XMM-Newton EPIC-pn:
Long-term CTI correction for window modes

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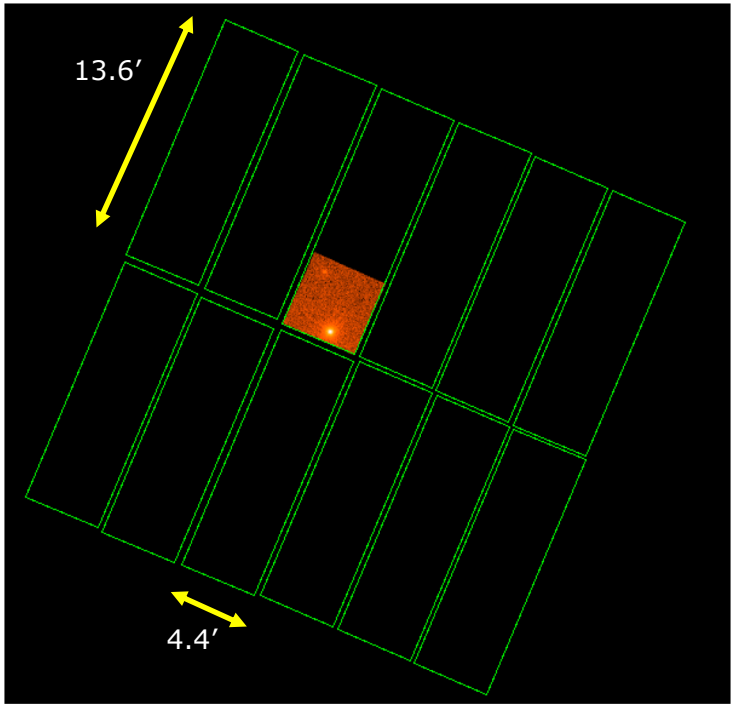
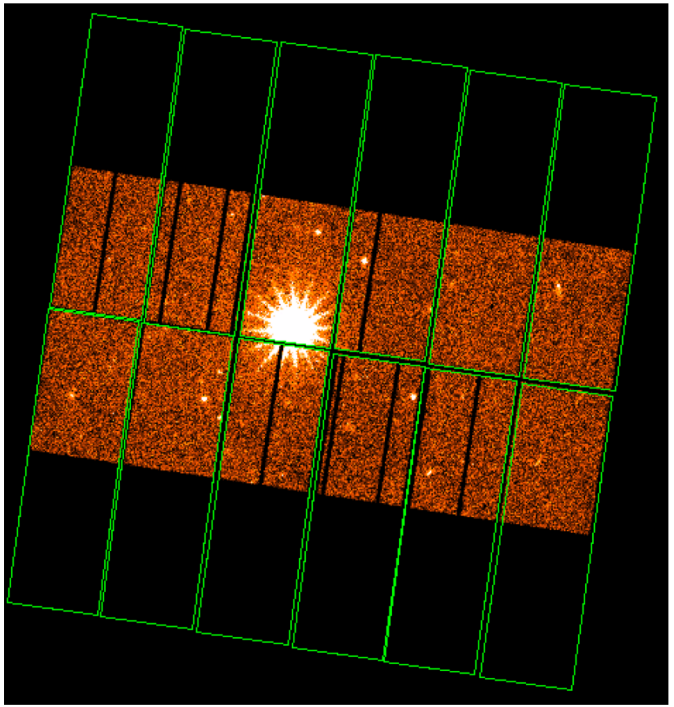
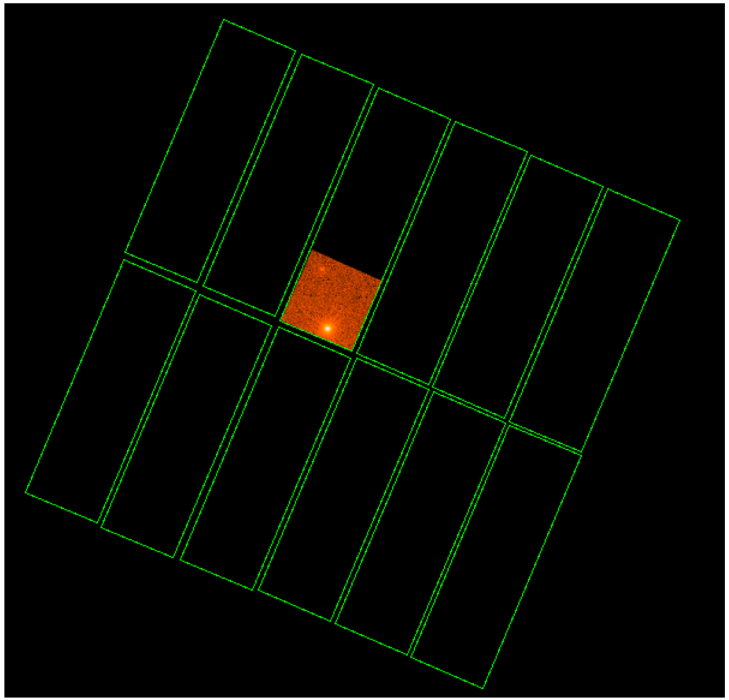
Small window mode

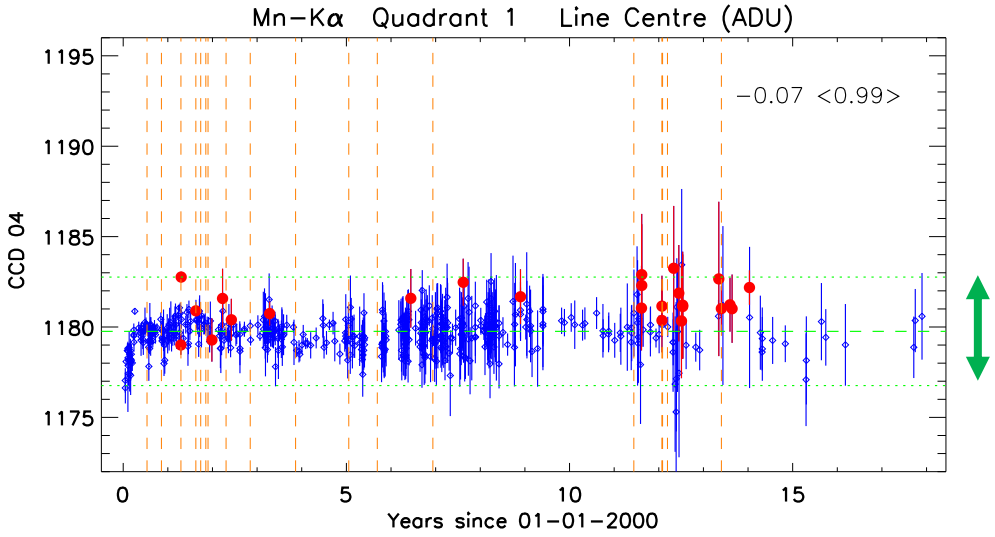


Large window mode



EPIC-PN Small Window Mode





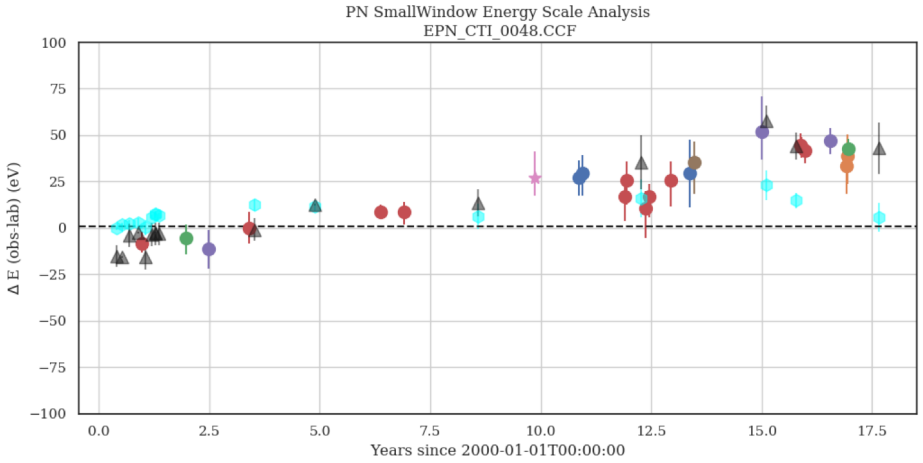
EPIC-pn Full Frame derived long-term CTI

CalClosed observations:
Mn Kα line at 5.8988 keV

Optimised for the boresight.

