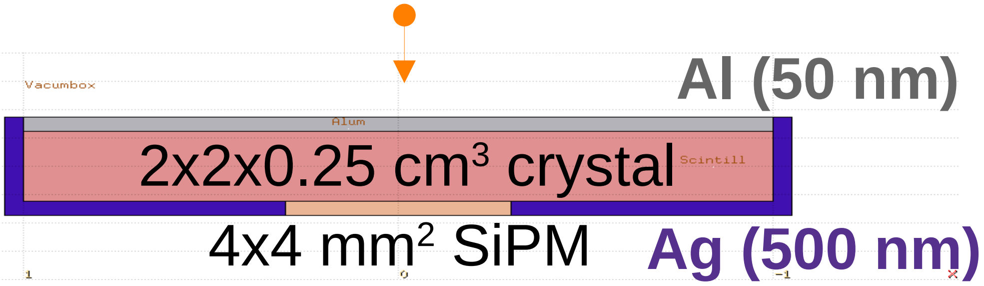
EPSI

1 July 2024

Single detection cell

GOAL Maximize X-ray detection efficiency down to 1 keV

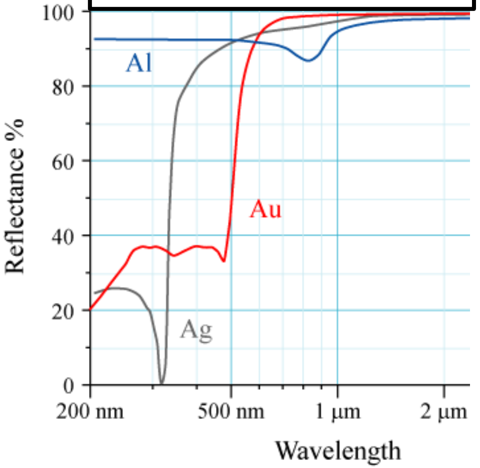
X-ray

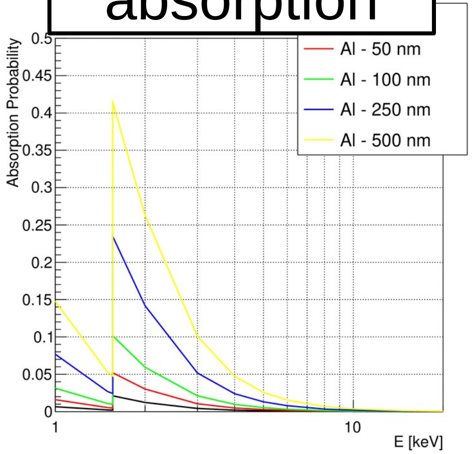


Key ingredient is "Wrapping"!

Metallic deposition (50-500 nm)

Large light reflectance	Small X-Ray absorption





Deposition via sputtering machine

A first measurement with a simpler system

Description

- TIC crystal (**3.6x3.6x1.8 cm^3 CsI:Tl**) → Not 2.0x2.0x0.25 cm^3
- **S14160-4050HS** (4x4 mm^2, 50 μm cell) → Not the best candidate
- Attach a **SiPM** using a optical grease → Not optical silicone
- Wrap the whole crystal using **Vikuiti** → Not Al/Ag deposition
- Use Raffaello's **operational amplifier**
- Sample **maximum** at oscilloscope

