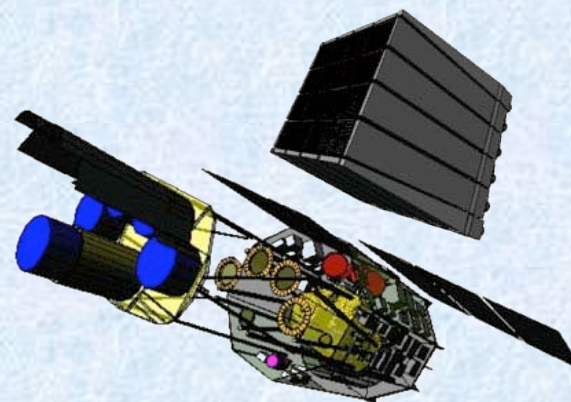


Suzaku HXD-WAM Observations of Gamma-ray Prompt Emission and Collaboration with GLAST



Y. Fukazawa, M. Ohno, T. Takahashi, T. Asano, T. Uehara (Hiroshima U.), K. Yamaoka, S. Sugita (Aoyama-Gakuin), Y. Terada, T. Tamagawa, M. Suzuki (RIKEN), S. Hong (Nihon U), M. Tashiro, Y. Urata, K. Abe, K. Onda, M. Suzuki (Saitama U), E. Sonoda (Miyazaki U), M. Kokubun, T. Enoto, K. Makishima (U of Tokyo), T. Takahashi, K. Nakazawa (ISAS/JAXA), G. Sato (NASA/GSFC) and the HXD-II team

Suzaku Wideband All-sky Monitor (WAM)

Suzaku/HXD

Anti for lowering the BGD of
main detector

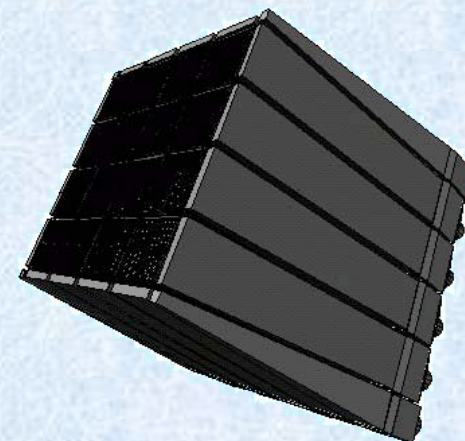
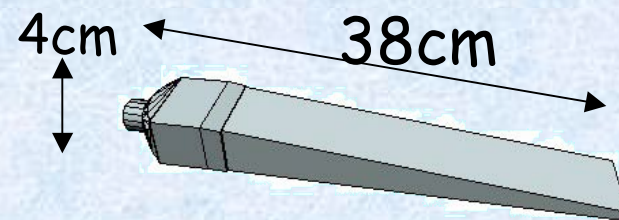
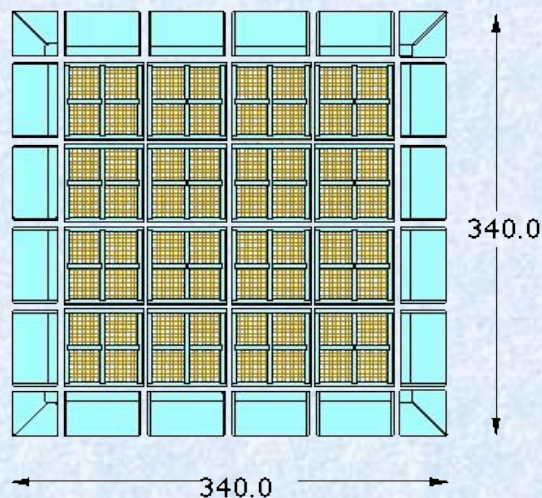
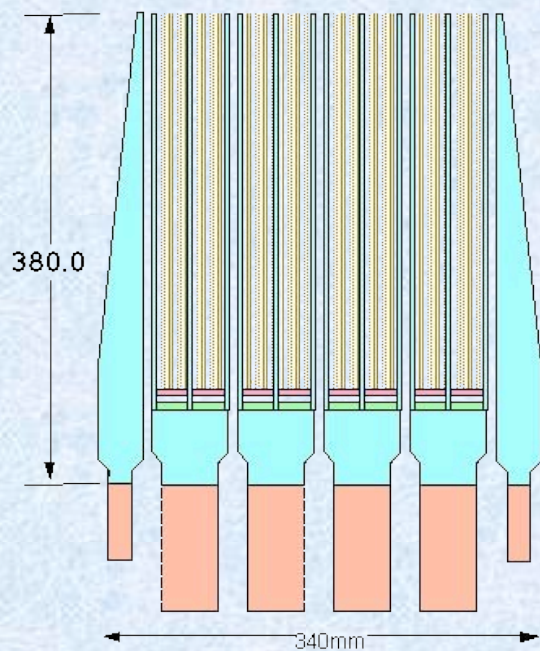
thick (4cm) large (38cm)
20 BGO crystals

All-sky monitor with high stopping



top view

cross-section



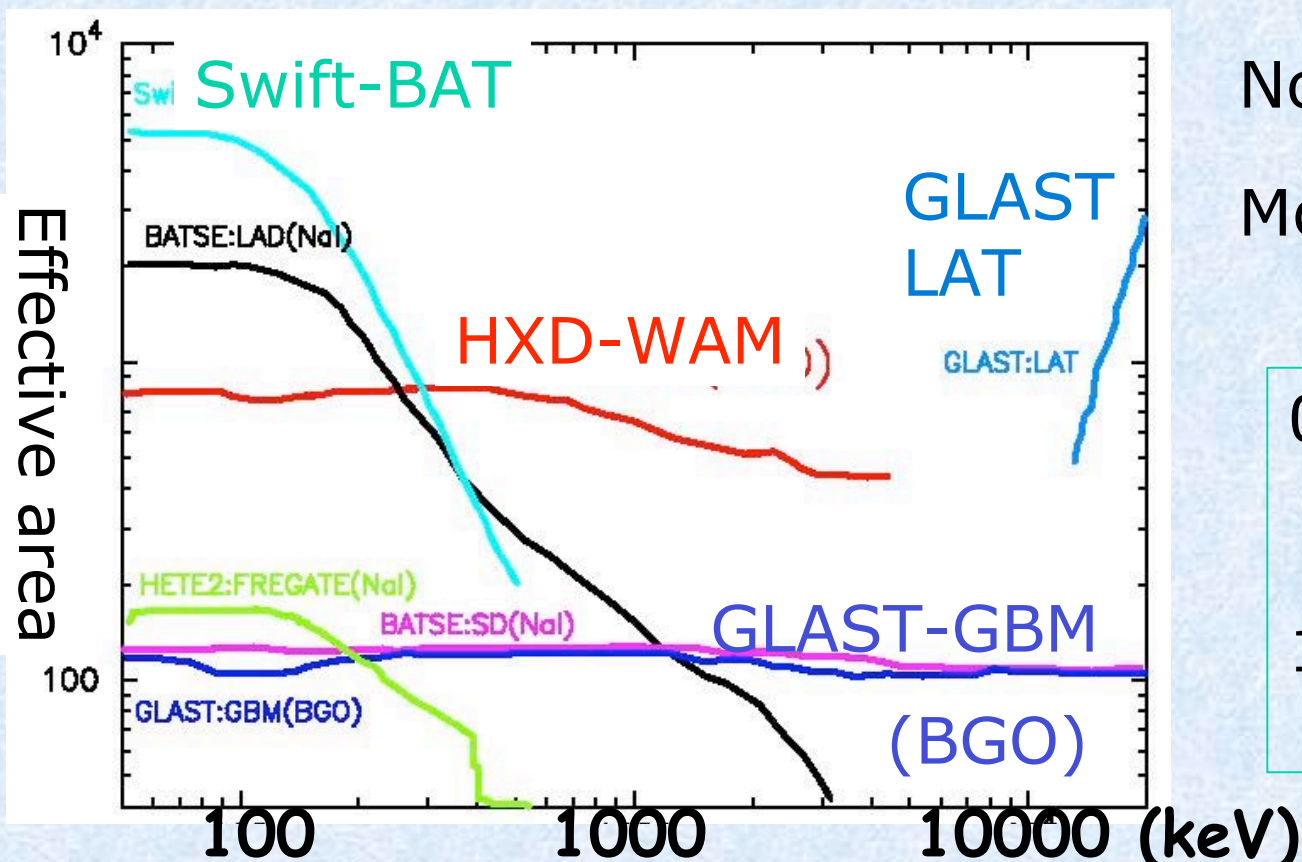
WAM Advantage for GRB observations



Large effective area

Highest sensitivity
from 300 to 5000 keV

Effective area : 800cm@300keV
400cm@1MeV



No alert system

Moderate
time resolution

0.5sec 55ch
(continuous)
or
1/64sec 4ch
(128s length)

GRB observations with WAM

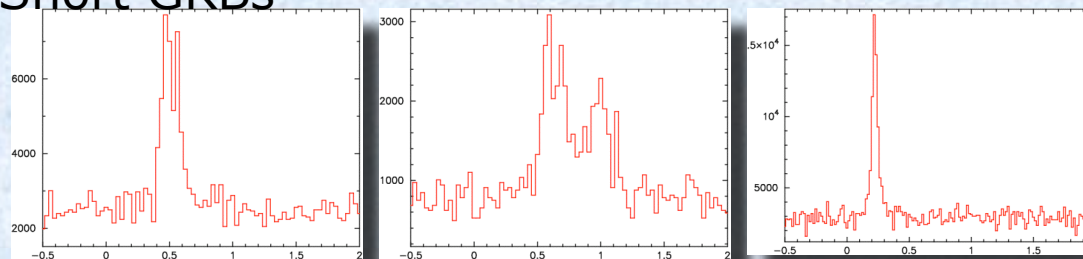
~Trigger status~

22 Aug 2005
--- 07 Jan 2007

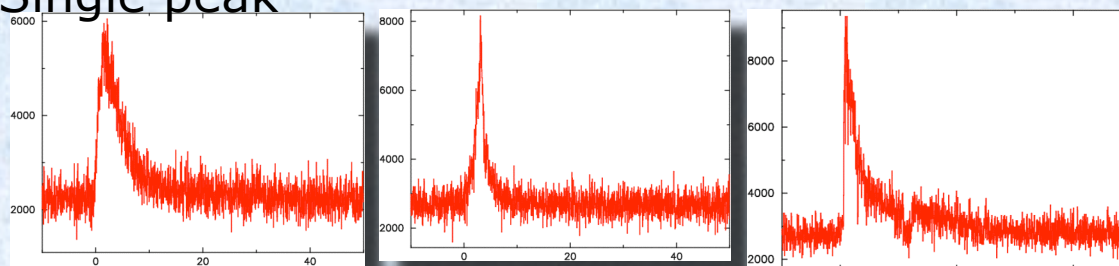
Localized GRB 26
Confirmed GRB 112
Possible GRB >30

Lightcurve samples

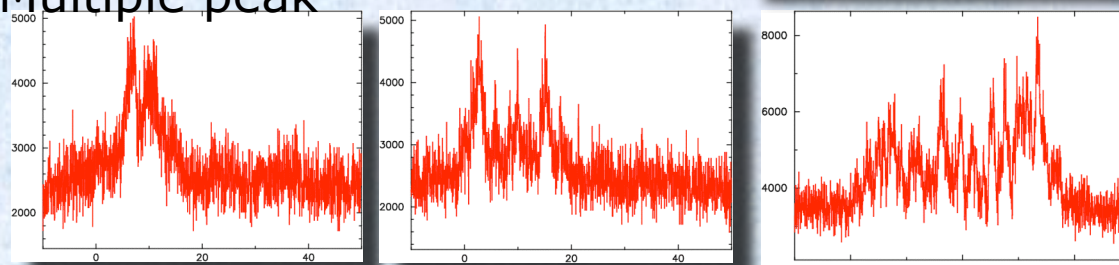
Short GRBs



Single peak



Multiple peak



GRB detection rate is ~ 120 / year

Simultaneous Detection of GRBs with other satellites

	number(triggered)
Swift	35 (15)
Konus	88 (56)
HETE-2	9 (4)
INTEGRAL/SPI	31 (19)
INTEGRAL/IBIS	2 (0)

GCN Circulars (as of 2006 Sep)

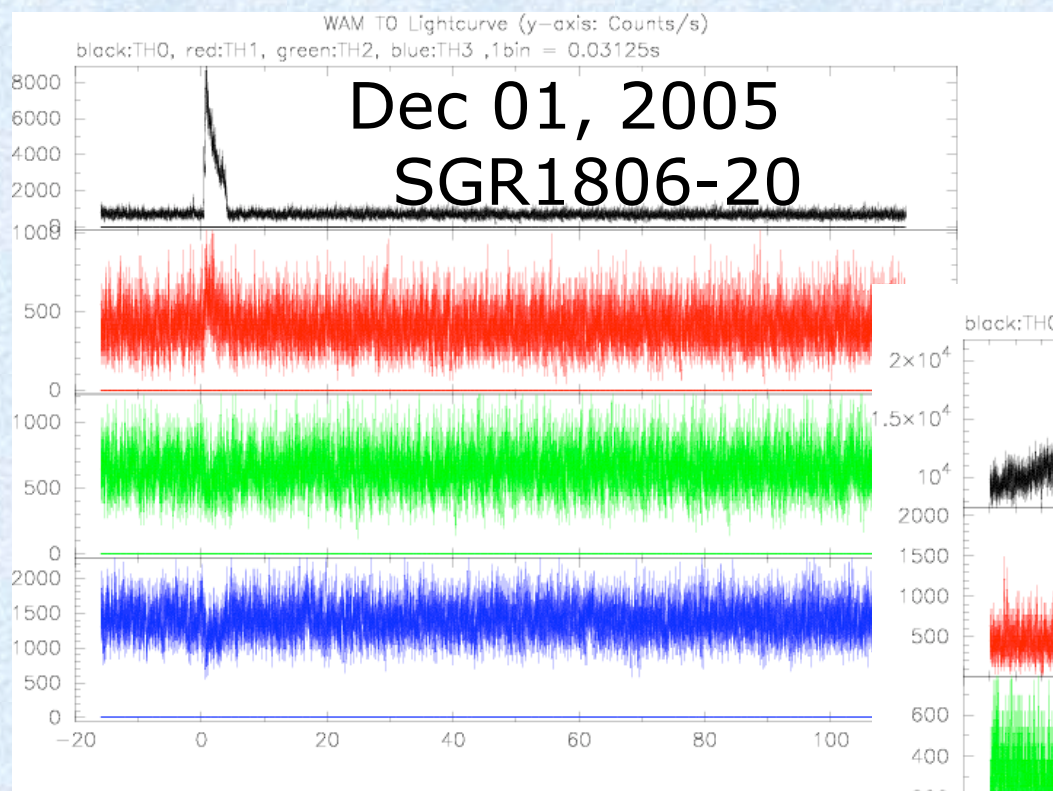
WAM:9 GRB051008, GRB051111, GRB051221A, GRB060111B,
 GRB060117, GRB060429, GRB060813, GRB060814, GRB060904A
 IPN :5 GRB060213,GRB060303,GRB060425,GRB060429,SGR1806-20(2)
 Joint:1 GRB060813

