Discrimination and Quantification of Contamination and Implanted Solar Wind in Genesis Collector Shards Using Grazing Incidence Synchrotron X-ray Techniques

K. Kitts[1], Y. Choi[2], P. Eng[2.3], S. Sutton[2, 3], S. Ghose[2], D. Burnett[4]

[1]Department of Geology & Environ. Geosciences, Northern Illinois University
[2]Consortium for Advanced Radiation Sources University of Chicago, [3]Department of Geophysical Sciences University of Chicago and [4]Geology & Planetary Sciences, Caltech.

March 22, 2009

NIU

GeoSoilEnviroCARS
The University of Chicago
Argonne National Laboratory • Advanced Photon Source

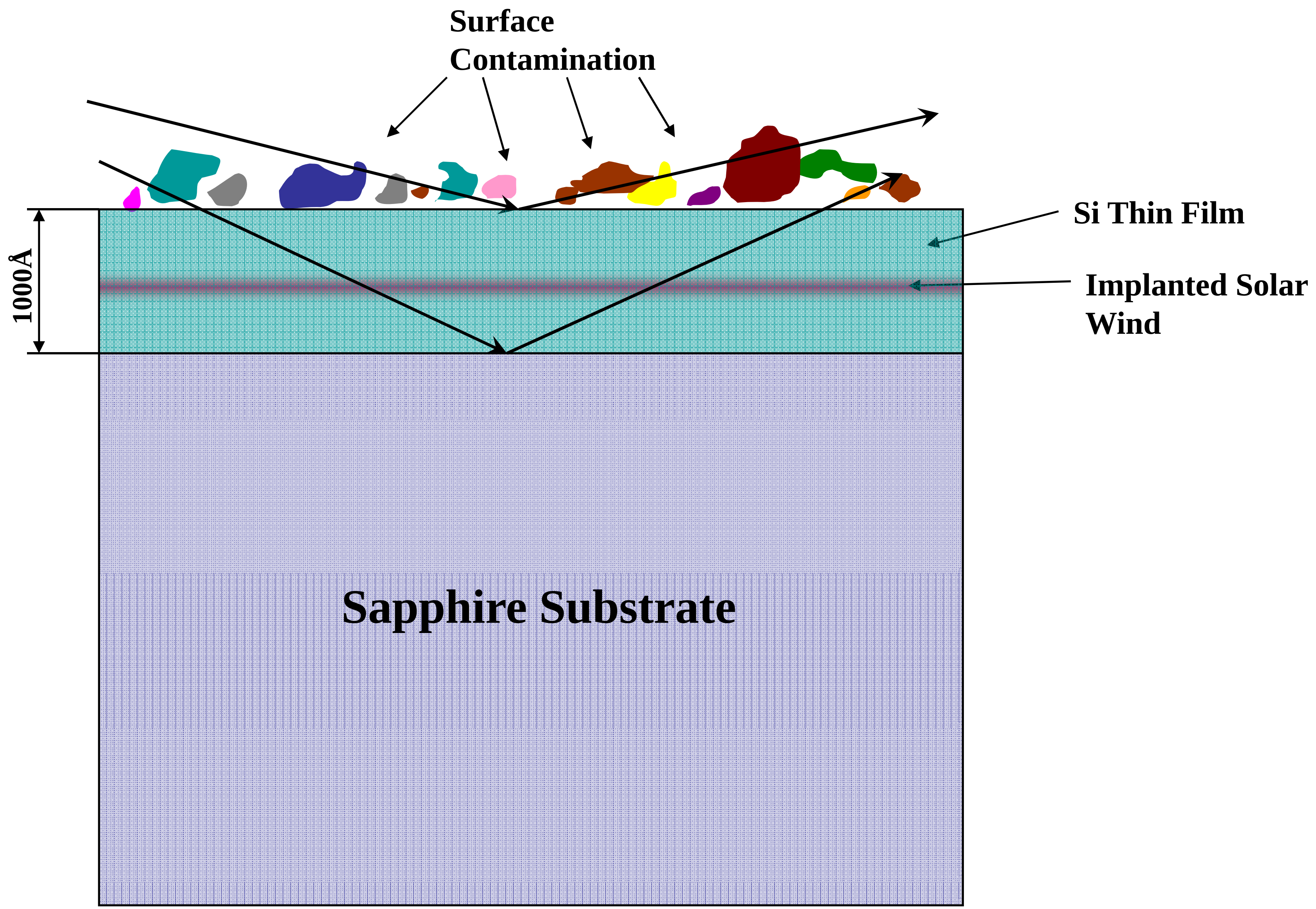
Acknowledgements

GSECARS, Advanced Photon Source

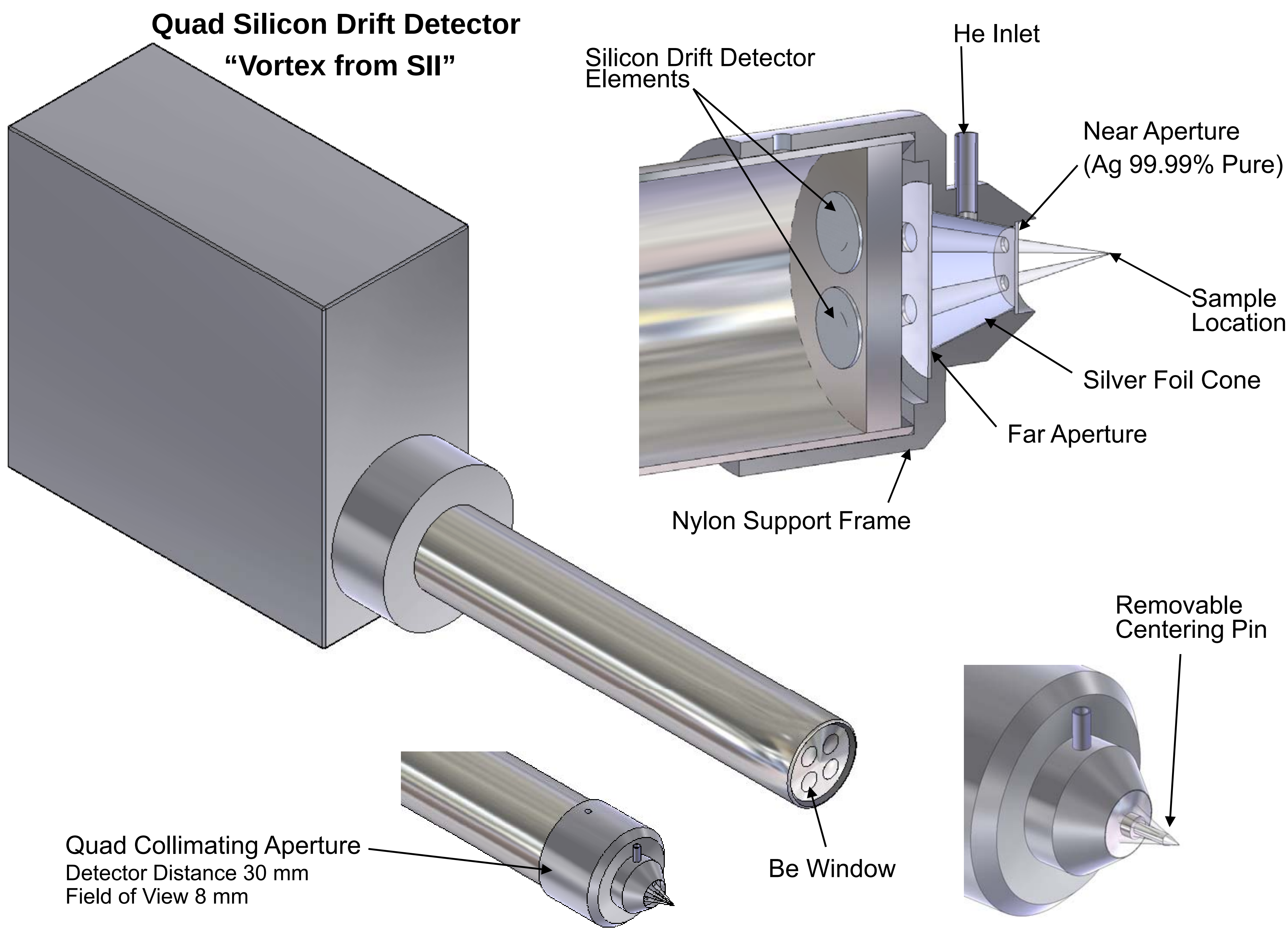
1. Yong Choi (NIU and now GSE-CARS)
2. Peter Eng (U. Chicago)
3. Steve Sutton (U. Chicago)
4. Sanjit Ghose (APS)
5. Curatorial Staff at Johnson Space Center (J. Allton, M. Calaway and M. Rodriguez)
6. Don Burnett (Cal Tech)

