

## RF Systems Overview

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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

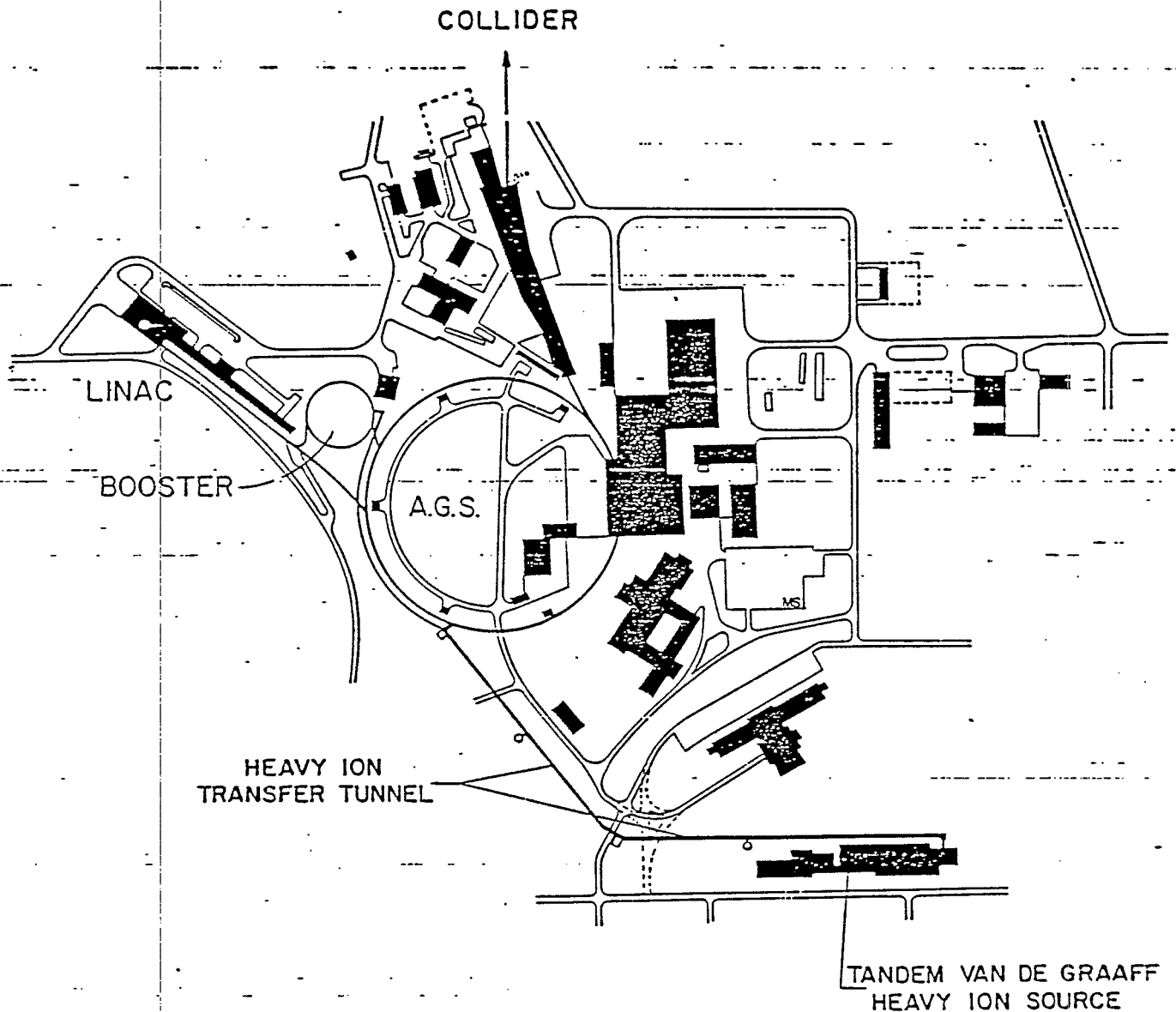


Fig. III-3. Injection system for Collider.

