



# J11 Aluminum thickness dependence of spatial profile in niobium-based superconducting tunnel junction

Masahiro Ukibe<sup>a,\*</sup>, Takashi Ikeuchi<sup>b</sup>, Tatsuya Zama<sup>a</sup>, Masataka  
Ohkubo<sup>a</sup>

AIST<sup>a</sup>□Meiji Univ.<sup>b</sup>

## Collaborators

Masaki Katagiri<sup>1</sup>, Takumi Kikegawa<sup>2</sup>, Daiji Fukuda<sup>3</sup>

JAERI<sup>1</sup>, KEK-PF<sup>2</sup>, Tokyo Univ.<sup>3</sup>





# Development of advanced X-ray detectors

## Goal

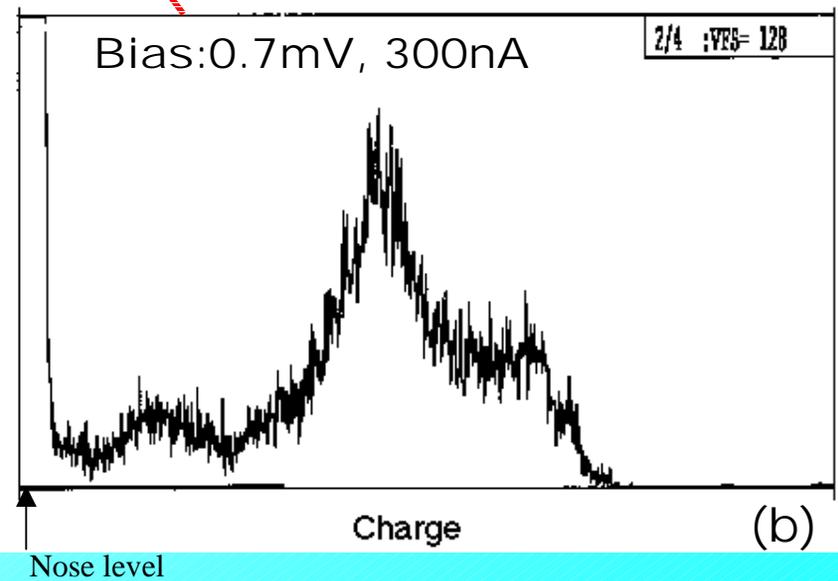
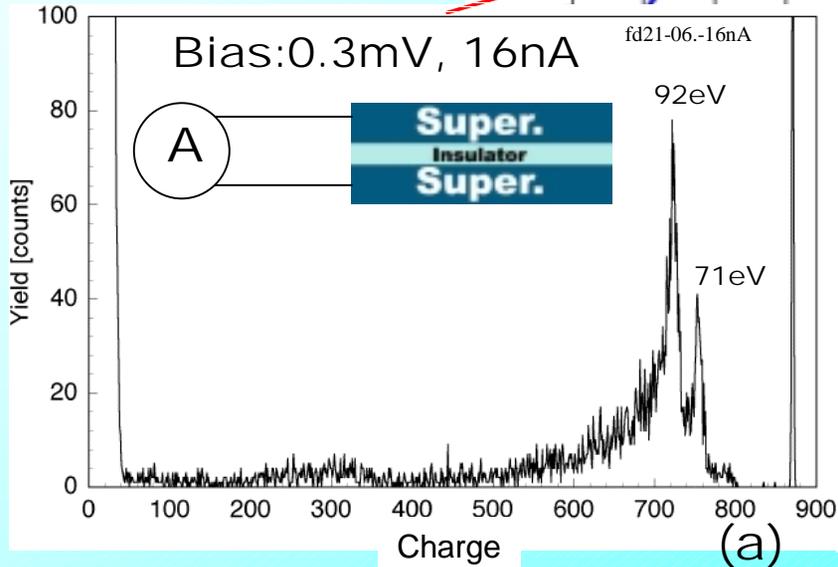
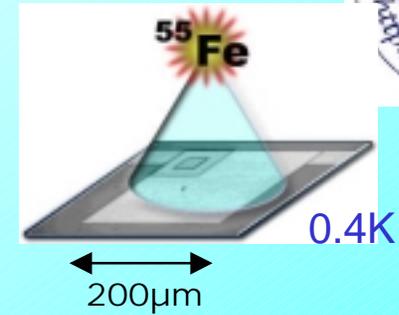
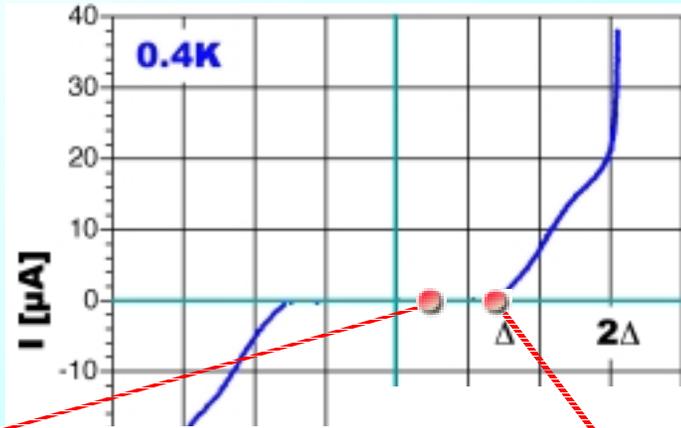
Energy resolution - **< 20 eV** for 6 keV x-ray

