Investigation in EPIC-MOS pattern fractions

EPIC calibration meeting, ESAC

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03.06.2024

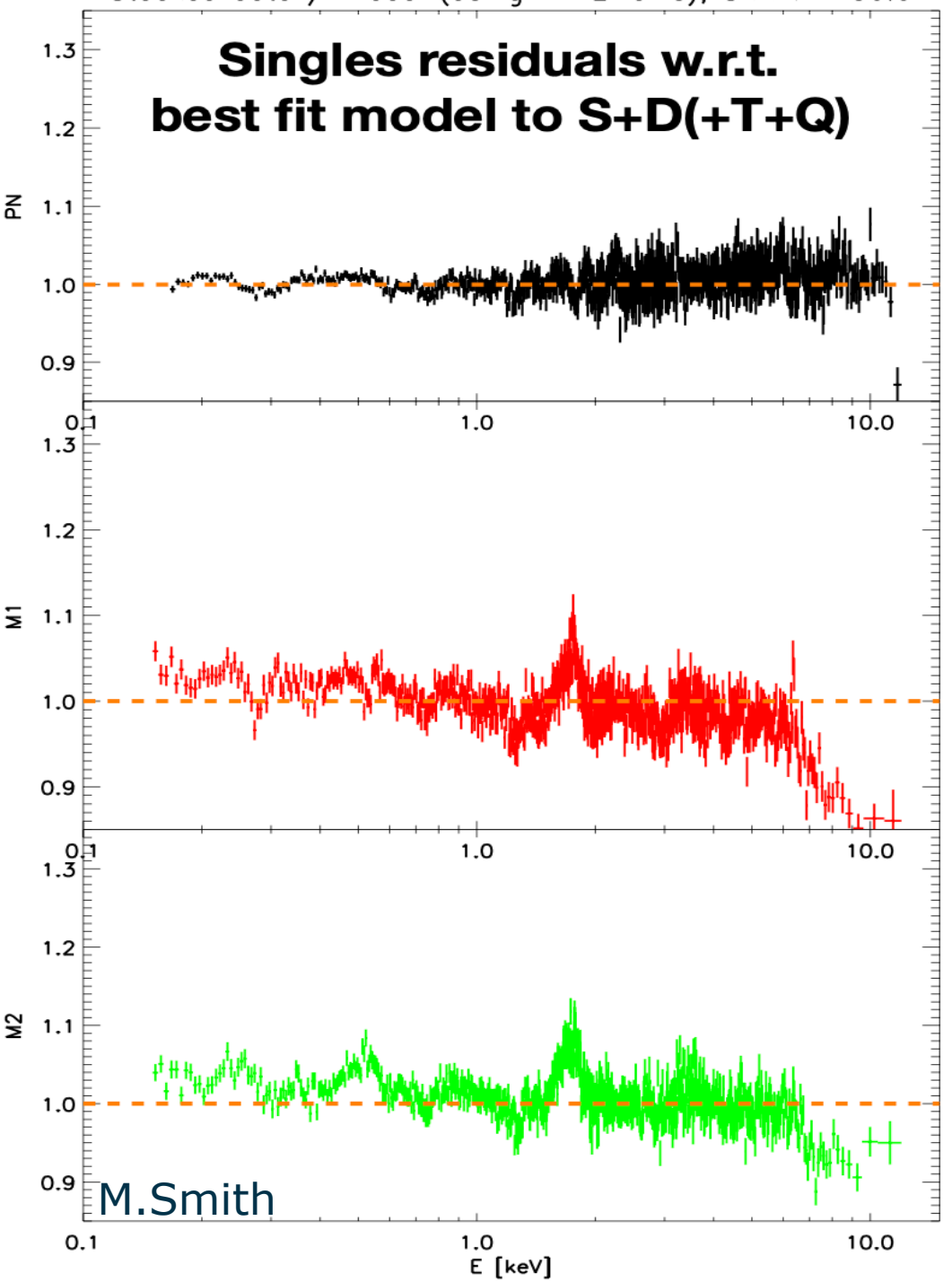
Motivation

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.

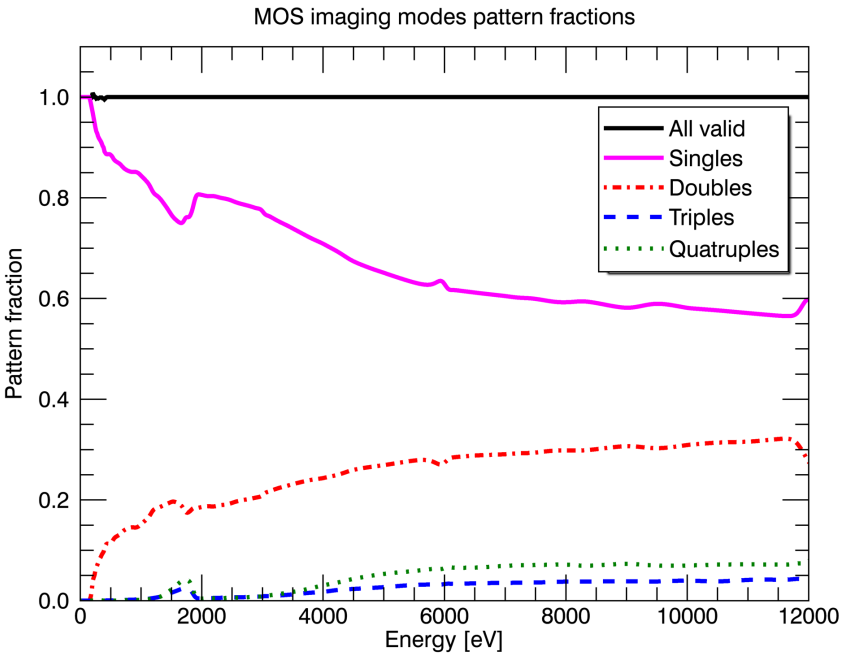


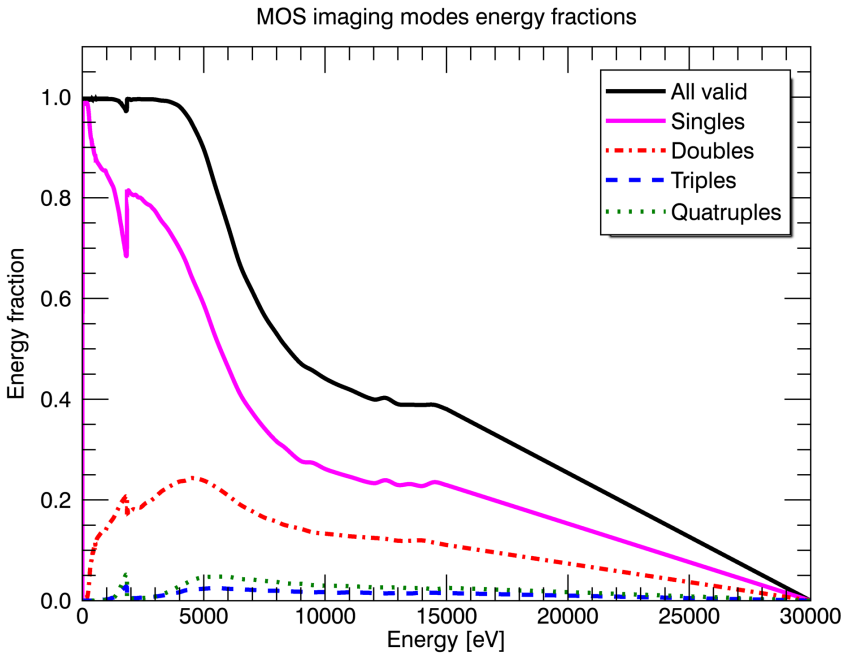
Motivation

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).





Data selection

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. — General exposure brightness limit.
- 2nd threshold: minimum 10 counts/pixel. — Source selection limit.
- 3rd threshold: maximum pile-up fraction of 1.0%. — Data pixel quality limit.
- 4th threshold: more than 1000 counts with E > 3 keV. — Hard source selection limit.

Thresholds might be adapted/optimized.

Separation into 4 spatial regions:

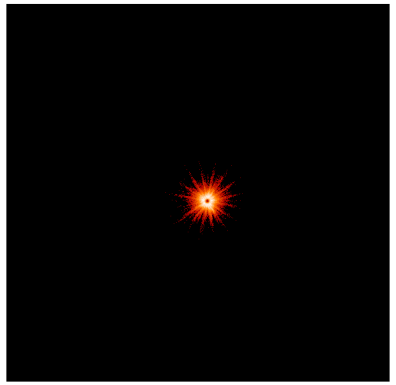
- On-patch (patch centre/patch wing)
- Off-patch
- All data

