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U.S. DEPARTMENT OF ENERGY

Brookhaven National Laboratory

Jefferson Lab

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CONCEPTUAL DESIGN OVERVIEW OF THE ELECTRON ION COLLIDER INSTRUMENTATION

D. M. Gassner†, J. Bellon, M. Blaskiewicz, A. Blednykh, K. A. Drees, T. Hayes, C. Hetzel, D. Holmes, R. Hulsart, P. Inacker, C. Liu, R. Michnoff, M. Minty, C. Montag, D. Padrazo Jr, M. Paniccia, V. Ptitsyn, V. Ranjbar, M. Sangroula, T. Shaftan, P. Thieberger, E. Wang, F. Willeke

BNL, Upton, New York

L. Dalesio, Osprey DCS LLC, Ocean City

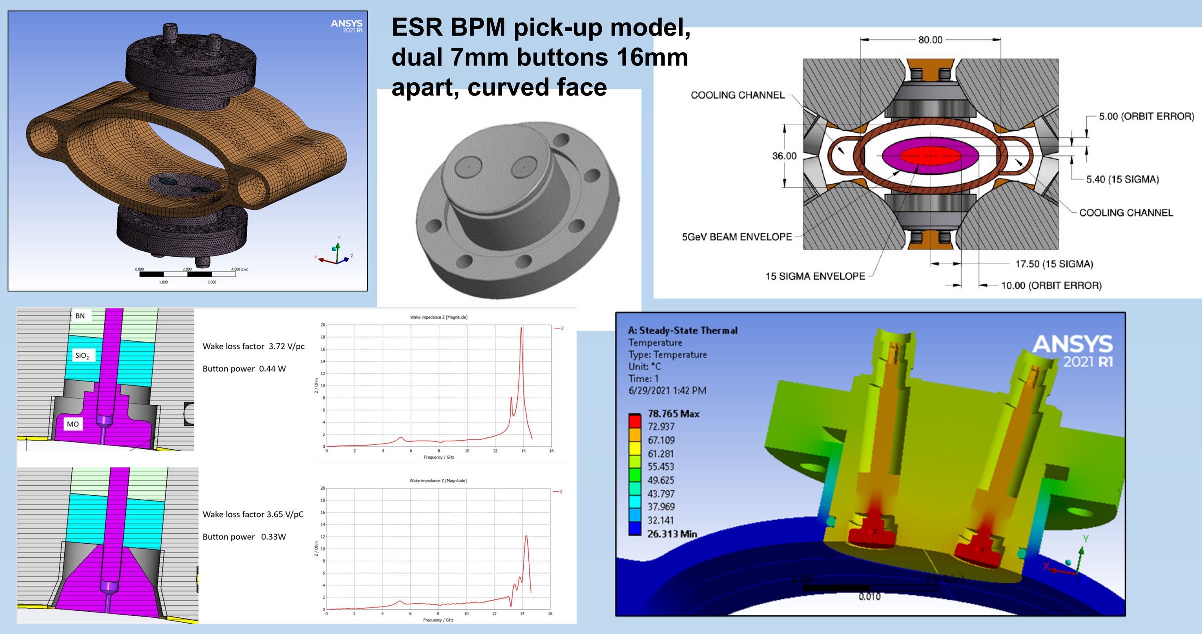
Abstract

A new high-luminosity Electron Ion Collider (EIC) is being developed at Brookhaven National Laboratory (BNL). The conceptual design [1] has recently been completed. The EIC will be realized in the existing RHIC facility. In addition to improving the existing hadron storage ring instrumentation, new electron accelerators that include a 350 keV gun, 400 MeV Linac, a rapid-cycling synchrotron, an electron storage ring, and a strong hadron cooling facility will all have new instrumentation systems. An overview of the conceptual design of the beam instrumentation will be presented

Introduction

The EIC [1,2] will be realized in the existing Relativistic Heavy Ion Collider (RHIC) facility, the primary additions will be a chain of electron accelerators and systems that will reside inside the RHIC tunnel and service buildings. The well-established beam parameters of the present RHIC facility are close to what is required for the highest performance of the EIC, except for the total hadron beam current which will be increased by a factor of approximately three by increasing the number of bunches. A strong hadron cooling facility will utilize 100 mA of 150 MeV electrons to reduce the hadron beam emittance and control emittance growth due to intrabeam scattering. Polarized electrons will be generated in a new 350 keV DC gun from a strained superlattice GaAs photocathode and will be accelerated to 400 MeV in an S-band normal conducting Linac. The 3.8 km rapid cycling synchrotron (RCS) then increases the electron energy to 5, 10 or 18 GeV in 100 - 200 ms, then fills the electron storage ring (ESR). The 3.8 km ESR will provide ~70% polarized electron beams at 5, 10 or 18 GeV for collisions with the polarized protons or heavy ions in the hadron storage ring (HSR) at 41, 100 and 275 GeV. To maintain high spin polarization, each of the ESR electron bunches will be replaced every one to three minutes.

