

Medidas neutrónicas con detectores CLYC

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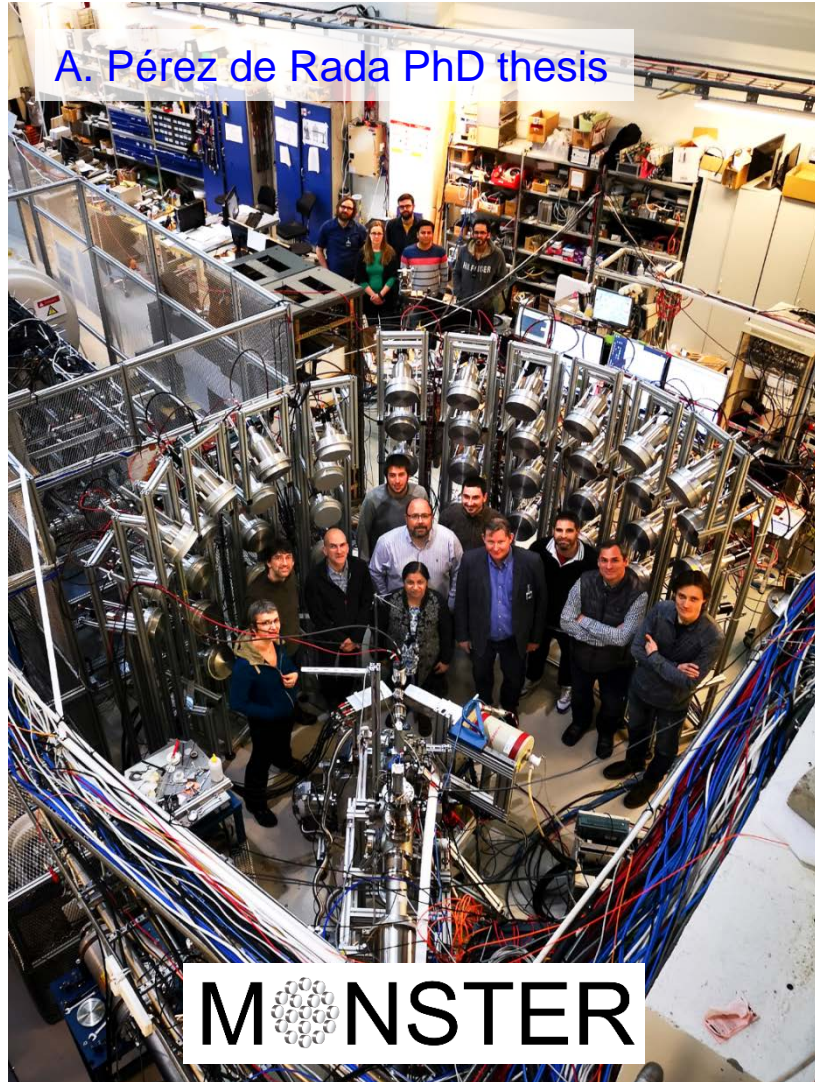
The Nuclear Innovation Unit

Activities:

- Nuclear reactor core design (MCNP, SERPENT...)
- Design and optimization of nuclear waste strategies
- Fundamental nuclear physics experiments at accelerators: CERN (n_TOF and ISOLDE), FAIR, SPIRAL2/Neutrons For Science, PTB...
- Design & construction of nuclear instrumentation: neutron and gamma-ray detectors
- Design of data acquisition systems.
- Development of Monte Carlo codes. Responsible of the G4ParticleHP package.

Nuclear instrumentation

A. Pérez de Rada PhD thesis



MONSTER neutron time of flight spectrometer

- DAQ designed, built and programmed
- Teledyne SP Devices 4-channel 14 bit 1GS/s cards
- Scalable (up to 16 cards)
- Online and offline process
- Online monitor and event builder
- Development of custom routines for analysis



Introduction

- $\text{Cs}_2\text{LiYCl}_6:\text{Ce}$ (CLYC) inorganic scintillator belonging to the “elpasolite” family of crystals.
- Typical gamma resolution $\sim 5\%$ @ 662 KeV
- Thermal neutron detection via ${}^6\text{Li}(n,\alpha){}^3\text{H}$ reaction
- Fast neutron detection possible with ${}^7\text{Li}$ and ${}^{35}\text{Cl}$

