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Informal Report

THE AGS BEAM STRUCTURE[†]

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ABSTRACT

The beam bunch structure of an accelerator due to the radio frequency (rf) cavities can make one-counter time-of-flight (TOF) measurements possible. This is particularly of interest for neutral particles in which TOF is otherwise impossible. Prompted by our interest in antineutrons we measured, and here report upon, the AGS structure as observed at an external target.

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Introduction

The beam bunch structure of an accelerator due to the radio frequency (rf) cavities can make one-counter time-of-flight (TOF) measurements possible. This is particularly of interest for neutral particles in which TOF is otherwise impossible. This method has been used in neutron and K_2 experiments. Among the present accelerators the Stanford Linear Accelerator (SLAC) has exceptionally narrow bunch width, and consequently the time-of-flight technique yields good resolution. On the other hand, with the 30 GeV/c proton Synchro-cyclotrons (AGS at BNL and PS at CERN) it is generally thought that their bunch widths are $\sim$ 12 nsec (FWHM), and thus would result in poor velocity resolutions for reasonable beam lengths.

Prompted by our interest[1] in antineutrons we measured the AGS structure as observed at an external target. The beam length is 450-ft., and the entire AGS beam was extracted in $\sim$ 600 msec. While the extraction is normally done with rf off, in this case it has been kept on with maximum voltage in order to preserve the beam structure. The accelerator was run at top energy and with an intensity of $\sim$ (3-6) $\times 10^{12}$ protons/pulse.

We measured the time structure of a secondary 20 GeV/c π^- beam from the external target using the logic shown in Fig. 1. Obviously, the pion and proton time structures are identical. The coincidence rate (scaler 2), normalized to the pion flux (scaler 1) is a product of the fluxes at times separated by the delay. The measured coincidence rate as a function of delay is presented in Figs. 2 and 3. The average pion flux was 1 π in about (10-20) AGS bunches or $\sim$ 200,000 π/pulse. Dead and resolving times were $\lesssim$ 40 nsec and (3-4) nsec respectively. We also looked in the structure through the oscilloscope (Fig. 4) by triggering on the "first" bunch and looking on the "second". Of interest for TOF experiments are (1) the bunch width, (2) the spacing of bunches, and (3) the shape of the beam away from the peak. The shape is of interest in those experiments in which the flux of the particles of interest (non-relativistic) is small in comparison to delayed relativistic particles which add to background problems.

WIDTH - From Fig. 2 we see that the measured width (FWHM) is $\sim$ (7 ± 1) nsec, and the distribution around the peak is reasonably Gaussian

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[1] T.E. Kalogeropoulos, AGS proposal June 5, 1973.

particularly when we consider that the beam intensity was not constant but fluctuated by a factor of about two. Since the distributions are products of two bunches (identical) as measured by the electronics, the width for one of them is $(7 \pm 1) / \sqrt{2} = (5 \pm .7)$ nsec. Clearly, the real width is smaller than this estimate since the coincidence resolving time increases it. Using $\sigma^2 = 2\sigma_0^2 + \sigma_{coin}^2$ where σ is the observed width (7 ± 1) nsec, σ_0 the actual width, and σ_{coin} is the width introduced by the coincidence. We evaluate σ_{coin} from $\sigma_{coin} = w_1 + w_2 - 2\tau$, where w_1, w_2 are the widths of the pulses coming to the coincidence circuit $(w_1 = w_2 = 4 \pm 1$ nsec), and τ the width of the pulse for triggering the scaler $(= 2 \pm 1$ nsec). We thus find that $\underline{\sigma_0 = (4 \pm 1.3)\ \text{nsec}}$. Since the errors quoted represent range - rather than Gaussian widths - of the respective variables, our estimate shows that the width (FWHM) of the bunches is in the range (3 - 5) nsec. This result is in agreement with the oscilloscope trace, and it is substantially smaller than what was generally accepted. With such an unexpected lower width one can achieve good time-of-flight resolutions at the AGS without unreasonably long path lengths.

SHAPE - The data of Fig. 3 have been fit by eye with straight lines and are well represented by $\exp(-|t-220|/3.7)$. Since the observed distribution is a product of the actual distribution, the actual distribution is $\exp(-|t-220|/1.7)$. Due to flux limitations the shape measurements do not extend beyond ~ 6 decades, but we do not have any reason to expect a change of this shape beyond this range.

In conclusion,

1. The separation between bunches is (219-221) nsec.
2. The FWHM is (3-5) nsec and most probably 4 nsec.
3. The bunch intensity decreases from the peak exponentially with a half time constant of ~ 1.2 nsec namely according to $\exp(-|t|/1.7)$.

We would like to thank the AGS staff for their cooperation; particularly, D. Berley, W. Glenn, D. Lazarus, and A. Maschke. Moreover we are indebted to E. Beier and H. Weisberg for their generous help, and for the use of their pion beam and data acquisition system.