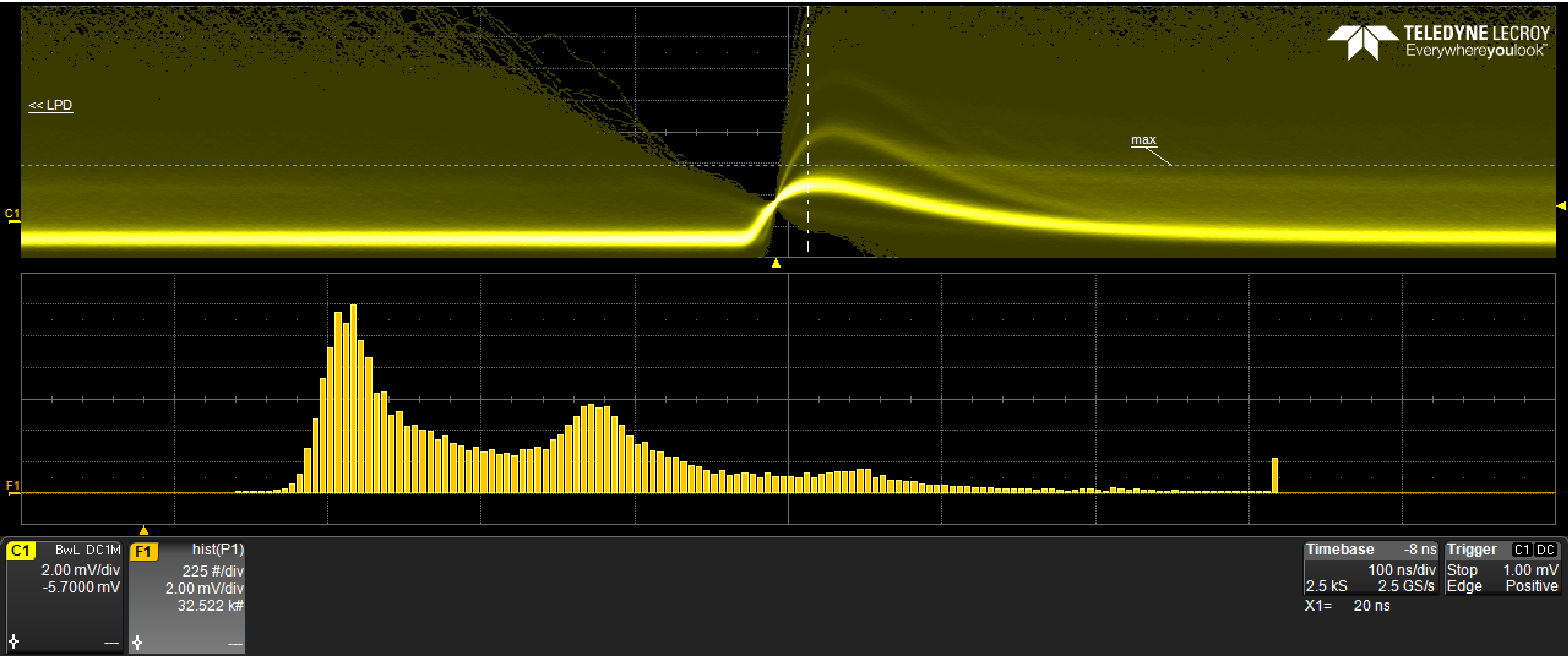
NB The crystal was old and not healthy

GOALS:

- Test the overall experimental setup for future use
- Understand how many keV of X-ray are necessary to detect a scintillation photon in the SiPM sensor

1) Need to see the dark count peaks
2) Need two sources for calibration

Pedestal



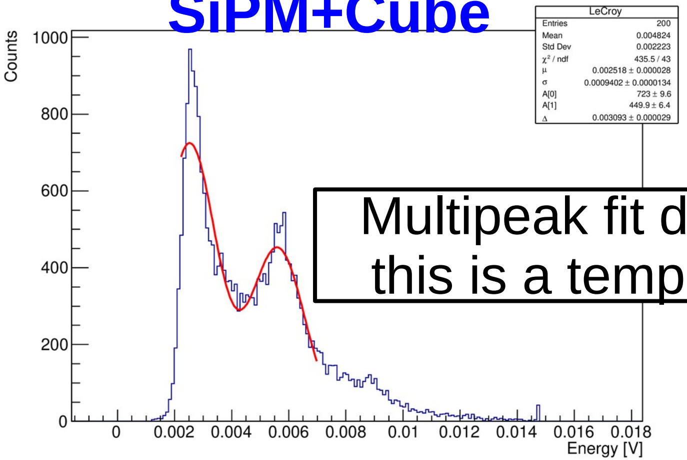
TELEDYNE LECROY
Everywhereyoulook
<< LPD
max
C1
F1
C1 BwL DC1M
2.00 mV/div
-5.7000 mV
F1 hist(P1)
225 #/div
2.00 mV/div
32.522 k#
Timebase -8 ns
100 ns/div
2.5 kS 2.5 GS/s
Trigger C1 DC
Stop 1.00 mV
Edge Positive
X1= 20 ns

