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RF Systems Overview

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USDOE Office of Science (SC)

DISCLAIMER

AD/RHIC-RD-8

RF Systems Overview

(Mini-Workshop on RHIC RF Systems)

July 11-15, 1988
Collider Center

A. G. Ruggiero
BNL

Transfer from AGS to RHIC
one bunch at the time
box-car fashion

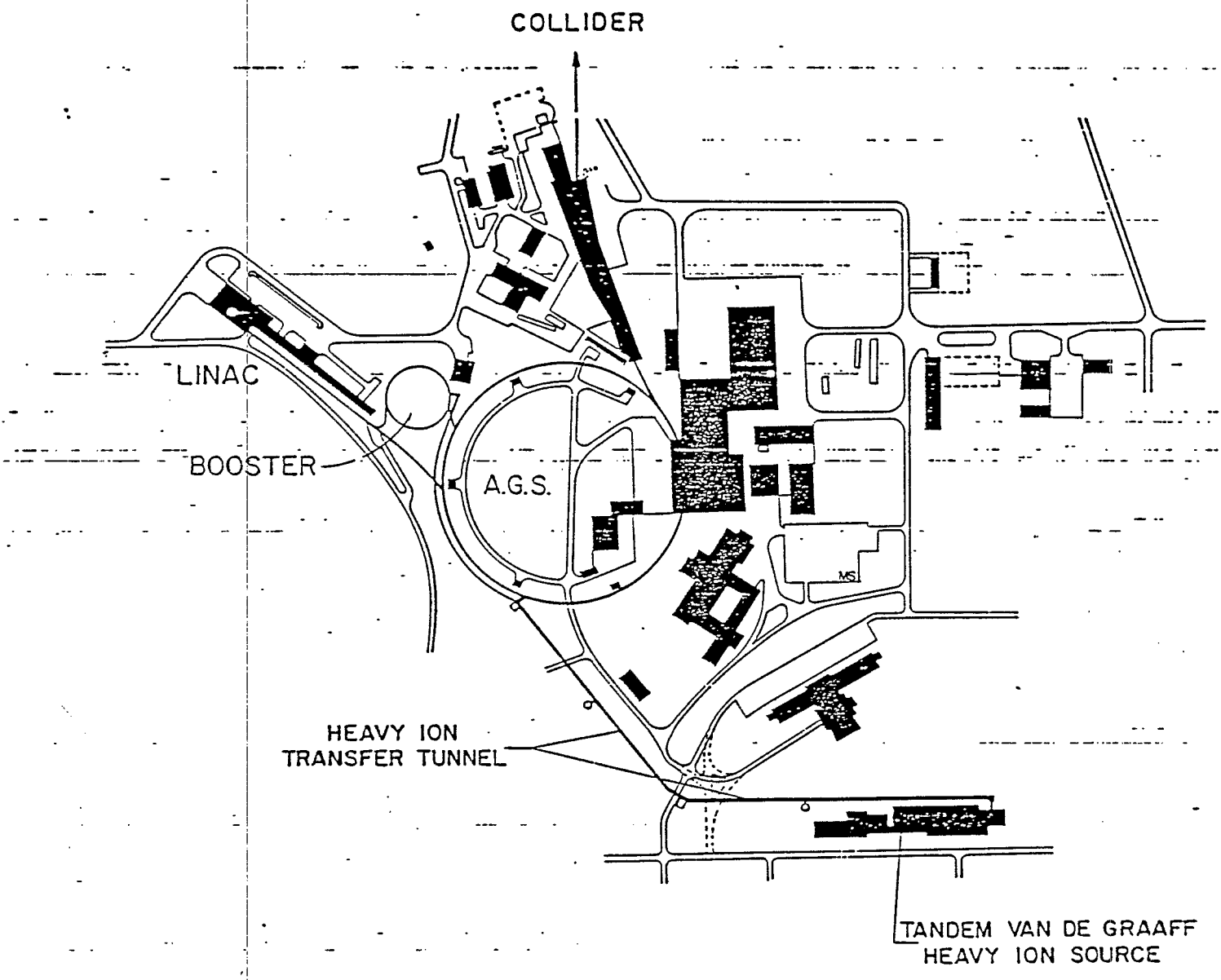


Fig. III-3. Injection system for Collider.

