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Non-power Applications of Nuclear Technology for Global Economy and Society

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Fukui International Meeting on HRD
for Nuclear Energy In Asia in 2017
Tsuruga

Contents

- FNCA
- Agriculture and Food
- Medicine
- Industry
- Solving Crimes and Fighting Terrorism
- Nuclear Science (B-Factory, J-PARC)

FNCA

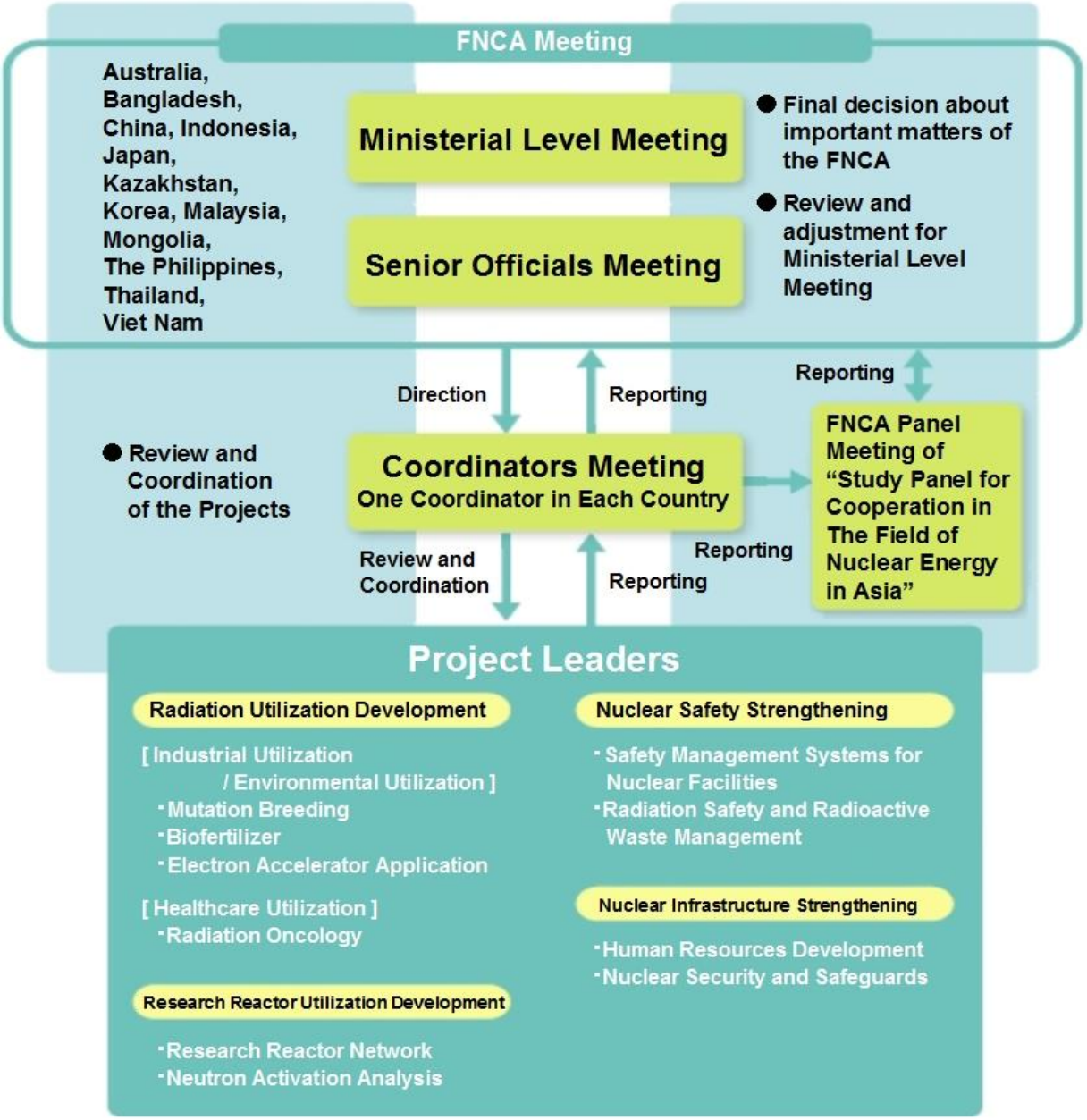
- 1990 ICNCA (International Conference for Nuclear Cooperation in Asia) held by Atomic Energy Commission of Japan

- Exchange of frank views by ministers in charge of development and utilization of nuclear energy on how to proceed with regional cooperation
- Practical cooperation on specified subjects

- 2000 FNCA (Forum for Nuclear Cooperation in Asia)

- Ministerial Level Meeting, Coordinator and Project Leader System
- Four Fields: (1) Radiation Utilization Development (Industrial Utilization/Environmental Utilization, and Healthcare Utilization), (2) Research Reactor Utilization Development, (3) Nuclear Safety Strengthening, and (4) Nuclear Infrastructure Strengthening.

