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Shifts of Rγ Propagation Speed in Water Kept in Different Dimension Containers

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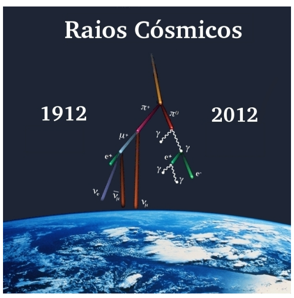

Ministério da
Ciência, Tecnologia e Inovação

CBPF-NF-007/12

Shifts of Rγ Propagation Speed in Water Kept in Different Dimension Containers

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Abstract: fitted central peaks of the coincidence spectra resulting from measuring the propagation speed (PS) of ^{22}Na-isotope γ-radiation 511 keV in water kept in containers with variable diameters were used in order to verify eventual PS shifts due to such differences of those containers.

Key Words: **propagation speed, ^{22}Na-isotope, electronic coincidence method, shifts in the fitted coincidence peaks**

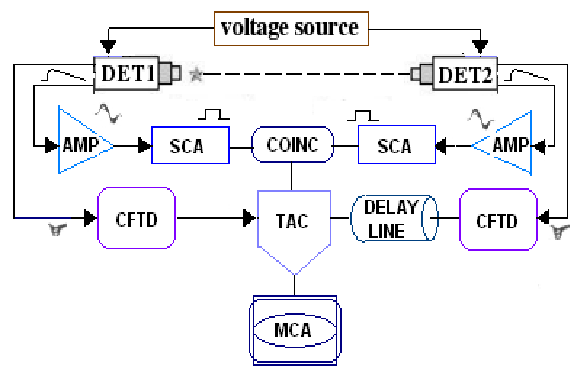
1) Introduction - The propagation speed (**PS**) of visible light -a short frequency range in the large frame of electromagnetic radiations (**ER**)- in air was measured, during the last hundred years[(1)], using a great deal of different methods, with high precision results being achieved.

Further improvements of detection and electronic measuring systems allowed to determine such parameters as **PS** by using **Rγ**[(2,3,4,5,6)] -order of magnitude values comparable to those measured for visible ligth[(7)]- with an advantage that such experiments could also be measured in a larger variety of propagation media. In this context, to compare with our already performed measurements in air[(8)], we extended such measurements in water as a propagation media. But, in such case, it may happen that interactions of the propagating **Rγ** with the water conditioned in vessels with different diameters, even with same long, could “shift” the **PS**.

As already well settled[(2-6,8)], to perform such **PS** measurements the availability of a **Rγ** source in which two **Rγ** are emitted simultaneously in opposite directions turns out to be essential to the feasibility of the experiment, as far as no reflection techniques could be used. Such suitable source, in all cases, was the positron emitter ^{22}**Na** placed in a metal container in which the positrons are stopped and annihilated when reacting with the medium electrons, in such way originating -as it is very well established from momentum/energy conservation laws[(9)]- two **Rγ-511 keV** each, both emitted simultaneously in opposite directions.

2) Experimental – The measuring setup [**MS-**(**Fig. 1-photo in ref. 8**)] included two **Rγ** detectors, **DET1** (photomultiplier XP-2020Q + BaF_2 scintillator) and **DET2** (photomultiplier XP-2020 + CsF scintillator), each of them connected to an electronic fast-slow coincidence circuit [slow branch: amplifier (**AMP**), timing single channel (**SCA**), universal coincidence (**COINC**); fast branch: constant fraction timing discriminator (**CFTD**); time to pulse amplitude converter (**TAC**)]. Finally, the slow-fast coincidences were recorded on an analog-digital-converter/multi-channel (**MCA**). More detailed explanations about construction and performance of such an **MS** can be found elsewhere[(10,11)]. The experiments consisted in the measurements of the eventual shifts of the fitted[(12)] coincidence spectra peaks when different water containers were interposed. The two oppositely emitted **Rγ** originated from a ~ **7 μCi/^{22}Na γ-emmiter**, as far as they appeared as coincidence spectra displayed in a **Multi-Channel**.

Fig. 1 - Measuring Setup (MS)



As a first step of the experiments, it was measured the *time calibration* of the **MS** by using a Time Calibrator (**TC**), range- **0.08μs**/period-**0.01μs**, which produces two pulses with highly precise variable delays between their outputs; which, by their way, were directed to the **TAC** whose amplitude outputs is related to those delays (**Table I**). Finally, the average ***time calibration*** displayed by the **MS** was **0.1002204 ns/ch**, a result extracted from fitting (**Fig. 2**).

