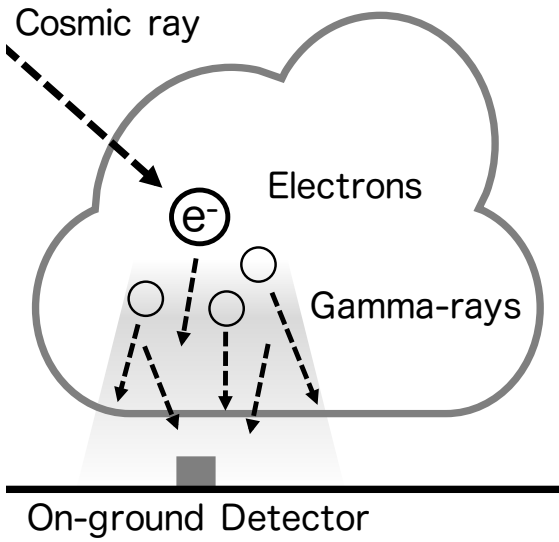
雷雲ガンマ線の多地点観測プロジェクト: 可搬型検出器の開発と2016年度冬季の観測成果

Multi-point Observations of Thundercloud Gamma-rays: Development of Portable Detectors and Results of Fiscal 2016 Winter Observation

和田有希 / Yuuki Wada (東大理 U.Tokyo / 理研 RIKEN)

榎戸輝揚 (京大理), 古田禄大 (東大理), 湯浅孝行 (理研)
中澤知洋 (東大理),中野俊男 (理研), 土屋晴文 (原研/理研)
鴨川仁 (学芸大),米徳大輔 (金沢大), 澤野達哉 (金沢大)
ほか GROWTHコラボレーション

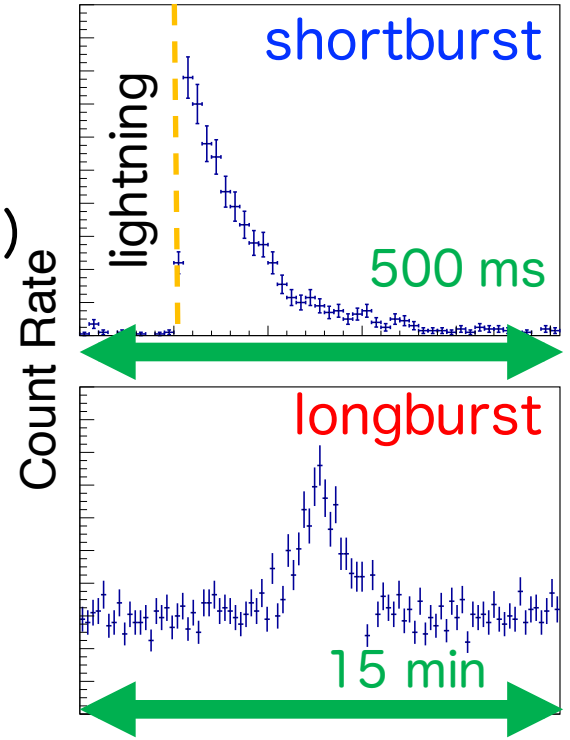
Thundercloud Gamma-rays



- Electron Accerelation in Thundercloud
  - Electric field of 200–300 kV/m
    accelerates electrons up to ~10 MeV.
  - Bremsstrahlung gamma-rays.
  - Relativistic Runaway Electron Avalanche Model
    (RREA; Grevich 1992, Dwyer+2004)

- GROWTH Experiment (2006-)

(Gamma-Ray Observation of Winter THundercloud)
  - On-ground remote observation at Niigata
  - 28 events for 10 years with 1-2 detectors.
    - Shortburst (associated with lightning)
    - Longburst (stable emission)
      (Tsuchiya+2007, 2013, Umemoto+2016 etc.)



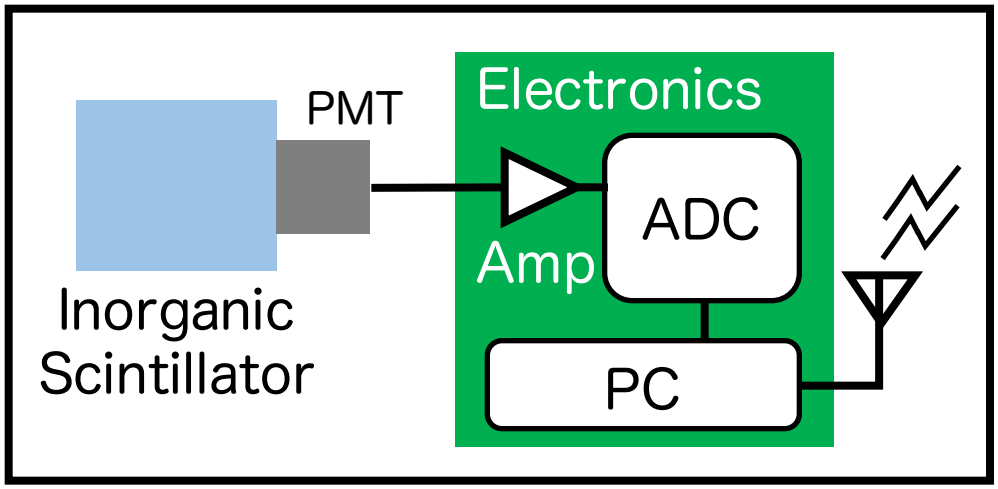
Questions and Methods

- Characterization of longburst: **Big questions**
  - How longburst starts, grows, and disappears?
    Key: Total duration, forming condition, time variation.
  - Can the conventional RREA model explain longburst mechanism?
    Key: Total photon number, size of irradiated area,
    2D distribution of gamma-ray flux and spectrum.
- Large Area Mapping Observation in Ishikawa (2015-)
  - Track longburst with gamma-ray detector array.
  - Wide area needed to install detector array.
  - Started in FY2015 at Kanazawa
    -> 3 longbursts detected (Enoto+ JpGU 2016).
  - Plan to equip ~30 detectors (finally) in Kanazawa.

Important to develop simple, small, low-cost detectors

Portable Gamma-ray Detector

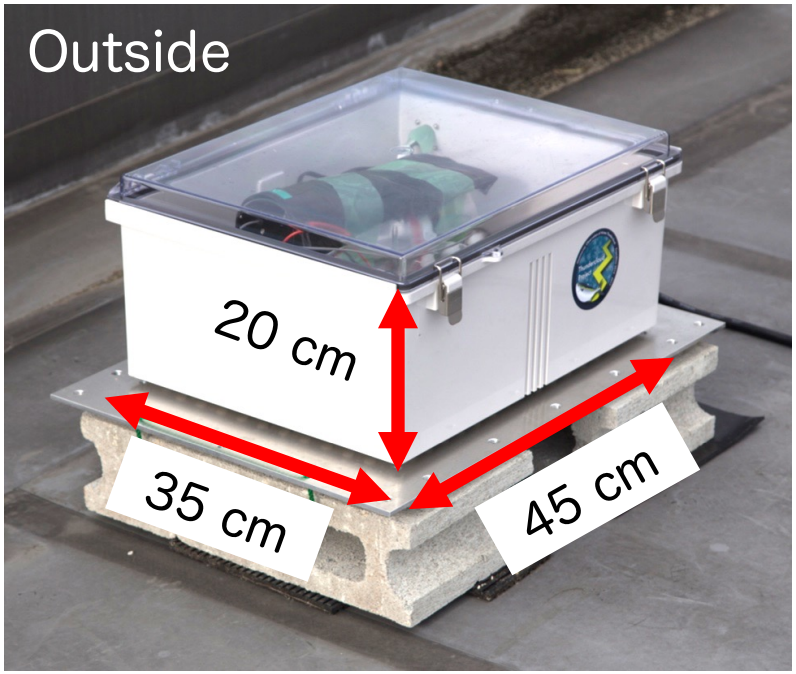
Configuration



- Inorganic scintillator for gamma-ray detection
- Photon-by-photon record to obtain energy and time
- Remote-controlled system

FY2016 Detector

- Packed inside water-proof box
- BGO scintillator (25×8×2.5 cm^3)
- Compact data acquisition system
- Mobile line (5GB/month) for monitoring and data transfer.