57 (x2) bunches per ring

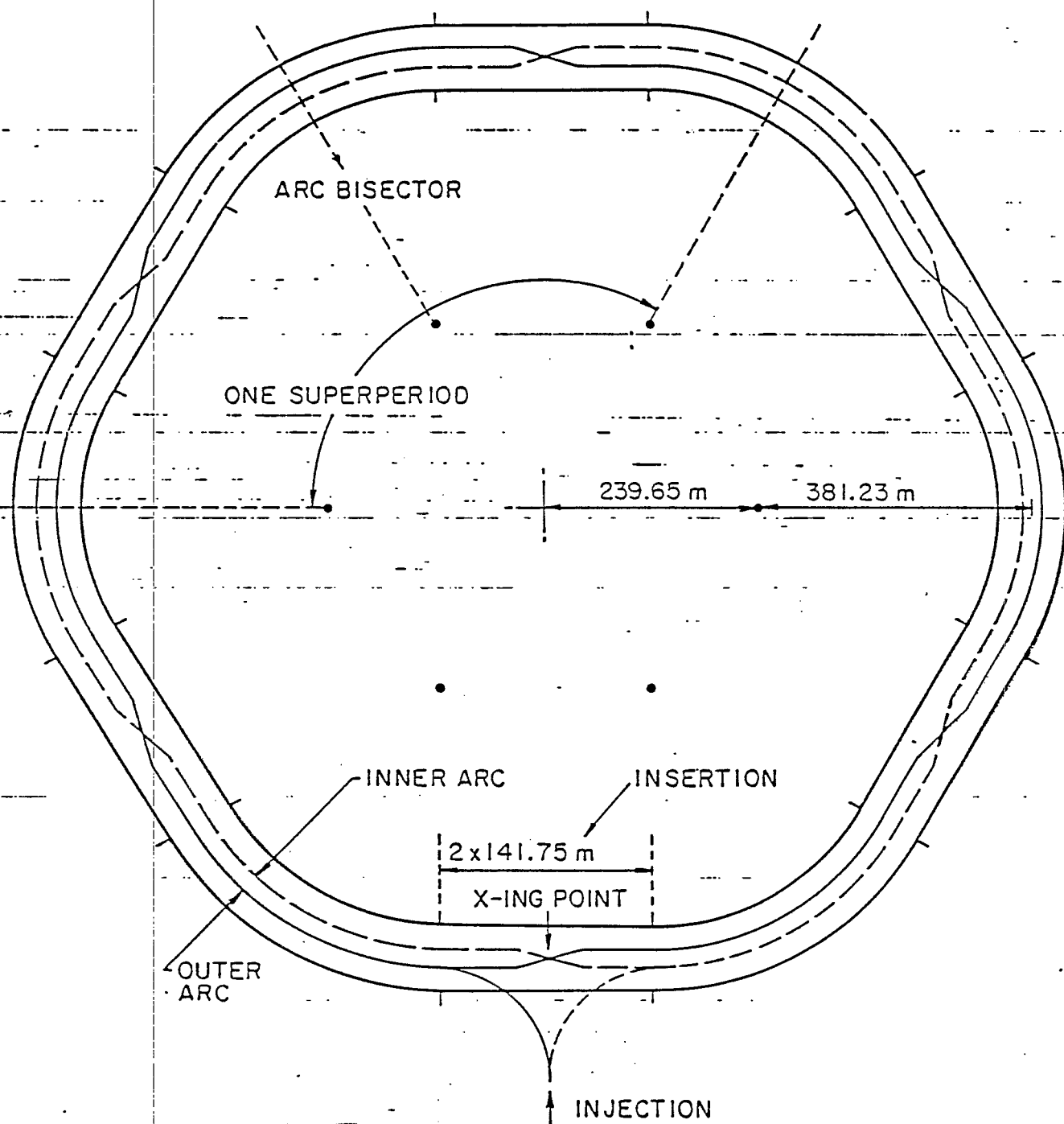
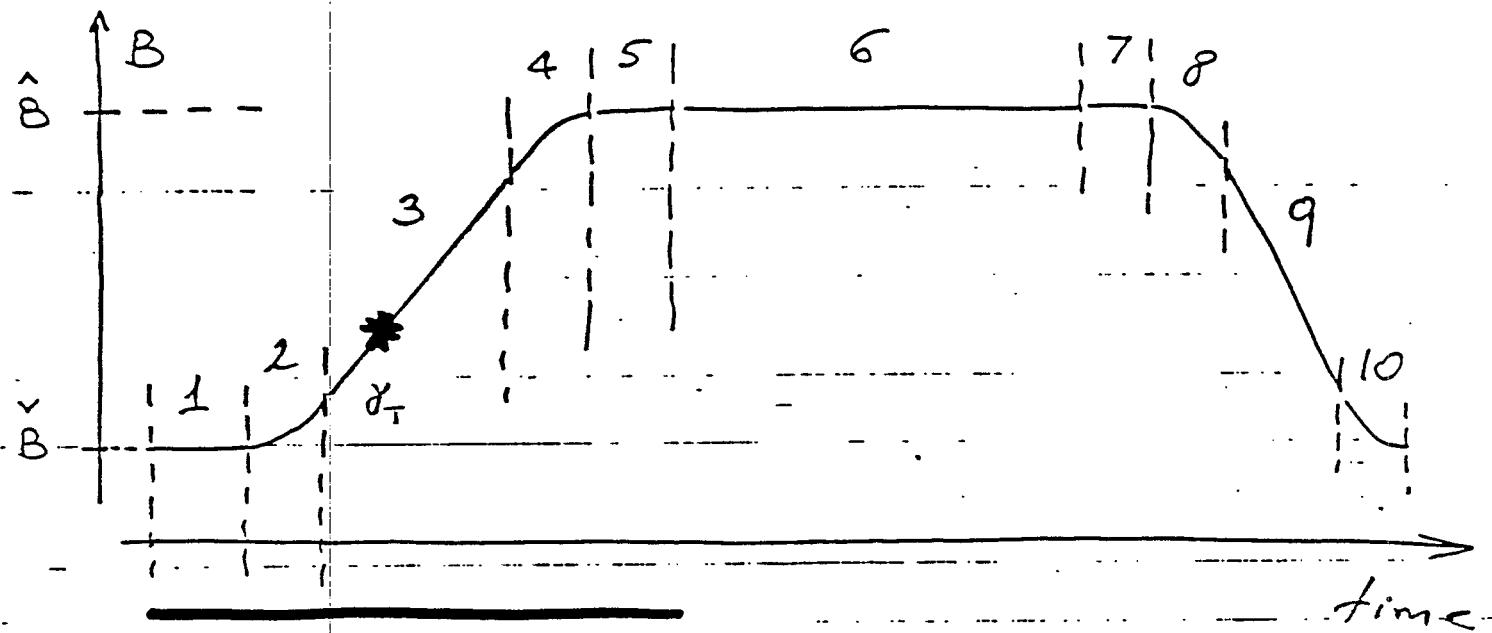


