E418

RCNP EXPERIMENT

PROPOSAL FOR EXPERIMENT AT RCNP

February 2013

TITLE:

MeV gamma-ray imaging test of 30cm-cube Electron Tacking Compton Camera for MeV gamma-ray astronomy under intense radiation environment.

SPOKESPERSON:

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Shotaro Komura	Department of Physics, Kyoto University	D1
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RUNNING TIME: two weeks

BEAM LINE: discussing with Prof. Hatanaka

BEAM REQUIREMENTS:

Type of particle H^{+}

Beam Energy 150MeV

Beam Intensity $1x10^{10}$ protons/sec and $1x10^{8}$ proton/sec/

BUDGET: if possible, travel and lodging fee ￥200,000

SUMMARY OF THE PROPOSAL

Recently high energy gamma-ray astronomy has become a very promising field in astronomy. On the other hands, in the Sub-Mev and MeV regions, there still remain many unobserved interesting celestial objects such as black holes and Gamma-ray Bursts. Until now only several ten celestial object emitting MeV gamma rays have been reported [1] although about 2000 objects have been found in the GeV region by Fermi [2]. Such a delay of MeV gamma-ray astronomy is due to the difficulty of imaging technique for MeV gamma rays and huge radiation background in the space [3]. In order to explore MeV gamma-ray astronomy, we have developed Electron Tracking Compton Camera (ETCC) consisting of a Time projection Chamber based on the micro pixel gas counter and pixel array scintillators as shown in Fig.1 [4, 5]. By measuring the track of a recoil electron in TPC event by event, ETCC measures the direction of each gamma-ray with an angular resolution of ~1degree, and provides both a good background rejection using the kinematical selection and the dE/dx of the recoil electron. Thus, ETCC has unique redundancies for identification of Compton scattering events compared to the conventional Compton camera. A 1m-cubic size ETCC in satellite would be a good candidate for All sky MeV gamma-ray survey of a wide band energy regions on 0.1-100MeV with several ten times better sensitivities of COMPTEL. Already we carried out the balloon experiment with a small ETCC (Sub-MeV gamma ray Imaging Loaded-on-balloon Experiment: SMILE-I) in 2006, and obtained diffuse cosmic and atmosphere gamma ray and reveal the excellent background rejection ability with a factor of ~2 orders using above features of the ETCC as shown in Fig2 [6]. In addition, we found that both secondary

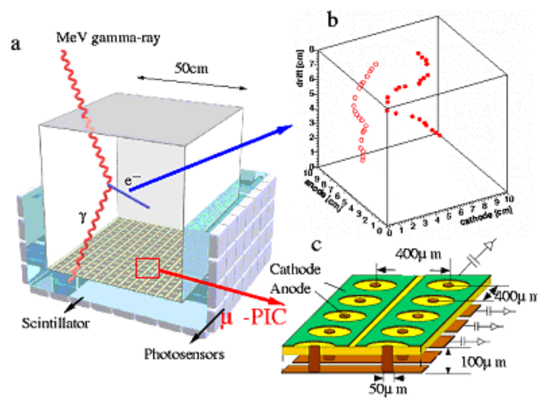

Fig. 1: (a) Conceptual structure of our gamma-ray camera. (b) Typical tracks (c) Schematic structure of the μ-PIC

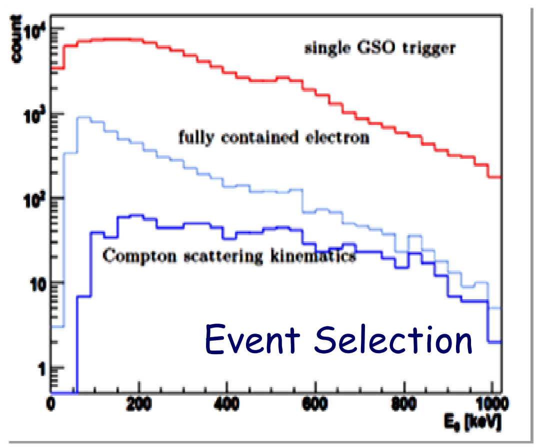

Fig.2. Reduction of the background in Analysis for SMILE-I observation data.

atmospheric fast neutron and gamma rays are main part of the background for MeV gamma-ray Compton camera near the space. In 2013, we have constructed a 30cm-cube ETCC to catch gamma-rays from the Crab and terrestrial gamma-ray burst in North Pole using the long duration balloon flight around the North Pole (SMILE-II project) as shown in Fig3 [7,8]. Terrestrial gamma-ray bursts are generated by relativistic electron precipitation in the Pole region. This experiment collaborates with Swedish, Finnish, Russian and US institutes, and plans the balloon flight from Kiruna Swedish space base.

