Characteristic of Internal Charge Distribution in PI Irradiated by Proton

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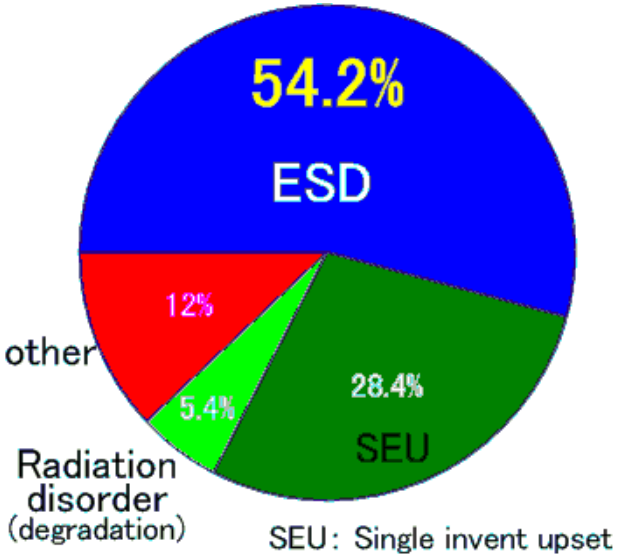
Introduction

The satellite anomaly happen on orbit.

More than **50 %** of the origin of accident is ESD.

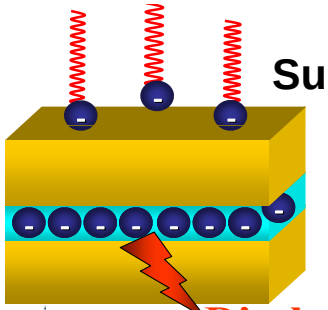


Satellite obstruction by space environment

(Total accident no. is 326 /1973-1997, Koons et al.)

Surface materials charge up due to irradiated radioactive rays (electron, proton…)

Surface charging



Surface charging

It will be presented at next(12th) time.

Internal charging

Discharge!!

Electron beam irradiation

Our group
V. Griseri and D. Payan et al. } have a lot of experience

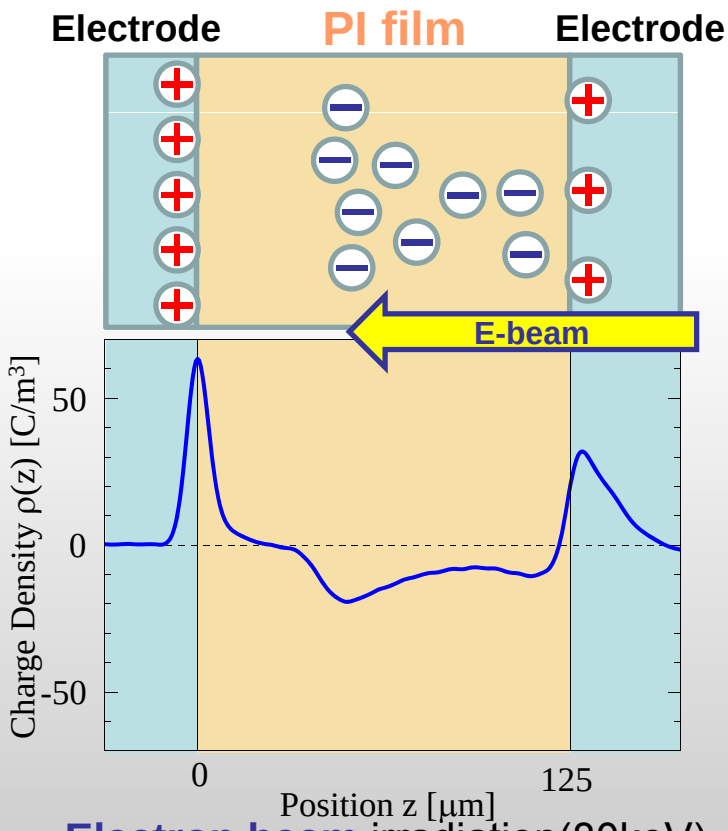
Proton beam irradiation

Anyone do not have experience → **The results show in this report**

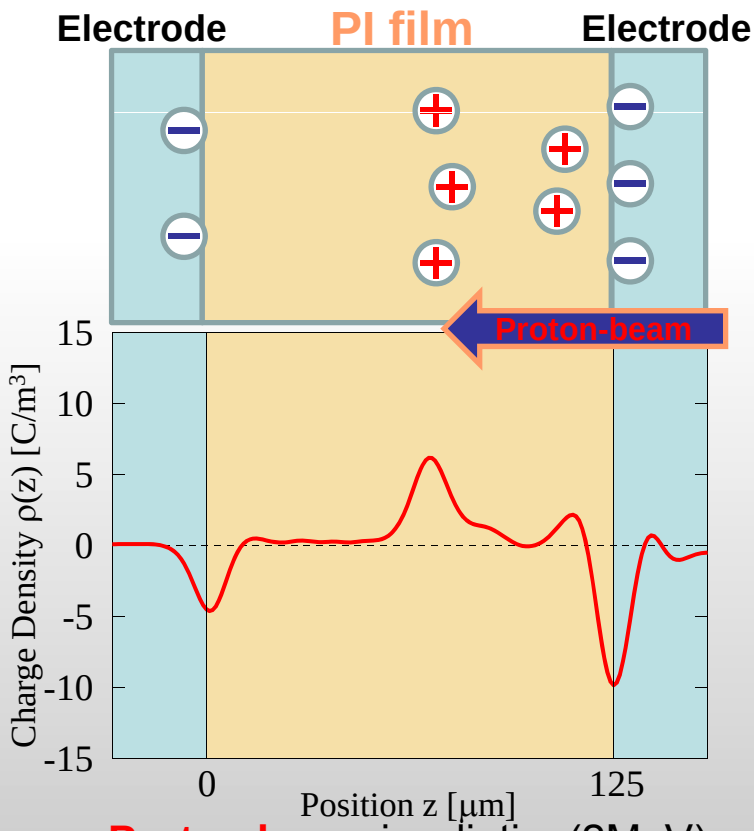
We focused the phenomena of the internal charging on the surface dielectric materials. We measure the internal charge distribution on PI films irradiated by **protons** using **Pulsed Electro Acoustic (PEA) method**.

