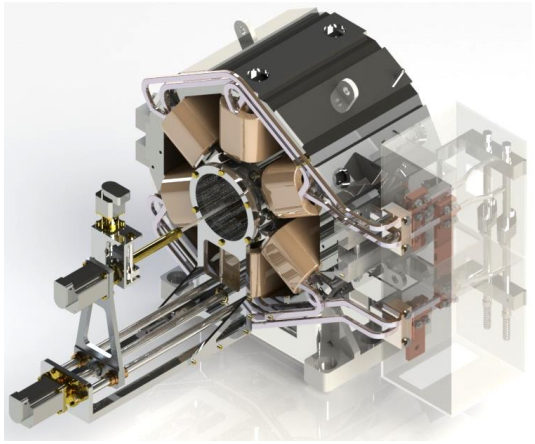
NATIONAL INSTITUTE FOR RESEARCH AND DEVELOPMENT IN ELECTRICAL ENGINEERING ICPE-CA
Splaiul Unirii 313, District 3, Bucharest - 030138
ROMANIA

NORMAL CONDUCTING MAGNETS AND POWER SUPPLY FOR FAIR – ICPE-CA PARTICIPATION TO THE IN-KIND CONTRIBUTION OF ROMANIA



- FAIR, the "Facility for Antiproton and Ion Research" is an integrated system of particle accelerators which will provide high energy and high intensity beams of ions from antiprotons to uranium particle, which will be set up in Darmstadt, Germany.

The existing GSI plus the future FAIR

- FAIR will give up to physicists and other scientists from Europe and from across the world the possibility to conduct cutting-edge research in the following fields:
  - physics of the structure of atomic nuclei;
  - physics of antimatter (antiprotons);
  - physics of nuclear matter under extreme conditions;
  - plasma physics, physics of the atomic shell;
  - related applications.

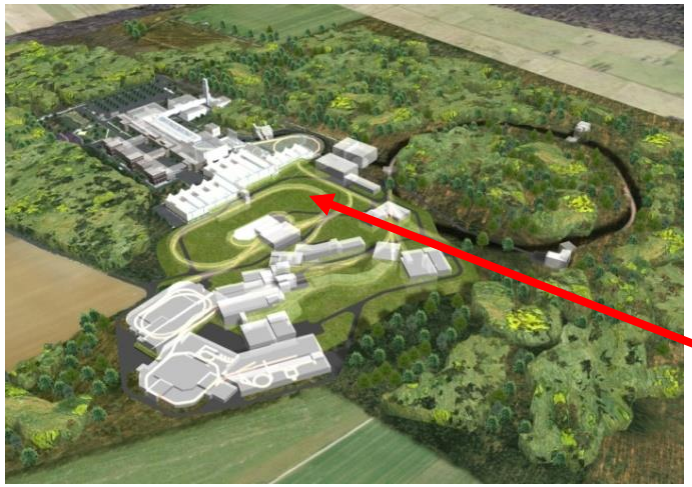
- Romania signed the FAIR Communiqué on the occasion of the official launch of the FAIR project on 7 November 2007 in Darmstadt and declared its contribution to the FAIR construction to be 11.87 M€€, which represents around 1% of the project total cost.

- On 4 October 2010, in Wiesbaden, nine countries, including Romania, signed the international agreement on the construction of the accelerator facility FAIR. The other eight countries are: Germany, Finland, France, India, Poland, Russia, Slovenia and Sweden.

FAIR start event 2007

FAIR GmbH foundation 2010

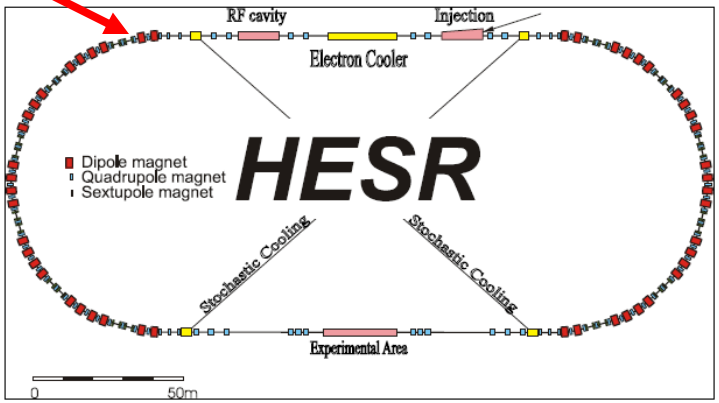
- The contribution of Romania to the FAIR project is coordinated by the Ministry of National Education, which also acts as the Romanian Shareholder within FAIR GmbH and it has three components:
  - ~5.4 mil. €€ **in-kind** contribution, consisting of equipments that will be integrated in various subprojects of FAIR;
  - ~**4**.0 mil. €€ consisting contribution by the participation of romanian scientists to the experiments that will be performed after the commissioning of FAIR accelerators;
  - ~2.**5** mil. €€ **cash** contribution.
- The largest part of the in-kind Romanian contribution will be provided by INCDIE ICPE-CA, the total value of this contribution rising to allmost ~4.0 mil. **€.**



High Energy Storage Ring

- Since 2007 **ICPE-CA** was adopted in the HESR consortium, created to develop the High Energy Storage Ring, important part of the FAIR project.

- With a circumference of 574 m the HESR is dedicated to Strong Interaction studies with antiprotons in the momentum range from 1.5 to 15 GeV/c.