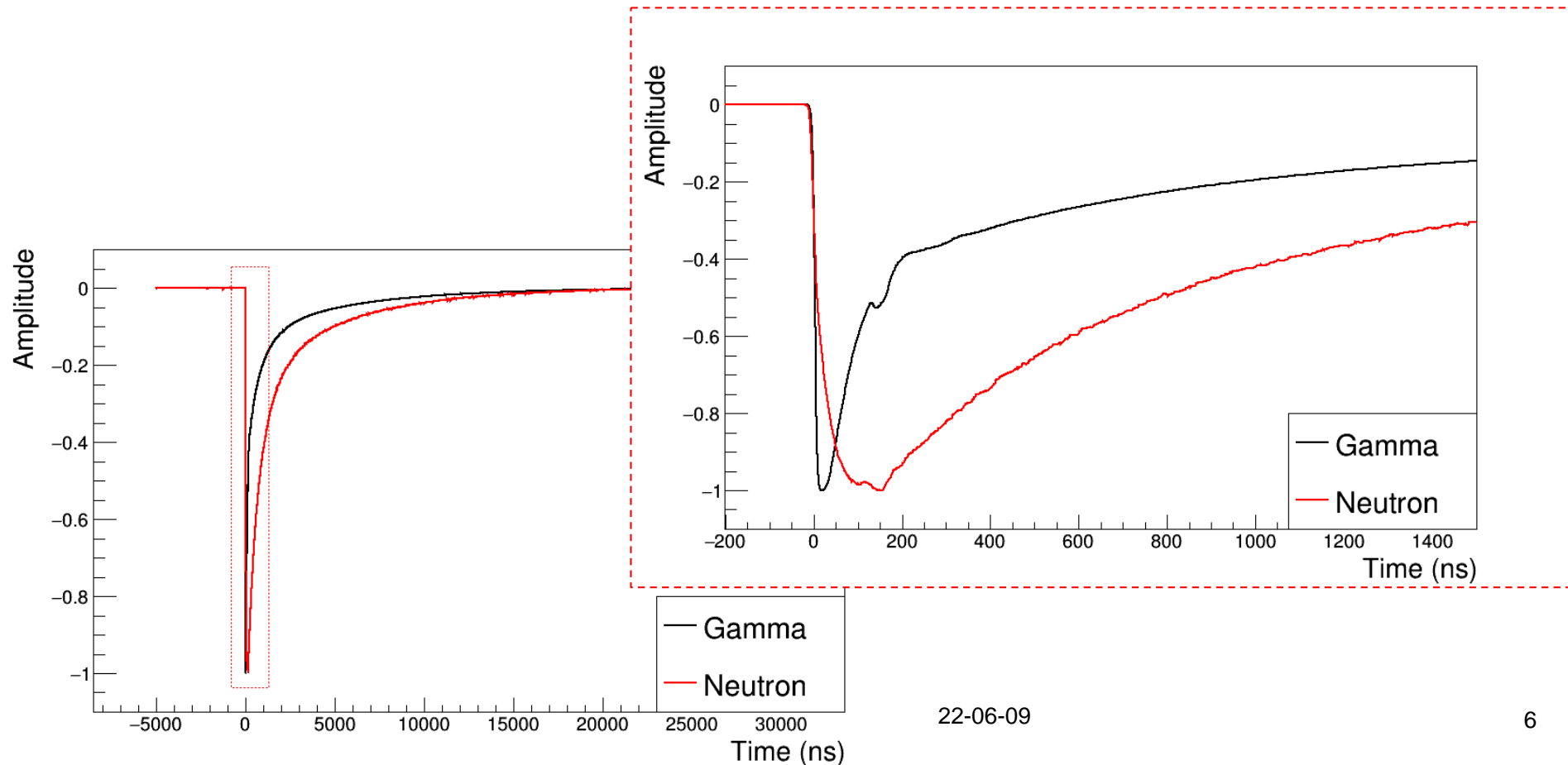
Introduction

- Growth of different sizes and shapes of crystals.
- Possible uses as:
 - Dual monitor system (neutron, gamma)
 - Gamma calorimeter in the presence of high neutron fields (cross section measurements)
 - Possible alternative to ^3He detectors for some applications



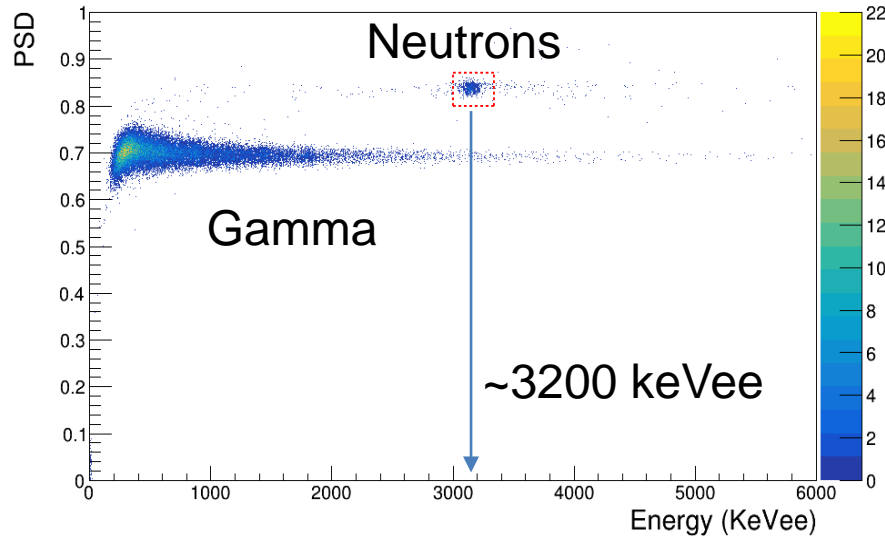
Neutron – gamma discrimination

- Digitalization of signals using our DAQ
- Different signals for gamma and neutron allow for gamma/neutron discrimination.
 - Fast component for gamma