Counting rate - **> 100K cps**

Detection area - **~ 1mm<sup>2</sup>**

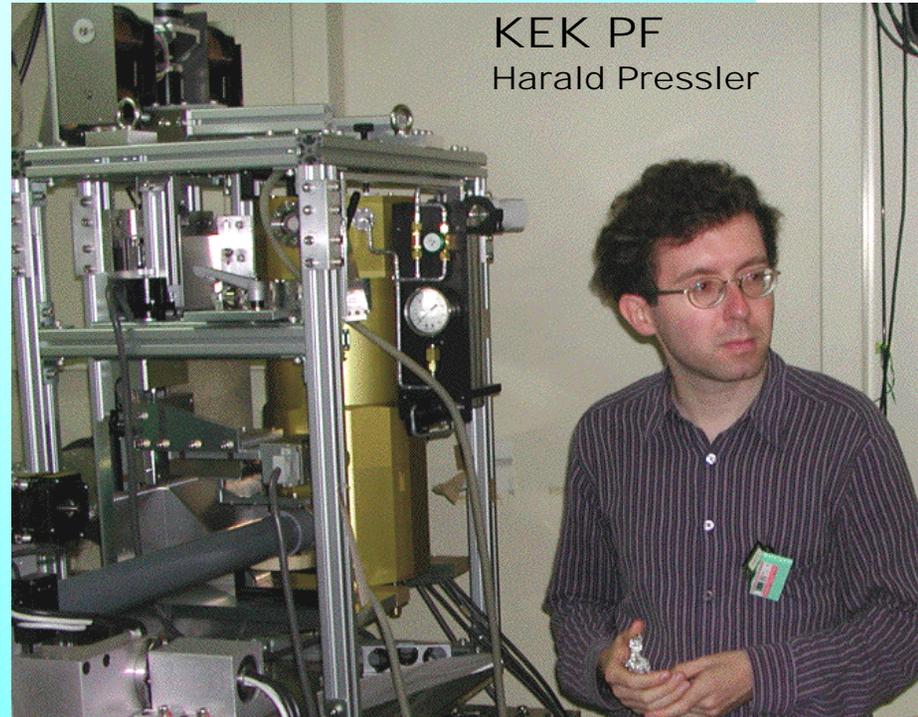
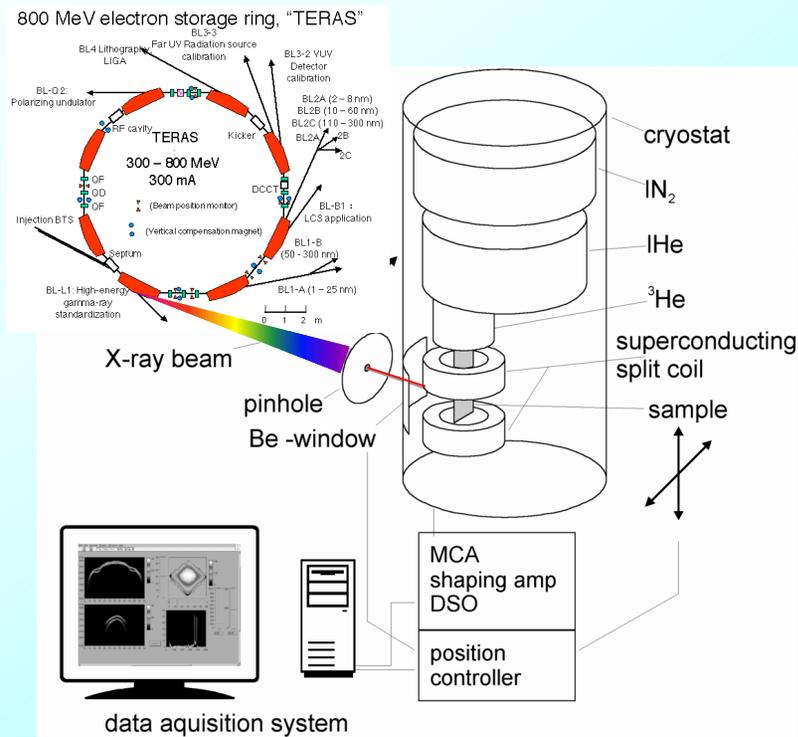
Absorption rate - **> 70%** for 6 keV x-ray

Full illumination with  $^{55}\text{Fe}$  X-ray source (5.9keV, 6.4keV)



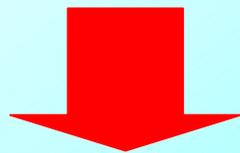
The answer is spatial nonuniformity.

