Development of compact Tissue Equivalent Proportional Counter (TEPC) for monitoring space radiation in the ISS, Cubesat and Aircraft

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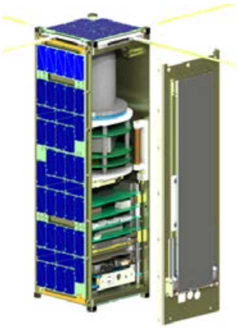
Introduction

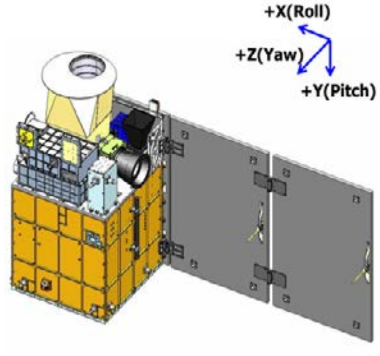
- NASA proposed the development of ISS radiation monitoring detectors as a Korea-NASA cooperation program in 2009.

- **KASI (Korea Astronomy Space and Science Institute)** has been funded $200k a year for developing TEPC since 2011 and it will be completed in 2016.

- In 2015, we will launch a cubesat (~3 kg) aboard the TEPC, and in 2017 we will launch a small satellite (~100 kg) for high LET cosmic ray measurements.

- We will also extend our research area to the monitoring space radiation on aircraft altitude.





Instrument Evolution

model-2012

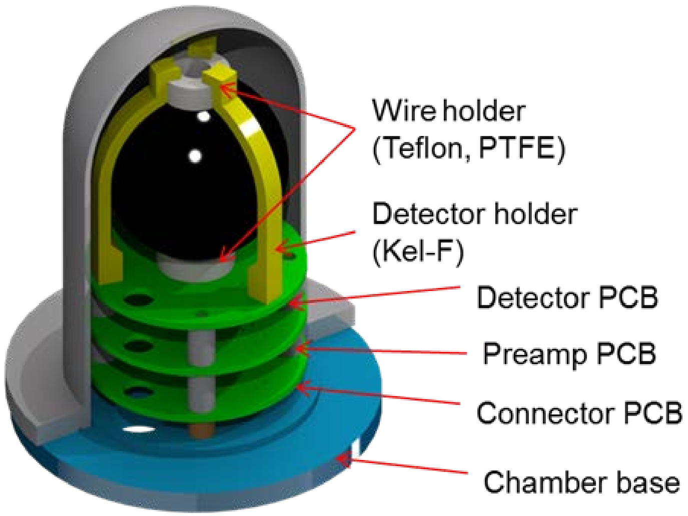
model-2013

Model-2014

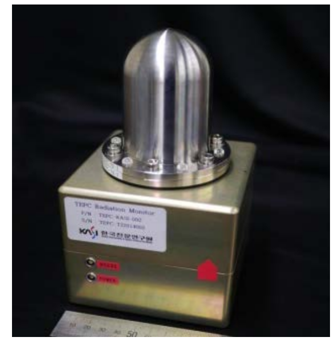
We have developed several models of TEPC and the instrument is still under improvement.

Brief Description of TEPC

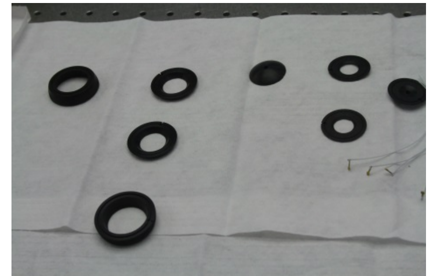
- Type: Spherical Tissue Equivalent Proportional Counter
- Tissue Equivalent Material: A-150
- Out Diameter : 40 mm
- Inner Diameter : 30 mm
- Internal Tissue Equivalent Gas:100% C_3H_8
- Pressure : 27.7 torr
- Simulated Site Diameter : 2μm
- Anode : 30 μm Stainless wire
- SUS304 Stainless Housing
- Diameter : 54 mm
- Thickness :1.5 mm

