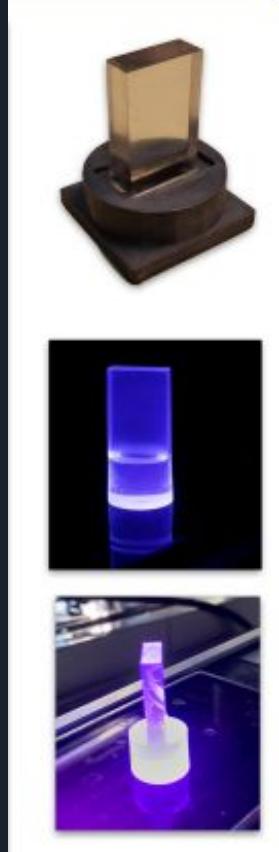


LUMINARIE

Misure e simulazioni su Organometalli



Introduzione Generale

Questo filone di ricerca nasce dalla collaborazione tra il nostro gruppo ‘sbai’ con i chimici del laboratorio LEOS (sempre di SBAI).

- Dal 2018 abbiamo iniziato a sviluppare con loro nuovi **scintillatori veloci** organici/plastici (es. tesi di [Alessandro Biondi](#), Gennaio 2019 - presentazioni e articolo [1]) che potessero competere con i commerciali più diffusi.
[1] R. Mirabelli, et al., “TOPS project: Development of new fast timing plastic scintillators”, Nuovo Cim. C. 43 (2020) 17. <https://doi.org/10.1393/ncc/i2020-20017-4>.
- In questi ultimi anni abbiamo ottenuto ottime prestazioni dal punto di vista temporale raggiungendo risoluzioni comparabili (e a volte migliori) di quelle ottenute con scintillatore plastico commerciale (BC-400, EJ200 ed EJ232). Le misure sono lunghe e soffrono molto dei limiti intrinseci dell’elettronica di readout.

In parallelo allo sviluppo di scintillatori veloci sono emerse le possibilità di:

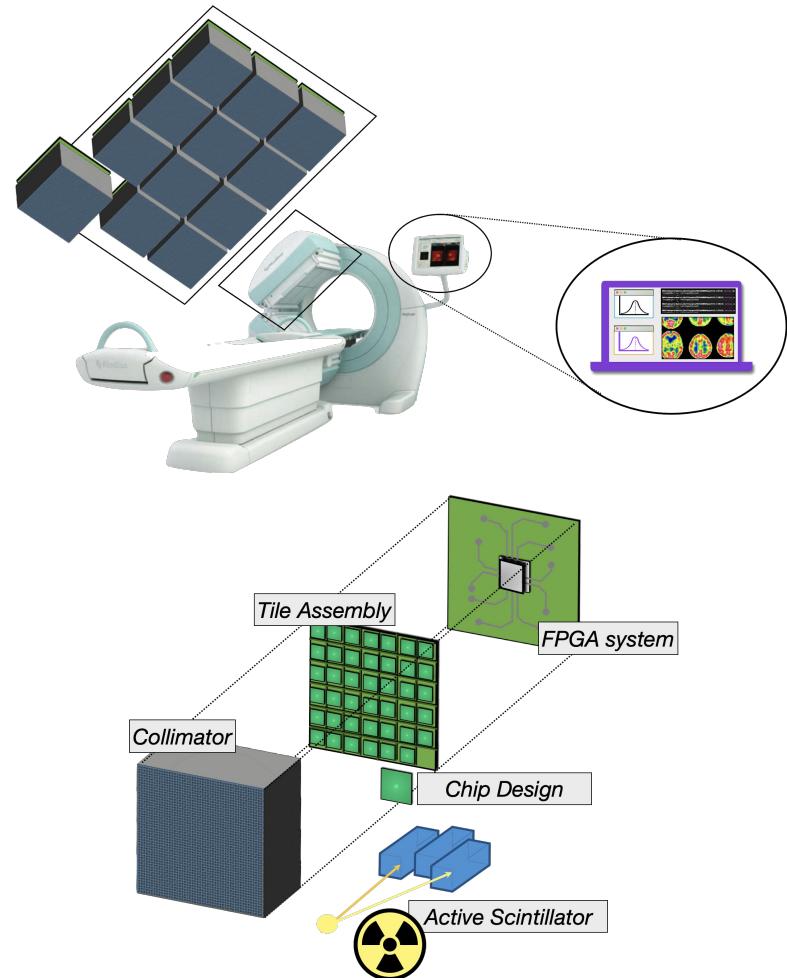
- incorporare lo scintillatore nel [‘veroclear’](#) per poter **stampare 3D gli scintillatori** - 3DIT: Bando di Ateneo;
- arricchire lo scintillatore plastico con **elementi ad alto Z** in modo da poterne aumentare la probabilità di rivelazione dei fotoni tramite effetto fotoelettrico;
- ..variazioni sul tema..

The reSPECT detector

- SPECT is a non-invasive diagnosis imaging;
- The detection technology of SPECT is based on the detection of photons at 140 keV deriving from the decay of the ^{99m}Tc , traditionally with inorganic crystals, ex. NaI(Tl).

The reSPECT detector:

