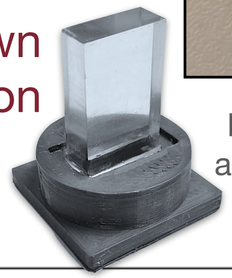
A new nuclear imaging detection technology for total body, flexible and fast SPECT diagnoses

G. Battistoni, A. De Gregorio, G. De Vincentis, Y. Dong, V. Frantellizzi, G. Franciosini, M. Garbini, N. Krah, M. Magi, M. Marafini, I. Mattei, L. Mattiello, R. Mirabelli, S. Muraro, A. Muscato, A. Robert, D. Rocco, A. Sarti, A. Schiavi, A. Sciubba, M. Toppi, G. Traini, A. Trigilio, V. Patera

Starting Point

After a long work of R&D we synthesised new organic molecules as fluorophores with very promising performances in terms of timing response and transparency, with concentration up to 30%.

Tests with charged particles (mip, electron and ion beams) shown that we can produce samples that allow to reach a time resolution better than the fast commercial plastic scintillators (EJ232).



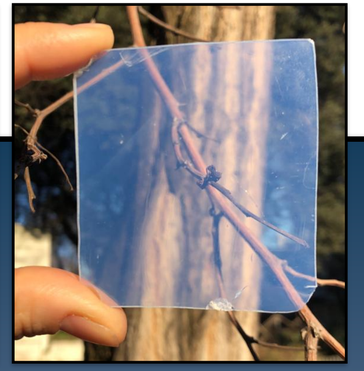
D.Rocco et al., "TOPS fast timing plastic scintillators: Time and light output performances". NIM A 1052 (2023) 168277; doi: https://doi.org/10.1016/j.nima.2023.168277

WaveDAQ doi:10.1016/j.nima.2018.07.067

Measured parameters of interest.

Samples	Primary dopant %	Wavelength Max emission [nm]	Light output % EJ232	Rise-time [ns]	Width [ns]	Time resolution [ps]
EJ-232	–	370	100	2	9	123
EJ-204	–	408	220	2.5	11	211
2N	14	405	118	2	12	81
2T	14	–	245	3	18	97
1N	14	414	157	3	17	102
2B	14	420	160	2.5	14	110

Results obtained with mips

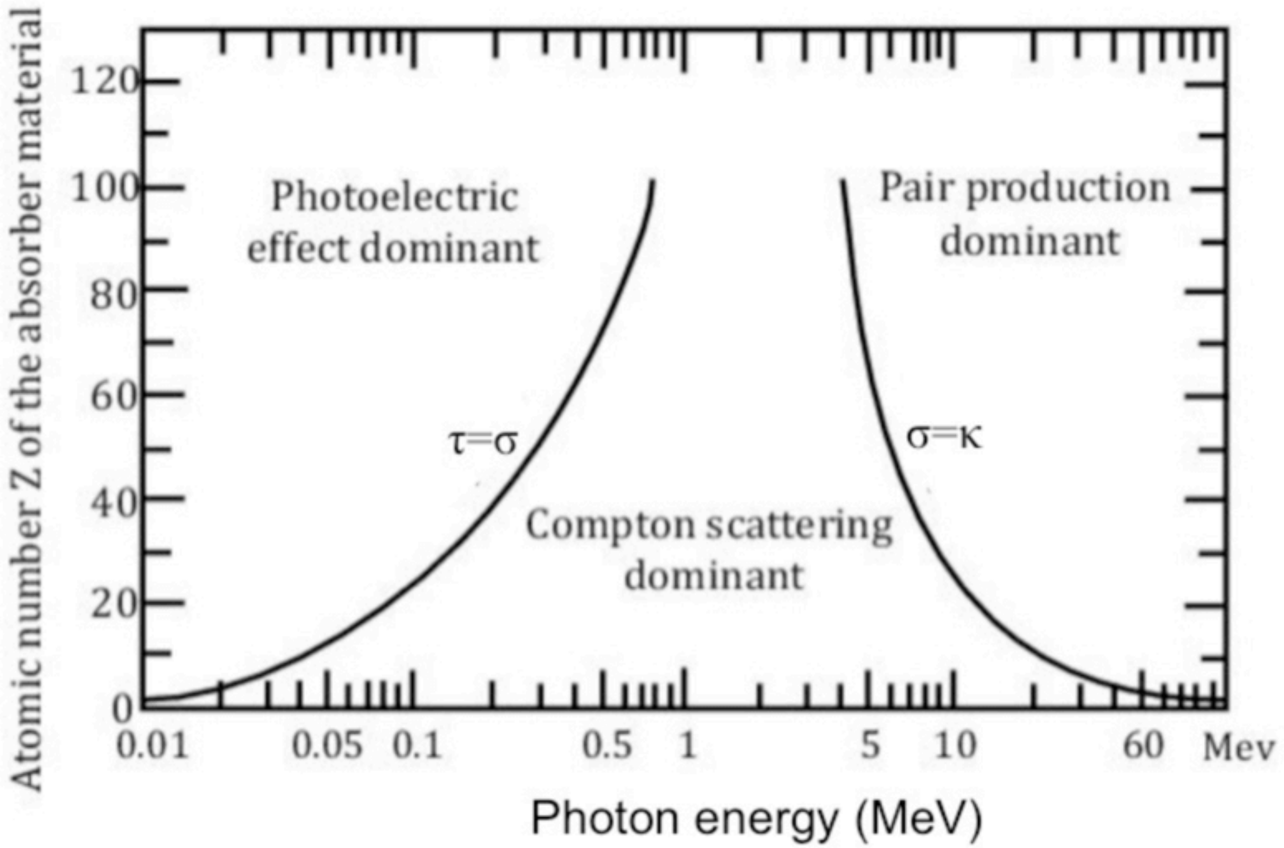


EDIT: 3D plastIc scinTillator

It is also possible to incorporate those new scintillators in the resin material and polymerise the samples by UV. Thin samples are the final target of the study.

Organic Scintillators for Imaging

Photons interactions with matter are defined by their energy and the Z of the absorber material, driving the choice of the detection strategy for each specific application.



There are applications where the interaction mechanism plays a crucial role in the detection technique.

SPECT Imaging

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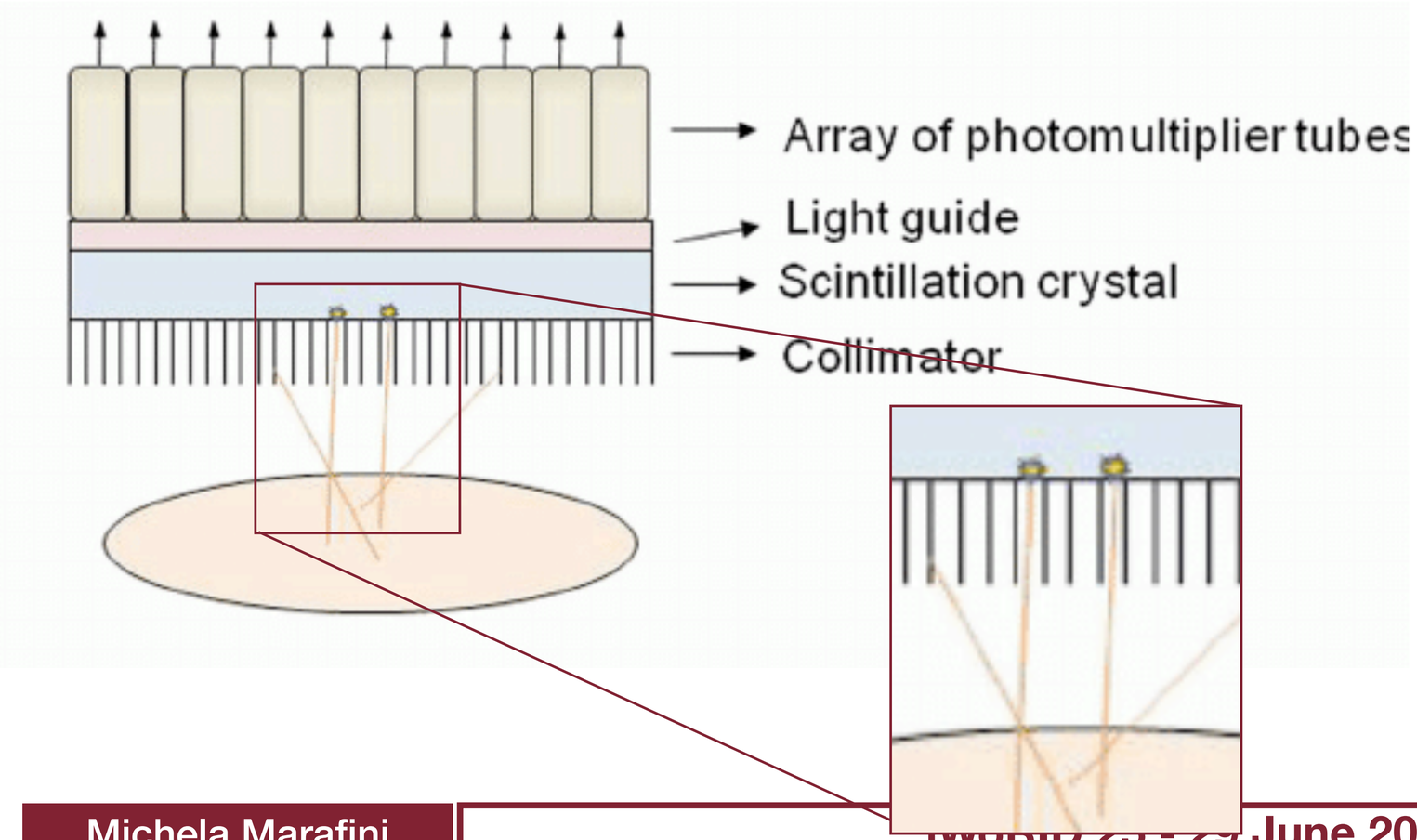

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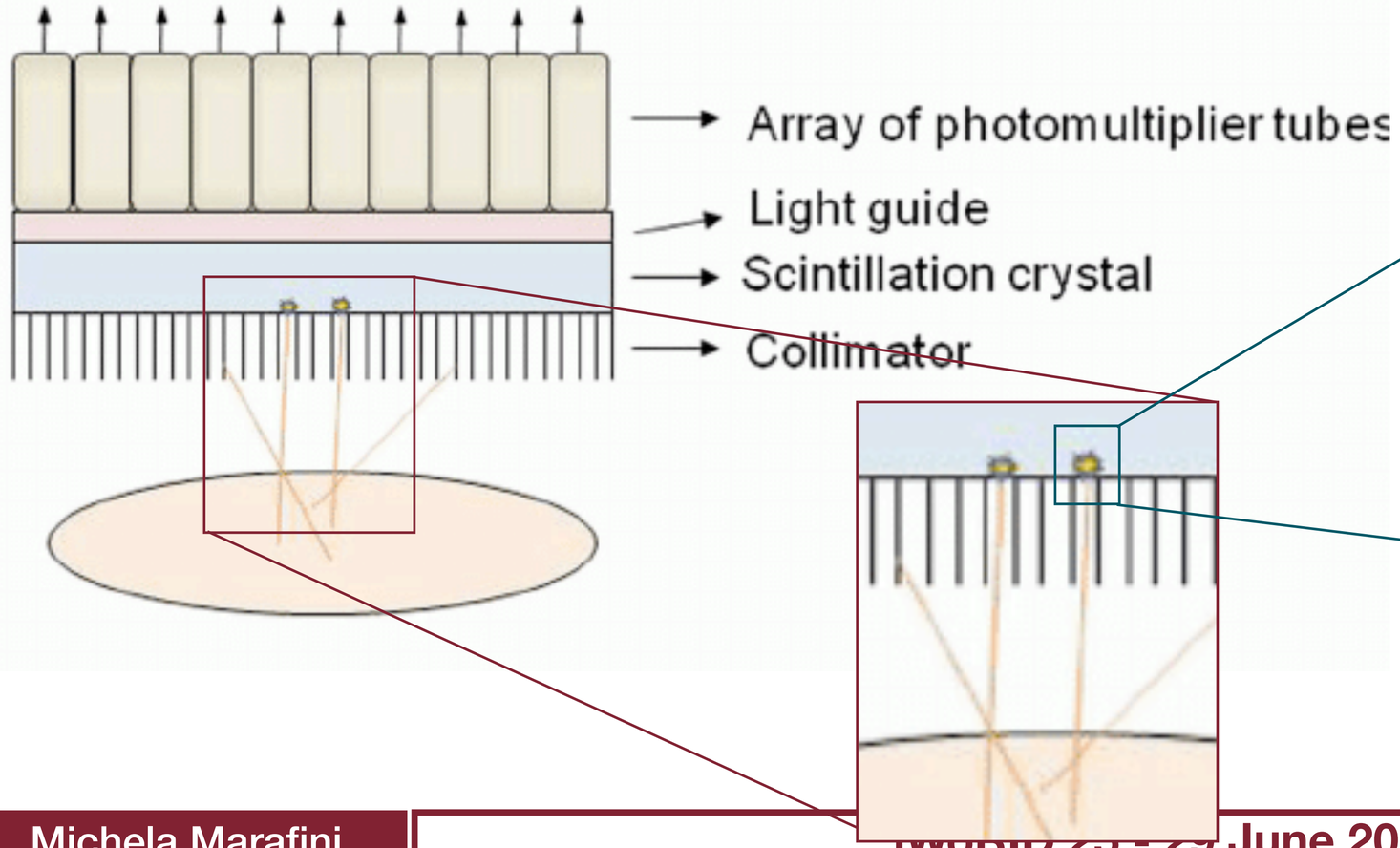

