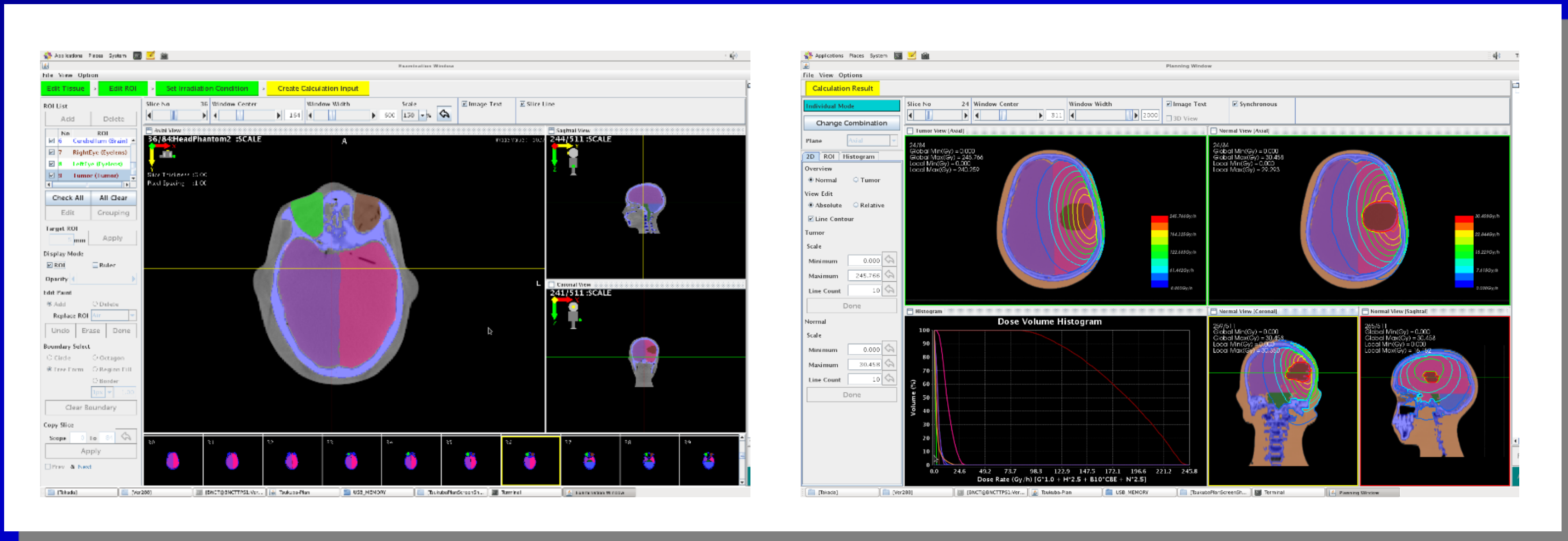
Verification of dose estimation for Monte-Carlo based treatment planning system for boron neutron capture therapy



H. Kumada, **K. Takada, T. Aihara, A. Matsumura**
H. Sakurai, T. Sakae

Proton Medical Research Centre, University of Tsukuba

iBNCT Project

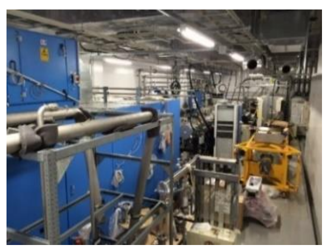
Progress of boron neutron capture therapy (BNCT)

Boron neutron capture therapy (BNCT) is based on the nuclear reaction that occurs when **boron-10** is irradiated with **neutrons** of the appropriate energy to produce high-energy alpha particles and recoiling lithium-7 nuclei. Therefore BNCT is categorized to **external beam therapy using neutron beam**. Clinical trials for BNCT is being performed using research rectors so far. However in recent years, many **accelerator-based neutron sources for BNCT are being developed**. In Japan in particular, **some devices have been generated enough neutrons**, and **two facilities are already being carrying out clinical trials using cyclotron-based neutron source for BNCT**.

University of Tsukuba is also developing a linac-base BNCT device.

BNCT facilities in Japan

University of Tsukuba (Ibaraki)