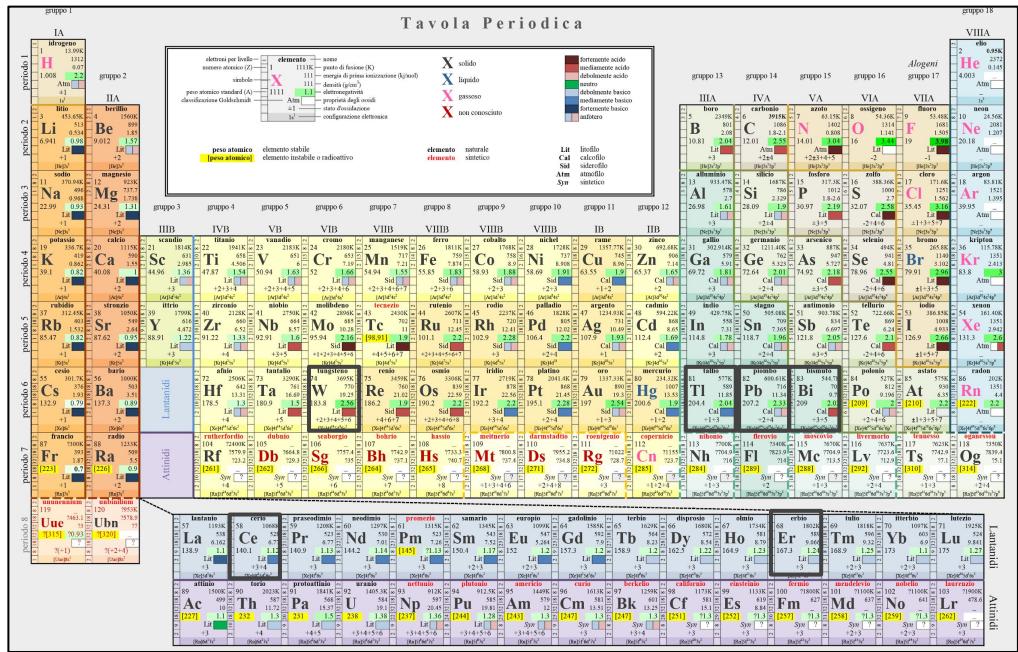
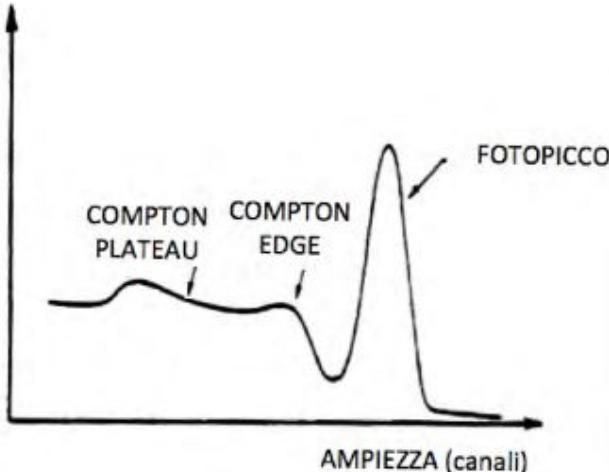
- The aim is to design a new gamma-ray detector that exploits enriched organic scintillator - ORGANOMETALLICS - **high-Z organic scintillators**;
- From the mechanical point of view, the goal is to polymerize a liquid-state plastic scintillator in the holes of a 3D printed collimator;
- From the detection point of view, the goal is to detect via photoelectric effect the “140 keV” photons in the high-Z organic scintillator.



Detection strategy

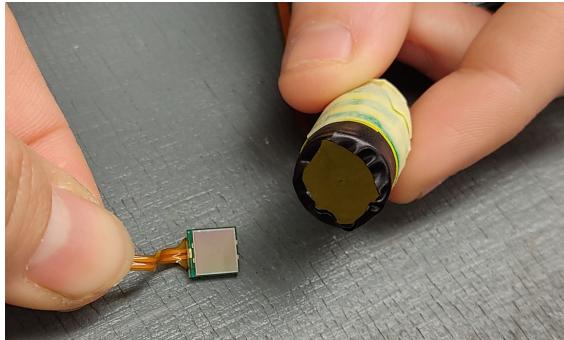
While an image has to be reconstructed, we are interested in the photoelectric gamma interactions and to make them as probable as possible at the desired energies in order to maximize the photons used for the image reconstruction. At those energies, compton effect is the dominant interaction in organic scintillators, while photoelectric is instead widely visible in the inorganic ones being high Z and a high density. To maximise the photoelectric effect even in organic scintillators, they are loaded with materials that allow scintillation thus increasing Z.

Frequenza
dei
conteggi

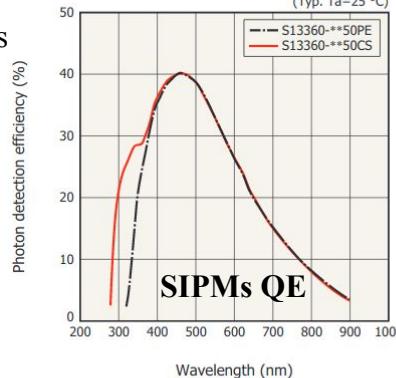
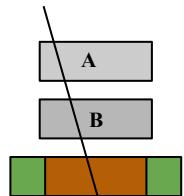


Scintillator development

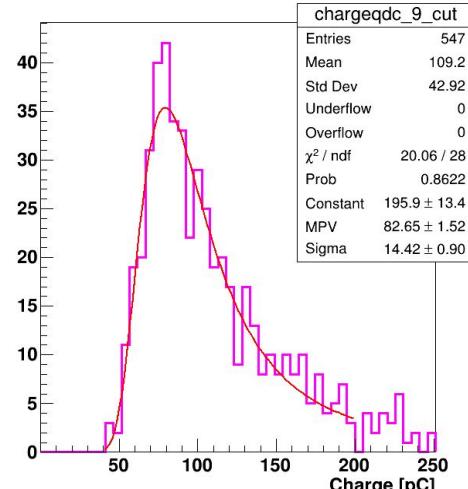
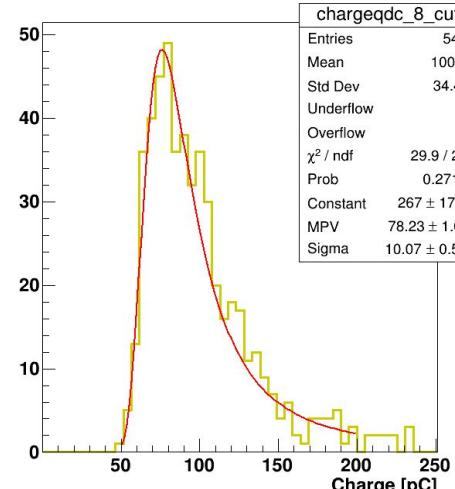
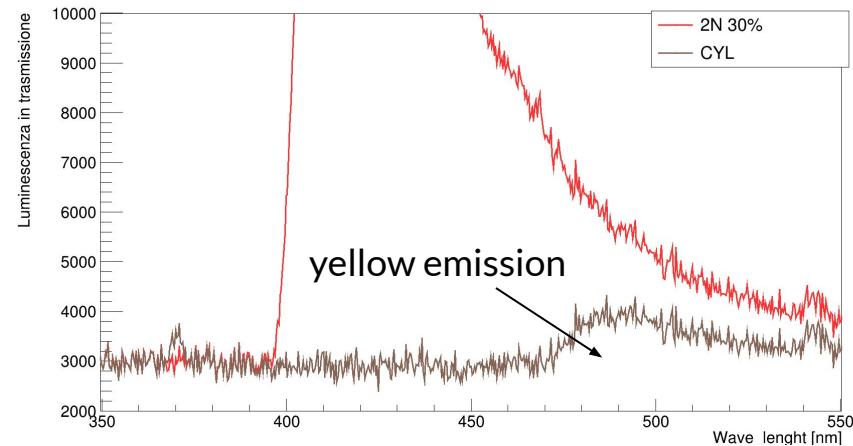
A very preliminary attempt has been made with Er combined with bromo chinolina as a ligand. (incomprensibile)



We tried to study the organometal with two SiPMs and two external triggers from system A and B.

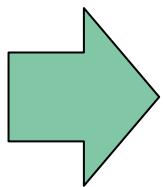


Experimental setup



Scintillator development

The second sample is “under construction”: a synthesized Bismuto salt will be dissolved in organic scintillator (PVT based).



