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Possible use of Small Accelerators in Student Laboratory for Engineering Education

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Motivations

- Any type of school should take account of ESD.
- Nuclear power engineers are becoming old without enough number of successors.
- Insufficient education of radiation basics for everybody.
- Jobs of some portion of graduates of National College of Technology are somehow related to construction and maintenance of nuclear-power plants.

Feasibility Study of

“Possible Radiation-related Education in National College of Technology in Harmony with Existing Engineering-Education Program. “

Partly supported by the Japanese governmental grant for *“Education Project for Nuclear Power Related Human Resources”*

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原子炉守る巨大リング

松江 島根3号機に設置

中国電力が建設を進めている島根原子力発電所3号機（松江市鹿島町）で十四日、原子炉格納容器の取り付け工事が始まった。直径約二十九㍍、高さ二十一㍍、重さ三百五十㌧の金属製の円筒が大型クレーン車で据え付けられた。

円筒は上部が鉄、下部

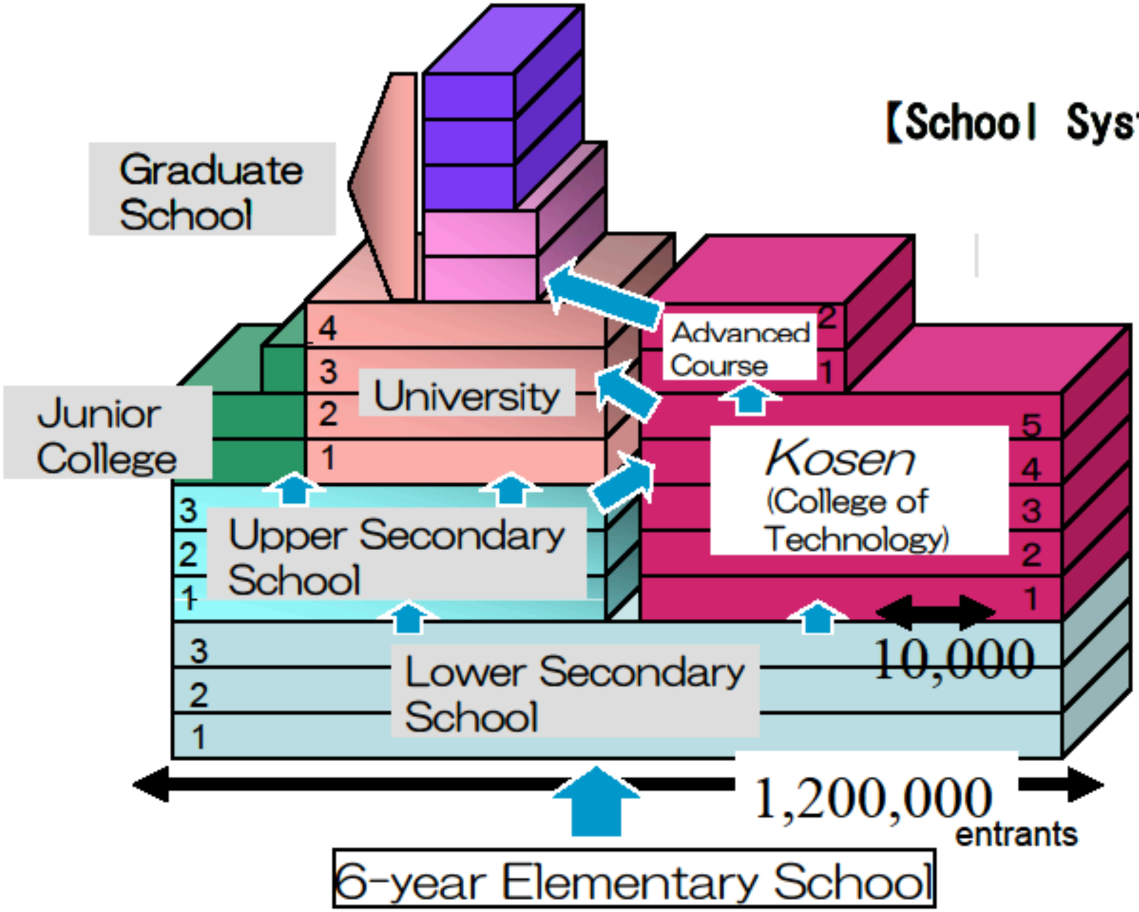
がステ
り、原
を高め
る。組
っくり
円筒は
㍍離れ
ばれ、
エリア
密閉度と耐震性を高め
るため、二〇〇九年春に

円筒周囲に厚さ二㍍のコンクリート壁を張り巡らす。呉市で製造中の原子炉圧力容器は同年夏に格納容器の内側に搬入する予定。一一年の営業運転開始を目指す3号機の建築工事の進ちょく率は15・2%。準備工事を含む総工事は41・1%となった。（加納亜弥）

ゆっくりとつり上げられる巨大な金属製の円筒（撮影・長部剛）

A Huge pressure vessel produced in Kure is being installed at a new Nuclear Power Plant in Shimane area.