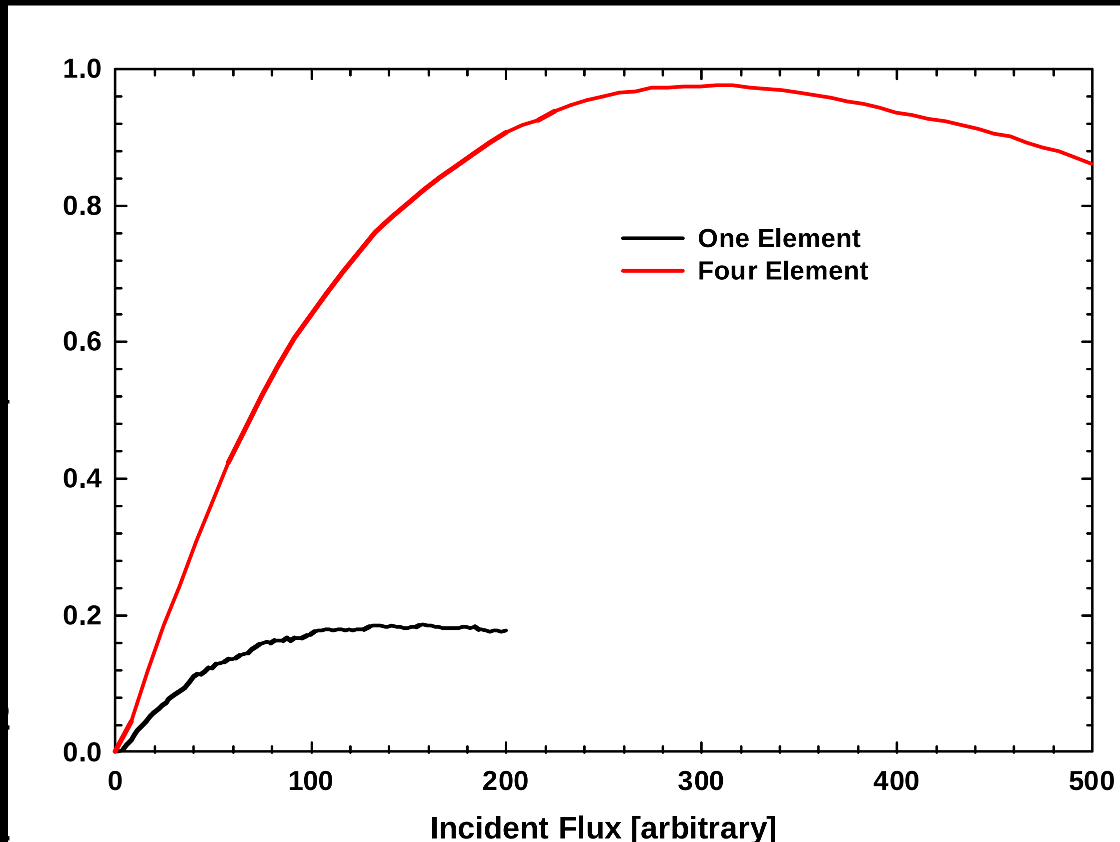
Materials and Methods

- The flight samples and spares are now being analyzed using x-ray reflectivity and grazing incidence x-ray fluorescence at APS GSECARS sector 13.