Light curves and Spectra are available at

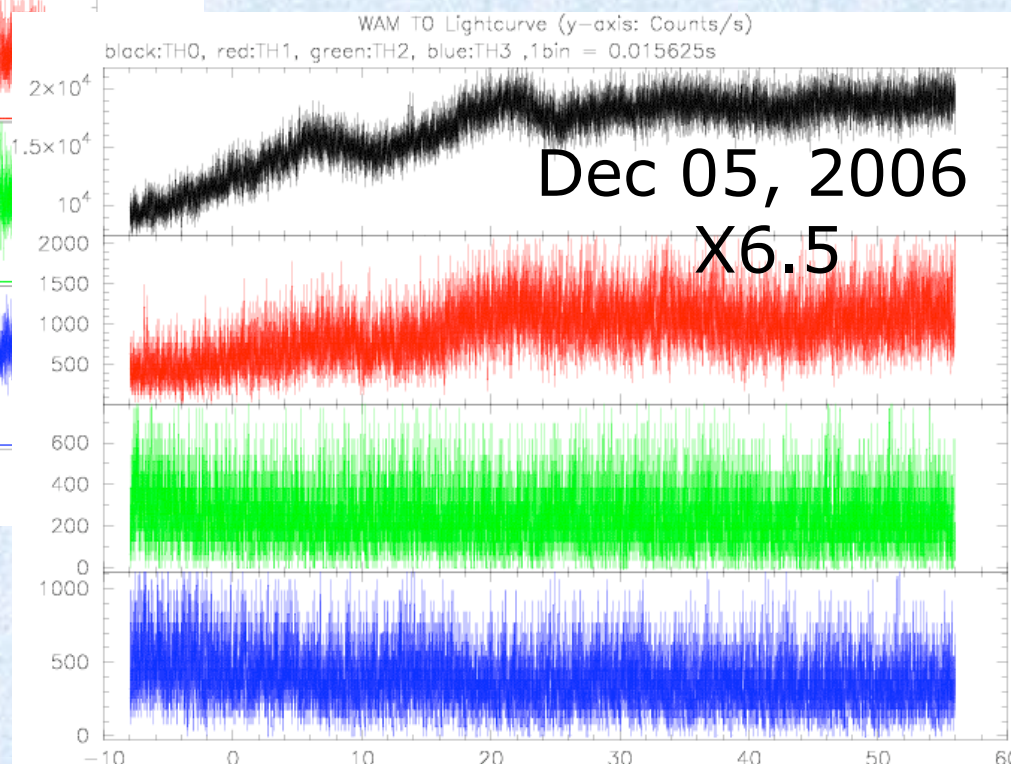
<http://www.astro.isas.jaxa.jp/suzaku/HXD-WAM/WAM-GRB/>

SGR (Soft Gamma-ray Repeater)

SGR1806-20, 1900+14



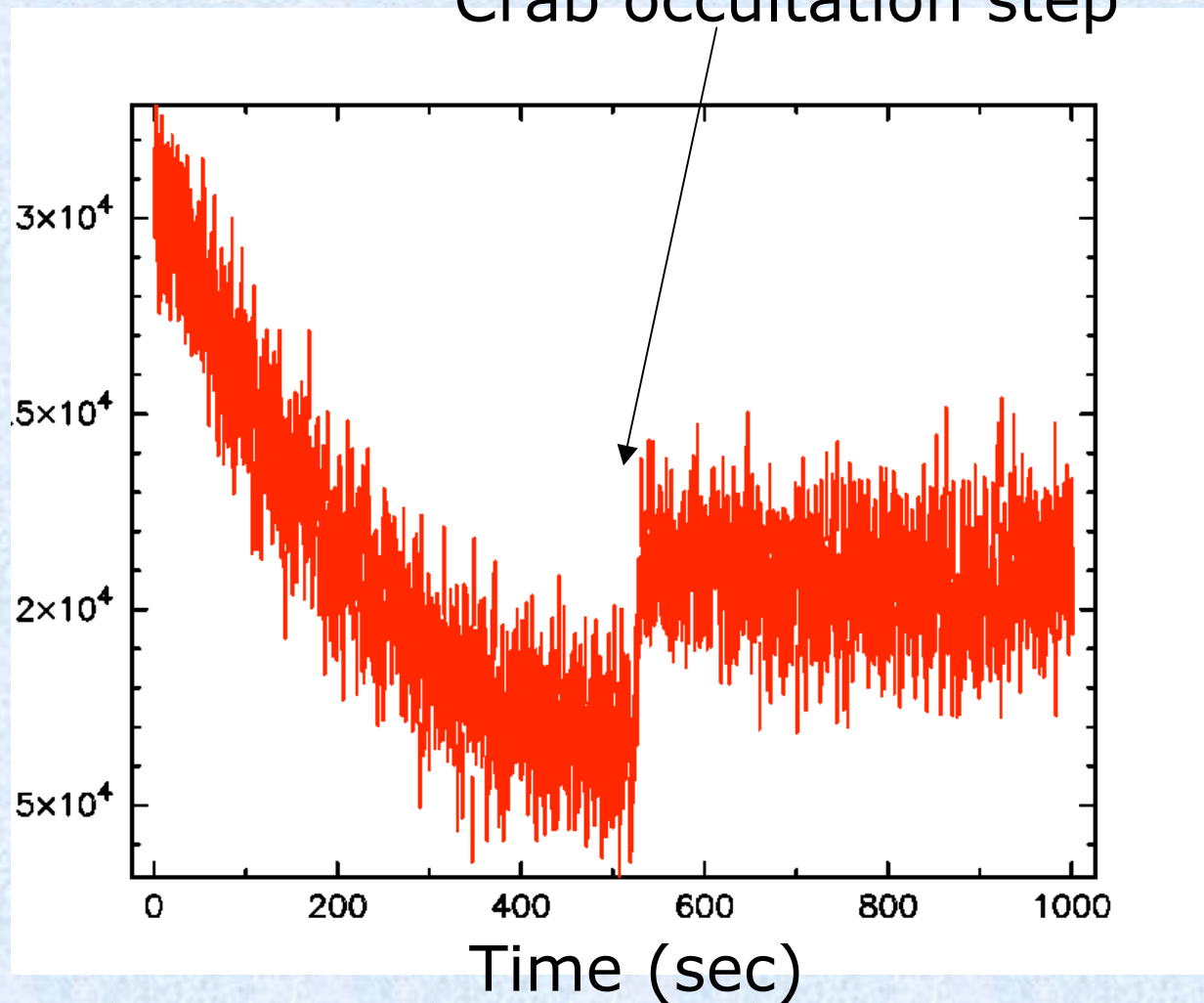
Solar Flares
>30 triggers (X,C-class)



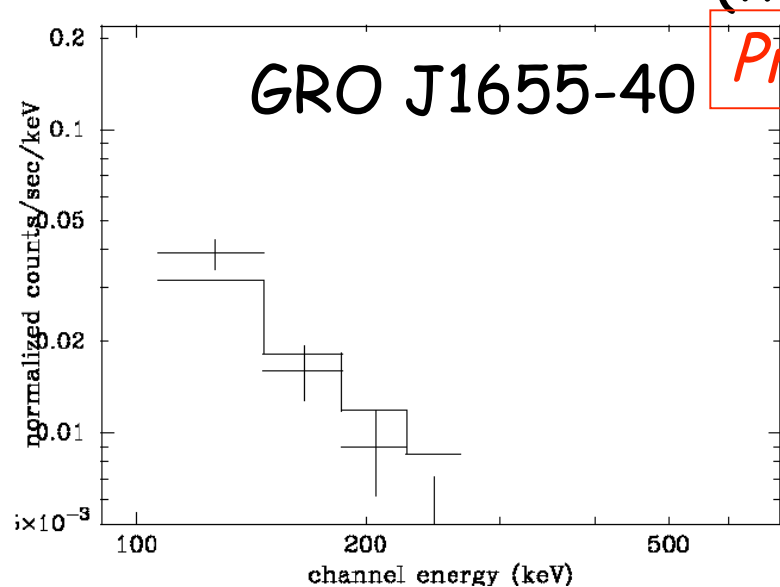
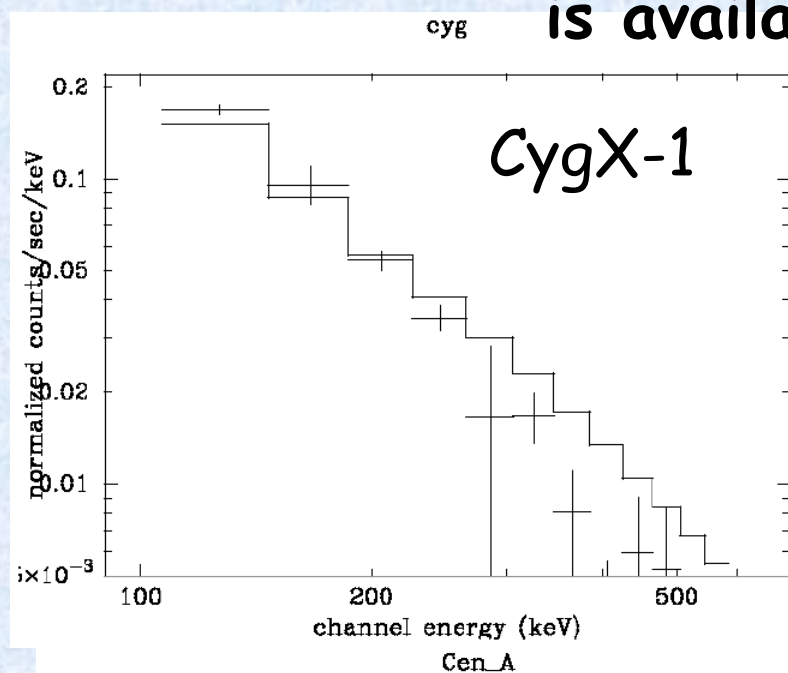
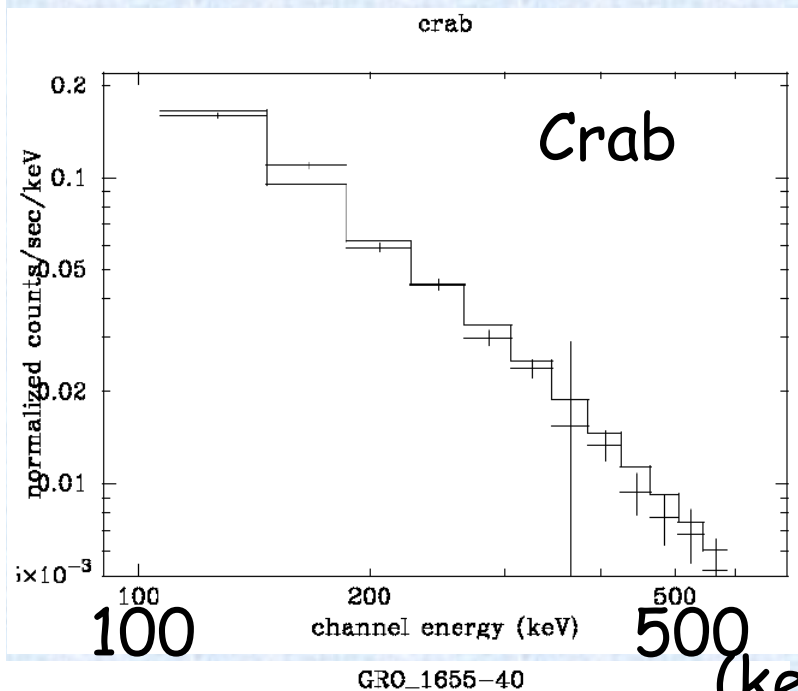
These data will be also useful with the *GLAST* data.

