Characterizing the X ray gun (Au target) with NaI(Tl) detector

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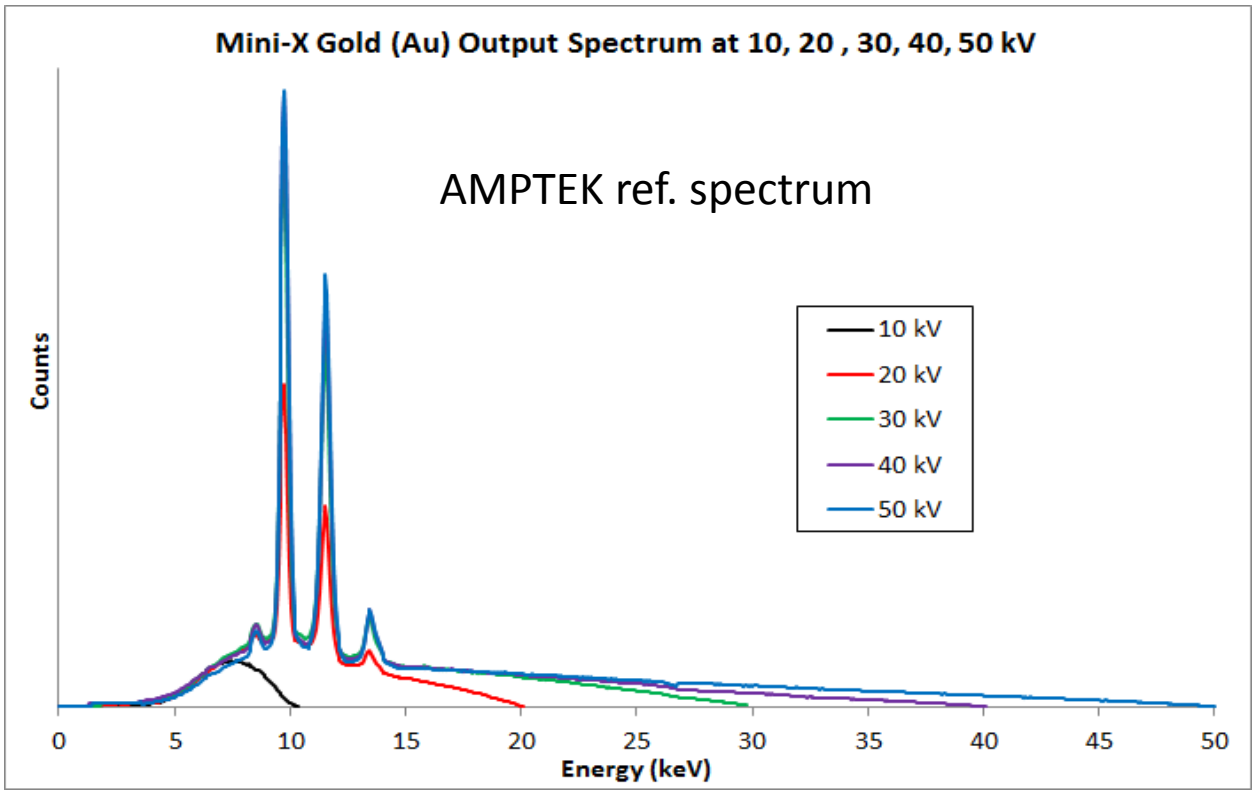
GEM detector hardware meeting

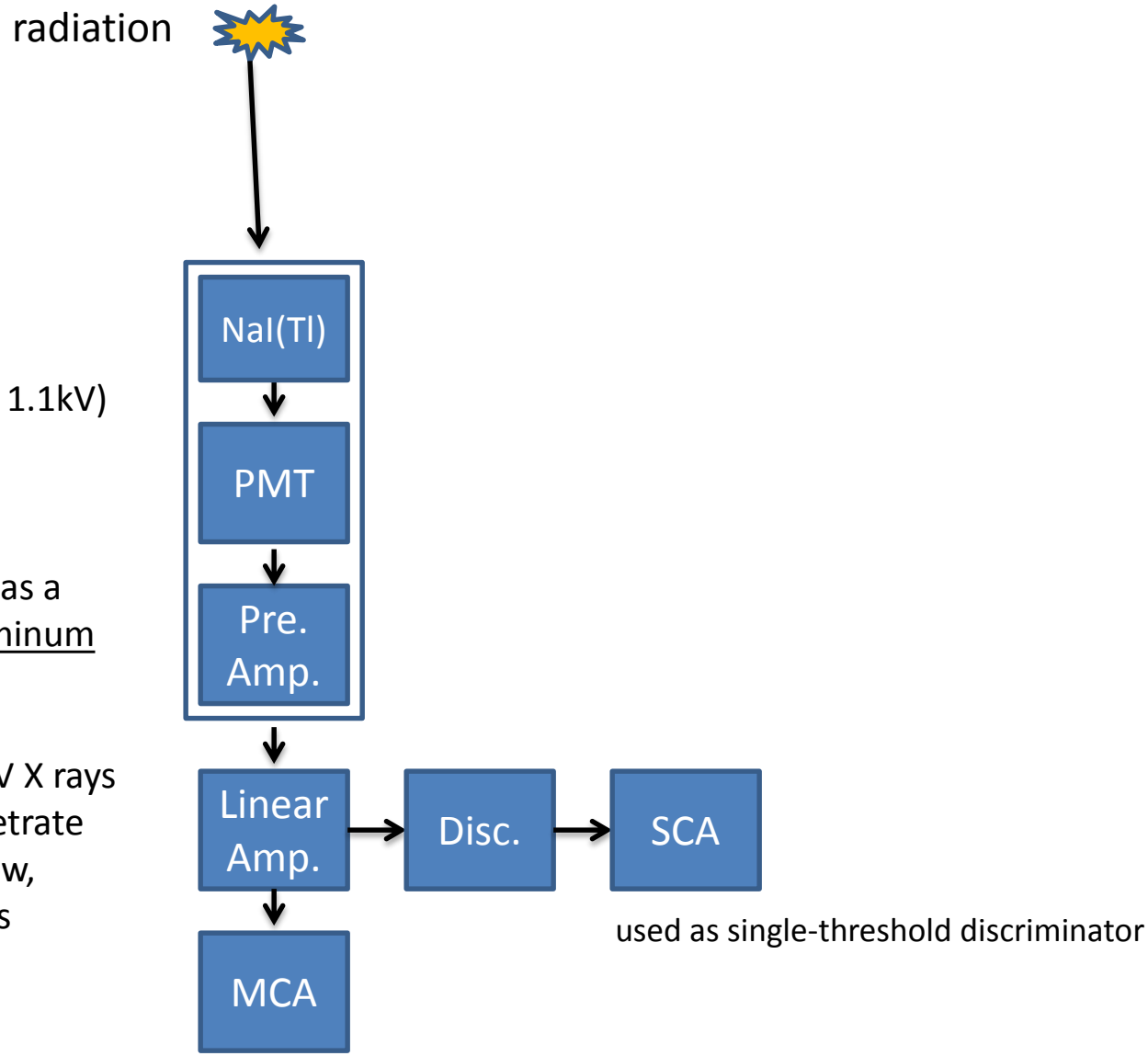
Motivation

- To understand our X-ray gun better
- To prepare for high rate tests on large GEM detectors.

