Low-energy RHIC electron Cooler (LEReC) Overview

April 9, 2014

Run Schedule for RHIC

Years	Beam Species and Energies	Science Goals	New Systems Commissioned
2013	• 500 GeV pol p+p	• Sea quark and gluon polarization	• upgraded pol'd source • STAR HFT test
2014	• 200 GeV Au+Au • 15 GeV Au+Au • Fixed Au target test	• Heavy flavor flow, energy loss, thermalization, etc. • Quarkonium studies • QCD critical point search	• Electron lenses • 56 MHz SRF • full STAR HFT • STAR MTD
2015-2016	• p+p at 200 GeV • p+Au, d+Au, ^{3}He+Au at 200 GeV • High statistics Au+Au	• Extract η/s(T) + constrain initial quantum fluctuations • More heavy flavor studies • Sphaleron tests	• PHENIX MPC-EX • Coherent electron cooling test
2017	• No Run		• Electron cooling upgrade
2018-2019	• 5-20 GeV Au+Au (BES-2)	• Search for QCD critical point and deconfinement onset	• STAR ITPC upgrade
2020	• No Run		
2021-2022	• Long 200 GeV Au+Au w/ upgraded detectors • p+p/d+Au at 200 GeV	• Jet, di-jet, γ-jet probes of parton transport and energy loss mechanism • Color screening for different QQ states	• sPHENIX
2023-24	• No Runs		• Transition to eRHIC

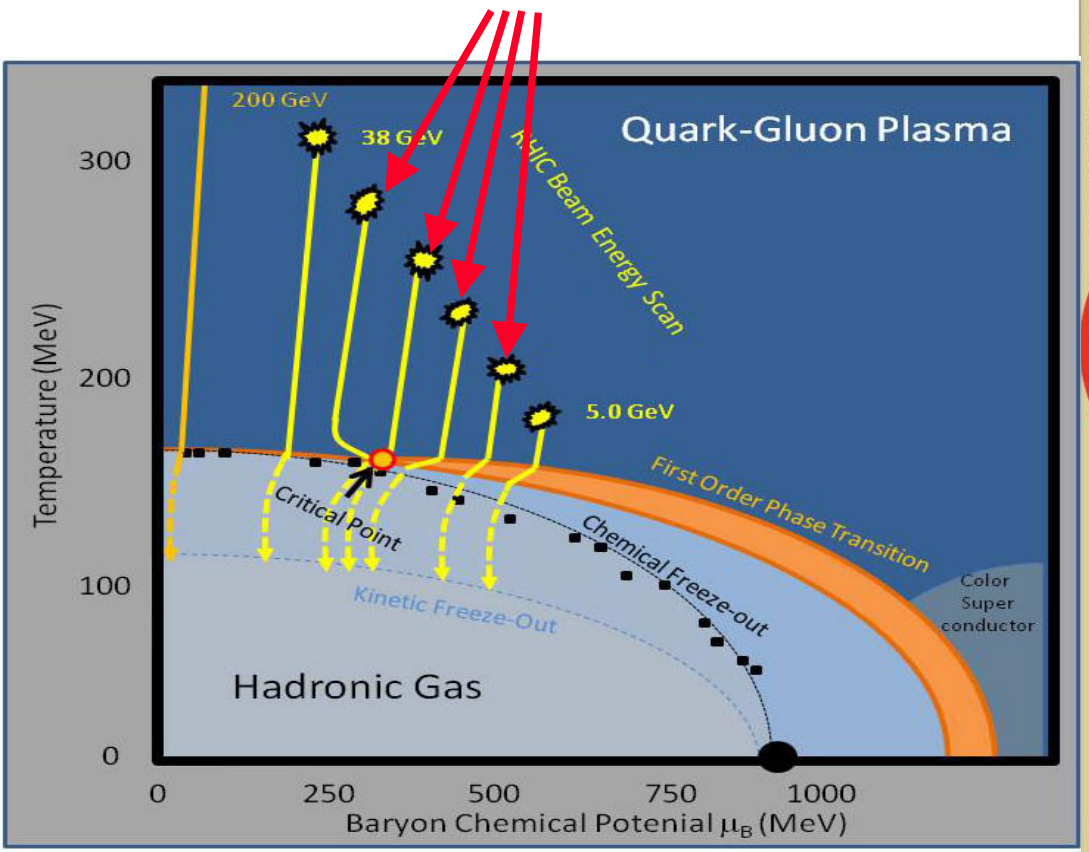
Low-Energy RHIC program:

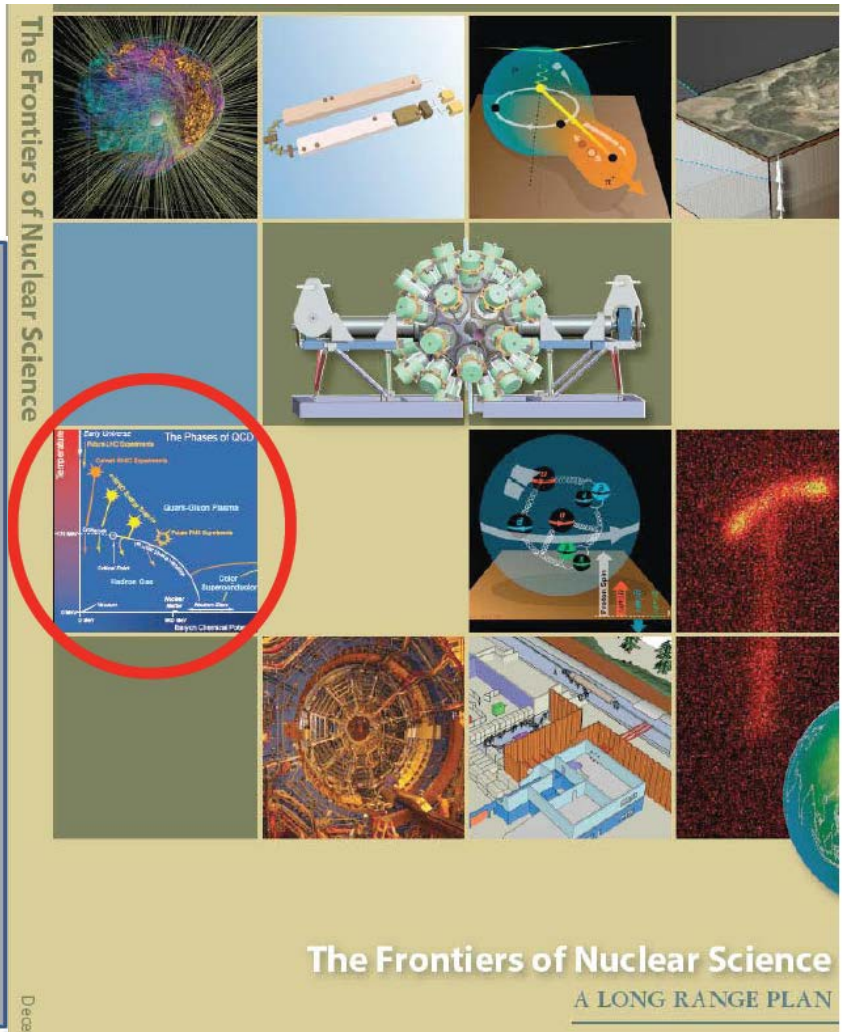
Operation with heavy ions to search for QCD phase transition Critical Point

Beam Energy Scan I, center of mass energies:

$\sqrt{s_{NN}}$ = 5, 6.3, 7.7, 8.8, 11.5, 14.6, 18, 27 GeV

(2010 & 2011 & 2014 RHIC runs)





Low-energy RHIC operation

Electron cooling (a well known method of increasing phase-space density of hadron beams):

- "cold" electron beam is merged with ion beam which is cooled through Coulomb interactions
- electron beam is renewed and velocity spread of ion beam is reduced in all three planes

requires co-propagating electron beam with the same average velocity as velocity of hadron beam.

At low energies in RHIC luminosity has a very fast drop with energy (from γ^3 to γ^6). As a result, achievable luminosity becomes extremely low for lowest energy points of interest.

However, significant luminosity improvement can be provided with electron cooling applied directly in RHIC at low energies.

Energy scan of interest:

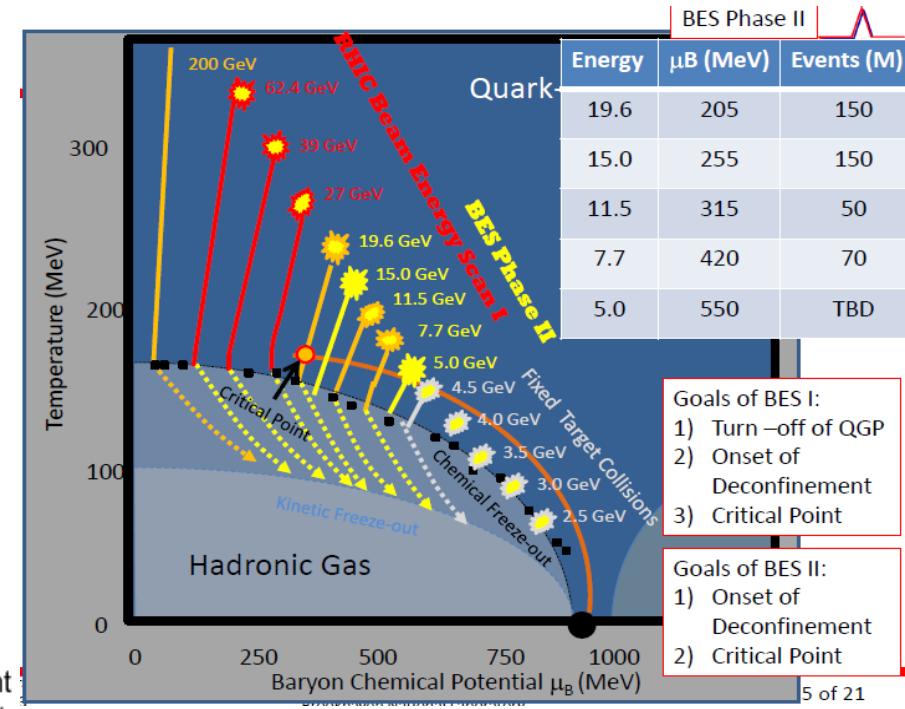
$\sqrt{s_{NN}}$ = 5, 6.3, 7.6, 8.6, 12, 16, 20 GeV

Electron accelerator:

