LEReC Meeting Presentation with Meeting Minutes

(LEReC) Low Energy RHIC electron Cooling Project

MEETING NOTICE

Collider-Accelerator Department

TO: A. Fedotov, K. Hamdi, D. Kayran, J. Kewish, G. Mahler, M. Mapes, W. Meng, I. Pinayev, L. Snydstrup,

FROM: J. Tuozzolo

DATE: **Wednesday, Sept. 17, 2014**

PLACE: SCR

TIME: **10:00am**

TOPIC: **LEReC Engineering Meeting – RHIC Cooling Section Beam Line Cooling Section Solenoid/Corrector/Vacuum Chamber mechanical design**

Info Copy: T. Roser, W. Fischer, P. Pile, T. Arno, K. Mirabella, C. Folz, D. Gassner, J. Kewisch, R. Lambiase, L. DiFilippo, A. Petway, P. Manning

LEReC Webpage:
http://www.c-ad.bnl.gov/esfd/LE_RHICeCooling_Project/LEReC.htm

Meeting Minutes

Meeting Minutes: LEReC Engineering Meeting – RHIC Cooling Section Beam Line Cooling Section Solenoid/Corrector/Vacuum Chamber mechanical design 9 17 2014

Attendees: A. Fedotov, K. Hamdi, D. Kayran, J. Kewisch, R. Lambiase, G. Mahler, M. Mapes, W. Meng, I. Pinayev, L. Snydstrup

Attachment: Presentation for the meeting J. Tuozzolo

The meeting was held to confirm the design requirements for the cooling section compensating solenoids and correctors. The magnet table from the white paper was presented for conformation of the magnet design specifications. The magnetic 2D results done by W. Meng back in April 2014 were presented.

Items discussed:

1. Compensating Solenoid correction end coils: It was noted that the length for the solenoid given on the white paper was 16 cm; but, the length of the modeled solenoid presented in slide 4 was 21 cm. The latest solenoid design has correction solenoid coils at both ends to reduce the solenoid end field into the cooling section. This continues to be a design requirement. W. Meng has designed the end correction solenoid coils so that they can be powered in series with the main coil. At this time the modeled solenoid field is 0.17 kG; the requirement is 0.20kG.
2. Compensating Solenoid correction end coil power supply: There was extended discussion that the two correction end solenoid coils on each magnet should be powered in series by a separate power supply separate from the main (center) solenoid coil. This is not in the present cost estimate. Also discussed was that each correction end solenoid coil should have a separate power supply – resulting in 3 solenoid power supplies/solenoid magnet. It was agreed that the leads for the correction end solenoid coils and the main solenoid coil should come out separately to a terminal block on the outside of the solenoid magnet assembly so that a decision can be made later about adding an additional correction end solenoid power supply for each compensating solenoid magnet. The cost for purchasing 16 additional solenoid power supplies would be ~$77K + controls, cables, testing, installation etc. This needs to be a risk list item (Action for R. Lambiase to provide an update to the cost estimate with the additional power supplies. The cost difference will be added to the risk list).

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3. Power Supply ripple: A requirement for 30 ppm current regulation on all the power supplies was discussed in the meeting. R. Lambiase pointed out that this would significantly increase the cost of the power supplies; the cost estimate is based on 100 ppm. After discussion, 100 ppm regulation was agreed upon for all power supplies.
4. Magnetic measurement: There was discussion that the solenoids would have to be magnetically measured and then located on their magnetic center rather than the "mechanical" center. Locating the solenoid magnets on the magnetic center would quicken the commissioning of the system and could negate the need for so many correctors. The tolerance for locating the solenoid magnetic center on the beam center was .050 mm (.002"). Considering survey tolerances (for both magnetic measurement and installation) and the location stability of the RHIC tunnel it was agreed that this accuracy was not possible and correctors were necessary. If magnetic measurements can be made without delaying the RHIC shutdown schedule they will be included and the magnets will be located on the magnetic center to the best accuracy possible. (Action G. Mahler)
5. Horizontal and vertical dipole corrector magnets: There was agreement that the specifications in the white paper are still correct. It was agreed that the coils should be located on the ID of the solenoid magnet coil and that the solenoid/corrector assembly ID should be no less ID 6" (15.2 cm). There was some discussion about using printed circuit style correctors on Kapton on the inner mandrel and winding the solenoid on that. (Action for W. Meng on analysis and G. Mahler on design.)
6. Horizontal and vertical dipole corrector magnets: There was concern that the corrector coils would also need compensating coils to prevent the end fields from migrating into the cooling section. (Action for W. Meng as part of the analysis).
7. Horizontal and vertical dipole corrector magnets: There is concern after discussion of the solenoid magnetic center location tolerance that the corrector coils field specification may need additional margin – higher magnetic strength. What is the survey accuracy specification for the center of the solenoid being on center and how does it relate to the corrector strength? This will affect item 5 and the method used to make the correctors. (Action for A. Fedotov).
8. Vacuum bakeout blankets: There was some concern that the bakeout blankets might not fit between the solenoid/corrector 15.2 cm ID and beam tube 12.7 cm OD. A proposed solution was to put thermal insulation in the magnet gap and end the bakeout blanket (w/heater) at the face of the solenoid. The concern is that the NEG surface in