Pedestal

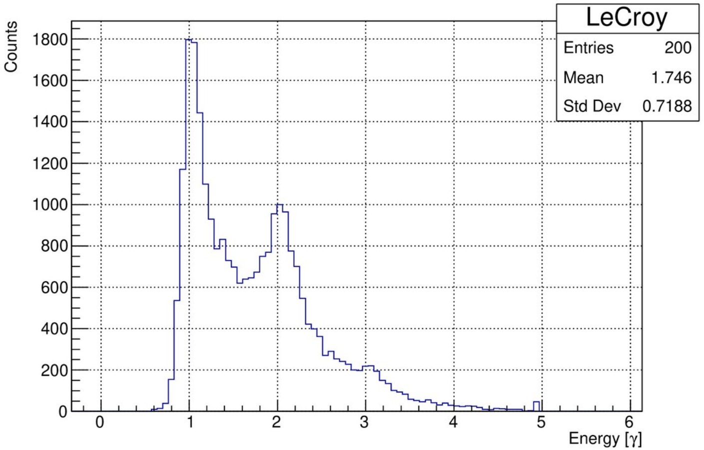
$$S[photon] = \frac{S[mV] - b}{a} + 1$$

$a = \Delta$ $b = \mu$

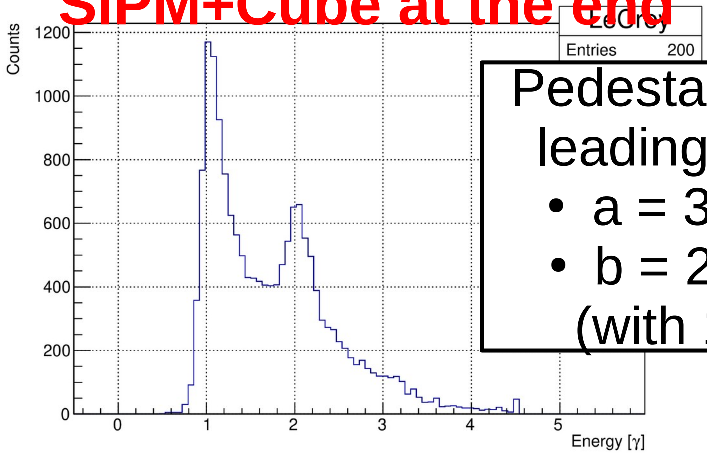
SiPM+Cube



Multipeak fit does not work well, this is a temporary workaround



SiPM+Cube at the end

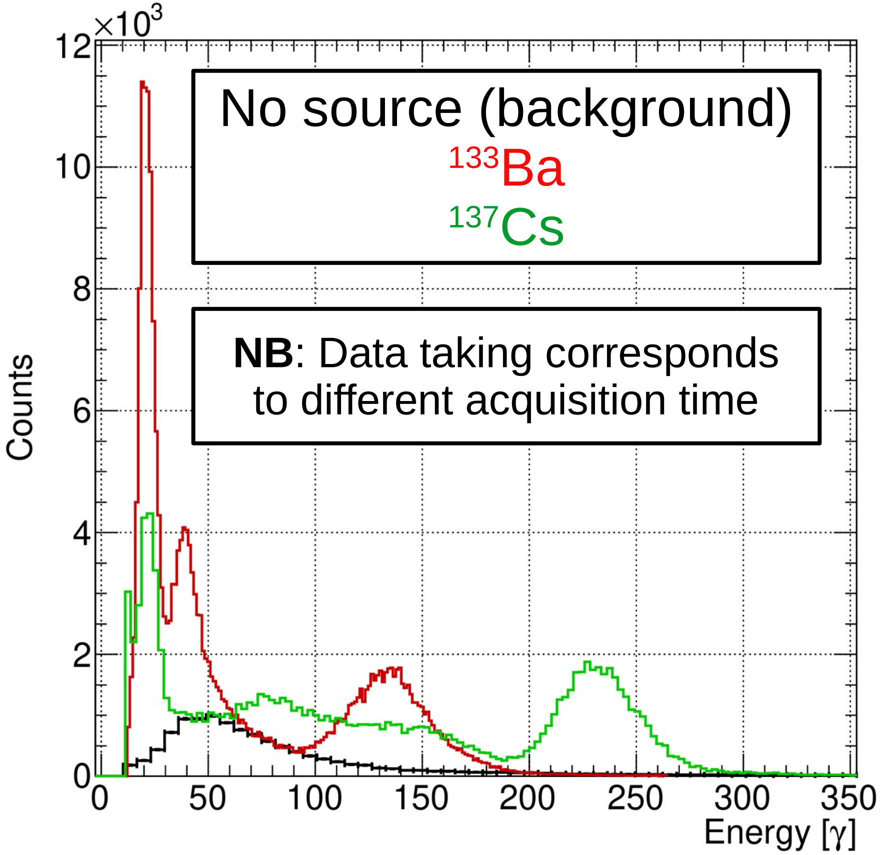


Pedestal fit with cube is stable, leading to these parameters:

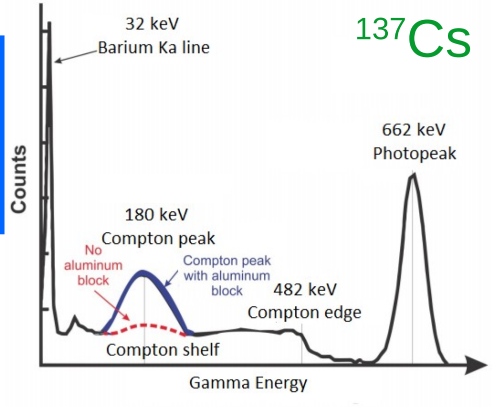
- $a = 3.093_{-43}^{+153}$ mV/photon
- $b = 2.518_{-??}^{+151}$ mV [offset]

