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U-Line Emittance Measurement at U618 by MSEM

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DISCLAIMER

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AGS STUDIES REPORT

Date 2/17/82 and 3/2/82 Time 11:00 a.m. - 1:00 p.m.; 1:00 p.m. - 4:30 p.m.

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Reported by W-T Weng

Subject U Line Emittance Measurement at U618 by MSEM

OBSERVATIONS AND CONCLUSION

Purpose

The purposes of the study are:

1. Test of the device performance in terms of its signal fidelity, calibration, background dependence and operational easiness.
2. AGS external beam emittance measurement at various intensities.

Description of the Device

This is the prototype unit of the external profile monitor SEM (secondary emission monitor) for the AGS fast beam measurement. The signal measured is due to the secondary emission of electrons from proton beam interaction with tungsten wires. Each wire is 10 mil in diameter and is stretched across an aluminum frame at 1.5 mm spacing. Overall, there are 30 channels in each plane and each plane has its own motor drive for location control. At both sides of the wire there are cleaning plates kept at 200 V to collect the electrons and keep them from striking the adjacent wires.

The device is located at the U618 instrumentation box with local vacuum at 10^{-5} Torr. The data are sent back to PDP-10 and a software program has been created to calculate the center, standard deviation and width of the beam. From the standard deviation and the center, a two-parameter Gaussian fit is also produced.

Description of the Method

The device is 136-ft. downstream of UQ10. By adjusting UQ10, we can obtain a series of beam profiles and widths. Assuming that the transfer matrix from the entrance of UQ10 to U618 is M_i for each UQ10 setting, then the beam size at U618 can be expressed as

$$X_i^2 = \varepsilon\,(M_{11}^2\beta_o - 2\,M_{11}M_{12}\,\alpha_o + M_{12}^2\,\gamma_o)_i$$

Where α_o, β_o, γ_o is the beam distribution parameter at the entrance of UQ10 and ε is the emittance of the beam at extraction energy. A reliable answer of parameters ε, α_o, and β_o can be found by least-square fitting method on several measurements.

Procedures and Observations

1. A typical profile observed is shown in Figure 1. From the figure alone several pieces of information are readily available. First, it shows that the center of the distribution is at - 71 mil. This number fluctuates from pulse to pulse with 10 mil. amplitude. Second, it shows that the standard deviation is 0.24 inches, hence, the beam width containing 95% of particles in two-dimensional phase space is given by $X_{FW} = 2(2.45 \times \sigma) = 1.18''$. Third, it shows that a two-parameter Gaussian fit gives a pretty accurate description of the one-dimensional beam profile. From now on we will assume that is the case unless the data shows otherwise.
2. On February 24, a cross-calibration of the profile monitor with the Al foil activation method was performed. In that particular setting, the profile of one single pulse gave $\sigma = 0.196''$, but is grew to 0.205" for the sum signal of ten pulses. It was consistent with a pulse-to-pulse position shift of 0.01" mentioned above. The foil measurement, necessarily taken over many pulses, gave $\sigma = 0.207''$. This clearly established the confidence in the SEM signal. Furthermore, the SEM device is less sensitive to the halo and background particles than the foil counting method and, hence, gives more truthful measurement of the beam size.
3. The linearity of the signal with respect to the beam intensity had been checked by varying the AGS beam intensity and by shifting the device location and record the reading from different wires corresponding to the same location of the beam. The second method had also been used to test the cross talk of different wires. Both tests showed no observable effect.

4. Tests on the dependence of the vacuum condition are not conclusive. In principle, it should not be too sensitive, but for the reliable result we put a turbo-molecular pump at the location to assure 10^{-5} Torr vacuum in the vicinity.
5. On February 17, a series of measurements was carried out to obtain the beam half sizes (as shown in Figure 2) corresponding to different settings of UQ10. This was done at the beam intensity around 7×10^{12} ppp. The same measurement was repeated on March 2 at an intensity around 10×10^{12} and the results of vertical beam size are shown in Figure 3. During the measurement care was taken to record the readings on the loss monitors to ensure that no beam scraping occured. Measurements were also taken for horizontal beam size. Unfortunately because of the location of the device, it was impossible to create a minimum in horizontal dimension.
6. Now we have ten measurements on the vertical beam size. The least square fitting program was activaated to predict the emittance parameter at the entrance of UQ10 as:

I(ppp)	$\varepsilon(10^{-6}$m-rad)	α	β(M/rad)
7×10^{12}	1.62 ± 0.03	-4.65 ± 0.13	228.7 ± 6.43
10×10^{12}	2.33 ± 0.02	-3.61 ± 0.05	181.75 ± 2.36

The normalized vertical emittance is 48×10^{-6} m-rad at 7×10^{12} ppp and 70×10^{-6} m-rad at 10×10^{12} ppp. These results are consistent with previous measurements in the past five years. The location of the SEM device precludes a precise measurement of horizontal emittance. But, the horizontal width variation as a function of the UQ10 setting is consistent with predictions of the TRANSPORT program with the assumption of $\Delta P/p = 0.12\%$ and ε_h of 45×10^{-6}m-rad.

