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Intrabeam Scattering Results for a High Frequency RF System

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AD/RHIC-RD-4

Intrabeam Scattering Results for a High Frequency RF System

(Mini-Workshop on RHIC RF Systems)

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Intra beam Scattering Results for a High Frequency RF System

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7/6/88

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"

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

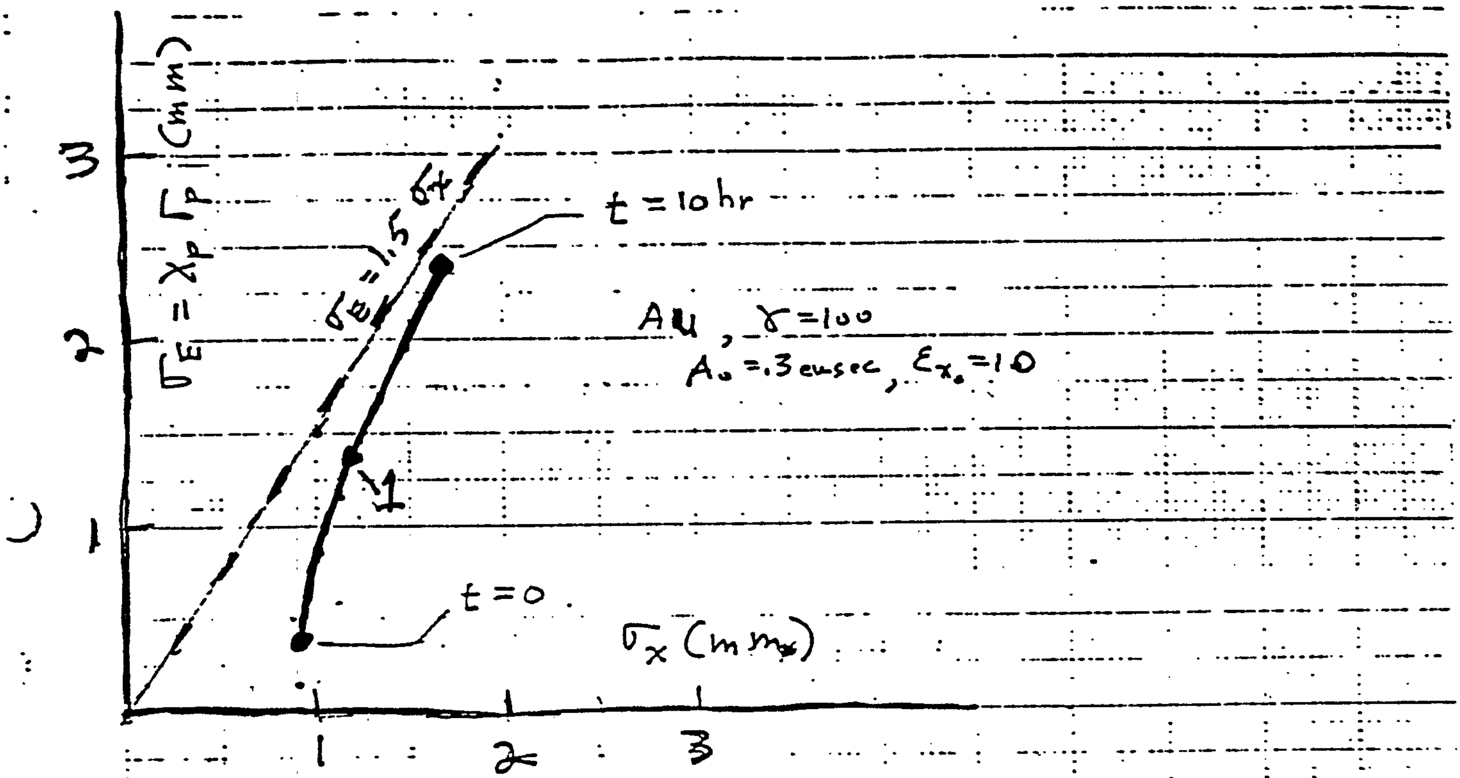
$\sigma_E = \chi_p \sigma_p$

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

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 σ_E will grow much faster than σ_x until $\sigma_E \sim 1.4\ \sigma_x$