Fig. IV-1. Layout of the Collider.

# The overall RHIC rf-cycle



1. Front-Porch for Injection

2. First Parabolic Ramp

3. Linear Ramp ( $\gamma_T$ )

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  $\left\{ \begin{array}{l} \text{low rf} \\ \text{high rf} \end{array} \right.$

AGSRHIC $2\pi R$ 

807.4 m

3833.4 m

 $\delta_T$ 

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

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 $(\Delta f/f)_{RF}$ 

0.1%

Storage Mode :  $h$  $6 \times 342$  $f_{rf}$ 

160 MHz

 $V$ 

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# Electric Current

	<u>Q</u>	<u>A</u>	<u>N</u>	<u><math>1 \times N</math></u>	<u><math>2 \times N</math></u>
				$M=57$	$M=114$
Proton	1	1	$100 \times 10^9$	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



COR

rf current  $\sim 1A$

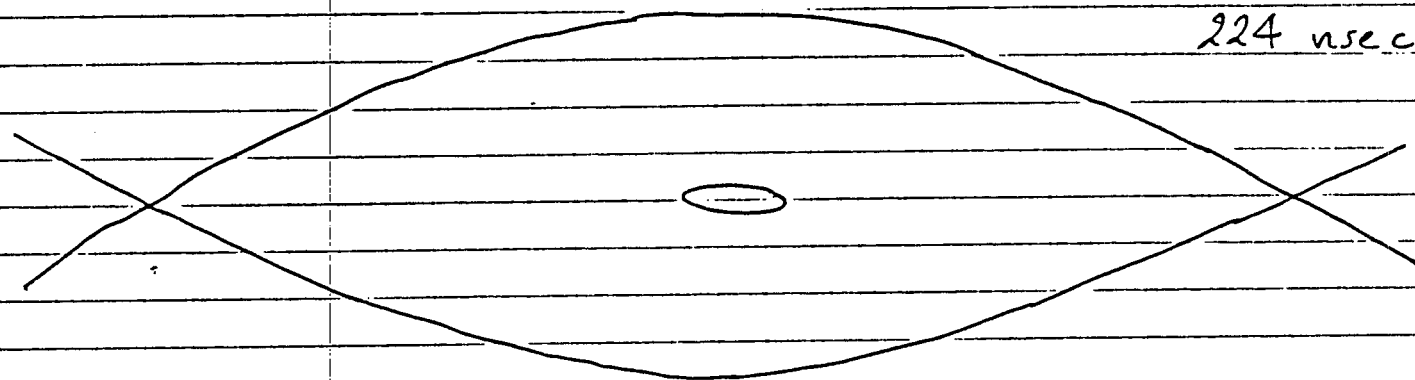
# Injection

No Acceleration

Bunch-to-Bucket Transfer

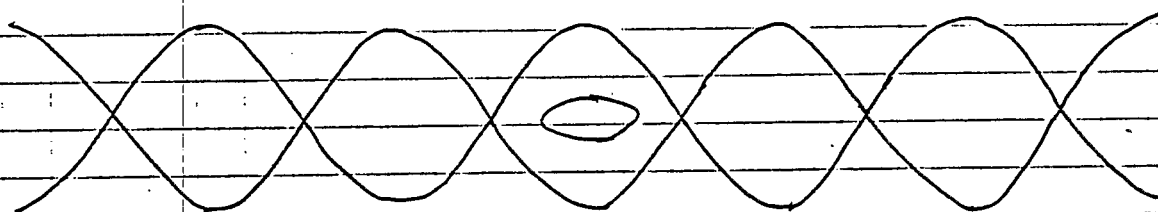
AGS

224 nsec



RHIC

37.3 nsec



Individual Bunch Area

for Protons and Heavy Ions

0.3 eV-sec/amu (total)

Inj. Energy	RHIC		
	V	$Q_s$	$S_B$

