# Combined steering magnets for CR. CDR Review.

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BINP, Novosibirsk

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# Outline

1. CDR documentation
2. Project management structure
3. Purpose and Basic Principles
4. Quantity in CR
5. Magnetic simulations
6. Risk analysis
7. Production and realization – manufacturing process chart
8. Production plan

# CDR Documentations

The Detailed Specification is outlined in EDMS
https://edms.cern.ch/ui/#!master/navigator/document?P:1987795909:1633987445:subDocs

The set of documents for the *CR_Combined horizontal/vertical Steering Magnets (AID:0002520)* is given in EDMS

3D-model
https://edms.cern.ch/ui/#!master/navigator/document?D:100364198:100364198:subDocs

Quality plan, Magnetic measurements plan
https://edms.cern.ch/ui/#!master/navigator/document?D:100364194:100364194:subDocs

Risk analysis and hazard analysis
https://edms.cern.ch/ui/#!master/navigator/document?D:100364190:100364190:subDocs

Installation and operation manual
https://edms.cern.ch/ui/#!master/navigator/document?D:100364192:100364192:subDocs

# Project Management Structure

- *Work Package Leader (WPL)*

Name: *Alexander Starostenko (A.A.Starostenko@inp.nsk.su, Head of BINP Division № 5-11)*

The Project Manager is responsible for:

  - Follow-up of production activities;
  - Regular and timely reporting on progress and problems;
  - Timely conduction/participation of reviews and provisions of feedback;

- *Deputies*

Name: *Aleksander Tsyganov (A.S.Tsygunov@inp.nsk.su, Research Scientist)*

The Deputy is responsible for:

  - Development of the technical documentation and manufacturing drawings for the deliverables;
  - Ensuring that the production of the magnets is according to the technical specifications and time schedule;
  - Preliminary magnet design, final magnet design (development, simulation);
  - Follow-up of production activities;
  - Magnetic measurements to ensure the required field and field quality;
  - Transportation, delivery of the equipment to the FAIR site;
  - Factory Acceptance Test (FAT) to verify the given specifications of the components;

Name: *Tatyana Rybitskaya (T.V.Rybitskaya@inp.nsk.su, Research Scientist)*

The Deputy is responsible for:

  - Magnetic field calculation;

- *Scientific Design Department*

Name: *Andrey Molokoedov (A.M.Molokoedov@inp.nsk.su, Principal Design Engineer)*

The Principal Design Engineer is responsible for:

  - Combined steering magnet design (3D-models, production drawings);

