Accelerator for BNCT

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Preface

- I would like to introduce a compact accelerator for cancer therapy.
- It's a prototype accelerator to validate our method of therapy.
- The accelerator has been developed by the collaboration with
  - University of Tsukuba, KEK, the Ibaraki prefectural government, Hokkaido University, JAEA, MHI, NAT, ATOX, COSYLAB, Toshiba.

Contents

What is “BNCT” ?

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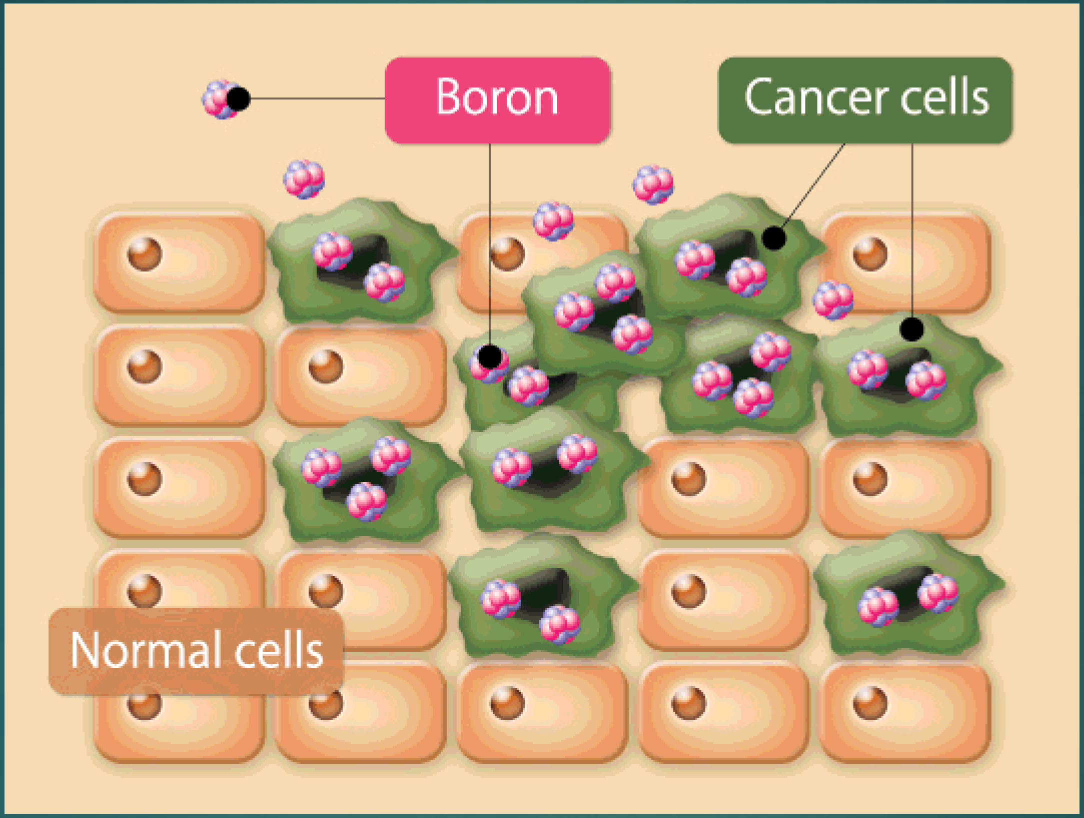
BNCT stands for

“Boron Neutron Capture Therapy”.