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

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

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

High Frequency RF system

To get shorter σ_ℓ suggests $f \sim 200$ MHz

New Suggested Procedure

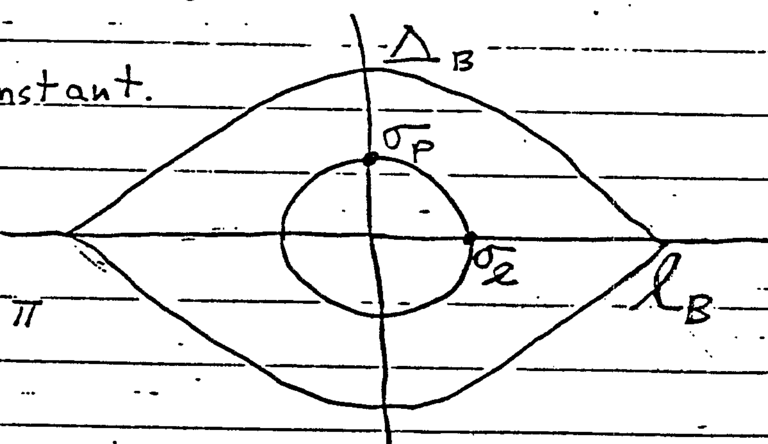
V varied with time so that bucket just contains the bunch, $\Delta_B = 2\,\sigma_p$ at all times.

For fixed σ_p/Δ_B, σ_ℓ 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, $\sigma_\ell \sim 1/f_B$, $\sigma_p \sim f_B$, $V \sim f_B^4$

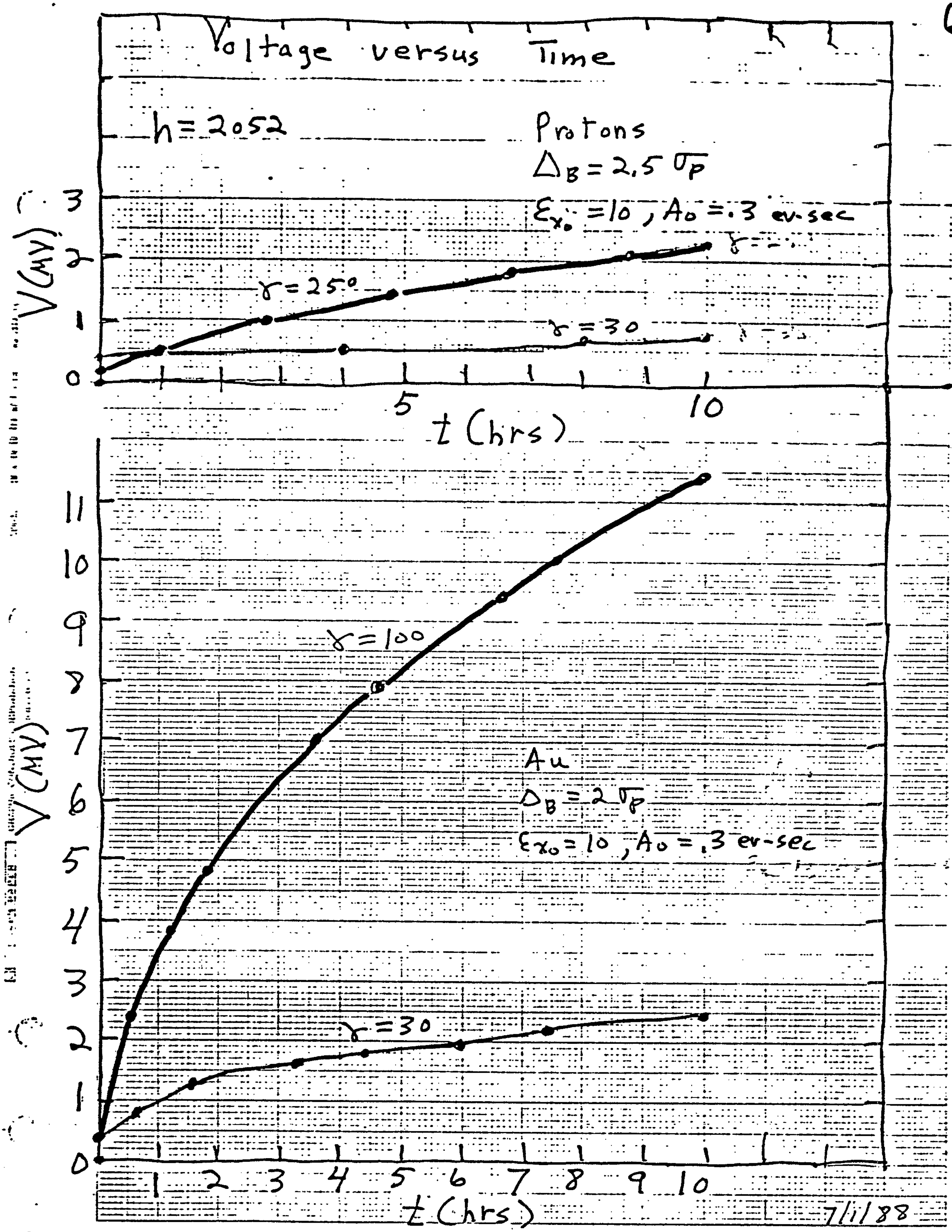
For final state , $V \sim f_B^{2.6}$ for one case.