*Details in "Quality Plan"*

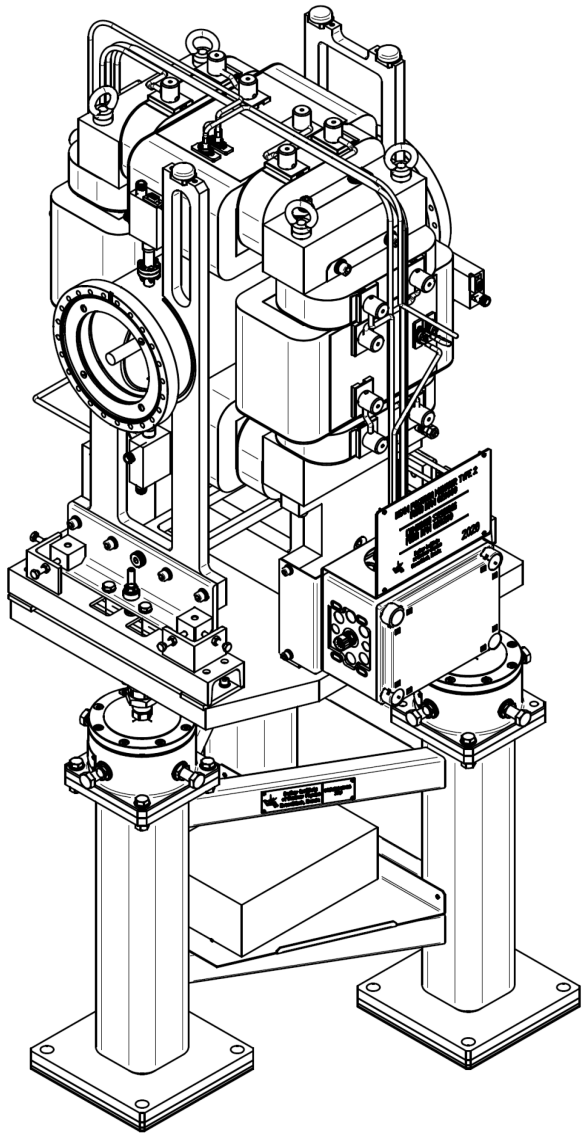
# Purpose and Basic Principles

Combined steering magnets are used to create a magnetic field of high quality for small-angle two-axis correction the of charged particle beam trajectories in the CR of FAIR.

These steerings are O-Shape magnets.

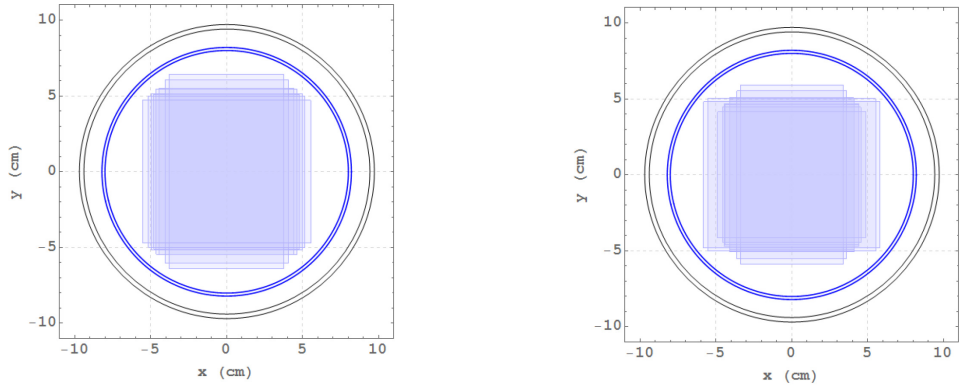
These coils of steerer are made of copper bar, which is cooled in the air.

This corrector is combined with the BPM (Type2).



# Quantity in CR

- 5 combined steering magnets.



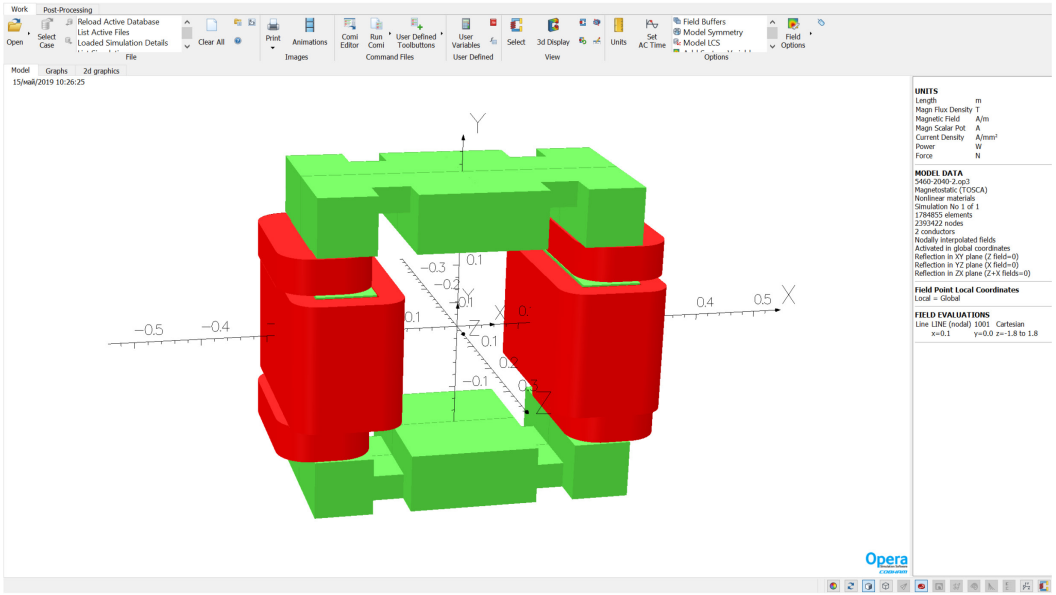

*Maximum beam size at different points along the CR straights pbar – left, ions – right.*