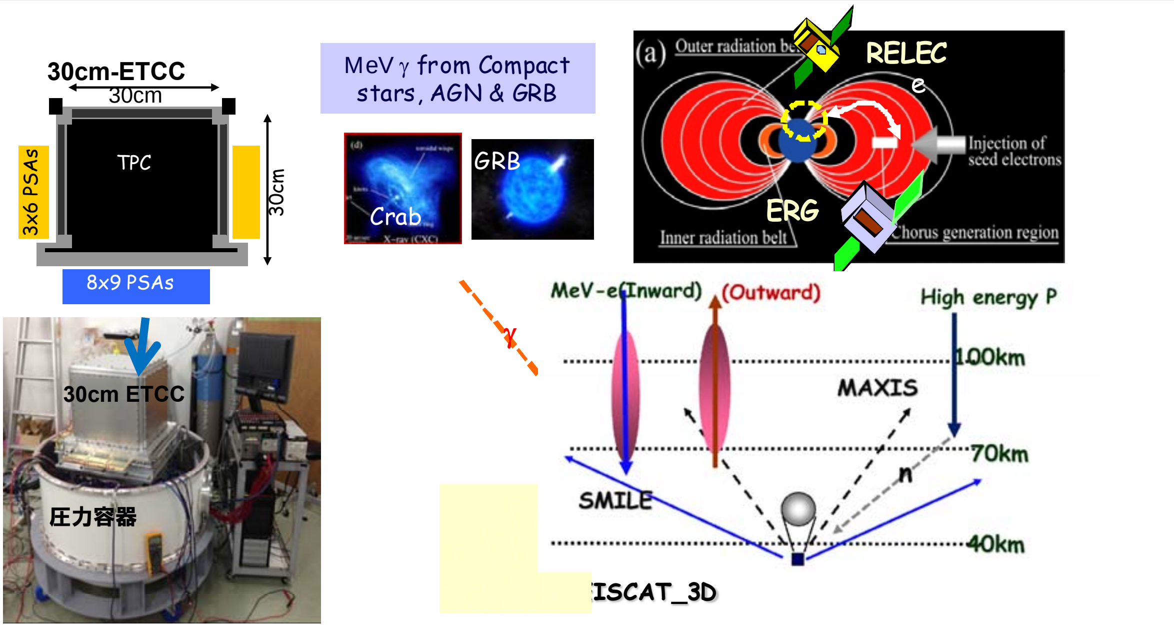

Fig.3: (left) SMILE-II ETCC and photo of Flight Model, (Right) schematic explanation of celestial and terrestrial science aimed by SMILE-II balloon experiment.

Recently a tracking efficiency of the recoil electron tracking in TPC of the ETCC has been dramatically improved by a factor of about 10, which has increased the detection efficiency more than 4 times than the design performance. Now we have obtained a 1-2cm^2@300keV effective area with Ar 1atm gas in ETCC which gives us 5sigma Crab detection for 2 hours observation. The use of CF4 or Xe 3atm gas simply improves the effective area up to 10cm^2 which is similar to that of COMPTEL as shown in Fig.4. This improvement enables us to realize a 40cm-cube ETCC with an effective area of 50cm^2 with ~50 times better sensitivity than COMPTEL and will give us ~thousand MeV celestial objects in a few years observation (Fig.4).

In addition, SMILE-II can detect the direction of fast neutron simultaneously. Solar proton precipitation at the Polar region is also considered to dissociate the atmosphere similar to REP. Solar protons with its energy > ~MeV generates secondary fast neutrons which penetrate to the stratosphere. Thus, ETCC will realize the neutron imaging observation of the Sun.

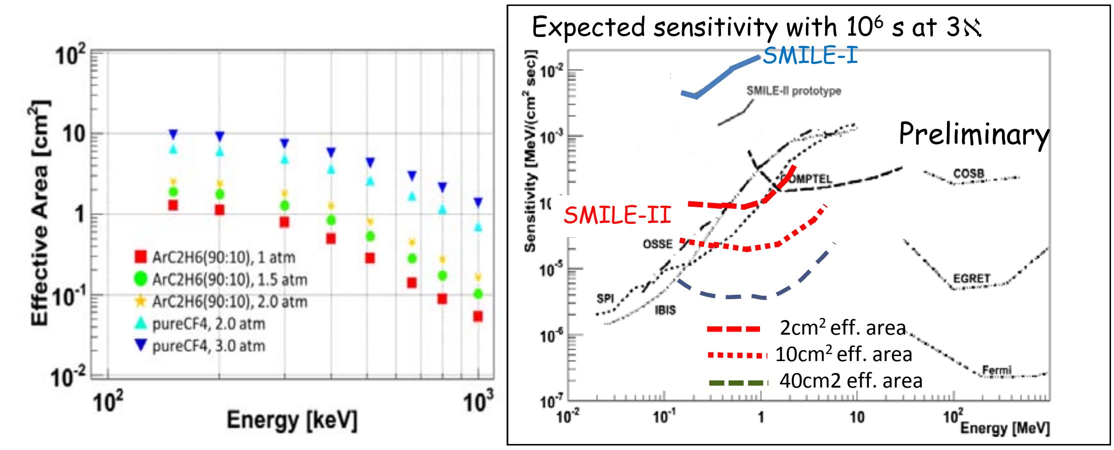

Fig.4: (Left) Simulated effective area of the SMILE-II for the variation of gas and pressure. (Right) simulated sensitivities SMILE-II and the 40cm-cube ETCC based on the performance of SMILE-II ETCC.