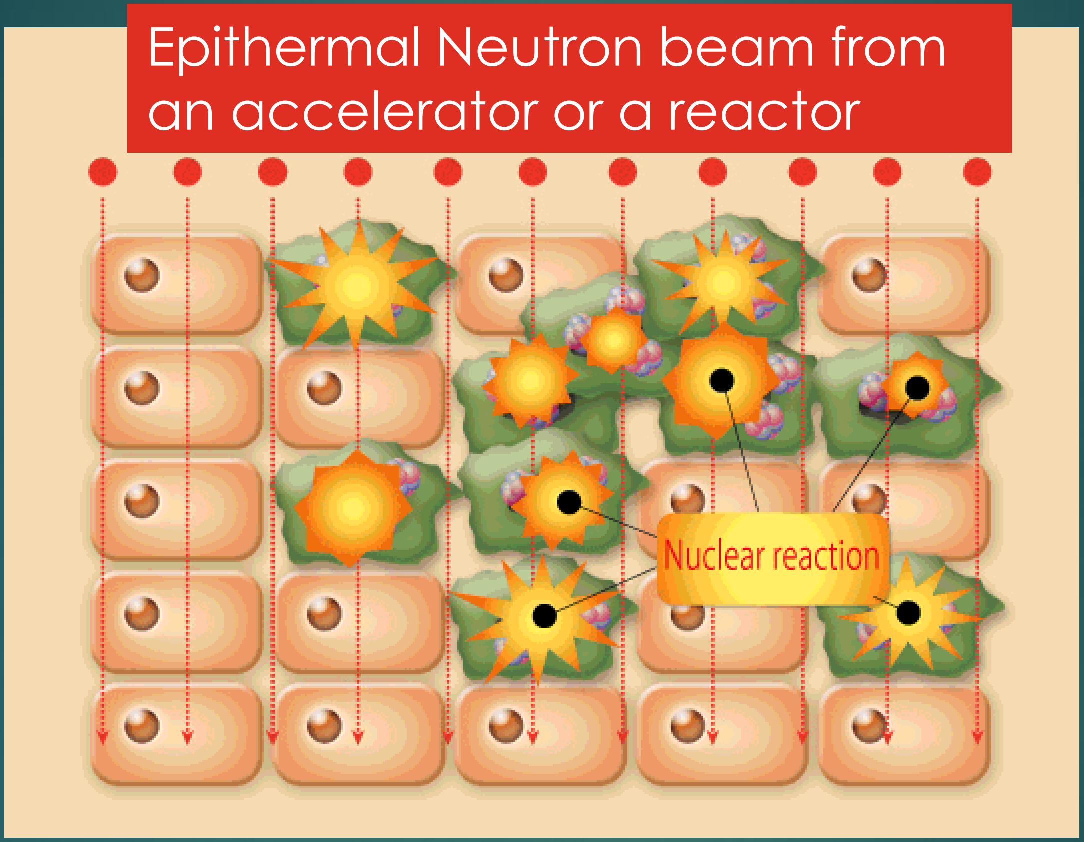
^{10}B Drug delivery to Cancer cells



A boron-containing drug that selectively accumulates in cancer cells is delivered in advance.

figure from http://bnct.kek.jp/eng/mechanism.html

Irradiation



Reaction cross section of ^{10}B (n, a) is exceptionally higher, so reaction selectively takes place in cancer cell.

figures from http://bnct.kek.jp/eng/mechanism.html

Reaction : $^{10}B + n_{th} \rightarrow {}^{4}He + {}^{7}Li + 2.31MeV$

Emitted alpha and lithium particles destroy the cancer cells.

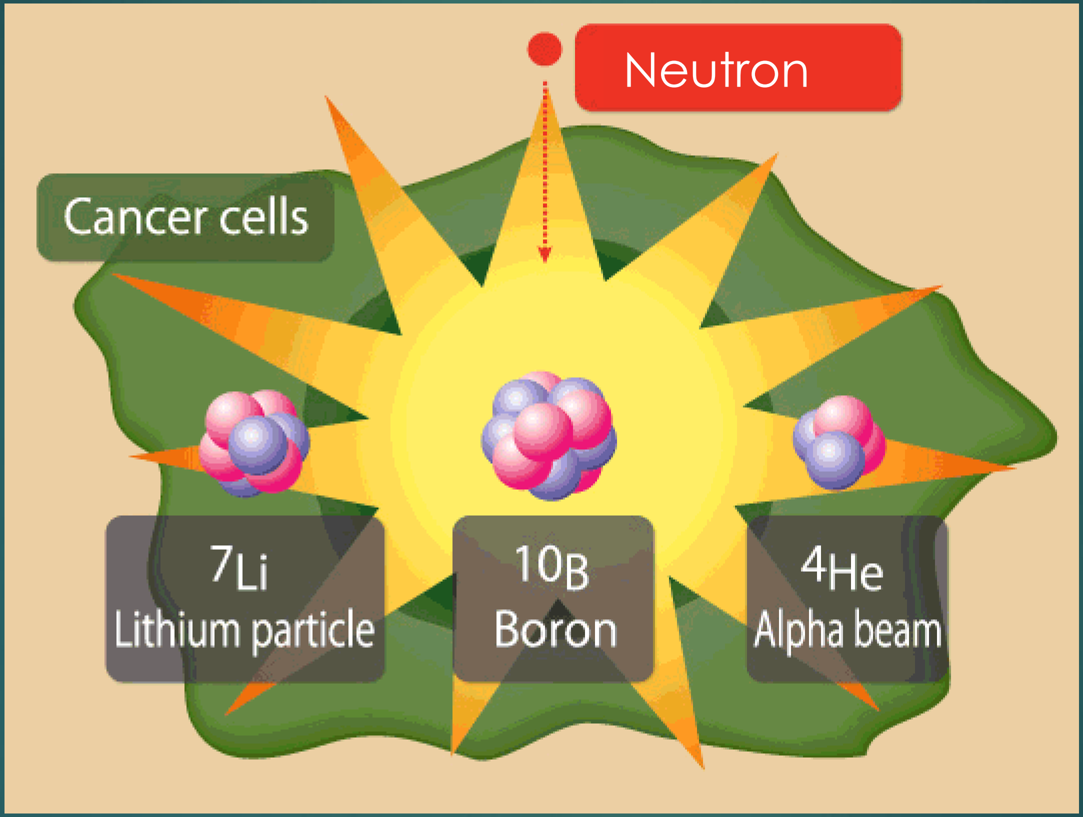


figure from http://bnct.kek.jp/eng/mechanism.html

Cell-level treatment

They only travel a distance of one cell width about 10 μm and don’t affect on normal cells

