

Investigation in EPIC-MOS pattern fractions

EPIC calibration meeting, ESAC

Martin Stuhlinger, Serco on behalf of ESA, SCO-04

23.56.2025

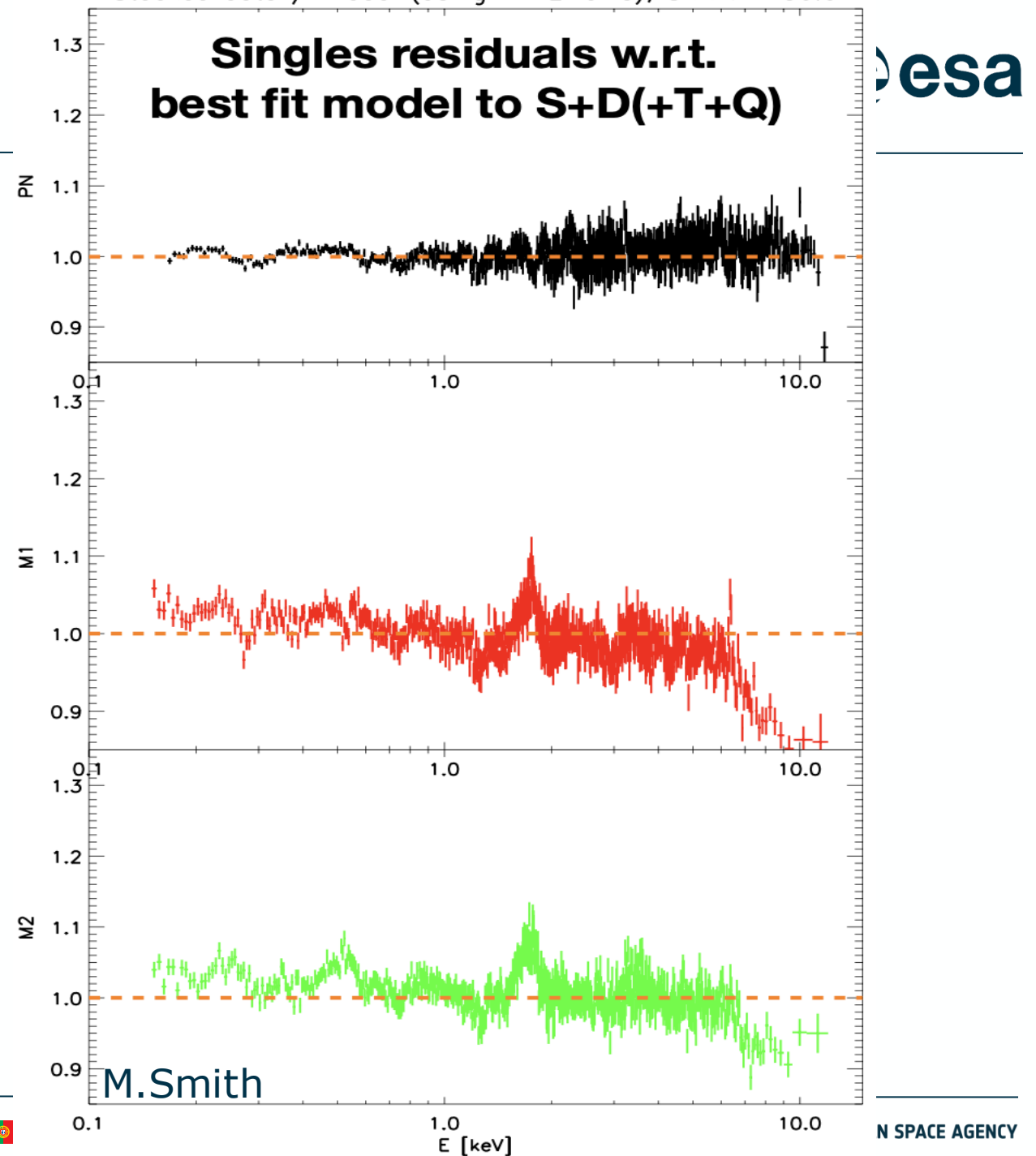
Motivation

Spectral comparison between EPIC-pn/EPIC-MOSes using data samples:

- Different appearance of stacked residuals dependent on PATTERN selection.
- More obvious for MOSes than for pn.

Example:

Stacked sample residuals for best fit models of valid pattern (pn: PATTERN in [0-4], MOS: PATTERN in [0-12]) when models are applied to single event (PATTERN==0) spectra.



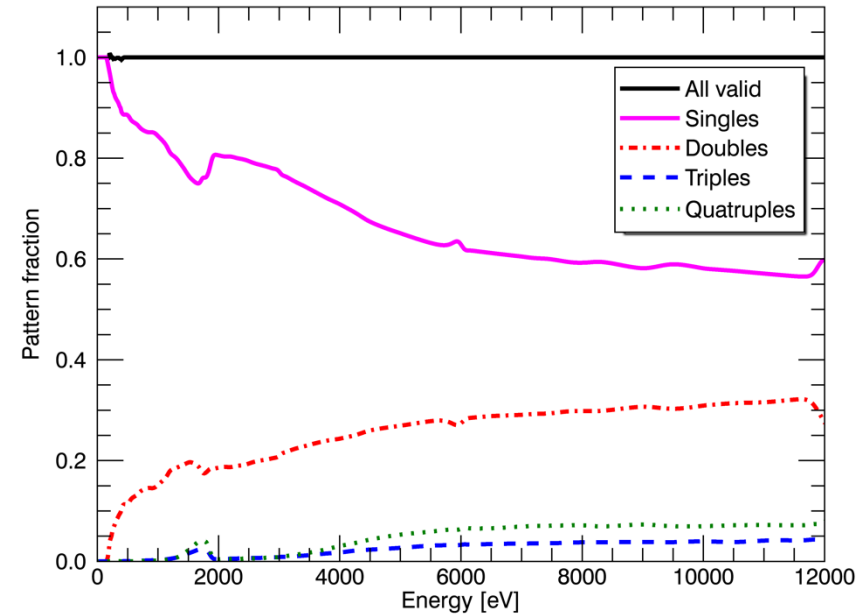
Motivation

Current CCF status:

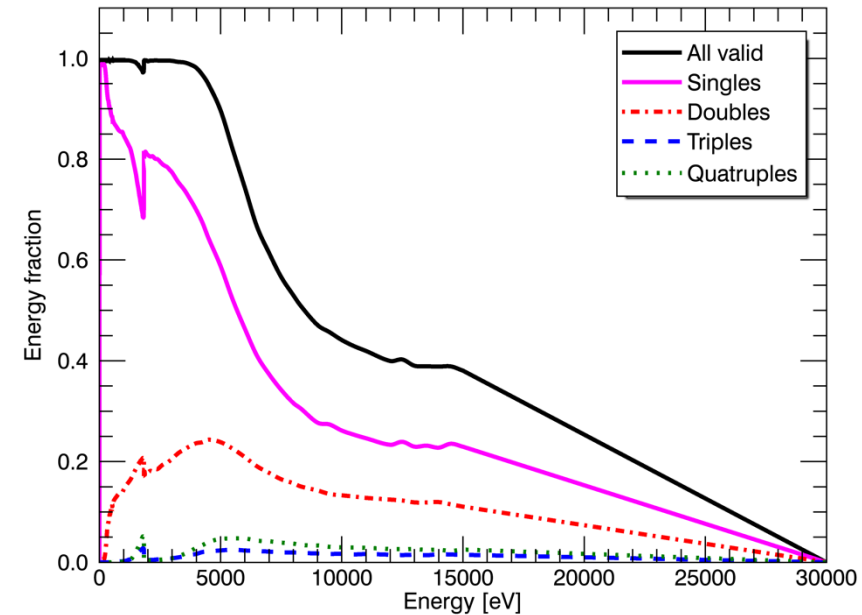
- Created in year 2002.
- 2 CCFs: time epochs before/after cooling.
- Identical values for different imaging modes.
- Identical values for different timing modes.
- Timing mode values composed using imaging mode pattern fractions.
- Identical values for MOS1 and MOS2.
- Origin of current CCF values is lost in time (physical model, measurement).



MOS imaging modes pattern fractions



MOS imaging modes energy fractions



Scan all observations (focal CCD1) of XMM-Newton archive:

Four selection criteria for data inclusion into analysis:

- 1st threshold: more than 20000 counts after flare screening.
- 2nd threshold: minimum 10 counts/pixel.
- 3rd threshold: maximum pile-up fraction of 1.0%.
- 4th threshold: more than 1000 counts with $E > 3$ keV.

General exposure brightness limit.

Source selection limit.

Data pixel quality limit.

Hard source selection limit.

Thresholds might be adapted/optimized.

Separation into 4 spatial regions:

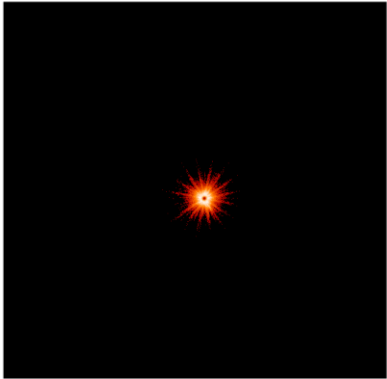
- On-patch (patch centre/patch wing)
- Off-patch
- All data

Usually patch centre and off-patch regions not available for same ObsID.

