BNL-101785-2014-TECH
AD/RHIC/RD/3;BNL-101785-2013-IR

Workshop Goals

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Collider Accelerator Department
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U.S. Department of Energy
USDOE Office of Science (SC)

DISCLAIMER

AD/RHIC-RD-3

Workshop Goals

(Mini-Workshop on RHIC RF Systems)

July 11-15, 1988
Collider Center

H. Hahn
BNL

MINI-WORKSHOP ON RHIC RF SYSTEM

JULY 11, 1988

REASON

- A HIGH-FREQUENCY 160 MHz RF SYSTEM WAS ADDED TO ASSURE SHORT BUNCHES AND SHORT DIAMOND LENGTH DURING STORAGE MODE
- CO-EXISTENCE OF TWO RF SYSTEMS POSES NEW PROBLEMS

OBJECTIVES

- REVIEW RF SYSTEMS REQUIREMENT

  DURING INJECTION, ACCELERATION, CROSSING OF TRANSITION ENERGY, TRANSFER FROM LOW-F TO HIGH-F SYSTEM, STORAGE OF BEAMS

- REVIEW CAVITY AND AMPLIFIER HARDWARE

  VOLTAGE RANGES, NUMBER OF 160 MHz CAVITIES, FEEDBACK REQUIREMENTS, INTERACTION OF TWO SYSTEMS, COUPLING IMPEDANCE REQUIREMENTS, INSTABILITIES

- ESTABLISH BASIS FOR REVISED CDR TEXT AND COST ESTIMATE
- WRITTEN SUMMARY AND TECH NOTES

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RELATIVISTIC HEAVY ION FACILITIES AT BNL

1986 BEGIN AGS FIXED TARGET EXPERIMENTS

ION SPECIES: ^{1}H TO ^{28}S :

BEAM ENERGY: UP TO 29 $\left(\frac{Z}{A}\right)$ GEV·c^{-1}/U

FLUX: $\simeq 10^{9}$ IONS/PULSE

RUNNING TIME: 5 - 10 WEEKS/YEAR

1991 AGS EXPERIMENTS WITH BOOSTER SYNCHROTRON

EXTEND ION MASS TO A $\simeq$ 200 (^{197}Au)

(1994?) BEGIN RHIC COLLIDER EXPERIMENTS

ION SPECIES: ^{1}H TO ^{197}Au

ENERGY/BEAM: UP TO 250 $\left(\frac{Z}{A}\right)$ GEV/U

C.M. ENERGY:	250 + 250 GEV (P)	100 + 100 GEV/U (AU)
LUMINOSITY:	10^{31} $cm^{-2}sec^{-1}$	5×10^{26} $cm^{-2}sec^{-1}$

RHIC MAJOR PARAMETERS

ENERGY RANGE (EACH BEAM), AU	(7) 10.7-100	GEV/U
PROTONS	28-250^{+}	GEV
LUMINOSITY, AU-AU @ 100 GEV/U HEAD-ON & 10 H AV.	4.4×10^{26}	$CM^{-2}SEC^{-1}$
OPERATIONAL LIFETIME AU @ >30 GEV/U	>10	H
DIAMOND LENGTH @ 100 GEV/U, 2 MRAD	± 27	CM RMS ±20
CIRCUMFERENCE, $4-3/4\ C_{AGS}$	3833.845	M
NUMBER OF CROSSING POINTS	6	
FREE SPACE AT CROSSING POINT	± 9	M
BETA @ CROSSING, HORIZONTAL/VERTICAL	6	M
LOW-BETA INSERTION	3	M
BETATRON TUNE, HORIZONTAL/VERTICAL	28.82	
TRANSITION ENERGY, γ_T	24.8	
FILLING MODE	BOX-CAR	
NO. OF BUNCHES/RING	57	
NO. OF AU-IONS/BUNCH	1.1×10^{9}	
FILLING TIME (EACH RING)	~1	MIN
MAGNETIC RIGIDITY, Bρ: @ INJECTION	96.74	T·M
@ TOP ENERGY	839.5	T·M
NO. OF DIPOLES (180/RING + 12 COMMON)	372	
NO. OF QUADRUPOLES (276 ARC + 216 INSERTION)	492	
DIPOLE FIELD @ 100 GEV/U, AU	3.45	T
DIPOLE MAGNETIC LENGTH	9.46	M
DIPOLE YOKE LENGTH	9.7	M
COIL I.D. ARC MAGNETS	8	CM
BEAM SEPARATION IN ARCS	90	CM
RF FREQUENCY	26.7	MHZ
RF VOLTAGE	1.2	MV
ACCELERATION TIME	1	MIN

