Fast and ultrafast secondary neutron measurements in proton therapy

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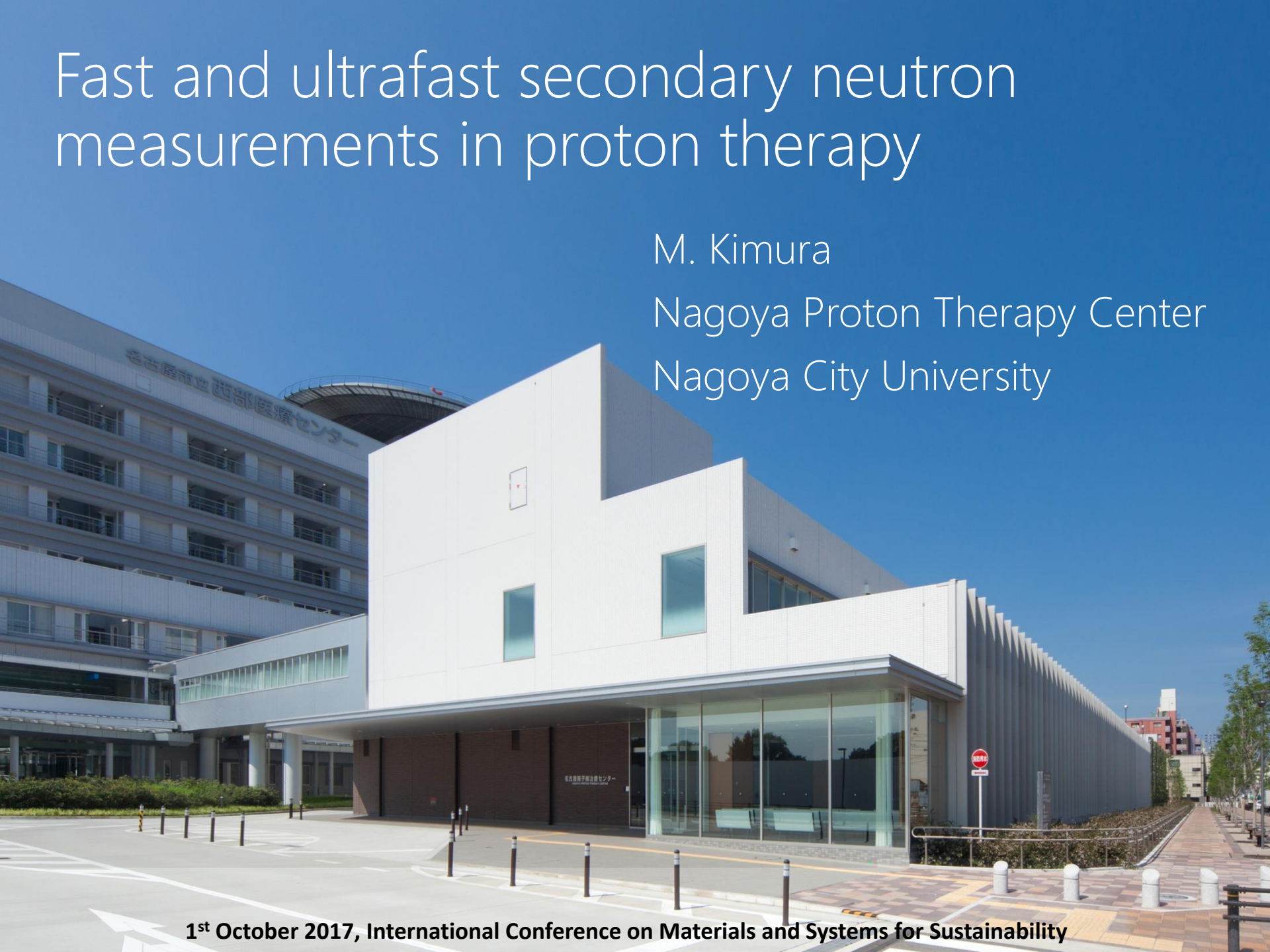
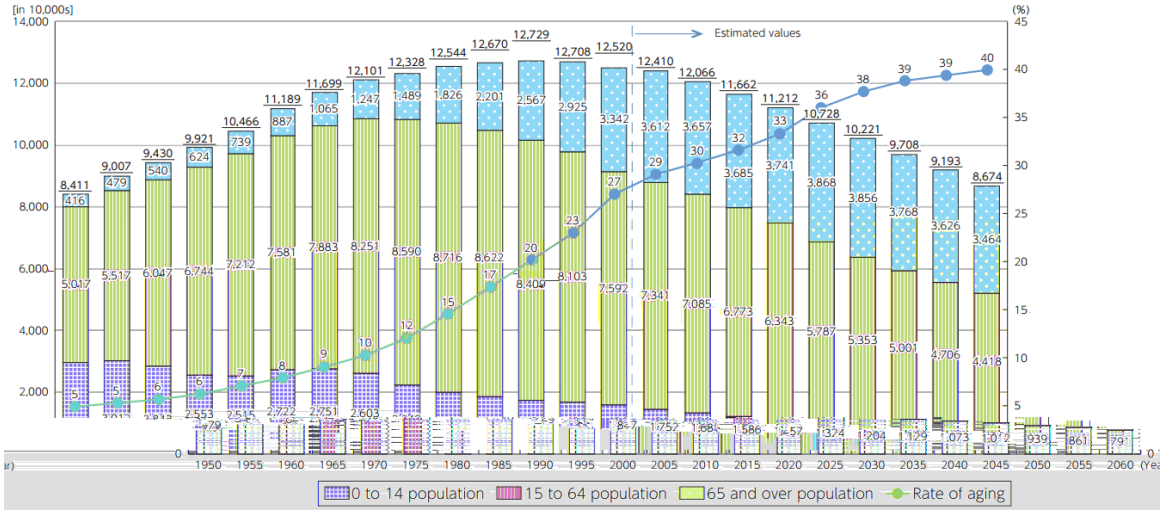