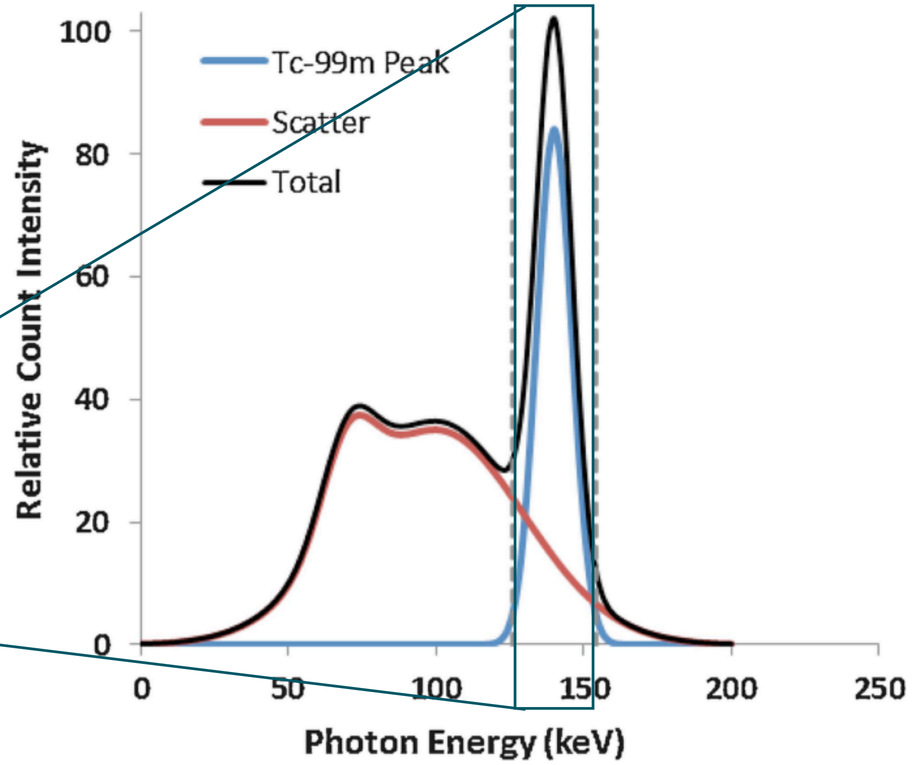

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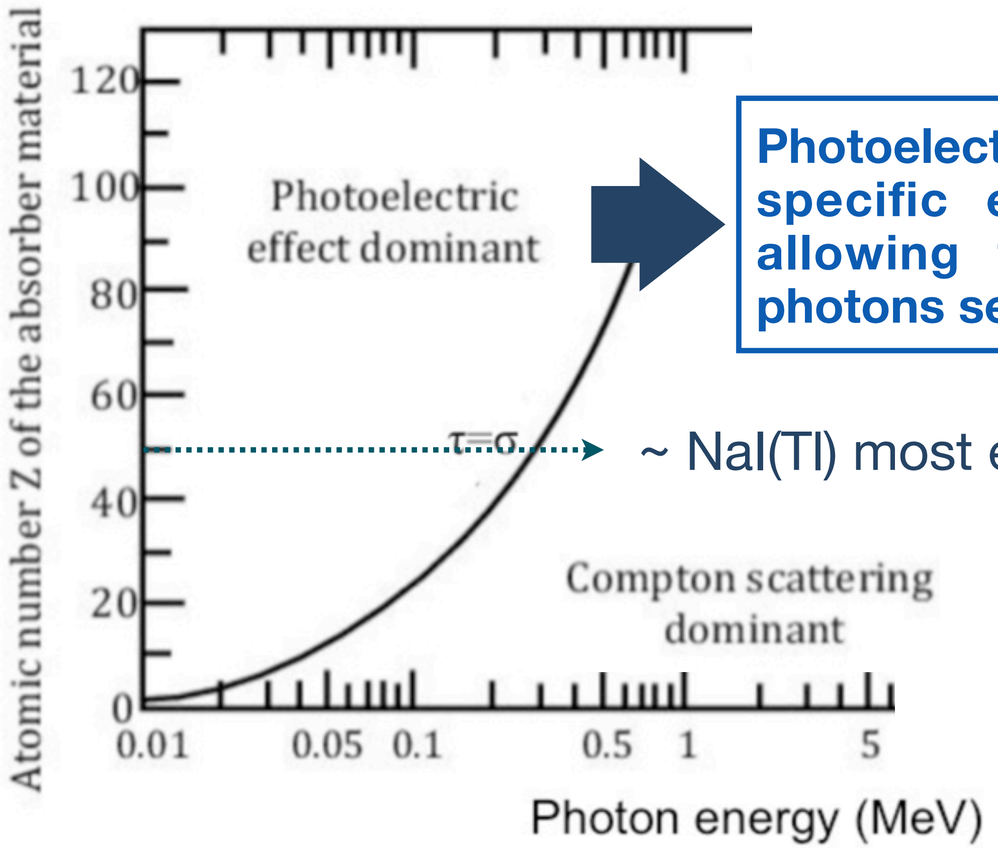
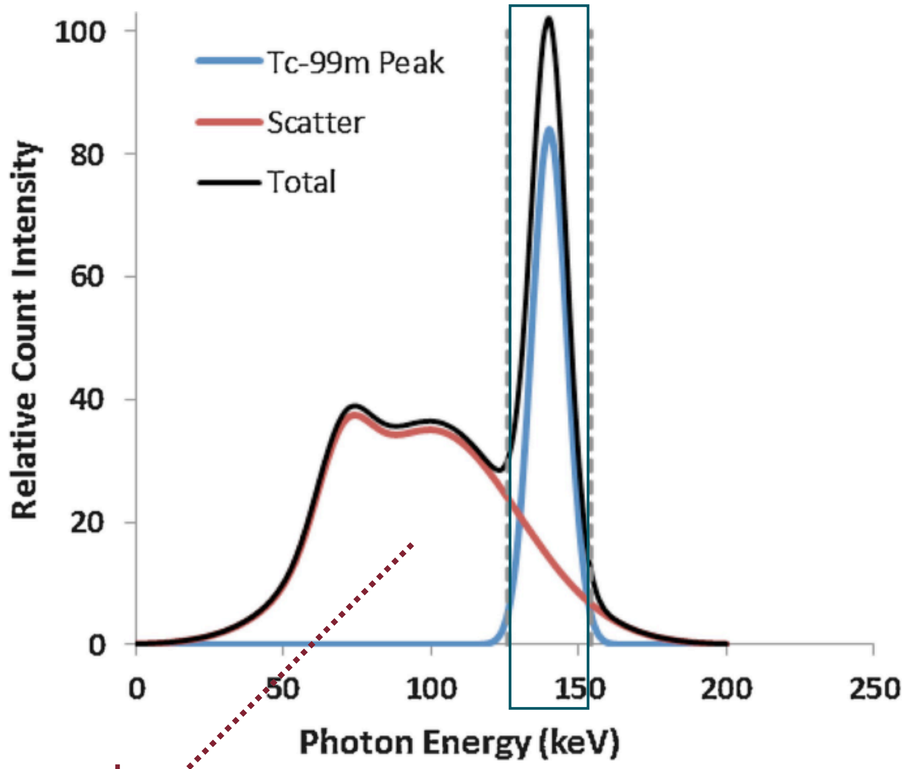


Photoelectric interactions give specific energy depositions allowing for an 'interesting photons selection'.

~ NaI(Tl) most exploited scintillator



Those events are not pointing to the right position.

Organic Scintillators for Imaging

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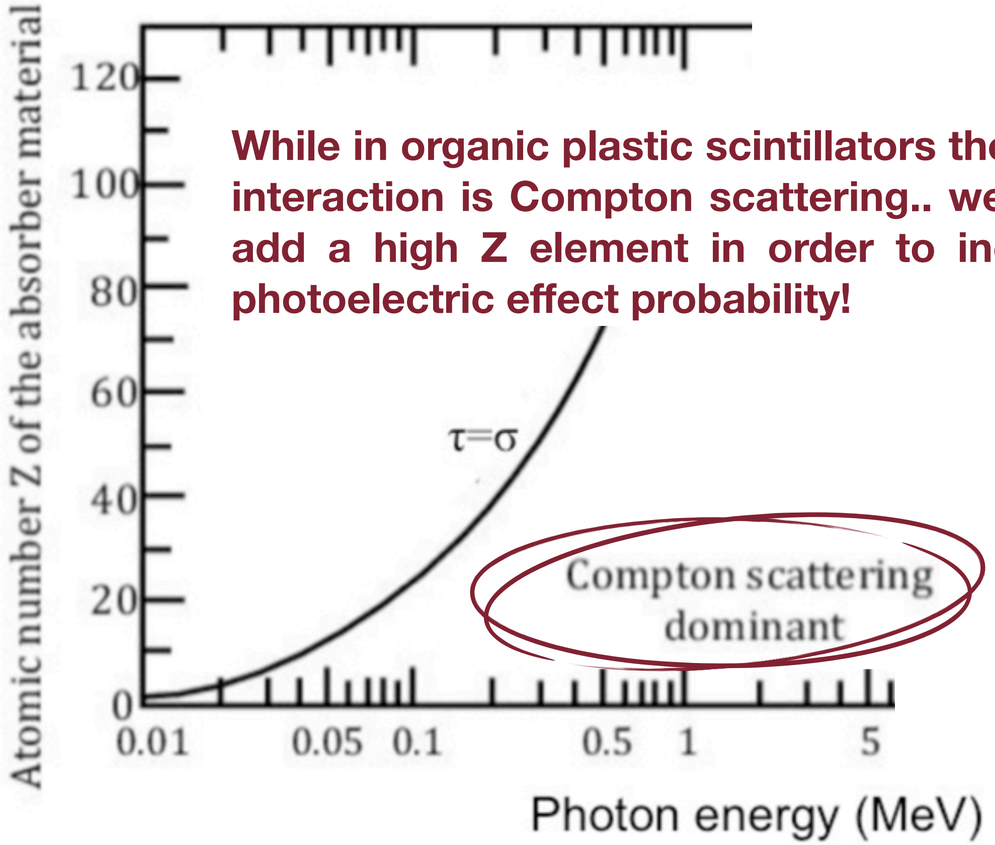
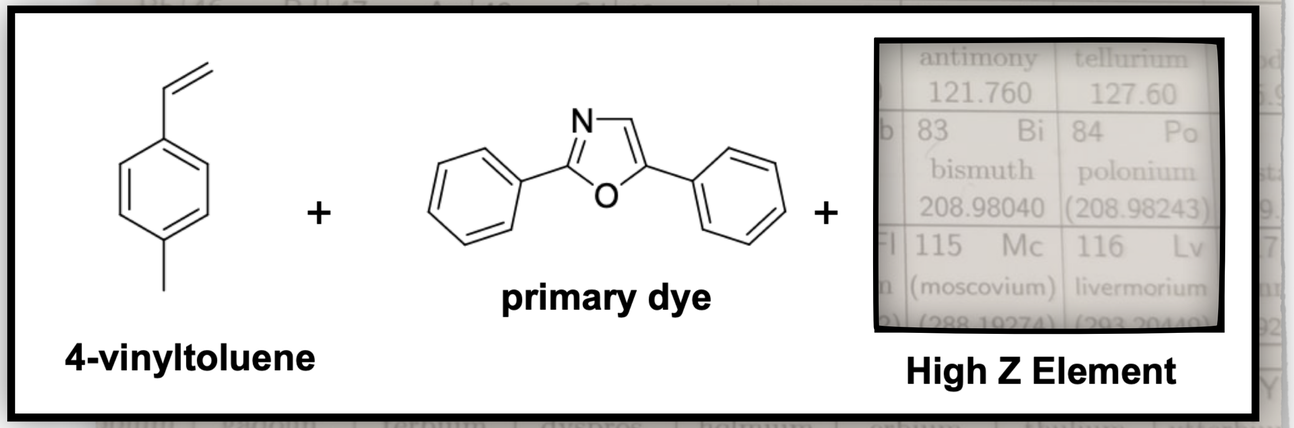


While in organic plastic scintillators the dominant interaction is Compton scattering.. we decide to add a high Z element in order to increase the photoelectric effect probability!