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the vacuum chamber at the solenoid may not get hot enough for pumping activation. It was noted that this represented 10% of the beam tube length and would be acceptable.

9. Vacuum bakeout blankets: The present design has the bakeout blankets being permanently installed under the mu metal magnetic shield. There was some concern that the nichrome wire might be magnetic. Similar concerns were raised about the flanges, bolts, bellows, etc. which will be in the cooling section under the mu metal shield. (Action for M. Mapes to investigate magnetic properties).
10. Vacuum Ion pumps: Because of the large aperture, the ion pumps will be located outside of the mu metal shrouded cooling sections.
11. Vacuum valves: The RHIC warm sectors between Q3 and Q4 are typically separate blue and yellow. Because there is no space in the 180o turn around section, there is no room for an isolation vacuum valve between blue and yellow. The vacuum valve control logic for this area of RHIC will be unique and will have to be updated. (Action for M. Mapes)

Items not discussed:

1. Matching solenoids: The specifications for the matching solenoids were presented from the white paper. The field required is significantly higher = 1.50 kG. These solenoids have not been magnetically modeled by W. Meng yet. The present design considers that the mu metal for the cooling sections will come up against these solenoids at the 4 ends. Are correction end coils needed for these magnets to prevent field migration beyond the end of the magnets? (Action: A. Fedotov).
2. Horizontal and vertical dipole corrector magnets matching section: These correctors are outside the cooling sections and will be located between the matching solenoids at both ends of both cooling sections. Correction windings to contain the end field are not required for the matching section correctors. (Confirmation: A. Fedotov)

Meeting Minutes – follow on discussion

From: Fedotov, Alexei
Sent: Friday, September 19, 2014 4:28 PM
To: Tuozzolo, Joseph E
Cc: Blaskiewicz, Michael M; Fischer, Wolfram; Kayran, Dmitry; Kewisch, Jorg
Subject: RE: Meeting minutes

I thought about this.

The maximum length which could be considered is 3m due to the space-charge from electron beam which we have to correct.

If we decide to switch to 3m long sections then charge of electron beam can only increased to 150pC if needed instead of 100pC at gamma=4.1.

To summarize:

1. If we stay with 2m sections: 16 Solenoids, 16 BPMs, 2m lost from each cooling section, Effective cooling region=14m, but it gives us about factor of 1.8 in current/cooling power safety margin (limited by power amps) if needed.
2. If we switch to longer 3m sections: 10 solenoids, 10 BMPs, 1.25 lost from cooling, Effective cooling region=14.75, but we have only factor 1.5 safety margin in case we want to operate with higher charge/stronger cooling.

We would need to decide how important to have 1.8 safety margin in current vs
1.5.

Alexei

Meeting Minutes – follow on discussion

From: Fedotov, Alexei

Sent: Friday, September 19, 2014 1:57 PM

To: Tuozzolo, Joseph E; Hamdi, Karim; Kayran, Dmitry; Kewisch, Jorg; Lambiase, Robert; Mahler, George J; Mapes, Michael D; Meng, Wuzheng; Pinayev, Igor; Snydstrup, Louis P

Cc: Fischer, Wolfram; Blaskiewicz, Michael M; Gassner, David M

Subject: RE: Meeting minutes

Requirement on electron angles for cooling is < 0.1 mrad. This gives requirement to shield magnetic field in cooling section to 5 mG level. Heating blankets will need to be removed after heating to make sure that wire does not introduce such fields. Every two meters we have gaps with solenoids. If they are not shielded then each gap produces electron angles 10 times larger than requirement of 0.1 mrad.