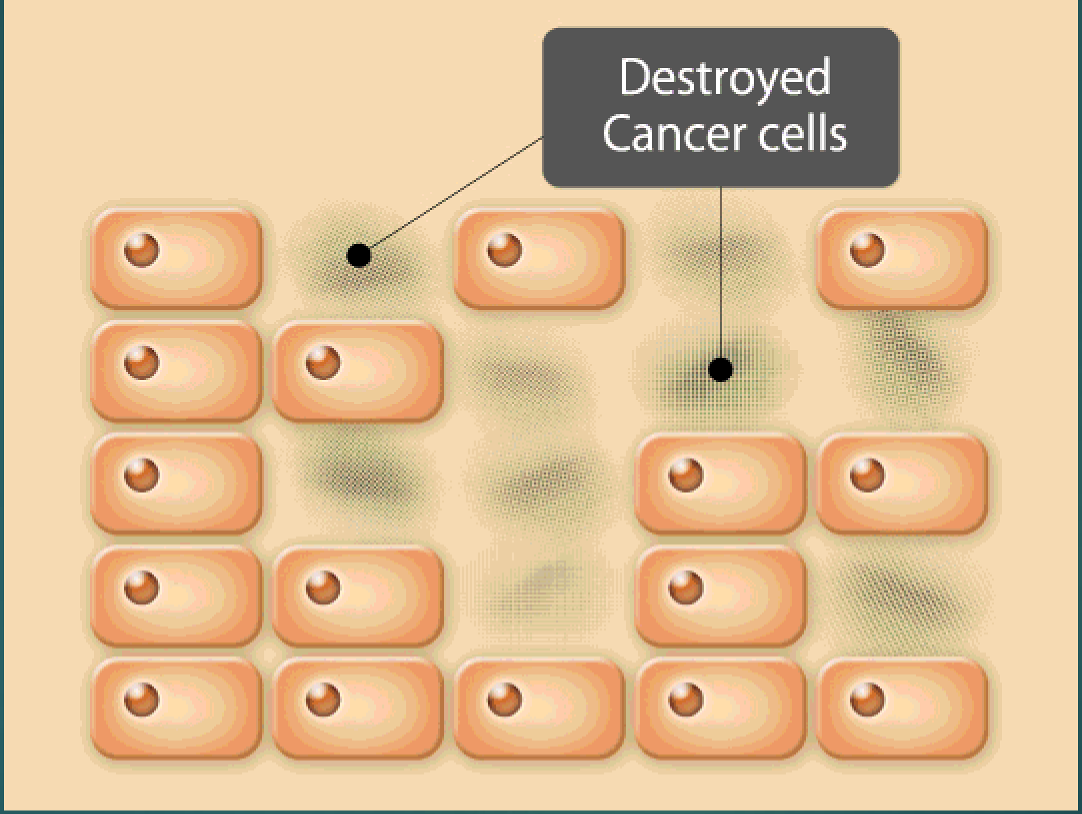


figure from http://bnct.kek.jp/eng/mechanism.html

Requirements for accelerator from medical side

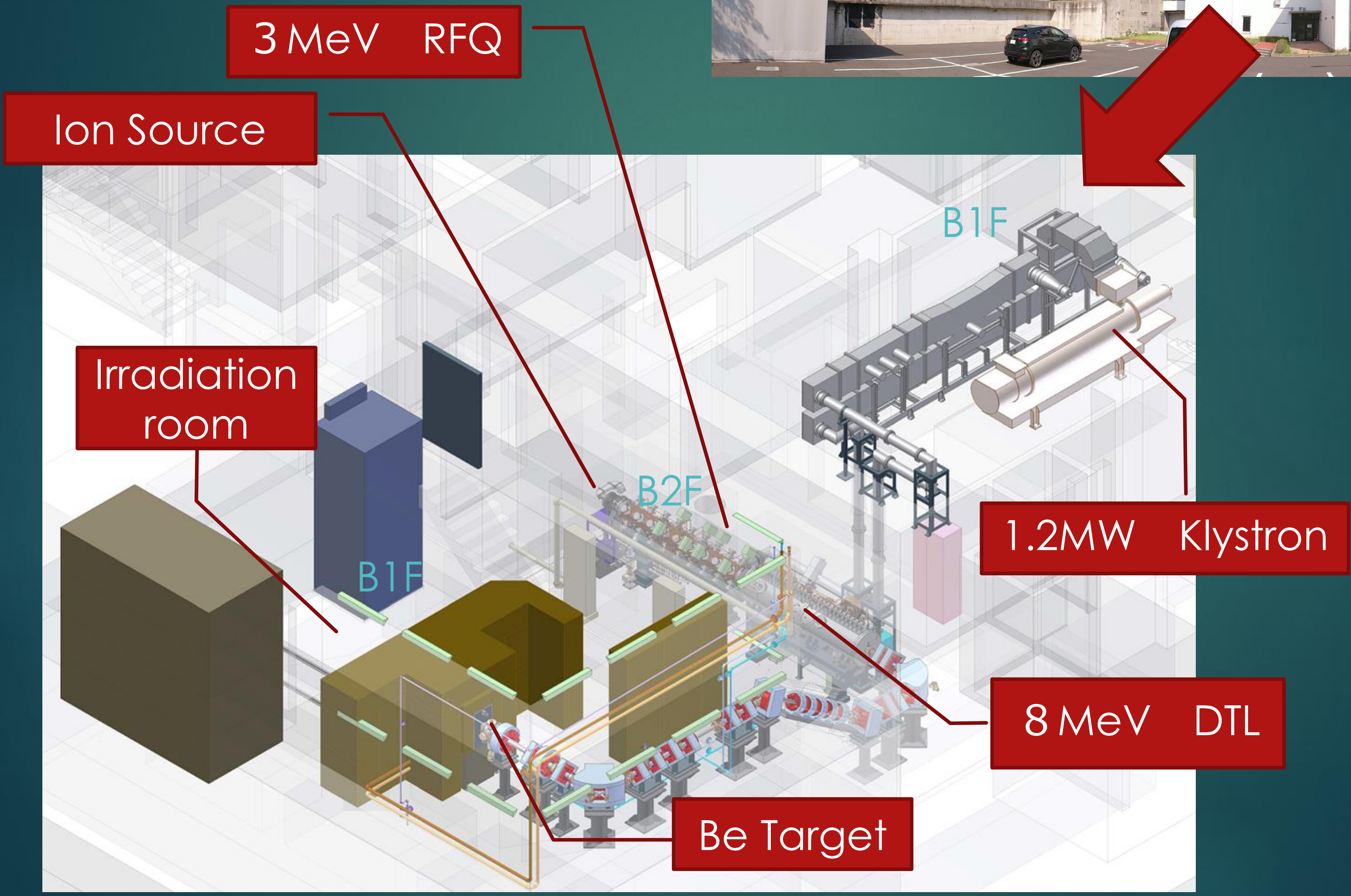
- epithermal neutron flux :
  1×10^9 neutron/cm^2/sec
  - From recent measurement,
    proton beam of 2 mA
    in average will be sufficient.
    - Of course, medical side call for much more.
- No accelerator fault is acceptable under medical treatment about 1 hour.
  - Stable operation is essential.

Key points of iBNCT 1

We call our BNCT project as “iBNCT”.
“i” stands for Ibaraki prefecture, where KEK established.

- Hospital-use equipment.
- compact footprint about 100 m^2.