1st October 2017, International Conference on Materials and Systems for Sustainability

Current situations

- Propose a policy of “Dynamic engagement of all citizens”
  - A falling birthrate and an aging population
  - increase the number of cancer patients
- Need to receive treatment while working business



(Sources) Figures to 2015 taken from the “National Census,” MIC (excluding the age-indeterminate population); figur
beyond taken from “Population Projections for Japan (estimated in January 2012),” (mediu
medium mortality assumption) National Institute of Population and Social Se

es for 2020 and
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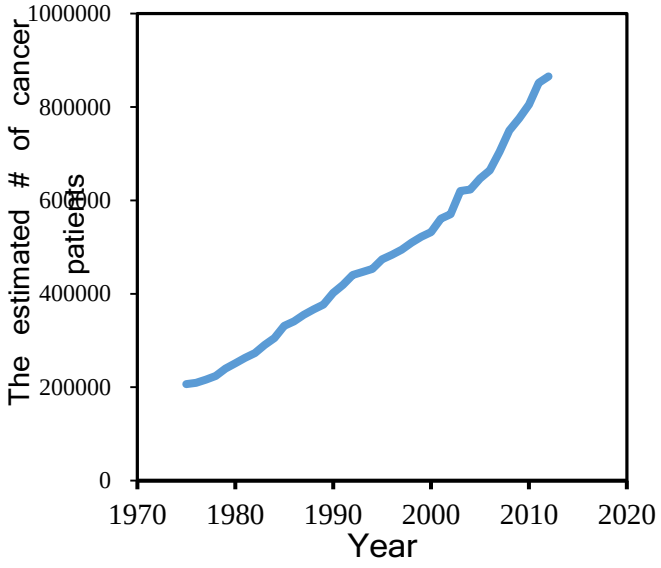
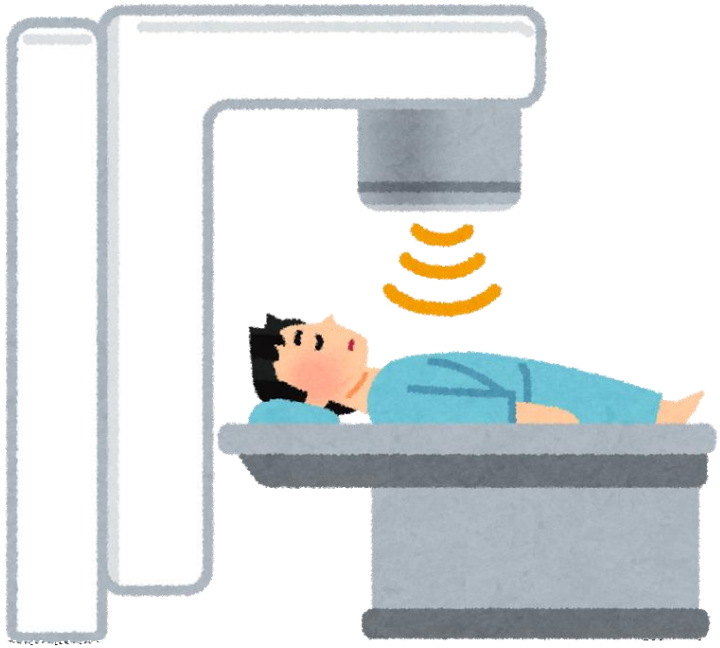


