Propagation Speed of ^{18}F γ-Radiation 511 keV in Air

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Key words: propagation speed, ^{18}F-isotope, electronic coincidence method

Abstract: propagation speed of ^{18}F-isotope γ-radiation 511 keV was measured in air; result comparable to the same parameter measured with ^{22}Na-isotope

1) Introduction – Recently, a set of experiments were performed in order to measure propagation speeds (PS) of 511 keV γ-radiation in several media[(1,2)]: the results obtained for the PS in air could be closely compared to the CODATA[(3)] value for visible light. To perform such measurements it was used the source ^{22}Na, closed in a metal container, which emmits, as it is well known, two 511 keV γ-rays simultaneously and in opposite directions. An eventual shortcoming in using ^{22}Na source is that it also emmits a 1,274 keV γ-ray which could, in certain specific situations, "to blur" the final results. In this sense it was tested the performance of ^{18}F, which only emmits the 511 keV γ-rays in the same conditions as those originated from ^{22}Na. To our knowledge, this is the first time that ^{18}F is used for such measuring purposes.

2) Experimental – The measuring setup (MS) (Fig. 1, photo 1) **-0.0549147 ns/ch time calibration** as measured by an electronic Time Calibrator- included: two detectors [DET1 (photomultiplier XP2020-Q/ 2"x2" BaF2 scintillator) and DET2 (photomultiplier XP2020/ 2"x2" CsF scintillator); in order to better avoid detection of dispersed γ-rays around the strict horizontal emission direction, shielding plates of lead -5 mm thick, central hole with 10 mm-ø- were put just in front the scintillators-], 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[(4,5)]. For comparison purposes two experiments were performed by using γ-rays emitted by ^{22}Na and ^{18}F; in both of them the two detectors DET1 and DET2 were attached to a 2 m iron trail, on opposite sides of the emitting γ-rays sources.

Fig. 1: Measuring Setup (MS)

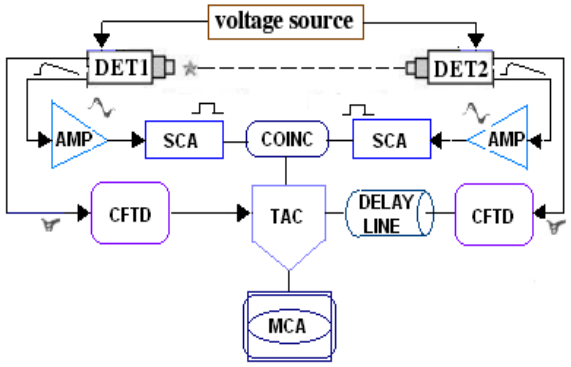

photo 1: trail and measuring setup

2a) – this experiment with ^{22}Na consisted of the PS in air estimation by measuring the transit-time differences of the two oppositely emitted **γ**-rays, as far as they appeared as coincidence spectra displayed in a Multi-Channel, according the different distances DET2 assumed on the trail. It was performed in two steps[(1)]: in a first step were measured successively five coincidence spectra, here included the first and the last ones, 0.40 m each one apart from the other; in a second step were measured four coincidence spectra, also successively and 0.40 m apart one from the other, and in such way that this second set could be computationally interposed to the first one, so finally displaying nine coincidence spectra, each of them 0.20 m apart from the immediately next and previous ones. The difference between both extreme spectra's fitted centers channels, corresponding to 1.60 m is: 243.45376586 ch - 145.35654986 ch= 98.09721600 ch; taking into account the setup's calibration time, the time interval related to this difference, **5.3869791 ns**, leads to the PS $\mathbf{c_{air}}$**= 297,012.40 Km/s → 99.073%** of CODATA value.

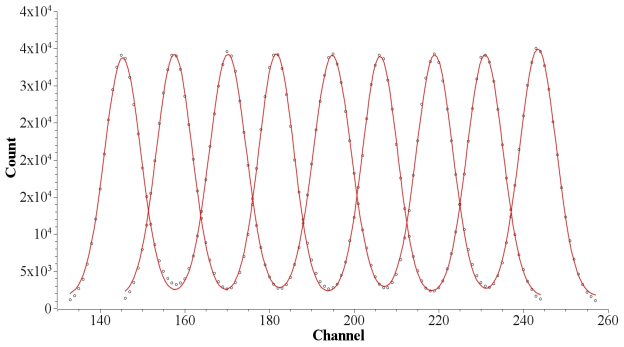

Fig. 2: Na-22 Coincidence Spectra in Air

2b) – this experiment was performed as a first attempt concerning ^{18}F performance in this kind of measurements; the isolated presence of it's 511 keV **γ**-radiation may be identified in both the emission detections: by CsF in Fig. 3 and BaF_2 in Fig. 4. The measuring procedure was similar to the above described ^{22}Na measurement. As far as ^{18}F has a short half-life -~110 minutes- it was possible to measure, with well defined spectra resolution, three coincidence spectra, each one apart from the other 0.40m, until the total isotope decay (Fig. 5). Taking into account 0.80m, which corresponds to 49.37657827 channels, the related time interval would be **2.71149998 ns** with a estimated PS $\mathbf{c_{air}}$**= 295,039.648 Km/s**, **98.141%** of CODATA value.

