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Lattice Alternative For RHIC

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RHIC-PG-26

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LATTICE ALTERNATIVES FOR RHIC

H. HAHN

(BNL, January 10, 1984)

ASSUMPTIONS

EQUAL IBS DIFFUSION RATES $z''_{H} = z''_{E} = 0.5 h''(=z'')$ $z''_{L} = 1 h''$

BEAM. BEAM TUNE SHIFT AVBB = 3× 103

BUNCHED BEAM OPERATION h_B = 57 T₂ = 1 m

EXISTENCE OF BOOSTER NO MOMENTUM STACKING

BUT DESIGN OF COLLIDER ALLOWS FOR FUTURE INSECTOR EMPROVEMENTS

NB = 1x10° ions/bunch

ONLY AU-JONS STUDIED

DEFINITIONS

rms beam radius
$$\sigma_{H,V} = \left(\frac{\beta_{H,V}}{6\gamma} \frac{\epsilon}{\pi}\right)^{1/2}$$
beam size maximum in arc $= 2\sqrt{6} \left(\sigma_H + X_p \delta_E\right)$ rms diamond length $\sigma_{diam} = \frac{\sigma_H \sigma_L}{2\sigma_H + \frac{1}{2} \alpha \sigma_L}$ rms bunch length $= \sigma_L$ bunch area $A_B = 6\pi \sigma_L \delta_E \gamma E_0/c$

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$$\Psi = phase shift/cell$$

$$L_{HC} = length of half cell$$

$$\Theta_{HC} = deflection/half cell$$

$$N_{CS} = number of cells/sextant$$

$$<\beta> = \frac{2 L_{HC}}{\sin \Psi}$$

$$\beta_{max} = <\beta> (1 + \sin \frac{1}{2}\Psi)$$

$$= L_{HC} \Theta_{HC} \frac{1}{\sin^{2} \frac{1}{2}\Psi}$$

$$Y_{tr} = \frac{<\beta>}{} \cos \frac{1}{2}\Psi (\times 1.37)$$

$$X_{p max} = (1 + \frac{1}{2}\sin \frac{1}{2}\Psi)$$

$$\Theta_{HC} = \frac{\pi}{6 N_{CS}}$$

$$J_{HC} B d\ell = \frac{388}{N_{CS}} Tesla \cdot meter$$

$$J_{quad} G d\ell = 9.61 N_{cs} \sin \frac{1}{2}\Psi Tesla$$

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$$L = \frac{f_0}{4\pi} h_B N_B^2 \frac{1}{\sigma_V \sigma_{\text{Heff}}}$$
$$f_0 = \frac{c}{2\pi R}$$
$$\sigma_{\text{Heff}} = (\sigma_{\text{H}}^{*2} + (\frac{1}{2} \alpha \sigma_{\text{L}})^2)^{1/2}$$

BEAM-BEAM TUNE SHIFT (
$$\Delta v_{BB} \le 3 \times 10^{-3}$$
)

$$\Delta v_{BB} = \frac{r_p}{2\pi} \frac{Q^2}{A} \frac{N_B}{\gamma} \frac{\beta_V^*}{\sigma_V (\sigma_V + \sigma_{Heff})}$$

TOLERABLE COUPLING IMPEDANCE

$$\frac{Z}{n} = 4 \frac{A}{Q^2} \frac{\gamma E_0}{e I_p} |n| \delta_E^2$$
$$n = \gamma^{-2} - \gamma_{tr}^{-2}$$
$$I_p = \frac{c}{\sqrt{2\pi}} \frac{N_B}{\sigma_L}$$

INTRA BEAM SCATTERING (Courant, Bjorken & Mtingwa)

Diffusion rate
$$(\gamma \gg \gamma_{tr})$$

 $\tau^{-1} = \tau_{H}^{-1} + \tau_{V}^{-1} + \tau_{E}^{-1}$
 $\tau_{V}^{-1} \approx 0$
 $\tau_{E}^{-1} = \left(\frac{\sigma_{H}}{\langle X_{p} \rangle^{\delta} E}\right)^{2} \tau_{H}^{-1}$
 $\tau_{H}^{-1} = \frac{9}{4} L_{g} r_{p}^{2} c \left(\frac{Q^{2}}{A}\right)^{2} \frac{N_{B}}{\sigma_{L}} \frac{1}{\gamma \delta_{E}} \frac{\pi^{2}}{\varepsilon_{H} \varepsilon_{V}} \frac{\langle X_{p} \rangle}{\langle \beta \rangle} \left[1 + \left(\frac{\sigma_{H}}{\langle X_{p} \rangle \delta_{E}}\right)^{2}\right]^{-1/2}$
 $- \frac{1}{L} \frac{dL}{dt} = \tau_{V}^{-1} + \frac{\sigma_{H}}{\sigma_{Heff}} \tau_{H}^{-1} + \frac{\frac{1}{2} \alpha \sigma_{L}}{\sigma_{Heff}} \tau_{E}^{-1}$
with $L_{g} \approx 20$

$$r_{\rm p} \approx 20$$

 $r_{\rm p} = 1.5347 \times 10^{-18}$ m
 $N_{\rm B} =$ number of ions/bunch
 $\sigma_{\rm L} =$ bunch length