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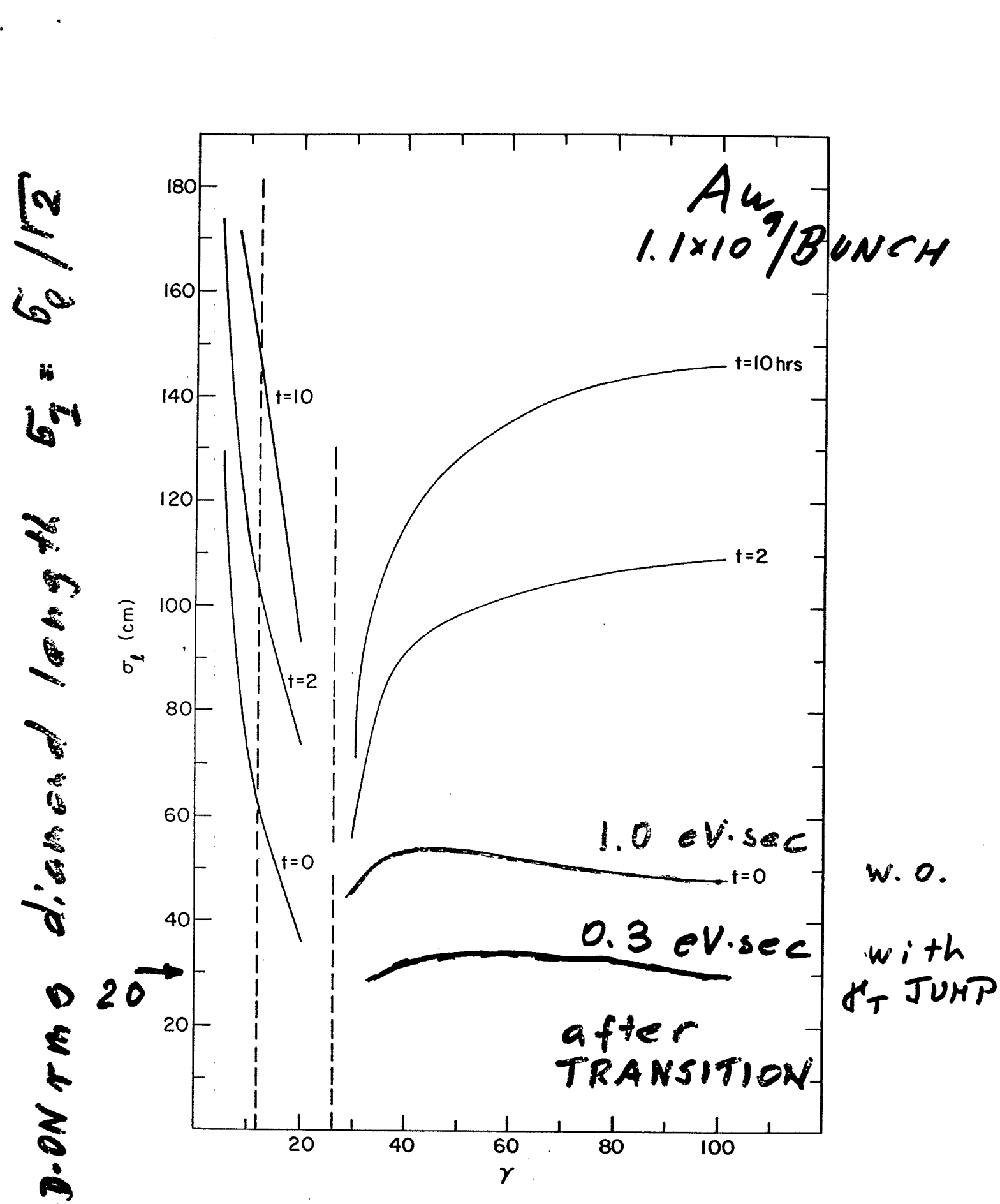
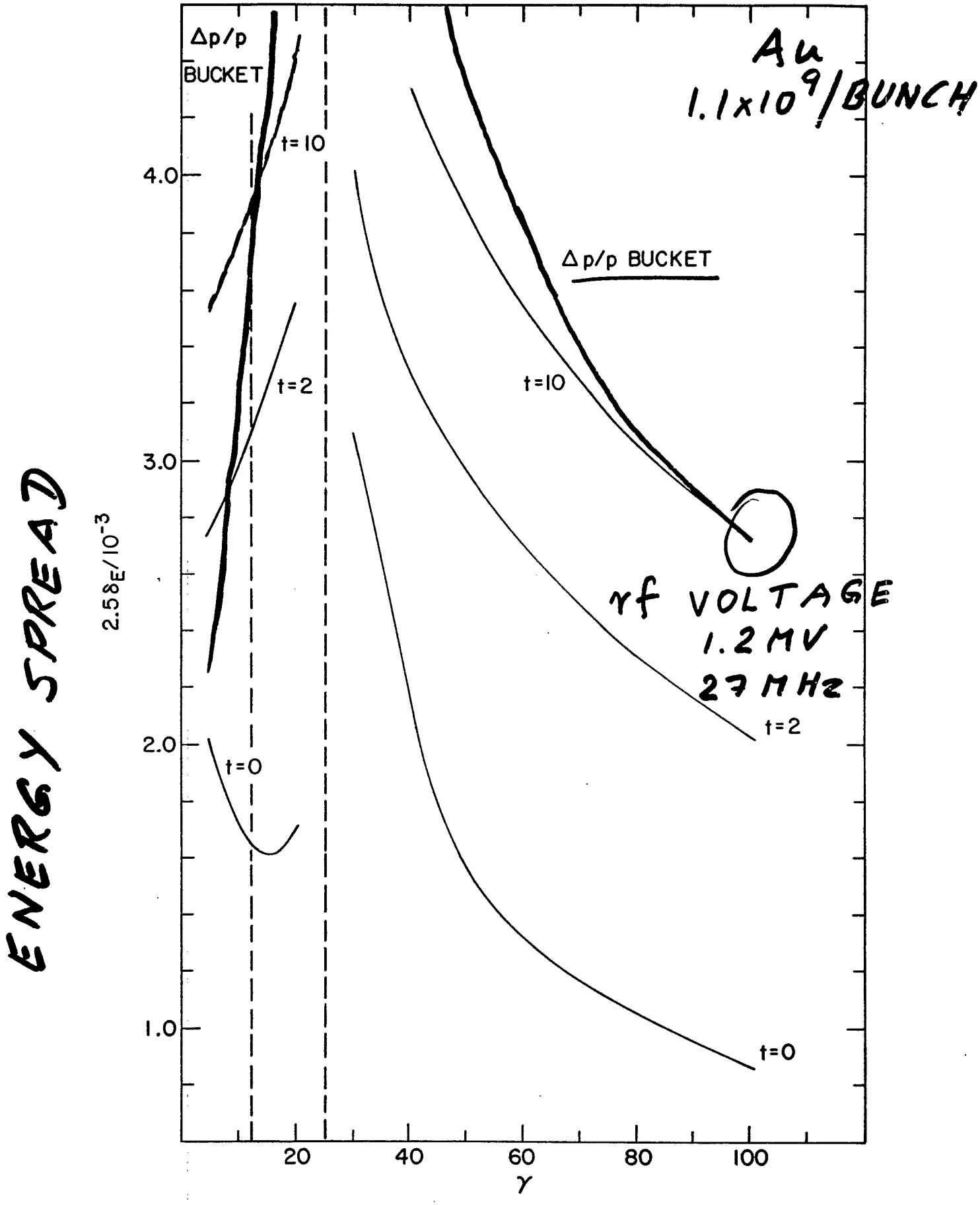