$E_{e,kinetic}$=0.86-4.9 MeV

Low-Energy RHIC electron Cooler (LEReC) for Au-Au $\sqrt{s_{NN}}$ = 7 – 20 GeV

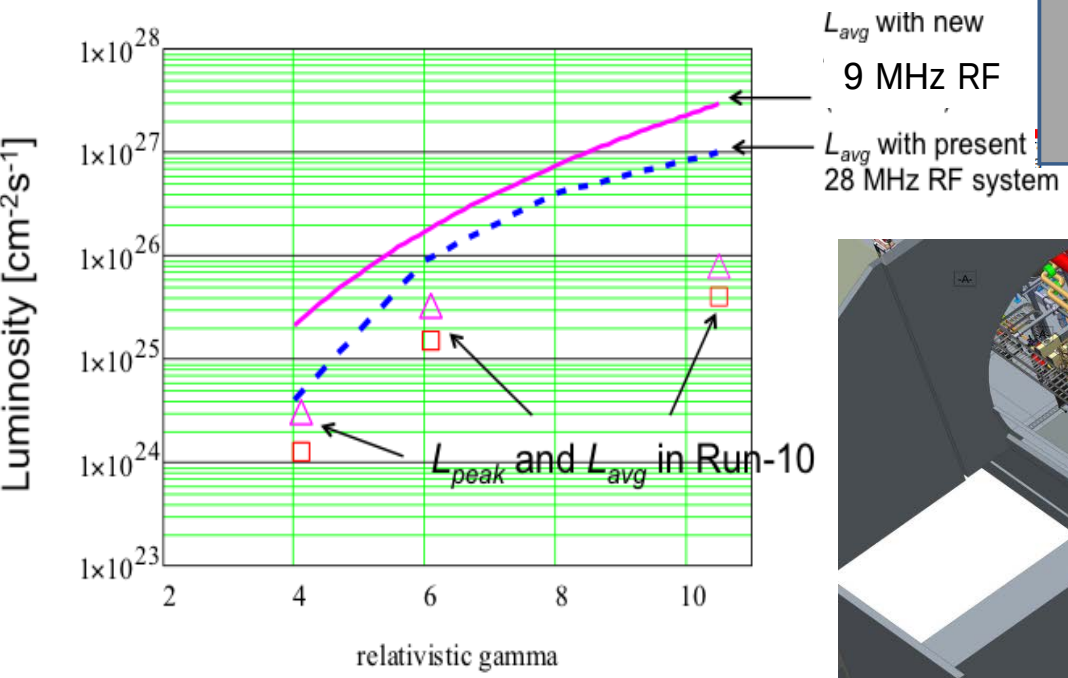
- **DOE review: July 9-11, 2014**
- **Finish installation in RHIC tunnel: summer of 2017**
- **Commissioning and operation for physics starting October 2017**



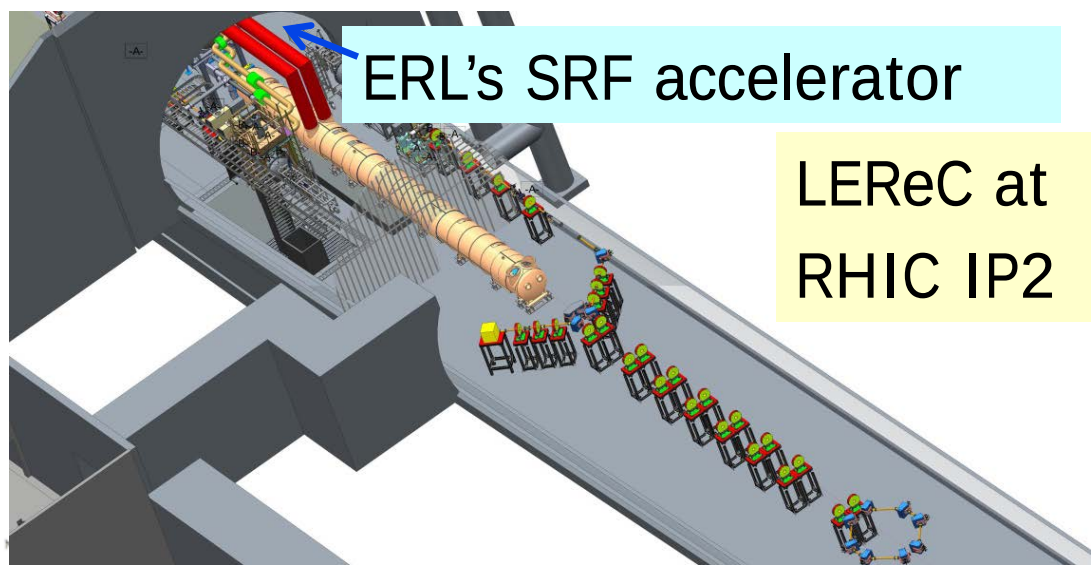
BES Phase II

Energy	μB (MeV)	Events (M)
19.6	205	150
15.0	255	150
11.5	315	50
7.7	420	70
5.0	550	TBD

5 of 21



LEReC luminosity gain: 10x with new RF system



DOE Review of Low-Energy RHIC electron Cooling (LEReC)

9-11 July 2014
Large Conference Room, Bldg. 911B

Day 1

08:00 Executive Session	(45 min)
08:45 Welcome	T. Roser (10 min)
08:55 LEReC overview – project goals and cooling approach	A. Fedotov (40+10 min)
9:45 Electron beam transport and system specifications	D. Kayran/J. Kewisch (30+10 min)
10:25 Coffee Break - Small Conference Room	
10:40 System design overview	J. Tuozzolo (30+10 min)
11:20 Project management	A. Fedotov (30+10 min)
12:00 Project cost, schedule, personnel	K. Mirabella (20+10 min)
12:30 Lunch - Small Conference Room	
13:30 Tour – ERL, RHIC location for LEReC	
14:30 SRF and RF components	S. Belomestnykh (30+10 min)
15:10 ERL SRF performance	W. Xu (20+10 min)
15:40 Coffee Break - Small Conference Room	
16:00 Photocathodes and performance	E. Wang (20+5 min)
16:25 Laser and timing	B. Sheehy (20+5 min)
16:50 Power amplifiers and low-level RF	A. Zaltsman (20+5 min)
19:30 Dinner (committee members and presenters)	

Day 2

08:30 Q&A ..... (30 min)

09:00 Magnets, power supplies, and vacuum system ..... G. Mahler (25+5 min)

09:30 Cryogenic system ..... R. Than (25+5 min)

09:55 Instrumentation ..... D. Gassner/T. Miller (20+5 m

10:20 Controls and communications ..... K. Brown (20+5 min)

10:45 Coffee Break - Small Conference Room

11:00 Beam dump ..... L. Snydstrup (20+5 min)

11:25 Buildings, AC, electrical and cooling water infrastructure..... A. Pendzick (20+5 min)

11:50 Systems and beam commissioning ..... D. Kayran (20+5 min)

12:15 9 MHz ion beam RF systems ..... S. Polizzo (20+5 min)

12:40 Lunch - Small Conference Room

13:30 Breakout Sessions:..... (90 min)
- SRF gun/laser/photocathode
- RF systems
- Electron beam transport and associated controls
- Project management

15:00 Executive Session ..... (120 min)

Day 3

08:30 Answers to questions/discussion..... (60 min)

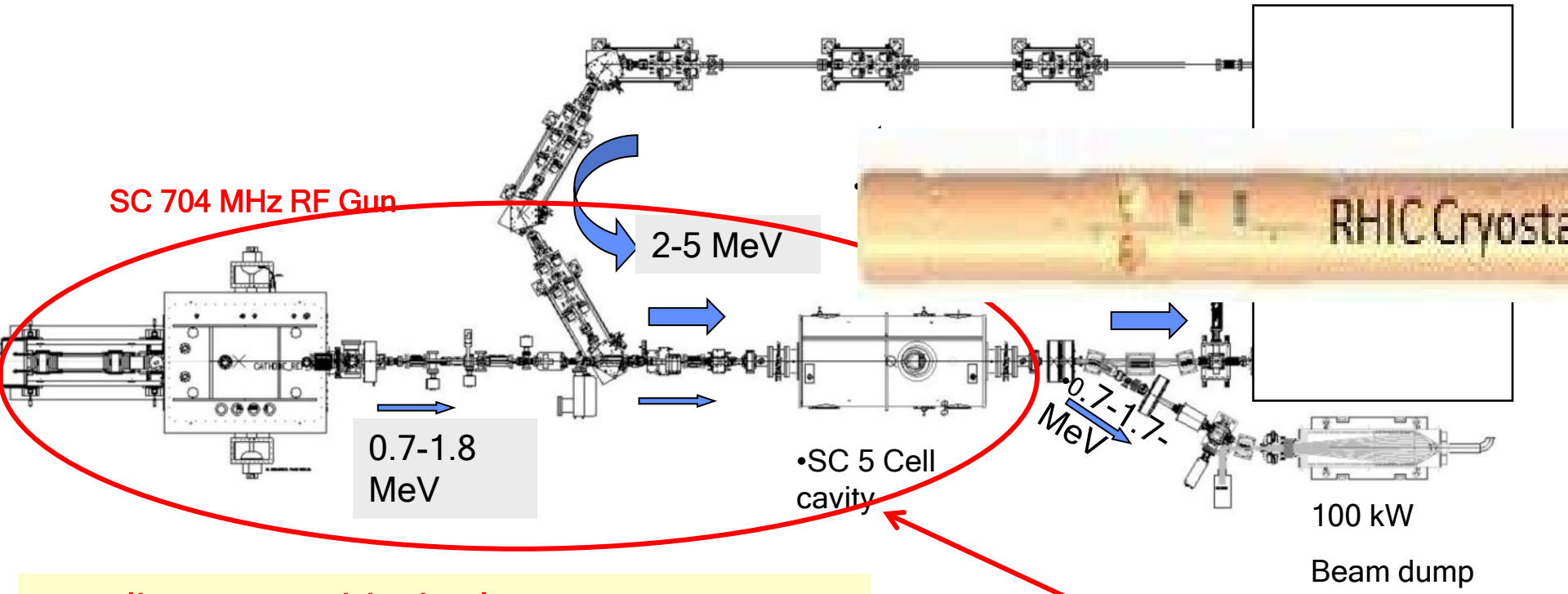
09:30 Coffee Break - Small Conference Room

09:45 Executive Session ..... (90 min)

12:00 Lunch - Small Conference Room

14:00 Close-out ..... (60 min)

ERL in LEReC



Baseline: ERL with the loop

-Up to 1.8 MeV kinetic energy: Gun-to-dump, no ER

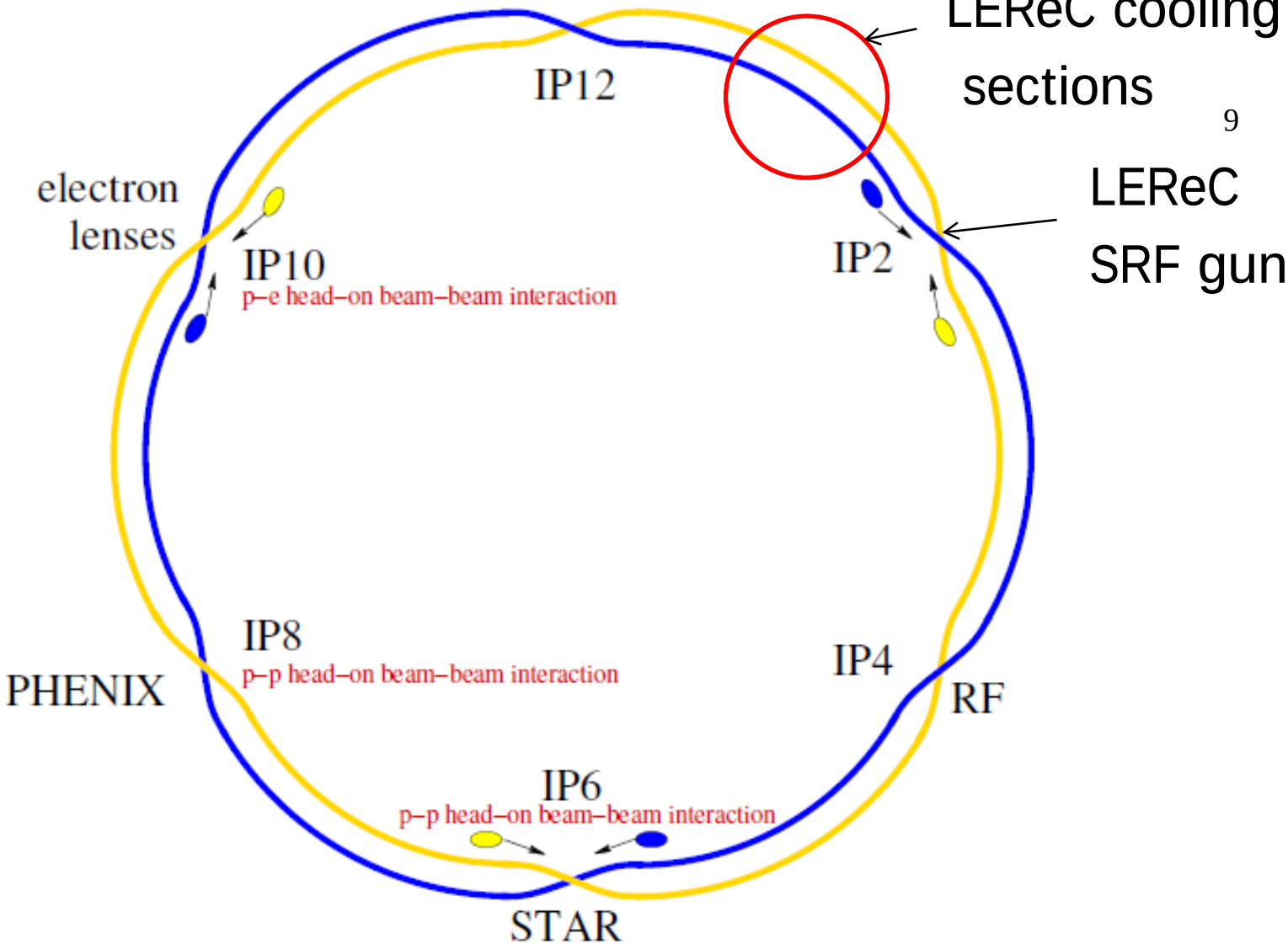
-Starting 2 MeV:

gun at 670kV, returning beam 2 MV;

keep ratio of energies 1:3 fixed

LEReC

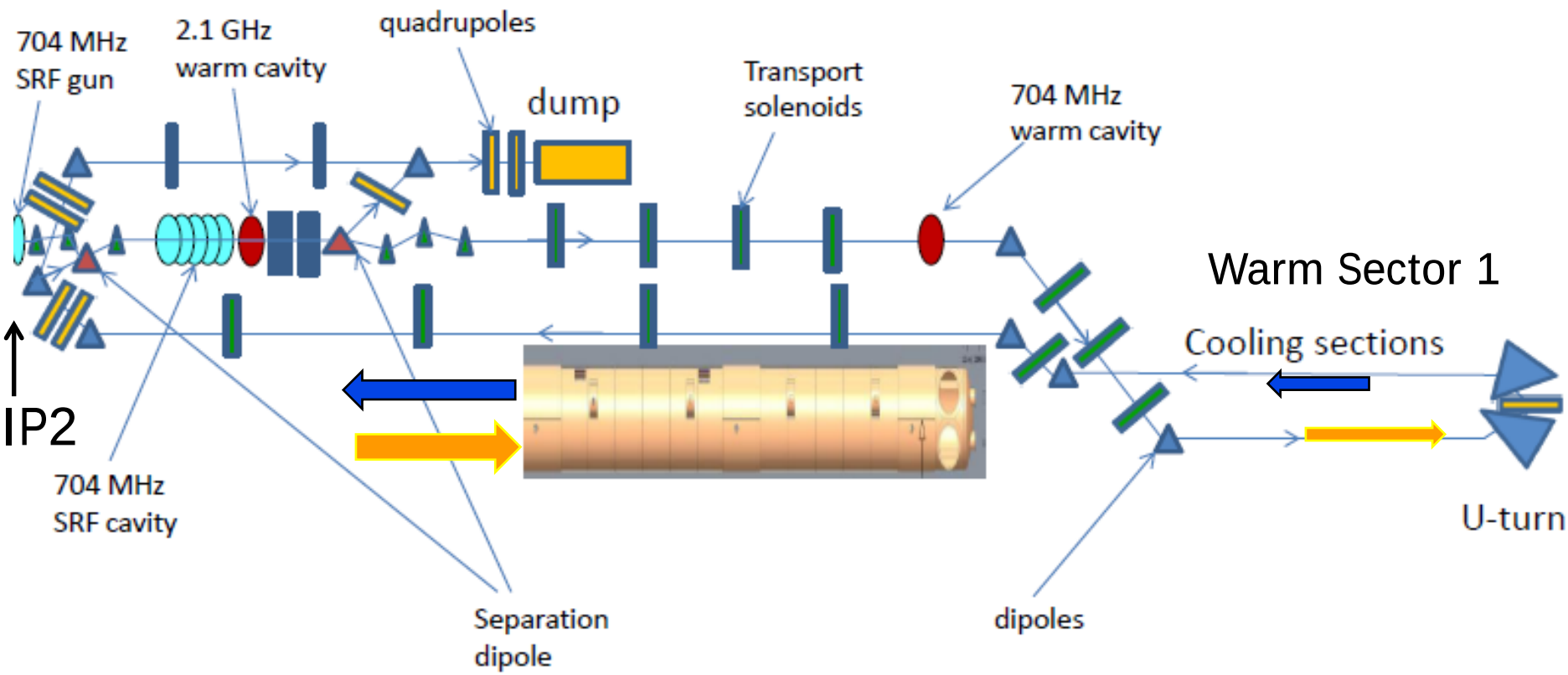
SRF accelerator


LEReC cooling sections
LEReC SRF gun
IP12
electron lenses
IP10
p–e head–on beam–beam interaction
IP2
IP8
p–p head–on beam–beam interaction
PHENIX
IP4
RF
IP6
p–p head–on beam–beam interaction
STAR

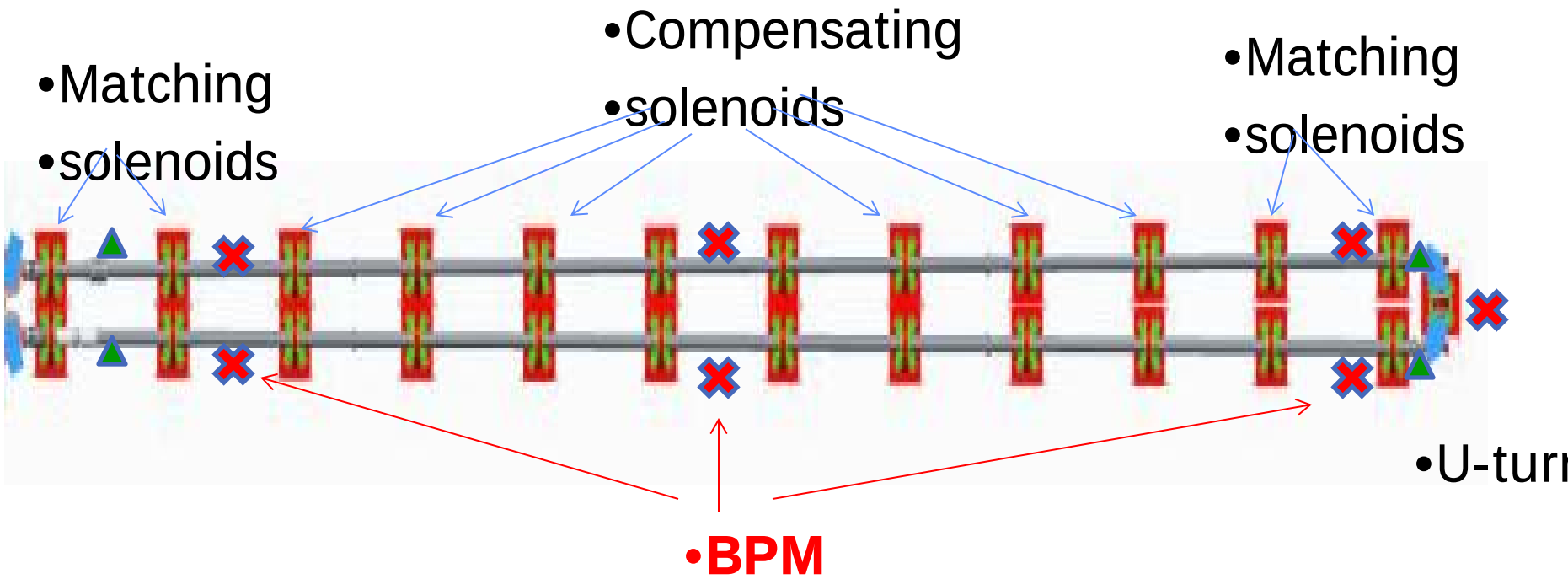
LEReC scope

- **704 MHz SRF gun with maximum energy of operation 1.8 MeV.**
- **704 MHz SRF 5-cell cavity extending energy of operation up 5 MeV.**
- **2110.7 MHz (3rd harmonic of the SRF frequency) copper cavity for bunch stretching and energy spread correction.**
- **704 MHz copper cavity for energy spread correction.**
- **Electron beam transport from IP2 region to cooling sections in warm sector 1.**
- **Cooling section in Blue RHIC ring – about 20 m long with few meters at the beginning and end of the cooling section taken by magnet elements to match transport beam optics to the optics needed for cooling. Short (16 cm) correction solenoids are located every 2 m. Free space between the solenoids is covered by several layers of the mu metal to shield magnetic field to a required level.**
- **U-turn magnets between cooling section in Blue and Yellow Rings.**
- **Cooling section in Yellow Ring.**
- **Return electron beam transport lines: directly to the dump and for ER.**
- **Electron beam dump.**

Schematic of LEReC layout



Cooling sections



Gun-only mode:

Gun Energy, MeV	Qe/bunch	Gun & dump beam power
0.9	30 pC (32 bunches)	
1.4	< 100pC	
1.6	100 pC	
1.8	100 pC (30 bunches) 30 mA	50 kW

ERL mode:

Gun energy, kinetic MeV	Final energy, Kinetic, MeV	Qe/bunch, pC	Gun & dump beam Power
0.67	2	100 pC	
1	3	100-150 pC	
1.33	4	200 pC	
1.67	5	300 (18 bunches) 50 mA	83 kW

Gun: beam power 100 kW with 50 kW/coupler

Cooler requirements

Ion beam parameters		
Gamma	4.1	10.7
RMS bunch length	3.2 m	2 m
N_{au}	0.5e9	2e9
I_peak	0.24 A	1.6 A
Frequency	9.1 MHz	9.34 MHz
Beta function@cooling	30 m	30 m
RMS bunch size	4.3 mm	2.7 mm
RMS angular spread	140 urad	90 urad

Baseline region of interest

Electron beam cooler requirement		
Cooling sections	2x20 m	2x20 m
Charge per ion bunch	3 nC (30x0.1nC)	5.4 nC (18x0.3 nC)
RMS norm. emittance	< 2.5 um	<2 um
Average current	27 mA	50 mA
RMS energy spread	<5e-4	< 4e-4
RMS angular spread	<150 urad	<90 urad

LEReC parameters

Beam			
Lorentz factor	2.7	4.1	10.7
RHIC RF frequency	8.72 MHz	9.10 MHz	9.34 MHz
Electron beam kinetic energy	0.87 MeV	1.58 MeV	4.96 MeV
Total charge per bunch train, nC	1 (32 bunches)	3 (30 bunches)	5.4 (18 bunches)
$\Delta p/p$, rms		5e-4	
Normalized rms emittance	2.0 mm·mrad	2.5 mm·mrad	2.5 mm·mrad
Transverse rms beam size	4 mm	4.3 mm	2.6 mm
Full bunch duration	50-100 ps	50-100 ps	50-100 ps
Average electron beam current	8.7 mA	27 mA	50 mA
Beam power (w/o energy recovery)	7.6 kW	43 kW	250 kW

704 MHz SRF gun			
SRF frequency	703.55 MHz	703.59 MHz	703.57 MHz
Gun voltage	0.87 MV	1.58 MV	1.65 MV
E_{pk}	16.6 MV/m	30.3 MV/m	31.7 MV/m
B_{pk}	33.8 mT	61.7 mT	64.4 mT
R/Q		96.2 Ohm	
Geometry factor		112.7 Ohm	
Cavity Q factor at 2 K		$1.1 \cdot 10^{10}$	
Gun RF power	10 kW	47 kW	83 kW