If they are shielded and if there are no dipole fields at mG level then everything should be o'kay. However if one cannot guarantee that there will be no such fields due to gaps in shielding, solenoid manufacturing, installation accuracy and just possible residual fields at such level then the only safe approach is to also have BPMs at each solenoid. Then such local angles can be measured and thus corrected.

It is then become the same approach how it was done at FNAL.

So, the most safe approach is:

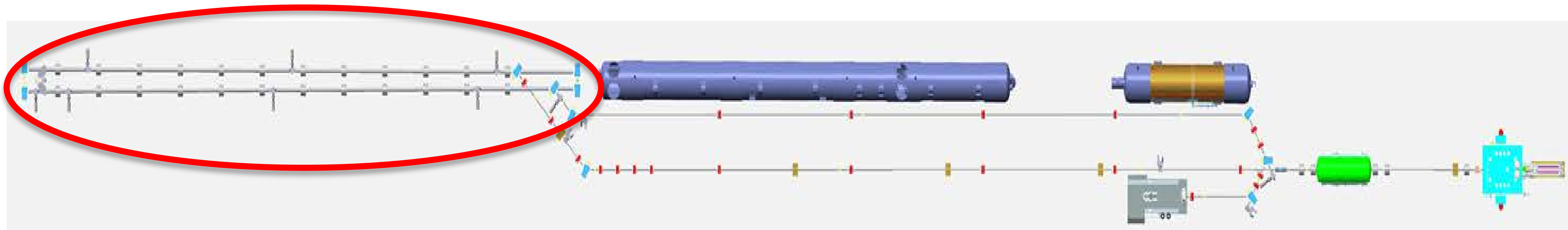
1. Shield not just cooling sections but also solenoids.
2. Install BPMs every 2m next or under each solenoid.
3. In that case it is probably better to make cooling section (16m)

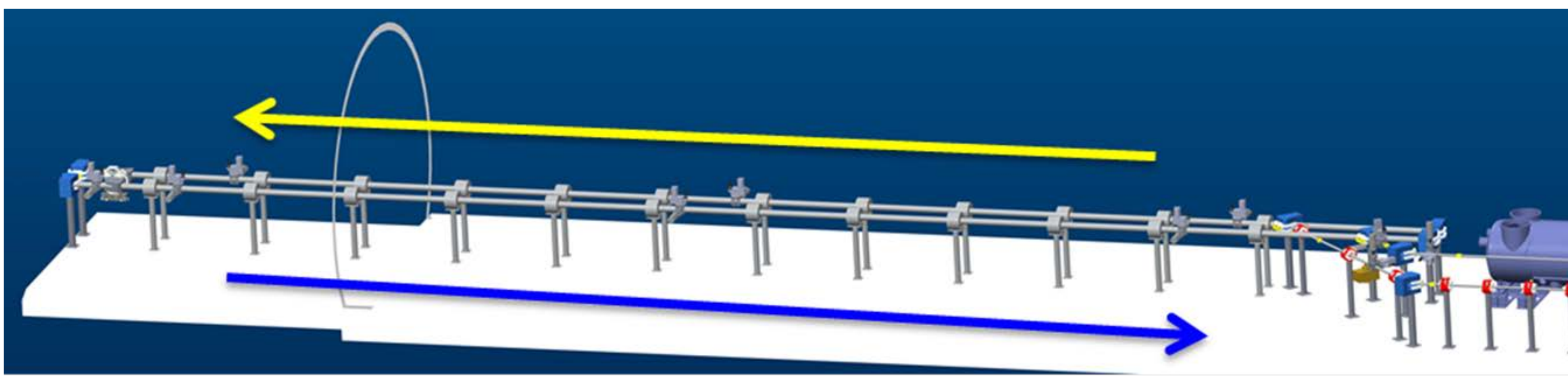
separately from 8 section each 2m long.

