Eysenhardtia polystachya (Kidneywood): Pigment and Fluorite Used as Scintillator Media.

Juan Carlos Toledo Sánchez, Pablo Iván Mora Soto, Haziel Bárcenas Flores, Paola González Hernández, Uriel Alexis Guzmán Arias, Erick Emmanuel Marino Cruz, Marco Alejandro Pacheco Conde, Diego Alfonso Ramírez Pérez, Oscar Uriel Guevara González

UNAM Escuela Nacional Preparatoria Plantel 6 "Antonio Caso"

Assessed by:
Laura Helena González Trueba, Rodolfo Ezequiel López Romero

April 2025

Pumas in Kollision

Contents

Abstract

Two scintillator detectors were constructed using the pigment Eysenhardtia polystachya, commonly known as Kidneywood, in an aqueous solution and a fluorite crystal, coupled to a silicon photomultiplier. These media were tested as scintillator media with a Sr^{90} electron source with an energy range of 0.5 to 2 MeV, obtaining a mean amplitude on the oscilloscope of 10 mV; with a frequency of 2 particles per second for flourite and 1 particle per second for the pigment.

1| Introduction

Scintillators are materials that emit light when interacting with ionizing radiation. This occurs when radiation excites the electrons of the material, which, when returning to their base state, emit photons on the ultraviolet-visible spectrum. This principle is widely used in the detection of particles in fields such as medicine, industry, and scientific research. Depending on its composition, scintillators can be organic (based on polymers or liquids) or inorganic, like crystals of NaI(Tl or CsI(Tl), each one with specific properties of sensibility and resolution.

Kidneywood (*Eysenhardtia polystachya* [1]) stands as a plant with broad uses in alternative medicine for its diuretic and antioxidant properties[1]. Its cultural and medicinal importance has made it widely marketed in markets and naturist stores of the country.

Also presents a peculiar optical phenomenon in its aqueous infusion: the light absorption in the ultraviolet spectrum generates a blue emission, similar to some colloidal scintillators. Another relevant resource in Mexico is the fluorite (calcium fluoride, CaF_2), a mineral with a great strategic and economic value, inasmuch as the country is one of the world's leading producers [2].

The fluorite is used in optics, metallurgy, and chemical industry [2]. In its doped form —particularly with rare-earth elements such as europium (Eu^{3+}) or cerium (Ce^{3+})—fluorite has been shown to function effectively as an inorganic scintillator, useful in applications such as radiation detection and dosimetry. Undoped CaF_2 scintillators are used in cryogenic conditions and for fast neutron detection [3] [4].

Scintillator materials are coupled to photosensors such as photomultiplier tubes (PMTs) or silicon photomultipliers (SiPMs). Silicon detectors are highly sensitive semiconductor devices that operate by generating electron-hole pairs when radiation is incident on them, enabling precise measurements in nuclear spectroscopy and particle physics. It is our interest to test such materials as scintillation detectors and make a comparison of their detection efficiency by observing their amplitude distributions, rise times, and obtaining a ratio of the particles measured per spill and the particles detected by both scintillation media 1, and using a commercial scintillator as a reference.

$$\epsilon_{tot} = \frac{\text{register events}}{\text{events emited by the source}} \tag{1}$$

2| Theoretical framework

2.1| Radiation-Matter Interaction

In inelastic collisions, heavy particles such as pions, kaons, or muons deposit energy into the atom, causing it to become ionized or excited. This energy loss by the particle is only a small fraction of its kinetic energy. The energy loss per unit length is given by the Bethe-Bloch formula, equation 2.

$$\frac{dE}{dx} = 2\pi N_a r_e^2 m_e c^2 \ \rho \frac{Z}{A} \frac{z^2}{\beta^2} \left[\ln \left(\frac{2m_e \gamma^2 v^2 W_{\max}}{I^2} \right) - 2\beta^2 \right] \tag{2}$$

where,
$2\pi N_a r_e^2 m_e c^2 \ = \ 0.1535 \ MeV\text{-}cm^2/g$
ρ: Material density
r_e: Electron radius
z: Charge of the incident particle
m_e: Electron mass
$\beta = \frac{v}{c}$ of the incident particle
N_a: Avogadro's number
$\gamma = \frac{1}{\sqrt{1-\beta^2}}$
I: Excitation potential
$W_{\max}$: Maximum energy transferred in a single collision
Z : Atomic number of the absorption medium
A: Atomic weight of the absorption medium

The energy loss as a function of kinetic energy can be seen in Figure 1.