How to see and understand internal charging data by PEA method

- The internal charge accumulation and distribution in dielectrics can be observed using PEA method. That is developed by Tokyo City University(Musashi Institute of Technology).
- We observed the **Negative** / **Positive** charge accumulation in the bulks of PI films irradiated by the **Electron** / **Proton** beams.

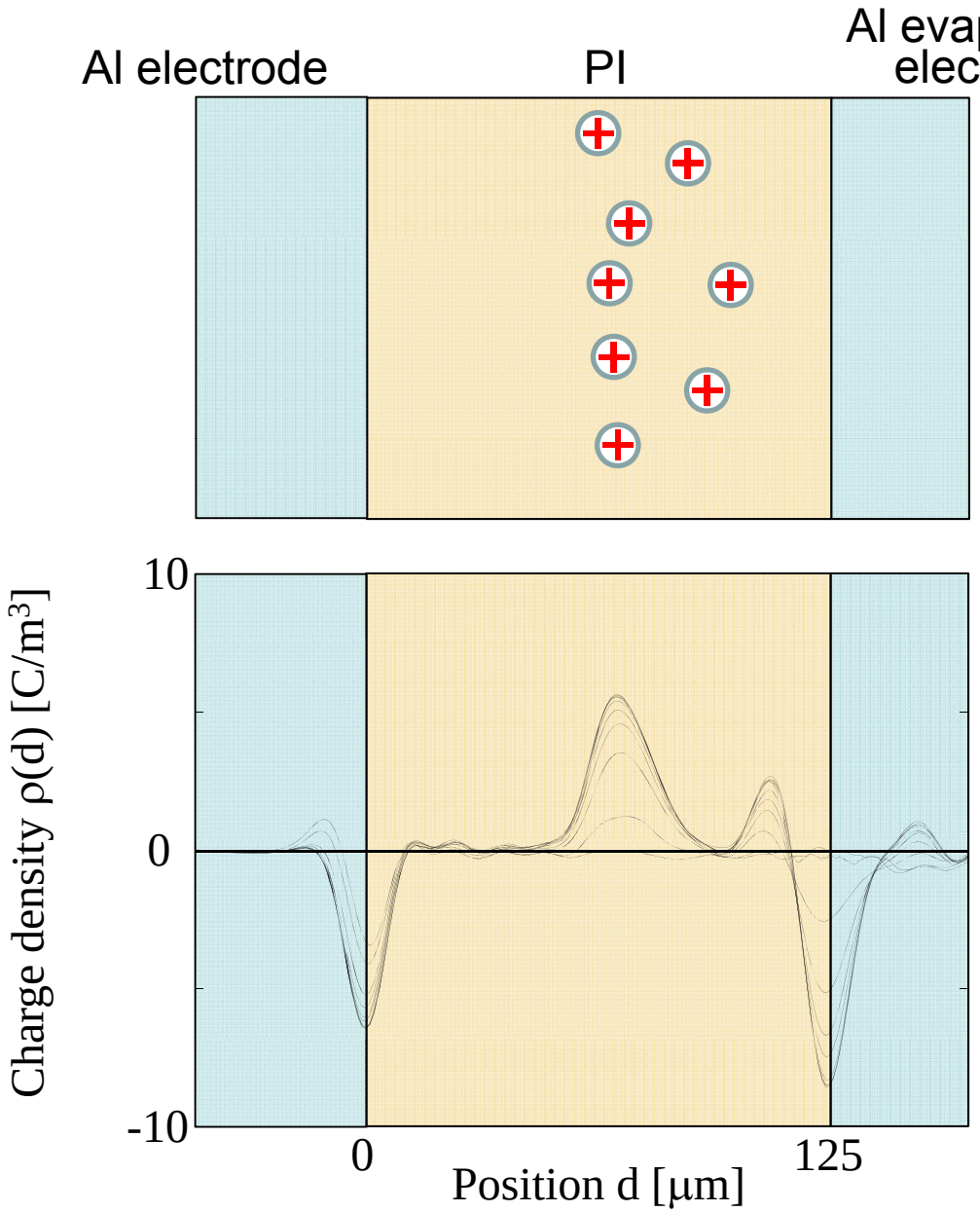


Electron beam irradiation(80keV)



Proton beam irradiation(2MeV)

PEA system can obtain the time dependent charge distribution



Proton-beam

2MeV, 0.3nA/cm^2

- This PEA system can obtain with the time interval of 30 sec.

