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SIS100 TUNNEL DESIGN AND CIVIL CONSTRUCTION STATUS

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Abstract

As the FAIR Project is proceeding, building designs have been frozen and the according work packages tendered. For the future FAIR main driver accelerator, SIS100, the 1.1 km long accelerator tunnel "T110", has been planned 17 m deep under ground. In this article, environmental boundary conditions, the chosen layout and the current status of civil construction is presented.

INTRODUCTION

Large progress has been achieved in the civil construction of the FAIR project which led to an early construction of the northern building site of FAIR - which includes the SIS100 tunnel, too.

ACCELERATOR

The originally proposed FAIR project comprised two main accelerators, SIS100 and SIS300 [1]. As it has been decided to build a modularized start version with the SIS100 first, only the space is reserved, but no HVAC infrastructure will be installed for the future SIS300 [2].

The SIS100 is a 1083.6 m long, superconducting heavy ion accelerator [3]. To achieve the demands for average beam intensity of the FAIR experiments, it is a fast ramped synchrotron ($\dot{B}$ = 4 T/s). Sufficient space for the necessary insertions had to be provided, which is fulfilled by a 6-fold symmetry with 51.6 m long straight sections, see Fig. 1. Both 2-phase-flow LHe and 13.1 kA electric current supply are bridged throughout the straight sections with an unique, integrated cryogenic bypass system. This bypass system supplies the long cryogenic arcs and straight section quadrupole doublet modules.

The SIS100 accelerates all ions from 28.8 GeV Protons to 2.7 GeV/u Uranium, but is optimized for high intensity heavy ion beams with a specific beam loss pattern - which impose constraints on the radiation protection. The SIS100 reference orbit height is 1.4 m above floor; later on, SIS300 will be suspended on the ceiling on top of SIS100 at 2.8 m orbit height. Both machines, their necessary infrastructure and transport space require an accelerator tunnel cross section of (W×H) 6.5 m×4.5 m.

TUNNEL DESIGN CONSIDERATIONS

The land development plan of the GSI/FAIR site in Darmstadt, approved by the authorities, regulates among type and degree of building, building positions, height, forest clearance and ecological balancing. Part of FAIR is constructed in public area, therefore these regulations hinder the economic placement of above ground supply buildings in the forest.

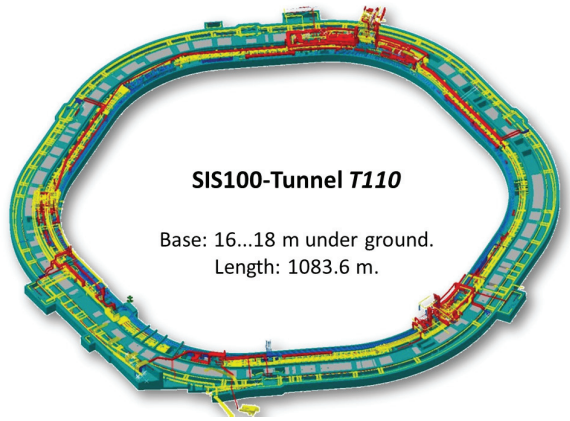

Figure 1: Overview of the lowest underground level of *T110*.

To fulfill the legal boundary conditions [4], the accelerator tunnel has to be shielded with 2 m, water-tight sealed concrete on all sides with additional shielding at the extraction section and the HEBT extraction line towards ground level. The height of soil required on top of SIS100 tunnel defines the vertical depth itself (17 m below ground level).

Electronics are prone to radiation damage or logic errors at dose rates which could be expected for the SIS100 supply areas without proper shielding [5]. Furthermore, activation of components and air in the *T110* supply areas could be expected, too. To provide a high availability of SIS100, a low dose rate in the supply areas has to be guaranteed.

The LHe for cooling of the s.c. magnets is fed into the bypass system by three feedboxes. They are situated in separate cryo niches which are attached to the outside of the tunnel.

The use of a tunnel boring machine (TBM) was not possible. On the one hand, a very high groundwater level (up to 1 m below ground) exists; on the other hand, the small bending radius of 50 m is technically not possible with a TBM; furthermore, the comparably short length of the tunnel is on the lower end for economic use of such a machine. Therefore, it was chosen to dig into the ground with an open excavation pit.