国立がん研究センターがん情報サービス「がん登録・統計」
地域がん登録全国推計値

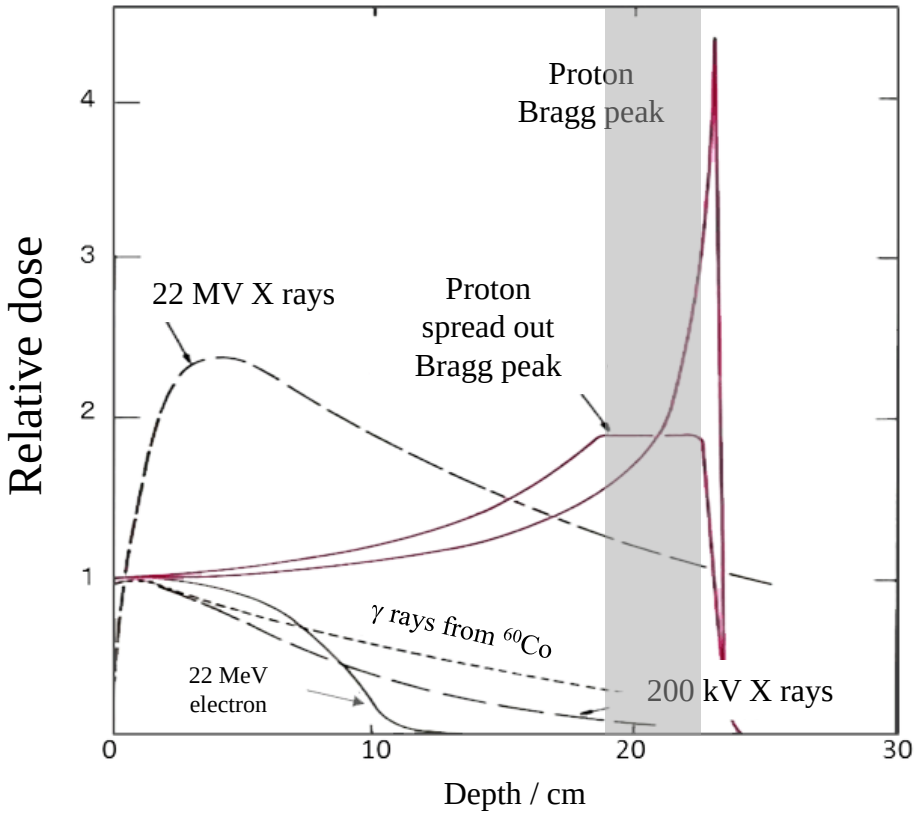
Radiation cancer therapy

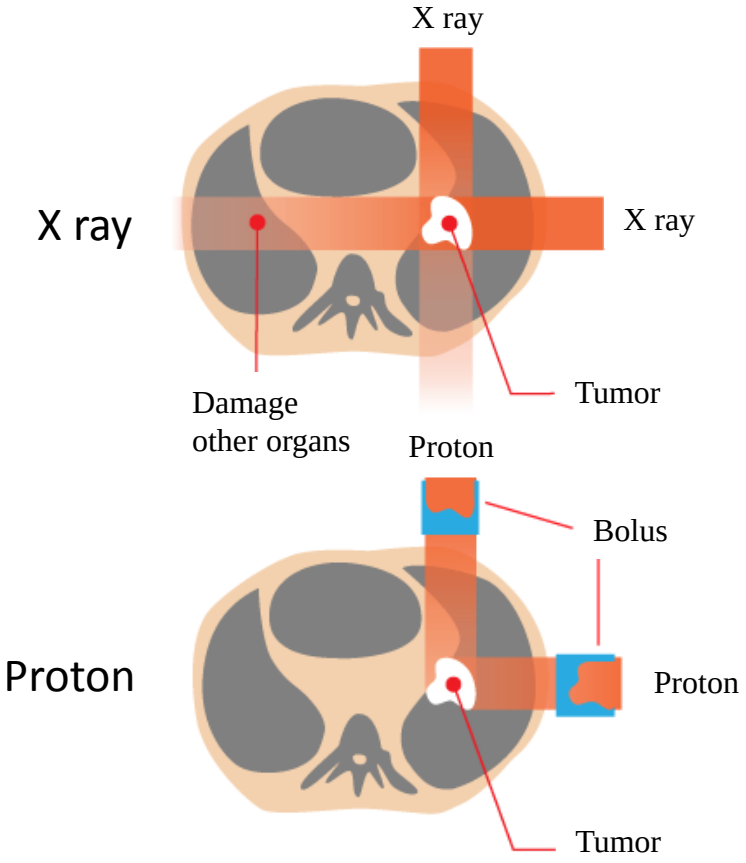
- Maintain quality of life (QOL)
- Radiation rays for the therapy
  - X-ray
  - Electron
  - Particles
    - Neutron (BNCT)
    - Carbon
    - Proton



Proton therapy

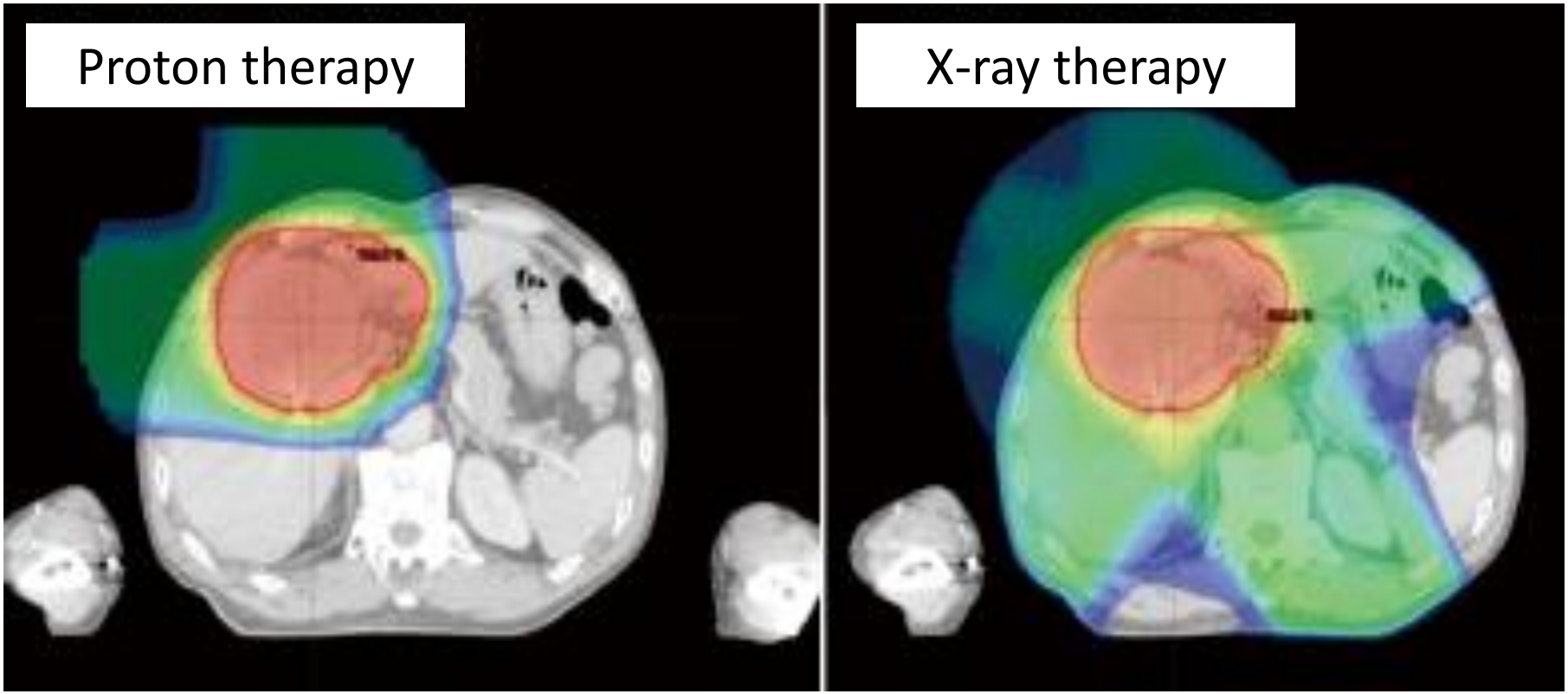
- Stop a beam in tumor
  - save normal organs
- Improve treatment results & reduce adverse events





