



# Development of gamma camera for localization of radiation hotspots using the Timepix

An effective system with divergent pin-hole collimator designed for high intensity radiation hotspots in Fukushima Daiichi NPS

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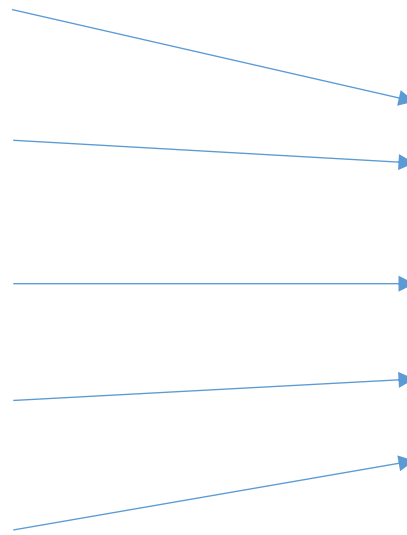
Timepix with Si or CdTe chip

USB interface

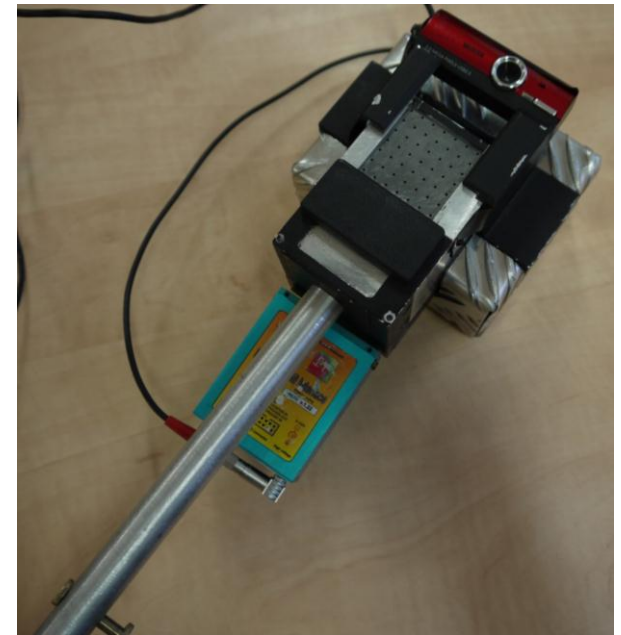
Pin-hole collimator

Lead shielding

Laptop + camera



Prototype of gamma camera



Light, portable and cheap device aimed on imaging of spatial distribution of multiple gamma sources:

$^{241}\text{Am}$  (60 keV),  $^{131}\text{I}$  (364.5 keV),  $^{137}\text{Cs}$  (661.6 keV),  $^{60}\text{Co}$  (1173.2 keV, 1332.5 keV)



# Motivation

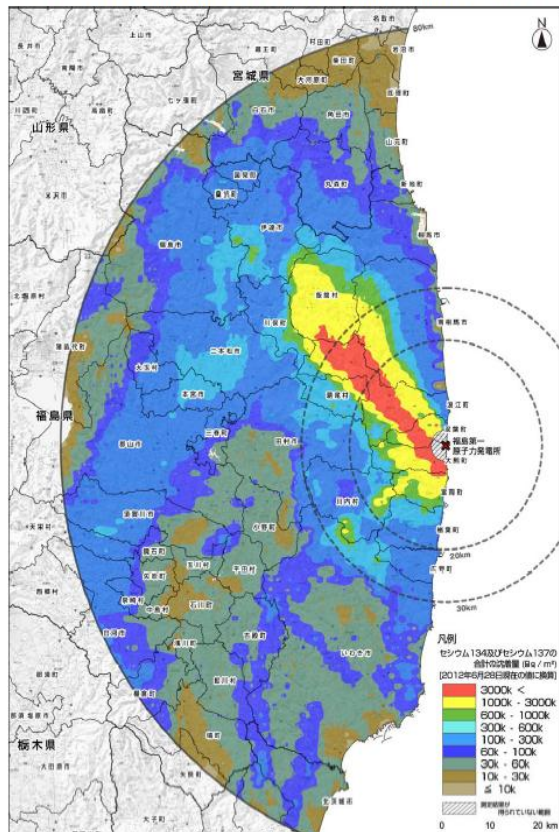
From the excursion to Fukushima Daiichi NPS (Courtesy of Tokyo Electric Power Company, INC.)

