

Aperture Requirements and Proton Performance in RHIC

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APERTURE REQUIREMENTS
AND
PROTON PERFORMANCE IN RHIC

G. Parzen

10/3/84

and Proton Performance in RHIC

G. Parzen, 10/3/84

Important Limitations

- 1) Intra beam scattering
- 2) Beam-Beam interaction
- 3) Instabilities, $Z_{||}/n$, Z_{\perp}/n
- 4) Aperture (closed orbit errors, random $\Delta B/B$, chromatic $\Delta B/B$)

Intra beam Scattering, $N_b = 10^8$ / bunch

- 1) Longitudinal growth
- 2) Transverse growth
- 3) aperture required $\gamma = 30, \pm 26 \text{ mm}$
 $\gamma = 320, \pm 320 \text{ mm}$
- 4) $t = 50 \text{ hr}$ operation
- 5) Luminosity

2.

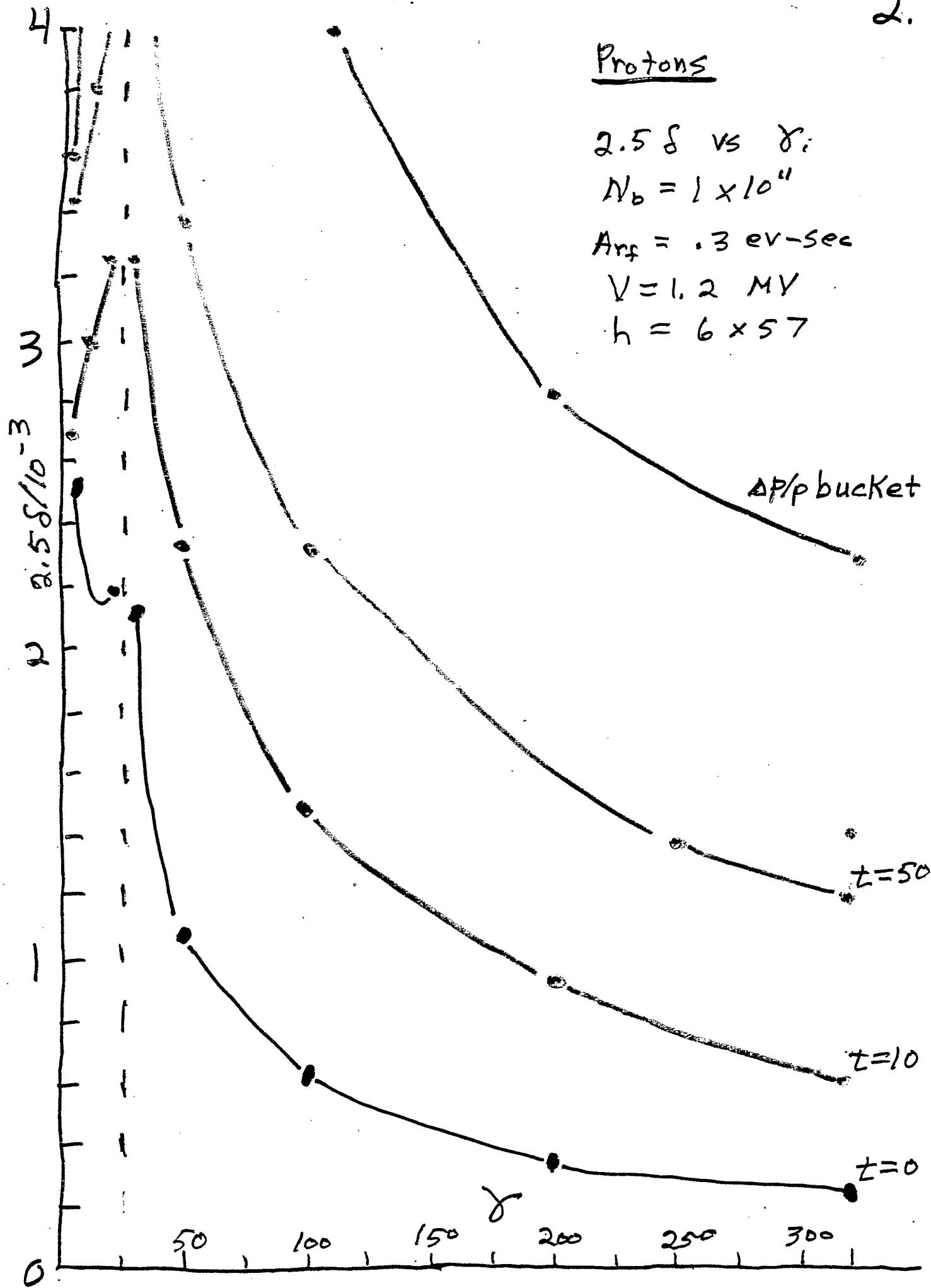
Protons2.5 δ vs γ :