The FNCA Framework



R&D Projects on Applications of Radiation and Isotopes

Applications for Sustainable Agriculture

- Mutation Breeding
- Bio-fertilizer
- Electron Accelerator Application

Application for Medical Care

- Radiation Oncology

Research Reactor Utilization

- Neutron Activation Analysis (NAA)
- Research Reactor Network

Projects for Building Infrastructure

Nuclear Safety Strengthening

- Safety Management Systems for Nuclear Facilities
- Radiation Safety and Radioactive Waste Management

Nuclear Infrastructure Strengthening

- Human Resources Development
- Nuclear Security and Safeguards

Study Panel for Cooperation in the Field of Nuclear Energy In Asia

Project on Mutation Breeding (FNCA)

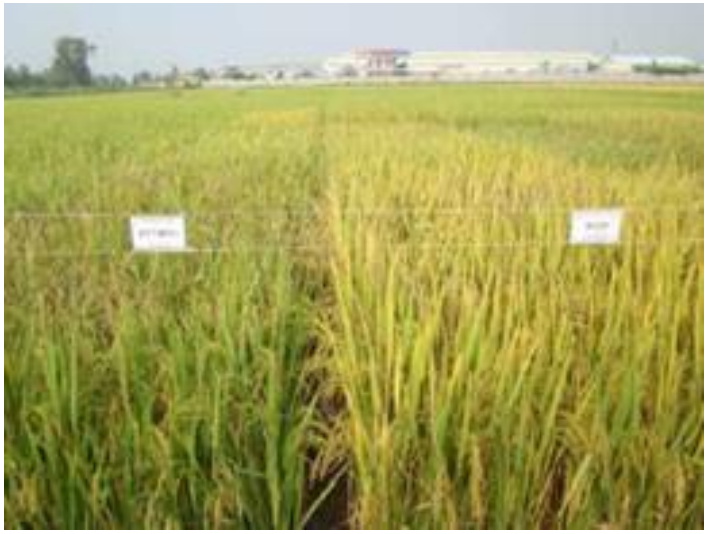
- 2002-2006 Drought tolerance of Sorghum and Soy beans
- 2003-2009 Insect resistance of Orchids
- 2004-2010 Disease resistance of Bananas
- 2007-2012 Composition or quality of Rice
- 2013~ Mutation breeding of Rice for sustainable agriculture

Using gamma-ray and/or ion beams to develop mutant varieties that are resistant to various environmental stresses, early-maturity, and low-input mutant varieties relevant to the demands of each country.

Mutation Breeding

Disease resistant banana in the Philippines

Insect resistant orchid in Malaysia



New disease resistant rice variety in Vietnam (right): 5-14% yield increase

Mutant Varieties of Rice

- Malaysia
- Bangladesh

Mutant NMR152 Parent MR 219

Drought tolerance and high yielding mutant NMR 152 (*Left*) with gamma irradiation and parent MR 219 (*Right*).

Mutant Parent

High yielding and early mature mutant line (*Left*) derived from the original variety BRRI dhan29 (*Right*) with carbon ion irradiation

Project on Electron Accelerator Application (FNCA)

- 2002-2005 Treatment of flue-gas
- 2006-2008 Radiation processing of natural polymers
- 2009~ R&D on plant growth promoter/elicitor and super water absorbent

  To develop a plant growth promoter and elicitor by degradation of natural polymers as well as applications of radiation cross-linked hydrogel for super water absorbent, aiming for technical transfer to the end users.