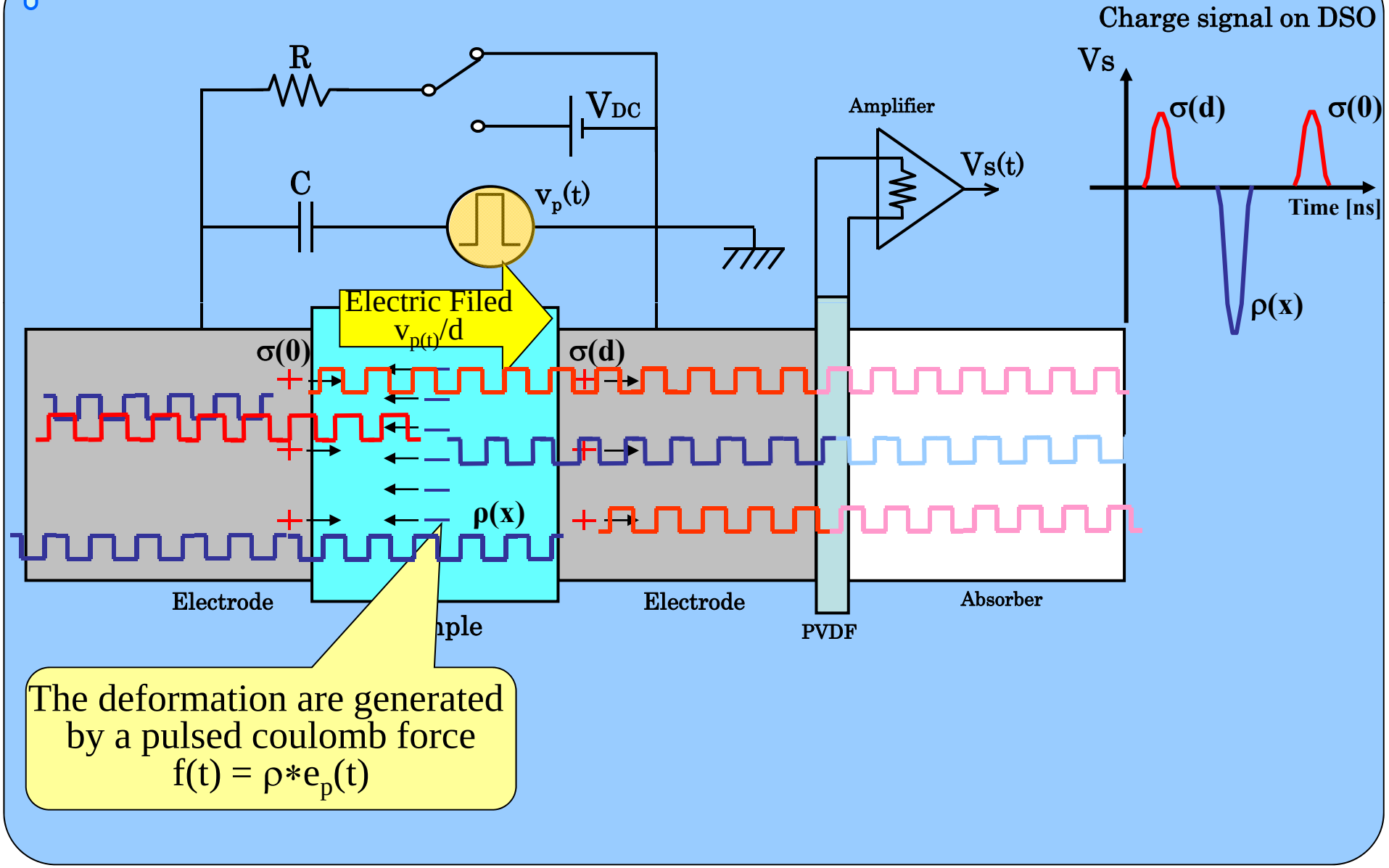
Why we use the Pulsed Electro-Acoustic(PEA) method for internal charging of dielectric bulks irradiated by radio-active rays?

1. **The PEA method is widely use on the high voltage insulating society.**
   The standardization process of PEA is in progress on IEC.

2. **The sensor (piezo-electric device) is completely isolated from charged sample. Therefor this method has a high resistivity for discharge noise.**

3. **We can improve to measure the surface and internal charge distribution, simultaneously.**
   (But, in this report, we only introduce the internal charge distribution.)

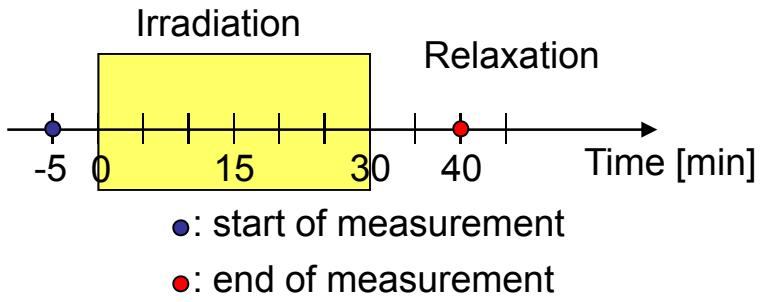
Principle of Pulsed Electro-Acoustic (PEA) method



Measurement Procedure

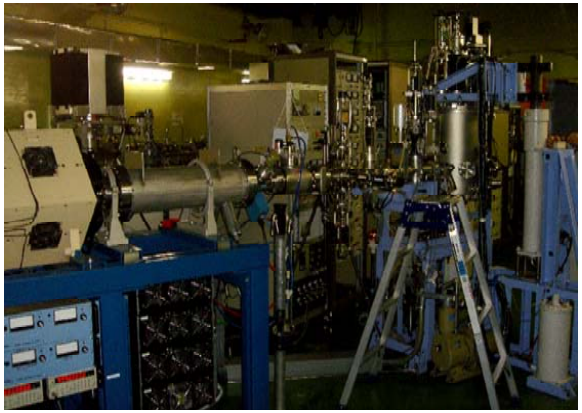
- Sample : PI, 125 μm
  (with the Al evaporated layer)
- Irradiation energy : 1.0, 1.5, 2.0 MeV
- Current density : 0.3, 3, 30 nA/cm^2
- Irradiation and measurements were carried out under vacuum condition with 10^{-5} Pa

