SPI Scientific Team Meeting
CNR Roma - March 17, 2005

- Presentations -

- 5th Annealing, Ged anomalies, IASW 4.3.1 — *J.P. Roques*
- ACS Status — *A. von Kienlin*
- Timing mode in SPIROS — *P. Connell*
- SPI Software for OSA 5.0 — *P. Dubath*
- The Electronic Noise Feature at 1.4 - 1.6 MeV — *T. Wunderer*
- .Decompostion Algorithm for Background studies — *H. Halloin*
- Analysis pipeline at MPE — *H. Halloin*
- Status of the SPI background analysis — *S. Schanne*
- Off axis Crab observations — *E. Jourdain*
- Search for Unpredicted Lines from Point Sources — *K. Watanabe*
- 60Fe, the next step — *M. Harris*
- Positronium Continuum Emission: All-Sky Distribution — *G. Weidenspointner*
- Status note on 26Al Studies in the Galaxy — *R. Diehl*

Agenda

❐ Hardware/Instrument status

- 5th Annealing - On board software - Telemetry	15 min	J.P. Roques
- ACS Status	10 min	A. von Kienlin

❐ Analysis Methods and Support

- Timing analysis and background modelling with SPIROS	20 min	P. Connell
- SPI software development for OSA5	15 min	P. Dubath
- SPI Electronic-Noise background at 1.4-1.6 MeV	15 min	T. Wunderer
- Decomposition method for background studies	15-20 min	H. Halloin
- Analysis pipeline at the MPE, application to the Galactic diffuse emission	15 min	H. Halloin
- Status of the Saclay background models for 511 keV and Al26 data analysis	15 min	S.Schanne

❐ Calibration/Software status/Sensibility

- Crab calibration, Off axis response	15 min	E. Jourdain

❐ Science analyses

- Search for unpredicted lines from point sources	15 min	K. Watanabe
- 60Fe, the next step	5 min	M. Harris
- Positronium Continuum: All-Sky Distribution	15 min	G. Weidenspointner
- Largescale 26Al study: Update and next steps	15 min	R. Diehl

❐ Other topics

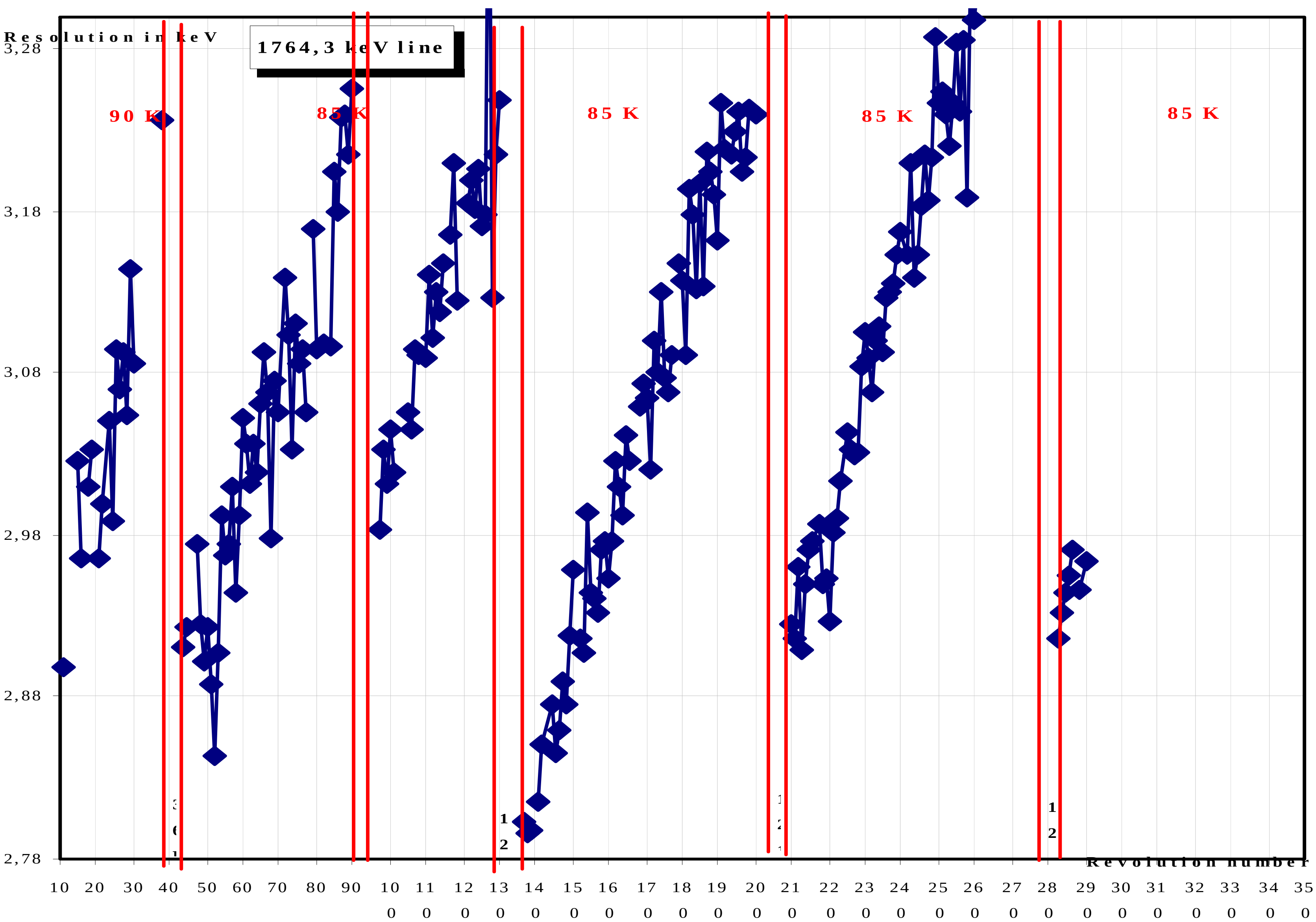
Team Matters (core program, data rights, research groups; papers; next meetings)

- Coffee breaks at 11.15-11.30 and 16.00-16.15 -

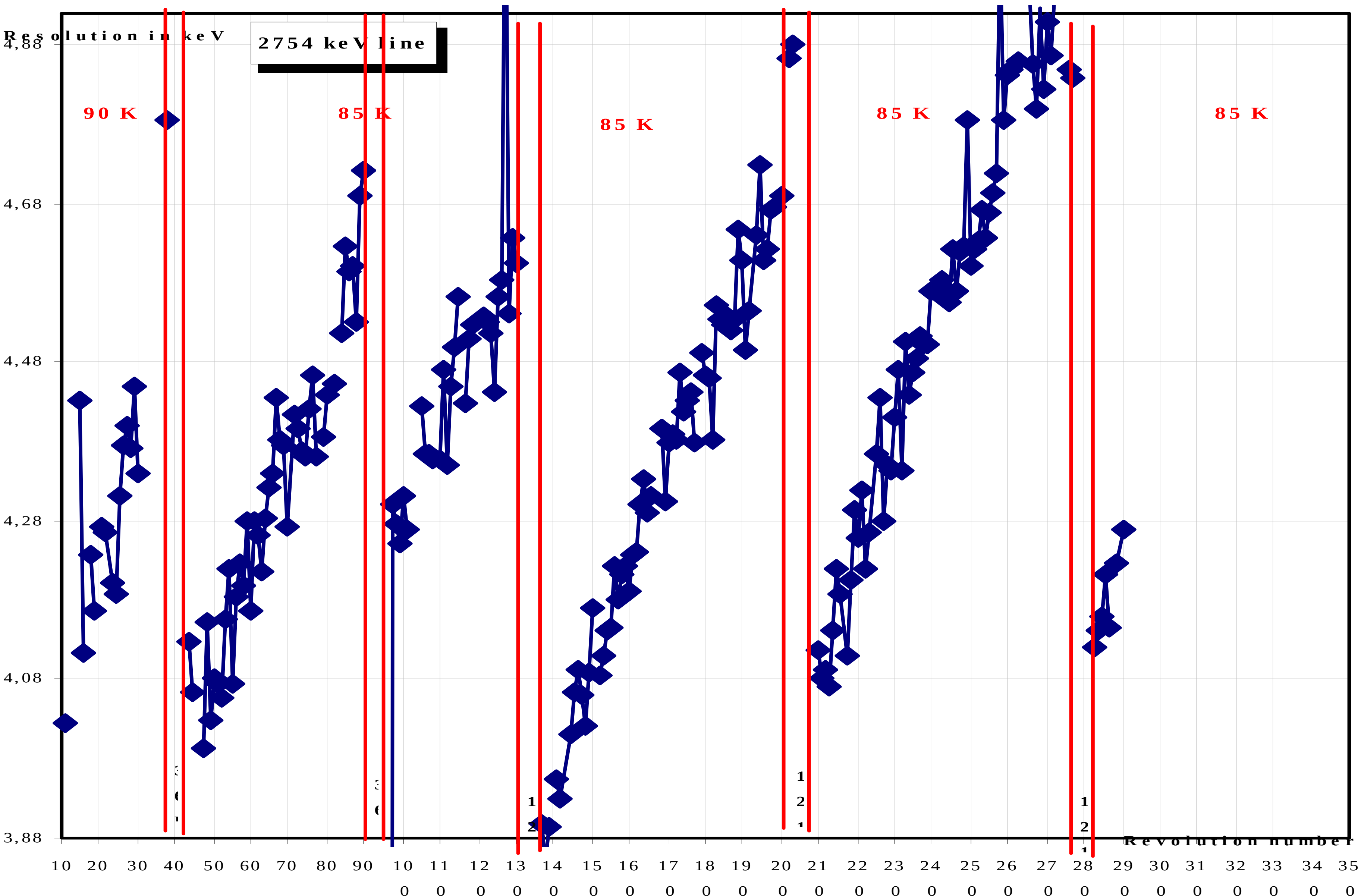
5th Annealing

- Duration approx 130 Hr
- Camera switch-on Feb 3th

No problem to report



1764,3 keV line
Resolution in keV
Revolution number
90 K
85 K
85 K
85 K
85 K
3,28
3,18
3,08
2,98
2,88
2,78



Resolution in keV
2754 keV line
90 K
85 K
85 K
85 K
85 K
4,88
4,68
4,48
4,28
4,08
3,88
Revolution number
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

GeD anomalies

- Detector 2 failure (Dec. 2003)
- Detector 17 failure (July 2004)
- GeD 2 preamp. offset non nominal
- GeD 17 preamp. offset « nominal »
- But no counts from the PA.
- No reaction of PA to change in HV.
- HV circuits seems to work properly.
- Problem located in the PA
- Primary cause unknown

Detector anomalies investigations

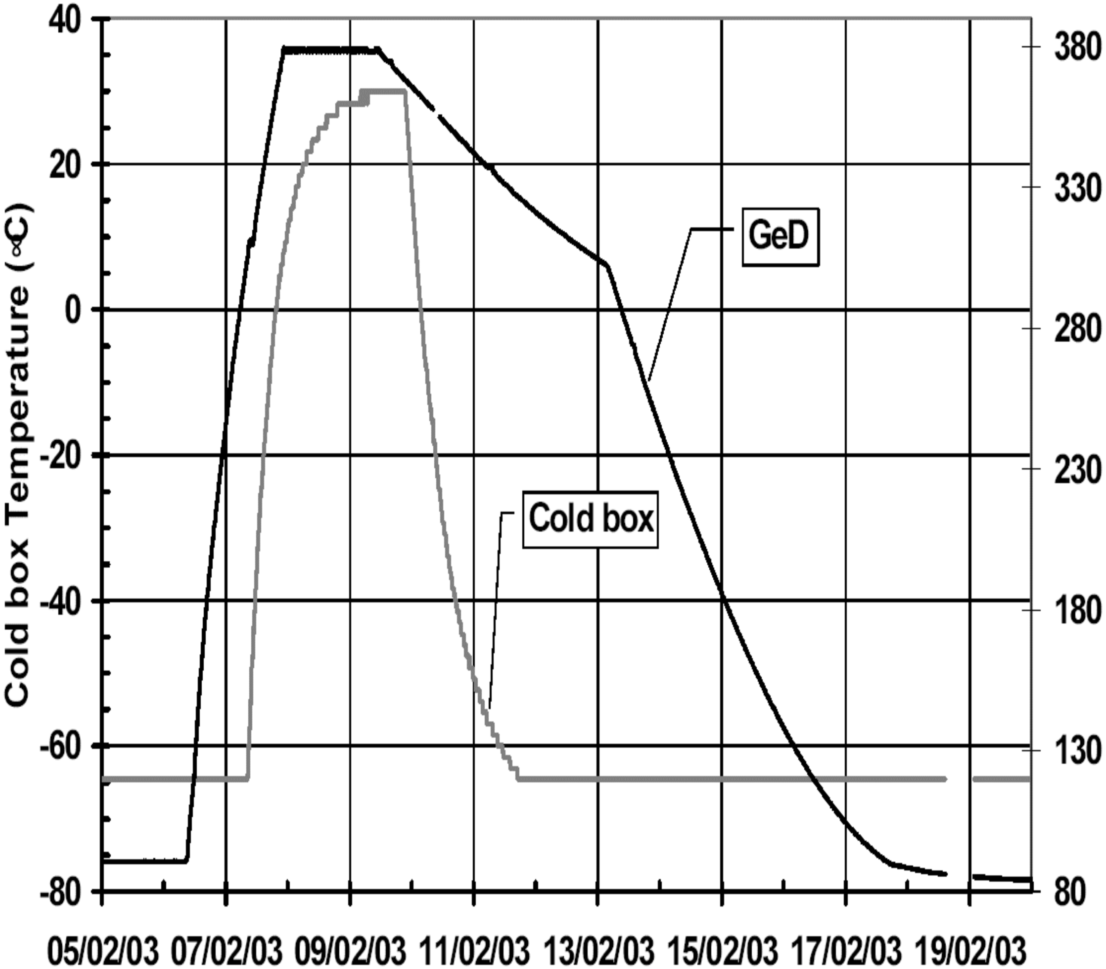
- The cause of the failures has not been identified.
- Long duration ground tests with a spare model camera are ongoing :
  - 3 annealing cycles 130 Hr each
  - 3 periods of operation at 82 K : > 1 month each
  - No problem to report

Preventive action

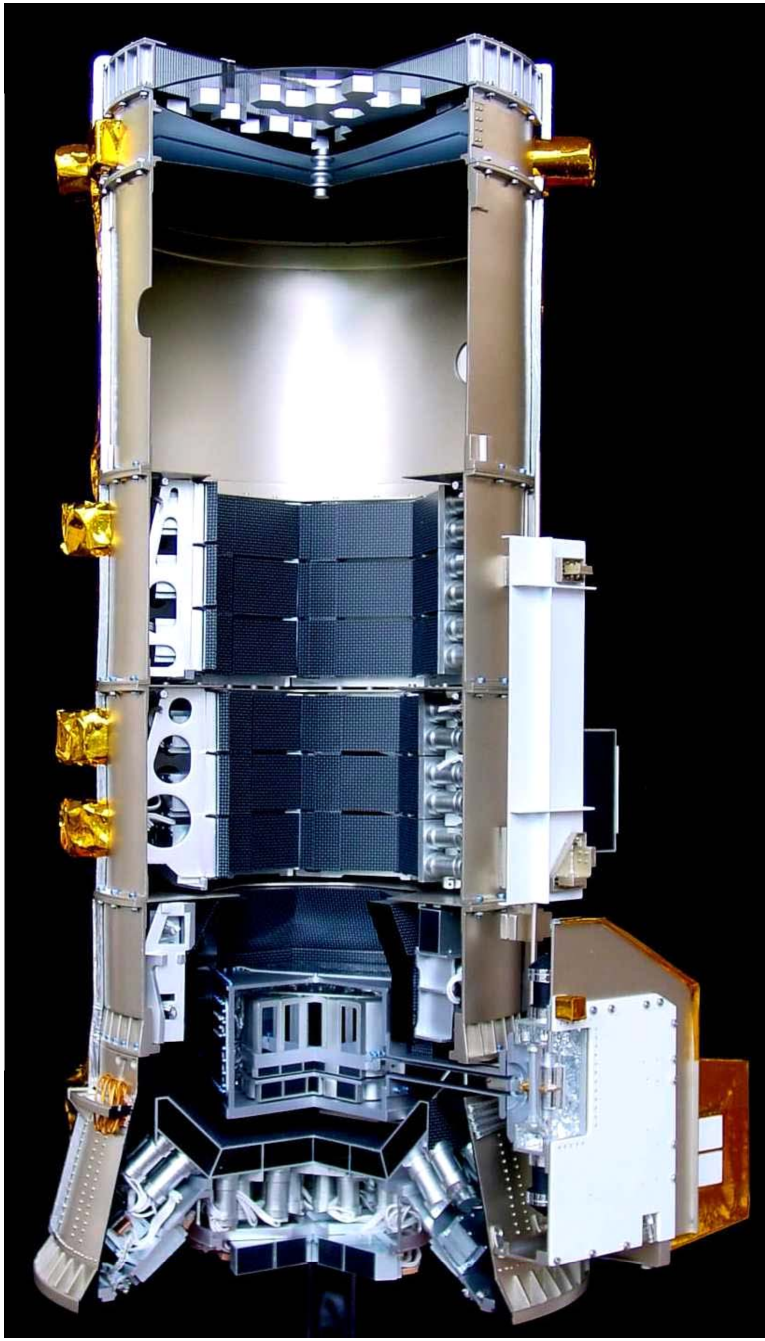
- New annealing procedure :

  Keep the cold box at -65 C

- This will avoid thermal cycling of the PA2, cables and feed throughs.
- This will avoid migration of contamination that can occur on the cold box



Cold box Temperature (°C)
GeD Temperature (K)
40
20
0
-20
-40
-60
-80
380
330
280
230
180
130
80
GeD
Cold box
05/02/03
07/02/03
09/02/03
11/02/03
13/02/03
15/02/03
17/02/03
19/02/03



IASW 4.3.1

- New IASW version has been uploaded
- Science HK can be transmitted below the belts
- Random Pb with ACS switch off at belt entry

ACS status:

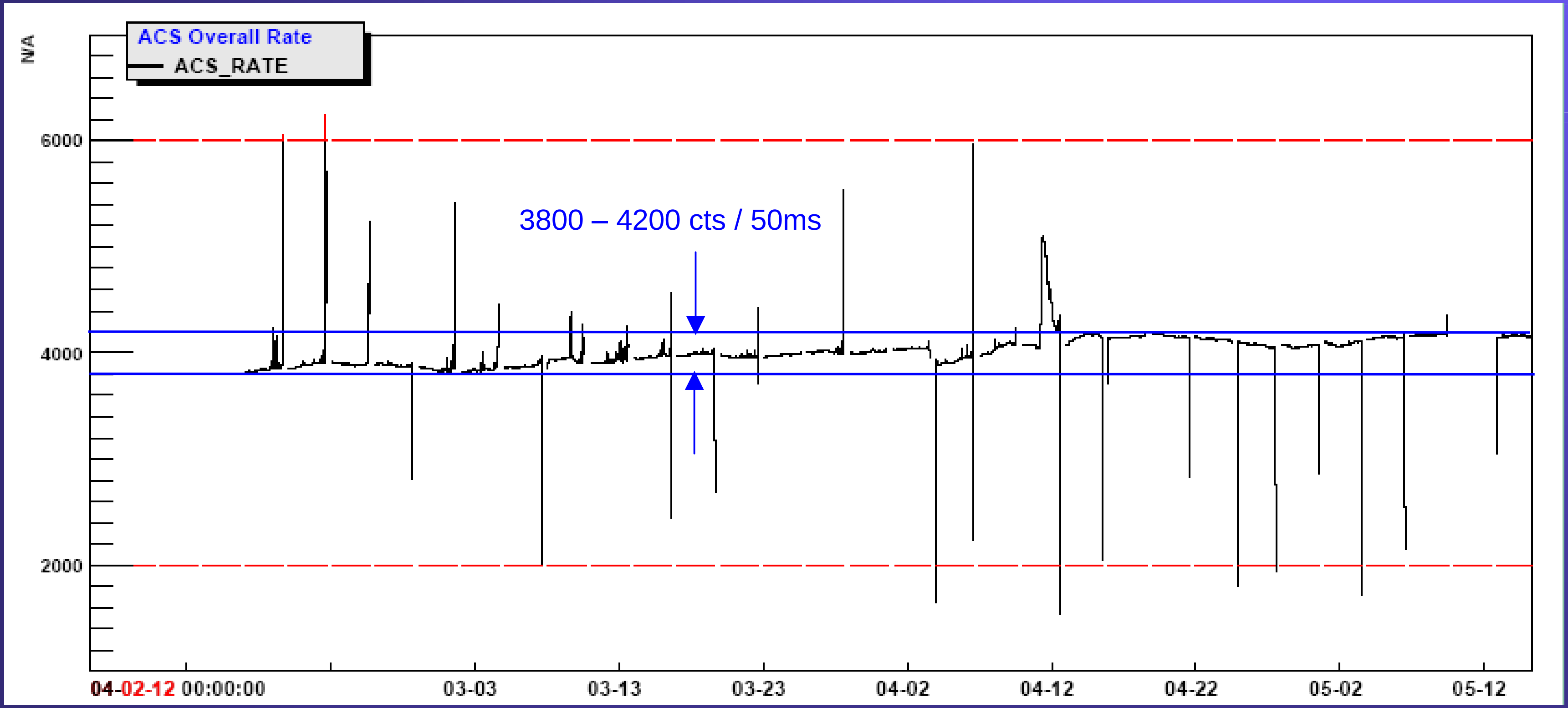
- Development of ACS FEE count rates

Andreas von Kienlin MPE

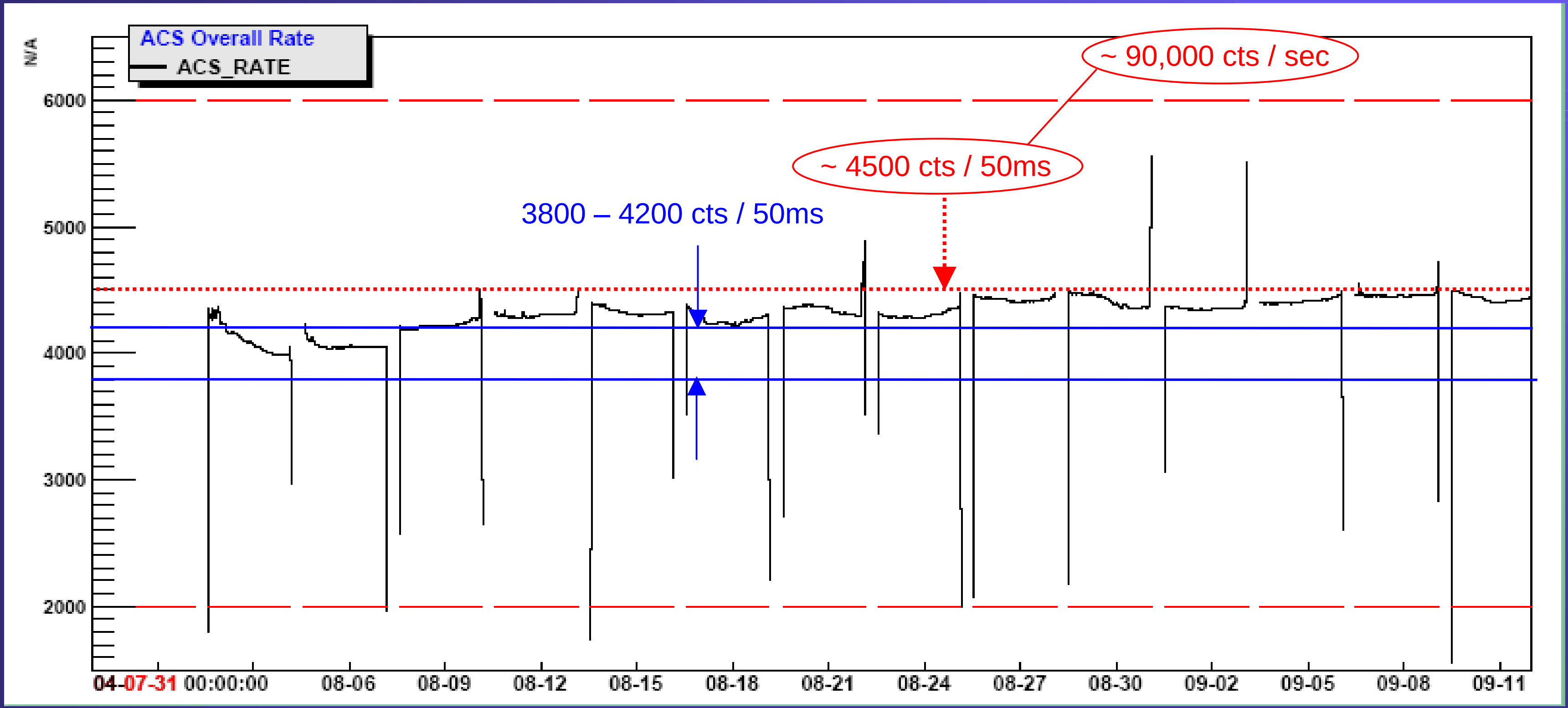
ACS health and performance monitoring

- Development of ACS single FEE count rates
  - Can be used for PMT gain monitoring
  - Will reveal PMT degradation
- Up to now
  - only 1 FEE failure (FEE57) since launch
- Long-term development :
  - Comparison of ACS FEE rates (UCR,LCR,SSA,ACS)
  - Beginning of 2003, 100 days: 27.02 – 06.06.2003
  - 46 days: 1. 12. 2003 – 15. 1. 2004
  - 100 days: 12. 2. 2004 – 15. 5. 2004
  - 46 days: 31. 7. 2004 – 12. 9. 2004
  - 36 days: 5. 2. 2005 – 11. 3. 2005

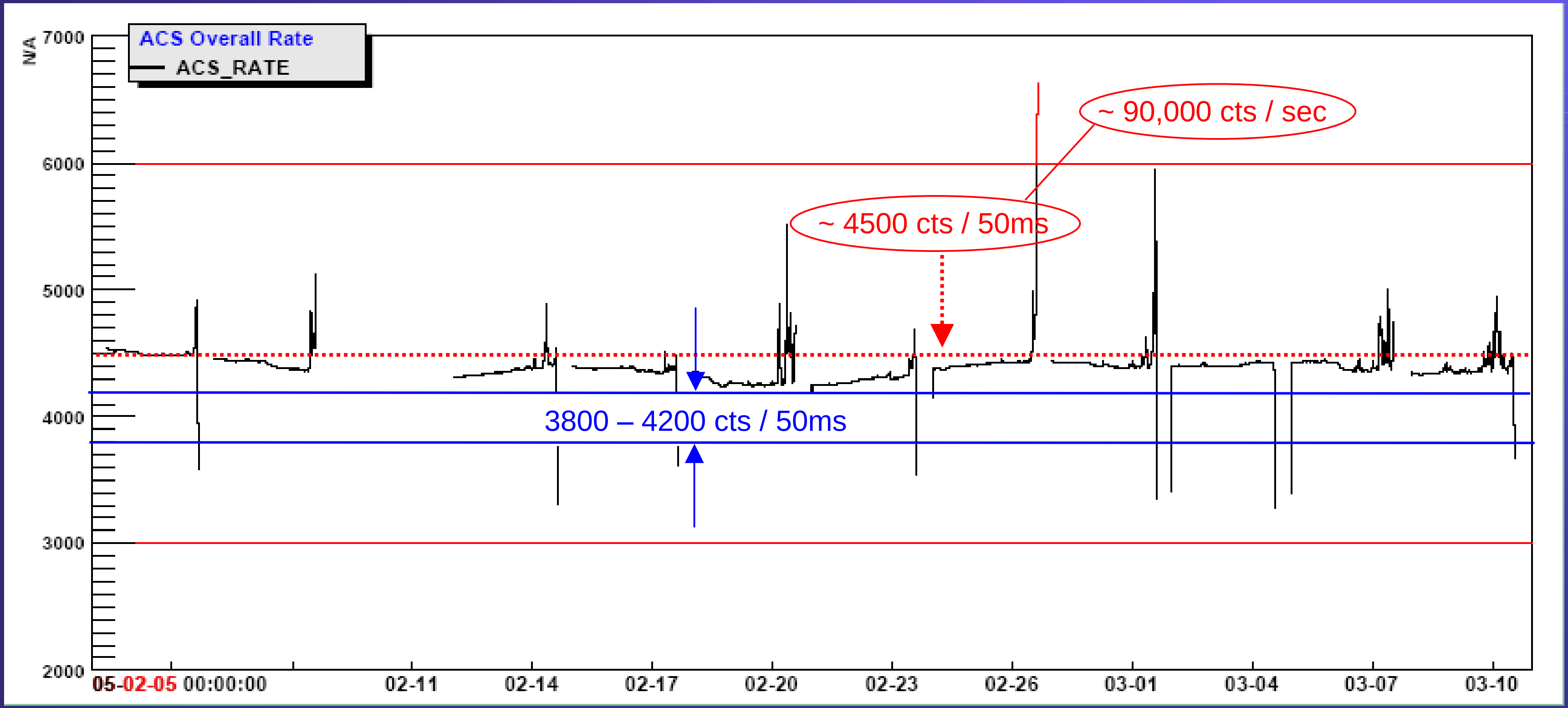
ACS
overall count rate of 100 days: 12.02. - 15.05.04



ACS
overall count rate of 46 days: 03.07. - 12.09.04



ACS
overall count rate of 36 days: 05.02. - 11.03.05

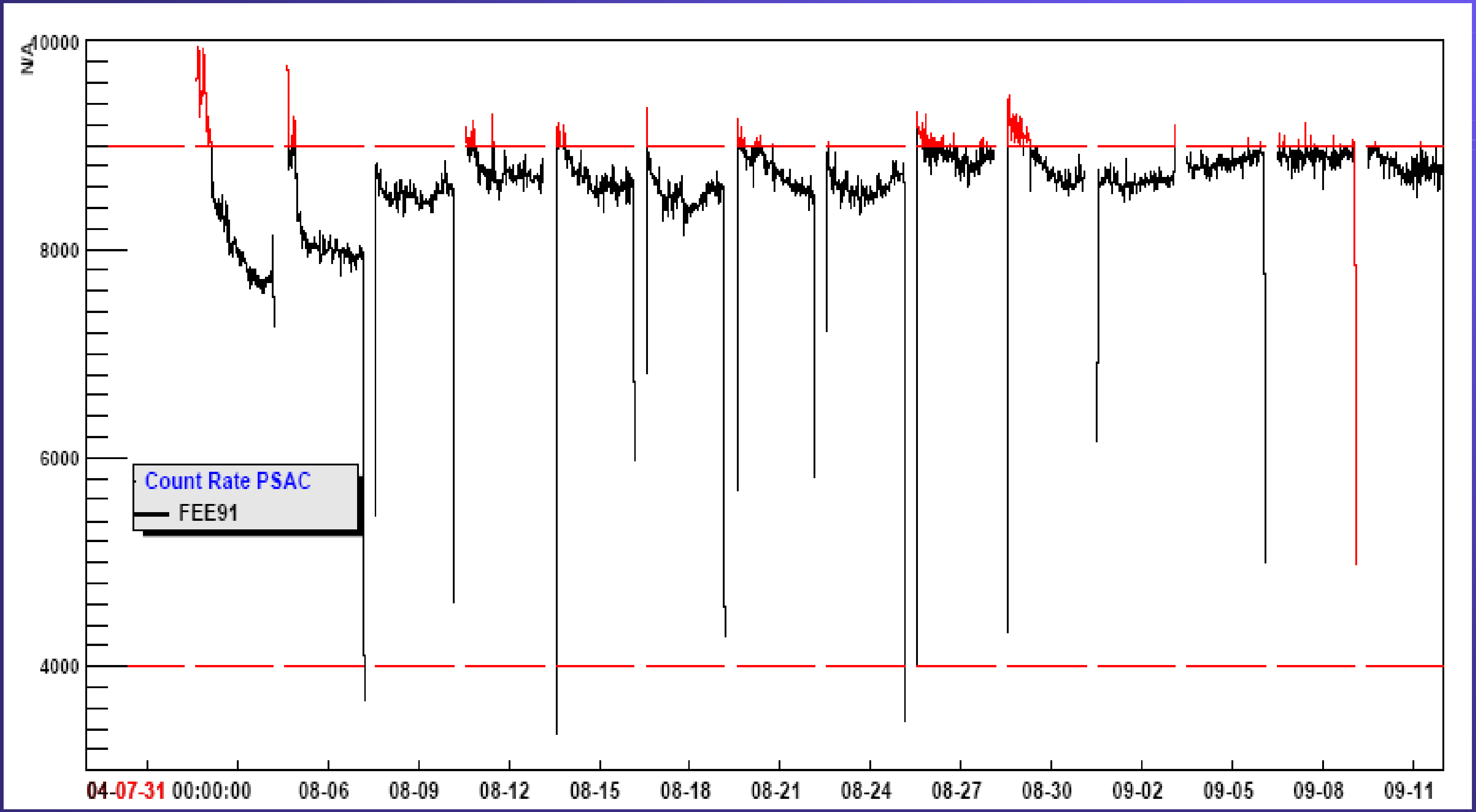


General trend observed

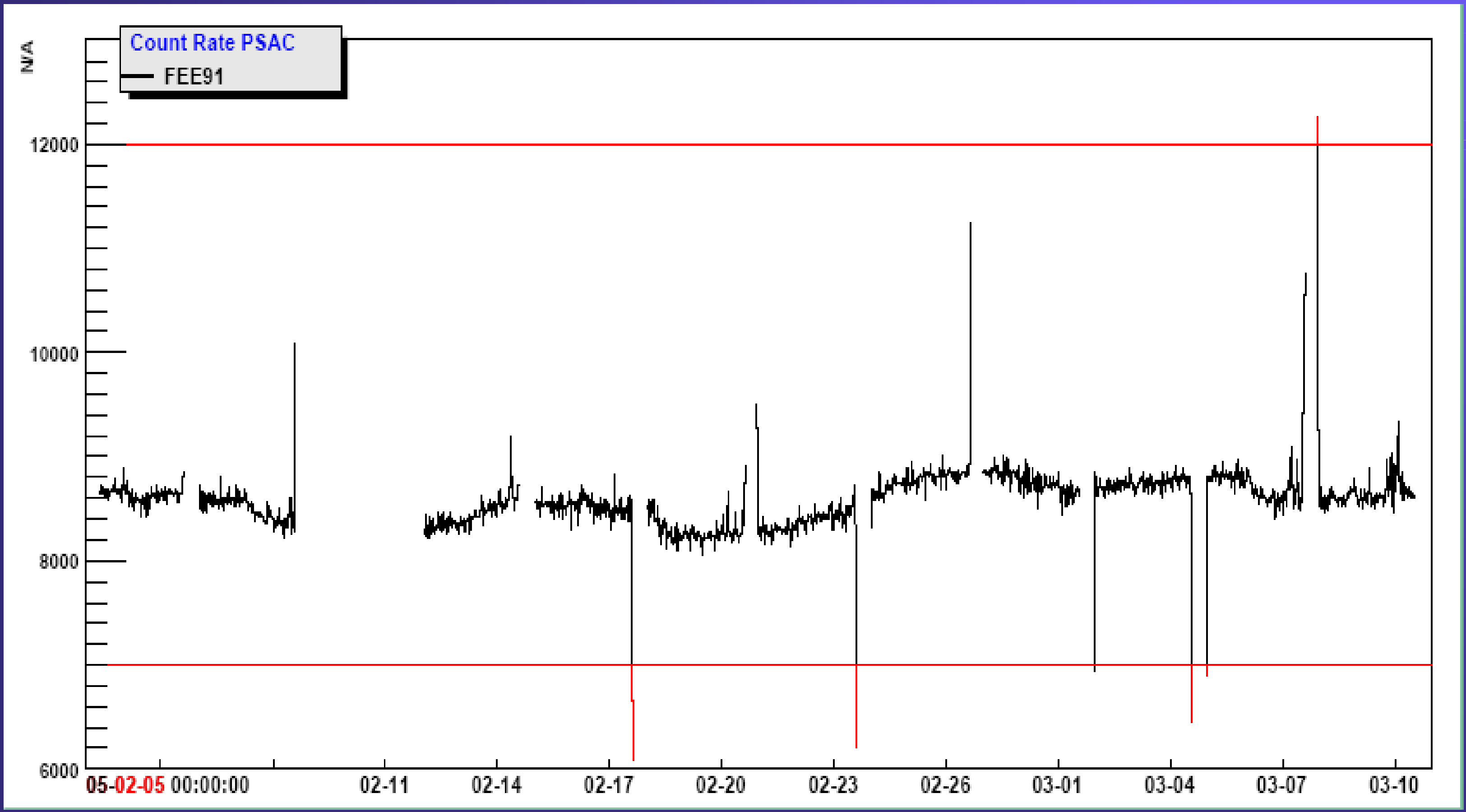
- No significant increase of ACS overall rate since last September
  - 5. 2. - 11. 3. 05 period compared to 3. 7. – 12. 9. 04
- Increase of ACS overall rate since last February: ~ 18 %
  - From 76 000 cts/s to 90 000 cts/s
  - 3. 7. - 12. 9. 04 period compared to beginning of 12. 02. – 15. 5. 04 period
  - Caused by solar minimum activity period