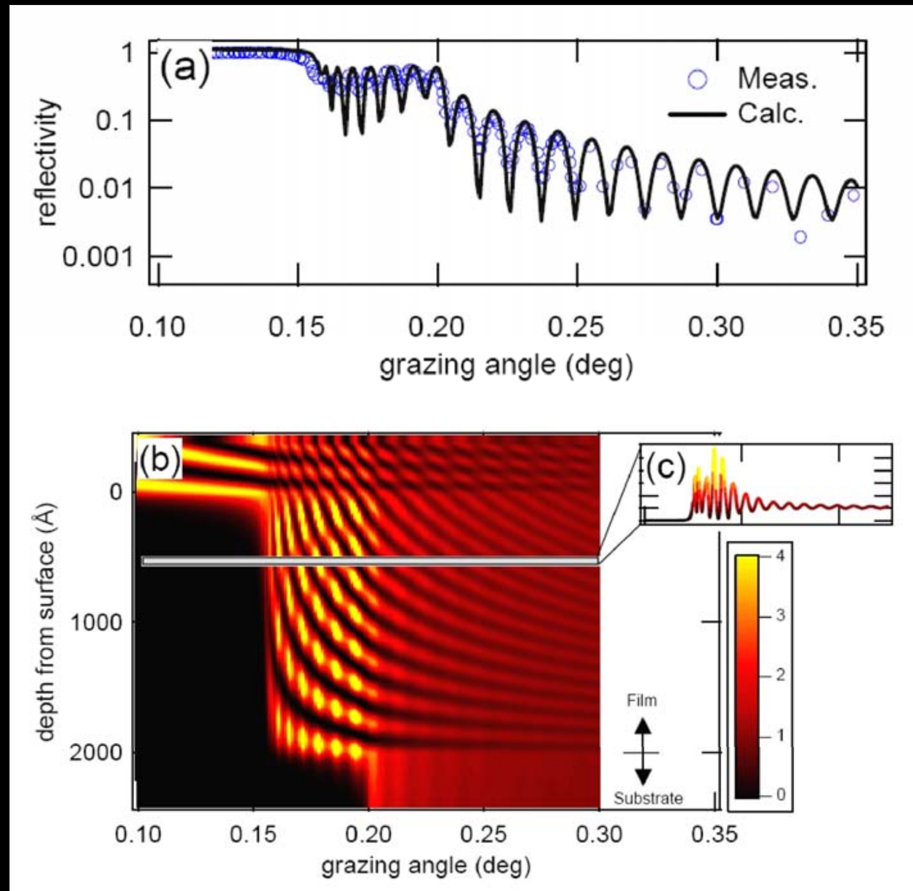


Surface
Contamination
Si Thin Film
Implanted Solar
Wind
1000Å
Sapphire Substrate


Quad Silicon Drift Detector
"Vortex from SII"
Silicon Drift Detector
Elements
He Inlet
Near Aperture
(Ag 99.99% Pure)
Sample
Location
Silver Foil Cone
Far Aperture
Nylon Support Frame
Removable
Centering Pin
Quad Collimating Aperture
Detector Distance 30 mm
Field of View 8 mm
Be Window

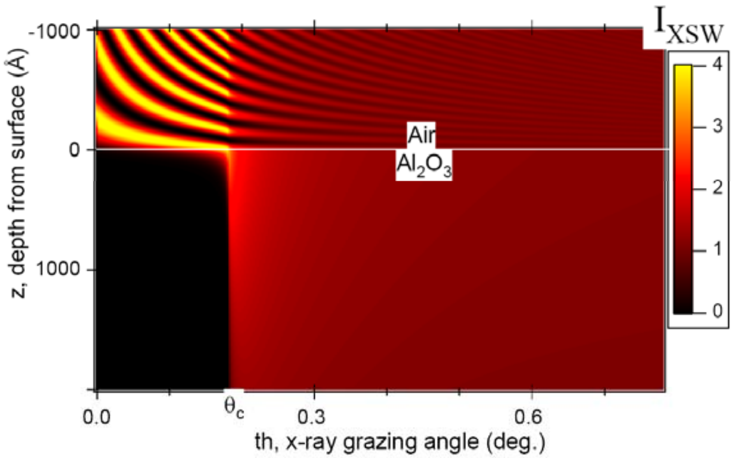


Comparison of count rate performance of the one and four element silicon multi-cathode detector operating at the same energy resolution.



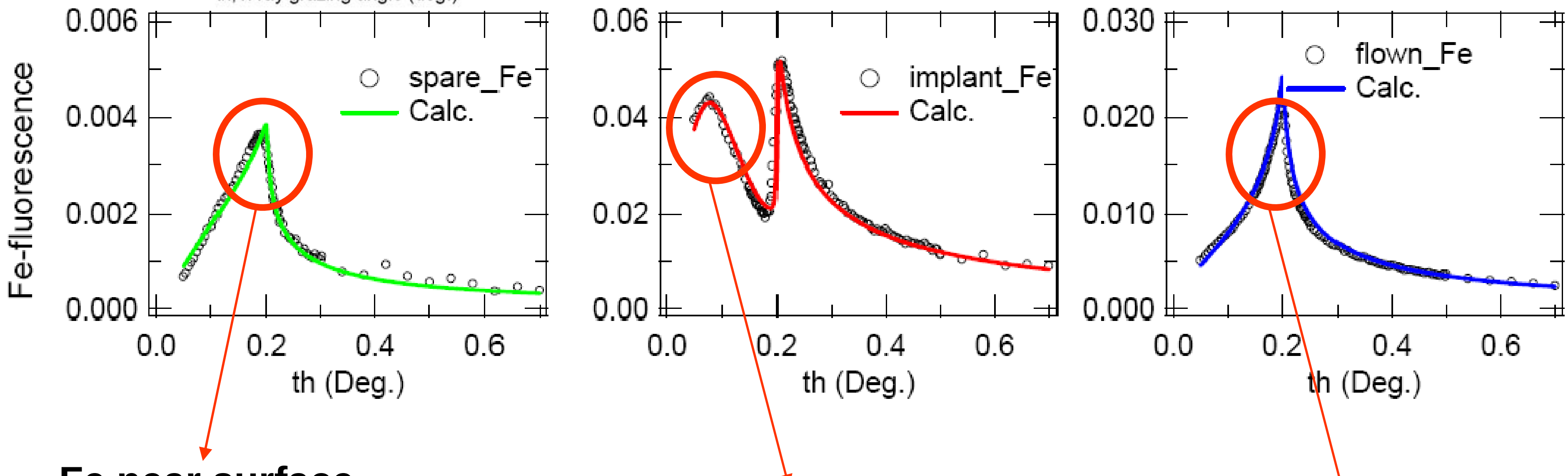
(a) Measured and calculated x-ray reflectivity curves for sample 60230 (SoS). (b) The calculated x-ray standing wave intensity variation inside the film as a function of the incident x-ray angle at various depth positions. (c) Calculated fluorescence yield from implanted atoms.

