Hadron Therapy Research and Applications at JINR

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Abstract

- Proton therapy in JINR.
- Experience in medical cyclotrons design.

    1. Collaboration with IBA (Belgium).

        Project of carbon superconducting cyclotron C400.

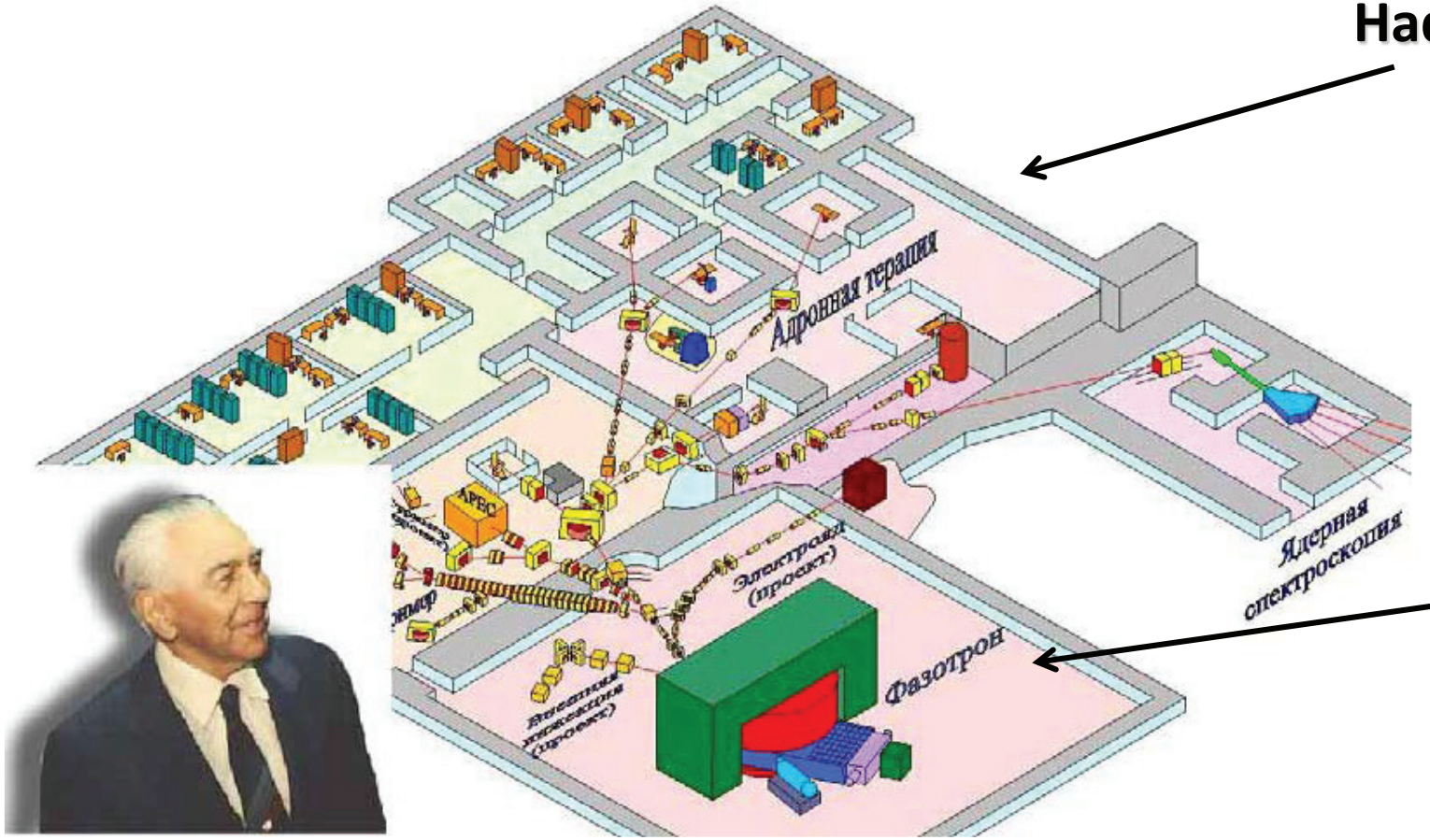
        Proton cyclotron C235-V3 for Dimitrovgrad.

    2. Collaboration with ASIPP (Hefei, China) .

        Superconducting proton cyclotron SC202.

Proton therapy in JINR

since 1967



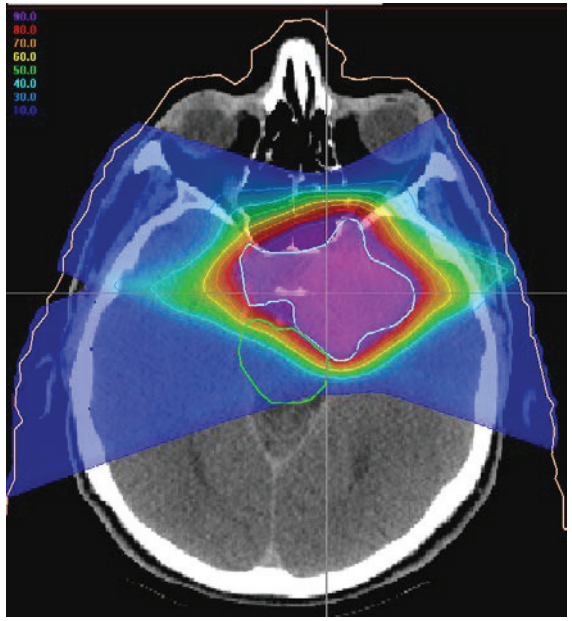
Proton therapy in JINR

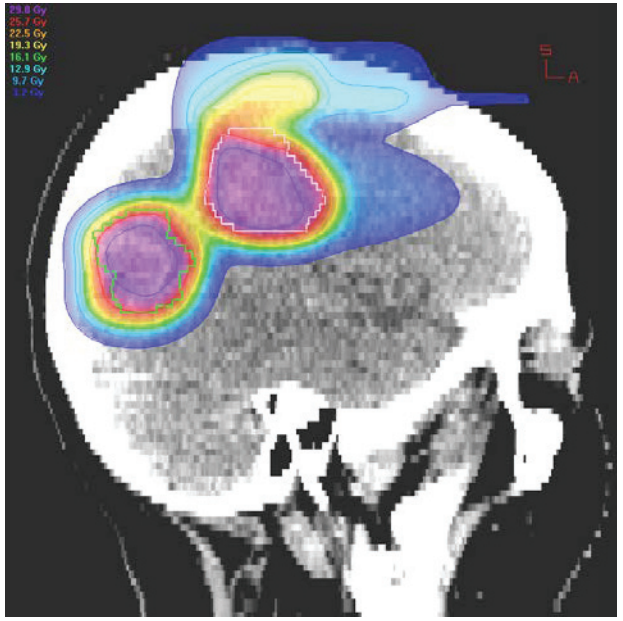
- 1967 – the beginning of the research on proton therapy;
- 1968 –1974 – first 84 patients treated with protons;
- 1975 –1986 – upgrading of accelerator and construction of a multi -room Medico -Technical Complex (MTC);
- 1987 -1996 – treating of 40 patients with protons;
- 1999– inauguration of a radiological department of the Dubna hospital;
- Since 2000 - treating of patients with tumors seated in the head, neck and thorax.

The technology of conformal three-dimensional proton therapy is realized on the JINR medical-technical accelerator complex which includes the synchrocyclotron, the beam delivery systems and medical cabins.

Proton therapy in JINR

There are about 450 thousands of new cancer patients appeared every year. The hadron therapy can be effective for treating 50 thousands cancer patients per year in Russia.





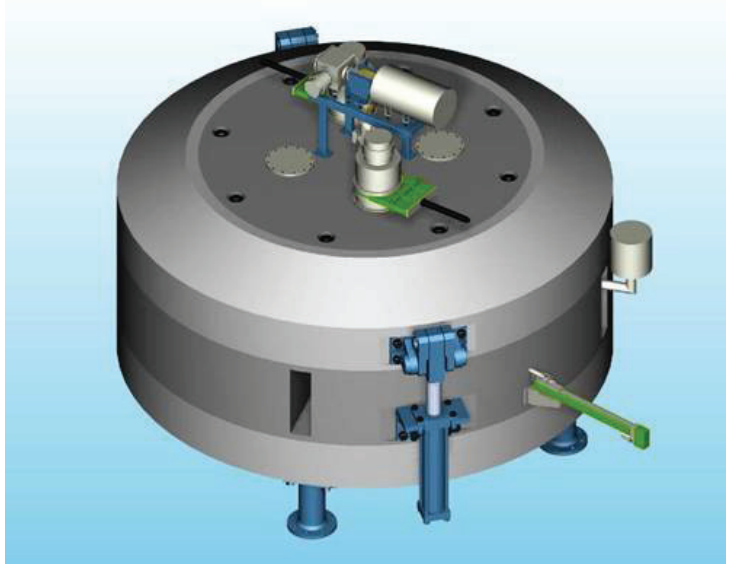
In Russia 3D conformal proton beam treatment were realized only in JINR.
About 1000 patients were treated by the proton beams at the JINR MTC .
More then 100 patients are treated here per year.

