

Overview

- Charge Injection
 - ★ Effects on XIS Performance: CTI Reduction and Knowledge vs. Resolution
 - ★ Proposed CCD Structure
 - ★ Risks
 - ★ Operational Scenarios
- Other CCD Design Changes
- Status/Schedule

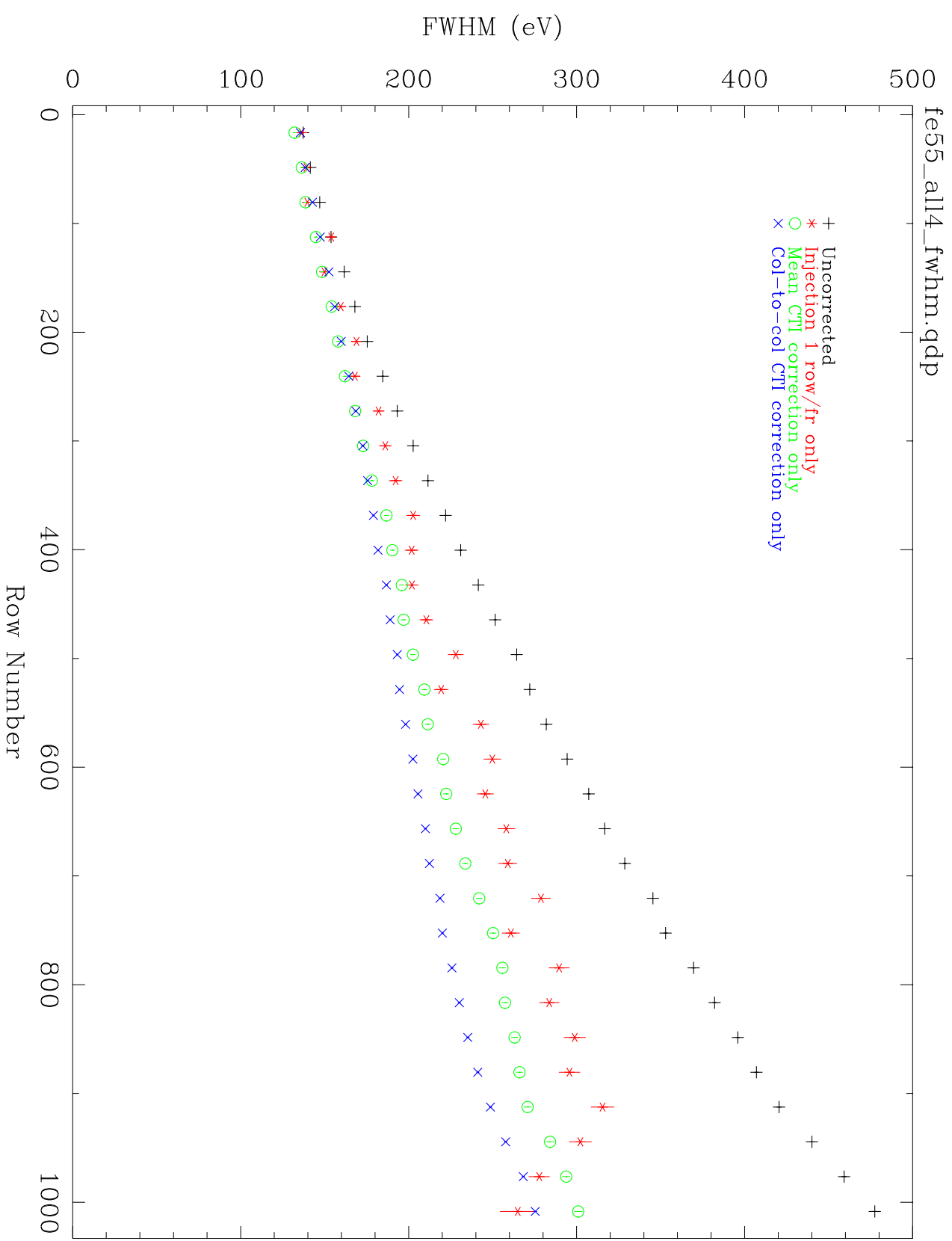
Charge Injection: Motivation

- XIS performance late in Astro-E2 mission is 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: $d\text{CTI}/dt \sim 3 \times 10^{-5} \text{ yr}^{-1}$ (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 significantly improve XIS spectral resolution late in mission.

