

## BNL-99522-2013-TECH C-A/AP/375;BNL-99522-2013-IR

# Energy Recovery Linac: Magnet

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January 2010

Collider Accelerator Department Brookhaven National Laboratory

## **U.S. Department of Energy**

USDOE Office of Science (SC)

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# **R&D ERL:** Magnet

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The BNL prototype ERL is the major experimental research and development effort towards RHIC II, the electron cooling project for RHIC. The objective is to reduce the risk and costs of the RHIC II project, as well as developing and demonstrating the electron beam parameters required for electron cooling. The prototype will also serve as a test bed for studying issues relevant to very high current ERLs. All quadrupole and dipole magnets are of the warm bore variety. All magnets are to be accurately CNC machined and will be installed on similarly machined bases. A portion of the ring will be mounted on a movable gantry with a total stroke of plus/minus 5cm.

X.X+-0.1 X.XX+-0.01 X.XXX+-0.001 ANG.+-0.5

- Ring Arc Dipole 3D60 Bends 20 MeV electrons by 60 degree with focusing in both horizontal and vertical planes and an entrance/exit angle of 15 degrees. Dipole gap is 3 cm with a central field of 3.3 kGauss. The magnetic length is around 19 cm with a field quality of sextupole b3 to dipole integral ratio approximately equal to 1.2E-4 at a radius equal to 1 cm and the quadrupole ratio required is about 2.1%.
- Ring Quadrupole 6Q12 Required gradient is 0.3 kGauss/cm. Pole diameter aperture is 6 cm, with a tip field of approximately 900 G and magnetic length of about 16 cm. The field quality 12-pole integral ratio is 1.6E-4 at a radius of 2.5 cm.
- The injection 30 degree z-bend Dipole/Quad combined magnet has a half-gap of 3.644 cm and is designed to minimize the b3 sextupole component. The central field is 191.3 G with a magnetic length of approximately 29.6 cm. The field quality has an integrated sextupole ratio of 4E-4 and octupole ratio of 3E-4 at a radius of 1.5 cm.
- The injection 15 degree z-bend Dipole/Quad combined magnet has a half-gap of 3.544 cm and is designed to minimize the b3 sextupole component. The central field is 145.1 G with a magnetic length of approximately 19.2 cm. The field quality has an integrated sextupole ratio of 2.3E-4 and an octupole ratio of 1.3E-4 at a radius of R=1.5 cm.
- The solenoid pair is designed with a peak field of 984 G, assuming a separation of 5 inches steel to steel or 9.5 inches center to center. Maximum coil current is 8.4 amps at a maximum voltage of 13.4 volts.
- Quadrupole Doublet 3Q6 Required field gradient of 58 Gauss/cm. The field quality, assuming all coils are powered, has an integrated octupole ratio of 5.3E-4 and a 12-pole ratio of 4.1E-4.

#### ERL Magnet Parameter Control 3D60 ERL Doc No.: N/A ERL Loop 60° Dipole – Chevron type –with 2% Trim Coil Comment: Revision: B Mar-03-2006 BNL Job No.: 010606068 MPC - 01 Magnet Function Page: 1 of 1 ECN: Magnet: 3D60 CERTIFICATION Initial Date Review Initial Date "UN 3-22-06 Type: Dipole Engineer: G. Mahler Mechanical: J. Tuozzolo ee W. Meng/ Designer: C. Longo Magnetic: WM 3/16/06 Electrical: J. Sandberg Manufacturer: TBD 3/16/06 Physics: D. Kayran D.K. Project Leader: I. Ben-Zvi R. Lambiase Power: 12/4 A P Group Head: V. Litvinenko **FIXED PARAMETERS DESIGN PARAMETERS** Quantities Core Length (cm): 39.72 Parameter Source: Measured TBD Ring: Gap or Aperture (cm): 6 3 Pole Tip Peak Field (KG): 4 Injection: 0 Bend Radius (cm): 20 Nominal Dipole Field (KG): 4 Extraction: 0 Turns Per Pole (turns): 20 Dipole Integrated Field (KG\*CM): 84 Total: 6 Trim Turns Per Pole (turns): 33 Maximum Coil Current (Amps): 260 Functions: 6 Weight Magnet + Coils (lbs): 230 Maximum Trim Coil Current (Amps): 3.3 Good Field Horz (cm): ± 3 Measured Nominal Current (Amps): TBM Good Field Vert (cm): ± 1 Calculated Nominal Current (Amps): 239 Field Radius (cm): N/A Power (W): 759 Cooling Water, Minimum (GPM): Magnetic Length (cm): 21.40 0.2 Spares Magnet Resistance (ohms): 13.3E-3 Magnet Inlet Temperature, Maximum (°C): 23 Magnets: 1 Magnet Inductance (microH): 2571 Trim Coil Inductance (microH): 7000 without trim coils Per Magnet

