Sextupole lens for CR.
CDR Review.

A. Tsyganov for CR team

BINP, Novosibirsk

May 23, 2019
2st FAIR Workshop, Darmstadt , Germany

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:1987795909:1338329016:subDocs

The set of documents for the *CR_TCR1_Sextupole magnets (AID:0002518)* is given in EDMS

3D-model
https://edms.cern.ch/ui/#!master/navigator/document?D:100364164:100364164:subDocs

Quality plan, Magnetic measurements plan
https://edms.cern.ch/ui/#!master/navigator/document?D:100364160:100364160:subDocs

Risk analysis and hazard analysis
https://edms.cern.ch/ui/#!master/navigator/document?D:100364156:100364156:subDocs

Installation and operation manual
https://edms.cern.ch/ui/#!master/navigator/document?D:100364158:100364158: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: *Alexander 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;
- 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: *Vladimir Korchagin (V.Ya.Korchagin@inp.nsk.su, Principal Design Engineer)*

The Principal Design Engineer is responsible for:

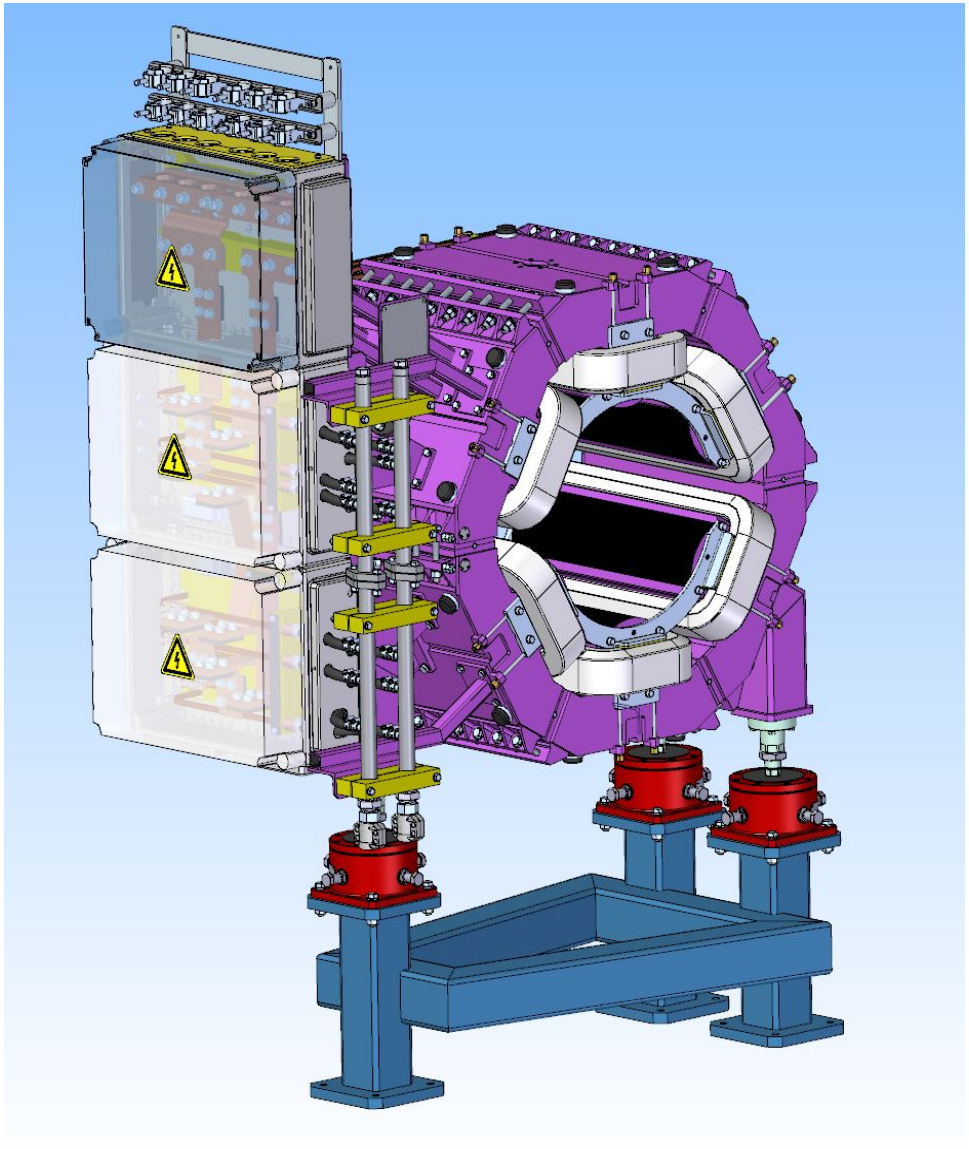
- Sextupole lens design (3D-models, production drawings);