⇨ Next viewgraphs: development of single FEE count rates

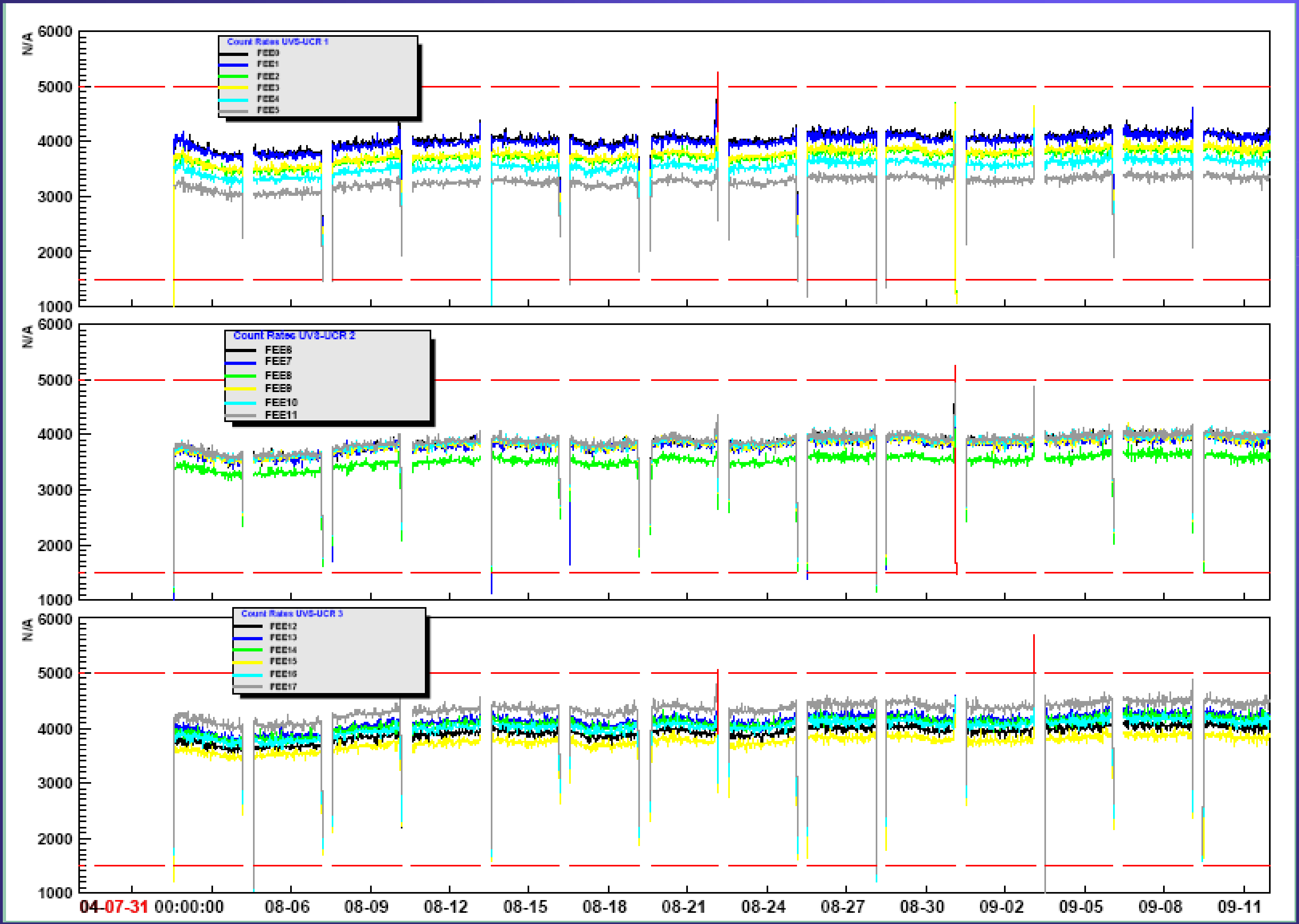
PSAC count rates: 03.07. - 12.09.04



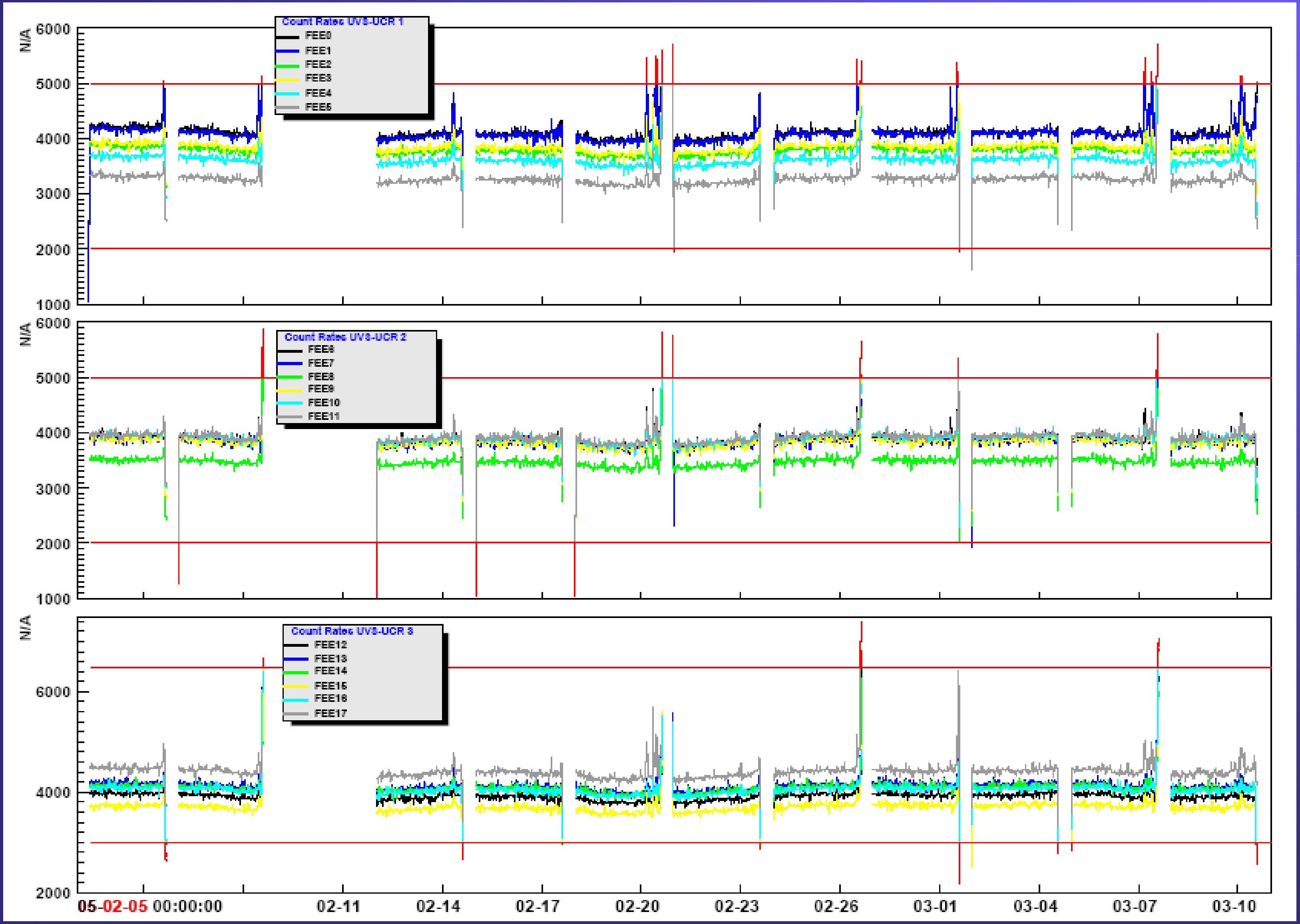
PSAC count rates: 05.02. - 11.03.05



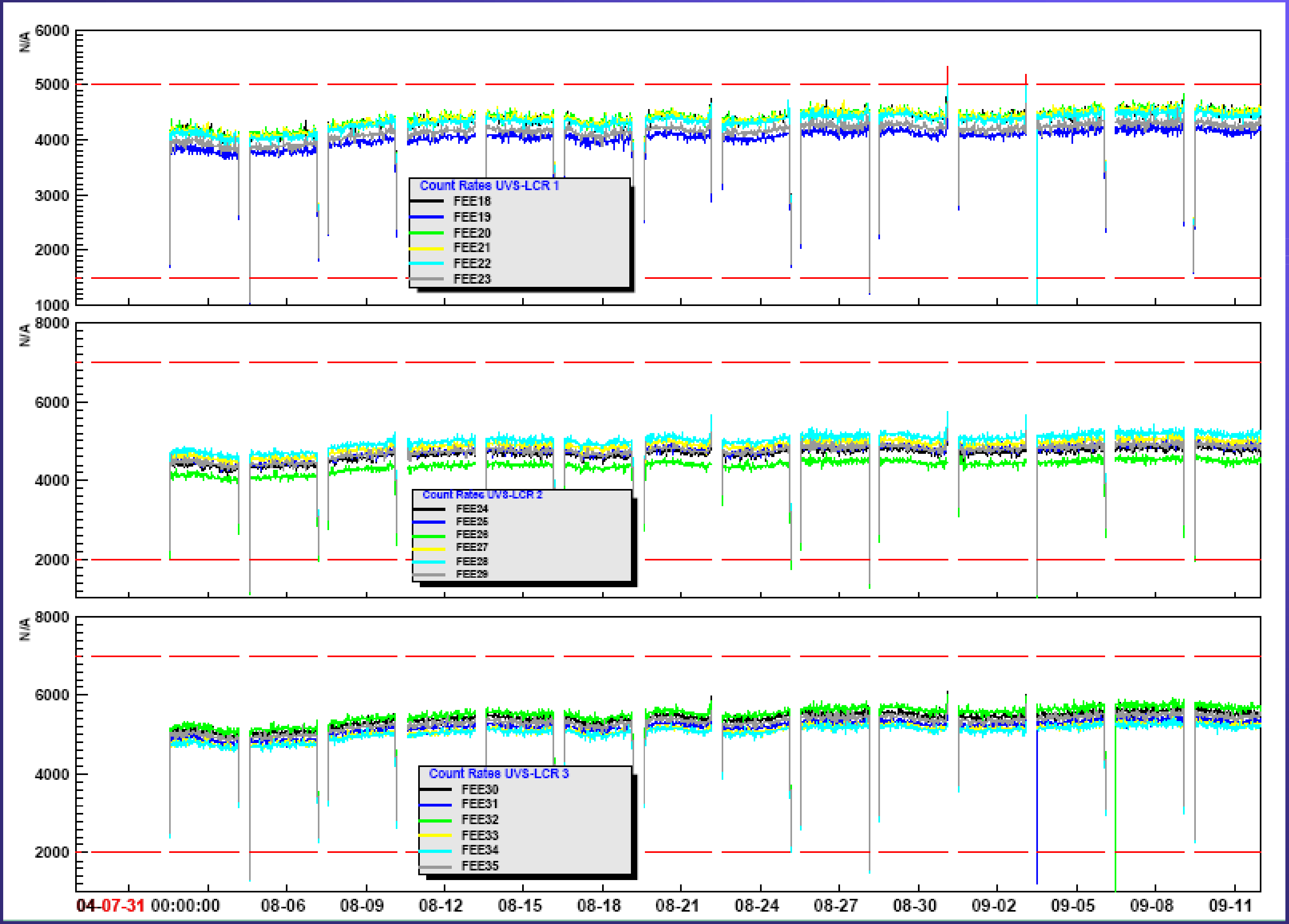
UCR count rates: 03.07. - 12.09.04



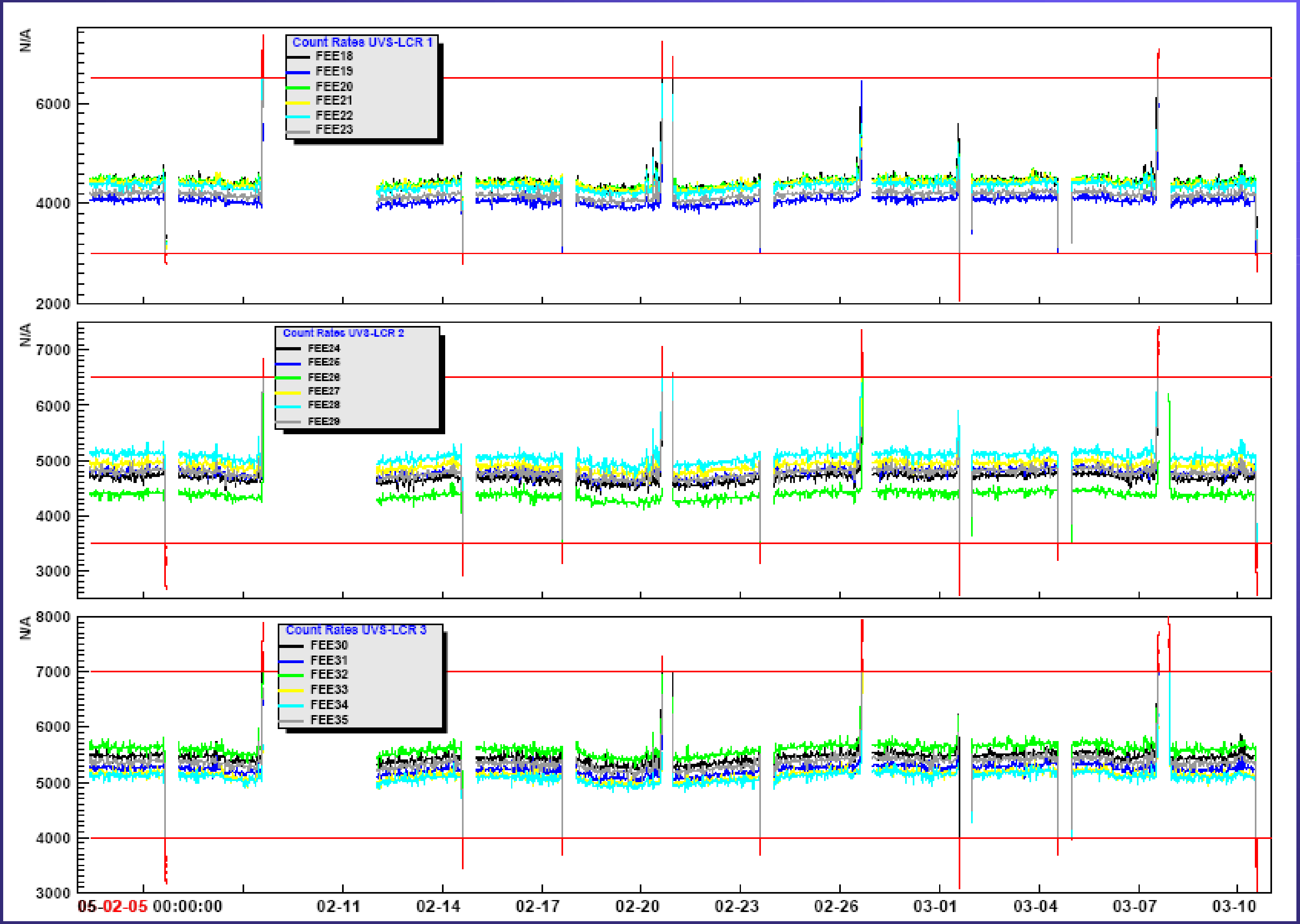
UCR count rates: 05.02. - 11.03.05



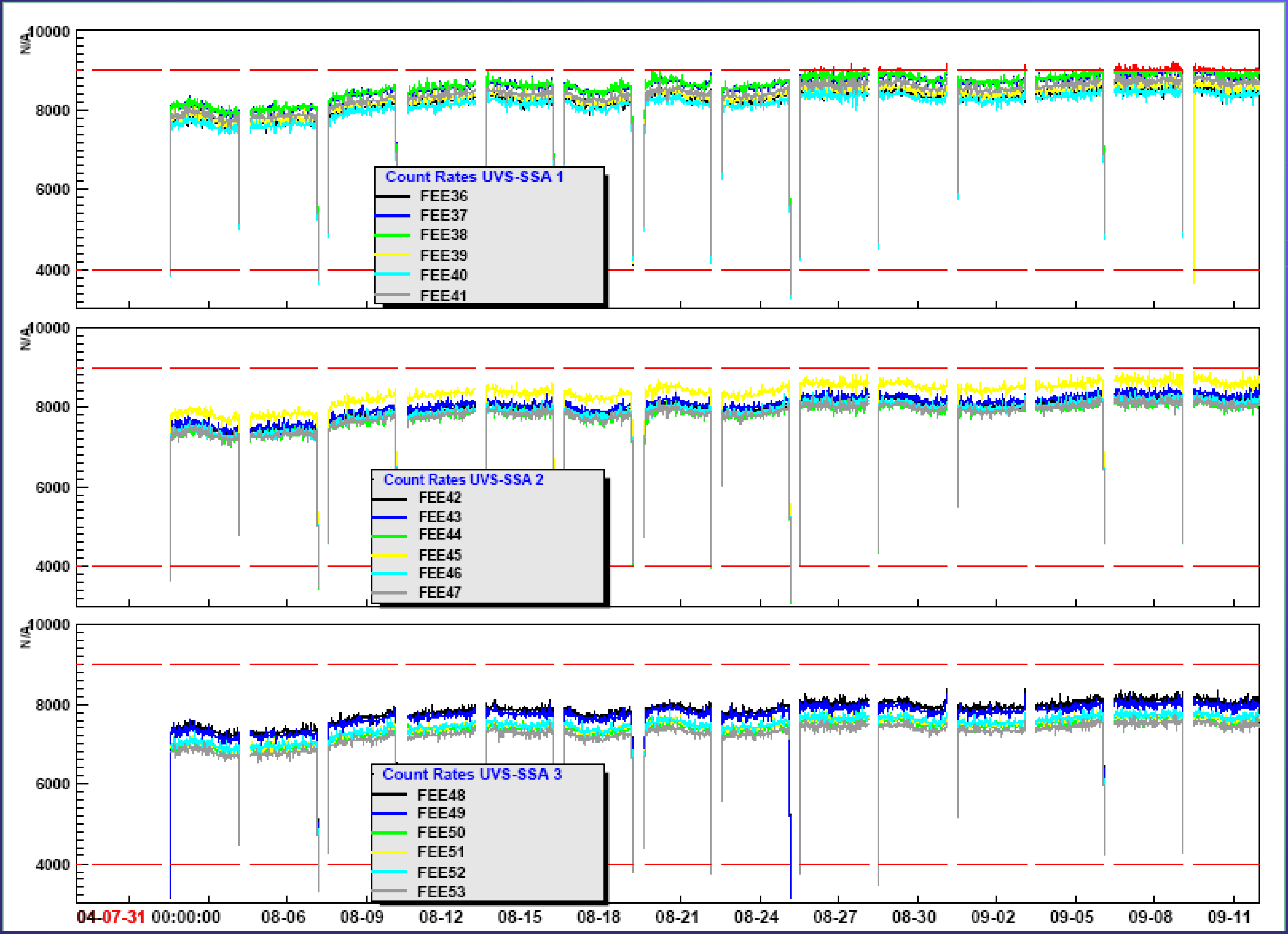
LCR count rates: 03.07. - 12.09.04



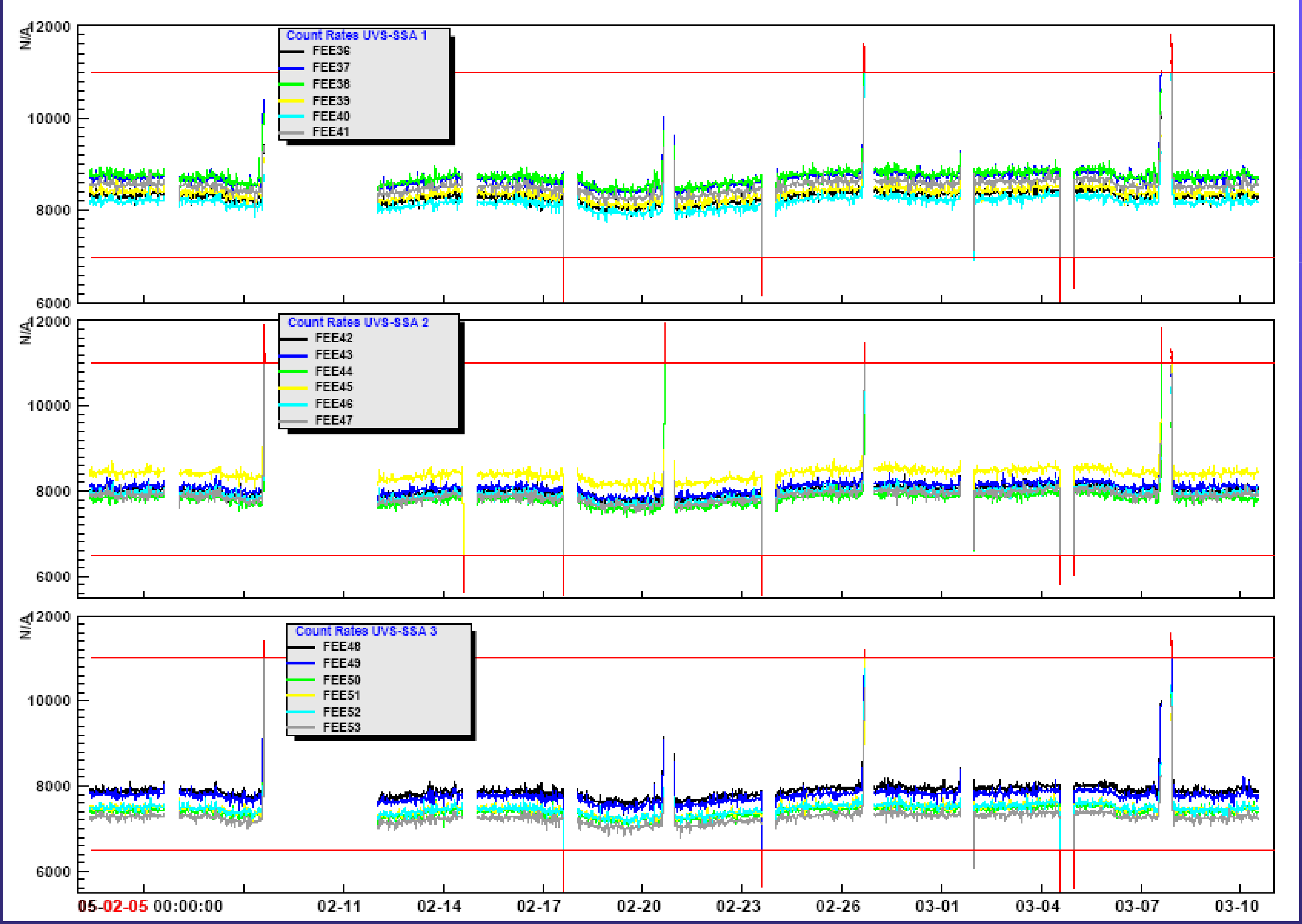
LCR count rates: 05.02. - 11.03.05



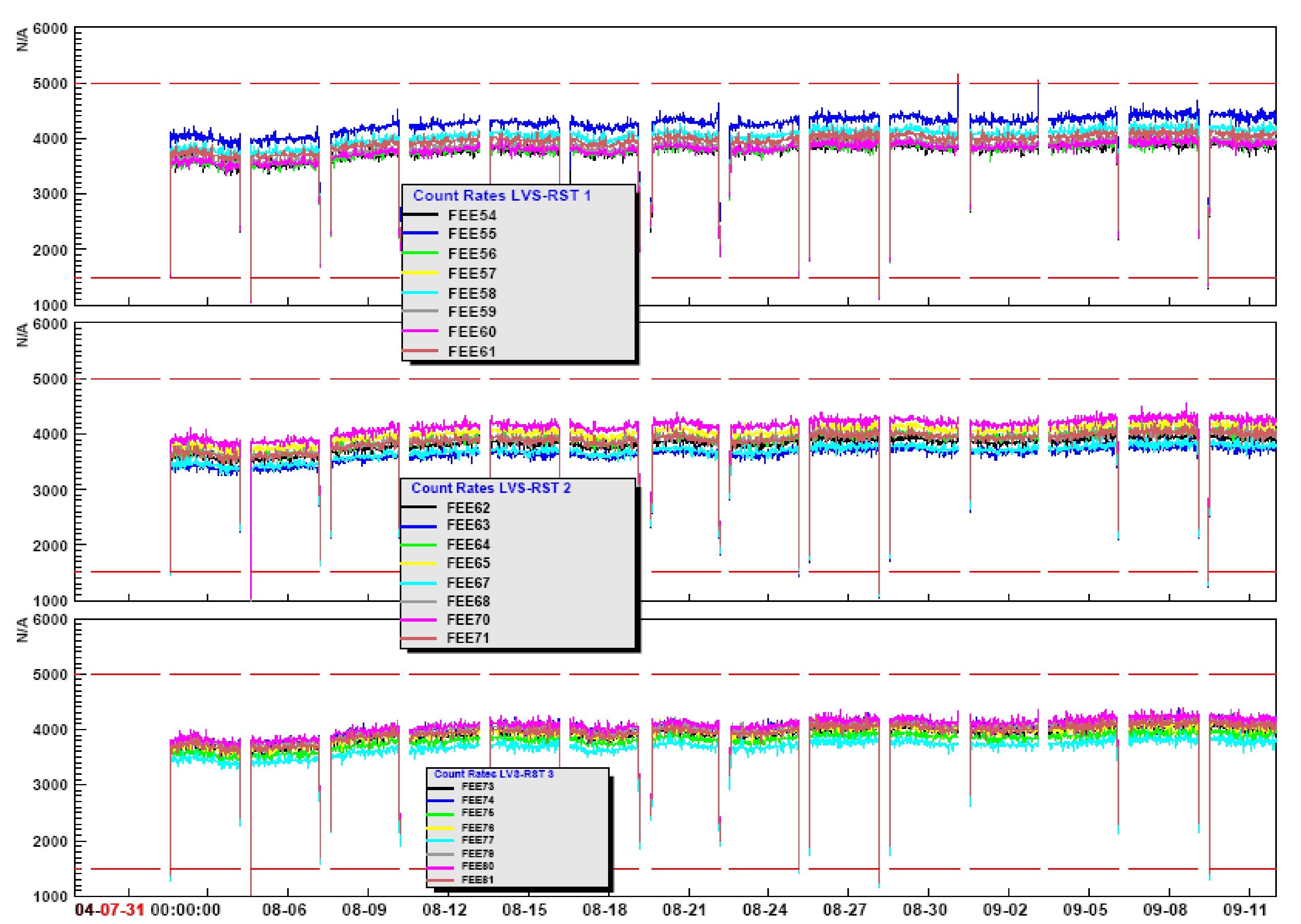
SSA count rates: 03.07. - 12.09.04



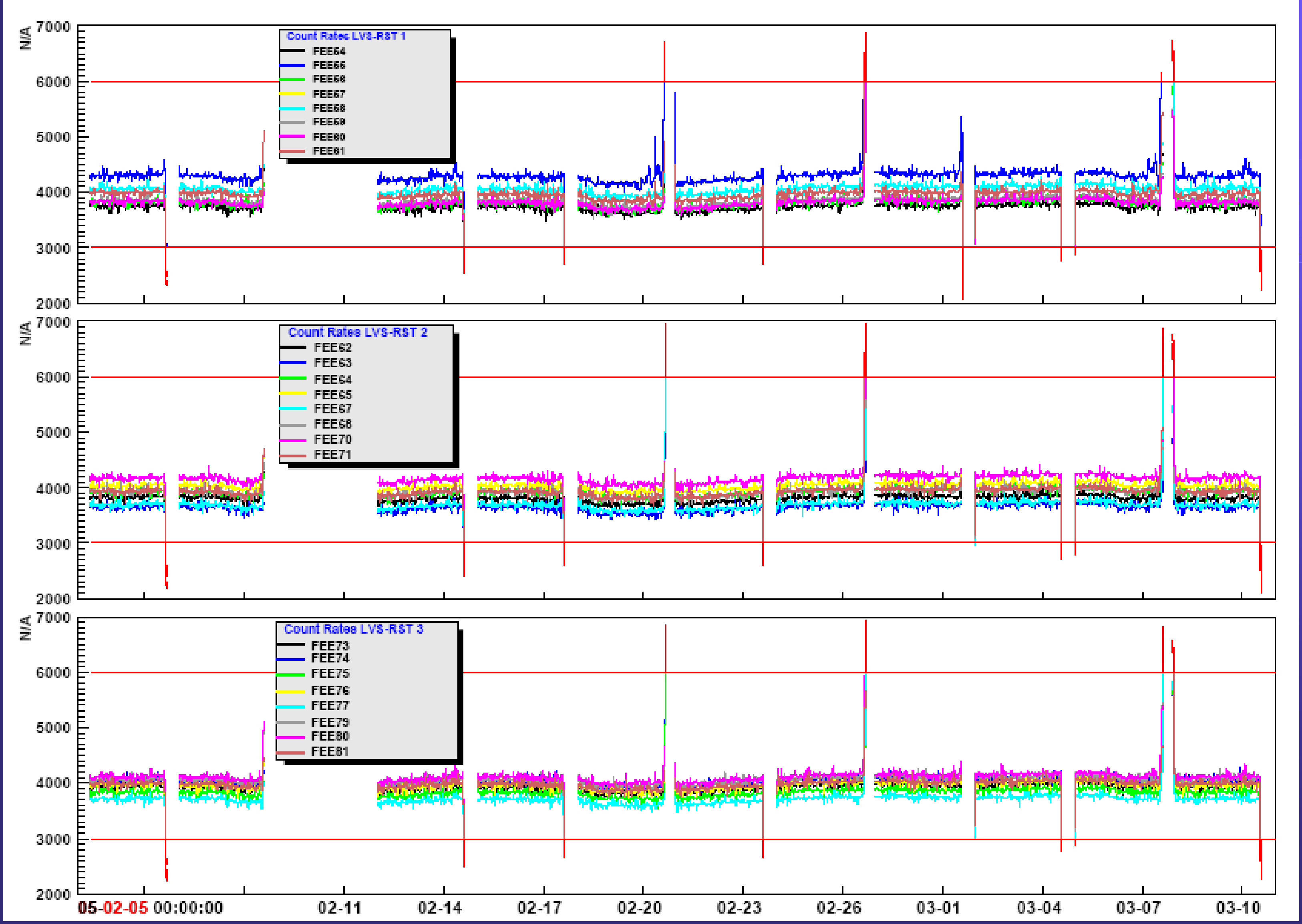
SSA count rates: 05.02. - 11.03.05



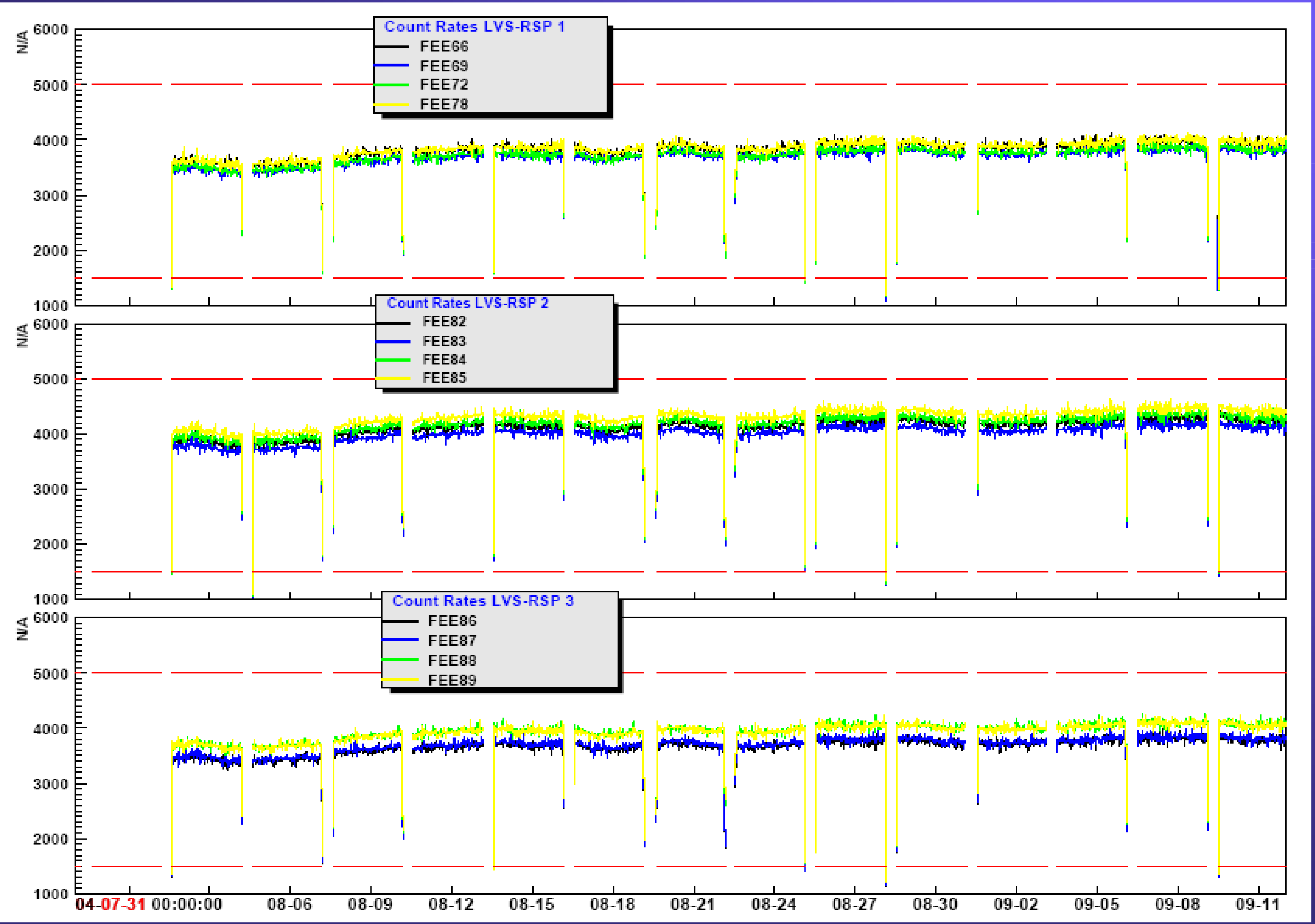
RST count rates: 03.07. - 12.09.04



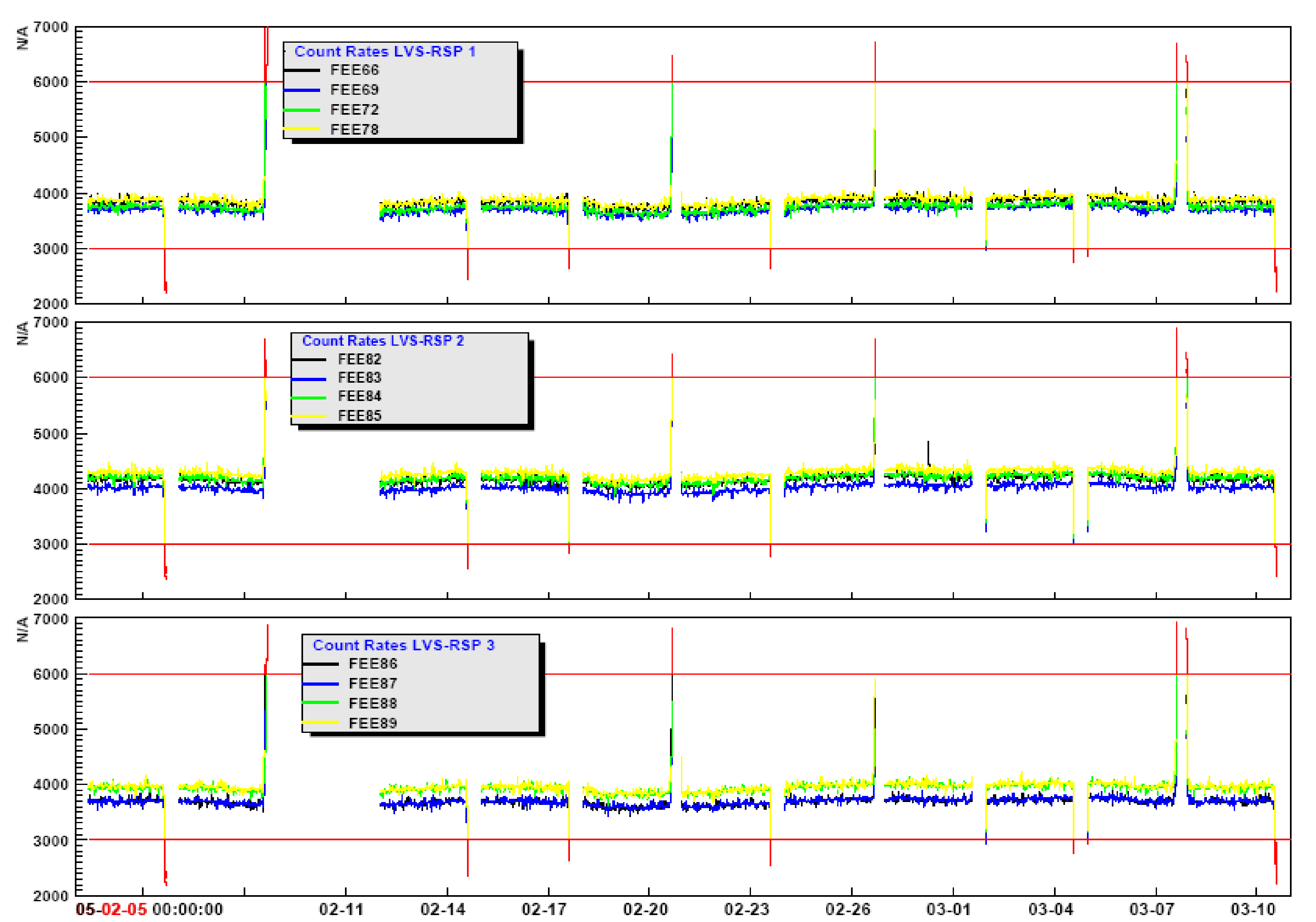
RST count rates: 05.02. - 11.03.05



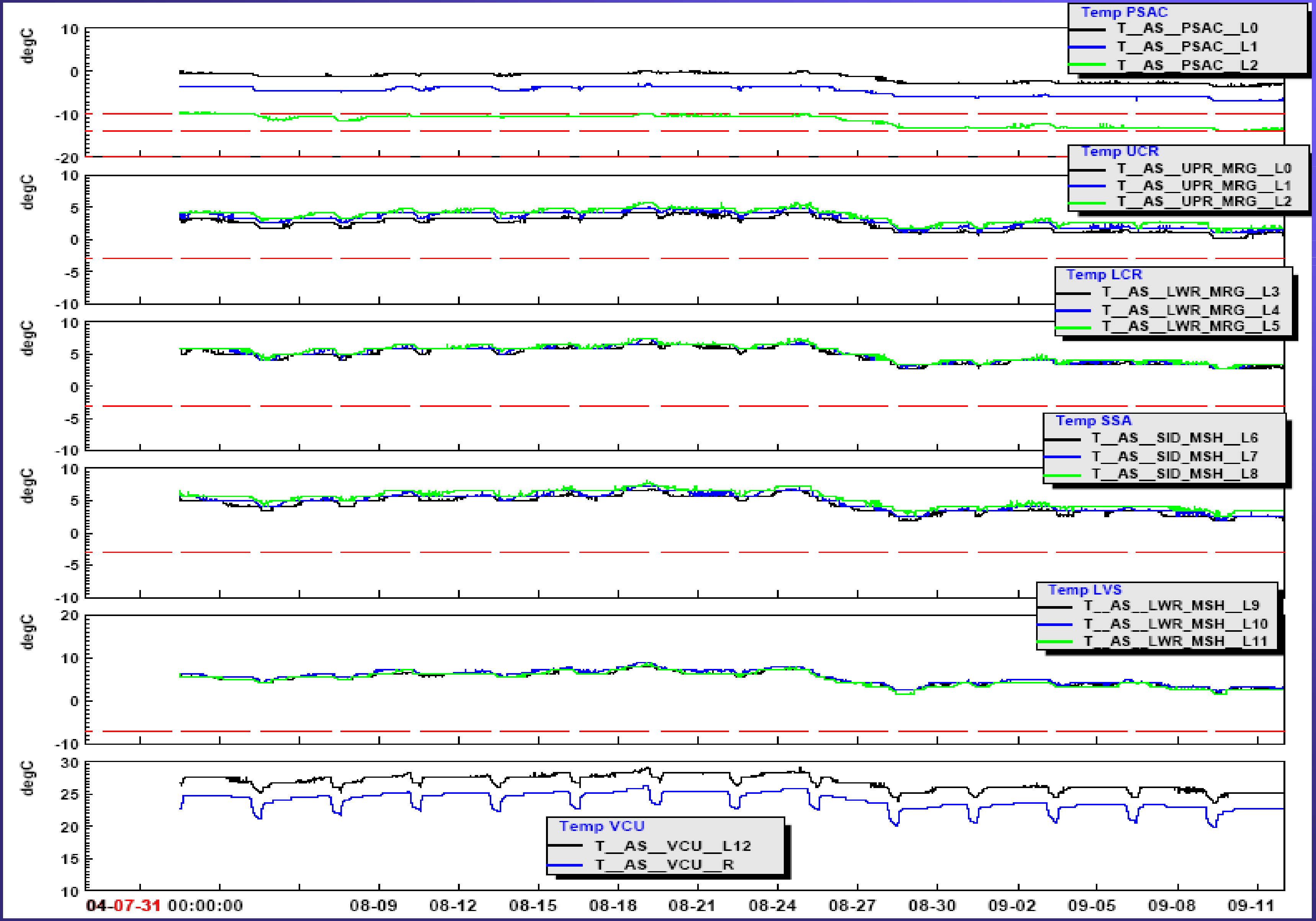
RSP count rates: 03.07. - 12.09.04



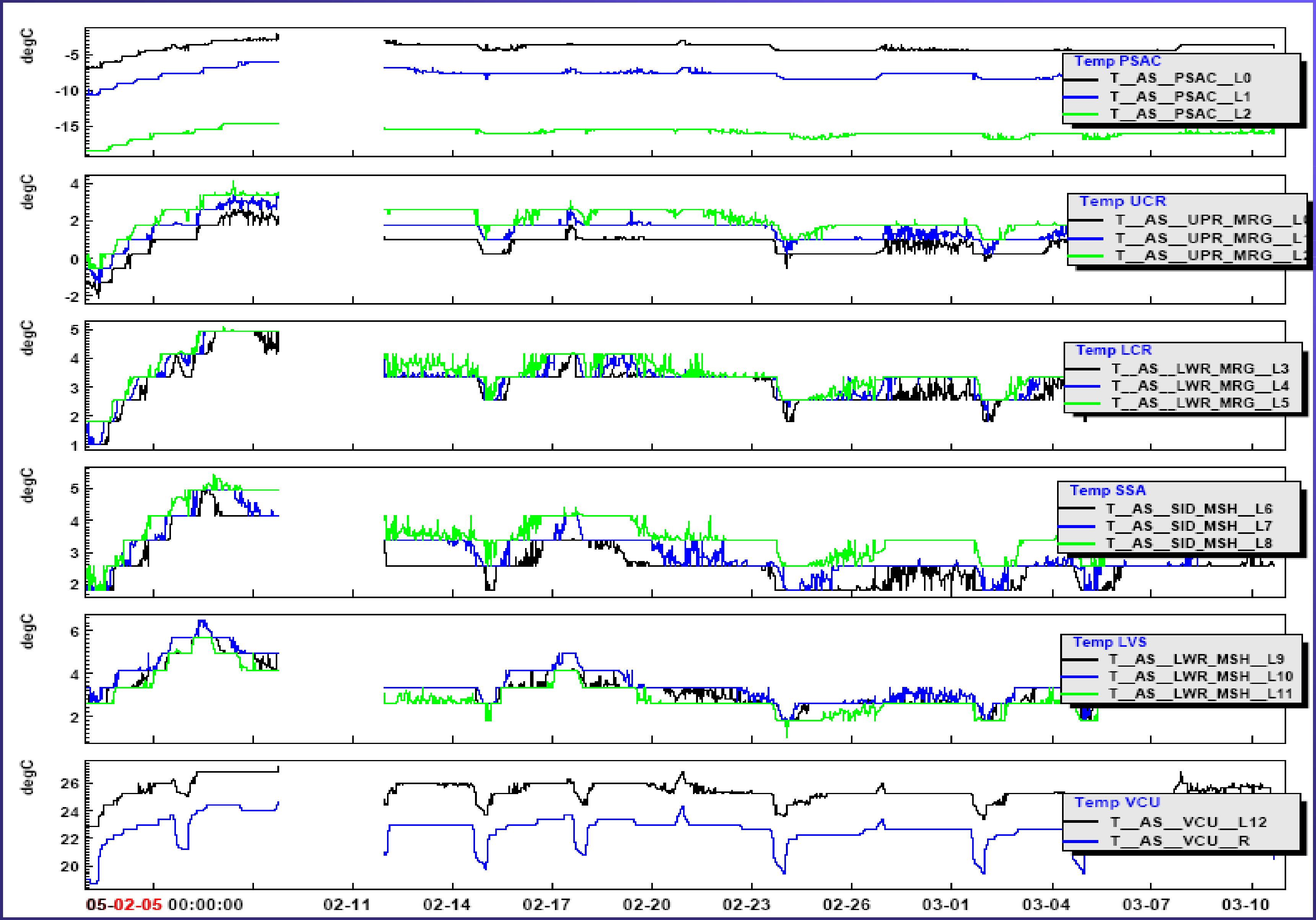
RSP count rates: 05.02. - 11.03.05



ACS temperature: 03.07. - 12.09.04



ACS temperature: 05.02. - 11.03.05



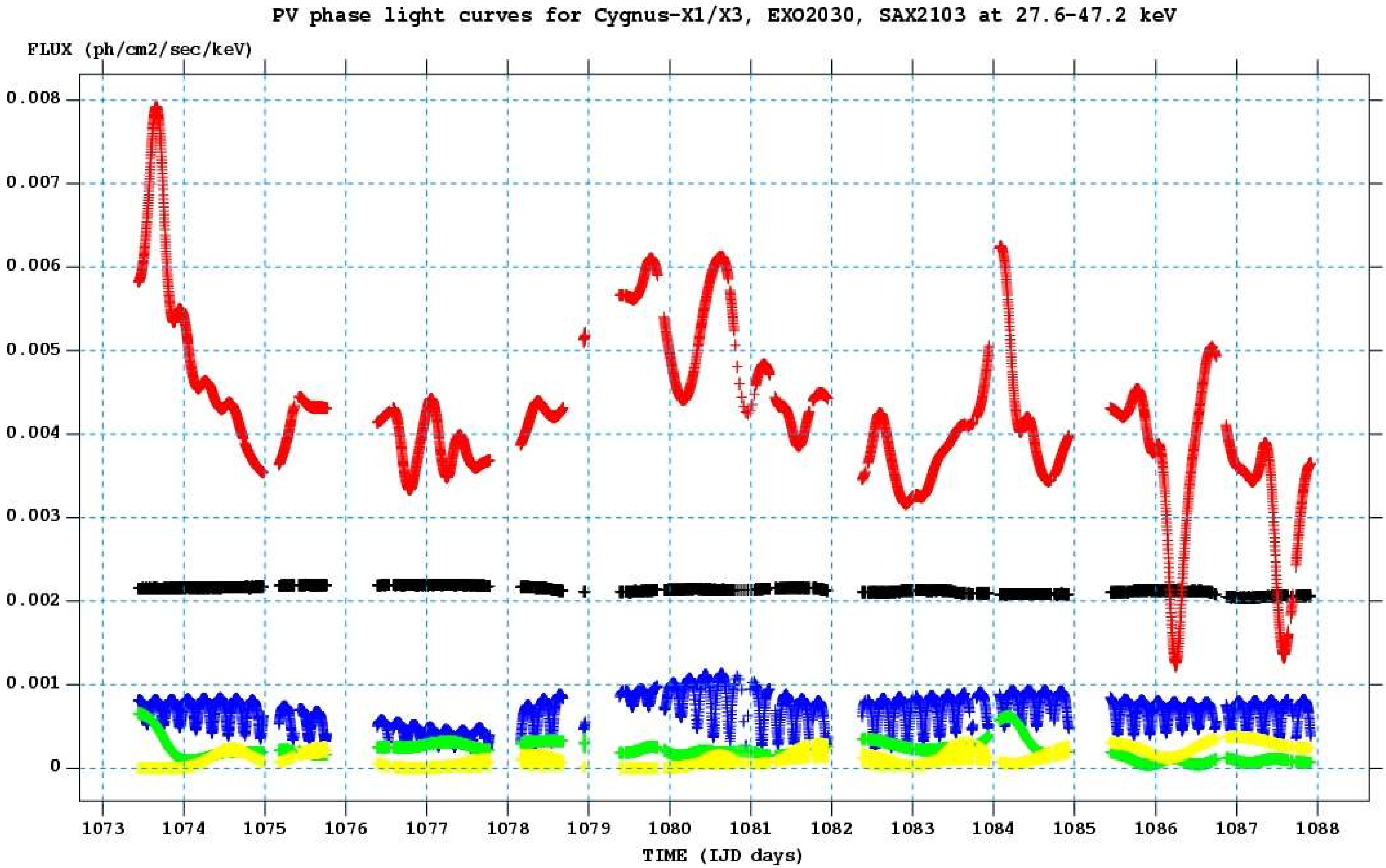
Timing mode in SPIROS

P.H.Connell
University of Valencia
Spain

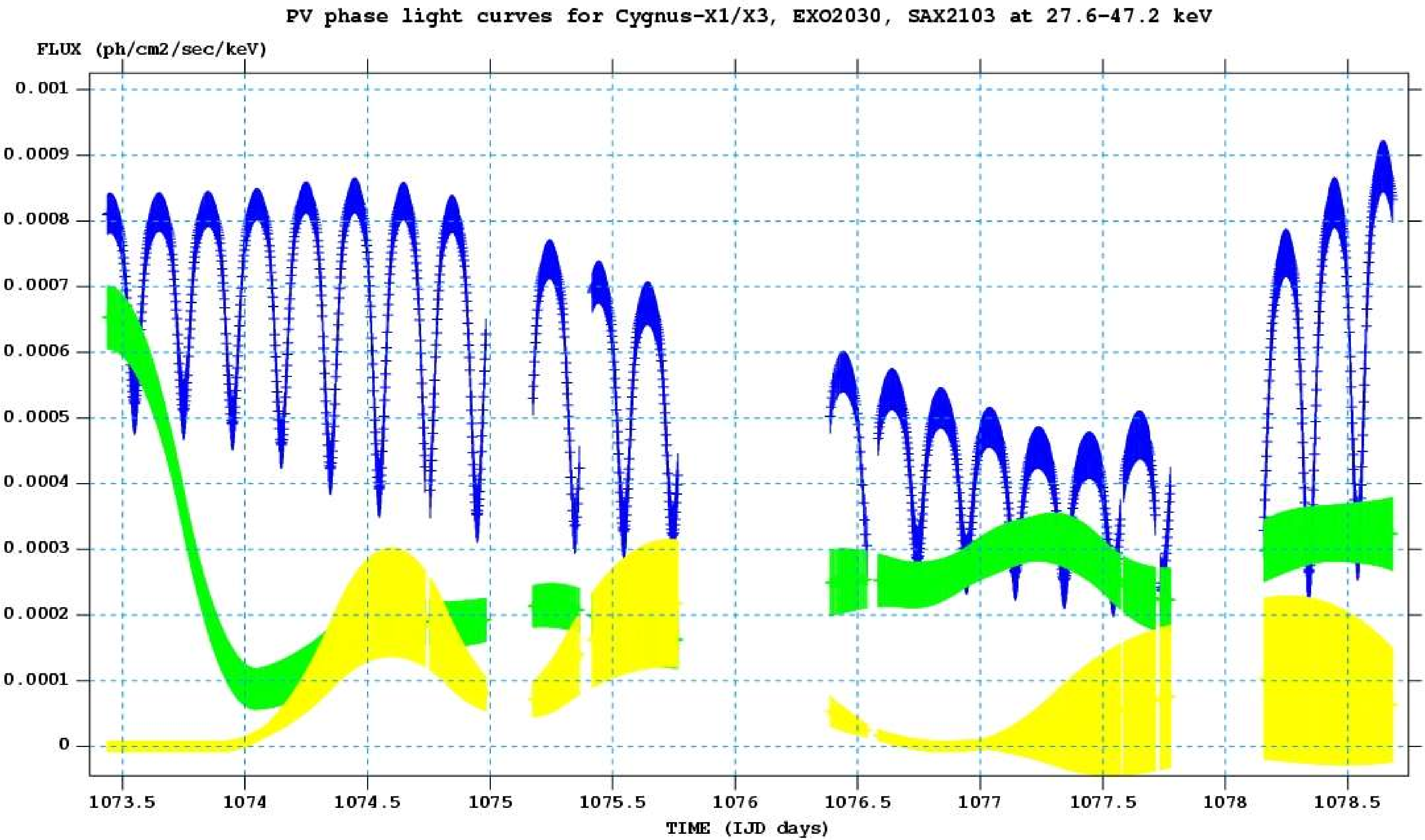
New options in timing mode analysis

- Individual time binning for each catalogue source
- General spline modelling of background – BH6
- QUICKSCAN option for a more detailed overview
- TRANSIENT option eclipsing and flaring functions
- Effects on output solution from background models

Light curves with different timescales in the Cygnus region



Light curves with regular eclipsing and flaring variability



Independent time binning for each catalogue source

- In timing mode the time bins of all sources normally have the same default length given by the input parameter “source-timing-scale”.

- Any catalogue source may have its own time bin length by setting its parameters VAR_MODL to “TIME-SCALE” and VAR_PAR(5) to a different time scale.

- This applies to TRANSIENT, WINDOW and QUICKSCAN mode.

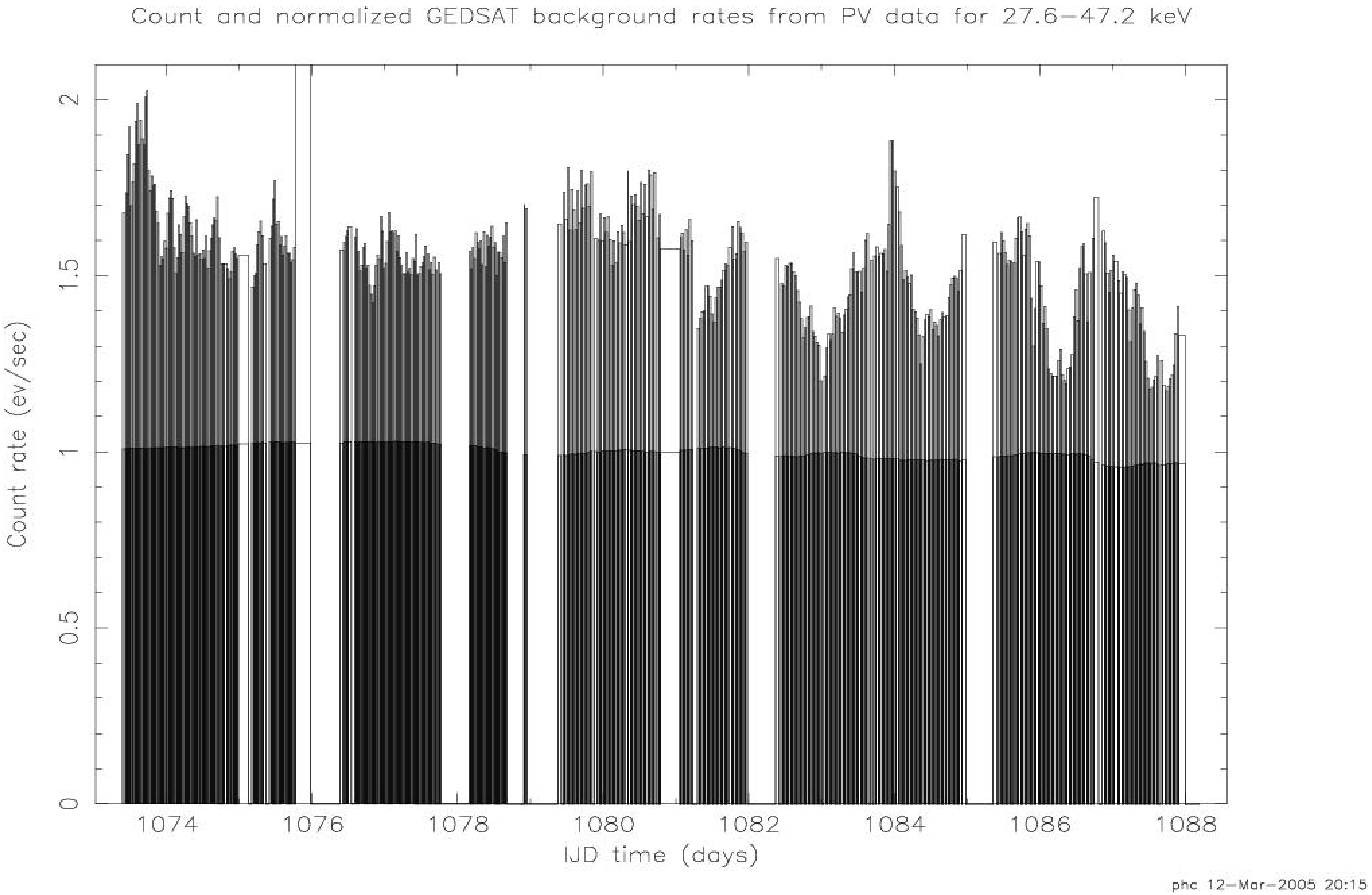
Generalized splined background modelling – BH6

SPIROS now has three basic background handling methods:

- Background tracers like GEDSAT, etc - BH2.
- Mean count modulation model – BH5.
  Returns a M(d)*B(p) background pattern with M(d) modulation values for each detector and mean background per pointing B(p).
- Splined time bin modelling on a minimal time scale – BH6.
  Detector background is handled exactly as sky sources with an effective mask pattern that is the same for all exposures.

  Used in WINDOW and TRANSIENT timing mode by dividing the observation period into a sequence of more or less equal time bins covering pointing groups with the parameter "source-timing-scale" or "backgr-timing-scale".

PV phase count data and its GEDSAT background tracer



Mean count modulation background model

Assuming detector background $\mathbf{B(d,p)}$ can be modelled as a multiplicative function of the type $\mu_\mathbf{d}\mathbf{B_p}$ the coded mask count response to sources $\alpha_\mathbf{n}$ can be written as

$$\mathbf{C_{d,p}} \; = \; \mu_\mathbf{d} \; \mathbf{B_p} \; + \; \sum_\mathbf{n} \mathbf{M_{d,p,n}} \; \alpha_\mathbf{n} \qquad (1)$$

The mean value over all detectors for each pointing is then

$$\overline{\mathbf{C}}_\mathbf{p} \; = \; \overline{\mu} \; \mathbf{B_p} \; + \; \sum_\mathbf{n} \overline{\mathbf{M}}_\mathbf{n,p} \; \alpha_\mathbf{n} \qquad (2)$$

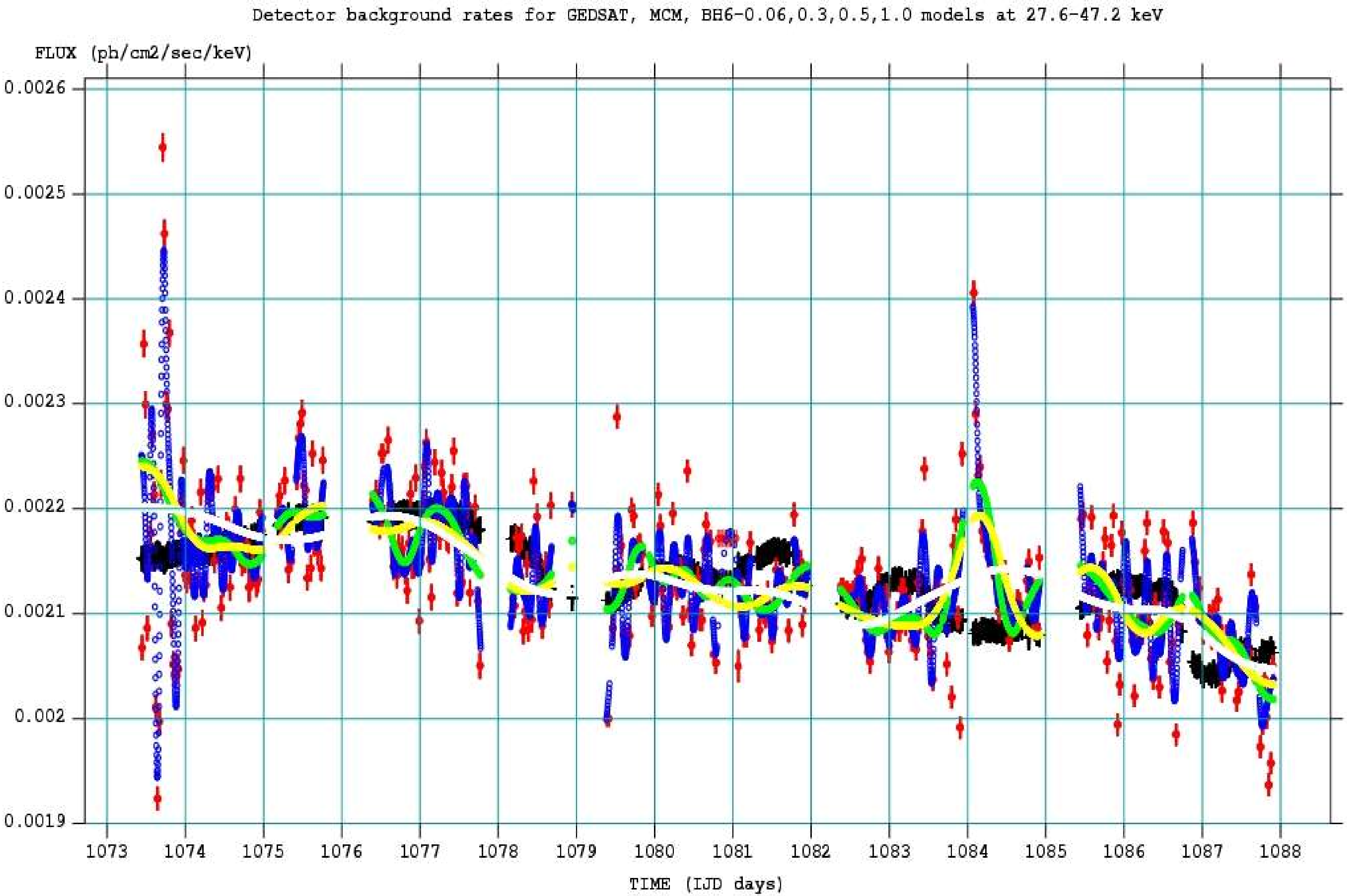
Multiplying by $\beta_\mathbf{d} = \mu_\mathbf{d}/\overline{\mu}$ the background can subtraced from (1) to give

$$\mathbf{C_{d,p}} - \beta_\mathbf{d} \; \overline{\mathbf{C}}_\mathbf{p} \; = \; \sum_\mathbf{n} \left[\mathbf{M_{d,p,n}} - \beta_\mathbf{d} \; \overline{\mathbf{M}}_\mathbf{n,p} \right] \alpha_\mathbf{n} \qquad (3)$$

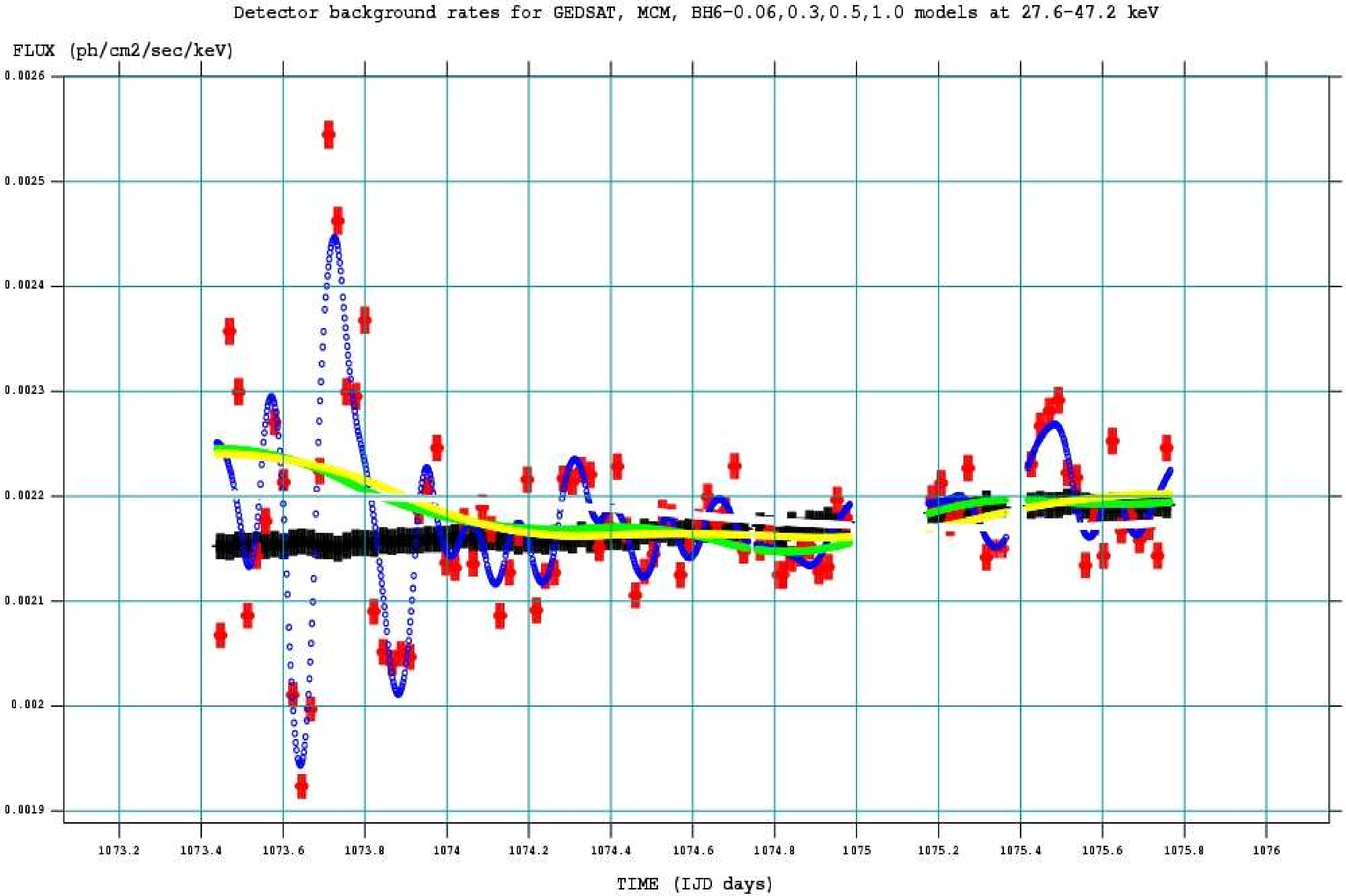
or the **MEAN COUNT MODULATION** background model equation

$$\mathbf{c_{d,p}}(\beta_\mathbf{d}) \; = \; \sum_\mathbf{n} \mathbf{m_{d,p,n}}(\beta_\mathbf{d}) \; \alpha_\mathbf{n} \qquad (4)$$

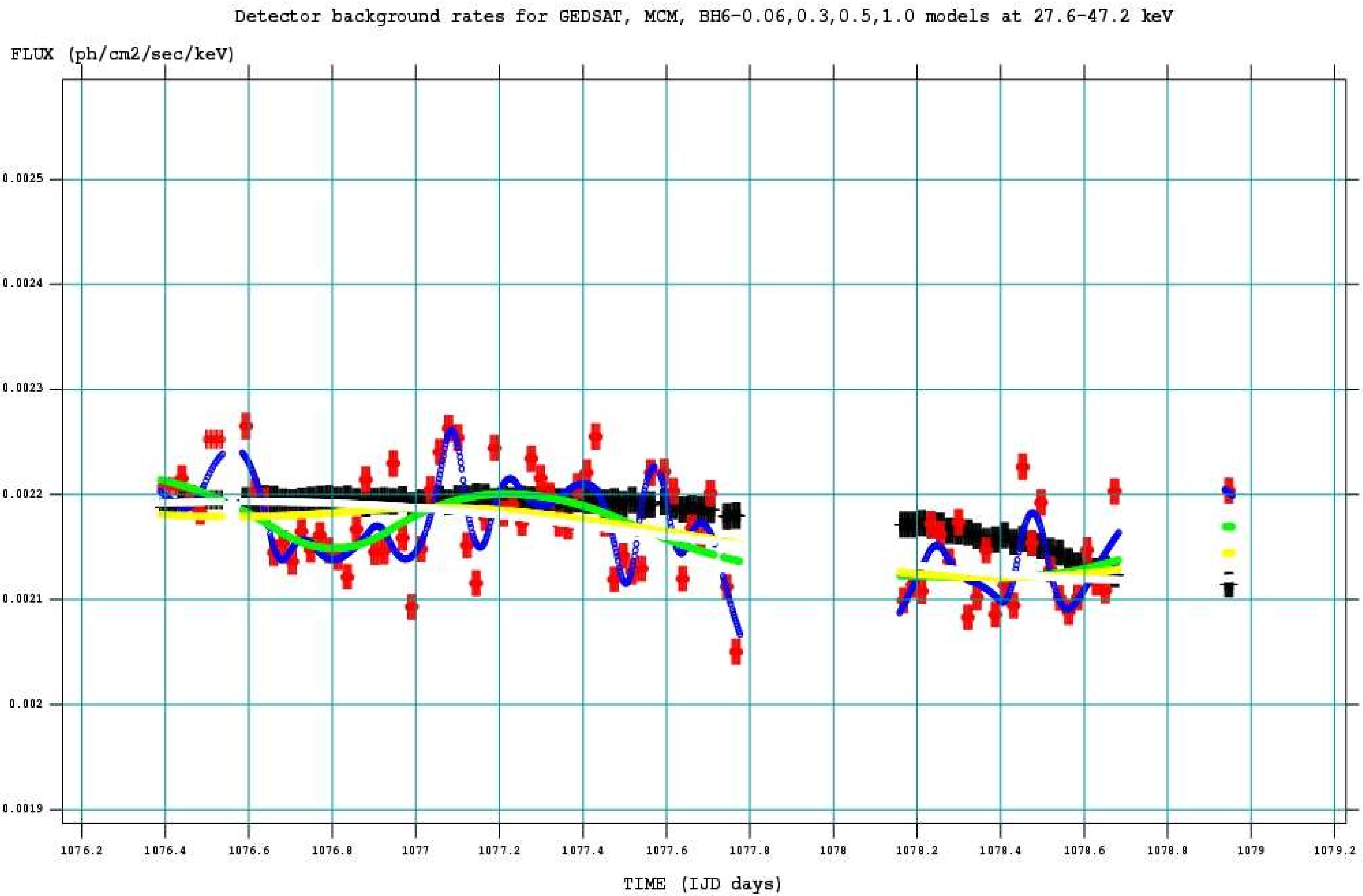
GEDSAT, MCM and BH6 background light curves



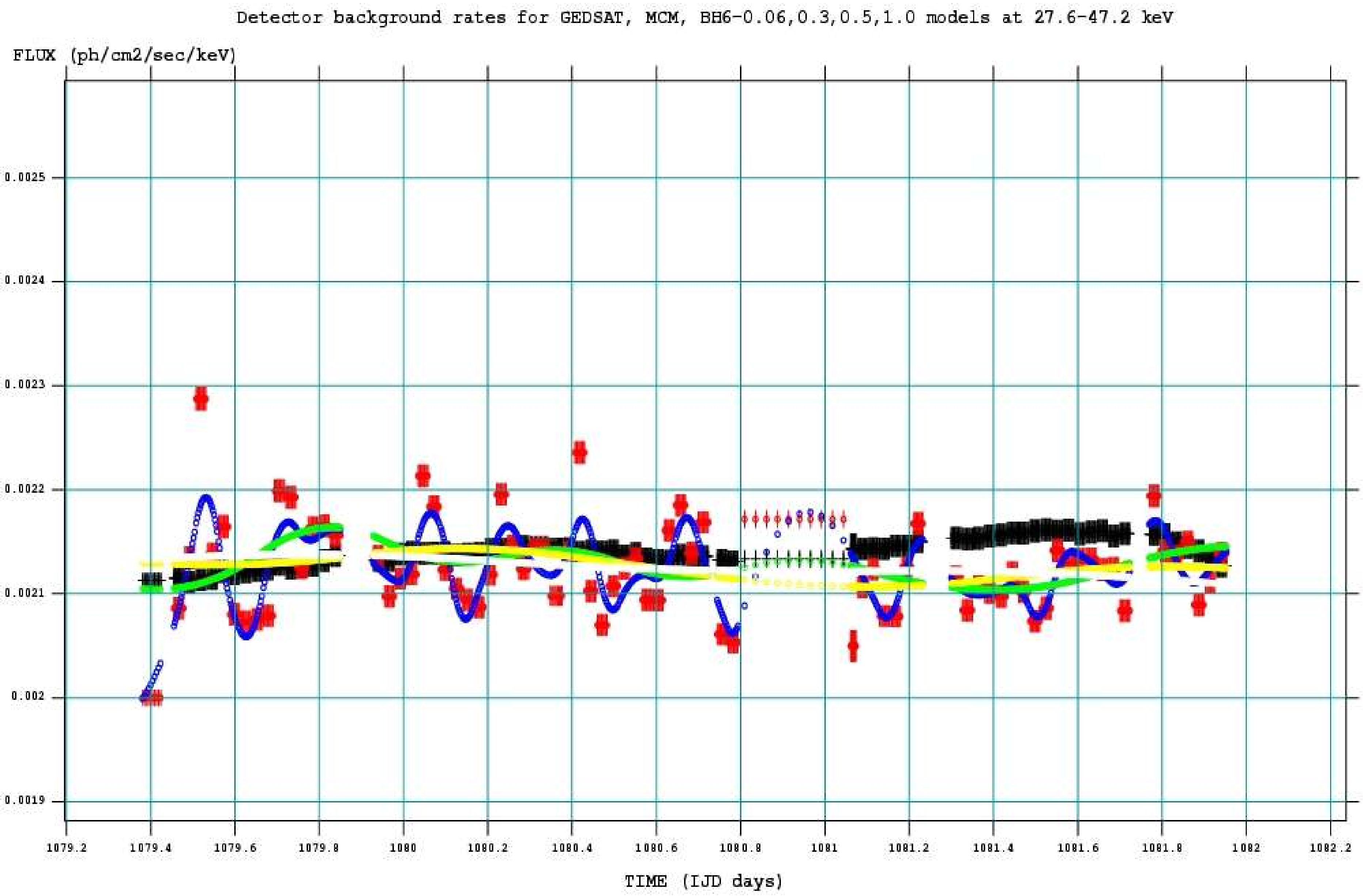
GEDSAT, MCM and BH6 light curves for orbit-19 PV data



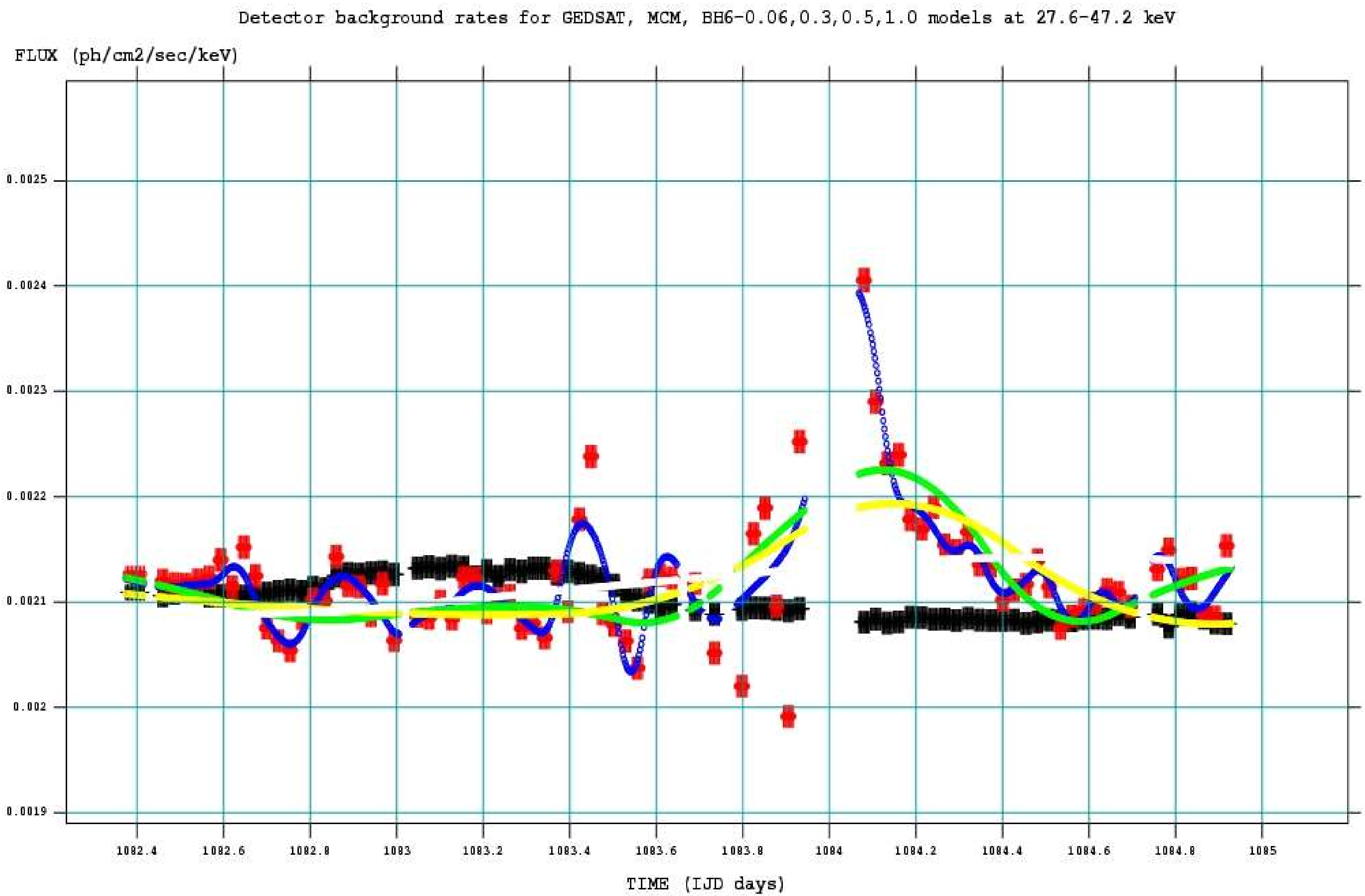
GEDSAT, MCM and BH6 light curves for orbit-20 PV data



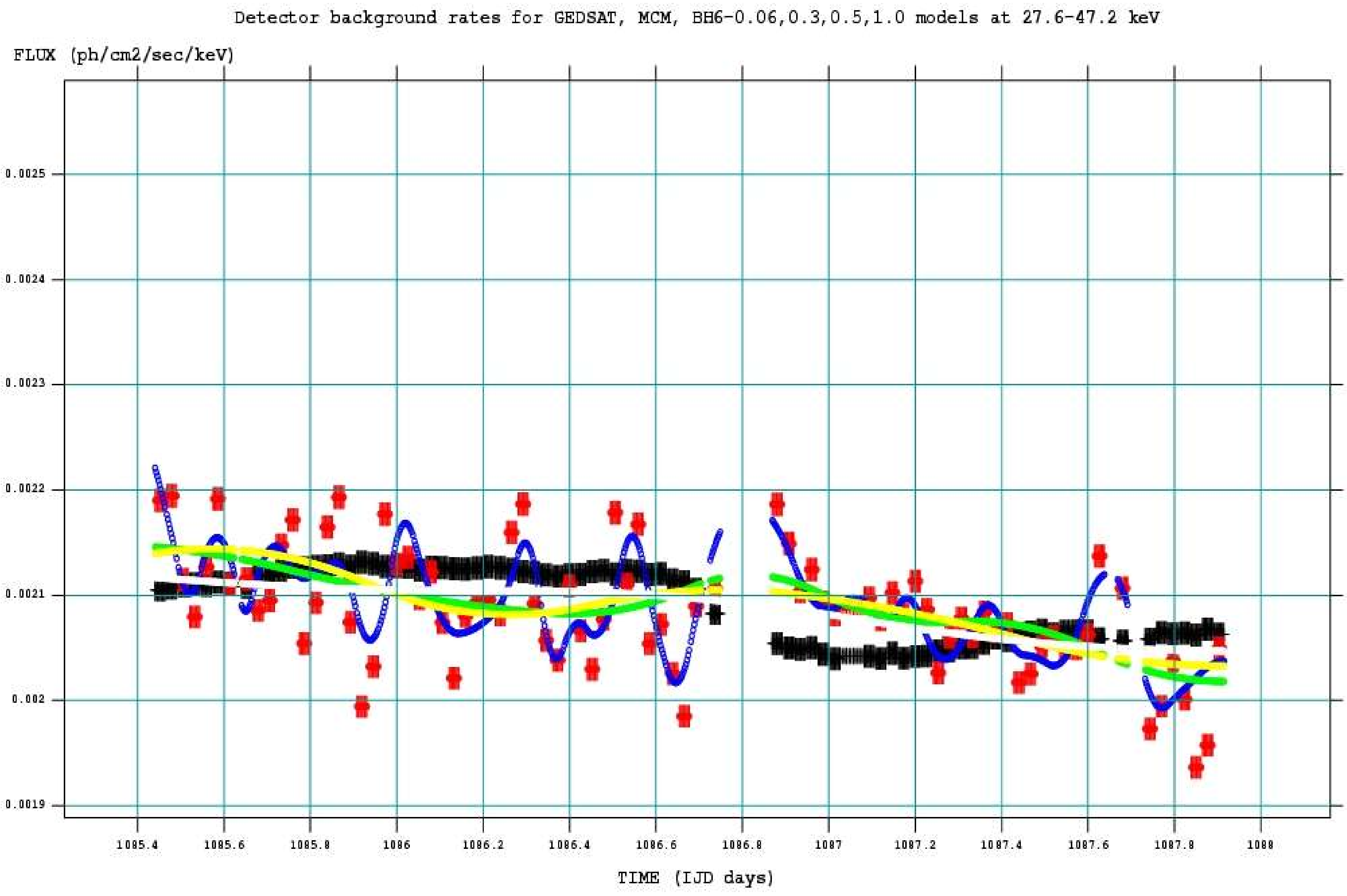
GEDSAT, MCM and BH6 light curves for orbit-21 PV data



GEDSAT, MCM and BH6 light curves for orbit-22 PV data



GEDSAT, MCM and BH6 light curves for orbit-23 PV data



Light curves with QUICKSCAN moving window scan

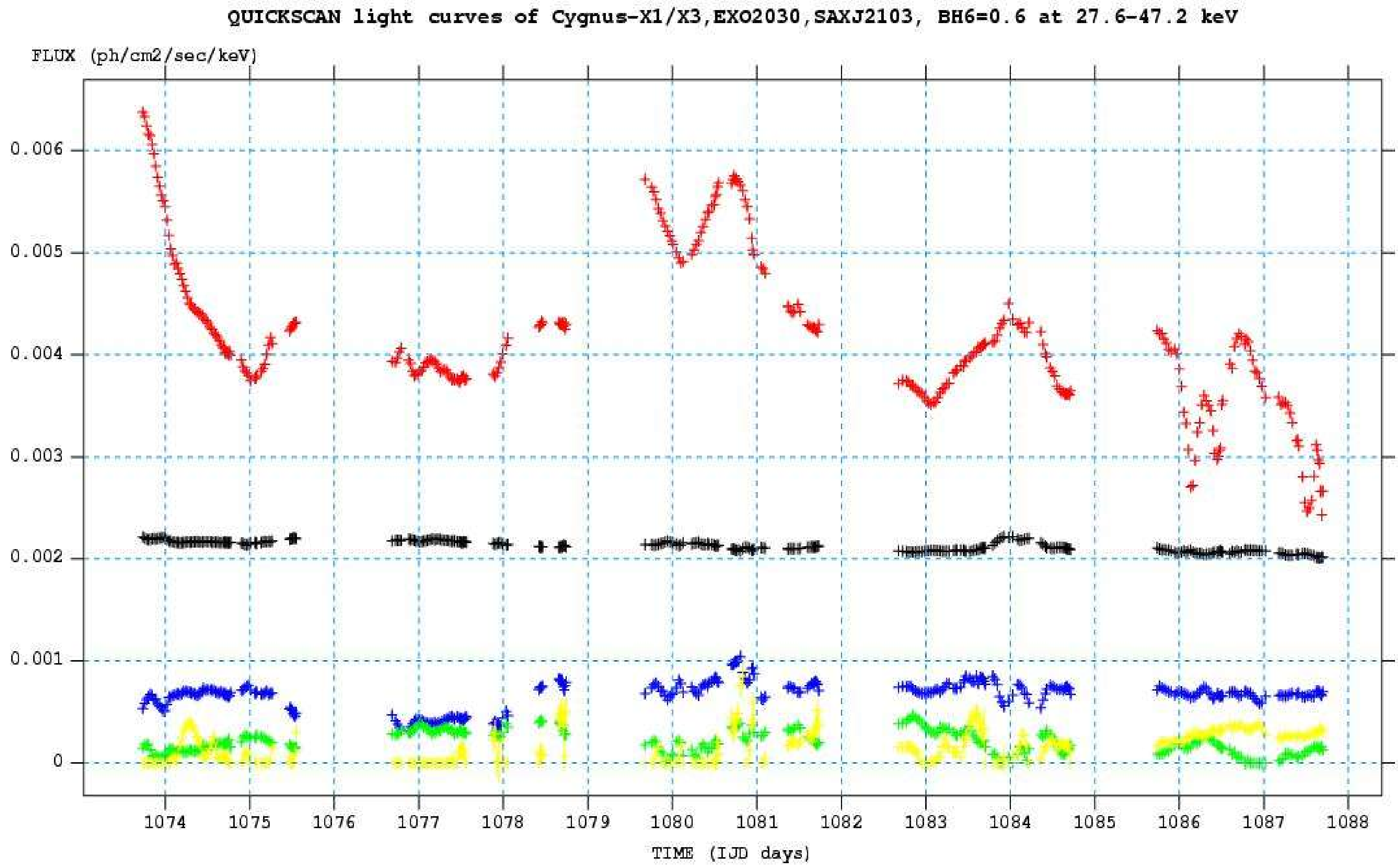
- QUICKLOOK scans an observation period in a sequence of roughly equal independent timebins covering non overlapping pointing groups. It does not give information about the period between adjacent timebins.

- QUICKSCAN scans an observation with a moving timebin or window, covering roughly equal length pointing groups, but beginning at each pointing to produce roughly smoothed "moving average" light curves.

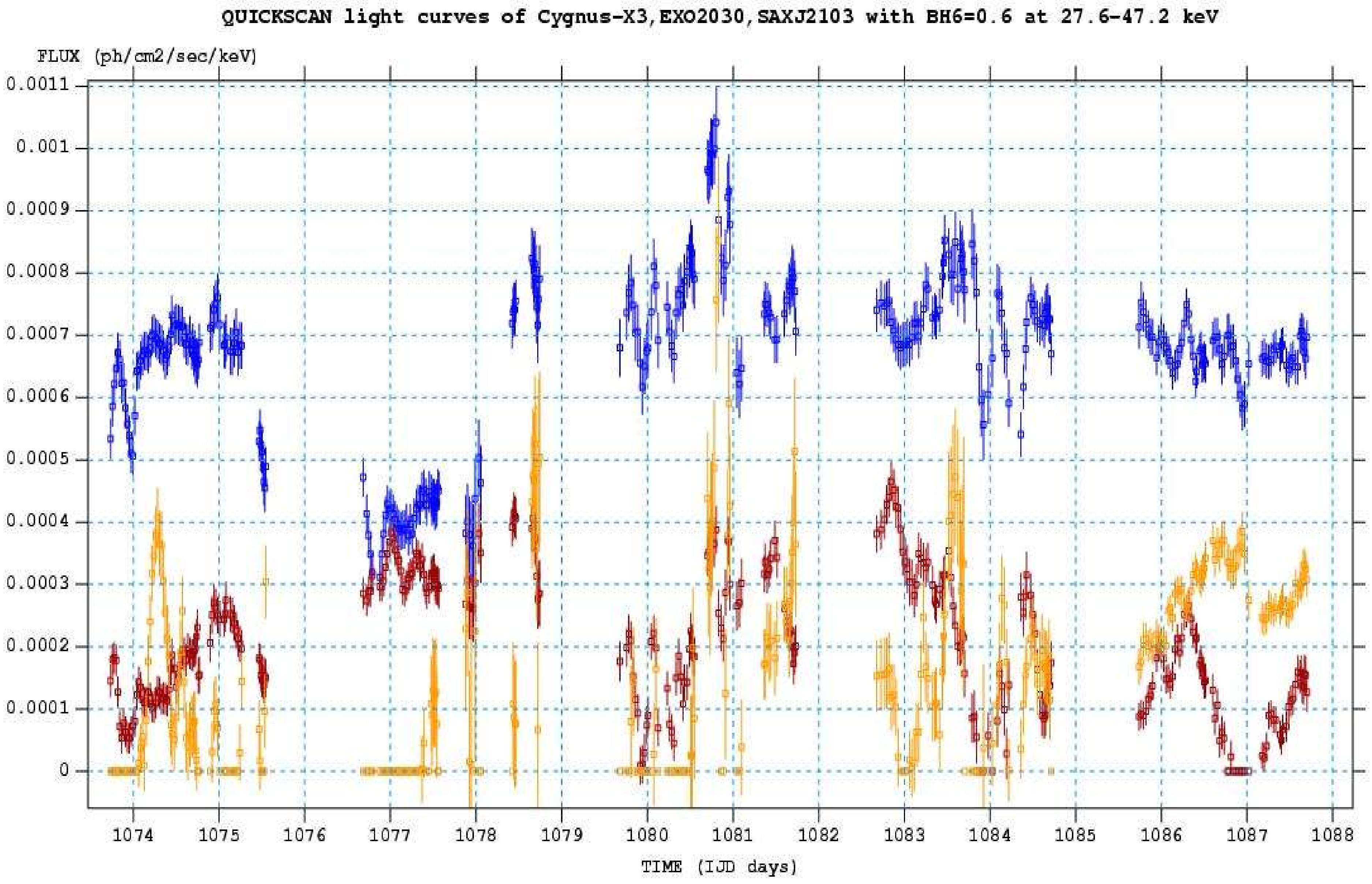
  The timebin length is given by parameter "source-timing-scale" but any source can have a finer time scale in parameter VAR_PARS(5).

  Background can also be estimated in timebins via BH6 with a length given by parameter "source-timing-scale" or "backgr-timing-scale".

QUICKSCAN light curves of Cygnus region using PV data



QUICKSCAN light curves of Cygnus region using PV data



Light curves with TRANSIENT function modelling

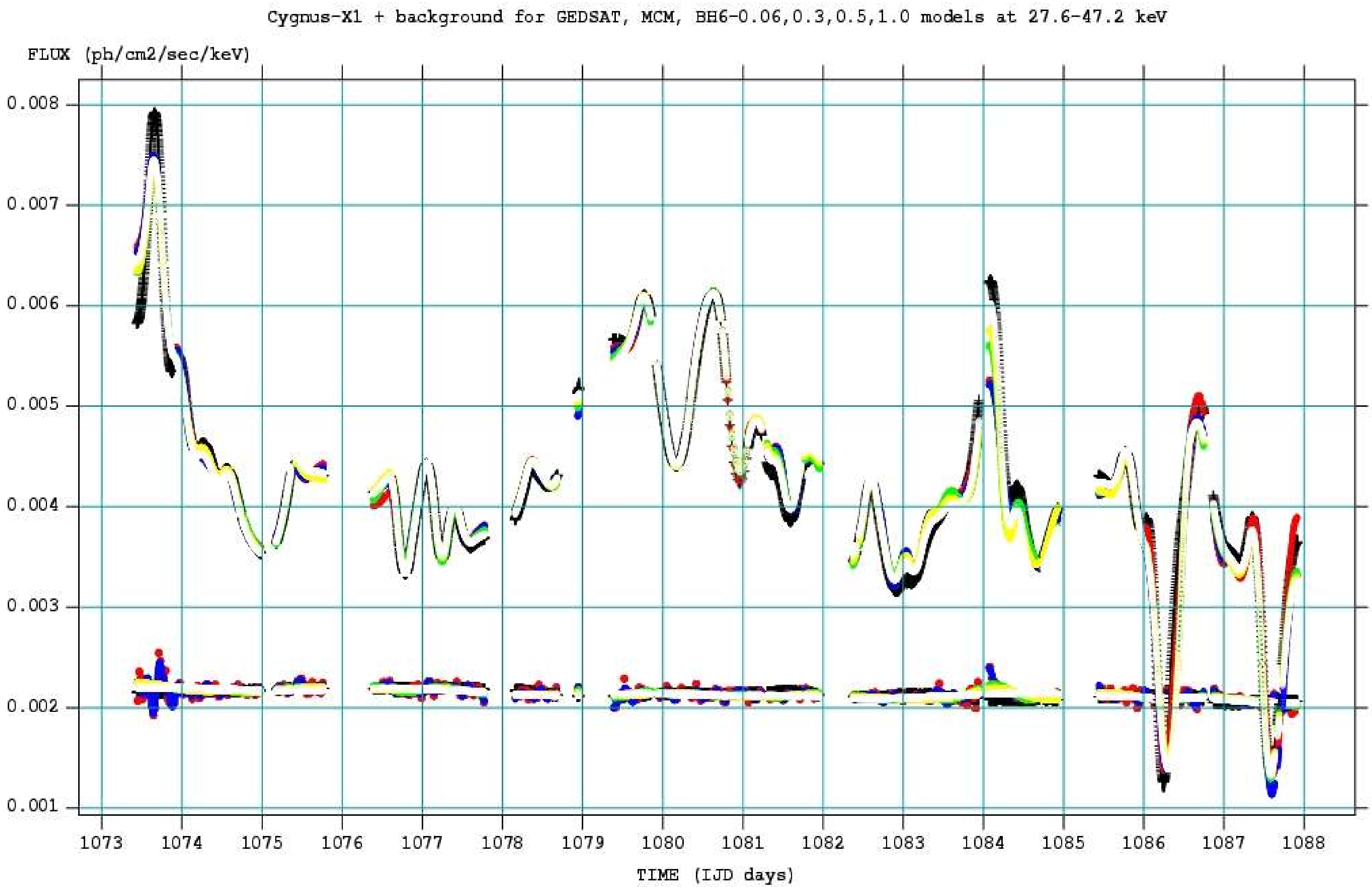
TRANSIENT mode will divide the observation period into groups of pointings of roughly equal length as in WINDOW mode but allows:

- HAT, LINEAR, QUADRATIC or CUBIC splining
- Cyclic flaring models
- Cyclic eclipsing model functions

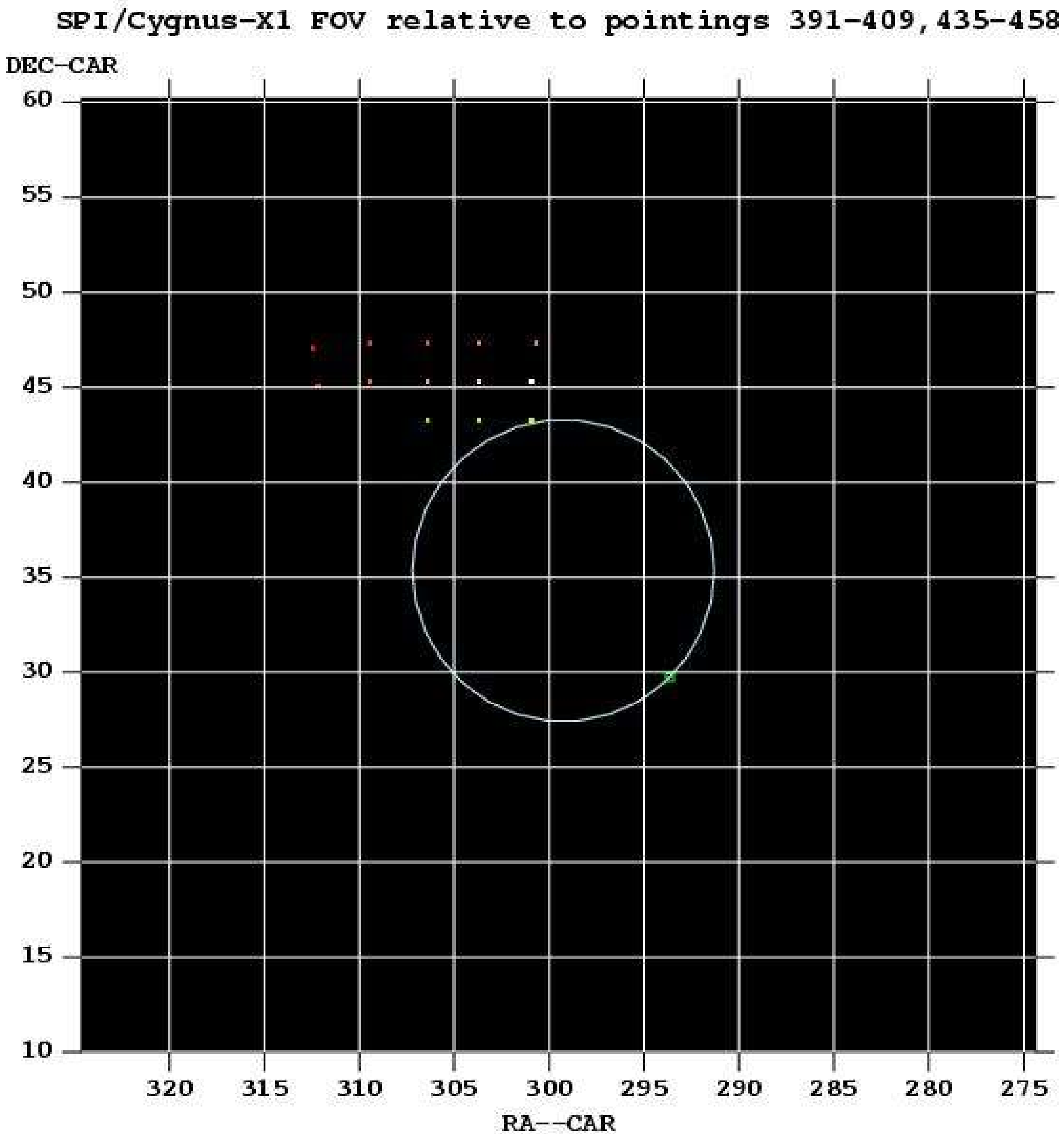
Each catalogue source will get the same default binning/splining type and time scale but may have its own specific modelling via parameters:

VAR_MODEL:	HAT, LIN, QUAD,CUBIC,FLARE,ECLIPSE-n,SINE
VAR_PARS(1):	Function start/reference time in whole days
VAR_PARS(2):	Day fraction of parameter (1)
VAR_PARS(3):	Flare duration
VAR_PARS(4):	Cycle period
VAR_PARS(5):	Timebin length or splining node separation
VAR_PARS(6):	Function factor
VAR_PARS(7):	Function factor

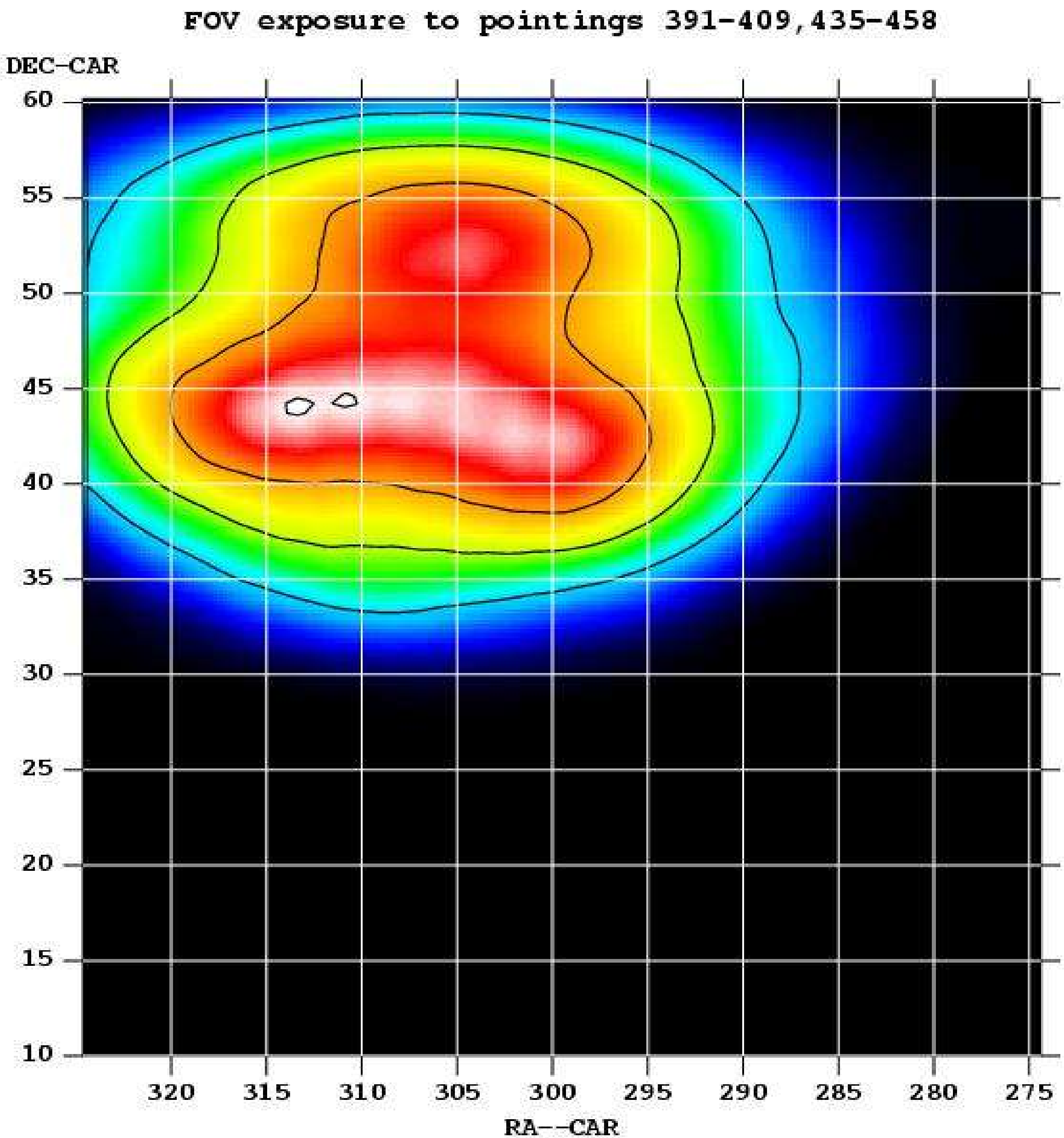
SPI light curves of Cygnus-X1 in PV phase



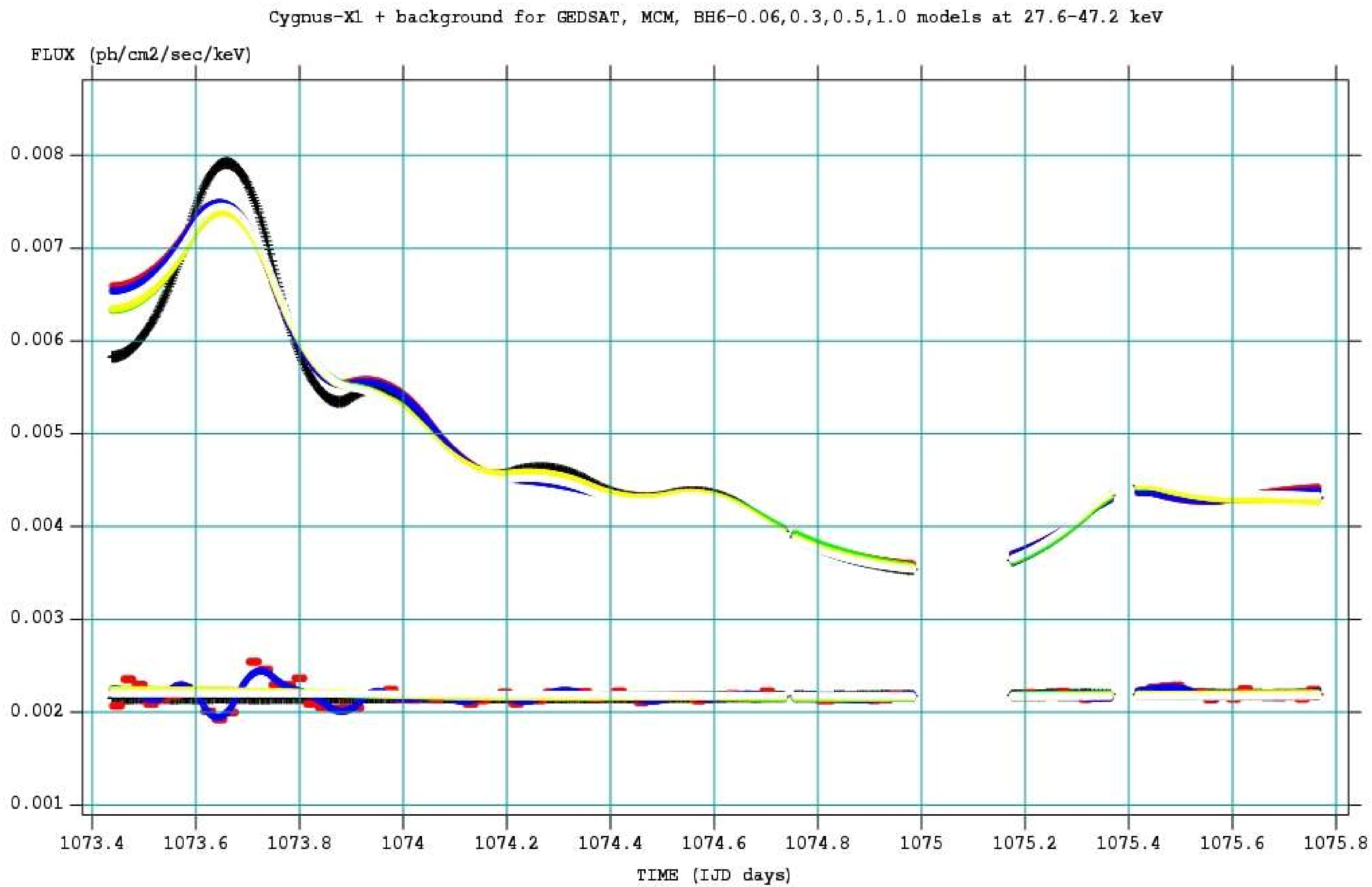
FOV pointings during Cygnus-X1 double dip



