PRELIMINARY STUDY OF THE ARC FOR A MUON COLLIDER WITH 1.5TEV CM ENERGY AND USING 20T HTS DIPOLE MAGNETS*

D. Cline, X. Ding, UCLA, Los Angeles, CA 90095, USA
R. Gupta, Brookhaven National Laboratory, PO BOX 5000, Upton, NY 11973-5000
B. Weggel, Particle Beam Lasers, Inc., Northridge, CA 91324-2807, USA

Abstract

We discuss the possibility of developing a 20T open midplane dipole and the resulting arcs for a high-energy muon collider.

INTRODUCTION

The interest in muon colliders was pushed forward in 1992 with the UCLA organized meeting in Napa Valley, California.[1] With the current issues with supersymmetry there is new interest in high-energy muon colliders. FNAL has set up a muon collider task force and the basic muon collaboration in the USA continues. Recently the P5 committee made a strong recommendation for muon collider R & D. In this paper we discuss the possibility of using 20T open midplane dipoles for this collider.

THE OPEN MIDPLANE PLANE

At the 1995 Muon Collider meeting held in San Francisco there was a realization that the normal Cos θ dipole will sustain considerable damage in a muon collider beam due to the large amount of muon decays and high energy electrons. Mike Green invented the first "open midplane" dipole concept shown in Fig. 1. [2]

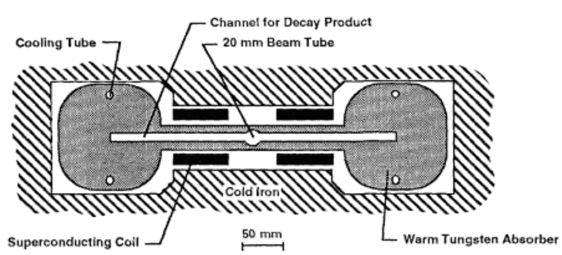

Figure 1: Concept of the first "open midplane" dipole

EARLY STUDIES OF A MUON COLLIDER LATTICE: FIRST STUDY OF A LATTICE FOR A $\mu^+\mu^-$ COLLIDER (A. GARREN ET AL., 1995)

In the first study of a muon collider an initial lattice design was carried out by Al Garren et al. Table 1 shows the parameters of this lattice [1]. It was clear that the normal cos θ dipoles would receive considerable energy and heating from the beam debris. This led Mike Green to propose the open midplane dipole as shown in Figure 1 [2][3].

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The advantage of this dipole is that much of the horizontal debris is in the plane of the beam that escapes the magnet in this concept.

Recently we have proposed that such an open dipole would be better constructed of HTS superconductor and could reach 20T in field strength. In this case the luminosity of the muon collider would increase by three over the designs of the 1990s.

Table 1: High Energy-High Luminosity $\mu+\mu^-$ Collider (see Nuclear Physics B, 51A, 1996, p. 149)

Maximum c-of-m energy [TeV]	4
Luminosity L [10^{35}cm^{-2} s^{-1}]	1.0
Circumference [km]	8.08
Time between collisions [μs]	12
Energy spread σ_e [units 10^{-3}]	2
Pulse length σ_x [mm]	3
Free space at the IP [m]	6.25
Luminosity lifetime [No. of turns]	900
rms emittance $\varepsilon^N_{x,y}$ [10^{-6} m-rad]	50.0
rms emittance $\varepsilon_{x,y}$ [10^{-6} m-rad]	0.0026
Beta function at IP, β* [mm]	3
rms beam size at IP [μm]	2.8
Quadrupole pole fields near IP [T]	6.0
Maximum beta function, β_{max} [km]	400
Magnet aperture closest IP [cm]	12
Beam-beam tune shift per crossing	0.04
Repetition rate [Hz]	15
rf frequency [GHz]	3
rf voltage [MeV]	1500
Particles per bunch [10^{12}]	2
No. of bunches of each sign	2
Peak current $T = \frac{eNc}{\sqrt{2\pi}\sigma_x}$ [kA]	12.8
Average current $T = \frac{eNc}{circum}$ [A]	0.032
Horizontal tune ν_x	55.79
Vertical tune ν_y	38.82

RECENT STUDIES OF THE HEATING IN AN OPEN DIPOLE MAGNET

Recently Mokhov et al have studied the heating in an open midplane dipole for a possible upgrade of the LHC at CERN [4]. Figure 2 shows the contours of heat loss in the magnet from this paper [4]. A private conversation with Mokhov gave the impression that a muon collider would give a similar acceptable heat loss in the magnet.