Observation Point of Fukushima Daiichi NPS Tour for HITSRS2013

On May, 20<sup>th</sup> 2013

別紙  
国土科学省による第5次航空機モニタリングの結果  
(福島第一原子力発電所から80km圏内の地表面への  
セシウム134、137の沈着量の合計) (平成24年6月28日時点)

1. Damage to the facilities at NPS from the earthquake and the tsunami
2. Present Status for Plant Stabilization
3. Progress status of preparation for fuel removal from Spent Fuel Pool
4. Progress status of countermeasures against contaminated/ treated water



**1mSv/h**

**Water Injection System to the Reactor Cores**  
The water injection systems to the reactor cores of Units 1 to 3 have redundancy and diversity with backups for water sources, pumps and water injection lines to ensure stable water injection in case of an emergency shutdown of the facilities due to a block of air large tsunami.

**Seismic Isolated Building**  
Emergency response facility with seismic isolated structure. The foundation base of activities towards the decommissioning NPS.

**Damage to the facilities at NPS from the earthquake**  
The collapse of the tower 55kV and 10kV transmission line tower due to the large-scale collapse of the adjacent embankment by ground.

**Damage to the facilities at NPS from the tsunami**  
Damage to the facilities of sea side area from the tsunami.

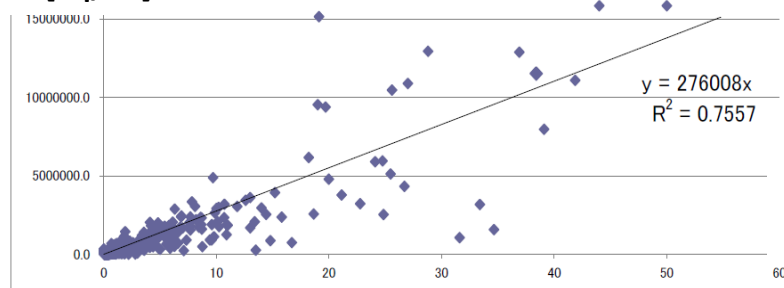
**Fuel removal from the Spent Fuel Pool of Unit 4.**  
The cover structure for the removal is being the operation at around mid FY 2013. In addition to the removal of work, the steel frame construction was started at July 2013.

**Multi-nuclide removal system installation**  
Multi-nuclide removal equipment was installed to further reduce the concentration of the radioactive materials included in the treated water. On Mar. 30th, hot cell using water could treated for the water treatment facility was started for the multi-nuclide removal equipment.

**Current status for storage of Contaminated water/ treated water.**  
The total capacity of existing storage tanks is approx. 314,000 m<sup>3</sup> (as of Apr. 19th 2013). Additional tanks are currently being built. Capacity of approx. 30,000 m<sup>3</sup> will be added, and approx. 300,000 m<sup>3</sup> planned to be added.

[http://radioactivity.nsr.go.jp/ja/contents/7000/6213/24/6213\\_20120912\\_rev20130701.pdf](http://radioactivity.nsr.go.jp/ja/contents/7000/6213/24/6213_20120912_rev20130701.pdf)

Soil activity [Bq/m<sup>2</sup>]



Air dose [μSv/h]

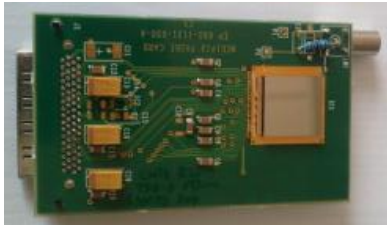
Total dose during 3hours of the excursion was low (21μSv) but intense radiation hotspots still exist.