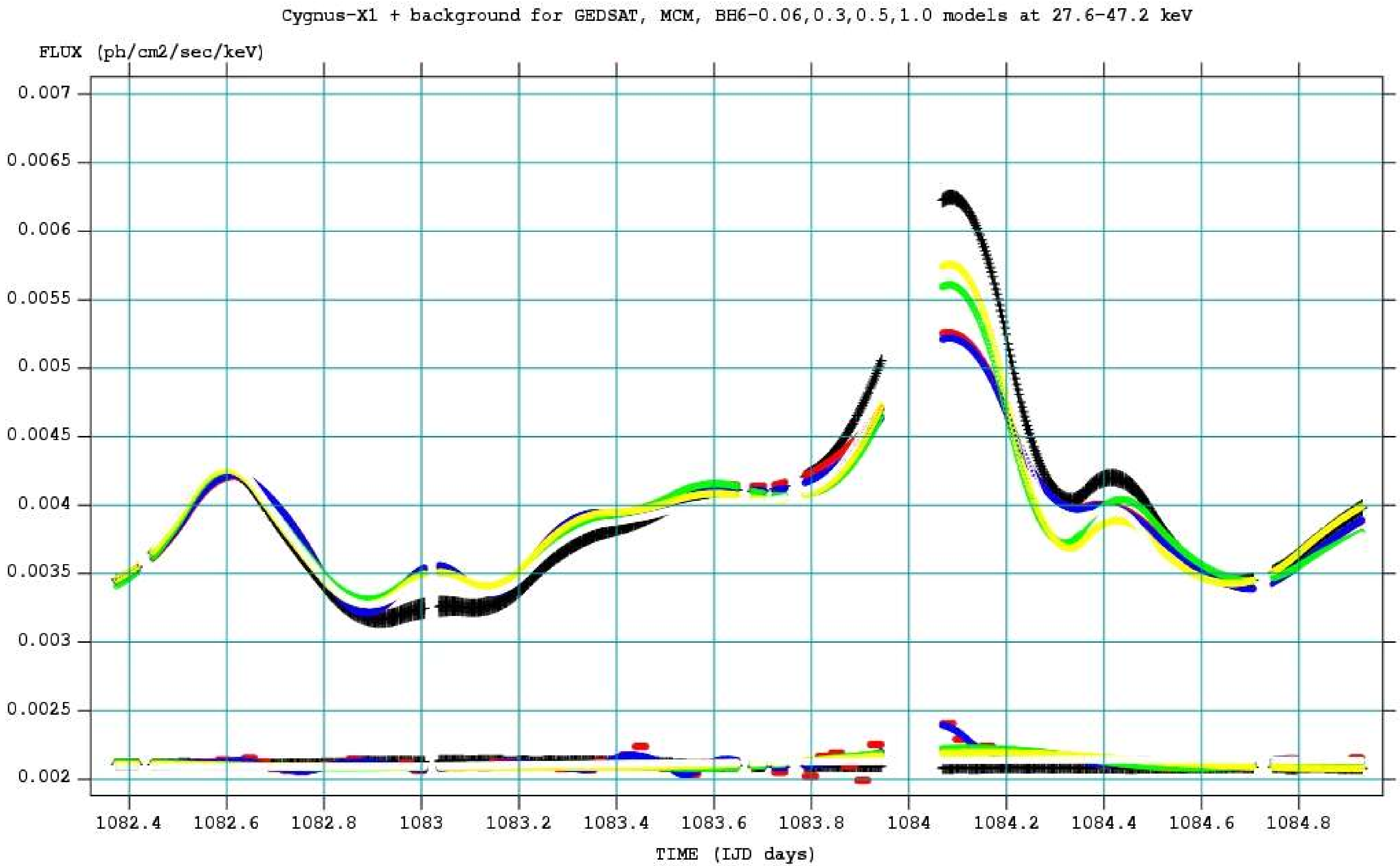
FOV exposure during Cygnus-X1 double dip



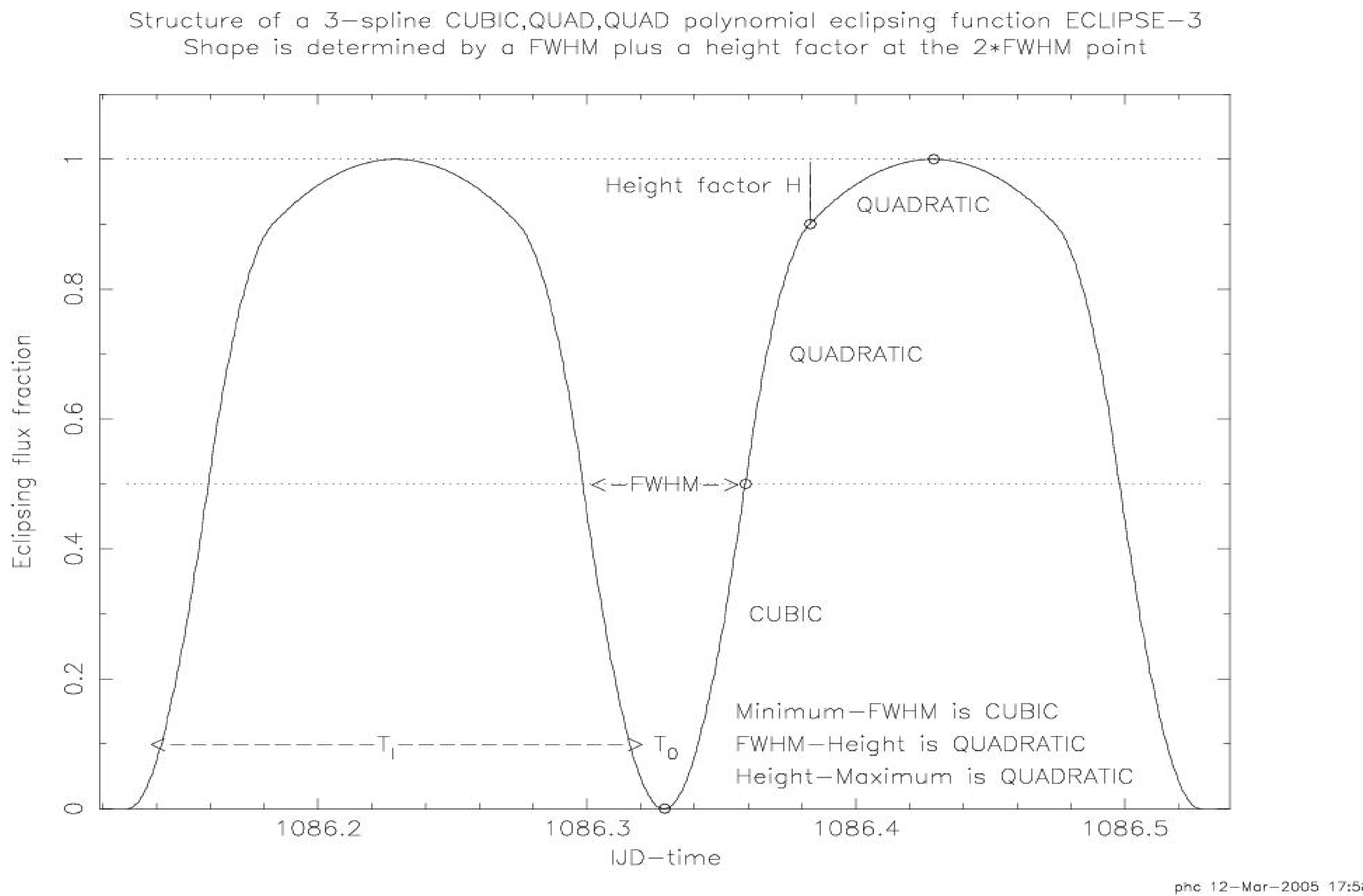
SPI light curves of Cygnus-X1 in orbit-19



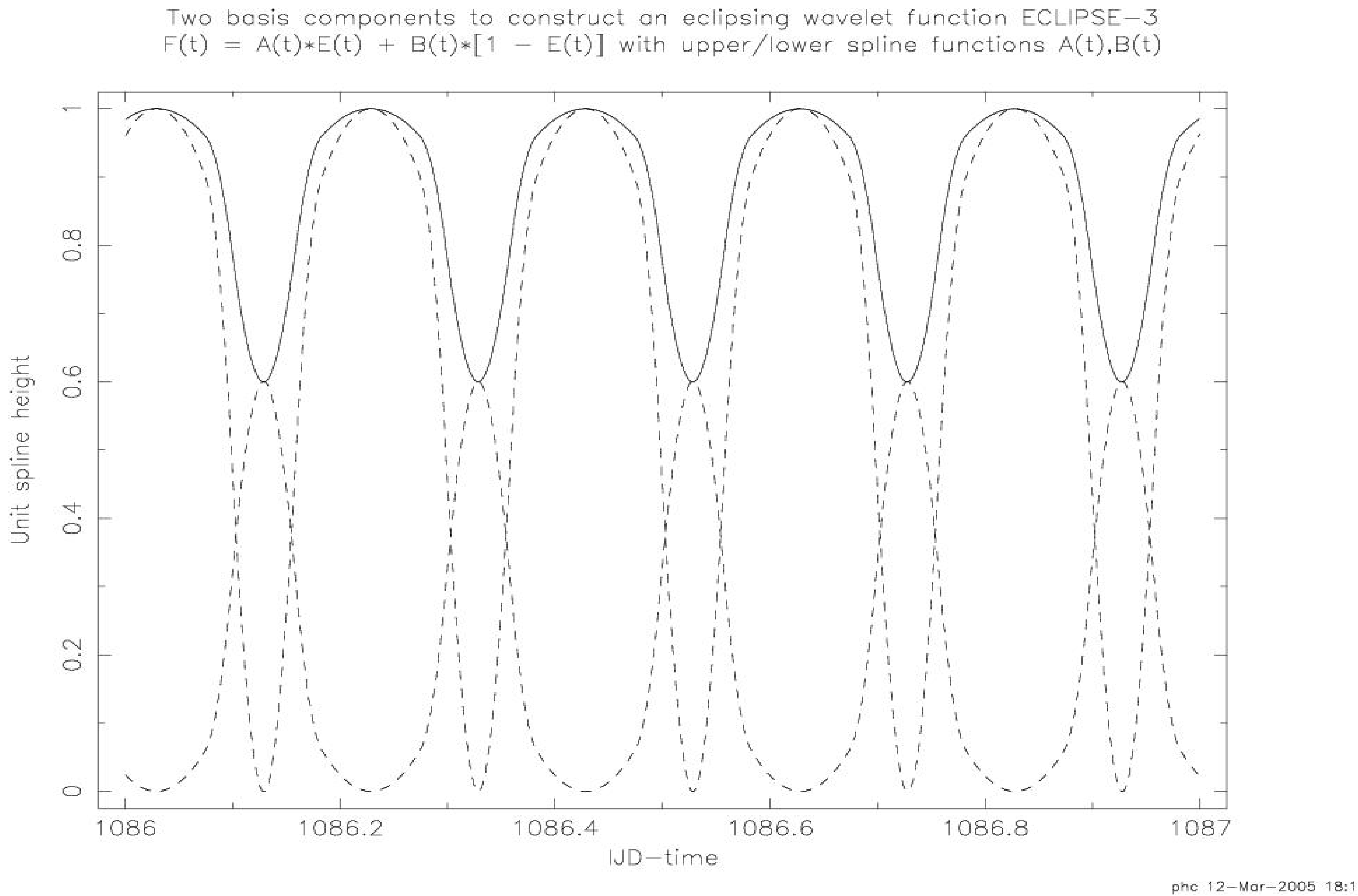
SPI light curves of Cygnus-X1 in orbit-22



Cygnus-X3 eclipsing model basis function ECLIPSE-3



Cygnus-X3 eclipsing wavelet function ECLIPSE-3



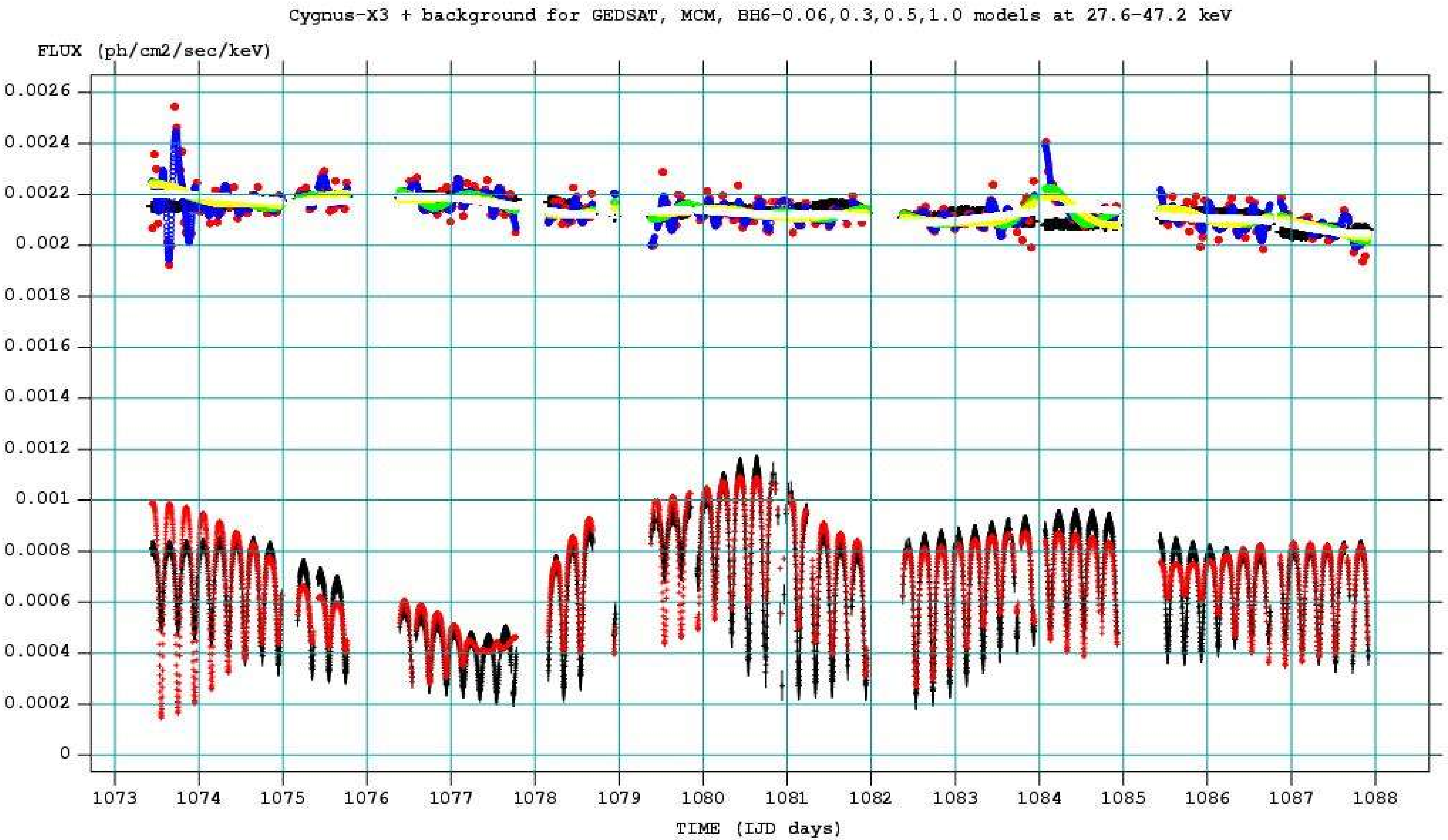
Cygnus-X3 eclipsing wavelet function ECLIPSE-3

The ECLIPSE-3 function may be specified in the source catalogue as:

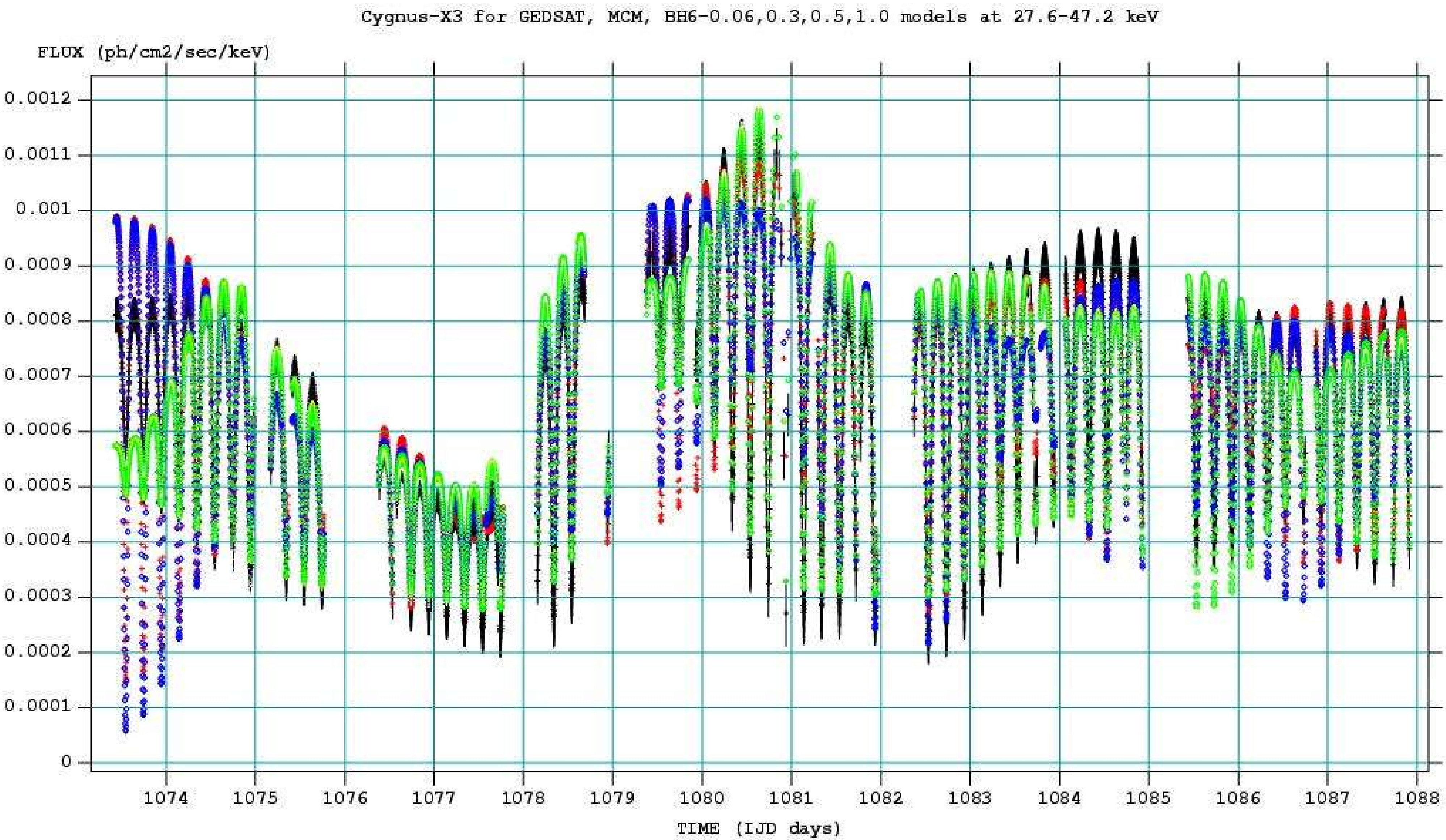
VAR_MODL:	ECLIPSE-3	A(t),B(t) are constant
	ECLIPSE-3*HAT	A(t),B(t) have hat splines/bins
	ECLIPSE-3*QUADR	A(t),B(t) have quadratic splines
	ECLIPSE-3*CUBIC	A(t),B(t) have cubic spline

VAR_PARS(1):	T0 in whole days – location of minimum
VAR_PARS(2):	T0 day fraction
VAR_PARS(3):	T1 - flare duration
VAR_PARS(4):	T1 - flare cycle period
VAR_PARS(5):	timebin scale for spline nodes/bins
VAR_PARS(6):	FWHM factor
VAR_PARS(7):	Height factor

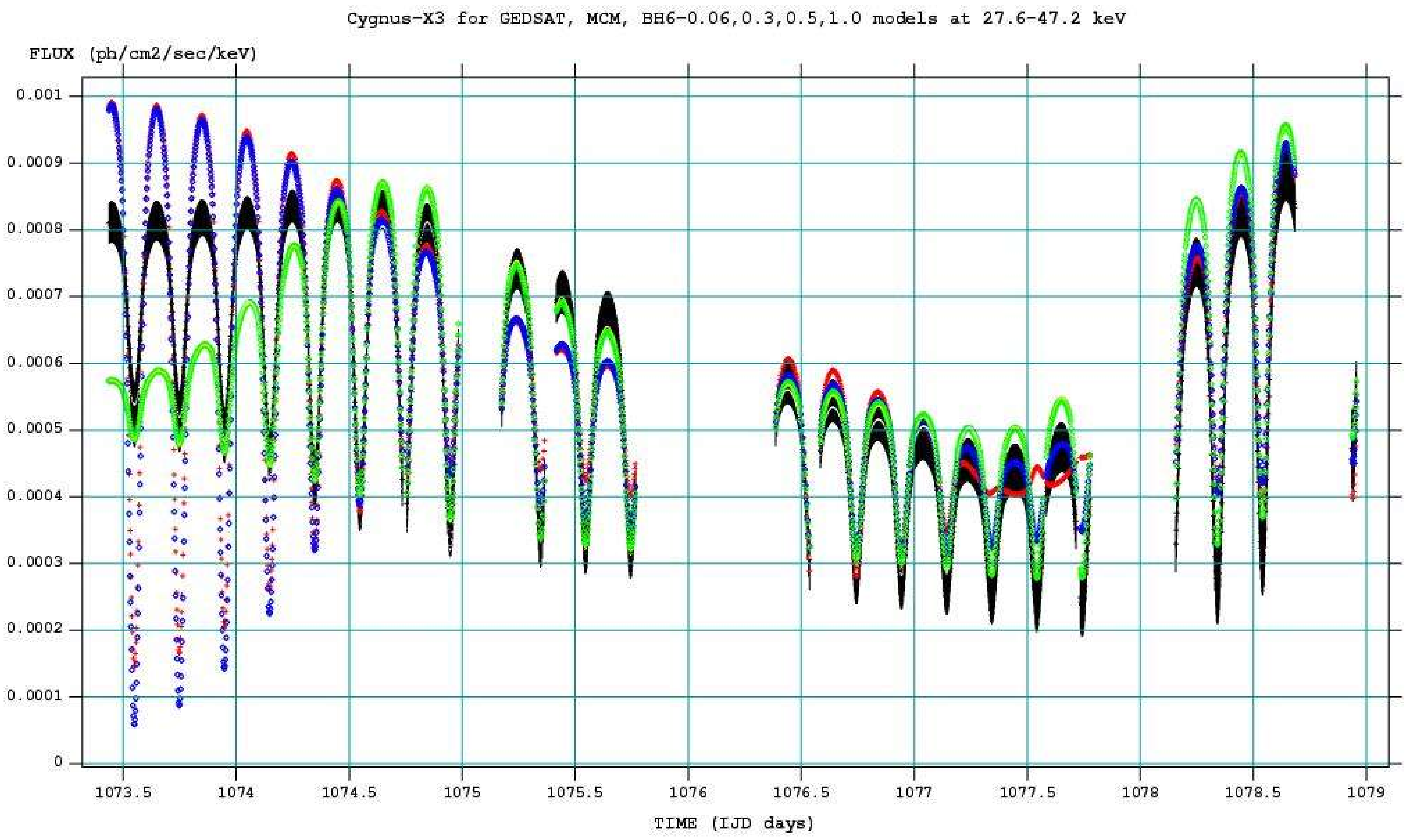
SPI light curves of Cygnus-X3 in PV phase



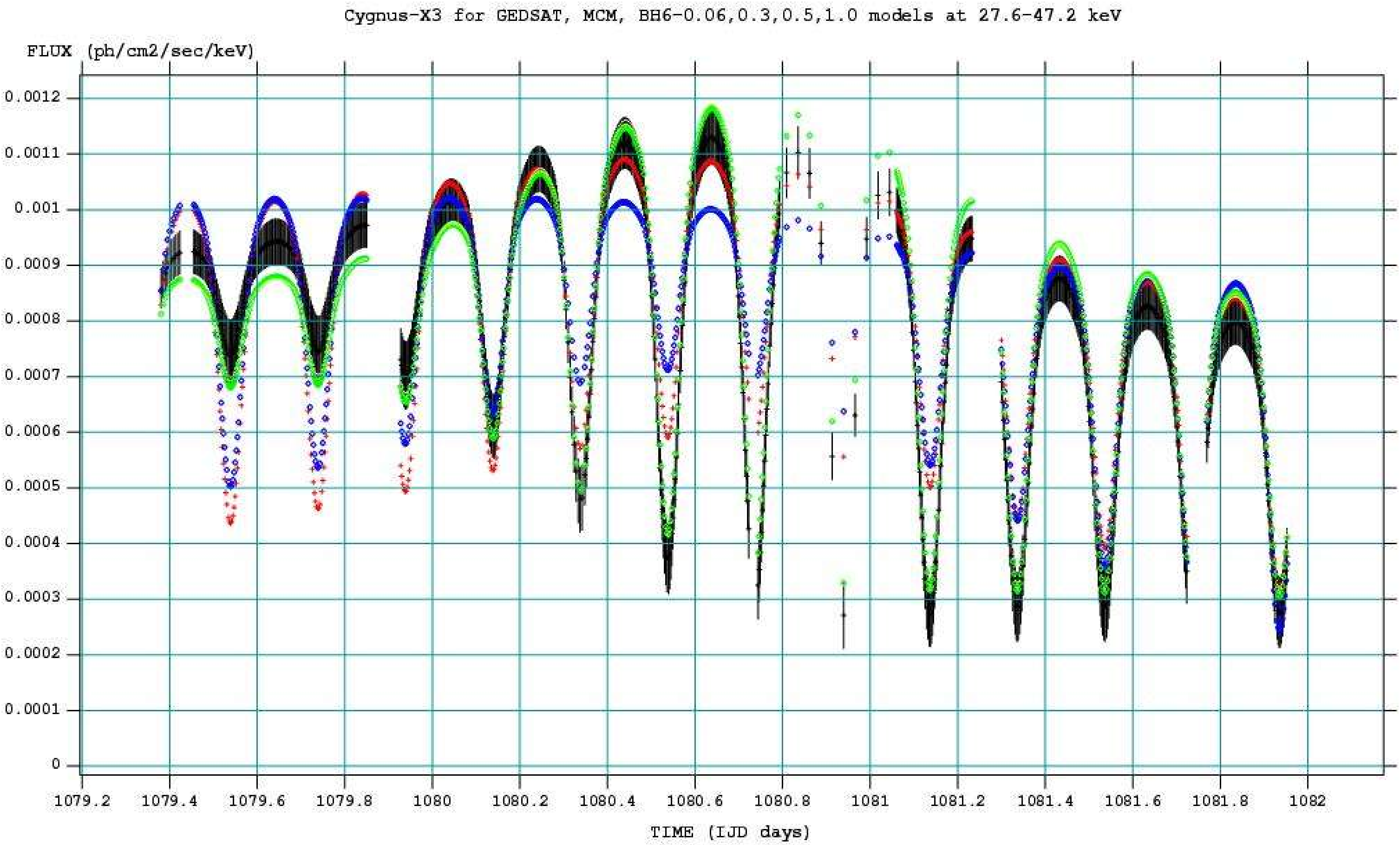
SPI light curves of Cygnus-X3 in PV phase



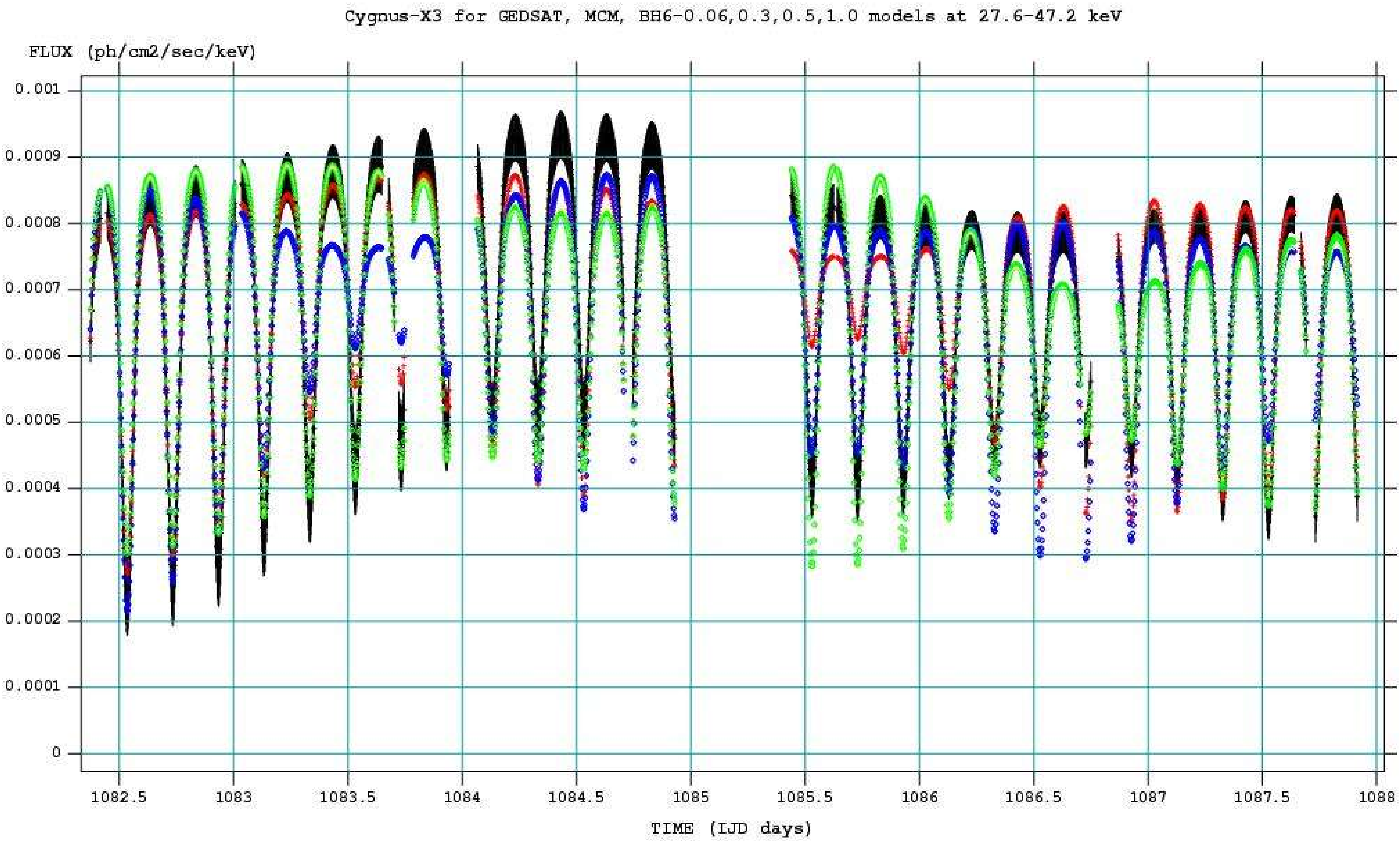
SPI light curves of Cygnus-X3 in orbits-19/20



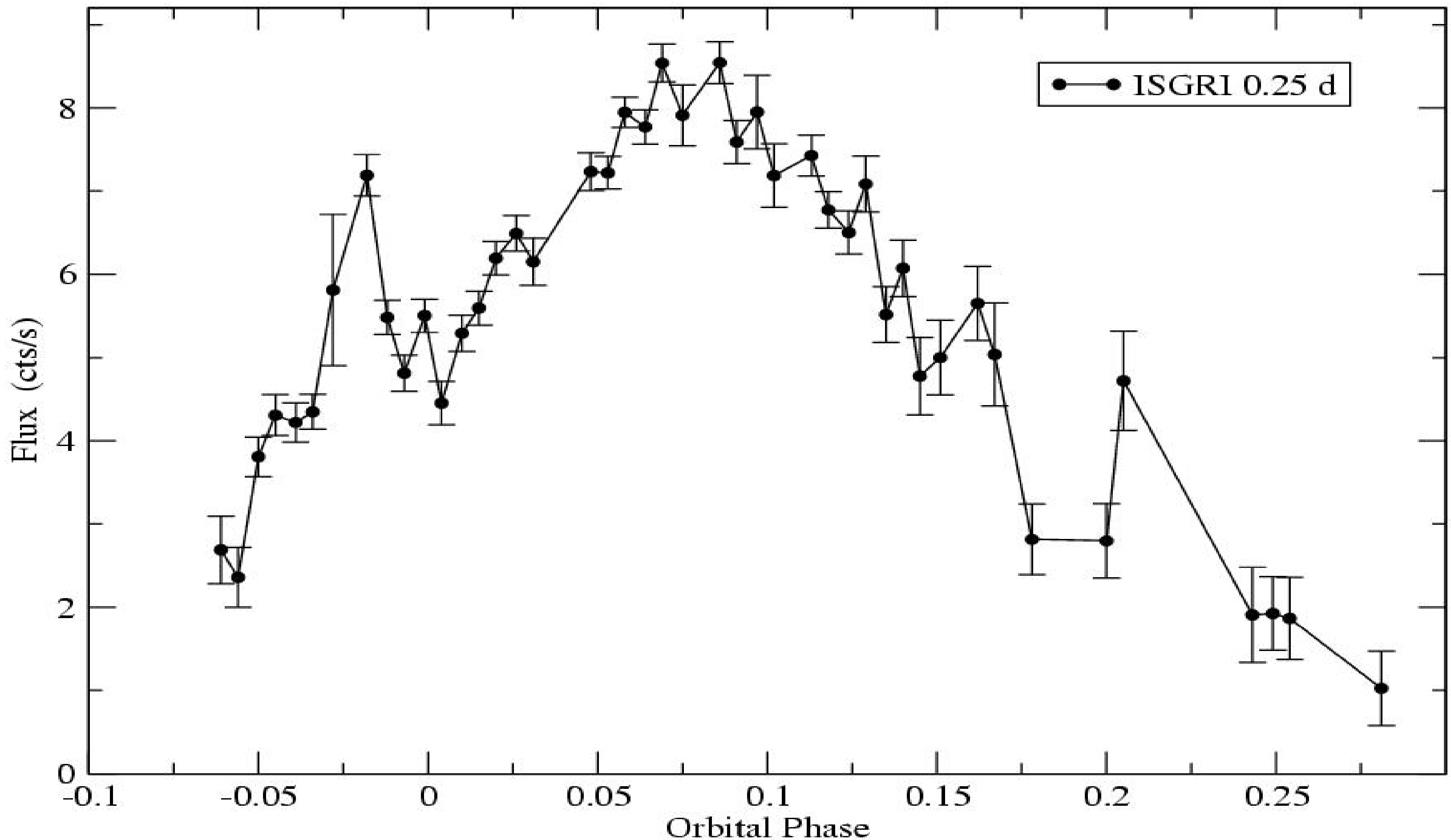
SPI light curves of Cygnus-X3 in orbit-21



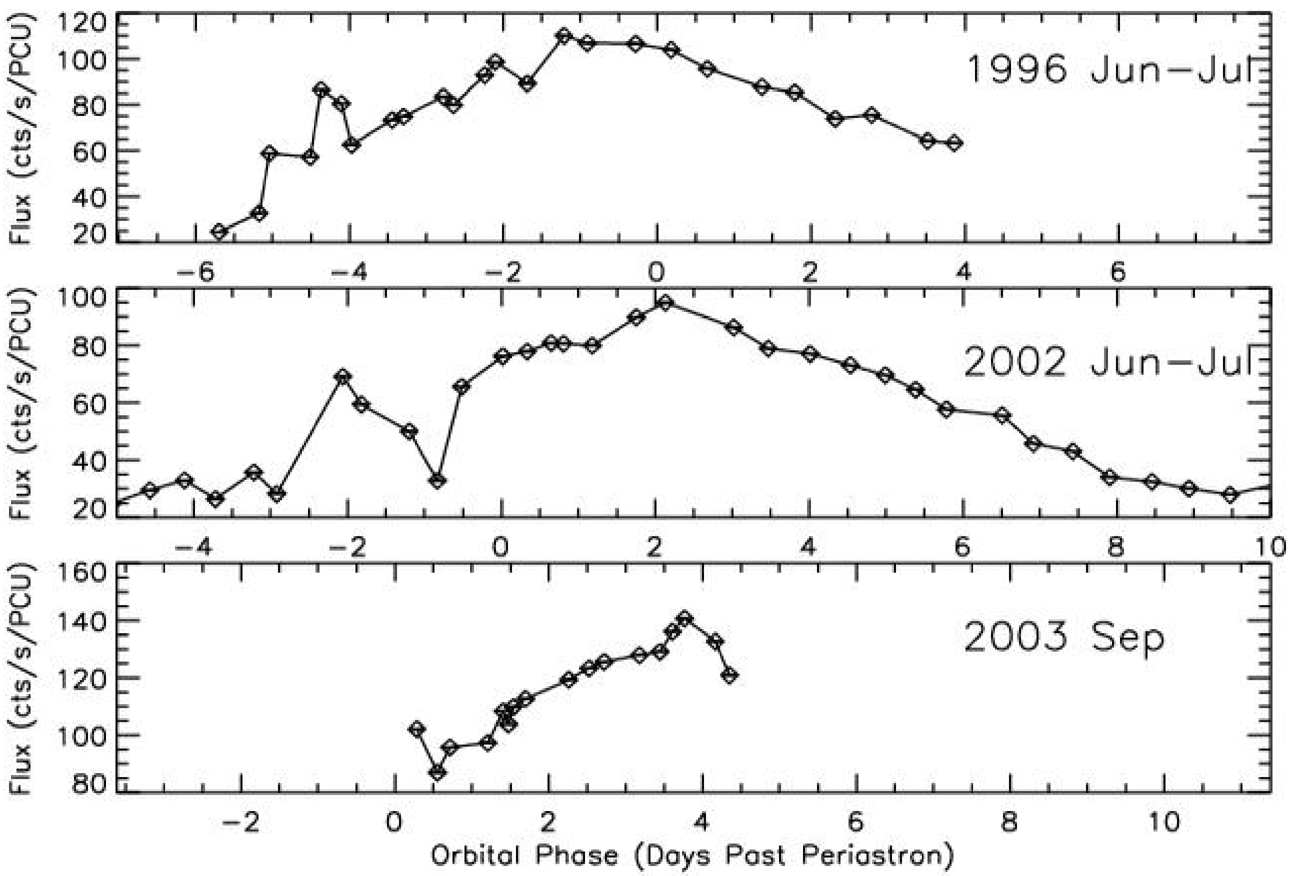
SPI light curves of Cygnus-X3 in orbits-22/23



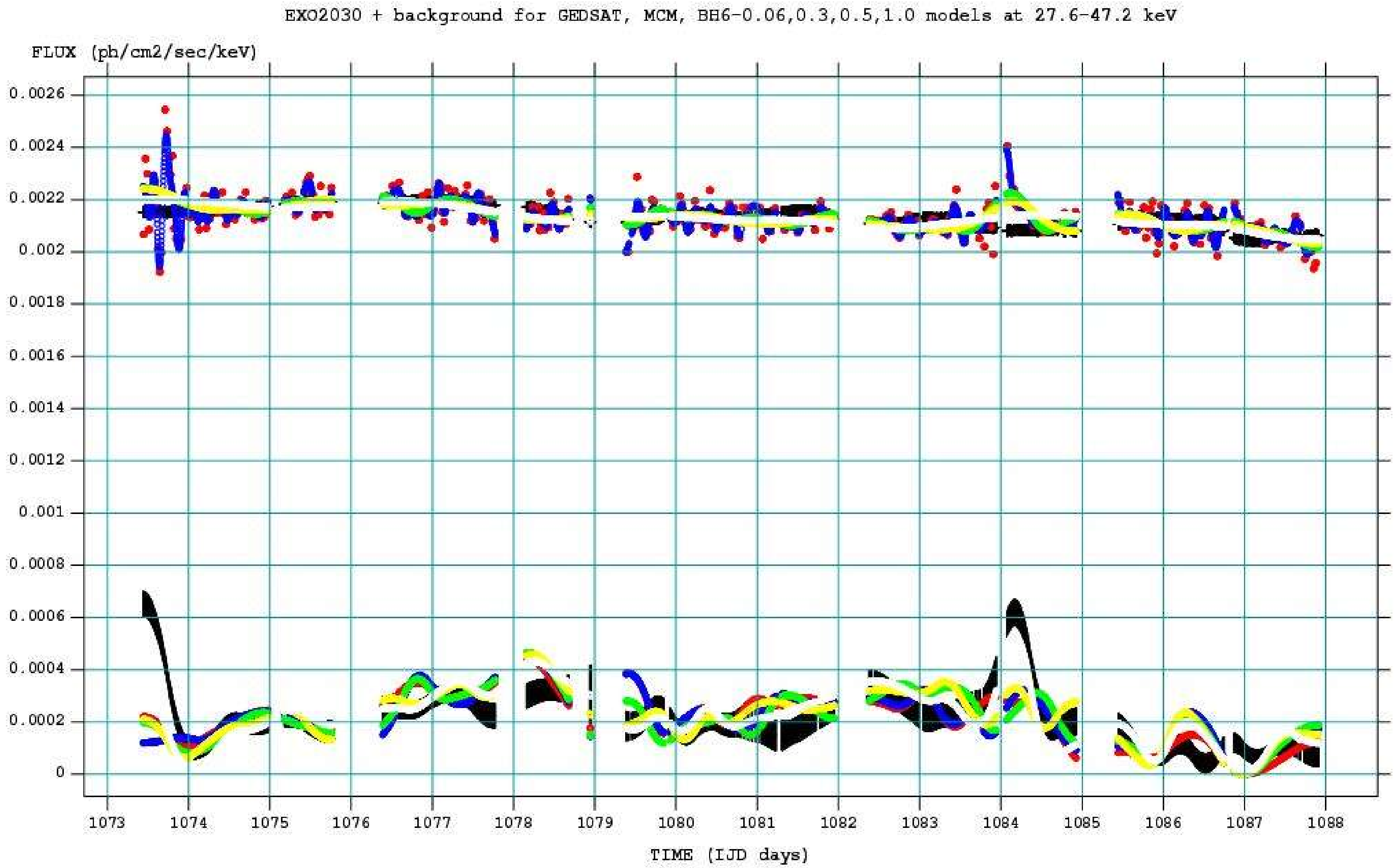
ISGRI light curve of EXO2030 in PV phase



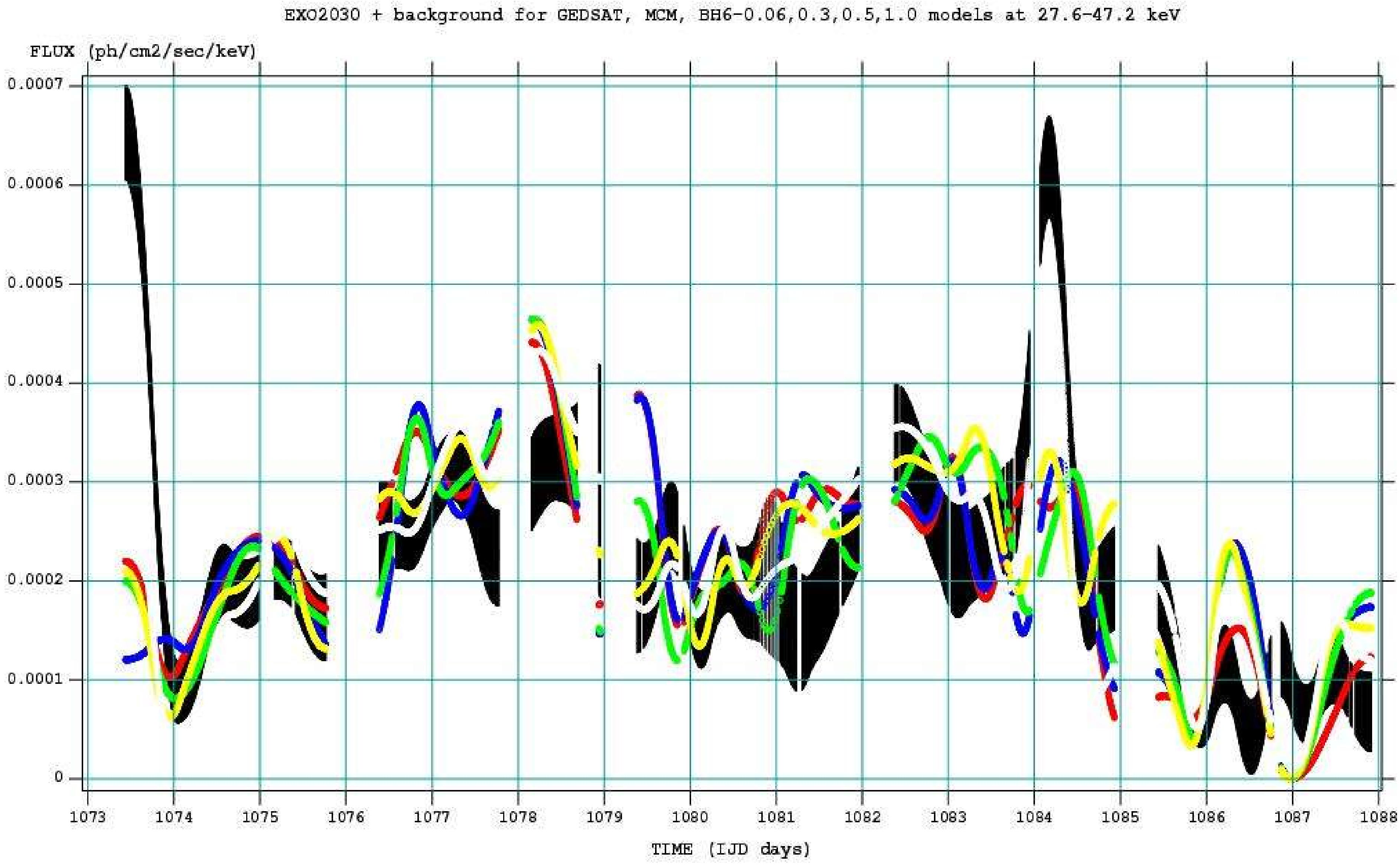
RXTE light curves of EXO2030



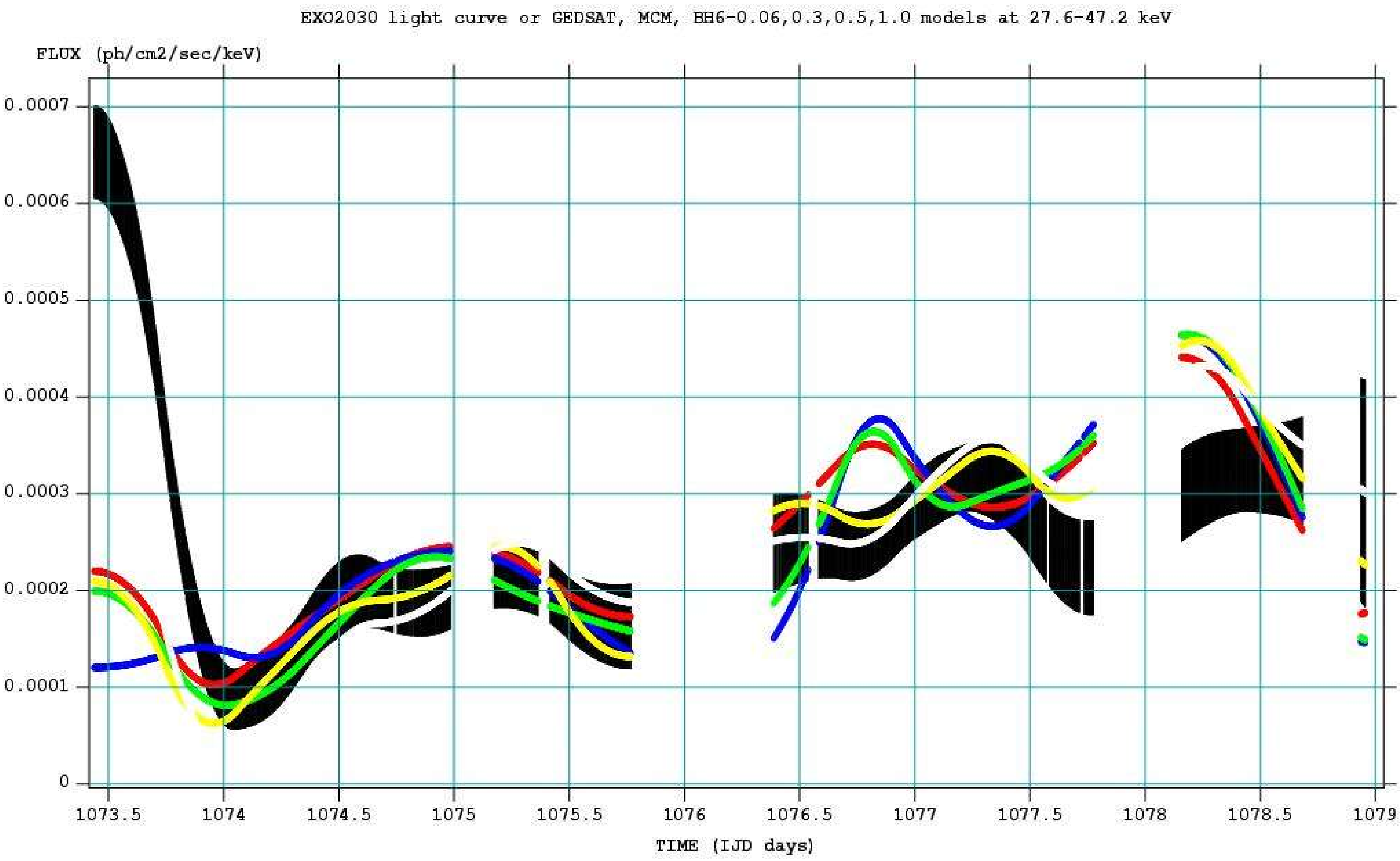
SPI light curves of EXO2030 in PV phase



SPI light curves of EXO2030 in PV phase



SPI light curves of EXO2030 in orbits-19/20

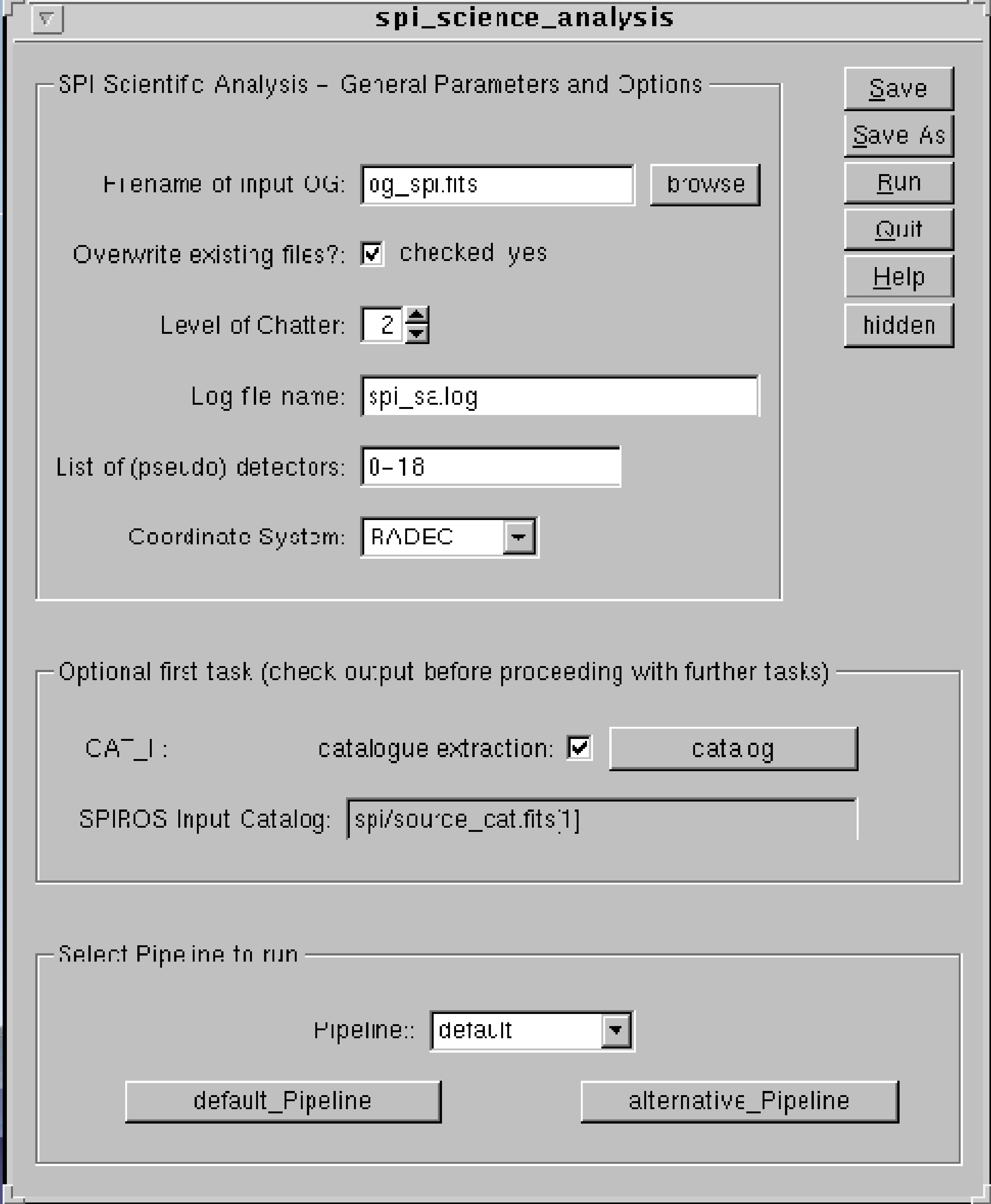


Conclusions

- SPIROS-9.2 allows sources to have independent time scales
- It has a new background method BH6 to model time variations
- It has a new QUICKSCAN option for "moving mean" light curves
- It allows for eclipsing modelling functions in TRANSIENT mode
- Light curve stability dependent on background and its modelling
- Suggestions for particular time variablity functions welcome

SPI Software for OSA 5.0

- New version of spiros
- Updates of Jürgen's executables (in particular spi_obs_hist and spi_obs_back)
- Instrument responses (IRFs and RMFs)
- Simpler spi_science_analysis script
- Distributed early June


spi_science_analysis
SPI Scientific Analysis – General Parameters and Options
Filename of input OG:
og_spi.fits
browse
Overwrite existing files?:
checked yes
Level of Chatter:
2
Log file name:
spi_sa.log
List of (pseudo) detectors:
0-18
Coordinate System:
RADEC
Save
Save As
Run
Quit
Help
hidden
Optional first task (check output before proceeding with further tasks)
CAT_I :
catalogue extraction:
catalog
SPIROS Input Catalog:
spi/source_cat.fits[1]
Select Pipeline to run
Pipeline::
default
default_Pipeline
alternative_Pipeline

New spi_science_analysis

- New executables in the default pipeline (spi_obs_gti and spi_obs_pha2)
- Remove “alternative” path (keeping spihist as a stand alone tool)
- Straightforward script that can be readily understood and copied in “any” languages

The Electronic Noise Feature at 1.4 - 1.6 MeV Revisited

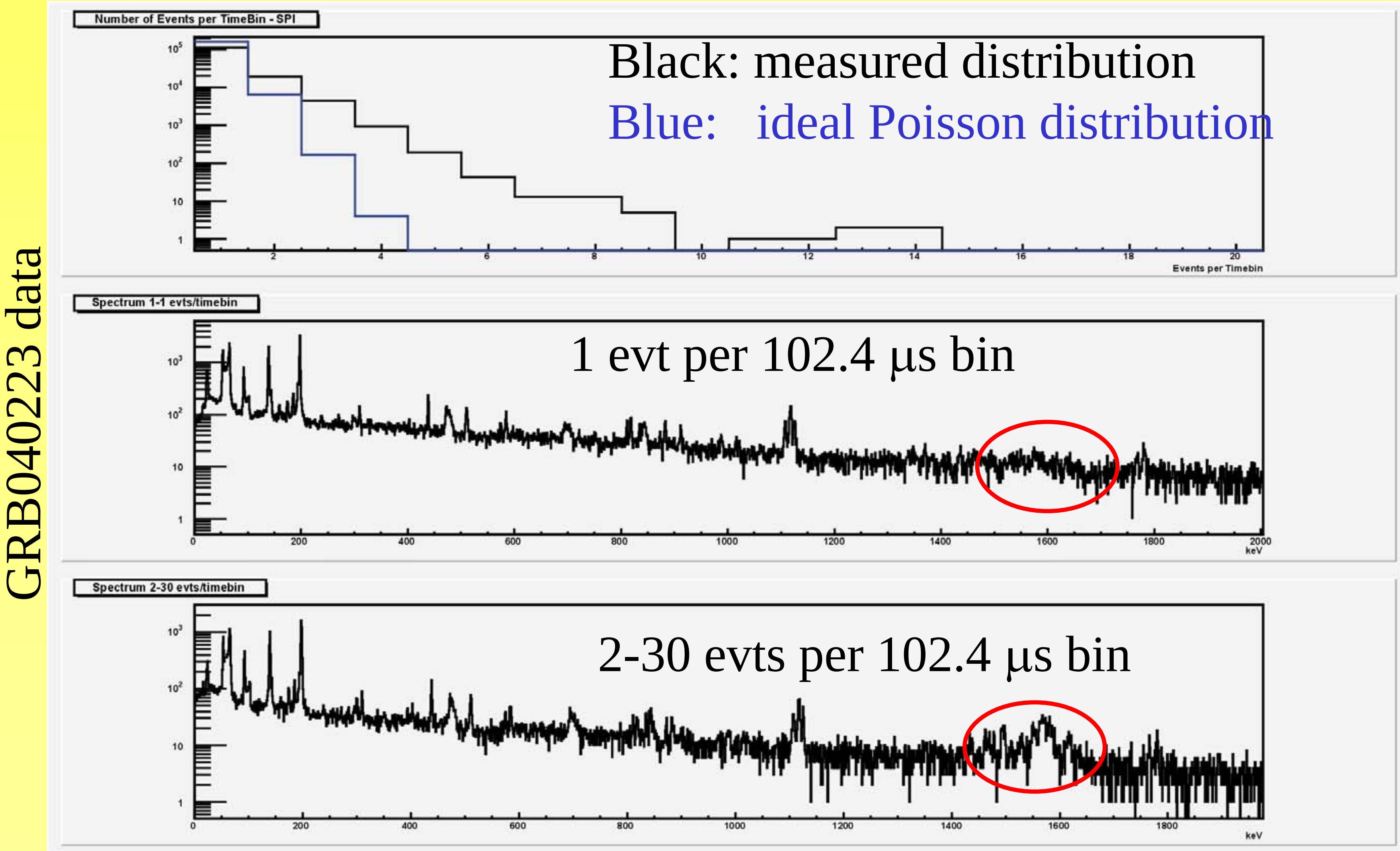
Trixi Wunderer

Recap …

- Noise feature (forest of ‘broad lines’) at 1.4-1.6 MeV, attributed to electronic noise
- Last October we thought our QG-motivated search for ms flares in GRBs had led us to a method to identify – and reject – this background

- Now we’ve tried to do this …
  … but unfortunately Bonnard et al were right, and the PSD is still the by-far-best method of rejecting this background component

GRB040223 data – shown in Oct



Approaches

- Assume noise events are close to each other in time (Δt up to 250 μs, i.e. up to 2 SPI time bins)
- Assume subsequent noise events happen in the same detector('s electronics)

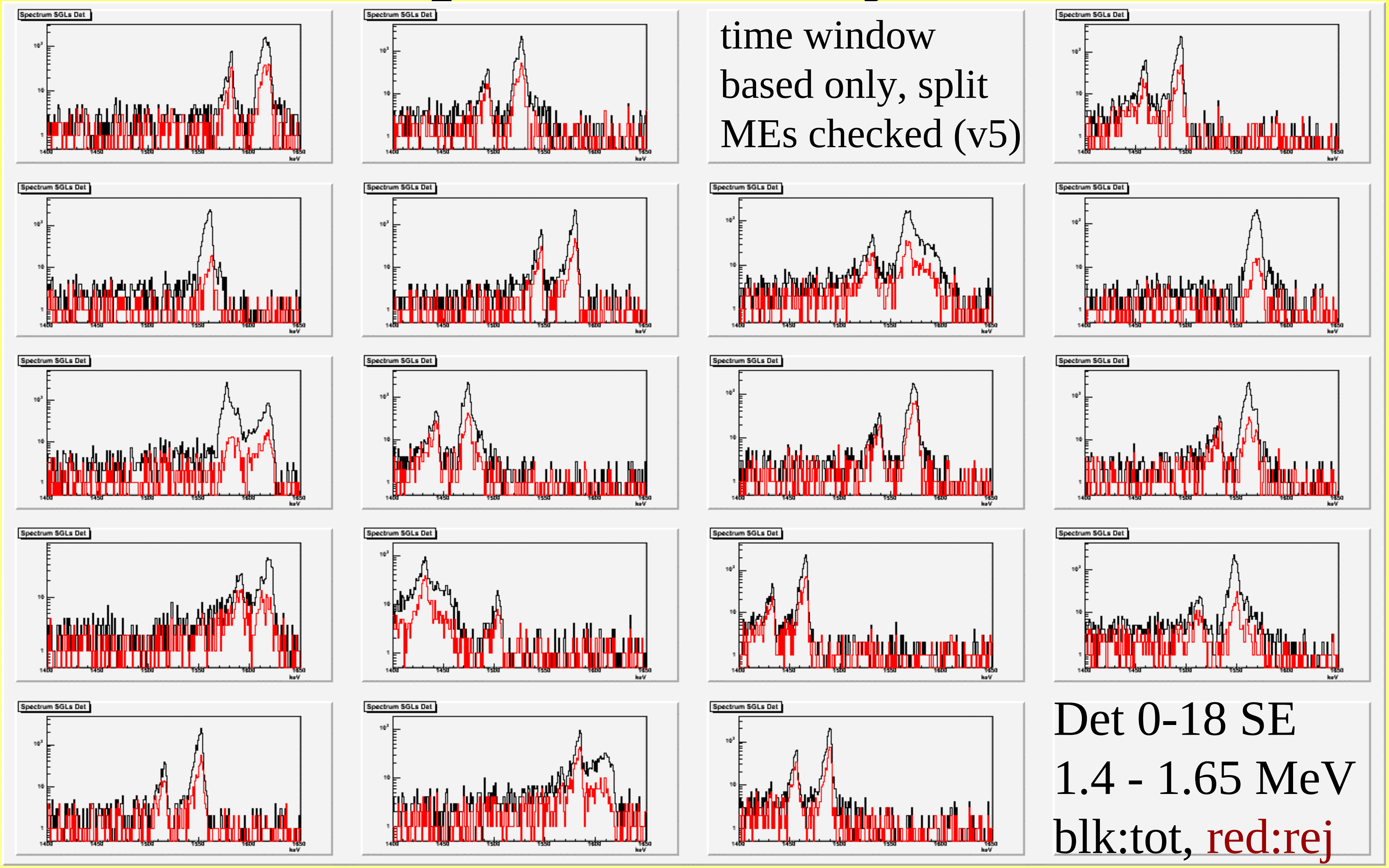
- Also consider parts of ME (2 and 3) events
- Take into account that the noise from different detector channels appears at different energies
- Also consider correlation between noise event and event at other energy or in other detector

Results in a Nutshell

- Most detector's SE spectra show a double-peak structure in the noisy region.
- For the most part, the two peaks' reduction by a given algorithm varies

- Noise 'peaks' in the individual detector's SE spectra reduced by up to 90%
- However, wildly varying performance for the different noise peaks from the different detectors
- Have not identified method good enough to make adding cleaned-up SE events to PSD events a viable option

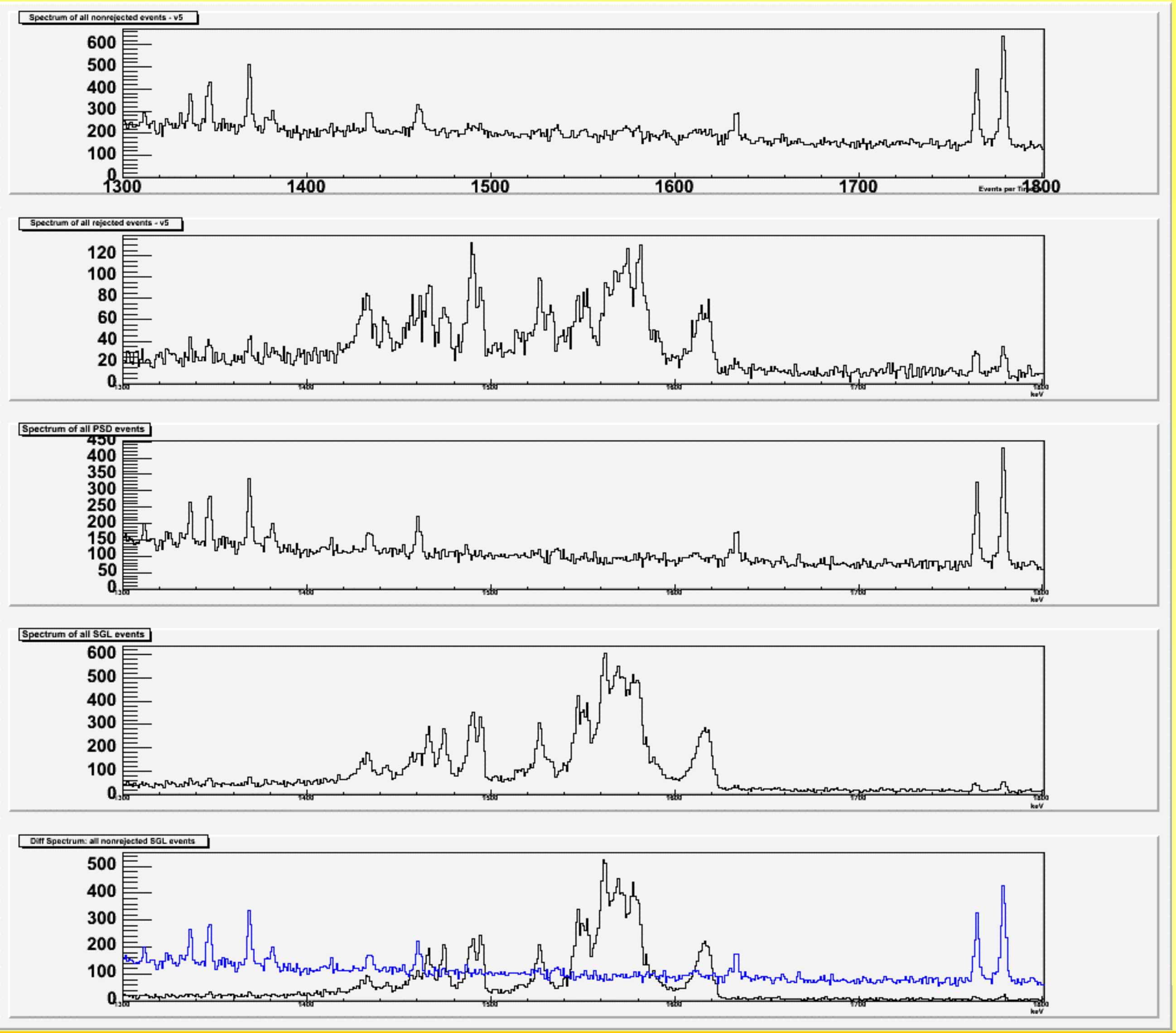
SE Spectra & Rejection I



time window based only, split MEs checked (v5)

Det 0-18 SE
1.4 - 1.65 MeV
blk:tot, red:rej

Result of I



All not rejected (SE,PSD,ME)

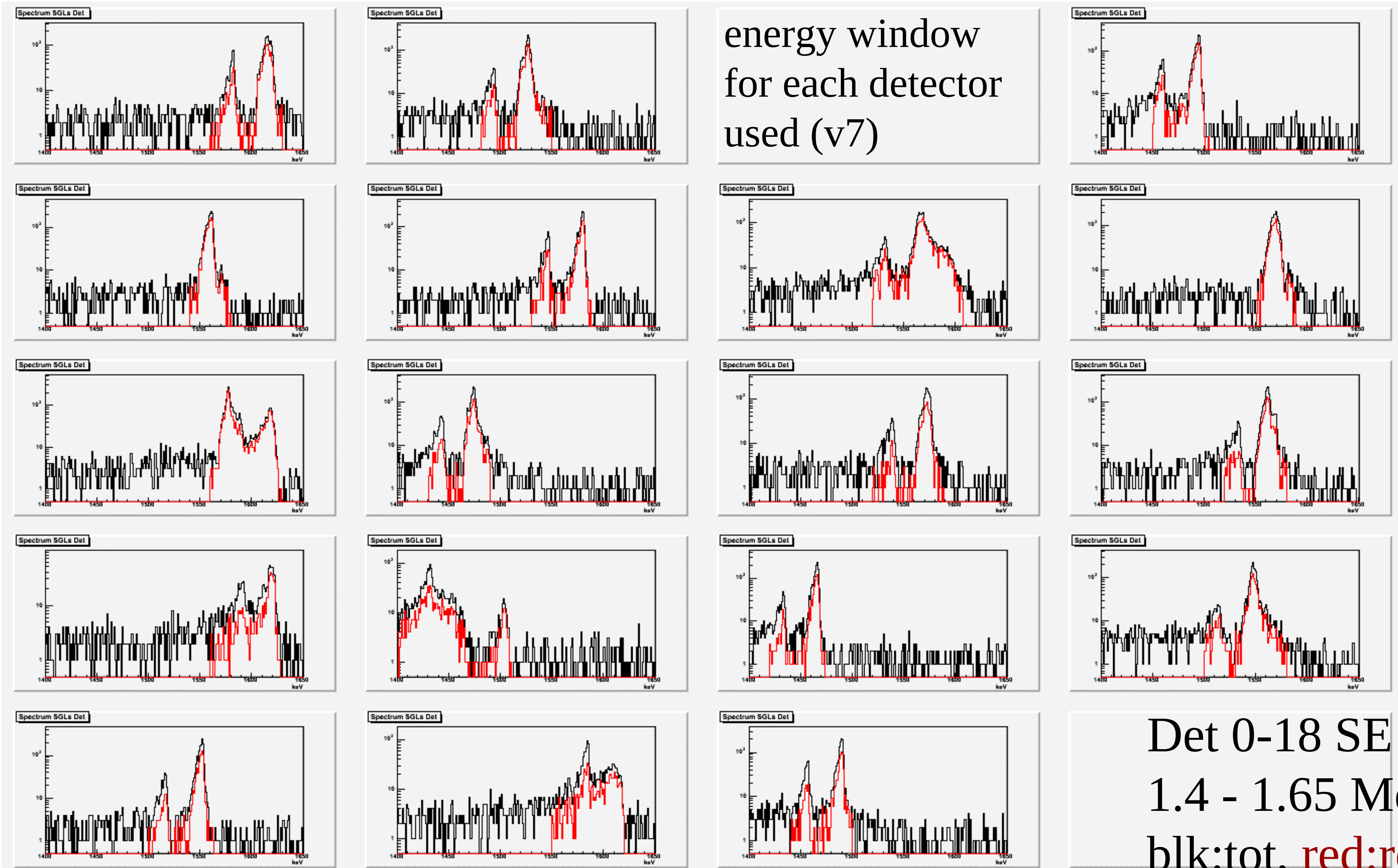
All rejected

All PSD (presumed good)

All SE (good & bad)

All PSD;
SE-rejSE

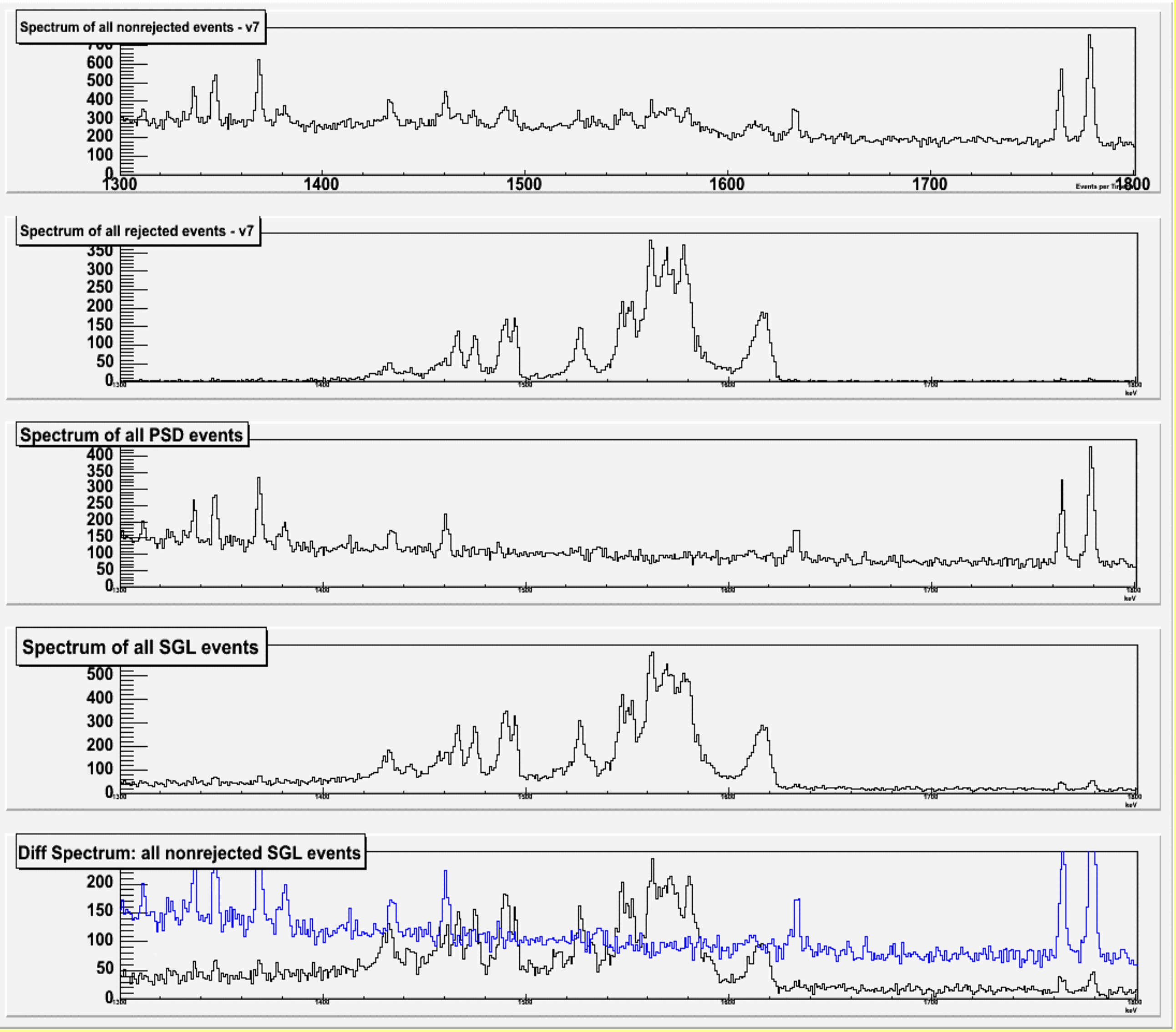
SE Spectra & Rejection II



energy window for each detector used (v7)

Det 0-18 SE
1.4 - 1.65 MeV
blk:tot, red:rej

Result of II



All not rejected (SE,PSD,ME)

All rejected

All PSD (presumed good)

All SE (good & bad)

All PSD;
SE-rejSE

Conclusions

- PSD by far best rejection method of electronic noise component
- Rejection algorithms reduce noise by ~ factor of 10 at best … not nearly good enough to make adding SEs to PSD events worthwile

- Different characteristics (or at least different susceptibility to rejection algorithms) of the electronic noise in the different channels
- One brute-force way that should work: cut the noisy region out of the data for det 0-18 and modify the response (‘dead detector’) accordingly

Decomposition Algorithm for Background studies

Hubert Halloin
MPE, Garching

Background modeling : objectives

- Background evolution templates for scientific analysis :
  - lines models : ^{26}Al, ^{44}Ti, e^+-e^-, …
  - continuum model : galactic diffuse emission
- Temporal evolution based on tracers :
  - HK data : GeDSat, IREM, ACS, …
  - "In situ" measurements : bgnd lines and continuum rates
  - …

$\Rightarrow$ How to select (and fit) appropriate tracers for a given observation ?