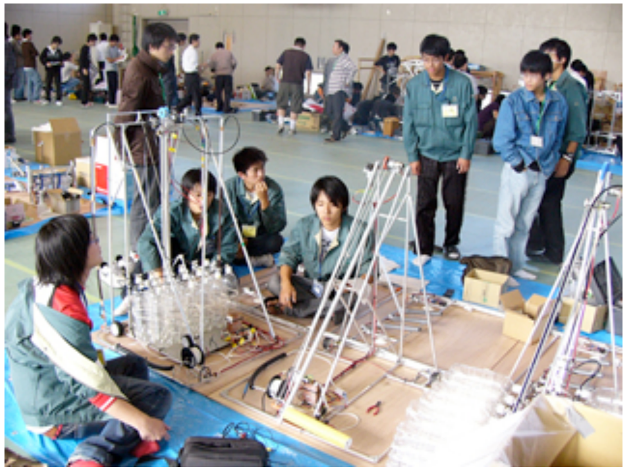
【School System】



Kure National College of Technology

- Five Year (Associate Degree) Programs:
  - Mechanical Engineering
  - Electric Engineering and Information Science
  - Civil and Environmental Engineering
  - Architecture
- Additional Two Year Advanced (Bachelor) Programs:
  - Mechanical and Electric Engineering
  - Construction Engineering

Education System is based on practical experiences + Lectures + Researches



Inter College Robot Contest

Attractive features of accelerator in college engineering education

- By combining the acquired knowledge and practical skills , students may design and construct a simple accelerator.-→ Good theme for Problem Based Learning and enhancement of collaboration among students with different interest.
- It can be a radiation source safely stored when switched off.---→ Student Lab. of Radiation basics
- Low intensity but pulsed radiation from an accelerators might enable new experiments that were difficult with low intensity RI.

Suitable type of accelerator

- Small
- Low cost
- Simple but Interesting principle
- Easy to produce a prototype
- Easy to handle

- -→ Low energy and low intensity betatron

Existing Small Betatron Ex1:

1MeV Betatron by High Beam Technology Ltd. (in collab. with Introscopy Institute, Tomsk and Hiroshima University)

<<Features>>

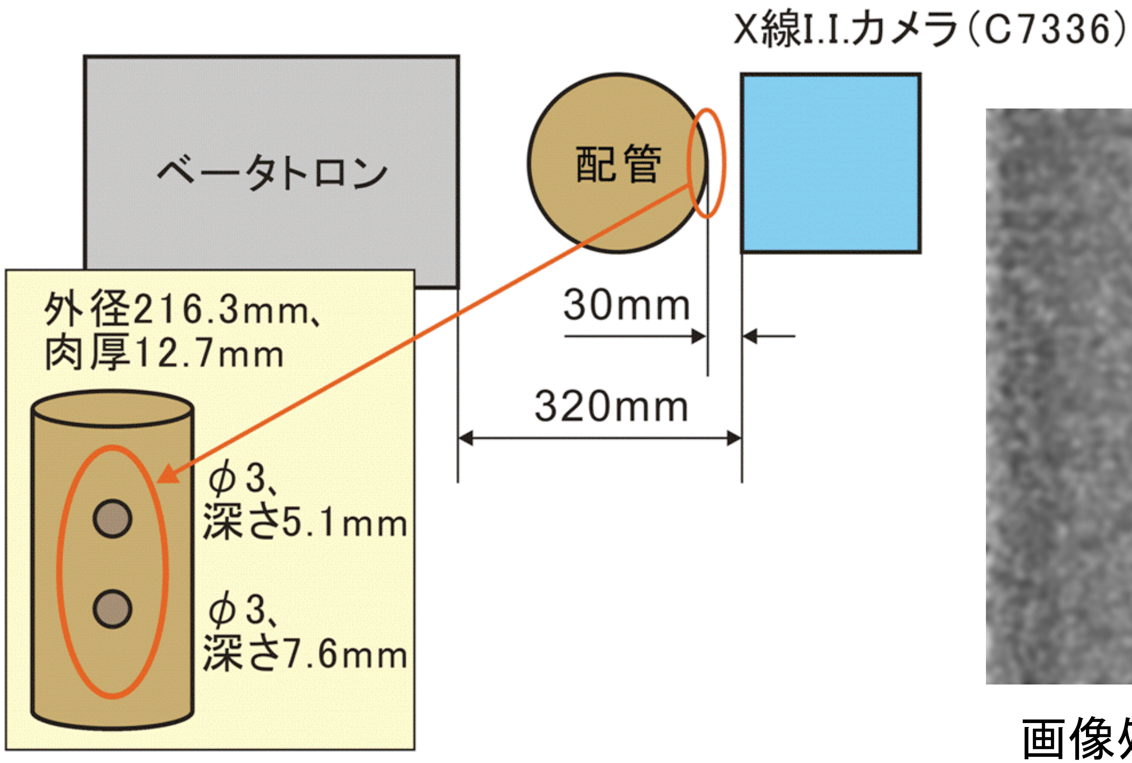
•Small (Dimensions：250×395×570mm）
•Light！（Total weight：50kg）
•No severe legal regulation!（Max Energy― 950keV）
•Easy to operate！
/ Main body containes all what you need except a controller for remote handling.
Air cooled.
Conventional mains supply at home and office is enough.