$$N_b = 1 \times 10^{11}$$

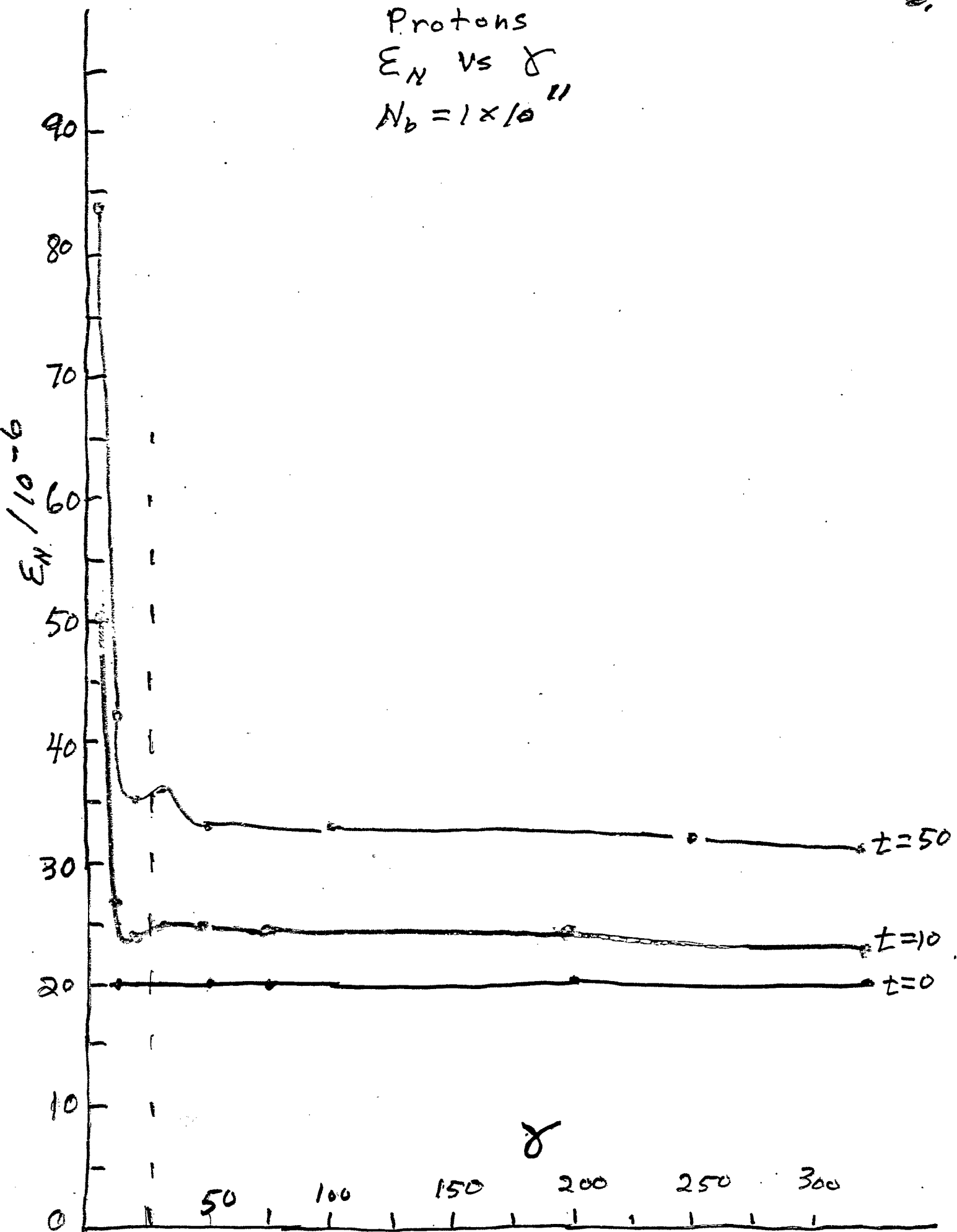
$$A_{rf} = .3 \text{ ev-sec}$$

$$V = 1.2 \text{ MV}$$

$$h = 6 \times 57$$