Alexei

Scope

Magnet	Designation	Location	Aperture Gap cm	Width cm	Aperture cm	Core Length cm	Operating Field kG	Qty	Grad. T/m	Main Power Supply Qty	Current Amps	Power kW	Trim Power Supply Qty	Current Amps	Power kW
Solenoid - Compensating	16S16	Cooling section (2 meter spacing)	N/A	N/A	16	16	0.20	16	N/A	16			0		
Solenoid - Matching Cool Sec	16S16	Cooling section (2 meter spacing)	N/A	N/A	16	16	1.50	8	N/A	8			0		
H & V Corrector Coil (0.2mrad)	16C16S	Cooling section compensating solenoids	16	16	N/A	coil in S	10 Gcm	16	N/A	0			32		
H & V Correctors (3mrad)	16C16	Cooling section	16	16	N/A	10	100 Gcm	4	N/A	0			8		





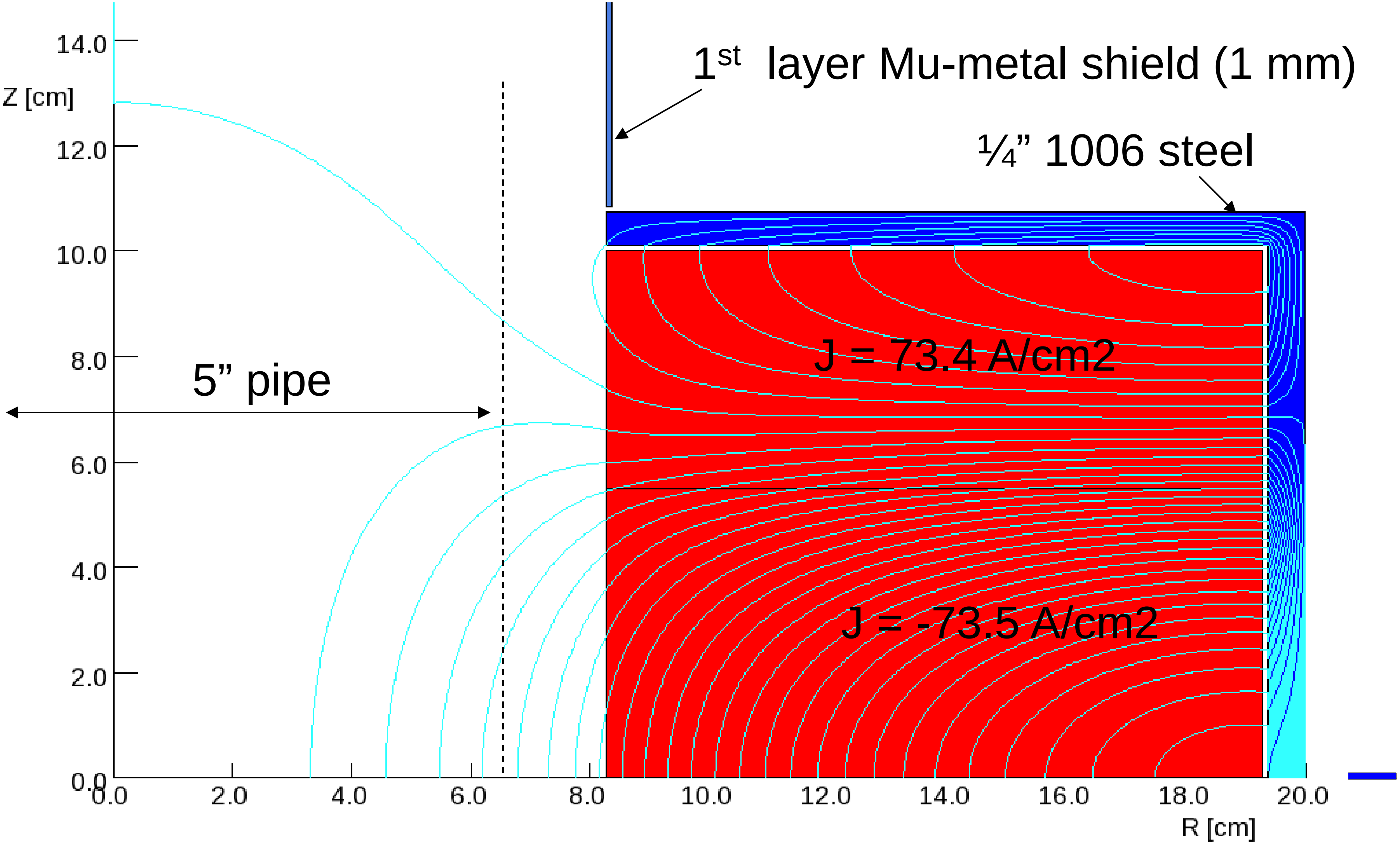
Compensating Solenoid and Corrector Specs.