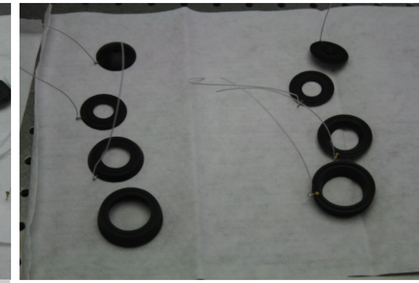


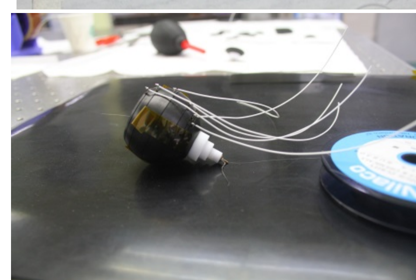
Improvement of TEPC

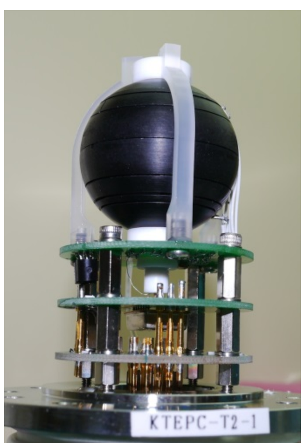
	Model-2013	Model-2014	Requirements
			
Volume/Mass	2,624 cm^3 / 1.8Kg	1,480 cm^3 / 1.5Kg	< 6,000 cm^3 < 5 Kg
Power	4.9 W	2.5W (Battery)	Low Power
Signal Processing	Analog Pulse Processing	Digital Pulse Processing	
Gain Channel	Single Gain	Two Gain Channel (64/1.1)	
Interface	TCP/IP	RS232	

Manufacturing



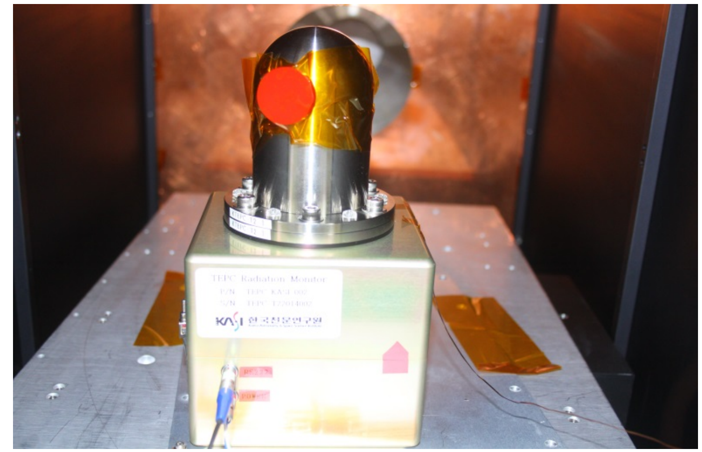




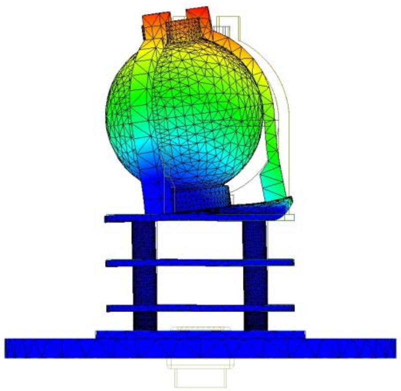
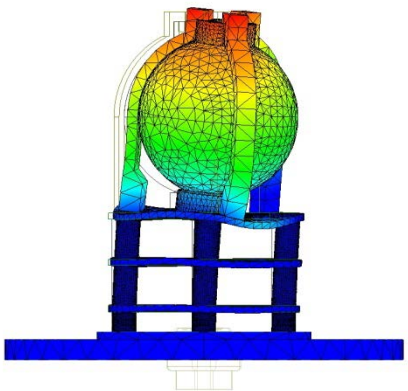
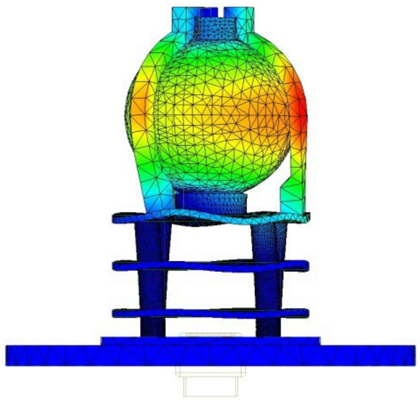
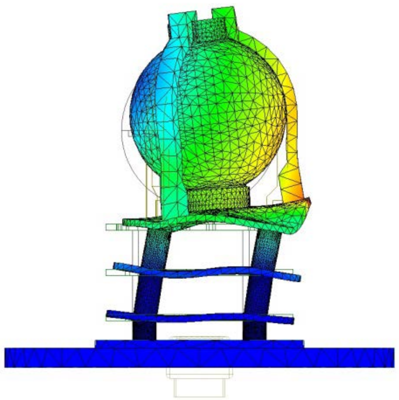