## PF@KEK, TERAS@AIST

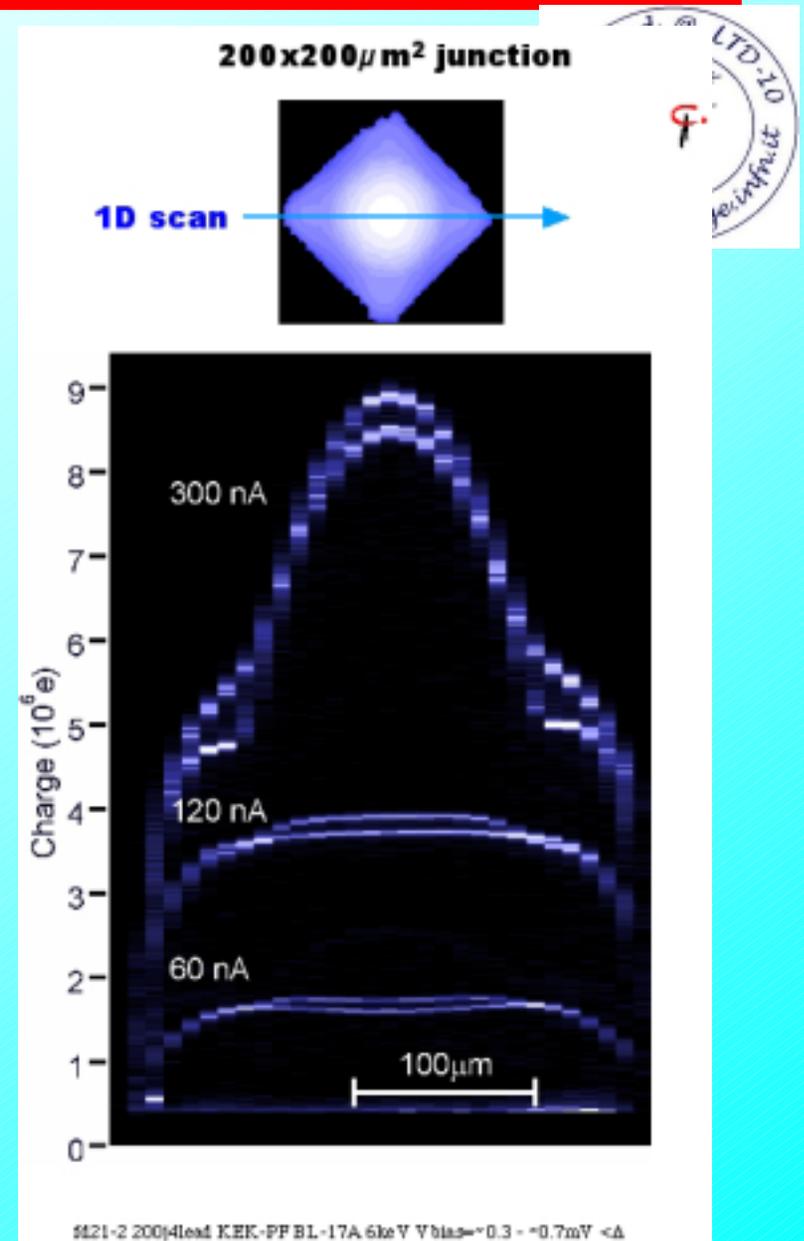


STJ : fd21 200 $\mu$ m-square junction

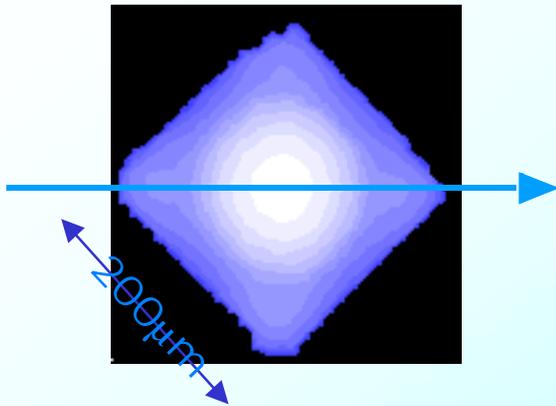
Bias current: **Low**  
Line shape: **concave**