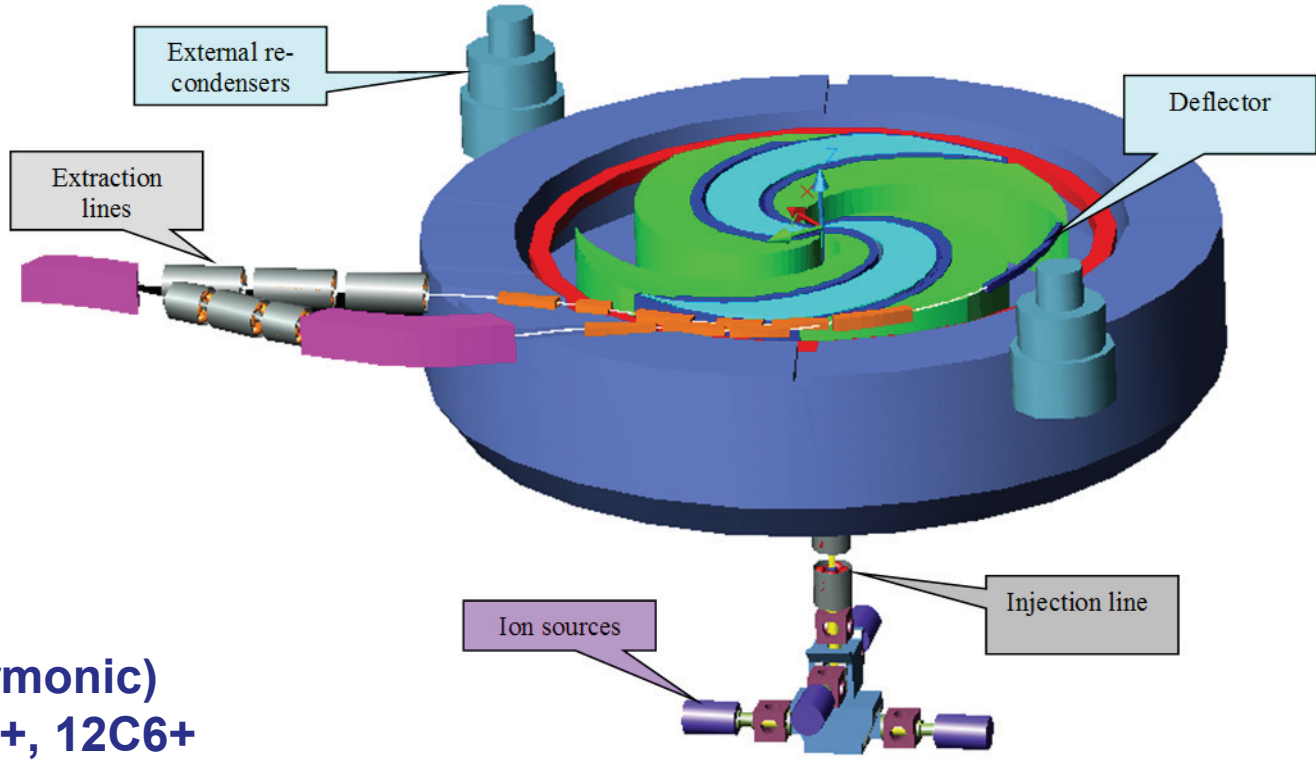
Collaboration on Hadron Therapy between JINR and IBA

- Technical design of the world first superconducting carbon cyclotron C400 (2005-2009)
- Modernization of serial proton cyclotron C230 – C235 V3 (2007 – 2009);
- Creation at JINR of a site for C235 V3 assembling and testing (2009);
- Scientific Collaboration Agreement between IBA-JINR in order to assemble, tune and test the C235 V3 at JINR in 2011-2012

Contract between IBA and JINR has been signed in April 2011 in the presence of His Majesty Crown Prince Philippe (the King presently) of Belgium

PROJECT OF SUPERCONDUCTING CYCLOTRON C400 FOR HADRON THERAPY (JINR-IBA)





Fixed energy and RF frequency (75 MHz, 4 harmonic)
Accelerated particles: H2+, 4He2+, 6Li3+, 10B5+, 12C6+
Q/M=1/2 ⇒ 400 MeV/n (p-260 MeV)
Superconducting coils (B_{max}/B_{min}=4.5/2.5 T)
External axial injection
Stripping extraction of H2+ ions
Extraction by electrostatic deflector for other ions (extraction efficiency 70%)
Total weight 700 t, diameter 6 m
The construction of C400 is starting in Arhade project (France, Caen)

JINR (Dubna) –IBA (Belgium) collaboration Model for magnet simulation 3D TOSCA

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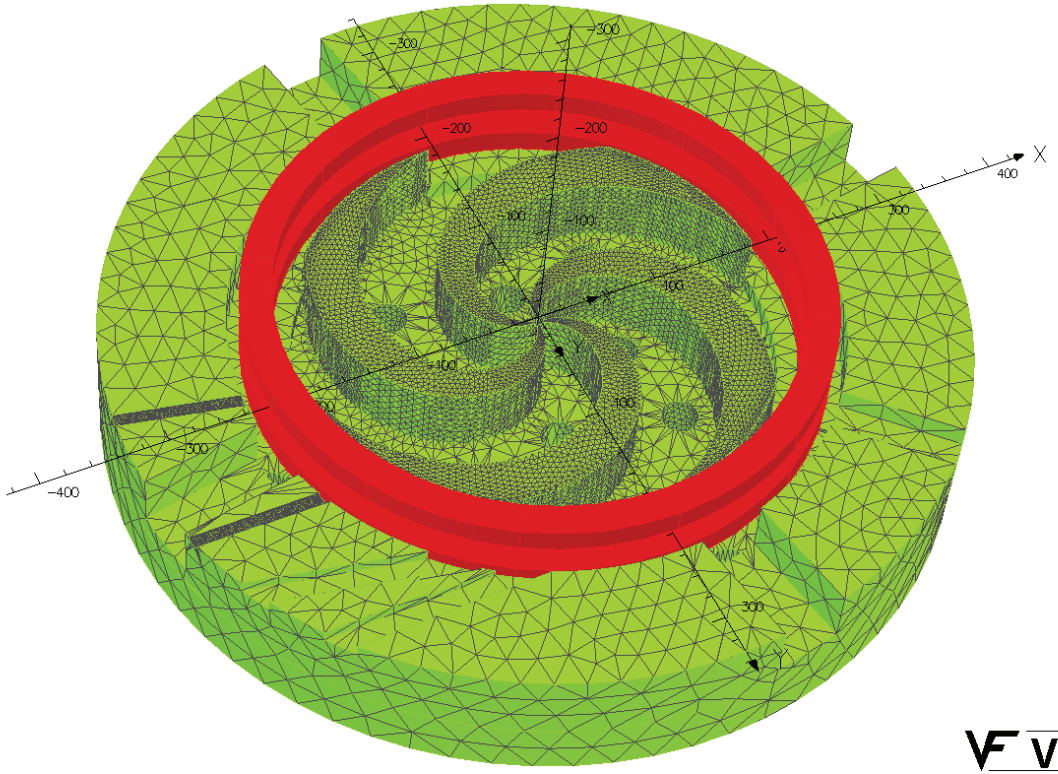
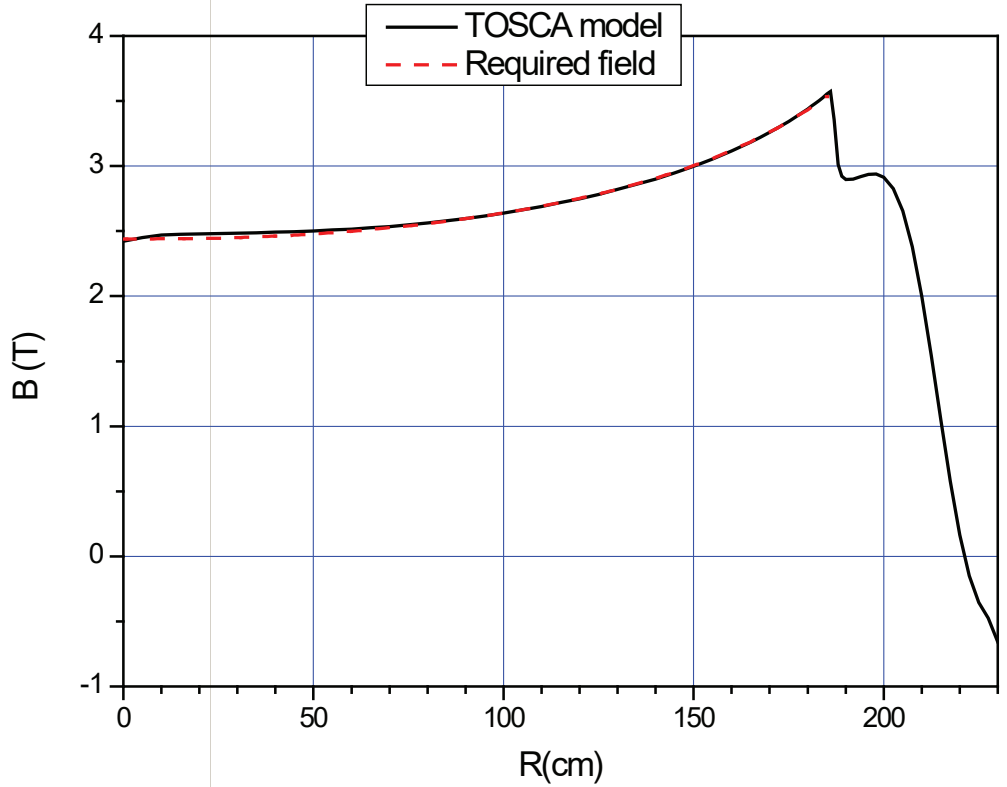
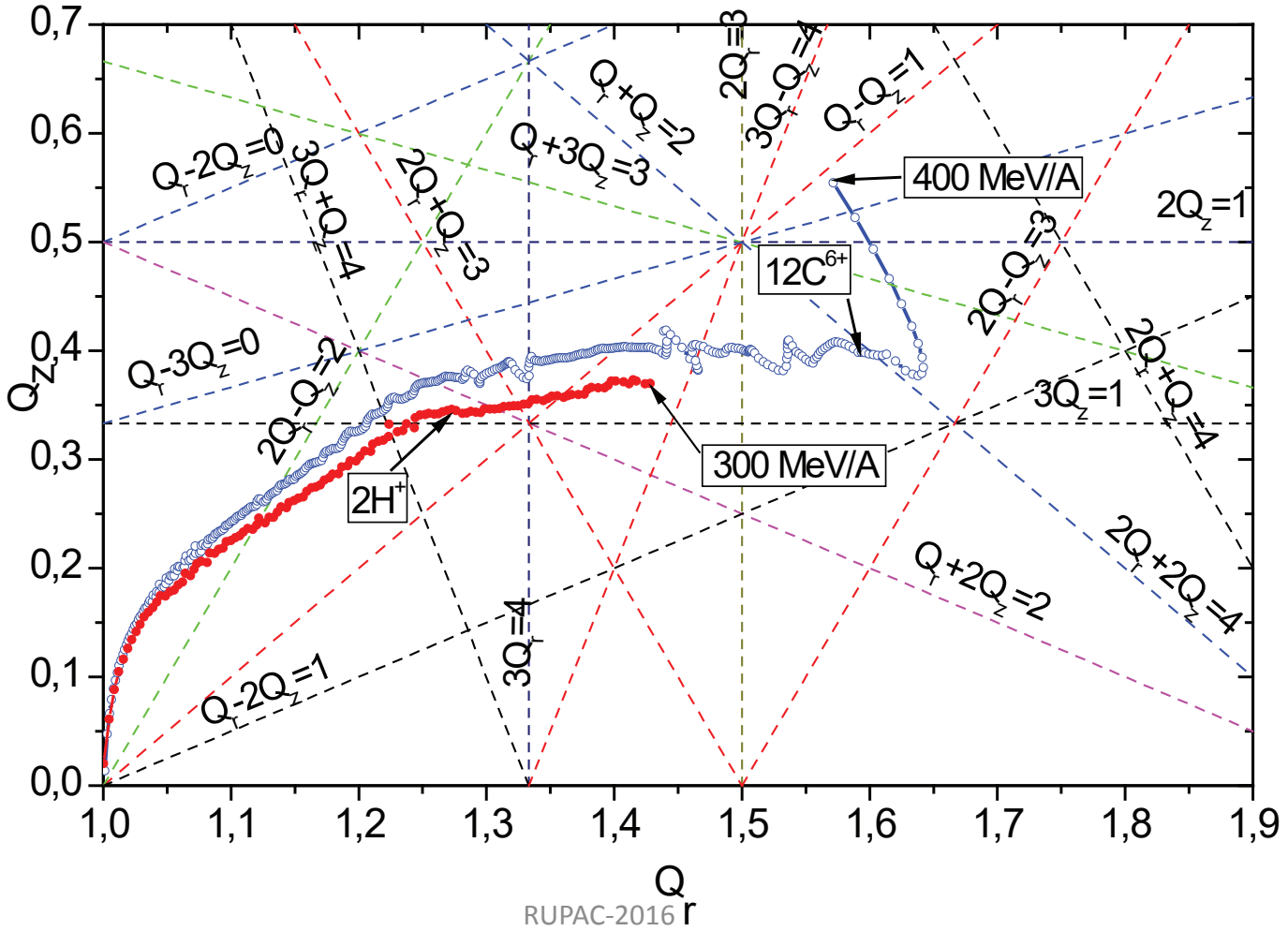