HEAD-ON rms diamond length $\sigma_l = \sigma_\theta / \sqrt{2}$
Au
1.1×10^9/BUNCH
180
160
140
120
100
80
60
40
20
σ_l (cm)
t=10
t=2
t=0
t=10 hrs
t=2
t=0
1.0 eV·sec
0.3 eV·sec
after TRANSITION
20
20
40
60
80
100
γ
W. O.
with γ_T JUMP

9-136-74


Au
1.1x10^9/BUNCH
Δp/p
BUCKET
t=10
t=2
t=0
Δp/p BUCKET
t=10
t=2
t=0
rf VOLTAGE
1.2MV
27MHz
ENERGY SPREAD
2.5δE/10^-3
4.0
3.0
2.0
1.0
20
40
60
80
100
γ

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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DIAMOND LENGTH

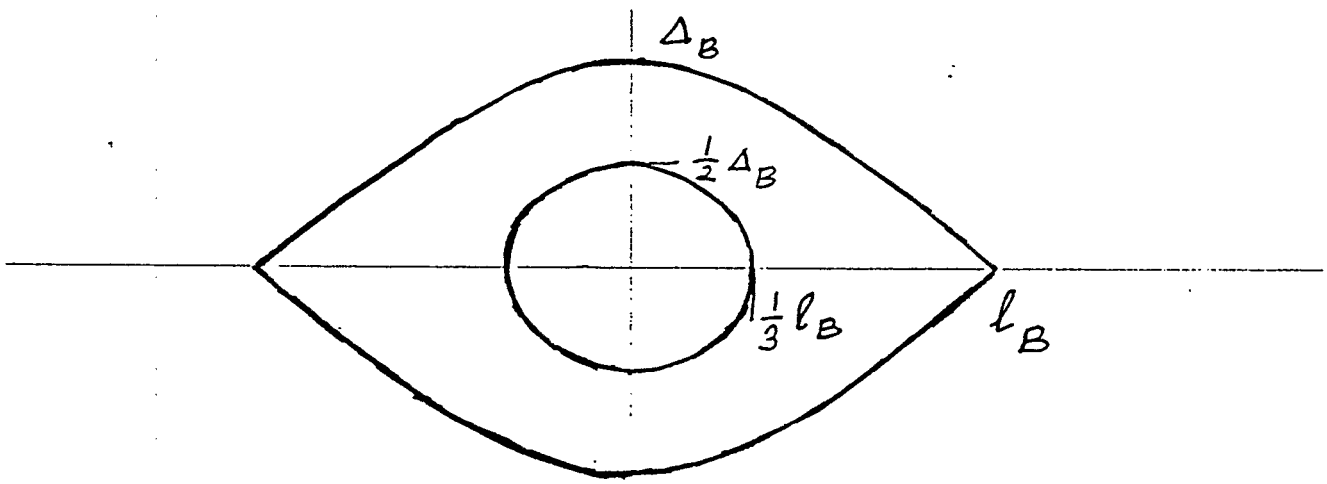
REQUIREMENT $\sigma_I \leq 20$ CM RMS

BUNCH RMS LENGTH $\sigma_\ell = \sqrt{2}\ \sigma_I \approx 28$ CM RMS

BUCKET HALF LENGTH 160 MHz (h = 2052)