Bias current: **High**  
Line shape: **convex**



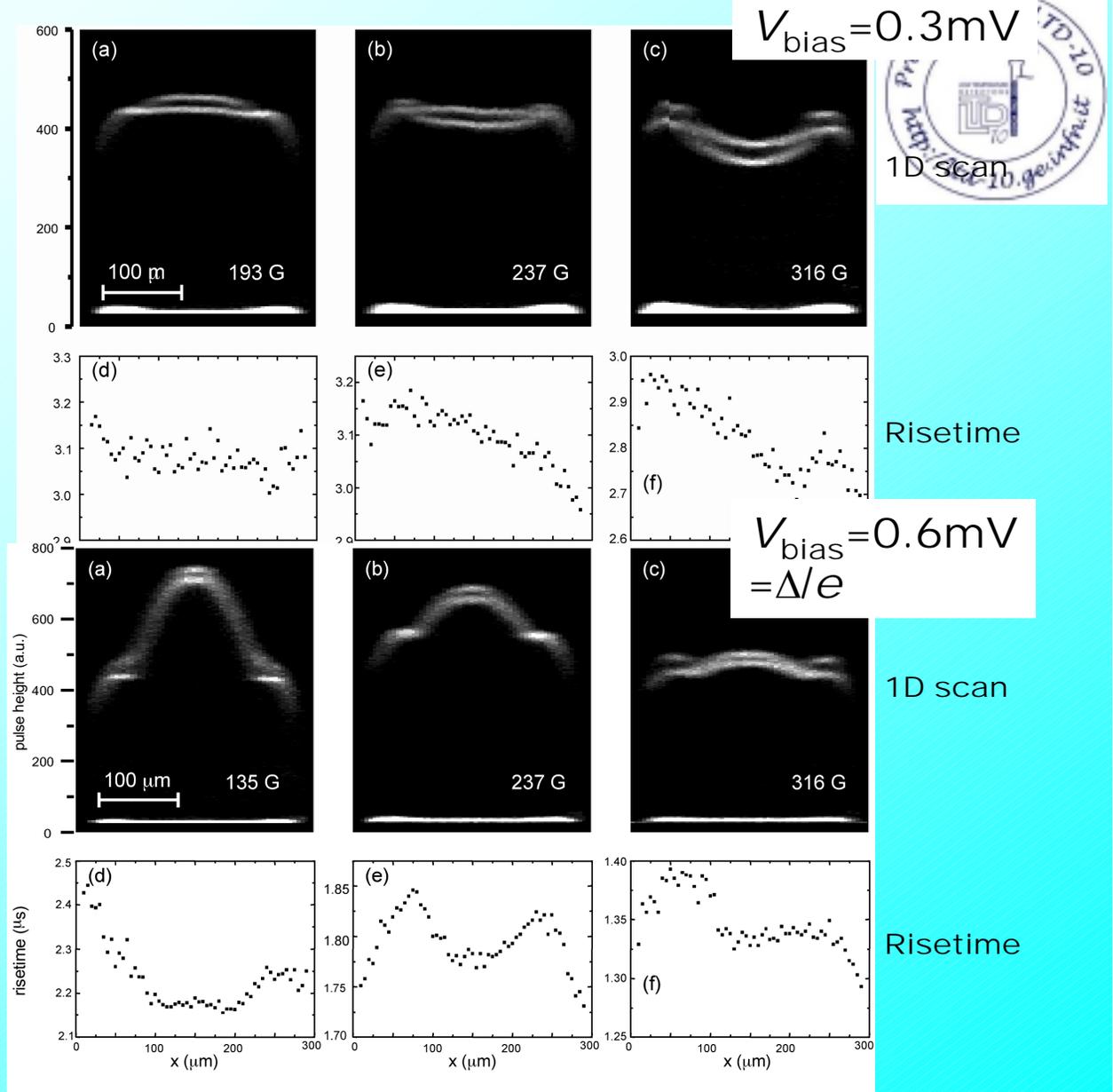
# H-dependence



H: High



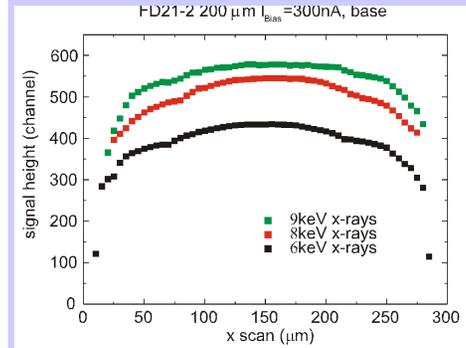
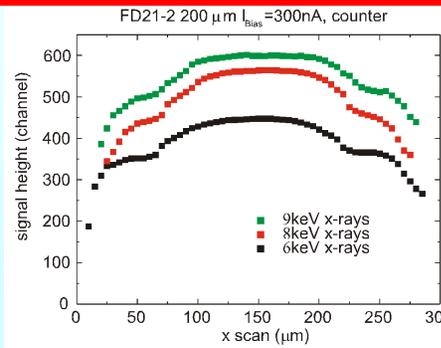
Large output area  
suppressed



# E-dependence of 1D scan



$V_{bias}$  [mV]  
0.5



Top

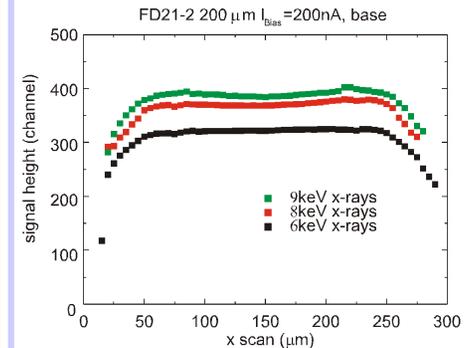
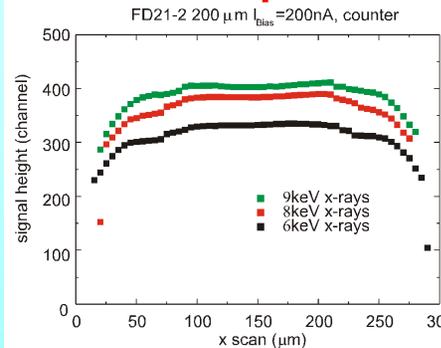
Bottom

$E_x: > \sim 1\text{keV}$

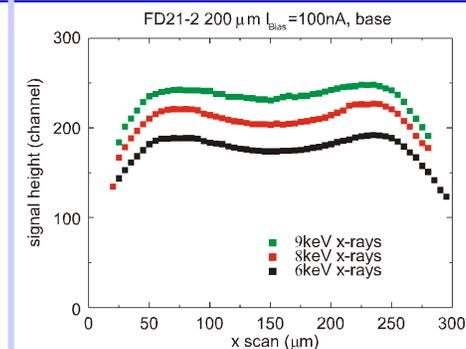
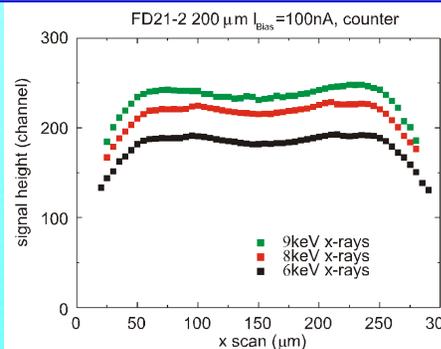


