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COMMENTS ON CONTINUOUS ASYMMETRY MEASUREMENT DURING POLARIZED PROTON ACCELERATION

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Technical Note

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Introduction

There are many depolarizing resonances during acceleration of polarized protons at the AGS. It is a serious problem to quickly determine which resonances contribute mainly to depolarization.

Dr. L. Ahrens mentioned that the internal polarimeter was used during acceleration; however, the use of the internal polarimeter in an energy scan mode caused a significant polarization loss due to the emittance blow up by the multiple scattering in the target material.[1]

In this report, the performance of the continuous measurement of the asymmetry at the KEK PS and consideration of this measurement at the AGS, will be described.

Measuring System at the KEK PS[2]

The internal polarimeter at the KEK PS consists of a thin polyethylene string target and a four-arm scintillation counter telescope. The beam polarization can be obtained by measuring the left-right asymmetry of the proton-proton elastic scattering in the polyethylene target. Figures 1 and 2 show a schematic of the counter telescope and mechanics of the target system respectively.

In order to use the four-arm counters, the telescope angles must be adjusted for the energy at which the measurement is made. It is very troublesome to make several fixed energy porches to measure the polarization. However, it is sufficient to measure the relative asymmetry using only backward counter telescopes to determine the depolarizing timing. Two target frames have a polyethylene string target and a carbon fiber target, respectively, for calibration measurement. On the other hand, for normal acceleration tuning of polarized protons, a thin (approximately 10 - 20 microns) polyethylene string is mounted instead of carbon.

Figures 3 and 4 show the logic and timing of this measurement. Six gates are fed to six CAMAC scalers divided into two groups. While channel 1 of the CAMAC interrupt register reads and clears the group 1 three scalers, channel 2 clears and reads the group 2 three scalers, and then this cycle will be continued sequentially. Data will be stored and analyzed by a personal computer, PC9800.

Figure 5 shows an example of the asymmetry data during acceleration with a 3.5 GeV flat top. We can identify the location of the spin flip resonance at $\gamma G = \nu_Z$ and $\gamma G = 7$, and we can see no depolarization during flat top. It takes about 40 minutes to take one data scan. After confirming the resonance timing by this method, a detailed scan of the tune jump or harmonic correction of the closed orbit can be made for each of the resonances.

Emittance Blow Up Due to the String Target

Emittance blow up by the string target due to the effect of multiple scattering is estimated as follows[3]:

$$\text{Horizontal} \quad n_H = \frac{2}{3} \frac{\pi}{\sqrt{\beta_H}} \frac{W_H^{2/3}}{< \theta^2 > d} (m^{3/2} - 1) \tag{1}$$

$$\text{Vertical} \quad n_V = \frac{2}{3} \frac{\pi}{\sqrt{\beta_H}} \frac{1}{<\theta^2 > d} \{(2W_V \frac{\beta_H}{\beta_V} + W_H)^{3/2} - W_H^{3/2}\} (m^{3/2} - 1) \tag{2}$$

where n_H and n_V are the number of turns until the emittance will blow up to m times, m is the emittance blow up factor, W_H and W_V are the horizontal and vertical emittance, β_H and β_V are the betatron amplitude at the target position and $<\theta^2>$ is the root mean square of the scattering angle in rad:

$$\sqrt{< \theta^2 >} = \frac{14.1 \text{ MeV/c}}{P\beta} Z_{inc} \sqrt{L/LR} \{1 + 1/9 \log_{10} (L/L_R)\} \tag{3}$$

where L is the target diameter and L_R is the radiation length of target material[4].

Calculations were performed using parameters as shown in Table I with the assumption of fixed energy.

For the AGS, if the string was flipped into the beam line at two times, 180 ms and 350 ms, from acceleration start, respectively, the time of the emittance blow up to m times is summarized in Table II, and for the KEK PS, the 30 micron target at 500 MeV is in Table III.

