Future Medical Accelerator

Kiyoshi Yasuoka

Proton Medical Research Center (PMRC)
University of Tsukuba, Japan
e-mail: kiyoshi@pmrc.tsukuba.ac.jp

Introduction (1)

Medical Accelerator

evolving into powerful equipments:

- an activator for radionuclide production

  ⟹ **PET & SPECT**

- a probe for radiation diagnostics
- a knife for

  radiation therapy (RT) : X-ray γ-ray e

  particle therapy (PT) : p C n

Introduction (2)

Medical Accelerator:

Mainly

- ✓ **RFQ/DTL LINAC**
- ✓ **CYCLOTRON**
- ✓ **SYNCHROTRON**

Demand

We (medical staff) have DEMAND
for radiation diagnostics
and
radiation/particle therapy.

We have NO SOLUTIONs to achieve
our demands.

You (accel.experts) HAVE the technical SOLUTION!

They could be NEW solution,
and they could be OLD solution
established already!

Risk Management

Find out OLD solution first before developing NEW technology!

Because

Medical accelerator is a medical machine.

Target is NOT material BUT human being in RD , RT/PT

Important Concepts:
"Medical"=Safe, Stable, Reliable, Precise, Established, …

Commercial Importance for Prevalence of RT/PT

Continue R&D for:

- Compactness ⇨
  - **Super Conductive (SC)**
  - **Lighter & Higher RBE Particle use**
- Cost Reduction
- Easy & Friendly Operation ⇨
  - **One Button Operation**

Radiation Therapy (RT)

