Structure Optimization of The Fast Scanning Magnets for Proton Therapy

Zhongqi Zhang, Ping Tan, Xingyu Li, Yinjie Lin, Yecheng Yu, Yuying Hu, Hao Lei, Jiadong Li

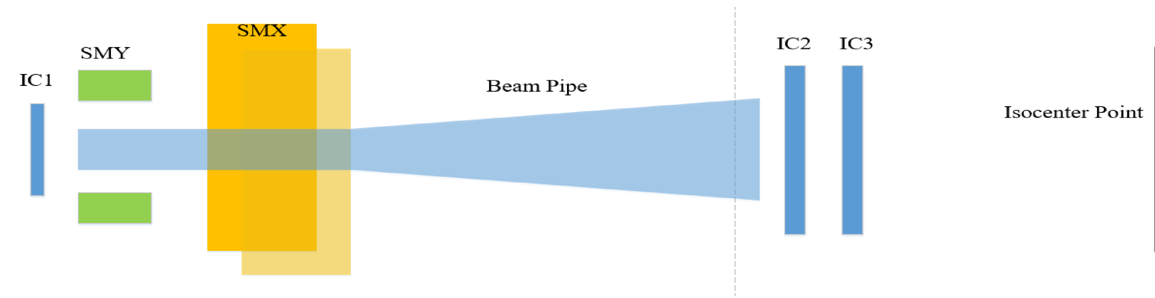
State Key Laboratory of Advanced Electromagnetic Engineering and Technology, Huazhong University of Science and Technology, Wuhan 430074, Hubei, China

MT 26 International Conference on Magnet Technology, Vancouver, Canada | 2019

Wed-Mo-Po3.04-03 [23]

I. Introduction

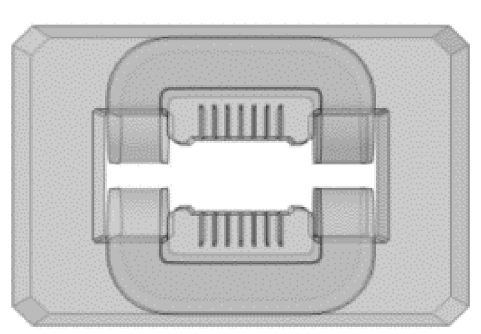
Huazhong University of Science and Technology is developing a set of new proton therapy facility (HUST-PTF).
The scanning magnets change the trajectory of the proton beam to illuminate the tumor area accurately.
The scanning system consist of two mutually perpendicular magnets, scanning magnet Y (SMY) and scanning magnet X(SMX), SMY placed before SMX.
The energy range of the incident proton beam is 70 MeV-230 MeV and the scan field is 30 cm×30 cm.



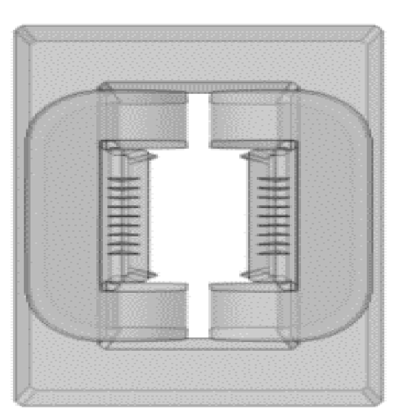
Layout of the treatment nozzle

II. Design of the Scanning Magnets

The maximum deflection angle of the scanning magnet is determined by the scanning range and the source axial distance (SAD). According to the design requirements of the device, the corresponding scan range is 30 cm×30 cm and the SAD of two scanning magnets are 1950 mm and 1550 mm respectively.
The models of the scanning magnets is shown below.
The key parameters of the two magnets are as follows.