Protons
 E_N vs γ
 $N_b = 1 \times 10^{11}$



Half - Aperture vs γ
 $(6\sigma_H + 2.5\lambda_p\sigma vs \gamma)$

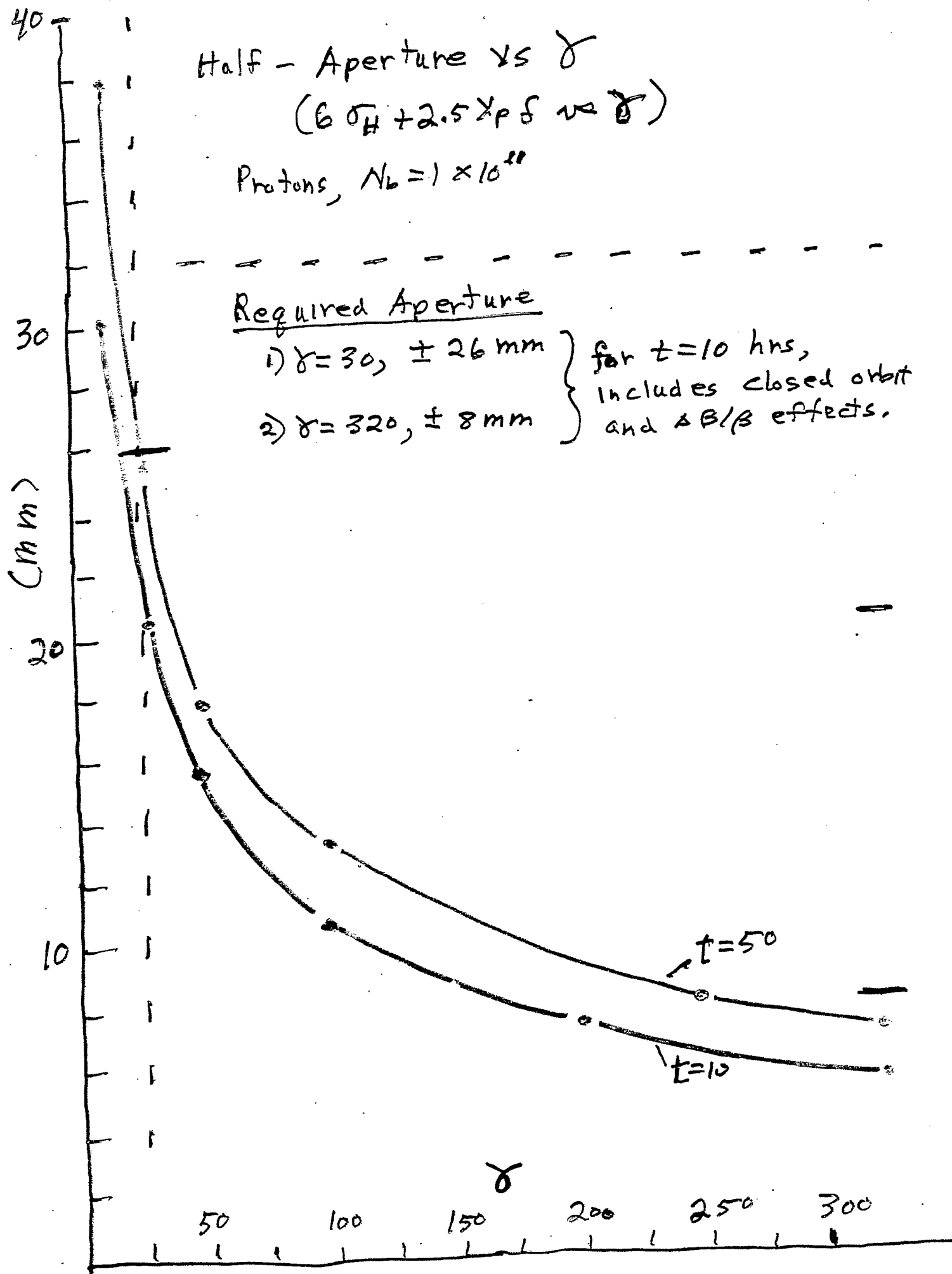