Example of dose distribution

Liver tumor with large size

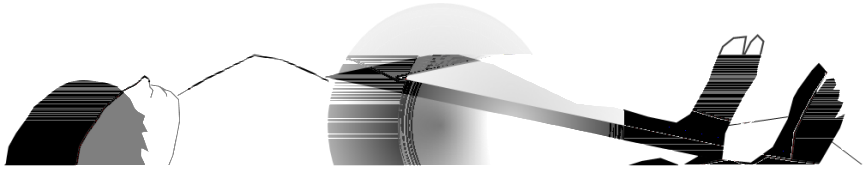


Web page of Hokkaido University
http://www.eng.hokudai.ac.jp/engineering/2012-07/feature1207-06.html

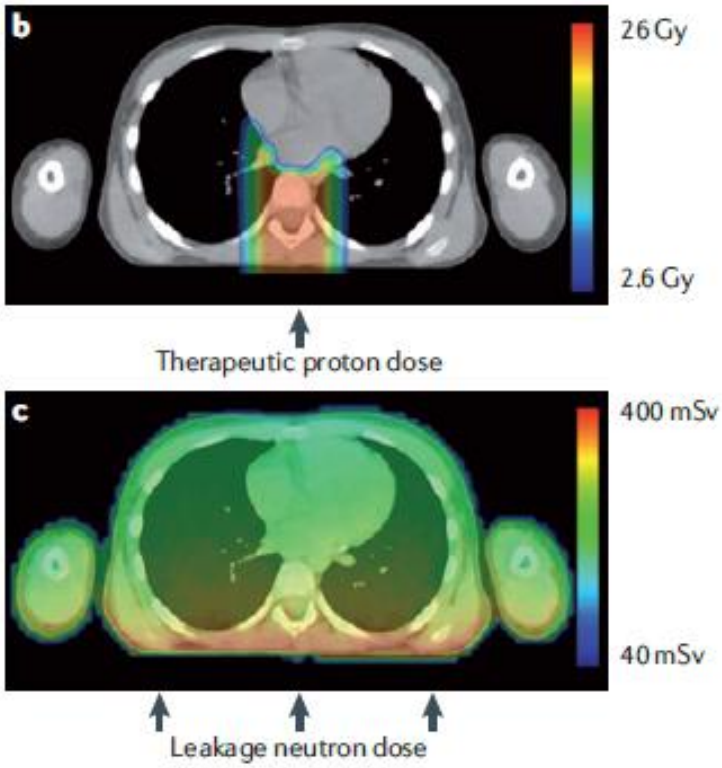
Extra dose from secondary neutrons

- A beam of protons produces secondary neutrons
- Deliver an extra dose to normal tissues

Produced in a body



Leakage neutron

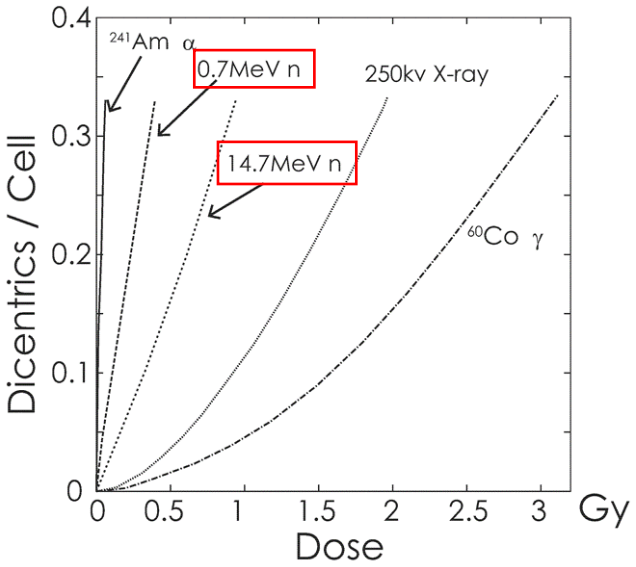


*Passive exposure

W.D. Newhauser, *et al.*, Nat. Rev. Cancer. 3069 (2011)

Second cancer

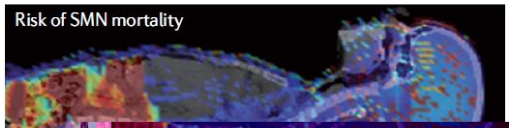
- Neutron is risk of second cancer incidence
  - destroy DNA effectively
  - take 20 years to reveal the effect
  - a big impact on pediatric cancer patients



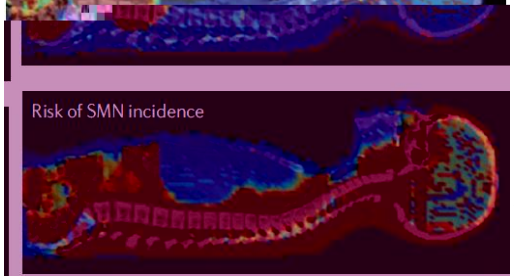
Rate of incidence of dicentric chromosome on human lymphocyte