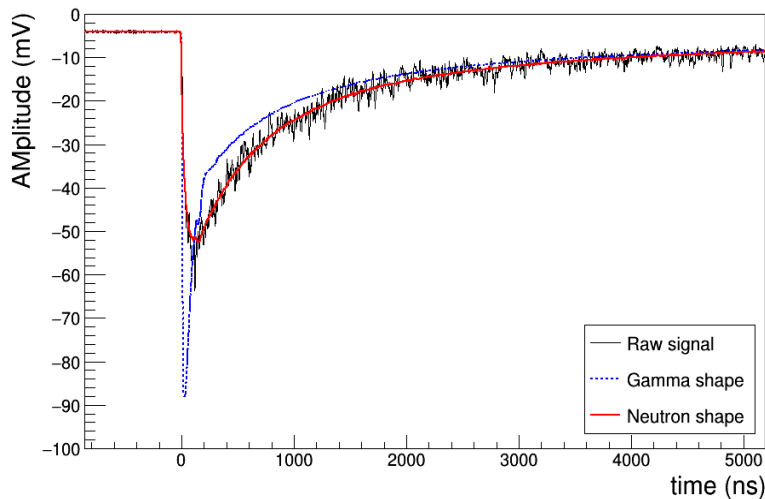
Neutron – gamma discrimination

Area discrimination

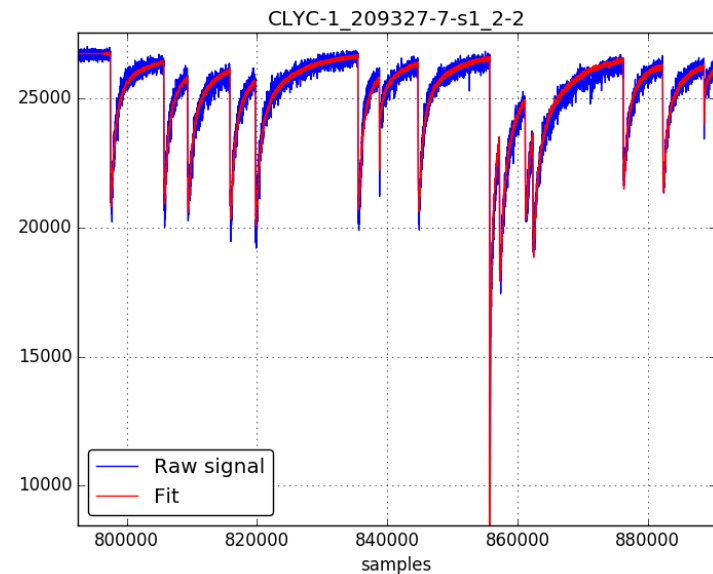


Digitalization of raw signals and development of custom routines allows to make dedicated analysis for each detector type.

Discrimination by fit of average signal

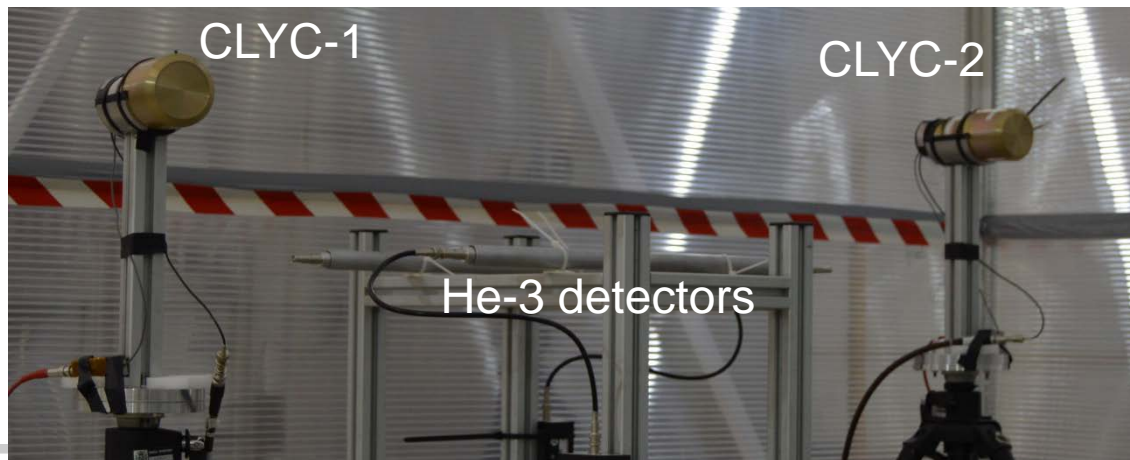


Pile up detection and reconstruction

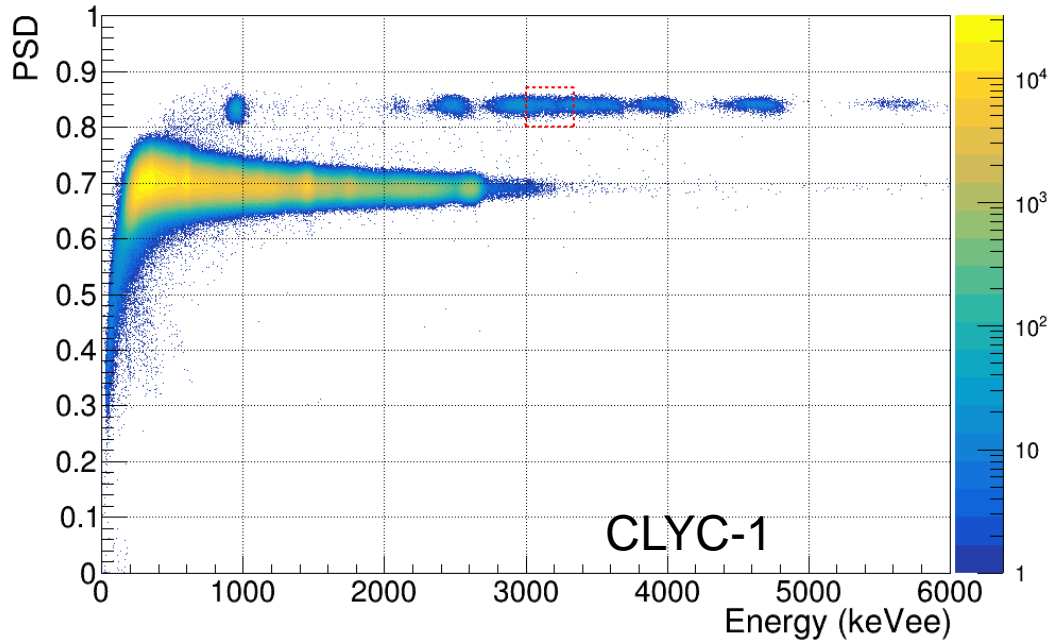


Characterization in low background

- Application in low background environment
 - Monitorization of thermal neutrons
 - Possible use in dark matter detection
- Two 2" CLYCs Characterized at LSC
 - Measurements in open air (background thermal neutrons)
 - Measurements in a 25 cm Pb shield (intrinsic gamma activity)
 - Measurements in a 40 cm Polyethylene Shield (intrinsic alpha activity)
- ^3He detectors for intercomparison