SMY



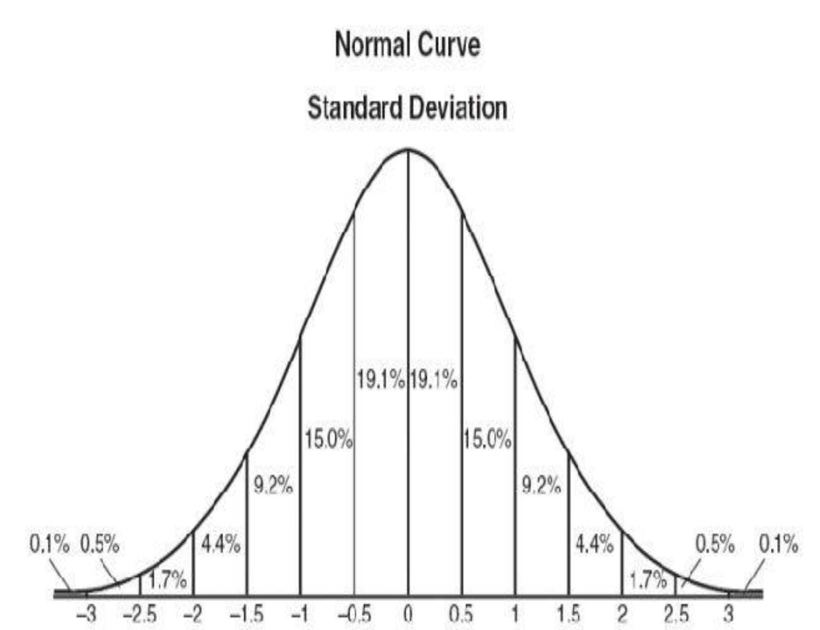
SMX

Key parameters of the scanning magnets

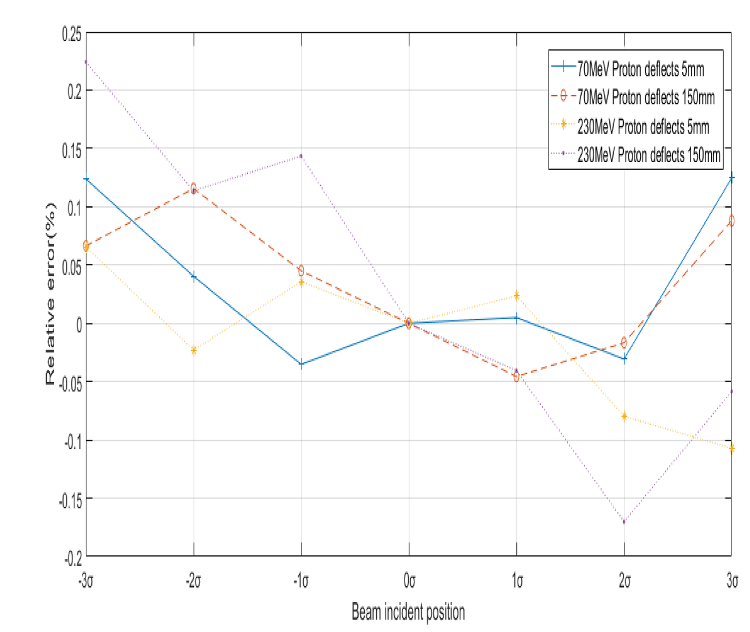
Parameter	Unit	SMY	SMX
Deflection angle	mrad	77	97
Scan speed	m/s	30	15
Max. field	T	0.6	0.7(middle of taper)
Max. field integral	T·m	0.170	0.246
Pole gap	mm	60	70-120
Pole length	mm	225	275