Organic Scintillators for Imaging

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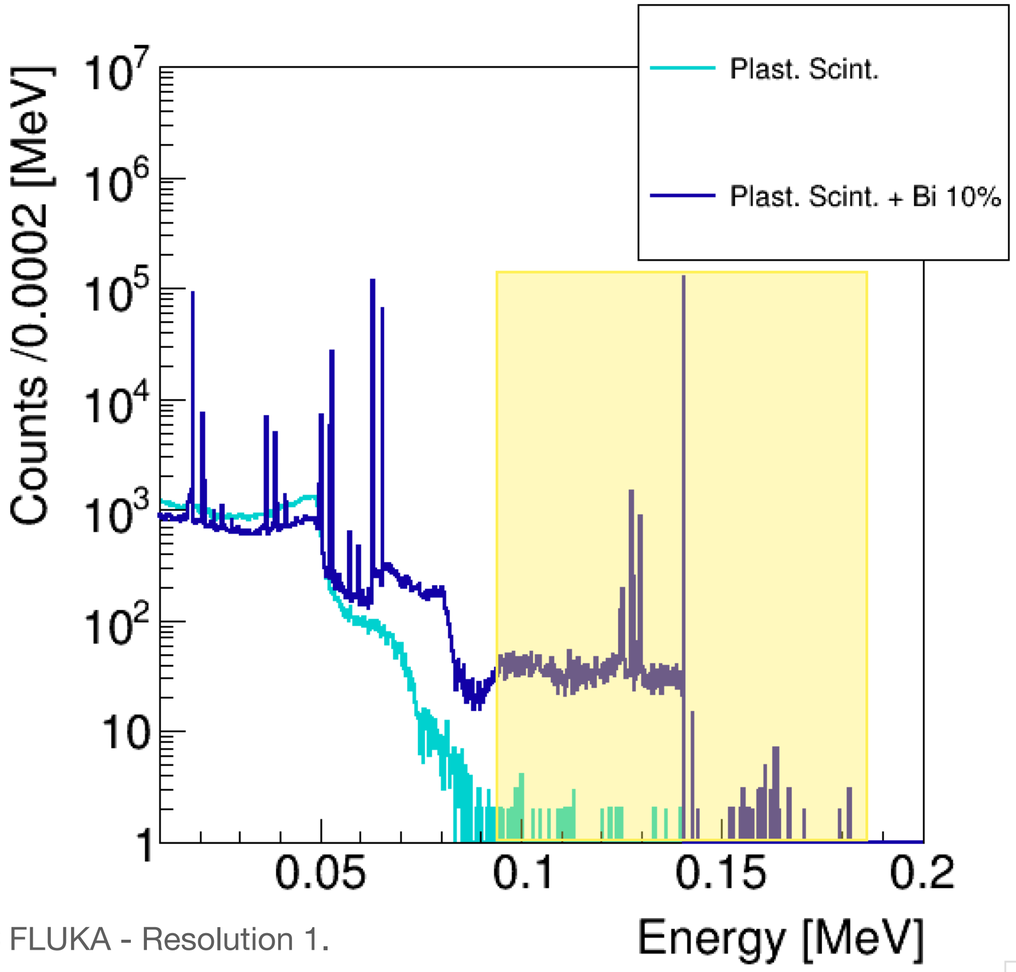
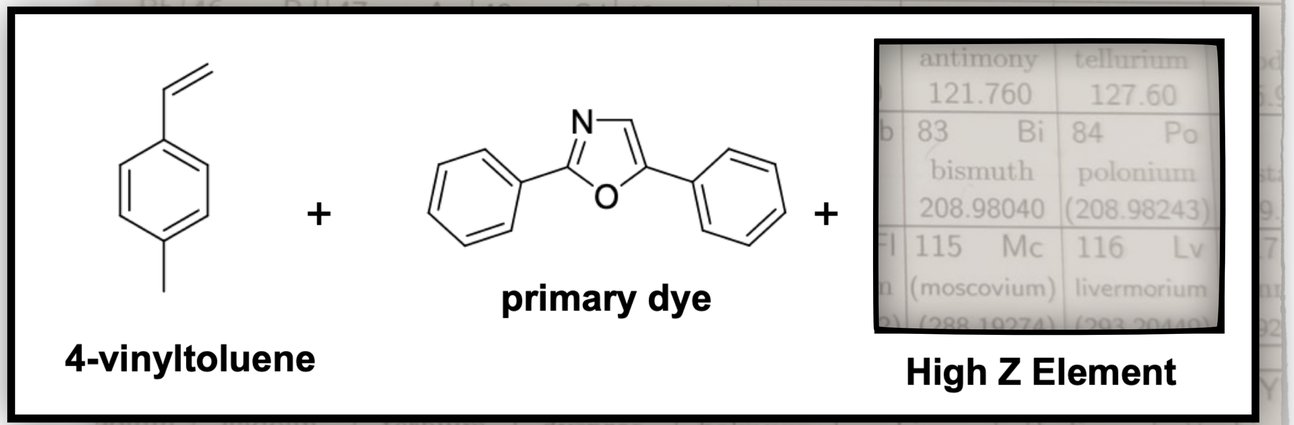


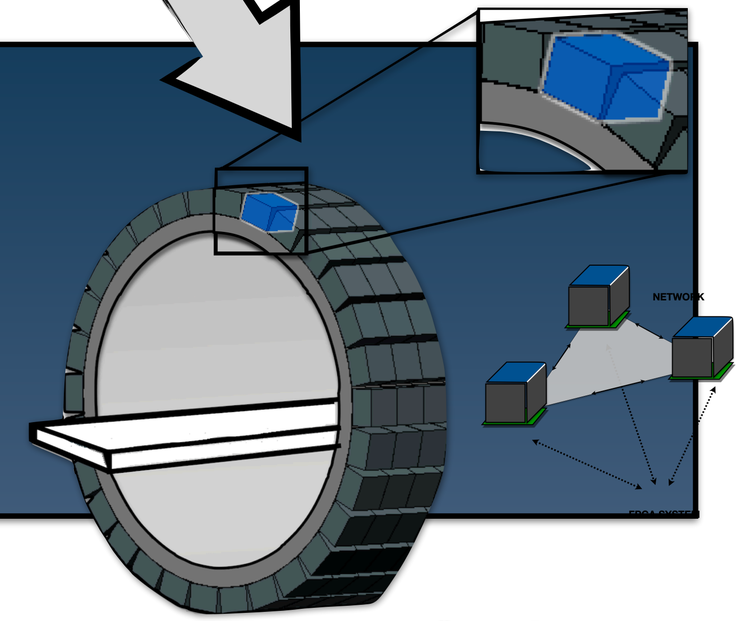
MC FLUKA - Resolution 1.