± 3 ADU (± 15 eV)

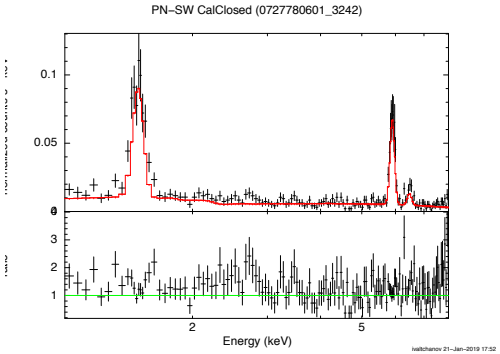
Correction implemented in
`EPN_CTI_0048.CCF`

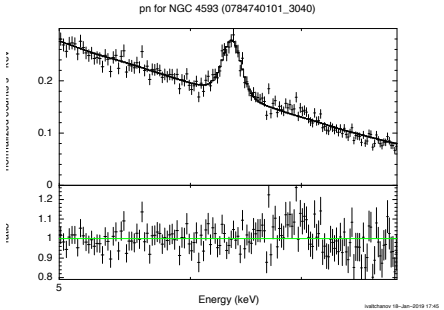


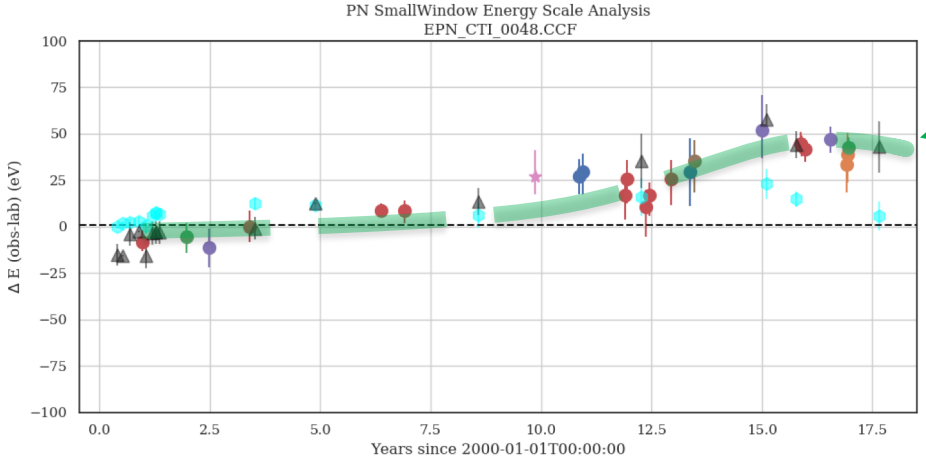
PN Small Window Mode

Processing with EPN_CTI_0048.CCF Correction is based on FF or eFF mode.

CalClosed
AGNs with narrow Fe Kα

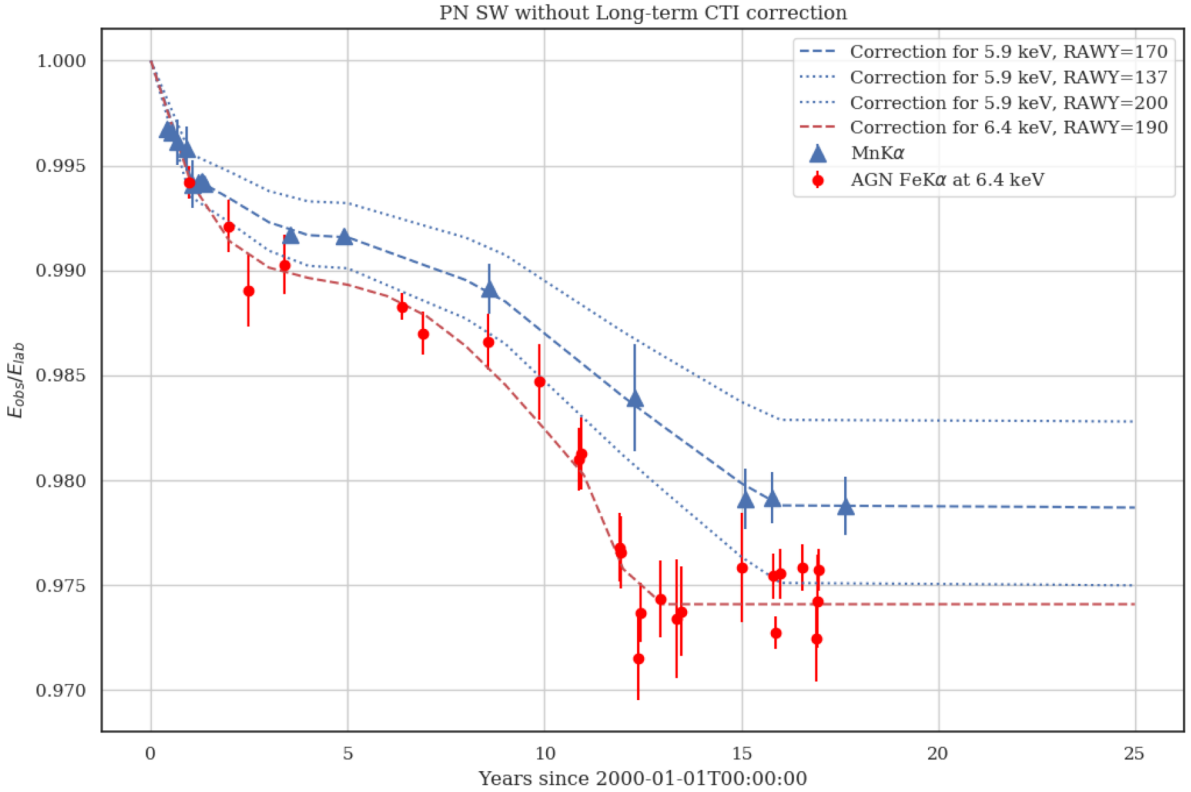




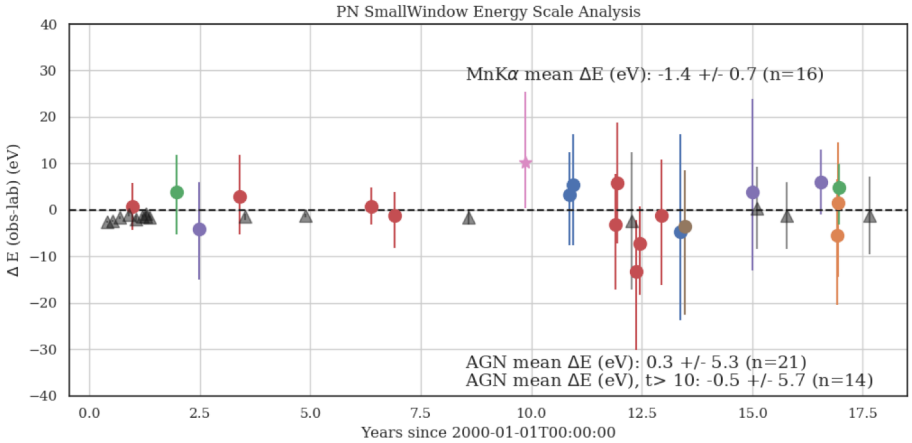


Systematic offset of 40-50 eV at t>15 years (rev > 2500) deviation starting at t ~ 10.

This is 0.5-0.7 % effect,
but it is systematic!



Use these curves to derive a new correction



PN Small Window Mode

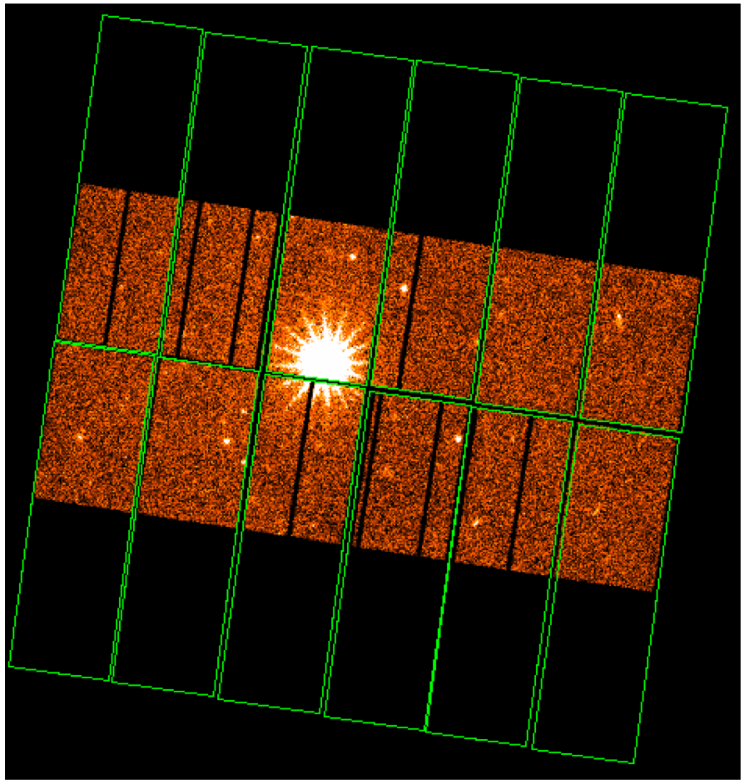
Results with the new correction

- Considered final for the moment
- Incorporated in the new CCF

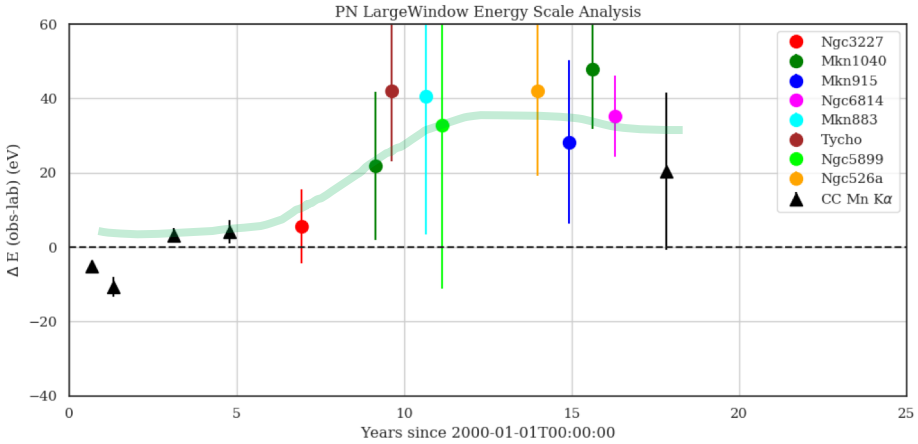
Current calibration!