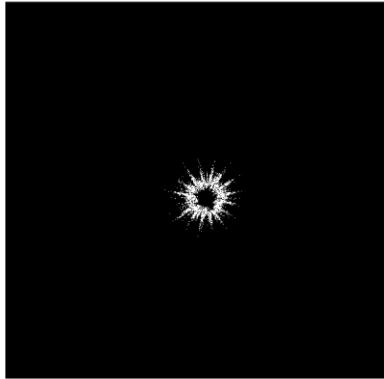
Data selection: FF examples

ObsID 0799_0067751001

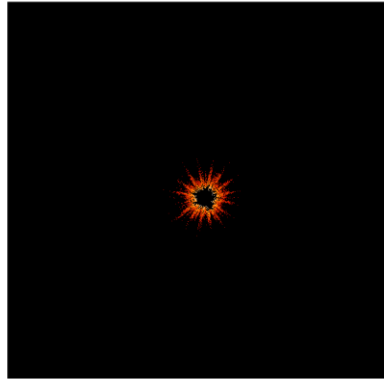
Flare screened



Pile-up mask

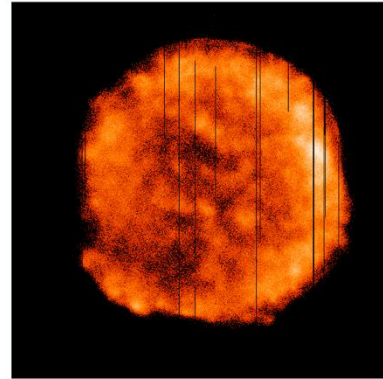


Pixel for analysis

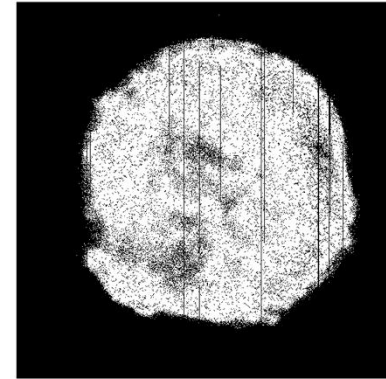


ObsID 1477_0511180201

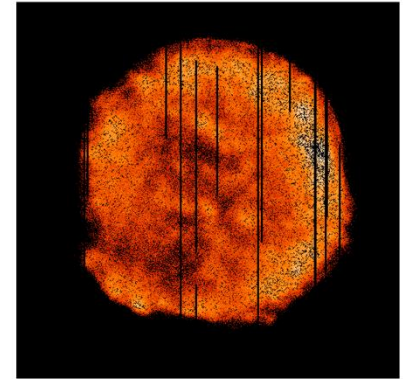
Flare screened



Pile-up mask

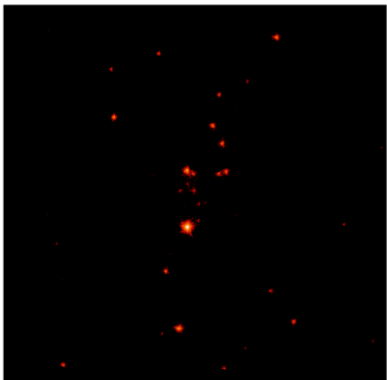


Pixel for analysis

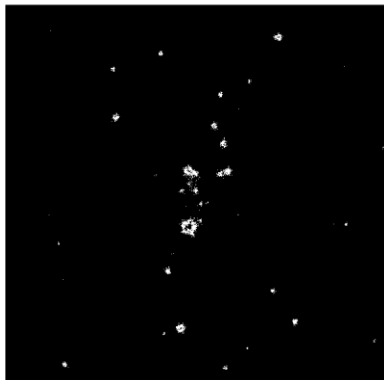


ObsID 0285_0109270101

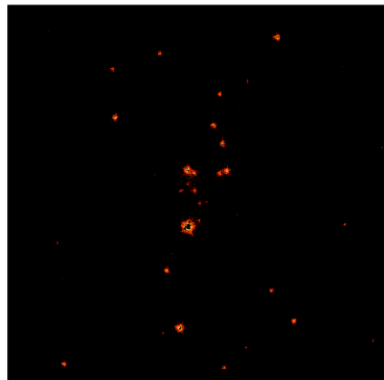
Flare screened



Pile-up mask

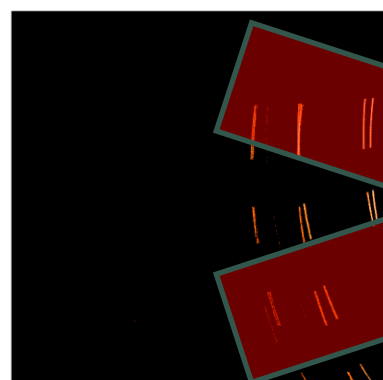


Pixel for analysis

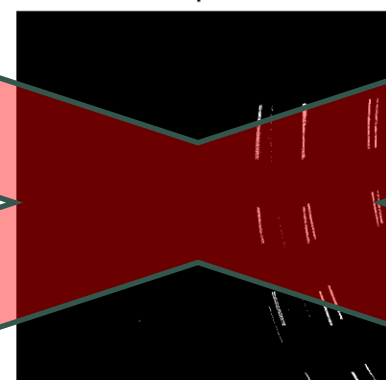


ObsID 3525_0820310601

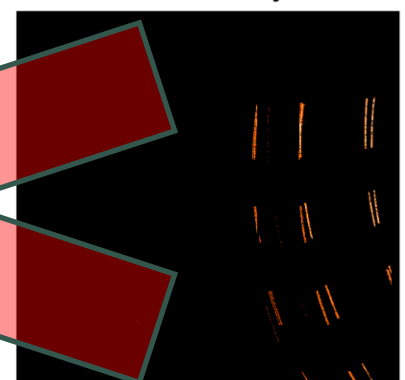
Flare screened



Pile-up mask



Pixel for analysis



Data selection: FF examples

ObsID 2451_0701981601 patch wing

patch centre (no off-patch available)

Flare screened

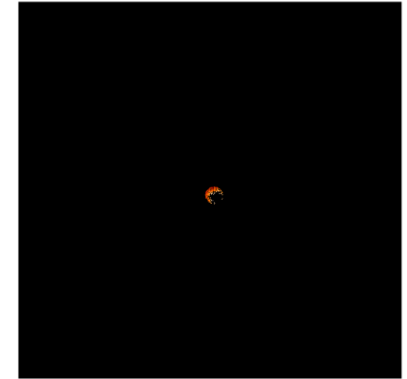
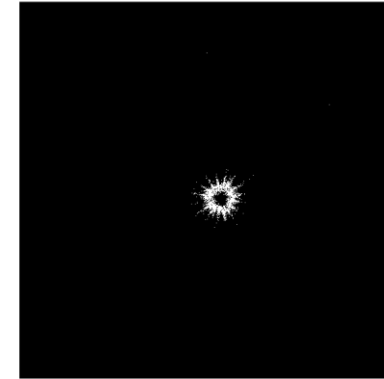
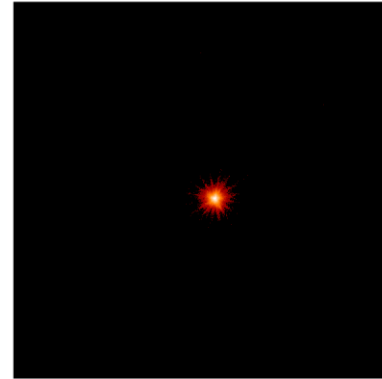
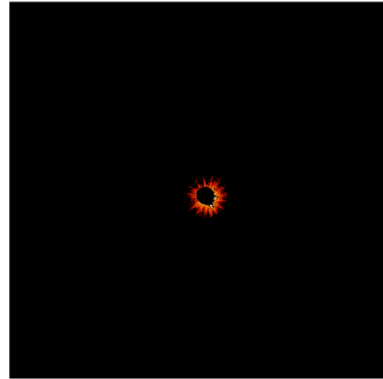
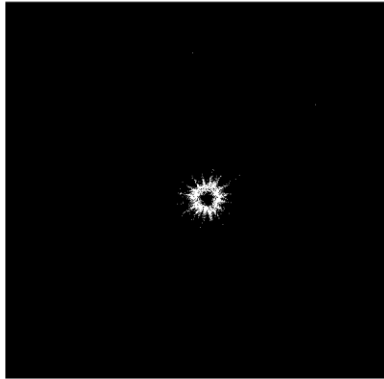
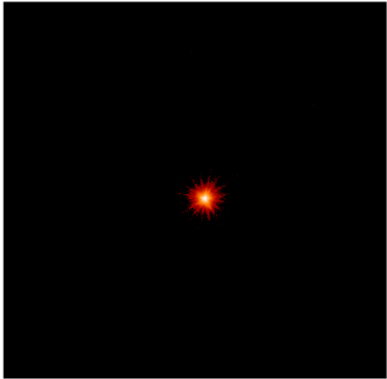
Pile-up mask

Pixel for analysis

Flare screened

Pile-up mask

Pixel for analysis



ObsID 2572_0722860401 patch wing

off-patch (no patch centre available)

Flare screened

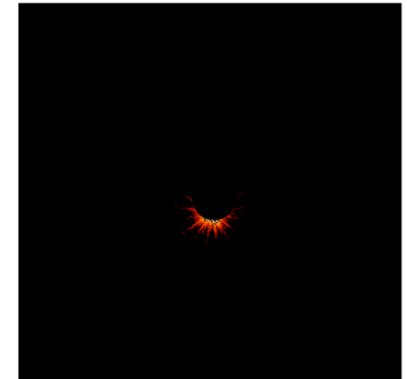
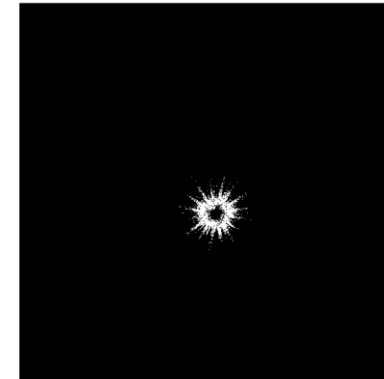
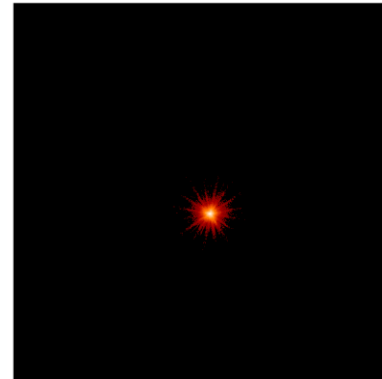
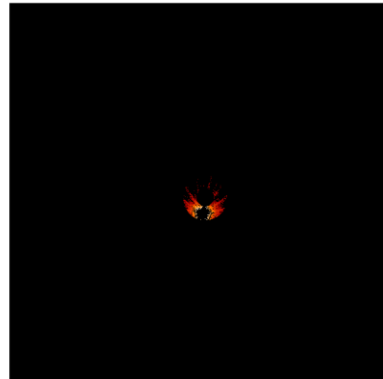
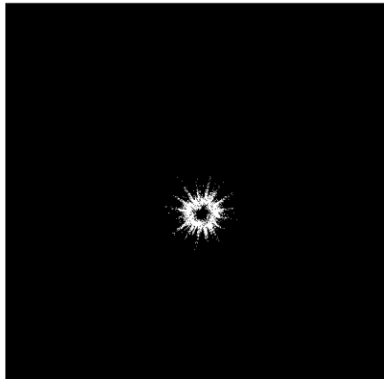
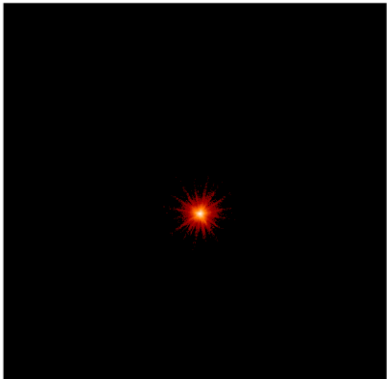
Pile-up mask