*Approximately R=100mm of useful aperture and maximum beam size at different points along the CR arcs: pbar – left, ions – right (Figs from CDR of BPM - TYPE 2)*

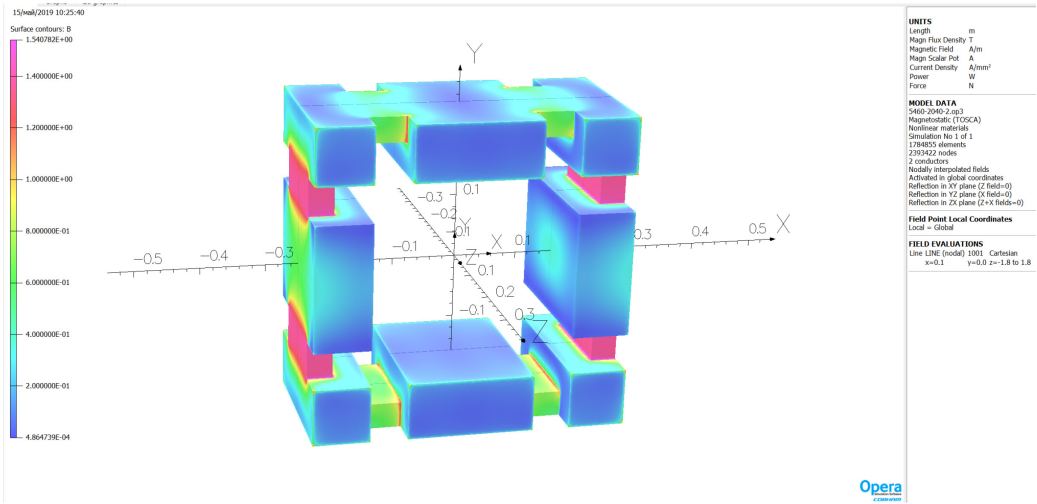
*The 3D model of combined steering magnet is ready.*

# Magnetic simulation

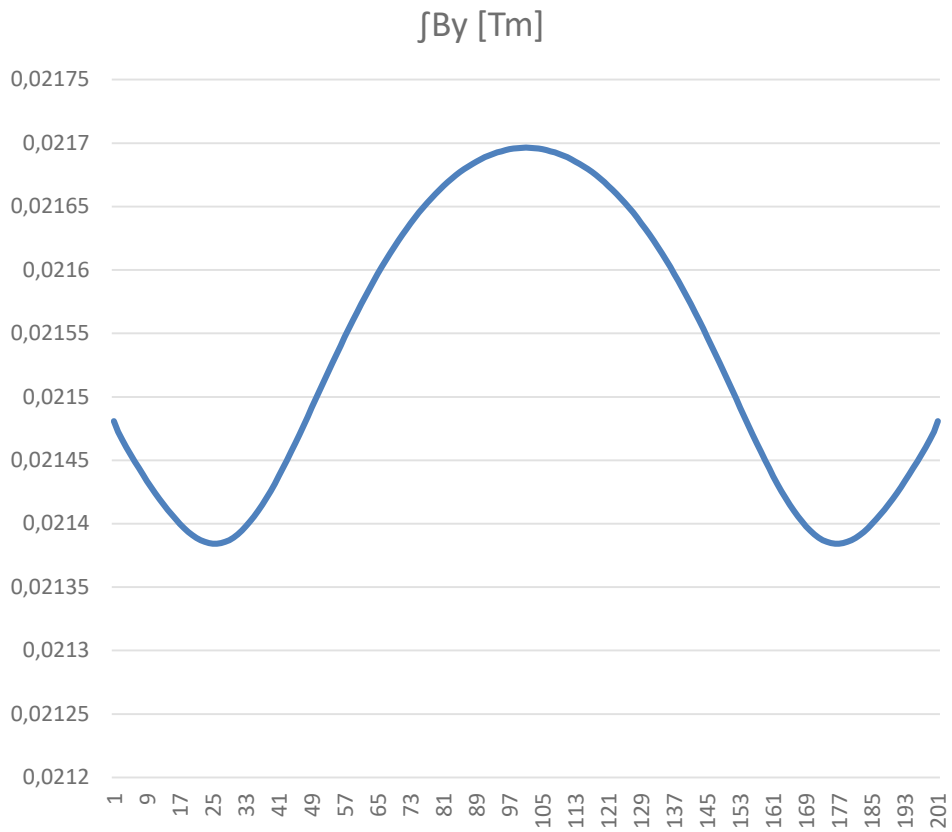
*The simulation model of combined steering magnet with coils only to the horizontal correction of beam trajectories..*