In order to verify such excellent feature of SMILE-II ETCC even in the space, we need to measure the imaging ability for continuum gamma rays in the energy region from 0.1 to several MeV under the intense background of MeV gamma-rays and fast neutron. Such a circumstance is only obtained by the irradiation of high energy proton with ~100 MeV to materials in particular water.

In 2009, we already carried out the similar calibration test using a small 10cm-cube ETCC for proton therapy gamma-ray imaging monitor, and successfully obtained the images for 511keV and continuum gamma rays from 400-2000keV from the human body phantom (water cylinder tank) irradiated by about 140 MeV proton beam with an intensity of 10^8 pps [9-11]. In this experiment, we found MeV gamma-rays above 500keV are dominantly emitted around the Bragg peak region within a few cm as shown in Fig.5. Also we found the amounts of circumstance gamma rays and fast neutron were similar order level as described after. Therefore, we think that this beam test is best for the evaluation of the SIMLE-II performance in the space on the ground. This test is quite significant to realize the long duration balloon experiment around the North Pole of which cost is about one million Euro. To get such a big funding, the verification of the instrument is inevitable. Furthermore, if we reveal the excellent performance of SIMLE-II in the background circumstance of the space, ETCC would be a good candidate of the next MeV gamma ray satellite which has been eagerly hoped a long time.

Then, we propose the imaging performance calibration of the 30cm-cube ETCC in the SIMLE-II instrument under the irradiation circumstance using about 150 MeV proton beam with an intensity of $10^{9\text{-}11}$pps. In addition, we will measure the imaging performance of the fast neutron by changing the water target to plastic plat. This fast neutron imaging test will be important data for the development of the fast neutron imaging device which will be surely significant for nondestructive testing for the buildings and infrastructures using a small neutron source.

This results will surely significant for the application of the medical ETCC which are being improved based on SMILE-II ETCC technology to the real-time imaging of proton therapy.

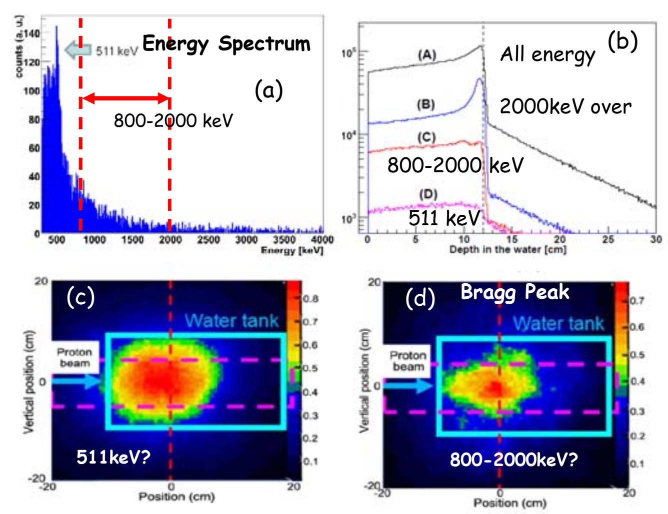

Fig.5: Results of previous experiment for proton therapy imaging test. (a) gamma-ray spectrum by ETCC, (b)simulated gamma-ray distributions from the water target, (c) obtained image of 511keV line-gamma, and (d) obtained image of continuum gamma rays between 800-2000keV.

Finally, this proposal may be first experiment to simulate the total radiation environment of the space including neutron and gamma-rays using the accelerator beams for checking the performance of the space detectors, although damage tests by space irradiation using accelerator beams has been quite common. If this experiment goes well, the accelerator use for the evaluation of the space devices will certainly increase the reliance of the space devices in the satellites.

DETAILED DESCRIPTION OF PROPOSED RESREARCH

Experimental procedure and set-up

The purpose of the requested experiment is to measure the imaging performance of a 30cm-cube ETCC in SMILE-II instrument using prompt gamma rays emanating from the 30cm long water tank and fast neutron from the metal sheet irradiated by about 150 MeV proton beam. Proton beam stops around the center region of the water tank, and generates prompt gamma rays in particular a continuum sub-MeV and MeV energy gamma rays which mainly emanate only around the Bragg peak position as mentioned previously. Figure6 shows the energy spectrum of gamma-rays around the bean line previously measured by GSO three scintillators with fast neutrons measured by a liquid scintillator. Thus, prompt gamma rays and fast neutron flux around the Bragg peak surely satisfy the requirement of the energy range of gamma rays and background