Earth Occultation step by WAM

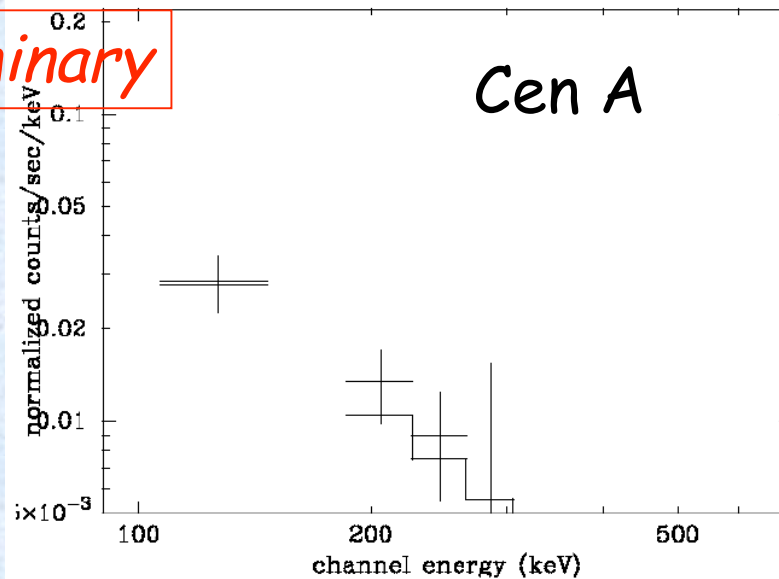
Crab occultation step



Month/Year monitoring of soft-gamma-ray sources is available



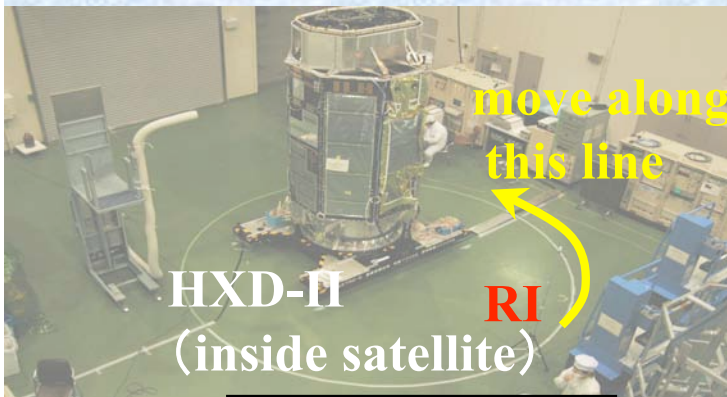
Preliminary



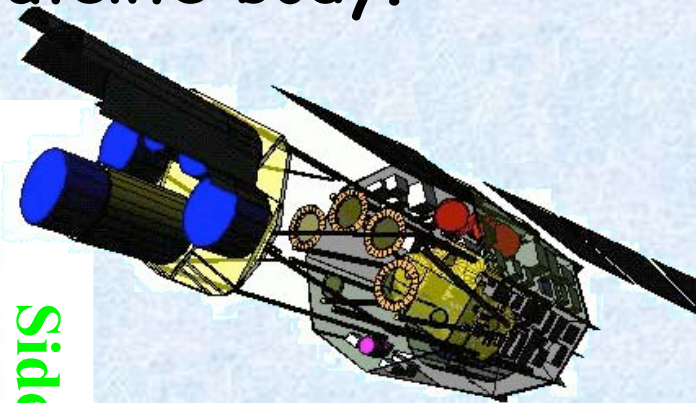
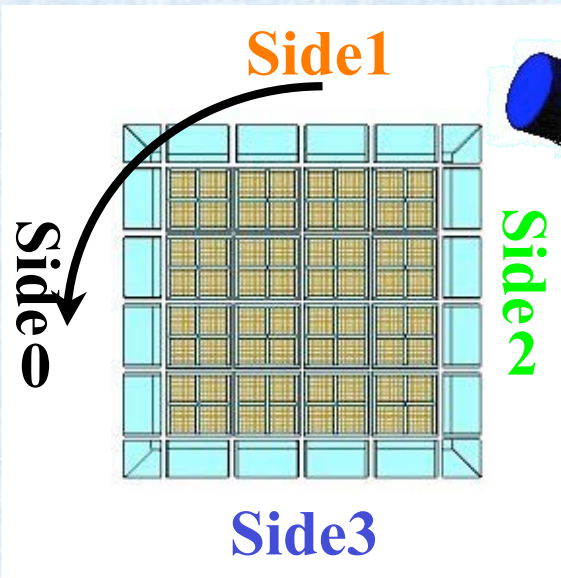
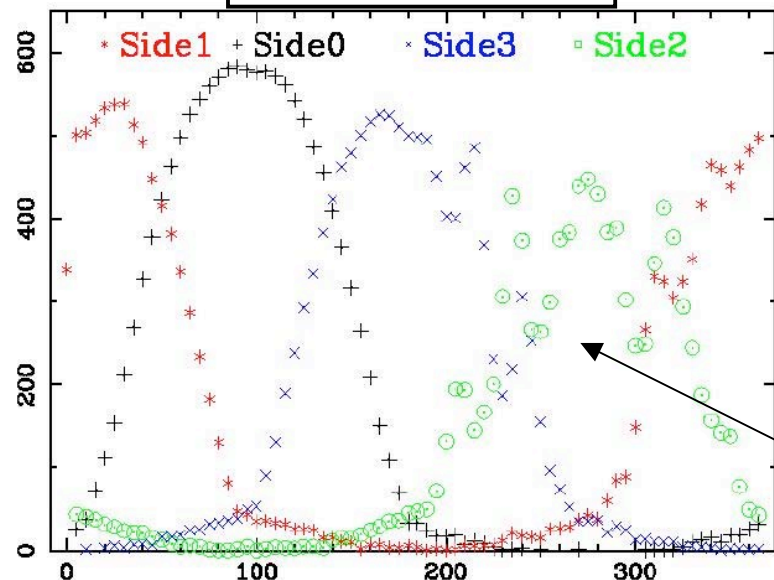
Calibration

WAM is located inside the satellite body.

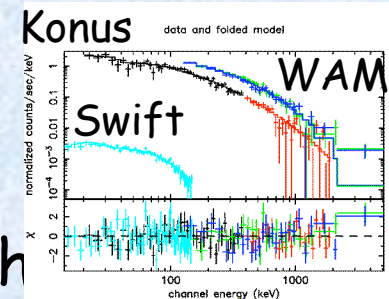
Ground calibration



511 keV count rate



Suzaku Mass Model
 Geant 4



Inflight Calibration

Cooperation with

Swift, Konus-Wind

by using the same GRBs

Crab by the earth occultation

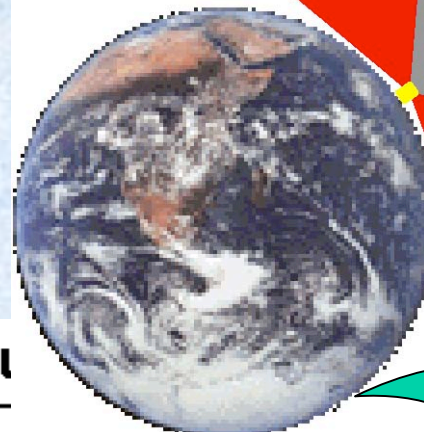
<30% accuracy for the response

Good matching with GLAST

Similar orbit (LEO, 30deg incl.)
Same BGO detector

Collabo. in Calibration and BGD
Highest sensitivity
around GRB peak

Field of view



LAT FoV

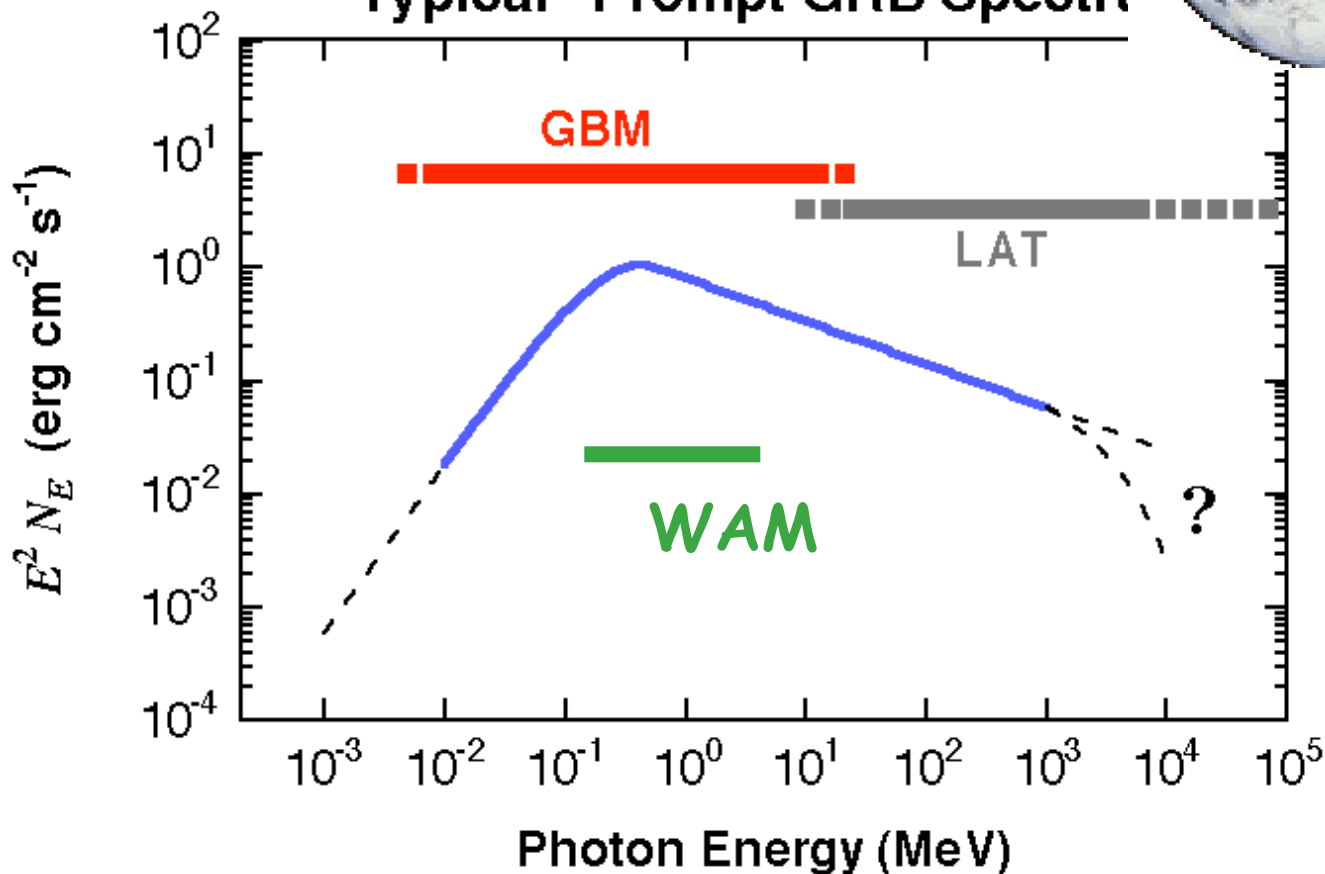
GBM FoV

WAM

Depending on the
Suzaku attitude

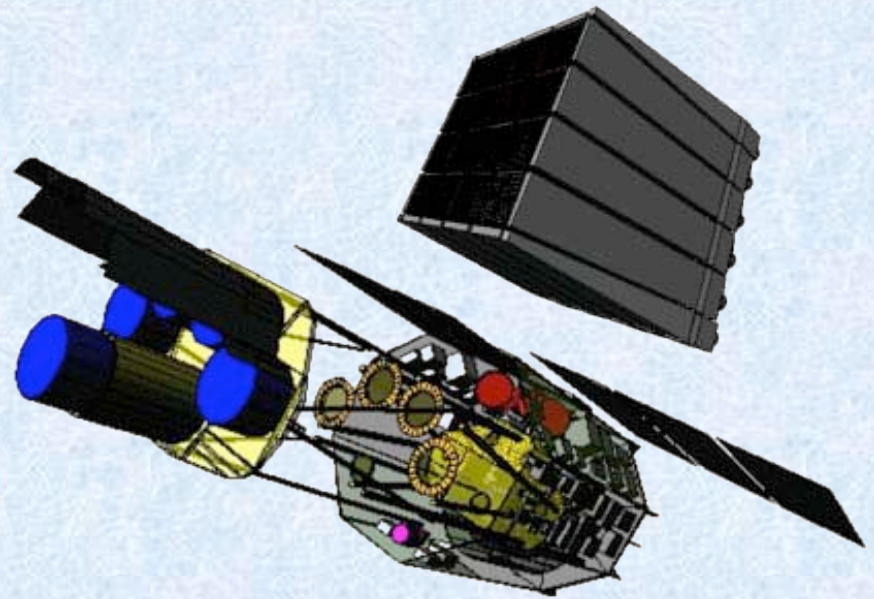
30% of GLAST
GRBs may be
Detected with
WAM.

