Line spectroscopy of ^{26}Al source regions

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spectral features of the ^{26}Al 1809 keV line

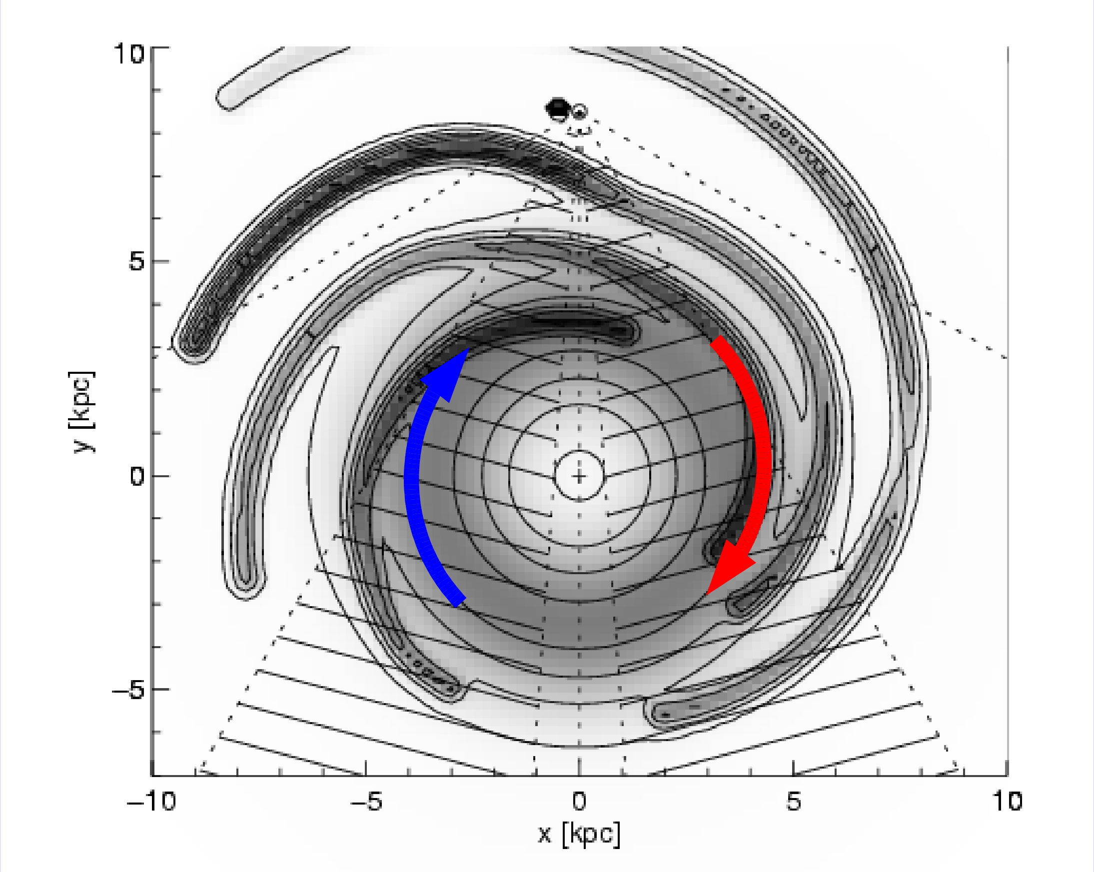
intrinsic line shape of the SPI Ge detectors

effect of detector degradation

Model: ^{26}Al in the Galaxy

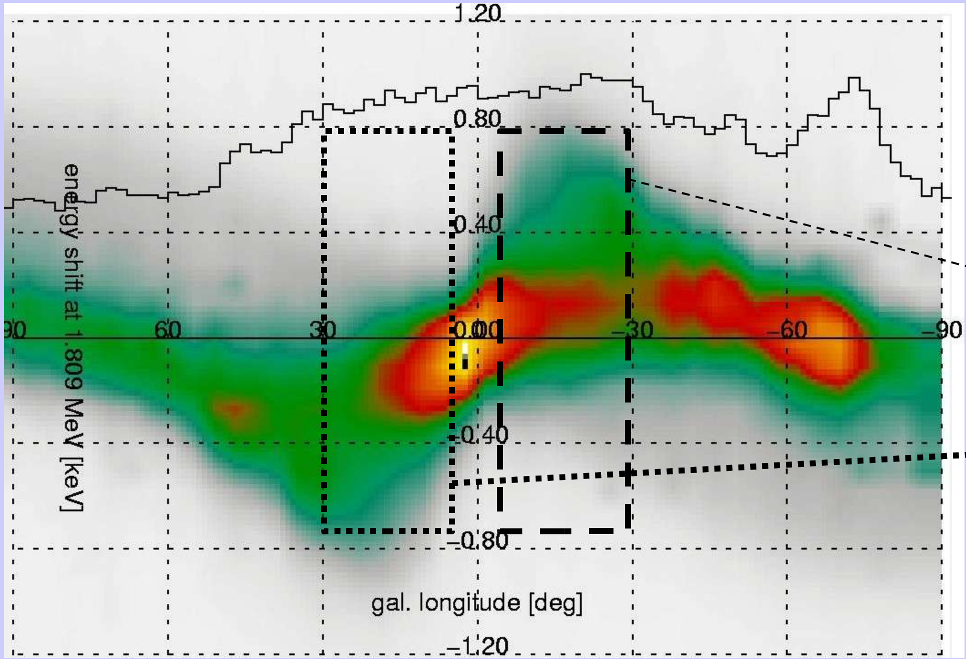
Components:

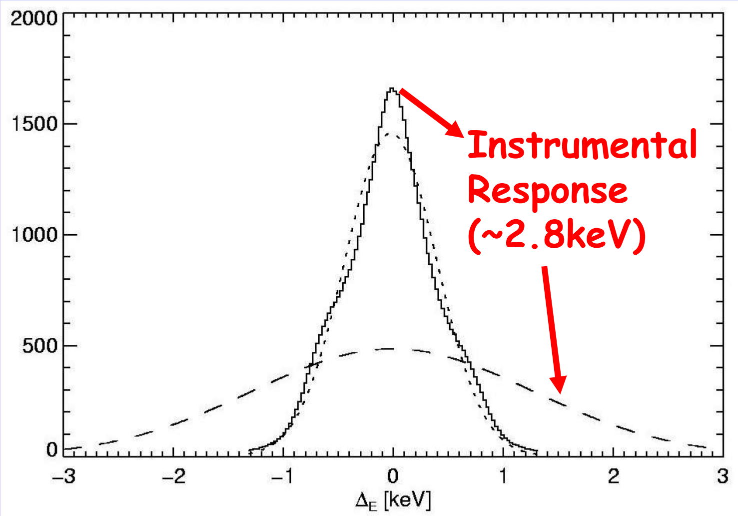
- source density: ~ free e^- density
- source characteristics: SNR expansion
- source motion: galactic rotation

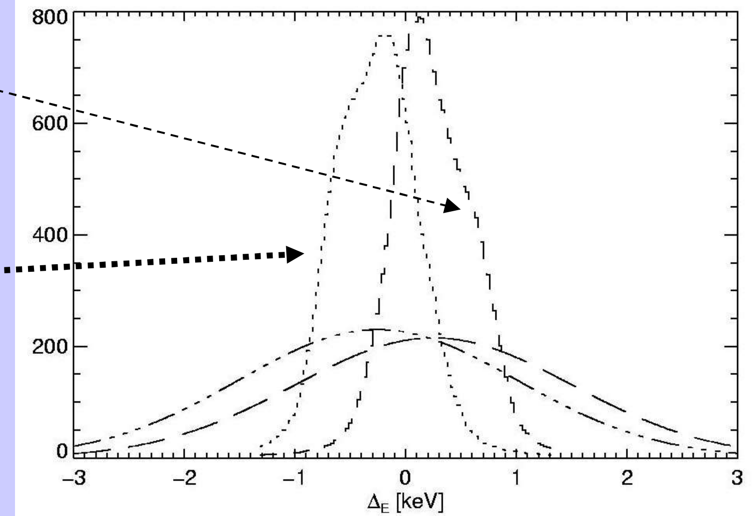


Model: line shape in the inner Gal.

- integrating over the sky toward the inner Galaxy
- east-west position shift: ± 0.25 keV
  (-30° < l < 0°, 0° < l < 30 °)