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

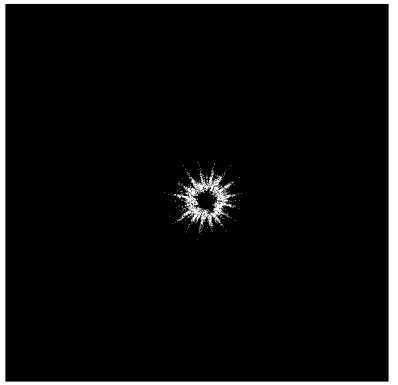
Data selection: FF examples

ObsID 0799_0067751001

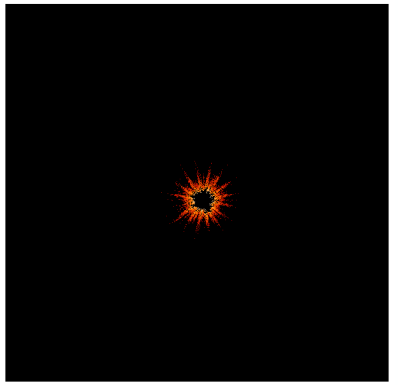
Flare screened



Pile-up mask

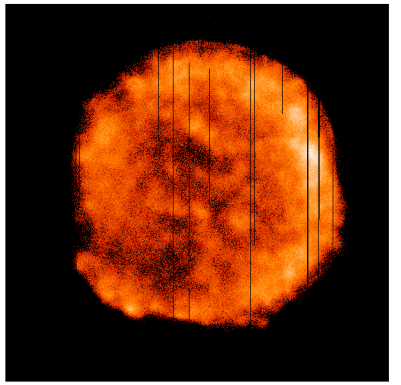


Pixel for analysis

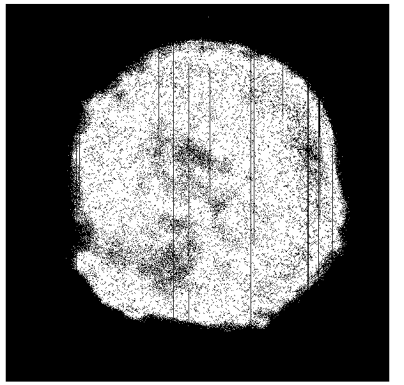


ObsID 1477_0511180201

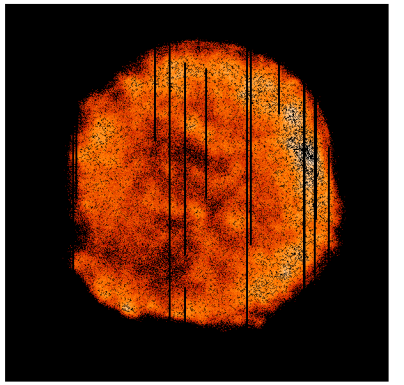
Flare screened



Pile-up mask

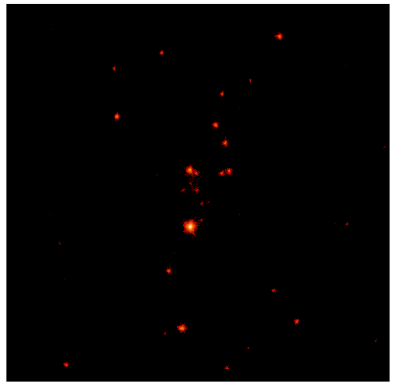


Pixel for analysis

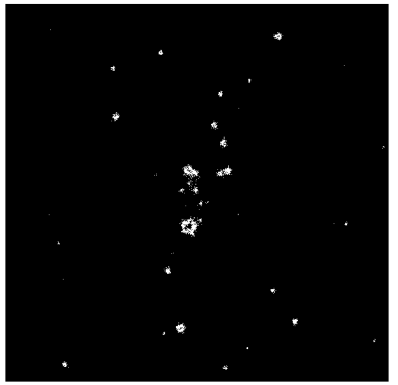


ObsID 0285_0109270101

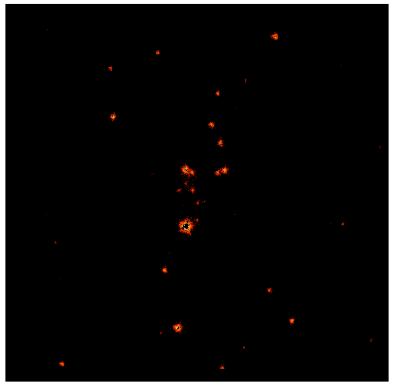
Flare screened



Pile-up mask

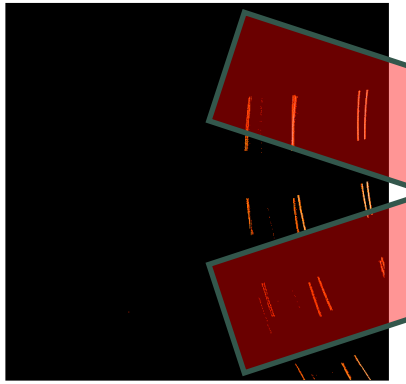


Pixel for analysis

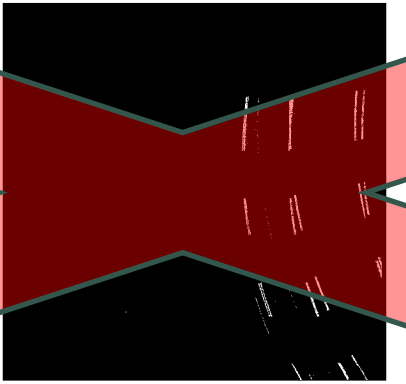


ObsID 3525_0820310601

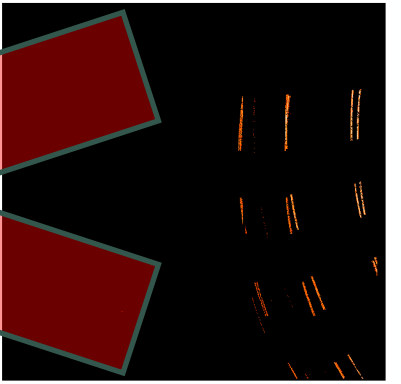
Flare screened



Pile-up mask



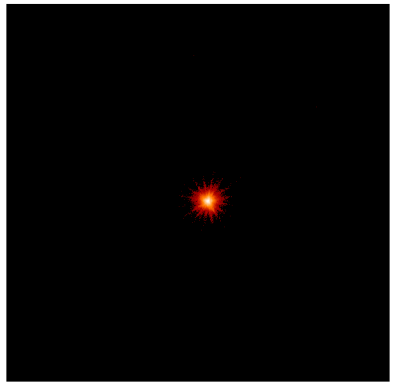
Pixel for analysis



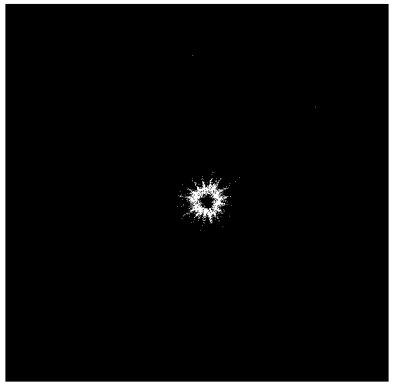
Data selection: FF examples

ObsID 2451_0701981601 patch wing

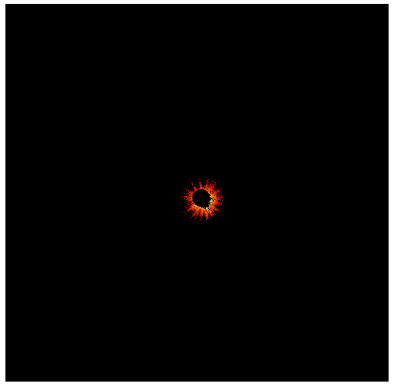
Flare screened



Pile-up mask

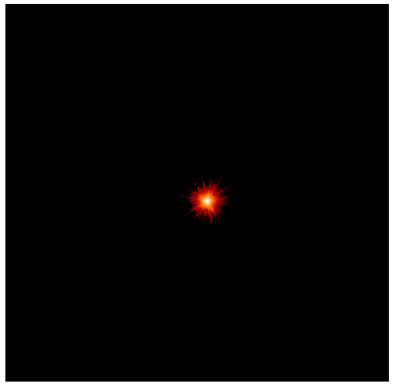


Pixel for analysis

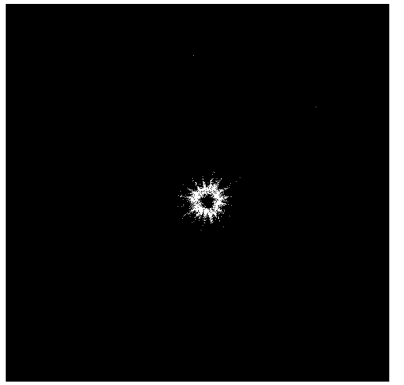


patch centre (no off-patch available)

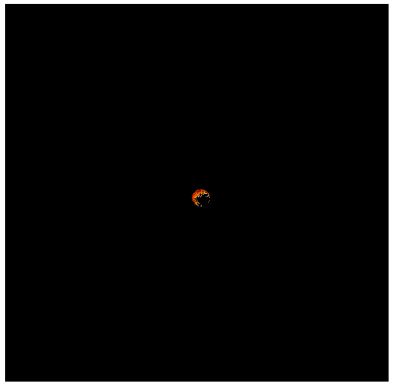
Flare screened



Pile-up mask

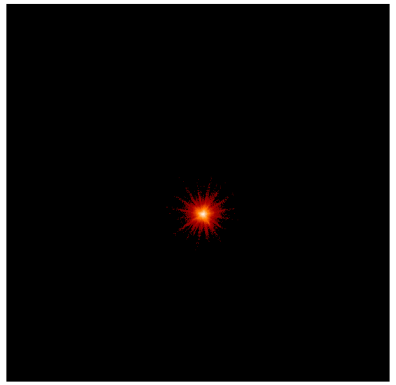


Pixel for analysis

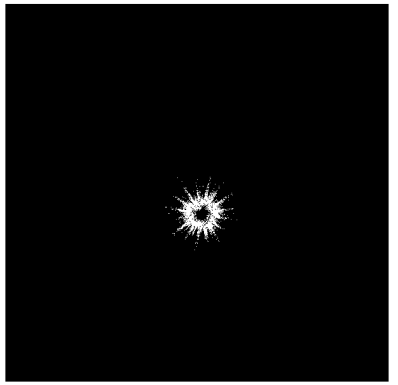


ObsID 2572_0722860401 patch wing

Flare screened



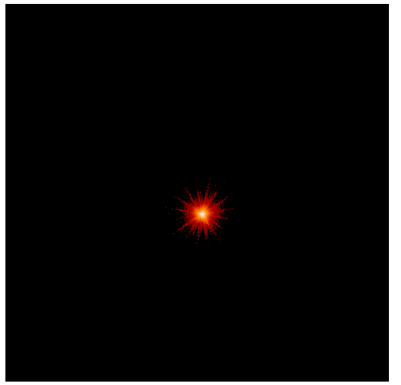
Pile-up mask



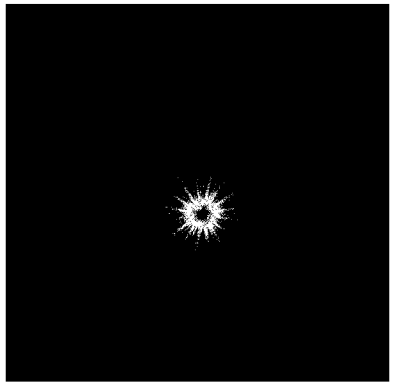
Pixel for analysis

off-patch (no patch centre available)