EPN_CTI_0049 and EPN_CTI_0050

EPIC-PN Large Window Mode



Single events: PATTERN == 0



PN Large Window Mode

Too few suitable CalClosed observations!

Boresight results (CCD#4).

- The two most recent CC are separated by ~13 years.
- The most recent one (rev 3274 with expo 14.4 ks) is short ➔ noisy line at 6 keV.
- Too few AGNs (9) and the iron lines (Fe Kα) are faint.
- At t > 8/9 years systematic offset of ~ 30-40 eV.

Cu Kα line at 8.04 keV comes to help!

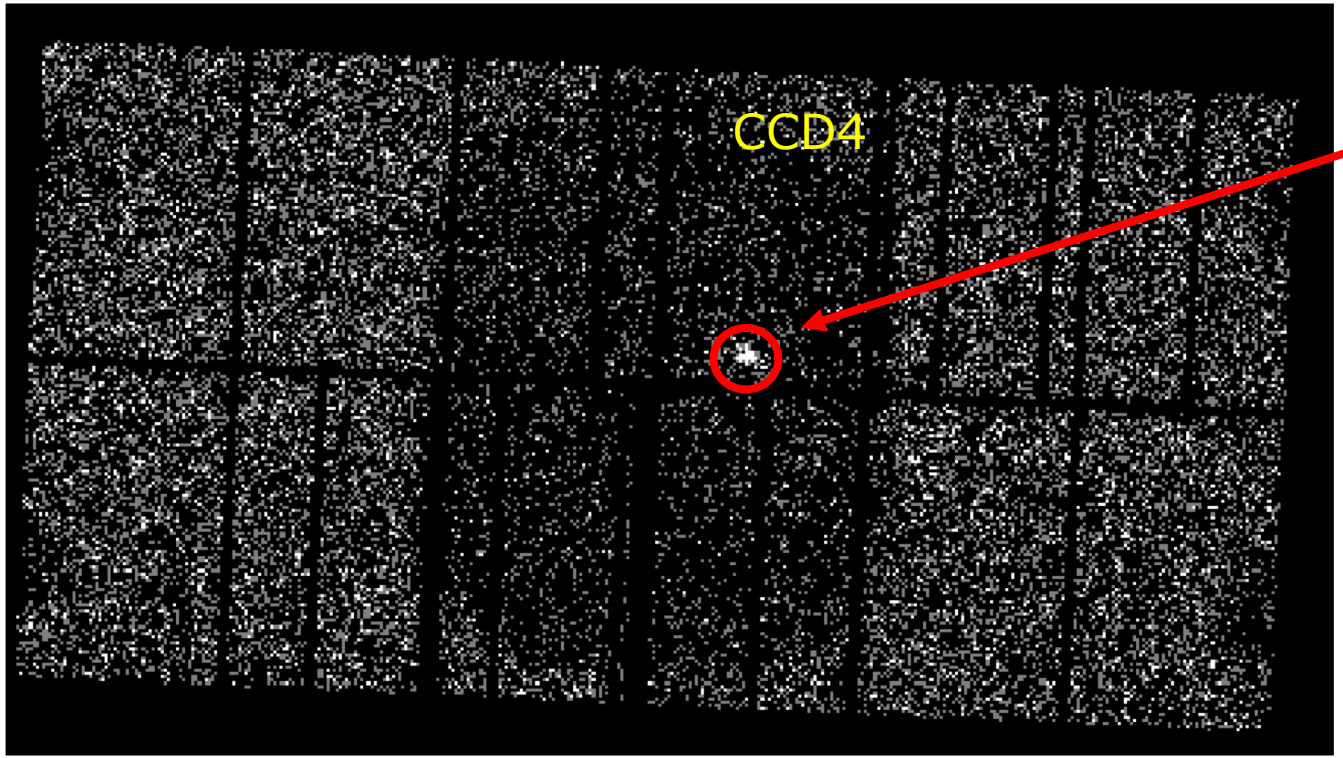
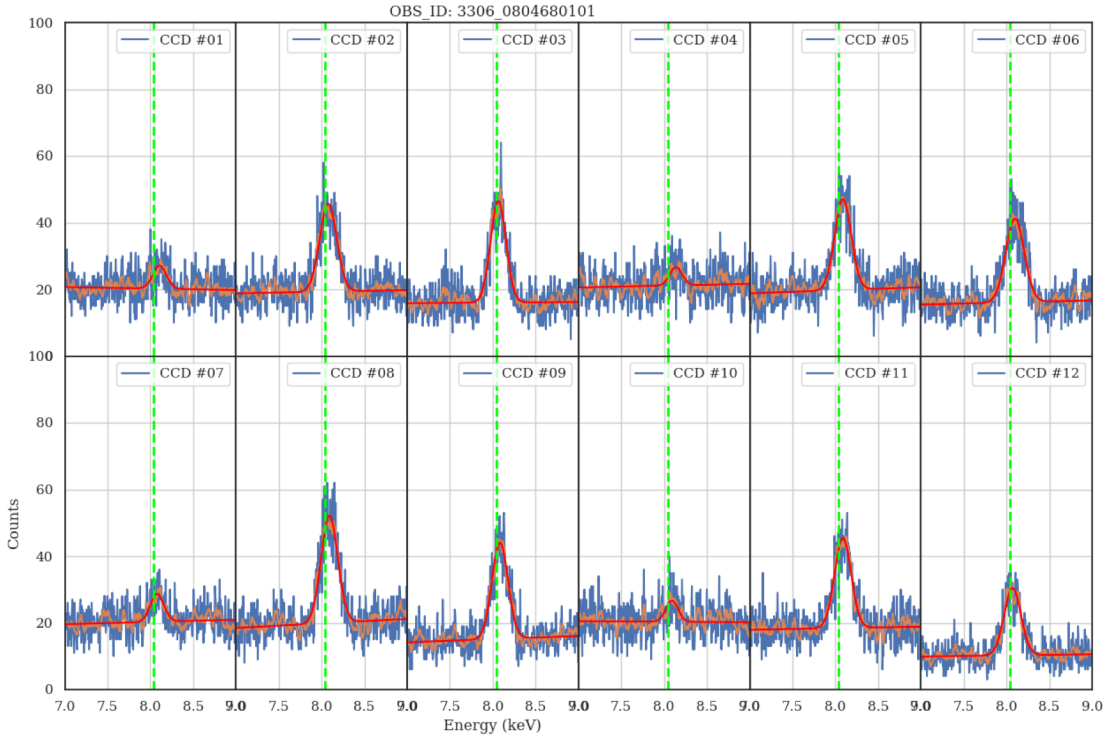