In a couple of weeks we will have something to test.

Simulation

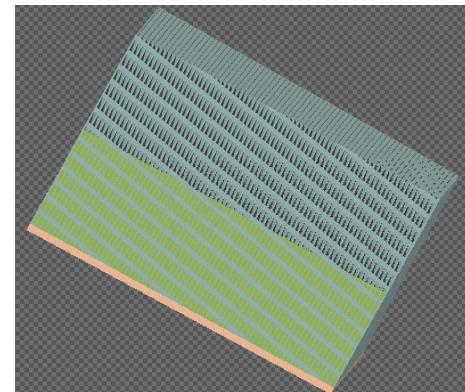
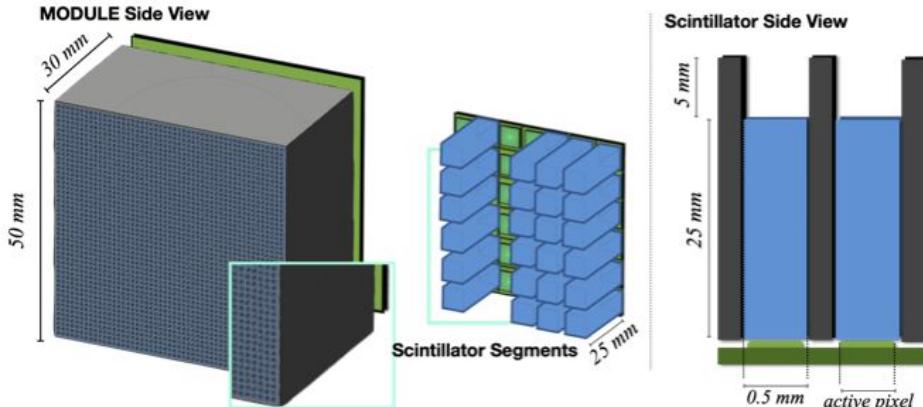
A collimator with parallel septa was simulated using Fluka, "sending" particles 10 cm from the end of the septum. The stretch of air once met the collimator corresponds to 1.5 cm and then there is the 2 cm of scintillator.

The dopants used to increase the Z of the plastic scintillator are of different types and in different percentages:

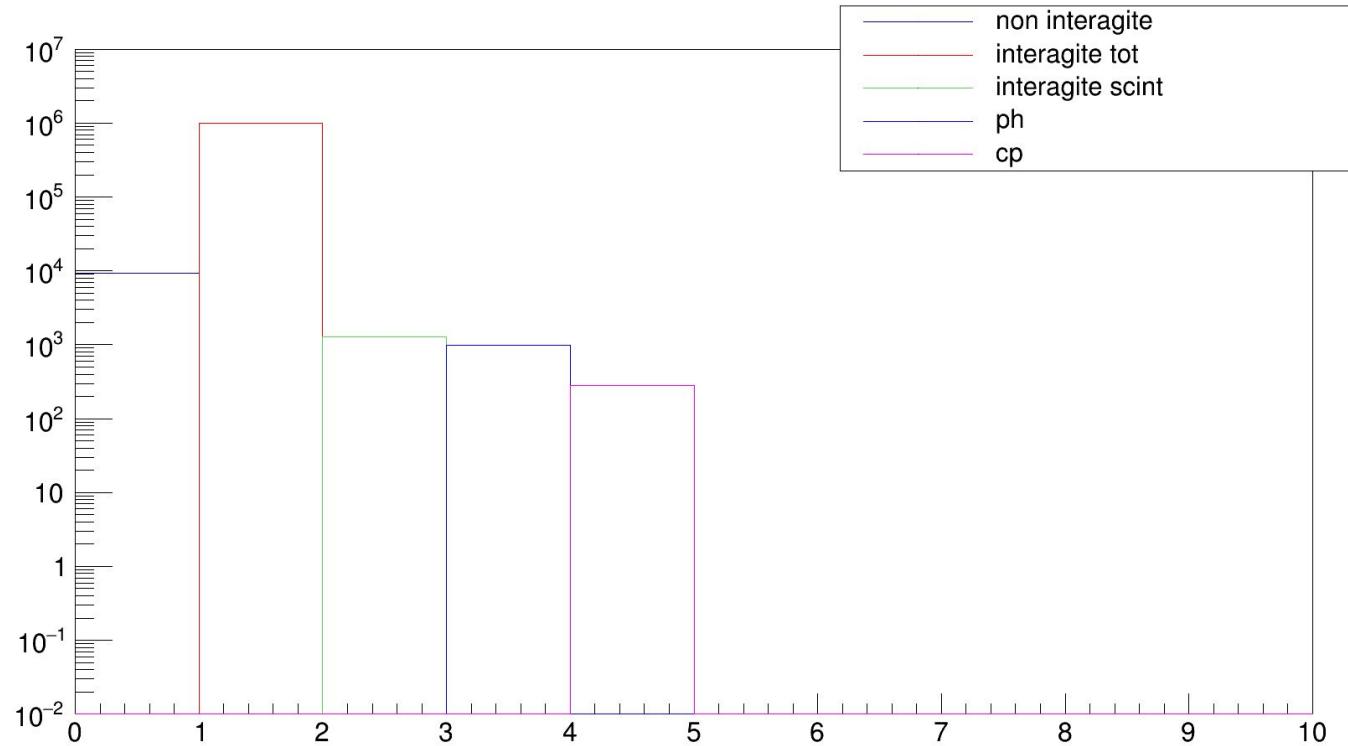


- Bi, Z=83
- Pb, Z=82
- Tl, Z=81
- W, Z=75
- Er, Z=68
- Ce, Z=58
- I, Z=53

All studied as a percentage of : 2%-5%10%-20%-30%-50%



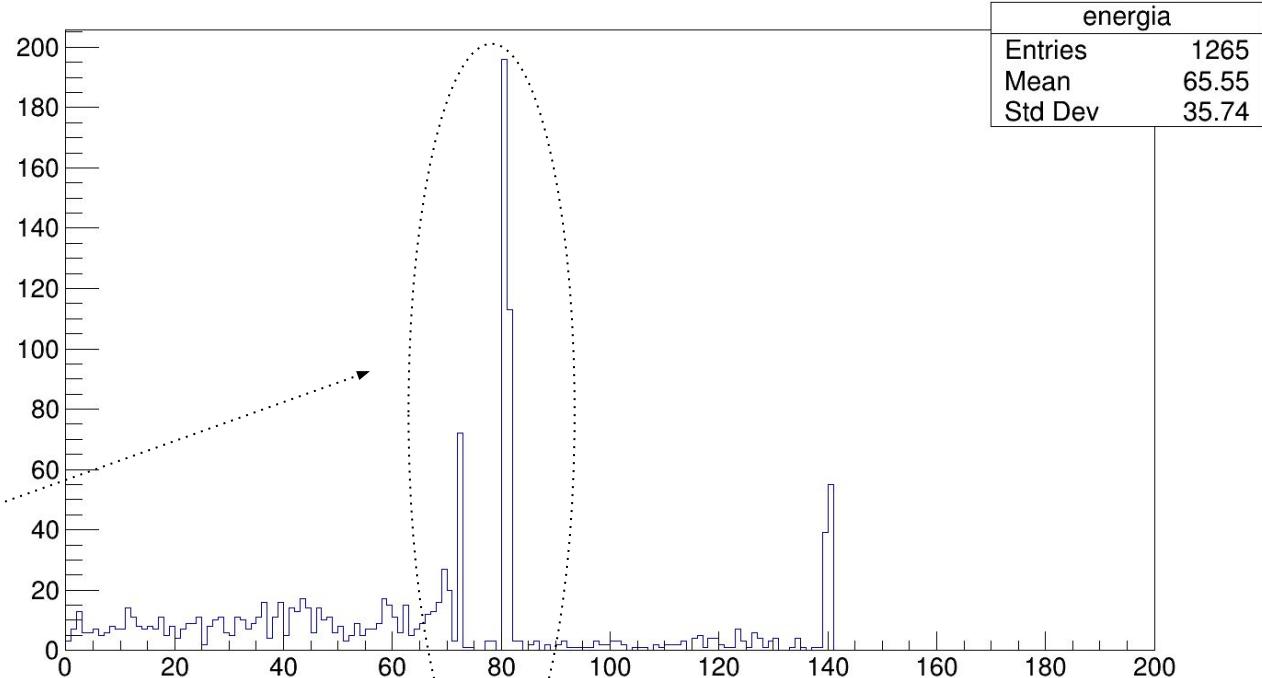
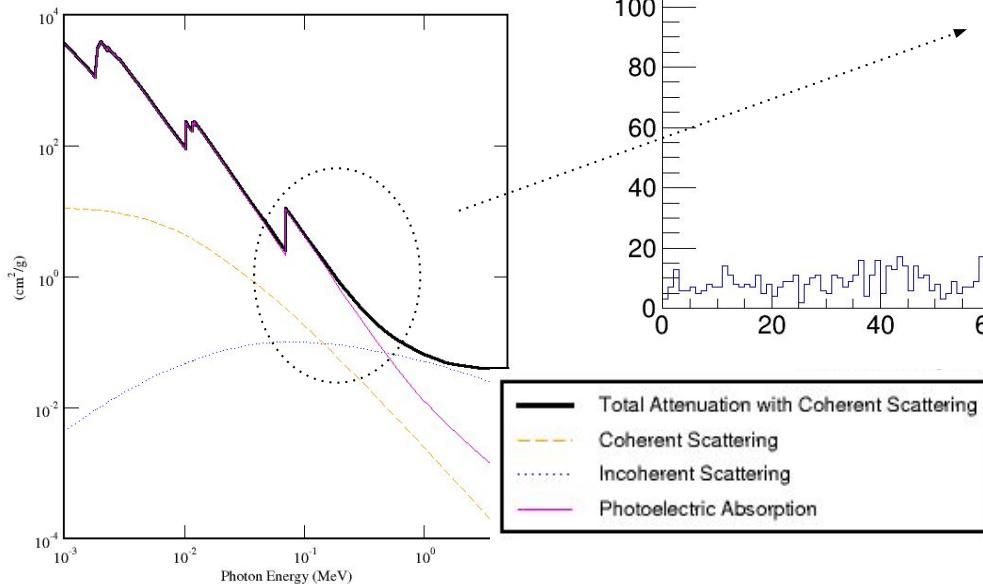
Simulation W 20%



Number of fired particles: 1 E6

Simulation W 20%

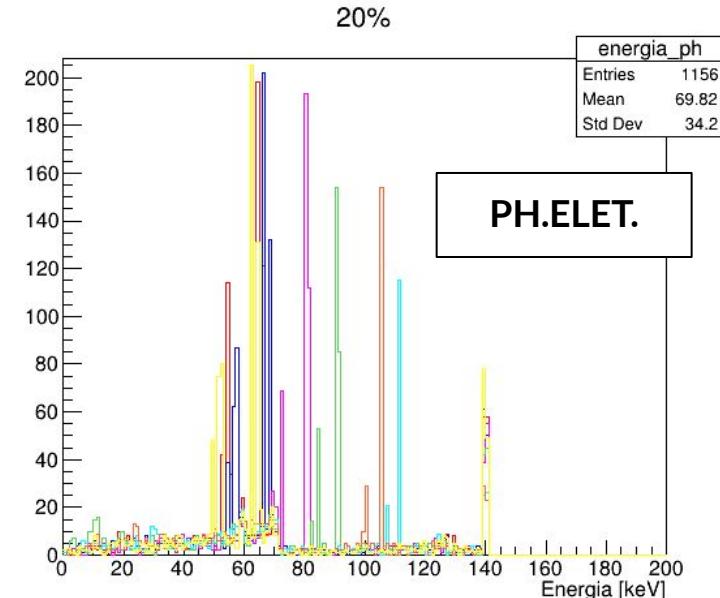
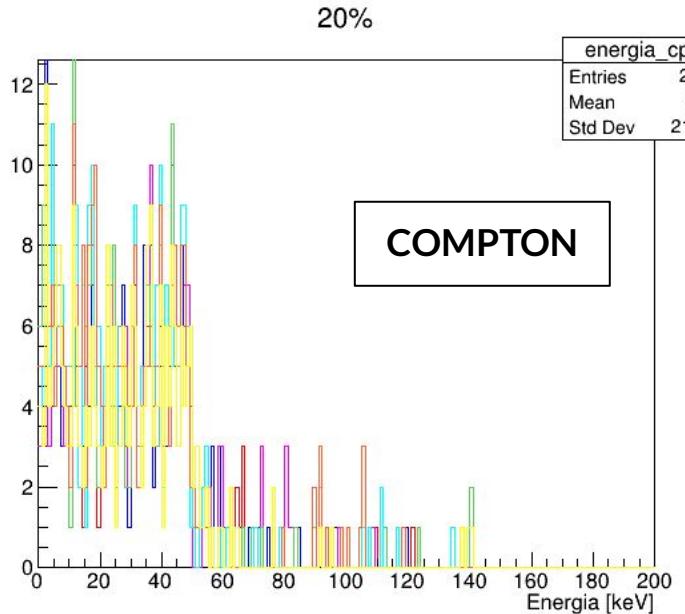
- Compton shoulder ending around 50 keV;
- Photo-peak at 140 keV;
- Additional peaks due to the dopants present in the scintillator.