Features near θ_C



Critical angle θ_C~0.2

Total external reflection below θ_C

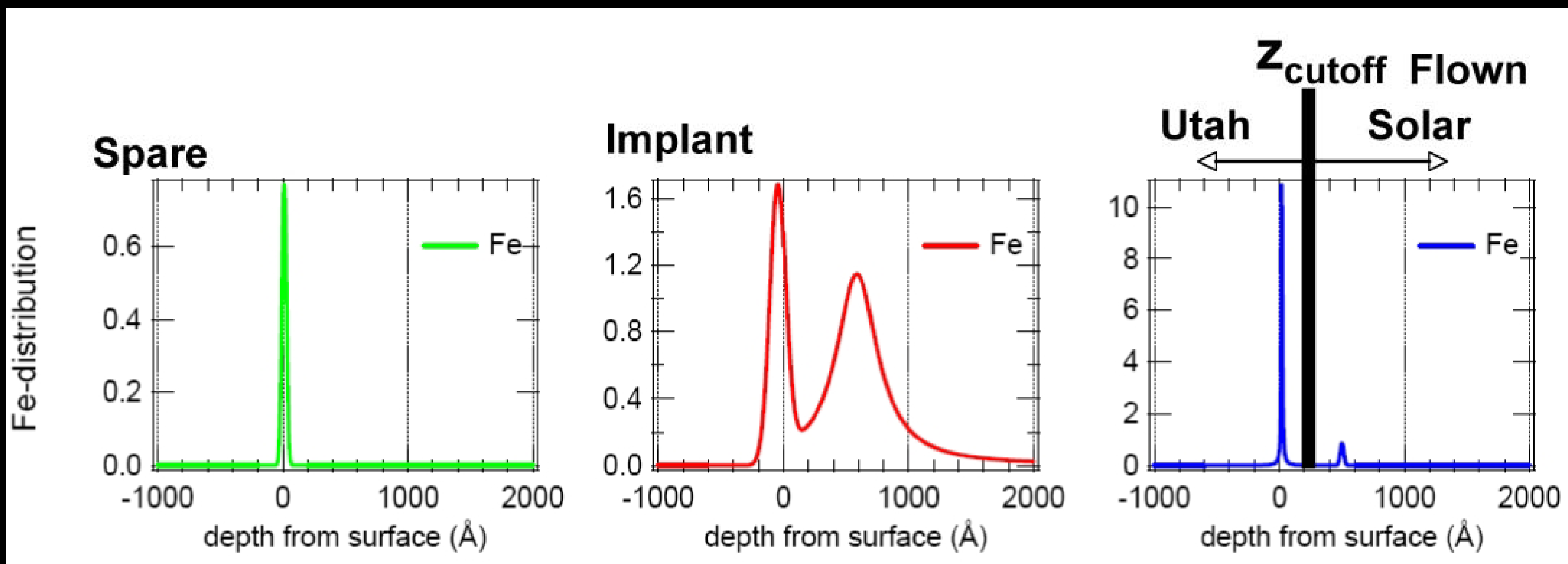


Fe near surface

Fe above substrate

implanted Fe near surface

Fe concentration for SAP



New Internal Reference Approach

- Due to its crystal structure and stoichiometry, the number of Al atoms per unit volume in the Al_2O_3 substrate can be calculated (4.690×10^{22} Al/cm^3).
- As the electric field intensity variation and attenuation length can be readily obtained, the fluorescence intensity from substrate elements can be used as an internal standard to calibrate the fluorescence intensity from an element of interest.