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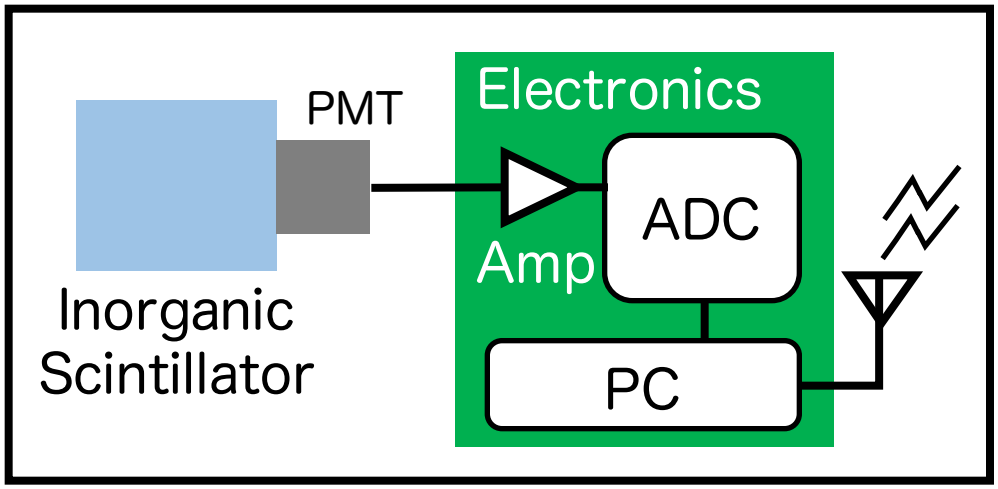

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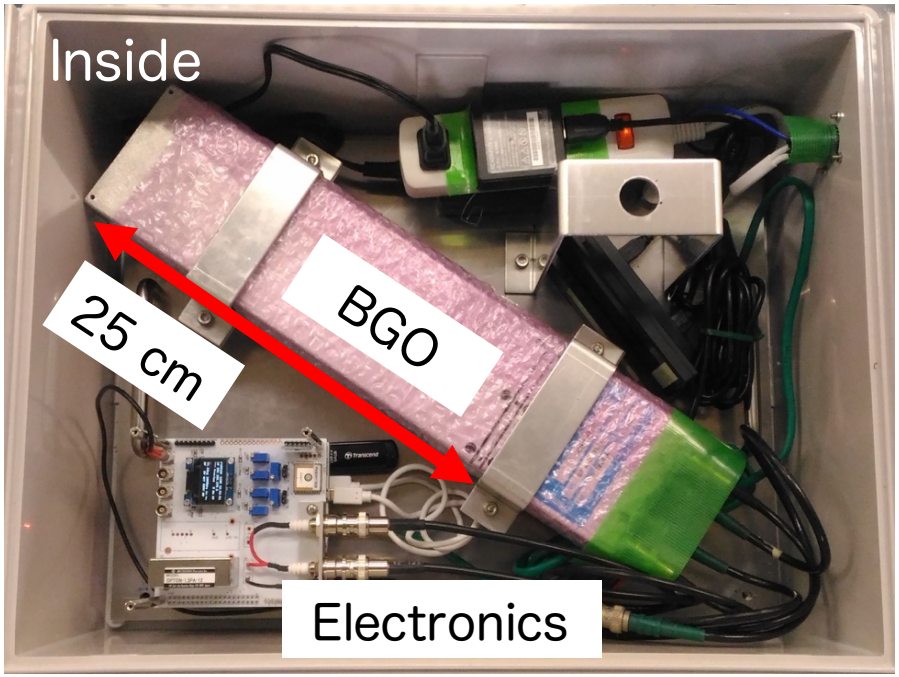
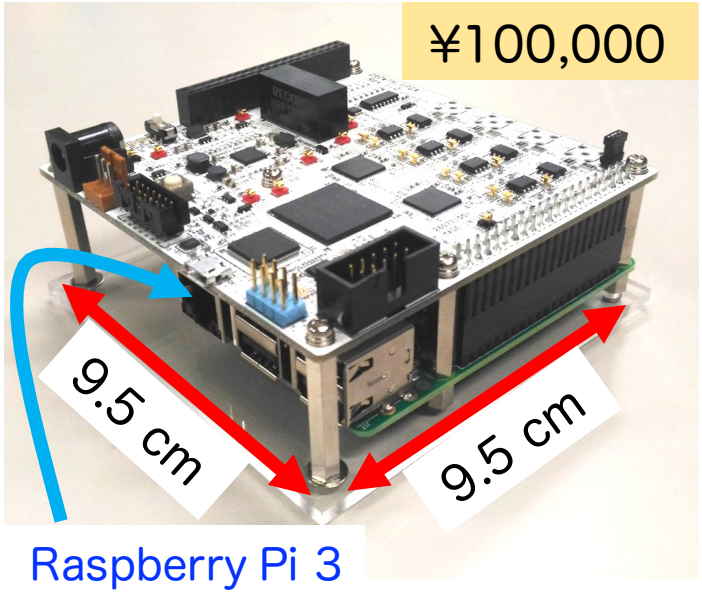


Brand-new Compact DAQ Electronics

Including HV supply, amplifier, ADC, data acquisition

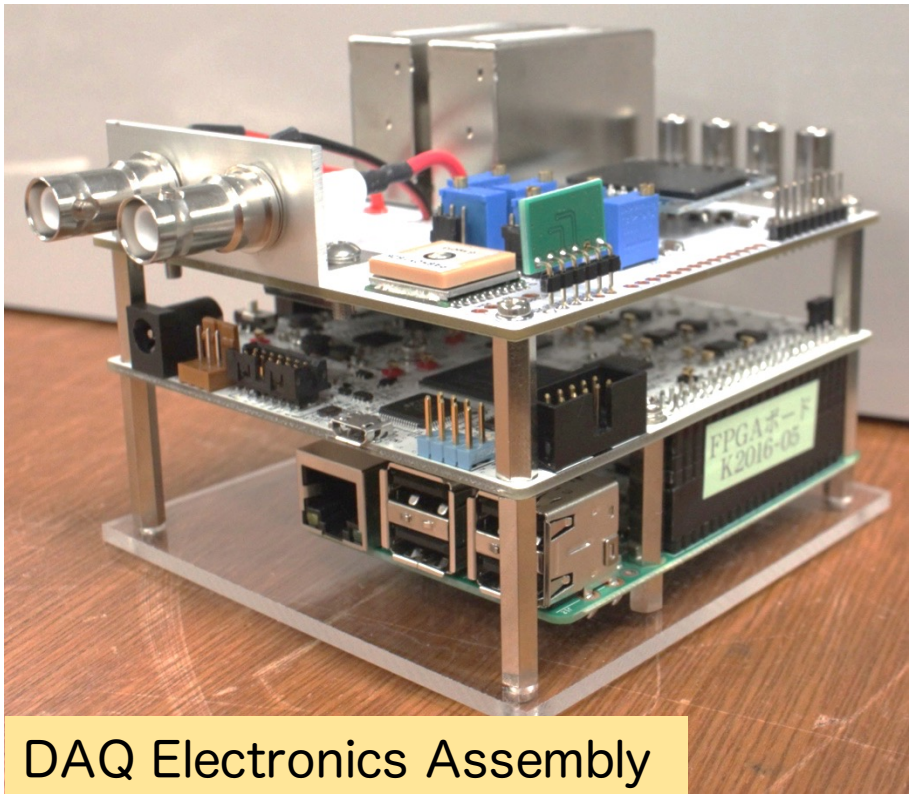


FPGA/ADC Board

- 12 bit ADC × 4ch
- Self-trigger photon by photon data acquisition with Raspberry Pi.

Analog Front-end Card

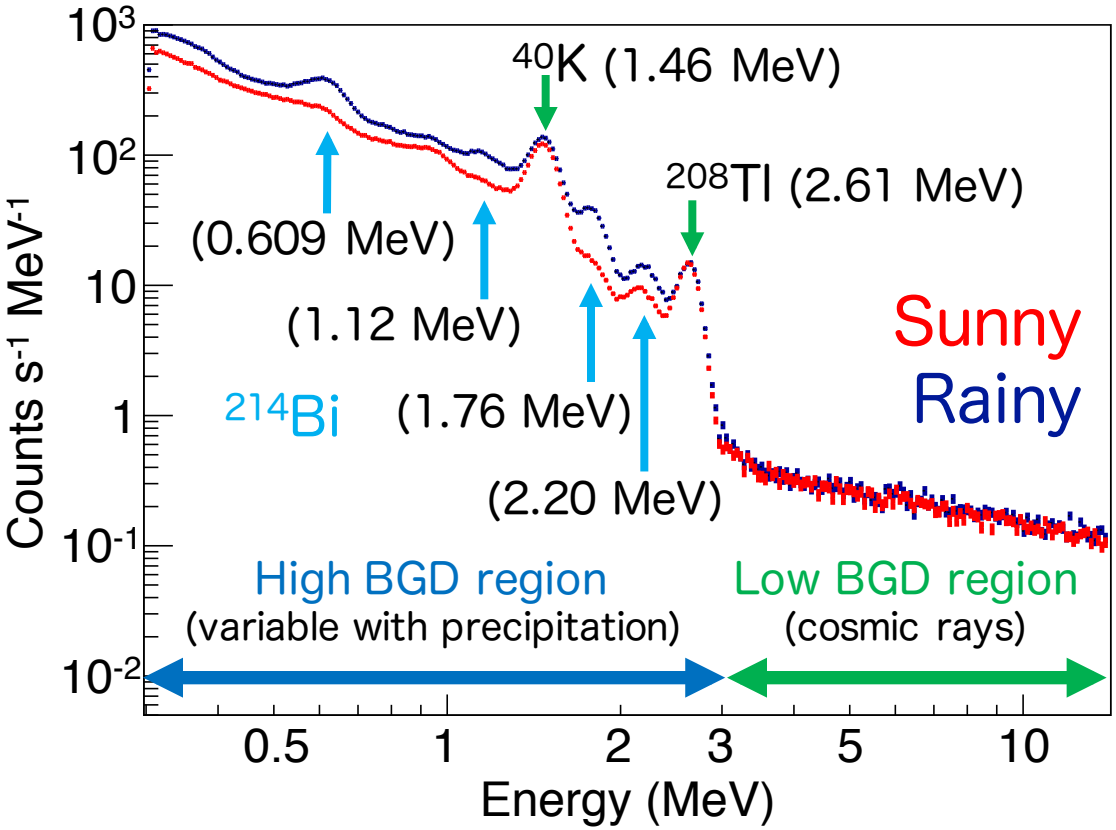
- Coupled with PMT
  - HV Power Supply
  - Preamp + Shaper
- GPS receiver
- Temperature senser, mini display
- Developed and designed by Wada


DAQ Electronics Assembly

Gamma-ray Spectra

Radiation background

- Natural Isotopes (^{40}K, ^{208}Tl, ^{214}Bi etc.)
- Cosmic Rays (Gamma-ray, electron, muon etc.)

