博士論文公聴会の公示（物理学専攻）

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論文題目：Design Study of High-Intensity Compact High-Temperature Superconducting Skeleton (Ironless) Cyclotron (HTS-SC)
（高強度小型高温超伝導（空芯型）スケルトンサイクロトロン（HTS-SC）の設計研究）

日時：　2021 年 2 月 5 日（金）　13：30 － 15：00
場所：　新型コロナウイルス感染防止のため，オンラインにより行う。URL 等については，学内の方は下記を参照。
https://www.phys.sci.osaka-u.ac.jp/naibu/kouchoukai.html
学外の方は主査福田（mhfukuda[at]rcnp.osaka-u.ac.jp [at]=@）に問い合わせること。

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論文要旨：

In accordance with the increasing demand of a compact accelerator in medical applications, a compact high-temperature superconducting skeleton cyclotron (HTS-SC) is proposed in this work, aiming to produce a high intensity H^+ beam for a significant reduction in treatment time of Boron Neutron Capture Therapy (BNCT). The HTS-SC adopts an air-core structure to avoid any residual magnetization from the hysteresis loop of an iron yoke, further results in a higher reproducibility of magnetic field in a shorter time. This structure favors the usage in a hospital environment. Besides, the linear relationship between the coil current and the magnetic field strength also provides an easy calibration of the magnetic field. This facilitates any field modification to accelerate different species of ions for radioisotope (RI) production in a hospital environment.

The proposed design is a compact K-80 cyclotron with a challenging small extraction radius of 40 cm for a 50 MeV H^+. It includes a series combination of circular high-temperature superconducting (HTS) coils, acting as the main coil and trim coils, as well as 3 sector coils with a maximum spiral angle of 40^o. Active-shielding using HTS coils is also adopted to provide an easier control of the background stray field. The isochronous property of the designed HTS-SC field is confirmed by various orbit analysis using a reference particle.

As a high-intensity beam is the key requirement of this machine, suppression of the space charge effect and minimization of beam overlaps have been the biggest challenge of this work. This is especially true at a central region with limited space and extraction with small beam turn-separation. Therefore, extensive beam dynamics study for multi-particle tracking is also performed using a particle-in-cell (PIC) code such as SNOP and OPAL in these regions for high-intensity beams. Electrostatic extraction is adopted in this work to prevent excessive particle loss due to Lorentz stripping in a high magnetic field for a negative ion such as H^-. In order to increase the turn-separation, a pair of harmonic coils is used, with its amplitude carefully optimized for the maximum extraction efficiency. Two extraction mechanisms namely brute-force and precessional extractions are also compared. As a result, the precessional extraction appears to be a better option in producing beams with satisfactory beam intensity and quality. It is able to achieve a maximum extraction efficiency of almost 100% for a low-intensity beam and >70% for an ideal 1 mA beam. If a higher energy gain per turn is allowed, a 1 mA beam could be extracted with an extraction efficiency of >90%. A preliminary design of the extraction beamline using gradient correctors is also studied to ensure sufficient focusing along the extraction beamline. Finally, this work concludes the feasibility of a compact HTS-SC to accelerate high-intensity H^+ beam for BNCT and RI production.