Extended source analysis in CHEX-MATE

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- CHEX-MATE: one of the first two MYH programmes, 3 Ms observations, 118 sources
- We are dealing with analysis of *faint, extended* sources (external regions of clusters of galaxies) which are always *background dominated*
- This presentation is not intended as criticism, we all appreciate the work that is done, and we know the context in which the work is being undertaken
- It is intended to help and inform for now and future SAS releases

CHEX-MATE pipeline philosophy

- The CHEX-MATE pipeline is built upon the best practices developed on previous XMM Large Programmes (REXCESS, Planck, X-COP, M2C) with significant additional development to adapt them to the characteristics of our observations.

- The data reduction level 1 (L1) and background treatment are largely based on the X-COP pipeline (tailored for faint regions), based on ESAS tools + ad-hoc corrections and calibration on external datasets (see Ghirardini+ 2019).

- We further developed corrections to ESAS and X-COP, basing on new results on the pn background (Marelli+ 2020) and built a new physical background model for spectral analysis (Rossetti+ in prep). Applied also in X-GAP (LP, PI: Eckert).

- CHEX-MATE dataset fully reduced with SAS 16 (same as in X-COP) without major problems. Now trying to move to SAS 20.

Why ESAS?

Pros:

- Builds the «best» dataset for quiescent particle background, chip by chip
- The only tool to take into account the vignetting of the soft protons (at least for MOS)
- All our further developement based on ESAS products

Cons:

- Rigid file structure and naming, all tools need to be run in the ESAS framework (up to SAS 20, changes in SAS 21)
- Tools as «black boxes»
- Poor handling of the errors
- **Minimal documentation and versioning**

Our pipeline calls directly ESAS commands. Not easy to update if the syntax is changed in SAS 21!

Issues moving from SAS 16 to SAS 20
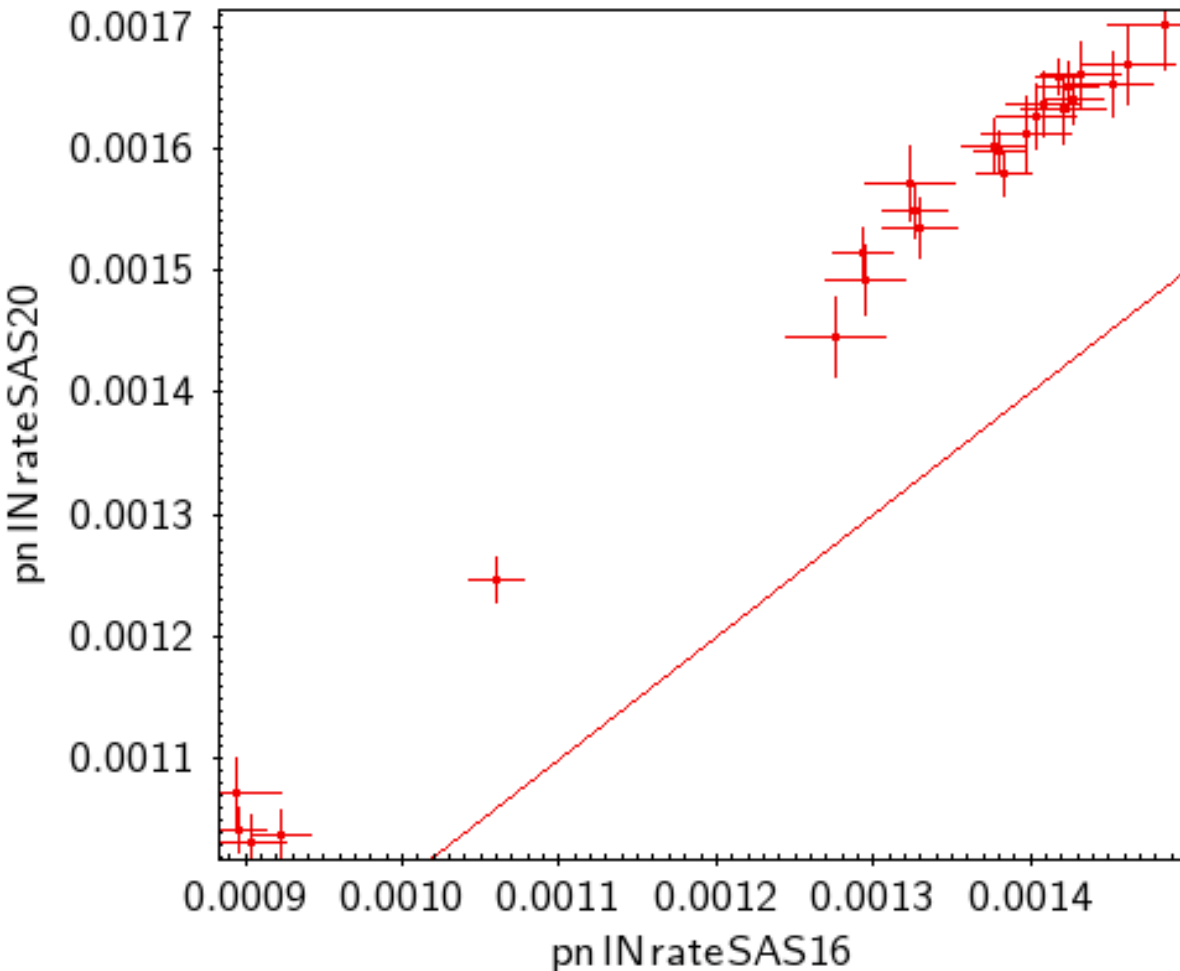
In our pipeline, we compute the pn count rate in the 10-14 keV band, to build the IN-OUT indicator of the residual soft proton component (Salvetti et al 2016).
Count rate directly extracted from the pn «clean» event file produced by *pn-filter*