Pixel for analysis

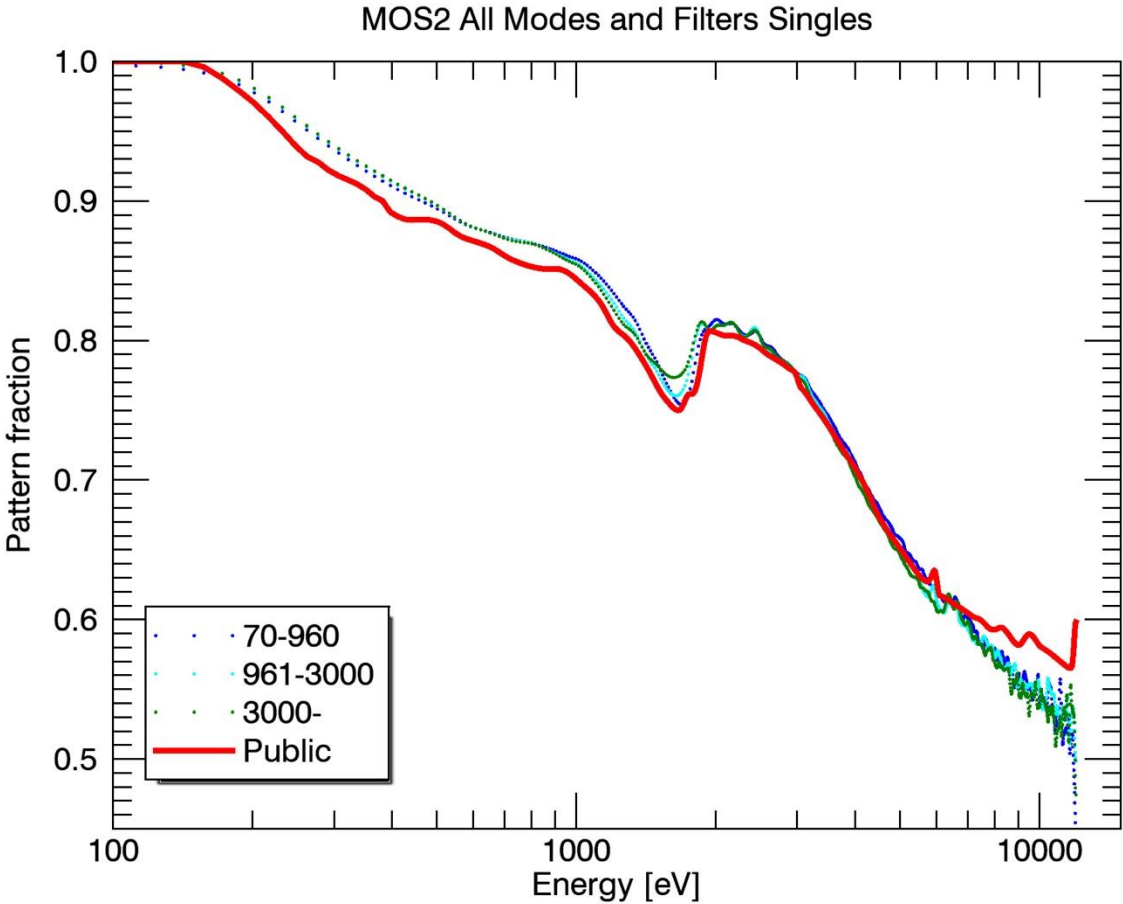
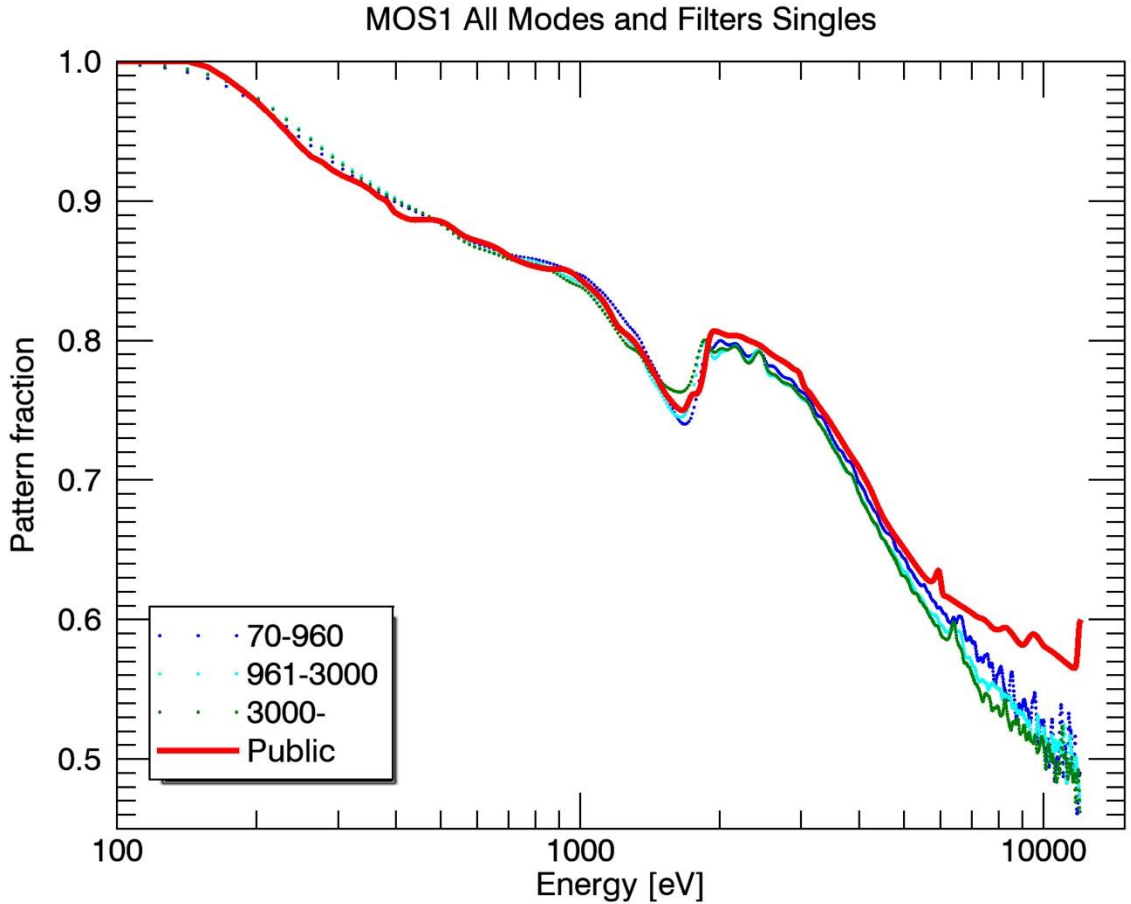
Flare screened