Thermal Vacuum Test

- Temperature Requirement of ISS
  - +5℃~ +40℃
  - Operating Temp: +20℃
  - 1 cycle

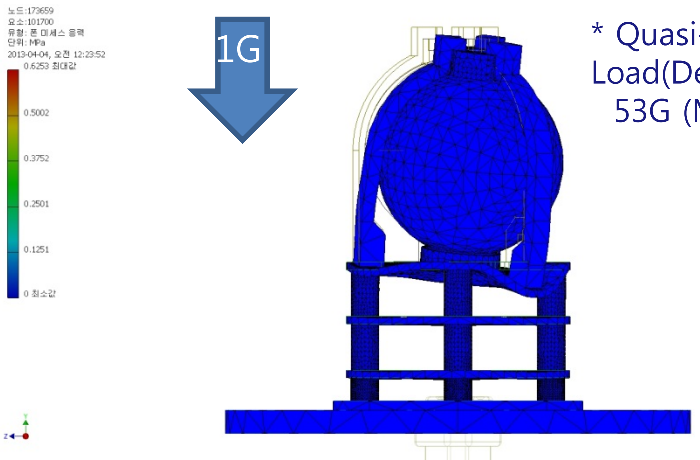


Mechanical Analysis

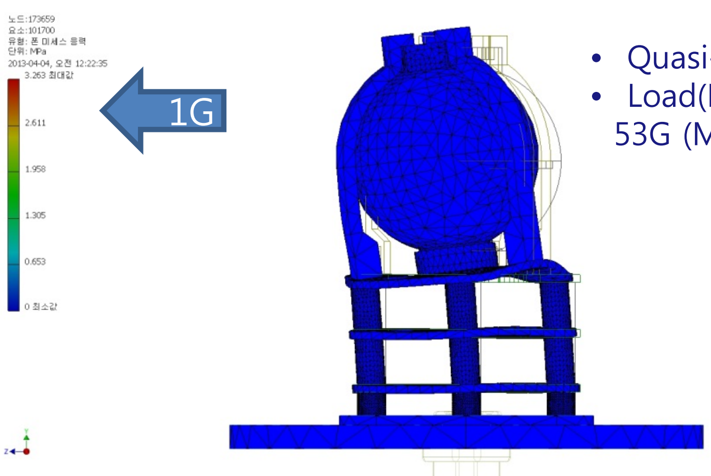
1st mode 249 Hz   2nd mode 352 Hz   3rd mode 635 Hz   4th mode 823 Hz

(NASA requirements : Payload > 100 Hz)



* Quasi-static Load(Design): 53G (Max. 32MPa)

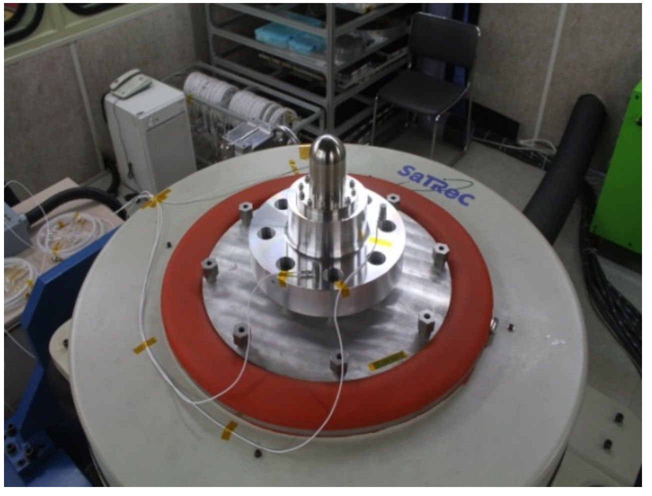
Max. 0.6MPa (PCB support/SUS304)



- Quasi-static
- Load(Design): 53G (Max. 175MPa)

Max. 3.3MPa (PCB support/SUS304)