Oligo-chitosan Effect on Bitter Cucumber Indonesia, BATAN, 2012

The crop yield increases by about 40% by application of Oligochitosan

Without Oligochitosan

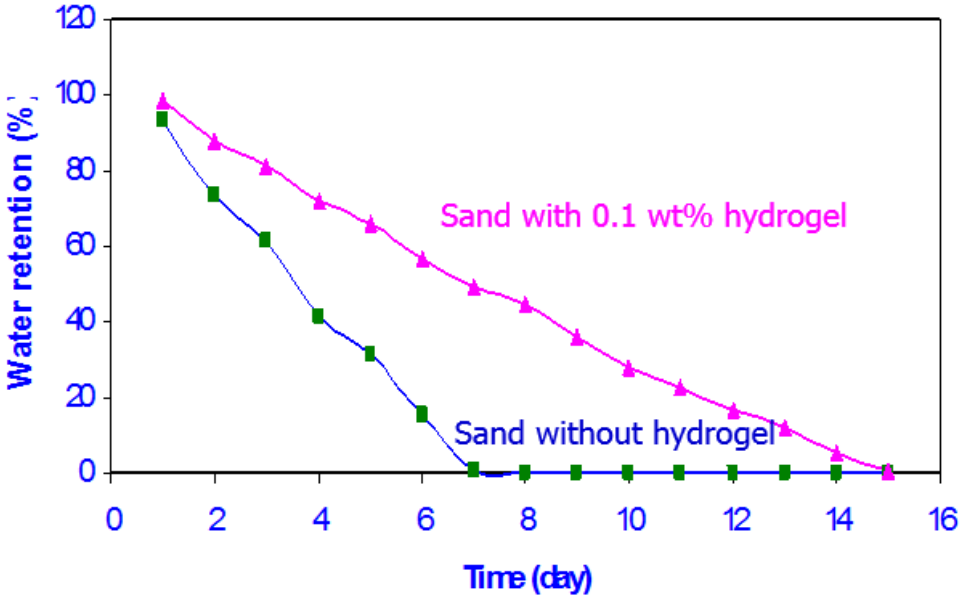
With Oligochitosan

Rice fields sprayed with PGP exposed to typhoons in the Philippines

Ricefields sprayed with PGPs (left) proved much more resilient to lodging compared to the ricefields without PGPs (right) when exposed to typhoons. (2015)

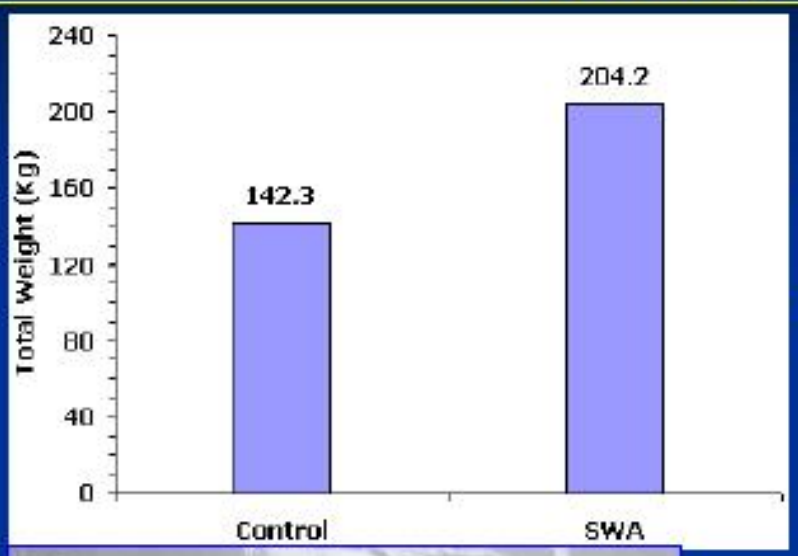
Water holding capacity of soil with super water absorbent (Thailand)

Cassava starch-g-PAA : Water Retention



- **After seven days the sand without hydrogel had nearly given off all water, while the sand with 0.1% wt hydrogel still retained 50 % water.**

Effects of Super Water Absorbent on Baby Corn Thailand, TINT, 2013



AAc grafted starch by radiation

Field test in Kanchanaburi Province

-Yield increase: 43.5%-
Reduced watering.

Without SWA

With SWA

- **Insect Control**
  - **Chemical Treatments:**
    - Create environmental pollution
    - Toxic residues remain in food chain
    - Insects develop tolerance to insecticides
      - Requiring increasingly higher doses
  - **Sterile Insect Technique (SIT)**
    - Produce or capture large numbers of insects and sterilize them
    - Release them into their native environment
    - No offspring!
      - Tsetse fly eradicated in parts of Africa (allowing human settlement)
      - Other examples: Mediterranean fruit fly, Mexican fruit fly, Boll Weevil, and Melon Fly in Okinawa

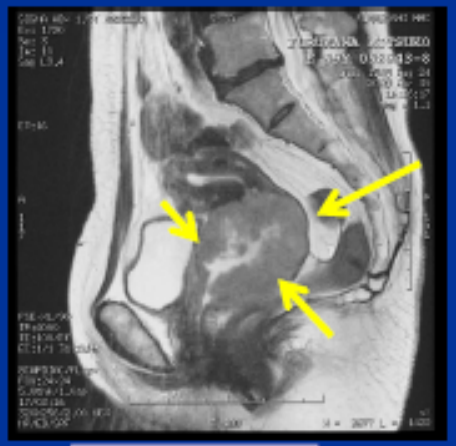
- **Food Irradiation**
  - Beta particles or gamma rays will kill bacteria & pathogens by breaking DNA bonds
    - (particularly effective during reproductive cycle)
  - Specific pathogens targeted include:
    - Salmonella
    - E-coli (0157:H7)
    - Listeria monocytogenes
- **Status of Food Irradiation**
  - Studied for over 40 years
  - Over 36 nations produce some irradiated food
  - Approved by wide body of scientific bodies;
    - World Health Organization
    - American Medical Association
    - etc.
  - NOTE: Goal is not to totally eliminate contamination
    - Some pathogens necessary in body to stimulate immune system
    - ~5 orders of magnitude reduction generally sufficient

