Status of the U.S. ATLAS High Luminosity LHC Upgrade Project

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on behalf of the
U.S. ATLAS HL-LHC Project Team

Brookhaven National Laboratory
Director's Review for OPA IPR
December 13-15, 2021

Outline

- Introductory remarks
- Project overview; scope & organization
- Project planning & status
- DOE funding guidance
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Thank You!

- On behalf of the team, thank you for investing your time and effort in preparing us for the next phase of DOE reviews.
- Such in-depth assessments and guidance is invaluable to us, and your help is very much appreciated.

Introductory Remarks

- This project was last reviewed in July 2019, at which CD-3a was approved.
- This was ~ 8 months before the COVID outbreak hit.
- The COVID impacts have been highly significant across the globe; this project is of course no exception.
- We have put much effort into developing a means of quantifying these impacts in a manner suitable to the requirements of a modern project.
- The ongoing pandemic and follow-on effects – future potential surges, budgets, supply chain issues, CERN and international ATLAS schedule, etc. -- have also introduced an unprecedented level of uncertainty into project planning and execution.
  - Many of these effects, of potentially large impact, are out of our hands.
- At this status review, we hope to obtain your view of how well we are managing these overall processes and preparing ourselves to deal with future external developments in the runup to CD-2/3.

U.S. Participation in the LHC

- From the European Strategy Group for Particle Physics 2013 Report:

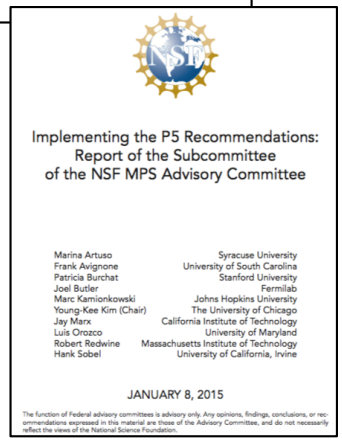
  Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030.

- The 2014 P5 report provided a clearly prioritized roadmap for high energy physics for the coming decade:

  Recommendation 10: Complete the LHC phase-1 upgrades and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.

- Endorsement by a subcommittee of the NSF Mathematical and Physics Sciences (MPS) Advisory Committee in 2015:

  The subcommittee strongly supports the NSF investment in the LHC phase-2 upgrades as a way to enable and participate in fundamental discoveries.

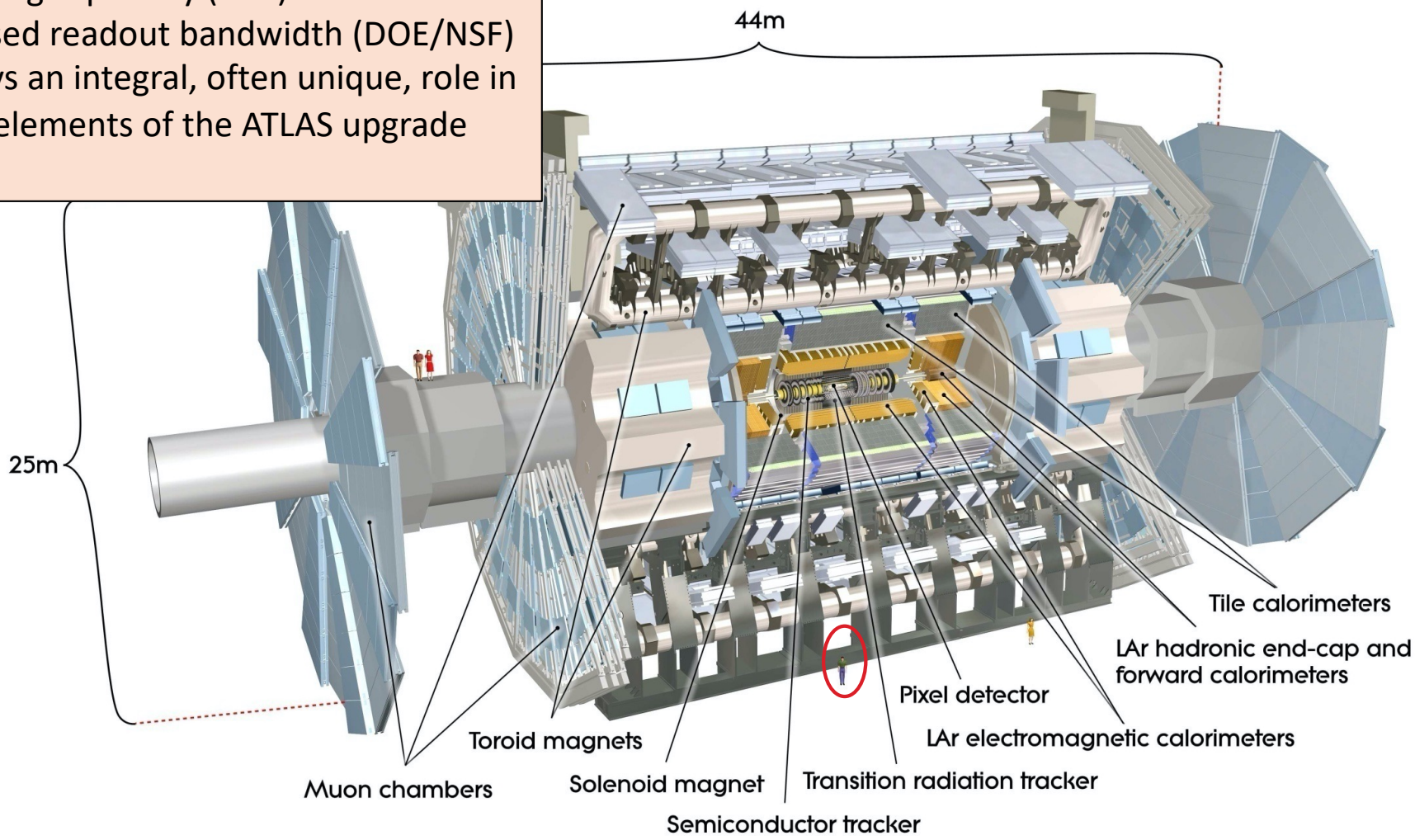


The priority to pursue the next phase of LHC physics has been established. The machine and detector upgrades are well underway.