The count rate changed by ~14% from SAS 16 to SAS 20 with the same selection and same data. Why?

Issues moving from SAS 16 to SAS 20
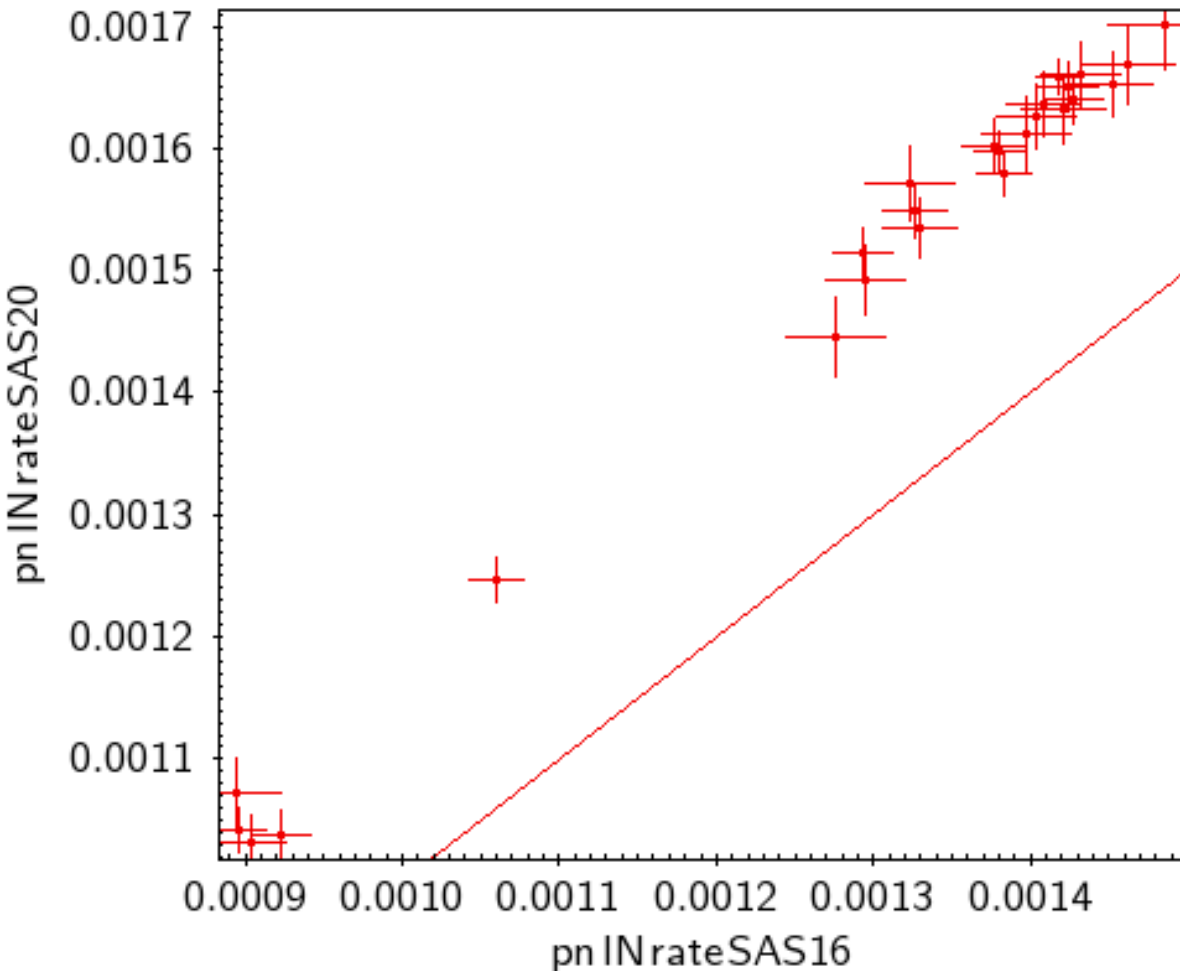
The count rate changed by ~14% from SAS 16 to SAS 20 with the same selection and same data. Why?