Project on Radiation Oncology

- 1996~ Radiation Therapy or Chemo-radiotherapy for Cervical Cancer
- 2005~ Chemo-radiotherapy for Nasopharyngeal Cancer
- 2009~ Hypofractionated Radiotherapy for Breast Cancer
- 2017~ CERVIX-V is planned to start.
  In CERVIX-V, 3-D IGBT (Three Dimension Image Guided Brachytherapy) is newly introduced.
  - The aim of this project is to contribute to improving the radiation treatment techniques for cancers that are more prevalent in the Asian region.
  - The protocols established by this project have been utilized in all the FNCA member countries.
  - The next challenge is the adoption of these protocols in hospitals in member countries.

Protocol Study for Radiation Therapy of Uterine Cervix Cancer・Head/neck Cancer

Advanced uterine cervix cancer treated by **new protocol** (CRT) 5-y survival 55% (40% by RT)



Before

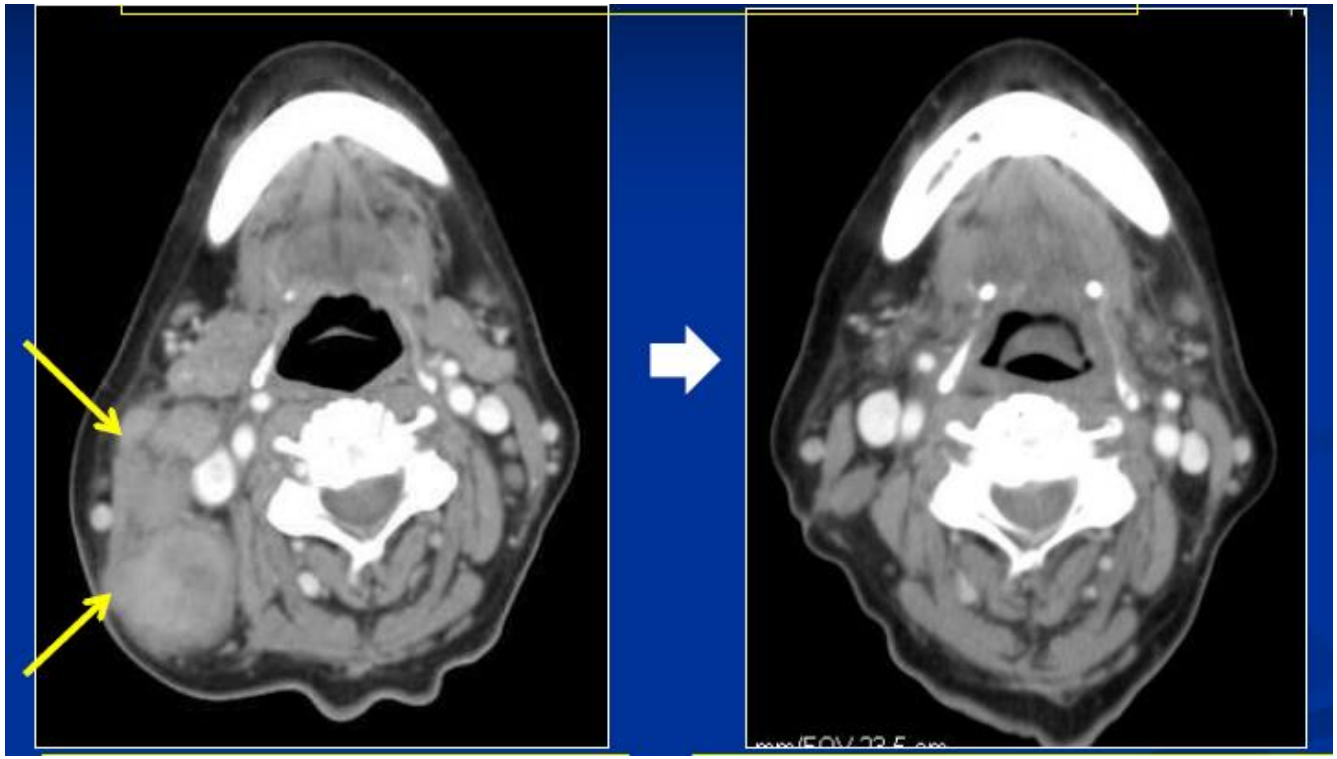
After

WS held in China, Jan. 2012

Standard Protocol in Indonesia, Malaysia, Thailand.