Main components of Accelerator



Key points of iBNCT 2

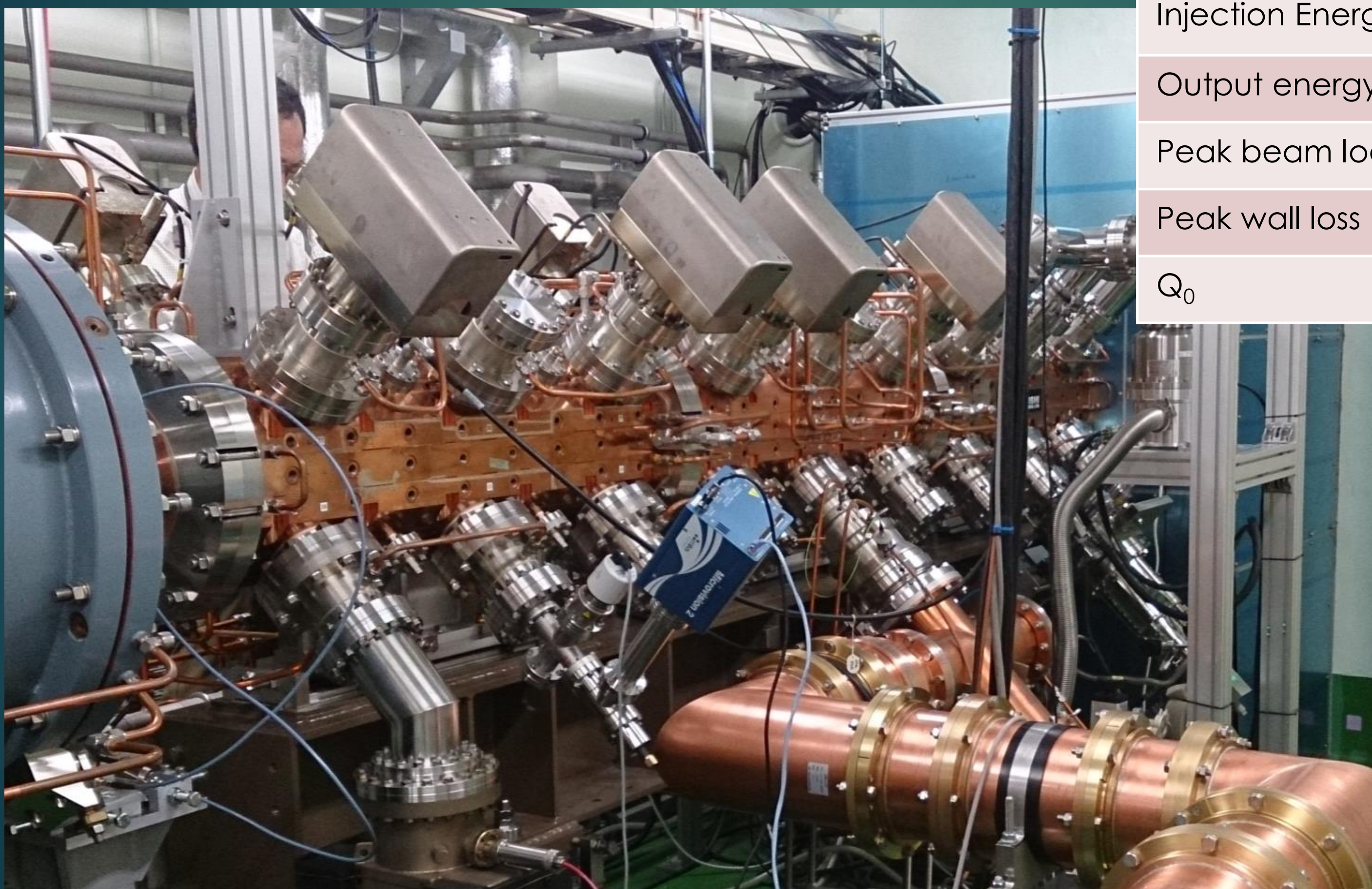
- The RF design of the RFQ and the DTL is based on the J-PARC Linac to reduce development work.
  - note: The duty factor of the iBNCT is much higher (20%) compared with that of J-PARC (1.25%).

Beam specification

