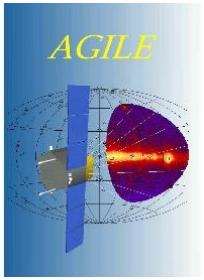

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The Mini-Calorimeter Onboard AGILE: the First Year in Space

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INAF-IASF Bologna

on behalf of the AGILE collaboration

CALOR 2008, Pavia, 26-30 May 2008

The AGILE mission

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- AGILE (Astrorivelatore Gamma a Immagini Leggero): an Italian Space Agency (ASI) mission with co-participation of INAF and INFN devoted to gamma-ray astrophysics
- Launched on 23rd April 2007 on a PSLV-C8 rocket from Satish Dawan Space Center (india)
- Quasi-equatorial Low-Earth Orbit: ~535 km altitude, 2.48° inclination

The AGILE Spacecraft

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Scientific Payload:
60x60x60 cm^3
100 kg
integration by
Thales Alenia-Space

2 m height
350 kg

attitude control:
star trackers,
reaction wheel,
magnetometer

timing: gps

spacecraft based on
MITA platform
provided by Garlo
Gavazzi Space

The AGILE Payload

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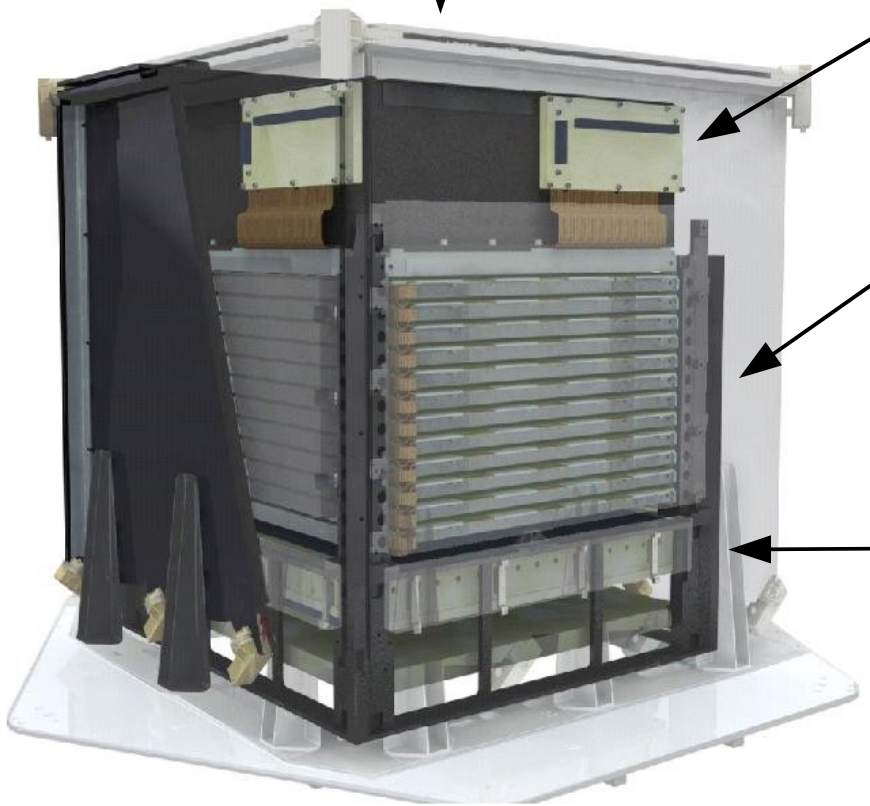
Anticoincidence Shield (AC) - INAF-IASF Milano
plastic scintillator + PMT readout

SuperAGILE (SA) - INAF-IASF Roma
silicon-strip + coded mask instrument
15 – 45 keV range



Silicon Tracker (ST) - INFN Trieste
tungsten / silicon-strip detector 12 trays
30 MeV – 50 GeV range

Mini-CALorimeter (MCAL) – INAF-IASF Bologna
in collaboration with Thales Alenia Space Italia
(formerly Laben), Milano
CsI(Tl) scintillating bars with PD readout

MCAL Design

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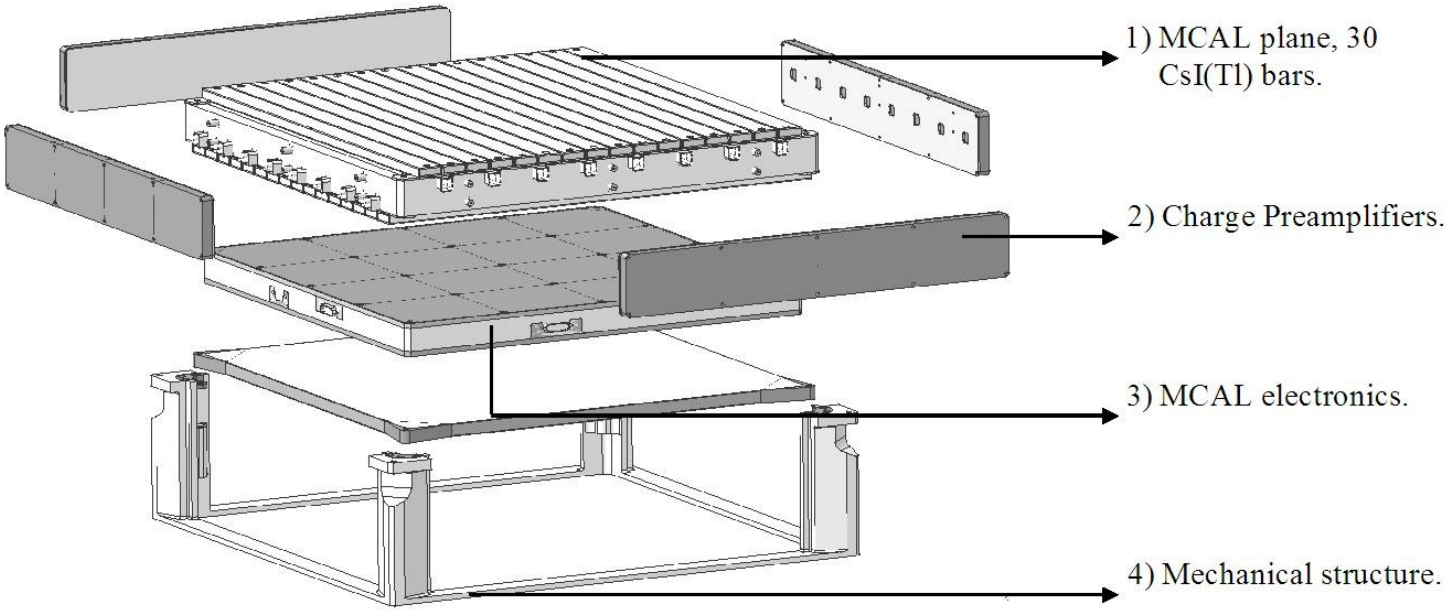