(with 1-5% fit uncertainty)

Radioactive sources [#photon]



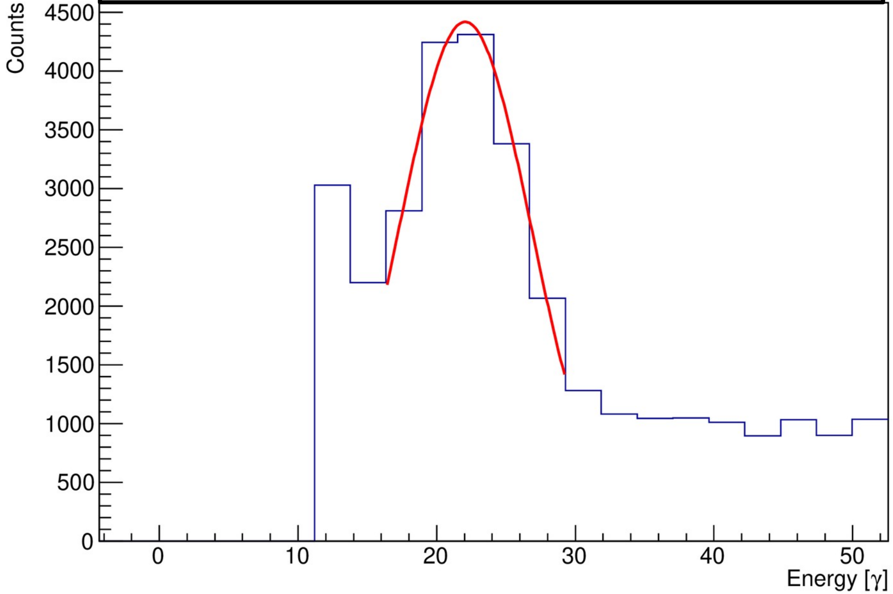
Energy scale calibration



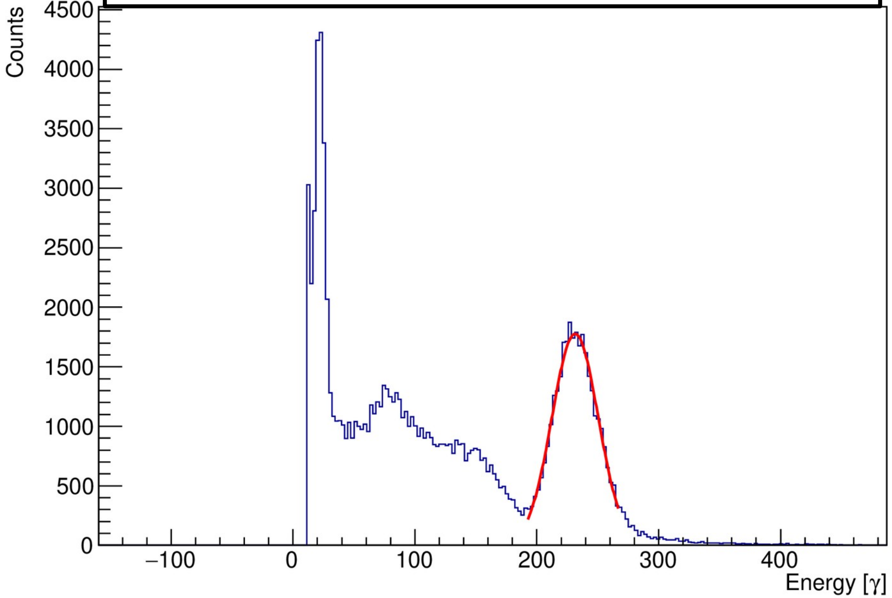
$$S[keV] = S[photon] * c + d$$

c = 3.0071023 keV / photon
d = -34.263650 keV

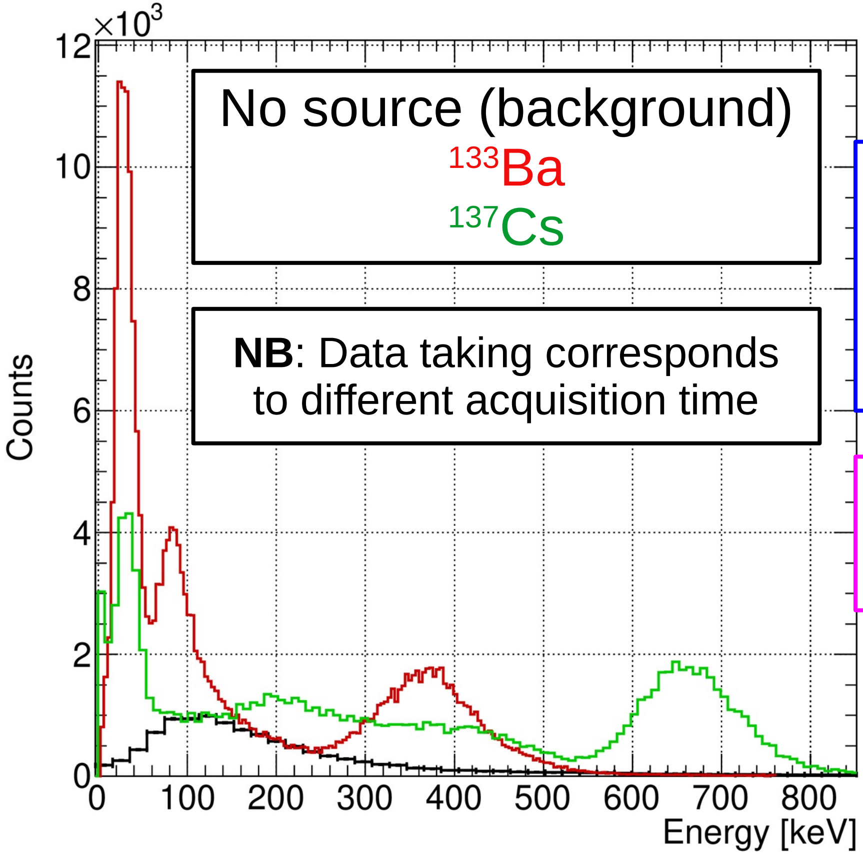
32.061 keV → 22.056 photons



661.655 keV → 231.425 photons



Radioactive sources [keV]



Once we calibrate with ^{137}Cs photoelectric peaks, ^{133}Ba photoelectric peaks have reasonable energies

^{137}Cs Compton structures are not well reproduced

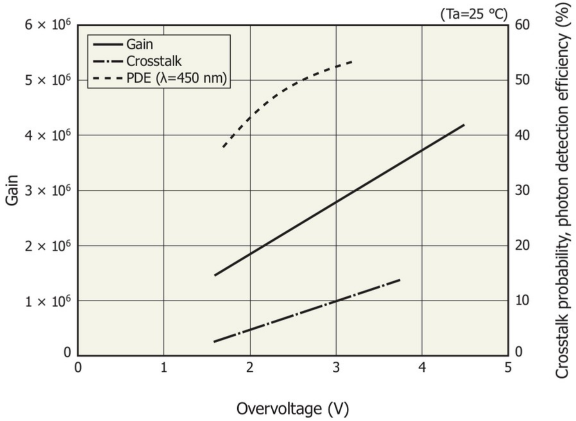
Dark count pile-up

$S[keV] = S[photon] * c + d$

From a simple estimation:

- Current 2.2 µA
- Overvoltage 4 V
- Gain 3.6×10^6 e/p

→ Dark Count = 3.8 MHz



c = 3.0071023 keV / photon
d = -34.263650 keV
→ Dark Count = 11.4
(should we correct for CT?)