57 (x2) bunches per ring

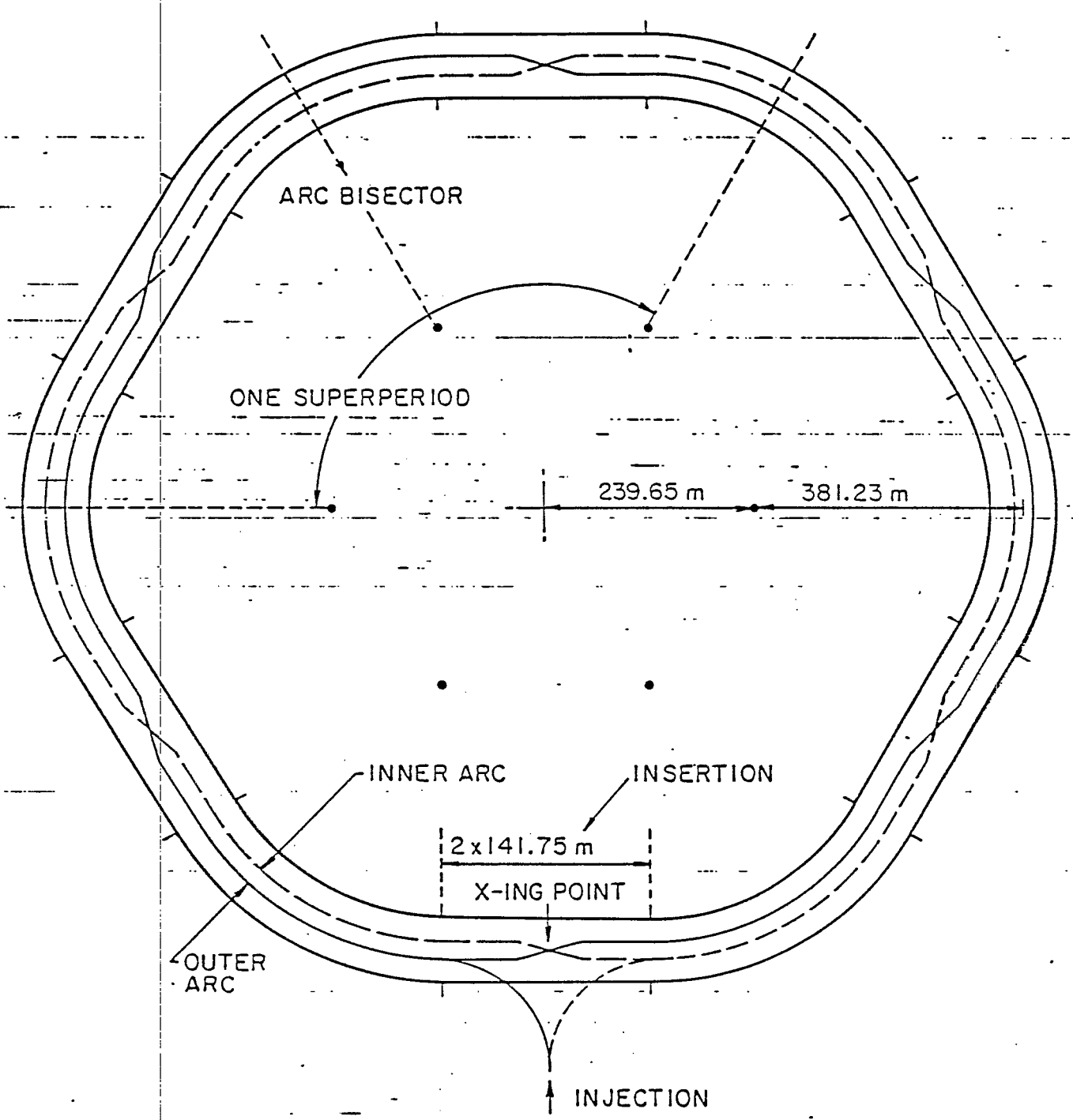
