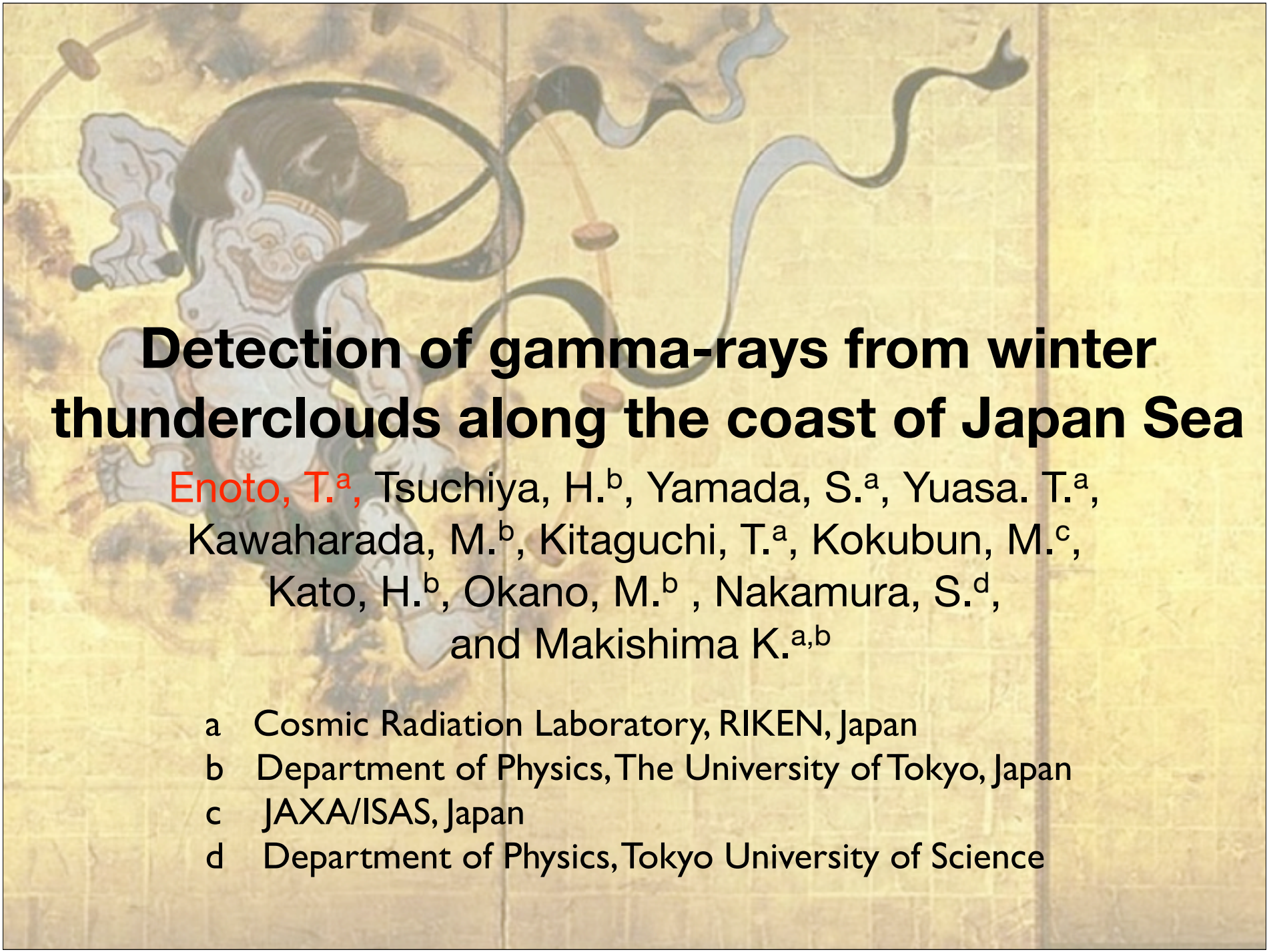


Detection of gamma-rays from winter thunderclouds along the coast of Japan Sea

Enoto, T.[a], Tsuchiya, H.[b], Yamada, S.[a], Yuasa. T.[a], Kawaharada, M.[b], Kitaguchi, T.[a], Kokubun, M.[c], Kato, H.[b], Okano, M.[b] , Nakamura, S.[d], and Makishima K.[a,b]

a Cosmic Radiation Laboratory, RIKEN, Japan
b Department of Physics, The University of Tokyo, Japan
c JAXA/ISAS, Japan
d Department of Physics, Tokyo University of Science

1. Introduction

- gamma-rays from thunderclouds.

  thunderclouds *(MacCarthy 1985, Eack 1996)*
  natural lightning *(Moore 2001)*
  rocket triggered lightning *(Dowyer 2003)*
  terrestrial gamma-ray flashes
  by satellites *(Fishman 1998, Smith 2004)*

