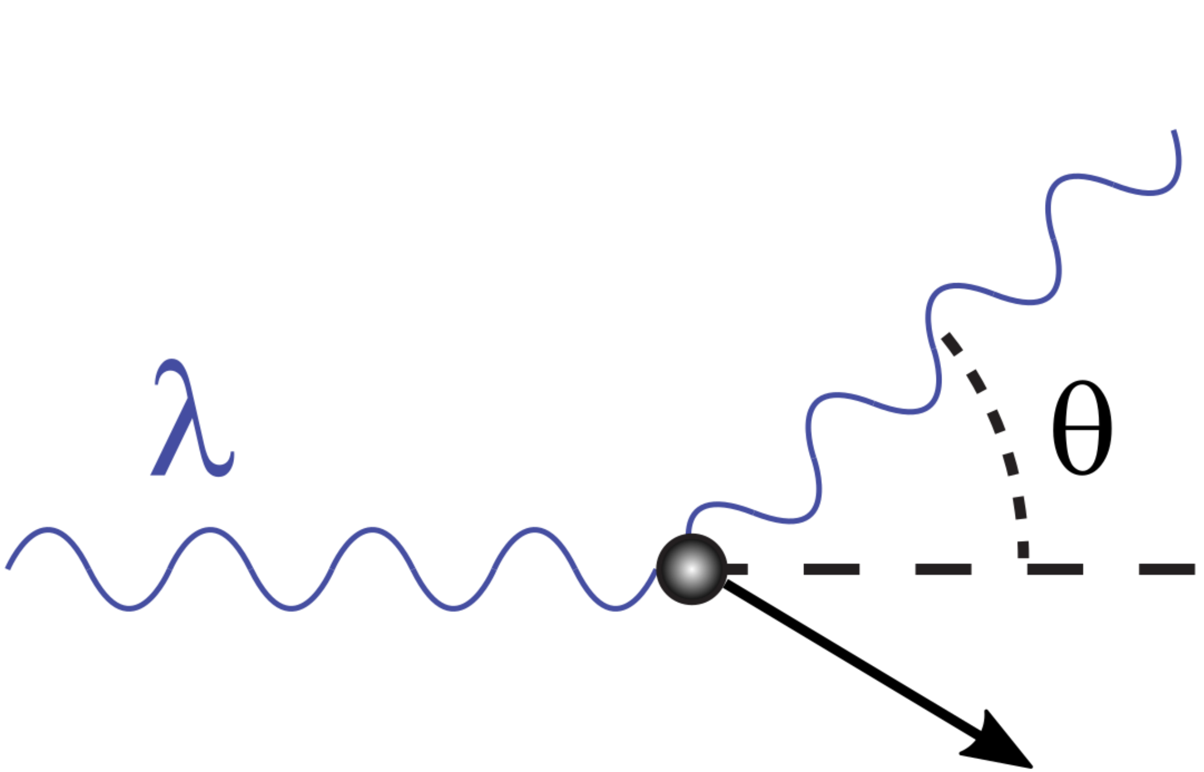
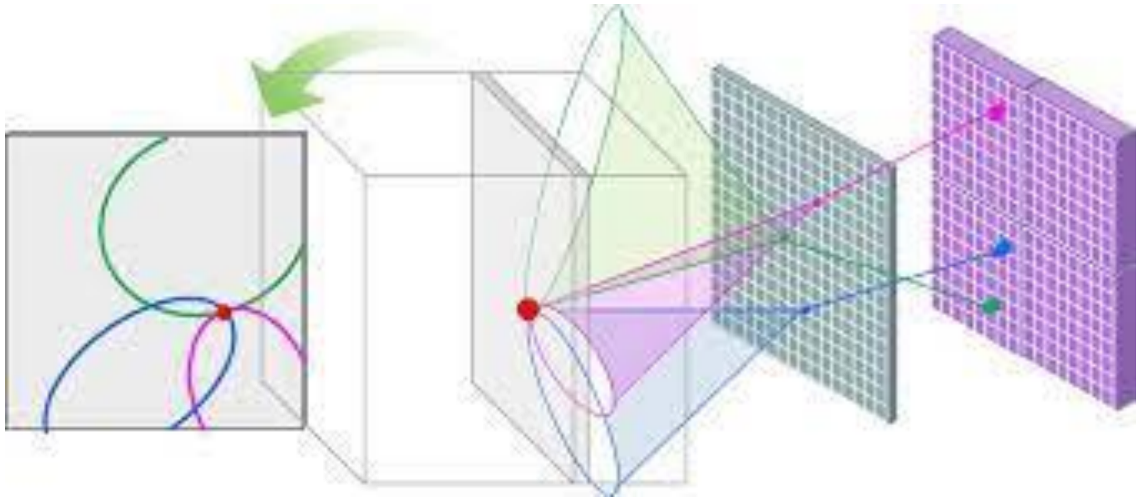
Development of a Compton Gamma-ray Imager using Cubes of CsI(Tl)