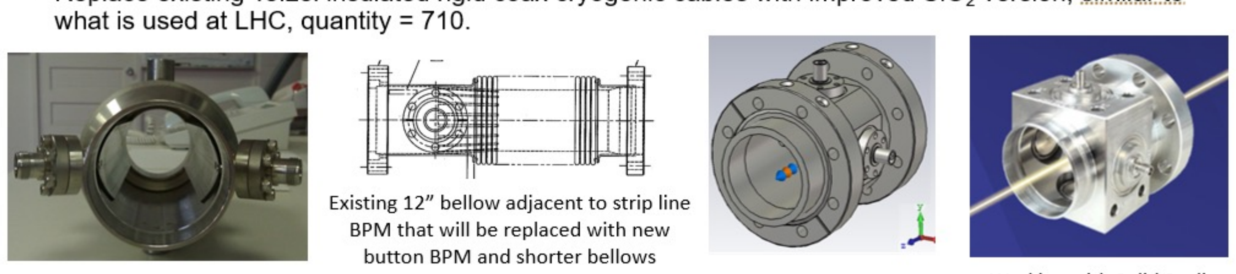
Electron Storage Ring BPM Pick-up Development, CST modeling and thermal analysis



Hadron Ring BPM Upgrade

New BPM pick-ups, cryo-cables, electronics

- To avoid heating of the cryogenic signal cables, the existing RHIC stripline BPMs will be shielded to minimize impedance; all Yellow Ring and one Blue sextant.
- 279 new button type BPMs will be installed in the hadron ring along the side shielded strip-line BPMs.
- Replace existing Tefzel insulated rigid coax cryogenic cables with improved SiO_2 version, similar to what is used at LHC, quantity = 710.



Existing strip line BPMs will be shielded with new beam screen

Existing 12" bellow adjacent to strip line BPM that will be replaced with new button BPM and shorter bellows

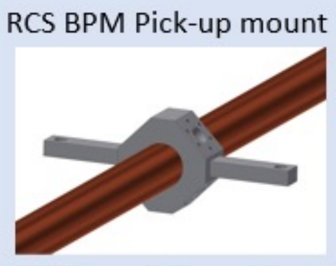
Concept BPM design, 69 mm ID, 11 mm diameter buttons

Working with Solid Sealing Technology Inc. on cryo button BPM design

Rapid Cycling Synchrotron BPM Model

NSLS-II Booster 11 mm button, SMA. Place holder until RCS BPM is designed

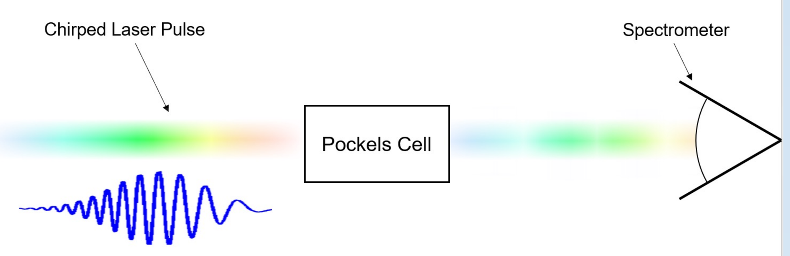
RCS BPM Pick-up mount



32.8 mm ID round beam pipe.