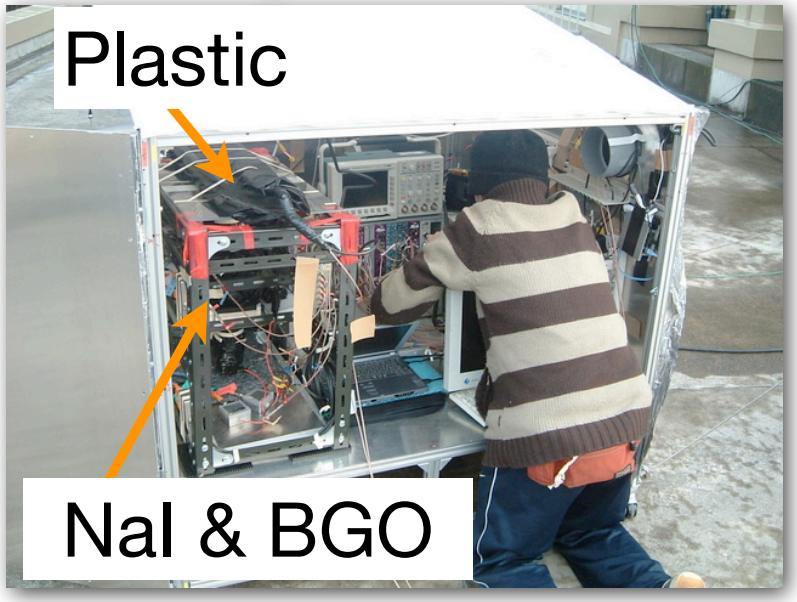
- E ~ 0.1 MV/m, L ~100 m --> 10 MeV accelerated electrons ?
- prolonged radiation enhancements (△t ~ 1-2 min) from winter thunderclouds by monitoring posts *(Torii 2002, Yamasaki, 1998)*.
- Neither the kind of radiation, spectrum, nor duration are well known.
- Dedicated photon counting gamma-ray detector. One successful detection *(Tsuchiya, H., & Enoto, T., et al., PRL submitted)*.

2. Observation plan and site

- Scintillation detectors with wide energy band (40 keV- 100 MeV).
- Winter thunderclouds along the Japan Sea ; lower in altitude (<1-3 km) and higher in energy output.
- Kashiwasaki-Kariwa nuclear power plant (Niigata Pref., Japan).
- Set up on December 2006. Observation continues.

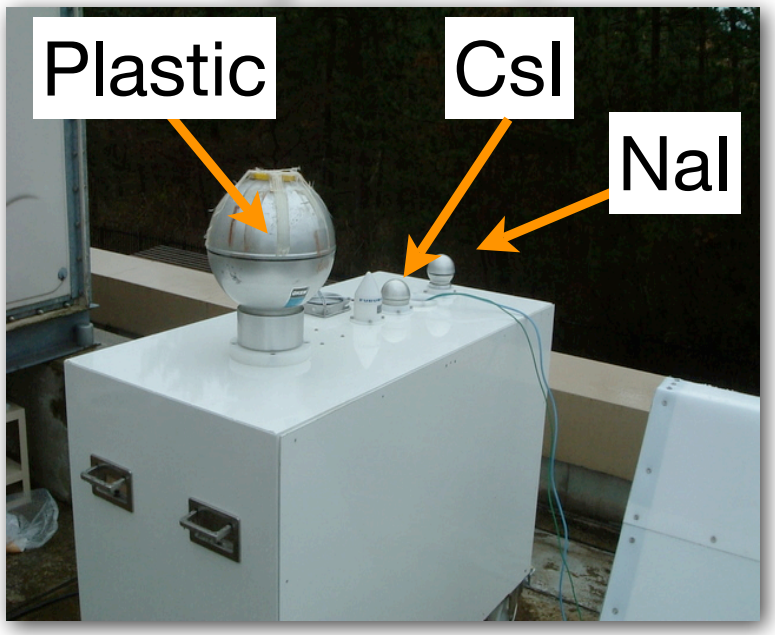
3. Detectors

System A



- NaI+BGO(shield)
  - Coarse collimation
  - 40 keV-3.3 MeV
  - single photon detection
- Plastic scintillator
- Optical & sound sensor