info@hi-beam.co.jp

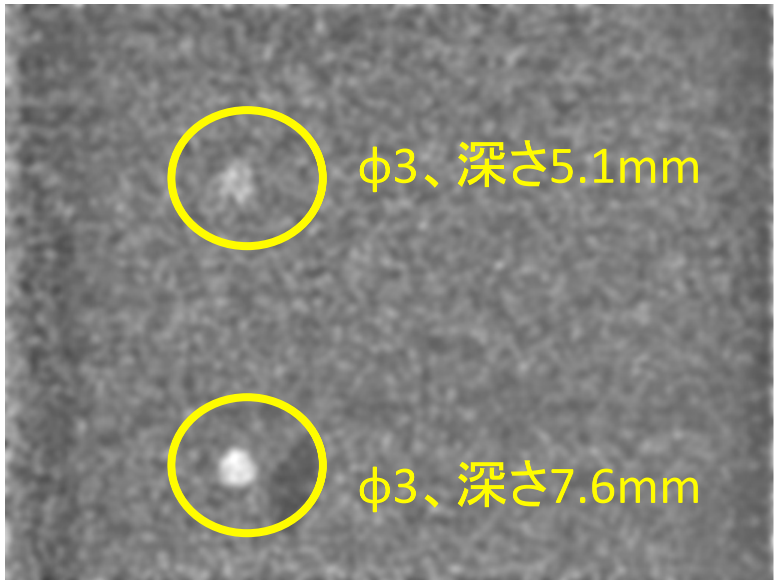
※H14H15ひろしま産振構ヤングベンチャーチャレンジ事業補助金により製作

Example of test exposure with Hamamatsu Image Intensified Xray Camera（C7336）

- Exposure time ：**1min**



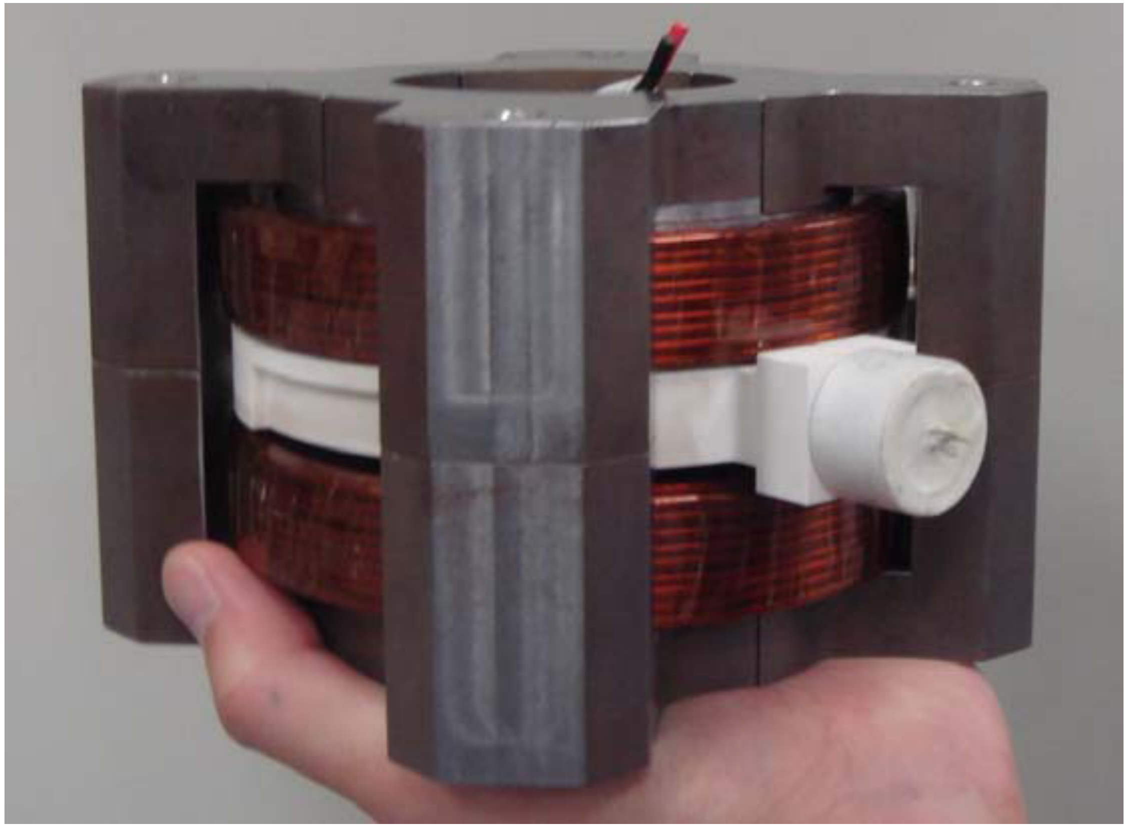
表面に人工穴を設けた配管を撮影した。



画像処理後の画像。
配管表面の人工穴が確認できる。

Existing Small Betatron Ex2:

