New CCD driving method of Xtend onboard the XRISM satellite for suppressing external charge intrusion

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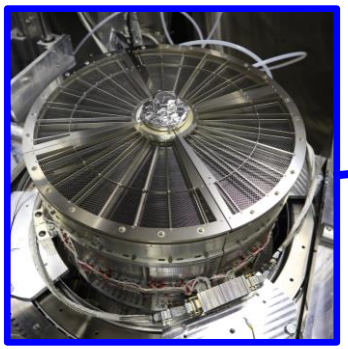
At Tanegashima Space Center on September 7th,2023

- Scientific goals to investigate
  - Structure formation of the Universe and evolution of clusters of galaxies
  - Circulation history of baryonic matter in the Universe
  - Transport and circulation of energy in the Universe
- Instruments
  - **Resolve** = XMA (X-ray Mirror Assembly) + SXS (X-ray micro calorimeter)

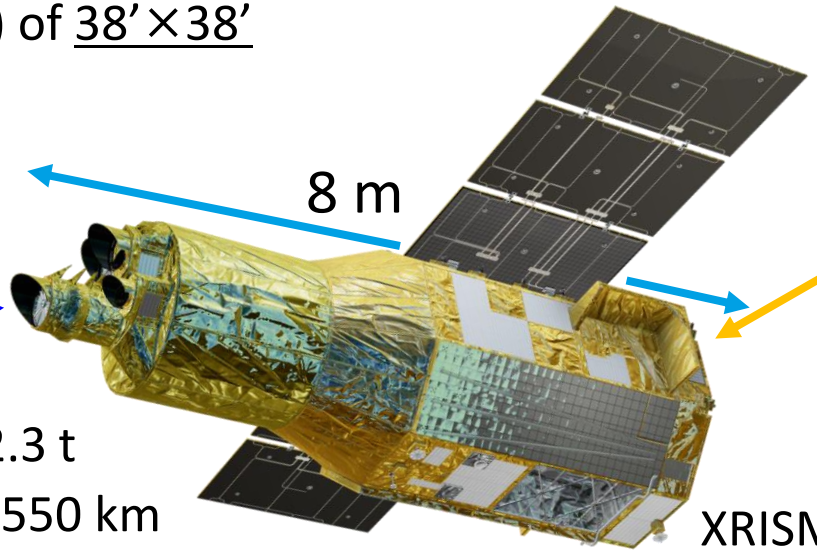
☆High energy resolution of 7 eV FWHM at 5.9 keV

  - **Xtend = XMA + SXI (X-ray CCD Camera)**

☆Large field of view(FoV) of 38’×38’



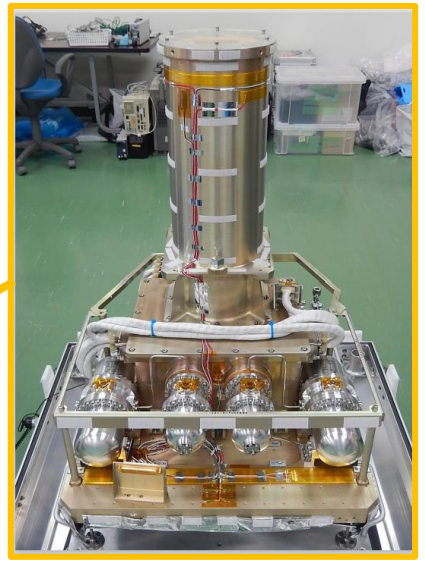
XMA



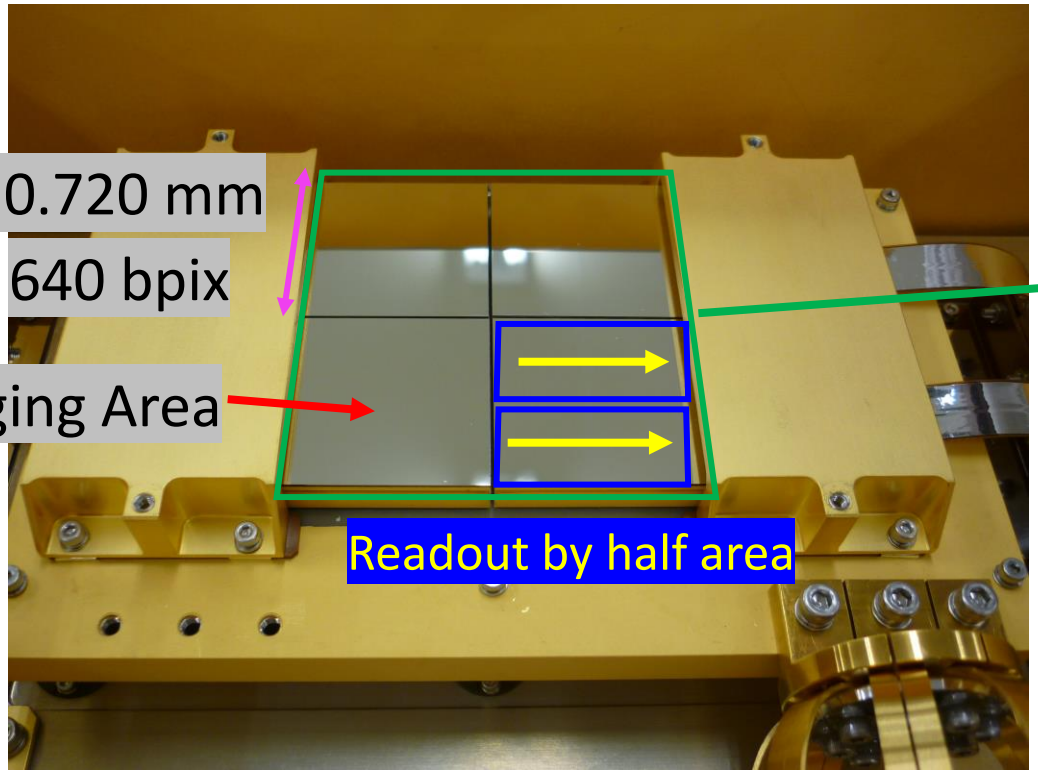
weight:2.3 t

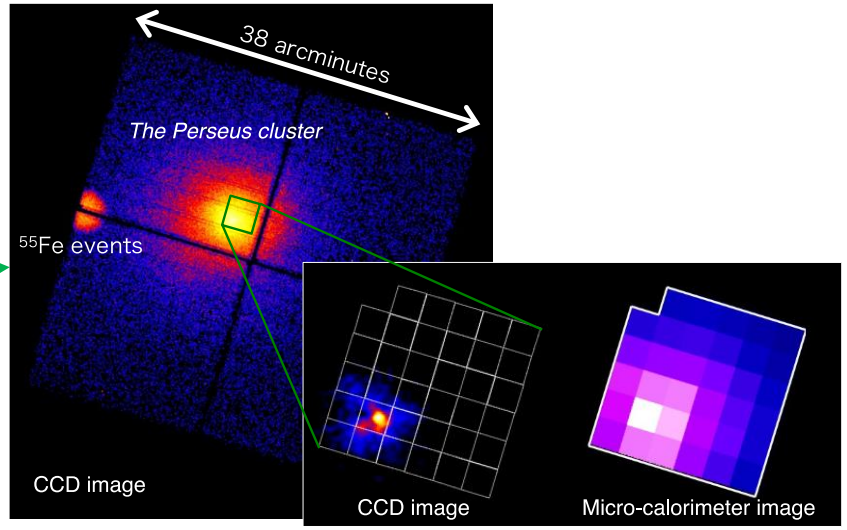
altitude:550 km

XRISM

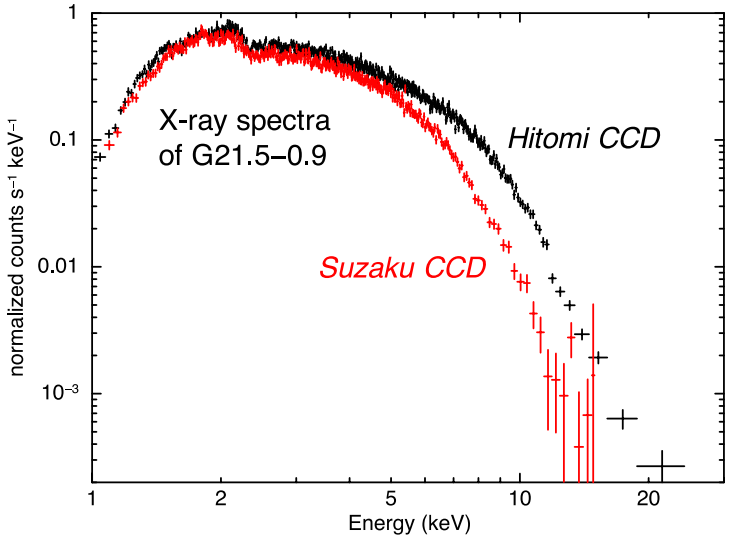


Xtend



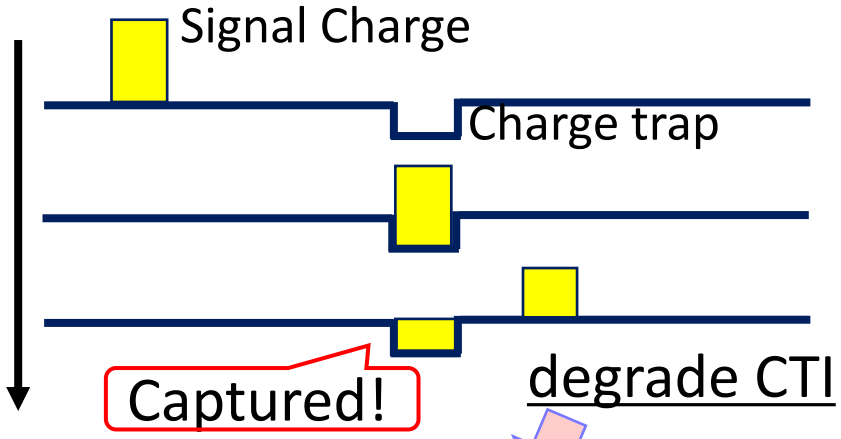


- Exposure：4 sec
- Energy range : 0.4 - 13 keV
- Back side illuminated type
- Depletion layer ：200 um

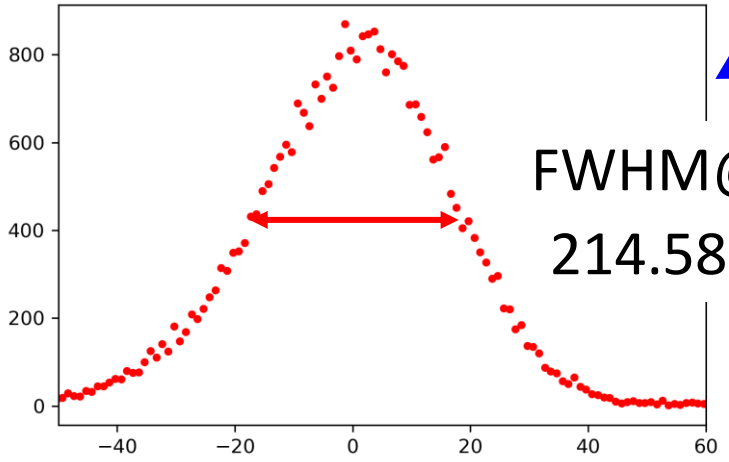


Charge Injection (CI)

