in a distant collision. This effect[4] is obviously proportional to the local density of air and to the incident nucleon intensity:

$$I_3(x)=BxI_1(x). \quad (4)$$

Expressions $I_1(x)+I_3(x)$ and $I_2(x)$ are respresented in curves II and III respectively. Formula (1) or curve I is obtained by adding the two mentioned expressions.

The influence of the production of secondary particles in the mass of the rocket is approximately proportional to the total intensity of the incident particles and does not affect the given formula.

[1] J. A. Van Allen and H. E. Tatel, Phys. Rev. **73**, 245 (1948).
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Rise Times of Voltage Pulses from Photo-Multipliers*

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May 1, 1950

A METHOD has been devised for measuring fast rise times of voltage pulses from photo-multiplier tubes without using high speed oscillographs.

1P21 tubes were operoted at voltages high enough (about 1600 v) to give 25-volt pulses from a radium source, when used in conjunction with a 6AG7 cathode follower. The time constant of the RC circuit on the last dynode from which the pulses are taken is $\sim 10^{-6}$ sec. The pulse is fed into a variable length of shorted RG63U cable, thus subtracting from it a delayed pulse of equal height. The maximum height reached by the resulting difference pulse is the height of the original pulse at a time after its start equal to the delay. The clipped pulse then is fed through a discriminator and scaler. By varying the length of the shorted delay line and adjusting the discriminator setting so that a constant counting rate is obtained from a given source, the shape of the pulse can be accurately plotted if the cathode follower and crystal diode responses are known (measurements showed them to be quite linear in the region used).

Plots of the rise of the pulses have been made for pulses from various organic phosphors, and for noise pulses (using both thermionically emitted electrons and those knocked out of the photo-cathode by gamma-rays). With slight deviations which are undoubtedly due to limiting or curvature of cathode follower or crystal diode characteristics, logarithmic plots of the curves in

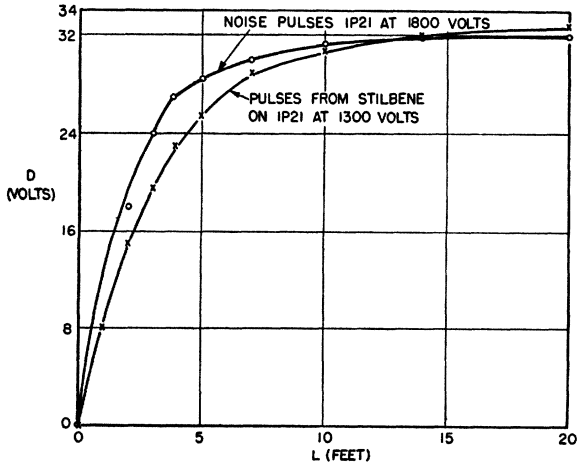

FIG. 1. Rise of noise pulses and pulses from stilbene. D is the discriminator reading corresponding to a constant counting rate. L is the length of shorted delay cable (4 feet of which correspond to a time delay of 10^{-8} sec.).

TABLE I. Rise time of voltage pulses from 1P21 at 1500 v.

Crystal	τ	Quality of crystal
Stilbene	$(0.85\pm0.05)\times10^{-8}$ sec.	Single crystal, colorless, transparent.
Phenanthrene	$(1.0\pm0.1)\times10^{-8}$ sec.	Microcrystalline, pale yellow.
Anthracene	$(2.1\pm0.2)\times10^{-8}$ sec.	Single crystal, colorless.
o-Phenylphenol*	0.9×10^{-8} sec.	Microcrystalline, pinkish
p-Phenylphenol*	2.0×10^{-8} sec.	Microcrystalline, colorless.
5-*sec*-butyl-2-hydroxy-α^1,α^3-xylenediol*	1.6×10^{-8} sec.	Microcrystalline, colorless.

* These rough measurements probably good to 0.4×10^{-8} sec., were taken with larger 1P21 voltages ($\sim$1700 v).

Fig. 1 show them to be of the form $V=V_0(1-e^{-t/\tau})$. The value of τ for the noise pulse is 5 to 6×10^{-9} sec., of which an unknown, but probably not the major, fraction is due to delay in the circuit following the photo-multiplier, and the remainder represents the spread of transit time through the photo-tube for the secondary electrons from a primary noise electron emitted at the photo-cathode.

