Development of a Diamond Detector as a Tissue Equivalent Semiconductor Detector for Space Radiation

Y.Uchihori[1], T.Kashiwagi[2], K.Hibino[2],
H.Kitamura[1], S.Okuno[2], T.Takashima[3]
K.Yajima[1], M.Yokota[2] and K.Yoshida[2]

[1] National Institute of Radiological Sciences, Chiba 263-8555, Japan
[2] Kanagawa Univ., Kanagawa 221-0802, Japan
[3] Japan Aerospace Exploration Agency, Kanagawa 229-8510, Japan

Introduction

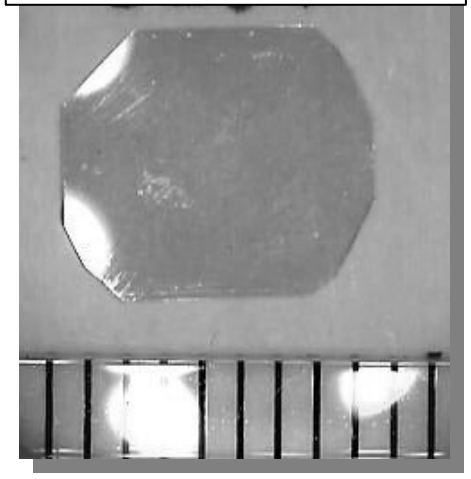
- Ideal diamonds are insulators but actually natural and synthesis diamonds be can used as semiconductor because of impurities.
- Diamond detectors have been developed using natural and artificial (CVD) diamonds but they do not have good energy resolution because of their lattice defect, uncontrolled impurities and etc.
- We have developed synthesis semiconductor diamond detectors using diamonds made by high temperature and high pressure method.
- These diamond detectors may have ideal character for radiation monitor in space radiation environment.

Characteristics

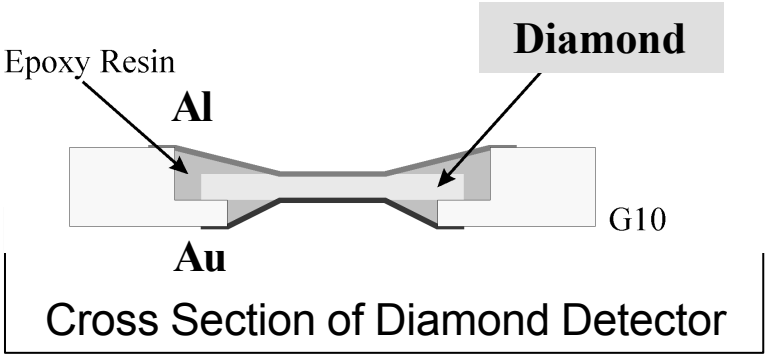
- Wide Band Gap (~5.5eV) --- low noise at room temperature & non-response to visible light
- High Resistivity --- low leakage current & high bias voltage
- Low Capacitance --- low noise & good energy resolution
- High Binding Energy --- resistance to radiation damage
- Low Z --- low response to gamma-ray & possibility of tissue equivalent

