# Polarisation studies of GRB041219a using the spectrometer INTEGRAL

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In collaboration with
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# Introduction

- Link between γ-ray production & linear polarisation can be used to constrain models
- Willis et al. (2005) $\Pi_s > 50\%$ and $\Pi_s > 35\%$ for 2 BATSE GRBs
- Reported $\Pi_s = 80 \pm 20\%$ in GRB021206 (Coburn &Boggs 2003) but was disputed by Rutledge & Fox (2004), Wigger et al 2004: $41^{+57}_{-44}\%$
- Studies of the mechanisms of producing large polarisation (eg Shaviv & Dar 1995; Nakar et al 2003; Waxman 2003; Granot 2003; Lazzati et al 2004; Dado et al 2007)

# Overview

- SPI as a polarimeter - previous talk by A. Dean
- ISGRI Compton Mode - M. Forot later in this session

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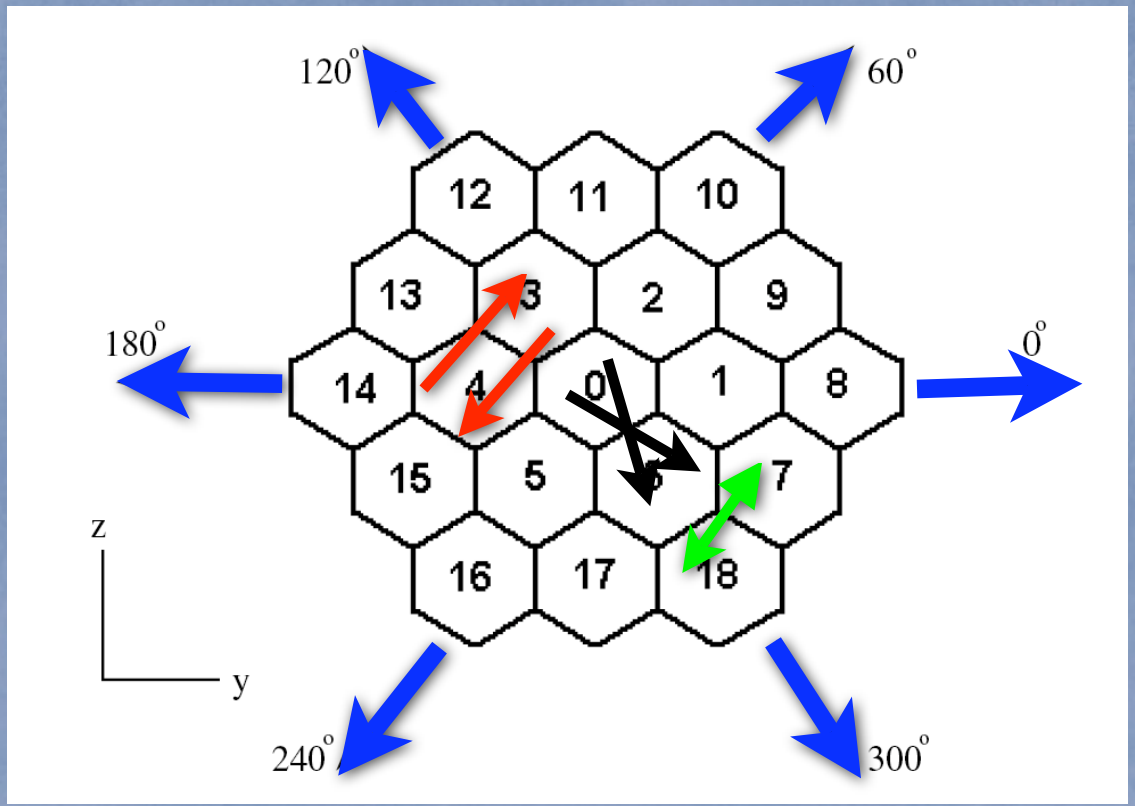
- Sensitivity to polarisation determined by
  - effective area to scatter events
  - Polarmetric modulation factor Q, which is the maximum variation in azimuthal scattering probability for polarised photons (Lei et al 1997).
- For SPI we calculate Q=24±7% from simulations.