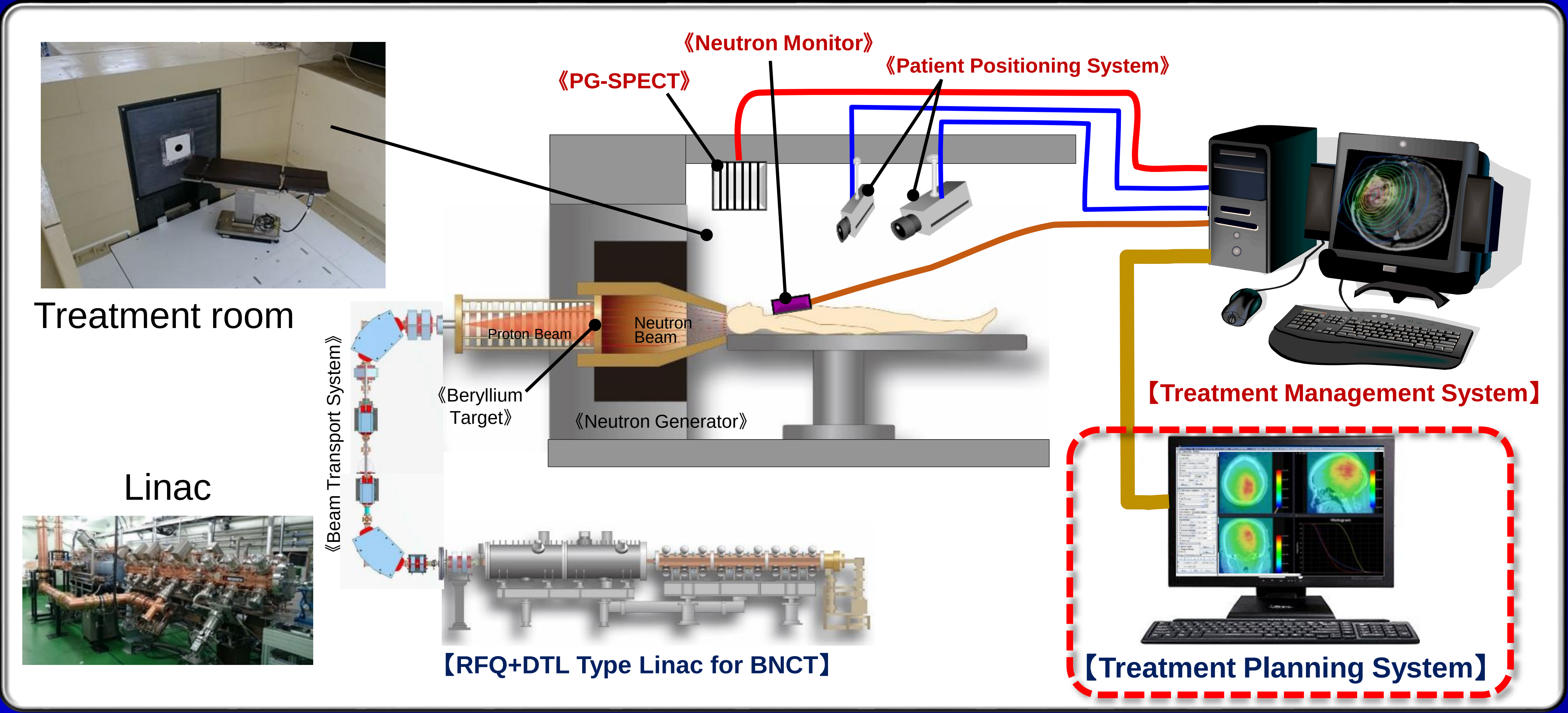


National Cancer Center Hospital (Tokyo)

Kyoto University Research Reactor Institute (Osaka)

Southern Tohoku BNCT Research Center (Fukushima)

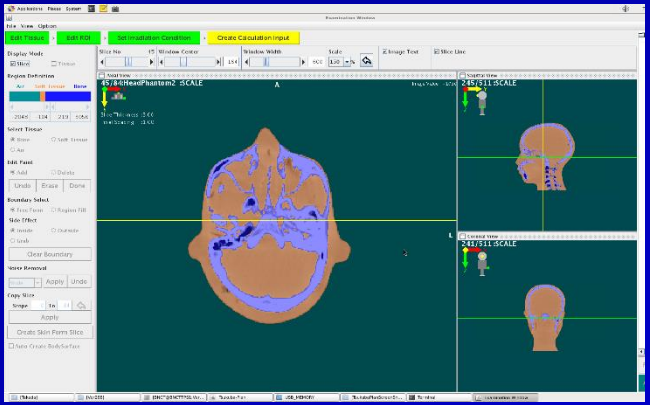
Development of Peripheral Equipment for BNCT



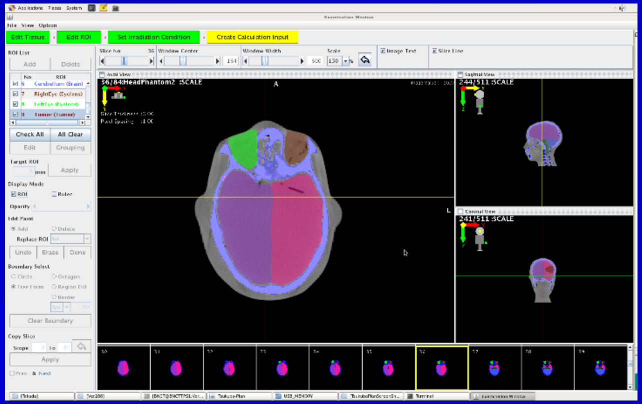
Not only neutron generator with accelerator but also peripheral devices which are needed to perform BNCT, are being developed.

- Monte-Carlo based treatment planning system
- Patient positioning system by using motion capture technology
- Real-time neutron monitor, PG-SPECT etc.

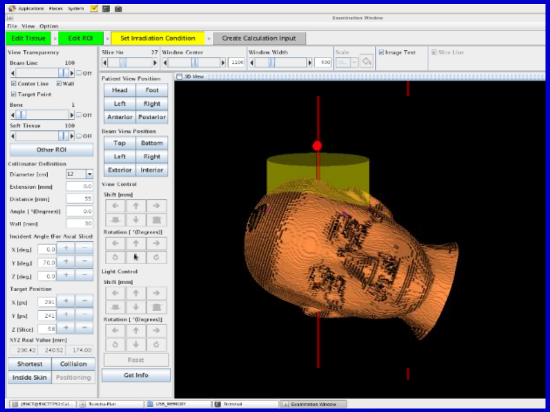
Dose estimation process with Tsukuba-Plan



Set Material

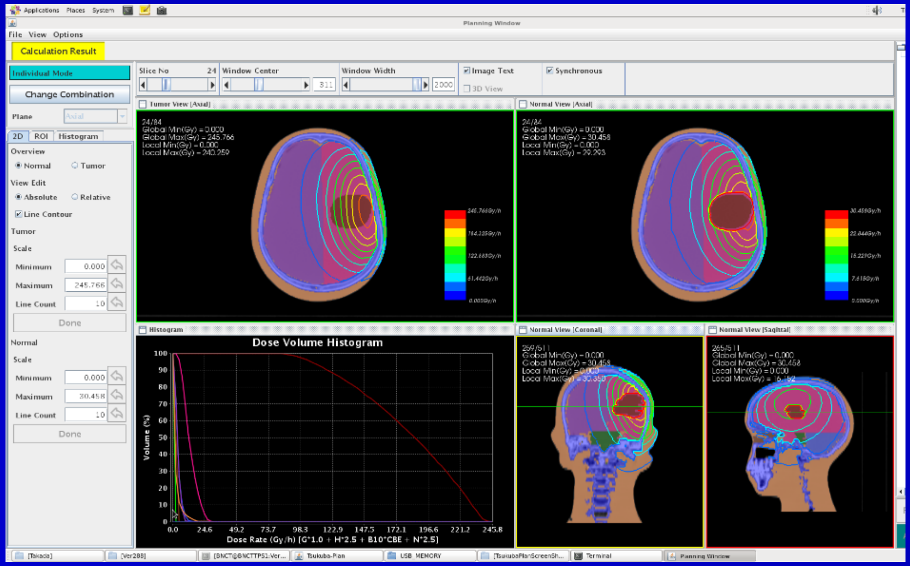


Set Region of Interest



Set Irradiation Condition

Monte-Carlo Calculation



Dosimetry Mode

Features of Tsukuba-Plan

Tsukuba-Plan has employed "**PHITS**" as the dose calculation engine. PHITS is multi-purpose MC transport code, and it can determine doses for **neutrons, photons as well as protons, heavy ions**. Therefore Tsukuba-Plan with PHITS enables to perform dose estimation for not only **BNCT** but also for **external beam therapies** as **particle therapy and X-ray therapy.** And it is also adaptable to **brachytherapy**.