A detected dark count pile up of 11.4 photons corresponds to a sampling time of 3 µs, which is larger than expected:

- 2.5 µs sampling after trigger
- 0.5 µs from trigger to maximum

First deposition attempts

Sputtering machine

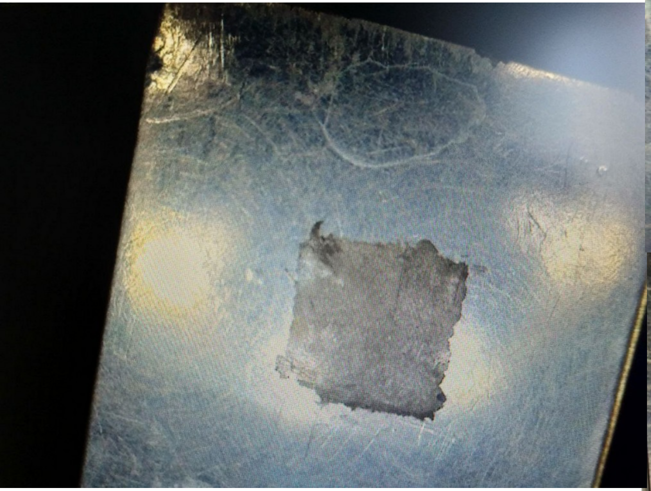
- It must be shared among experiments
- Each deposition requires about **1 day**
- Deposition is homogeneous for ~300 nm
- The sample is fixed using **carbon tape**
- Two depositions per crystal are necessary
- A **small window** must be done for SiPM

NB Deposition made on new crystals cut to 1.8x1.8x0.5 cm^3

GOALS:

- Test the deposition procedure
- Estimate deposition non-homogeneity
- Estimate contamination in deposition
- Understand if dead layers are formed
- Measure the optical parameters

Al



Al deposition works well but:

- There are imperfections near the crystal corner
- Removing the tape does not leave clean edges

Glue SiPM before deposition?

