WBS 6.11
HL-LHC Installation & Commissioning

Hal Evans
US ATLAS HL-LHC Deputy Project Manager, I&C L2 Manager
Indiana University

U.S. ATLAS NSF Operations Program
NSF Proposal Panel Review
July 20-21, 2021

Outline

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  - ATLAS HL-LHC Upgrade
- Overview
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- Budget and Schedule
  - I&C schedule
  - Budget and Effort
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Introduction
ATLAS HL-LHC Upgrade

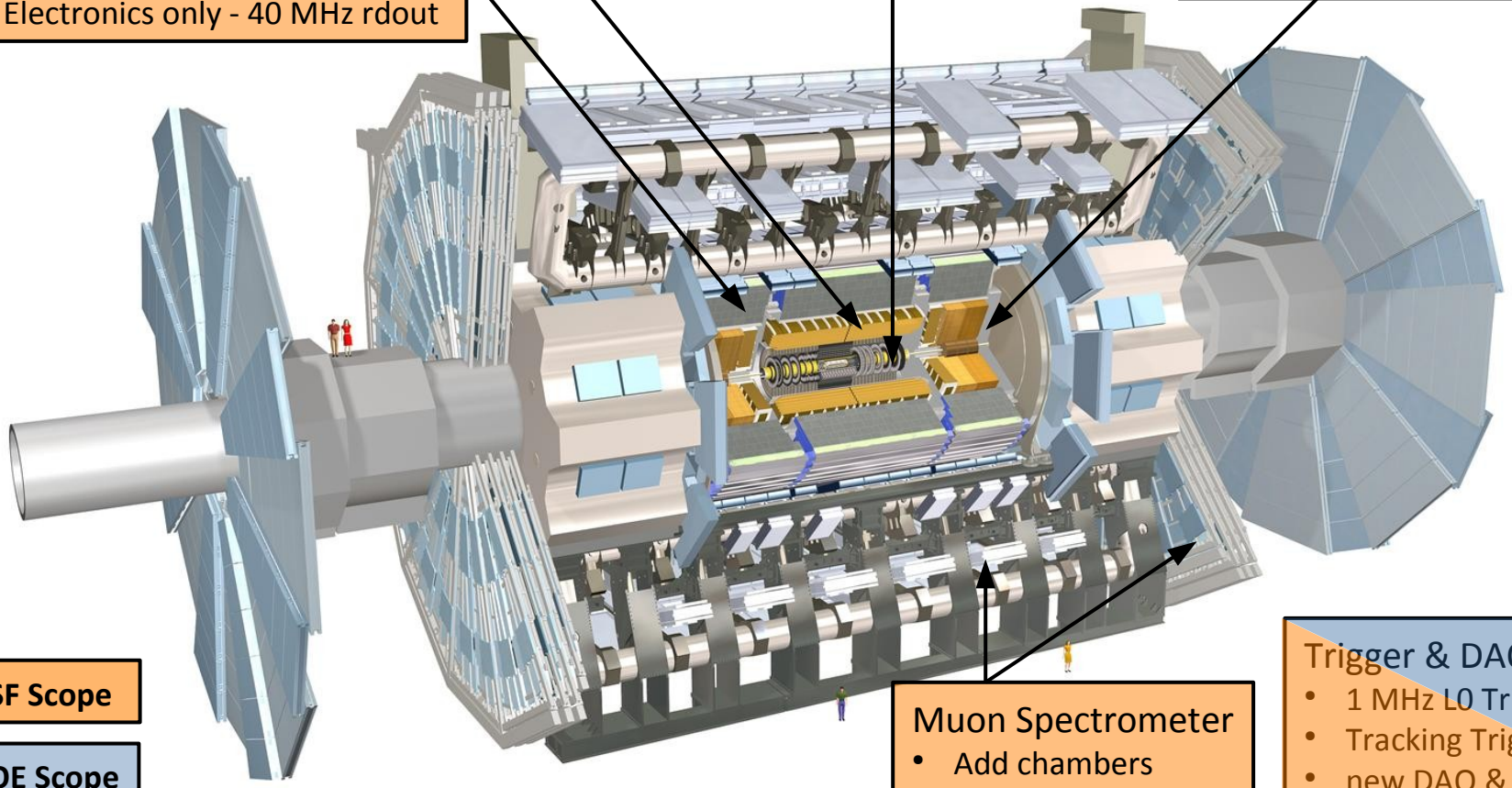
ATLAS HL-LHC Upgrade

Liquid Argon Calorimeter (LAr)
- Electronics only - 40 MHz rdout

Tile Calorimeter (LAr)
- Electronics only - 40 MHz rdout

New Inner Tracker (ITk)
- Pixel & Strips detectors
- Mechanics & Electronics

New High Granularity Timing Detector (HGTD)
- Improve pileup rejection at high eta



Muon Spectrometer
- Add chambers
- Replace electronics

Trigger & DAQ (TDAQ)
- 1 MHz L0 Trigger
- Tracking Trigger
- new DAQ & Dataflow

NSF Scope

DOE Scope

US ATLAS HL-LHC – NSF Scope

WBS		Deliverable	Institutes
6.4	**Liquid Argon**		**John Parsons (Columbia), Hong Ma (BNL, deputy)**
	6.4.1	Front End Electronics	Columbia, SMU, UTAustin
	6.4.2	Front End Board 2	Columbia
	6.4.3	Back End Electronics	Arizona, NYU, Stony Brook
6.5	**Tile Calorimeter**		**Mark Oreglia (Chicago), David Miller (Chicago, deputy)**
	6.5.1	Main Board	Chicago
	6.5.3	ELMB Motherboard	MSU
	6.5.4	Low Voltage Power Supply	NIU, UTArlington
6.6	**Muon**		**Tom Schwarz (Michigan), Anyes Taffard (Irvine, deputy)**
	6.6.1	sMDT Chambers	Michigan, MSU
	6.6.3	TDC	Michigan
	6.6.4	CSM	Michigan
	6.6.5	L0MDT Trigger	Boston, Irvine, U.Mass
6.8	**Trigger**		**Stephanie Majewski (Oregon), Jinlong Zhang (ANL, deputy)**
	6.8.1	L0Calo	MSU
	6.8.2	HW Track Trigger Processing	Arizona, Penn, Chicago, Illinois, *NIU*
	6.8.3	Global Trigger Algorithms	Chicago, Indiana, MSU, Oregon, Pitt