The official spectrum of X ray gun (Au target) (what we expect)



Setup for the NaI(Tl) detector



Canberra
PMT:2007P
(operated at 1.1kV)
NaI(Tl): 802
2×2 inches

The device has a
0.5 mm Aluminum
window

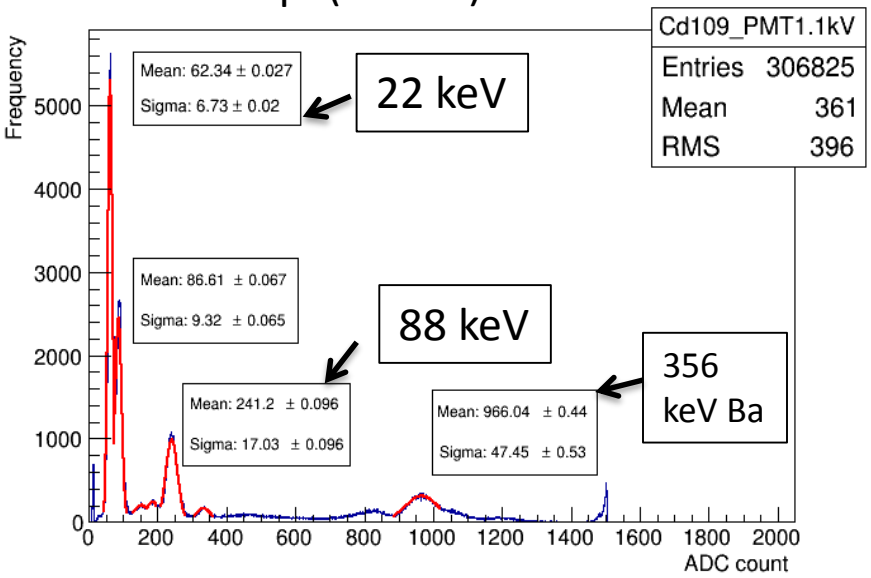
Fe-55 5.9 keV X rays
can not penetrate
the Al window,
no signal was
observed.

used as single-threshold discriminator

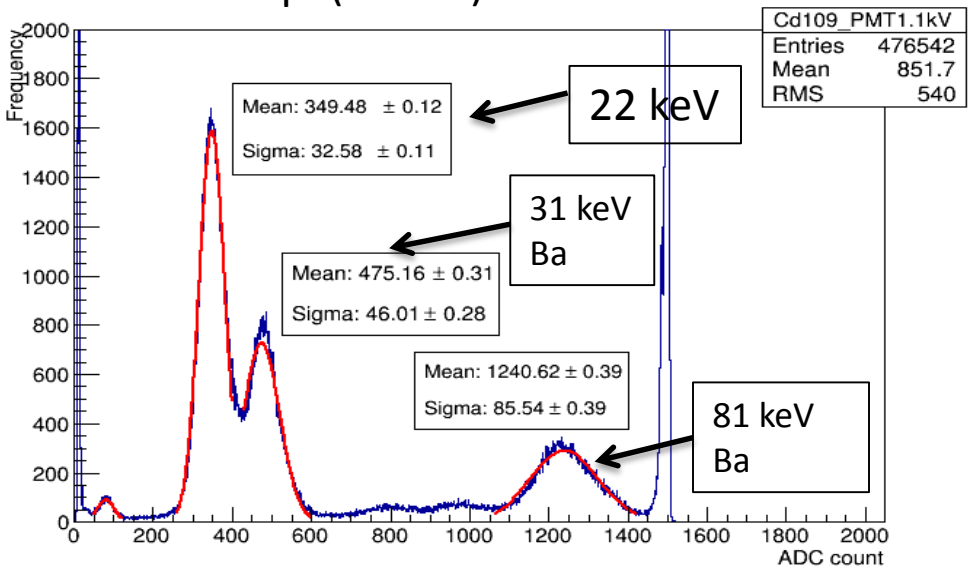
Cs-137 and Cd-109 calibration of NaI(Tl)

- PMT voltage 1.1 kV;

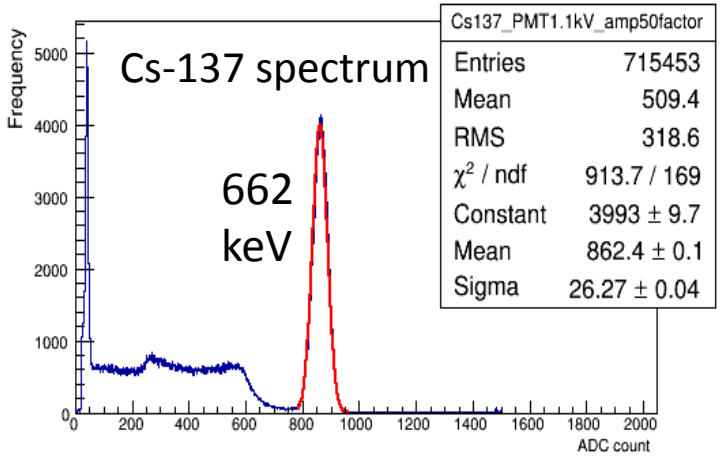
Linear amp. (coarse) factor 100



Linear amp. (coarse) factor 500



Linear amp. (coarse) factor 50

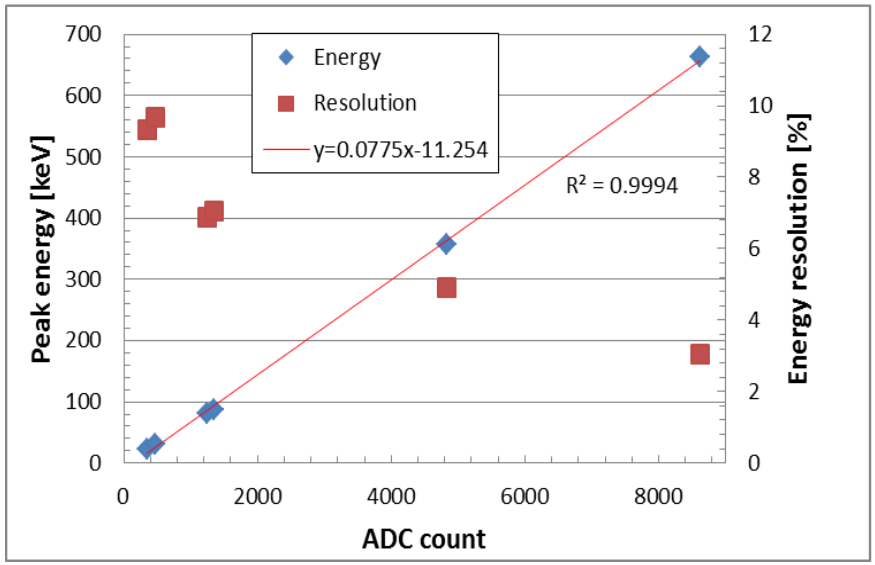


- Linear amp. factor has to be adjusted to allow the peaks to be well measured over full energy range
- Non-linearity of the MCA is ignored, the reason to do so is that we don't have small energy X-ray sources to calibrate the system.
- It turned out that our Cd-109 is not pure, it appears that it may contain some contamination with Ba-133.