Press Release by Mitsubishi Electric Ltd. Oct.28, 2008



990KeV betatron 5A , 1kHz http://www.mitsubishielectric.co.jp/corporate/randd/inquiry/index_at.html

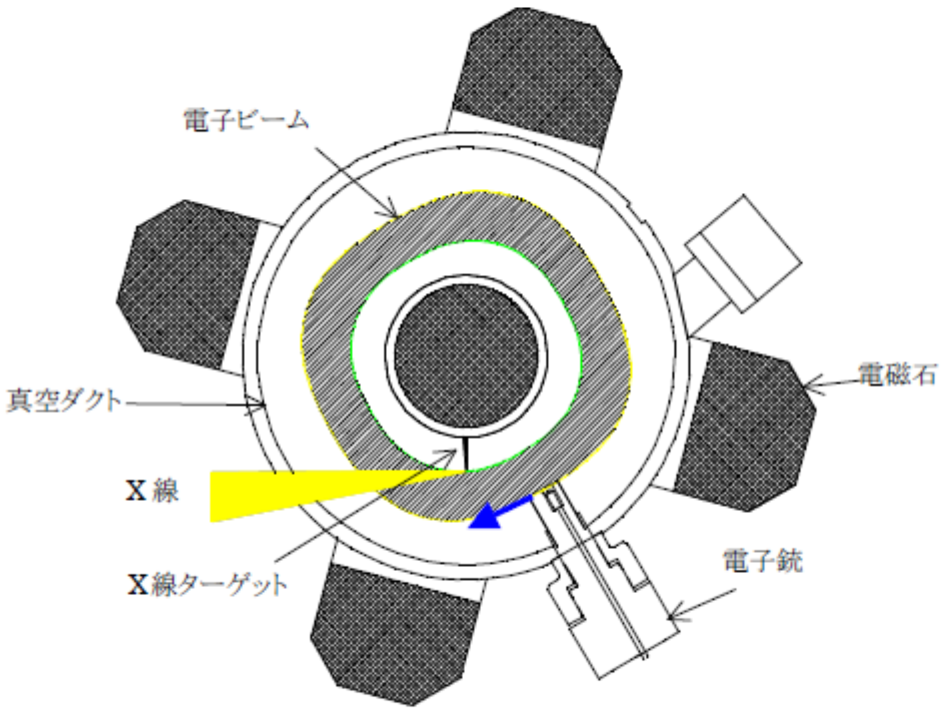


図 2. ラップトップ加速器の機器構成

Indirect Information is found in a paper by H.Tanaka and T. Nakanishi presented at the International Cyclotron Conference (2004)