Tradeoff between science goals and mission constraints:

- same footprint of the Silicon Tracker
- low weight available → limited thickness/stopping power
- low power consumption → limited number of channels

Goal: compensate stringent constraints with clever architecture and logic

The Mini-Calorimeter (MCAL)

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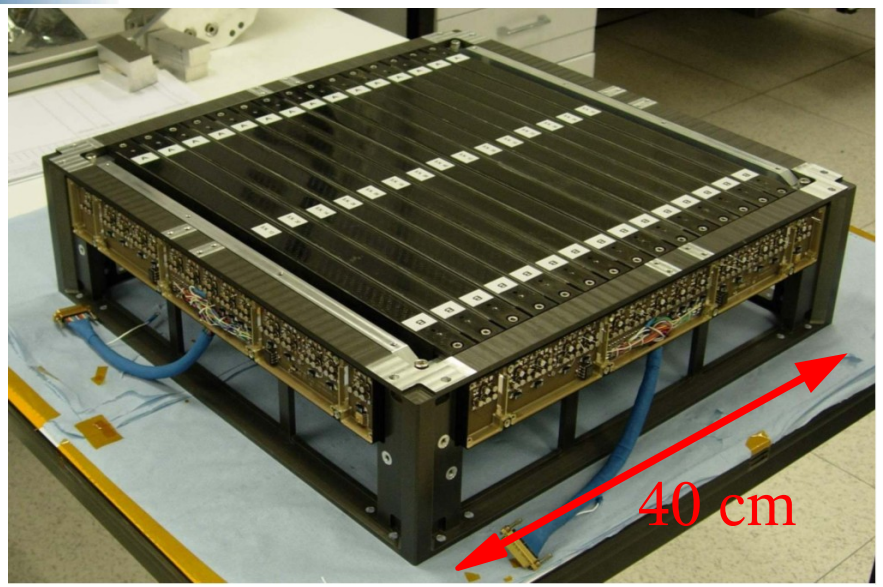
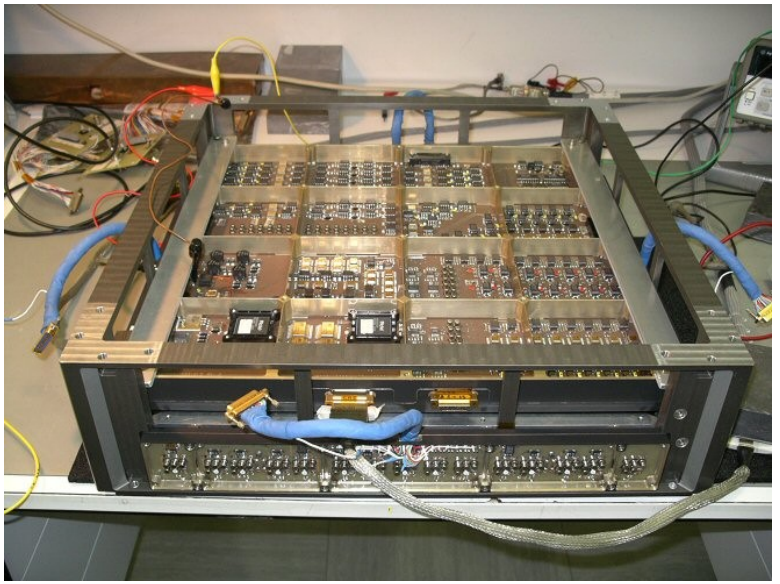
Top view



Bottom view



- 30 CsI(Tl) bars with Photodiode readout, like these
- 1400 cm^2 geometrical area
- ~360 cm^2 effective area @ 1 MeV
- 330 keV – 100 MeV energy range
- 14% energy resolution FWHM @ 1.3 MeV
- 2 μs timing accuracy in photon-by-photon mode
- Clever, fully-programmable GRB trigger logic

MCAL Bars Detectors

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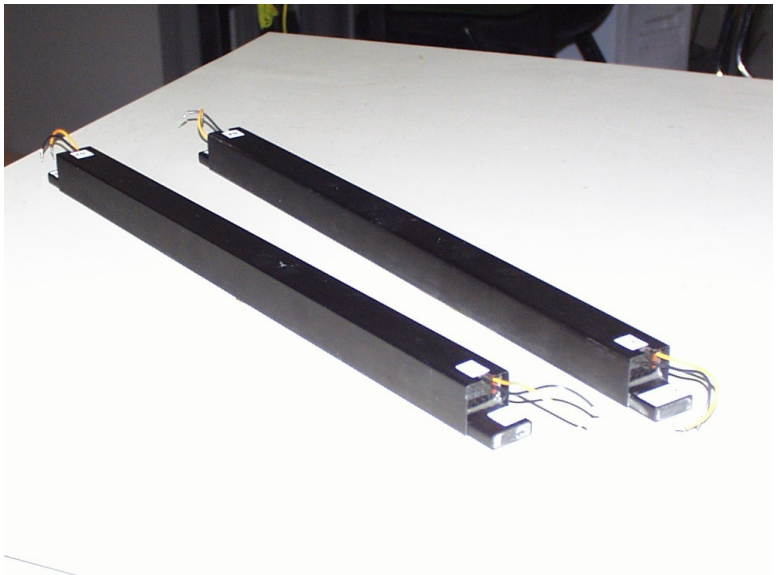