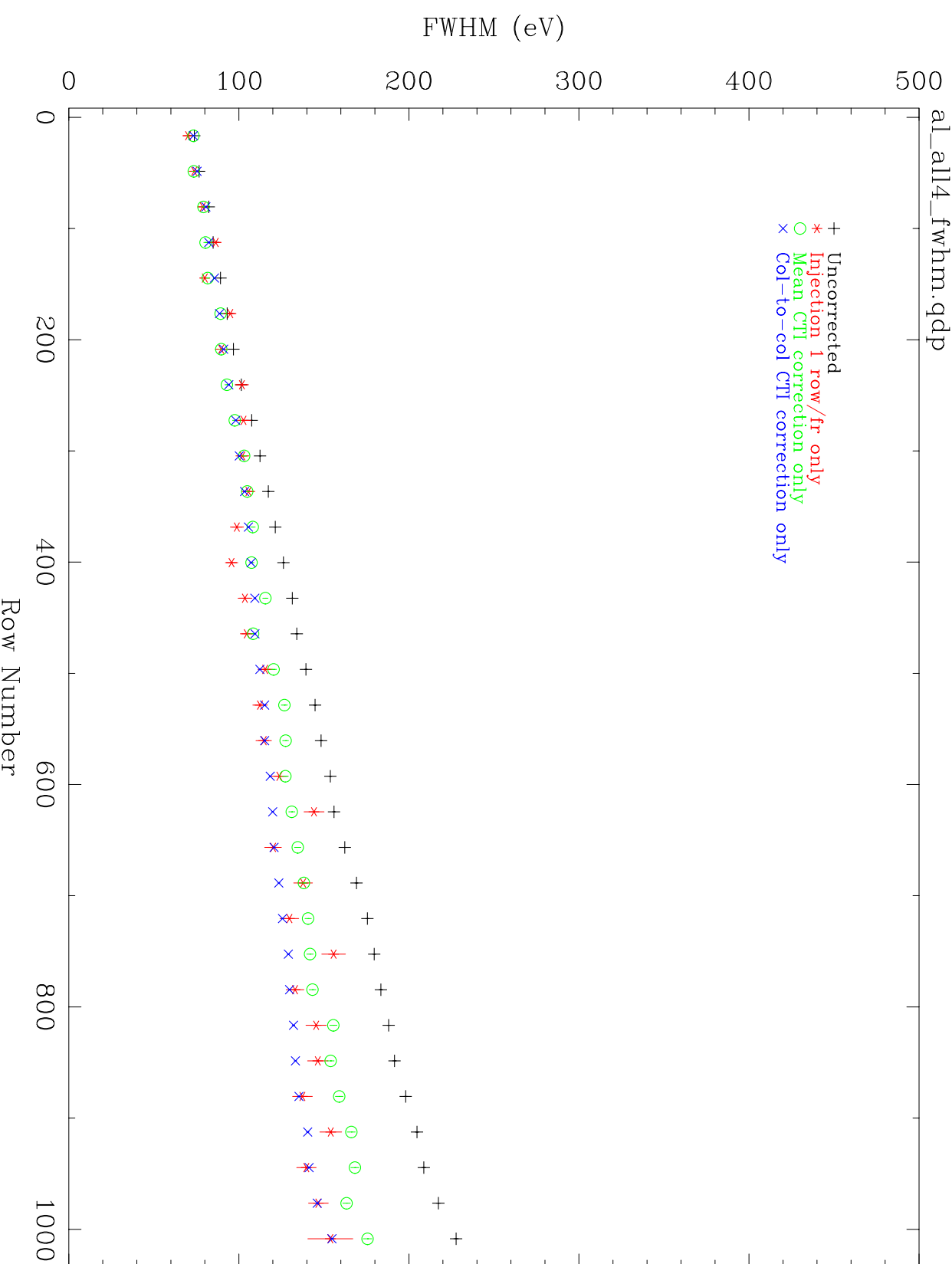
ACIS Experience with Charge Injection and CTI Measurement

- 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.