Challenge: Dissemination to all hospitals in MCs

Concurrent Chemo-radiotherapy (CCRT) for Nasopharyngeal Cancer (NPC)



Before Treatment:
Large neck node metastases

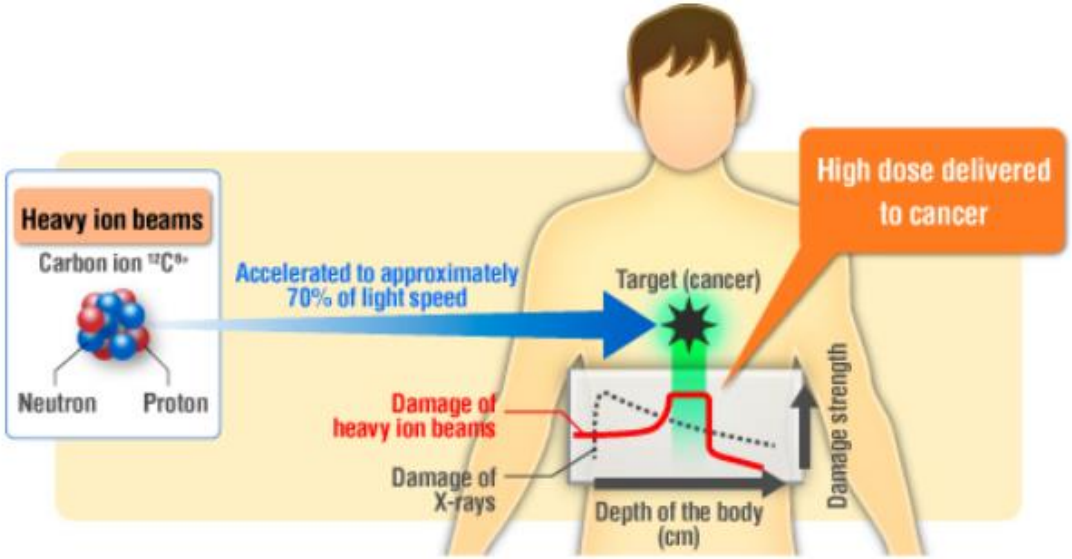
After treatment:
Complete response

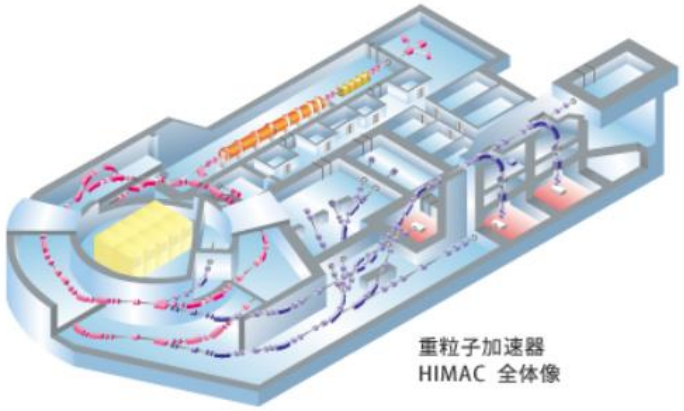
NPC-I Protocol: 5 year survival rate of 81%

Heavy Ion Radiotherapy

POINT Heavy ions accelerated to 70% of light speed are delivered to cancer.

In heavy ion radiotherapy, heavy ions (carbon ions) accelerated to approximately 70% of light speed are used to attack cancers deep in the body. In conventional X-ray radiotherapy, the radiation dose decreases as the depth of penetration in the body increases. In heavy ion radiotherapy, however, the radiation dose increases with depth to produce a peak (called a Bragg peak) in a finite depth of the body, enabling selective irradiation of cancers. In addition, the cell killing effect of heavy ions increases with depth, reaching the maximum at the peak region.

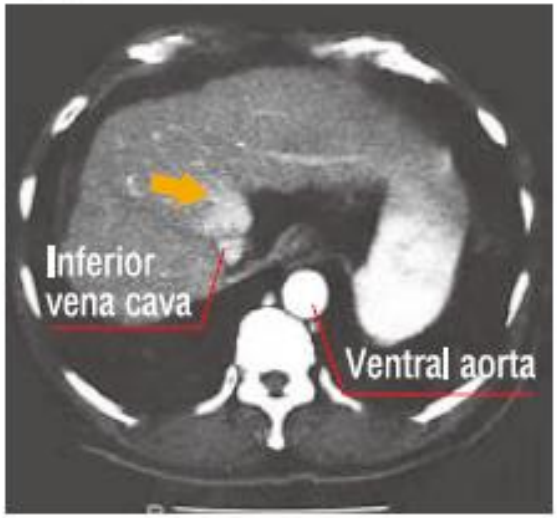




Proton Beam Radiotherapy Research at WERC

Example of liver carcinoma

Before treatment



Site of liver carcinoma (➡) was irradiated in synchronization with patient breathing

After 1 month of proton beam irradiation

After one month irradiation, tumor in that area has disappeared.

