The Refined AGILE Angular Resolution

S. Sabatini

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Motivation

• Perspectives for future instrumentation
Motivation

- Perspectives for future instrumentation
- Better understanding of the AGILE performances

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Main configuration parameters affecting the angular resolution

- pitch (size of the silicon strip) and readout system
- distance between planes
Main configuration parameters affecting the angular resolution

- pitch (size of the silicon strip) and readout system
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- thickness of tungsten layers
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Main configuration parameters affecting the angular resolution

- pitch (size of the silicon strip) and readout system
- distance between planes
- thickness of tungsten layers
- reconstruction and classification algorithms
Approach: Simulations and in-flight data

- **Simulations:** monochromatic crab-like spectrum
Approach: Simulations and in-flight data

• **Simulations:** monochromatic crab-like spectrum

• **In-flight data:** AGILE vs Fermi (Crab < 30°)
# AGILE vs Fermi

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AGILE-GRID</th>
<th>Fermi-LAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of towers</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Total number of Tracker planes</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Vertical spacing ($s$) between adjacent planes</td>
<td>1.8 cm</td>
<td>3.2 cm</td>
</tr>
<tr>
<td>Silicon tile size</td>
<td>9.5x9.5 cm²</td>
<td>8.95x8.95 cm²</td>
</tr>
<tr>
<td>Silicon detector array for each plane</td>
<td>4x4</td>
<td>4x4</td>
</tr>
<tr>
<td>Silicon-strip pitch ($\delta_P$)</td>
<td>121 µm</td>
<td>228 µm</td>
</tr>
<tr>
<td>Readout pitch</td>
<td>242 µm</td>
<td>228 µm</td>
</tr>
<tr>
<td>Signal readout</td>
<td>analog</td>
<td>digital</td>
</tr>
<tr>
<td>Ratio $\delta_P/s$</td>
<td>0.007</td>
<td>0.007</td>
</tr>
<tr>
<td>Tungsten converter thickness per plane</td>
<td>0.07 $X_o$</td>
<td>0.03 $X_o$ (front)</td>
</tr>
<tr>
<td>Number of planes with W converter</td>
<td>10</td>
<td>12 (front)</td>
</tr>
<tr>
<td>Average readout strip multiplicity per hit (0-30°)</td>
<td>2-3</td>
<td>4 (back)</td>
</tr>
<tr>
<td>Effective spatial resolution, $\delta_x$ (0-30°)</td>
<td>40 µm</td>
<td>130-200 µm</td>
</tr>
<tr>
<td>Ratio $\delta_x/s$</td>
<td>0.002</td>
<td>0.004-0.006</td>
</tr>
</tbody>
</table>
Approach: Simulations and in-flight data

- **Simulations**: monochromatic crab-like spectrum
- **In-flight data**: AGILE vs Fermi (Crab < 30°)
- **SAME analysis for simulated and real data**
1. **GAMS**: GEANT simulation of parallel beams of photons
DATA ANALYSIS

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3. **FM3.119**: on-ground refined classification and reconstruction

4. **IMAGE RECO:**
Angular Resolution determination: method

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1. Angular Resolution determination: method

- Normalized average counts
- Radial Aperture (deg)

- Cumulative Occurrence
- Spherical distance (deg)

- 68% CR
Angular Resolution determination: method

1. Cumulative Occurrence
   - Spherical distance (deg)
   - 68% CR

2. Normalized average Counts
   - Radial Aperture (deg)
   - HWHM
Ideal Characterization of the instrument.
Parallel beam, $6 \times 10^7$ photons, at different off-axis angles with energies:

$50, 100, 200, 400, 1000$ MeV

Fig. 1.—Left panel: AGILE-GRID 68% containment radius versus photon energy for simulated monochromatic photons of different incident angles. Right panel: angular resolution (FWHM) versus photon energy, shown for comparison to the CR68.

Ideal Characterization of the instrument. Parallel beam, $6 \times 10^7$ photons, at different off-axis angles with energies:

<table>
<thead>
<tr>
<th>Centroid Energy (MeV)</th>
<th>Energy band (MeV)</th>
<th>$\theta = 1, \phi = 0$</th>
<th>$\theta = 1, \phi = 45$</th>
<th>$\theta = 30, \phi = 0$</th>
<th>$\theta = 30, \phi = 45$</th>
<th>Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>30 - 70</td>
<td>4.0</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>0.5</td>
</tr>
<tr>
<td>100</td>
<td>70 - 140</td>
<td>2.25</td>
<td>2.25</td>
<td>2.5</td>
<td>2.25</td>
<td>0.25</td>
</tr>
<tr>
<td>200</td>
<td>140 - 300</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
<td>1.2</td>
<td>0.1</td>
</tr>
<tr>
<td>400</td>
<td>300 - 700</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>1000</td>
<td>700 - 1700</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>5000</td>
<td>1700 - 10000</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Theoretical and measured performance of an instrument for monochromatic photons of different incident angles. Right panel: angular resolution (FWHM) versus photon energy, shown for comparison to the CR68.