Passive

Dynamic

3D

+ respiration gating system

3.1D

+ motion tracking technology

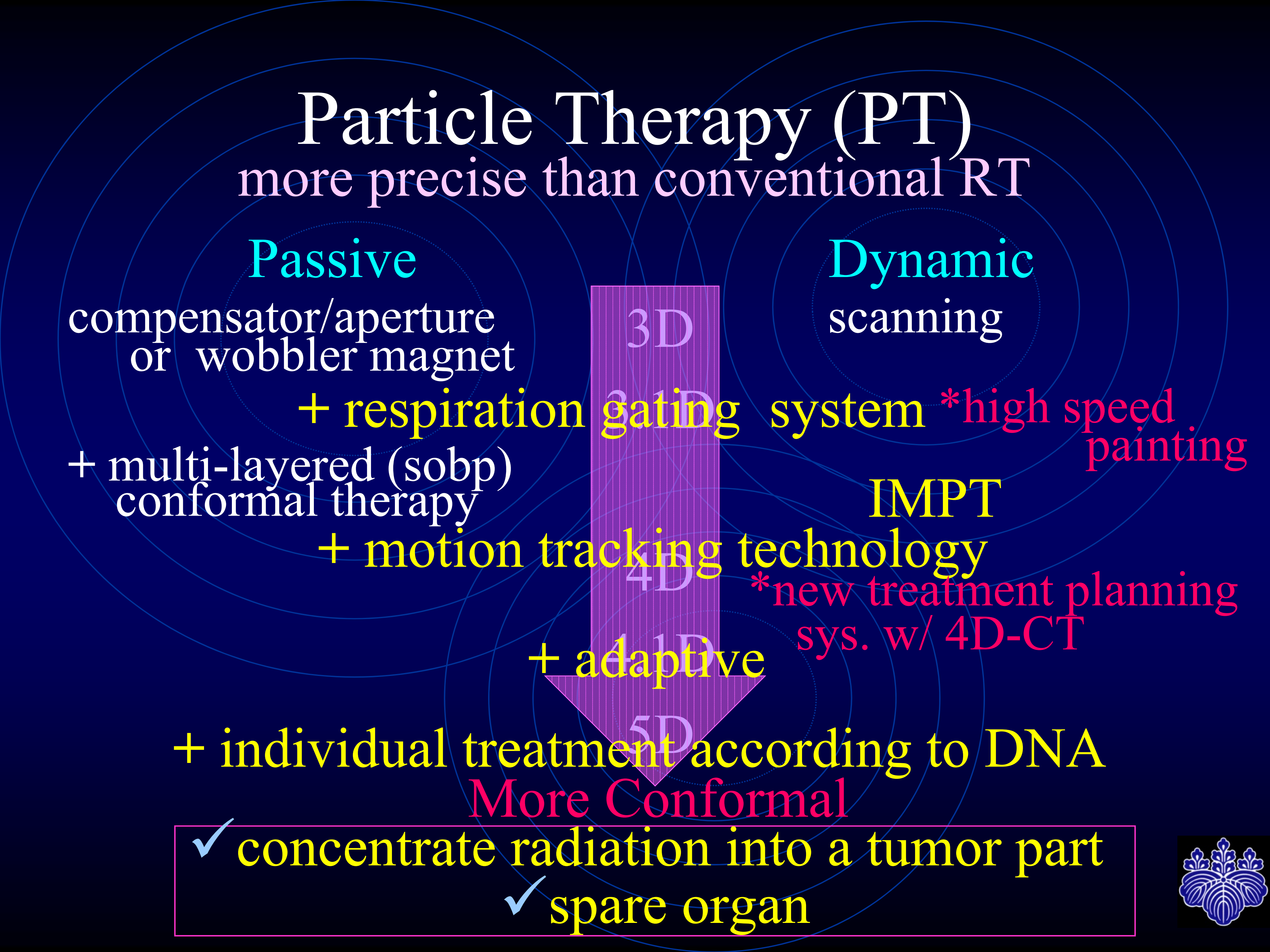
4D

4.1D

More Conformal

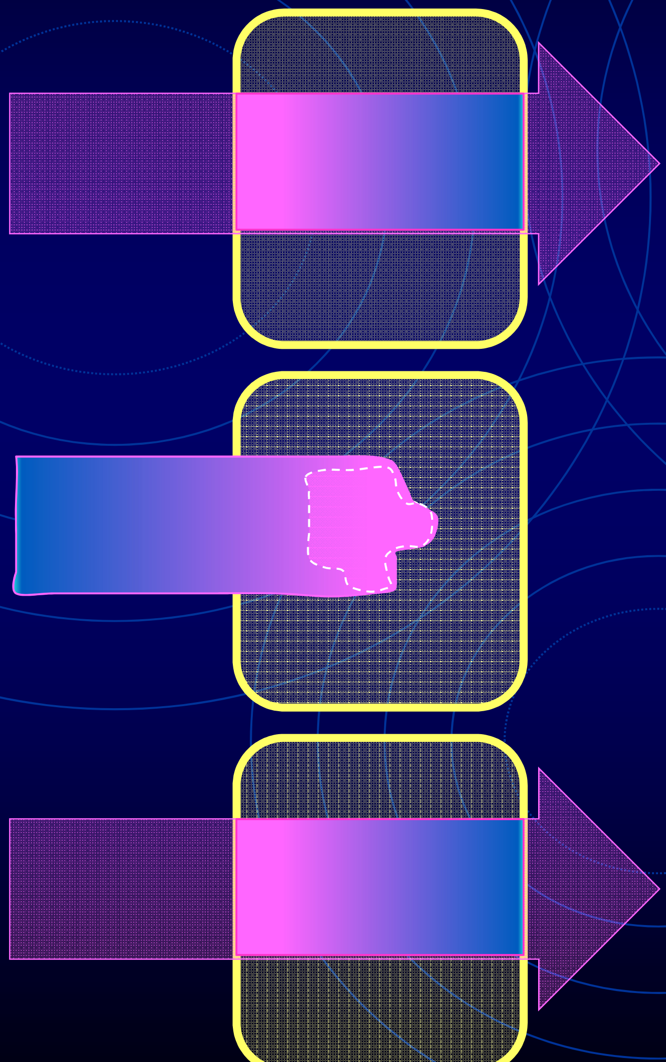
IMRT

✓ Technology: c-band linac, SC linac


Particle Therapy (PT)
more precise than conventional RT
Passive
compensator/aperture
or wobbler magnet
Dynamic
scanning
3D
3.1D
+ respiration gating system
*high speed painting
+ multi-layered (sobp) conformal therapy
IMPT
+ motion tracking technology
4D
*new treatment planning sys. w/ 4D-CT
4.1D
+ adaptive
5D
+ individual treatment according to DNA
More Conformal
✓ concentrate radiation into a tumor part
✓ spare organ