GENERAL TUNNEL LAYOUT

Given the above mentioned constraints, the SIS100 tunnel *T110* was chosen to be separated into an outer ring tunnel housing the accelerator itself, an inner ring tunnel for the supply installations and a 7 m wide soil shielding package in between, see Fig. 2. These segments are sitting on a common

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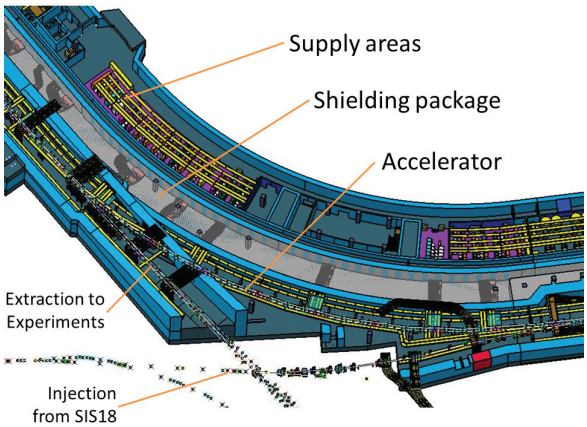

Figure 2: Detailed view of *T110* layout.

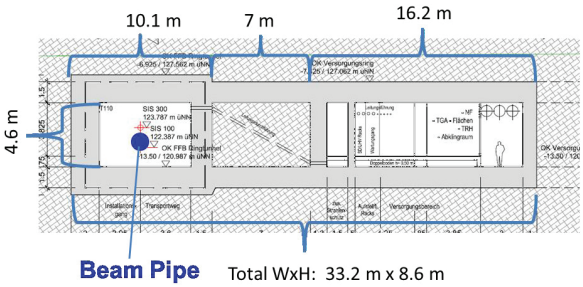

Figure 3: Typical *T110* tunnel cross section.

base plate and form a rectangular shaped, massive concrete structure with a 5-beam layout, see Fig. 3 (the 5th beam is a pile and not shown).

For radiation protection reasons, cables between the accelerator and the supply area are routed diagonally in ductwork which is air tight sealed at one side. To fit all SIS100 and future SIS300 accelerator supply components, a total supply area floor space of 12 670 m^2 has been planned. The whole tunnel is separated into 6 segments with fireproof walls and has three access labyrinths. At some places (in the vicinity of the access points), the tunnel is up to 5 stories high.

CURRENT STATUS OF CIVIL CONSTRUCTION

In 2016, major efforts aiming for an earliest possible start of civil construction of the SIS100 tunnel and related parts have been undertaken. This has been done with a priority to the northern buildings of the FAIR construction site:

- SIS100 tunnel (*T110*),
- HEBT tunnels from SIS18 to SIS100 (*T101*) and from SIS100 to the CBM experiment (*T112*),
- HEBT crossing and supply building (*G004/4a*),
- CBM building (*G014*) and cryogenic central building (*G017A*),
- FAIR main electrical distribution and cooling/heating water supply building (*G17.1*).

Figure 4: Groundbreaking ceremony.

Figure 5: View into the excavation pit.

The radiation protection permit has been received already 09/2013. The contract for the northern site excavation pit was awarded to a consortium of BÖGL, STRABAG, STUMP and ZÜBLIN in 05/2017. As the real start of works was eminent, the official groundbreaking ceremony was held on 4th of July 2017 (see Fig. 4).

Before start of digging the open excavation pit for the tunnel, the ground water has been lowered by use of an overlapping bored pile wall and suitable placed wells and pumps. This wall has been stabilized by earth anchors. Some problems due to larger than expected groundwater flows have been solved by installation of additional water pumps. As of now, the pit has reached its lower limit of 20 m below ground level at the first section (SIS100 sectors 4/5 in the northwest), see Fig. 5. Further construction will follow counter-clockwise, completing one arc and one straight section each step.

Figure 6: Actual view of the construction site.

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The FAIR civil construction, on the other hand, imposes a difficulty for the running GSI experiment program: The reduced groundwater level leads to a settlement of the nearby SIS18 accelerator tunnel (RT) [6]. Latest laser-tracker measurements show a one-sided lowering of SIS18 by ≈1 cm. As further movement was already predicted beforehand [7], this misalignment is constantly monitored and will be adjusted before start of the beam time in June 2018.

In the meanwhile, FAIR's main transformer station north (2x63 MVA) has been brought to operation; the southern transformer station is nearing completion, as well. Finally, the shell building of the above mentioned northern buildings was contracted to company PORR in 01/2018. Shortly afterward, the concrete mixing plant installation started. The handover of the excavation pit and start of concrete shell building construction is scheduled to follow in 05/2018.

As of now, HVAC and electrical planning, as well as supply area planning is finalized to start the European tendering procedure, as well.

After construction of the tunnel, the pit will be filled up with earth again. The upper part of the constructed wall will be removed to allow ground water to flow to the forest's trees again. It is planned to finish the FAIR buildings construction end of 2022. An actual view of the construction site can be seen in Fig. 6 or on the FAIR webcam [8].

CONCLUSIONS

Parts of FAIR will be constructed in very special environmental conditions. The chosen SIS100 parallel tunnel design respects the environmental boundary conditions and fulfills the German regulations and laws for radioprotection and fire protection. Civil construction of the northern FAIR site has successfully started and is currently in schedule. Due to set priorities, the southern part of the site is lagging a little behind schedule but is believed to catch up.

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