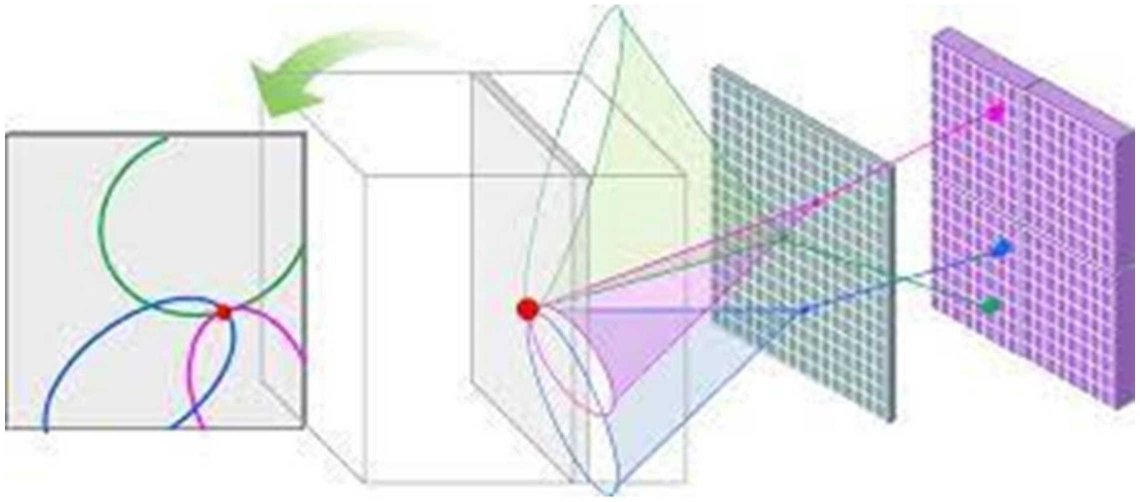
By: Fadi Younes
fadi.younes@mail.mcgill.ca
With: Professor David Hanna,
Dr. Stephen O'Brien,
Guilherme Caumo

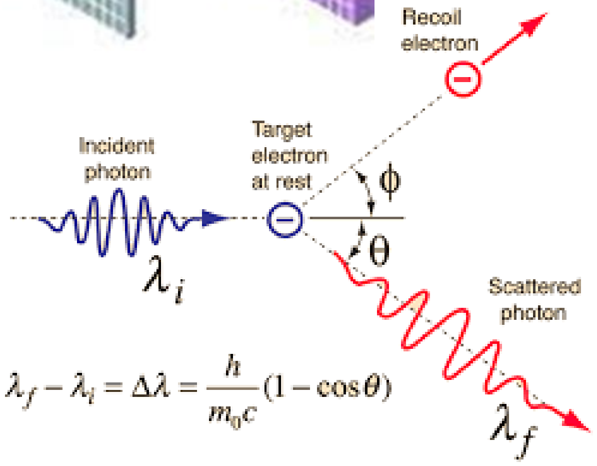
McGill

CSA ASC

NSERC CRSNG

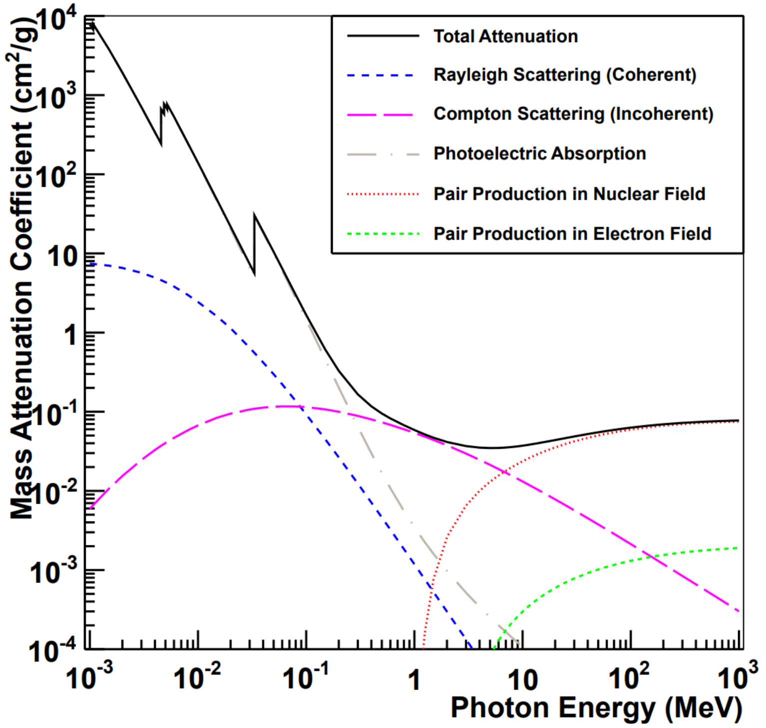
Underlying Theory for the Imager





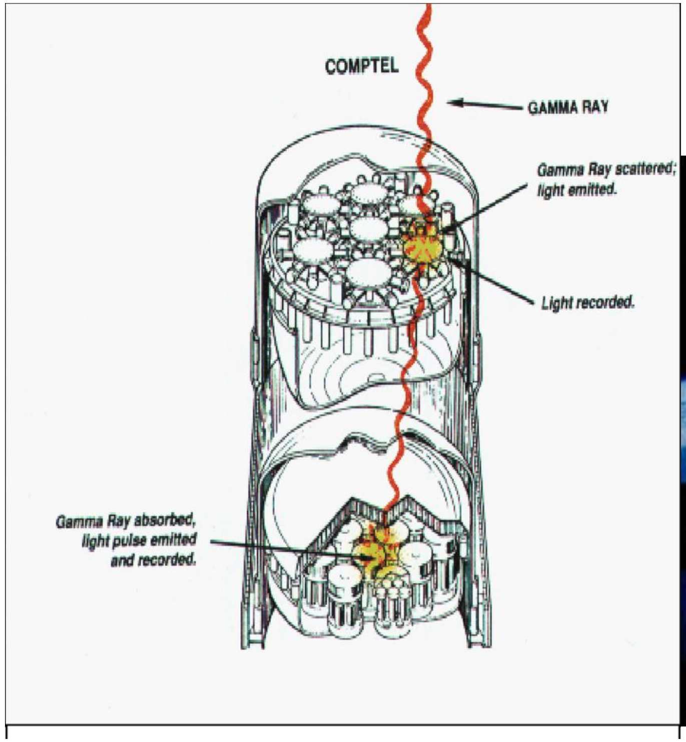
$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$