Decomposition algorithm

- Objectives :
  - Find a “minimal” set of tracers for a given observation (i.e pointings + detectors + energy selection)
  - Final set of uncorrelated tracers (better fitting process)
  - Initial observation approximated with a linear combination of tracers

Decomposition algorithm

- Input data :
  - $f(t)$: events rate (for a given set of detectors/energy range) defined on $T=\cup[a_j:b_j]$
  - $\tau_i(t)$: set of N possible initial tracers (probably correlated)
- Output data :
  - $\tau'_i(t)$: set of N' ($\leq$N) final tracers (normalized, uncorrelated)
  - c_i : decomposition coefficients

$$f(t) = \sum c_i \tau'_i(t) + \varepsilon(t)$$

$$\int_T \tau'_i \tau'_j = \delta_{ij}$$

Decomposition algorithm

- Def : $\langle u,v\rangle = \frac{1}{T}\int_T uv \Rightarrow \|u\| = \sqrt{\frac{1}{T}\int_T u^2}$
- First step : tracers normalization $\tau_i \leftarrow \frac{\tau_i}{\|\tau_i\|}, i = 1..N$
- Iterative process (N steps) :

$$r_0 = f$$

$$\begin{cases} r_i = r_{i-1} - \langle \tau_{s_i}, r_{i-1}\rangle \tau_{s_i}, i \geq 1 \\ \forall j \notin \{s_1, s_2, \ldots, s_i\}, \tau_j \leftarrow \frac{\tau_j - \langle \tau_{s_i}, \tau_j\rangle \tau_{s_i}}{\|\tau_j - \langle \tau_{s_i}, \tau_j\rangle \tau_{s_i}\|} = \frac{\tau_j - \langle \tau_{s_i}, \tau_j\rangle \tau_{s_i}}{\sqrt{1 - \langle \tau_{s_i}, \tau_j\rangle^2}} \end{cases}$$

s_i = selected tracer at step i, to be defined…

Decomposition algorithm

- At the end of the algorithm :

$$f(t) = \sum a_{s_i} \tau_{s_i}(t) + r_N(t), a_{s_i} = \langle r_{i-1}, \tau_{s_i} \rangle = \langle f, \tau_{s_i} \rangle$$

$$\frac{1}{T} \int_T \tau_i \tau_j = \delta_{ij}$$

$$\|r_0 = f\| \geq \|r_1\| \geq \ldots \geq \|r_N\|$$

$$cor(r_{i-1}, \tau_{s_i}) = \frac{a_{s_i}}{\|r_{i-1}\|}$$

~ information content added at step i

- Stable algorithm : first coefficients identical if the algorithm is stopped at iteration N’<N

Decomposition algorithm

- Selection possibilities :
  - "matching pursuit"

$$s_i = \arg\max_{j \notin \{s_1, \ldots, s_{i-1}\}} \left| \left\langle r_{i-1}, \tau_j \right\rangle \right|$$

=> at the end, templates ordered according to correlation coef :

$$\left| \left\langle f, \tau_{s_1} \right\rangle \right| \geq \left| \left\langle f, \tau_{s_2} \right\rangle \right| \geq \ldots \geq \left| \left\langle f, \tau_{s_N} \right\rangle \right|$$

  - prior order :
    - from "matching pursuit" on averaged detector rates
    - "physical" knowledge
    - …

Decomposition algorithm

- Background model generation :
  - select the N' first "build" tracers (user choice…)
  - direct use of algorithm coef :

$$b_i(t) \approx a_{s_i} \tau_{s_i}(t), i \leq N'$$

  - fit tracers coefficients through least squares minimization (handle error bars)

$$b_i(t) \approx \hat{a}_{s_i} \tau_{s_i}(t), i \leq N'$$

The two approaches are equivalent for high statistics (otherwise should use lsq fitting)

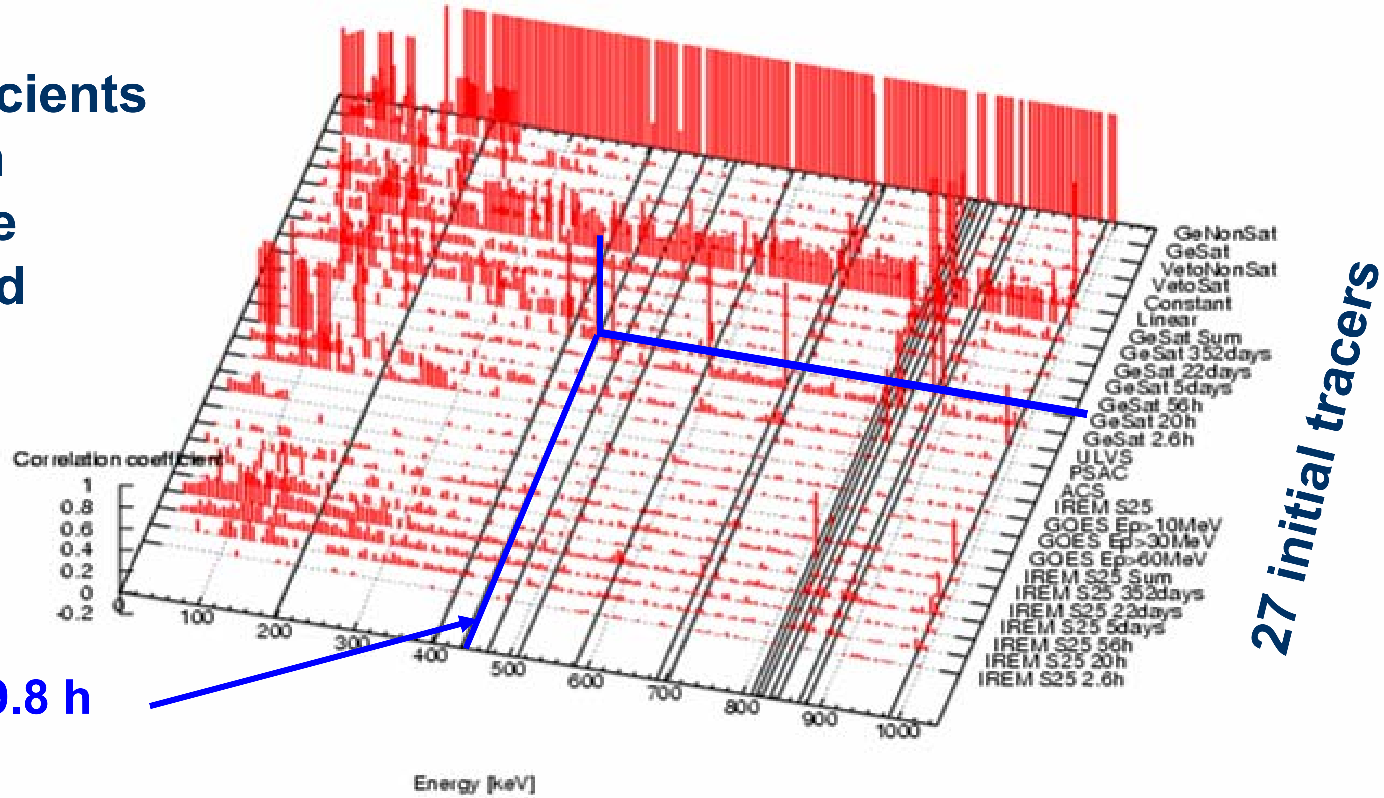
Examples

- Choice of the “background” observation :
  - “OFF” data :
    - pro : no signal expected in the dataset
    - cons :
      - small observation time
      - possible systematic effects (solar activity, deficient tracer during “ON” data, …)
  - “OFF+ON” data
    - pro :
      - longer exposure
      - add information on transient events
    - cons : risk of including signal in the background model
- Why using “ON+OFF” data :
    - choice of the tracers, uncorrelated with signal
    - usually negligible signal/noise ratio
    - used to select “good” tracers, final background coefficients fitted with the signal parameters

Examples

- All public observations, rev 15-139, mean detector rates, sgle events

Correlation coefficients of the information extracted from the 15 most correlated tracers

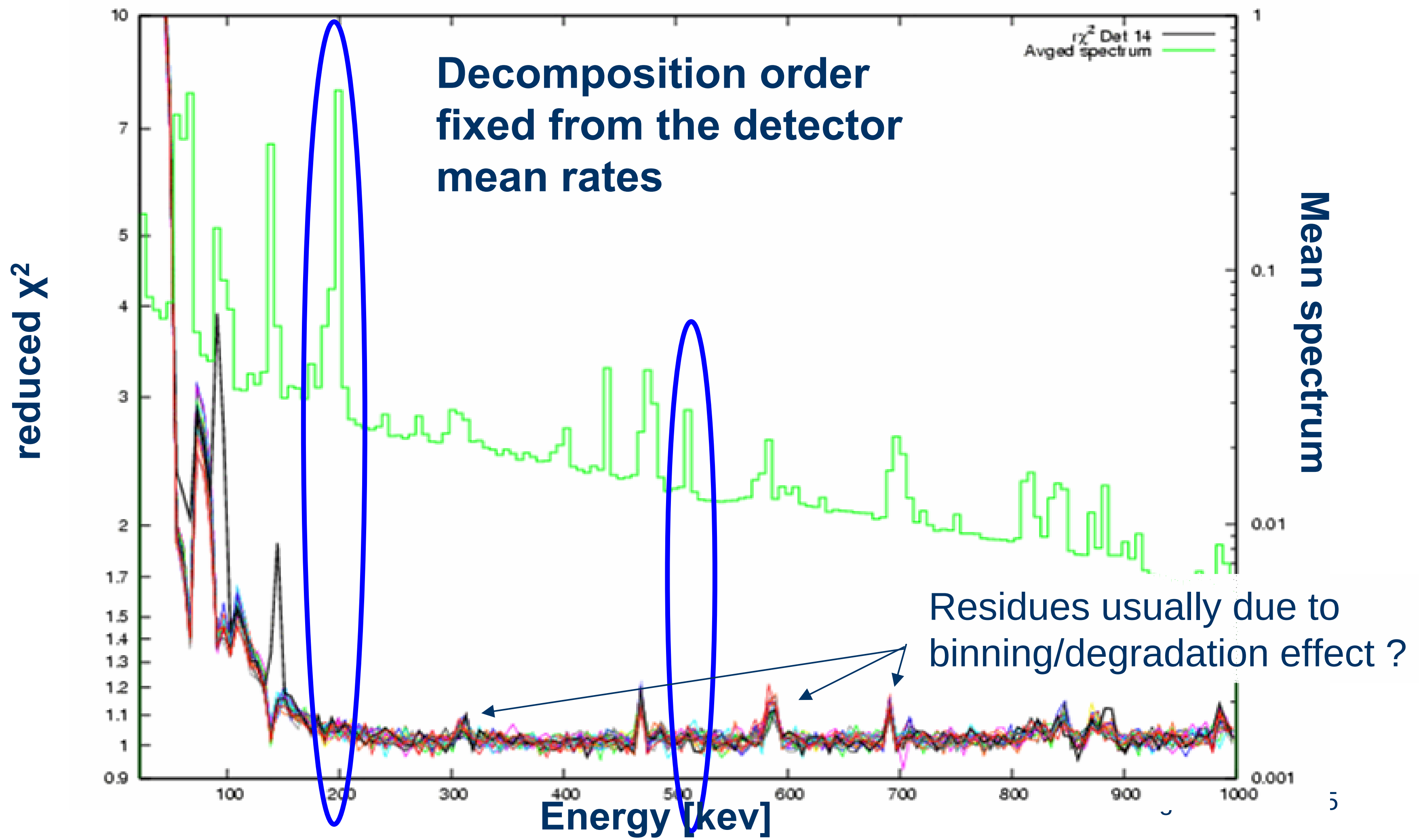


438.6 keV, ^{69}Zn, T=19.8 h

Energy : 22 keV – 1 MeV bin = 6keV

Examples

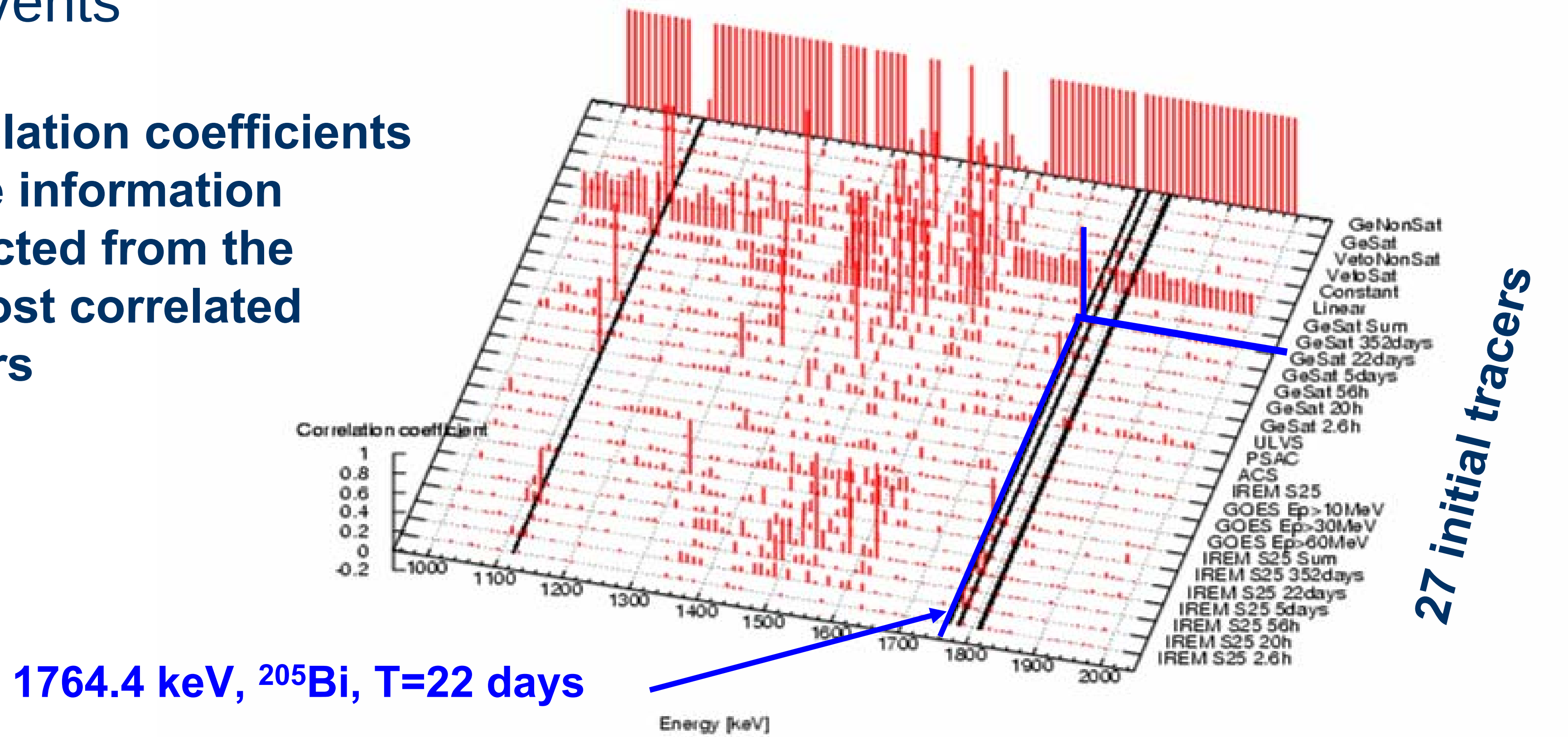
- All public+survey observations, rev 15-139, individual detectors



Examples

- All public observations, rev 15-139, mean detector rates, sgle events

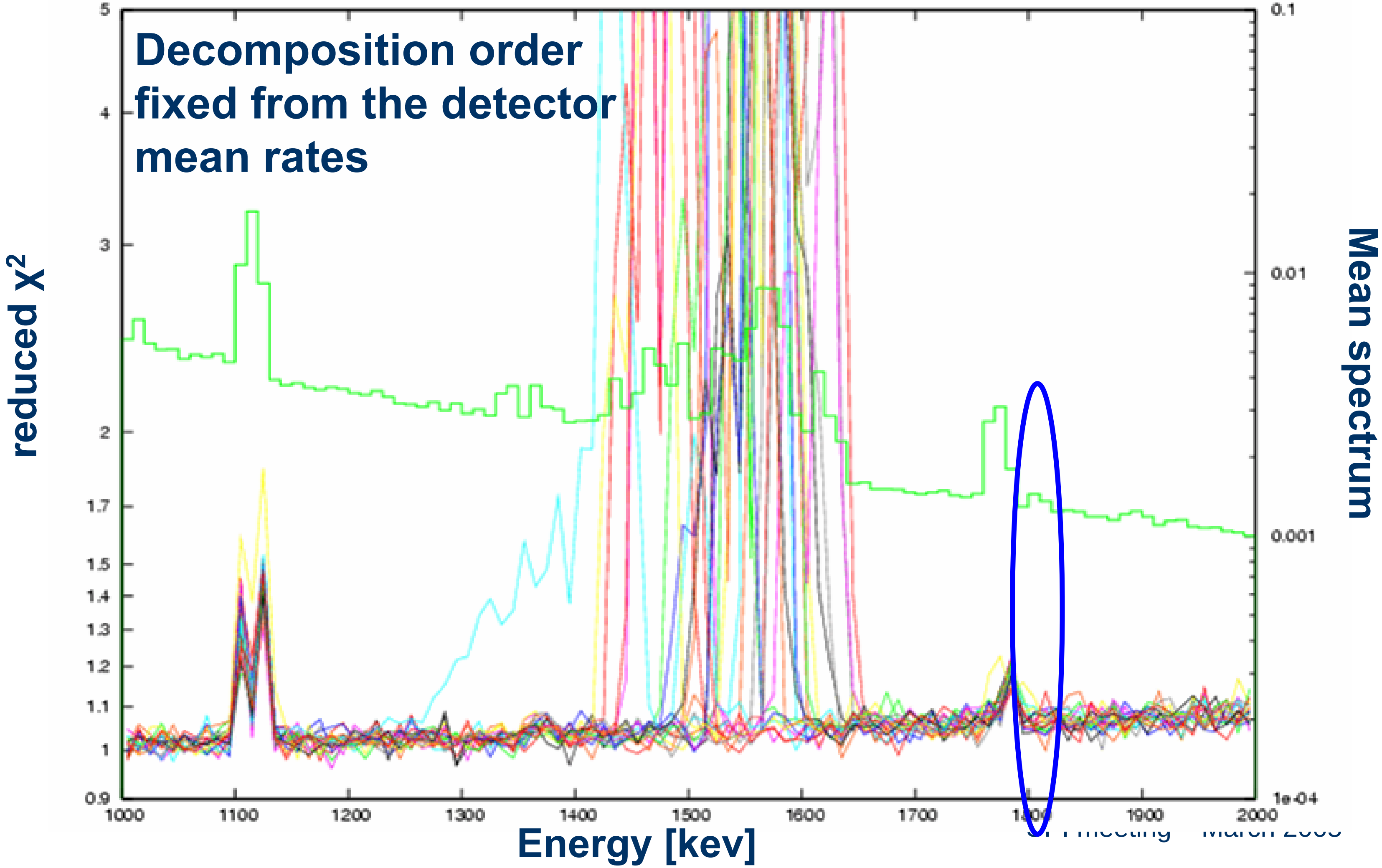
Correlation coefficients of the information extracted from the 15 most correlated tracers



Energy : 1 MeV – 2 MeV bin = 10 keV

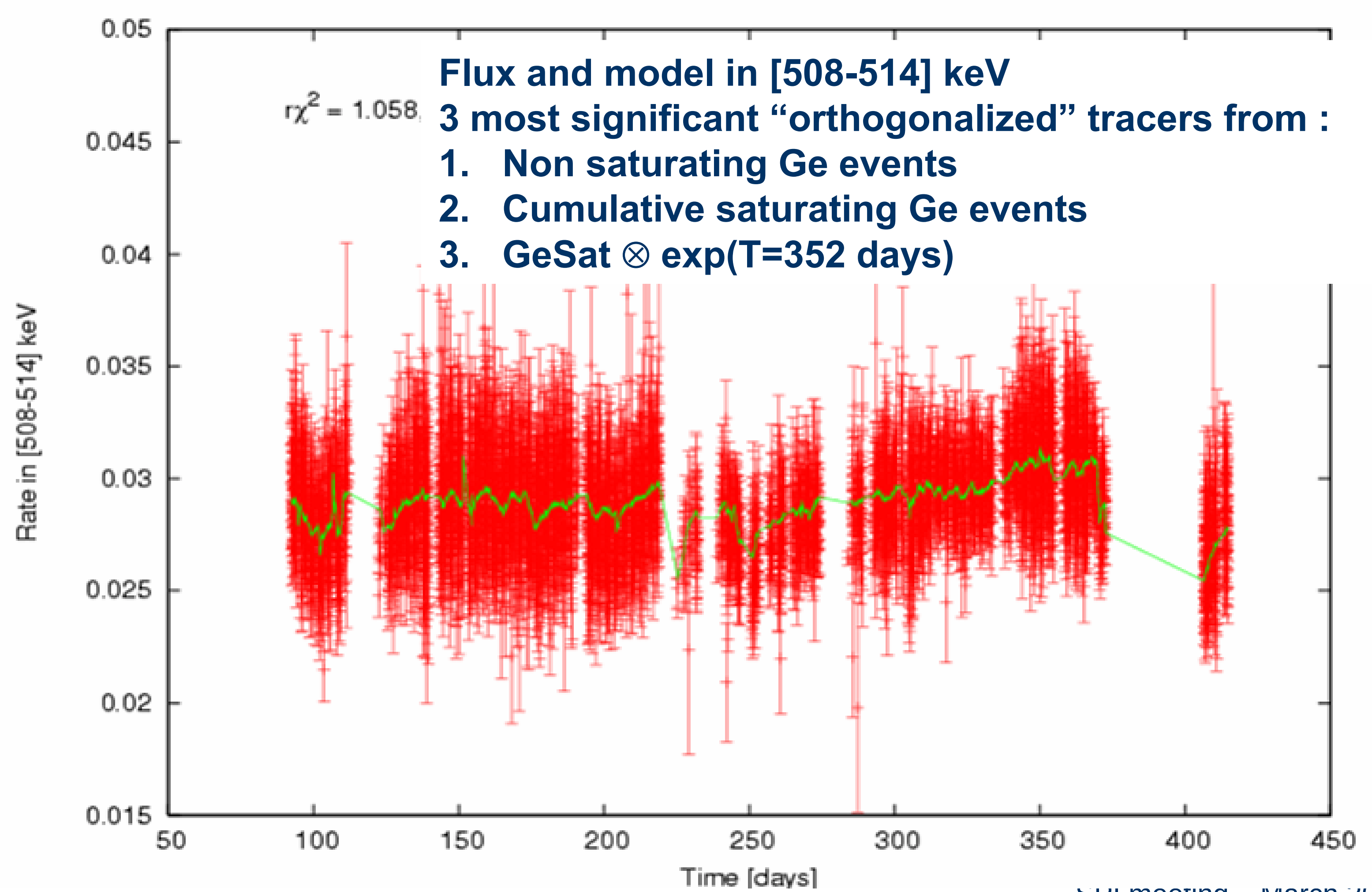
Examples

- All public+survey observations, rev 15-139, individual detectors



Examples

- All public+survey observations, rev 15-139, det 0, sgle events



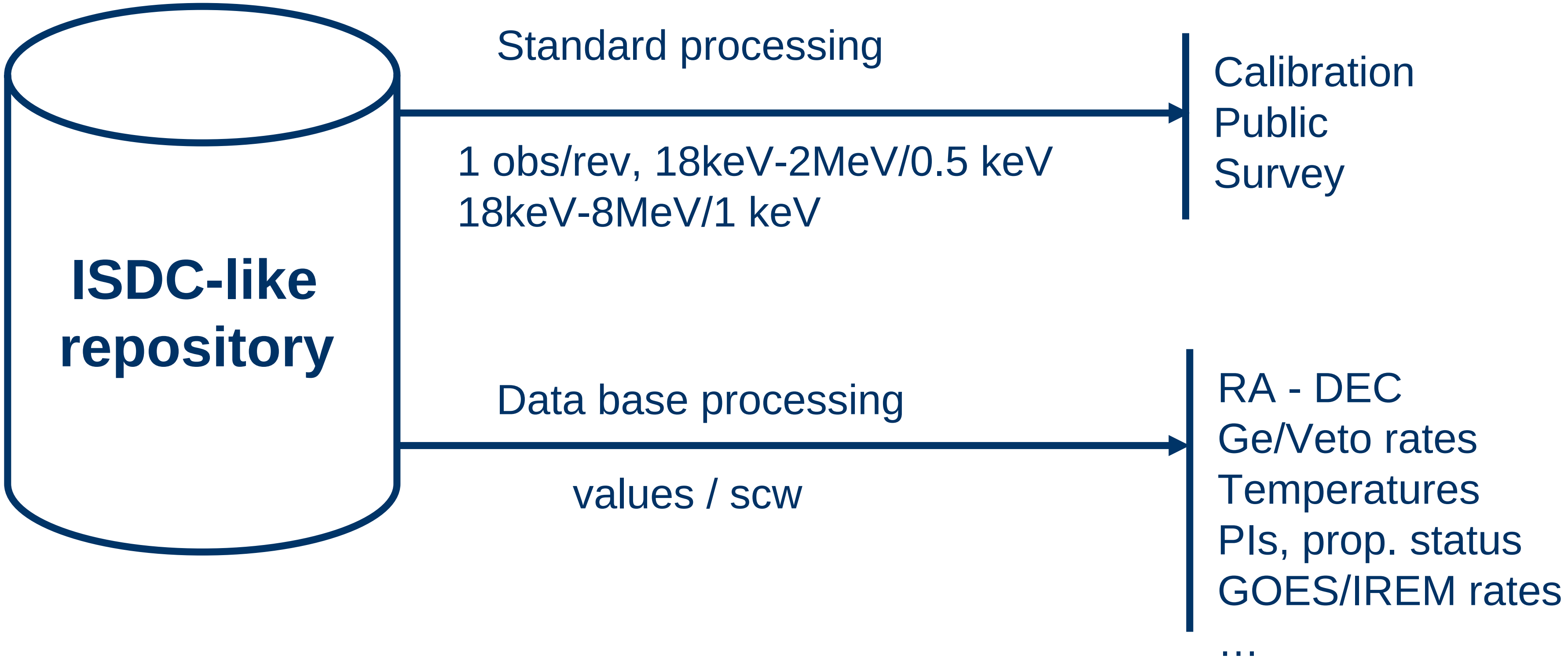
Conclusion

- Decomposition algorithm allowing to :
  - build a set of orthogonal tracers
  - discard redundant information
  - truncation leads to a “minimal” set of templates (for the correlation)
  - final background components as a linear combination of a subset of initial tracers
- Limitations
  - linear approach
  - decomposition order depends on observation…

Analysis pipeline at MPE
Application to diffuse emission

Hubert Halloin
MPE, Garching

Building the observation data



Building the observation

pre-processed data

scw database

spiselectscw

Selected observation
• events
• pointings
• GTIs
• Corrected livetimes
• scw list

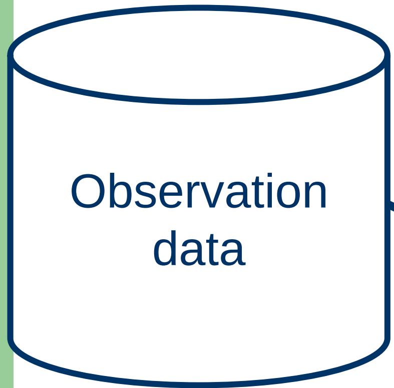
spiexttpl

Background templates
• GeDSat + convolved
• Veto rate
• Charged particles

spiorthomodel / spi_obs_back

Background model / components
• orthogonalization
• proportionnal to template

Observation model fitting



gensky / genskymodel
Diffuse emission models

Source catalog

spimodfit

Original algorithm from *spidiffit* :
- less memory (÷ 2-3)
- (usually) faster (÷ 5-10)
- (possibly) NAG free

Model fitting :
- time variability (sources, bgnd components) : splines
- time dependent IRFs
- max. likelihood fitting
- constrained fit (parameters boundaries)
- energy bins fitted independently
- error bars from hessian / likelihood profile / MCMC

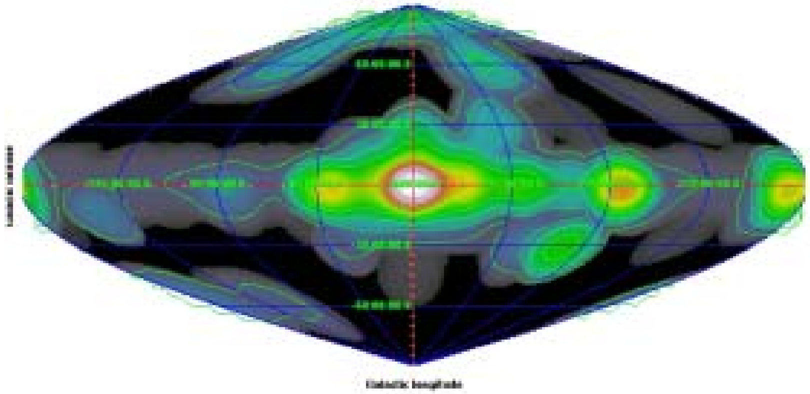
To add :
- multi-energy fitting (spectral shape, non diagonal IRFs terms)

Outputs :
- sources/models spectra
- fitted bgnd components
- updated source catalog

Application to diffuse emission

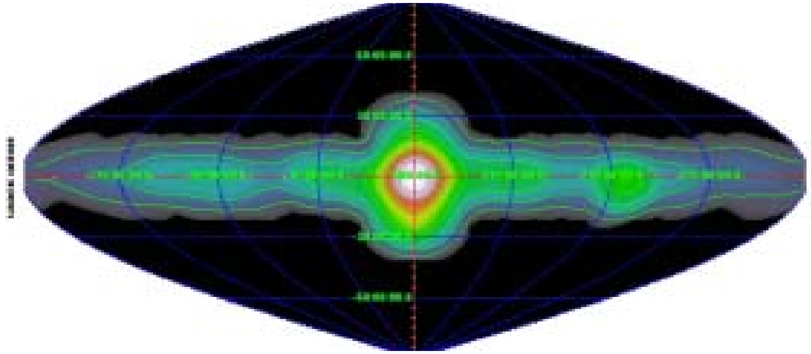
Selected data : Public + survey data, 3 datasets (19 -> 18 -> 17 detectors)
Remove : first and last 10% of orbits, high solar activity (from GOES E_p>30MeV)

Rev 15 - 139



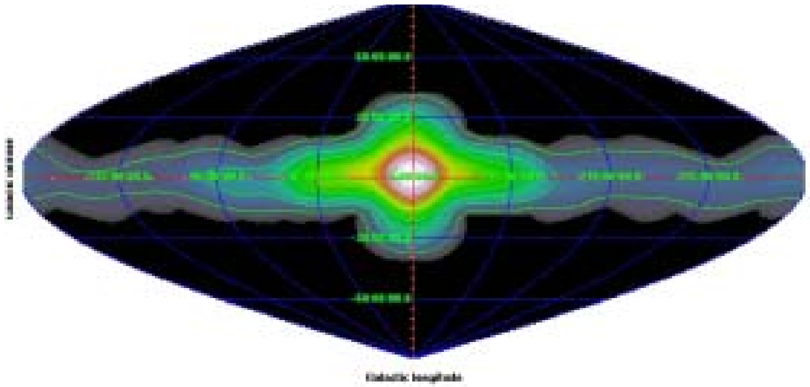
+

Rev 140 - 214



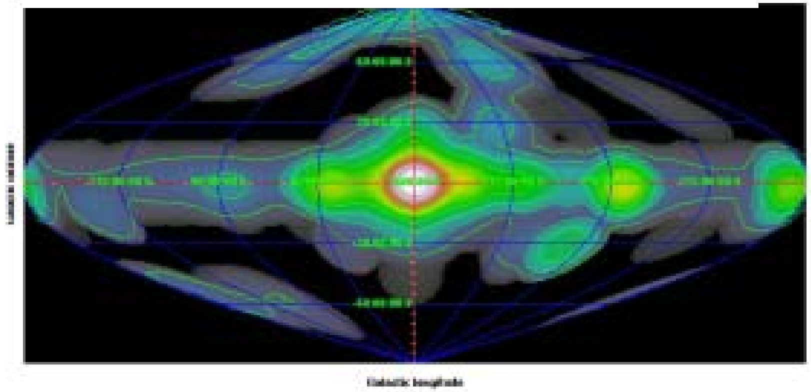
Rev 215 - 259

+



=

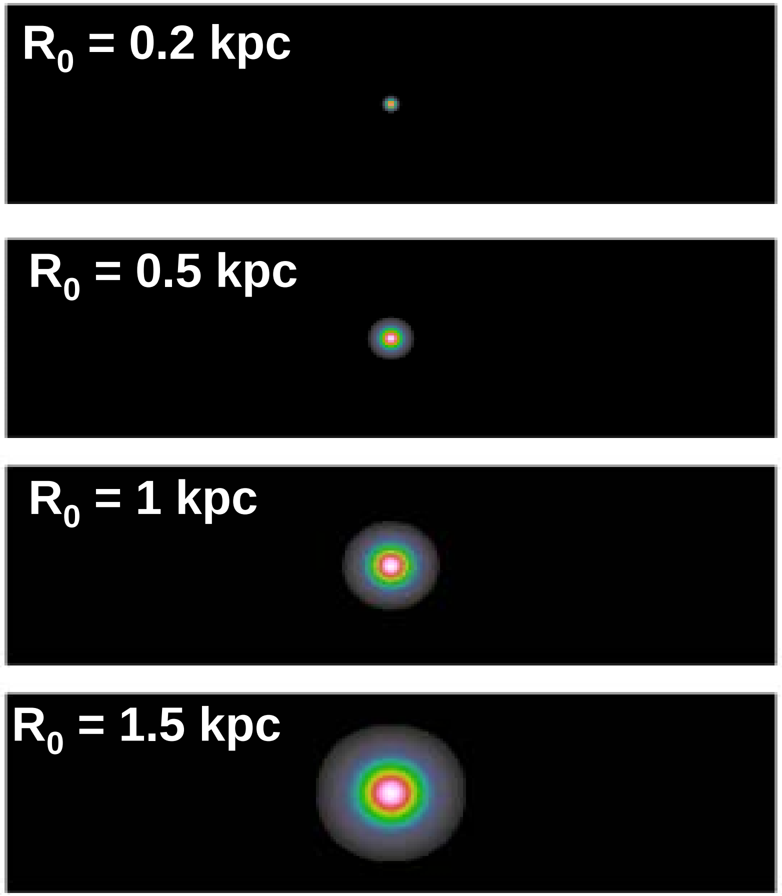
exposure ~ 3.6 Ms at Gal. center
Tot. exposure ~18 Ms



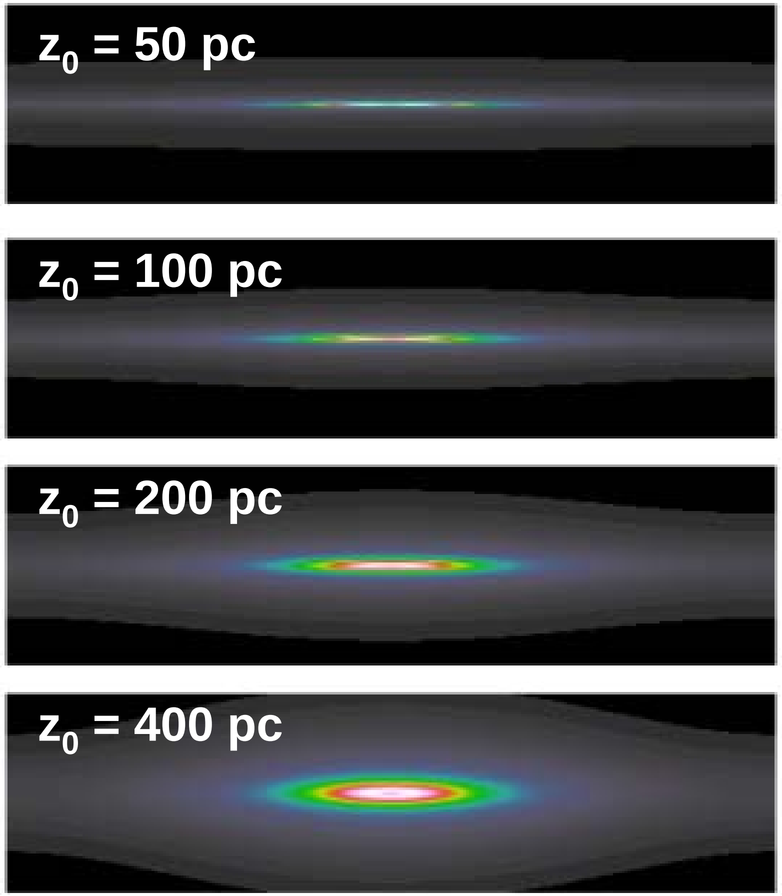
Galactic diffuse emission (testing …)

2 diffuse emission components (16 combinations) :

Gaussian bulge models : R_0



Truncated exponential disc : z_0



Galactic diffuse emission (testing …)

- Background model
  - 3 main components from orthogonalization
  - Detector ratios fitted for revolutions ranges 15-139, 140-214, 215-259 and merged
  - variability :
    - first component : 1 amplitude par / 10 days
    - 2^{nd}, 3^{rd} component : 1 amplitude par / observation

- Input sources positions :
  - central radian : SPI survey (L. Bouchet), 64 sources
  - outside : IBIS sources, 24 sources
  - too many sources at high energy (>400 keV), only for program testing …

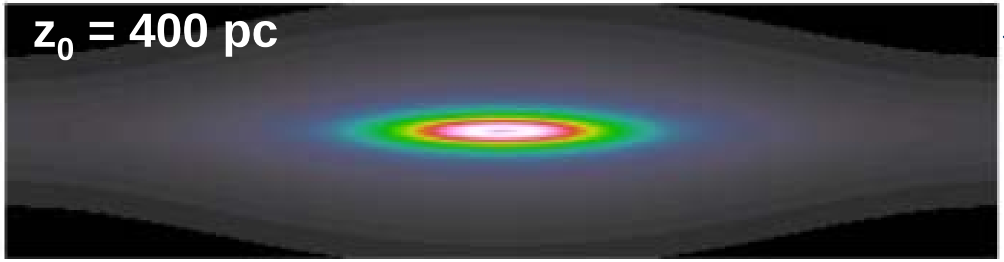
Galactic diffuse emission (testing)

400 – 454 keV :

- Only sources ⇒ $F_{sources}$ ~1.0±0.1 10^{-4} ph/(s.cm^2.keV)
- Sources + maps :
  - No bulge flux
  - No gal disc, except for z_0 ~ 400 pc (F_{disc}~2.8±1.4 10^{-4} ph/(s.cm^2.keV) ?)
  - $F_{sources}$ unchanged

454 – 508 keV :

- Only sources ⇒ $F_{sources}$ ~7.3±1.4 10^{-5} ph/(s.cm^2.keV)
- Sources + maps :
  - No bulge flux
  - No gal disc, except for z_0 ~ 400 pc (F_{disc}~4.9±1.5 10^{-4} ph/(s.cm^2.keV) ?)
  - $F_{sources}$ unchanged

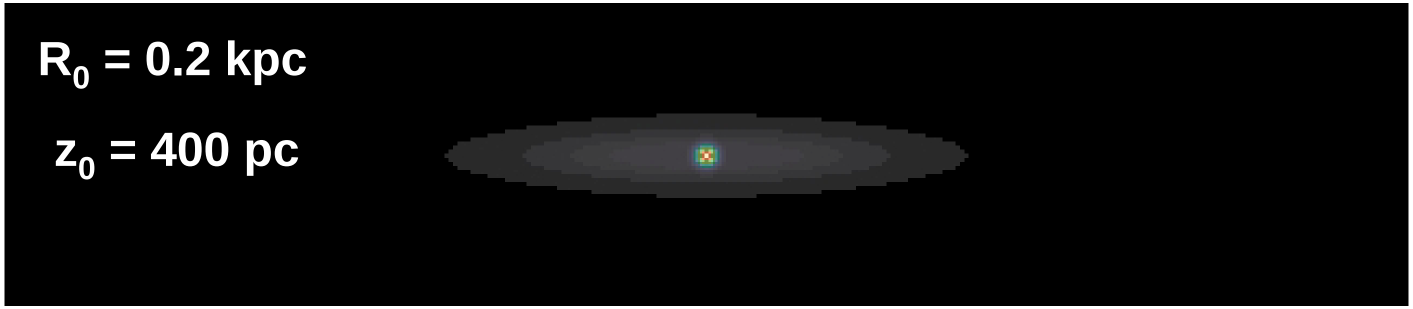


"Non physical" point sources !
Crosstalk with diffuse models

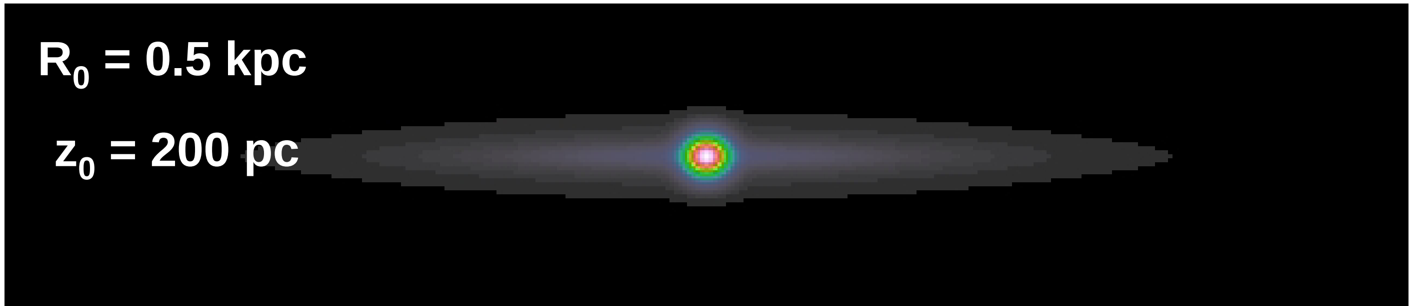
Galactic diffuse emission (testing)

508 – 514 keV :

- No input sources …
- Formally, best likelihood for R_0=200 pc, z_0=200-400 pc



- almost equally good : R0=500 pc, z0=50-400 pc (not constrained)



F_{bulge} ~ 5.5 – 8.0 10^{-4} ph/(s.cm^2.s)
F_{disc} ~ 1.3 – 2.8 10^{-3} ph/(s.cm^2.s)
F_{tot} ~ 2.1 – 3.3 10^{-3} ph/(s.cm^2.s)

Need more sky models and residues check !

SPI Co-I meeting

held at CNR in Rome, March 15-17, 2005

Status of the SPI background analysis

S. Schanne, P. Sizun, D. Maurin, B. Cordier

^{26}Al source in Galactic Plane

511 keV source in Galactic Center

Stéphane Schanne
CEA Saclay / DAPNIA / SAp, bât. 709, F-91191 Gif sur Yvette
S.Schanne@cea.fr

SPI data set used

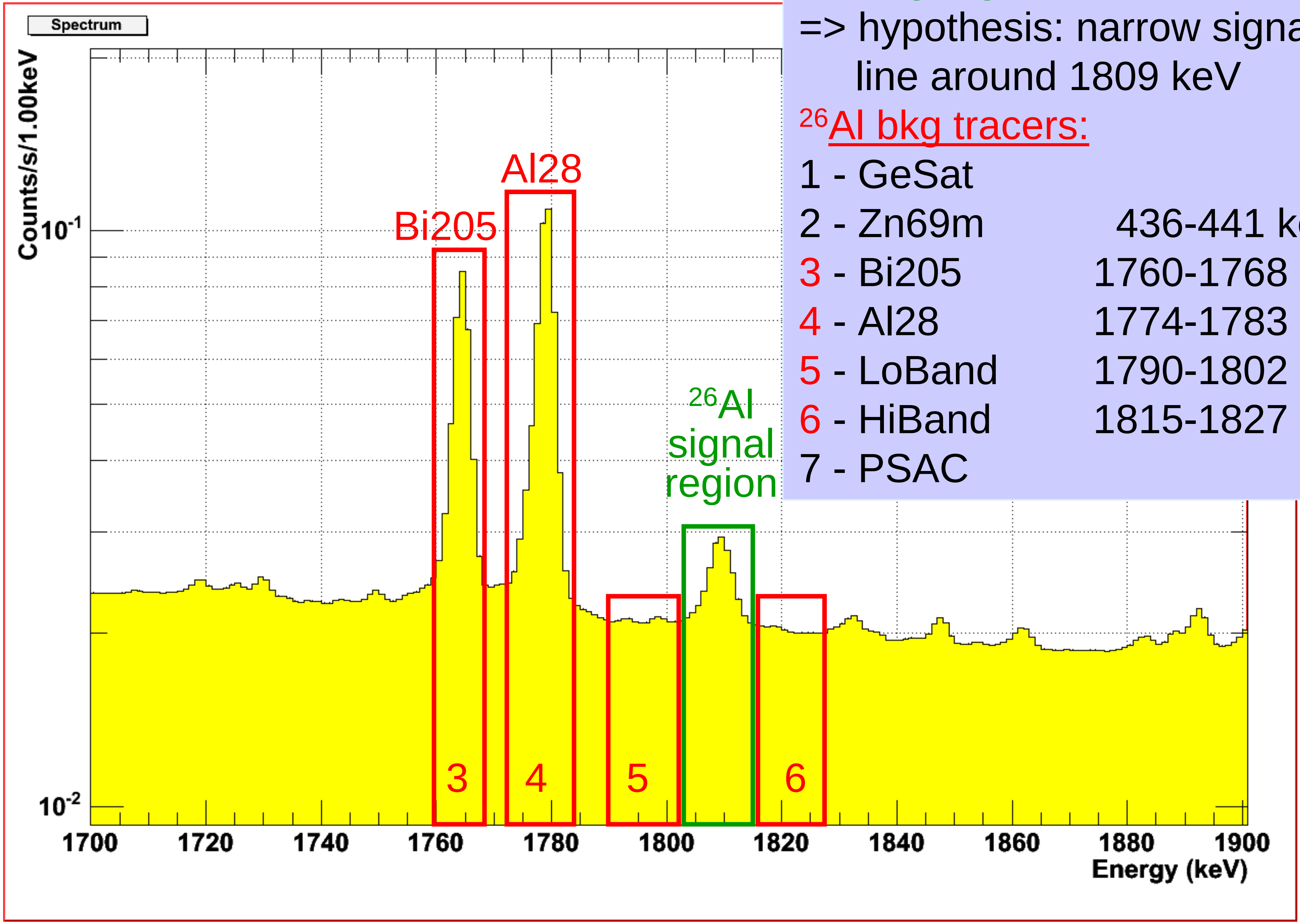
- Rev 40 - 139 (public data + ISWT data)
- “Light Bucket” (sum counts of all detectors, 1 keV binned, per SCW)
- #SCW:

8719	All data		
6613	Good quality	(Data, ScHK & IREM complete)	
6430	Temperature T0	84 - 86 K	
6017	PSAC activity	700 - 1000 counts/s (remove end of revs)	
5785	IREM protons 11-30 MeV	< 0.14 counts/s (remove solar flares)	
5606	PSAC activity	750 - 1000 counts/s (=)	
1326	OffPlane	outside -10° < B < 10°	500 ks
4280	GalPlane	inside -10° < B < 10°	9000 Ms
274	Vela	GalPlane & -101° < L < -89°	900 ks

=> GalPlane : search for Al26 & 511 keV signal

OffPlane : for background model fitting (hypothesis: free of signal)

SPI background around Al26 region (IE)

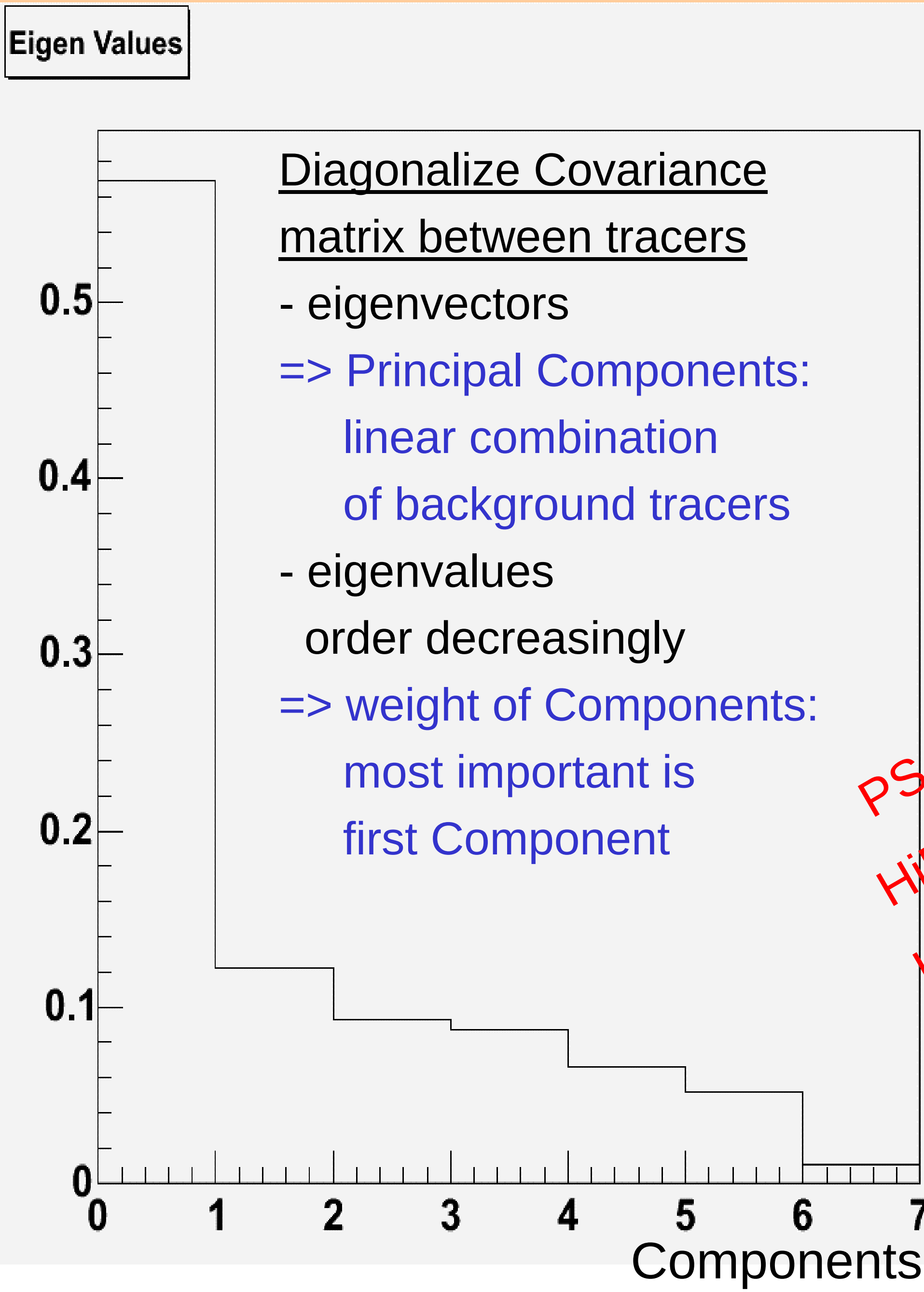


^{26}Al sig region: 1803-1815 keV
=> hypothesis: narrow signal line around 1809 keV

^{26}Al bkg tracers:

1 - GeSat
2 - Zn69m 436-441 keV
3 - Bi205 1760-1768
4 - Al28 1774-1783
5 - LoBand 1790-1802
6 - HiBand 1815-1827
7 - PSAC

OffPlane+GalPlane : Principal Components



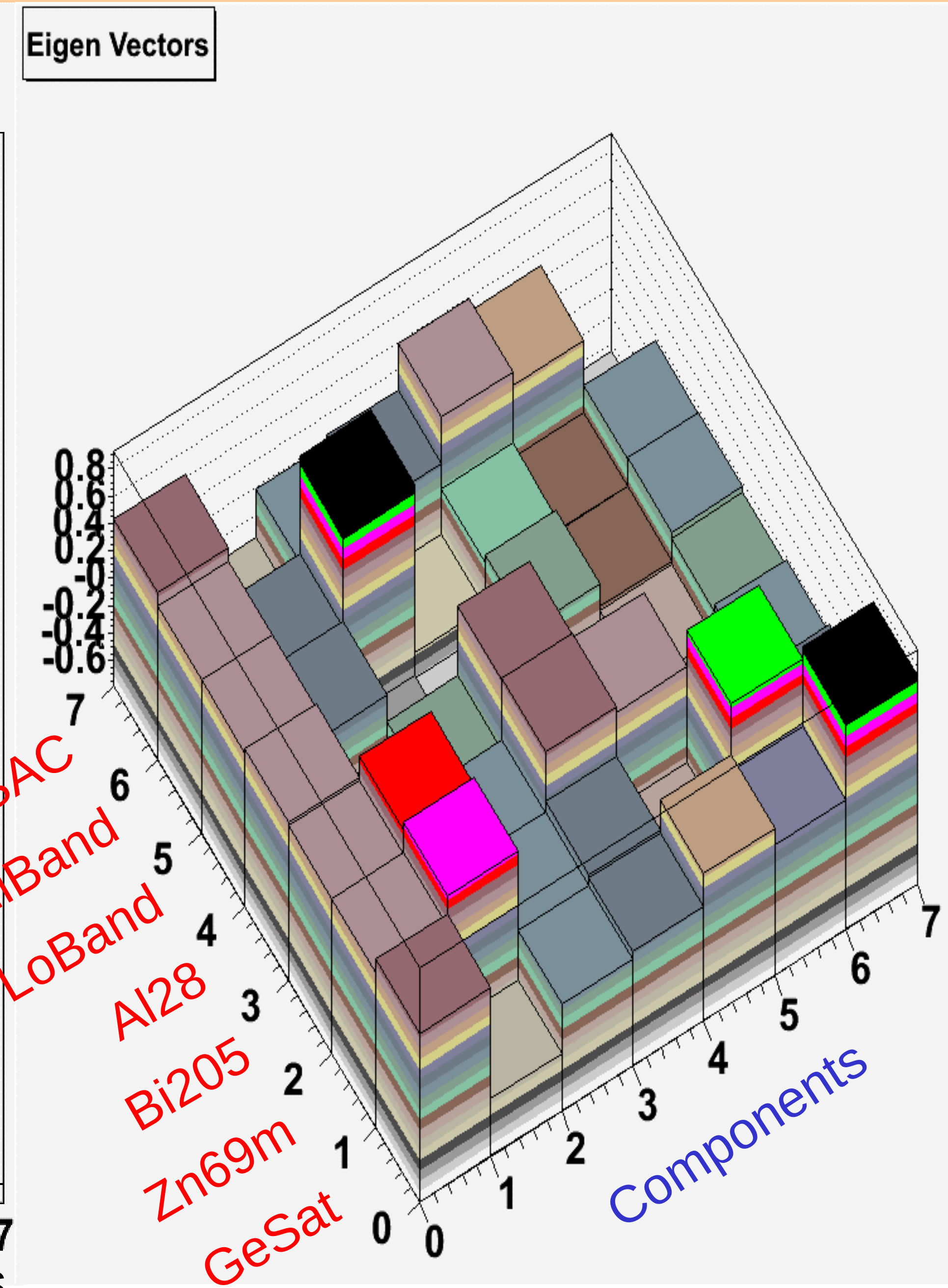
Diagonalize Covariance matrix between tracers

- eigenvectors

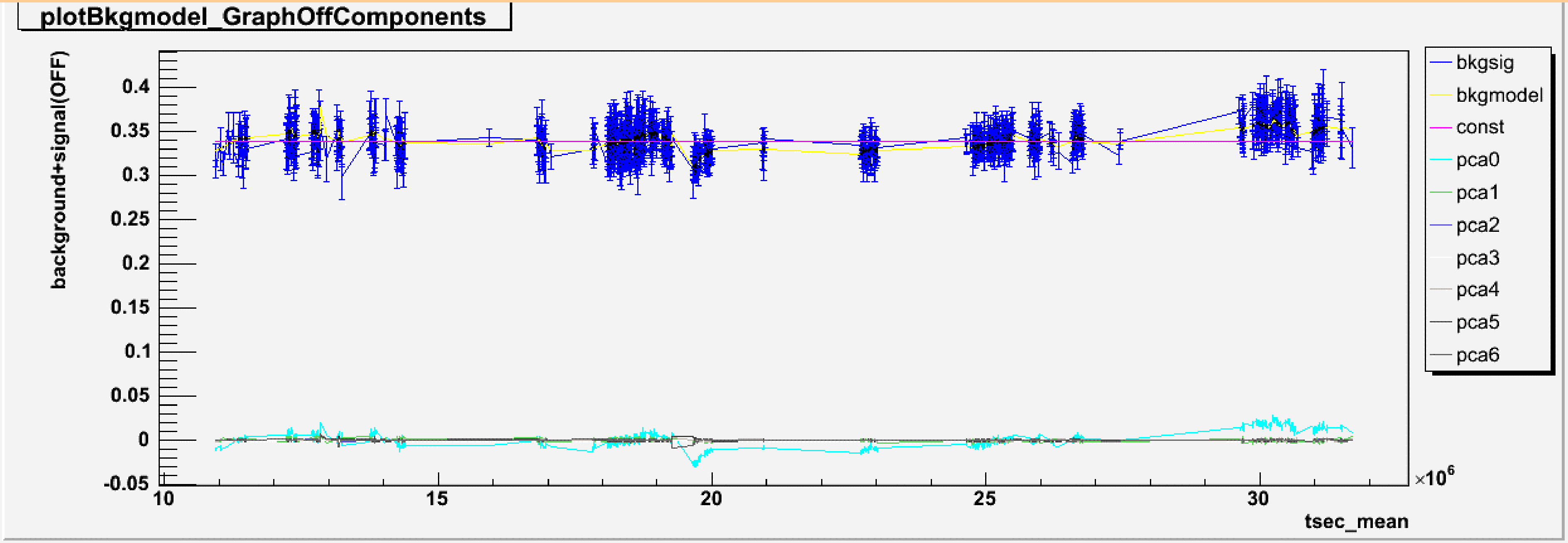
=> Principal Components:
linear combination
of background tracers

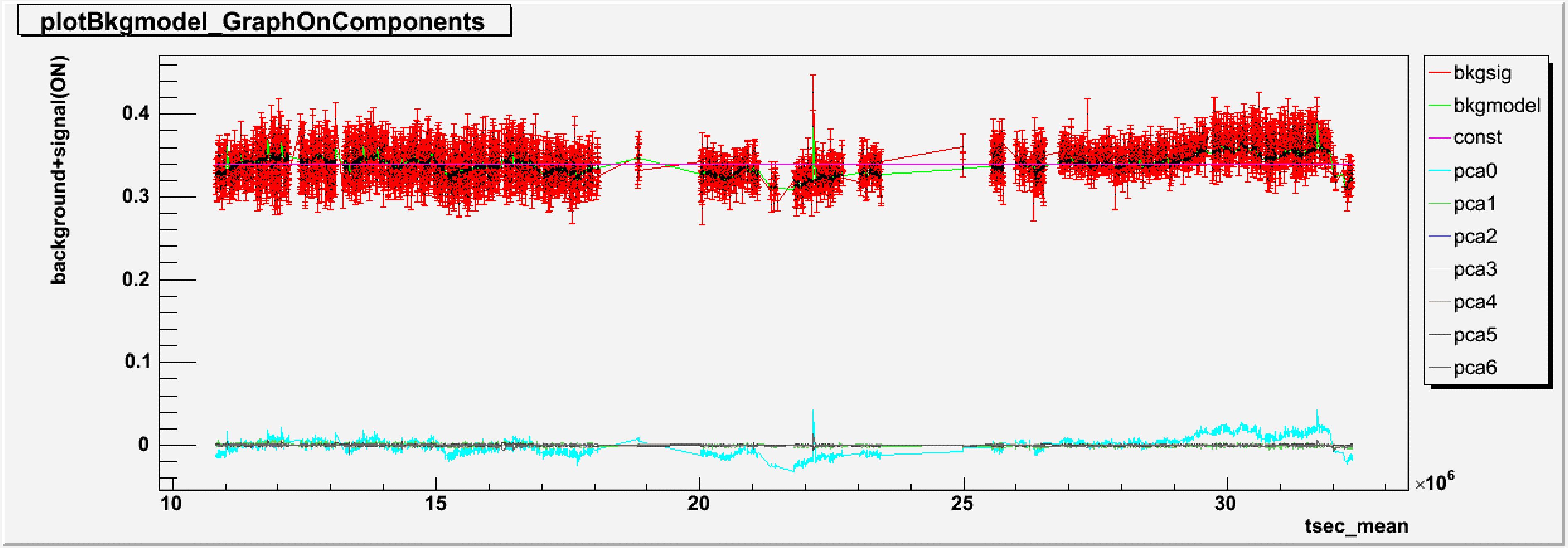
- eigenvalues
order decreasingly

=> weight of Components:
most important is
first Component

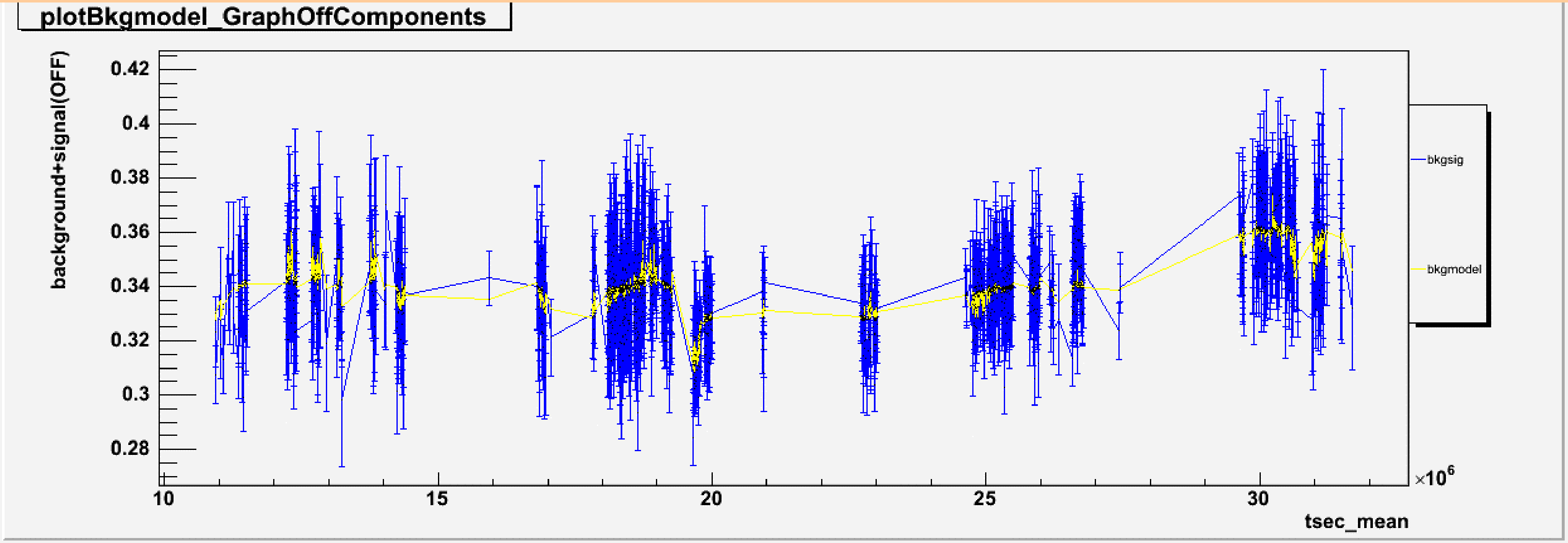


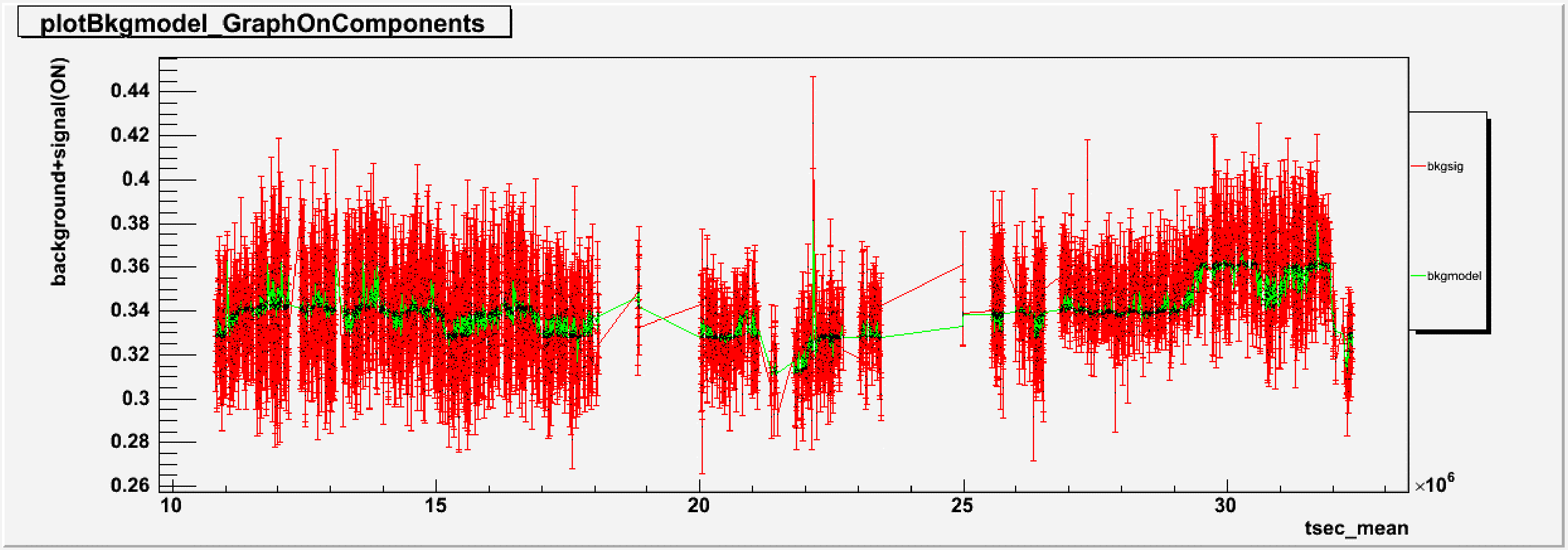
Linear background model





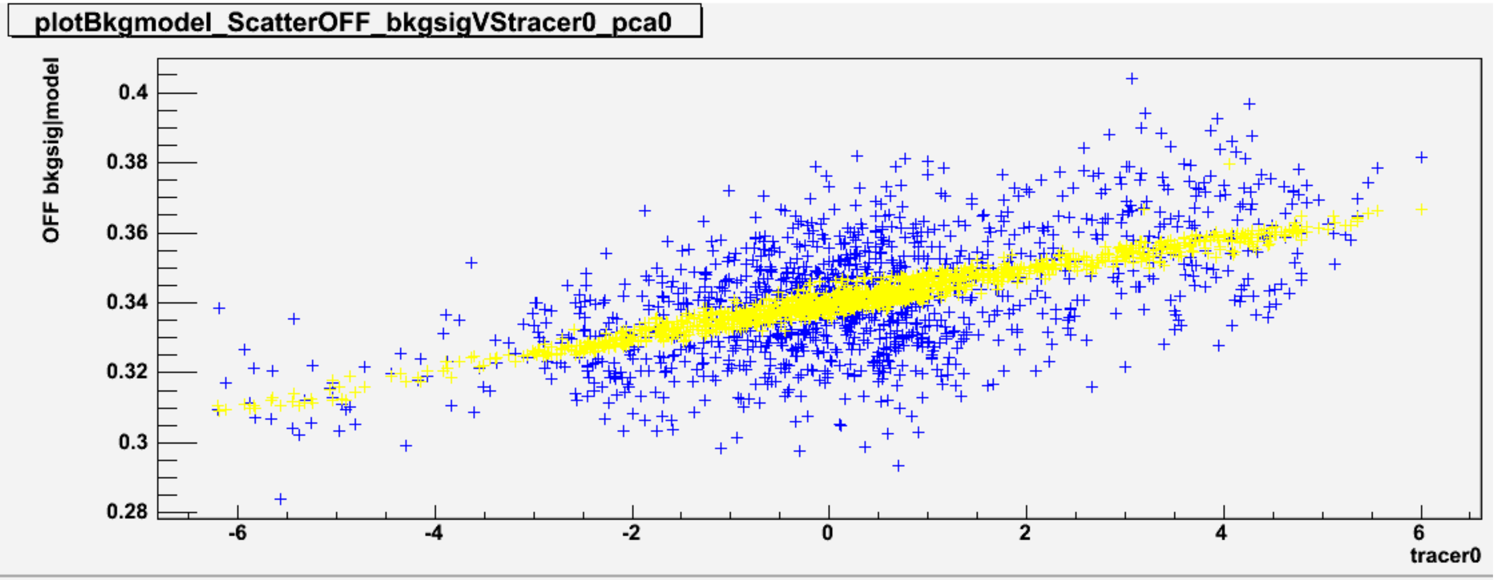
Bayesian background model (non-linear probabilitic neural net)