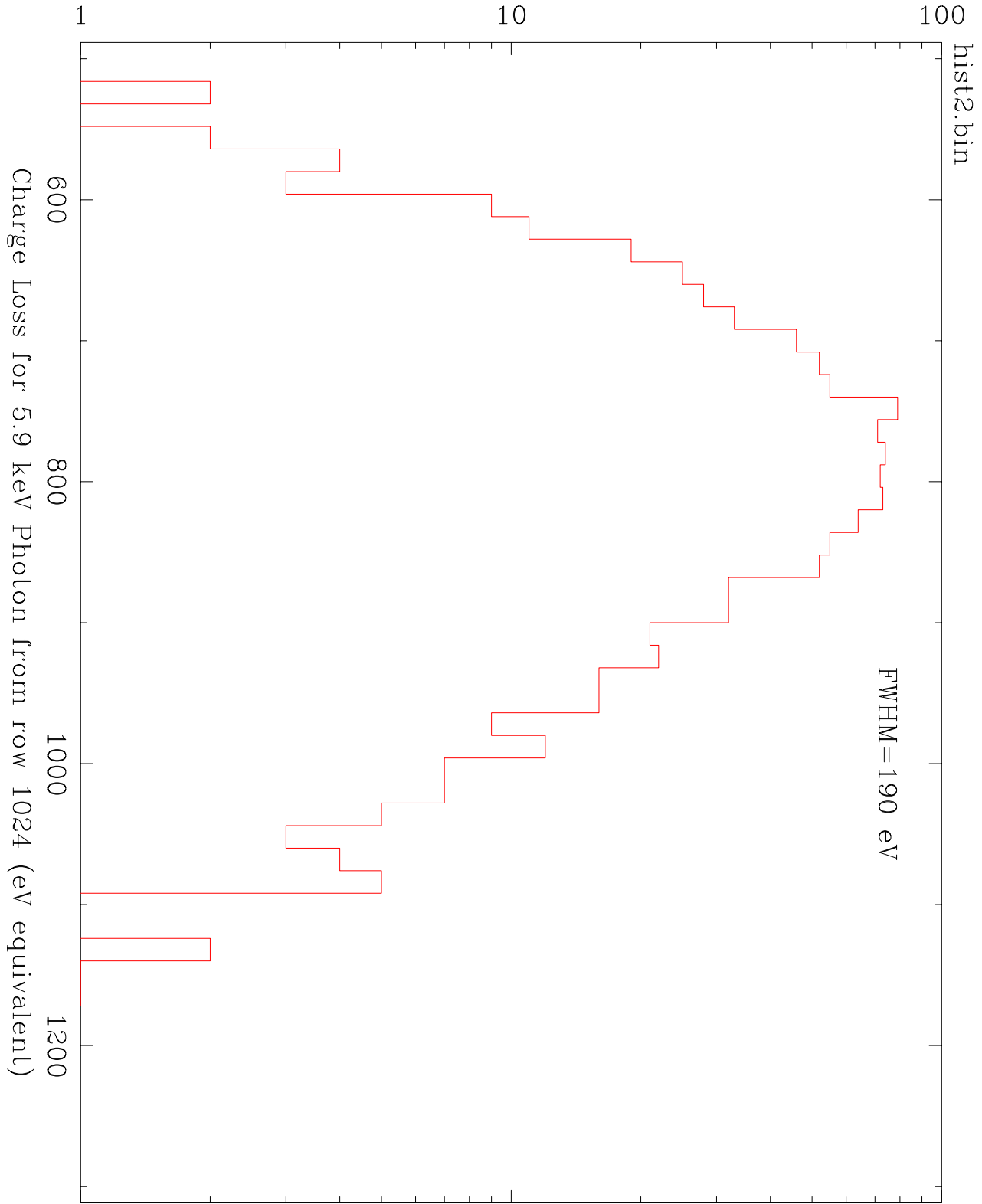
FWHM with Charge Injection or CTI Correction
ACIS at 5.9 keV



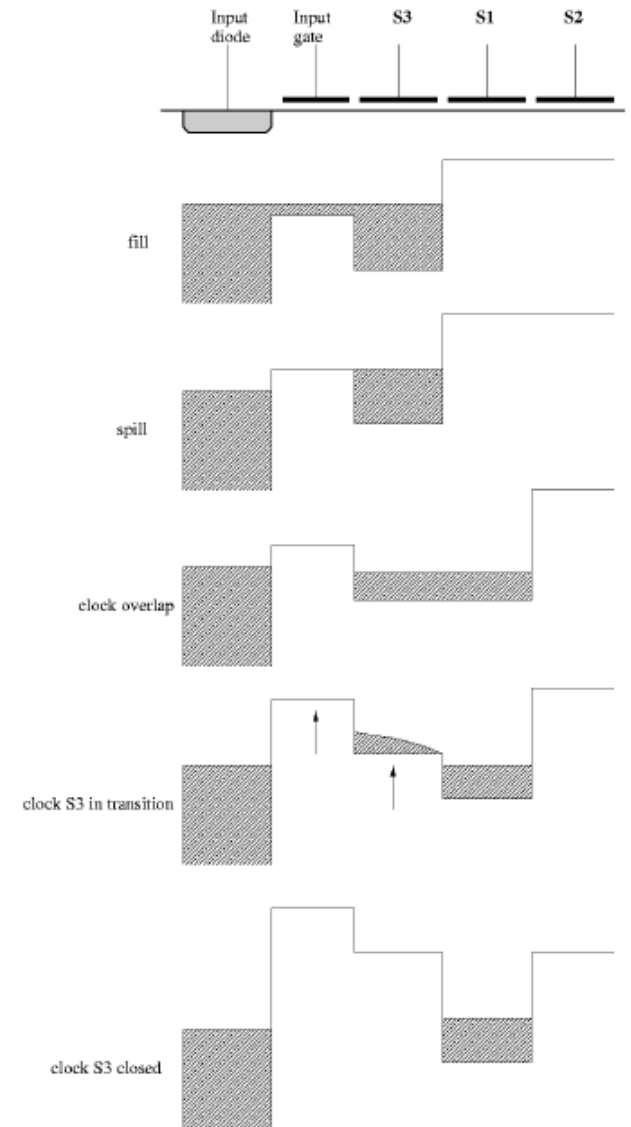
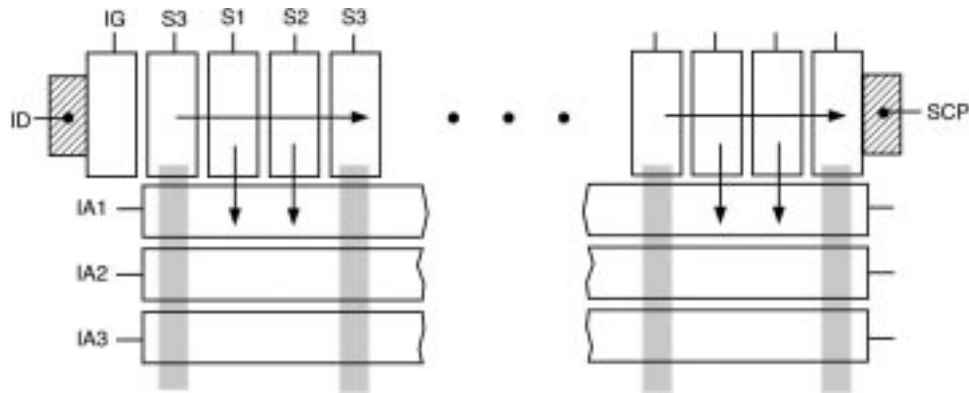
FWHM with Charge Injection or CTI Correction
ACIS at 1.49 keV



