Results on a beam test of n-in-p silicon strip sensors before and after irradiation

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Outline

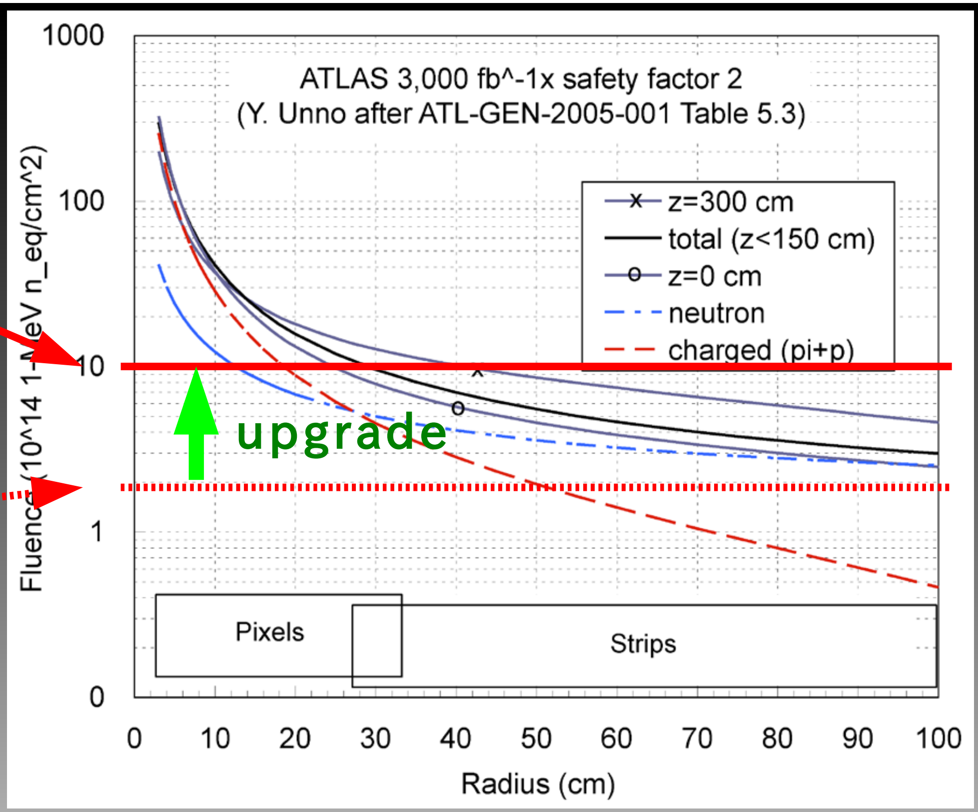
1. Motivations
2. Detectors and irradiations
3. ABCN Chip
4. Beam test setup
5. Charge Collection Efficiency
6. PTP structure
7. Summary

1.Motivations

- Studying Full Depletion Voltage(FDV) from Charge Collection Efficiency(CCE) of n-in-p silicon strip sensors with test beams with ABCN read-out chips
- Studying the PTP structure effects on active regions of n-in-p silicon strip sensors before and after irradiation

10^{15} [$n_{eq}cm^{-2}$] radiation-tolerance is required for new silicon strip sensors against the ATLAS detector upgrade

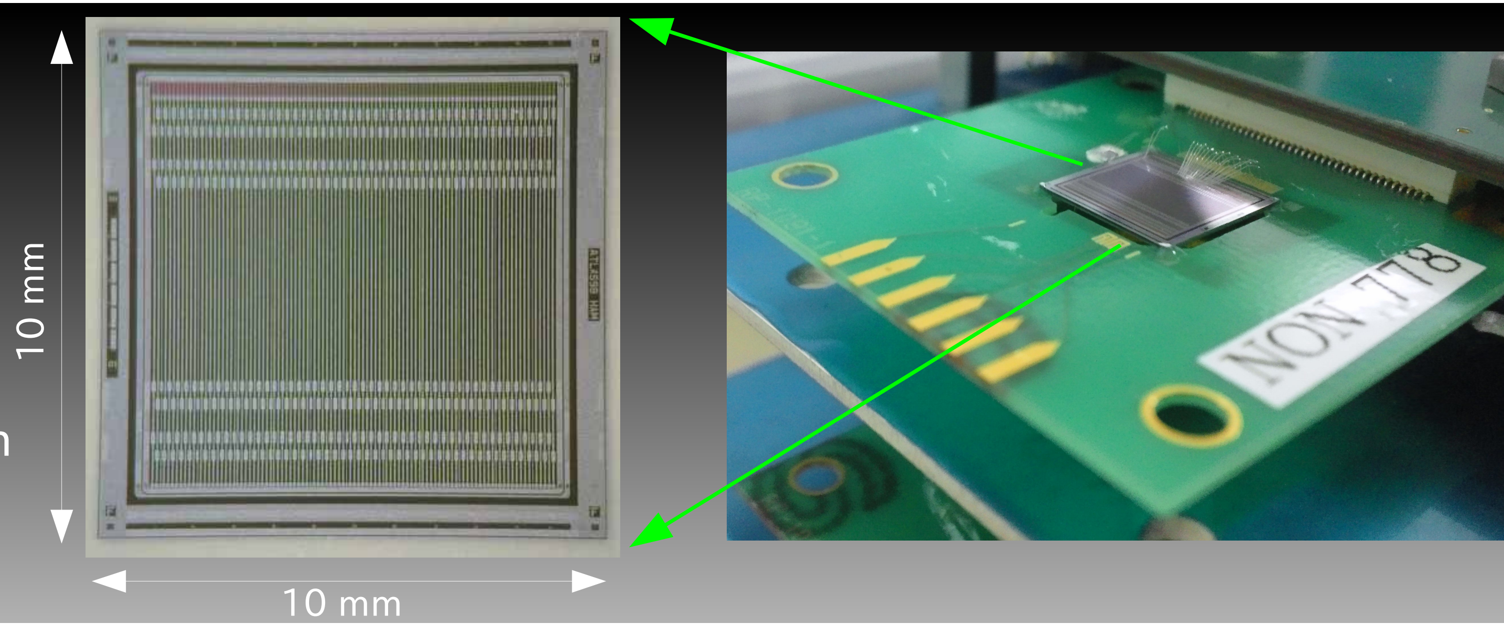
Radiation-tolerance of the present SCT is 2 x 10^{14} [$n_{eq}cm^{-2}$]



2.Detectors and irradiation

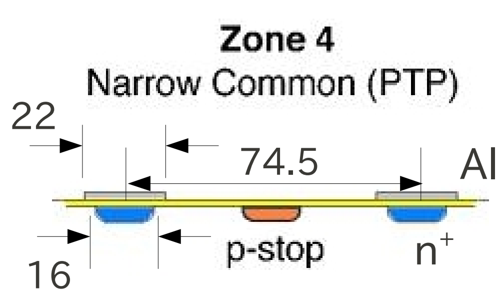
<u>N-in-P</u>
Mini sensors for beam tests

- 103 strips
- 74.5 μm pitch
- 8050 μm length
- FZ4D type

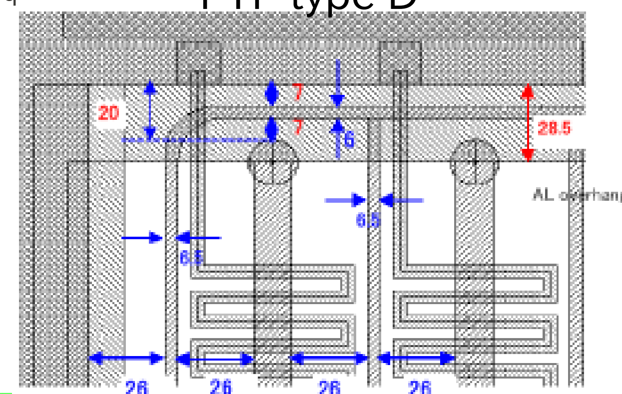


- **Irradiation**
  70 MeV protons irradiation at Cyclotron and Radioisotope Center (CYRIC), Tohoku University, Japan

  Fluence : 5.7×10^{12}, 1.1×10^{13}, 1.2×10^{14} ,1.2×10^{15} [$n_{eq}cm^{-2}$]