*The magnetic saturation in the yoke. Units of measure [T].*



# Magnetic simulation

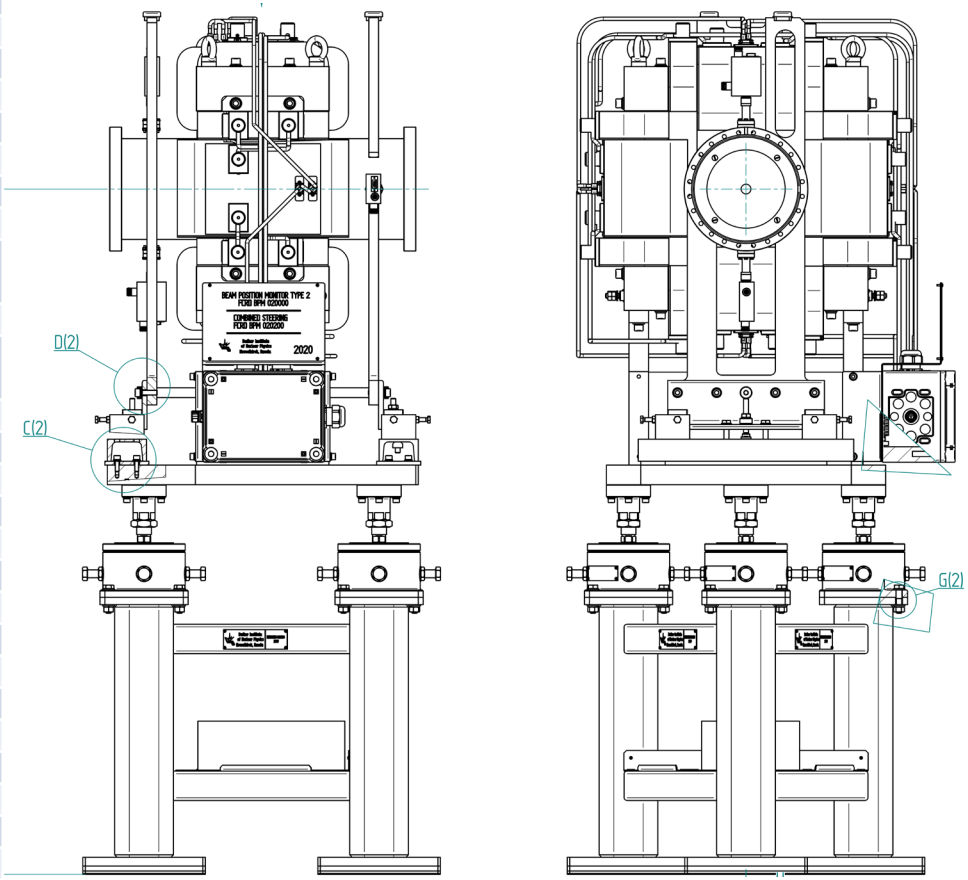



The simulation values of integral in the magnetic field By [T] for different points for the half circle with radius 0,1m.