LEReC parameters (continued)

Lorentz factor	2.7	4.1	10.7
704 MHz 5-cell SRF cavity			
Cavity voltage	0	0	3.3 MV
E_{pk}	0	0	6.1 MV/m
B_{pk}	0	0	17.9 mT
R/Q		404 Ohm	
Geometry factor		225 Ohm	
Cavity Q factor at 2 K		$2.2 \cdot 10^{10}$	
Cavity RF power	0	0	0.34 kW
Other parameters			
Number of single cell 704 MHz normal conducting cavities		2	
Total 704 MHz voltage	605 kV	605 kV	605 kV
RF power per two cavities	44 kW	44 kW	44 kW
Harmonic 7-cell cavity frequency	2110.6 MHz	2110.8 MHz	2110.7 MHz
Harmonic cavity voltage	460 kV	460 kV	460 kV
2.11 GHz RF power	11 kW	11 kW	11 kW
Laser wavelength		532 nm	
Average optical power on cathode	0.85 W	1.52 W	1.67 W
Laser time jitter, rms	100 ps	100 ps	100 ps

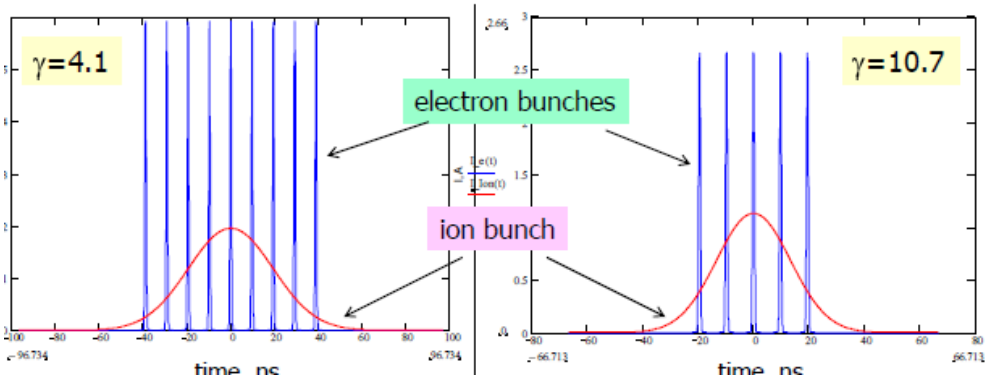
Low-energy RHIC electron Cooler (LEReC)

Present baseline :

cooling with “trains” of electron bunches:

-frequency of bunch trains 9 MHz

-frequency of bunches within train 704 MHz



Design is based on existing

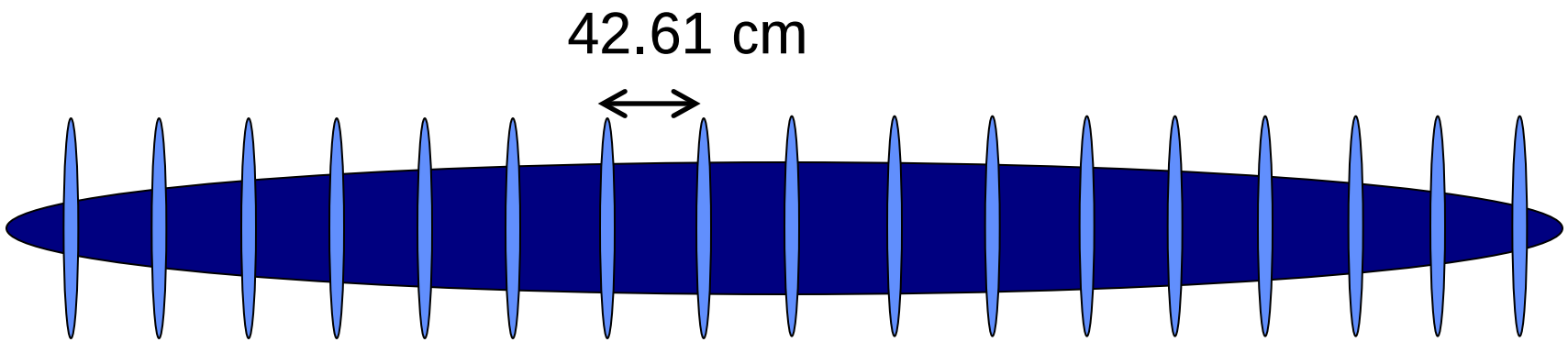
704 MHz SRF gun and 704 MHz SRF cavity from R&D ERL

- Needed beam parameters from the SRF gun should be demonstrated in the nearest future
- All relevant questions related to the SRF gun and ERL operation will be tested at R&D ERL before moving hardware to RHIC

R &D ERL: LEReC accelerator under commissioning

30 electron bunches:

gamma=4.1: 100 pC/bunch 42.61 cm apart



9 MHz Ion bunch: rms length ~ 3 m

+/-2 sigma=12m; ~ 30 electron bunches

LEReC beam structure in cooling section gamma 4.1

9 MHz RHIC RF

- Ions structure:

120 bunches

f_rep=120x75.8347 kHz=9.1 MHz

N_ion=5e8, I_peak=0.24 A

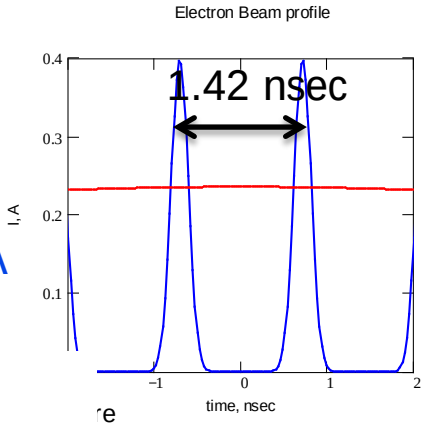
Rms length=3.2 m

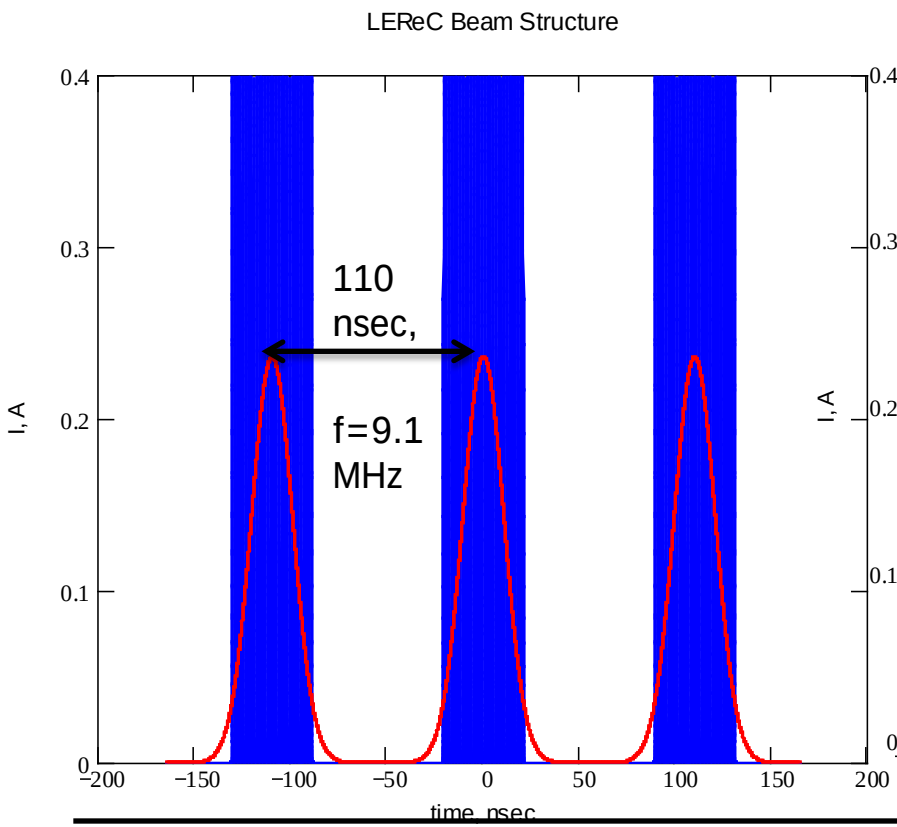
- Electrons:

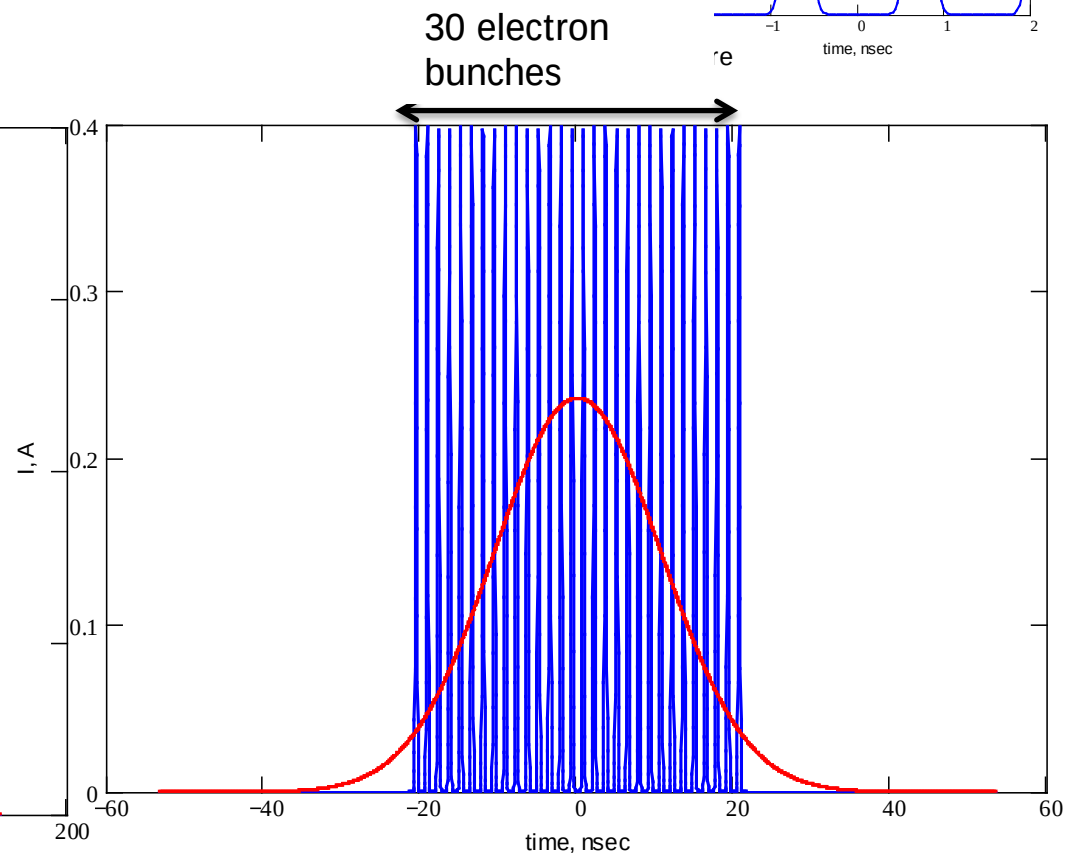
f_SRF=703.518MHz

Rms length=3 cm, I_peak=0.4 A

Q_e=100 pC



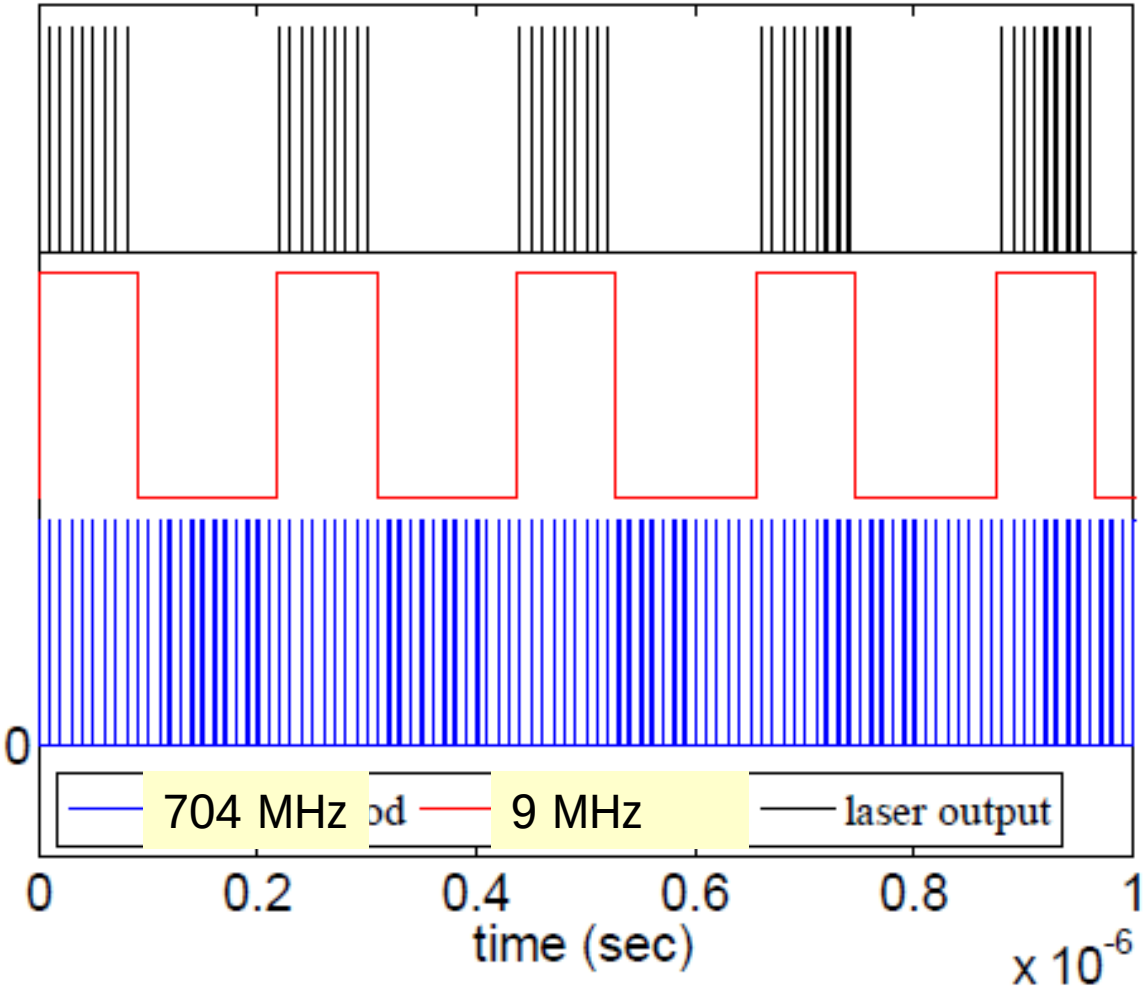




Bunch pattern

Laser pulse:

about 50 ps



Electrons:

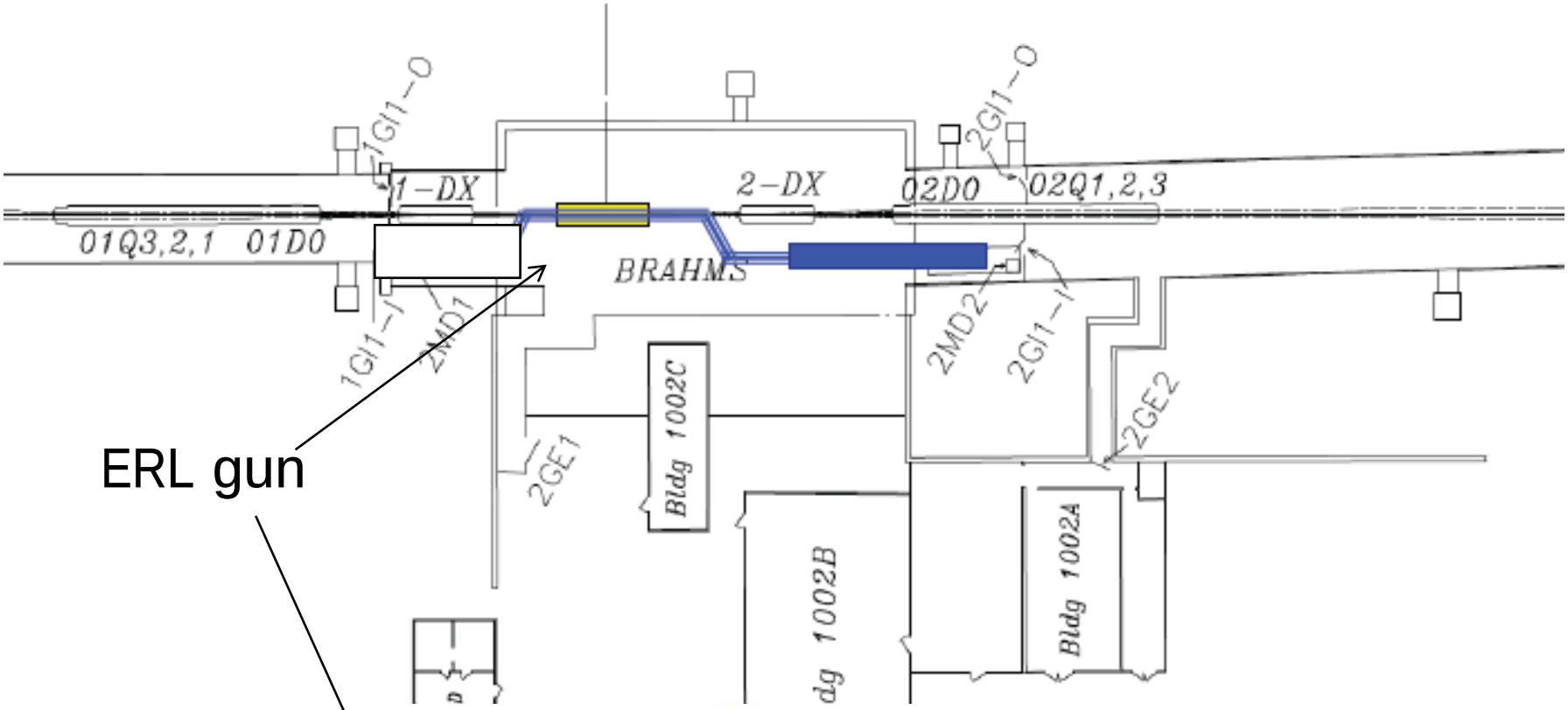
f_srf: 704 MHz

Ions:

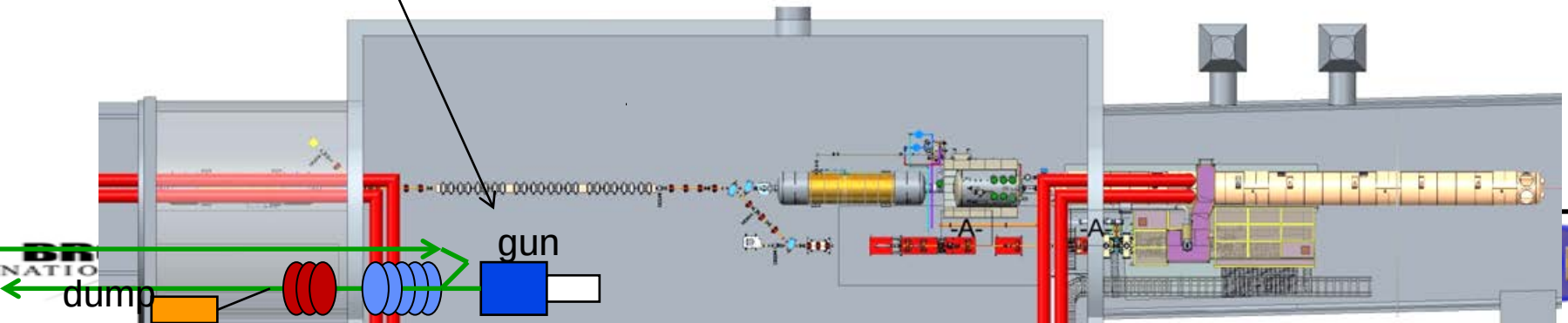
f_rf_RHIC: new 9 MHz (changing with energy 8.7-9.3 MHz)

- Bunch train frequency is locked at 120th harmonic of RHIC revolution frequency (changes with energy).

- Microbunch frequency is Mth harmonic of revolution frequency.


1GI1-O
1-DX
2-DX
02D0
2GI1-O
02Q1,2,3
01Q3,2,1
01D0
BRAHMS
1GI1-I
2MD1
2MD2
2GI1-I
2GE1
2GE2
Bldg 1002C
Bldg 1002B
Bldg 1002A

ERL gun


gun
dump
-A-
-A-

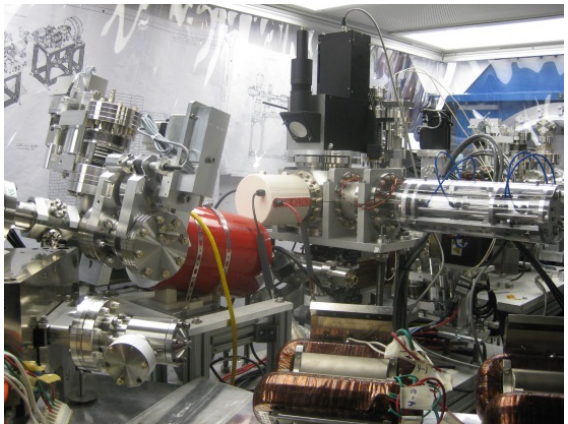
Cost Estimate Guidelines

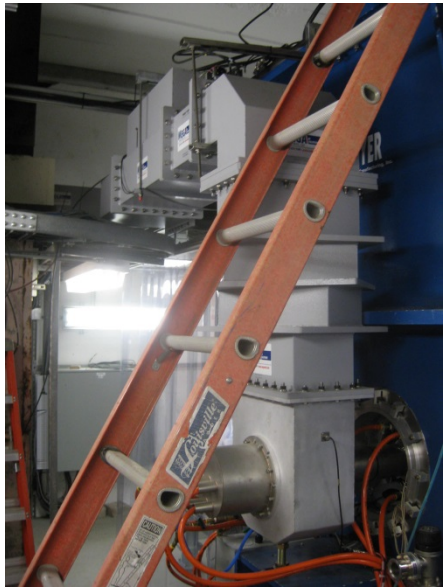
- Physics parameters are still being finalized; go with what is known – first step is to get a rough cost estimate.
- Keep it cheap, LEReC only operates for 2 years.
- Use as much ERL and CeC existing equipment as possible; but, don't break it – both systems are in future eRHIC plans.
- Making the ERL gun meet its design specifications is outside the scope of this project.
- Use your spreadsheets from the last LEReC effort – take advantage of similar equipment requirements.
- Use the ERL test schedule in 912 to commission equipment if possible.
- Include C-AD manpower hours for project planning.
- Use Kerry's spreadsheets to allow fast transfer of total dollars.
- Update the WBS as needed; but, transfer the information to Kerry.