VECTOR FIELDS

Working point diagram of superconducting carbon C400 cyclotron



	C235	C235-V3
Vertical betatron frequency at R>80cm	Qz=0.25	Qz=0.45
Vertical coherent beam Displacement due to median plane effects	3-4mm	1-2mm
Possible beam losses at acceleration without installed diaphragms	50%	25%
Beam losses at extraction	50%	25%
Reduction of irradiation dose of cyclotron subsystems		2-3 times

With finishing of this project in JINR the new milestone on JINR activity in applied researches is completed

C235 transportation from Antwerpen to Dubna

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Pit for C235 assembling, tuning and testing at JINR

- building floor reinforcement
- foundation under vault
- special plates inside the foundation for cyclotron feet
- technological pit

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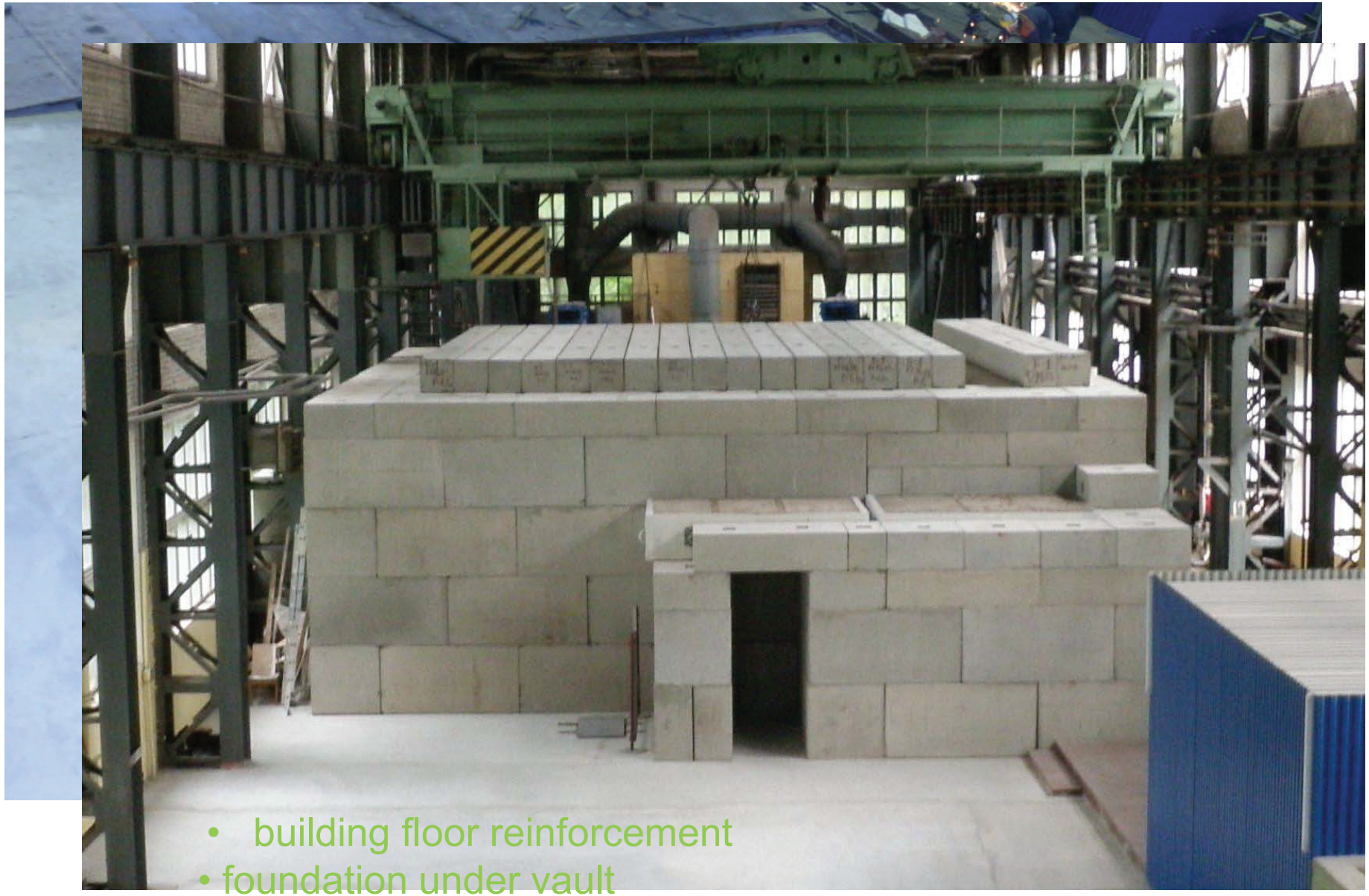

