Luminarie

Time Of flight Plastic Scintillators and Hi-Z Organic Scintillators

11/11/2021 - Rome

Main Task

- Fast Timing Plastic Scintillators — Particle Physics
  - 3DIT (3D printed scint.)
- Hi-Z Plastic Scintillators — Imaging (SPECT, etc.)
- Additional ideas.. (not discussed today)
  - particle identification (gamma/neutron) — Particle Physics
  - …

Main Links:

- LEOS Group for the chemistry development
- FBK Team for the readout
- Partner of the EIC (Molecubes, Synective, Univ. Utrecht)

TOPS: Time Of flight Plastic Scintillator

The R&D on fast timing plastic scintillators stared in early 2018 with the chemistry LEOS group of SBAI (L.Mattiello, D.Rocco). Liquid and solid samples have been tested and in the spread panorama of the new elements that we explored so far.. after more than 70 samples, 2 master students, and many many many hours wanting for cosmic rays.. we and up to some promising fluorophores.

This has become …

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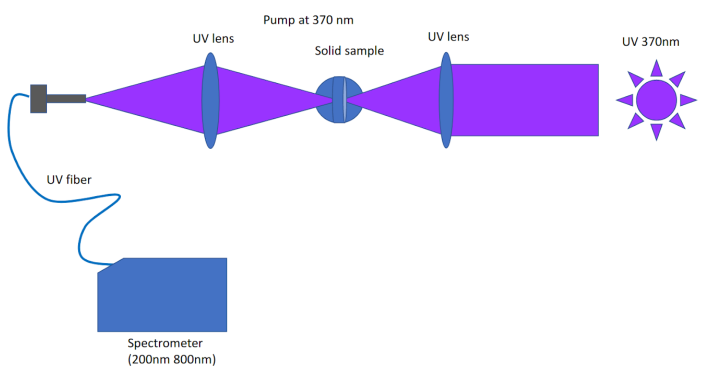
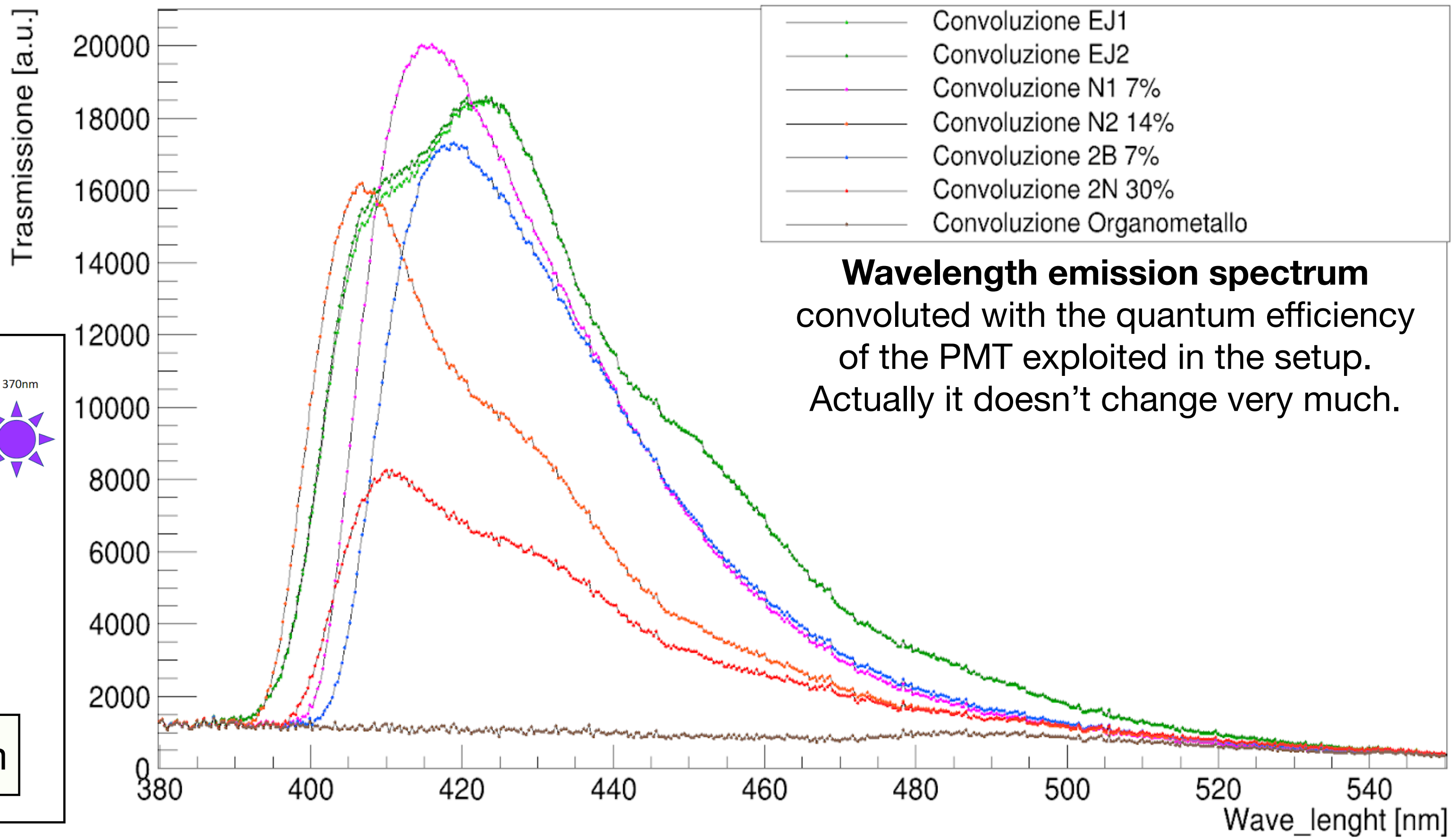
TOPS

We select therefore the 4 new fluorophores that show the best performances in terms of scintillation light spectrum, sample transparency as a function of concentration, overall light output and time response.