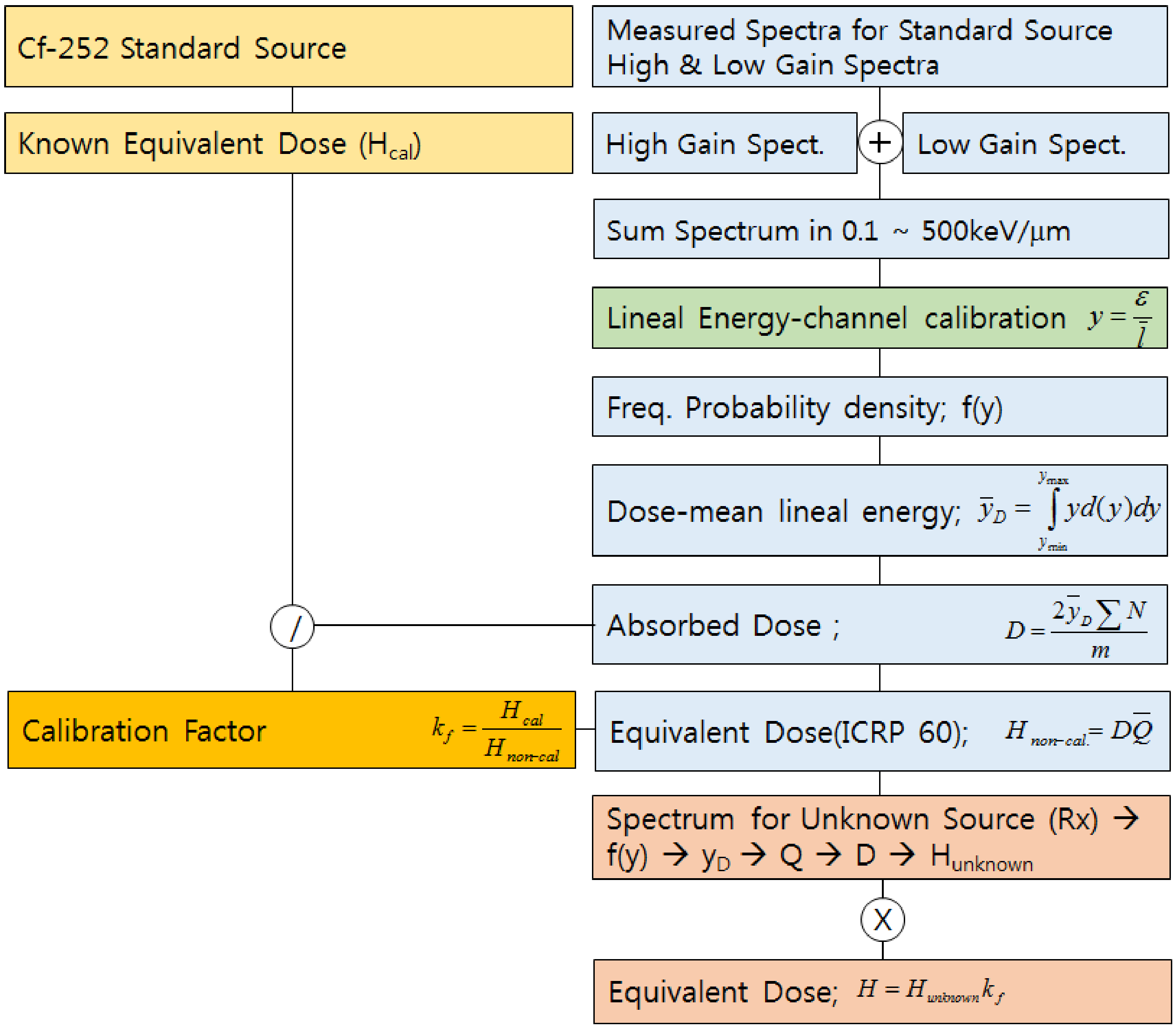
Vibration Test



Random Vibration	3.6 (grms)
Shock Level Test	9 (g-load)
Number of Shock	10

TEPC passed successfully the vibration and shock test required for ISS.