Image in [7.9,8.1] keV

Boresight, CCD#4

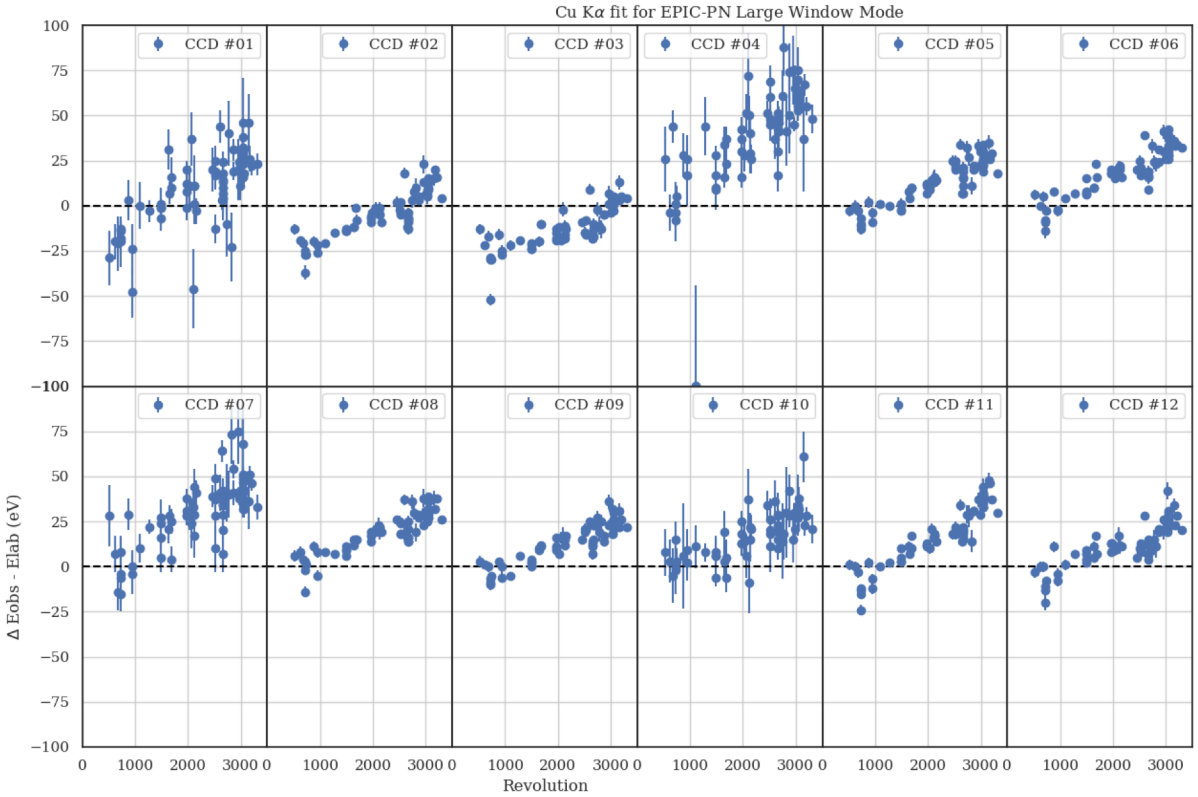
Example Cu Kα fit

CTI CCF v48



Spectra extracted from each CCD after masking

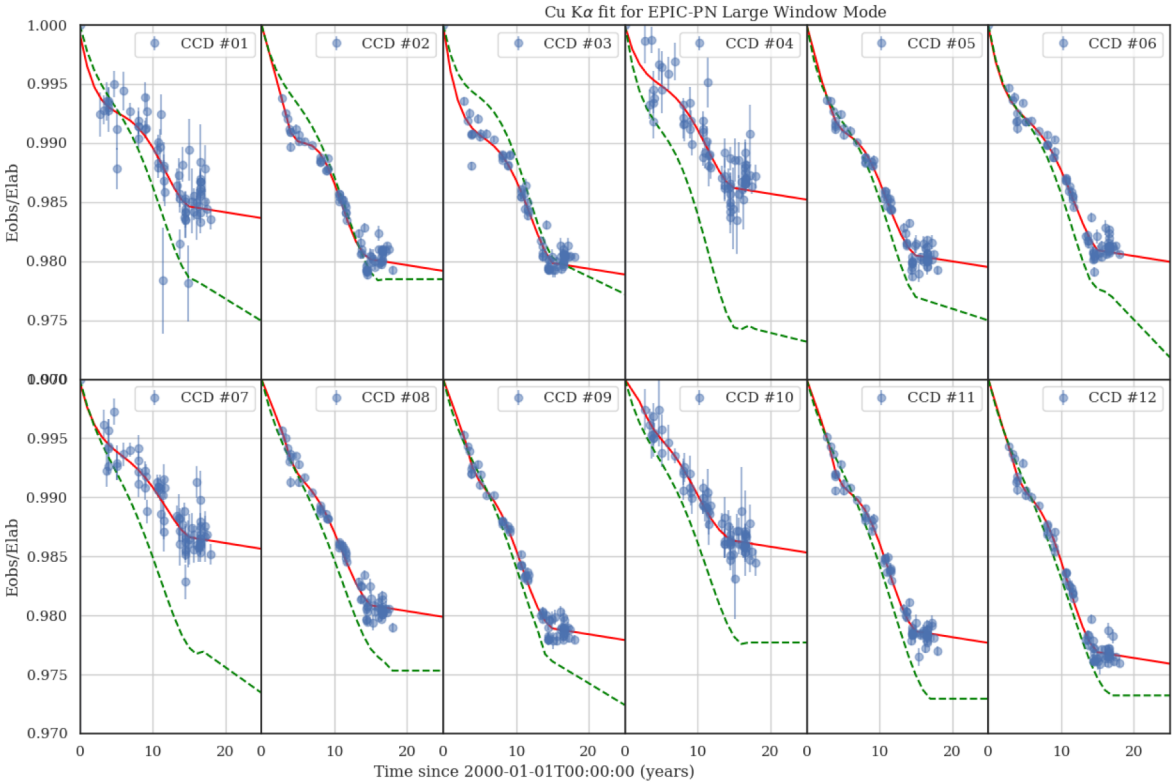
Note: the mask per CCD was derived from the illumination pattern of the calibration source at the Mn Kα line.
➔ not optimal for Cu Kα especially for CCDs 1 and 7.



PN LW

LTCTI (v48)

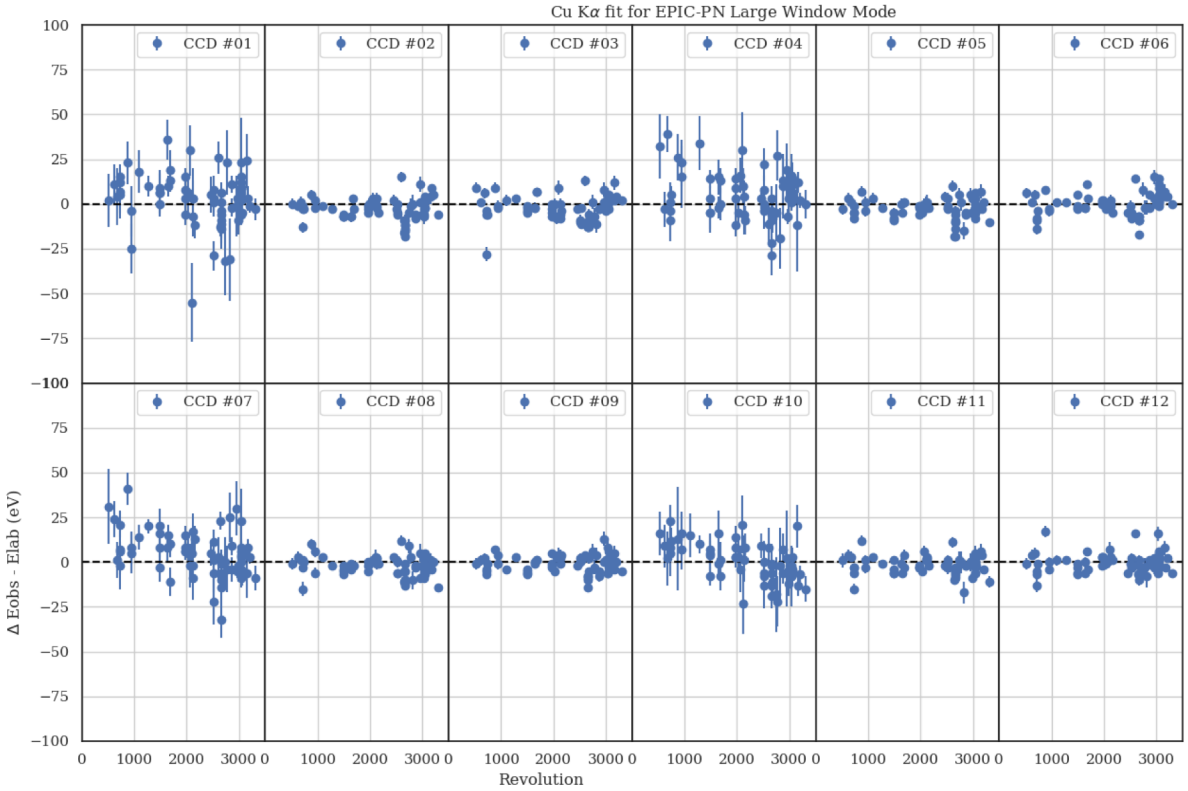
Cu Kα (8.04 keV)