-Irradiation & measurement schedule-



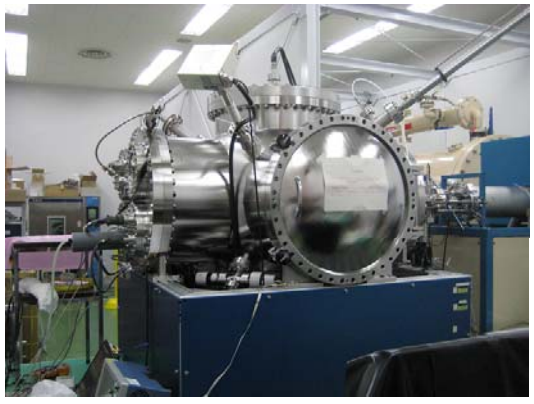
- Irradiation time: *30 min*
- Measurement interval: each *30 sec*

3MeV Tandem Accelerator
Takasaki Advanced Research Institute, JAEA

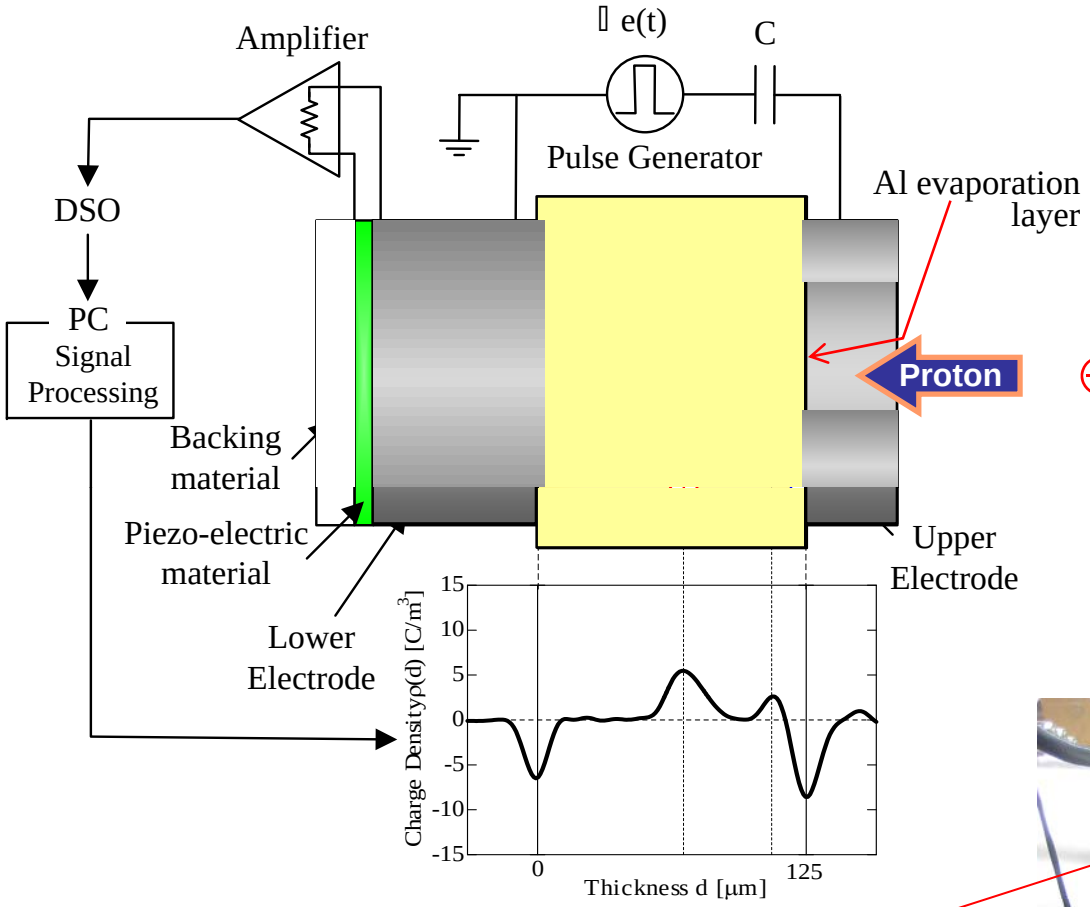


Van de Graff
High Fluence Irradiation Facility, The University of Tokyo

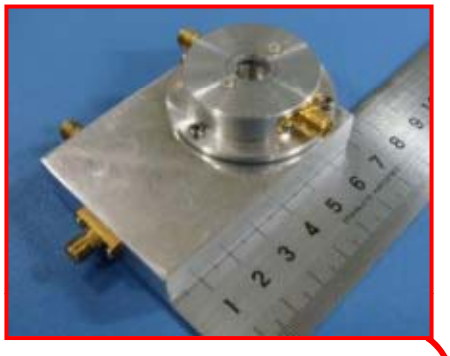
***The test facility of space environment*,**
Space Environment Group, JAXA

