RHESSI Studies of Solar Flare Hard X-Ray Polarization

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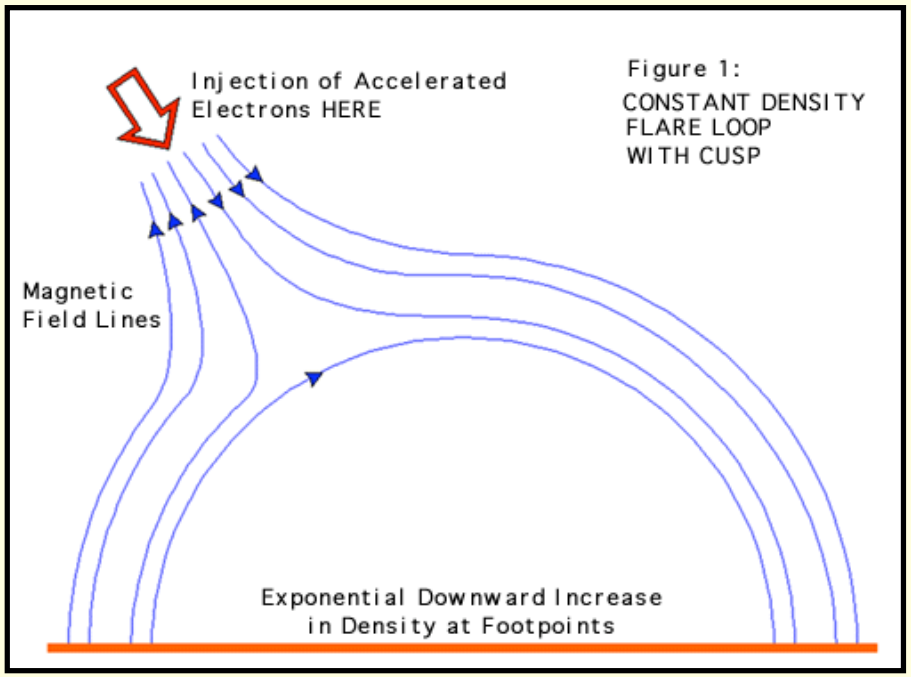
Polarization in Solar Flares

The hard X-ray continuum is dominated by electron bremsstrahlung emission.

Measurements of hard X-ray polarization can shed light on the geometry of the acceleration process.



Model parameters include :

1) pitch angle distribution
2) B-field geometry
3) viewing angle
4) atm density profile

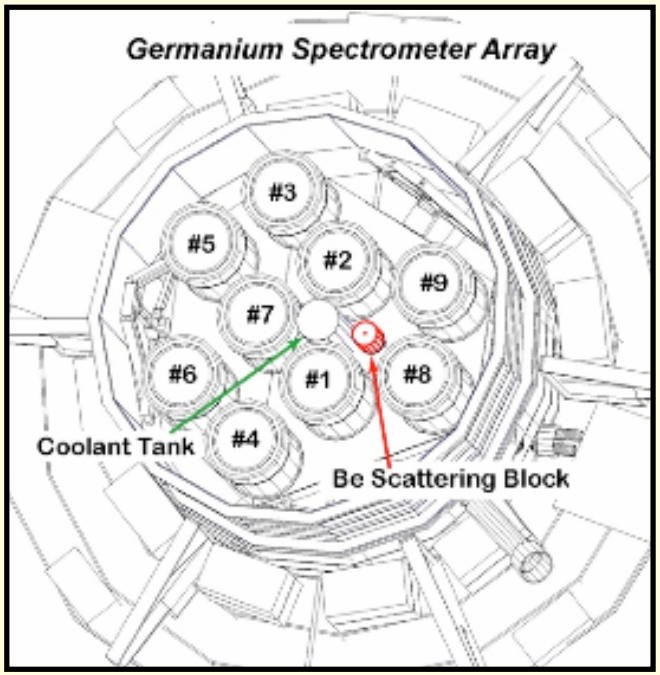
Models predict polarization levels as high as 20 or 30%.

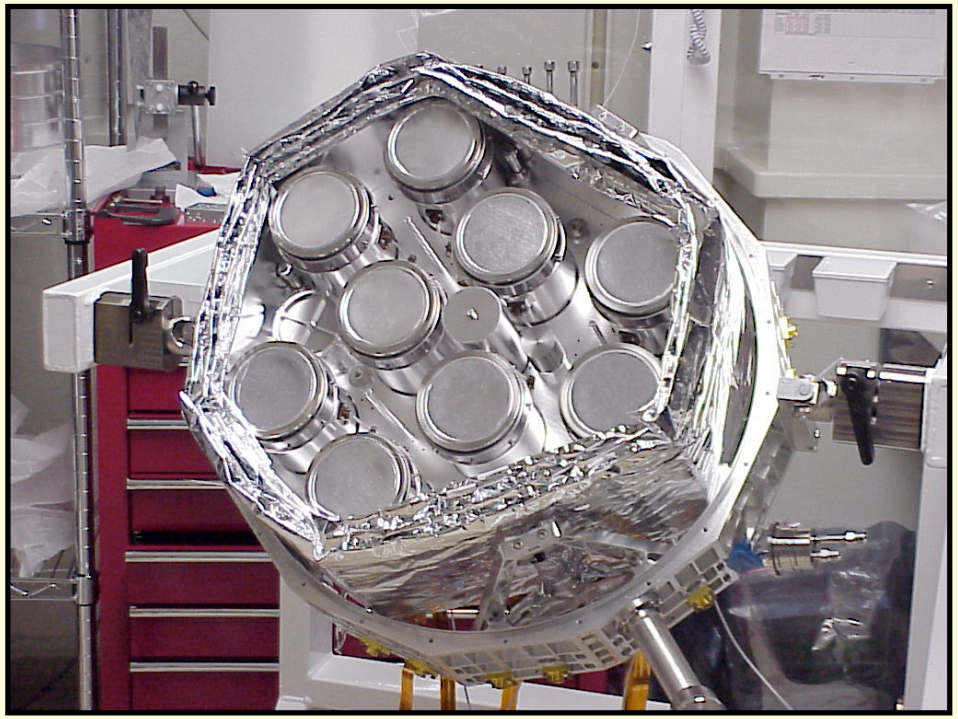
RHESSI as a Polarimeter (20 – 100 keV)

A small (3 cm diam by 3.5 cm high) cylinder of Be serves as a Compton scattering element that scatters photons into the rear segments of the adjacent Ge detectors.

The Ge detectors measure the distribution of the scattered radiation.

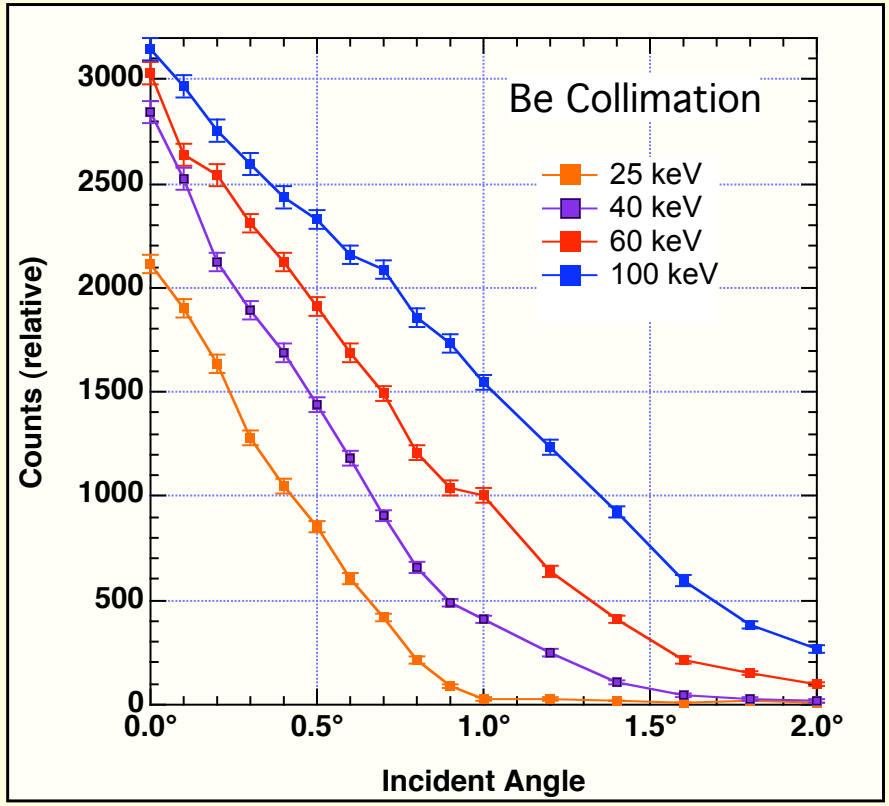
Spacecraft rotation provides for fine sampling of scatter distribution.