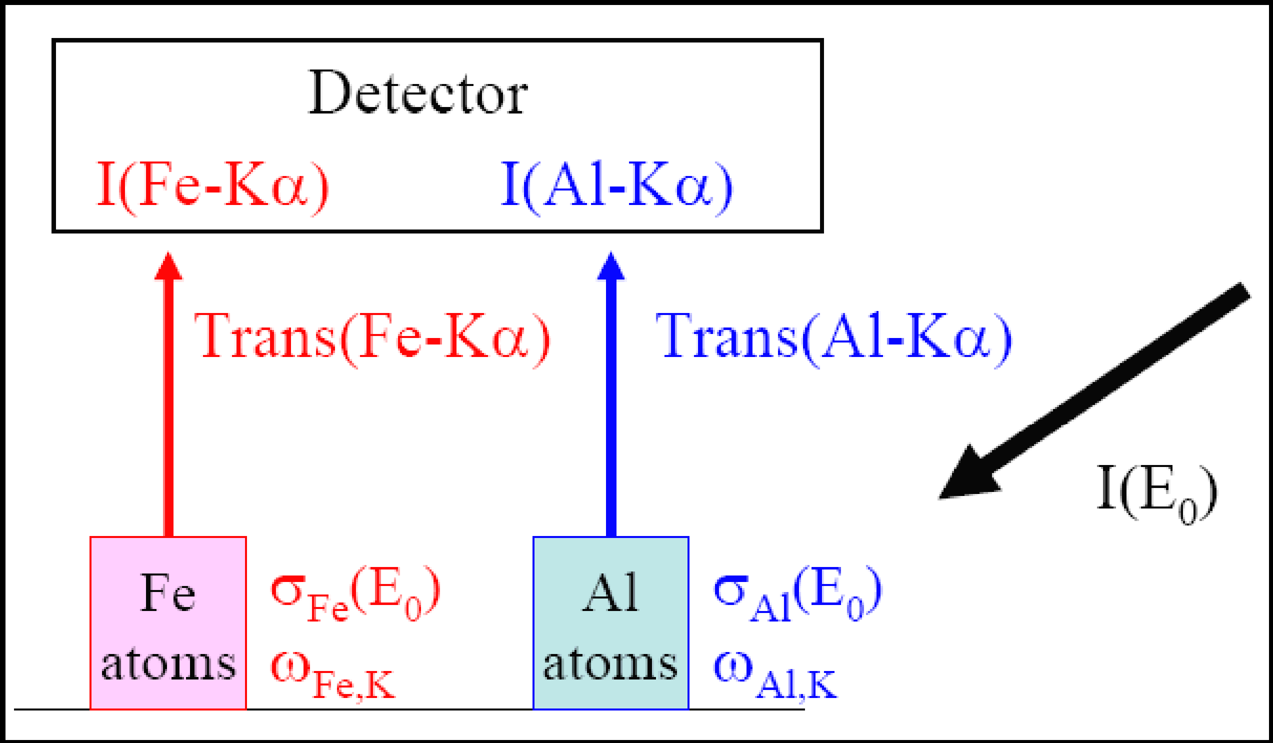
Modeling Fe Distribution

The fluorescent yield for a particular element as a function of incident angle θ is given by:

$$Y(\theta) = F \int_{z_{\min}}^{z_{\max}} I(\theta, z) N(z) e^{-z/l_a} G(\theta) dz$$

N(z) = abundance depth profile of the fluorescing element,
l_a = the attenuation length,
$I(\theta, z)$ = the electric field intensity at depth z and angle θ,
F = the x-ray energy-, element-, and setup-dependent factor,
G(θ) = the footprint correction that accounts for the change with θ,
$I(\theta, z)$ is calculated using Parratt's recursive formalism with the parameters obtained from the reflectivity fits.

Schematic summarizing the element and energy dependent factors included in the Fe in Al_2O_3 data analysis (F in Eq. 1).