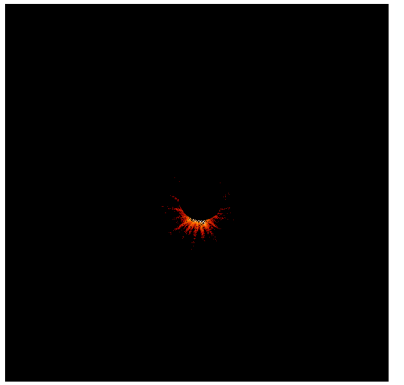
Flare screened



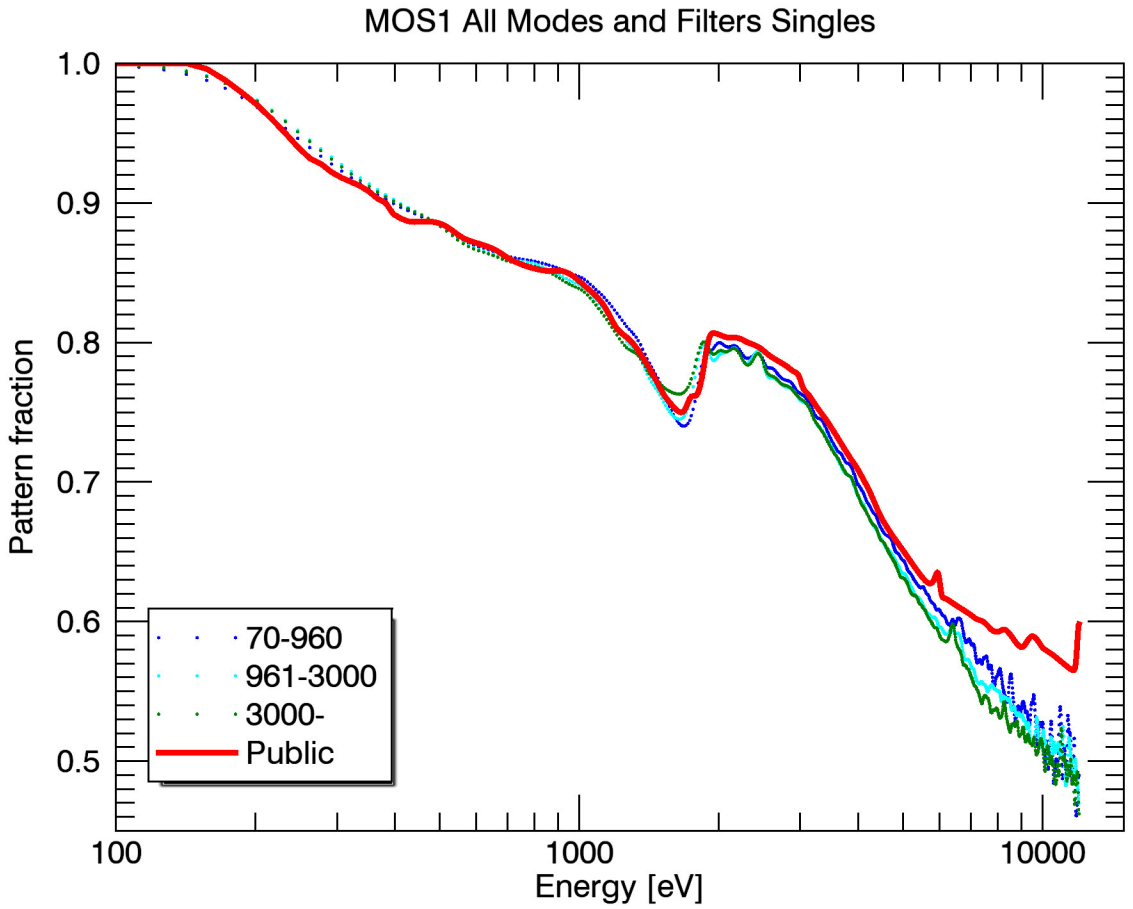
Pile-up mask

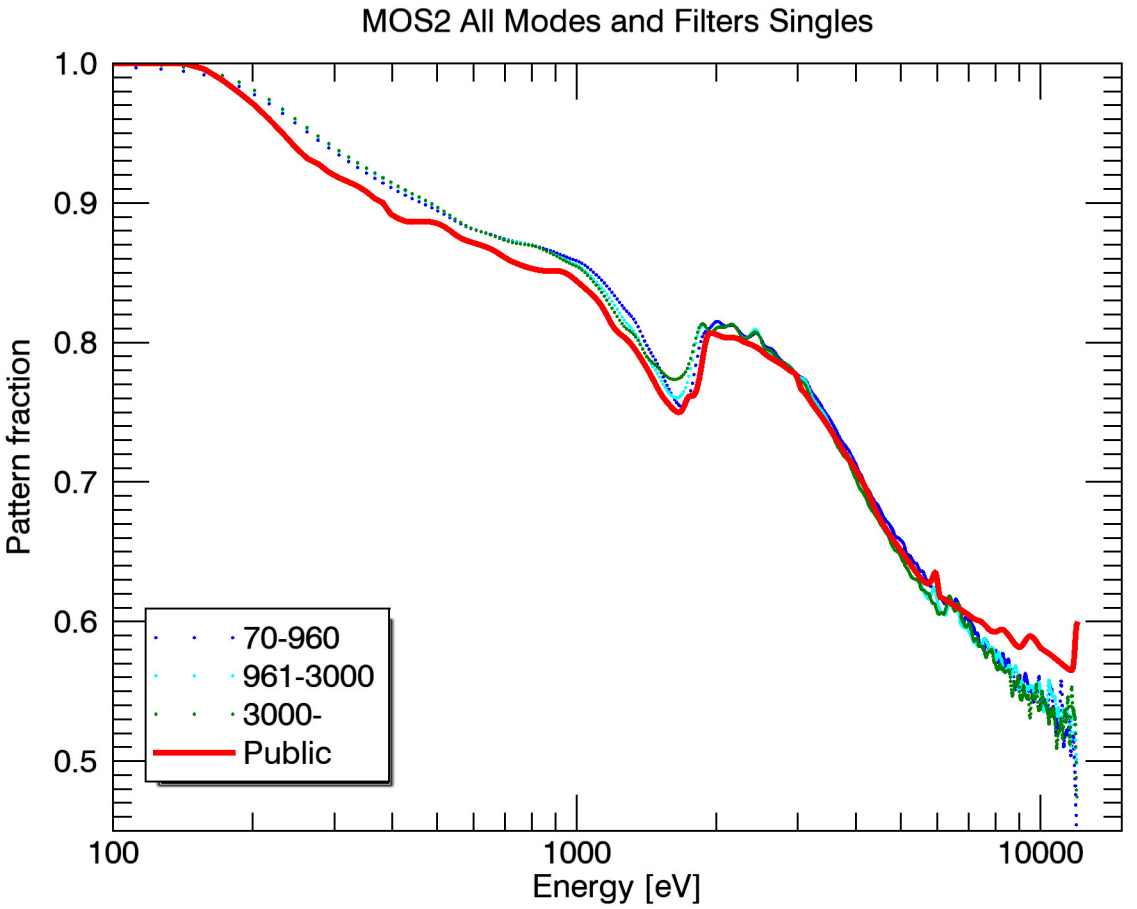


Pixel for analysis

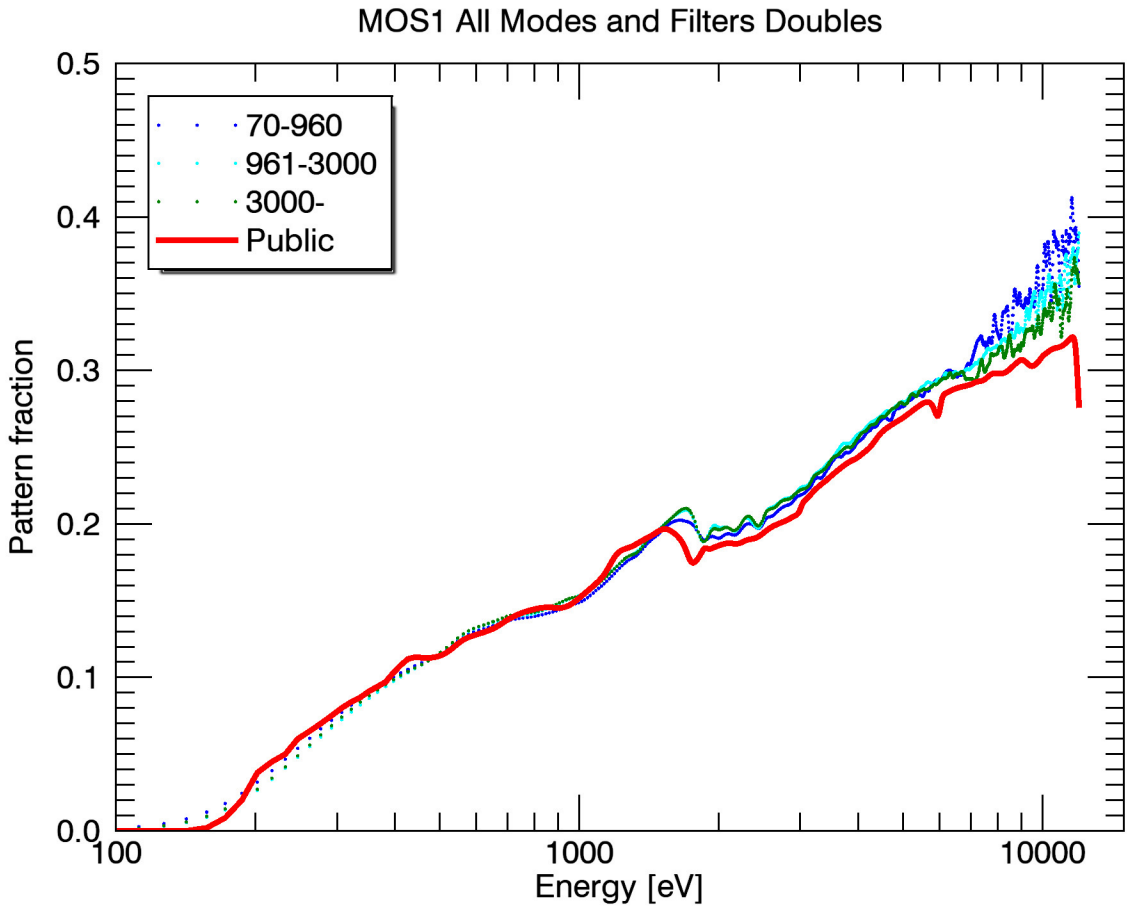


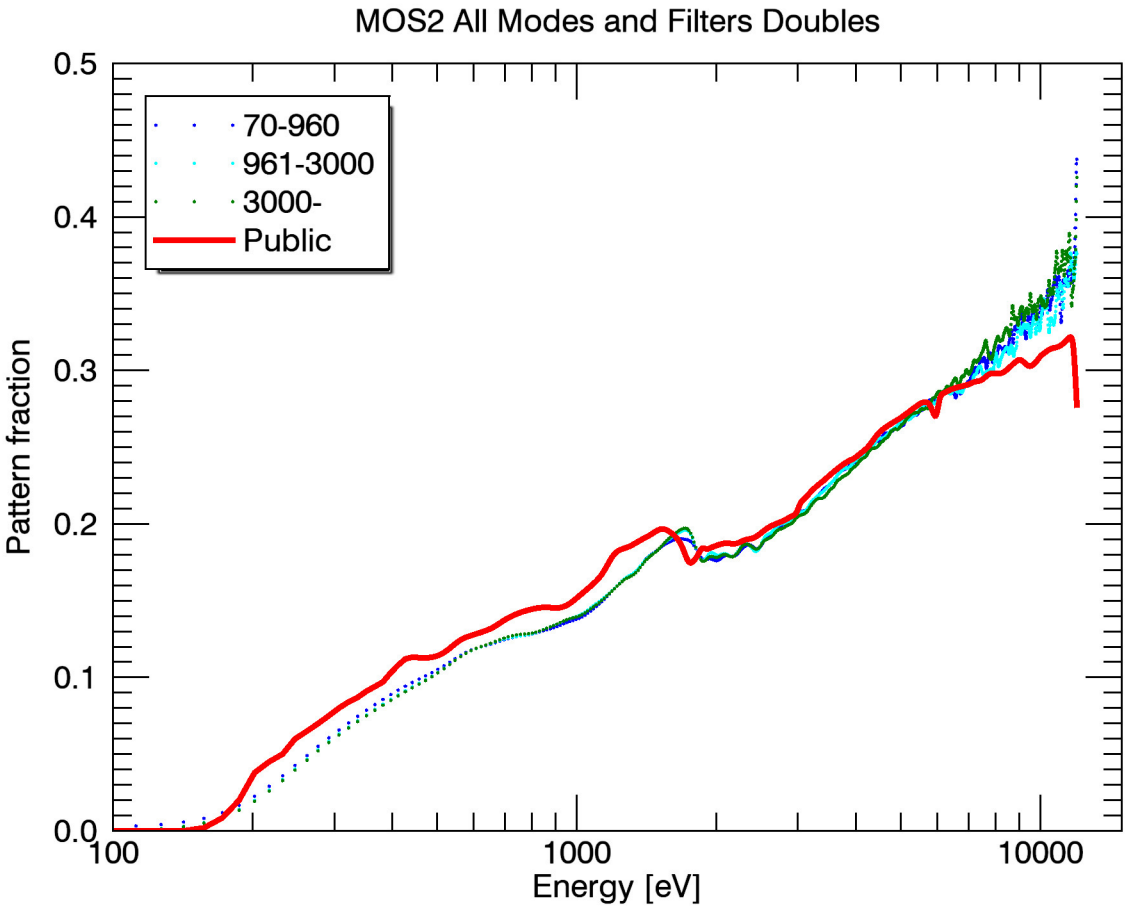
Combined modes/filters: singles time evolution