Protons, $N_b = 1 \times 10^{11}$

Required Aperture

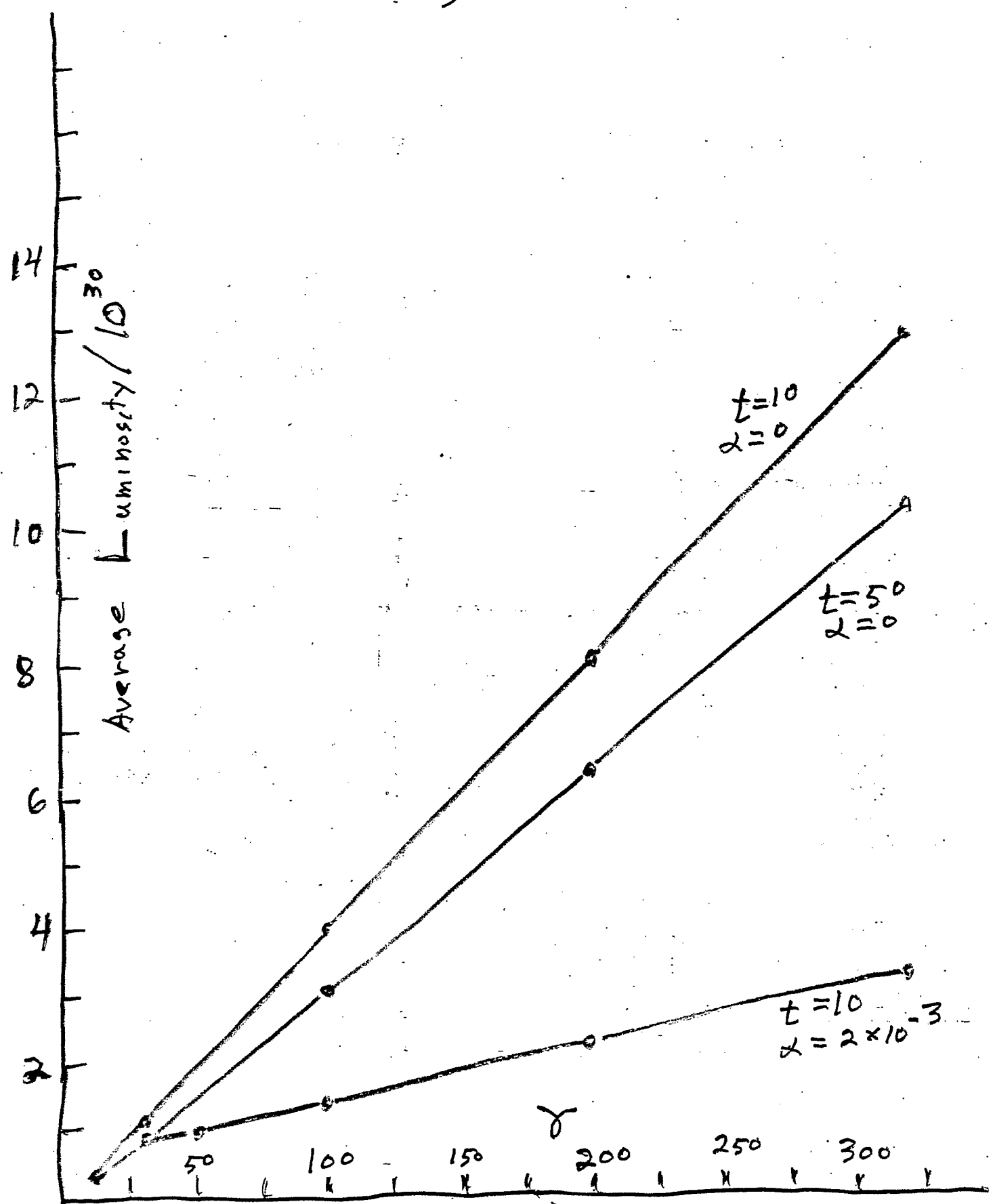
1) $\gamma = 30, \pm 26 \text{ mm}$