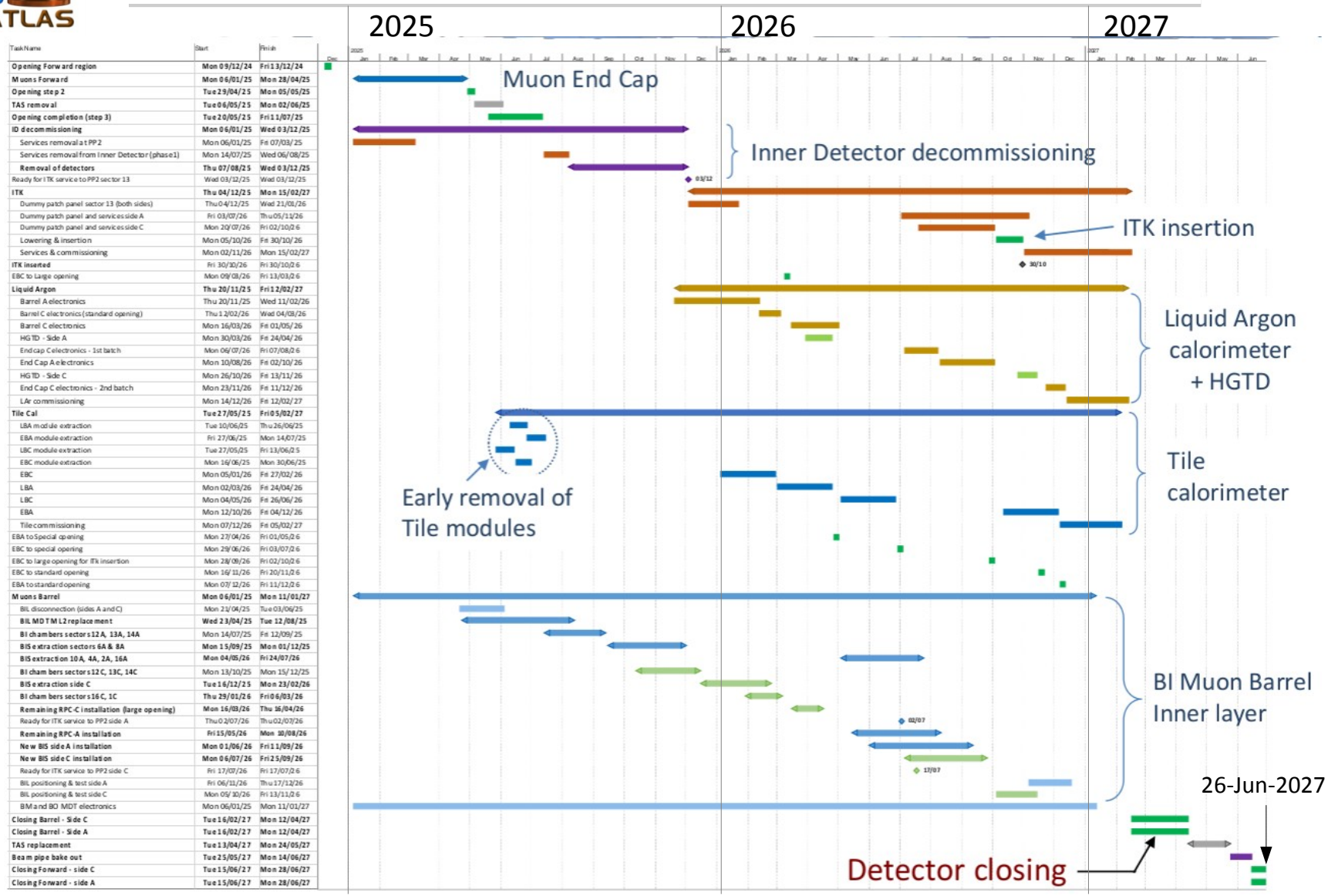
- NSF Scope Funded through MREFC Award: $75M (+ COVID)
  - DOE Scope: $163M (+ COVID) – CD-1, July 2018

Overview
ATLAS HL-LHC I&C

ATLAS I&C Planning

- I&C Planning is led by ATLAS Technical Coordination
  - I&C plans for each detector system included in TDRs and schedules
- I&C Choreography has been evolving from the earliest stages of HL-LHC Upgrade Planning
  - Large mechanical interventions (Muon chambers, Inner Tracker) have been driving forces in upgrade planning
  - Detailed mechanical manipulation models/simulations have been developed
  - Plans have been reviewed by external committees (CERN's P2UG)
- Current I&C Schedule (v8.1) from February 2020
  - Assumes LS3 duration: Dec-2024 – Jun-2027 (30 months)
  - Critical path goes through Barrel Inner Muon system and Inner Tracker
    - all other systems constrained by these
  - Next updates: end-2021 – beginning-2022