Details in "Quality Plan"

Purpose and Basic Principles

Sextupoles are used to create a magnetic field of high quality for chromatic corrections in the FAIR Collector Ring System.

These coils of sextupole are made of copper bus, which is cooled in the water.

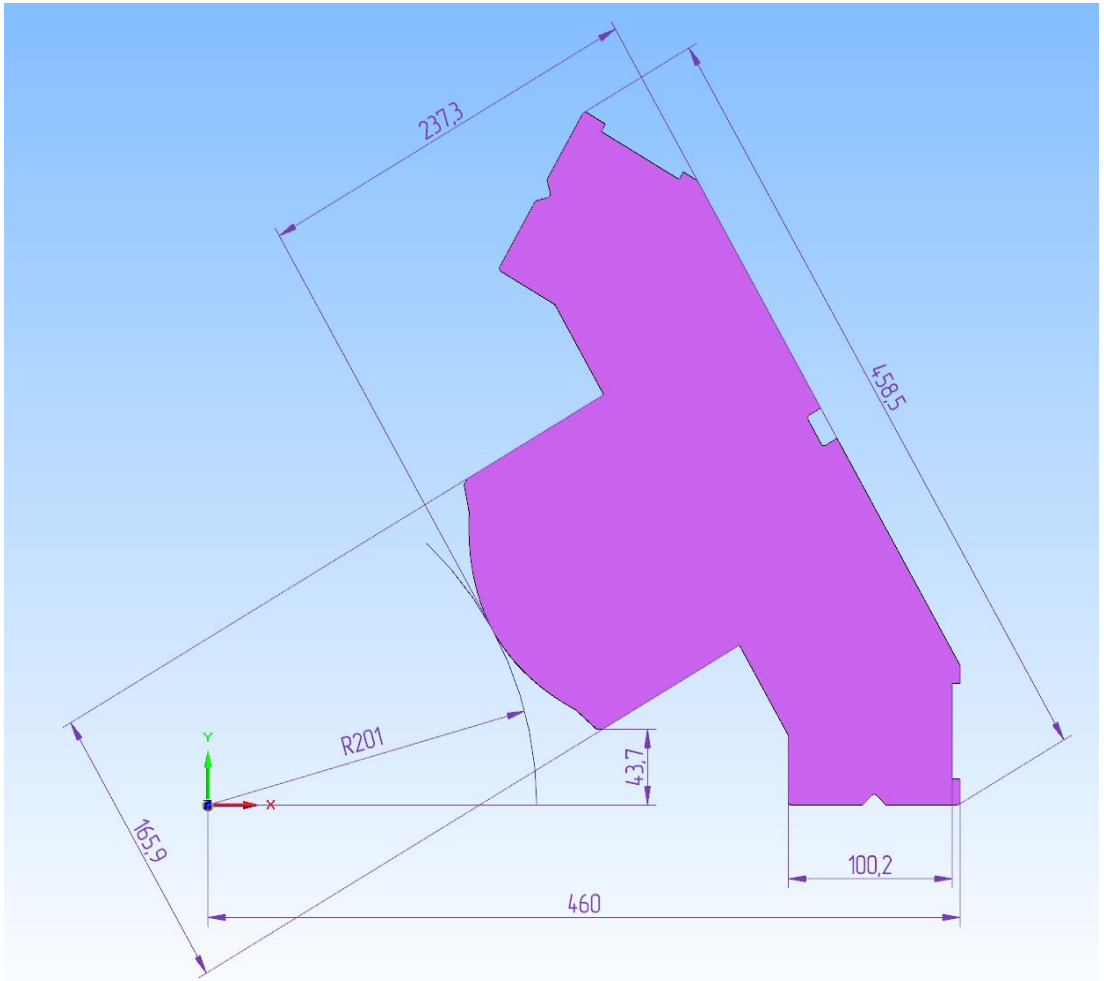


Quantity in CR

- 26 sextupole lens : 24 in CR and 2 in TCR1.