	iBNCT Goal	iBNCT Present	J-PARC
particle	proton	←	H^-
Beam energy	8 MeV	←	400 MeV
Peak beam current	50 mA	25 mA	50 mA
Average beam current	10 mA	1.2 mA	0.63 mA
Beam pulse width	～925 μsec	←	500 μsec
Max repetition	～ 200 Hz	50,67,75 Hz	25 Hz
Duty factor	20%	5~7.5%	1.25%

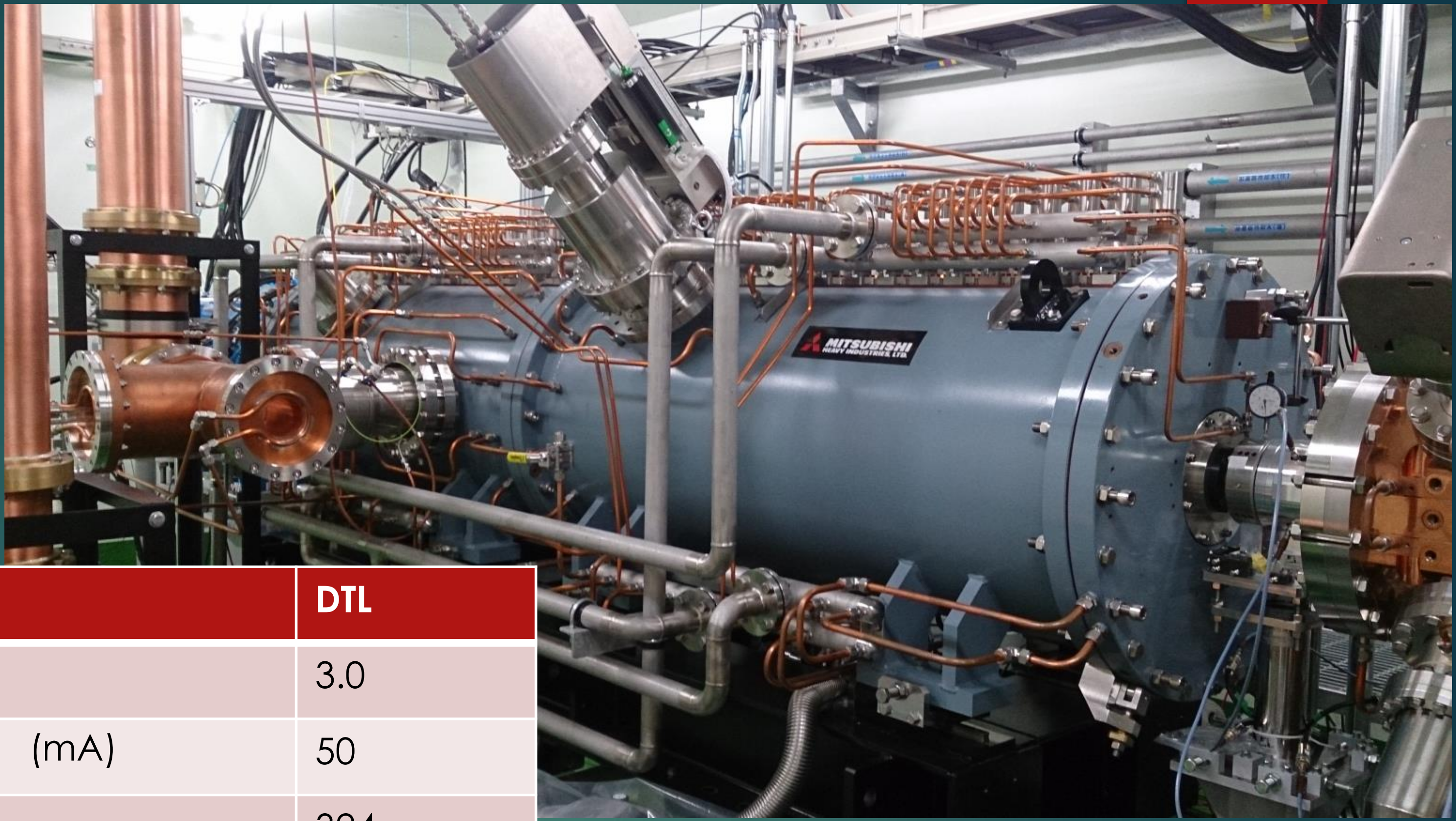
RFQ (iBNCT)