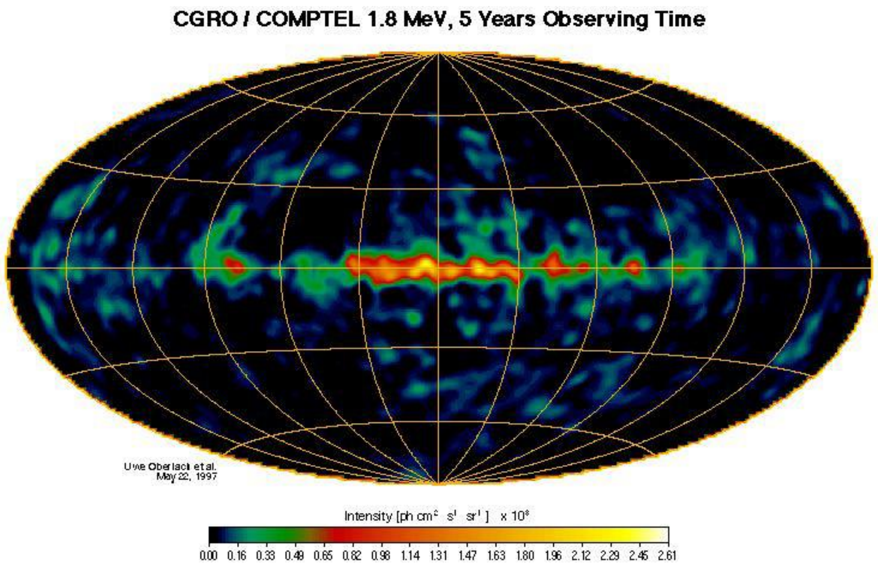
The Compton equation is used to determine the opening angle of the cone and the position of the 2 photons is used to determine the axis of the cone. Multiple events are recorded and the intersection of multiple cones tells the location of the gamma-ray source.



Compton Scattering is best for detecting gamma rays of 100 keV to 10 MeV.

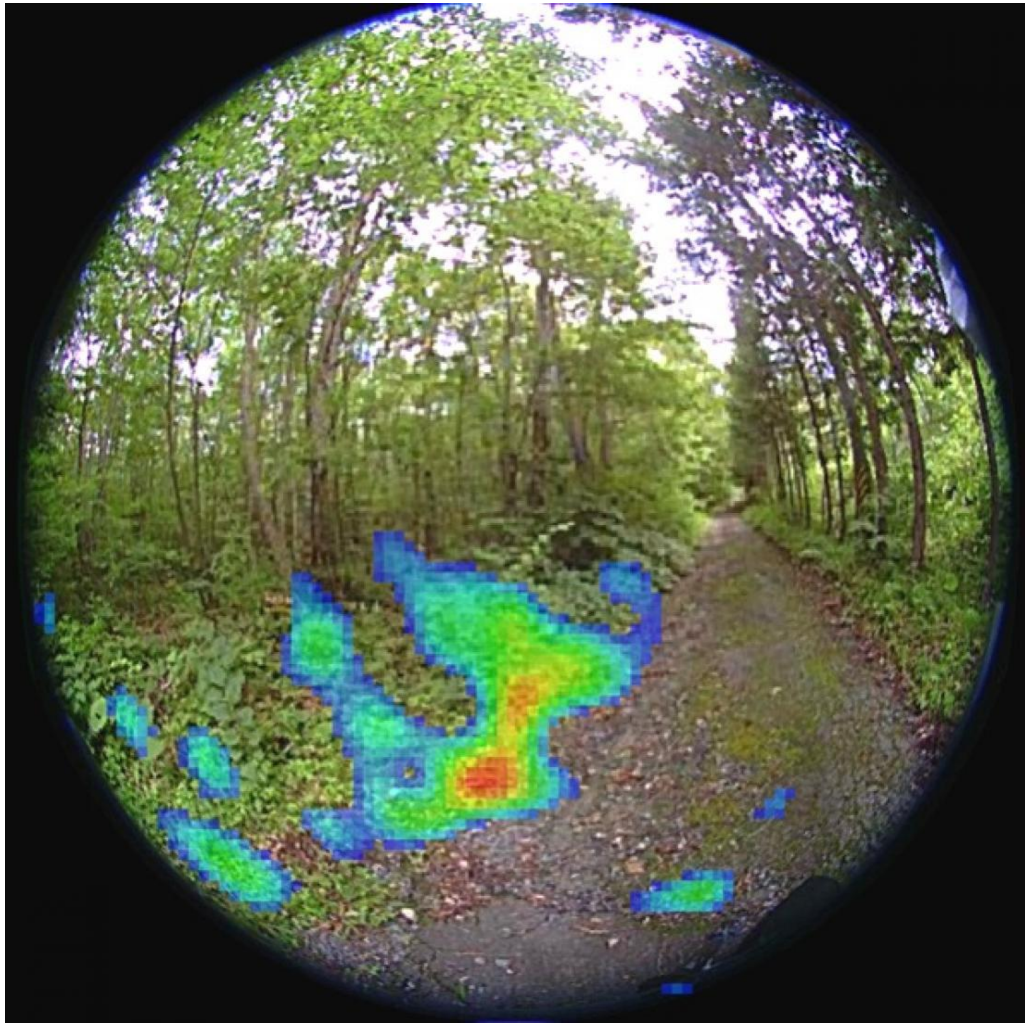
COMPTEL: MeV Compton gamma-ray telescope