PN LW

Deriving a correction with Cu Kα

Green dashed line: current extrapolated (constant) from 5.9 keV



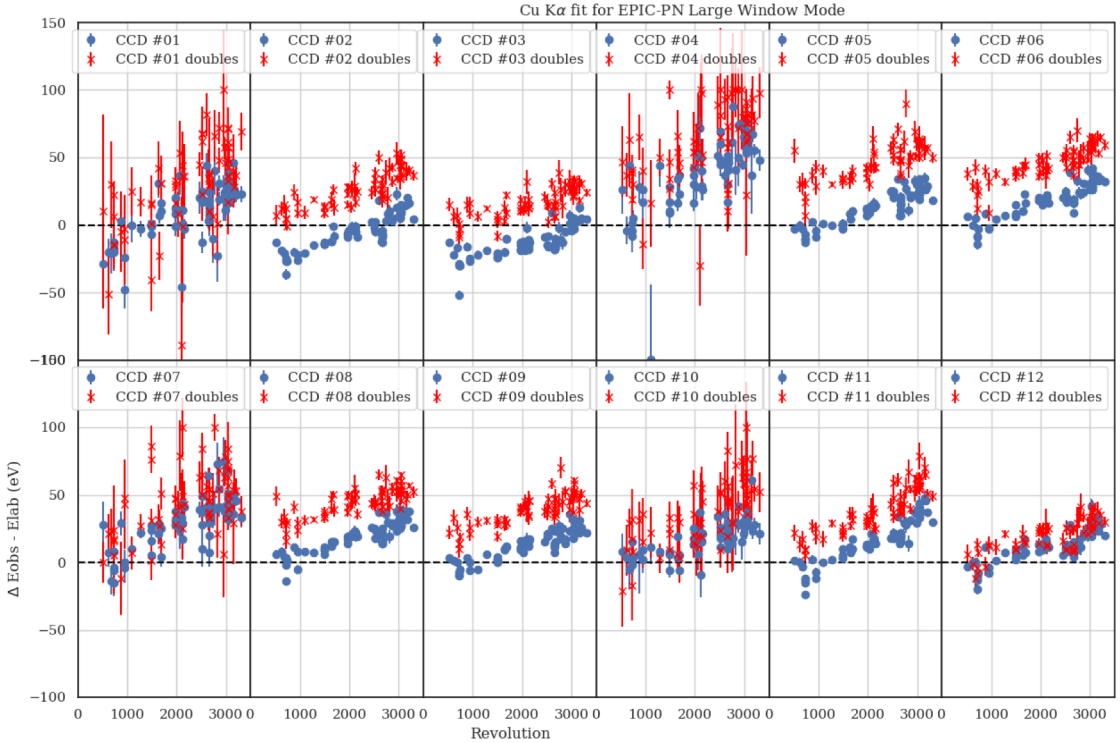
PN LW

Results at Cu Kα

Applying the correction

PN LW double events

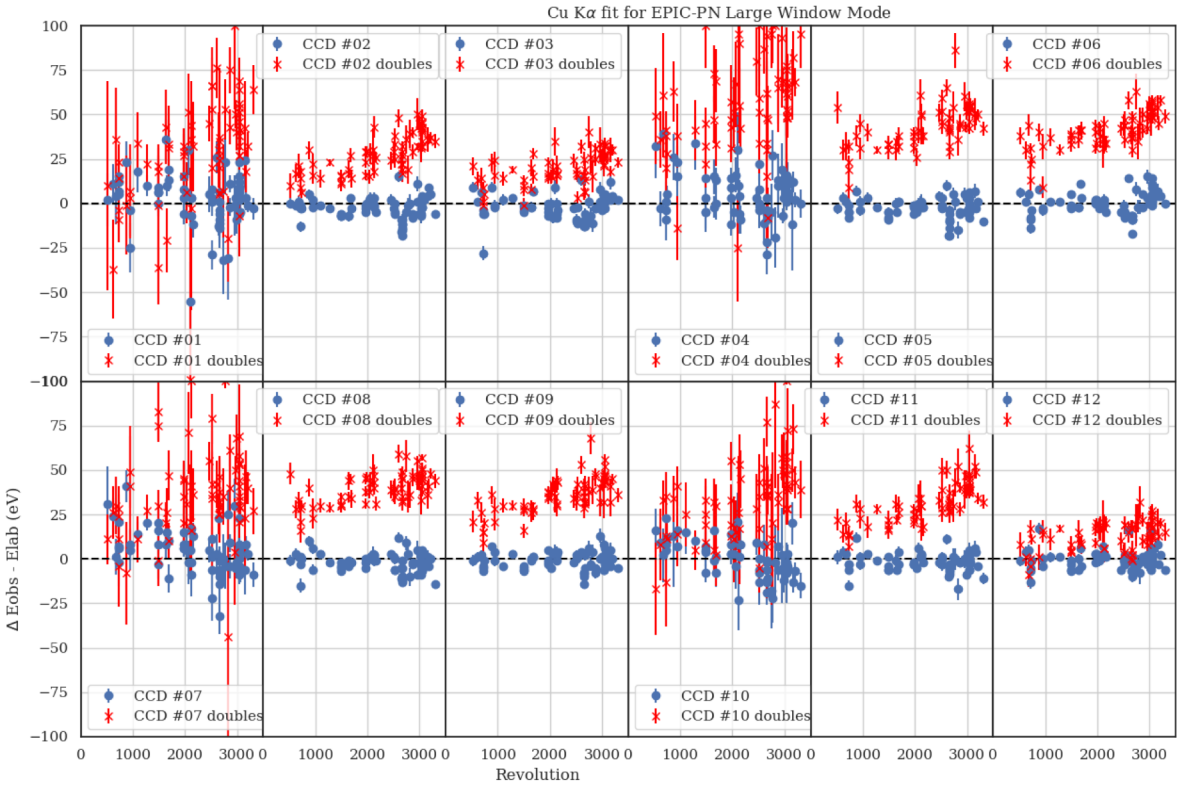
➔PATTERN in [1:4]



Double events

Using CCF v48

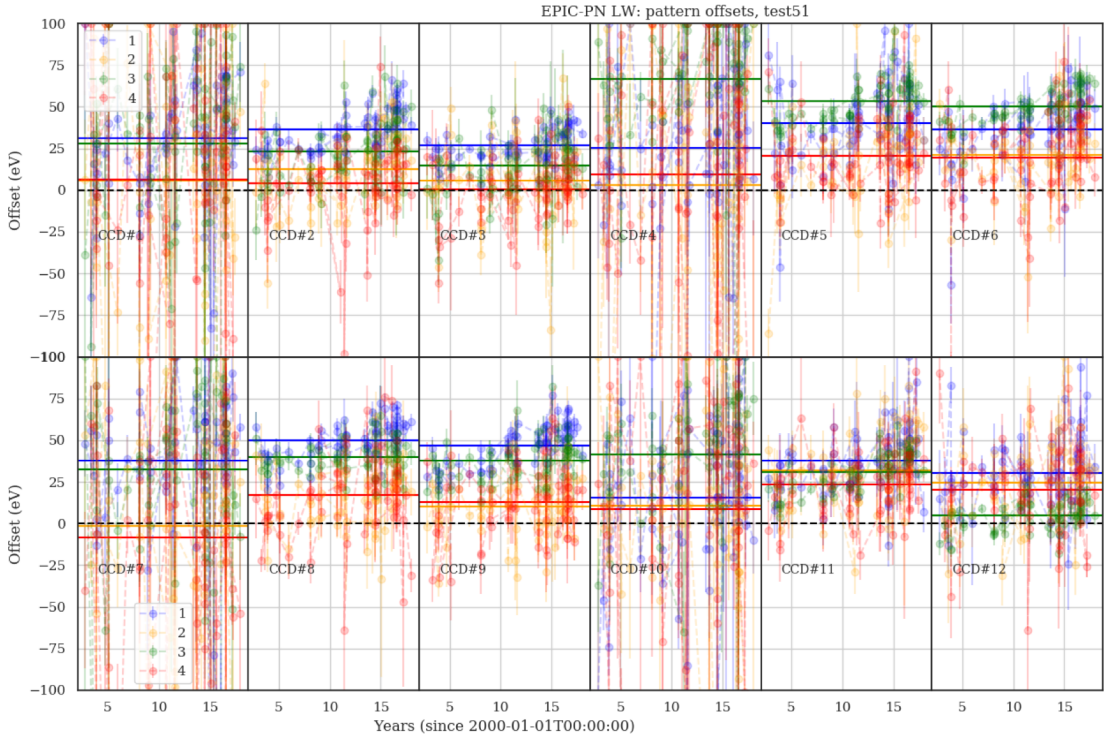
PATTERN in [1:4]



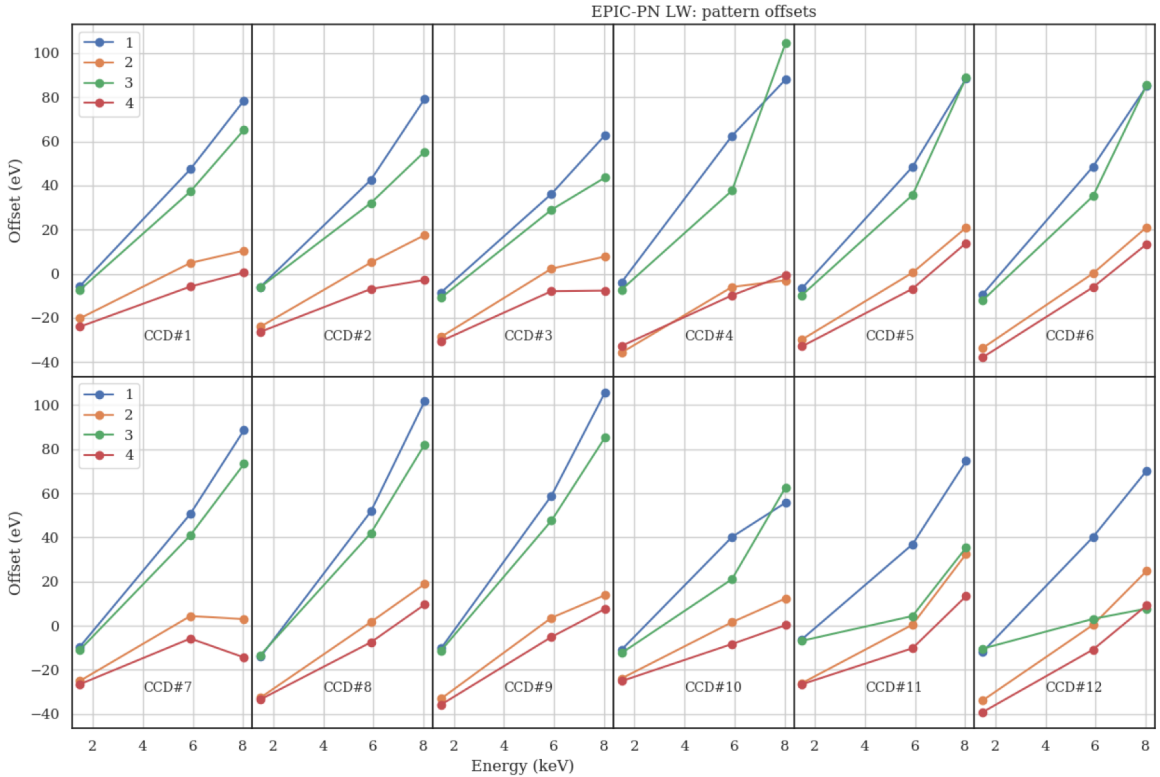
Double events

Using CCF v49 (new)