# Compton Scatter




100-500 keV - 6 directions

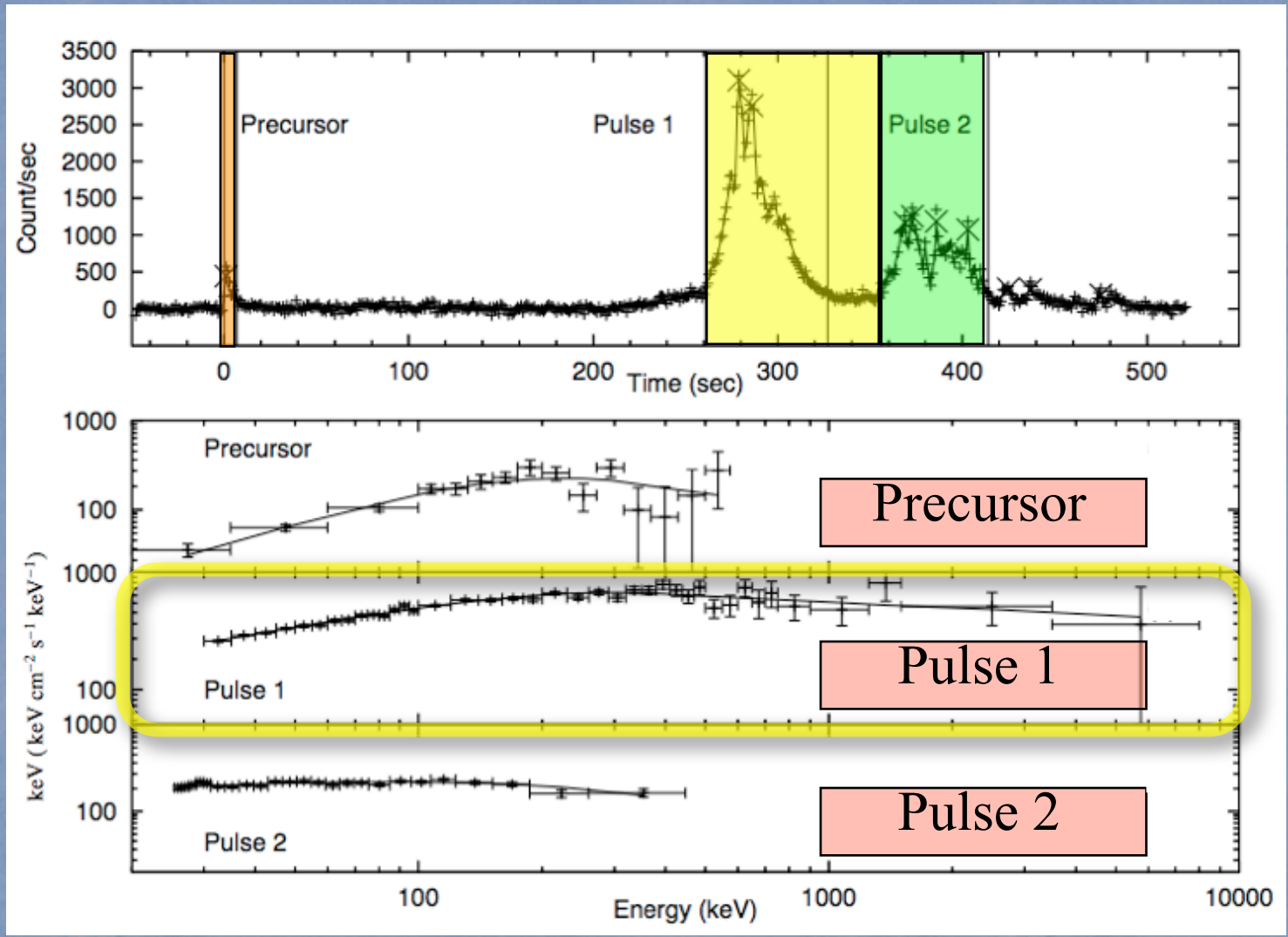
Otherwise 3 directions

Dominant mode of interaction of photons with energy above a few hundred keV is Compton scatter -> linearly polarised photons scatter preferentially perpendicular to the incident polarisation vector.

# GRB 041219a

- Very intense GRB
- Peak flux 43 photons $cm^{-2}$ $s^{-1}$ with emission up to a few MeV
- 3.08 degrees from x-axis
- Swift, Rossi ASM, prompt optical and near IR observations
- SPI results and broad-band spectra see McBreen et al 2006.

