



# HL-LHC Installation & Integration NSF Scope

Hal Evans



Indiana University

US ATLAS Ops Program Review Rehearsal

29-Aug-2024



# Outline



- **Background Information**
  - ATLAS HL-LHC Upgrade and the US Contribution
  - Installation & Integration Planning
  - Phases in Transition to Stable Operations
  - Project-Supported I&I (DOE)
- **Proposed Scope for NSF Operations-Supported I&I**
  - US NSF Scope I&I activities
  - Bottom-up estimate of I&I needs
- **I&I Risks**
  - Estimate of impact on I&I scope
- **Conclusions**



# ATLAS HL-LHC Upgrade



## Liquid Argon Calorimeter (LAr)

- electronics only - 40 MHz r'dout

## Tile Calorimeter (Tile)

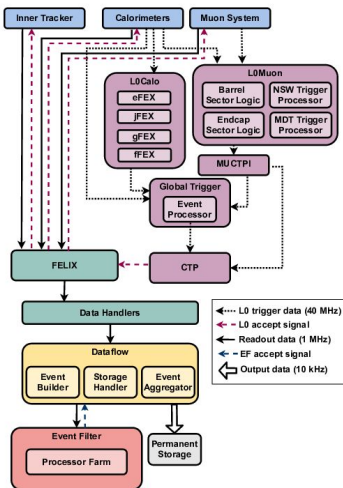
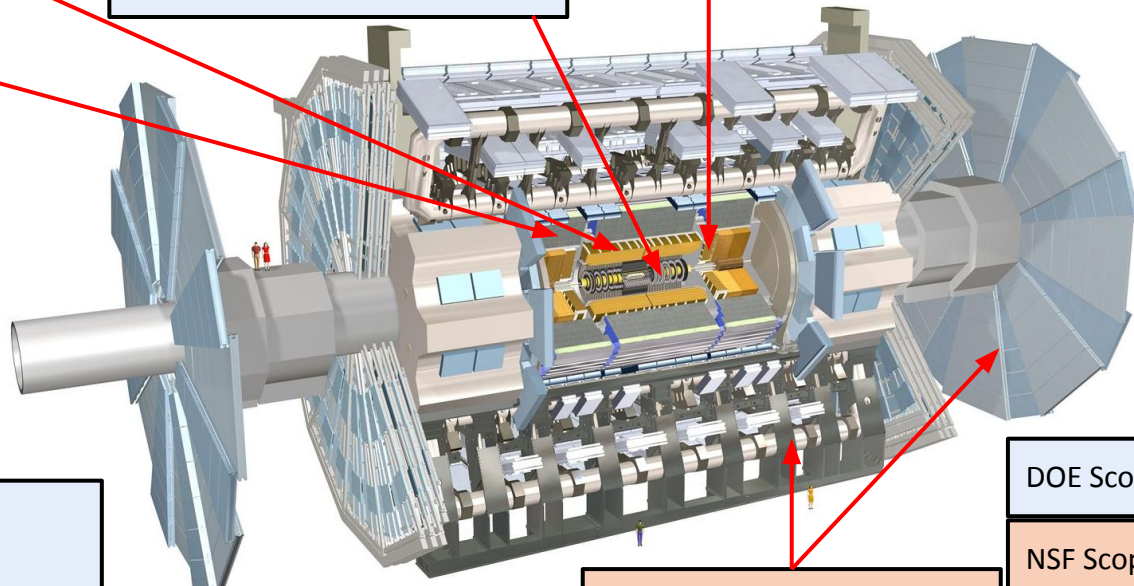
- electronics only - 40 MHz r'dout