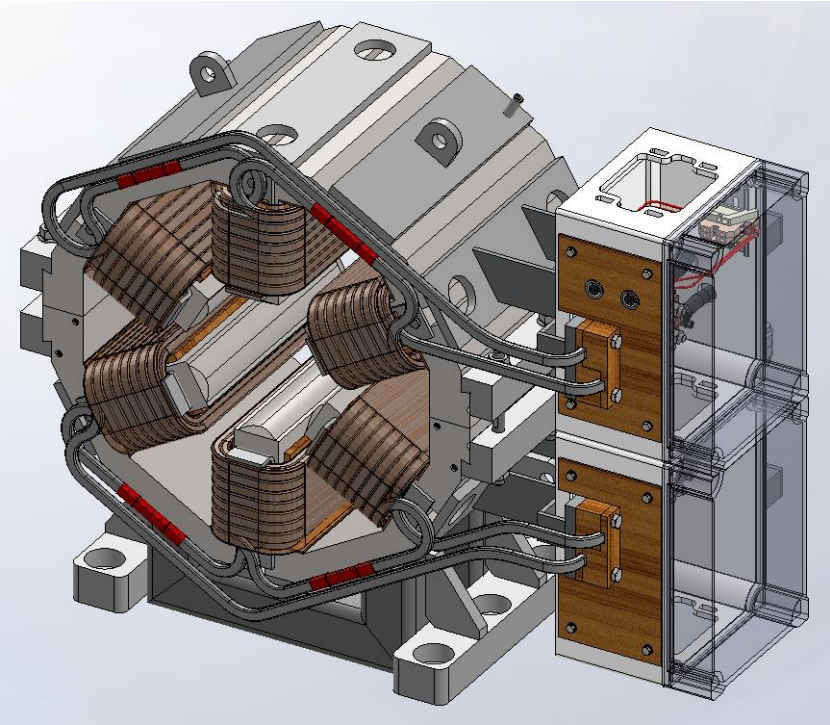


- The collaboration within the consortium have included several work visits made by researchers from ICPE-CA at FZJ - Forschungszentrum Jülich Germany, leader of the HESR consortium. Also, scientists from Nuclear Physics Institute – IKP from FZJ have visited ICPE-CA and several industrial companies, in order to evaluate the Romanian research and technological capabilities in the field of particle accelerators.

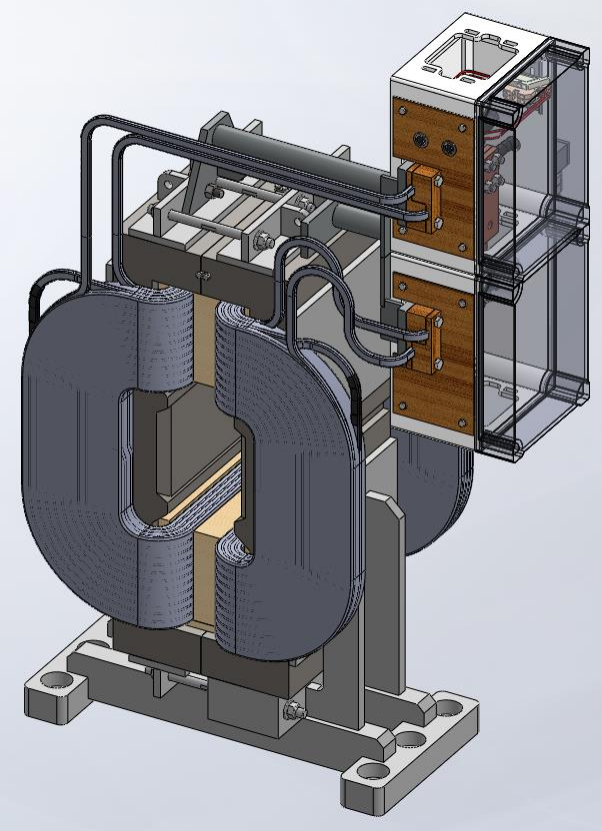
COSY synchrotron from FZJ

- A team of researchers have been created in ICPE-CA to work together with the foreign specialists. This team include specialists from various fields, like: CAD, electromagnetic design and simulation, mechanical, electrical and magnetic measurements, materials, machining, technology. Members of this team have made repeated visits to the HESR consortium members, FZJ, GSI Darmstadt, University of Mainz and University of Uppsala, with the occasion of biannual consortium meetings. At every of these meetings there have been presented scientific papers describing the achievements and the status of the project in process. One of these meetings was organized by ICPE-CA, in August 2009.

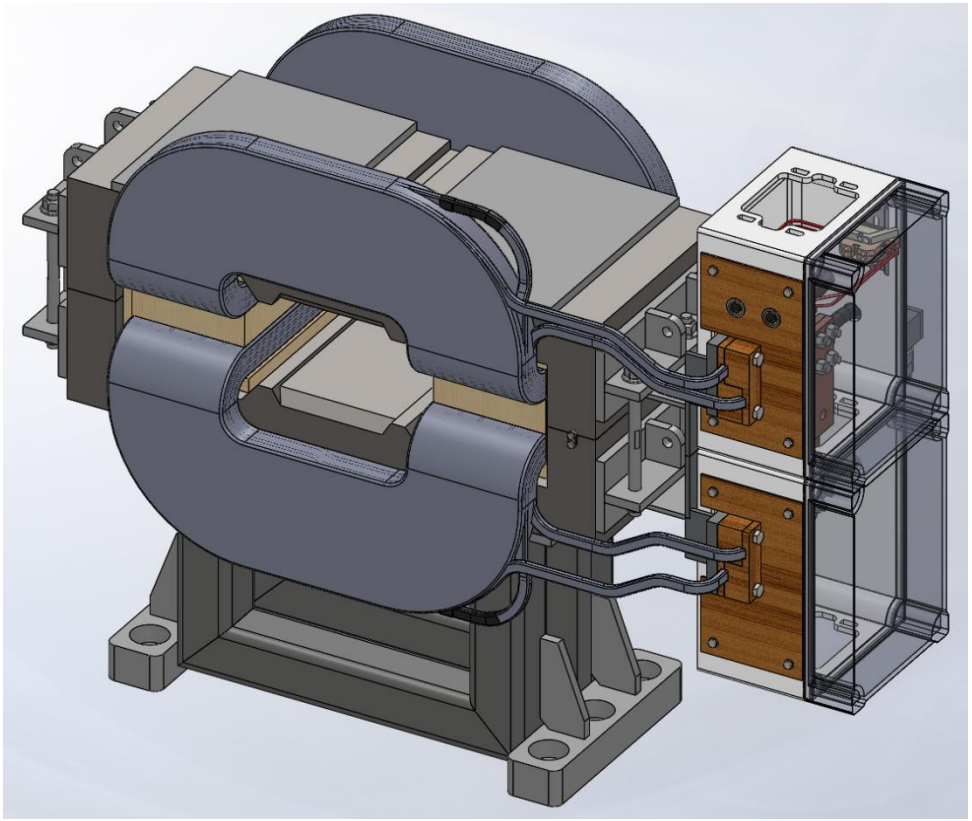
- The main results achieved until now consits of the design of three magnets – one sextupole magnet, one vertical steerer magnet and one horizontal steerer magnet, the manufacture and testing of the sextupole and vertical steerer magnet prototypes and the manufacture and testing of a power supply prototype.