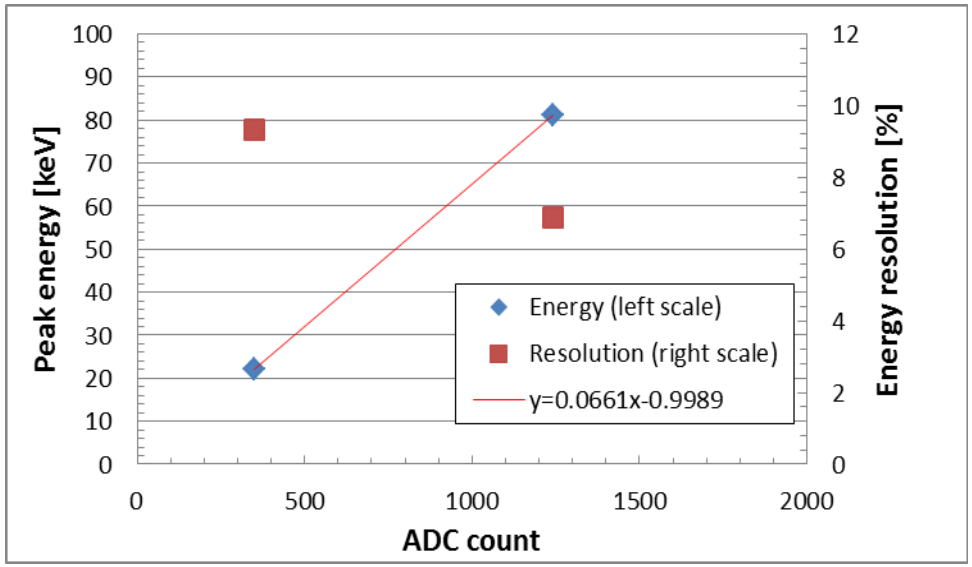
- For X ray gun tests, linear amp. factor is set to 500.

Calibration of the electronic system (at amp. gain 500):

- Use all peaks of both radiation sources



- Use peaks of < 100 keV (2 points)



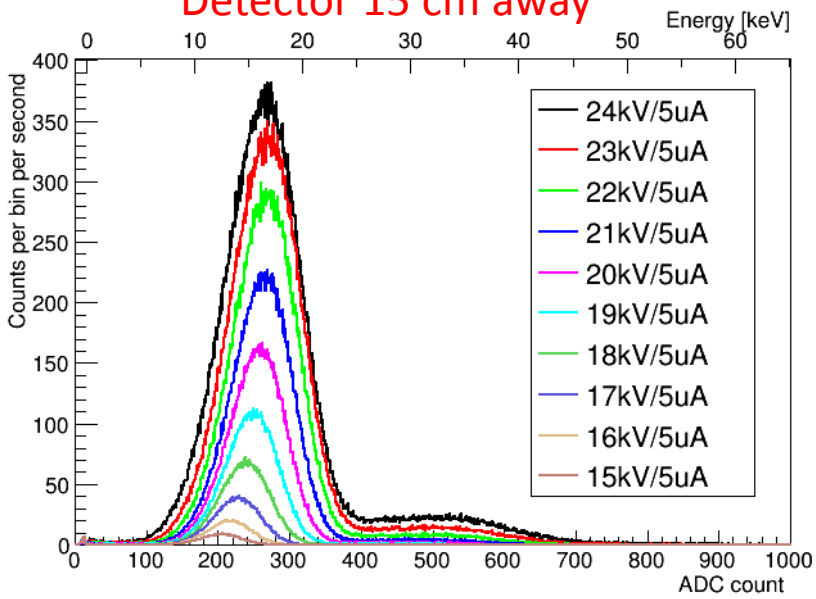
- The 2-point calibration (on the right) is taken; reasons:

(1) To use only the Cd-109 spectrum taken with linear amp. gain of 500. Cd-109 has a 22 keV line which is close to the energies that X ray gun outputs;
(2) On that spectrum, the 22 keV and 81 keV peaks are more or less single energy peaks, the 31 keV peak actually contains different energies (30.3,30.6,30.9 keV) that are not resolved. So, 31 keV peak is not used.

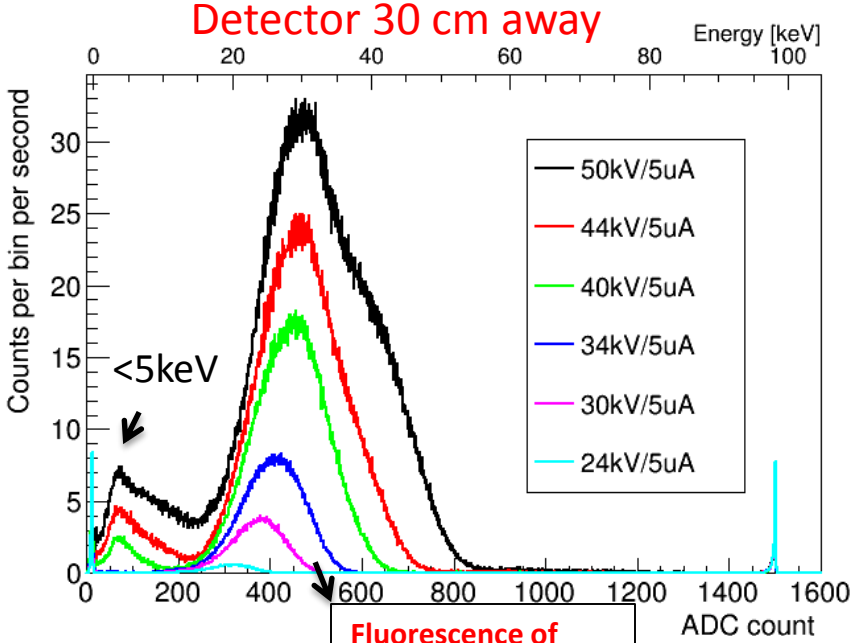
X-ray gun voltage scan at 5 μA, 1 mm collimator is used

- For each tested voltage, there is only one peak on the spectrum;
- Energy scale is calibrated with the previous Cd-109 spectrum (at amp. gain 500).

Detector 15 cm away



Detector 30 cm away



Fluorescence of 28-32 keV K lines of Iodine in NaI ??

