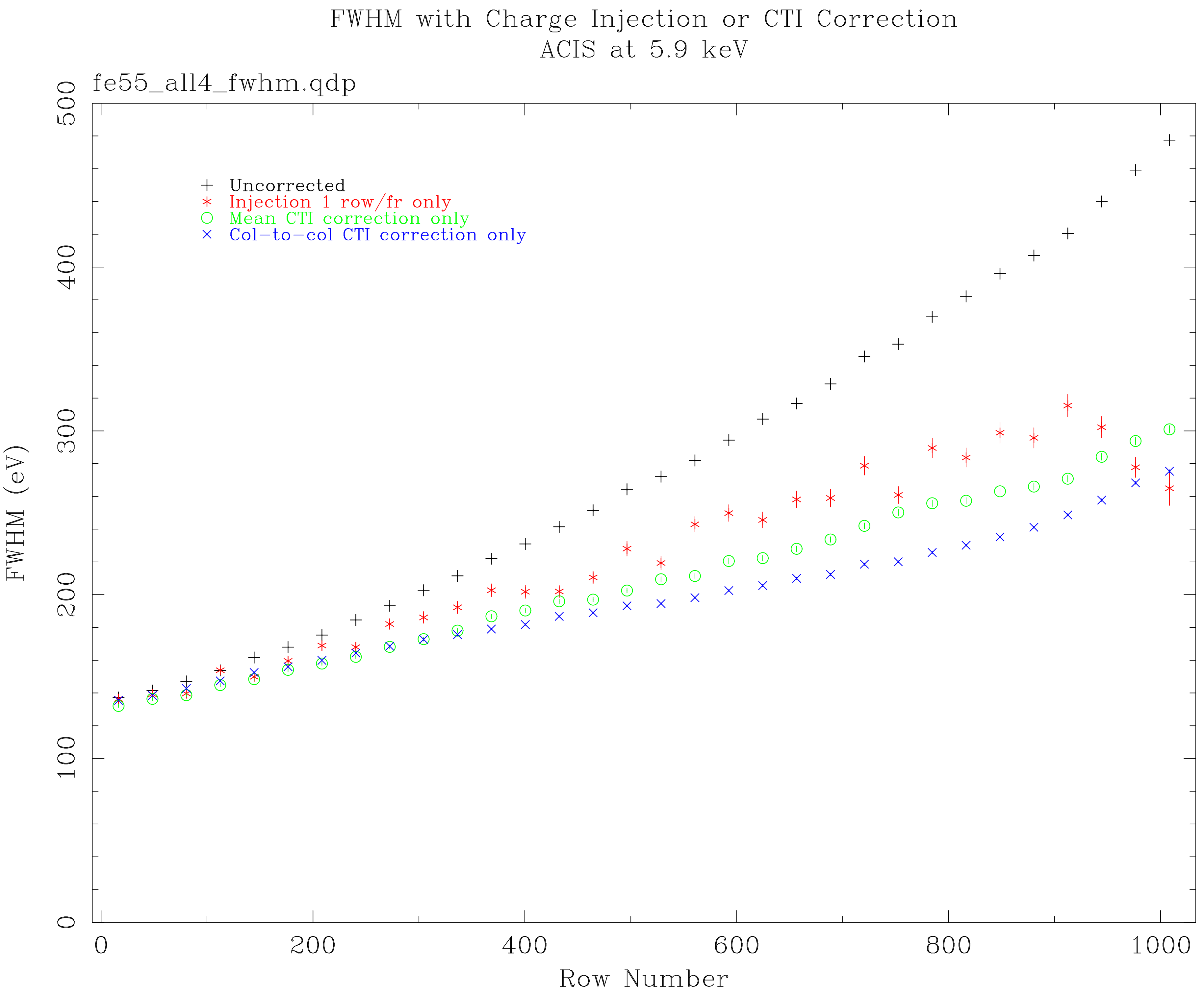
Charge Injection: Motivation

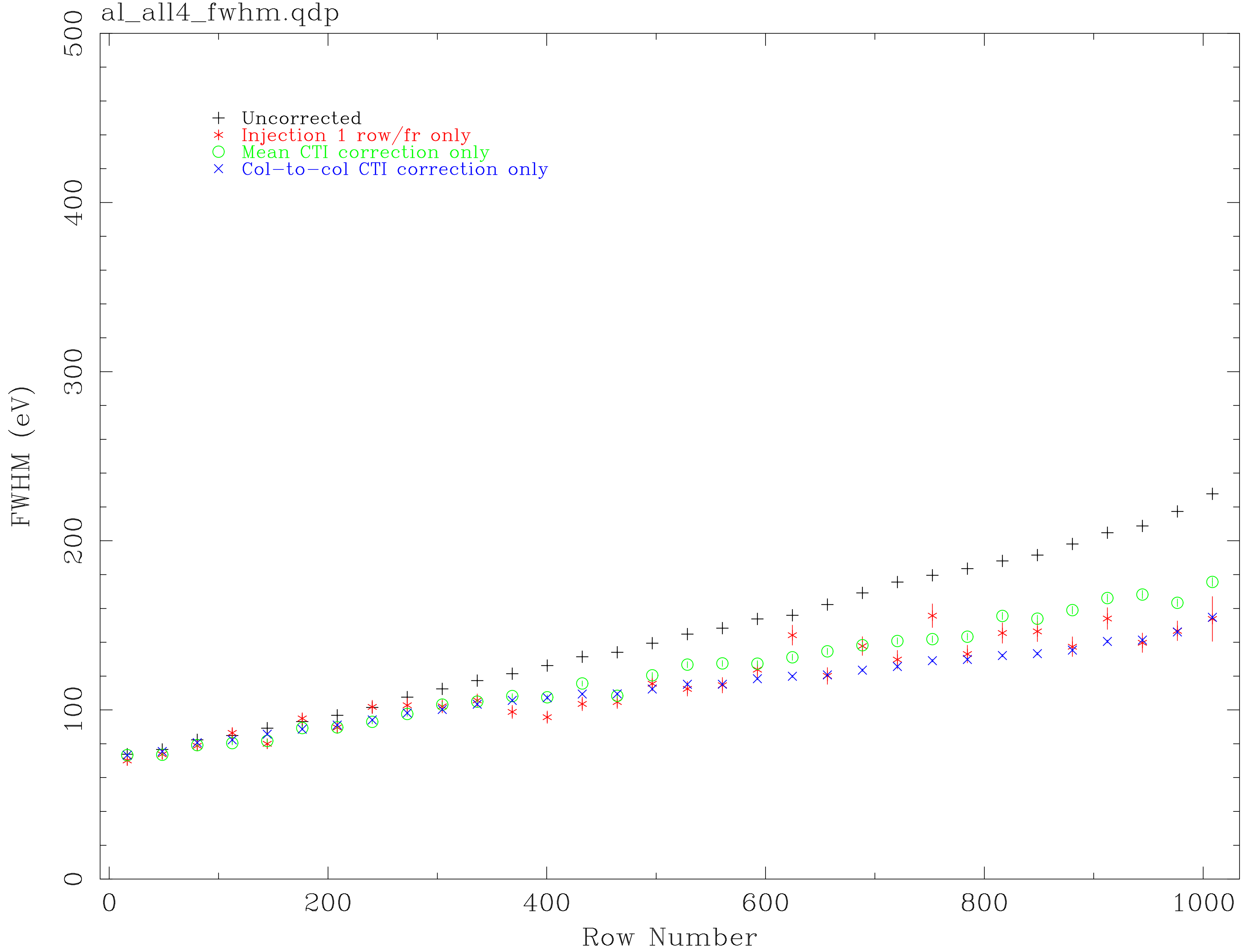
- **XIS performance late in Astro-E2 mission is especially important:**
  - ⋆ **Science driven by XRS in first two years**
  - ⋆ **XIS will be sole soft-X-ray instrument on Astro-E2 years 3-8**
- **Radiation-induced CTI increase for XIS will be comparable to SIS:**
  - ⋆ **SIS: dCTI/dt $\sim 3 \times 10^{-5}$ yr^{-1} (Yamashita, Dotani et al. 1999 NIM-A 436 68)**
  - ⋆ **Lower XIS temperature makes modest ($\sim \times 2/3$) CTI improvement (for high energy protons!)**
  - ⋆ **Orbit and solar cycle phase similar to ASCA**
  - ⋆ **Shielding may be better for XIS, but XIS must transfer charge farther from aimpoint to readout (1.25 cm vs 1.0 cm)**
- **Laboratory and flight tests show charge injection can significantly reduce effective CTI (by $\sim \times 3 - 5$)**
- **Charge injection may signficantly improve XIS spectral resolution late in mission.**