Proton	28.5 GeV	12 kV	0.00012	1.52 eV·sec
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Deuterium	13.6 GeV/amu	41 kV	0.00044	0.71 eV·sec/amu
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Carbon	13.6	40	0.00043	0.71
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Sulfur	13.6	40	0.00042	0.70
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Copper	12.4	56	0.00058	0.68
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Iodine	11.2	84	0.00082	0.65
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Gold	10.7	101	0.00095	0.65
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		protons	H.I.
$Q_s$	AGS	$180^\circ$	$180^\circ$
	RHIC	$180^\circ$	$0^\circ$

V	AGS	300 kV	200 kV
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## 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

$$\alpha^2(\phi_s) V(t) = \epsilon(t) V_{\text{injection}}$$

where

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

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

$$\phi_s = 12^\circ$$

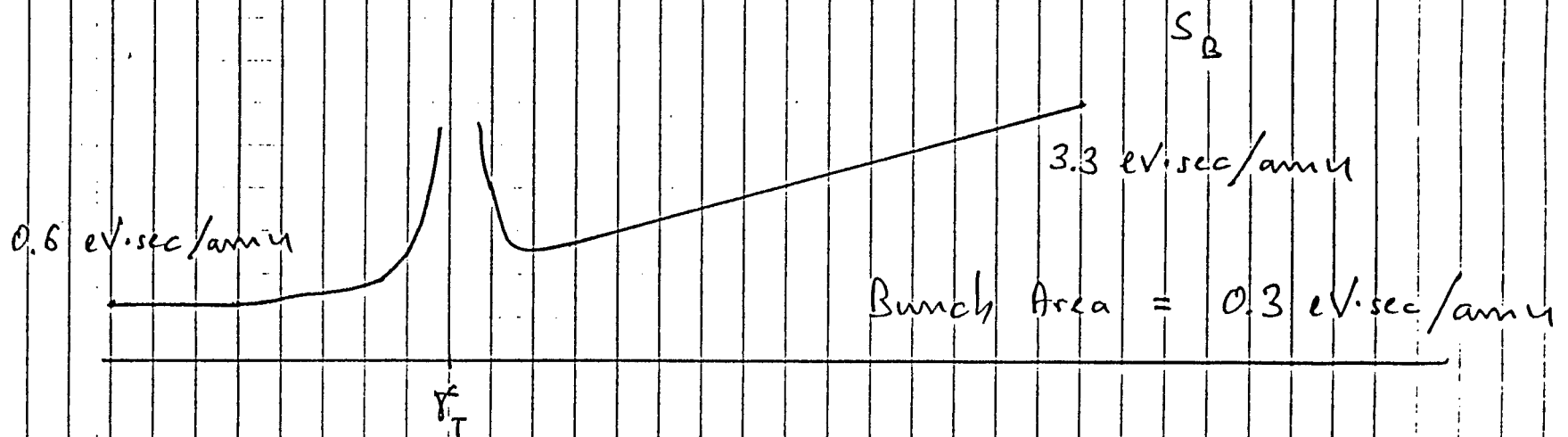
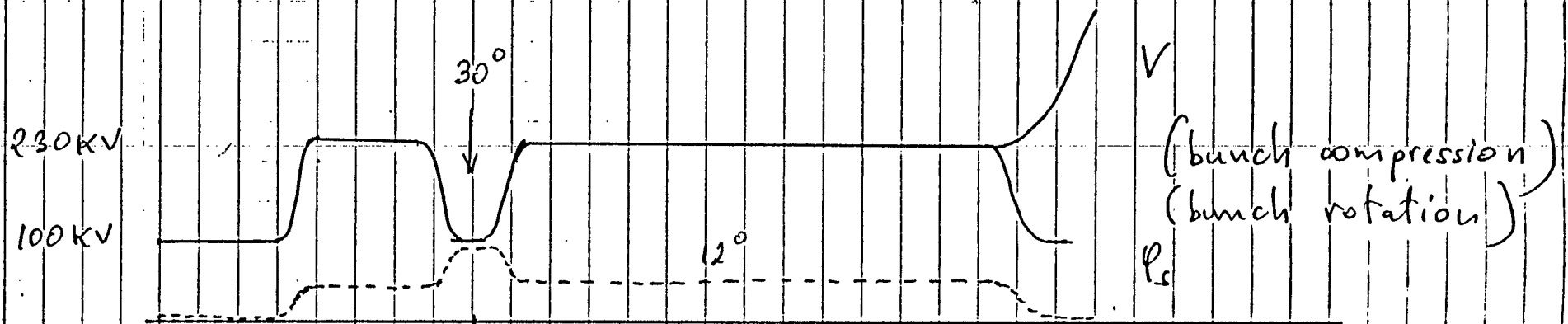
$$V = 230 \text{ KV}$$