## Inner Tracker (ITk)

- Pixel & Strips Detectors
- Mechanics & Electronics

## High Granularity Timing Detector (HGTD)

- improve pileup rejection at high eta



## Trigger & DAQ (TDAQ)

- 1 MHz L0 Trigger
- EF tracking trigger
- new DAQ & dataflow

## Muon Spectrometer (Muon)

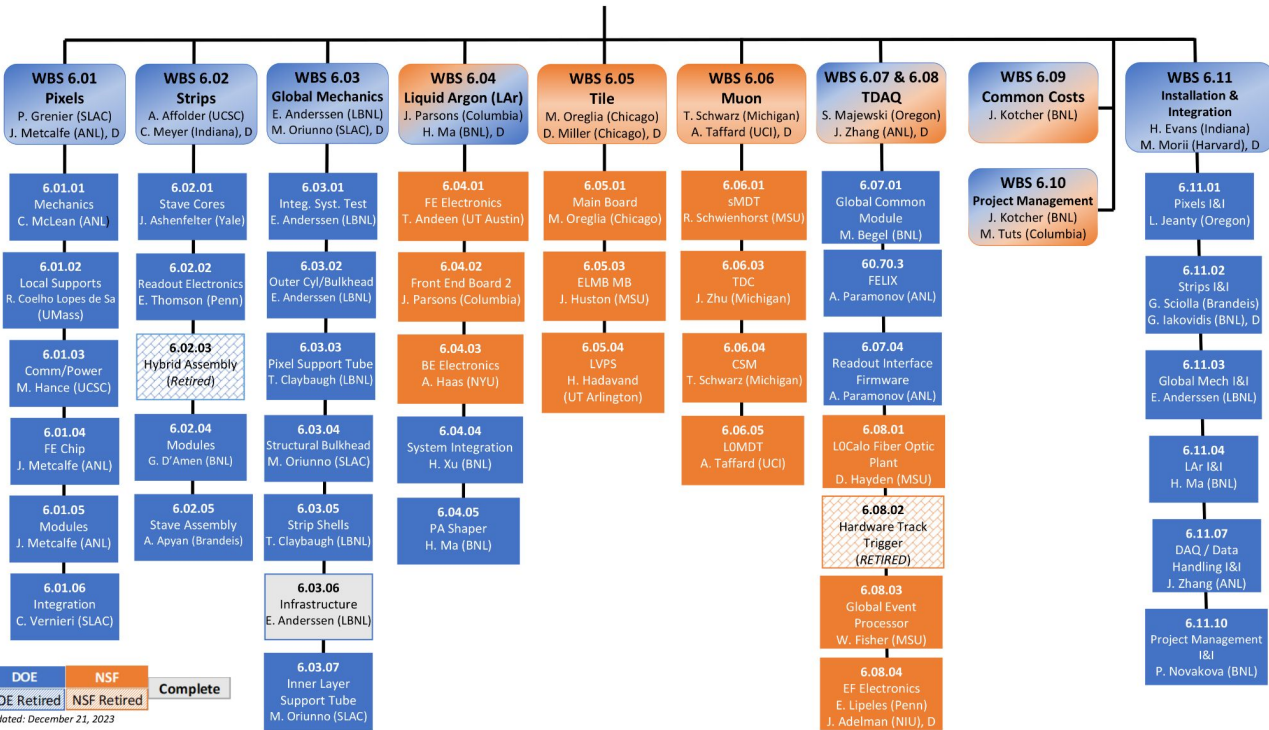
- add chamber coverage
- replace electronics

DOE Scope

NSF Scope



# US ATLAS HL-LHC Upgrade Project



	DOE (M\$)	NSF (M\$)
<b>Base Cost</b>	<b>173.3</b>	<b>65.6</b>
Actuals (Jul-24)	107.1	30.9
Cost to Go	66.2	34.7
<b>Funding</b>	<b>200</b>	<b>82.8</b>
Contingency	26.7	17.2
Cont. % on CTG	40%	50%

Updated: December 21, 2023



# NSF HL-LHC Scope



- NSF supports critical scope for the ATLAS HL-LHC Upgrade
  - US plans for NSF-scope I&I are well-aligned with ATLAS needs