Wavelength emission spectrum



Wavelength emission spectrum convoluted with the quantum efficiency of the PMT exploited in the setup. Actually it doesn't change very much.

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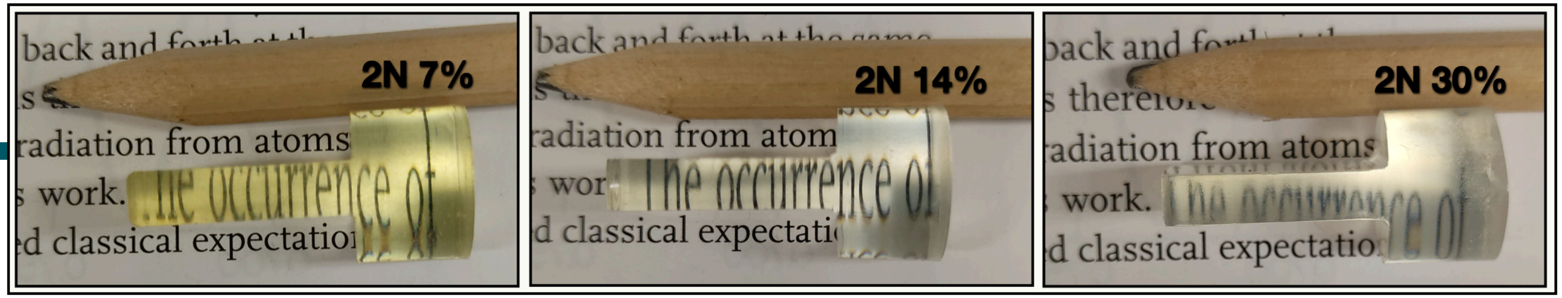
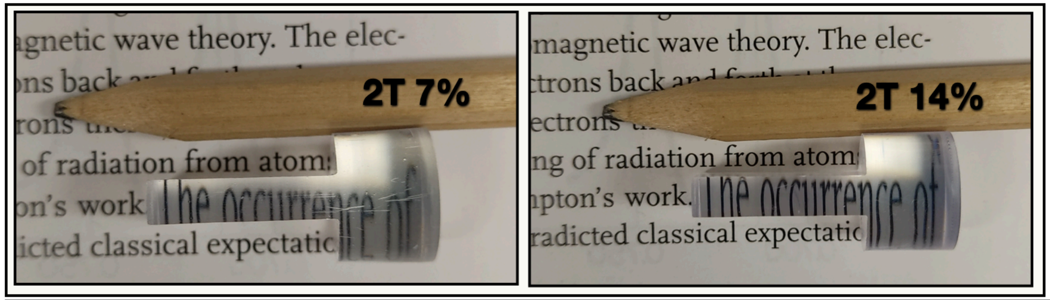
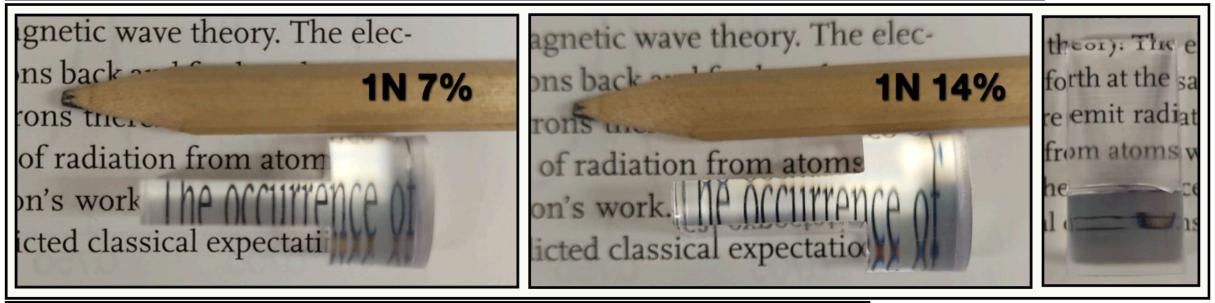
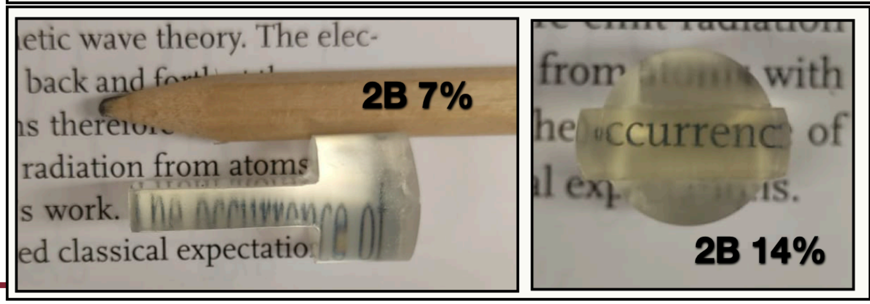




The cylindrical shape is not optimal to take pictures





TOPS

We performed test with cosmics, protons and carbon ions beams. The most recent results have been obtained with cosmic rays at SBAI.

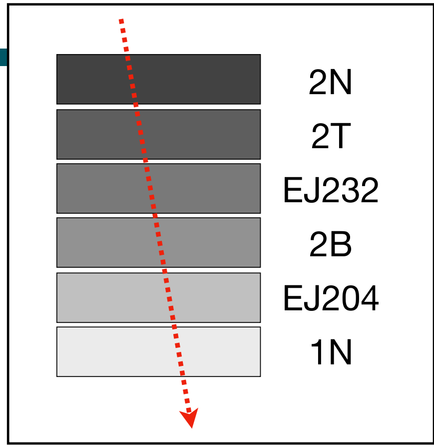
Readout system:

- PMT H10721-20
  - quantum efficiency impacts on the final light output (QE peak at 400nm)
  - rise time (from datasheet) 0.57 ps

DAQ system:

- WaveDAQ

Experimental SETUP



Samples	Primary Dopant	Wavelength emission	Light Output* % EJ232	Rise-Time [ns]	Width [ns]	Time Resolution [ps]
	%	[nm]	*systematic and statistics error 10%*			
EJ-232	-	370	100	2	9	123
EJ-204	-	408	200	2.5	11	211
2N	14%	405	110	2	12	81
2T	14%	-	240	3	18	97
1N	14%	415	155	3	17	102
2B	14%	420	160	2.5	14	110

Best performances have been obtained with samples of a concentration of fluorophores at 14%.