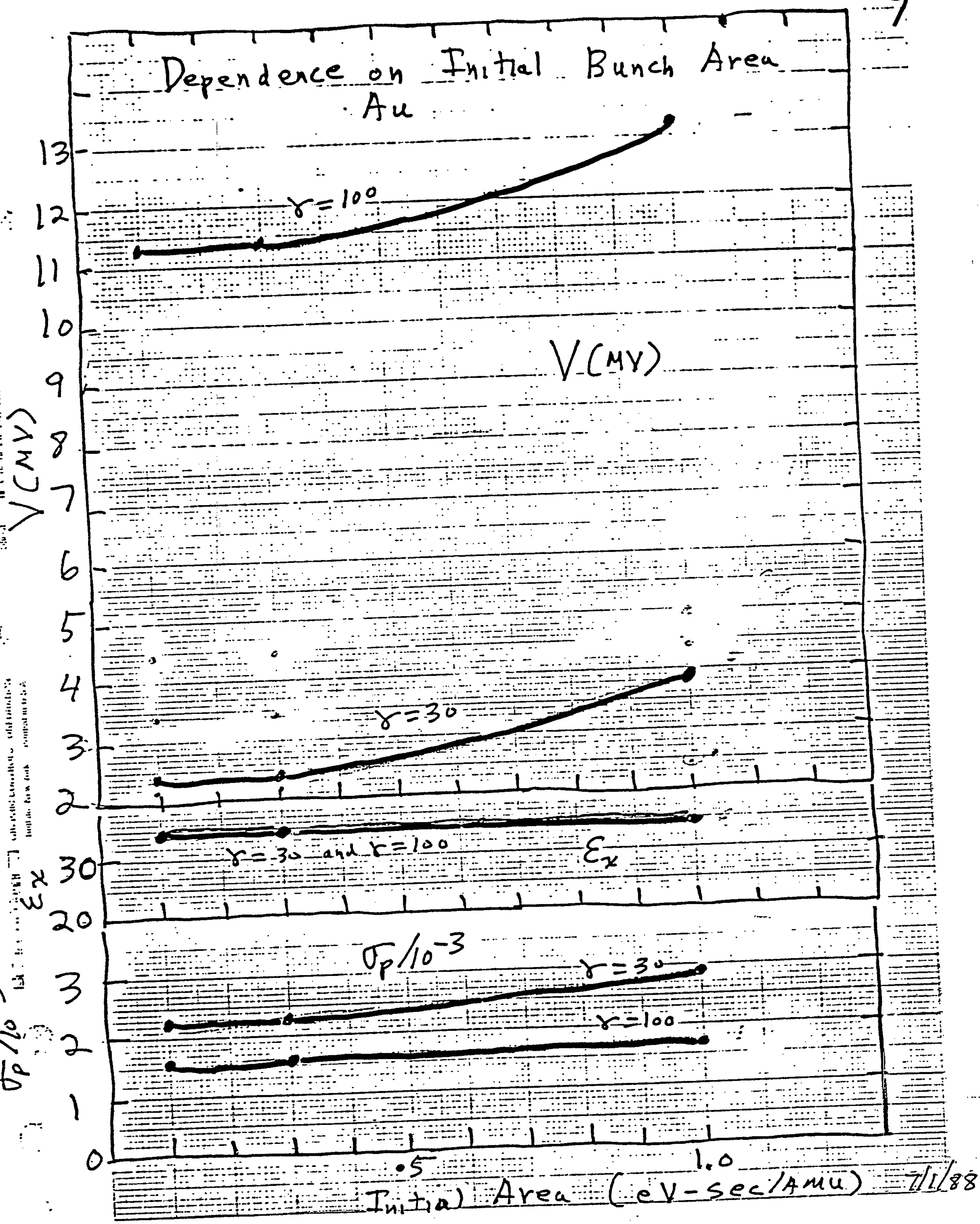
Intrabeam Scattering Results, 10 hrs

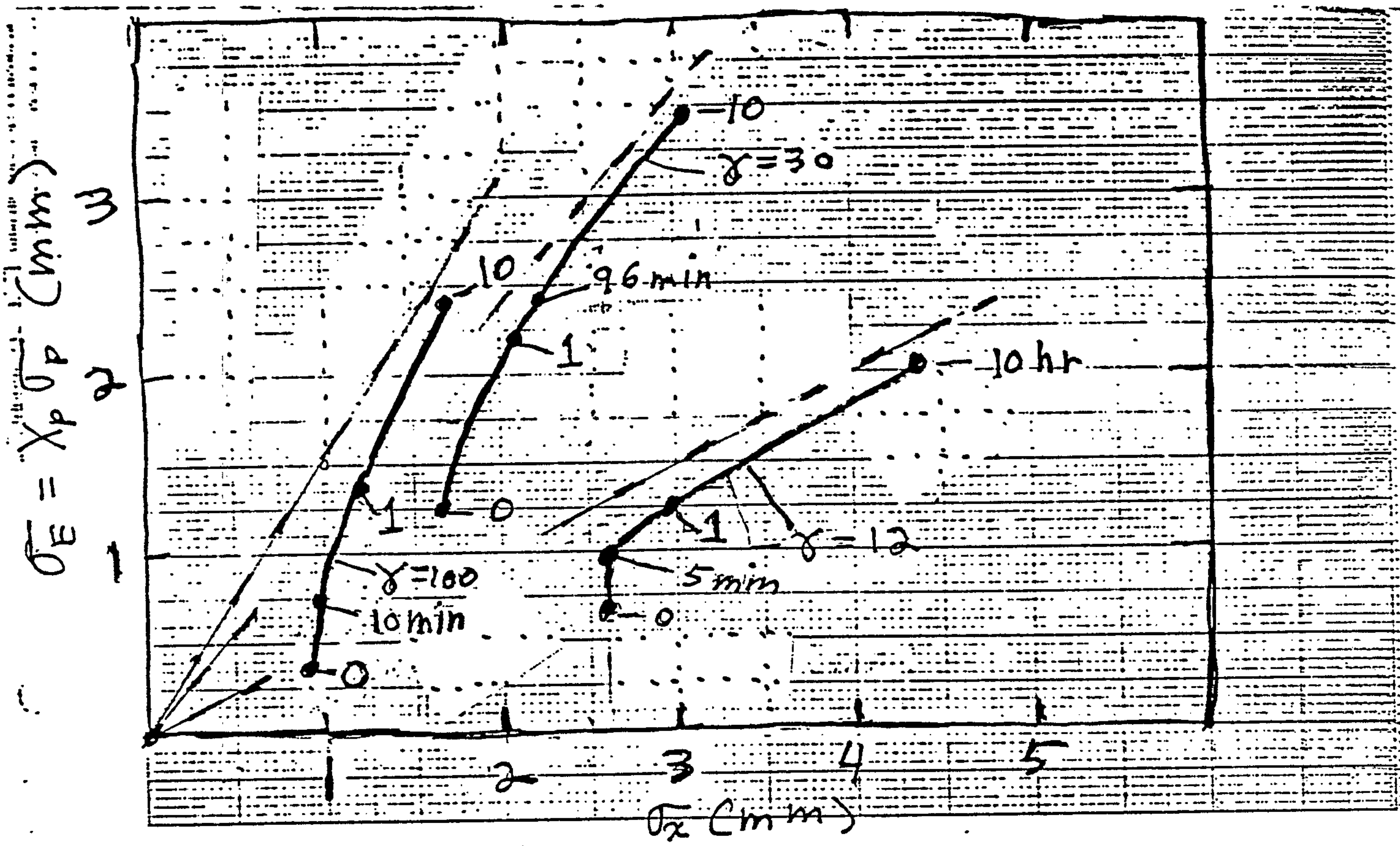
G. Parzen, 6/28/88

	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, $N_b=1.1\times10^9$, $\Delta_B=2\sigma_p$, $h=2736$, $A=.3$, $\varepsilon_{x_0}=10$	
γ	30	100	30	100
$\sigma_{\ell 0}$ (cm)	31	31	23.4	23.4
$\sigma_{p0}/10^{-3}$	.827	.248	1.09	.327
σ_ℓ (cm)	31	31	23.4	23.4
$\sigma_p/10^{-3}$	2.27	1.58	2.42	1.70
σ_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, $N_b=1\times10^{11}$, $\Delta_B=2.5\sigma_p$, $h=2052$, $A=.3$, $\varepsilon_{x_0}=10$	
γ	30	100	30	100
$\sigma_{\ell 0}$	24.4	24.4	24.4	24.4
σ_p	1.05	.315	1.05	
σ_ℓ	24.4	24.4	24.4	.126
σ_p	2.40	1.68	1.53	.545
σ_x	3.21	1.76	2.14	.754
ε_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