Between the maximum and minimum values of the integral ∫Bydz difference ± 0,72 %

# Main parameters for combined steering magnets

| Parameter | Value | Units |
|---|---|---|
| Maximum flux density | 0.0335 | T |
| Field quality, ΔB/B | ±1.5 | % |
| Maximum field integral | 0.02 | T·m |
| Correction angle | ±1.5 | mrad |
| | | |
| Overall weight without stand | 670 | kg |
| | | |
| Time for polarity change less | 1 | s |
| External radius of the vacuum chamber in the steering magnet | 100 | mm |
| Packing factor | solid | |
| BH-curve | M1200-100A or AISI 1010 | |
| Yoke length | 270 | mm |
| Iron weight without stand | 358 | kg |
| Data of coils | | |
| Corrector length with coils | 350 | mm |
| Corrector height without stand | 597 | mm |
| Corrector width | 597 | mm |
| Current density in conductor | 1 | A/ $mm^2$ |
| Number of turns | 1272x2 | |
| | | |
| Conductor cross section | 2.5x6.3 | $mm^2$ |
| Copper weight per magnet | 312 | kg |
| Current at max field | 15 | A |
| Voltage | 16.5 | V |
| Power consumption per magnet | 250+250 | W |
| Resistance per magnet | 1.1+1.1 | Ohm |
| Inductance per magnet | 320 | mH |




Details available in EDMS:
https://edms.cern.ch/ui/#!master/navigator/document?P:1987795909:1633987445:subDocs

# Risk Assessment Table (I)

| Risk Log | | Risk Identification | | | Risk Rating Pre-Mitigation | | | Risk Mitigration | Post-Mitigation Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Risk- ID | № | Description of Risk (orientating to the hazard) | Life cycle | Possible consequences | Probability of Occurrence | Impact | Risk Level | Mitigration Strategy | Probability of Occurrence | Impact | Risk Level |
| | | TECHNICAL RISKS | | | | | | | | | |
| | | Mechanical hazards | | | | | | | | | |
| RL-001 | 1 | Dent in the magnet (pole) | BCI | Damage of parts of the magnet;<br><br>Performance below specification;<br><br>Failed to reach the required field quality | 2 | 3 | 2 | Check that fastening bolts between the yoke plates and blocks are correctly tightened;<br>Check that lifting eye bolts are correctly tightened;<br>Check that used chains, straps and hooks have the weight rating adapted to the magnet weight, corresponding number of attachment points and corresponding lifting angles.<br>Magnet must be properly fastened to a suitable stand to prevent any fall during installation, operation, maintenance and storage.<br>Obey warning signs and boundaries.<br><br>Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_SHV_Installation_Operation_manual_A. | 1 | 3 | 2 |
| RL-002 | 2 | Failure of welding joints | ABCI | Damage of parts of the magnet | 2 | 3 | 2 | Carry out inspection of welding lines on a regular basis.<br>Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_SHV_Installation_Operation_manual_A. | 1 | 3 | 2 |
| RL-003 | 3 | Failure of brazing joints | ABCI | Damage of parts of the magnet; | 2 | 3 | 2 | Carry out inspection of brazing joints on a regular basis.<br>Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_SHV_Installation_Operation_manual_A. | 1 | 3 | 2 |
| RL-004 | 4 | Magnet falling during handling | BCJ | Damage of parts of the magnet up to complete loss of the magnet;<br><br>Personnel injury | 2 | 4 | 3 | Check that fastening bolts between the yoke plates and blocks are correctly tightened;<br>Check that lifting eye bolts are correctly tightened;<br>Check that used chains, straps and hooks have the weight rating adapted to the magnet weight, corresponding number of attachment points and corresponding lifting angles.<br>Magnet must be properly fastened to a suitable stand to prevent any fall during installation, operation, maintenance and storage.<br>Obey warning signs and boundaries.<br><br>Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_SHV_Installation_Operation_manual_A. | 1 | 4 | 2 |
| | | Electrical hazards | | | | | | | | | |
| RL-005 | 5 | Contact with live parts | ACDF GHI | Electrical shock;<br><br>Personnel injury | 1 | 1 | 1 | Electrical equipment must be de-energized before work is conducted unless special exceptions exist.<br>Only qualified and authorized personnel may work with or near live parts, and only with a valid Electrical Work Permit.<br>Rule out accidental touching of live parts while an employee works with or near them.<br>Use proper Personal Protective Equipment.<br>Obey warning signs and boundaries. | 1 | 1 | 1 |
| RL-006 | 6 | Cracks or breaks in the insulation (turn-to-turn insulation, layer-to-layer insulation, coil-to-yoke insulation) | CI | Loss of equipment functionality;<br><br>Short circuits and fire | 2 | 3 | 2 | Carry out inspection of insulation (including thermal imaging) on a regular basis.<br>Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_SHV_Installation_Operation_manual_A. | 1 | 3 | 2 |
| RL-007 | 7 | Cable breaks (power, diagnostic, etc.) including cracks or breaks in the insulation, failure of cable connections | CI | Loss of equipment functionality;<br><br>Electrical shock;<br><br>Fire;<br><br>Personnel injury | 2 | 3 | 2 | Cables must be labelled.<br>Cables ust be traceable, viewable and accessible.<br>Cables must be protected from mechanical damage.<br>Avoid creating stumbling hazards with cables.<br>Regular inspection of insulation and connections.<br>Braked cables must be marked, apply a do-not-use tag.<br>Braked cables must be replaced. | 1 | 3 | 2 |

