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# Intrabeam Scattering Results for a High Frequency RF System

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# DISCLAIMER

AD/RHIC-AP-66

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7/6/88

BNL

The results given in this note replace the results given in the previous note, AD/RHIC-AP-63.

# Factors Leading to Growth

1) $\frac{1}{\sigma}\frac{d\sigma}{dt} \sim (Q^2/A)^2$

2) $\frac{1}{\sigma}\frac{d\sigma}{dt} \sim N_b$ / 6-dimensional Phase Space

3) Distance from "Equilibrium State"

Invariant, $\sigma_E^2 - 2\,\sigma_x^2 = \text{constant}$

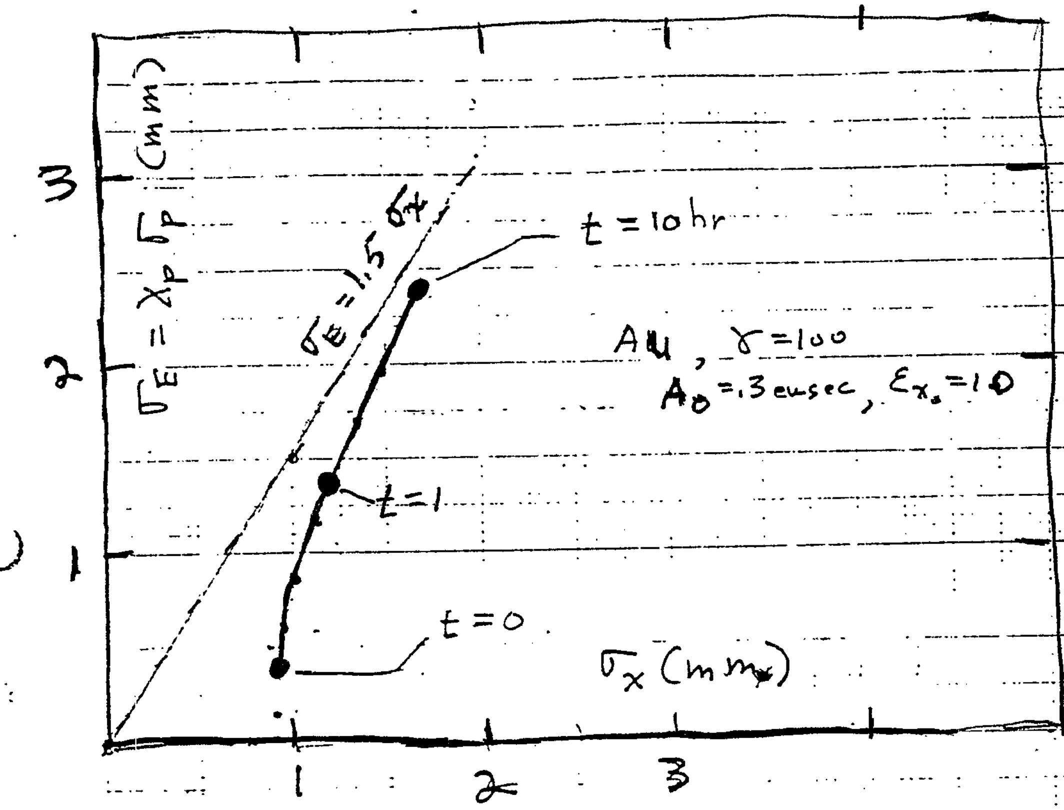
$\sigma_E = X_p\,\sigma_p$

holds for $\gamma > \gamma_t$, cells only lattice complete coupling, bunched beams

a) $t \to \infty$, $\sigma_E \sim 1.4\,\sigma_x$

b) $\frac{1}{\sigma_p}\frac{d\sigma_p}{dt} = 2\left(\frac{\sigma_x}{\sigma_E}\right)^2 \frac{1}{\sigma_x}\frac{d\sigma_x}{dt}$

If $\sigma_E \ll \sigma_x$ at $t=0$, then $\sigma_E$ will grow much faster than $\sigma_x$ until $\sigma_E \sim 1.4\,\sigma_x$




Protons may show large growth in $\sigma_E$,
if $\sigma_E << \sigma_x$ at $t = 0$

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$$\frac{1}{\sigma_x}\frac{d\sigma_x}{dt} \simeq \frac{\sigma_E}{(\sigma_E^2 + \sigma_x^2)^{1/2}}$$

$$\frac{1}{\sigma_p}\frac{d\sigma_p}{dt} \simeq 2\,\frac{\sigma_x}{\sigma_E}\,\frac{\sigma_x}{(\sigma_E^2 + \sigma_x^2)^{1/2}}$$

