SC200 superconducting cyclotron for proton therapy

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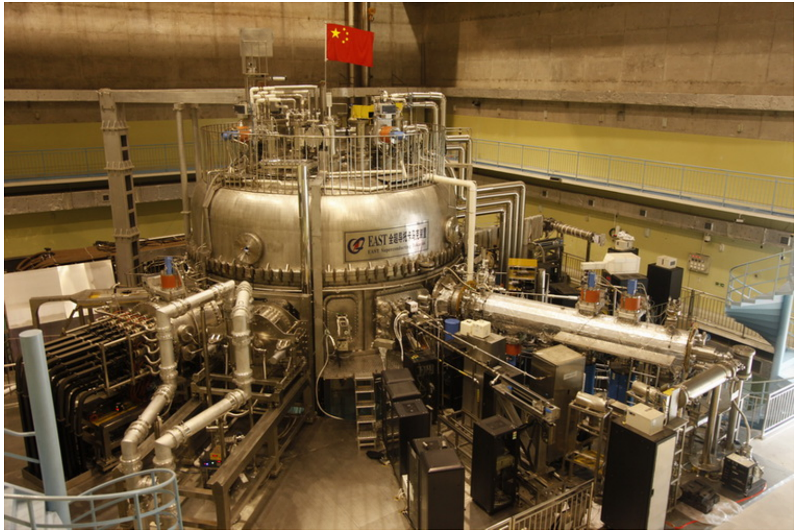
Overview

- Motivation
- Overview
- Magnet design
- Beam dynamics
- Extraction
- RF
- Central region
- Summary

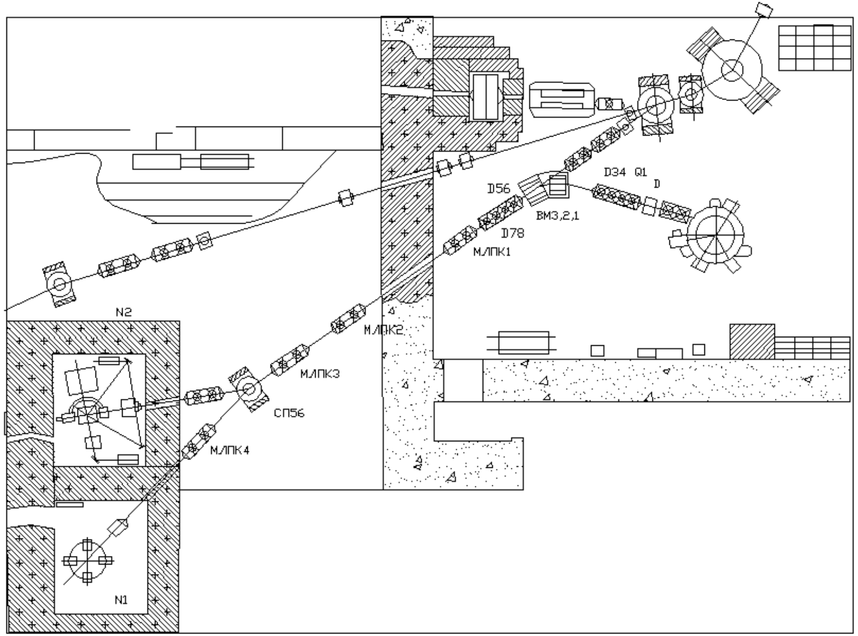
Motivation

- JINR experience: cyclotron design, treatment
- ASIPP experience: TOKAMAK, superconductivity etc…



EAST Tokamak
50 mln K for 2 minutes

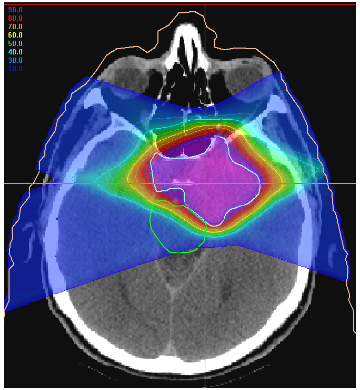
Why SC200?