- 30 CsI(Tl) scintillating bars arranged in two orthogonal layers
- each bar is 375x23x15 mm with custom PIN PD glued at the bar's ends
- 256 mm^2 PD: 130 pF capacitance, 1.5 nA leakage current @ 20°C
- all bars wrapped with reflective coating and housed in a carbon fibre structure
- all bars characterized independently before integration

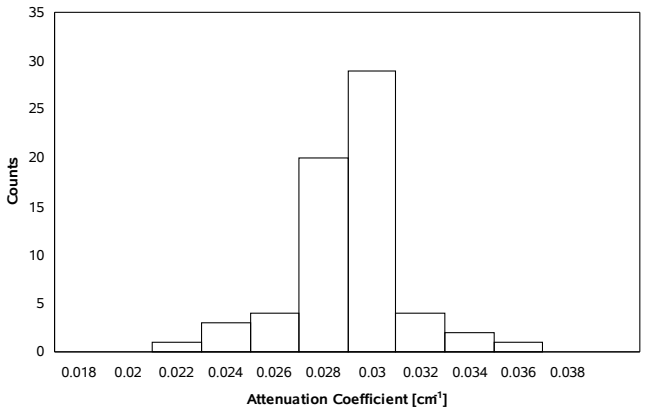
- collected signal well described l exponential law:

$$U(x) = EU_0 e^{-\alpha x}$$

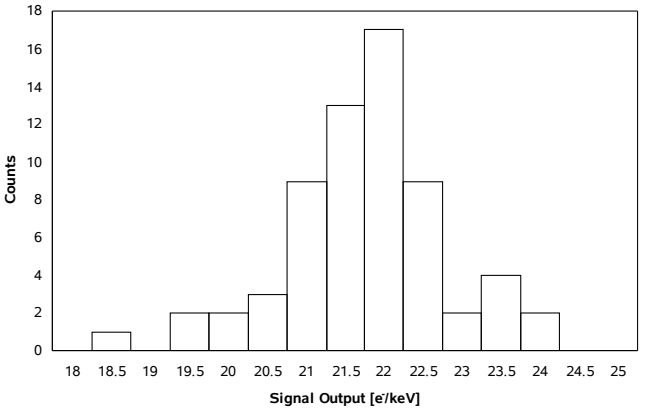
U_0 signal output at PD

α light attenuation coefficient

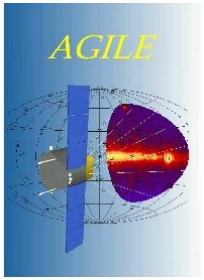
E inciden energy, x incident position



$\alpha = 0.028 \pm 0.002$ cm^{-1}



$U_0 = 21 \pm 1$ e^-/keV



Operative Modes

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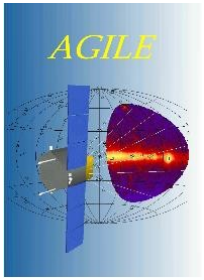
- GRID mode: MCAL slave to the Tracker. After a trigger, all bars above a threshold are acquired. Scientific objective: contribution to GRID events energy reconstruction.
- BURST mode: MCAL works as an independent detector. After a dedicated logic has triggered a significant count rate increase, all MCAL data are saved in photon-by-photon mode. Scientific objective: GRB and intense transients high energy spectral coverage
- Scientific Ratemeters: due to telemetry limitations, in normal operating conditions MCAL cannot work in photon-by-photon mode. Self triggered events are used to fill two 11 bands energy spectra (one per detection plane) that are recorded and sent to telemetry every second. Scientific objective: all-sky gamma-ray background monitoring



MCAL and GRBs 1

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- Several GRB detectors currently operating onboard different spacecrafts: different energy range, effective area, trigger criteria, time resolution...

  -> different contributions to GRB science

- MCAL strength points:
  - good effective area in the MeV range
  - high time resolution data for triggered events (photon-by-photon data)
- MCAL weak point:
  - relatively high energy threshold
- MCAL tailored for the detection of medium-bright short / hard bursts
- In the MeV range, apart from MCAL only RHESSI allows photon-by-photon data with microsec timing accuracy: DISCOVERY SPACE!

MCAL and GRBs 2

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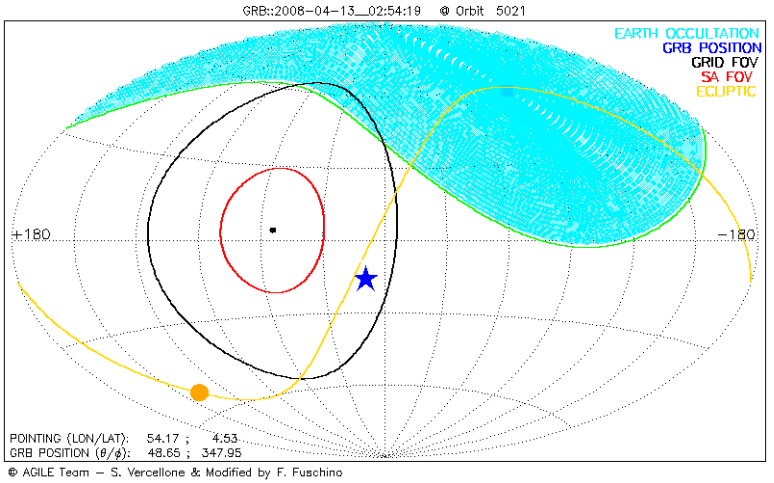
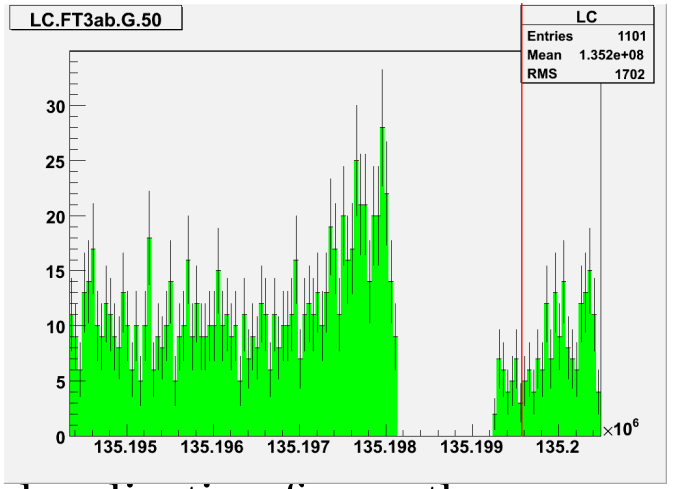
- Quick pathfinder for the GRID: GRBs with emission above ~100 MeV are expected to be bright in the ~MeV range; MCAL can provide a "ranking" of the GRB