# Risk Assessment Table (II)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **RL-008** | **8** | **Thermoswitch internal interlock failure (temperature of coil)** | **D** | **Coils overheating** | **1** | **3** | **2** | **Check visually/electrically the continuity of thermoswitches.<br>De-energize magnet in case of coils overheating.** | **1** | **3** | **2** |
| **RL-009** | 9 | Power/ power supply failure (supply interrupted due to external reason) | D | Loss of equipment functionality | 2 | 1 | 1 | Does not require any action (supply interrupted due to external reason). | 2 | 1 | 1 |
| **RL-010** | 10 | Magnet still energized | ALL excluding BEJ | Would be no consequences | 1 | 1 | 1 | Does not require any action (would be no consequences). | 1 | 1 | 1 |
| **RL-011** | 11 | Work with power tools | ALL excluding BD | Electrical shock;<br><br>Personnel injury | 1 | 1 | 1 | Maintain tools so they are in good condition.<br>Inspect tools before each use.<br>Use the right tool for the job.<br>Use tools in accordance with manufacturers' instructions.<br>Obey all labels and instructions.<br>Worn-out tools must be marked, apply a do-not-use tag.<br>Worn-out tools must be replaced. | 1 | 1 | 1 |
| | | Humidity hazards | | | | | | | | | |
| **RL-012** | 12 | Dysfunctioning of thermoswitches | CGHI | Risk of coils overheat | 2 | 2 | 1 | Follow installation instructions according to the BINP Installation and Operation Manual, FCRM_SHV_Installation_Operation_manual_A. | 1 | 2 | 1 |
| **RL-014** | 14 | High air humidity in the environment around the magnet | BD | Corrosion | 4 | 1 | 1 | Magnets will be packed for transportation under the conditions to avoid contact of product with rain water, spatter or condensates.<br><br>Use climate-control system in the tunnel.<br>Carry out preventive diagnostic measures in the tunnel on a regular basis. | 3 | 1 | 1 |
| | | Thermal hazards | | | | | | | | | |
| **RL-015** | 15 | Fire/high temperature also origin of noxious gases (initiator inside/outside of the magnet) | ALL excluding BEJ | Equipment failure up to complete loss of the magnet;<br><br>Personnel injury | 1 | 5 | 2 | Use fire supervision system in the tunnel.<br>Carry out preventive diagnostic measures in the tunnel on a regular basis.<br>Use automatic fire suppression system in the tunnel.<br><br>Use fire-proof and non-toxic materials.<br>Verify that the area is free from unnecessary inflammables.<br><br>Follow the GSI Safety Regulations. Complete the required GSI Safety Trainings. | 1 | 5 | 2 |
| | | Radiation hazards | | | | | | | | | |
| **RL-016** | 16 | Accidental release of radiation to the tunnel environment (initiator fire and/or mechanical damage to the equipment) | D | Tunnel environment radioactive contamination;<br><br>Workers exposure to radiation;<br><br>Difficulties to repair and maintenance of equipment | 1 | 5 | 2 | Use radioactivity supervision system in the tunnel.<br>Carry out preventive diagnostic measures in the tunnel on a regular basis.<br><br>Follow the GSI Safety Regulations. Complete the required GSI Safety Trainings. | 1 | 5 | 2 |