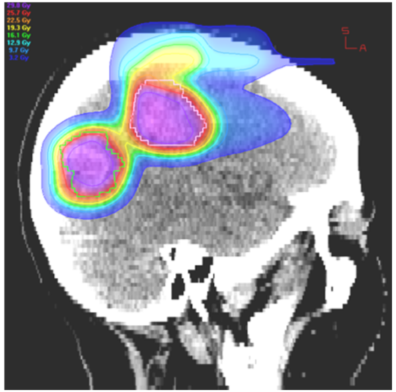


Dubna ”Fazatron”
Originally build in 1949
Modernised in 1984

Why SC200?

SC200 = Superconducting Cyclotron 200 MeV

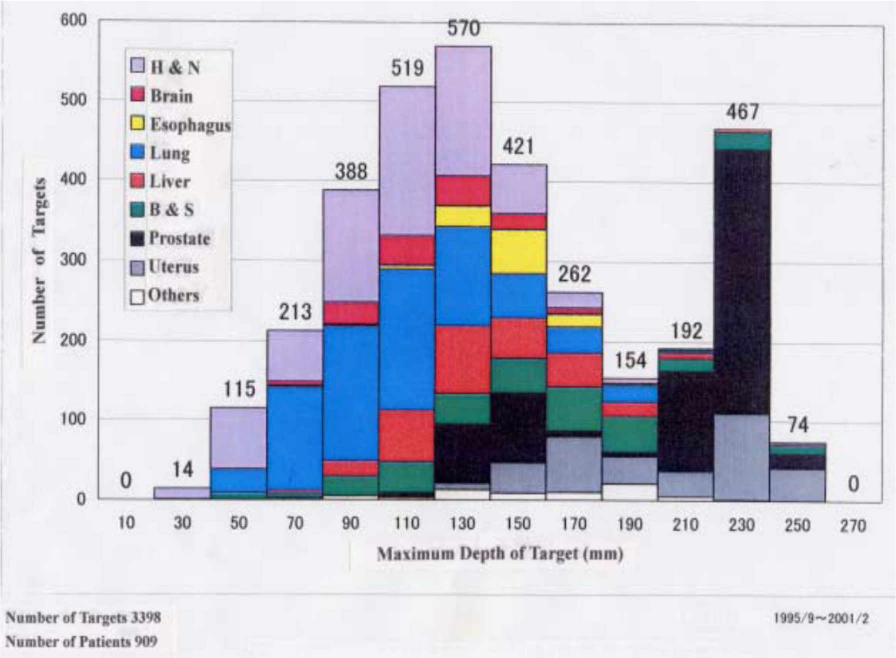




Treatment in JINR: First patient in 1968

In JINR beams under 200 MeV ONLY!

Why SC200?



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!

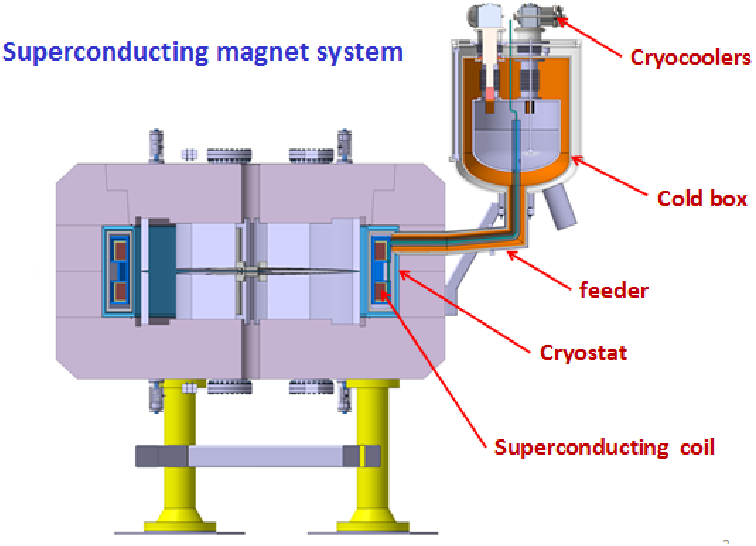
Eye melanoma treatment – 60 MeV
Degrading the energy from 250 MeV down to 60 MeV reduces the current of the beam