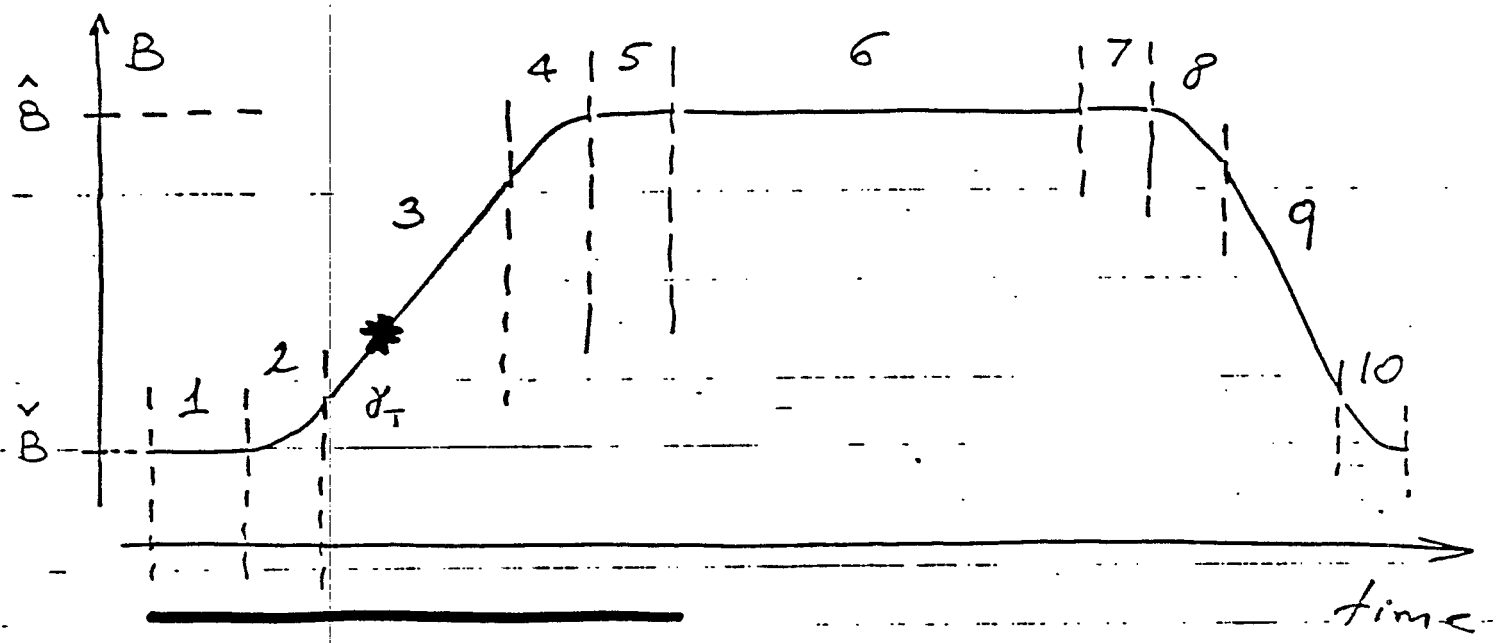