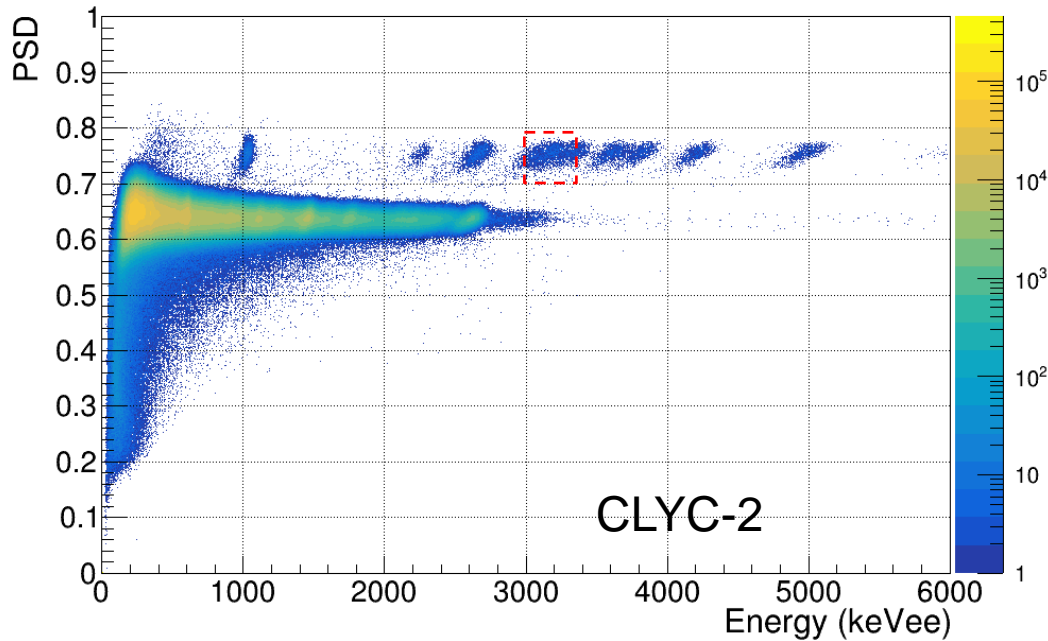


Characterization in low background

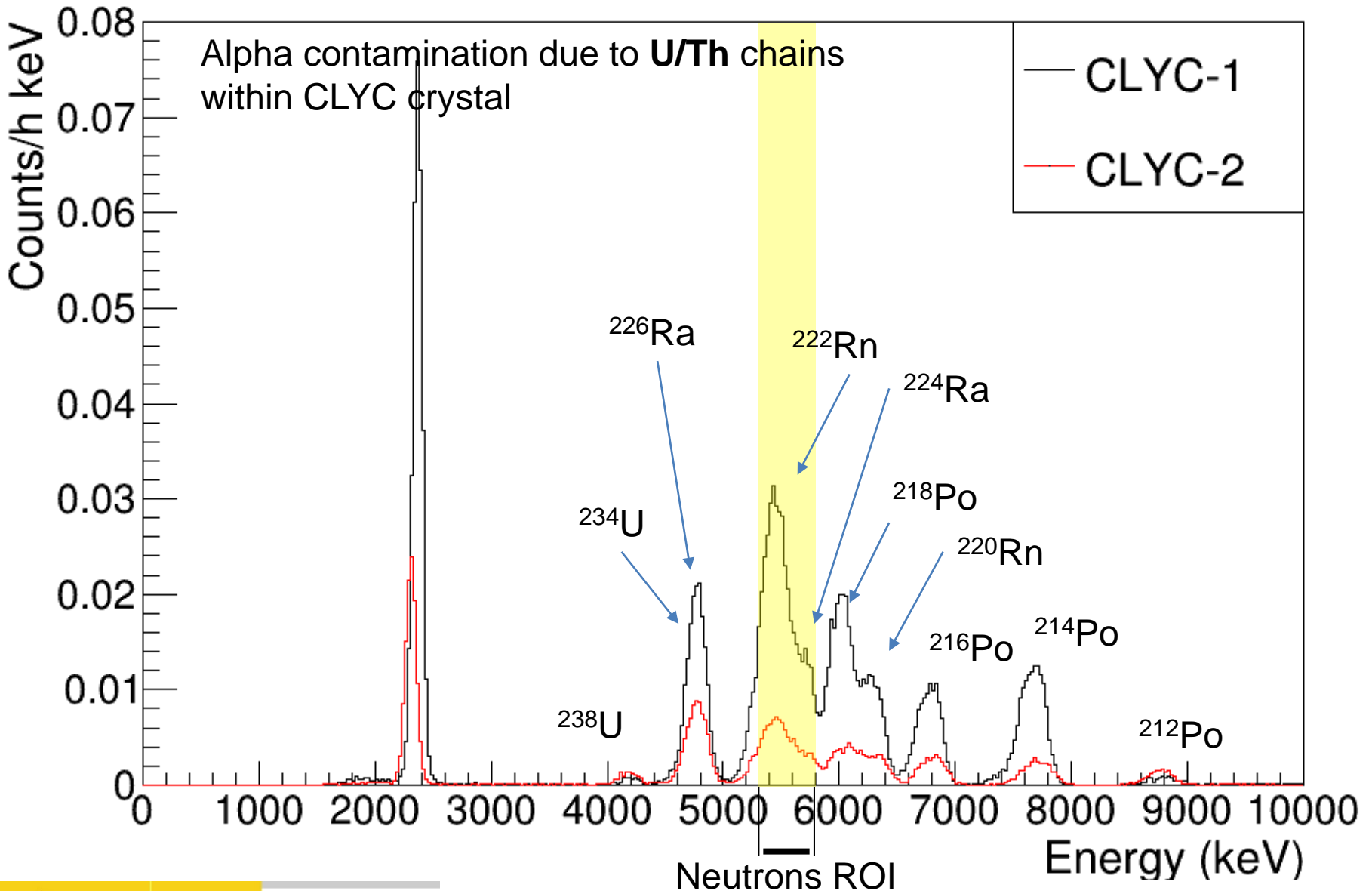


Alpha activity overlaps with neutron signals!