ATLAS I&C Schedule



Task Name	Start	Finish
Opening Forward region	**Mon 09/12/24**	**Fri 13/12/24**
Muons Forward	**Mon 06/01/25**	**Mon 28/04/25**
Opening step 2	**Tue 29/04/25**	**Mon 05/05/25**
TAS removal	**Tue 06/05/25**	**Mon 02/06/25**
Opening completion (step 3)	**Tue 20/05/25**	**Fri 11/07/25**
ID decommissioning	**Mon 06/01/25**	**Wed 03/12/25**
Services removal at PP2	Mon 06/01/25	Fri 07/03/25
Services removal from Inner Detector (phase1)	Mon 14/07/25	Wed 06/08/25
Removal of detectors	**Thu 07/08/25**	**Wed 03/12/25**
Ready for ITK service to PP2 sector 13	Wed 03/12/25	Wed 03/12/25
ITK	**Thu 04/12/25**	**Mon 15/02/27**
Dummy patch panel sector 13 (both sides)	Thu 04/12/25	Wed 21/01/26
Dummy patch panel and services side A	Fri 03/07/26	Thu 05/11/26
Dummy patch panel and services side C	Mon 19/07/26	Fri 02/10/26
Lowering & insertion	Mon 05/10/26	Fri 30/10/26
Services & commissioning	Mon 02/11/26	Mon 15/02/27
ITK inserted	Fri 30/10/26	Fri 30/10/26
EBC to Large opening	Mon 09/03/26	Fri 13/03/26
Liquid Argon	**Thu 20/11/25**	**Fri 12/02/27**
Barrel A electronics	Thu 20/11/25	Wed 11/02/26
Barrel C electronics (standard opening)	Thu 12/02/26	Wed 04/03/26
Barrel C electronics	Mon 16/03/26	Fri 01/05/26
HGTD - Side A	Mon 30/03/26	Fri 24/04/26
End cap C electronics - 1st batch	Mon 06/07/26	Fri 07/08/26
End Cap A electronics	Mon 10/08/26	Fri 02/10/26
HGTD - Side C	Mon 26/10/26	Fri 13/11/26
End Cap C electronics - 2nd batch	Mon 23/11/26	Fri 11/12/26
LAr commissioning	Mon 14/12/26	Fri 12/02/27
Tile Cal	**Tue 27/05/25**	**Fri 05/02/27**
LBA module extraction	Tue 10/06/25	Thu 26/06/25
EBA module extraction	Fri 27/06/25	Mon 14/07/25
LBC module extraction	Tue 27/05/25	Fri 13/06/25
EBC module extraction	Mon 16/06/25	Mon 30/06/25
EBC	Mon 05/01/26	Fri 27/02/26
LBA	Mon 02/03/26	Fri 24/04/26
LBC	Mon 04/05/26	Fri 26/06/26
EBA	Mon 12/10/26	Fri 04/12/26
Tile commissioning	Mon 07/12/26	Fri 05/02/27
EBA to Special opening	Mon 27/04/26	Fri 01/05/26
EBC to special opening	Mon 29/06/26	Fri 03/07/26
EBC to large opening for ITk insertion	Mon 28/09/26	Fri 02/10/26
EBC to standard opening	Mon 16/11/26	Fri 20/11/26
EBA to standard opening	Mon 07/12/26	Fri 11/12/26
Muons Barrel	**Mon 06/01/25**	**Mon 11/01/27**
BIL disconnection (sides A and C)	Mon 21/04/25	Tue 03/06/25
BIL MDT M L2 replacement	**Wed 23/04/25**	**Tue 12/08/25**
BI chambers sectors 12 A, 13A, 14A	Mon 14/07/25	Fri 12/09/25
BIS extraction sectors 6A & 8A	**Mon 15/09/25**	**Mon 01/12/25**
BIS extraction 10 A, 4A, 2A, 16A	**Mon 04/05/26**	**Fri 24/07/26**
BI chambers sectors 12 C, 13C, 14C	Mon 13/10/25	Mon 15/12/25
BIS extraction side C	**Tue 16/12/25**	**Mon 23/02/26**
BI chambers sectors 16 C, 1C	**Thu 29/01/26**	**Fri 06/03/26**
Remaining RPC-C installation (large opening)	**Mon 16/03/26**	**Thu 16/04/26**
Ready for ITK service to PP2 side A	Thu 02/07/26	Thu 02/07/26
Remaining RPC-A installation	**Fri 15/05/26**	**Mon 10/08/26**
New BIS side A installation	**Mon 01/06/26**	**Fri 11/09/26**
New BIS side C installation	**Mon 06/07/26**	**Fri 25/09/26**
Ready for ITK service to PP2 side C	Fri 17/07/26	Fri 17/07/26
BIL positioning & test side A	Fri 06/11/26	Thu 17/12/26
BIL positioning & test side C	Mon 05/10/26	Fri 13/11/26
BM and BO MDT electronics	Mon 06/01/25	Mon 11/01/27
Closing Barrel - Side C	**Tue 16/02/27**	**Mon 12/04/27**
Closing Barrel - Side A	**Tue 16/02/27**	**Mon 12/04/27**
TAS replacement	**Tue 13/04/27**	**Mon 24/05/27**
Beam pipe bake out	**Tue 25/05/27**	**Mon 14/06/27**
Closing Forward - side C	**Tue 15/06/27**	**Mon 28/06/27**
Closing Forward - side A	**Tue 15/06/27**	**Mon 28/06/27**

I&C Schedule Drivers

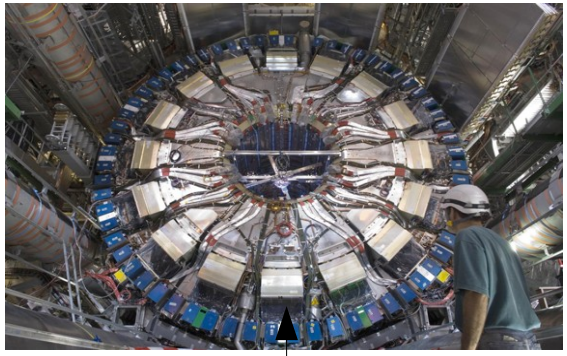
- Inner Detector replacement (DOE contributes)
  - decommission current Inner Detector as early as possible
  - insertion of ITk as late as possible to allow more surface testing time
- Muon System changes (NSF contributes)
  - replacement of on-detector electronics: very limited access
  - new and replacement chambers in inner region of barrel: complicated mechanical manipulation
- Activation of detector elements in forward region
  - especially quadrupole shielding (TAS)
  - impacts both NSF and DOE work

U.S. I&C Strategy

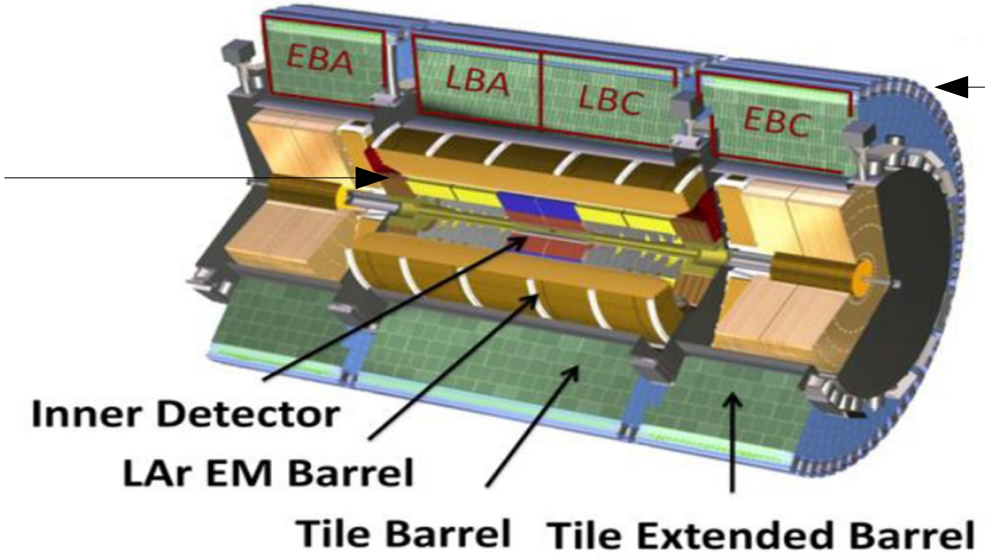
- General U.S. I&C Assumptions
  - Deliverable reception at CERN (or other end point) marks completion of Construction Phase
  - All deliverables fully tested (including integration tests with external systems) before start of I&C
- I&C Schedule captured as Planning Packages in P6
  - Will be refined as ATLAS I&C plans evolve
- Transition to steady-state operations (during next CA period)
  - U.S. I&C phase ends with ATLAS ready for cosmic running: (July 1, 2027)
    - note this is after the end of the proposed NSF-CA
  - Next steps after I&C end
    - Continuous running with cosmics (data taking stability) until LHC beam (spring 2028)
    - Early running with beam → final integration, set operating parameters, etc