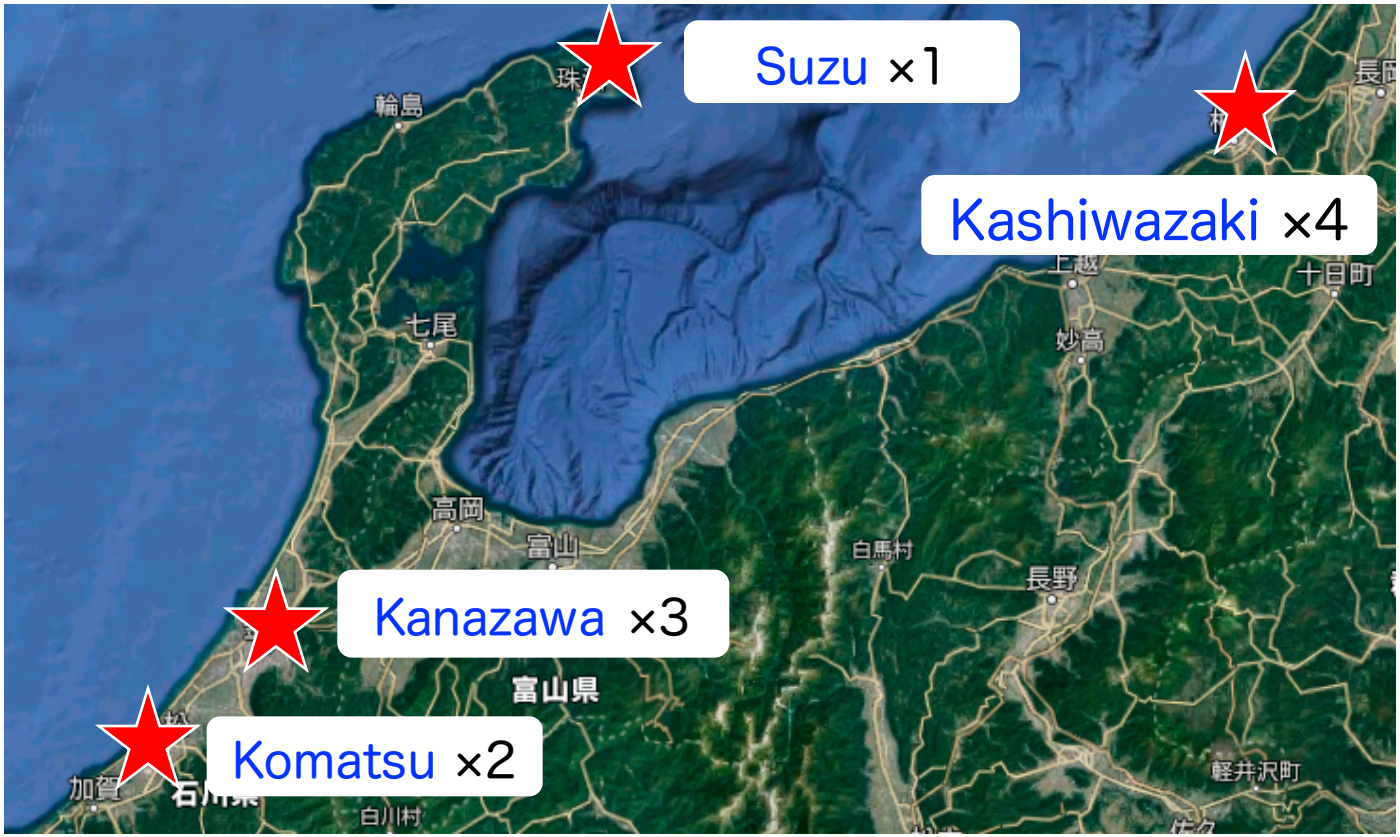


- Strength of ^{40}K & ^{208}Tl Lines are constant
  - Use for energy calibration
- ^{214}Bi Lines are variable with precipitation (Rn wash out)
- >3 MeV region mainly consists of cosmic rays
  - stable
  - high S/N ratio for thundercloud gamma-rays

Use >3 MeV region for Thundercloud Gamma-ray search

FY2016 Campaign - Location

・We operated 8 portable detectors and 2 conventional detectors.
- From October 2016 to March-April 2017



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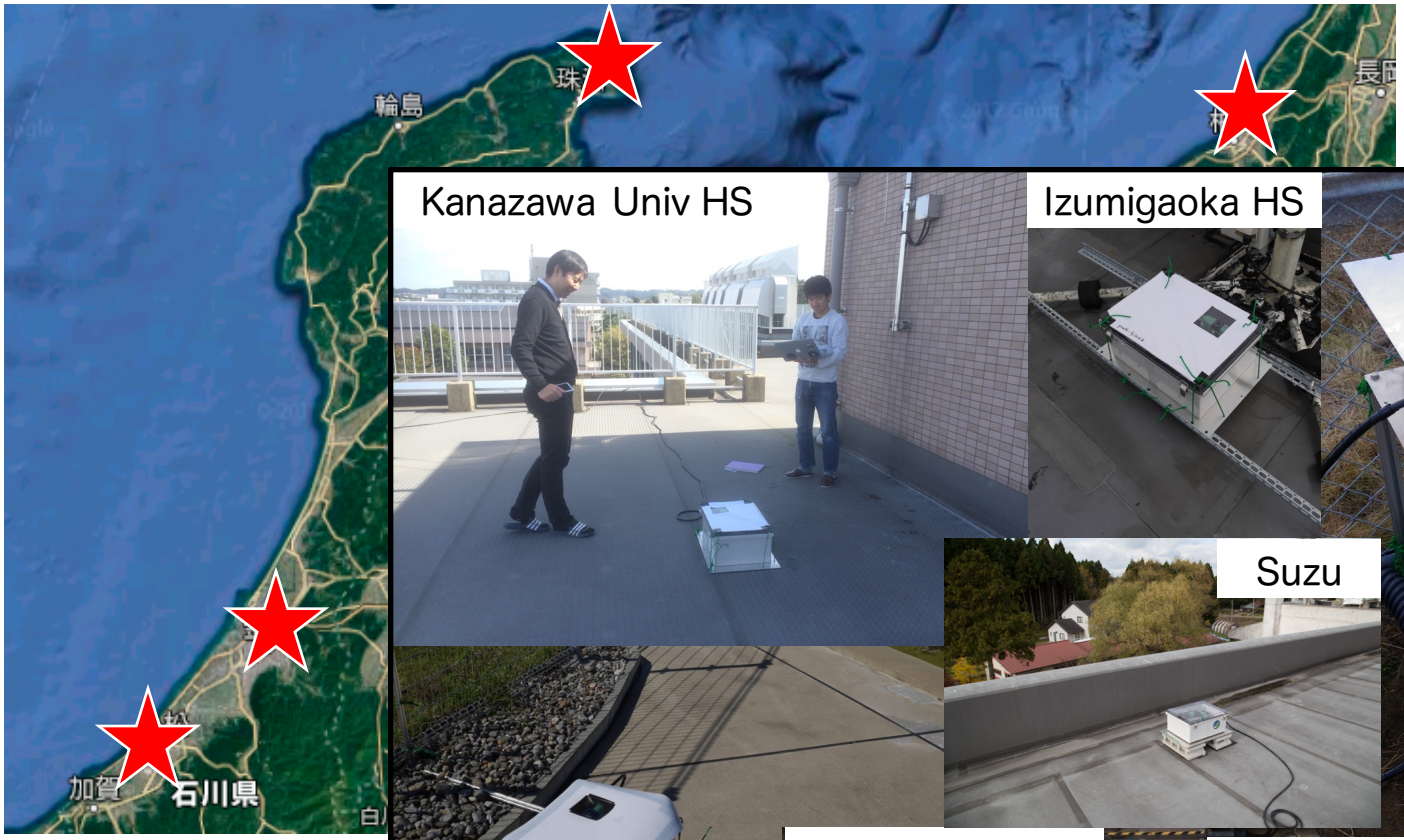

Results of FY2016

We detected 10 longbursts and 2 shortbursts.