Number of Columns per Loss Bin



Proposed XIS Charge Injection Structure and Timing



Input register timing during injection

- 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

Hardware vs. Software Charge Injection

- Hardware Charge Injection:
 - ★ Requires dedicated input structure on CCD.
 - ★ Allows multiple line/frame injection with minimal deadtime penalty.
 - ★ Good knowledge of injected charge quantity available even after radiation damage: should allow reliable CTI measurement.
 - ★ Has been demonstrated in-flight on XMM EPIC MOS (1 line/frame, fixed amplitude.)
- Software Charge Injection
 - ★ Relies on special-purpose microcode to inject charge.
 - ★ Single line/frame can be injected with minimal deadtime if background is high enough (ACIS squeegee).
 - ★ Injecting multiple lines/frame increases deadtime to $\sim 50\%$
 - ★ Quantity of injected charge sensitive to radiation damage: difficult to measure CTI reliably after damage.
 - ★ Multi-line injection demonstrated in lab tests with radiation-damaged CCDs (Steve Kissel)

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 will be 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	390 μm	540 μm	Larger dead-area Greater load on DE
Scratch Glass	PSG, removed from IA	0.25 – 0.5 μm BPSG + PSG removed from IA	Better yield but significant loss of QE < 1 keV. Hope to reduce BPSG thickness.

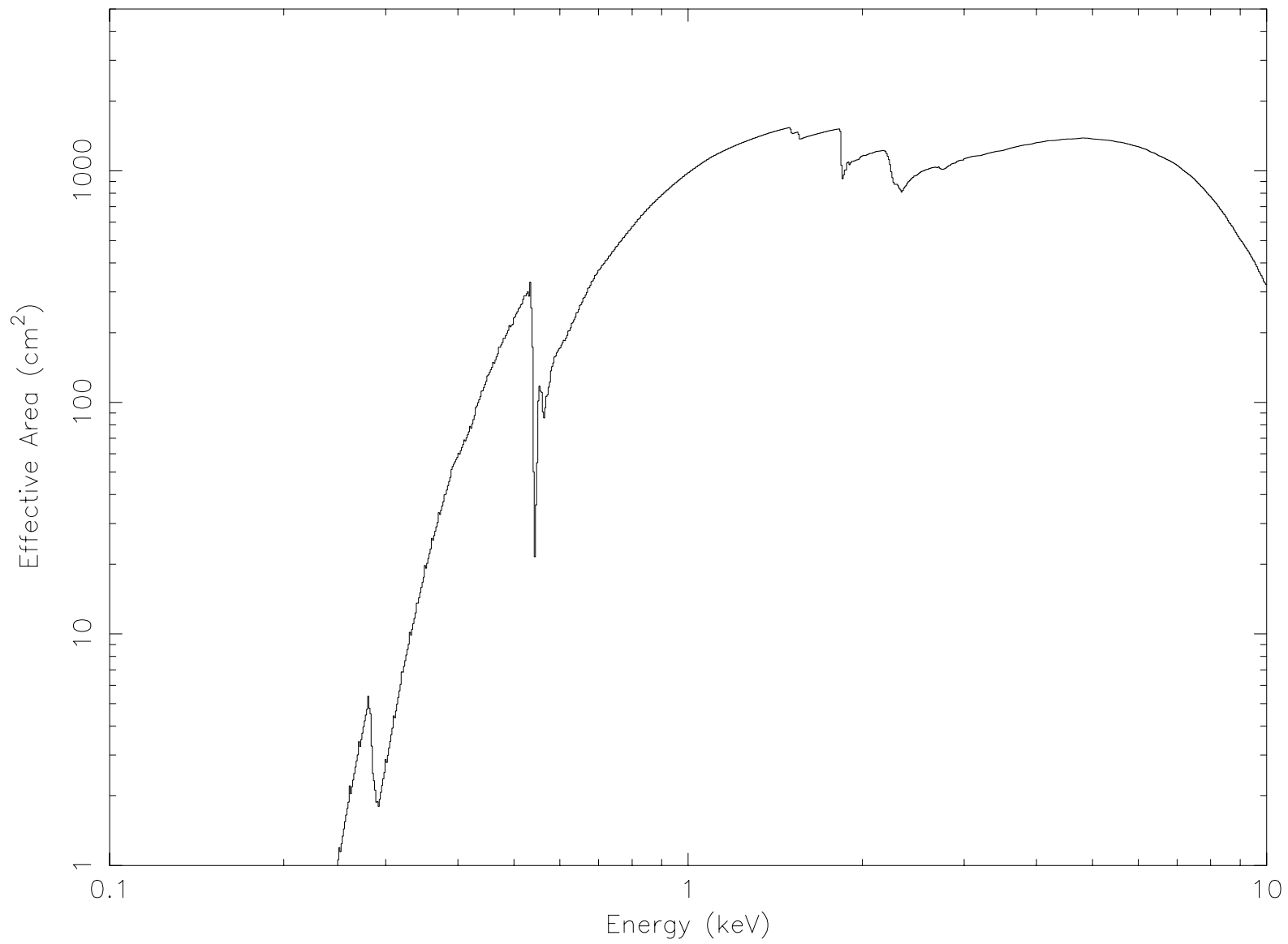
Borophosphosilicate Glass (BPSG)

