

# SC202 (SC200) superconducting cyclotron for proton therapy

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# 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;

#### 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

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.



# Motivation

• JINR experience: cyclotron design, treatment.

• ASIPP (Hefei, China) experience: TOKAMAK, superconductivity etc...



EAST Tokamak 50 mln K for 2 minutes



# Why SC200?





Dubna "Fazatron" Originally build in 1949 Modernised in 1984

1mln \$ per year 3MW power





#### SC200 = Superconducting Cyclotron 202 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



### SC202 cyclotron. Main parameters



Mass	55 Tonn
RF Freq	91.4 MHz
Coil current	720 kA
lon source	PIG
Sector azimuthal lenght	20-35 deg
Vertical gap between sectors	38->9 mm Decreasing to extraction. Not elliptical!
Valley depth	250mm



# Project is successfully finished



Magnet

**RF** cavity

Beam dynamics

### Current status:

# production

### Source





# ESD

#### Septum electrode: 0.1mm Aperture 3mm



### Magnet for Hefei



# SC coil



#### Magnet section view



### Diagnostics



## RF system



# **Central region**



Cooperation Progress of the SC200 Superconducting Proton Therapy System at ASIPP

### Background



#### **Collaboration**





China-Russia joint statement in 2014



20th and 21st Prime Minister Regular Meeting btw RU. and CN.



Russian Prime Minister Dmitry Medvedev visited ASIPP



Memorandum of Cooperation between NICA and EAST



JINR-ASIPP Superconducting Proton Therapy Joint Research Center



1st ASIPP&JINR workshop on Energy S&T and the Applications



SC200 Cooperation btw JINR & CIM 19

### S&T Cooperation btw China and Russia

The international cooperation platform between Russia and China is essential for the realization of nuclear fusion energy and ion accelerator used for treat the cancer community.



**T-7 Tokamak** 



HT-7 Tokamak



EAST



NICA



**SC200** Proton Therapy



**PHASOTRON & C235 Testing** 





**MORE COOPERATION IN FUTURE** 

science and Technology co

#### **Cooperation on SC200 Proton Therapy System**

#### **Cooperation on Proton Therapy System**

The SC200 proton therapy system is a very complex medical device which aims the precise radiation treatment of tumor with high energy proton beam. It is consisted of a superconducting cyclotron, one 360 degrees gantry room and one fixed beam room. The physical and engineering design of beam line, gantry and spot scanning nozzle is finished, the biggest feature of the accelerator system is compact,



#### What's Proton Therapy?

Proton therapy is a kind of advanced radiation treatment which delivers the majority of the destructive energy within a small range inside the tumor, known as the Bragg peak, thereby reducing adverse effects to adjacent healthy tissues.



#### **Benefits of Proton Therapy**

- Causing fewer and less severe side effects during and after treatment.
- Allowing for a higher radiation dose to the tumor and increasing chances that all tumor cells are destroyed.
- Delivering up to 60% less radiation to healthy tissue around the tumor and lowering the risk of damage to these tissues.

#### **Cooperation Objective of SC200 System**

#### **Objective:**

Design and develop a most compact 200 MeV superconducting cyclotron for SC200 proton therapy system.

Independent R&D is undertaken byJINR, ASIPP and CIM, including beam dynamics simulation, ion cource, central region, magnet system, superconducting coil, radio frequency system, extraction system, beam diagnostics et al.

**Design Parameters of SC200 Cyclotron** 

Parameters	Values
Type of Accelerator	Isochronous cyclotron
Particles	Proton
Magnet Type	Superconducting Coil
Extraction Beam Energy (MeV)	70-200
Extraction Beam Current (nA)	~400
Tumor Depth Range (cm)	4-26
Accelerator Diameter (m)	~2.4
Total weight (ton)	~50



#### Structure of SC200 Superconducting Cyclotron Benefits from Superconducting Technology

- Lower down the manufacturing cost. Save more than 50% the total mass.
- Lower down the operation cost. Save more than 60% power load compared to conventional resistive magnets.
- Lower down the building cost. More compact dimension reduces the space occupation.
  - All above can reduce the patient cost significantly! 22

### **Progress of SC200 Cyclotron Design**



**Isochronous Magnetic Field Simulation** 



**Proton Beam Orbit Simulation** 





**Cyclotron Control System Design** 



#### 1<sup>st</sup> International Experts Review



**Middle Plane Design** 



**Electrical Distribution in Middle Plane** 



2<sup>nd</sup> International Experts Review





**Central Range Design** 



**Beam Extraction Design** 



**RF System Design** 

#### **Progress of SC200 Cyclotron Integration & Test**



**Superconducting Coil Test** 









CT)

**Cyclotron Control System Development** 

**Core Control System** 



Superconducting Coil with Cryostat Test



Ion Source Extract Beam Test



**Cyclotron Integration** 



**Magnet Pole Manufacture** 



#### **Progress of Beamline & Control system**



**Degrader Test** 



Beam Stopper



Limit Slit



Quadrupole magnet

Dipole magnet



Superconducting Magnet Power Supply Control System

LLRF Control System

Ion Source Control System

#### **Proton System Integration & Therapy Center**

**Radiation shielding building is one of the important work** The integration work is on going including all the auxiliary system such as the necessary treatment planning, power supply, cooling water system etc.. A proton therapy clinical center where the 1<sup>st</sup> PT system will be installed and used for patient treatment is under construction. The manufacturing and testing center for the series PT production is under design and will be finished in next June.

**Fixed Beam** 

Gantry

Treatment Control

Room



#### **Time Schedule**



- Russia and China have long history in cooperation research work on plasma science, ion physics and nuclear fusion energy. SC200 superconducting proton therapy system is an important and highlight project which has great social benefits under the cooperation framework.
- Physics simulation and design of the SC200 superconducting cyclotron have been done and got approval by international experts.
- SC200 project goes smoothly and gets great achievement under the hard work of both parties. We have fully confidence to make sure this cooperation successful.
- > JINR and ASIPP hope to deepen the cooperation on more areas.



### **Proton Therapy Strategy at JINR**

«MIN Programm»:

SC202 instead of Phasotron.

«MAX Programm»:

**a)** Medical center with proton therapy outside the JINR territory on the base of Compact IBA Synchrocyclotron *Proteus ONE* 

b) cooperation on hadron therapy with ASIPP and build a joint proton therapy center in JINR and ASIPP (?)

Future Programm:

Carbon Experimental Therapy with NICA Booster ???





# Thanks for your attention!