Electro-Optical Longitudinal Profile Monitor

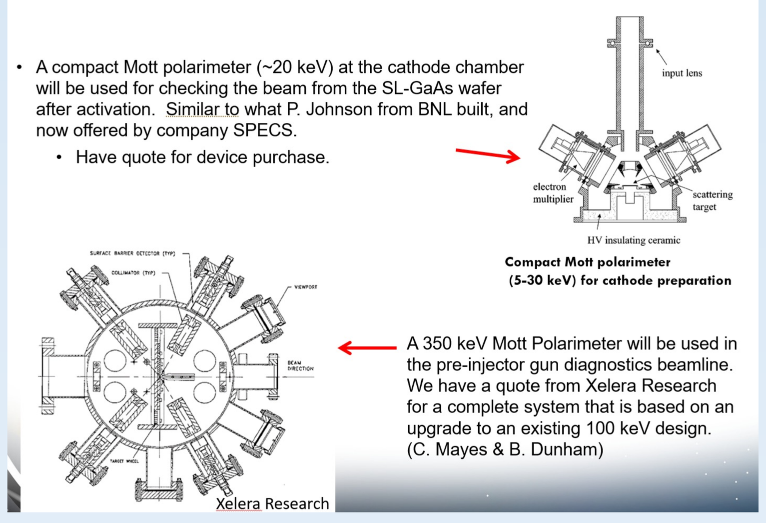
TROG (Temporally Resolved Optical Gating) Resolution:



Use of a chirped laser pulse instead of a single frequency laser establishes a time – frequency rlationship.
Readout of the intensity modulation is done using a commercial spectrometer rather than a photodiode.

2 Mott e-Polarimeters at the pre-injector

- A compact Mott polarimeter (~20 keV) at the cathode chamber will be used for checking the beam from the SL-GaAs wafer after activation. Similar to what P. Johnson from BNL built, and now offered by company SPECS.
  - Have quote for device purchase.



A 350 keV Mott Polarimeter will be used in the pre-injector gun diagnostics beamline. We have a quote from Xelera Research for a complete system that is based on an upgrade to an existing 100 keV design. (C. Mayes & B. Dunham)

Hadron Storage Ring Crab Tilt BPM

Crab tilt determined by difference of horizontal BPM signals at zero crossing

Concept by P. Thieberger IPAC2018-WEPAF018

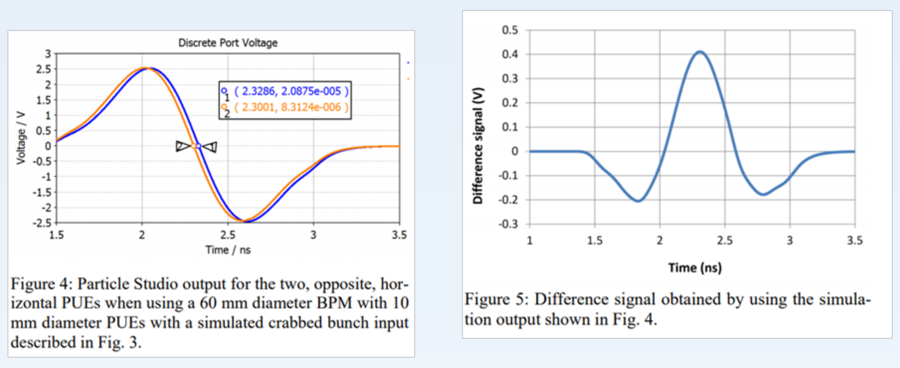
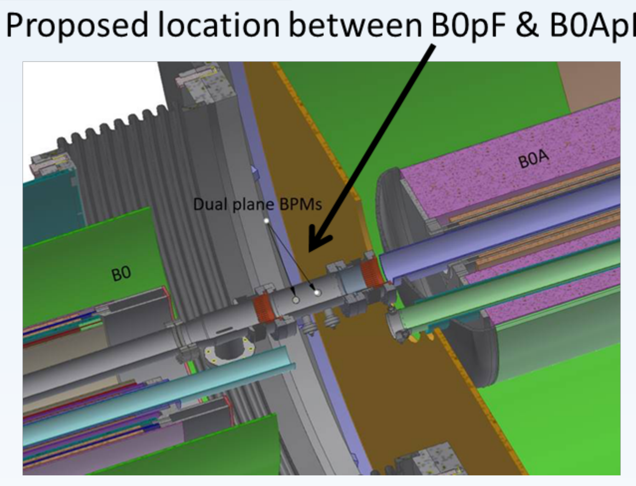