^{53}I	^{58}Ce	^{64}Gd	**^{68}Er**	^{81}Tl	^{82}Pb	**^{83}Bi**

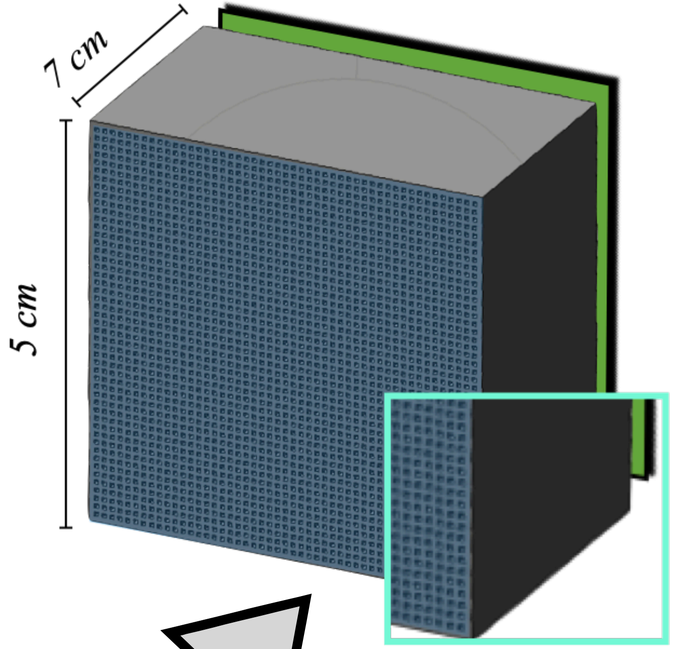


ReSPECT: system geometry concept

1 Modular structure

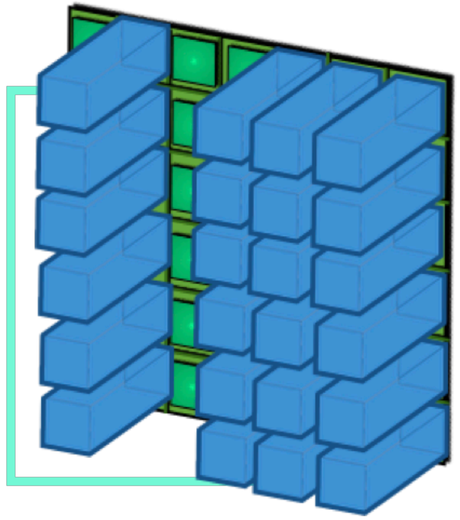


MODULE Side View



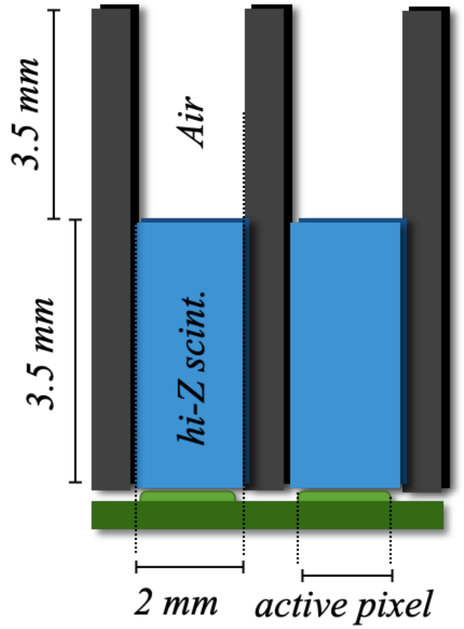
2 Collimator: 3D printed in tungsten

Scintillator Segments



3 Enriched plastic scintillator, polymerisation in the collimator

Scintillator Side View

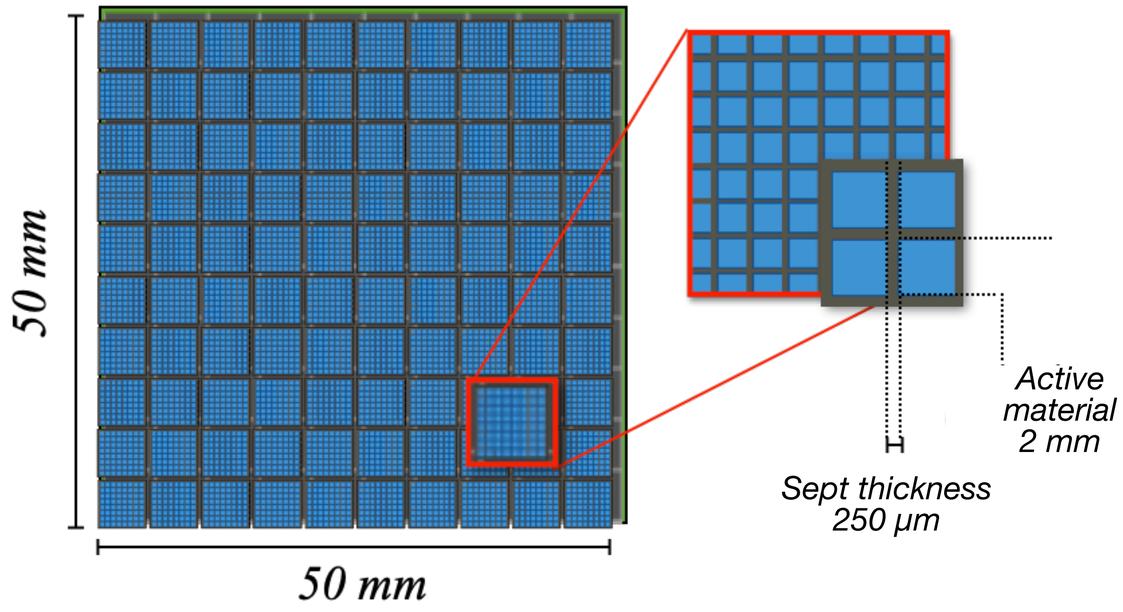


4 Readout segmentation

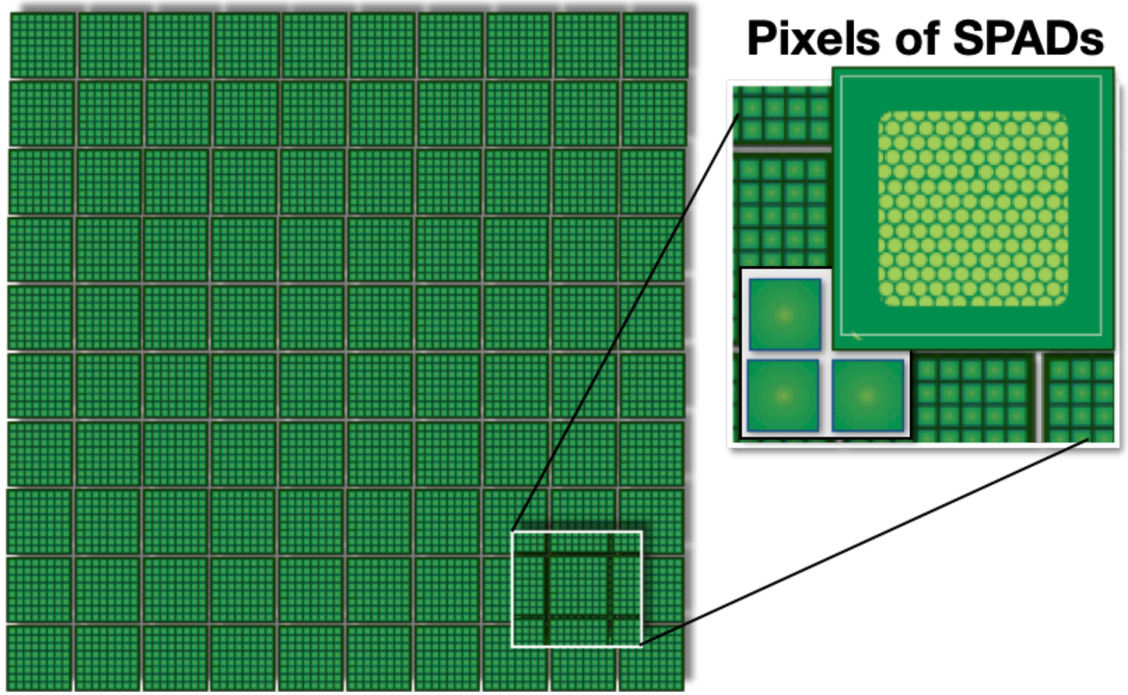
ReSPECT: module geometry

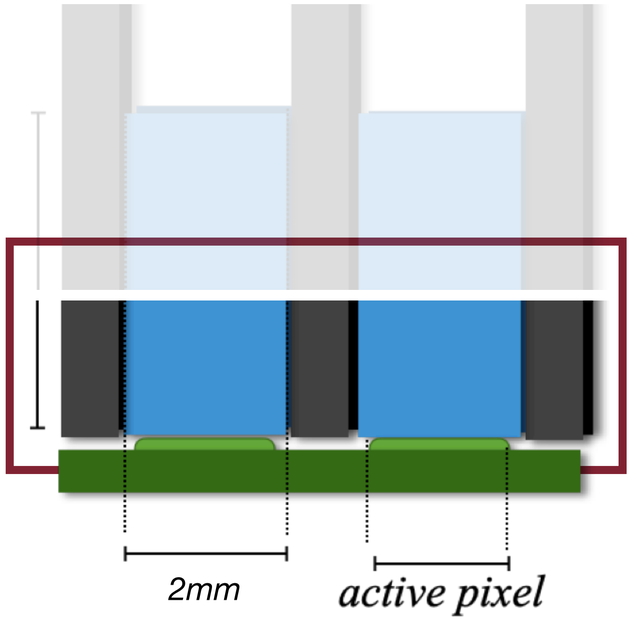
The granularity of the active material is crucial in order to keep a good space resolution the same pixel size has been maintained for the readout.

