

Injection For RHIC

J. Claus

March 1984

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.DE-AC02-76CH00016 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

INJECTION FOR RHIC

J. Claus

Brookhaven National Laboratory
March 19, 1984

4 Clans
19 March '84

Injection for RHIC.

We assume an injection septum magnet in one of the L670 drift spaces with its exit 1 m upstream of Q70, followed by an injection kicker (full aperture) in the adjoining L780 drift space, 2 m long and its exit 1 m upstream of Q80, thus with its center 2 m upstream of that magnet.

We calculate for the Betatron parameters at the septum magnet exit and the kicker center in the present

$$\beta_x^* * \beta_y^* = 17 * 3 \text{ m}^2 \text{ lattice:}$$

	Horizontally		Vertically	
	β_H (m)	$\psi_H/2\pi$	β_V (m)	$\psi_V/2\pi$
Septum magn.	16.98012	1.92844	22.73199	1.8784
Kicker	37.81594	1.98960	11.04818	1.94608

The leverage arm length between kicker and septum magnet is then:

	Horizontally	Vertically
$\sqrt{\beta_s \beta_k} \sin \Delta\psi$ (m)	9.50	6.53

The circulating beam requires (after two hours) an aperture of

	Horizontally	Vertically
Septum magnet (mm) ²	2 * 18	2 * 18
Kicker (mm) ²	2 * 27	2 * 13

Based on 6σ for an emittance $\epsilon_{\mathcal{P}} = 30/6 * 10^{-6} \text{ rad-m}$ and a momentum spread of $\frac{\Delta\mathcal{P}}{\mathcal{P}} = 2 * 0.003$, and local values for β_s and $x_{\mathcal{P}}$ (dispersion)

The beam to be injected has cross sectional dimensions in the ~~septum~~ septum magnet's exit of

$$H \times V = 2 \times 4.7 \times 2 \times 4.3 \text{ (mm} \times \text{mm)}$$

assuming that that beam has $\frac{\Delta p}{p} = 2 \times 0.0013$ and taking the σ_{TB} values for an emittance of $\gamma \epsilon = 10/6 \times 10^{-6} \text{ rad-m}$.

We also assume that the effective septum thickness will be $\leq 5 \text{ mm}$. It follows that the kicker must provide a deflection $\Delta x' \geq (18 + 5 + 4.7)/9.5 = 3 \text{ mrad}$ if it deflects horizontally and

$$\Delta y' \geq (18 + 5 + 4.3)/6.53 = 4.2 \text{ mrad}$$

if it deflects vertically.

Evidently horizontal deflection requires less kicker

3. length

The B_p value of the incoming beams is 98.22 Tm , therefore for a horizontally deflecting kicker requires at least

$$Bl = \alpha B_p = 3 \times 98 \times 10^{-3} = 0.3 \text{ Tm}$$

We choose it to have a length of 2 m , thus $B = 1.5 \text{ kg}$, quite manageable for conventional ferrites.

Using this value we find for the stored energy, the excitation current and the self inductance:

$$E = \frac{1}{2\mu_0} B^2 \times \text{Volume} \geq \frac{0.15^2 \times 2 \times 54 \times 26 \times 10^{-6}}{2 \times 4\pi \times 10^{-7}} \geq 2.5 \text{ Joule}$$

$$I = \frac{Bq}{\mu_0} = \frac{0.15 \times 26 \times 10^{-3}}{4\pi \times 10^{-7}} = 3100 \text{ A}$$

$$L = \frac{\mu_0}{4\pi} \frac{L \times w}{q} = 4\pi \times 10^{-7} \times 2 \times \frac{54}{26} = 5.2 \mu\text{H}$$

A linear rise from no excitation to full excitation in 150 nsec (bunch centers are 220 nsec apart)

requires a voltage of $V_k = L \frac{di}{dt} = 5.2 \times \frac{3100}{0.15} = 108 \text{ KV}$ and an instantaneous power of 166 MW .

Aperture in ψ_70

The path of the injected beam is displaced by $3(\text{mrad}) \times 6\text{m} = 18\text{mm}$ from the reference orbit in this quad. The beam's half width at that point is

$$\begin{aligned}hw &= x_p \frac{\Delta p}{p} + \sqrt{\frac{\epsilon \beta}{\gamma}} \\ &= 0.714324 \times 1.3 + \sqrt{\frac{10 \times 15.2995}{12.5}} \\ &= 4.427\text{mm}.\end{aligned}$$

ψ_70 must provide a physical aperture of at least $p = 18 + 4.427 = 23\text{mm}$ for that reason, slightly larger than the 20mm required vertically by the circulating beam after 2 hours.

Beam direction at septum magnet exit.

The injected beam leaves the septum magnet with an angle

$$x' = -(1 + l q_7) x'_k = -(1 + 6 \times 0.129) 3 = 4.77\text{mrad}.$$

relative to the reference orbit.

Kicker considerations.

We estimated kickers of 2, 3, 4, 5 m length, all ending 1 m upstream of ψ_80 , and all with sufficient aperture to contain the circulating beam after two hours ($\epsilon \gamma = 6 \times 30 \times 10^{-6}$, $\Delta p/p = \pm 0.003$). We tabulate the results below:

Length (m)	Deflection Angle (mrad)	Field (T)	Aperture (mm x mm)	Stored Energy (Joule)	Current (A)	Inductance (μH)
2	2.915	0.142	58 x 27	25.1	3051	5.4
3	3.123	0.102	30	21.6	2435	7.3
4	3.362	0.0824	33	20.7	2164	8.8
5	3.640	0.0713	35	20.5	1986	10.4

The longest kicker seems to be the best one because it stores least energy and can easily be subdivided into a number of modules in order to reduce the requirements on the switch thyatron.

Errors.

The deflection angle produced by the kicker are uncertain for a number of reasons, primarily variations in pulse height and reflections on imperfect terminations. I/s assume that the deflecting field can be kept within 1%,

$$\text{i.e. } |\Delta B/B| \leq 0.01$$

or ΔB obtain for the deflection angle

$$\left| \frac{\Delta \theta}{\theta} \right| = \left| \frac{\Delta B}{B} \right| \leq 0.01$$

Thus $\Delta \theta \sim 30 \mu\text{rad}$.

The angular spread in the incoming beam is of the order of $\sqrt{\frac{2}{10}} = \sqrt{\frac{10}{30}} = \frac{166}{577} \mu\text{rad}$, the kicker error is negligible compared to this at 100% stability.

It may be advantageous to inject intentionally with a coherent betatron error in both horizontal and vertical planes, because this leads quickly (via filamentation) to a circulating beam of large and controllable emittance and of somewhat controllable density distribution. It may be worth while to enhance the filamentation process with the aid of some octupoles.