- Clean glue edges?
- Number of SiPM?
- Outgassing?

Ag

Ag deposition works well but it quickly oxidizes/corrodes!

What generate corrosion?

- Need to treat CsI surface?
- Need to passivate Ag?

Non-homogeneity and contamination

Non-homogeneity:
- SEM → Cannot access it!

Contamination:
- RBS → Failed to detect O!

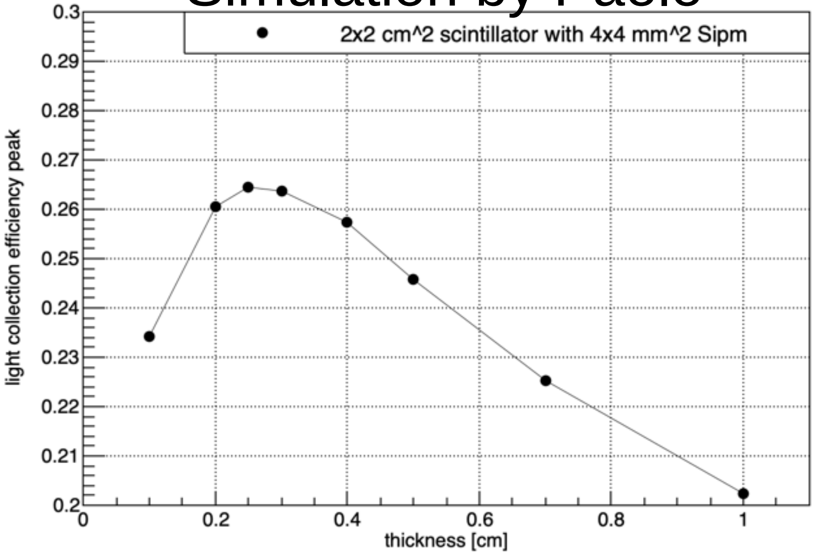
✗ Need of a Al/Ag deposition on a thinner, lighter, O-free substrate layer…

- XPS → No information yet

✗ This techniques works well but only for a few *nm* (incomplete information)

Optical parameters

Simulation by Paolo



Several parameters are necessary to tune the optical simulation:

- CsI self-absorption length
- Al and Ag reflectivity
- Surface roughness

However, it was not possible to measure any of them...

Activity Plan

Desposition

Open Problems

Ag

- Understand the origin of corrosion
  - Study a solution for this effect

Al and Ag

- Study a solution for crystal corner and SiPM edge imperfections
  - Fix the SiPM gluing and LEMO soldering procedure on crystal
  - Find a way to get contamination and non-homogeneity in metal

TO DO: Deposition

Al

- Estimate how collection efficiency changes with deposition depth

Interaction with crystals

- Understand if deposition changes crystal surface to become passive

Mechanics

- Implement a soft mechanics to test just one channel with source

Crystal and SiPM

TO DO: Crystals

CsI(Tl) and **GAGG(Ce)**

- Compare collection efficiency (and rise time) of the two crystals
- Measure how collection efficiency changes with surface polishing
- For **GAGG(Ce)**, measure light yield change at low temperatures

I hope that order will be completed in a few weeks...

TO DO: SiPM

- Compare collection efficiency with different SiPM by Hamamatsu
- Measure how collection efficiency changes with overvoltage
- Study a system to stabilize operating point vs temperature

We have already received new SiPM by Hamamatsu

Prototype (far future)

Idea: Prototype

- Build a small prototype (5-10 channels) to be tested [LABEC?]

TO DO: Prototype

- Build a simple mechanics compliant with fragility of Al/Ag
- Study/Buy electronics for front-end and data acquistion

Back Up

^{137}Cs

	Energy (keV)	Photons (per 100 disint.)
$\gamma_{1,0}$(Ba)	283,46 (7)	0,0006 (1)
$\gamma_{2,1}$(Ba)	378,20 (7)	0,0000106 (9)
$\gamma_{2,0}$(Ba)	661,655 (3)	85,01 (20)

