TECHNICAL NOTE

S. C. Snowdon

July 25, 1967

SLOW INJECTION INTO 1000 METER RADIUS ACCELERATOR

Purpose

To date, the Lawrence Radiation Laboratory booster rapid cycling booster system has been studied in the greatest detail. In order to determine if a slow booster system warrants greater attention, the following injection system is considered. A 50-MeV linac injects into a 10 m radius, 1 BeV rapid cycling (30/sec) booster. Ten cycles of this beam, in turn, is synchronously injected into a 100 m radius, 30 BeV slow cycling booster. Decaturn extraction and subsequent fast injection places the beam into the main ring accelerator.

Linac Parameters

T = 50 MeV
Rep. Rate: 30/sec
Beam Current: 50 mA
Beam Emittance (each transverse mode): 2.5 π mrad-cm
Energy Spread following debuncher: $\pm$ 75 keV

1 BeV Rapid Cycling Booster Parameters

$\langle R \rangle$ = 10 m.
$\langle B \rangle$ = 5.657 kG
C. F. = 2
B_{max} = 11.314 kG
T_{inj} = 50 MeV
B_{inj} = 2.070 kG
Aperture: 10" x 5.5" or 25.4 cm x 13.97 cm
Rep. Rate: 30/sec.
Average Revolution Time/Turn: .3183 μsec.
Turns to Accelerate: 52370
Peak Cavity Voltage: 36 kV/turn (ϕ_s = 30°)
Harmonic Number: 10
Average Field Index: 4

At Injection (50 MeV)
Revolution Frequency: 1.4985 MHz
ν_s = .0191
Bunching Factor: .25
Average Radial Betatron Amplitude: 7.0 cm
Average Vertical Betatron Amplitude: 3.5 cm
Radial Beam Emittance: 11 π mrad-cm
Vertical Beam Emittance: 2.75 π mrad-cm
Space Charge Limit (Incoherent): 3.36 x 10^{12} protons
Required Linac Current: 37 mA (20 turns)
Charge in Accelerator: 3 x 10^{12} protons
At Final Energy (1 BeV)
Revolution Frequency: 4.1751 MHz
Radial Beam Emittance: 20 π mrad-cm
Vertical Beam Emittance: 5 π mrad-cm

30 BeV Slow Booster Parameters

$\langle R \rangle$ = 100 m.
$\langle B \rangle$ = 10.315 kG
C. F. = 1.245
B_{max} = 18 kG
T_{inj} = 13 MeV
B_{inj} = 221 G
Aperture: 7" x 4.5" or 18.26 cm x 11.43 cm
Rep. Rate: .5/sec.
Acceleration Rise Time: 1.2 sec.
Front Porch Time: .33 sec.
Average Revolution Time/Turn: 2.112 μsec.
Turns to Accelerate: 568130
Peak Cavity Voltage: 102 kV/turn (ϕ_s = 30°)
Harmonic Number: 100
Average Field Index: 40
At Injection
Revolution Frequency: .4175 MHz
ν_s = .0110
Bunching Factor: .25
Average Radial Betatron Amplitude: 5.66 cm
Average Vertical Betatron Amplitude: 2.83 cm
Radial Beam Emittance: 20 π mrad-cm
Vertical Beam Emittance: 5 π mrad-cm
Space Charge Limit (Incoherent): 3.62 x 10^{13} protons
Circulating Beam Current: 2.3 A

At Final Energy (30 BeV)
Revolution Frequency: .4769 MHz
Radial Beam Emittance: 1.10 π mrad-cm
Vertical Beam Emittance: .27 π mrad-cm

Extracted Beam (30 BeV)
Horizontal Beam Emittance: .11 π mrad-cm
Vertical Beam Emittance: .27 π mrad-cm

Note: A decaturn extraction system gives 1.1 /10 = .11 mrad-cm emittance. Subsequent interchange of horizontal with vertical phase space is carried out in transport channel.

400 BeV Main Ring Parameters

$\langle R \rangle$ = 1000 m.
$\langle B \rangle$ = 13.374 kG
C. F. = 1.346
B_{max} = 18 kG
T_{inj} = 30 BeV
B_{inj} = 1.388 kG
Aperture: 5" x 2" or 12.70 cm x 5.08 cm
Rep. Rate: .5/sec
Acceleration Time: 1.5 sec
Average Revolution Time/Turn: 20.96 μ sec
Turns to Accelerate: 71564
Peak Cavity Voltage: 10 MV/turn ($\phi_s = 30^\circ$)
Harmonic Number: 1000
Average Field Index: 400
At Injection
Revolution Frequency: 47.69 kHz
ν_s = .0090
Bunching Factor: .15
Average Radial Betatron Amplitude: 1.15 cm
Average Vertical Betatron Amplitude: .74 cm
Radial Beam Emittance: .27 π mrad-cm
Vertical Beam Emittance: .11 π mrad-cm
Space Charge Limit (Incoherent): 3.45×10^{14} protons.

Comments

Item	Advantages	Disadvantages
Main Ring	1. Eliminates front porch to give 1.5 sec. acceleration time. 2. 30 BeV injection permits percentage frequency swing to be .046 percent. 3. Low ν_s.	
Slow Booster	1. Radio Frequency System is inexpensive. 2. Magnet Power Supply is inexpensive. 3. Low ν_s.	1. Multiturn extraction is considered difficult - inefficient and variable shape of phase area. 2. Higher radiation damage because of higher injection energy. 3. Possible longitudinal phase and space blow up in passing high intensity beam through transition. 4. Magnet aperture larger than LRL booster aperture 5. Requires all of charge in final ring.
Rapid Cycling Booster	1. Uses only a 50 MeV linac. 2. Low ν_s.	
General	Space charge limits are too conservative. Can reduce apertures of both boosters.	

SCS:cms