Date	Time (JST)	Location	Type
20161208	00:14	Kanazawa Univ.	long
	02:56	Komatsu HS	long
	02:58	Science Hills Komatsu	long
20161209	16:29	Kanazawa. Univ. HS	long
20170113	01:43	Kanazawa Univ.	long
	05:05	Kanazawa Univ.	long
20170115	05:31	Kanazawa Univ.	long
20170116	12:19	Kashiwazaki	short
20170206	05:07	Kanazawa Univ.	long
	05:10	Kanazawa Univ.	long
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20170211	17:10	Suzu	long

28 event / 10 years / 1-2 detectors (2006-2015)
-> 12 events / year / 10 detectors (FY2016)

Five times improvement

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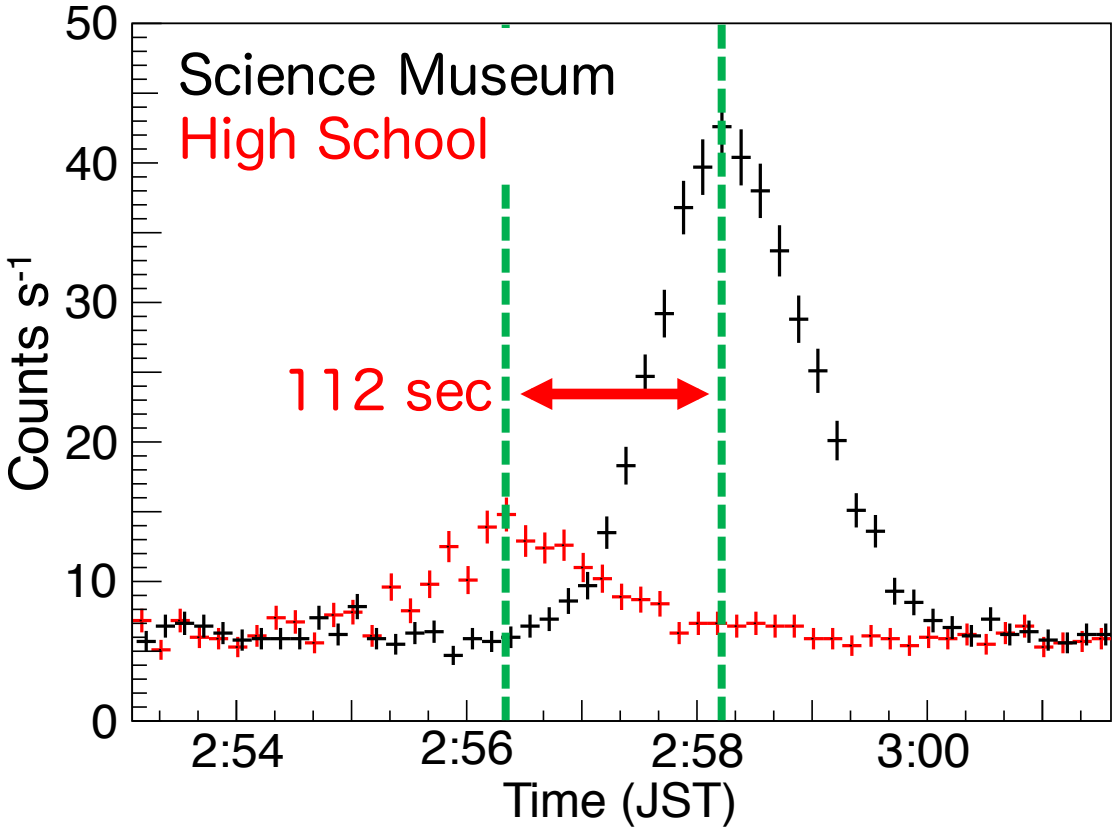
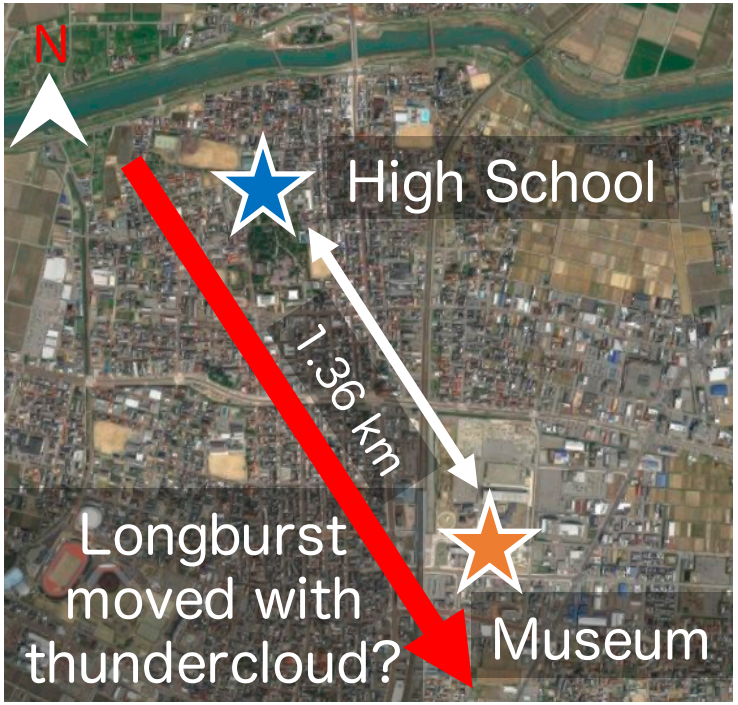
Five times improvement

Longbursts on 20161208 at Komatsu

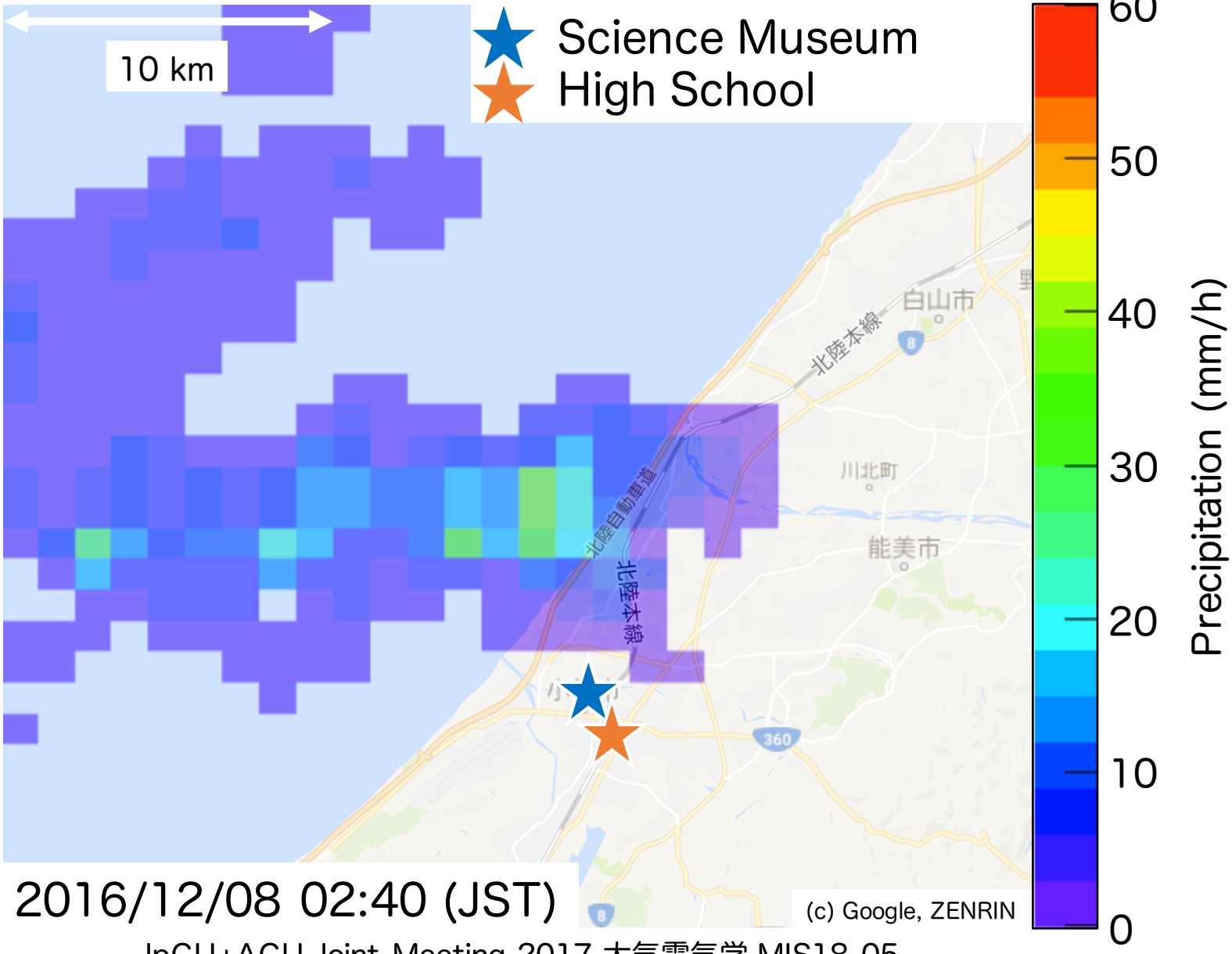
- Count rate history of 2 longbursts
  - Brighter at “Science Museum” then “High School”.
  - Symmetric in time (>3 MeV)
- 112 sec time lag
  - Gamma-rays from the same thundercloud passing above the 2 detectors?