R.J. DuFrain, et al., Huebner, K.F.; Fry, S.A. (eds.); p. 357-374; 1980

Dose of protons



Risk of second cancer mortality



Risk of second cancer incidence

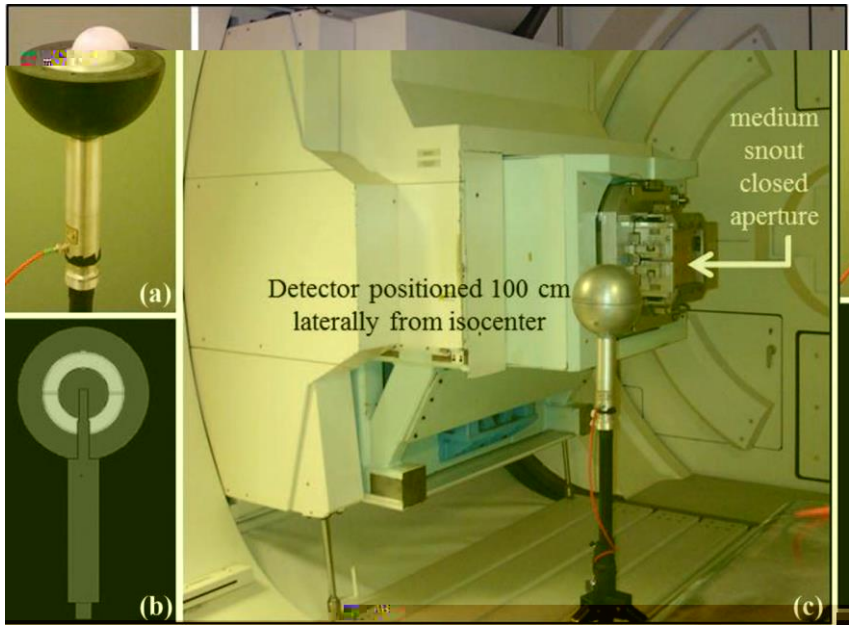
W.D. Newhauser, *et al.*, Nat. Rev. Cancer. 3069 (2011)

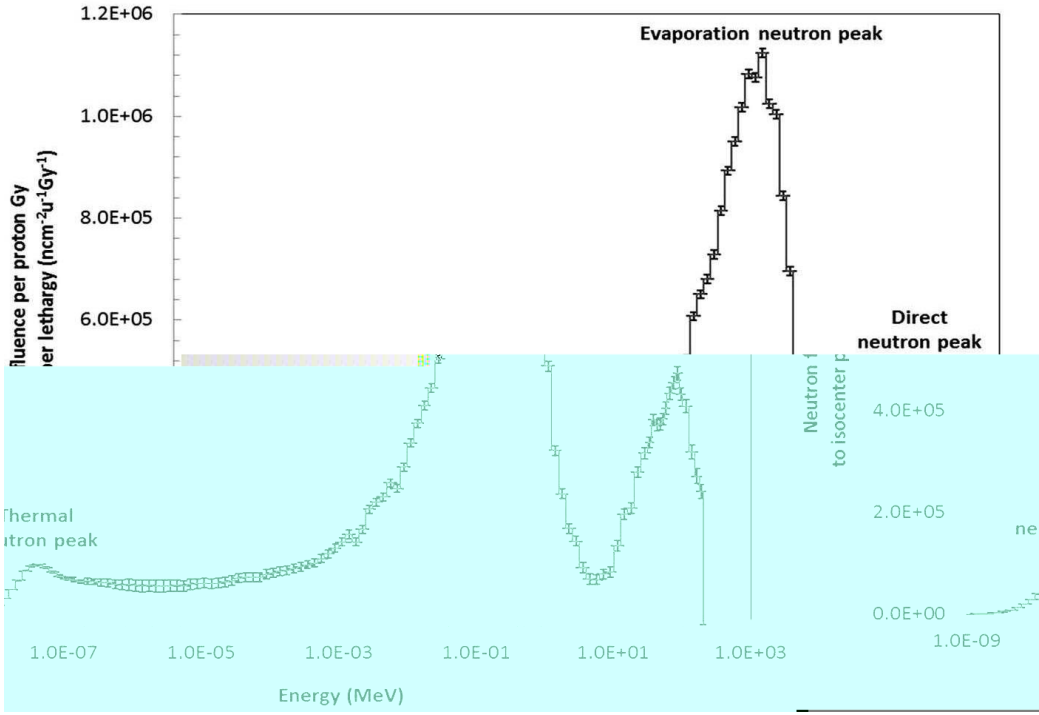
Properties of secondary neutron

- Not small radiation exposure (~ 1 mSv/Gy)
- Wide energy spectrum
  - thermal to 250 MeV (= max energy of protons)
- Ultrafast neutron (E > 20 MeV)
  - no biological data
  - fewer measurements for energy spectrum
    - detector: limited or no response to the neutron

Energy spectrum

- Contain production and transportation processes
- Need dose + energy spectrum





Neutron spectrum by Boner sphere extension (BSE) measurements
R.M. Howell, et al., Med. Phys. 41(2014) 092104-1.