MODULE Top View



Readout Tile top View



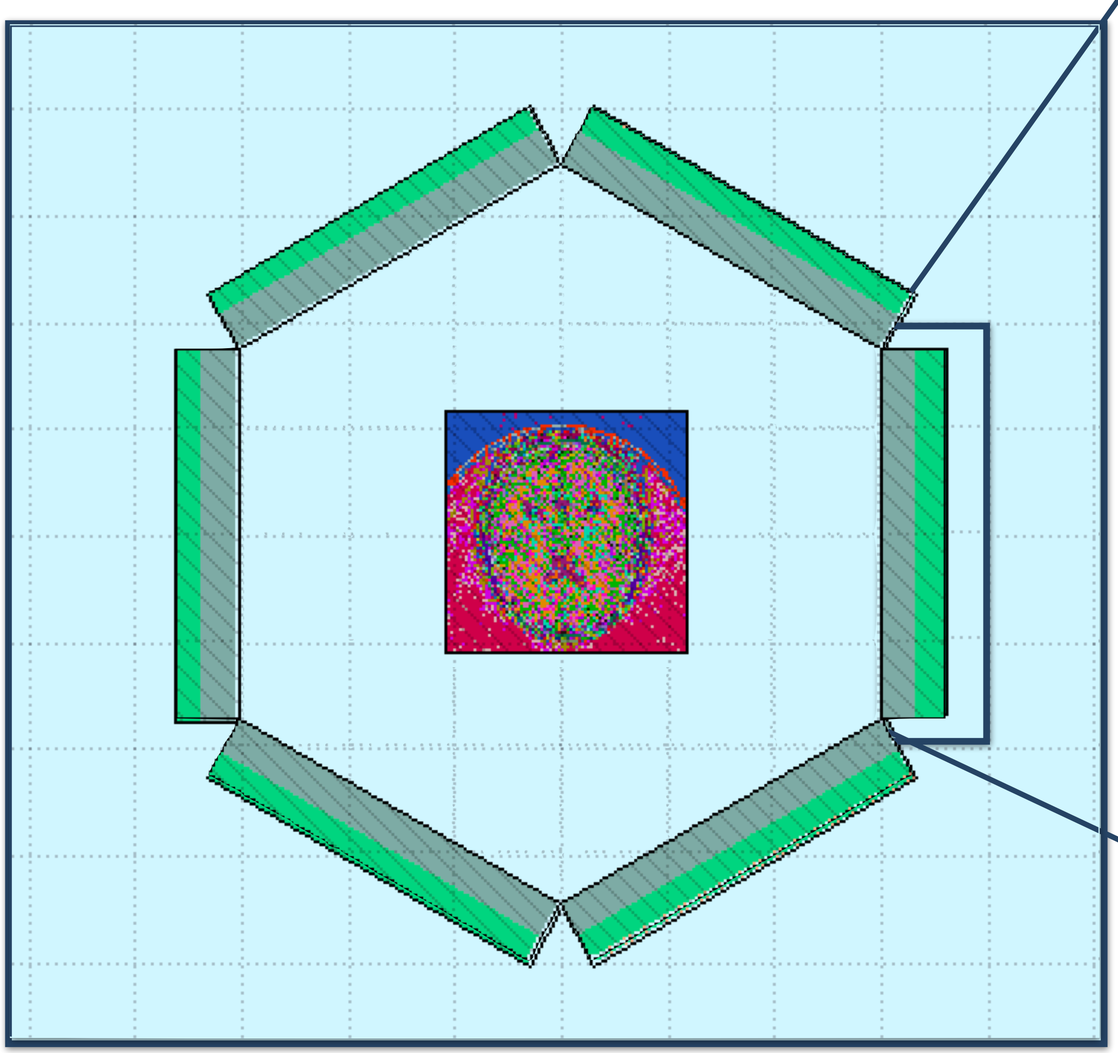


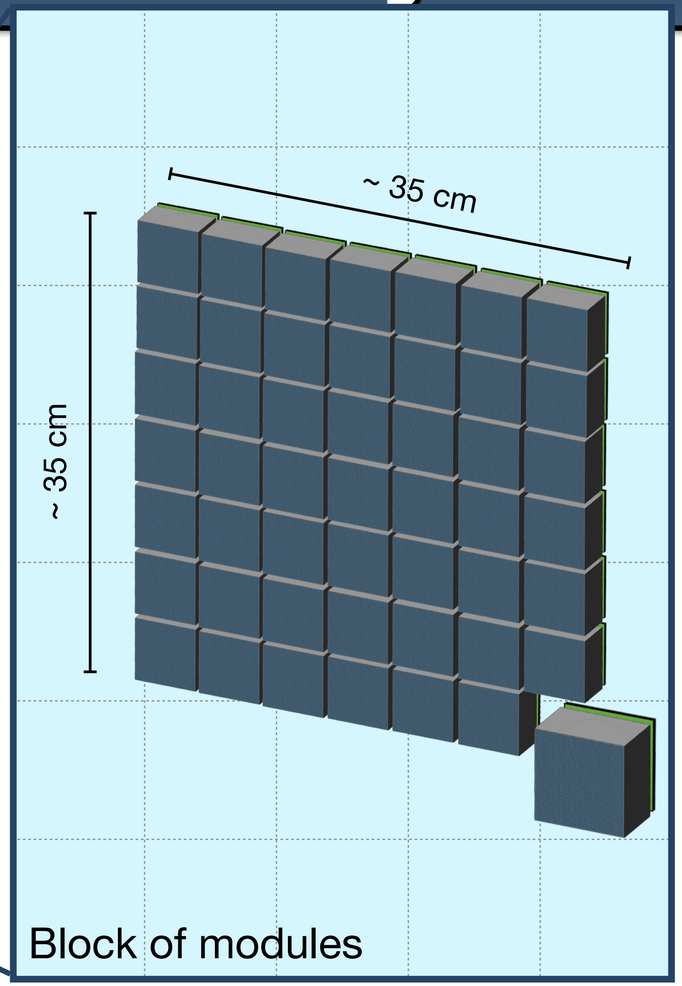
SPAD Based chip

The readout system is under study

ReSPECT simulation study

FLUKA



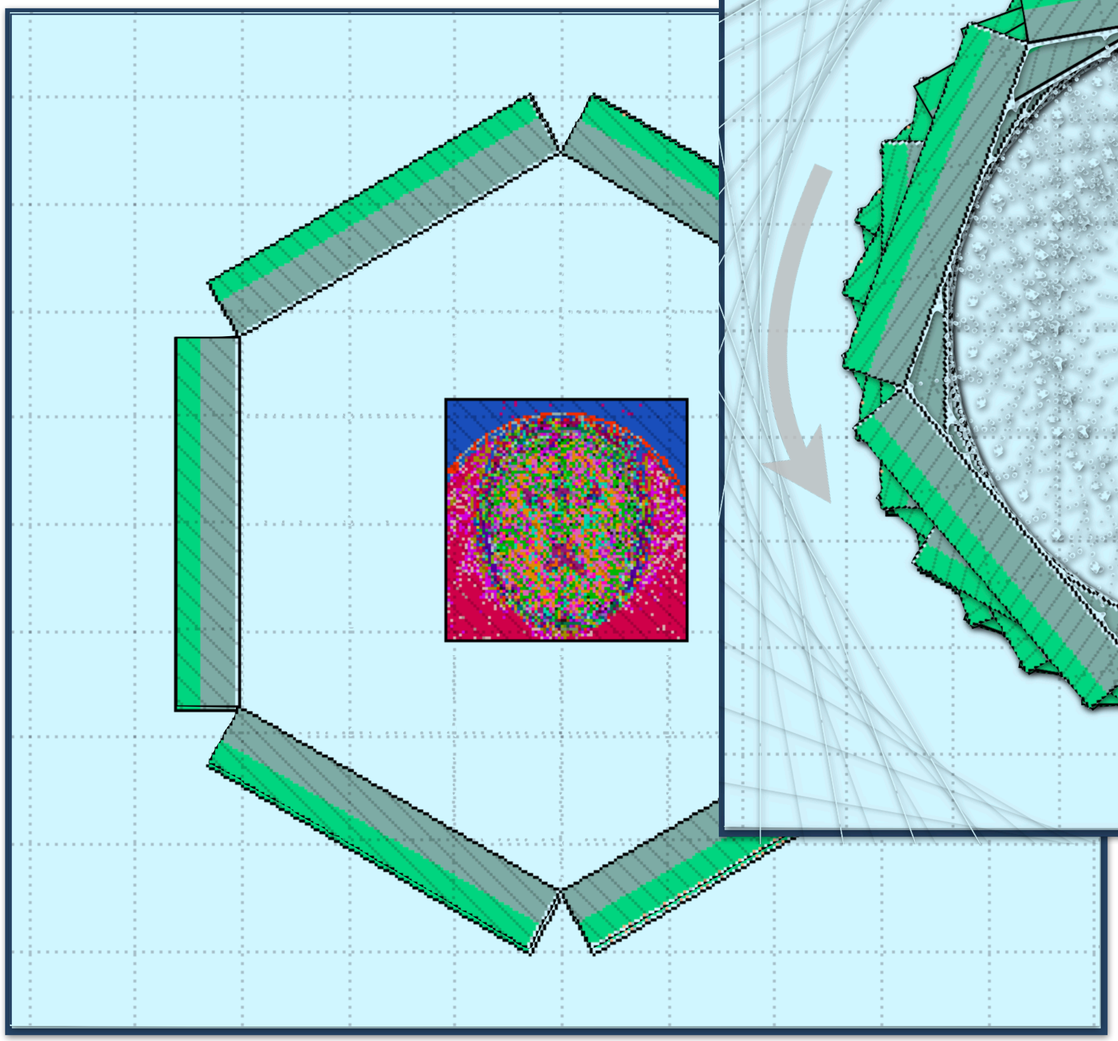


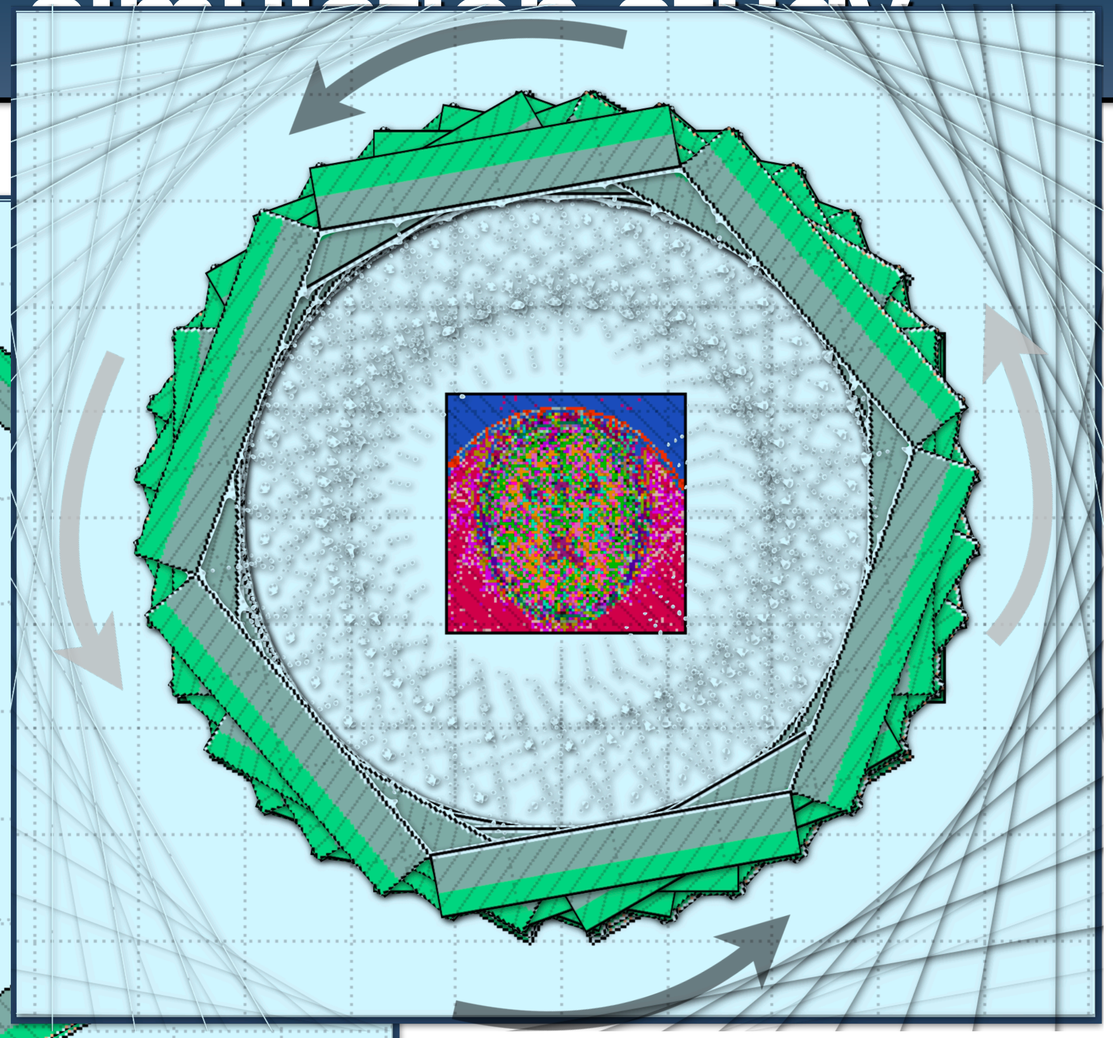
- About 300 Modules organised in blocks
- six blocks

- Collimator in Tungsten, high Z and allows to realise very precise geometry (3D printed)
- The high-Z organic scintillator is simulated with a concentration of 10%

ReSPECT simulation study

FLUKA





- About 300 Modules organised in blocks
- six rotating blocks
- 120 projections => “reconstruction team” in Lyon (FR)

- Collimator in Tungsten, high Z and allows to realise very precise geometry (3D printed)
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ReSPECT simulation study

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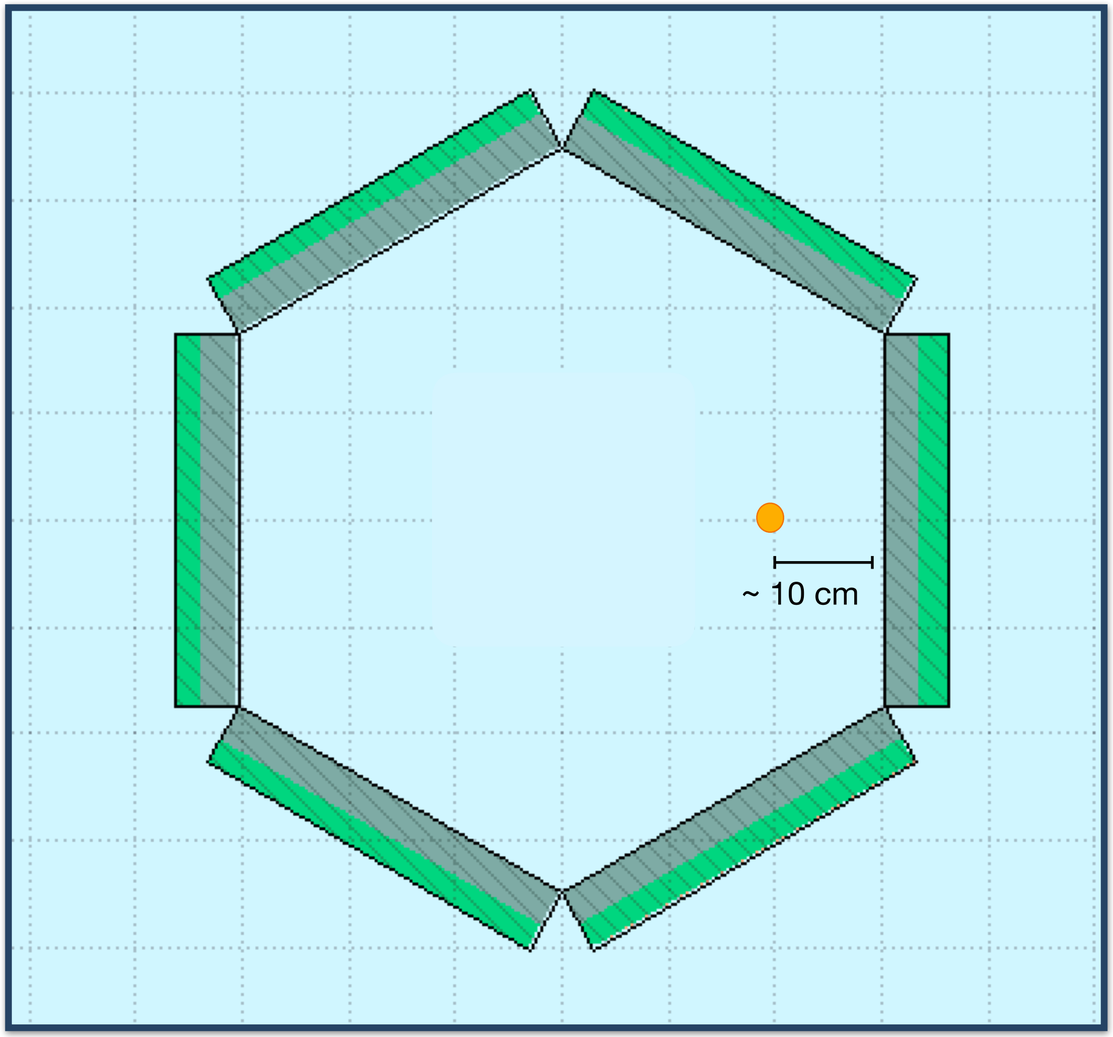
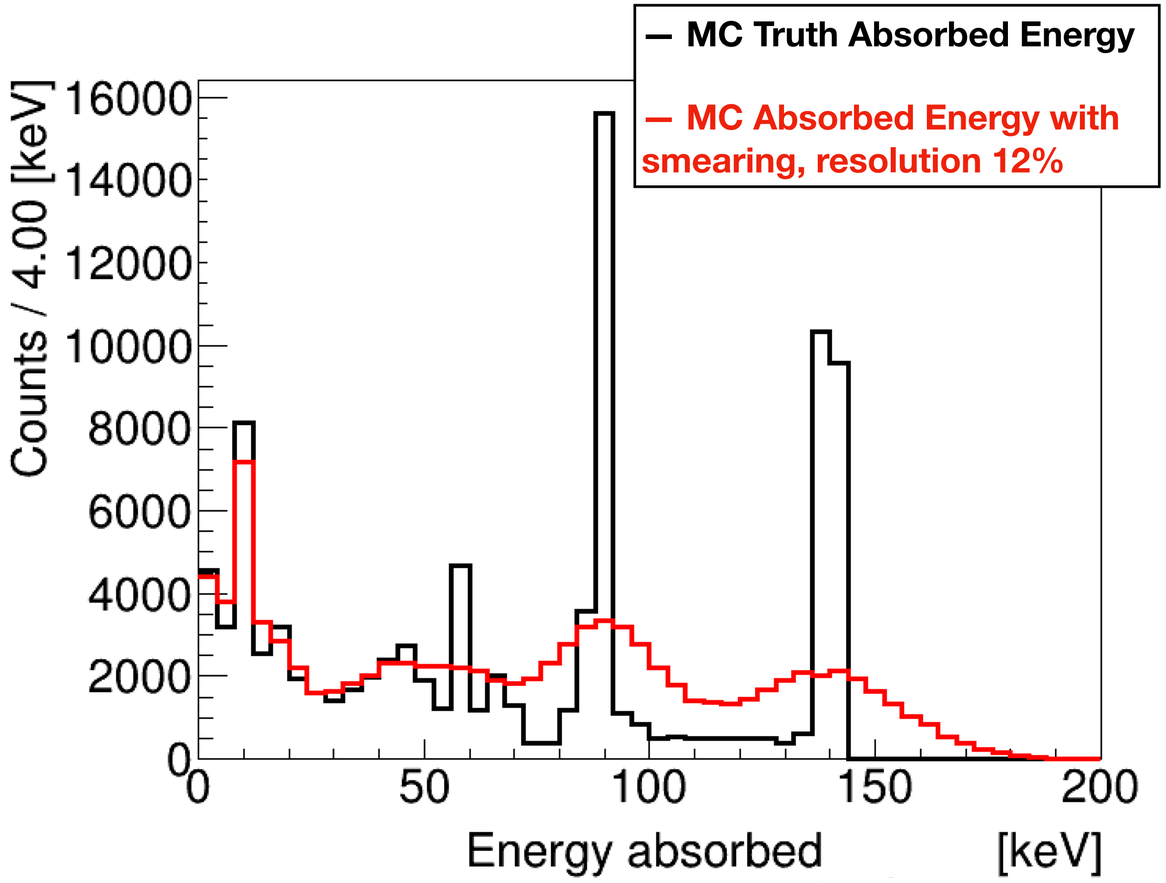


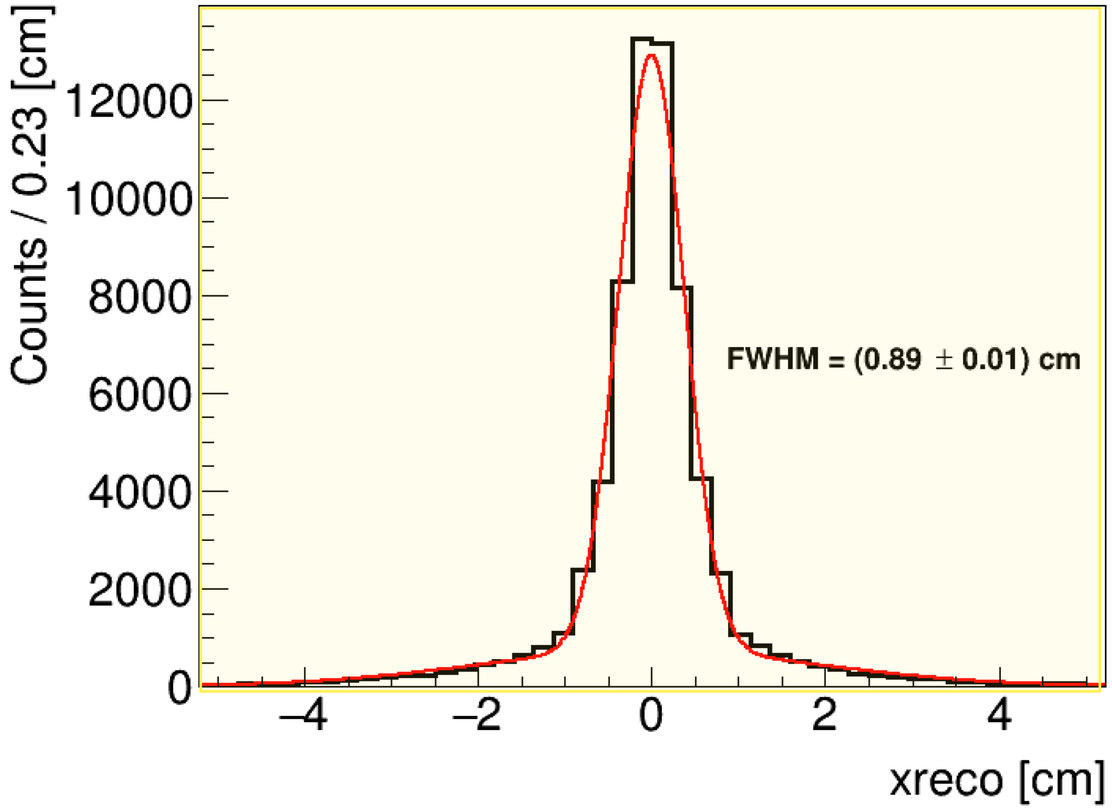
- MC study: a ^{99m}Tc point source at 10 cm
- The absorbed energy in the front module



ReSPECT simulation study

FLUKA

Photons directly coming from the source can be selected applying an energy cut, requiring an energy release consistent with the photoelectric interaction hypothesis. The resolution on the source position that can be obtained, depends on the details of the chosen geometry (pixel size, collimator length).