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EQUIPARTITION

$$\tau_{\rm E} = \tau_{\rm H}$$
$$\delta_{\rm E} = \frac{\sigma_{\rm H}}{\langle \chi_{\rm P} \rangle}$$

GOAL: $\tau_{\rm H} = \tau_{\rm E} = 2$ hours

DESIGN CONSTRAINTS: $\varepsilon = \varepsilon_{\text{H}} = \varepsilon_{\text{V}} \propto (\tau_{\text{H}} \cdots)^{1/2 \cdot 5}$

 $\delta_{E} \propto (\tau_{H} \cdots)^{1/5}$

H. Hahn 1/9/84

Lattice	L _{HC}	<×x _p >	X _{p max}	<β>	β _{max}	^Y tr	∫ _{HC} Bd1	∫ _{quad} G d1
	(m)	(m)	<u>(m)</u>	(m)	(m)		(Txm)	(T)
9/90°	19.8	2.05	2.77	39.5	67.5	19	2x4.94x4.36	61.2
9/105°	19.8	1.63	2.27	40.9	73.4	21	2x4.94x4.36	68.7
9/120°	19.8	1.37	1.96	45.6	85.2	23	2x4.94x4.36	74.9
12/90°	14.8	1.15	1.56	29.7	50.6	25	2x3.3 x4.9	81.6
15/120°	11.9	0.49	0.70	27.4	51.1	38	3.3 x7.83	124.9
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LATTICE ALTERNATIVES

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χρ= 4μκ <u>λτρ</u>	2.05	XPMAX	= ?.77	HE TA=	39.53	BE TAMAX=	07.49	AETA*V=	3.0	BETA*H=	3.0	
13 A M M A =		<u>t</u> , =		<u>, na 79</u>	•••			· · · · · · · · · · · · · · · · · · ·				
ЧН= 	PARTZBUNC	н і	ΕΜΙΤΤΑΠΟΕΖΡΙ	DELTA F RM	S FV	SEC/BUNCH	LUMINOSITY	NU SHIFT	DIAM	RMS	BEAM SIZE	Z/N
	1.00F+u	9	1.355-05	4.6) =-04		2.72F+00	5.25E+26	1.72E-03	5,00	E-01	1.23E-02	3.4F
·	2.0000+0	<u> </u>	1.78E-05	5.24E-04		3,12E+00	1.59E+27	2.60F-03	5.04	E-01	1.41E-02	2.2E
•	3.00E+0	c,	2.106-05	5.74E-04		3.385+00	3.04E+27	3.32E-03	5.00	E-01	1.53E-02	1.8E
•	<u> </u>	<u>o</u>	<u>- 2,35E-05</u>	<u>6.08F04</u>		3.59F+00	4. <u>82E+27</u>	<u> </u>	<u> </u>	<u>F =0 1</u>	1.62E=02	
•	5.00E+0	ц	2.57E-05	6.35E-04		3.758+00	6,89E+27	4.5IE-03	5,00	E-01 E-01	1.76E-02	1,31
T	7 005 0	0	$-\frac{C_{-1}}{C_{-1}}\frac{E_{-05}}{E_{-05}}$	<u> </u>	·····	<u>3.896100</u>	<u> </u>	5.525-03	5 00	F - 0 1	1.82F = 0.2	1.15
•	7.00E+0	9	1.11F-05	6.08F-04		4 12F+00	1,16E+28	5.9RE=03	5.00	E-01	1.86E-02	9.7E
•	9.00E+0	9	3.26F-05	7.15E-04	. 4	4.22E+00	1.76E.+28	6.42E-03	5,00	E-01	1.91E-02	9.1F
		<u></u>								r 0-		
<u>-005-03</u>	<u>1_00E+0</u>	<u>0</u>	<u>1.355-05</u>	<u>4_61E=04</u>		$2 72 \pm 0.0$		6.90E.04	<u>_</u>	r = 01	<u>1,23E=02</u>	
. UDE-03	2.00E+0	ч о	1.785-05	5.245-04		3.126+00	4.505+20	1+165-03	1.87	E-01 F-01	1.525-02	2.64
	<u> </u>	<u>ن</u>	2 35E-05			3.59F±00	1 6F+27	1.935-03	2.03	F-01	1.62F-02	1.5
00E=03		a	2.575-05			3.75F+00	2 135 +27	2.28F.03	2.09	E-01	1.70E-02	1.3
00E-03	6.00E+0	9	2.77E-05	6.59E-04		3.89E+00	3.22E+27	2.60E-03	2.13	E-01	1.76E-02	1.2
005-02-	7.0.0E+0	۹		6_80E-04		4-01 E+00	4 23E+27	2.915.03	2,17	E-01	1.82E-02	
00E-03	8.00E+0	9	3.11E-05	6.98E-04		4.12E+00	5. J6E+27	3.21E-03	5.50	E-01	1.86E-02	9 • 7 1
<u>•00€=03</u>	9_00 <u>E</u> +0	Q	<u></u>	7 <u>-15E-04</u>		4.22E+00	60E+27	<u>3.49E-03</u>	2_23	E=01	1,91E-02	<u> 9 1</u>
00F-02	1.00F+0	<u></u>	1.355-05	4.61F-04		2.725+00	2 72F+25	1-70F-04	4.71	E-02	1.23E-02	3.45
00F-02 .	2.00E+0	9	1.78E-05	5.29E-04	<u></u>	7.12F+00	9.48E+25	2.93E-04	5.34	F-02	1.41E-02	2.2
.00E-02	3.00E+0	9	∠.10E-05	5.74E-04		3.38E+00	1.97E+26	4.03E-04	5.73	E-02	1.53E-02	1.84
.00F-02	4.00E+0	<u>u</u>	2.35E-05	6.08E-04	·	3,59E+00	3_JOE+26	<u>5.05E-04</u>	6.03	E-02	1.62E=02	
.00E-02	5.00E+0	9	2.57E-05	6.35E-04		3.75E+00	4.93E+26	6.02E-04	6.27	E-02	1.765-02	1.3
00E-02	<u> </u>	0	2 045 05	6.59 = -04		1.09F+00	0 425+20	7 855 04	<u> </u>	F=02	1.825-02	1 - 1
00E-02	1.00C+0 8.00E+0	9	4.115-05	6.00E-04		4.01 <u>2</u> +00 4.12 <u>5</u> +00	2.03E+20 1 15E+27	8.715-04	6.81	E-02	1.86F-02	9.7
.00E-02	9.00E+0	Q	3.26E-05	7.15E-04		4.22E+00	1.42E+27	9.55E-04	6.95	E-02	1.91E-02	9.1
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RHIC PERFORMANCE ESTIMATES - Au