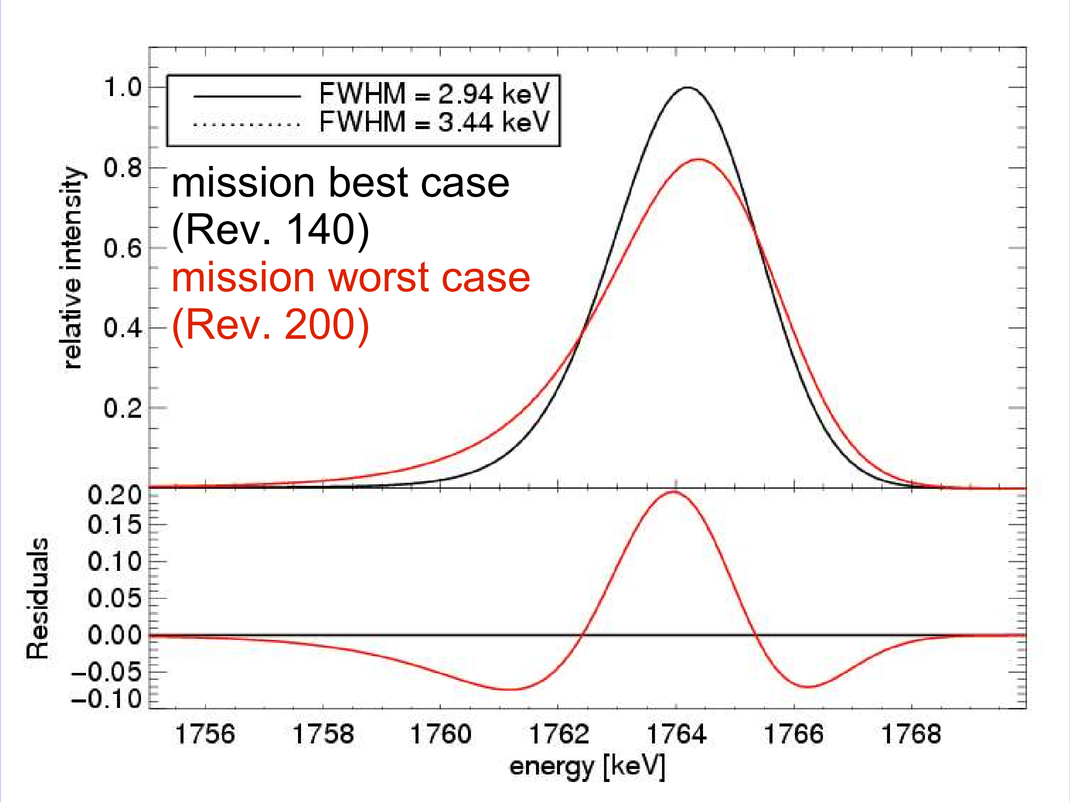




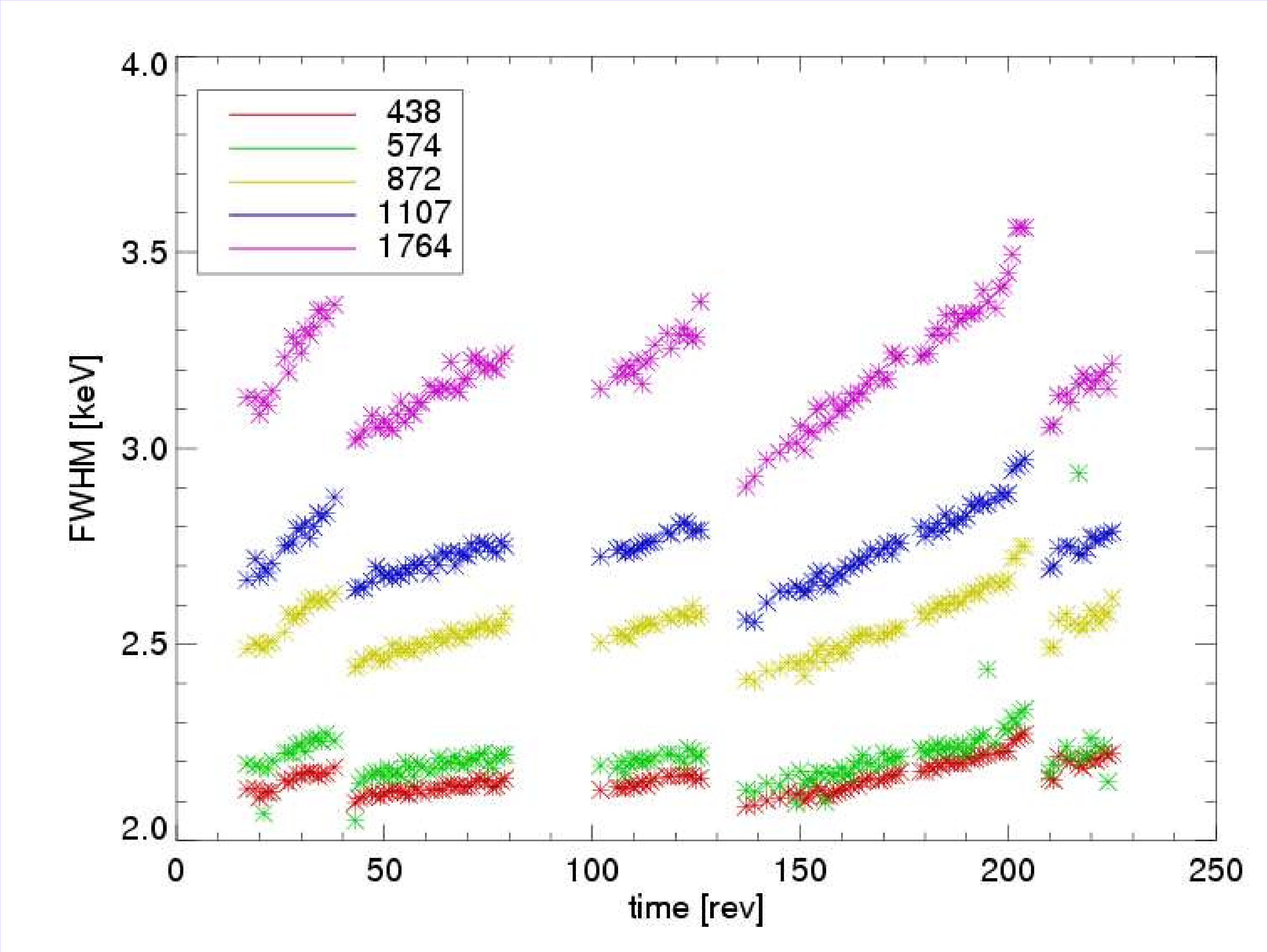


Detector line response model

- **Function used:**
  - Gaussian convolved with truncated exponential
  - 2 parameters:
    - FWHM of Gaussian
    - e-folding energy interval of exponential
  - error function-shaped step
- **Assumptions:**
  - The detector has a gaussian response in its pristine state.
  - This response is dis-torted due to degra-dation effects.
  - The shape of the gaussian remains constant over time, only the degradation component varies.2

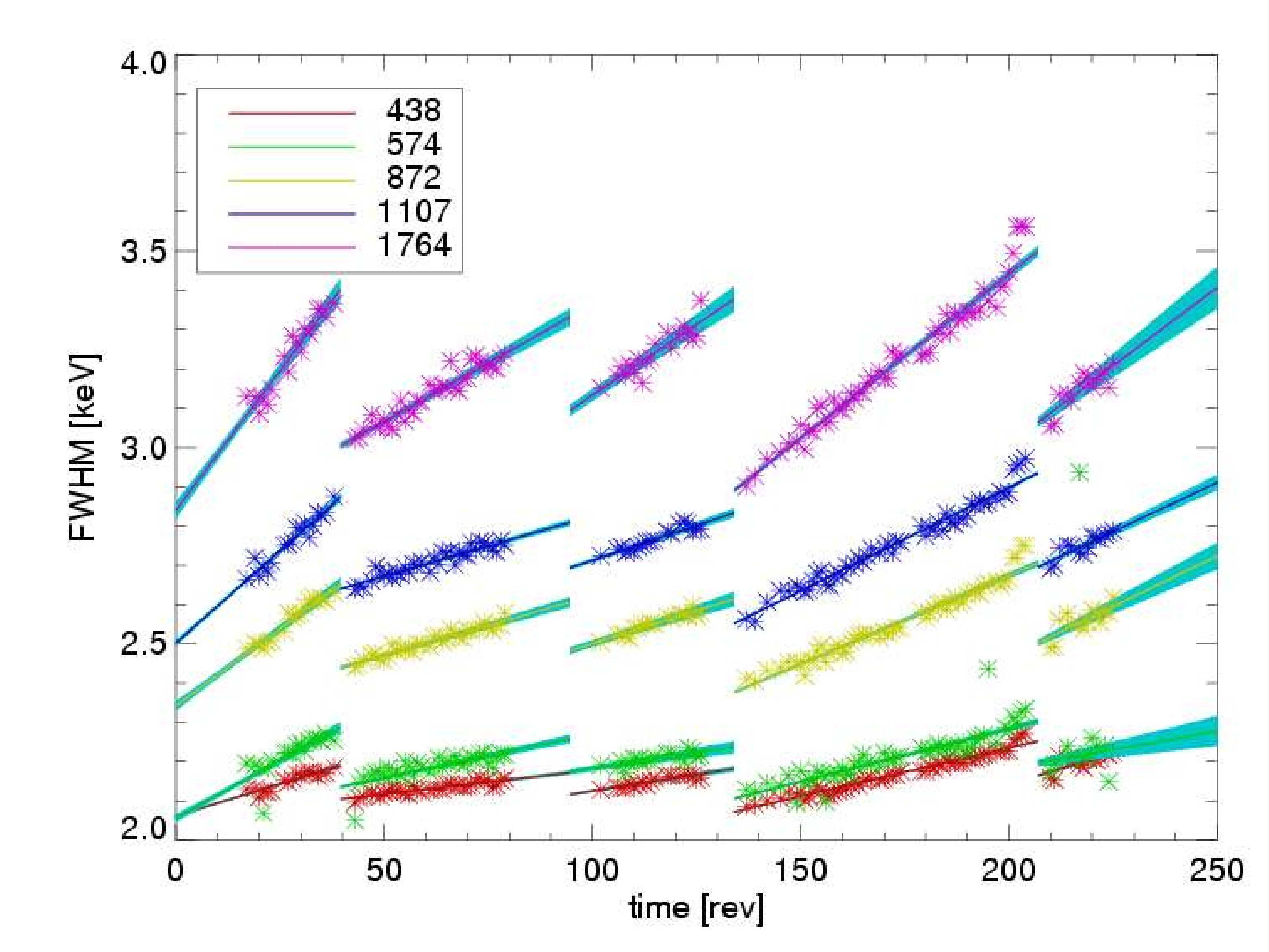


FWHM as *f(t, E)*



4.0
3.5
3.0
2.5
2.0
0
50
100
150
200
250
FWHM [keV]
time [rev]
438
574
872
1107
1764