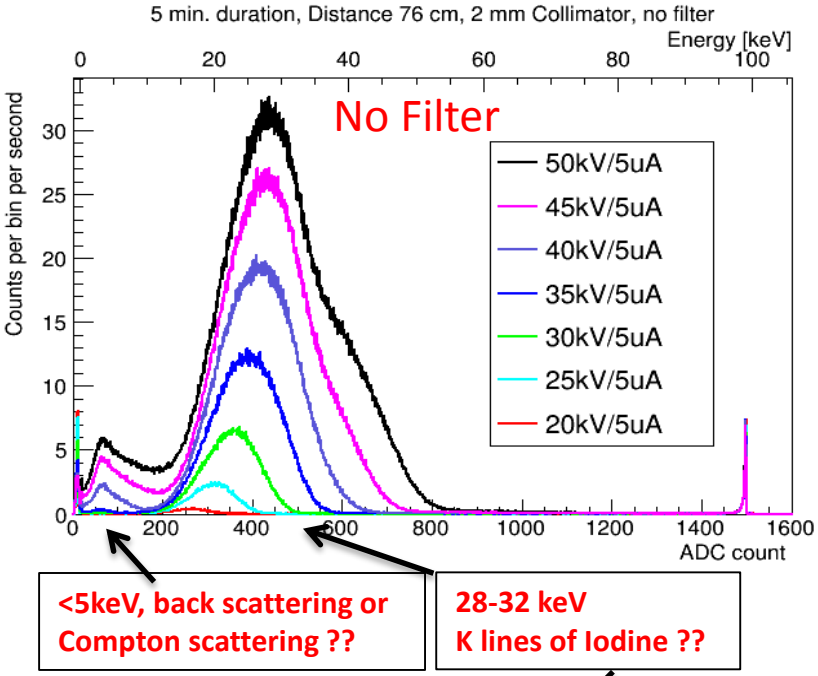
To **reduce pileup** and to speed up tests:

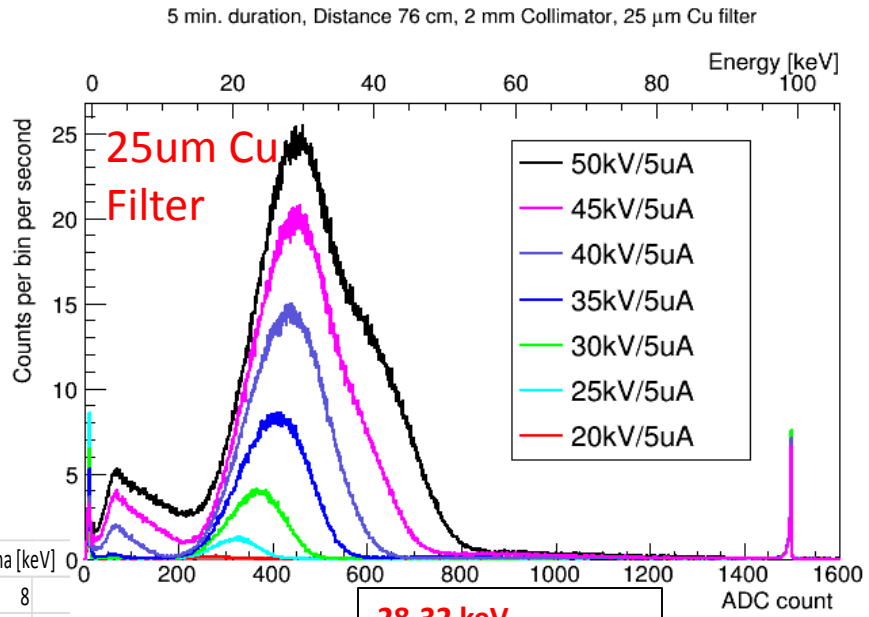
(1) X ray gun is put 30 cm (15 cm) away from detector when testing 24kV-50kV (12kV-24kV). For each case, at highest tested voltage there is a little pileup which distorts the spectrum by adding a shoulder to the right and shifting the main peak to the left.

(2) The distance to the detector is very close (~ 1cm) when testing 11kV. Rate is very low even for this situation. Could not take 10kV data (don't make into the NaI)

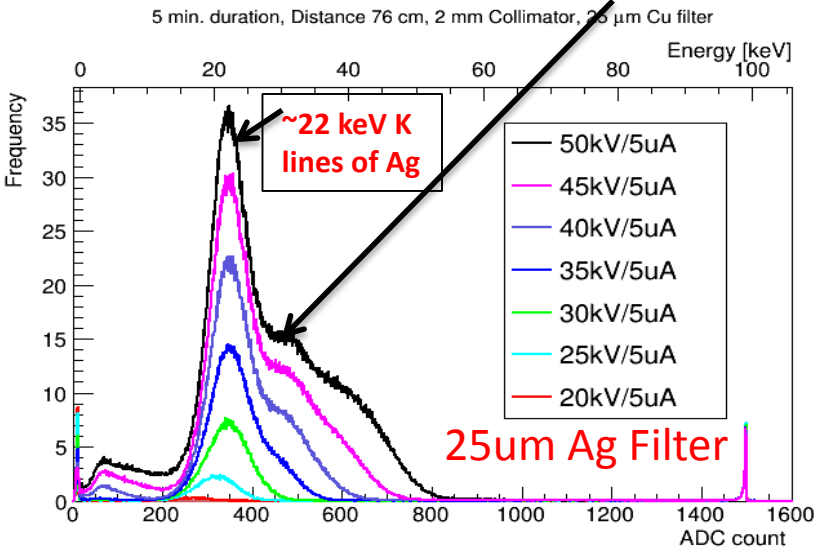
(3) While changing the distance, X rays may be hitting different positions on the detector, this could give small bias.

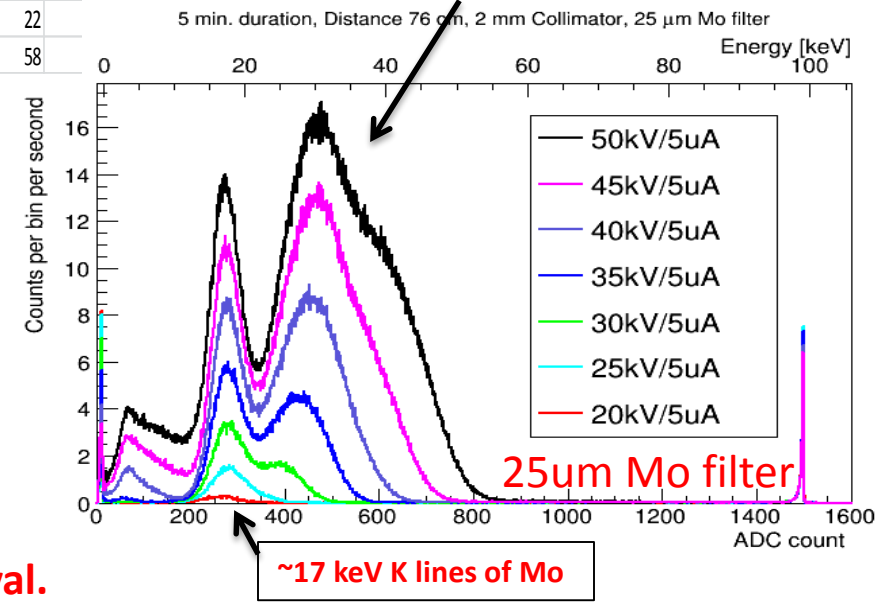
WITH FILTERS: X ray gun is 76cm away from NaI, 2mm collimator; Amp. Gain 500.