Radiation/Particle Therapy

body · tumor cell · target



photon

Conventional RT
✓ spare organ

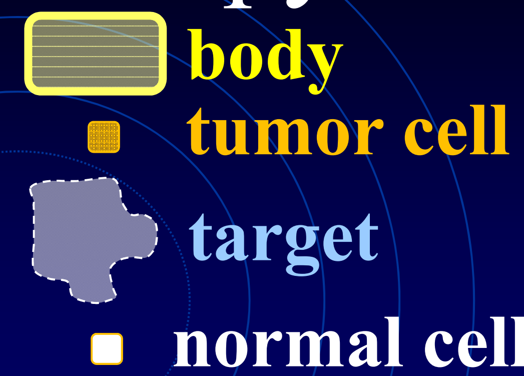
IMRT
✓ spare organ

proton
carbon

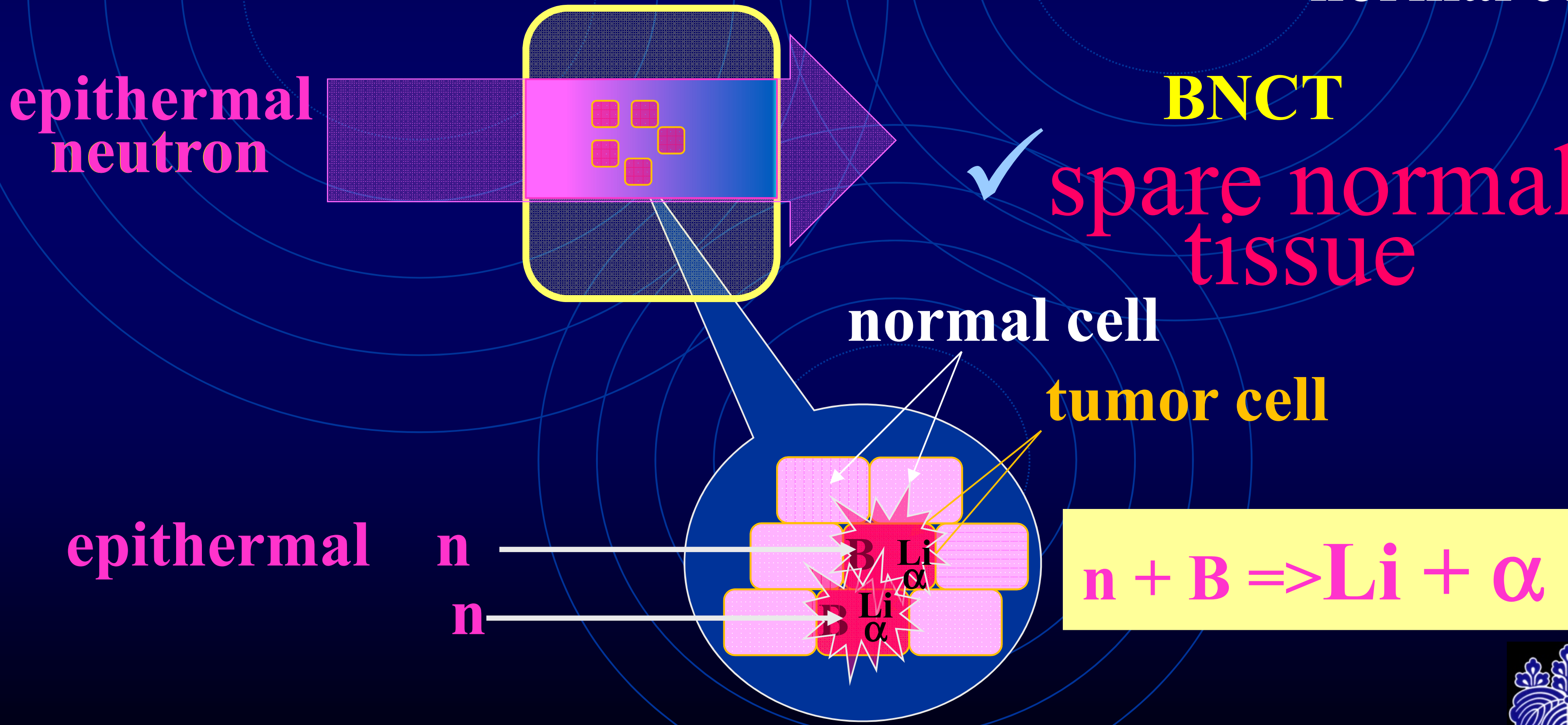
✓ spare organ

fast
neutron

Boron Neutron Capture Therapy (BNCT)



Tumor Cell Selective!



Neutron Source Specification @ BNCT

IAEA recomendation

- Exposure Time < 1 hour

  Epithermal (0.1eV – 10keV) neutron

  flux $>10^9$[/cm^2/s]