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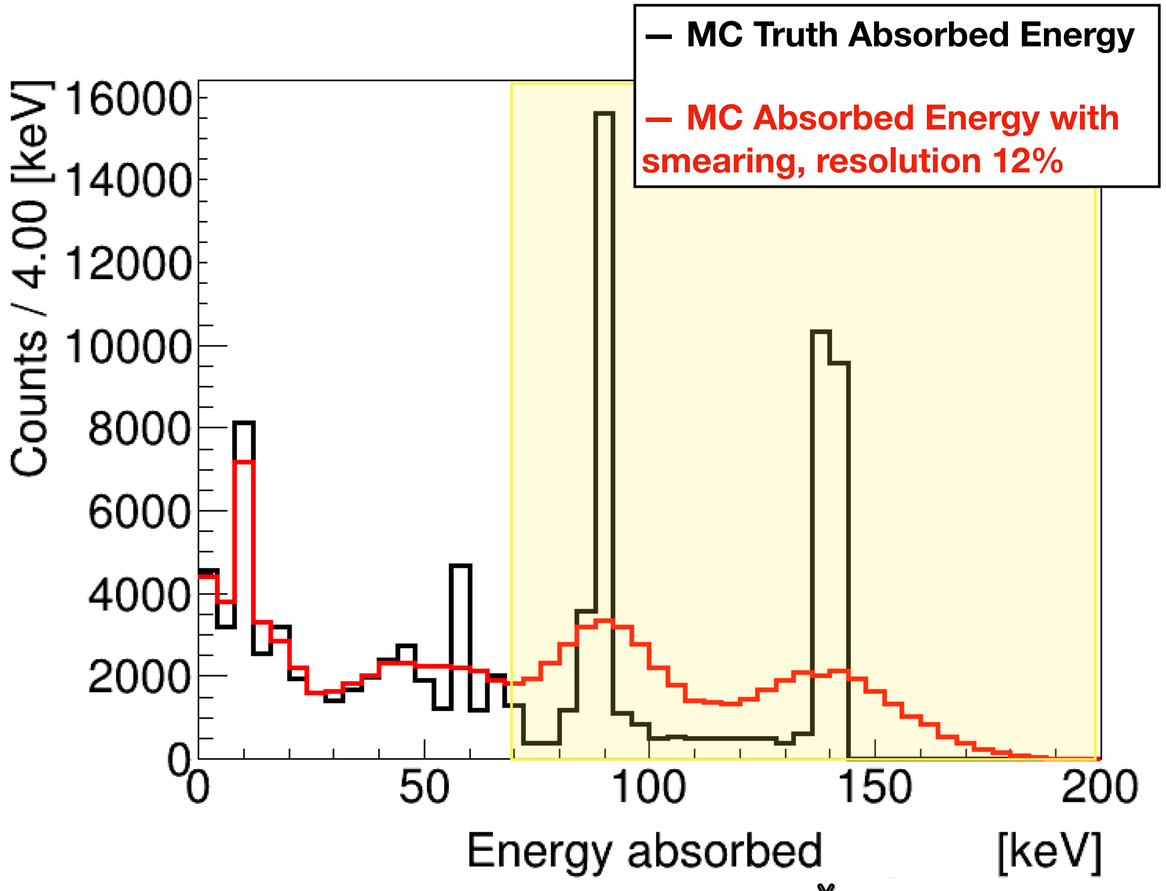

ReSPECT simulation study

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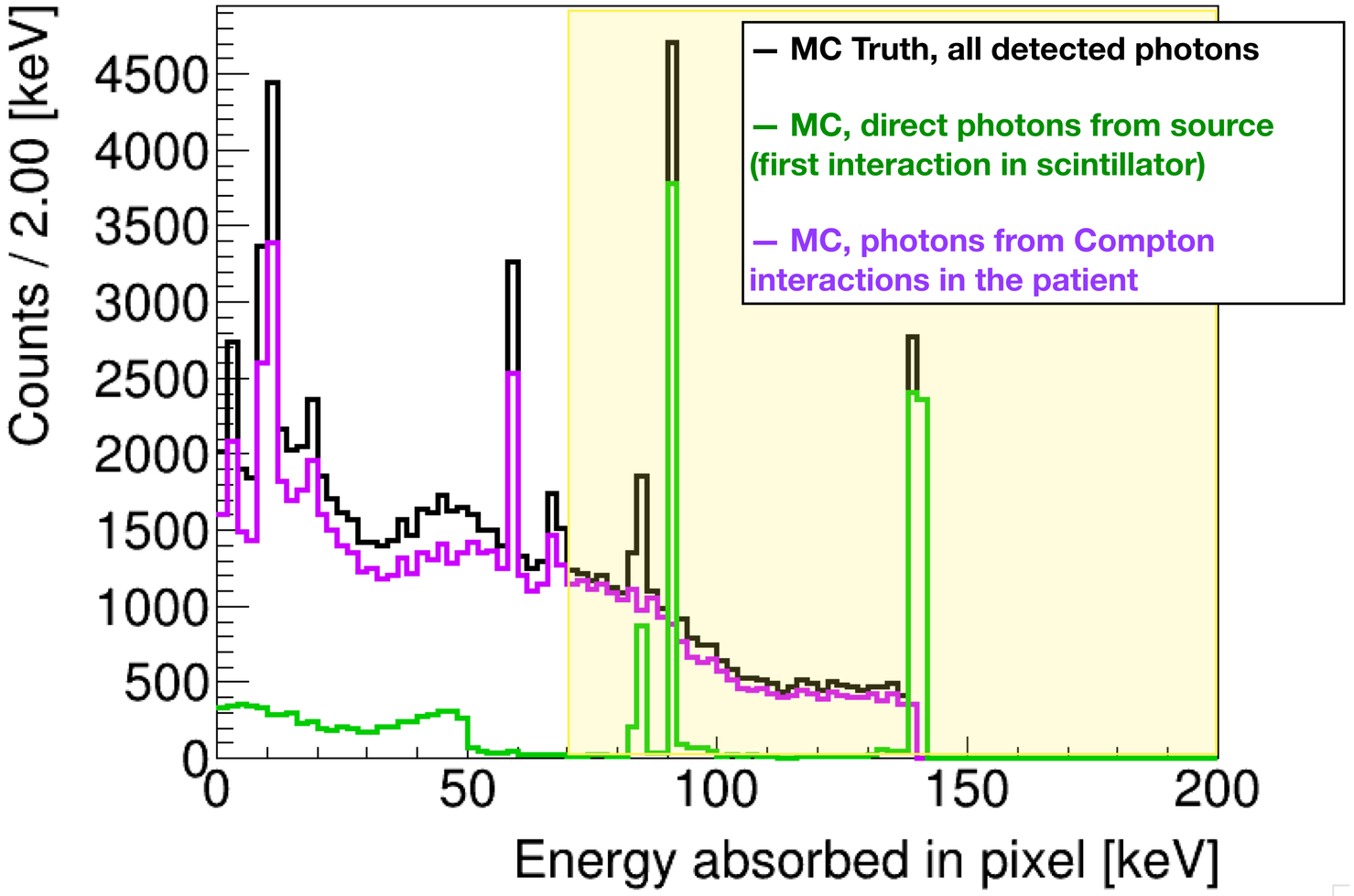
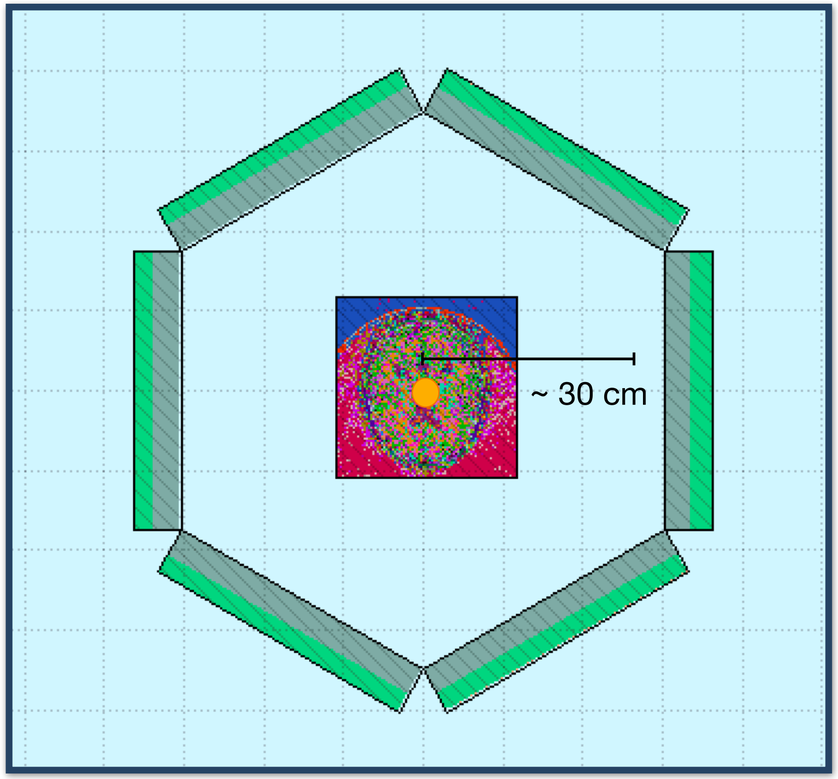




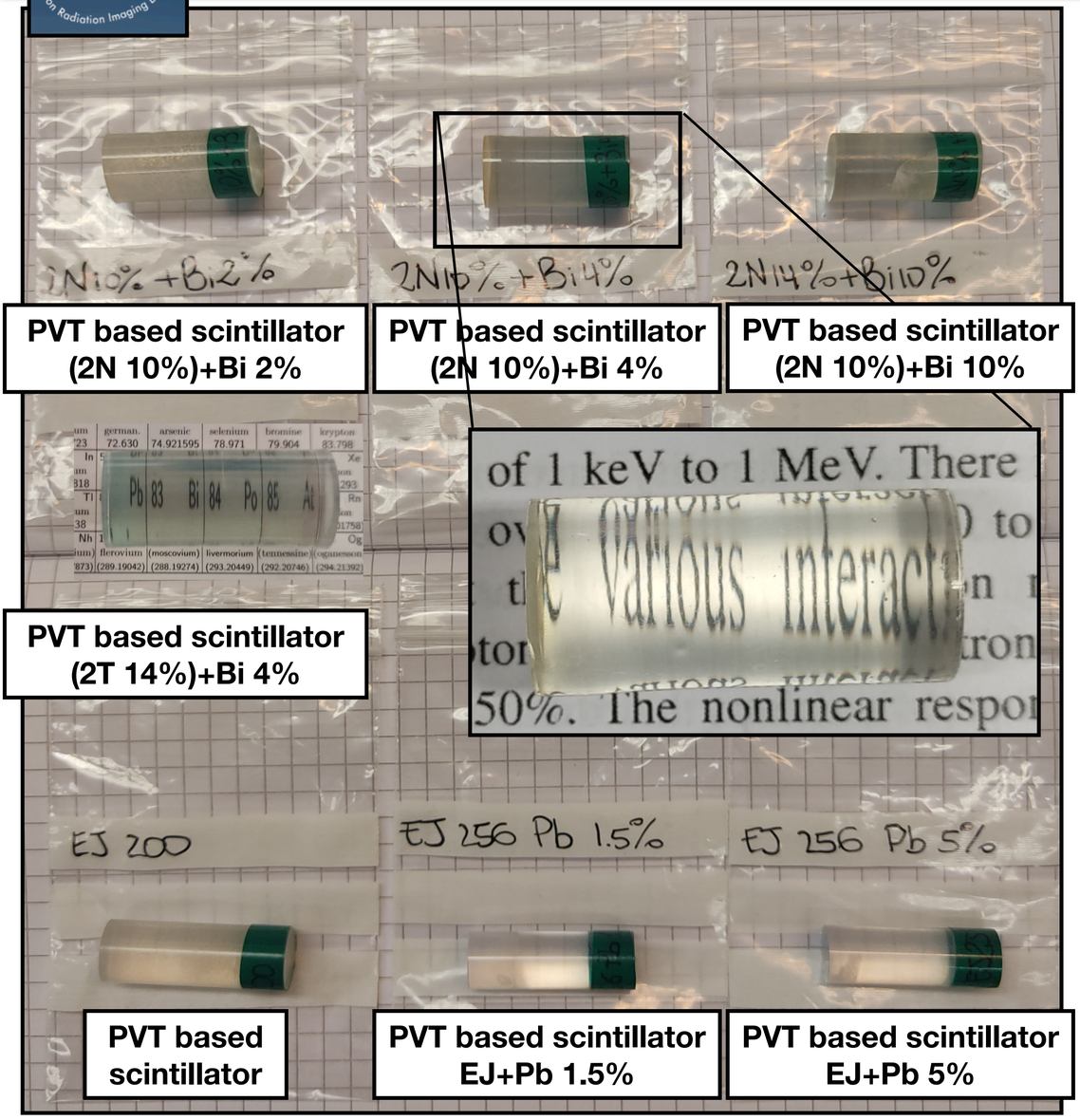
- MC study: a ^{99m}Tc point source in a Patient CT at 30 cm form the block