Detector

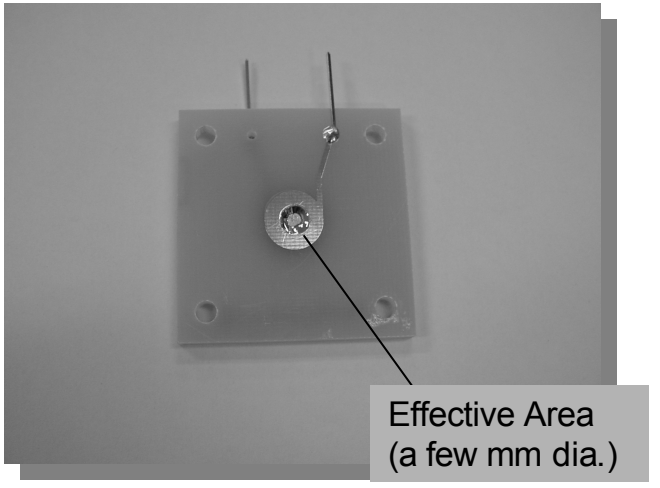
Mono-Crystal IIa type Synthesis Diamond



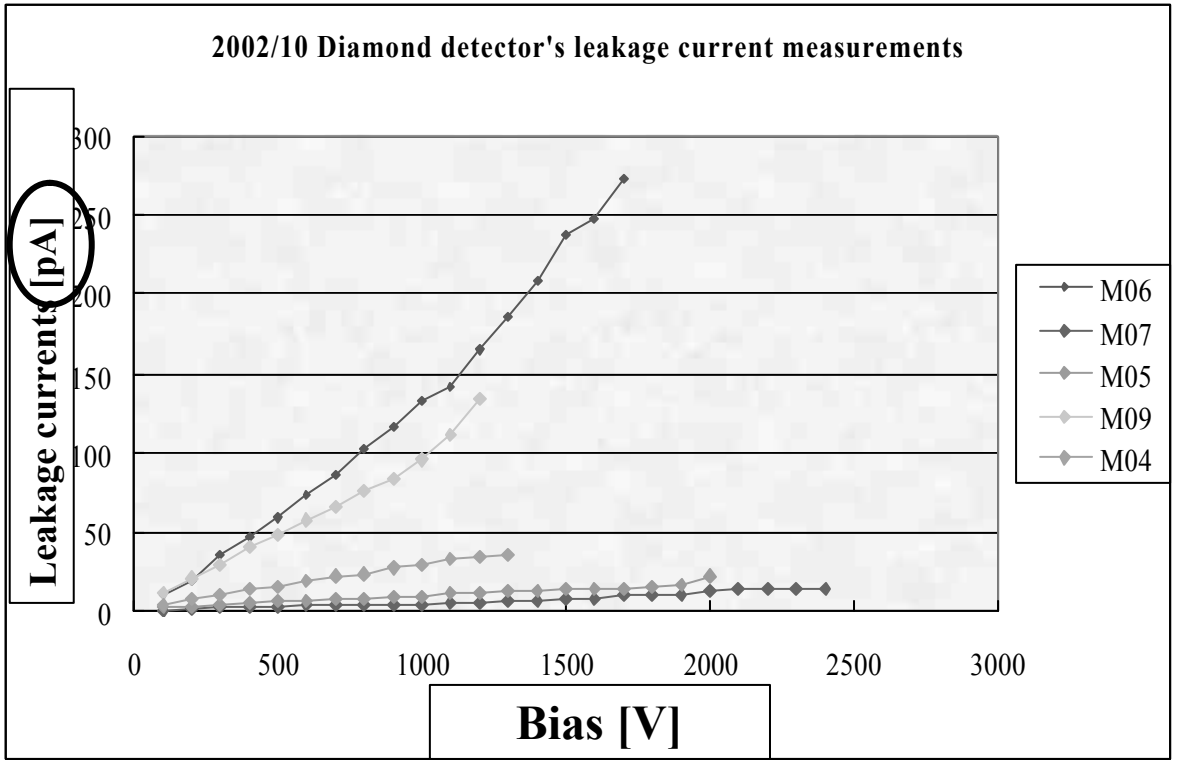
ex. 8mm x 6mm x 0.2mm



Cross Section of Diamond Detector

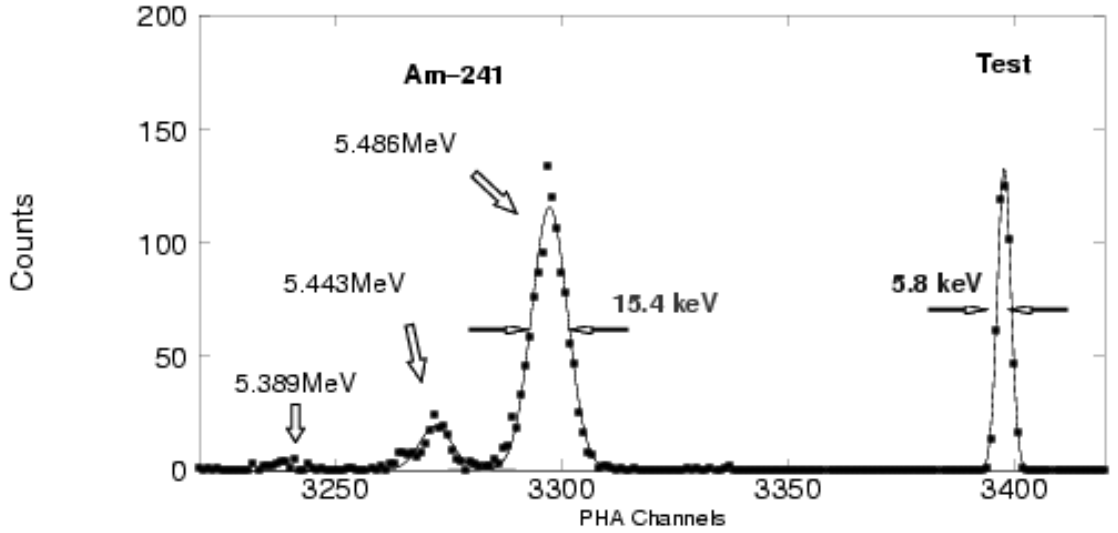