Additional Factors

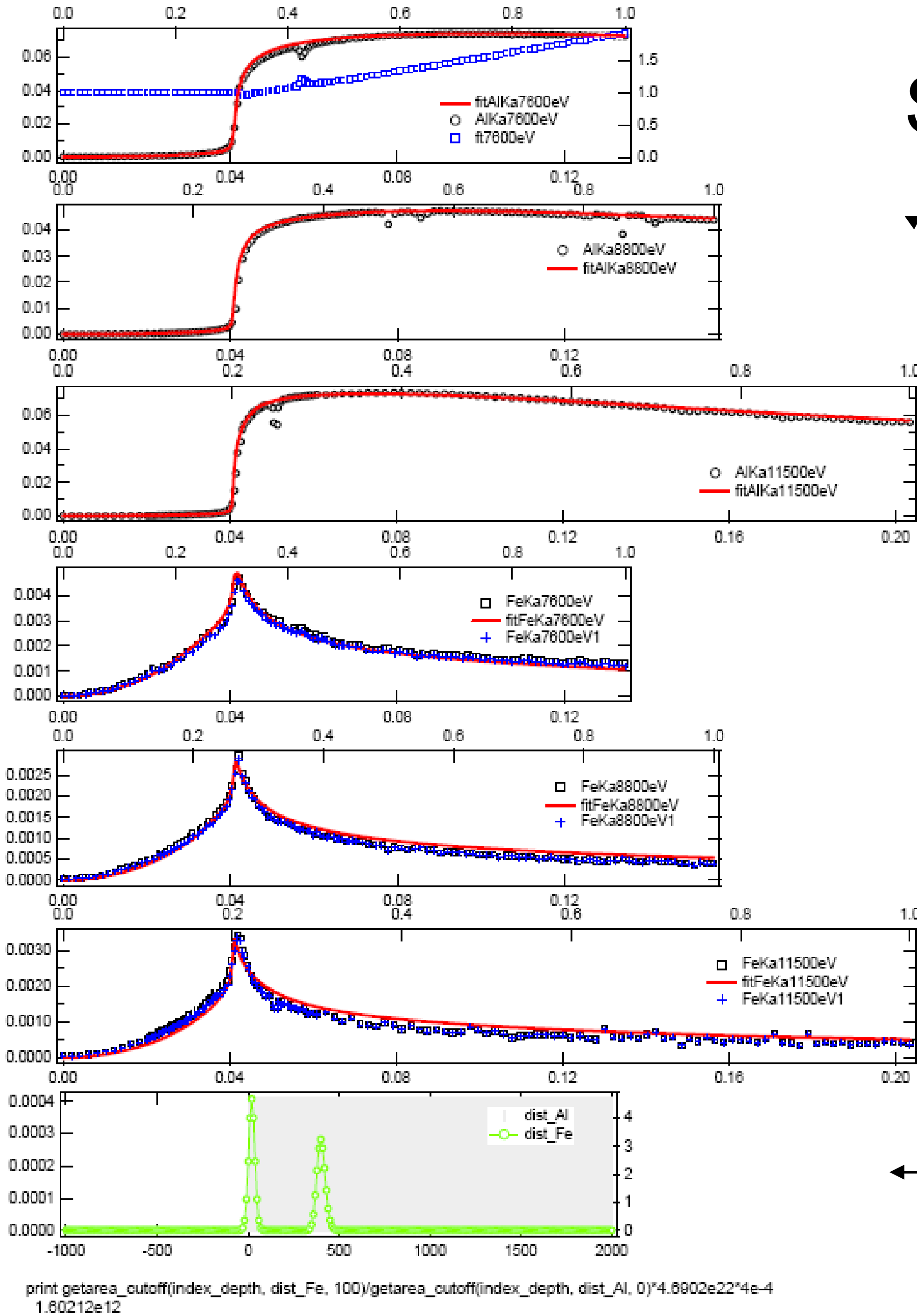
- I(Al-Kα) and I(Fe-Kα) are proportional to the element-dependent and incident-energy-dependent cross-section $\sigma(E_0)$, the fluorescence yield ω_K, the transmission ratios from the sample surface to the detector, and the detector efficiency.
- $\sigma(E_0)$ *and* ω_K, are well documented
- The attenuation inside the sample is included in Eq. 1.
- For each fluorescence emission, the different transmission rate from the sample surface to the fluorescence detector can be determined as the distance and materials between them are known.

Implant Example

New Internal Standard Method

- We measured both an SAP (50722) and an Si (60171) at 4 energies (11.5, 8.8, 7.6, 5.1 keV).
- One model was used to fit 3 sets of data simultaneously. (In the examples on the next two slides, we excluded the 5.1 keV data.)

SAP (flown sapphire)