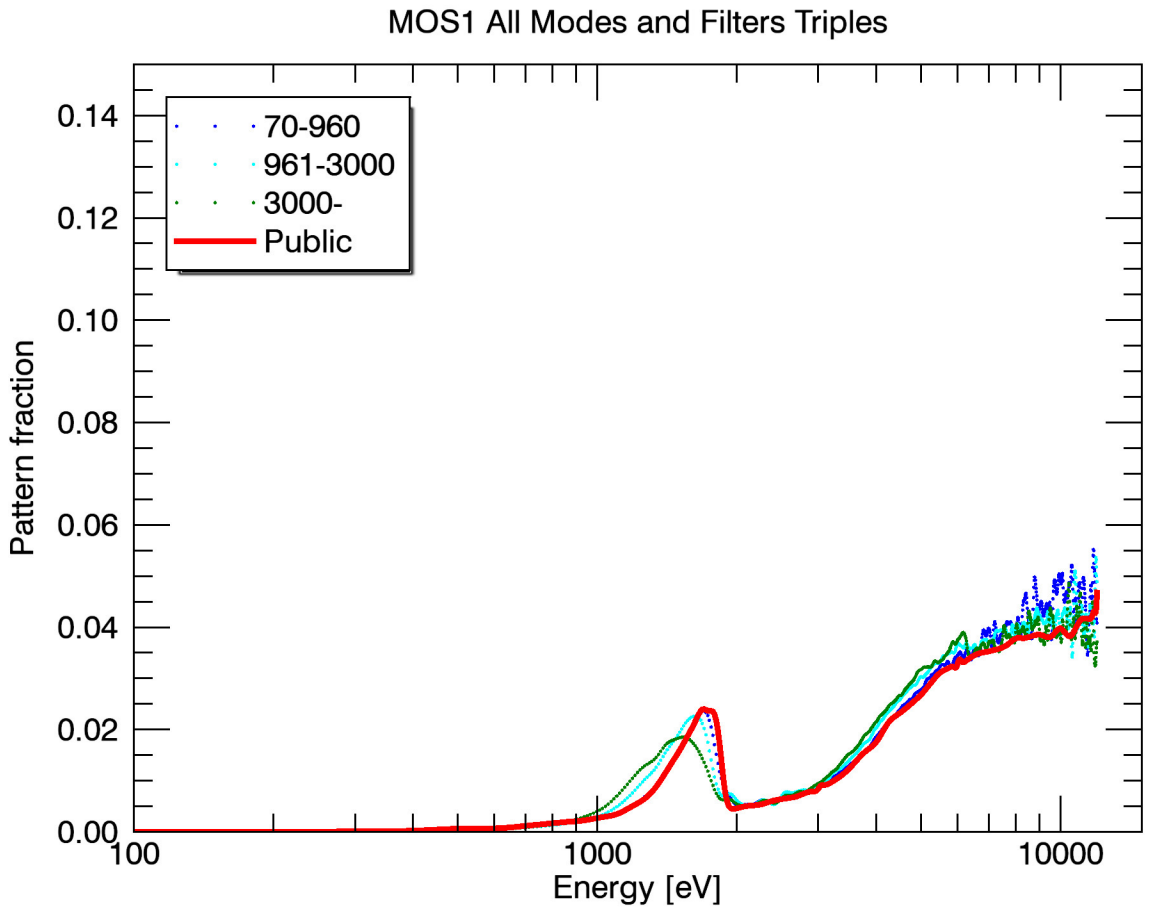


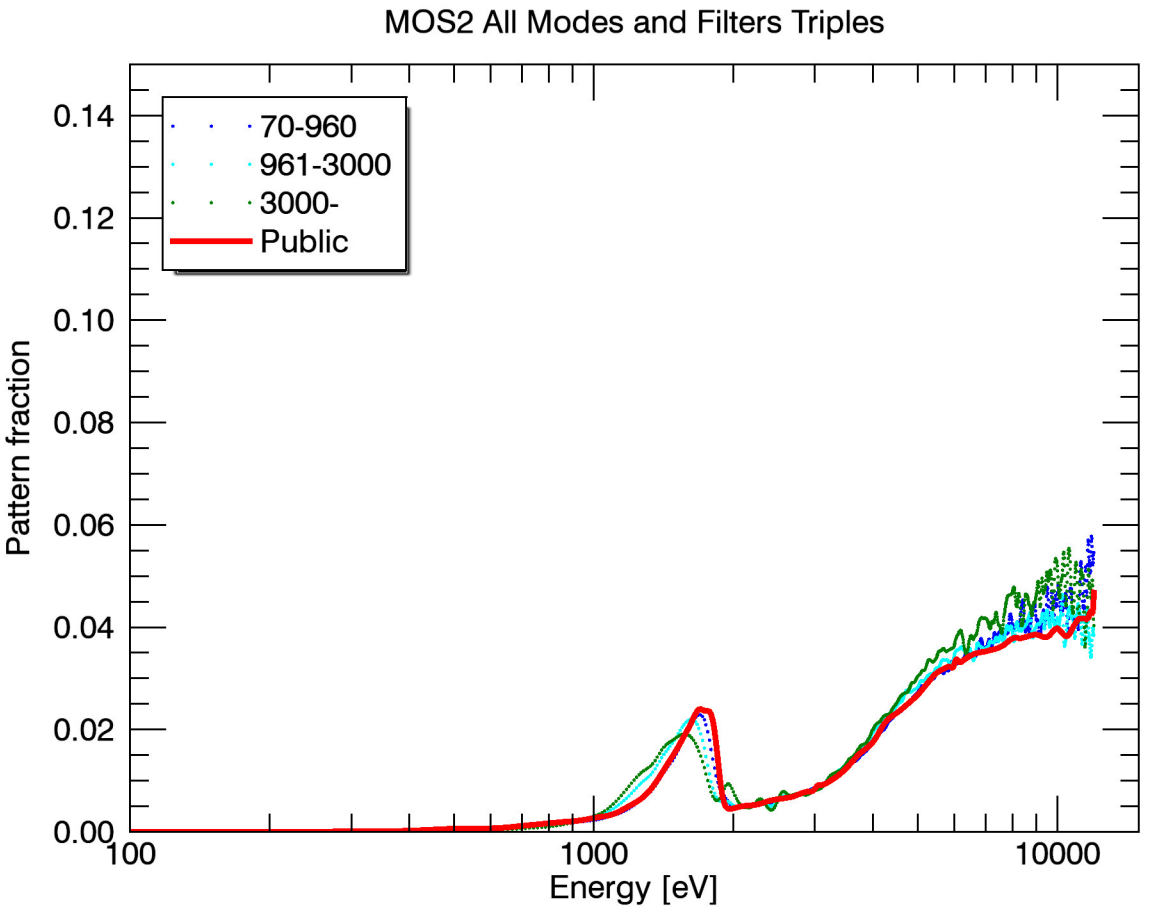
Combined modes/filters: doubles time evolution



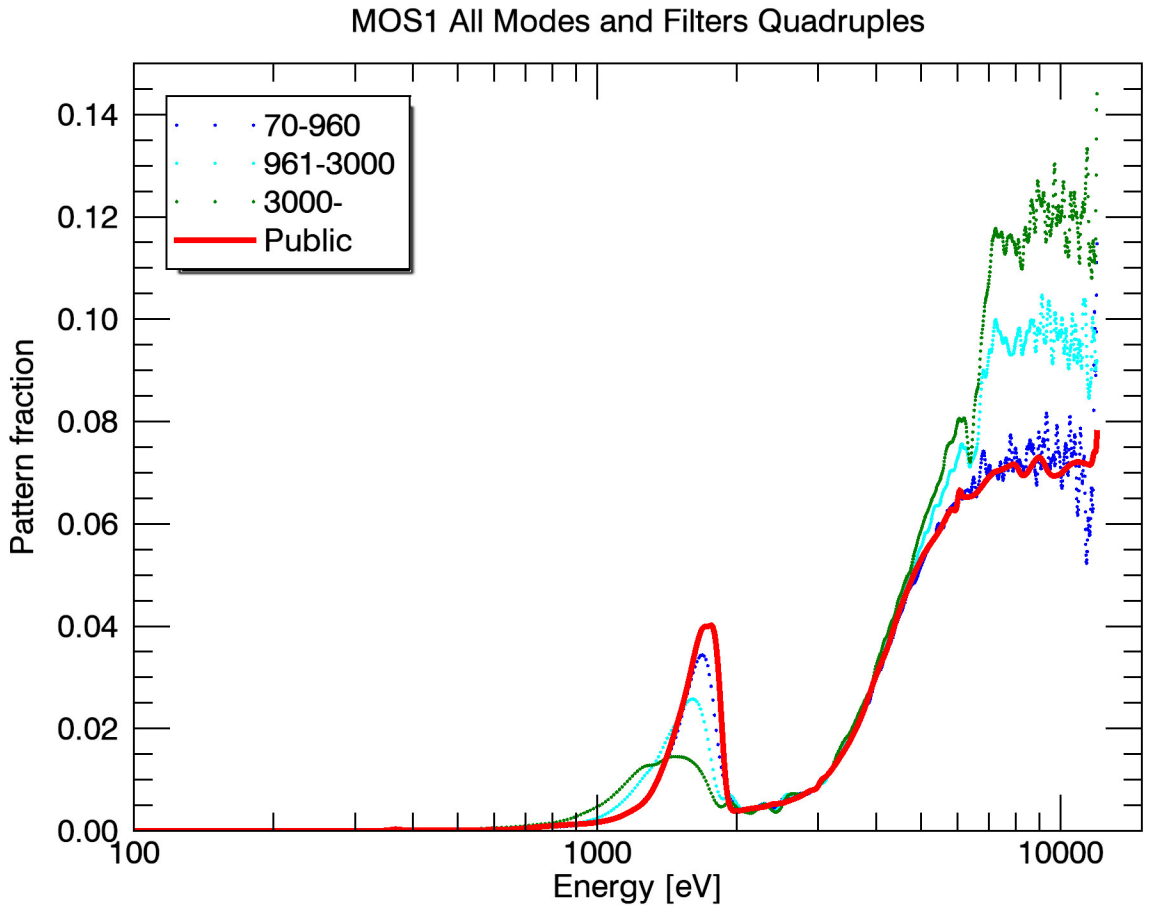


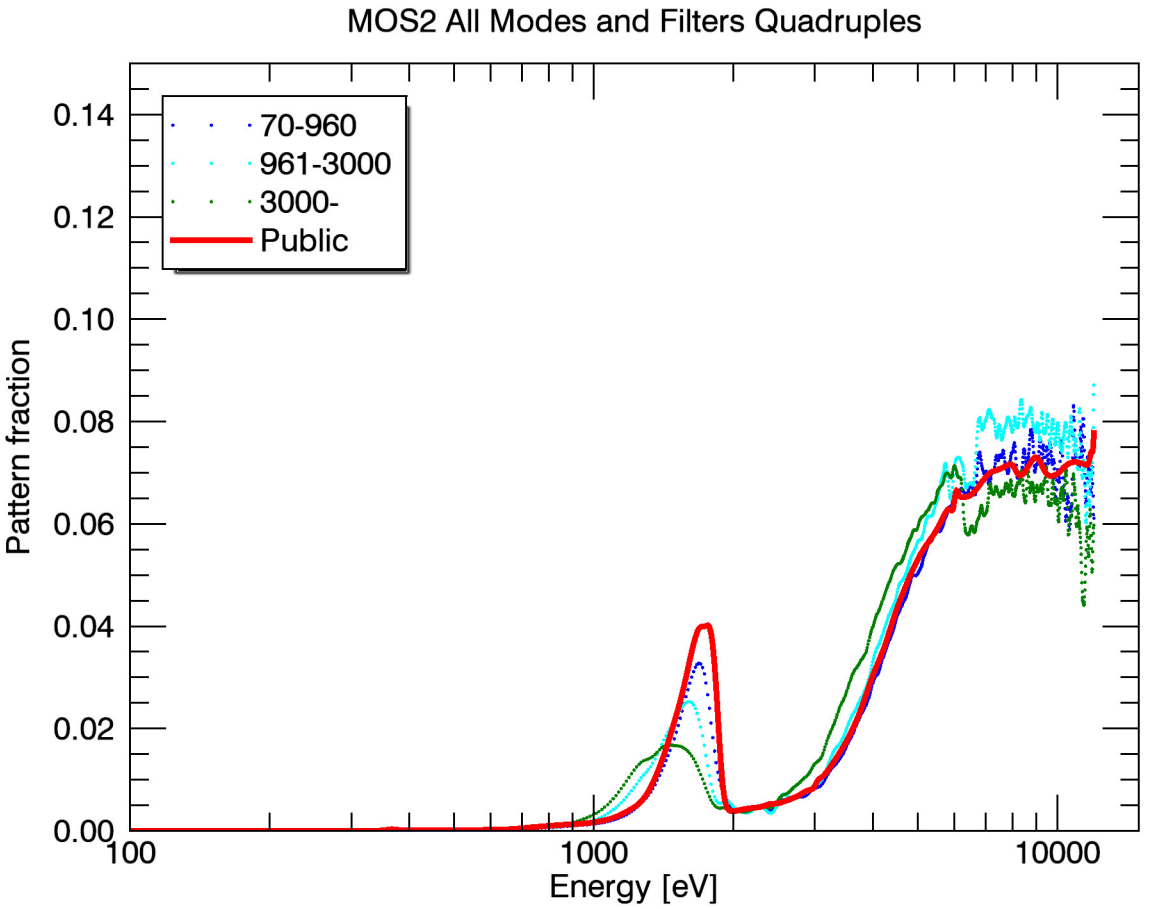
Combined modes/filters: triples time evolution





Combined modes/filters: quadruples time evolution



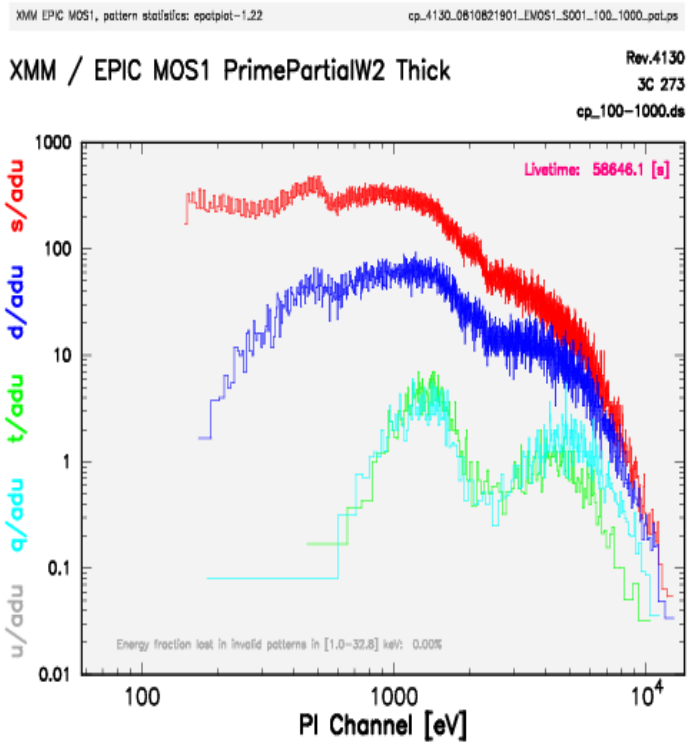


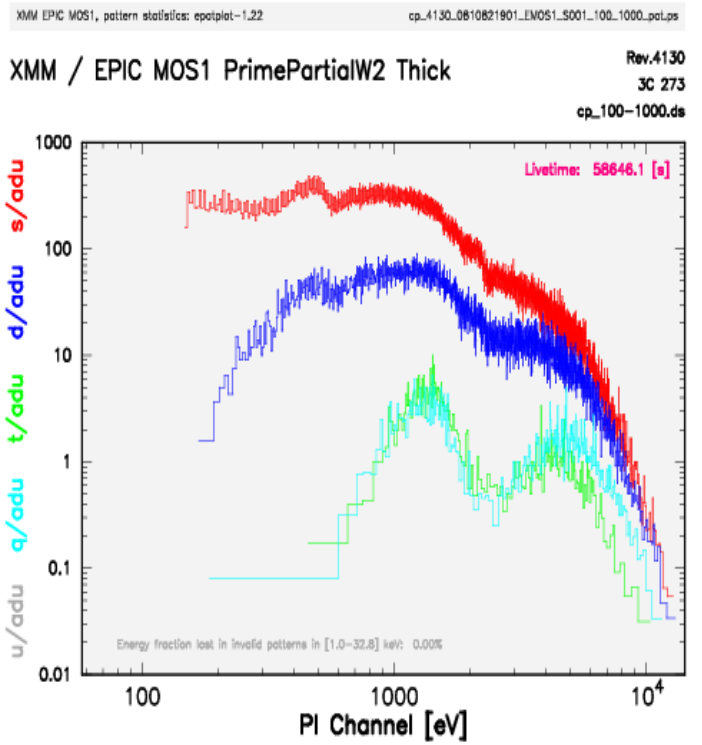
Effect on pileup estimate:

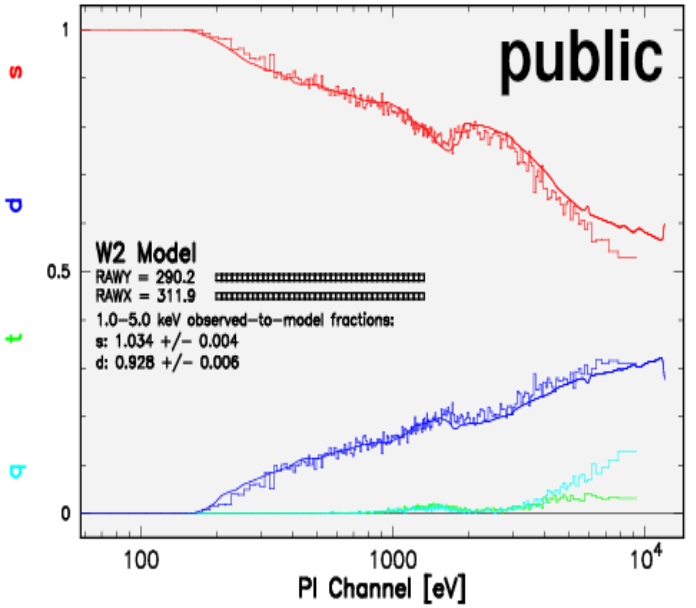
Using measured pattern fractions for pileup estimates using SAS task epatplot:

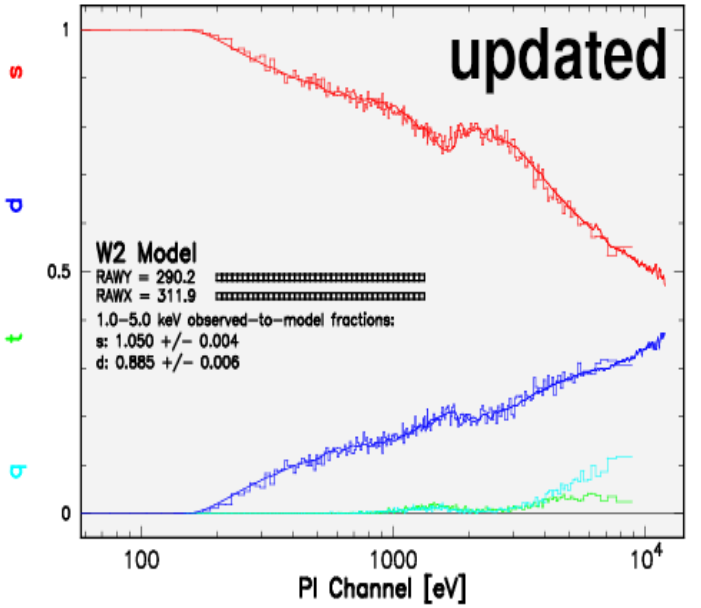
- Example source: 3C273
- SW mode
- Source centre piled up to r<100 (X,Y)

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







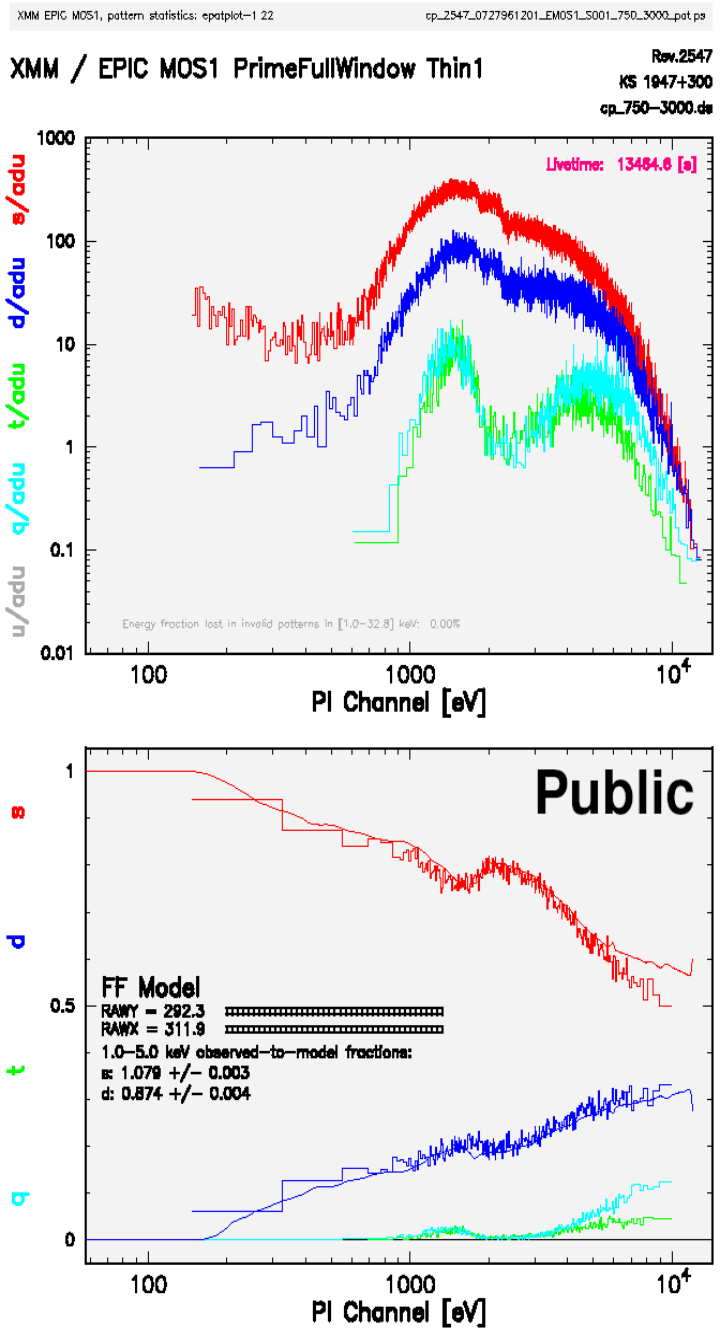


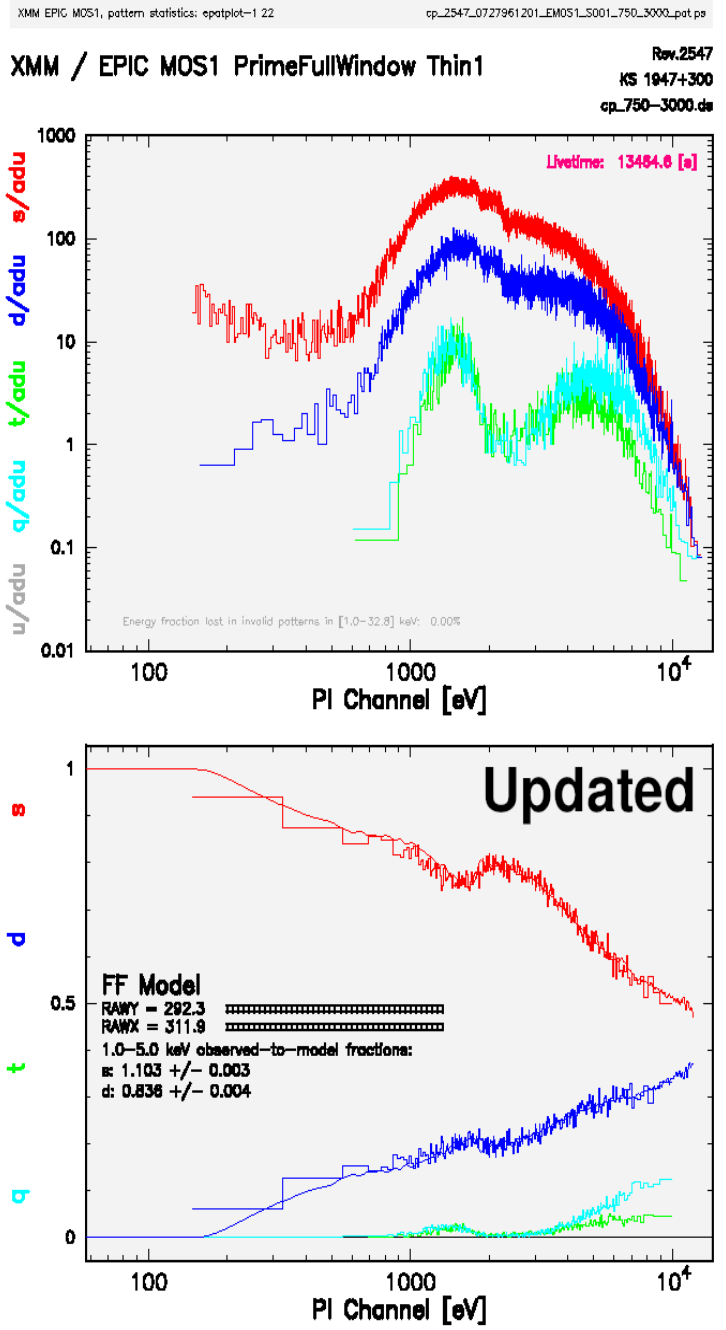
Effect on pileup:

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.





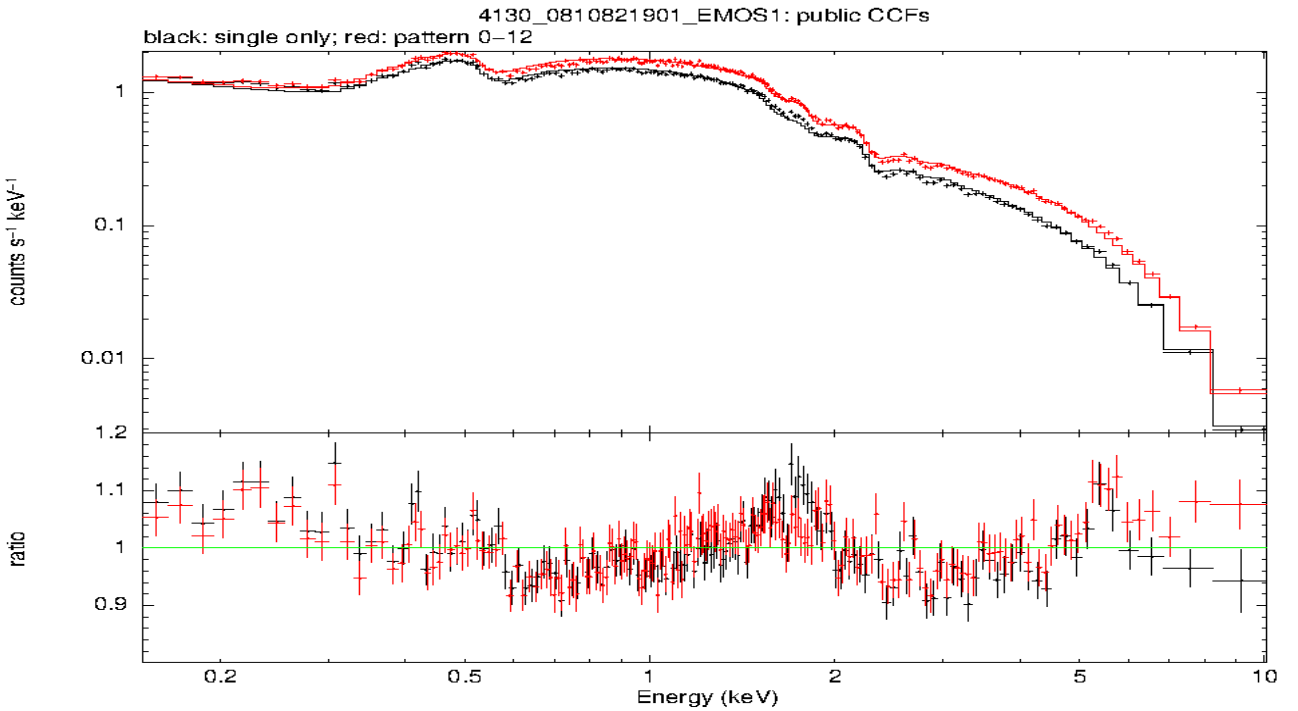
Effect on spectral responses:

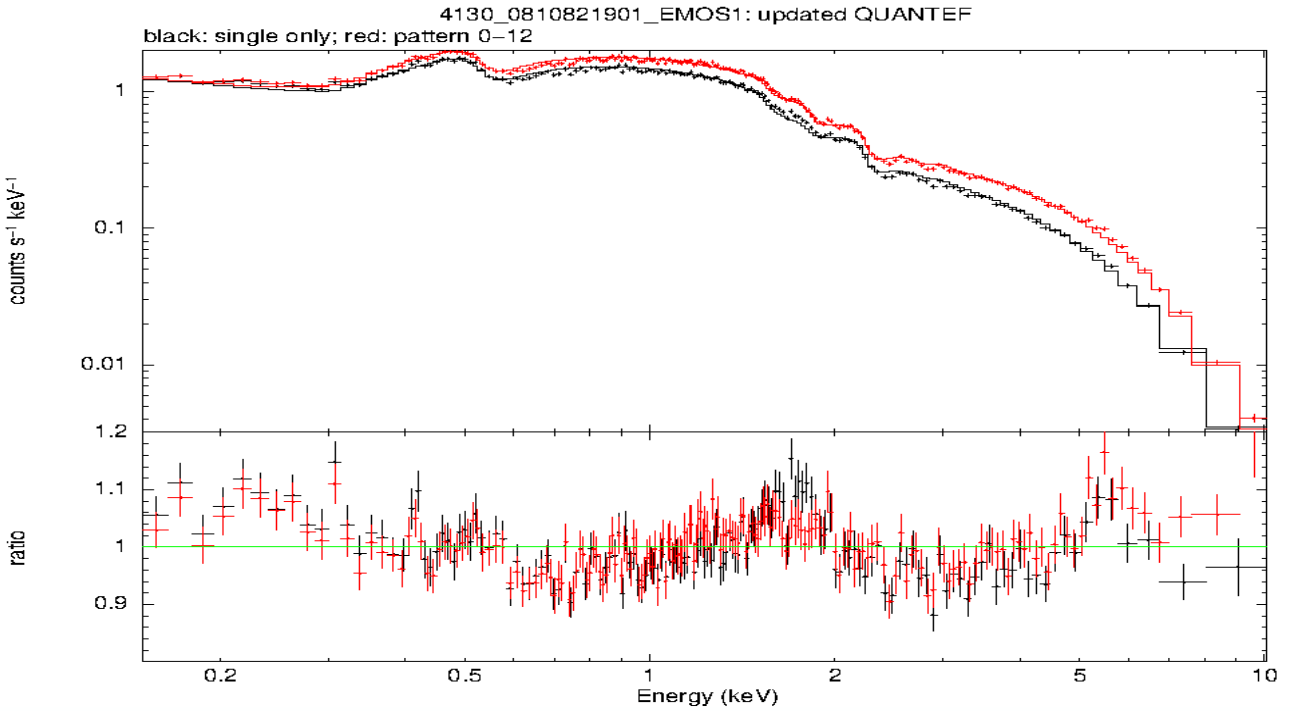
Using measured pattern fractions for spectral fitting:

- Example source: 3C273 (same as before)
- Singles vs. pattern patten 0-12.
- Top: public CCF
- Bottom: modified pattern fractions

- No significant changes can be seen in the fit residuals.

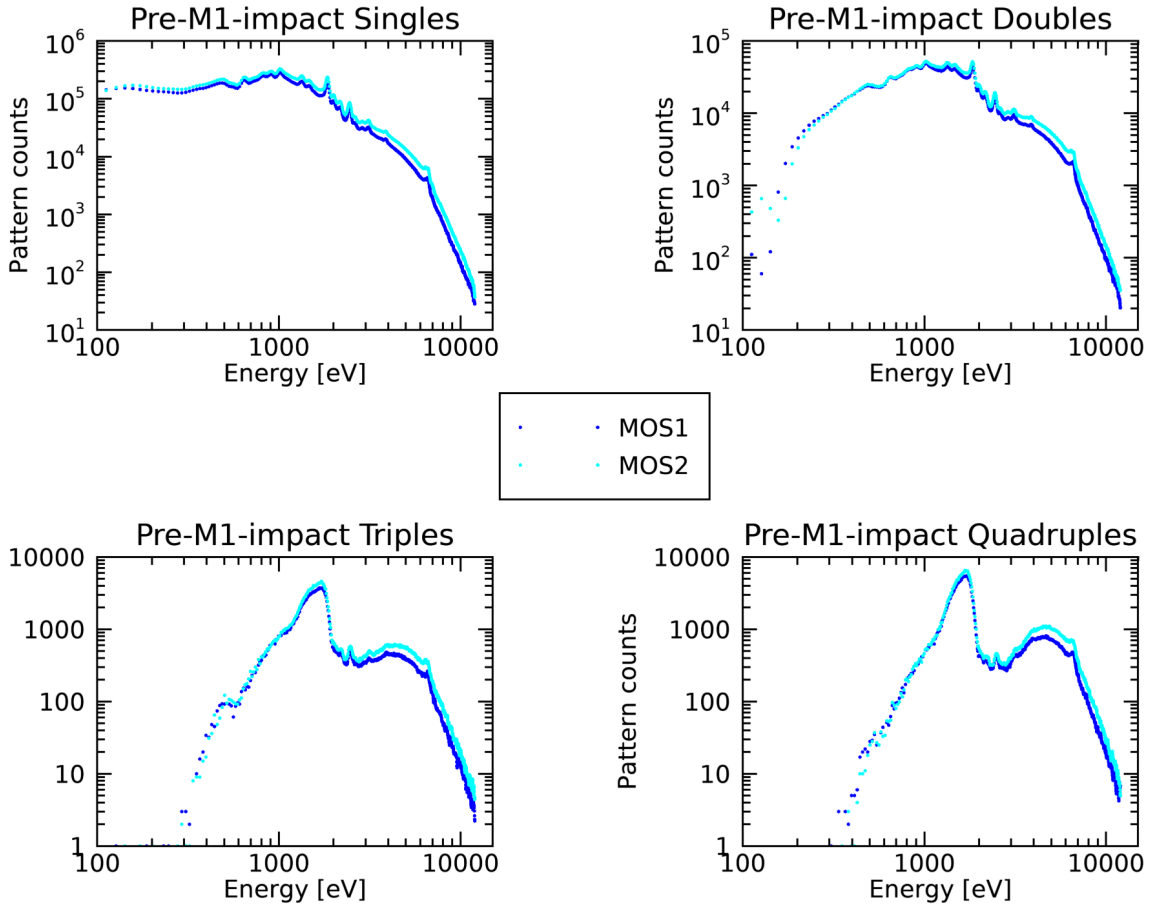
- Verified in SAS code: response generation uses energy fraction tables, not pattern fraction tables.



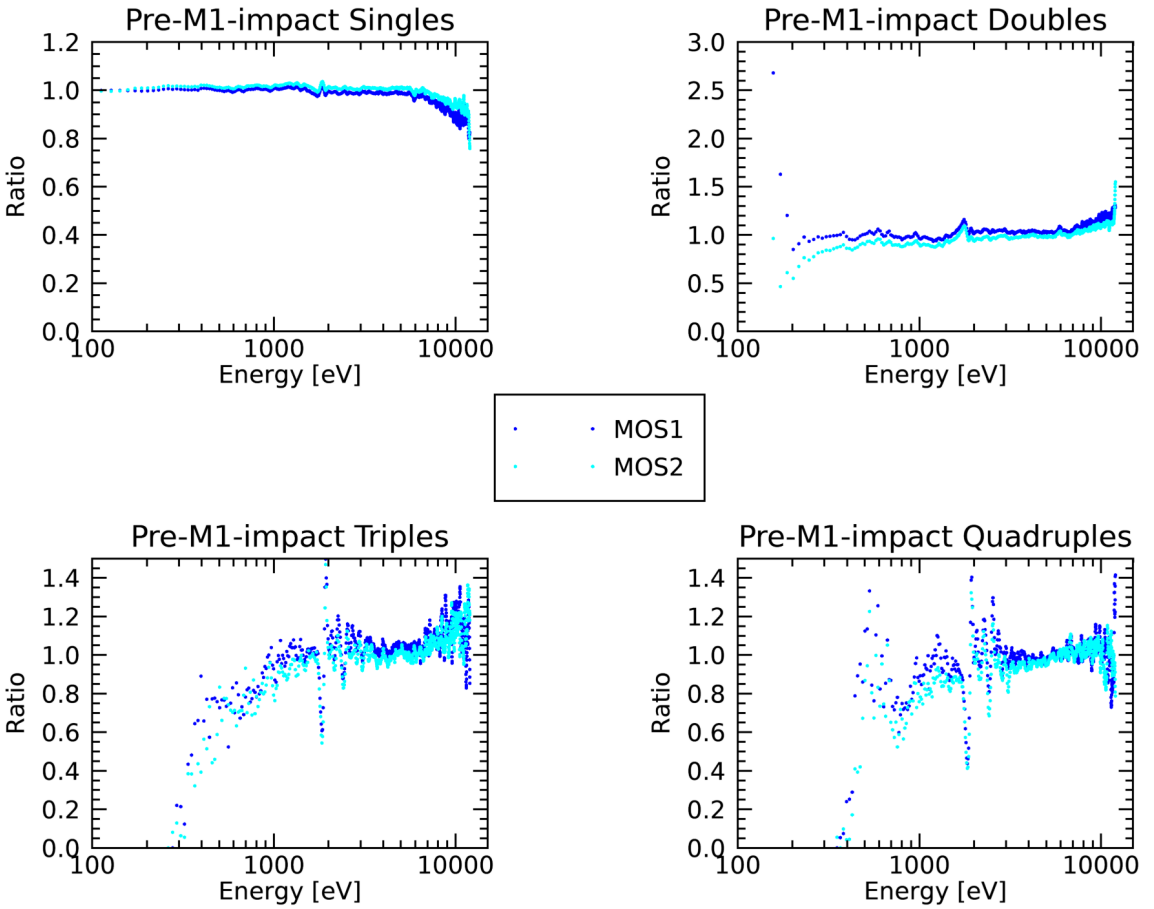


Transfer results to energy fraction tables:

Counts:

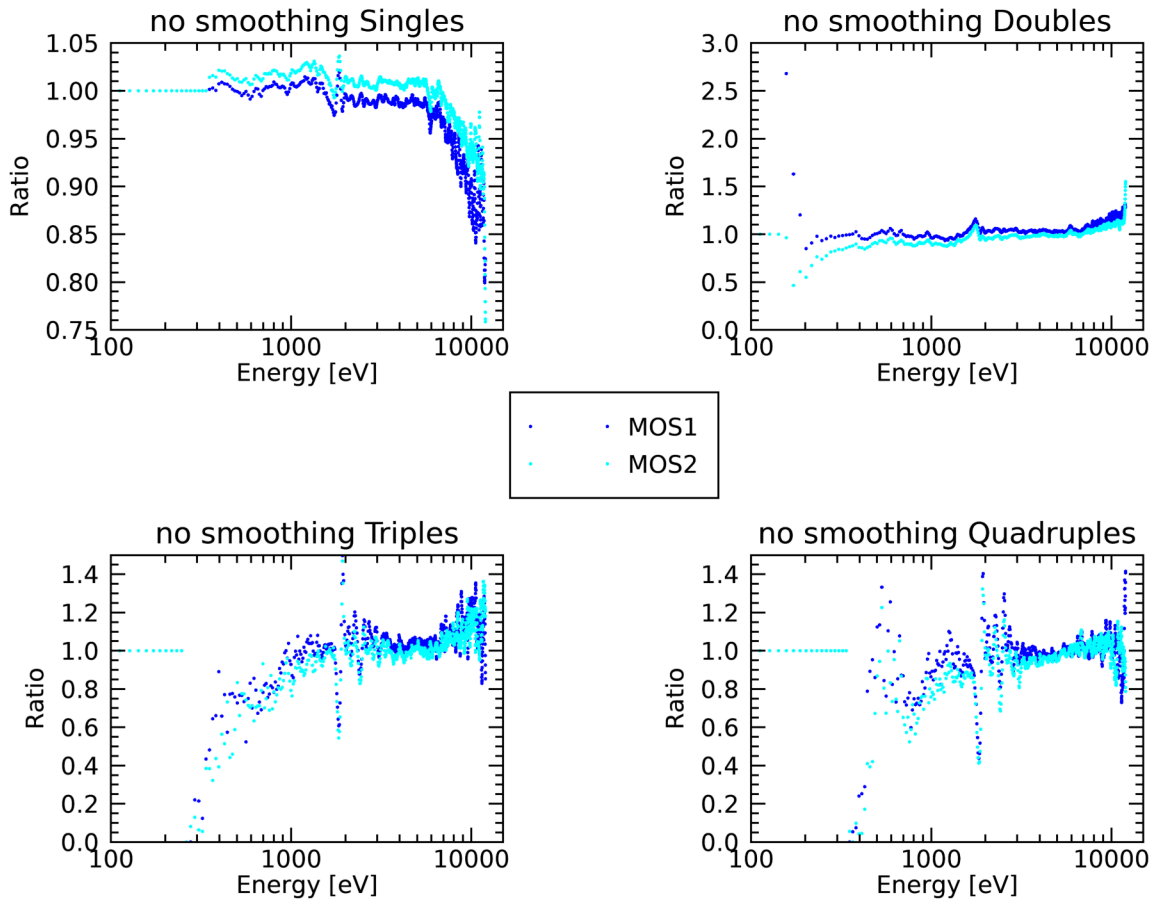


Difference to CCF data:

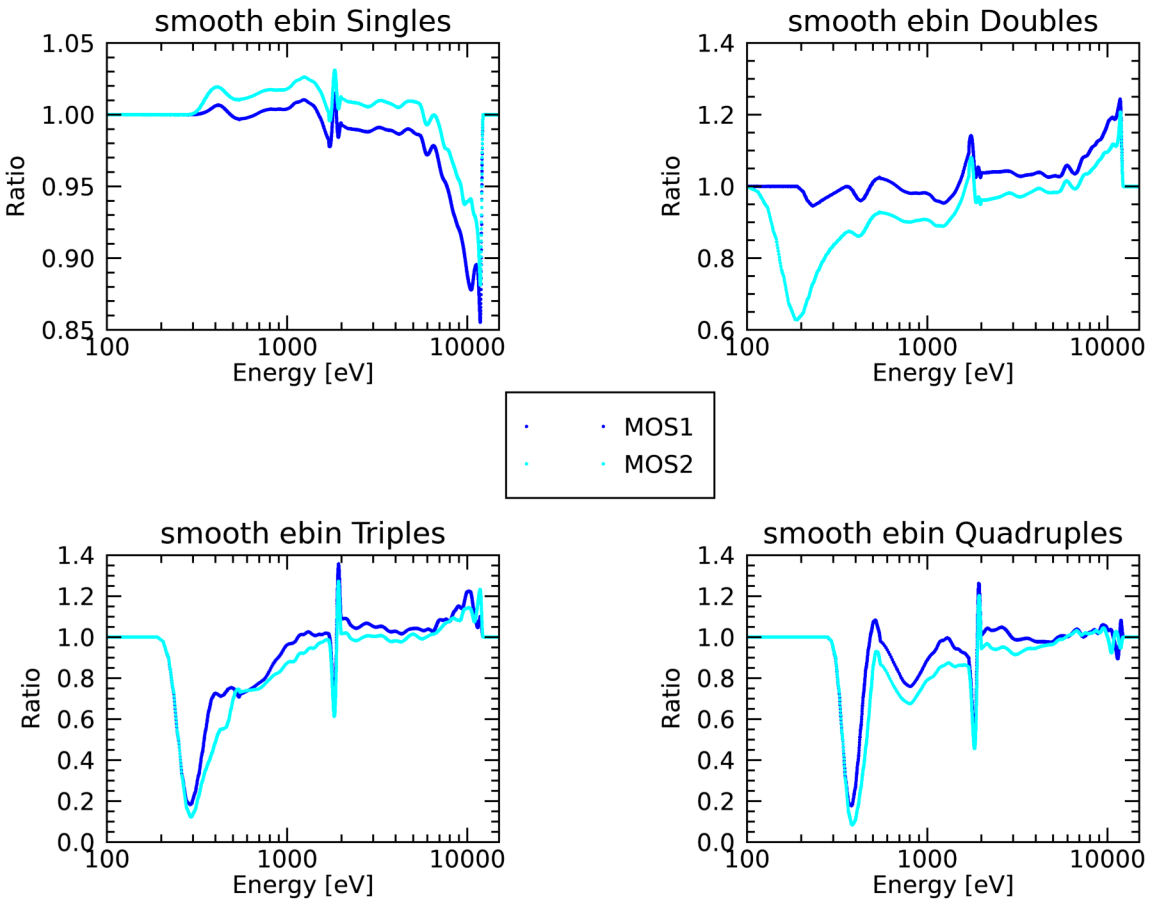


Transfer results to energy fraction tables:

Difference function (800 channel):

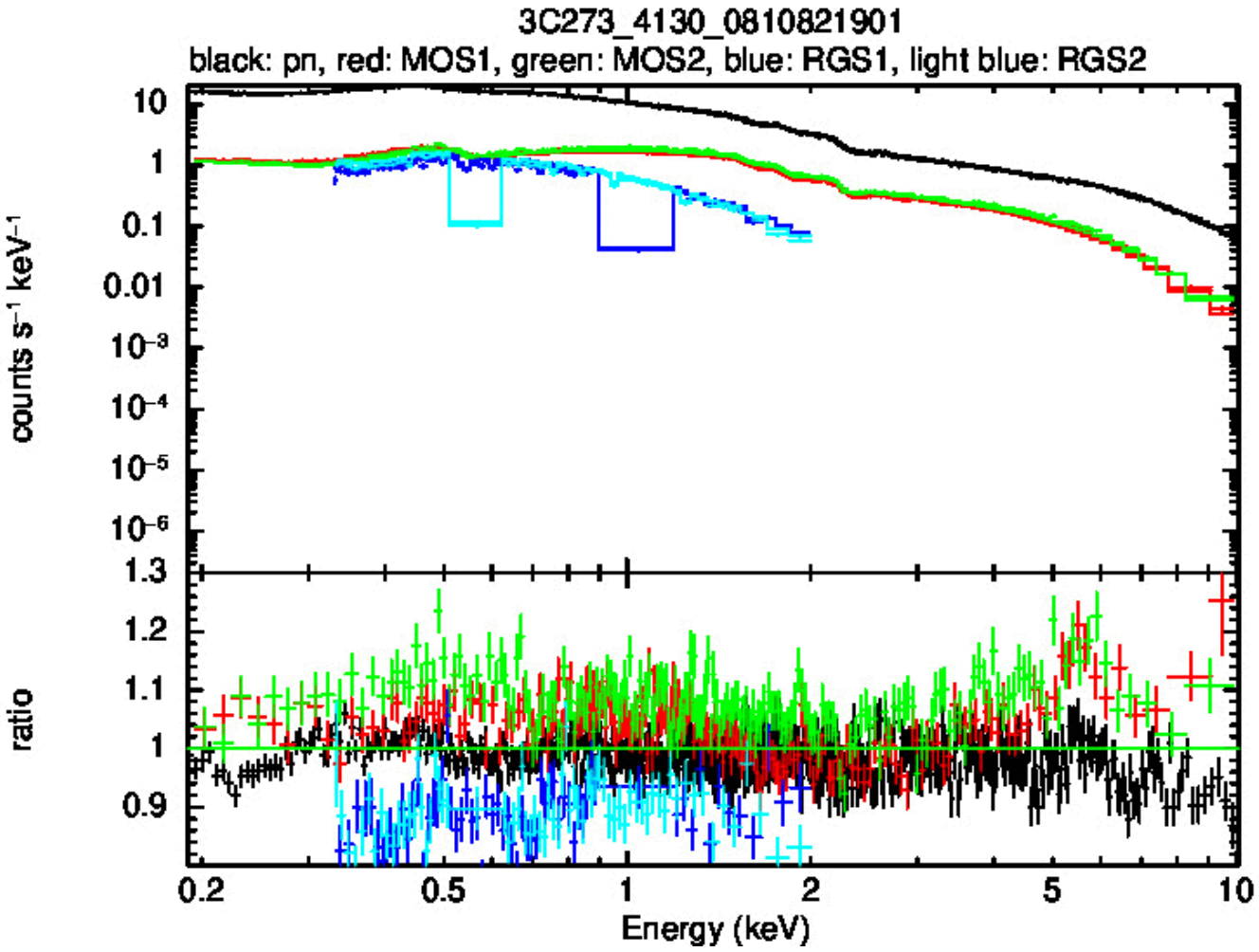


Difference function (2186 channels) smoothed:

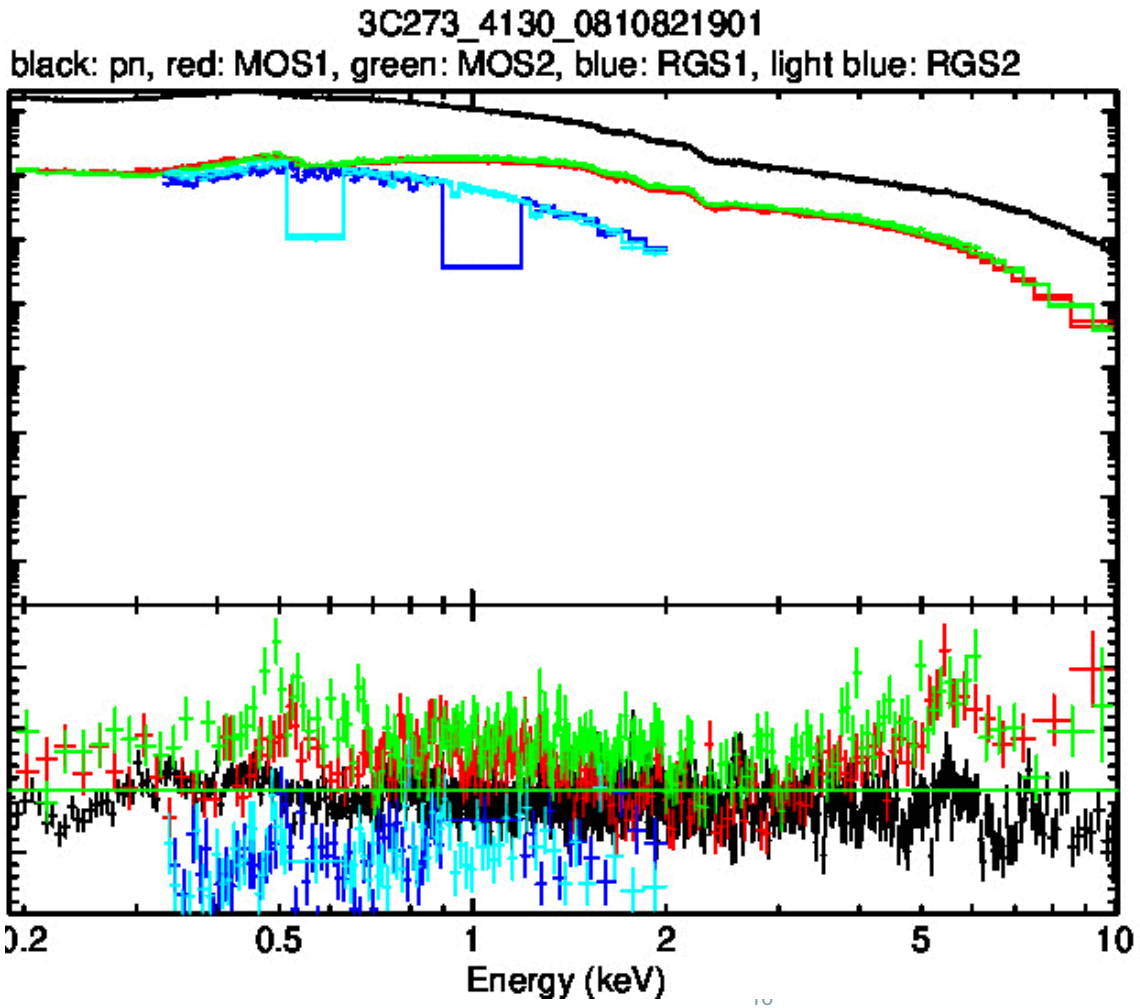


Test CCF: 3C273

SASv21.0 public CCFs:

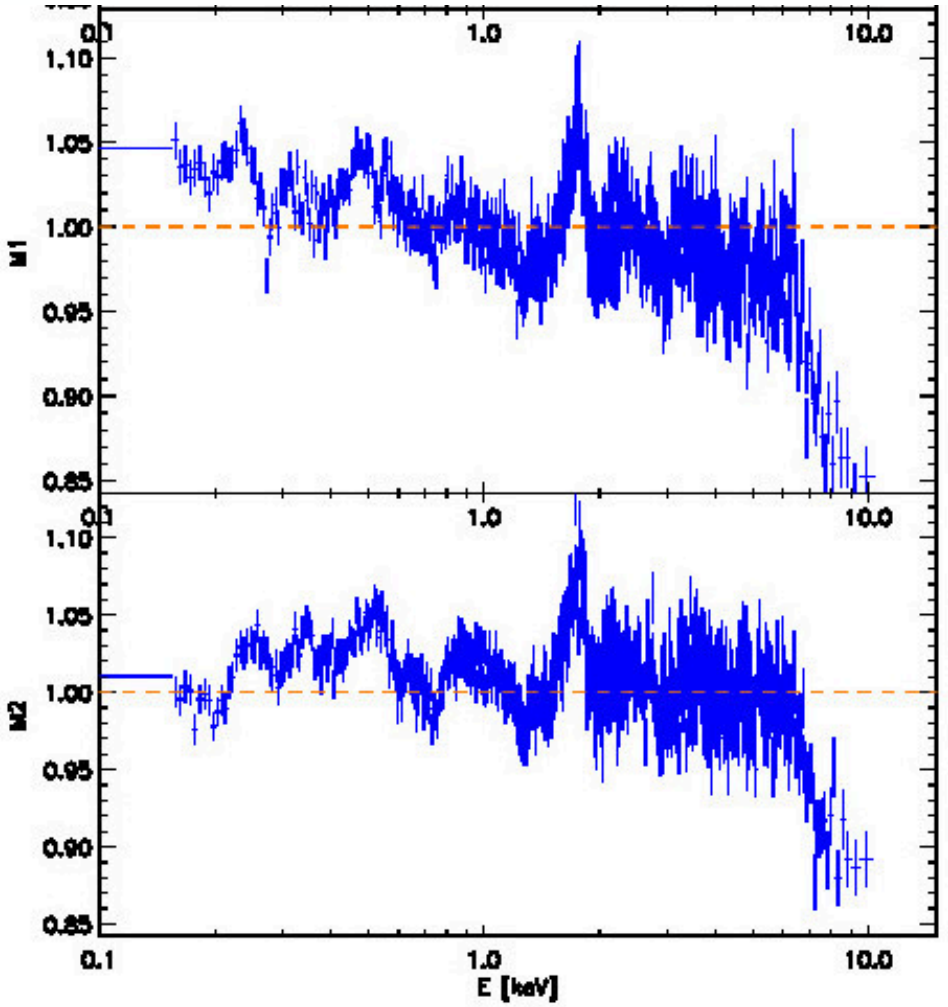


SASv21.0 using test CCF:

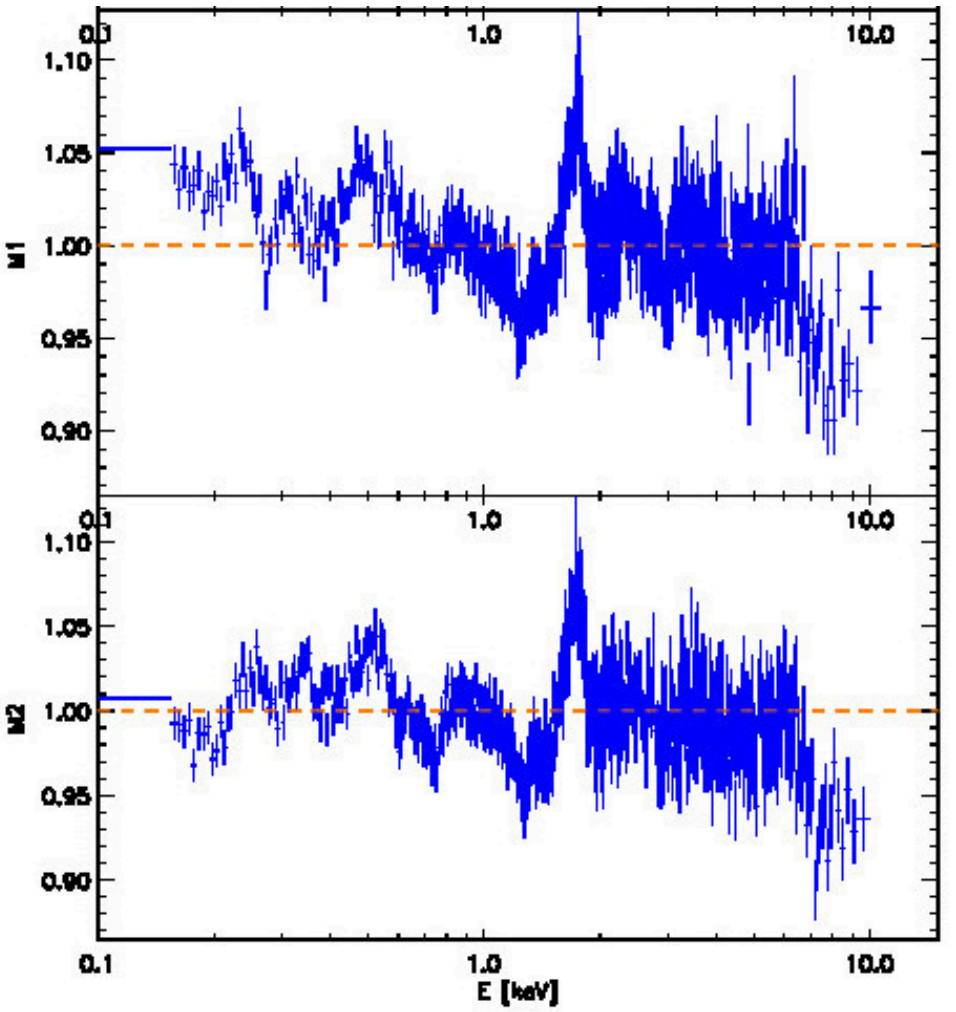


Test CCF: single residuals to pattern 0-12 best fit

SASv21.0 public CCFs:



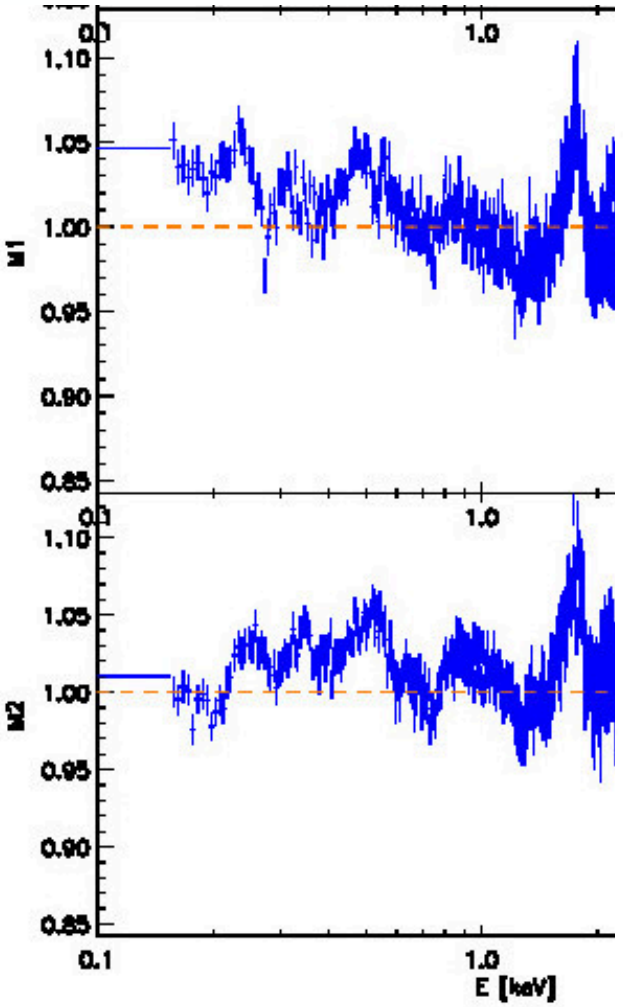
SASv21.0 using test CCF:

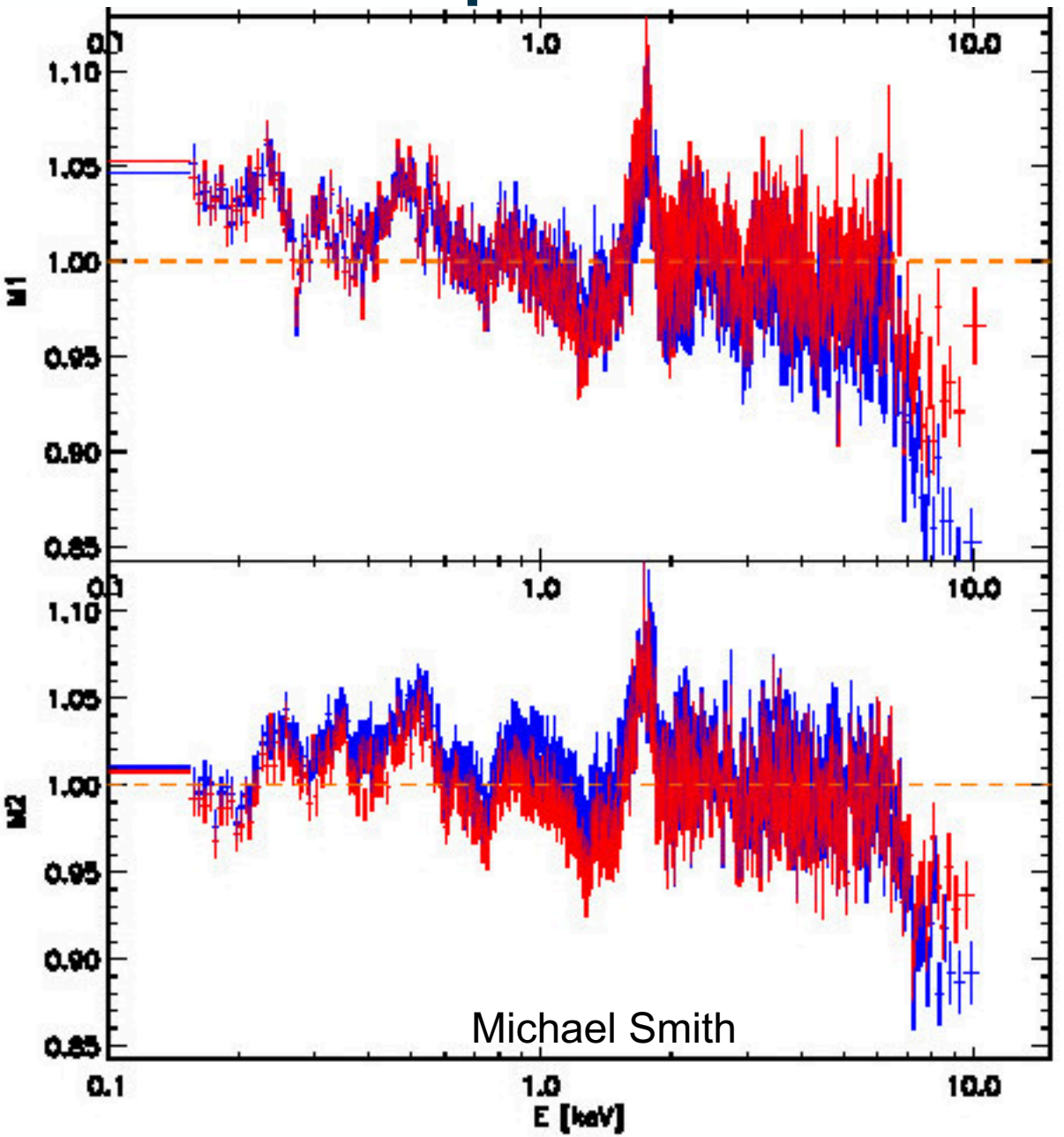


Michael Smith

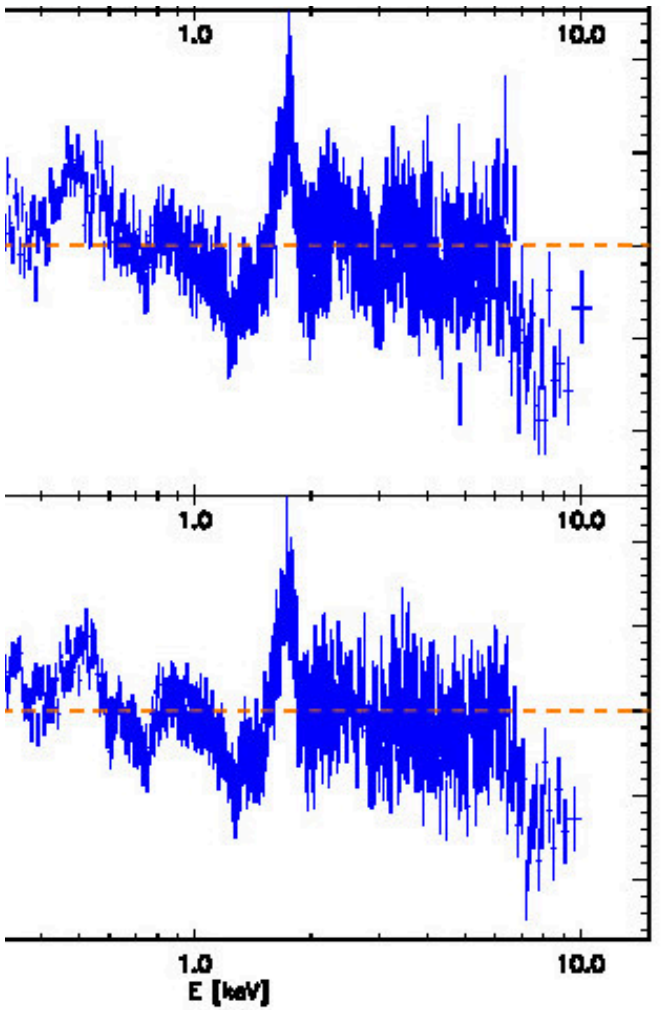
Test CCF: single residuals to pattern 0-12 best fit

SASv21.0 public CCFs:





SASv21.0 using test CCF:



Michael Smith

Conclusion:

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.
- Most likely ground calibration data. These tables need to be modified to show effects on responses.
- Transfer modifications of pattern fraction tables to energy fraction tables keeping total for scientific pattern neutral.
- Analyses using test CCF ongoing, differences point in direction of improvement.