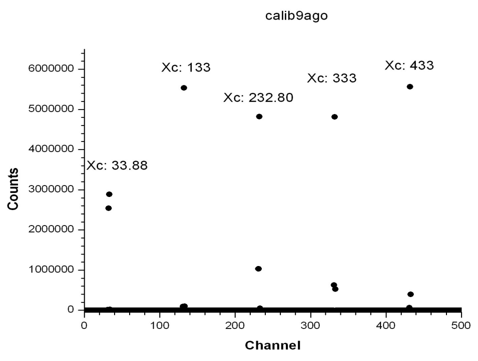


Fig. 2 - Time-Calibrator Output Spectrum

The following **PS** experiments -all fitted data are in **Table I**- were performed with the **Rγ-511 keV**, detected by **DET2**, after propagating in water; therefore, it was essential to know if it was not completely attenuated during this propagation and still appeared in the **DET2**: a comparison between the **^{22}Na** emission spectra in air and after propagating across water in the different water plastic PVC vessels used in the following experiments; from the displays it may be realized that the **Rγ-511 keV** is more attenuated as longer is the water containing vessel, with the vessel diameter playing a much smaller rôle; but, even when attenuated, it's resolution is still visible. Such emission-spectra (**length x diameter**) were the following: for a standard comparison, **emission spectrum in air** (**Fig3**); emission spectrum after water in **20cmx20cm** vessel (**Fig4**); emission spectrum after water in **40cmx26cm** vessel (**Fig5**); emission spectrum after water in **40cmx20cm** vessel (**Fig6**); emission spectrum after water in **20cmx7cm** vessel (**Fig7**); emission spectrum after water in **40cmx7cm** vessel (**Fig8**)

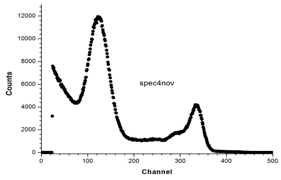


Fig3-emission in air

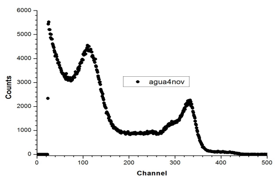


Fig7-vessel20cmx7cm/water

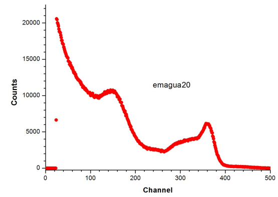


Fig4-vessel20cmx20cm/water

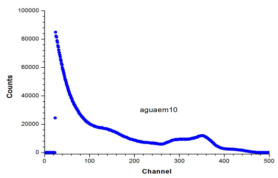


Fig8-vessel40cmx7cm/water

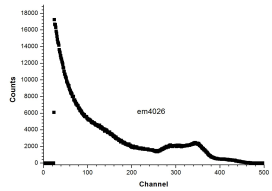


Fig5-vessel40cmx26cm/water

Next steps, in order to realize contributions of eventual interferiences of the vessel's dimensions in the **Rγ-511 keV PS**, coincidence experiments were performed where in the fitted measured spectra the peaks centers were determined (**Table I**)[12*].