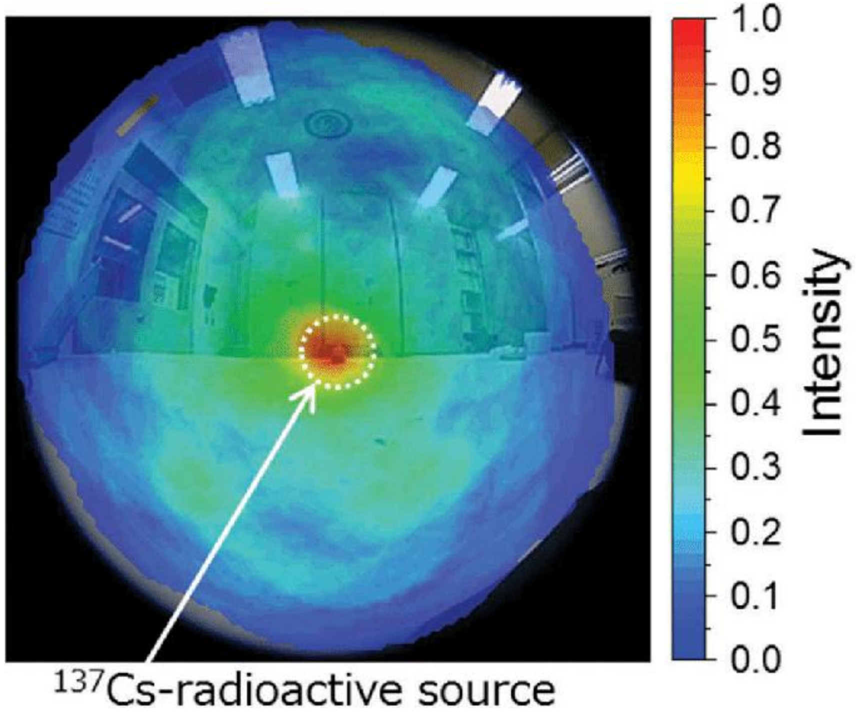
100 keV – 10 MeV energy range which is important for nuclear astrophysics is not well studied because of angular and energy resolution limits.

Possible Applications



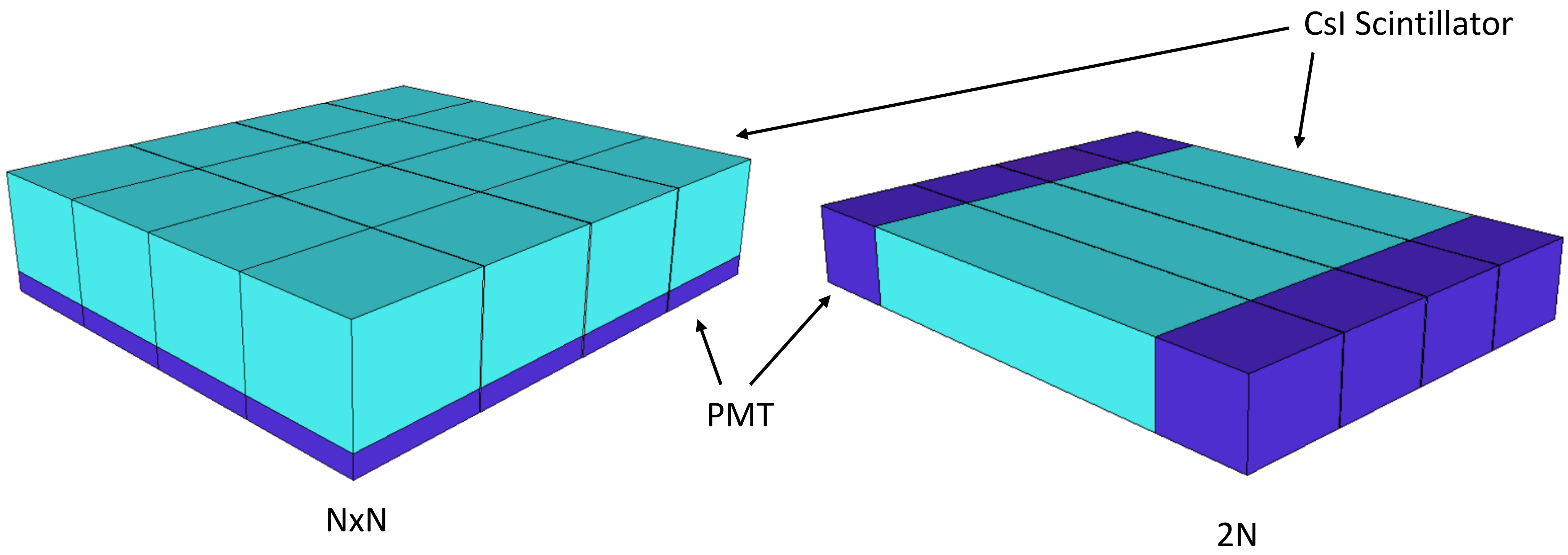
Fukushima decontamination, Waseda University, 2015.

This imager would have applications such as:
-Nuclear disaster decontamination
-Clandestine nuclear material detection