# GRB041219a

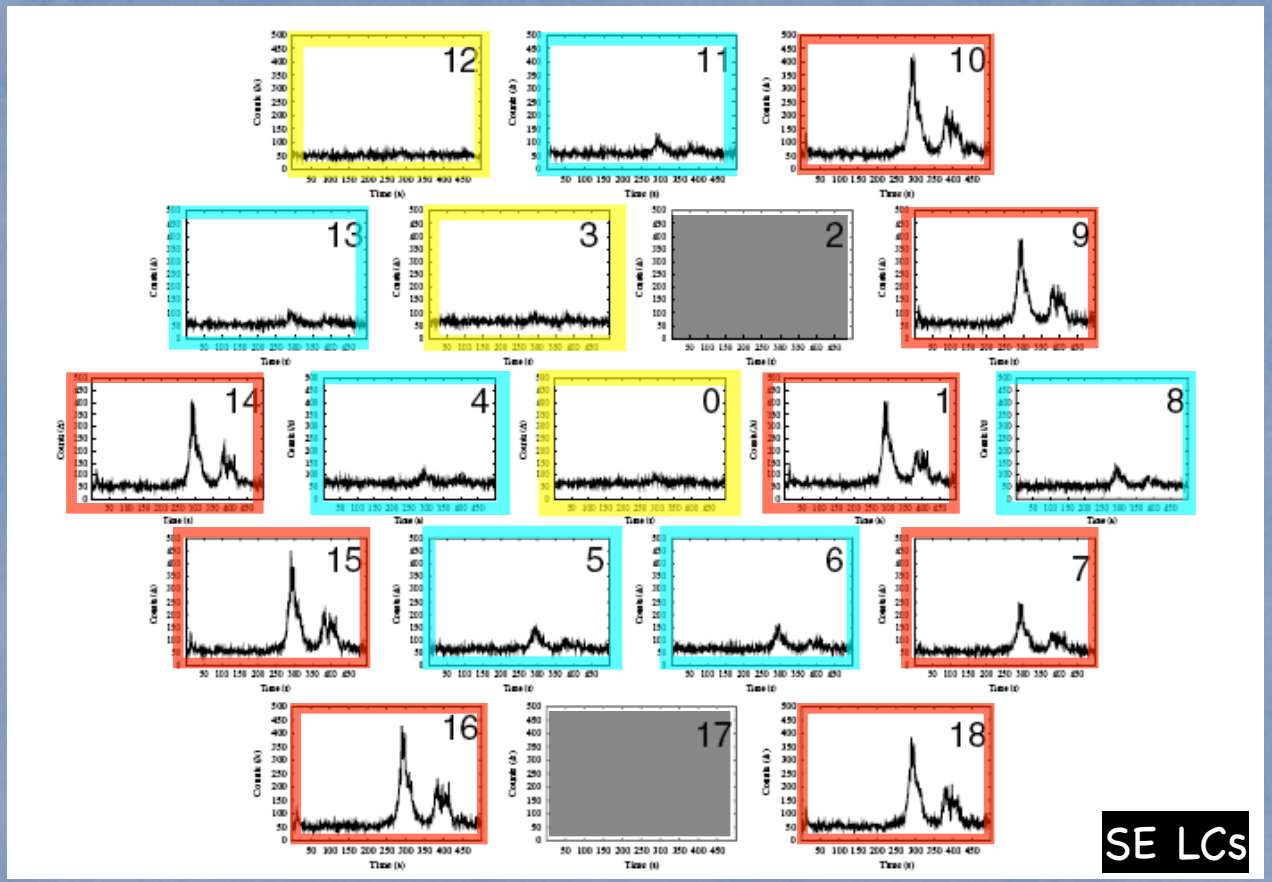



Band spectral parameters $\alpha$=-1.50,$\beta$=1.95,$E_0$=568 keV (McBreen et al A&A 2006)

# Simulations

Mask elements (yellow) overlaying the detectors (blue) as viewed by incoming photons.

# GRB041219a




The failure of two detectors reduced the effective area for single events (SE) to ~90%. For multiple events (ME) events to ~75%, number of adjacent detector pairs reduced from 84 to 64.

