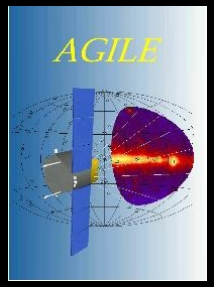


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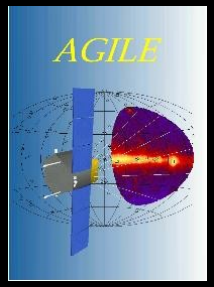
# Localization of Terrestrial gamma-Ray Flashes by AGILE

Martino Marisaldi (INAF-IASF Bologna)

on behalf of the AGILE Team

Workshop on TLEs and TGFs

October 25-28 2010, Amsterdam




# Outline

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- AGILE TGF detection capabilities in context
- Characteristics of the AGILE TGF sample
- **NEW!** Localization of TGFs in space
- Conclusions

# Operating TGF detectors

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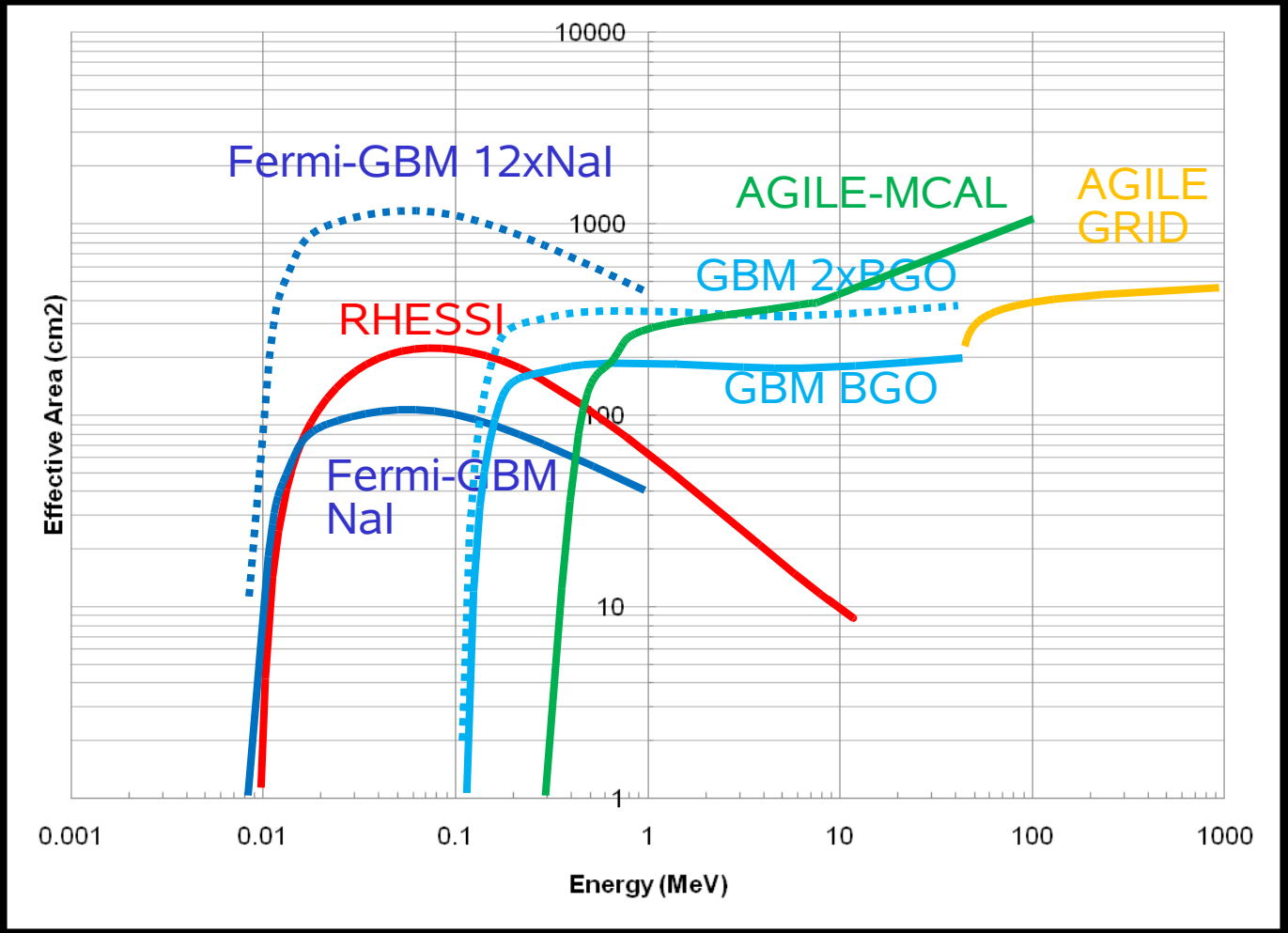
Effective Area vs. Energy




Data from: Smith et al. (2002), Meegan et al. (2009), Labanti et al. (2009), Tavani et al. (2009)

# The AGILE Mini-Calorimeter (MCAL)

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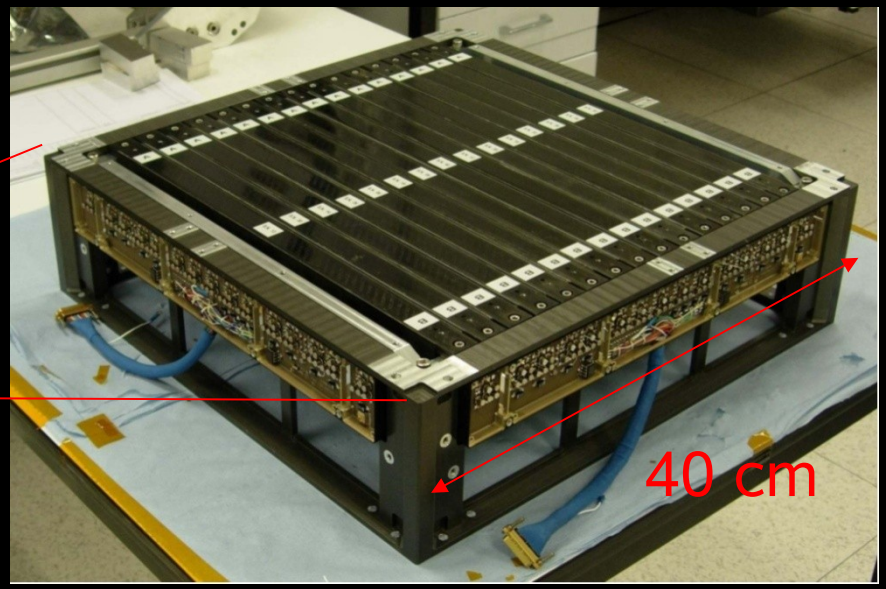
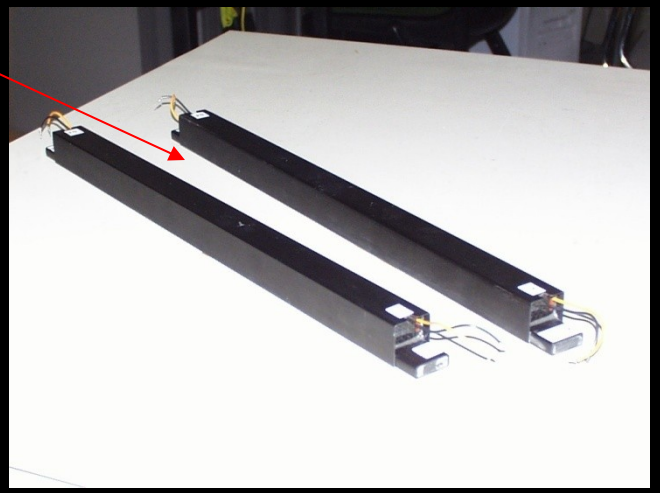
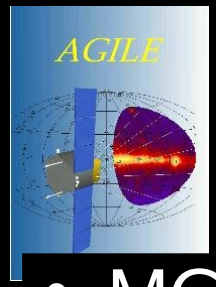



30 CsI(Tl) bars with Photodiode readout, like these
1400 cm² geometrical area
~300 cm² effective area @ 1 MeV
330 keV – 100 MeV energy range
14% energy resolution FWHM @ 1.3 MeV
2 μs timing accuracy in photon-by-photon mode
Clever, fully-programmable trigger logic on time scales from 8s to 16ms, 1ms and 300μs




Labanti et al., NIM A (2009): instrument paper
Fuschino et al., NIM A (2008): trigger logic
Marisaldi et al., A&A (2008): GRB detections
Marisaldi et al., JGR (2010): TGF detections




# Why AGILE is good for TGF science?

INAF

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- MCAL energy range is extended up to **100 MeV**: probing the high energy tail of the TGF spectrum
- Efficient trigger at **ms** and **sub-ms** time scale (the TGF time scale): not biased toward brightest events
- **segmented independent detectors**: low dead time and pile-up
- **photon-by-photon data** download for triggered events with 2μs time resolution
- **<100μs absolute timing accuracy**: mandatory for sferics correlation
- **AGILE orbit at 2.5° inclination** is optimal for mapping the equatorial region, where most of the events take place, with unprecedented exposure