➡ Dose estimation/treatment planning for each radiotherapy
➡ Treatment planning for combined radiotherapy
➡ Dose estimation for total dose given to a patient

And Tsukuba-Plan allows to estimate incidental dose caused by **secondary neutrons** in particle therapy.

Furthermore, PHITS has "**MKM**" which can perform **micro-dosimetry**. Thus **Tsukuba-Plan can determine equivalent dose based on micro-dosimetry** in addition to conventional way as "**RBE x Physical dose**"

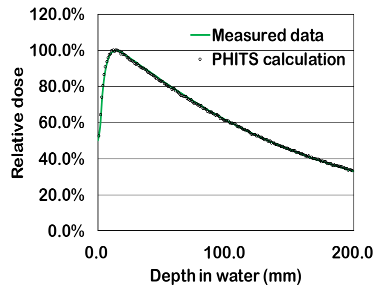
Application of Tsukuba Plan to Proton therapy and X-ray therapy

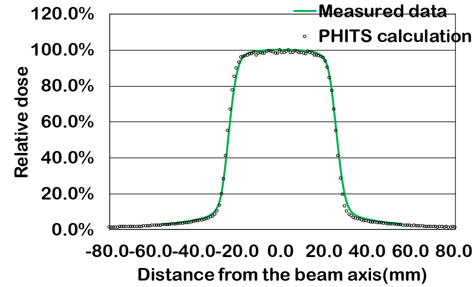
iBNCT Project

X-ray Therapy

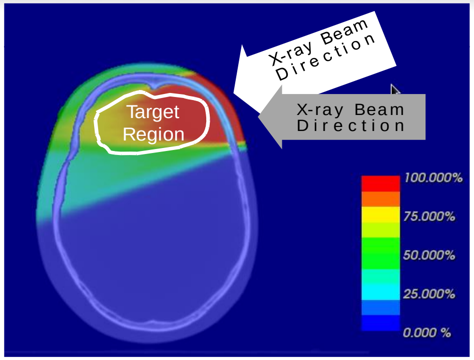
6 MV

Irradiation field: 5 cm × 5 cm





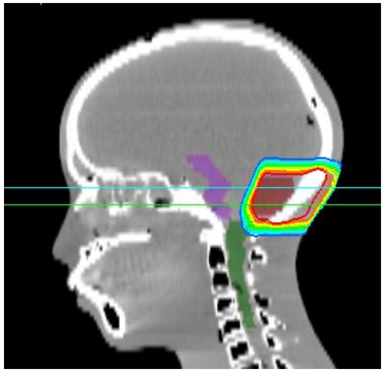
Comparison results of PDD and OCR for 6-MV beam

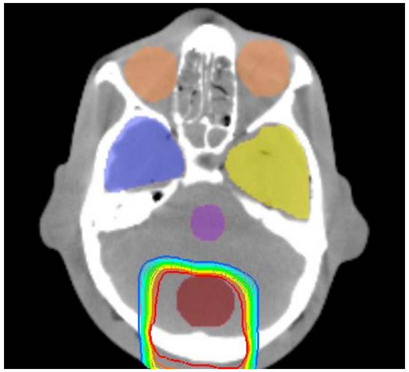


Two-field fractionated X-ray irradiation

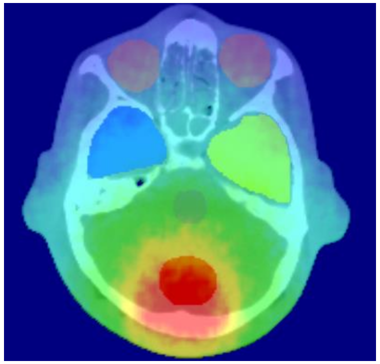
Proton

Secondary neutron dose estimation in Proton therapy





Proton dose distributions



Secondary neutron dose distributions

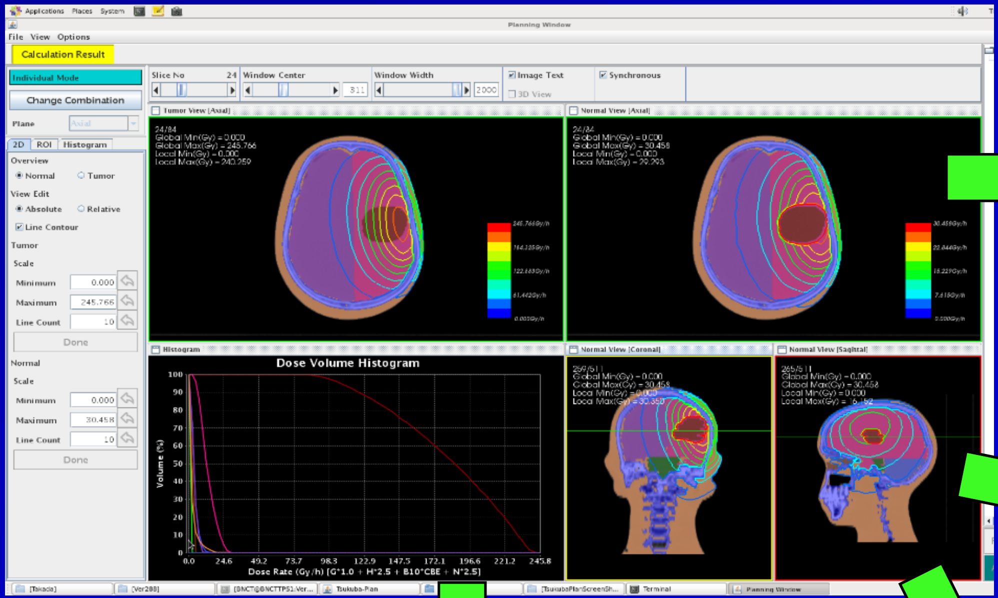
Poster No. 124: H. Kumada, et al., “Application expansion of the Monte-Carlo based treatment planning system for BNCT to particle radiotherapy and X-ray therapy.”

Poster No. 125: K. Takada, et al., “Fundamental study for practical application of radiotherapy treatment planning system capable of evaluation neutron dose generated by various radiotherapy beams.”