Pole tip radius 201 mm

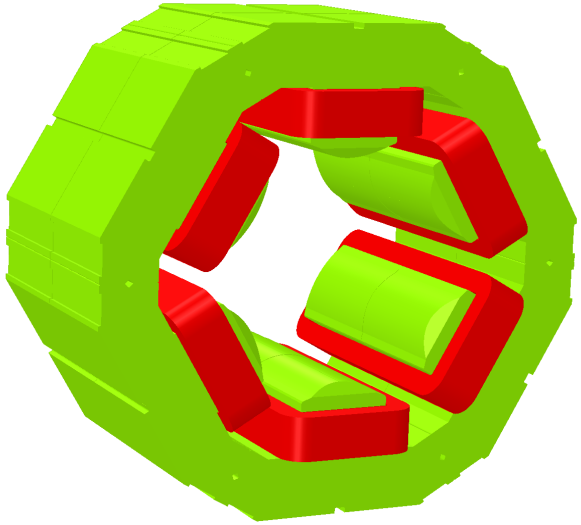
The 3D model of sextupole lens is ready.



Cross-section (1/6) of CR Wide Sextupole

Magnetic simulation(I)

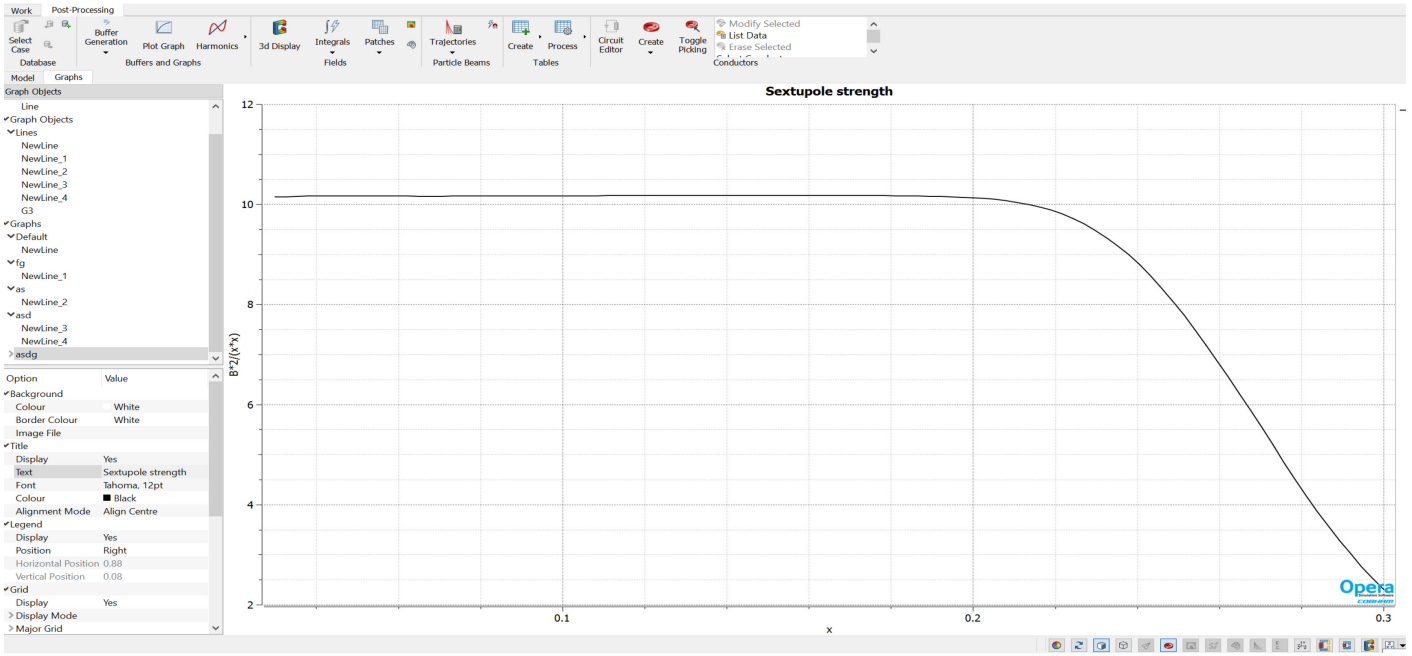
The simulation model of sextupole lens with chamfer.