Measured Alpha Activity:
CLYC-1 : 28.9 mBq/kg
CLYC-2 : 8.7 mBq/kg



Characterization in low background



Characterization in low background

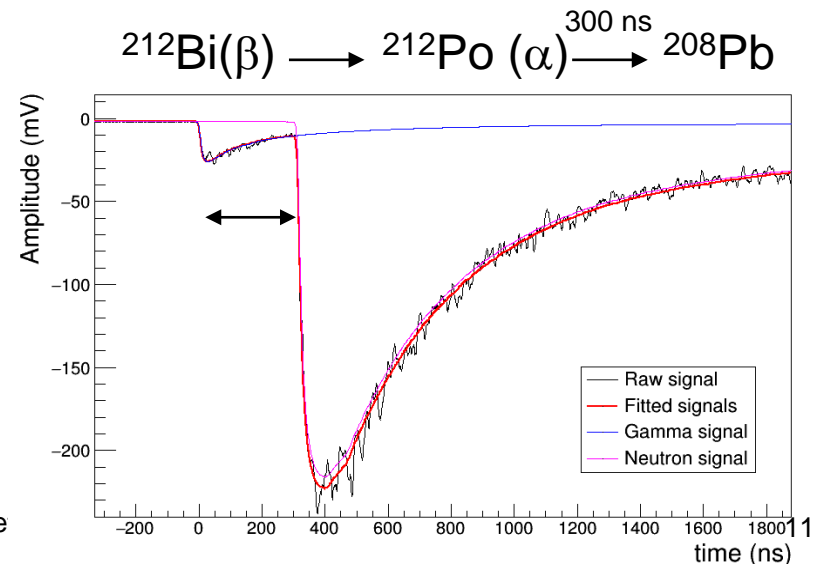
Isotope	Specific Activity (mBq/Kg)	Specific Activity (mBq/Kg)
Th-228	2.08 ± 0.19	0.67 ± 0.11
Ra-224	2.94 ± 0.06	0.82 ± 0.03
Rn-220	2.59 ± 0.05	0.88 ± 0.02
Po-216	2.54 ± 0.04	0.81 ± 0.02
Bi-212 (α)	0.44 ± 0.10	0.24 ± 0.07
Po-212	0.30 ± 0.01	0.47 ± 0.01
U-238	0.15 ± 0.01	0.31 ± 0.01
U-234	2.83 ± 0.13	1.27 ± 0.10
Ra-226	1.24 ± 0.13	0.71 ± 0.10
Rn-222	3.97 ± 0.13	0.97 ± 0.07
Po-218	4.06 ± 0.12	0.76 ± 0.06
Po-214	3.20 ± 0.05	0.78 ± 0.02
Po-210	1.58 ± 0.10	0.37 ± 0.06
Po-215	0.27 ± 0.02	--

Each alpha decay was identified and quantified using a Bayes unfolding

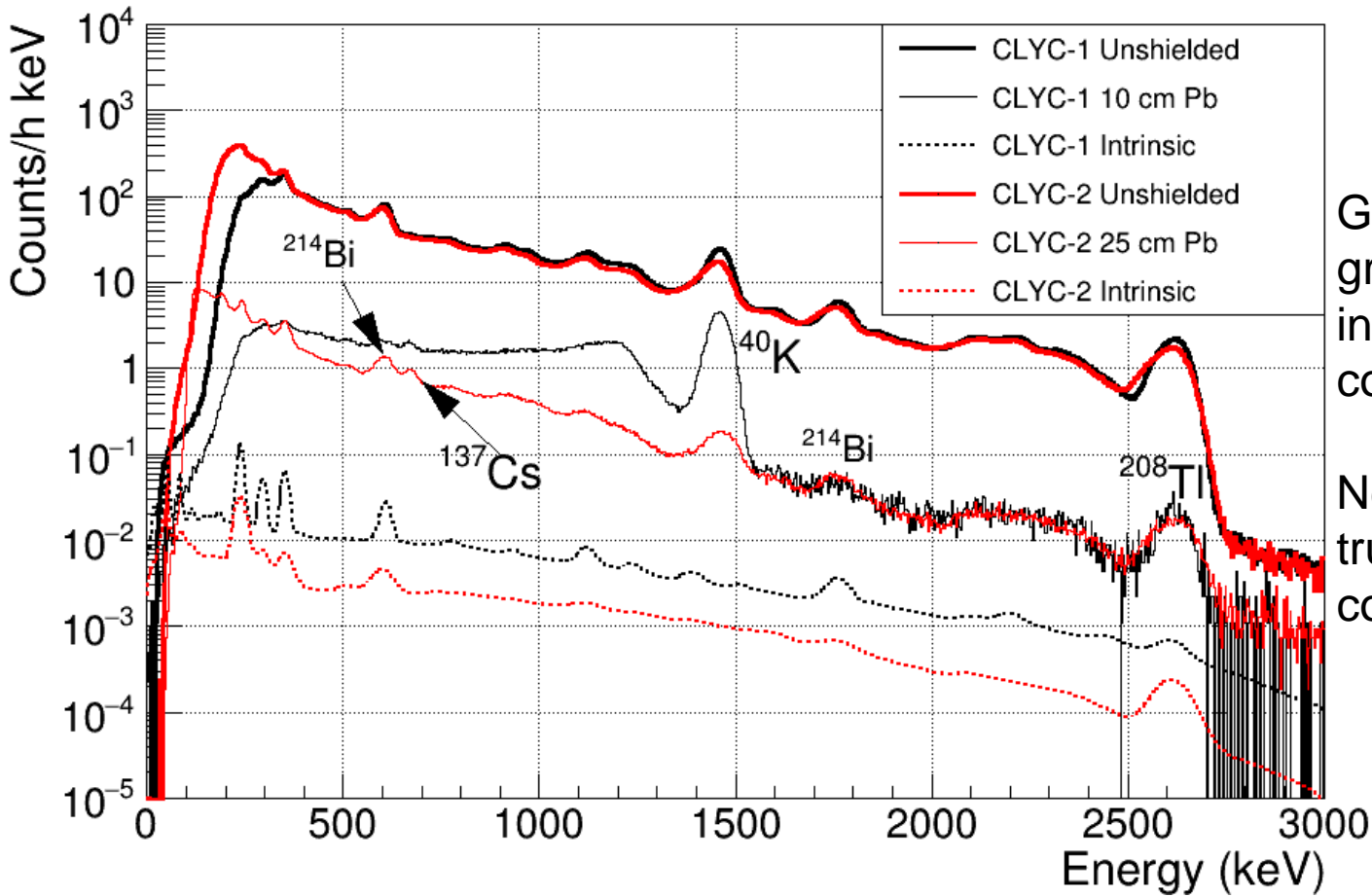
[D'Agostini, NIM-A 362 \(1995\) 487](#)