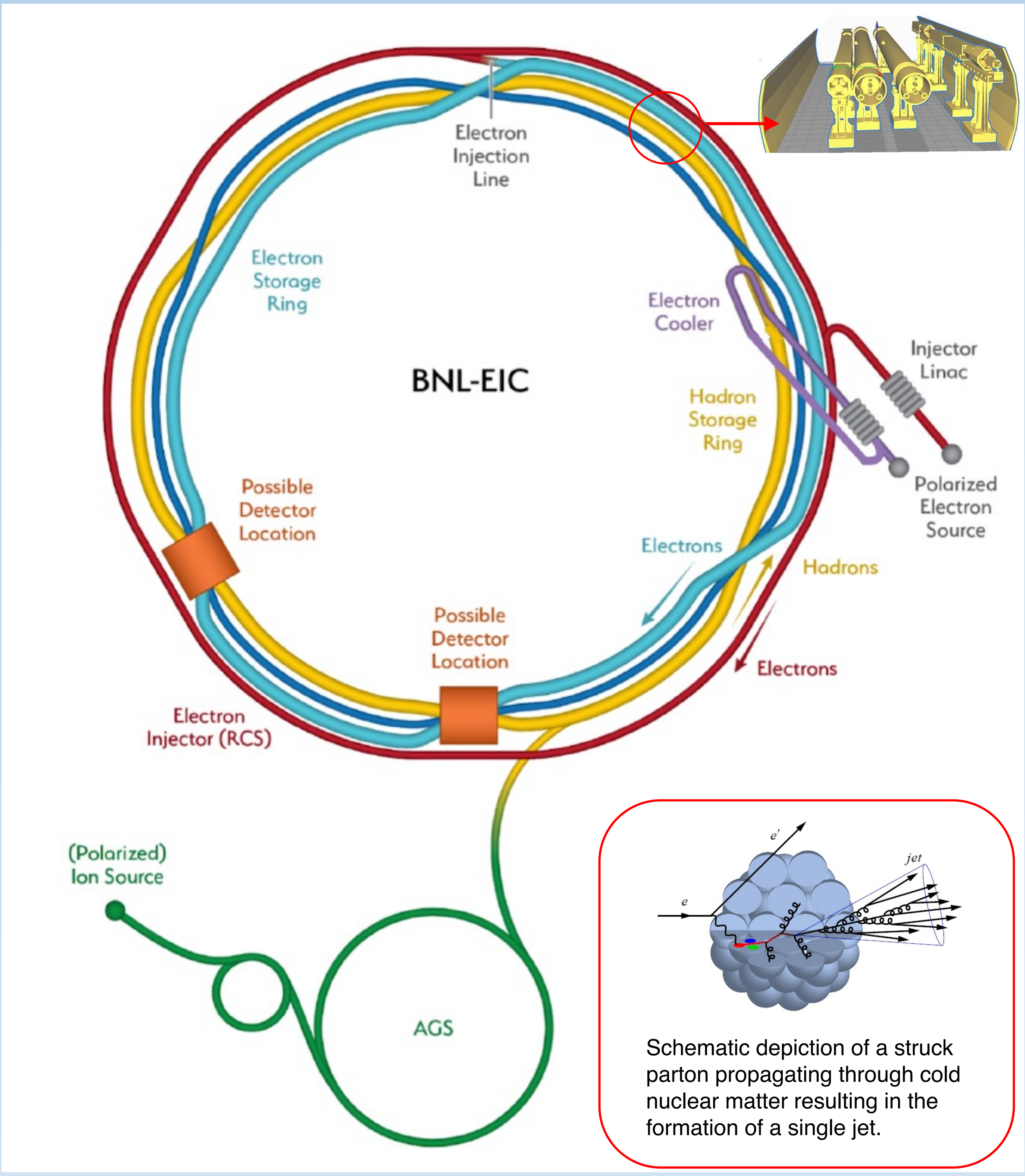
Figure 4: Particle Studio output for the two, opposite, horizontal PUEs when using a 60 mm diameter BPM with 10 mm diameter PUEs with a simulated crabbed bunch input described in Fig. 3.

Figure 5: Difference signal obtained by using the simulation output shown in Fig. 4.