Be Collimation

Thinned windows above the Be scattering block provide collimation with a FoV ~ 1°.



The fine collimation of the Be block results in significant attenuation even at small flare angles.

The attenuation is most apparent at lower energies.

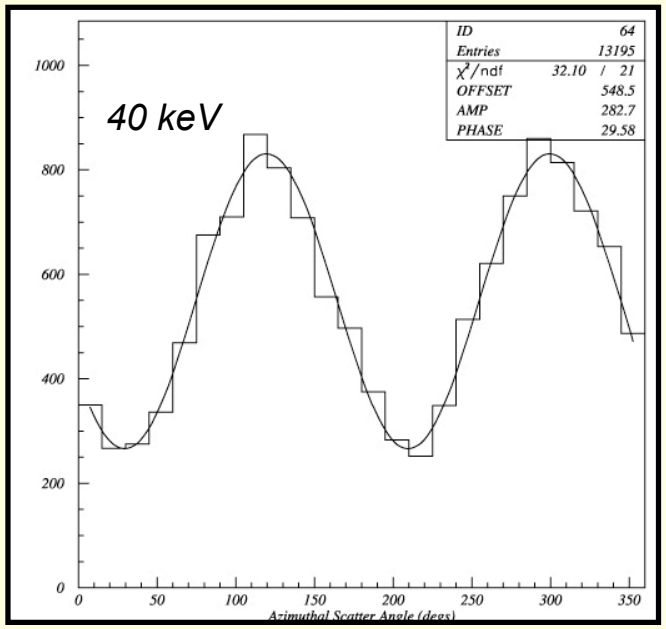
These effects can be simulated.

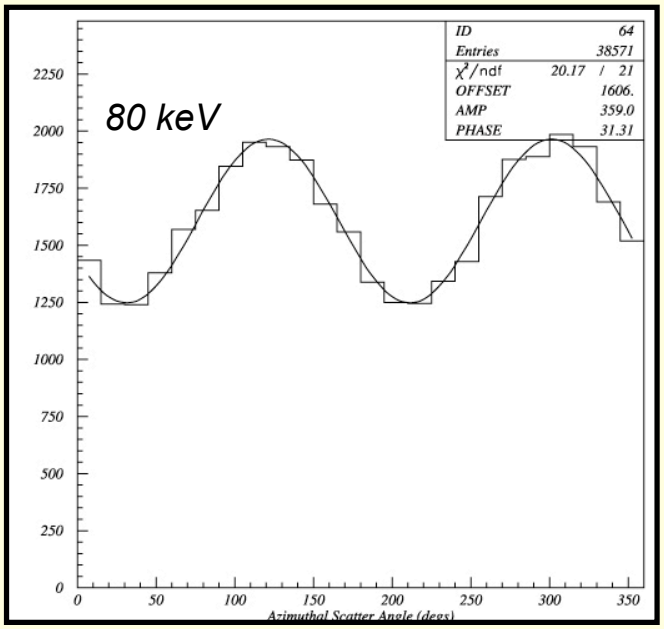
The Polarization Signal - Simulation Results

We have used a modified version of GEANT3 to carry out Monte Carlo simulations of the polarimetric capabilities of RHESSI.

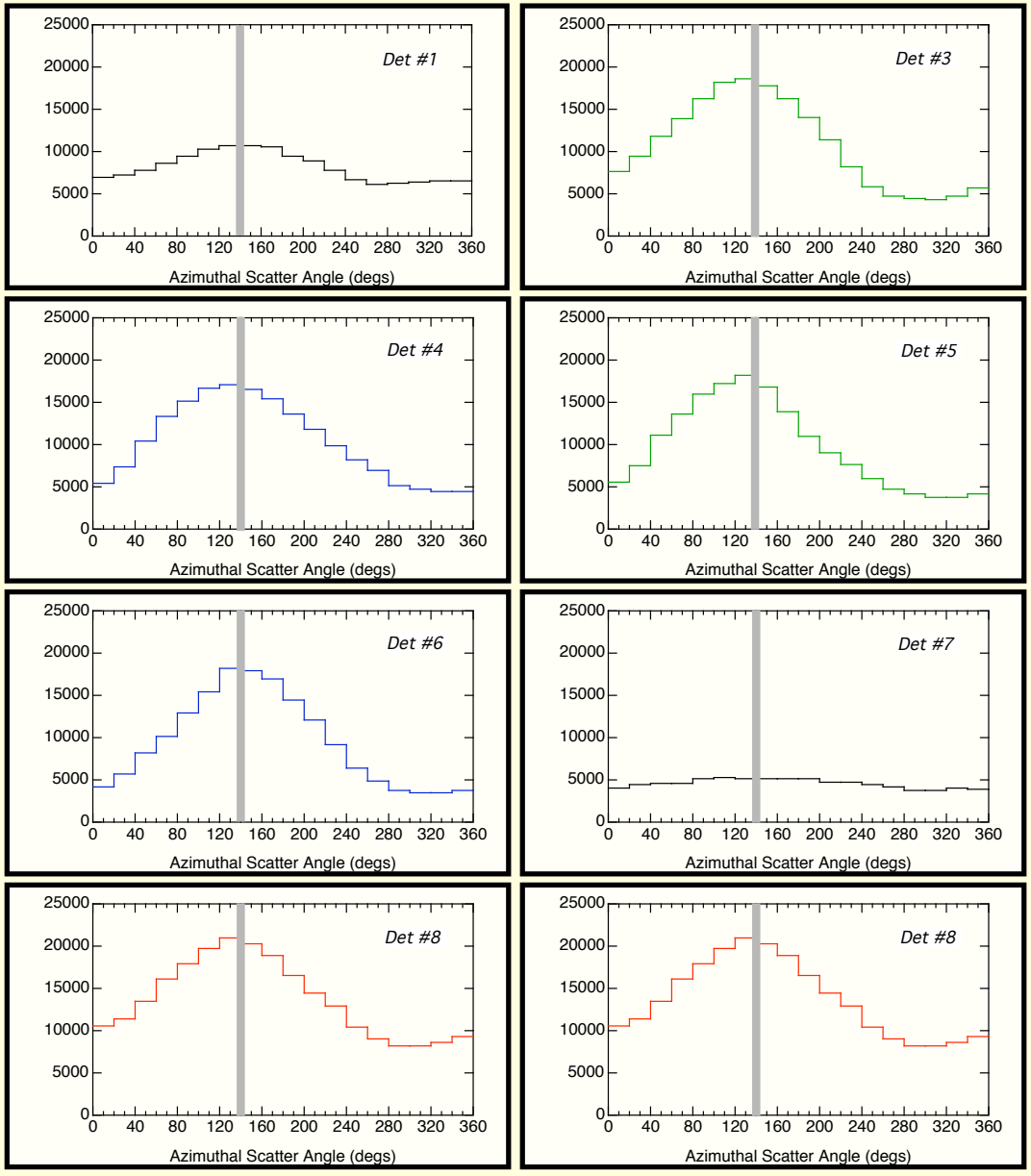
A valid polarimeter event is one which produces a measurable energy deposit in the rear segment of Ge detectors 1, 8, or 9.

Detector 2 is not currently operating as a segmented detector.