- MCAL has no imaging capabilities: must rely on localization from other spacecrafts (Swift, INTEGRAL) or the Interplanetary Network (K. Hurley @ UC Berkeley http://www.ssl.berkeley.edu/ipn3/)

- MCAL (as well as SA) joined the 3rd Interplanetary Network (IPN): AGILE is the 4th spacecraft in LEO currently operative in the IPN after Swift, RHESSI and Suzaku

MCAL and its IPN partners

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AGILE & IPN: 37 confirmed cosmic GRBs detected by AGILE between 22nd June '07 - 31st Jan. '08:

	MARS-ODYSSEY / GRS	MESSENGER / GRNS	INTEGRAL / SPI-ACS	WIND / KONUS	SUZAKU / WAM	RHESSI / GeD	SWIFT / BAT
Energy range	50 keV – 10 MeV	> 50 keV	> 75 keV	10 keV – 10 MeV	50 keV – 5 MeV	20 keV – 17 MeV	15 - 150 keV
Spectral capabilities in trigger mode	NO	NO	NO	YES: 63ch / 3 ch	YES: 4 ch	YES	YES
Minimum time resolution	32 ms	1 s	50 ms	>64 ms / >2 ms	>16 ms	~µs (photon-by-photon)	~µs (photon-by-photon)

Detector with superposition > 80% with the MCAL sample and good spectral capabilities: cross-calibration activity ongoing

Detectors with spectral capabilities in the MeV range

Detector with photon-by-photon microsecond timing accuracy in the MeV range

MCAL Trigger Logic

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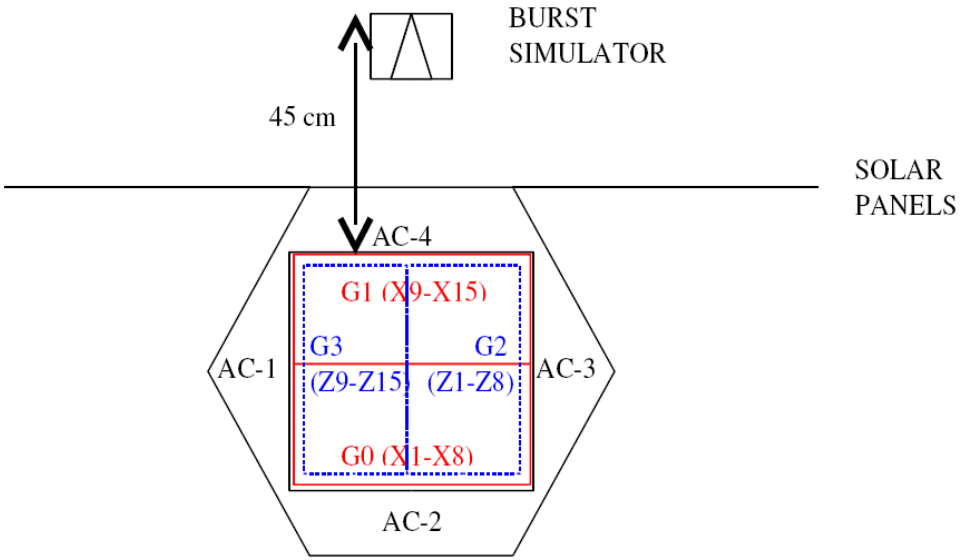

MCAL Burst Search logic:

- 1ms, 16ms, 64ms, 256ms, 1.024s, 8.192s Search Integration Time (SIT)
- 4 spatial zones and 3 energy ranges (<700 keV, 700-1400 keV, >1400 keV)
- static and dinamic thresholds for start and stop generation
- dedicated look-up tables to accept/reject triggers
- very flexible: more than 2000 parameters for full configuration

Configured in November 2007, steadily active since February 2008

MCAL Trigger Logic in action: GRB 080303

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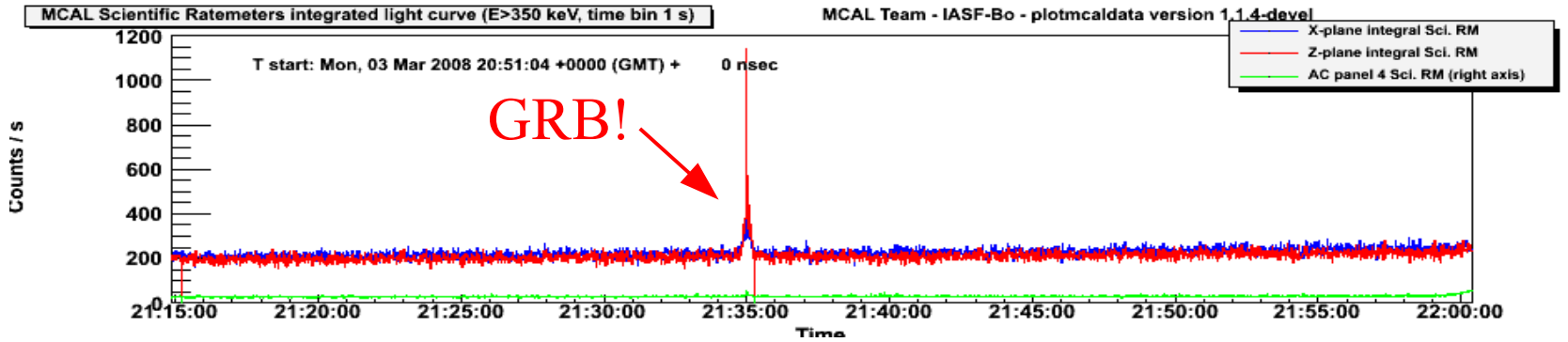