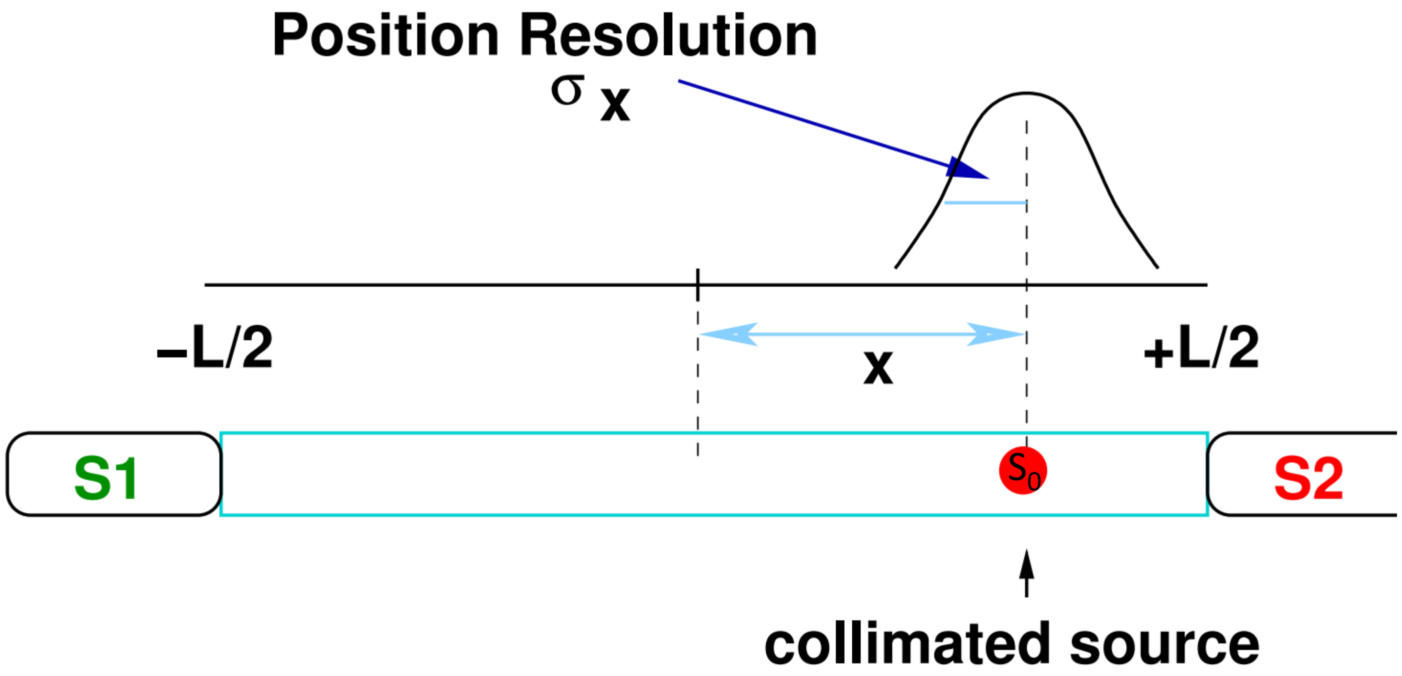
Compton camera mounted on a crawler robot, Sato et al., 2019.

Improving current Compton Imagers



An improvement would be to use 2N electronics channels in place of NxN channels to reduce costs and power consumption of the compton imager.

Determining the Position and Energy



$$S_1 = S_0\, e^{-\frac{(\frac{L}{2}+X)}{X_0}}$$

$$S_2 = S_0\, e^{-\frac{(\frac{L}{2}-X)}{X_0}}$$

$$\frac{S_1}{S_2} = e^{-2\frac{X}{X_0}}$$

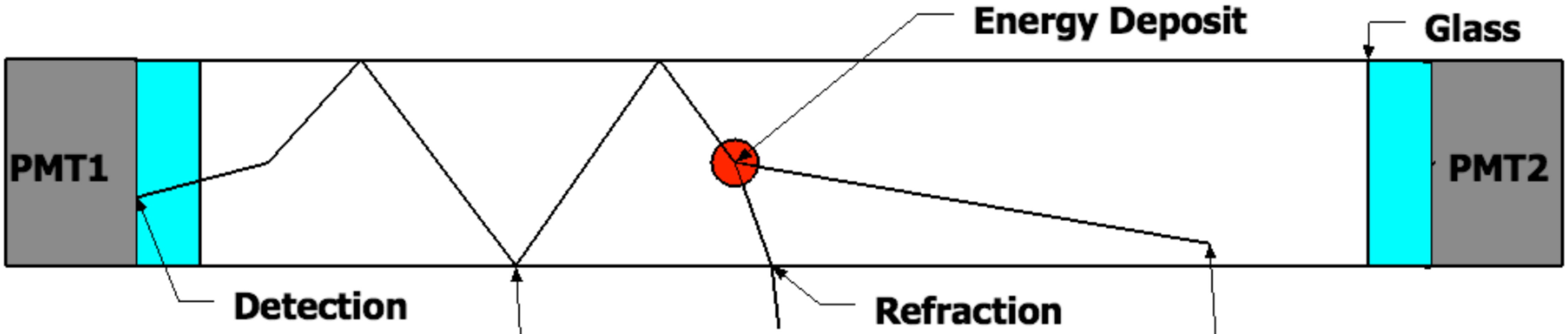
$$X = \frac{-X_0}{2} \ln(\frac{S_1}{S_2})$$

$$S_1 S_2 = S_0^2\, e^{-\frac{L}{X_0}}$$

$$S_0 = \sqrt{\frac{S_1 S_2}{e^{-\frac{L}{X_0}}}}$$

Quotient of signals is used as proxy for position of photons and product of signals is used as proxy for energy of photons.

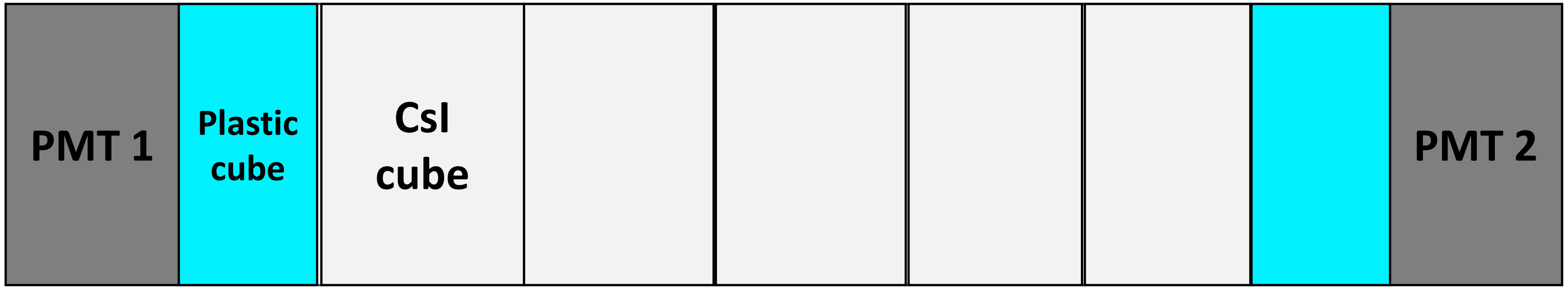
How the Scintillator bar works ?