Proposed location between B0pF & B0ApF

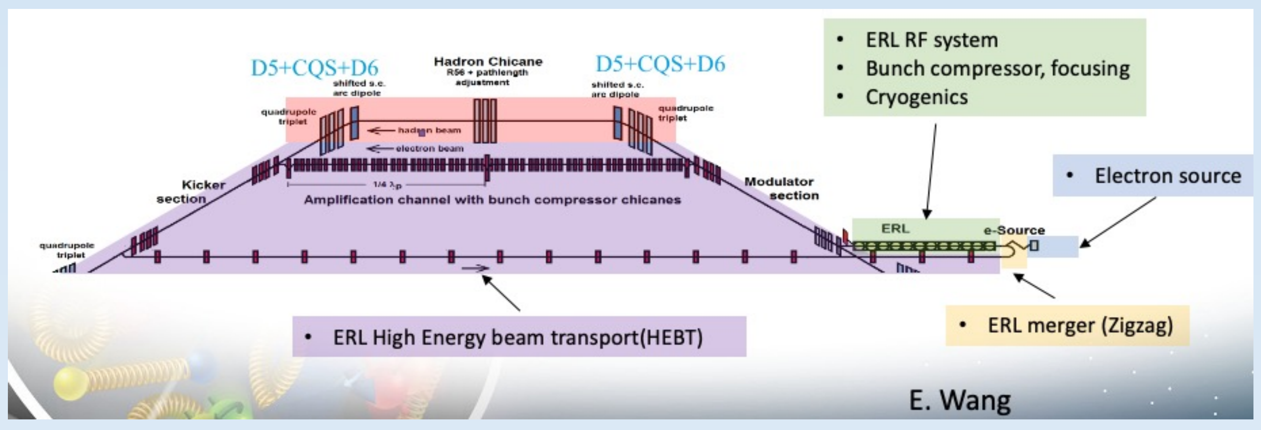


Electron Ion Collider Facility Layout



Schematic depiction of a struck parton propagating through cold nuclear matter resulting in the formation of a single jet.

EIC Strong Hadron Cooling Facility Layout Schematic



Strong Hadron Cooling Diagnostics Table

EIC Strong Hadron Cooling Instrumentation Table

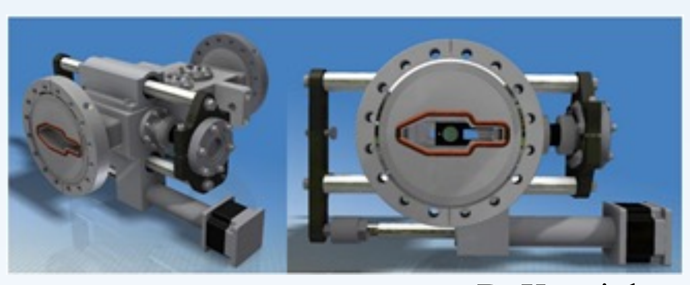
Gassner, Paniccia 21Oct20

System	400 MeV LEReC Gun to Linac transport (2 bunchers) with zig-zag merge	SCRF Linac 150 MeV 591 MHz (9 cavities) 60m	Linac to Modulator transport 10m	Linac HE Diagnostics Beamline 10m?	SHC Modulator Common Region 50m	SHC Amplifier Chicane electrons 100m	SHC Hadron Chicane 100m	SHC Kicker Common Region 50m	electron return to merge 230m	HP Dump transport & HP Dump 5m	LP Dump transport & LP Dump 5m	LE electron Diagnostics Beamline 5m	Quantity Totals
Beam Position Monitors													
BPMs	8	12	5	5	8	20	10	8	25	3	3	3	110
Current and Charge Monitors													
DCCT	1									1			2
ICT	1		1	1		1			1	1	1	1	8
FCT	1		1	1		1			1	1	1	1	8
Dump/Faraday Cups	2	1	1	1	1	1		1	1	1	1	1	12
Profile and Emittance Monitors													
Screen Profile Monitors	4	4	2	2	4	4		4	6	2	1	2	35
Wire Scanners	1	3	1		1	1		1	1				9
Emittance Slit Scanners	1	3				1		1	1				7
Halo Scrapers/Collimators	1		1						1			1	4
Transverse Deflecting Cavity				1									1
Synchrotron Light Monitors													
Longitudinal, H & V profiles				1	1	1		1					4
Relative bunch alignment								1					1
Beam Loss Monitors													
PMT/Scintillator BLMs	5	10	4	4	4	10	10	4	25	4	4	4	88
Thermal monitors													
Beam pipe temperature	6	5	5	5	5	5	5	5	10	8	8	3	70
Totals	31	38	21	21	24	45	25	26	72	21	19	16	359