"Typical" Prompt GRB Spectra



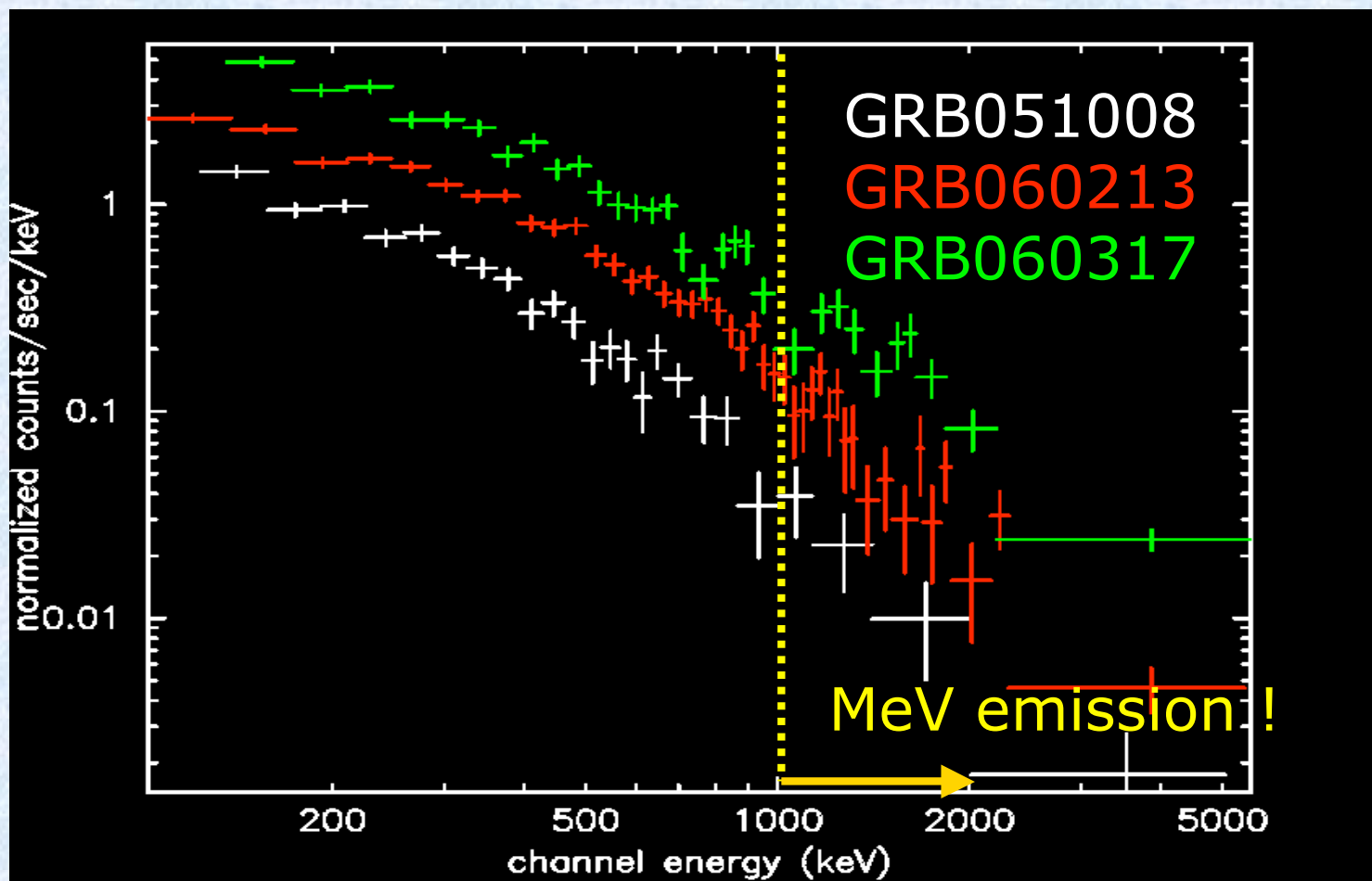
GRB results

1. Epeak distribution
2. short GRBs vs long GRBs
hardness, spectral delay...
3. Spectral Evolution

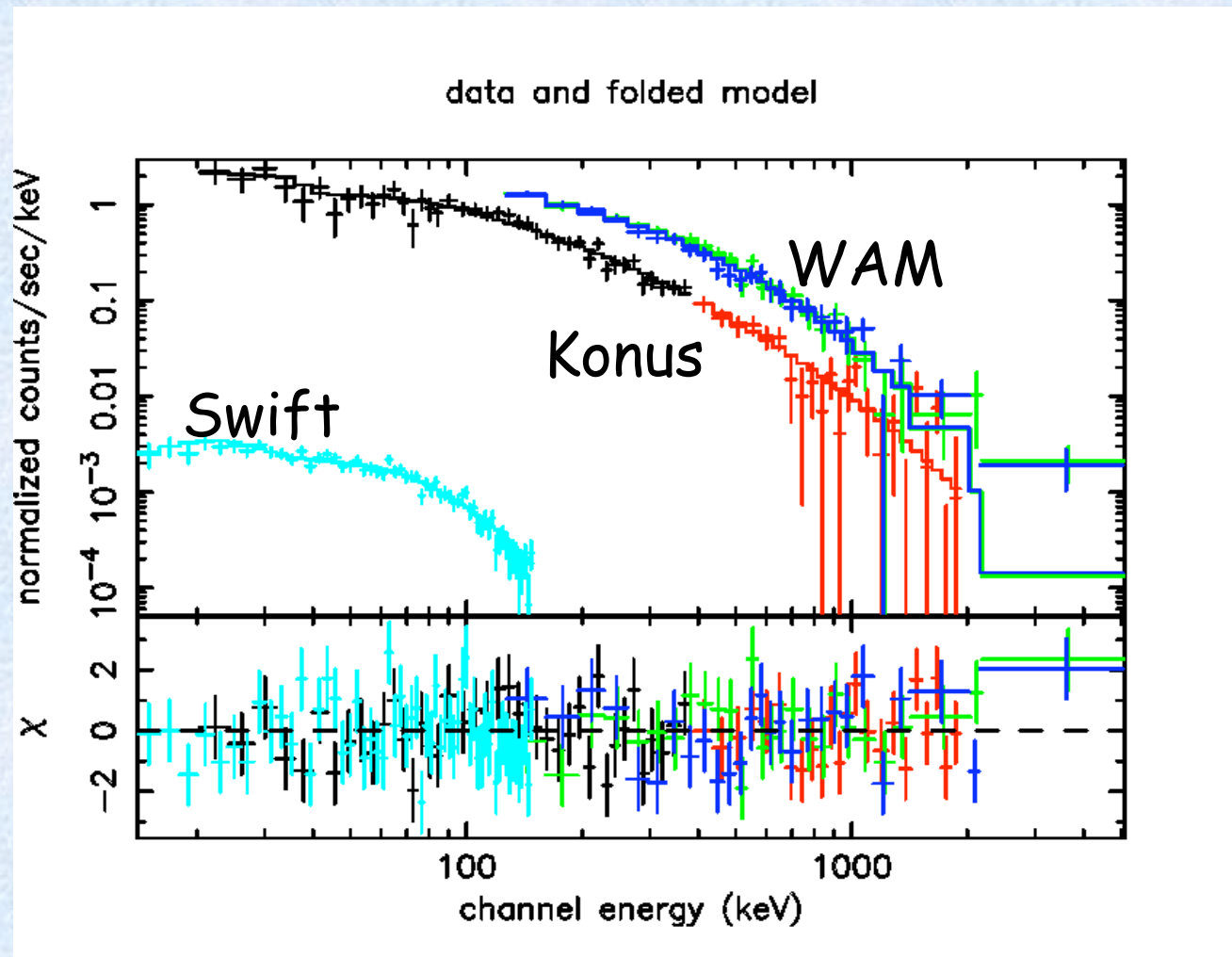


1. Epeak Distribution toward the higher energy

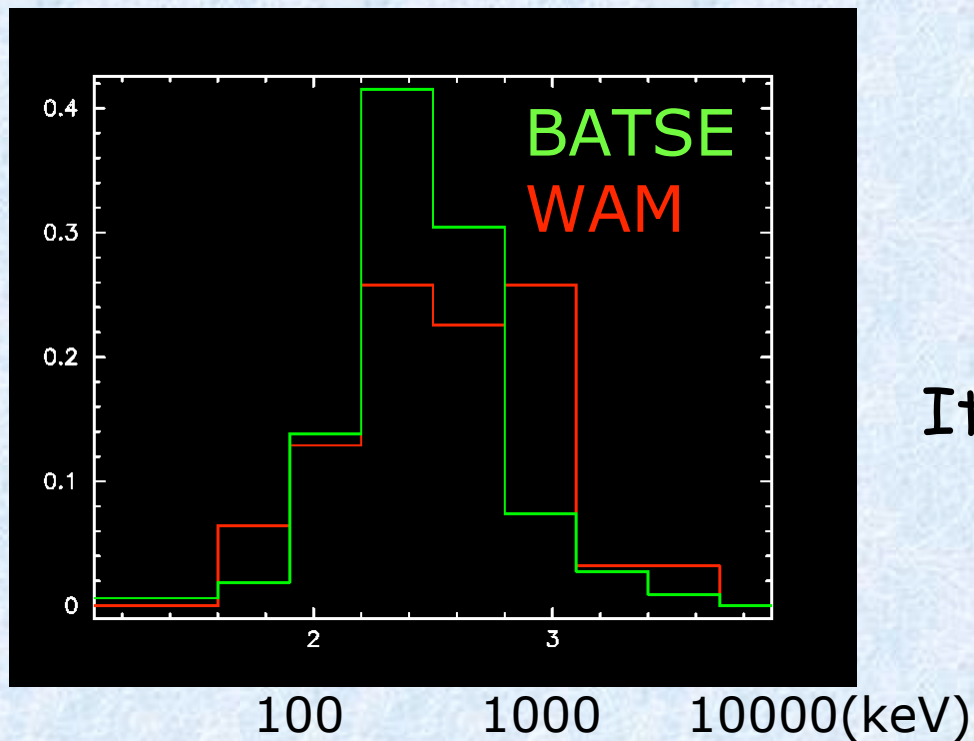
MeV emission is clearly detected from GRBs !



Simultaneous fits with other satellites
 strongly constrain the spectral shape and then Epeak.



Comparison of Epeak dist.



Kolmogorov-Smilnov
 probability: ~15%

It seems almost similar ?

Still need more study.

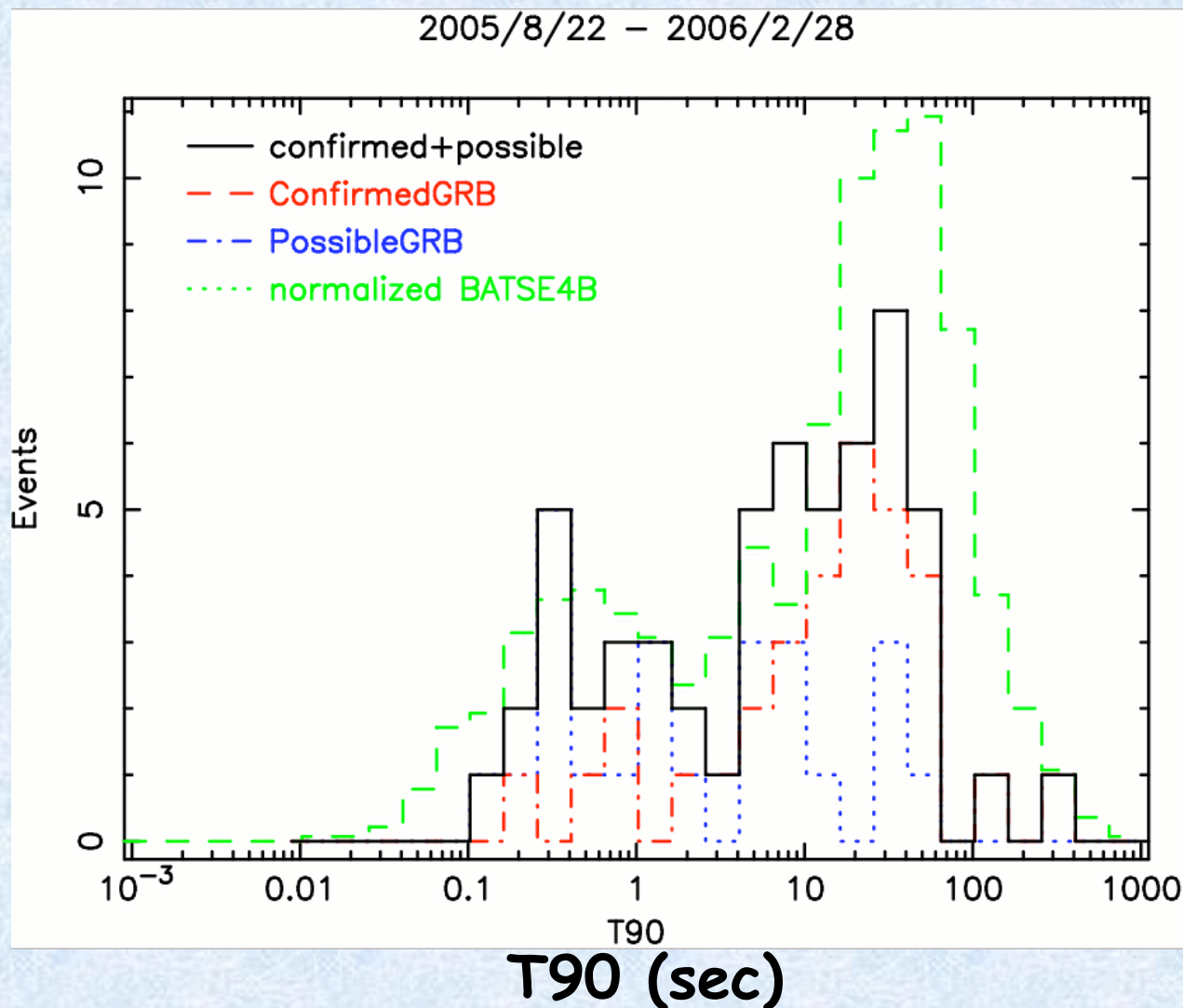
Selection effect ?

More sample

Hope with GLAST

2. Short GRBs vs Long GRBs

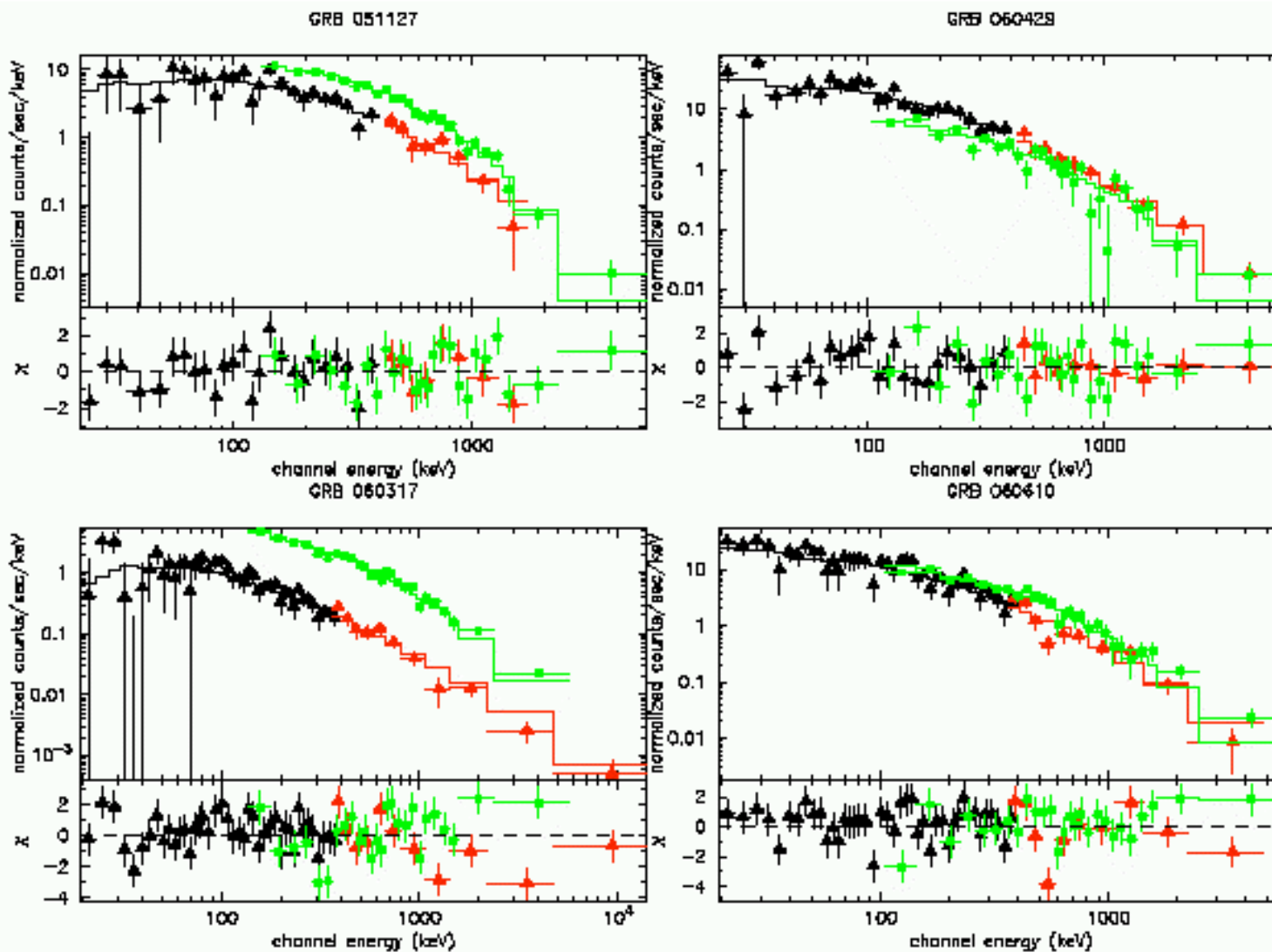
T90 distribution



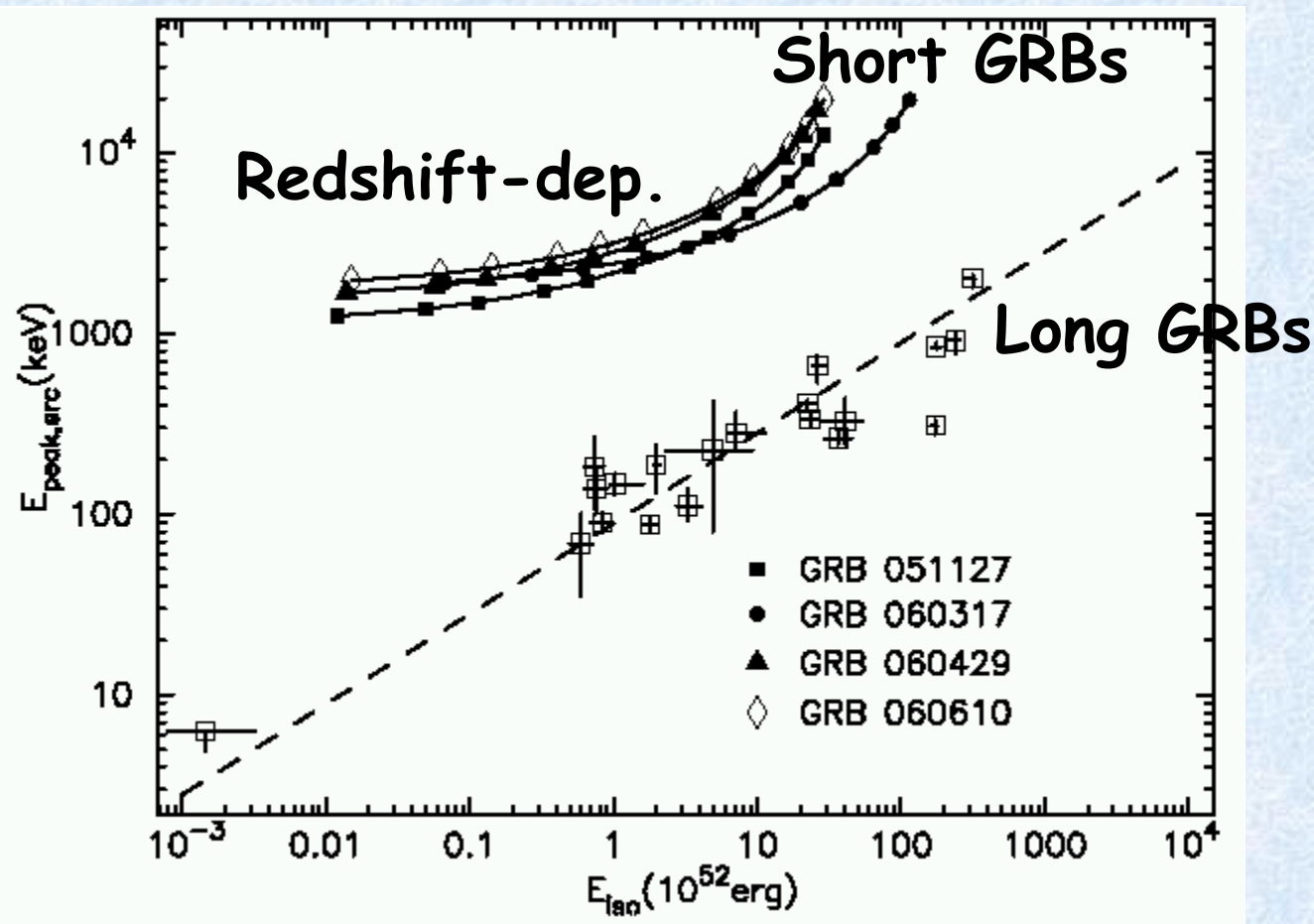
T90 distribution shows bimodal structure same as BATSE

We pick up 4 bright short GRBs (Konus, IPN).
 Constrained the Epeak accurately.