Shortening the attenuation length by degrading the total internal reflection improves position resolution since it widens the difference between the two signals.

But this is not always necessary…

New design for the Scintillator bar



Instead of using a bar of crystal where it is needed to degrade the attenuation length, one can use cubes and rely on Fresnel reflection to accomplish the same effect.

This is then all put into a plastic tube to hold everything in place.

Assembling the imager

Tube's inside.

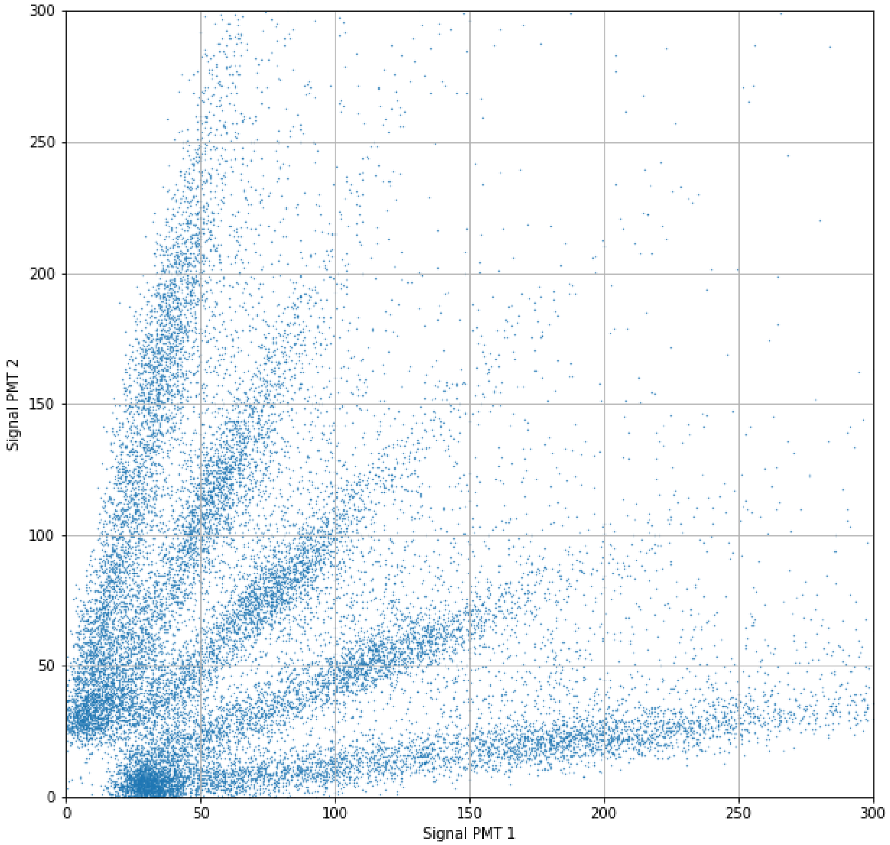
Five CsI cubes with a plastic cube acting as a light guide at each end.

Hamamatsu
R580 PMT

Instead of using a bar of crystal where it is needed to degrade the attenuation length, one can use cubes and rely on Fresnel reflection to accomplish the same effect.

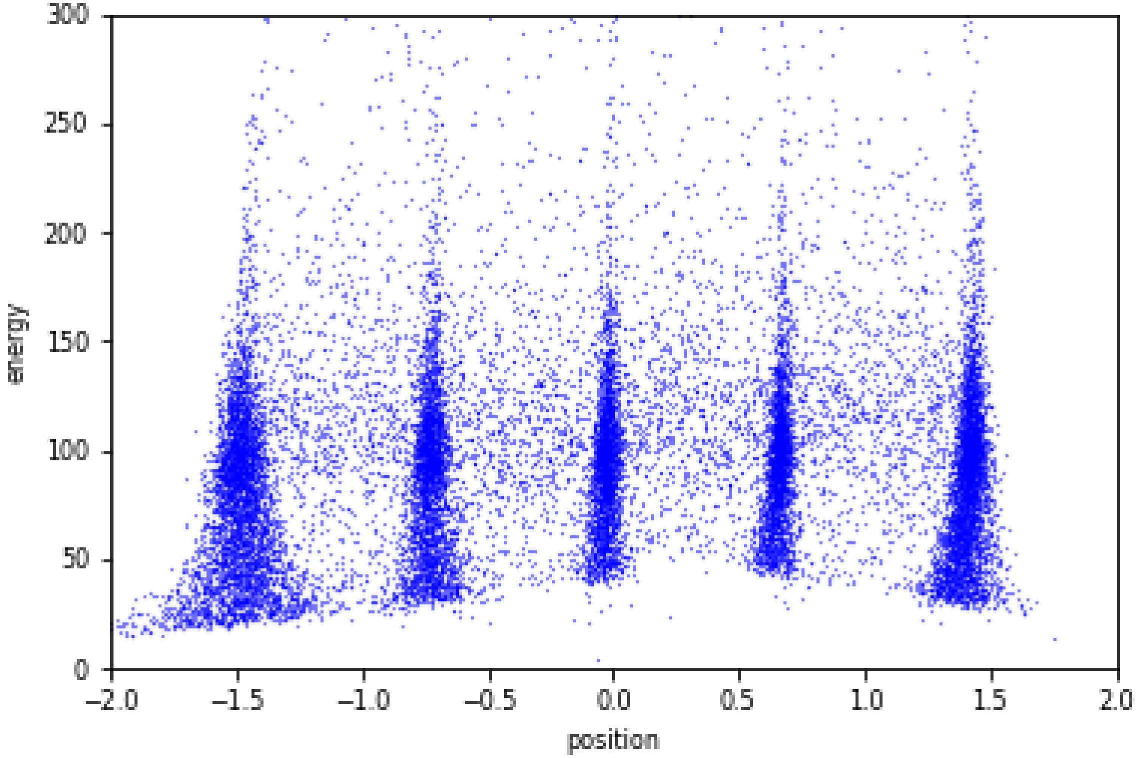
Assembled tube.