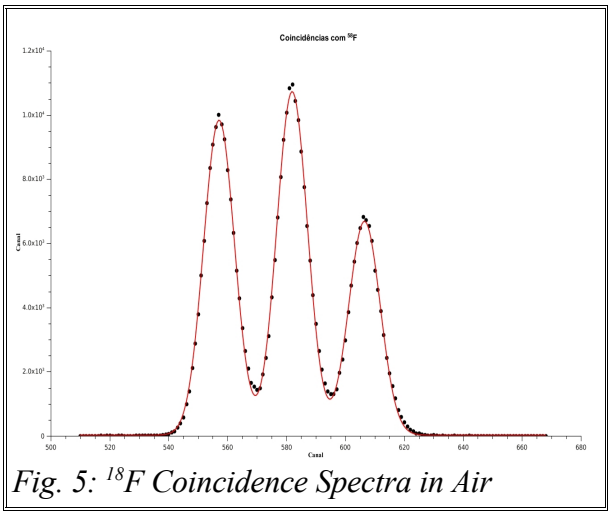

Fig. 5: ^{18}F Coincidence Spectra in Air

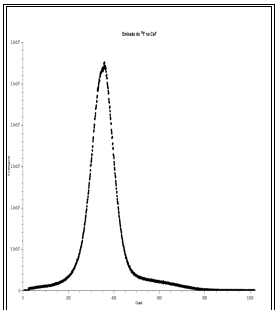
Fig. 3: ^{18}F Emission Spectrum (CsF)

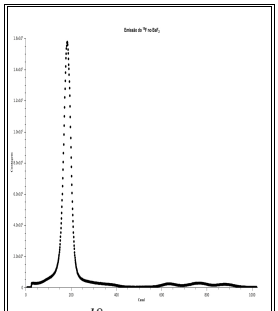
Fig. 4: ^{18}F Emission Spectrum(BaF_2)

All the measured coincidence spectra were fitted with "gaussian function" as found in the QTIPLOT software[(6)]. The so obtained fitted parameters are in Table I.

Acknowledgment – Instituto de Engenharia Nuclear (IEN/CNEN), in Rio de Janeiro/RJ, is gratefully acknowledged for providing us the ^{18}F-isotope.

Table I: Fitted Parameters

fitted spectra centers – n (ch)	fitted spectra centers amplitudes	hwhm (ch)	Δn: [(n+1) – n] (ch)	Δn x calibration (ns)
		^{22}Na		
145.35654986	32,245 (69.816)	8.53849559	12.19505402	0.66280118
157.55160388	32,983 (71.250)	8.44913136	12.66615218	0.68840537
170.21775606	32447 (72.778)	8.67196794	11.43024142	0.62123362
181.64799748	32,479 (74.711)	8.24922619	13.20901479	0.71790995
194.85701227	32,502 (72.979)	8.88229777	11.28310206	0.61323660
206.14011433	32,129 (74.372)	8.24063147	12.91098403	0.70171198
219.05109836	32,558 (73.630)	8.54666409	11.89296232	0.64638250
230.94406068	32,548 (70.635)	8.50714968	12.50970518	0.67990247
243.45376586	33,433 (70.798)	8.63378924		
		^{18}F		
557.14951622	9,808.343	10.48613158	24.81585873	1.36275544
581.96537495	10,697.844	10.41995569	24.56071954	1.34874455
606.52609449	6,656.255	10.66916290		

3) Concluding Remarks –

a) the electronic **γ-γ** coincidence method showed to be a valuable method to measure propagation speed of electromagnetic radiation in air, mainly taking into account the short distances needed for this kind of process;
b) in the above estimations it was taken into account only the ***fitted peak's centers*** of the coincidence spectra, neglecting any deviation concerned these values as done, for instance, by the ***hwfm*** of those spectra;
c) the ^{18}F-isotope showed a very positive performance in this kind of measurements;
d) experiments related to the measurement of propagation speeds in material media non-transparent to visible light is a topic that our LCA/CBPF is presently extending to plastics and metals.

4) References:

(1) "Propagation Speed of γ-Radiation in Air" - Marcelo A.V. Macedo et al.; CBPF-NF-034/08
(2) "Propagation Speed of γ-Radiation in Brass" - José T.P.D. Cavalcante et al.; CBPF-NF-008/09
(3) "CODATA" – The Committee on Data for Science and Technology.
(4) "Espectroscopia de Radiação-Gama" - H. Saitovitch et al.; LCA/EXP/CBPF; Monografia/CBPF-MO-001/07; março/2007; attached references about instrumentation.
(5) "Radiation Detection and Measurements" - Glenn F. Knoll; J. Wiley&Sons, eds. 1979-1989.
(6) QtiPlot - Data Analysis and Scientific Plotting; http://soft.proindependent.com/qtiplot.html