- Borophosphosilicate glass (BPSG) coating (0.25 - 0.50 μm) now part of standard MIT LL practice.
- BPSG smooths sharp edges from finer photolithography, reduces chance of discontinuities in aluminum traces, improves yield and reliability.
- BPSG causes significant reduction in low-energy QE.
- May be possible to reduce thickness of BPSG over imaging area.

XIS-1 Effective Area (4 sensors)

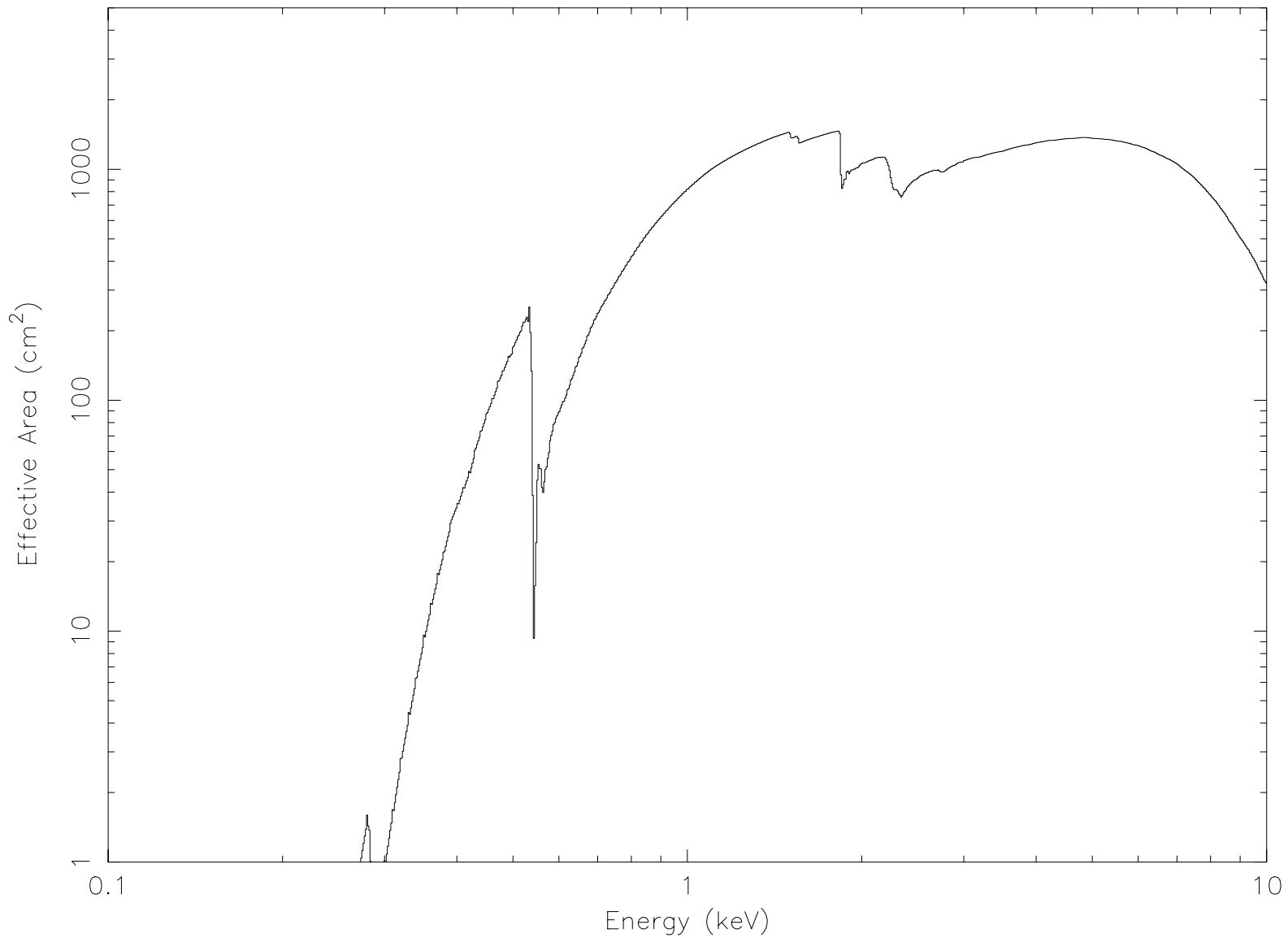
Total efficiency