Sextupole Magnet



Vertical Steerer Magnet



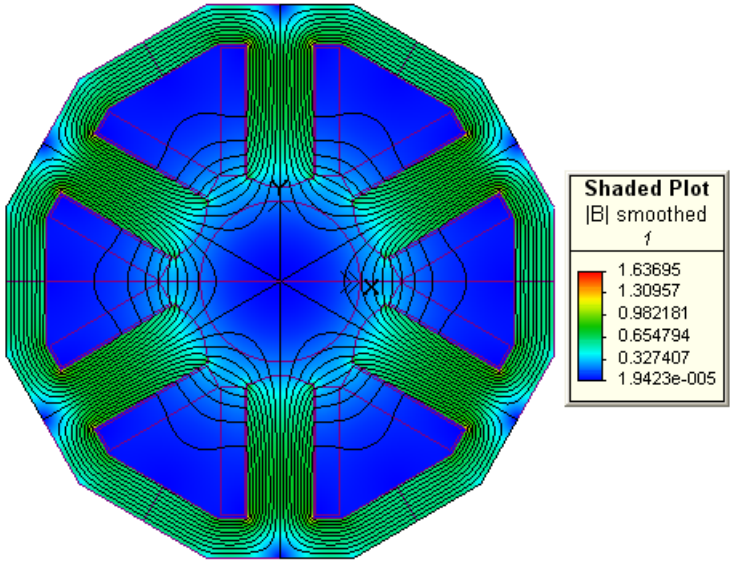
Horizontal Steerer Magnet

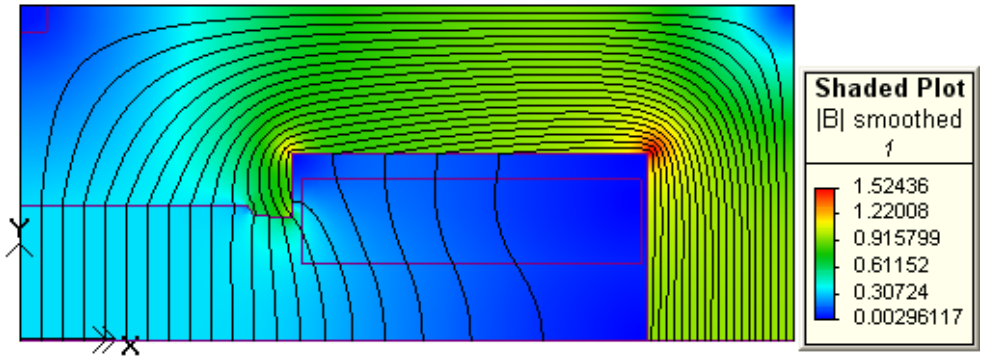
Magnets Power Supply

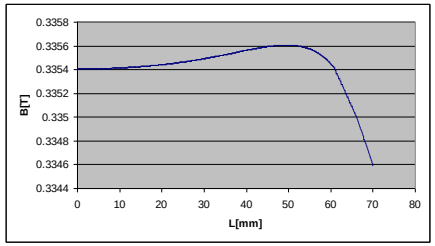
Magnets characteristics

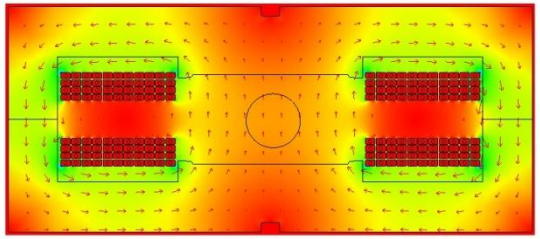
Parameter	Sextupole Magnet	Steerer Magnet
Sextupole strength (max d^2B/dx^2)	45 T/m^2	-
Max deflection angle	-	2 mrad at p_{max}
Aperture (diameter)	140 mm	100 mm
Magnetic length	300 mm	300 mm
Iron yoke length	270 mm	270 mm
Iron yoke width	450 mm	580 mm
Iron yoke height	450 mm	450 mm
Number of coils	6	2
Windings / coil	15	44
Layers / coil	2	4
Windings / layer	7.5	11
Conductor dimensions	10.6 x7 mm^2	10.6 x7 mm^2
Cooling bore	4 mm	4 mm
Copper crossection	60.77 mm^2	60.77 mm^2
Length of conductor / coil	~ 12 m	~ 72 m
Current	290 A	304.1 A
Current density	4.77 A/mm^2	5 A/mm^2
Total mass	~ 220 kg	~ 350 kg
Voltage (DC)	6.12 V	12.84 V
Resistance	21.12 mΩ	42.2 mΩ
Inductivity	3.4 mH	0.28 mH
Power (DC)	1.8 kW	3.9 kW
Water flowrate	~ 0.86 l/min	~ 1.81 l/min
Pressure drop Δp	~ 1.14 bar	~ 5.21 bar

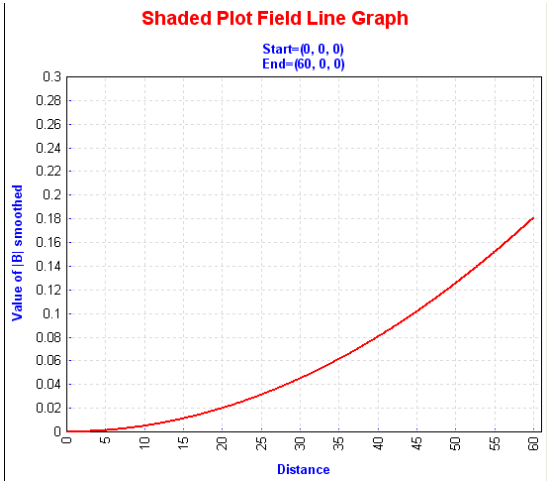
- Various electromagnetic computing and simulations were performed in order to optimize the solution for the design of the sextupole and steerer magnetic circuit.