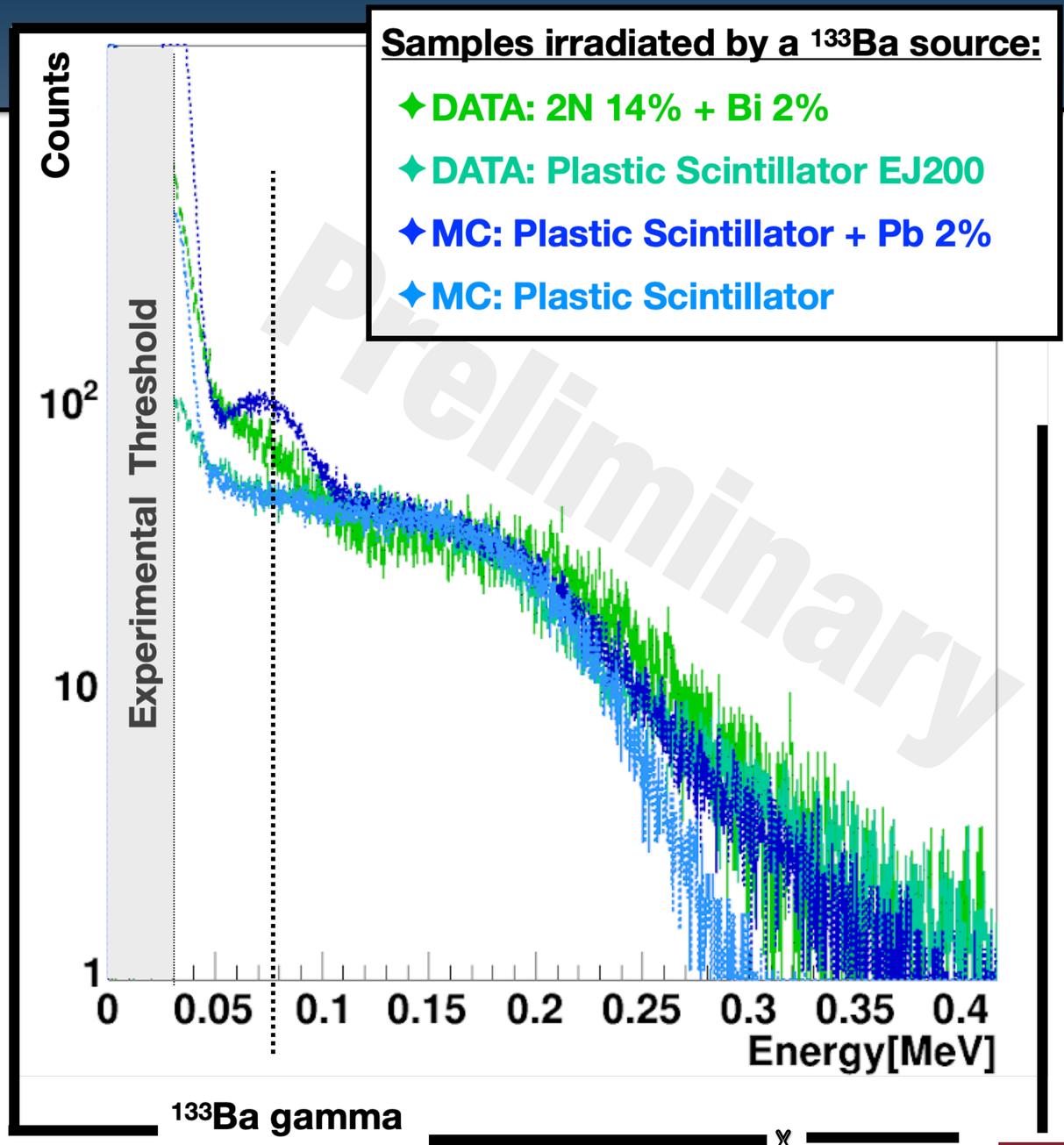
ReSPECT expected performances

SPECT SYSTEM	Sensitivity per module [cpm/μCu]	System Spatial Resolution [FWHM] [mm]	Decay Time	Rate Capability	COST scintillator/ FoV	COST full geometry	COMPLIANCE	
	@140 keV	*@10 cm*	*[ns]*	*[cps/cm2]*	*[€/cm2]*	*[€]*	*MRI*	*Radiometabolic Dosimetry*
SPECT (NaI) FoV 53 x 39 cm2	170	7.4	250	0.25-3k	4	400k	no	no
SPECT CZT FoV 39 x 51 cm2	190	7.6	350	30-700k	35	-	yes	yes
reSPECT 6 rotating Modules: 35 x 35 cm2	*184**	8.9 (pixel 2 mm)	2-5	50-200M	4	180k	yes	yes

***energy cut at 80 keV**

Scintillators R&D



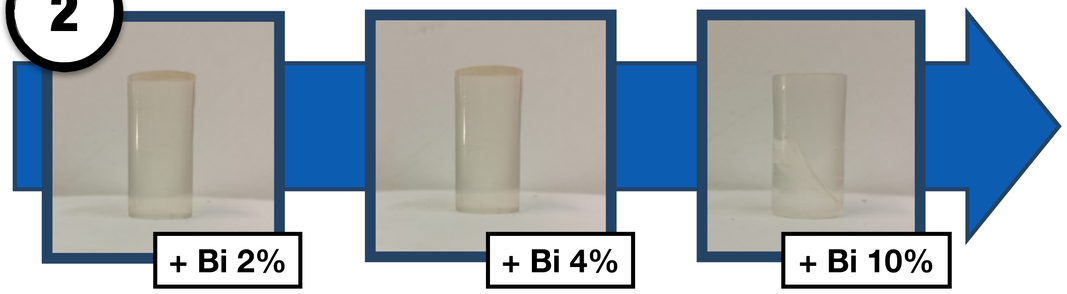


^{133}Ba gamma at 80 keV

Scintillators R&D

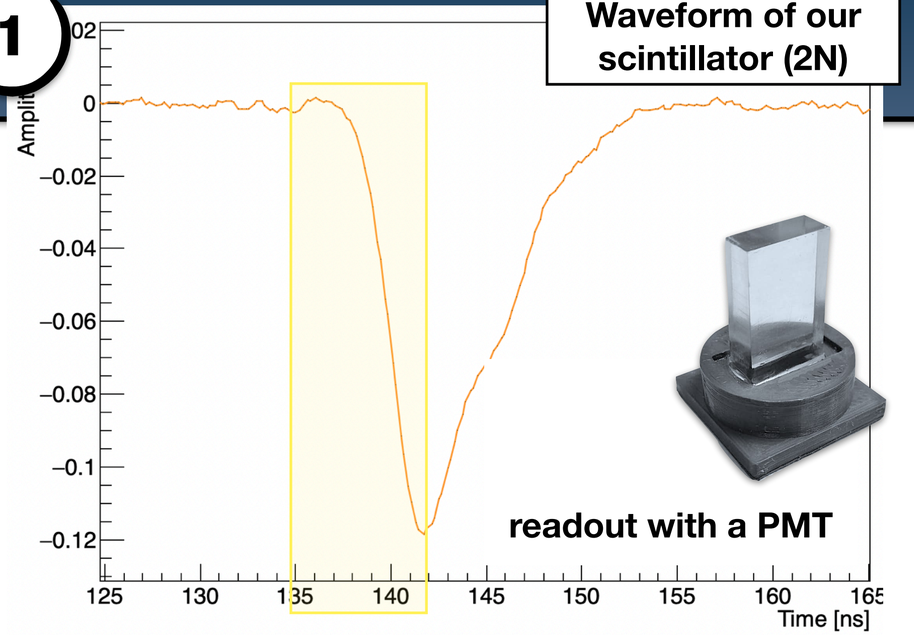
- We are producing samples of high-Z organic scintillators
- Transparency is good up to very high concentrations
- Test with laboratory sources and different readout systems

2



Scintillator	Light Output [a.u.]	Ph.el
New 2% Bi	100	+
New 4% Bi	71	++
New 10% Bi	67	+++

1



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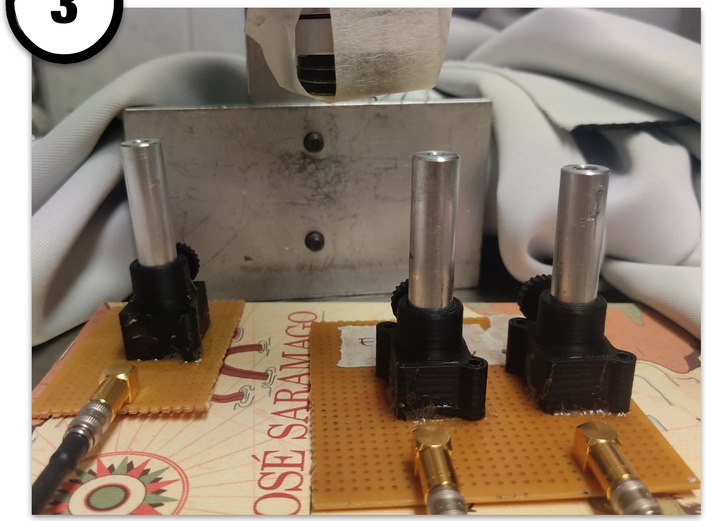
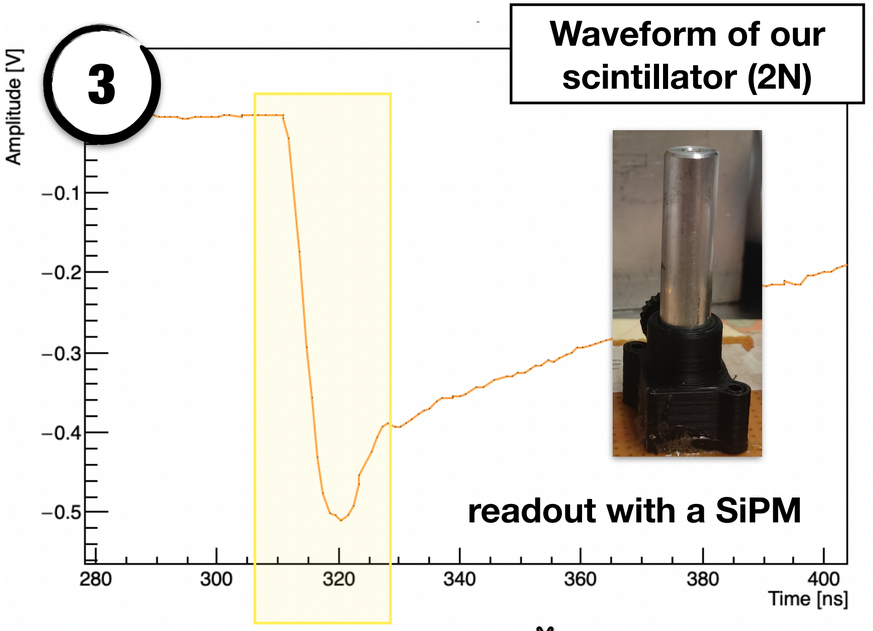


Scintillator	Light Output	Ph.el	Timing
Commercial pure	100%	-	reference
Commercial 1.5% Pb	80%	+	lower
Commercial 5% Pb	60%	++	ongoing
New pure	80%	-	faster
New 2% Bi	ongoing	+	ongoing
New 4% Bi	ongoing	++	ongoing
New 10% Bi	ongoing	+++	ongoing

3



Take home messages

- **Organic scintillators are fast, cheap and easy to manipulate**
- **With reSPECT project we are targeting a total body SPECT, accessible to National Healthy System in terms of cost, space and diagnose**
- The goal is to reduce diagnosis time and dose to the patient
- Radio-metabolic dosimetry is also possible with the same reSPECT system

- We are producing and characterising samples of hi-Z organic scintillators at different concentrations
- Transparency is good up to very high concentrations => Light Output is important to keep a good energy resolution!
- Test with laboratory sources and different readout systems

- Polymerisation in metal is ongoing
- Test with ^{99m}Tc at Policlinico => Fall 2023
- Realisation of the first module in 2024/2025