Comparison between materials

The events related to the photoelectric effect and Compton have been analyzed. The peaks of the photoelectric relative Pb, Tl (higher Z) are closer to the edge Compton while for lower Z elements the ph.el. events are at higher energies. From the detection strategy point of view Er and W ph.el. events are easier to be identified.

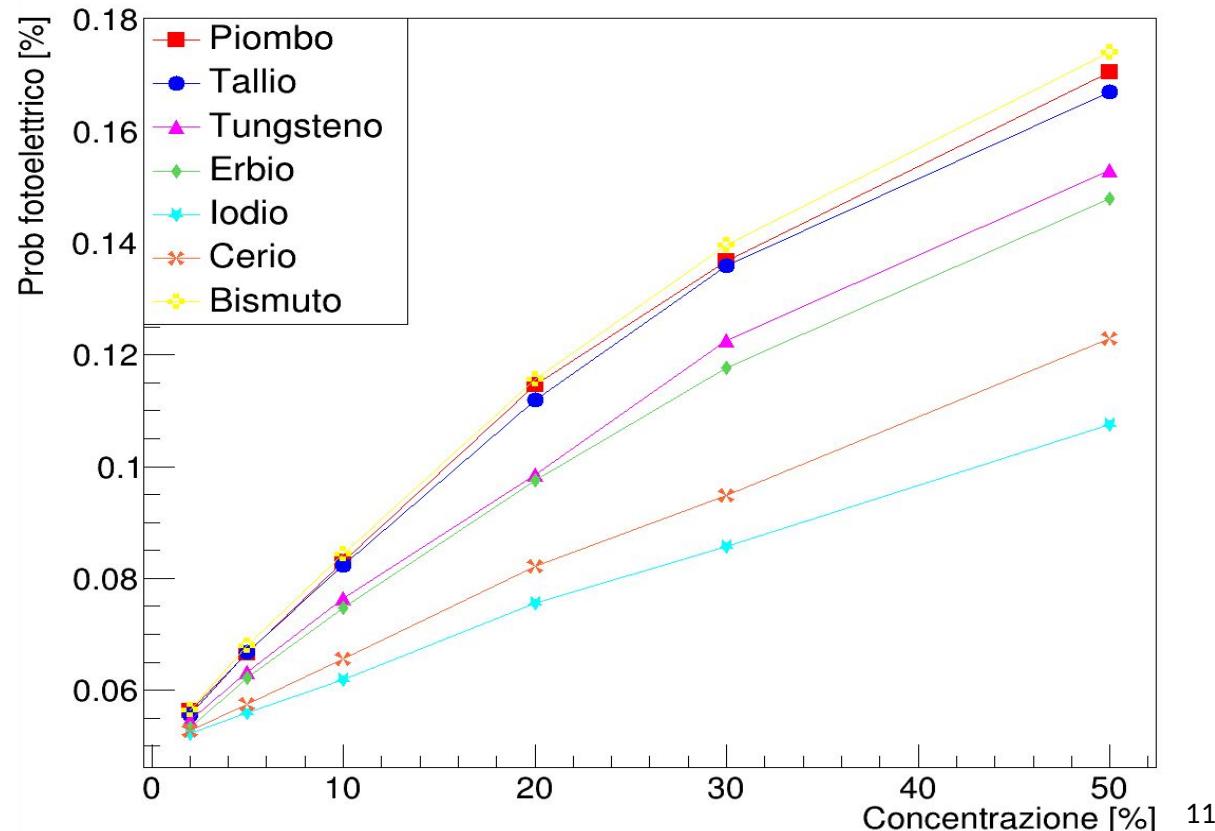
- Piombo
- Tallio
- Tungsteno
- Erbio
- Iodio
- Cerio
- Bismuto



Comparison between materials

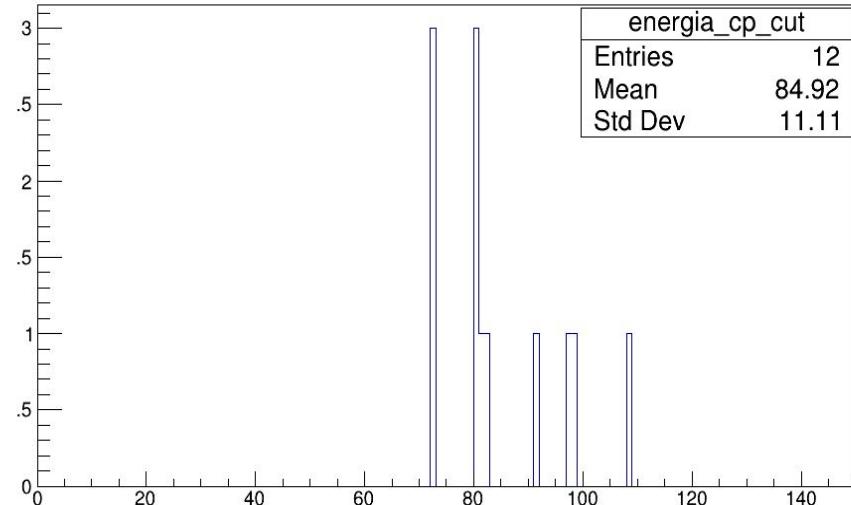
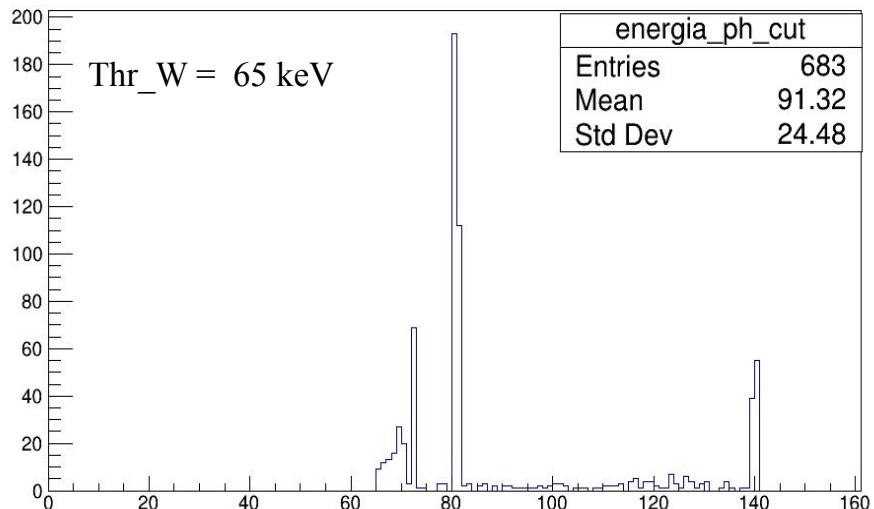
- High probability of photoelectric effect for Pb and Tl;
- Low probability of photoelectric for I;
- For Er and W a good compromise between photoelectric probability and deviation from the Compton effect.

