A multi-spectrograph using non-overlapping asymmetric diffraction from a single KAP crystal

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Abstract: Acid phthalates crystals such as KAP crystals are the method of choice to record x-ray spectra in the soft x-ray regime (E~1keV) using the large (001) 2*d*=26.63Å spacing. Burkhalter et al., J. Appl. Phys., 1981, showed that (013) reflection is about or more reflective as the 2nd order reflection (002) and can even overlap the main first order reflection when the crystal *b*-axis is contained in the dispersion plane, thus contaminating the main (001) measurement. We present a new concept of a spectrograph utilizing these asymmetric reflections in the non-typical case when the crystal *b*-axis is perpendicular to the dispersion plane. In such case, asymmetric reflections do not overlap with the main (001) reflection and each reflection can be used as an independent spectrograph. Here we demonstrate an achieved spectral range of 0.8-13keV with a prototype setup. The detector measurements were accurately reproduced with 3D ray-tracing.

Previous work

Z experiments

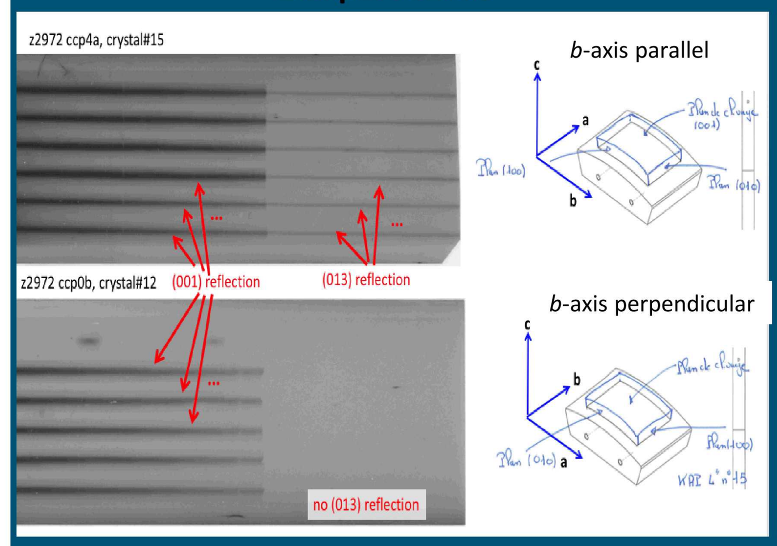
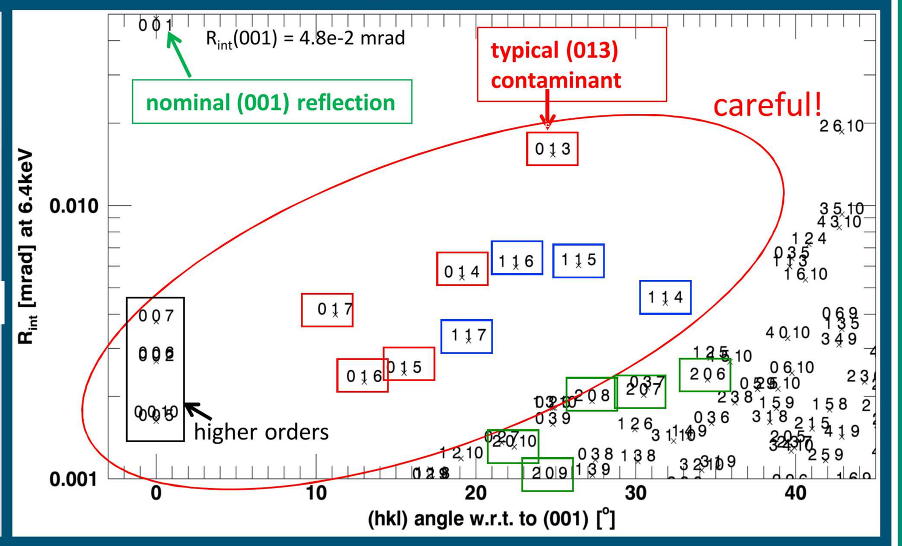


Diagram R_{int} vs angle deviation



Pioneer work of multiple reflection studies with KAP by Burkhalter et al. , 1981 [1], see also, [2], [3].