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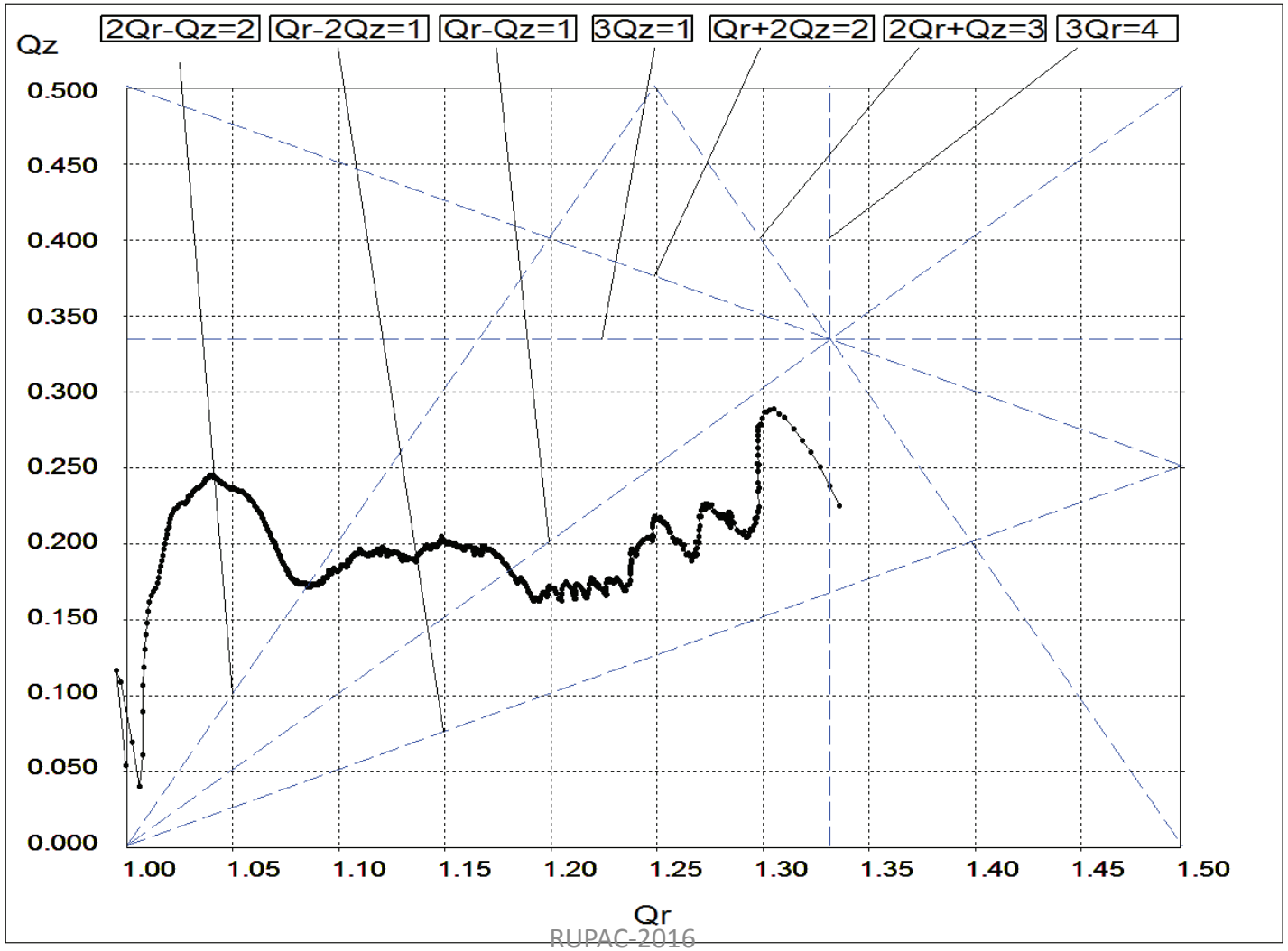
JINR Engineer center for assembling and testing of the medical accelerator equipment.

The building 5 in JINR was refurbish and adapt for performance assembly and beam tests of C235 V3 for Dimitrovgrad.

The connections of electricity, water cooling, ventilation, radiation safety and fire alarm were provided. Building floor reinforcement, vault shielding by concrete blocks, technological pit were prepared.

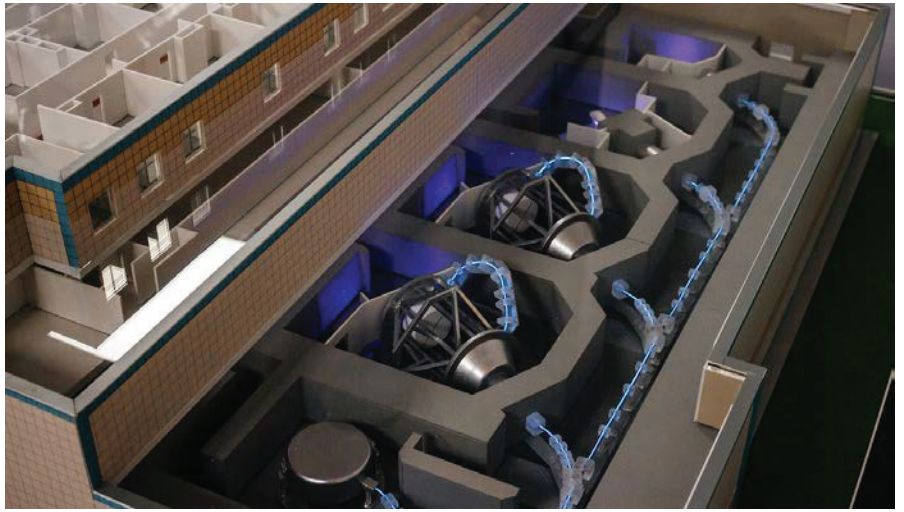
Working point diagram of the C235 cyclotron

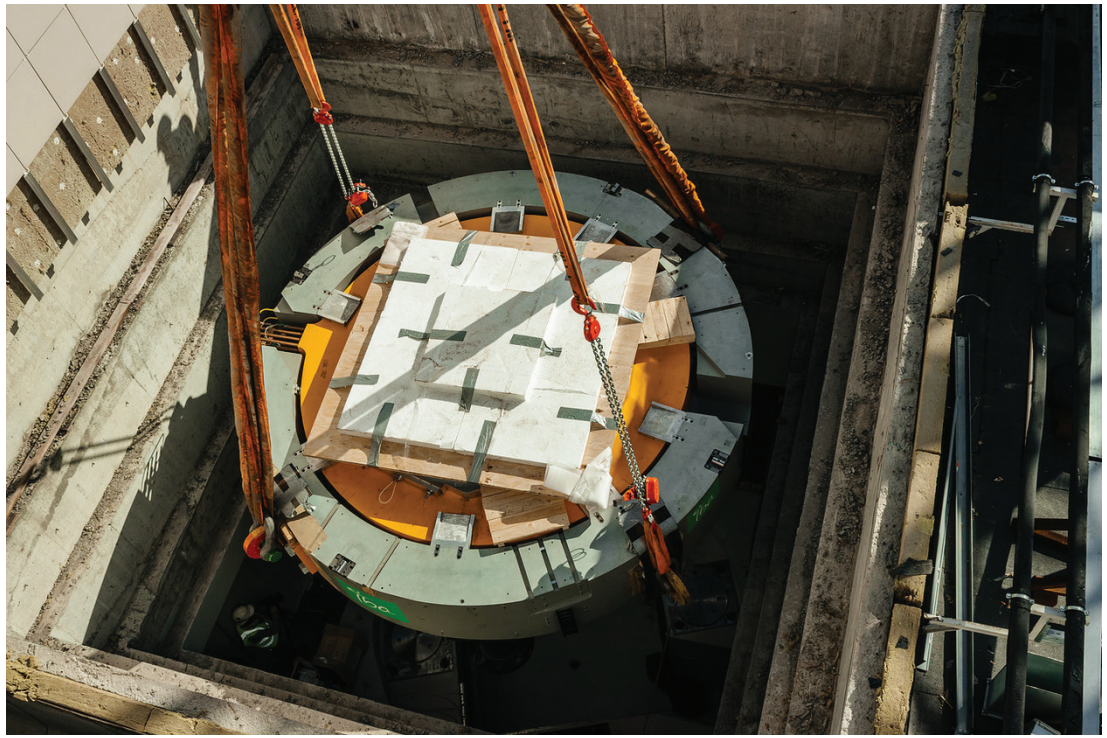


The first Russian hospital center of the proton therapy.

Hospital center of radiation medicine is being founded in Dimitrovgrad under the guidance of the Federal Medical and Biological Agency .

C235 V3 designed in IBA-JINR Collaboration was assembled, tuned and tested at JINR in 2012 and was installed on the working position in Dimitrovgrad on 14.10.2016