Fig. IV-1. Layout of the Collider.

The overall RHIC rf-cycle



1. Front-Porch for Injection
2. First Parabolic Ramp
3. Linear Ramp (γ_T)
4. Second Parabolic Ramp
5. Bunch Compression - Switch to large rf
6. Storage and colliding
7. Beam Abort
8. 9. 10. Reset Cycle

Two rf systems { low rf —
high rf —

		AGS	RHIC
$2\pi R$		807.4 m	3833.4 m
γ_T		8.5	24.5
E	proton	28.5 GeV	250 GeV
	gold	10.7 GeV/amu	100 GeV/amu
h		12	$342 = 6 \times 57$
f_{RF}		4.5 MHz	26.8 MHz
V		0.2 - 0.3 MV	--
$(\Delta f/f)_{RF}$			0.1 %

Storage Mode : h 6×342

f_{rf} 1-60 MHz

V --

Electric Current

	Q	A	N	H = 57 1×N	H = 114 2×N
Proton	1	1	100×10^9	75 mA	300
Deuterium	1	2	100	75	300
Carbon	6	12	22	99	396
Sulfur	16	32	6.4	77	308
Copper	29		4.5	98	392
Iodine	53		2.6	103	412
Gold	79	197	1.1	65	260

↓

CDR

rf current ~ 1 A

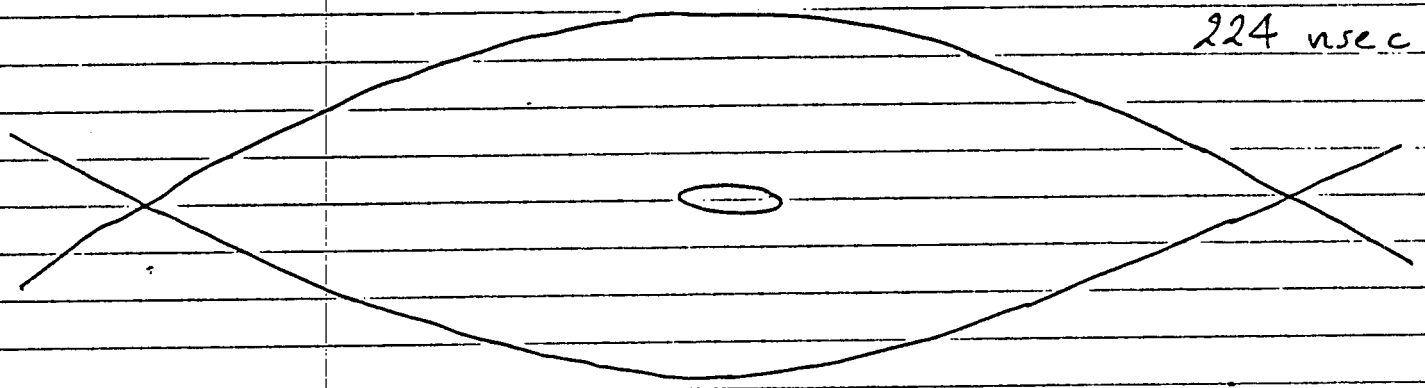
Injection

No Acceleration

Bunch-to-Bucket Transfer

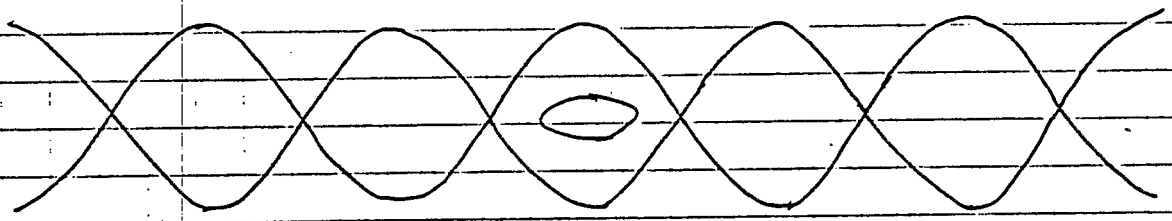
AGS

224 nsec



RHIC

37.3 nsec



Individual Bunch Area

for Protons and Heavy Ions

0.3 eV-sec/amu (total)

RHIC

	Inj. Energy	V	Q_s	S_B	
Proton	28.5 GeV	12 KV	0.00012	1.52	eV.sec
Deuterium	13.6 GeV/amu	41 KV	0.00044	0.71	eV.sec/amu
Carbon	13.6	40	0.00043	0.71	
Sulfur	13.6	40	0.00042	0.70	
Copper	12.4	56	0.00058	0.68	
Iodine	11.2	84	0.00082	0.65	
Gold	10.7	101	0.00095	0.65	

		protons	H.I.
φ_s	AGS	180°	180°
	RHIC	180°	0°
V	AGS	300 KV	200 KV

2. The First Parabolic Ramp

This is a transient region where B and the rf parameters are varied smoothly to prepare for acceleration.

We could assume a parabolic variation of B over a period of time of T seconds

$$B = B_{inj} + \alpha t^{-2}$$

$0 < t < T$, where $t=0$ is at beginning of this interval.