Epeak is constrained to be 1-5 MeV.



E peak



E iso

Different origin between short and long

Spectral lag

Cross Correlation Function (CCF)

TH0:50-110keV

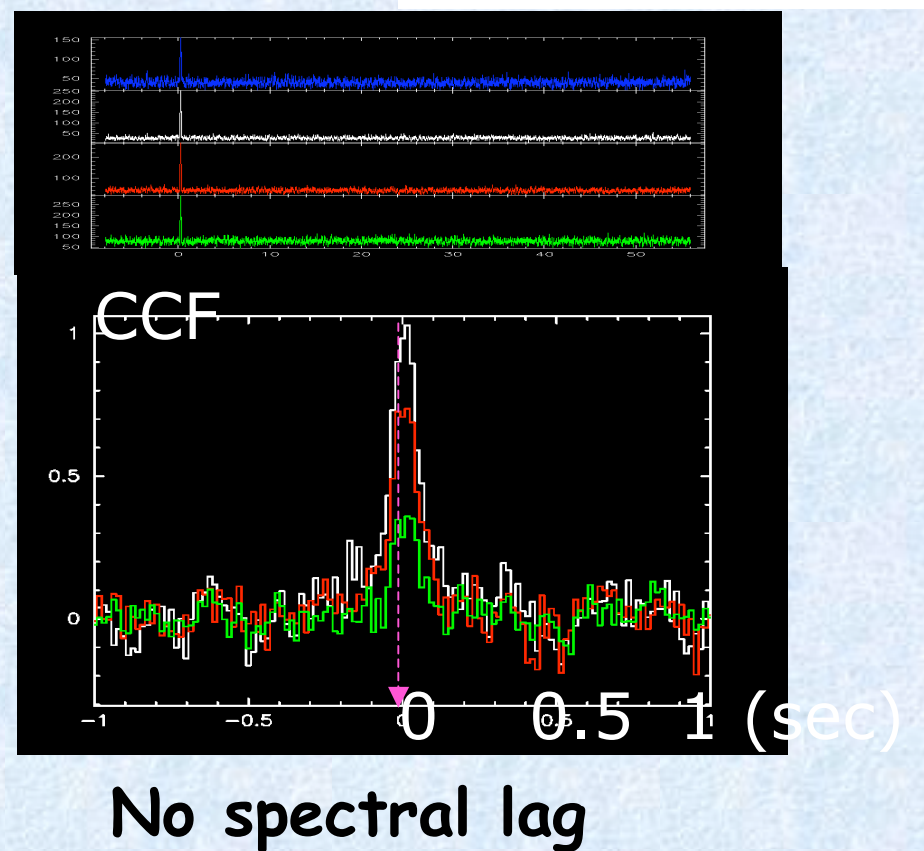
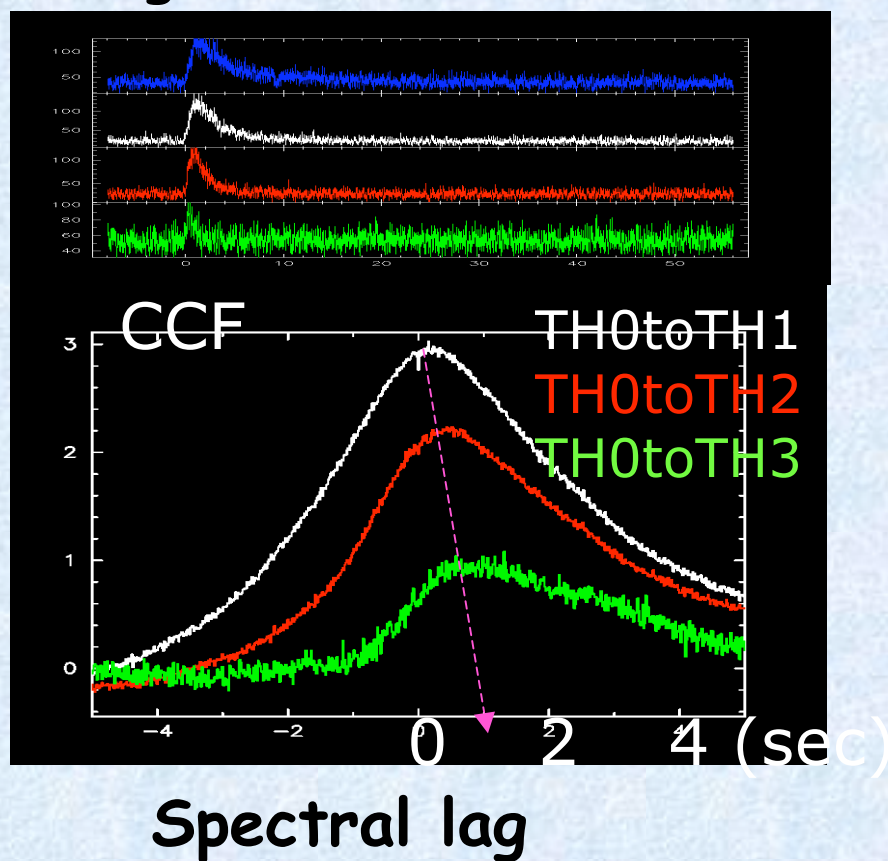
TH1:110-240

TH2:240-520

TH3:520-5000

Long GRB

Short GRB



Short GRBs vs Long GRBs

Spectral lag

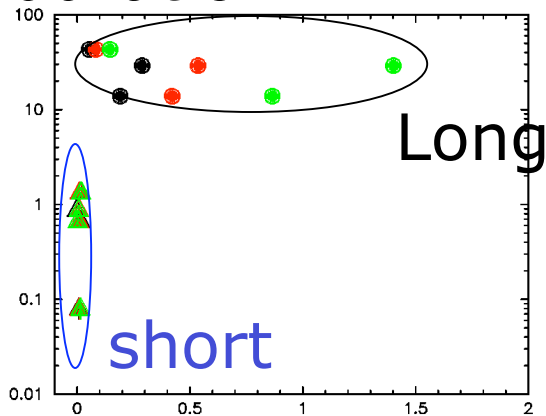
Hardness Ratio

Energy index

$$\frac{100-300\text{keV}}{50-100\text{keV}}$$

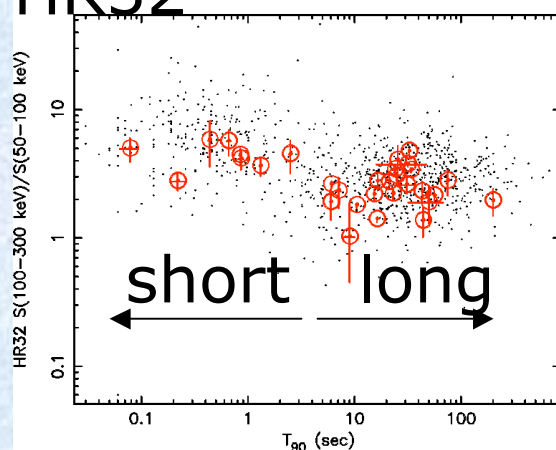
Toward
low energy

duration

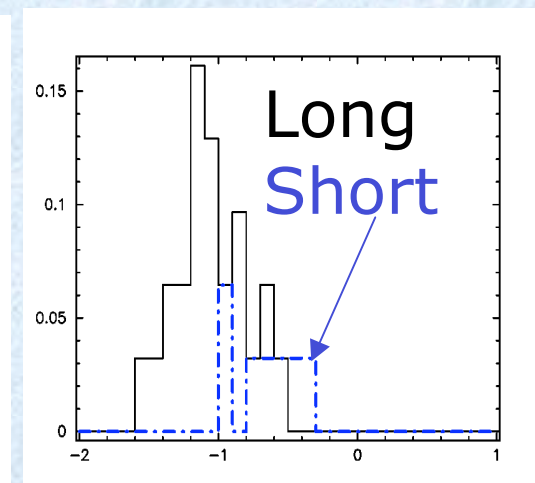


Lag

HR32



duration



index(α)

Different
Lorentz Factor?

Different physics of emission?

3. Spectral Evolution of GRBs

~ variability upto MeV energy band ~

Spectral evolution upto MeV band from some GRBs

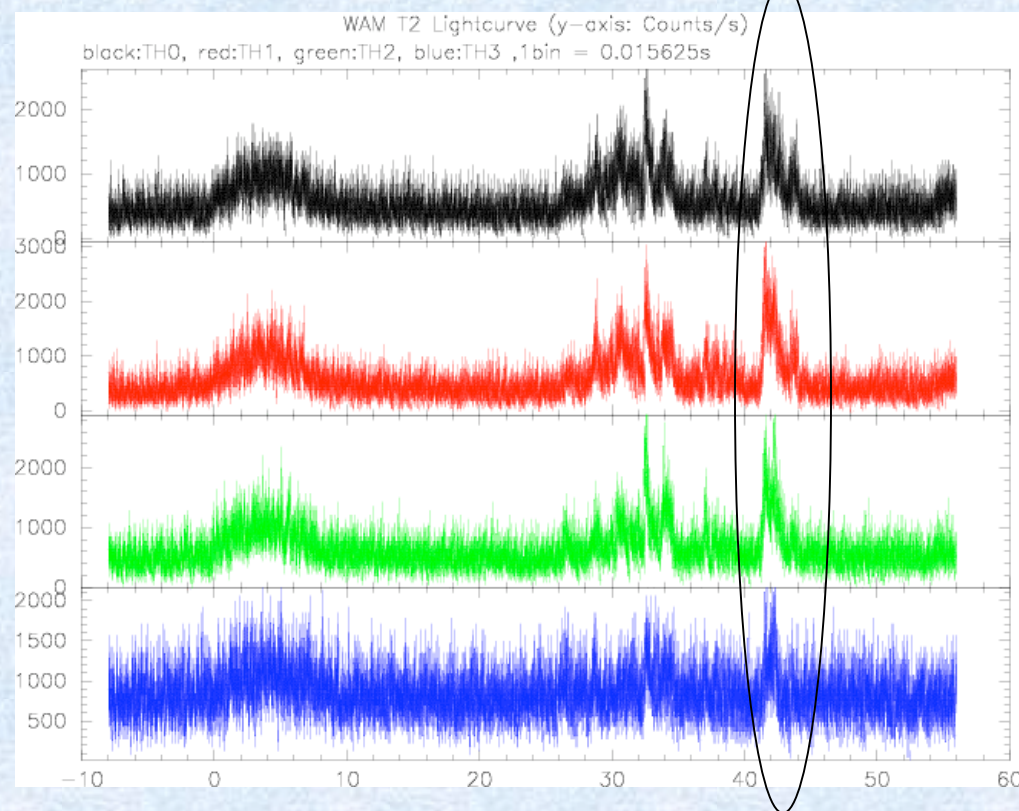
GRB070125

50-110keV

110-240keV

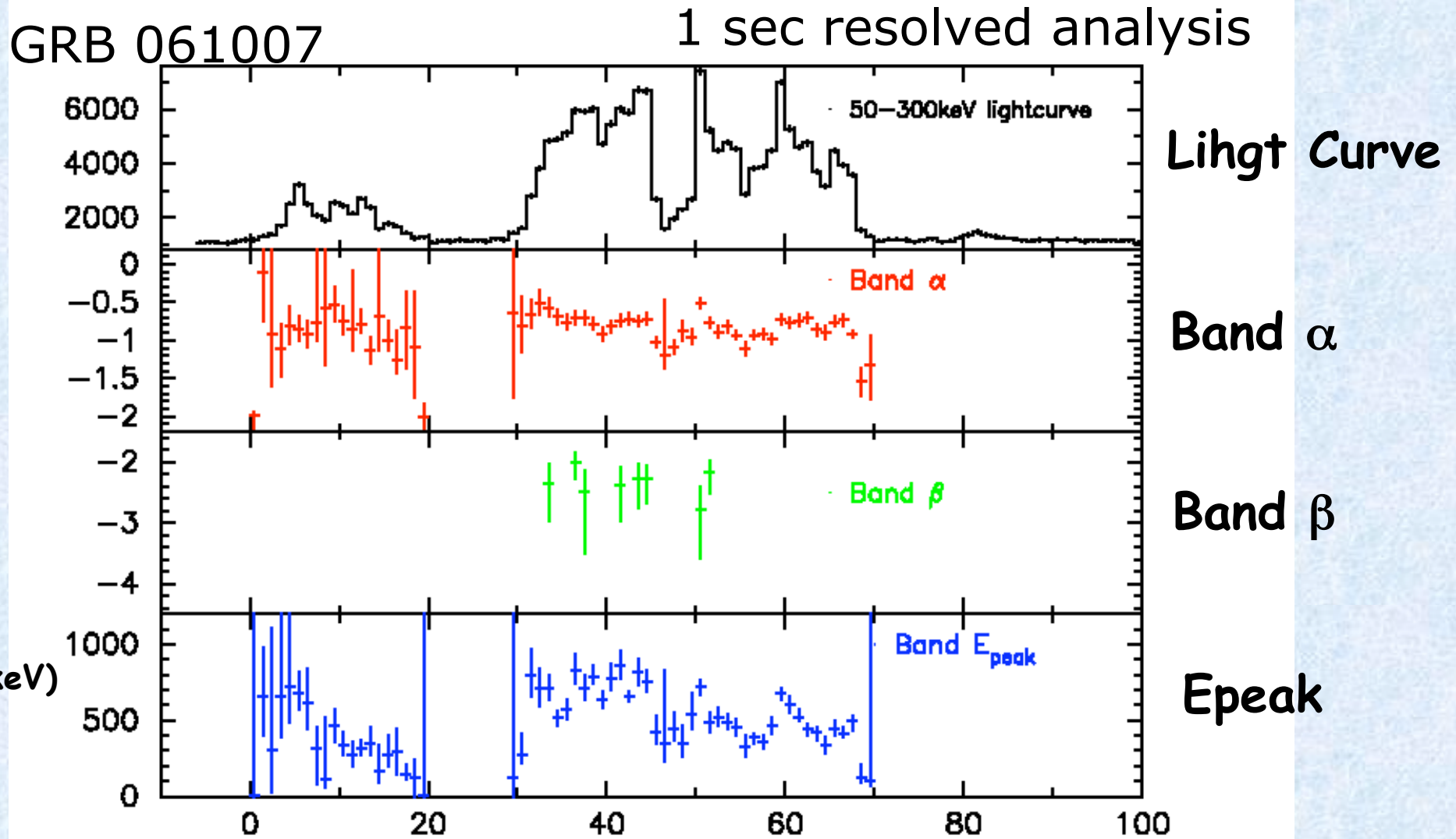
240-520keV

520-5000keV



GRB051008	GRB060213	GRB060813
Variable Epeak	Constant Epeak	Variable Epeak
<p>lightcurve</p> <p>2000 500</p> <p>2000(keV)</p> <p>Epeak</p>	<p>2000</p> <p>500</p> <p>2000</p> <p>Epeak</p>	<p>8000 6000 4000 2000</p> <p>500 200</p> <p>500</p> <p>Epeak</p>
Time since trigger(sec)		

