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LETTERS TO THE EDITOR

EXPERIENCE WITH DI-POTASSIUM 2-AMINO-6, 8-NAPHTHALENE-DISULPHONIC ACID AS A WAVELENGTH SHIFTER IN A WATER CHERENKOV DETECTOR

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Results are reported on the use of the di-potassium salt of 2-amino-6, 8-naphthalene-disulphonic acid as a wavelength shifter in a water Cherenkov detector. No unusual or exceptional precautions were taken in preparing the radiator. All results are consistent with an increase in light output of ~3.8 when using the wavelength shifter, without any detectable contribution from scintillation phenomena.

In a series of tests of a prototype water Cherenkov detector for experiment S159[1]) at the CERN PS we have investigated the effect on the light output of the water radiator of the addition of 10 mg/l of amino G-salt (di-potassium salt of 2-amino-6, 8-naphthalene-disulphonic acid). Earlier studies with this type of light shifter have found that the amount of light increase depends quite critically on the physical conditions of the radiator and chemical purity of the light shifter[2,3]). Using an industrially prepared chemical[§] without any special mechanical[†] precaution, we have found an increase in light output by a factor of ~3.8.

Test beam T1 at the CERN PS was used to provide pions and protons with momenta between 0.8 and 1.8 GeV/c[+]. Time-of-flight (TOF) measurements were made on the beam particles using two scintillators 7.1 m apart; with an on-line resolution (fwhm) of ~0.25 ns, excellent π/p separation was obtained. The prototype water Cherenkov box was placed in the beam between the TOF scintillators with the particles crossing the water box in the centre (defined by a 5×5 mm^2 scintillator). Fig. 1 shows details of the water Cherenkov detector. The distilled water is contained in a $135\times135\times150$ mm^3 aluminium box coated on the

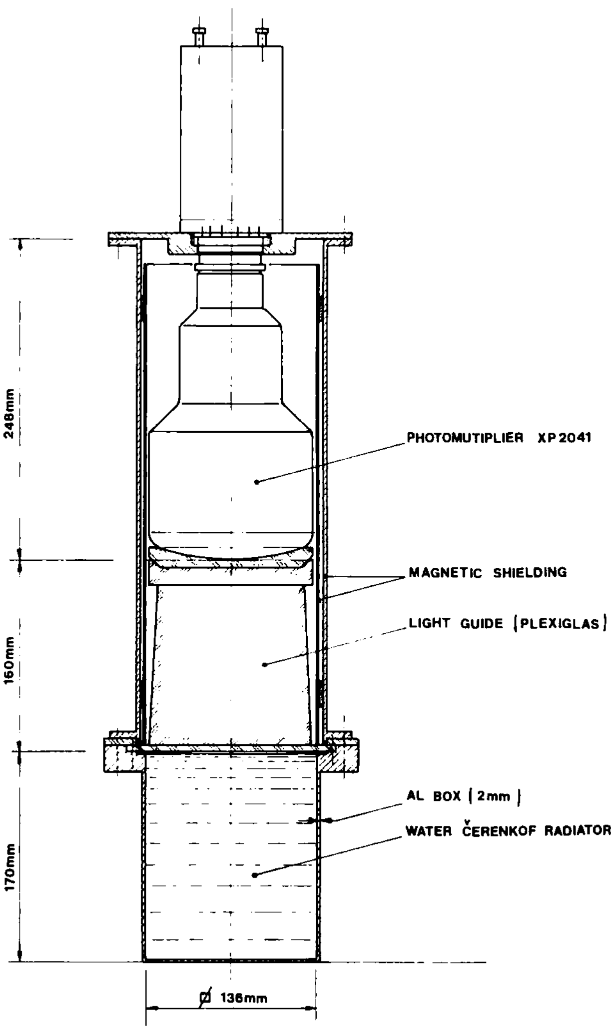

Fig. 1. Details of the prototype water Cherenkov detector.

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† In particular nitrogen was not bubbled through the water[3]).

+ The nominal momentum bite was ±1.2% ; however, since the beam is transported through air, this momentum spread will be enlarged significantly so for low energy protons.

TABLE 1

Cherenkov pulse height information. The calculated number of photoelectrons is deduced using the approximate formula $N_\gamma = 500 \sin^2 \theta_c$ photons/cm, where θ_c is the Cherenkov half angle. The CERN Monte Carlo program GUIDE10 [4]) was used (assuming an isotropic diffusing coating on the walls of the Cherenkov box) to obtain 30% light collection efficiency. This was incorporated into the calculation along with a 15% photocathode quantum efficiency. See text for other definitions and discussion.