The sextupole strength along axis of x ,z=0, y=0.

Units of measure [T/m^2].

I=500A

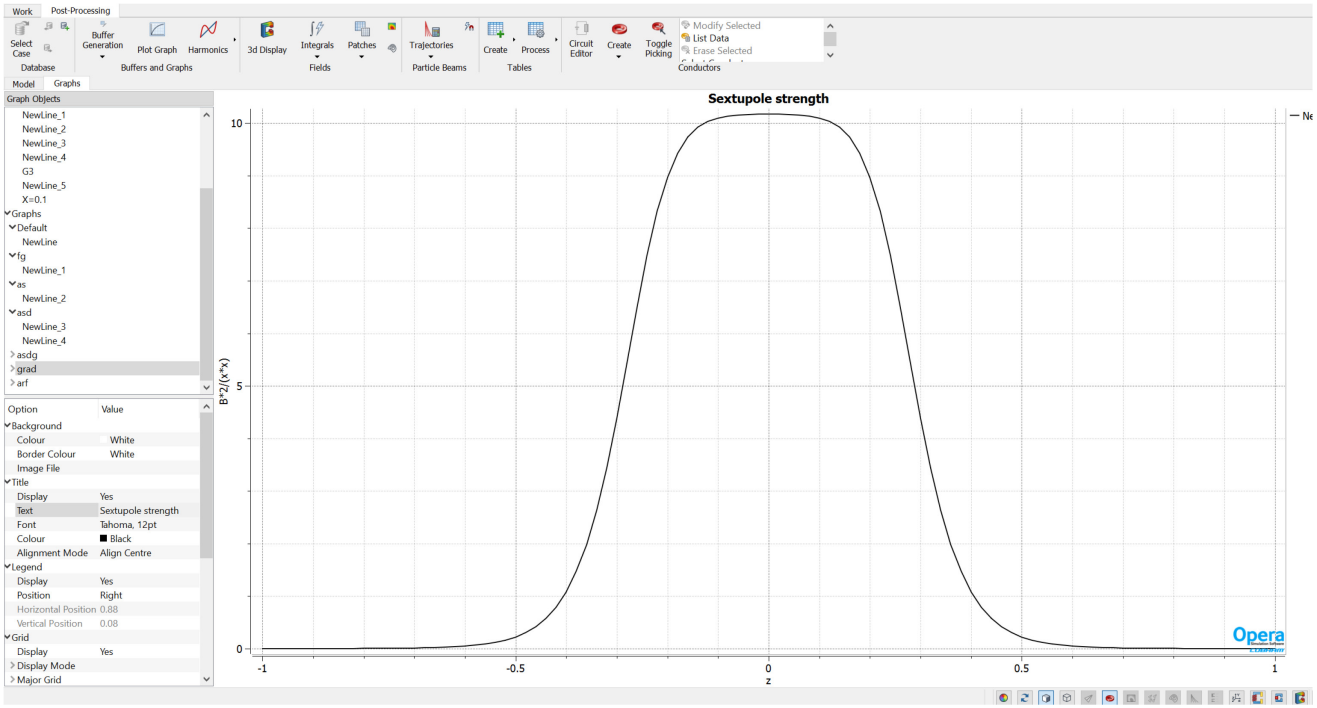


Magnetic simulation(II)

Sextupole strengths along z (T/m2) x=0.1 m , integrated gradient 5.98151 T/m

Values of integrated gradient for different of x (y=0)