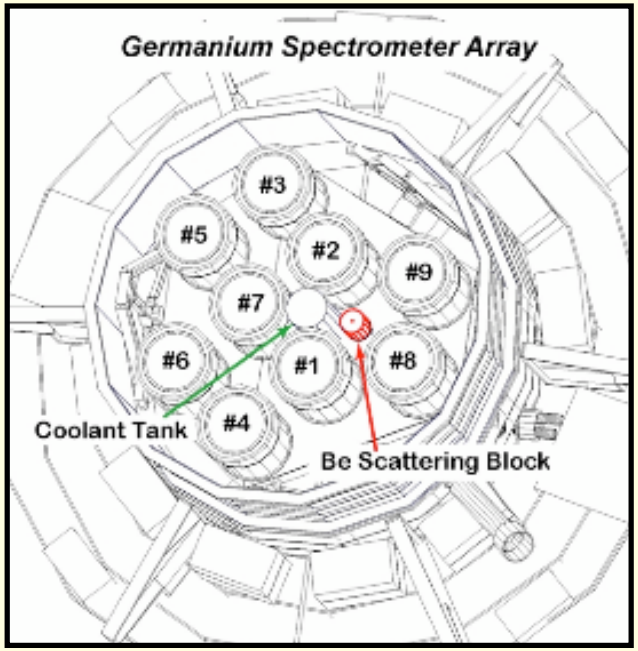
Nature of the RHESSI Data



X4.8 Flare - 23 July 2002

00:26 – 00:42 UT

Rear Segment Data
(20 – 40 keV)
dominated by spin modulation of atmospheric background and albedo

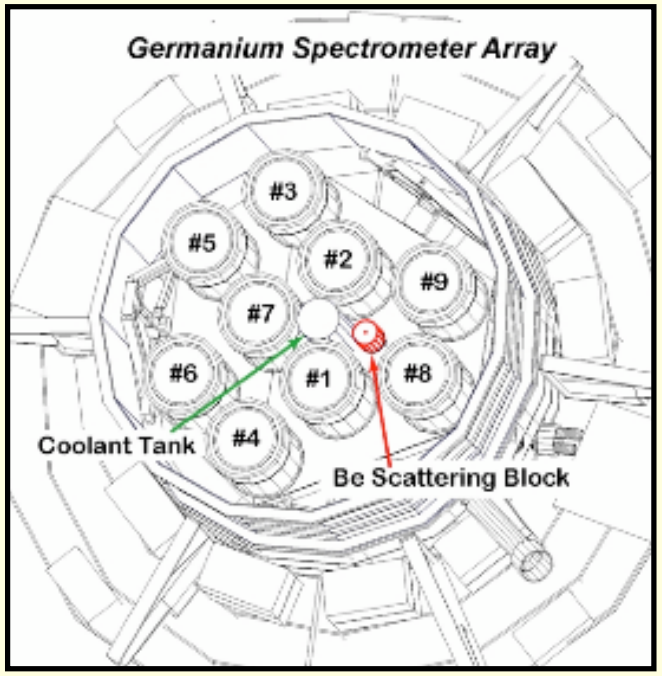


An Initial Approach to RHESSI Analysis

Three pairs of detectors with similar background :

detectors 8/9, detectors 3/5 and detectors 4/6.

The data from detectors 3-6 can be used as background estimate for the polarimeter mode detectors 8/9.



Limitations **:**

- **Does not use detector #1**
- **Assumes symmetric geometry**
- **No modeling of Earth albedo**
- **Need relative count rate corrections**

Polarization Analysis

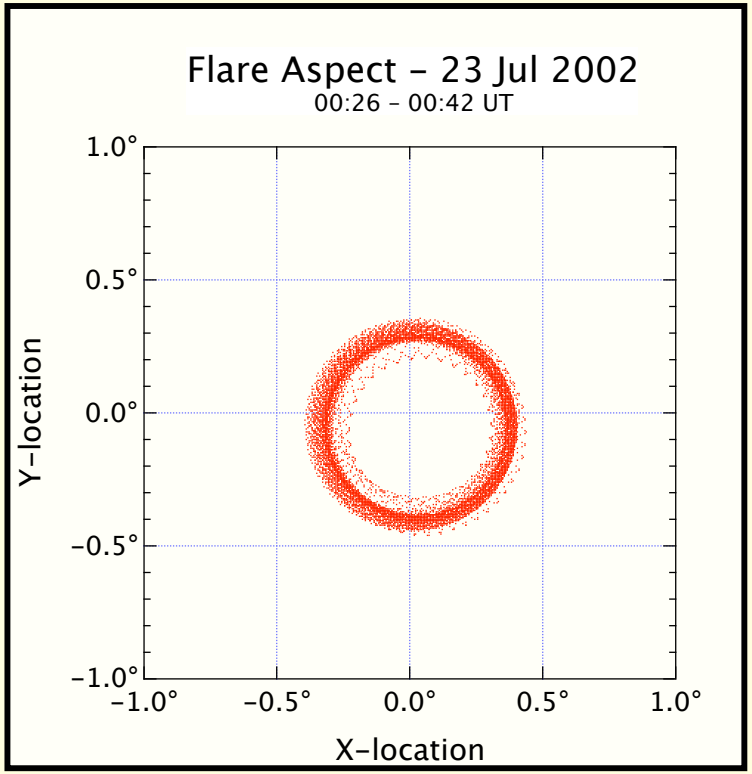
Two Component Analysis

$$f(\eta) = \underbrace{A + B\sin 2(\eta - \varphi)}_{\text{Polarization signal}} + \underbrace{C\sin\alpha(\eta - \psi)}_{\text{Systematic Component}}$$

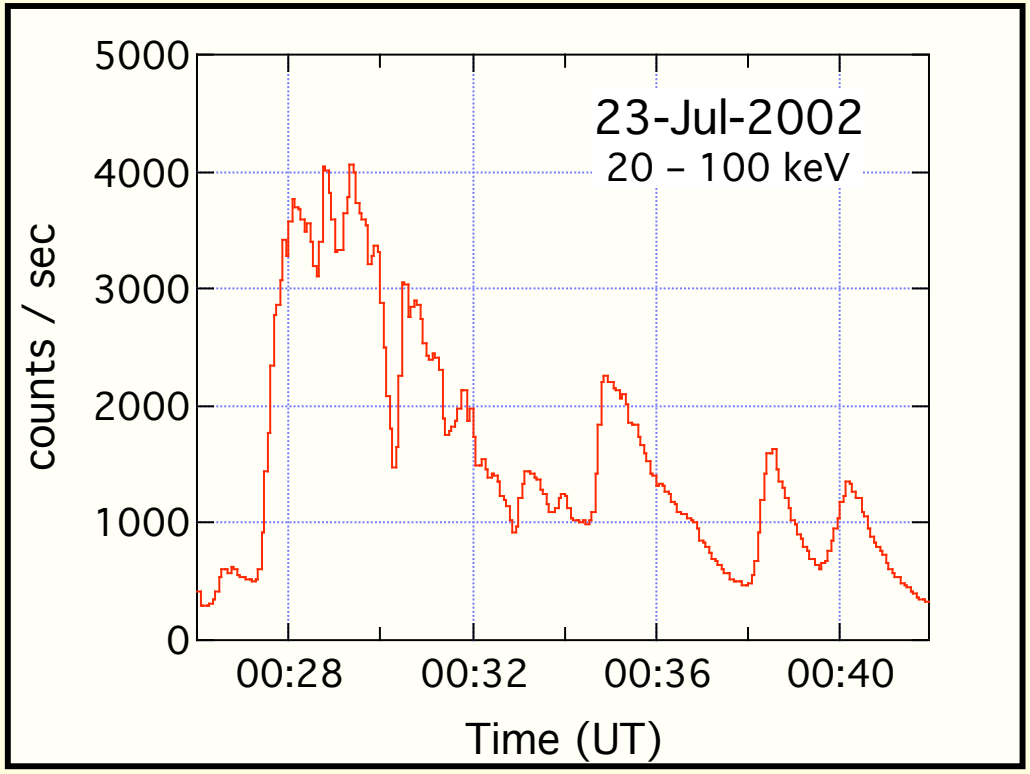
1. Systematic Component:
   - Single sinusoid component.
   - Dominates the response at high energies.
   - Appears to be due to vignetting of the source by spacecraft rotation (collimation effects).
   - This component averages to zero.
2. Polarization Signal
   - Double sinusoid component.