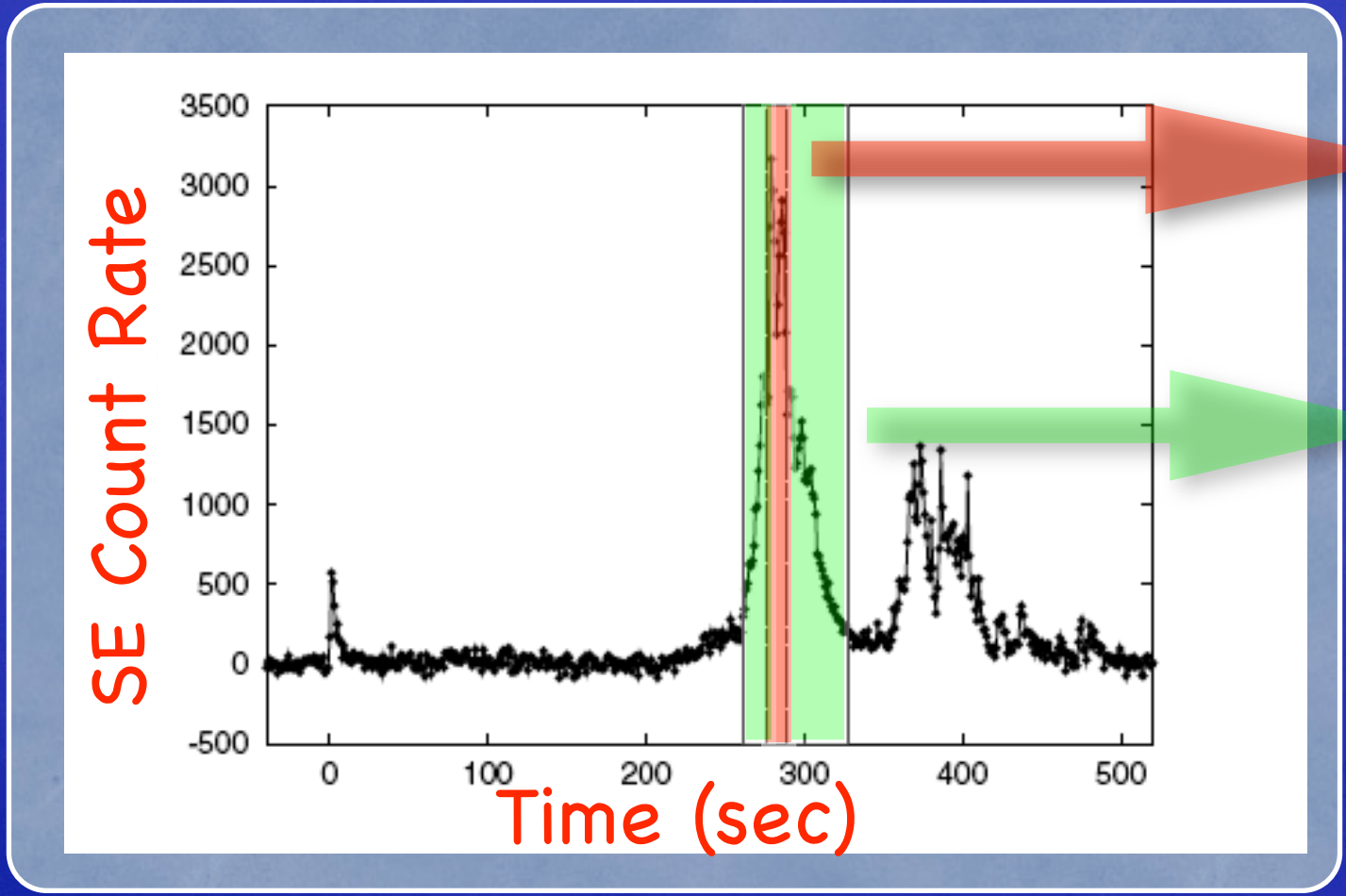
# Method

- Select all double events between adjacent detectors during the time intervals
- Coincident pairs whose combined energy 100-350, 100-500 & 100-1000 keV were selected
- In the range 100-511 keV - 6 directions because photons predominantly scatter from the low to high energy otherwise 3 directions
- Do the same process for background events (4 time regions chosen & scale)
- Make Asymuthal Scatter Angle Distribution (ASAD) and compare to simulations

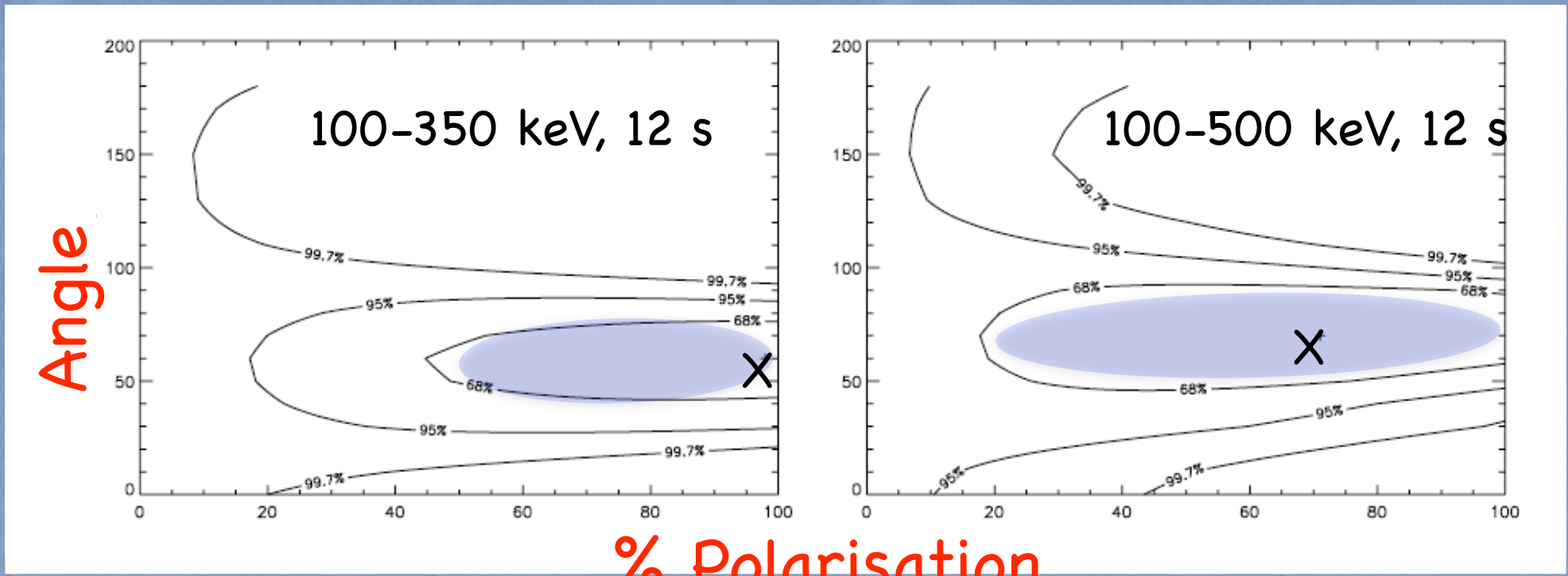
# Simulations

- Written in Geant4 (Angostinelli et al 2003) and based on TIMM (Ferguson et al 2003)
- Source spectrum simulated
- Polarisation angles of 0 - 180 deg in 10 deg steps
- 0% and 100% polarised beams simulated and mixed to produce interim values
- Events recorded in the Ge and BGO detectors
- ASADs for all angles and % generated and compared to data