ACIS Experience with Charge Injection and CTI Measurement

- **Charge injection can help performance two ways:**
  - ⋆ **"Sacrificial charge" effect reduces CTI and improves resolution.**
  - ⋆ **Accurate measurement of CTI (vs. energy and position) allows ground correction and leads to better resolution.**
- **ACIS Squeegee experience (sacrificial charge effect):**
  - ⋆ **Inject one bright line ($> 10^4 e^-$ per 3.2s frame (T = -120C)**
  - ⋆ **Improves spectral resolution by $\times 1.7$ at 5.9 keV, by $\times 1.4$ at 1.5 keV.**
  - ⋆ **XIS results would probably not be this good with single injected line per frame, since XIS has higher detector temperature, longer frame time.**
- **ACIS experience with CTI measurement and ground correction:**
  - ⋆ **Charge loss varies significantly with charge-packet size ($\delta Q \sim Q^{0.53}$) so energy-dependent correction improves resolution for split events (helps high-energies most)**
  - ⋆ **CTI varies significantly with column (low-trap density statistical fluctuations) so column-by-column correction also helps.**


FWHM with Charge Injection or CTI Correction
ACIS at 5.9 keV
fe55_all4_fwhm.qdp
Uncorrected
Injection 1 row/fr only
Mean CTI correction only
Col−to−col CTI correction only
FWHM (eV)
Row Number
0
100
200
300
400
500
0
200
400
600
800
1000

FWHM with Charge Injection or CTI Correction
ACIS at 1.49 keV



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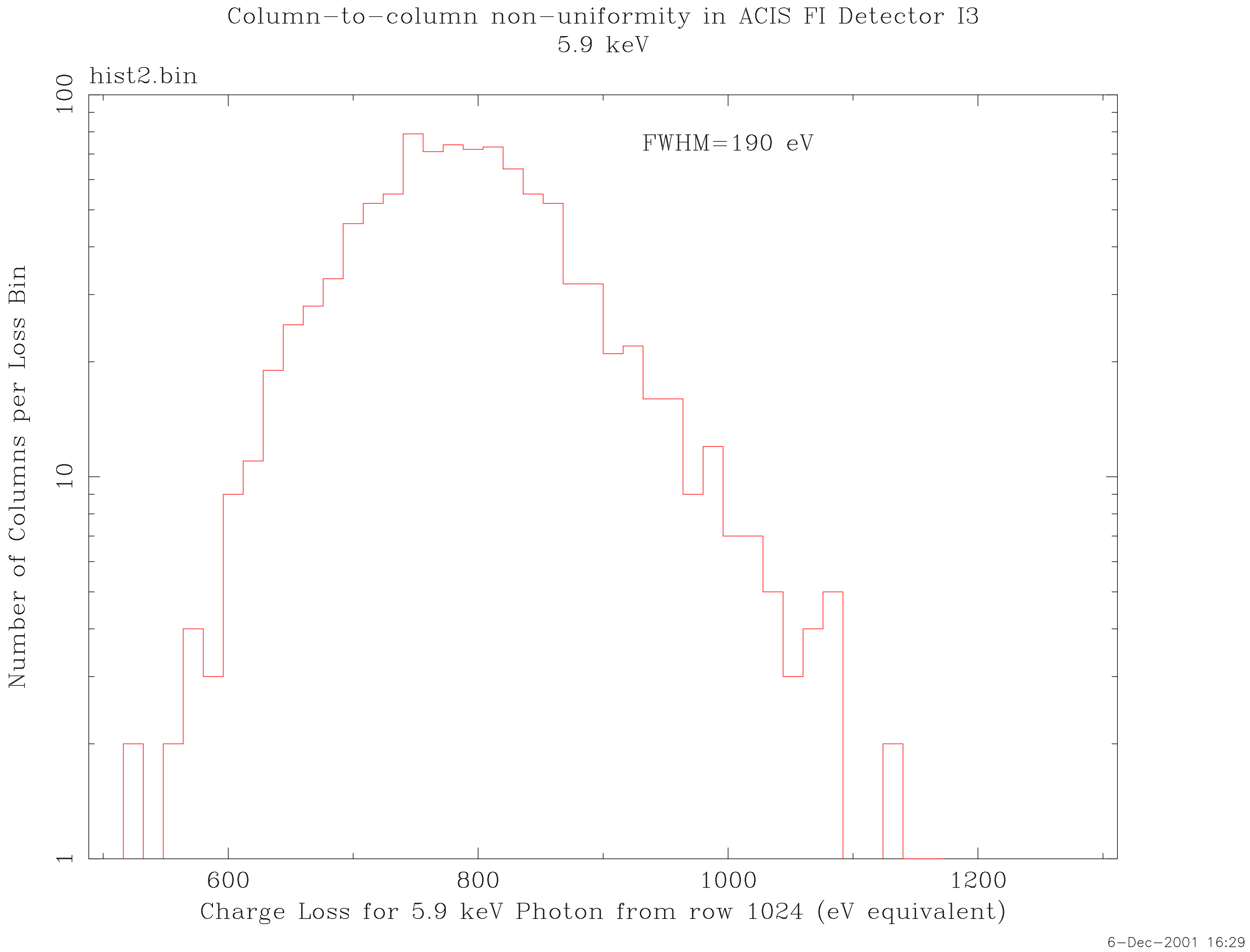