$\ell_B = \pi R/h = 0.934$ M

DUE TO BUCKET NONLINEARITY $\sigma_\ell < \ell_B/\sqrt{6} = 38$ CM RMS



$\sigma_E = \Delta_B/\sqrt{6}$ YIELDS $\sigma_\ell = 0.268 \times \ell_B = 25$ CM RMS

ECONOMY CONDITION:

$\sigma_E = \Delta_B/2$ $\sigma_\ell = \ell_B/3 = 31$ CM RMS

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RF BUCKET AND LONGITUDINAL BUNCH PARAMETERS

BUCKET HALF HEIGHT

$$\Delta_B = \left[\frac{2.\, e\, V}{\pi\, h\, |\eta|\, \gamma\, E_o} \frac{Q}{A} \right]^{1/2}$$

BUCKET AREA/AMU

$$A_B = 8\, \Delta_B \frac{\gamma\, E_o}{h\, \omega_o}$$

BUNCH PHASE HALF WIDTH

$$0 < \phi < \pi$$

COLE-MORTON:

$$N = \sin^2 \phi/2$$

RMS BUNCH LENGTH

$$\sigma_\ell = \frac{1}{\sqrt{6}} \frac{R}{h} \phi$$

RMS BUNCH HEIGHT

$$\delta_E = \frac{1}{\sqrt{6}} \Delta_B \sin \phi/2$$

BUNCH AREA/AMU

$$S = A_B \left\{ (N-1)\, K(N) + E(N) \right\}$$

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

h870929b.vg

R H I C RF SYSTEMS PARAMETER

- BEAM PARAMETERS FROM AGS

  p 10^{11}/ BUNCH } 0.3 eV·sec/u
  Au 10^{9}/ BUNCH } 10 π mm·mrad

- ASSUME ESSENTIALLY NO GROWTH OF BUNCH AREA AT INJECTION AND DURING TRANSITION

- ACCELERATION RF SYSTEM — 26.7 MHz
  - 2 CAVITIES (CDR-TYPE) — 300 kV
  - TUNING RANGE — 1% (> 7 GeV/u)

- STORAGE RF SYSTEM — 160 MHz
  - TUNING RANGE — 0.1% - (> 30 GeV/u)
  - VOLTAGE @ 10 HR — 11.4 MV - Au ($\Delta_B = 2\ \sigma_E$)
    17.7 MV - Au ($\Delta_B = \sqrt{6}\ \sigma_E$)
    2.3 MV - p ($\Delta_B = \sqrt{6}\ \sigma_E$)
  - SCALED CERN-TYPE CAVITY
  - NUMBER OF CAVITIES, VOLTAGE/CAVITY ?
  - SUPERCONDUCTING CAVITIES ?

- DESIGN FOR FUTURE UPGRADE
  - 2 × 57 BUNCHES, 2 × NUMBER IONS/BUNCH

- DESIGN FOR 2 - 3 MISSING BUNCHES (BEAM DUMP GAP)

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MINI WORKSHOP ON RHIC RF SYSTEMS

MONDAY, JULY 11 -- 2:30 PM

BLDG. 1005 CONFERENCE ROOM 4TH FLOOR

WELCOME & WORKSHOP GOALS	H. HAHN
RF SYSTEMS OVERVIEW	A.G. RUGGIERO
INTRABEAM SCATTERING RESULTS	G. PARZEN
BEAM TRANSFER AGS/RHIC, LOW F - HIGH F	E.C. RAKA
PASSAGE THROUGH TRANSITION	S.Y. LEE
SIMULATION OF TRANSITION & TRANSFER	J. WEI
RF CAVITIES AND AMPLIFIERS	J.G. COTTINGHAM
GAMMA-TRANSITION QUADRUPOLES	P.A. THOMPSON