- Reduction of

  fast neutron dose < 2×10^{-13} Gy cm^2 /epithermal neutron

  γ-ray dose < 2×10^{-13} Gy cm^2 /epithermal neutron

  thermal/epithermal ratio < 0.05

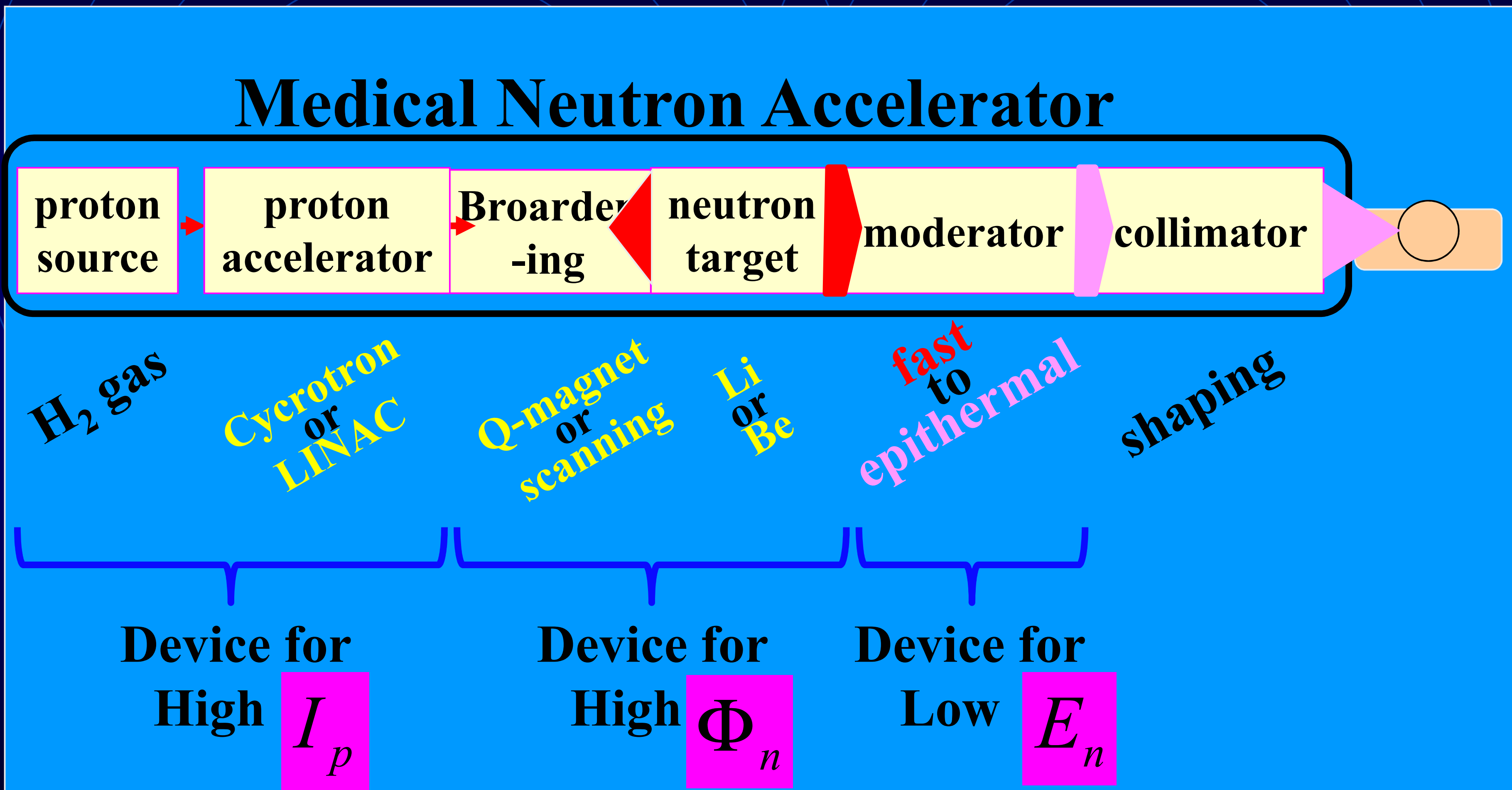