Verification for the dose estimation performance of Tsukuba Plan for boron neutron capture therapy (BNCT)

Verification in all BNCT facilities in Japan

Tsukuba Plan




University of Tsukuba, iBNCT Facility


Southern Tohoku Hospital, BNCT Center

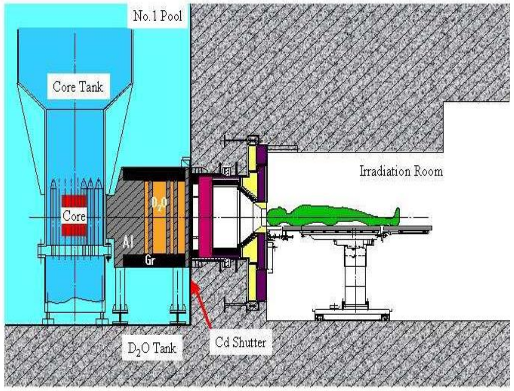
Accelerator

Irradiation room

National Cancer Center Hospital

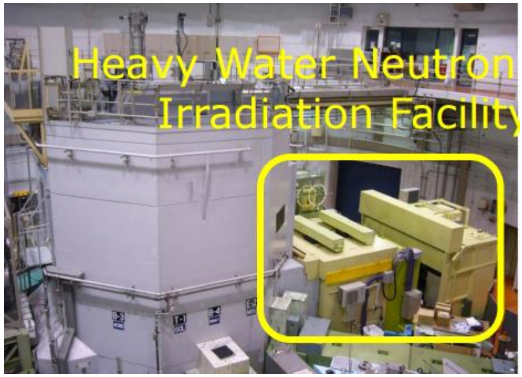

Kyoto University KUR, BNCT facility

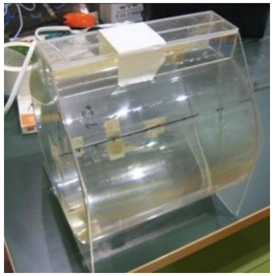
Create three neutron source for BNCT



Water Phantom

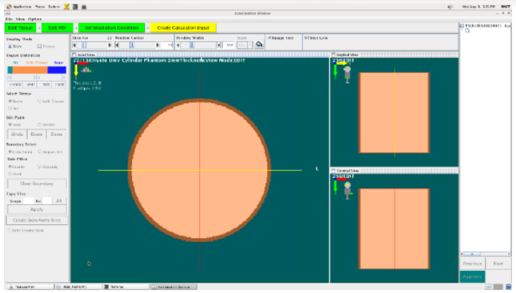
JRR-4 in JAEA

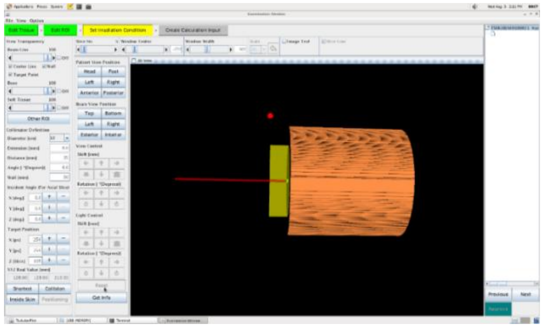


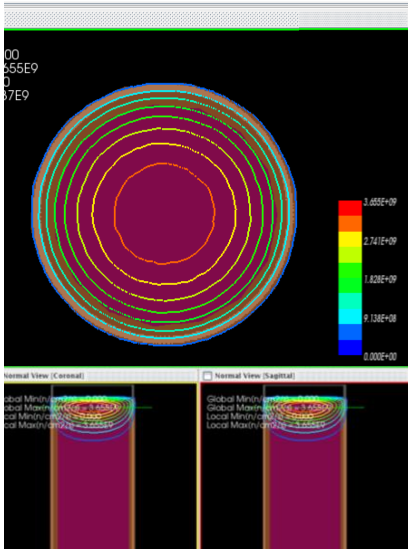


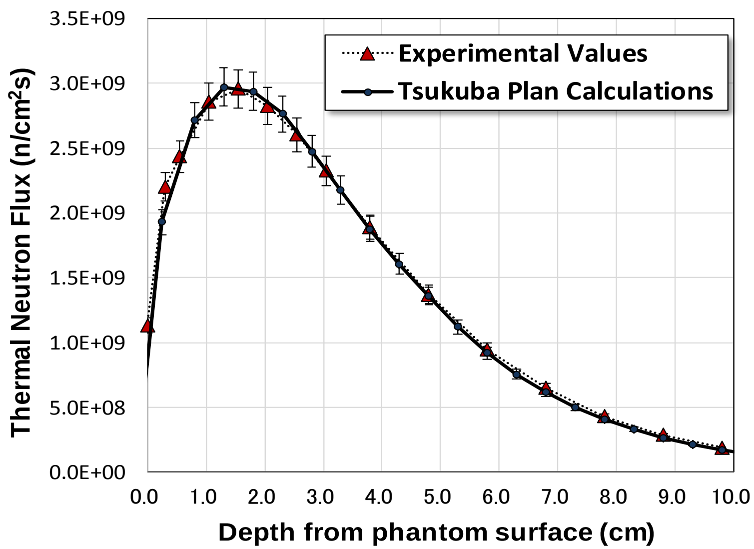
Water Phantom

KUR in Kyoto University Research Reactor





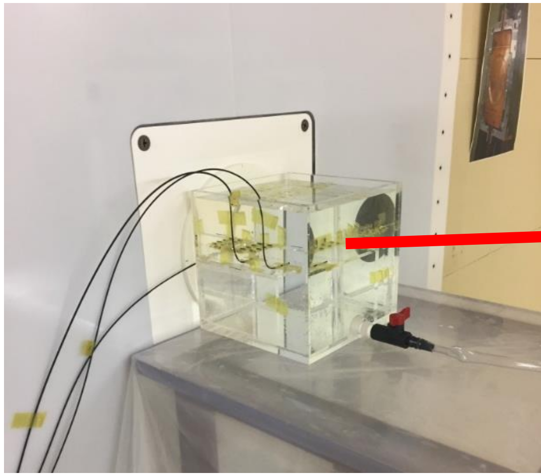




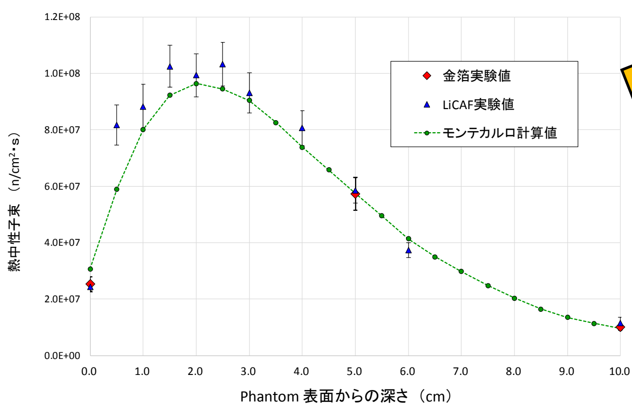
Thermal neutron flux distributions in a cylindrical water phantom