PATTERN in [1:4]

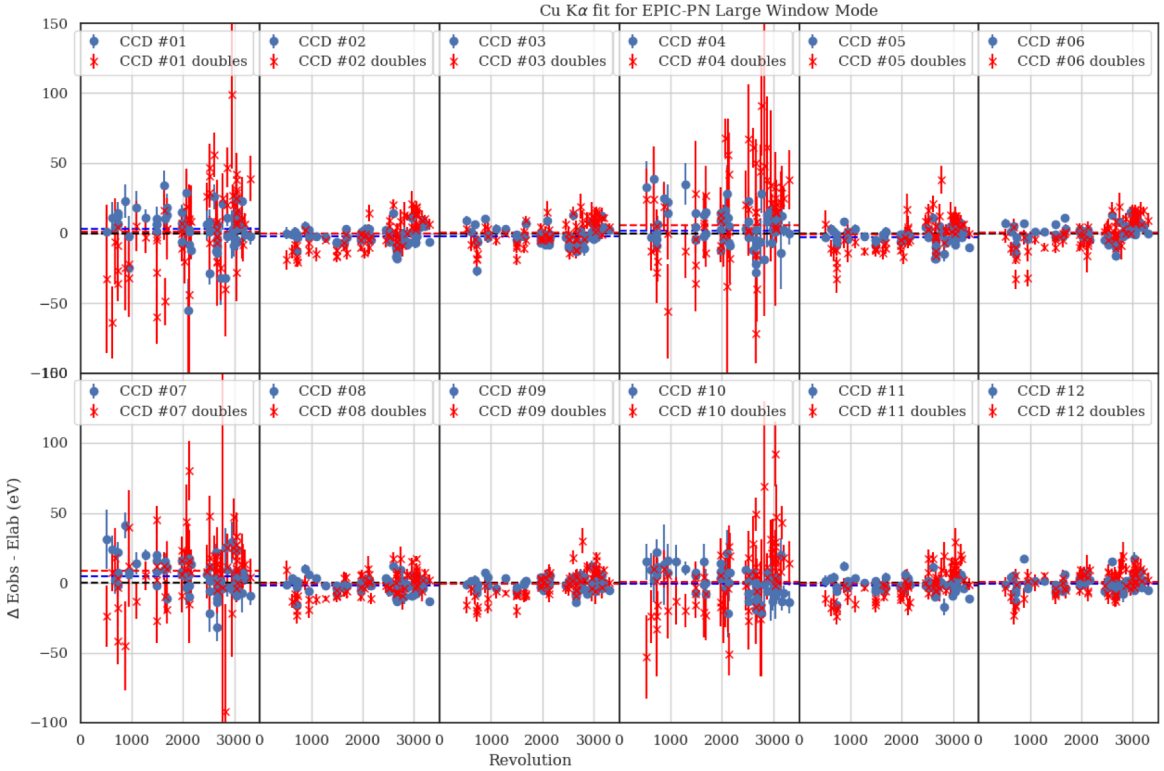


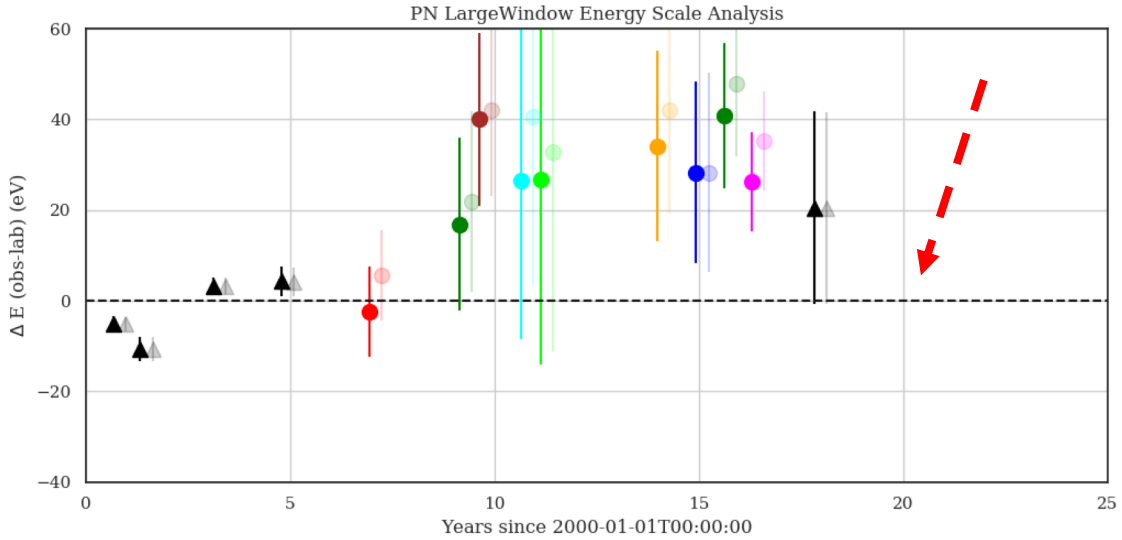
Horizontal lines are the mean values per pattern



Offset energy dependence

Incorporate the derived offsets in COMB_EVT_OFFSET at 8.04 keV


Cu Kα fit for EPIC-PN Large Window Mode
CCD #01
CCD #01 doubles
CCD #02
CCD #02 doubles
CCD #03
CCD #03 doubles
CCD #04
CCD #04 doubles
CCD #05
CCD #05 doubles
CCD #06
CCD #06 doubles
CCD #07
CCD #07 doubles
CCD #08
CCD #08 doubles
CCD #09
CCD #09 doubles
CCD #10
CCD #10 doubles
CCD #11
CCD #11 doubles
CCD #12
CCD #12 doubles
Δ Eobs - Elab (eV)
Revolution



Fe Kα sources:

The heavy symbols are the new LTCTI for PN LW
based on Cu Kα

Some small improvement but still a systematic ~ 30 eV offset.

More details

Two release notes:

XMM-CCF-0366:

EPIC-pn Energy Scale for Small Window Mode: long-term CTI and pattern corrections

XMM-CCF-0367:

EPIC-pn Energy Scale for Large Window Mode: long-term CTI and pattern corrections

Conclusions

In current `/ccf/pub EPN_CTI_0049` and `0050` CCFs:

PN Small Window mode: new long-term CTI at 5.9 and 6.4 keV derived and implemented. Based on CalClosed and AGNs.

PN Large Window mode: new long-term CTI derived and implemented at 8.04 keV, based on Cu Kα line.

Offsets for patterns 1 to 4 at 8.04 keV derived and implemented.

PN Large Window mode: not enough observations to allow update to the long-term CTI at 5.9 and to add 6.4 keV energy point
(work in progress).

Future improvements

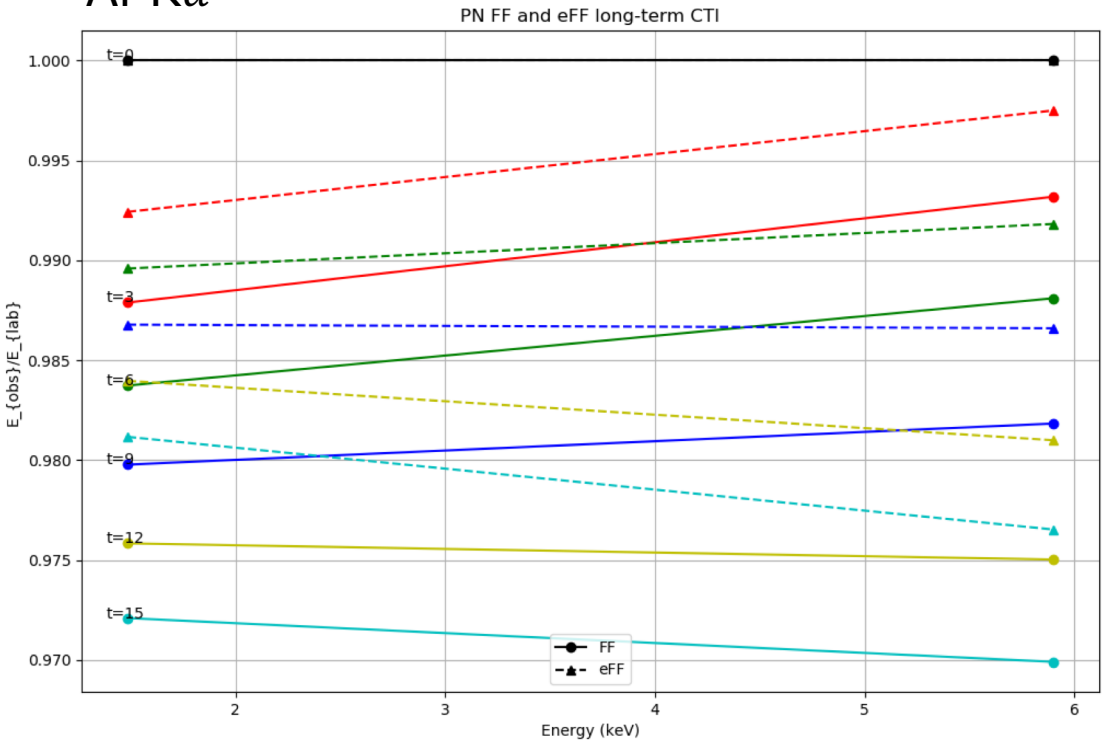
Update the long-term CTI for both SW and LW modes with new observations ➔ currently extrapolation from t=15 to t=25.