Neutron Source

BNCT used to be performed by using thermal neutrons produced in nuclear reactors.

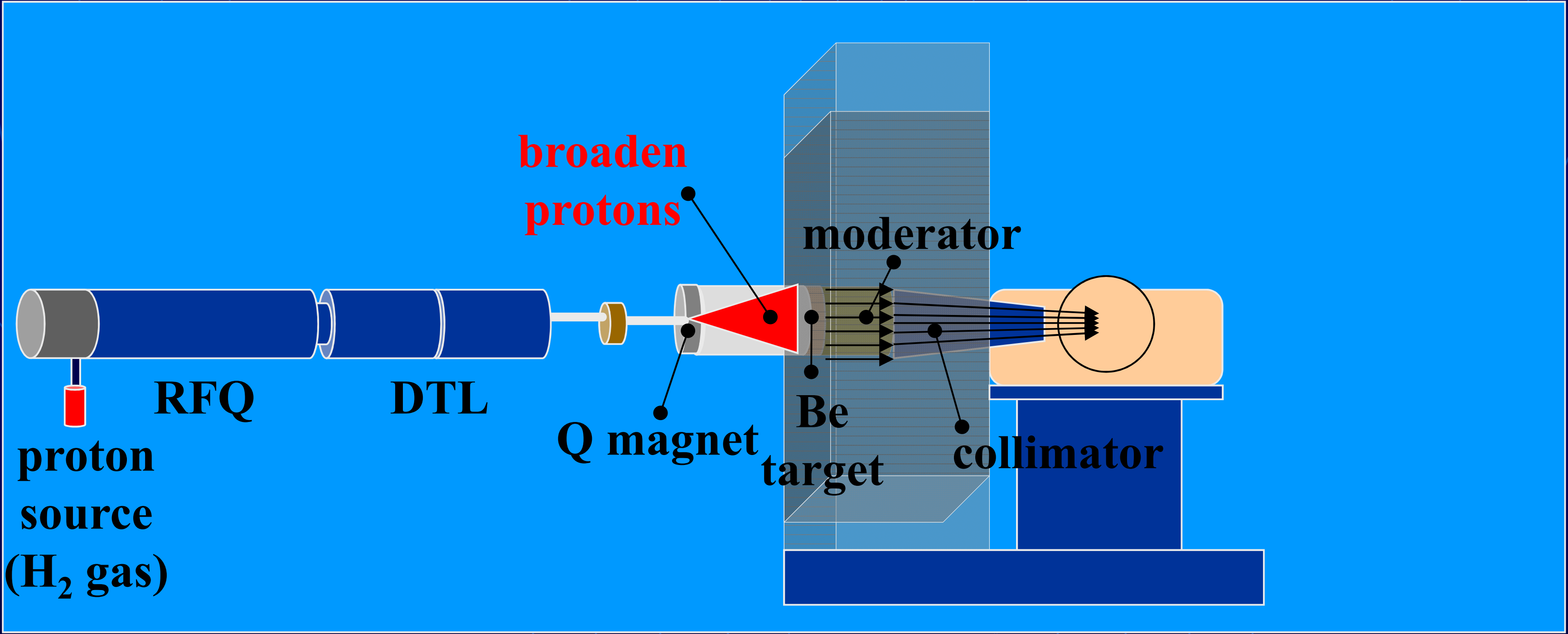
In the recent decades, the BNCT is changed to Accelerator-based BNCT.