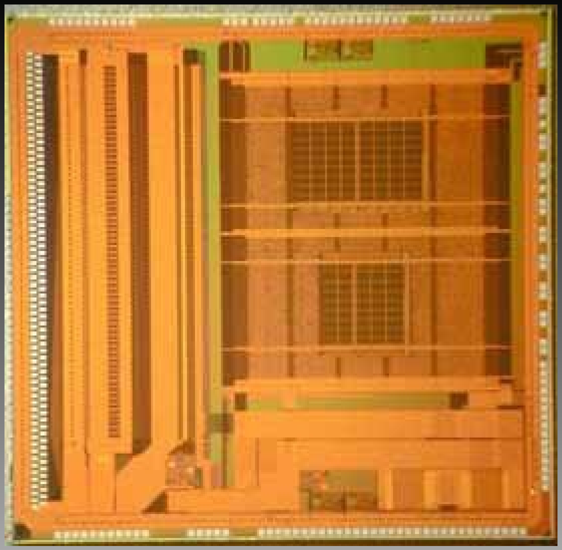
PTP type D



3.ABCN Chip

"ATLAS Binary Chip Next (ABCN) Front-end chip"
(250 nm IBM COMS6 technology)

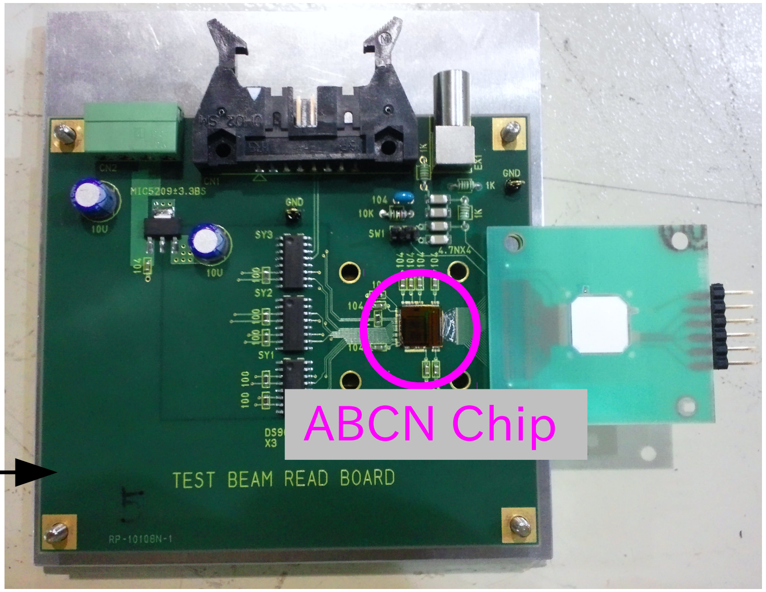
- 128 channels
- Binary front-end
- Optimized for readout of short strips
  5 pF detector capacitance / 2.5 cm silicon strip
- Compatible with both signal polarities
- Input Signal Linearity
  - +/- 6 fC : <3% , +/- 10 fC : < 6%



New read-out chip for n-in-p silicon strip sensors

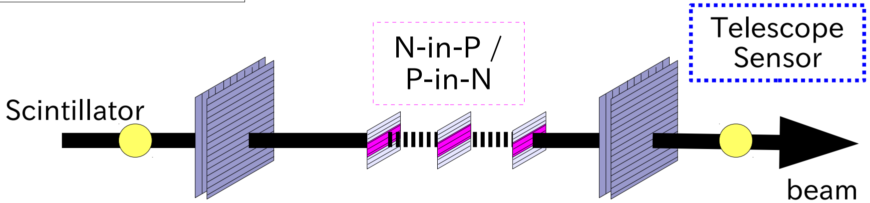
- The basic concept follows the one of the ABCD3T Chip used in the present ATLAS SCT detector

Read-out board of ABCN Chip for the beam test



4.Beam test setup - DAQ System -

Overview



ABCN DAQ

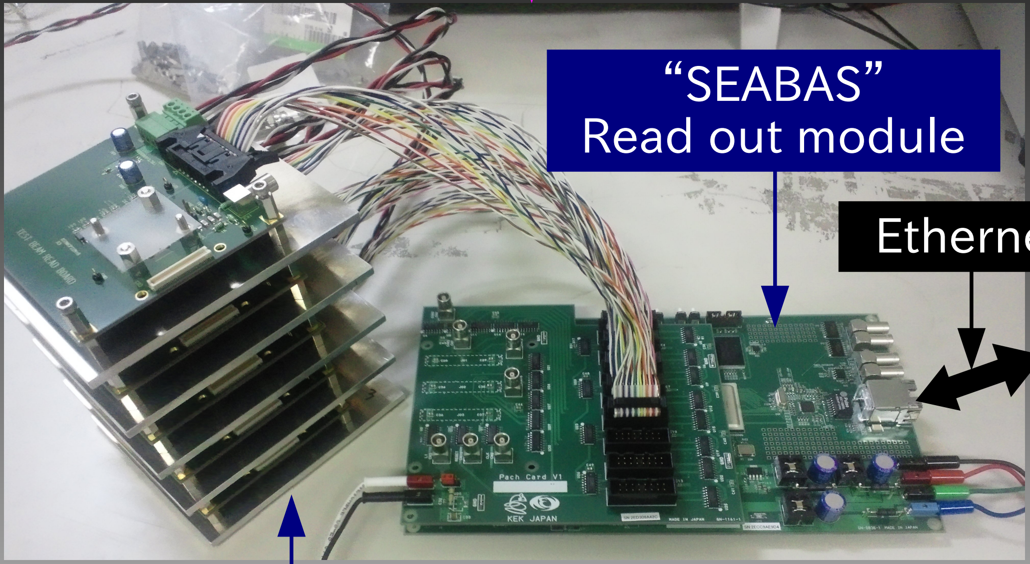
For DUTs(Device Under Tests)

- N-in-P / P-in-N
  - Si strip sensor for SCT
  - DAQ rate : ～10 kHz

Telescope DAQ

For beam tracking

- Telescope detector
  - Si strip sensor
  - Sensor size : 20 x 20 mm^2
  - Tracking resolution : >10 μm
  - Tracking rate : ～100 Hz

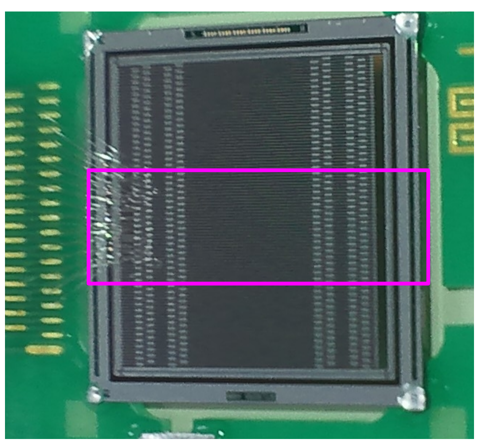


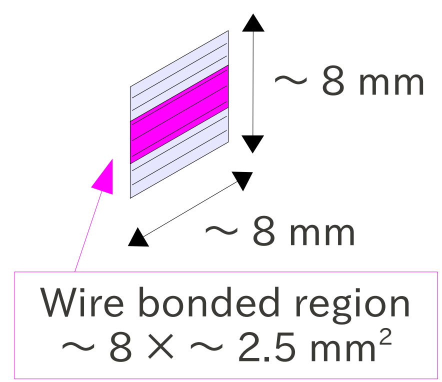
4.Beam test setup - basic information -

"Beam information"