X4.8 Flare of 23-July-2002

Flare location : S13E72



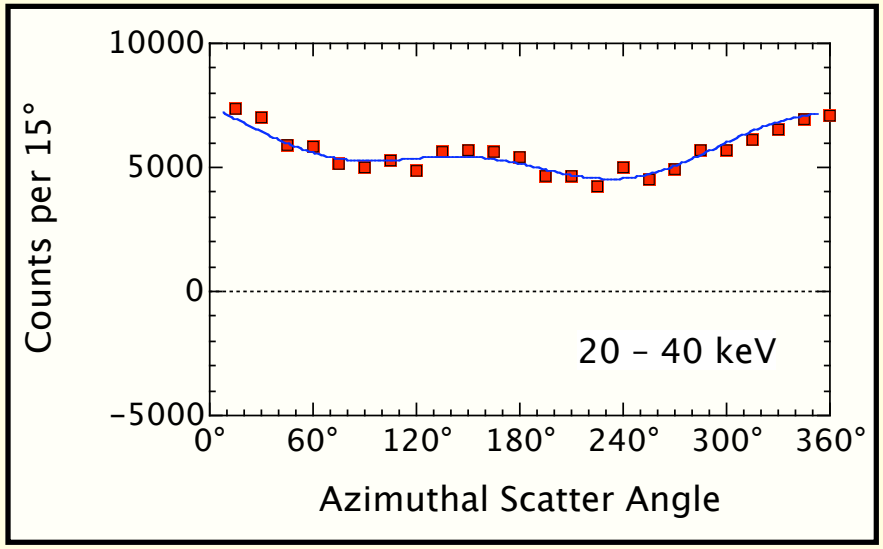
location vs. time within FoV

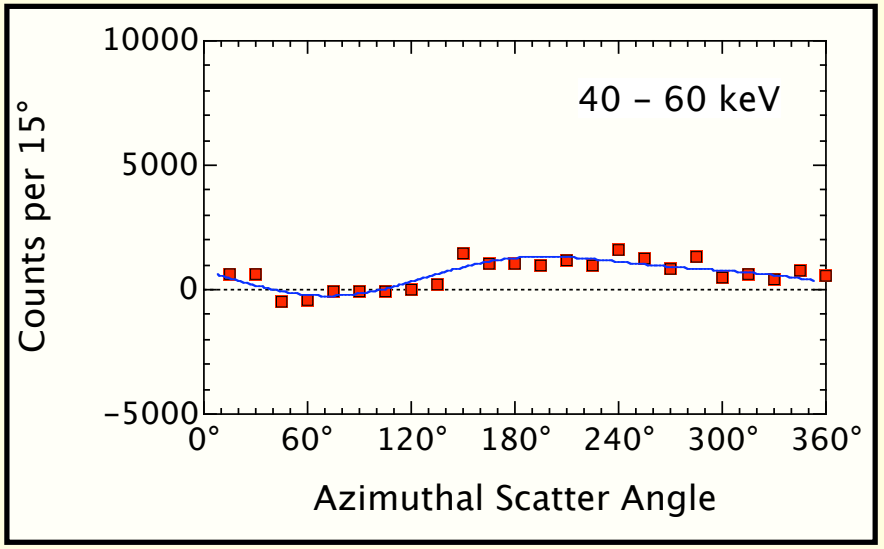


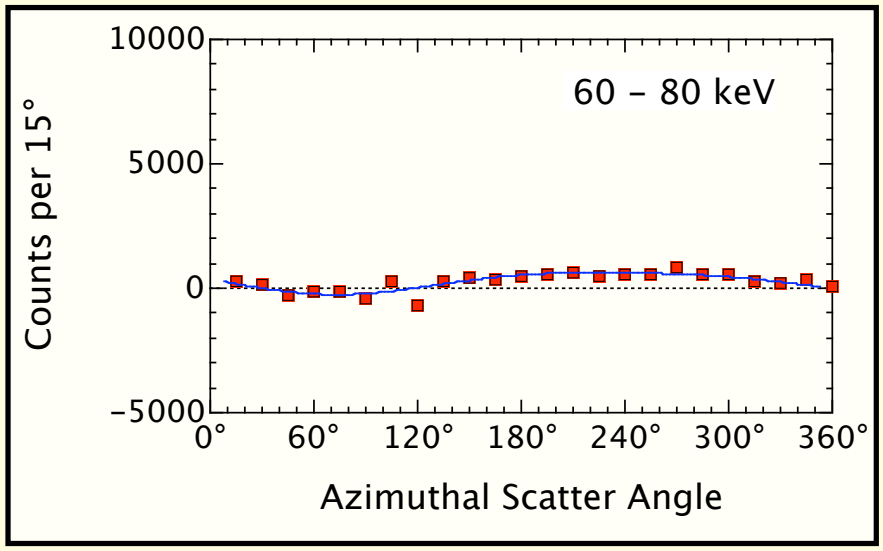
rear segment count rate

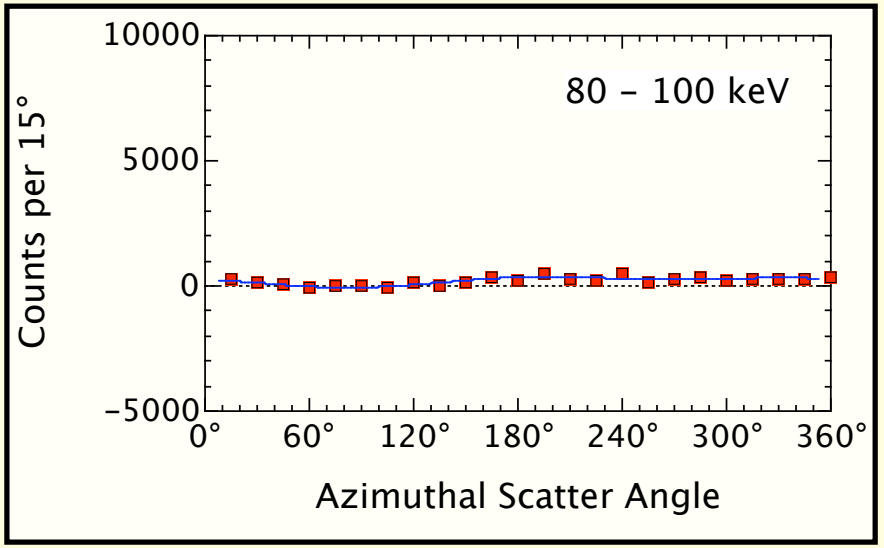
“Background” Subtracted Data vs. Energy

X4.8 Flare, 23 July 2002, 00:26 - 00:42 UT



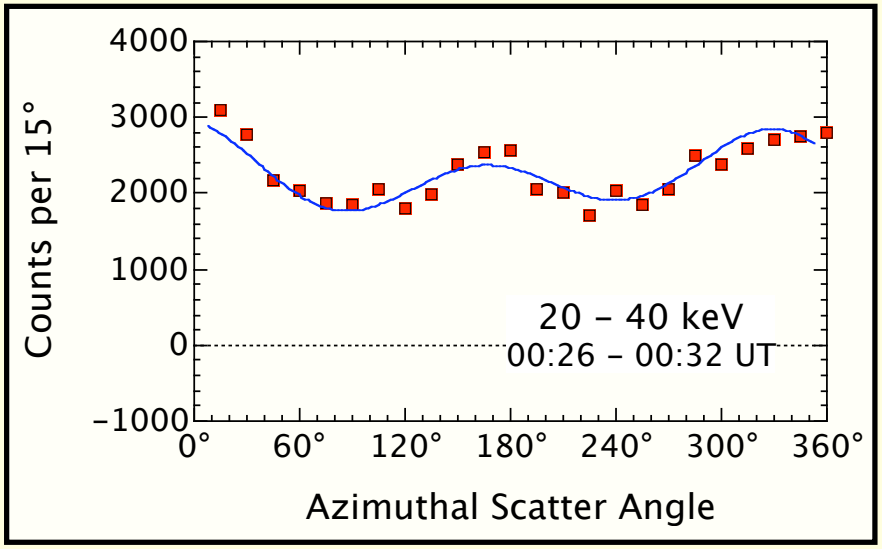


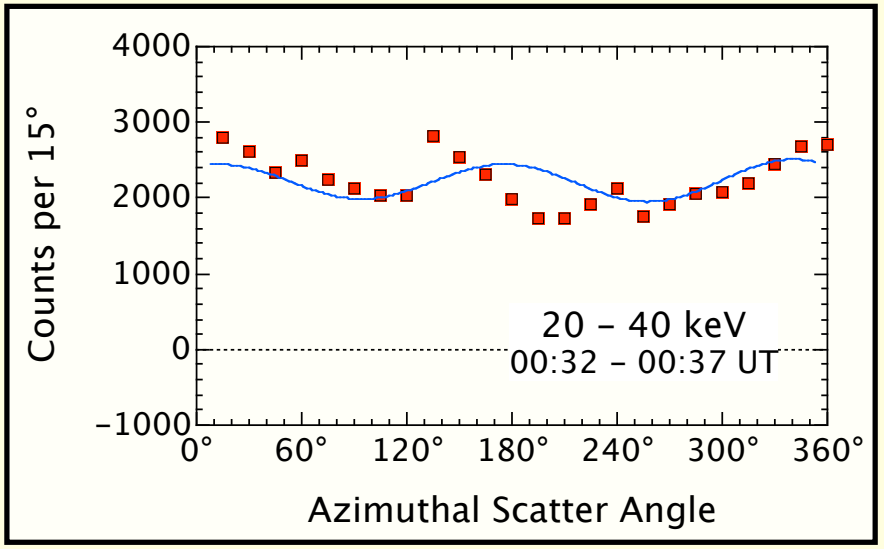


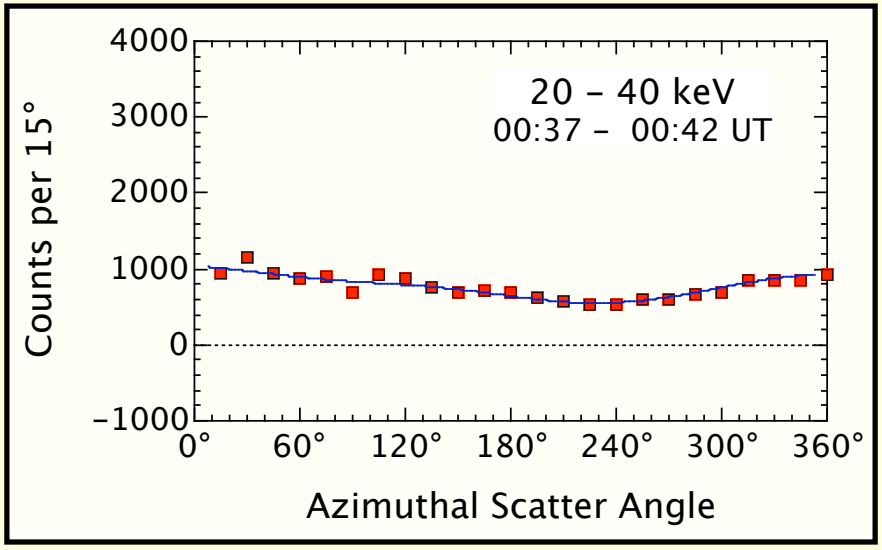


