SMILE-2+:
The 2018 balloon campaign in Australia of MeV gamma-ray telescope

Kei Yoshikawa
T. Tanimori, A. Takada, Y. Mizumura, S. Komura, T. Kishimoto,
T. Takemura, T. Taniguchi, Y. Nakamura, K. Onozaka, K. Saito,
H. Kubo, S. Kurosawa\textsuperscript{A}, K. Miuchi \textsuperscript{B}, K. Hamaguchi \textsuperscript{C},
T. Sawano \textsuperscript{D}, M. Kozai \textsuperscript{E},

Kyoto University, \textsuperscript{A} Tohoku University, \textsuperscript{B} Kobe University,
\textsuperscript{C} Maryland University, \textsuperscript{D} Kanazawa University, \textsuperscript{E} ISAS/JAXA

photo : Just before Launching @ Alice Springs, Australia, April 7th 2018
Contents

• Introduction of SMILE-2+ experiment
  - aim and requirements
• 2018 balloon flight overview
• Quick check from 2018 balloon flight
  - analysis of data in level flight
• Summary
Balloon Experiment: SMILE-2+

Aim: certificate imaging spectroscopy of ETCC using celestial objects

Targets: $e^\pm$ annihilation line from the galactic center region
  Crab nebula

Requirements of detections with the significance of $\sim 5 \sigma$:
  • Altitude: $\sim 39$ km (atmospheric depth $\sim 3.5$ g/cm²)
  • Half Power Radius (HPR): $\sim 10$ degrees
  • Effective area: a few cm²
  • Energy Range: 0.3 – 1.5 MeV
  • galactic center region: $> 6$ hours
  • Crab nebula: $\sim 6$ hours
SMILE-2+ gondola

- Detector (ETCC)
- Geomagnetic Sensor
- GPS antenna
- MLI
- Crash pad
- Ballast box

- Weight: 511 kg
- Power: 214 W
- No posture control
- Position sensor: ~1°
**Flight Overview of April 7 - 9**

<table>
<thead>
<tr>
<th>April 7 (local time)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2:47-3:09</td>
<td>power on sequence</td>
</tr>
<tr>
<td>3:09</td>
<td>start of data acquisition</td>
</tr>
<tr>
<td>6:24</td>
<td>launching</td>
</tr>
<tr>
<td>8:44</td>
<td>start of level flight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>April 8</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10:45</td>
<td>end of data acquisition</td>
</tr>
<tr>
<td>10:45-10:53</td>
<td>power off sequence</td>
</tr>
<tr>
<td>11:07</td>
<td>cut off</td>
</tr>
<tr>
<td>11:40</td>
<td>landing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>April 9</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>recovering</td>
</tr>
</tbody>
</table>

We could observe two targets as planned, and recover the gondola safety and perfectly.

We appreciate balloon managing by JAXA.

Level flight ~26 hours
- crab nebula ~6 hours
- galactic center >8 hours

~150 m
5 x 10^5 m³

©google

42th COSPAR Pasadena, July 17 2018
Atmospheric Depth and Direction

The balloon flight satisfied the requirements of atmospheric depth. We succeeded in monitoring the direction of the gondola.
The ETCC trigger rate as preflight expectation was \( \sim 500 \text{ Hz} \) in level flight.

Our detector was stable at the balloon altitude as planned.

Small noises did not degrade data acquisition so far. No problem.
Our gas detector succeeded in getting charged particles.
Two type of event analysis
Here we present
only fully contained $e^-$ event.

Event selection
1. single scintillator hit
2. fully contained electron selection
3. certification of Compton kinematics using $\alpha$ angle selection
   - Only simple selection
   - No gamma-ray veto
Quick Check of Level Flight

- Level flight: ~19 hours
- Live time: $5.7 \times 10^4$ sec

Our simple event selection succeeded in noise reduction.
**Compare with First Balloon Experiment**

SMILE-I is the first balloon experiment using a small ETCC.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of gamma-ray events to all events</td>
<td>~1.2%</td>
<td>~1%</td>
</tr>
<tr>
<td>All gamma-ray rate[Hz]</td>
<td>~3.6 × 100</td>
<td>~0.06</td>
</tr>
<tr>
<td>Downward gamma-ray rate[Hz] zenith angle 0° - 60°</td>
<td>~1.7 × 100</td>
<td>~0.03</td>
</tr>
</tbody>
</table>

Effective area of SMILE-I: ~0.01 cm² (~1/100 of SMILE-2+)

SMILE-2+ quick checks seems consistent with SMILE-I results.

From this simple analysis, the performance of our detector looks as we planned.
The difference of spectra is due to PSF.

$e^\pm$ annihilation line is stronger at larger zenith angle, because of larger mass of the atmosphere and the instruments. Image enables us separate to the origin of 511 keV gamma-ray roughly.
Summary

• The aim of SMILE-2+ is to certificate imaging spectroscopy of ETCC using celestial objects.
• The balloon flight lasted 29 hours, and the level flight continued during 26 hours at altitude 38.4-40.5 km.
• Observation times of $e^\pm$ annihilation line from the galactic center region and the Crab nebula were $>8$ hours and 6 hours, respectively.
• Our detector was stable at the balloon altitude.
• The quick checks of SMILE-2+ seems consistent with the first balloon experiment, SMILE-I.
• Soon, we will show the results of observations of the $e^\pm$ annihilation line from the galactic center and the Crab nebula.

Thank you.
House-keeping Sensors

**Sensors** for location, direction, and atmospheric depth:

- **GPS compass**
  - location: < 2.5 m (RMS)
  - azimuth angle: < 0.15° (95% CL)

- **Inclinometer**
  - X 2
  - East – West
  - North - South
  - elevation angle: < 0.002° (RMS)

- **Geomagnetic aspect sensor**
  - X 3
  - x, y, z axis
  - accuracy: ±1.5°

- **outer pressure gauge**
  - range: 0 – 130 hPa
  - accuracy: ±0.2 hPa

©SPA
noises of
gaseous detector
several strip
(\sim 1 \text{ cm})
Our event selection succeeded in excluding random coincidence events.