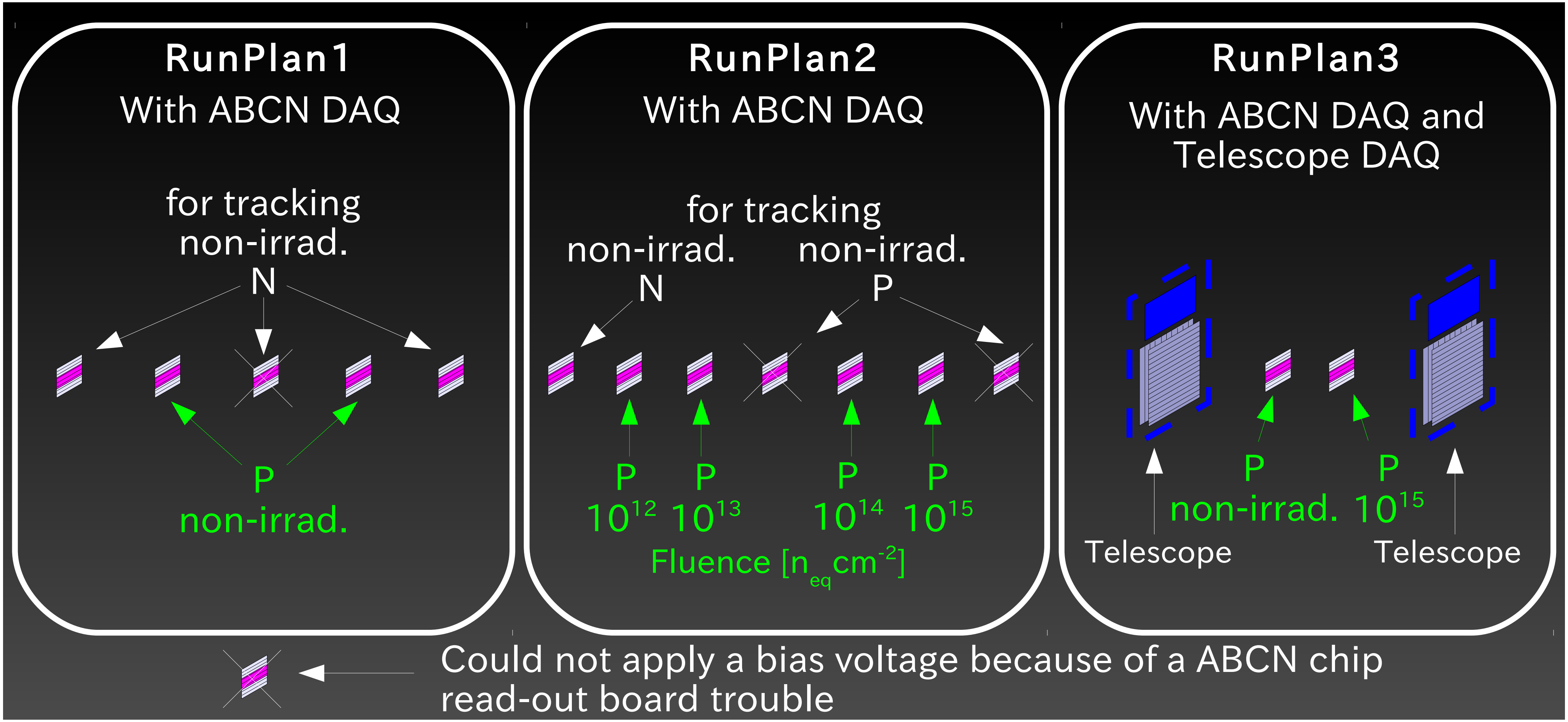
place	Research Center for Nuclear Physics at Osaka Uni. (RCNP)
date	14/12/2011 - 17/12/2011
beam particle	proton
Beam energy	392 +/- 1 MeV
Trigger rate	~80 Hz or ~10 kHz

"Active region of DUT"



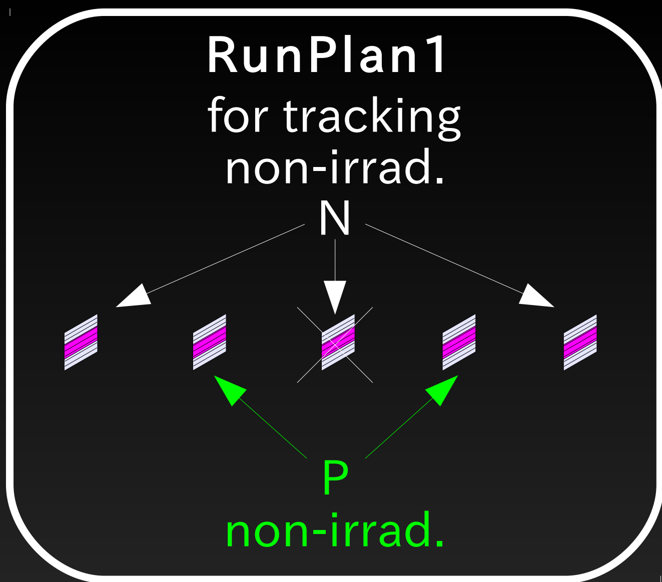


4.Beam test setup - RunPlans -



- RunPlan1 : evaluation of non irradiated n-in-p(P) sensors
- RunPlan2 : evaluation of irradiated n-in-p(P) sensors
- RunPlan3 : study of PTP structure effects

4.Beam test setup - RunPlan1 -

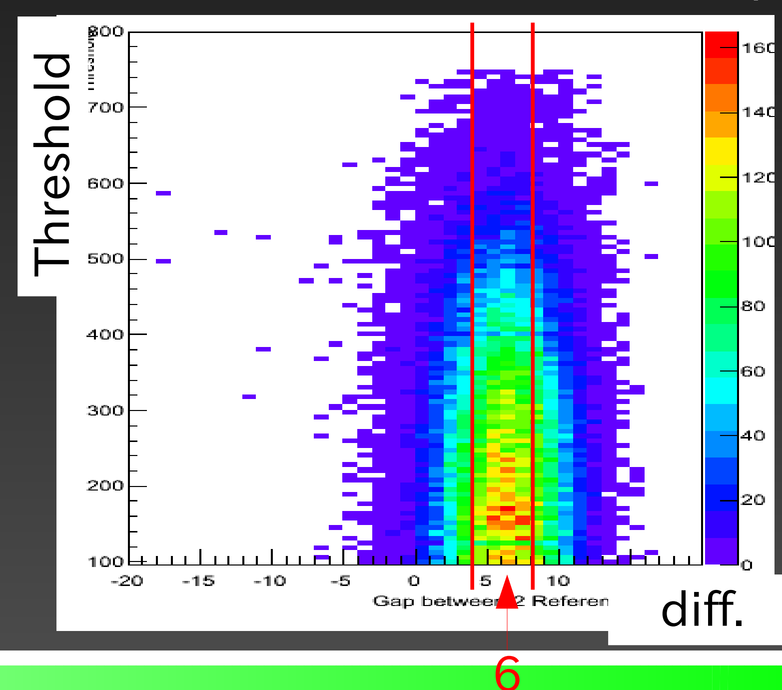


- non-irrad. N (p-in-n) :
  - Reference sensors
  - Bias voltage 250 V fixed
- non-irrad. P (n-in-p) :
  - Device under test (DUT)
  - Bias voltage 15 – 400 V

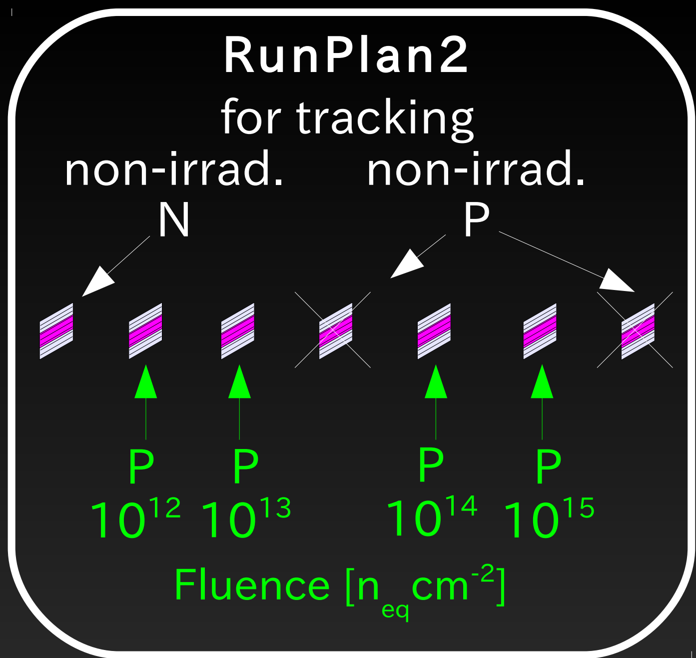
"Beam definition"

Selection cuts on Reference sensors
- Cluster Number : 1 cluster
- Cluster Width : < 3 strips
- Difference of Reffernce : 6 +/- 2 strips

Difference of Reference Hit Strip



4.Beam test setup - RunPlan2 -



- non-irrad. N (p-in-n) & P (n-in-p) :
  - Reference sensors
  - Bias voltage 250 V fixed
- irrad. P (n-in-p) :
  - Device under test (DUT)
  - Bias voltage 50 – 400 V
    (400 – 950 V)