FWHM as *f(t, E)*



438
574
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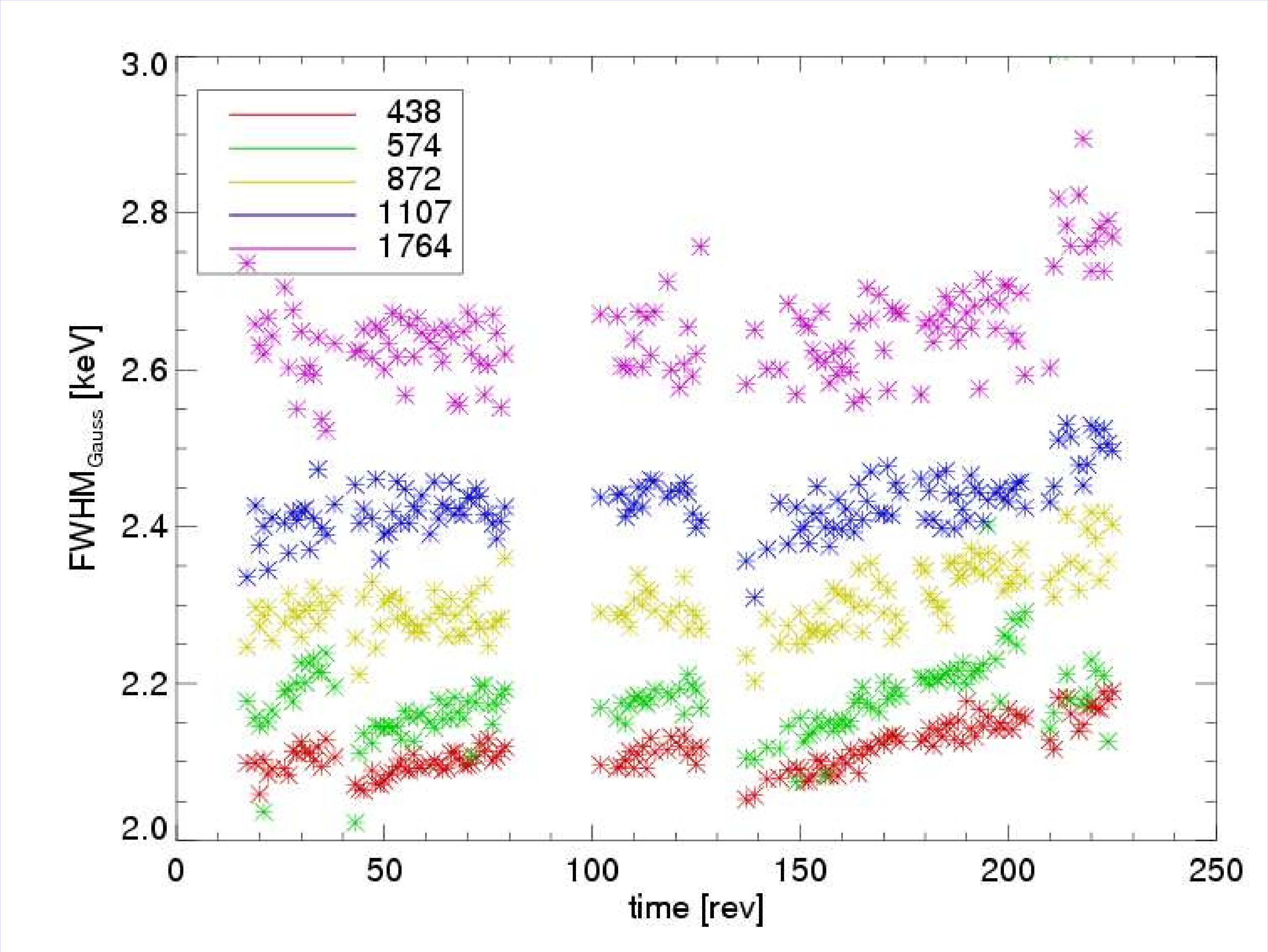
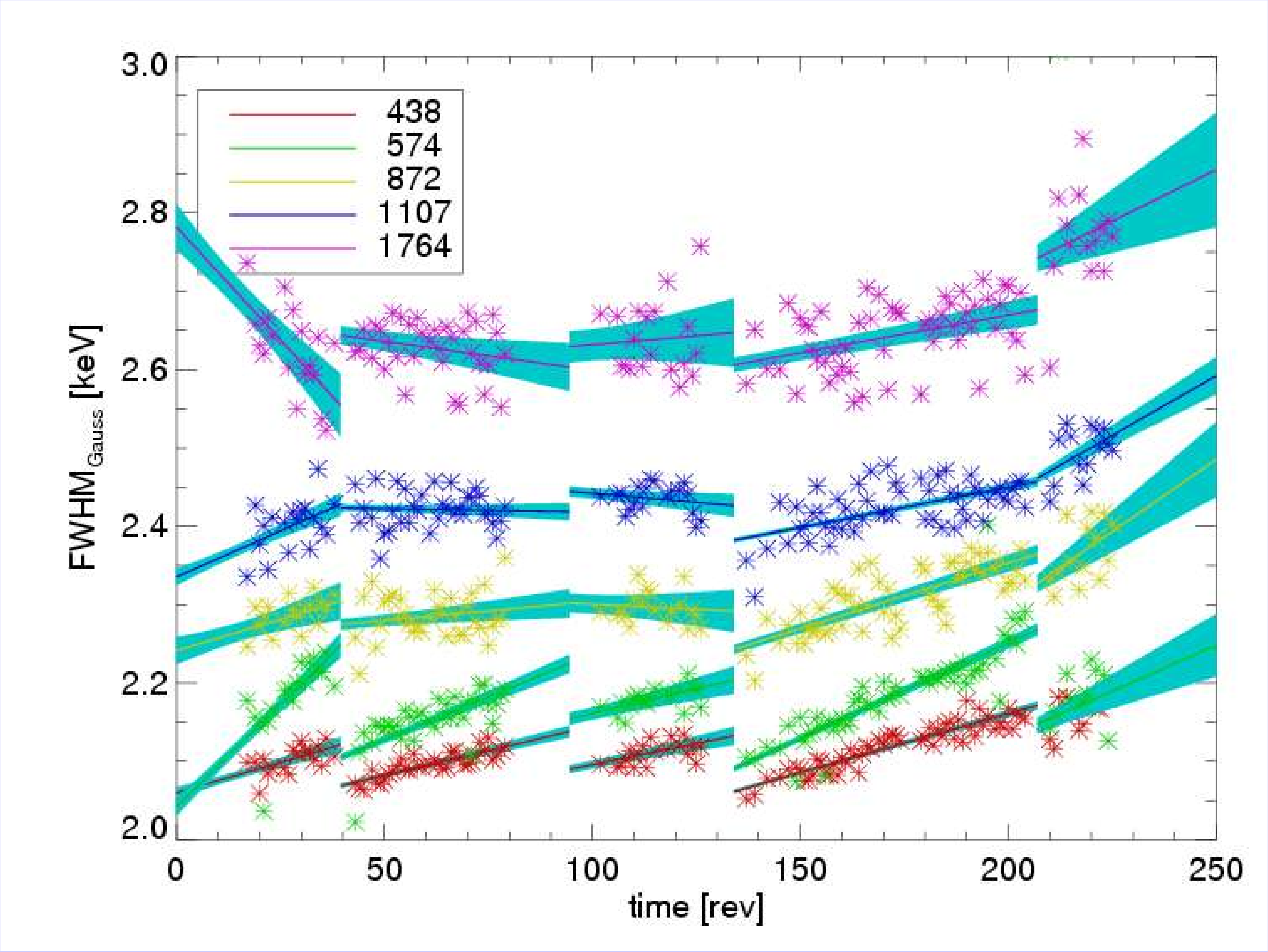
4.0
3.5
3.0
2.5
2.0
FWHM [keV]
0
50
100
150
200
250
time [rev]