Equivalent Dose Calculation Protocol

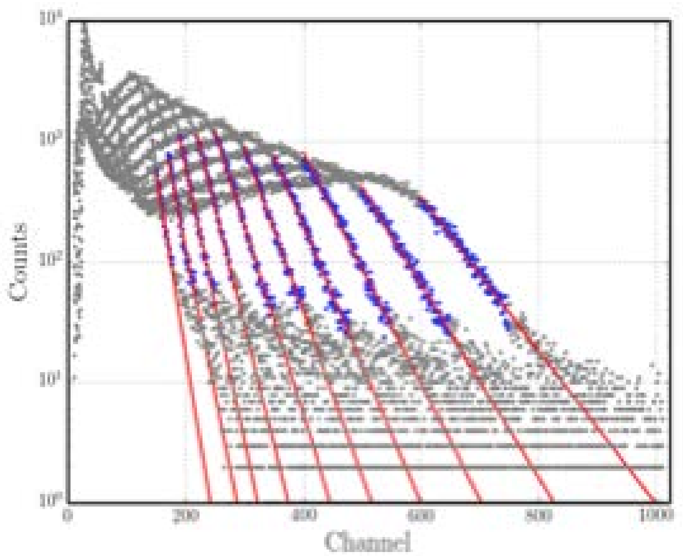


HIMAC Experiments

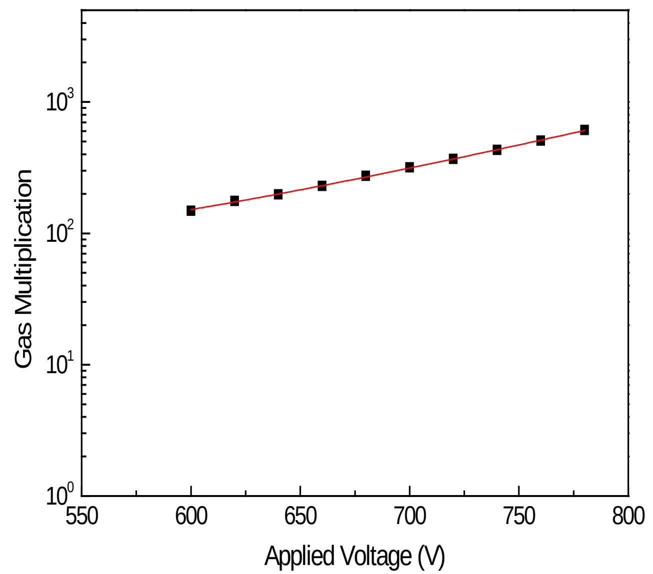
Experimental set up in HIMAC bio beam line

Gas Multiplication

Pulse height spectra and gas multiplication of C-135 MeV/u ions as a function of applied voltage