Inspection of the log file by *pn-filter* shows differences in the FLAG filtering for the event file in ESAS
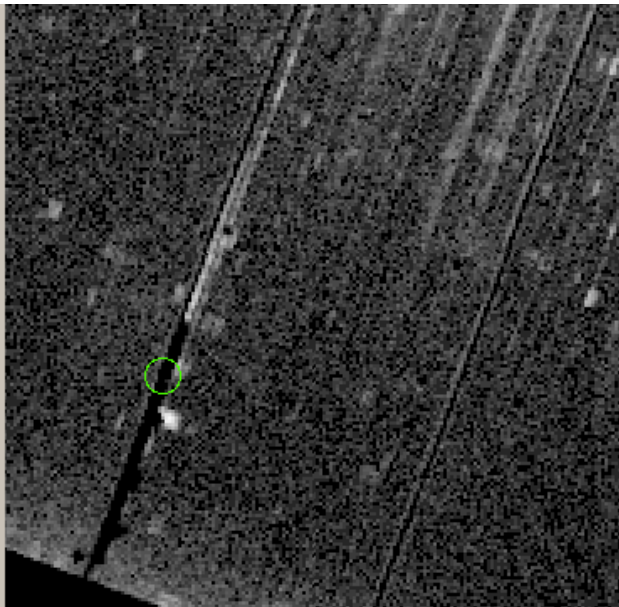
SAS 16:
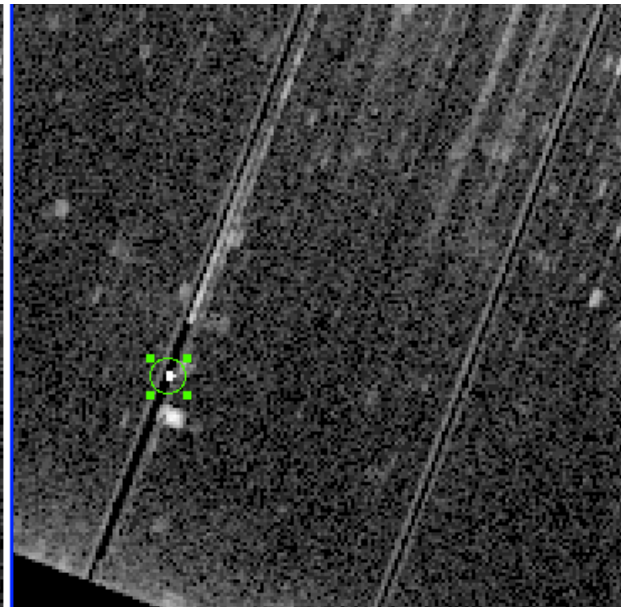expression='(PATTERN<=4)&&GTI(P0827060401PNS003-gti.FIT,TIME)&&((FLAG & 0x766a0f63)==0)'

SAS 20:
expression=(PATTERN<=4)&&GTI(pnS003-gti.fits,TIME)&&(#XMMEA_EP)

Issues moving from SAS 16 to SAS 20

SAS 16

SAS 20

Effect visible also on images, where (some) bright pixels are not excluded in SAS 20, that were in SAS 16