# MCAL TGF detection rate

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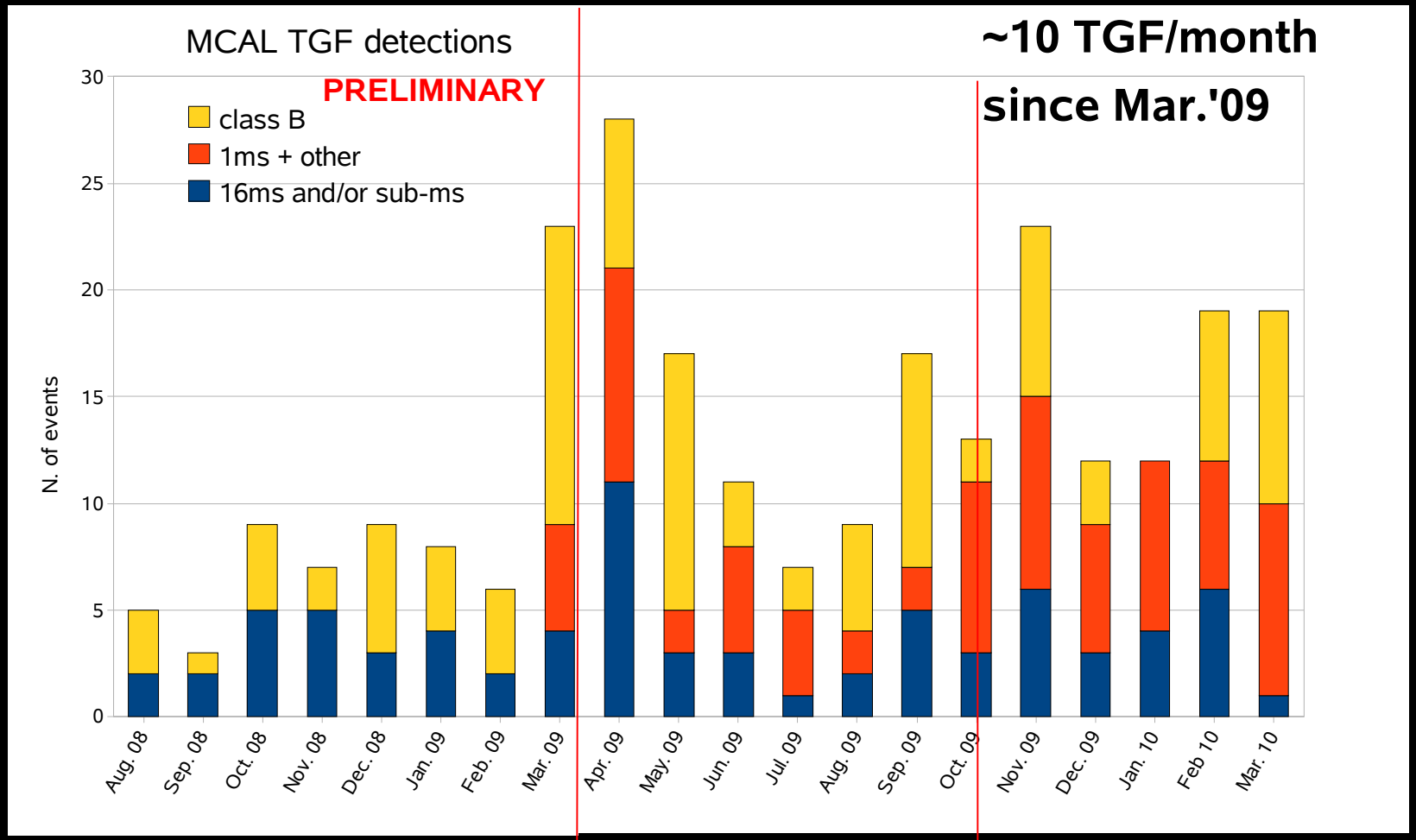
**> 190 class A TGFs + ~130 class B TGFs since June2008**




34 TGFs Published in M. Marisaldi et al., J. Geoph. Res., 115, A00E13, 2010.

After entering Spinning mode

# The AGILE TGF sample

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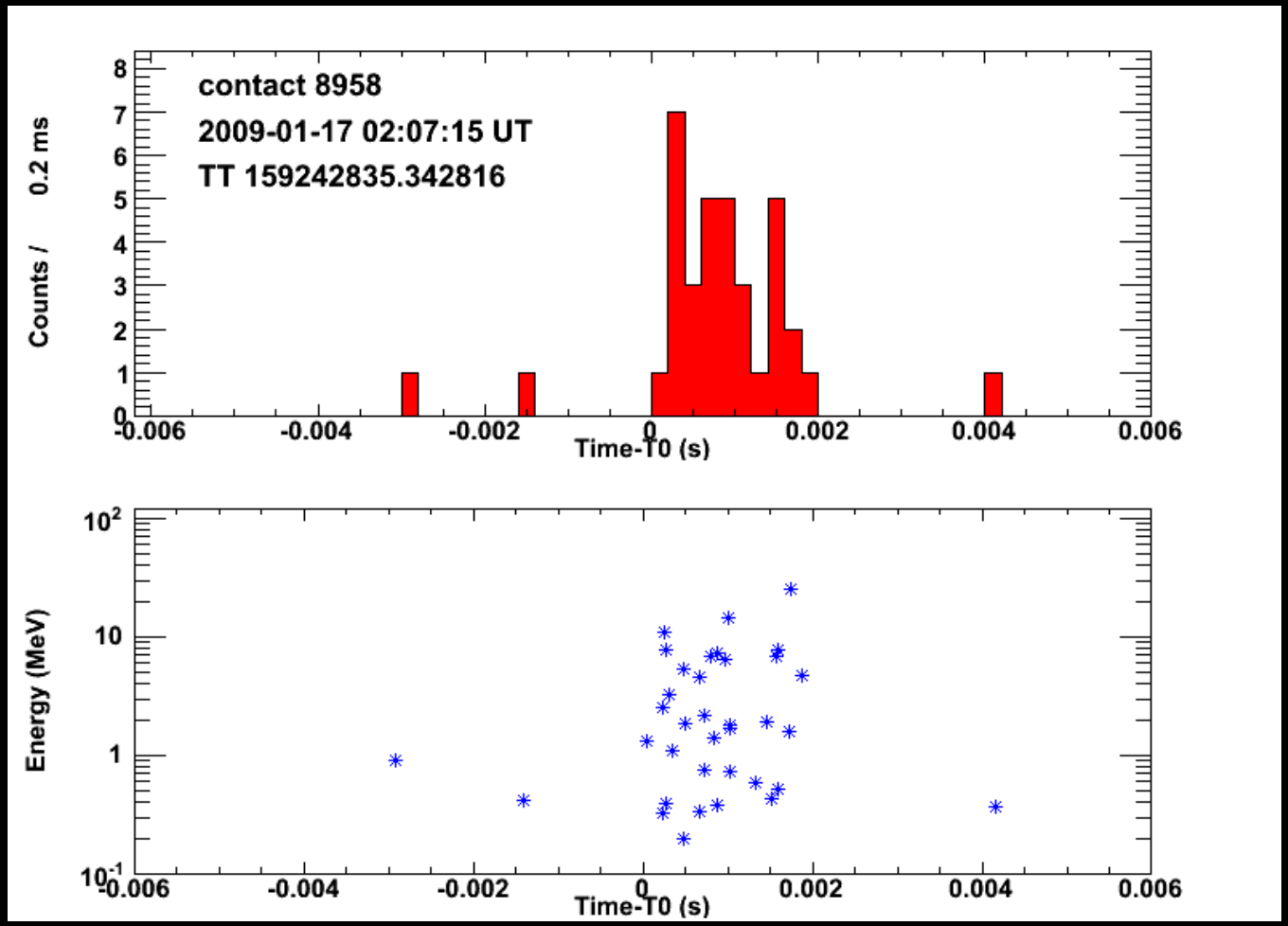