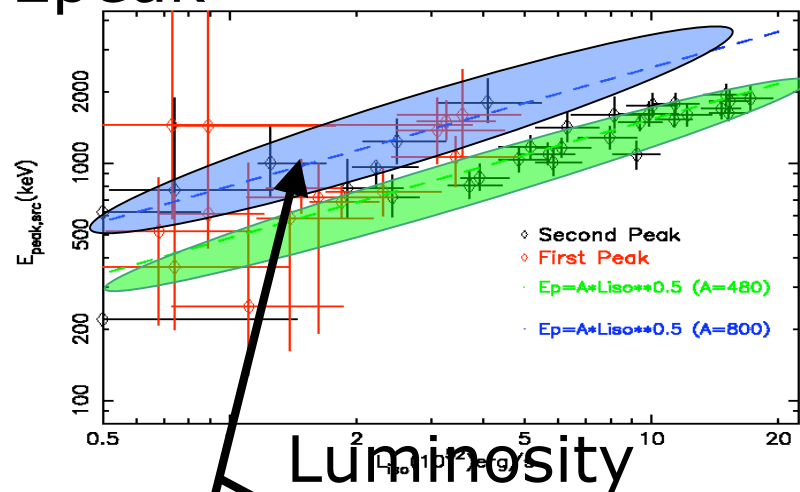
Time resolved analysis



Epeak - Eiso scatter plot for the time-resolved data of GRB 061007

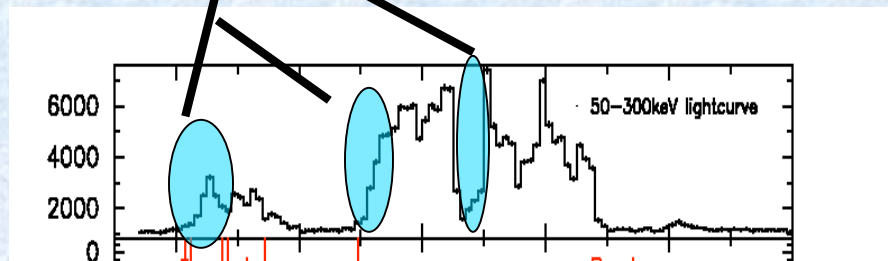
Most data satisfy
 $E_p \propto L_{iso}^{0.5}$

Epeak



Outlier?
 Higher E_p ?
 at the beginning of flares

Physical state transition?



This will be important to constrain the physics of the central engine.

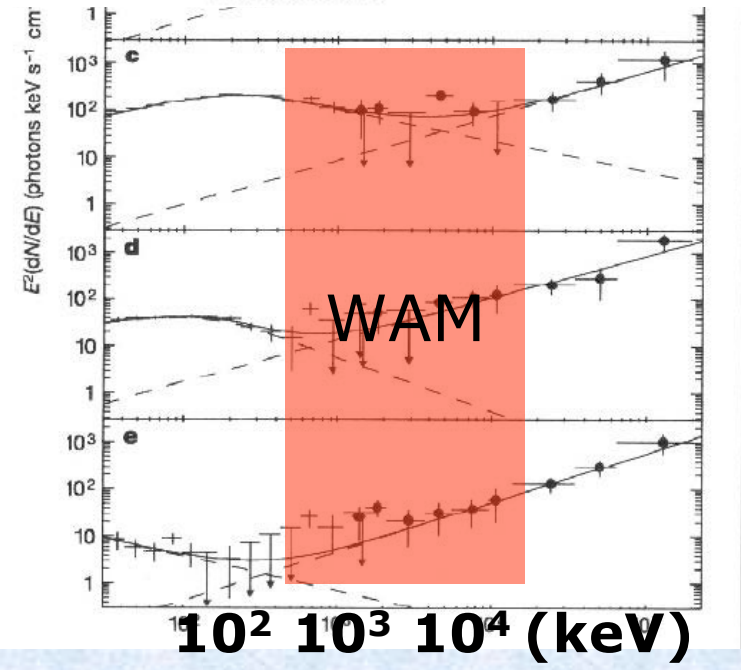
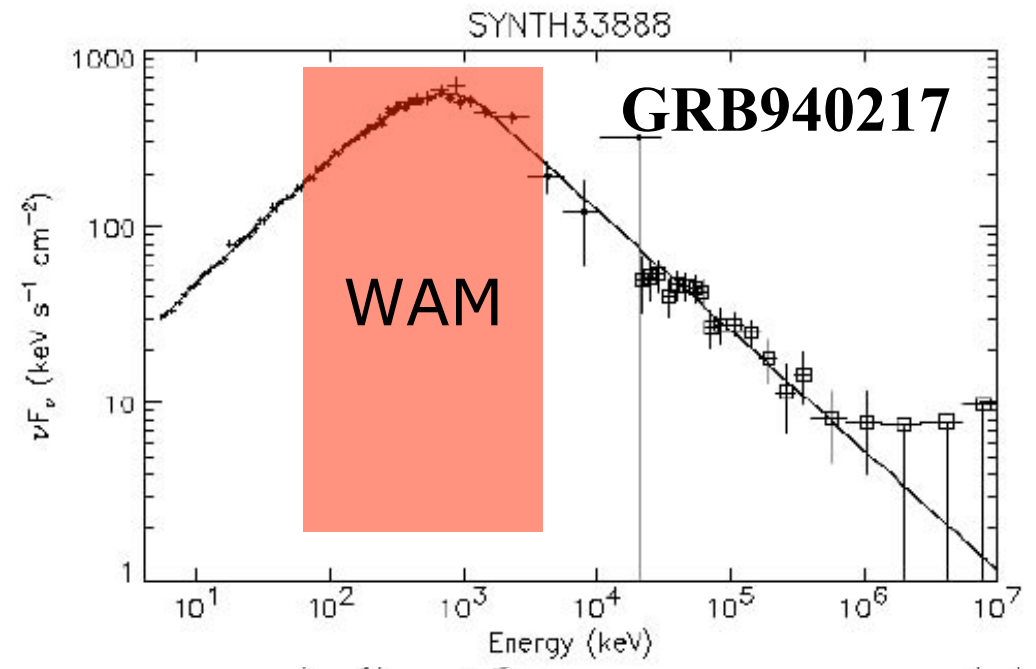
Expected science with GLAST

Smooth hard tail ?
Cut-off + other tail?
Epeak distribution?

Emission mechanism
Synchrotron?
Hadron?

Spectral evolution of the
high energy tail.

WAM will give a good photon
statistics around 100–5000 keV,
to constrain the spectral shape
and trace the spectral evolution.



Summary

WAM observations of GRBs

Some detailed spectral and timing analyses are being available

Ep distribution is similar (broader?) as BATSE
Different properties between Short and Long
Spectral evolution .. etc



WAM has been giving more accurate measurements of spectra and timing of prompt emission, following BATSE.

Collaboration with GLAST is hoped to open the new window for the high energy GRB emission !

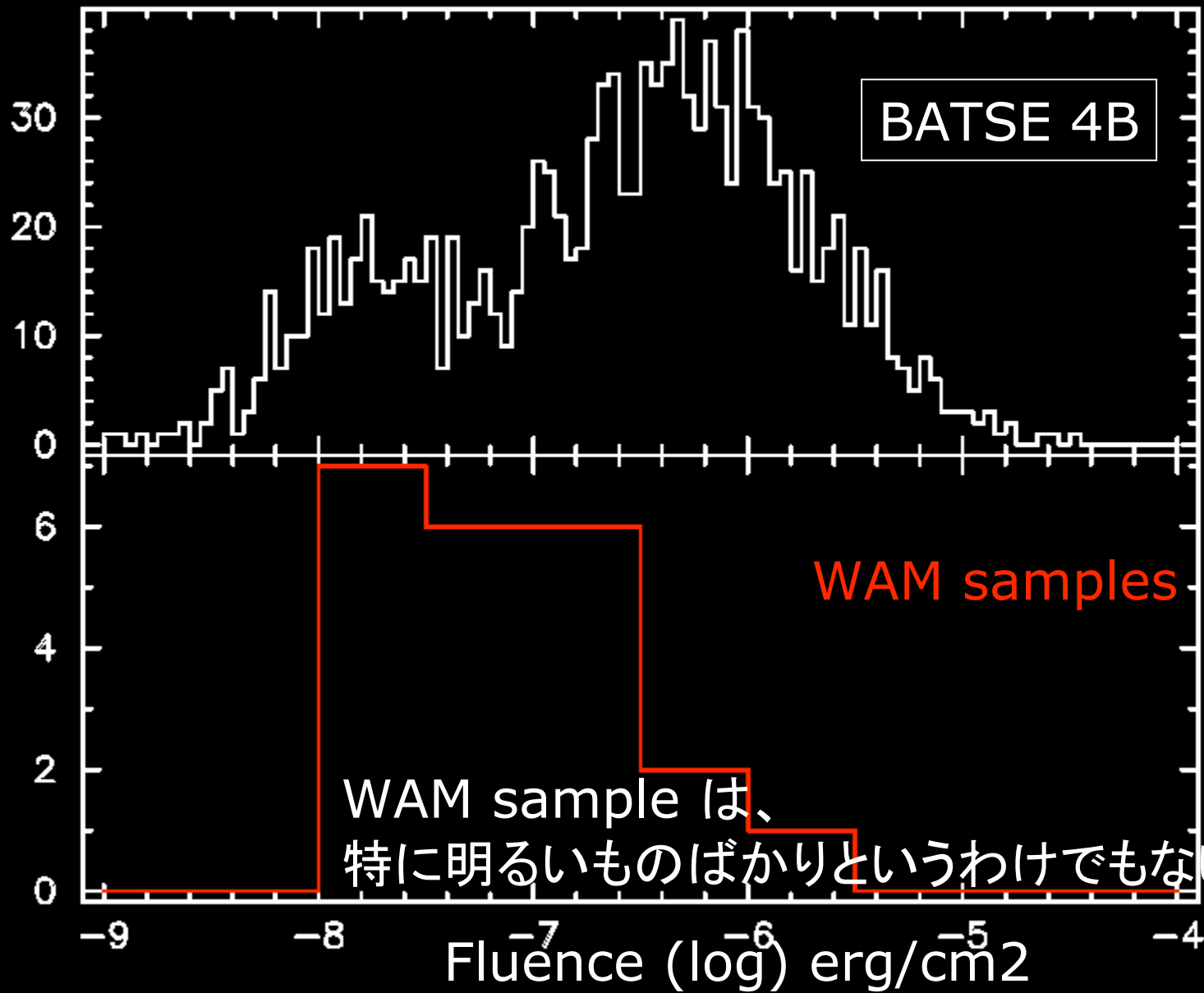
II. WAM performance

Comparison with other GRB missions

	Suzaku HXD-WAM	Swift BAT	BATSE LAD
Energy range (keV)	50 – 5000	15 – 150	20 – 2000
Energy resolution (@662keV)	30%	**%	20%
Effective area	400	5000	150
Time resolution	31.25ms	** ms	2 ms

HXD-WAM is very useful for GRB observation
in hard X-ray band complementary with Swift-BAT.

100-300 keV Fluence distribution



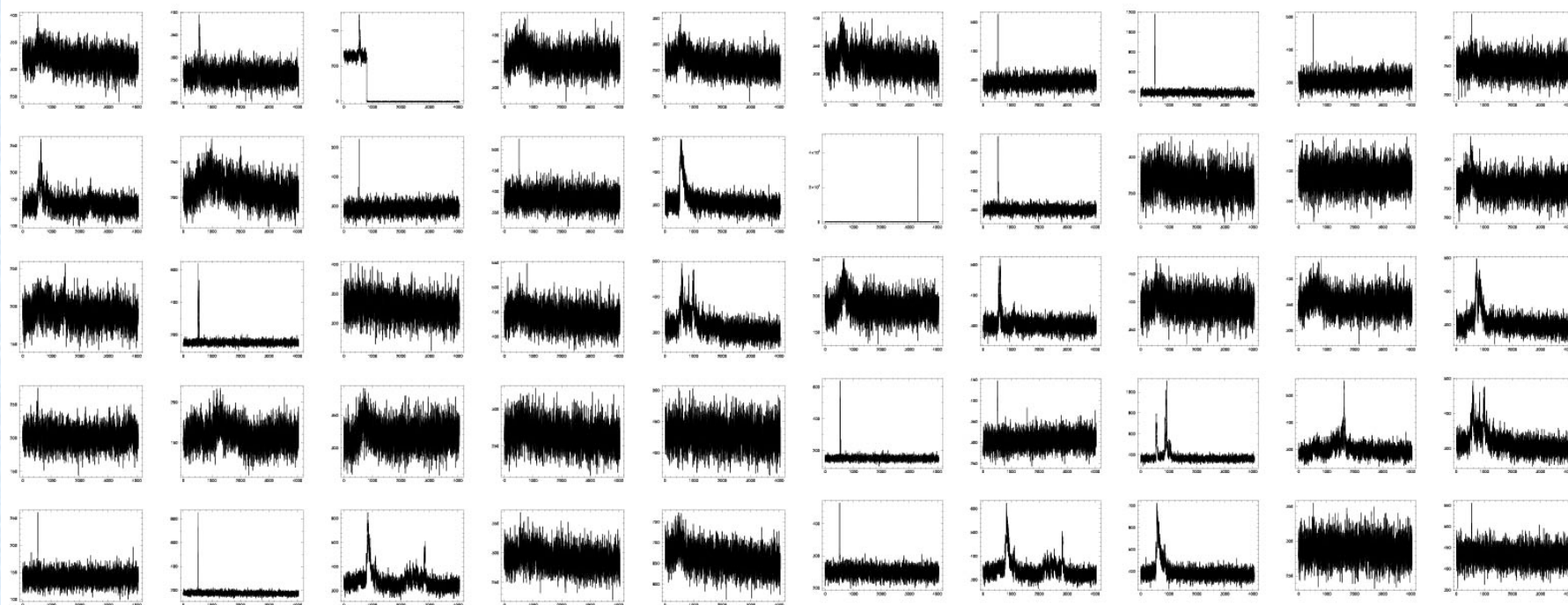
WAM sample は、
特に明るいものばかりというわけでもない(?)