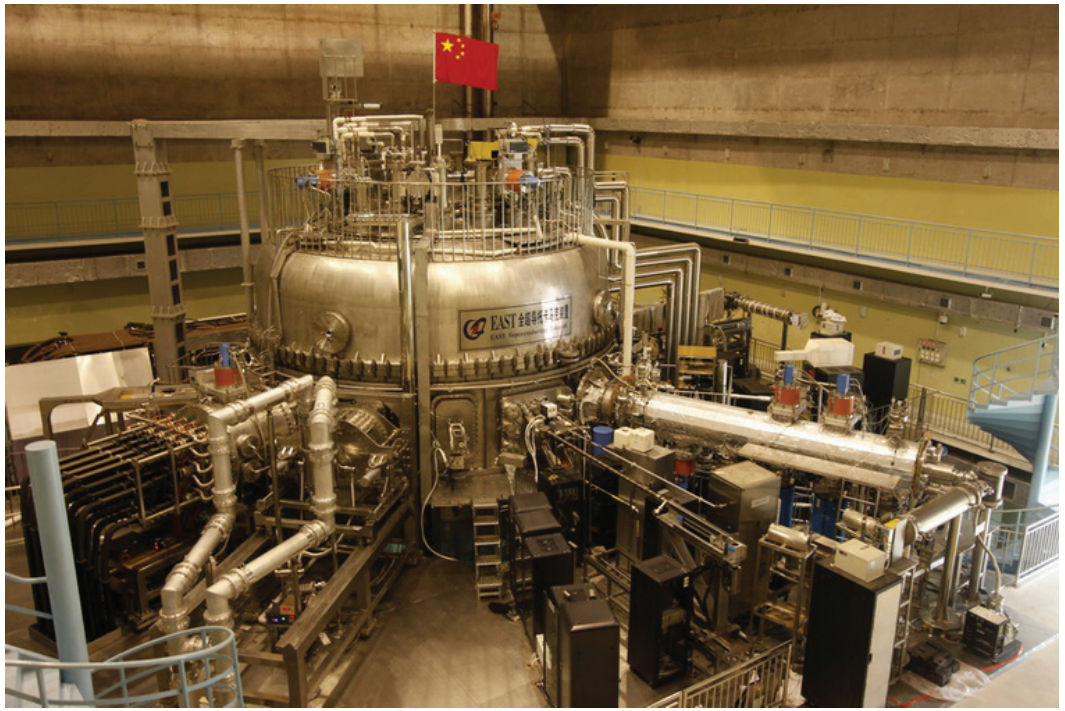




JINR –ASIPP (China) collaboration

- JINR experience in proton therapy and cyclotron design

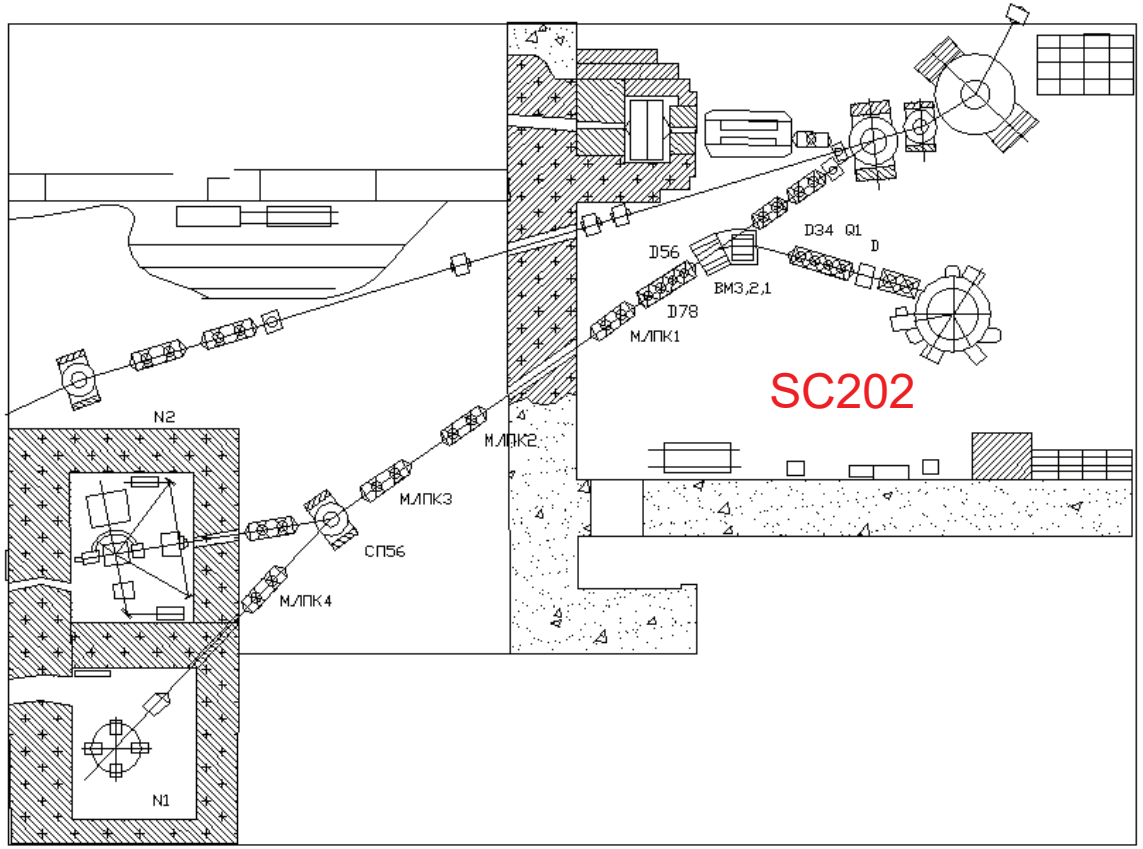
- ASIPP experience: TOKAMAK, superconductivity …



EAST Tokamak
50 mln K for 2 minutes

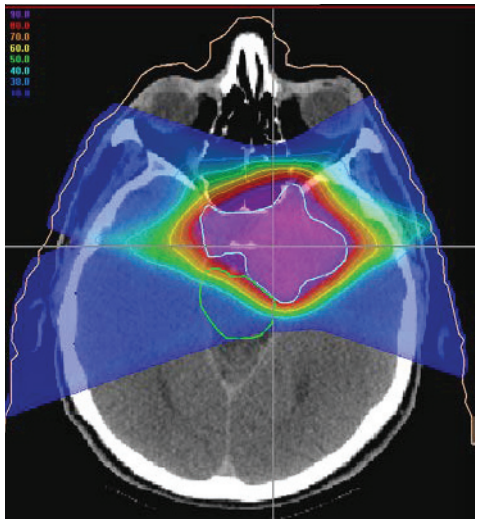
Future accelerator SC200 =>
SC202 = Superconducting Cyclotron 202 MeV

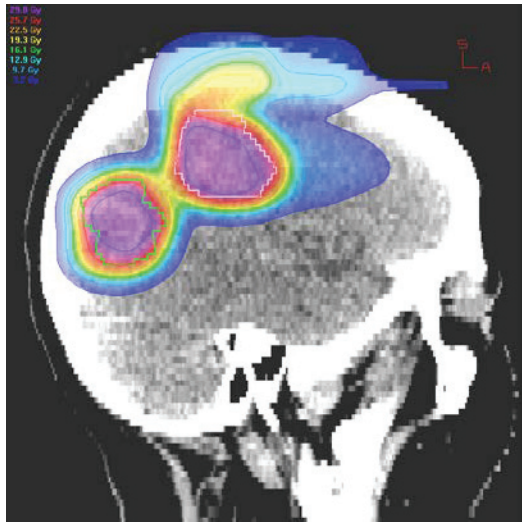
JINR MEDICAL TECHNICAL COMPLEX with future SC202 cyclotron



Dubna ”Fazotron”
Originally build in 1949
Modernised in 1984

Why SC202 energy is about 200 MeV ?

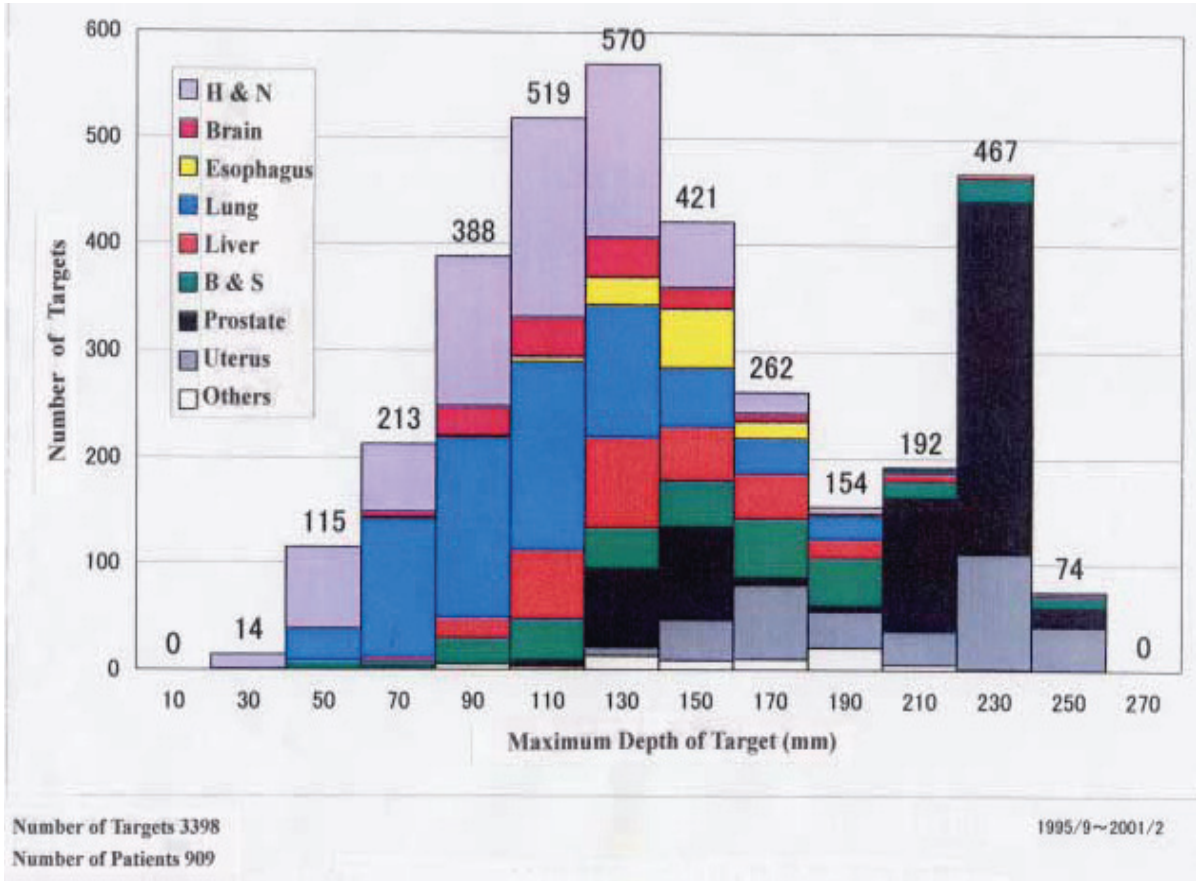




Treatment in JINR: First patient in 1968

In JINR beams under 200 MeV ONLY!

Why SC202 energy is about 200 MeV ?



Yasuo Hirao, RESULTS FROM HIMAC AND OTHER THERAPY FACILITIES IN JAPAN, Cyclotrons and Their Applications 2001, AIP Conference Proceedings;2001, Vol. 600 Issue 1, p8.

In JINR beams under 200 MeV ONLY!