Pile-up mask

Pixel for analysis

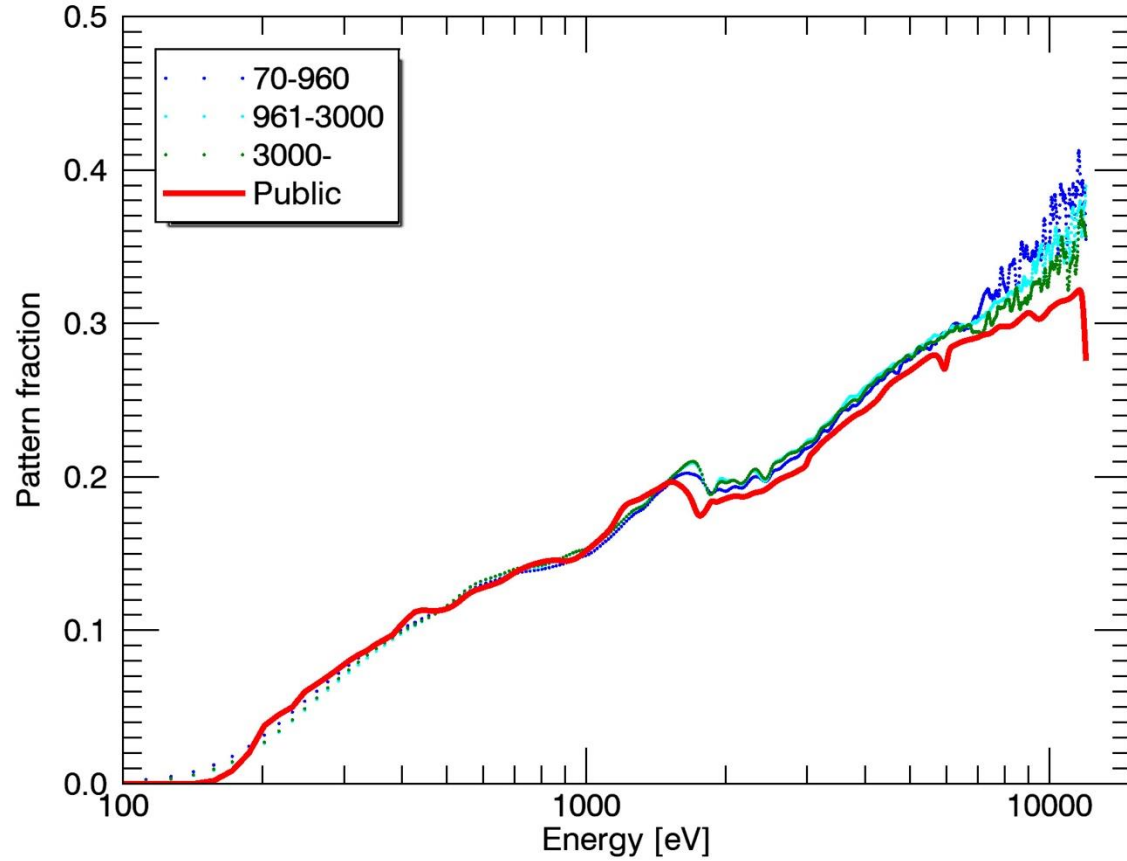


Combined modes/filters: singles time evolution

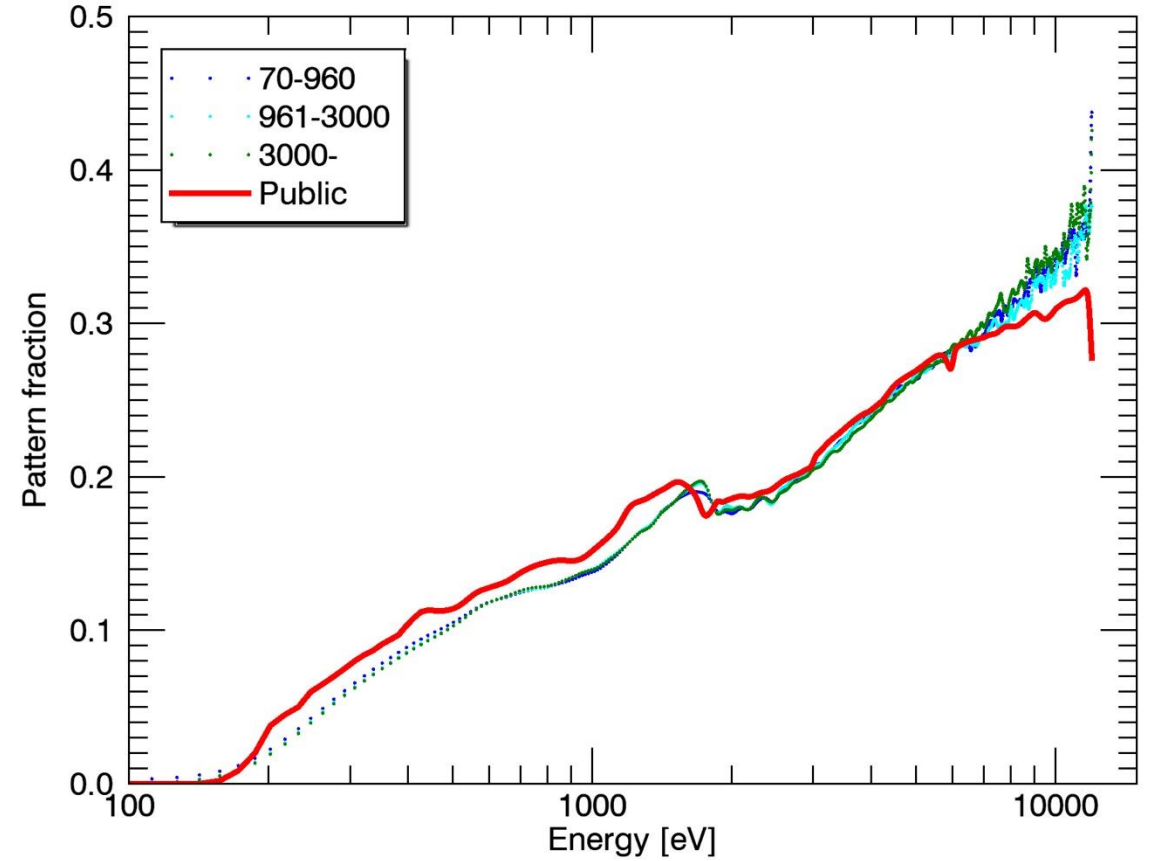


Combined modes/filters: doubles time evolution

MOS1 All Modes and Filters Doubles

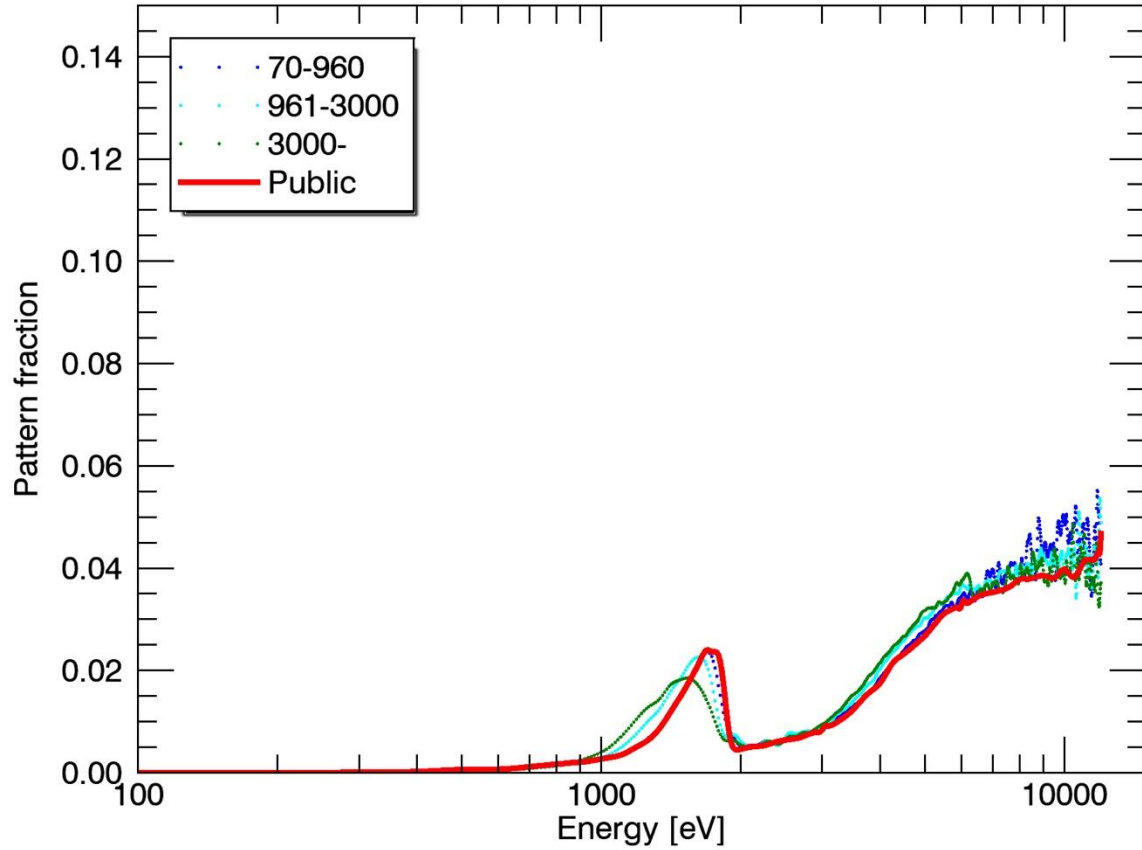


MOS2 All Modes and Filters Doubles

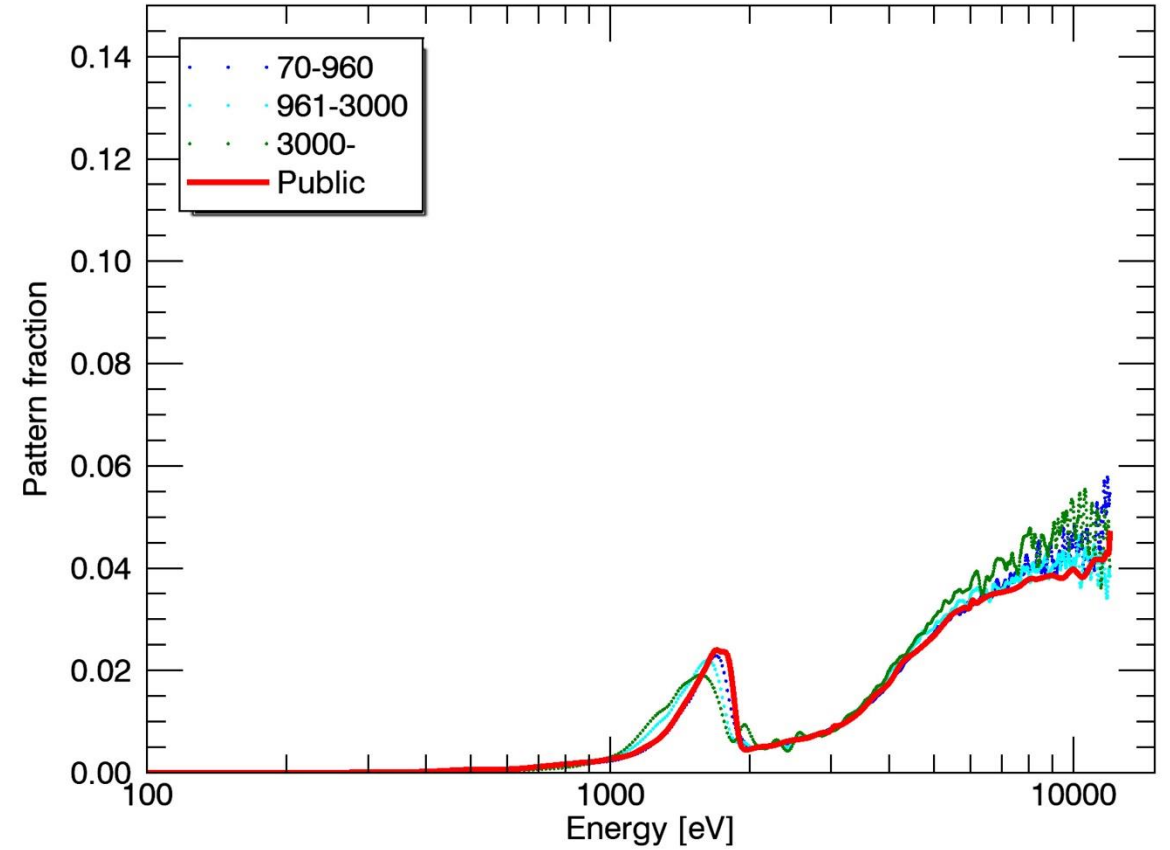


Combined modes/filters: triples time evolution

MOS1 All Modes and Filters Triples

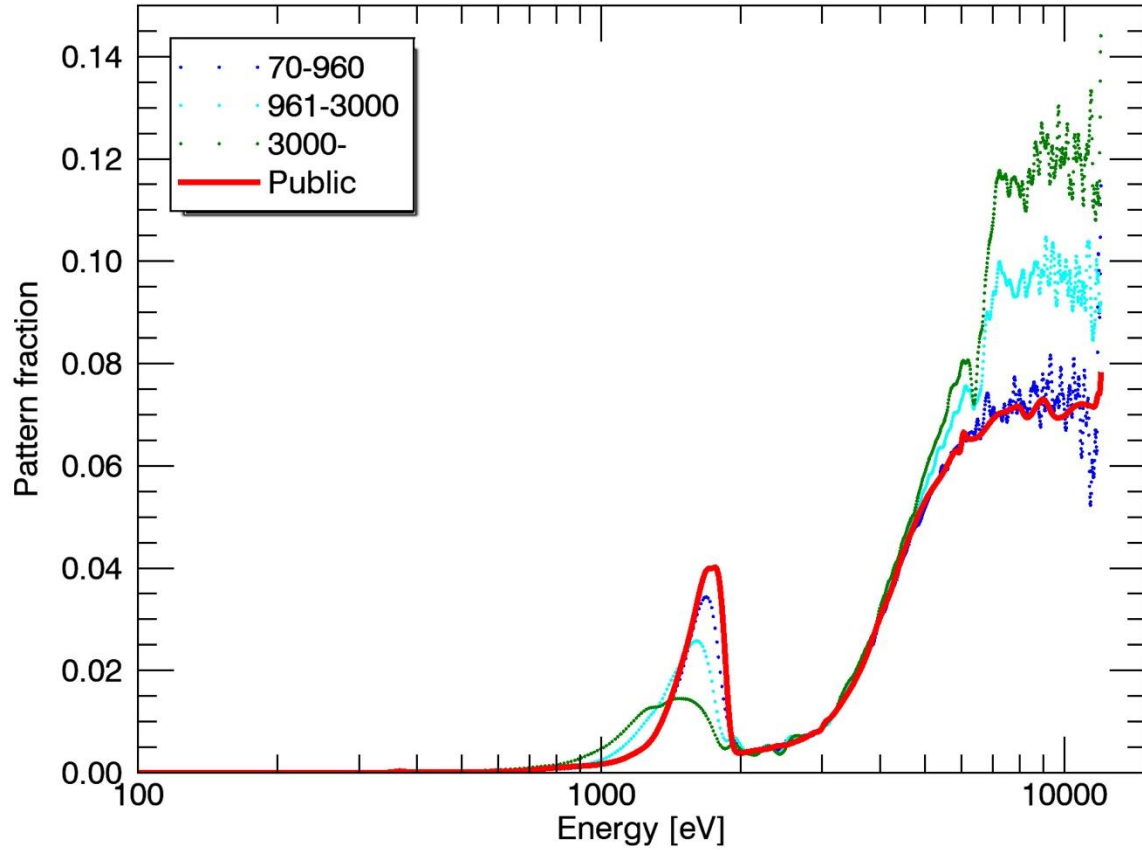


MOS2 All Modes and Filters Triples