## High Frequency RF system

To get shorter $\sigma_\ell$ suggests $f \sim 200$ MHz

## New Suggested Procedure

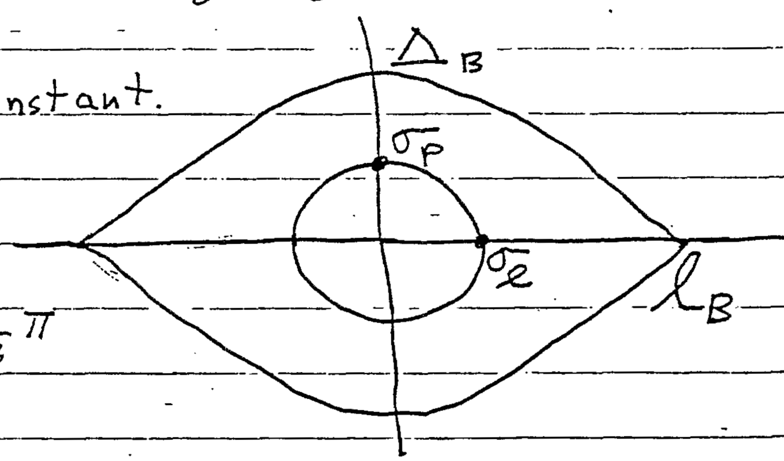
$V$ varied with time so that bucket just contains the bunch, $\Delta_B = 2\sigma_p$ at all times.

For fixed $\sigma_p/\Delta_B$, $\sigma_\ell$ is constant.

$$\frac{\sigma_p}{\Delta_B} = \sin \phi/2$$

For $\Delta_B = 2\sigma_p$, $\phi = 60^\circ = \frac{1}{3}\pi$

$$\sigma_\ell = \frac{1}{3}\ell_B$$



## Proposed RF System

$f = 160$ MHz , $h = 2052$

$\sigma_\ell = 31$ cm , $A_0 = .3$ eV-sec

$\Delta_B = 2\,\sigma_p$

## frequency dependence

Initially, $\sigma_\ell \sim 1/f$ , $\sigma_p \sim f$ , $V \sim f^3$

For final state , $V \sim f^{1.54}$ for one case–

## Dependence on $f_B = \Delta_B / \sigma_p$

Initially, $\sigma_\ell \sim 1/f_B$ , $\sigma_p \sim f_B$ , $V \sim f_B^4$

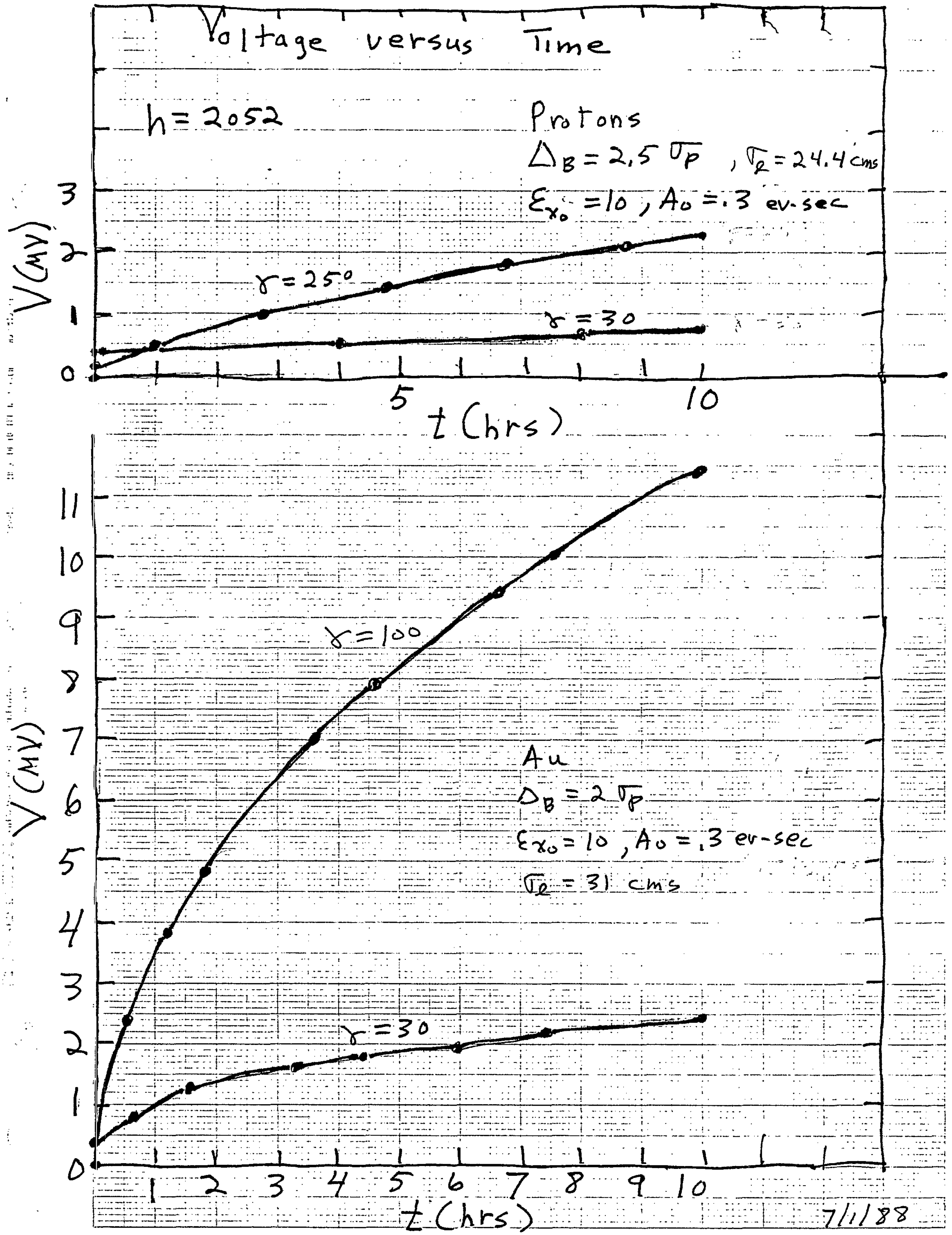
For final state , $V \sim f_B^{2.6}$ for one case.