This is also the subject of a proposal to the HEP DOE. There has also been recent work at the BNL Laboratory by Gupta et al [5].

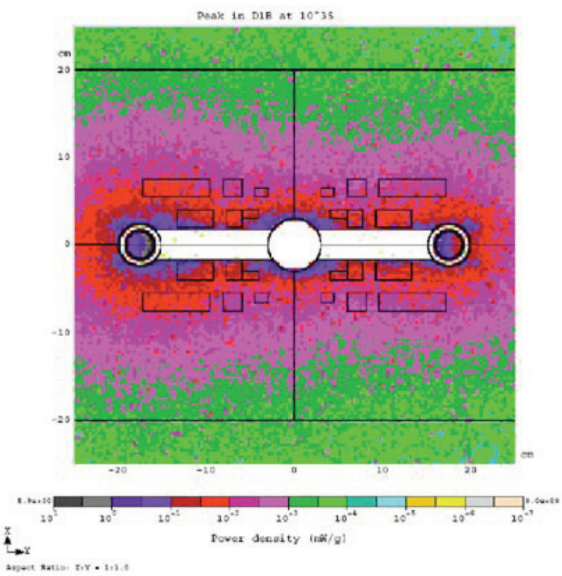

Figure 2: Heating calculation for LHC circulating beam in open midplane dipoles by N. Mokhov

RECENT STUDIES OF MUON COLLIDER LATTICE

Recently the FNAL Muon Collider Task Force has restarted the lattice calculations of Garren et al [6]. Figure 3 and Table 2 show some of the results of these new calculations. Our group plans to carry out a similar study but with 20T open midplane dipoles.

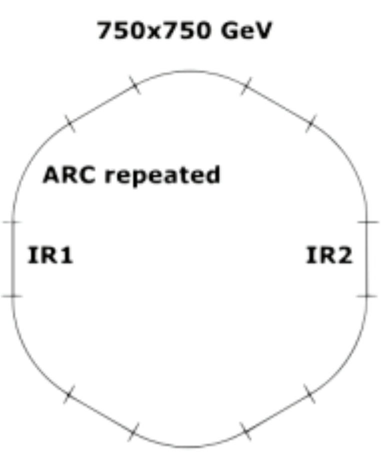

Figure 3: The 750*750 GeV lattice scheme

Table 2: Parameters of different MC options

Parameters of Different MC options

	Low Emit.	High Emit.	MCTF07	MCTF08
$\sqrt{s}$ (TeV)		1.5		
Av. Luminosity (10^{34}/cm^2/s) *	2.7	1	1.33-2	
Av. Bending field (T)	10	6	6	
Mean radius (m)	361.4	500	500 ⇒	495
No. of IPs	4	2	2	
Proton Driver Rep Rate (Hz)	65	13	40-60	
Beam-beam parameter/IP	0.052	0.087	0.1	
β^* (cm)	0.5	1	1	
Bunch length (cm)	0.5	1	1	
No. bunches / beam	10	1	1	
No. muons/bunch (10^{11})	1	20	11.3	
Norm. Trans. Emit. (μm)	2.1	25	12.3	
Energy spread (%)	1	0.1	0.2	
Norm. long. Emit. (m)	0.35	0.07	0.14	
Total RF voltage (GV) at 800MHz	$407\times10^3\alpha_c$	0.21**	0.84** ⇒	0.3†
Muon survival $N_\mu/N_{\mu 0}$	0.31	0.07	0.2	?
μ+ in collision / proton	0.047	0.01	0.03	?
8 GeV proton beam power	3.62***	3.2	1.9-2.8	?

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PLANS FOR OUR STUDY

We have been in communication with Carol Johnstone (figures 4 and 5 are from her).