Improve the correction at 6 keV for PN LW

Better understanding of the long-term CTI correction behaviour as function of energy

Al Kα

Mn Kα

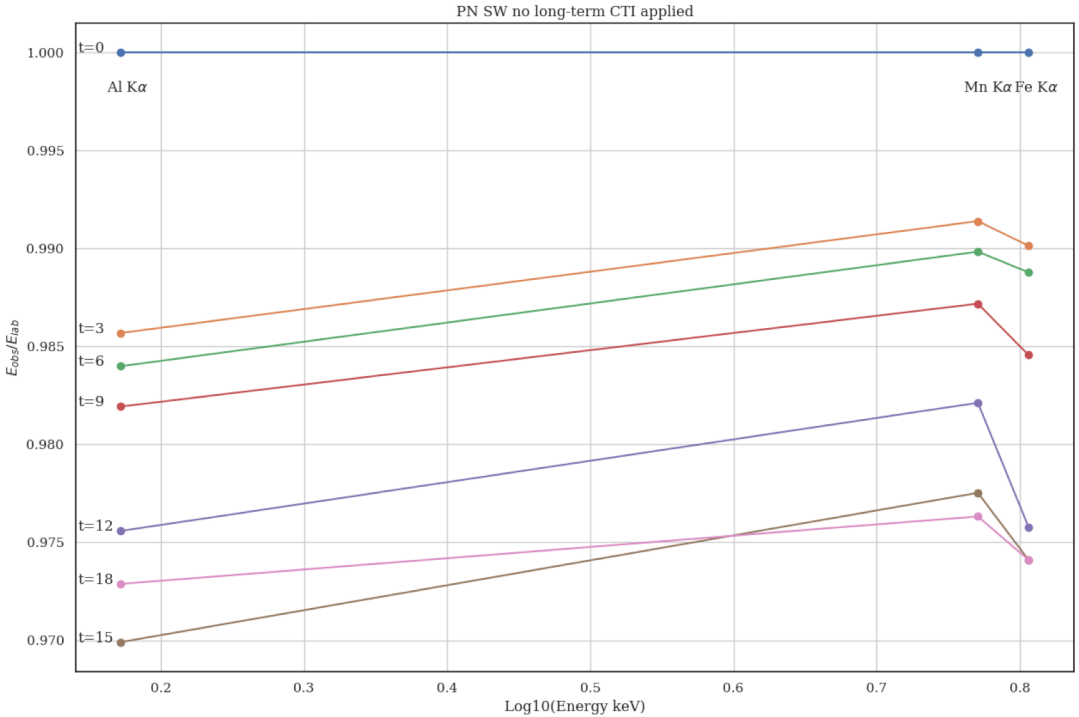


LTCTI energy dependence

FullFrame and extendedFF

PN Small Window Mode

Q



RAWY = 190 for all figures

Fe Ka and Mn Ka are measured

Al Ka (1.486 keV) points come from PN Full Frame

The long-term CTI correction:

Each photon energy is corrected with these curves (in epevents):

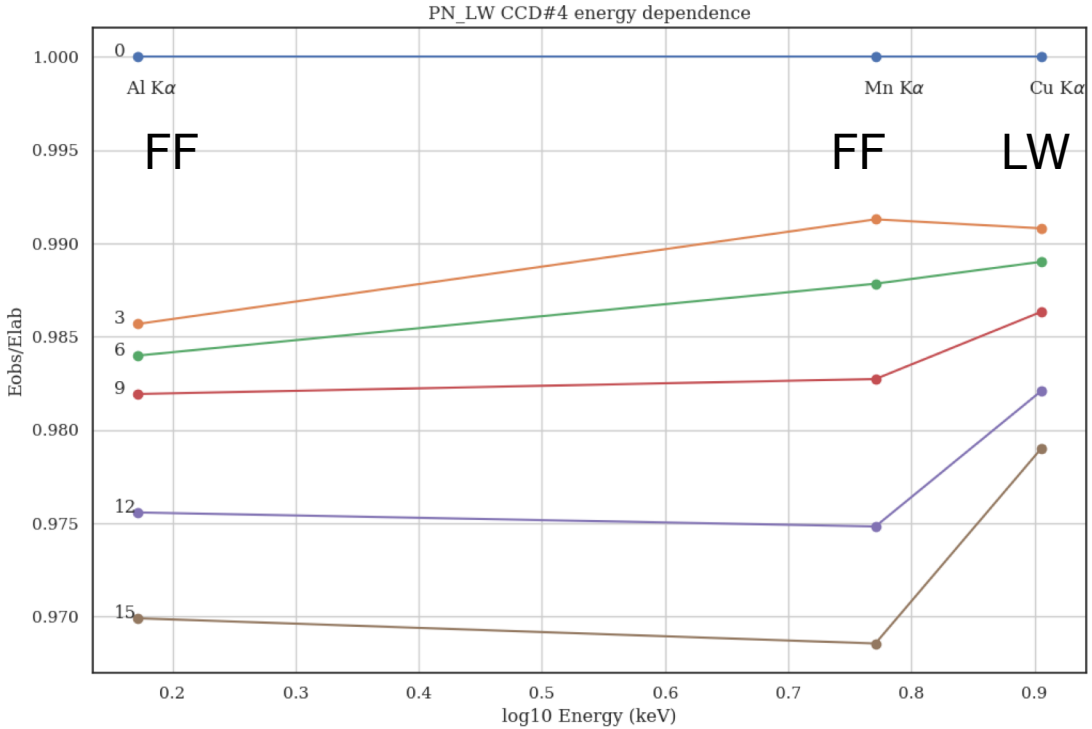
$E_{corr} = E_{obs}/Q$

Where

$Q = E_{obs}/E_{lab}(t,E,RAWY)$

Is the empirical curve.

PN Large Window Mode, CCD#4 boresight



Q

Al Ka and Mn Ka are from PN Full Frame

(not enough CalClosed PN LW observations)

Only Cu Ka line is measured

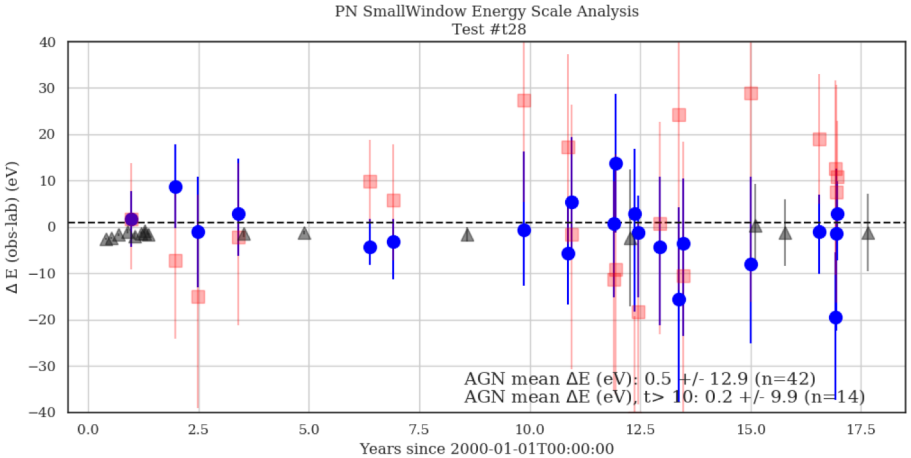
The end

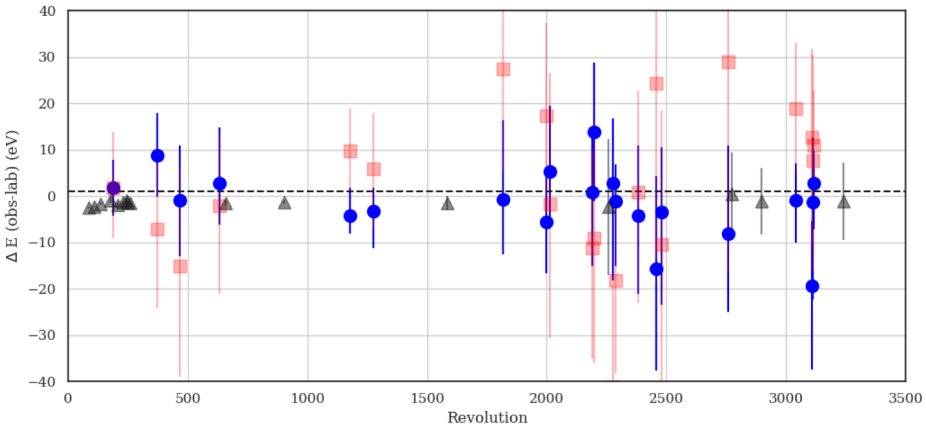
PN Small Window mode: pattern analysis

Notes:
CalClosed events selection is with **pattern** == 0 and **pat_seq** == 0 and **flag** == 0

AGNs selection: **pattern** <= 4 and **flag** == 0

Not enough statistics to split the analysis per pattern.