Observations

No problems on the hardware

From Aug 25 – 2005 to Nov 2006, WAM detected
 160 self-triggerred GRBs and possible GRBs.

(~100 per 1 year)

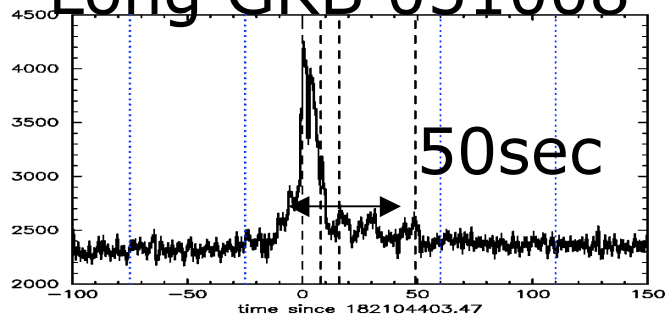


III. Results and Discussion

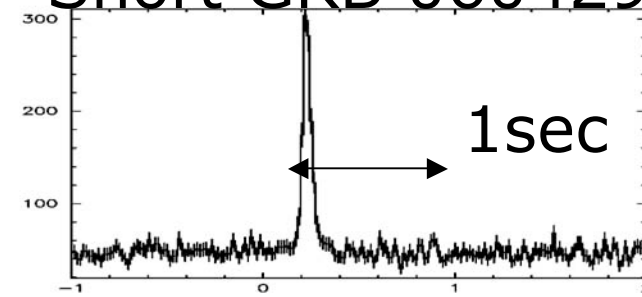
A. Time averaged analysis

45個のうち、31個のGRBにおいて、simple PL よりも cutoffPL, Band model で fit 改善 → Epeakを決めることができた

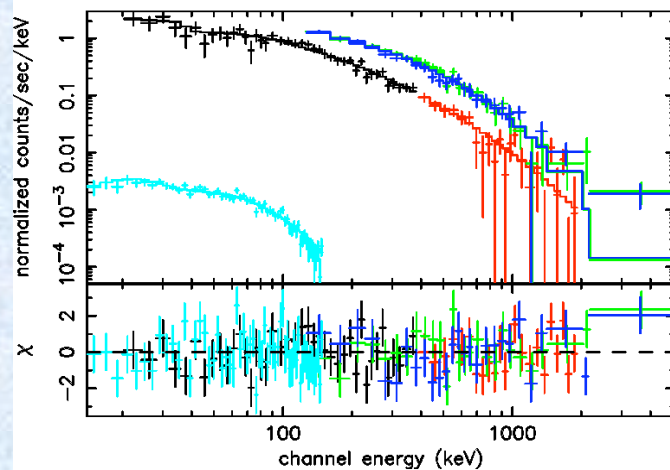
Long GRB 051008



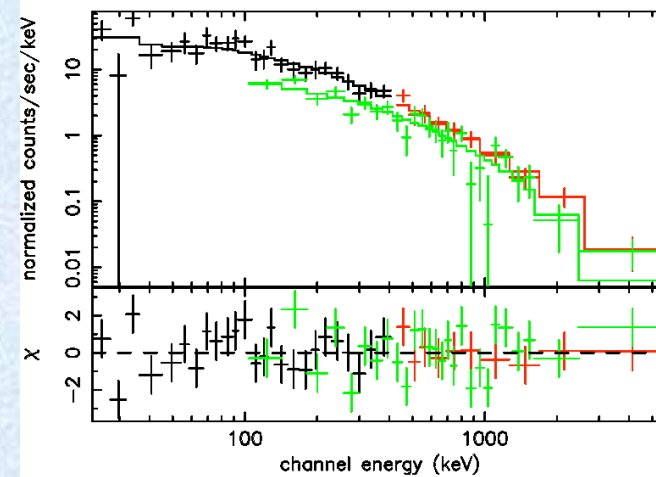
Short GRB 060429



data and folded model



data and folded model

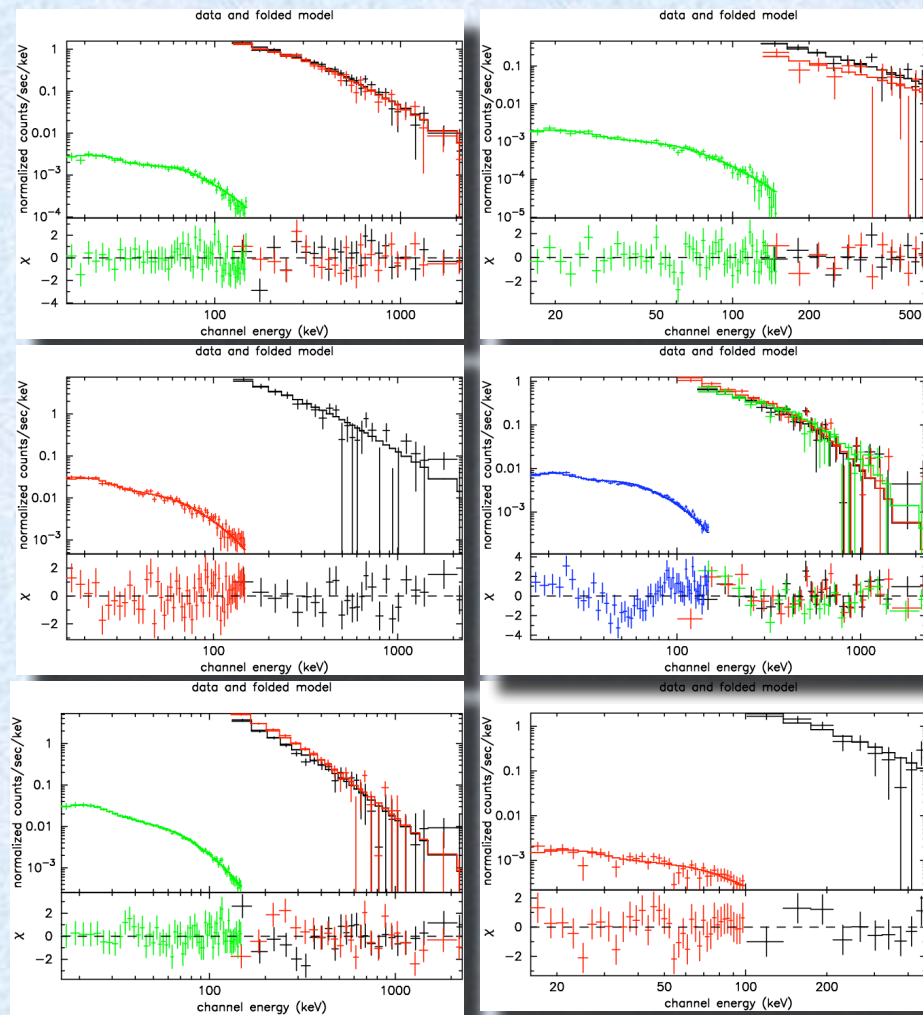


IV. WAM+BAT joint analysis

~ Epeak with WAM-BAT joint fitting ~

Many GRBs can be determined the E_p by joint fit

with Swift/BAT



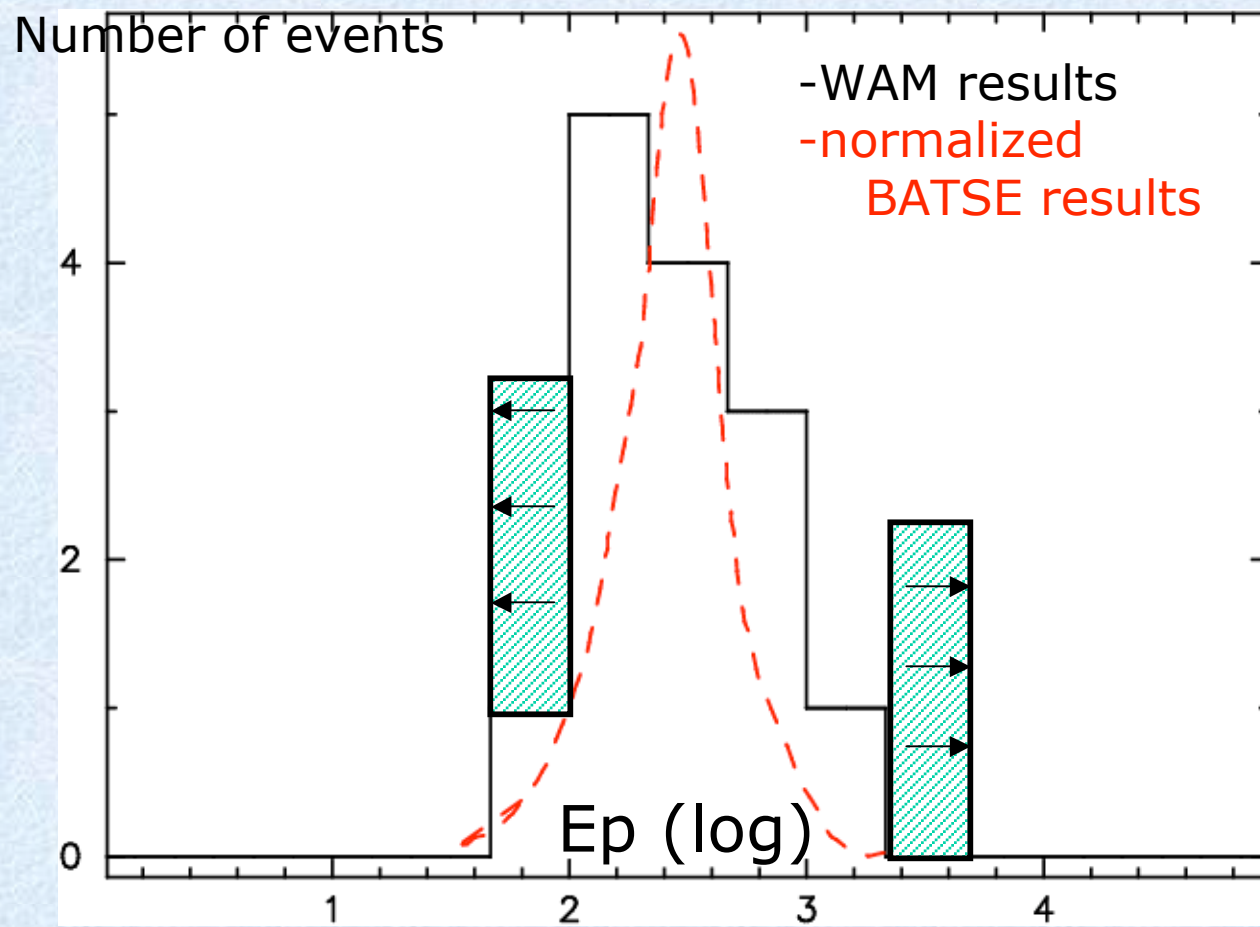
	Epeak (keV)
GRB051008	822^{+779}_{-329}
GRB051111	174^{+263}_{-131}
GRB051221	461^{+938}_{-244}
GRB060105	450^{+71}_{-30}
GRB060111	462^{+290}_{-242}
GRB060117	68^{+34}_{-27}
GRB060306	112^{+110}_{-70}
GRB060501	220^{+296}_{-86}
GRB060502	170^{+5000}_{-120}

WAM+BAT joint fit
 is very powerful tool for E_p !

IV. WAM+BAT joint analysis

~ *E_{peak}* distribution ~

E_{peak} distribution from all position determined GRBs
 (WAM-BAT joint fit + IPN localized GRBs)



Similar to
 BATSE results

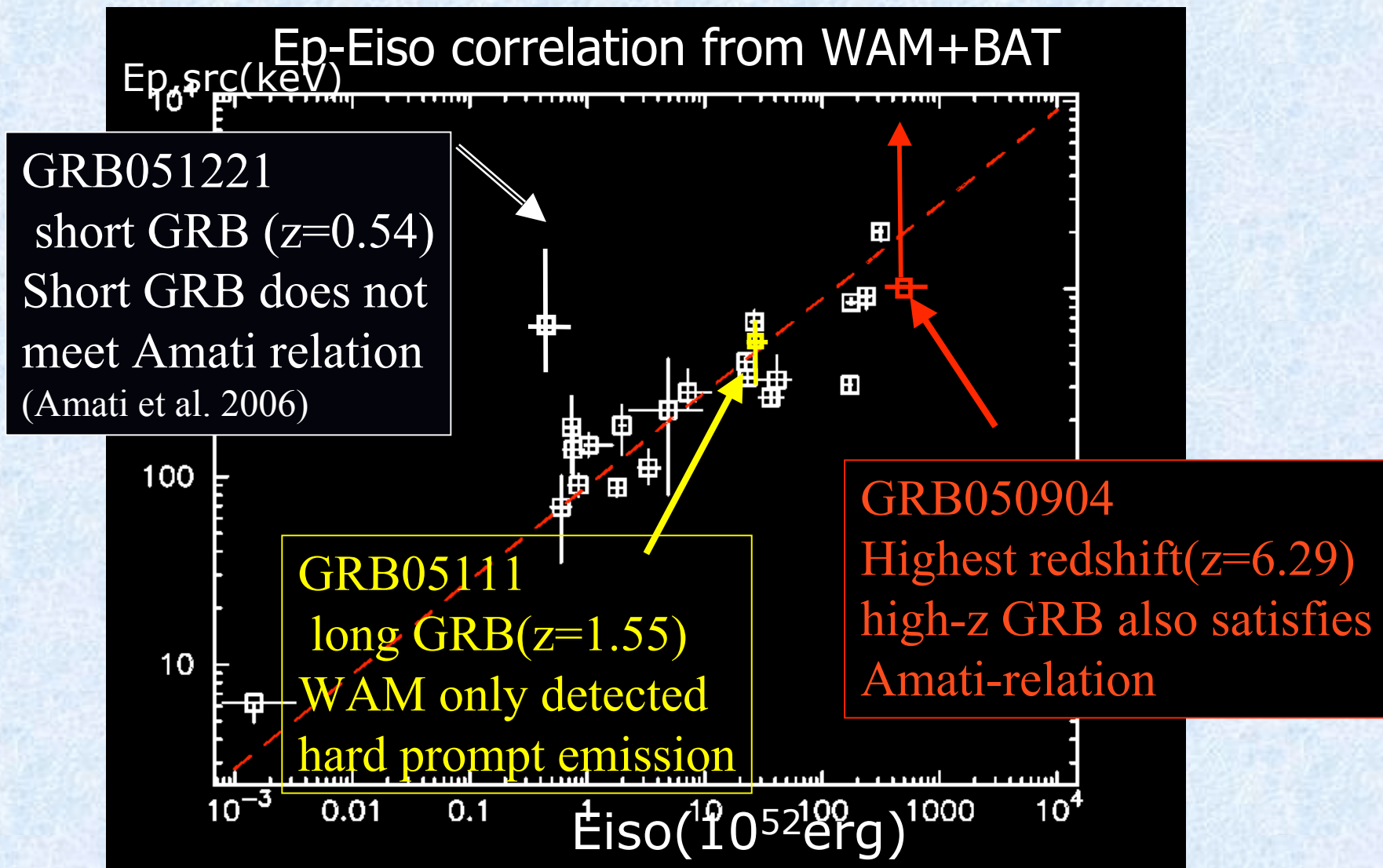
but

Broader in high
 energy band than
 BATSE ??

more samples
 are required !