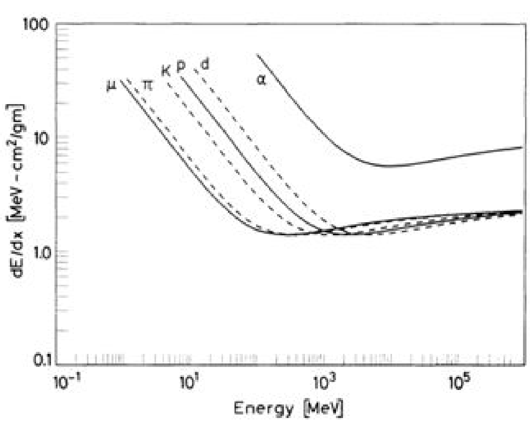

Figure 1: Energy loss as a function of kinetic energy for different particles [9].

The energy loss decreases as the particle increases its speed to $v = 0.96c$, so a loss minimum is reached (figure 1), and this particle is therefore known as the ionizing minimum. This minimum of 1 MeV is observed for pions and muons [9].

When heavy particles slow down as they pass through the material, the rate of energy loss changes as the kinetic energy changes, so there will be an increase in energy per unit length accumulated at the end of the particle's path.

Fluorite (CaF_2) absorbs best at specific wavelengths within the ultraviolet spectrum, particularly around 254 nm and 365 nm, depending on the excitation conditions. These properties are related to its fluorescence, which is due to the presence of elements such as uranium, manganese, and rare earths [6].

The absorption spectra of *Eysenhardtia polystachya* (Kidneywood) have been investigated for its phytochemical compounds, such as flavonoids and tannins [5]. These compounds exhibit absorption peaks in the ultraviolet spectrum, typically between 280 and 350 nm, although this may vary depending on the experimental conditions and the solvents used in the extraction [5].

3| Why we want to go?

BL4S represents more than just a competition - it is a valuable opportunity to gain experience as aspiring researchers. Our common goal is to contribute to the scientific and technological advancement of our country and to demonstrate that young people are capable of conducting high-level scientific work. A significant source of our inspiration has been the members of Teomiztli team (winners of BL4F 2021), who are now part of a research group participating in the ALICE experiment.

Through this project, we aim to highlight aspects of Mexican culture as well as the quality of education we have received at the high school level from our university. For this reason, *Eysenhardtia polystachya* will play a key role in our experiment. This plant is traditionally used in alternative medicine by indigenous healers and serves as a cultural symbol that connects us to our pre-Hispanic heritage. Likewise, fluorite holds great importance in Mexico's mining industry due to its use in the production of glass, ceramics, steel, and ornamental materials. However, our interest lies in studying the fluorescent properties of both materials - a key factor that led us to design a scintillator composed of elements representative of our national identity.

Our objective is to gain new experiences, deepen our understanding of the scientific world, and approach science from a perspective that goes beyond theoretical knowledge.

4| Experimental setup

We propose to use a beam of negative pions in a range of 2-6 GeV. Using 2 scintillator pallets in the x,y directions at the beginning to ensure an alignment of the beam, and another scintillator pallet at the end of the setup, this will be the trigger. In the middle of it, we will locate the detector and a commercial scintillator detector of the same size as a reference (figure 2).

For electronic equipment, it will be required a ADC module to digitize our signals and to obtain the charge amplitude generated by the particles that pass through the medium.

4.1| Inorganic detector

For the inorganic detector, a CaF_2 crystal was obtained from a region of high natural production in Peña de Bernal, Mexico, Figure 3-A.

A 1 cm^3 cube was cut from the raw crystal and polished with fiber optic polishing sheets, Figure 3-B.
Once polished, it was covered with Tyvek to recover the light emitted by the fluorite through reflection and subsequently covered with black tape to prevent external contamination. A 6 cm^2 area was left uncovered on one side to couple a Hamamatsu S14160 SiPM with optical grease. Finally, the detector was tested, using an oscilloscope Tektronix TDS7254B, where it was observed signals of at least 10 mV with a frequency of approximately 2 signals per second. The shape of the signals obtained by this detector can be seen in Figure 4.

