Plans for DAQ/Electronics Integration/Testing/Installation and needs for Off-Project Support

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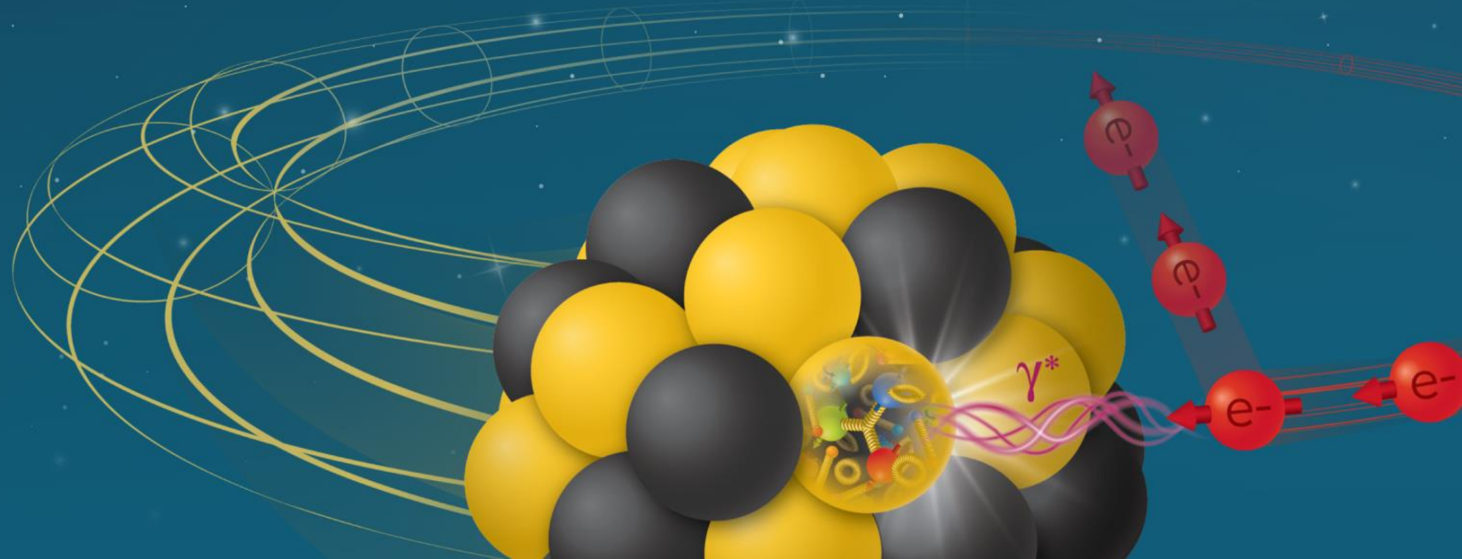
EIC Experimental Dependencies Review
August 22-23, 2024

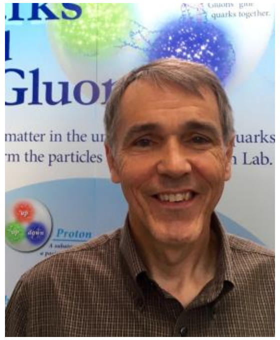
Electron-Ion Collider



About the Authors

Jeffery M. Landgraf

- L3 co-CAM for 6.10.09 (DAQ)
- Senior Technology Architect at Brookhaven National Laboratory
- Physics Ph.D. from University of Michigan, 1995
- Developed and supported the DAQ, Trigger and online computing systems for the STAR detector since 1999
- Co-Convener for ePIC Electronics and DAQ WG



David J. Abbott

- L3 co-CAM for 6.10.09 (DAQ)
- Staff Scientist at Jefferson Lab
- Nuclear Physics Ph.D. from UNC Chapel Hill, 1990
- Developed and supported the data acquisition systems for all JLab experiments as part of the Physics DAQ and Fast Electronics support groups (33 years).

Fernando Barbosa

- L3 CAM for 6.10.08 (Electronics)
- EIC Detector: Chief Electrical Engineer
- MSEE, BSEE, BS Physics [UFRJ (Brazil), UMass, SUNY, MIT]
- Chief Electrical Engineer, L3 CAM – JLab 12 GeV Hall D/GlueX.
- Joined JLab in 1990, after working at BNL on detector instrumentation for experiments at the AGS.
- Various patents on instrumentation, some in collaboration with NIH.