Table I

	AGS	KEK PS
target material	nylon	polyethylene
target thickness	6 mil	20 - 50 micron
W_H (π mm. mrad)	30	40
W_V (π mm. mrad)	20	10
β_H	17.4m	20m
β_H	13.5m	5m
Z_{inc}	1	1
L_R	47.9×10^{-2}m (for carbon)	

Table II (AGS 6 mil)

m (blow up factor)		1.1	2.0
Insertion Time (180 ms)	Horz.	1.8 ms	34 ms
	Vert.	6.4 ms	118 ms
Insertion Time (350 ms)	Horz.	4.6 ms	85 ms
	Vert.	16.0 ms	295 ms

Table III (KEK 30 micron)

m (blow up factor)	1.01	1.1
Horz.	267 ms	303 ms
Vert.	395 ms	449 ms

Figure 6 shows typical data of the emittance blow up at the AGS. Target time of flipping into the beam is 180 ms. It took 35 - 50 ms to blow up the emittance by a factor of 2 for horizontal and vertical. This is rather faster than the calculation. However, the emittance blow up was not observed at KEK PS by the beam profile monitor. The calculation is summarized in Table III.

Although the KEK target system has a spooling system to reduce the beam heating, the beam intensity is less than 1.0 x 10^{10} and it is not necessary to spool the target so the very thin string can be used.

For the high intensity beam at the AGS, it is necessary to use the spooling system so the high tension of the target wire is required.

If the 50 micron or 25 micron string is used in the AGS, the time of 10% emittance blow up (m = 1.1) is shown in Table IV.

Table IV

		50 micron	25 micron
180 ms	Horz.	19 ms	92 ms
	Vert.	66 ms	321 ms
350 ms	Horz.	38 ms	173 ms
	Vert.	133 ms	601 ms

These results show that an energy scan mode seems to be worthwhile to measure the asymmetry for some periods during acceleration.

Resonance Strengths by Emittance Blow Up

Asymmetry measurement is a very useful method to quickly show which of the resonances mainly contribute to depolarize the polarized protons. However, there is a fear that intrinsic resonance strength will be increased by the beam size growth.

Figure 7 shows the measured polarization on five interval gates positioned between the intrinsic resonances, $\gamma G = 24 - \nu_z$, $12 + \nu_z$, $36 - \nu_z$, and $24 + \nu_z$ at various target insertion times.[1]

Table V

Resonance	ϵ (Strength)	P/P_o (ϵ)	P/P_o (2ϵ)	P/P_o (3ϵ)
$12 - \nu_z$	0.0003	1.000	1.000	0.999
ν_z	0.0154	0.969	0.840	0.673
$24 - \nu_z$	0.0006	1.000	1.000	0.999
$12 + \nu_z$	0.0054	0.996	0.979	0.953
$36 - \nu_z$	0.0137	0.975	0.871	0.732
$24 + \nu_z$	0.0010	1.000	0.999	0.998
$48 - \nu_z$	0.0015	1.000	0.998	0.996

$$P/P_o = \frac{\delta^2 - \epsilon^2}{\delta^2 + \epsilon^2} \left\{ 2e^{-\frac{\pi\epsilon^2}{2\alpha}} - 1 \right\}$$

where $\delta = 0.125$, $\alpha = 0.0597$, and $\nu_z = 8.75$

Table V shows the calculation of the polarization ratio on passing through resonances depending on the beam size. Resonance strengths are taken from Ref. 5. There are no severe depolarization problems except $\gamma G = \nu_z$ and $36 - \nu_z$, which are very strong resonances. I speculate on the data of Fig. 7, that the denser part of the high polarization beam is spilled out from the bucket due to the energy loss by the target material. Further, it is strange that the depolarization at $\gamma G = 24 + \nu_z$ is larger than that of $\gamma G = 36 - \nu_z$. It is suggested that $\gamma G = 24 + \nu_z$ may not be tuned to jump completely.[6]

Consideration of the Measurement During Acceleration

Spin is a very sensitive probe of the beam optics parameter. For example, if the slow quadrupole will be excited to vary the vertical tune, the timing of the intrinsic resonance will shift. Further, asymmetric excitation of the fast quadrupole causes the deformation of the beta function and emittance blow up[7] and then the resonance strength would be changed.