Linear background model

each pointing: cnt/s in signal region *vs* pca0 (normalized, centered component 0)



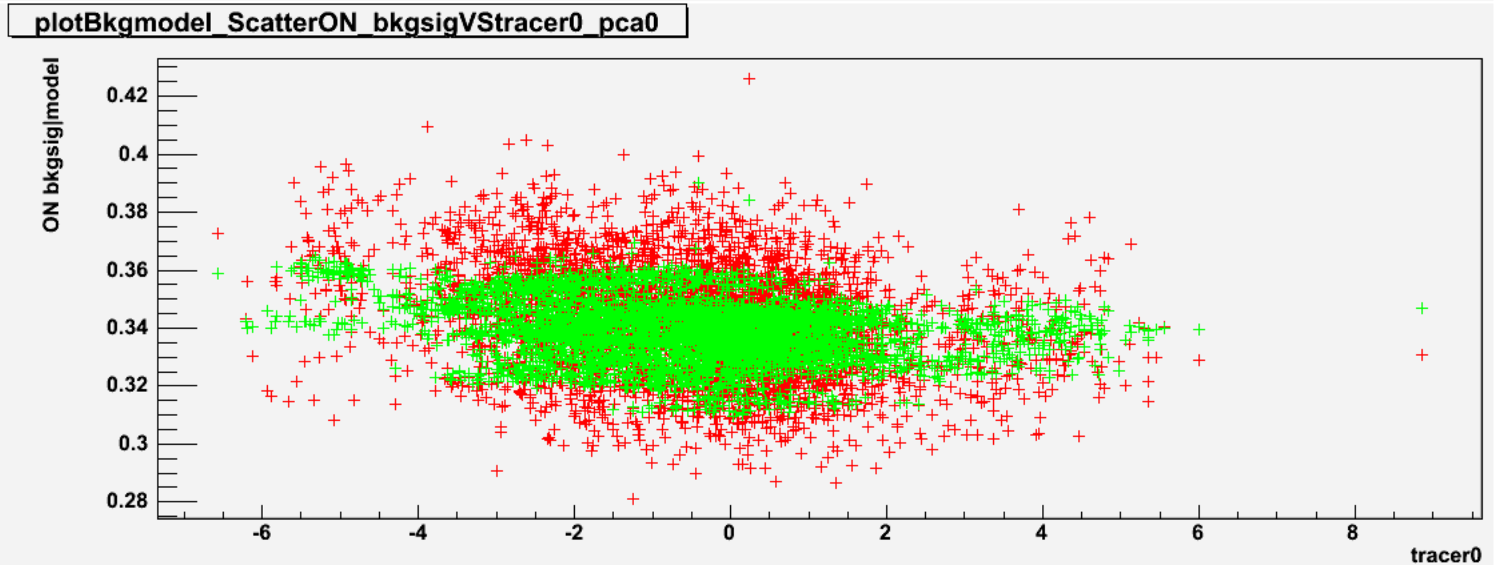
Blue:

bkg vs pca0

Yellow:

bkg model fit

using all tracers



Red:

bkg+sig vs pca0

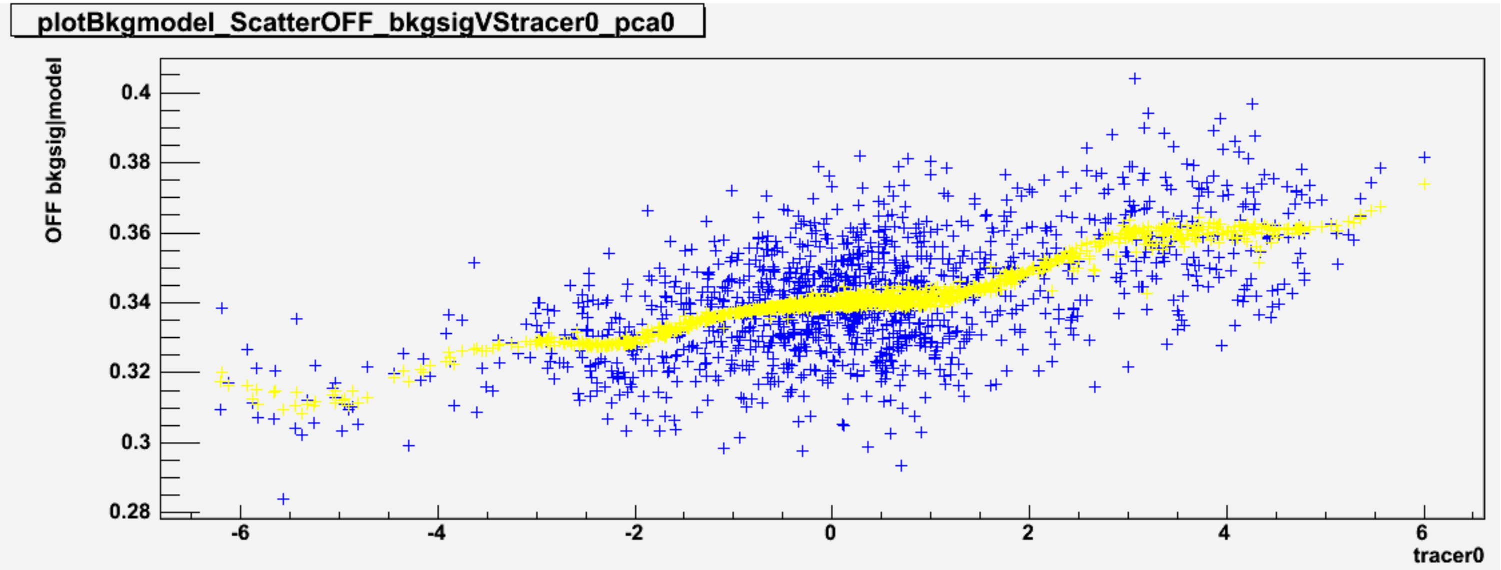
Green:

bkg prediction

using all tracers

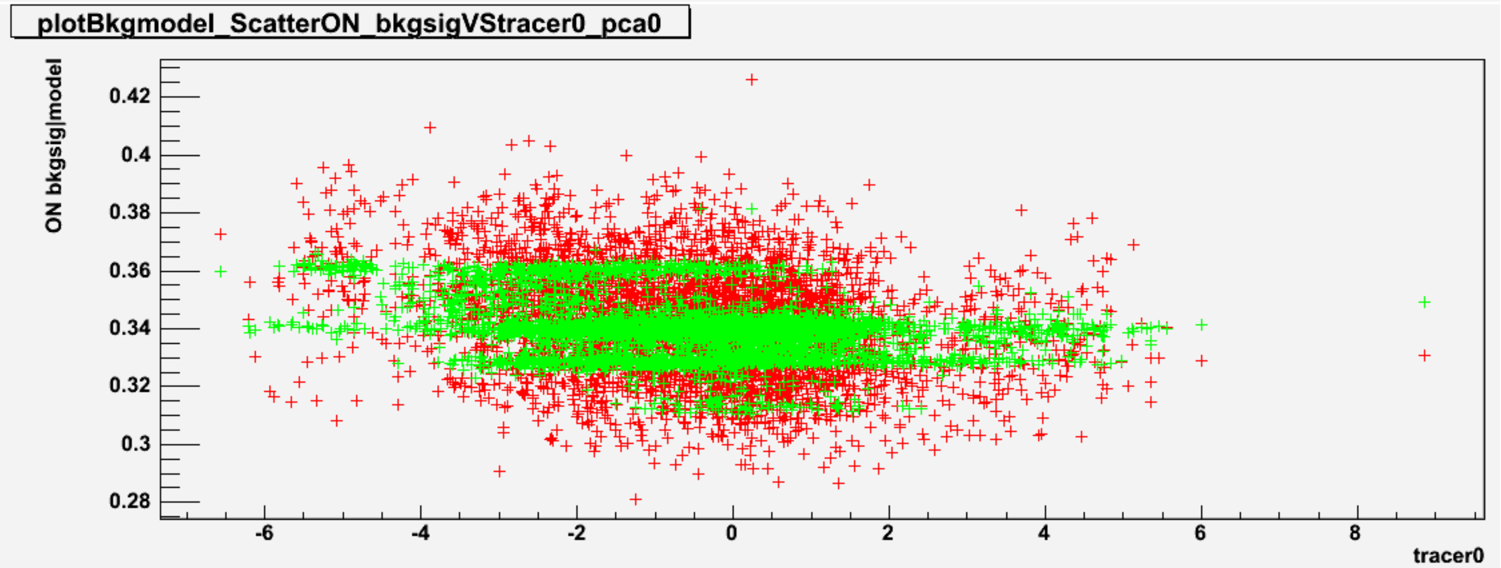
Bayesian background model

each pointing: cnt/s in signal region *vs* pca0 (normalized, centered component 0)



Blue:
bkg vs pca0

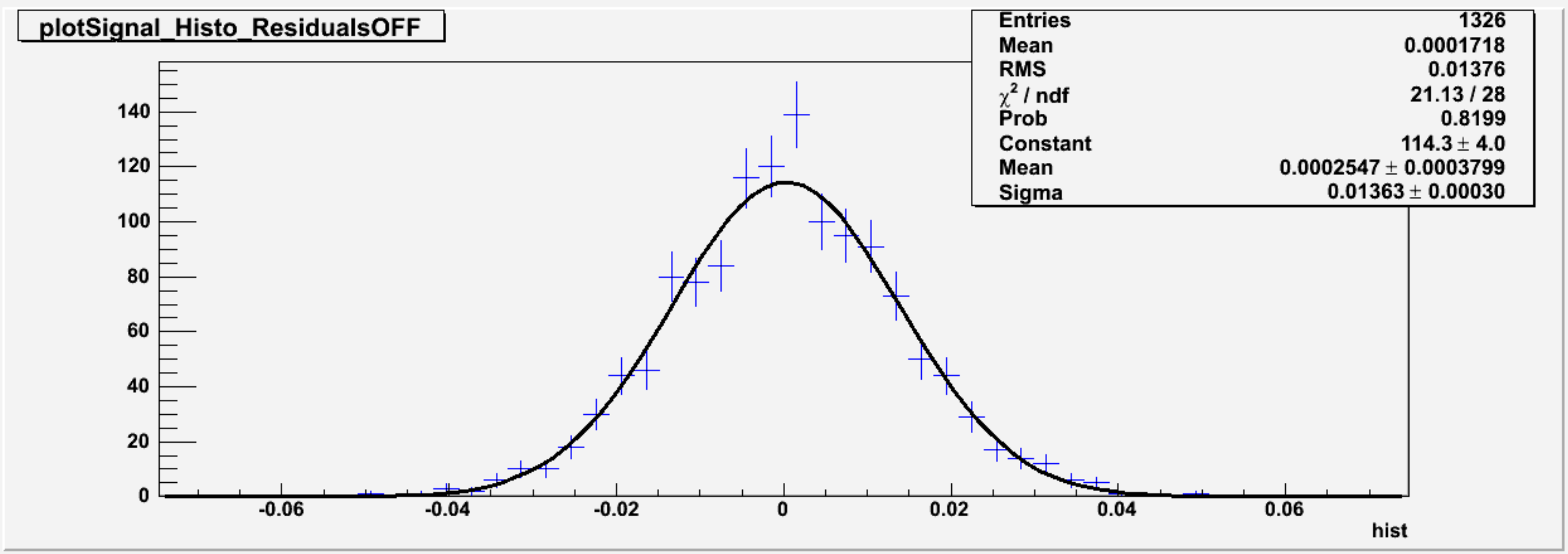
Yellow:
bkg model fit
using all tracers

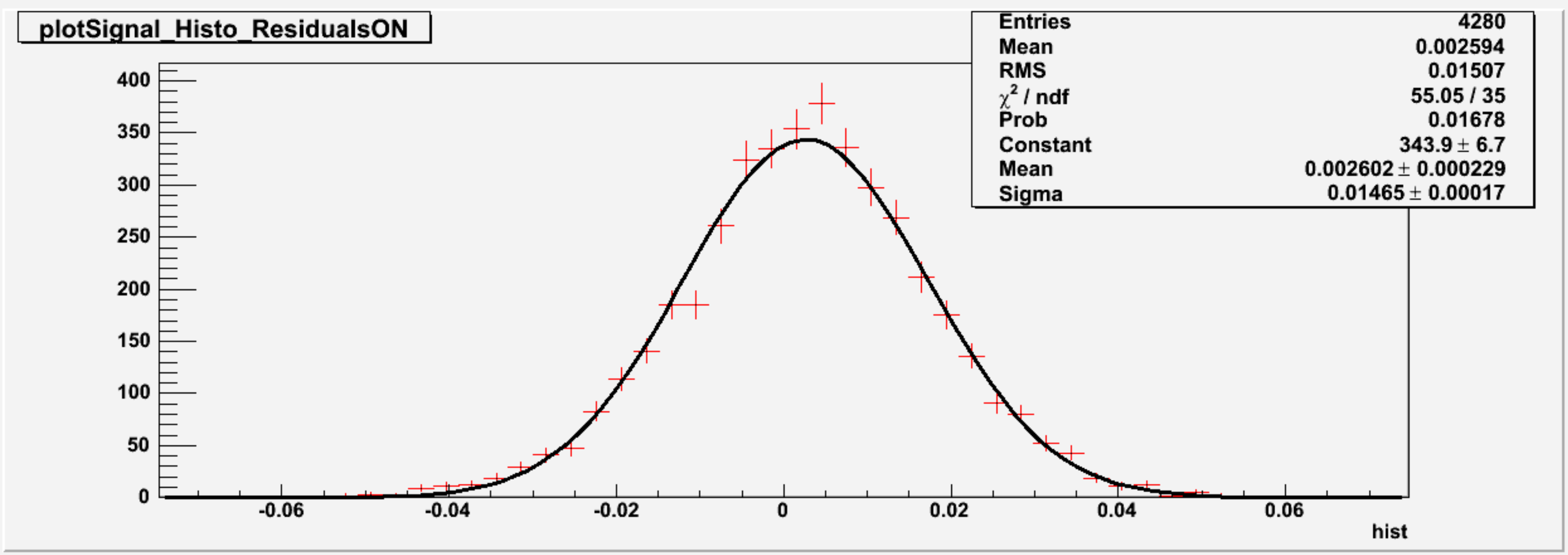


Red:
bkg+sig vs pca0

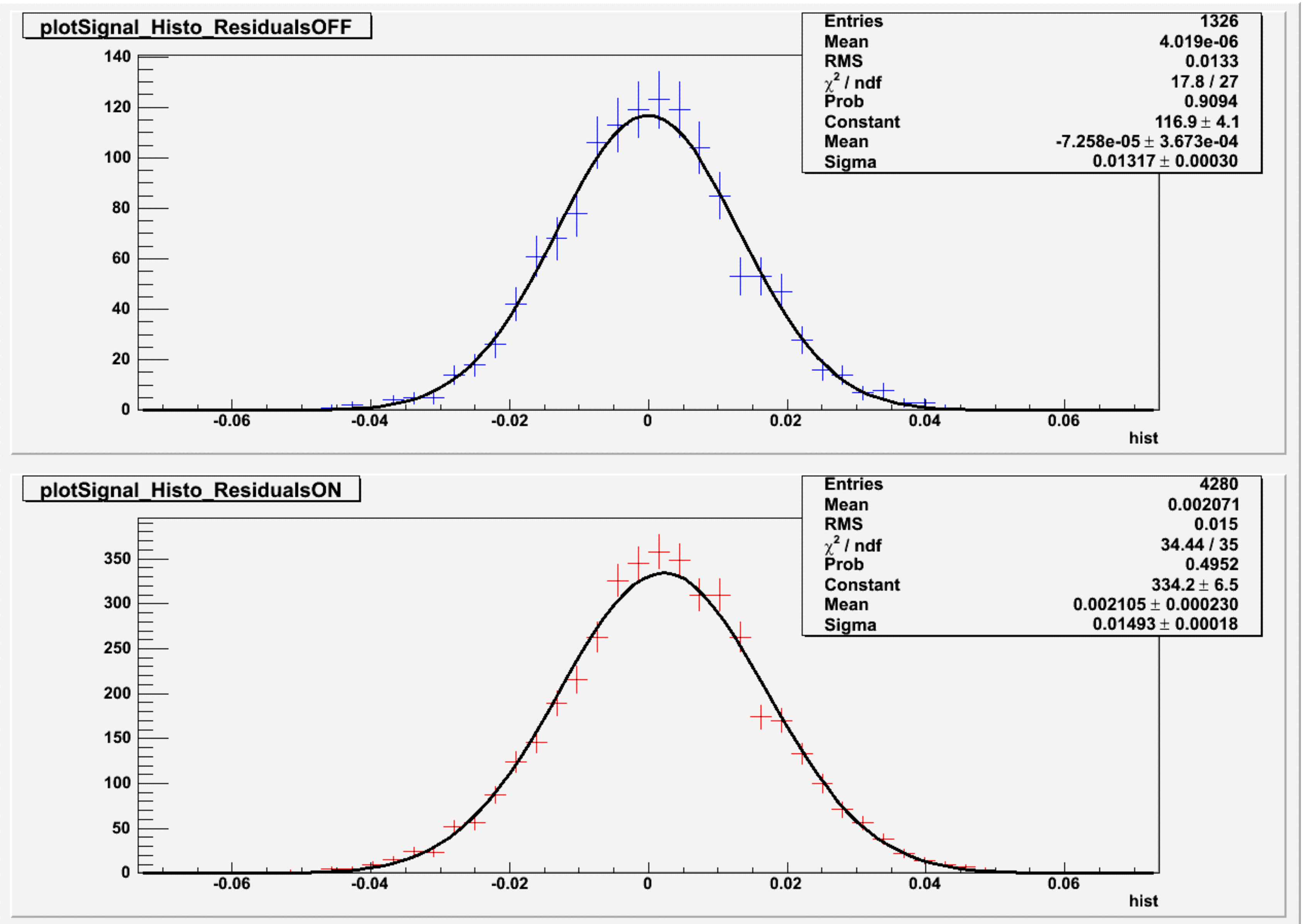
Green:
bkg prediction
using all tracers

Residuals (cnt/s) - Linear model, 7 tracers

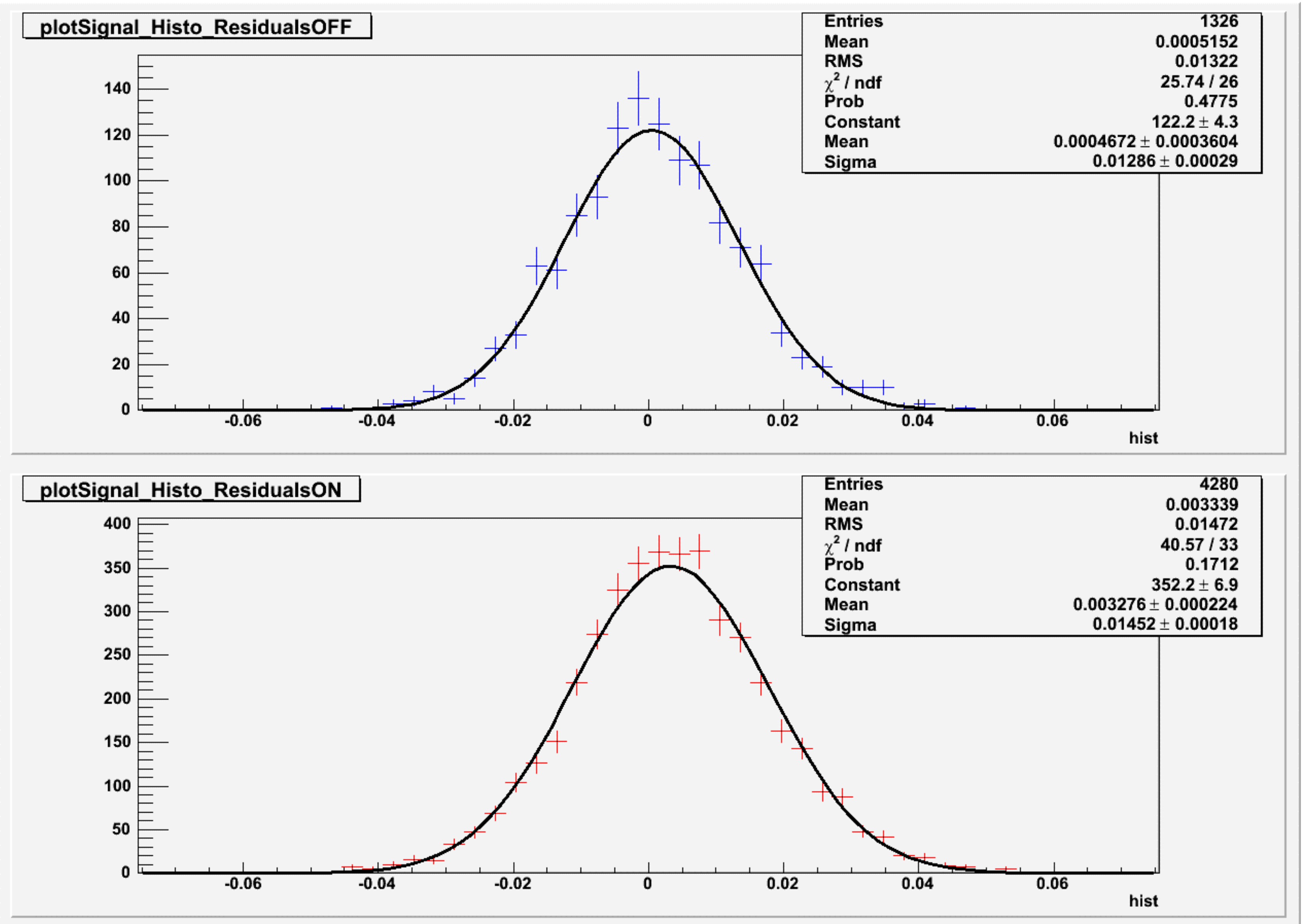




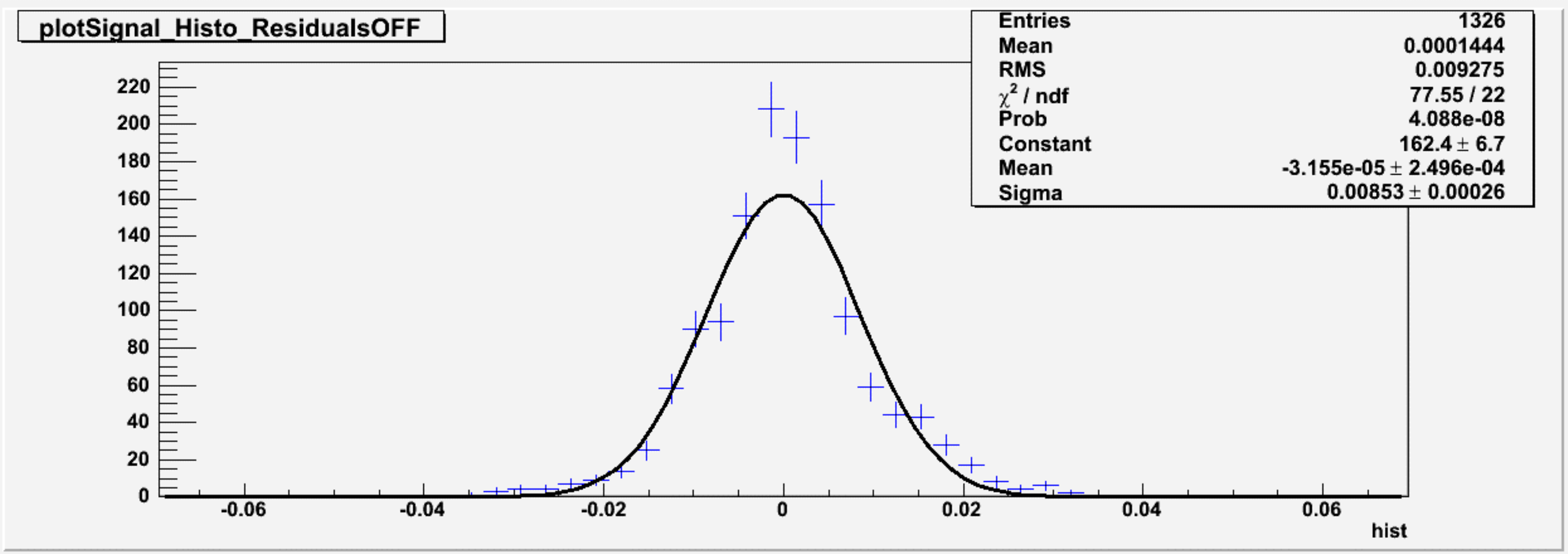
Residuals (cnt/s) - Bayesian model, 7 tracers

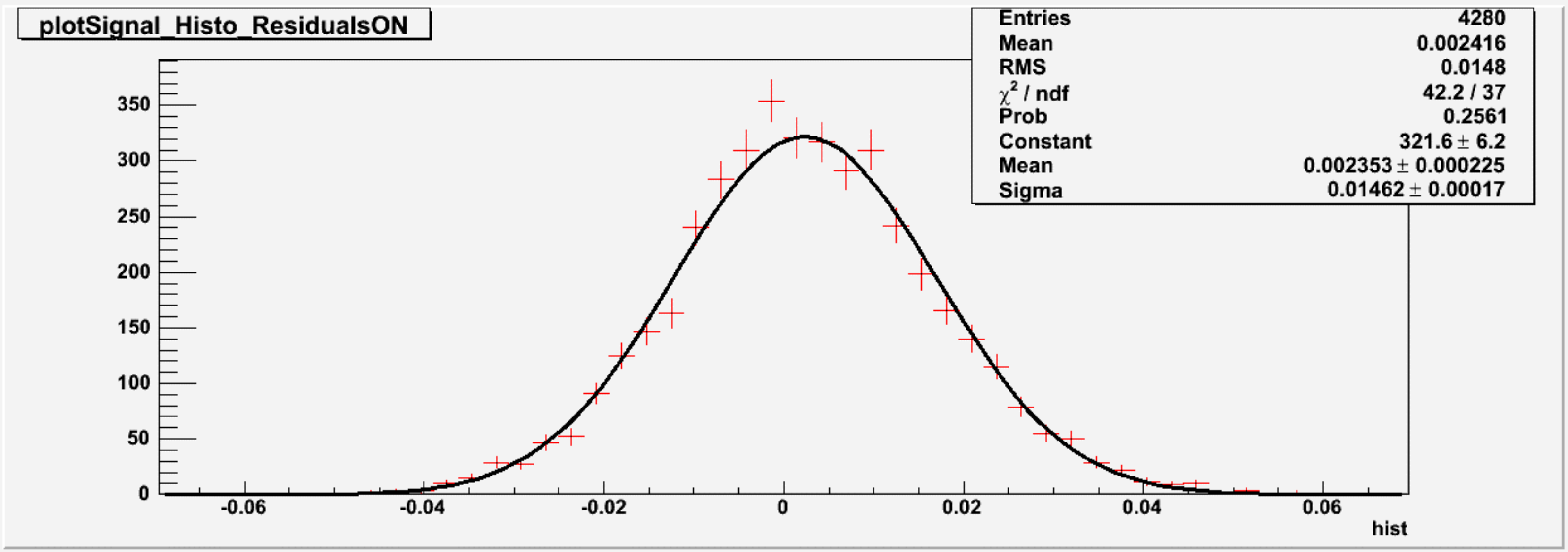


Residuals (cnt/s) - Linear model, 36 tracers

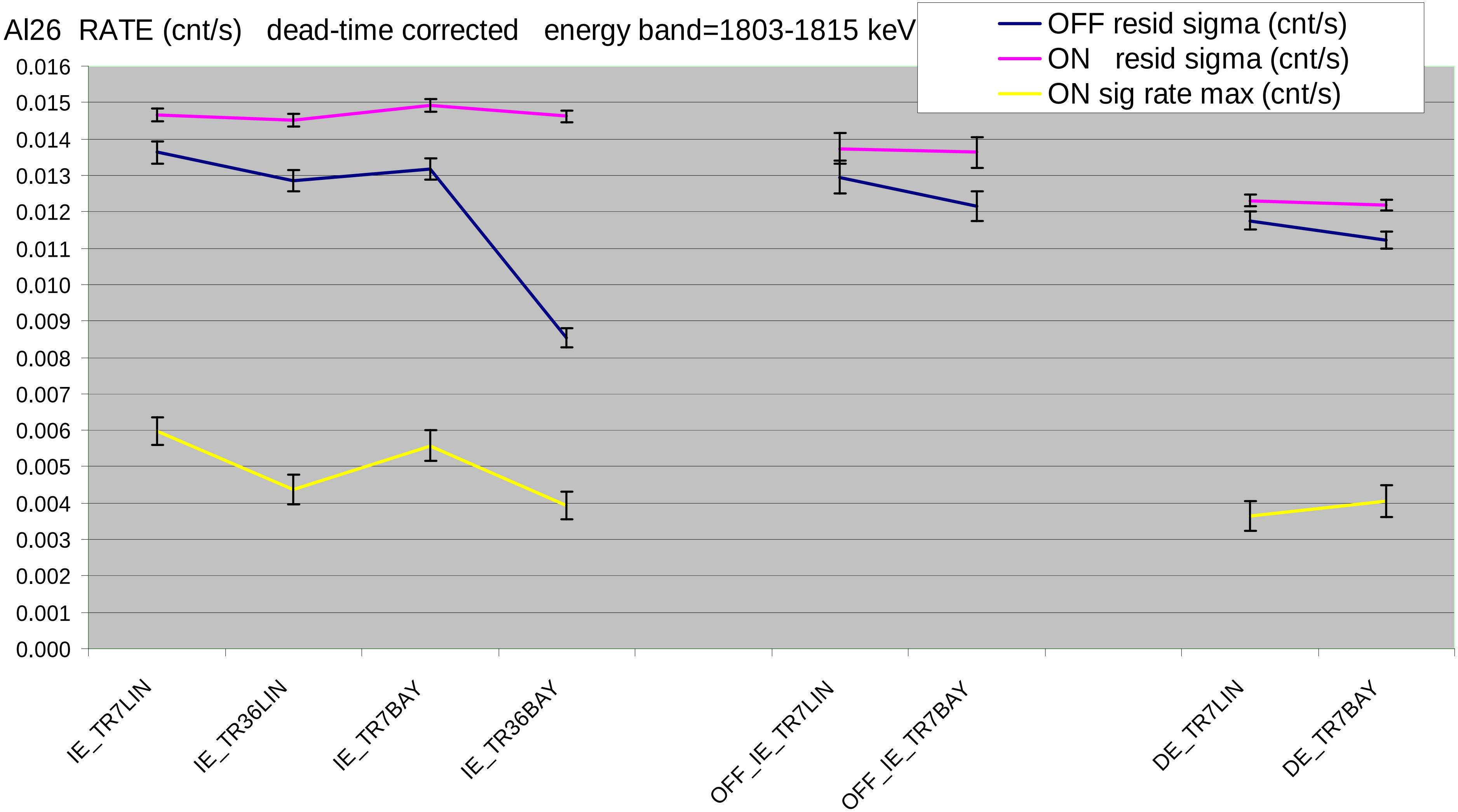


Residuals (cnt/s) - Bayesian model, 36 tracers

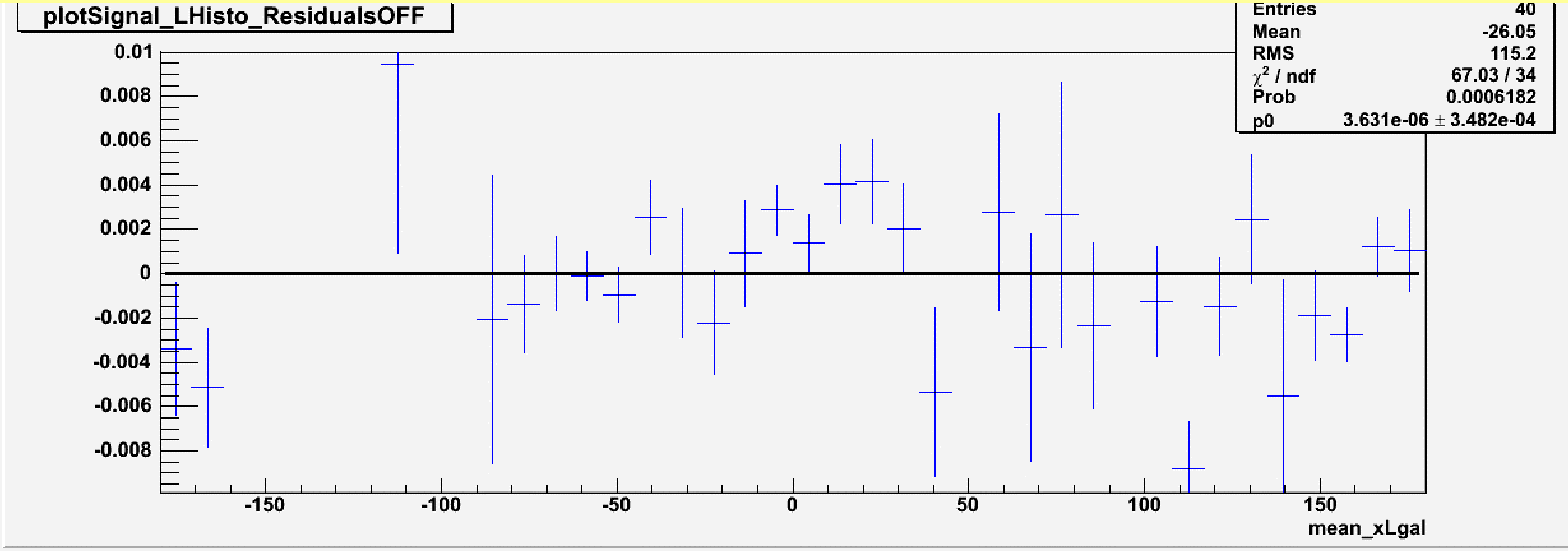


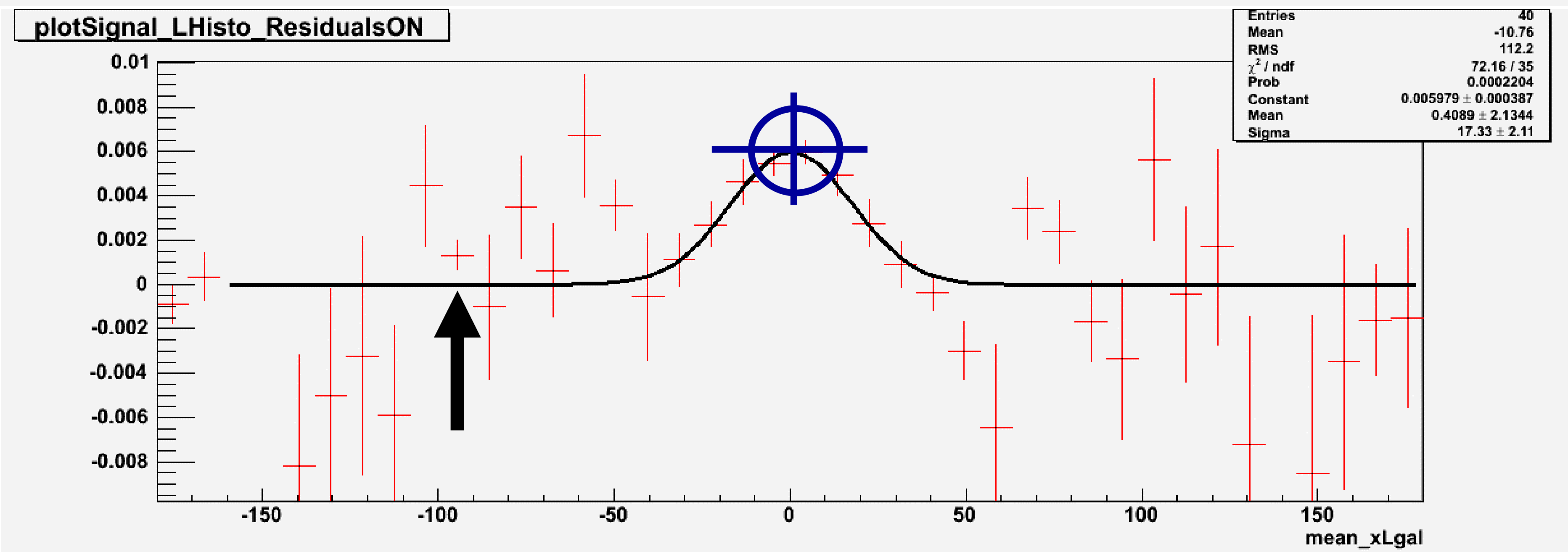


Al26 rates

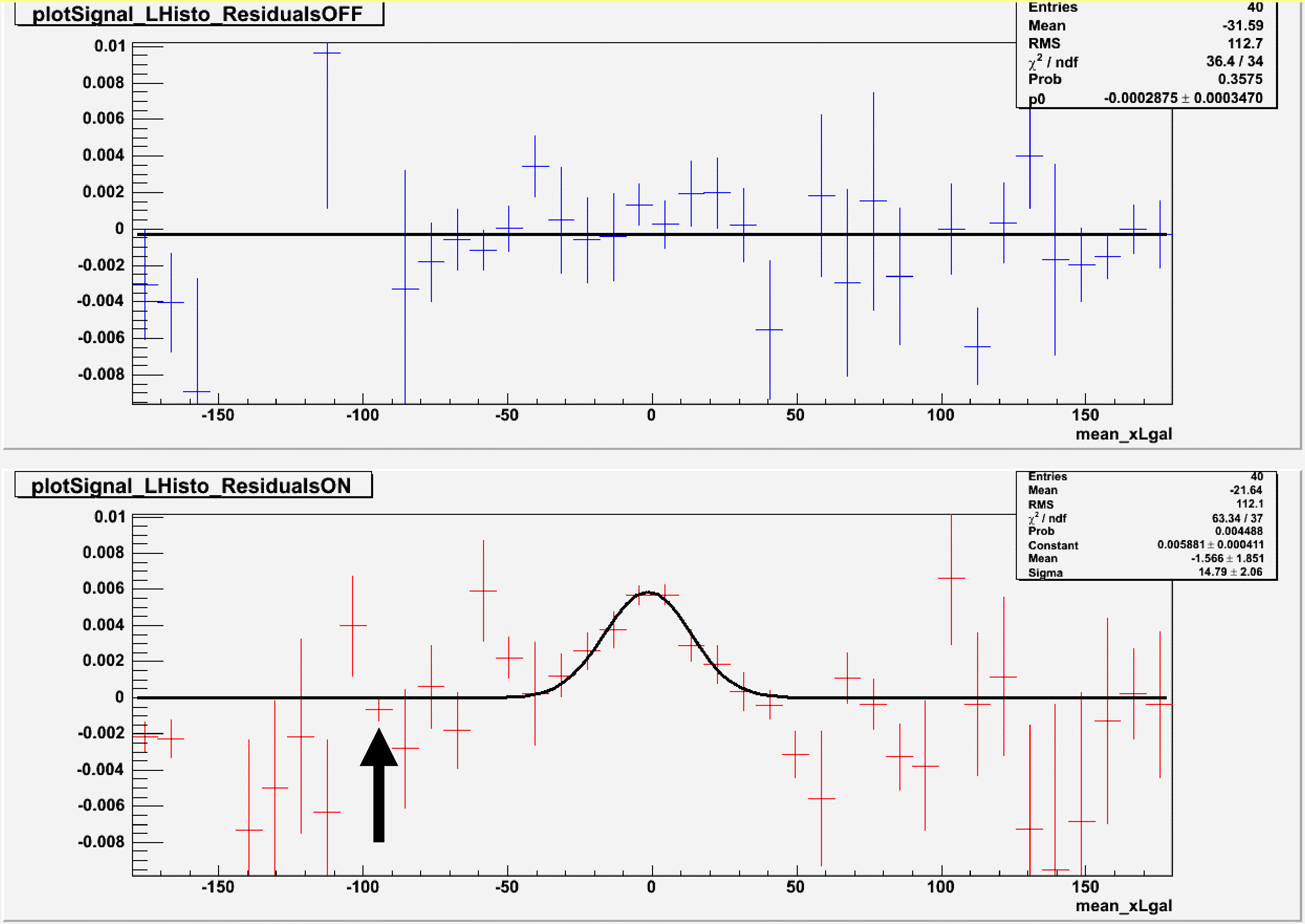

Al26 RATE (cnt/s) dead-time corrected energy band=1803-1815 keV
OFF resid sigma (cnt/s)
ON resid sigma (cnt/s)
ON sig rate max (cnt/s)
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
IE_TR7LIN
IE_TR36LIN
IE_TR7BAY
IE_TR36BAY
OFF_IE_TR7LIN
OFF_IE_TR7BAY
DE_TR7LIN
DE_TR7BAY

Al26 signal vs L, Linear model, 7 tracers, IE

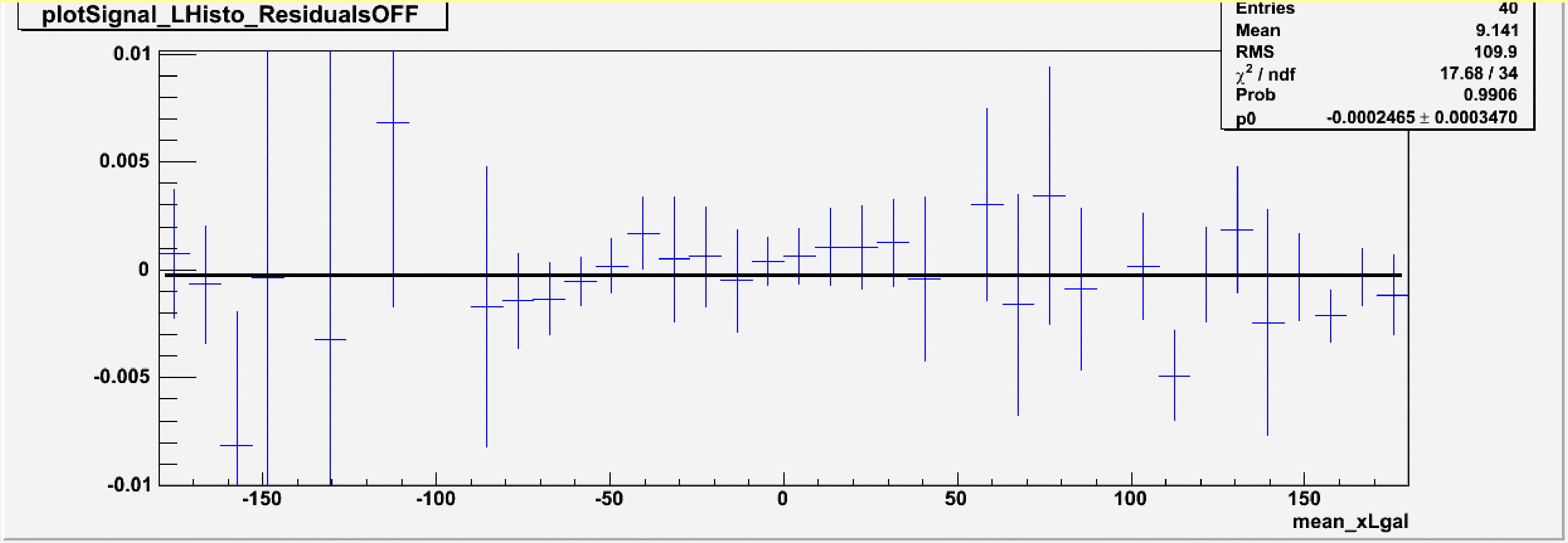


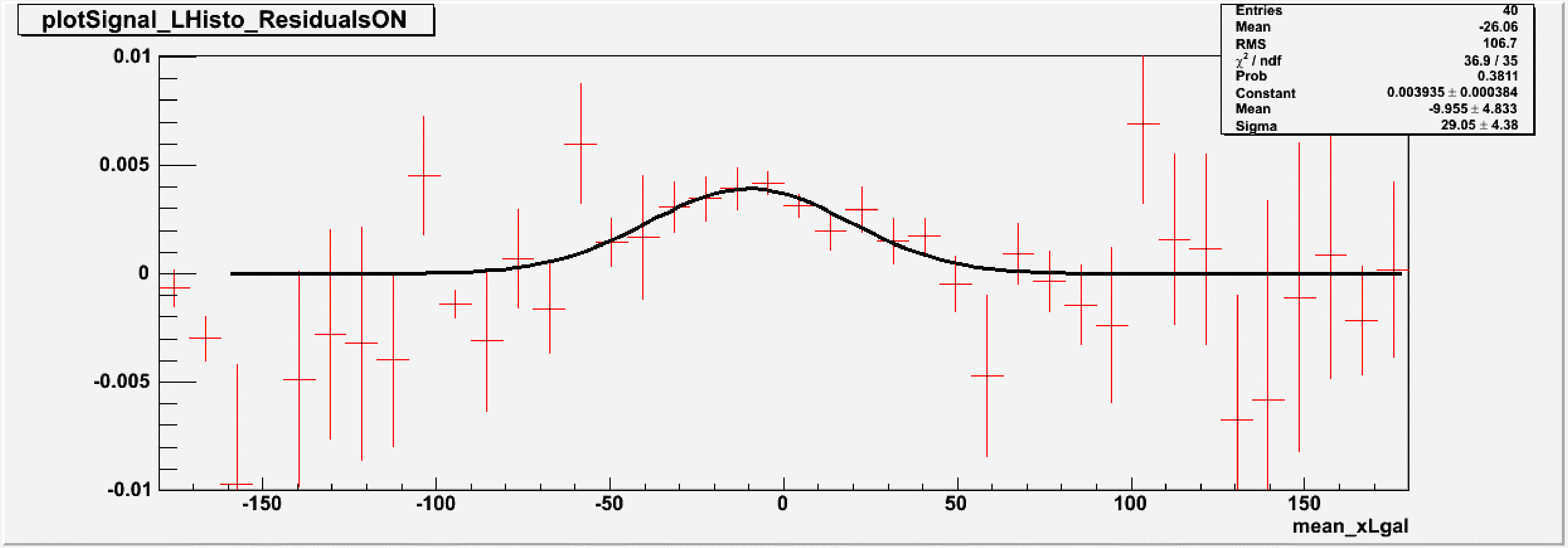


Al26 signal vs L, Bayesian model, 7 tracers, IE

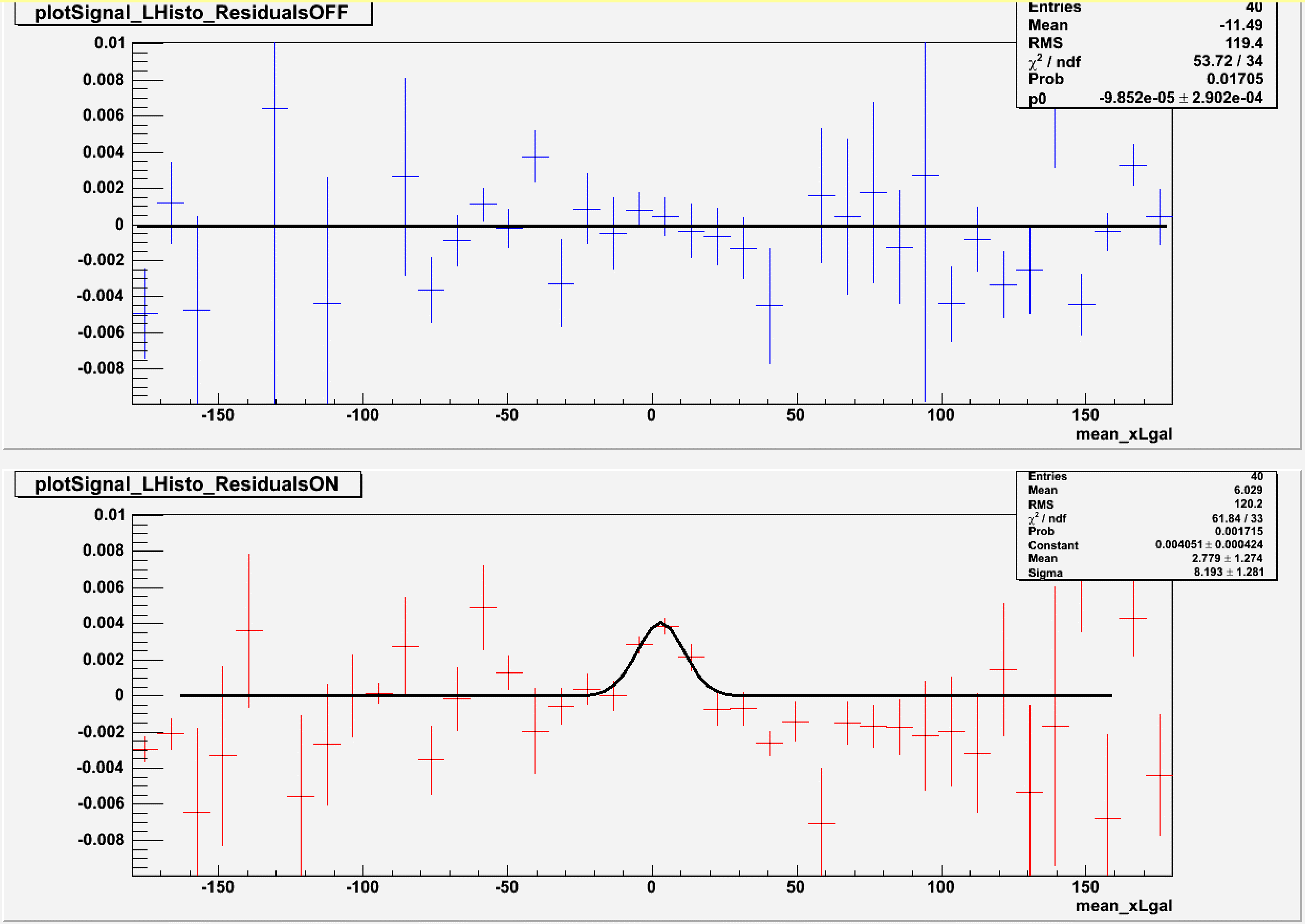


Al26 signal vs L, Bayesian model, 36 tracers, IE





Al26 signal vs L, Bayesian model, 7 tracers, DE

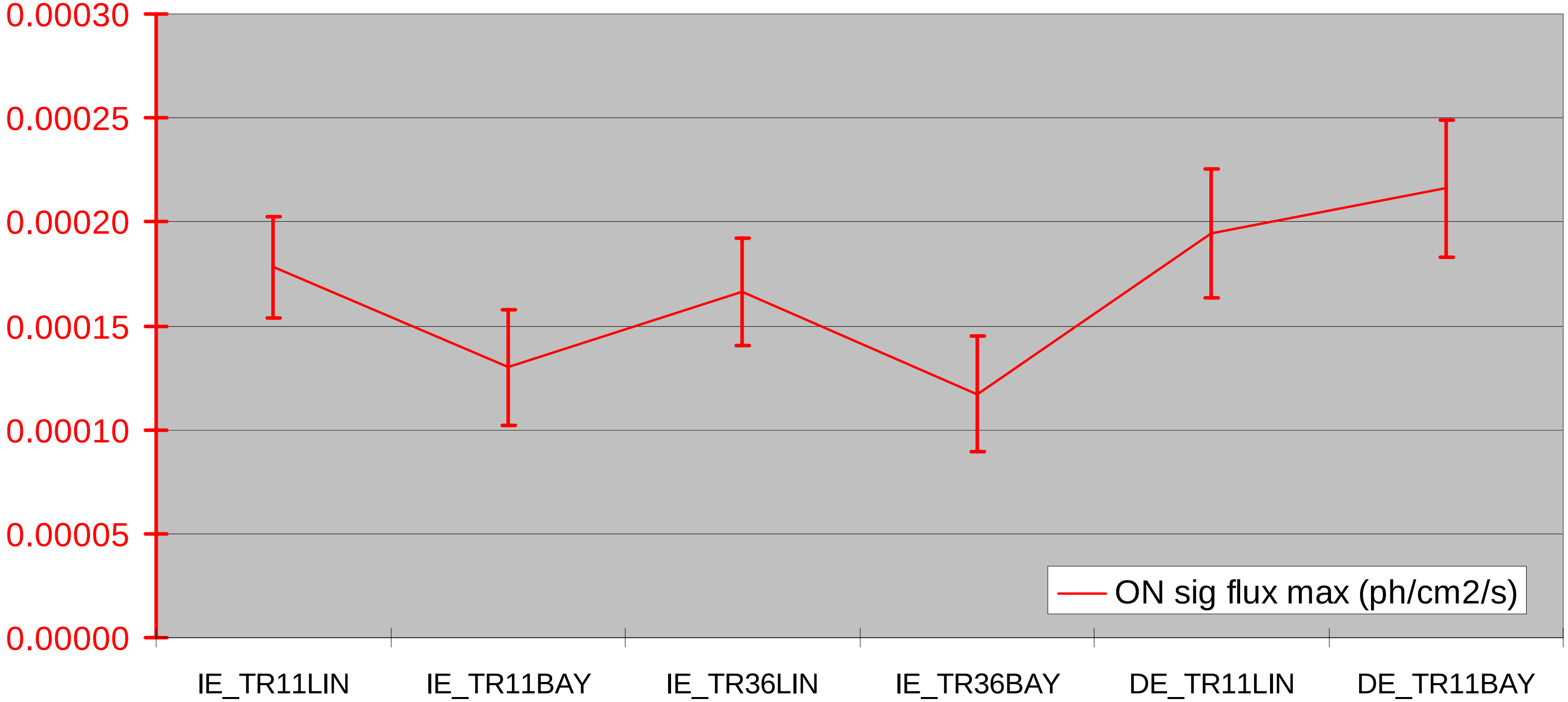


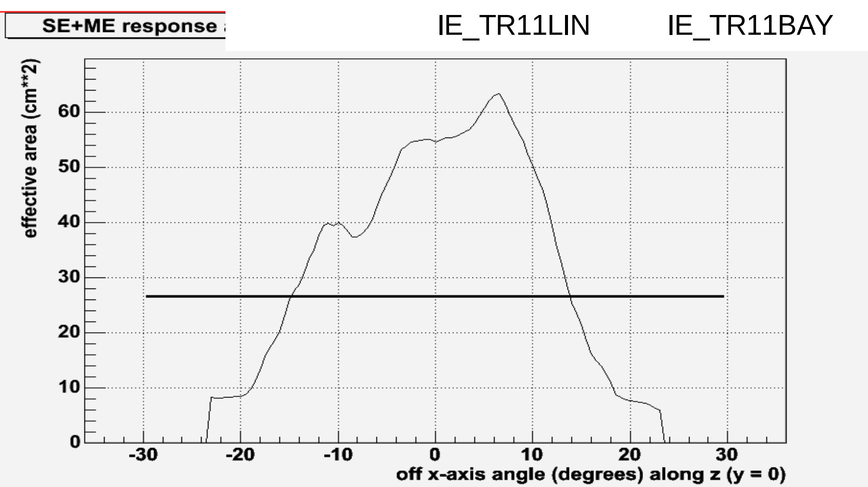
Al26 flux

At 1809 keV for a point source on axis: Aeff(IE) = 33.5 cm^2 Aeff(DE) = 18.7 cm^2

=> point source hypothesis : cross-check if IE and DE gives the same rate, yes !

Al26 FLUX (flux maximum, insided FOV, SPI light-bucket)





=> response for a diffuse source, uniform in -30 - 30° :

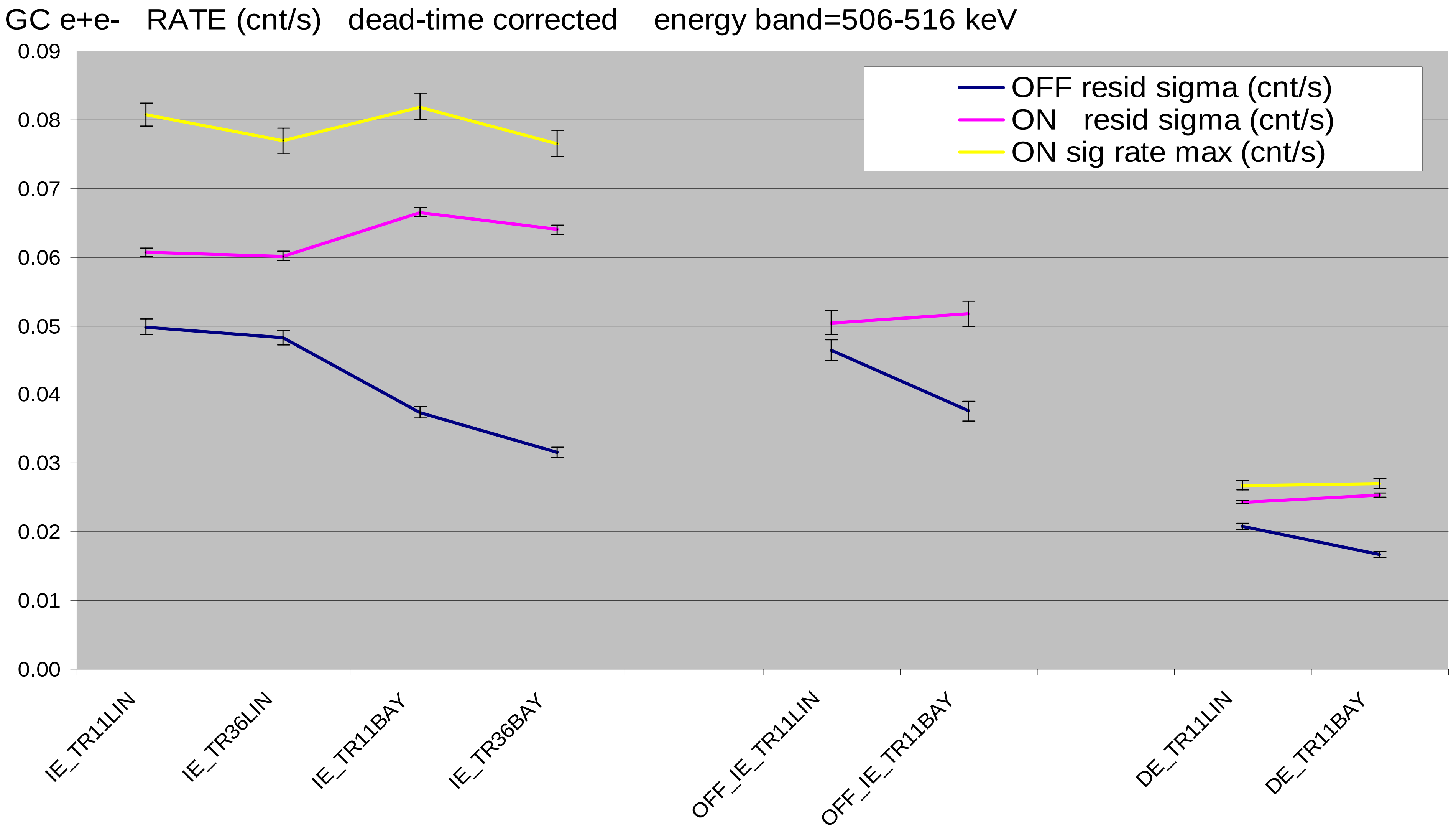
$Aeff(IE+ME)_{Point/Diffuse}$ = 55 cm^2 / 26 cm^2 = 2.11

multiply the fluxes by this number!

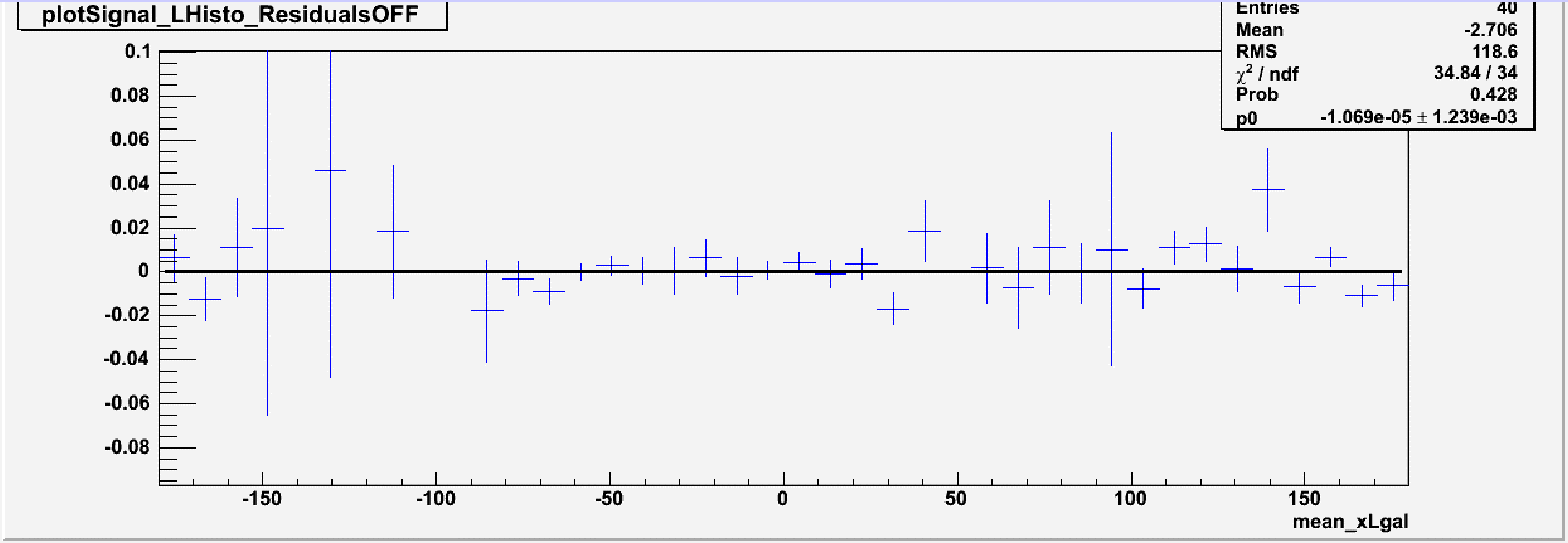
=> $(3.53 \pm 0.32 \pm 0.64) \times 10^{-4}$ ph/cm^2/s

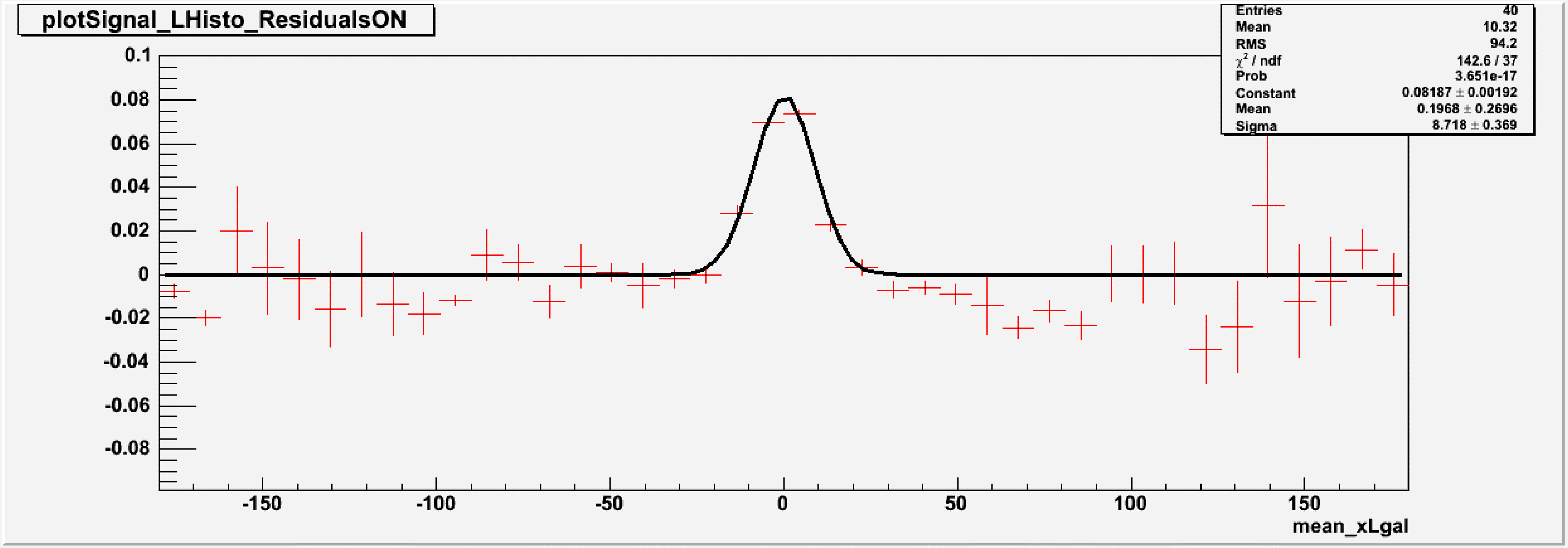
COMPTEL: $(2.8 \pm 0.15) \times 10^{-4}$ ph/cm^2/s

511 keV rates

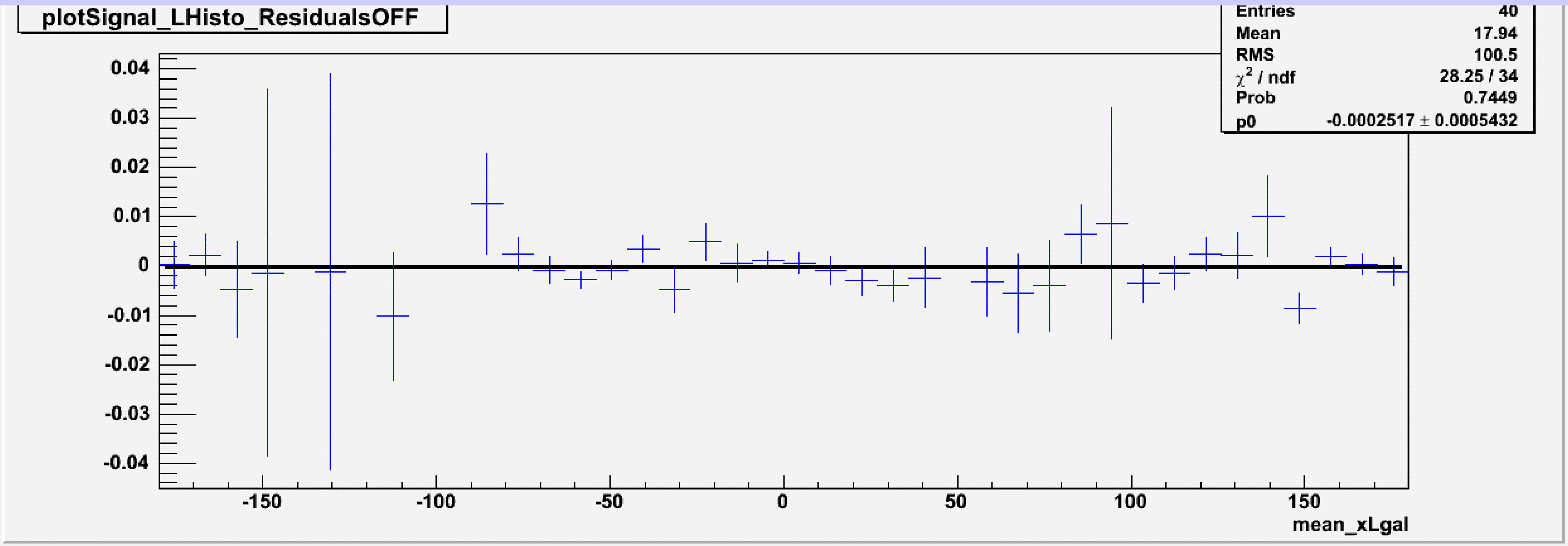


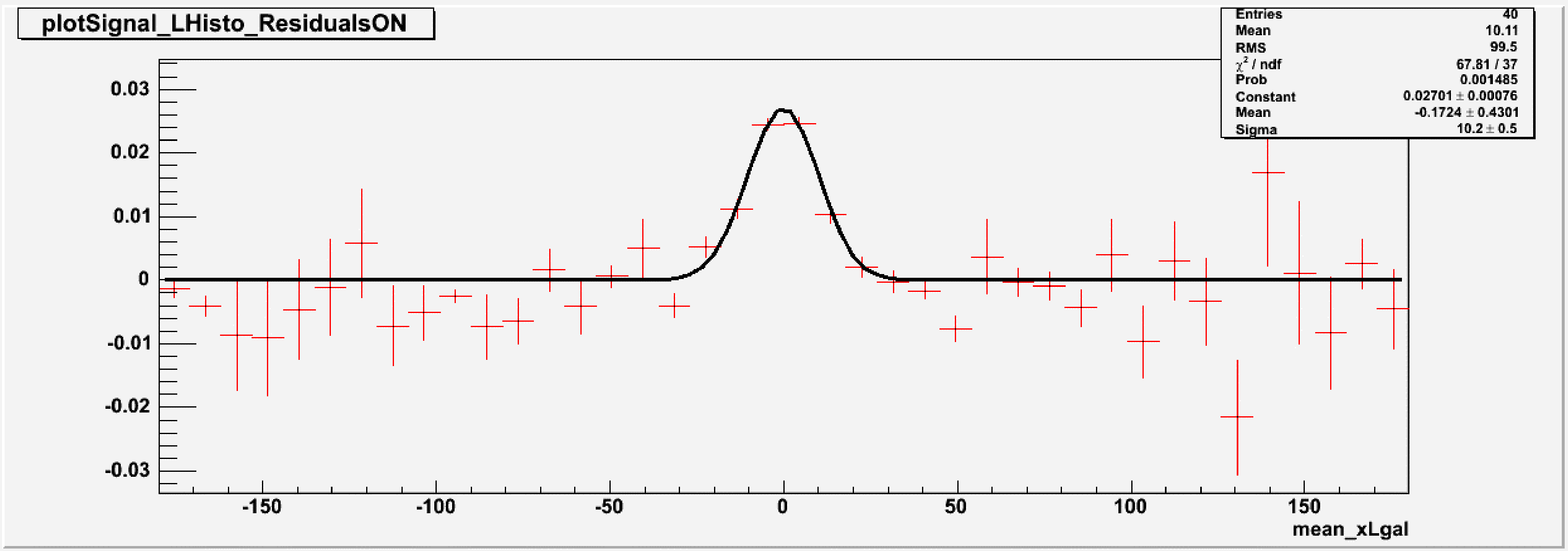
511 keV signal vs L, Bayesian model, 11 tracers, IE





511 keV signal vs L, Bayesian model, 11 tracers, DE

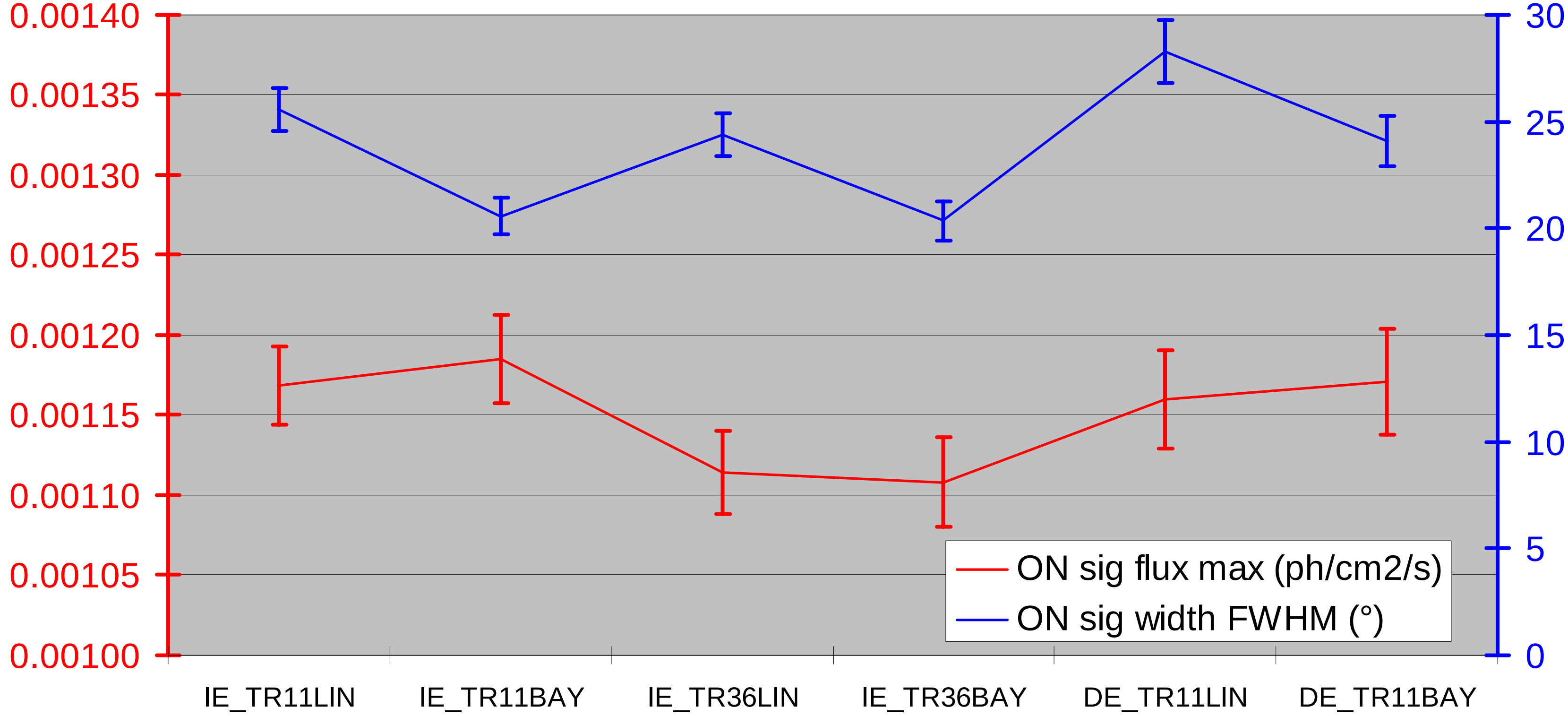




511 keV flux

At 511 keV for a point source on axis: Aeff(IE) = 69.1 cm^2 Aeff(DE) = 23.1 cm^2

GC e^+e^- FLUX and SIZE (including instrumental)



511 keV line flux (if spatially size < full eff. region)

=> $(1.15 \pm 0.28 \pm 0.27) \times 10^{-3}$ $ph/cm^2/s$

Conclusions

- Tracers must be centered / normalized or transformed to Principal Components
- The more Tracers used, the better the fit
- Bayesian model gives better fit than Linear for same number of Tracers

- However, the prediction of the model is only slightly better for Bayesian than Linear
  Split OFF into 2 data sets -> fit on one, check prediction on other.