Educational Features related to Betatron

partly included and yet to be included in the standard college curriculum

- Basic principle of betatron
  - Lorentz force, Induction acceleration, Orbit stability, Introductory relativistic mechanics
- Electron gun
  - Electron source ,High voltage generator, Focusing electrodes
- Vacuum system
  - Pumping, Vacuum gauge

- AC magnet
  - Magnetic material, Shape designing and machining, Magnetic field measurement, Pulsed current supply
- Electron beam control and monitoring
- Radiation target
- Radiation safety
- Radiation detection
- Applications of radiation

Program1
Design and prototyping of a betatron : Problem- based Learning

- Total design
- Magnet design
- Power Electronics design
- Vacuum and Electron gun design
- Shielding design

Program2
Radiation Experiments with a small electron accelerator in a student lab.

Is it Possible to operate an accelerator in a room for student lab.?

Requirement of safety control:

- Accelerator based X ray generator below 1MeV.
- Operation should be under the control of a Licensed X-ray Chief Specialist. (License is not difficult to acquire)
- Need a well defined control area for safety.

Possible structure

- Control area is to be confined in a small shielding box equipped with a safety interlock system just like a laboratory X-ray device.
- 

RIGAKU
RINT 2500/PC

Estimation of dose rate for Electron Linac below 10MeV

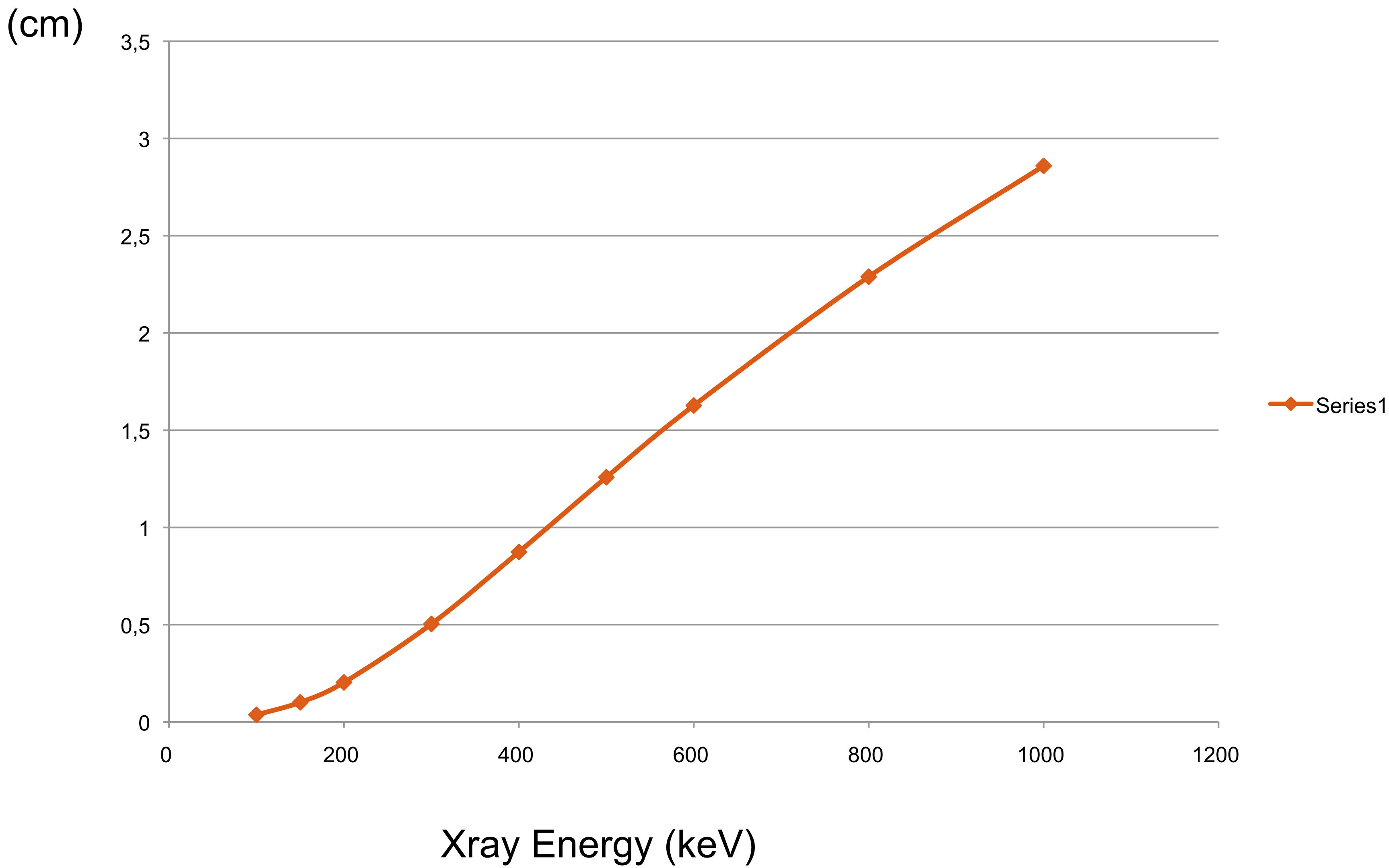
(Ref. IAEA Technical Report No.188(1979))