So, the continuous measurement of the asymmetry during acceleration is a very attractive method to quickly know the resonance position. The intensity of the AGS polarized beam is higher that than of KEK, and a thin target cannot be used because of the spooling system which is needed to avoid beam heating. However, even if the measurement period would be 100 ms - 200 ms, the measurement which is performed by narrow gates may give us much information on several resonances, that is, the sequential one intrinsic resonance and 5 or 6 imperfection resonances would be covered by the 100 ms period.

The curve of asymmetry will be decreased gradually versus time due to the kinematics factor and continuous polarization loss. If there are discontinuity positions, it shows the effect of depolarizing resonances or a physical mechanism of scattering.

Furthermore, if the fishing wire which is less than 6 mils, typically 2 mils could be used, multiple scattering and energy loss would be decreased and then the measurement can be made during the full acceleration period and can be performed in one data run.

Acknowledgments

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2. H. Sato et al., Proc. on the Eighth Intern. Symp. on High Energy Spin Physics, Minneapolis, MN, Sept. 1988.

3. K. Yokoya, Private Communication.

4. Particle Properties Data Booklet published by the Particle Data Group at CERN and Berkeley.

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6. S.Y. Lee, Private Communication.

7. E.D. Courant et al., Acc. Div. Tech. Note #229 (1985)

Figure Captions

Fig. 1 Schematic of the KEK internal polarimeter.

Fig. 2 Target system of the KEK internal polarimeter.

Fig. 3 Logic diagram of the sequential asymmetry measurement during acceleration.

Fig. 4 Timing chart of the sequential asymmetry measurement during acceleration.

Fig. 5 Continuous asymmetry measurement data up to 3.5 GeV at KEK PS.

Fig. 6 Vertical emittance blow up when the insertion time of the target is 180 ms from acceleration start at the AGS.

Fig. 7 Measured polarization on five interval gates positioned between the intrinsic resonances, $\gamma G = 24 - \nu_z$, $12 + \nu_z$, $36 - \nu_z$, and $24 + \nu_z$ at various target insertion times.