2) $\gamma = 320, \pm 8 \text{ mm}$

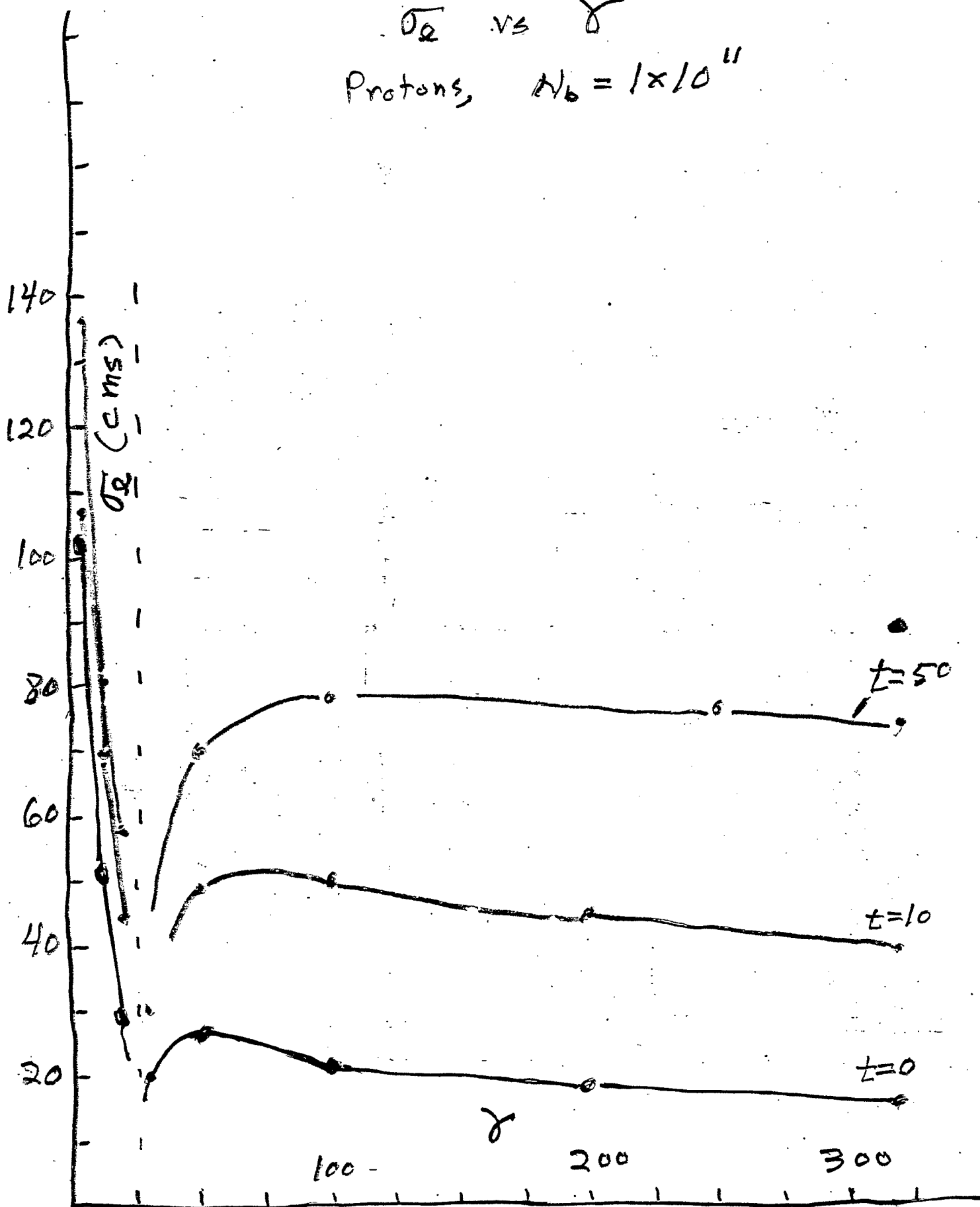
for $t = 10 \text{ hrs}$,
 includes closed orbit
 and $\Delta B/B$ effects.