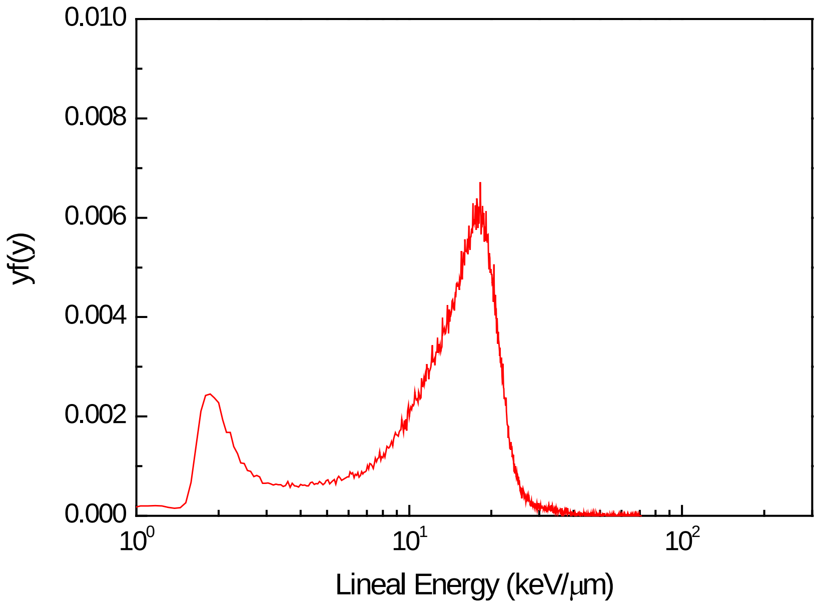
(a) pulse height spectra



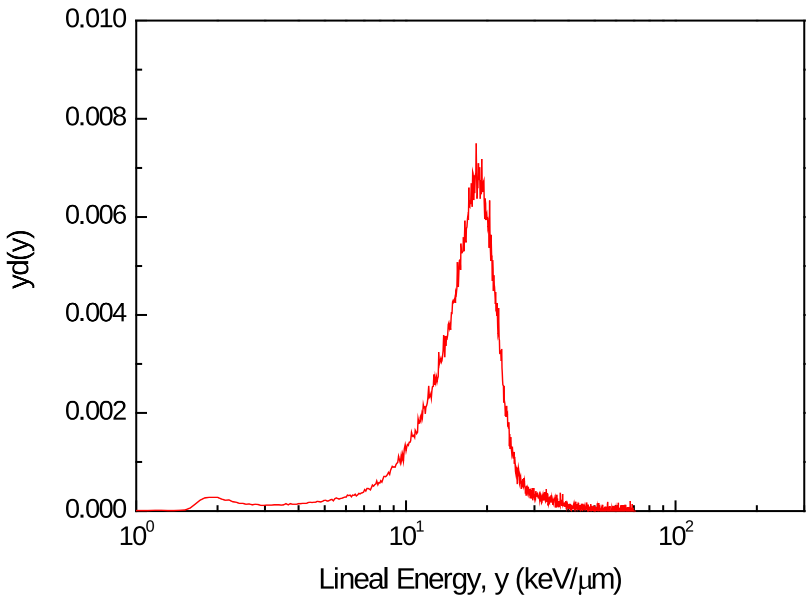
(b) gas multiplication

$$Gas\ \ Gain = \frac{No.\ \ of\ \ e\ \ per\ channel \cdot proton\ \ drop\ \ point\ \ \ channel}{\varepsilon / W}$$

Measured LET Spectra from C-135 beam line



(a) Frequency distribution

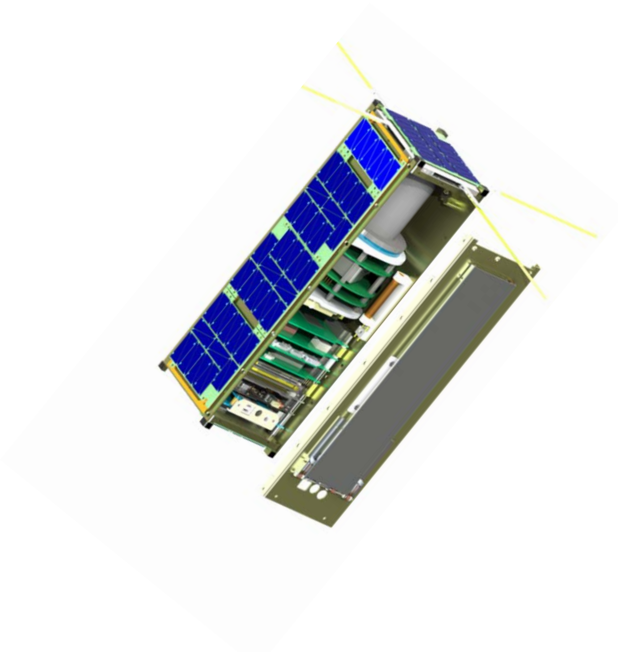


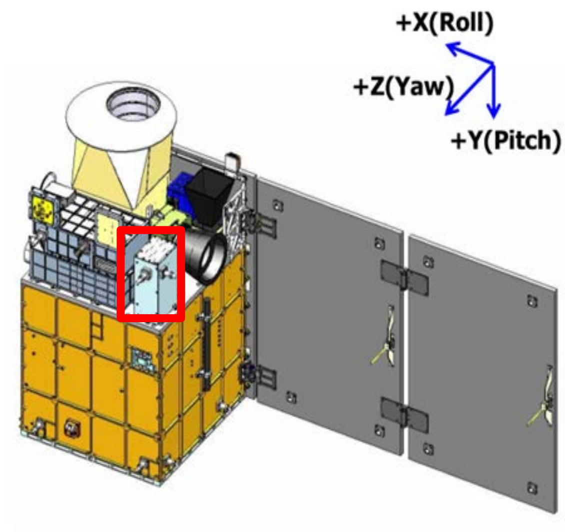
(b) yd(y) micro-dosimetry spectrum

$$\bar{y}_F = \int_{y_{min}}^{y_{max}} y f(y) dy = \frac{\sum_i y_i N_i}{\sum_i N_i} = 14.0 keV / \mu m$$

$$\bar{y}_D = \int_{y_{min}}^{y_{max}} y d(y) dy = \frac{1}{\bar{y}_F} \int_{y_{min}}^{y_{max}} y^2 f(y) dy = \frac{\sum_i y_i^2 N_i}{\sum_i y_i N_i} = 20.5 keV / \mu m$$