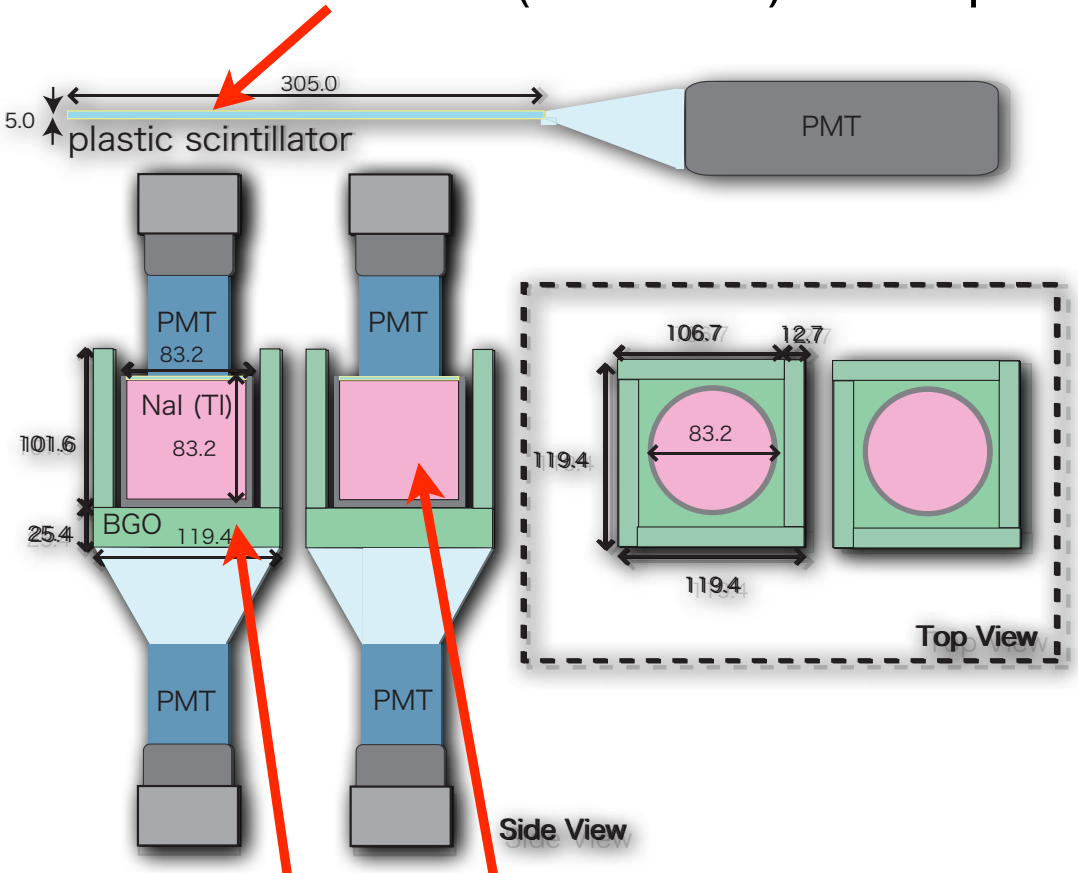
System B

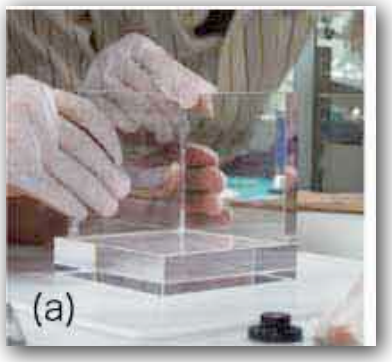


- NaI,CsI,Plastic scintillator
  - Omni direction
  - 40 keV-100 MeV
  - Pulse heights (6 s) & rates (1 s)
- Electric field sensor & barometer

4. Detectors (System-A)

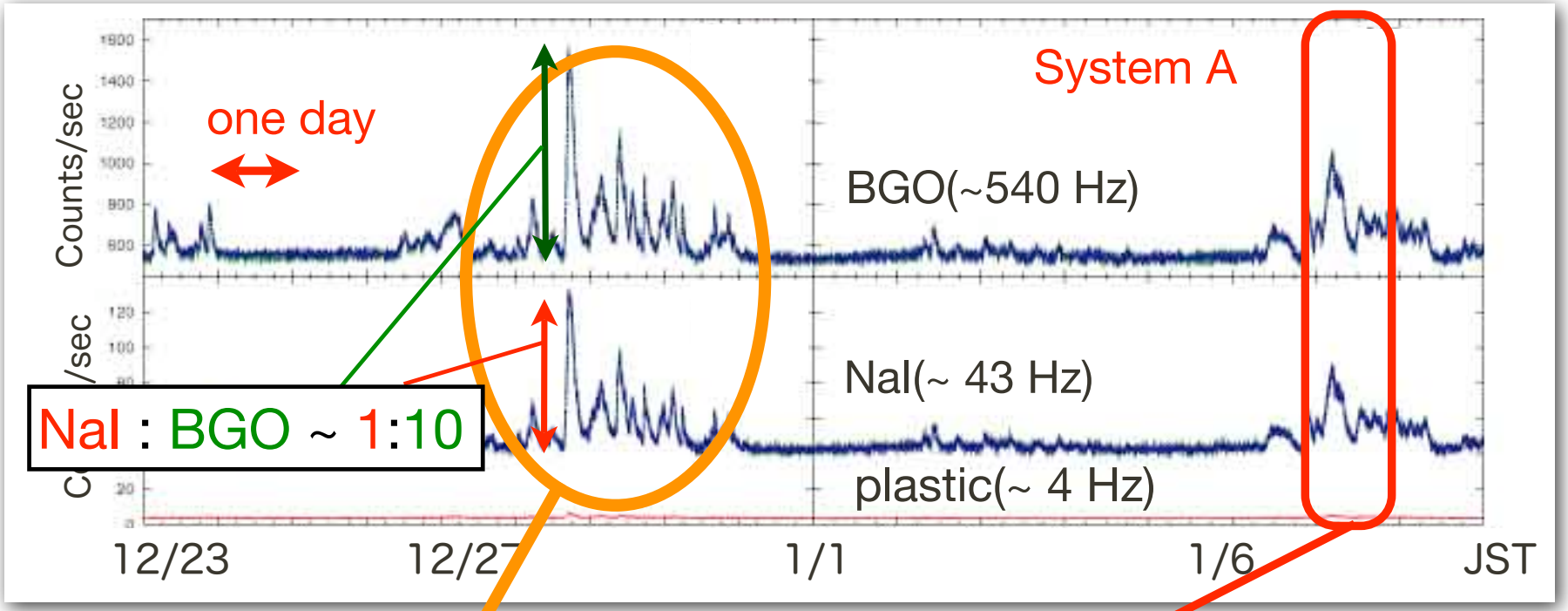
- Plastic scintillator (0.2” thick) : ID of photons and electrons.