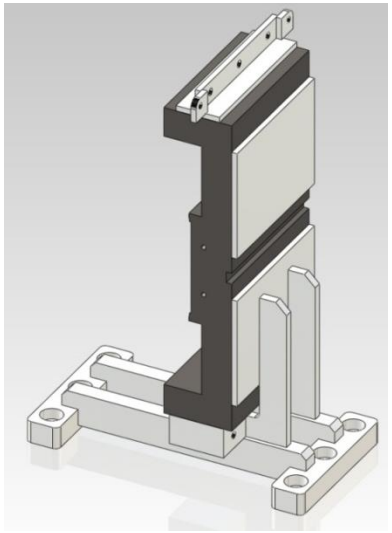


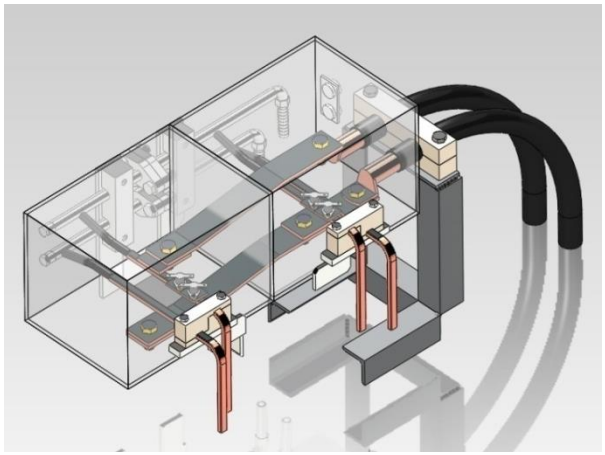


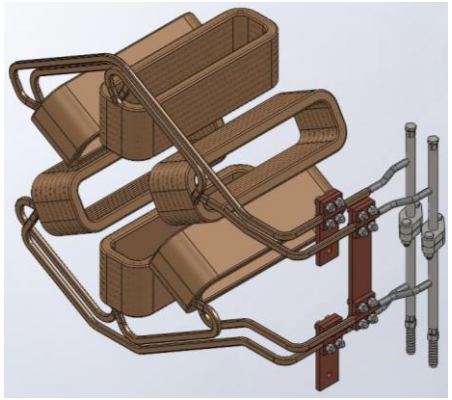


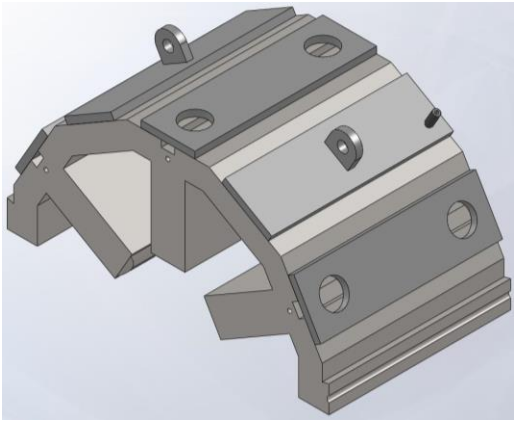


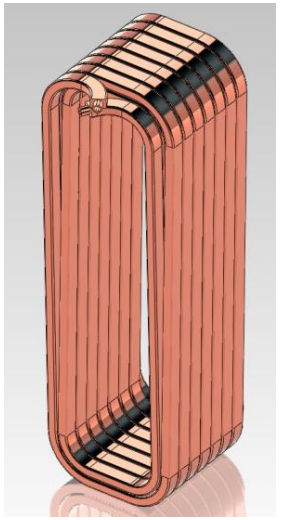
- 3D models for all the components of the magnets were realized and optimized using powerful parametric software.