ERL SCRF Cavities Work Scope

ERL eGun (after initial ERL tests with beam)

- Two New 50kW RF Power Supplies w/RF waveguides
- Remove eGun assembly from ERL Block House to SCRF shop. (critical lift?)
- Remove eGun from cryostat. (critical lift?)
- Upgrade HTSC solenoid warm lead heat stationing
- Upgrade cathode assembly (multipacting)
- Upgrade Cathode assembly He cooling
- Upgrade FPC assemblies
- Reassemble and reinstall at ERL.
- Test at ERL (50kW??)
- Reinstall at 02:00

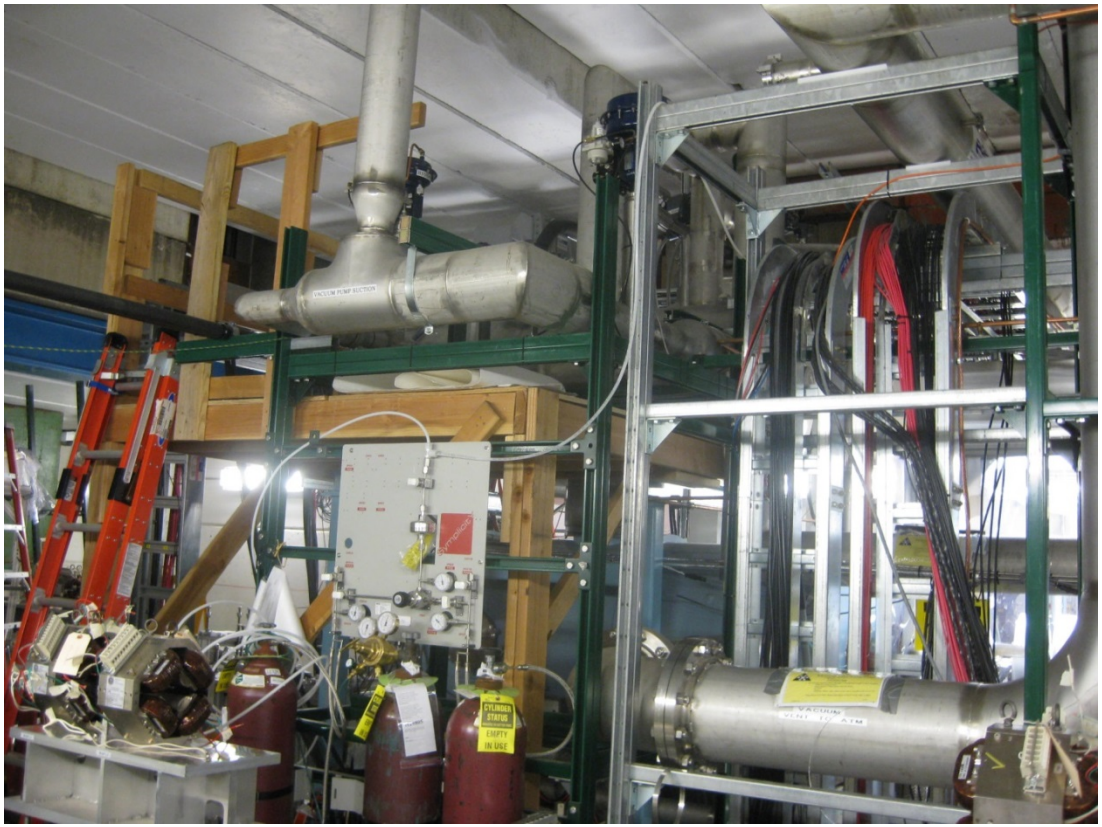




ERL SCRF Cavities Work Scope

ERL 5 cell SCRF Linac Cavity

- Use CeC PA (@20 kW) w/new tube and RF waveguides. ERL LLRF
- Test at ERL with beam
- Remove and reinstall at 02:00



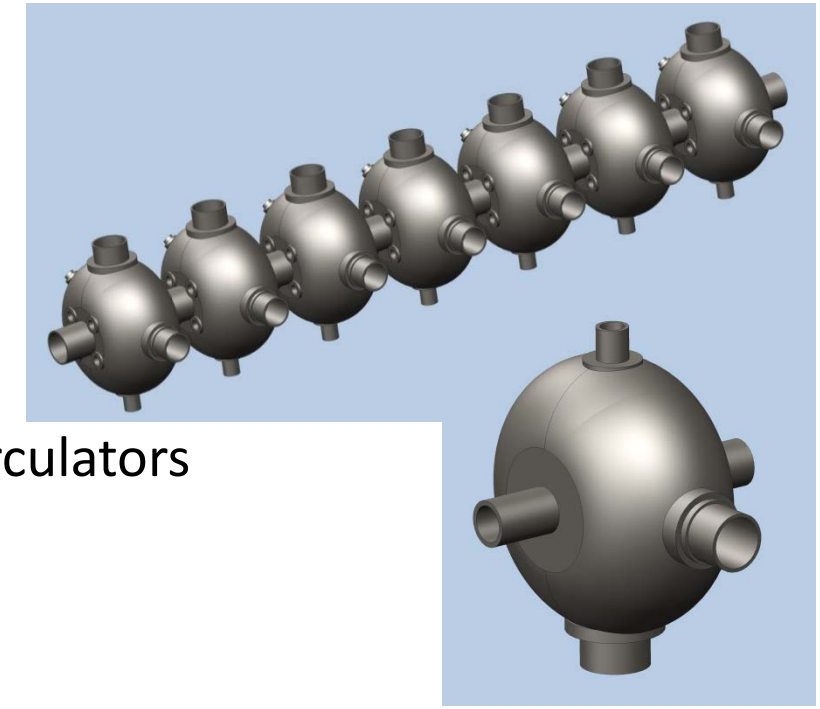
Warm RF Cavities
Need Specs ASAP for design and cost estimate.

"3rd Harmonic" 2.111 GHz 6 or 7 cell copper cavity

- 460 kV, 20 kW PA, new circulator, new LLRF, small waveguide.
- Aperture: 2 ID"
- Cell size: 13 cm gap

704 MHz one 3 cell cavity or two 1 cell cavities or one 1 cell cavity or no cavity

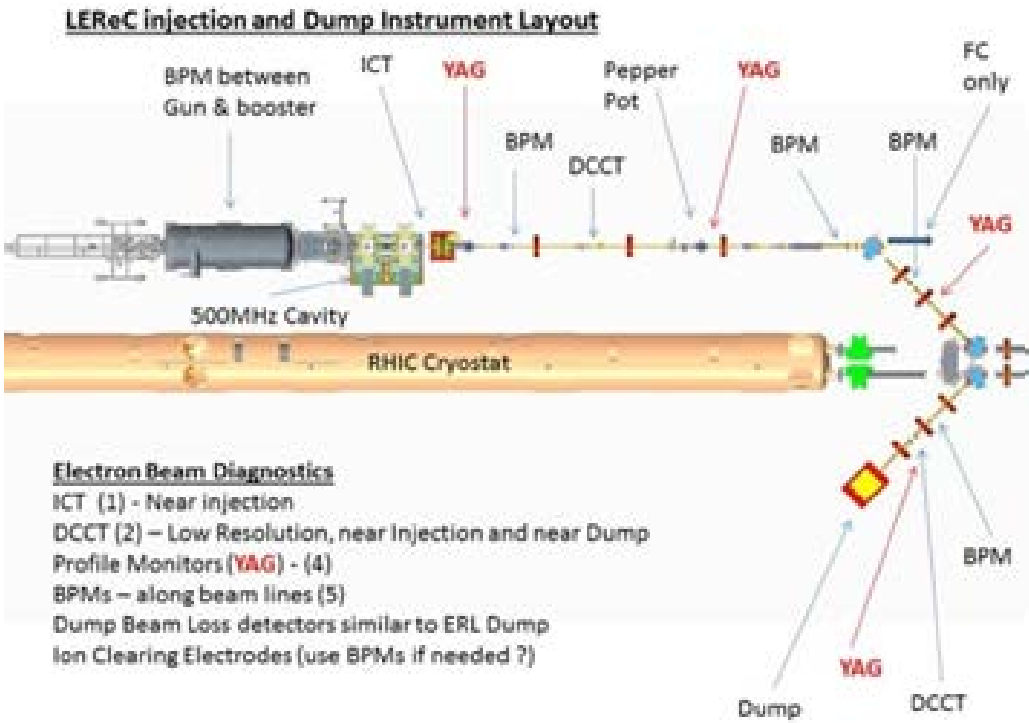
- 605 kV, 50 kW "used/retuned" PA from CeC PoP buncher, new circulator,
- waveguide/coax?
- Aperture: 2 ID"
- Cell size: 13 cm gap



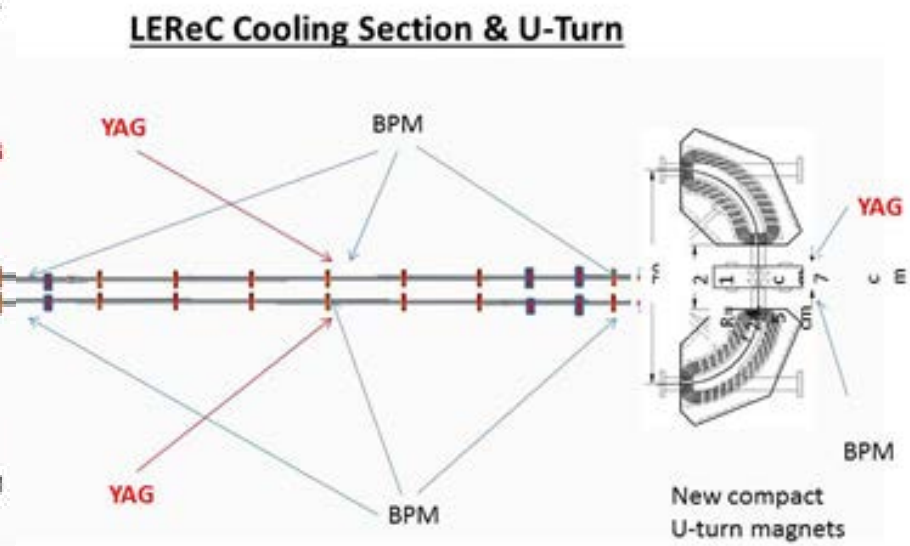
Both Cavities:

- Water cooled cavity and PA
- Water cooled – temperature controlled circulators

LEReC Beam Diagnostics

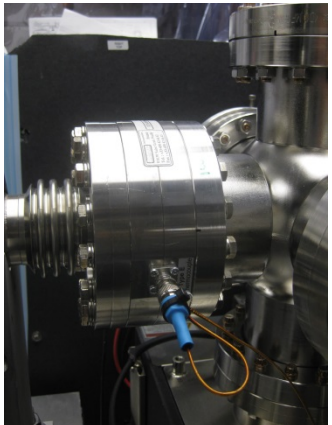


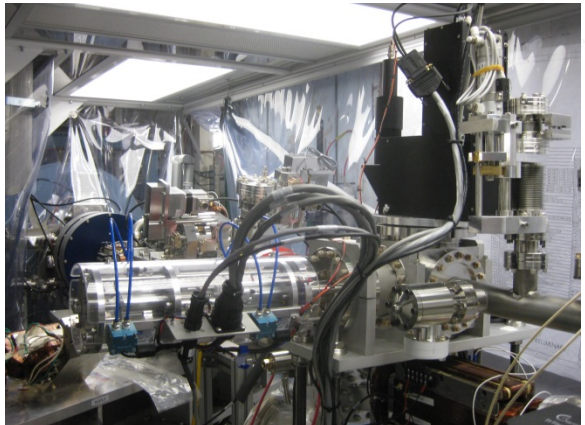
Electron Beam Diagnostics
ICT (1) - Near injection
DCCT (2) – Low Resolution, near Injection and near Dump
Profile Monitors (YAG) - (4)
BPMs – along beam lines (5)
Dump Beam Loss detectors similar to ERL Dump
Ion Clearing Electrodes (use BPMs if needed ?)