WBS	Deliverable	Institutes [& BCWS from May RLS]
<b>6.4</b>	<b>Liquid Argon</b>	<b>John Parsons (Columbia, L2 Manager); Hong Ma (BNL, Deputy) [\$22.7M]</b>
6.4.1	Front End Electronics	Columbia, SMU, UT Austin
6.4.2	Front End Board 2	Columbia, Pittsburgh
6.4.3	Back End Electronics	Arizona, Stony Brook, NYU, SMU, Columbia
<b>6.5</b>	<b>Tile Calorimeter</b>	<b>Mark Oreglia (Chicago, L2 Manager); David Miller (Chicago, Deputy) [\$5.4M]</b>
6.5.1	Main Board	Chicago
6.5.3	ELMB 2 Motherboard	Michigan State University
6.5.4	Low Voltage Power Supply	NIU, UT Arlington
<b>6.6</b>	<b>Muon</b>	<b>Anyes Taffard (UC Irvine, L2 Manager) [\$14.9M]</b>
6.6.1	sMDT Chambers	Michigan, Michigan State University
6.6.3	TDC	Michigan
6.6.4	Chamber Service Module	Michigan
6.6.5	LOMDT Trigger	Boston, UMass, UC Irvine
<b>6.8</b>	<b>Trigger</b>	<b>Stephanie Majewski (Oregon, L2 Manager); Jinlong Zhang (ANL, Deputy) [\$12.4M]</b>
6.8.1	L0Calo	Michigan State University
6.8.3	Global Event Processor	Chicago, Pittsburgh, Indiana, MSU, Oregon, SMU, Stanford
6.8.4	Event Filter Tracking	Chicago, Penn, Illinois, Arizona, UC Irvine, NIU

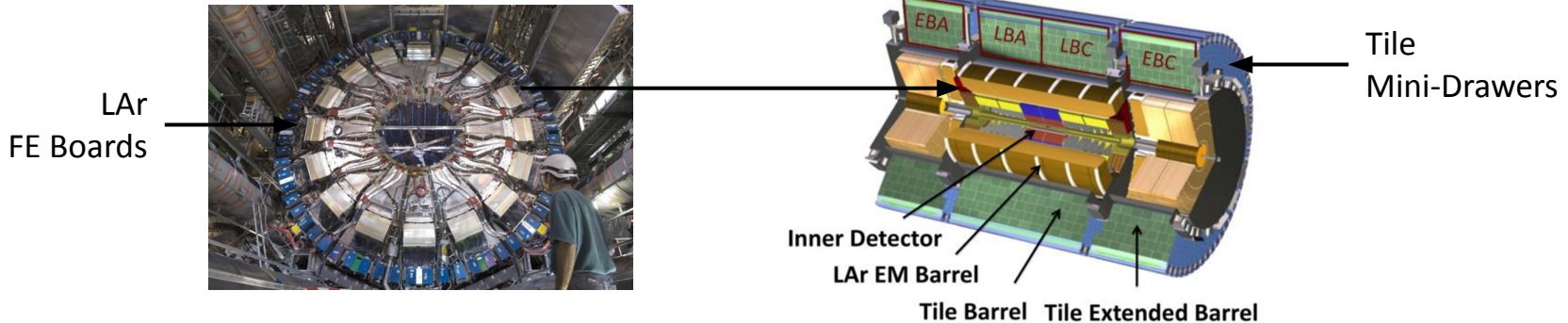


# ATLAS I&I Planning



- Installation & Integration have been important considerations in the ATLAS HL-LHC Upgrade since its conception
  - Main drivers: ITk readiness, installation of new Muon chambers
  - Overseen by: ATLAS Technical Coordination (UX15), Detector Integration Group (integration)
- Planning for I&I is now in high gear
  - Not only activities in the Pit, but also integration activities that prepare us for Installation
    - The latter are overseen by the Detector Integration Group
- I&I activities have already started
  - Mainly preparations for the assembly of the ITk on the surface (SR1)
- Latest ATLAS-level Installation Schedule is very tight
  - Adapted to new May-2029 end-date of LS3
    - Several options being considered
    - But further changes to the start and/or end of LS3 have not yet been considered
  - Strongly impacted by ongoing ITk delays
    - Detailed study ⇒ ITk must be installed during LS3 (not enough time in EYETS)

- **Liquid Argon Calorimeter**
  - Installation/Connection/Test of front-end electronics (1524 FEB2)
  - Installation/Test of back-end electronics in counting room (USA15)
  - Commission overall readout system
  
- **Tile Calorimeter**
  - Installation/Test of mini-drawers on detector
  - Full system commissioning
  - Project oversight: Project Engineer (Seyedali), Upgrade Project Leader (Usai)