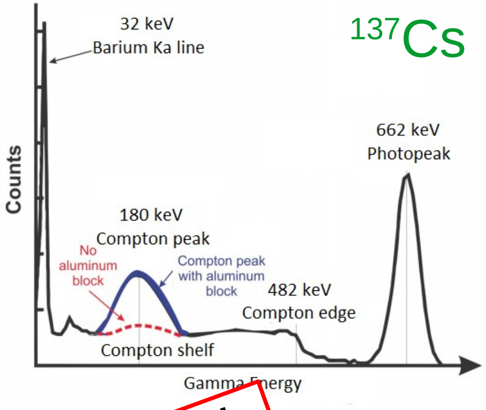
		Energy (keV)	Photons (per 100 disint.)	
XL	(Ba)	3,9544 - 5,8104	0,919 (16)	
$XK\alpha_2$	(Ba)	31,8174	1,99 (4)	} $K\alpha$
$XK\alpha_1$	(Ba)	32,1939	3,66 (6)	
$XK\beta_3$	(Ba)	36,3045	} 1,078 (20)	$K'\beta_1$
$XK\beta_1$	(Ba)	36,3786		
$XK\beta_5''$	(Ba)	36,654		
$XK\beta_2$	(Ba)	37,258	} 0,272 (8)	$K'\beta_2$
$XK\beta_4$	(Ba)	37,312		
$XKO_{2,3}$	(Ba)	37,425		

^{133}Ba

		Energy (keV)	Photons (per 100 disint.)	
XL	(Cs)	3,7946 - 5,5525	15,87 (26)	
$XK\alpha_2$	(Cs)	30,6254	33,8 (4)	$K\alpha$
$XK\alpha_1$	(Cs)	30,9731	62,4 (7)	
$XK\beta_3$	(Cs)	34,9197	18,24 (29)	$K'\beta_1$
$XK\beta_1$	(Cs)	34,9873		
$XK\beta''_5$	(Cs)	35,252		
$XK\beta_2$	(Cs)	35,822	4,45 (12)	$K'\beta_2$
$XK\beta_4$	(Cs)	35,907		
$XKO_{2,3}$	(Cs)	35,972		

	Energy (keV)	Photons (per 100 disint.)
$\gamma_{4,3}$(Cs)	53,1622 (18)	2,14 (6)
$\gamma_{2,1}$(Cs)	79,6142 (19)	2,63 (19)
$\gamma_{1,0}$(Cs)	80,9979 (11)	33,31 (30)
$\gamma_{2,0}$(Cs)	160,6121 (16)	0,638 (6)
$\gamma_{3,2}$(Cs)	223,2368 (13)	0,450 (5)
$\gamma_{4,2}$(Cs)	276,3989 (12)	7,13 (6)
$\gamma_{3,1}$(Cs)	302,8508 (5)	18,31 (11)
$\gamma_{4,1}$(Cs)	356,0129 (7)	62,05 (19)
$\gamma_{3,0}$(Cs)	383,8485 (12)	8,94 (6)

Model II
Validation



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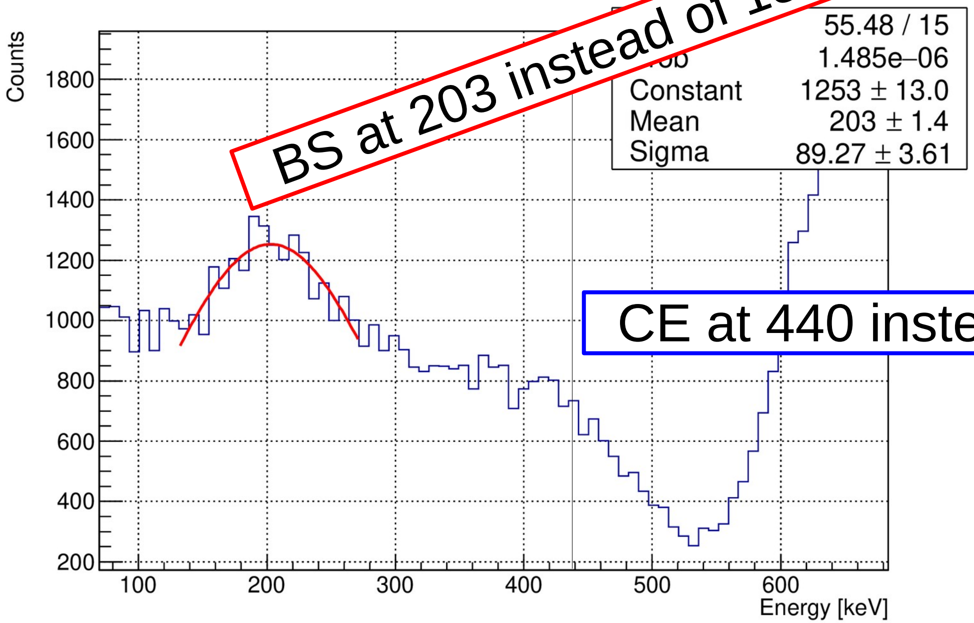
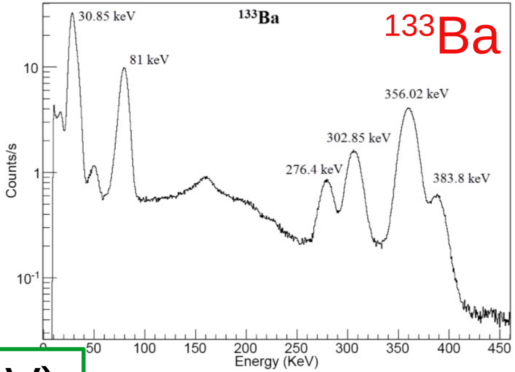


BS at 203 instead of 180 keV!

