Design and Status for the Electron Lens Project at the Relativistic Heavy Ion Collider J.P. Jamilkowski, Z. Altinbas, M.R. Costanzo, T. D'Ottavio, X. Gu, M. Harvey, P.K. Kankiya, R.J. Michnoff, T.A. Miller, S. Nemesure, T.C. Shrey

e-Lens Goals & Design



The Blue and Yellow e-Lenses are installed in the RHIC Ring at Interaction Region 10, in order to partially counteract the head-on beam-beam tune shift effect on the colliding RHIC beams, and thus permit RHIC proton beam operations at higher beam intensities, and therefore higher colliding beam luminosities for RHIC experiments. the First commissioned during the FY2014 run, both electron lenses were successfully operated on a routine basis in a DC mode during the FY2015 RHIC 100 GeV polarized proton run.

Synoptic User Interface



Schematic of an Electron Lens installed at RHIC IR 10: one apparatus for the Blue Ring, and one for the Yellow Ring.

The main components of each e-Lens are the electron gun, electron collector, and superconducting solenoid magnet, though a set of additional systems are required for their routine operation. Beam transport magnets of both superconducting and non-superconducting varieties are controlled through two separate sets of standard VME hardware and software: warm magnets use equipment (PSC, QFG, and PSI) developed for the Injector machines within the Collider-Accelerator Department, and the cold magnets utilize the RHIC equipment (WFG, MADC) for reference control and readbacks. Another system of note is beam instrumentation, which is primarily comprised of BPMs, current transformers, YAG crystal-based beam profile monitors, pinhole raster scan beam profilers, as well as new electron backscatter detectors (described below, right).

Key Controls Infrastructure

- Timing System
 - VME hardware based (VxWorks)
 - RHIC Event Link core
 - RHIC Beam Sync Link
 - Server-based remote interface for e-Lens mode control



Beam Modes and Timing Off	Beamline Status	Gun vacuum (Torr): 2.1	e-10 B-GSY curren	nt [A]: -80 -80	E	3-SLY current [A]:	0	B-CSY current [A]: 80	80 Collector	vacuum [Torr]: 4.1e
O Burst	YAG screen:	Cathode Heater Status:	Recovery Tape	PS HV Status:	Recovery Tap	Beam Ready :		Gauges P	et Page PS Pet Pag	ge MPS Pet Pa
 Continuous Parasitic 	lon collector:	Beam Modes and Timit	ng	Beamline Status		Beam Current and Energy	<u>▲</u> 0_50	Current Im Al:		Modulator Const _[P Value (uA V^-
 TrueDC NotchedDC 	eBSD rate [Hz]: 5.50	OBurst Continuous Pulse w	idth [bkts]: β30 📩	YAG screen:	Home	Reflector [KV]: 1.6	× -1.60	Beam size [mm]:	0.84	DC:
Make Live	Gun valve:	Parasitic D	elay [bkts]: 288	lon collector:	In	Cathode heater [A]: 2.7	× 2.68	Beam energy [keV]:	-4.978	Paras:
Off Burst Timing Pet Page	Collector valve:	NotchedDC Charge w	idth [bkts]: 100	eBSD rate [Hz]:	1.5e+01	Cathode bias [kV]: -5	-4.98	Collector [kV]:	1.6 1.58	Scale
		Make Live	elay [bkts]: -150	Gun valve:	0pen	Modulator 1 [kV]: 2.1	× 2.08	MPS Status e I	Beam p Beam	DC:
•		Parasitic Burst	Timing Pet Page	Collector valve:	0pen	Modulator 2 [kV]: 1.8	× 1.76	ОК	On Off	Paras:

Synoptic-type user interfaces for the Blue and Yellow e-lenses, developed using the Syndi application.

In addition to the more commonly used user interfaces within the Controls System at the Collider-Accelerator Department at Brookhaven National Laboratory, the Syndi editor and display application has been adapted from the original version developed at FermiLab. Due to the compact and complex nature of the electron lenses, these synoptic displays have evolved to serve an important role in the operation of the equipment.

Development of the control pages themselves has migrated since their inception from the Syndi software developer, to the project physicist, and ultimately to a member of the RHIC Operations group. While capable of embedding complex business logic within each page, we have elected to minimize the amount of such logic implemented within the page in favor of server-based software that leverages critical functionality, such as parameter caching.



- Machine Protection System
 - National Instruments CRiO
- Beam Instrumentation
 - Gigabit Ethernet Cameras (Aravis library)
 - SiS VME scalers
 - CAEN VME ADCs
 - OMS VME stepper motor controllers
 - VMIC 3122 ADCs





Schematic of the e-Lens timing system, including RHIC components (bldg. 1004A) and e-Lens-specific components (1010B).