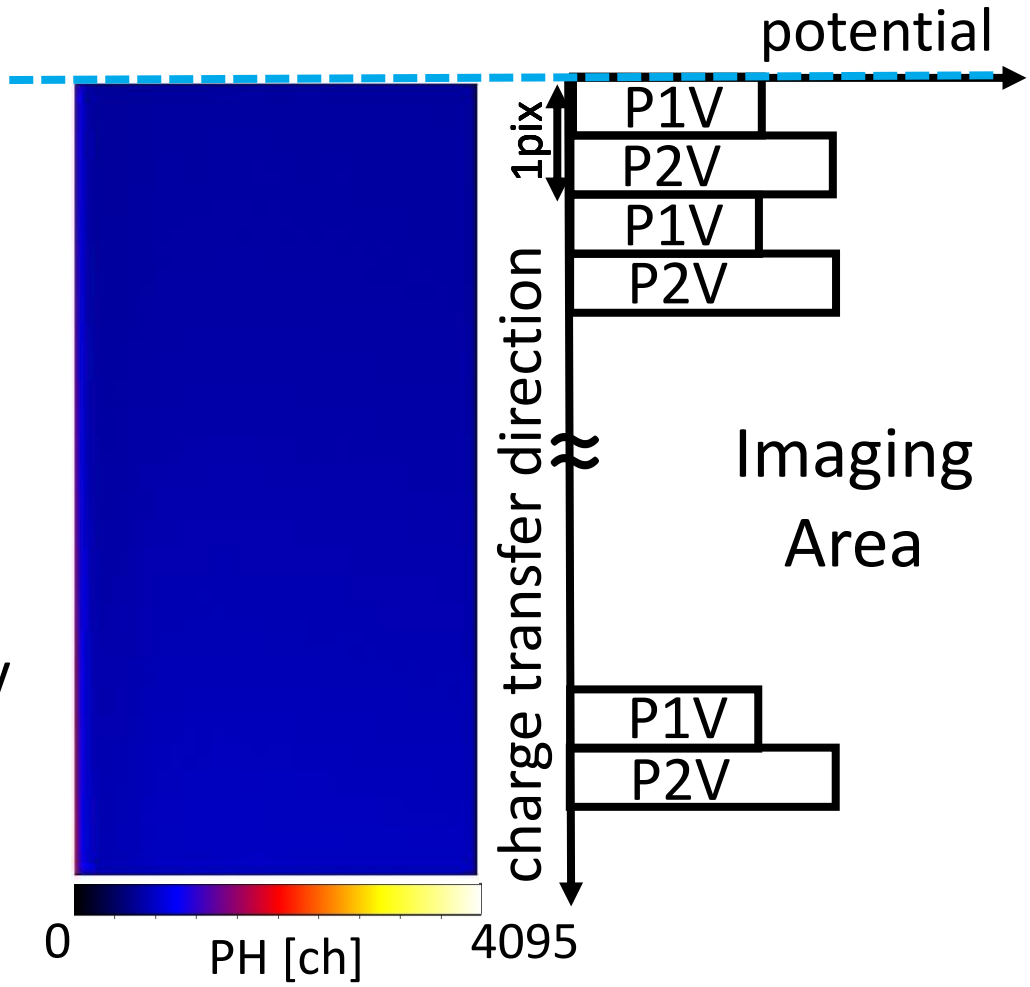
Charge Transfer Inefficiency (CTI) : Percentage of charge lost/transfer