Material	K alpha [keV]
Cu	8
Al	1.5
Mo	17
Ag	22
W	58

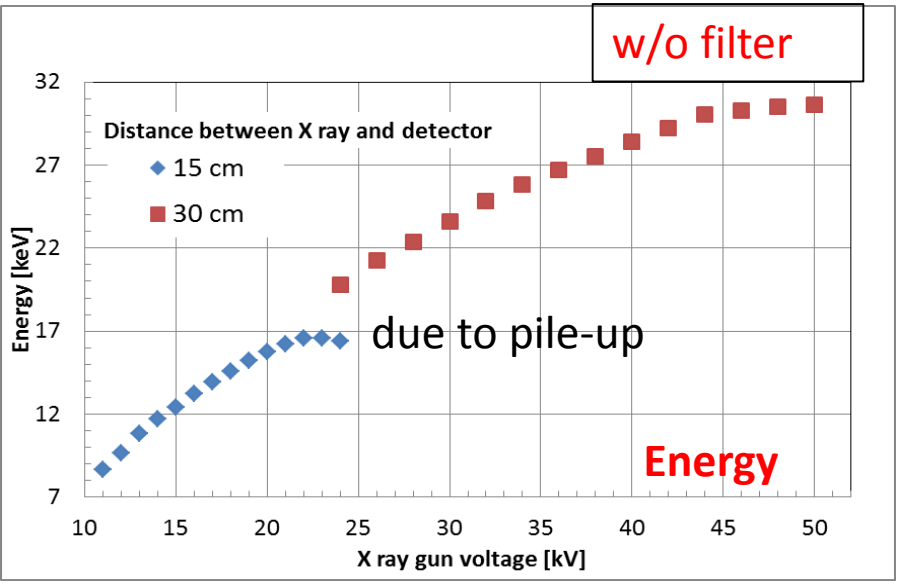




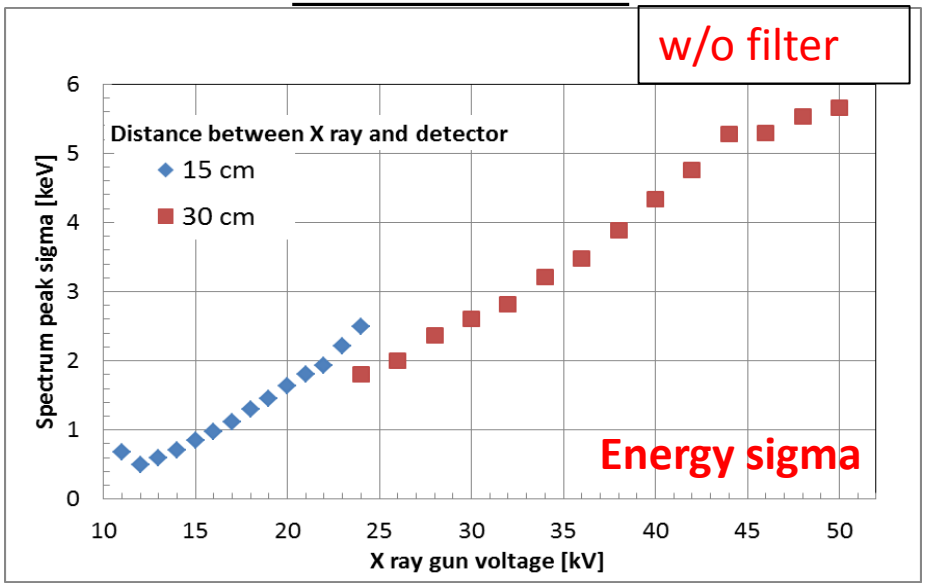
- **Each single spectrum is taken in a 5 min. interval.**
- **http://xdb.lbl.gov/Section1/Periodic_Table/X-ray_Elements.html**