# Risk Assessment Table (III)

| | | Magnetic field hazards | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RL-017 | 17 | Magnetic field | ALL excluding BEJ | Personnel injury | 1 | 1 | 1 | The area surrounding the magnet is not recommended to the people carrying a pacemaker.<br>Obey warning signs and boundaries. | 1 | 1 | 1 |
| RL-018 | 18 | Magnetizable objects | D | Equipment failure | 4 | 1 | 1 | Do not use magnetizable tools when the magnet is powered. | 2 | 1 | 1 |
| | | Ergonomic hazards | | | | | | | | | |
| RL-019 | 19 | Accidents of the magnet sharp edges | ALL | Personnel injury | 3 | 1 | 1 | Use the rubber corner bumpers.<br>Use the basic Personal Protective Equipment (hard hats, safety glasses, steel tip shoes). | 2 | 1 | 1 |
| | | Combination of hazards | | | | | | | | | |
| RL-020 | 20 | Design alteration and/or performance below specification | A | Delays to the schedule;<br><br>Failed to reach the required field quality | 3 | 3 | 3 | The Parties shall monitor the scientific and technical progress of the Collaboration Contract activities.<br>The Parties shall clarify the Technical Specifications during the project development.<br><br>(Risk originated mainly from unpredictable deviation of the magnetic susceptibility of the stainless steel material of combined steerers vacuum chambers from the specified low value.) | 2 | 3 | 2 |
| RL-021 | 21 | Lack of knowledge about GSI site, GSI safety regulations and procedures | ALL excluding AB | Damage to the personnel health due to hazards created by others | 2 | 1 | 1 | The Parties shall coordinate efforts to create and maintain a clean and organized work environment.<br>Follow the GSI Safety Regulations. Complete the required GSI Safety Trainings. | 1 | 1 | 1 |

Based on Arrangement of Risks

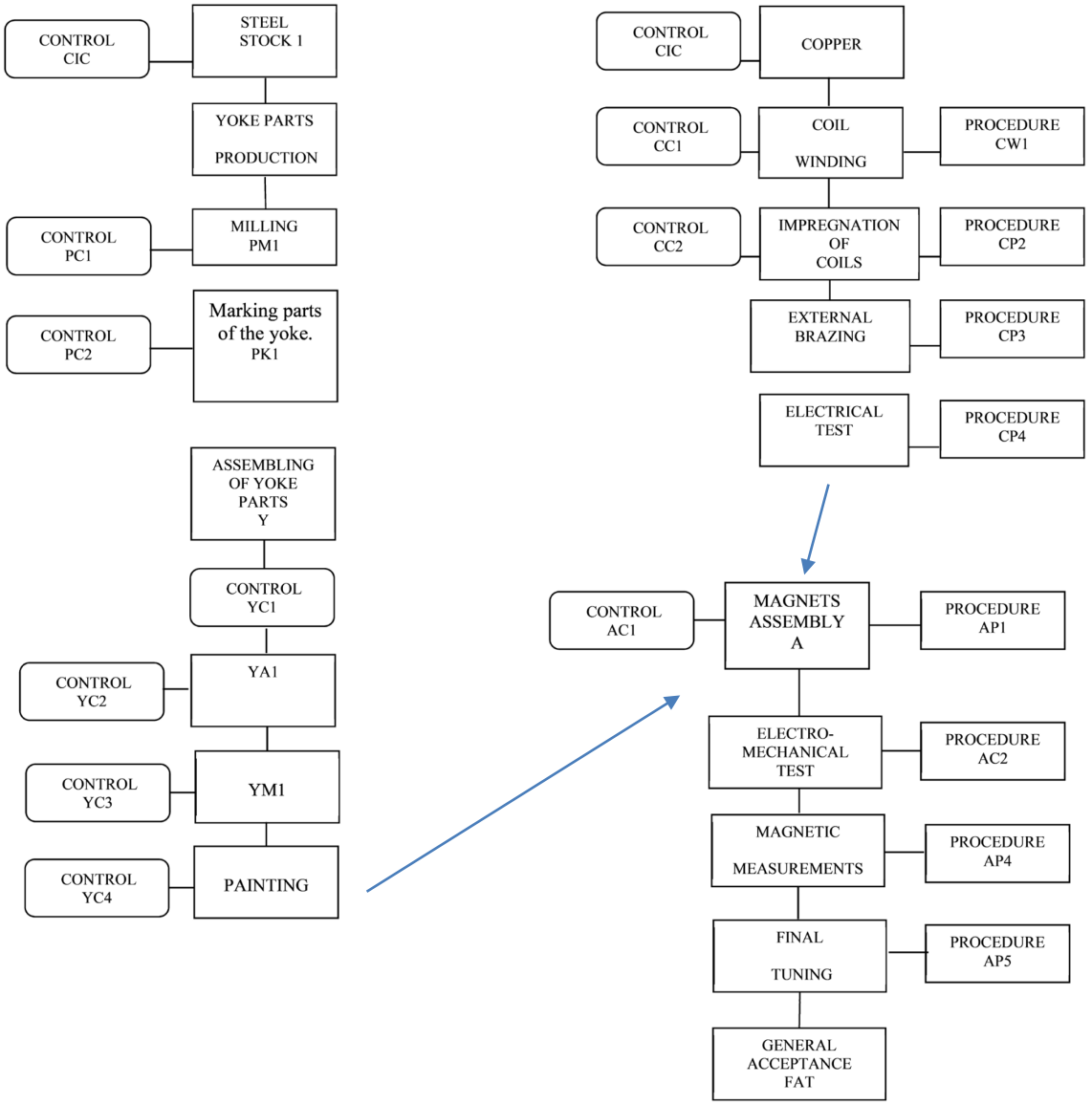
Includes: Mechanical, Electrical, Thermal, Humidity, Radiation, Magnetic, Ergonomic and Combined hazards.