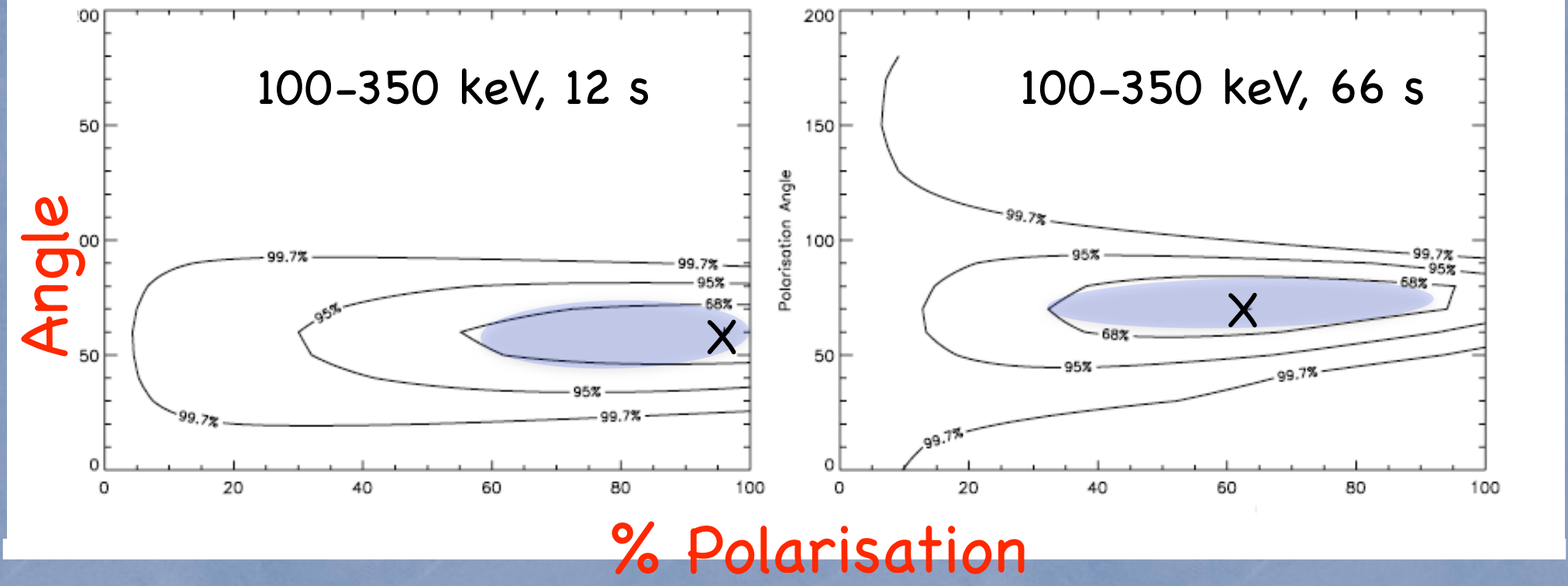
# Data selection



# 6 directions



# 3 directions



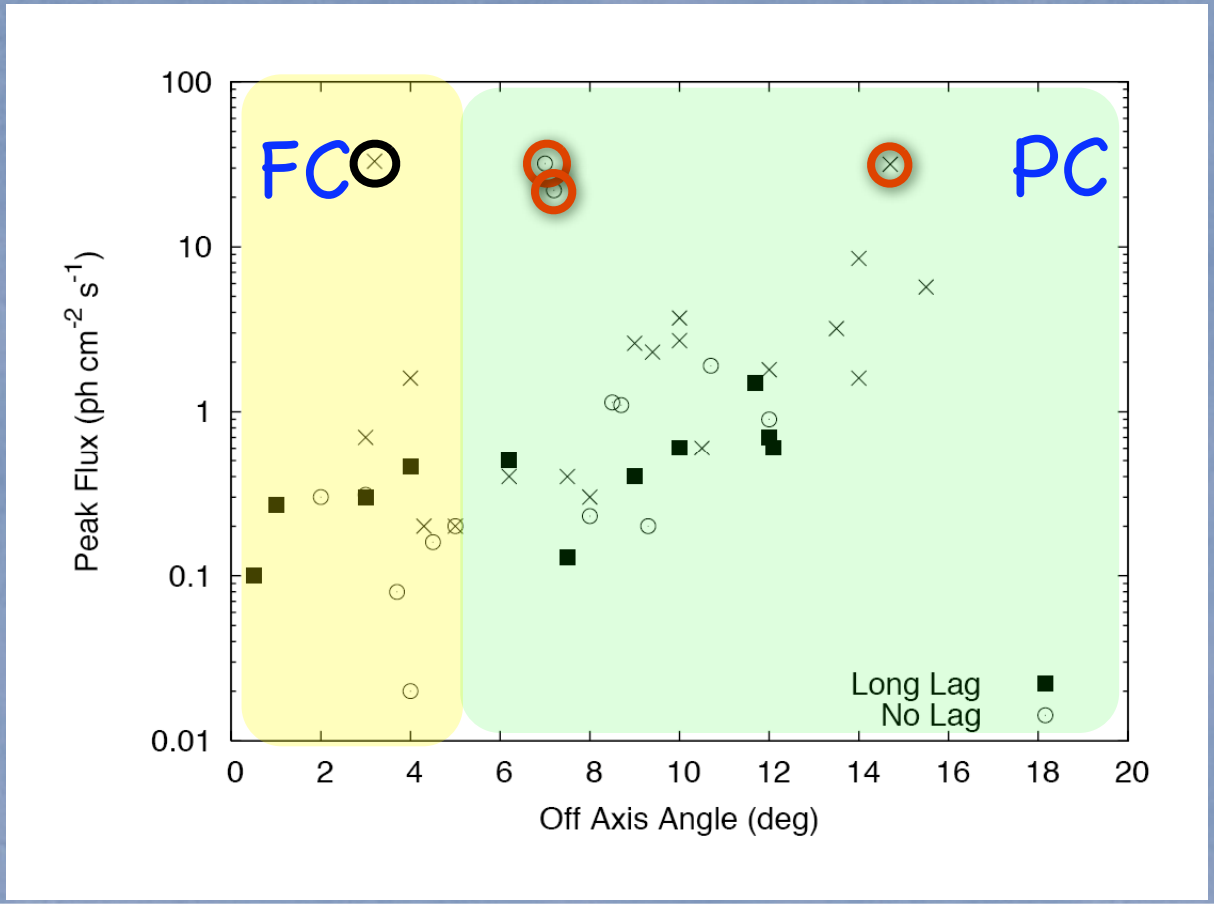
# Results

| Time | Directions | % Polarisation | Angle (deg) |
|---|---|---|---|
| 12 sec | 6 | 96±53 | 60±19 |
| 12 sec | 3 | 96±40 | 60±12 |
| 66 sec | 6 | 70±20 | 70±10 |
| 66 sec | 3 | 63±31 | 70±14 |