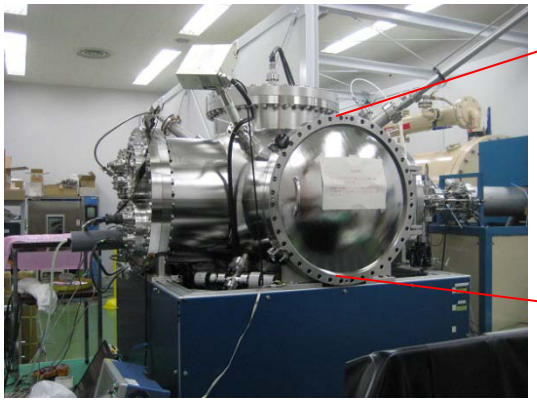


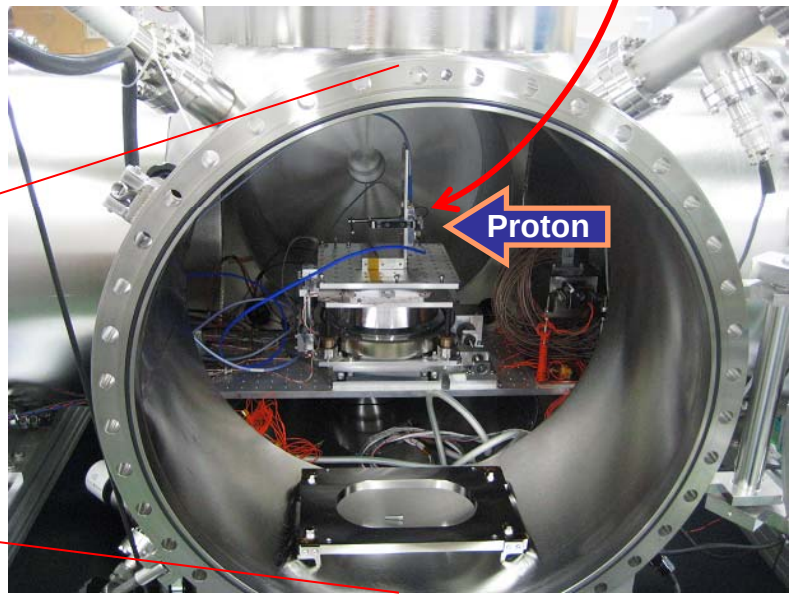
Improvement of PEA apparatus for proton irradiation



Detector part of PEA

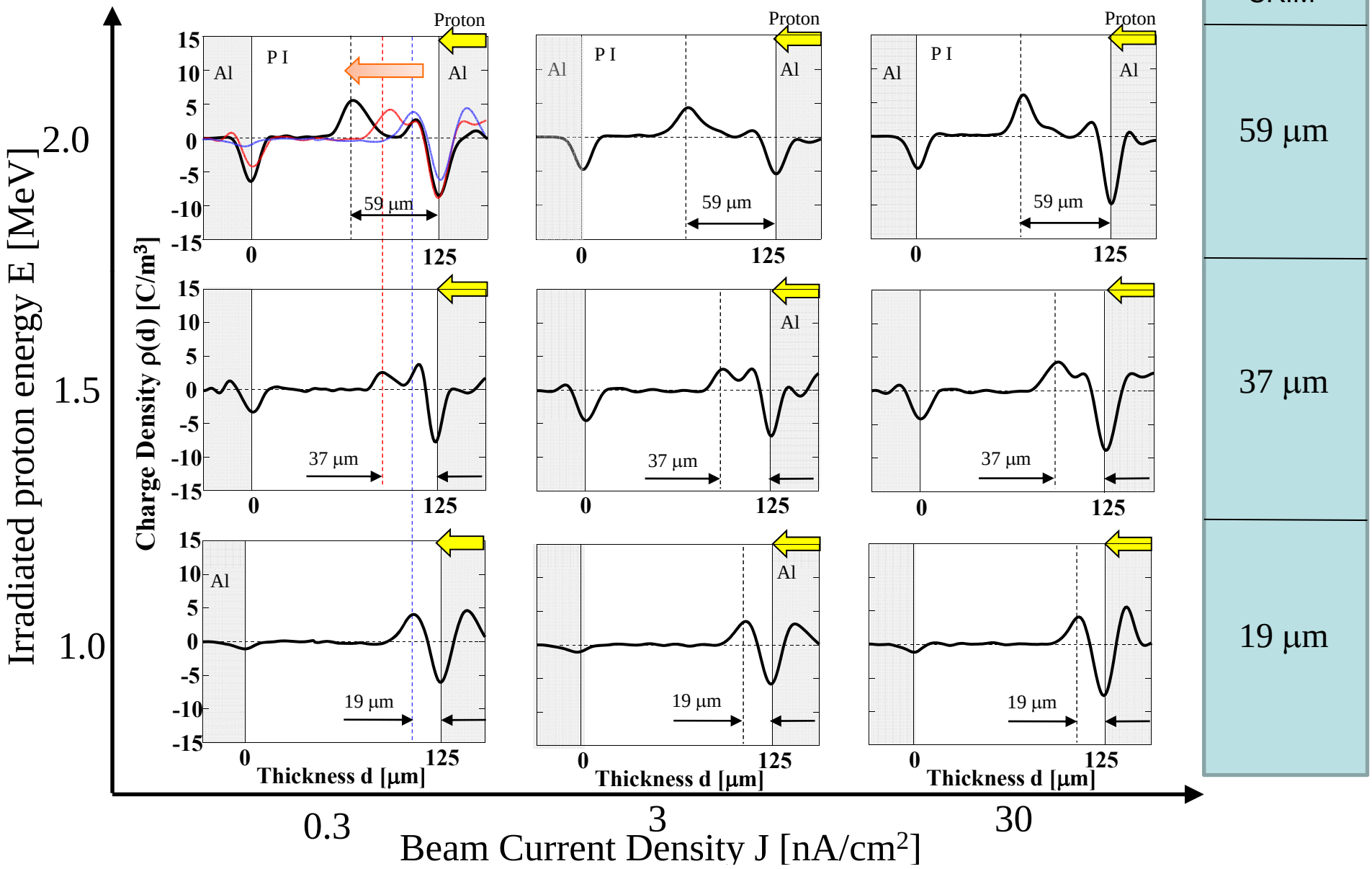






Measurement results Each result shows the maximum accumulation during irradiation.