X [m]	Integrated gradient [T/m]
0.1	5.98151
0.15	5.9781
0.2	5.91704

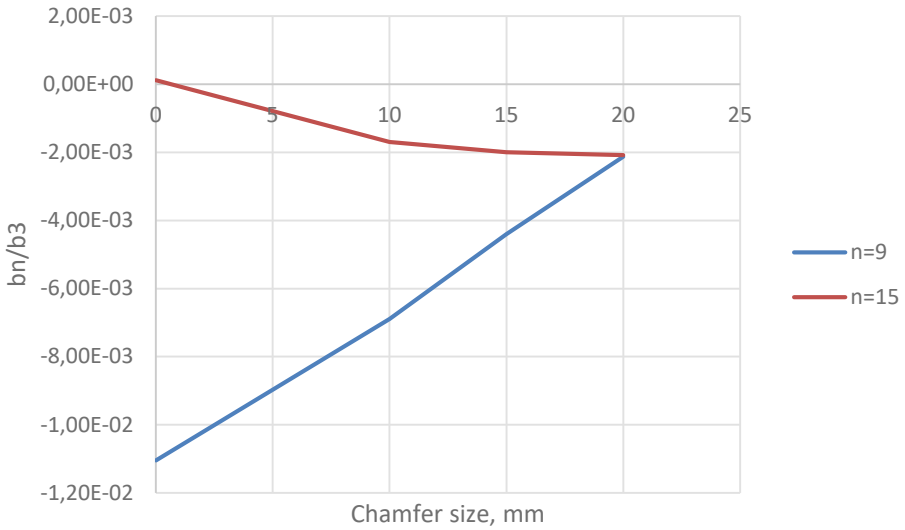


Magnetic simulation (III)

Harmonic terms on circle r=188.1mm in the middle plane

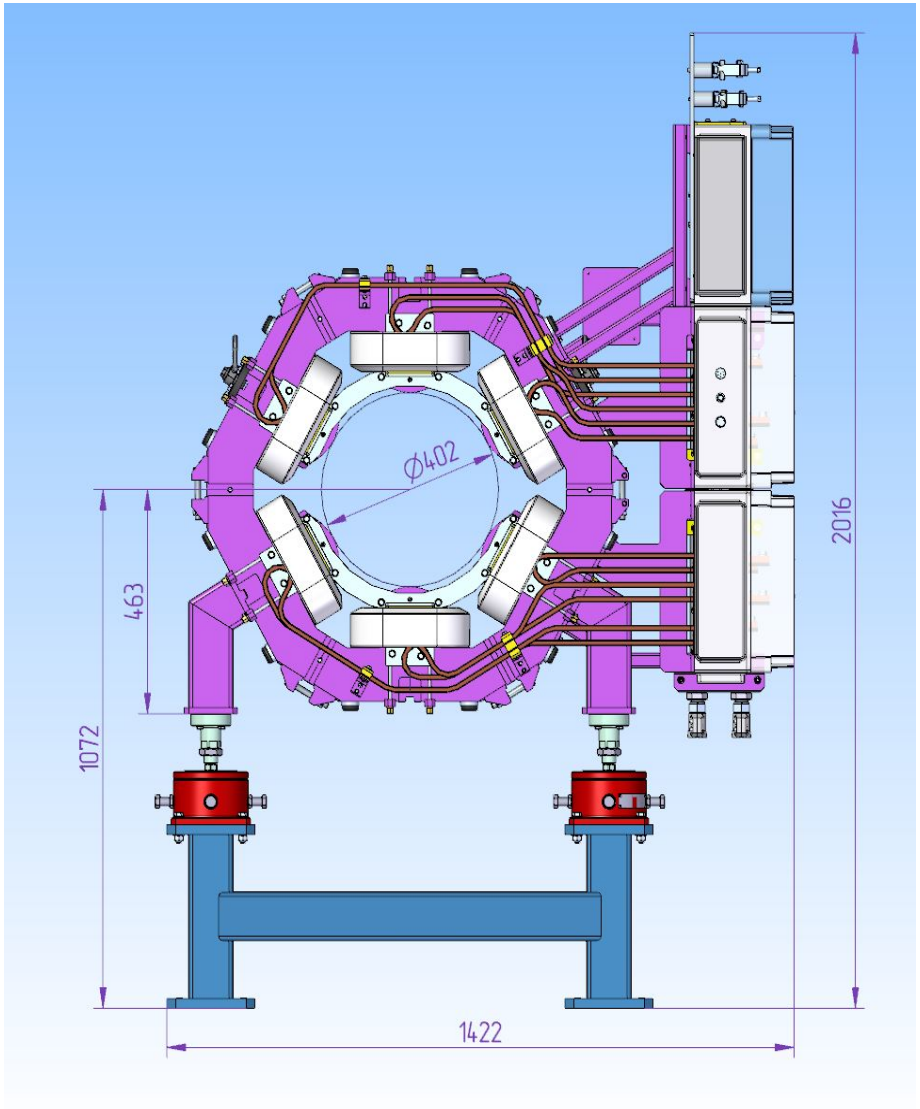
n	B_n
0	0.00
1	-0.08
2	0.00
3	10000.00
4	0.00
5	-0.07
6	0.00
7	-0.02
8	0.00
9	5.31
10	0.00
11	0.06
12	0.00
13	-0.05
14	0.00