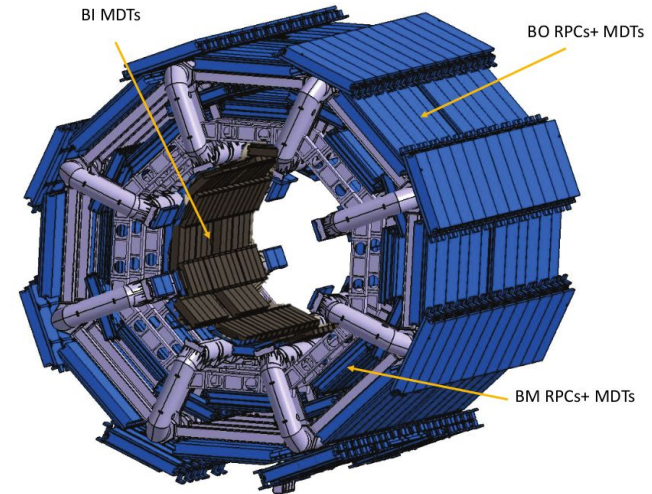


- Muon System

- Install/Test sMDT/RPC modules & electronics on the detector
- Install/Test LOMDT in counting room (USA15)
- LOMDT commissioning with cosmics

- Trigger

- Fiber Optics Exchanges (FOX)
  - installation and validation in USA15
- Global Trigger Firmware
  - Commissioning in USA15
- EF Tracking system
  - EF integration in batches
  - Full EF commissioning in loopback
  - Full EF commissioning with cosmics/beam







# Transition to Stable Operations



Phase	Description	Funding
Deliverables	Produce, Test, Ship to CERN (or final destination)	DOE: US HL-LHC Project NSF: MREFC
Enhanced Testing	Additional tests with full “vertical slices” on the surface <ul style="list-style-type: none"><li>Now feasible due to better understood ATLAS production end-game</li></ul>	NSF: MREFC Scope Opportunity[1]
Install & Test	Installation and testing of US deliverables in their final locations in ATLAS	DOE: US HL-LHC Project NSF: Operations
Commiss. w/ Cosmics	Running the full ATLAS detector after cavern closeup	DOE[1]/NSF: Operations
Commiss. w/ Beam[2]	Extra effort required to understand operations & calibration with early beams	DOE/NSF: Operations

[1] NSF approval required to exercise Scope Opportunity

[2] DOE Cosmics Commissioning estimate in progress - largely scientific effort

[3] Beam Commissioning not included here - largely scientific effort for both DOE/NSF



# NSF I&I Schedule



System/Phase	FY25				FY26				FY27				FY28				FY29			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<b>LAr/NSF</b>																				
Deliverable Completion	■				■				■											
Surface Integration	■				■				■											
Install/Test									■				■							
Cosmics Commiss													■				■			
<b>Tile</b>																				
Deliverable Completion	■				■				■											
Surface Integration	■				■				■											
Install/Test					■				■				■							
Cosmics Commiss													■				■			
<b>Muon: Detector</b>																				
Deliverable Completion	■				■															
Surface Integration	■				■															
Install/Test					■				■											
<b>Muon: LOMDT</b>																				
Deliverable Completion	■				■				■											
Surface Integration	■				■				■											
Install/Test					■				■				■							
Cosmics Commiss													■				■			
<b>Trigger: Optical Plant</b>																				
Deliverable Completion	■				■															
Surface Integration	■				■								■							
Install/Test													■		■					
<b>Trigger: GEP</b>																				
Deliverable Completion	■				■				■											
Surface Integration	■				■				■											
Install/Test					■				■				■							
Cosmics Commiss																	■			
<b>Trigger: EF Tracking</b>																				
Deliverable Completion	■				■				■											
Surface Integration	■				■				■				■							
Cosmics Commiss																	■			