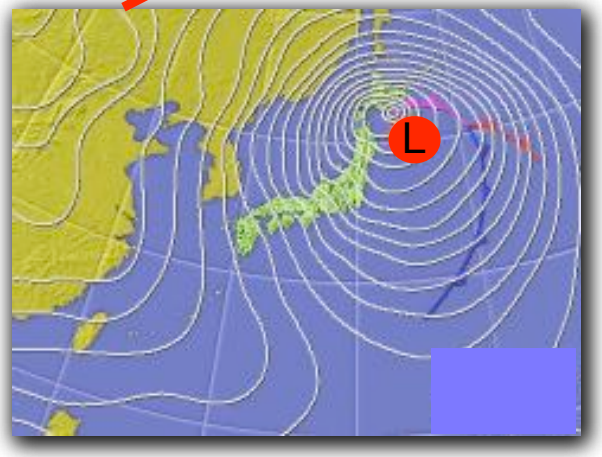
- 3”φ x 3” NaI scintillator
- Well-type BGO active shield/collimator (0.5”,1” thick)

5. Long term count rate history

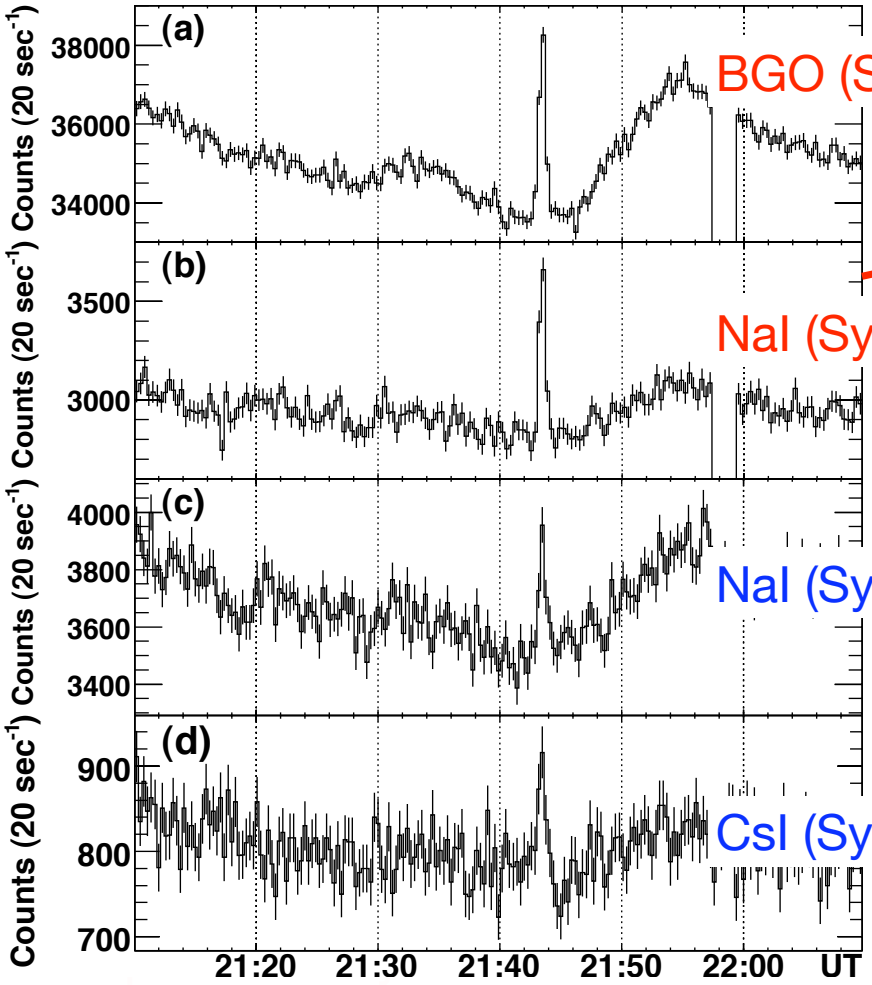


Radon fall out associated with snow and/or rain fall (△t ~ hours).

Typical winter thunderstorm above the Japan Sea (on 6-7 January 2007).