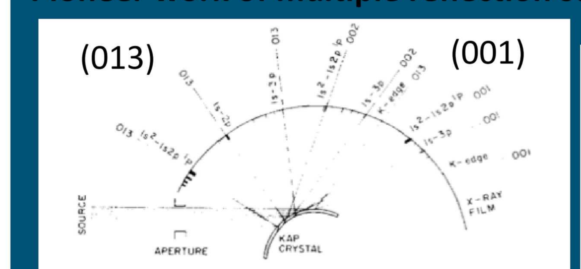


FIG. 1. Schematic of the KAP curved-crystal spectrograph showing the ray paths for selected lines of highly ionized Al and diffracting planes.

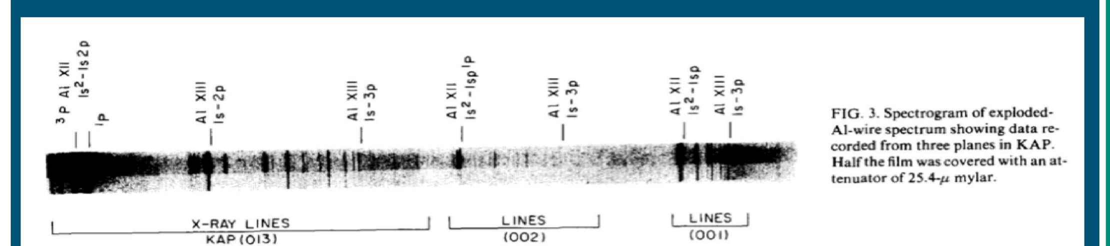
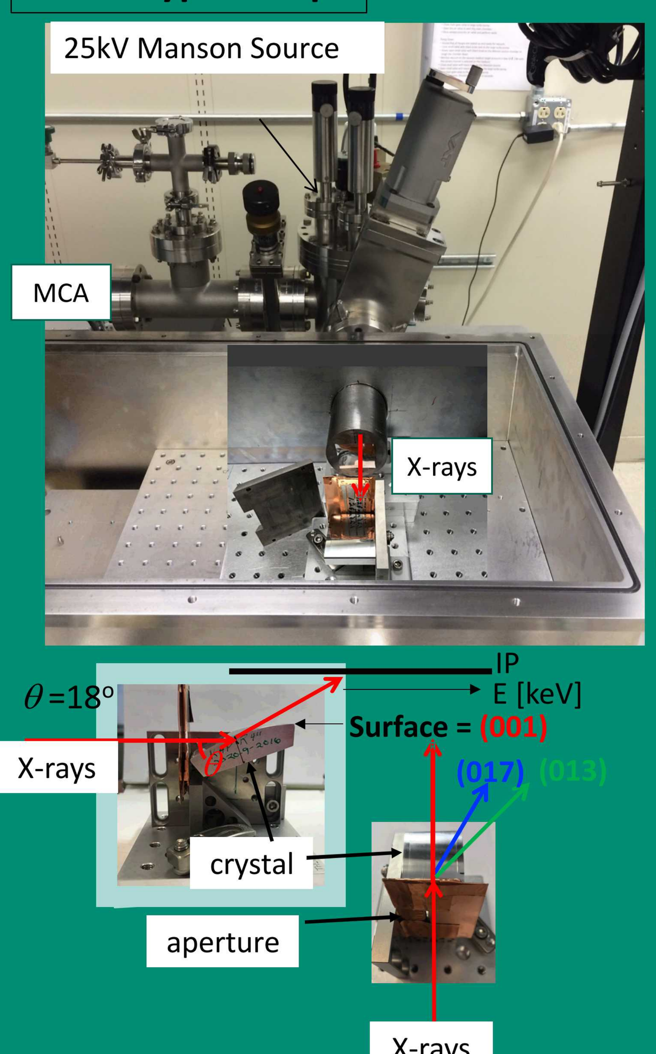
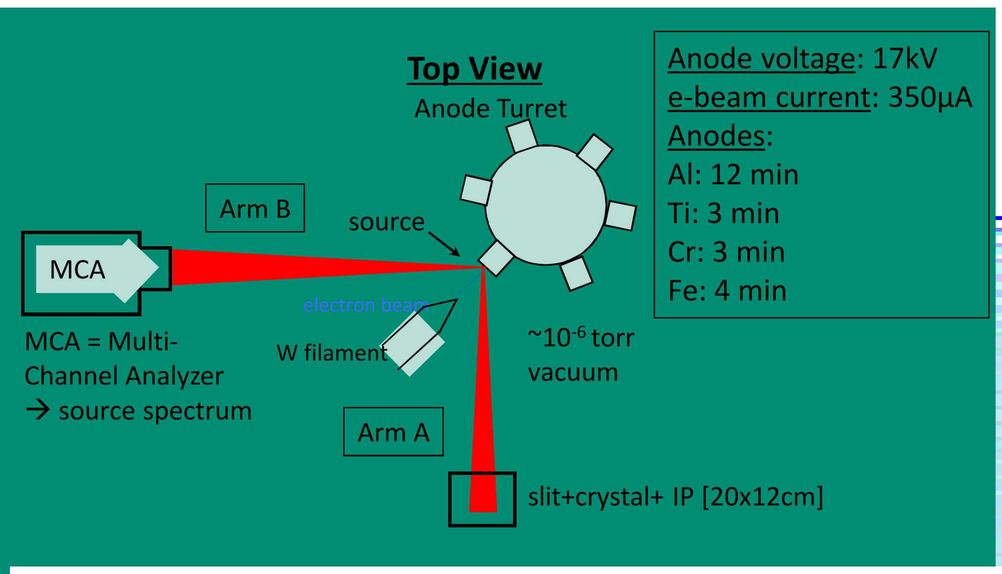