MREFC supported  

 Operations supported

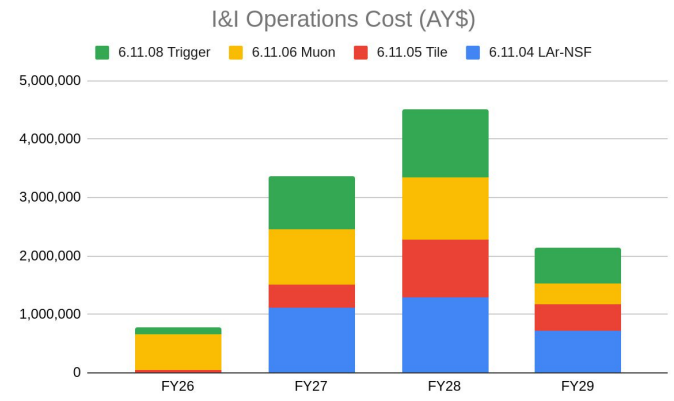


# NSF I&I Cost Estimate



- Bottom-Up schedule & cost estimate produced
  - Google Sheet: Tasks at the “planning package” level
  - Effort and Duration estimates based on experience from Phase-I Upgrade and Original ATLAS Installation

System	SUM of Total Cost (AY\$)				
	FY26	FY27	FY28	FY29	Grand Total
6.11.04 LAr-NSF		1,110,415	1,296,742	712,186	3,119,343
6.11.05 Tile	47,528	392,381	979,206	457,679	1,876,794
6.11.06 Muon	618,288	953,899	1,065,487	354,667	2,992,341
6.11.08 Trigger	114,299	915,089	1,168,484	608,013	2,805,885
<b>Grand Total</b>	<b>780,116</b>	<b>3,371,784</b>	<b>4,509,919</b>	<b>2,132,545</b>	<b>10,794,364</b>





# I&I Risks



- Risk Register for I&I Activities: [docdb #196](#) (review/p2-lhc)
  - Individual sub-system risks affecting I&I
  - Additional risks if we are not able to exercise “enhanced surface testing” Scope Opportunities
    - Compare to total estimated cost of Enhanced Surface Testing: \$3,376k

NSF System	Impacts at CL 90%		No Enhanced Testing	
	Cost (k\$)	Max Delay (mo)	Added Cost	Max Delay (mo)
6.11.4 LAr/NSF	507	4.0	519	9.0
6.11.5 Tile	102	2.0	1,054	17.4
6.11.6 Muon	988	6.9	1,462	11.4
6.11.8 Trigger	754	9.6	2,635	16.8
<b>NSF Total</b>	<b>2,351</b>	<b>9.6</b>	<b>5,671</b>	<b>17.4</b>

- Not yet captured in the Risk Register

- Impact of extension of LS3
  - assume LS3 ends May 2029
- Impact of extension of Run3
  - assume LS3 starts Dec 2025
  - Simple shift in start of I&I activities tested
    - See presentation by S.Rajagopalan

System	Pre-Install Burn Rate (k\$/mo)	Post-Install Burn Rate (k\$/mo)
LAr	65	110
Tile	91	83
Muon	90	56
Trigger	52	89



# Conclusions



- **Planning for HL-LHC Installation & Integration is in full swing**
  - I&I activities have already started for ITk
  - US NSF-scope I&I is well-integrated into overall ATLAS plans
- **First Bottom-Up Estimate of HL-LHC NSF Scope I&I**
  - Task effort and durations based on Phase-I and Original ATLAS
  - Total I&I funding required: \$10.8M (FY26 - 29)
- **I&I Risk Analysis at Individual System Level**
  - Estimated impacts: cost ~\$2.4M ; schedule ~10 mo (90% CL)
  - Additional impact if unable to exercise Enhanced Testing Scope Opportunities: ~\$5.7M (90% CL)
  - Starting to quantify impacts of further shifts in LS3 start and end
- **First US NSF-scope I&I activities start in spring 2026**