Leakage Current



- In case of Silicon Detector, Leakage Current is order of 1 nA or more.
- Expected higher energy resolution.
- Low Power Consumption.

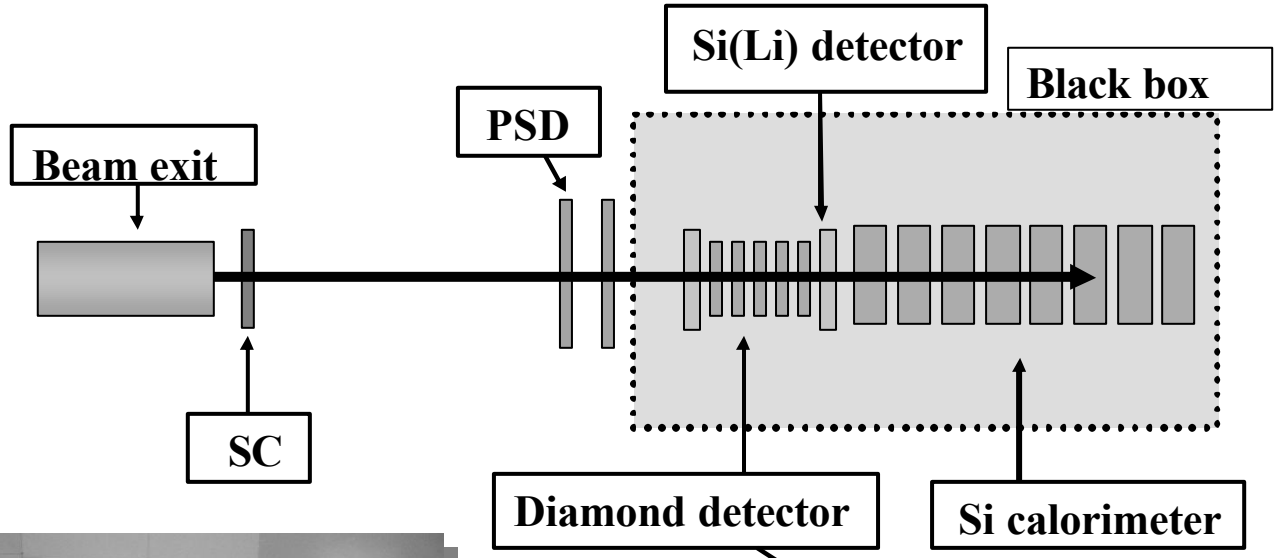
Energy Resolution for Alpha-rays from ^{241}Am Source