Epithermal neutrons (0.1eV-10keV) better than fast (>10keV) & thermal (<0.1eV) neutrons as a source

Accelerator-based BNCT



Accelerator-based BNCT



I_p ~ order of mA!

Medical Neutron Accelerator @ Tsukuba

Hospital-based compact proton LINAC

TYPE	RFQ+DTL PROTON LINAC (*)	
Proton Energy	8 MeV	low activation
Peak Current	50 mA	same spec. as J-PARC
Averaged Current	>5 mA (10mA@max)	optimized thermal design of acc. tube
Repetition Frequency	>100 Hz (=>200Hz)	optimized thermal design of acc. tube
Power onto Target	>40kW (80kW@max)	optimized thermal design of target
Length, Area	<7m , <50m^2	

Duty factor >10% => CW technology

(*) Design based on J-PARC linac technology

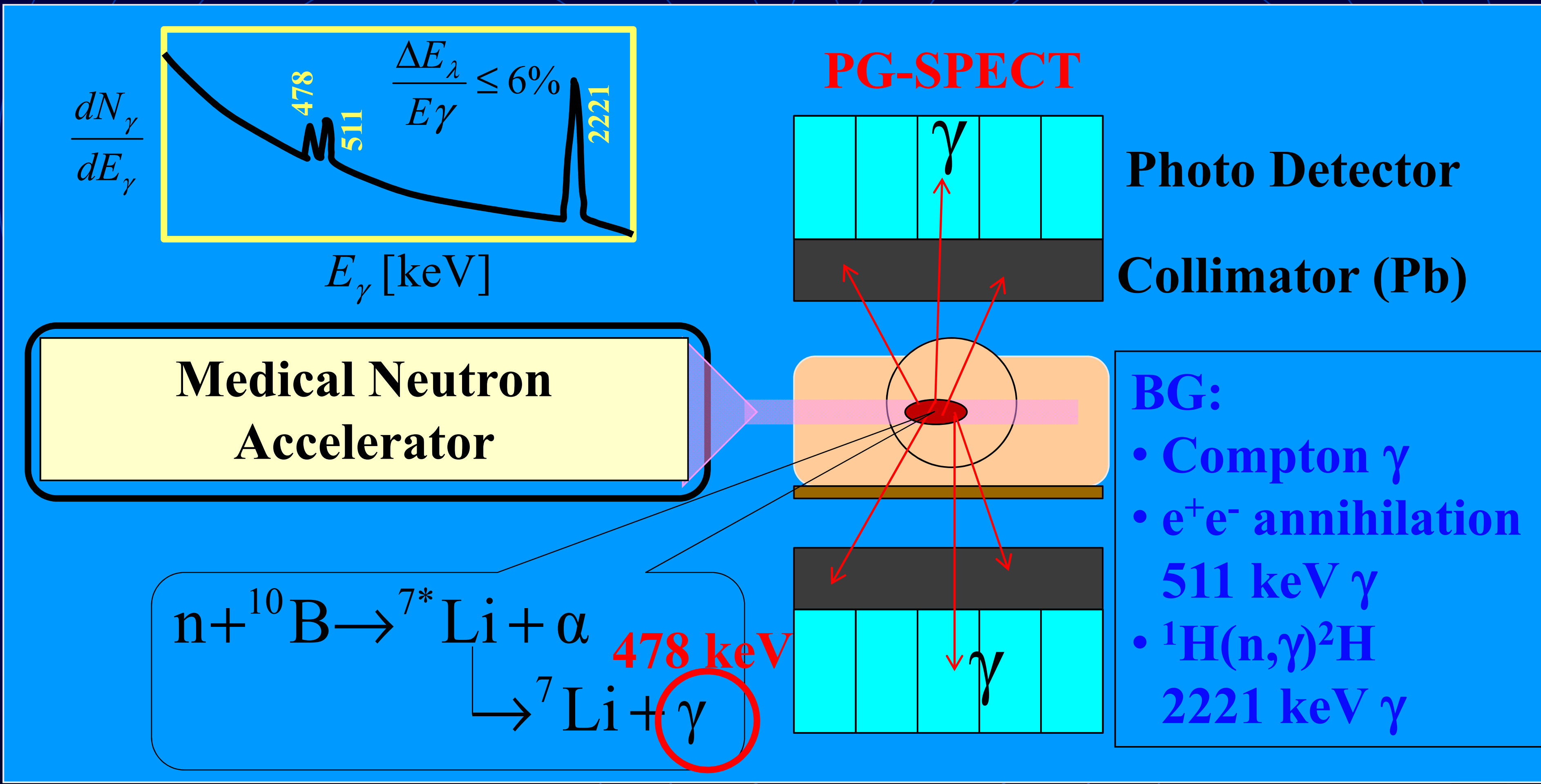
Neutron Production Target

Material		Advantage	Disadvantage
Be	solid	1. 8 MeV protons generate neutrons => less activation 2. High melting point 1287℃ 3. Easy handling 4. Stable	1. Need remove high temperature density 2. HE(>4MeV) neutrons activate materials around
Li	solid	1. Simple moderator 2. Low beam energy => 2.5 MeV	1. Low melting point 180 ℃ => need fine, absolute , stable temperature control 2. Generate radioactive ^{7}Be => 5.2 TB/yr (500hrs operation)=> >20mSv/h in exposure room 3. ^{3}H generated
	liquid	1. Simple moderator 2. Low beam energy => 2.5 MeV 3. No target damage	1. Explosive if mixed with water 2. Generate radioactive materials