Uncertainties are only of statistical natures

Equilibrium was not imposed in the unfolding procedure



Characterization in low background

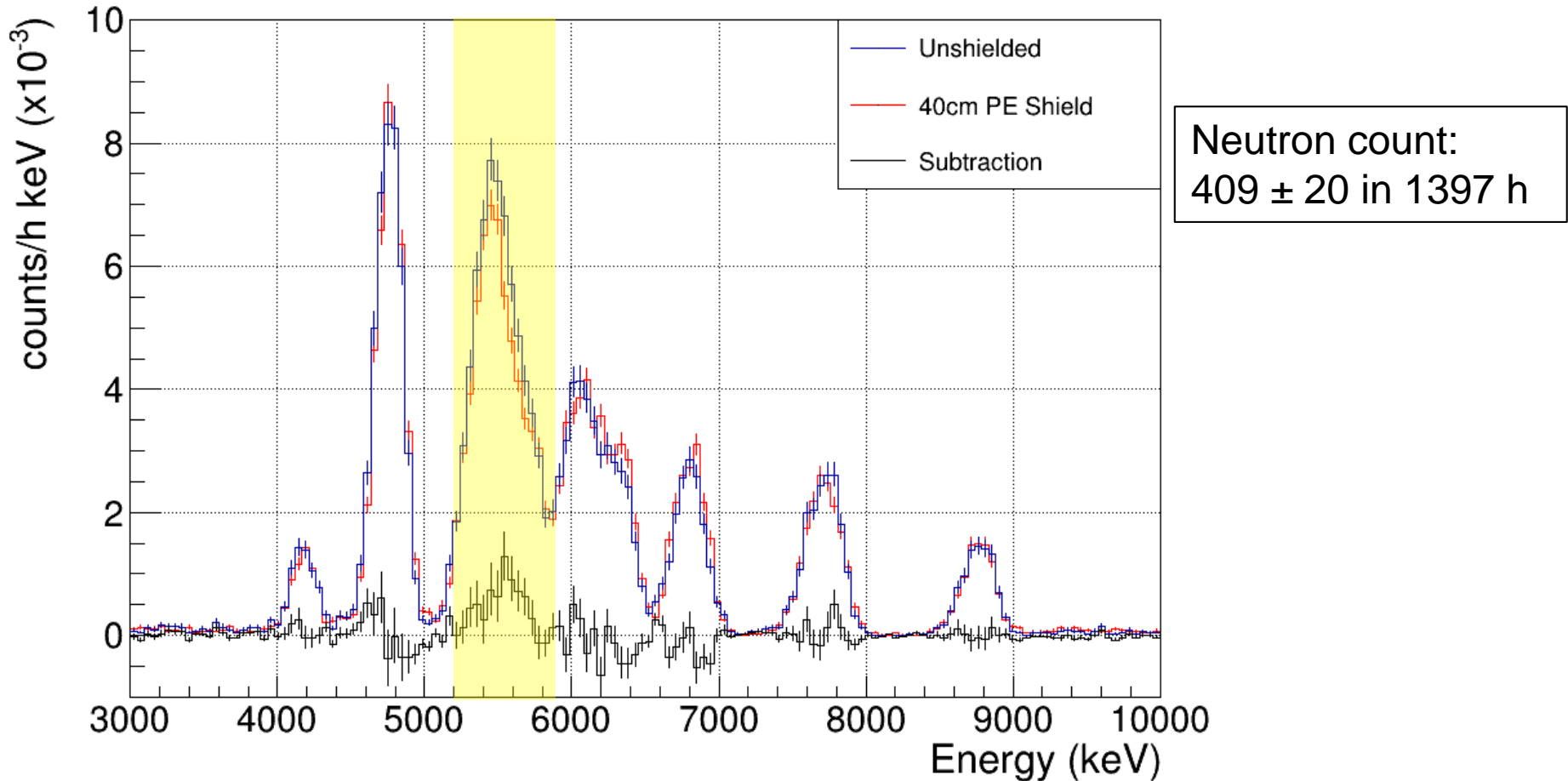


Gamma contamination greater than only taking into account alpha contamination

Need a screening to truly identify the contamination sources

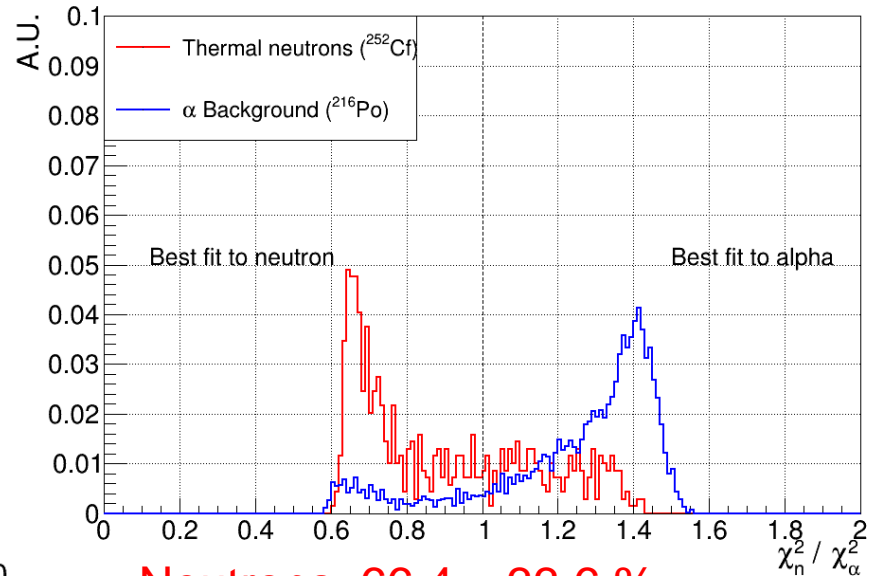
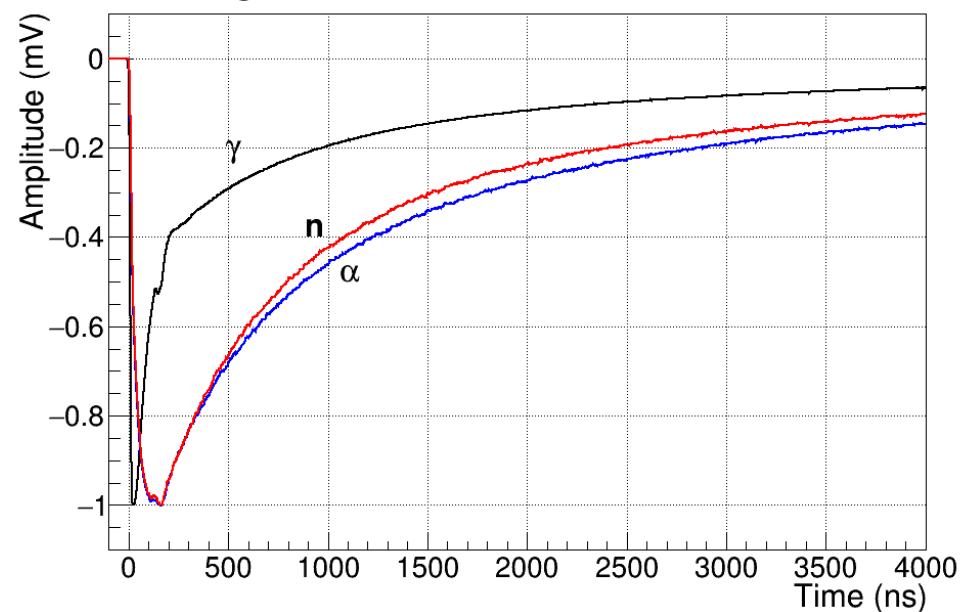
Neutron measurements in low background

- Alpha signals overlap and hide neutrons
- Subtraction method: Open air vs Polyethylene measurements



Neutron measurements in low background

- Alpha signals overlap and hide neutrons
- Pulse shape analysis method: small differences between alpha and neutron shapes
- Fit signals to each shape



Neutrons: 66.4 – 33.6 %

Alphas: 14.7 – 85.3 %

Mixed: 20.9 – 79.1 %