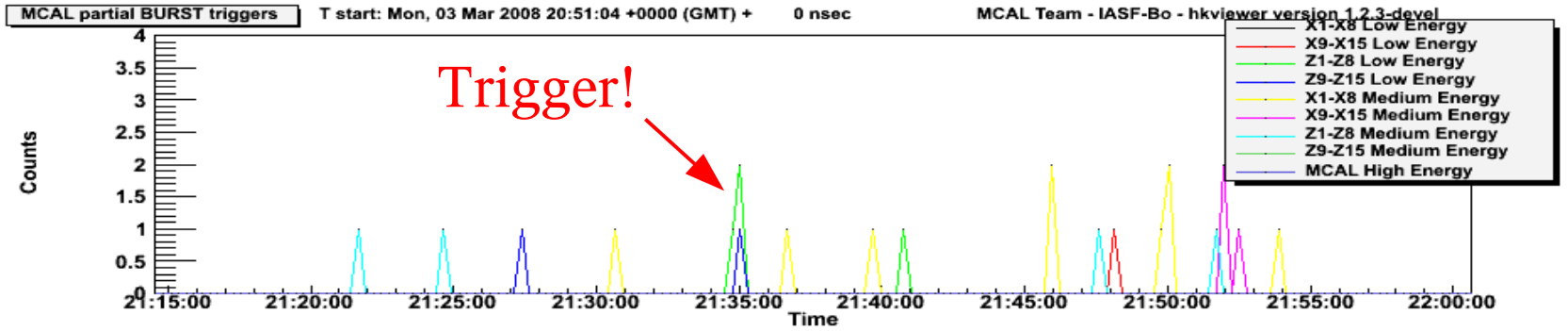

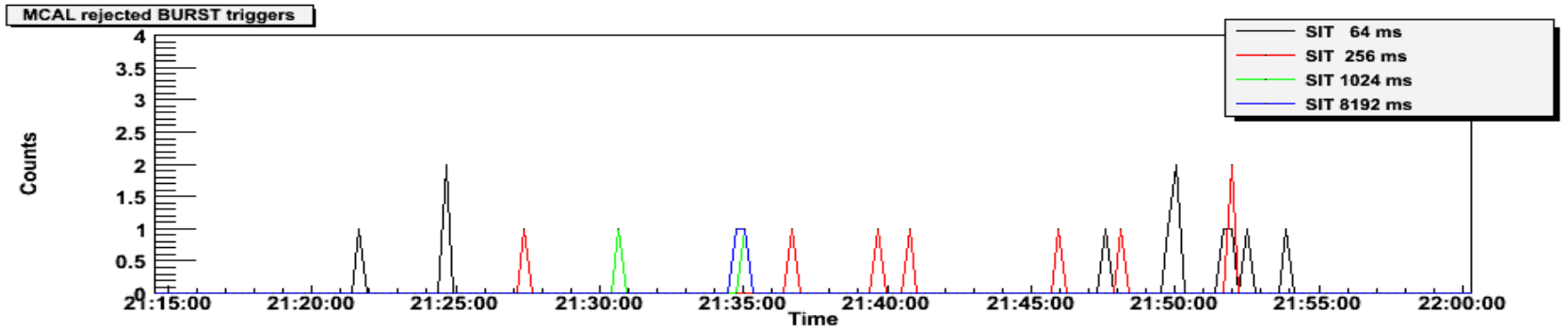

Trigger Logic results: GRB 080303 in photon-by-photon

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