fabricated by milling and brazing



	RFQ
Length(m)	3.1
Maximum Peak current (mA)	50 (20)
Frequency (MHz)	324
Injection Energy (keV)	50
Output energy (MeV)	3.0
Peak beam loading (kW)	150(60)
Peak wall loss (kW)	340
Q_0	9400

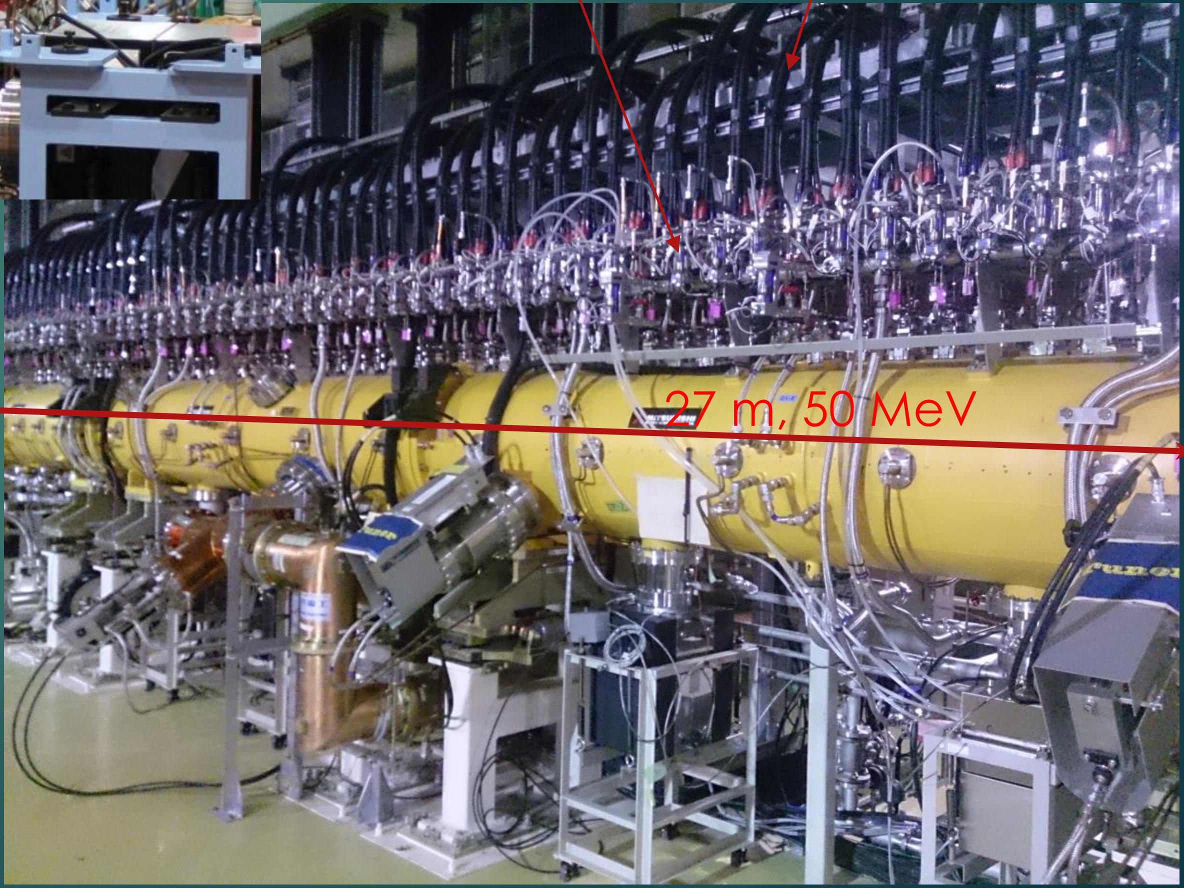
DTL (iBNCT)