Integral harmonic terms on circle R=188.1mm



Main parameters for sextupole lens of CR

Parameter	Value	Units
Maximum sextupole strength	10	T/m^2
Maximum integrated gradient	6	T/m
Field homogeneity (in radius 190 mm)	$\pm 5\times10^{-3}$	
Effective length	600	mm
Overall weight	1350	kg
Yoke data		
Filling factor	0.98	
BH-curve	M1200-100A	
Pole tip radius	201	mm
Yoke length	500	mm
Iron weight	1191	kg
Lamination thickness	1	mm
Number of turns per pole	22	
Conductor cross section	10x10	mm^2
Cooling channel diameter	5	mm
Fill factor	0.64	
Copper weight	146	kg
Current at max field	500	A
Current density in conductor	5.44	A/m^2
Voltage	17.3	V
Power consumption	8.650	kW
Temperature rise in sextupole	7	°C
Cooling water flow rate	19.8	l/min
Water pressure in sextupole	10	bar
Resistance per magnet	34.56	mOm
Inductance per magnet	5.9	mH



Details available in EDMS:
https://edms.cern.ch/ui/#!master/navigator/document?P:1987795909:1338329016: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
		TECHNICALRISKS									
		Mechanical hazards									
RL-001	1	Dent in the sextupole (pole)	BCI	Damage of parts of the magnet; Performance below specification; Failed to reach the required field quality	2	3	2	Check that fastening bolts between the yoke plates and blocks are correctly tightened; Check that lifting eye bolts are correctly tightened; Check that used chains, straps and hooks have the weight rating adapted to the sextupole weight, corresponding number of attachment points and corresponding lifting angles. Magnet must be properly fastened to a suitable stand to prevent any fall during installation, operation, maintenance and storage. Obey warning signs and boundaries. Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_S_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. Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_S_Installation_Operation_manual_A.	1	3	2
RL-003	3	Failure of brazing joints	ABCI	Damage of parts of the magnet; Water leakage from cooling system	2	3	2	Carry out inspection of brazing joints on a regular basis. Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_S_Installation_Operation_manual_A.	1	3	2
RL-004	4	Magnet falling during handling	BCIJ	Damage of parts of thesextupole up to complete loss of the magnet; Personnel injury	2	4	3	• Check that fastening bolts between the yoke plates and blocks are correctly tightened; • Check that lifting eye bolts are correctly tightened; • Check that used chains, straps and hooks have the weight rating adapted to the sextupole weight, corresponding number of attachment points and corresponding lifting angles. • Magnet must be properly fastened to a suitable stand to prevent any fall during installation, operation, maintenance and storage. • Obey warning signs and boundaries. Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_S_Installation_Operation_manual_A.	1	4	2
		Electrical hazards									
RL-005	5	Contact with live parts (hydraulic fittings, etc.)	ACDF GHI	Electrical shock; Personnel injury	1	1	1	Electrical equipment must be de-energized before work is conducted unless special exceptions exist. Only qualified and authorized personnel may work on or near live parts, and only with a valid Electrical Work Permit. Rule out accidental touching of live parts while an employee works on or near them. Use proper Personal Protective Equipment. 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; Short circuits and fire	2	3	2	Carry out inspection of insulation (including thermal imaging) on a regular basis. Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_S_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; Electrical shock; Fire; Personnel injury	2	3	2	Cables must be labelled. Cables must be traceable, viewable and accessible. Cables must be protected from mechanical damage. Avoid creating stumbling hazards with cables. Regular inspection of insulation and connections. Braked cables must be marked, apply a do-not-use tag. 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. De-energize sextupole 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; Personnel injury	1	1	1	Maintain tools so they are in good condition. Inspect tools before each use. Use the right tool for the job. Use tools in accordance with manufacturers' instructions. Obey all labels and instructions. Worn-out tools must be marked, apply a do-not-use tag. Worn-out tools must be replaced.	1	1	1
		Humidity hazards									
RL-012	12	Confusion of water inlet and outlet (dysfunctioning of thermoswitches/ thermoswitch malfunction)	CGHI	Risk of coils overheat	2	2	1	Follow installation instructions according to the BINP Installation and Operation Manual, FCRM_S_Installation_Operation_manual_A.	1	2	1
RL-013	13	Water leakage from cooling system (leaking sources: encapsulation failure due to corrosion, failure of brazing joints, mechanical damage, etc.)	ALL excluding BJ	Risk of humid floor short circuits	3	3	3	Visual inspection of cooling circuit (hoses, water connections, etc.). Satisfactory condition is absence of patches on the surfaces/tunnel floor. Measure and compare the water flow rate to the design value. Follow handling and installation instructions according to the BINP Installation and Operation Manual, FCRM_S_Installation_Operation_manual_A.	2	3	2
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. Use climate-control system in the tunnel. 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; Personnel injury	1	5	2	Use fire supervision system in the tunnel. Carry out preventive diagnostic measures in the tunnel on a regular basis. Use automatic fire suppression system in the tunnel. Use fire-proof and non-toxic materials. Verify that the area is free from unnecessary inflammables. 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; Workers exposure to radiation; Difficulties to repair and maintenance of equipment	1	5	2	Use radioactivity supervision system in the tunnel. Carry out preventive diagnostic measures in the tunnel on a regular basis. 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 sextupole is not recommended to the people carrying a pacemaker. 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 sextupole is powered.	2	1	1
		Ergonomic hazards									
RL-019	19	Accidents of the sextupole sharp edges	ALL	Personnel injury	3	1	1	Use the rubber corner bumpers. 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; Failed to reach the required field quality	3	3	3	The Parties shall monitor the scientific and technical progress of the Collaboration Contract activities. The Parties shall clarify the Technical Specifications during the project development.	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. Follow the GSI Safety Regulations. Complete the required GSI Safety Trainings.	1	1	1