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$$N_{B} = 1 \times 10^{9}$$

$$\beta_{V}^{*} = \beta_{H}^{*} = 3 m$$

$$\alpha = 0$$

$$\sigma_{L} = 1 m$$

$$h_{B} = 57$$

Lattice	ε/π (m)	δ _E	H•size (cm)	L (cm ⁻² sec ⁻¹)	Δv _{BB}
	×10 ⁻⁶	×10 ⁻³		×10 ²⁶	×10 ⁻³
		$\gamma = 10$	10		
9/90°	13.5	0.46	1.23	5.25	1.72
9/105°	11.0	0.53	1.16	6.44	2.11
9/120°	9.0	0.60	1.13	7.91	2.59
12/90°	10.1	0.61	0.92	7.00	2.29
15/120°	5.4	1.0	0.68	13.2	4.32
		γ = 10	(to be veri	fied)	
9/90°	21.4	1.83	4.90	0.33	1.08
9/105°	17.5	2.12	4.62	0.41	1.33
9/120°	14.2	2.41	4.51	0.50	1.63
12/90°	16.1	2.44	3.67	0.44	1.44
15/120°	8.5	4.01	2.71	0.83	2.72

RHIC PERFORMANCE POTENTIAL - Au

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$$\gamma = 100$$
; $\Delta v_{BB} = 3 \times 10^{-3}$
 $\beta_V^* = 2$ $\beta_H^* = 4.5 \text{ m}$
 $\sigma_L = 1 \text{ m}$ $h_B = 57$

Lattice	α	N _B	ε/π (m)	δ _E	L (cm ⁻² sec ⁻¹)	Diamond (cm rms)
	×10-3	×10 ⁹	×10 ⁻⁶	×10 ⁻³	×10 ²⁷	
9/90°	0	3.7	22.8	0.60	4.26	50
	2	9.3	33.0	0.72	8.28	24.9
9/105°	0	2.6	16.1	0.65	2.97	50
	2	7.7	24.9	0.80	6.70	23.2
9/120°	0	1.9	11.6	0.69	2.21	50
	2	6.4	18.8	0.88	5.43	21.5
12/90°	0	2.3	14.1	0.73	2.65	50
	2	7.1	22.2	0.91	6.08	22.5
15/120°	0	0.8	4.9	0,96	0.92	50
·	2	4.2	9.6	1.34	3.39	17.4

CONCLUSIONS

- ACCURACY MAY BE QUESTION ABLE BUT TREND IS CORRECT

- WEAK FOCUSSING-LARGE APERTURE HIGHEST LUMINOSITY POTENTIAL REQUIRES BETTER INTECTOR

- STUDY & COST IN MORE JETAIL 2 OPTIMUM-COMPREMISE LATTICES (JAR < 30)

9/120° CBA MAGNETS

12/90° NEW MAGNET 3.37 ~3in. coilid. (boot) ~31/2in. coilid. (stroight)

INTECTOR DESIGN

NB = 2 × 10 4 (AG)

BOOSTER ENERBY ?