# Intrabeam Scattering Results, 10 hrs – G. Parzen, 6/28/88



| | Au, 160 MHz, $N_b = 1.1\times10^9$, $\Delta_B = 2\sigma_p$, $h = 2052$, $A = .3$ eV-Sec, $\varepsilon_{x_0} = 10$ | | Au, 214 MHz, $N_b = 1.1\times10^9$, $\Delta_B = 2\sigma_p$, $h = 2736$, $A = .3$, $\varepsilon_{x_0} = 10$ | |
|---|---|---|---|---|
| $\gamma$ | 30 | 100 | 30 | 100 |
| $\sigma_{\ell 0}$ (cm) | 31 | 31 | 23.4 | 23.4 |
| $\sigma_{p0}/10^{-3}$ | .827 | .248 | 1.09 | .327 |
| $\sigma_\ell$ (cm) | 31 | 31 | 23.4 | 23.4 |
| $\sigma_p/10^{-3}$ | 2.27 | 1.58 | 2.42 | 1.70 |
| $\sigma_x$ (mm) | 3.06 | 1.69 | 3.24 | 1.78 |
| $\varepsilon_x/10^{-6}$ | 34 | 34 | 38 | 38 |
| $V$ (MV) | 2.4 | 11.4 | 3.67 | 17.7 |
| $\Delta p/p = 2\sigma_p/10^{-3}$ | 4.54 | 3.16 | 4.84 | 3.40 |
| $V_0$ (MV) | .321 | .283 | .744 | .656 |

| | Au, 160 MHz, $N_b = 1.1\times10^9$, $\Delta_B = 2.5\sigma_p$, $h = 2052$, $A = .3$, $\varepsilon_{x_0} = 10$ | | Protons, 160 MHz, $N_b = 1\times10^{11}$, $\Delta_B = 2.5\sigma_p$, $h = 2052$, $A = .3$, $\varepsilon_{x_0} = 10$ | |
|---|---|---|---|---|
| $\gamma$ | 30 | 100 | 30 | 100 |
| $\sigma_{\ell 0}$ | 24.4 | 24.4 | 24.4 | 24.4 |
| $\sigma_{p0}$ | 1.05 | .315 | 1.05 | .126 |
| $\sigma_\ell$ | 24.4 | 24.4 | 24.4 | 24.4 |
| $\sigma_p$ | 2.40 | 1.68 | 1.53 | .545 |
| $\sigma_x$ | 3.21 | 1.76 | 2.14 | .754 |
| $\varepsilon_x$ | 37 | 37 | 16 | 17 |
| $V$ | 4.22 | 20.2 | .689 | 2.25 |
| $\Delta p/p$ | 4.80 | 3.36 | 3.06 | 1.09 |
| $V_0$ | .810 | .713 | .324 | .120 |