Based on Arrangement of Risks

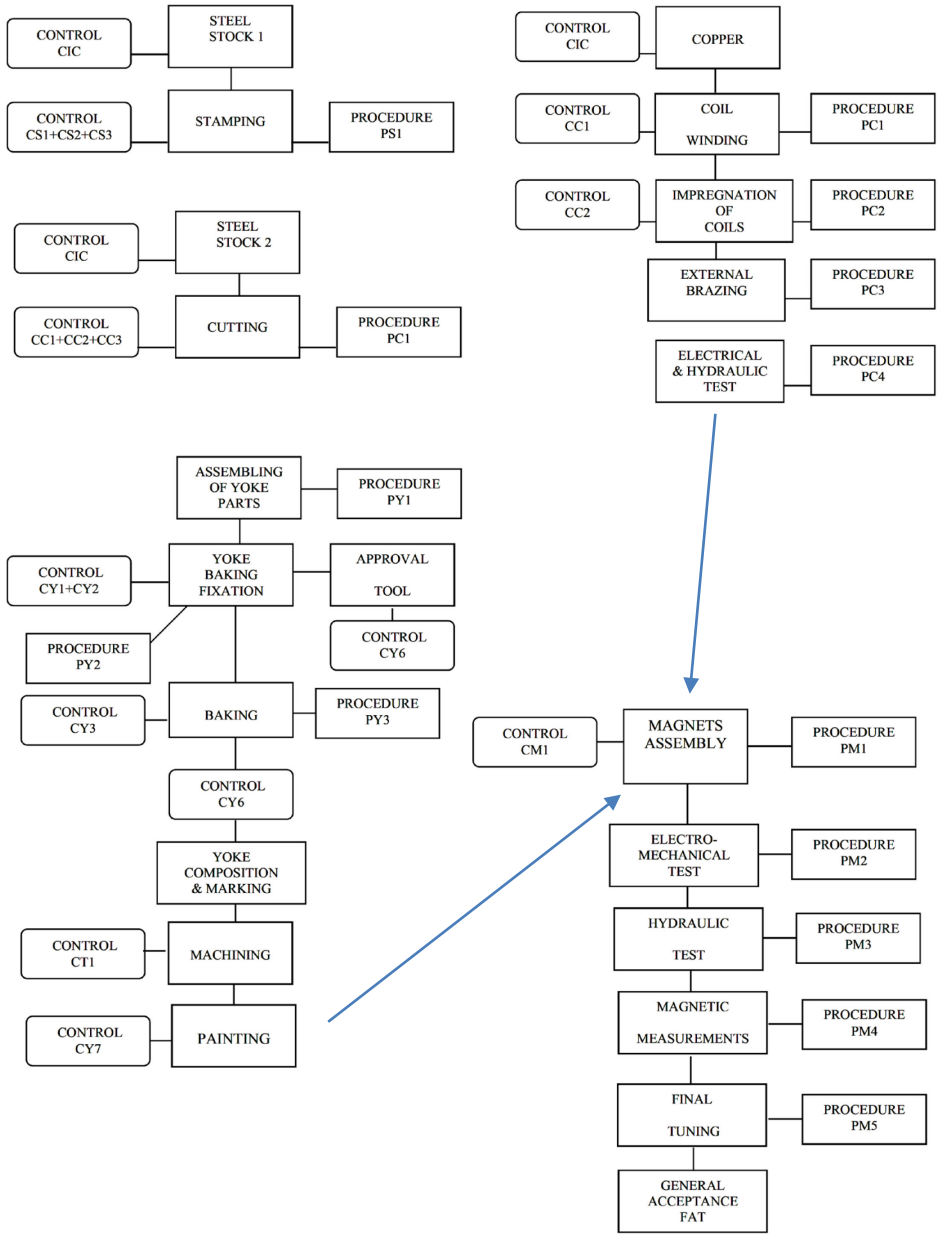
Includes: Mechanical, Electrical, Thermal, Humidity, Radiation, Magnetic, Ergonomic and Combined hazards.