**Weighted mean of all results 60% at 2 σ level**

McGlynn et al A&A 2007 and are in agreement with Kalemci et al ApJ 2007

# Other GRBs

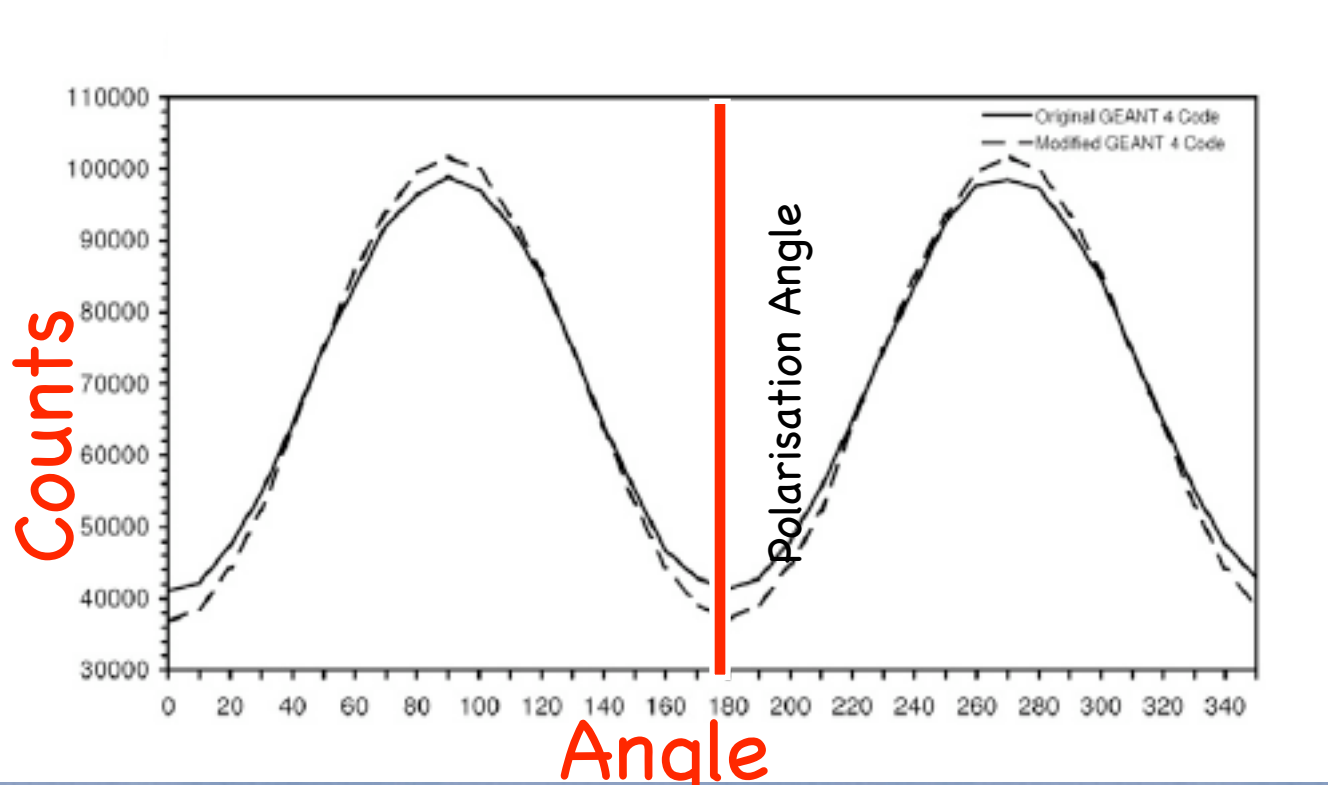



3 other bursts which are bright, so perhaps limits on the polarisation can be achieved for theses GRB060901, GRB061122 and GRB050525a.