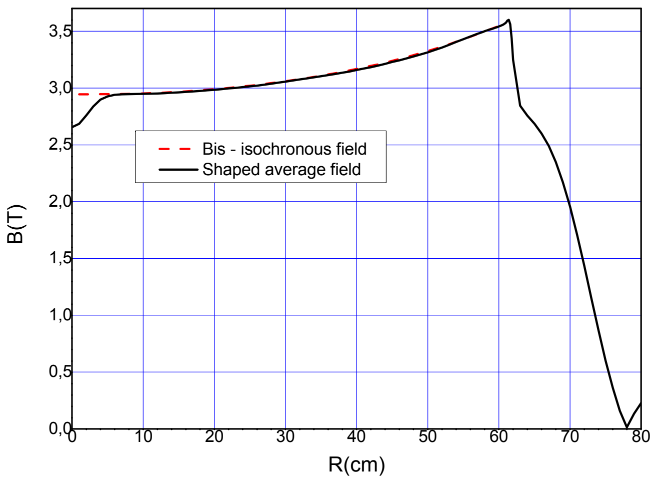
SC200 parameters

Magnet type	Compact, SC coil, warm yoke
Pole diameter (m)	1.24
Magnet diameter (m)	2.2
Magnet height (m)	1.22
Hill gap, max/min (m)	0.04-0.005
Valley gap, max/min (m)	0.6/0.53
Yoke material	St.1010
Extraction radius (m)	0.6
Average magnetic field (R_o/R_{extr}) (T)	2.9/3.5
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)	30