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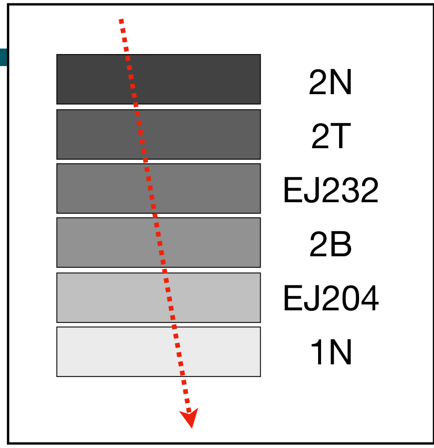

Increase of 55% the light output wrt the most performing commercial scintillator in terms of LY

35% betted than faster commercial scintillator

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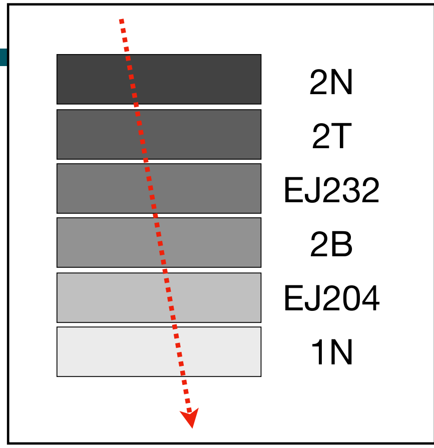
Possible Applications:

- Timing Detectors
- dE/dx Detectors
- Combination of the two

PATENT-PENDING

Experimental SETUP



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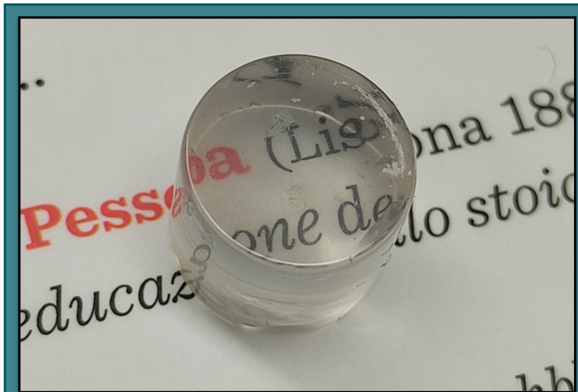
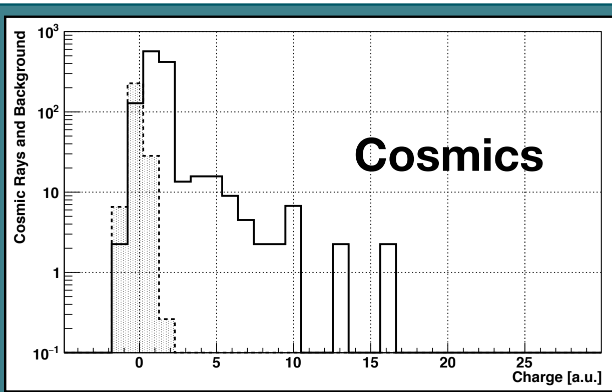
ℇDIT: 3D plastIc scinTillator

Funded by a small Bando di Ateneo 2021-2022 (L.Mattiello)

- CREF (MM) and INFN (Silvio M., Valerio P., Silvia M.)'in kind'
- LEOS (chimici) and SBAI

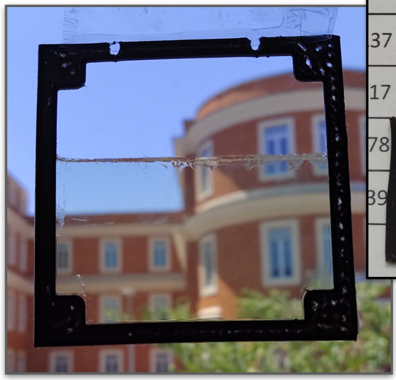
The idea is to exploit the *veroclear* material of the 3D printers and try to integrate in the resin the scintillator.