B2 Distribution

FIG. I

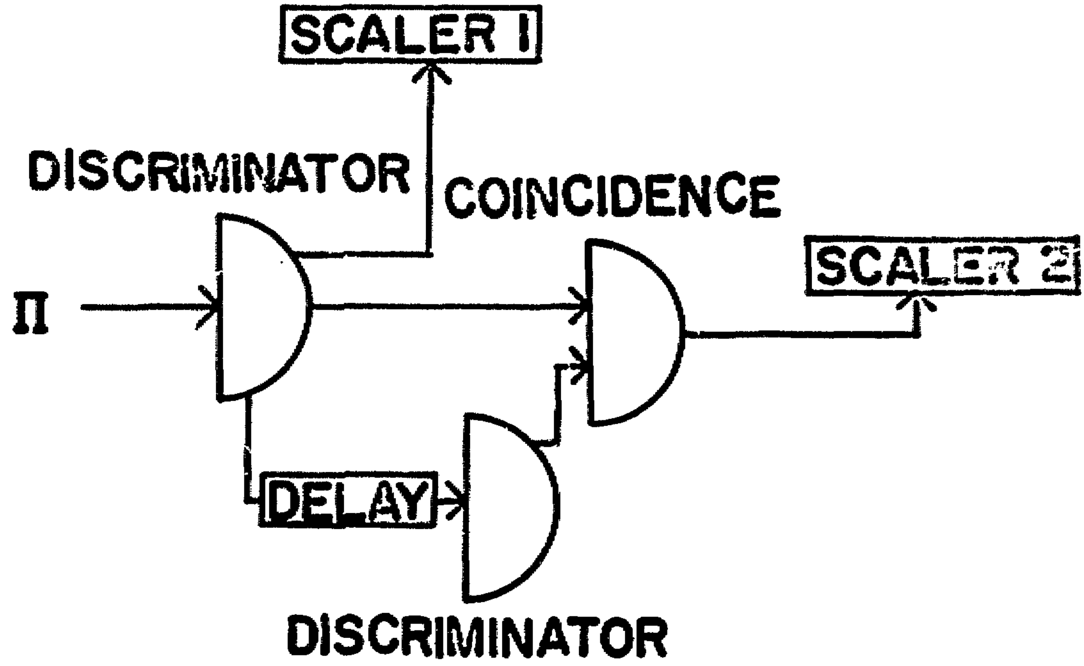

SCALER I
DISCRIMINATOR
COINCIDENCE
SCALER 2
Π
DELAY
DISCRIMINATOR

FIG. 2

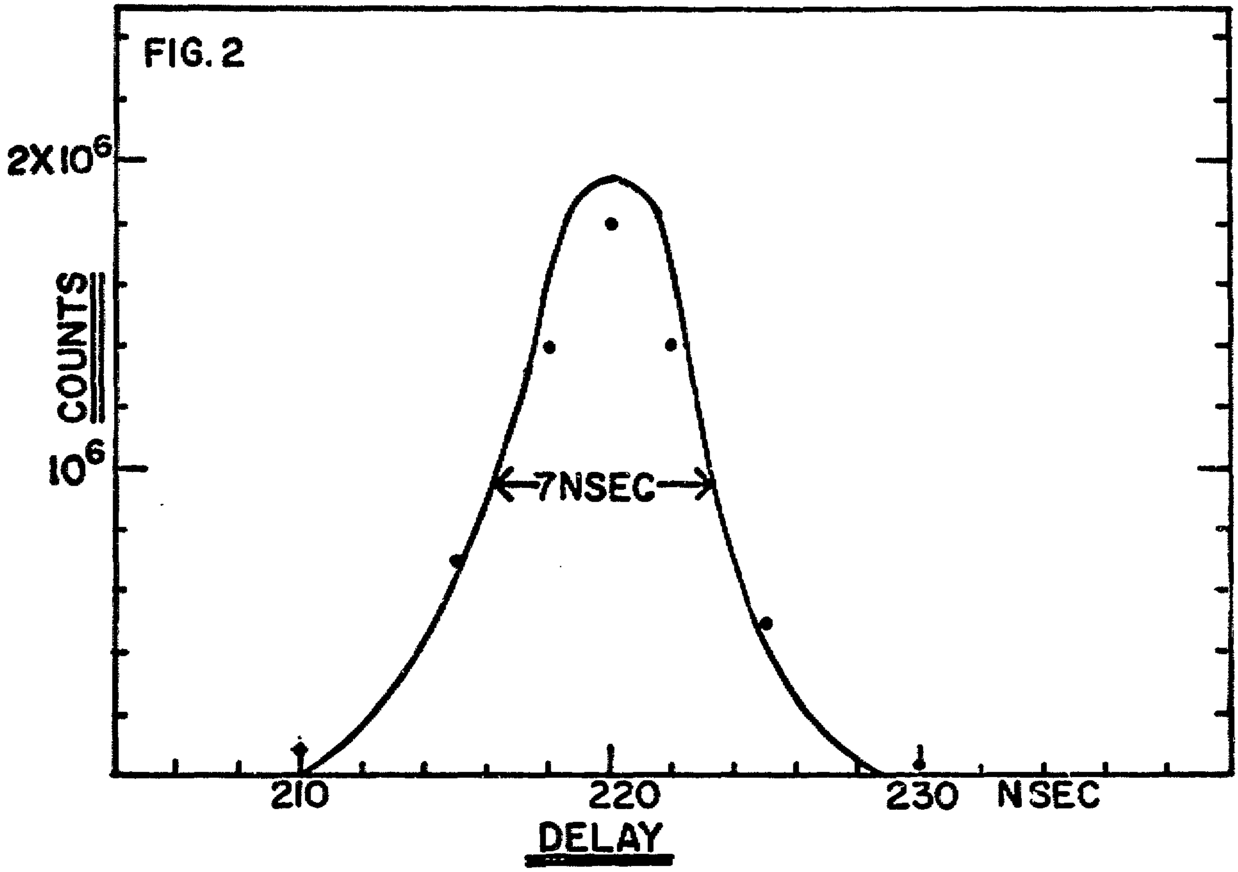