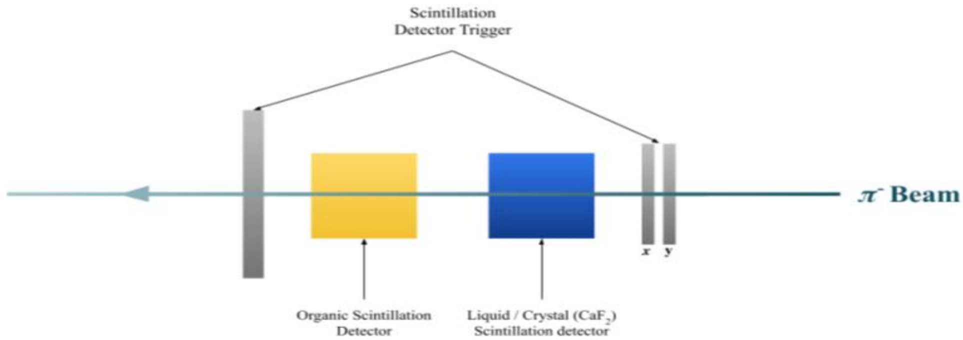

Figure 2: Experimental Setup diagram for T9 laboratory using a beam of negative pions at a range of 2-6 GeV.

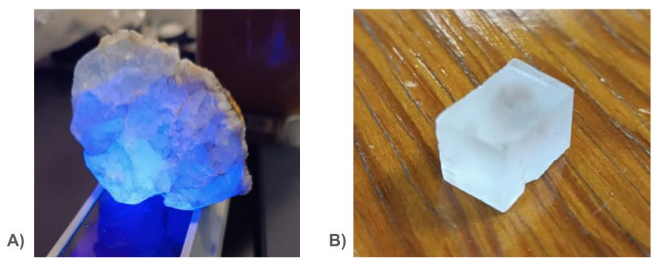

Figure 3: A) Raw Fluorite crystal obtained in Peña de Bernal, Mexico. B)Raw fluorite was cut into an approximately 1cm3 sample [3].

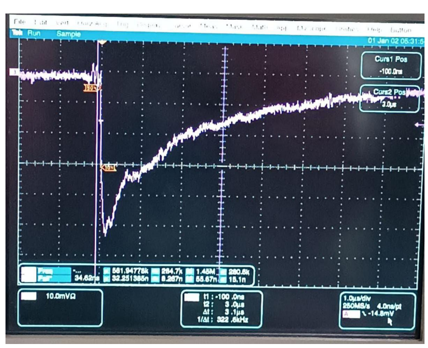

Figure 4: Output voltage signal obtained by a CaF_2 detector.The signal was 50 mV.

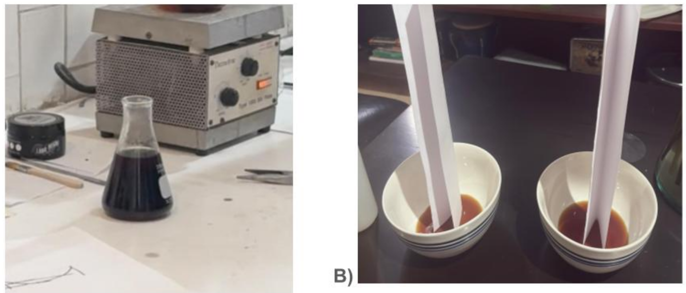

Figure 5: A) Sample of Eysenhardtia polystachya (kidneywood) infusion using purified water. B) Stationary phase (opaline) absorbing pigments contained in the infusion.

4.2| Detector methodology from Eysenhardtia Polystachya.

To obtain the *Eysenhardtia polystachya* pigment, we made an infusion of kidneywood using 25.1 g of it and added 200 mL of purified water at the boiling point, which is 92°C for México City, see Figure 5-A.

We used the chromatography on paper technique [8] to extract the luminescent pigment from the infusion. A sheet of opaline paper was introduced into the infusion to separate the pigments by capillarity.

The absorption process lasts 6 hours and must be carried out in a dark space to prevent the photoluminescent pigments from oxidizing. This process is shown in Figure 5-B.

After this time, we take out the sheet of opaline and let it dry, then we place it into 1 cm^3 of purified water and leave it to stand for 8 hours for pigment separation. It was not exposed to light.

As a result, it is easier to identify the pigment we need, which is found on the top of the strip of paper, as shown in Figure 6-A.

Finally, the part on the sheet containing the yellow pigment is cut. To recover it, the strip is left in 40 mL of water for 10 minutes. This way, we obtain only the photoluminescent pigment. The result is shown in Figure 6-B.

Once this pigment was obtained, it was placed in a clear glass jar, covered with Tybek and wrapped with black tape. The SiPM was attached to the base of the container containing the scintillation liquid. This jar is approximately 4 cm long and 1.5 cm in diameter, Figure 7A and B.

Signals of 10 mV amplitude on average were observed, the same as the inorganic scintillator with a frequency of approximately 1 pulse per second, see Figure 8.