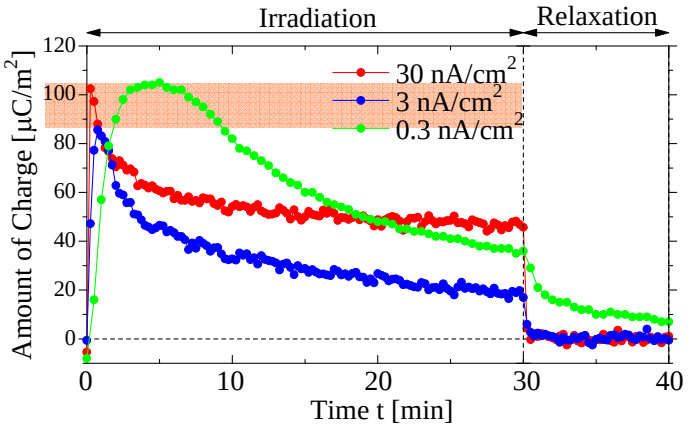
- We can confirm the positive charge accumulation in those bulks.
- Those accumulated positions have good relation with proton penetration depth.



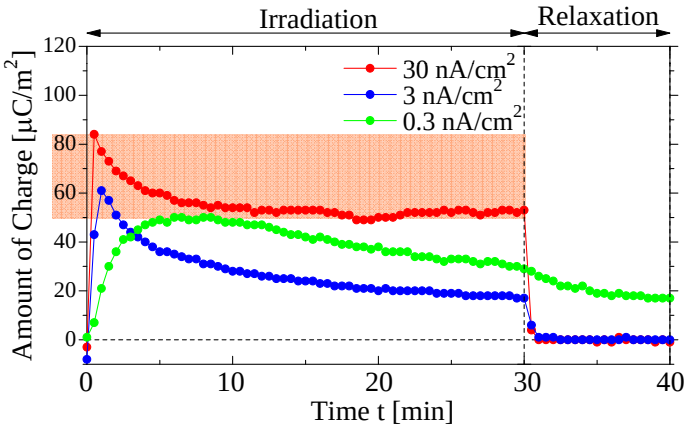
Calculated penetration depth using SRIM
59 μm
37 μm
19 μm

Characteristics of total charge amount in irradiation time progress

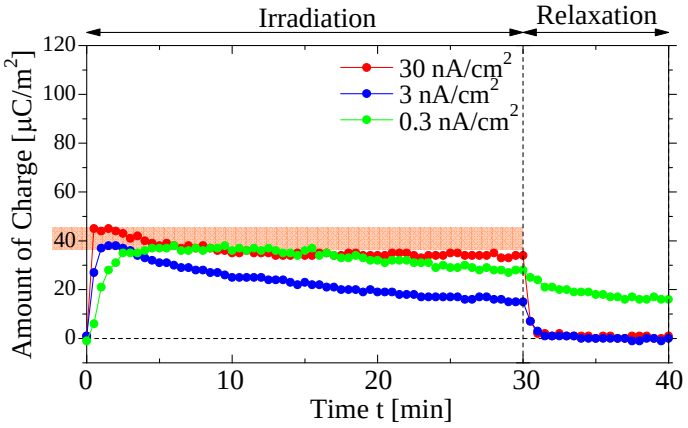
2.0 MeV

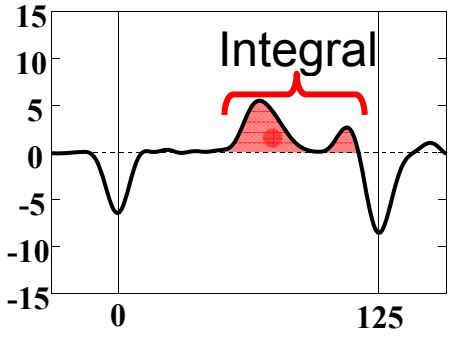


1.5 MeV

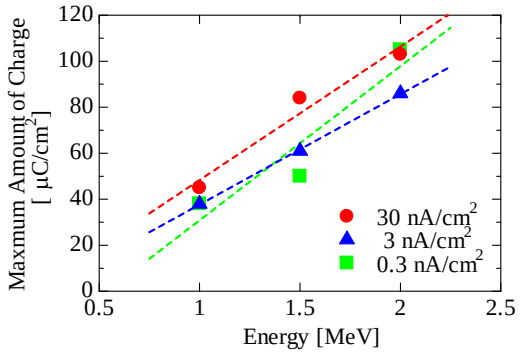


1.0 MeV

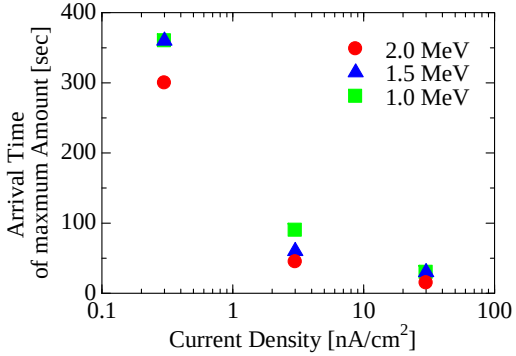




Charge amount VS **Energy**



Maximum arrival time VS **Current Density**



Irradiation energy

The amount of charge accumulation is proportional to energy.

Current

The strength of current density influence …

The arrival time of maximum amount is different.

The decay speed is different.

The total amount of charges saturate and decrease during the irradiation.

It is indicate that the conductivity may change during irradiation due to **RIC**.