Table I summarizes results on organic phosphors. The figures given are averages of a number of crystals, which show some variation in τ. For these experiments, the rise time of the voltage pulse differs from that of a noise pulse due to the decay time of the fluorescence of the phosphor.

These results show fair agreement with those of other investigators.[1] The three last ones have not been previously covered in the literature.

* We should like to thank the AEC which aided materially in this research.
[1] For example, Hofstadter, Liebson, and Elliot, Phys. Rev. **78**, 81 (1950); J. R. Bell, unpublished results.

Altitude Dependence of Neutron Production by Cosmic-Ray Particles*

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THE counters and circuits used in the cloud-chamber study of neutron coincidences[1] (carried out jointly with the Harvard cosmic-ray group) have been employed in a preliminary study of the changes in neutron coincidence rates between Climax, Colorado (3400 meters) and St. Louis, Missouri (170 meters). The experimental arrangement is shown in Fig. 1. The crossed four-fold G-M tube telescopes[2] are placed between a 10.16-cm Pb filter and a 10.16-cm Pb absorber. The double anticoincidence tray C more than covers the cone defined by the telescopes. Below C is a large paraffin thermalizer containing five thermal neutron counters, proportional counters filled with enriched BF_3.[3]

The following events were recorded: telescope coincidences (AB), anticoincidences ($AB-C$), neutron counts (N), and neutron counts in delayed coincidence (3 to 150 μsec.)[4] with AB events ($AB:N$) and $AB-C$ events ($AB-C:N$). The neutron counters were, in addition, in prompt anticoincidence (±1 μsec.) with the C tray; this feature discriminated against pulses due to showers.

TABLE I. Neutrons associated with stoppings (AB-C:N).

	Climax	St. Louis
With absorber (115 g/cm² Pb)	$7.02\pm0.48/h$	$1.16\pm0.09/h$
	Expected $\pm0.15/h$ Casuals	Expected $\pm0.005/h$ Casuals
	Corrected rate $6.87\pm0.48/h$	Corrected rate $1.15\pm0.09/h$
Sans absorber (0.69 g/cm² brass in counter walls)	$0.16\pm0.09/h$	$0.051\pm0.01/h$
	Expected $\pm0.19/h$ Casuals	Expected $\pm0.002/h$ Casuals

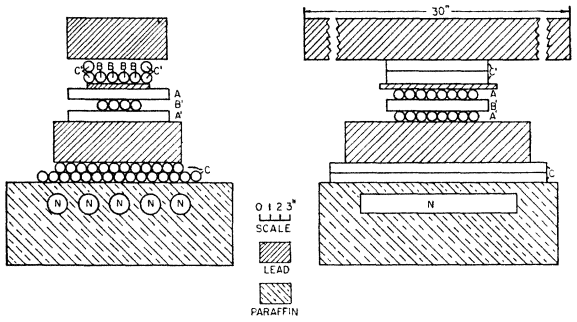

FIG. 1. Experimental arrangement.

It had no effect at St. Louis. At Climax it changed the N rate little; however, when 1 mm Cd sheaths were slipped over the neutron counters, the anticoincidence feature reduced the rate 40 percent. The "with Cd" rate at Climax was less than 5 percent of the "without Cd" rate. Certain refinements were found necessary at Climax' higher elevation. We added four anticoincidence C' counters in the top of the telescopes and also placed one cm of Pb in the telescopes. This discriminated against side showers and low energy stars in the telescope and filter.

Data were taken with and without the absorber. The results are given for neutrons coincident with apparent stoppings in the absorber $(AB-C:N)$ and neutrons coincident with apparent penetrations of the absorber $(ABC:N)$. The $(AB-C:N)$ results are shown in Table I, the $(ABC:N)$ results in Table II. The uncertainties given are the estimated statistical standard errors. The expected casuals are computed from the measured rates and neutron coincidence resolving time. The corrected rates are found[5] by subtracting the expected casual rates from the measured rates. The observed $(AB-C:N)$ rates without absorber may be attributed to accidentals. Previous experience has shown that the observed rates with Cd are always of the order of magnitude of the expected casuals. The factor of increase of the $(AB-C:N)$ coincidences from St. Louis to Climax is seen to be 6.0 ± 0.6. The factor of increase of the $(ABC:N)$ coincidences from St. Louis to Climax is seen to be 16.3 ± 1.2 with absorber and 18.9 ± 1.7 without absorber. These two factors are equal within the statistical uncertainty. The rate of apparent stoppings $(AB-C)$, corrected for the zero effect, increases 2.8 times, in agreement with Kraushaar's[6] results for μ-mesons. The intensity of the hard component (ABC), increases 2.1 times.

