Workshop Goals

(Mini-Workshop on RHIC RF Systems)

July 11-15, 1988
Collider Center

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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.
1986 BEGIN AGS FIXED TARGET EXPERIMENTS

Ion Species: \(^{1}\text{H} \text{ to } ^{28}\text{S}\):

Beam Energy: \( \text{Up to } 29 \left( \frac{Z}{A} \right) \text{ GeV} \cdot \text{c}^{-1}/\text{u} \)

Flux: \( \approx 10^9 \text{ ions/pulse} \)

Running Time: 5 - 10 weeks/year

1991 AGS EXPERIMENTS WITH BOOSTER SYNCHROTRON

Extend ion mass to \( A \approx 200 \) (\(^{197}\text{Au}\))

1994 BEGIN RHIC COLLIDER EXPERIMENTS

Ion Species: \(^{1}\text{H} \text{ to } ^{197}\text{Au}\)

Energy/Beam: \( \text{Up to } 250 \left( \frac{Z}{A} \right) \text{ GeV/u} \)

C.M. Energy: 250 + 250 GeV (p) 100 + 100 GeV/u (Au)

Luminosity: \(10^{31} \text{ cm}^{-2} \text{ sec}^{-1}\) \(5 \times 10^{26} \text{ cm}^{-2} \text{ sec}^{-1}\)
RHIC MAJOR PARAMETERS

Energy Range (each beam), Au Protons

(7) 10.7-100 GeV/u
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

3 m

Low-beta insertion

Betatron tune, horizontal/vertical

28.82

Transition Energy, \( \gamma_T \)

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, Bp: @ 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
HEAD-ON two diamond length $\delta_1 = \delta_0 / \sqrt{2}$
ENERGY SPREAD

2.58E/10^{-3}

RF VOLTAGE 1.2 MV 2.5 kHz

A

1.1 x 10^{9}/BUNCH

ΔP/Δ

BUCKET

t=0

1.0 2.0 3.0 4.0

20

40

60

80

100
INTRABEAM SCATTERING
ABOVE TRANSITION

\[ \tau_{E}^{-1} = \frac{1}{\delta_{E}} \frac{d\delta_{E}}{dt} = \left( \frac{\langle \sigma \rangle}{\langle X \rangle \delta_{E}} \right)^{2} \tau_{H}^{-1} \]

with

\[ \tau_{H}^{-1} = \frac{27\pi}{2} L_{g} g \frac{r_{p}^{2}}{L_{\sigma}} \frac{2}{E_{0} \gamma} \left( \frac{N_{B}}{e_{H} e_{V}} \right) \frac{\langle X \rangle}{\langle \beta \rangle} \frac{1}{1 + \left( \frac{\langle \sigma \rangle}{\langle X \rangle \delta_{E}} \right)^{2} \frac{Q^{2}}{A}} \]

where

\[ L_{g} \approx 20 \]

\[ r_{p} = \frac{\mu_{0} c^{2}}{4\pi E_{0}} \]

\[ \langle \sigma \rangle = \left( \frac{e_{H}}{6\pi} \frac{\langle \beta \rangle}{\gamma} \right)^{1/2} \]

\[ S = 6\pi \sigma_{L} \delta_{E} \gamma E_{0}/c \]

\[ e_{H,V} = \text{normalized transverse emittance} \]

\[ \langle X \rangle = \text{averaged dispersion} \]

\[ \langle \beta \rangle = \text{averaged betatron function} \]

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DIAMOND LENGTH

Requirement

\[ \sigma_I \leq 20 \text{ cm RMS} \]

Bunch RMS Length

\[ \sigma_I = \sqrt{2} \sigma_I = 28 \text{ cm RMS} \]

Bucket Half Length

160 MHz ( \( h = 2052 \) )

\[ l_B = \pi R/h = 0.934 \text{ m} \]

Due to bucket nonlinearity

\[ \sigma_I < l_B/\sqrt{6} = 38 \text{ cm RMS} \]

\[ \frac{1}{2} \Delta_B \]

\[ \frac{1}{3} l_B \]

\[ l_B \]

\[ \sigma_E = \Delta_B/\sqrt{6} \] Yields \[ \sigma_I = 0.268 \times l_B = 25 \text{ cm RMS} \]

Economy Condition:

\[ \sigma_E = \Delta_B/2 \]

\[ \sigma_I = l_B/3 = 31 \text{ cm RMS} \]
RF BUCKET AND LONGITUDINAL BUNCH PARAMETERS

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

BUCKET AREA/AMU
\[ A_B = 8 \, \Delta_B \, \frac{\gamma \, E_o}{h \, \omega_o} \]

BUNCH PHASE HALF WIDTH
\[ 0 < \phi < \pi \]

COLE-MORTON:
\[ N = \sin^2 \frac{\phi}{2} \]

RMS BUNCH LENGTH
\[ \sigma_\ell = \frac{1}{\sqrt{6}} \, \frac{R}{h} \, \phi \]

RMS BUNCH HEIGHT
\[ \delta_E = \frac{1}{\sqrt{6}} \, \Delta_B \, \sin \frac{\phi}{2} \]

BUNCH AREA/AMU
\[ S = A_B \left\{ (N-1) \, K(N) + E(N) \right\} \]
\[ \approx 6 \, \pi \, \sigma_\ell \, \delta_E \, \gamma \, E_o / c \]
RHIC RF SYSTEMS PARAMETER

- Beam parameters from AGS
  \[
  \begin{align*}
  \text{p} & \quad 10^{11} / \text{bunch} \quad \{ 0.3 \text{ eV} \cdot \text{sec/} \text{u} \\
  \text{Au} & \quad 10^9 / \text{bunch} \quad \{ 10 \pi \text{ mm}^2 \cdot \text{mrad} 
  \end{align*}
  \]

- Assume essentially no growth of bunch area at injection and during transition

- Acceleration RF system
  \[
  \begin{align*}
  & \text{2 cavities (CDR-type)} \quad 300 \text{ kV} \\
  & \text{Tuning range} \quad 1\% \quad (> 7 \text{ GeV/u})
  \end{align*}
  \]

- Storage RF system
  \[
  \begin{align*}
  & \text{Tuning range} \quad 0.1\% \quad (< 30 \text{ GeV/u}) \\
  & \text{Voltage @ 10 hr} \quad 11.4 \text{ MV} - \text{Au} (\Delta_B = 2 \sigma_E) \\
  & \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad 17.7 \text{ MV} - \text{Au} (\Delta_B = \sqrt{6} \sigma_E) \\
  & \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad 2.3 \text{ MV} - \text{p} (\Delta_B = \sqrt{6} \sigma_E)
  \end{align*}
  \]

  Scaled CERN-type cavity
  Number of cavities, voltage/cavity ?
  Superconducting cavities ?

- Design for future upgrade
  \[
  \begin{align*}
  & \text{2} \times 57 \text{ Bunches, 2} \times \text{number ions/bunch}
  \end{align*}
  \]

- Design for 2 - 3 missing bunches (beam dump gap )

jh71188d
**MINI WORKSHOP ON RHIC RF SYSTEMS**

**Monday, July 11 -- 2:30 pm**

**Bldg. 1005 Conference Room 4th Floor**

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