# References

McBreen et al 2006
McGlynn et al 2007 & references therein
Foley et al 2007
Kalemci et al 2004,2006

# ASAD




Scatter azimuthal angle distribution:

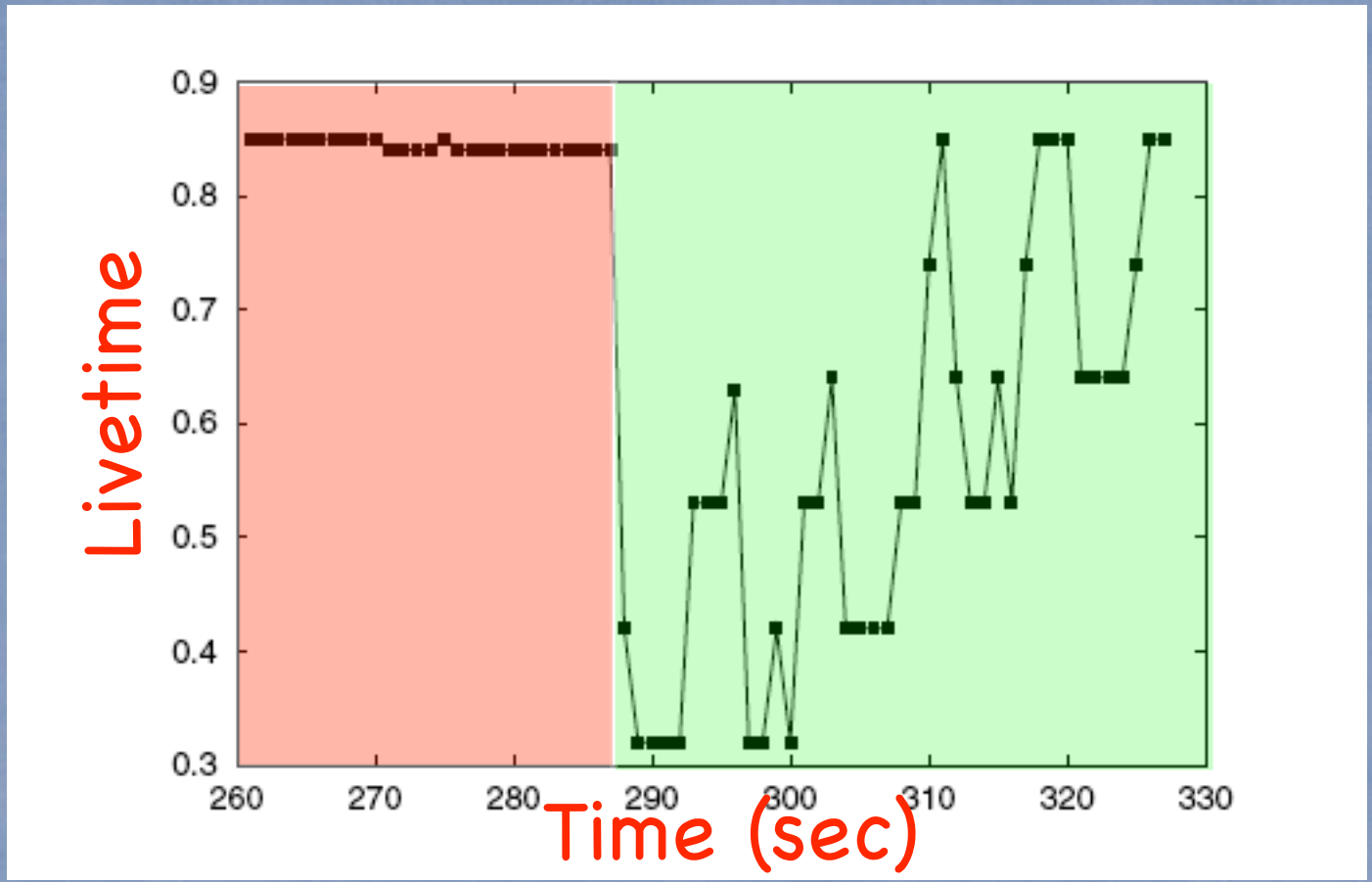
$dS/d\phi = (S/2\pi)\,[1 - Q\,\Pi\cos(2(\phi - \eta))]$