Discussion

The increase of the vertical emittance from 7×10^{12} to 10×10^{12} is approximately linear. If we assume that the emittance dependence on the intensity is linear, then the predicted emittance at 3×10^{12} is 0.69×10^{-6}m- rad which is higher than the assumed emittance of 0.5×10^{-6}m-rad for ISA injection. There are two factors we should take into consideration for the extrapolation. First, it has been observed that the AGS beam blows up passing through transistion at intensities higher than 5 x 10^{12} ppp. This implies that the linear extrapolation from 7 x 10^{12} ppp is a very conservative one. Second, the measurement is taken with regular AGS operation mode. For ISA injection, the AGS injection will be different.

In order to really understand the beam quality for ISA injection, we have to repeat the emittance measurement at 3 x 10^{12} ppp with both AGS normal operation set-up and special AGS injection configuration for ISA injection. Starting November of 1982, the AGS injection will be converted to H^- charge exchange mode. It will be much easier to obtain optimal conditions for ISA injection with H^- AGS injection.

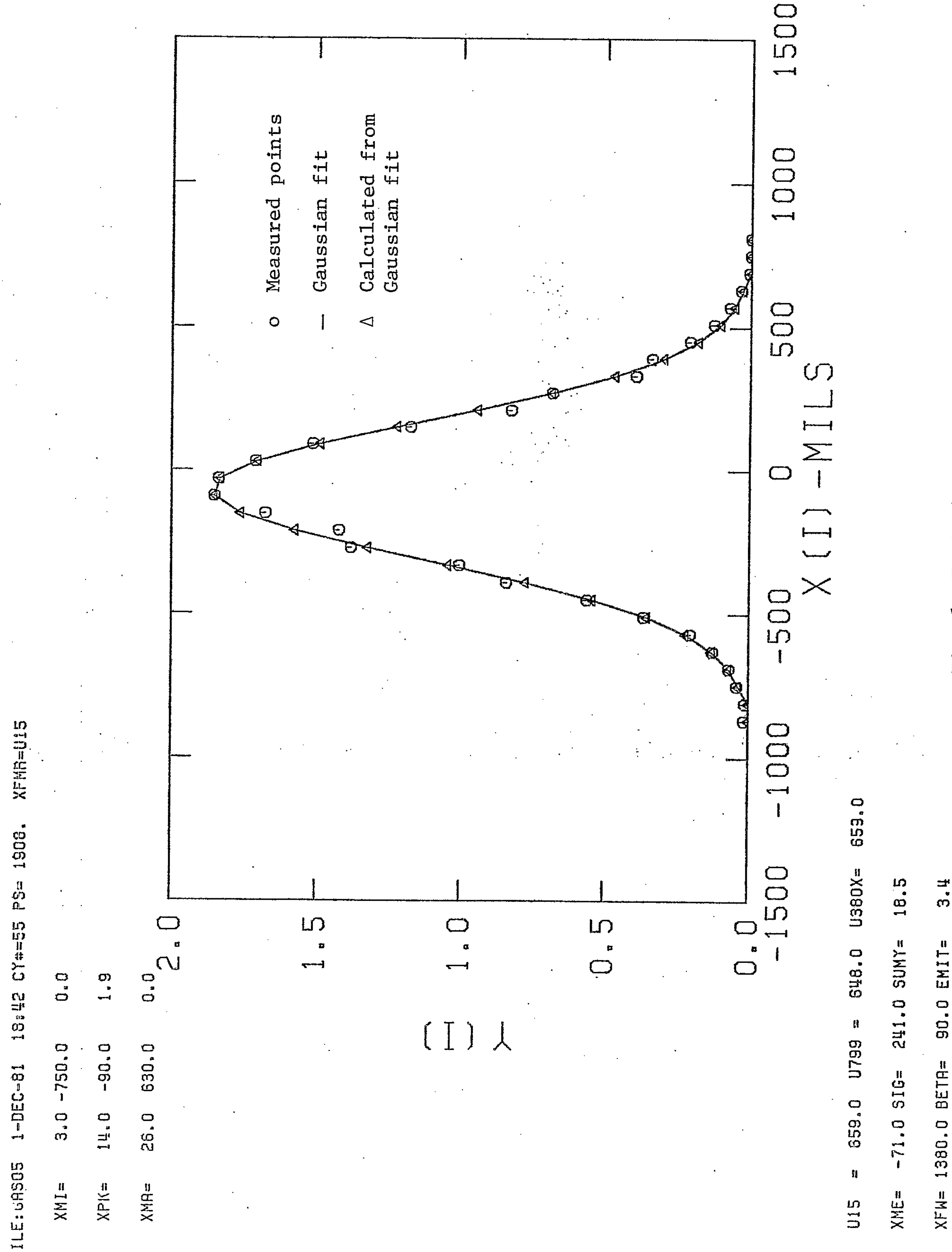

Fig. 1 Typical Profile Observed

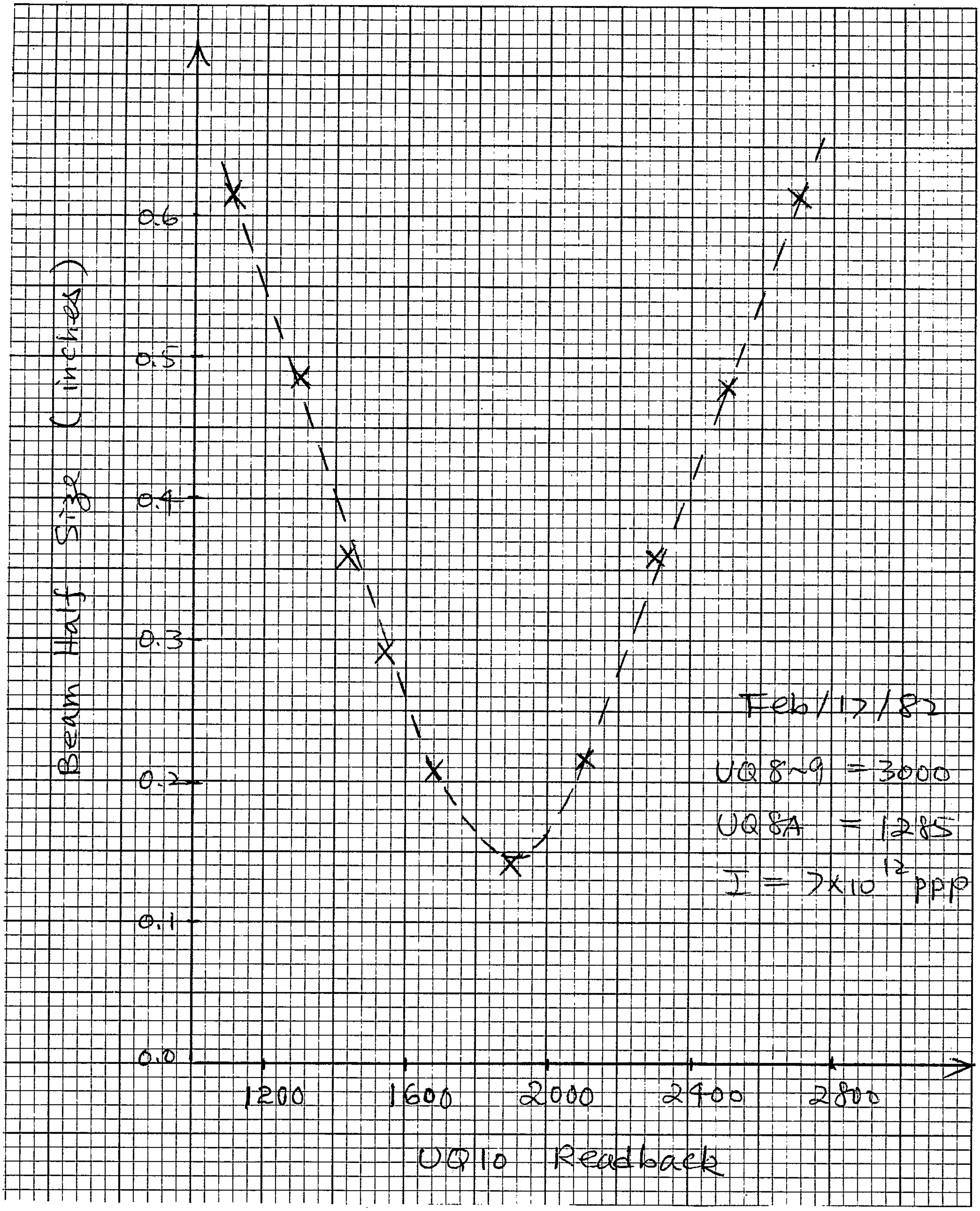

Fig. 2 Vertical beam half sizes at U618 (Feb. 17, 1982)