Preliminary results



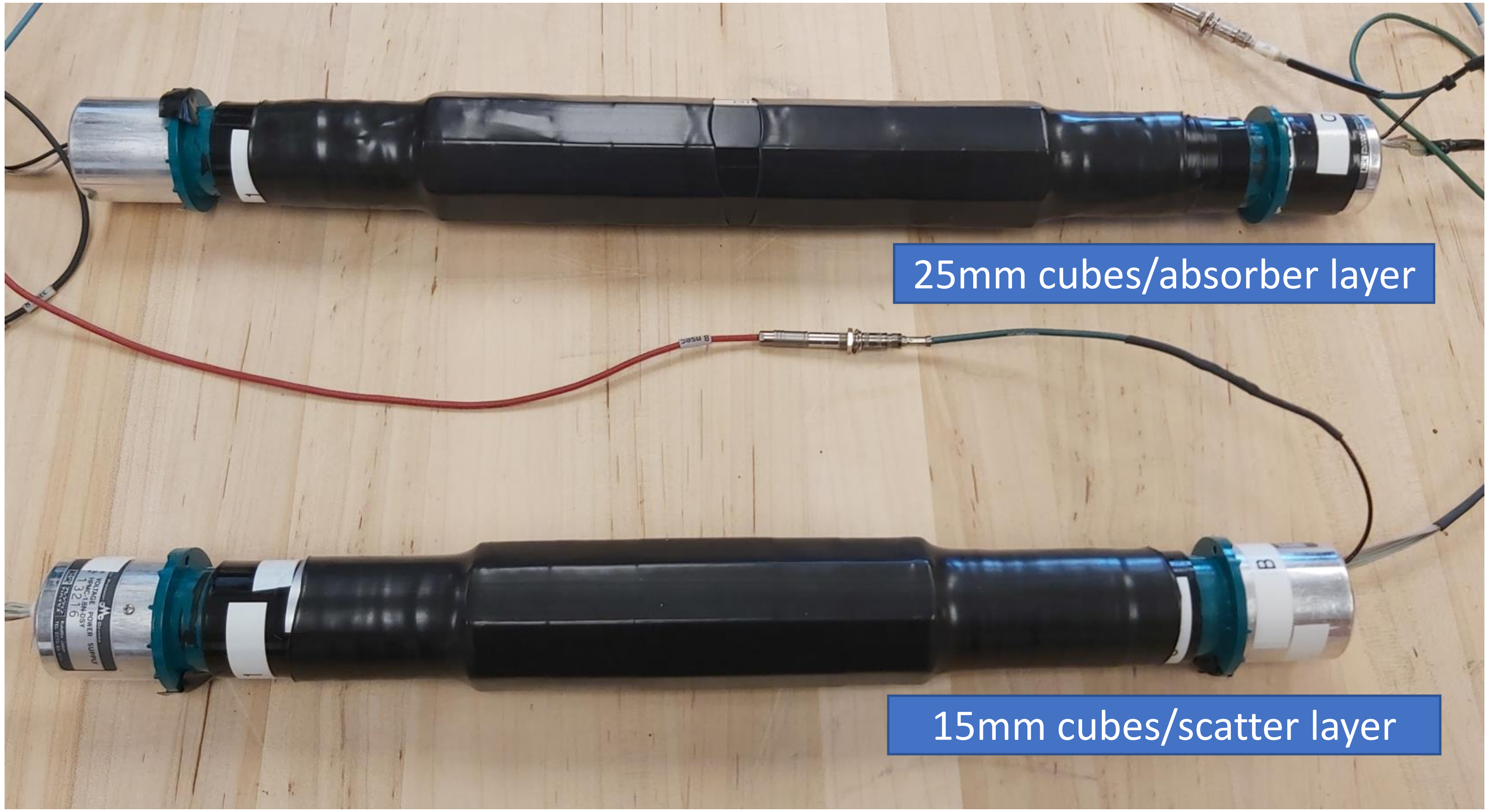
Scatter plot of signal coming from PMT #1 on the X-axis and PMT #2 on the Y-axis.

Finger pattern is caused by the cubes design for scintillators.



Total signal coming from both PMTs as a function of position of the energy deposit. Determined using previous equations

Still a lot of work needs to be done…



Future work:

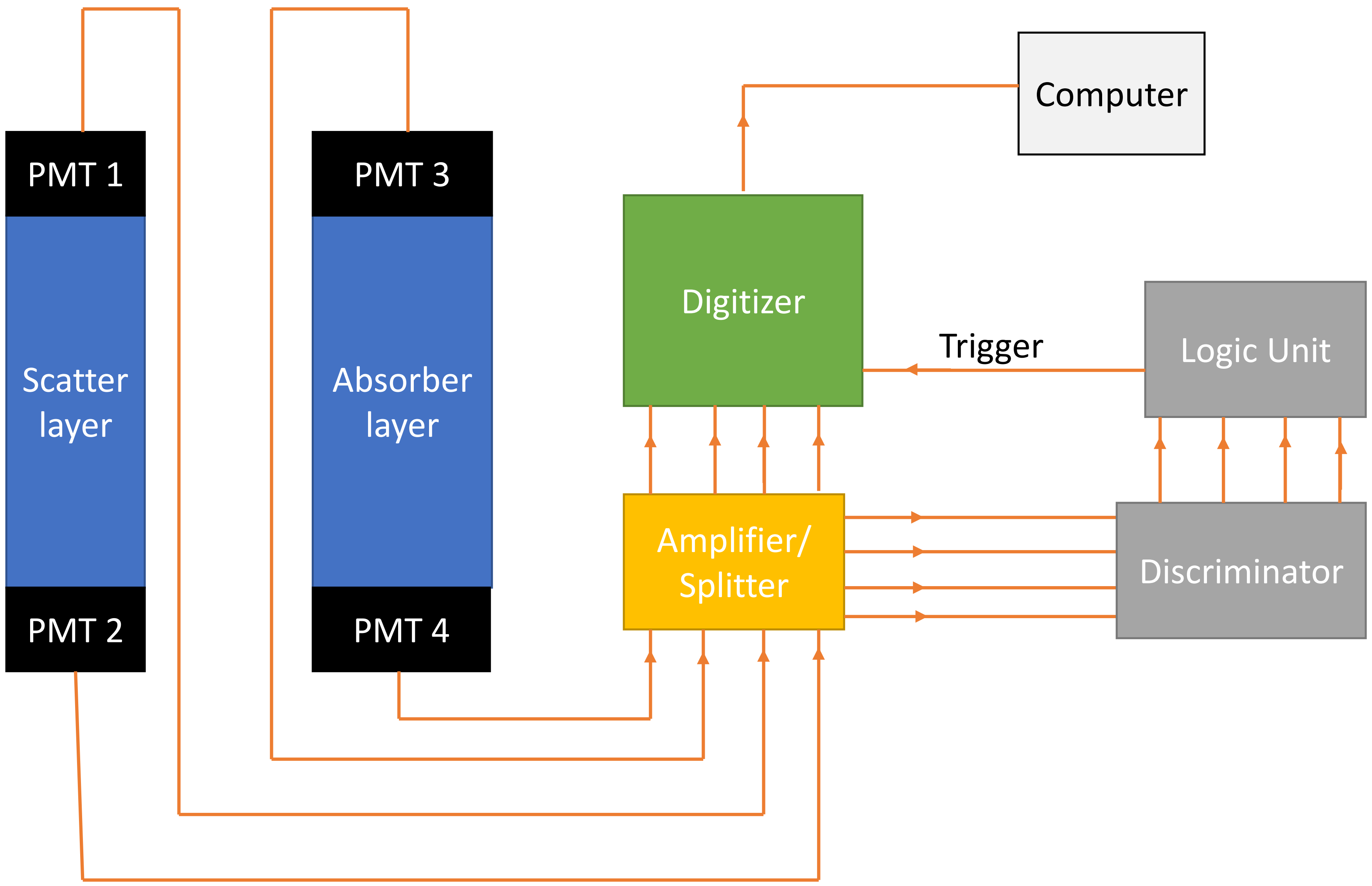
-Get coincidences with 2 bars.

-Study energy resolution with the 2 signals.

-Try making virtual detector by moving vertically the bars to simulate a whole plane.

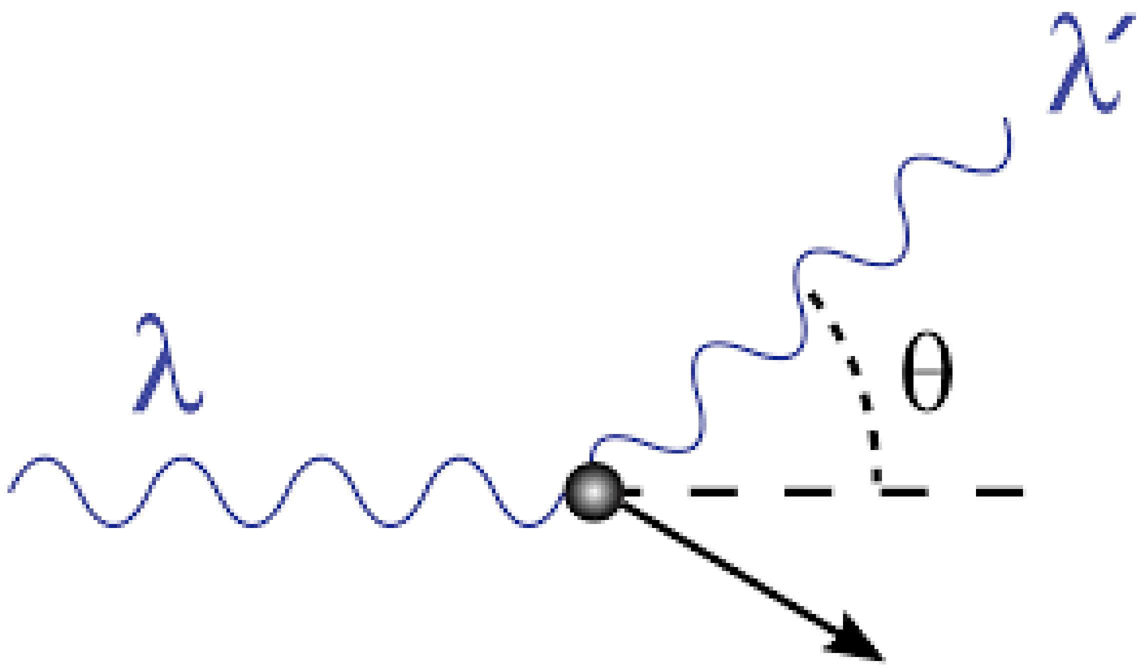
-Add tubes to the detector to complete each layers.

Electronics scheme for final design



In Conclusion:

We are trying to improve the design of current Compton imagers by reducing the number of data channels from NxN to 2N, thus reducing costs which is important for security applications and reducing power consumption wich is important for space based applications. This is a work in progress.



Thank you very much for your time.