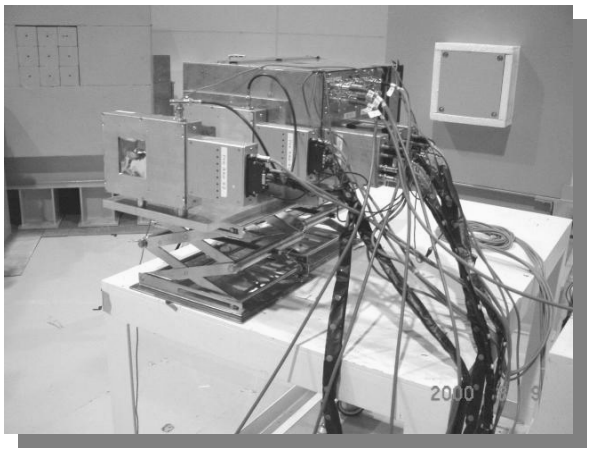


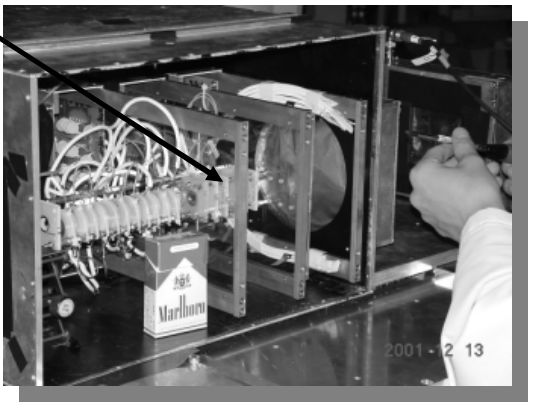
Energy Resolution (FWHM)	Diamond detector	Test pulse
	15.4[keV]	5.8[keV]

- The energy resolution of our diamond detector is comparable to silicon detectors.