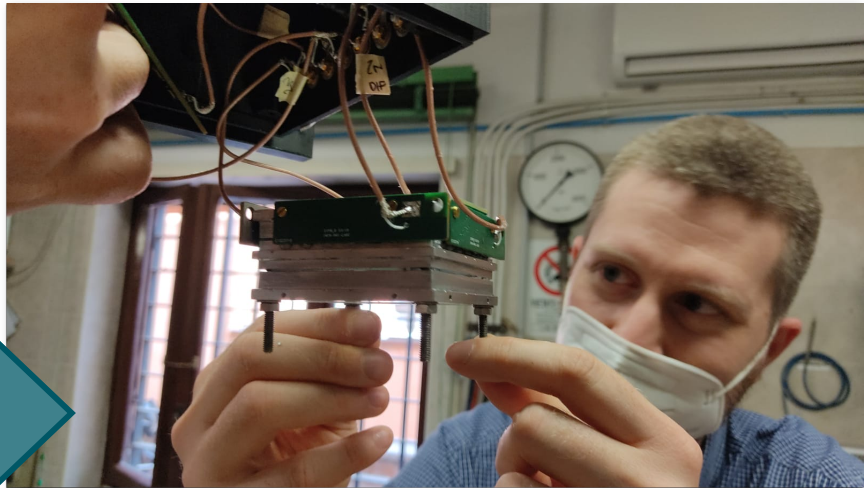


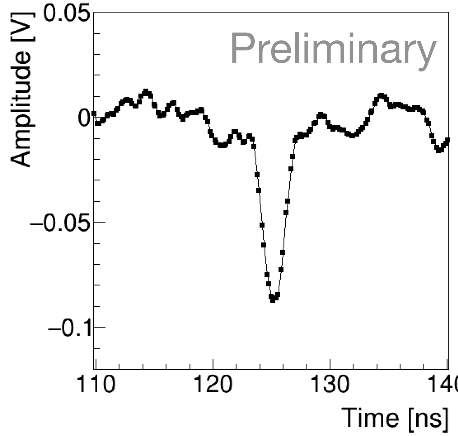
The samples of scintillator dissolved in *VeroClear* liquid and polymerised by UV, have been irradiated with minimum ionising particles (m.i.p, cosmic rays). The light output of the first prototype obtained with m.i.p. irradiation is shown. The background contribution has been superimposed (dashed line) to the signal (black line). The energy loss (dE/dx) of the muon is clearly contributing to the scintillation response with its typical landau shape.

Several Prototypes



Nice pictures but bad performances for now





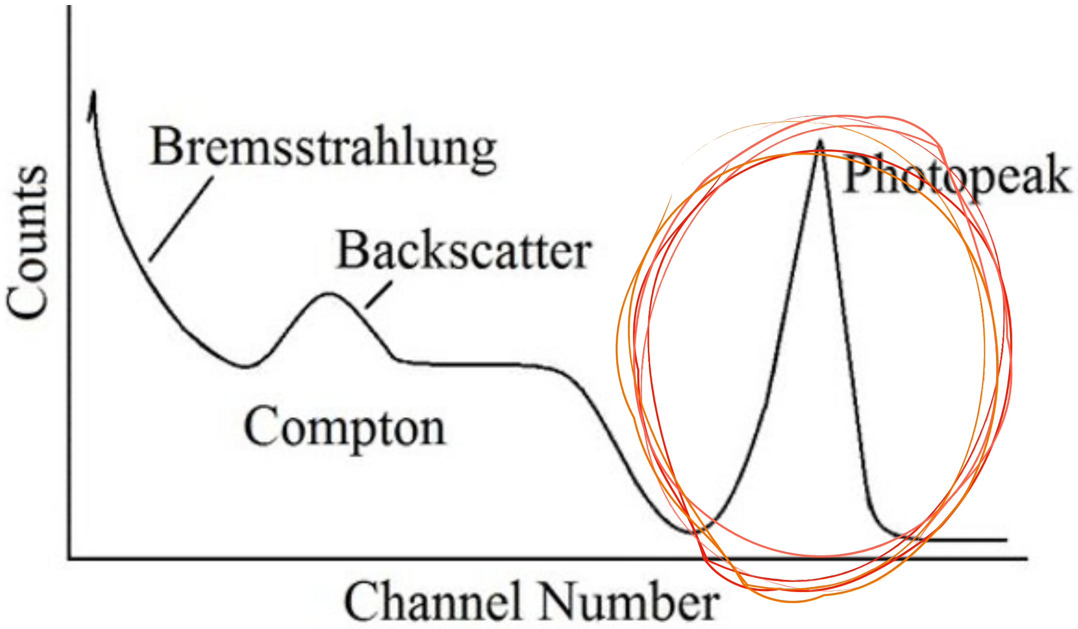
Fast Scintillators

We are starting understanding and really characterising the samples

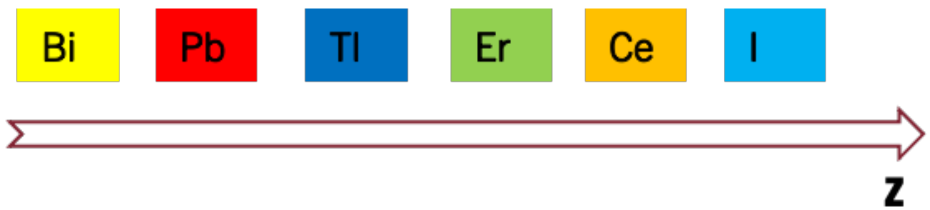
- We characterised the fluorophores from the emission spectra point of view
- We are able to produce samples of scintillators faster than commercial one
- We can also exploit the light output performances, thanks to the high concentration that we can reach with this fluorophores
- Concentration up to 30 %: we need to understand if fluorophore saturates or the transparency decrease the light transmission..
- the 3D potentiality is very interesting.. we have to work..
- ☑ Sometimes we find impurity in the samples (in the fluorophores) that decreses the performances.

Hi-Z Scintillators

The idea (2020) is to work on the R&D of a hi-Z element enriched plastic scintillator, always with the chemistry LEOS group of SBAI (L.Mattiello, D.Rocco). The main goal is to obtain a plastic scintillator in witch low energy photons (100-500 keV) interact via photoelectric effect.



The first application we are working on is the realisation of a SPECT based on hi-Z plastic scintillators.



Several elements have been studied via MC and investigated from a chemistry point of view as a function of concentration (2%-5%-10%-20%-30%-50%)