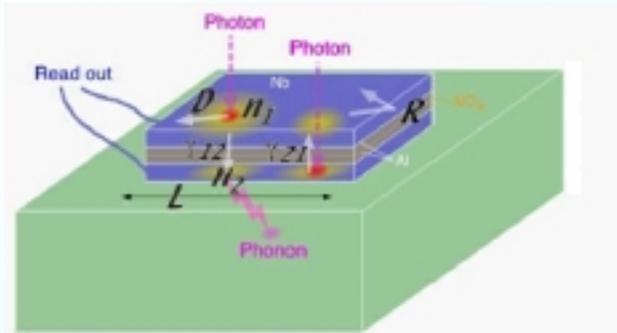
No obvious dependence

0.3



0.15





$$\frac{\partial n_1}{\partial t} = D \nabla^2 n_1 - \gamma_{12} n_1 - \gamma_{13} n_1 + \gamma_{21} n_2$$

$$\frac{\partial n_2}{\partial t} = D \nabla^2 n_2 - \gamma_{21} n_2 - \gamma_{23} n_2 + \gamma_{12} n_1$$

$$n_1(x, y, t) = Q_0 \delta(x - x_0) \delta(y - y_0),$$

$$n_2(x, y, t) = 0,$$

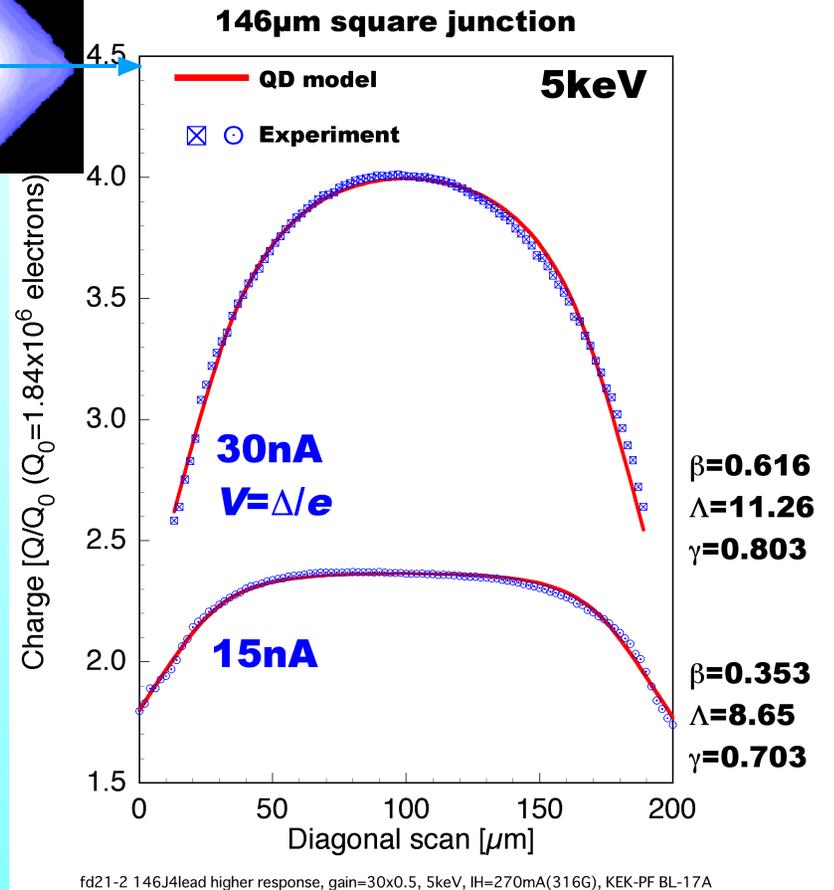
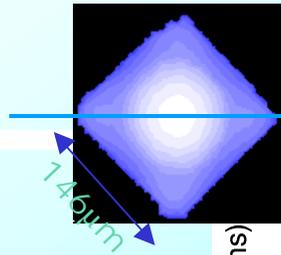
$$\left. \frac{\partial n_1}{\partial x} \right|_{x=\pm L/2} = \pm n_1 (1-R) 2L \quad (L: \text{mean free path of quasiparticle}),$$

$$Q = \int_0^t dt \int_{-L/2}^{L/2} dx \int_{-L/2}^{L/2} dy (\gamma_{12} n_1 + \gamma_{21} n_2),$$