CE at 440 instead of 482 keV!

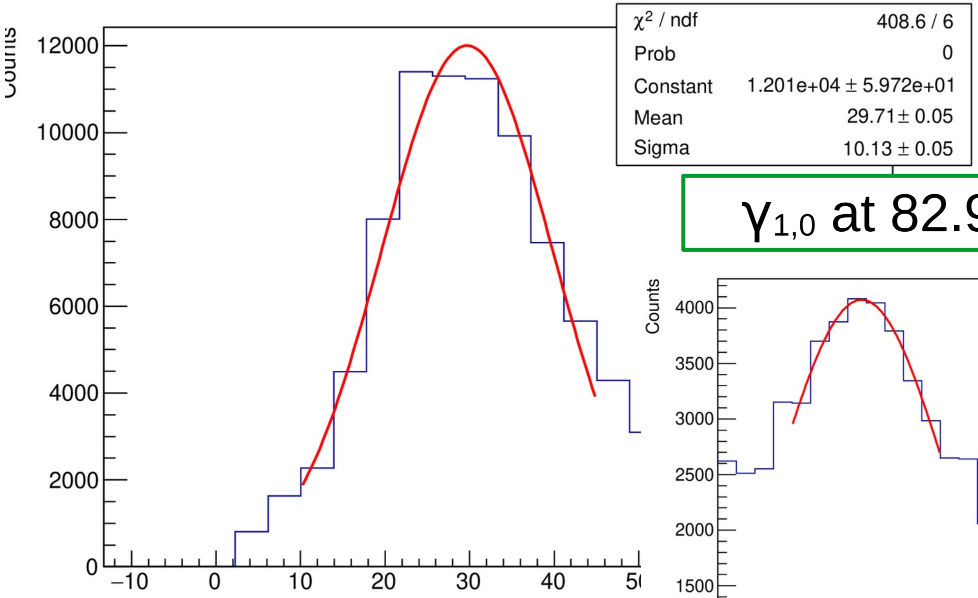
...geometric effect?

Model II
Validation

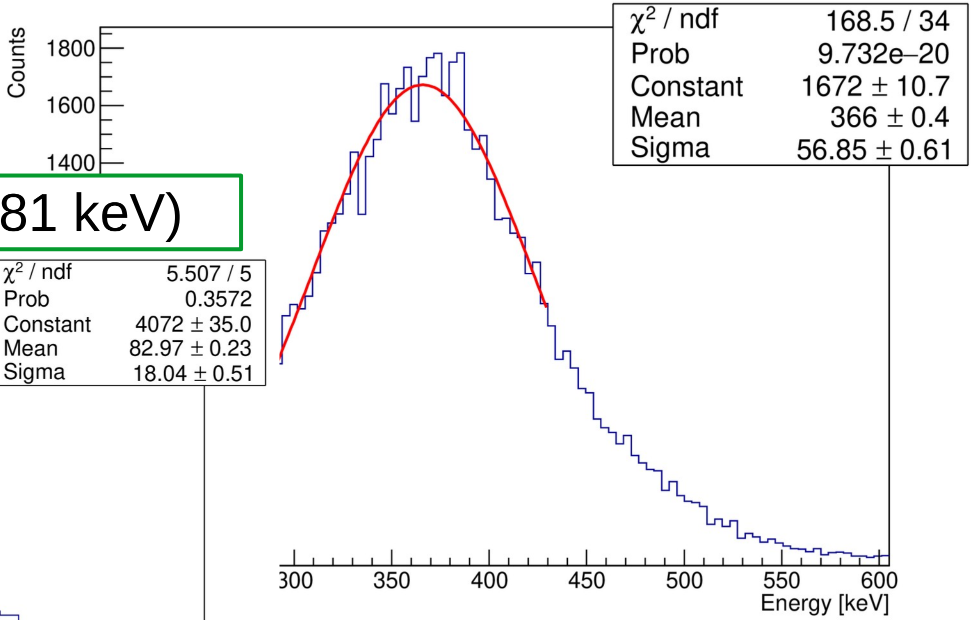


$$S[keV] = S[photon] * c + d$$

Kα at 29.71 (vs 30.85 keV)



$\gamma_{3.0}*\gamma_{4.1}$ at 366 (vs 359 keV)



$\gamma_{1,0}$ at 82.97 (vs 81 keV)