Boron Neutron Capture Therapy

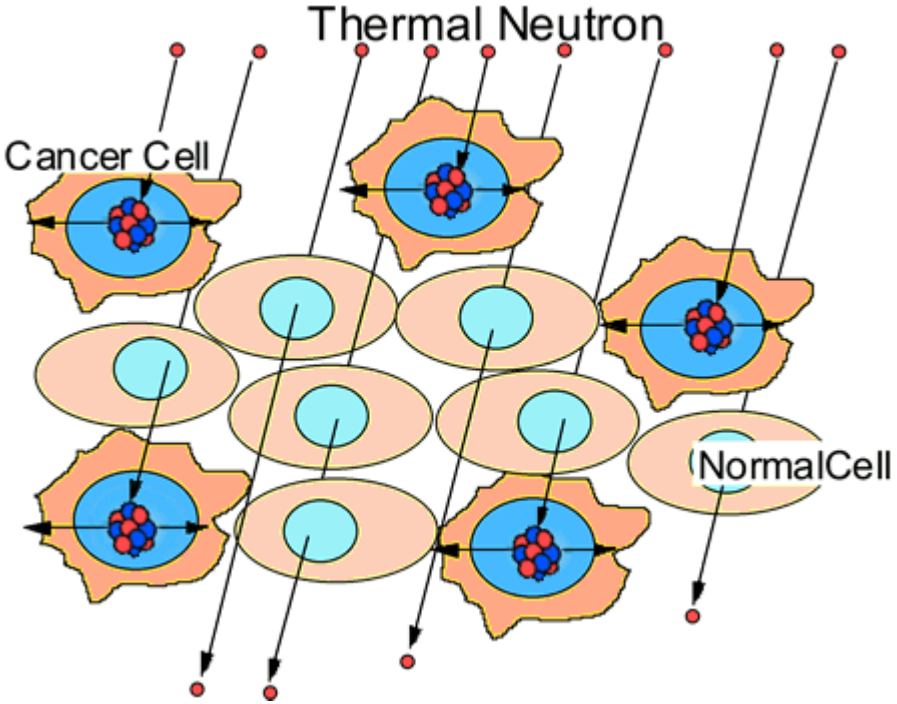
$^{10}B\ (n,\alpha,\gamma)\ ^{7}Li$

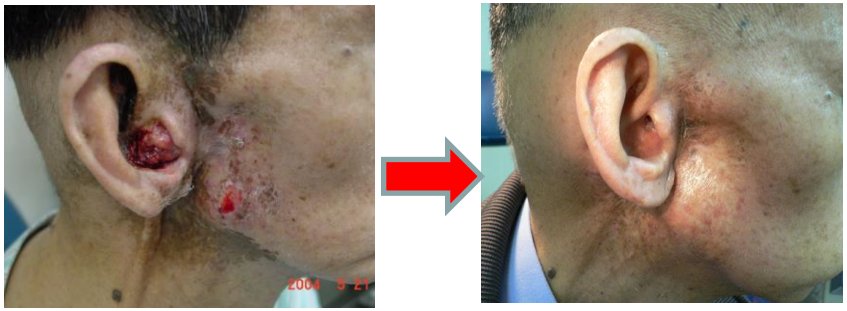
binary technique

high LET particles

BNCT could become useful for highly-fatal tumours:

- *Extended (e.g. liver, lung)*
- *Radioresistant (melanoma)*
- *Localized near vital organs (glioblastoma)*





Radiation and Modern Industry

- Process Control
  - **Thickness Gauges (sheet metal, paper, textiles)**
  - **Density & Level Gauges (oil and food industries)**

  Plant Diagnostics
  - **Tracers (pipeline leaks, malfunctions, wear and corrosion)**
- Materials Development
  - **Cross linking (e.g. heat shrink)**
  - **Gamma curing (e.g. floors)**
  - **Vulcanization (e.g. tires)**
- Materials Testing and Inspection
  - **Engine wear**
  - **Welds in airplanes, oil and gas pipelines**
  - **Corrosion in pipes**

Radiation and Modern Industry (cont.)

- Energy (Non-Nuclear)
  - Gamma sources to determine ash content in **coal plants**
  - Borehole logging (**oil well** prospecting)
  - Gamma sources to determine material failures in **oil refineries**
  - E-Beam processing to remove sulfur and nitrogen oxides from **flu gas**

Project on Nuclear Activation Analysis (NAA) (FNCA)

- With neutron activation analysis (NAA), multiple elements can be determined with high accuracy for a common and single sample, and even solid samples can be non-destructively analyzed.
- 2002-2004 Introduction of k0 standardization method in each country, common analysis of SPM (suspended particulate matter)
- 2005-2007 establishment of k0 standardization method in each country
- 2008-2014 NAA for geochemical samples, food samples, and marine sediments
- 2015~