degrage FWHM

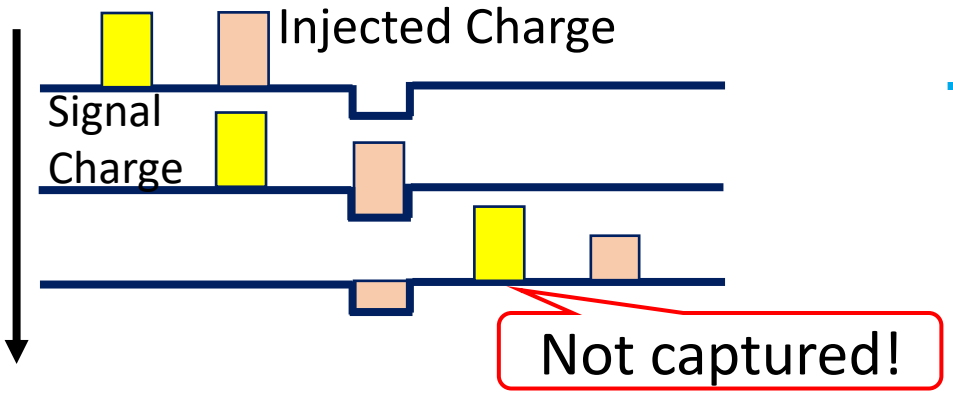


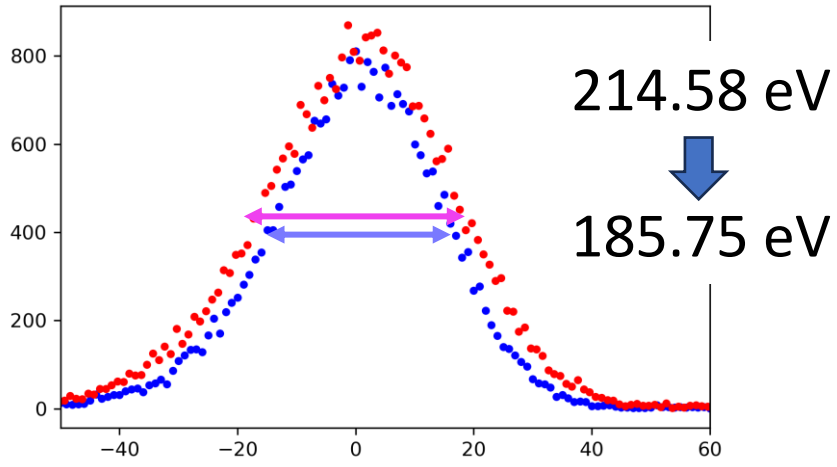
FWHM@5.9keV
214.58 eV

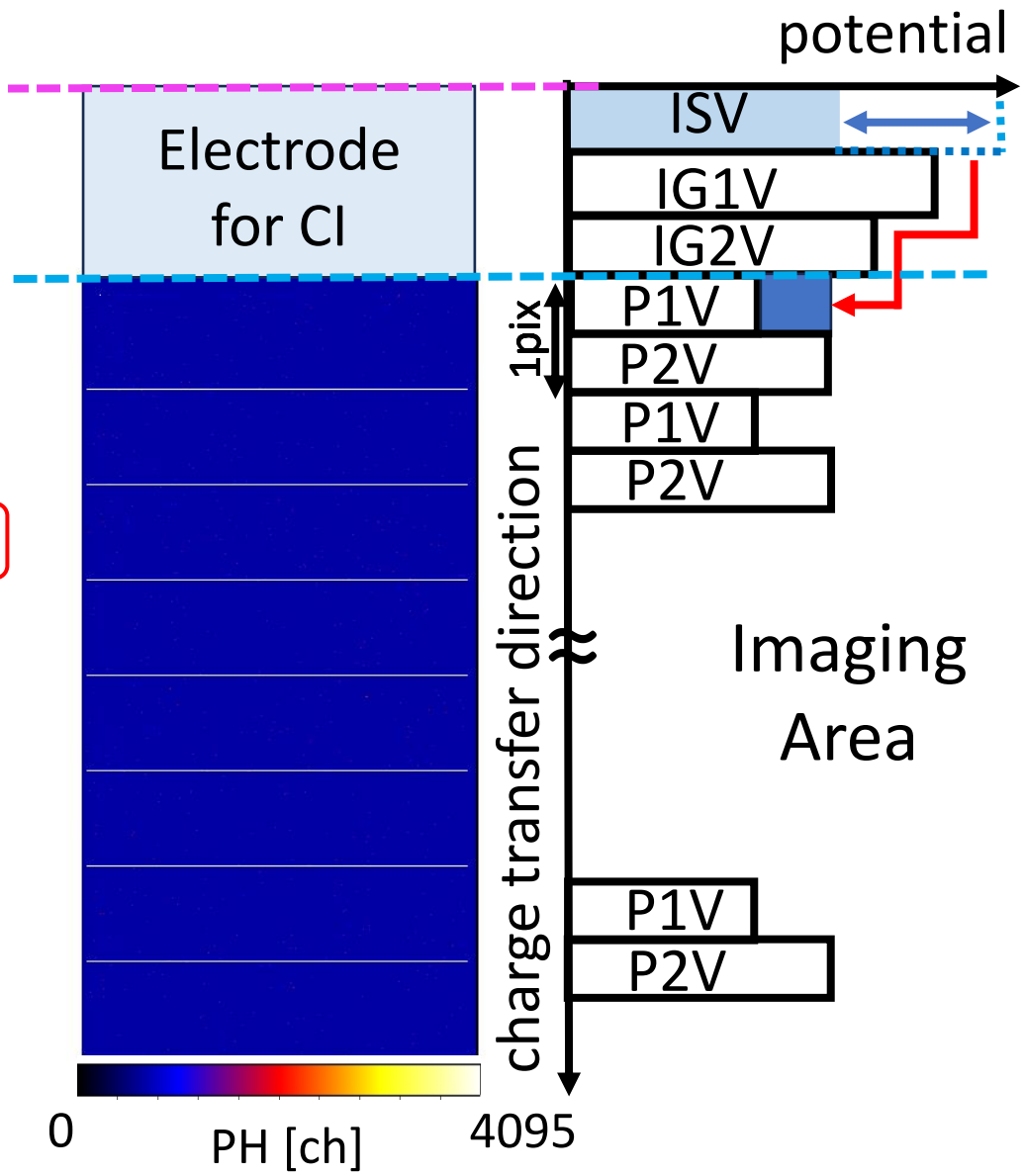


Charge Injection （CI）

Filling charge traps by
artificially injecting charge







Anomaly event

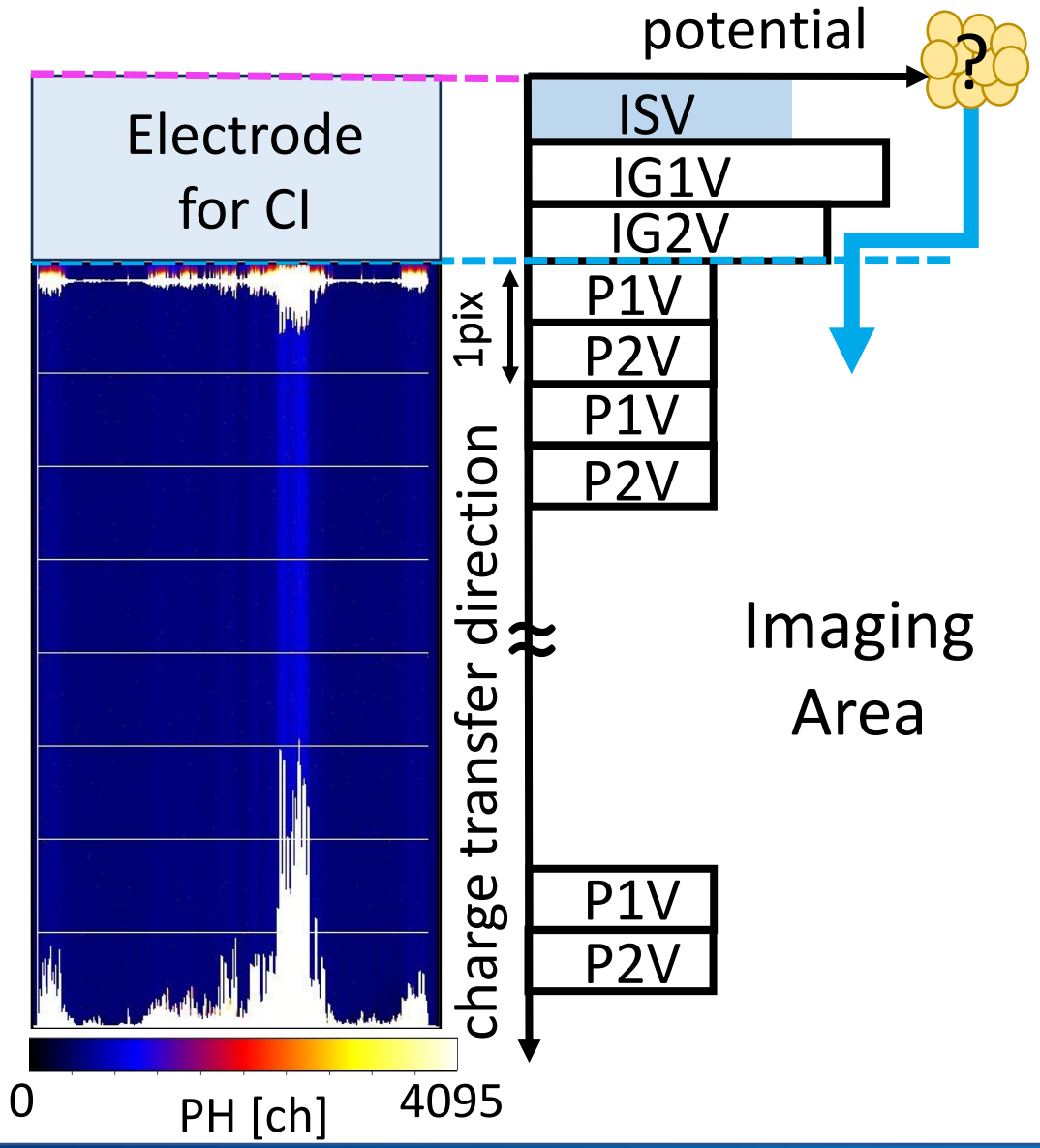
CI is important function, but…

Anomaly event occurred as shown the frame image on the right.