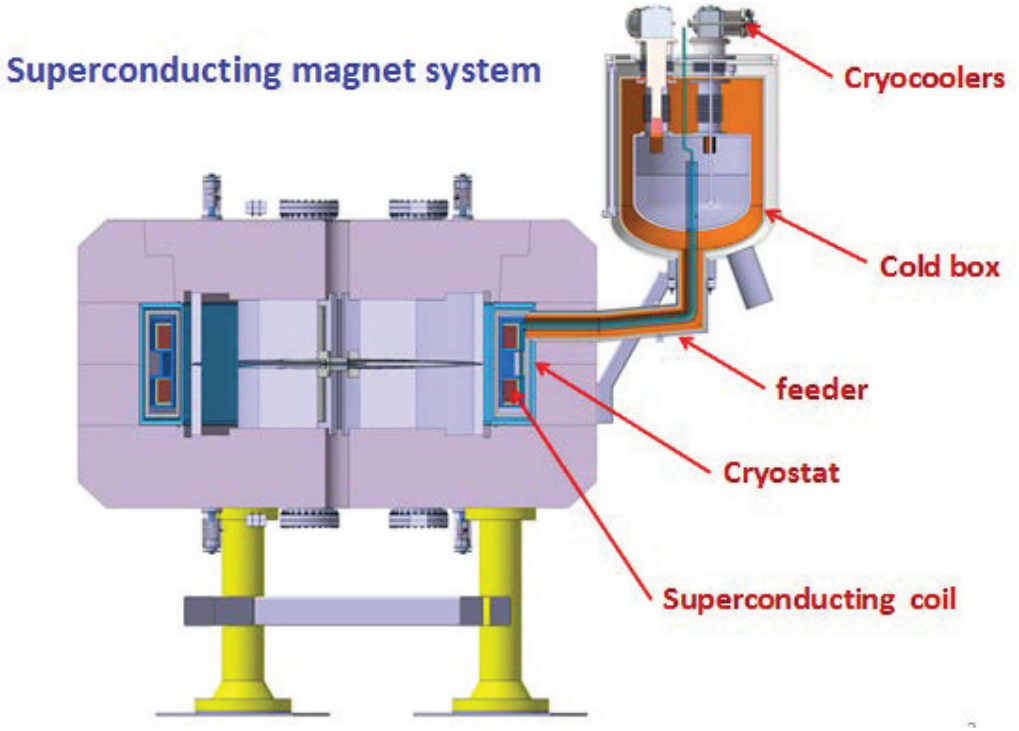
Eye melanoma treatment – 60 MeV
Degrading the energy from 250 MeV down to 60 MeV reduces the current of the beam

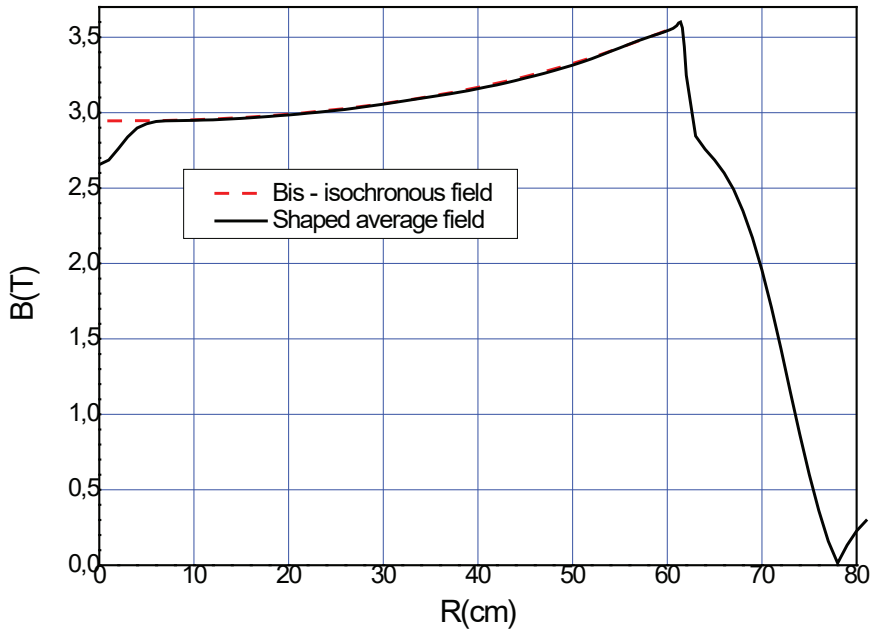
SC202 parameters

Magnet type	Compact, SC coil, warm yoke
Pole diameter (m)	1.22
Magnet diameter (m)	2.5
Magnet height (m)	1.7
Hill gap, max/min (m)	0.04-0.01
Valley gap, max/min (m)	0.3
Yoke material	St.1010
Extraction radius (m)	0.6
Average magnetic field ($R_o/R_{extr.}$) (T)	3.0/3.6
Excitation current (1 coil) (A*turns)	750 000
Magnetic field in the coil (T) max.	4.5
Cryostat and coils weight (t)	5
Total magnet weight (t)	55

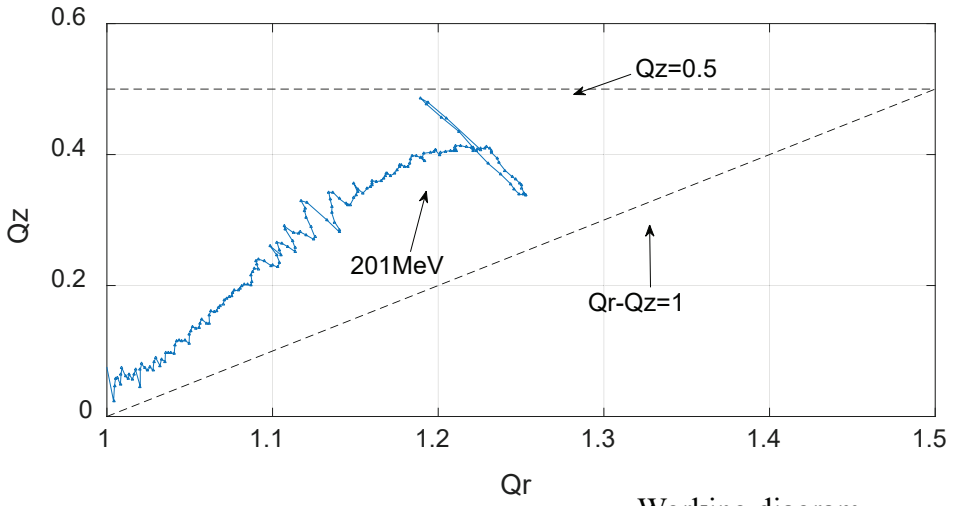
RF cavities	warm
Number of cavities	2
Operating frequency, MHz	90
Harmonic number	2^{nd}
Radial extension of the cavity, m	0.63
Radial extension of the dee, m	0.61
Number of stems	1
Diameter of the stem, m	0.09
Radial position of the stem, m	0.398