Three possible causes of $(AB-C:N)$ events are known, μ^--capture, π^--capture, and low energy proton stars (type 0_p in the Bristol notation[7]). The first should increase by a factor of 2.8. We consider the second and third together as events of nucleonic origin. It is known[8] that the factor of increase for both low and high energy nuclear interactions is greater than 10. It is unlikely that the nucleonic component giving rise to $(AB-C:N)$ events increases less rapidly. If we use the factor of increase for the $(ABC:N)$ events (17.3), we find 75 percent for the fraction of $(AB-C:N)$ events at sea level due to μ^--mesons, and 35 percent at Climax.

TABLE II. Neutrons associated with penetrations $(ABC:N)$.

	Climax	St. Louis
With absorber (115 g/cm² Pb)	$33.7\pm1.1/h$	$2.04\pm0.13/h$
	Expected $\pm1.1/h$ Casuals	Expected $\pm0.04/h$ Casuals
	Corrected rate $32.6\pm1.1/h$	Corrected rate $2.00\pm0.13/h$
Sans absorber (0.69 g/cm² brass in counter walls)	$19.4\pm1.2/h$	$1.02\pm0.07/h$
	Expected $\pm0.7/h$ Casuals	Expected $\pm0.03/h$ Casuals
	Corrected rate $18.7\pm1.2/h$	Corrected rate $0.99\pm0.07/h$

The author wishes to express his thanks to Professor R. D. Sard for his advice and guidance during the course of this work.

* Work supported by the joint program of the ONR and the AEC.
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On the Shift of the Nuclear Magnetic Resonance in Paramagnetic Solutions*

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May 18, 1950

IN the measurement of gyromagnetic ratios of nuclear spins, paramagnetic ions are often added to the liquid sample in order to reduce the relaxation time.[1] The resonance frequency depends, however, on this addition, because the effective magnetic field at the nucleus is given by

$$H_{\text{eff}}=H_0+(4/3\pi-\alpha)M+qM. \quad (1)$$

Here H_0 is the externally applied field. The second term represents the contribution to the local field from the magnetization of the sample outside a spherical cavity around the nucleus under consideration, α being the demagnetizing factor and depending on the shape of the sample. For a sphere the second term vanishes.

The last term is the contribution to the local field at the nucleus from the paramagnetic ions inside a small sphere around the nucleus. This term has heretofore been put equal to zero. This is theoretically correct for pure dipole-dipole interaction in a liquid or in a solid with cubic symmetry.[2]

Experiments show, however, that this term cannot be neglected and represents an important correction in the comparison of gyromagnetic ratios. The value of q depends strongly on the type of chemical compounds used in the liquid sample. An example of the effect is shown in Fig. 1. More detailed experimental results covering different paramagnetic ions will be published in a subsequent paper by one of us (W.C.D.). Although q is usually positive, several cases of negative values of q have been observed.

The effect must not be confused with the chemical binding effect arising from the second-order paramagnetic correction in diatomic or polyatomic molecules.[3-5] The purpose of this letter is to present a possible explanation of the interaction factor q.

The paramagnetic ion in the liquid is subjected to strong varying electric fields. These are responsible for the quenching of the orbital momentum so that the effective magnetic moment of the ion is close to the "spin only" value.[6] Although the average electric field in the liquid will have spherical symmetry, the field at any instant will deviate from the average. Let us consider as a specific example the resonance of a F^{19} nucleus in a solution containing both fluorine ions and paramagnetic ferrous ions. The electric field produced by the F^- ion at the position of a neighboring Fe^{++} ion will have cylindrical symmetry around the radius vector connecting the two ions. Let us take the overall effect of the other particles in the liquid into account by a dielectric polarization, which reduces the field of the F^- ion by a factor ϵ, where ϵ is the dielectric constant of the solution. Now the effective g-value of the paramagnetic ion will depend on the angle between the axis of the electric field and the magnetic field H_0.

$$g^2=g_{\parallel}^2\cos^2\theta+g_{\perp}^2\sin^2\theta. \quad (2)$$

The values of $g_{\parallel}$ and $g_{\perp}$ may be different by a considerable amount, as is well known from observations of the magnetic susceptibility