Magnet	Designation	Location	Aperture Gap cm	Width cm	Aperture	Core Length cm	Operating Field kG	Qty
Dipole 45D + Trim	10D39-45	RHIC/e Beamline + compensation	10	20	N/A	30	0.50	9
Dipole 90D + Trim	10D25-90	Cooling Line U-turn	10	20	N/A	25	1.00	2
Dipole 15D	5D15	ERL's 15 deg magnet	5	10	N/A	25		1
Dipole 30D	5D30	ERL's 30 deg magnet	5	10	N/A	25		1
Dipole 15D	5D15	ERL's 15 deg magnet	5	10	N/A	25		1
Dipole 6D/15	10D6H	**1st zig-zag dipole High-Low Energy Merger (Double Aperture)**	10	10	N/A	25	1.50	1
	10D15L		10	10	N/A	25	0.30	1
Dipole 15D/45	**10D15-45**	**2st chicane Low-High Energy Separator**	10	10	N/A	13	0.80	1
Dipole 30D	10D30	2nd chicane dipoles	10	10	N/A	25	0.80	2
Dipole 15D	10D15	2nd chicane dipole	10	10	N/A	25	0.80	1
Quad	10Q10	60D U-turn	N/A	N/A	10	8	N/A	8
Quad	10Q10	beam dump	N/A	N/A	10	8	N/A	2
Quad	10Q10	90D U-turn	N/A	N/A	10	8	N/A	1
Quad	10Q10	Chicane merger to beam dump	N/A	N/A	10	8	N/A	1
Solenoid - dog-leg	10S10	e Beamline merger into RHIC	N/A	N/A	10	16	1.50	2
Solenoid - Transport	10S10	e Beamline transport	N/A	N/A	10	16	1.00	10
Solenoid - Compensating	16S16	Cooling section (2 meter spacing)	N/A	N/A	16	16	0.20	16
Solenoid - Matching Cool Sec	16S16	Cooling section (2 meter spacing)	N/A	N/A	16	16	1.50	8
H & V Corrector Coil (0.2mrad)	16C16S	Cooling section compensating solenoids	16	16	N/A	coil in S	10 Gcm	16
H & V Correctors (3mrad)	16C16	Cooling section	16	16	N/A	10	100 Gcm	4
H & V Correctors (3mrad)	12C12	RHIC/e Beamline	12	12	N/A	10	100 Gcm	8

Matching Section Solenoid and Corrector Specs.