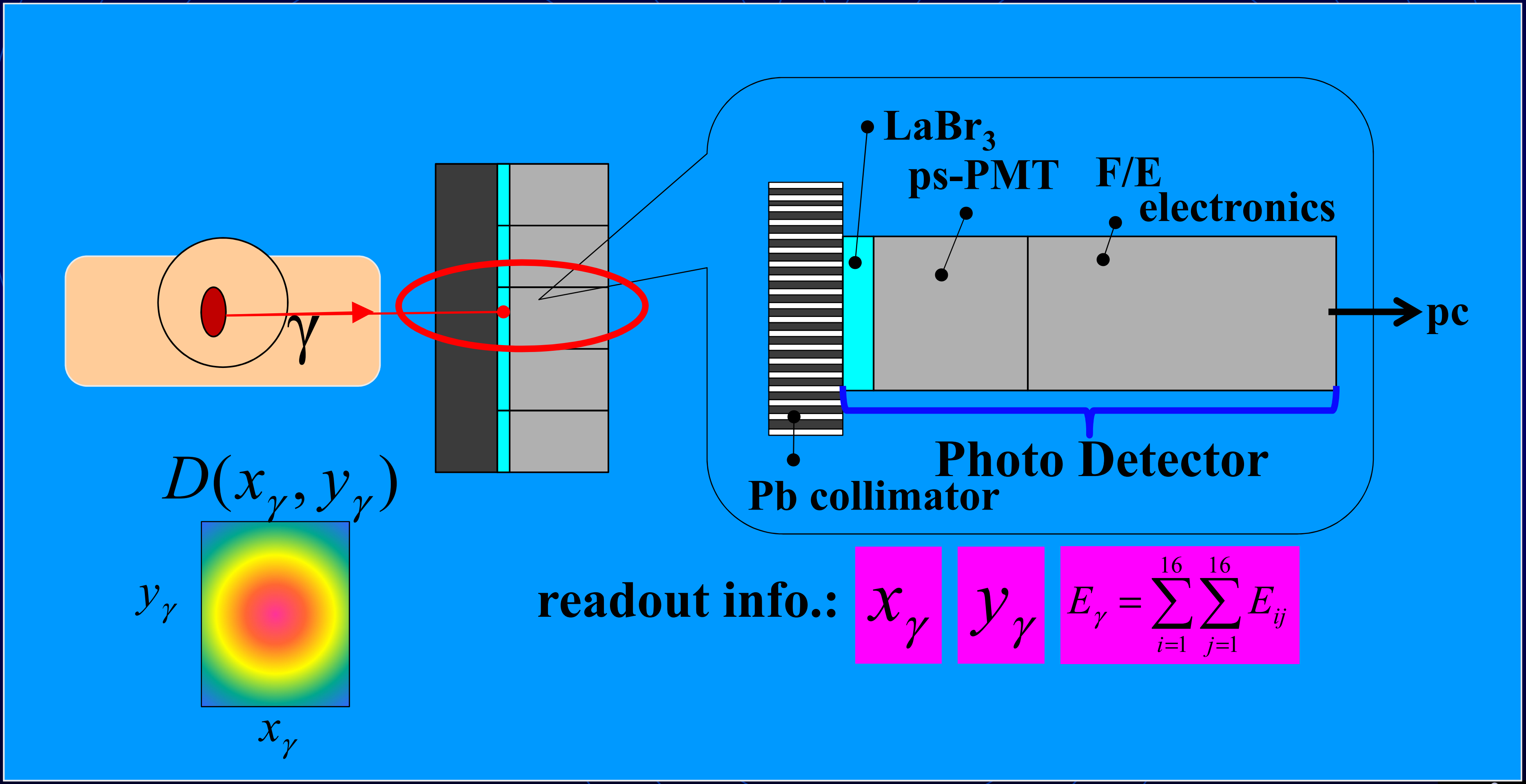
Subjects in Development of Neutron Production Target

1. Reduction of high-dense thermal energy from Be target (4.5MW/m^2)
2. How to prevent a target from blistering due to H_2 gas generated inside
3. Low radio-activation
4. Fast interlock system for fast temperature rise causing damage to target
5. Damage monitor for target

Dose Distribution Monitor @Accelerator-based BNCT



PG-SPECT
(Dose Distribution Monitor)



Summary (1)

- Demands from BNCT:
  - High intensity beam (10mA!)
  - Highly efficient & non-damaged target
  - Less radio activities remained in the hospital!

Summary(2)

- Future medical accelerator:
  - Compactness & Cost Reduction for prevalence ⟹ **New type of hospital-based PT**
  - Integration of multi-type particle delivery for patients in the same facility

    ⟹ **A center of RT/PT**
  - Many sparing normal cell/organ technology (High QA!)