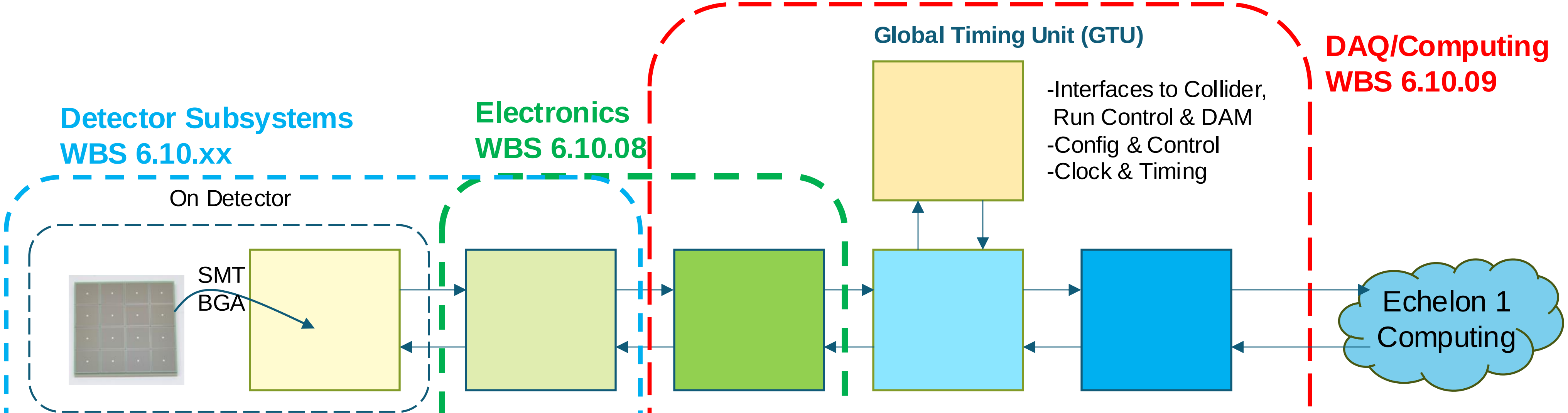
Charge Questions

1. Is BNL/JLab (EIC project, NPP-CAD, NPP-PO, other areas?) properly organized to manage and coordinate the ePIC detector scope (on and off-project) at this stage of the project?
2. Has the Project identified in sufficient details all the anticipated dependencies required for its success at this stage of the project?
3. Have the proposed responsible parties been identified and have the needs been communicated to the parties?
4. Are In-Kind contributions adequately clarified to identify any special requirements and needs of receiving the contributions and store & test them at the host laboratories?
5. Do the responsible parties have a credible plan to obtain the needed resources to satisfy the needs?
6. Are there risks identified and a mitigation plan developed in the event the dependency scope is not delivered on time? Are there risk trigger dates identified?
7. Are need-by dates for dependencies established and appropriate? Do they contain enough detail and visibility, such as the start of design, funding/resources identified, and work start and completion dates? Are they identified in the Project Plan (P6)?
8. Has the project identified the issues and risks associated with dependencies and are they adequately addressed?
9. Has the project identified the ES&H issues and risks and how are they being addressed?

Outline

- Overall scope – the ePIC readout chain
- DAQ and Electronics timelines
- Space needs
- Computing and Network infrastructure requirements
- Summary

ePIC Readout Chain



Name	Sensor	Adapter	Front End Board (FEB)	Readout Board (RDO)	Data Aggregation Module (DAM)	Computing
Design	Detector Specific	Detector Specific	Detector Specific	Few Variants	Common	Common
Function	Multi-Channel Sensor	-HV/Bias Distribution -HV divider -Interconnect Routing	-Amplification -Shaping -Digitization -Zero Suppression -Bias Control & Monitoring	-Communication -Aggregation -Formatting -Data Readout -Config & Control -Clock & Timing	-Computing Interface -Aggregation -Software Trigger -Config & Control -Clock & Timing	-Data Buffering – -Calibration Support -QA/Scalers -Collider Feedback -Event ID/Building -Software Filter -Monitoring
Attributes	MAPS, AC-LGAD MPGD, MCP-PMT SiPM, LAPPD	-Sensor Specific -Passive	-**ASIC/ADC** -Discrete -Serial Link	-**FPGA** -Fiber Link	-**Large FPGA** -PCIe -Ethernet	-**COTS** -Ethernet

Readout Scale

Detector Group	Channels					RDO	Fiber Pairs	DAM	Data Volume (RDO) (Gb/s)	Data Volume (To Tape) (Gb/s)
	MAPS	AC-LGAD	SiPM/PMT	MPGD	HRPPD/ MCP-PMT					
Tracking (MAPS)	16B					183	6046	7	15	15
Tracking (MPGD)				164k		160	160	5	27	5
Calorimeters	500M		100k			510	510	17	70	17
Far Forward		1.5M	10k			80	80	7	36	12
Far Backward	66M	128k	4k			60	82	14	301	16
PID (TOF)		6.1M				500	500	14	50	12
PID Cherenkov			318k		143k	1283	1283	32	1275	32
TOTAL	**16.6B**	**7.7M**	**432k**	**164k**	**143k**	**2816**	**2798**	**96**	**1774**	**109**

Readout Board (RDO) Flavors

Detector	Characteristics
TOF	Highest Timing Requirement (Generic)
dRICH	Small Footprint (VTRX+ optics)
ITS-3 (MAPS)	Detector side uses direct fiber (lpGBT/VTRX+)
Imaging Calorimeter	Integrated with ASTROPIX Sensor
Low Q Tracker	TimePix: High Rates, 20 TX fibers expected / RDO
Direct Photon Calorimeter	Pure 200MHz Streaming (bypass DAQ protocol)

- FEB electronics will be managed through individual Detector Subsystem Groups (DSG)
- RDO electronics "belong" to DSGs but development and testing will be done in conjunction with DAQ

DAQ/Online Schedule

- The DAQ and computing schedule is planned to be accelerated. A functional DAQ will be necessary for small scale detector testing and development.
- Computing resources will be staged to make purchases when the hardware is needed, taking advantage of price savings and performance improvements (**3 separate procurements throughout construction**).

Hardware and software development early in the construction phase will produce several DAQ releases with increasing functionality.

DAQ Releases:

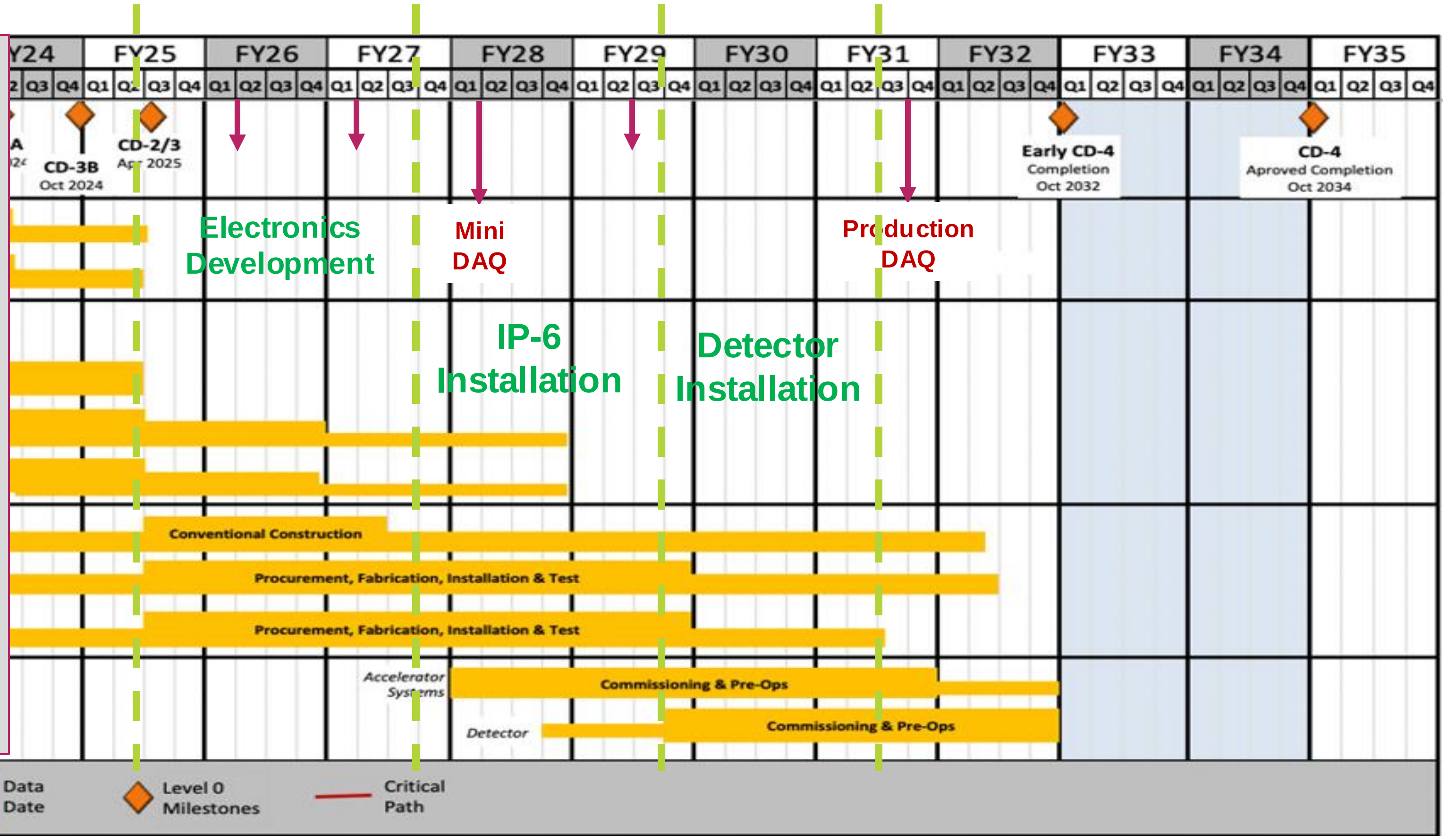
PicoDAQ FY26Q1
Readout test setups

MicroDAQ: FY27Q1
Readout detector data in test stand using engineering articles

MiniDAQ: FY28Q1
Readout detector prototypes using full hardware and timing chain

Full DAQ-v1: FY29Q2
Full functionality DAQ ready for full system integration & testing

Production DAQ: FY31Q3
Ready for cosmics



Electronics Resources – Design, Development, Construction

Detector System		Channels	SensorTechnology	Redout Technology	Institution
Si Tracking					
	3 vertex layers	7 m^2	MAPS	lpGBT, VTRX+	STFC, UK, ORNL
	2 sagitta layers	368 pixels	MAPS	lpGBT, VTRX+	STFC, UK, ORNL
	5 backward disks	5,200 MAPS sensors	MAPS	lpGBT, VTRX+	STFC, UK, ORNL
	5 forward disks		MAPS	lpGBT, VTRX+	STFC, UK, ORNL
MPGD Tracking					
	Barrel, e & H Endcaps	202 k	uRWELL, MicroMegas	SALSA	CEA, OMEGA, JLab
Forward Calorimeters					
	LFHCAL	63,280	SiPM	CALOROC	ORNL, Debrecen
	HCAL Insert	8 k	SiPM	CALOROC	ORNL, Debrecen
	pECAL W/SciFi	16,000	SiPM	Discrete	IU
Barrel Calorimeters					
	HCAL	7,680	SiPM	CALOROC	ORNL, Debrecen
	ECAL SciFi/Pb	5,760	SiPM	CALOROC	U Regina, ORNL
	ECAL Imaging Si ASTROPIX	500 M pixels	Astropix		KIT,NASA (GSFC), ANL
Backward Calorimeters					
	nHCAL	3,256	SiPM	CALOROC	ORNL
	ECAL (PWO)	2,852	SiPM	Discrete	IU, EEEMCAL Consortium
Far Forward					
	B0: 3 Crystal Calorimeter	135	SiPM/APD	Discrete	IU, JLab
	B0: 4 AC-LGAD layers	688,128	AC-LGAD Pixel	EICROC	IJCLab, OMEGA, BNL, ORNL, Rice
	2 Roman Pots (RP)	524,288	AC-LGAD Pixel	EICROC	IJCLab, OMEGA, BNL, ORNL, Rice
	2 Off Momentum (OMD)	294,912	AC-LGAD Pixel	EICROC	IJCLab, OMEGA, BNL, ORNL, Rice
	ZDC: Crystal Calorimeter	900	SiPM/APD	Discrete	IU, JLab
	ZDC: HCAL	9,216	SiPM	CALOROC	ORNL, Debrecen, JLab
Far Backward					
	Low Q Tagger 1	33,030,144	Timepix4		U. Glasgow
	Low Q Tagger 2	33,030,144	Timepix4		U. Glasgow
	Low Q Tagger 1+2 Cal	420 (2x210)	SiPM	CALOROC	U. York
	2 Lumi PS Calorimeter	3,360 (2x1680)	SiPM	Discrete	U. York
	2 Lumi PS Tracker	128,000 (2x64,000)	AC-LGAD Strip	FCFD/EICROCx	FNAL, OMEGA, Hiroshima, NTU, ORNL, UIC, UH, Rice, KSU, Tokyo
	Lumi Direct Photon Calorimeter	100	SiPM	Flash250	AGH Krakow, JLab
PID-TOF					
	Barrel bTOF	2,359,296	AC-LGAD Strip	FCFD/EICROCx	FNAL, OMEGA, Hiroshima, NTU, ORNL, UIC, Rice, BNL, KSU, Tokyo
	Hadron Endcap fTOF	3,719,168	AC-LGAD Pixel	EICROC	IJCLab, OMEGA, BNL, ORNL, Rice
PID-Cherenkov					
	dRICH	317,952	SiPM	ALCOR, VTRX+	INFN (BO, FE, TO)
	pfRICH	69,632	HRPPD	FCFD/EICROCx	BNL, FNAL, JLab
	hpDIRC	73,728	MCP-PMT or HRPPD	FCFD/EICROCx	BNL, FNAL, JLab