FIG. 3. Spectrogram of exploded-Al-wire spectrum showing data recorded from three planes in KAP. Half the film was covered with an attenuator of 25.4μ mylar.

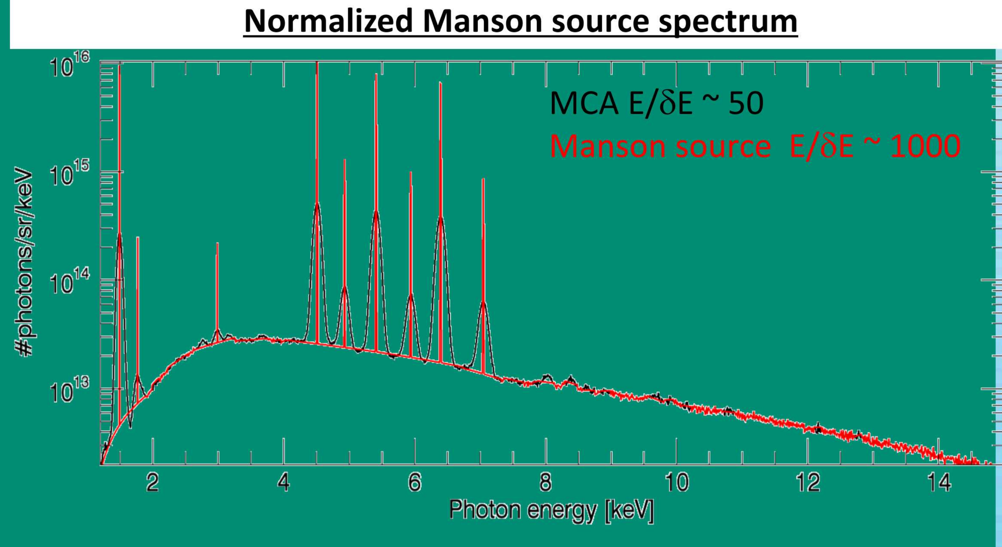
Prototype setup



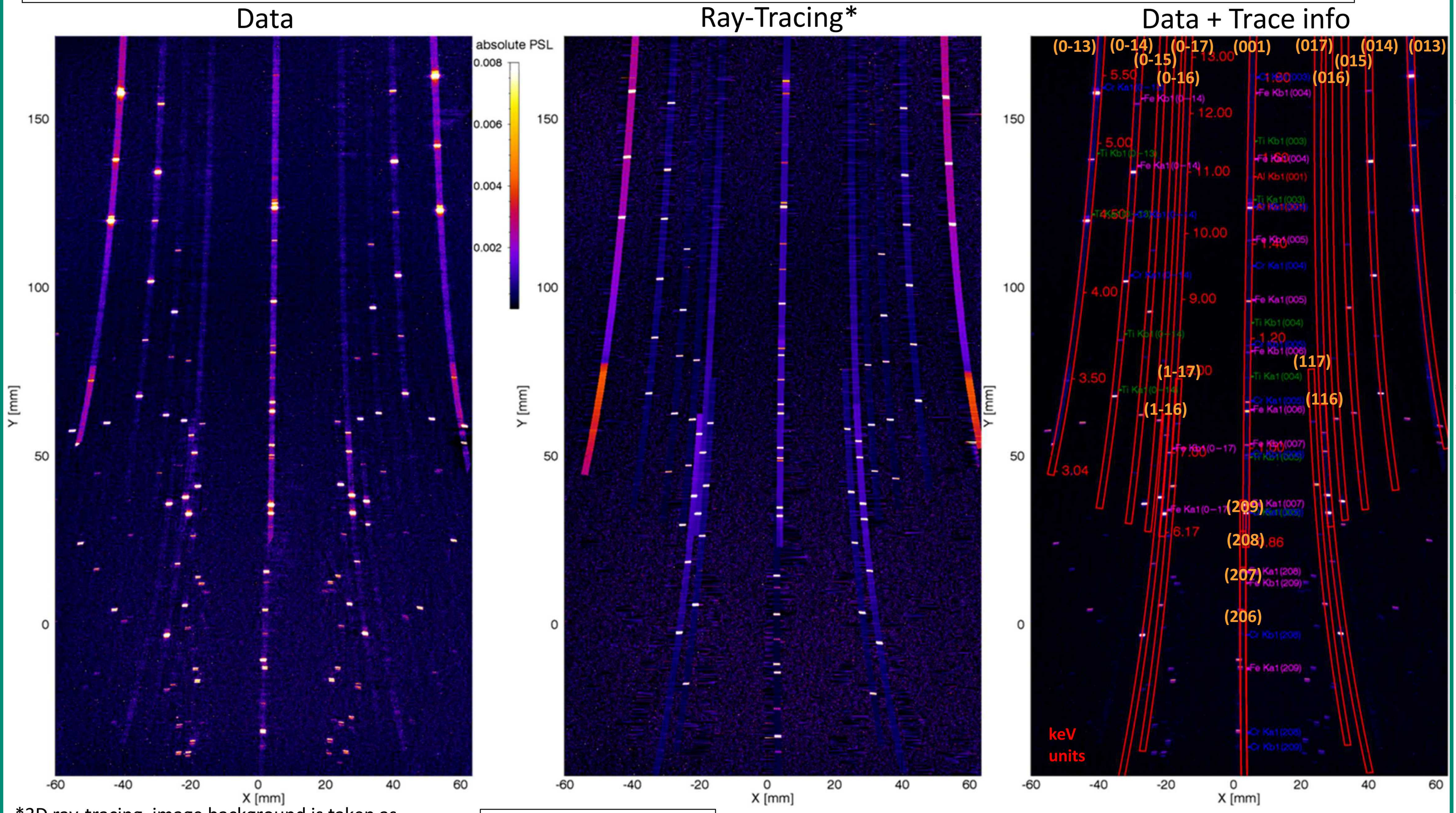


Anode voltage: 17kV
e-beam current: 350μA
Anodes:
Al: 12 min
Ti: 3 min
Cr: 3 min
Fe: 4 min