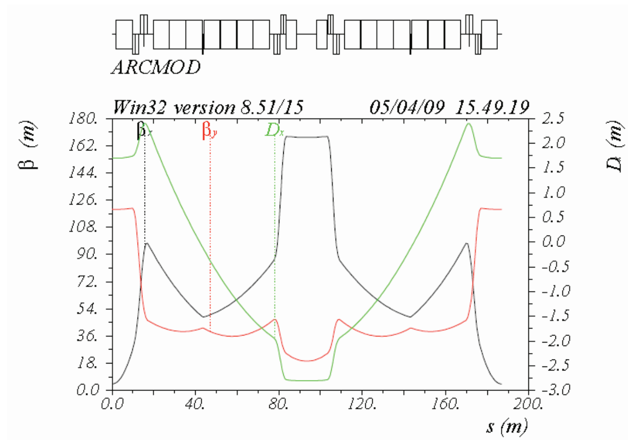

Figure 4: Arc module, 2TeV μ+μ- collider

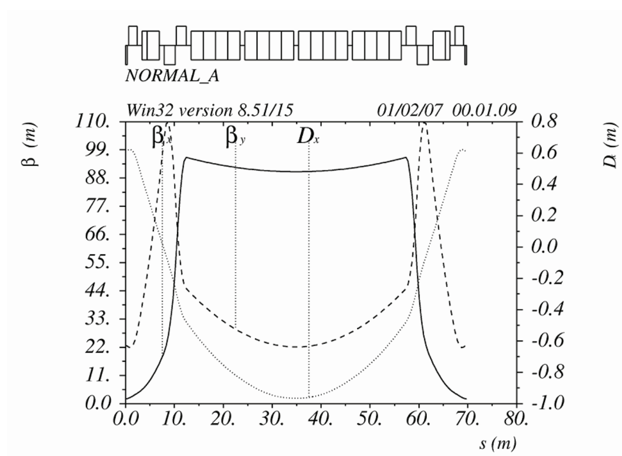

Figure 5: Arc module, 1.5TeV μ+μ- collider

(PAC07-THPAN109)

The next steps are:

- Conceptual layout of 1.5 TeV muon collider with 20 T open midplane dipole
- Determine preliminary good field aperture
- Develop parameters of the Open Midplane Design
- Lattice calculations
- Develop magnetic design
- Mechanical design
- Energy deposition analysis

We thank H. Kirk for discussions.

REFERENCES

[1] Proceedings from the first workshop on Muon Colliders (Napa, California, 1992), Nucl. Inst. Methods, Vol. A350, pp. 24-56, 1994, P. Chen and K. MacDonald, Summary of the Physics Opportunities Working Group, AIP Conference Proceedings, 279, Advanced Accelerator Concepts, 853 (1993). Proceedings of the Mini-Workshop on mu+ mu- Colliders, Particle Physics and Design, Napa CA, Nucl. Inst. And Met, A350 (1994); ed. D. Cline; Physics Potential and Development of mu+ mu- Colliders, 2nd Workshop, Sausalito CA, ed. D. Cline, AIP Press, Woodbury, New York (1995); Proceedings of the 9th Advanced ICFA Beam Dynamics Workshop, ed. J, Gallardo, AIP Press (1996); Proceedings Symposium on Physics Potential and Development of mu+ mu- Colliders, San Francisco CA, December 1995, Supplement to Nucl. Phys. B, ed. D. Cline and D. Sanders.

[2] M. Green and E. Willen, "Superconducting Dipoles and Quadrupoles for a 2 TeV Muon Collider", IEEE Transactions on Applied Superconductivity, Vol. 7, No. 2, June 1997.

[3] G. Greene, R. Gupta and W. Sampson, "The Effect of Proton Irradiation on the Critical Current Commercially Produced YBCO Conductors", Presented at Applied Superconductivity Conference, August 2008, Chicago.

[4] N.V. Mokhov, et al., "Energy Deposition Limits in A Nb3Sn Separation Dipole in Front of the LHC High-Luminosity Inner Triple," PAC, Portland, USA, May 2003.

[5] R. Gupta, et al., "Open Midplane Dipole Design for LHC IR Upgrade," International Conference on Magnet Technology (MT-18) at Morioka City, Japan (2003); R. Gupta, et al., "Optimization of Open Midplane Dipole Design for LHC IR Upgrade," 2005 Particle Accelerator Conference, Knoxville, TN, USA (2005); R. Gupta and W. Sampson, "Medium and Low Field HTS Magnets for Particle Accelerator and Beam Lines", Presented at Applied Superconductivity Conference, August 2008, Chicago.

[6] P. Snopok, M. Berz and C. Johnstone, "A New Lattice Design for a 1.5 TeV CoM Muon Collider Consistent with the Tevatron Tunnel," Proceedings of the PAC07, Albuquerque, New Mexico (2007).