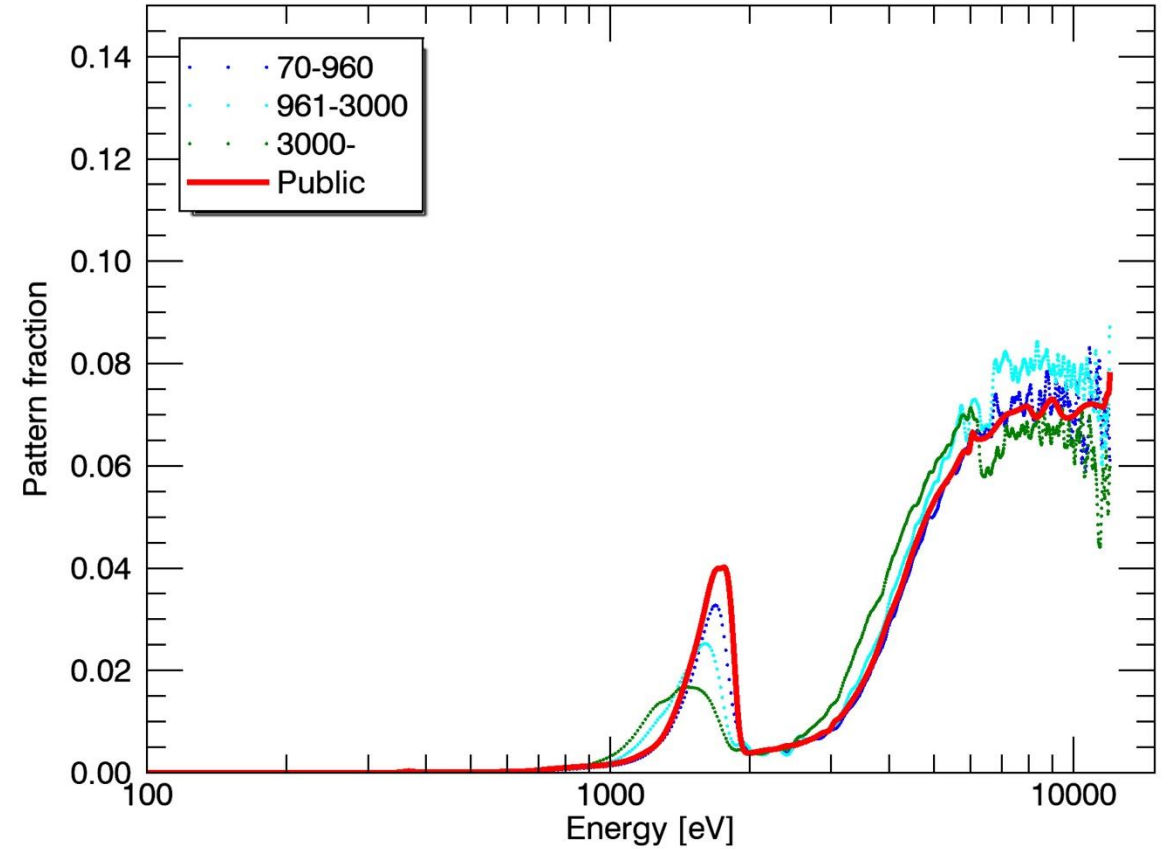


Combined modes/filters: quadruples time evolution

MOS1 All Modes and Filters Quadruples



MOS2 All Modes and Filters Quadruples

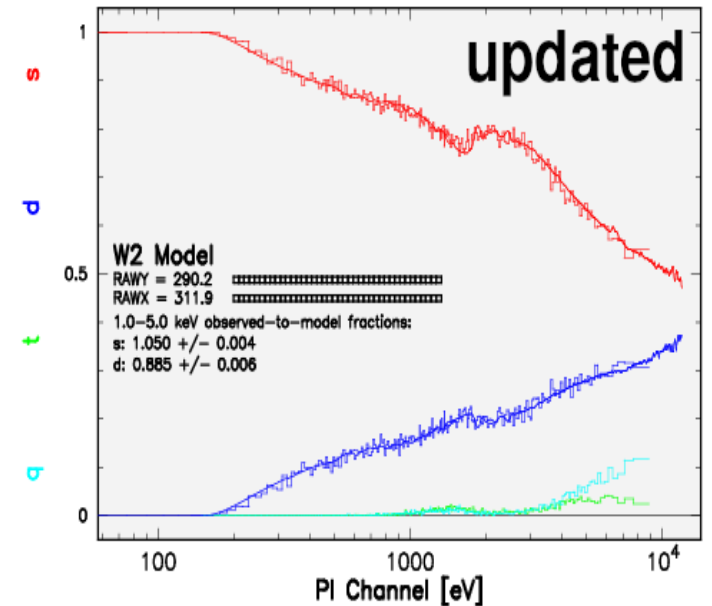
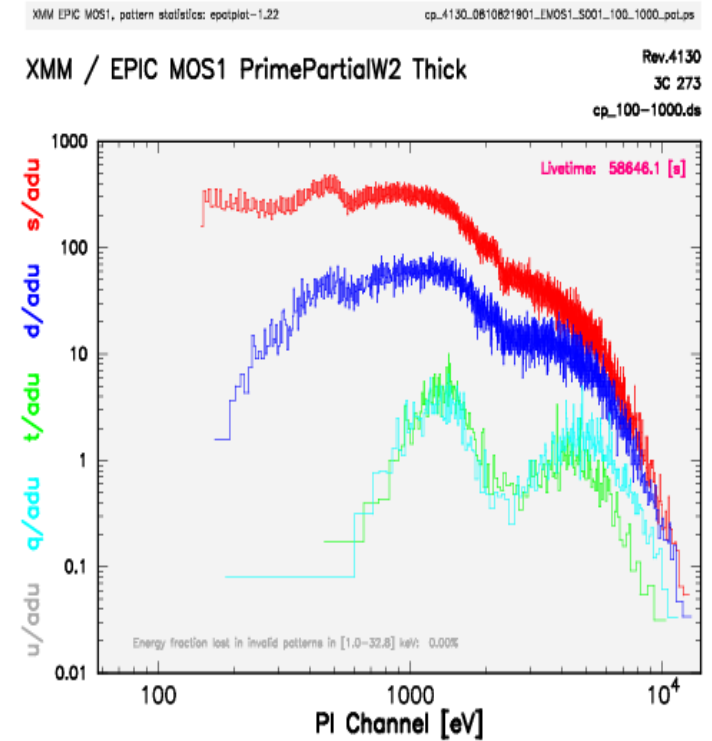
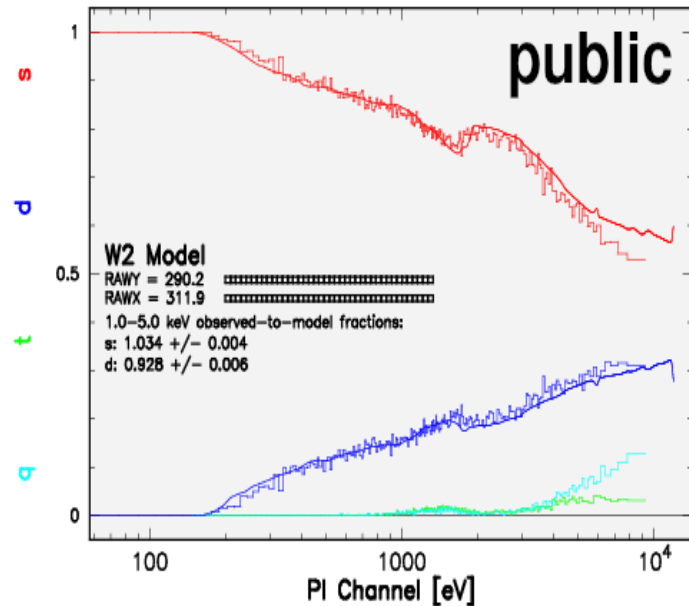
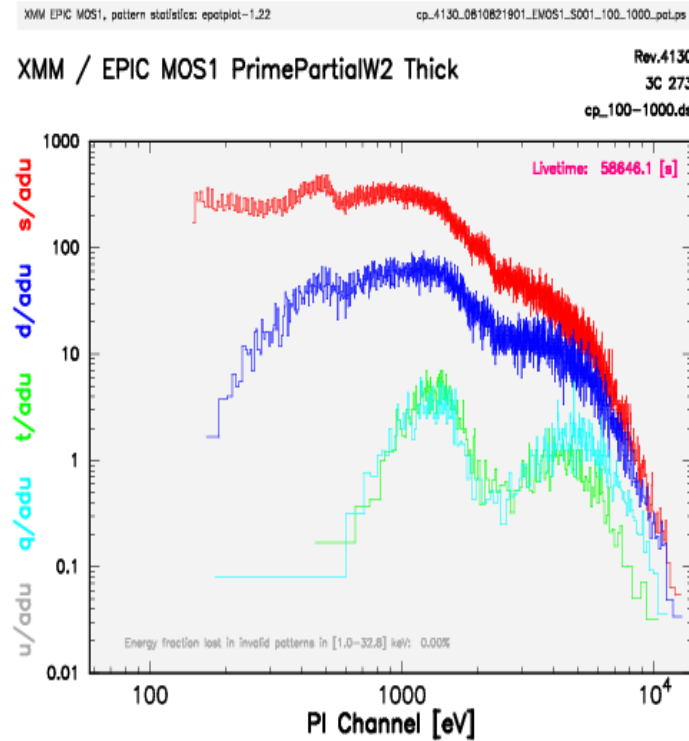


Effect on pileup estimate:

Using measured pattern fractions for pileup estimates using SAS task epatplot:

- Example source: 3C273
- SW mode
- Source centre piled up to $r < 100$ (X,Y)