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	0.365

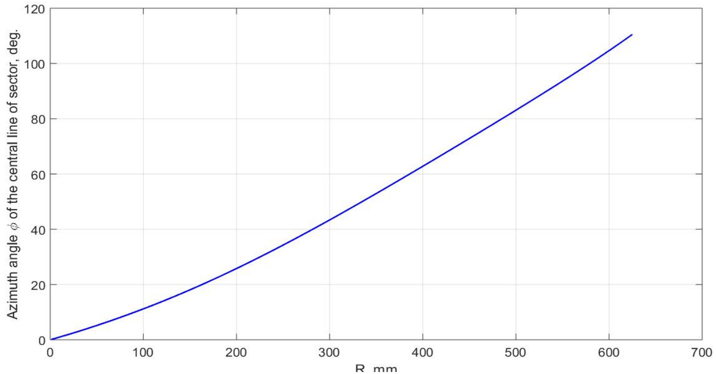
SC200 magnet



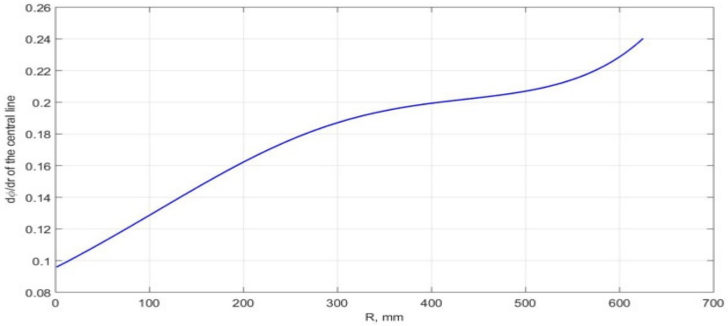


Poster THP20
N.Morozov

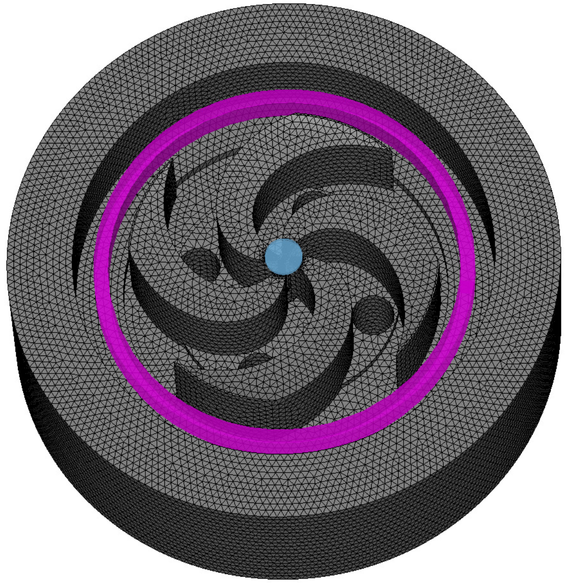
SC200 magnet



Central line φ of sector

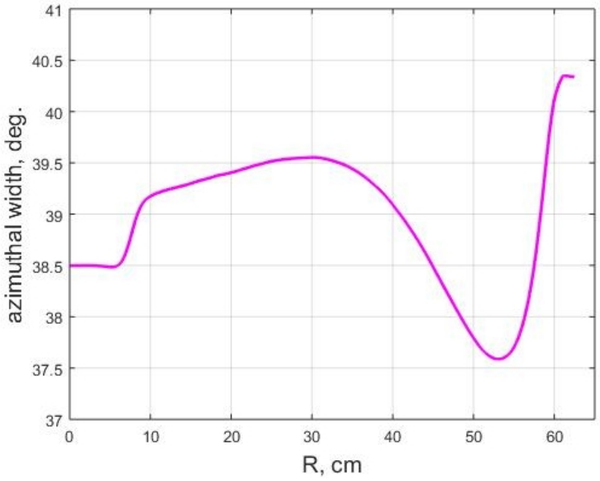


Central line dφ/dr of sector

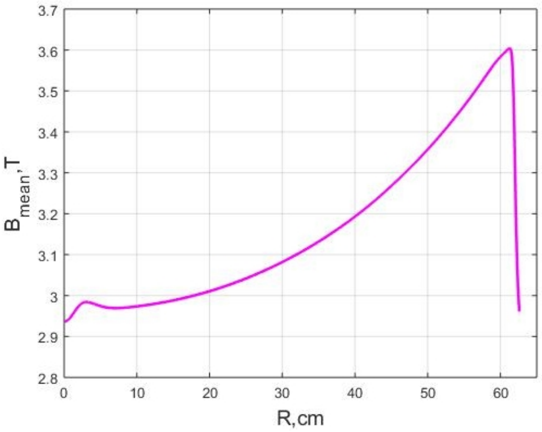


3D meshed model of the magnet

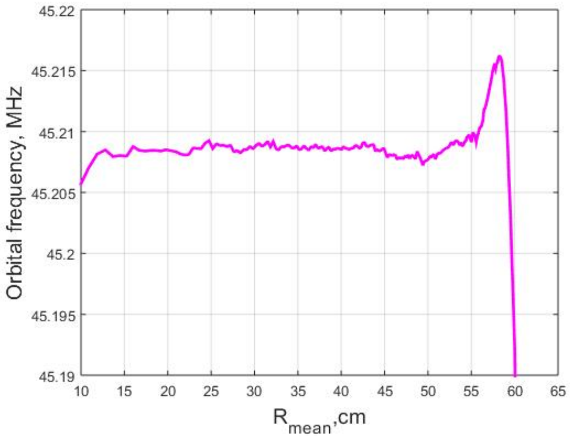
SC200 magnet



Azimuthal width of sector.