The ATLAS Detector

- The ATLAS HL-LHC upgrade focuses on:
  - Inner tracker replacement (DOE)
  - Triggering capability (NSF)
  - Increased readout bandwidth (DOE/NSF)
- The U.S. plays an integral, often unique, role in all principal elements of the ATLAS upgrade scope.

See talks from H. Evans, L2 Mgrs & Deputies, L3 Mgrs.



Overall Context

- The principal laboratory for the LHC program is CERN, which assumes the ultimate responsibility for mounting and guiding the LHC program.
- The U.S. contribution to HL-LHC consists of upgrades to the accelerator (DOE) and to both ATLAS and CMS (DOE and NSF), totaling ~ $750M.
- DOE guidance for U.S. ATLAS HL-LHC = $181M.
  - Critical Decision 0 (CD-0) was approved April 13, 2016.
  - CD-1: July 10-12, 2018, followed by ESAAB approval in Sep 23, 2018.
  - CD-3a: July 9-11, 2019, ESAAB approval October 16, 2019.
- NSF MREFC (construction funding) = $75M See breakout talk from M. Tuts
  - After a three-tier approval process (2016-2020), MREFC funding began in March 2020.
  - The MREFC is submitted jointly with U.S. CMS: total = $150M, evenly split.

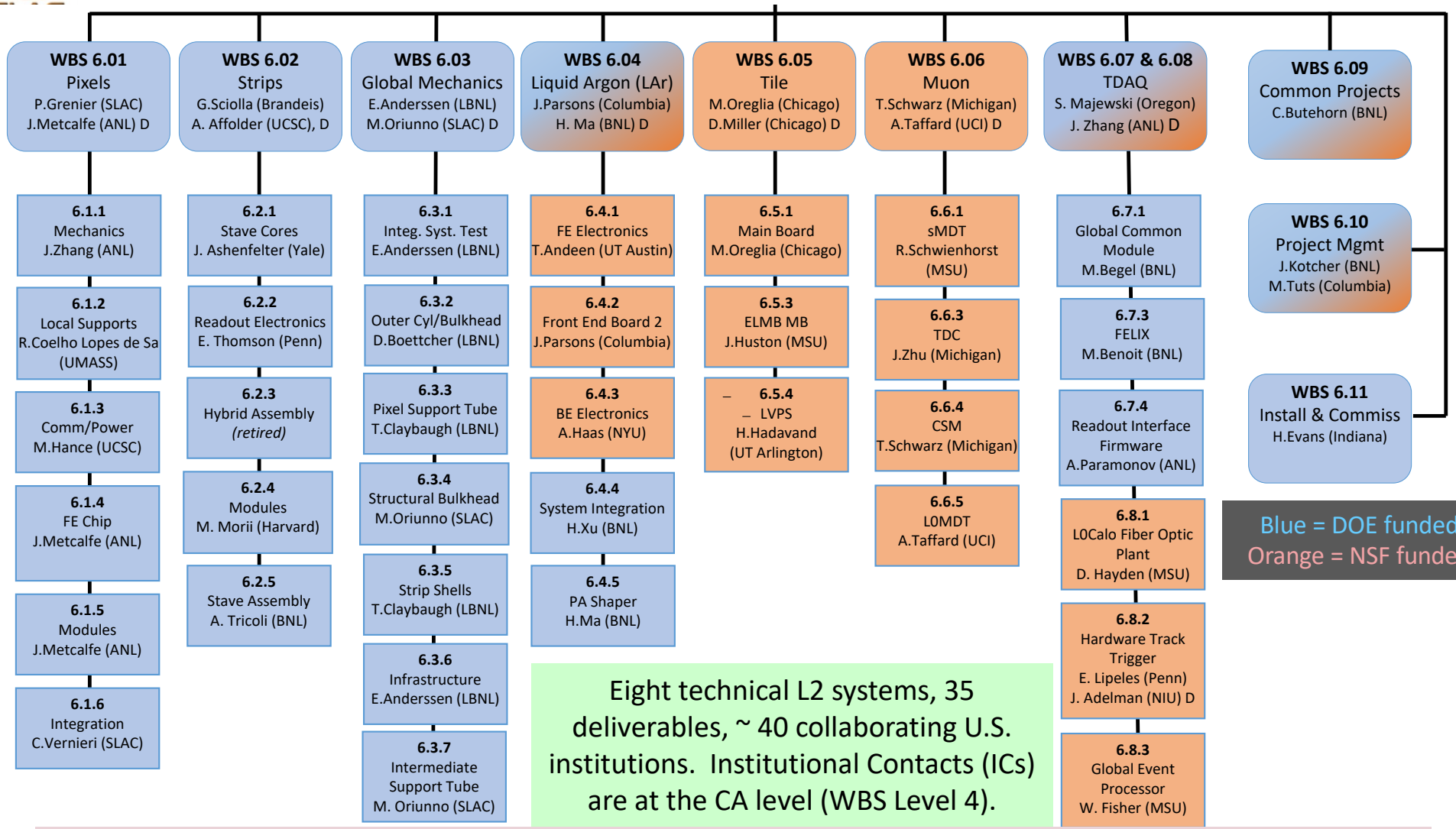
U.S. Involvement in ATLAS

- ATLAS is a large international collaboration, consisting of ~ 3000 authors from 182 institutes in 38 countries.
- Approximately ~ 17.8% of these Ph.D. physicists are from the U.S – 14.3% on the DOE side.
- This “fair share” is used to compute the U.S. financial contribution to the upgrade, used for each of the collaborating countries.
- The U.S. holds ~ 30% of the Level 1, 2 & 3 leadership positions on the International ATLAS HL-LHC upgrade.
- This reflects the broad and well-recognized expertise in the U.S., and its strong historical engagement in the experiment.