- Model works for Single Events (IE) or Double Events (DE)
  with the same tracers (lines picked up in IE or DE spectra respectively)
  for:
  - Al26 in Galactic plane
  - 511 keV in Galactic Center

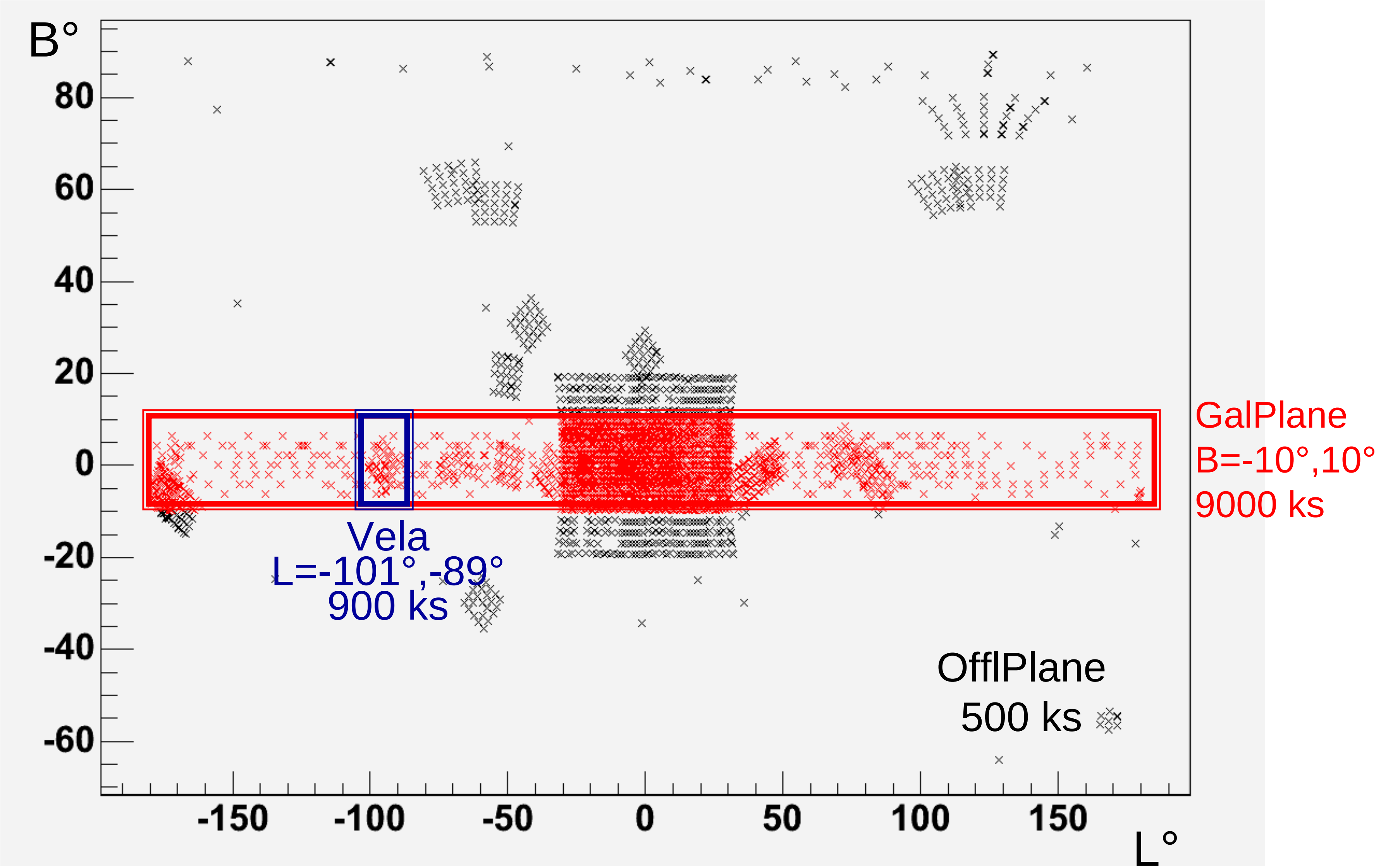
- Nothing significant yet for Al26 / 511 keV in Vela

- Future: quit light-bucket method and produce model for each Ge for deconvolution

Thank you !

Distribution of pointings in Galactic coordinates

number of SCW: 5606   good time: 9500 ks



OffPlane+GalPlane : Principal Components Analysis

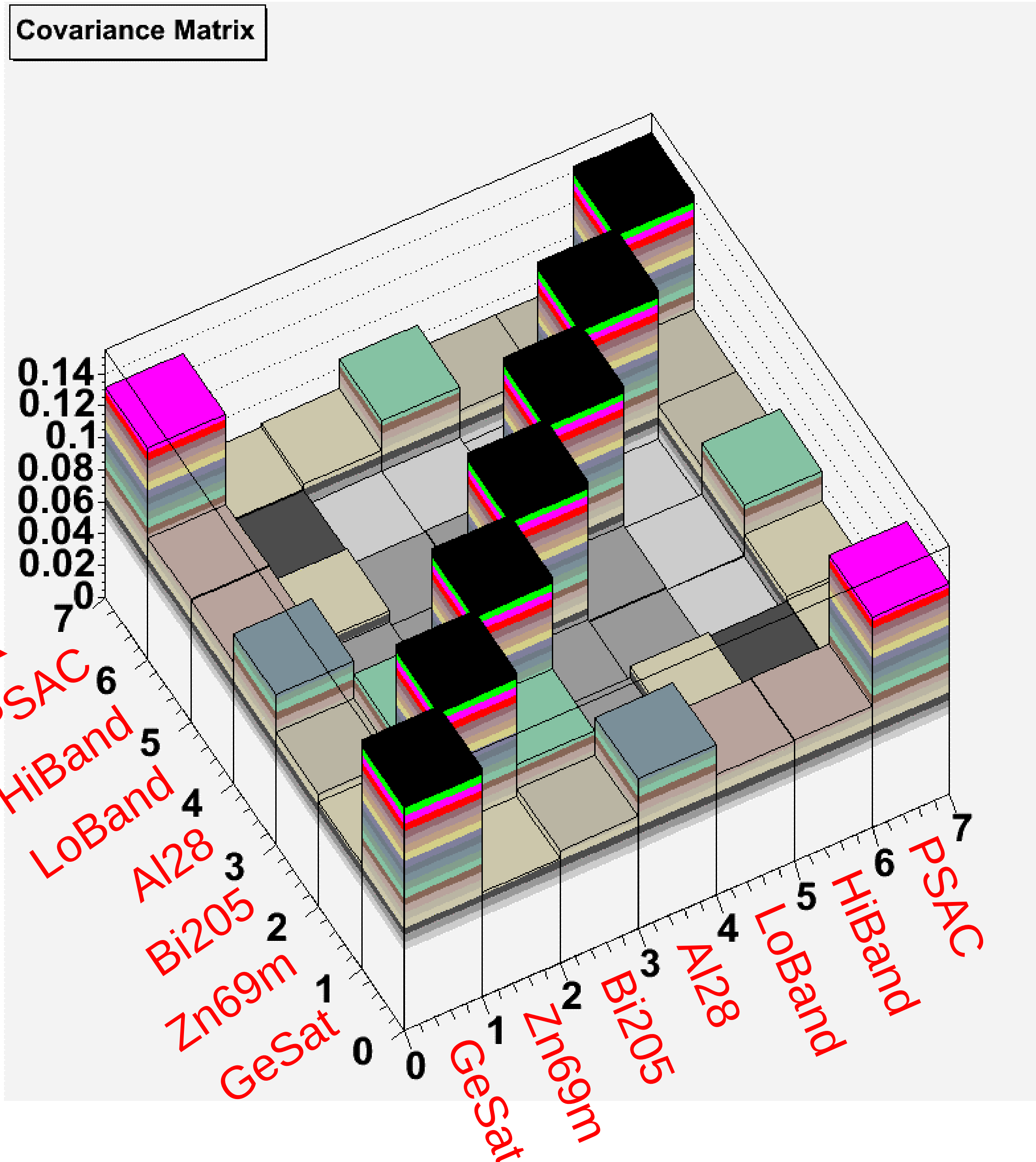
<u>All data</u> (Off+GalPlane)

<u>Use Bkg Tracers:</u>

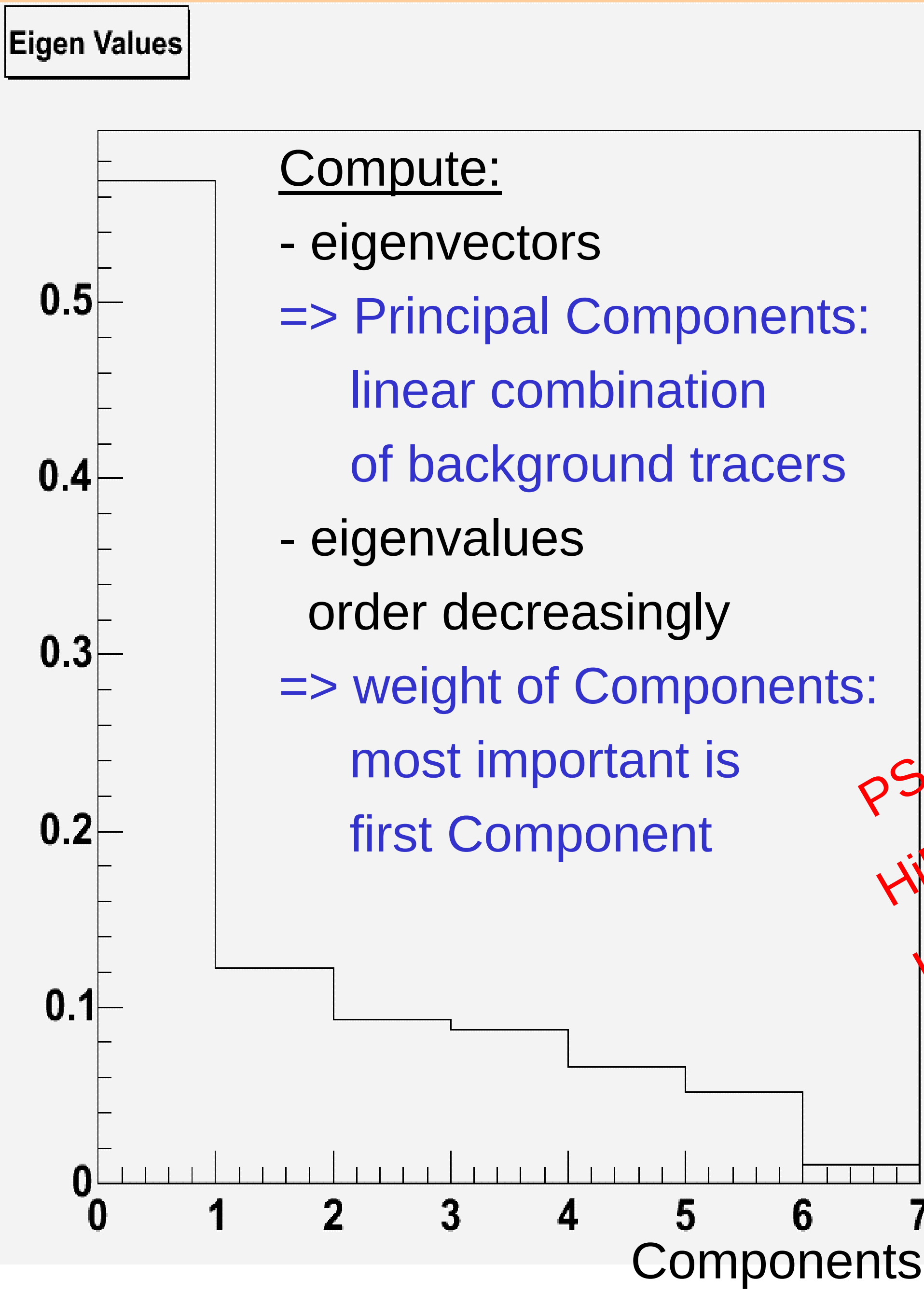
- normalize
- center

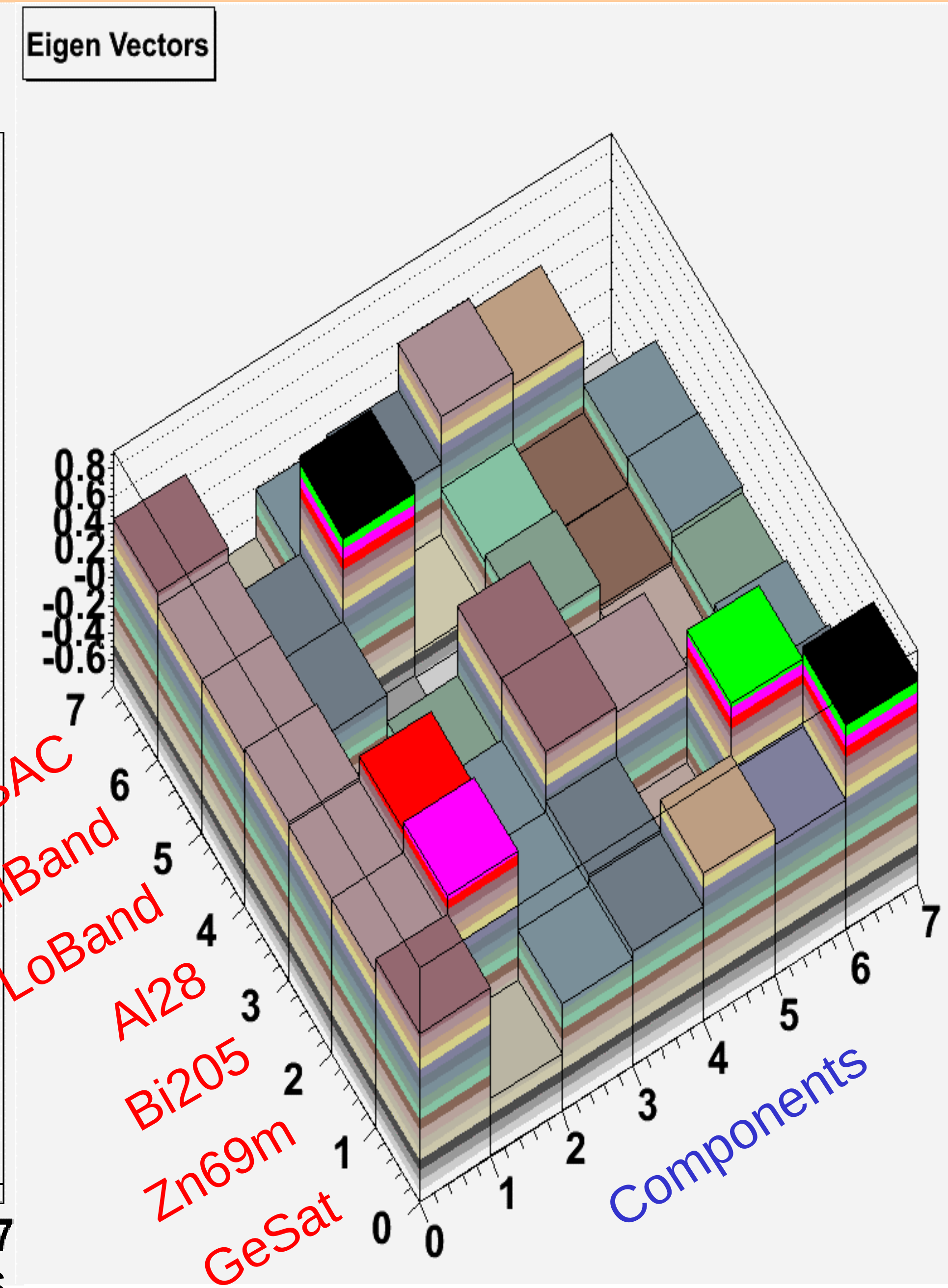
<u>Between Tracers:</u>

- covariance matrix →
  diagonalize (SVD)

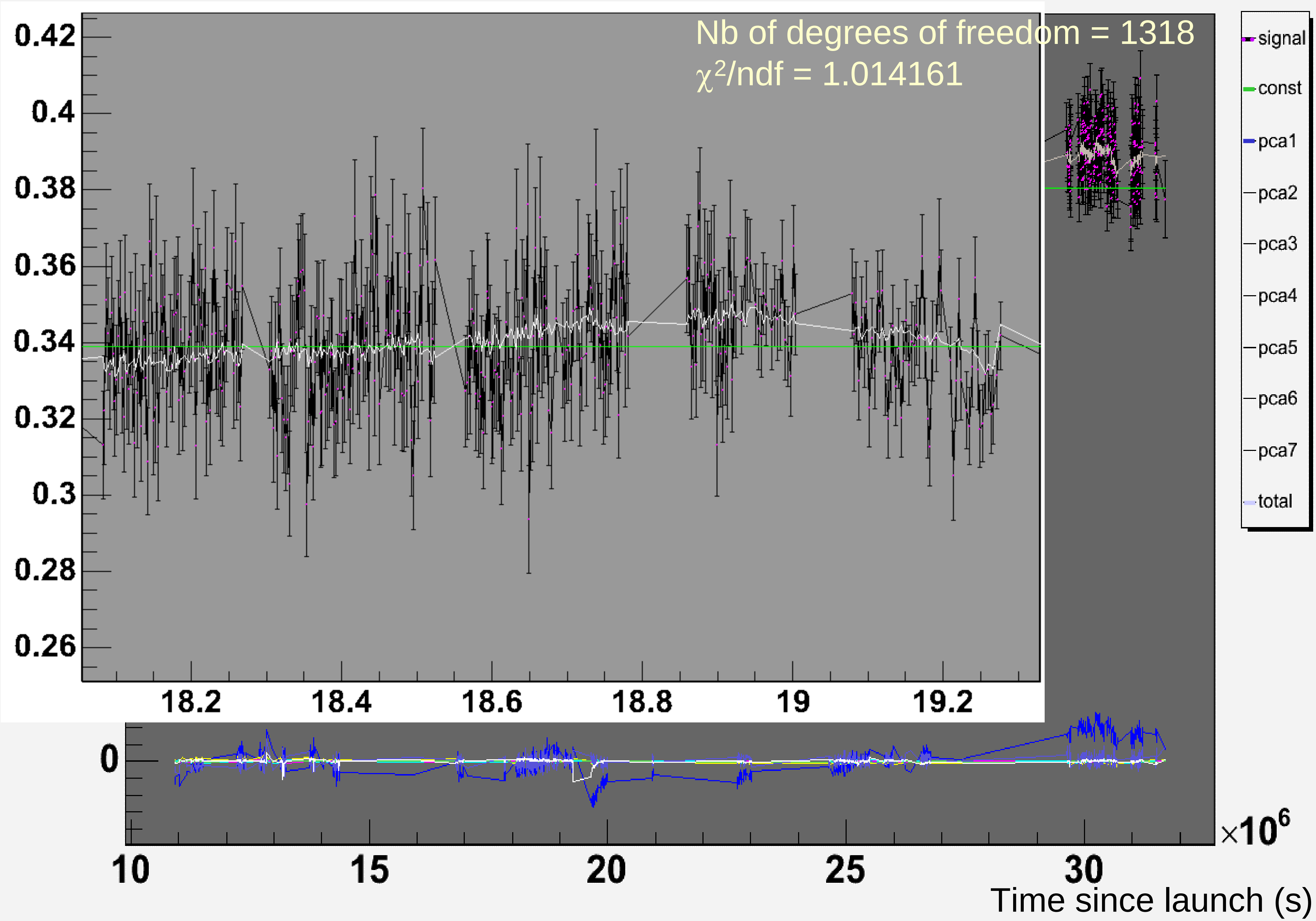


OffPlane+GalPlane : Principal Components

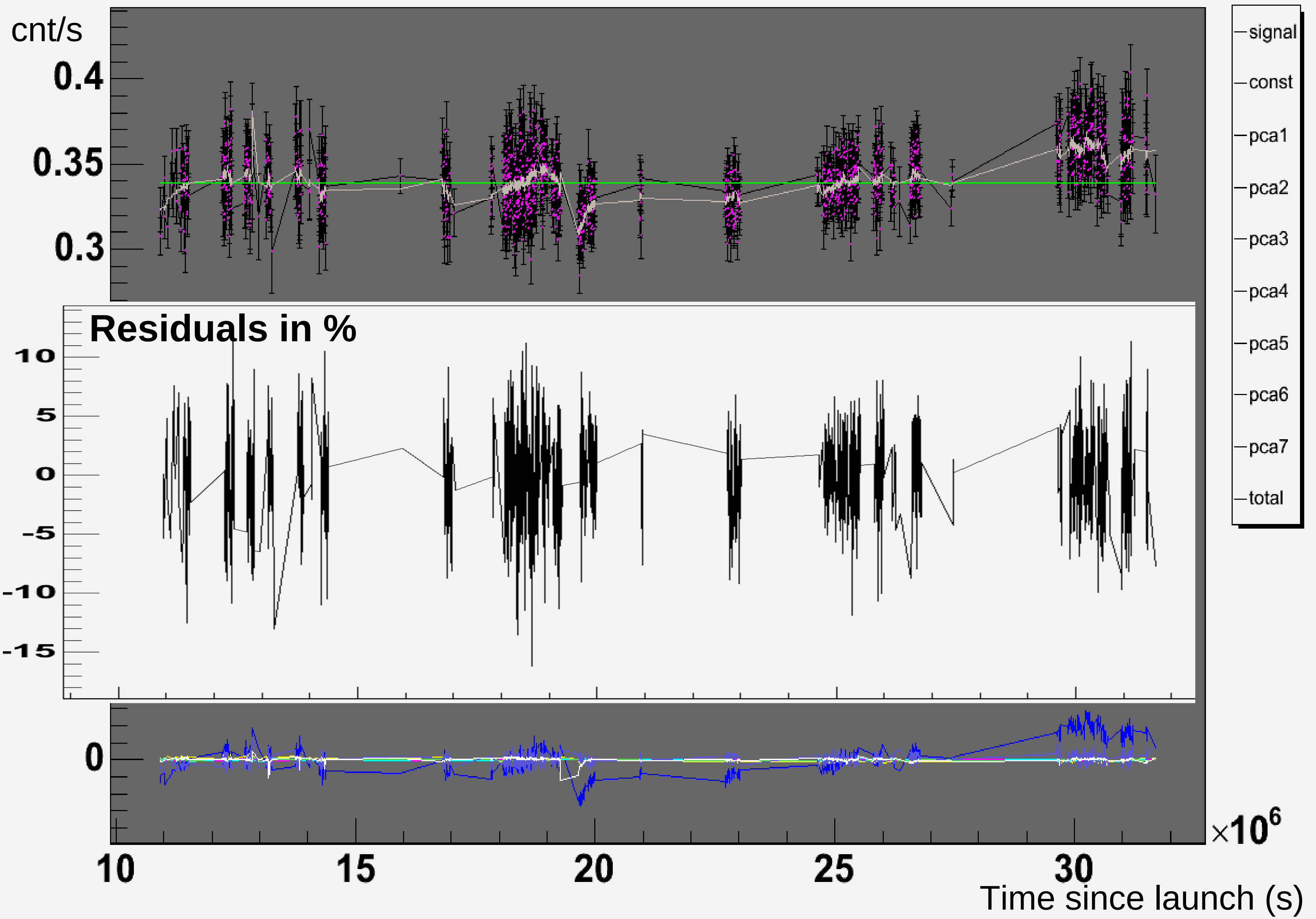




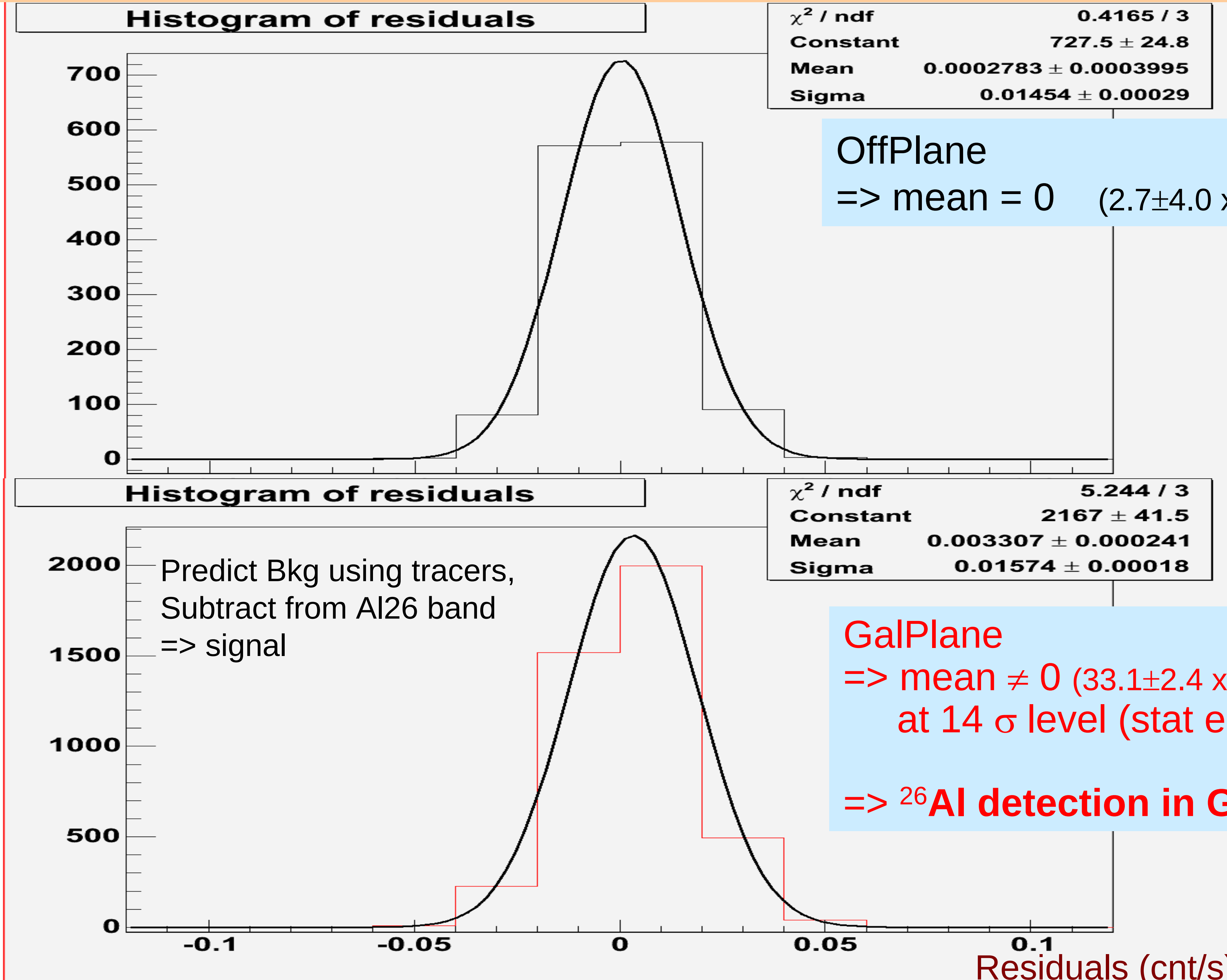
OffPlane : Fit linear combi. of Components to Bkg in ^{26}Al band



OffPlane : Model subtracted from Bkg in ^{26}Al band



OffPlane & GalPlane : Distribution of Residuals in ^{26}Al band



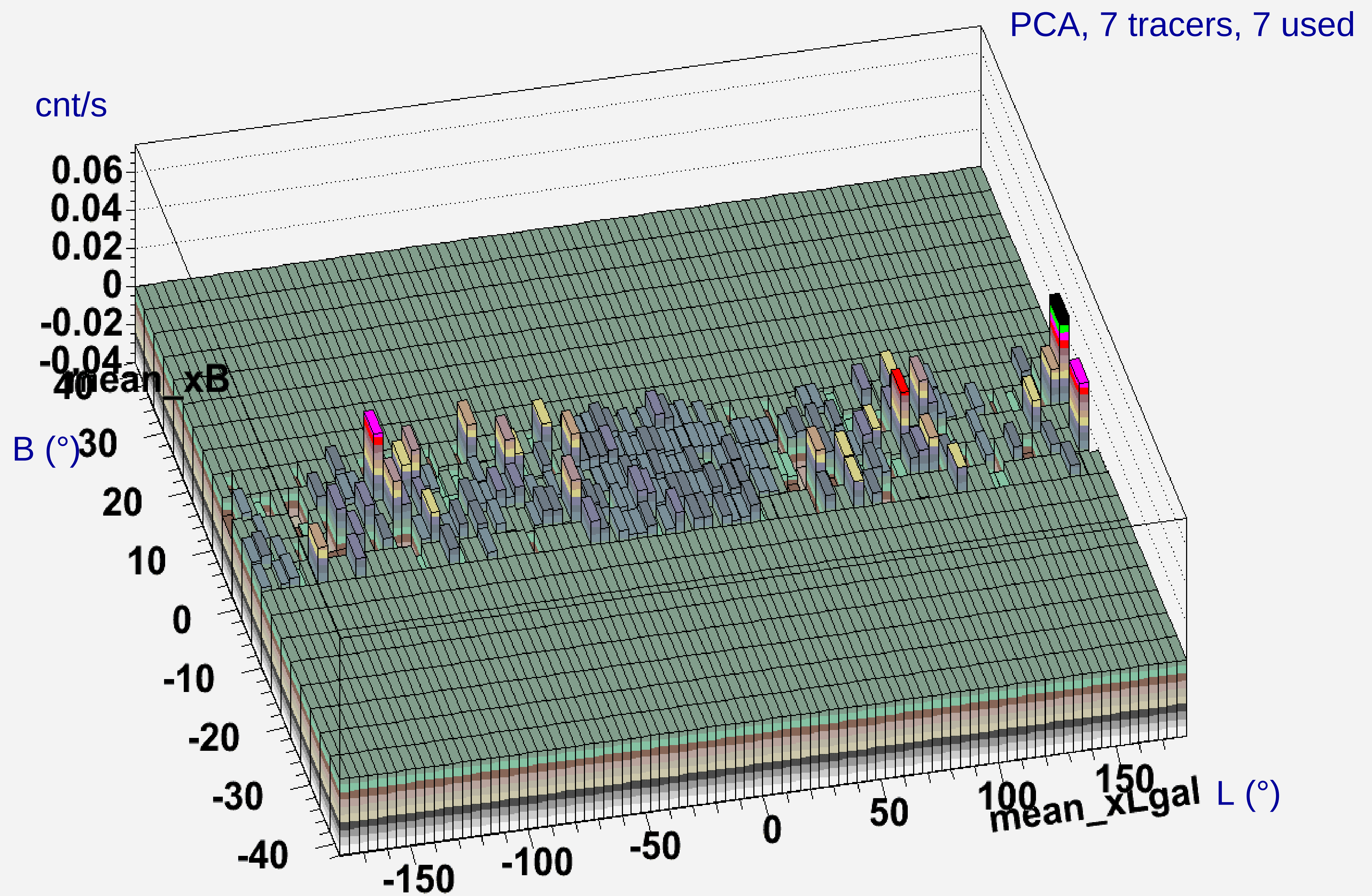
OffPlane
=> mean = 0 (2.7±4.0 x 10^{-4} cnt/s)

Predict Bkg using tracers,
Subtract from Al26 band
=> signal

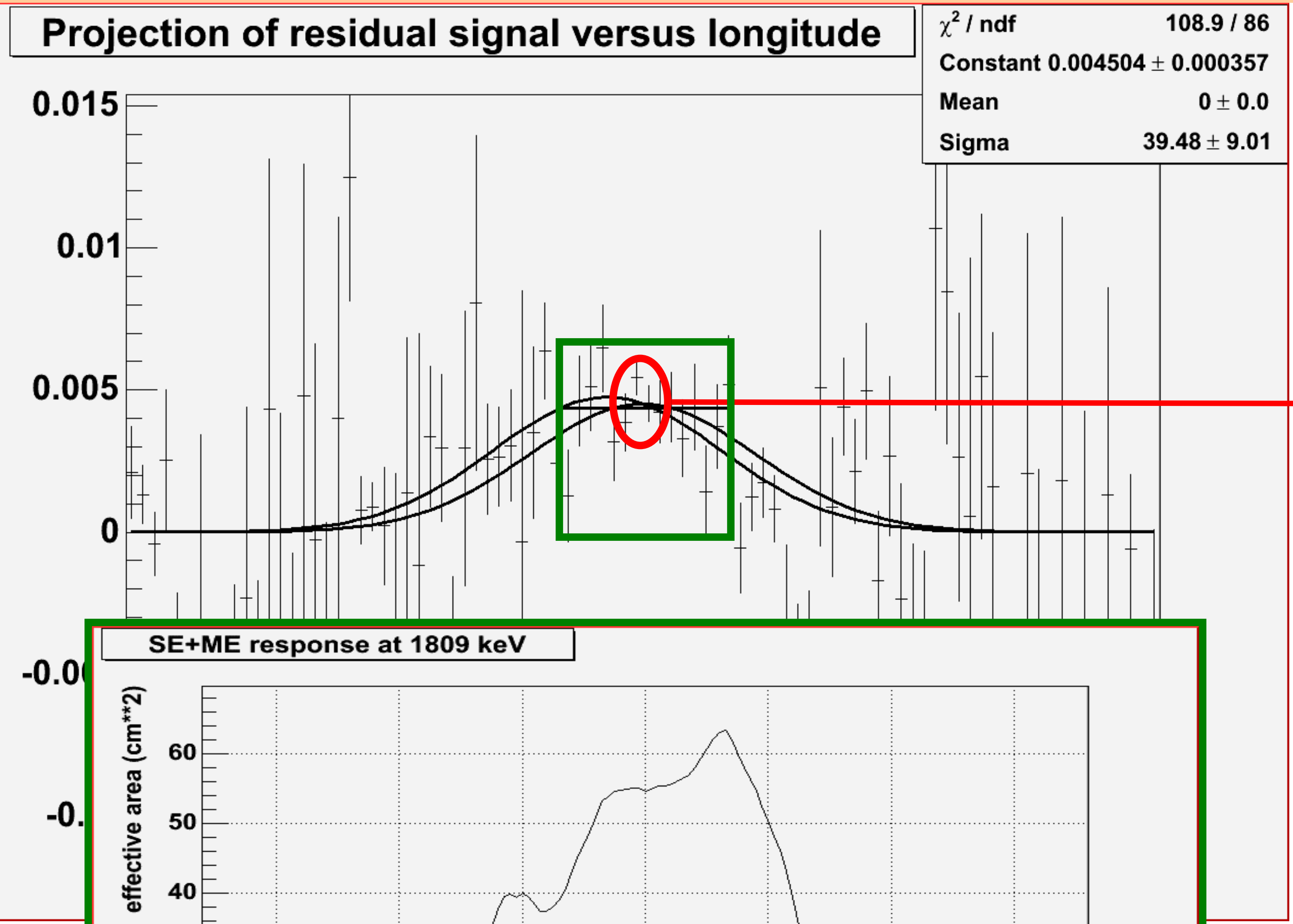
GalPlane
=> mean ≠ 0 (33.1±2.4 x 10^{-4} cnt/s)
at 14 σ level (stat error only)

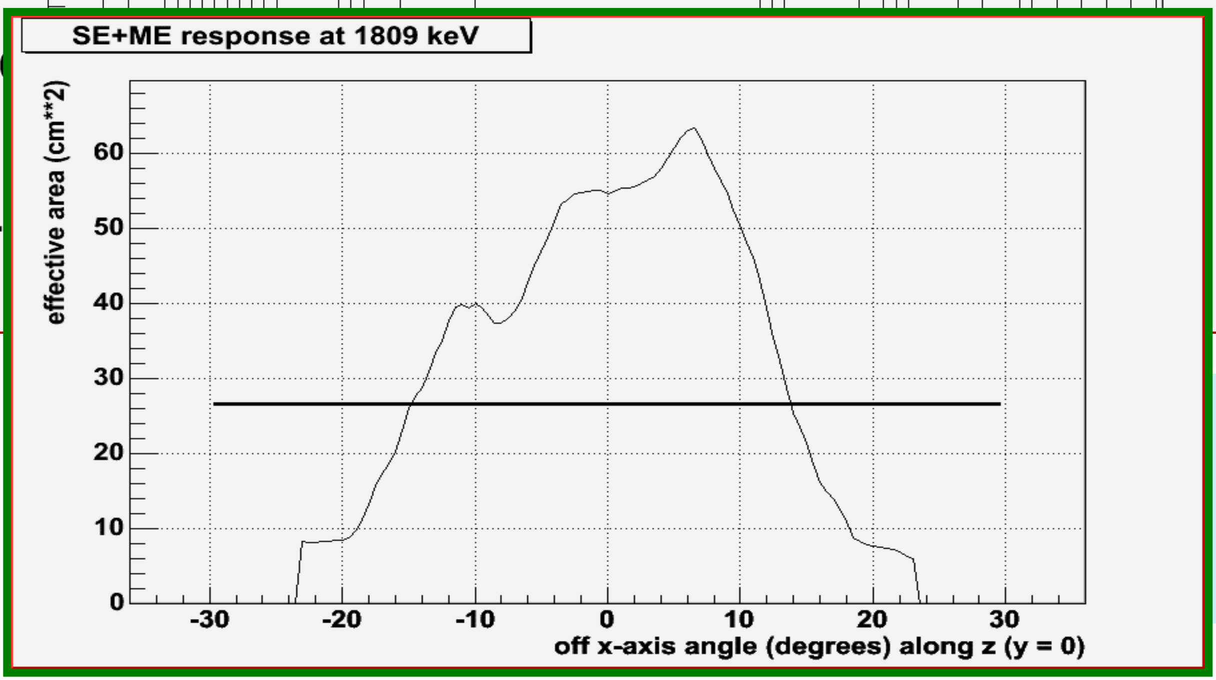
=> ^{26}**Al detection in GalPlane**

GalPlane Residuals : ^{26}Al signal map



Galactic plane ^{26}Al flux - measurement





PCA, 7 tracers, 7 used

fit Gaussian
with Mean=0 fixed

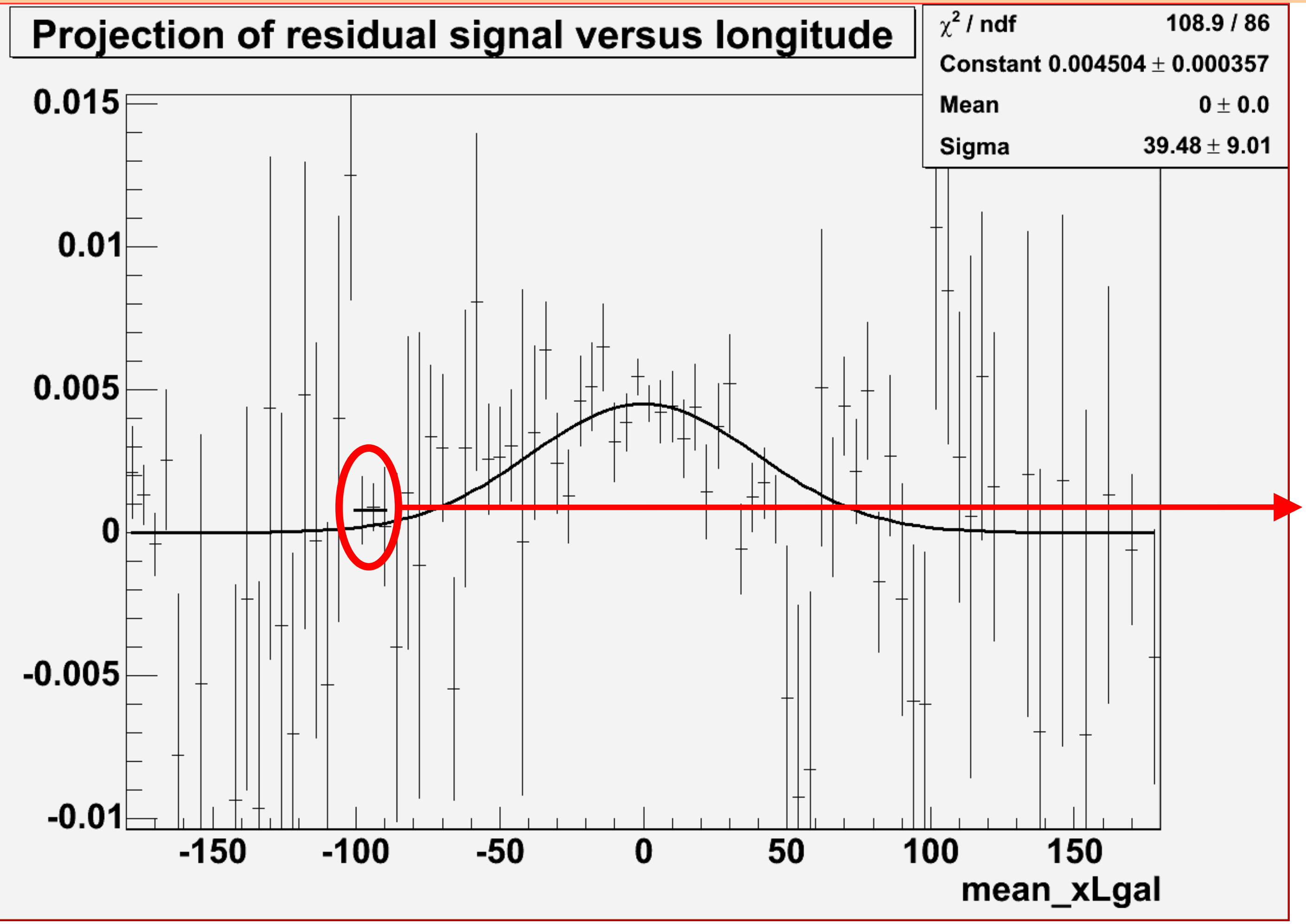
At L=0°, ^{26}Al Rate:
45.0±3.6 x 10^{-4} cnt/s
(12 σ, stat error only)

SPI response
at 1809 keV

- for a point source:
  Aeff = 55 cm^2
- for a diffuse source integrated over -30° to 30° :
  Aeff = 26 cm^2

^{26}Al Flux in L=-30° to 30°
(assume: uniform in region)
around Galactic center
1.73±0.14 x 10^{-4} ph/cm^2/s

Vela ^{26}Al flux - upper limit



7 tracers

Vela : fit Constant
L=-101° to -89°

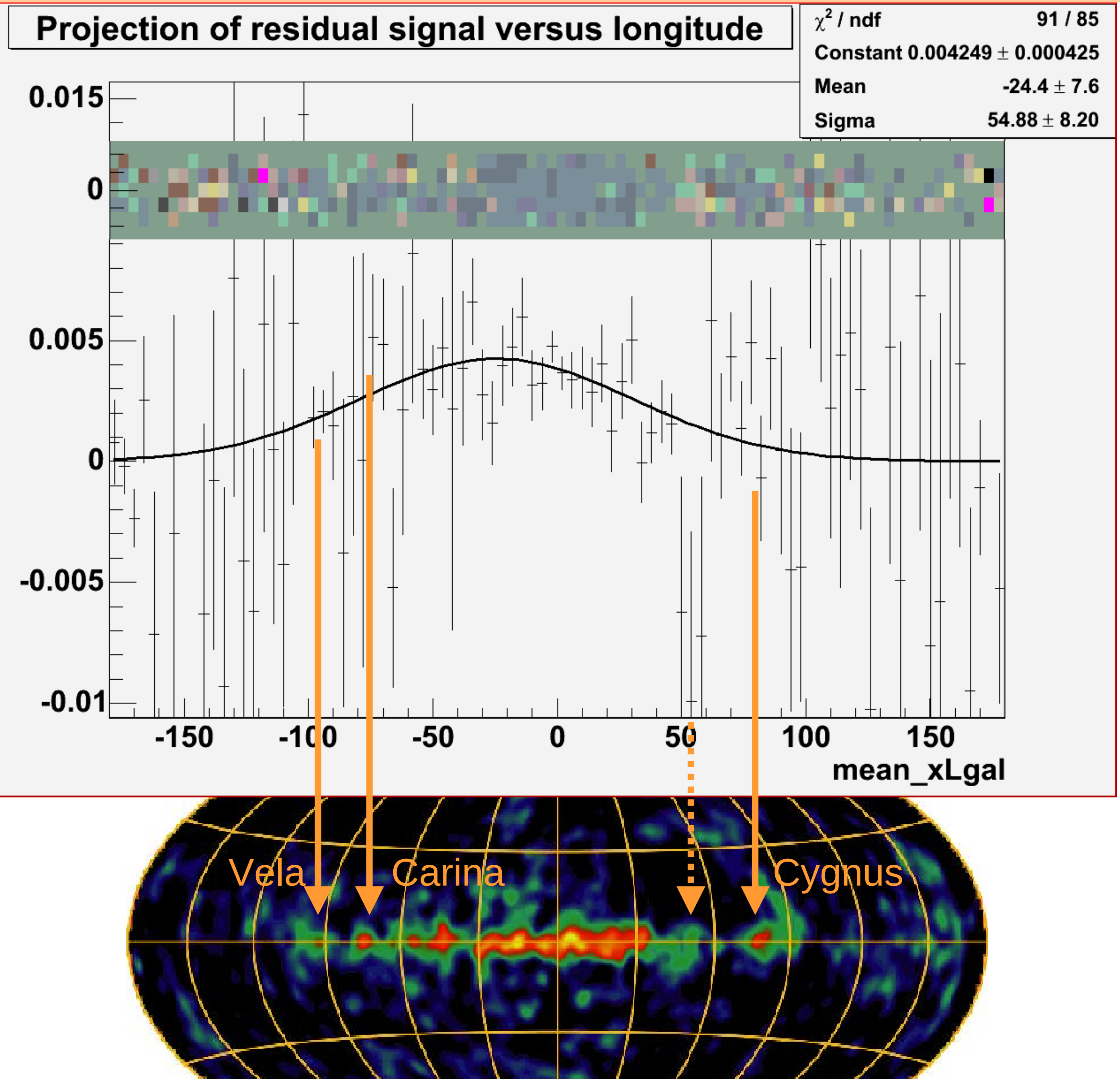
Vela ^{26}Al Rate:
8.0±6.4 x 10^{-4} cnt/s
(1.2 σ, stat error only)
NO DETECTION

3 σ (stat) upper limit:
< 19 x 10^{-4} cnt/s

point source hypothesis
Aeff = 55 cm^2

Vela 26Al Flux, 3 σ (stat) upper limit:
< 0.34 x 10^{-4} ph/cm^2/s

Towards a mapping of ^{26}Al in the Galaxy?



46 tracers (before: 7)

=> our best Bkg fit,
χ^2=1.003 (1.014)
σ_R=0.0143 c/s (0.0145)

^{26}Al Flux [10^{-4} ph/cm^2/s] (stat errors only):

- L=-30 to 30°
  1.43±0.14 (1.73±0.14)
  10.2 σ (12.3 σ)

  COMPTEL: 2.80±0.15
- Vela
  0.35±0.13 (0.14±0.12)
  2.8 σ (1.2 σ)

  COMPTEL: 0.36±0.12

Systematic errors

7 tracers, PCA used=	1	2	3	4	5	6	7	Error
Fit Bkg Chi2/NDF	1.0746	1.0670	1.0676	1.0666	1.0671	1.0232	1.0142	
Fit Big NDF	1324	1323	1322	1321	1320	1319	1318	
GCR 10^{-4} ph/cm^2/s	***1.72***	***1.88***	***1.88***	***1.87***	***1.88***	***1.61***	***1.73***	***0.13***
Vela 10^{-4} ph/cm^2/s	***-0.14***	***0.01***	***0.01***	***0.03***	***0.05***	***0.08***	***0.14***	***0.12***

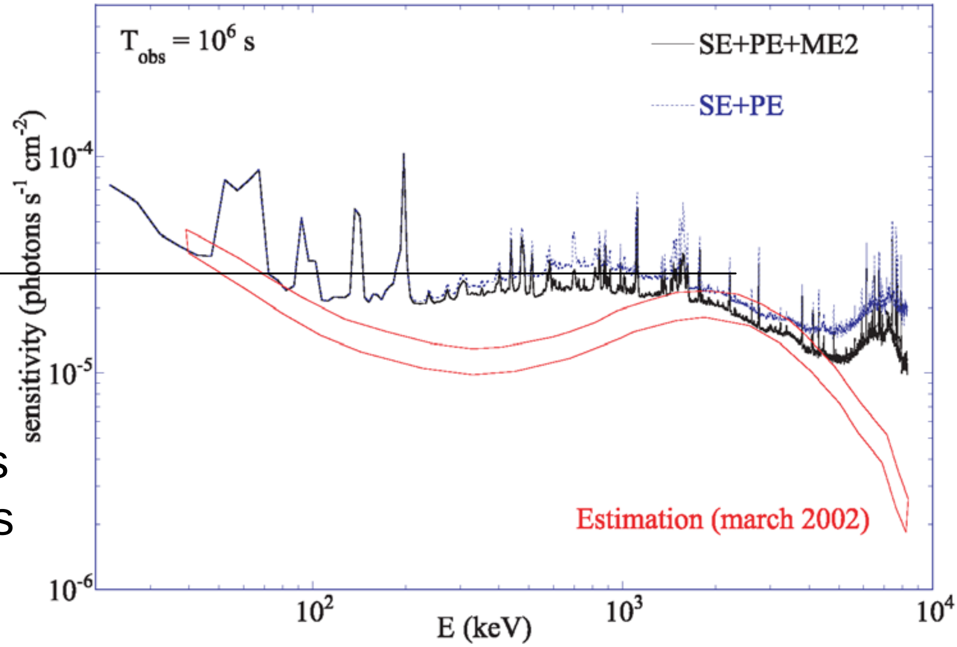
46 tracers, PCA used=	1	3	9	22	31	40	46	Error
Fit Bkg Chi2/NDF		1.0233	1.0195	1.0073	1.0082	1.0045	1.0032	
Fit Big NDF		1322	1316	1303	1294	1285	1279	
GCR 10^{-4} ph/cm^2/s		***1.53***	***1.45***	***1.44***	***1.32***	***1.46***	***1.43***	***0.12***
Vela 10^{-4} ph/cm^2/s		***0.02***	***0.00***	***0.03***	***0.08***	***0.34***	***0.35***	***0.12***

SPI mean value	*Value*	*Stat*	*Syst*	*Stat+Syst*	*N sigma*
GCR 10^{-4} ph/cm^2/s	***1.63***	*0.13*	*0.21*	***0.24***	*6.75*
Vela 10^{-4} ph/cm^2/s	***0.08***	*0.12*	*0.21*	***0.24***	*0.33*
Vela 10^{-4} ph/cm^2/s 3 sigma		*0.35*	*0.62*	***0.71***	

COMPTEL	
Value	*Stat+Syst*
2.80	***0.15***
0.36	***0.12***

Conclusions

SPI narrow line sensitivity at 1809 keV
for : 1 Ms observation, 3 σ (stat only)
0.25 x 10^{-4} ph/cm²/s

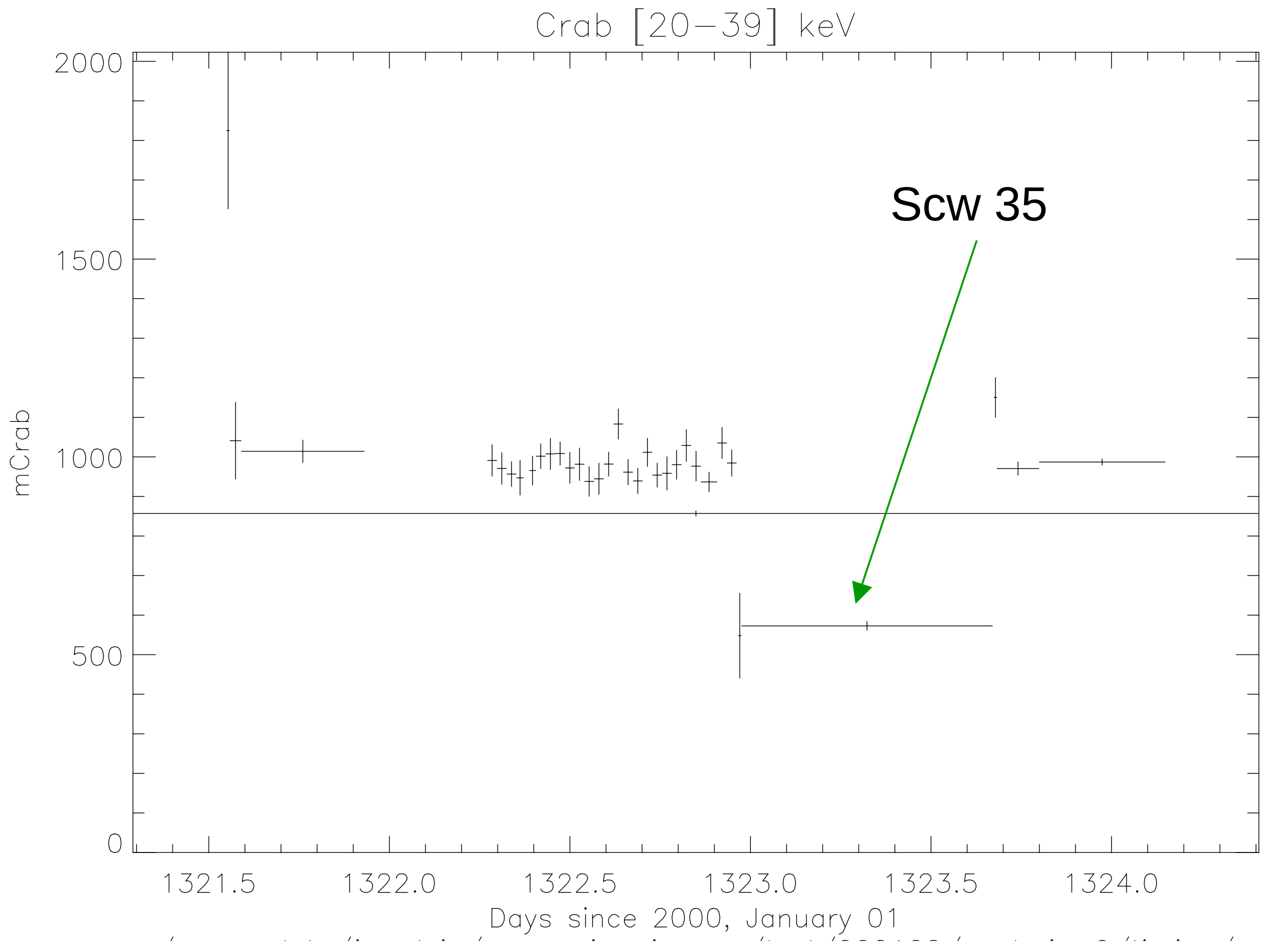


• **Vela** : 0.9 Ms observation,
3 σ (stat): expected = 0.26 x 10^{-4} ph/cm²/s
measured = 0.36 x 10^{-4} ph/cm²/s
=> COMPTEL Flux: 0.36 x 10^{-4} ph/cm²/s
with 0.9 Ms, could not expect detection
AO-3 Open Time proposal accepted (2 Ms Vela observation)
We should detect ^{26}Al in Vela (hopefully no solar flare pollutes the data again...)

• **GCR** : 5 Ms observation in -30° to 30° (9 Ms total)
3 σ (stat): expected = 0.11 x 10^{-4} ph/cm²/s (0.08 total)
measured = 0.39 x 10^{-4} ph/cm²/s
=> Stat error estimate : factor 3 too pessimistic ??
Due to limited OffPlane observations (only 0.5 Ms useable)
Urgently needed: more off-plane data
for SPI line analyses (core prog & open time)
but not scheduled in sufficient amount...

OFF AXIS CRAB OBSERVATIONS

REV 102



E. Jourdain - CESR

SCW 102 0035

- ATTITUDE OK
- CRAB AT 12.8 ^{0}

- USE SPIROS OUTPUT FILE (SPECTRAL MODE)
  - TOTAL COUNTS / DETECTOR
  - BACKGROUND COUNTS / DETECTOR
  - SOURCE COUNTS / DETECTOR
  - RESIDUALS / DETECTOR

B
Y

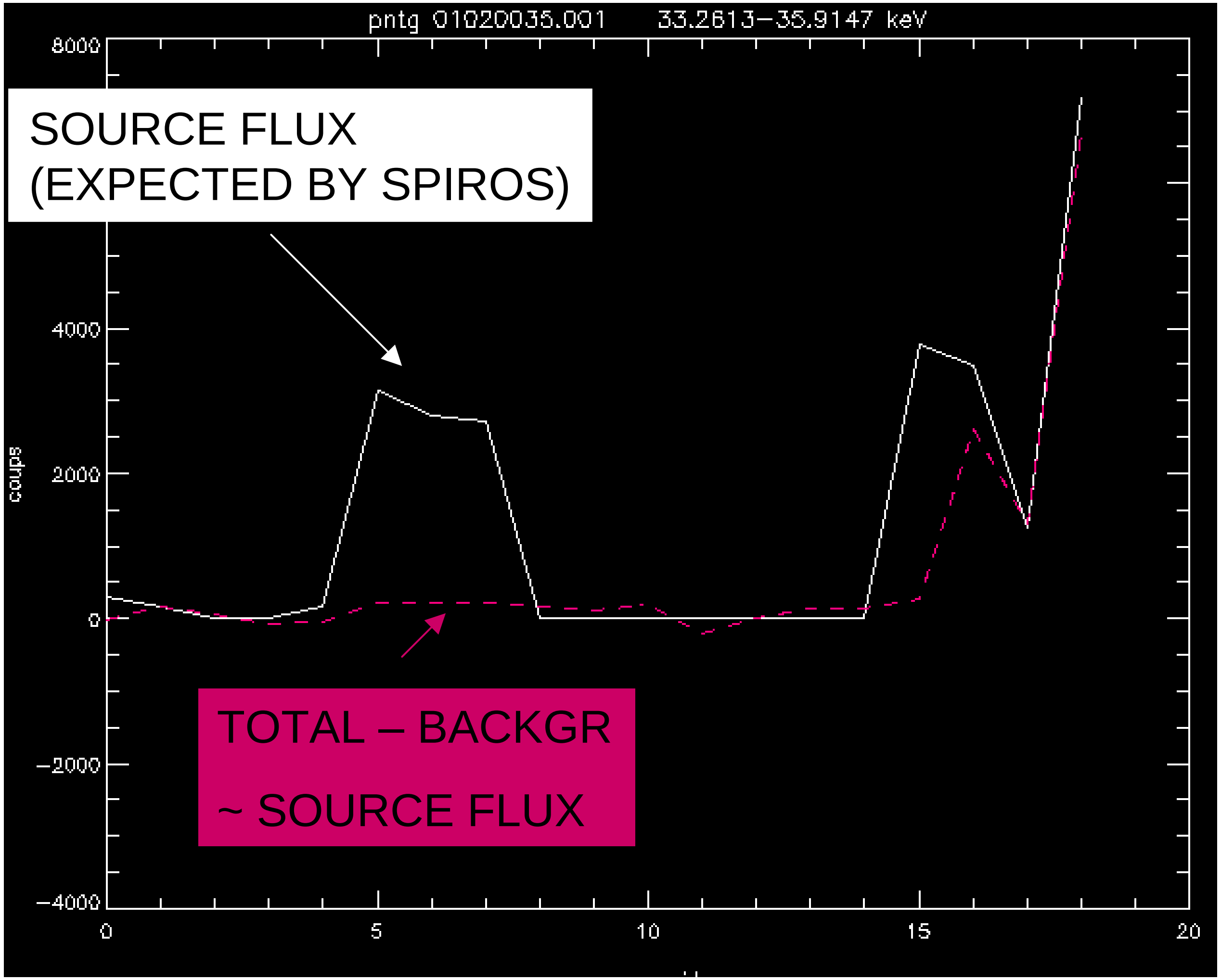
P
O
I
N
T
I
N
G

SCW 102 0035

1 SOURCE : CRAB

POSITION

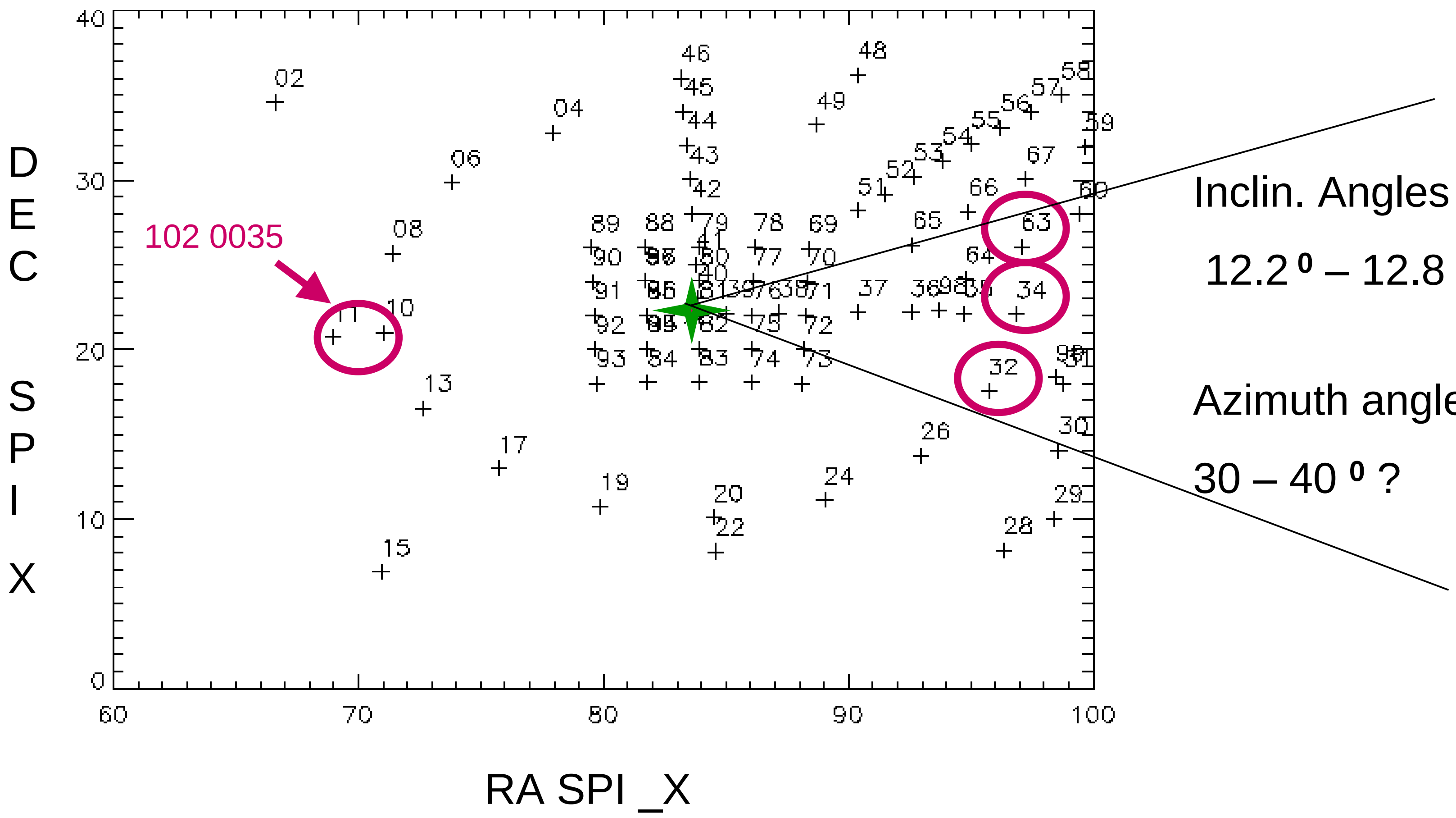
UN / LIGHTED
DETECTORS



DETECTOR NUMBER

REV 170
CRAB FROM ALL ANGLES

POINTING DIRECTION DURING REVOLUTION (LABEL =SCW)

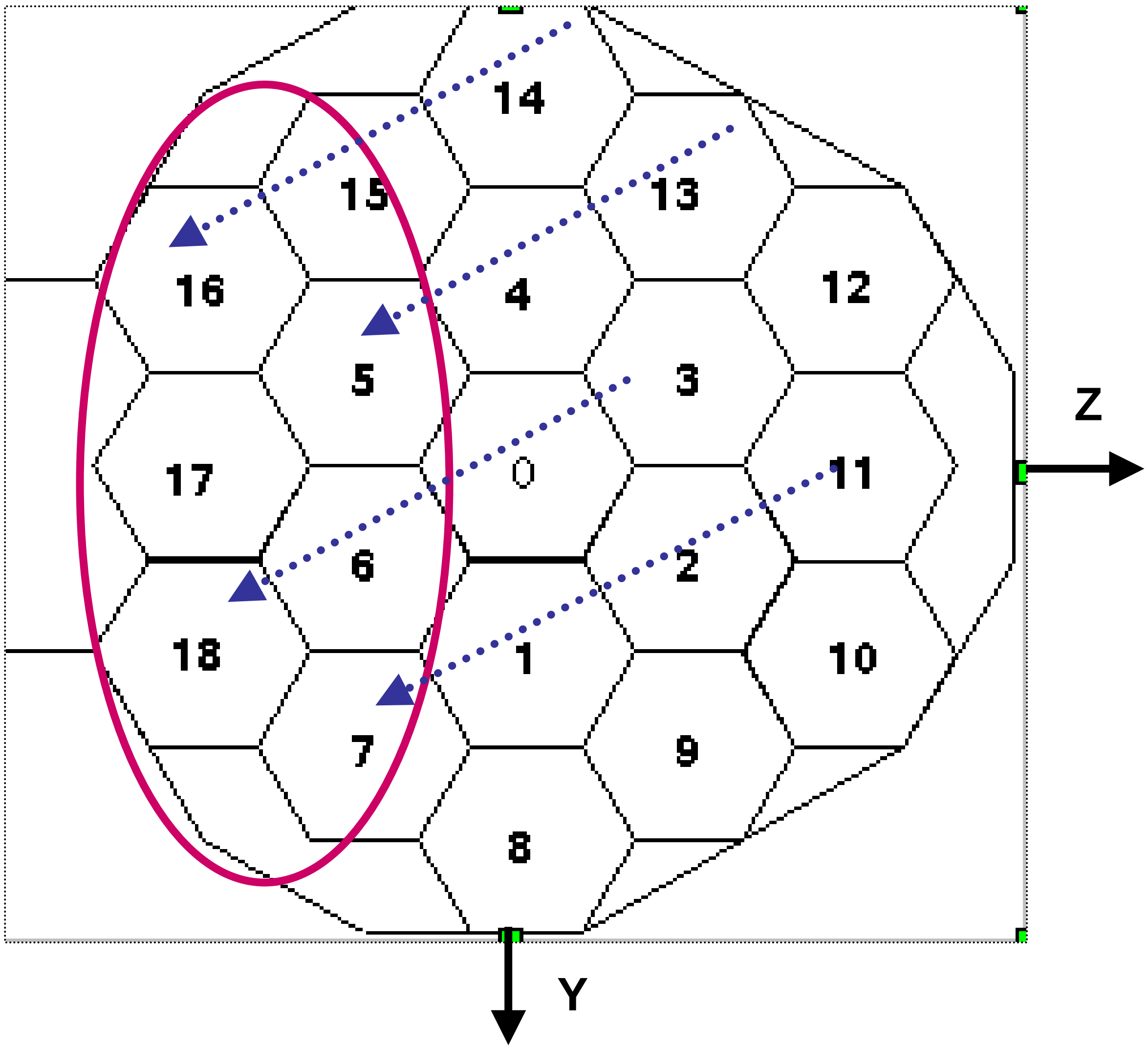


Inclin. Angles :

12.2 ^{0} – 12.8 ^{0}

Azimuth angle

30 – 40 ^{0} ?