2 of 3 references did not work

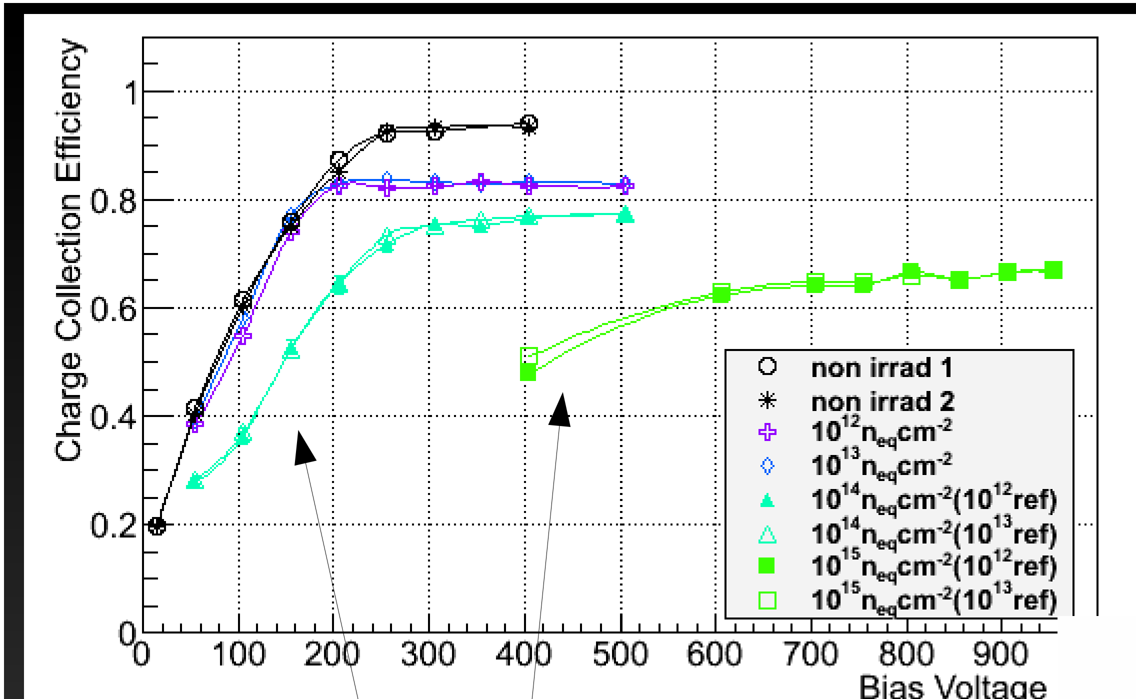
"Beam definition"

Reference sensors are
Reconstruction pattern 1:
- non-irrad. N
- 10^{12} irrad. P

Reconstruction pattern 2:
- non-irrad. N
- 10^{13} irrad. P

Selection cuts on Reference sensors
- Cluster Number : 1 cluster
- Cluster Width : < 3 strips
- Difference of Reffernce :
  5 +/- 1 strips (pattern 1)
  9 +/- 1 strips (pattern 2)

5.Charge Collection Efficiency

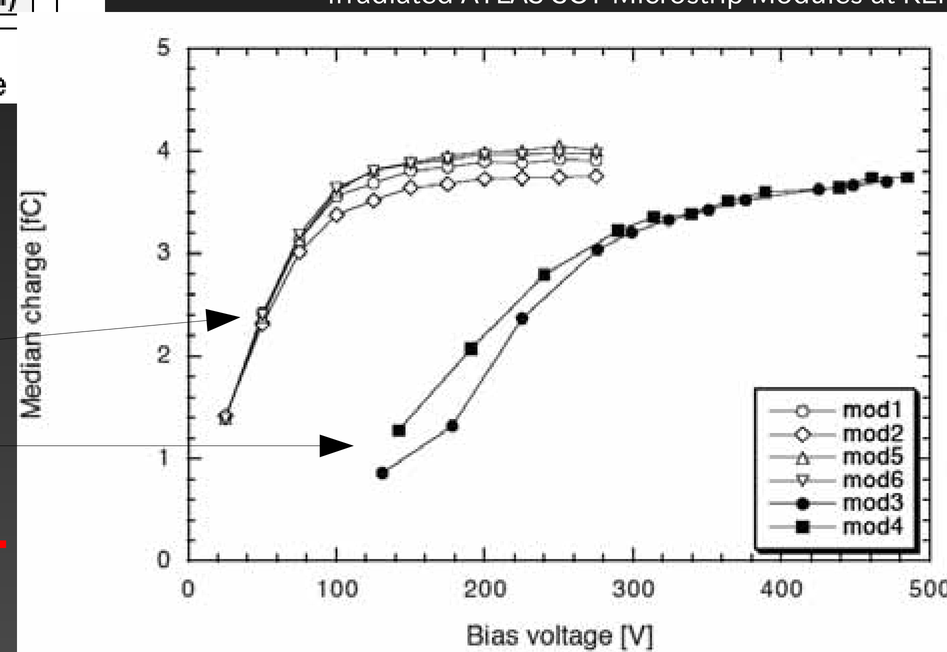


Charge Collection Efficiency of n-in-p sensors (New)

CCE is computed as the ratio of the charge calculated by Bethe-Bloch

10^{14} , 10^{15} [n_{eq} cm^{-2}]

Y. Unno et al "Beam test of Non-irradiated and Irradiated ATLAS SCT Microstrip Modules at KEK"

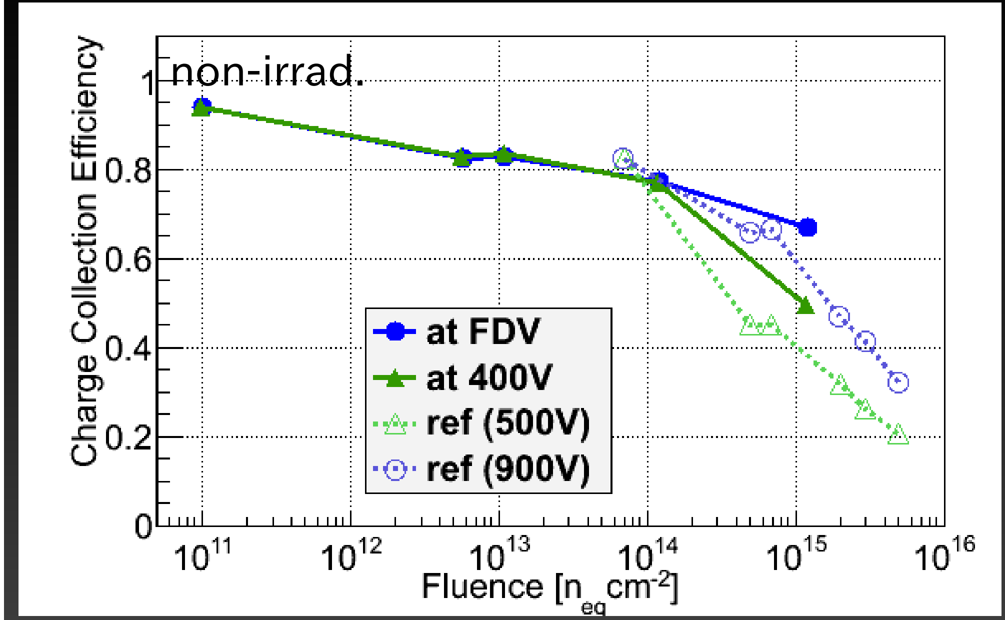


non-irrad.

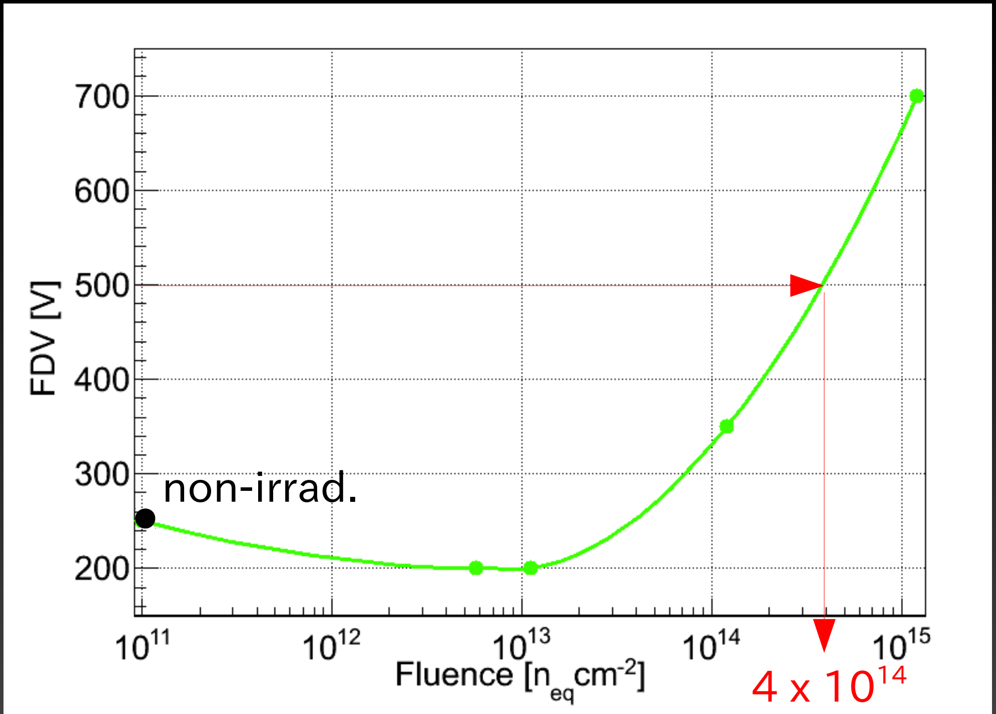
2 x 10^{14} [n_{eq} cm^{-2}]