Project Scope

- Each of the 8 U.S. L2 systems is funded via a unique source (DOE, NSF).
  - Sole exception is LAr, which is split between NSF/DOE (but unique at Level 3).
- DOE scope: Inner Tracker and Data Handling
  - Level 2: Silicon Pixels, Strips and Global Mechanics, and DAQ.
  - Silicon accounts for 80% of the DOE subproject base cost.
  - Multiple U.S. laboratory involvement – ANL, BNL, LBNL, SLAC
- NSF scope: Triggering
  - Level 2: LAr, Tile Calorimeter, Muon and Trigger.
- The project scope is cleanly apportioned, and there is a discrete separation of the deliverables by funding agency.
  - Interfaces between the two sets of deliverables are minimal.
  - Each Level 2 system has its own critical path to deliverable completion.
  - Sub-detectors are integrated primarily during the installation & commissioning phase.
- The development of the U.S. ATLAS HL-LHC project plan has benefited greatly from a strong multi-year effort in HL-LHC R&D.

Subproject Organization to L3



U.S. project personnel are deeply embedded in the ATLAS experiment and within the HL-LHC upgrade effort.

Project Office

- BNL hosts the central upgrade Project Office (PO).
  - Columbia serves as the principal NSF institution for the MREFC.
  - The HL-LHC PO effort is co-funded by DOE and NSF.
- This PO structure follows from the original ATLAS construction, having been implemented in the original construction, Phase I and HL-LHC upgrades.
  - The group brings much collective experience in all aspects of project management, development and execution.
- The HL-LHC Project Office (PO) and management team functions in a fully integrated fashion, managing both NSF- and DOE-funded scope.
  - The team is cohesive and well-integrated.

U.S. ATLAS HL-LHC Upgrade Project Office

J. Kotcher (BNL), Project Manager
G. Brooijmans (Columbia), Deputy PM, Project Development
H. Evans (Indiana), Deputy PM, Technical Coordination
M. Tuts (Columbia), NSF Principal Investigator
P. Novakova (BNL), Assistant PM, Project Finances & Controls
C. Meyer (Indiana), Risk Manager
J. Hobbs (SBU), Operations Cooperative Agreement PI
L. Stiegler (BNL), ES&H Liaison
C. Gortakowski (BNL), QA/QC Liaison

Finances & Administration:

R. Freedman (BNL), Financial & Administration Manager, DOE
A. Garwood (Columbia), Financial & Administration Manager, NSF
J. Bloch (Columbia), Financial Assistant
C. Butehorn (BNL), Financial Oversight

Status of the CERN Schedule

- Long Shutdown 3 (LS3) – currently, a 2.5-year shutdown and installation period beginning in Jan 2025 – is the overall milestone that drives the upgrade construction completion schedule.
- CERN is currently considering a one-year delay to the LS3 start (Jan 2025 => Jan 2026) and a six-month extension of its duration (2.5 => 3 years).
- A formal announcement will be made at Chamonix Workshop (end Jan '22).
- Such changes to the RLS, as well as updated need-by dates from ATLAS, will be fully integrated into the plan presented at CD-2/3, which we are targeting for Jul/Aug 2022.

Information Provided at This Review

- All material presented at this review reflects a technically-driven schedule.
  - The subsystems' technical workflow is, by design, not funding-constrained.
- In the evaluation of float, we assume the current CERN schedule -- Jan 2025 LS3 start, 2.5-year duration – and the corresponding ATLAS need-by dates.
  - These are the only approved schedules available to us right now.
- The above is what is loaded into P6/COBRA and posted on the web site.
- As mentioned, a number of significant factors are likely to alter our path forward in the near-term.
  - FY22+ funding, CERN and ATLAS schedule updates, ongoing COVID issues, etc.
- At this review, as at the January 2022 OPA IPR, our intention is to speak to this technically-driven schedule as the base plan.
  - This plan is also intended to serve as a jumping off point for discussion of the path toward a project baseline.
- We will continue managing to this technically-driven schedule after the likely LS3 delay/extension is announced by CERN.

Current Project Milestones & CD-4

Milestone	Milestone Title	Schedule Date
CD-0	Approve Mission Need	4/13/2016 (A)
CD-1	Approve Alternative Selection and Cost Range	9/21/2018 (A)
CD-3a	Approve Long Lead Procurements	10/16/2019 (A)
CD-2/3	Approve Project Baseline & Start of Construction	Q4 FY 2022
CD-4	Approve Project Completion	Q4 FY 2029

- The project's most recent approval gate was for CD-3a, approved by the ESAAB in October 2019.
  - Long lead procurements for Strips (6.2) and Global Mechanics (6.3) => $12.6M.
- Approval for a combined CD-2/3 is being targeted for Q4 FY 2022.
  - This is somewhat aggressive, but we believe it to be achievable, circumstances permitting.
- The current project plan has the project moving into production in fall 2022.

DOE Funding Guidance

- DOE provided funding guidance at the July 2019 review that was more aggressively front-end loaded than the previous guidance.
  - It supported the technically driven schedule at that time.
- FY21 and FY22 saw drastic cuts to this budget enacted/proposed.
  - -36% in FY21 (enacted), -61% in FY22 (proposed in the PBR).
  - All US LHC projects were affected.
- DOE updated the profile in August 2021.
- This is the profile to which we are now working.