$\Pi$ is the fractional polarization

S - Source Counts
Π - % Polarisation
Q - Quality Factor
η - Polarisation Angle

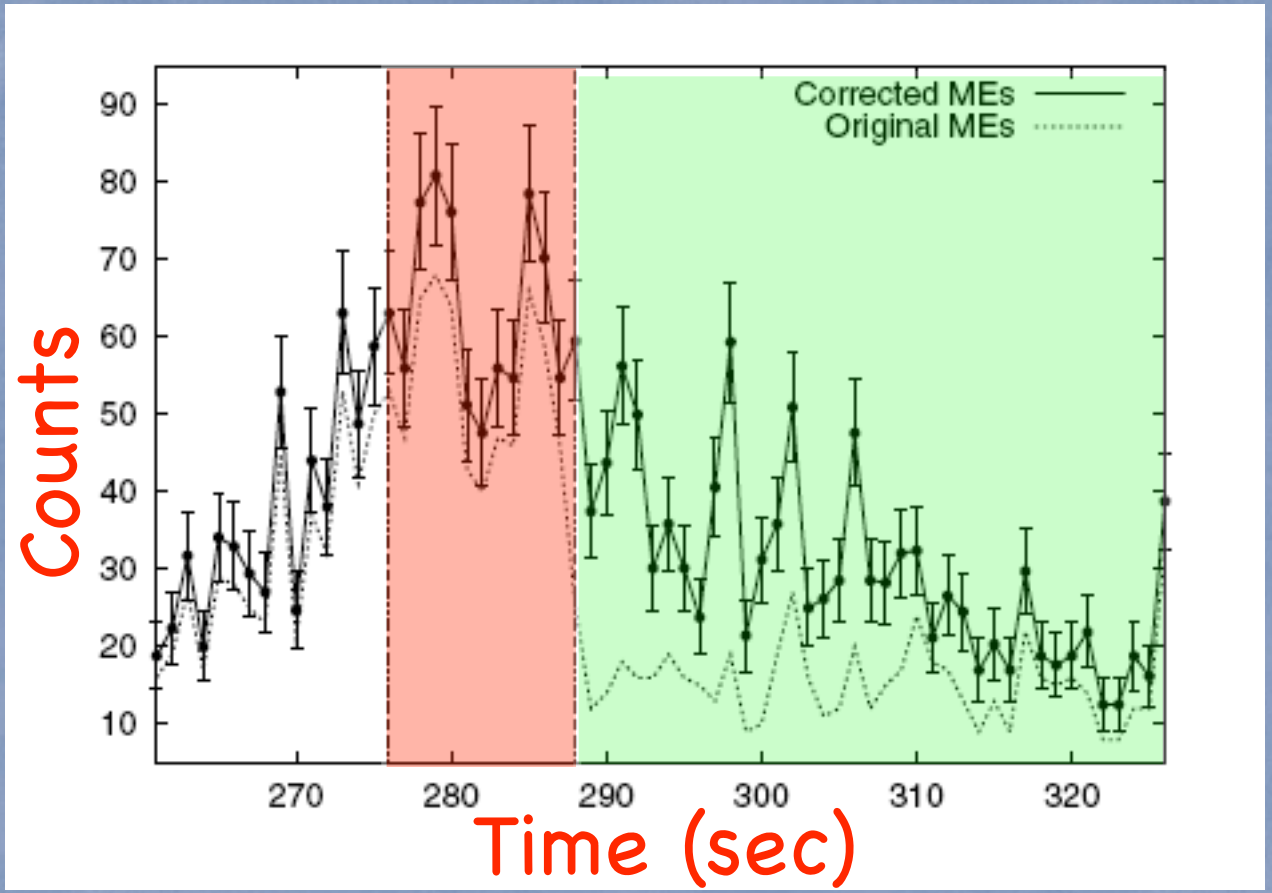
Lei et al 1997

# Deadtime




Livetime per detector drops suddenly 288 s due to telemetry constraints and a high data rate. About half the multiple events were lost.

# Deadtime




The solution was to reduce the ME background to take this into account.

Red - 12 s

Green - 66 s