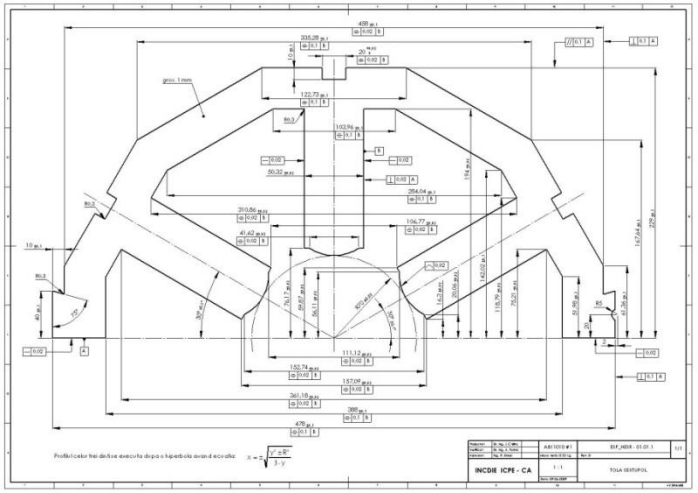


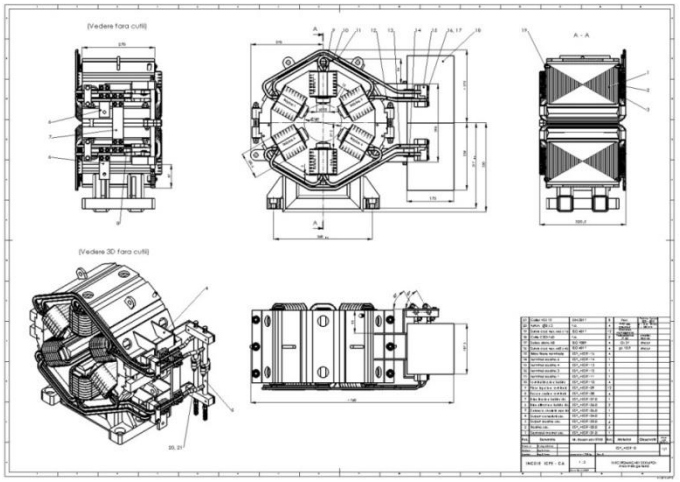


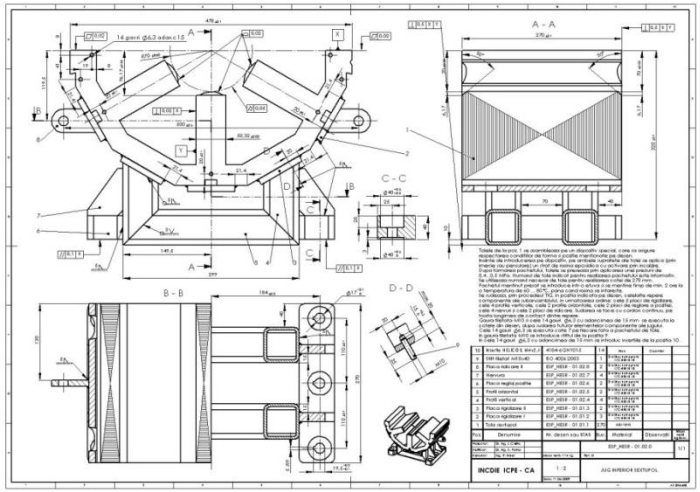


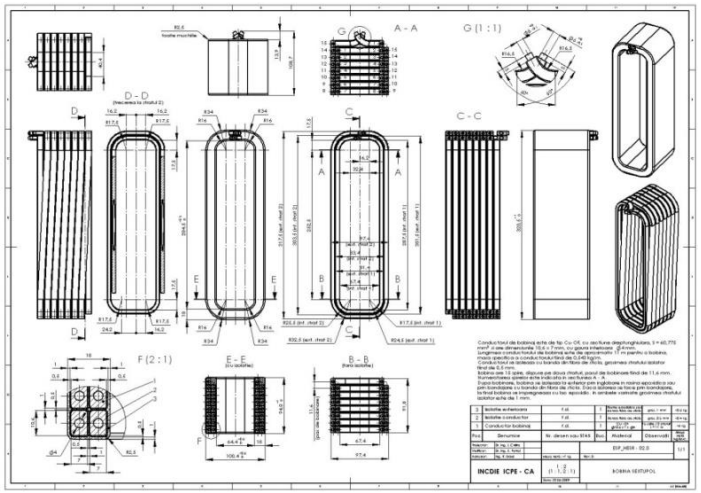


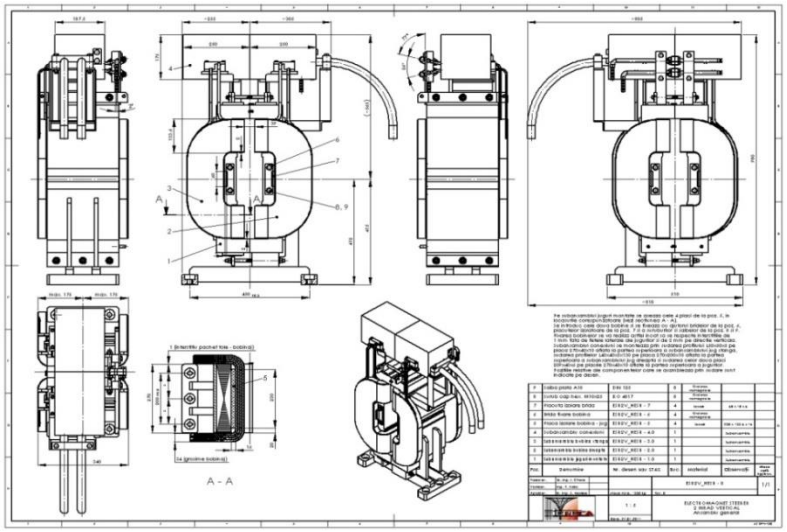
- Technical 2D drawings were also realized, needed for the manufacturing and assembling process of the magnets.