X ray gun voltage scan at 5 µA

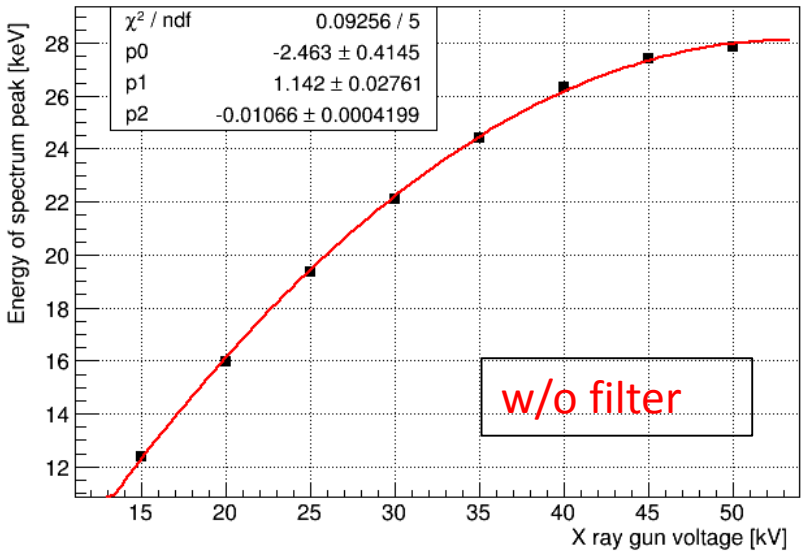
1 mm collimator

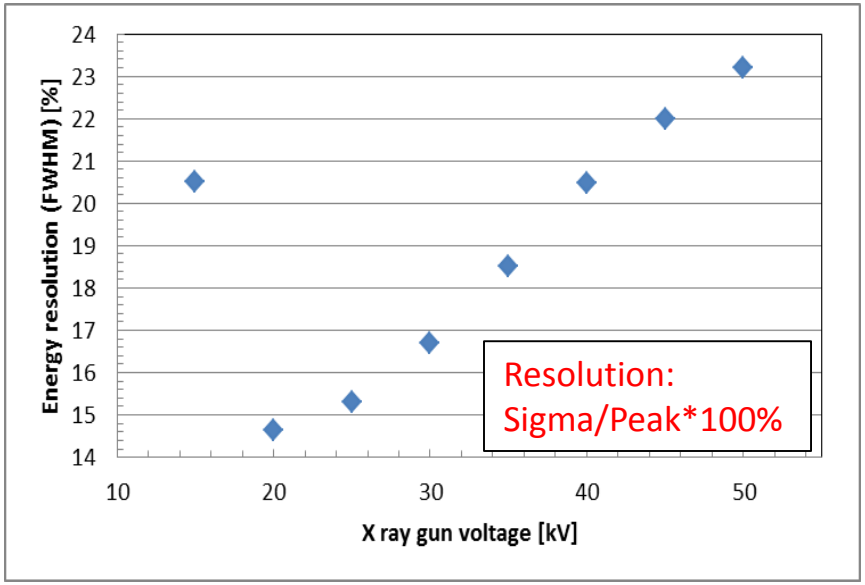


1 mm collimator



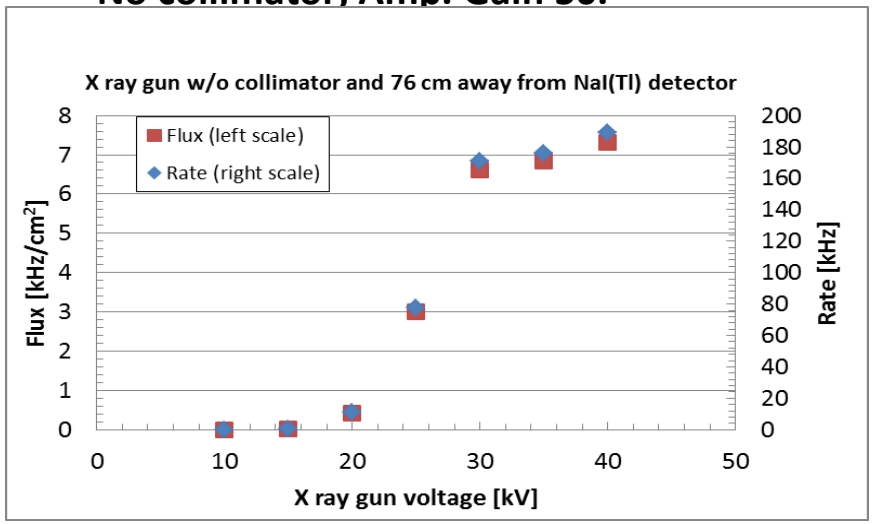
2 mm collimator; 76cm distance



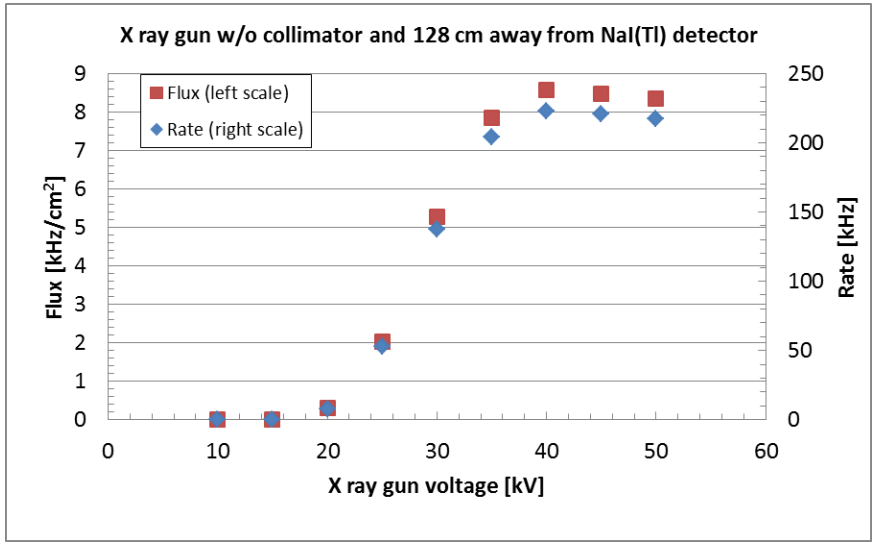


Rate curves

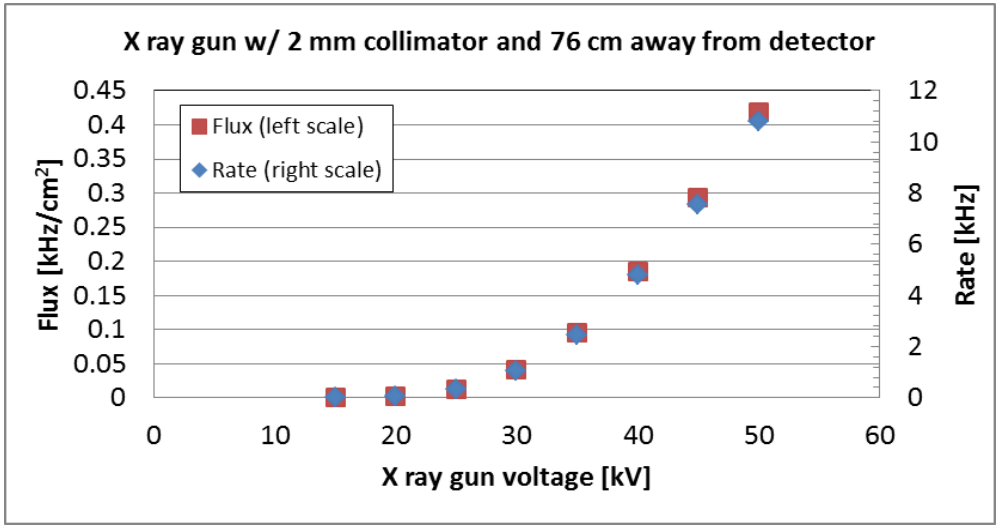
X-ray gun 76 cm away from NaI;
No collimator; Amp. Gain 50.



X-ray gun 128 cm away from NaI;
No collimator; Amp. Gain 500.



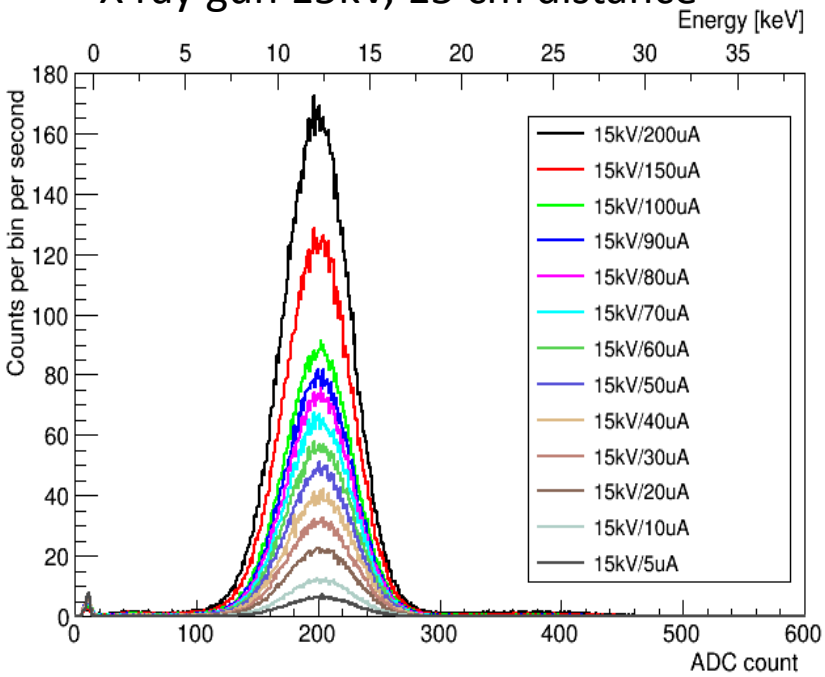
X-ray gun 76 cm away from NaI;
With 2mm collimator; Amp. Gain 500.
(when calculating the flux, I assume that the whole detector area is in the beam. Because the output X ray is in a 120° cone, and beam after collimator is not only perpendicular. See backup slide)