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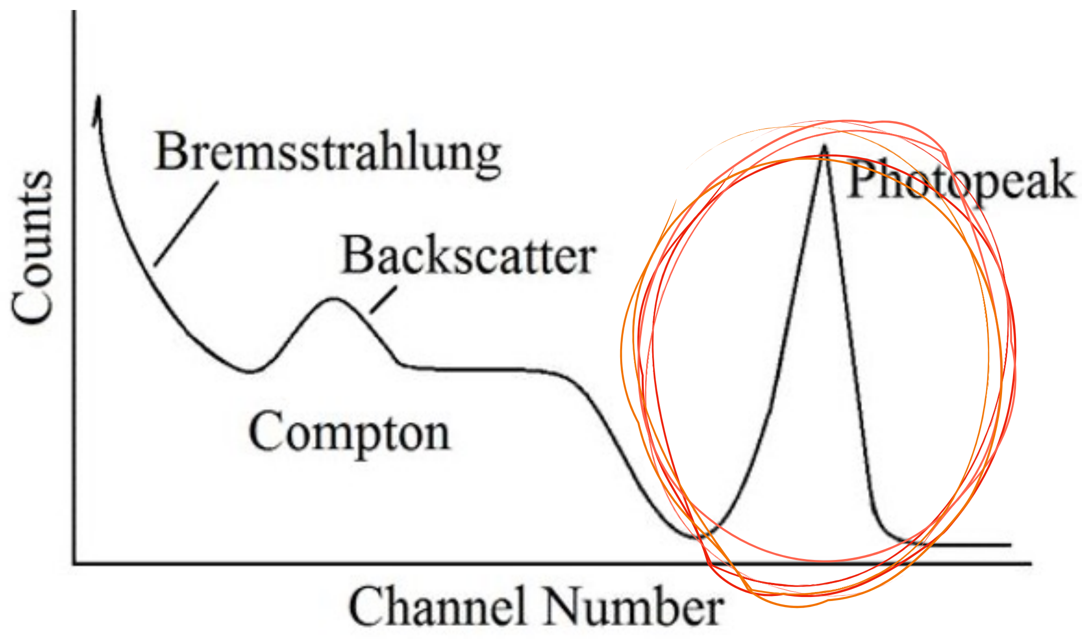

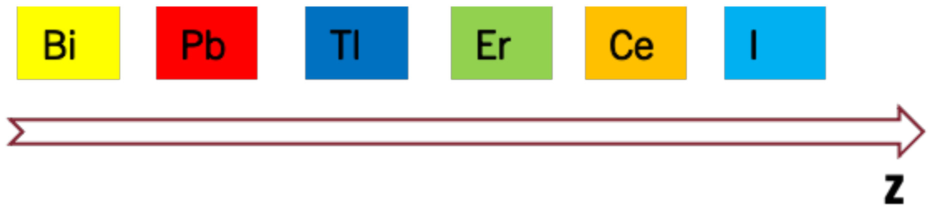

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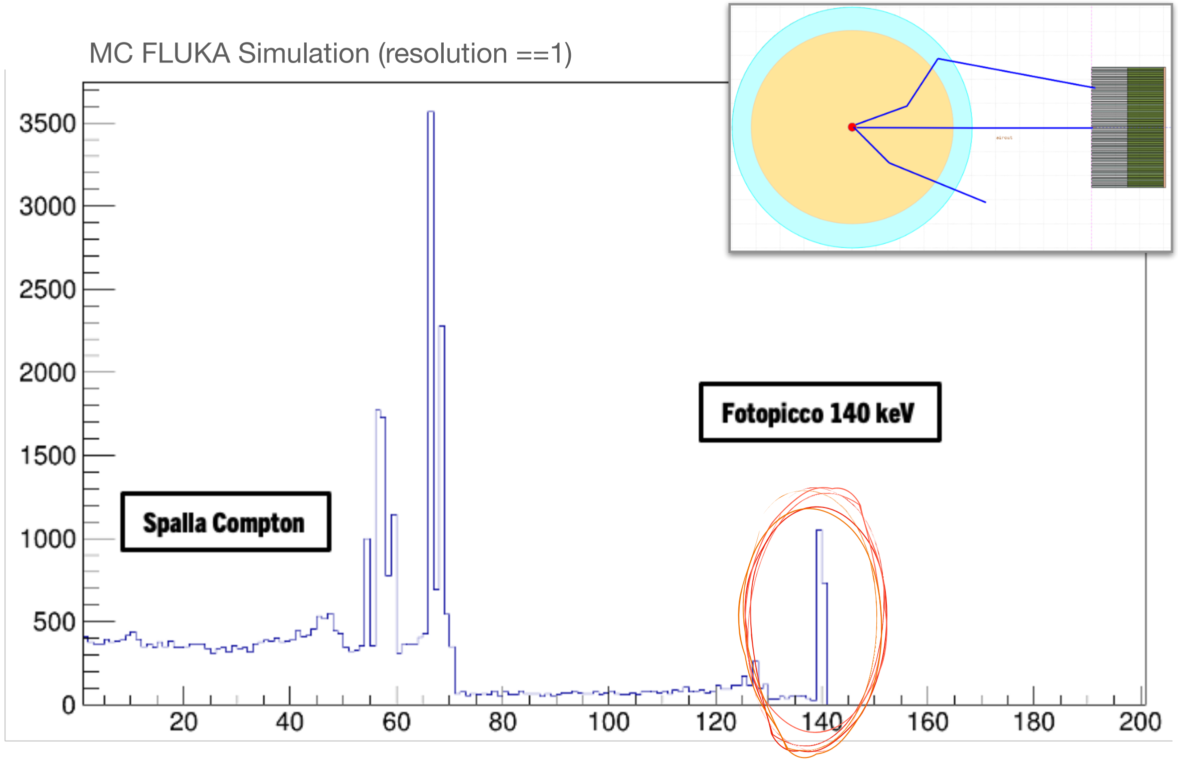