DOE Funding Guidance (AY$k)

DOE Profile, Updated Aug 2021

Project Name	BRN	FY 2019 and Prior	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY_26	Total
HL-LHC ATLAS	TEC	27,500	24,500	16,000	20,000	28,000	15,700	17,000	5,785	154,485
HL-LHC ATLAS	OPC	16,515	-	-	-	1,000	3,900	3,050	2,050	26,515
HL-LHC ATLAS	TPC	44,015	24,500	16,000	20,000	29,000	19,600	20,050	7,835	181,000

Profile Difference, Aug 2021 – July 2019

Project Name	BRN	FY 2019 and Prior	FY 20	FY 21	FY 22	FY 23	FY_24	FY_25	FY_26	Total
HL-LHC ATLAS	TEC	-	1,040	(9,040)	(5,910)	10,800	3,300	13,110	5,185	18,485
HL-LHC ATLAS	OPC	-	-	(310)	(990)	(700)	1,400	(250)	850	-
HL-LHC ATLAS	TPC	-	1,040	(9,350)	(6,900)	10,100	4,700	12,860	6,035	18,485

- The updated profile:
  - Partially ameliorates impacts due to FY21 and FY22 funding reductions.
  - Shifts more funding to the out-years (back-end loaded).
    - It intrinsically builds in a ~ 1 year delay.
  - Increases the TPC by $18.5M to $181M, the CD-1 upper range. This is intended, in part, to cover COVID and related cost impacts.
- The FY22 allocation has yet to be resolved.

COVID Impact Estimates

90% CL Limits	BCPs	Simulation	TOTAL
Cost (AYM$)	8.0	8.4	**16.4**
Schedule (mos., max. delayed subsystem)	16.1	1.8	**17.9**

See talks from P. Novakova, G. Brooijmans

- DOE recognizes that COVID-related impacts are beyond the project's responsibility, and that additional funds will be needed in order to cover them in order to retain scope.
- COVID estimates are tabulated independently to allow discussions of compensation with the agencies.
- COVID estimates consist of two components, updated every 4-5 months:
  - Formal COVID-only Baseline Change Proposals (BCPs) covering past work, the results of which are integrated into the project baseline. There have been 3 thus far (3/20-8/21).
  - Simulation estimating future impacts from BCP end thru Dec 2022, which incorporates work efficiencies using EVMS data.
- The cost and schedule impacts – BCP + simulation – have been quite stable with each COVID impact update.

Vendor Impacts & Supply Chain Effects

- Vendor delays and cost increases and supply chain effects (SCE) continue to have a significant impact on the project.
  - Examples: pre-preg, high density foam, electronics components, ASICs, silicon sensors.
- Some of these effects are more quantifiable than others:
  - General supply chain delays, related cost increases and outlook.
  - Significant delays and cost impacts due to private sector consolidations and buyouts, affected by COVID financial impacts and the supply chain.
  - COVID protocols introduced by some fabrication vendors.
  - Weather events can introduce palpable impacts, as seen after the Texas storm in Feb '21 => plastic production, pre-preg, carbon fiber, availability of raw materials.
- Invariably, judgement calls are involved in quantifying these effects.
  - Often, costs incurred seem to be passed on to the consumer in a rather opaque manner.
- We are developing a method of estimating SCE in the risk Monte Carlo, discussed in later presentations.
- An analysis of supply chain/vendor impacts will be completed for CD-2/3.