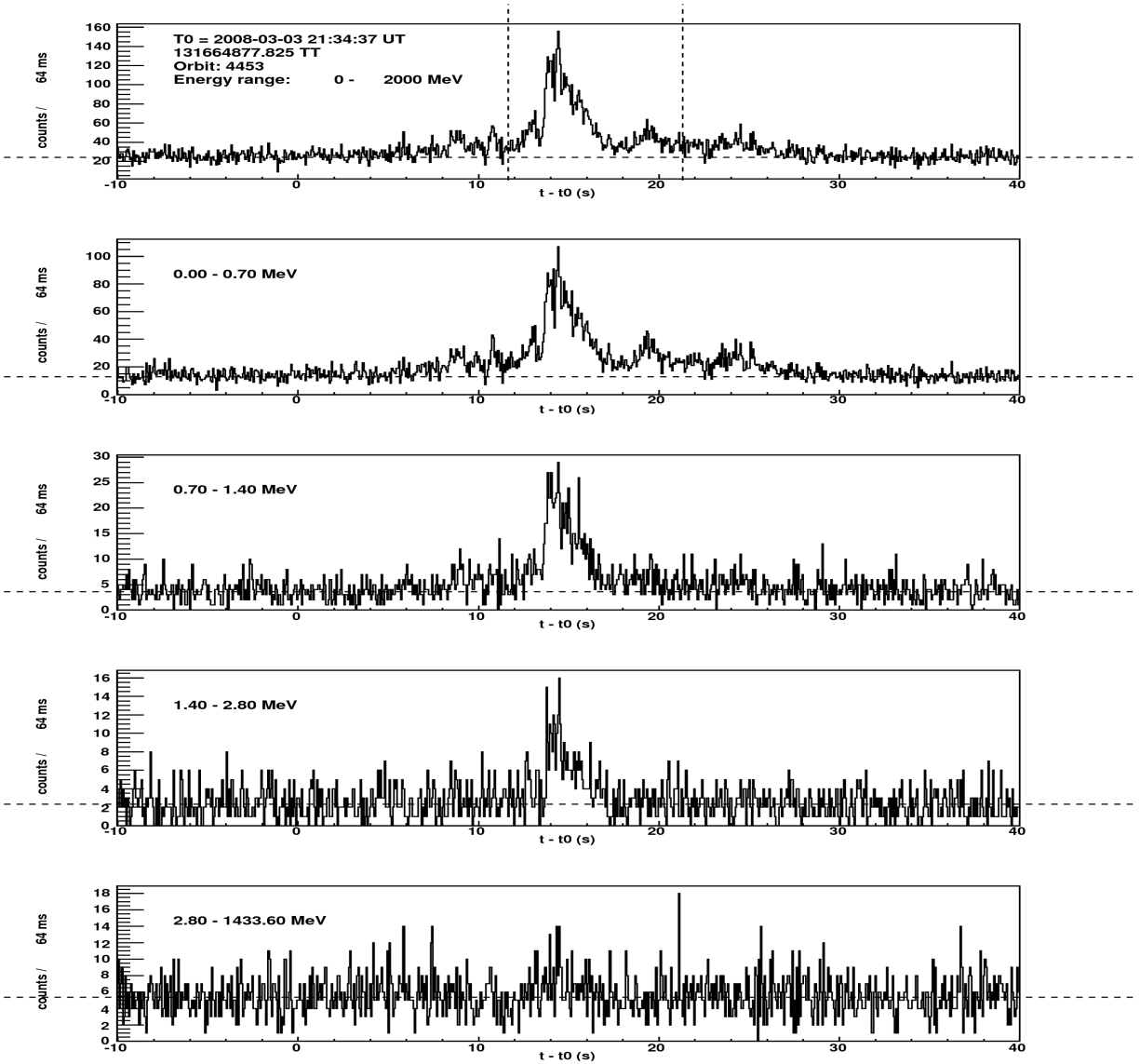
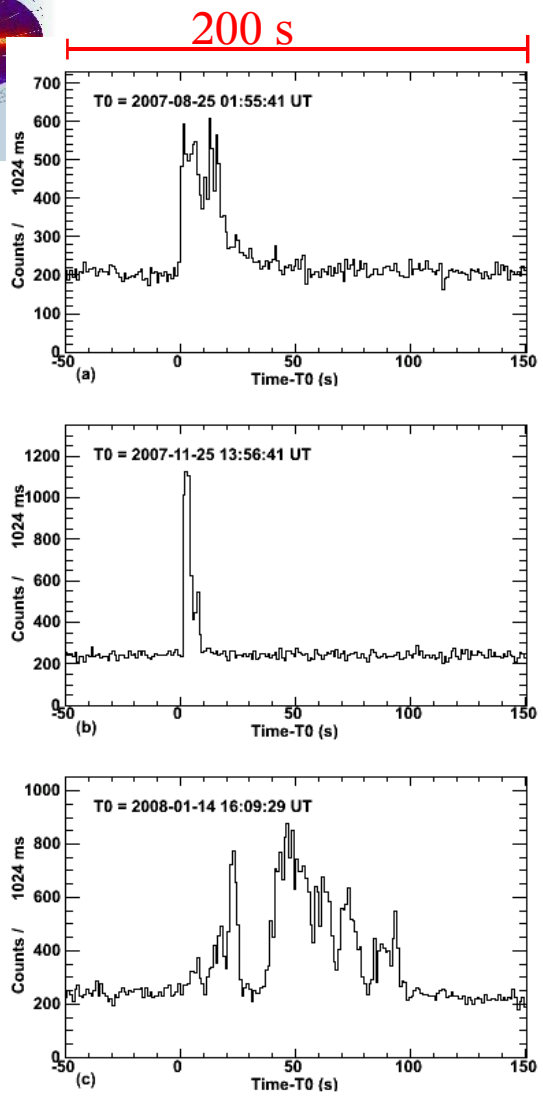
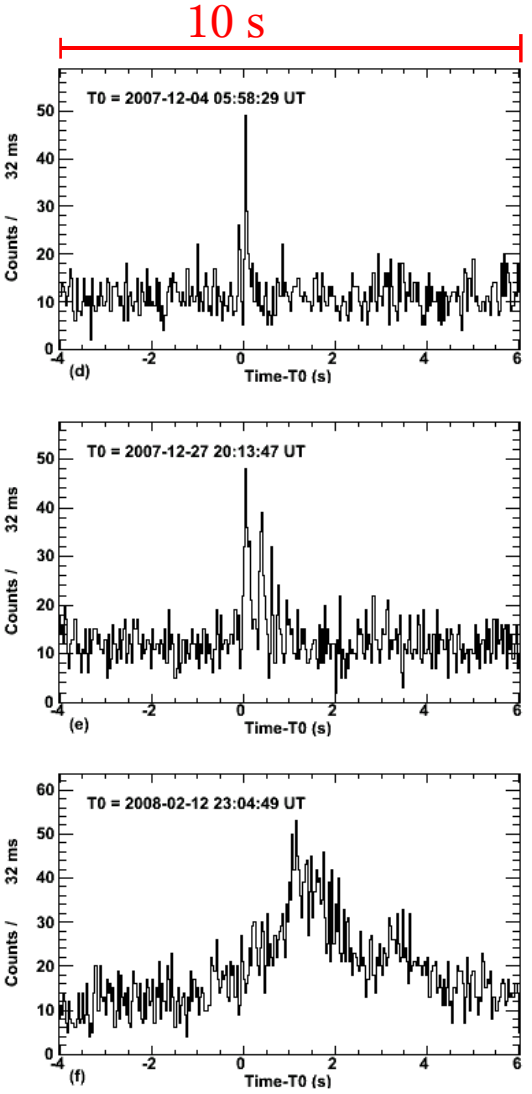
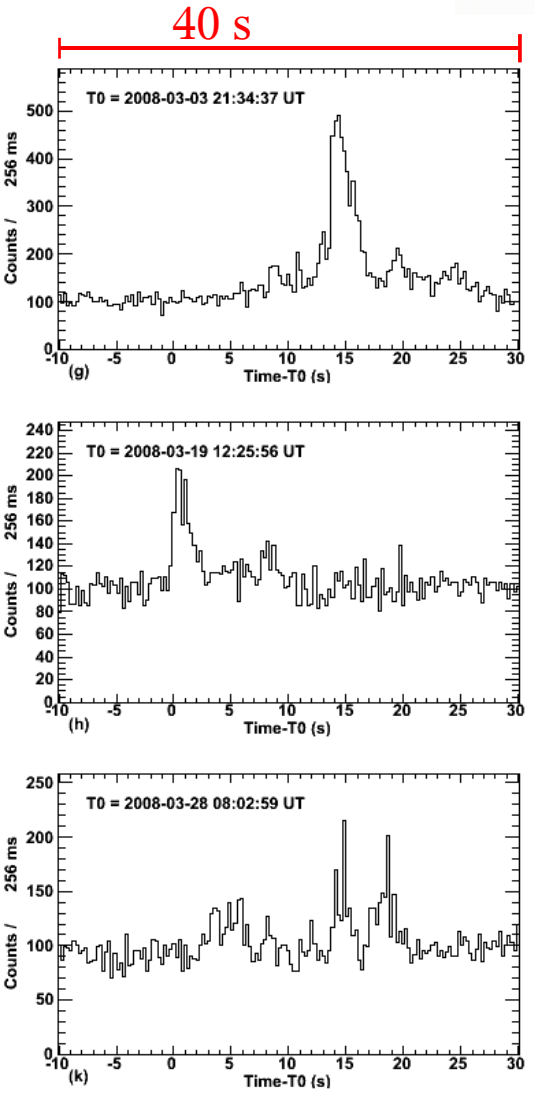