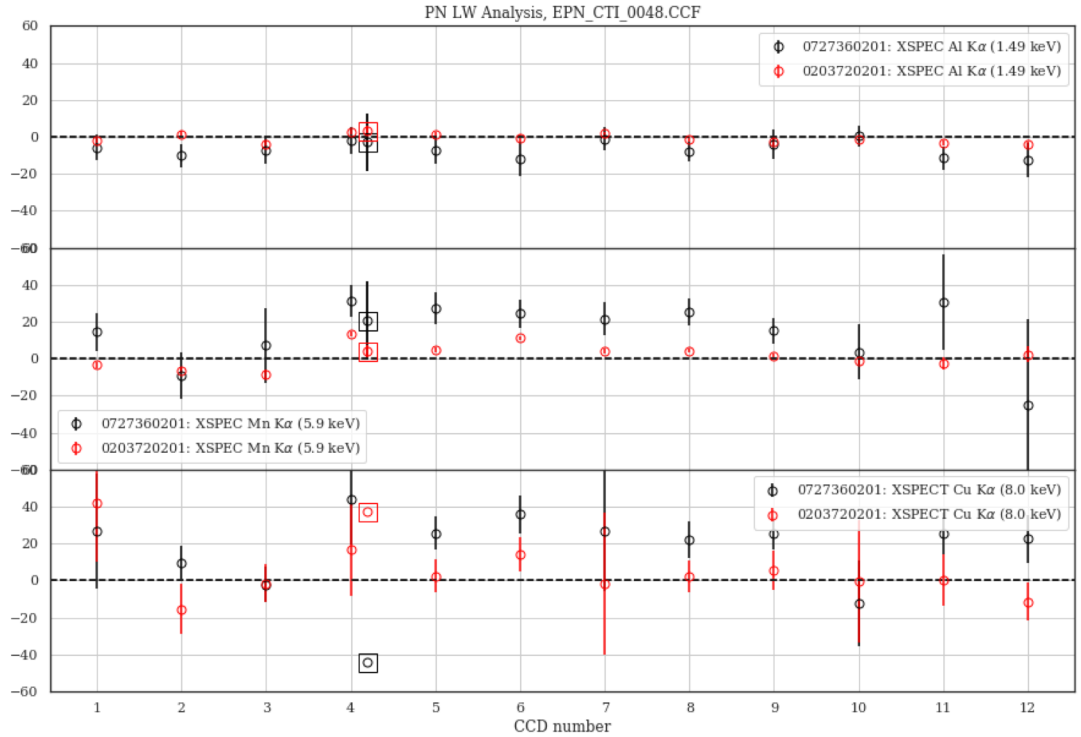


AGNs results:

Blue: pattern == 0
Red: pattern in [1,4]

No change for the energy offset per pattern for this mode (MODE_ID==3)

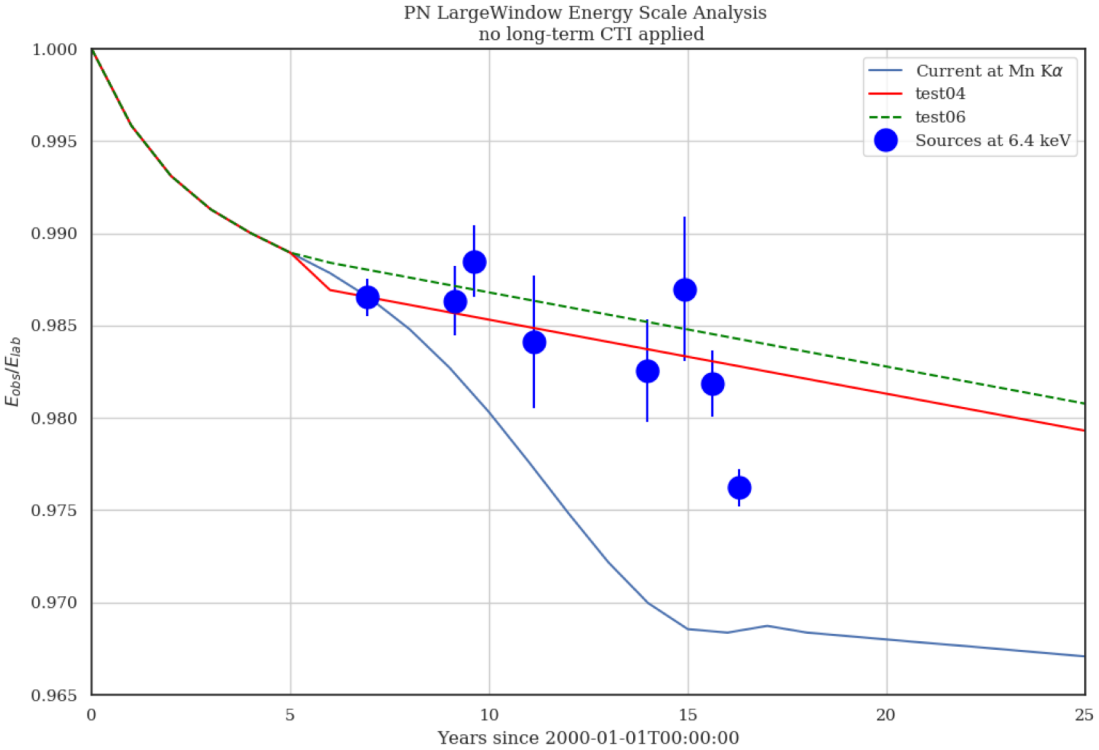
CALCLOSED analysis per CCD



Only two epochs

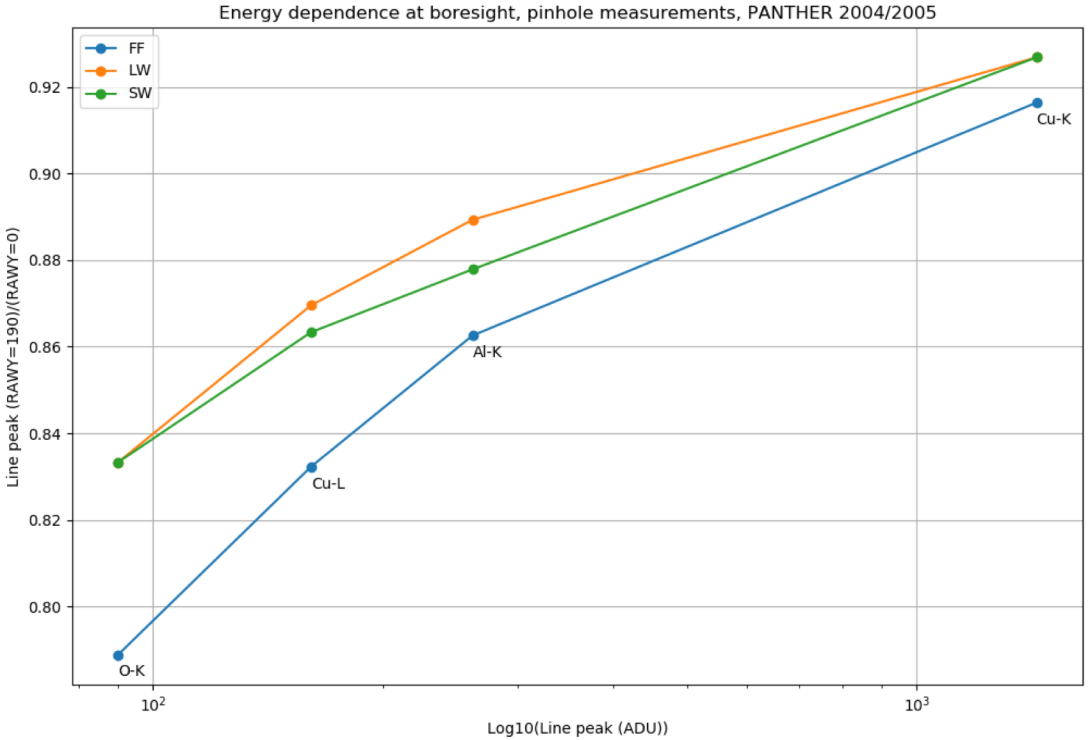
Three lines investigated:

Top: Al Kα at 1.49 keV
Middle: Mn Kα at 5.9 keV
Bottom: Cu Kα at 8 keV



Work in progress:

Deriving a correction curve at 6.4 keV


Energy dependence at boresight, pinhole measurements, PANTHER 2004/2005
FF
LW
SW
Line peak (RAWY=190)/(RAWY=0)
0.92
0.90
0.88
0.86
0.84
0.82
0.80
Cu-K
Al-K
Cu-L
O-K
10^2
10^3
Log10(Line peak (ADU))