	DTL
Length(m)	3.0
Max. Peak current (mA)	50
Frequency (MHz)	324
Injection Energy (MeV)	3.0
Output energy (MeV)	8.0
Q-Magnet type	permanent
Peak beam loading (kW)	250(100)
Peak wall loss (kW)	320
Q_0	44000

fabricated by copper plating on a steel tank

J-PARC RFQ II & DTL



The length of J-PARC DTL section is 27 m and the extraction energy is 50 MeV. iBNCT DTL is based on the first 3 m.

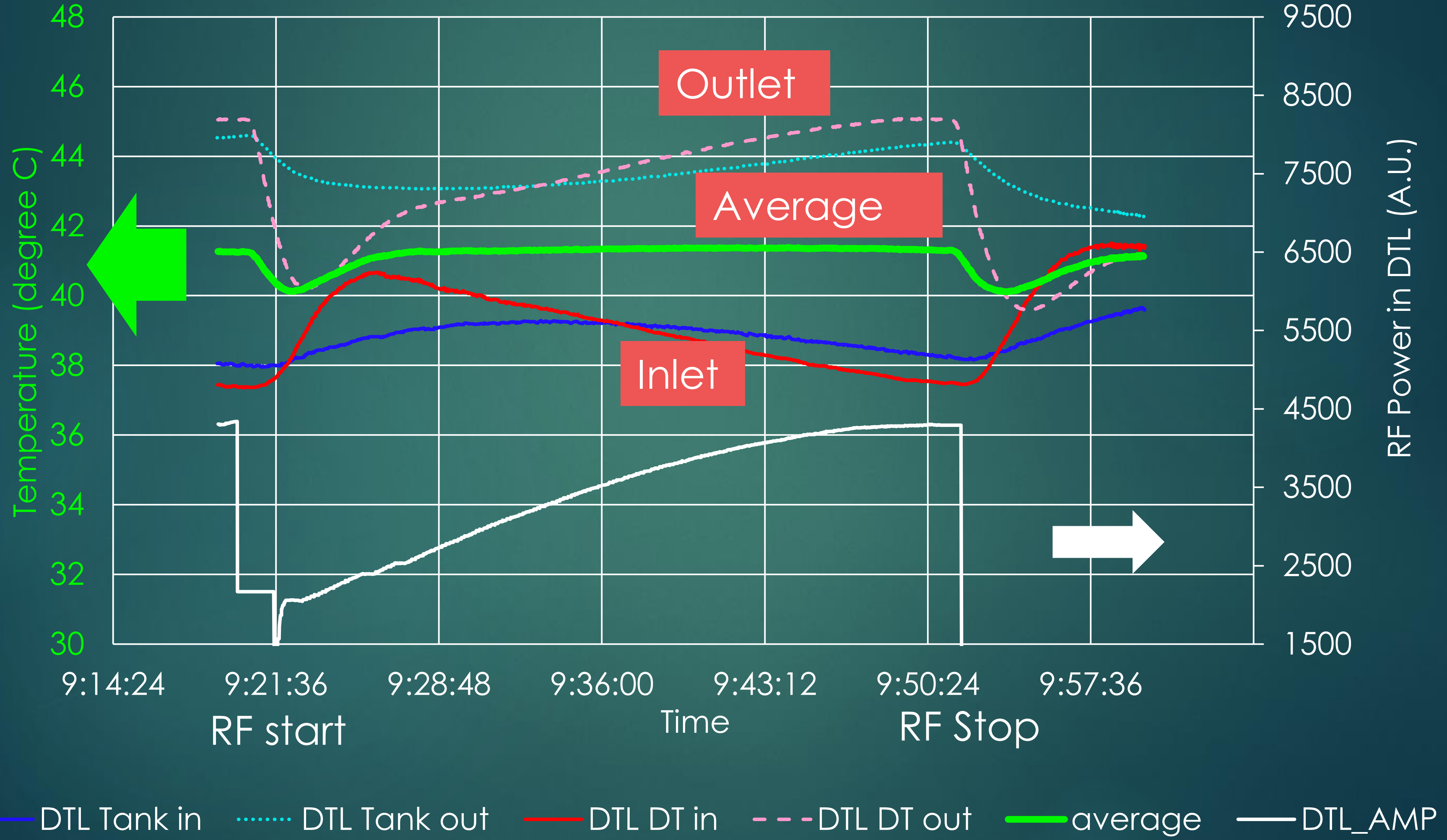
Key points of iBNCT 3

come along with Key points 1

- One klystron feeds both of an RFQ and a DTL to reduce cost and foot-print.
- Allowing a large temperature difference (ΔT) up to 10 °C between inlet and outlet cooling water of RF cavities, cooling water system shrinks in size.
  - It's a big challenge.