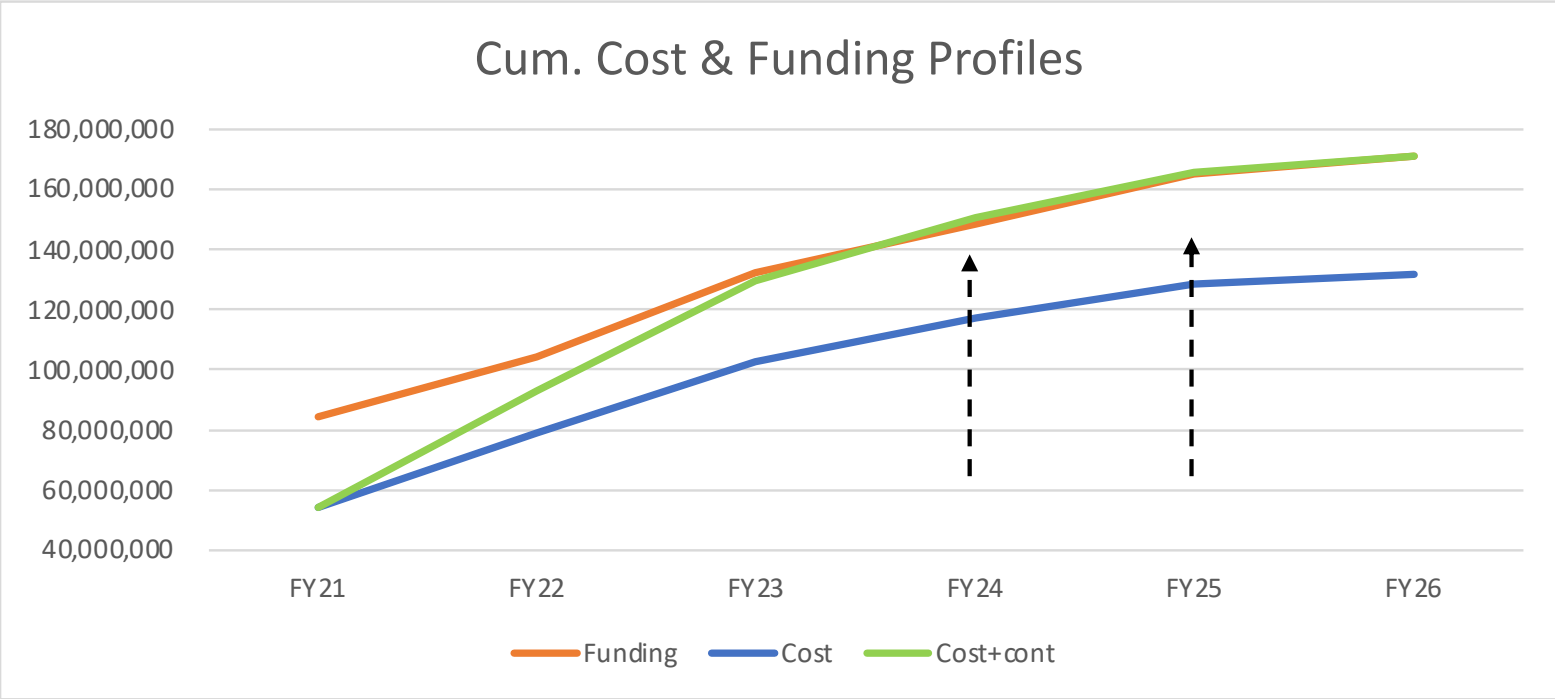
Project Cost/Funding Profile

- The Project's current point estimate is shown in the following slide.
- Deliverables dominate the effort and expenditures (~95%). They are broken out and treated separately from I&C.
  - Contingency is also generated independently for each.
- The deliverables – subsystems, common projects and the PO -- are funded via TEC and early OPC (FY16-18).
  - These costs are based on bottom-up estimates in the RLS.
- I&C is funded via out-year OPC and is loaded in P6 in planning packages.
  - The granularity of this work, both on ATLAS and in the US, supports only coarsely described activities at this time.
  - The PO has capped I&C at $10M; the remaining I&C work will be supported through complementary funding of the OPS program, as agreed to with DOE.
- The Cost to Go (CTG) is computed using actuals through FY21.
- The available deliverable contingency is applied top-down and evenly distributed, by fraction, across fiscal years.

Project Cost/Funding Profile (AY$)

WBS	FY 2021 and Prior	FY22	FY23	FY24	FY25	FY26	Grand Total
Deliverables only							
6.01 Pixels	12,077,554	7,171,633	7,192,926	3,388,522	1,595,370	284,251	31,710,255
6.02 Strips	18,045,503	6,997,103	7,711,342	5,864,598	5,851,943	1,075,195	45,545,684
6.03 Global Mechanics	10,422,991	3,509,999	2,118,783				16,051,773
6.04 LAr	2,861,009	998,195	1,116,267	1,072,549	650,668	100,602	6,799,290
6.07 Data Handling/DAQ	4,049,969	2,700,076	3,111,437	1,779,878	1,087,493	74,101	12,802,953
6.09 Common Costs	205,707	1,680,557	532,390	951,390			3,370,044
6.10 PMO	6,833,535	1,620,754	1,679,969	1,719,539	1,672,531	1,722,675	15,249,004
Total Deliverable Base Cost	**54,496,269**	**24,678,317**	**23,463,114**	**14,776,475**	**10,858,005**	**3,256,823**	**131,529,004**
Total Deliverable CTG	**-**	**24,678,317**	**23,463,114**	**14,776,475**	**10,858,005**	**3,256,823**	**77,032,735**
Contingency, Remaining Covid							
Cont.	-	9,961,958	9,471,414	5,964,857	4,383,078	1,314,690	31,095,996
Fractional Cont.	-	0.404	0.404	0.404	0.404	0.404	0.404
Remaining COVID cost	-	3,756,831	3,756,831	-	-	861,338	8,375,000
Total Deliverable Cost	**54,496,269**	**38,397,107**	**36,691,359**	**20,741,332**	**15,241,083**	**5,432,851**	**171,000,000**
Funding							
DOE Funds, Guidance (no I&C)	84,515,000	20,000,000	28,000,000	15,700,000	17,000,000	5,785,000	171,000,000
Guidance + Carryover	30,018,731	50,018,731	39,621,624	18,630,266	14,888,934	5,432,851	-
Balance/Carryover	**30,018,731**	**11,621,624**	**2,930,266**	**(2,111,066)**	**(352,149)**	**0**	-
TPC: Deliverables + I&C							
I&C Base Cost	-	-	837,191	3,860,704	2,908,642	1,893,685	9,500,221
I&C Cont.	-	-	2,809	189,296	151,358	156,315	499,779
Total I&C Cost	**-**	**-**	**840,000**	**4,050,000**	**3,060,000**	**2,050,000**	**10,000,000**
Total Deliverable Cost	**54,496,269**	**38,397,107**	**36,691,359**	**20,741,332**	**15,241,083**	**5,432,851**	**171,000,000**
Total Project Cost	**54,496,269**	**38,397,107**	**37,531,359**	**24,791,332**	**18,301,083**	**7,482,851**	**181,000,000**