"Background" Subtracted Data vs. Time

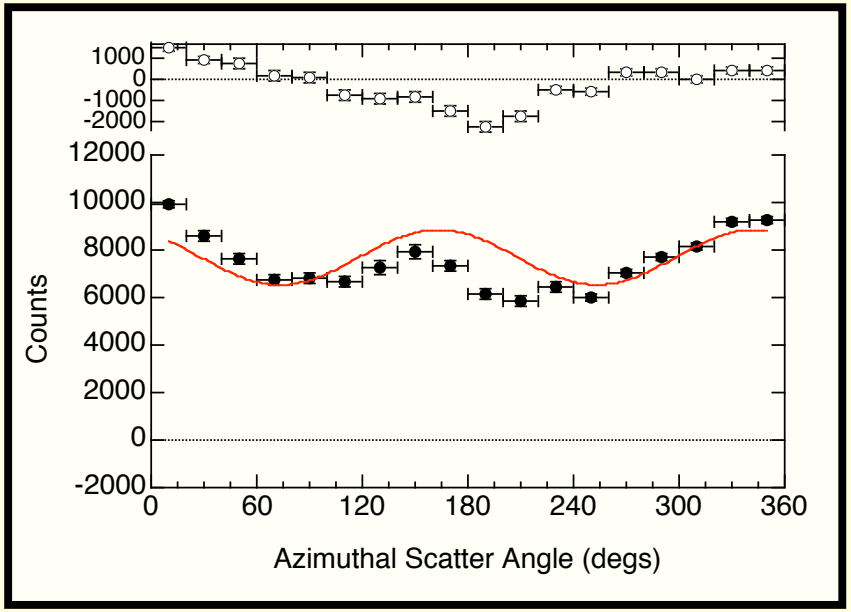
X4.8 Flare, 23 July 2002, 20 - 40 keV

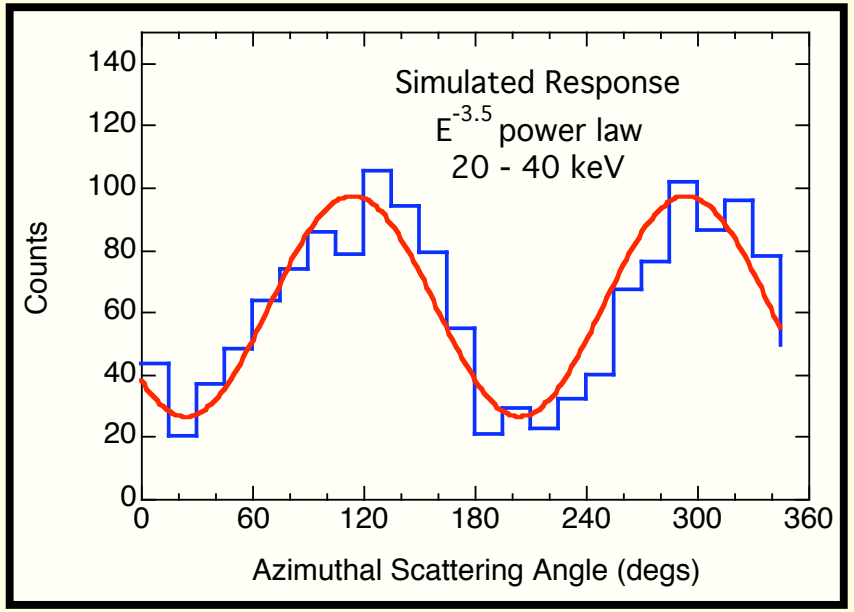






20 - 40 keV Analysis





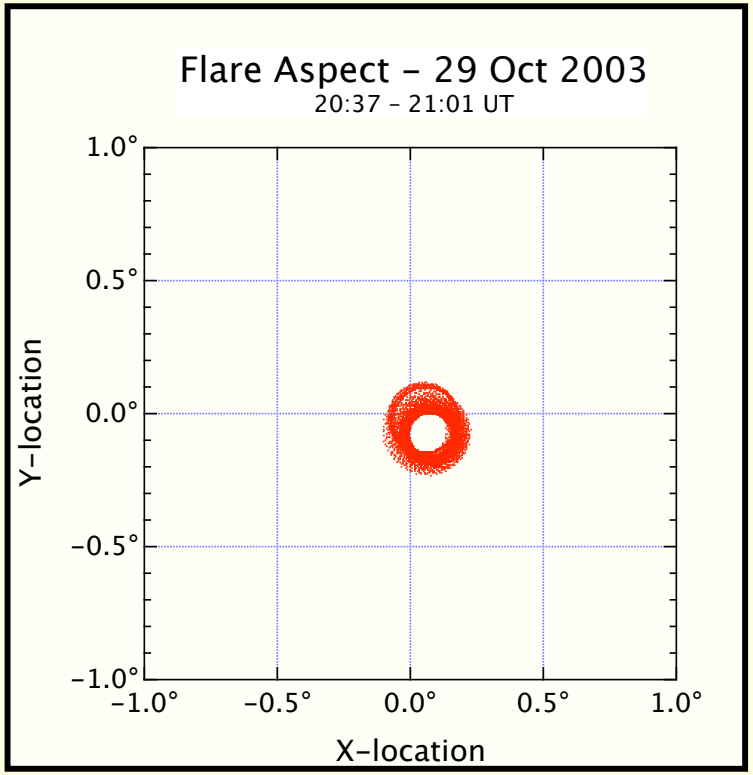
$Q_{data} = 0.15$ $Q_{100} = 0.57$

$\pi = Q_{data} / Q_{100} = 0.26$

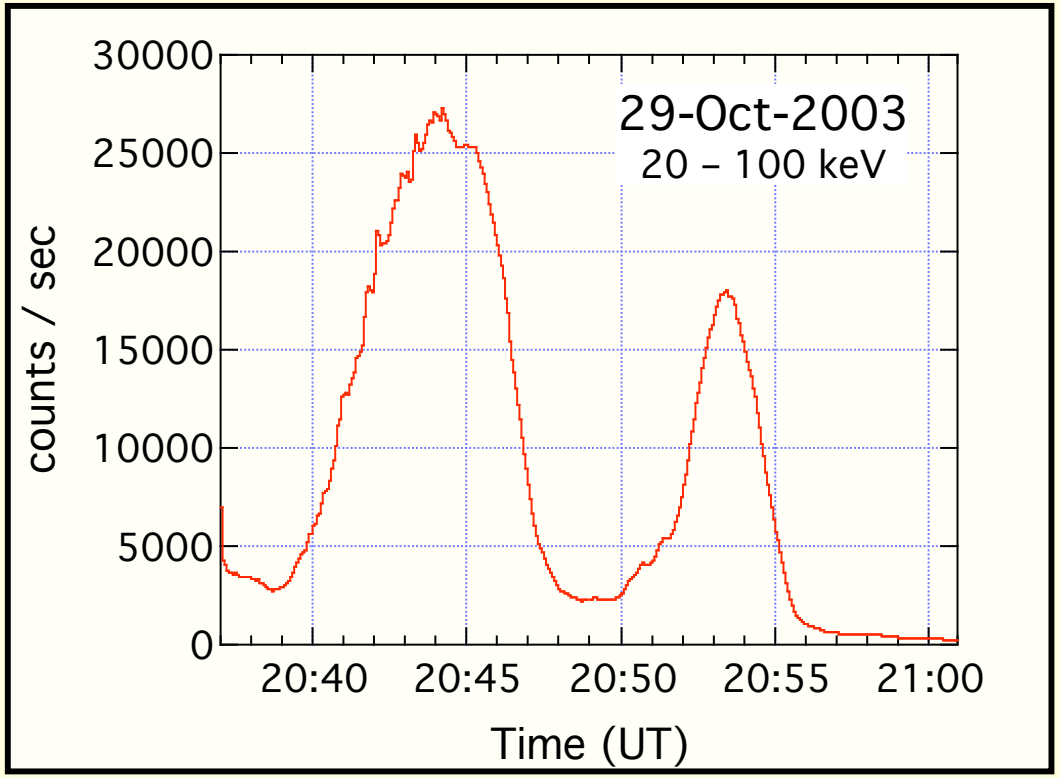
Estimated Polarization ≈ 26%

X10.0 Flare of 29-Oct-2003

Flare location : S15W02



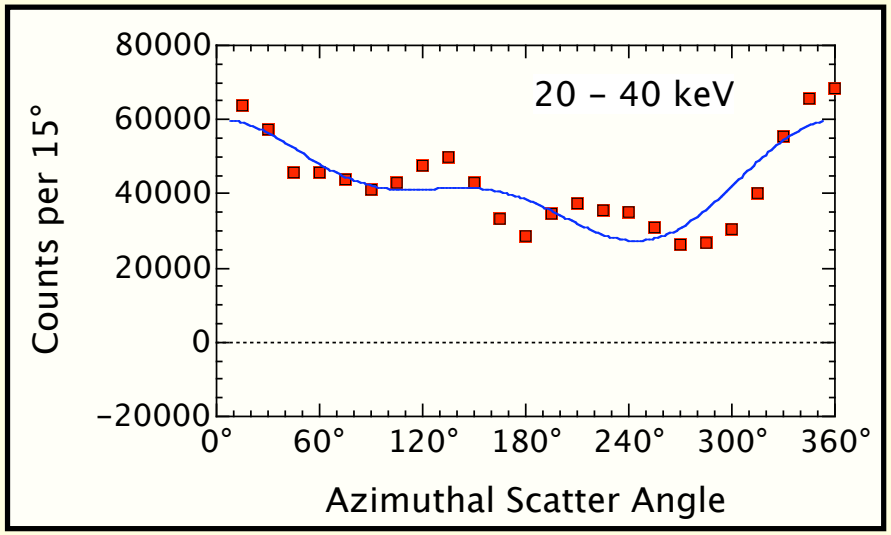
location vs. time within FoV