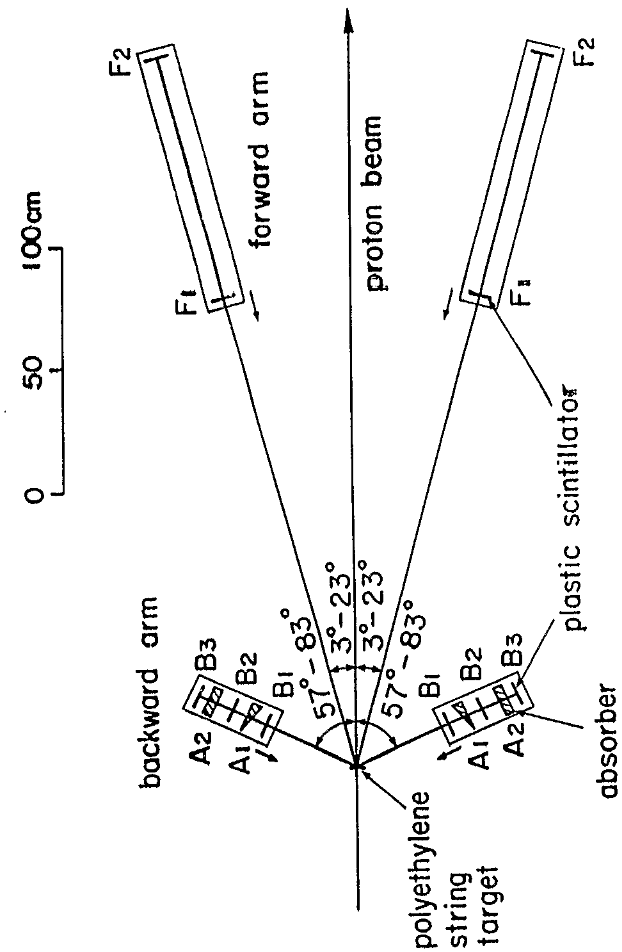


Figure 1

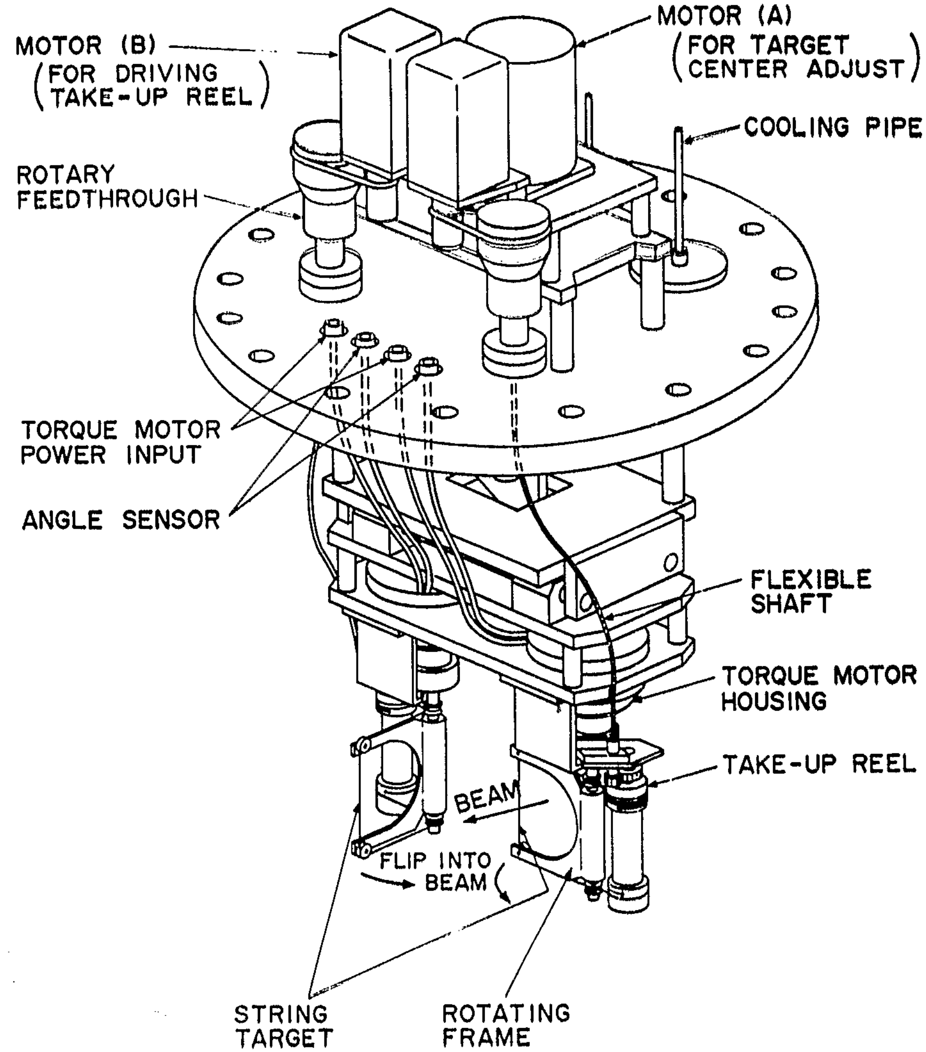