During this period, the rf voltage and phase will change slowly in such a way that the bucket area is preserved to the value it had during injection.

Or at least is not smaller than the value at injection.

Acceleration — linear Ramp

* Total Acceleration Period : 60 sec

* The following is required for Acceleration (protons and H.I.)

$$V \sin\phi_s = 47.4 \text{ KV/turn}$$

* The following condition is to be satisfied to provide an rf bucket

$$\alpha^2(\phi_s)\, V(t) = \varepsilon(t)\, V_{injection}$$

where

$$\varepsilon(t) = S_B(t) / S_B(@\text{injection})$$

* @ beginning of Acceleration for Gold ($\varepsilon = 1$).

$$\phi_s = 12^\circ$$

$$V = 230 \text{ KV}$$

$$S_B = 0.6 \text{ eV-sec/amu}$$

Transition Energy Crossing (H.I.)

* Kinematic Effects
* Space Charge Effects
* Microwave Instability

* Space Charge Effects and Microwave Instability can be greatly reduced with γ_T and/or γ jump schemes

* Kinematic Effects can be reduced within acceptable limits with a smaller $\Delta p/p$ — This is accomplished chosing at $\gamma \approx \gamma_T$

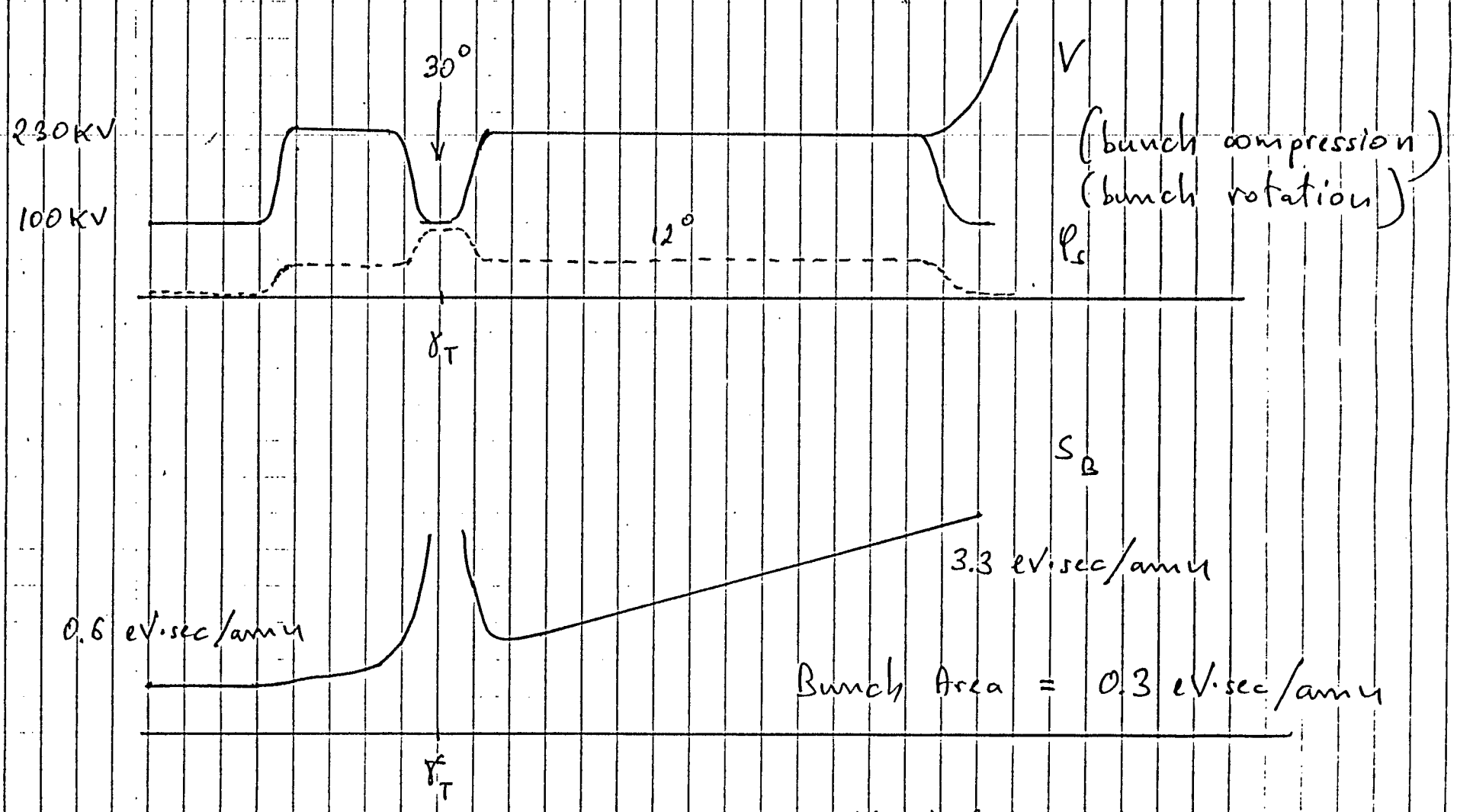
$$V = 100 \text{ KV}$$

$$\phi_s = 28.6^\circ$$

* Recapture of the bunches at $\gamma \approx \gamma_T$ by the higher rf system

* Protons do not cross transition energy

$h = 342$ rf system (26 MHz)



Gold

No Dilution during