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SAS 16:
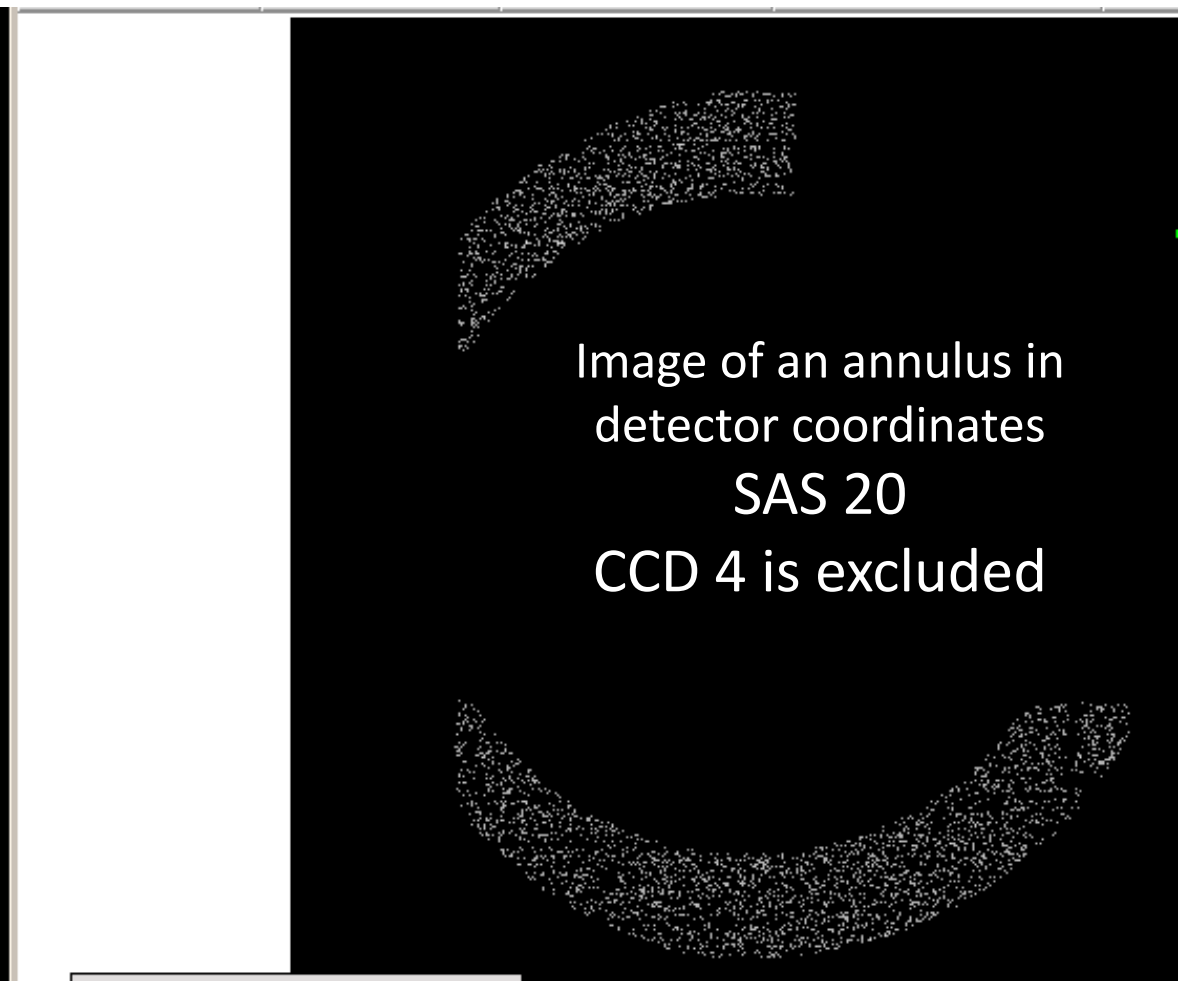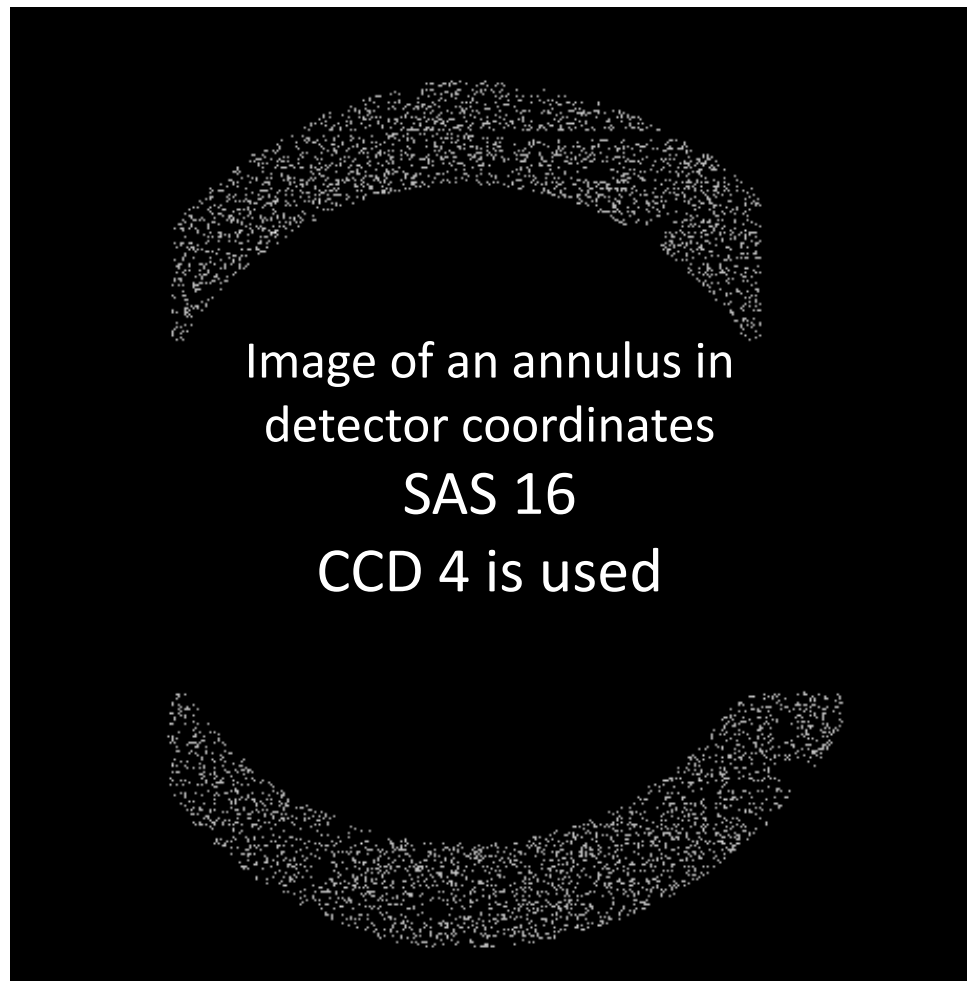expression='(PATTERN<=4)&&GTI(P0827060401PNS003-gti.FIT,TIME)&&((FLAG & 0x766a0f63)==0)'