Figure 2

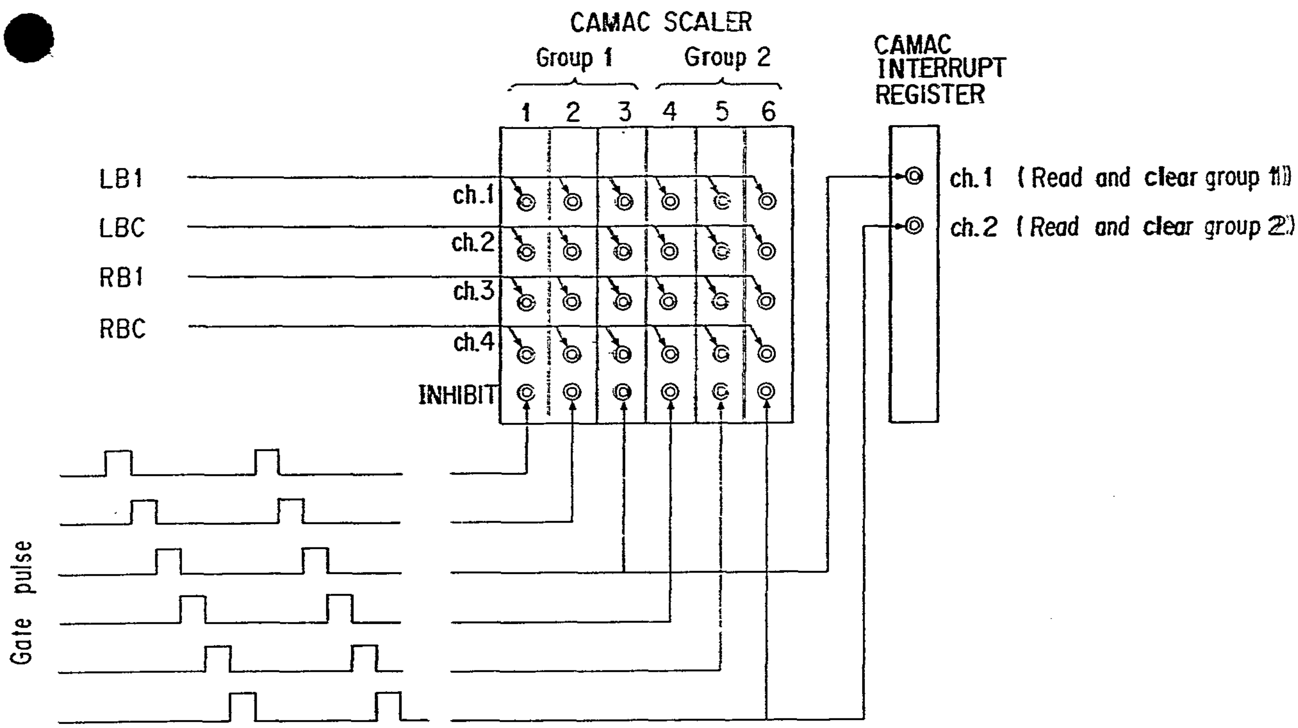


Figure 3

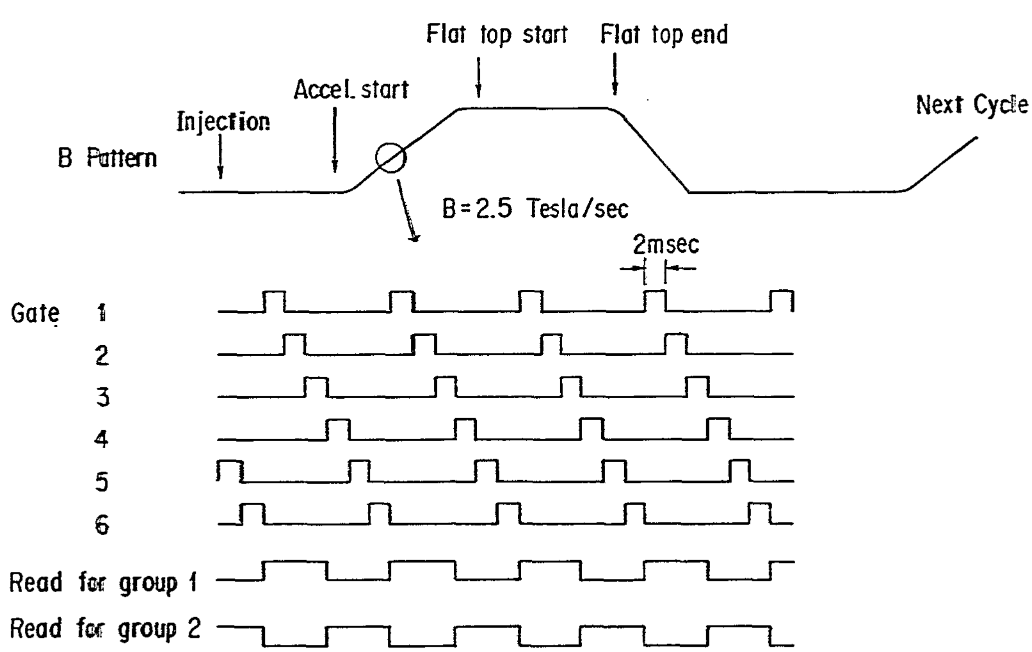