- Institutions – expressions of Interest.
- BNL, JLab – Support as needed.
- Covering - Adapters, FEBs, RDOs

ASIC Development

- SALSA
  (CEA-Saclay, U. Sao Paulo)
- CALOROC
  (OMEGA/IN2P3/ORNL)
- EICROC
  (OMEGA/IN2P3/IJLab/CEA-IRFU/AGH)
- FDFC
  (FNAL)
- ALCOR
  (INFN – BO, TO)

Space Requirements for Electronics

- Although there are no current firm commitments yet, it is anticipated that the production tests and integration of the Front-End electronics (FEB) into the detectors will be performed by groups and institutions associated with each of the sub-detectors:
  - Production of ASICs, FEBs and RDOs - by industry.
  - Production tests of ASICs and FEBs – by groups associated with each of the sub-detectors. Project support from BNL and Jlab.
  - Production tests of RDOs – mostly at BNL with Project support from BNL, Jlab and Det. groups.
  - Integration and System tests – all at BNL with Project support from BNL, Jlab and Det. groups.

- The FEBs will be shipped to BNL with each of the sub-detectors.

- A couple of dedicated labs for electronics testing and storage space for about 20 - 30 boxes of different sizes would be needed (off-project).

DAQ Space Requirements

- DAM board testing (~140 boards)
  - ~10 feet of five foot shelves
  - Unit Testing (racks, servers and related hardware)

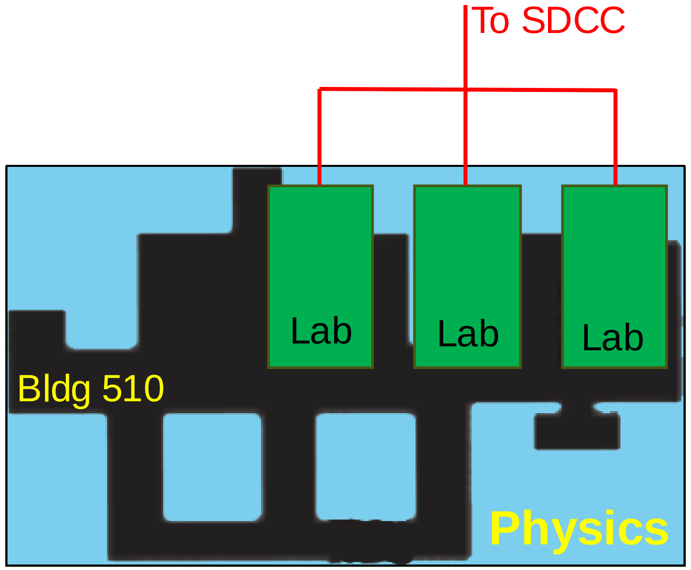
- RDO board testing (~3000)
  - ~300 boxes of electronics @ 10”x10”x20”   ~ 40 feet of 5 foot shelves
  - Unit testing (see table)
  - Delivery / storage / spot unit testing at BNL

Count	Firmware	Hardware Design	Unit Testing at BNL?
620	TOF (EICROC)	TOF	Yes
1240	dRICH (ALCOR)	INFN	No
510	Calorimeters (CALOROC)	(as per TOF)	Yes
160	MPGDs (SALSA)	(as per TOF)	Yes
32	Low Q2 (Timepix)	Low Q2	No
100	Discrete	(as per TOF	Yes
160	MAPS	CERN	Yes
340	Astropix	NASA	Yes
100 channels FLASH	Direct Photon	JLAB	no

- Installation / integration
  - Storage of components until installation is possible
  - Detector level: Assumed to take place in detector testing spaces (no additional space request)
  - Full experiment level: Assumed to take place in IP-6 Assembly building (no additional space request)