SC202 magnet design

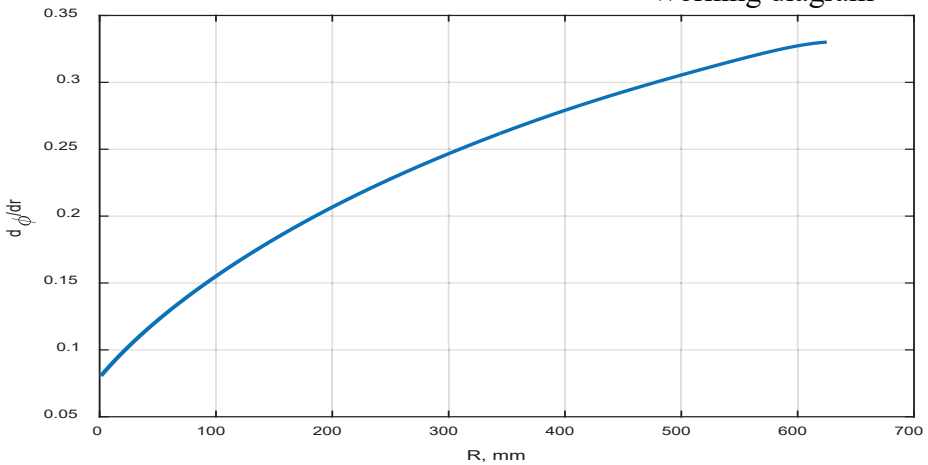




SC202 magnet design

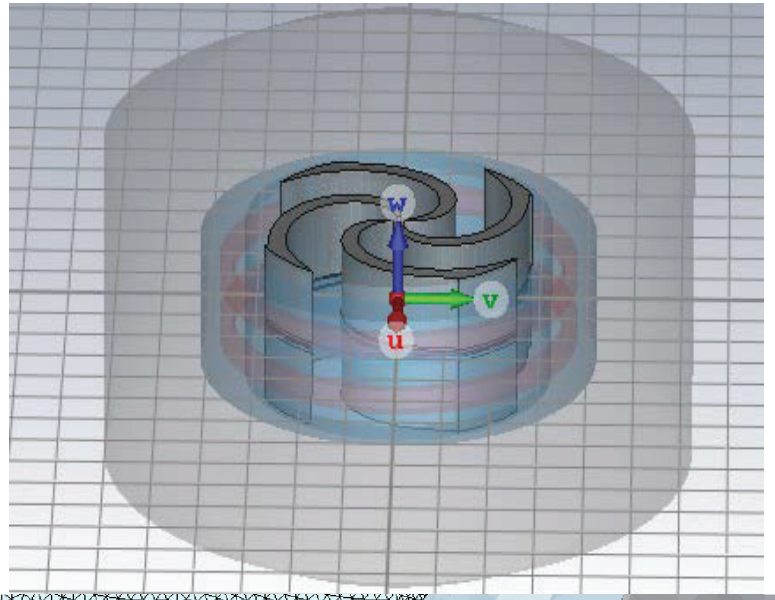


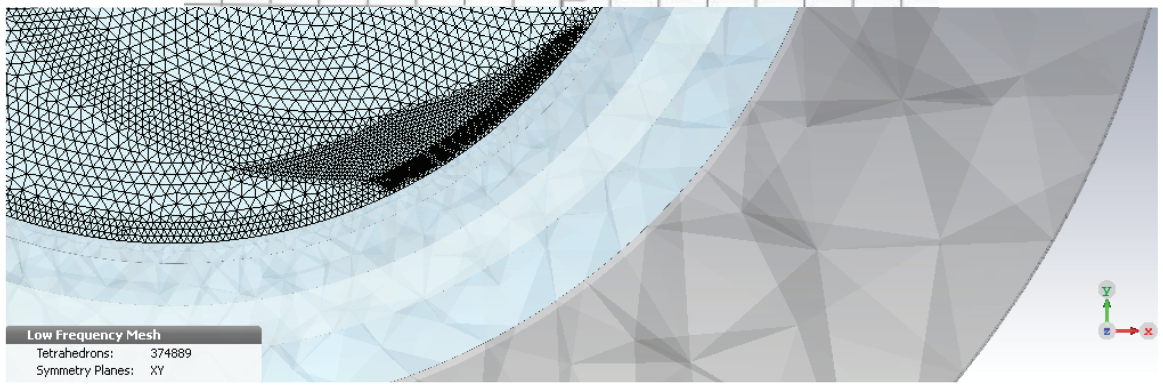
Working diagram



Central line dφ/dr of sector

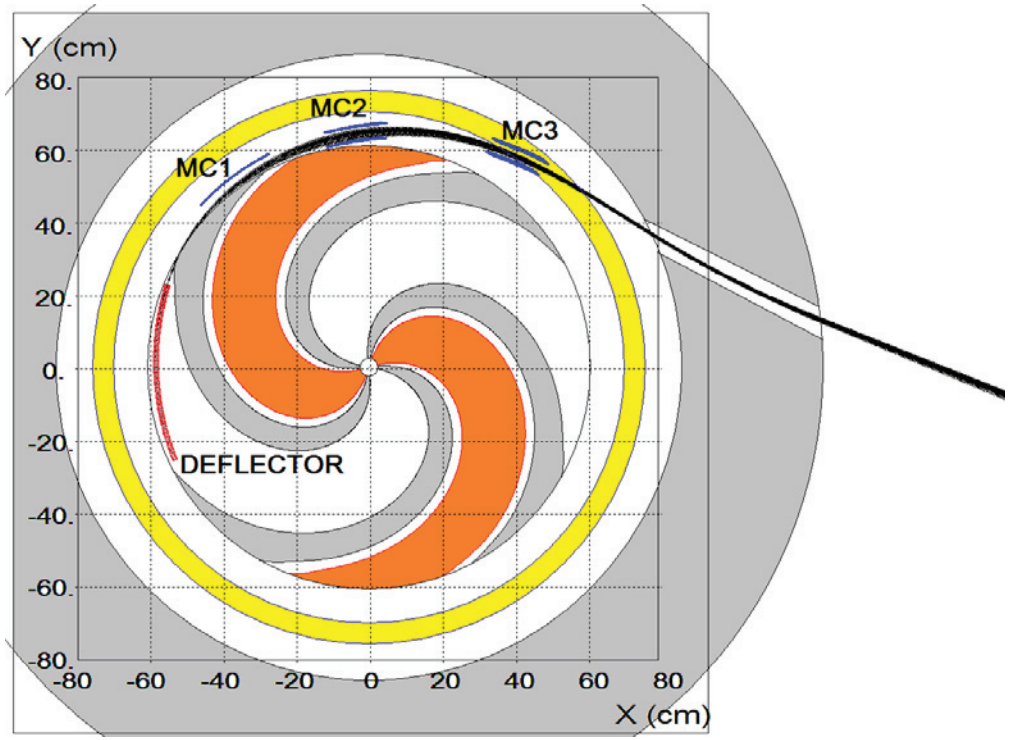
Computer model of the magnet

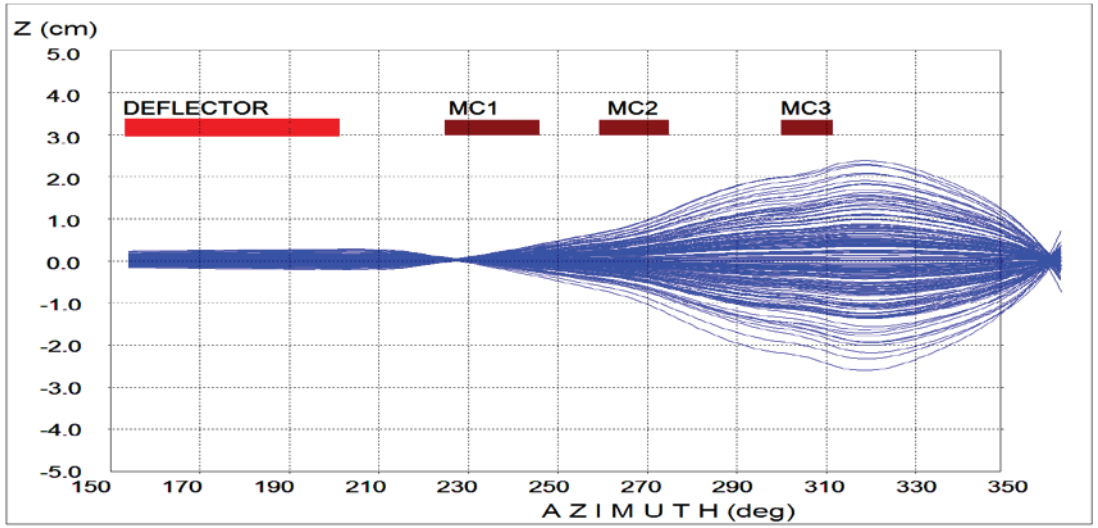




Meshed model

Beam extraction from SC202

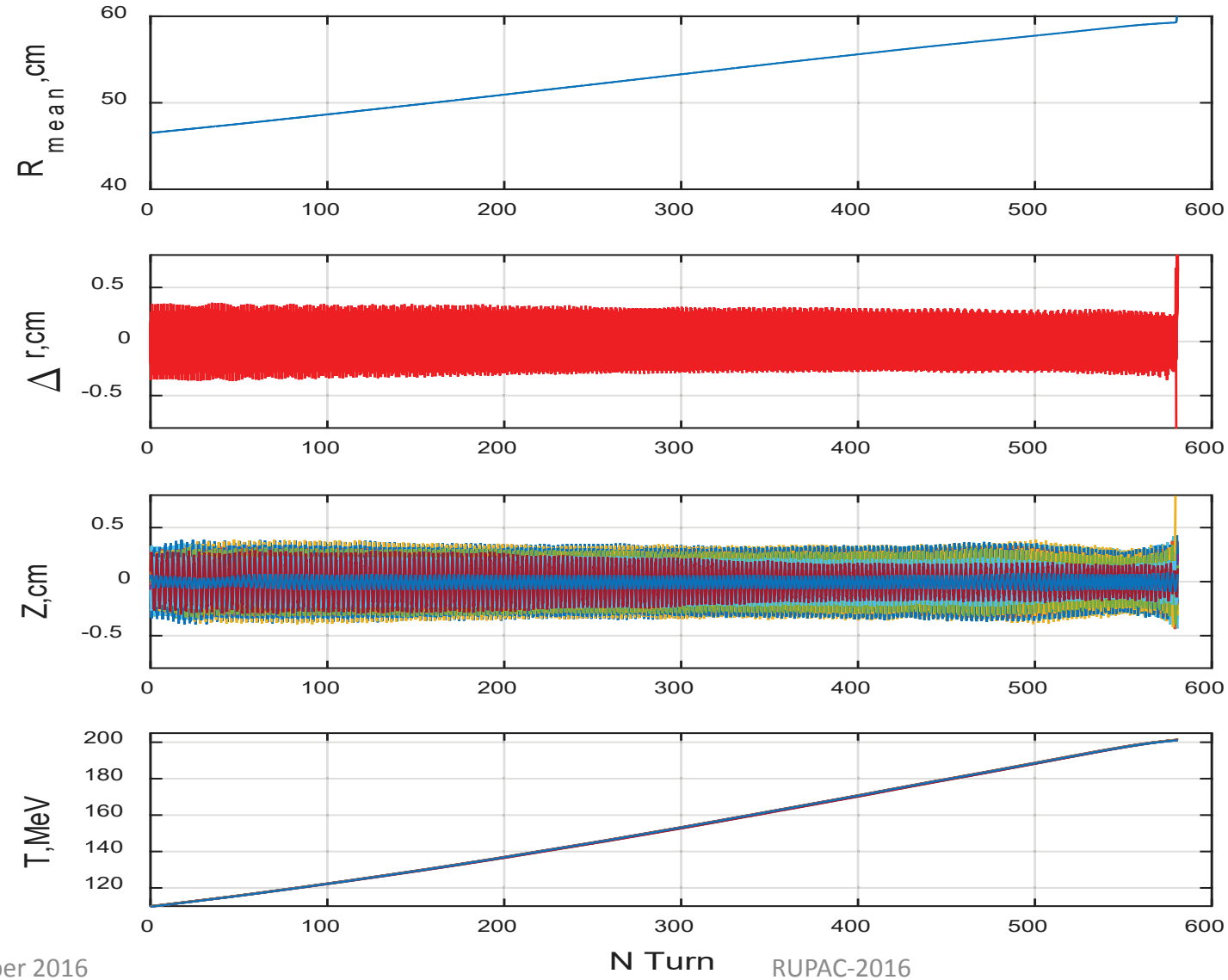




Axial trajectories

Plan view of the cyclotron with extracted beam. Ed=150 kV/cm.