Space Radiation Experiments on LEO satellites

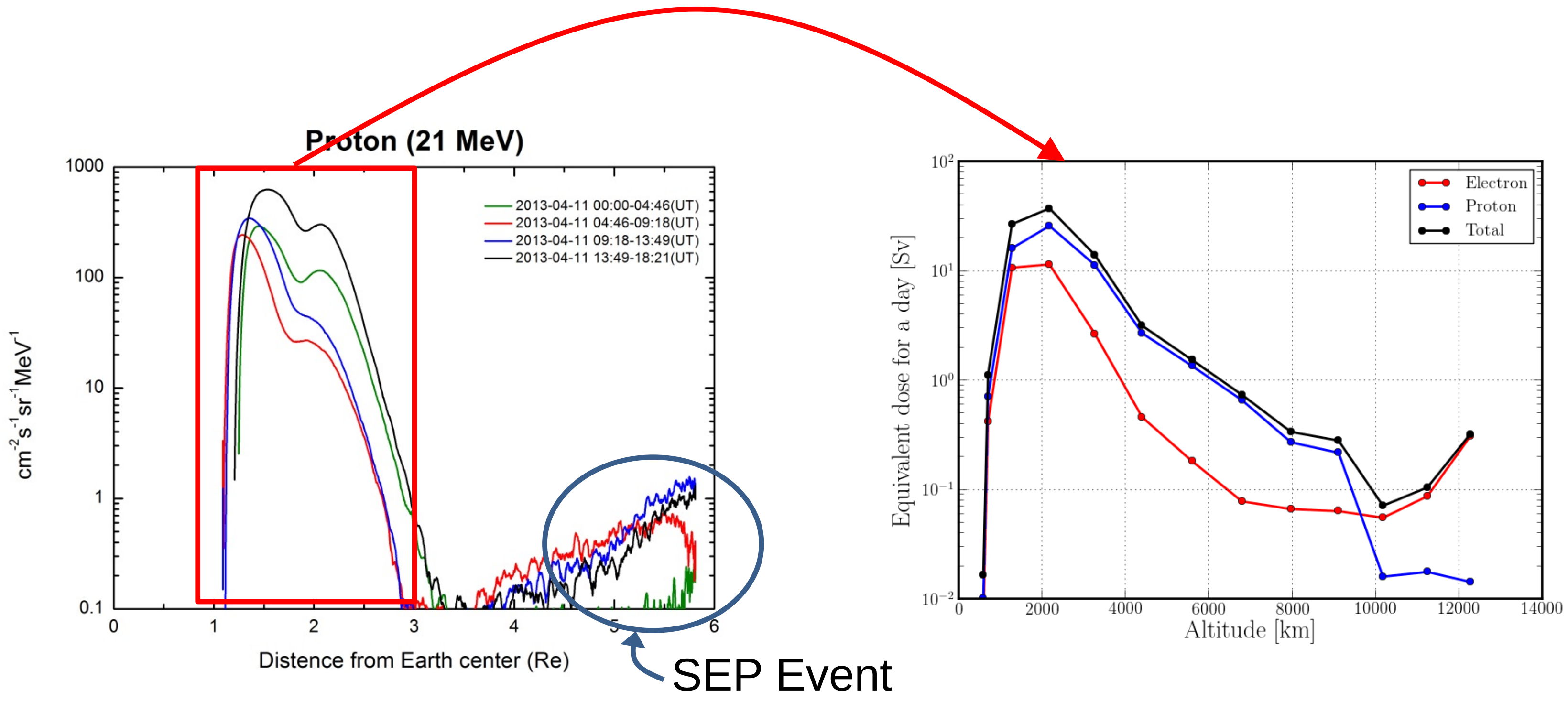




- **Korean Cubesat Program**
- **Spacecraft Developed by Kyunghee University**
- **KASI provides TEPC as a main payload**
- **Launch in 2015**

- **Korean Small Satellite Program**
- **Spacecraft Developed by KAIST**
- **KASI provides TEPC as an payload**
- **Launch in 2017**

Dose Estimation in LEO (science mission)