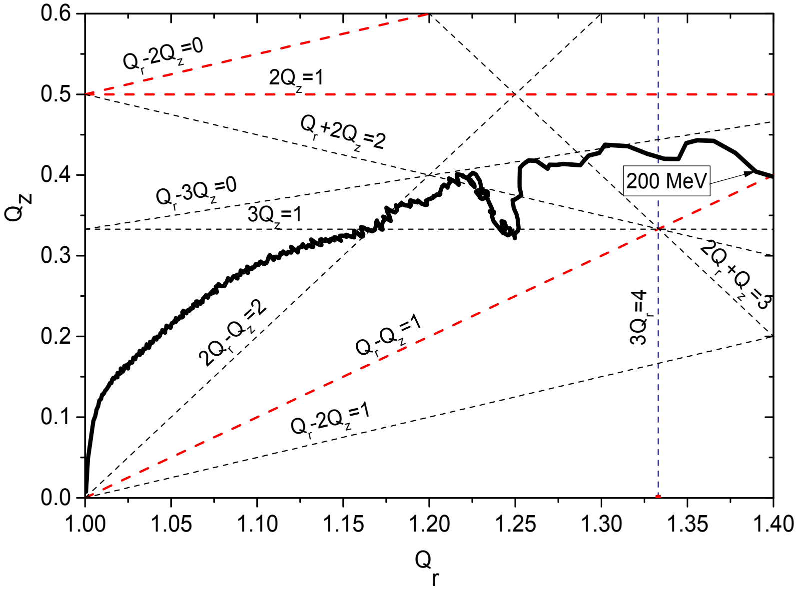


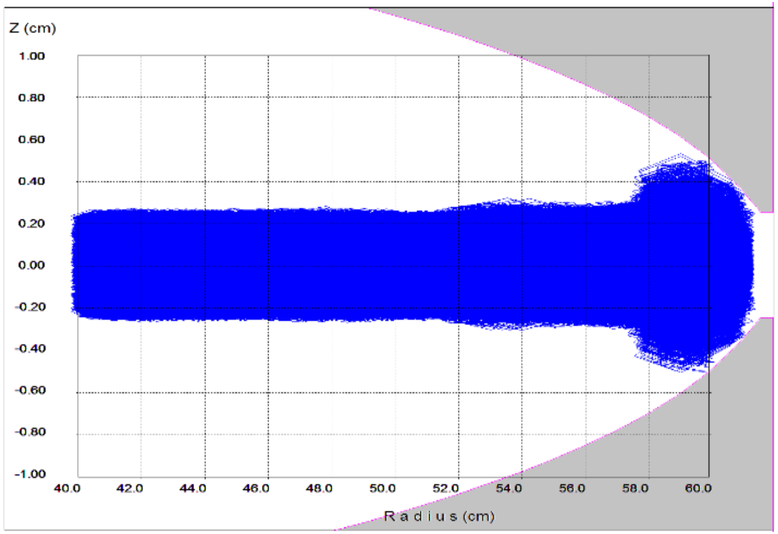
Average magnetic field along the radius.