Voltage versus Time
h = 2052
Protons
$\Delta_B = 2.5\ \sigma_p$ , $\sigma_\ell = 24.4$ cms
$\varepsilon_{x_0} = 10$ , $A_0 = .3$ ev-sec
V(MV)
3
2
1
0
γ = 250
γ = 30
5
10
t (hrs)
11
10
9
8
7
6
5
4
3
2
1
0
γ = 100
Au
$\Delta_B = 2\ \sigma_p$
$\varepsilon_{x_0} = 10$ , $A_0 = .3$ ev-sec
$\sigma_\ell = 31$ cms
γ = 30
1 2 3 4 5 6 7 8 9 10
t (hrs)
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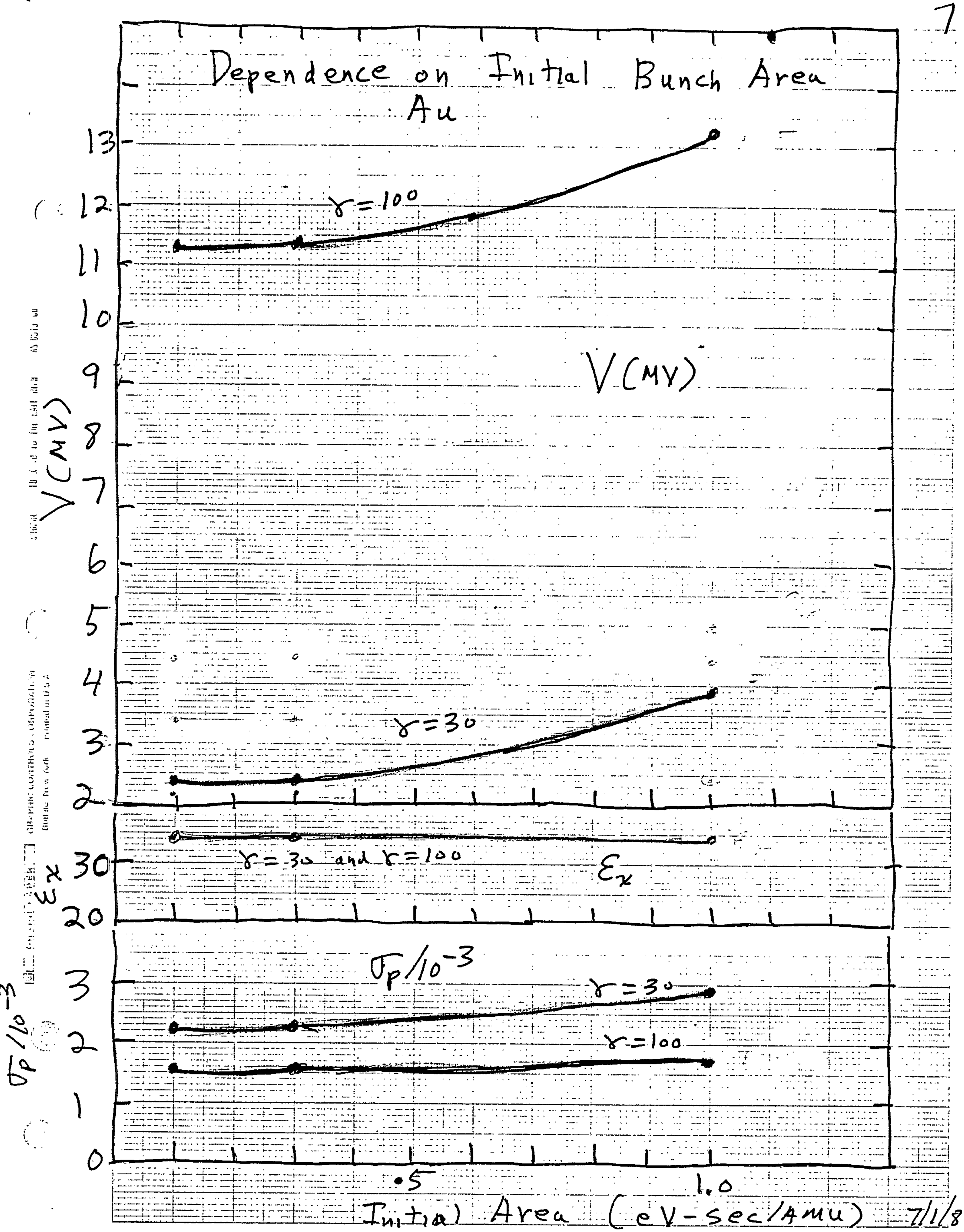
Dependence on Initial Bunch Area
Au
V(MV)
γ=100
γ=30
13
12
11
10
9
8
7
6
5
4
3
2
V(MV)
εx
γ=30 and γ=100
εx
30
20
σp/10^-3
γ=30
γ=100
σp/10^-3
3
2
1
0
.5
1.0
Initial Area (eV-sec/AMU)