Charge Collection ~~Efficiency~~ of p-in-n sensors (Present)

5.Charge Collection Efficiency



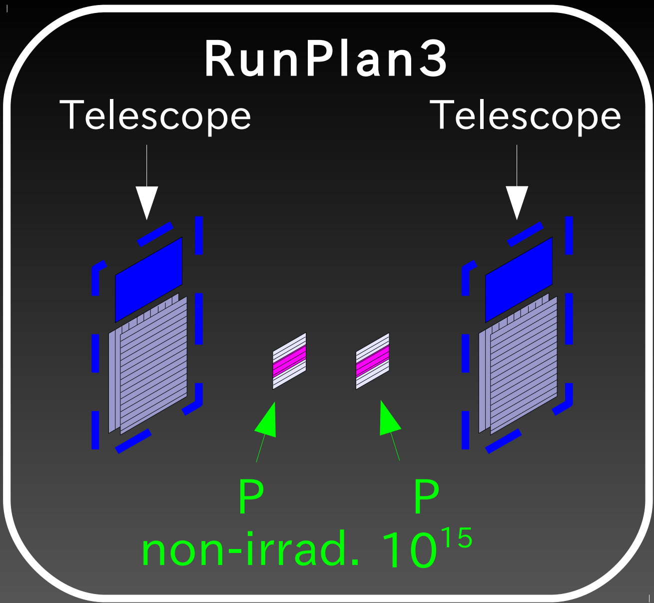
Ref data from
A. Affolder "Collected charge of planar silicon detectors after pion and proton irradiations up to 2.2 x 10^{16} n_{eq} cm^{-2}"



The CCE(solid line) is in good agreement with the data from β-ray tests(dashed line).

The fluence at FDV 500 V (ATLAS constraint) of n-in-p is higher than the one of p-in-n by ～200%.

6.PTP structure



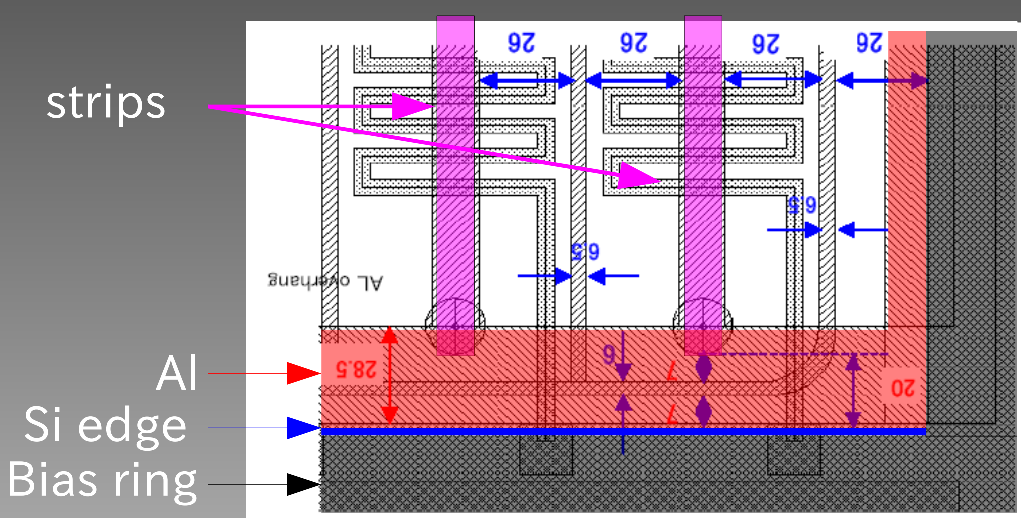
Punch Through Protection(PTP):

This structure is for preventing read-out ASIC from being applied large voltages by beam losses etc …

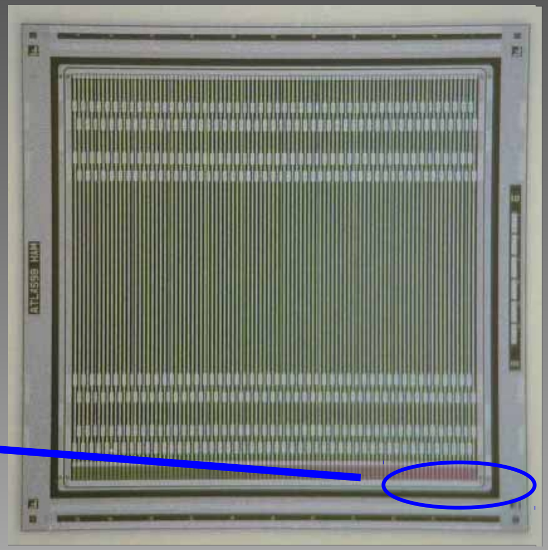
What to check here :

The effects of PTP structure on the active region of the sensors

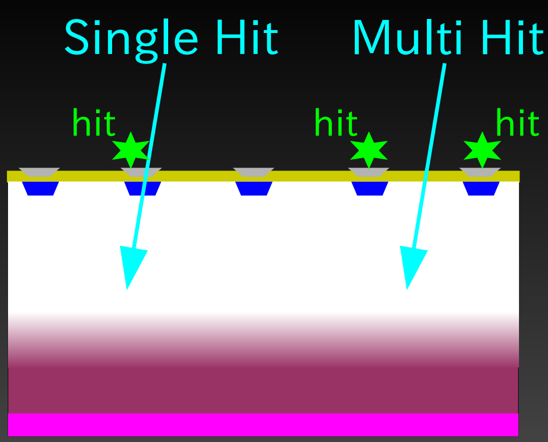
PTP type : FZ4D (best performance in samples)