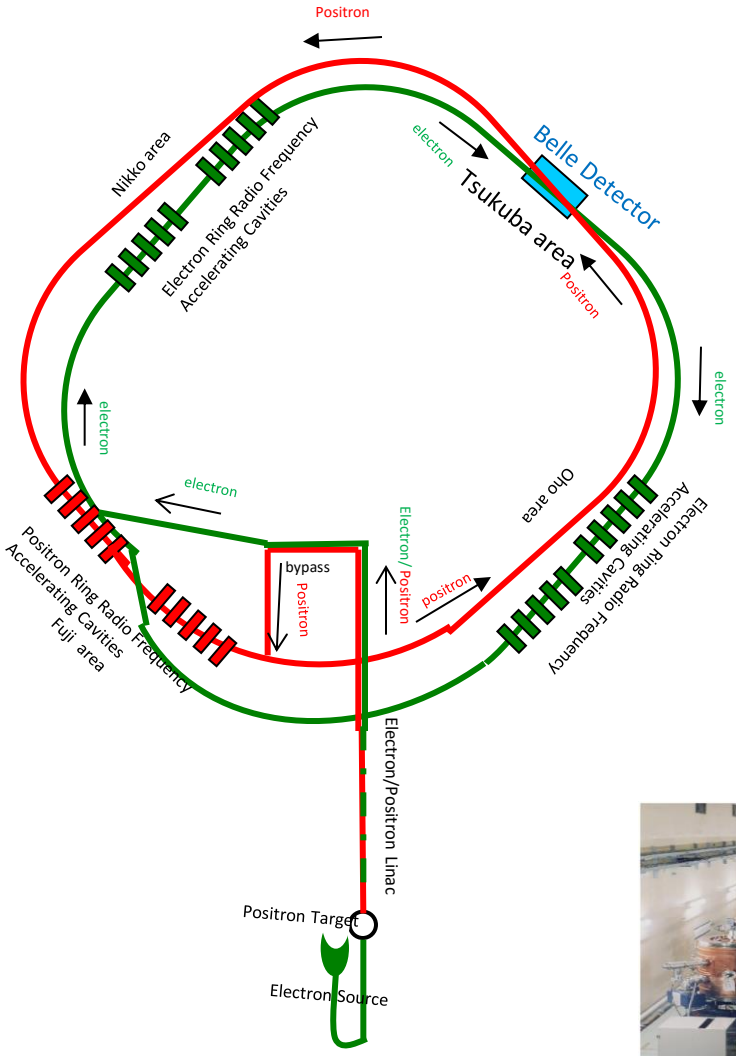
  (1) NAA of PM2.5 for environmental monitoring in Asian region

  (2) NAA of rare-earth elements for resource exploration in Asian region

Terrorism, Crime, and Public Safety

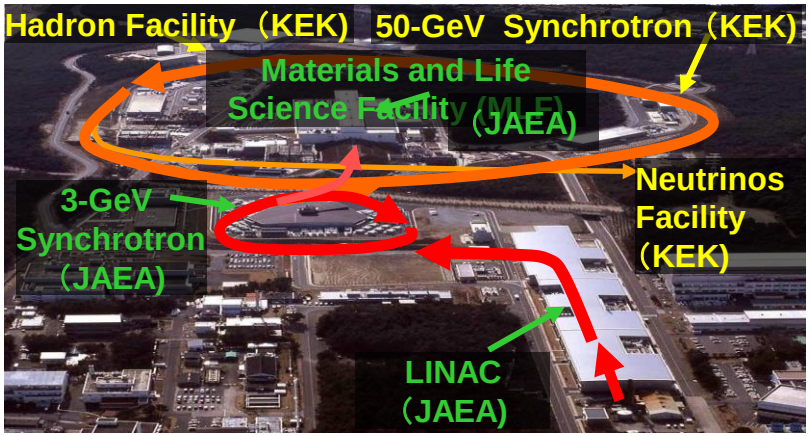
- **Public Safety**
  - Smoke Detectors
  - Exit Signs
  - Airport Runway Lighting
  - Reduce Static Electricity (printing process, paper making)
- **Fighting Crime**
  - Neutron Activation of Body Samples
  - DNA Analysis
- **Fighting Terrorism**
  - Luggage Inspections (weapons, explosives, etc.)
  - Anthrax in Mail
  - Portal Monitoring
  - Detecting Mine Fields
  - Sensing Clandestine Weapons Testing
  - Sensing Contamination Releases (e.g. “Dirty Bombs”)