5. Long term count rate history

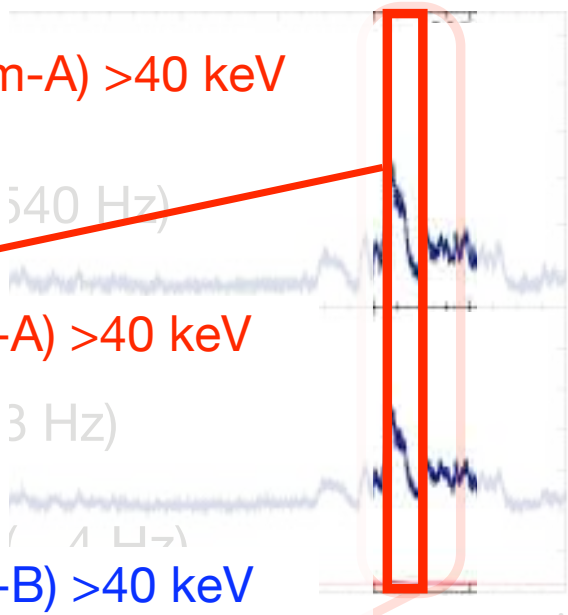


BGO (System-A) >40 keV

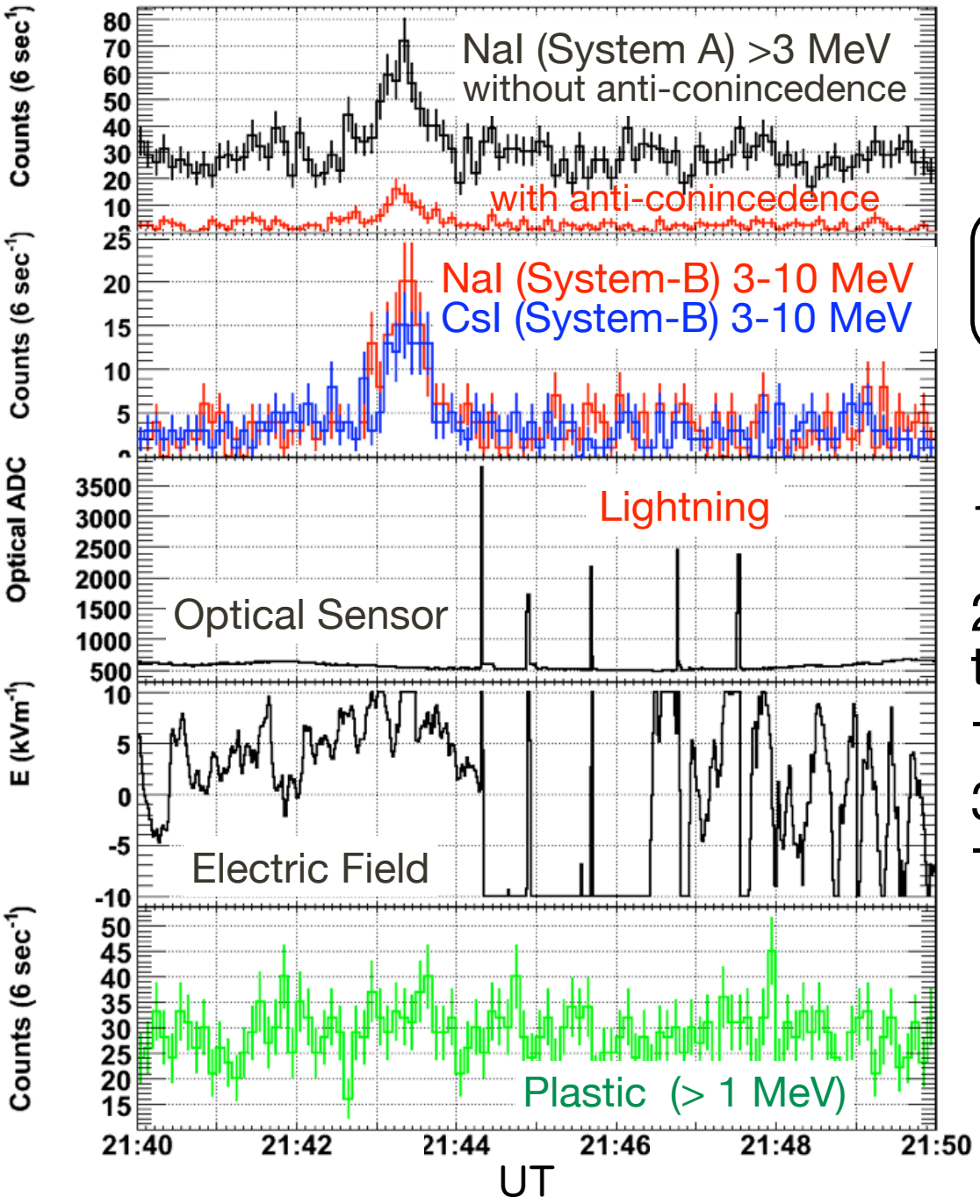
NaI (System-A) >40 keV

NaI (System-B) >40 keV

CsI (System-B) >600 keV



- A short dose enhancement with △t~40 sec !!