SAS 20:
expression=(PATTERN<=4)&&GTI(pnS003-gti.fits,TIME)&&(#XMMEA_EP)

No indication of this change in the SAS 20 documentation

Issues moving from SAS 16 to SAS 20

The ESAS tool *mos-filter* measures the hardness ratio in each MOS CCD. If the measured value is below a threshold, the CCD is flagged as anomalous and excluded from the rest of the analysis

Image of an annulus in
detector coordinates
SAS 16
CCD 4 is used

Image of an annulus in
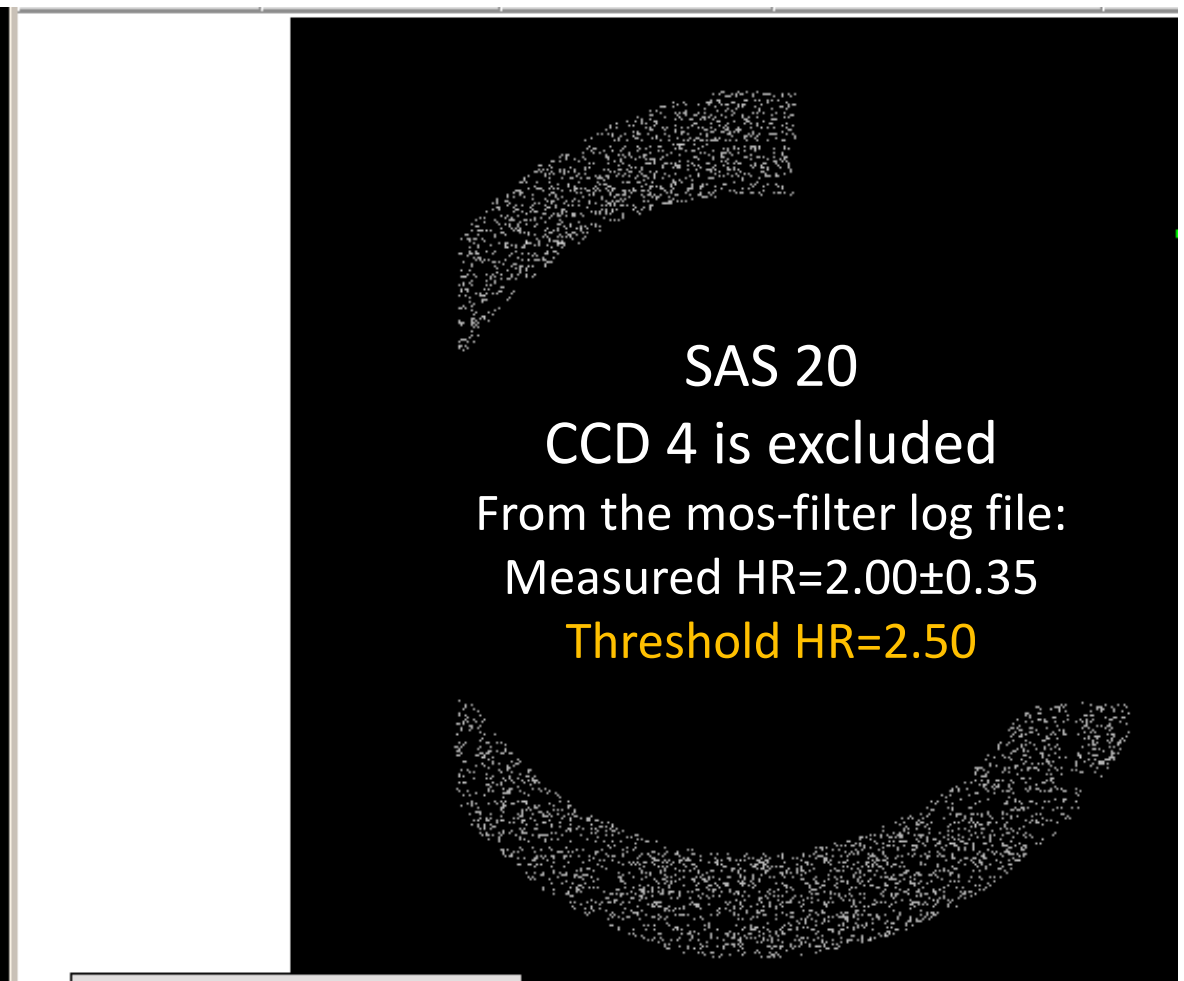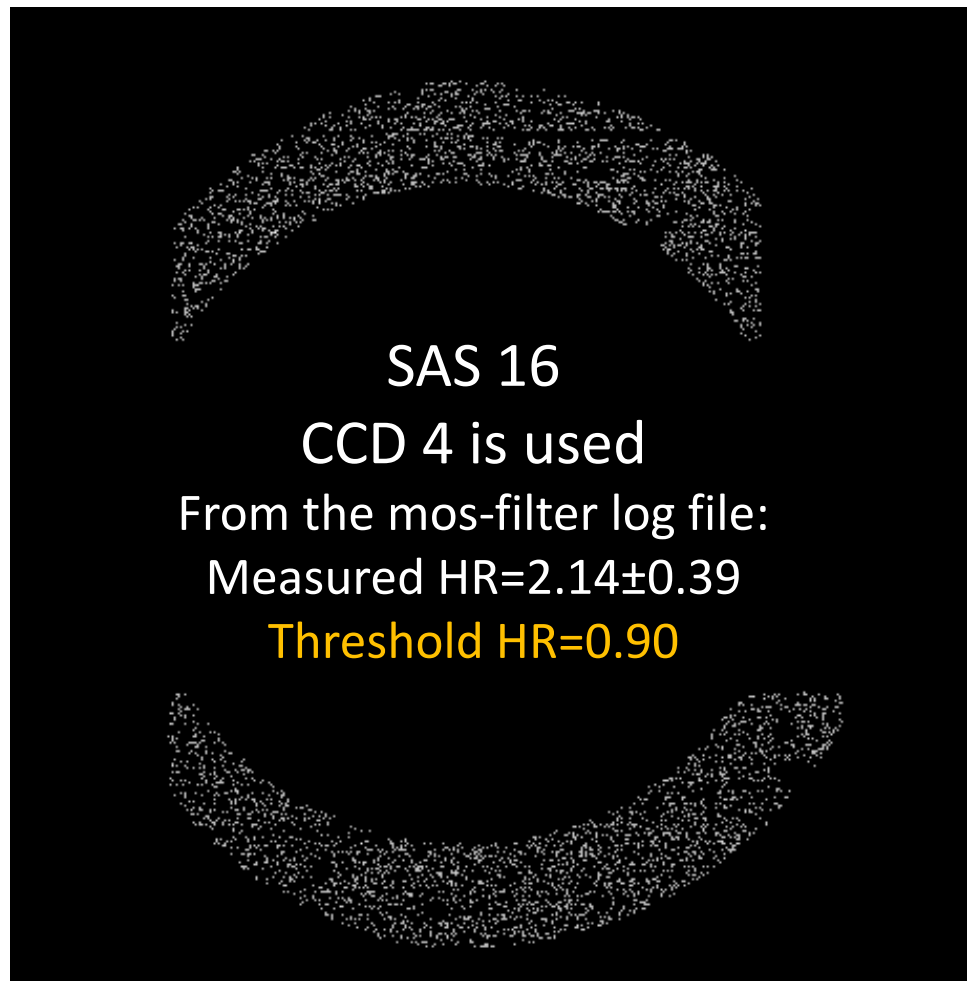detector coordinates
SAS 20
CCD 4 is excluded