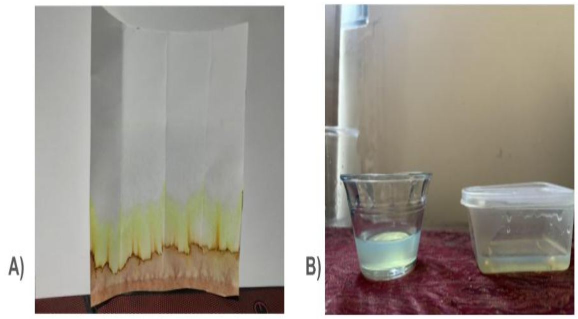

Figure 6: A) Result of the pigment separation. B) Luminescent pigment recovered in an aqueous medium obtained by chromatography on paper technique.

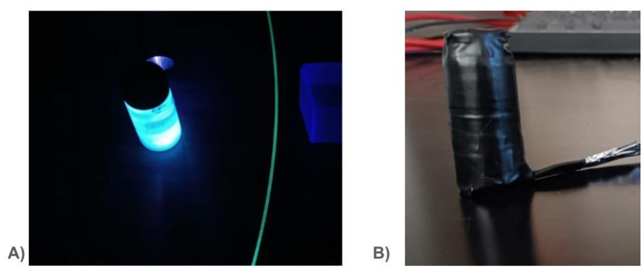

Figure 7: A) Kidneywood pigment emission using a UV-lamp of 365 nm. B) the detector is already assembled.

Figure 8: Signal obtained by the Kidneywood liquid pigment scintillator, this signal proved to be 18 mV.

5| Conclusions

Output amplitudes of approximately 10 mV were obtained for both scintillating media using a Sr-90 source. These signals indicate a low gain; however, we expect to observe signals with higher amplitudes when using a negative pion beam in the energy range of 2 to 6 GeV. At these energies, we believe it will be possible to achieve output voltage amplitudes greater than those observed with the electron source (Sr^{90}). Access to a beam provided by an accelerator would allow us to test these materials as detection media with improved statistics and data acquisition capabilities, which we currently do not have. Part of our team has experience with the Python programming language, and we are highly motivated to learn how to use the ROOT platform for data analysis.

6| Acknowledgment

- C. Dra. Samanta Pérez Arevalo, Ing. Pablo López Arriaga, Laboratorio de Física de Nuevos Materiales del IFUNAM.
- Dr. Varlen Grabski, Laboratorio de Detectores de Radiación IFUNAM.
- José Reyes Castillo, Laboratorio Gotatrón IFUNAM.

References

[1] María Andrade Rodríguez, et.al. *Usos del palo dulce <i>Eysenhardtia polystachya</i> (Ort.) Sarg., en cuatro municipios del estado de Morelos, México*. POLIBOTÁNICA, (55). https://doi.org/10.18387/polibotanica.55.11

[2] Secretaría de Economía de México *Perfil de Mercado de la Fluorita* Dirección General de Desarrollo Minero. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.gob.mx/cms/uploads/attachment/file/624810/9Perfil_Fluorita_2020__T_.pdf

[3] N. D. Quang, et.al. *Pure CaF2 crystal for fast neutron detection*. Radiation Physics and Chemistry 221 (2024) 111756. https://doi.org/10.1016/j.radphyschem.2024.111756

[4] V.B. Mikhailik, et.al. *Scintillation properties of pure CaF2*. Nuclear Instruments and Methods in Physics Research A 566 (2006) 522–525. https://doi.org/10.1016/j.nima.2006.06.063

[5] Herrera Cárdenas, J. A. (2024). *Una revisión bibliográfica de los fitoquímicos presentes en Eysenhardtia polystachya. Universidad Tecnológica de Izúcar de Matamoros.* https://mixtec.utim.edu.mx/articulosv6/articulo05.pdf

[6] Museo Virtual de Mineralogía. (n.d.). *Fluorescencia de los minerales*. Url: https://museomine.unizar.es/fluorescencia/

[7] Castañeda León, R. (2019). *Cambios en los puntos de fusión y de ebullición del agua devido a una variación en la presión*. Secretaría de Educación Pública. Url: https://educacionmediasuperior.sep.gob.mx/work/models/sems/Resource/12235/5/images/agua-ciencias.pdf

[8] Museo Nacional de Ciencias Naturales, (s.f.). *Conceptos fundamentales de cromatografía*. Secretaría de Educación Pública. Url: https://www.mncn.csic.es/docs/repositorio/es_ES/investigacion/cromatografia/principios_de_cromatografia.pdf

[9] Leo W. *Techniques for Nuclear and Particle Physics Experiments* 2nd edition, Ed. Springer-Verlag. Berlin, Germany 1994.