Eff fotoelettrico vs Concentrazioni



Simulation W 20%

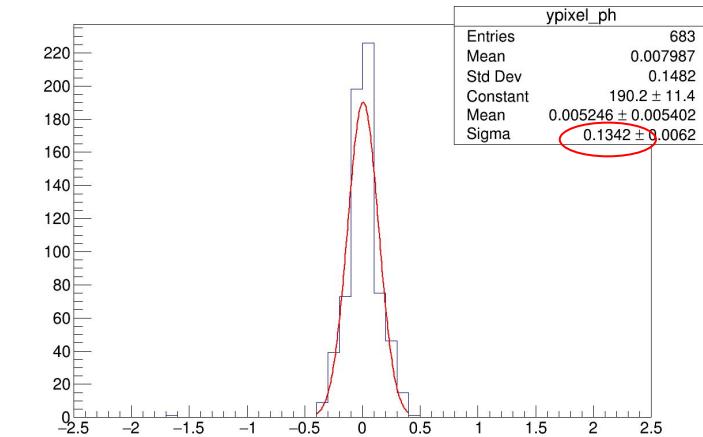
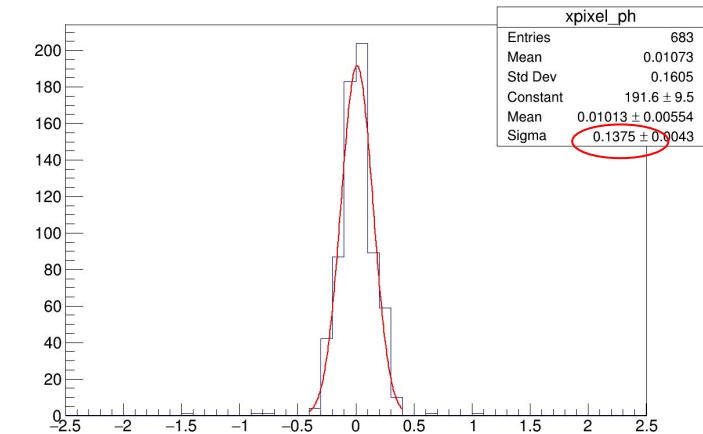
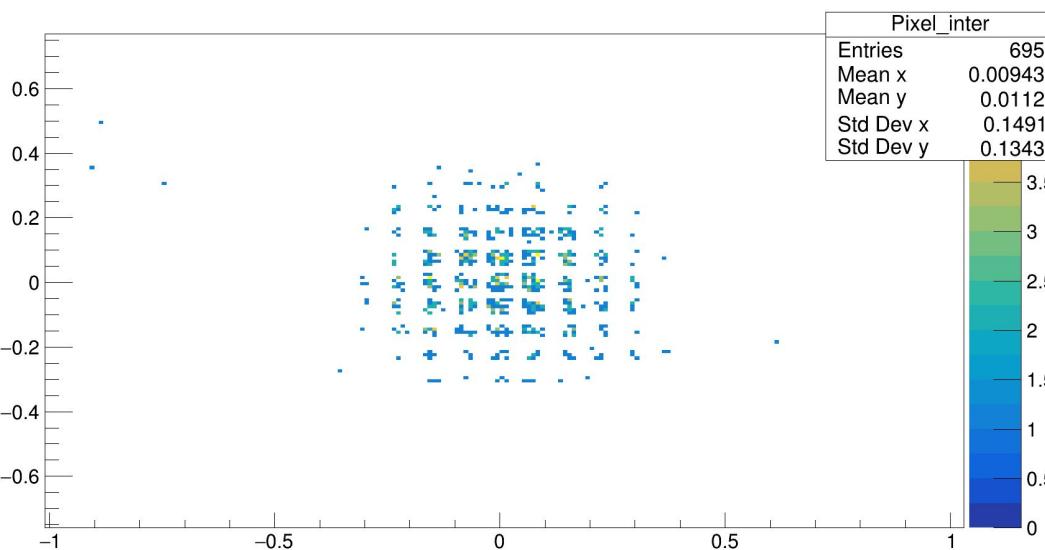
We want to select gammas that interacts via photoelectric effect, thus we can set a threshold in the energy deposition to separate and reject the Compton events. We analyze the efficiency of this selection expliting MC truth on the nature of the interactions.



A specific threshold has been set depending on the dopant.