Coils: 2

Operating Temp. Core Edge Angle (degrees) 14 Trim Coil Resista TBM – to be measured

TBM

Magnet Resistance (ohms) @

Trim Coil Resistance (ohms) @ Operating Temp: TBM

Trim Coil Resistance per Magnet (ohms)

3.10



Note 1: Units are KG, KG/CM, KG/CM<sup>2</sup> for Quadrupole, Sextupole or Octupole respectively. Note 2: Units are T/m or T/m<sup>2</sup> for Quadrupole or Sextupole respectively.

	ERL	Magnet	Paramet	er Con	trol	ERL Doc No.:	N/A		6Q12
Comment: E	ERL Loop Quad	with 5% Trin	n Coil				Revis	sion: B Ma	r-03-2006
BNL Job No.:	010606064 MI	PC – 01	Magne	t Functior	<b>n Page:</b> 1 of	1		ECN:	
Magnet:	6Q12	CERTIF	ICATION	<u>Initial</u>	<u>Date</u>	<u>Revie</u>	<u>w</u>	<u>Initial</u>	<u>Date</u>
Туре:	Quadrupole	Engineer:	G. Mahler	ph _	3-22-06	Mechanical:	J. Tuozzolo	J.T.	3/17/06
Designer:	C. Longo	Magnetic:	W. Meng	wm	3/16/06	Electrical:	J. Sandberg	12	3/17/06
Manufacturer:	TBD	Physics:	D. Kayran	p. U.	3/16/06.	Project Leader:	I. Ben-Zvi	138	Sinla
		Power:	R. Lambiase	RAL	3/22/06 A	P Group Head:	V. Litvinenko	VL	3/25/01

#### FIXED PARAMETERS

<u>Quantities</u>		Core Length (cm):	12.8
Ring:	26	Gap or Aperture (cm):	6
Injection:	0	Turns Per Pole (turns):	190
Extraction:	0	Trim Turns Per Pole (turns):	110
Total:	26	Weight Magnet + Coils (lbs):	110
-unctions:	26	Good Field Horz (cm):	2.5
		Good Field Vert (cm):	2.5
		Field Radius (cm):	2.5
		Magnetic Length (cm):	15.6
<u>Spares</u>		Magnet Main Coil Resistance (ohms):	1.42
Magnets:	2	Magnet Inductance (microH): without trim coils	2.07E
Coils:	4	Magnet Resistance (ohms) @ Operating Temp.	TBN

#### **DESIGN PARAMETERS**

.8	Parameter Source: Measured	TBD
	Pole Tip Peak Field (KG):	0.9
0	Nominal Gradient (Note 2):	3
0	Integrated Gradient (Note 1):	4.50
0	Measured Nominal Current @ Field (Amps):	TBM
5	Calculated Nominal Current @ Field (Amps):	5.8
5	Maximum Main Coil Current (Amps):	6.4
5	Power (W):	48
68	Maximum Trim Coil Current per Magnet (Amps):	0.55
2	Magnet Operating Temp (°C):	140°F
E5	Trim Coil Resistance (ohms):	21.12
	per Magnet	
M	Trim Coil Resistance, Magnet (ohms) @	TBM
	Operating Temp.	
	Trim Coil Inductance per Magnet (microH):	6.94E4



Note 1: Units are KG, KG/CM, KG/CM<sup>2</sup> for Quadrupole, Sextupole or Octupole respectively. Note 2: Units are T/m or T/m<sup>2</sup> for Quadrupole or Sextupole respectively.