Issues moving from SAS 16 to SAS 20

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SAS 16
CCD 4 is used
From the mos-filter log file:
Measured HR=2.14±0.39
Threshold HR=0.90

SAS 20
CCD 4 is excluded
From the mos-filter log file:
Measured HR=2.00±0.35
Threshold HR=2.50

Issues moving from SAS 16 to SAS 20

The ESAS tool *mos-filter* measures the hardness ratio in each MOS CCD. If the measured value is below a threshold, the CCD is flagged as anomalous and excluded from the rest of the analysis

Thresholds have changed from SAS 16 to SAS 20 (maybe in between)
The current choice is more conservative and may be reasonable but we could not find documentation for it
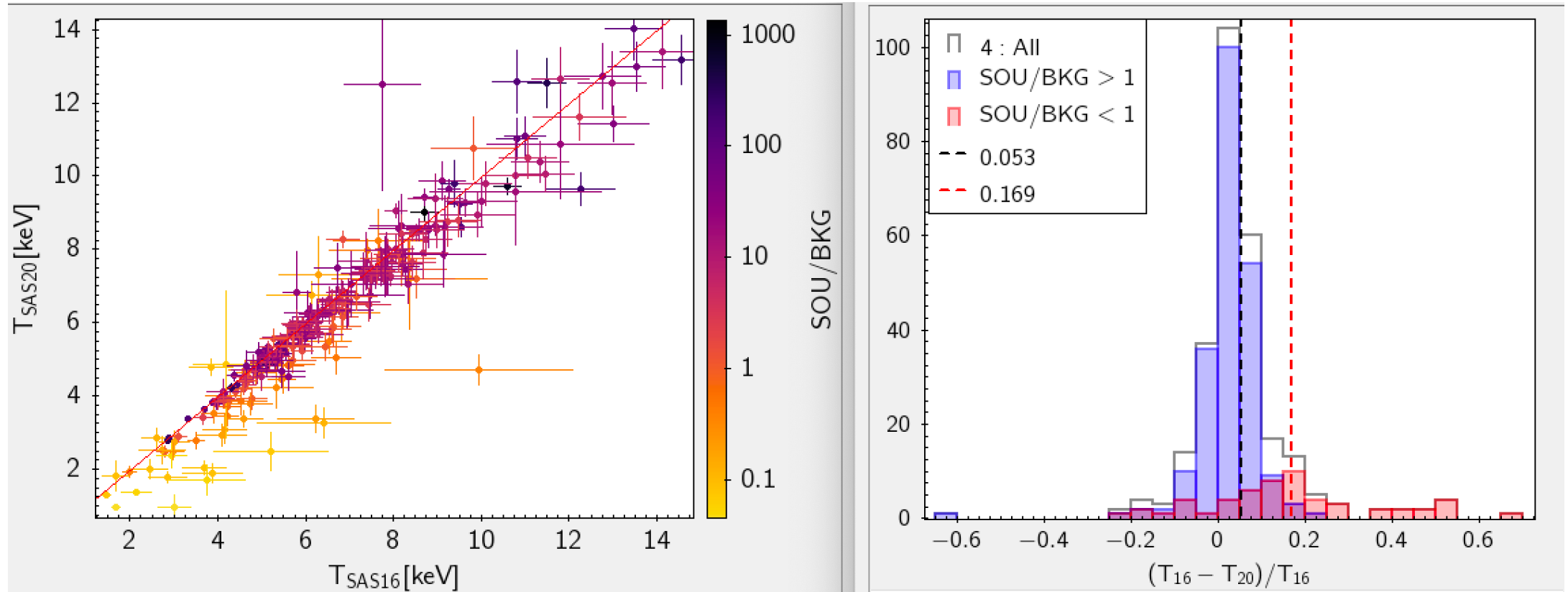
Issues moving from SAS 16 to SAS 20
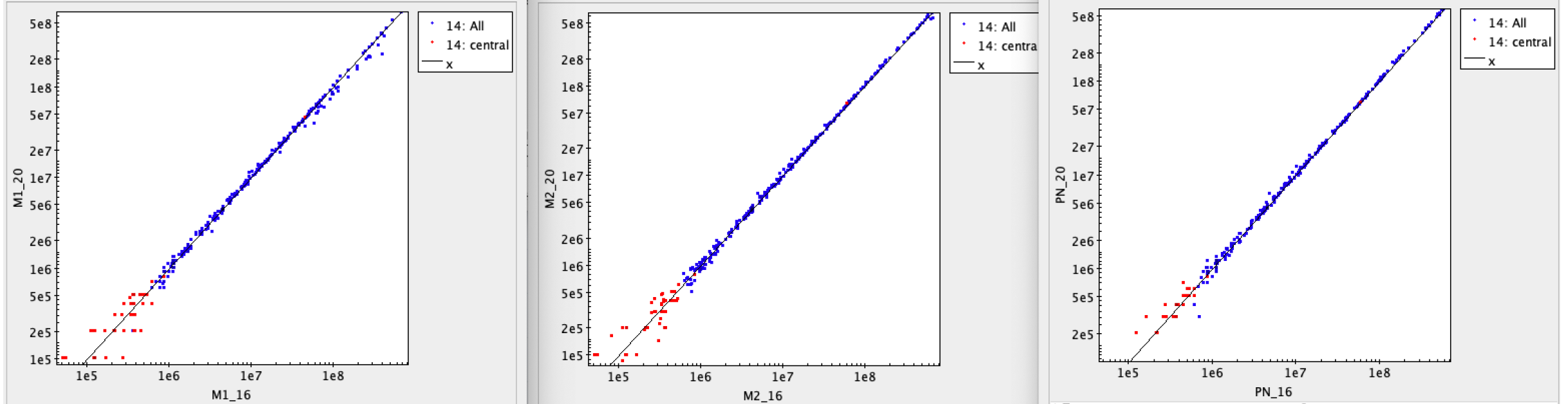
Newly-discovered (yesterday) SAS 20 backscale problem:
for small regions (radial width < 30 arcsec) in the centre of the detector (red), the SAS 20 backscale values are discretised and in some cases appear to be larger than geometric area
Origin of this problem not yet identified

Issues moving from SAS 16 to SAS 20

These changes have an impact on our scientific results, especially in background-dominated regions. We can correct for some of them (once understood) but it's very time consuming identifying the source of the differences and correcting retrospectively

SAS 21?

- The major update of ESAS, becoming modular and less rigid in the nomenclature, is what we hoped for at the beginning. But it's probably too late for CHEX-MATE now (tests are being performed on subsamples, analysis of full sample is ongoing)

- Moving to SAS 21 requires a major rewriting of the CHEX-MATE code, especially if the names of the ESAS tools changed (they did: *mos-spectra -> mosspectra*) and if they don't automatically search for standard ESAS names when optional parameters are not provided (to be checked)

- We would recommend keeping the old ESAS names and, while preserving the possibility to call the new tools with new parameters, keeping the old ESAS structure and file naming as default.

Recommendations

- Provide a rapid patch to SAS 20 to apply the same FLAG selection as in previous versions (it should be only one line of code in *pn-filter*)

- Provide full documentation to ESAS tool and change log with ALL changes from version to version, including default filtering values

- Try to keep any new version of ESAS tools backward-compatible, using the standard ESAS names as default.