NSF I&C Activities (1)

- LAr Calorimeter
  - Installation/Connection/Test of front-end electronics (1524 FEB2)
  - Installation/Test of back-end electronics in USA15
  - Commission overall readout system
- Tile Calorimeter
  - Surface assembly/certification of mini-drawers
  - Installation/Test of mini-drawers on detector

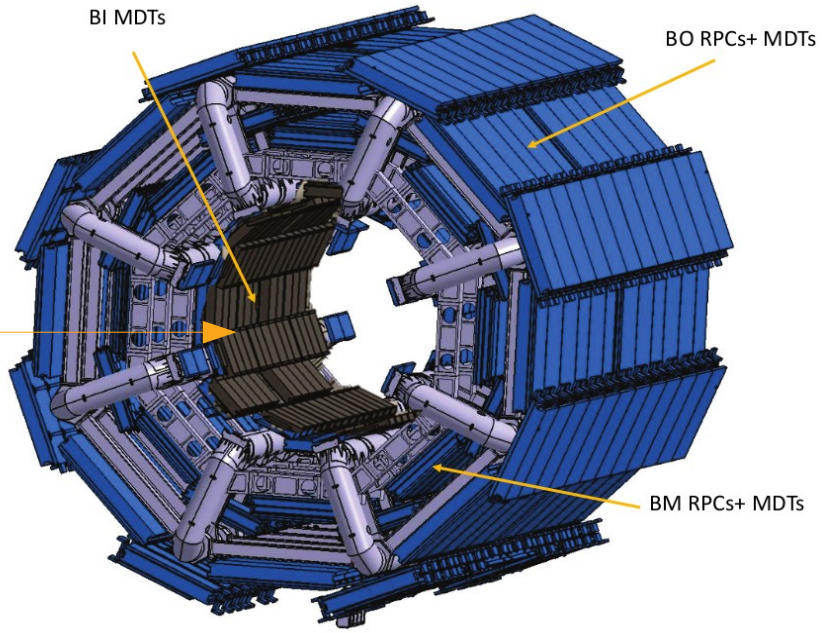


LAr
FE Boards



NSF I&C Activities (2)

- Muon System
  - Prep/Assemble sMDT+RPC chambers on the surface
  - Install/Test sMDT+RPC chambers, Mezzanine Cards, CSMs on detector
  - Test Stand commissioning of L0MDT
  - Install/Test L0MDT in counting room (USA15)



- Trigger/DAQ
  - Global Trigger Firmware commissioning in Test Stand and USA15
  - Install/Test HTT in USA15
  - Detector integration validation & commissioning
  - Cosmic ray running

Budget & Schedule
US ATLAS HL-LHC I&C – NSF Scope

Cost/Effort/Schedule Estimate

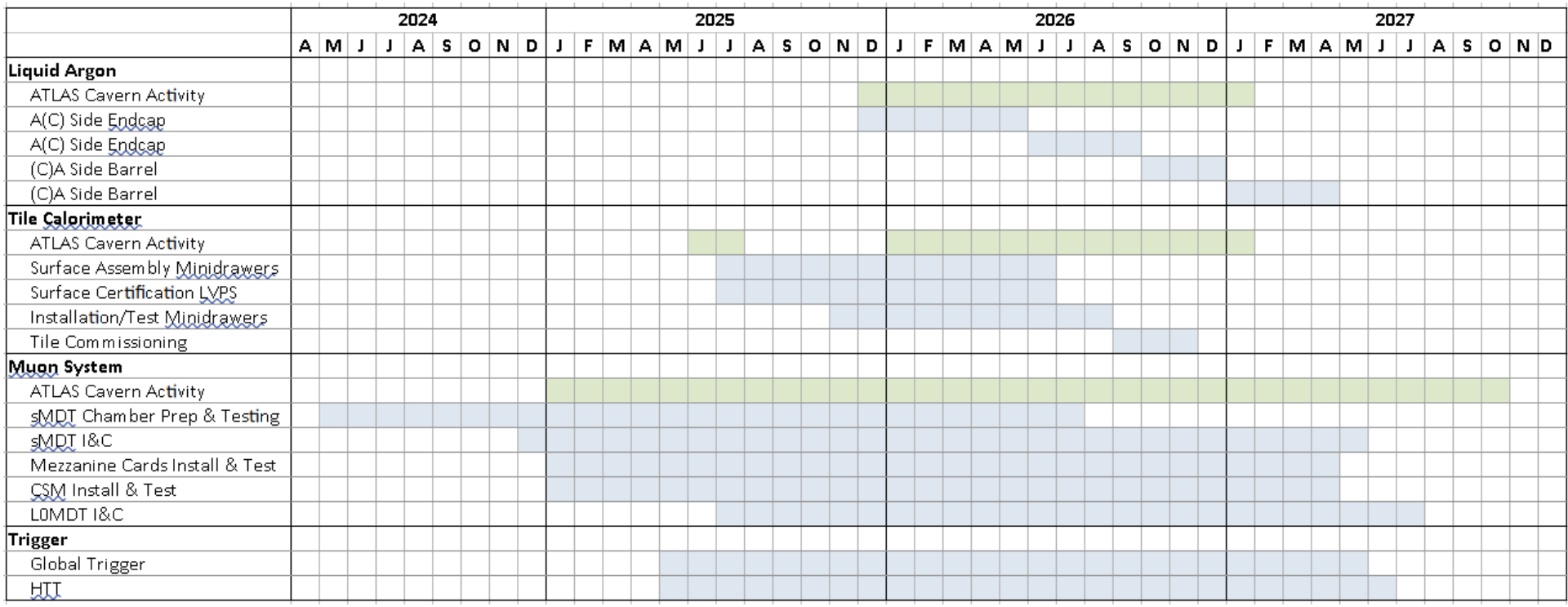
- Effort/Schedule estimated using analogy to similar activities in
  - Phase-I: LAr, TDAQ activities very similar to HL-LHC
  - Original ATLAS: Tile,Muon activities essentially the same for HL-LHC
  - HTT & LAr-BE: used as basis for L0MDT