**Average properties:**

**Number of counts =**

**17.3 +/- 6.4**

**Duration =**

**(1.7 +/- 0.9) ms**

**Energy =**

**(4.0 +/- 1.7) MeV**

# TGFs and Lightnings

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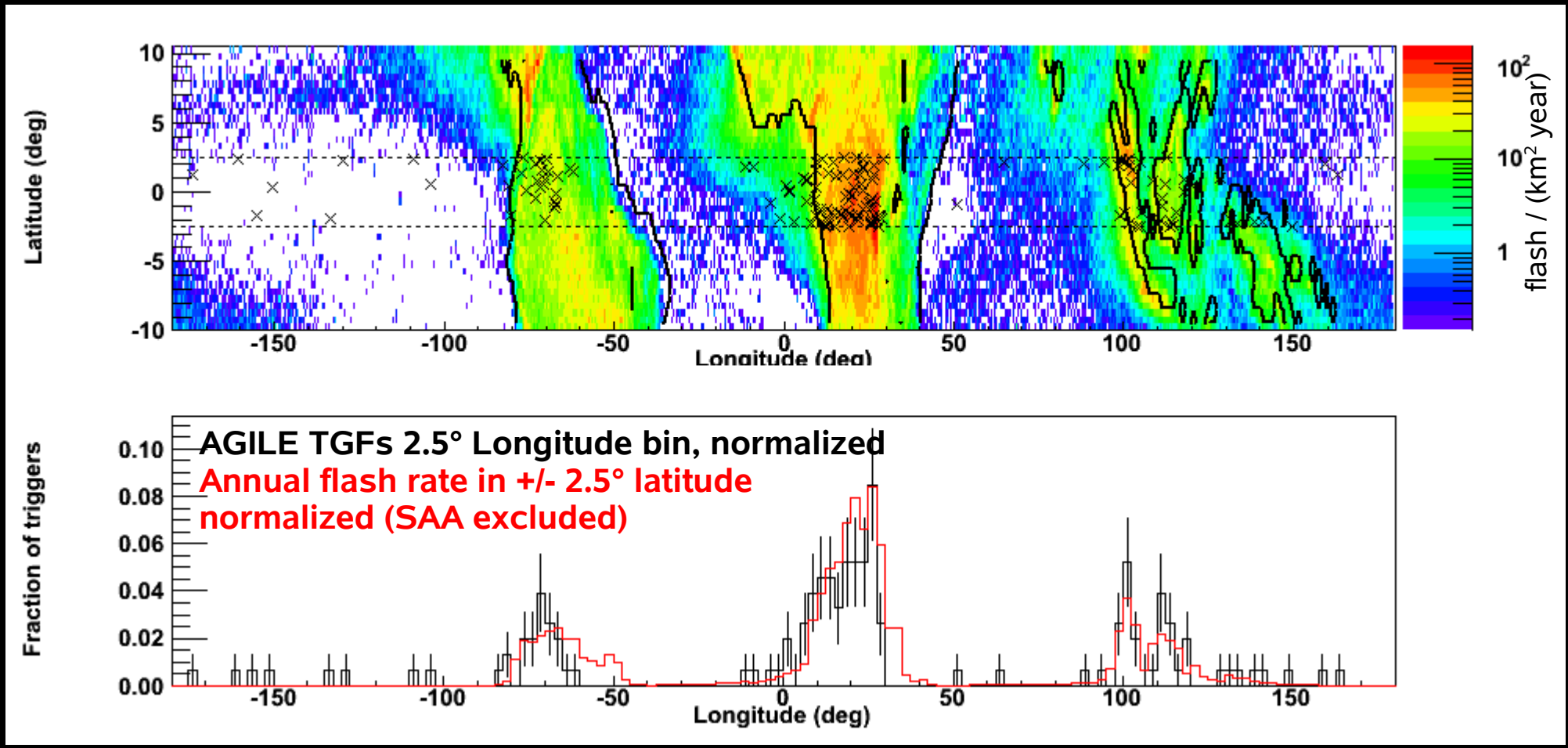
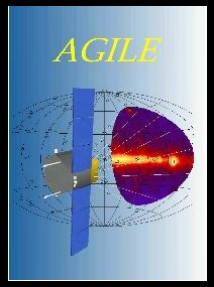
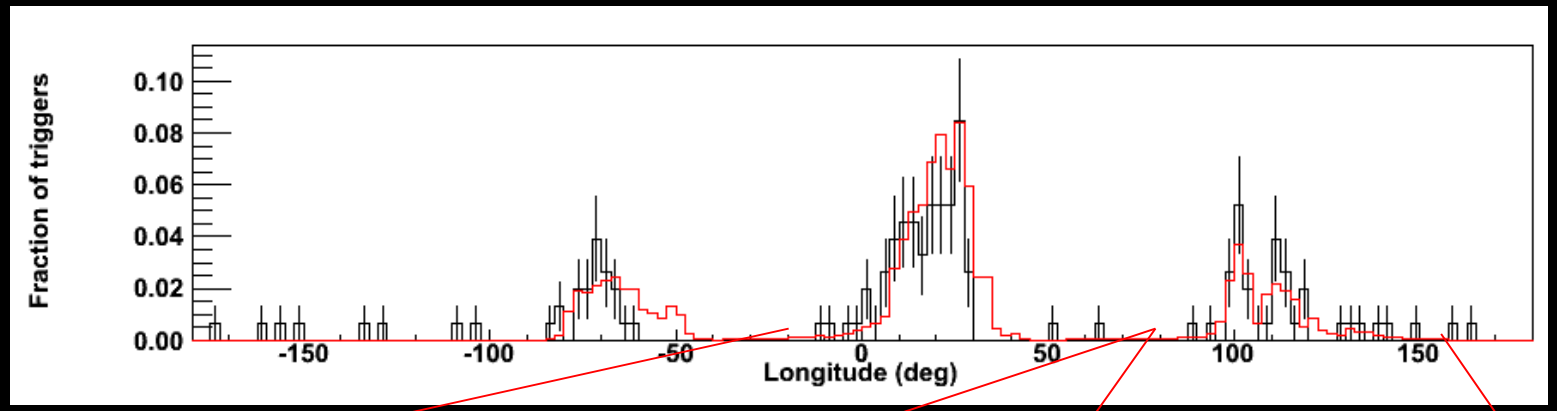



LIS-OTD High Resolution Full Climatology available at http://thunder.msfc.nasa.gov/data/

Good match between AGILE TGF pattern and lightning map Fuschino et al., in preparation

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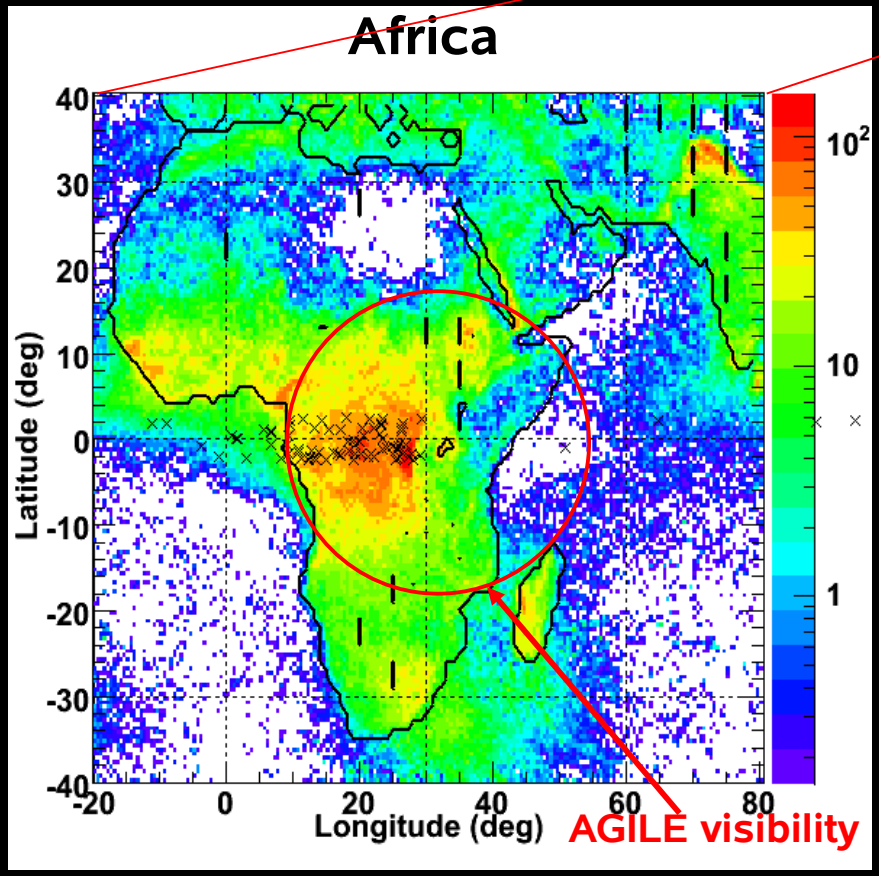
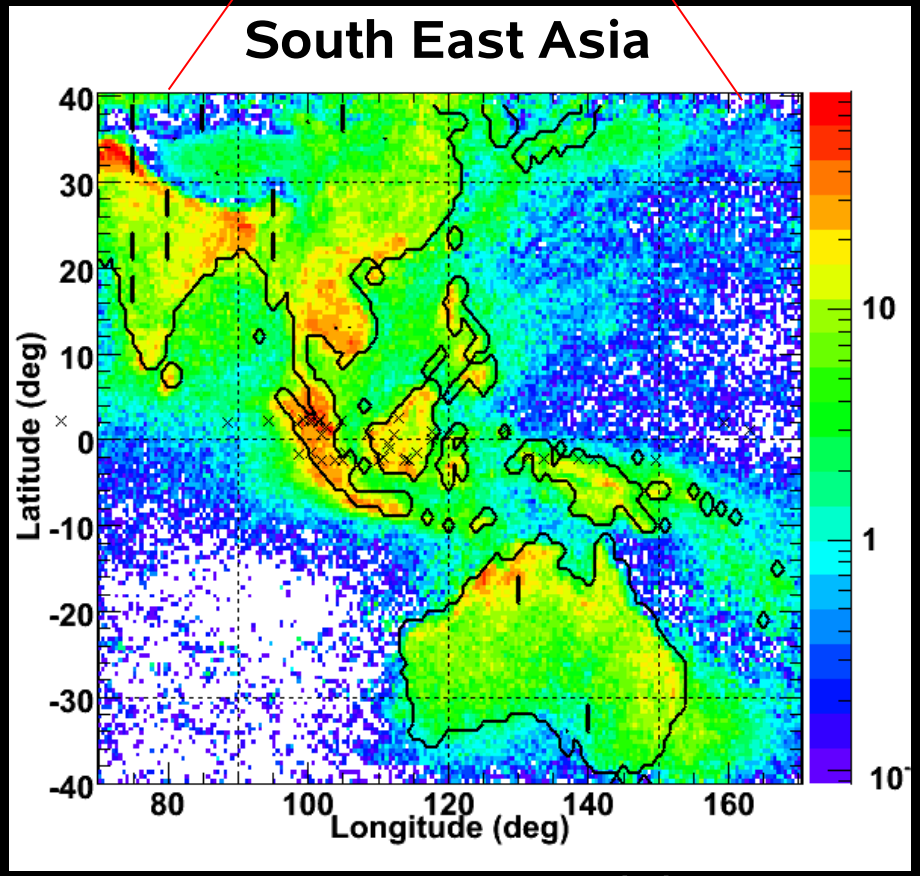