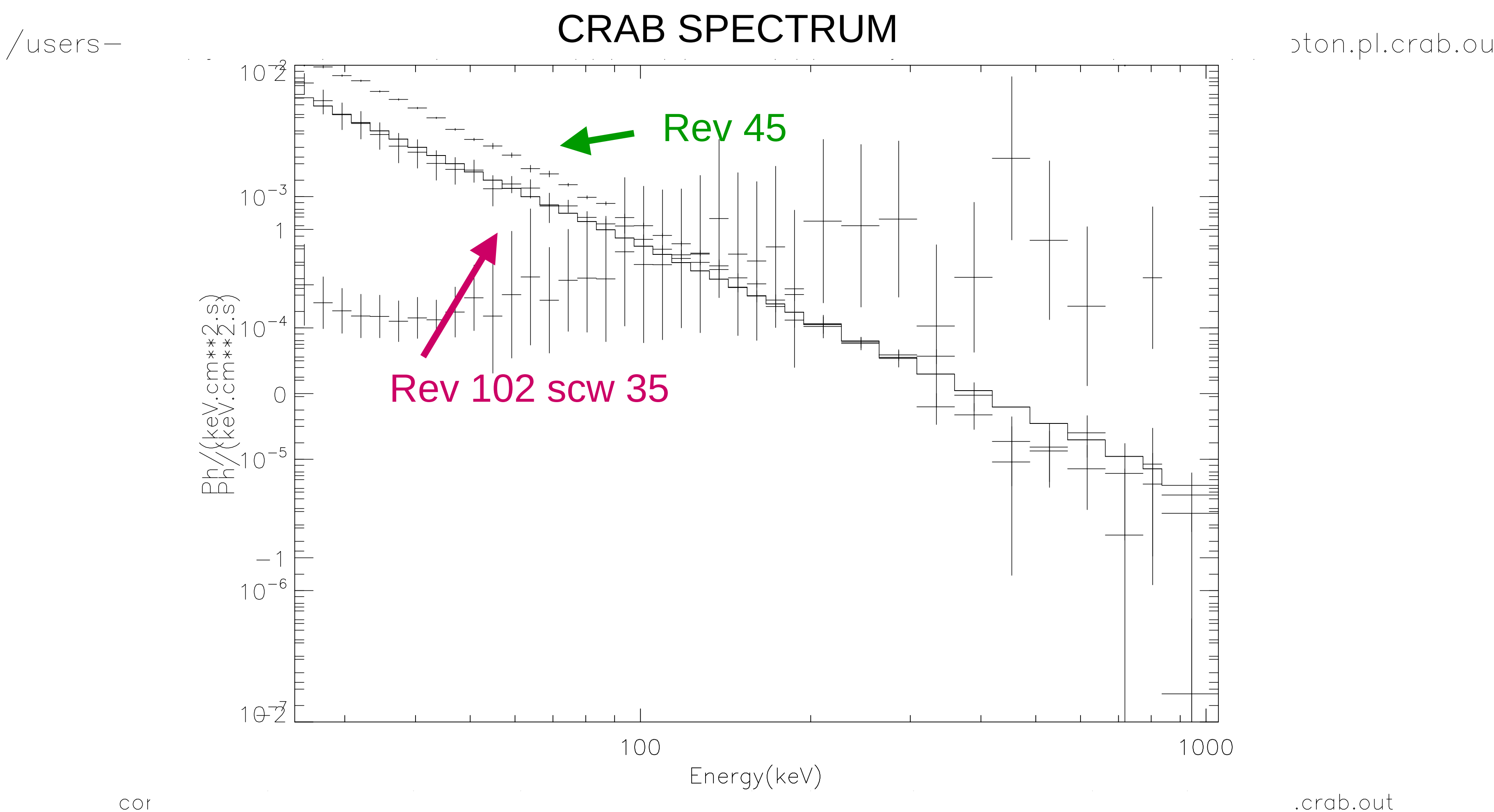


IBIS

JEM-X

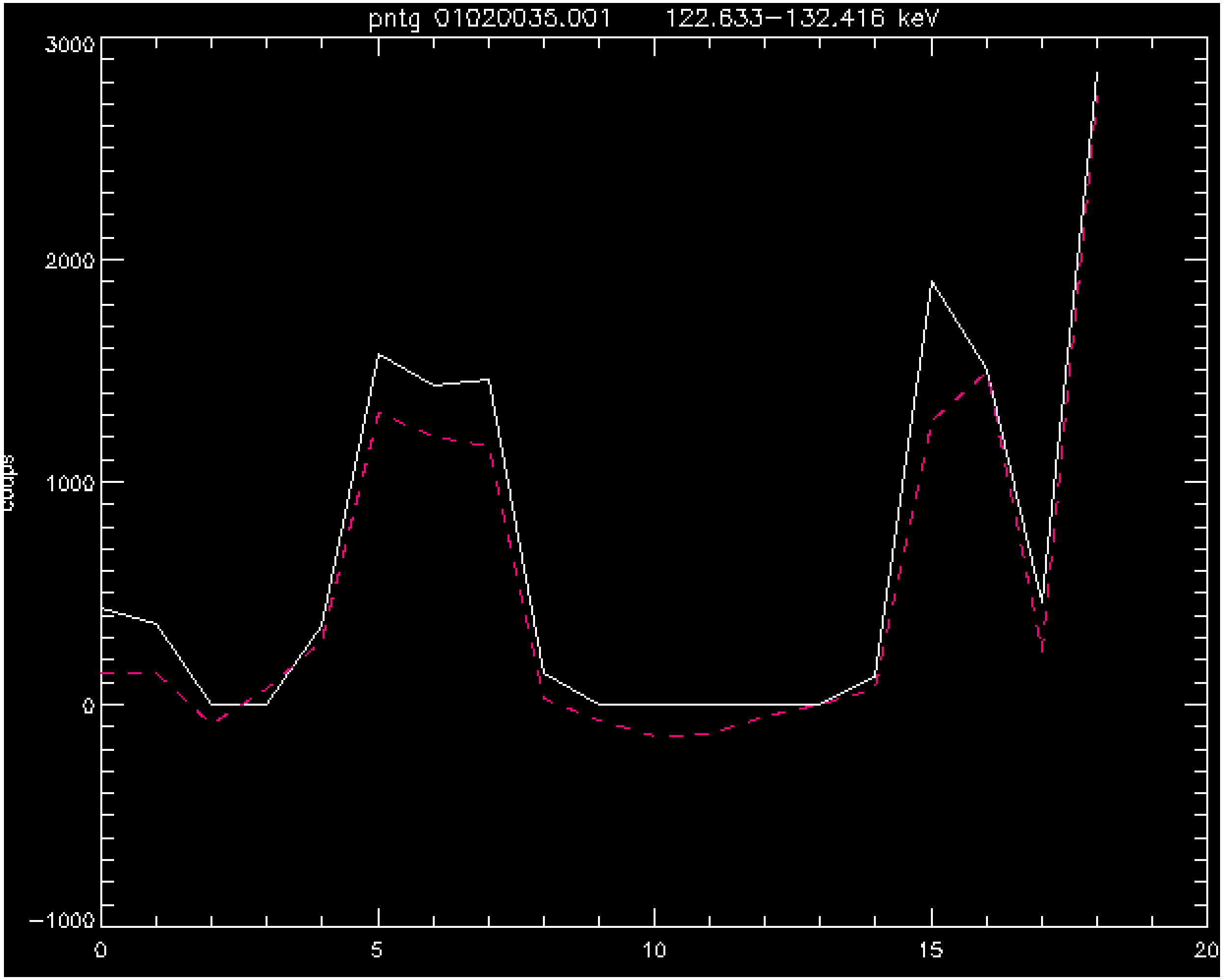
OMC

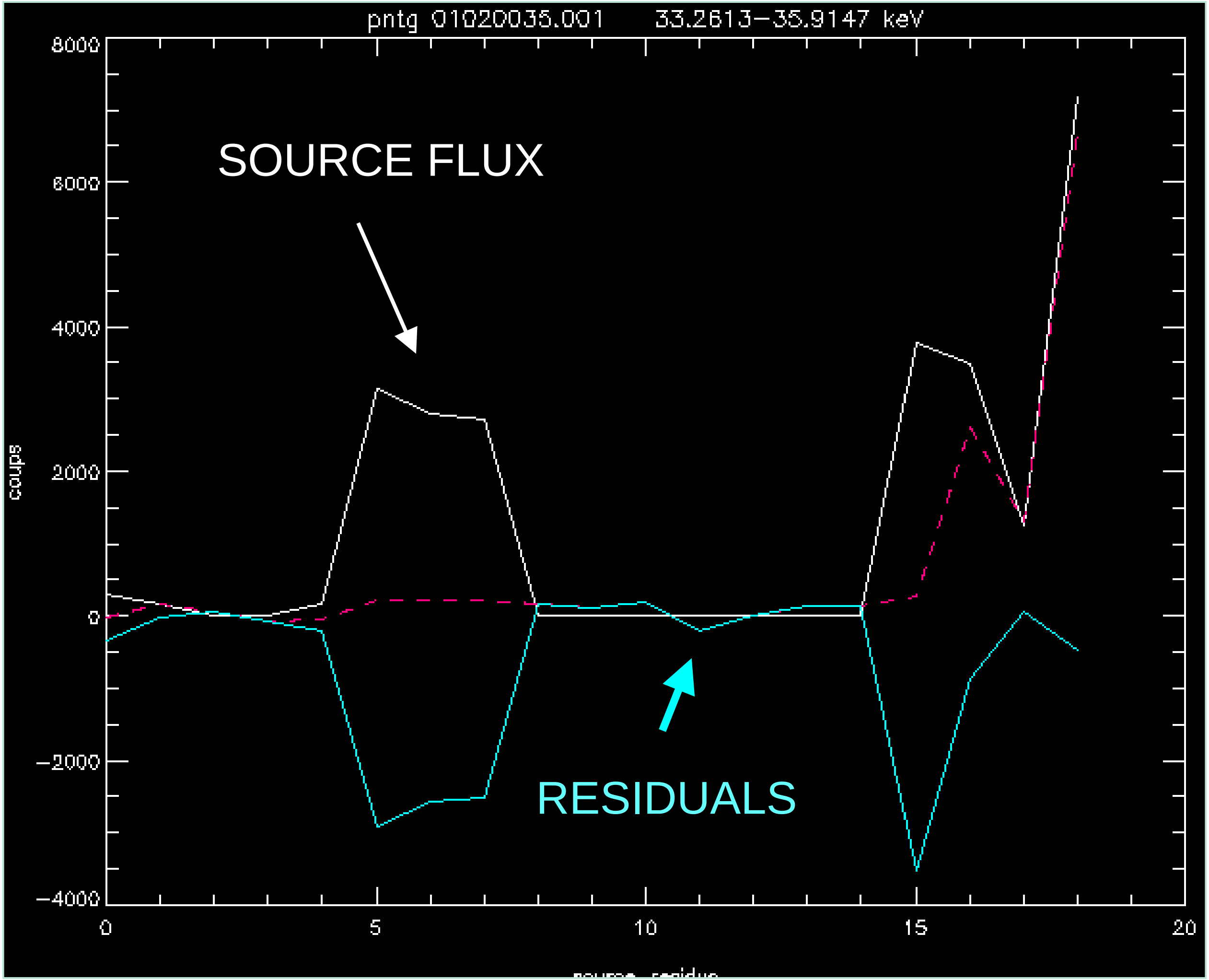
EVOLUTION WITH ENERGY



SCW 102 0035

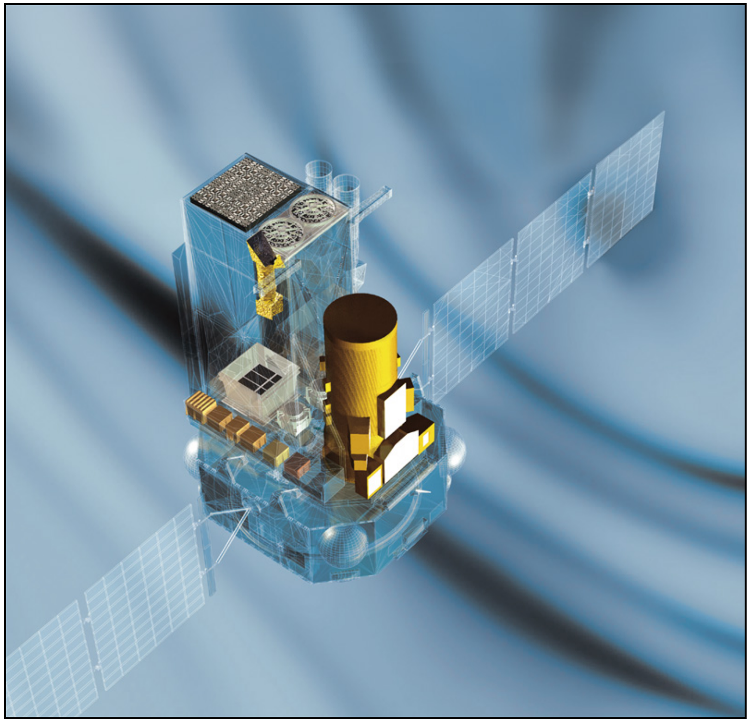
122 -132 KEV




pntg 01020035.001 33.2613–35.9147 keV
SOURCE FLUX
RESIDUALS
coups
8000
6000
4000
2000
0
−2000
−4000
0
5
10
15
20

Search for Unpredicted Lines from Point Sources

K. Watanabe (GSFC/UMD) and B. J. Teegarden (GSFC)



SPI CoIs Meeting (3/17/05)

Updates for the Temporal & Diffuse Line Search

Line Search Method 1 (temporal)

1. Reduce the SPI data with the latest gain corrections.

=> Spectra with 1 keV binning for each Science Window (SCW) and Detector.

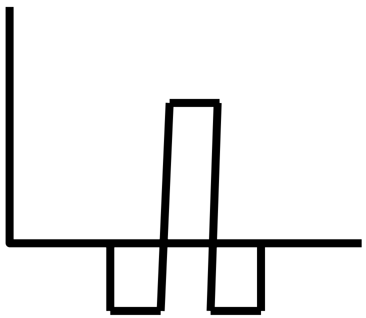
2. Sum all the detectors (sumdet) for each SCW.

=> ~100 Spectra per Rev.

3. Subtract convolved "source-free" reference spectrum.

4. Time Average (1 Day)

5. Convolve difference spectrum with template.



⇒ Repeat convolution with different template widths (3 -500 keV).

Line Search Method 2 (diffuse)

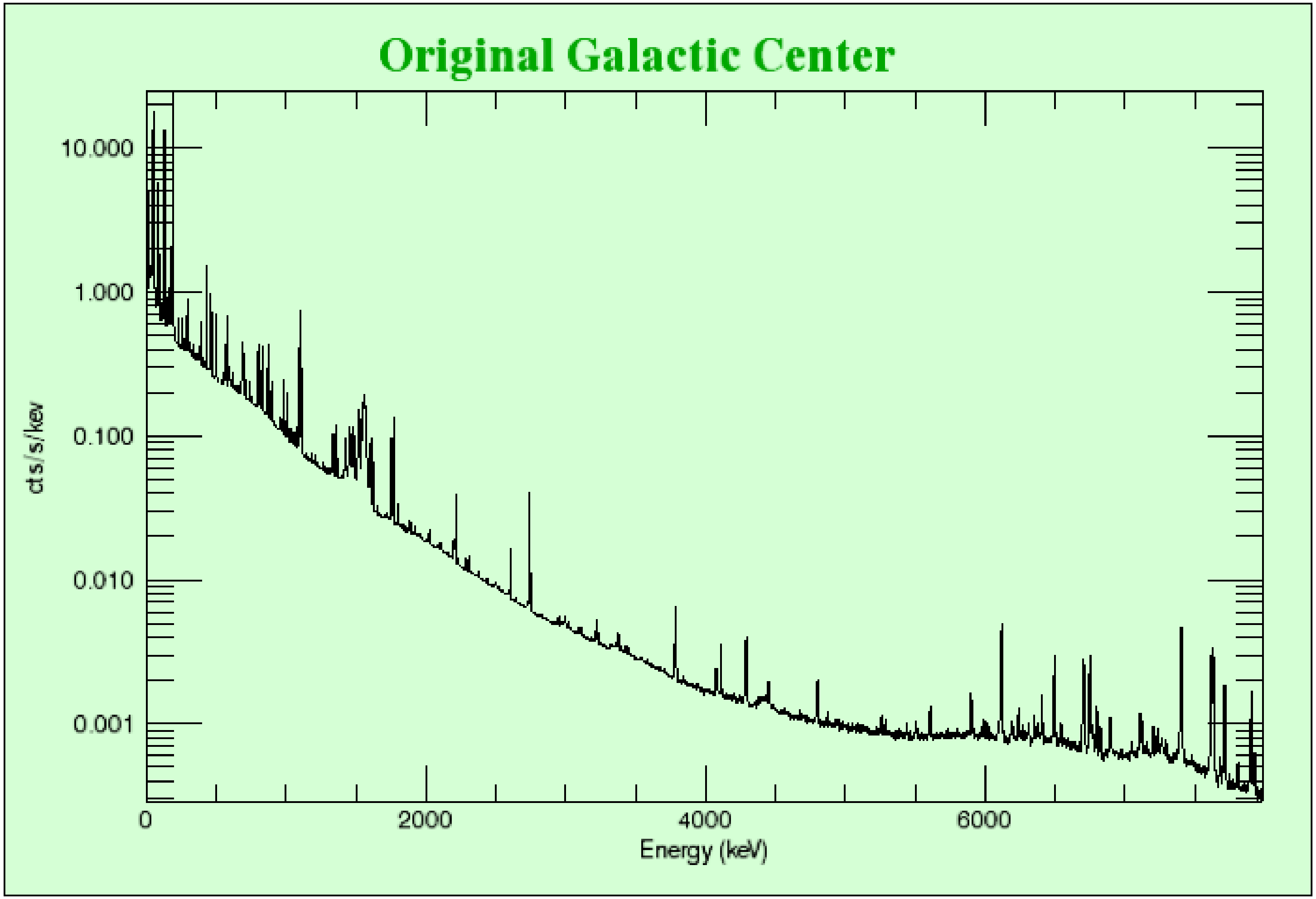
Steps (1) and (2) are the same as those of Method 1.

3. Accumulate spectra over large-scale regions and make convolved difference spectra (similar to Step (3) of Method 1)

- (Galactic Center) - (Off-Center)
- (Galactic Plane) - (Off Plane)

4. Convolve difference spectrum with template (same as Step (5) of Method 1.

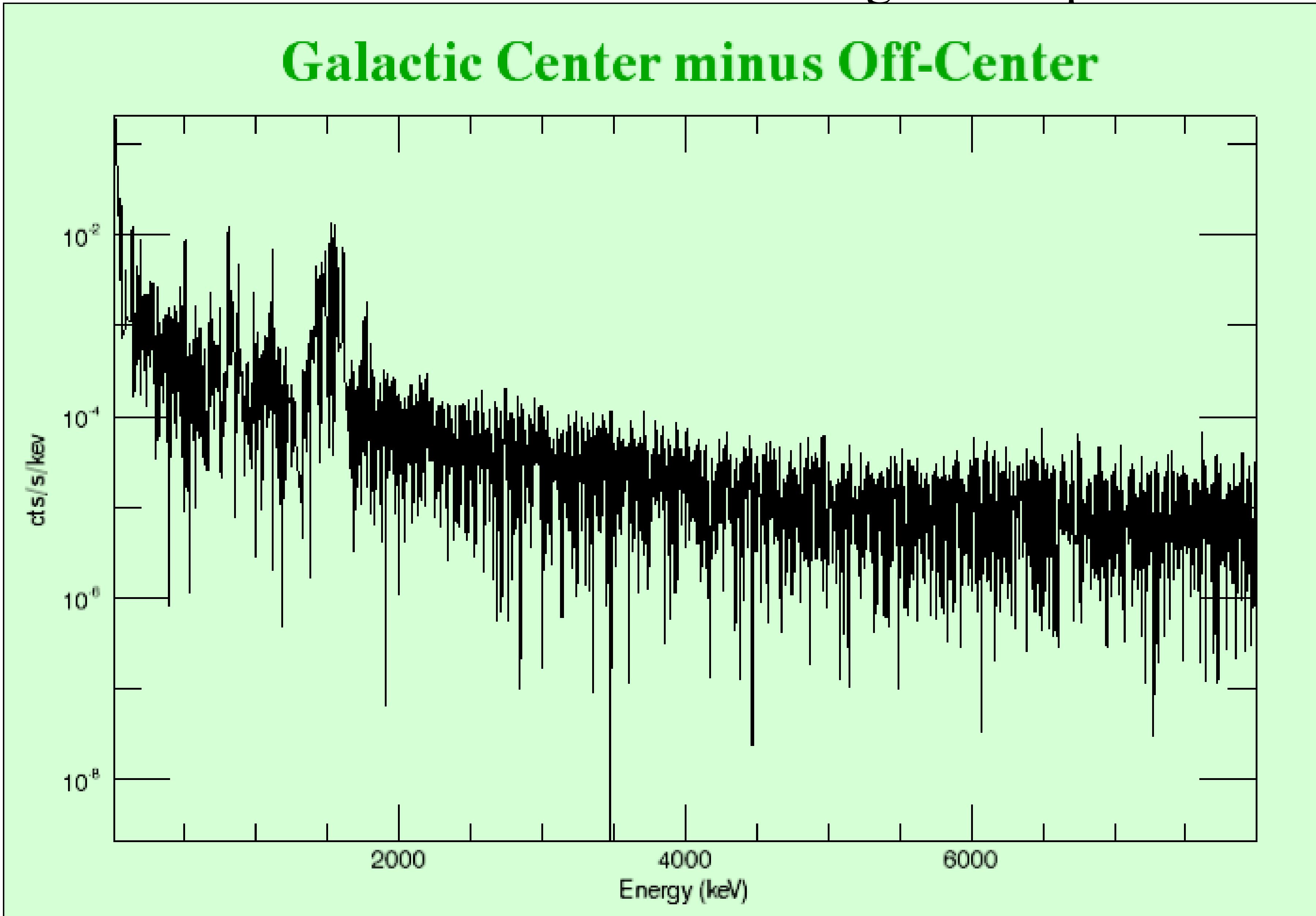
Raw Galactic Center Spectrum

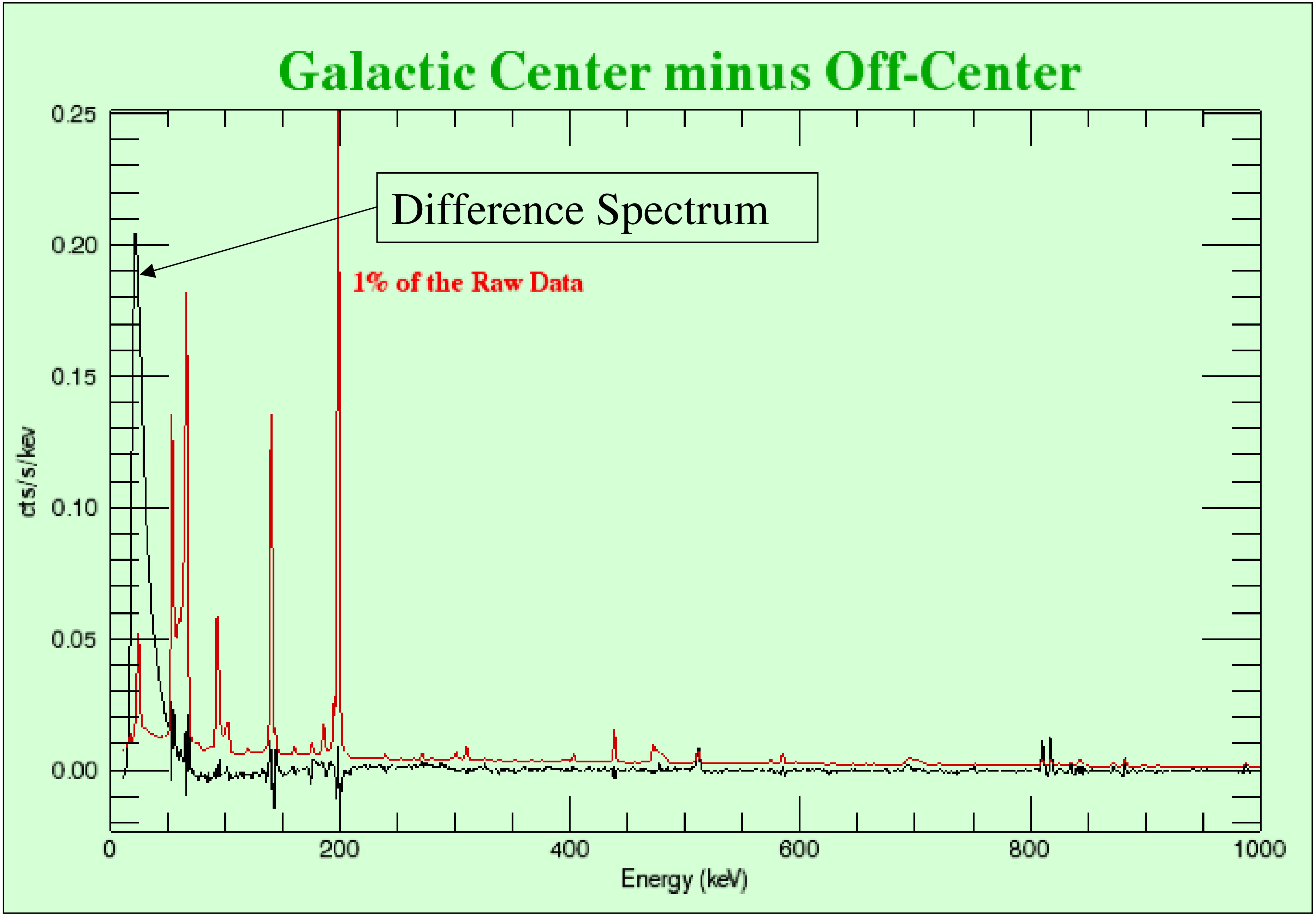


Background Subtraction

- Imperfect background line subtraction due to
  - –Lines from long half-life decays.
  - –Changing line widths due to radiation damage.
  - –Small uncorrected gain shifts.
  - –Small variations in line strength ratios.
  - –Solar Flare activation.
- Assume that source spectrum can be expressed as energy-dependent convolution of background spectrum (takes all of above effects into account).
  - –Express convolution as matrix multiplication.
  - –Solve for convolution function using singular value decomposition (SVD).
  - –Convolve background spectrum and take difference.

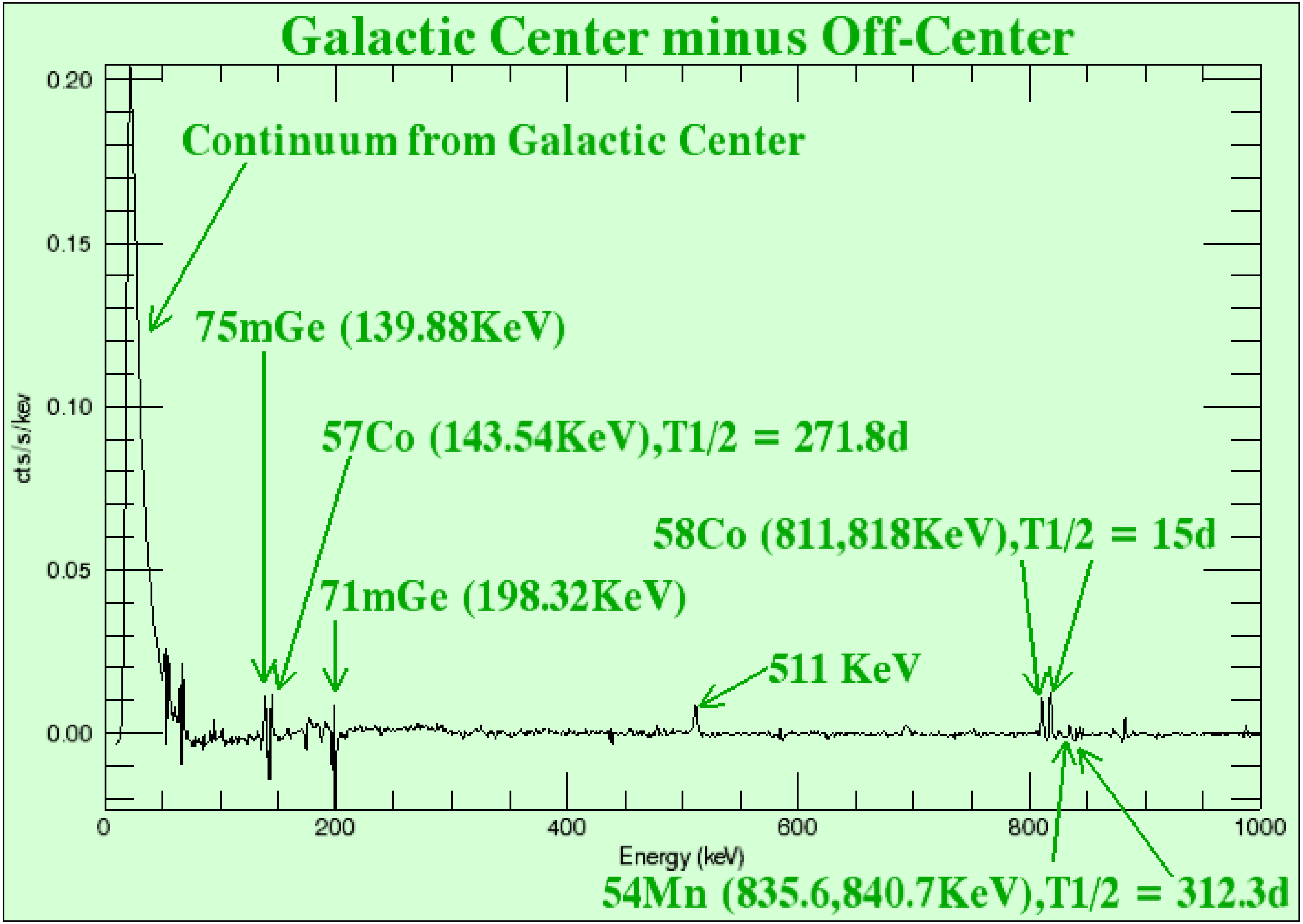
Source Minus Convolved Background Spectrum



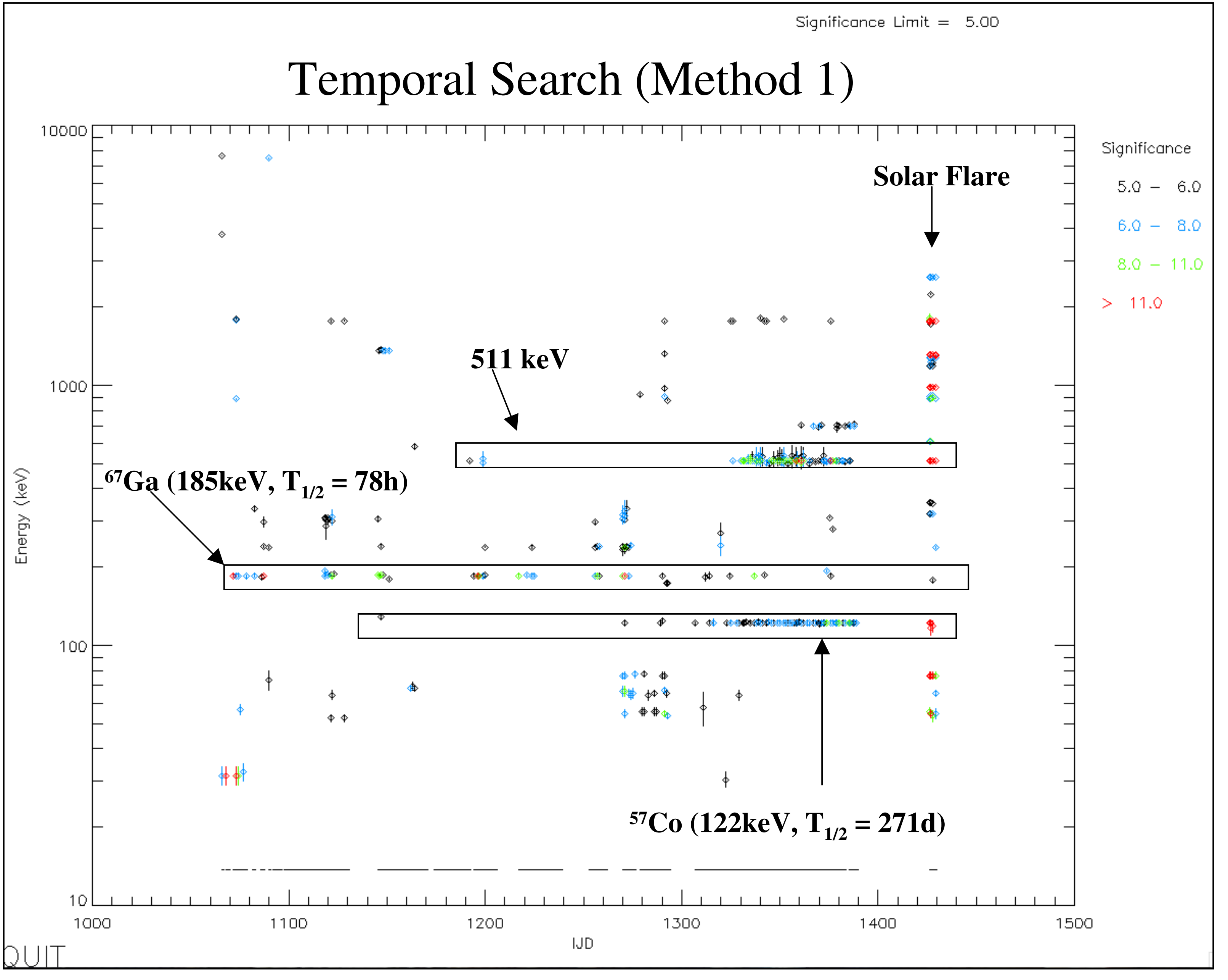


Galactic Center minus Off-Center
Difference Spectrum
1% of the Raw Data
0.25
0.20
0.15
0.10
0.05
0.00
cts/s/keV
0
200
400
600
800
1000
Energy (keV)

Reference: Weidenspointner et al. 2003, A&A 411, L113 & private communication



Temporal Search (Method 1)



Line Search from Point Sources

INTEGRAL/SPI Bright Source Catalog

HMXB

1E 1145.1-6141
3A 2206+543
4U 0115+634
4U1700-377
AX J1820.5-1434
Cen X-3
Cyg X-1
EXO 2030+375
GX 301-2
GX 304-1
H 1538-522
IGR J16318-4848
IGR J16320-4751
KS 1947+300
LMC X-4
OAO 1657-415
SAX J2103.5+4545
Vela X-1
X Per
XTE J1908+094
XTE_J1855-026

LMXB

1A 1742-294
1E 1740.7-2942
3A 1728-169
3A 1822-371
4U 1630-47
4U 1722-30
4U 1730-335
4U 1735-444
4U 1812-12
4U 1916-053
Aql X-1
AX J1748.0-2829
Cir X-1
Cyg X-2
EXO 0748-676
Ginga 0836-429
Ginga_1826-24
GRS 1739-278
GRS 1758-258
GRS 1915+105
GX 1+4
GX 13+1
GX 17+2
GX 3+1
GX 339-4
GX 340+0
GX 349+2
GX 354-0
GX 5-1
GX 9+1
H 0614+091
H 1608-522
H 1636-536
H 1702-429
H 1705-250
H 1705-440
H 1820-303
IGR J16418-4532
IGRJ16358-4726
KS 1741-293
Sco X-1
Ser X-1
SLX 1735-269
XTE J1550-564

Seyferts

MR2251-178
NGC 4151
MCG -05-23-16
Cen A
NGC 4388
NGC 4945
NGC 4736

Microquasar: SS 433
Neutron star: IGR J17597-2201
Pulsar: XTE J1807-294
SNR: Crab
Blazar: 3C 273

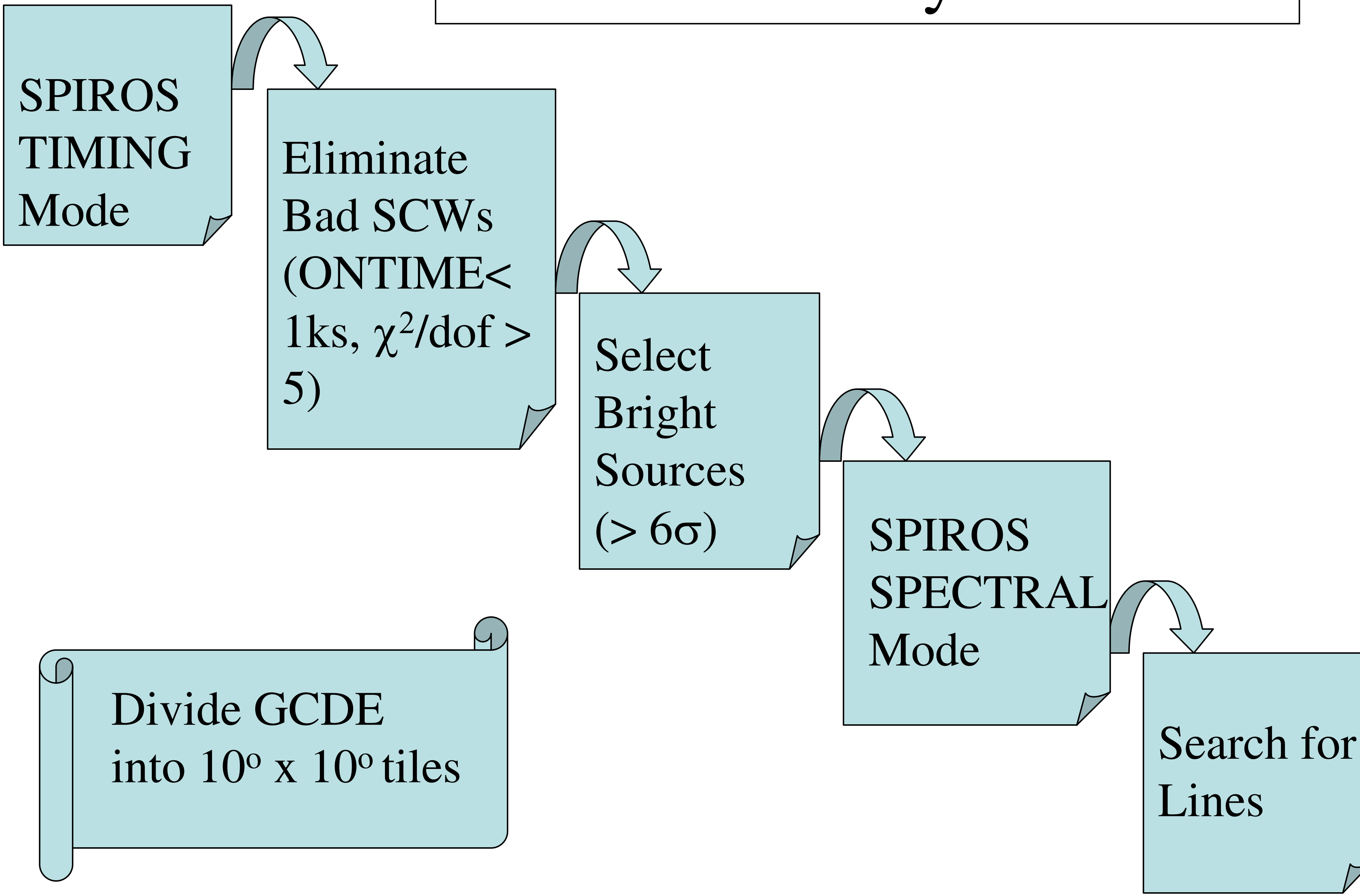
XB

Cyg X-3
IGR J19140+0951
XTE J1720-318

Others

4U 1901+03
4U 1909+07
IGR J06074+2205
IGR J15479-4529
IGR J16479-4514
IGR J16558-5203
IGR J17252-3616
IGR J18325-0756
IGR J18406-0539
IGR J18450-0435
IGR J18483-0311
SAX J1744.7-2916
SAX J1805.5-2031
IGR_J17391-3021
IGR J17464-3213

Basic Data Analysis Process

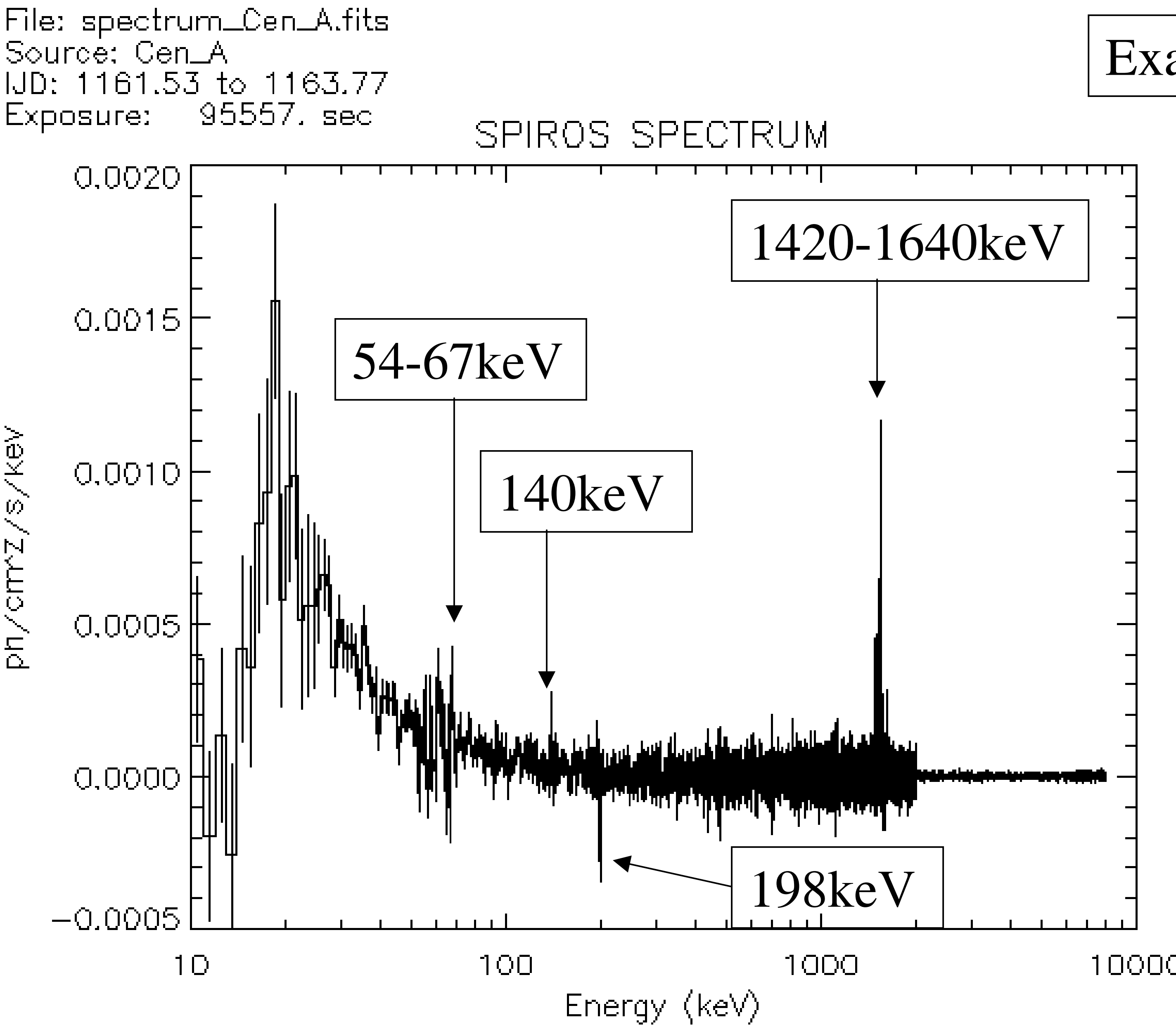


Choice of Energy Bin Sizes

- Want to bin at SPI resolution for line search
  - But fine binning at high energies can lead to small (< 1) no. of counts/bin and non-gaussian errors.
- Found through tests that if binning is chosen to maintain > 1 count/bin on average that errors are well-behaved when SPIROS is run in chi2 mode.
  - Hence the following choice of binning.

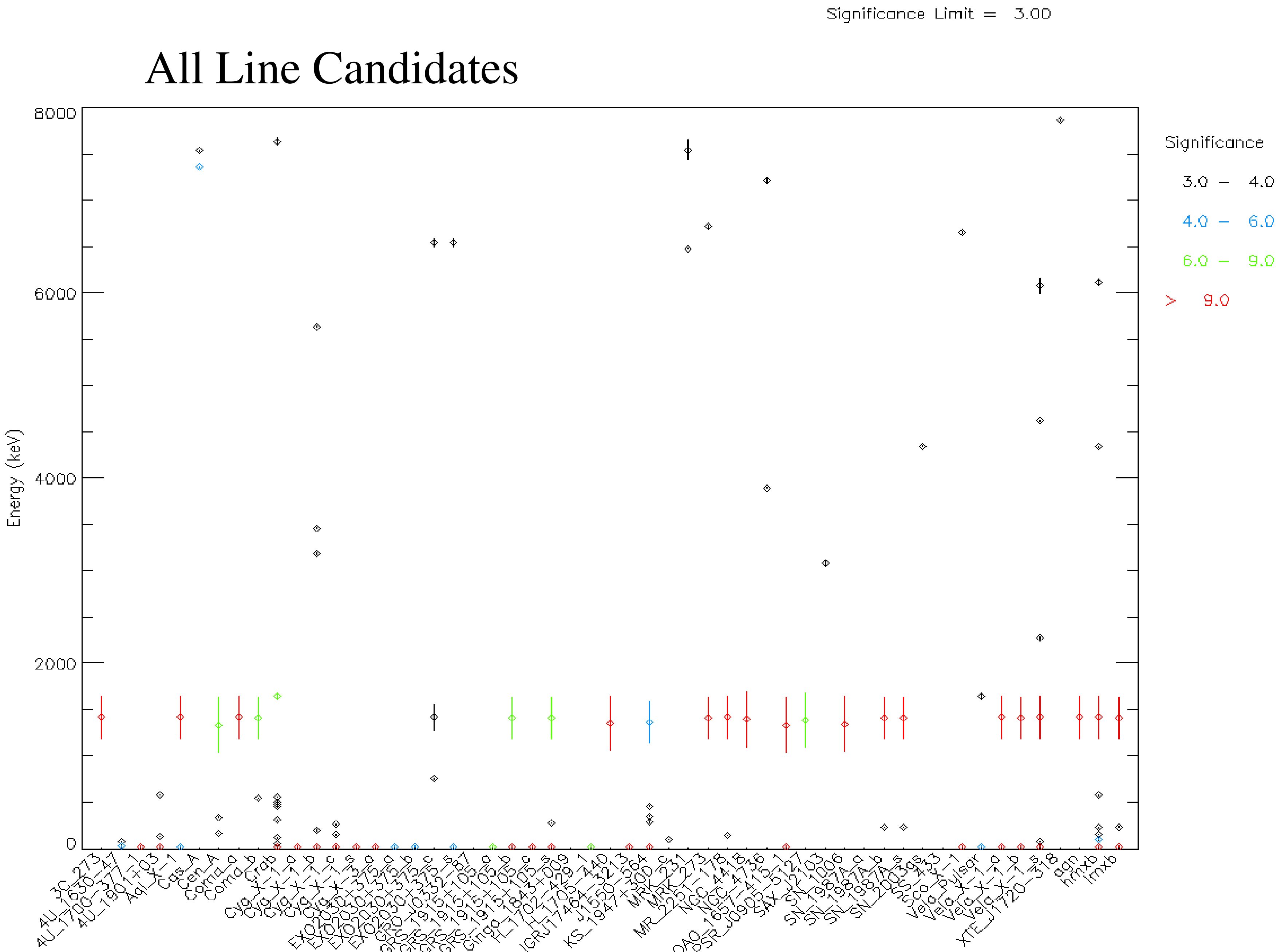
20keV-2MeV:1keV
2MeV-8MeV:10keV

Example



File: spectrum_Cen_A.fits
Source: Cen_A
IJD: 1161.53 to 1163.77
Exposure: 95557. sec
SPIROS SPECTRUM
0.0020
0.0015
0.0010
0.0005
0.0000
−0.0005
ph/cm^2/s/keV
10
100
1000
10000
Energy (keV)
54-67keV
140keV
1420-1640keV
198keV

All Line Candidates

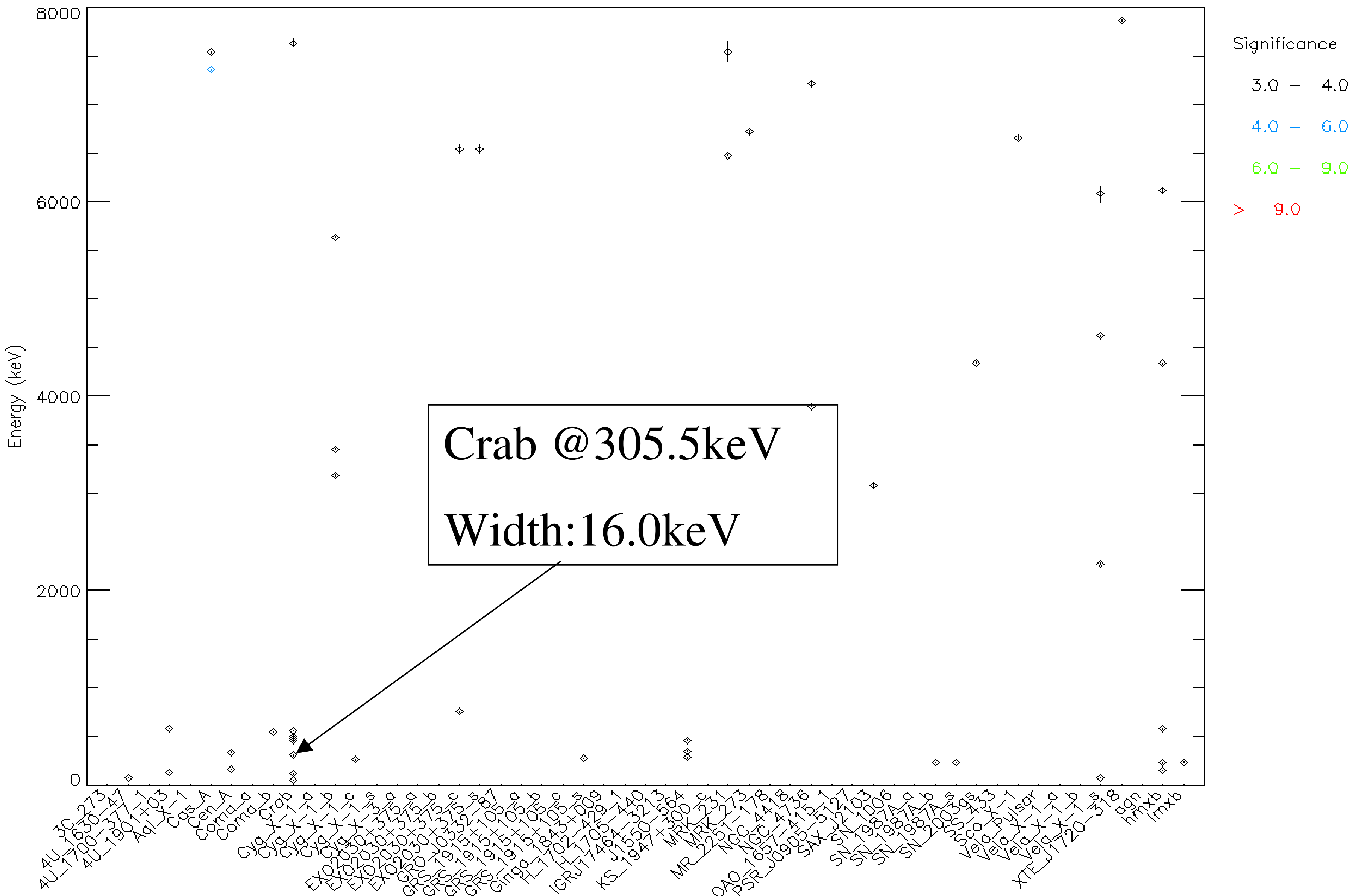


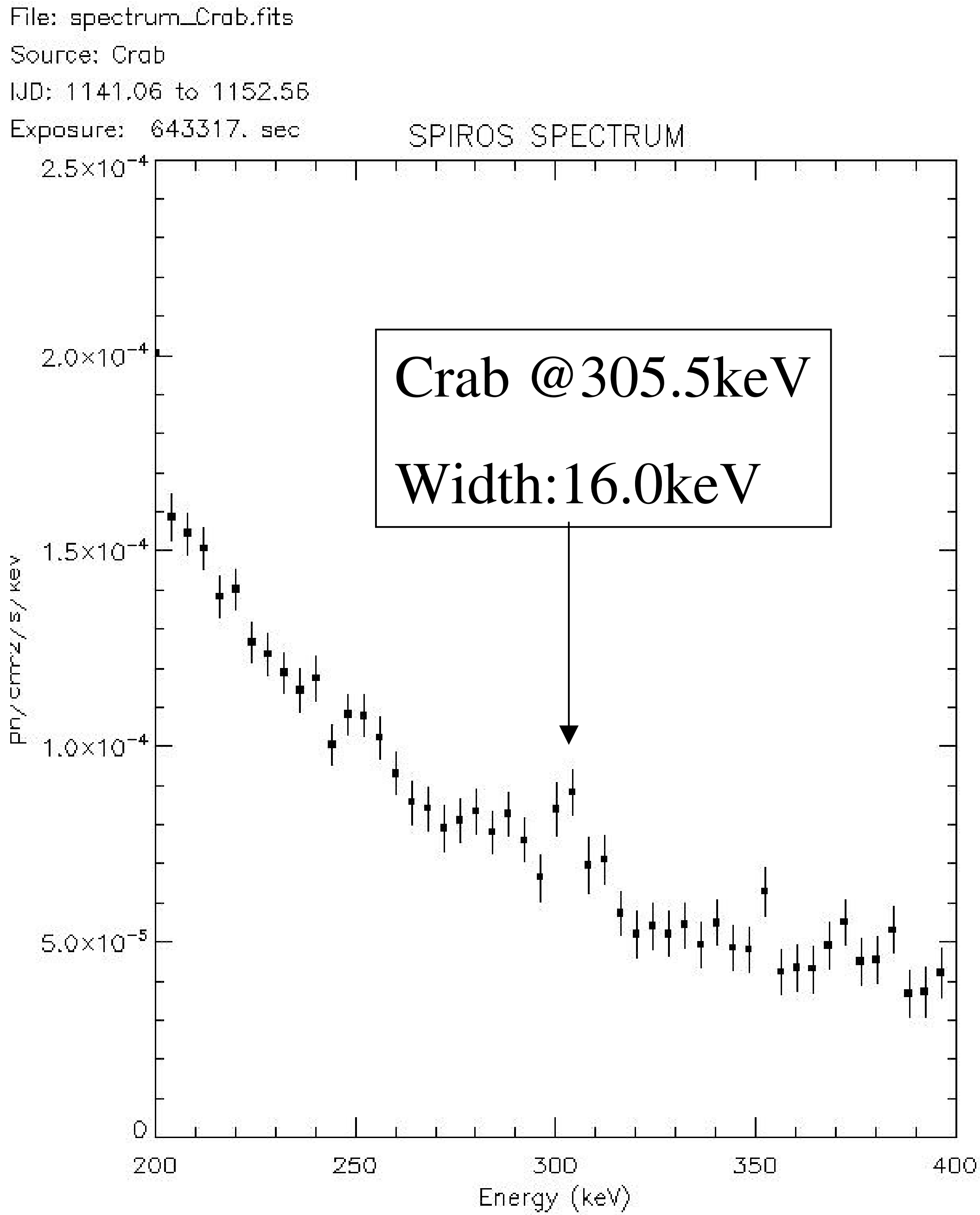
SPI CoIs Meeting (3/17/05)

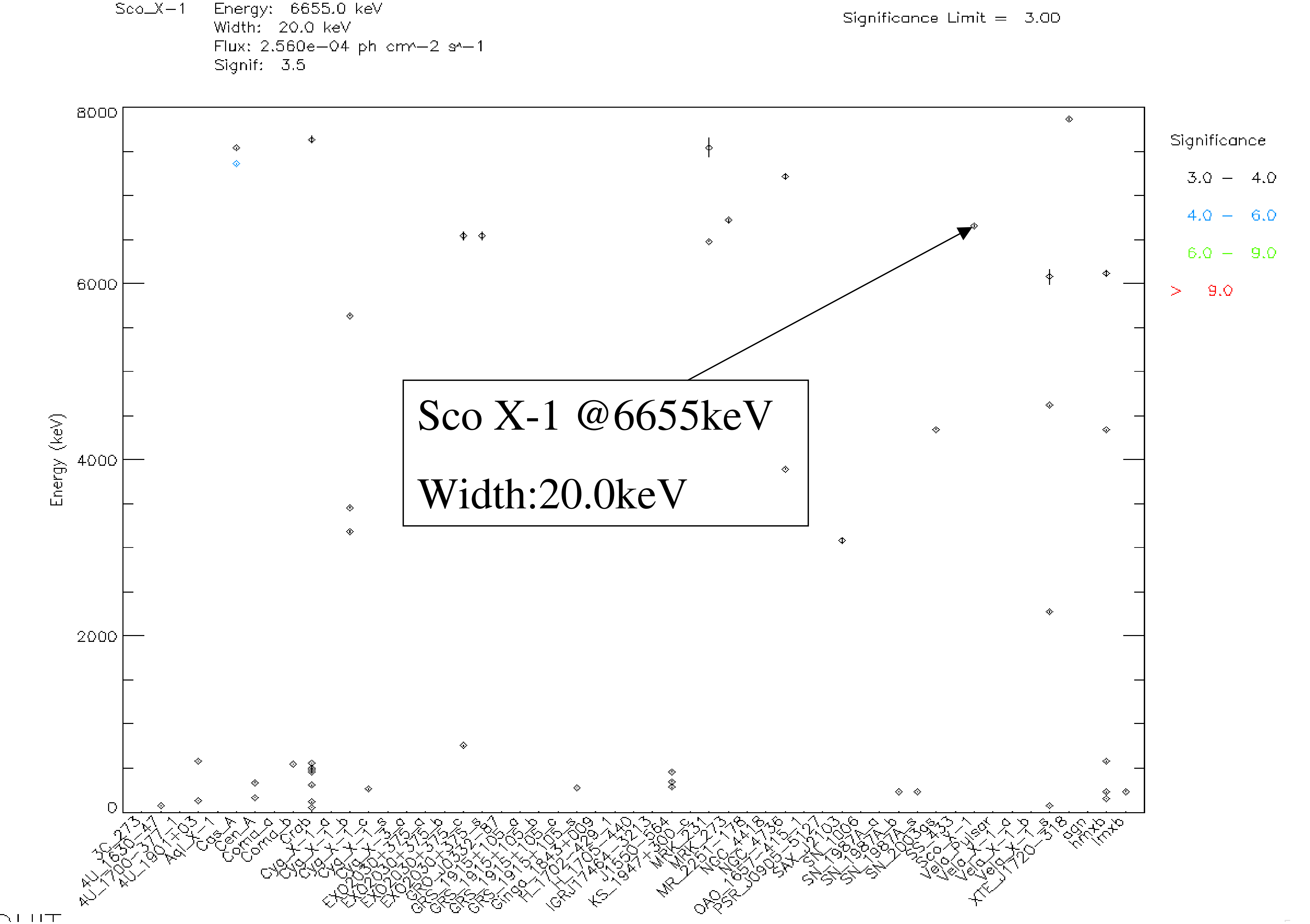
Crab Energy: 305.5 keV
Width: 16.0 keV
Flux: 2.349e−04 ph cm^−2 s^−1
Signif: 3.7

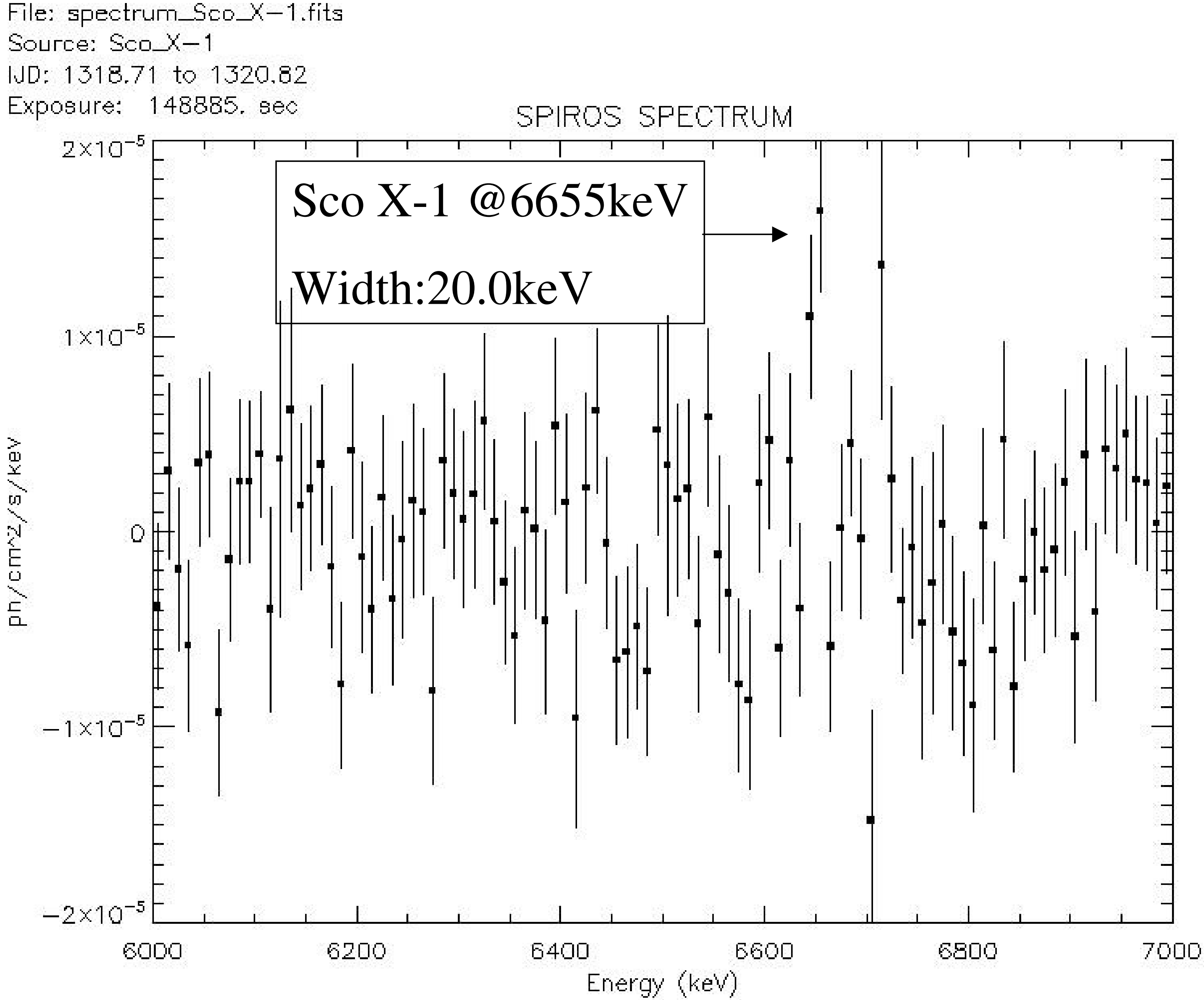
Significance Limit = 3.00

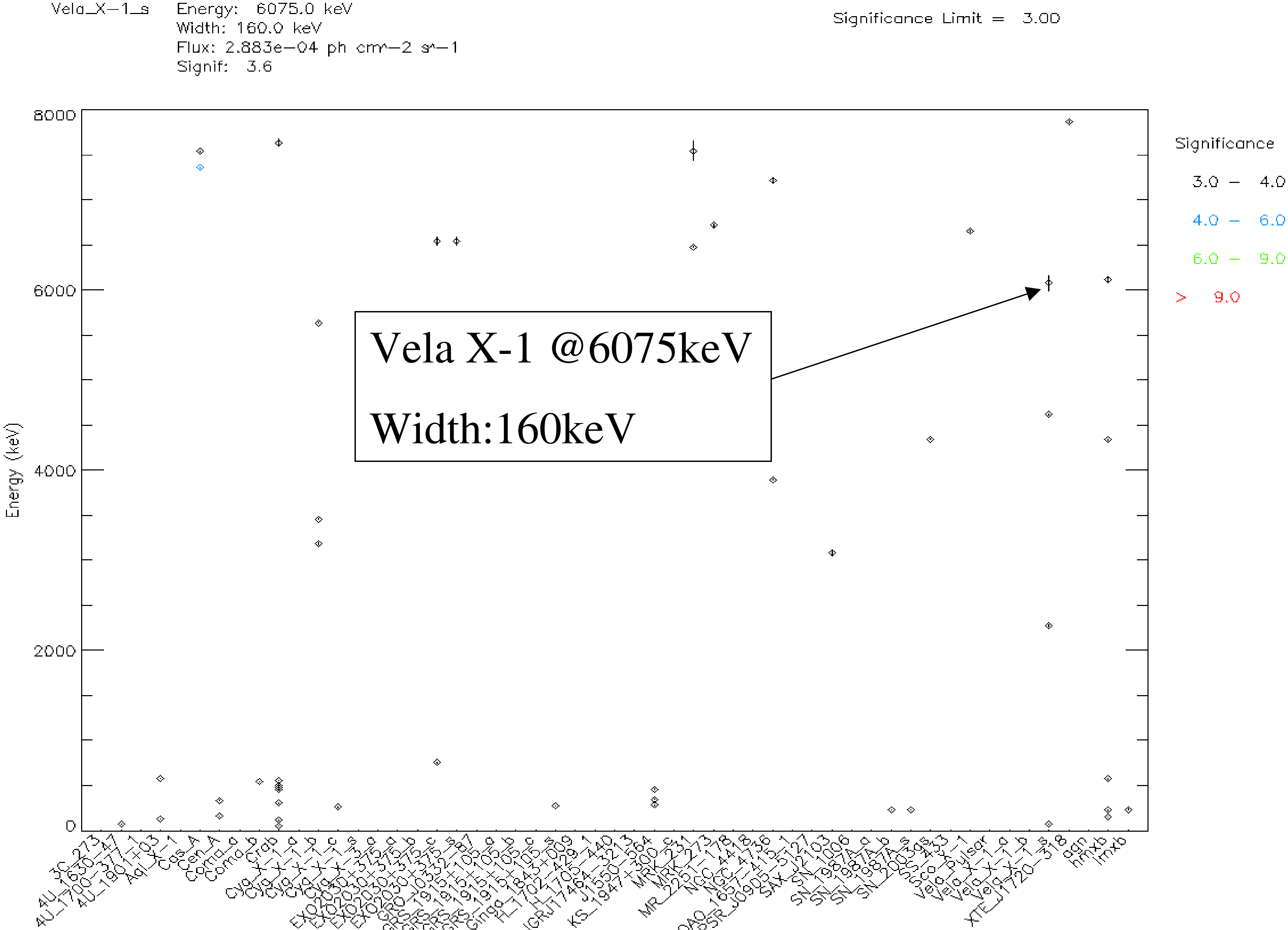
Line Candidates (known background lines removed)

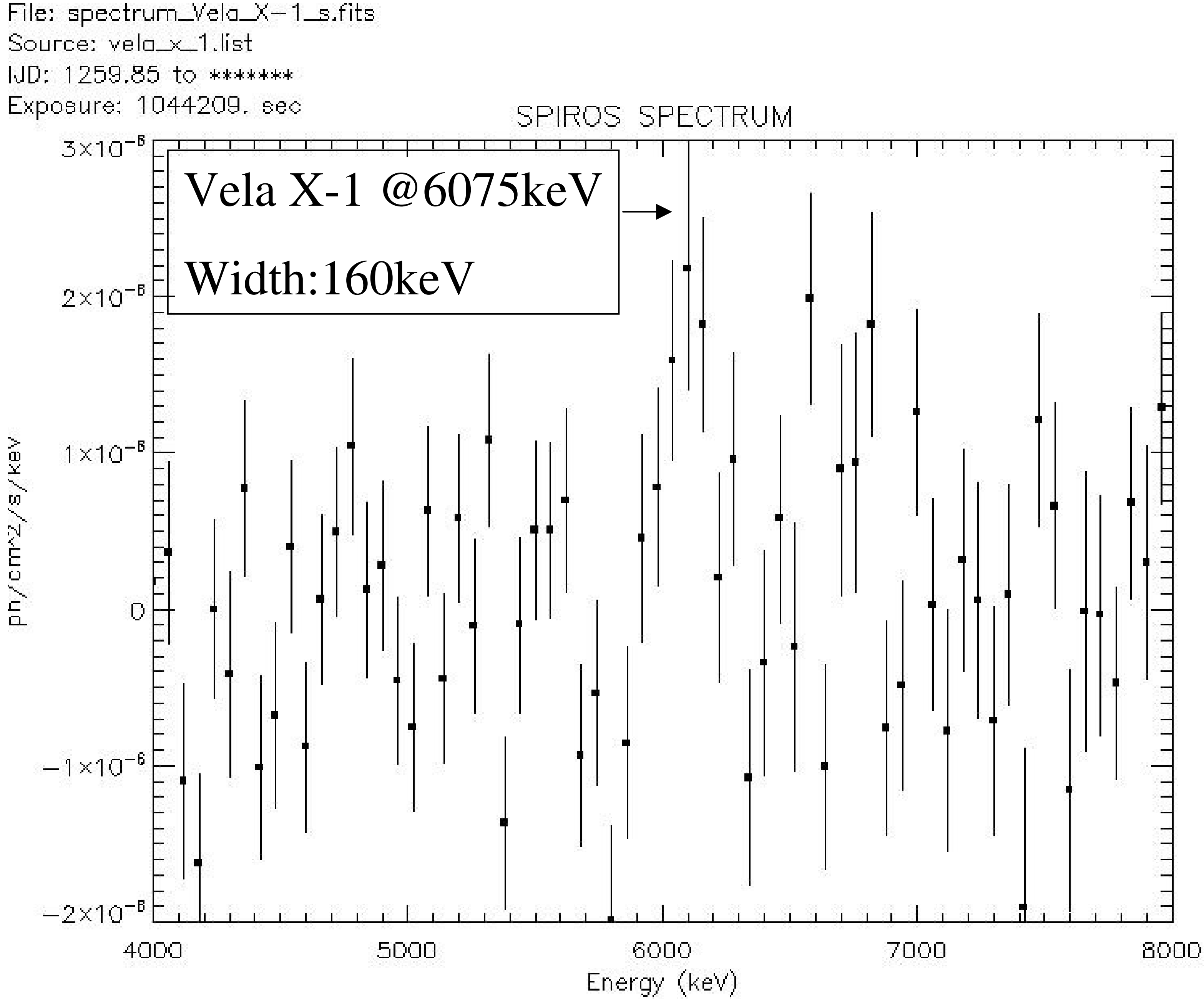



File: spectrum_Crab.fits
Source: Crab
IJD: 1141.06 to 1152.56
Exposure: 643317. sec
SPIROS SPECTRUM
Crab @305.5keV
Width:16.0keV
ph/cm^2/s/keV
2.5×10^{-4}
2.0×10^{-4}
1.5×10^{-4}
1.0×10^{-4}
5.0×10^{-5}
0
200
250
300
350
400
Energy (keV)


Sco_X-1
Energy: 6655.0 keV
Width: 20.0 keV
Flux: 2.560e-04 ph cm^-2 s^-1
Signif: 3.5
Significance Limit = 3.00
Significance
3.0 – 4.0
4.0 – 6.0
6.0 – 9.0
> 9.0
Energy (keV)
8000
6000
4000
2000
0
Sco X-1 @6655keV
Width:20.0keV


File: spectrum_Sco_X-1.fits
Source: Sco_X-1
IJD: 1318.71 to 1320.82
Exposure: 148885. sec
SPIROS SPECTRUM
Sco X-1 @6655keV
Width:20.0keV
2x10^-5
1x10^-5
0
-1x10^-5
-2x10^-5
ph/cm^2/s/keV
6000
6200
6400
6600
6800
7000
Energy (keV)


Vela_X-1_s
Energy: 6075.0 keV
Width: 160.0 keV
Flux: 2.883e-04 ph cm^-2 s^-1
Signif: 3.6
Significance Limit = 3.00
Significance
3.0 – 4.0
4.0 – 6.0
6.0 – 9.0
> 9.0
Energy (keV)
0
2000
4000
6000
8000
Vela X-1 @6075keV
Width:160keV



File: spectrum_Vela_X-1_s.fits
Source: vela_x_1.list
IJD: 1259.85 to *******
Exposure: 1044209. sec
SPIROS SPECTRUM
Vela X-1 @6075keV
Width:160keV
3×10⁻⁶
2×10⁻⁶
1×10⁻⁶
0
−1×10⁻⁶
−2×10⁻⁶
ph/cm^2/s/keV
4000
5000
6000
7000
8000
Energy (keV)

Current Status/Future Work

- Diffuse Sources

~ No new lines found in large-scale searches.

—Upper limits vary between few x 10^{-5} ph cm^{-2} sec^{-1} and ~ 10^{-3} ph cm^{-2} sec^{-1} depending on energy, width and exposure.

~ Diffuse line search.

—Search over 10° grid in the Galactic Plain and selected off plain areas with significant exposures.

- Point Sources

~ No significant candidates found so far.