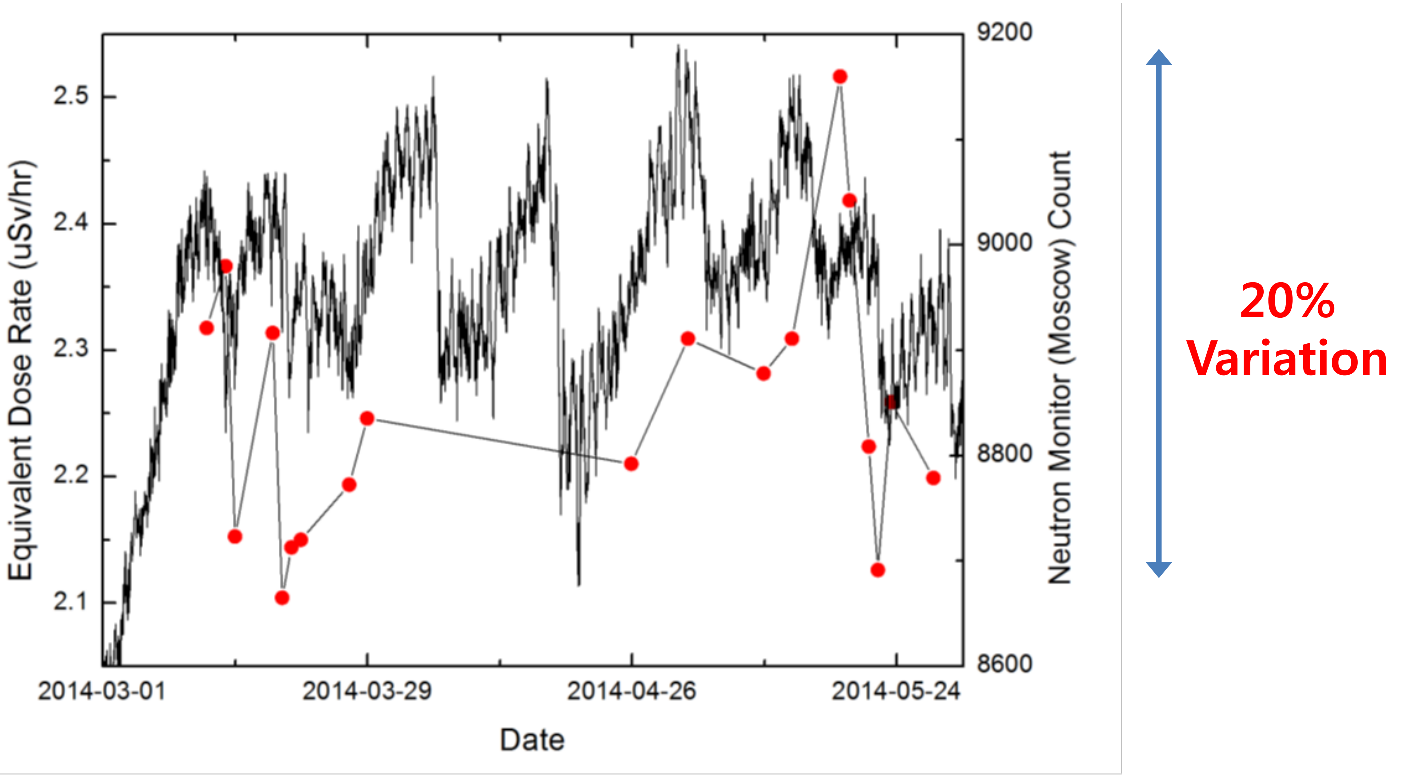


We estimated low altitude dose rate from the Van Allen Probes mission data.

Geo-magnetic field effectively shields the most solar energetic protons.

However, what happen for high LET particles that have large gyro-radii?

Experiments of Radiation Measurement on Aircraft Altitude



We have measured space radiation on the altitude of 30,000 ft in the Korean Peninsular with **Liulin-6**.

In the future, we will do the measurements with our own **TEPC**.

Conclusions

- A TEPC was designed and fabricated with A-150 ionization cavity, preamp + amplifier circuit, spectrometer, and HVPS for micro-dosimetry in ISS.
- The TEPC has been characterized and calibrated by using C-135MeV/u ions in HIMAC.
- We confirmed that the TEPC was well operated below 100 keV/μm.
- Applications
  - Cubesat launched in 2015
  - Korean small satellite, NEXTSat-1 launched in 2017
  - Air Crew Radiation Monitoring
- **Even though we cannot send our TEPC to ISS, we will measure space radiation on the aircraft altitude (~10 km) and LEO (~700 km). We think these experiment would be valuable in understanding radiation environment at the ISS altitude (~ 350km).**