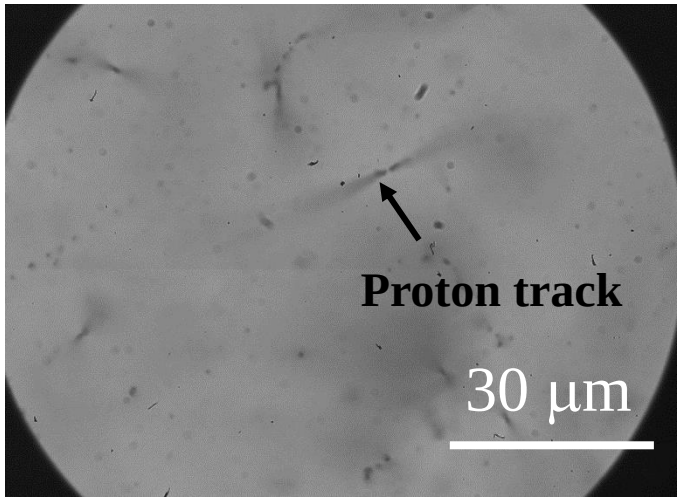
Ultrafast neutron measurements

Nuclear emulsion is one of the promising detector for ultrafast neutron measurement.

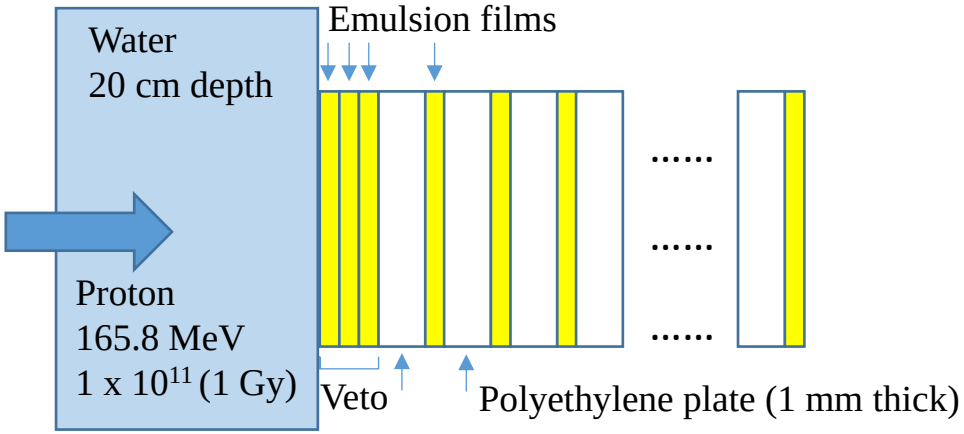
Detector	Energy measurement	PID
Boner sphere extension	Indirect (< 250 MeV)	Material
Liquid scintillator	Direct (< 30 MeV)	Delayed coincidence
Solid scintillator	Direct (< 30 MeV)	Pulse shape
Nuclear emulsion (ECC)	Direct (< 250 MeV)	Grain density

First trial

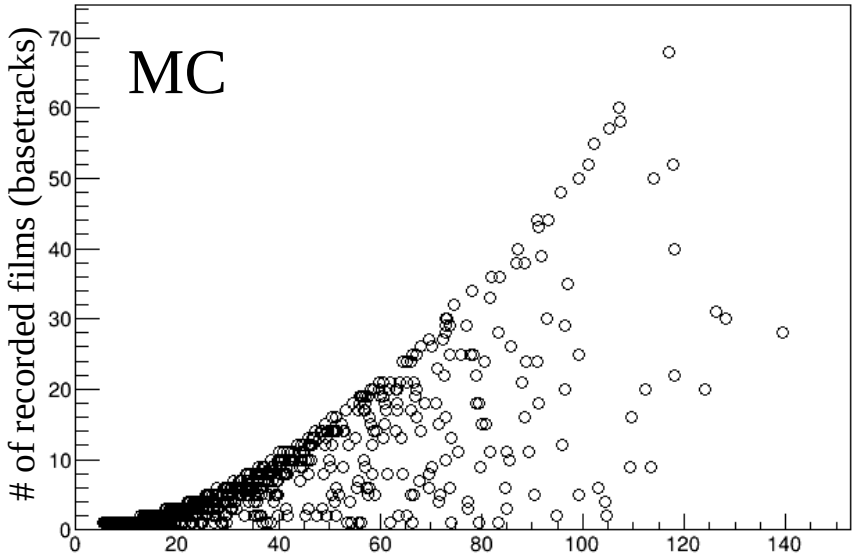
- ECC type
  - 5 cm x 6.25 cm x 70 μm x 90 films
  - 1 mm thick polyethylene plate
- A lot of γ rays
- Analysis is in progress