Al fluorescence

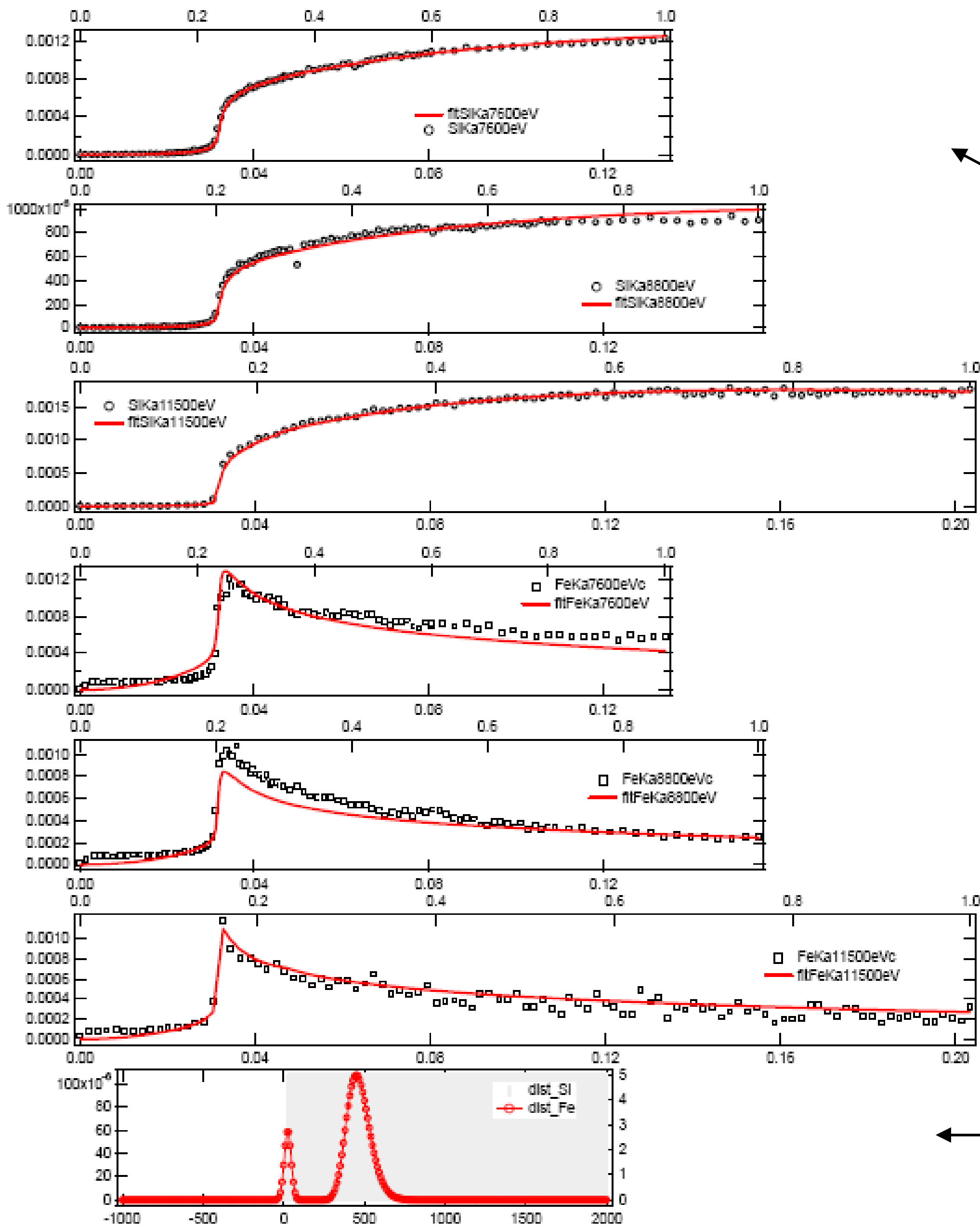
Scales
top: angle in degrees
bottom: qz in inverse Angstroms
left: normalized intensity

Fe fluorescence

two Al, Fe depth profiles used for the six data sets

Fe: 1.6e12 atoms/cm^2

Si (flown Silicon)



print getarea_cutoff(index_depth, dist_Fe, 200)/getarea_cutoff(index_depth, dist_Si, 0)*4.99591e22*6e-4
1.91851e+12

Si fluorescence

Scales
top: angle in degrees
bottom: qz in inverse Angstroms
left: normalized intensity

Fe fluorescence

two Si, Fe depth profiles used for the six data sets

Fe: 1.9e12 atoms/cm^2

Fe concentration for SAP

As reported in Kitts et al, 2009, using the Standard Method, there is a systematic variation of approximately 5% added to the measurement depending on the standard used thus:

$Fe_{flown} = 1.6 \pm 0.4\ e^{12}/cm^2$

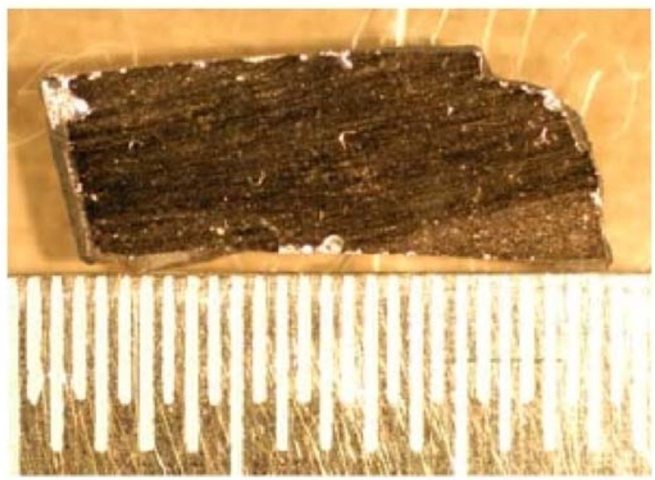
Using our new self-consistent internal standardization (assuming perfect sapphire crystal):

$Fe_{flown} = 1.6 \pm 0.2\ e^{12}/cm^2$

Fe concentration for Si

Using our new self-consistent internal standardization (assuming perfect silicon crystal):

Fe_{flown} = 1.9 ± 0.3 e^{12}/cm^2


60171

SIMS Fe fluences (Burnett et al.)