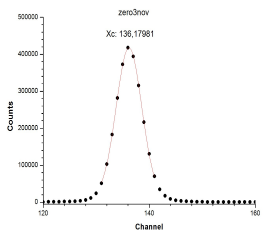


Fig9-air coinc. spectrum

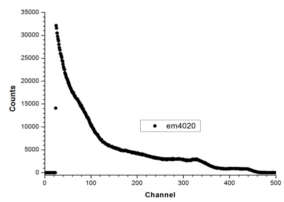


Fig6-vessel40cmx20cm/water

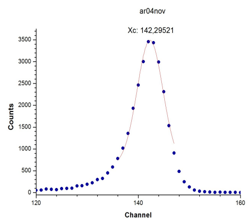


Fig10-air coinc. spectrum

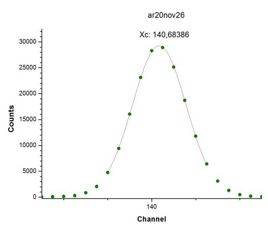


Fig11-air coinc. spectrum

As a beginning coincidence experiment, in order to fix standards spectra, both detectors **DET1/DET2** were disposed at **5 cm** from the **^{22}Na** source, in air: the peak's center was fitted at the **136.17981** ch (**Fig9**). Next experiment, in air, **DET2** was shifted **20 cm** apart: peak's center was fitted at the **142.29521** ch (**Fig10**). As far as the **ADC** switch has been previously "desacessed" for **COINC** mode, we repeated the previous experiment with the "coincidence key" now acessed: the experiment in air with **DET2** at **20 cm** had it's peak's center fitted at **142.25628** ch (**Fig11),** essentially the same value as before. The next coincidence experiment was performed with interposition of a **20 cmx7 cm** vessel with water: peak's center fitted at **136.17726** ch (**Fig12**). As a next coincidence experiment, it was performed with interposition of a **20 cmx20 cm** vessel with water: peak's center fitted at **140.70832** ch (**Fig13**). With the same tube interposed, it was performed an emission experiment (**Fig. 4**). As a next experiment, it was started with a vessel with water, **40 cmx7 cm** and performed an emission experiment (**Fig7**). Keeping the same conditions, it was performed a coincidence experiment, with peak's center fitted at the **147.38108** ch (**Fig14**). Going on with coincidence experiments, a next one was performed with interposition of a container **40 cmx26 cm**, with water: peak's center fitted at **147.67105** ch (**Fig15**). This same experiment went on to improve statistics, with peak's center fitted at the **146.8085** ch (**Fig16**), a value very close to the previous one. A next experiment was performed without any container, in air, with **DET2** at the same **40 cm** shifted position: peak's center fitted at the **147.37996** ch (**Fig16**). This experiment was further concluded: peak's center at **147.22937** ch (**Fig17**); a final coincidence experiment was performed with water vessel **40 cmx20 c**m interposed: peak's centers at **147.96008** ch and **148.0667** ch, respectively (**Figs18/19**).