Normalized Manson source spectrum

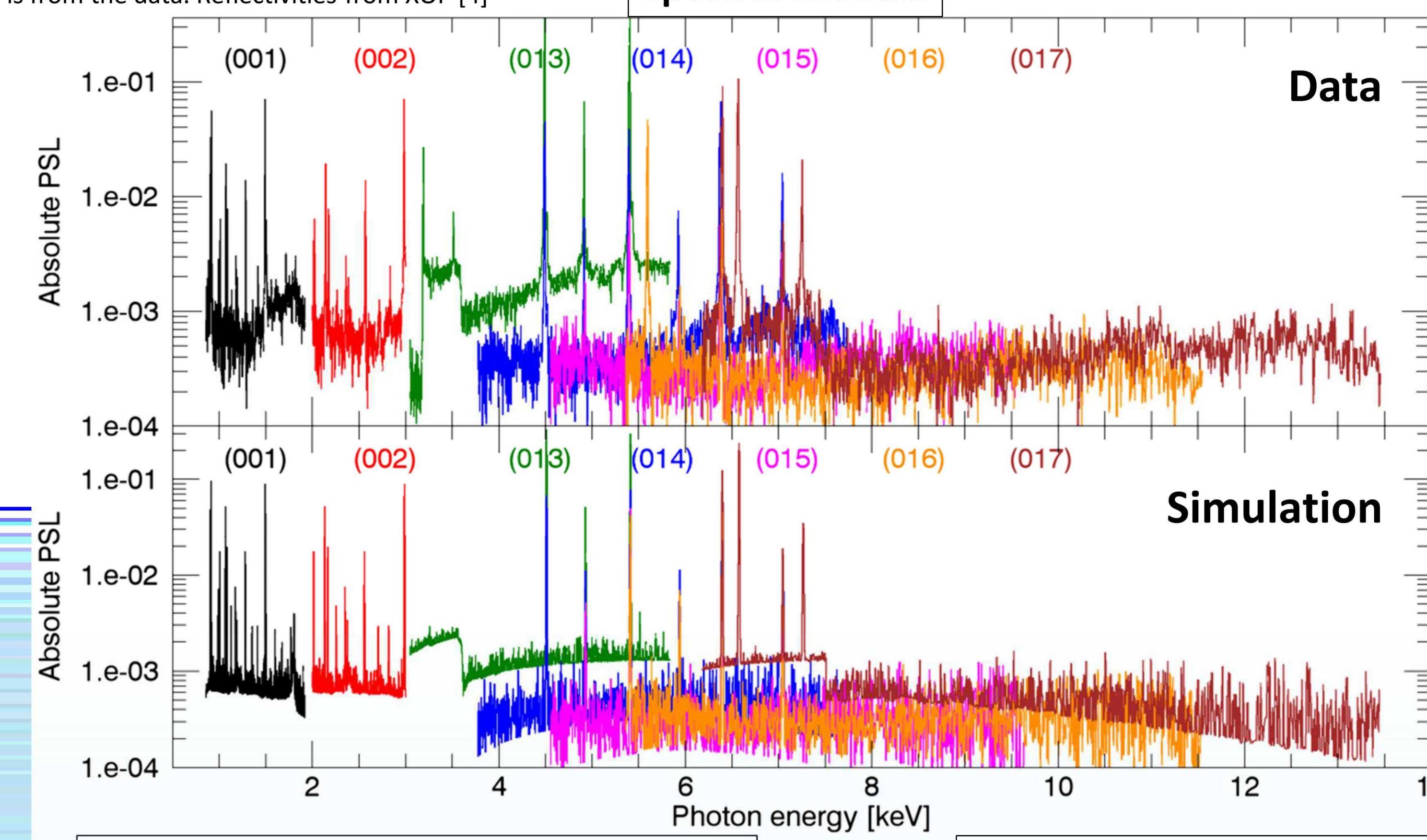


Comparison with ray-tracing prediction: Raytracing simulation provides absolute agreement with data