Angular Resolution – Crab Sim

CRAB-LIKE SPECTRUM

## CRAB-LIKE SPECTRUM

### HWHM for the Crab simulations

<table>
<thead>
<tr>
<th>Centroid Energy (MeV)</th>
<th>Energy Band (MeV)</th>
<th>$(\theta, \phi)$ (1,0)</th>
<th>$(\theta, \phi)$ (1.45)</th>
<th>$(\theta, \phi)$ (30,0)</th>
<th>$(\theta, \phi)$ (30,45)</th>
<th>$(\theta, \phi)$ (50,0)</th>
<th>$(\theta, \phi)$ (50,45)</th>
<th>Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>30 - 70</td>
<td>3.5</td>
<td>3.5</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>4.0</td>
<td>0.5</td>
</tr>
<tr>
<td>100</td>
<td>70 - 140</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.4</td>
<td>2.4</td>
<td>0.4</td>
</tr>
<tr>
<td>200</td>
<td>140 - 300</td>
<td>1.0</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.4</td>
<td>1.4</td>
<td>0.2</td>
</tr>
<tr>
<td>400</td>
<td>300 - 700</td>
<td>0.6</td>
<td>0.6</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>1000</td>
<td>700 - 1700</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>5000</td>
<td>1700 - 10000</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>100 - 400</td>
<td>100 - 400</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>400 - 1000</td>
<td>400 - 1000</td>
<td>0.45</td>
<td>0.45</td>
<td>0.35</td>
<td>0.35</td>
<td>0.45</td>
<td>0.35</td>
<td>0.05</td>
</tr>
<tr>
<td>100 - 50000</td>
<td>100 - 50000</td>
<td>0.50</td>
<td>0.50</td>
<td>0.40</td>
<td>0.40</td>
<td>0.45</td>
<td>0.30</td>
<td>0.05</td>
</tr>
</tbody>
</table>

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100 1000 10000 Energy (MeV)

AGILE – REAL DATA (Crab)

100-400 MeV

FWHM: 2.5°

400-1000 MeV

FWHM: 1.2°

AGILE vs Fermi—REAL DATA (Crab)

Sabatini et al., 2015, submitted
AGILE vs Fermi—REAL DATA (Crab)

Same angular resolution within the errors!

EXPECTED vs MEASURED values

AGILE (0.085 X0)

Angular resolution (degrees)

Energy (MeV)

10.0
1.0
0.1
EXPECTED vs MEASURED values

Fermi (0.04 X0)

Angular resolution (degrees)

Energy (MeV)

100 1000 10000
EXPECTED vs MEASURED values

![Graph showing the comparison between expected and measured values against energy (MeV).]
PERSPECTIVES

• The consolidated AGILE angular resolution, allows to carry out a complete **tomography of the Galactic Plane** -> diffuse emission, cat2, low energy CR (ASTROGAM)
AGILE deep 8 yrs integrated count map
Cygnus Region

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PERSPECTIVES

• The consolidated AGILE angular resolution, allows carry out a complete \textbf{tomography of the Galactic Plane} -> diffuse emission, cat2, low energy CR (ASTROGAM)

• Cross-correlation with other catalogues, new use of AGILE data :
  – star formation (HERSCHEL)
  – high energy neutrino sources (ICECUBE)
AGILE vs HERSHEL: Mapping the effects of cosmic ray flux on the SFR

CO emission in Orion A (Dame et al., 2001)

Integrated column density (NH) (Herschel data)

Gamma-ray emission (AGILE)

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AGILE vs ICECUBE: Investigating the origin of neutrino sources

cascade events only
p-value = 18 %
AGILE vs ICECUBE: Investigating the origin of neutrino sources
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CONCLUSIONS

- AGILE angular resolution very good, unique in the low energy band.
- Angular resolution stable across the field of view, ensures stable performances also in spinning.
- Read-out system and reconstruction algorithms crucial in defining the final angular resolution.

- Works in progress: cross-correlation with other catalogues, new use of AGILE data:
  - star formation (HERSCHEL)
  - high energy neutrino sources (ICECUBE)