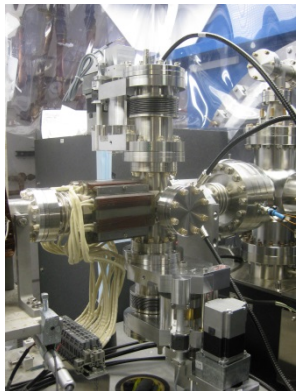


Electron Beam Diagnostics
Profile Monitors (YAG) - (3) – Plunging YAG screens
BPMs – (7)
Corrector locations – at every solenoid,
For sector 1: L=18m with 9 solenoids every 2 m.

Diagnostics will expand on the old LEReC layout







LEReC Beam Diagnostics (Gassner)

System	Gun/Inj	Loop	dump	total
BPM	4	11	1	**16**
ICT	1			**1**
DCCT	1		1	**2**
Faraday Cups	1		1	**2**
Profile Monitor	3	3	1	**7**
Pepper Pot	1			**1**
PMT BLM	2	11	1	**14**
Pin Diode BLM	1	6	1	**8**
Heliax BLM		4	24	**28**
Thermal camera	1			**1**
		Total devices		**80**

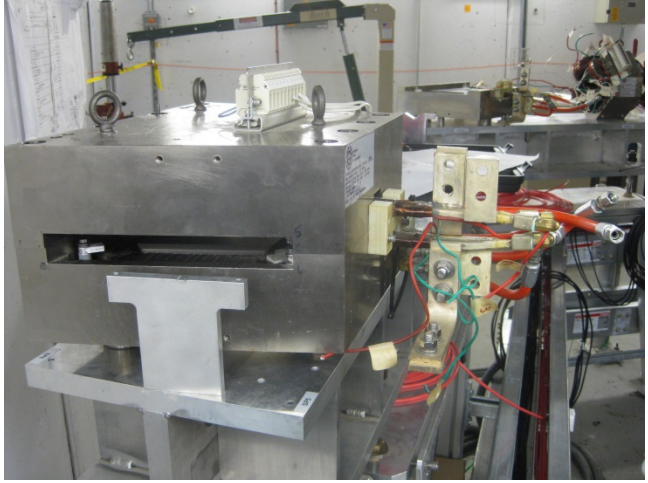
Gun/Inj	transports	cooling	dump	total
2	1	7	1	**11**
1				**1**
1			1	**1**
1			1	**1**
2	1	3	1	**7**
1				**1**
	8			**8**
	2			**2**
	4			**4**
1				**1**
		Total devices		**37**

Gun/Inj	transports	cooling	dump	total
2	18	7	1	**28**
1				**1**
1			1	**2**
1	1		1	**3**
3	6	3	1	**13**
1				**1**
2	10	4		**16**
	2			**2**
	6	3	24	**33**
1				**1**
		Total devices		**100**

Notes:

- Keep **ERL zig-zag diagnostics essentially intact**, assume aux straight beam line for gun testing.
- Add 1 BPM every 5 meters in the new straight sections (70/5 = 14) + 4 at new bends = 18
- Keep original one **from ERL** near gun
- Re-use DCCT's **from ERL**, differential measurement capability.
- One at aux dump (for gun testing), one additonal as needed, and at isolated dump .
- **Re-use 3 in ERL** zig-zag, add 5 more in new transports and bends.
- **Re-use pepper pot** in aux straight beam line from gun.
- Distribute PMT BLMs as needed, 8 ch/VME module, use 2 modules.
- Pin diodes can be moved around as needed.
- Heliax BLM's at beam line bends. Re-use ERL dump as is?
- Re-use FLIR thermal camera from ERL, can be located as needed.

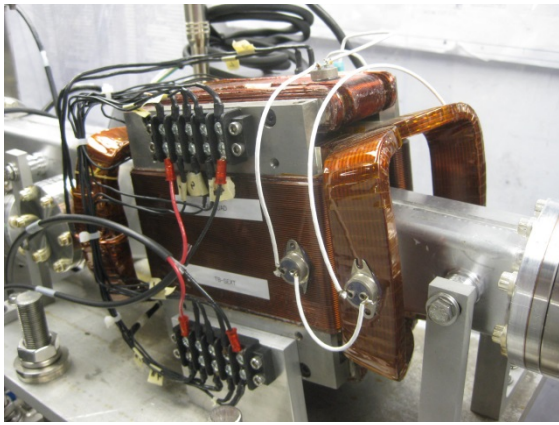
RHIC/ERL Magnets Work Scope



128 meters of ERL electron beam line.

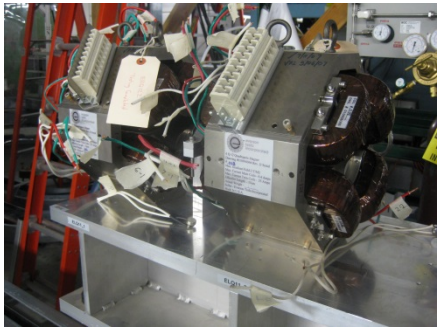
Dipole Magnets

- 180° return magnets: 90° and 60°
- RHIC inject/extract 45° dipole magnets
- Zig Zag dipole magnets (multipole)
- Energy merging and separating magnets



Focusing

- RHIC interaction: 5” beam tube, 6” ID solenoids
- ERL transport: 3” transport beam tube, 4” ID solenoids
- Beam dump and ERL return, 3” ID quads



Correctors

- 3” and 5” horz & vertical corrector coils in each solenoid

ERL Magnet Power Supplies Work Scope

128 meters of ERL electron beam line.

Dipole Magnets PS

- 180° return magnets: 90° and 60° **in series w/trim windings and PS**.
- RHIC inject/extract 45° dipole magnets **independent**.
- Zig Zag dipole magnets w/multipole windings? **independent**.
- Energy merging and separating magnets independent. **independent**.

Focusing

- RHIC interaction: 5” beam tube, 6” ID solenoids **independent**.
- ERL transport: 3” transport beam tube, 4” ID solenoids **independent**.
- Beam dump and ERL return, 3” ID quads **independent**.

Correctors

- 3” and 5” horz & vertical corrector coils in each solenoid **independent**.

ERL Magnet Power Supplies Work Scope

Update magnet and power supply specifications

Magnet	Designation	Location	Aperture Gap cm	Width cm	Aperture	Core Length cm	Operating Field kG	Qty	Grad. T/m	Main Power Supply Qty	Current Amps	Power kW	Trim Power Supply Qty
Dipole 45D + Trim	10D39-45	RHIC/e Beamline + compensation	10	20	N/A	30	0.50	8	N/A	1			4
Dipole 90D + Trim	10D25-90	Cooling Line U-turn	10	20	N/A	25	1.00	2	N/A	1			2
Dipole 60D + Trim	8D25-60	Return Line U-turn + dump lines	10	16	N/A	45	0.50	4	N/A	1			4
Dipole 30D/10D	**8D30-10**	**1st chicane dipole High-Low Energy**	8	8	N/A	13	0.50	1	N/A	1			0
		Merger (Double Aperture)	8	8	N/A	13	0.25	1	N/A	1			0
Dipole 15D/45	**10D15-45**	**2st chicane dipole Low-High Energy**	10	10	N/A	13	0.25	1	N/A	1			0
		Separator (Double Aperture)	10	10	N/A	13	0.50	1	N/A	1			0
Dipole 30D	10D30	2nd chicane dipoles	10	10	N/A	25	0.25	3	N/A	3			0
Dipole 15D	10D15	2nd chicane dipole	10	10	N/A	25	0.25	3	N/A	3			0
Quad	16Q10	60D U-turn	N/A	N/A	16	8	N/A	4	2.0	1			0
Quad	16Q10	beam dump	N/A	N/A	16	8	N/A	2	2.0	1			0
Quad	16Q10	90D U-turn	N/A	N/A	16	8	N/A	1	2.0	1			0
Quad	16Q10	Chicane merger to beam dump	N/A	N/A	16	8	N/A	1	2.0	1			0
Solenoid - Transport	10S10	e Beamline transport (5 meter spacing)	N/A	N/A	16	16	1.00	14	N/A	14			0
Solenoid - Compensating	16S16	e Beamline transport (2 meter spacing)	N/A	N/A	16	16	0.20	16	N/A	16			0
Solenoid - Transport	16S16	e Beamline transport (2 meter spacing)	N/A	N/A	16	16	1.50	8	N/A	8			0
H & V Corrector Coil	16C16	RHIC/e Beamline	16	16	N/A	20	0.10	24	N/A	0			48
H & V Corrector Coil	10C10	RHIC/e Beamline	12	12	N/A	20	0.10	24	N/A	0			48
										55			**106**

Beam Dump

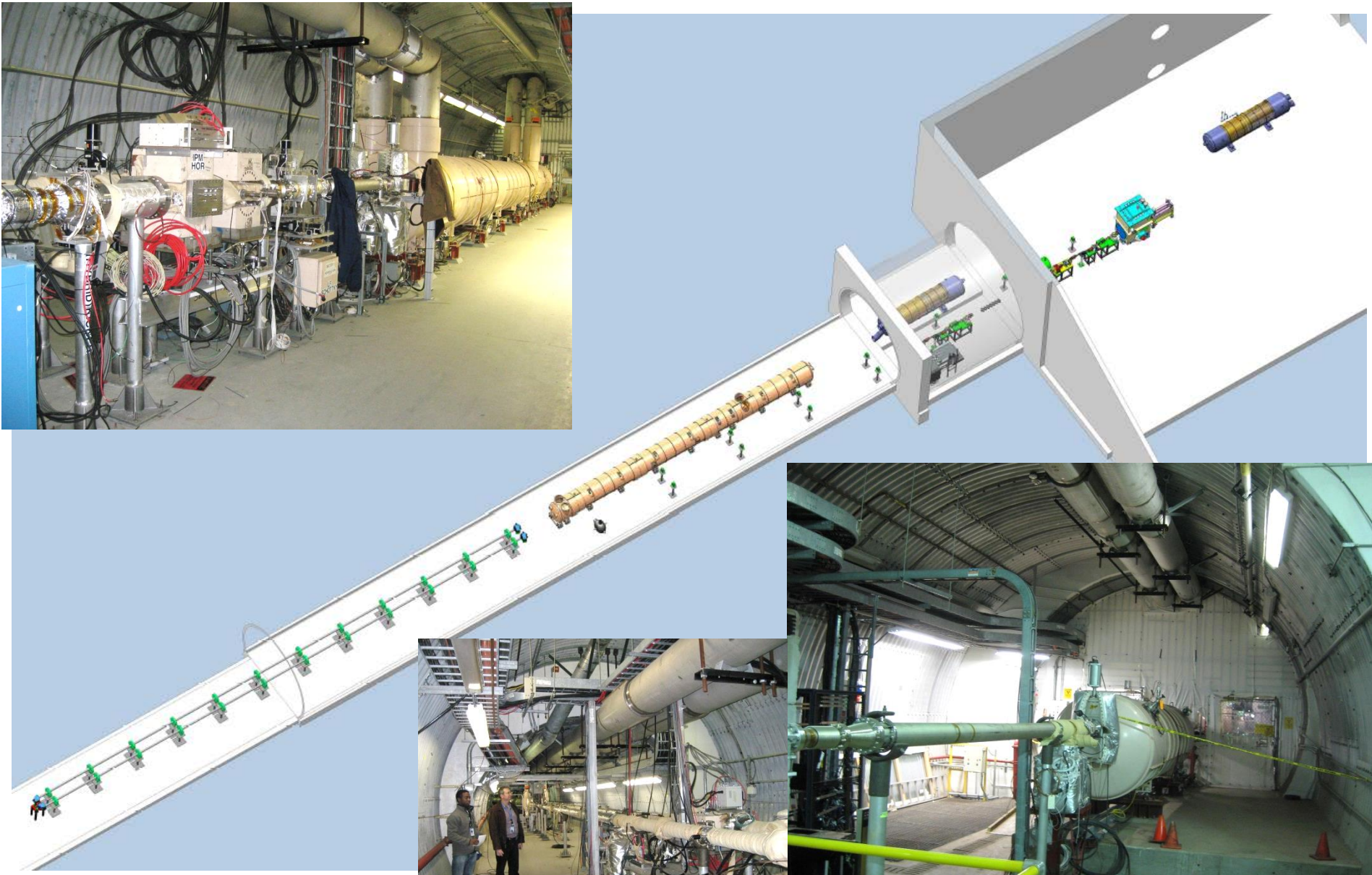
Use ERL 1 MW beam dump:

Gun only operations 1.0, 1.2, 1.4, 1.6 1.8 MeV 50 kW

ERL mod 2, 3, 4, 5 MeV 100 kW

- Location – beam line configuration drawing (out of crane reach)
- Shielding – RHIC tunnel shielding + lower intensity; affect on other equipment in RHIC.