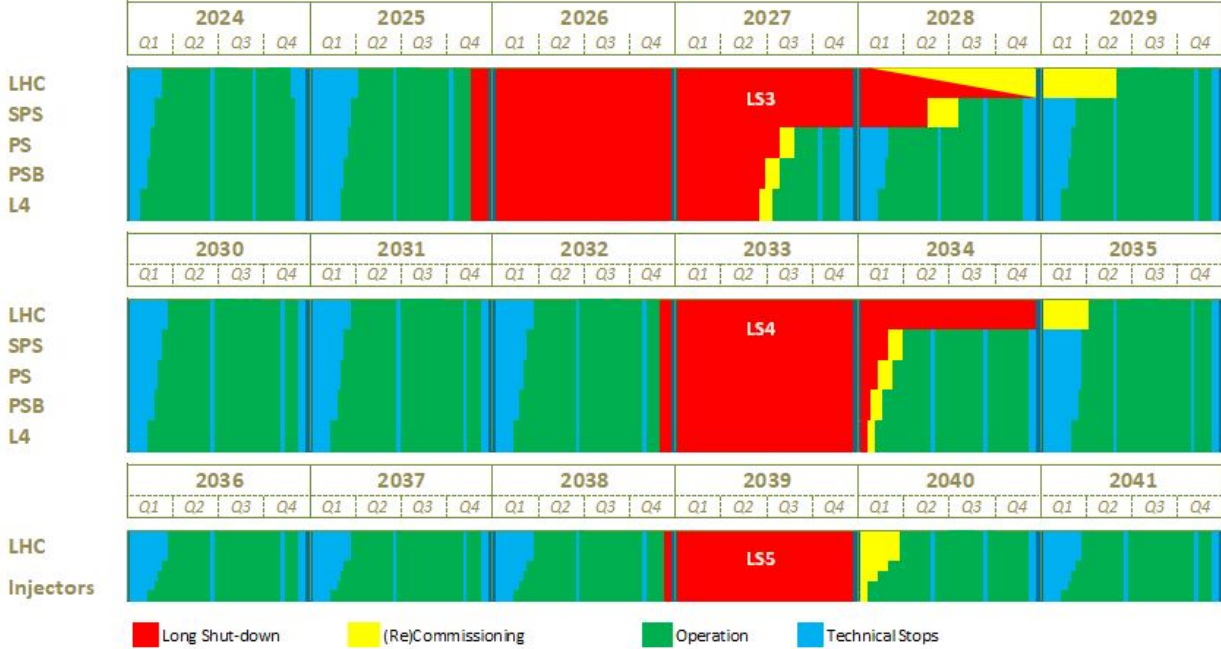
# BACKUP



# CERN Master Schedule



Long Term Schedule for CERN Accelerator complex



- Updated on 20-Jun-2024
  - [EDMS 2311633](#)
- LS3 Dates
  - Start: 17-Nov-2025
  - Cavern Closure: 14-May-2029



# NSF Scope Opportunity



- Costs related to Enhanced Surface Testing are shown below
  - Captured in HL-LHC NSF Scope Contingency & Opportunity document
    - [docdb #969 \(review/p2-lhc\)](#)

<i>SUM of Total Cost (AY\$)</i>					
<i>System</i>	FY25	FY26	FY27	FY28	Grand Total
6.11.04 LAr-NSF			308,502		308,502
6.11.05 Tile		233,768	677,578		911,346
6.11.06 Muon	987,557	107,511	77,987		1,173,055
6.11.08 Trigger		544,873		437,937	982,810
<b>Grand Total</b>	<b>987,557</b>	<b>886,152</b>	<b>1,064,067</b>	<b>437,937</b>	<b>3,375,713</b>





# I&I Funding: NSF Coop Agreement



- US ATLAS NSF Operations funding via a Cooperative Agreement
  - Current CA covers Feb-2022 - Jan-2027
  - Includes ~\$6.4M set aside for NSF-scope HL-LHC I&I

WBS	2/22-1/23	2/23-1/24	2/24-1/25	2/25-1/26	2/26-1/27	Total*
6.11.4 LAr/NSF	-	-	-	108,092	690,357	798,449
6.11.5 Tile	-	-	4,719	93,985	191,107	289,811
6.11.6 Muon	-	10,882	288,667	1,433,044	1,363,780	3,096,374
6.11.8 Trigger	-	-	49,690	849,473	1,321,514	2,220,677
<b>TOTAL</b>	-	<b>10,882</b>	<b>343,076</b>	<b>2,484,595</b>	<b>3,566,758</b>	<b>6,405,381</b>

\*Note: these numbers differ slightly from the final NSF CA award

- No CA funds have been used so far for NSF-scope I&I
  - In current base I&I plan first need for funds would be in Spring 2026