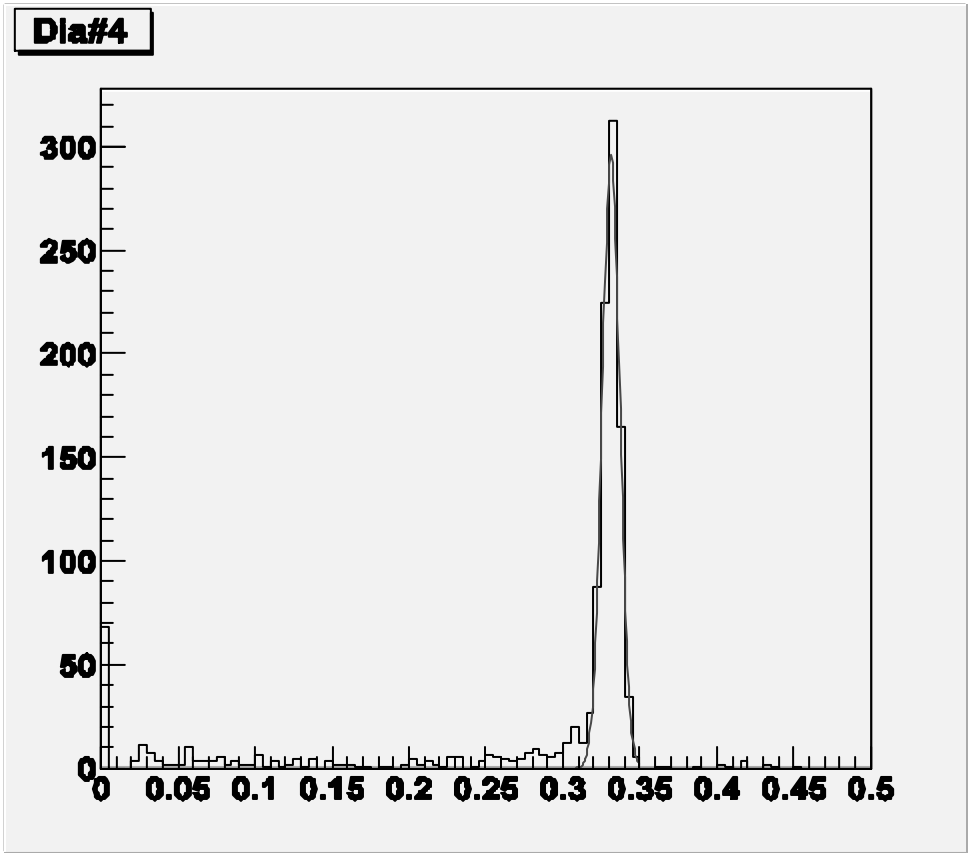
Beam Experiments in HIMAC



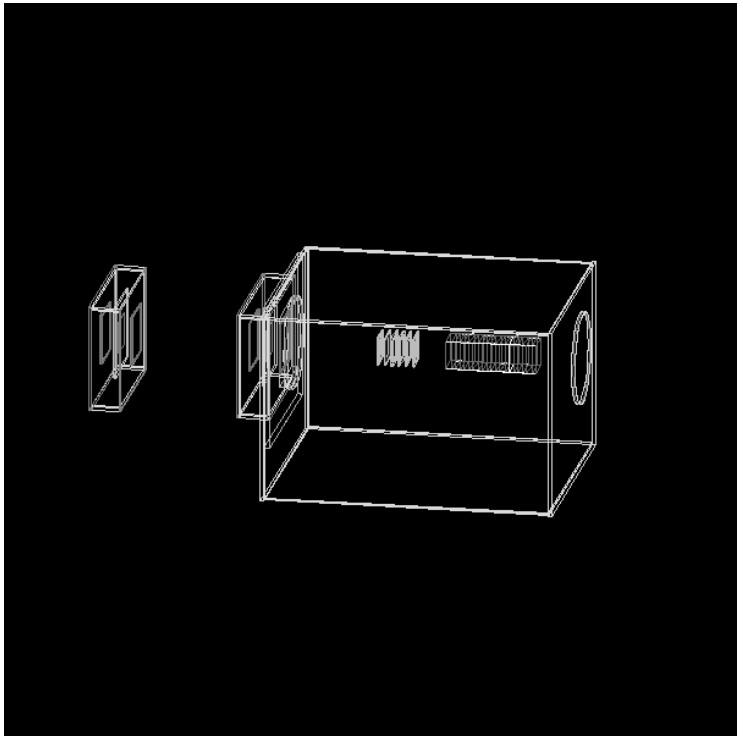




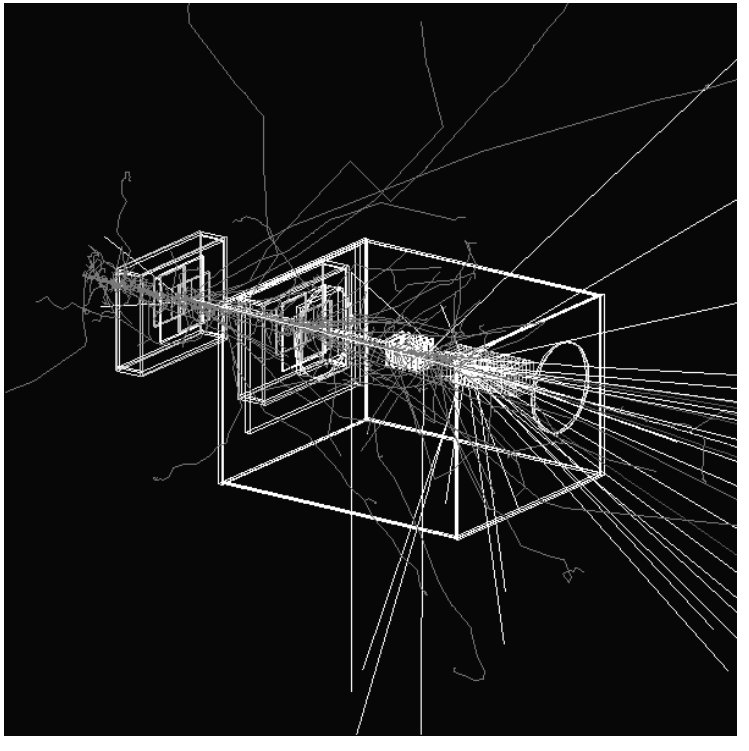
Energy Resolution for Fe 500 MeV/u Beams