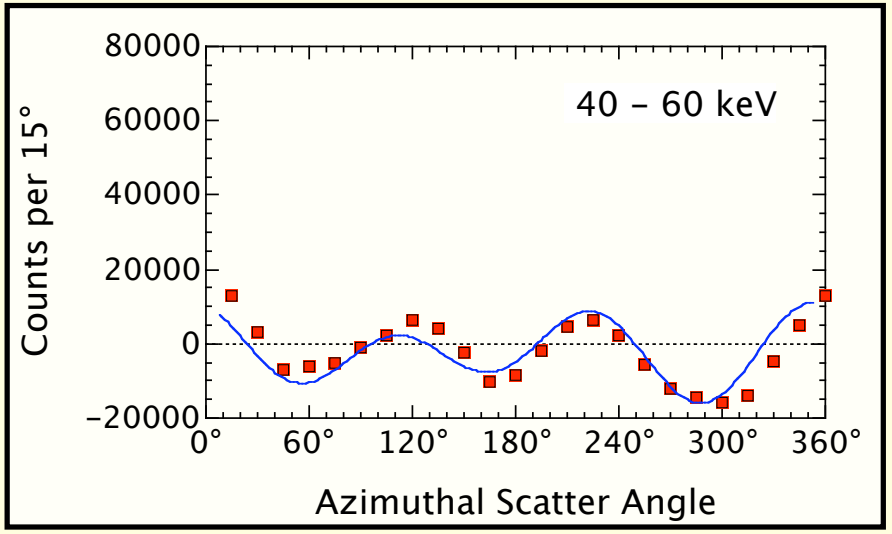


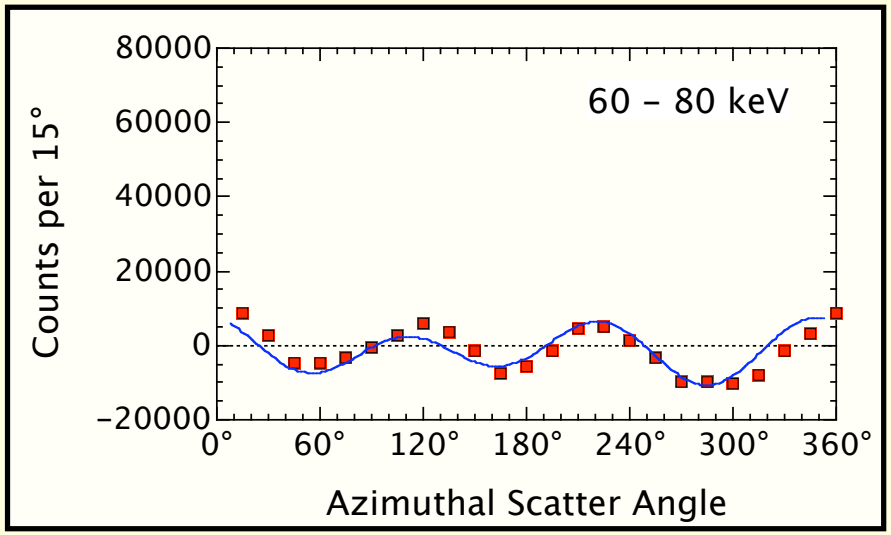
rear segment count rate

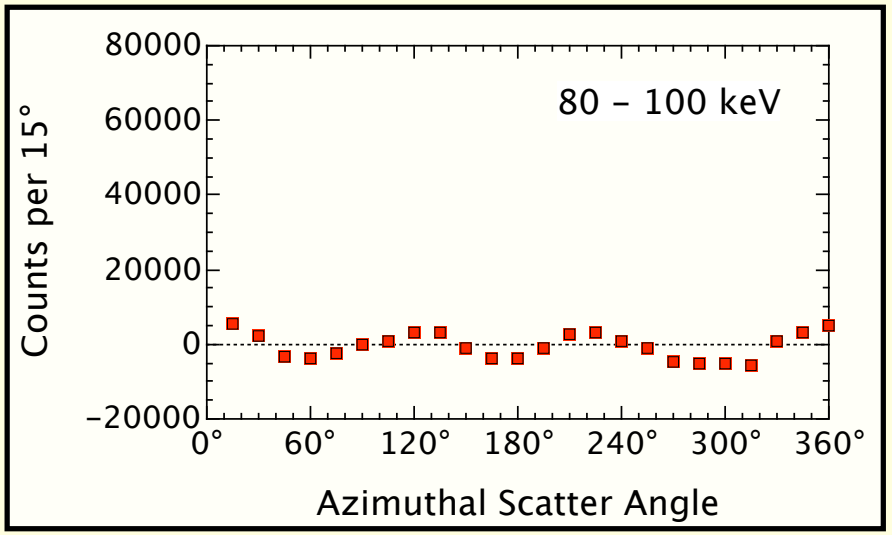
“Background” Subtracted Data

X10.0 Flare, 29 Oct 2003, 20:40 - 20:56 UT



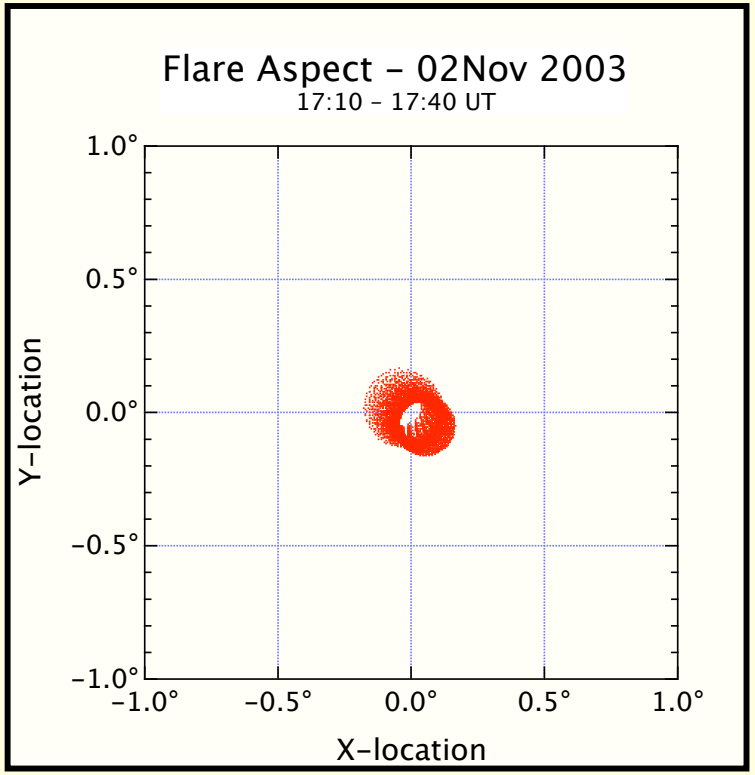




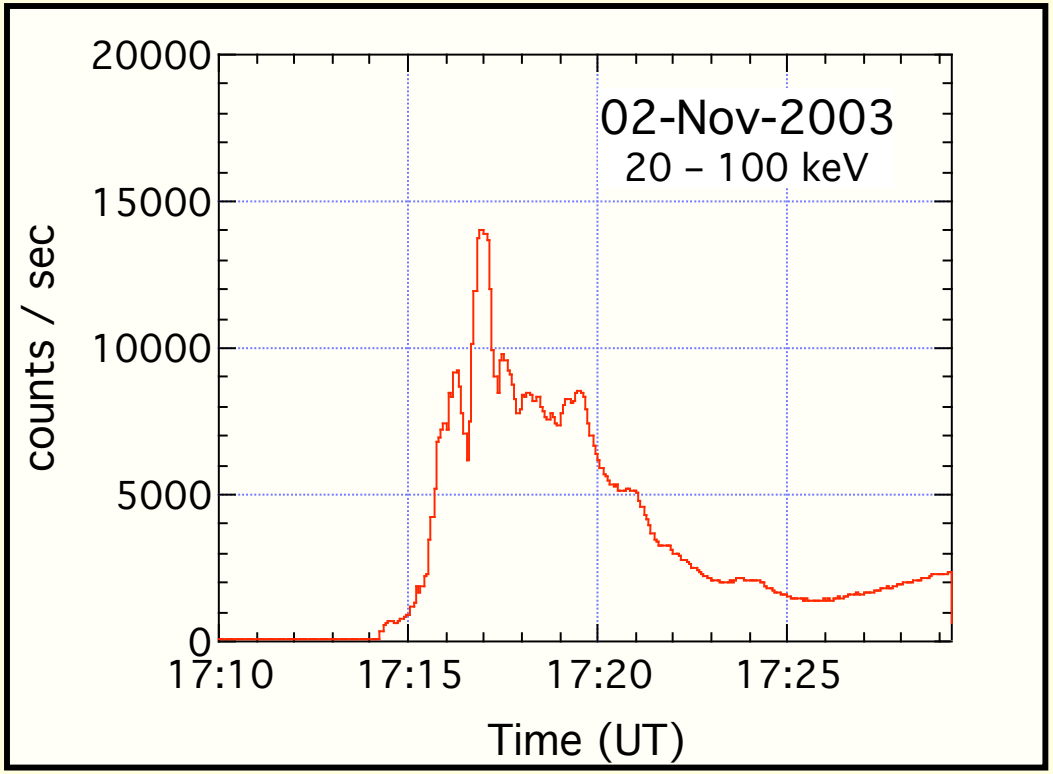


X8.3 Flare of 02-Nov-2003

Flare location : S14W56



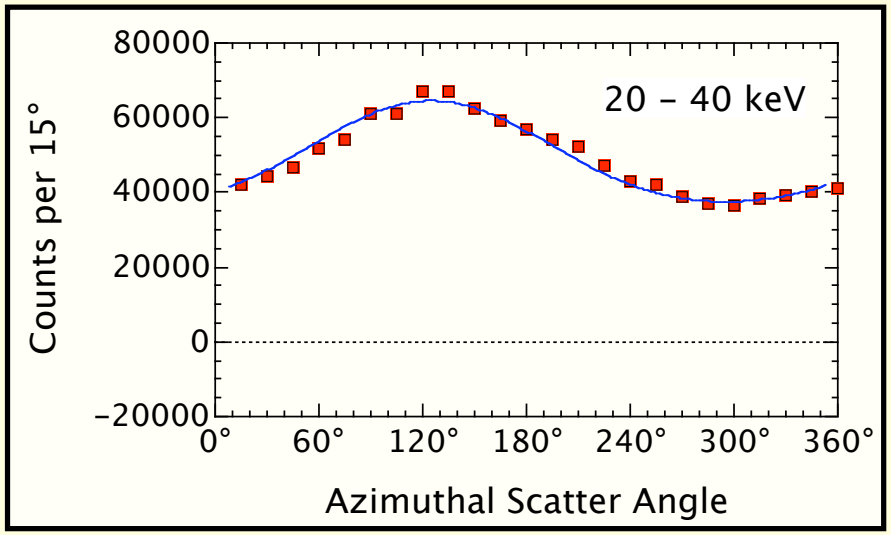
location vs. time within FoV

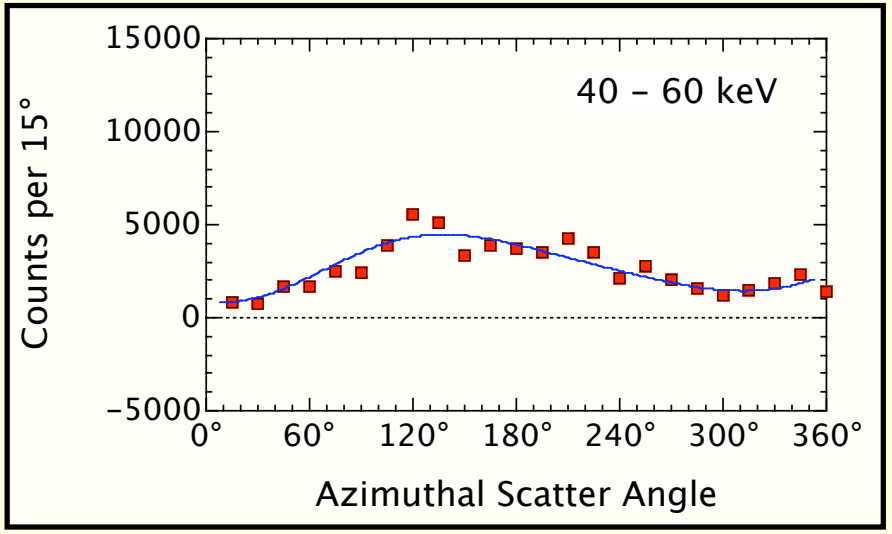


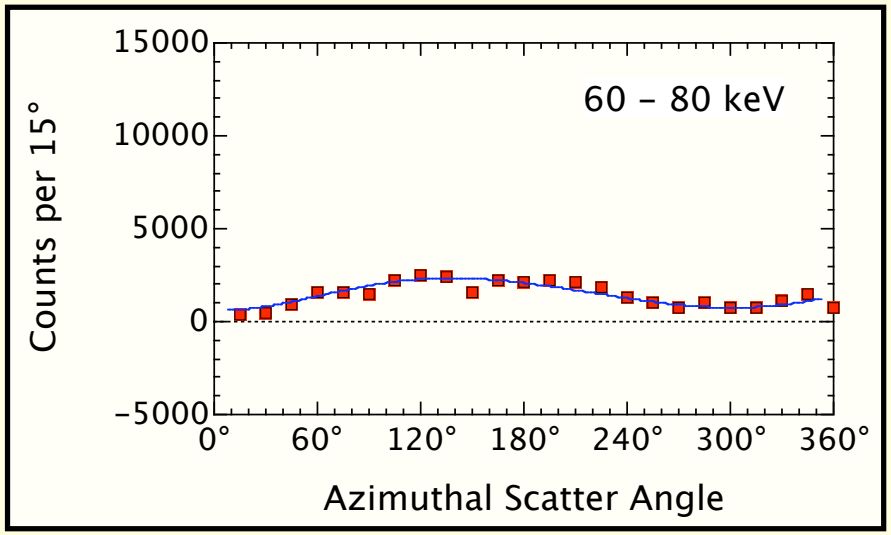