6. The short enhancement

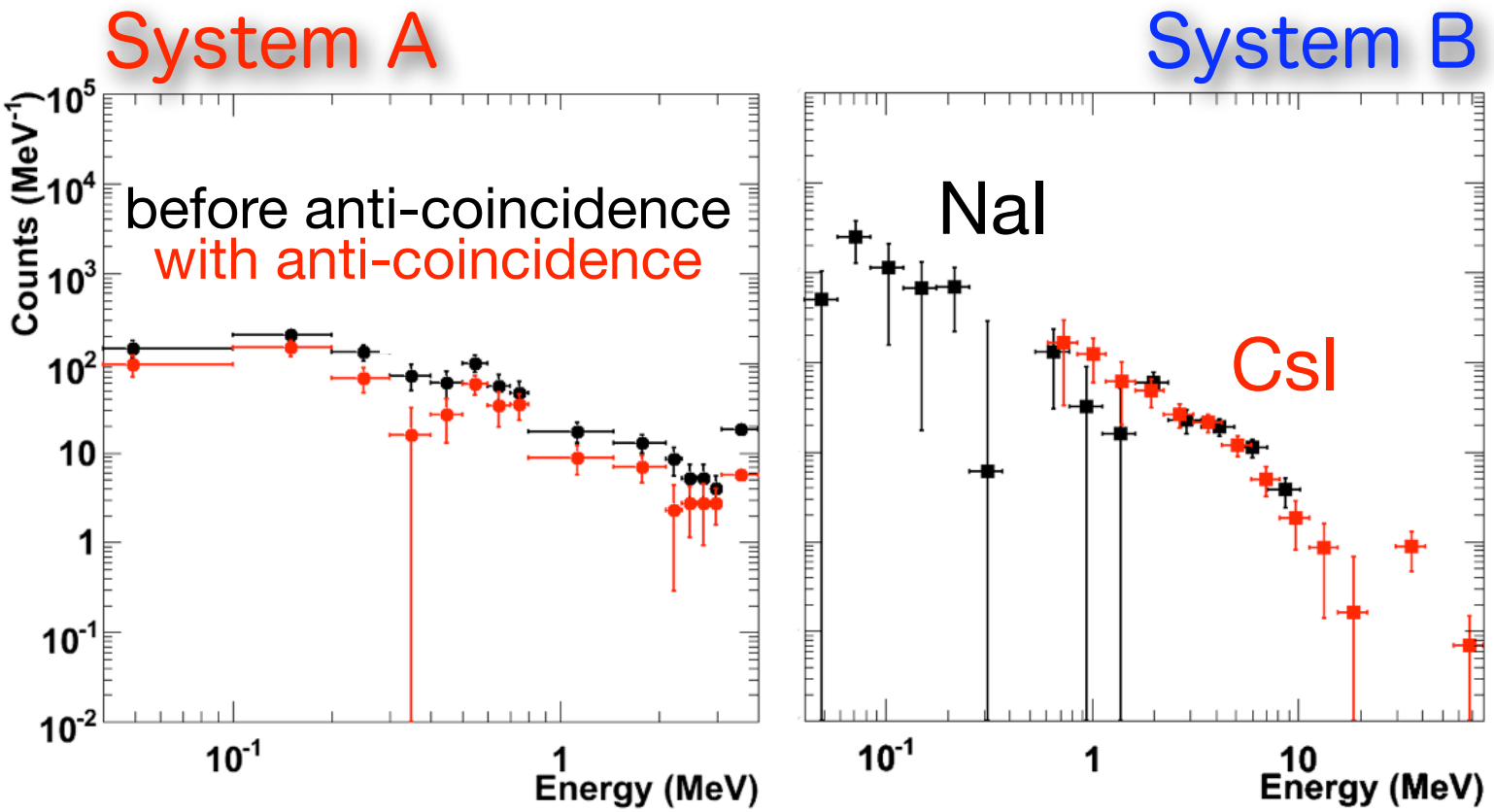
~40 sec duration 70 sec ahead of lightning