Conclusions

- We observe the positive charge accumulation in the PI bulks irradiated by protons.

- Charge peaks agree well with theoretical estimation penetration depth.

- Maximum accumulated charge amount is proportional to irradiation energy.

- Charge accumulation and decay speed is depend on the irradiation current density.
→ RIC may be influenced by the proton flux(current density).

- Positive charge accumulation possibly remain the bulk for long time with the nominal flux on the orbit.

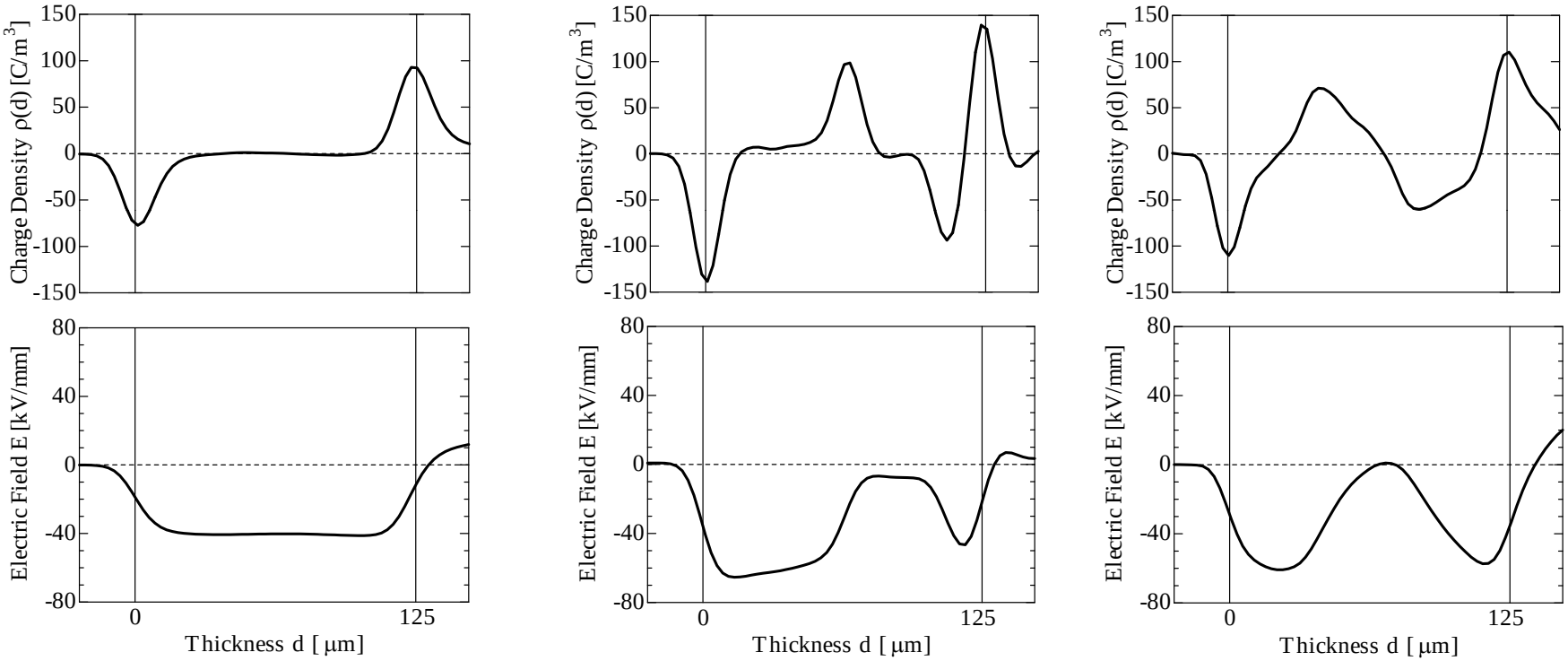
Future works…

- We make the charge accumulation and decay model to understand the charging phenomena.

- We measure the volume resistivity of PI irradiated by protons.

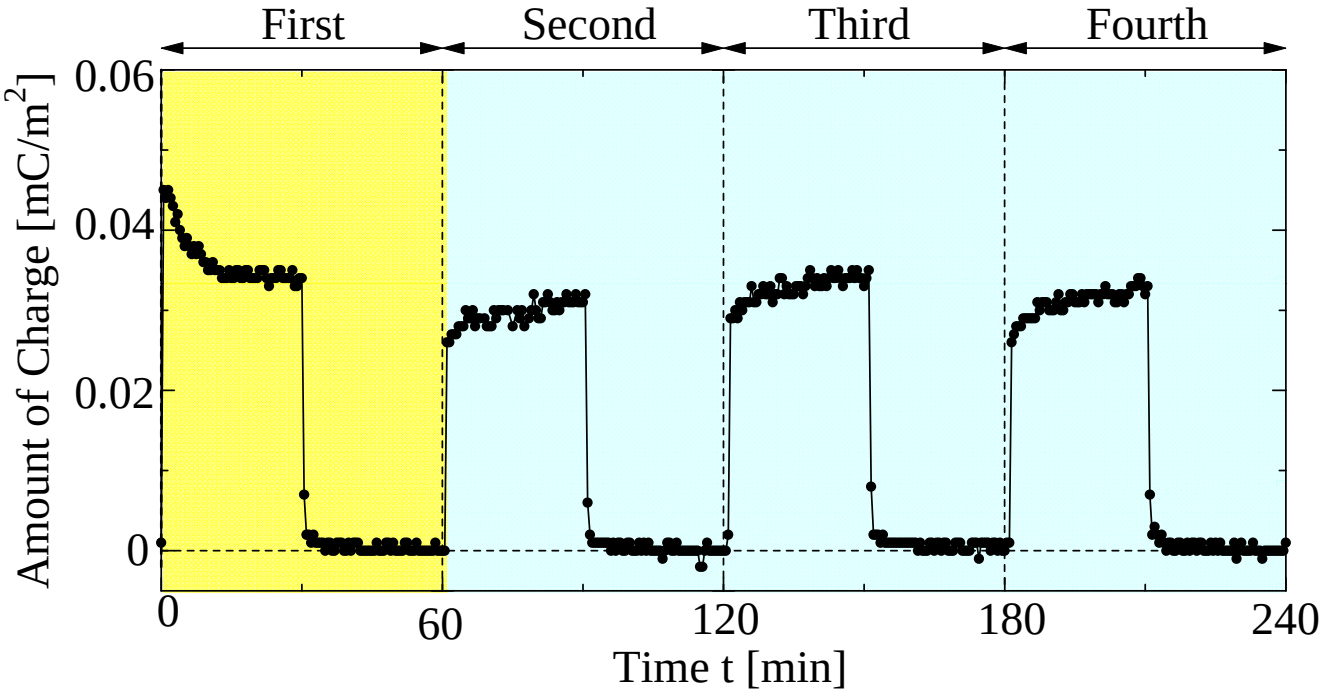
- New improved PEA measurement system which can measure the surface and internal charging will be available in next few month.