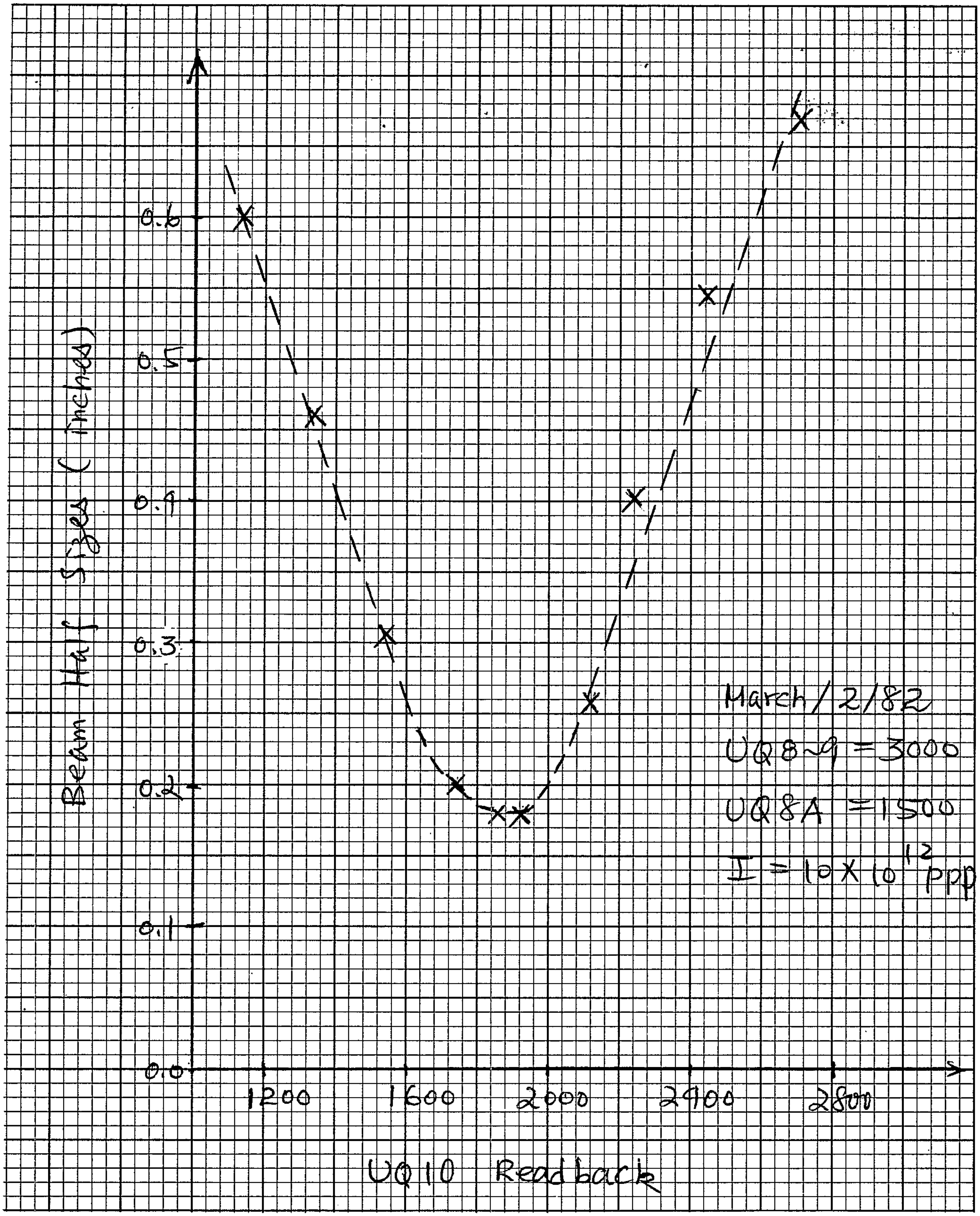

Fig. 3 Vertical beam half sizes at U618 (March 2, 1982)