Verification (2) in iBNCT accelerator-based neutron source

Experiments in iBNCT facility in Univ. Tsukuba



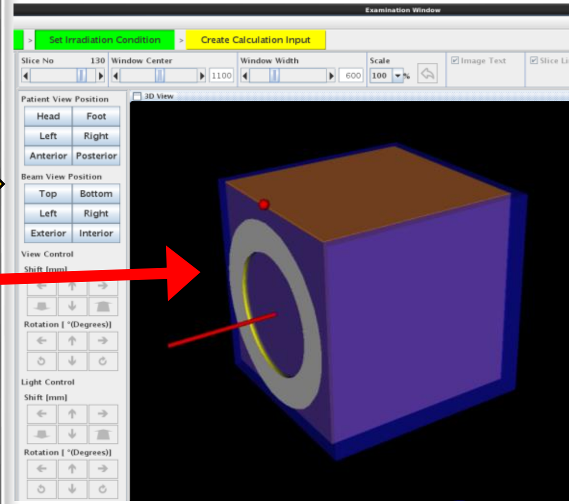
Water phantom experiments



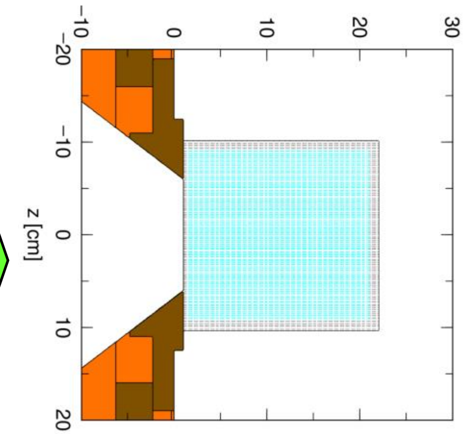
Experimental values for thermal neutron flux