- thorough the electrode for CI
- not always occurs

Replacing chips

need to take measures in case anomaly occurs in orbit

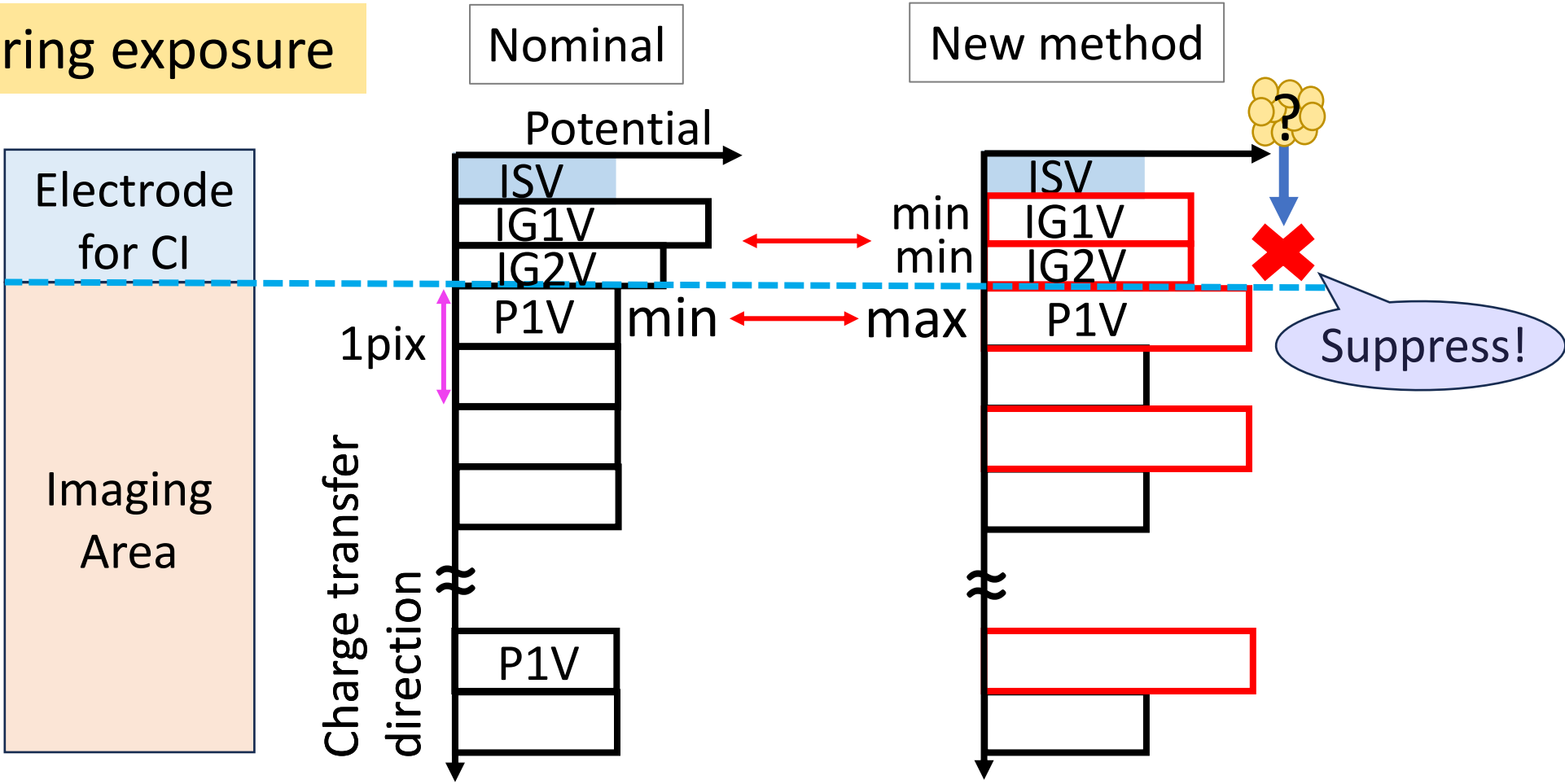


New CCD driving method

Important points

①Suppressing charge intrusion
②Maintaining spectroscopic performance

During exposure



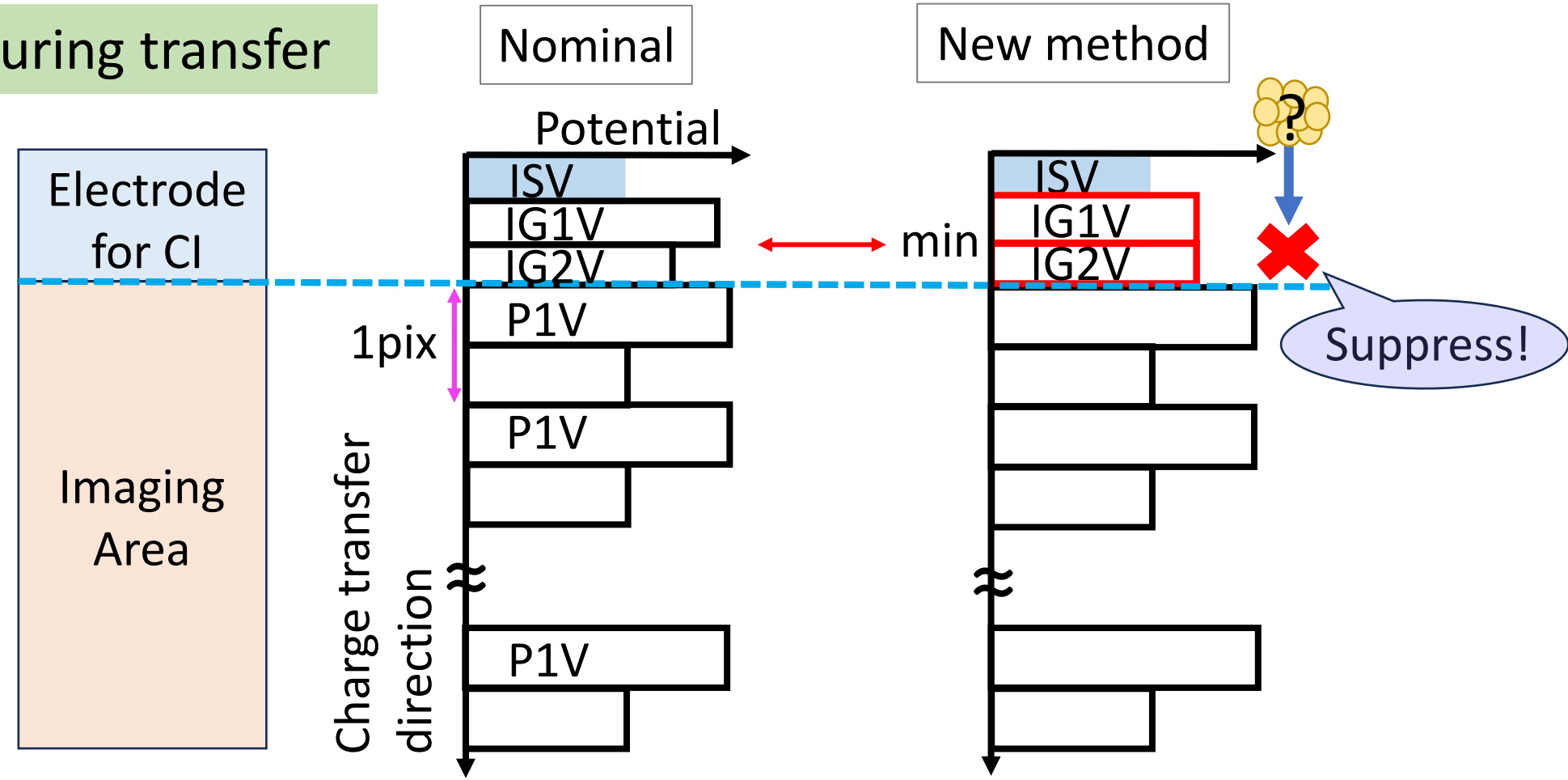
New CCD driving method

Important points

①Suppressing charge intrusion

②Maintaining spectroscopic performance

During transfer



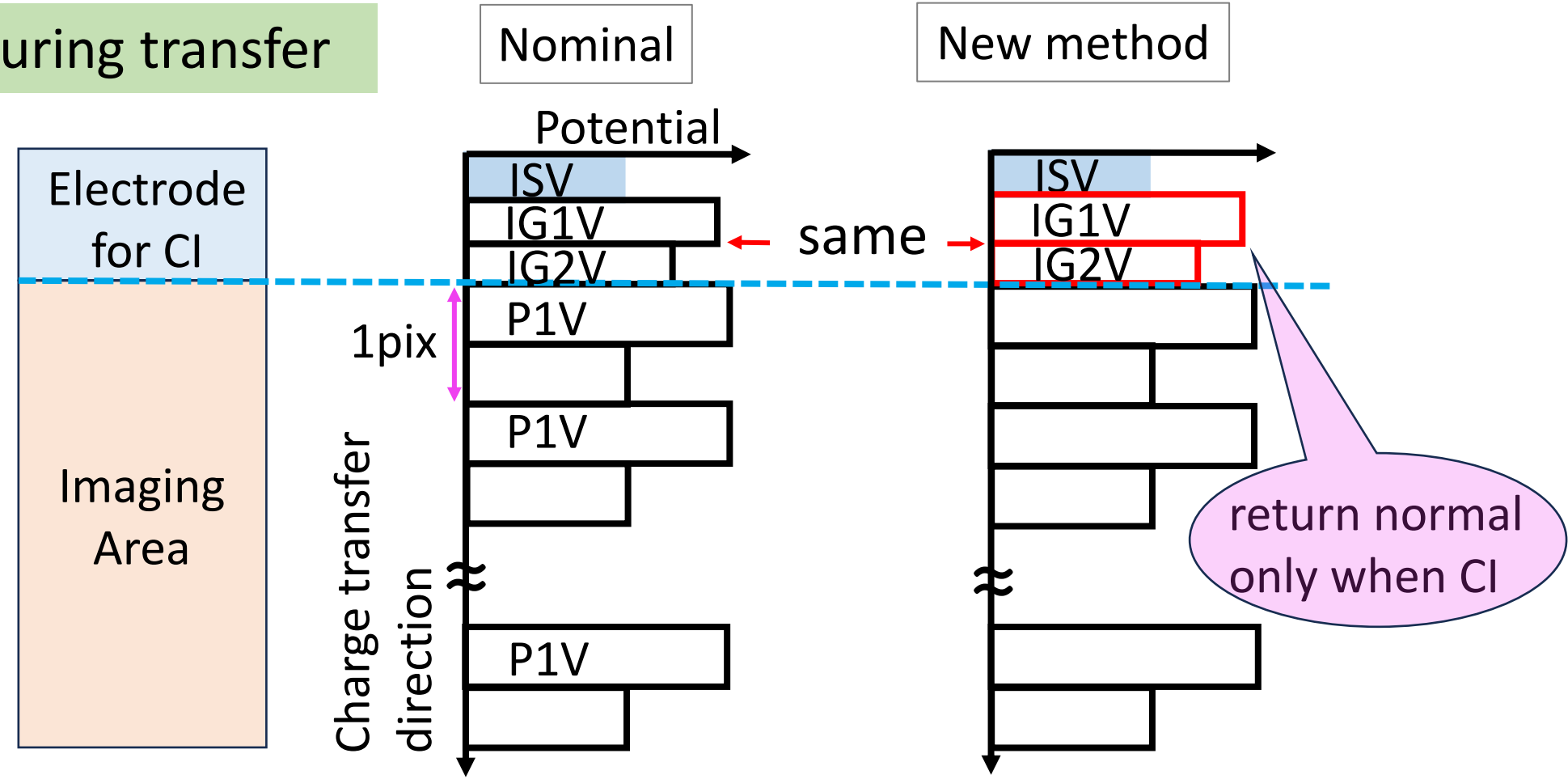
New CCD driving method

Important points

①Suppressing charge intrusion

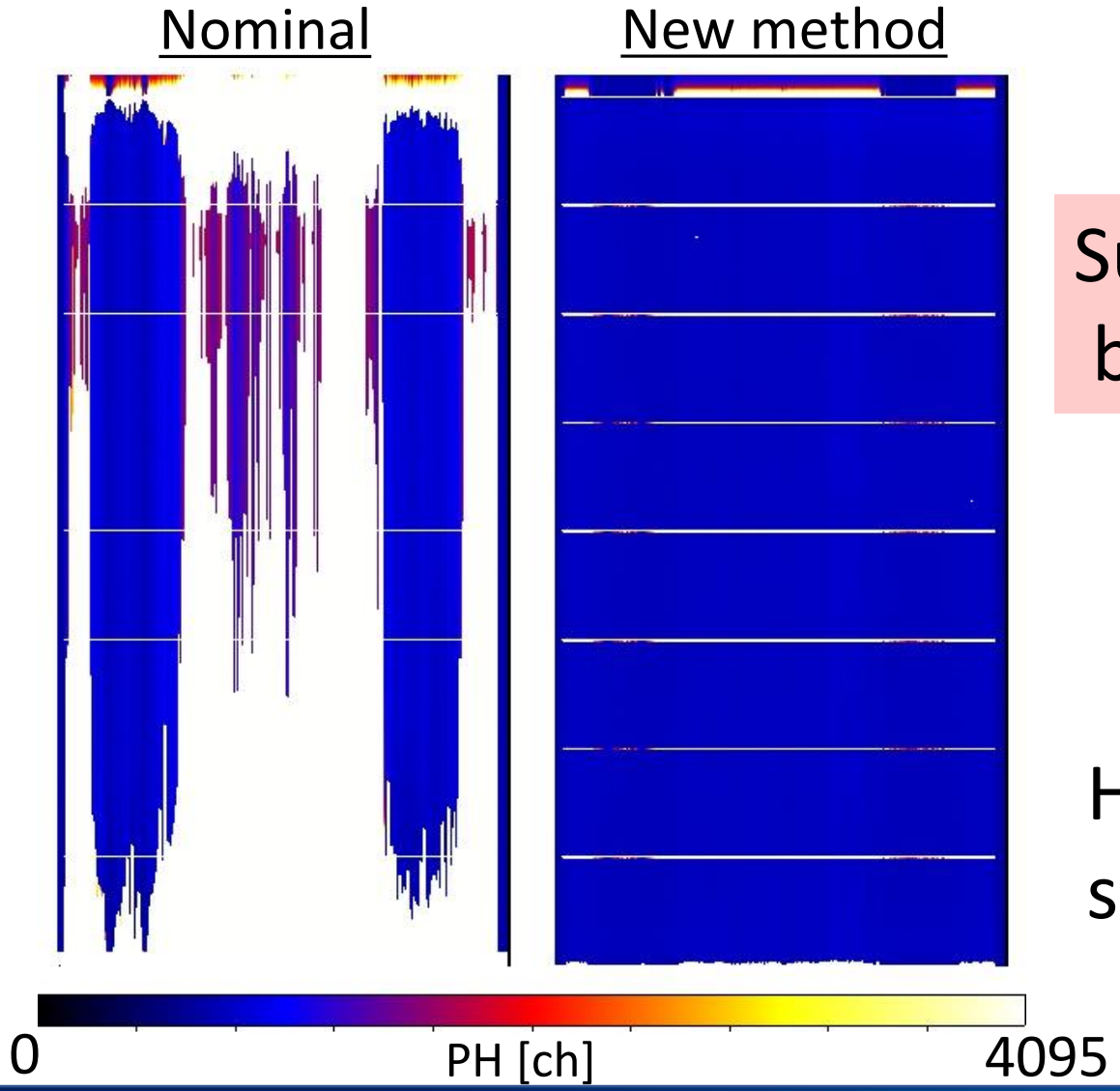
②Maintaining spectroscopic performance

During transfer



Evaluate anomaly reduction

In a clean booth at Osaka University in FY2021



Suppressing Anomalies by new method !!

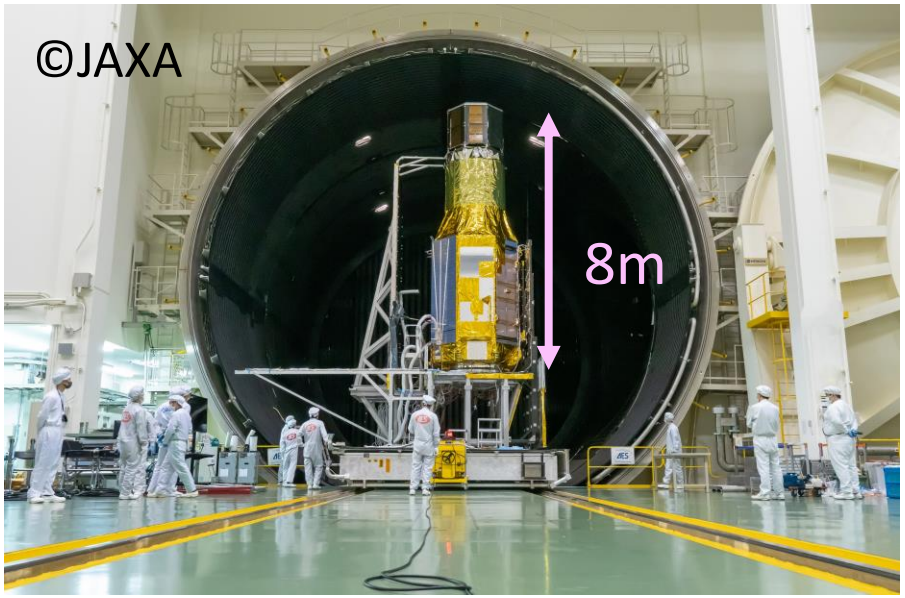
How about spectral performance??

Spectral performance of flight model

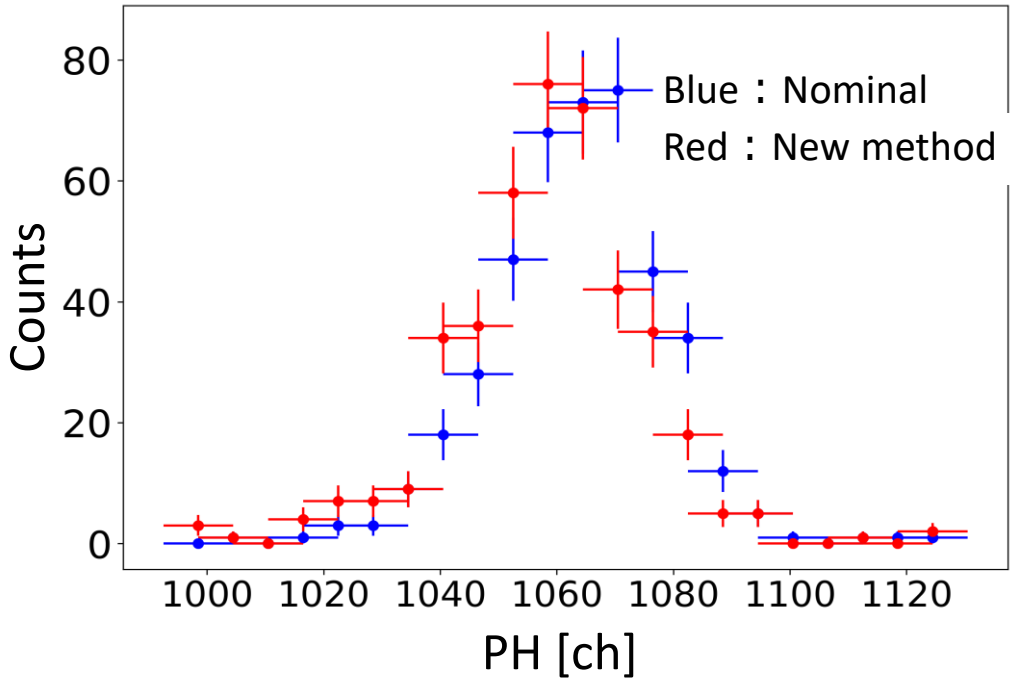
In Satellite Thermal Vacuum Test at Tsukuba Space Center in August 2022

- Exam period：August 5th – 25th ,2022
- Degree of vacuum：~10e-8 Torr
- CCD temperature： -110℃

Xtend was already onboard XRISM



Spectra of 5.9keV emission line



Spectroscopic performance equivalent to nominal method

Launch

Thanks to new CCD driving method,

We could finish developing SXI on ground.

Let’s launch !!

If anomalies occur in orbit,
We use the new method!

Summary

◆ Charge intrusion anomaly occurred.