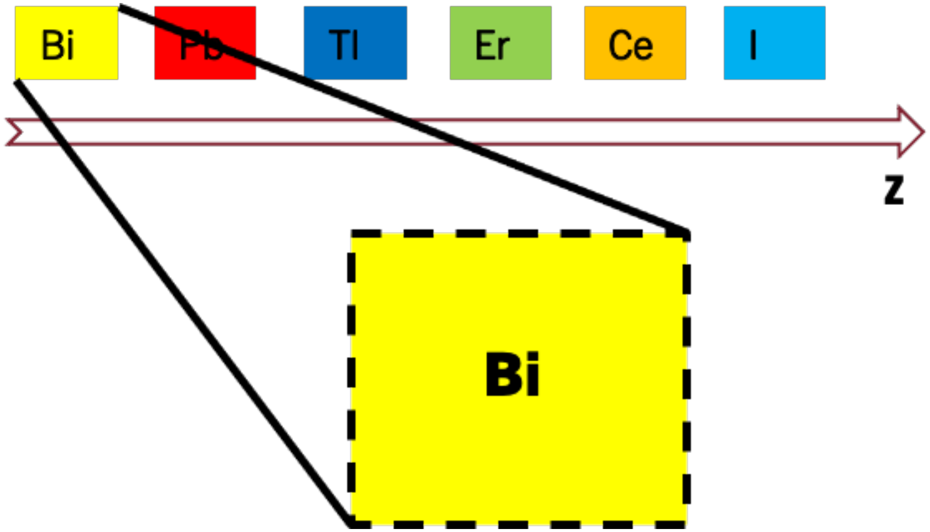

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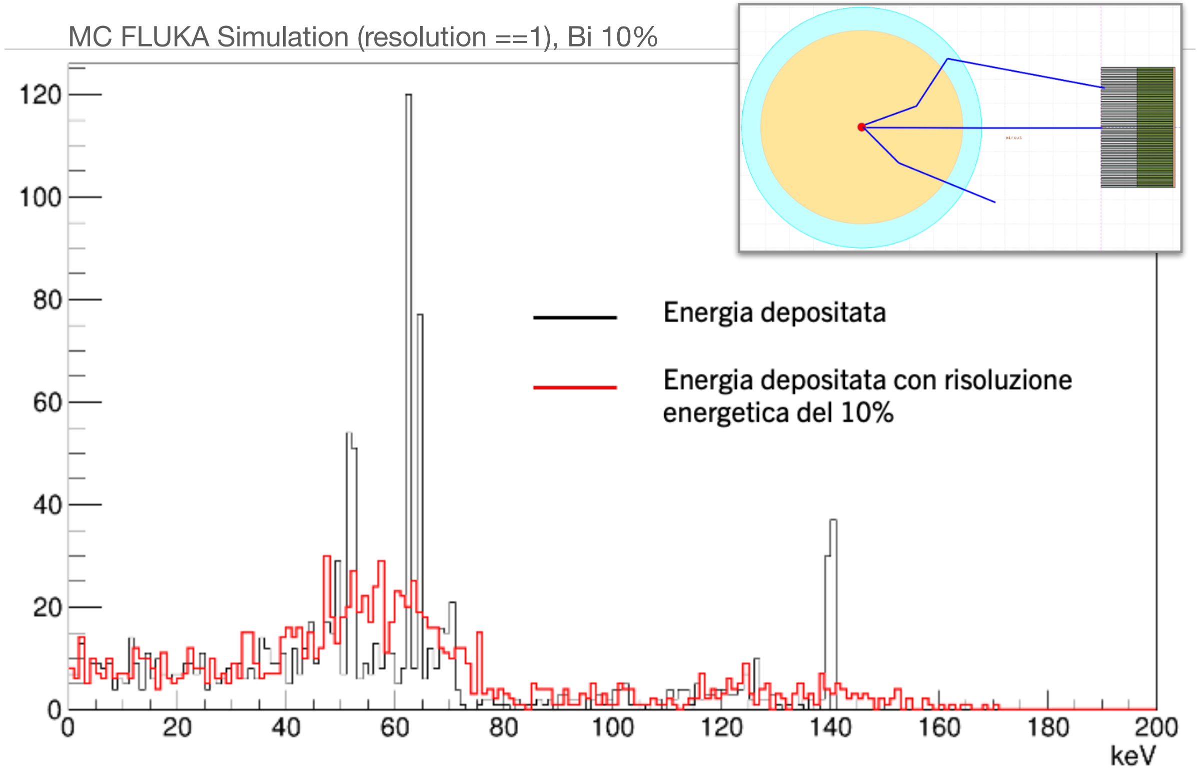
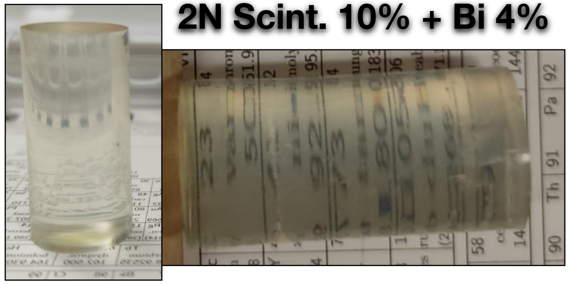


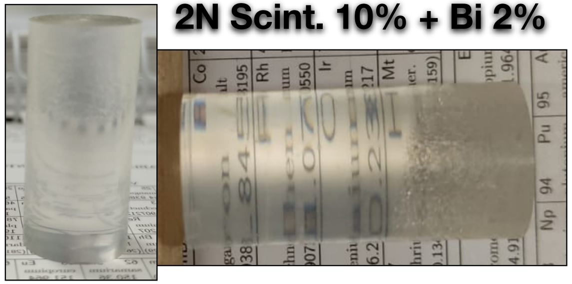
We produced some MC work because of COVID-19.. :) but of course is meaning less if we are not able to produce samples..

Hi-Z Scintillators

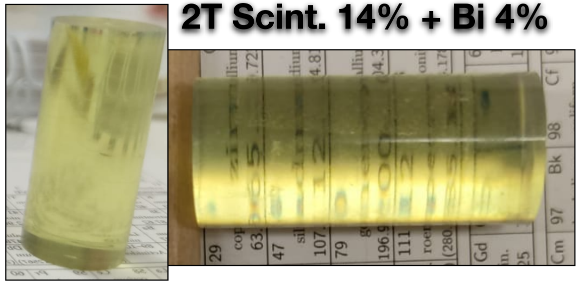
We started with some very bad tentative.. after almost an year we ‘end up’ with nice samples:



2N Scint. 10% + Bi 4%



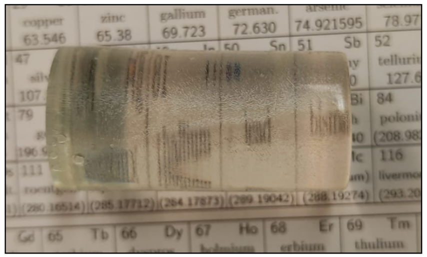
2N Scint. 10% + Bi 2%



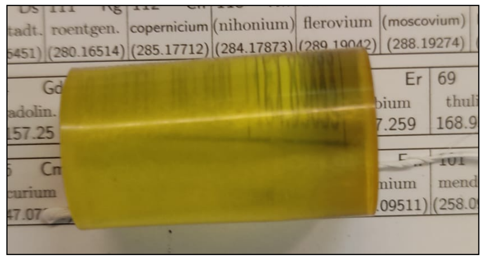
2T Scint. 14% + Bi 4%

standalone hi-Z element

Bi pivalato 5%



Er chinolina



Hi-Z Scintillators

Unfortunately we do not have a 144 keV photon source.. but..