Column−to−column non−uniformity in ACIS FI Detector I3
5.9 keV
hist2.bin
FWHM=190 eV
Number of Columns per Loss Bin
1
10
100
600
800
1000
1200
Charge Loss for 5.9 keV Photon from row 1024 (eV equivalent)
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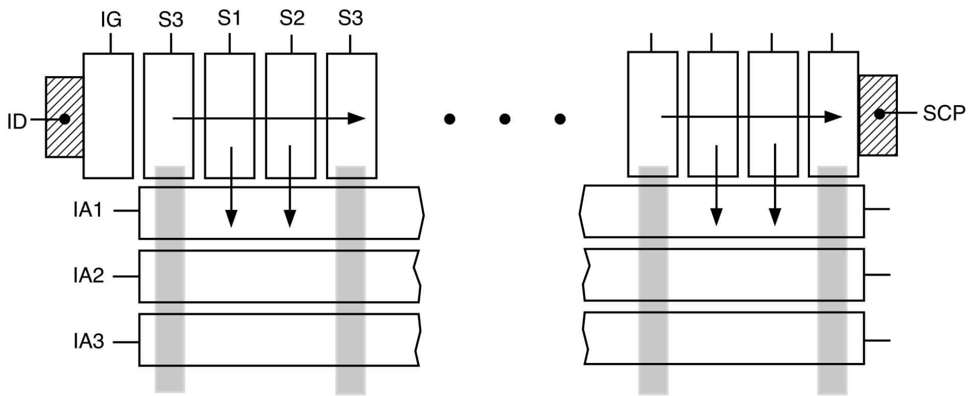
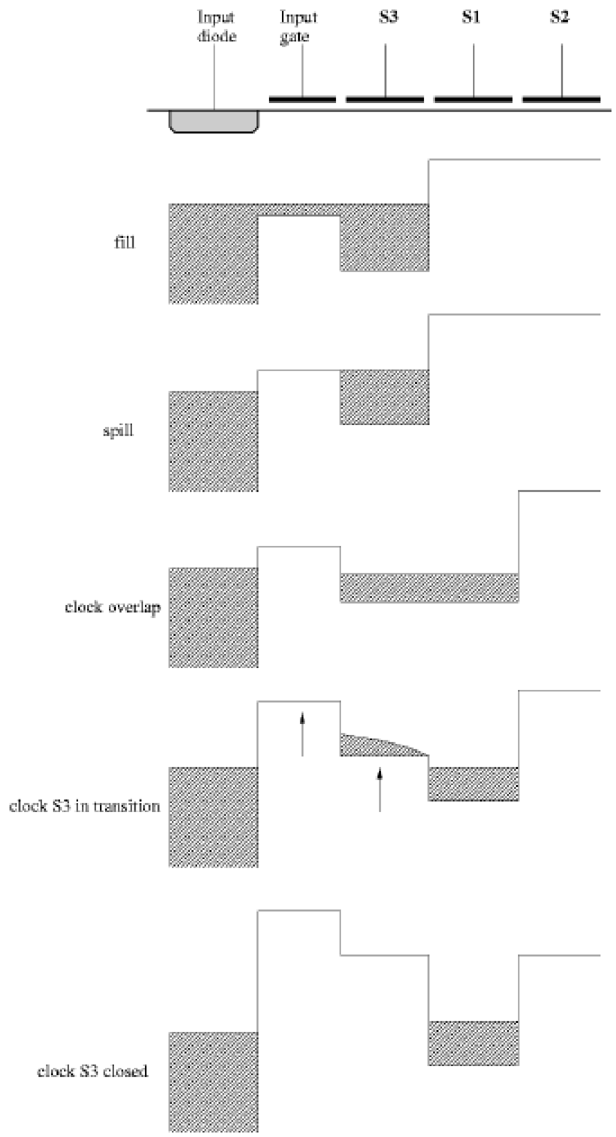
Proposed XIS Charge Injection Structure and Timing