➡Developed a new method for suppressing charge intrusion and maintaining spectral performance

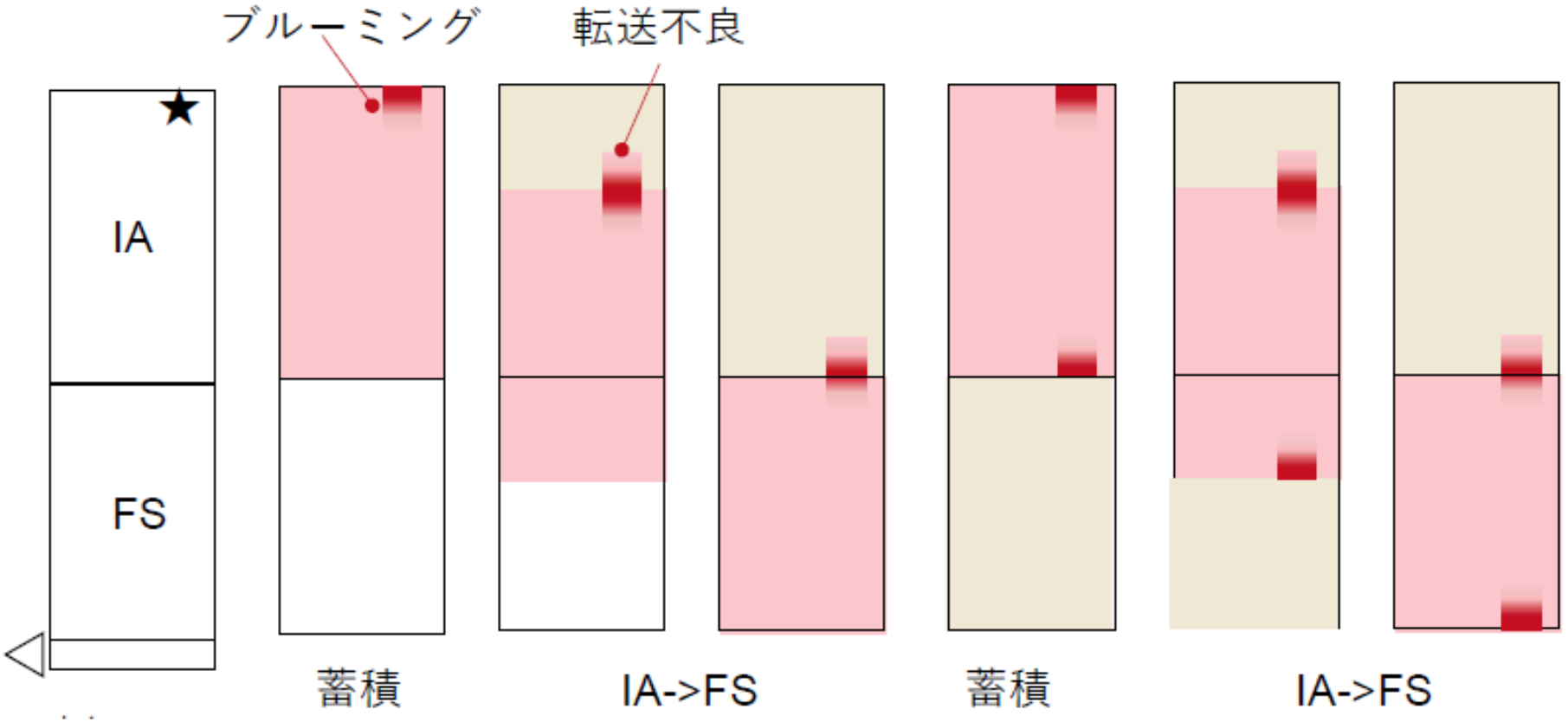
◆ Evaluated performance of new method in Osaka Univ. in FY2021 and satellite Thermal Vacuum Test (TVT) in August,2022

➡Spectral performance equivalent to normal method and consistent to Osaka Univ. results

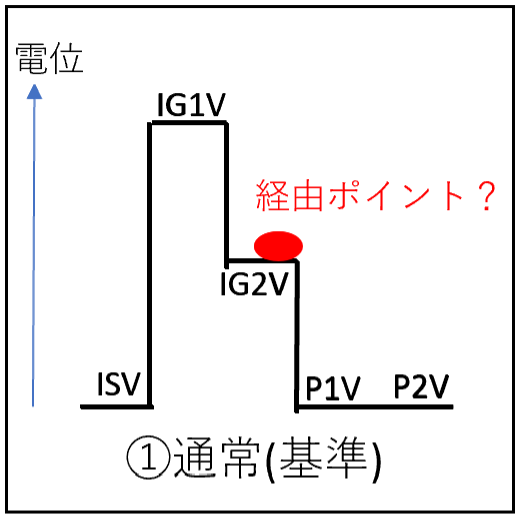
◆ Launched from Tanegashima Space Center on September 7th,2023

APPENDIX

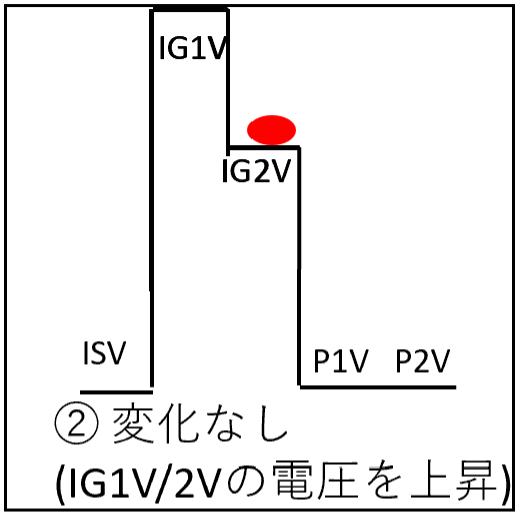
Formation of anomalies



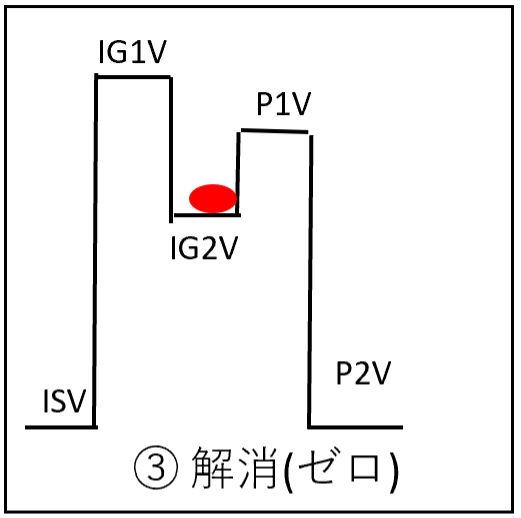
Experiments to identify intrusion routes



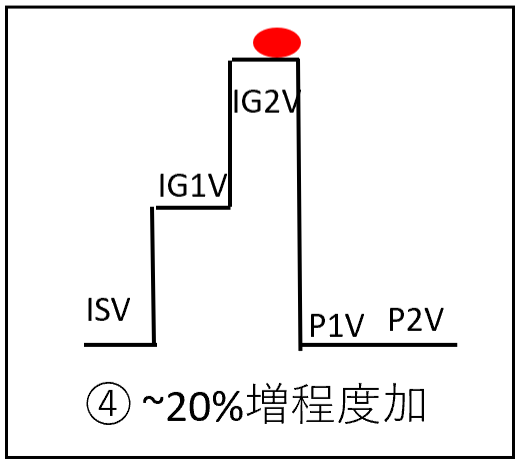
①通常(基準)



② 変化なし
(IG1V/2Vの電圧を上昇)



③ 解消(ゼロ)



④ ~20%増程度加

電場勾配を変えてCCD端(P1V/P2V)に蓄積する電荷量を測定。

② IG1Vから外(ISV側)からの電荷侵入を防ぐためにIG1V/2V電圧を高くしたが顕著な変化は無し

③IG2V経由とするならP1Vで止めればよいと考えて試験。効果あり。

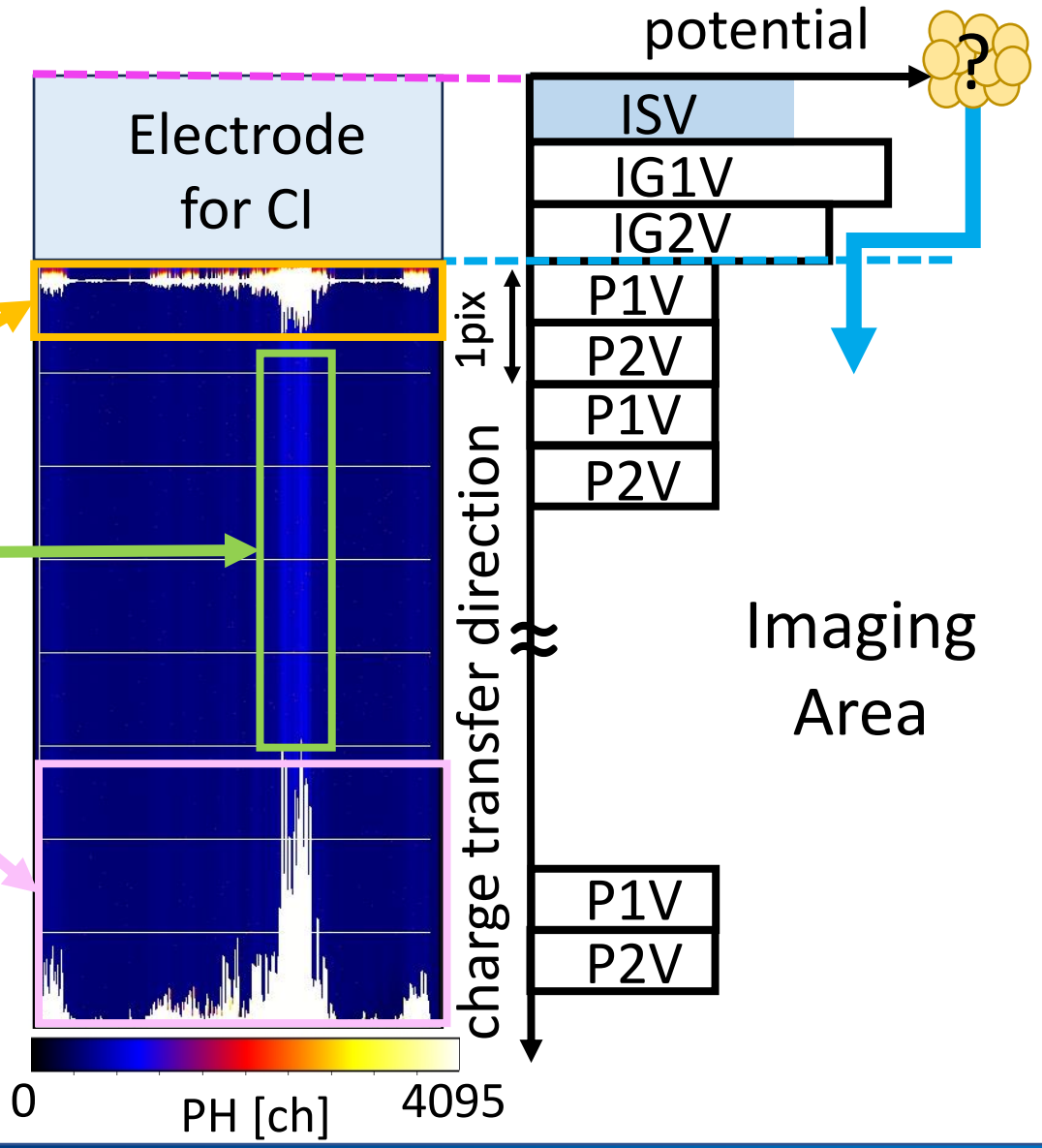
④ IG2V経由とするならある程度の電荷がISV側へ逃げる(CCD端電荷は減少)と期待したがむしろ増加。IG2V/P1V間の電位差が大きくなったことで増加した可能もある。