System	Analogy	Institutes for Original ATLAS / Phase-I
LAr	• Front End: Phase-I LTDB • Back End: Phase-I LDPS	• Columbia, SMU, UT Austin • Arizona, Stony Brook
Tile	• Main Board: original ATLAS • LVPS: original ATLAS	• Chicago • ANL, MSU
Muon	• sMDT: original ATLAS MDT • CSM: original ATLAS CSM • TDC: original ALTAS mezzanine • L0MDT: HTT, LAr DPS	• Michigan • Michigan • Michigan • Chicago, Penn, Columbia
Trigger	• GEP: Phase-1 gFEX Algorithms • HTT: Phase-1 FTK	• BNL, Chicago, Indiana, MSU, Oregon, Pitt • ANL, Chicago, Illinois, Stanford

Institutes in red are participating in HL-LHC activities in this area

US I&C Schedule

- US HL-LHC I&C schedule implemented as work packages in P6
  - summarized below and compared to ATLAS LS3 schedule
  - modular US activities allow some flexibility in terms of scheduling
  - synchronization of US vs ATLAS schedules is an ongoing process



US I&C Effort

- Costed HL-LHC I&C effort requested in the proposal
  - first attempt at uncosted effort estimate also made – being updated

System (FTE)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
6.11 Total	**-**	**0.05**	**1.14**	**7.28**	**9.76**	**18.23**
6.11.4 LAr	-	-	-	0.24	1.56	**1.80**
6.11.5 Tile	-	-	0.03	0.39	0.81	**1.22**
6.11.6 Muon	-	0.05	0.99	5.01	4.77	**10.81**
6.11.8 Trigger	-	-	0.13	1.65	2.62	**4.40**

US I&C Costs

- US ATLAS HL-LHC I&C cost dominated by Labor
  - Material from ATLAS Common Costs
  - some Travel included in the numbers below

I&C Risks

- I&C Risk Register will be developed as ATLAS plans mature
  - after end of LS2
- Main issues affecting current I&C planning
  - Uncertainty in LHC schedule
    - CERN announcement of delay to start of LS3 expected at end of 2021
    - most probable delay is 1 year, but this is very uncertain
  - COVID-related delays to construction schedule
- Effect of LS3 delay on US NSF I&C plans
  - technical experts from HL-LHC construction need to be maintained for work during the I&C period
  - this issue is at least partially mitigated by the plans to do I&C work on the surface before access to the cavern is needed
    - pre-assembly, integration testing, etc.
  - how much this bridges any gap between end of construction and access to the cavern will depend on details of the LS3 shift and on final COVID-related delays

I&C Surface Work Examples

- Should we include a few examples by L2 of work that is planned to happen on the surface ???

Next Steps

U.S. I&C: Next Steps

- Next updates to ATLAS I&C plan expected: end-2021 - beginning-2022
  - These updates will be done by sub-system to address specific issues
  - Next global update of the schedule will happen after the end of LS2
    - U.S. groups providing significant input on updated plans
    - Will incorporate more experience from Phase-1 I&C

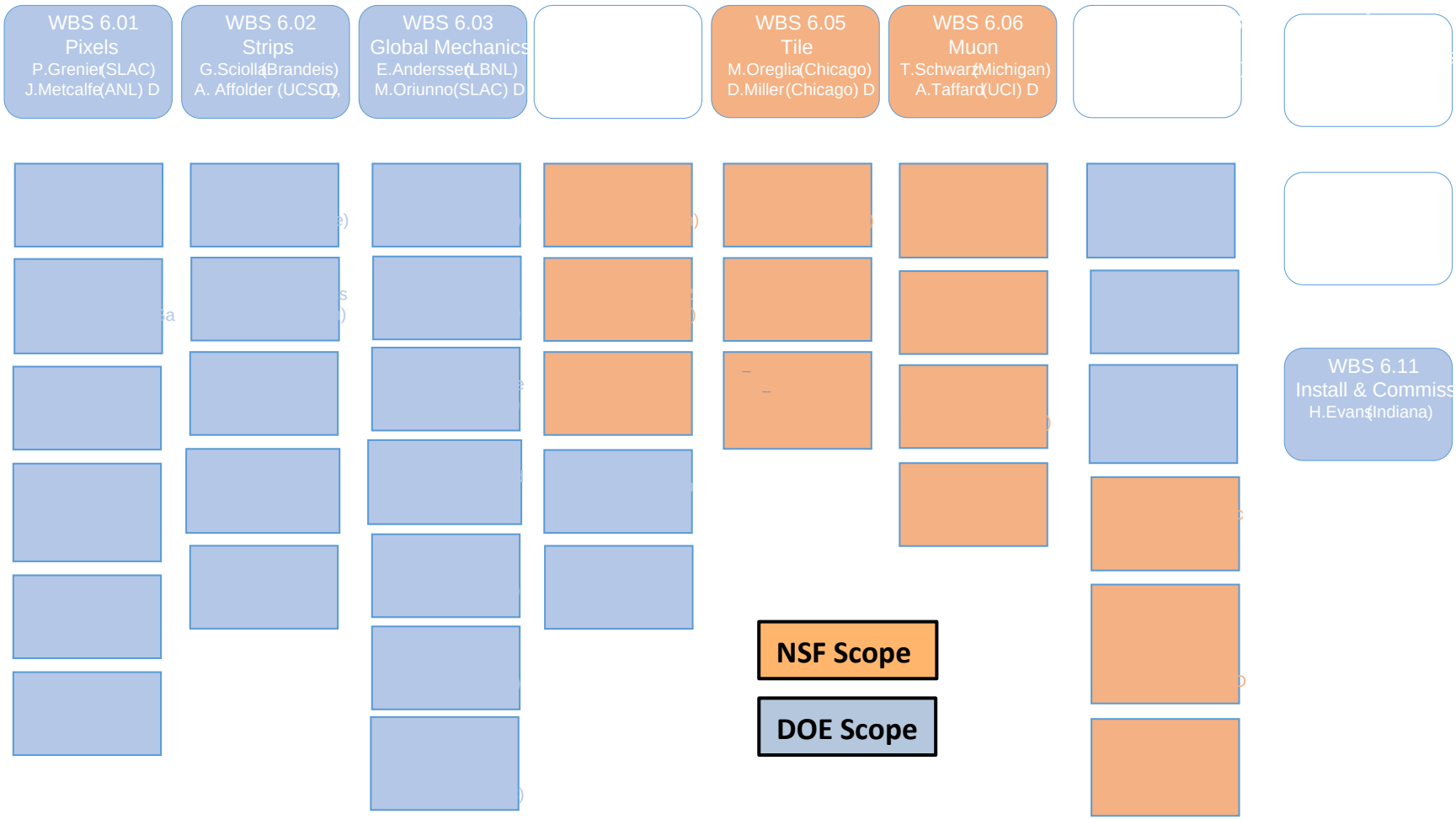
- Begin move from Planning Packages → Tasks: after Run-3 start
  - Important that this is synchronized with ATLAS plans
    - we are already doing this for the Construction Project
  - Will include a more careful estimate of required scientific effort
  - Do not expect major changes to funding needed from U.S. ATLAS/NSF