DAQ/Electronics Lab Space Requirements cont…

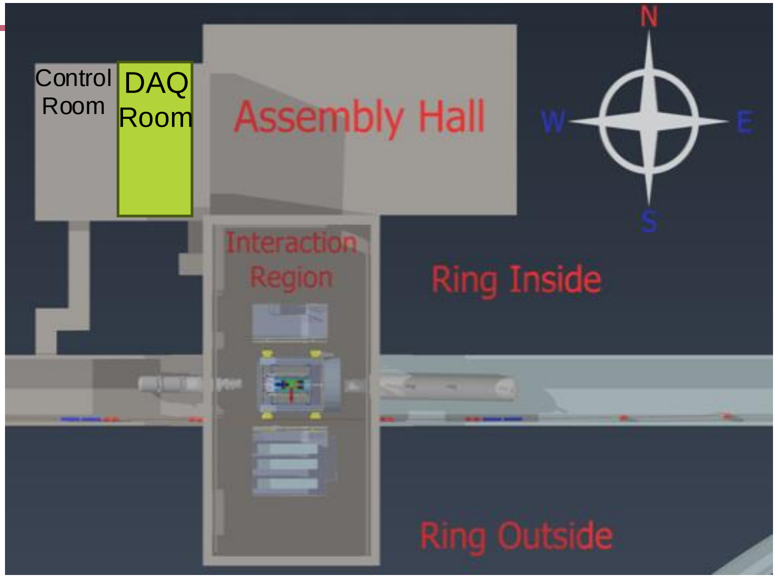
- Three Medium / Large labs (e.g. STAR labs 1-231, 1-236, 1-238 or similar.) **[Needed from end of RHIC operations: 2026 – 2034+]**
  - Work spaces for BNL and techs and engineers
  - Storage for Felix / RDO that are waiting to be installed in detector (40 feet of 5 foot shelving)
  - Storage for Scopes / tools / supplies for electronic work
  - Storage for power supplies, cables, spare crates
  - Dedicated DAM test stands (bench, chair, space for electronics rack ~ 10’ x 10’ space with power and network)
  - Dedicated RDO test stands (bench, chair, space for electronics rack ~ 20’x10’ space with power and network)
  - Space for debugging / servicing other electronics components – power supplies, crates.

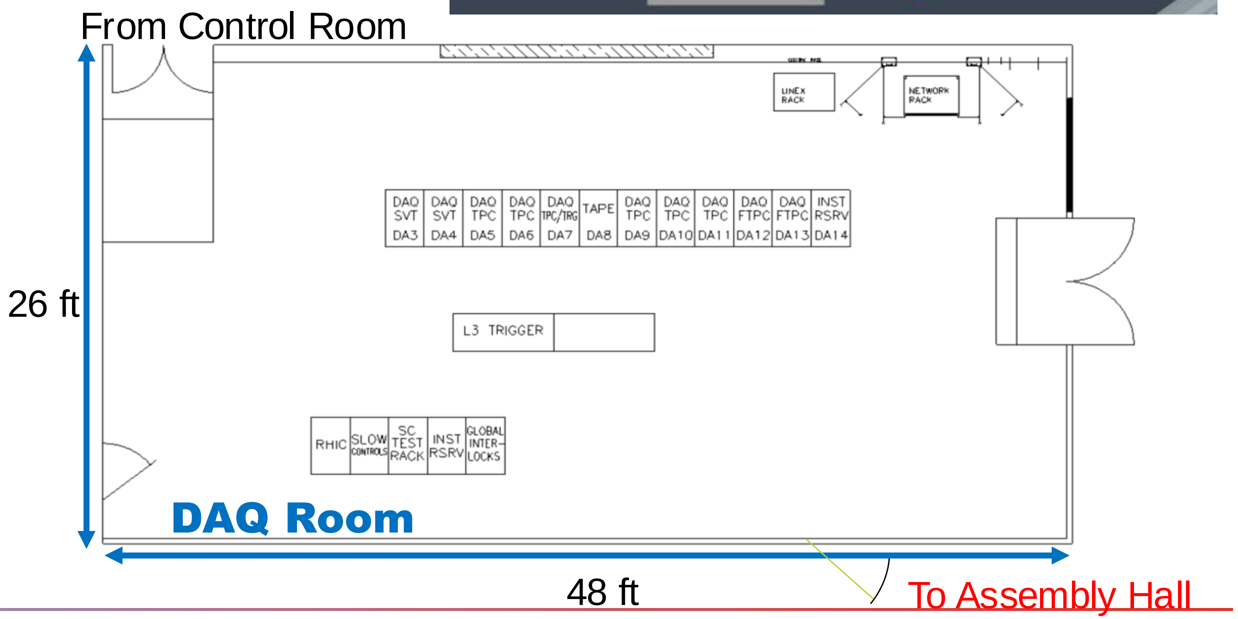


- The first stage of computing purchases would be ideal to install in dedicated EIC racks in the SDCC.
  - All 3 Labs would have high bandwidth access to DAQ computing (100Gb).
  - Direct fiber access to an EIC switch/router in SDCC would be ideal
  - **Initially 2 racks in SDCC (sometime in 2026 or early 2027)**

Scale of Echelon 0 (DAQ) Computing

- Current Project estimates provide for roughly a total of 20 racks/cabinets
  - 200+ total CPU nodes
  - ~6000 fibers from the IR (~150m run)
  - 100-110 DAM Servers (all must reside in the DAQ Room)
- Expected total power requirements are between 300-350kW.
- Current power infrastructure at IP-6 for the DAQ Room is sufficient (two 330kW taps avaiable):
  - Some additional power distribution will be needed
  - Existing cooling infrastructure needs to be updated.
  - Overall cooling efficiency will need to be improved if everything will be housed locally (DAQ Room).
- Default option would be splitting Echelon 0 resources between IP-6 and the BNL Data Center (SDCC).