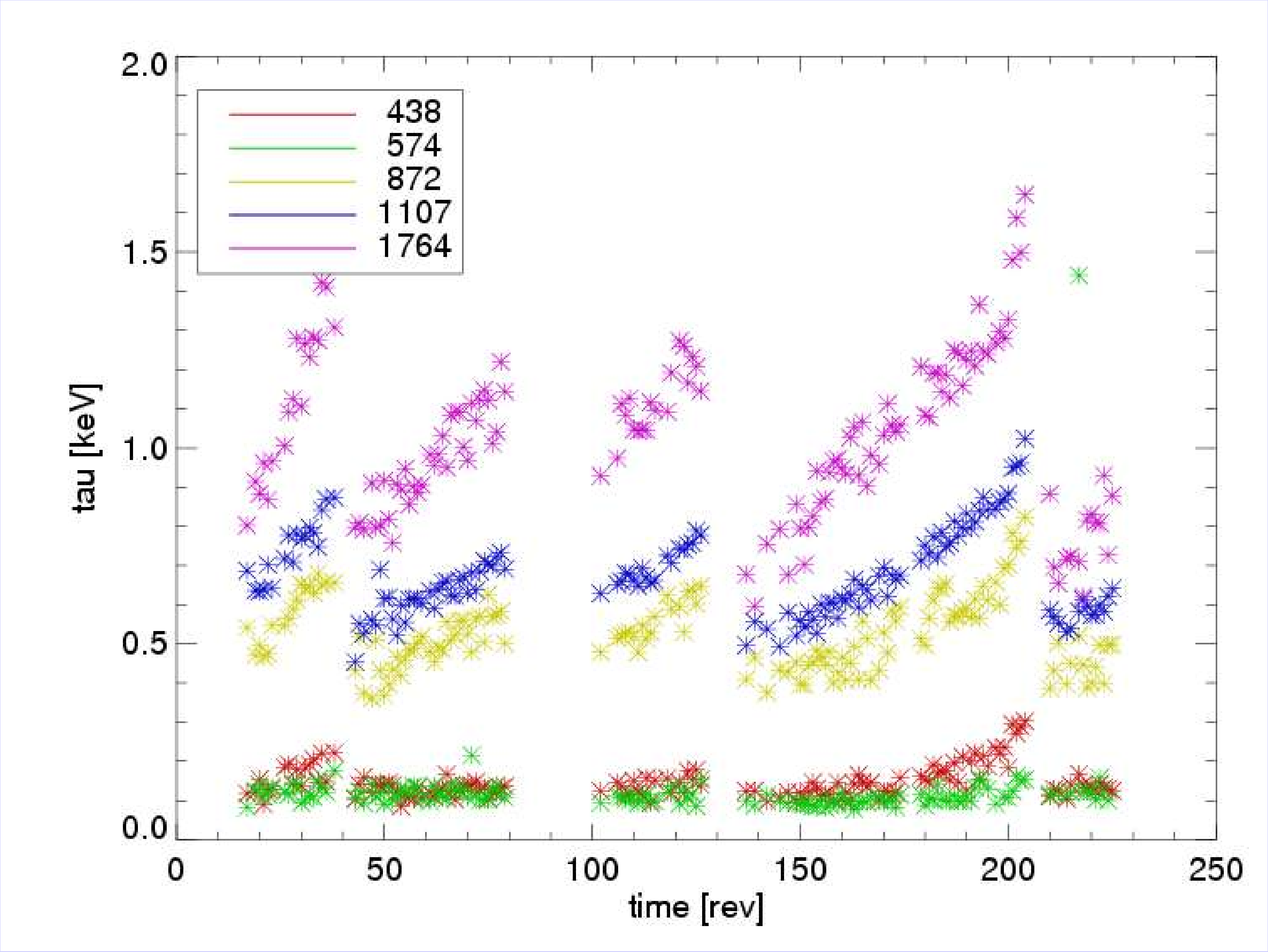
FWHM of Gaussian as *f(t, E)*



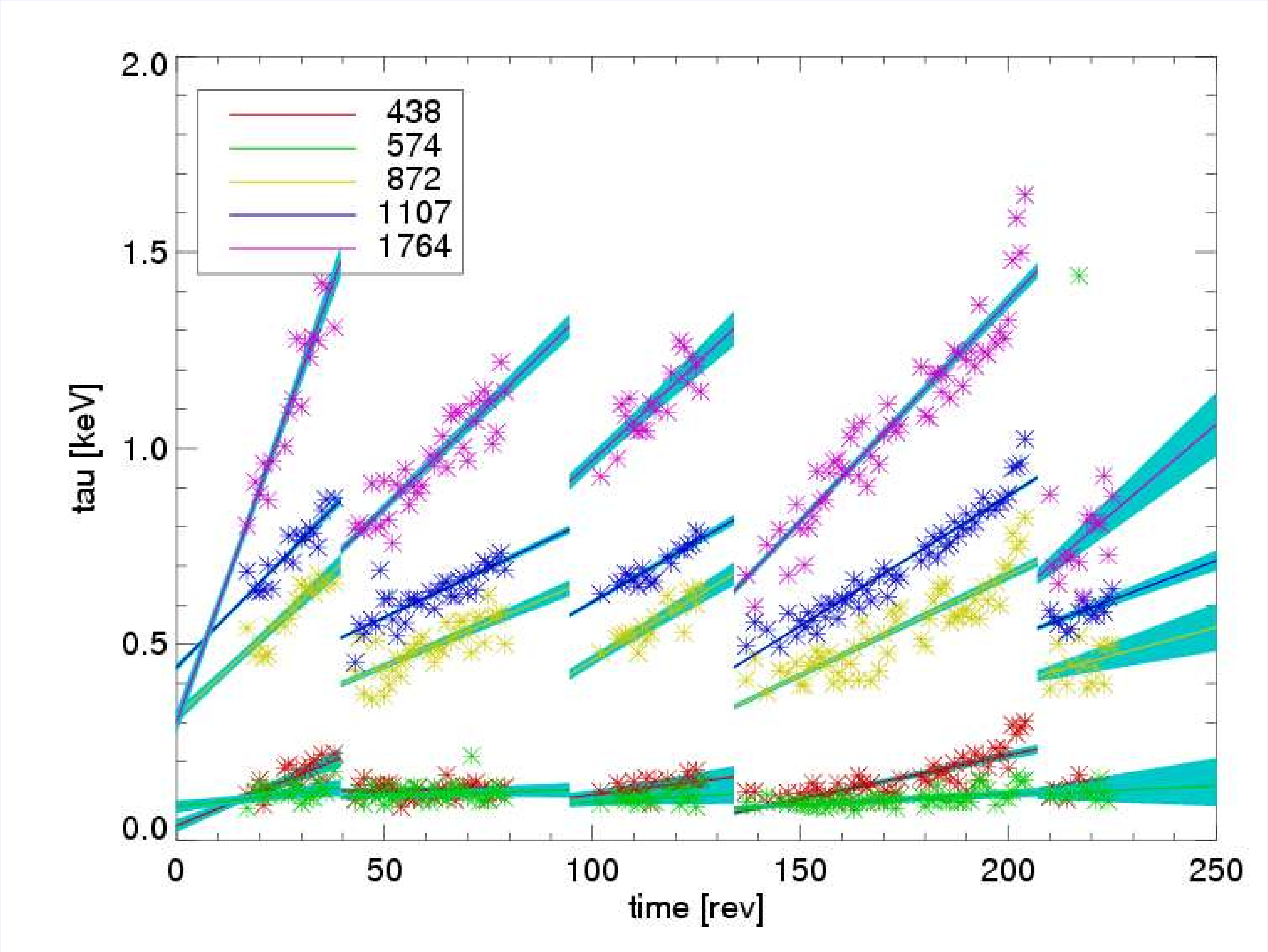
FWHM of Gaussian as *f(t, E)*



scale of exponential as *f(t, E)*



scale of exponential as *f(t, E)*



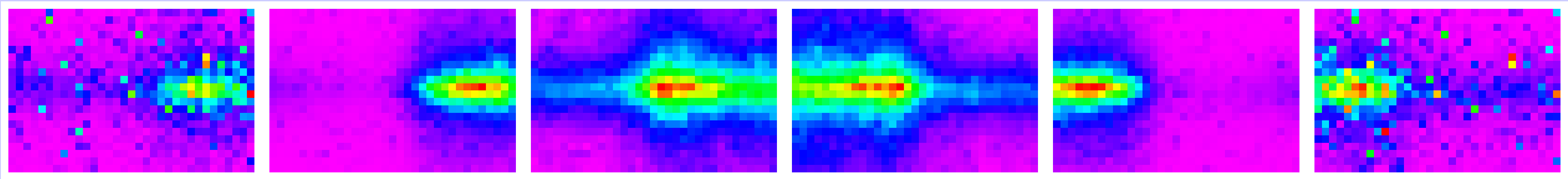
application

- **Achievable line position accuracy:**

Uncertainty (10^{-5} ph s^{-1} keV^{-1})	Position accuracy (keV)
2.5	0.19
1.5	0.11
0.77	0.06

- **comparing two target regions, e.g. GC and -30°:**
  2x 3 Ms of exposure => 0.09 keV uncertainty in peak pos. difference
  => 0.25 keV difference at 2.8 σ

- **Improvements:** make use of knowledge of morphology of emission as a function of energy from models.