Simulation with GEANT4



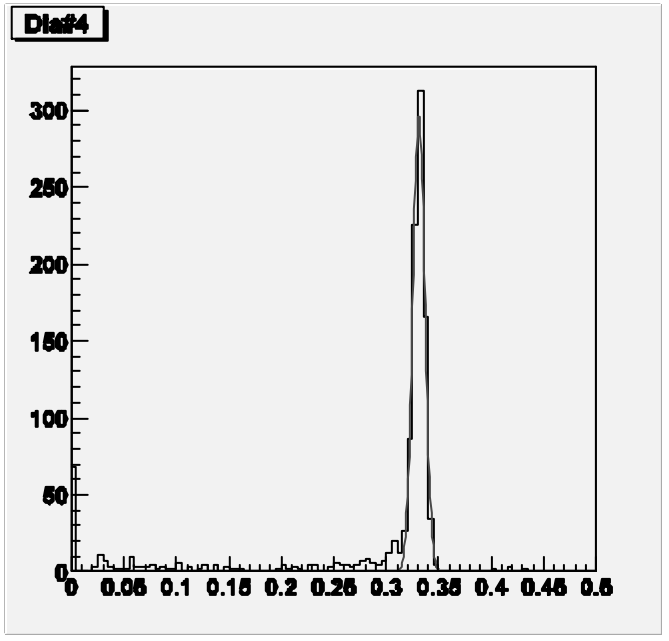
Modeling of our Set up



Simulation of 1 particle of Fe:500[MeV]

Comparison with GEANT4

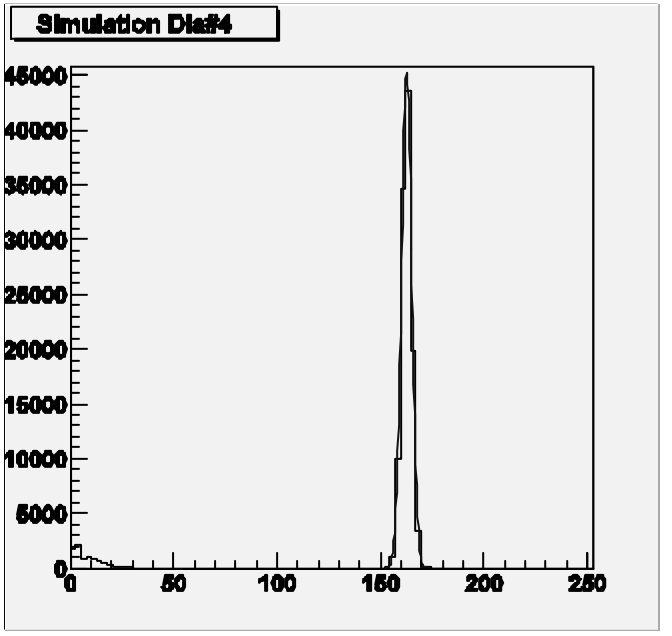
Experiment



Energy Resolution: 0.0172

Energy Deposition: ~145[MeV]