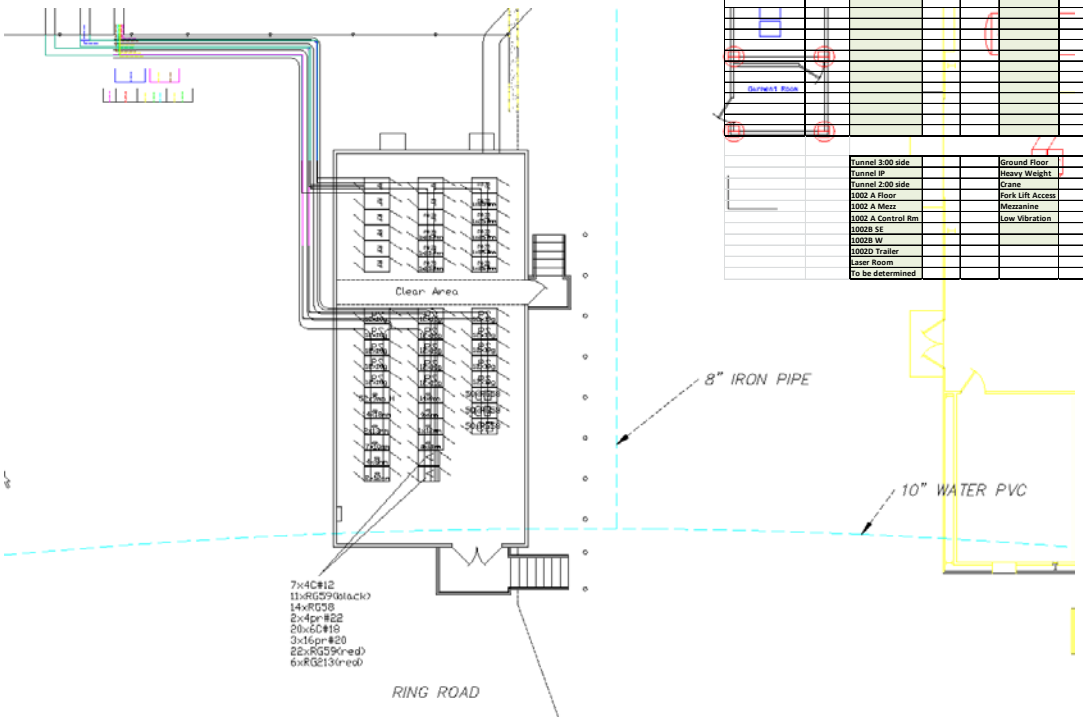
Overall layout



Conventional Facilities

Need update specifications sheets:

- Added beam line length; more components, more racks, more power
- Added warm cavities
- Rigging into RHIC tunnel
- Beam dump shielding



Low Energy RHIC electron Cooling Proof of Principle Utility Requirements

System Identity		Location				Cable Size		Tunnel Penetrations (cables and utility/cryo piping)						Electrical Power		Water Cooling					Heat Dumped to Air and Air Conditioning Needs			Notes
Equipment Description	Responsible Engineer	Support Building or Tunnel	Floor Area ft^2	or # of 19" std racks	Comments	(area or dia.) cm^2	cm	Type	# of cables	Heat Loss W/m	Pipe Size (dia.) cm	Type	# of pipes	Power kW	Voltage	Heat Load kW	Water Pressure Psi	Type	Temp	Special Needs	Heat Load kW	Temp	Special Needs	

Drop-down Menu Choices in Green Columns

Tunnel 3:00 side			Ground Floor			high current				water						De-ionized	Chilled <30 C	Accurate Control		<25C	Accurate Control	
Tunnel IP			Heavy Weight			high voltage				air						deoxygenated	30 - 40 C	None		<30C	AC not needed	
Tunnel 2:00 side			Crane			instrumentation				LN2						Open Tower	See Notes	See Notes		AC not needed	Humidity Control	
1002 A Floor			Fork Lift Access			fiberoptic				LHe VJP						See Notes					None	
1002 A Mezz			Mezzanine			heliax				Warm He/LN2												
1002 A Control Rm			Low Vibration							RF Transmission												
1002B SE																						
1002B W																						
1002D Trailer																						
Laser Room																						
To be determined																						

LEReC timeline

March 2014:	Physics approach/accelerator design
March 2014:	Engineering baseline, start working on layout in RHIC tunnel
March 31:	Preliminary accelerator design
April 2014:	White paper on ERL based LEReC, WBS
Apr-June 2014:	Engineering system specifications, facility support requirements, cost estimate, risk assessment, PEP, safety, etc.
<u>July 9-11 2014:</u>	<u>DOE Technical/Cost/Management Review:</u>
July 2014:	Final white paper ERL based LEReC
July 2014:	Project approval/funding

LEReC timeline – Project Milestones?

May 2014:	ERL Gun commissioning w/beam
June - July 2014:	ERL Complete Gun to 5 cell dump installation
Aug 2014:	ERL Gun to 5 cell commissioning w/beam
Sept – Oct 2014:	ERL Complete ring installation
Nov – Dec 2014:	ERL Ring commissioning w/beam
Jan - June 2015:	ERL shutdown for gun modifications and LEReC test preparation (in 912 blockhouse).
July - Dec. 2015:	**ERL commissioning CW mode (LEReC test in 912)**
Jan – June 2016:	Move PS other electronics to RHIC 02:00 Prep Gun, 5 cell, zig zag, and dump for move.
July 2016 - June 2017:	Install Gun, 5 cell, zig zag, and dump in RHIC
July - Sept 2017:	**Cooldown gun and 5 cell w/RHIC refrigerator commission ERL beamline. (1/2 RHIC Blue)**
October 2017:	**Run 18, low energy Au beam.**

LEReC timeline

FY 2015 (early):	Detailed system design, procurement specifications, engineering design reviews, facility modifications plans and drawings.
FY 2015 (mid):	Purchase orders and contracts for major elements.
FY 2015 (late):	Receive and test new equipment.
June – Dec 2015:	Renovate Brahms trailer.
	Remove equipment from 01:00 Q3-Q4 sectors
	Install magnets and vacuum chambers (where possible)
	Install cable tray and cryogenic piping (where possible)
Jan – June 2016:	**RHIC run 16 – CeC PoP.**
July 2016 - June 2017:	Installation, system commissioning of beamline components, SCRF, and cryogenic components.
July - Sept 2017:	**Cool-down gun and 5 cell w/RHIC refrigerator commission ERL beamline. (1/2 RHIC Blue)**
October 2017:	**Run 18, low energy Au beam.**

Estimate and Review Schedule

April 9:	**Kick-off**
April 18:	**Updated cost estimate sheets due to Kerry: All except warm RF, Controls, and civil construction**
April 18:	**Update conventional facilities estimated needs: AC power, water and air-conditioning, floor and rack space, heavy equipment, cables and cable tray, . . . All except warm RF and Controls**
April 29:	**Freeze Physics design: LEReC Lattice, RF systems, beam diagnostics.**
May 8:	**Updated engineering parameters in cost estimate spread sheets (if needed) and controls cost estimate**
May 12:	**Update conventional facilities estimated needs: All**
May 16:	**Project Execution Plan first draft (w/Risk List).**
May 19:	**Parameters and Cost estimates for warm RF systems**
June 6:	**Project Execution Plan distributed internally for review and approval.**
June 24:	**DOE Presentation Dry Run**
June 27:	**Project Execution Plan sent to DOE.**
July 9-11:	**DOE Review 2 ½ days.**

~ April 2014 ~

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Responsibility Legend **LEReC team** Kerry **Alexei and a few others**		1 Alexei et al begin writing PEP sections	2	3 KM vacation	4 KM vacation	5
6	7 KM vacation	8	9 estimate kickoff	10	11	12
13	14 RVW Vaca Risk list and instructions are sent out	15 RVW Vaca	16 RVW Vaca	17	18 Some estimate sheets due to Kerry, parameters to Joe	19
20	21 Milestone instructions are sent out. Risk lists are due.	22 Draft PEP sections due to Kerry	23	24 First look at total cost	A Draft request for Extraordinary construction G&A.	26
27	28 schedule creation with milestones begins (with Bob VW)	29 Freeze Physics design: LEReC Lattice, RF systems, beam diagnostics.	30			

~ May 2014 ~

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Responsibility Legend **LEReC team** Kerry **Alexei and a few others**				1	2	3
4	5	6	7	8 revised estimates to Kerry, revised parameters to Joe	9	10
11	12 Update conventional facilities requirements	13	14	15 Schedule, reportable milestones, funding plan, cost plan	16 Draft PEP to BNL upper mgmt and DOE	17
18	19 Warm RF Systems Estimates	20	21	22	23	24
25	26 Holiday	27	28	29	30	31

~ June 2014 ~

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6 Final PEP to BNL upper mgmt for approval	7
8	9 KM vacation	10 KM vacation	11 KM vacation	12 KM vacation	13 KM vacation	14
15	16 KM vacation/IPAC14	17 IPAC14	18 IPAC14	19 IPAC14	20 IPAC14	21
22	23	24 1st Dry Run for LEReC review	25	26	27 Final PEP sent to DOE	28
29	30 Documents posted on Indico (or other site)	Notes:				

Responsibility Legend

LEReC team

Kerry

Alexei and a few others

~ July 2014 ~

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Responsibility Legend **LEReC team** Kerry **Alexei and a few others**		1	2	3	4 Holiday	5
6	7 2nd Dry Run for LEReC review (Problems Only)	8	9 LEReC Technical, Cost Schedule review	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		Notes:

(The last time) Estimate and Review Schedule

October 21: ***Freeze design parameters: 14 M or 20 M, (final white paper).***

01:00 Side, 2K cryogenics, passive magnetic shielding, 20 M

November 4: Provide conventional facilities estimated needs: AC power, water and air-conditioning, floor and rack space, heavy equipment, beamline components, cables and cable tray, . . .

November 18: round 1 - Cost estimate spreadsheets, milestone schedules, system operating/design parameters.

December 6: round 2 - Cost estimate spreadsheets, milestone schedules, system risk list and risk mitigation.

December 20: Project Execution Plan first draft (w/Risk List).

Janary 3: Project Execution Plan distributed internally for review.

January 7: DOE Presentation Dry Run

January 13: Project Execution Plan sent to DOE.

January 27 (Monday): DOE Review 2 ½ days.