Anomaly event

Leakage of charge piled up at the edge of CCD

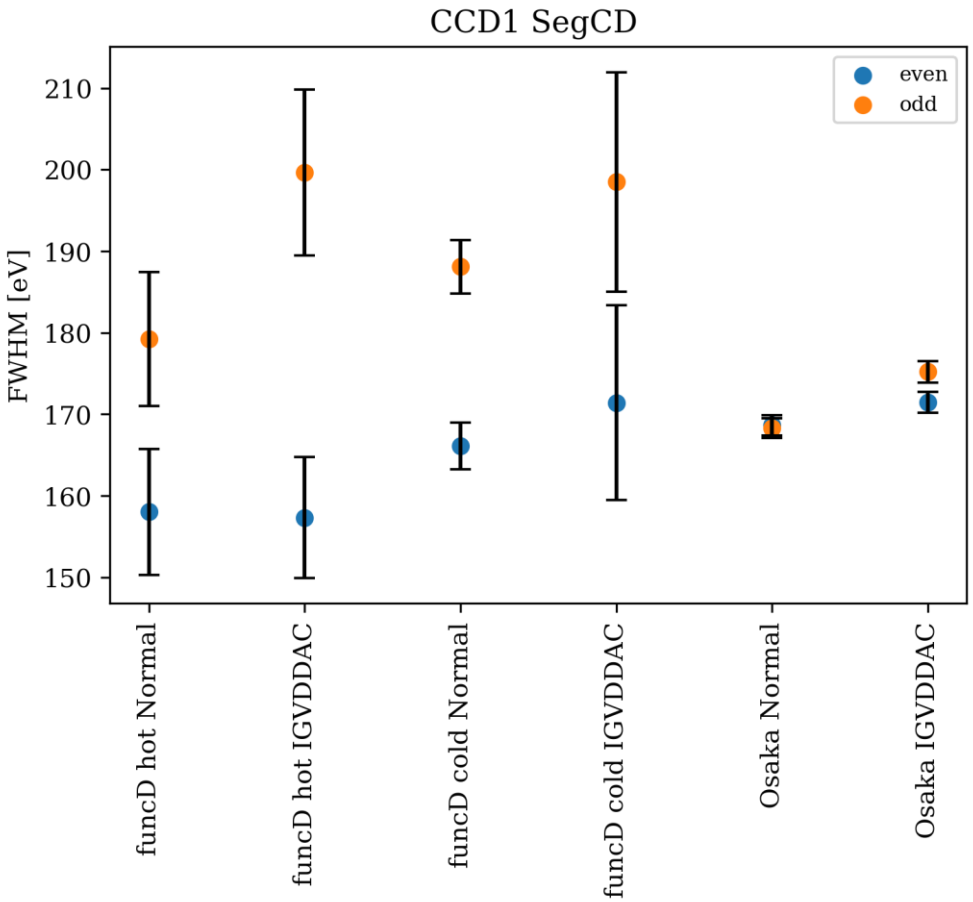
Charge intrusion during transfer

Remaining charge not fully transferred

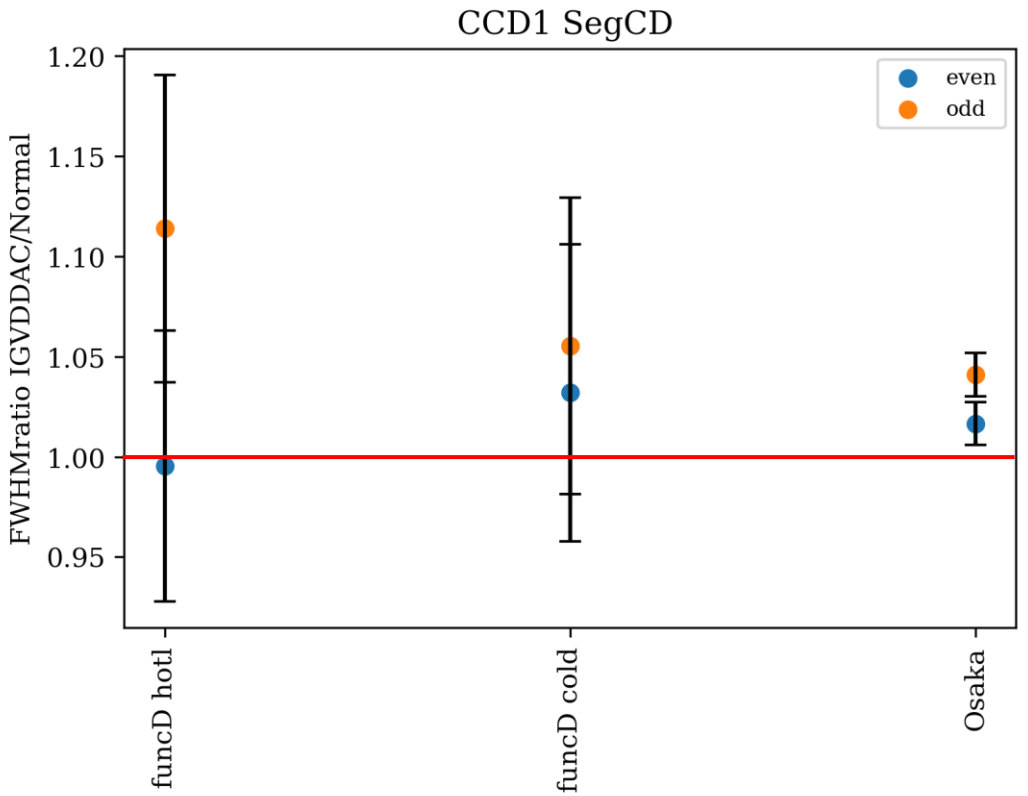


Spectral performance （CCD1CD）

FWHM

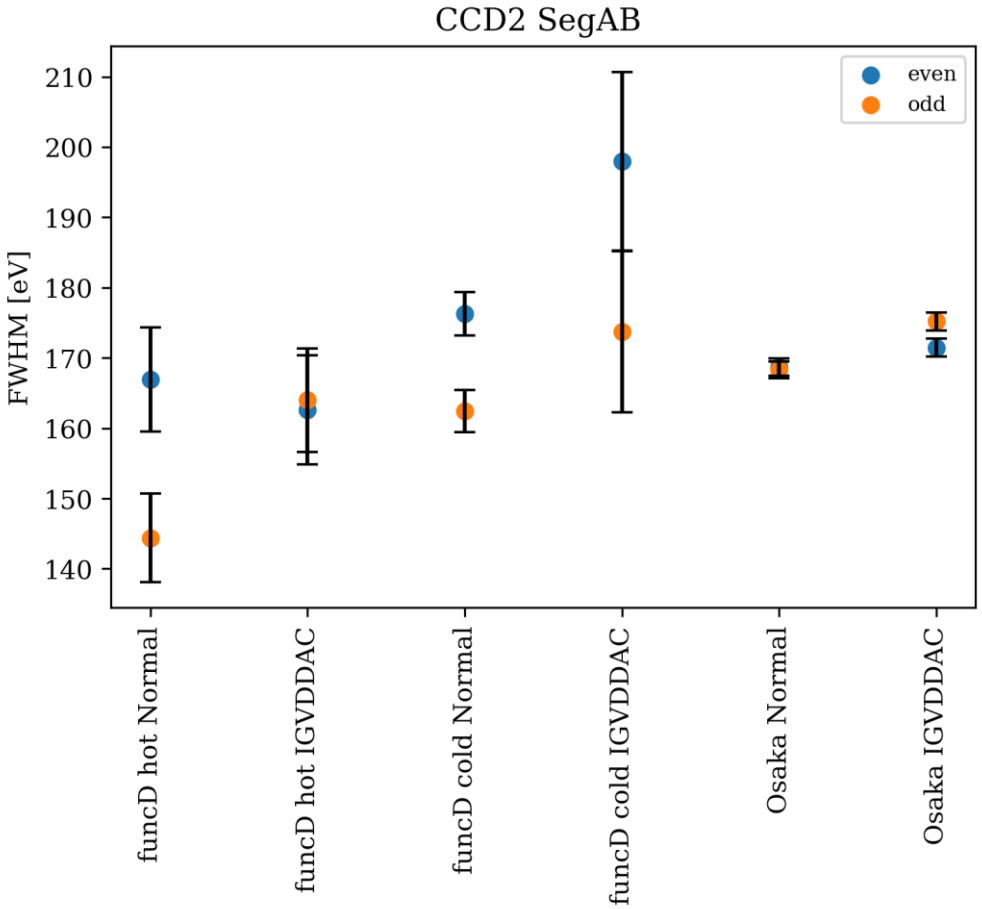


$FWHM_{New\ method}/FWHM_{Normal\ method}$

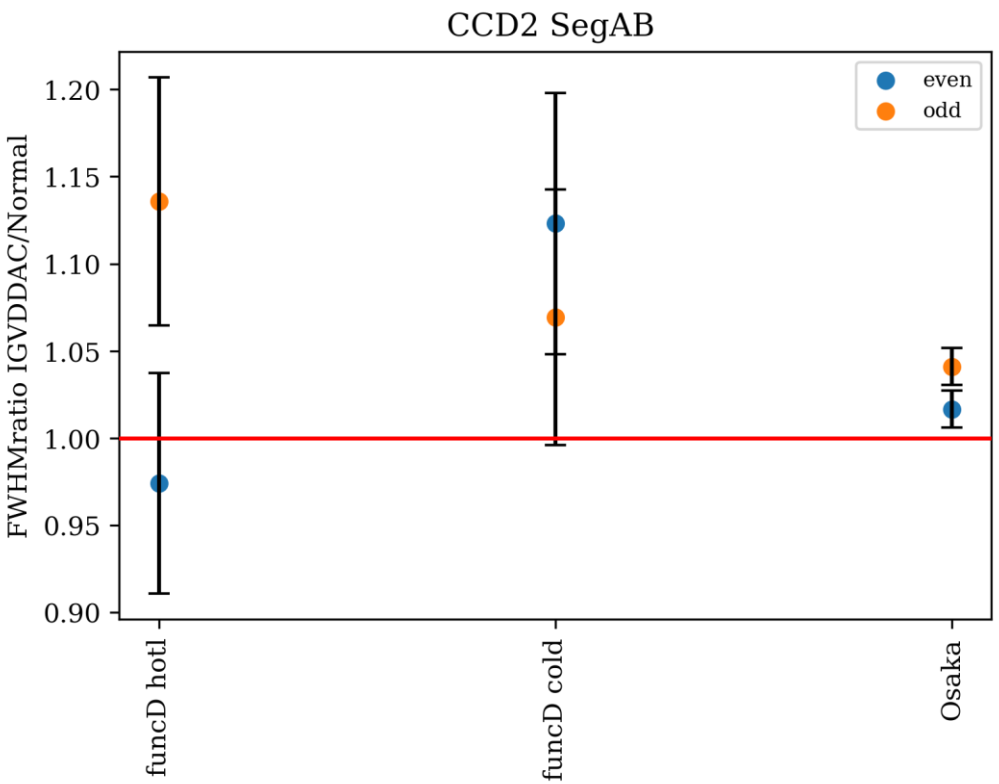


Spectral performance （CCD2AB）

FWHM

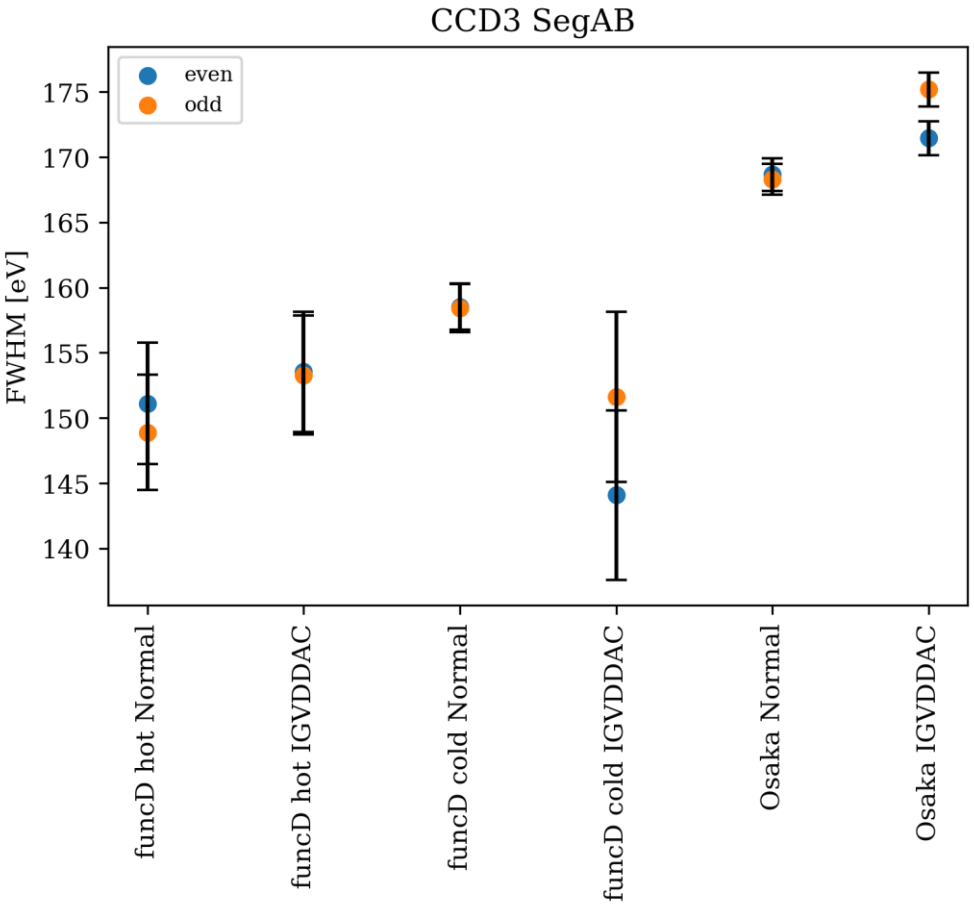


$\mathrm{FWHM}_{\text{New method}}/\mathrm{FWHM}_{\text{Normal method}}$