$$\beta = L(1-R)2L,$$

$$\Lambda = [D(\gamma_{12} + \gamma_{21})]^{-1/2},$$

$$\gamma = \gamma_{12} / (\gamma_{12} + \gamma_{21})$$



R. Cristiano *et al.*, *J. Appl. Phys.* **86**, 4580 (1999).



**Inadequate** for explaining characteristics  
(bias dependence, etc)



UpTech

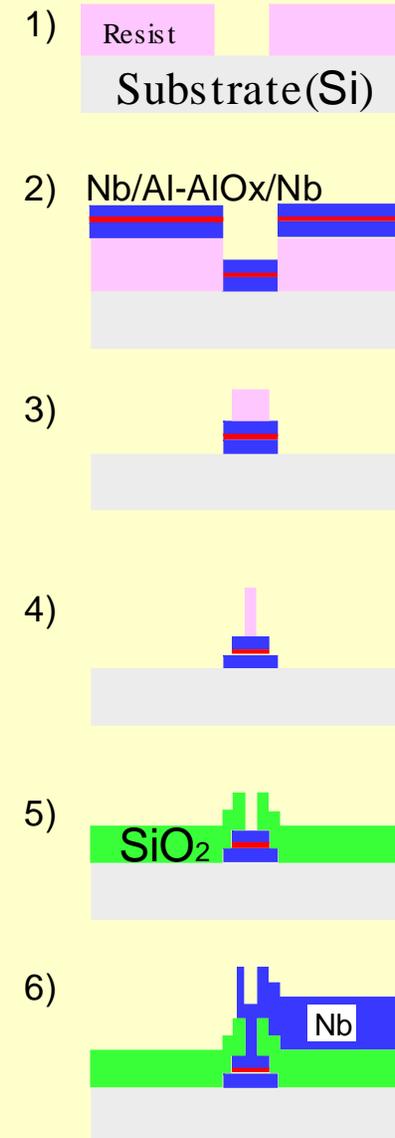


AIST



# AI thickness dependence?

1. Using **lift-off technique**, tri-layers were patterned on the wafer. The tri-layer, Nb(100-200)/Al-AIOx(50-100)/Al(50-100)/Nb(100-200) in nm, was deposited by **DC-sputtering**. The surface of the Al layer was oxidized for 1 hour in O<sub>2</sub> atmosphere of 9 torr at room temperature. [1)+2) show]
2. To form the top electrodes, top Nb and Al layers were removed by **RIE** and **Ar ion milling**, respectively. [3) shows]
3. A SiO<sub>2</sub>(800-1200nm) isolation layer was deposited by **RF-sputtering** and patterned by the **lift-off technique**. [4)+5) show]
4. A Nb film with a thickness between 1000 and 1400 nm was deposited by **DC-sputtering**. Electric leads and contact pads were formed by the **lift-off technique**. [6) shows]



KEK-PF BL 13B2

Energy range: 4-29keV

Photon Flux

$\sim 1 \times 10^{12}/\text{s}\cdot\text{mm}^2$

(11keV, 300mA)

Energy resolution:

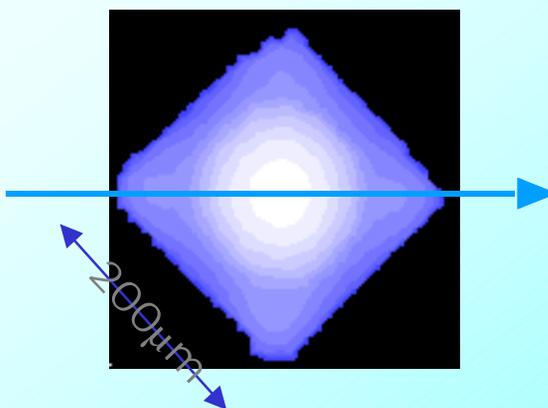
$E/\Delta E = \sim 5000$

Light source: Type: Linear Multipole Wiggler MPW #13-W  
( $\lambda_u$ : 18cm,  $N_{\text{period}}$ : 27,  $E_c$ : 6.24keV)

Optics: Double-Crystal Monochromator [Si(111)]  
with Saggital Focusing optics

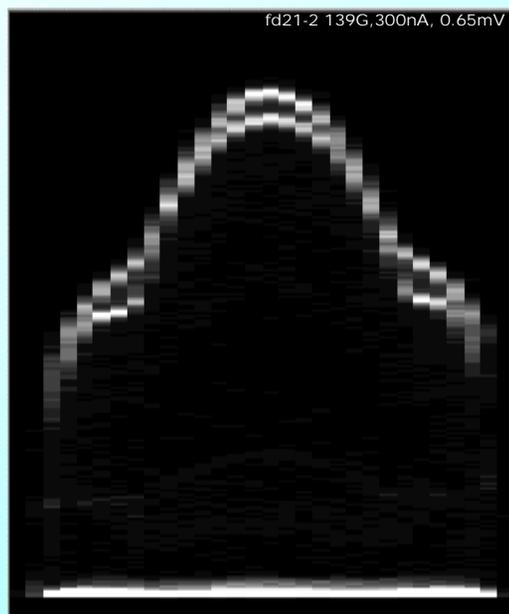


# Al-dependence of 1D scan



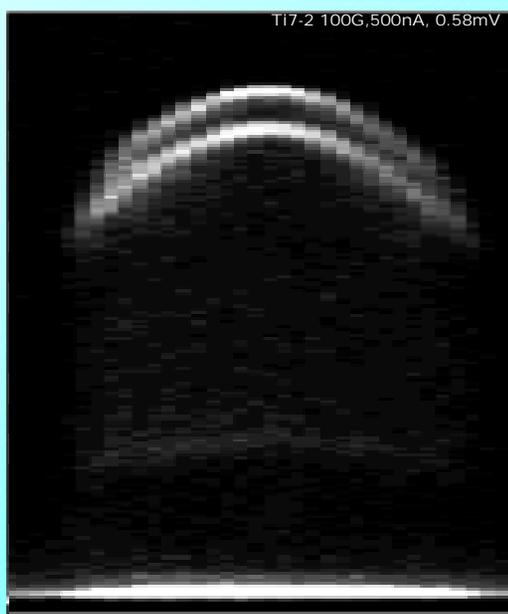
$$E = 6 \text{ keV}$$
$$V_{\text{bias}} = \Delta/e$$

charge output ↑

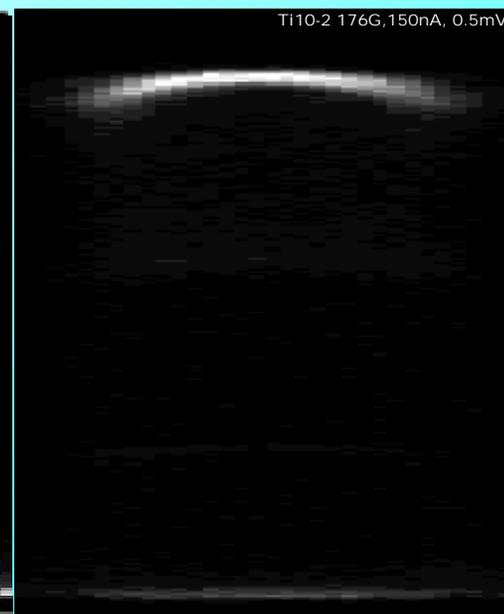


Al(30nm)