Particle type	Momentum (GeV/c)	Calculated number of photo-electrons	*Without* wavelength shifter: Pulse height ±half-width (arbitrary units)	*Without* wavelength shifter: Measured nb. of photo-electrons	*With* wavelength shifter: Pulse height ±half-width (arbitrary units)	*With* wavelength shifter: Measured nb. of photo-electrons	R_H	R_N
π^+	0.8	~13	140±50	8±1	560±100	31±5	4.0	3.9
π^+	1.0	~13	140±50	8±1	580±100	34±5	4.1	4.3
π^+	1.15	~13	150±45	11±2	590±100	35±5	3.9	3.2
π^+	1.4	~13	150±45	11±2	560± 90	39±5	3.7	3.5
π^-	1.4	~13	150±45	11±2	560± 85	43±5	3.7	3.9
π^+	1.8	~13	–	–	550± 80	47±5	–	–
Average $\pi^\pm$	(0.8–1.4)	~13	146±47	9.6	570± 95	36	3.9	3.8
p	1.15	~2	~20±15	2	80± 40	~4	~4	2.2
p	1.4	~5	~55±~25	5	240± 70	~12	~4.3	2.5
p	1.8	~9	–	–	400± 80	~25	–	–

inside with Nuclear Enterprises NE 560 titanium dioxide reflecting paint. The surface of the water is in contact with a 5 mm plexiglass window which is connected optically to a Philips XP2041 photomultiplier tube through an aluminised mylar wrapped cylindrical plexiglass light guide (130 mm diameter × 156 mm length). Data acquisition utilized Le Croy 2228 TDC (50 ps/channel) and 2249 ADC for the TOF and Cherenkov pulse height measurements, respectively. All Cherenkov and TOF information was recorded on magnetic tape using an on-line Nord-10 computer. The analysis of the data was performed off-line at the CERN 7600.

Data were collected with beam momenta of 0.8, 1.0, 1.15, 1.4 and 1.8 GeV/c for a positive beam (i.e. π^+ and p) and at 1.4 GeV/c for a negative beam (i.e. predominantly π^-). The runs were repeated with and without wavelength shifter. The results at 1.4 GeV/c are presented in fig. 2, where we give also a scatter plot of Cherenkov pulse height (in arbitrary units) versus the time-of-flight of the beam particle to demonstrate the π/p separation. Fig. 2a shows the data using distilled water, fig. 2b that with distilled water plus 10 mg/l of amino G-salt. It is clear that the wavelength shifter is giving a significant increase in light output. Table 1 gives a summary of all the data runs. R_H