END

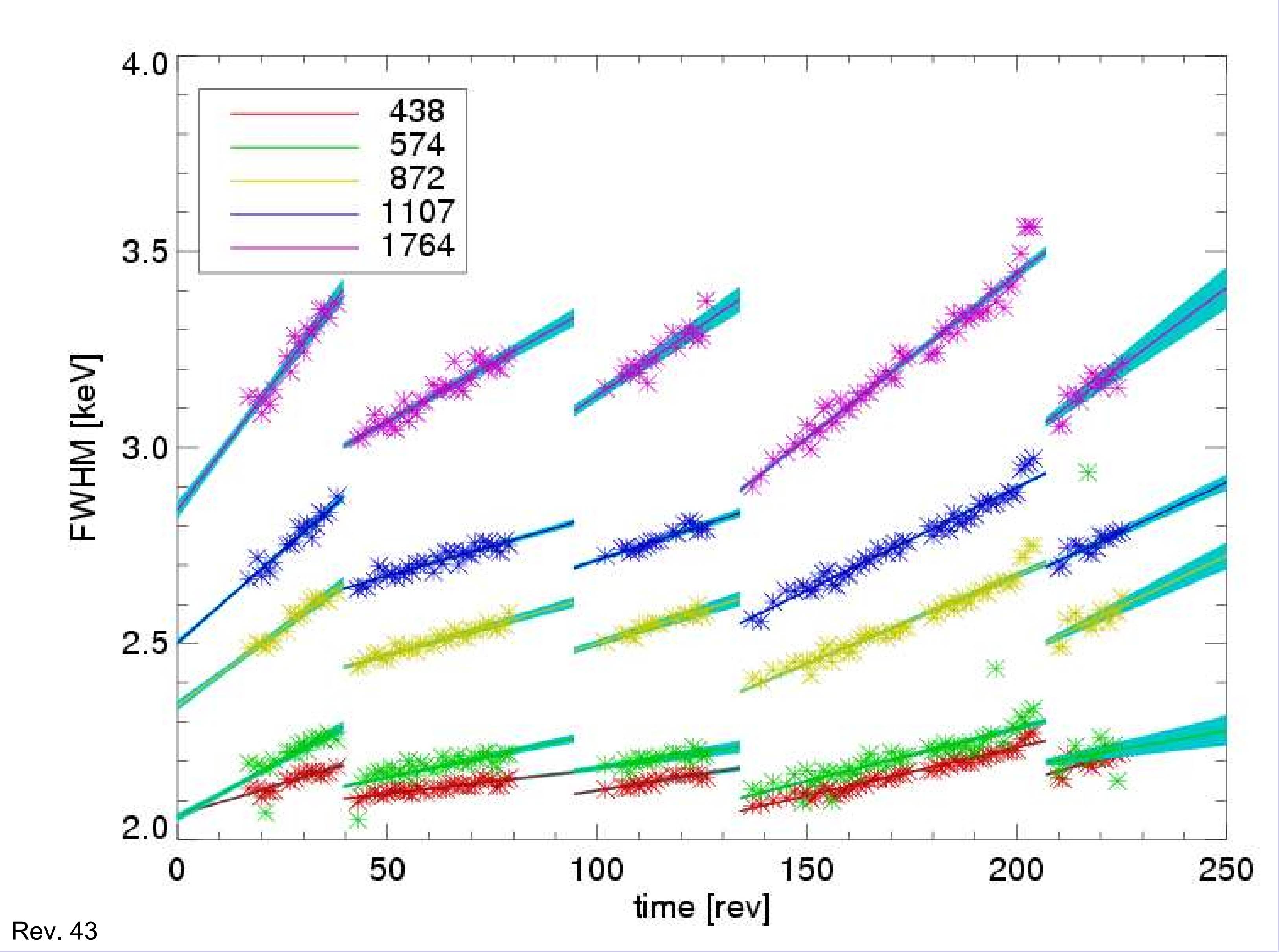
Model function

- Det 0, 600 ks:
- 0: 695.958 11.0738 0.0159116
- 5: 1940.69 280.802 0.144691
- 7: 968.138 273.559 0.282562
- Det 0, 75 ks:
- 0: 94.8501 3.65273 0.0385106
- 5: 247.740 108.266 0.437015
- 7: 139.998 94.8083 0.677211
-

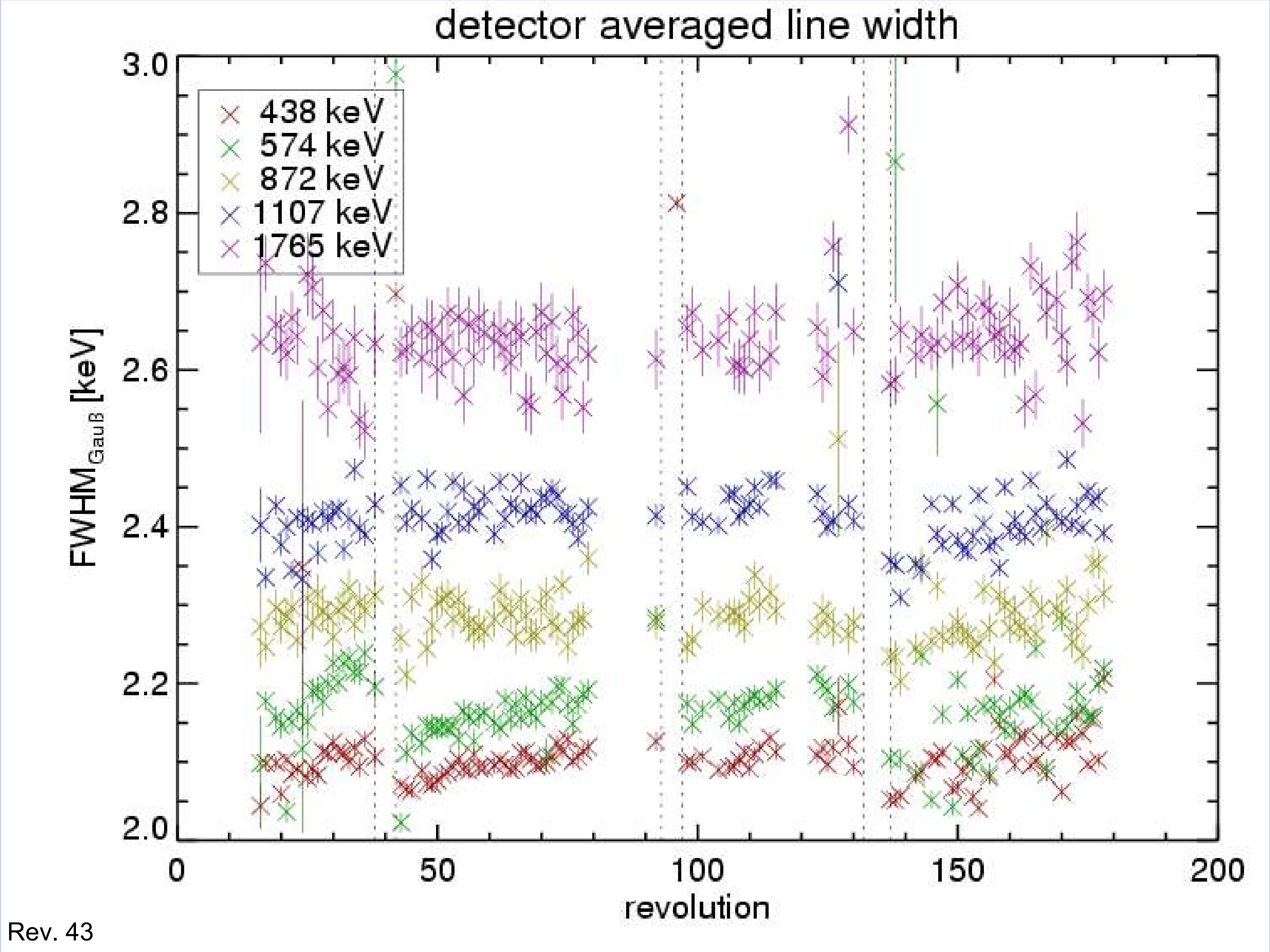
Fit method

- Line shape is assumed constant for an energy interval
  - 5 parameters per region:
    - 2 for continuum (level and slope),
    - 3 for shape (width of Gaussian and exponential, size of the step)
  - + 2 parameters per line (count rate, energy)
- Use conventional gradient-expansion algorithm (IDL CURVEFIT function) to find start values
- Use Bayesian MCMC method to find best fit under constraints (positivity, scale invariance, …) specified in form of a prior.
- Standard deviation of MCMC sample gives uncertainty of fit parameters.
- A sample of derived values (e.g. FWHM of the line) can be obtained after the MCMC sampling, automatically taking care of correlations between parameters.

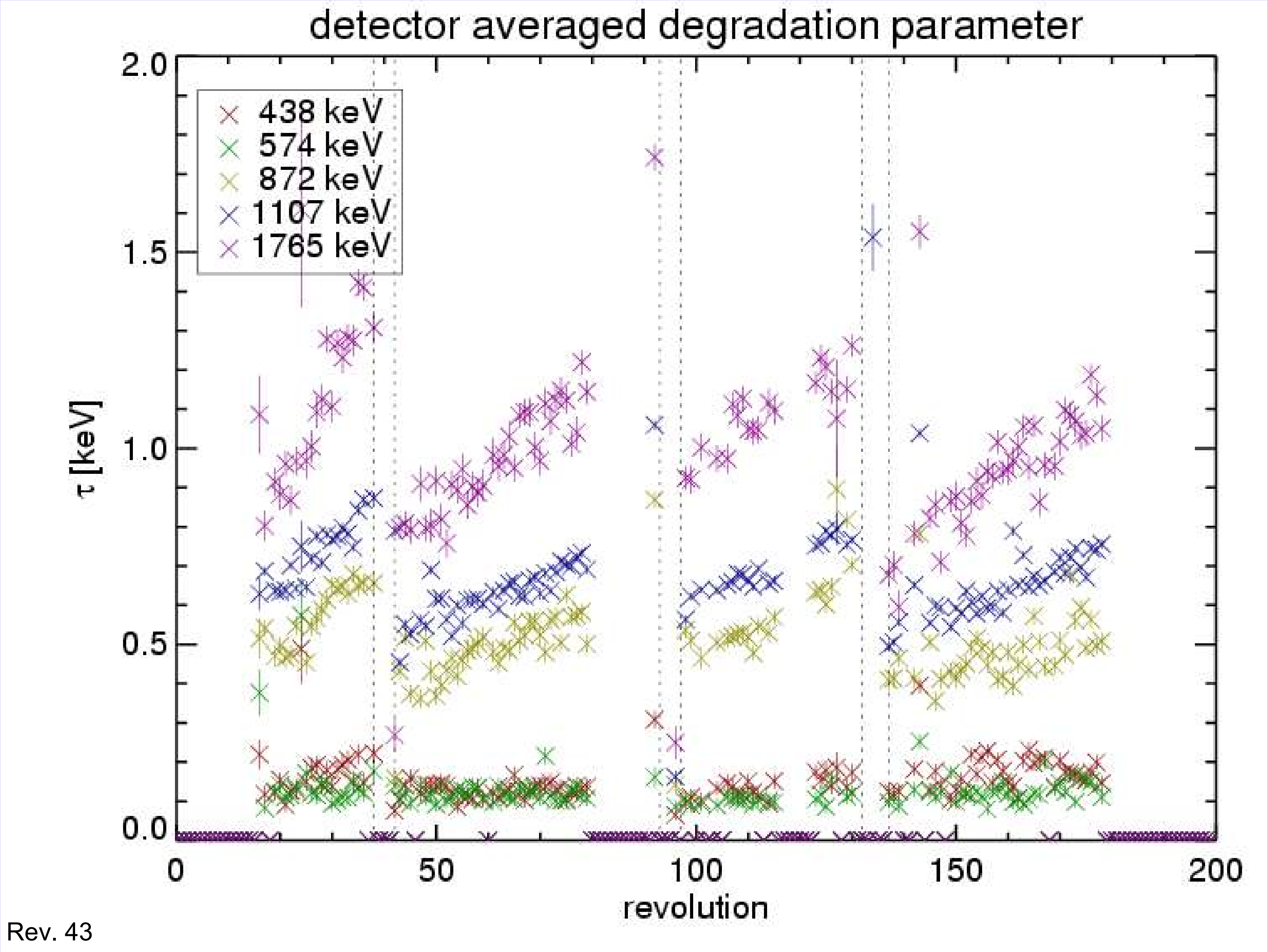
FWHM as a function of (E, t)