Contact

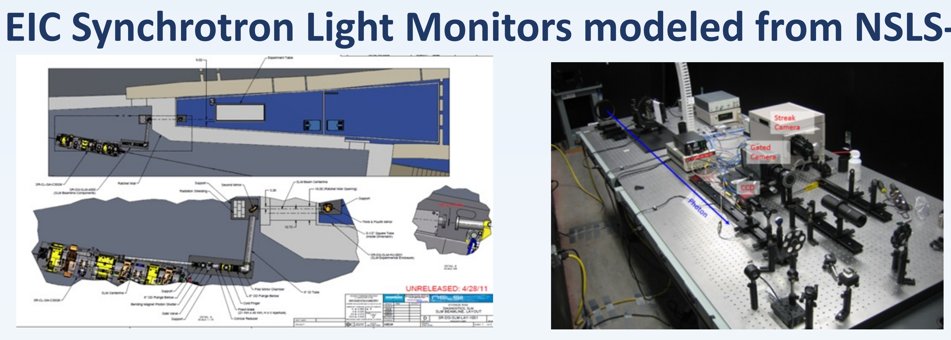
David M. Gassner
Instrumentation Systems Group Leader
Electron Ion Collider
Brookhaven National Laboratory
Building 911A
Upton, NY 11973
631-344-7870

NSLS-II Storage Ring plunging YAG/OTR screens. Plan to modify design for RCS



B. Kosciuk

EIC Synchrotron Light Monitors modeled from NSLS-II



NSLS-II Synchrotron Light Monitor layout

NSLS-II Optical table with Streak camera

REFERENCES

[1] F. Willeke et al, "Electron Ion Collider Conceptual Design Report 2021", BNL-221006-2021-FORE (2021)

[2] C. Montag et al, "Design Status Update of the Electron Ion Collider", presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper WEPAB005.

Table 1: Electron Pre-Injector Instrumentation

Type	Quantity
Beam Position Monitors	9
Beam Loss Monitors	5
Fast Current transformers	1
Integrating Current transformers	7
Faraday Cups	4
YAG/OTR Screen profile monitors	9
Longitudinal Profile Monitors	2
Mott Polarimeters	2
Slit scanner	1
Wire scanners	7

Table 2: RCS Instrumentation

Type	Quantity
Beam Position Monitors	576
Synchrotron Light Monitor	1
DCCT	1
Fast Current Transformer	1
Tune Monitor	1
Fluorescent Screens	7

Table 3: Transfer beamline Instrumentation

Type	Quantity
Linac to RCS transfer	
Beam Position Monitors	15
YAG/OTR Screens	7
Integrating Current Transformer	1
Fast Current Transformer	1
RCS to ESR transfer	
Beam Position Monitors	14
YAG/OTR Screens	3
Integrating Current Transformer	1
Fast Current Transformer	1
Sector 6 to HSR ion transfer	
Beam Position Monitors	6
Screen Profile Monitors	6
Integrating Current Transformers	2
Beam Loss Monitors	10

Table 4: Electron Storage Ring Instrumentation

Type	Quantity
Beam Position Monitors	494
Beam Loss Monitors	30
Synchrotron Light Monitors	2
X-ray Pin-Hole Monitor	1
DCCT	1
Fast Current Transformer	1
Compton Polarimeter	1
Longitudinal BbB feedback	1
Transverse BbB feedback	1
Slow orbit feedback	1
Tune Monitor	1

Table 5: Hadron Ring Instrumentation

Type	Quantity
Beam Position Monitors	276
Beam Loss Monitors	200
Ionization Profile Monitors	2
DCCT	1
Longitudinal Profile Monitor	1
HF Schottky	1
LF Schottky	1
Polarimeters (H-jet & pC)	2
Tune Meter kicker	1
Base-Band Tune Meter	1
Longitudinal Damper	1
Injection Damper	1
Gap Cleaner	1
Head-Tail Pick-up	1

Table 6: Strong Hadron Cooling Instrumentation

Type	Quantity
Beam Position Monitors	110
Beam Loss Monitors	88
Synchrotron Light Monitors	4
DCCT	2
Integrating Current Transformers	8
Fast Current Transformers	8
Faraday Cup/Dump Monitors	12
Screen Profile Monitors	35
Emittance Slit Monitors	7
Wire Scanners	9
Collimators	4
Relative Bunch Alignment	1
Beam Pipe Temperature Monitors	70

Table 7: Interaction Region Instrumentation

Type	Quantity
Beam Position Monitors	78
Beam Loss Monitors	30
Crab Tilt Monitor	1
IP Orbit Correction	2
Beam Pipe Temperature Monitors	40