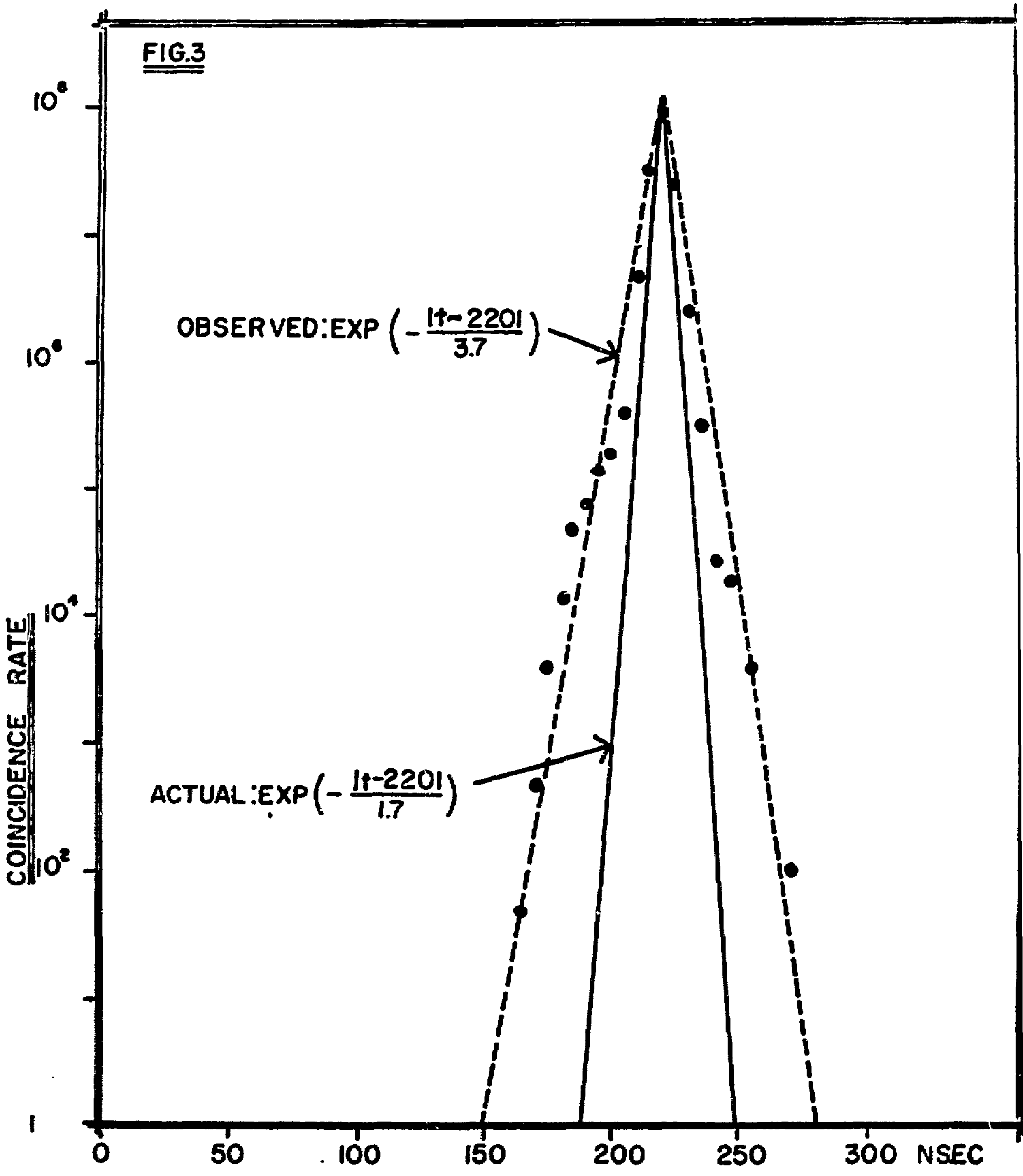


FIG.3



10⁸
10⁶
10⁴
10²
1
COINCIDENCE RATE
OBSERVED: EXP $\left(-\frac{|t-220|}{3.7}\right)$
ACTUAL: EXP $\left(-\frac{|t-220|}{1.7}\right)$
0
50
100
150
200
250
300
NSEC