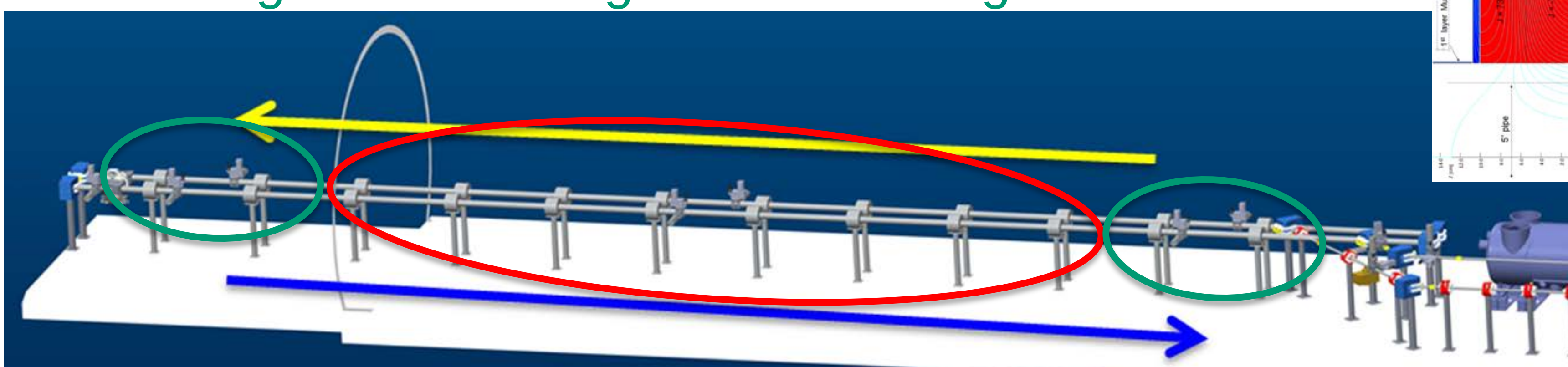
Magnet	Designation	Location	Aperture Gap cm	Width cm	Aperture	Core Length cm	Operating Field kG	Qty
Dipole 45D + Trim	10D39-45	RHIC/e Beamline + compensation	10	20	N/A	30	0.50	9
Dipole 90D + Trim	10D25-90	Cooling Line U-turn	10	20	N/A	25	1.00	2
Dipole 15D	5D15	ERL's 15 deg magnet	5	10	N/A	25		1
Dipole 30D	5D30	ERL's 30 deg magnet	5	10	N/A	25		1
Dipole 15D	5D15	ERL's 15 deg magnet	5	10	N/A	25		1
Dipole 6D/15	10D6H	**1st zig-zag dipole High-Low Energy Merger (Double Aperture)**	10	10	N/A	25	1.50	1
	10D15L		10	10	N/A	25	0.30	1
Dipole 15D/45	**10D15-45**	**2st chicane Low-High Energy Separator**	10	10	N/A	13	0.80	1
Dipole 30D	10D30	2nd chicane dipoles	10	10	N/A	25	0.80	2
Dipole 15D	10D15	2nd chicane dipole	10	10	N/A	25	0.80	1
Quad	10Q10	60D U-turn	N/A	N/A	10	8	N/A	8
Quad	10Q10	beam dump	N/A	N/A	10	8	N/A	2
Quad	10Q10	90D U-turn	N/A	N/A	10	8	N/A	1
Quad	10Q10	Chicane merger to beam dump	N/A	N/A	10	8	N/A	1
Solenoid - dog-leg	10S10	e Beamline merger into RHIC	N/A	N/A	10	16	1.50	2
Solenoid - Transport	10S10	e Beamline transport	N/A	N/A	10	16	1.00	10
Solenoid - Compensating	16S16	Cooling section (2 meter spacing)	N/A	N/A	16	16	0.20	16
Solenoid - Matching Cool Sec	16S16	Cooling section (2 meter spacing)	N/A	N/A	16	16	1.50	8
H & V Corrector Coil (0.2mrad)	16C16S	Cooling section compensating solenoids	16	16	N/A	coil in S	10 Gcm	16
H & V Correctors (3mrad)	16C16	Cooling section	16	16	N/A	10	100 Gcm	4
H & V Correctors (3mrad)	12C12	RHIC/e Beamline	12	12	N/A	10	100 Gcm	8

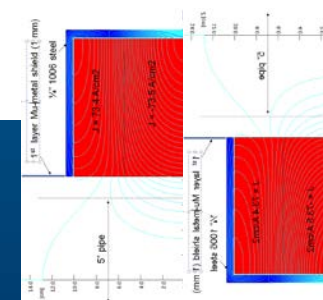
Focusing Solenoid for (Higher Energy)



Solenoid/Corrector and Vacuum Chamber Requirements:

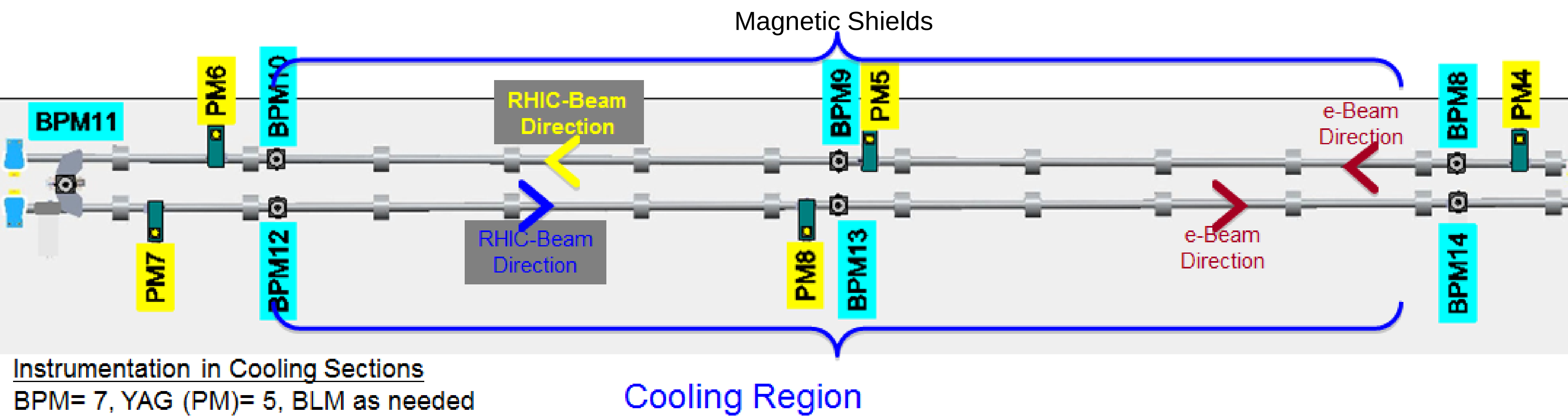
- **Compensating solenoid/corrector single assembly?**
  Solenoid trim coil? 20cm length (16cm)
  Combined H & V correctors every 2 meters. Trim coil?
- Matching section separate solenoid and correctors.
  Solenoid trim coil?
  Combined H & V correctors, one at each end of cooling section.
  H & V corrector locations?
  Magnetic Shielding in the matching section?





Vacuum Chamber/System Requirements:

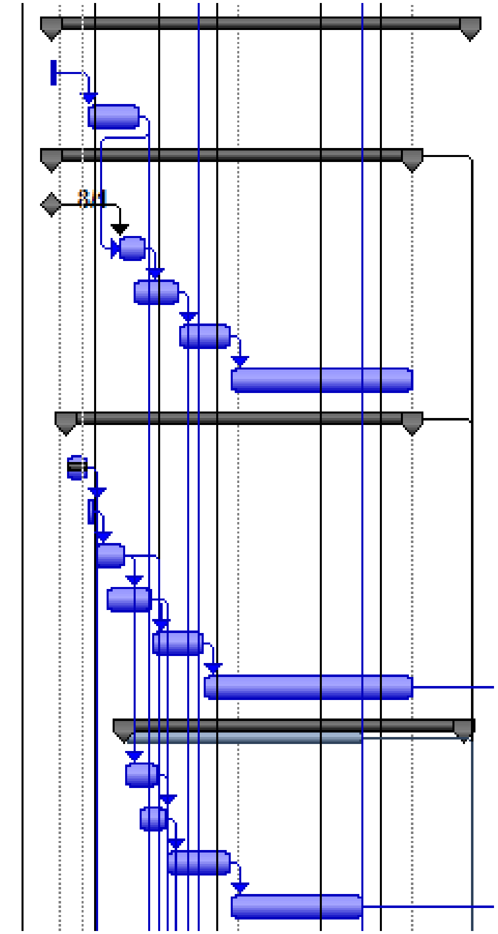
- 5" (12.7 cm) OD vacuum chamber, bake-out temperature.
- 6.25" (16 cm) solenoid ID: Corrector ID? Removable Corrector?
- Breaks in cooling section for beam diagnostics and ion pump tees.
- Any concerns: flanges, bolts, bellows, ion pump magnets, etc.
- Transitions to 9 cm aperture dipole magnets.
- Dipole magnet vacuum chambers.