Rif. vostro ordine: Trattativa 1854286 - Ns. rif.: 877-2021MN

Descrizione sorgente	Quantità	Attività sorgente
BDR8122 Ba-133 Gamma Reference Activity tolerance: + 30 %, - 10 % Activity calibrated, DAkkS certificate Drawing: VZ-0477-001 Active diameter: 1 mm Overall dimensions: Ø 25 mm x 3 mm	1	37 kBq

80 keV @ 36%
356 keV @ 69%

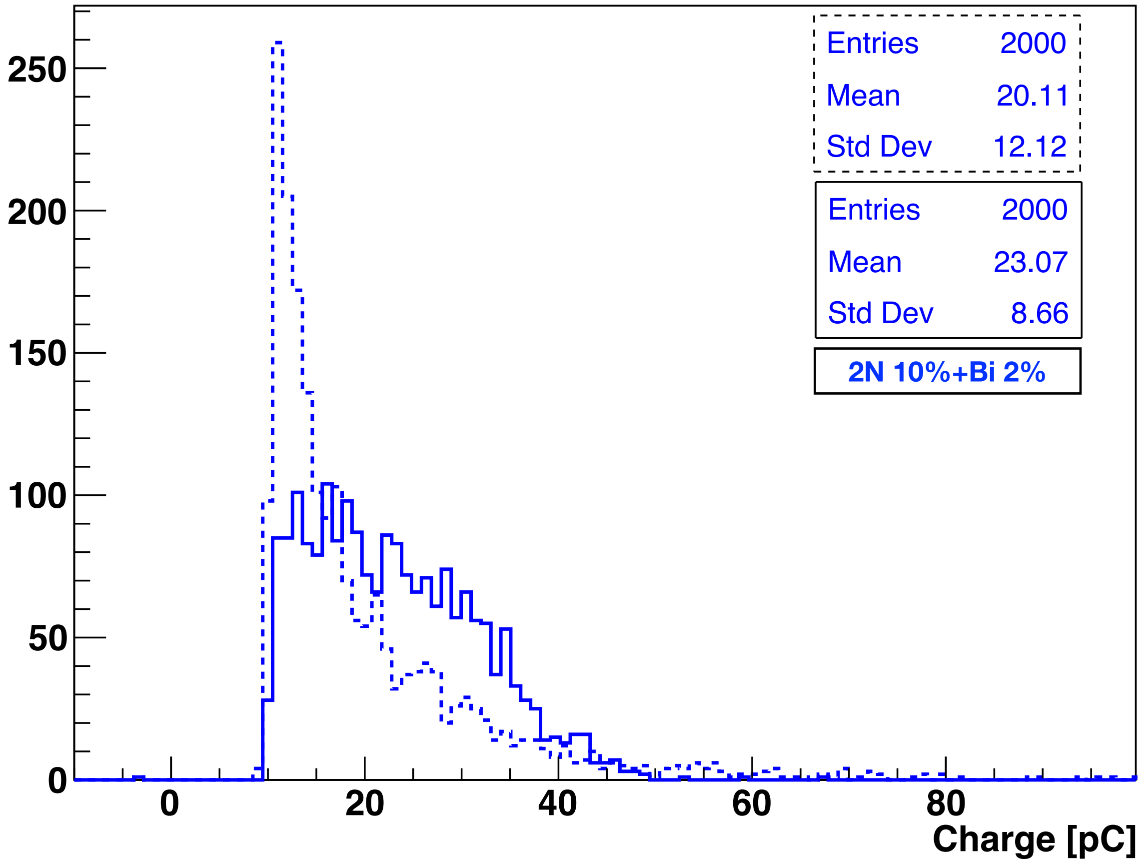
Salvo imprevisti, saremo in grado di consegnarvi il materiale tra fine novembre e inizio dicembre.
Sarà mia cura contattarla all'arrivo della sorgente per prendere accordi sulla consegna.
Rimango a disposizione per eventuali necessità di chiarimento.
Cordiali Saluti

CAMPOVERDE
WAYS TO BE SAFE

In the mean wile we are testing at least the light output of the samples..

Hi-Z Scintillators

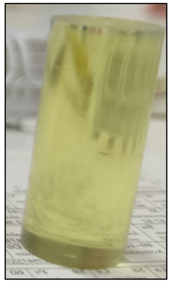
Test of light output with and without 90Sr source