Closing Remarks

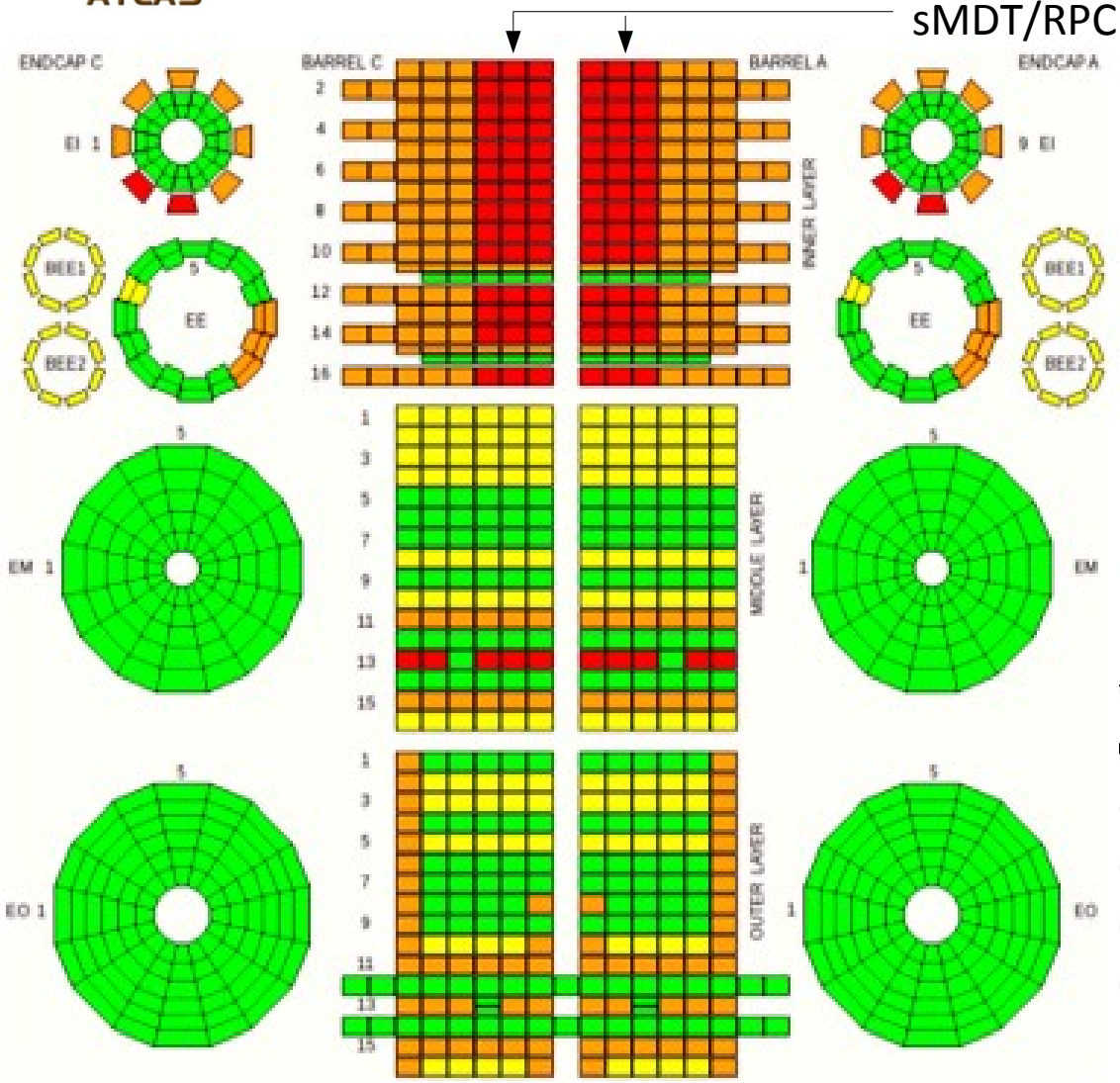
- ATLAS I&C Planning well advanced
  - System plans detailed in TDRs
  - All major issues addressed – but many details to sort out
- U.S. ATLAS NSF I&C Activities
  - Estimated based on Phase-1 and Original ATLAS I&C experience
  - Entered as Planning Packages in P6 (resource loaded)
- Evolution of I&C Plan
  - Next full ATLAS update after LS2
  - U.S. planning will evolve/refine along with this
    - do not expect this to lead to significant cost changes
- Availability of funding for I&C of NSF HL-LHC upgrade scope in this CA is critical to the ATLAS I&C plans