Dynamic water temperature control

Average temperature keeps constant.



Key points of iBNCT 4

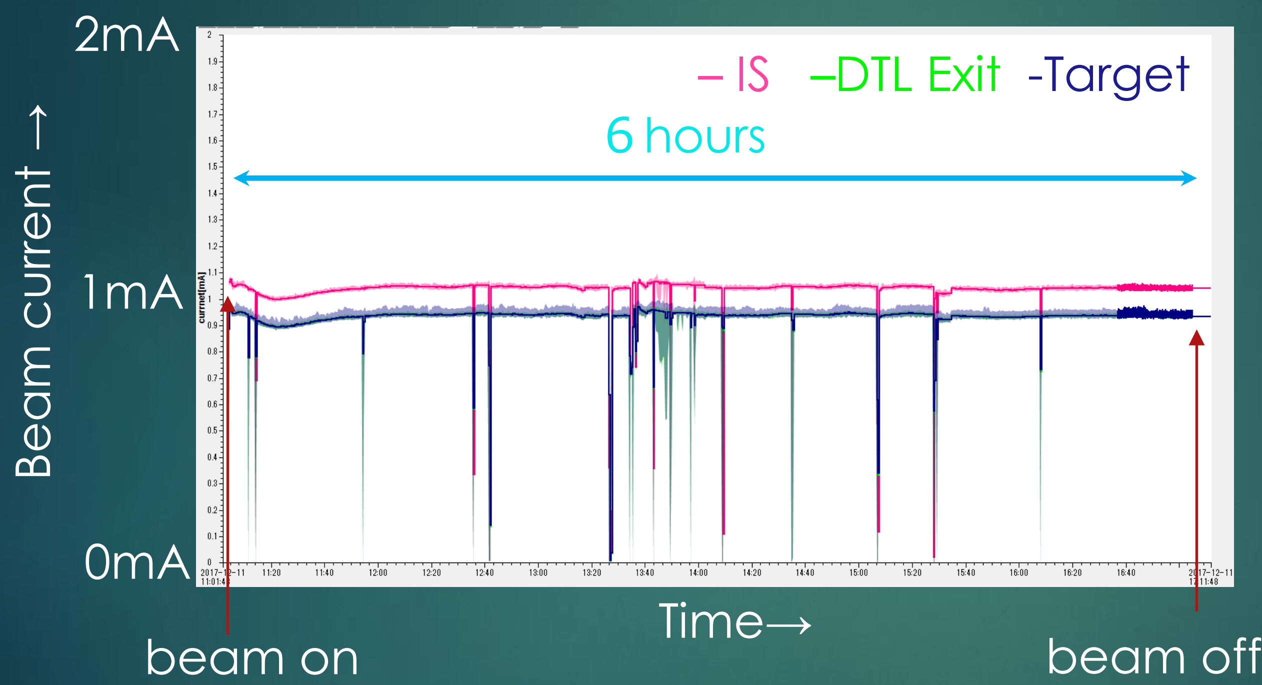
- There are some choices for an accelerator based BNCT.
  - Type: Linac, cyclotron, electrostatic accelerator,,,
  - Energy: 8 MeV, 30 MeV,,,,
  - Target material: solid Li, liquid Li, solid Be ,,,
- iBNCT selected 8MeV linac with Be target.
  - Low residual activity is essential in a hospital.

These selections characterize iBNCT.

What has achieved in iBNCT

beam current: 1 mA on target

@50Hz, 6hours



There are some short beam stops.

High beam current and stable operation are opposite concepts. we need to find some meeting point.

Neutron flux: 5.3×10^8 neutron/cm^2/sec @0.95 mA by preliminary measurement

Summary

- Introduced BNCT
- iBNCT accelerator:
  - Small foot print suitable for hospital-use.
  - RF Cavity design is based on J-PARC LINAC.
  - Feeding two different cavities from one klystron.
  - Large ΔT of cooling water for cavities to shrink cooling system in size.
  - 8MeV linac with Be target.
- iBNCT achieved average current of 1 mA and thermal neutron flux of 5.3×10^{8} neutron/cm^{2}/sec .
- We are still in a half of the way there.

Thank you for your attention.