1. Significance ~ 12σ

2. NaI/BGO ratio x2 higher than Radons,
-> radiation from the sky.

3. no signal in plastic
-> gamma-rays

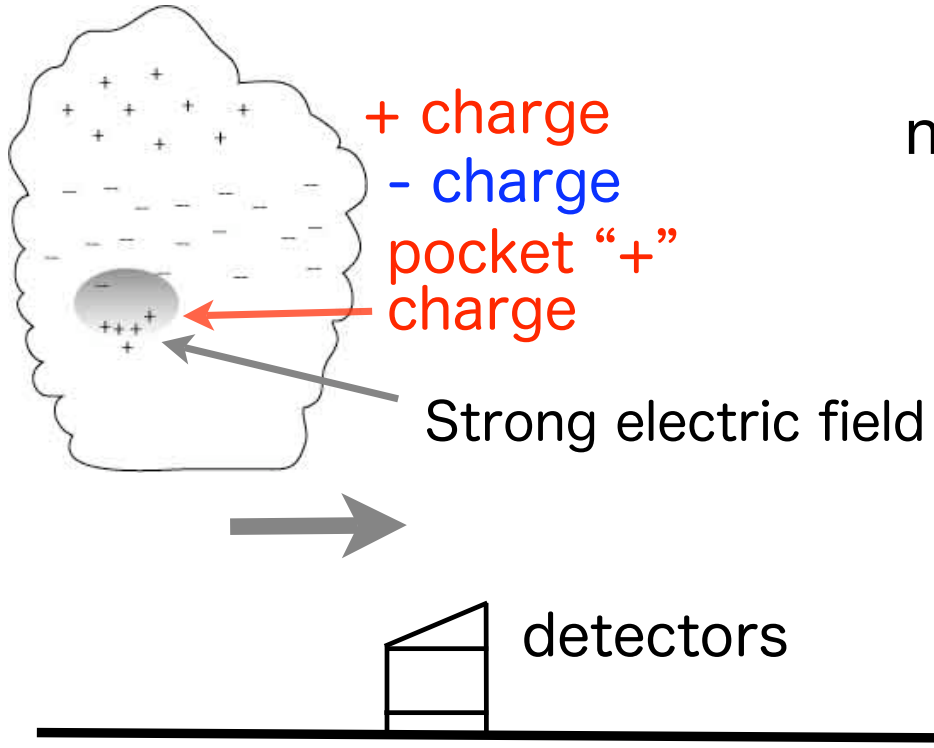
7. Gamma-ray Spectra



- Spectra extends up to 10 MeV. The photon index (1-10 MeV) is Γ = -1.66±0.13

- attenuation corrected
  d ~ 100 m -> Γ = -1.8 d ~ 1 km -> Γ = -3.0

8. Discussion



Energy budget

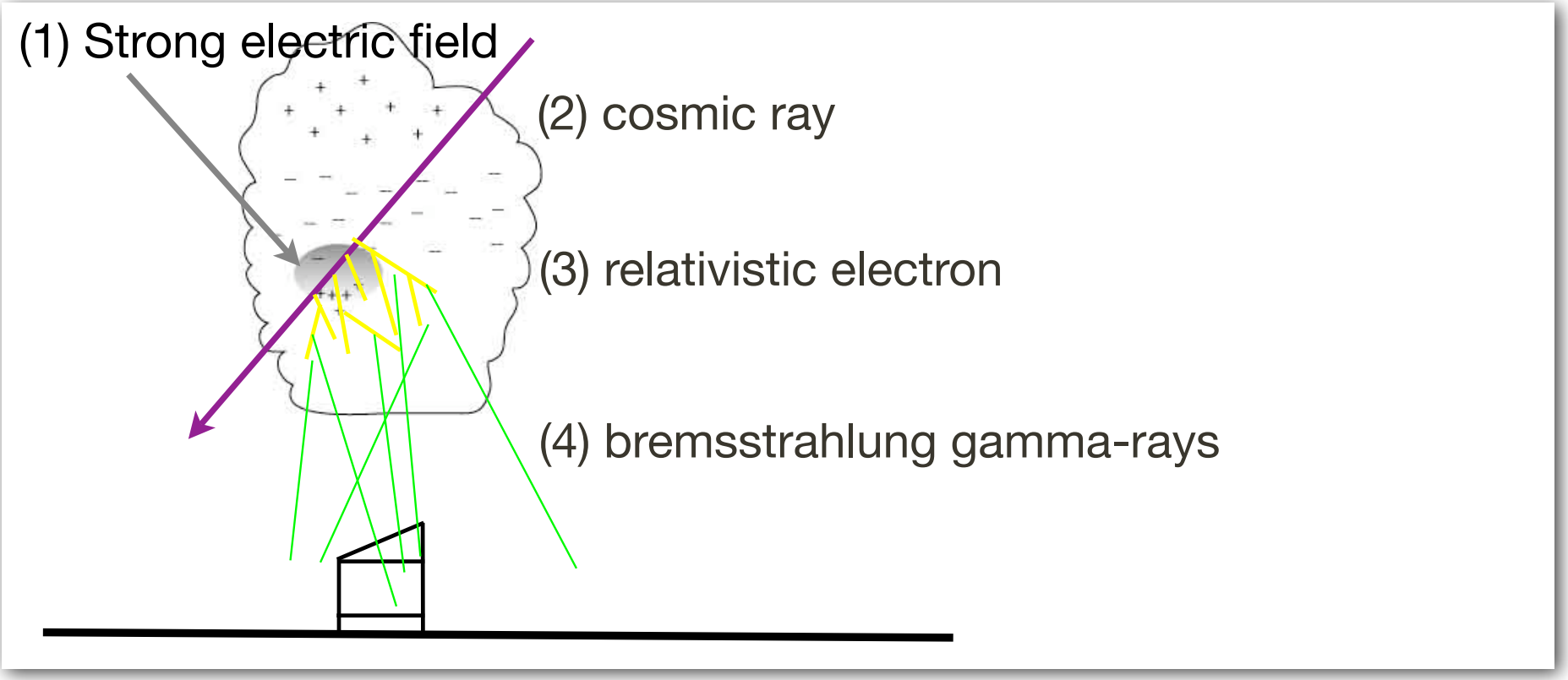
$n_\gamma = 2.4 \times 10^4$ cnt/m^2 (1-10 MeV)