GEANT4

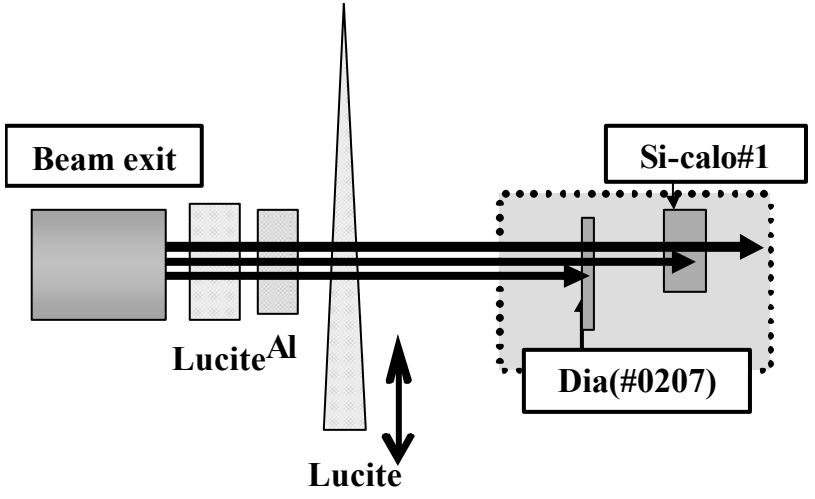


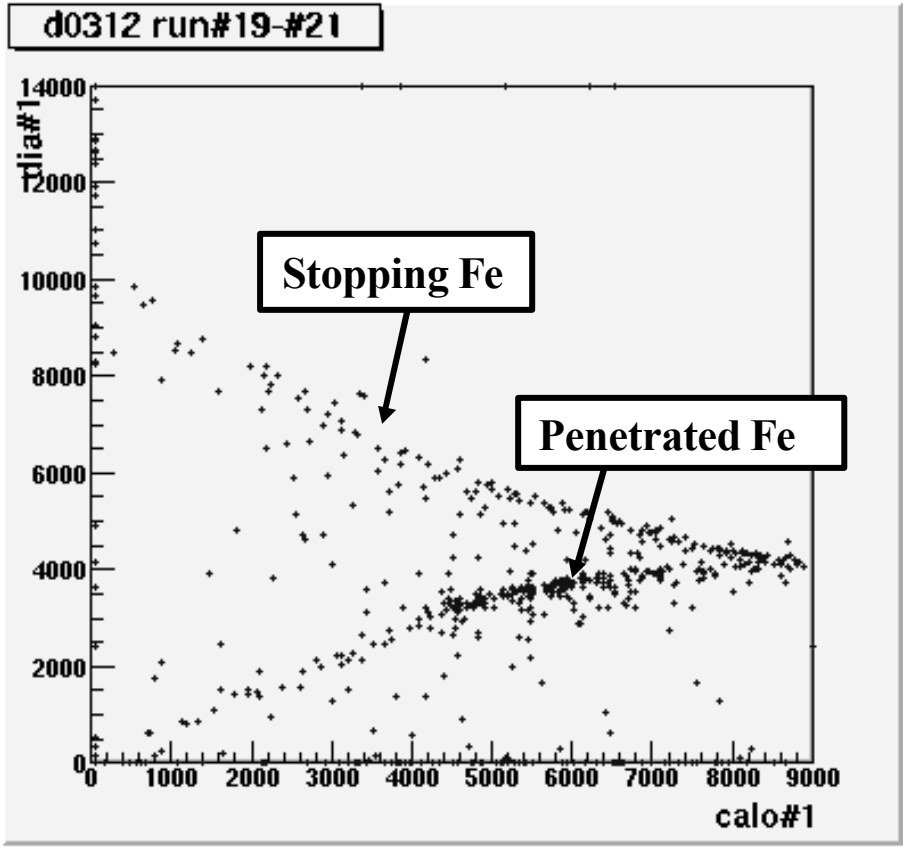
Energy Resolution: 0.0155

Energy Deposition: ~163[MeV]

~166[MeV] from Bethe-Bloch

dE-E Scatter Plot for Fe Beams with Various Energy

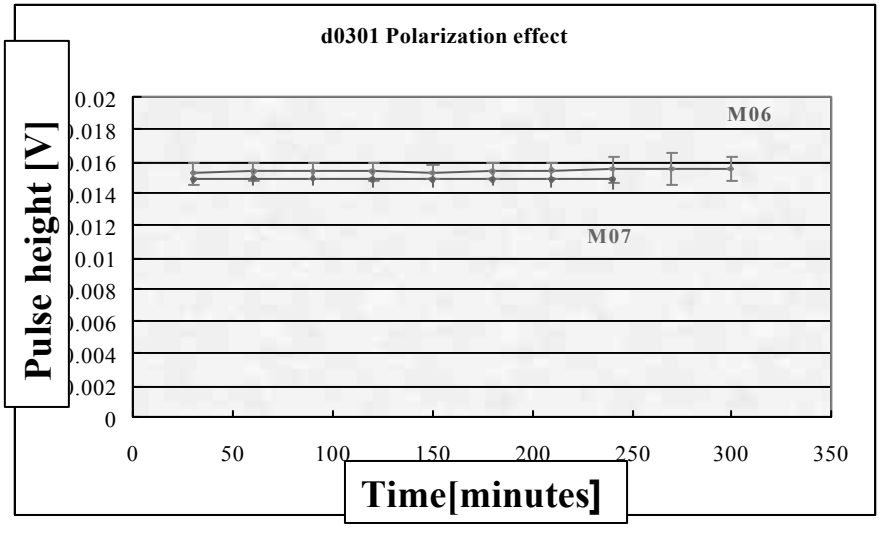




- The Diamond Detector had good response to Fe beams with various energy.