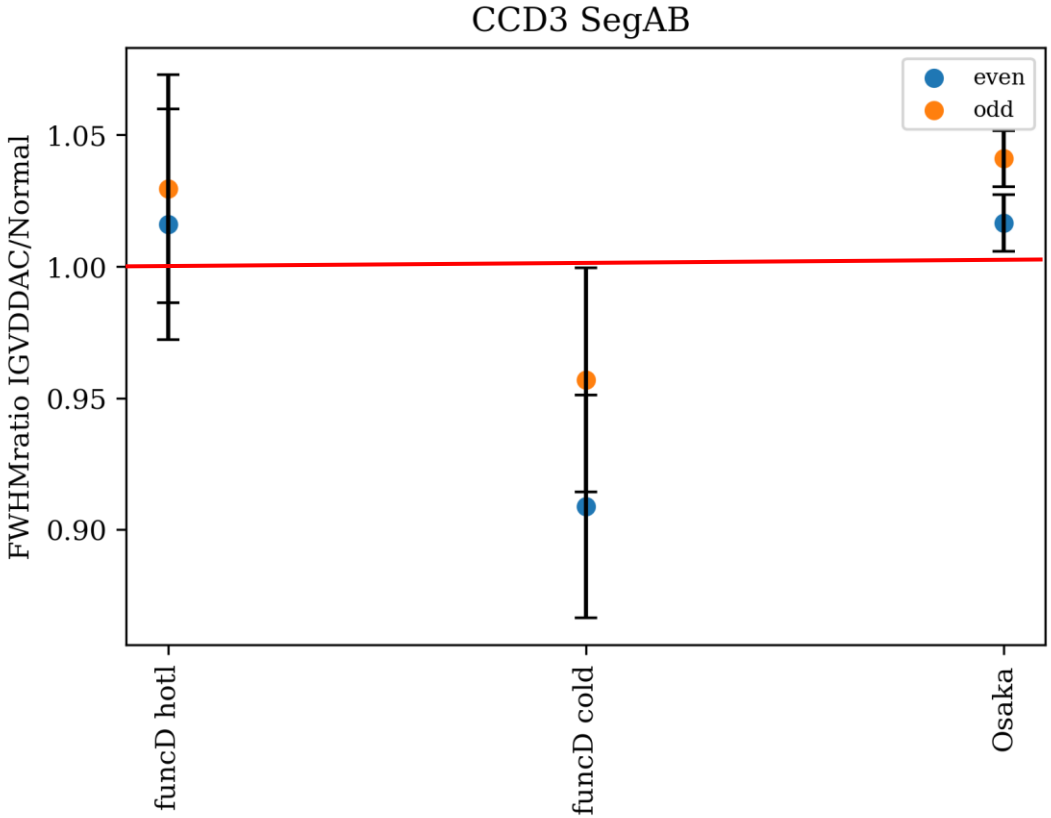


Spectral perfoermance （CCD3AB）

FWHM

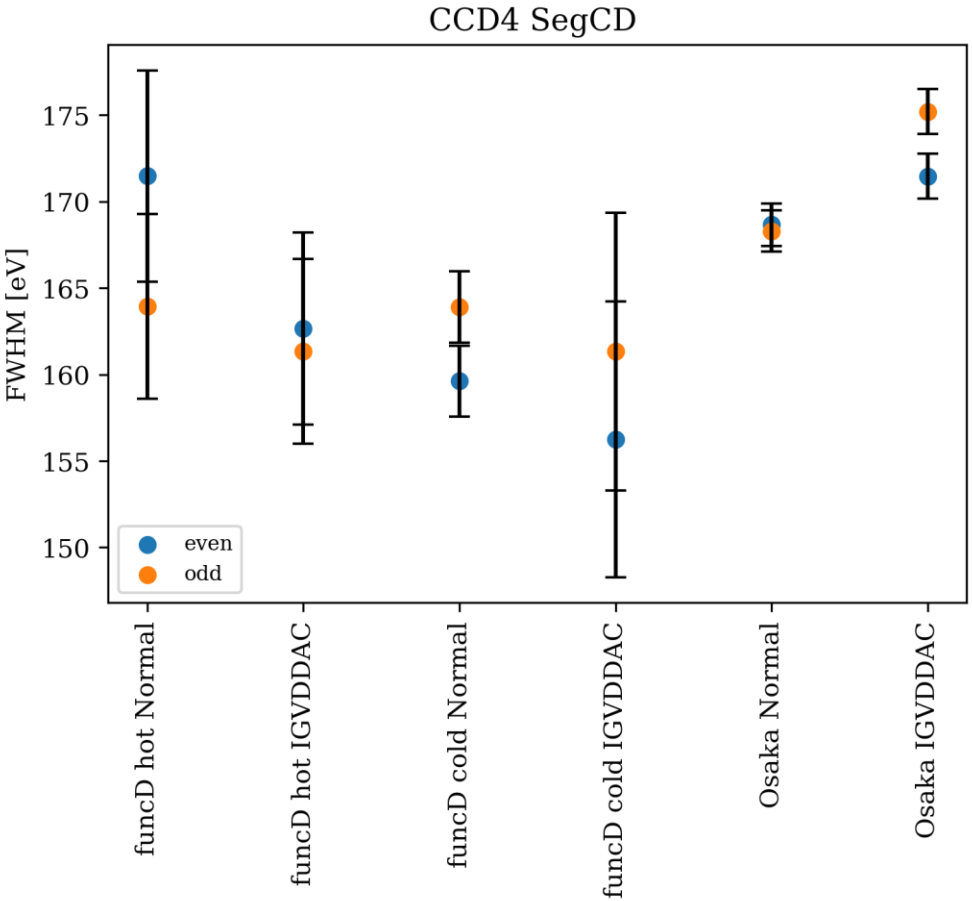


$FWHM_{New\ method}/FWHM_{Normal\ method}$

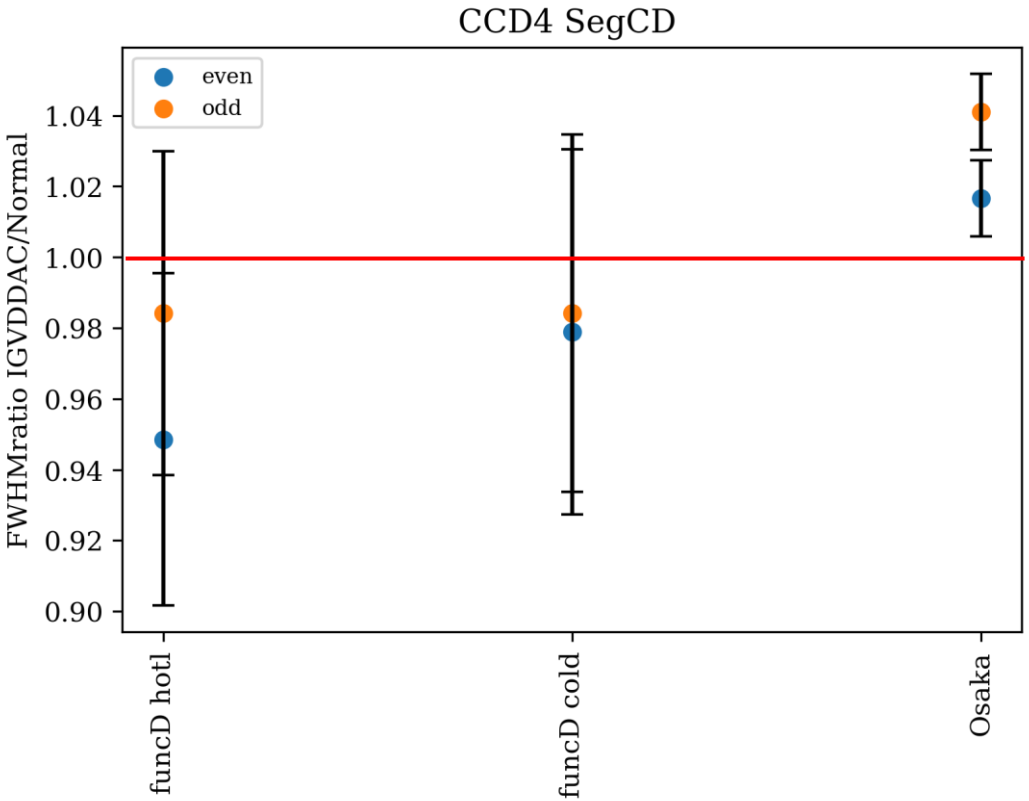


Spectral performance （CCD4CD）

FWHM

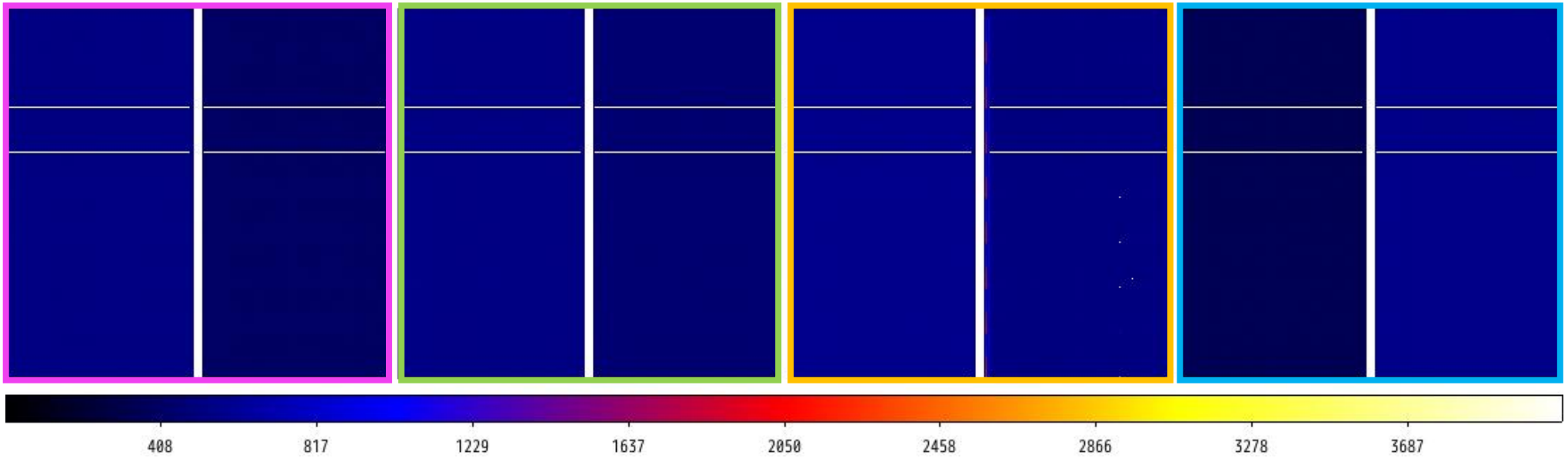


$\mathrm{FWHM}_{\text{New method}}/\mathrm{FWHM}_{\text{Normal method}}$



Frame image at TVT

CCD1 CCD2 CCD3 CCD4



大阪大学における異常事象原因究明

◆阪大のクリーンブースで2021年 12月より異常事象の原因究明を実施

◆2022年1月、2023年1月に異常が再現