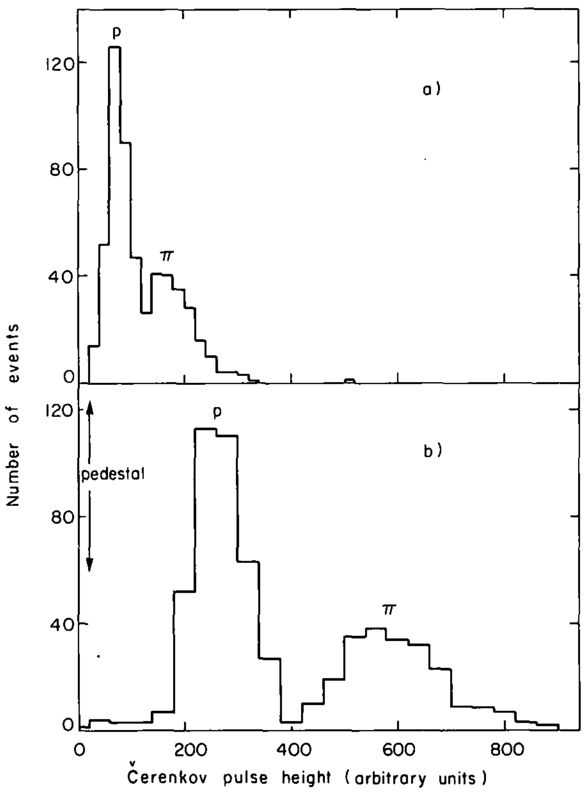
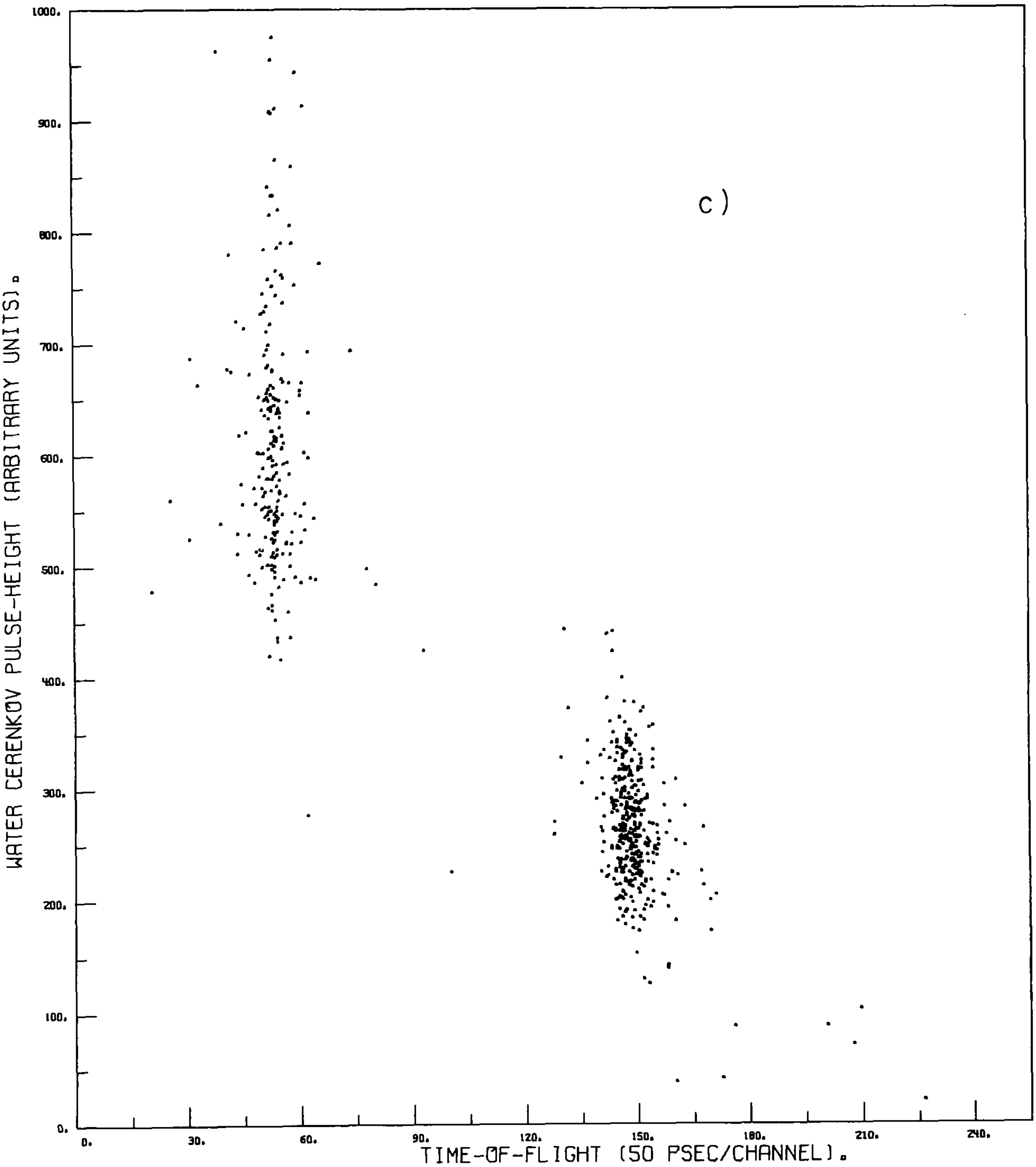


Fig. 2. Cherenkov pulse-height distribution (arbitrary units) for a beam momentum of 1.4 GeV/c:
(a) distilled water Cherenkov radiator, (b) distilled water plus 10 mg/l amino G-salt.



The scatter plot (c) shows the Cherenkov pulse height vs time-of-flight (50 ps/channel) for the data of situation (b).

is defined as the ratio of the peak values of the pulse-height distributions with and without wavelength shifter. R_N is the ratio of the measured number of photo-electrons with and without wavelength shifter (the number of photo-electrons per track is computed assuming that the width of the pulse-height distribution is given by $\sqrt{N}$). With the exception of R_N for protons – whose pulse-height distribution width at low energy is broadened by scattering of the beam particles in the air giving an artificially low estimate of the number of photo-electrons — all ratios R_H and R_N are consistent and indicate an increase in light output of ~ 3.8.

Analysis of the proton pulse-height distribution below threshold (i.e. at 0.8 and 1.0 GeV/c) indicates that any scintillation contribution is negligible. In fact, comparison of the proton pulse-height spectra at 0.8 and 1.0 GeV/c shows that the behaviour with energy is exactly the reverse of what one would expect from scintillation phenomena and is consistent in amount and ratio with what one expects due to δ-rays produced from the protons in the water radiator.

Finally, after a delay of several weeks, data collection was repeated for the situation with wavelength shifter. The values obtained for R were in complete agreement with those determined earlier indicating no deterioration of the radiator over this period.

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