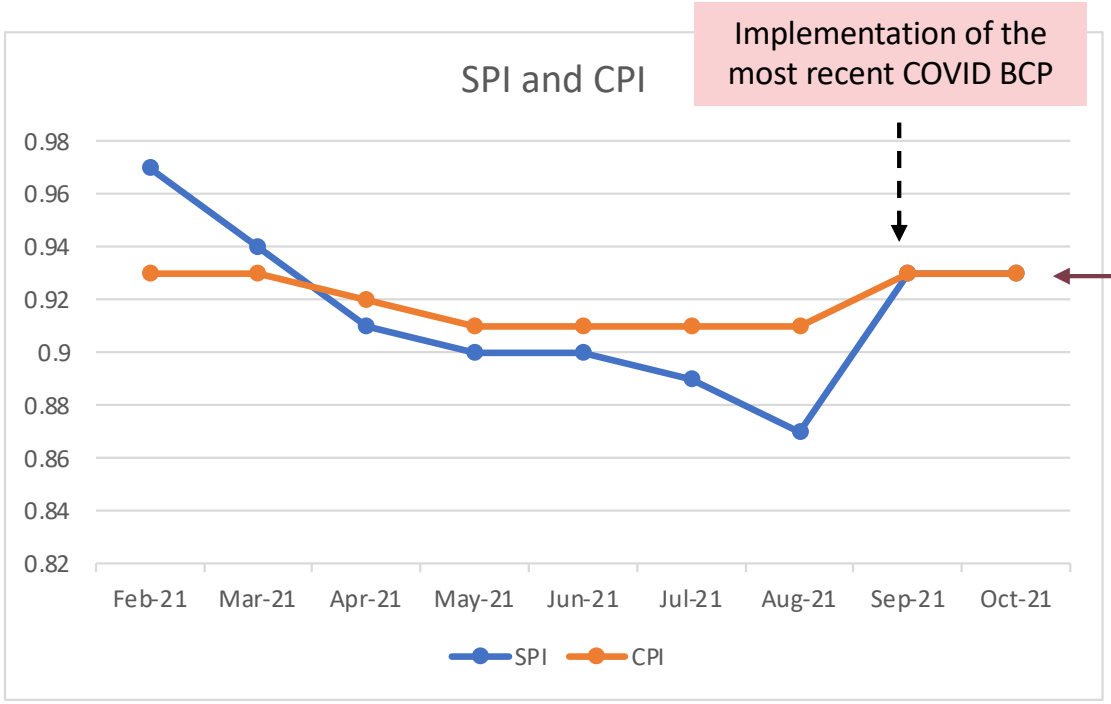
Cumulative Cost/Funding Profiles



- The funding profile does not quite support a technically driven schedule.
  - The principal pinch point is currently in FY24 ($2.1M).
- Near-term issues – budgets, CERN schedule, etc. -- will greatly influence the path forward, which we are preparing for to the extent possible.

EVMS: SPI/CPI from Feb-Oct 2021

See talk from P. Novakova



Current SPI = CPI = 0.93

- The project has been under formal change control since August 2018.
  - Baseline Change Proposals (BCPs) are submitted to the Change Control Board (PO and L2M, Deputies) for approval. Approximately 60 BCPs have been processed to date.
- The most recent (3rd) COVID BCP covered the period Feb–Aug 2021.
  - Improvement is visible as the work and RLS are "trued-up".
- Values are reasonable, particularly in light of the COVID-related challenges.

Key Performance Parameters (KPPs)

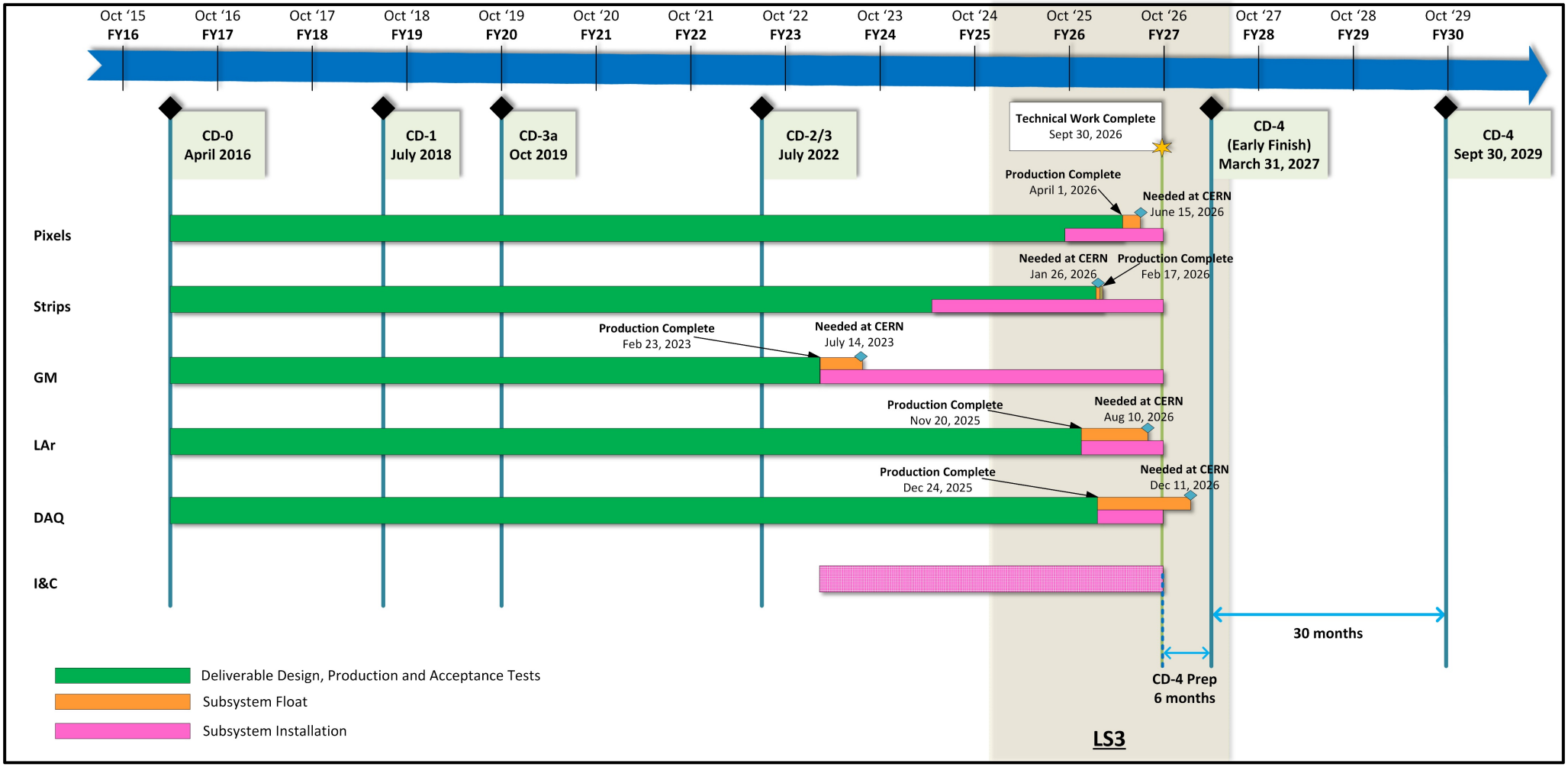
- The project plan has been designed to the Objective KPPs (OKPPs).
- They contain broader specifications than the threshold KPPs (TKPPs), and more explicit involvement in I&C.
  - Threshold KPPs are chosen to ensure adequate performance with room to accommodate scope contingency, should it be needed.