Orbital frequency against mean radius on the equilibrium orbit

SC200 beam dynamics

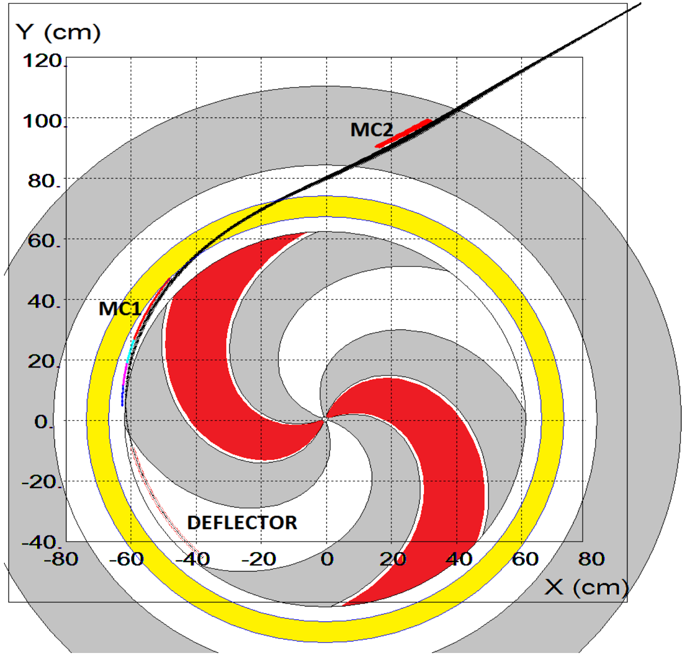


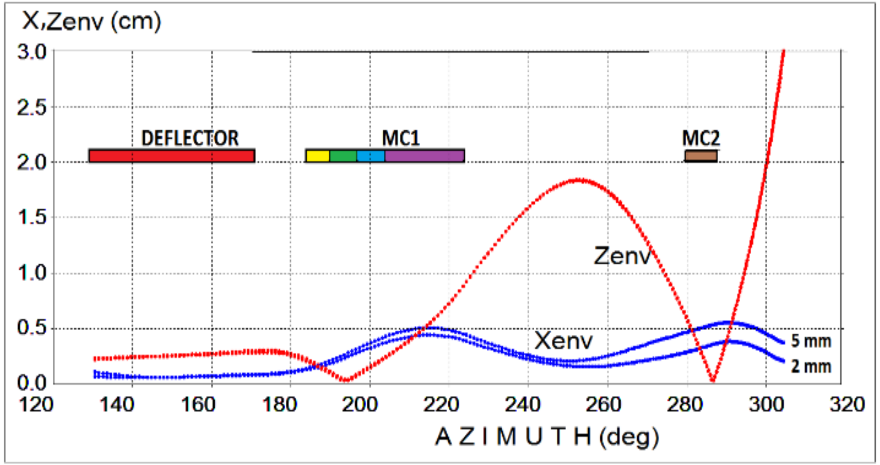


Poster MOP14

E.Samsonov, K.Ding

SC200 extraction system

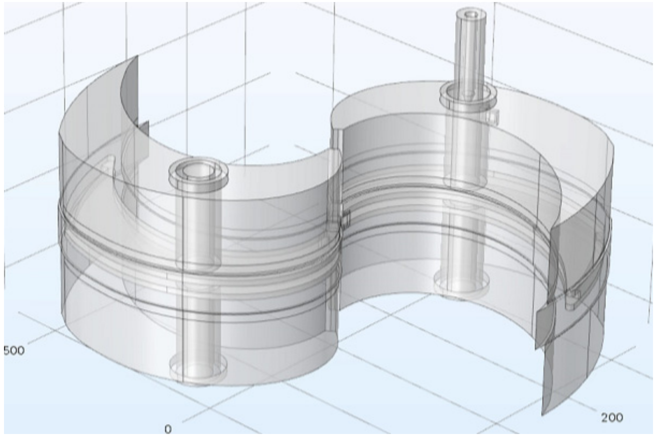




Poster MOP14
E.Samsonov, K.Ding

SC200 RF system

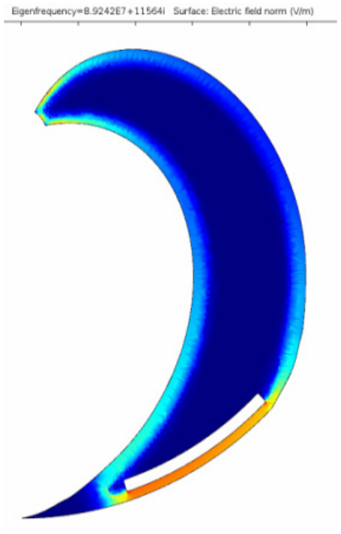
Parameter	Value
Frequency	90 MHz(2 harmonic)
Cavity number	2
Source power	~120 kW
Accelerate voltage	60 kV(Center)~ 120 kV(Extraction)
Dee azimuthal extrention	40°
Cavity azimuthal extrention	50°