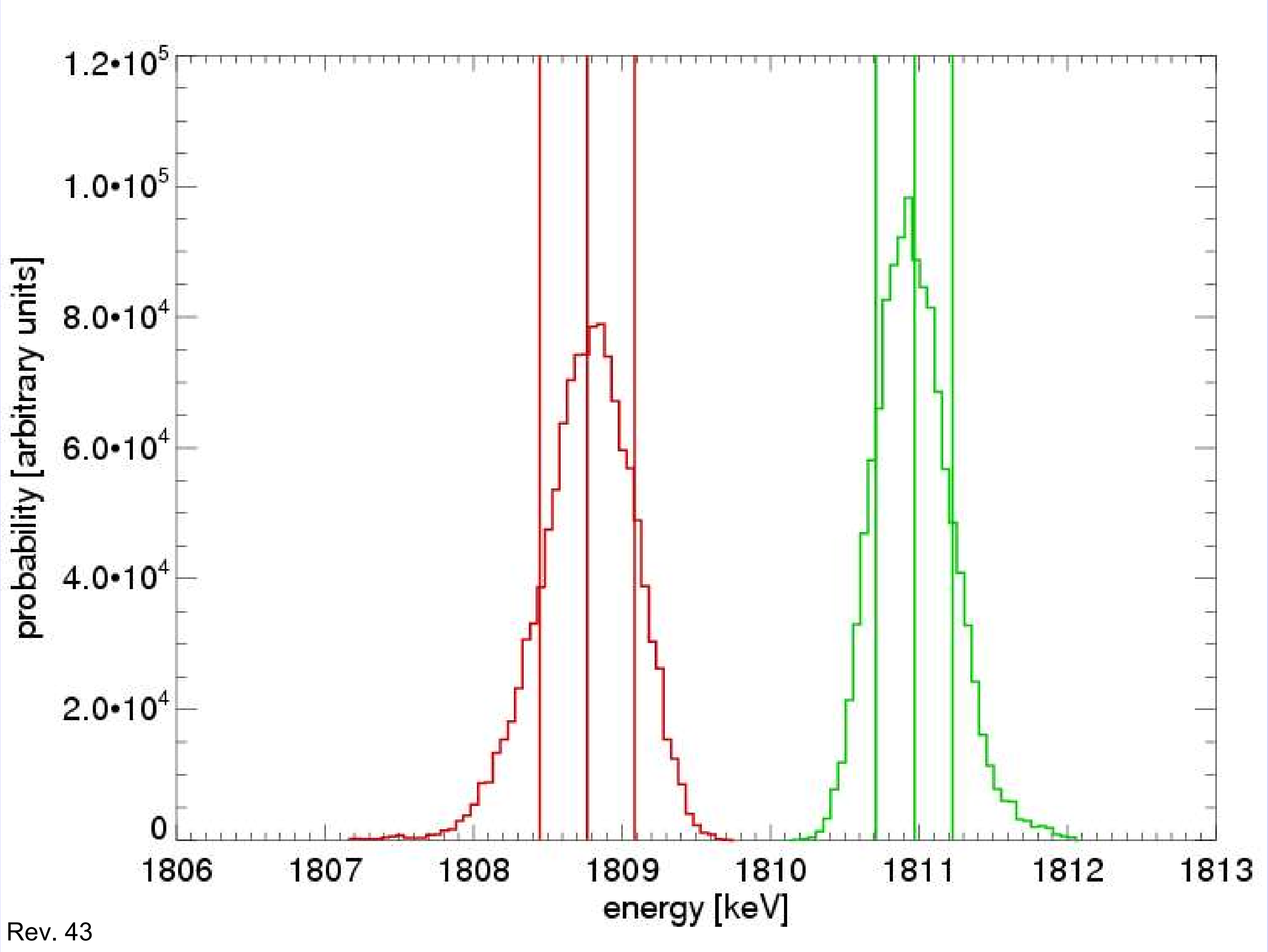
FWHM of Gaussian



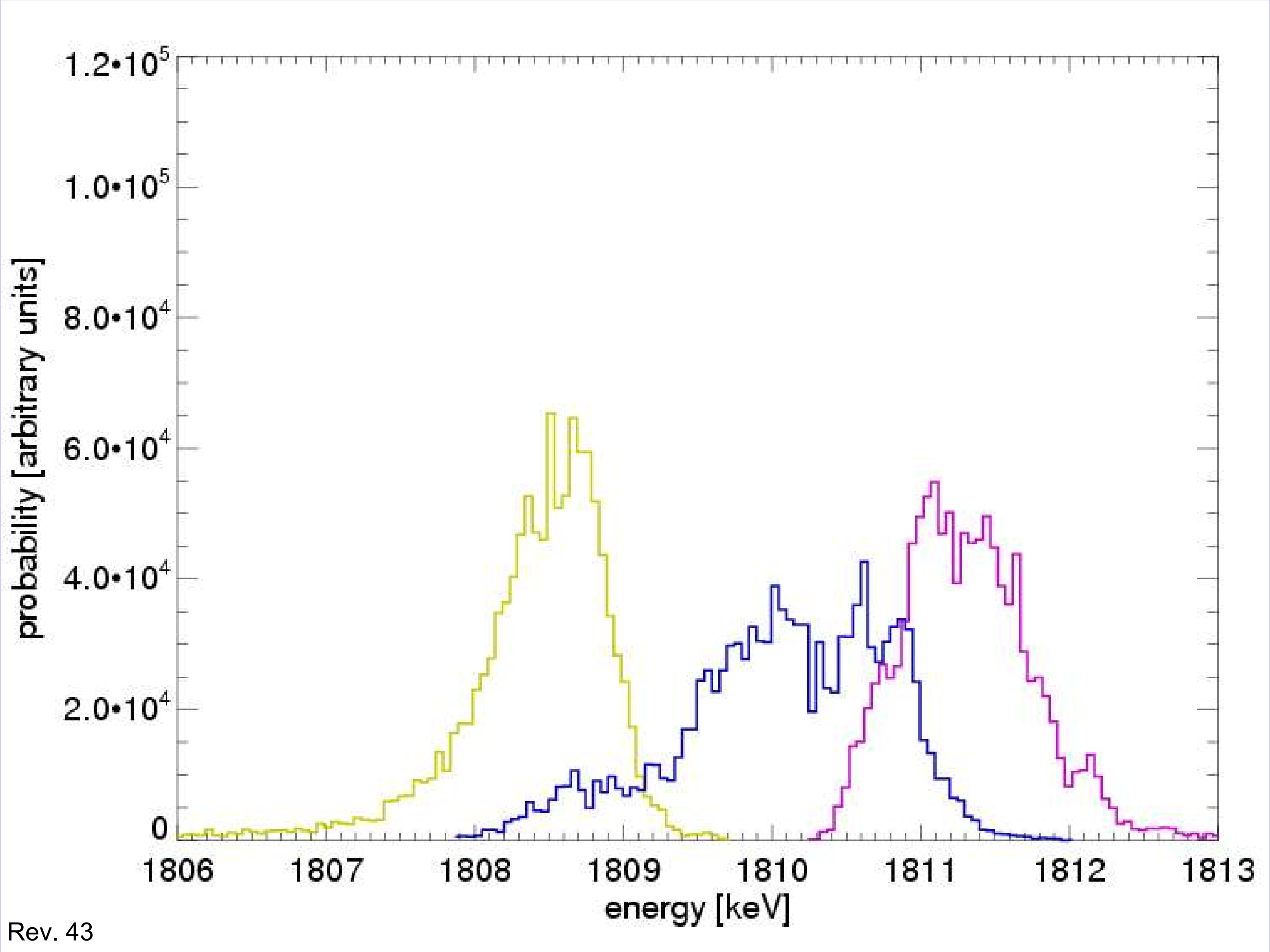
degradation parameter



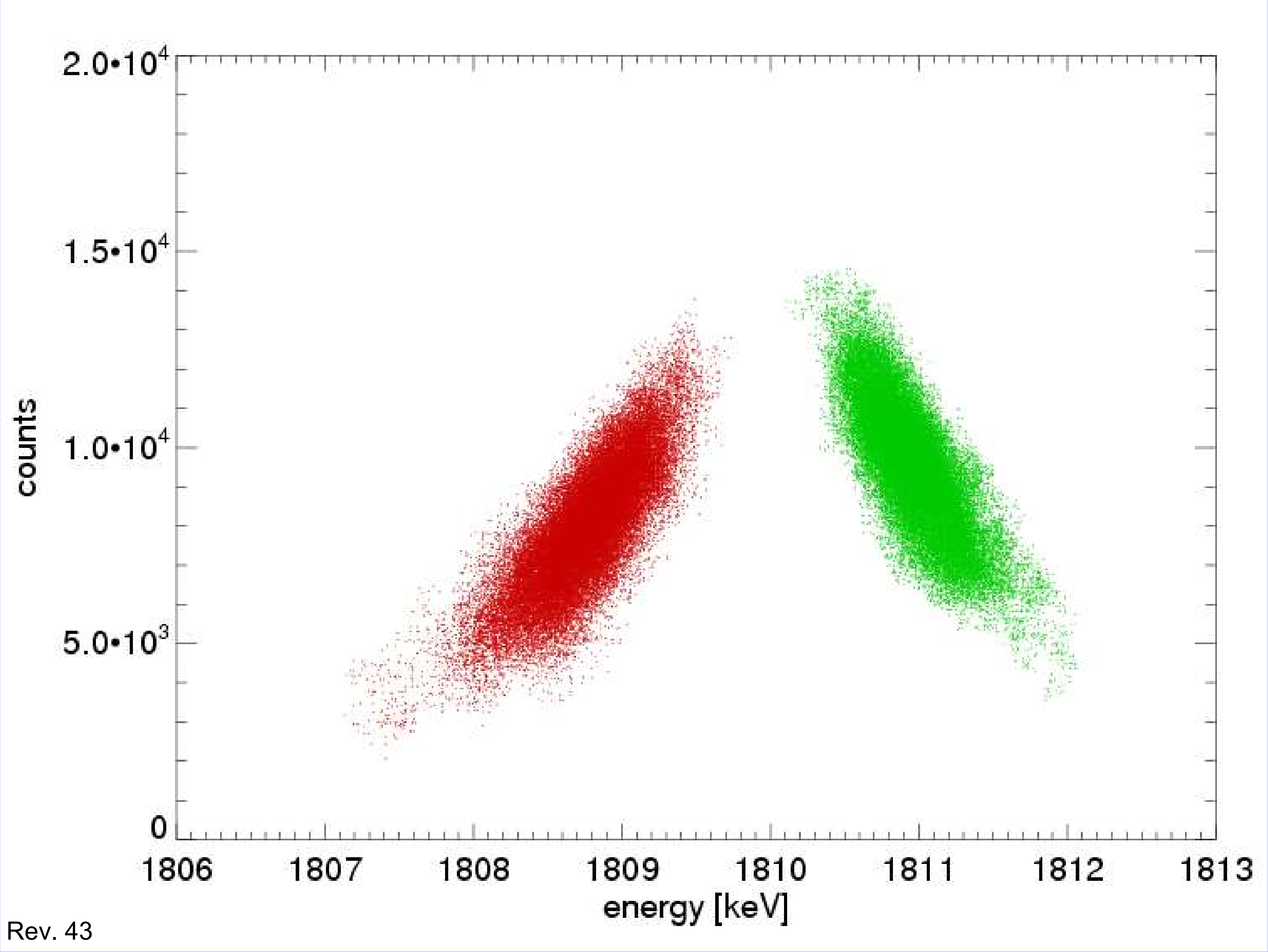
line position: 2 lines



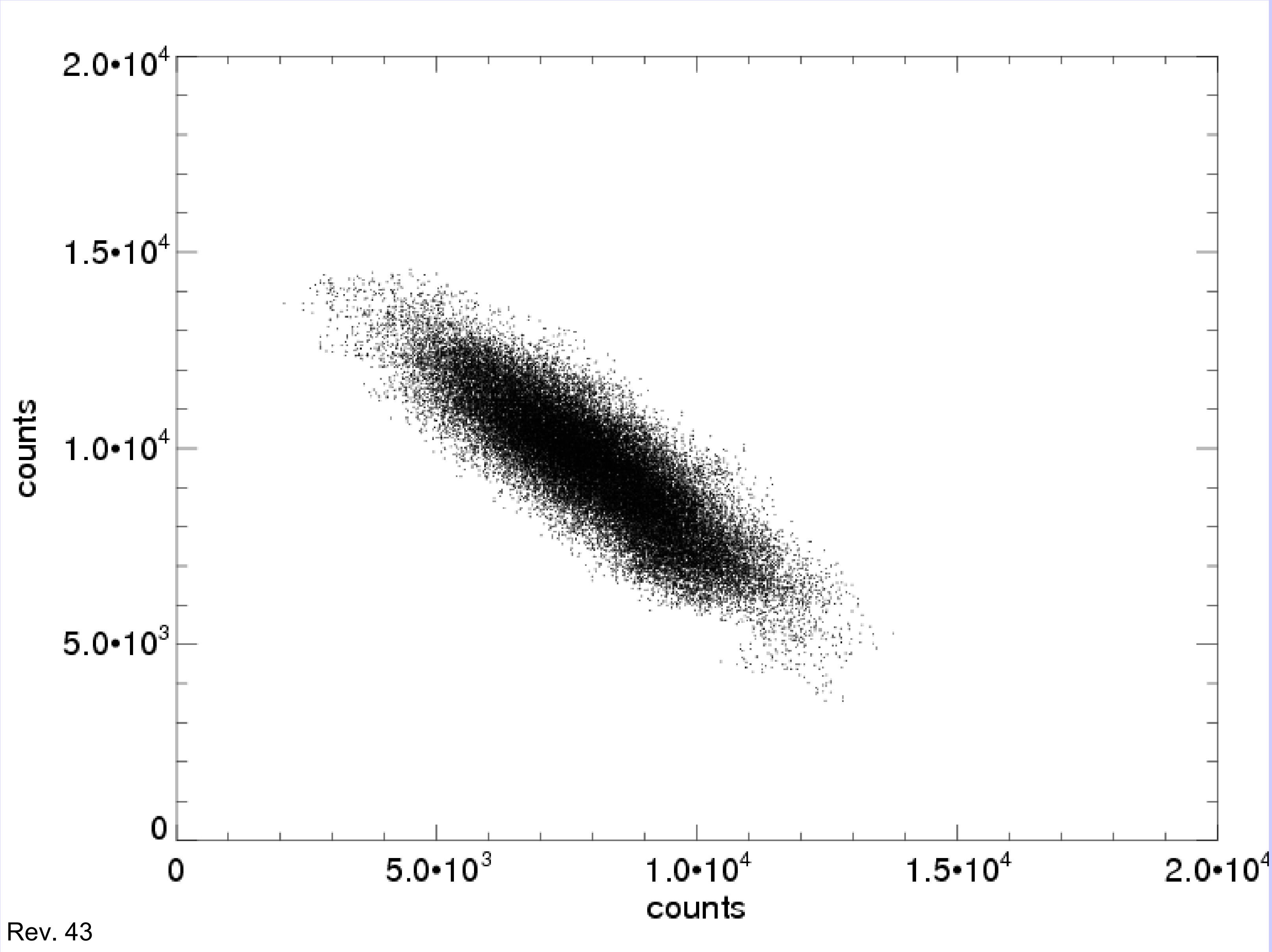
line position: 3 lines



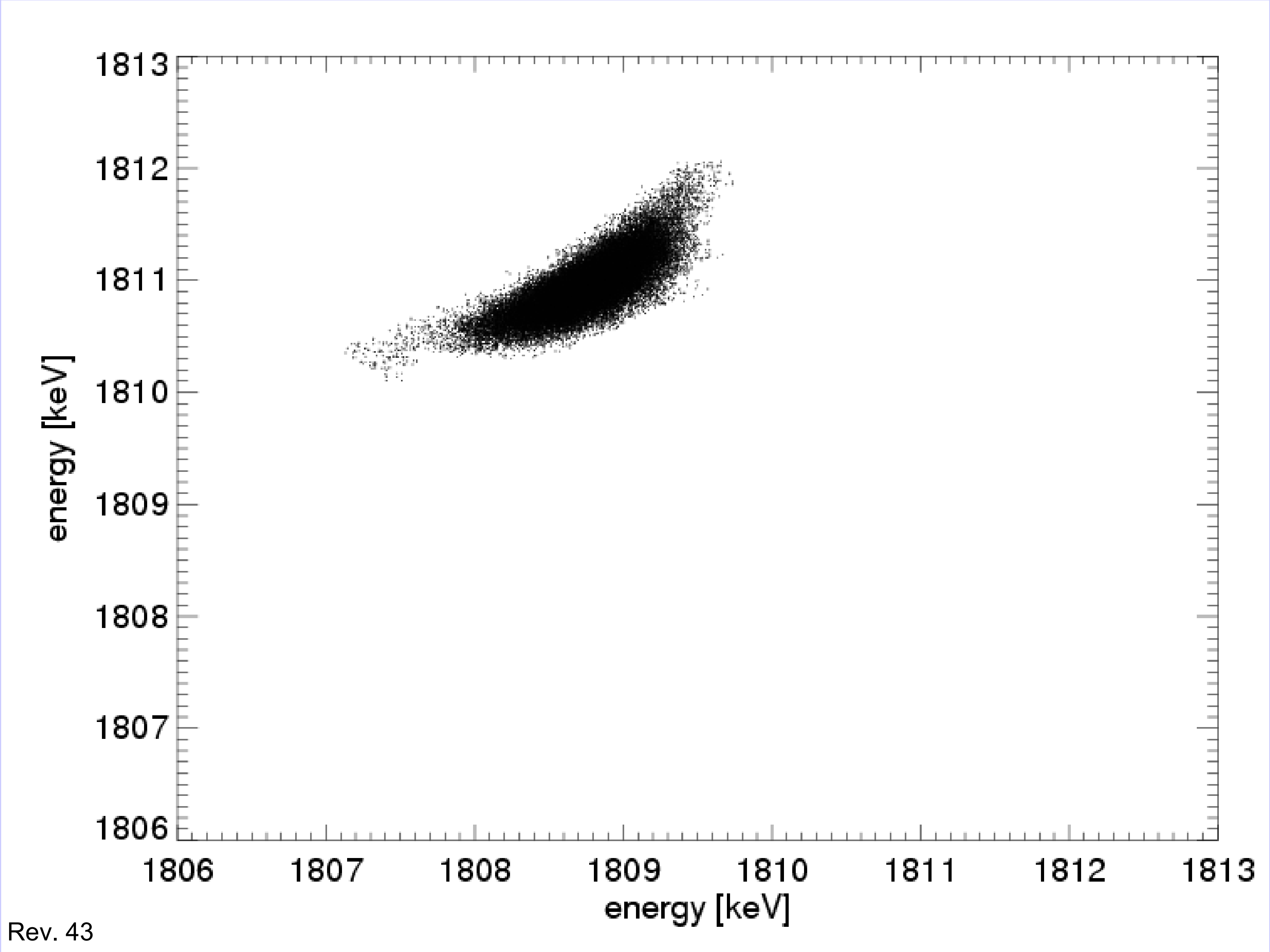
probability distribution



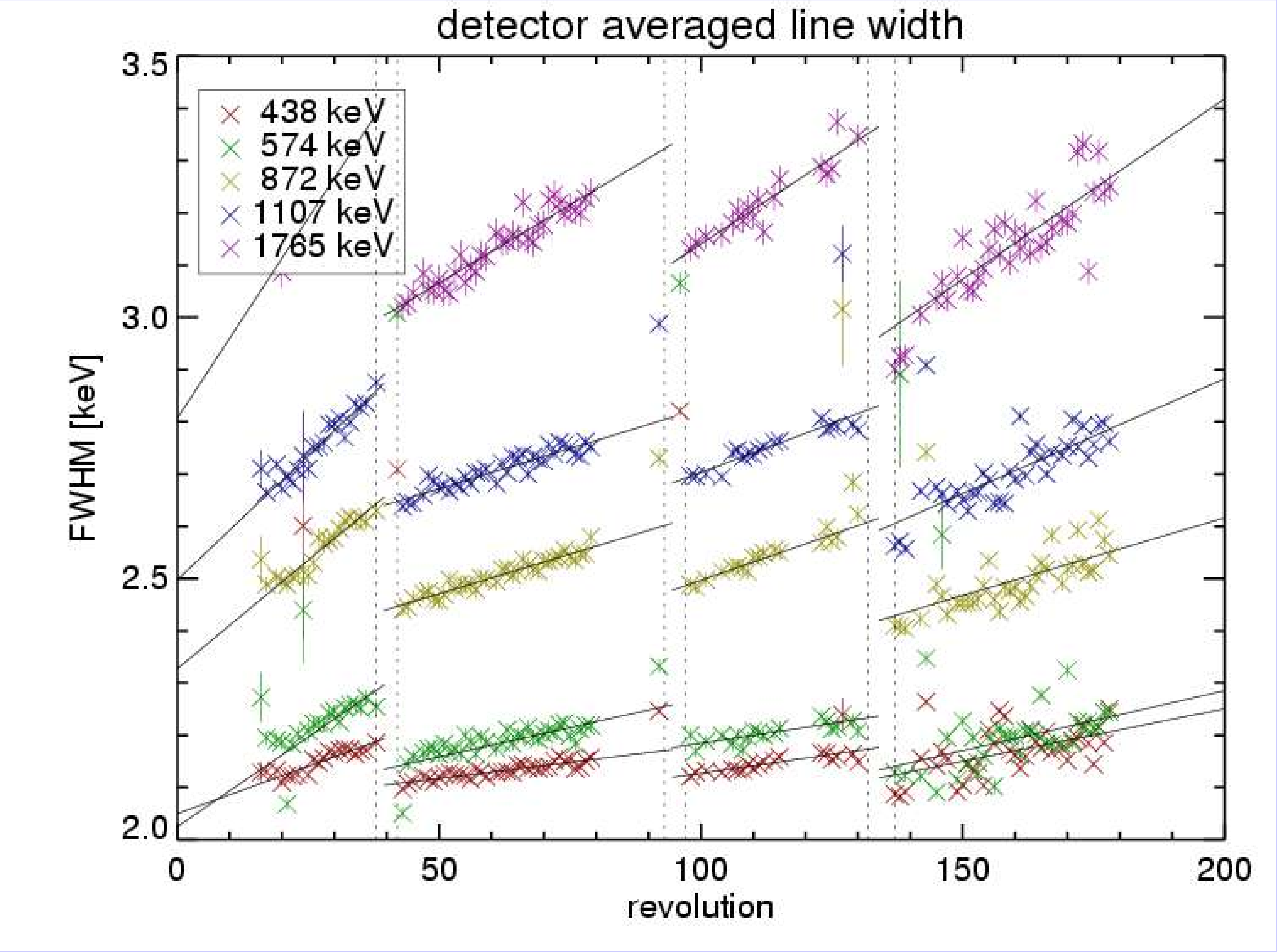
probability dist.: count rate



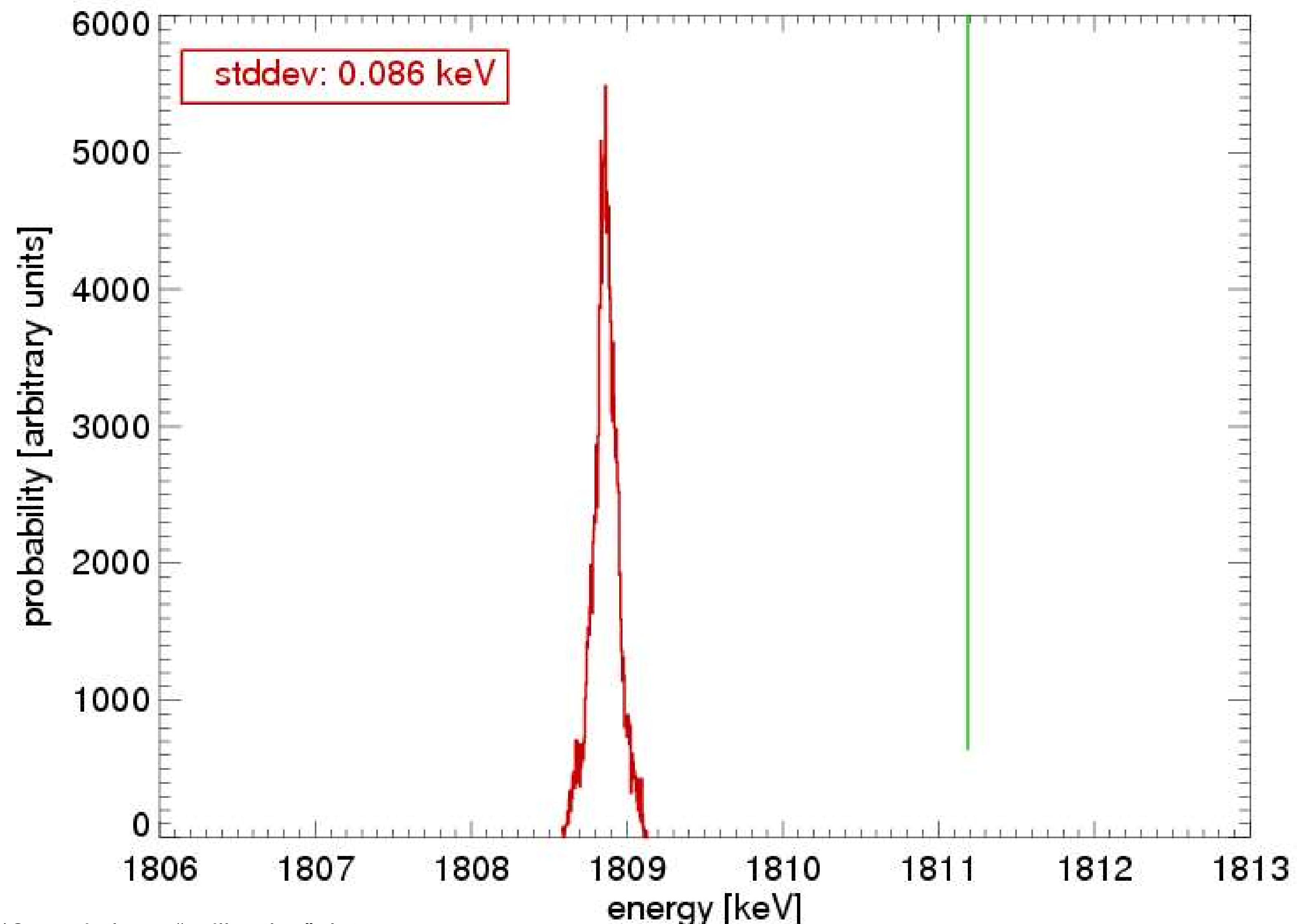
probability dist.: energy



FWHM as a function of (E, t)



probability dist.: energy



112 revolutions, “calibration” data

Summary

- The spectral shape assumed may not be perfect, but the desired effect of measuring the degradation separately was achieved for E > 1 MeV.

- **Observations:**
  - The assumption of a constant intrinsic gaussian shape seems justified by the fit results.
  - This degradation model causes energy offsets compared to the ISDC calibration. Some values for Rev. 123:

438 keV:	0,17(7) keV	[D0-D6]
1764 keV:	0,67(7) keV	[D0-D18]

  - Due to correlation between position and degradation, the uncertainty in the position estimation increases if the amount of degradation is not known:

Rev. 123:

438 keV:	$0{,}01 \rightarrow 0{,}054$	[D0-D6]
1764 keV:	$0{,}03 \rightarrow 0{,}07$	[D0-D18]

Future

- **Further goals:**
- model time evolution of degradation parameter $\tau(t, E)$ and energy shifts relative to the ISDC calibration
- use this knowledge of time dependent line shape to separate the 1810 keV complex into its components
- Fixing the degradation will improve the position resolution. The same accuracy as for pure Gaussian fits should be achieved.