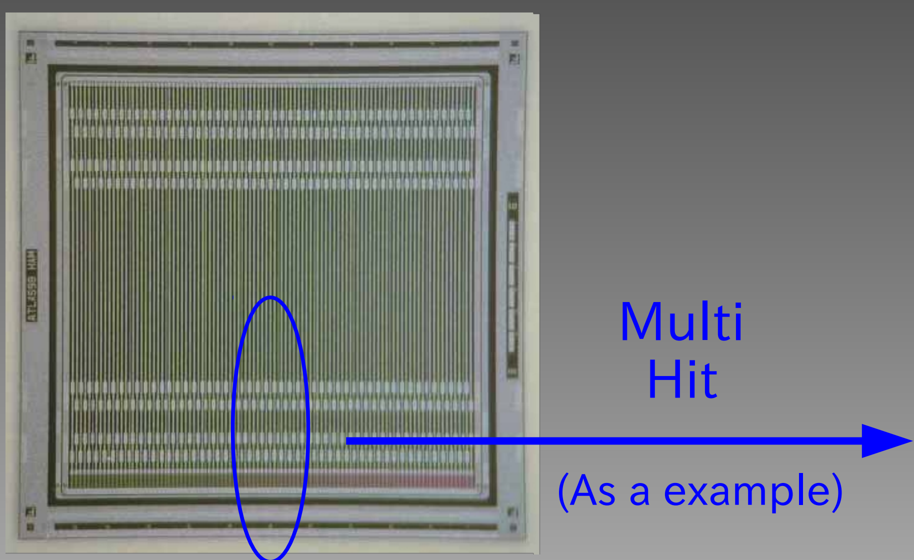
Zoom in the strip edges



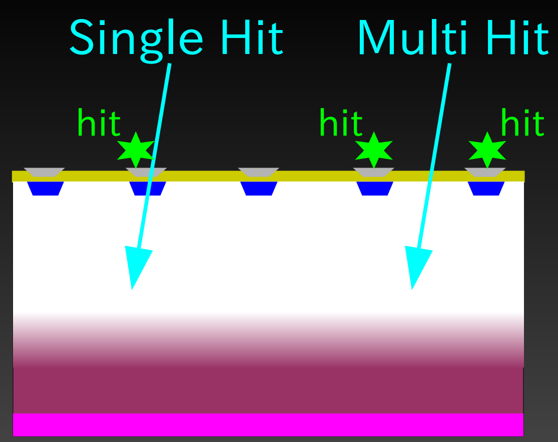
6.PTP structure



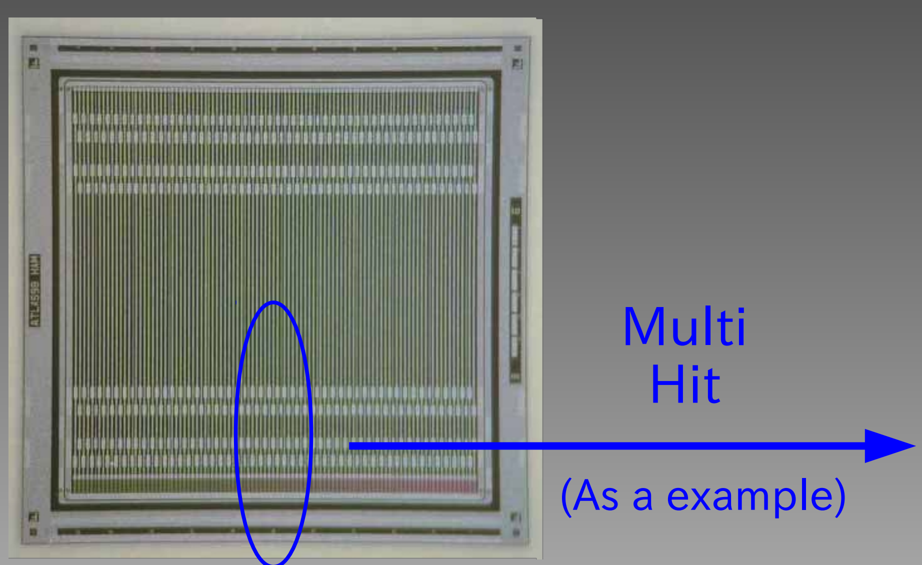
- Single Hit Cluster :
  Clusters consisting of 1 hit strip
- Multi Hit Cluster :
  Clusters consisting of consecutive hit strips

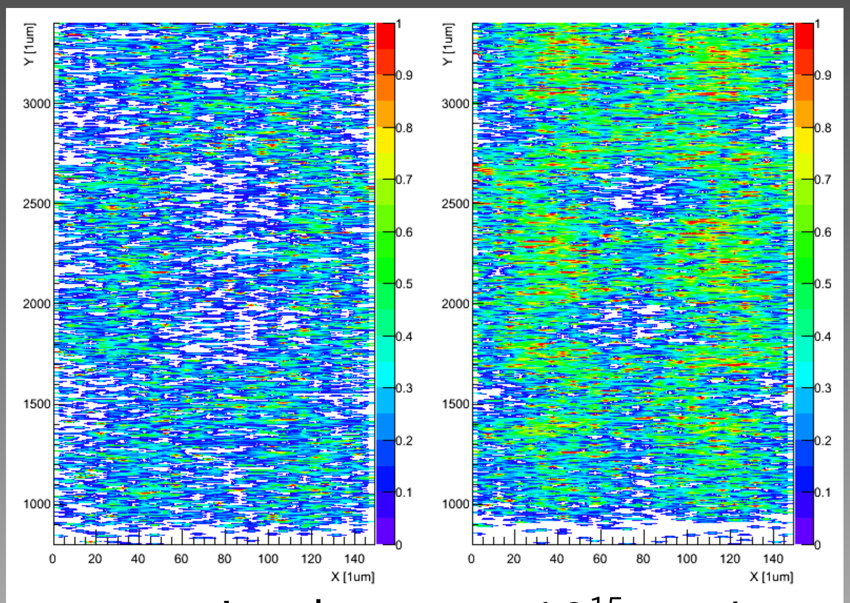


6.PTP structure



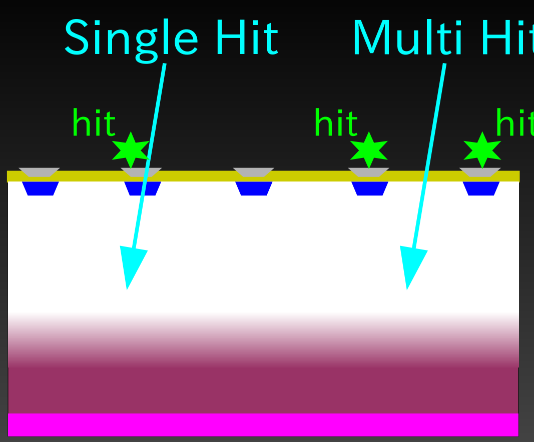
- Single Hit Cluster :
  Clusters consisting of 1 hit strip
- Multi Hit Cluster :
  Clusters consisting of consecutive hit strips





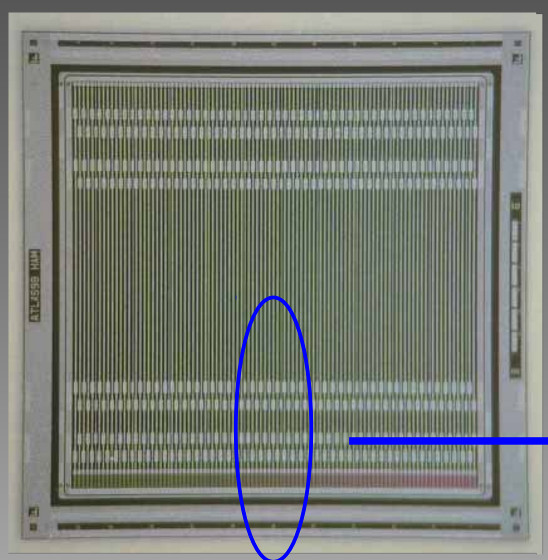
non-irrad. 10^{15} irrad.

6.PTP structure



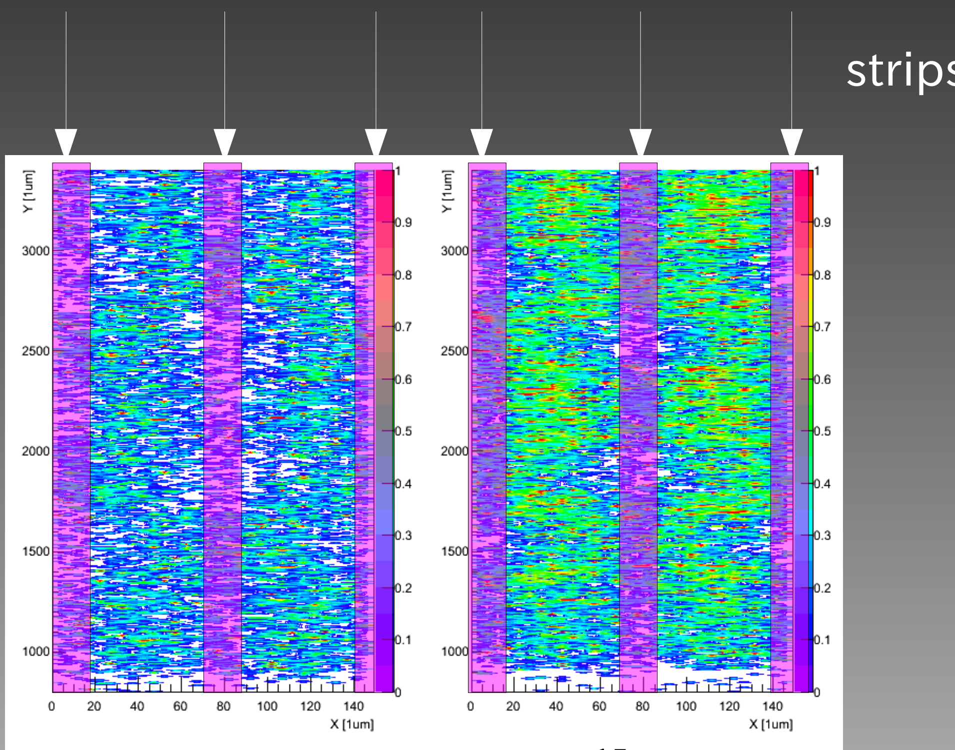
- Multi Hit Cluster :
  Clusters consisting of consecutive hit strips

Hit positions will be intermediate strips



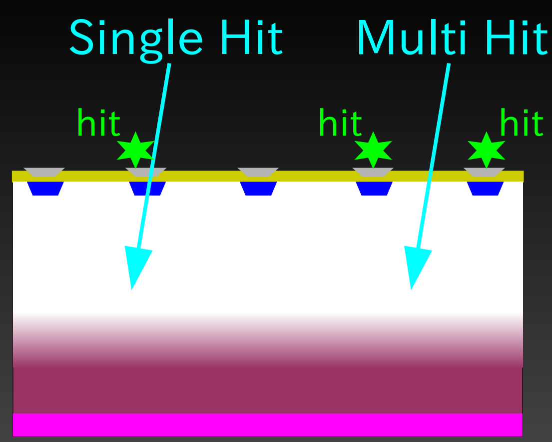
Multi Hit

(As a example)