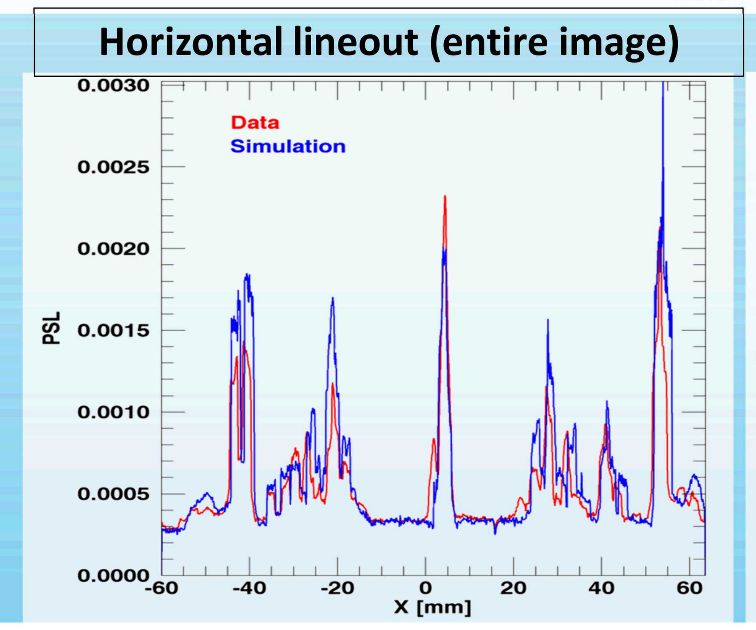
*3D ray-tracing, image background is taken as-is from the data. Reflectivities from XOP [4]

Spectral lineouts

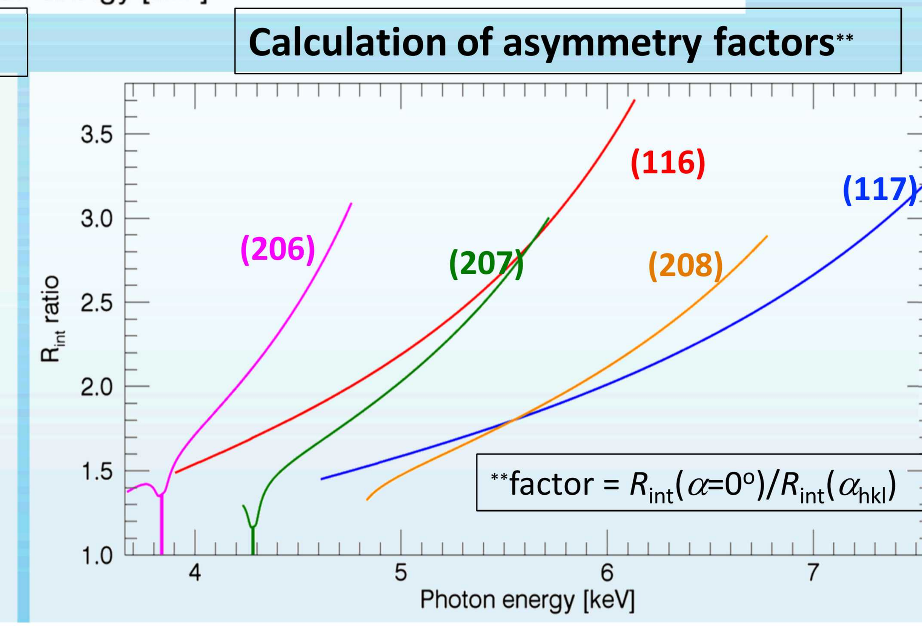


- Spectral and spatial shapes are well reproduced with a 3D ray-tracing model.
- A good absolute agreement is obtained with asymmetric angle factor of 5, i.e. R_{int}(simu) = R_{int}(XOP) / 5 [see figure below]. XOP can not take as input an asymmetry angle that is outside the dispersion plane (limited for the application here).

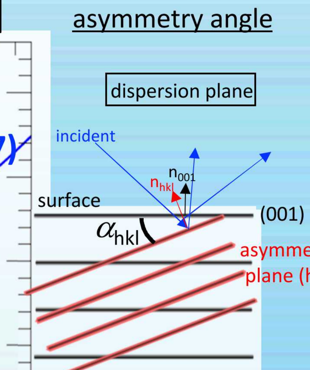
Horizontal lineout (entire image)