Microscopic view of a film in the most downstream position



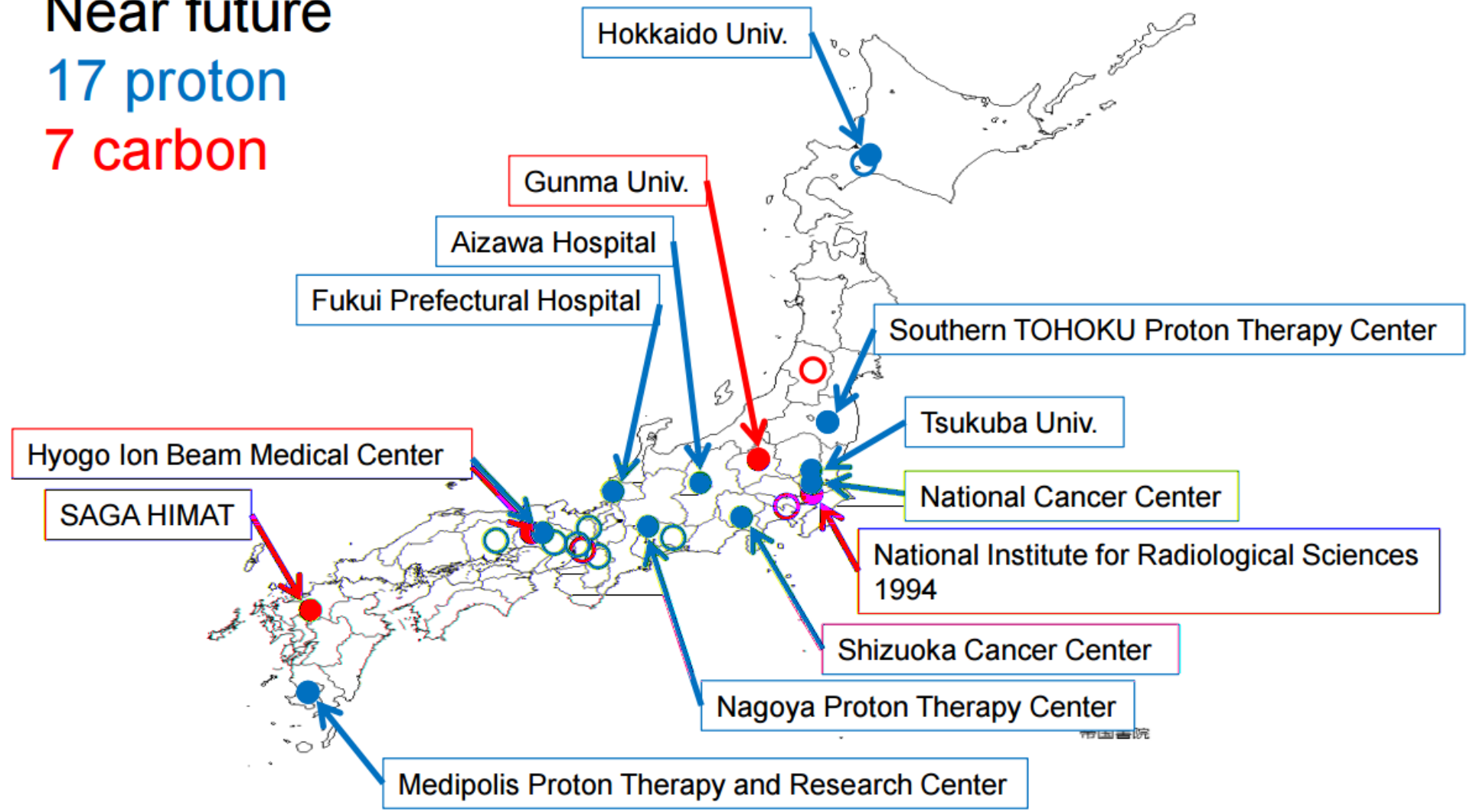
Experimental arrangement



Conclusions

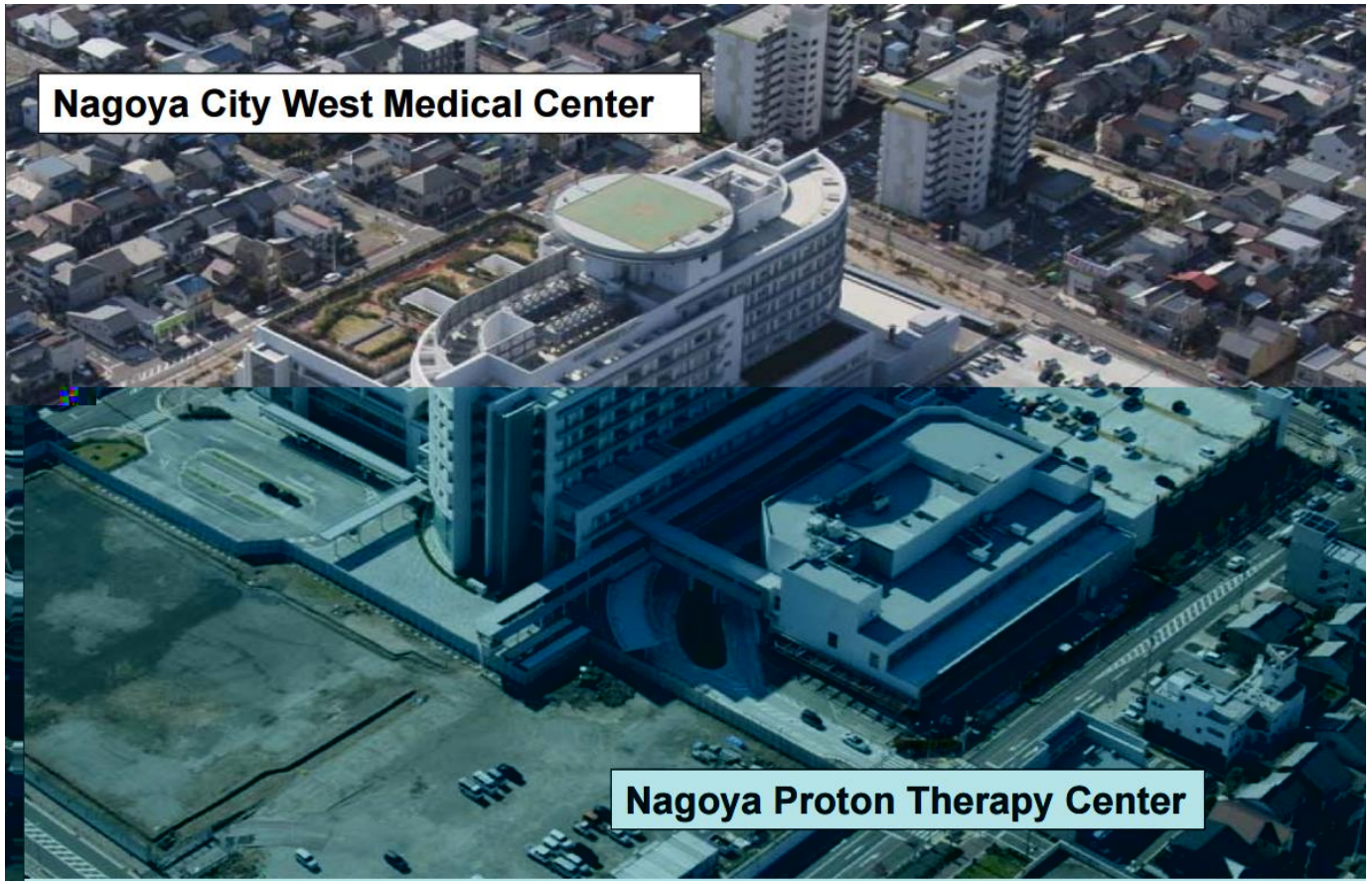
- Proton therapy can maintain the QOL of a patient
- Secondary neutron deliver an extra dose to normal tissues
- Nuclear emulsion provides technical expertise
- We want to develop a precise dose distribution estimation system to provide better healthcare