EJ204/BC400

2N 10%+Bi 4%

2N 10%+Bi 2%



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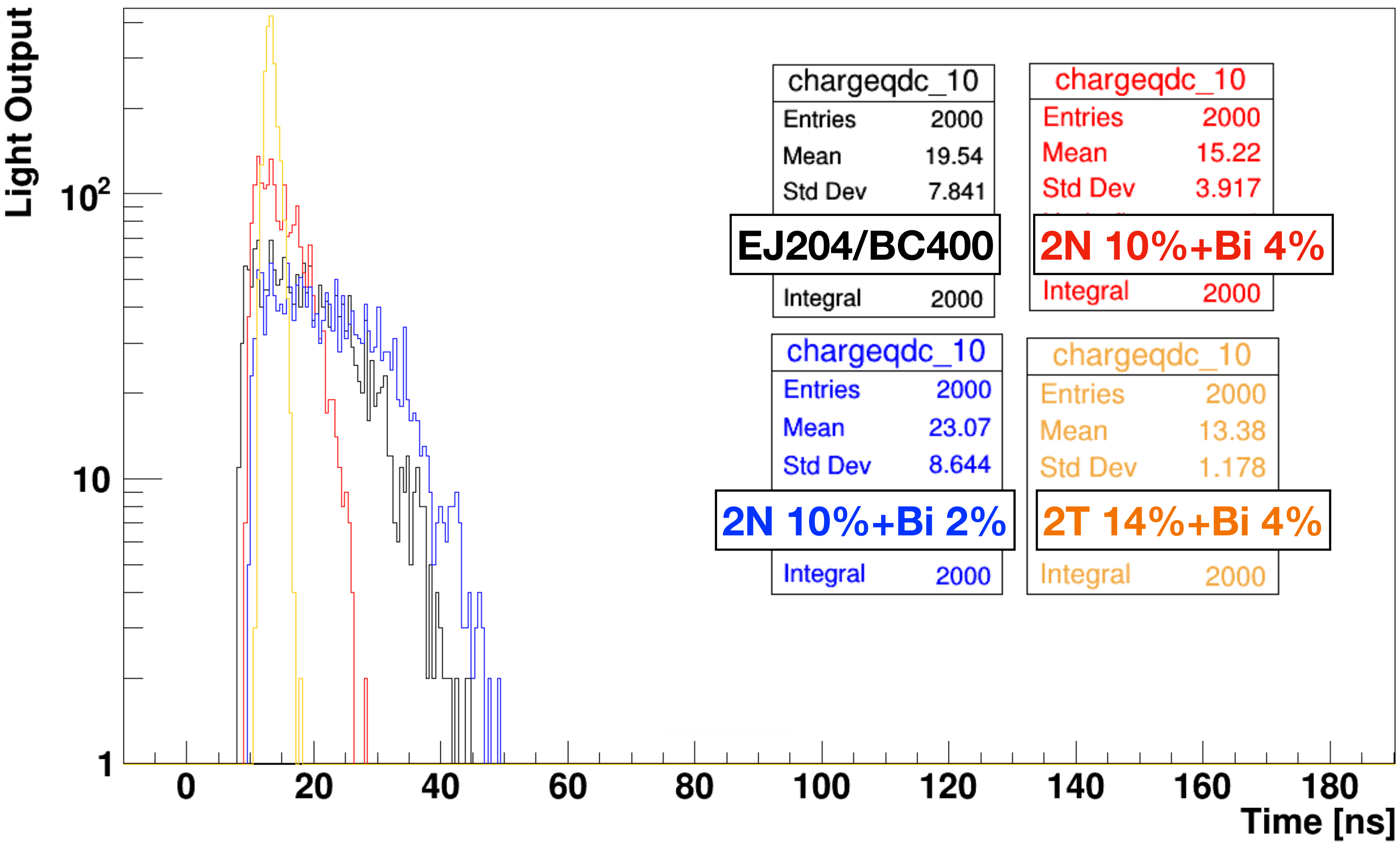

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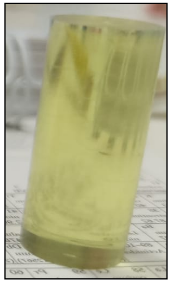


2T 14%+Bi 4%

Hi-Z Scintillators

We are far from understanding if stuff are working.. but at least:

- We are able to produce samples of enriched hi-Z organic scintillators
- Exploiting our scintillators allows to mix staff easily
- Up to 4% we have no transparency problem
- ☑ There is an impurity in half of the Bi pivalato that we produced that has to be removed before producing more samples.

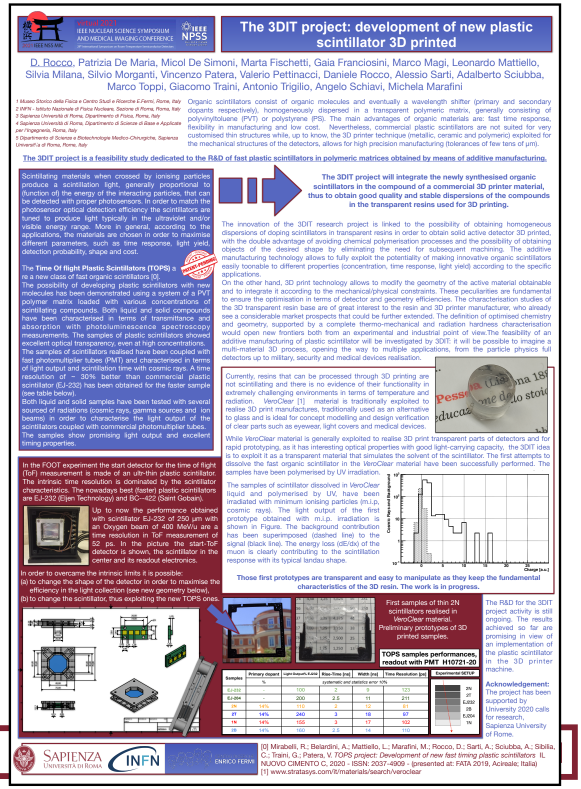
A new master student (Biomedica), Eleonora is working on it..

So.. at the end of the story

- **Fast Timing Plastic Scintillators:**
  - ☑ Patent under submission
  - ☑ Measurements at CNAO (November 2022)
  - ☐ I am my own master student.. can I have one? (Physics)
  - ☑ 3DIT (3D printed scint.): no student but it is ok for now

Paper in preparation

Poster IEEE2021



- **Hi-Z Plastic Scintillators**
  - ☑ Work in progress
  - ☑ A new master student (Biomedica), Eleonora is working on it.
  - ☐ 133Ba source will arrive soon
- **Additional ideas.. (not discussed today)**
  - particle identification (gamma/neutron): we have no time.. next in fashion

Come fai..SBAI