Extra slides

Early Procurements

RHIC Beam Line Magnets (w/stands)	**316 days**	**Fri 8/1/14**	**Wed 11/4/15**	
Cooling Lattice Complete and approved	1 day	Fri 8/1/14	Fri 8/1/14	
Beam line layout drawing complete	40 days	Tue 9/9/14	Mon 11/3/14	50FS+25 days
6" High and low field solenoid magnets	**271 days**	**Fri 8/1/14**	**Tue 9/1/15**	
Magnet analysis complete	0 days	Fri 8/1/14	Fri 8/1/14	
Magnet specification control drawings approved	20 days	Tue 10/14/14	Mon 11/10/14	51FS-15 days,53
Procurement Package (Spec, Drawings, Bid List, Req.)	35 days	Tue 10/28/14	Thu 12/18/14	54FS-10 days
Bid and Award	35 days	Fri 12/19/14	Thu 2/12/15	55
Vendor Fabrication and Delivery	140 days	Fri 2/13/15	Tue 9/1/15	56
45o dipole magnets (w/compensating magnets (8))	**260 days**	**Mon 8/18/14**	**Tue 9/1/15**	
Magnet analysis complete	15 days	Mon 8/18/14	Mon 9/8/14	
Magnetic analysis approved	5 days	Tue 9/9/14	Mon 9/15/14	59
Magnet specification control drawings approved	25 days	Tue 9/16/14	Mon 10/20/14	60
Procurement Package (Spec, Drawings, Bid List, Req.)	35 days	Tue 9/30/14	Tue 11/18/14	61FS-15 days
Bid and Award	35 days	Wed 11/19/14	Wed 1/14/15	62
Vendor Fabrication and Delivery	160 days	Thu 1/15/15	Tue 9/1/15	63
45o dipole magnets vacuum chambers (8)	**255 days**	**Tue 10/21/14**	**Wed 10/28/15**	
Magnet specification control drawings approved	25 days	Tue 10/21/14	Tue 11/25/14	61
Procurement Package (Spec, Drawings, Bid List, Req.)	20 days	Tue 11/4/14	Thu 12/4/14	66FS-15 days
Bid and Award	45 days	Fri 12/5/14	Thu 2/12/15	67
Vendor Fabrication and Delivery	100 days	Fri 2/13/15	Tue 7/7/15	68



Early Procurements

180o dipole magnets	**290 days**	**Tue 9/9/14**	**Wed 11/4/15**	
Magnet analysis complete	25 days	Tue 9/9/14	Mon 10/13/14	59
Magnetic analysis approved	5 days	Tue 10/14/14	Mon 10/20/14	71
Magnet specification control drawings approved	20 days	Tue 10/21/14	Tue 11/18/14	72
Procurement Package (Spec, Drawings, Bid List, Req.)	35 days	Tue 11/4/14	Tue 12/30/14	73FS-10 days
Bid and Award	35 days	Wed 12/31/14	Fri 2/20/15	74
Vendor Fabrication and Delivery	180 days	Mon 2/23/15	Wed 11/4/15	75
180o dipole magnets vacuum chambers (8)	**175 days**	**Wed 11/19/14**	**Tue 8/4/15**	
Magnet specification control drawings approved	25 days	Wed 11/19/14	Tue 12/30/14	73
Procurement Package (Spec, Drawings, Bid List, Req.)	20 days	Fri 12/5/14	Wed 1/7/15	78FS-15 days
Bid and Award	45 days	Thu 1/8/15	Fri 3/13/15	79
Vendor Fabrication and Delivery	100 days	Mon 3/16/15	Tue 8/4/15	80
180o Quadrupole magnet	**275 days**	**Tue 10/14/14**	**Thu 11/19/15**	
Magnet analysis complete	30 days	Tue 10/14/14	Tue 11/25/14	71
Magnet specification control drawings approved	25 days	Wed 11/26/14	Wed 1/7/15	83,61,66
Procurement Package (Spec, Drawings, Bid List, Req.)	35 days	Fri 12/19/14	Thu 2/12/15	84FS-10 days
Bid and Award	35 days	Fri 2/13/15	Fri 4/3/15	85
Vendor Fabrication and Delivery	160 days	Mon 4/6/15	Thu 11/19/15	86
RHIC Beam Line Vacuum (Chambers, Valves, Bellows)	**185 days**	**Tue 11/4/14**	**Tue 8/4/15**	
Beam line vacuum component parts list	20 days	Tue 11/4/14	Thu 12/4/14	51
Procurement Package (Spec, Drawings, Bid List, Req.)	40 days	Fri 12/5/14	Thu 2/5/15	89
Bid and Award	25 days	Fri 2/6/15	Fri 3/13/15	90
Vendor Fabrication and Delivery	100 days	Mon 3/16/15	Tue 8/4/15	91
RHIC Beam Line Diagnostics (BPM buttons, YAG, vacuum)	**235 days**	**Tue 11/4/14**	**Wed 10/14/15**	
Beam line vacuum component requirements approved	20 days	Tue 11/4/14	Thu 12/4/14	51
Procurement Package (Spec, Drawings, Bid List, Req.)	80 days	Fri 12/5/14	Fri 4/3/15	94
Bid and Award	25 days	Mon 4/6/15	Fri 5/8/15	95
Vendor Fabrication and Delivery	110 days	Mon 5/11/15	Wed 10/14/15	96