Particle therapy center in Japan



Nagoya Proton Therapy Center

- Nagoya City West Medical Center exists in the same place



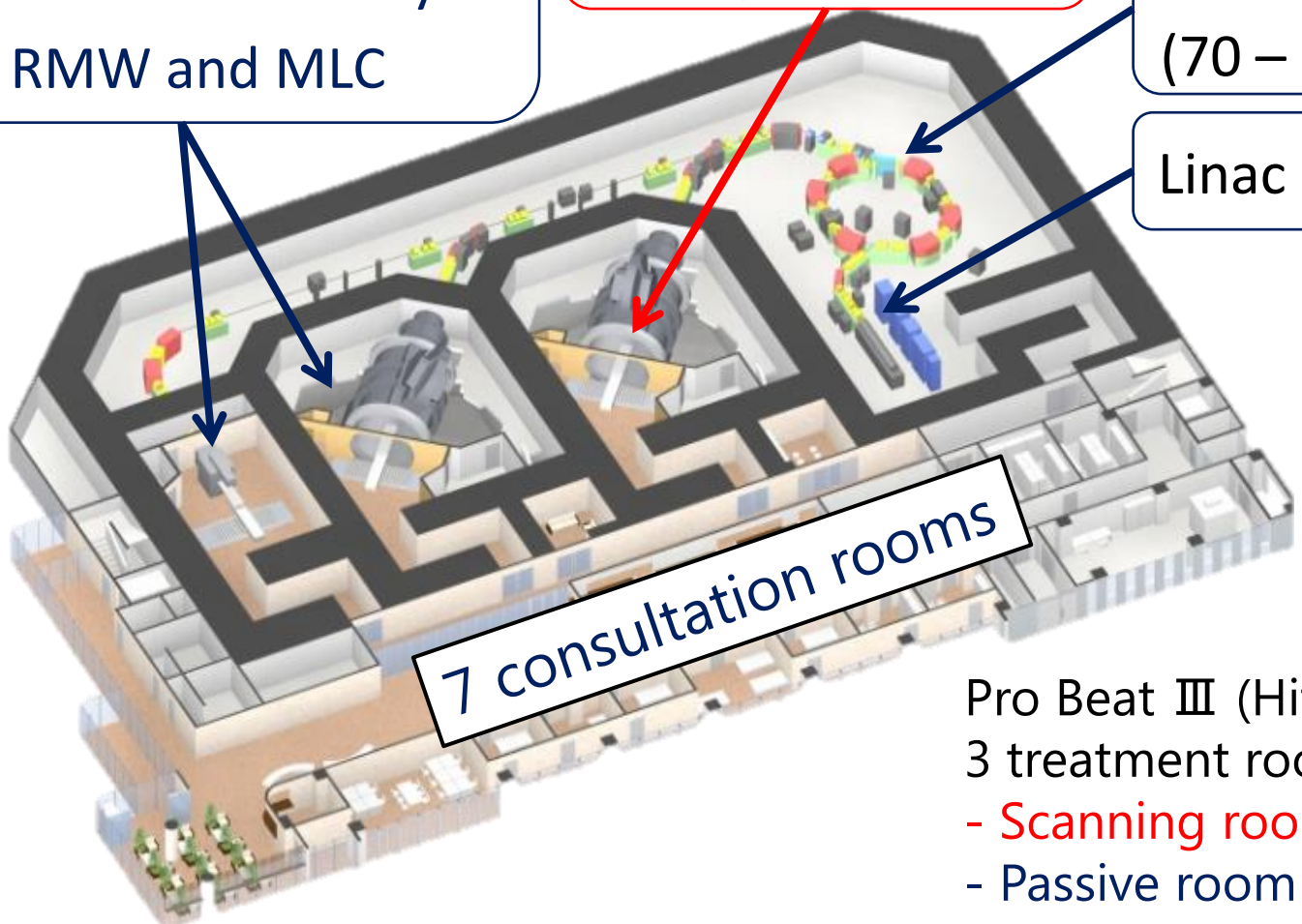
The system layout at NPTC

Passive Nozzle x 2
Fixed beam and Gantry
Using RMW and MLC

Scanning Nozzle
Gantry

Synchrotron
(70 – 250 MeV)

Linac injector



Pro Beat Ⅲ (Hitachi Co.Ltd)
3 treatment rooms
- Scanning room (G1)
- Passive room (FX, G2)

Radiation-induced cancer

- Take twenty years to reveal the effects

ガン発生部位	平均潜伏期間（年）	症例数
甲状腺	20.3	20
膀胱	20.7	10
乳腺	22.6	10
喉咽頭	23.4	37
頭頸部	24.1	113
皮膚	24.5	38
咽頭	25.0	10
喉頭	27.3	130

[出典] UNSCEAR 1977年 Report

http://www.rist.or.jp/atomica/data/dat_detail.php?Title_No=09-02-03-02