Ranges risk hazards on its impacts and propose Mitigation Actions

# Manufacturing Process Chart

Acronyms and Abbreviations:

| | |
|---|---|
| P | The yoke parts production |
| PM1 | Milling the yoke parts |
| PC1 | Checking the dimensions and the holes' positions of the yoke parts during production. |
| PC2 | Checking the number and types of yoke parts. |
| PK1 | Marking parts of the yoke. |
| Y | Yoke production |
| YC1 | Check completeness (availability of all parts and fasteners) |
| YA1 | Assembling of yoke parts procedure. |
| YC2 | Check the assembling. |
| YM1 | Processing of the assembled yoke |
| YC3 | Check the dimensions of the machining. |
| YC4 | Visual check the paintwork. |
| C | Coil production |
| CW1 | Coil winding procedure. |
| CC1 | Check dimensions and interturn insulation of the coils before impregnation. |
| CP2 | Coil impregnation procedure. |
| CC2 | Check dimensions of the coils after the impregnation. |
| CP3 | Brazing procedure for external brazing. |
| CP4 | Electrical tests of the coils. |
| A | Magnet assembly |
| AP1 | Magnets assembly procedure. |
| AC1 | Check the magnet dimensions. |
| AC2 | Electrical tests procedure. |
| AP4 | Magnetic measurements procedure. |
| AP5 | Final tuning procedure if necessary. |
| | General acceptance. FAT. |
| | Packing. |



# Milestones

- April 2019 – May 2019 : preparation and **passing milestone M6 (CDR)**
- June 2019 – October 2019: detail designing, preparation of drawings**. Passing milestone M7 (FDR)**. Purchasing required accessories, materials, components
- November 2019 – May 2020: tooling production, test bench development and production, tooling manufacturing in experimental workshop-1 (EW-1)
- June 2020 – October 2020: **FoS testing, QA, magnetic measure, FoS revision. Passing milestone M8**
- March 2021 – November 2022: manufacturing and testing the other combined steering magnets, FAT, delivering to FAIR facility, SAT, pre-installation assembling. Approximately 1 combined steering magnets every 5 month.
- December 2022 – February 2023: final installation in CR tunnel **[All series M10 – January 2023]**

# Summary

- Quality plan is prepared and uploaded to EDMS – Q2-2019
- Risk Analysis is prepared and uploaded to EDMS – Q2-2019
- 3D models is ready and uploaded to EDMS (2D drawings in EW) – Q2-2019
- Production chart and main milestones defined and presented – Q2-2019
- FoS production is started (material procurement as well) – Q4-2020

- Ready for CDR check and approval (protocol signature) for combined steering magnet – Q2-2019