Work in Progress

National Funding Summer 2023 - Summer 2025

PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2022 Prot. 2022Z72Y3K

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

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GRAZIE

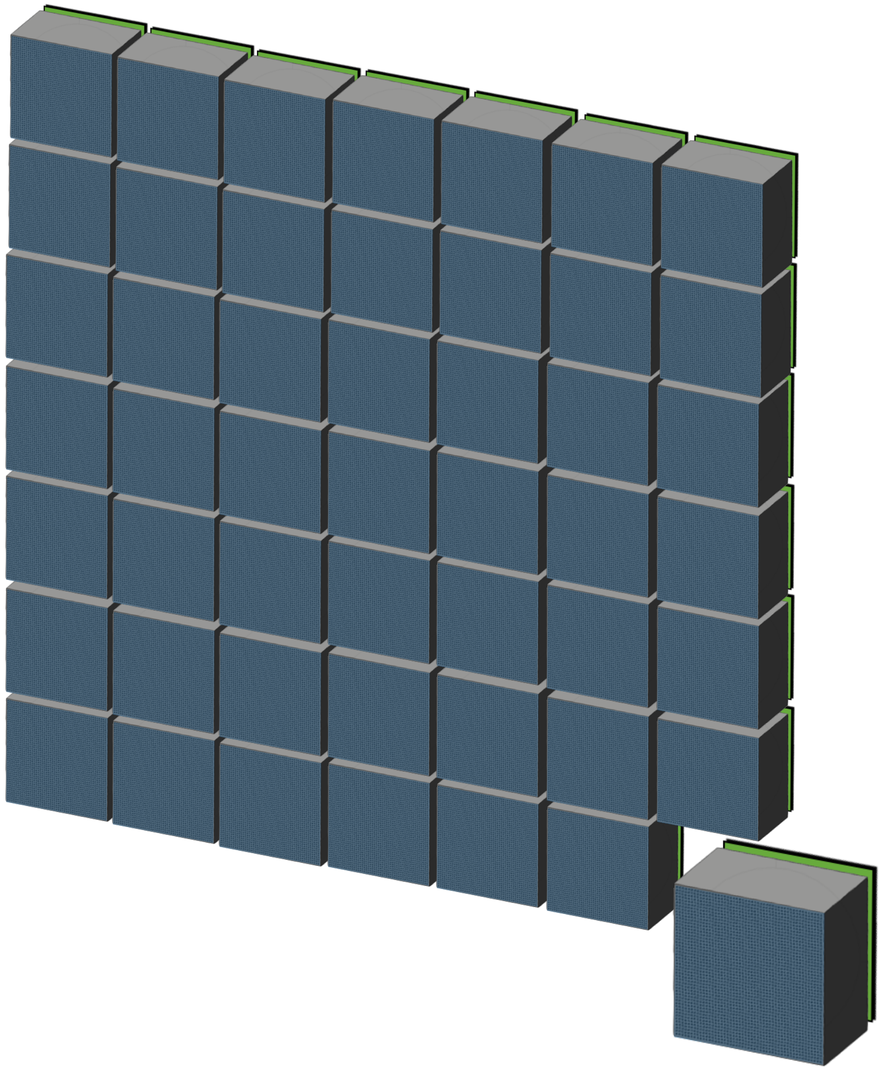
To join us:

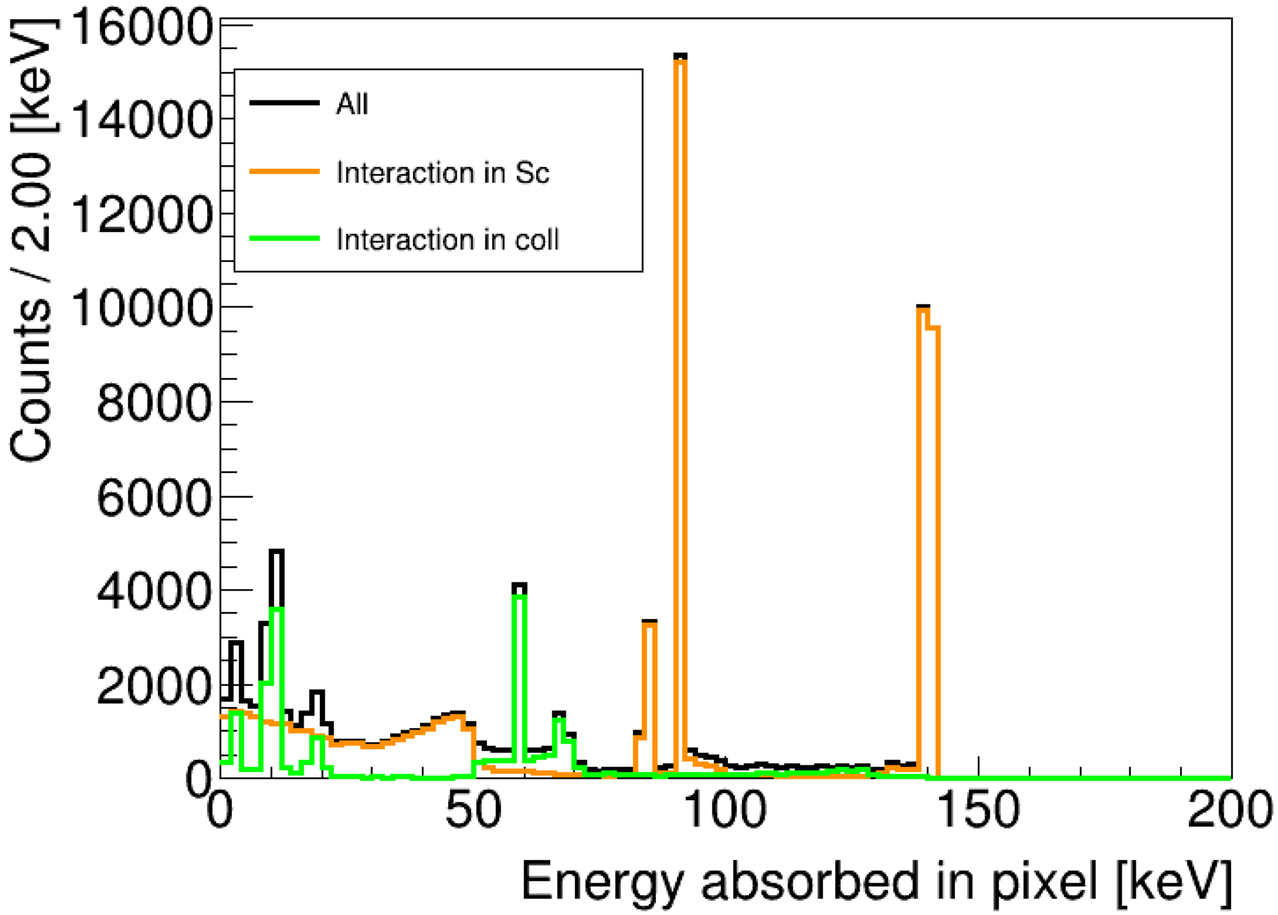
- michela.marafini@cref.it
- https://arpg.sbai.uniroma1.it/index.php/state-of-art/thesis
- www.cref.it
- Master and Ph.D. thesis:

  Physics and SBAI Departements at the Università Sapienza di Roma
- Medical physics school: Hospital Policlinico Umberto I Università Sapienza di Roma

come fai..SBAI

ReSPECT




Counts / 2.00 [keV]
16000
14000
12000
10000
8000
6000
4000
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0
0
50
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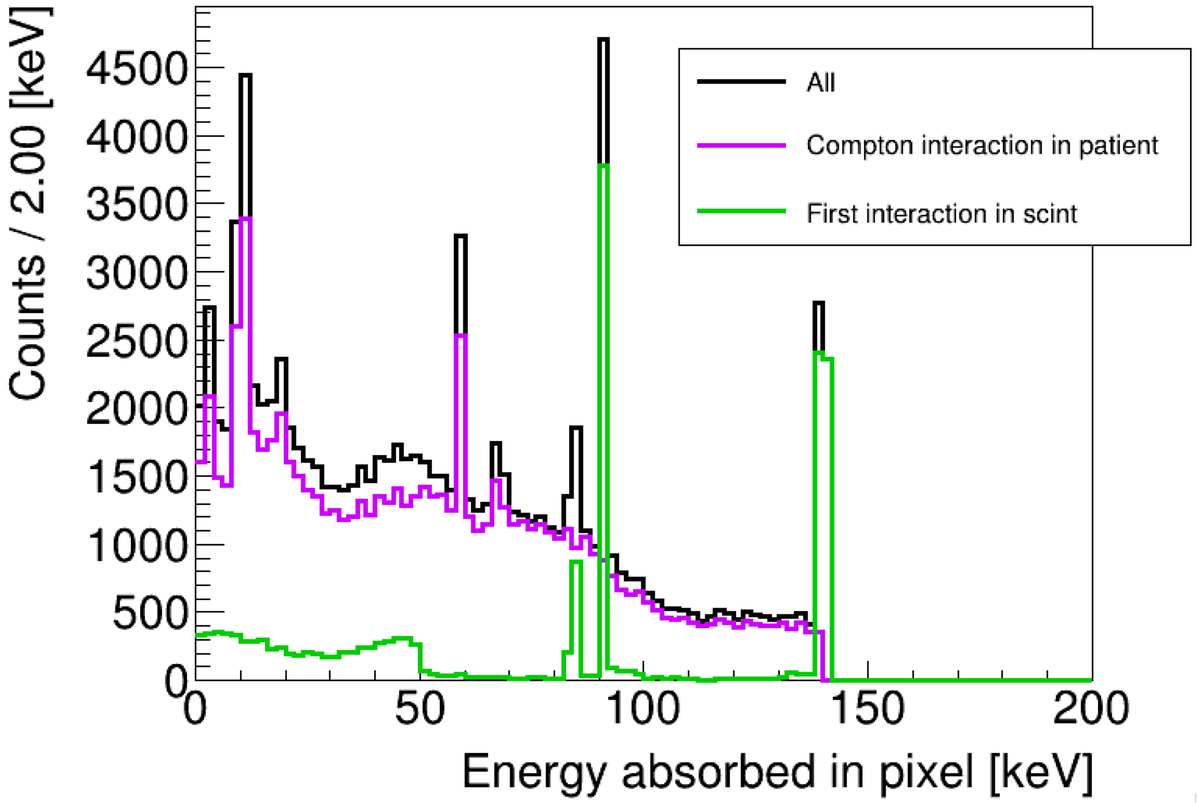
200
Energy absorbed in pixel [keV]
All
Interaction in Sc
Interaction in coll

ReSPECT


Counts / 2.00 [keV]
4500
4000
3500
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2500
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Energy absorbed in pixel [keV]
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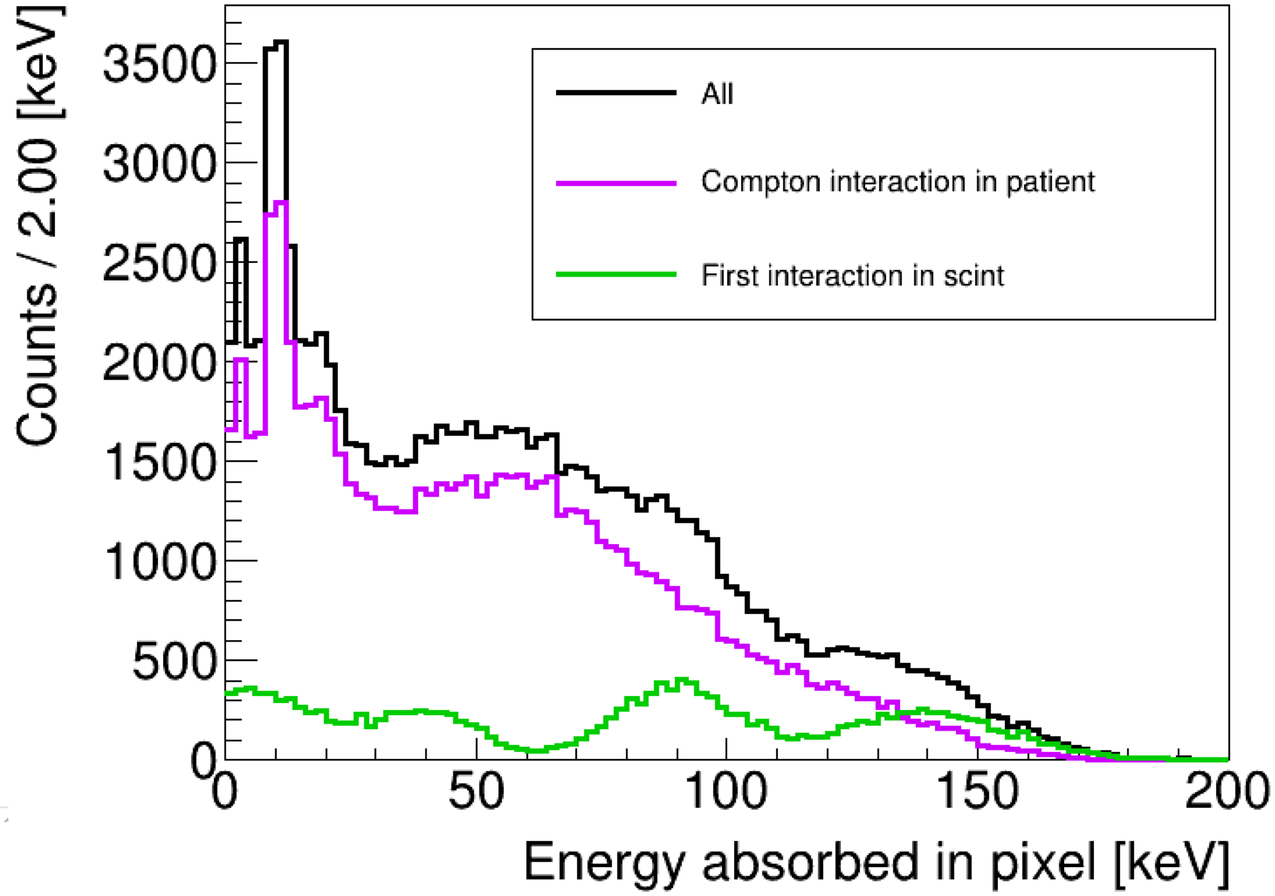
Compton interaction in patient
First interaction in scint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