IV. WAM+BAT joint analysis

~ E_p -Eiso correlation ~



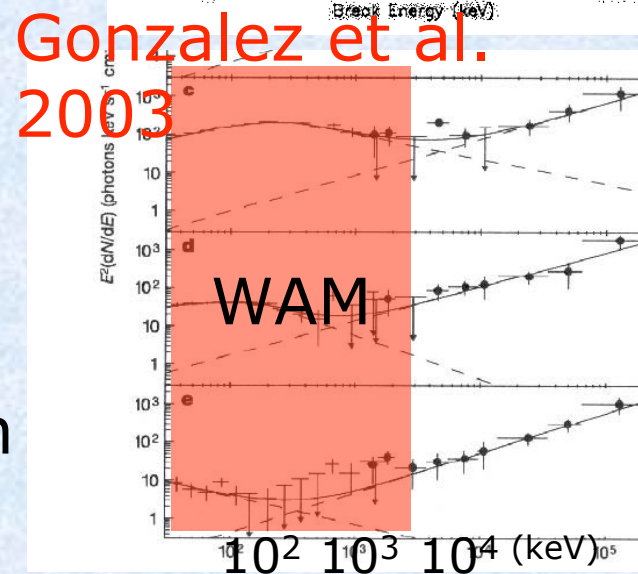
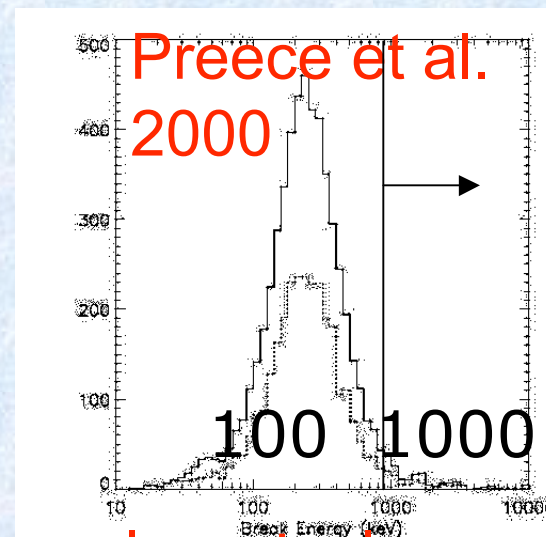
II. GRB sciences with the WAM

Obtain the unbiased E_{peak} distribution.

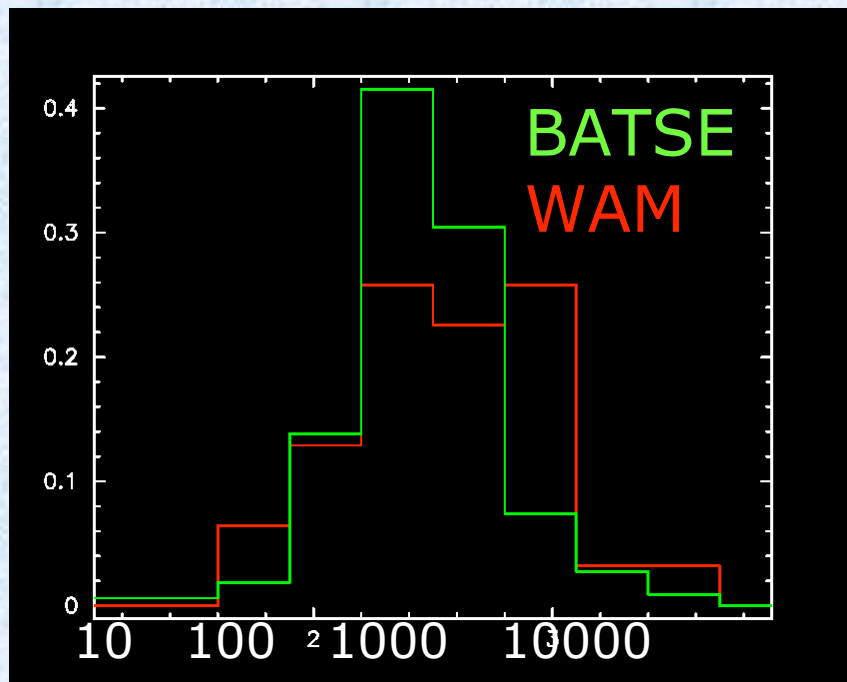
- ✧ There are few sample of high energy E_{peak} .
- ✧ High sensitive observation up to MeV region is needed.

Does MeV-GeV excess emission really exists? What's origin?

- ✧ Delayed excess emission against main synchrotron emission.
- ✧ Time variability around MeV region is important.



Comparison of Epeak dist.



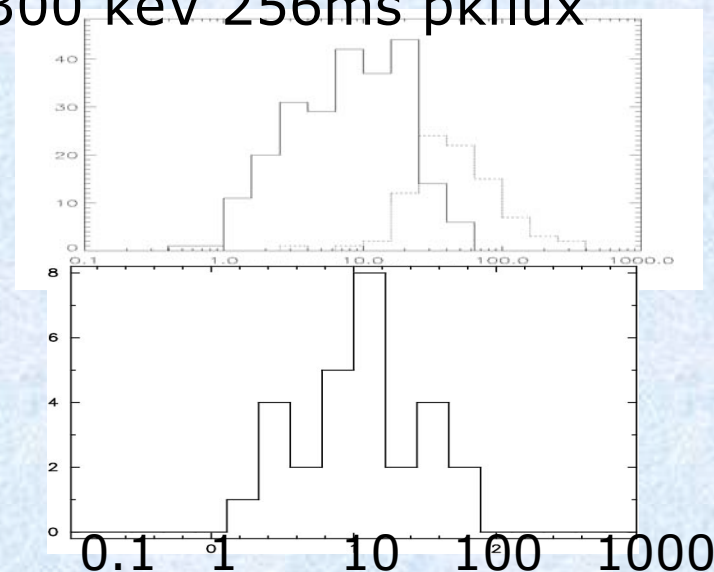
Kolmogorov-Smilnov
probability: ~15%

It seems almost similar ?

Selection effect ?

Epeak は明るさに比例する
という報告(Shaefer 2003)。
同じような明るさのGRBを捉えて
いたとするならば、分布は
似てくるかも

0-300 keV 256ms pkflux



IV. Spectral Evolution of GRBs

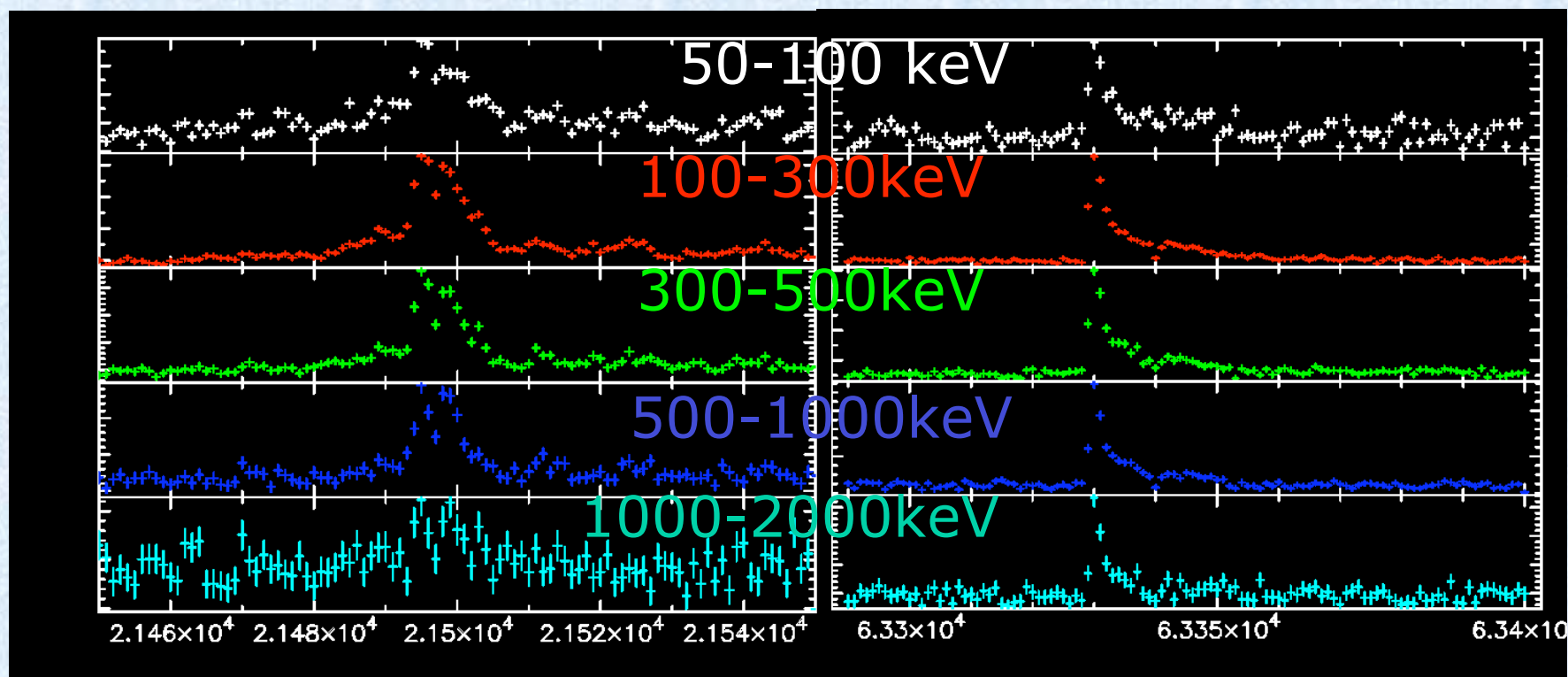
~ variability upto MeV energy band ~

Time variability upto MeV band from some GRBs

- Search for spectral evolution in MeV region
- Detail analysis is in progress

GRB051008

GRB060213

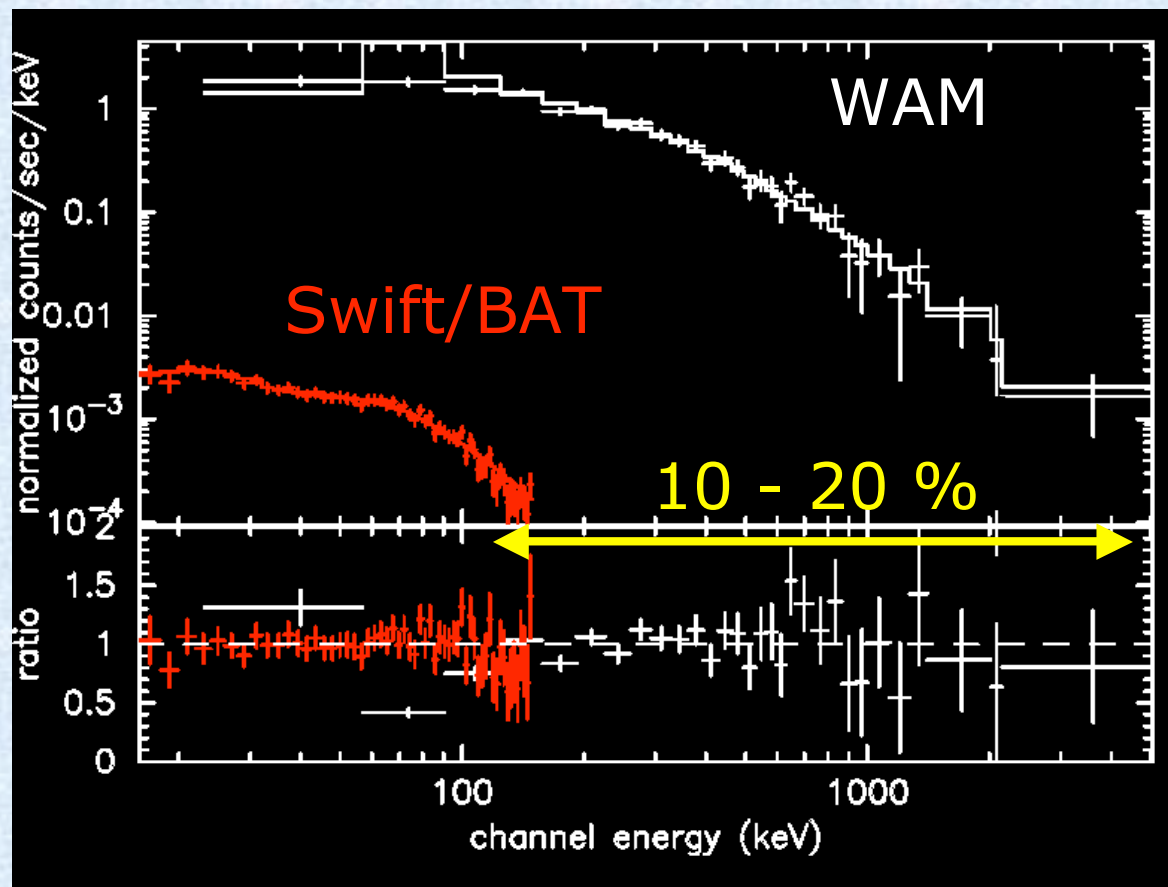


IV. WAM+BAT joint analysis

~ joint fitting with Swift/BAT ~

Some GRBs are detected by WAM and Swift/BAT simultaneously

WAM+BAT joint fitting



➤ More wide coverage for Epeak

➤ Cross calibration for each other

Now, WAM response uncertainty was fixed within 10-20% in more than 100 keV band