MCAL GRB detections





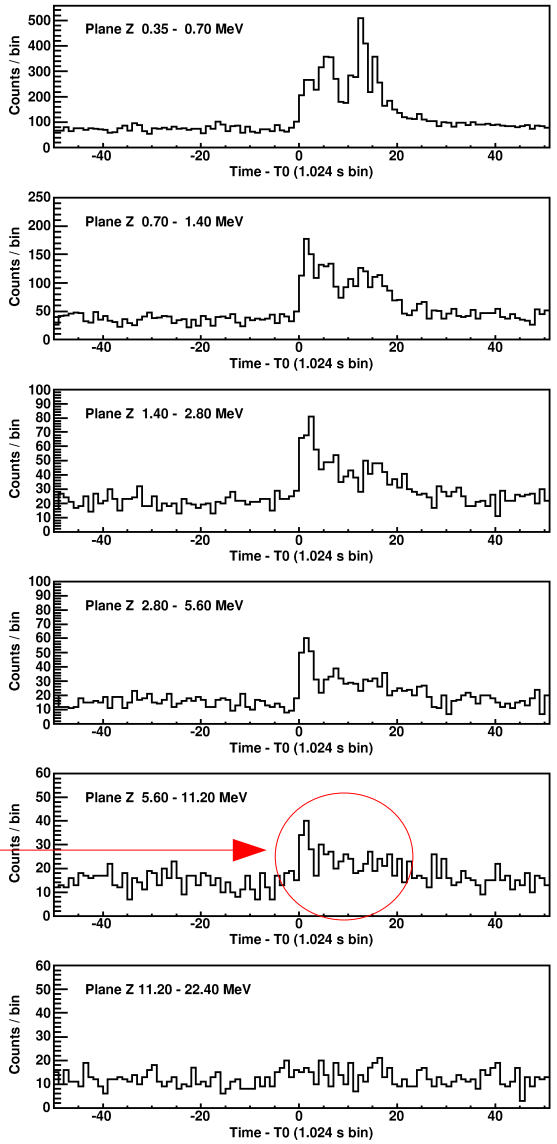


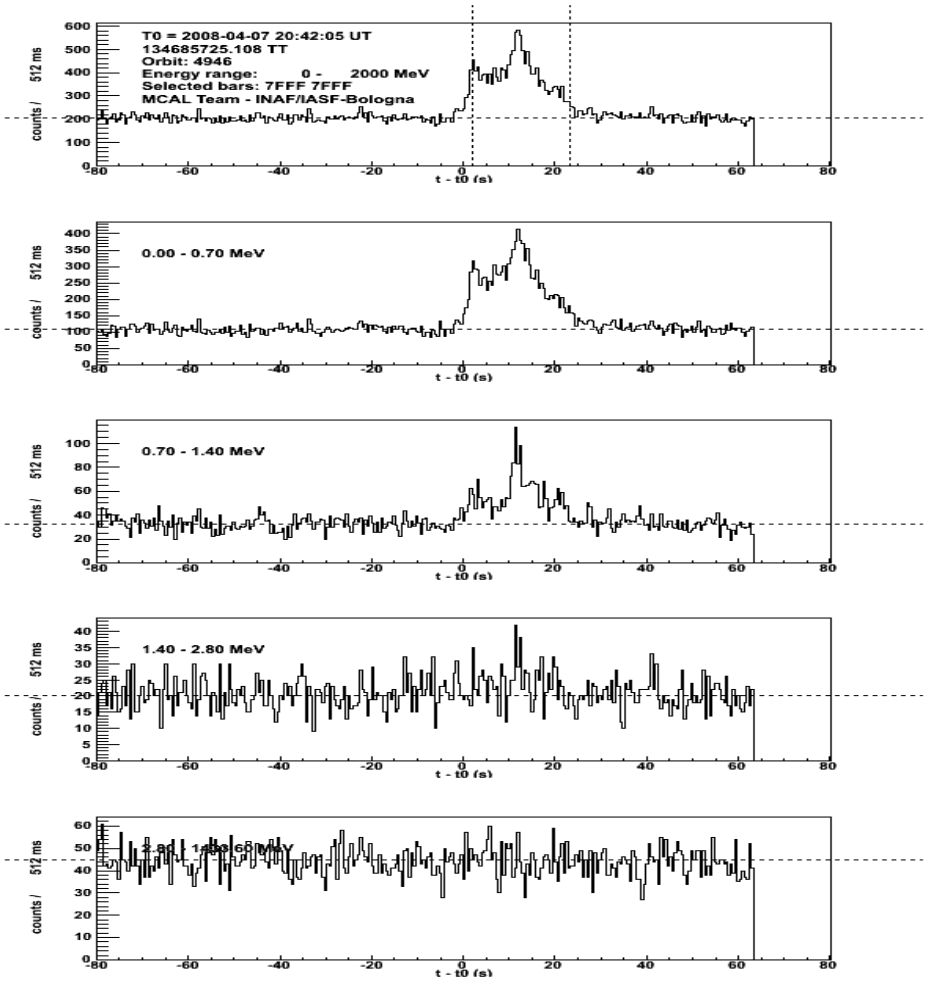
Detections with scientific ratemeters, 1 s time resolution, 11 energy bands, before Feb. 2008

