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!

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

<table>
<thead>
<tr>
<th>Magnet type</th>
<th>Compact, SC coil, warm yoke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pole diameter (m)</td>
<td>1.24</td>
</tr>
<tr>
<td>Magnet diameter (m)</td>
<td>2.2</td>
</tr>
<tr>
<td>Magnet height (m)</td>
<td>1.22</td>
</tr>
<tr>
<td>Hill gap, max/min (m)</td>
<td>0.04-0.005</td>
</tr>
<tr>
<td>Valley gap, max/min (m)</td>
<td>0.6/0.53</td>
</tr>
<tr>
<td>Yoke material</td>
<td>St.1010</td>
</tr>
<tr>
<td>Extraction radius (m)</td>
<td>0.6</td>
</tr>
<tr>
<td>Average magnetic field ( R_o/R_{extr.} ) (T)</td>
<td>2.9/3.5</td>
</tr>
<tr>
<td>Excitation current (1 coil) ( A*\text{turns} )</td>
<td>750 000</td>
</tr>
<tr>
<td>Magnetic field in the coil (T) max.</td>
<td>4.5</td>
</tr>
<tr>
<td>Cryostat and coils weight (t)</td>
<td>5</td>
</tr>
<tr>
<td>Total magnet weight (t)</td>
<td>30</td>
</tr>
</tbody>
</table>

### RF cavities

<table>
<thead>
<tr>
<th>warm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cavities</td>
</tr>
<tr>
<td>Operating frequency, MHz</td>
</tr>
<tr>
<td>Harmonic number</td>
</tr>
<tr>
<td>Radial extension of the cavity, m</td>
</tr>
<tr>
<td>Radial extension of the dee, m</td>
</tr>
<tr>
<td>Number of stems</td>
</tr>
<tr>
<td>Diameter of the stem, m</td>
</tr>
<tr>
<td>Radial position of the stem, m</td>
</tr>
</tbody>
</table>
SC200 magnet

Superconducting magnet system

Cryocoolers
Cold box
feeder
Cryostat
Superconducting coil

Bis - isochronous field
Shaped average field

Poster THP20
N. Morozov

15 September 2016
Cyclotron conference 2016
SC200 magnet

3D meshed model of the magnet

Central line $\varphi$ of sector

Central line $d\varphi/dr$ of sector
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

15 September 2016 Cyclotron conference 2016
### SC200 RF system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>90 MHz(2 harmonic)</td>
</tr>
<tr>
<td>Cavity number</td>
<td>2</td>
</tr>
<tr>
<td>Source power</td>
<td>~120 kW</td>
</tr>
<tr>
<td>Accelerate voltage</td>
<td>60 kV(Center)~120 kV(Extraction)</td>
</tr>
<tr>
<td>Dee azimuthal extension</td>
<td>40°</td>
</tr>
<tr>
<td>Cavity azimuthal extension</td>
<td>50°</td>
</tr>
</tbody>
</table>

Poster TUP17
O.Karamyshev, G.Chen
SC200 RF system

Poster TUP17
O.Karamyshev, G.Chen
SC200 central region

Simulation model (dee tips will be connected)
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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.
Simulations

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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.
Fix the physical concept – October 2016

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

Production stage starts October 2016

Ambitious target – beam by end of 2017...
Thank you for attention!