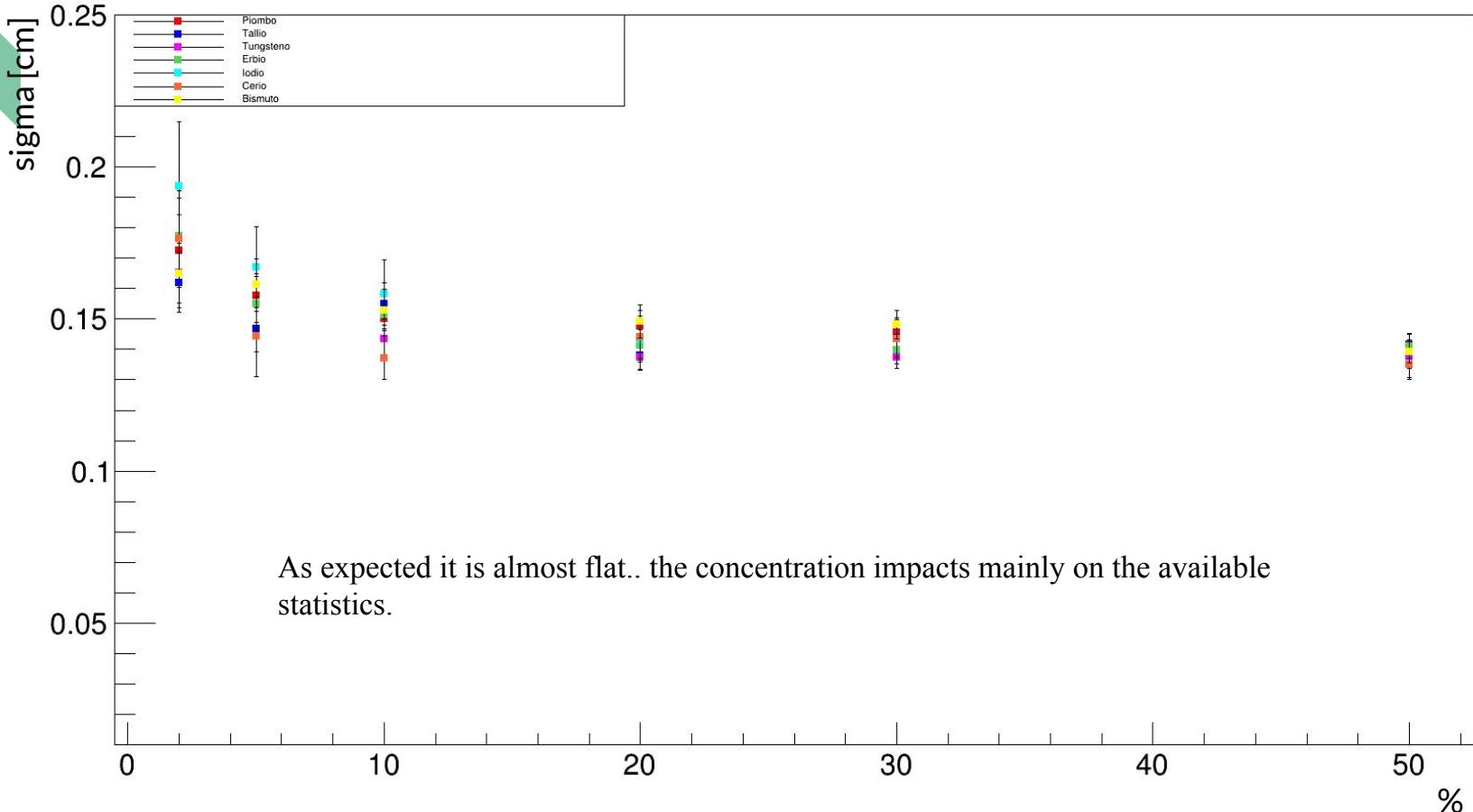
Simulation W 20%

The selected events (release of energy over threshold), the image of the source has been reconstructed:



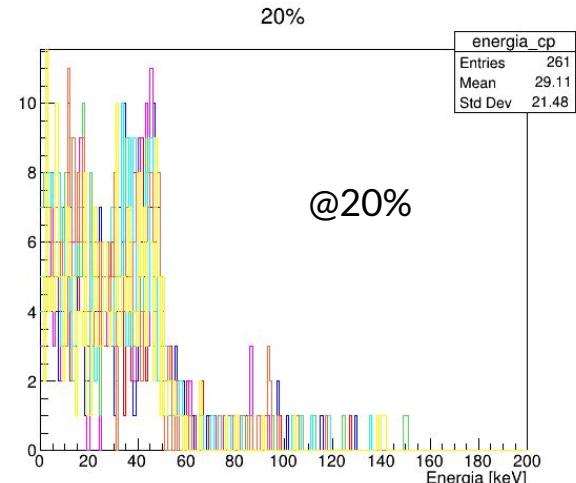
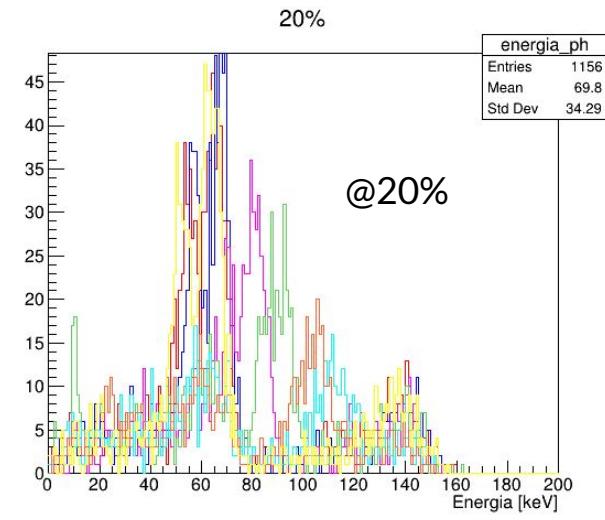
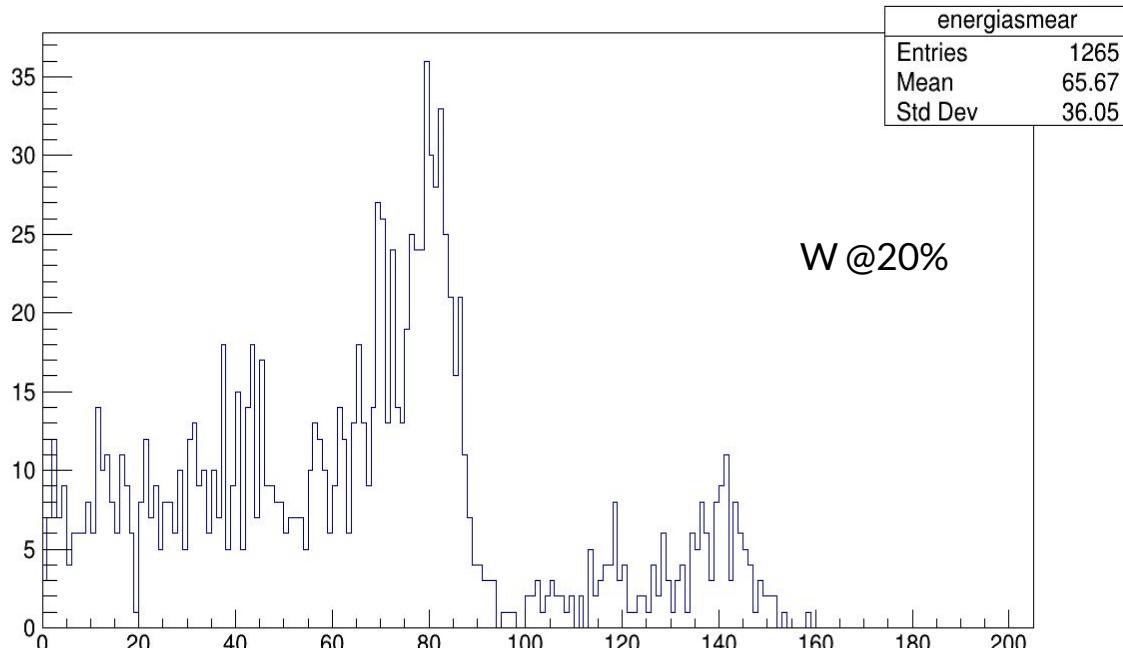
A sigma of 1.4 mm is obtained for x and y directions. This is the intrinsic space resolution available with this system (collimator and scintillator). NB: The isotropic source is placed at 10 cm.