Example KPPs: WBS 6.1, Pixels

	Threshold	Objective
WBS 6.1 – Silicon Pixels	(a) Fabricate, test and deliver to CERN an inner pixel system with coverage to |eta| < 3.0, constructed to ATLAS specifications. (b) Prepare for the integration and testing of the inner pixel system at CERN.	(a) Fabricate, test and deliver to CERN an inner pixel system with coverage to |eta|< 4.0, constructed to ATLAS specifications. (b) Integrate and test the inner pixel detector at CERN. (c) Participate in the installation and commissioning of the inner pixel detector at CERN.

- The explicit inclusion of I&C activities in only the OKPPs, and not the TKKPs, is intended in part to decouple project completion, CD-4, from the CERN shutdown schedule, should that be necessary.
- Should delays render I&C completion inconsistent with CD-4, the deliverable-based TKPPs will satisfactorily define project closeout.

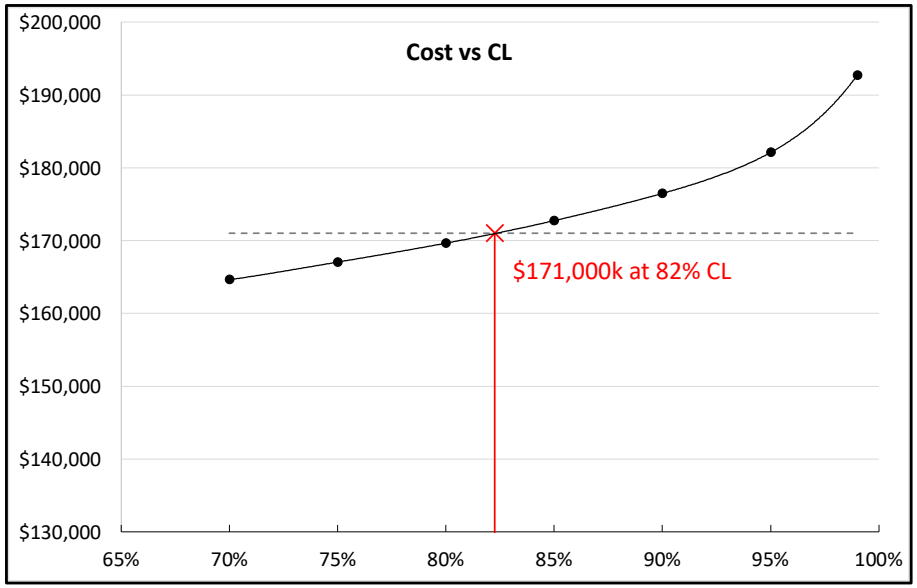
Project Summary Schedule



Monte Carlo

See talks from
G. Brooijmans, C. Meyer

- The MC is run on technical maturity scores and risks using Primavera Risk Analysis (PRA).
  - I&C is not included – deliverables only.
- The funding profile supports the deliverable cost envelope at the 82% CL.
- The silicon systems are synced to access to the pit and drive the ATLAS schedule.



- They are estimated to require a maximum of ~ 22 additional months at the 90% CL, relative to our technically-driven schedule.
  - Assumes the current CERN schedule, prior to the delay/extension of LS3.
- Further refinements are being implemented, and these results will be informed by a hopefully more stable global situation in early spring.

Major Procurements (>$200k)

WBS/Activity	Activity Name	Start	Finish	DIRECT
6.01 Pixel				
LS301910M	PMT: for Graphite Foam Order (production)	03-Feb-22	03-Feb-22	377,038
CCP11610M	PMT: Contribution to CERN Procurements	04-Jan-22	04-Jan-22	225,000
CCP11620M	PMT: Contribution to CERN Procurements (FY22)	04-Jan-22	04-Jan-22	1,182,600
CCP11810M	PMT: Contribution to CERN Procurements (FY23)	03-Jan-23	03-Jan-23	1,496,000
6.02 Strips				
SC200485M	PMT: Material Payment for Ordering Production Bus Tapes (Payment 2)	16-Aug-22	16-Aug-22	1,106,261
SC200475M	PMT: Material Payment for Ordering Production Bus Tapes (total payment)	15-Aug-22	15-Aug-22	463,606
SC501204M	PMT: Material Payment for Order, Receive, Inspect Batch of Honeycomb (Ultracor)	14-Dec-22	14-Dec-22	414,163
RE261412M	PMT: Material Payment for Load Boards Production - Batch 2 - 12	23-Dec-22	09-Jan-23	643,750
RE170040M	PMT: US Contribution to HV Power Supplies	14-Jan-25	14-Jan-25	645,966
RE320650M	PMT: Material Payment for HCCstar Pre-Production Submission Wafers	03-Jun-21	03-Jun-21	412,460
RE310390M	PMT: Material Payment for ABCstar Production by CERN	06-Apr-22	06-Apr-22	1,034,059
RE321030M	PMT: Material Payment for HCCstar Production Order	03-Oct-22	03-Oct-22	543,750