III. Electromagnetic Simulation

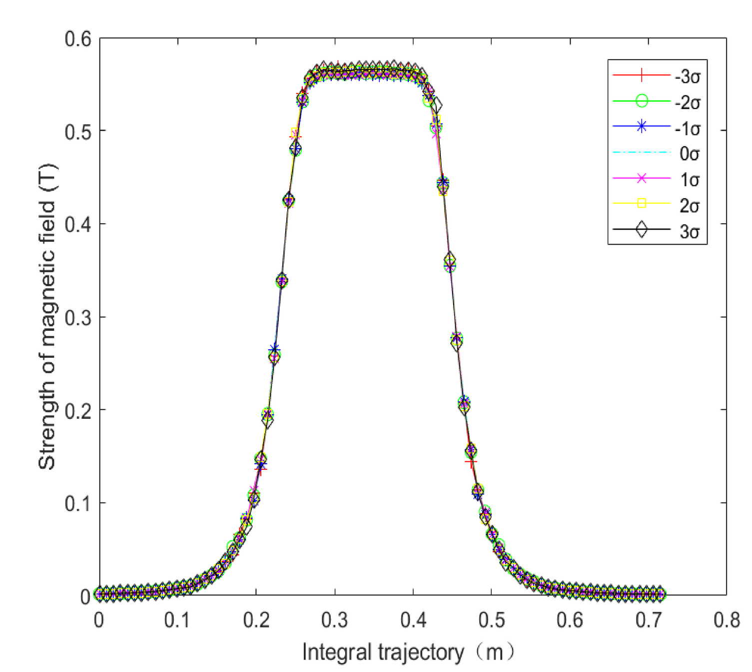
Coupling analysis of multiple physical fields is carried out by COMSOL electromagnetic thermal module to optimize the magnetic model of HUST-PTF scanning magnet.
The simulated proton beam follows the Gaussian distribution on the forward track.
The relative errors of integral field of 70 MeV and 230 MeV deflection 150 mm and 5 mm respectively are within ±0.25%