▼ SRHIC/Systems/ELens/MPS/BlueMPS					
Page PPM Device Data Tools Buffer		H			
BLUE E-LENS MPS					
	Reset	UpdateA11			
	CTATUC				
	STHIUS	ENHOLE STHIE			
ANODE MODULATOR POWER SUPPLY	Fault				
ANODE MODULATOR BEAM PULSE TRIGGER	Fault				
BSD Beam Intercept	Disabled	Disable			
Global Beam Loss via Cathode Bias PS	Disabled	Disable			
Cathodo Riac PS Voltago Loco	OK	Enable			
Electron Collector PS Voltage Loss	Eault	Enable			
Electron Reflector PS Voltage Loss	Fault	Enable			
	, auto	LIGNIG			
CS1 B & Y PS Current Loss	Fault	Enable			
GS1 B & Y PS Current Loss	Fault	Enable			
GSB & CSB PS Current Loss	ОК	Enable			
GS2 & CS2 PS Current Loss	0K	Enable			
Steerer GSX PS Current Loss	Fault	Enable			
Steerer GSY PS Current Loss	Fault	Enable			
Steerer CSX PS Current Loss	Fault	Enable			
Steerer CSY PS Current Loss	Fault	Enable			
Flasher Callester Temperature	F]+	Europh Le			
Electron Collector Temperature	Fault	Enable			
SC Eninge 1-2 PS Cumpont Loop	Fault	Enable			
SC Main PS Current Loss	Fault	Enable			
Extraction Arm Valve Status		Enable			
Extraction Arm Pressure	OK	Enable			
Injection Arm Valve Status	OK	Enable			
Injection Arm Pressure	0K	Enable			
Ring Pressure	ОК	Enable			
Water System Flow	Fault	Enable			
Water System Switch	ОК	Enable			
Water System Temperature	Fault	Enable			
	F	En el 1			
Anode Modulator 1 and 2 PS Status	Fault	Enable			
HNODE MODULATOR FW & Freq Limiter Status	Fault	Enable			
Electron Collector PS Status	Fault	Enable			
GS1 B & Y PS Status	Fault	Enable			
GS1 B & Y PS Current Under Limit.	Disabled	Disable			
Anode Bias Voltage Measurement Status	Disabled	D LOOM LO			
0-					
ANODE MODULATOR BEAM PULSE TRIGGER	Fault				
GUN DRIFT TUBE BEHLKE SWITCH	ON				
Anode Bias PS Voltage Loss	Fault	Enable			

For RHIC Run FY2015, a beam new type of instrumentation called an electron backscatter detector (eBSD) was commissioned in both e-Lenses. Positioned on gun side of the the apparatus, it provides a scaler signal representing the count of backscattered electrons the fraction of from successful interactions between the electron beam and RHIC beam. Since this alignment signal is dependent, it can be used for automated tuning feedback within the standard Interaction Region steering application for RHIC, called LISA.



LISA application plot showing X and Y transverse beam steering optimization in RHIC IR 10 based on eBSD measurements.

At right, you can see the application output after one pass of optimization on the eBSD scaler data for the Yellow e-Lens.

Jul 19, 2013 5:28:13 PM: Opening 20130719_YAG beam profile.png Jul 19, 2013 5:28:18 PM: Finding Center of Gravity... Jul 19, 2013 5:28:28 PM: Determining Arbitrary Axis...

Electron beam profile data provided by the e-Lens Image Analysis application using GigE camera data obtained by inserting YAG crystal instrumentation into the beam path.

The two inputs below are						
for troubleshooting purposes UNLY: Anode Modulator Ream Trigger	Disshlad					
Anode Modulator Negative Bias Voltage	Disabled					
Libuo houliuoor hoyuorro Diub forougo	DIDUDIDU					
CATHODE BIAS POWER SUPPLY	0K					
Injection Arm Pressure	ОК	Enable				
CATHODE HEATER POWER SUPPLY	ОК					
Injection Arm Pressure	OK	Enable				
Cathode Heater Over I or V	OK	Enable				
Cathode Heater Current OK	Fault					
CONTROL ELECTRODE POWER SUPPLY	0K					
Injection Arm Pressure	0K	Enable				
ELECTRON COLLECTOR POWER SUPPLY	Fault					
₩(17,1) "text"	Nu	dge:0 🛒 🛓 🕄				
monitoring Wed Oct 7 21:12:57 2015: Get and Async requests complete.						

Gun Drift Tube Behlke Switch Status OK

Anode Modulator 1 and 2 PS Status Fault

node Bias PS Status - Fault

Anode Bias Voltage Measurement Status Disabled Disable

Enable

The Machine Protection System interface for the Blue e-Lens, showing a sampling of the current logic inputs and outputs.



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