BACKUP

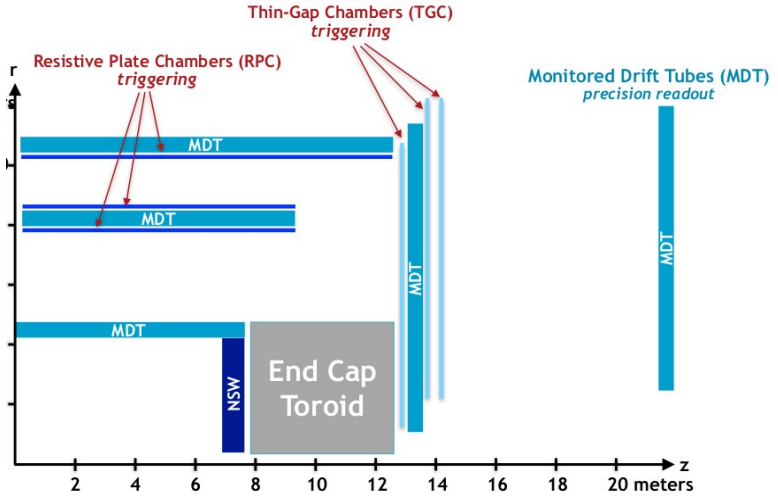
US ATLAS HL-LHC Scope



Muon Electronics Replacement



- Straightforward
- Requires scaffolding
- More study (but doable)
- Requires chamber move



Muon Chambers

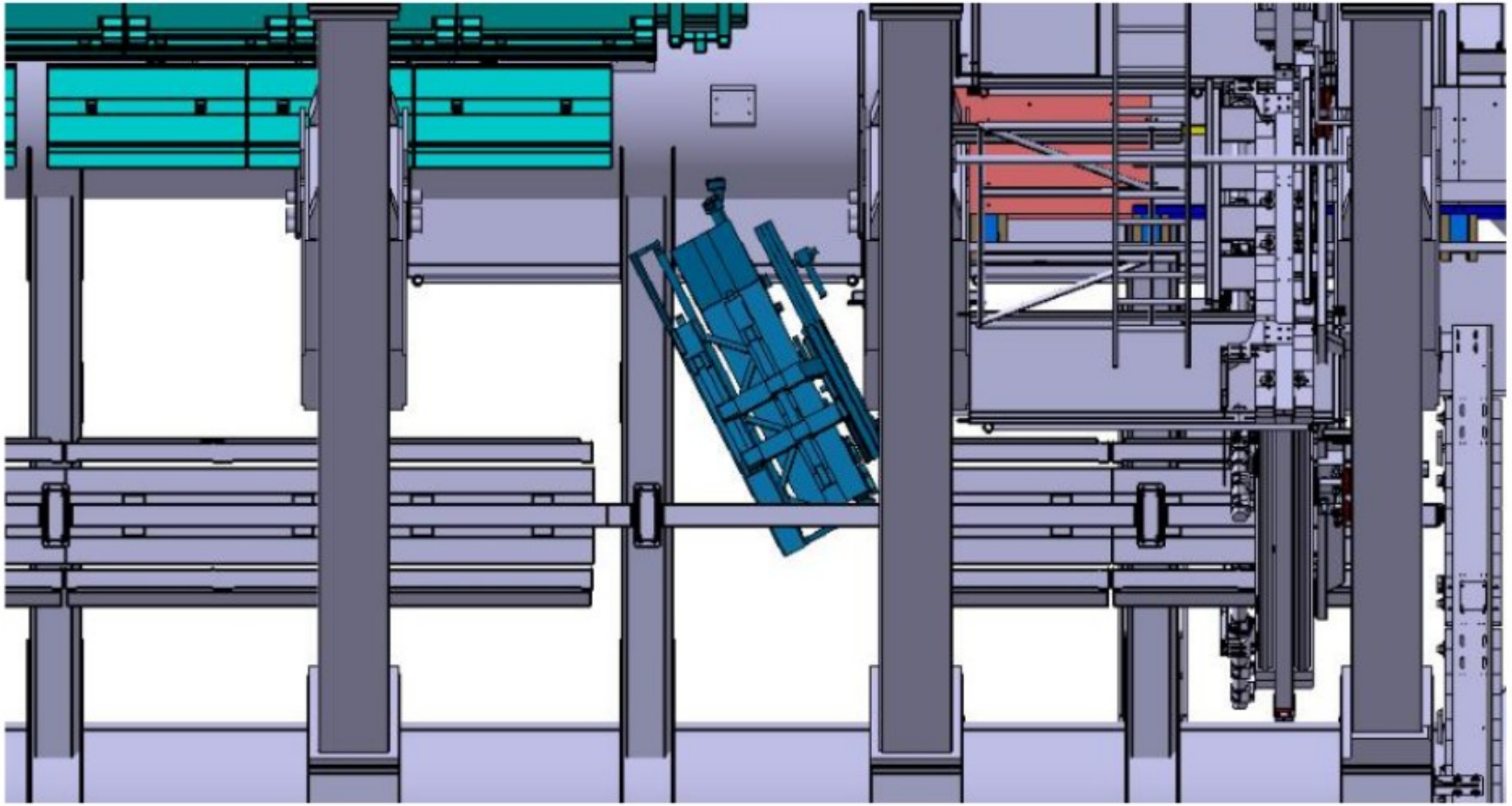
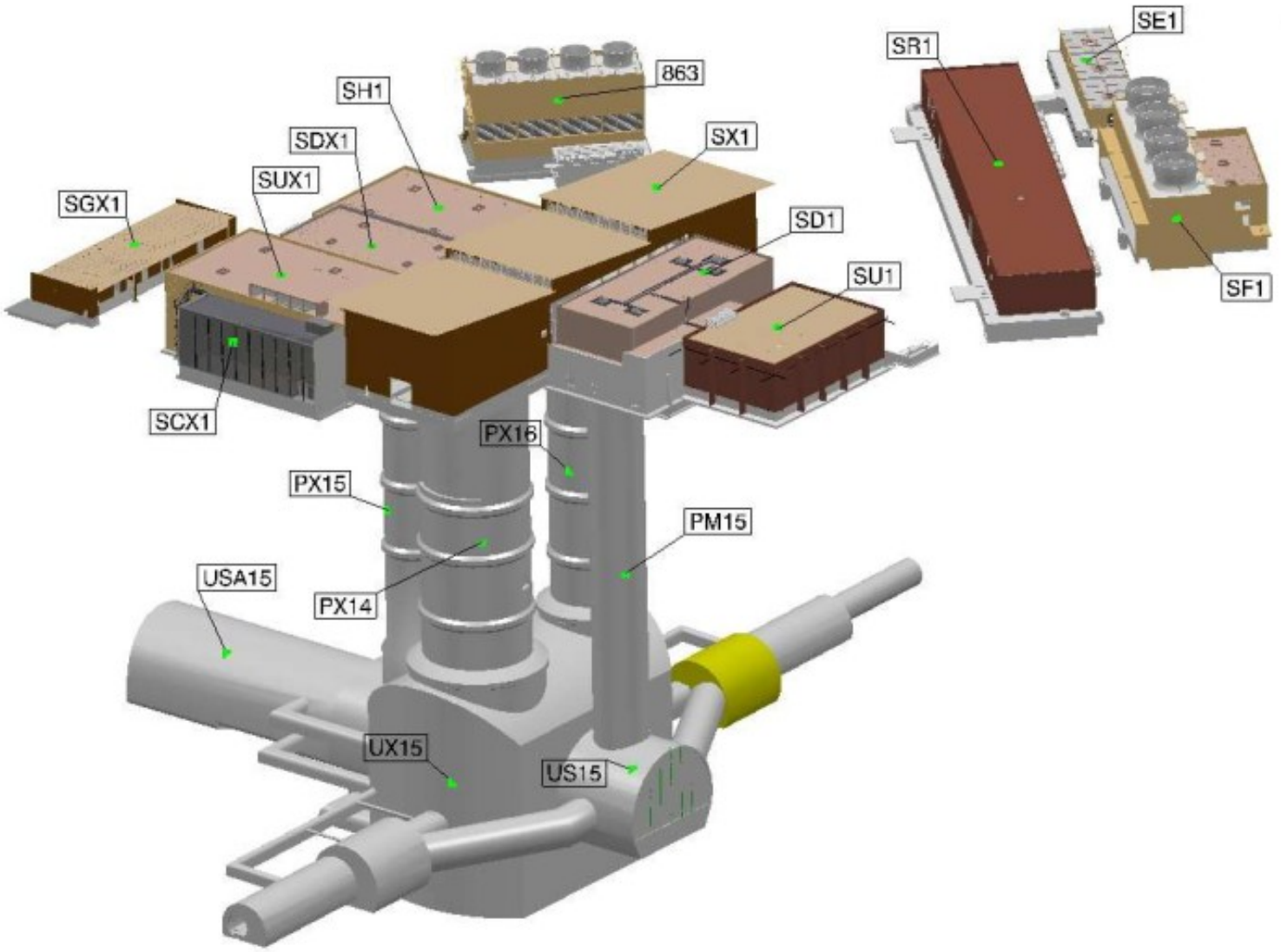