Average Luminosity vs γ
 Protons, $N_b = 1 \times 10^{11}$



σ_Q vs γ
 Protons, $N_b = 1 \times 10^{11}$



Beam Beam Interaction

$$N_b = 1 \times 10^{11}, \quad \epsilon = 2 \times 10^{-6}$$

$$\Delta V_{BB} = .0052, \text{ head on collisions, } t=0$$

$$\Delta V \sim N_b / \epsilon_N \text{ independent of energy}$$

Instabilities, $N_b = 10^{11}$

$$\gamma = 320, \quad \sigma_{be} = 15.8 \text{ cm}, \quad \delta_0 = .102 \times 10^{-3}$$

$$A_{rf} = .3 \text{ eV-sec}, \quad I_{pk} = 12 \text{ A}, \quad I_{av} = .43 \text{ A}$$

$$Z/n = 10 \text{ ohms}$$

$$N_{b,T} = .5 \times 10^{11} \text{ (Threshold)}$$

(AGR says 1×10^{11})

$$N_{b,T} \sim \delta^3$$

$$\left(\begin{array}{l} I_p < \frac{4\pi E}{e} |\eta| \frac{\delta^2}{(Z/n)} \\ I_p = N_b e \beta c / \sqrt{2\pi} \sigma_z \end{array} \right)$$

$$\delta = .1 \times 10^{-3} \rightarrow .13 \times 10^{-3}$$

takes 1/3 hour due to TBS

$$N_{b,T}(\text{Transverse}) = 2.9 \times 10^{11} \quad \text{for } \delta = .13 \times 10^{-3}$$

Problem if $N_b > N_{b,T}(\text{Transverse})$

$$\text{Transverse } I_p < \frac{10 \epsilon}{c} |\eta| \frac{\delta}{B} \frac{1}{(Z_1/n)}$$

$$N_{b,T} \sim \delta^2$$

May require δ increase by other means.

$$N_b = 10^{12}$$

Intrabeam Scattering

$$\int \rightarrow \phi \cdot 4.76 \times 10^{-3} \text{ (t = 10 hrs)} \quad , \delta = 320$$

$$2.5 \delta = 1.4 \times 10^{-3} \quad \left(\frac{\Delta p}{p} \right)_{\text{bucket}} = 2.3 \times 10^{-3}$$

$$\begin{aligned} \text{Aperture required} &= 7.8 \text{ mm} + 2.5 \text{ mm} \\ &= 10.3 \text{ mm} \end{aligned}$$

Beam-Beam Interaction

$$\Delta V \sim \frac{N_b}{\epsilon_N} \quad L_0 \sim \frac{N_b^2 \delta}{\epsilon_N}$$

$$\text{To keep } \Delta V = .0052, \quad \epsilon_N \rightarrow 10 \times 20 = 200 \times 10^{-6}$$

$$\sigma_H = 2.3 \text{ mm}$$

$$\delta = .48 \times 10^{-3}, \quad X_p \delta = .78 \text{ mm}$$

$$\text{Aperture Required} = 6 \sigma_H + 2.5 X_p \delta = 16 \text{ mm}$$

With closed orb, t and DFB effect

$$\text{Aperture Required} = \pm 20.5 \text{ mm}$$

$N_b = 10^{12}$, Instabilities

$$z/h = 10, \quad N_{b,T} = .5 \times 10^{11}$$

$$\delta = .1 \times 10^{-3} \rightarrow .27 \times 10^{-3}$$

(would take $\frac{1}{2}$ hr due to IBS)

$$N_{b,T} (\text{transverse}) = 1.3 \times 10^{12} \text{ for } \delta = .27 \times 10^{-3}$$

Luminosity, $N_b = 10^{12}$, $\delta = 320$

$$L_0 = 13 \times 10^{32}, \quad L = 1.3 \times 10^{32} \text{ at end.}$$

$$L_{AV} \simeq 2 \times 10^{32}$$

Added Notes

- 1) The result used for the threshold current for the longitudinal Instability is in error by a factor of 2. This was pointed out by Harald Hehn. The result should read

$$I_p < \frac{2\pi E}{e} \frac{|\eta|}{(Z_{||}/n)} \delta^2$$

and the numerical results should be modified by this factor of 2.

- 2) One possibly important effect has not yet been looked at in regard to operating RHIC with $N_b = 1 \times 10^{12}$ protons/bunch. This is the incoherent space charge effect, which is the V-shift caused by the charge and current of the beam.