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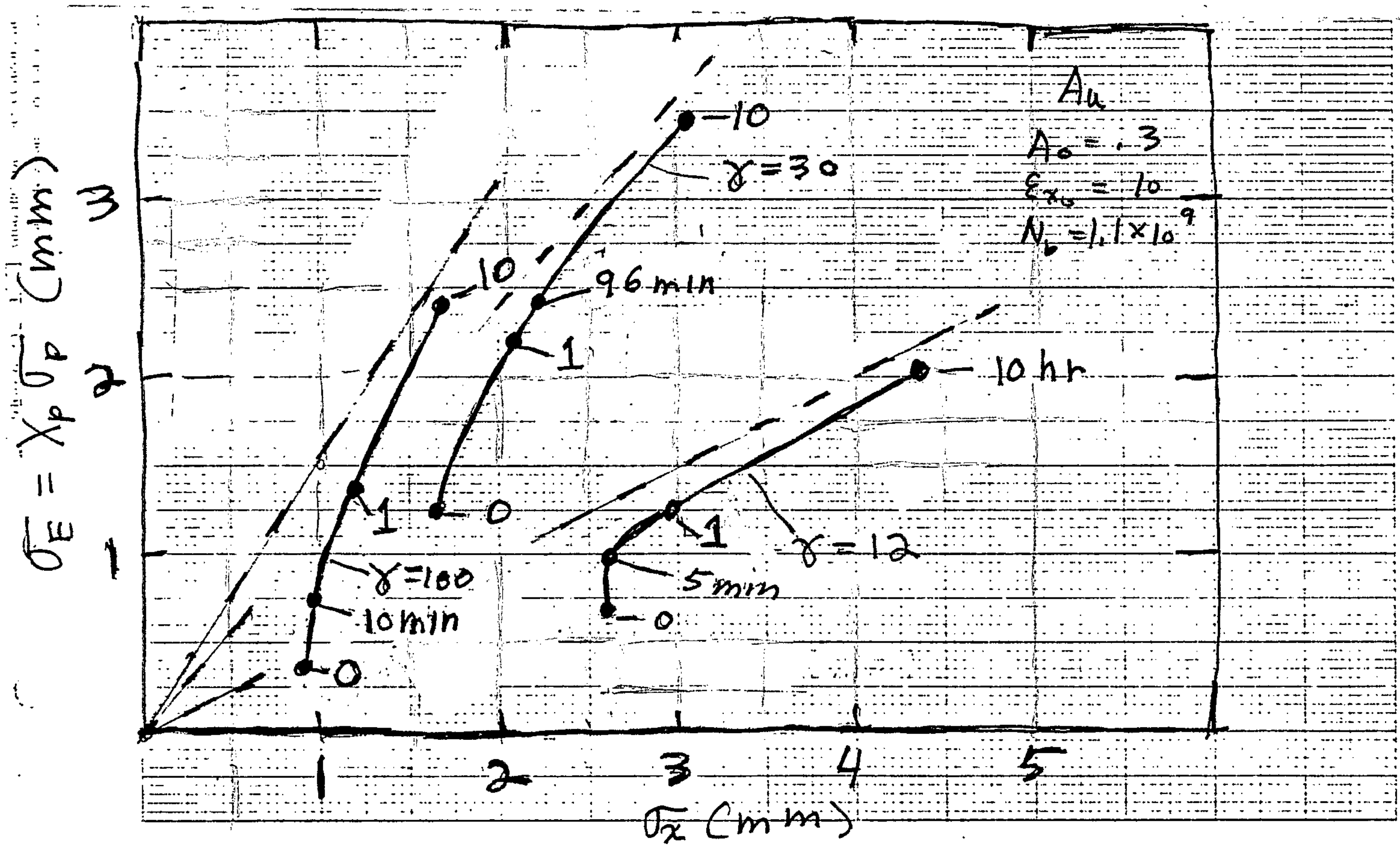
$\sigma_E - \sigma_x$ plots for Gold




Times given in minutes are doubling times for the longitudinal phase space.