Figure 4

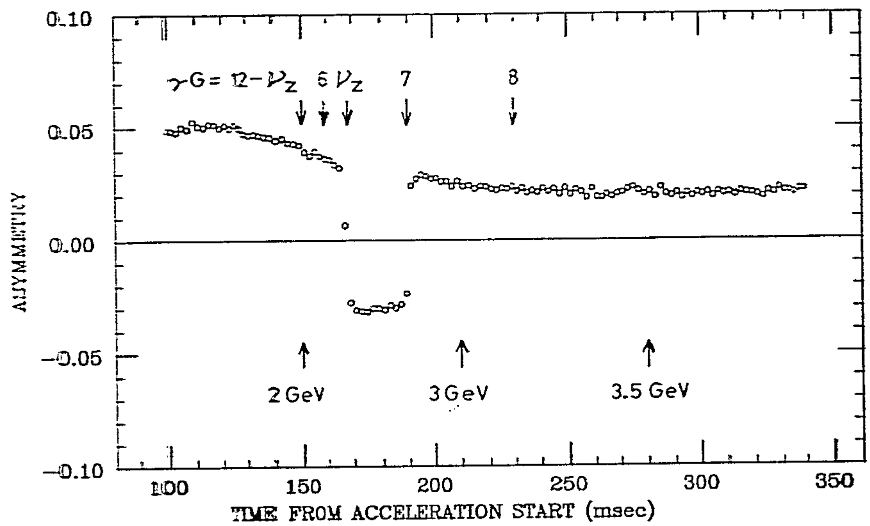
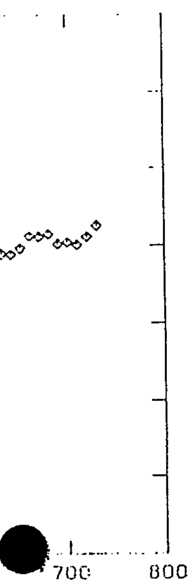