xis_1999-01-15.rmf

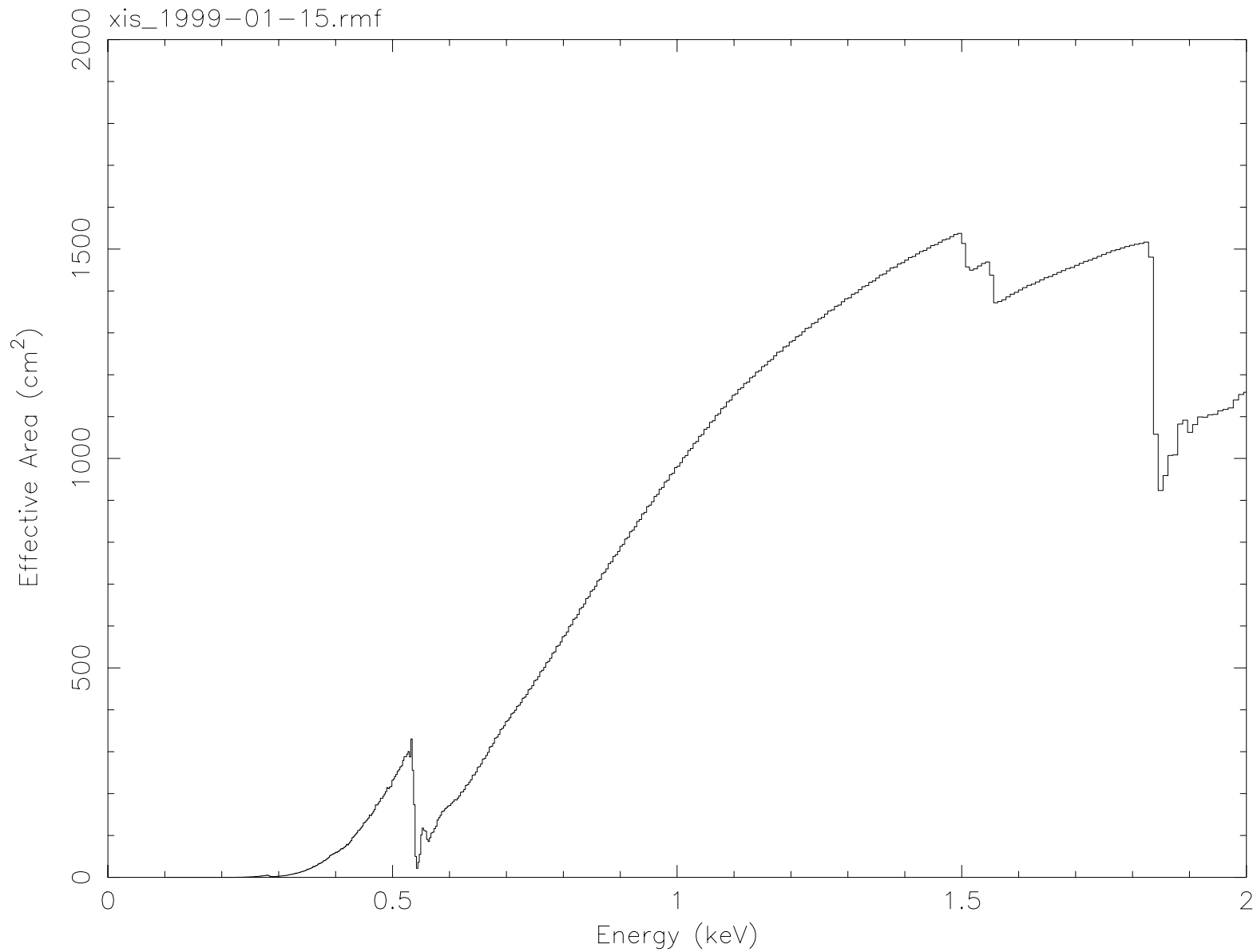


CCID-17 Effective Area with 2500 A BPSG
4 XIS Sensors with BPSG
Total efficiency

xis_1999-01-15.rmf



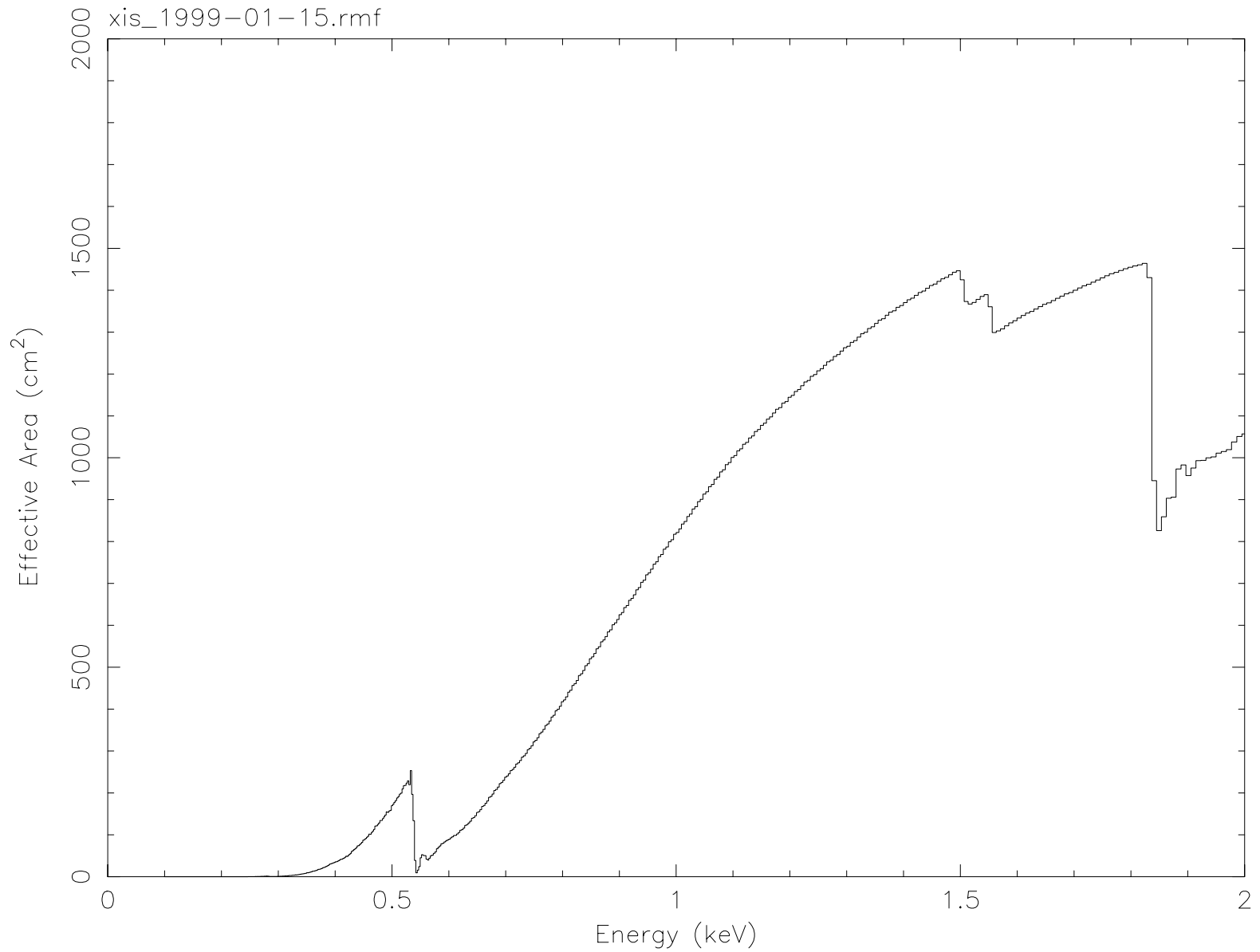
XIS-1 Effective Area (4 sensors)
XRT+CCD Effective Area (no BPSG)
Total efficiency



CCID-17 Effective Area with 2500 A BPSG

XRT+CCD Effective Area with BPSG

Total efficiency



Science Impact of BPSG

- Preliminary simulations performed with 2500 Å BPSG, but CCID17 QE
- Actual CCID41 device may have thicker BPSG (up to 5000 Å), but will have smaller gate overlaps and narrower channel stops than CCID17.
- Sample Counting rate ratios for low-column ($4 \times 10^{20} \text{ cm}^{-2}$) spectral models (counts ccid41/counts ccid17):

Spectrum	Count-rate ratio in Band (keV)		
	0.1 - 10	0.3 - 2	0.3 - 1
7 keV Thin Thermal	0.86	0.82	0.81
1 keV Thin Thermal	0.84	0.83	0.80
Power Law ($\Gamma = 1.7$)	0.88	0.86	0.75