Longbursts on 20161208 at Komatsu

・Dynamics of thundercloud with JMA Weather Radar



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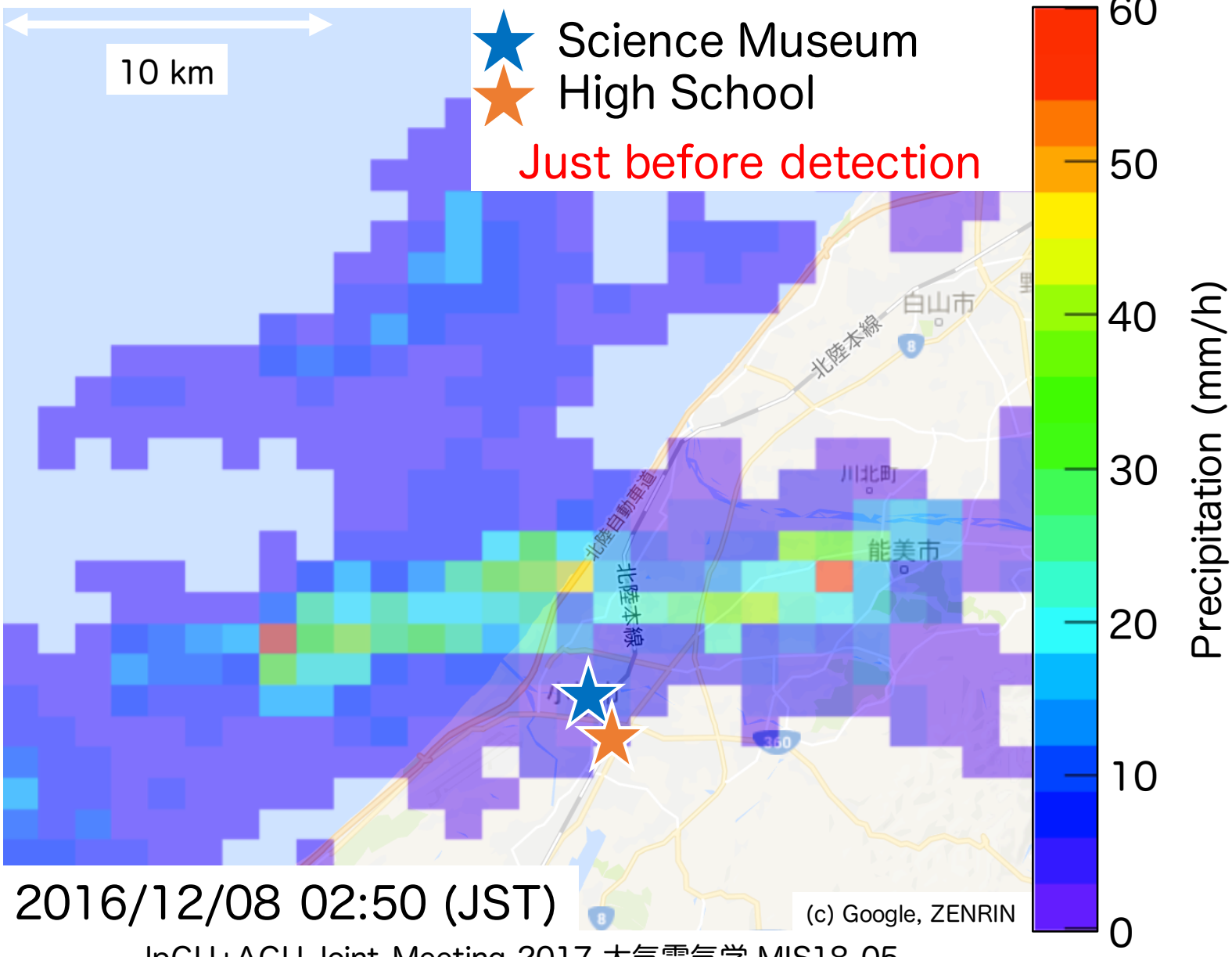

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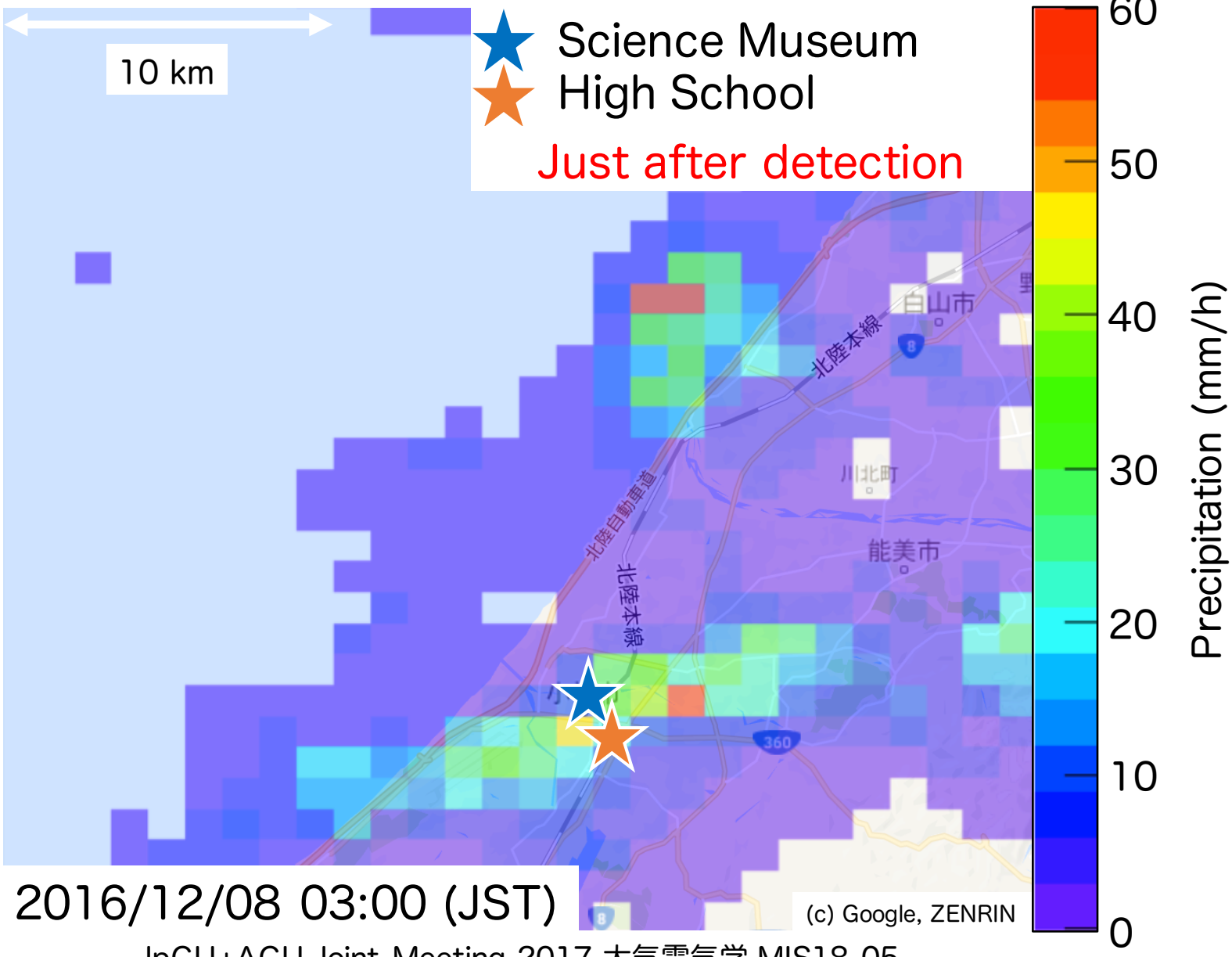

