alignment of Buildings

Each of the sections of the accelerator facility has to be placed on a foundation of its own. As experience has shown machines are subject to movements in vertical and horizontal directions up to millimeters. This is not only due to ground settlements but also to different subsurface structures and their different behavior due to seasonal changes.

Finally, all sections on their individual foundations are interconnected at well defined interface points and are surveyed by monitors.

4.3 Basic measurements

The existing UNILAC and synchrotron SIS will be used as injector for the new synchrotron accelerator complex. In order to connect the geometrical grid of the new facility to that of the existing plant, a comprehensive geodetic network has to be established, i.e. the positions of the existing machinery and new reference points have to be integrated into a homogeneous coordinate system. The absolute accuracy of the reference points should be better than a millimeter over the whole site.

Since the experimental caves and the storage ring halls are on the surface while the tunnel of the synchrotron is underground, it is necessary to connect the underground reference system with that on the surface. Special care has to be taken of the vertical measurement. The surface network should be measured by a high-precision triangulation and a network adjustment using theodolites, distance meters (total stations) and GPS.

4.4 Component fiducialization

Fiducialization determines the relation between the effective beam line of a component to external mechanical points that are accessible for survey measurements. It takes at least three of these points to fix height, radial and tangential position as well as yaw and pitch of the magnet. Roll for the last part can be measured directly. Alternatively, a concept based on three or four mechanical points could be used making a direct measurement of the roll unnecessary.

All components should be fiducialized before starting any pre-alignment. Experience has shown that the use of a laser tracker system is the best instrumentation for these measurements.

4.5 Superconducting magnets

For both synchrotrons, superconducting magnets will be used. This means the magnet itself is enclosed in a tank, cooled down by liquid helium and is therefore not directly accessible.

As we use reference targets for the positioning of the magnets, one has to be sure of the stability of the geometric connection between the fiducial points and the magnetic axis. In case of a superconducting magnet the targets are not fixed directly to the magnet but to the tank. In contrast to classical magnets the position of the fiducial target of a superconducting magnet and its magnetic field can change in the course of time due to, for example, thermal constraints. This is why particular attention must be paid to the method used to survey the movements of the inner components with respect to the tank.

Another point that is not to be neglected is the magnet support as an interface that allows mechanical mounting of components and their subsequent alignment to a nominal position in three dimensions. They must provide both, stability and precision of positioning which are substantially exceeding the final alignment tolerances.

4.6 Pre-Alignment

Pre-alignment will either be carried out for each component individually or different components will be assembled on girders, pre-aligned outside the tunnel and then be positioned as marked on the floor.

Girders have to be aligned after the transport to their final place. The measurements can be carried out by use of a motorized high-precision laser tracker systems.

4.7 Reference network

Network simulations and pre-analyses of different models lead to the design of an optimum number and location of instrument stations within the tunnel near the beam line providing the requested accuracy for the final alignment of the magnets.

New reference points are added to the existing reference system in order to increase their density and ensure coverage for all objects to be surveyed. A new complete network has to be measured after the construction work on buildings has been completed and after the pre-aligned girders and components have been brought onto the marked beam line. The measurements should include all reference points and magnet points. The comprehensive least square adjustment of the redundant observations provides adjusted coordinates of all measured points with an accuracy (standard deviation) generally better than 0.1 mm.

The reference network will be defined by many pillars and fixed points on the buildings that allow for the installation and observation of different survey instrumentation. E.g., in order to obtain good redundancy, each magnet point must be measured at least twice from neighboring instrument stations. The reference system must be constructed to meet these requirements. This also assumes structural conditions that allow the connection of networks between all sections of the accelerator facility (e.g. horizontal and vertical sight pipes).

4.8 Final alignment procedure

Based on the reference system all components are aligned with respect to the neighboring magnets within defined tolerances so that the positions of all parts of the facility are identified in a homogenous coordinate system. The best instrument for the final alignment is a state-of-the-art laser tracker system controlled by optimizing software, which helps control the movement and alignment process. The calibration and maintenance of the hardware and software is of utmost importance in order to provide a good alignment within an acceptable time, something which will also be reflected in the total costs of the installation.