IP-6 Off-Project Infrastructure Support (for DAQ)

- Control Room overhaul should include total replacement of old consoles and replacement with sufficient workspaces to support the 24+ detector subsystems and their associated control systems

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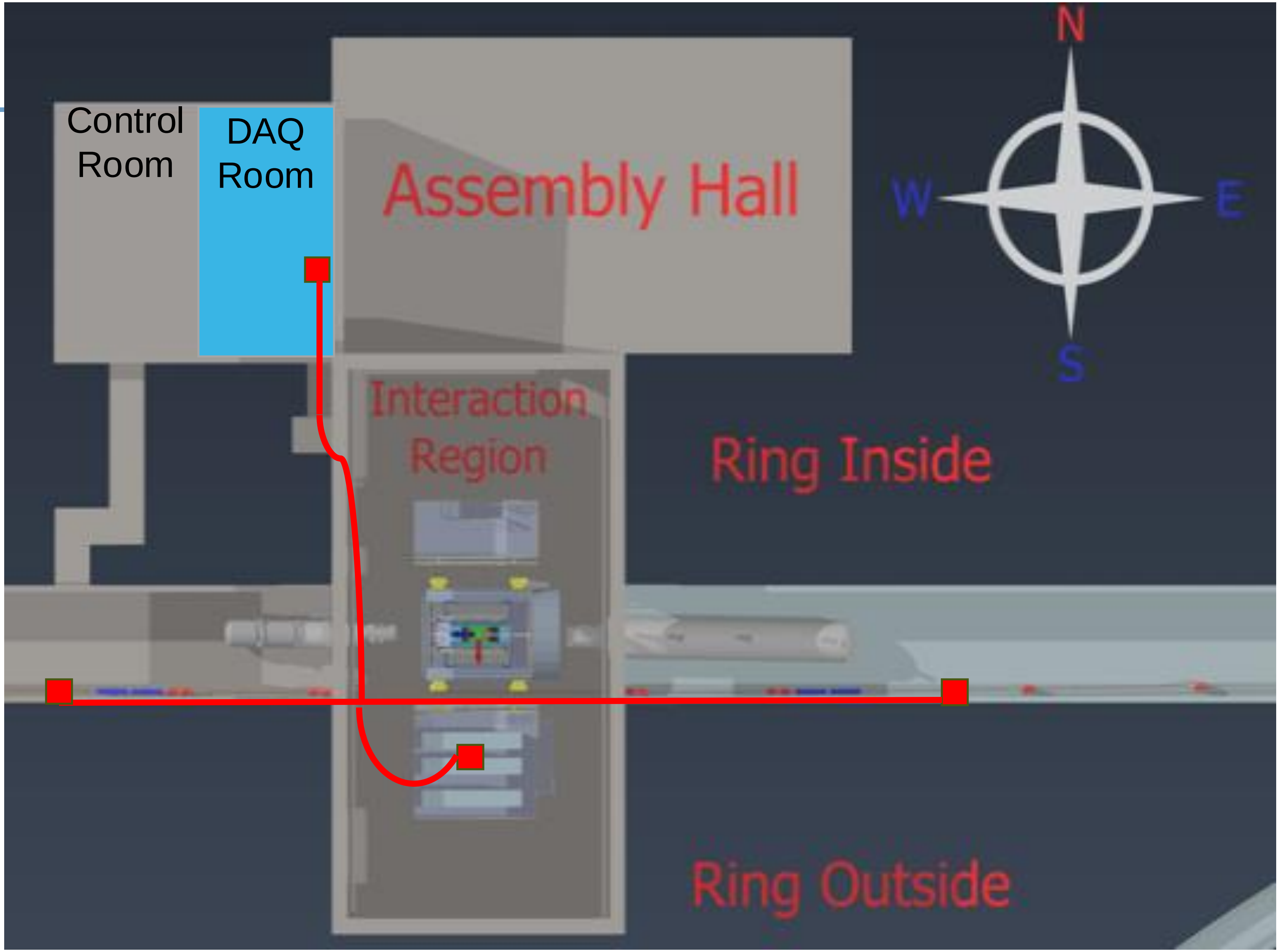
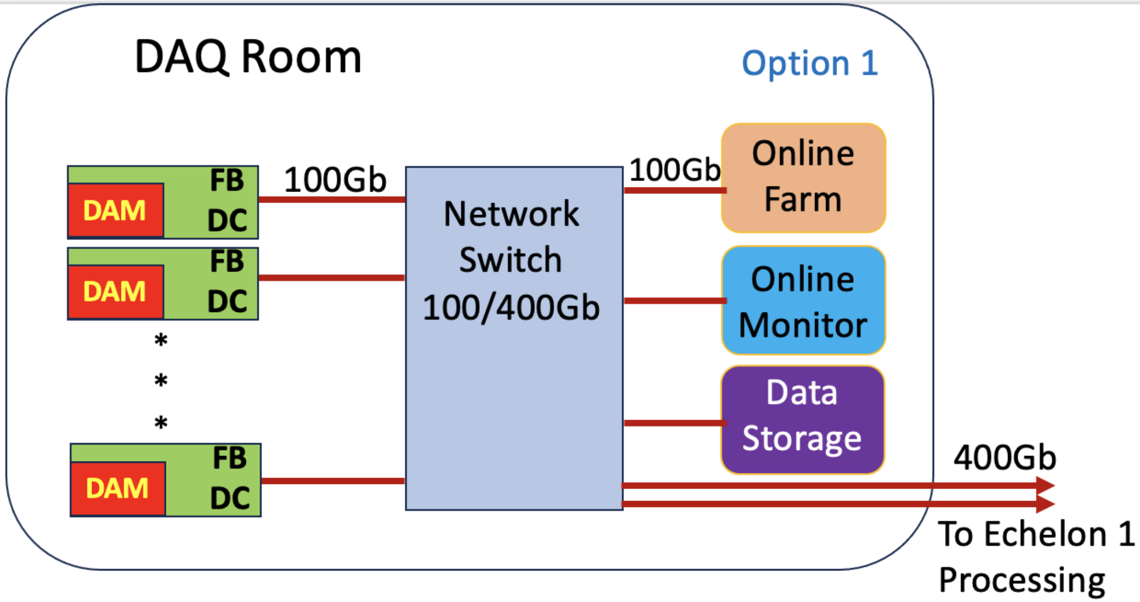
- DAQ room upgrades (cooling and power) will be dependent on how much of the online computing is housed there.