Acceleration

γ_T - crossing

End of Acceleration (h = 342)

$\varphi_s = 180^\circ$ $\quad S = 0.3$ eV·s/amu

$V = 100$ KV

	Energy	S_B	τ	$\Delta p/p$
	GeV/amu	eV·s/amu	nsec	%
Proton	250.7	8.0	± 2.60	± 0.015
Deuterium	124.9	4.1	3.65	0.021
Carbon	124.9	4.1	3.65	0.021
Sulfur	124.9	4.1	3.65	0.021
Copper	114.9	3.7	3.80	0.022
Iodine	104.1	3.4	3.91	0.021
Gold	100.0	3.3	4.06	0.023

Microwave Instability

$|Z/n|$ limit

Proton	2.3 ohm	1.5 ohm
Deuterium	33	4.3
Carbon	25	3.2
Sulfur	32	4.2
Copper	35	3.7
Iodine	47	4.6
Gold	86	6.8

* Wall contribution $|Z/n| \sim 1$ ohm

* Concern is the contribution of the 160 MHz rf system, especially at injection

Requirements

* Head-on Collision
* Rms Interaction length — 20 cm
* Rms Bunch length σ — 28 cm (1 nsec)

* Bucket length = $6 \times \sigma$ = 6 nsec

* Chose 160 MHz ($h = 6 \times 342$)

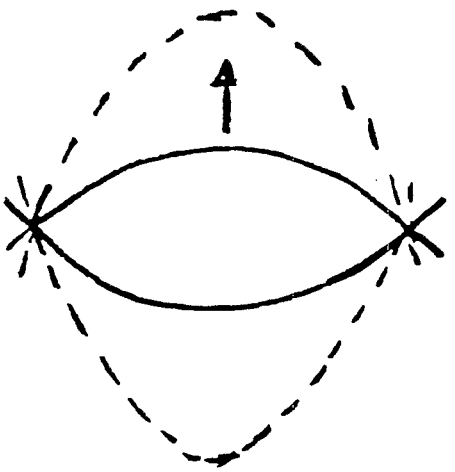
λ = 6.2 nsec

* Bunch Compression

$h = 342$ $\quad S = 0.3$ eV·sec/amu

V	Bunch length Proton	Gold
0.1 HV	± 2.6 nsec	± 4.1 nsec
0.3	2.0	3.1
1.0	1.5	2.3

Storage Mode



Strategy to cope with IBS

160 MHz ($h = 6 \times 342$)

* @ Beginning $S = 0.3$ eV-sec/amu

	Proton	Gold
$\Delta p/p$	$\pm 0.026\%$	$\pm 0.045\%$
V	0.04MV	0.10 MV
Q_s	0.00027	0.00064

* After 10 hour $\Delta p/p$ increases a factor 5 for gold and considerably less for protons

V	< 1MV	5MV