Detections with onboard trigger logic, any time and energy resolution, Dec. 2007 and since Feb. 2008

MCAL & GRB: spectral coverage

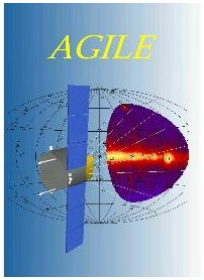
GRB070825: significant detection in the 5.6-11 MeV band





GRB080407B: the highest fluence GRB detected with onboard trigger logic

MCAL all-sky detection capabilities



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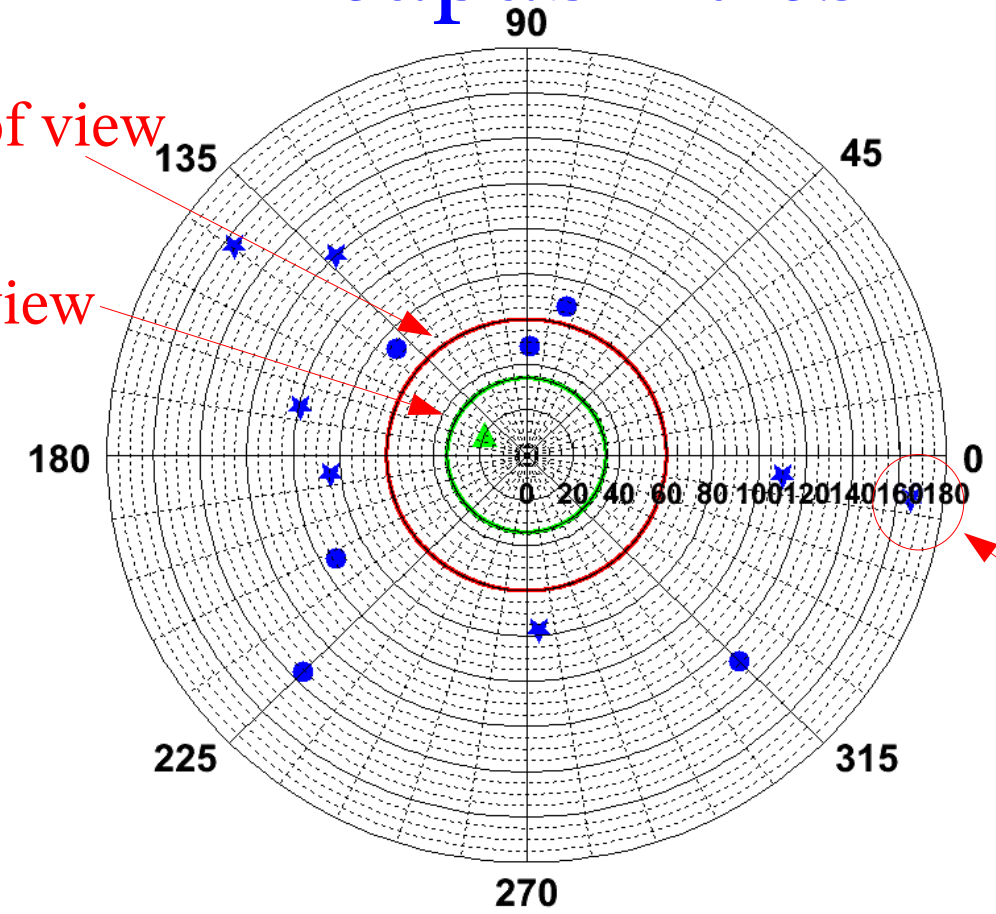
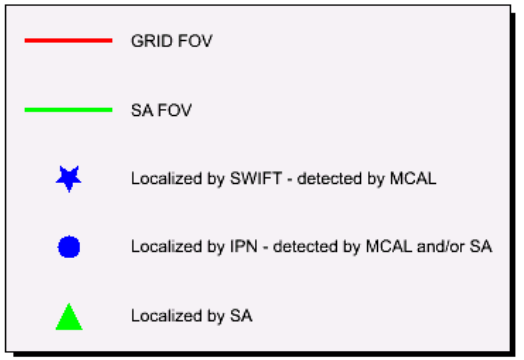
GRID field of view

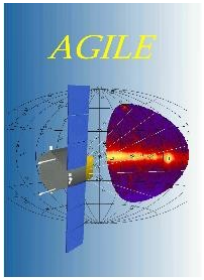
SA field of view





The most off-axis: 166 deg!

In the period July '07 – March '08: 39 GRBs detected (~1 GRB / week)
7 localized by SWIFT
6 localized by IPN (many more expected)
1 localized by SuperAGILE (other SuperAGILE localizations without MCAL detection)



Conclusions:

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- Designed within stringent constraints compensated with clever architecture and flexible logic
- Spectral capabilities in the MeV range and μs timing accuracy: very few instruments with these characteristics
- Good sentinel for the GRID: detected GRB 080514B the first GRB detected above 100 MeV after EGRET!

Work in progress:

- spectral cross-calibration with other instruments (Konus-WIND, Suzaku-WAM): mandatory!
- onset of the 1 – 16 ms time windows for burst search