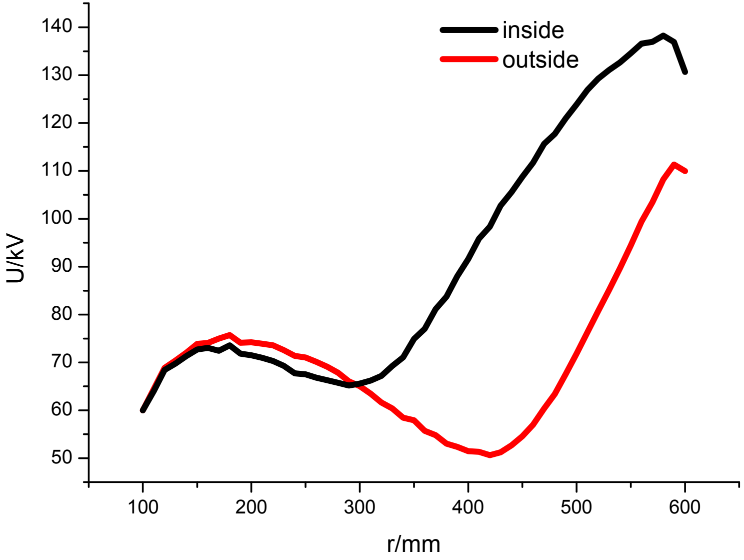


RF overview

Poster TUP17
O.Karamyshev, G.Chen

SC200 RF system





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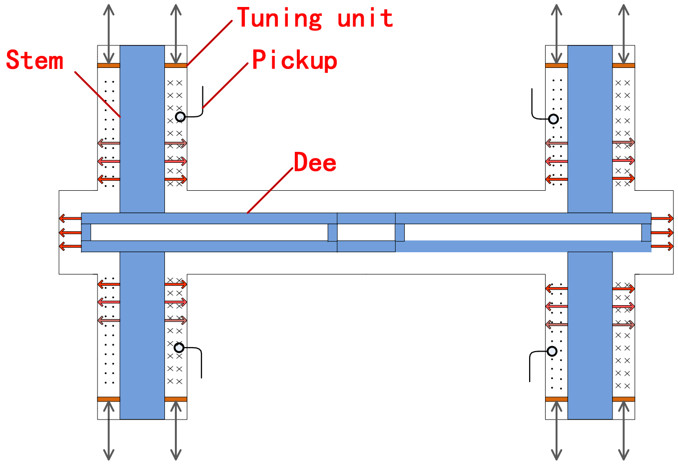
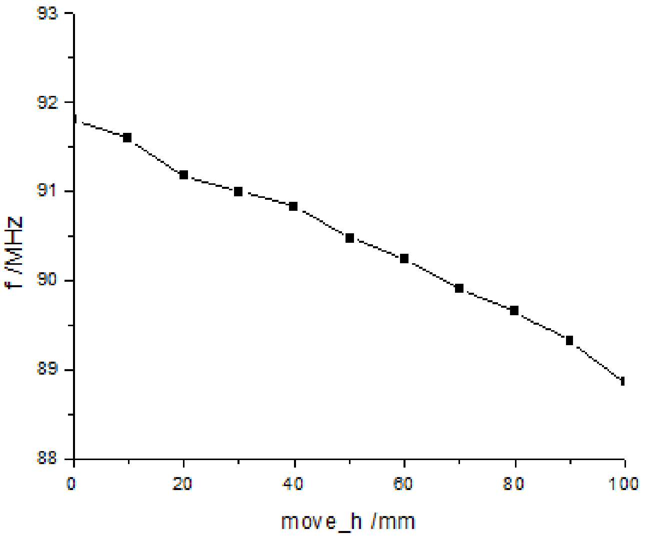
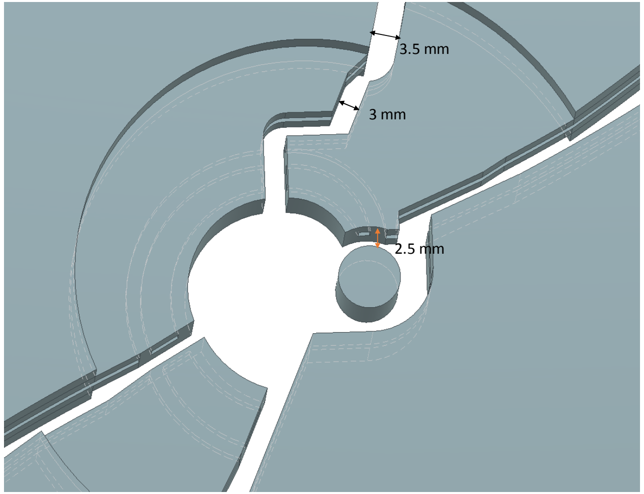