Beam dynamics in SC202 close to extraction region



Mean radius against turn number

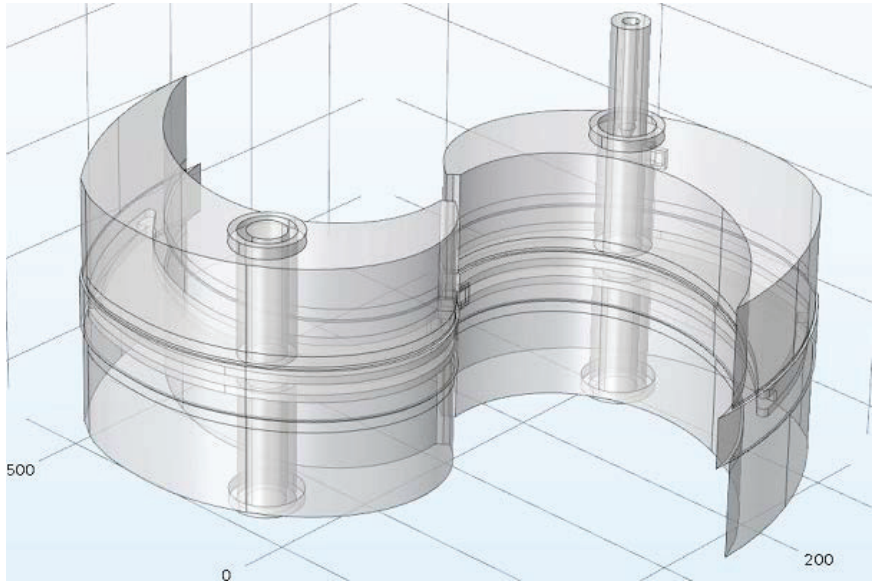
Radial amplitudes

Axial motion

Beam energy

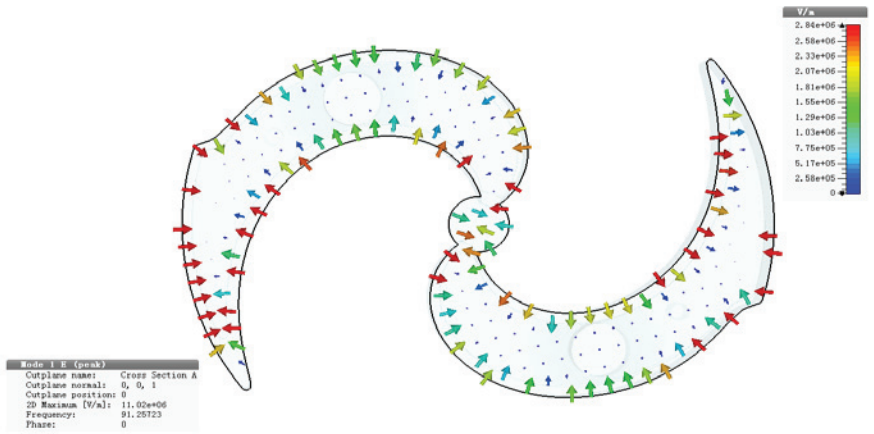
Accelerating system

Parameter	Value
Frequency	91 MHz(2 harmonic)
Cavity number	2
Source power	~120 kW
Accelerate voltage	60 kV(Center)~ 120 kV(Extraction)

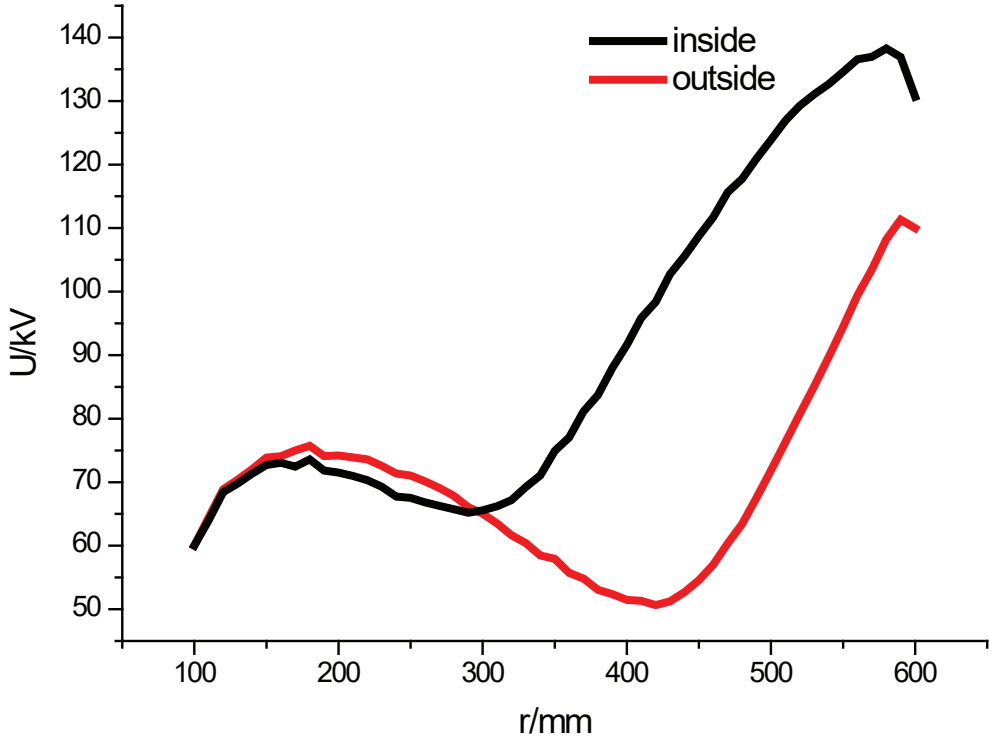


RF cavity overview

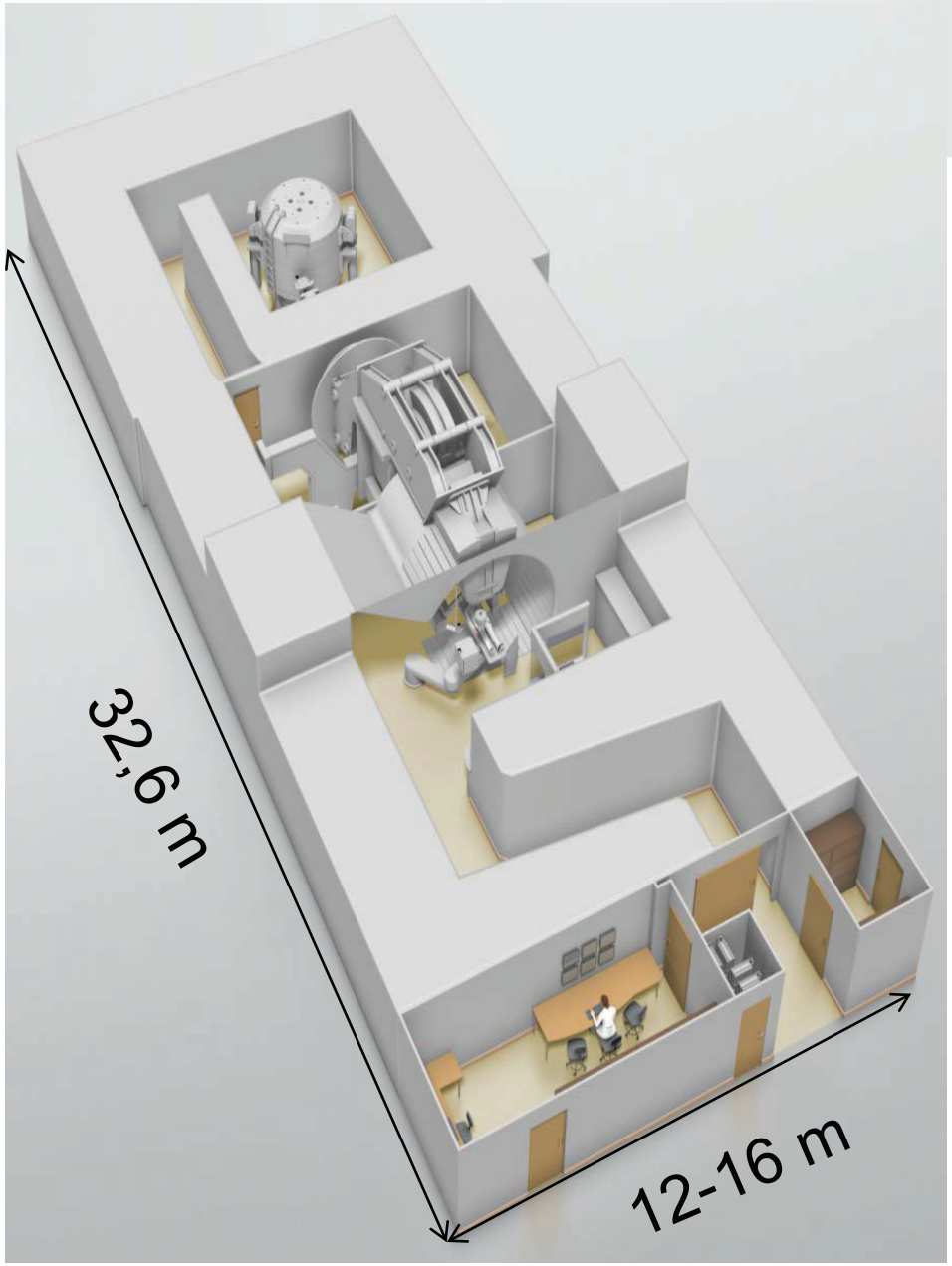
RF cavity simulation



Electric field at f=91.2MHz



Accelerating voltage along radius



Compact IBA Synchrocyclotron

Proteus ONE

could be a new facility for proton therapy instead of Phasotron in Dubna

Possible places for Dubna Center of Radiation Medicine based on the Proteus ONE

In 2016 JINR celebrates its 60th anniversary