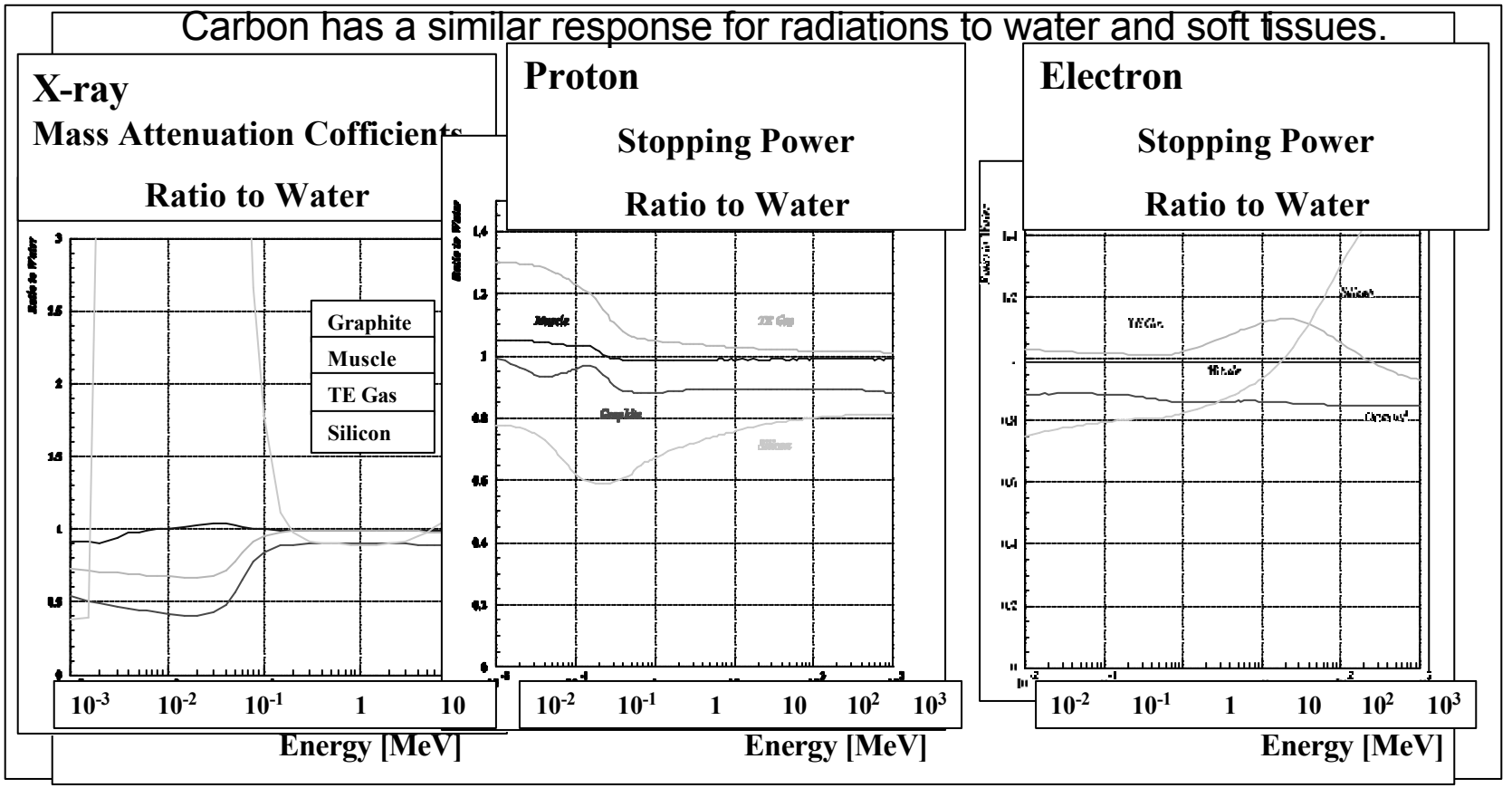
Polarization Effect

- Diamond detectors which were developed other groups had “Polarization Effect” but our detectors overcome this problem using certain electric node structures.
- Polarization effect induces decreasing pulse heights of output from a detector.



Tissue Equivalent

Carbon has a similar response for radiations to water and soft tissues.



Carbon has a similar neutron cross section to tissue and these diamond detectors may use in neutron radiation environment.

Summary

- We have developed synthesis diamond detectors.
- The sensitivity and resolution for charged particles are very good.
- The diamond detectors have possibility as tissue equivalent semiconductor detectors.
- We consider the diamond detector as radiation monitor in space environment.