Figure 5



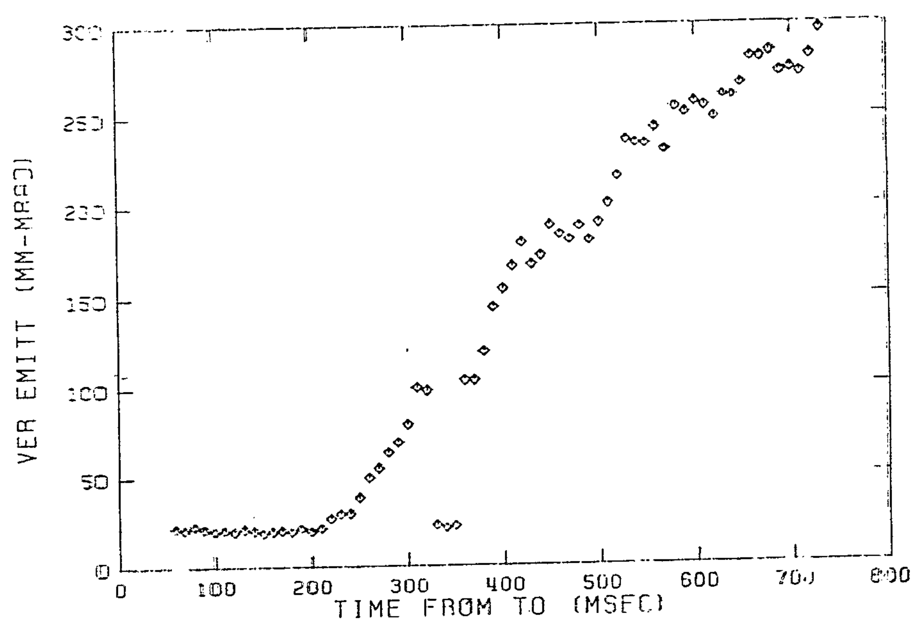


Figure 6

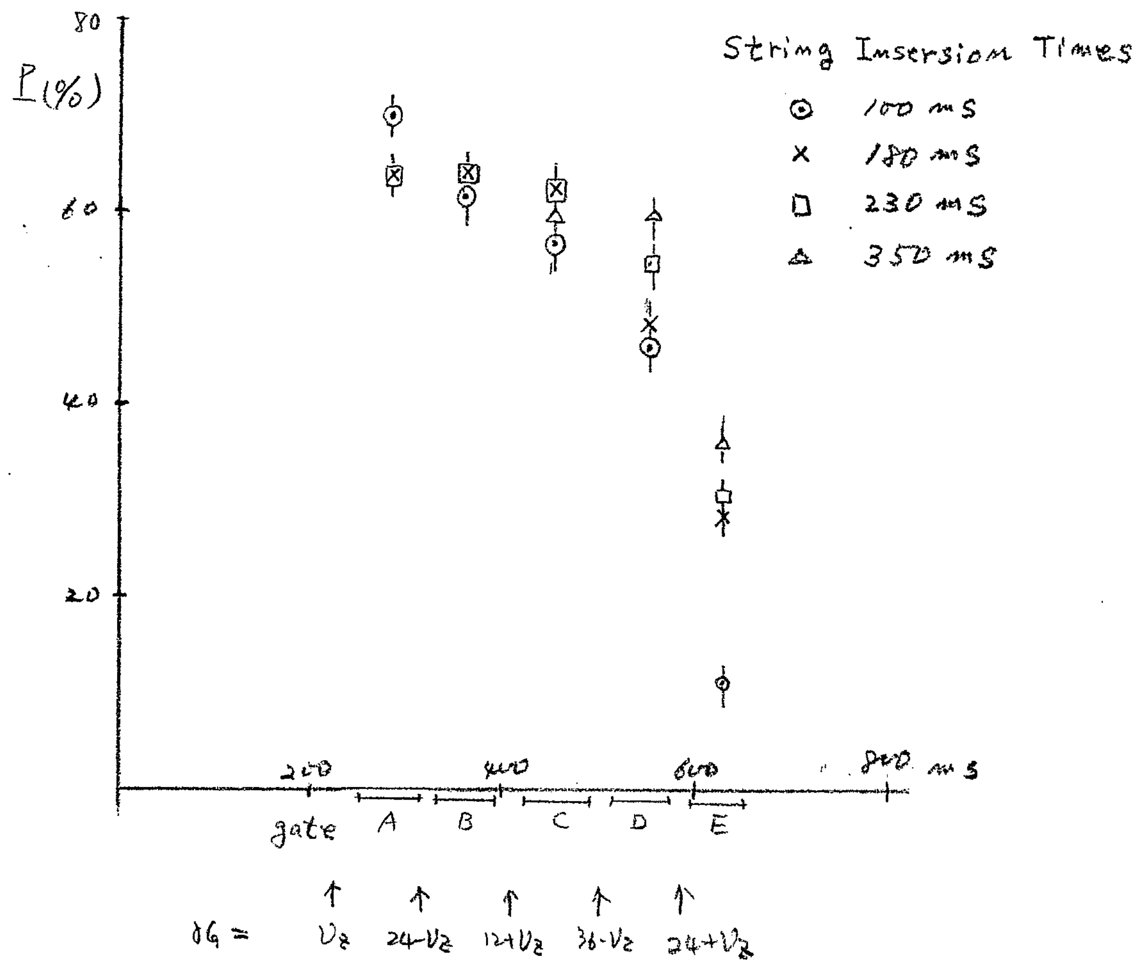

80
P(%)
60
40
20
String Insersion Times
100 mS
180 mS
230 mS
350 mS
200
400
600
800 mS
gate
A
B
C
D
E
δG =
ν/2
24-ν/2
12+ν/2
36-ν/2
24+ν/2

Figure 7