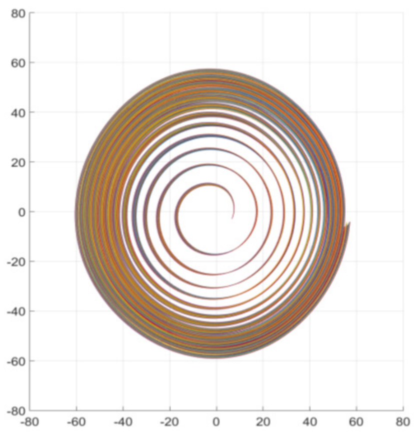


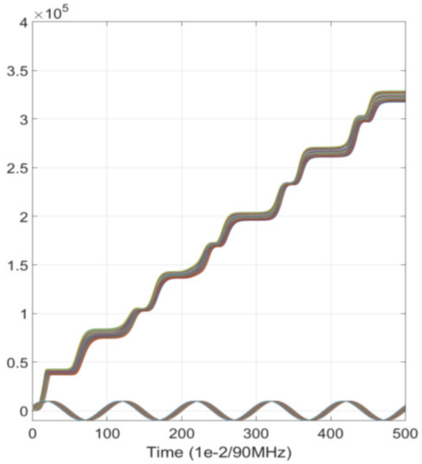
Poster TUP17

O.Karamyshev, G.Chen

SC200 central region

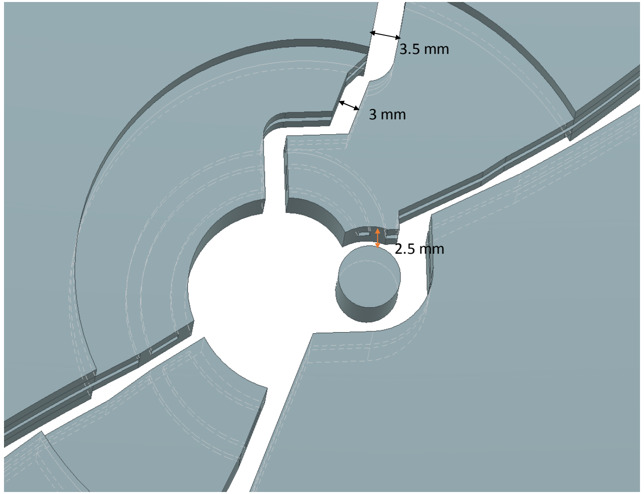


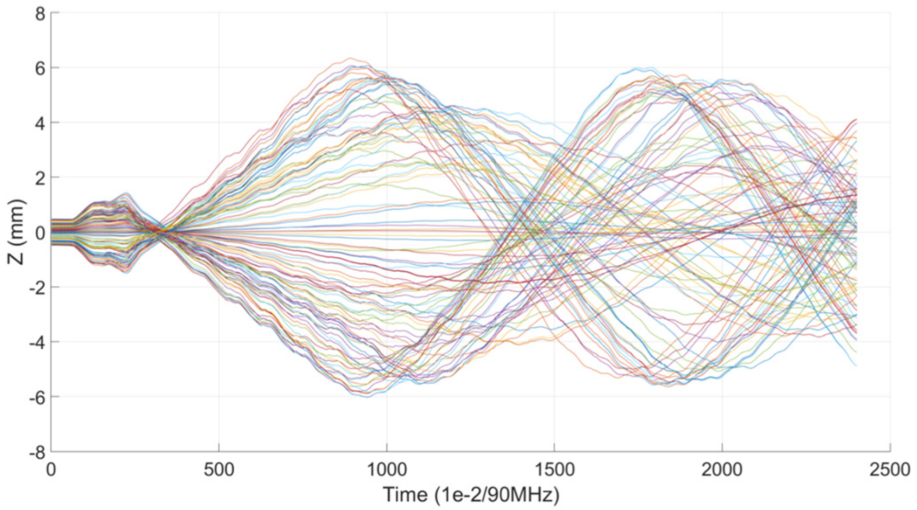




Simulation model (dee tips will be connected)

SC200 central region





Simulation model (dee tips will be connected)

Simulations

Even personal computers of prosumer level allow to achieve “absolute” accuracy of electro-magnetic fields simulations.

”Absolute” = accuracy of the simulations is order higher then accuracy of the manufacturing and tolerances

For magnetic field 3D simulation the value is +- 0.25 Gauss.

Full 3D map from simulation, not calculating from median plane

For electric field - much easier.

Particle Accelerators
1984 Vol. 16 pp. 39–62
0031-2460/84/1602–0039$25.00/0

COMPUTATION OF CLOSED ORBITS AND BASIC FOCUSING PROPERTIES FOR SECTOR-FOCUSED CYCLOTRONS AND THE DESIGN OF “CYCLOPS”†

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Michigan State University
East Lansing, MI 48824

(*Received November 7, 1983*)

$$B_r = B_r(z=0) + z\left(\frac{\partial B_z}{\partial r}\right) + \frac{z^2}{2}\left[\frac{\partial^2 B_z}{\partial r \partial z}\right]$$

$$B_\theta = B_\theta(z=0) + \frac{z}{r}\left(\frac{\partial B_z}{\partial \theta}\right) + \frac{z^2}{2r}\left[\frac{\partial^2 B_z}{\partial \theta \partial z}\right]$$

$$B_z = B_z(z=0) + z\left(\frac{\partial B_z}{\partial z}\right) - \frac{z^2}{2}\left(\Gamma^2 B_z\right)$$

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Simulations

Accuracy of the simulations >> manufacturing tolerances

Optimized models on prosumer level PC (top intel-i7, 64-128 Gb of RAM) >> Human speed

Magnet model is isochronous ± 2-3 Gauss (possible 1 Gauss)

Electrostatic field accuracy ±5 V/m (already unnecessary good, can be even better)

RF electro-magnetic field accuracy – similar.

Plans...

Fix the physical concept – October 2016

Additional simulations to improve the design - October 2016-... till comissioned.

Production stage starts October 2016

Ambitious target – beam by end of 2017...

Thank you for attention!