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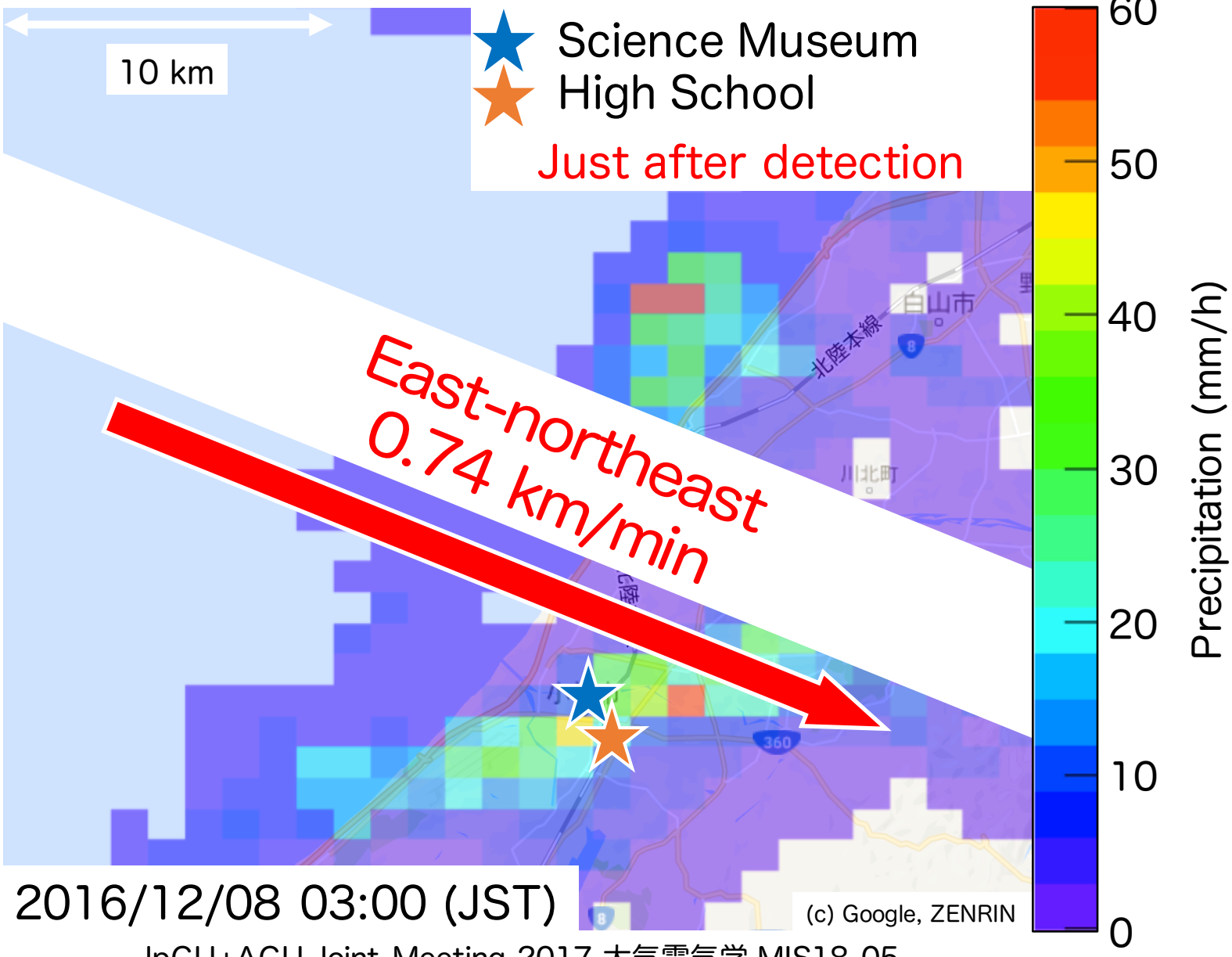

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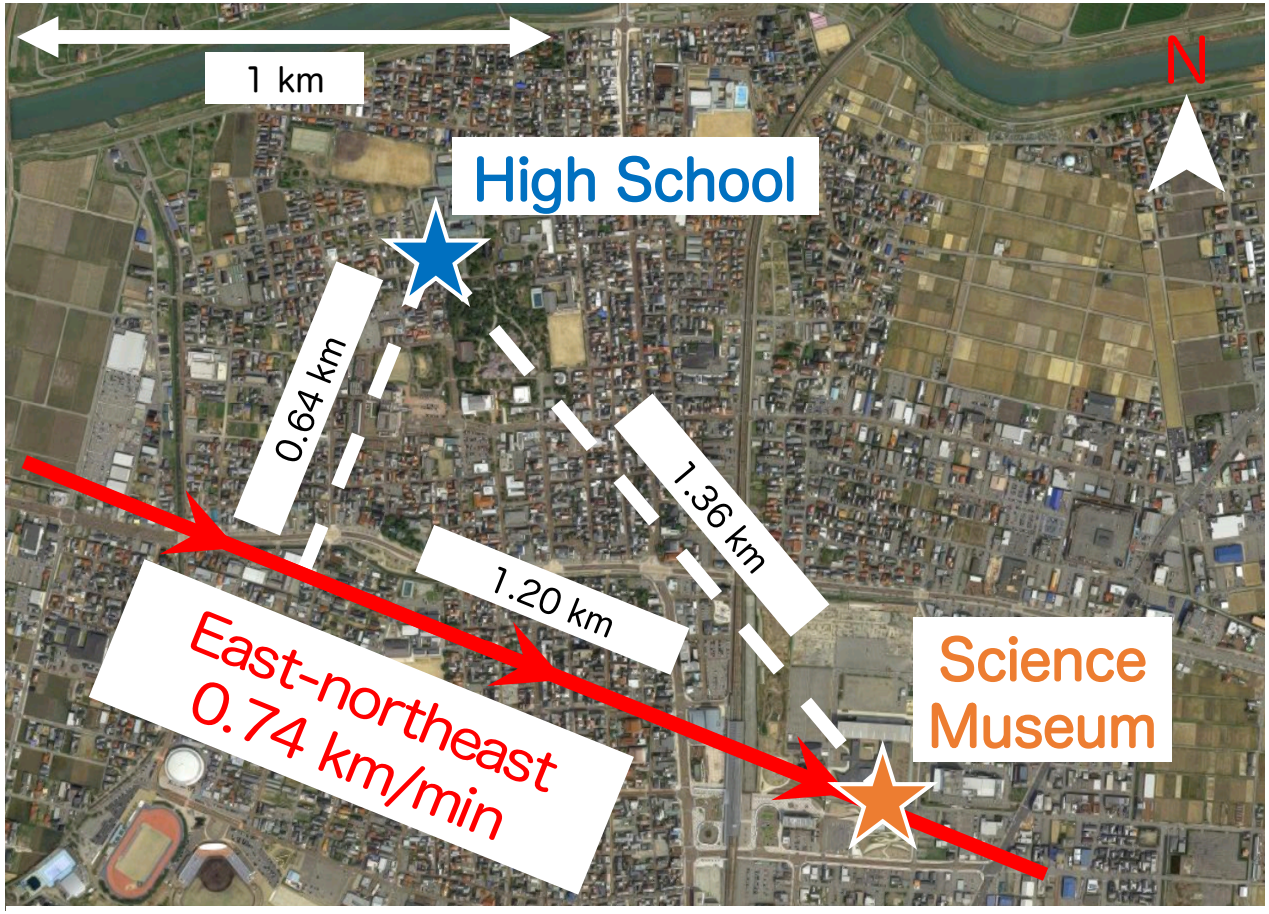
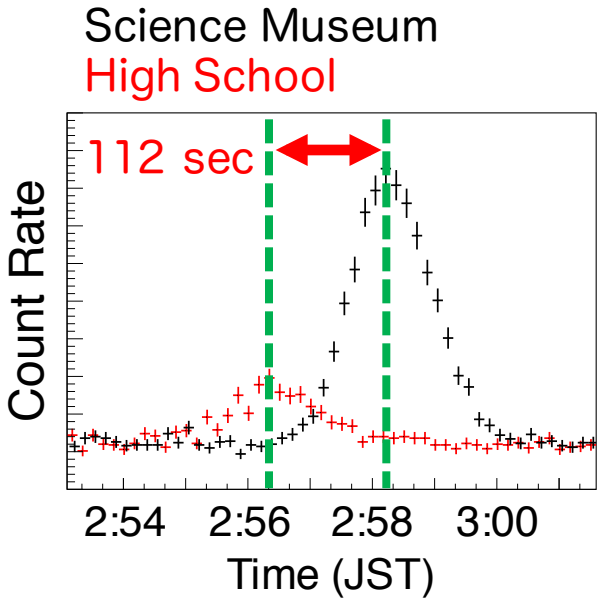