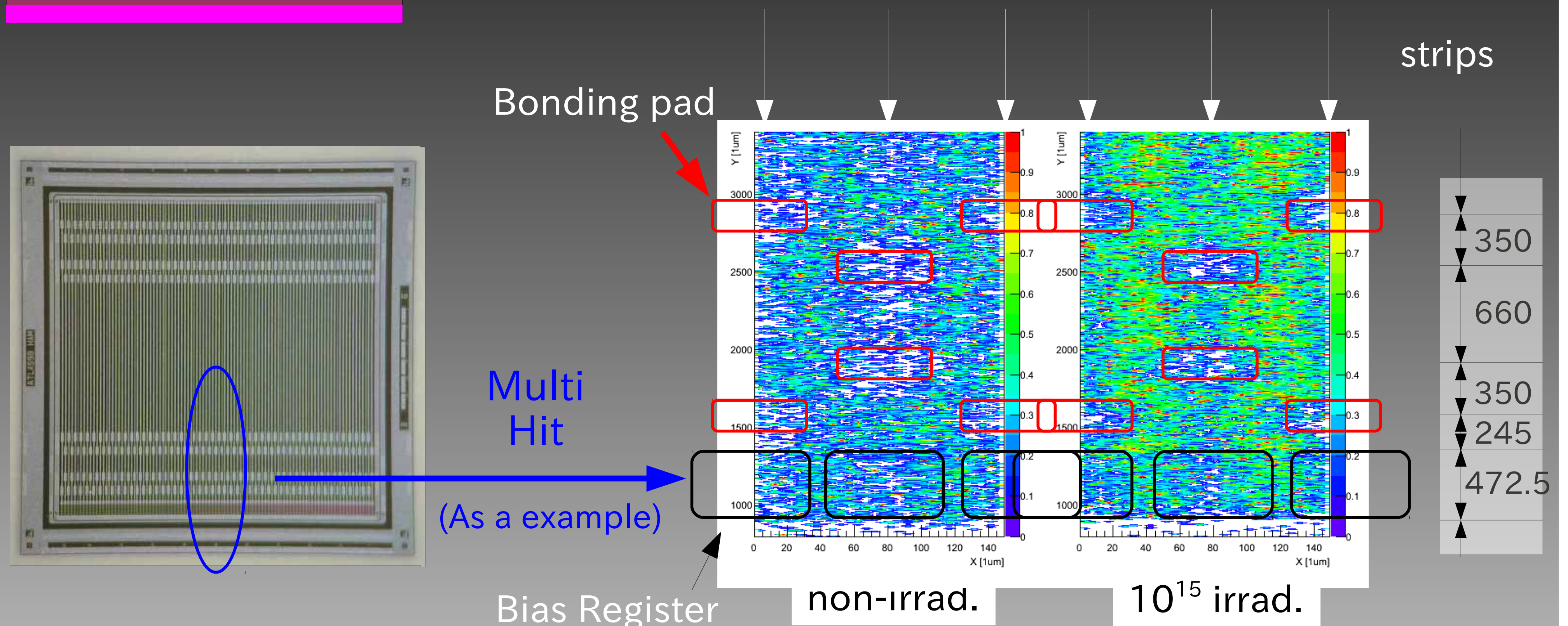


non-irrad. 10^{15} irrad.

6.PTP structure



- The shapes of the “bonding pads” and “bias registers” stand out.
- The position of the bonding pad can be a landmark to measure the active region in the strip end.

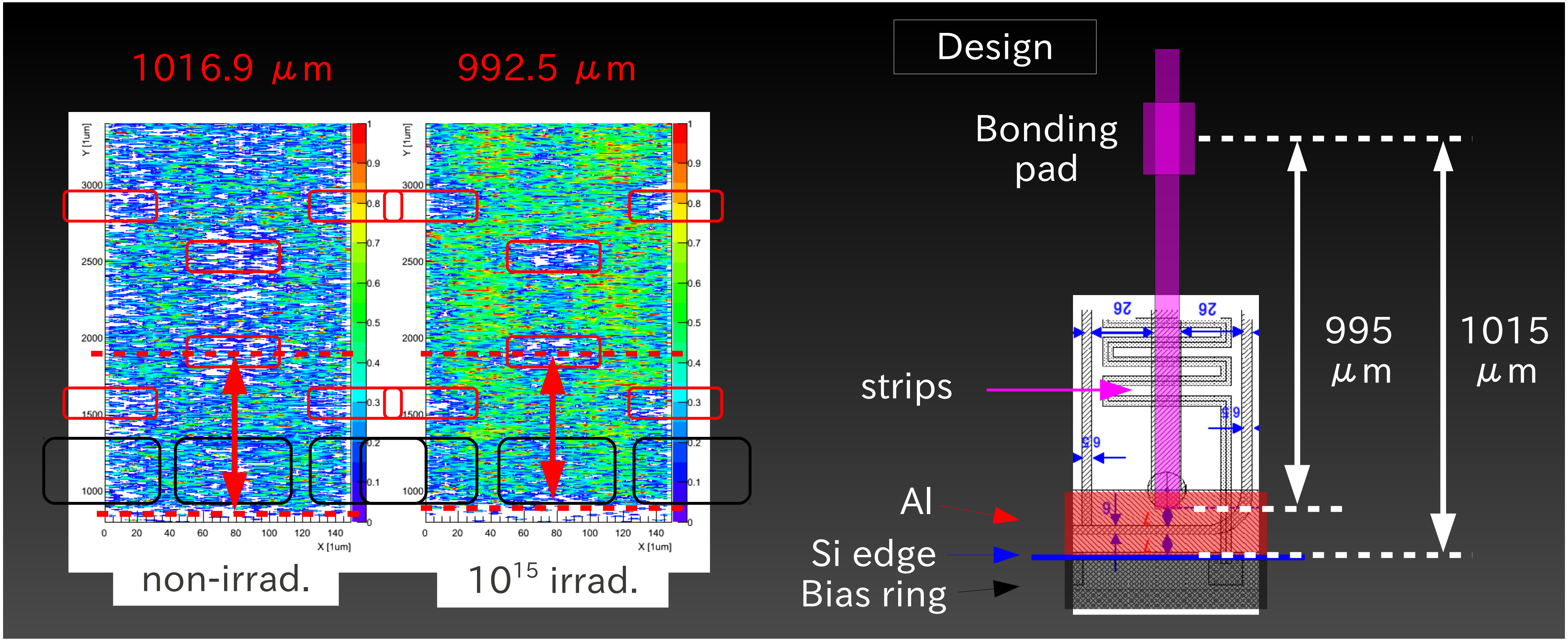


6.PTP structure

The active regions in the strip ends was estimated as lengths from the center of bonding pads

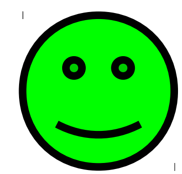
- non-irrad. : 1016.9 +/- 9.5 μm
- 10^{15} irrad. : 992.5 +/- 5.6 μm

The active region on the strip end reached to
the bias rail in the non-irradiated sensor,
the strip end in the irradiated sensor.
(with approx. 10 μm errors)