B Factory



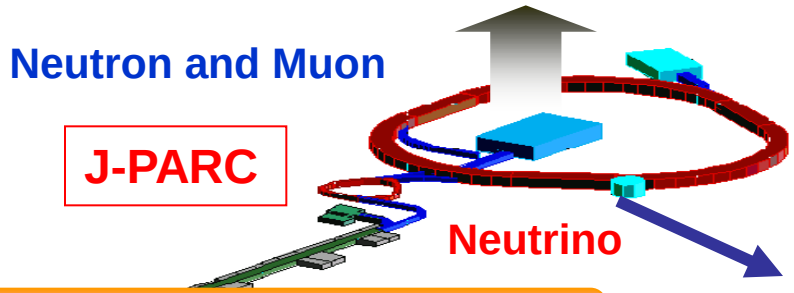
B Factory is an electron-positron collider. The KEK B factory experiment （Belle) was initiated in 1999. Using a large data sample that corresponds to an integrated luminosity of ~0.8 ab^{-1} or 900 million B anti-B meson pairs, which is the highest value in the world, the Belle experiment has verified the Kobayashi - Maskawa theory that explains CP violation and quark mixing in the weak interaction. This research eventually led to a Nobel prize for Kobayashi and Maskawa in 2008.

J-PARC Project



J-PARC is located in Tokai-mura,120km from Tokyo

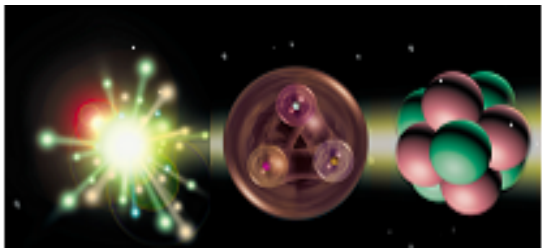
○J-PARC is one of the world largest accelerator-driven secondary particle source (neutron, muon, pion, kaon, neutrino, etc.), which can provide a broad research development from basic science to industrial development.



Kaon, Pion, Proton, Muon

Hadron physics

Origin of Matter

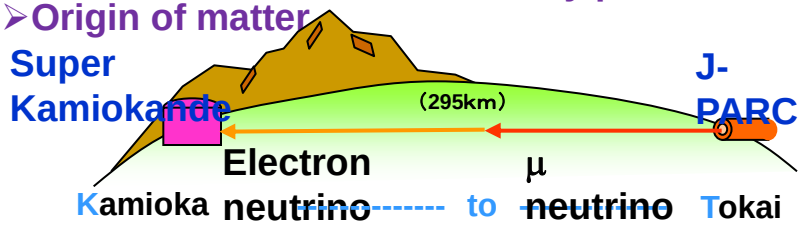


- Mystery of the Origin of Mass
  Why dose the mass of the hadrons are much heavier than that of free quarks?
- Particle/Anti-particle asymmetry beyond Kobayashi-Maskawa Theory
  Asymmetries in quark and lepton sectors

Neutrino Experiment: T2K

Uncover unknown nature of neutrinos by precise measurement of "neutrino oscillation" and find clues toward

- Fundamental law of elementary particles
- Origin of matter



Primary goal is to discover μ neutrino to electron neutrino oscillation

FNCA Activities and MEXT Training Programs on Nuclear Energy and Radiation Utilization

Forum for Nuclear Cooperation in Asia (FNCA)

Nuclear Researchers Training Program

1. FNCA Research Course

This course is set up to perform research activities related to the FNCA project themes. (3～6months)

2. Individual Research Course

This course is set up to match the ANTEP Needs from Asian Countries. (3～6months)

3. Basic and Fundamental Course

This course is set up to give various lectures on Nuclear Engineering/Nuclear Safety Engineering. (1～3months)

NSRA

Instructors Training Program

1.Instructors Training Course

This course is set up to invite participants, who are expected to be instructors in their countries in the future. (6～8weeks)

2.Follow-up Training Course

Japanese experts visit Asian countries and give a technical advice to local instructors who have participated in Instructors Training Course. (1～2weeks)

3.Seminars on Nuclear Technologies

(1)Nuclear Plant Safety
(2)Atomic Energy Administration
(3)Basic knowledge of Radiation
(4)Site Location of Nuclear Facility
(1～4weeks)

JAEA

MEXT Human Resources Development Program

＜Nuclear Researchers Training Program＞

	JFY2013	JFY2014	JFY2015
Bangladesh	4	2	4
China	1	1	1
Indonesia	4	1	3
Kazakhstan	2	1	1
Malaysia	2	1	1
Mongolia	1	1	0
The Philippines	2	1	2
Sri Lanka	2	2	1
Thailand	2	3	3
Vietnam	3	7	4
Total	23	20	20

＜Nuclear Instructors Training Program＞

	JFY2013	JFY2014	JFY2015
Bangladesh	9	8	8
China	0	0	0
Indonesia	9	8	8
Kazakhstan	9	3	5
Malaysia	17	9	8
Mongolia	7	8	6
The Philippines	5	5	5
Sri Lanka	2	3	5
Thailand	10	10	8
Vietnam	21	15	13
Turkey	-	4	10
Saudi Arabia	-	0	1
Total	89	73	77

THANK YOU

FOR

YOUR ATTENTION