Back up


Charge Density ρ(d) [C/m3]
150
100
50
0
-50
-100
-150
Electric Field E [kV/mm]
80
40
0
-40
-80
0
125
Thickness d [μm]

Frequently irradiation

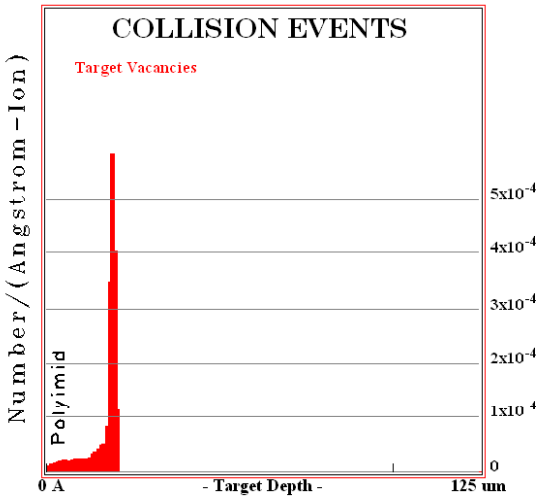
Sample: PI　　Energy: 1.0 MeV　　Current density: 4 nA/cm^2

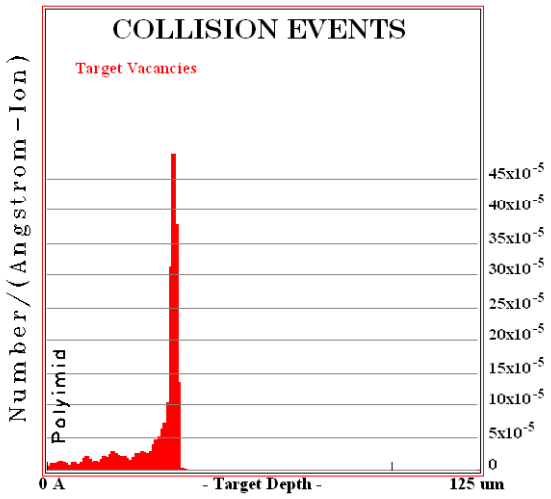


- 1回目の照射と、2,3,4回目の照射では蓄積挙動が異なる
- 一度プロトンを照射した際の変化は不可逆的

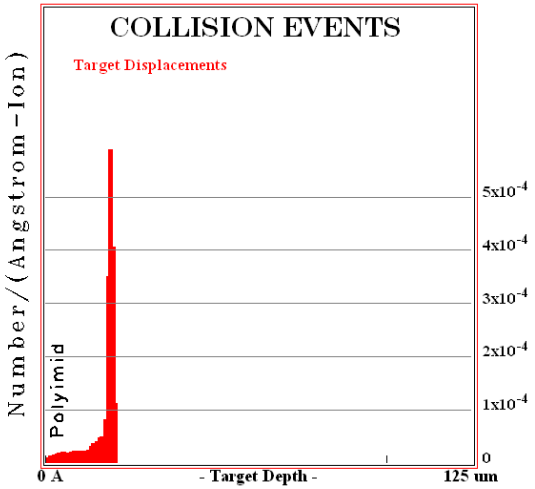
Number of vacancy and displacement in PI using TRIM coad

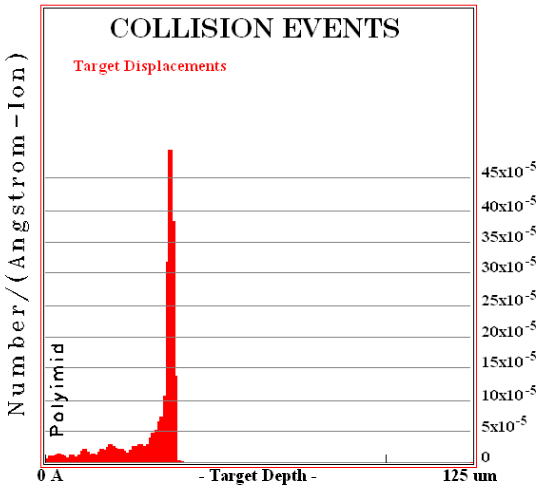
Vacancies





Displacement





空孔、変移量共に１MeVの方が多い

1MeV, 2000 particle

1.5MeV, 2000 particle