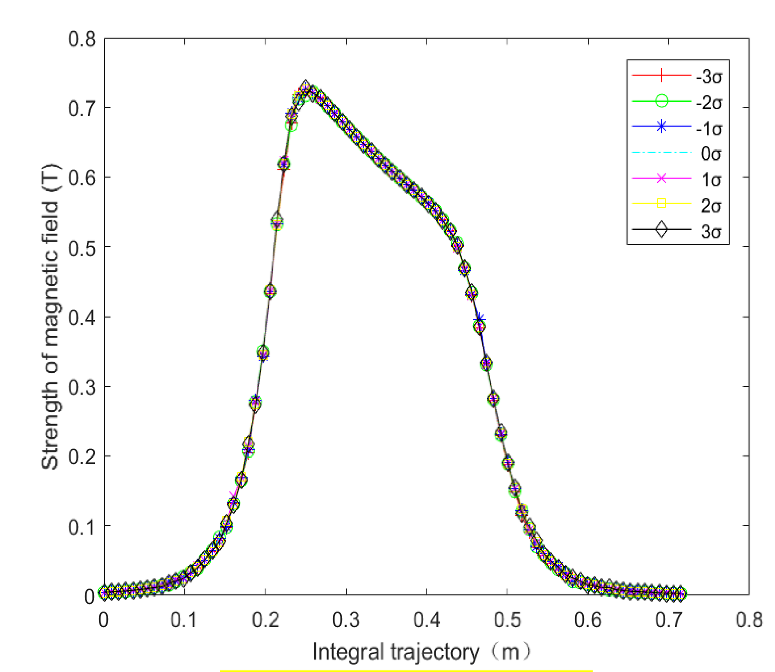
Gaussian distribution



Relative error of integral field



SMY integral field



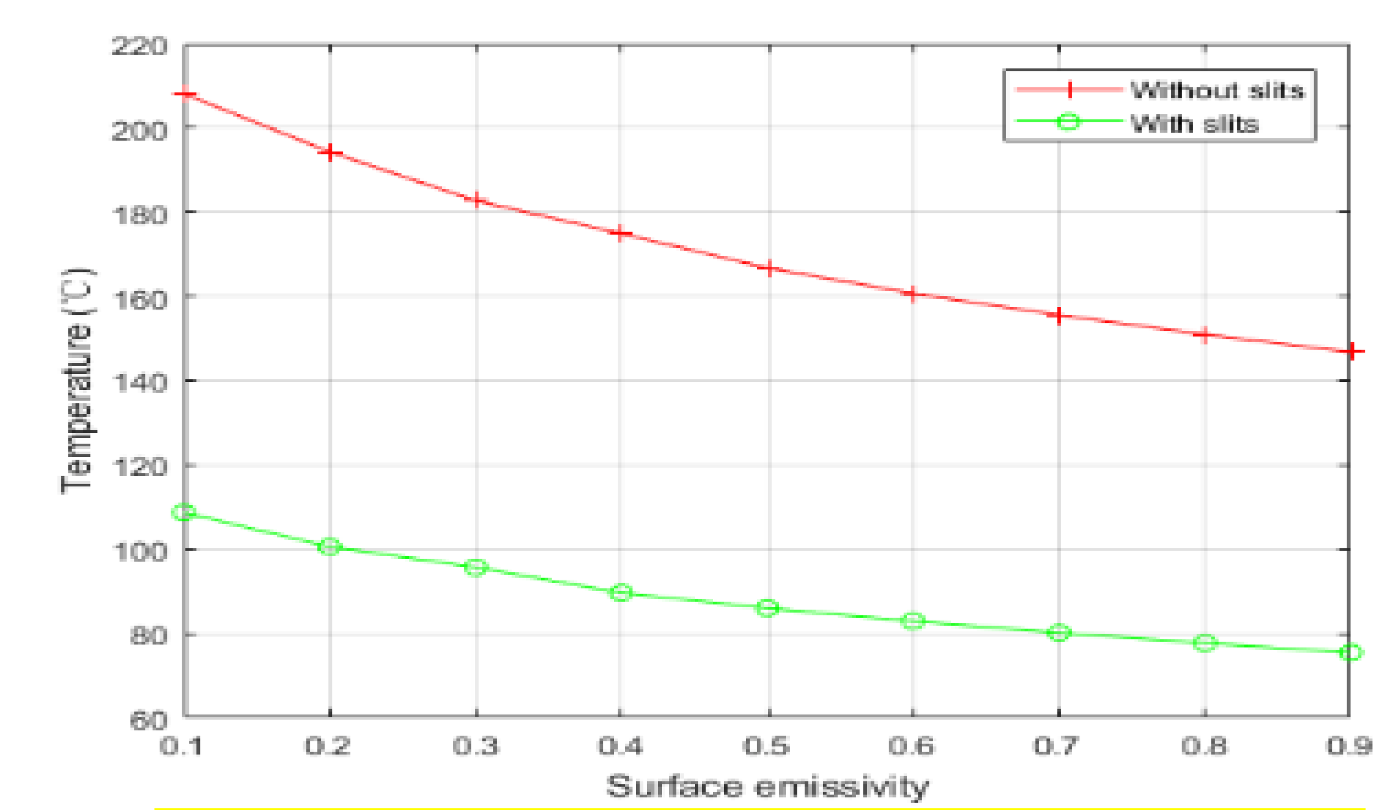
SMY integral field

IV. Thermal Results

Assume the ambient temperature is 20 ° C, the scanning frequency is 50 Hz, and the heat transfer coefficient is 14 W/(m²·K). A steady state analysis of SMY deflecting a 230 MeV proton beam by 150 mm was conducted. The maximum temperature of SMY without slits is 175.96 ° C, and with slits is 73.13 ° C.
According to the Stephan-Boltzmann formula, it is available after simplification.

$$h_{rad} = \varepsilon\sigma(T_{amb}^2 + T^2)(T_{amb} + T)$$

ε is the surface emissivity. Since the surface emissivity is related to the materials, surface roughness, temperature and other properties, the surface emissivity of the magnet is set to 0.1-0.9, respectively.
The actual maximum temperature of the magnet should be between 75.45 ℃ - 108.68 ℃, meeting the design requirements, but greater than 73.13 ℃.



Maximum temperature of SMY varies with surface emissivity

V. Conclusion

1. Designed of the two scanning magnets meet the requirement of uniformity of integral field.

2. The heat transfer coefficient of the scanning magnet should be slightly smaller than 14 W/(m²·K). Therefore, the simulation should be carried out in a more practical way.