The different distributions of fits for neutron, alpha, and mixed signals, allows to interpolate and estimate the real number of neutrons within the total counts in the region of interest.

$$K_{mix} = K_n x + K_\alpha (1 - x)$$

$$N_{neutrons} = x N_{ROI}$$

Neutron counts: 420±80 in 1397 h

Neutron measurements in low background

$$R = S\Phi$$



Calculated by Monte Carlo (GEANT4, MCNP)

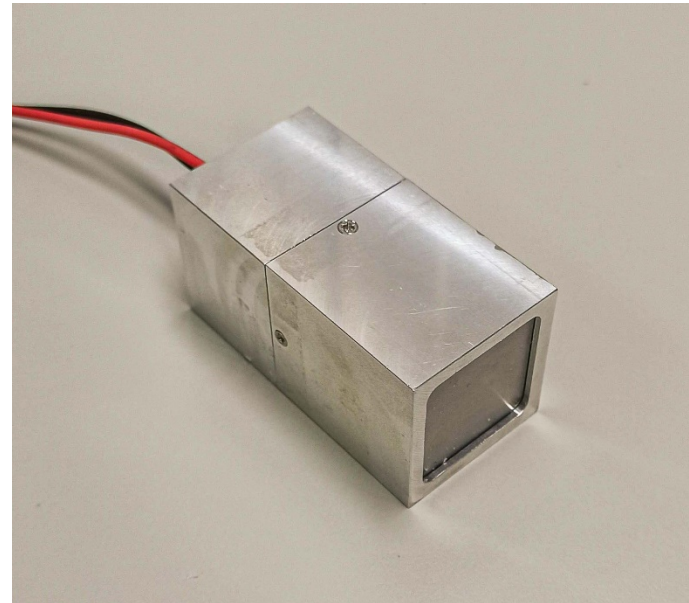
Detector	Neutron rate (c/s)	Sensitivity (cm ²)	Flux (cm ⁻² s ⁻¹)
CLYC – 1 (pulse shape)	$(0.84 \pm 0.16) \times 10^{-4}$	20.14	$(4.1 \pm 0.8) \times 10^{-6}$
CLYC – 2 (subtraction)	$(0.81 \pm 0.04) \times 10^{-4}$		$(4.0 \pm 0.2) \times 10^{-6}$
³ He	$(2.64 \pm 0.06) \times 10^{-4}$	67.69	$(3.9 \pm 0.1) \times 10^{-6}$

Despite the intrinsic contamination and different methods used, the results are compatible with that obtained using ³He detectors.