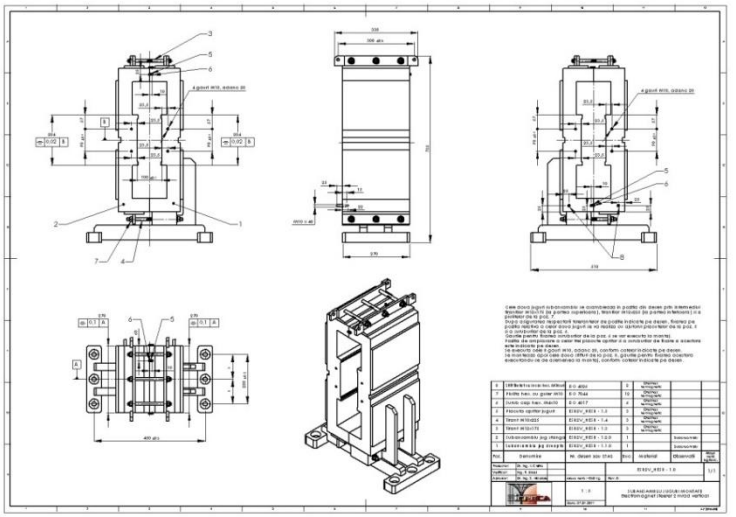


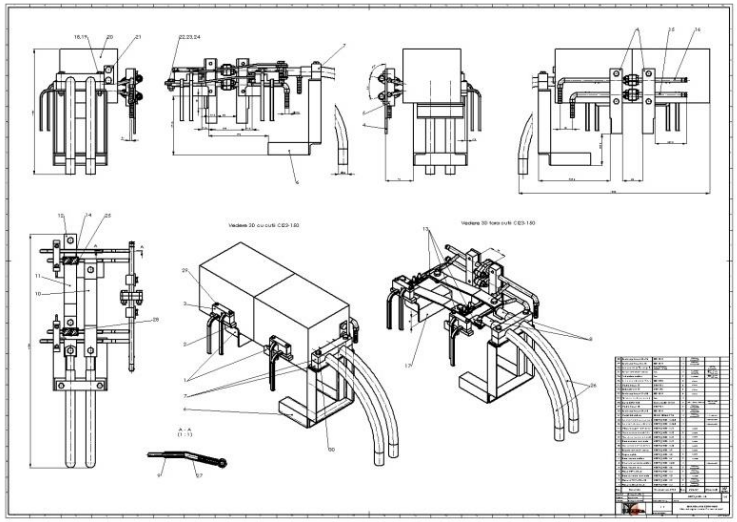


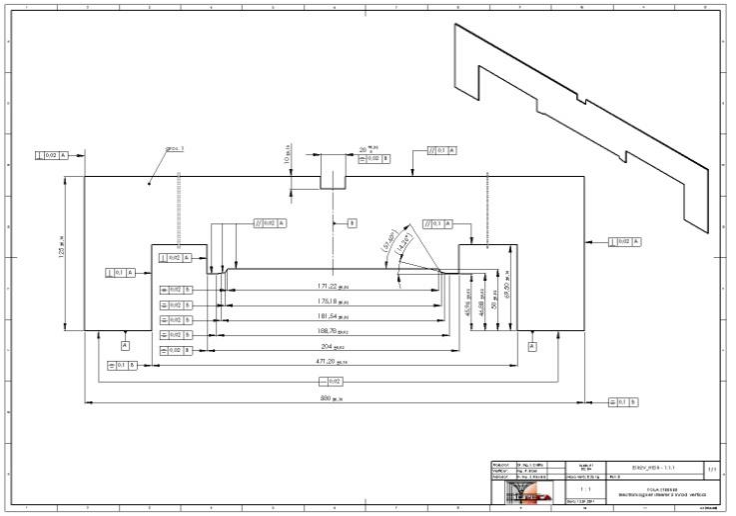




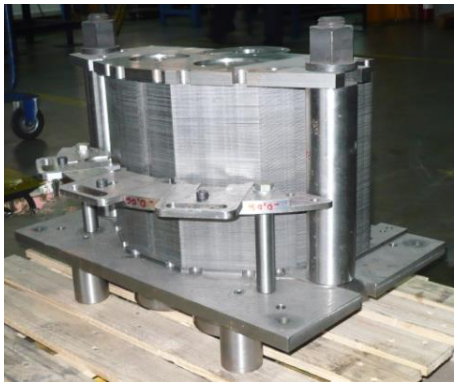


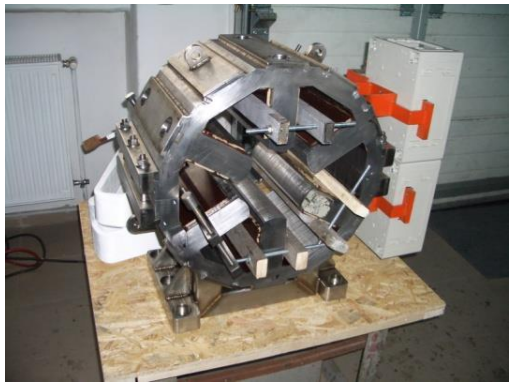
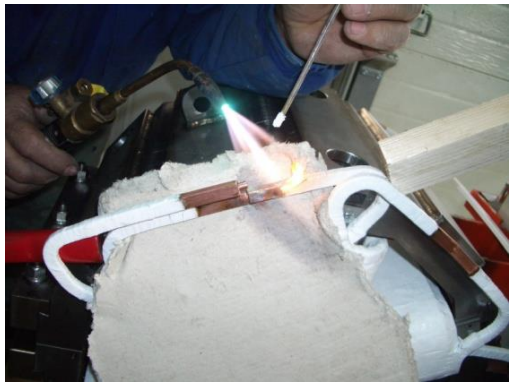


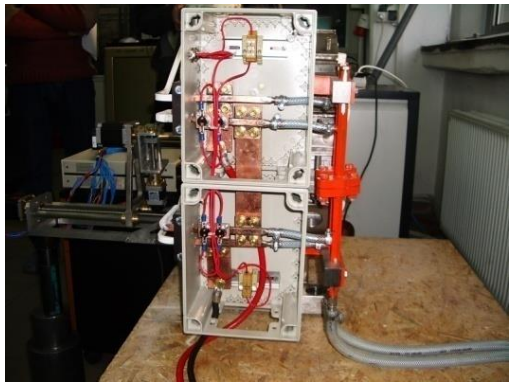




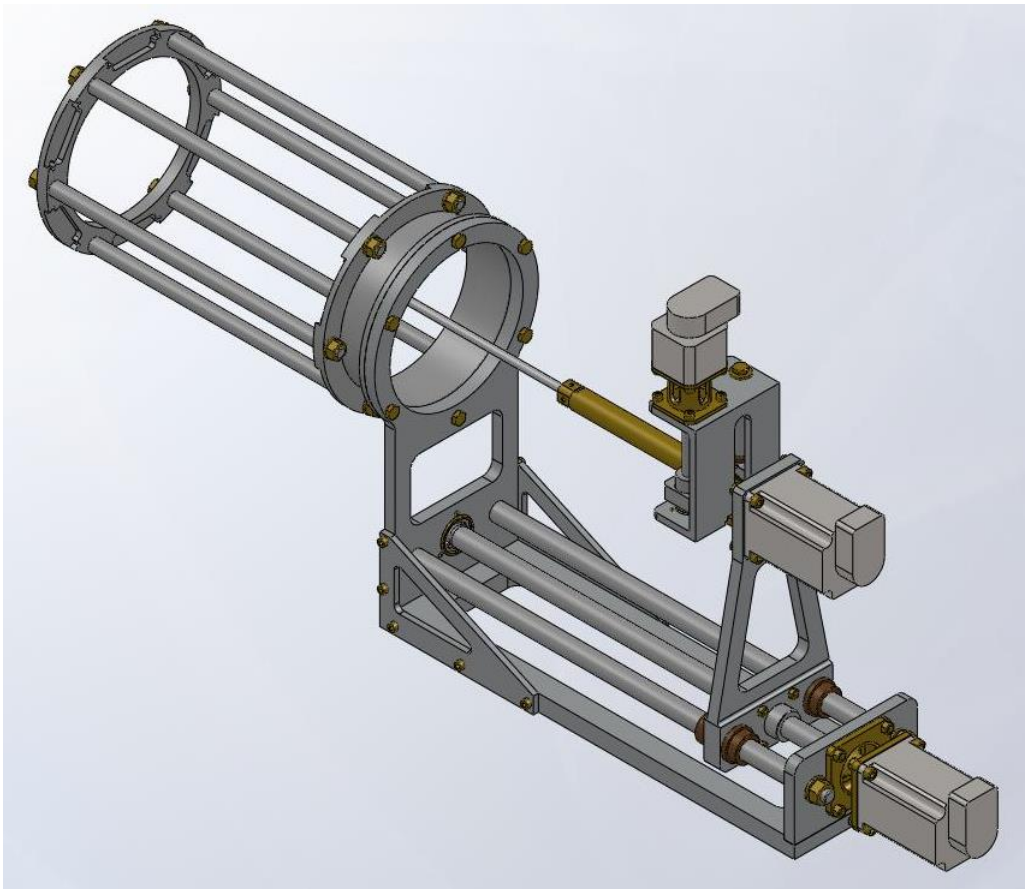
- The prototypes of the magnets were manufactured and assembled, using special devices and technologies able to ensure the high precision required for the execution of the magnets.