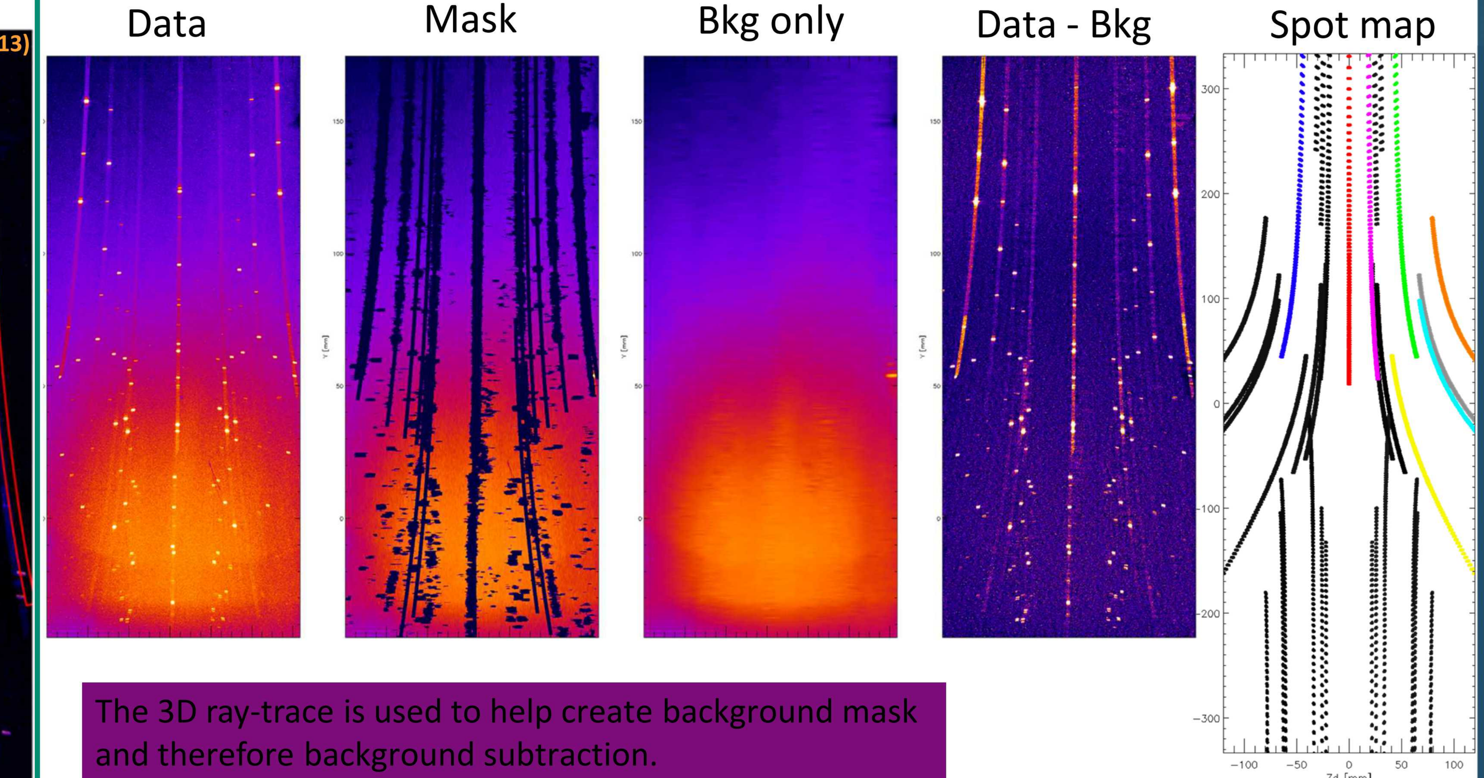
Calculation of asymmetry factors**



XOP geometry for asymmetry angle



Background subtraction with ray-tracing



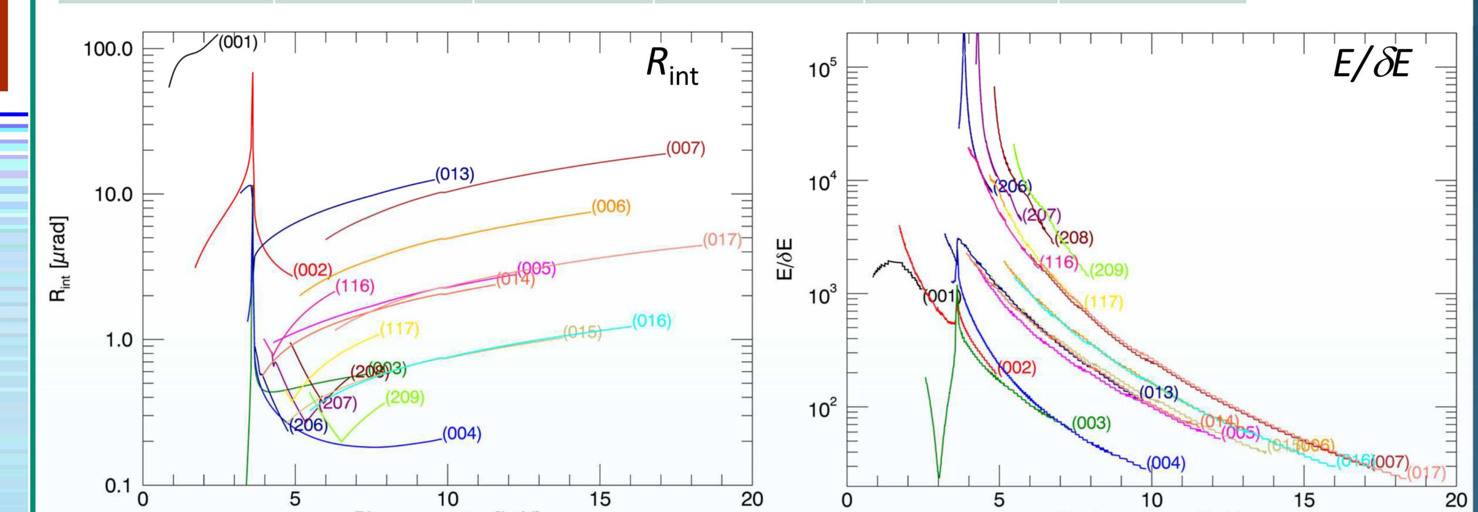
The 3D ray-trace is used to help create background mask and therefore background subtraction.

Main reflections parameters

Plane	asymmetric angle [°]	hc/2d [keV]	E-range [keV]	R_{int} [μrad][4]	E/δE [4]
(001)	0.0	0.47	0.9 – 2.5	54 – 124	1098 – 1944
(002)	0.0	0.93	1.7 – 4.9	2.7 – 69	197 – 4000
(003)	0.0	1.39	2.6 – 7.3	1.e-3 – 11.5	23 – 1200
(004)	0.0	1.86	3.4 – 9.8	0.18 – 7.85	29 – 2537
(005)	0.0	2.33	4.3 – 12.2	0.96 – 2.80	53 – 1698
(006)	0.0	2.79	5.2 – 14.7	2.0 – 7.50	41 – 1926
(007)	0.0	3.26	6.0 – 17.1	4.9 – 18.9	29 – 2200
(013)	24.8	1.54	3.2 – 9.6	2.74 – 12.5	119 – 3354
(014)	19.1	1.97	3.9 – 11.6	0.6 – 2.4	66 – 2270
(017)	11.2	3.32	6.3 – 18.3	1.2 – 4.4	23 – 1930
(209)	24.6	4.61	5.5 – 7.9	0.2 – 0.4	1430 – 21000
(116)	22.5	3.02	3.9 – 6.3	0.8 – 2.1	1680 – 19500
(117)	19.5	3.46	4.7 – 7.7	0.4 – 1.1	550 – 11000

θ=18°
Total range
0.9 -17keV

θ=30°
Total range
0.5 -15keV



Perspectives:

- Understand better asymmetric plane reflectivities
- Calibrate with the old orientation in KAP
- Calibrate RAP in equivalent setup
- Field in an experiment with optimized detector geometry for a broad spectrum

References:

[1] P. Burkhalter, D. Brown and M. Gersten, Journal of Applied Physics **52**, 4379 (1981).
[2] L. Birks, Review of Scientific Instruments **41**, 1129 (1970).
[3] J. F. Seely, A. Henins, and U. Feldman, Review of Scientific Instruments **87**, 053101 (2016).
[4] R. Caciuffo, C. Ferrero, O. Francescangeli, and S. Melone, Review of Scientific Instruments **61**, 3467 (1990), code: XOP, M. Sánchez del Río and R. Dejus, SPIE Proc. **8141**, 814115 (2011)

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