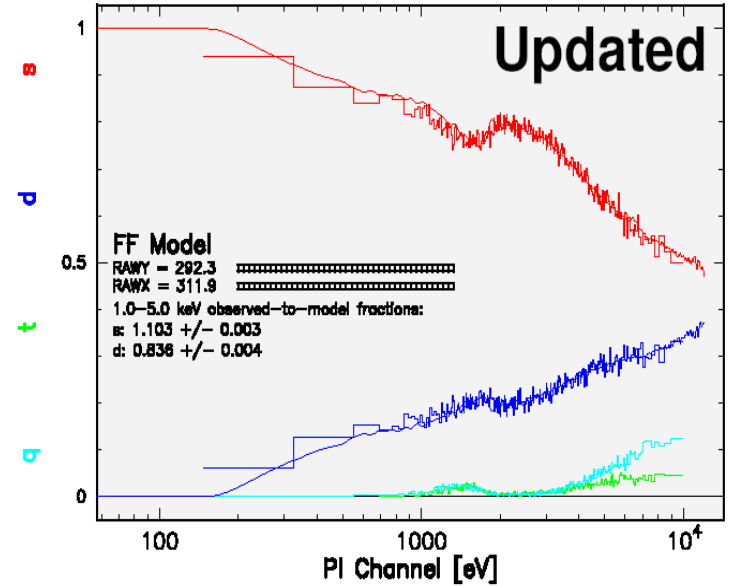
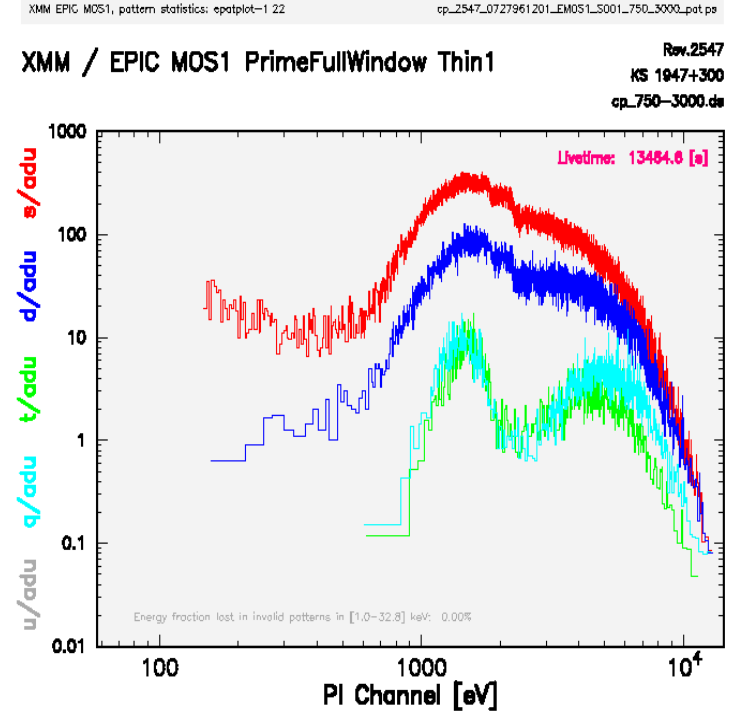
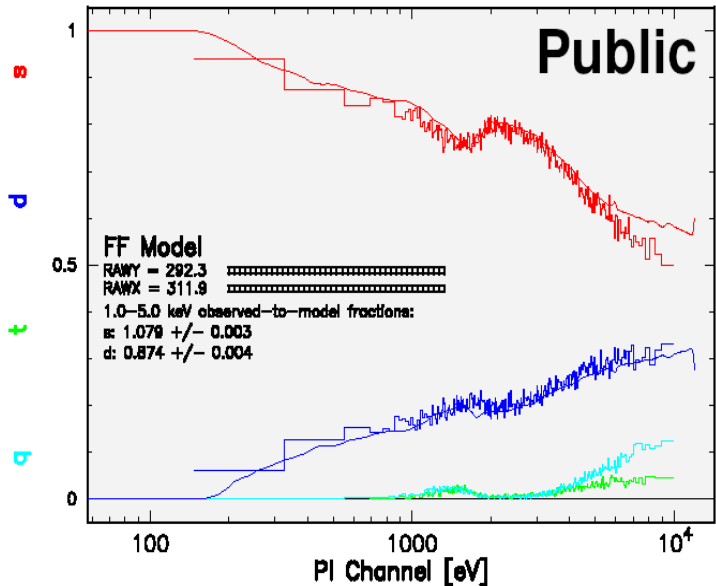
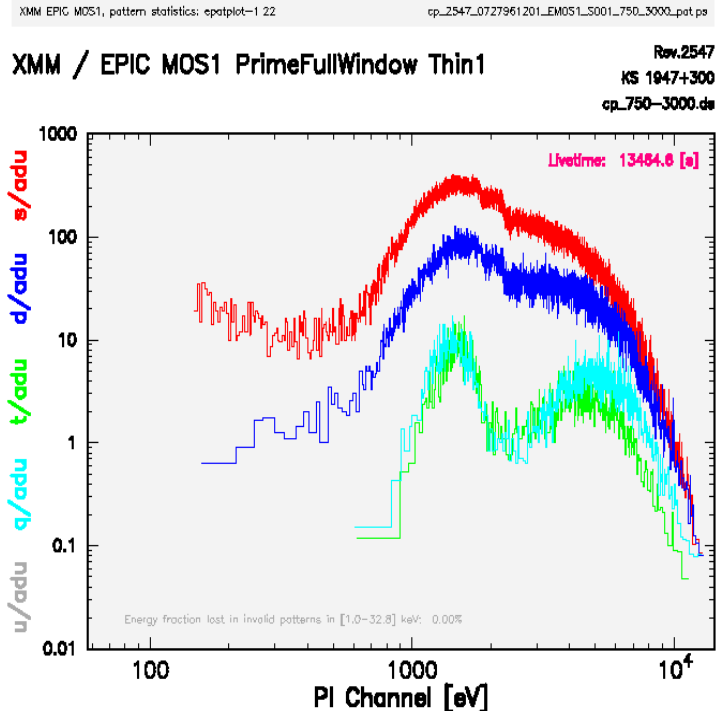
- Left: epatplot using public CCF
- Right: epatplot using measured pattern fractions.



Effect on pileup:

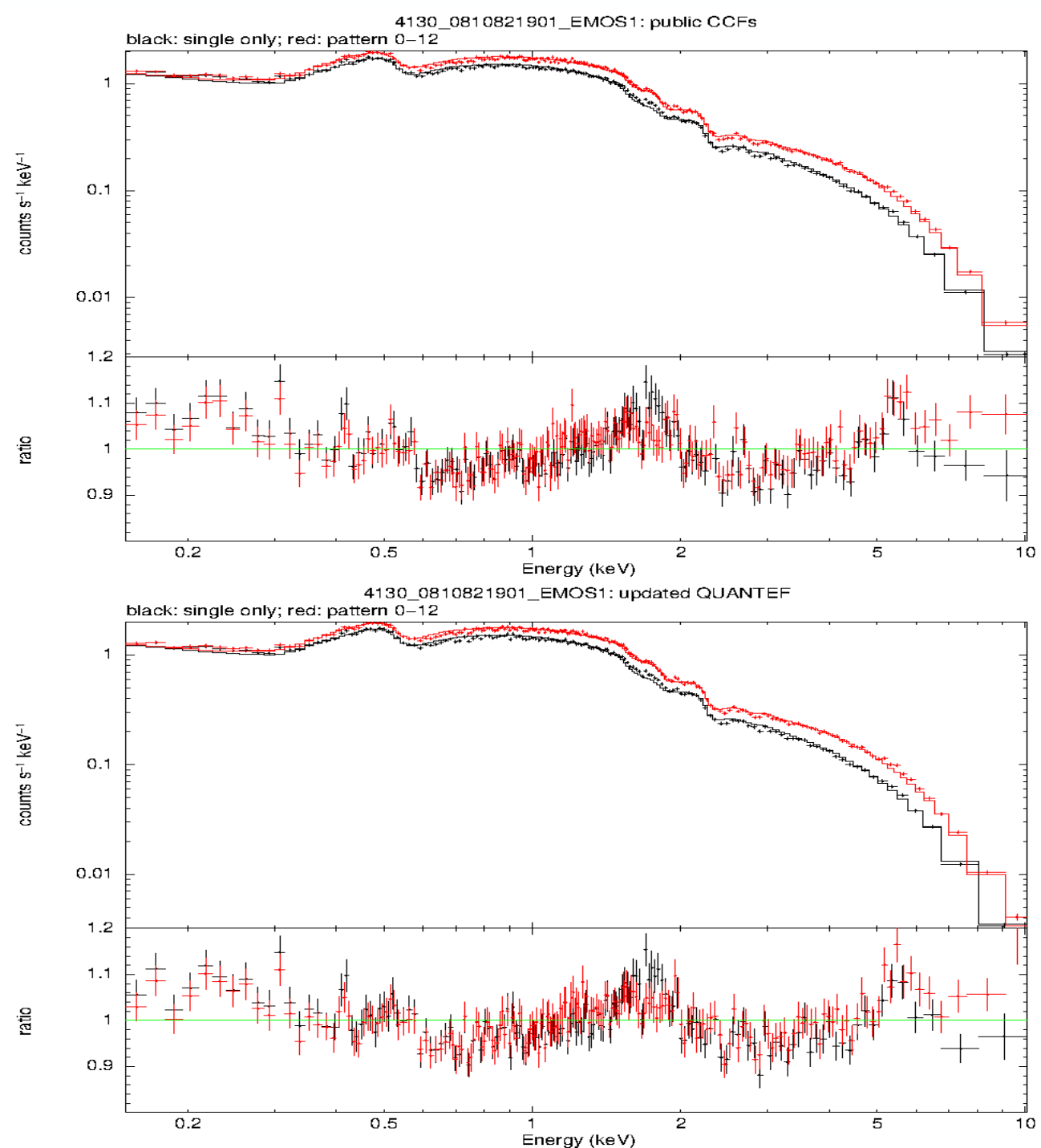
Case with extreme pile-up:

- Example source: KS 1947+300
- EPIC-pn/MOS2 in timing mode
- MOS1 in FF mode
- Source centre piled up to $r < 750$ (X,Y)
- Left: epatplot using public CCF
- Right: epatplot using measured pattern fractions.