**1mSv/h ~ 275MBq/m<sup>2</sup>**

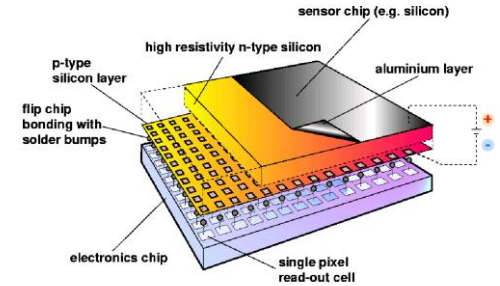


# Technical details of the gamma camera

- Timepix

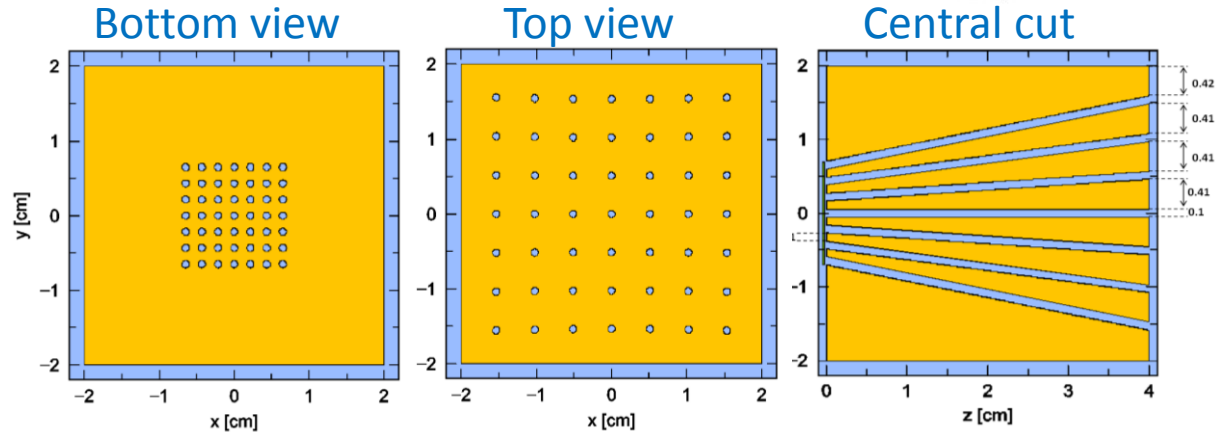


semiconductor pixel detector which is able to detect single particles, their positions, deposited energies (in TOT mode) and their time of arrival.

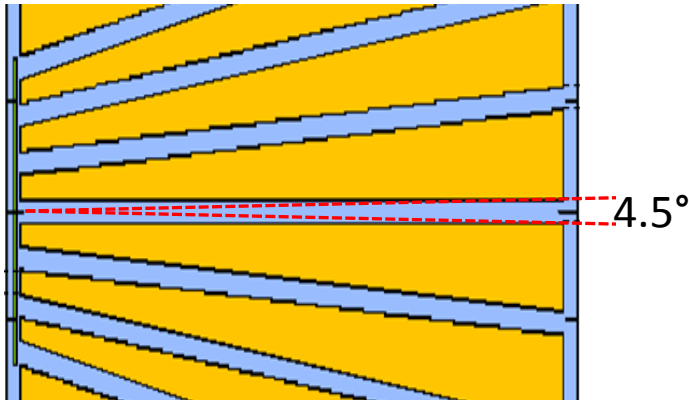


- Collimator design

Lead cube 40 x 40 x 40 mm<sup>3</sup>, mass: 708 g  
Pin-holes: 7x7 equidistant diverging pin-holes 1mm  
Pin-holes distances : 1mm at bottom, 4.1mm on top  
Pin-holes angles: 4.2°, 8.4°, 12.5°  
Field of view: 25° (much higher than for parallel collimator)



- Angular resolution:

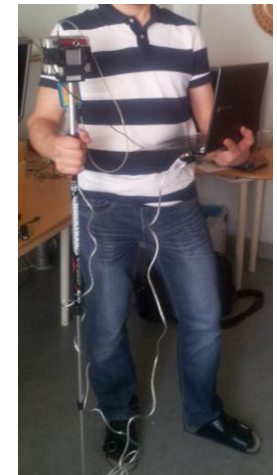


- Shielding design

- To eliminate noise coming from all directions
- 2cm of lead 10x attenuate 660keV gamma (<sup>137</sup>Cs)



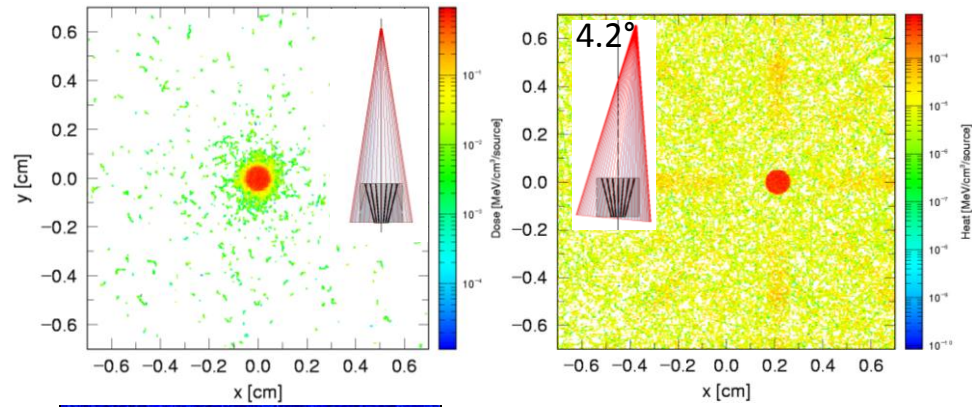
- Ready to go



# Monte Carlo simulations

PHITS simulations of spatial distribution of energy depositions in a silicon chip

