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MeVcube  

Towards a Network of GRB Detecting Nanosatellites  
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Budapest, Hungary
MevCube

Structure similar to e-ASTROGAM, AMEGO (Si DSSD, CsI, …)
Test sensors, readout, validate design (*pathfinder*, at 1/1000 cost)
Evaluate environment in quasi-equatorial LEO (activation, SAA rates, …)
Do science (at least at the COMPTEL level) including GRBs (so *not a dedicated instrument*)

Design is almost fixed, some preliminary performance estimates
Most of the work done by students!
Evaluating mission plan now
Performance (Berlato, Lucchetta, with updates)

ARM at 1 MeV ~ 5°
SPD at 1 MeV ~ 30°

(See Lucchetta 2017)

With current design
PRELIMINARY

(Updated)
Now finalize

Biggest issue is SNR (5% for a steady source at the sensitivity limit, $10^6$ s)
No quality cuts – background rejection cuts yet, since geometry was not fixed
Close a bit FOV and get rid of some of the mess from the Earth limb
Radiation environment (Dal Moro)

Primary protons, main source of activation for quasi-equatorial orbits (5° and less)
Differences in proton models up to 1 order of magnitude (AP8 vs AP9)
Conservative estimate

(Corti 2015)
Results: irradiation profiles (trapped)

1) average

2)

3)

4)
Results: inclination

Average 30°:
$T_{ON} \approx 20$ min
@ 1 MeV $\approx 5 \times 10^6$ p/cm$^2$/MeV

Average 5°:
$T_{ON} \approx 16$ min
@ 1 MeV $\approx 10^6$ p/cm$^2$/MeV
Activation (Andreetta)

For now only primary protons (main)
To do: trapped, neutrons, etc.

Isotopes with highest activity in Si

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Activity $[Bq]$</th>
<th>$T_{1/2}$ and error</th>
<th>Decay</th>
<th>$\gamma$ produced $[keV]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{20}_{9}F$</td>
<td>$(6.93 \pm 0.19) \cdot 10^{-4}$</td>
<td>11.00 (2) $s$</td>
<td>$\beta^-$</td>
<td>1633.602</td>
</tr>
<tr>
<td>$^{24}_{11}Na$</td>
<td>$(1.51 \pm 0.02) \cdot 10^{-3}$</td>
<td>14.9590 (12) $h$</td>
<td>$\beta^-$</td>
<td>1368.633; 2754.028</td>
</tr>
<tr>
<td>$^{28}_{13}Al$</td>
<td>$(8.90 \pm 0.03) \cdot 10^{-3}$</td>
<td>2.214 (12) $m$</td>
<td>$\beta^-$</td>
<td>1778.969</td>
</tr>
<tr>
<td>$^{29}_{13}Al$</td>
<td>$(8.04 \pm 0.23) \cdot 10^{-4}$</td>
<td>6.56 (6) $m$</td>
<td>$\beta^-$</td>
<td>1273.367</td>
</tr>
<tr>
<td>$^{24m}_{11}Na$</td>
<td>$(7.47 \pm 0.08) \cdot 10^{-4}$</td>
<td>20.20 (7) $ms$</td>
<td>IT</td>
<td>472.202</td>
</tr>
</tbody>
</table>

Table 4.3: Residual isotopes in Silicon
Results: gamma lines

<table>
<thead>
<tr>
<th>Energy [keV]</th>
<th>Rate [γ/s]</th>
<th>Decay mode</th>
<th>Saturation</th>
<th>Provenience</th>
</tr>
</thead>
<tbody>
<tr>
<td>472.202</td>
<td>(7.47 ± 0.08) · 10^{-4}</td>
<td>IT</td>
<td>yes</td>
<td>$^{24m}_{11}Na$</td>
</tr>
<tr>
<td>1273.367</td>
<td>(7.28 ± 0.21) · 10^{-4}</td>
<td>$\beta^-$</td>
<td>yes</td>
<td>$^{29}_{13}Al$</td>
</tr>
<tr>
<td>1368.633</td>
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<td>$\beta^-$</td>
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<td>$^{24}_{11}Na$</td>
</tr>
<tr>
<td>1633.602</td>
<td>(6.93 ± 0.19) · 10^{-4}</td>
<td>$\beta^-$</td>
<td>yes</td>
<td>$^{20}_{9}F$</td>
</tr>
<tr>
<td>1778.969</td>
<td>(8.90 ± 0.09) · 10^{-3}</td>
<td>$\beta^-$</td>
<td>yes</td>
<td>$^{28}_{13}Al$</td>
</tr>
<tr>
<td>2754.028</td>
<td>(4.45 ± 0.03) · 10^{-3}</td>
<td>$\beta^-$</td>
<td>yes</td>
<td>$^{24}_{11}Na$</td>
</tr>
</tbody>
</table>

511 keV, from positrons (mostly $\beta^+$ decay)

Worst: ~0.1 Bq (CAL)
511 keV: ~1ph/s
Simulate as source inside the payload
Triggering eff.: ~$10^{-3}$
GRB sensitivity
(Canevarolo)
The exact formulation of the question affects the results. We opted for the following:

- we will have an alert (it could be internally generated);
- we want to confirm the alert at 3-sigma significance (<0.3% chance probability);
- we want to provide a location of the GRB;
- the procedure could be automated to run unassisted.

Take the *Fermi*-GBM GRB catalog: 1405 GRBs in 6 years. Divide the sample by time duration, simulate 2 representative GRBs per band (average, hard). Semi-analitical estimate of flux to have 3-sigma sensitivity.
Preliminary results

~7 short GRBs per year (comparable with COMPTEL)
first unassisted localization: sigma ~10°

GRB sensitivity

~7 short GRBs per year (comparable with COMPTEL)
first unassisted localization: sigma ~10°
Future activities

Evaluate quality cuts, define response (sensitivity, SNR, FOV, …)

Evaluate mission plan (launch, orbit, …) - preliminary plan developed as a student project at UF (course EAS 4700 – AEROSPACE DESIGN 1)

Submitted proposal to Italian ministry (PRIN2017) for an active-pixel MeV payload (adapting an INFN patented technology), fallback to this design if R&D is not satisfactory

The End