Compare

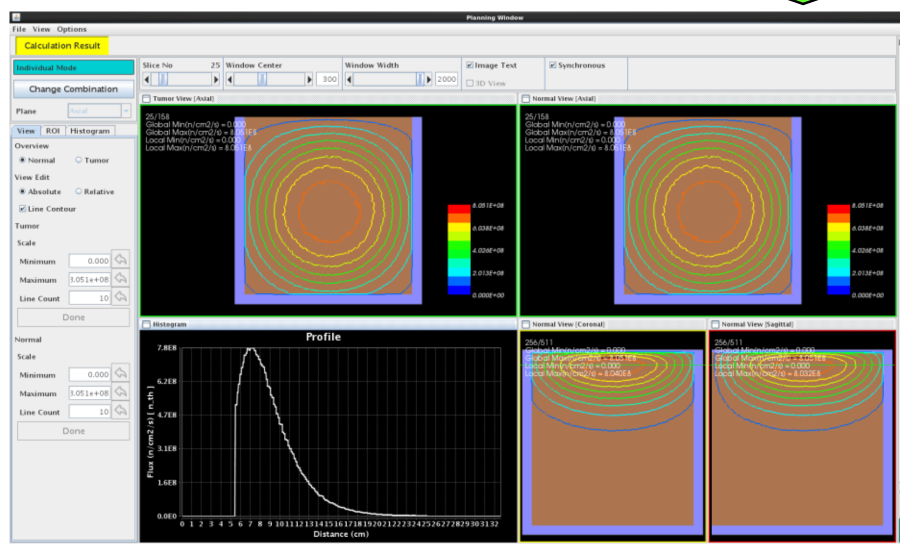
Dose estimations by using Tsukuba Plan



3D-Model of water phantom

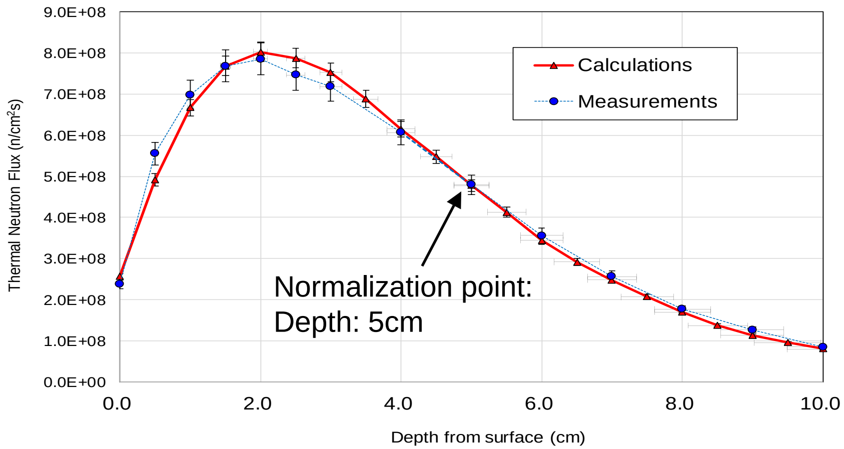


Calculation Model

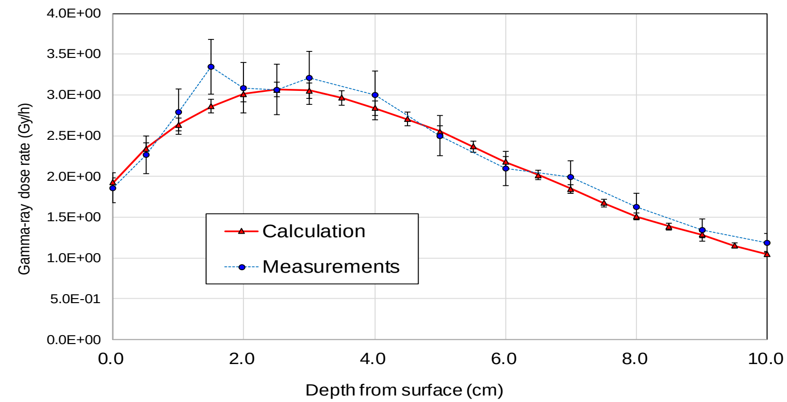


Thermal neutron flux distributions

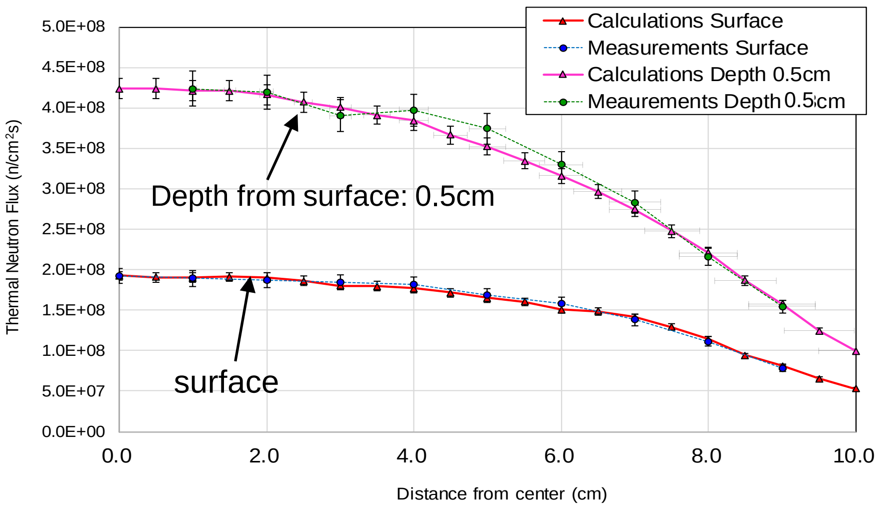
Comparison with Tsukuba-Plan Calculations and Experiments



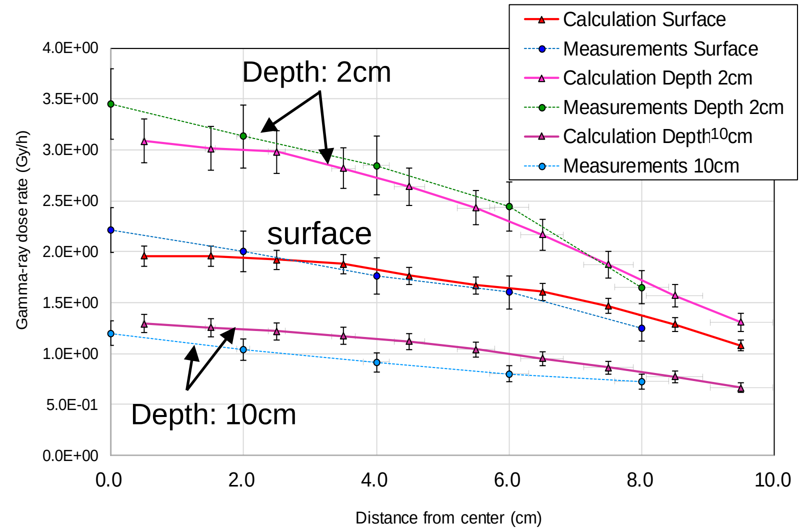
Beam central axis



Beam central axis



Lateral distributions

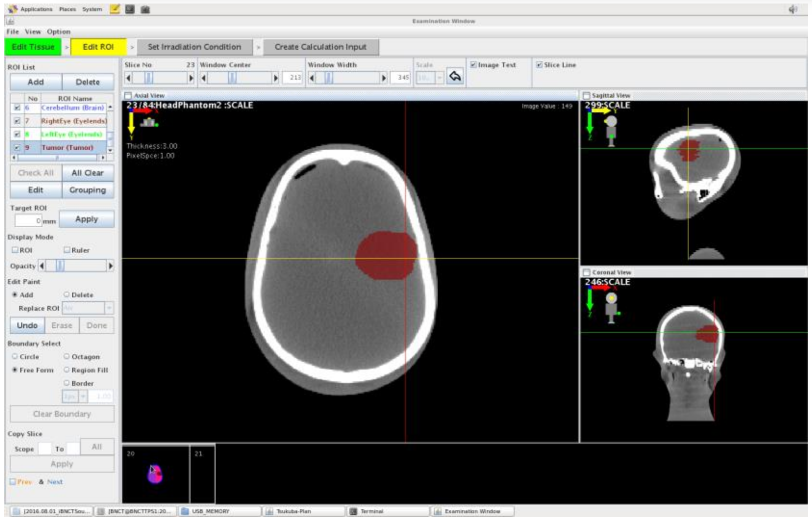


Lateral distributions

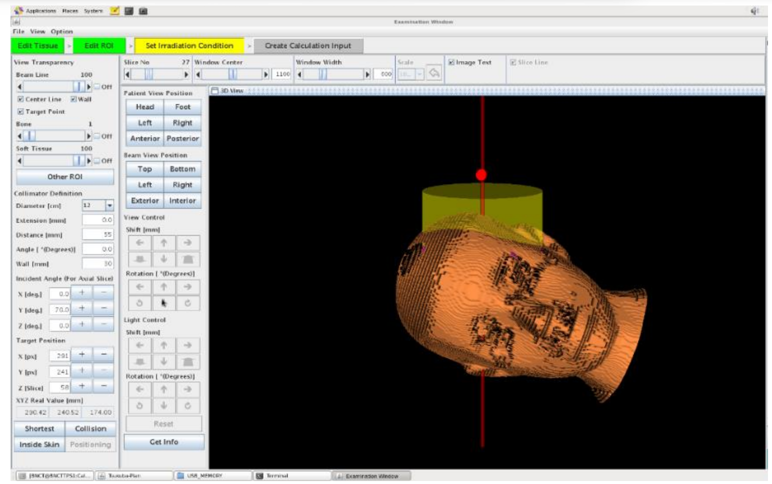
Thermal neutron flux distributions

Gamma-ray dose rate distributions

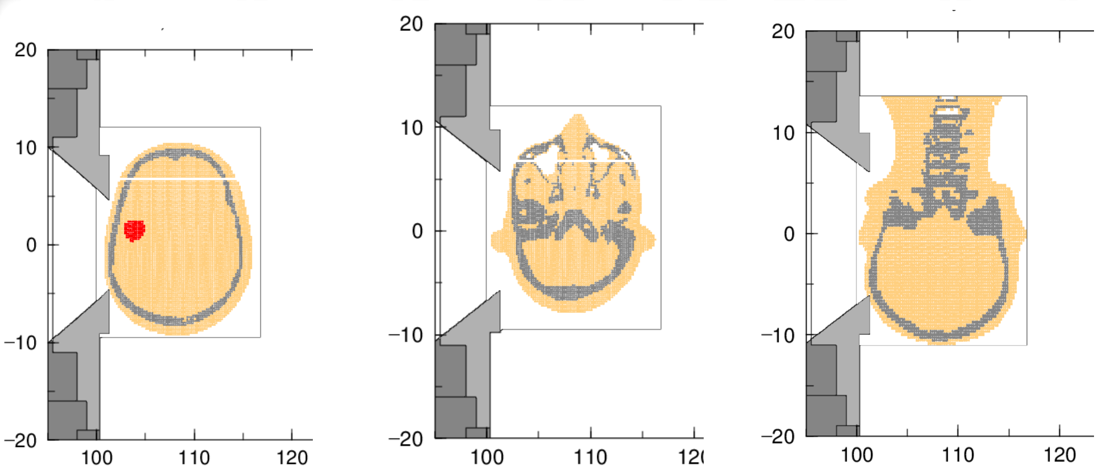
Dose estimation for realistic human model