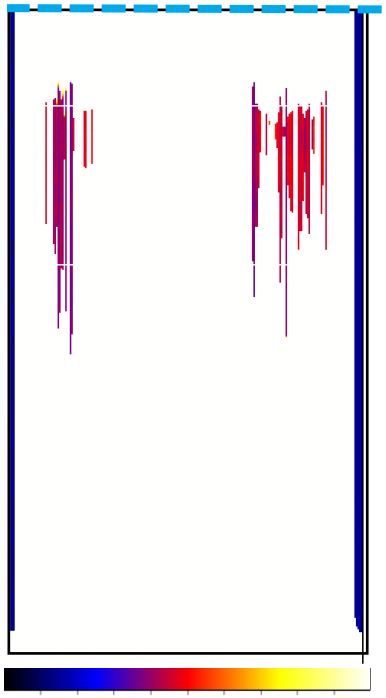
実験のセットアップ

・フライト品と同等の検出器構体
・2021/02に異常が発生した素子

真空配管

2023年1月

フレーム画像



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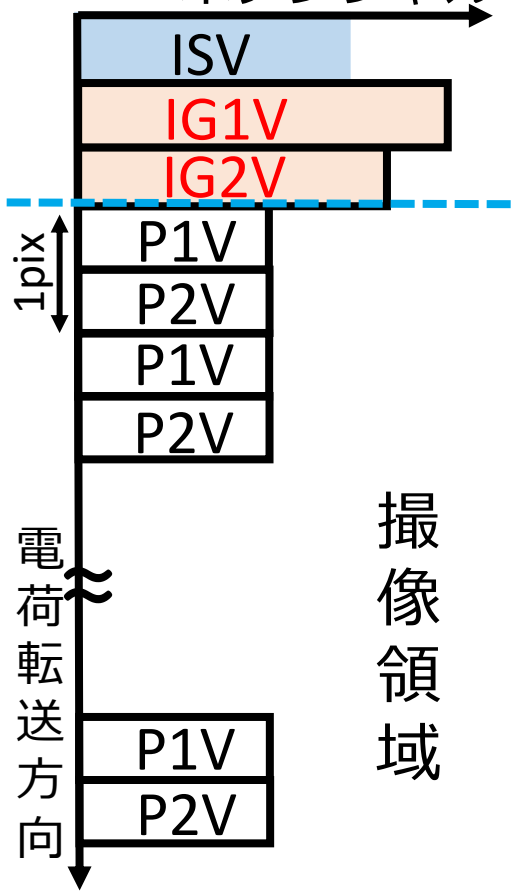
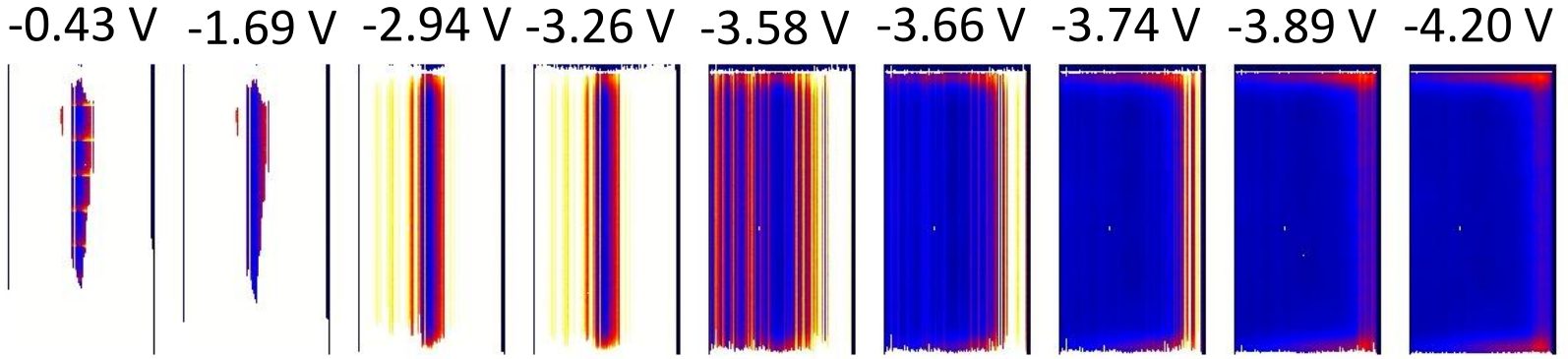


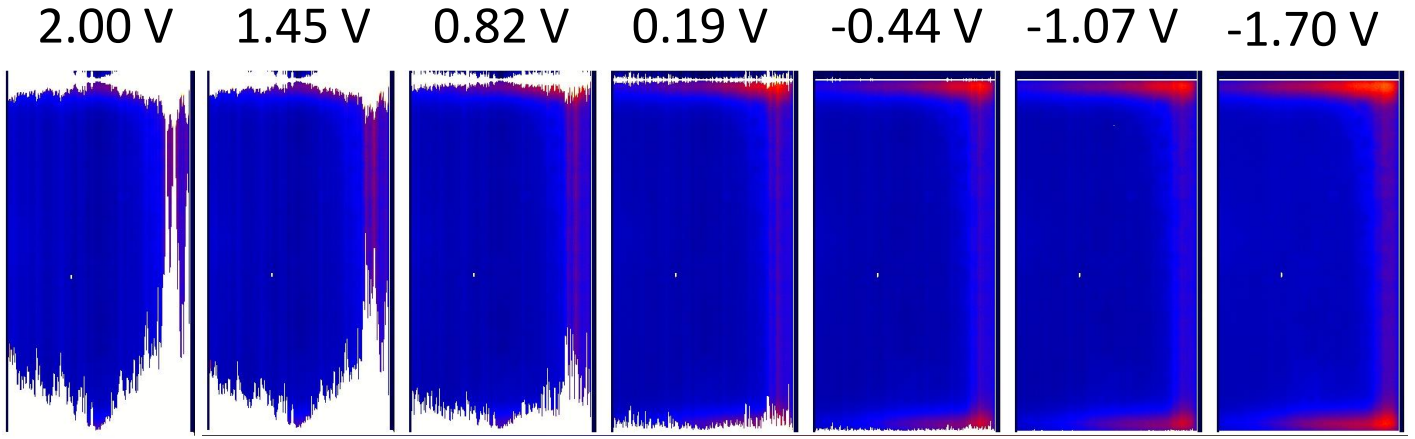
IG1V/2V の印加電圧を変化させながら異常の度合いの変化を調べた

電極の印加電圧による異常の度合いの変化

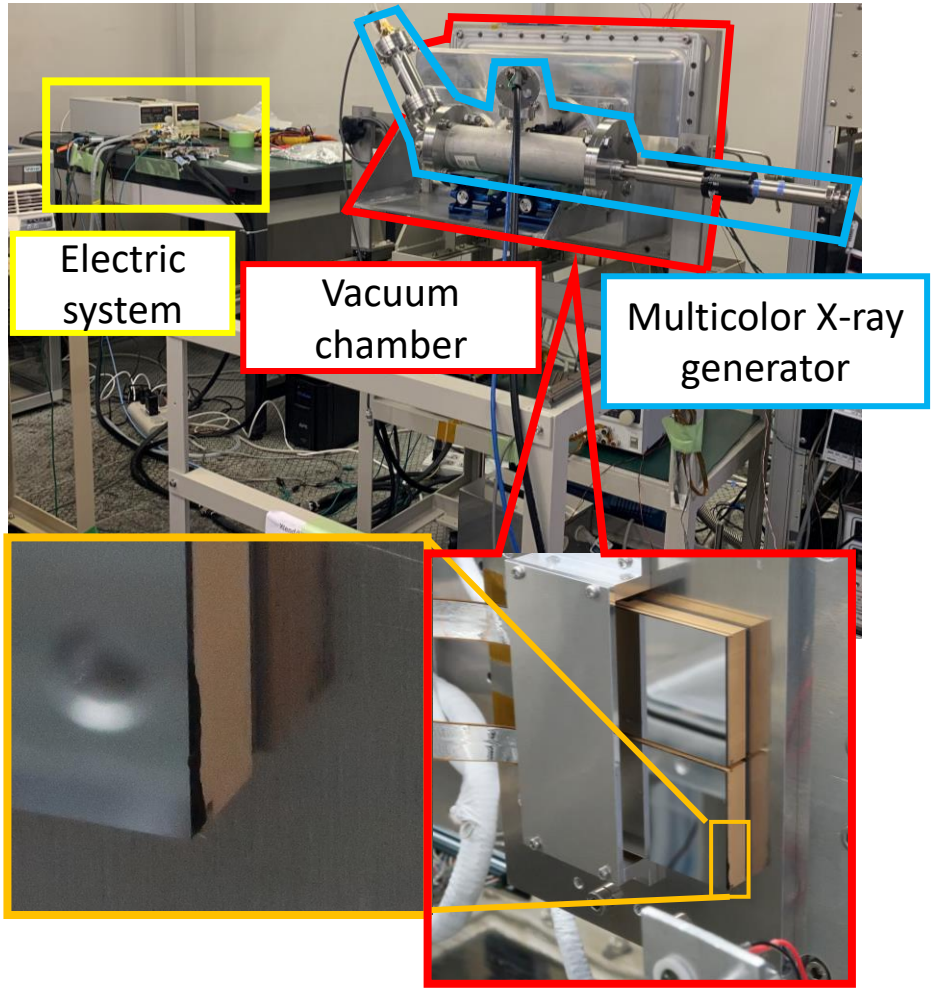
IG1Vを変化



IG2Vを変化



◆ IG1V/2Vの印加電圧が変化すると異常の度合いも大きく変化する
◆ IG1V/2Vの印加電圧が大きいほど異常の度合いが強い
→原因不明の電荷はこれらの電極から生じている可能性も



Inside the vacuum chamber