cluster over western Africa




cluster over Sumatra and the Borneo

TGF production <~300km close to sub-satellite point, Cummer et al., GRL (2005)

# Cumulative spectrum

110 TGFs  1806 photons  142 γ E> 10 MeV  26 γ E> 20 MeV

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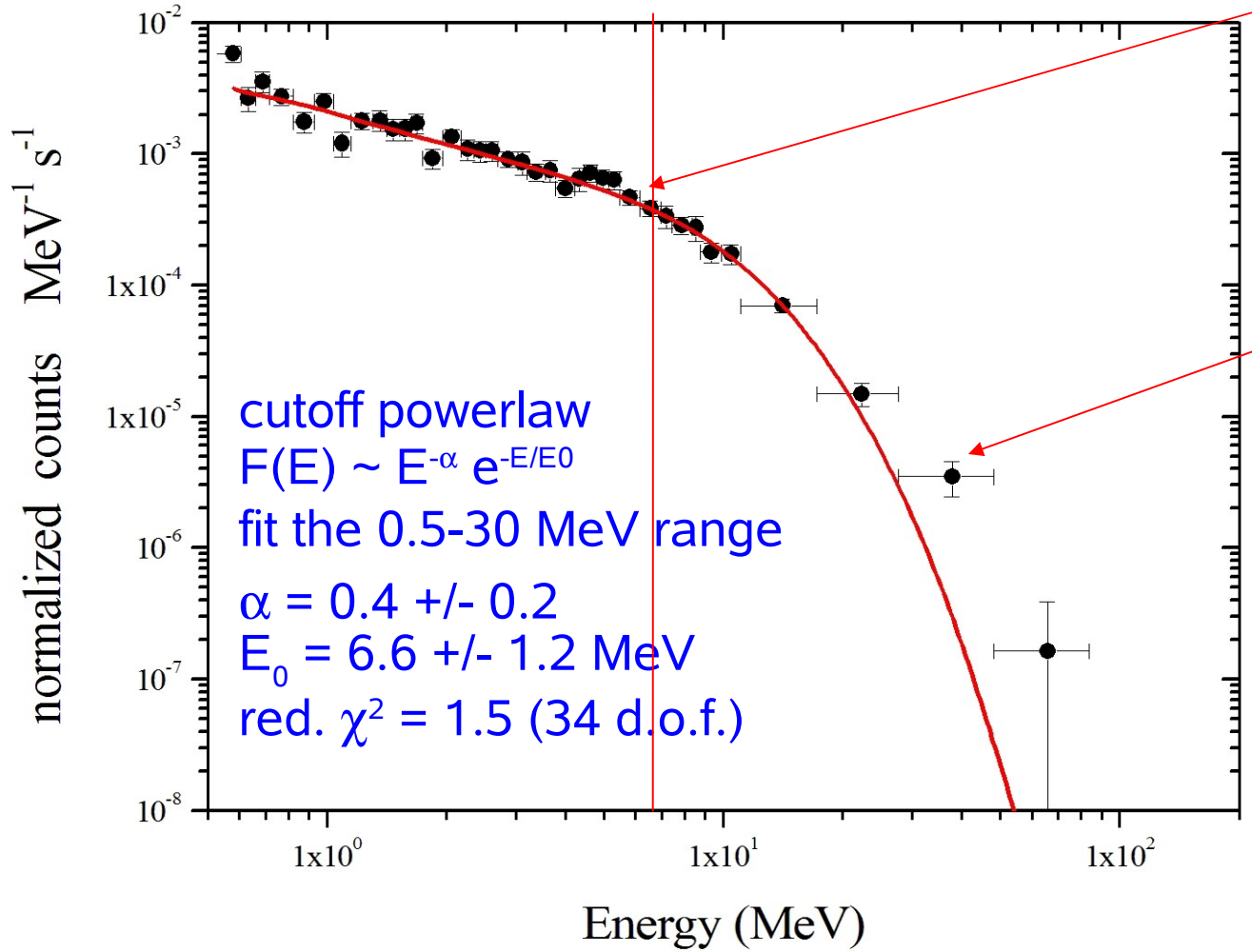
Preliminary




E0 compatible with the ~7.6 MeV average energy for RR electrons

significant detection of γ >40 MeV: challenge for emission models

# Imaging TGFs from space?

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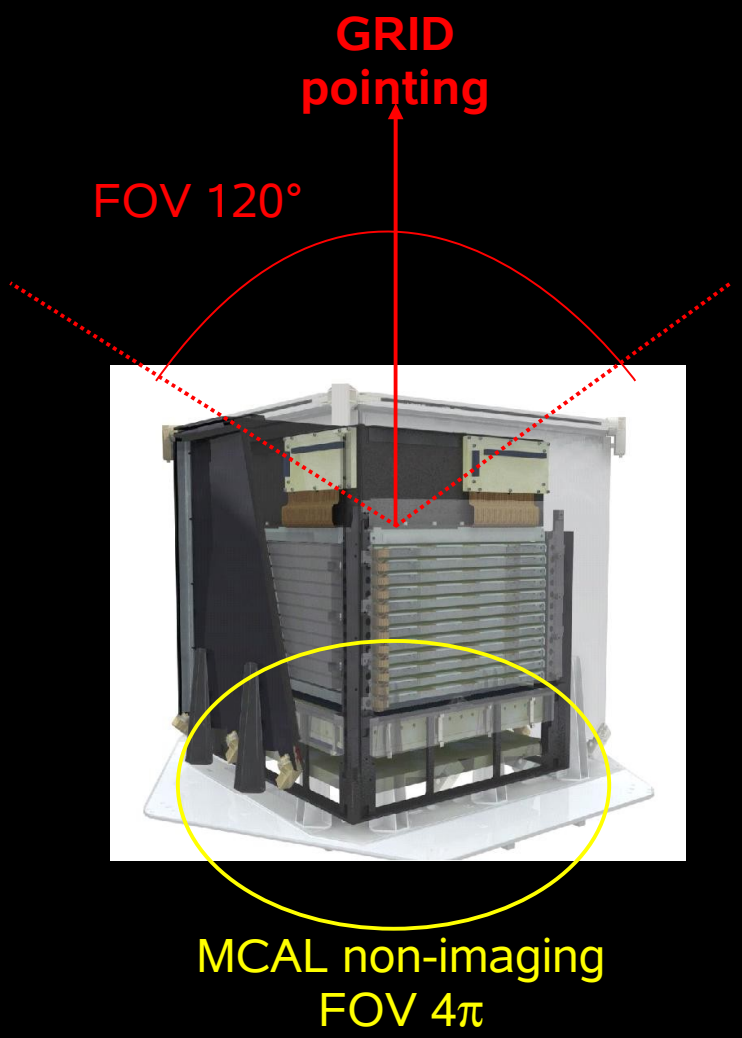
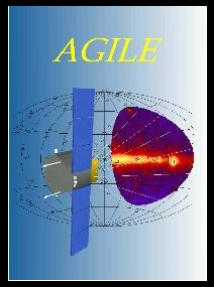


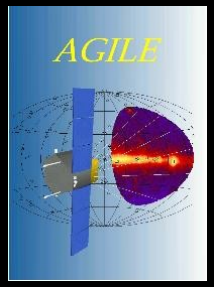

- MCAL detected TGF photons up to 40 MeV and possibly above
- So, why not looking for detections in the AGILE gamma-ray imager (GRID) sensitive above 20 MeV?
- It would be the first direct localization of TGFs in gamma-rays