rear segment count rate

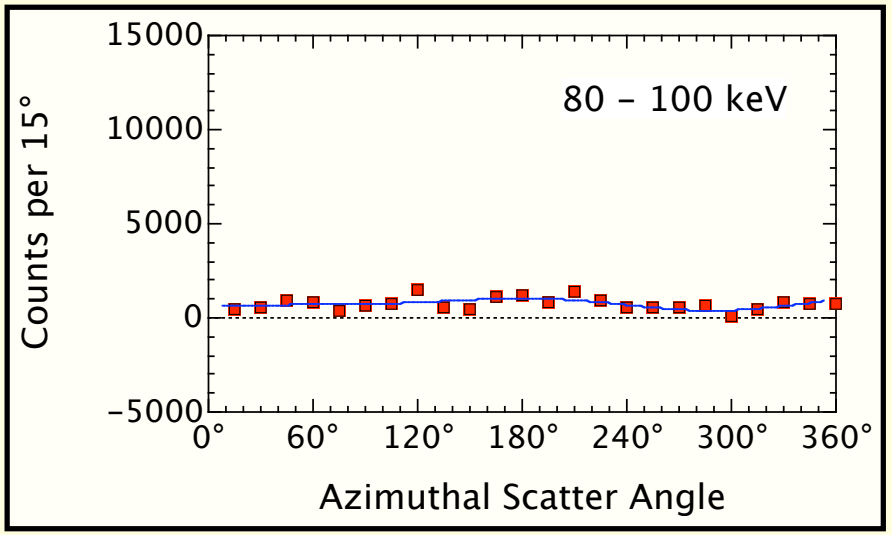
“Background” Subtracted Data

X8.3 Flare, 02 Nov 2003, 17:10 - 17:40 UT



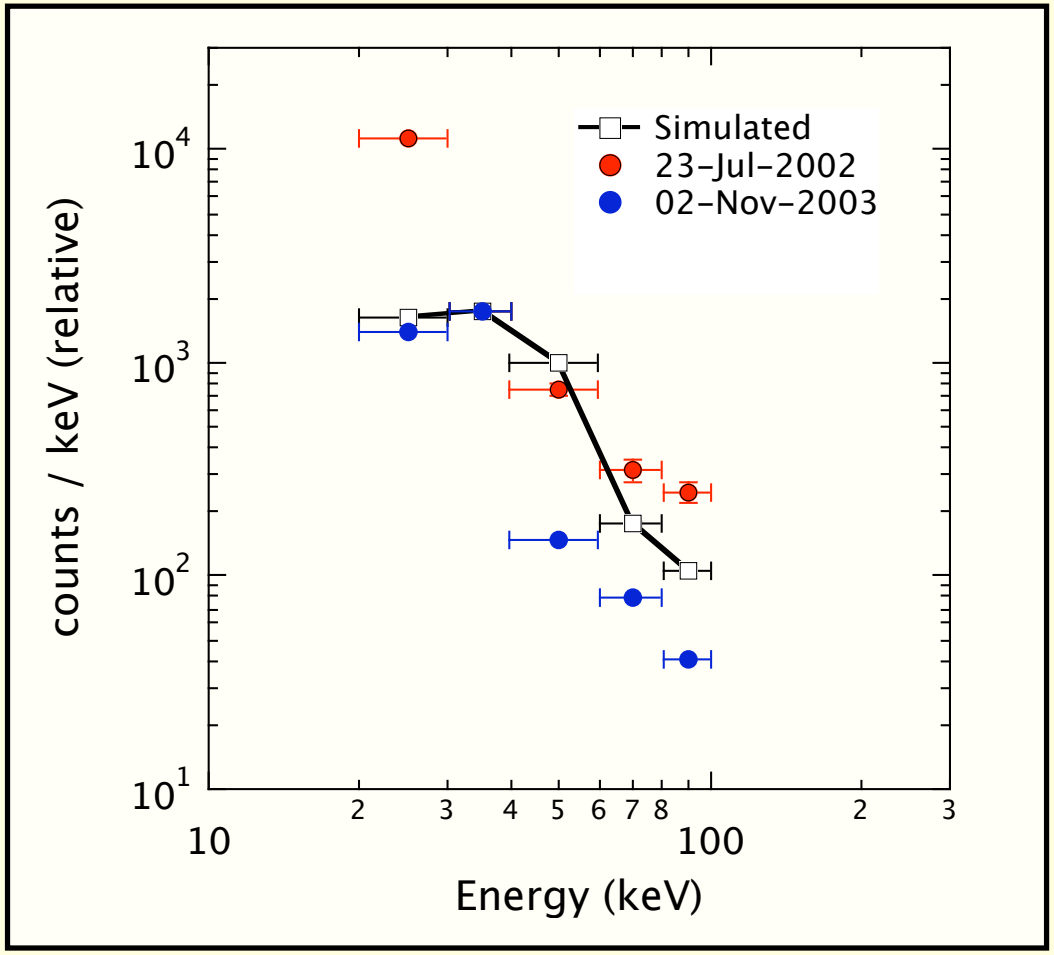






Be-Scattered Flux Spectra

Flare data compared with simulated data.



all spectra normalized at 35 keV

The data show a generally decreasing count rate versus energy.

The simulated spectrum is based on an incident $E^{-3.5}$ photon spectrum.

Comparison with simulations show some discrepancies.

Summary

- Addition of a Be scattering block provides HESSI with significant polarimetric capability.
- Polarization sensitivity predicted to be less than a few percent for some X-class flares.
- Several X-class flares observed by RHESSI.
- Initial results from flare of 23-July-2002 suggested a polarization level of ~26%.
- Systematic effects have not yet been ruled out.
- Inclusion of data from flares of 29-Oct-2003 and 02-Nov-2003 does not (yet) yield a consistent picture of these data.