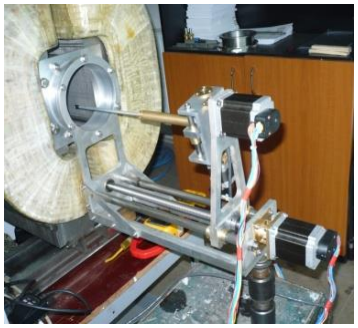


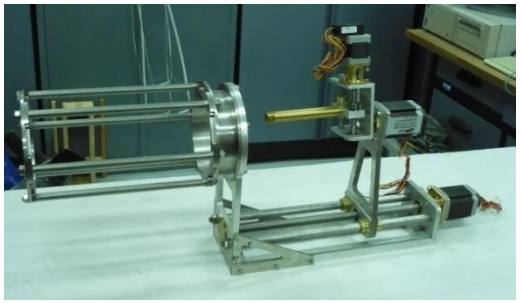





- A special system for measuring the field inside the aperture of the magnets with a 3 axis Hall probe, was designed and manufactured.

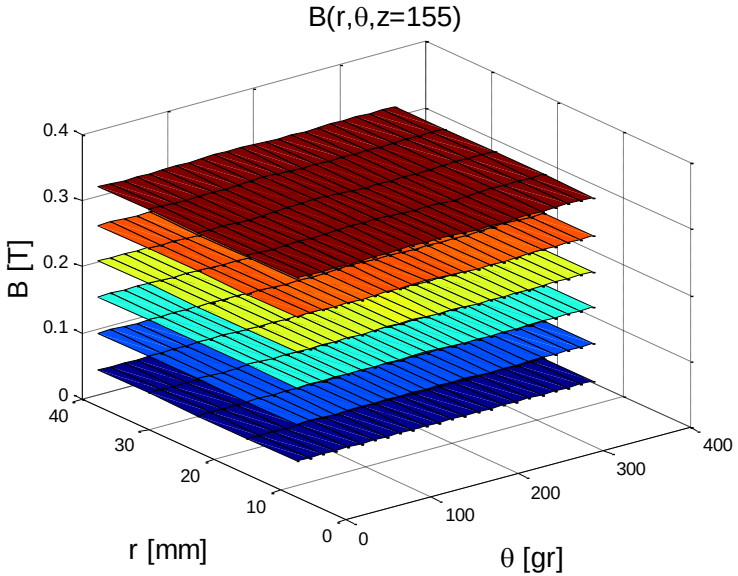


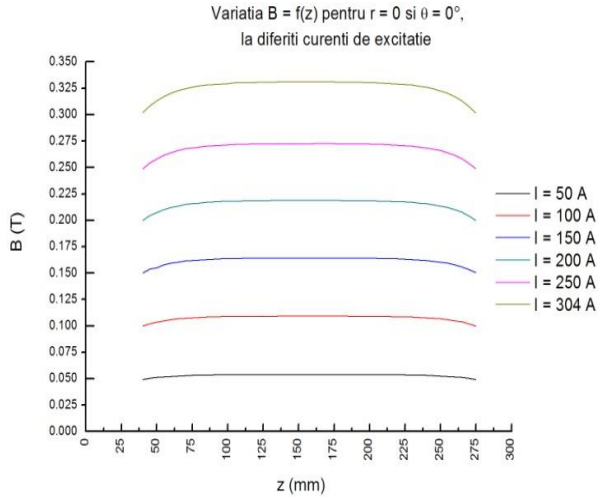


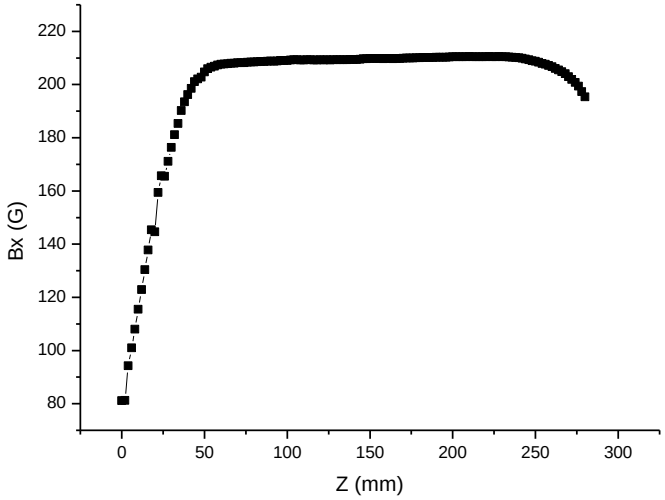


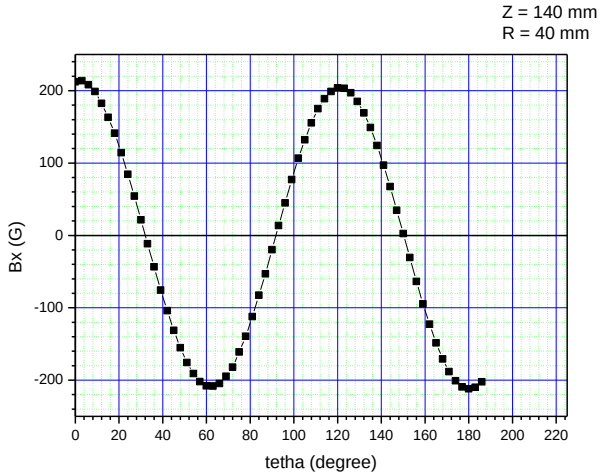
- Extended measurements have been performed, both for the sextupole and for the steerer, inside the aperture of the magnets, in different points situated at different angles, radii and longitudinal positions, at various values of the current supplied by the power supply.