Figure 11.5: Y-Z view of the detector showing some of the detector movements required to move the BIL (green) out of ATLAS, along the rails: EIL4 (blue) have to move radially outwards and be rotated, and for this BML5–7 (grey) have to move along the rails and BML7 also has to be rotated.

ATLAS Point-1



Construction Project End Dates

- Current baseline “end dates” and “needed-at-CERN” dates per L2 system
  - Float = difference between needed-at-CERN and end dates

System	End Date	Needed-at-CERN
6.4 LAr	30-Dec-1899	30-Dec-1899
6.5 Tile	30-Dec-1899	30-Dec-1899
6.6 Muon	30-Dec-1899	30-Dec-1899
6.8 Trigger	30-Dec-1899	30-Dec-1899

Effort Estimate

Group	TOTAL EFFORT (FTE.year) FY23	FY24	FY25	FY26	Total
LAr	**-**	**-**	**2.94**	**2.56**	**5.50**
A(C) Side Endcap			1.40		1.40
A(C) Side Endcap			1.35		1.35
(C)A Side Barrel			0.19	1.16	1.35
(C)A Side Barrel				1.40	1.40
Tile	**-**	**0.33**	**3.87**	**0.05**	**4.25**
Surface Assembly Minidrawers		0.04	0.15		0.20
Installation/Test Minidrawers			2.32		2.32
Surface Certification LVPS		0.29	0.96		1.25
Installation LVPS			0.30		0.30
Tile Commissioning			0.13	0.05	0.18
Muon	**1.56**	**15.08**	**14.34**	**4.63**	**35.60**
Surface Assembly Chambers	1.56	8.81	5.03	1.31	16.70
Installation/Test Chambers		6.05	8.27	2.54	16.86
Surface Test L0MDT		0.22	0.26		0.48
Installation/Test L0MDT			0.78	0.78	1.56
Trigger	**-**	**1.84**	**5.27**	**2.30**	**9.41**
GEP		0.99	3.68	1.70	6.36
HTT		0.85	1.59	0.60	3.05
	1.56	**17.25**	**26.41**	**9.54**	**54.76**

Cost Estimate

	TOTAL COST (AY$)				
Group	**FY23**	**FY24**	**FY25**	**FY26**	**Total**
LAr	**$ -**	**$ -**	**$ 563,141**	**$ 505,409**	**$ 1,068,549**
A(C) Side Endcap			$ 263,458		$ 263,458
A(C) Side Endcap			$ 263,458		$ 263,458
(C)A Side Barrel			$ 36,225	$ 234,048	$ 270,274
(C)A Side Barrel				$ 271,360	$ 271,360
Tile	**$ -**	**$ 12,709**	**$ 264,754**	**$ 12,348**	**$ 289,811**
Surface Assembly Minidrawers		$ 4,236	$ 17,616		$ 21,852
Installation/Test Minidrawers			$ 179,938		$ 179,938
Surface Certification LVPS		$ 8,473	$ 35,231		$ 43,704
Installation LVPS					$ -
Tile Commissioning			$ 31,970	$ 12,348	$ 44,318
Muon	**$ 100,683**	**$ 1,018,778**	**$ 1,055,000**	**$ 382,330**	**$ 2,556,792**
Surface Assembly Chambers	$ 100,683	$ 586,062	$ 345,082	$ 92,202	$ 1,124,029
Installation/Test Chambers		$ 402,924	$ 566,695	$ 179,482	$ 1,149,101
Surface Test L0MDT		$ 29,792	$ 35,801		$ 65,593
Installation/Test L0MDT			$ 107,423	$ 110,645	$ 218,068
Trigger	**$ -**	**$ 474,373**	**$ 1,389,183**	**$ 645,948**	**$ 2,509,504**
GEP		$ 247,864	$ 946,554	$ 450,274	$ 1,644,693
HTT		$ 226,509	$ 442,628	$ 195,674	$ 864,811
	$ 100,683	**$ 1,505,861**	**$ 3,272,077**	**$ 1,546,035**	**$ 6,424,656**