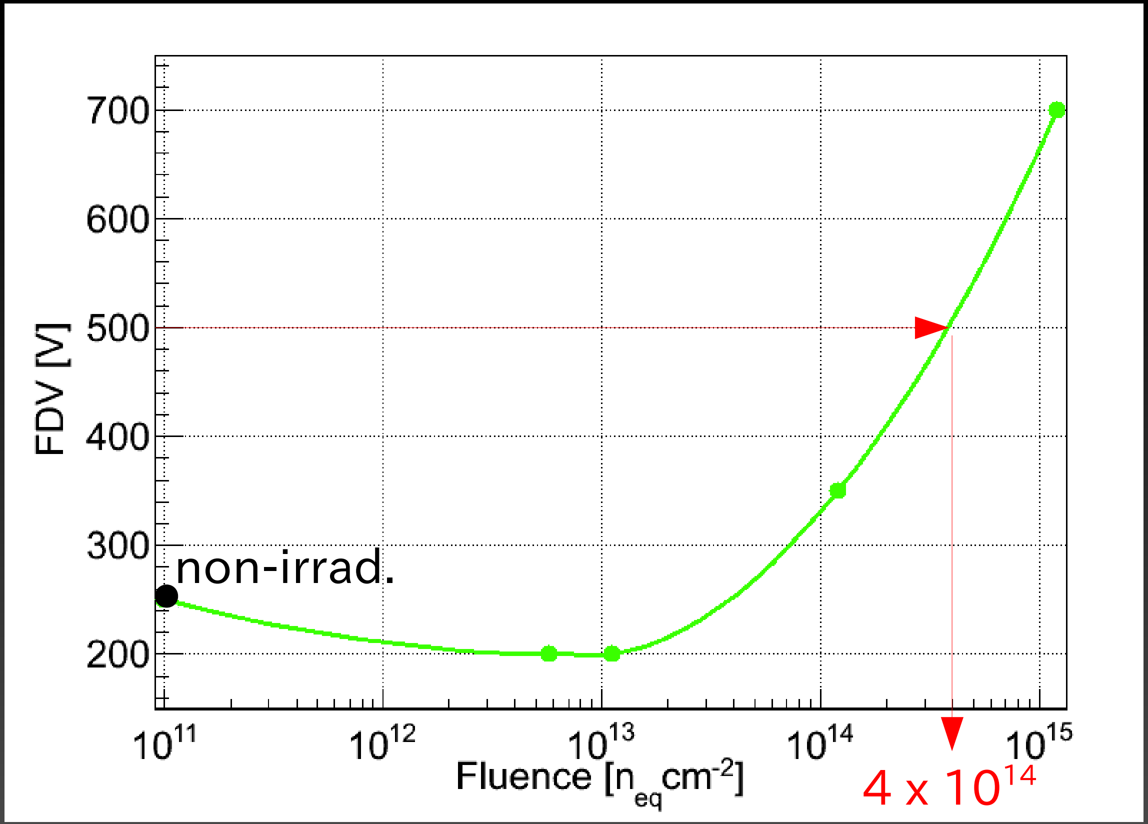


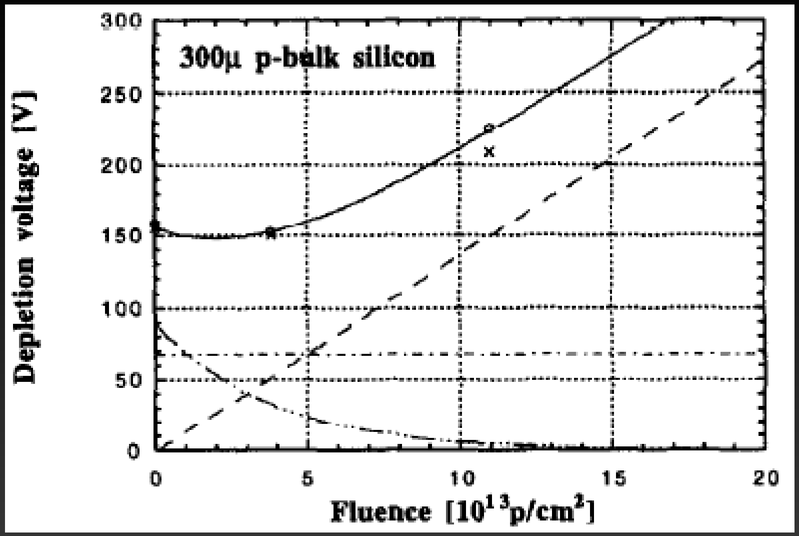
7.Summary

- Results from the beam test of n-in-p silicon strip sensors with ABCN ASICs
  - The charge collection efficiency is in good agreement with the one from β-ray tests.
  - The estimated full depletion voltage of the n-in-p sensor reached to 500 V at fluence 4 x 10^{14} [$n_{eq}cm^{-2}$].
    (Although expected fluence at the upgrades is 10^{15} [$n_{eq}cm^{-2}$], n-in-p sensors do work even if they are not fully depleted.)
  - Compared to the non-irradiated sensor, the active region in the strip end (around the PTP structure) of the 10^{15} irradiated sensor could be considered, with approx. 10 μm errors, to be decreased by the extended aluminum electrode length (20 μm).

- Thank you for listening 

FDV of P type silicon



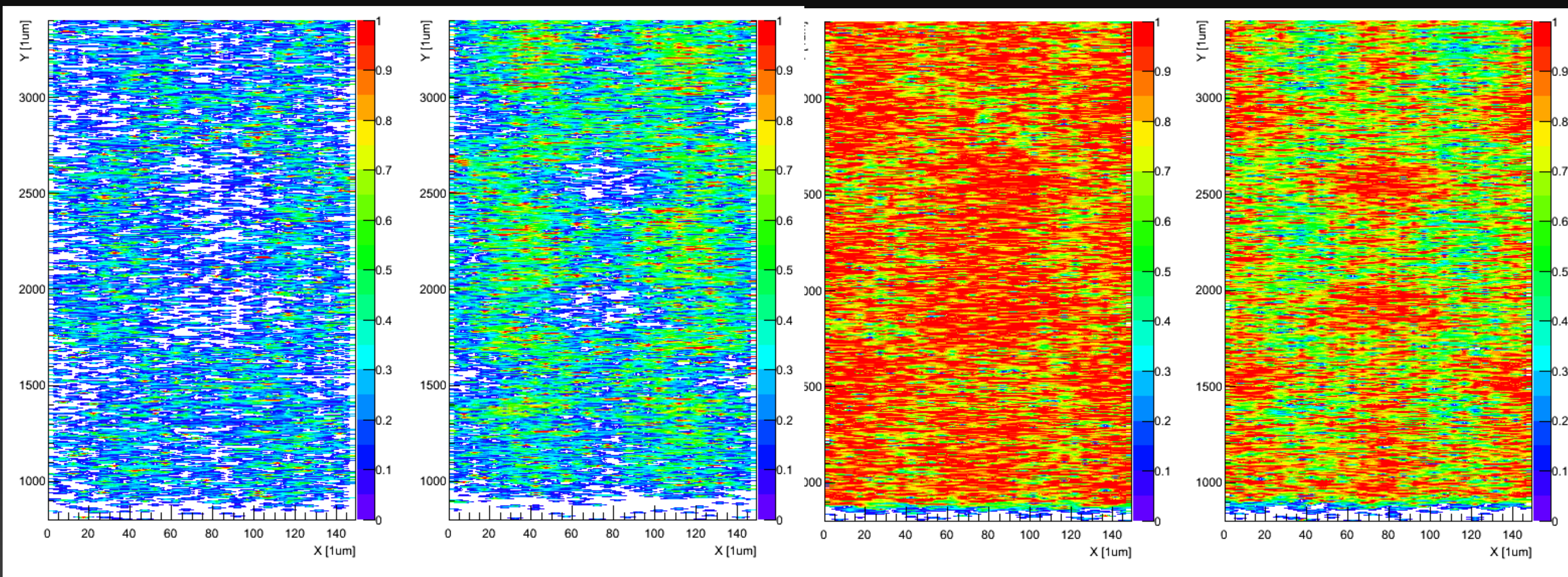


Solid curve :
combining of the three (simulation) dash curves

S. Terada et al “Proton irradiation on p-bulk silicon strip detectors using 12 GeV PS at KEK”

Hit Map in RunPlan3

Multi Hit Cluster | Single Hit Cluster



non-irrad. | 10^{15} irrad. | non-irrad. | 10^{15} irrad.

Bethe-Bloch

$$\frac{-dE}{dx} = \frac{4\pi N_A r_e^2 m_e c^2 z_1^2 Z}{A\beta} \ln \frac{2m_e c^2 \beta^2}{I(1-\beta^2)}$$

From 加藤 貞幸著「放射線計測」　P43

$$4\pi N_A r_e^2 m_e c^2 = 0.3071[MeV/(g/cm^2)]$$
$$A=28$$
$$Z=14$$
$$I=16 Z^{0.9}$$

In this beam test :

- β =0.71
- Proton
- 320 um

$$\frac{-dE}{dx} = 0.305 \times 8.71 = 2.67 [MeV g^{-1} cm^2]$$

$$dE = 2.67 \times 2.33 \times 320 \times 10^{-4} = 199\, keV$$

$$199\, keV \times 0.75 \div 3.62 = 41229\, e = 6.6\, fC$$

MP of Landau　E for e-h pair

MIP electron(ref):

- β =0.95
- Electron
- 300 um

$$\frac{-dE}{dx} = 0.170 \times 10.91 = 1.85 [MeV g^{-1} cm^2]$$

$$dE = 1.85 \times 2.33 \times 300 \times 10^{-4} = 129\, keV$$

$$129\, keV \times 0.75 \div 3.62 = 26727\, e = 4.3\, fC$$