Nr. Crt.	z [mm]	r [mm]	ϑ [°]	B [T]					
				I = 50 A	I = 100 A	I = 150 A	I = 200 A	I = 250 A	I = 304 A
1	0	0	0	0.0342	0.0699	0.1054	0.1403	0.1744	0.2116
2	5	0	0	0.0355	0.0726	0.1090	0.1455	0.1867	0.2262
3	10	0	0	0.0378	0.0772	0.1160	0.1546	0.1926	0.2334
4	15	0	0	0.0403	0.0817	0.1236	0.1648	0.2100	0.2547
5	20	0	0	0.0425	0.0866	0.1300	0.1732	0.2153	0.2676
6	25	0	0	0.0444	0.0905	0.1366	0.1819	0.2304	0.2794
7	30	0	0	0.0464	0.0943	0.1416	0.1868	0.2386	0.2896
8	35	0	0	0.0479	0.0972	0.1466	0.1946	0.2424	0.2981
9	40	0	0	0.0491	0.0999	0.1502	0.1998	0.2485	0.3020
10	45	0	0	0.0502	0.1019	0.1536	0.2042	0.2542	0.3080
11	50	0	0	0.0510	0.1034	0.1549	0.2074	0.2581	0.3129
12	55	0	0	0.0515	0.1049	0.1578	0.2102	0.2617	0.3173
13	60	0	0	0.0521	0.1058	0.1593	0.2121	0.2640	0.3202
14	65	0	0	0.0525	0.1066	0.1605	0.2136	0.2659	0.3228
15	70	0	0	0.0528	0.1072	0.1614	0.2149	0.2676	0.3246
16	75	0	0	0.0531	0.1076	0.1621	0.2157	0.2687	0.3260
17	80	0	0	0.0532	0.1079	0.1626	0.2165	0.2695	0.3272
18	85	0	0	0.0534	0.1082	0.1630	0.2170	0.2702	0.3281
19	90	0	0	0.0535	0.1084	0.1633	0.2173	0.2706	0.3287
20	95	0	0	0.0535	0.1085	0.1635	0.2177	0.2712	0.3292


B(r,θ,z=155)
B [T]
r [mm]
θ [gr]


Variatia B = f(z) pentru r = 0 si θ = 0°,
la diferiti curenti de excitatie
B (T)
z (mm)
I = 50 A
I = 100 A
I = 150 A
I = 200 A
I = 250 A
I = 304 A


Bx (G)
Z (mm)


Z = 140 mm
R = 40 mm
Bx (G)
tetha (degree)

- The prototype of the sextupol magnet was realized in collaboration with our sub-contractor **SC ELECTROMAGNETICA SA Buc**harest. After ICPE-CA finalize the assembling and testing of the prototype, the sextupole magnet was exibit at the Hanover 2011 fair. From the fair the sextupole was delivered to FZJ where it has undergone a thoroughly testing by the german specialists.

- The prototype of the steerer magnet was also realized in collaboration with **SC ELECTROMAGNETICA SA Buc**harest. He was assembled and tested by ICPE-CA and then was exibit at the TIB 2011 fair.

- The prototype of the magnets power supply was also realized, in collaboration with another sub-contractor, SC AAGES SRL Tg. Mures.

The characteristics of the power supply are:

- **Input: 400 V, 3 phases, 50 Hz;**
- **Output voltage: +/-45 V;**
- **Output current: 0...350 A;**
- **Current slew rate: 20 A/s;**
- **Statically and dynamical accuracy: 0.0001;**

- The prototype of the power supply was also evaluated by **FZJ** specialists, receiving a very good apreciation.

- The in-kind contribution that ICPE-CA will deliver for the **FAIR** project is subject of a Contract with the following signatory parts:
  - FAIR GmbH, as the recipient Company;
  - MEN, as Shareholder;
  - ICPE-CA, as Provider.

- The Contract stipulates that ICPE-CA will deliver to **FAIR GmbH,** between **2013** and **2018,** following equipments:
  - Sextupol Magnet - **66** pieces;
  - **Steerer** Magnet – **53** pieces;
  - Magnet Power Supply – **82** pieces;

- To fulfill the objectives of the Contract there are foreseen following activities:
  - Elaboration of the technical and manufacturing projects;
  - Manufacturing of the pre-series ;
  - Manufacturing of the series components;
  - Elaboration of the quality assurance plan, including testing procedures for FAT (Factory Acceptance Tests) and SAT (Site Acceptance Tests);
  - Packing and shipment of the equipments to the FAIR site;
  - Assembly at the final location;
  - The final system and integration tests;
  - Preparation and delivery of documentation.

- The results of the carried out and foreseen activities for the FAIR project opens new direction to involve for ICPE-CA:
  - ELI Project - Extreme Light Infrastructure, it's a project for which ICPE-CA allready expresed the firm intention to involve since the preparatory phase, especialy in the research, manufacturing and testing of the normal and superconducting magnets.
  - ICPE-CA intend to involve in projects for the construction of hadrontherapy facilities that can be located in hospitals or in other special centers.
  - Past and present collaborations with famous research centers in the field of nuclear physics, like CERN and JINR Dubna, will allow the participation of the ICPE-CA researchers in projects similar to the FAIR project.
  - ICPE-CA can also become a potential supplier for the existing research facilities in the field of nuclear particles, ICPE-CA allready beeing on the list of CERN suppliers.

THANK YOU VERY MUCH FOR YOUR ATTENTION!