d~300 m, ϵ~0.3

Ee ~ 10^{-2} J

single lightning ~ $10^{7\text{-}10}$J

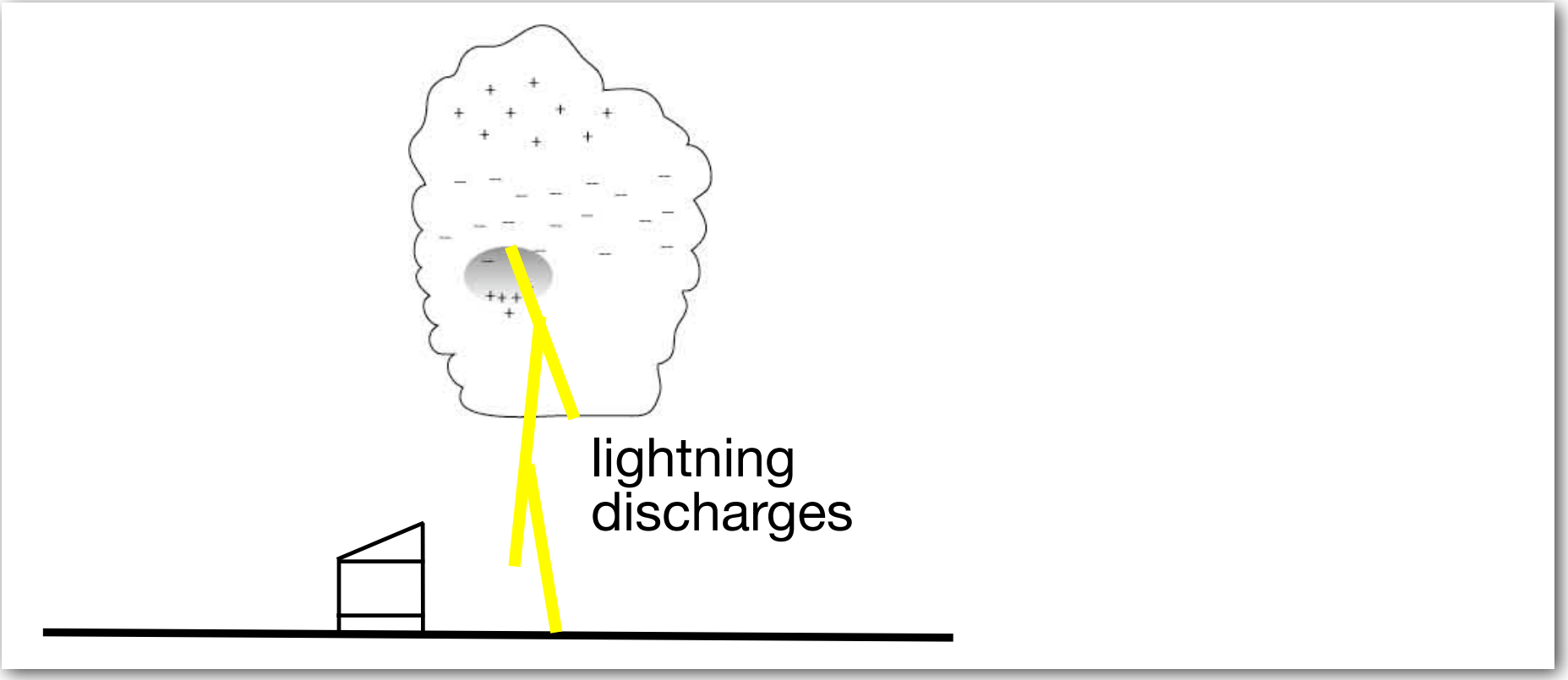
8. Discussion



Relativistic runaway electrons avalanche *(Gurenvich et al,1992)*.
threshold electric field Eth > 0.15 MV/m
seed electron energy Ee > 10 keV

Directional gamma-ray beam $\theta < m_e c^2/\epsilon \sim 3°$ like a searchlight.

8. Discussion



Relativistic runaway electrons avalanche *(Gurenvich et al,1992)*.
threshold electric field Eth > 0.15 MV/m
seed electron energy Ee > 10 keV

Directional gamma-ray beam $\theta < m_e c^2/\epsilon \sim 3°$ like a searchlight.

Strong electric fields generate preceding lightning discharges.

9. Summary

- We fabricated two complementary instruments (System-A and system-B) for the observation of radiations from winter thunderclouds along the Japan Sea coast.

- During a thundercloud passage on 6th January 2007 (UT), we detected a high-energy gamma-ray enhancement (up to 10 MeV) ~70 sec ahead of lightning discharges.

- It is possible that runaway electrons are accelerated up to a relativistic energy in a strong electric field producing bremsstrahlung gamma-rays.