Complex dome



Al(50nm)



Al(70nm)

Simple dome



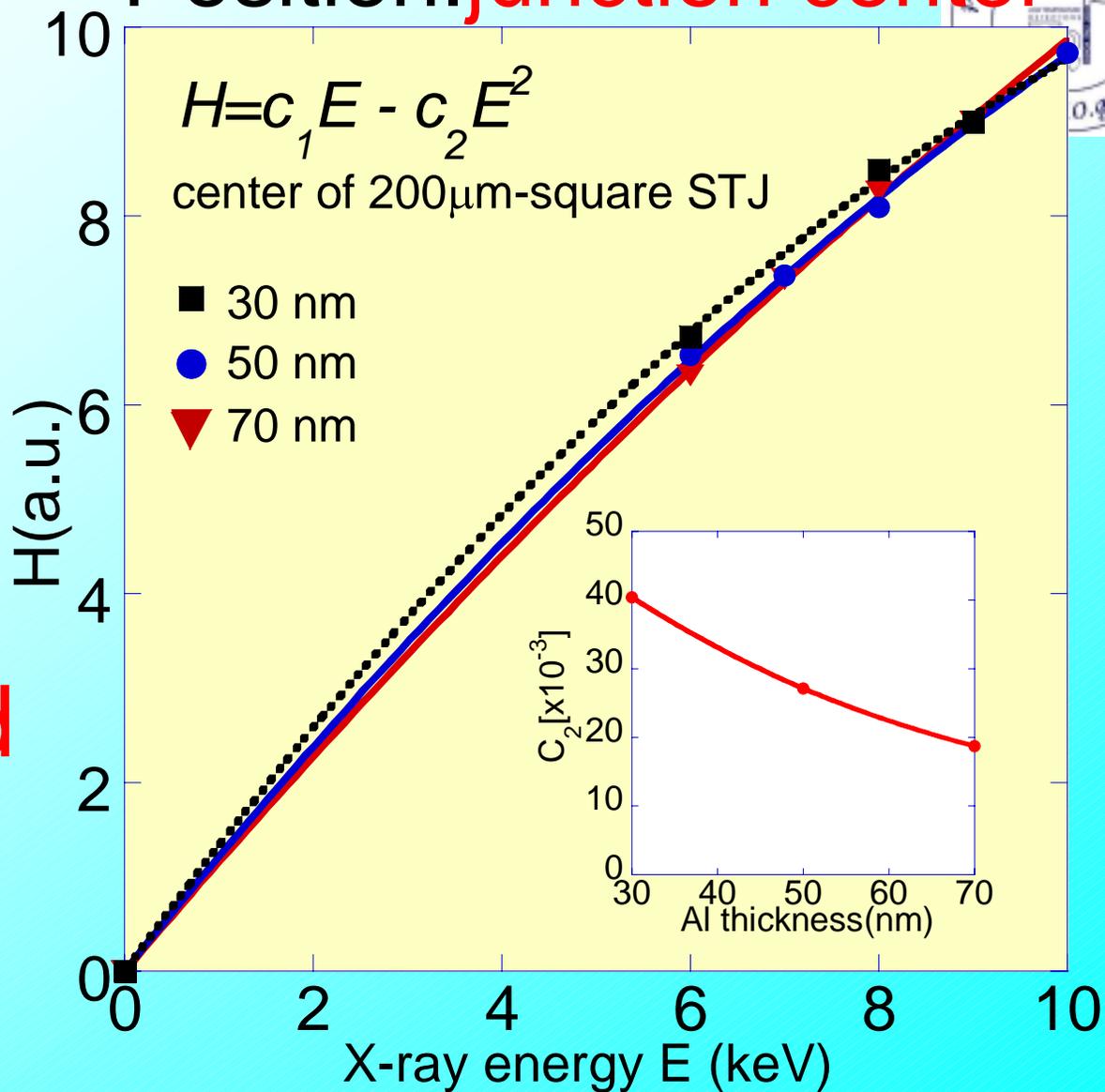
Position: **junction center**



Al thickness  
**Thin**

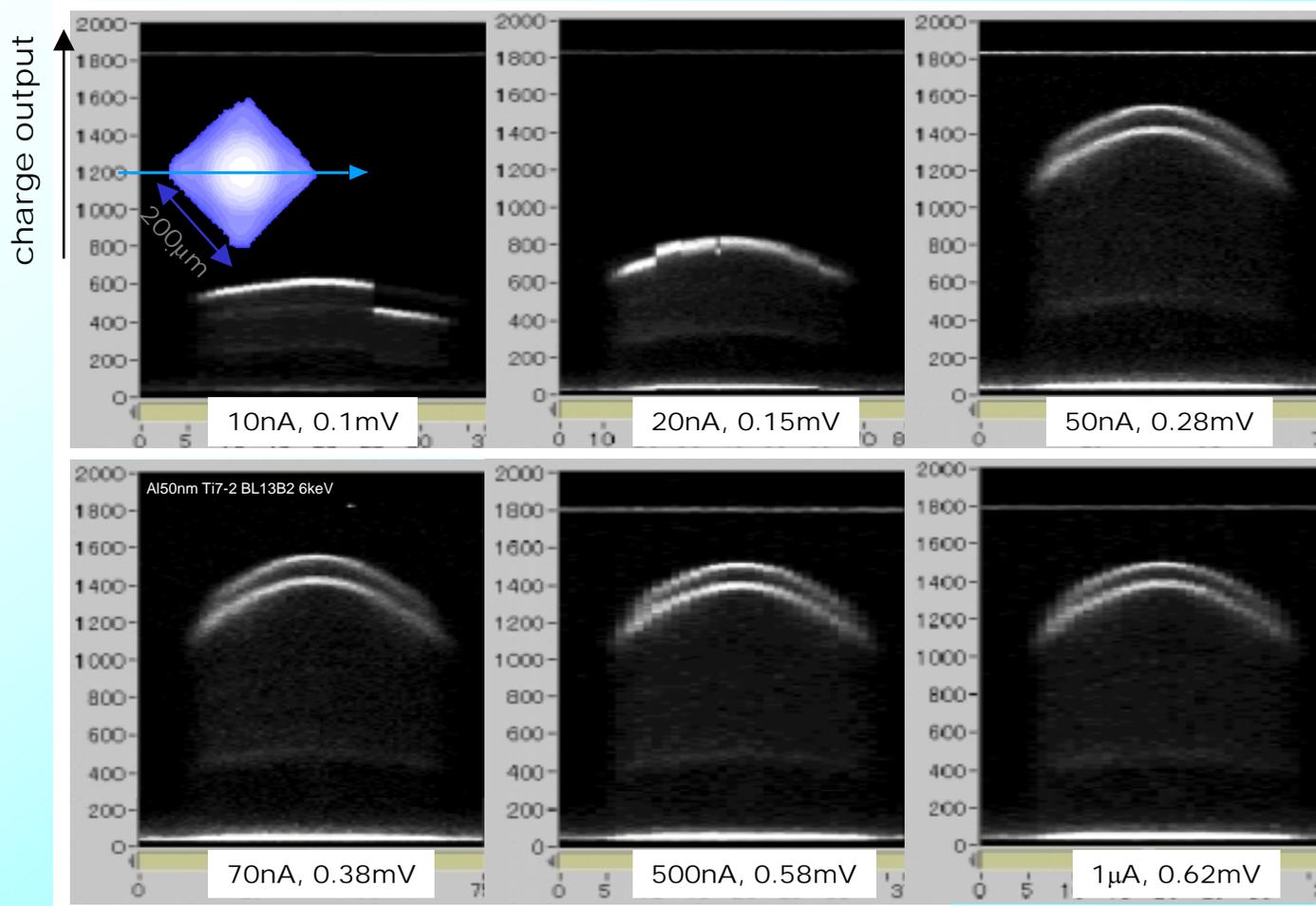
↓

E-non-linearity  
**pronounced**



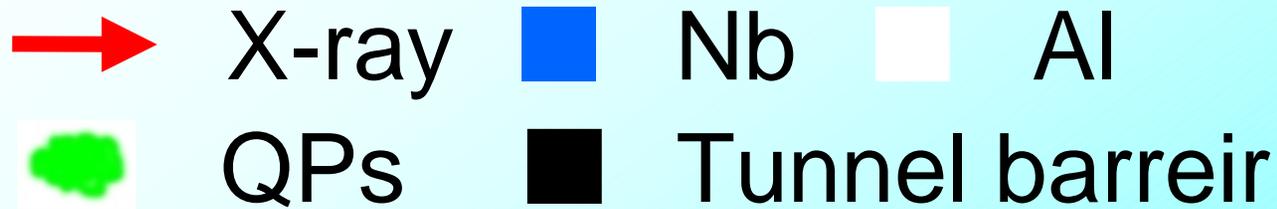
# Bias-dependence (Al50nm)

$E_x: 6\text{keV}$

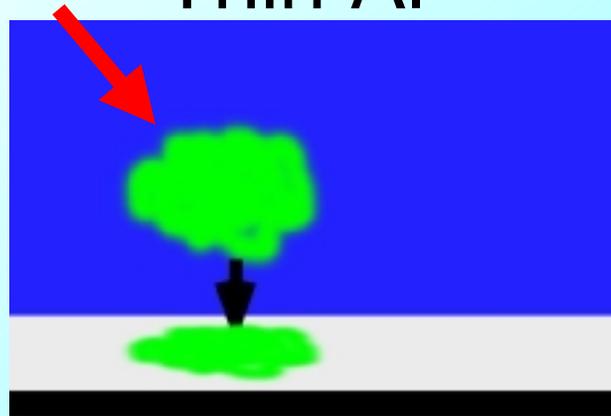


No obvious dependence

# Explanation of Al-thickness dependence



Thin Al



Thick Al



QP density	High	Low
$P_{\text{Recombination}}$	High	Low
QP loss	Large	Small

1. We fabricated the Nb-STJs having the Al layers of different thicknesses by the lift-off technique.
2. The Al thickness dependence of the spatial profile was measured by LTSSM.
3. The spatial uniformity is improved by increasing the Al thickness.
4. The Nb-based STJ is not appropriate for the direct detection of high-energy X-rays above about 1keV.