Status

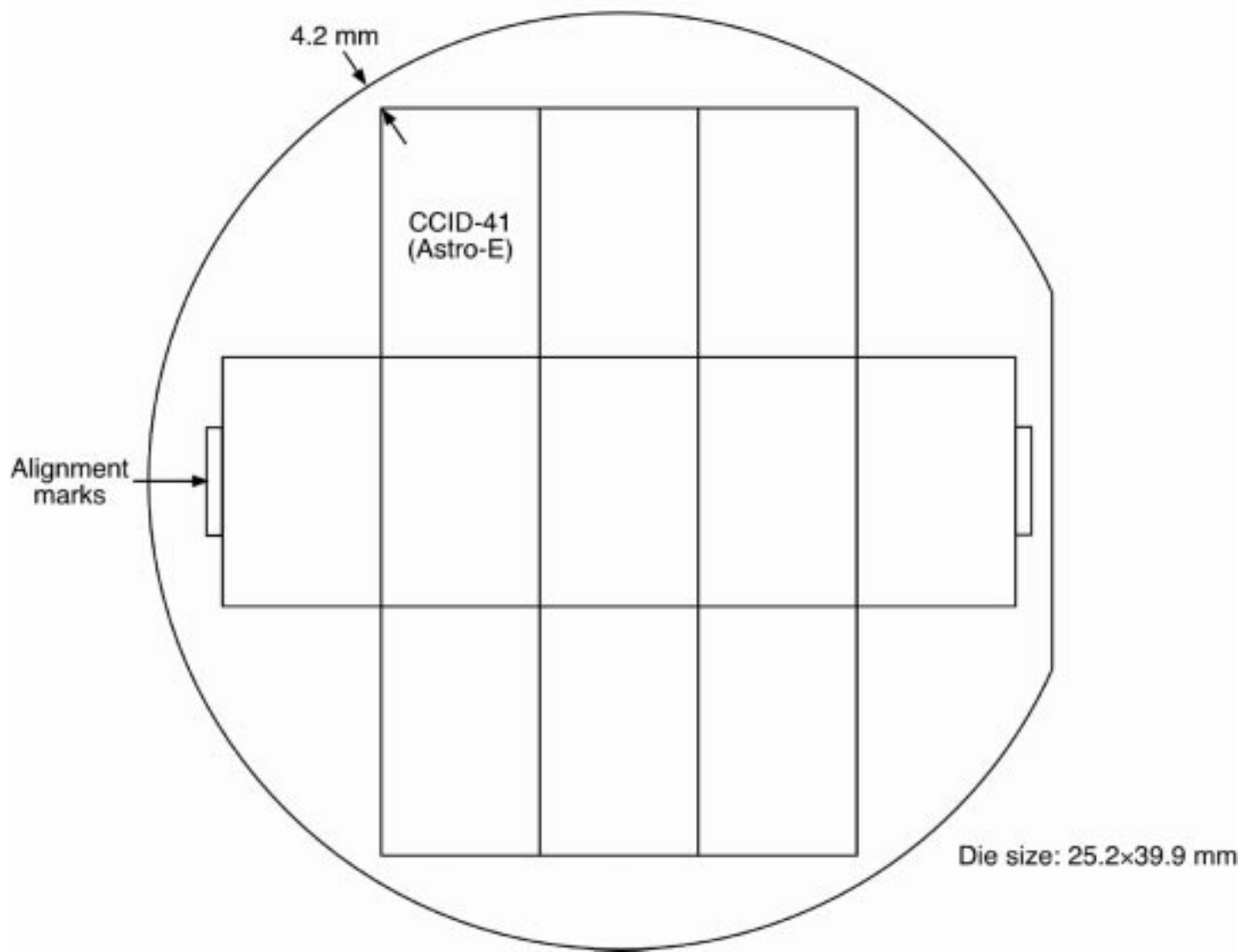
Using “Phase-A” funding provided by ISAS directly to MIT CSR:

- CCID41 mask set (including non-injection version) has been designed
- Flexprint design is under review
- Design revisions for detector package/TEC interface in progress (A. Pillsbury)
- Frank LaRossa (digital designer) contract is being negotiated. (No word yet on FPGA revisions.)

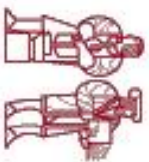
Schedule

- Near-term milestones (2002):
 - ★ Mid-January: Masks fabricated
 - ★ April: Flexprints fabricated
 - ★ July/August: First flight detectors delivered to CSR from Lincoln.
- Long-term schedule: If NASA/ISAS agreement is signed very soon, can still maintain schedule proposed by Rick Foster in September, 2000.

CCID-41 Wafer Layout



11 XIS-2 CCID41 Devices per Wafer



Massachusetts Institute of Technology
Center For Space Research

Schedule Assumptions

- **July 2001 - Official (i.e funded) start at MIT**
 - Japanese FY starts April 1
 - Gives some time to get the contract/money moved to MIT
 - Funding of for atleast the CCD development required
 - *Contract for the actual flight build can come later, but we need to work on the detectors in this time frame.*
- **July 2002 - 1st Flight CCDs from Lincoln Laboratory**
 - Need early coordination/funding of contract with LL
- **Sept 2002 - Flight Build Start**
 - Engineering effort up to CDR completed
- **Sept 2003 - Flight units delivered to Japan**
 - Approximately 15 months prior to launch
 - System Calibration
 - Spacecraft Integration & Test
- **February 2005 - AstroE-II Launch date from Kagoshima**
 - Great Success !!