- An input register is added "above" the imaging area ("row 1025")
- During injection, input register is filled, pixel-by-pixel, from input diode, to create a line of charge which is then transferred through imaging area (IA)
- Adjustment of Input Gate (IG) to S3 potential allows precision control of quantity of injected charge: $\sigma_Q \sim 30\, e^-$, RMS



Input register timing during injection

Charge Injection: Summary

- **Flight and ground tests show charge injection can significantly reduce the spatial variation of the energy scale in radiation-damaged CCDs (effective CTI reduced by $\sim \times 3 - 5$)**
- **ACIS flight experience shows that accurate knowledge of CTI (*vs.* column and energy) allows improved energy resolution through ground correction.**
- **XIS does not have multi-energy calibration source illuminating entire detector.**
- **Hardware charge injection will significantly improve XIS spectral resolution and calibration accuracy in the post-XRS phase of AstroE2.**
- **Risks have been considered and found to be modest compared to those inherent in fabrication of new mask. Backup masks (without charge injection) are being fabricated.**
- **Required modifications to AE have been identified and are feasible.**
- **Detailed plans for calibration and use of charge injection remain to be determined.**

Other XIS CCD Design Changes

- **New XIS CCD is designated CCID41 (XIS-1 CCD was CCID17, as in ACIS.)**
- **Several changes will be made to accomodate current MIT Lincoln Lab design rules.**
- **These changes have each been demonstrated on at least one other MIT LL device.**

Parameter	CCID17 (XIS-1)	CCID41 (XIS-2)	Remarks
Charge Injection Capability	S/W only	Input Register Available	
Channel Stop Width	4 μm	2 μm	Better low-energy QE Better high-energy QE
Gate Overlap	2 μm	1 μm	Better low-energy QE Lower capacitance
Undepleted Si	390μm	540 μm	Larger dead-area Greater load on DE
"Scratch" Glass	$1.0\,\mu$m PSG removed from IA	$0.25 - 0.5\,\mu$m BPSG and $1.0\,\mu$m PSG removed from IA	BPSG provides better yield. Will use same etch as on XIS-1 to remove BPSG and PSG from IA

Science Impact of BPSG

- **Current plan (revised since 12/01 SWG) is to remove entire BPSG layer from imaging area.**
- **Therefore BPSG should have no effect on XIS-2 detection efficiency.**
- **BPSG will be removed from imaging area using same process used to remove PSG from imaging area of XIS-1 detectors.**

XIS CCD Backup Plan

- Two CCD production lots are planned.
- Lot 2 production will not begin until performance has been verified at CSR through tests of a sample of Lot-1 devices.
- If unforseen problems with the charge-injection structure compromise performance of Lot-1 devices, these structures can be omitted from Lot-2 devices with a simple change in production sequence; all necessary masks exist.
- Decision is required on Lot-2 CCD configuration by 15 October 2002.
- If all flight devices had to be obtained from Lot 2, XIS sensors could still be delivered in September, 2003.

AE/TCE Electronic Parts Availability

- All parts required for flight complement of AE/TCE hardware (2 units plus spare boards) are either in-house at MIT or readily available.
- XIS-1 parts list was reviewed in 2001 and 4 potentially obsolete integrated circuits (of 24 used) were identified.
- Sufficient quantities of these parts either were found in MIT CSR inventory or have been procured through specialty distributors.
- Two IC subsitutions for XIS-2: CA3080A for CA3080A3; REF43FZ for REF43BZ. Substitute parts qualified for full military temperature range.

CCD Production Status

- **CCID41 production Lot 1 is on schedule for delivery of first devices to MIT CSR in August:**
  - ⋆ **224 of 284 production operations completed as of 14 June 2002.**
  - ⋆ **Mean (high-priority) processing rate at fabrication facility is 60 operations/month. XIS has high priority.**
- **First wafer-level electrical test results expected in July.**