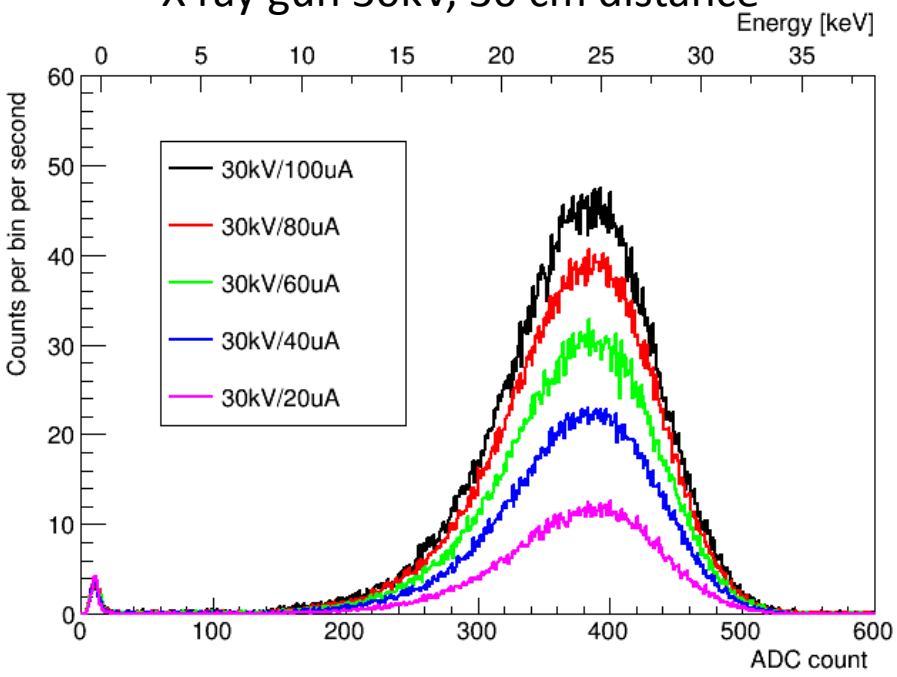
- For doing the measurements, threshold is 50 mV (the minimum of discriminator) for both amp gain 50 and 500 cases. This is fine because signals are well above 50 mV.
- Shaping time of amp. ~ 1 μs; width of signal from amp. is ~3 μs. So the max. rate that it can handle is ~0.3 MHz. Due to pileup events, the rate we can measure should be much less than 0.3 MHz.
- We are seeing plateau at rate around 0.2 MHz, where we already have a lot of pileup issue.

X-ray gun current scan, 1 mm collimator is used, No filter

X ray gun 15kV, 15 cm distance



X ray gun 30kV, 30 cm distance

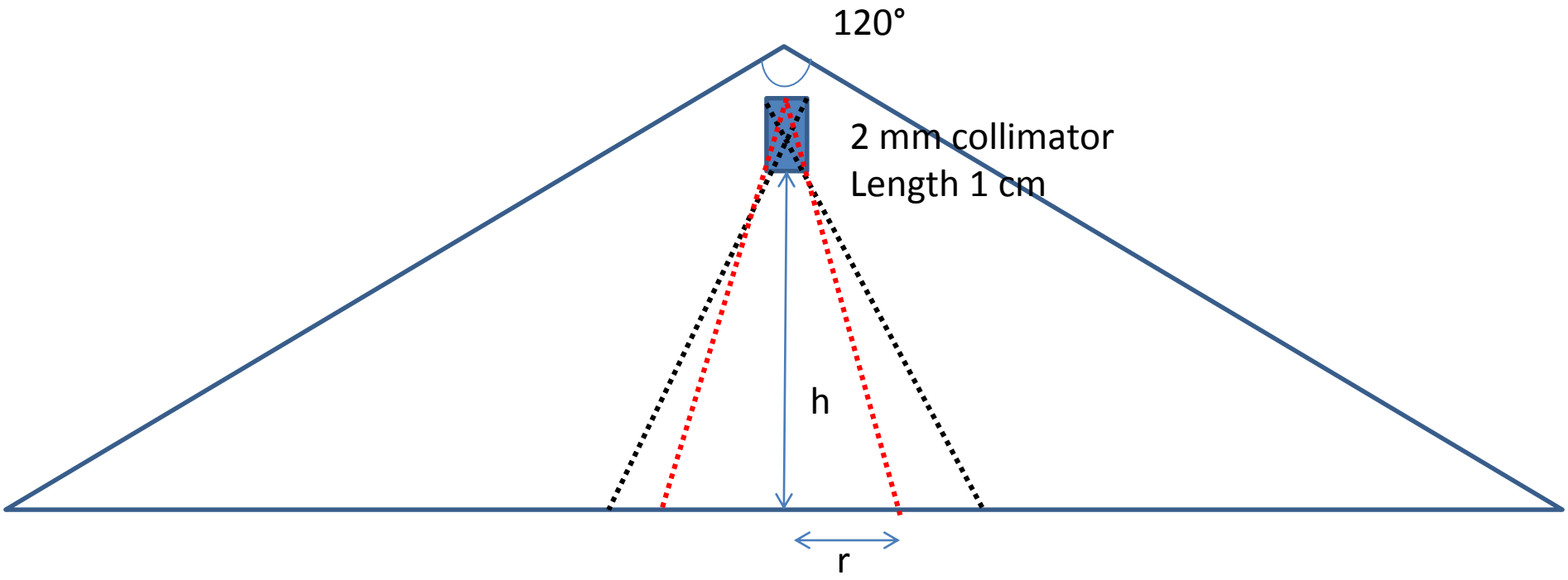


- Current of X ray gun controls the intensity, it has no influence on the X ray energy.

Summary

- Find out that the Cd-109 source in our lab is actually not pure, very likely it contains Ba-133 contamination.
- Scanned X ray voltage (energy) at fixed current (5 μA) and find that the measured X-ray peak energy is a square root function of the applied X-ray voltage.
- Also scanned X ray current at fixed voltage (15kV,30kV) , the energy peaks don't change at all; only rate changes. This confirms that the current does not change X ray energy.
- Some fluorescence X rays are recognized in the X ray gun voltage scan, such as: K lines of Iodine (28-32keV), K lines of Ag (22keV), K lines of Mo (17keV).
- K lines of Cu (8 keV) are NOT measured (even with a Cu filter) due to a 0.5 mm Al window.
- The measurable flux of X ray from the gun reaches up to 8 kHz/cm^2 (rate ~200 kHz). This is limited by our slow electronics (~1 us shaping time, 3 us signal width, max. 0.33MHz w/o pileup).