# Imaging TGFs from space with AGILE GRID

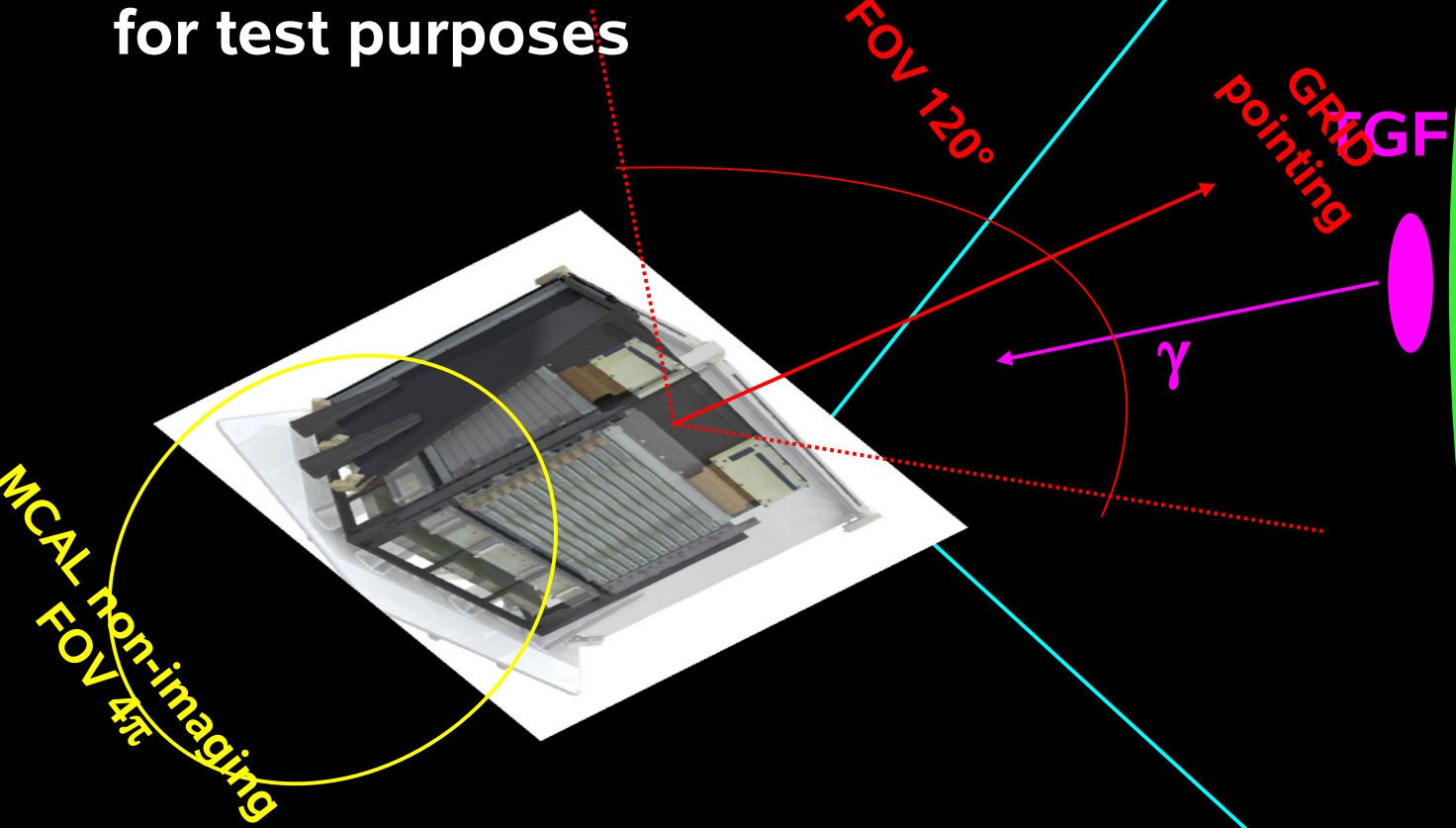



**Two ways to bypass it...**



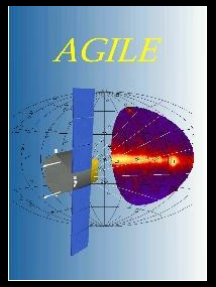

# Imaging TGFs from space with AGILE GRID

**1. Albedo filtering disabled**
**~ 100 days between 2008 – 2009**
**for test purposes**



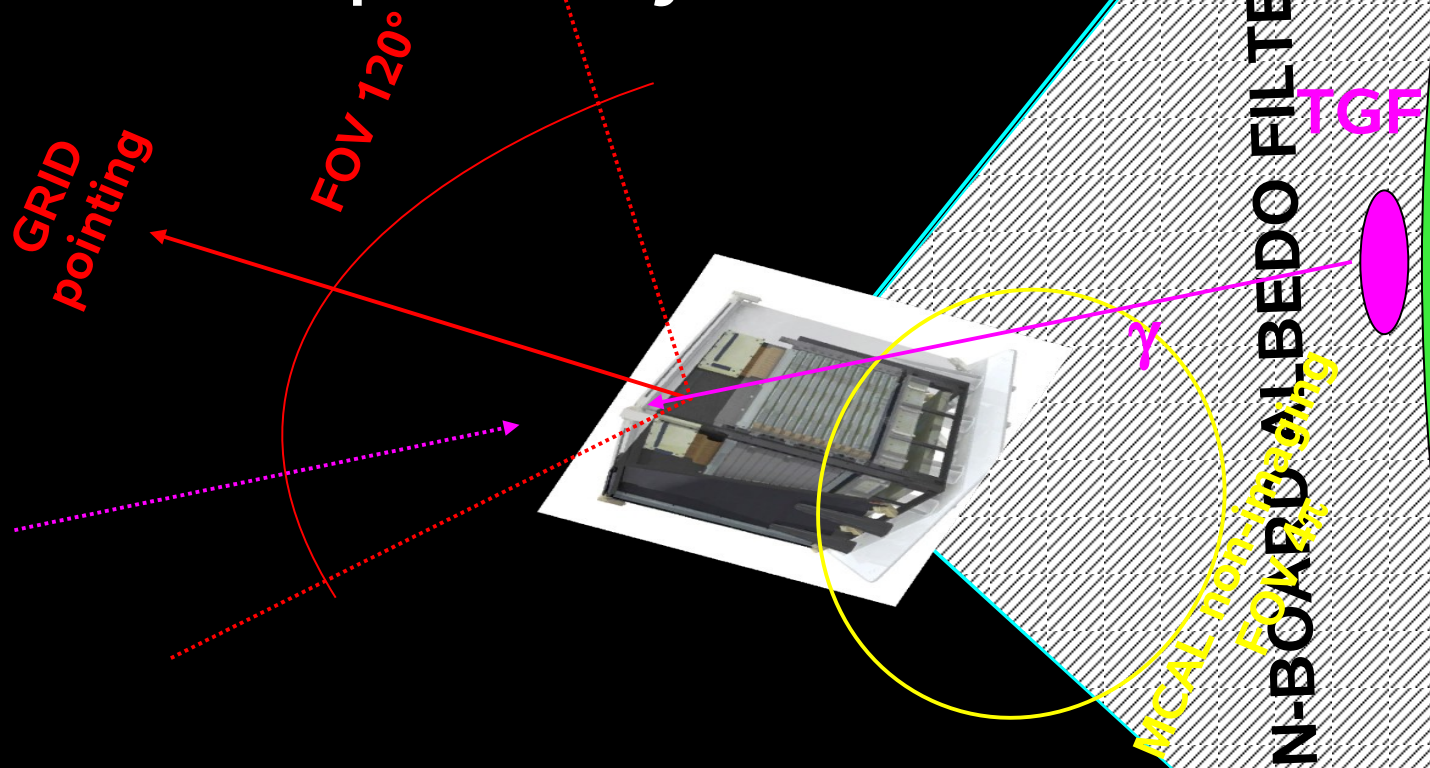

**Forward events.**

Cannot be default because of telemetry limitations




# Imaging TGFs from space with AGILE GRID

2. Sometimes the albedo filter can "mistake" a track with the complementary one




So, events coming from the Earth can be accepted by the on-board filter and sent to telemetry: Reverse events