$$H = 3.2 \times 10^{-9} NE^3 / R^2 (\mu Gy / h)(sMeV^{-3}m^2)$$

H=Dose rate in μGy/h

N=Number of electrons/s
E=Electron energy in MeV
R=Distance from the source point in m

Xray Attenuation(1/10) Length in Pb



Possible Shielding Box size

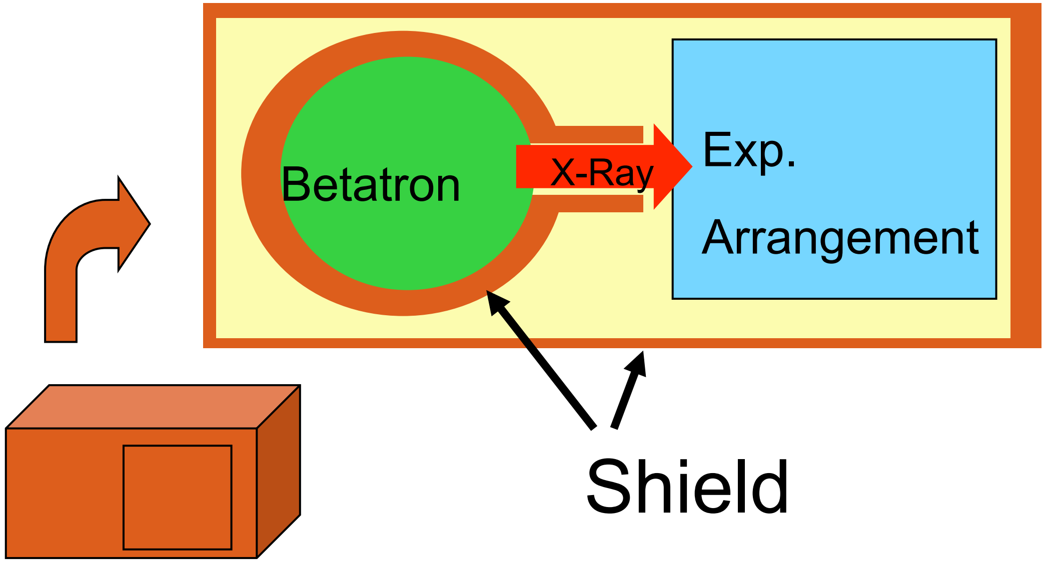
- Safety regulation → Dose rate should be less than 20μSv/h at the outer surface.

Type#	E(MeV)	N(e/s)	2R(m)	T(cm Pb)	Comment
#1	1	6E9	2	0	
#2	1	1.5E9	1	0	
#3	1	0.4E9	0.5	0	
#4	0.63	6E9	1	0	
#5	0.63	6E10	1	1.5	Pb weight =1ton
#6	0.4	6E9	0.5	0	
#7	0.4	6E10	0.5	1	Pb weight =170kg

Note: N=1E10 ～1E13 ? for Mitsubishi Betatron

Summary

- Betatron design and prototyping may be useful in engineering education.



●Low energy (<1MeV) and low intensity (<1E10 e/s) betatron is possible to operate in a student laboratory equipped with a shielding box of reasonable size.

●Small accelerator allow various type of radiation experiments.

Thanks to:

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- Japanese Ministry of E and S and T.

Collaborators are welcome