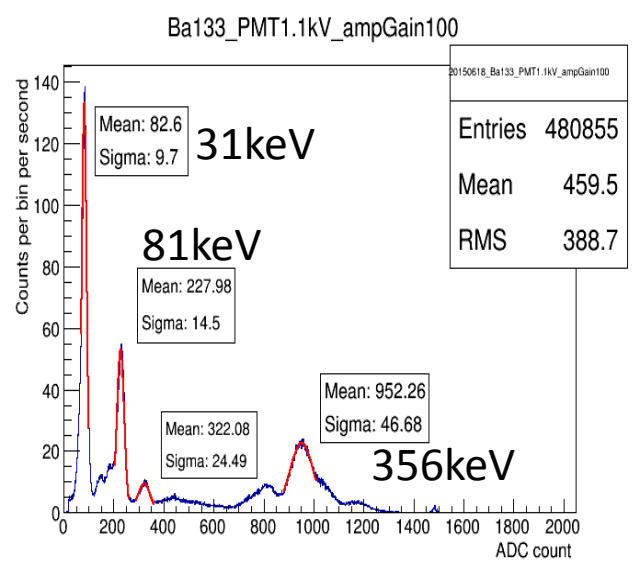
Backup – explanation of flux calculation on page 10

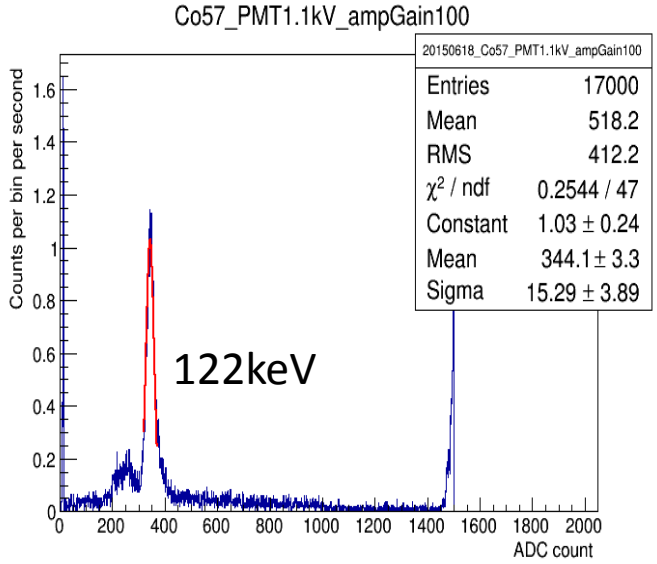


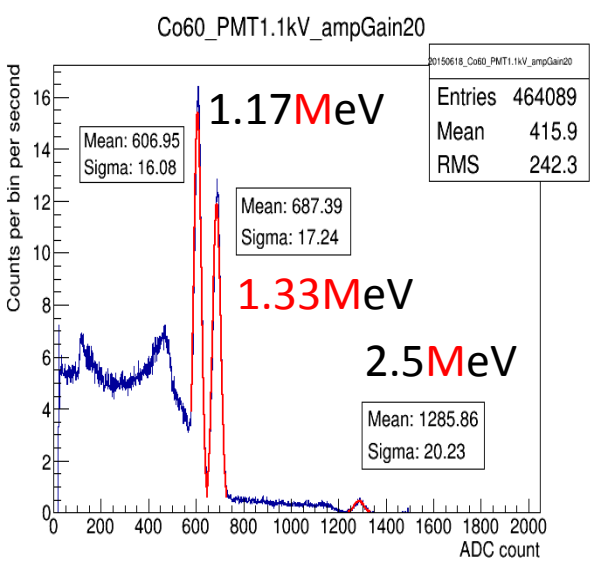
$$r = (h + 1) * \frac{0.1}{1}\ (cm)$$

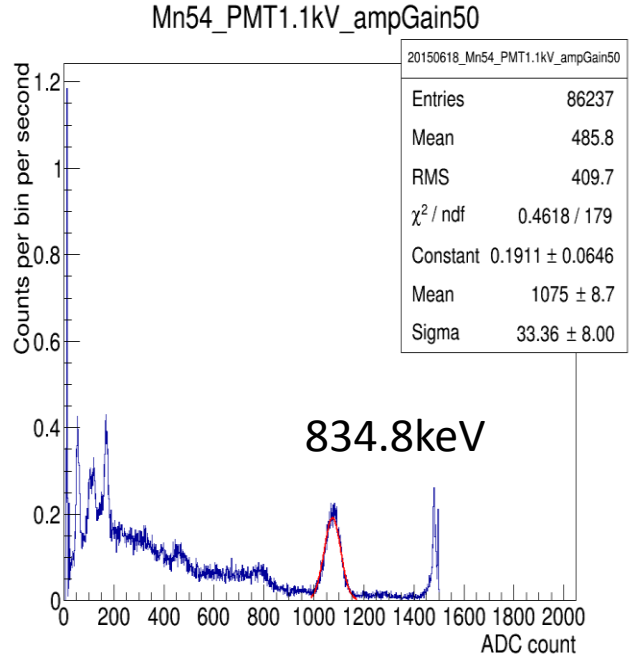
In case of h = 30 inch = 76.2 cm, r = 7.72 cm, larger than the NaI(Tl) size

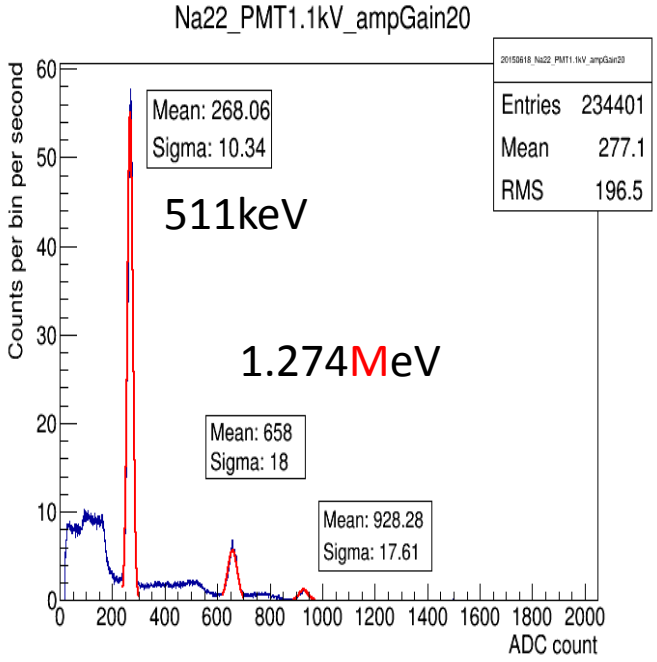
spectra for other sources obtained with the NaI(Tl) detector

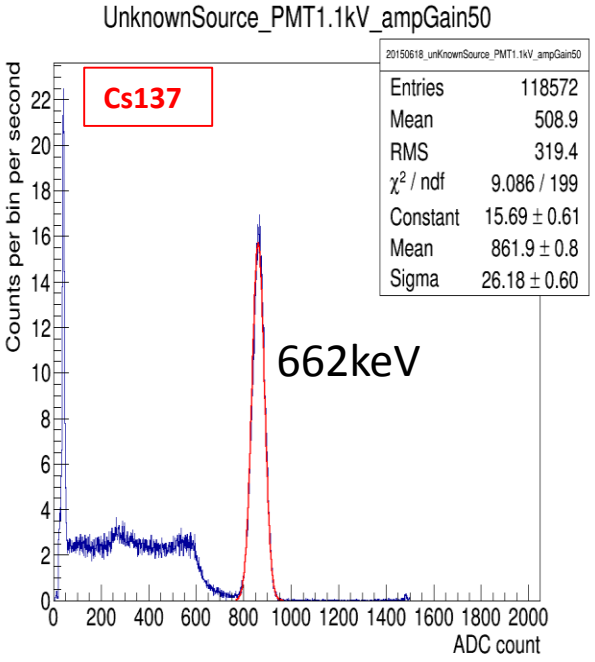












- These spectra indicate non-linearity of our electronics.