# GRID events vs MCAL TGFs

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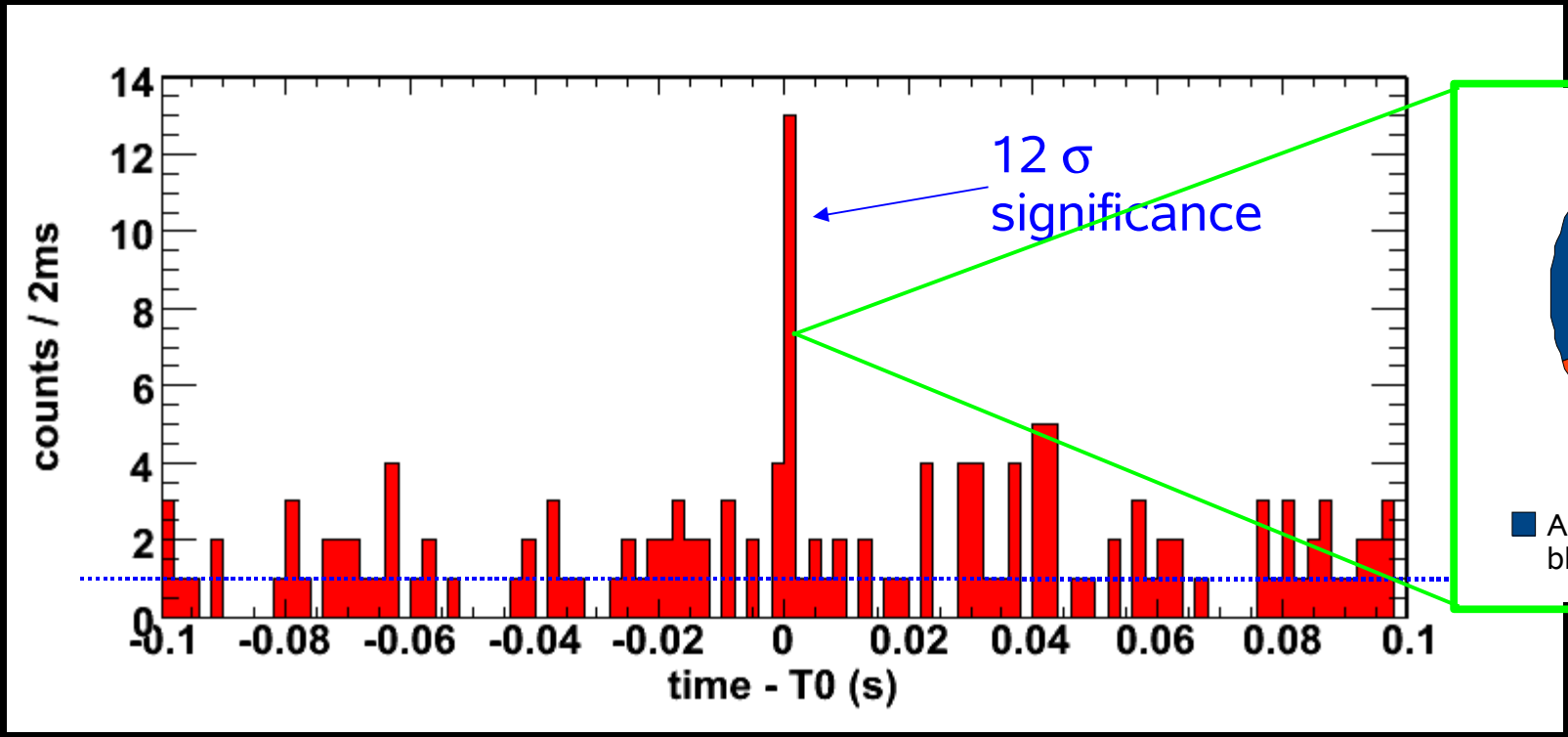
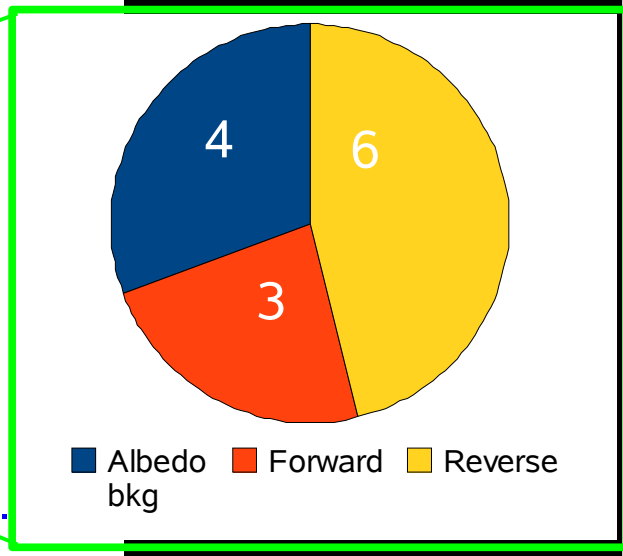
**Search for GRID events in temporal coincidence with 119 MCAL TGFs detected between Jun. 2008 – Dec. 2009**




**13 GRID events within 2 ms from TGFs T0!**

# Geographical distribution

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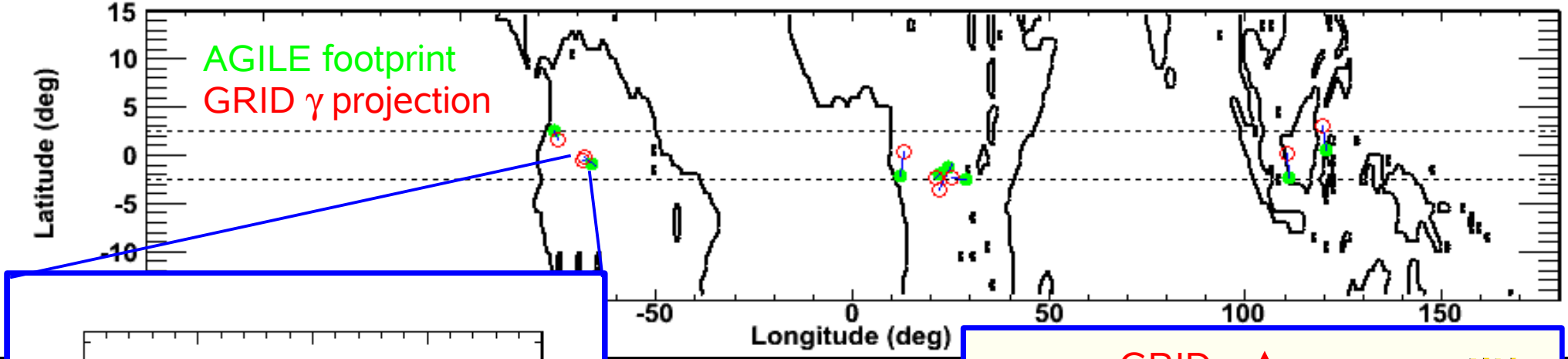
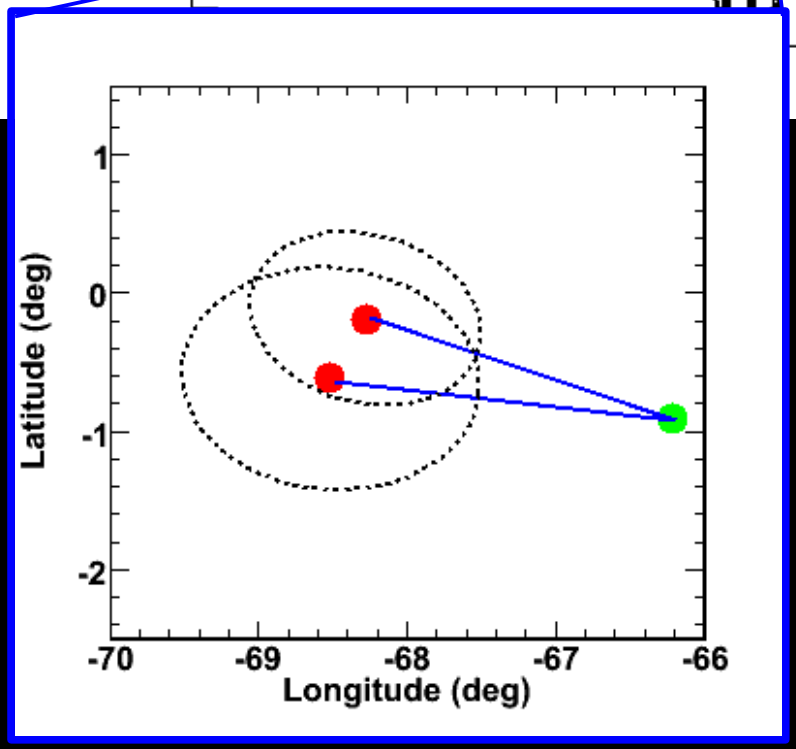
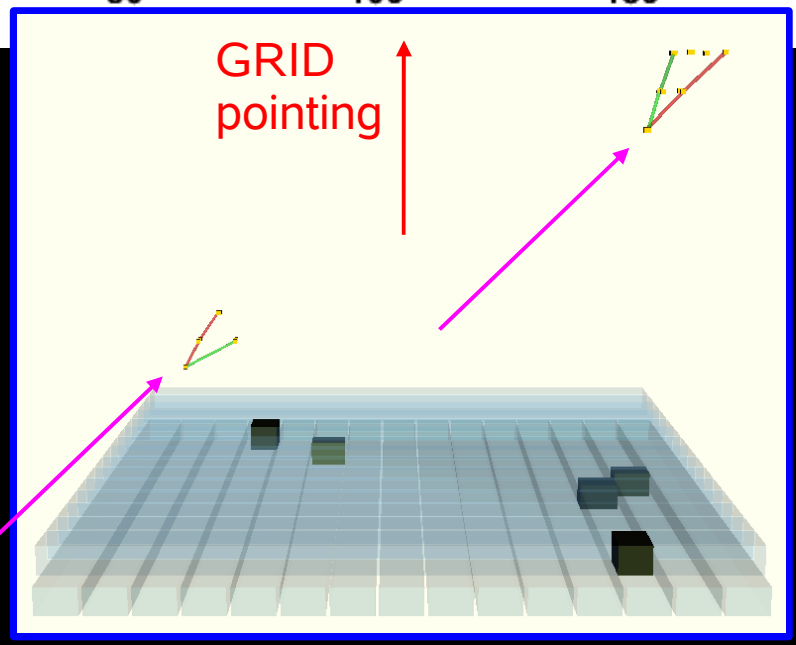