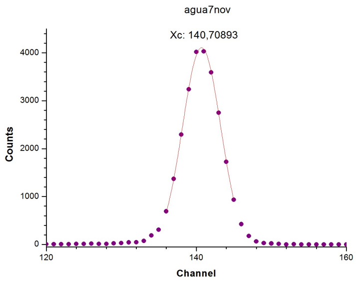


Fig12-agua7nov

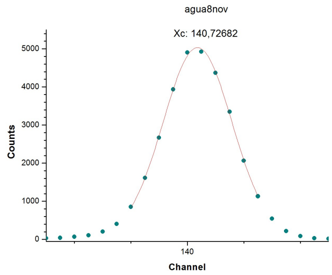


Fig13-agua8nov

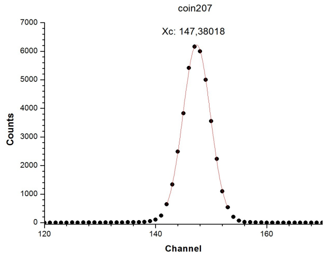


Fig14-coin207

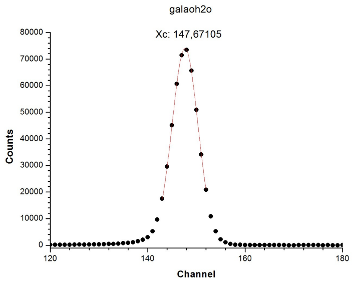


Fig15-galaoh2o

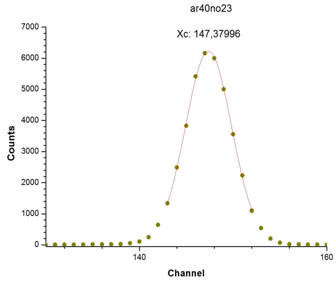


Fig16-ar40no23

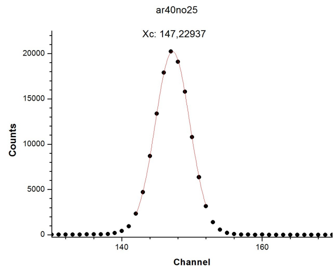


Fig17-ar40n025

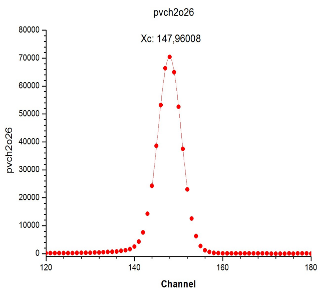


Fig18-pvch2o26

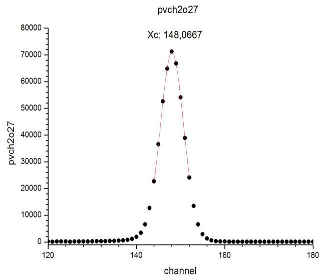


Fig19-pvch2o27

Table I – Measurements Fitted Parameters

experiment's conditions	archives	central fitted channel
coincidence spectrum in air (detectors in "zero positions")	*zero3nov*	136.17981 (Fig. 9)
coincidence spectrum in air with DET2 at 20cm	*ar04nov*	142.29521 (Fig. 10)
coincidence spectrum in air with DET2 at 20cm	*ar20nov6*	140.68386 (Fig. 11)
emission spectrum in air (DET2 20cm apart)	*spec4nov*	Fig. 3
emission spectrum with 40cmx7cm tube with water interposed	*agua4nov*	Fig. 8
coincidence with 20cmx7cm tube with water interposed	*agua7nov*	140.70893 (Fig. 12)
coincidence with 20cmx20cm tube with water interposed	*agua8nov*	140.70832 (Fig.13)
emission spectrum with 20cmx20cm tube with water interposed	*emagua20*	Fig. 4
emission spectrum with 20cmx7cm tube with water interposed	*aguaem10*	Fig. 7
coincidence spectrum with 40cmx7cm tube with water interposed	*coin207*	147.38018 (Fig. 14)
coincidence spectrum with 40cmx26cm tube with water interposed	*galaoh2o*	147.67105 (Fig. 15)
emission spectrum with 40cmx26cm tube with water interposed	*em4026*	Fig. 5
coincidence spectrum in air with DET2 40cm apart	*ar40no23*	147.37996 (Fig. 16)
conclusion of the previous experiment	*ar40no25*	147.22937 (Fig. 17)
coincidence spectrum with 40cmx20cm tube with water interposed	*pvch2o26*	147.96008 (Fig. 18)
coincidence spectrum with 40cmx20cm tube with water interposed	*pvch2o27*	148.0667 (Fig. 19)
emission spectrum with 40cmx20cm tube with water interposed	*em4020*	Fig. 6

Table II – Coincidence Spectra Measurements Fitted Parameters

experiment's conditions	archives	central fitted channel
coincidence spectrum in air (detectors in "zero positions")	***zero3nov***	**136.17981 (Fig. 9)**
item 1: coincidence spectrum in air with DET2 at 20cm apart	***ar04nov***	**142.29521 (Fig. 10)**
item 1: coincidence spectrum in air with DET2 at 20cm apart	***ar20nov6***	**140.68386 (Fig. 11)**
item 2: coincidence spectrum in air with DET2 at 40cm apart	***ar40no23***	**147.37996 (Fig. 17)**
item 2: conclusion of the previous experiment	***ar40no25***	**147.22937 (Fig. 18)**
item 3: coincidence spectrum with 20cmx7cm tube with water interposed	***agua7nov***	**140.70893 (Fig. 12)**
item 4: coincidence spectrum with 40cmx7cm tube with water interposed	***coin207***	**147.38018 (Fig. 14)**
item 5: coincidence spectrum with 20cmx20cm tube with water interposed	***agua8nov***	**140.70832 (Fig.13)**
item 6: coincidence spectrum with 40cmx20cm tube with water interposed	***pvch2o26***	**147.96008 (Fig. 19)**
item 6: coincidence spectrum with 40cmx20cm tube with water interposed	***pvch2o27***	**148.0667 (Fig. 20)**
item 7: coincidence spectrum with 40cmx26cm tube with water interposed	***galaoh2o***	**147.67105 (Fig. 15)**

item 2 (average) – item 1= 147.30466 ch – 140.68386 ch= 6.6208 ch → 0.6635392 ns → PS= 301,413.90 km/s
item 4 – item 3= 147.38018 ch – 140.70893 ch= 6.67125 ch → 0.6685953 ns → PS= 299,134.61 km/s
item 6 (average) – item 5= 148.01339 ch – 140.70832 ch= 7.30507 ch → 0.732117 ns → PS= 273,180.37 km/s
item 7 (average) – item 5= 147.67105 ch – 140.70832 ch= 6.96273 ch → 0.6978075 ns → PS= 286,611.99 km/s

3) Concluding Remarks –

a) the electronic **γ-γ** coincidence method showed to be a valuable method to measure **PS** of electromagnetic radiation in air and water, even with measurements performed in very short distances.
b) in the above estimations it was taken into account only the ***fitted peak's centers*** of the coincidence spectra, neglecting any deviation concerning these values as appears, for instance, in the ***fwhm*** of those spectra.
c) the **PS** final results are closely related to the **MS** calibration conditions due to crystal scintillator's shapes and sizes, as well as detectors distances to emmiting source.
d) possibility of measuring such **PS** in material media with higher density compaired to air/vacuum; here included material media non-transparent to visible light, a topic that the LCA/CBPF is presently extending to plastics.
e) it seems that the measured **PS** shift has mainly to do with the **diameters** of the containing water vessels.

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(12*) all the so measured coincidence spectra were fitted with "gaussian function", as founded in the **ORIGIN** software(www.originlab.com):

$$y = y_0 + \frac{A}{\sqrt{2\pi}\,\sigma} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right]$$

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