These detectors were NOT specifically designed for low background. It means there is room for improvement

CLYC as γ -n spectrometer / dosimeter

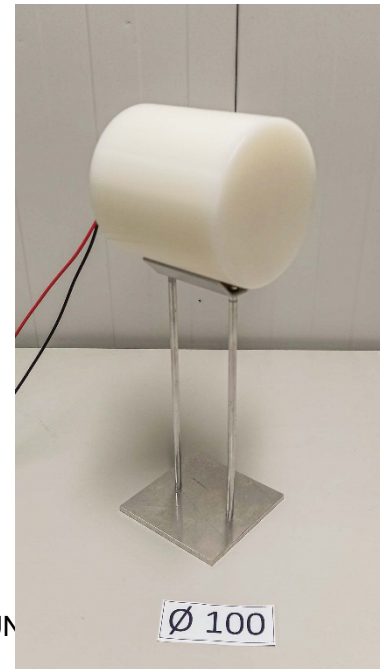
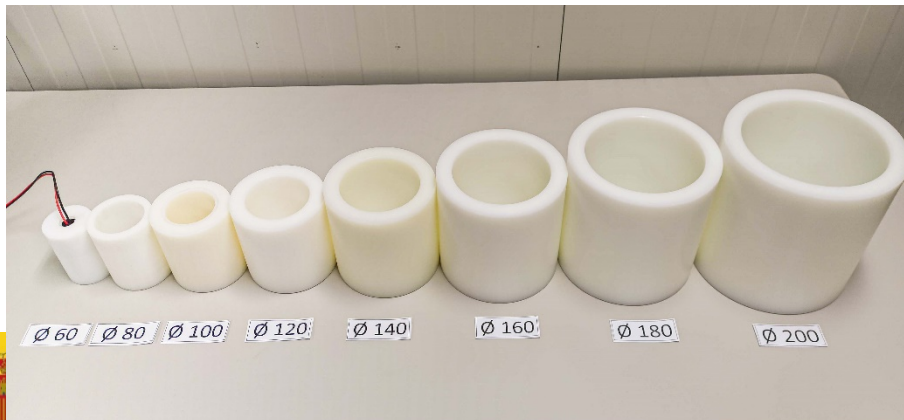
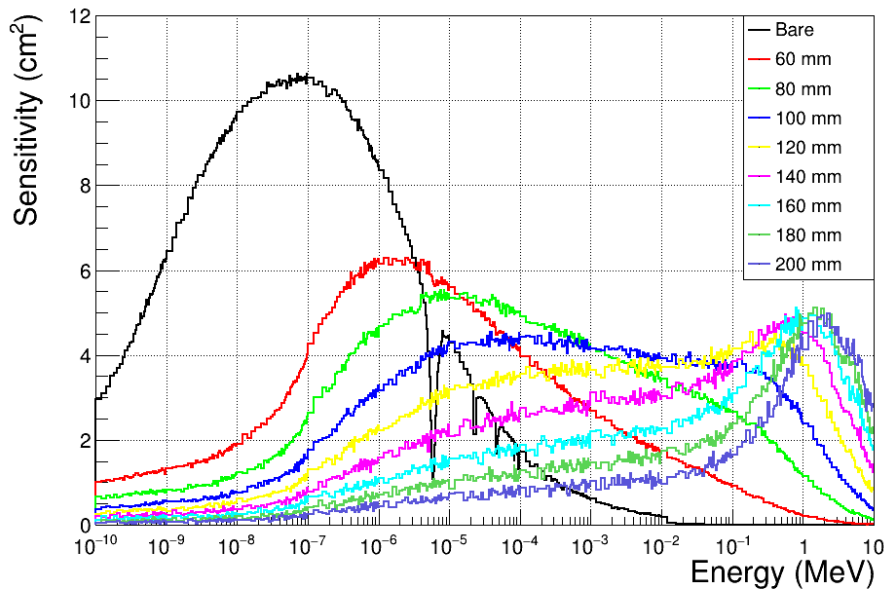
- Characterization of nuclear waste
- Dosimetry in nuclear facilities
- Measurement of neutronic fields in proton therapy



CLYC signals are 10 – 100 times faster ($\sim 1 \mu\text{s}$ vs $100 \mu\text{s}$) compared to ^3He preamplified signals -> good features for measuring at high counting rates: flash proton therapy or closer to the phantom

CLYC as γ -n spectrometer / dosimeter

- 1" cubic CLYC inserted in polyethylene cylinders (Bonner– like system)
- Monte Carlo calculation of response for each cylinder
- Deconvolution process to obtain the dose
- Measurements at LPN



Conclusions

- CLYC main feature is a good n-gamma discrimination. It presents a high efficiency due to ${}^6\text{Li}$ reaction
- Two 2" detectors were characterized for use in Low Background environments. Despite the contamination, two methods were used to obtain the neutron flux, and is compatible to the one obtained with ${}^3\text{He}$ detectors.
- Detectors were not specific for low background applications: there is room for improvement
- Currently developing a spectrometer for dosimetric applications, using Bonner-like setups. Potential applications in Nuclear Waste characterization, radiation measurements at nuclear & proton therapy facilities.