(c) Google



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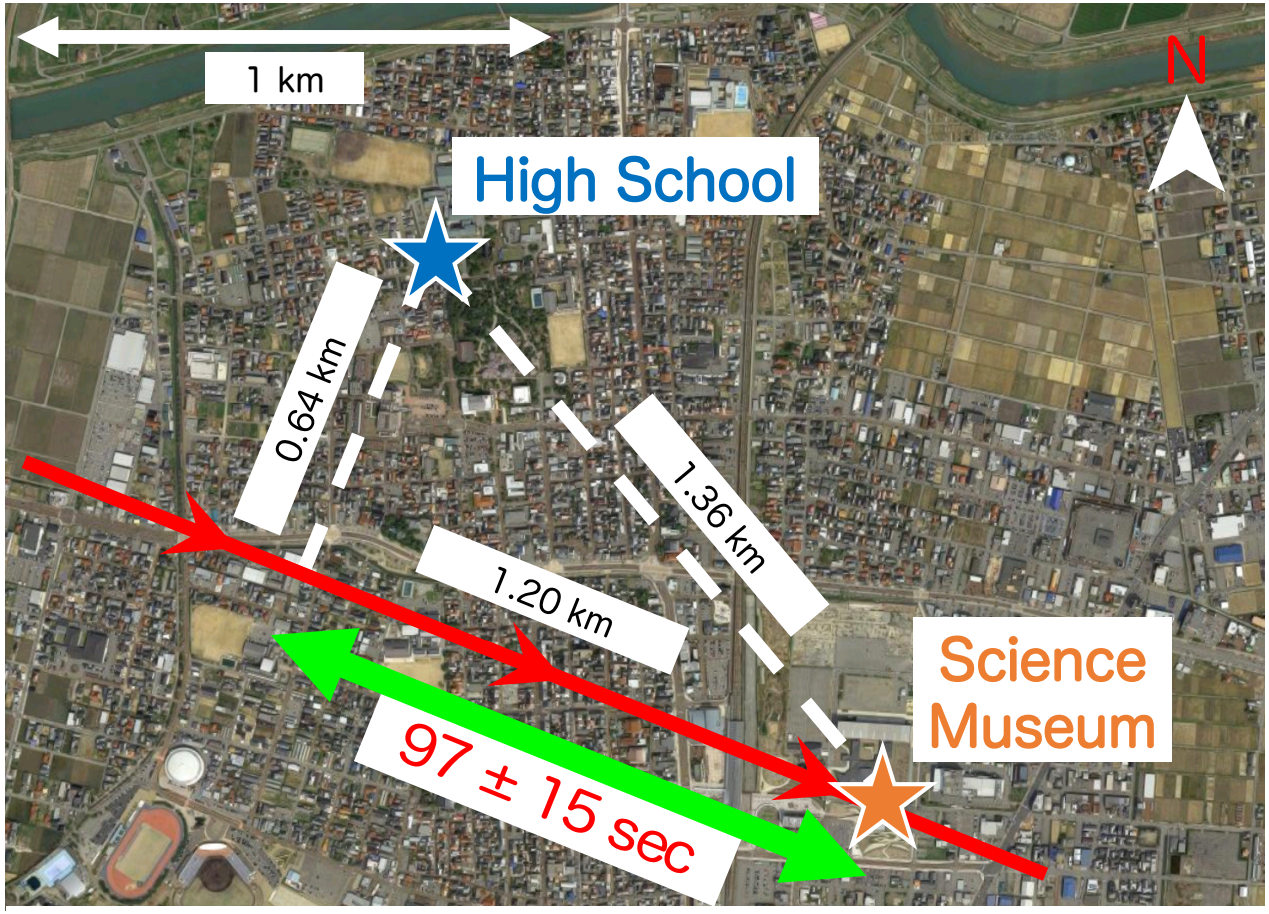

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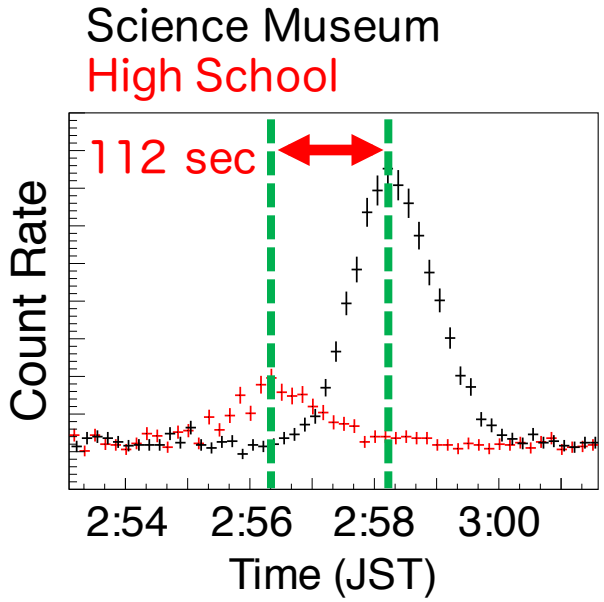
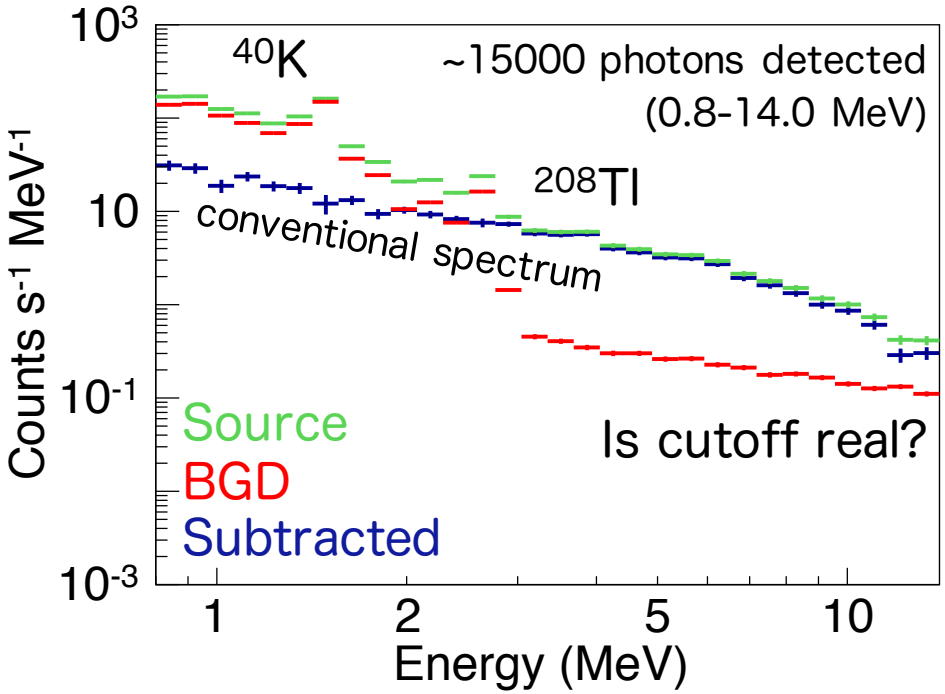


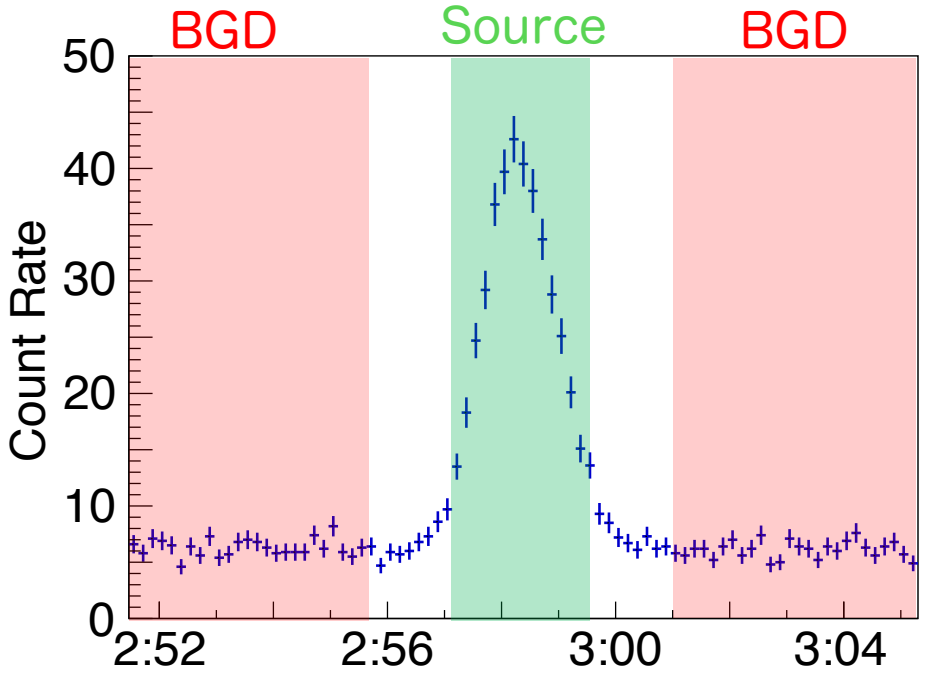
"Electron accelerator" moved at least 1.2 km with the thundercloud.

Spectral Analysis

Longburst at Science Museum

- We generated background subtracted spectrum.





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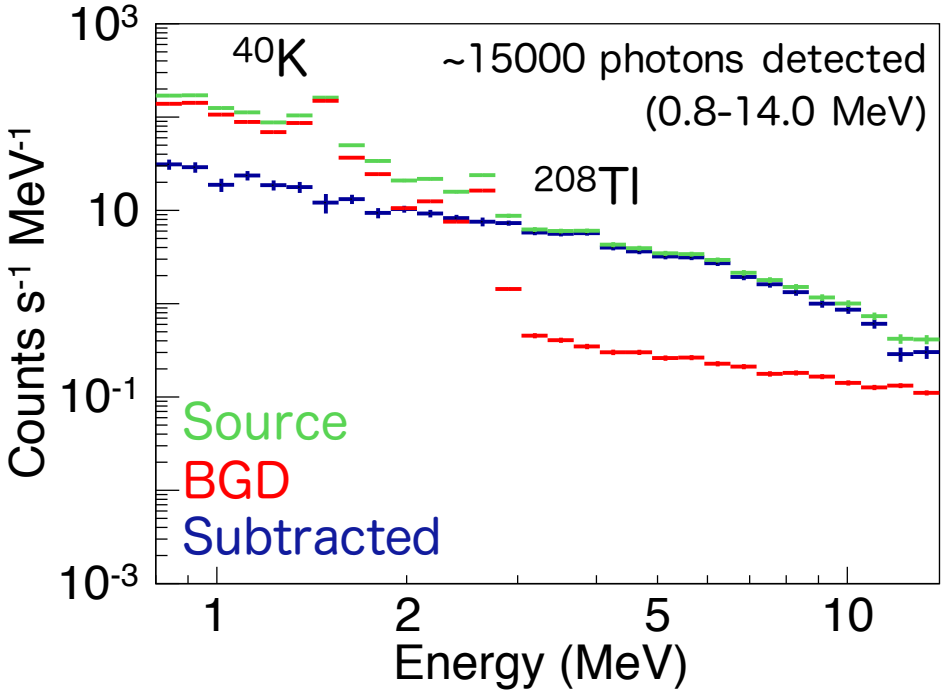