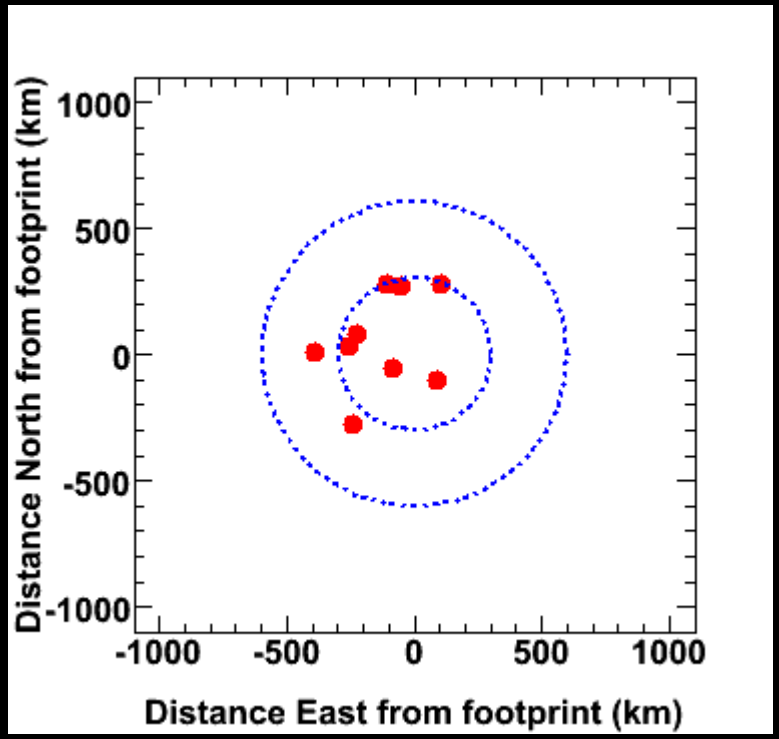



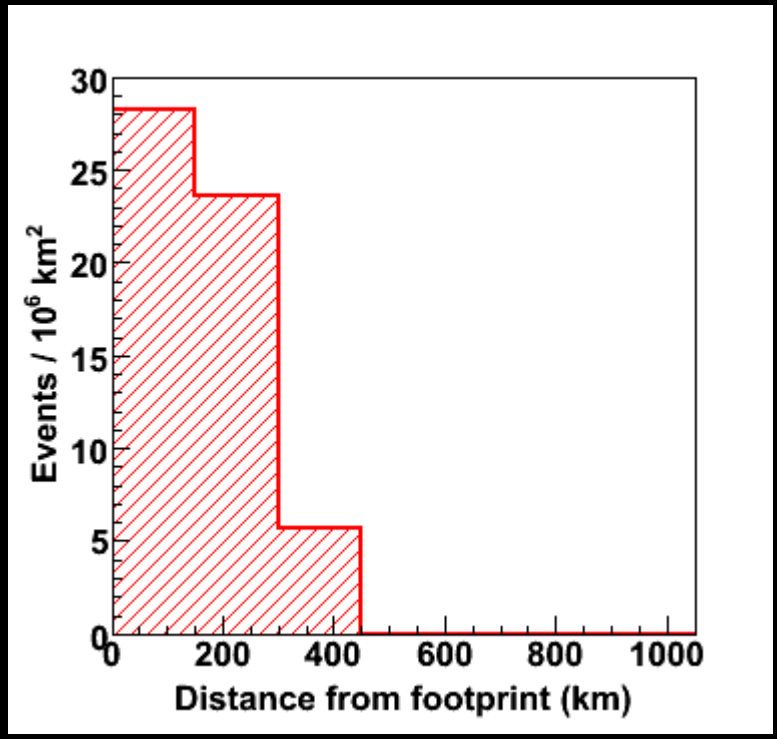




**Reverse event direction (TGF source)**

# Geographical distribution

IASF Bologna




Event clustering at < 400 km from AGILE footprint
Consistency with pervious detections based on RHESSI TGFs and sferics (Cummer et al., GRL 2005, Cohen et al., GRL 2010)

**Results published in Marisaldi et al., Phys. Rev. Letters 105, 128501 (2010)**

# Do GRID photons come directly from the production region?

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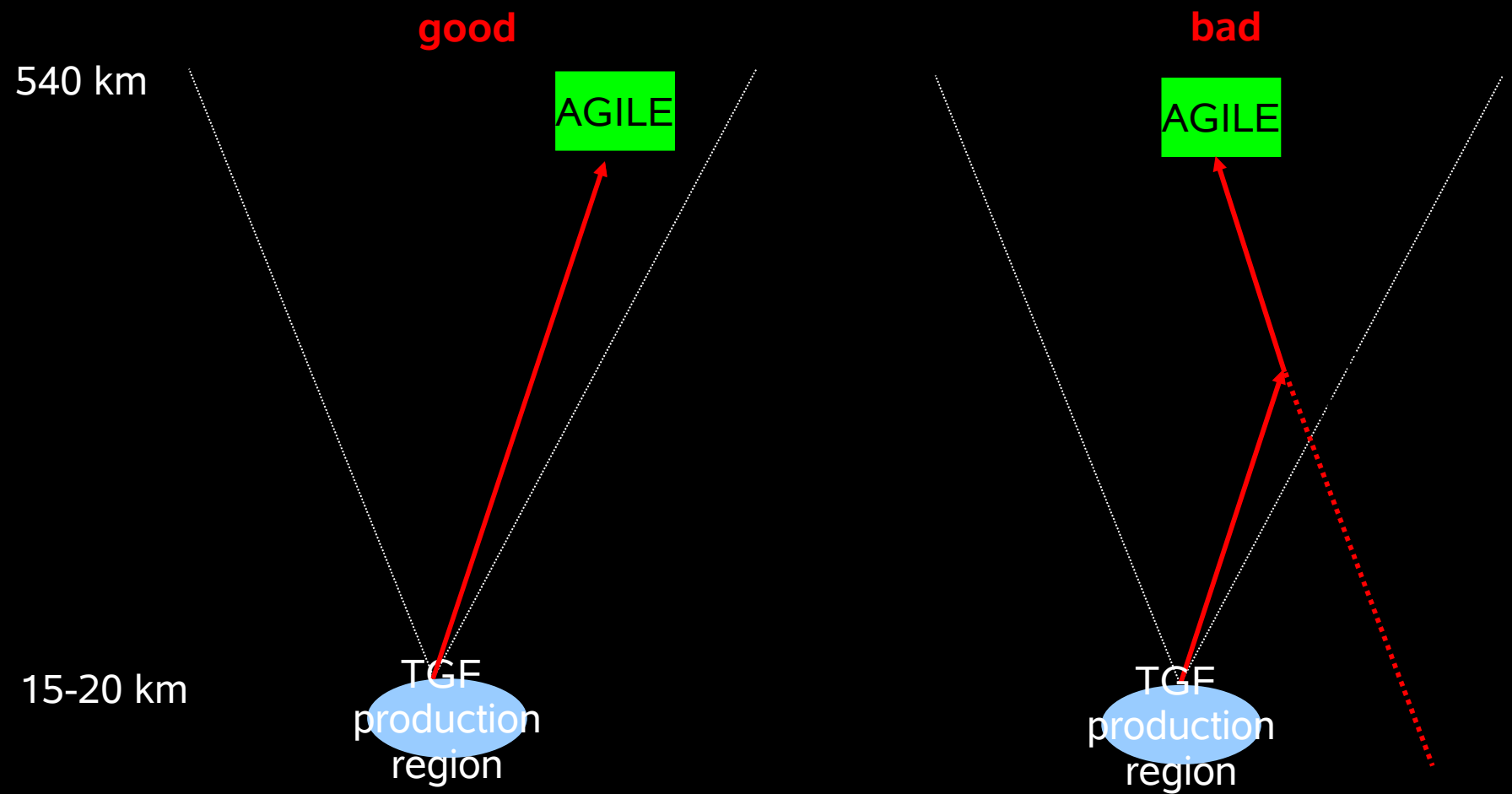
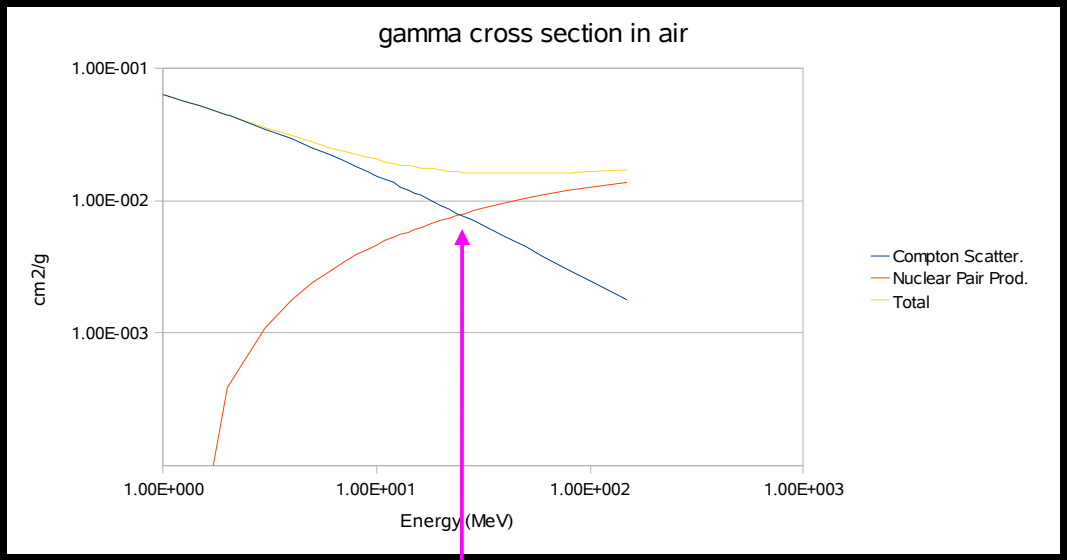



the incoming photon direction tracks the production region.