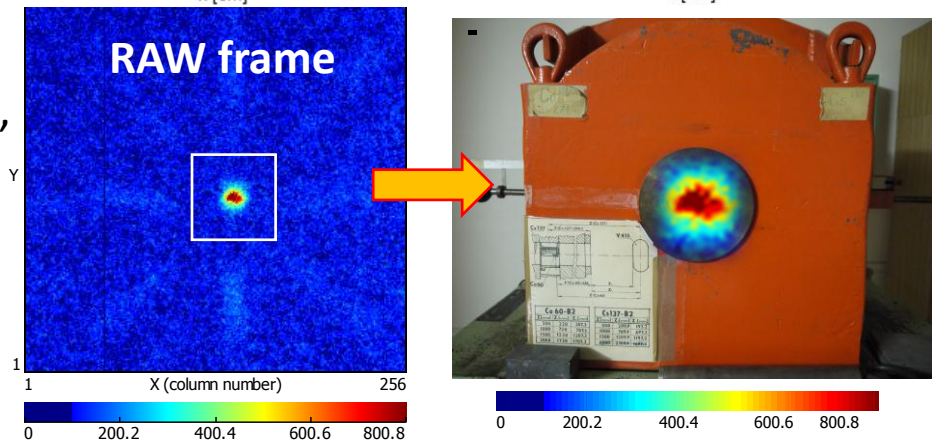
- different positions of  $^{137}\text{Cs}$  (0.662 MeV)
- Number of source events:  $10^8$



# Laboratory experiments

$^{241}\text{Am}$  (60 keV),  $^{131}\text{I}$  (364.5 keV),  $^{137}\text{Cs}$  (661.6 keV),  $^{60}\text{Co}$  (1173.2 keV, 1332.5 keV)

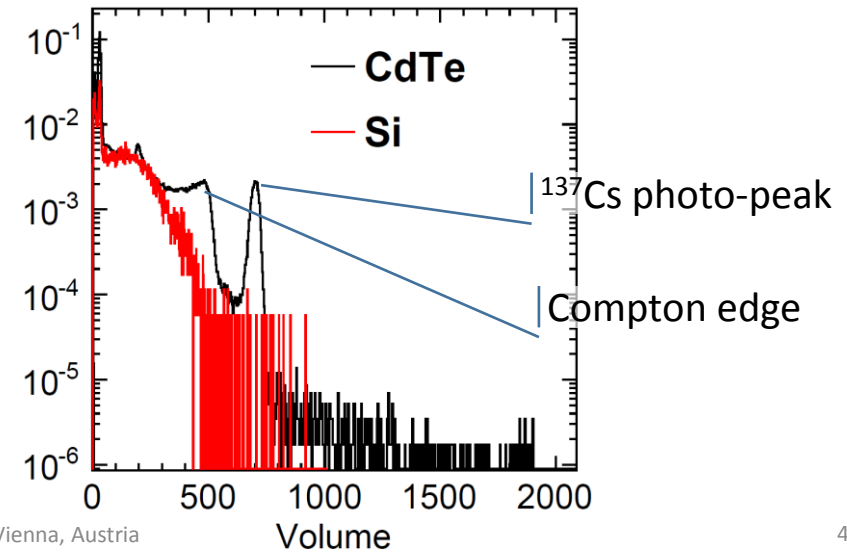
Superimposition of the camera picture with the Timepix frame



# Spectrometry with CdTe

CdTe chip (1000 $\mu\text{m}$ ) vs Si chip (300 $\mu\text{m}$ ) spectra in  $^{137}\text{Cs}$  source

- Application: characterization of the radionuclide
- Additional gamma camera components are needed for the CdTe chip:
- (1) fan to cool down,
  - (2) external high voltage source



# Future work

- Rotational collimator to eliminate the radiation transmissions at the location of collimator's holes.
- Development of software for superimposition of the visible video with the gamma camera frame
- Portable prototype with CdTe chip (including fan and high-voltage source)

## Acknowledgement

- To our technician Václav Sýkora who developed the gamma camera body and the holder for collimator and shielding.
- To the Japan Society of Promotion of Science for initial funding.
- To the Project RANUS-TD for funding the further development.



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Thank you for your attention!