Ranges risk hazards on its impacts and propose Mitigation Actions

Manufacturing Process Chart

Acronyms and Abbreviations:

S	Stamping of yoke pole
PS1	Stamping procedure.
CS1	Check the dimensions of the laminations for production release.
CS2	Check the dimensions of the laminations during production.
CS3	Check the number of the laminations, their type and orientation.
C	Cutting of yoke plates and blocks
PC1	Cutting procedure.
CC1	Check the dimensions of the laminations for production release.
CC2	Check the dimensions of the laminations during production.
CC3	Check the number of the laminations, their type and orientation.
Y	Yoke production
PY1	Assembling of yoke parts procedure.
CY1	Check the assembling.
CY6	Tool approval.
PY2	Fixation procedure for backing.
CY2	Check the fixation.
PY3	Baking procedure.
CY3	Check during baking.
CY4	Check the dimensions.
CT1	Check the dimensions of the machining.
CY7	Visual check the paint work.
C	Coil production
PC1	Coil winding procedure.
CC1	Check the coils before impregnation.
PC2	Coil impregnation procedure.
CC2	Check the coils after the impregnation.
PC3	Brazing procedure for external brazing.
PC4	Electrical and hydraulic tests of the coils.
M	Magnet assembly
PM1	Magnets assembly procedure.
CM1	Check the magnet dimensions.
PM2	Electromechanical test procedure.
PM3	Hydraulic test procedure.
PM4	Magnetic measurements procedure.
PM5	Final tuning procedure.
	General acceptance. FAT.
	Packing.



Milestones

- April 2019 – May 2019: preparation and **passing milestone M6 (CDR)**
- June 2019 – November 2019: detail designing, preparation of drawings**. Passing milestone M7 (FDR)**. Purchasing required accessories, materials, components
- December 2019 – June 2020: tooling production, test bench development and production, tooling manufacturing in experimental workshop-1 (EW-1)
- July 2020 – December 2020: **FoS manufacturing and testing, QA, magnetic measure, FoS revision. Passing milestone M8**
- March 2021 – November 2022: manufacturing and testing the other sextupole lenses, FAT, delivering to FAIR facility, SAT, pre-installation assembling. Approximately 1 sextupole lens every 0.85 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 sextupole lenses – Q2-2019