Effect on spectral responses:

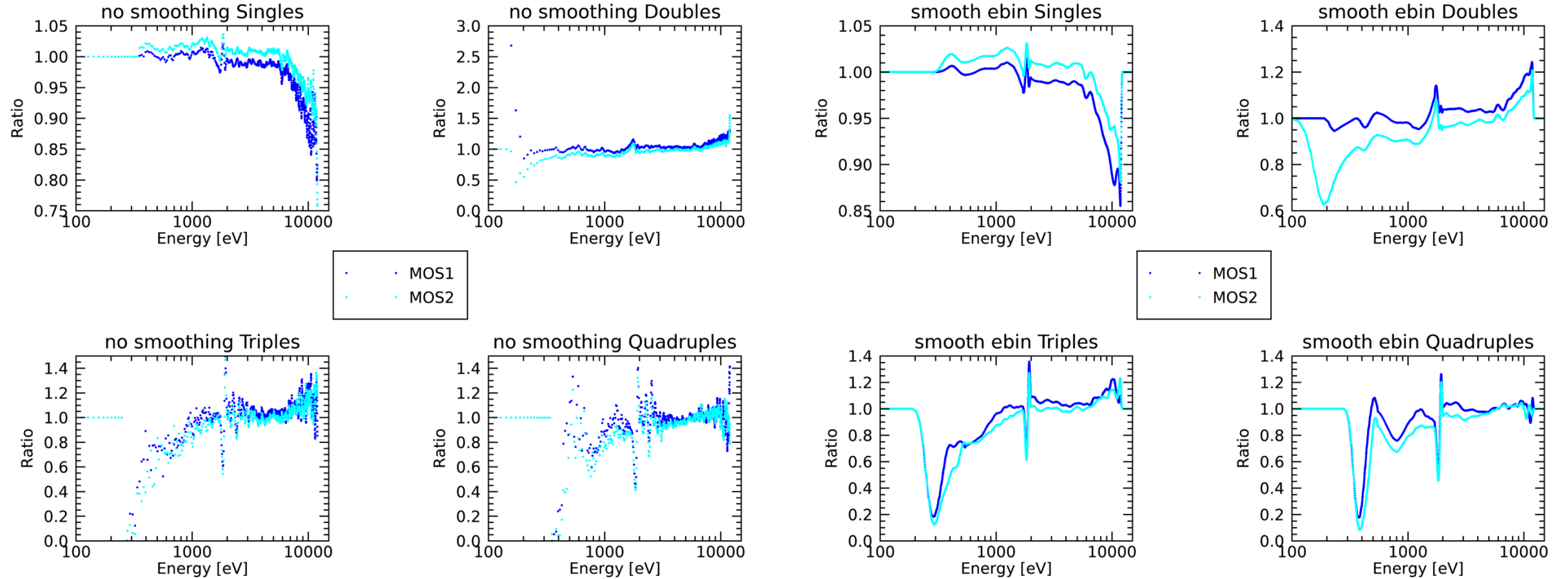
- Verified in SAS code: response generation uses energy fraction tables, not pattern fraction tables.
- No documentation found on how the energy fraction tables were defined in 2002.
- Transfer modifications of pattern fractions tables to energy fraction tables keeping total for scientific pattern neutral.



Transfer results to energy fraction tables:

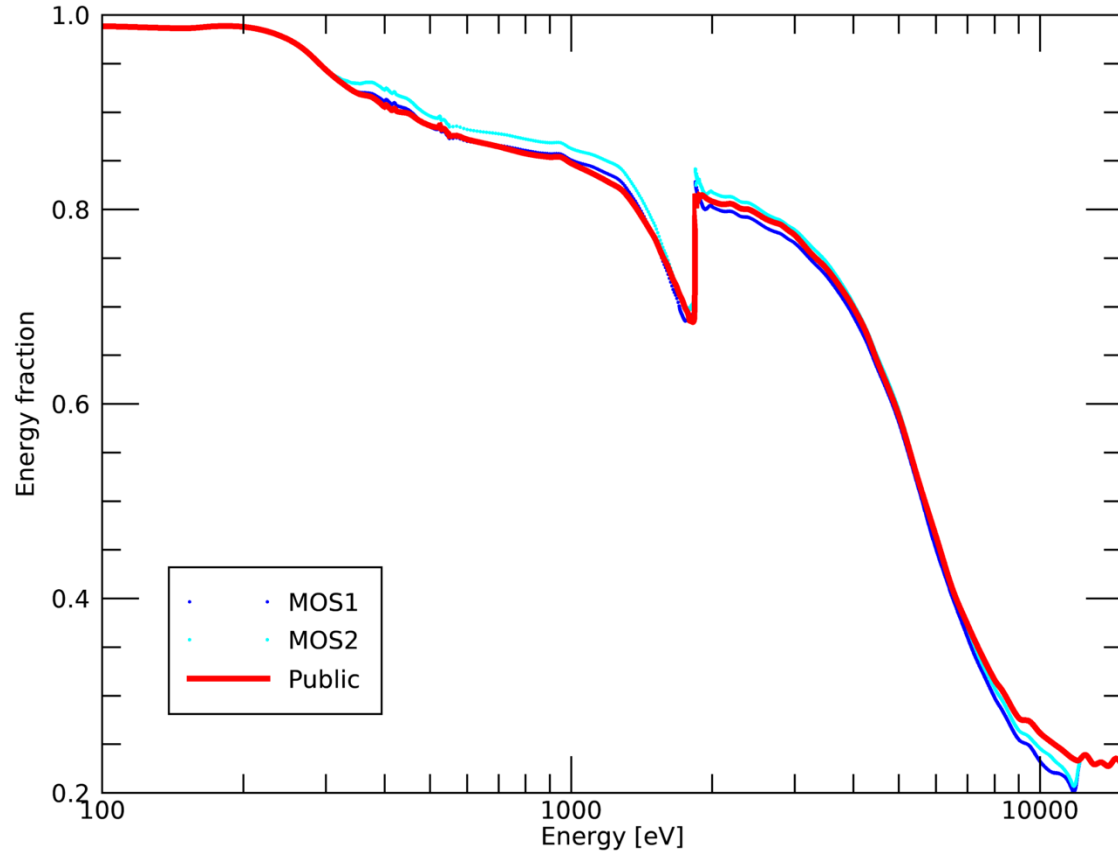
Difference function (800 channel):

Difference function (2186 channels) smoothed:

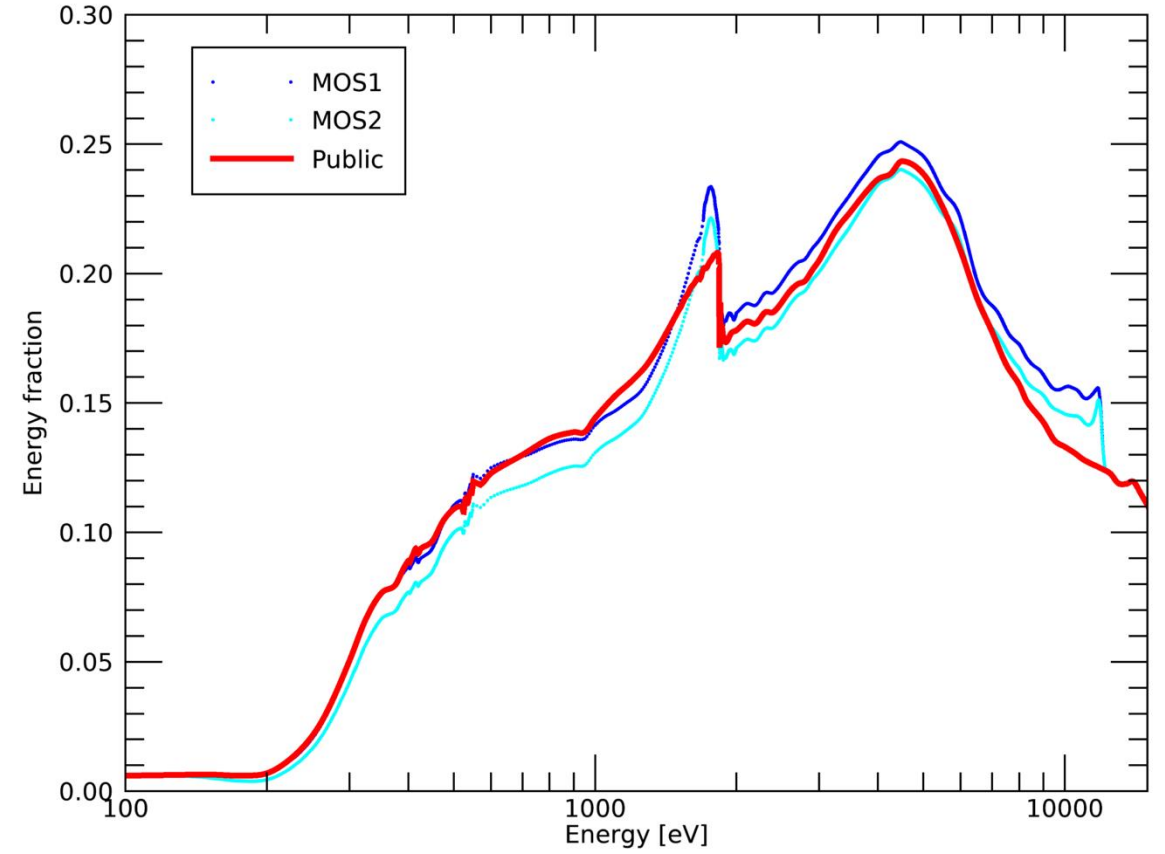


Energy fraction data inside CCF:

Energy fractions Singles

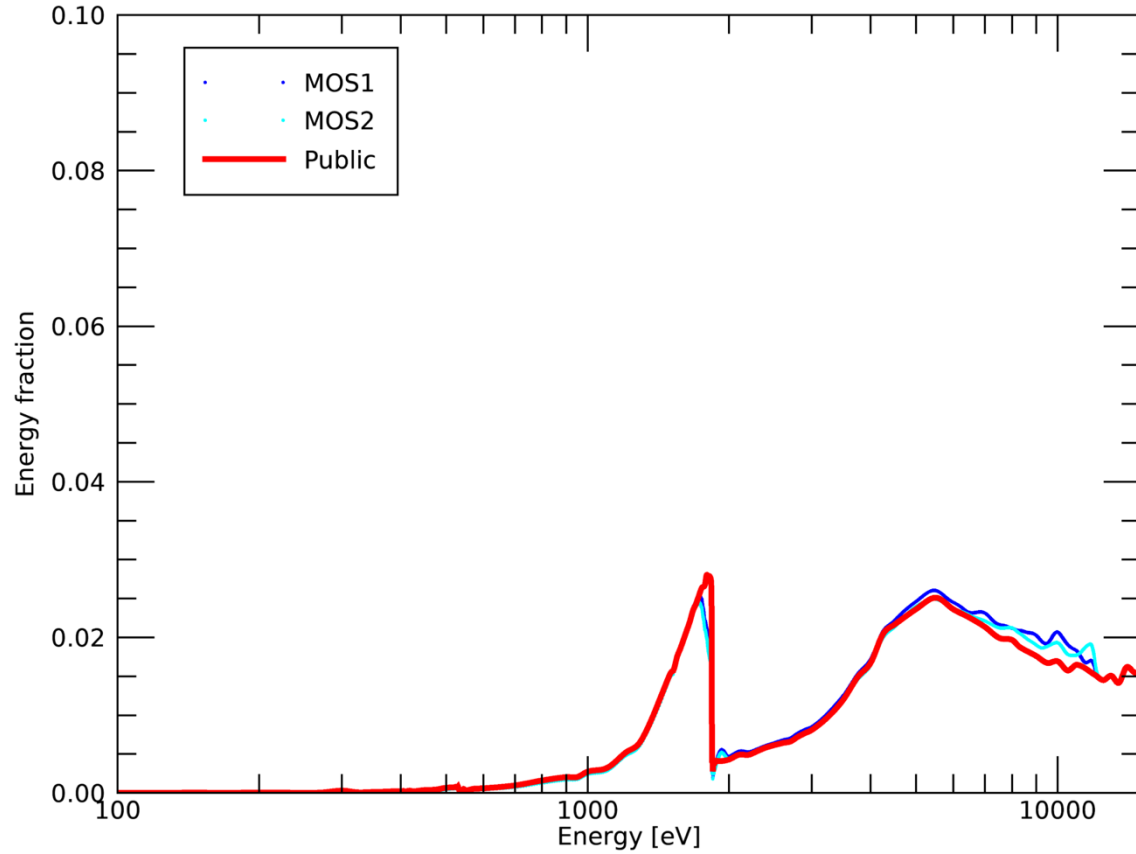


Energy fractions Doubles

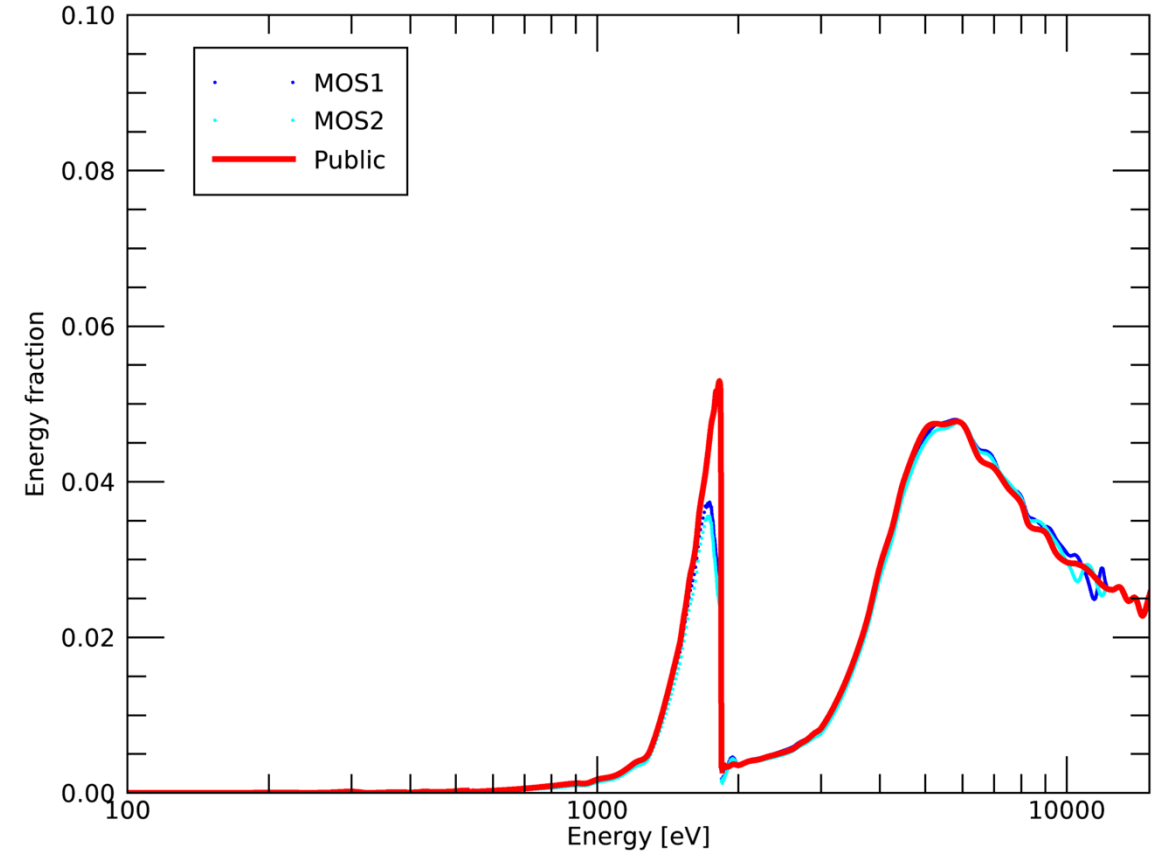


Energy fraction data inside CCF:

Energy fractions Triples

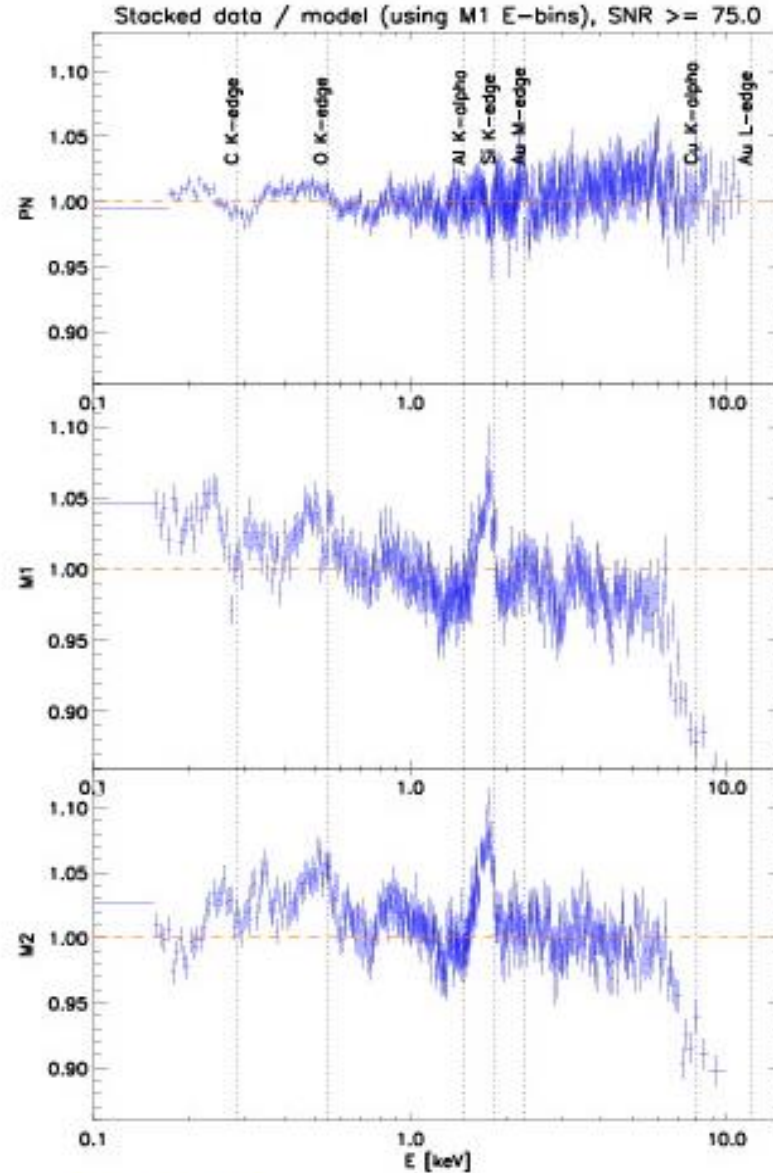


Energy fractions Quadruples

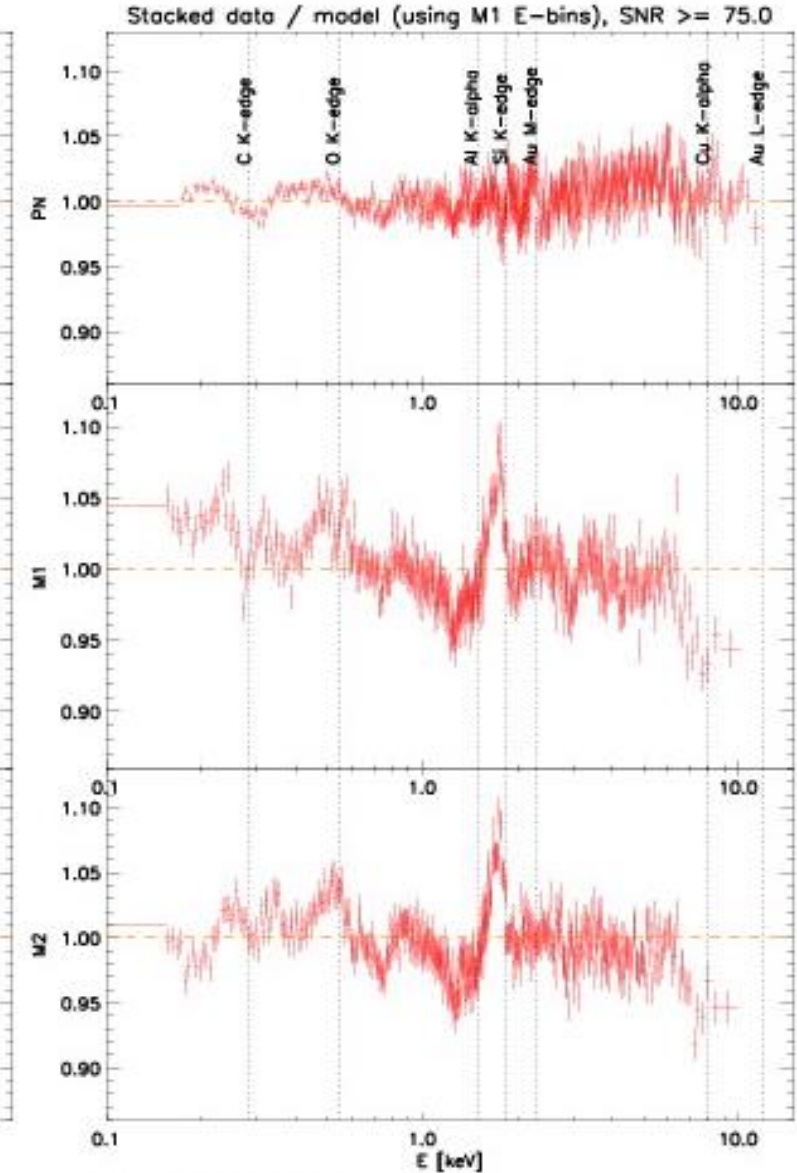


Test CCF: single residuals to pattern 0-12 best fit

- Residuals of best fit model for s+d(+t+q) data applied on single only data.
- Test CCFs reduce the drop at highest energies by about 50%.
- Slight improvement in the overall slope difference between MOS/pn.
- Nearly no changes for residual structures at instrumental edges except at O-edge.



SAS22sss s_ad free



SAS22_MS1QEs s_ad free

Pattern fractions:

- Pattern ratios of different mode / filter are very similar for individual MOS detectors.
- Using identical pattern ratios for modes/filters for individual detectors seems to be justified.
- MOS1/MOS2 pattern ratios show differences, using identical data for individual detectors not justified.
- Pattern ratios show time evolution, e.g. broadening at Si-feature. Resembles response degradation.
- Possible time evolution differences in on-patch/off-patch spatial regions. Data sampling problematic.
- No effect on spectral responses.

Energy fractions (used for spectral responses):

- Look like quantum efficiency curves of pattern types. Take into account non-scientific pattern, too.
- Not clear how these tables were in 2002.
- Transfer modifications of pattern fractions to energy fraction tables keeping total for scientific pattern neutral.
- General slope differences point in direction of improvement.
- Some issues at instrumental edges.