Δ_B = 2.5 σ_p
ε_x0 = 10, A_0 = .3 ev-sec
γ = 250
γ = 30
V (MV)
t (hrs)
γ = 100
Au
Δ_B = 2 σ_p
ε_x0 = 10, A_0 = .3 ev-sec
γ = 30
V (MV)
t (hrs)
7/1/88


Dependence on Initial Bunch Area
Au
V(MV)
γ=100
γ=30
γ=30 and γ=100
ε_x
$\sigma_p/10^{-3}$
γ=30
γ=100
13
12
11
10
9
8
7
6
5
4
3
2
30
20
3
2
1
0
.5
1.0
Initial Area (eV-sec/AMU)
7/1/88



$\sigma_E = \chi_p \sigma_p$ (mm)
σ_x (mm)
1
2
3
4
5
10
$\gamma = 30$
96 min
1
0
10
1
$\gamma = 100$
10 min
0
10 hr
1
$\gamma = 12$
5 min
0

INTRABEAM SCATTERING ABOVE TRANSITION*

$$\tau_E^{-1} = \frac{1}{\delta_E}\frac{d\delta_E}{dt} = \left[\frac{\langle\sigma_H\rangle}{\langle X_p\rangle\,\delta_E}\right]^2 \tau_H^{-1}$$

with

$$\tau_H^{-1} = \frac{27\pi}{2} L_g\, r_p^{\,2}\, E_o \frac{N_B}{S\,\varepsilon_H\,\varepsilon_V}\frac{\langle X_p\rangle}{\langle\beta\rangle}\frac{1}{\left[1+\left[\frac{\langle\sigma_H\rangle}{\langle X_p\rangle\,\delta_E}\right]^2\right]^{1/2}}\left[\frac{Q^2}{A}\right]^2$$

where

$$L_g \approx 20$$

$$r_p = \frac{\mu_o\, e^2 c^2}{4\pi\, E_o}$$

$$\langle\sigma_H\rangle = \left[\frac{\varepsilon_H}{6\pi}\frac{\langle\beta\rangle}{\gamma}\right]^{1/2}$$

$$S = 6\pi\,\sigma_\ell\,\delta_E\,\gamma\,E_o/c$$

$\varepsilon_{H,V}$ = normalized transverse emittance

$\langle X_p\rangle$ = averaged dispersion

$\langle\beta\rangle$ = averaged betatron function

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*G. Parzen, Nucl. Instr. Meth. A251, p. 220 (1986), A256, p. 231 (1987).

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