Resolutions with different elements and concentrations



Smearing of the energy resolution

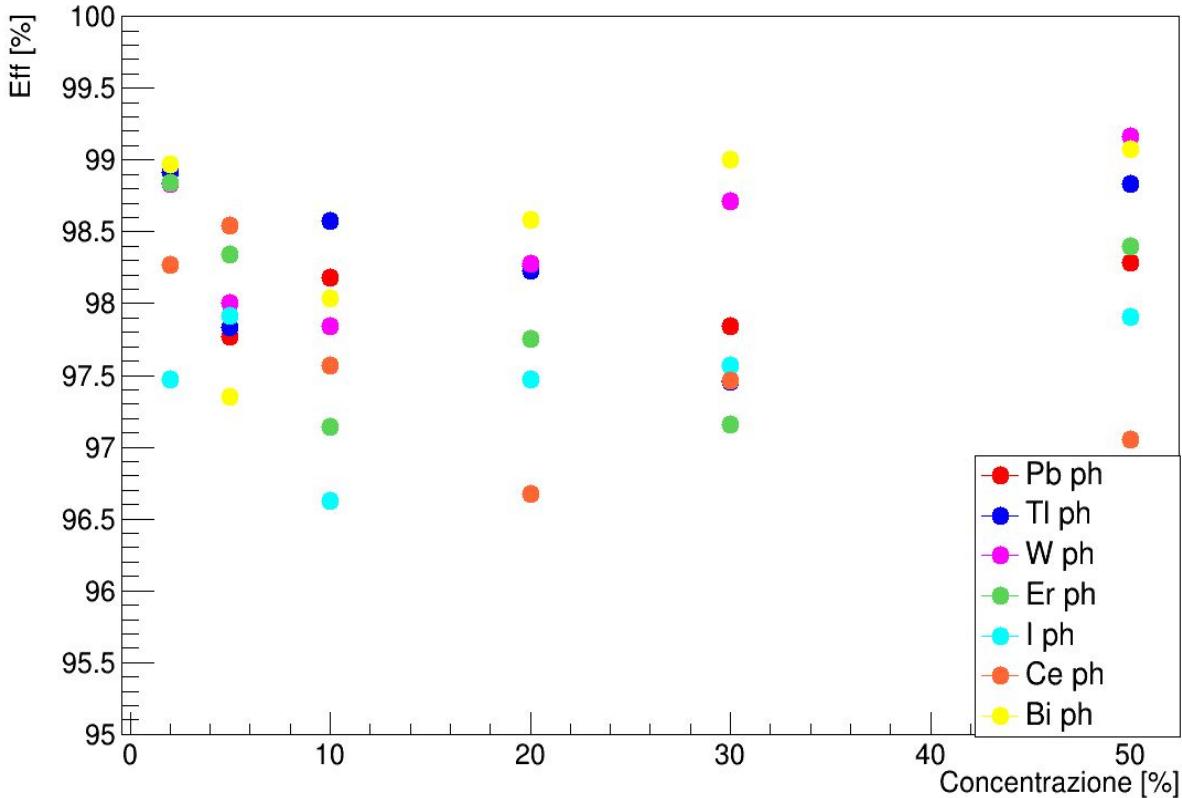
We implement in the MC a smearing of the deposit energy to reproduce an energy resolution of about 5% (“realistic” expectation).



Selection efficiency

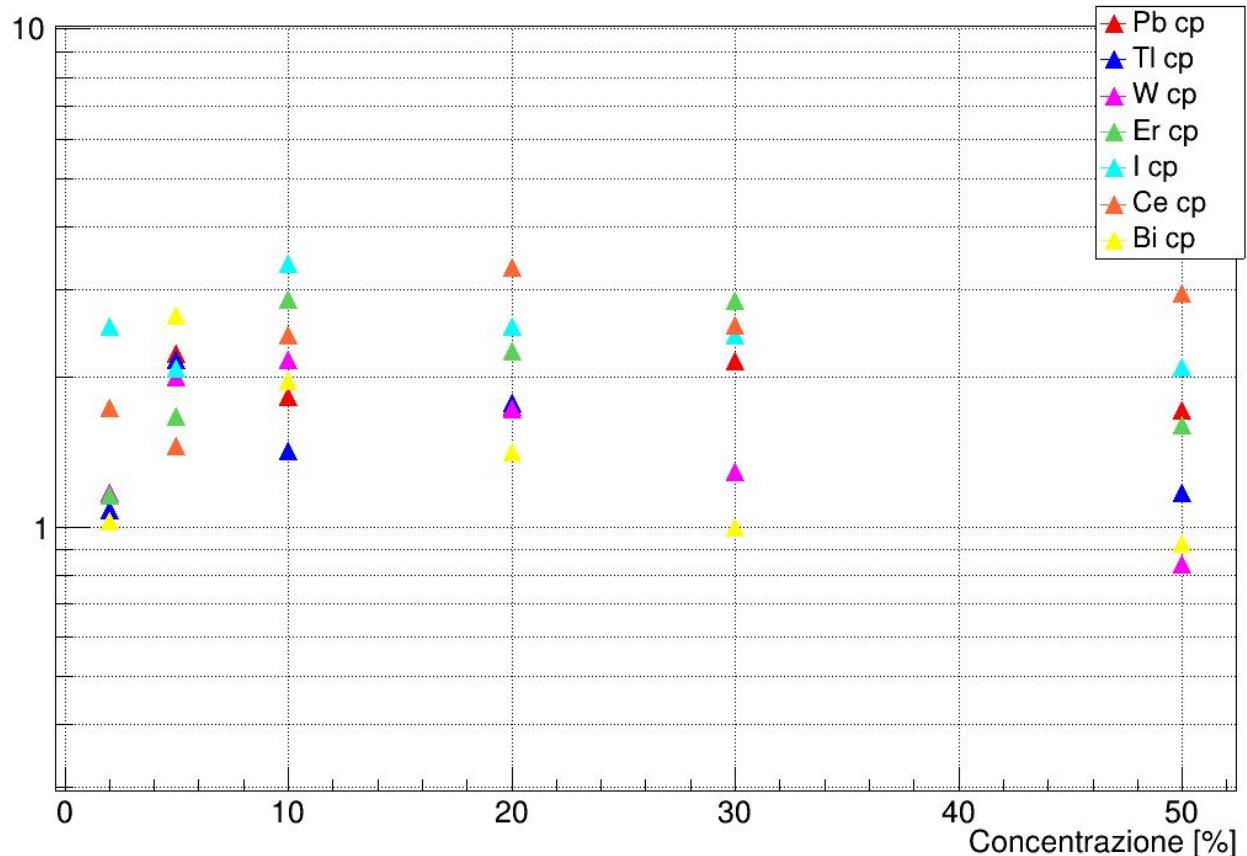
- An efficiency of 98% in the selection of photoelectric events has been evaluated;

Efficienza ph vs cp



Compton background

- The number of compton events that is over threshold is only about 2%.



Conclusions

Simulazione

- Ottimizzazione della geometria;
- Analisi delle performance attese;

Sviluppo Hardware

- Primi sample tra pochi giorni
- Analisi in trasmissione, assorbimento, trasparenza
- Analisi in laboratorio..
 - Criticità (1) la sorgente di più bassa energia che abbiamo e' il ^{22}Na .. 511 keV

Possibilità/Varie ed eventuali

- a parte le nostre applicazioni SPECT e co.. potrebbero esserci delle sovrapposizioni con le specifiche delle applicazioni di 'sonda/widmap'