- Updates to available cable tray routing and availability of Riggers are needed to support pulling some 6000+ fibers to three different areas of the Interaction region (south platform and tunnels).



Echelon 0 Computing Options

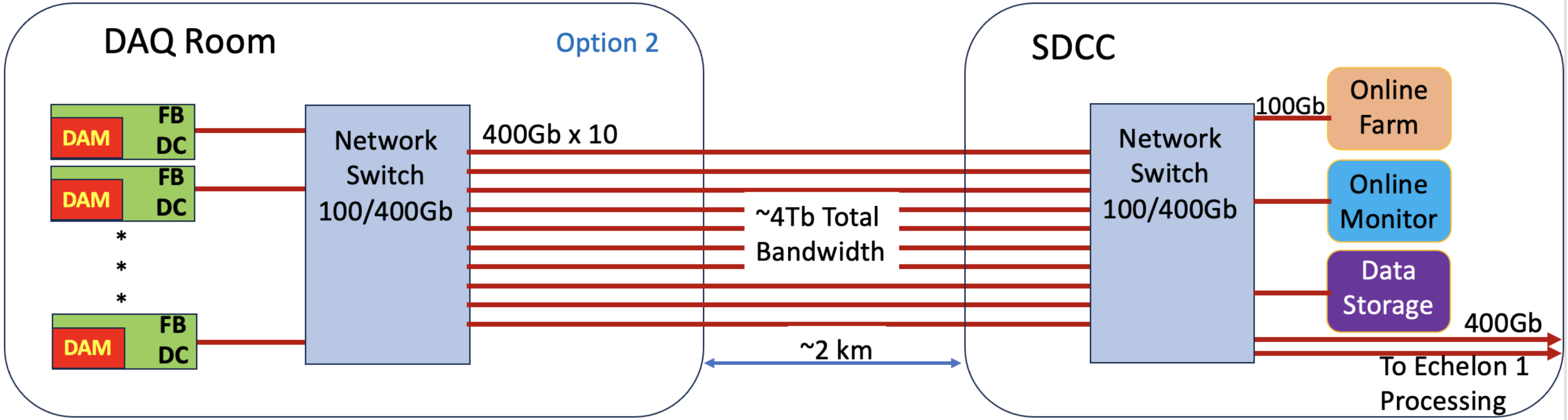


ePIC DAQ/Online Computing

Option 1: Fully in DAQ Room

Option 2: Split with BNL Data Center

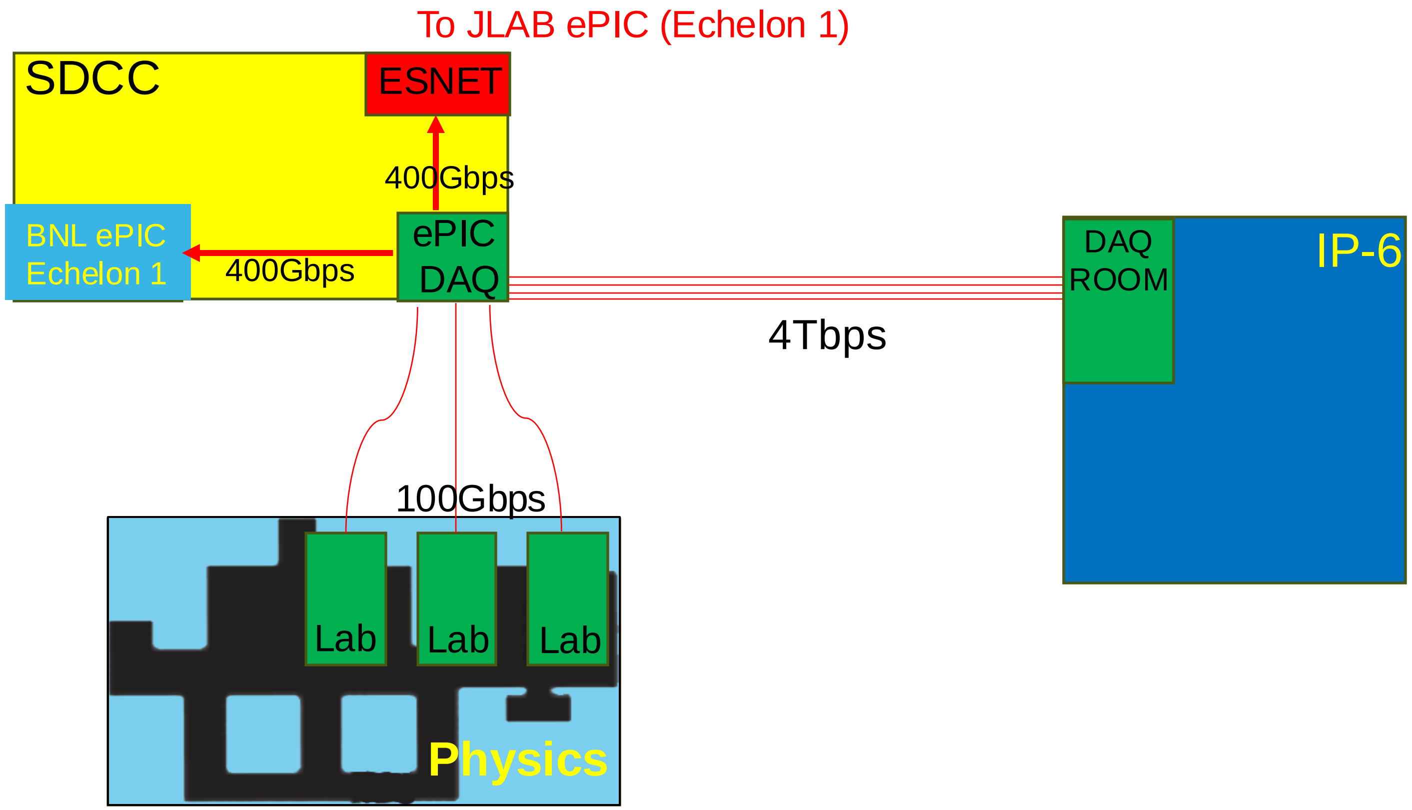
(with Option 2 we need off-project support for enough direct fiber between IP-6 and SDCC)



Network Infrastructure

ePIC DAQ and computing will require network connectivity at BNL between resources in IP-6, SDCC as well as development labs that is bandwidth guaranteed and minimizes routing.