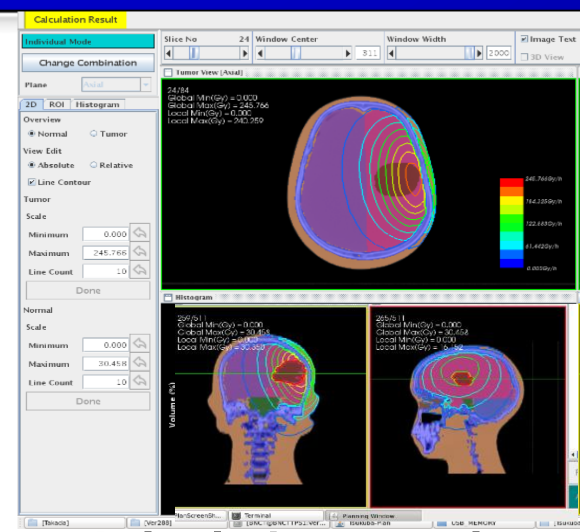
Set ROI and target point



Set irradiation conditions

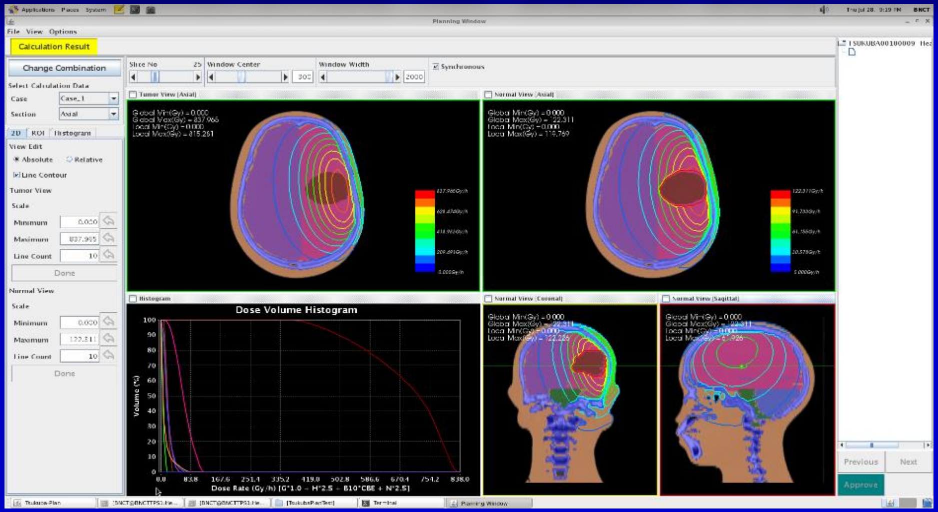


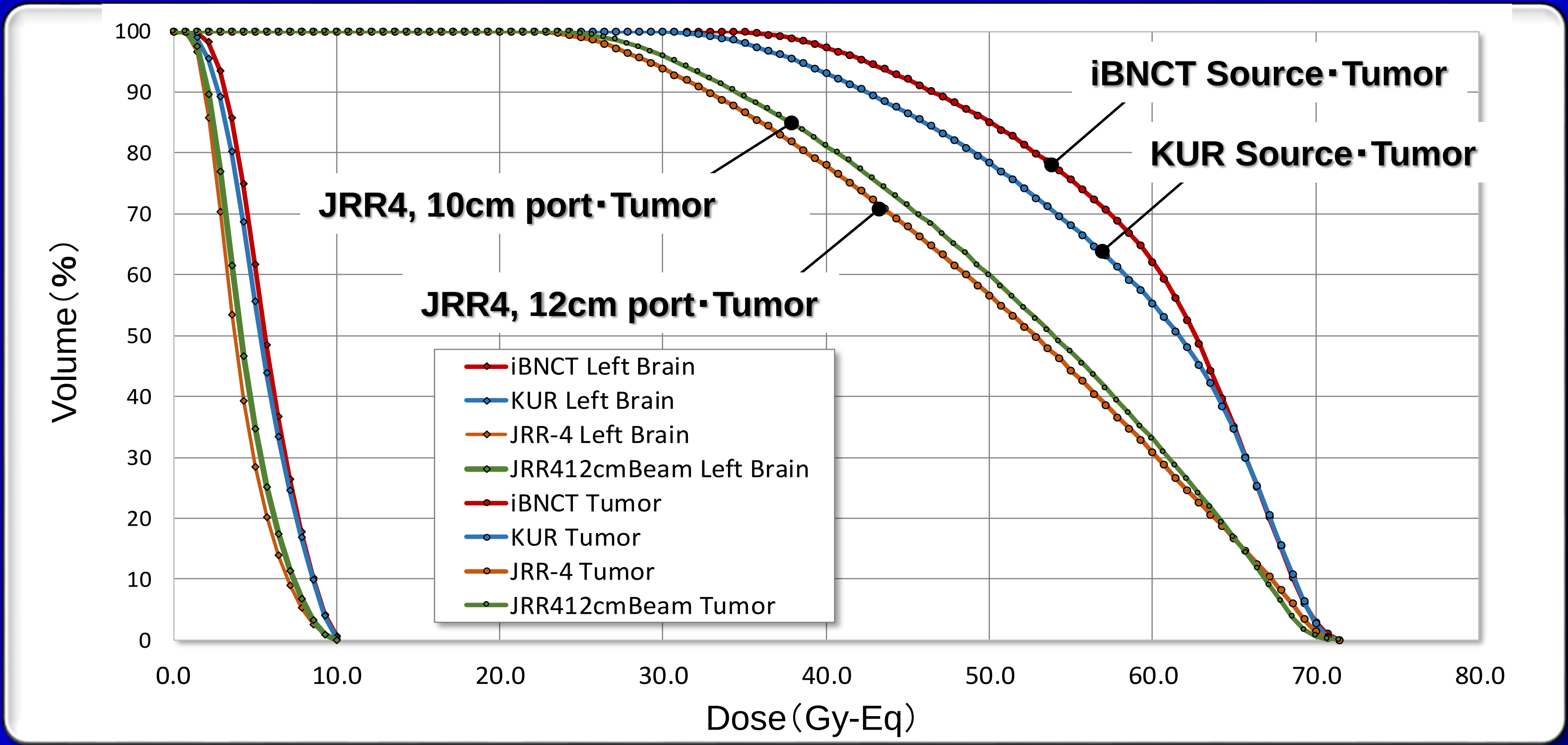
Calculation models



Calculation Results

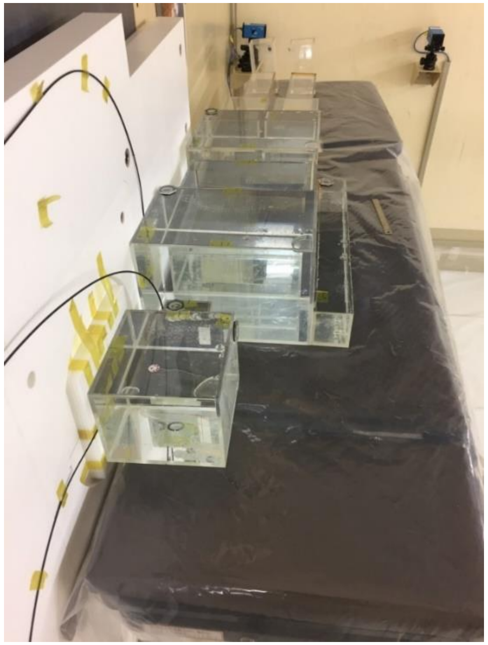
Influence for difference for beam sources, D.V.H.



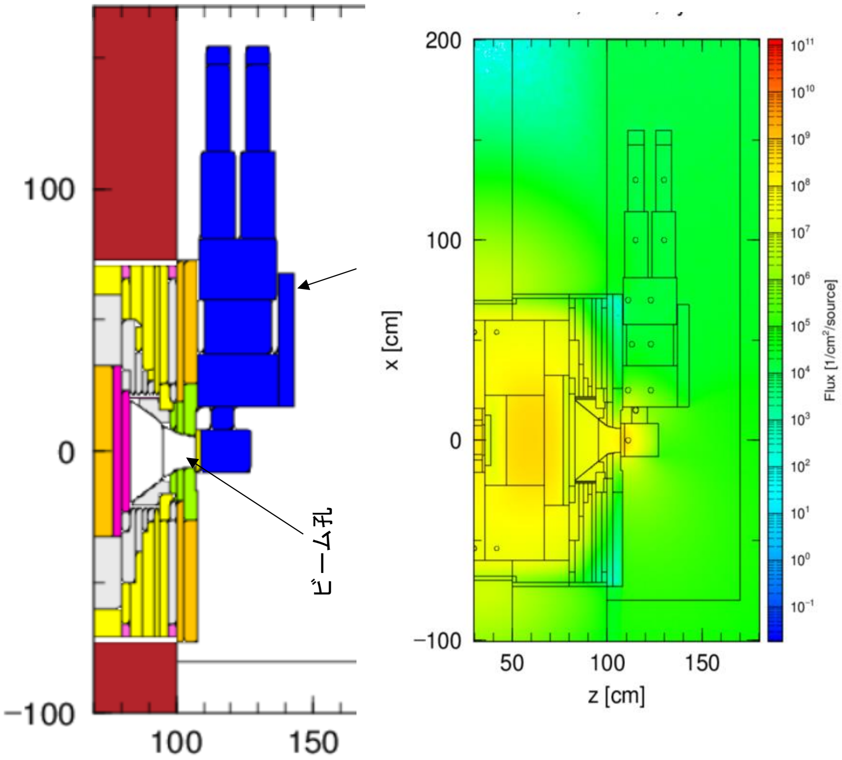


Futures: Estimation for whole body exposure

At the moment

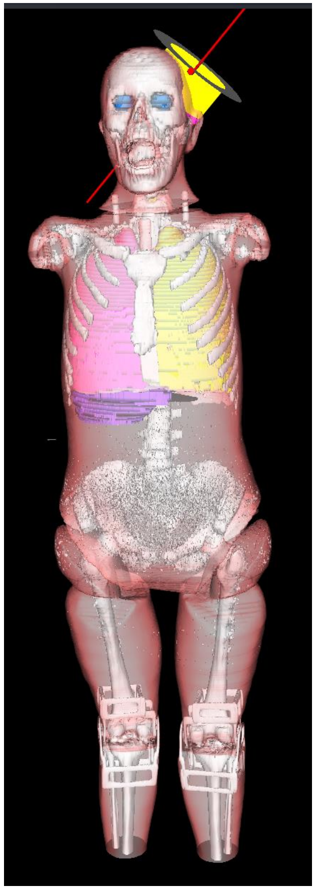


Measurement for whole body exposure in BNCT using a whole body phantom



Dose estimation for whole body exposure in BNCT irradiation using **PHITS**

Near future



Dose estimation for whole body exposure using **Tsukuba-Plan**

IMAGINE THE FUTURE.

iBNCT Project

Conclusions

- ✓ University of Tsukuba is being developed the **Monte Carlo based treatment planning system "Tsukuba-Plan"** for BNCT.
- ✓ Tsukuba-Plan has employed **PHITS** as a MC dose calculation engine.
- ✓ Tsukuba-Plan enables to perform dose estimation/ treatment planning for not only **BNCT** but also **particle therapy, X-ray therapy**. And the system is also applicable to the dose estimation for **brachytherapy**.
- ✓ **Incidental doses caused by secondary neutrons** in radiation therapy are also able to be estimated.

ご清聴有難うございました。

Thank you for your attentions!!

- ➢ At present, **several verification in BNCT dosimetry for Tsukuba-Plan are being carrying out**.
- ➢ In comparison between measurements from water phantom experiments and calculations, **distributions for thermal neutron flux and gamma-ray dose in the phantoms were in good agreement**.
- ➢ Further verifications are planned in order to **put into practical use of BNCT treatment** and **to get license for pharmaceutical approval**.