~ 60% of search completed.

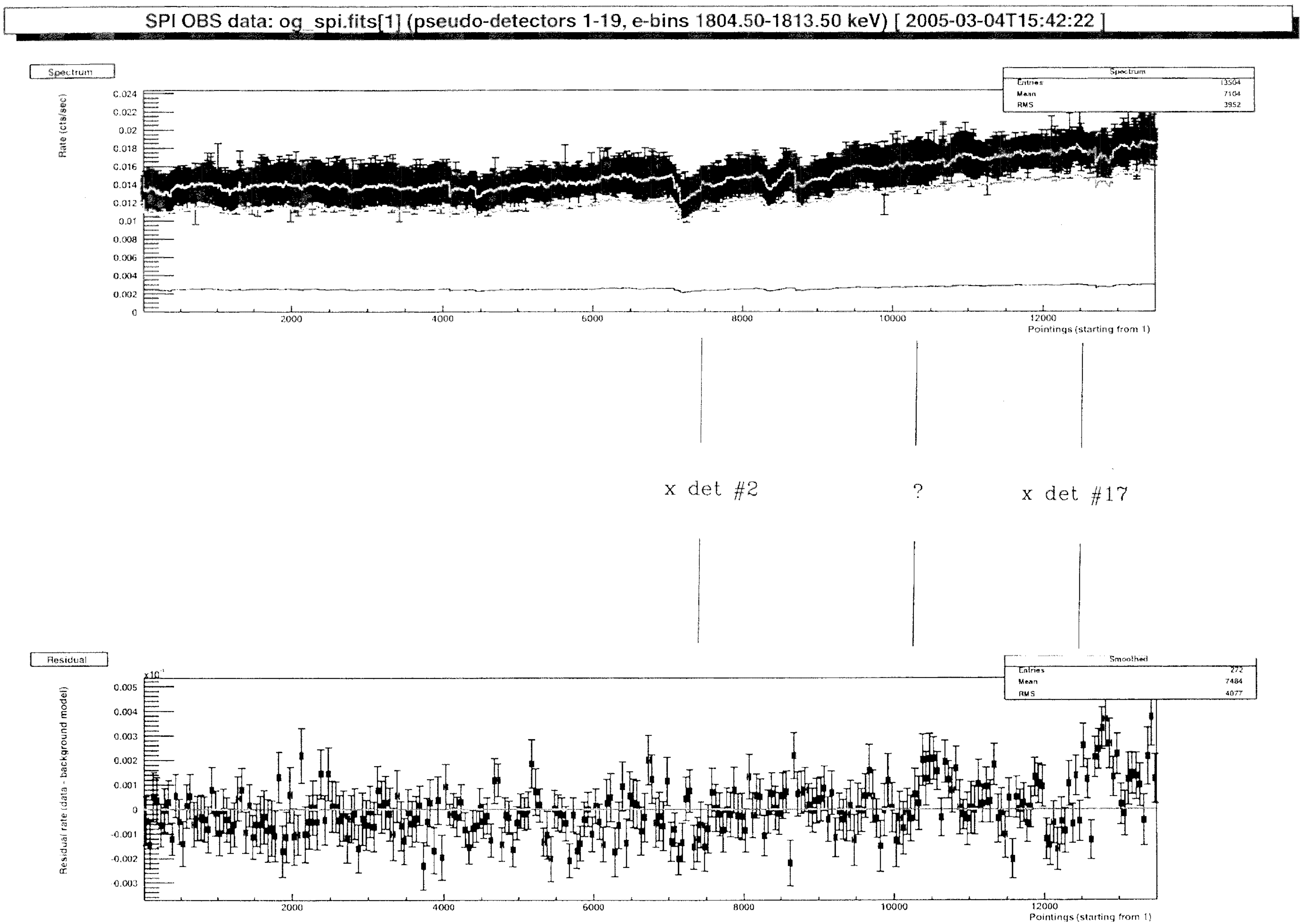
NEXT STEP

Data from orbits 19–130 have been analysed, interpreted and accepted for publication in A&A Letters. The next step is to acquire as much data as possible from the following year (up to revolution 229) in order to check the robustness of the analysis.

(1) Do the statistics and significance of the result improve as more data come in?

(2) Are there new sources of systematics corresponding to the new problems experienced (failure of detectors 2 and 17)?

This work is now only just beginning.


SPI OBS data: og_spi.fits[1] (pseudo-detectors 1-19, e-bins 1804.50-1813.50 keV) [2005-03-04T15:42:22]
Spectrum
Rate (cts/sec)
Entries 13504
Mean 7104
RMS 3952
Pointings (starting from 1)
x det #2
?
x det #17
Residual
Residual rate (data - background model)
Smoothed
Entries 272
Mean 7484
RMS 4077
Pointings (starting from 1)

Positronium Continuum Emission: All-Sky Distribution

by

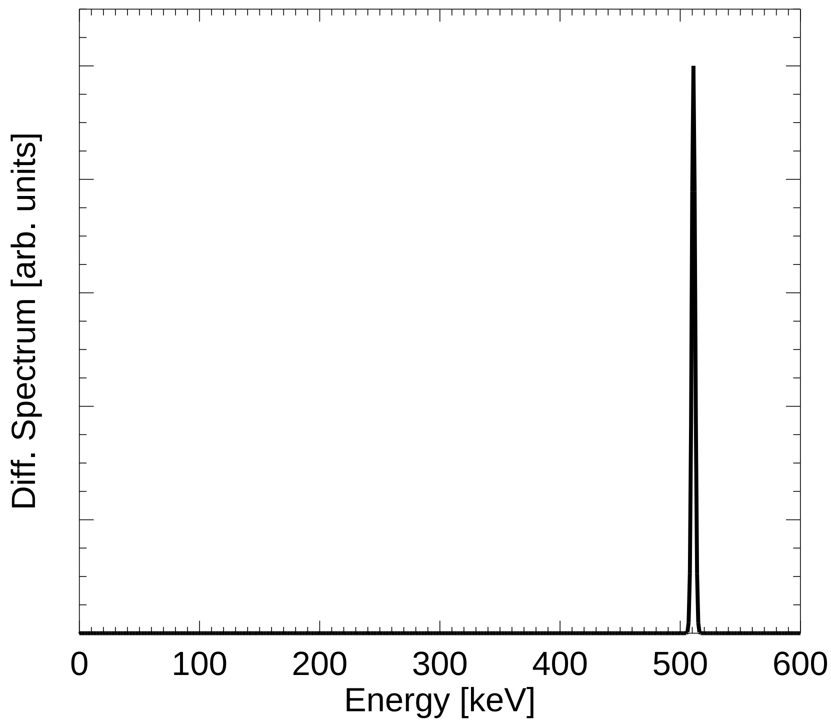
Georg Weidenspointner

CESR

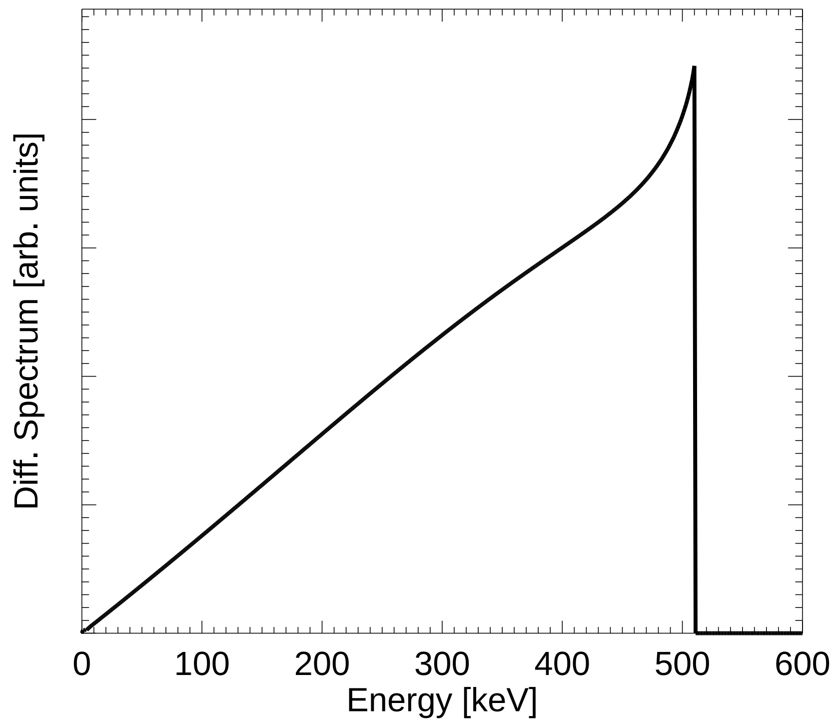
on Behalf of the CESR SPI Team

Motivation

- **Two γ-ray signatures of positron annihilation: 511 keV line and P_s**
- **For $f \sim 0.92$: $F_{3\gamma}/F_{2\gamma} \sim 3.5$**
  $\Longrightarrow$ most of γ-ray signal due to positron annihilation is in P_s!



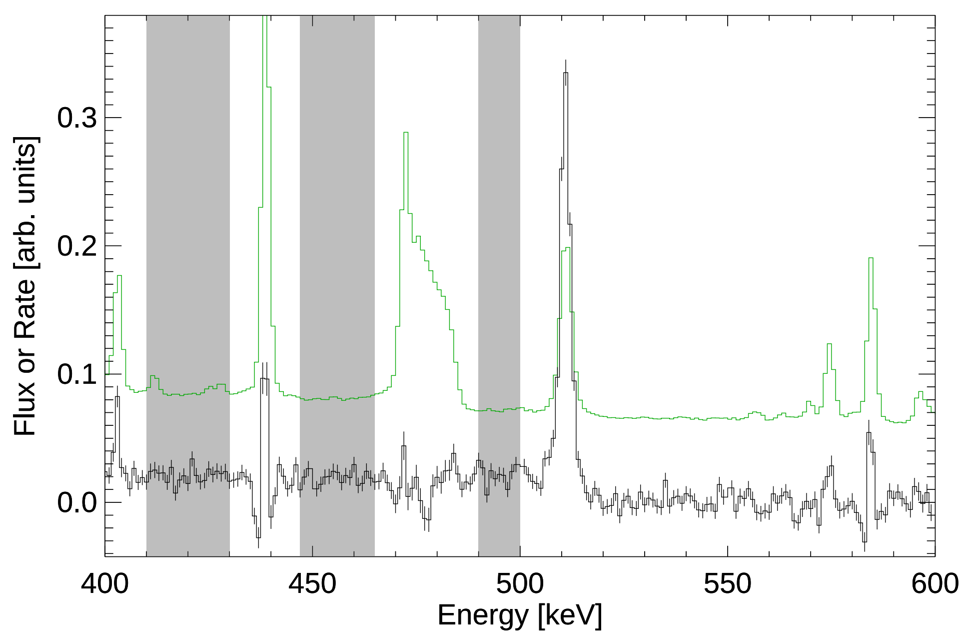
511 keV Line



Positronium Continuum

Background Model / Data Analysis

- As usual, the background modelling is crucial...
- S/B is small: simple and robust
- So far: used 3 components of 511 keV line background model:
  - GeDsat
  - constant
  - GeDsat convolved with ^{65}Zn ($T_{1/2} = 244$ d)
- Application to 400-600 keV, public data release from Dec. 10, 04 ("first year of mission"):
  - Works well in general
  - A few strong residuals
  - For Positronium continuum: 410-430, 447-465, 490-500 keV



Model Fitting I

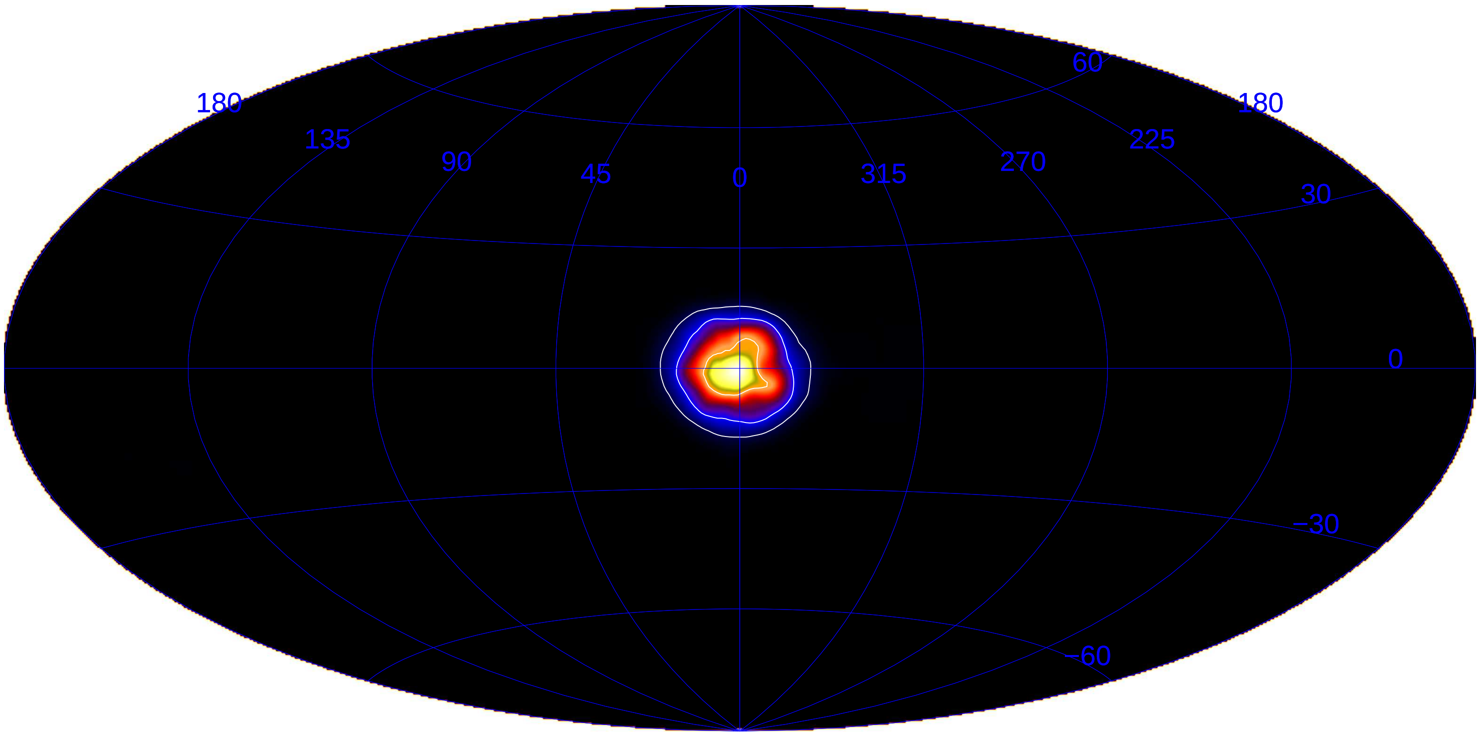
- First step: "2D Gaussians" in individual and combined energy bands: consistent within statistics $\Longrightarrow$ use combined bands
- Crab and Cyg X-1 are significant $\Longrightarrow$ included in fits
- Models for Galactic continuum emission:
  - CO
  - HI
  - DIRBE 3.5 μm
  - DIRBE 240 μm

Model Fitting II

Bulge only	l_0, b_0 [°]	1.3 ± 0.8, -0.8 ± 0.6
	FWHM$_l$, FWHM$_b$ [°]	$10.0^{+4.1}_{-1.9}$, $6.6^{+1.4}_{-1.2}$
	ϵ	0.66 ± 0.23
	f [ph/cm^2/s]	$(1.22 \pm 0.12) \times 10^{-3}$
Bulge + HI	l_0, b_0 [°]	1.3 ± 0.8, -0.9 ± 0.6
	FWHM$_l$, FWHM$_b$ [°]	$9.3^{+2.6}_{-1.5}$, $6.8^{+1.5}_{-1.2}$
	ϵ	0.74 ± 0.22
	f_b [ph/cm^2/s]	$(1.16 \pm 0.11) \times 10^{-3}$
	f_{HI} [ph/cm^2/s]	$(4.18 \pm 1.52) \times 10^{-3}$
Bulge + CO	l_0, b_0 [°]	1.3 ± 1.1, -1.2 ± 1.0
	FWHM$_l$, FWHM$_b$ [°]	$9.2^{+3.1}_{-2.1}$, $7.8^{+3.2}_{-1.7}$
	ϵ	0.85 ± 0.36
	f_b [ph/cm^2/s]	$(0.86 \pm 0.14) \times 10^{-3}$
	f_{CO} [ph/cm^2/s]	$(1.97 \pm 0.48) \times 10^{-3}$

- **Centroid consistent with GC, ellipticity consistent with spheroid**
- **Bulge consistent with 511 keV line**
- **Remember: is total emission (P_s and Galactic continuum)**

Mapping



- Map of total (extended) emission in 3 analysis bands, early iteration...
- Crab and Cyg X-1 are subtracted
- Emission is concentrated in bulge, roughly symmetric, “no” disk
- Very similar to 511 keV line map...

Point Sources

- Searched for point sources with SPIROS in 3 energy bands combined
- Outside bulge: Crab and Cyg X-1
- In bulge: formally 6 point sources, but none corresponds to known objects

$\Longrightarrow$ Assume for now: bulge emission is diffuse

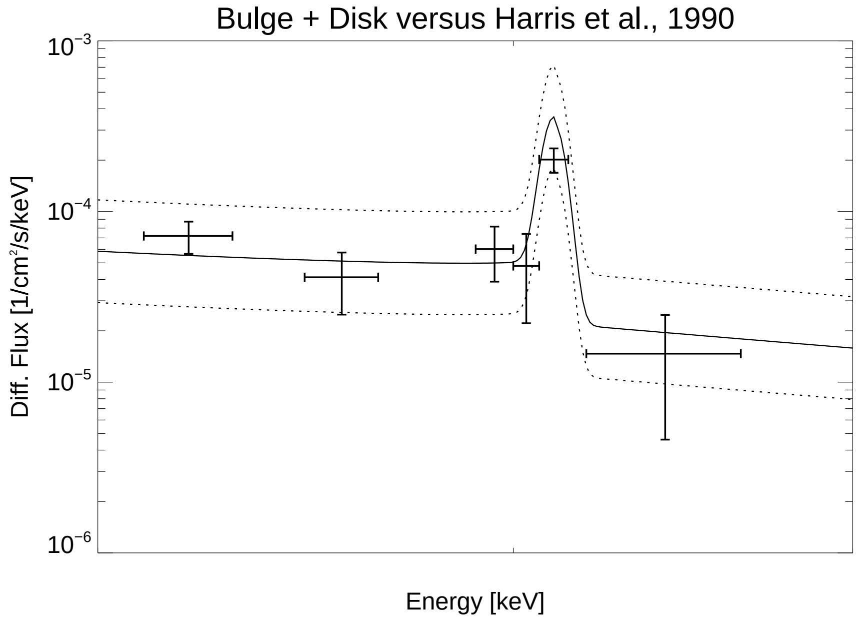
Spectroscopy I

- Idea: demonstrate that bulge emission is dominated by P_s
- Difficulty: requires assumption on sky distribution,
  in particular for Galactic diffuse emission there are uncertainties...
- Bulge: assume spherical "2D Gaussian", 8° FWHM, at GC
- Disk: no disk, CO, HI
  CO appears best fit, but poor statistics...
- Determined flux in 6 energy bands
  - 410–430 keV
  - 447–465 keV
  - 490–500 keV
  - 500–507 keV
  - 507–515 keV
  - 520–565 keV

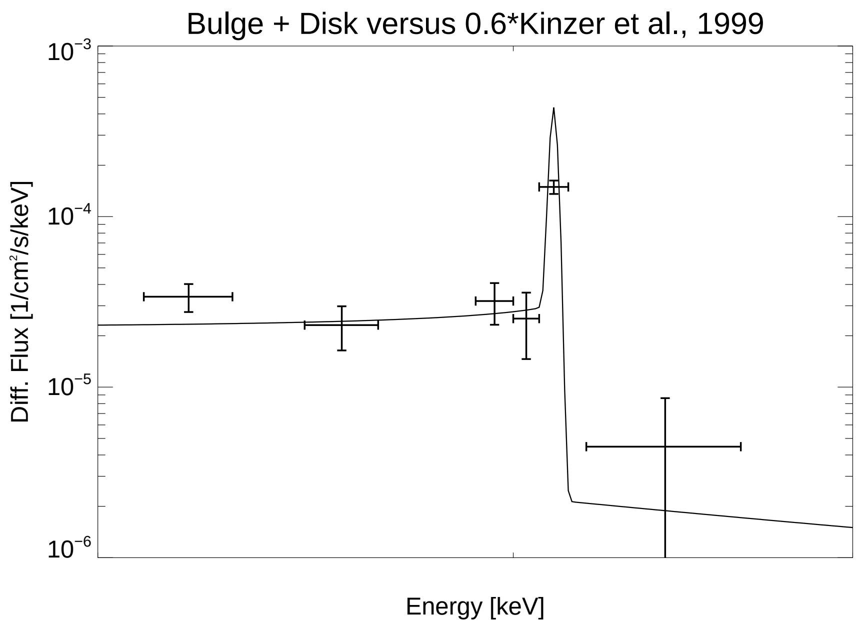
Spectroscopy II

- **Bulge + CO disk**

- **All-sky spectrum: consistent with Harris et al., 1990 SMM result**



- **Inner Galaxy spectrum: consistent with Kinzer et al., 1999 OSSE result**



Summary

- Sky distribution of P_s is consistent with 511 keV line
- Flux/spectrum is consistent with previous results (SMM, OSSE)
- Full-blown XSPEC analysis is in progress. . .
- Background modelling in more energy bands is in progress. . .

Status Note on ^{26}Al Studies in the Galaxy

- Reminder: Jan 2005 Noordwijk Results
- Towards optimizing spectral resolution
- Updated results rev 15-259

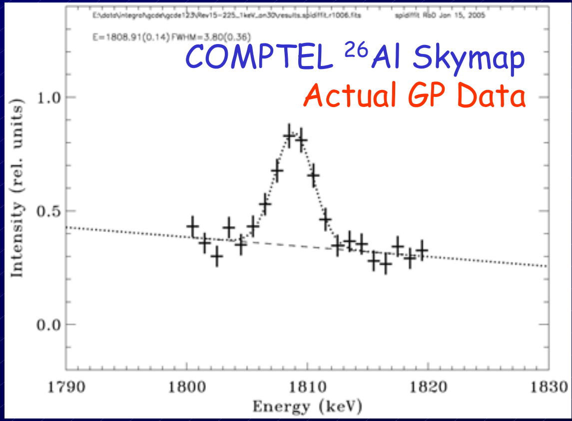
Roland Diehl

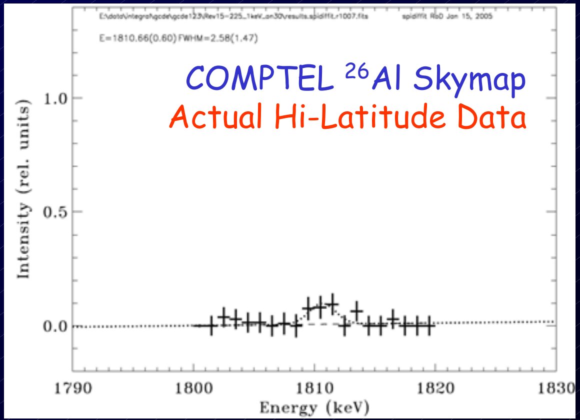
Imaging Spectroscopy: Validation of Sky Signal

Method: Sky Model (&Bgd) Fitting per Energy Bin -> Spectrum

Perform Identical Analysis on "OFF" Reference Dataset

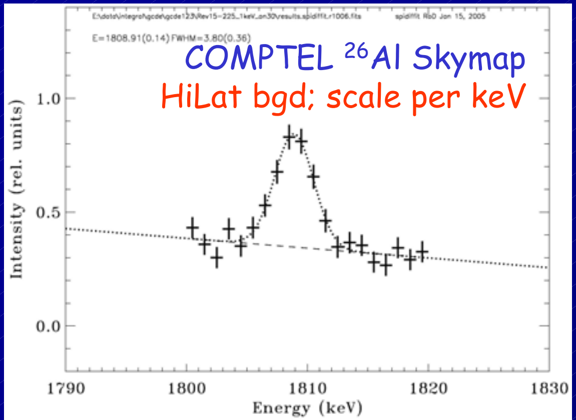
- Key Aspects:
  - Identical Sky and Background Models
  - Different Measurement without ^{26}Al Counts
    - Choose High-Latitude Reference (all pointings b>30°)
    - Match to Pointing/Exposure Scheme of Real Dataset
- Expectations:
  - "DC-Level"/Offset: Reflects Background Model Accuracy
    - Continuum Part Dominates Count Spectrum
    - Poor Bgd Fit Increases Apparent Sky Correlation of Data
  - Spectral Feature:
    - If Instrumental-Background Feature:
      - Spectral Features ~Similar for Both Cases
      - Spectral Feature Mirrors Instrumental Feature (Width, I_{line}/I_{cont})
    - If Celestial Signature:
      - Spectral Feature ~Absent for OFF Data
      - Spectral Feature Differs from Instrumental Feature (Width, I_{line}/I_{cont})

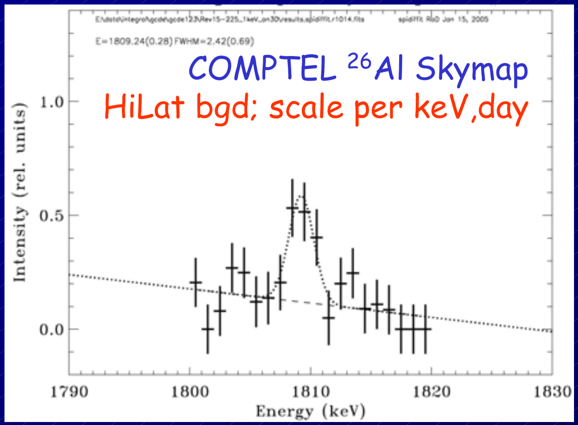


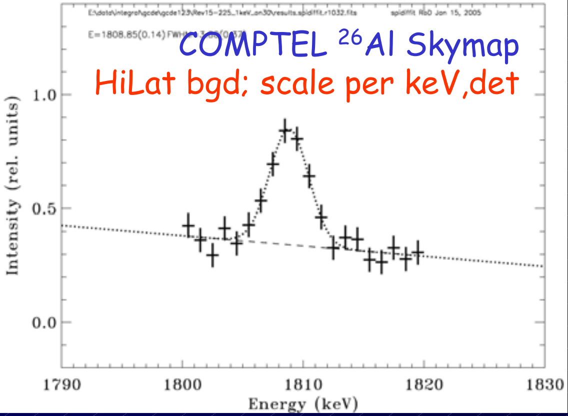


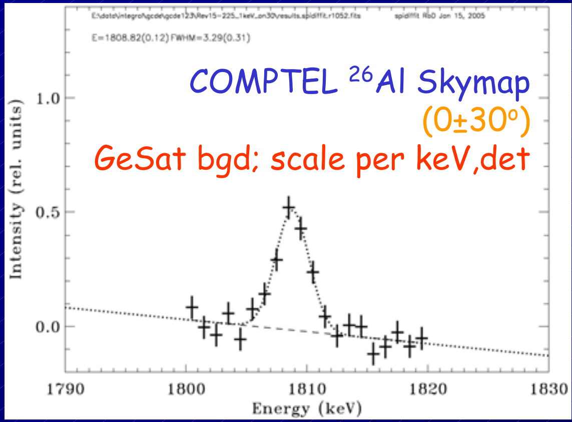
Imaging Spectroscopy: Sky Signal Systematics

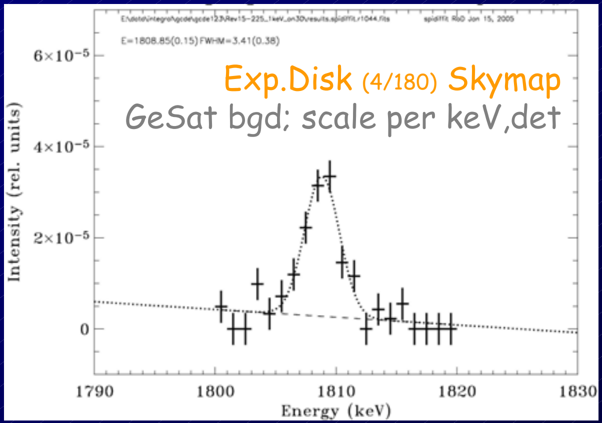
Variations of Input Models: Background, Sky

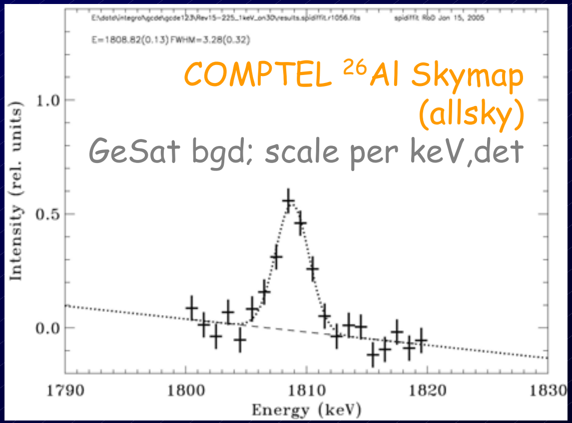










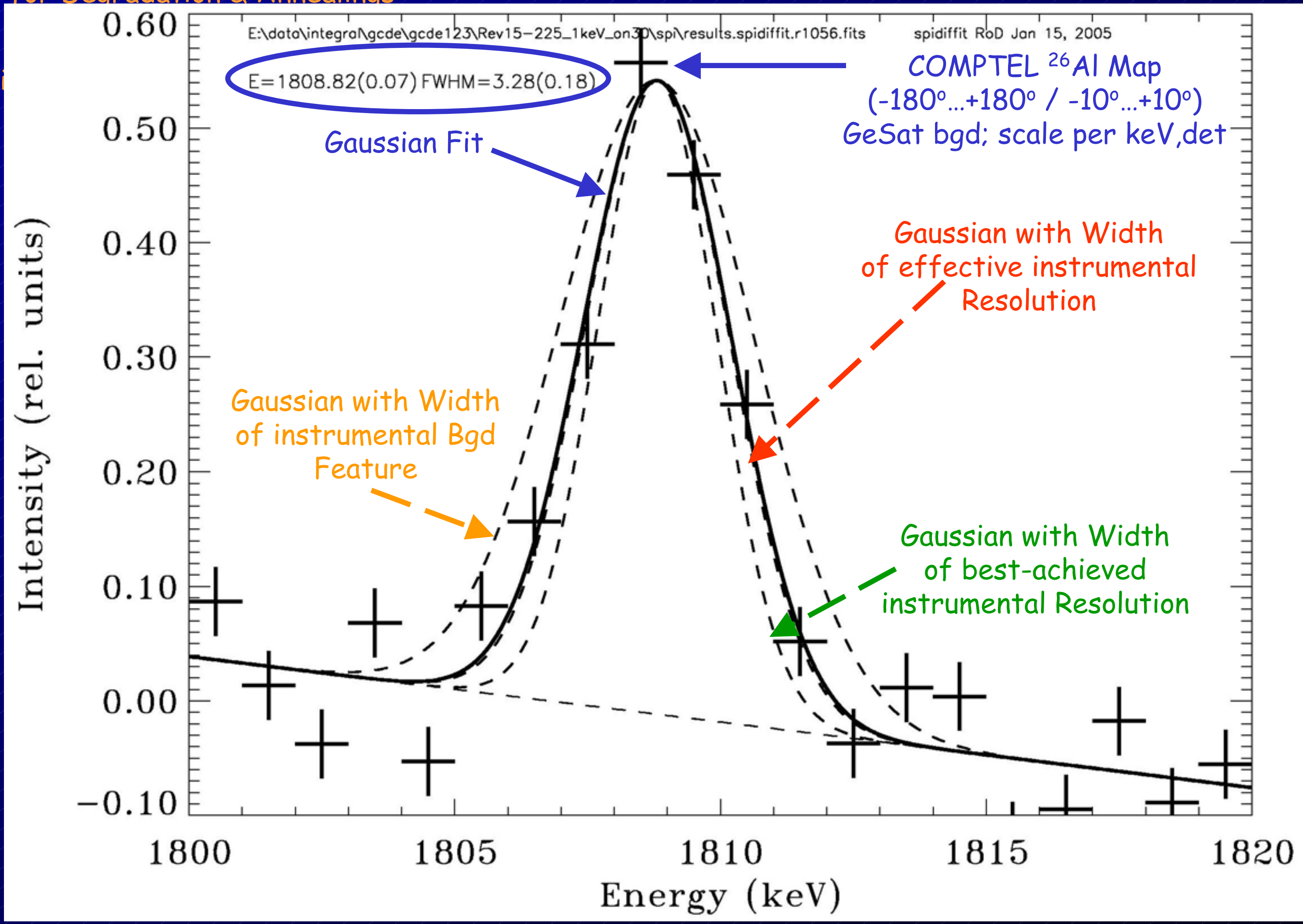


- ☞ Need to Use Reliable Background Time Variability Model; Sky Model ~Uncritical
- ☞ Width~Stable

Imaging Spectroscopy: ^{26}Al Line Shape (1)

- Standard Processed Data
  - "ISDC" Energy Calibration, Livetime Correction, Detector Failure Handling
  - No "Corrections" for Degradation & Annealings
- Standard Response
  - No Time Variabili

The Galactic ^{26}Al Line is not significantly broadened



^{26}Al Studies after Internal Workshop

- SPI Studies at MPE Relevant for ^{26}Al: (Dec'04…Mar'05)
  - ☆ Background Model Developments and Tests
  - ☆ Spectral-Response Determination for Fine Spectroscopy
  - ☆ Spectral Analysis through Model Fitting
  - ☆ Imaging

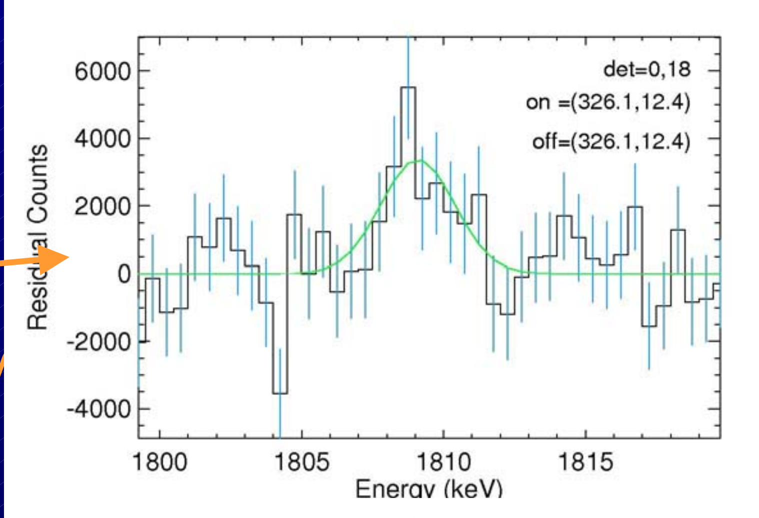
  - ☆ *Roland Diehl, Hubert Halloin, Karsten Kretschmer, Andy Strong, Christian Ciemniak, Michael Lang, Gabi Schächner, Laurent Lerusse, et al.*

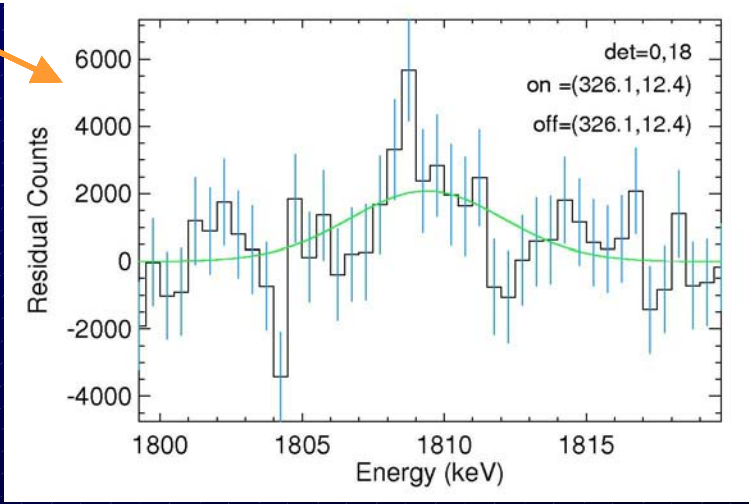
Data

- Available at MPE:
  - Rev.15-225 (Jan'05)
  - Rev 15-259 (Mar05): 7130 pntgs, 11.48 Ms GP, 1.56 Ms High-Latitude)
- Usages:
  - "Calibration" Data
    - Rev 1-139: Background Tracer Studies
    - Rev 30-212: Spectral Degradation
  - "Survey" Data
    - Background Modelling
    - Science Analysis
- Selections
  - (spiselectscw)
    - Orbit Phase 0.1-0.9
    - GeDSat Rate
    - IREM

Results Update: Simple/Straightforward ON/OFF

- ☆ Inspect "on-off":
  - ☞ 13σ Residual Signal
  - ☞ Width ~ "instrumental"
  - ☞ Width < background feature at 1810 keV
  - ☞ Width < GRIS Result
  - ☞ Intensity ~as Expected
    - 21000 counts; expect 25000 from I~3 10^{-4} ph cm^{-2} s^{-1} rad^{-1} for this exposure (at GC 3.31 Ms) and A_{eff}~25 cm^2





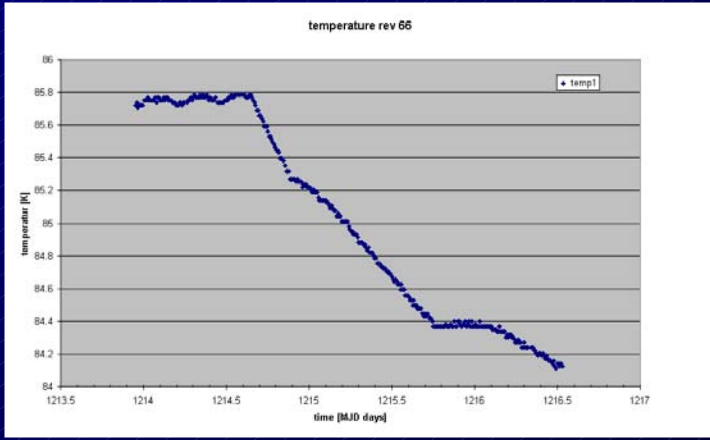
Value	Name	Error
1809.09	Centroid	0.12
3.06	Width	0.00
22014	Counts	1655
13.30	sigma of detection	

Corrections for Gain Variations within Orbits

- ☆ Cmp. Lonjou et al. ESA-SP 552, Roques SPI Mtg

Temperatur-Based Gain Correction of Raw Data

- ☆ Processing Modification ('std'-> 'std-1')
  - ☞ Cold Plate Temperature from HK Data
  - ☞ ch -> ch' (T) per pntg
  - ☞ -> energy calibration per rev
    -> histogramming
- ☆ Investigations
  - ☞ Rev 66 and 96 (large T variations):
    - Spectra changes: Line Centroids and Widths

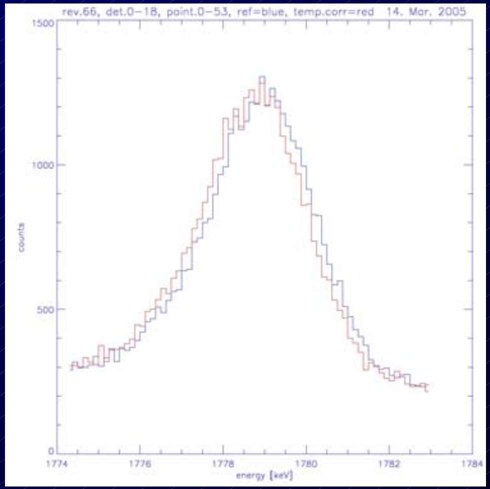


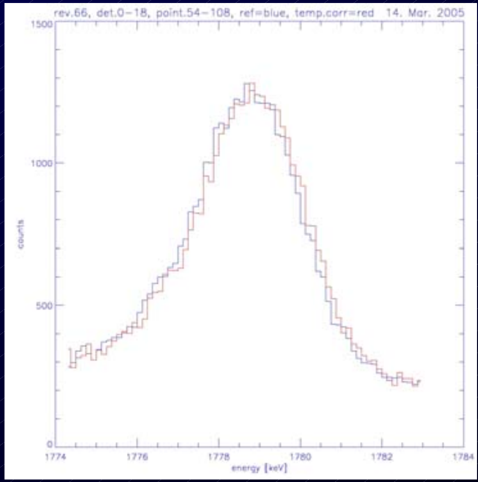
Expectations

- ☆ 0.04 keV Variability per Revolution (ref. Lonjou Fig. 4)

Results:

- ☆ …not yet finished…





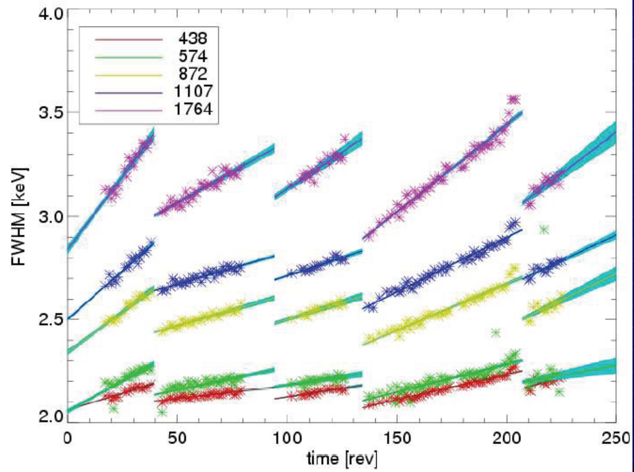
Studying Spectral Response of Degraded Camera

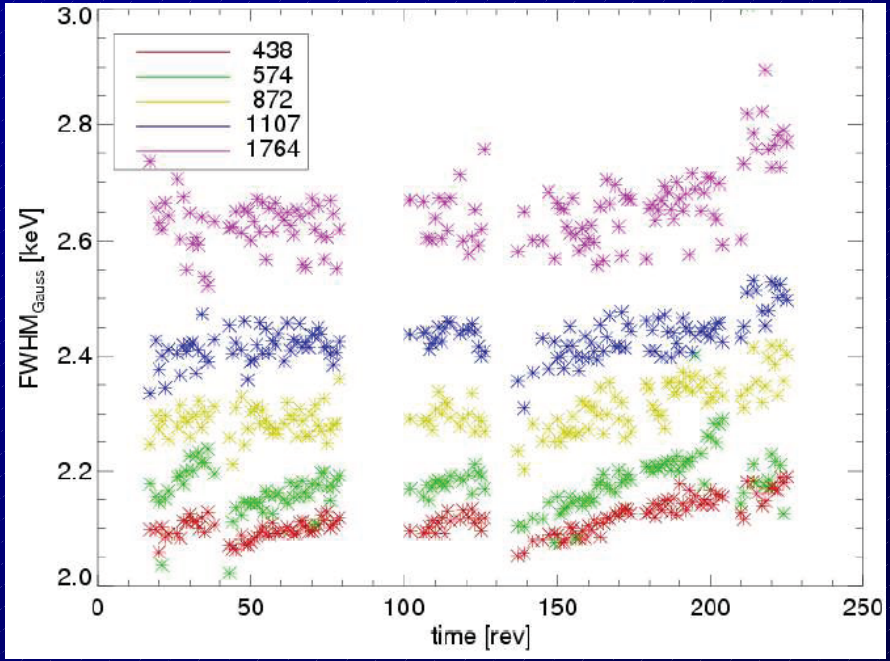
- Determination of Spectral Response vs. Time
  - Fit Spectra in Line Regions with Gaussian+Exponential
  - Fit Response Parameters (Gaussian Width, Exponentail Width) Between Annealings
  - Determine Intrinsic Detector Resolutions (Gaussian Width)
  - Provide Algorithm for “Effective Response Width” per Pntg

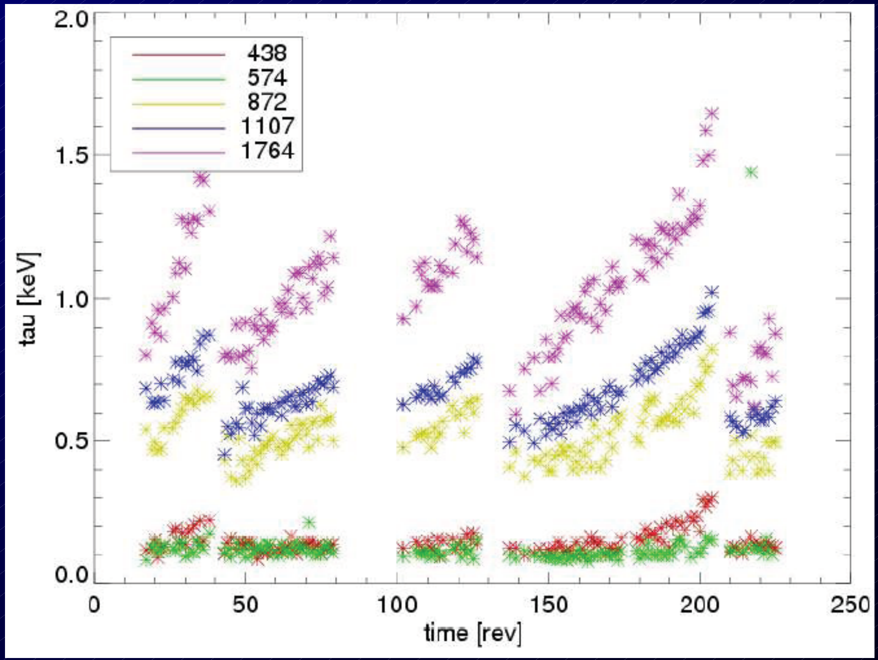
- Application
  - Determine “Effective Response Width” per Selected Dataset

Assembly of Spectral Response f(E,t)

- Separate observed FWHM
  - ☆ Intrinsic detector resolution
  - ☆ degradation

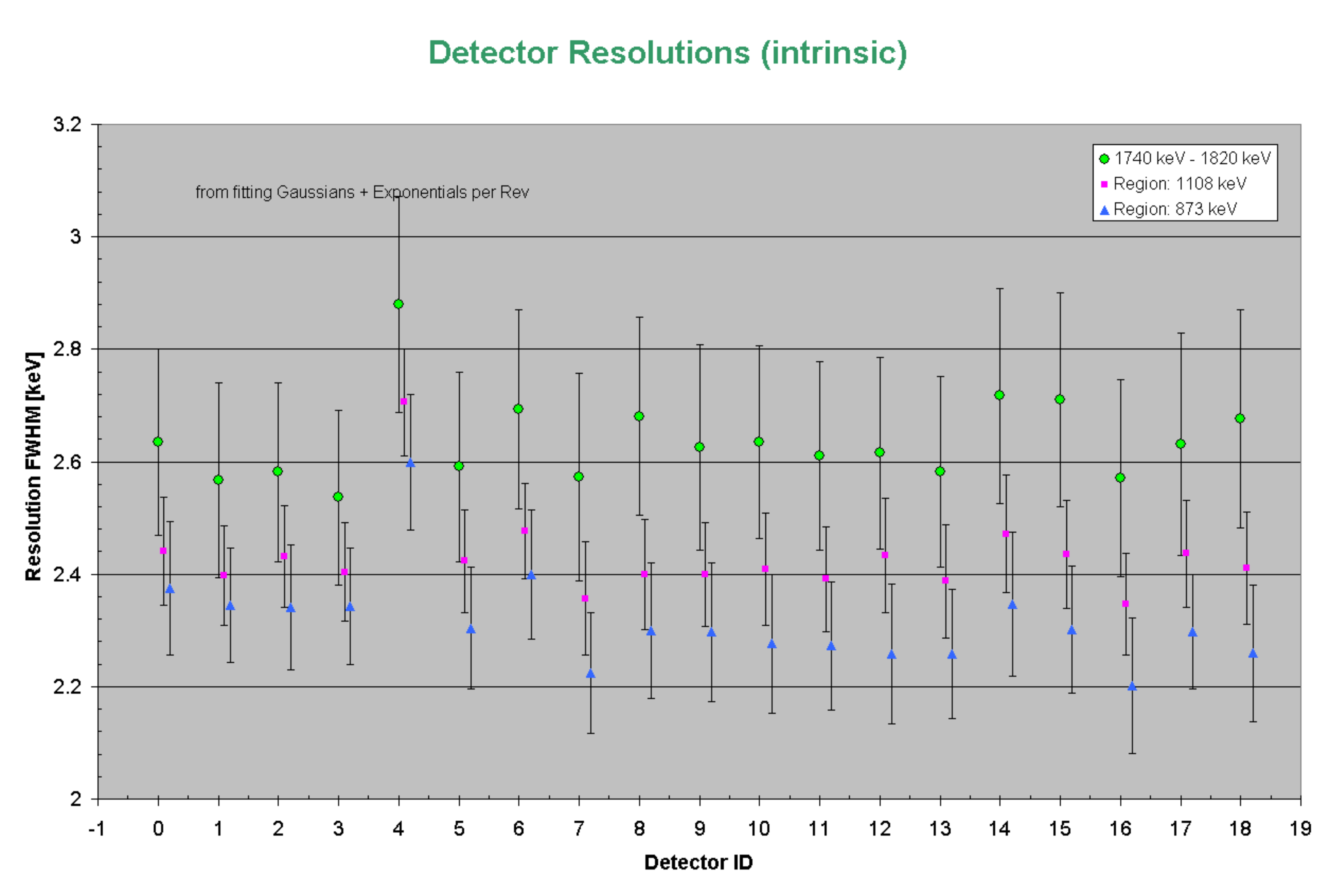






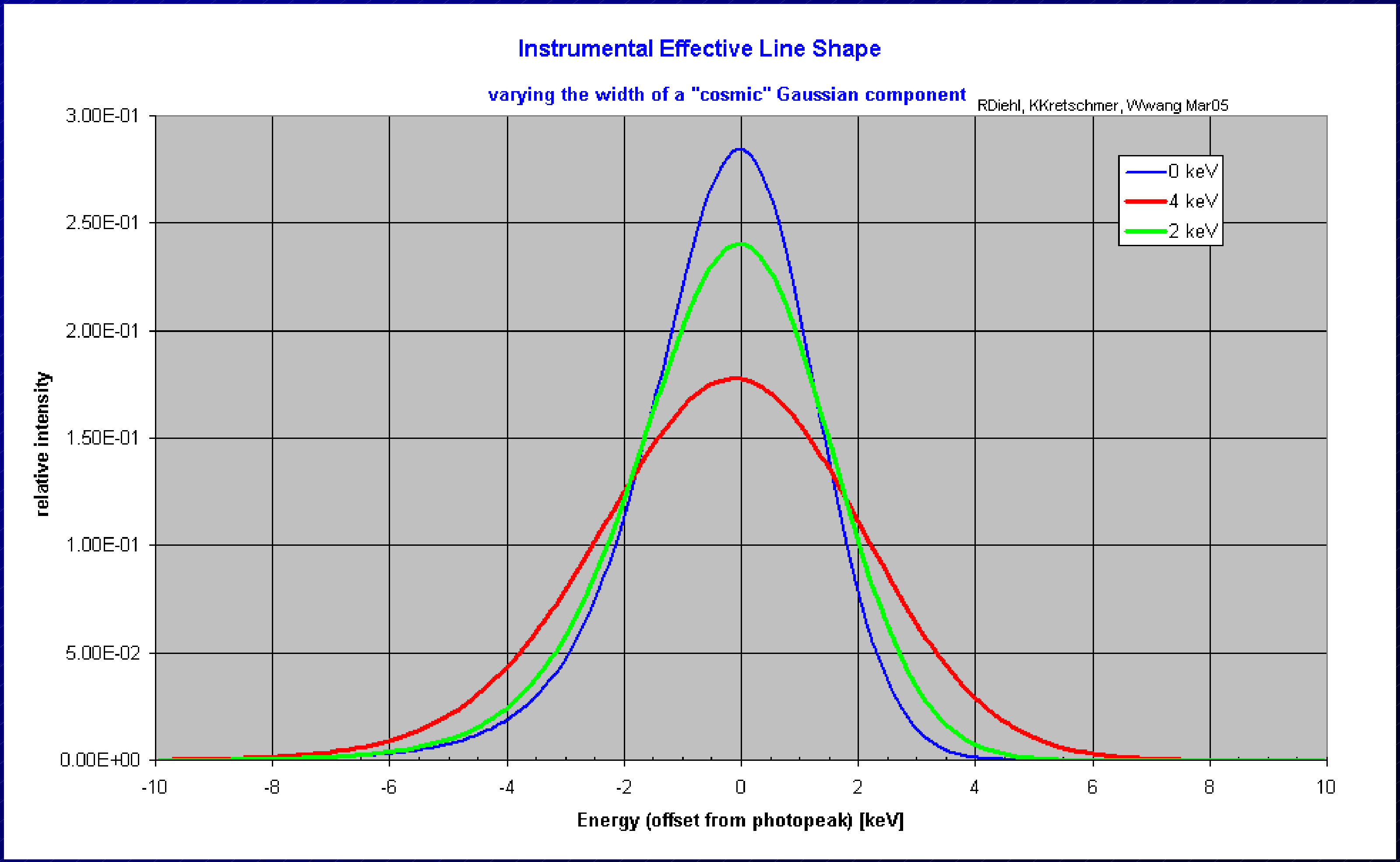
Derived Detector Resolutions

☞ After Elimiting Effects of Degradation



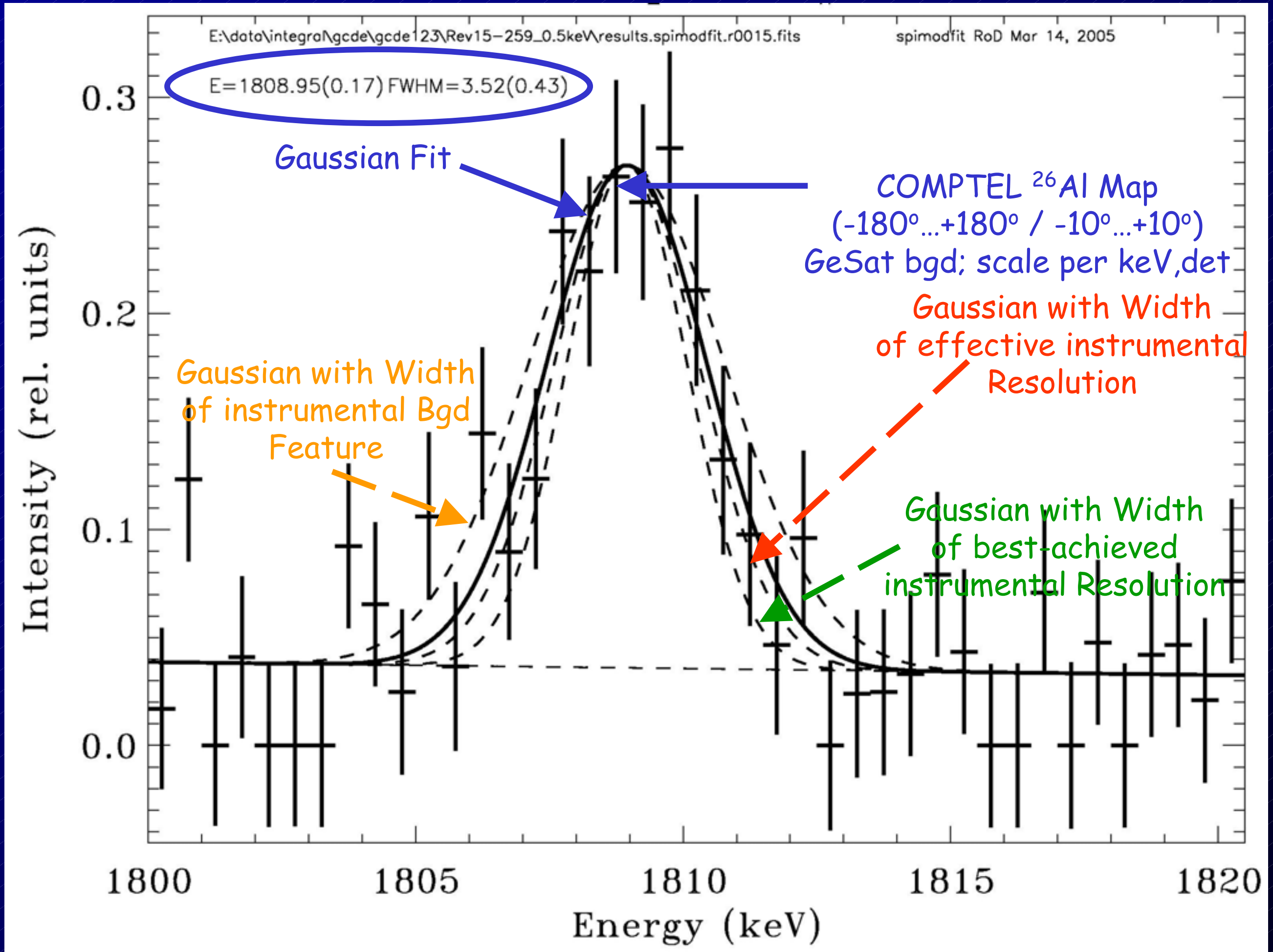
Derived Line Shapes

- Example for Rev 15-259 Galactic-Plane Data (±30°)
- Line at ~1800 keV
  - Convolved with Gaussian of increasing Width ("cosmic line")



^{26}Al Line from Inner Galaxy

- ☆ COMPTEL ^{26}Al Allsky Map
- ☆ Background from Combined & Orthogonalized Tracers
- ☆ Rev 15-159, Galactic Plane +/- 30°, 0.5 keV bins



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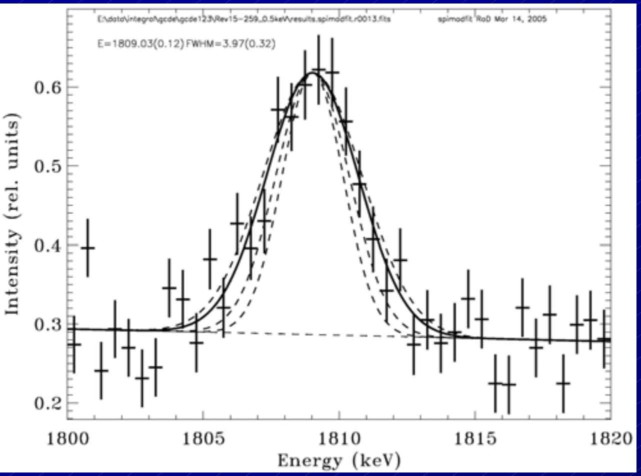
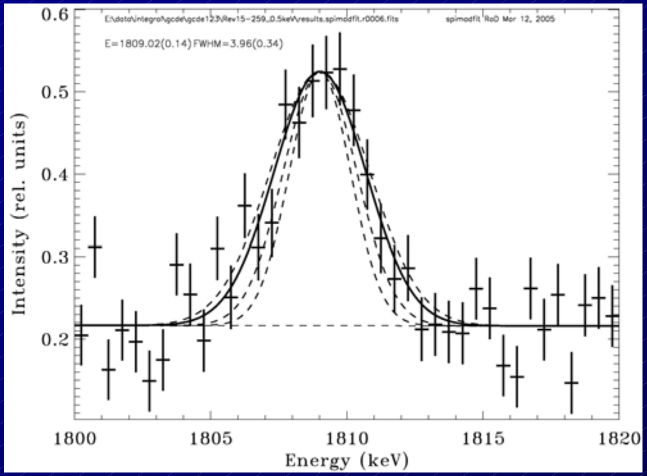
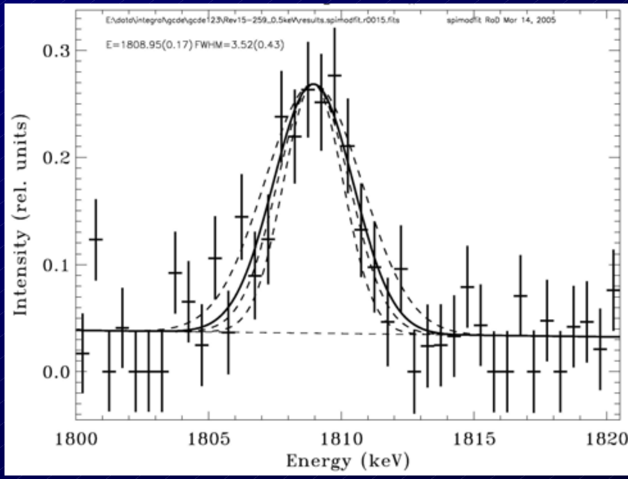
Checks and Systematics: Different Backgrounds

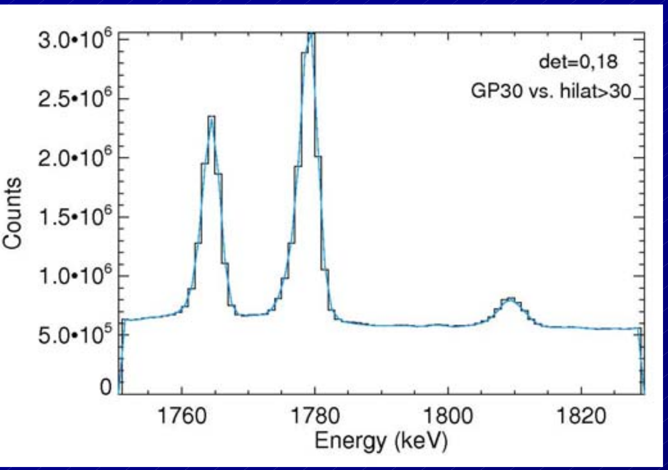


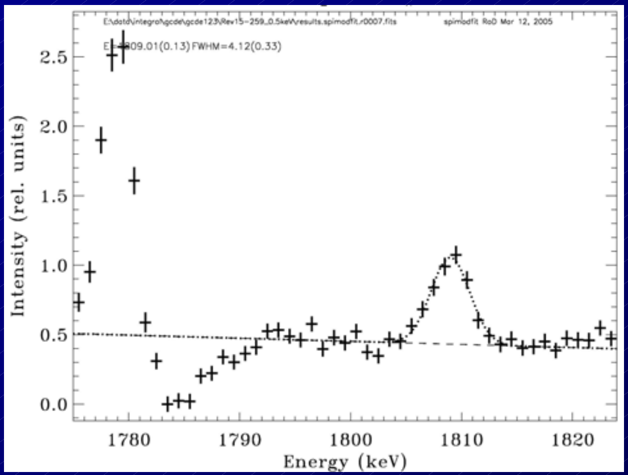


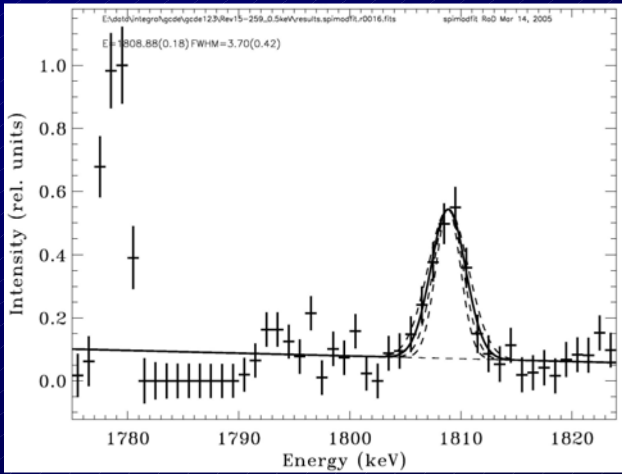


- data average
- high latitudes
- orthogonalized tracers

Checks and Systematics: Near Strong Instrumental Lines







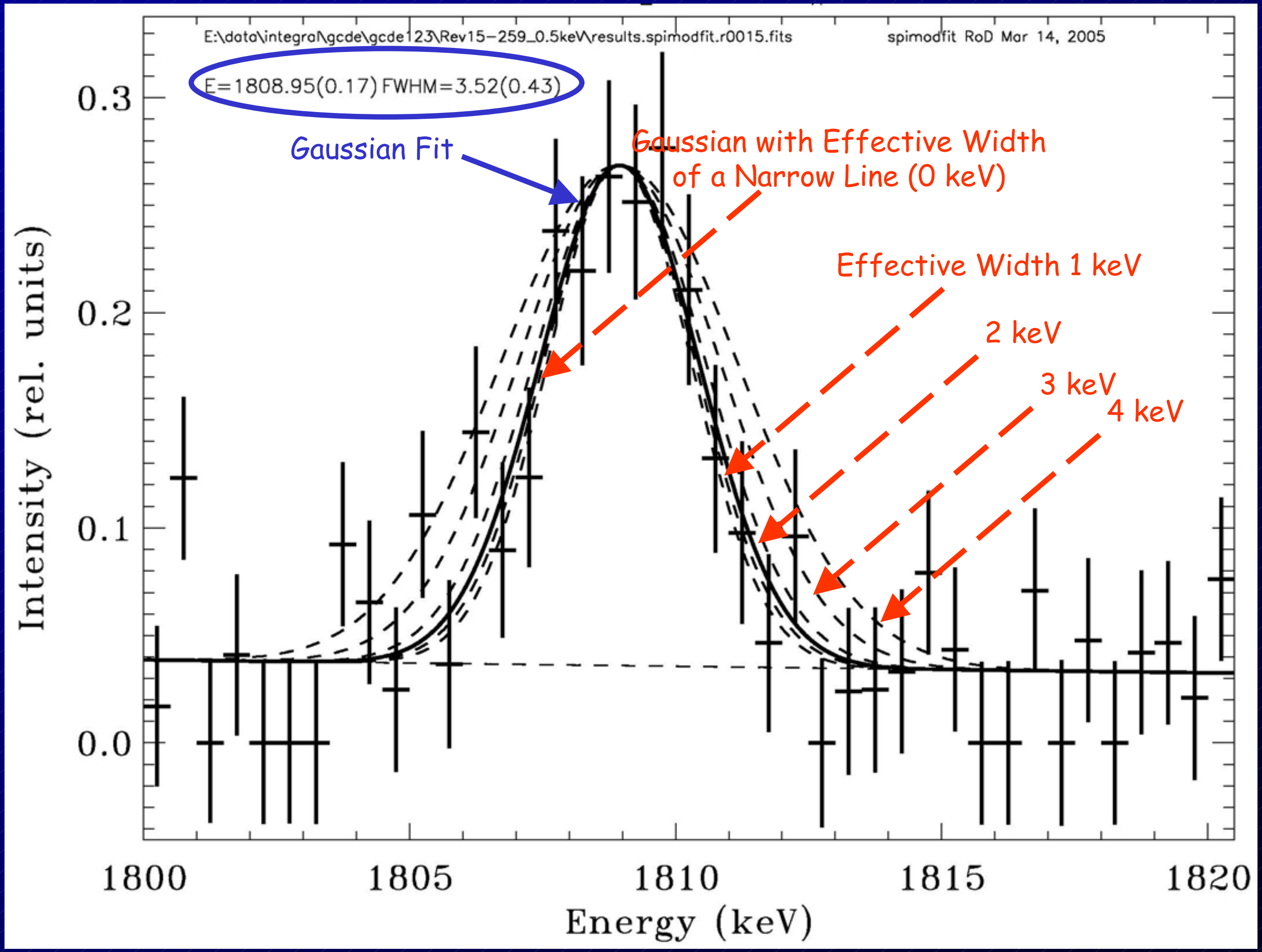
raw events

high-latitudes bgd

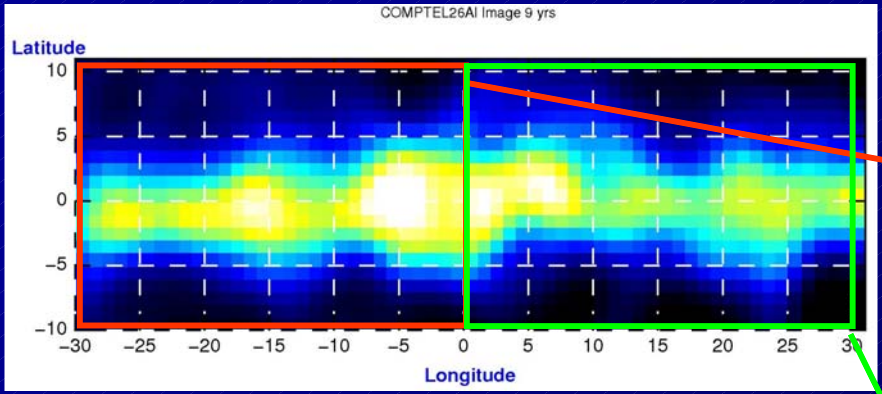
tracers bgd

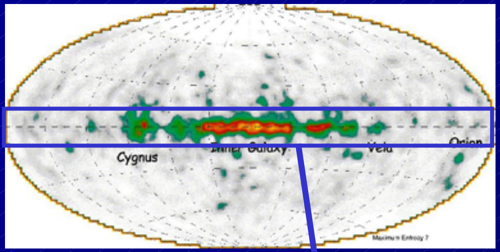
^{26}Al Line from Inner Galaxy

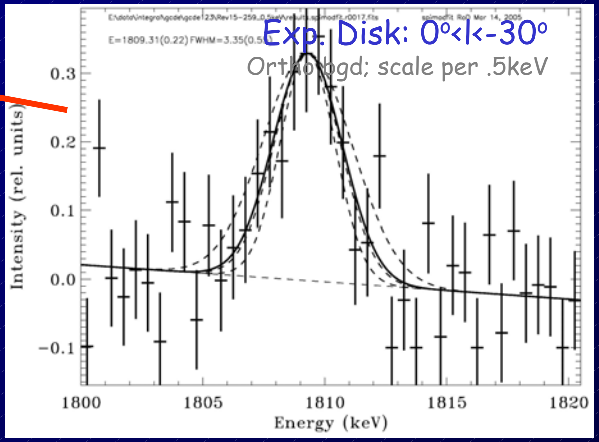
- ☆ Comparison to "Effective Line Width" of Broadened Lines
  - ☞ Different "cosmic-line" widths -> 1.x keV

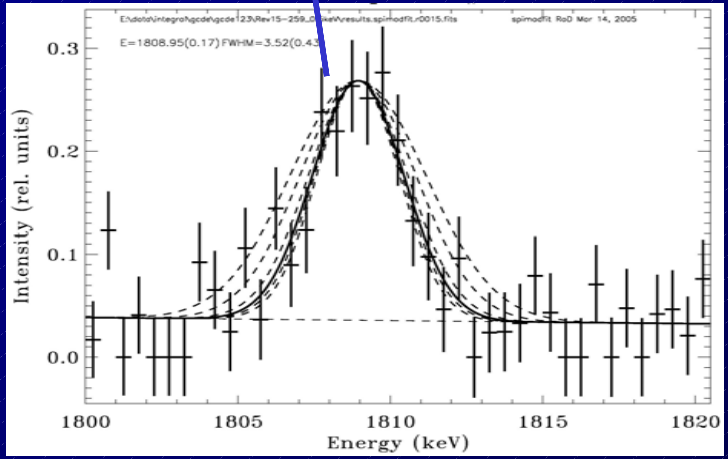


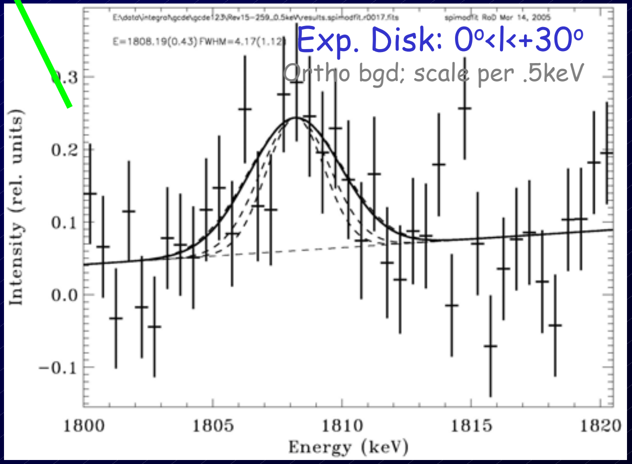
Imaging Spectroscopy: Line Shape Variations in the Galaxy?











- Need Statistics & High-Resolution Data Processing & Analysis (Degradation!)

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