- Early DAQ & Electronics development will be in labs (Physics, early 2026-).
- Initial computing needs for development would best be placed in a central location (SDCC, initially 1-2 racks, by Q2 FY27).
- As construction and installation ramps up at IP-6 additional Echelon 0 computing resources can be placed in both sites (5-6 racks at SDCC, Q2 FY29).
- For production running it is important to all network infrastructure in place (Q1 FY32) and have equal and transparent network access from SDCC to both Echelon 1 sites (BNL and JLAB)



Summary

- Electronics/DAQ/Computing are critical support items for all detector subsystem development plans.

- The default plan for online computing (Echelon 0) is to split resources between IP-6 and SDCC
  - Important to have sufficient direct fiber access between these two sites.

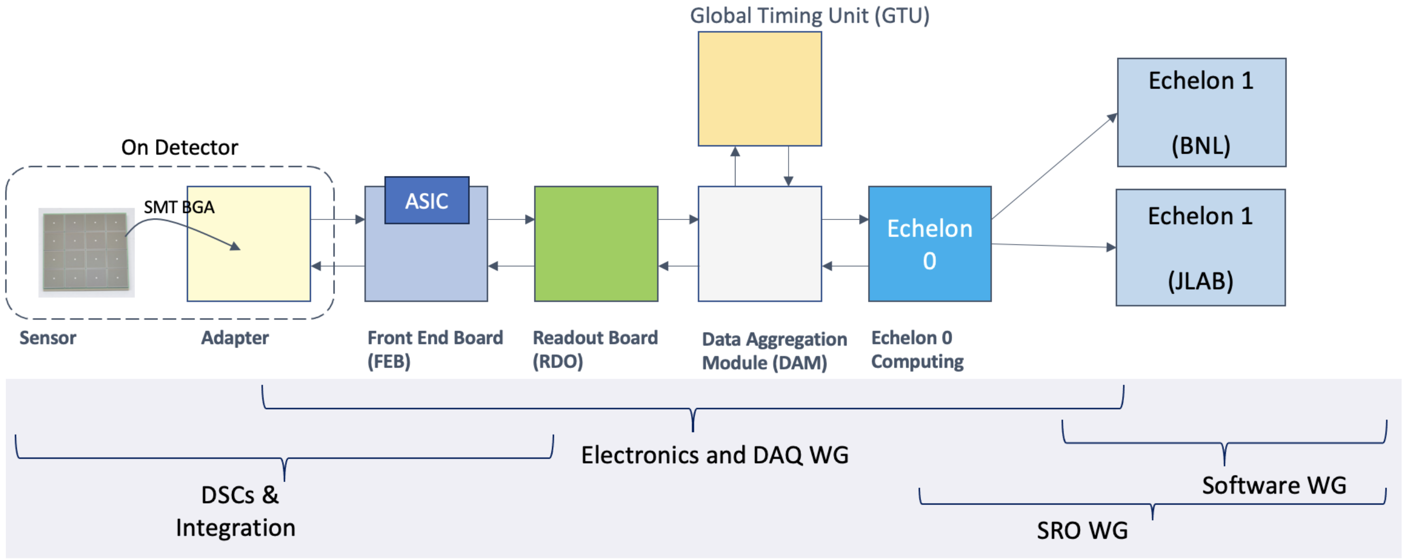
- The general construction timeline and off-project needs at BNL can be broken down in 3 stages.
  - Electronics/hardware development and testing: requiring adequate BNL Lab space, and rack space in SDCC starting early 2026.
  - DAQ fiber, IP-6 Network and computing hardware installation: requiring IP-6 Infrastructure upgrades (Control, DAQ rooms) and rigging support, completed by Q2 FY29.
  - Detector installation at IP-6 and final electronics/DAQ/computing installation: upgraded network infrastructure between IP-6 and SDCC should be available before the end of detector installation (April 2031).

- Making adequate lab space available for DAQ/Electronics development in a timely manner after shutdown of RHIC operations will be the most effective to mitigate any future schedule delays.

Backup Slides

EIC Streaming Readout (SRO) Community

- **The EIC Streaming Readout (SRO) Consortium**
  - Formed in 2018 with the goals of engaging the nuclear physics community to explore a streaming architecture for the EIC detector.
  - Led to adoption of SRO for the Yellow Report and the physics program for EIC.
- **ePIC Electronics/DAQ Working Group**
  - **Conveners: F. Barbosa (JLab), J. Huang (BNL), J. Landgraf (BNL)**
  - Regular meetings to focus on design and requirements specifically for the new ePIC detector
  - Interface to detectors, readout, DAQ, online processing, monitoring and control.
- **ePIC Software/Computing Working Group**
  - **Conveners: M. Diefenthaler (Jlab), S. Joosten (ANL), T. Wenaus (BNL), W. Deconinck (UM)**
  - Coordinate software development for EIC physics
- **ePIC Software/Computing SRO DAQ Working Group**
  - **Conveners: M. Battaglieri (JLab), J. Huang (BNL)**
  - Streaming Reconstruction



ASIC Timeline – (H2GCROC, ALCOR, EICROC, CALOROC, FCFD, SALSA)

- Development through Construction (not to scale)