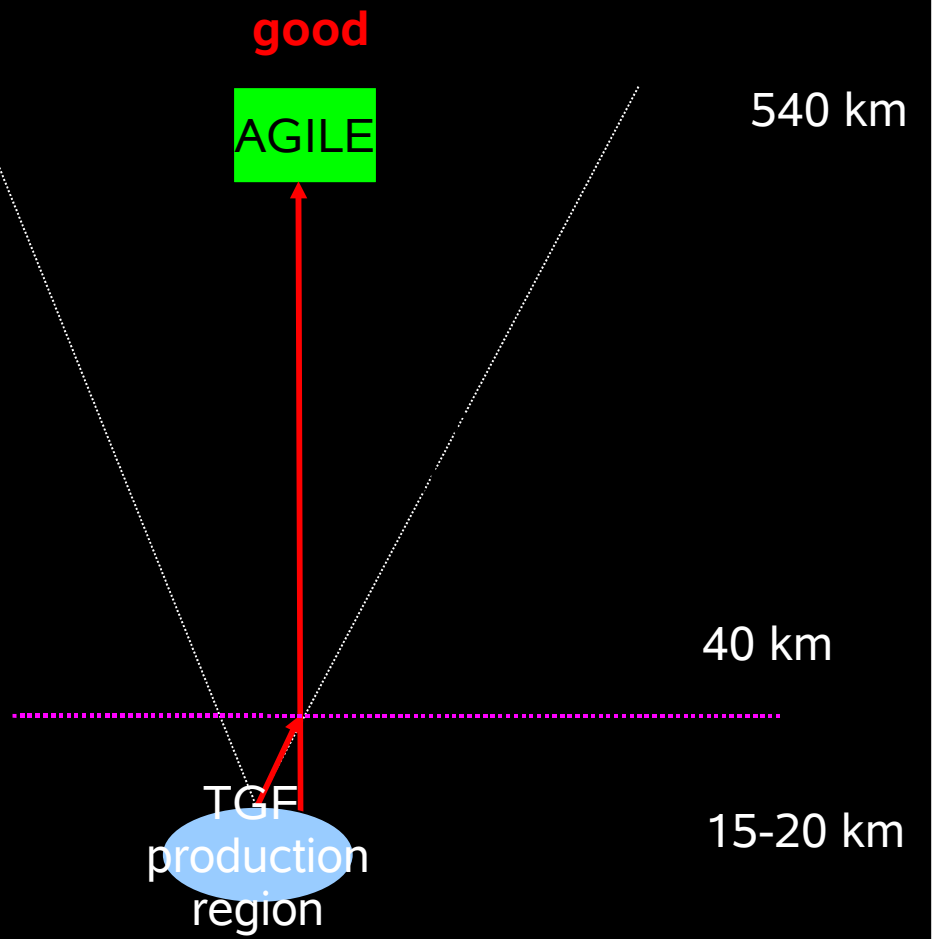
the incoming photon direction DOES NOT tracks the production region. No way to be aware of it. Is it probable???

# Do GRID photons come directly from the production region?

IASF Bologna




Compton and pair production cross section in air become equivalent at ~25MeV:
Compton interaction for low-energy GRID events cannot be ignored




<3% probability to scatter above 40 km: the GRID photon tracks the source within the angular resolution

# Implications for production models

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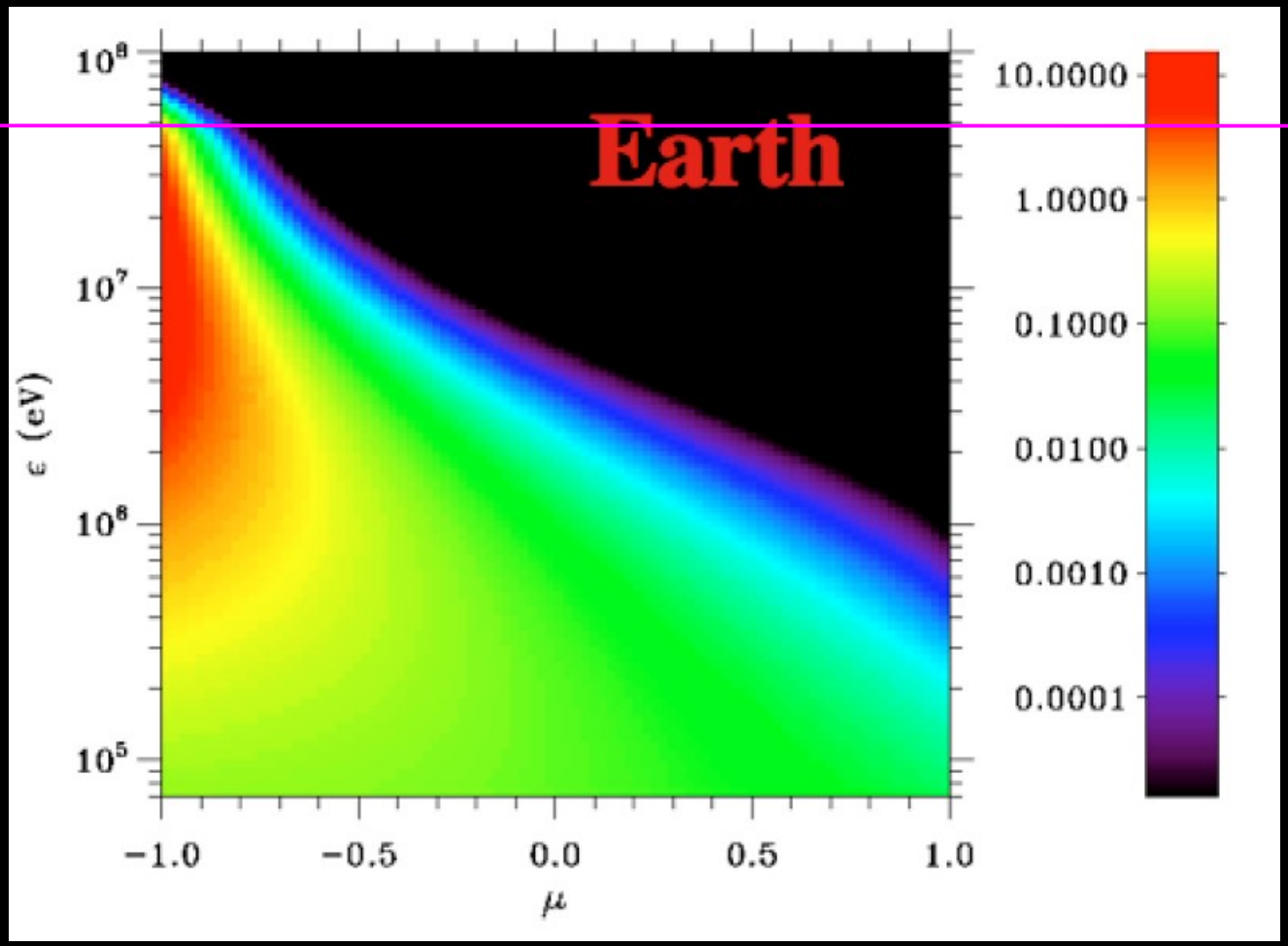
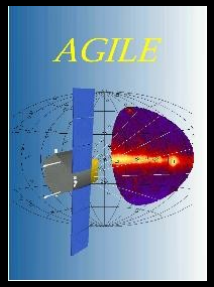



50 MeV

Roussel-Doupre et al.
Sp. Sci. Rev. 2009

High energy photons track well the electric field orientation at the source

A new tool to probe remotely the production site electric field




# Conclusions

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- AGILE is an important instrument for TGF science:
  - the only one with energy range extended up to 100 MeV
  - the only one with <1ms trigger logic
  - photon-by-photon with μs timing
  - ~equatorial orbit
- AGILE detects ~10 TGFs / month with current selection criteria. Rate can be almost doubled with improved selections
- First TGFs localized in space by means of the AGILE gamma-ray imager. Work in progress: improve the detections, implications for production models