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

## Transition Energy Crossing (H.I.)

- \* Kinematic Effects
- \* Space Charge Effects
- \* Microwave Instability
- \* Space Charge Effects and Microwave Instability can be greatly reduced with  $\gamma_T$  and/or  $\gamma$  jump schemes
- \* Kinematic Effects can be reduced within acceptable limits with a smaller  $\Delta p/p$  - This is accomplished choosing at  $\gamma \approx \gamma_T$   
 $V = 100 \text{ kV}$   
 $\theta_s = 28.6^\circ$
- \* Recapture of the bunches at  $\gamma \approx \gamma_T$  by the higher rf system
- \* Protons do not cross transition energy

$h = 342$  of system (26 MHz)



Gold

No Dilution during  
Acceleration  
 $x_T$  - crossing

## End of Acceleration ( $h = 342$ )

$$\phi_s = 180^\circ$$

$$S = 0.3 \text{ eV}\cdot\text{s}/\text{amu}$$

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

	Energy	$S_B$	$\tau$	$\Delta r/p$
	GeV/amu	eV·s/amu	nsec	%
Proton	250.7	8.0	$\pm 2.60$	$\pm 0.015$
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 of system, especially at injection

## Requirements

- \* Head-on Collision
- \* Rms Interaction length 20 cm
- \* Rms Bunch length  $\sigma$  28 cm  
(1 nsec)
- \* Bucket length =  $6 \times \sigma = 6$  nsec
- \* Chose 160 MHz ( $h = 6 \times 342$ )

$$\lambda = 6.2 \text{ nsec}$$

- \* Bunch Compression

$$h = 342 \quad S = 0.3 \text{ eV} \cdot \text{sec} / \text{amu}$$

Bunch length

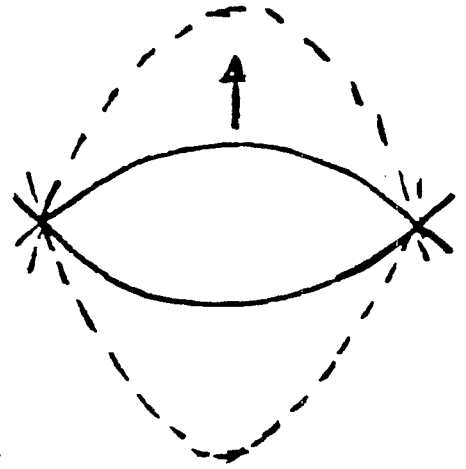
V	Proton	Gold
0.1 MV	$\pm 2.6$ nsec	$\pm 4.1$ nsec
0.3	2.0	3.1
1.0	1.5	2.3

## Storage Mode

Strategy to cope with IBS

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

\* @ Beginning  $S = 0.3 \text{ eV-sec/amu}$



	<u>Proton</u>	<u>Gold</u>
$\Delta r/p$	$\pm 0.026\%$	$\pm 0.045\%$
$V$	0.04 MV	0.20 MV
$Q_s$	0.00027	0.00064

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

$V$	$< 1 \text{ MV}$	5 MV
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