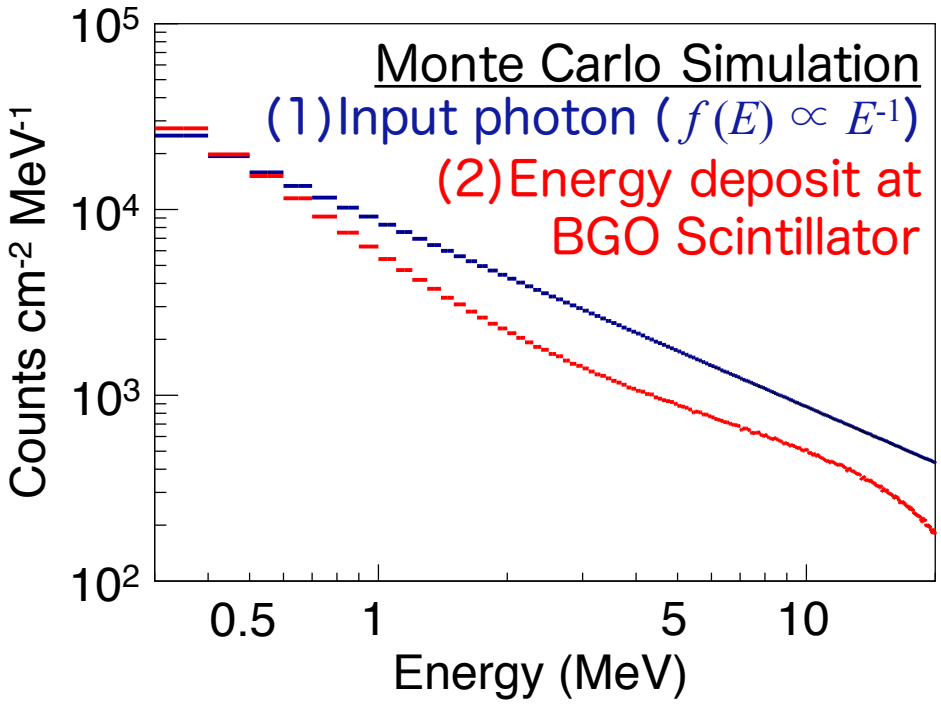

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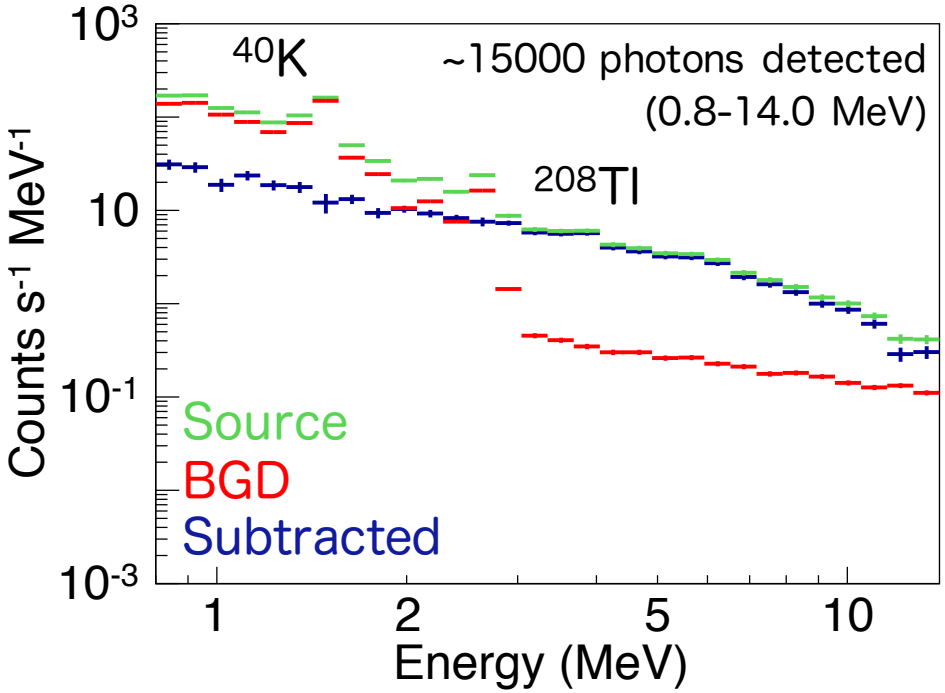
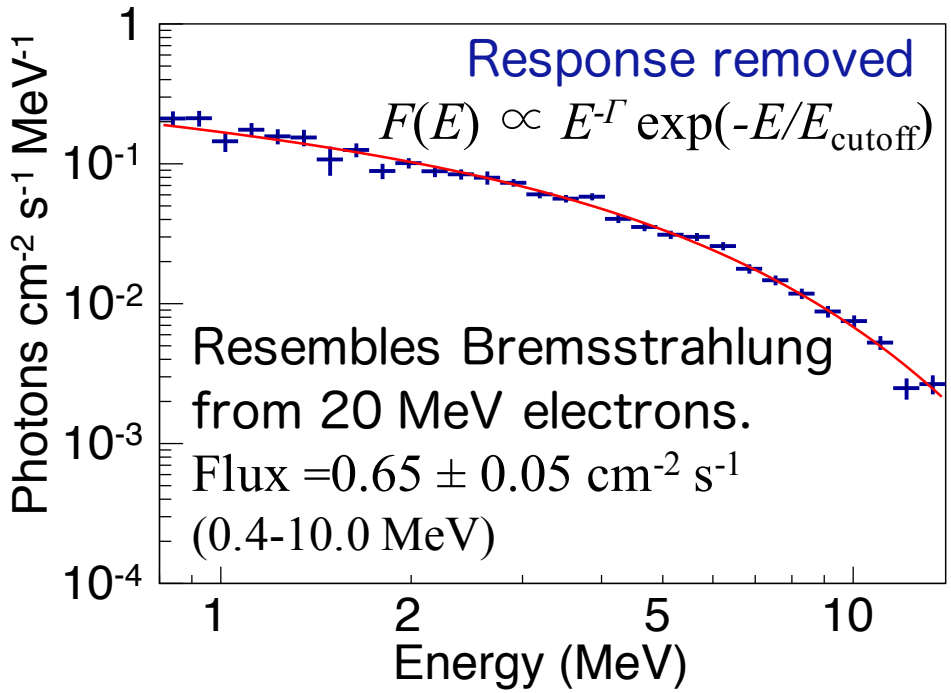
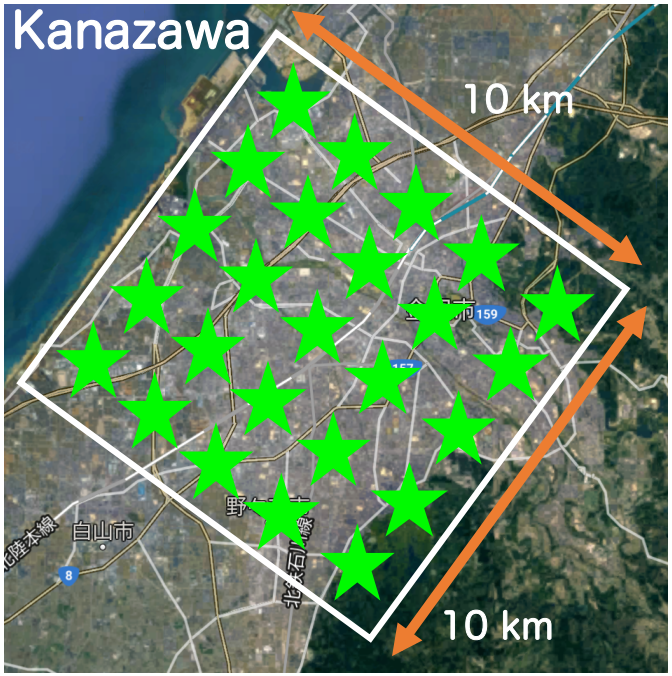




The response-resolved spectrum consists of a powerlaw continuum with cutoff.

Conclusion and Future Prospects

- We deployed 10 detectors in FY2016 winter and detected 10 longbursts and 2 shortbursts.
- Detectors in Komatsu successfully tracked a longburst moving with thundercloud.
- Spectrum was apparently consistent with Bremsstrahlung from 20 MeV electrons.



(c) Google, ZENRIN, DATA SIO, NOAA, US Navy, NGA, GEBCO, Landsat

Future array will reveal

- "Life of longbursts" by tracking from "birth" to "death".
- Acceleration mechanism (RREA?) by measuring fluxes and spectra.

We will answer the questions of longburst