WBS/Activity	Activity Name	Start	Finish	DIRECT
6.03 GM				
OC20471M	PMT: Vendor Milestone 5 Forward Fabrication	03-Jun-22	03-Jun-22	274,550
OC20473M	PMT: Vendor Milestone 6 Barrel Fabrication	03-Jun-22	03-Jun-22	205,907
PST10410M	PMT: Material for Prepreg PST Production	27-Apr-23	27-Apr-23	221,000
6.07 DAQ				
GCM40100M	PMT: Material for Long-Lead Procurement Production Boards (Payment to CERN)	25-Apr-25	25-Apr-25	619,105
FLX40110M	PMT: Material Payment to CERN for FELIX Prod Boards (215 Boards)	23-Jun-22	23-Jun-22	775,252
FLX40130M	PMT: Material Payment for Production Card FPGAs	11-Aug-23	11-Aug-23	1,184,587
FTK40100M	PMT: Procurement of 51 PCIe I/O Cards (Production)	07-Dec-23	09-Jan-24	508,551

- The project has much experience with these procurements and many of the vendors.
  - ASICs, foam/honeycomb, pre-preg, PCB fabrication.
  - Many of the business/technical relationships pre-date this project, for individuals & institutions.
- CERN procurement apparatus, where used, is highly seasoned and experienced.
- Procurement processes and management are mature for this stage, and well on track for a summer ‘22 CD-2/3.

Status of CD-3a/Long Lead Procurements

WBS L4 (Cost Acount)	CD-3a Review	Base Cost Oct 2021	Diff (cont. used)	% Complete (9/30/2021)	Completed Work	Remaining Work
6.02 ATLAS Upgrade Phase II - Strips	**5,873,368**	**6,652,895**	**779,527**	**25%**	**1,655,594**	**4,997,301**
6.02.01.32 Stave Core LBNL - CD-3a	126,620	295,833	169,213	0%	-	295,833
6.02.01.35 Stave Core Yale - CD-3a	959,872	1,485,100	525,227	35%	516,615	968,484
6.02.02.31 Readout Electronics-BNL - CD-3a	298,179	159,650	(138,529)	30%	47,612	112,037
6.02.02.32 Readout Electronics-LBNL - CD-3a	1,379,035	1,669,448	290,413	9%	146,775	1,522,673
6.02.02.03 Readout Electronics-Penn - CD-3a	2,481	2,481	2,481	0%	-	2,481
6.02.02.35 Readout Electronics-Yale - CD-3a	154,095	137,047	(17,049)	100%	137,047	0
6.02.04.31 Modules-BNL - CD-3a	16,741	16,795	54	0%	-	16,795
6.02.04.32 Modules-LBNL - CD-3a	332,871	209,596	(123,275)	88%	184,445	25,152
6.02.04.34 Modules-UCSC - CD-3a	23,110	23,110	0	100%	23,110	-
6.02.05.31 Stave Assy-BNL - CD-3a	148,796	94,414	(54,382)	0%	-	94,414
6.02.07.01 US Contributions to CERN Procurements (core)	2,431,568	2,559,421	127,854	23%	599,990	1,959,432
6.03 ATLAS Upgrade Phase II - Global Mechanics	**3,039,708**	**4,248,185**	**1,208,478**	**59%**	**2,510,265**	**1,737,920**
6.03.02.31 Outer Cylinder LBNL CD-3a	1,694,238	2,563,357	869,119	60%	1,539,004	1,024,353
6.03.04.31 Structural Bulkhead SLAC CD-3a	283,565	320,613	37,048	88%	281,151	39,462
6.03.04.33 Structural Bulkhead LBNL CD-3a	85,927	112,536	26,609	29%	32,367	80,169
6.03.05.31 Strip Barrel Shells LBNL CD-3a	975,978	1,251,679	275,701	53%	657,743	593,935
Total Base	**8,913,076**	**10,901,080**	**1,988,005**	**38%**	**4,165,859**	**6,735,221**
CD-3a Contingency	**3,686,924**	**1,698,920**				
Total Cost (Base + Cont.)	**12,600,000**	**12,600,000**				
CCTG	**41%**	**25%**				

See L2 talks from G. Sciolla, E. Anderssen + breakout talks

Strips: ASICs, electronics components, honeycomb, foam

GM: Outer CF cylinder, bulkheads, CF support shells

- GM is vendor-driven: a firm fixed-price contract is in place and work is quite advanced and proceeding well; the remaining scope has limited exposure.
- Strips is advancing, but some procurements are experiencing vendor cost/supply chain impacts & related technical risks.
- COVID impact estimate: $400k => would result in 31% CCTG.
  - Vendor's COVID impacts are not always easy to quantify – we consider this to be a lower bound.
- We are not requesting approval for additional contingency at this time, as agreed to by DOE.

Environment, Safety, & Health

See talk from L. Stiegler

- The Project's ES&H Plan is predicated on a commitment to Integrated Safety Management (ISM) principles.
  - Define scope of the work; identify hazards; establish controls on hazards; provide mechanism for feedback and improvement.
  - BNL's Standards Based Management System (SBMS) is the basis for compliance where no HL-LHC institutional policy exists.
- The BNL ES&H Liaison provides oversight and advice on ES&H. She/he serves as a BNL Physics Department resource to assist the Project in developing and implementing its ES&H plans.
- U.S. ATLAS HL-LHC principals and their institutions are the parties responsible for complying with all applicable ES&H laws, regulations and requirements, with guidance from the Liaison.

Quality Assurance & Control

See talk from C. Gortakowski

- The U.S. ATLAS HL-LHC QA Plan conforms to the criteria of DOE Order 414.1D (Quality Assurance) and is compliant with BNL's SBMS.
- The QA/QC Liaison provides oversight and advice on all work performed at BNL and at remote U.S. sites, ensuring that it conforms to QA standards and practices, and that required procedures are followed during Project execution.
- He/she serves as a BNL Physics Department resource, assigned to assist the Project in developing and implementing its QA plans and procedures.
- The QA Plan will embody the concept of a graded approach, whereby an appropriate level of analysis and control is selected and applied to the work activities.
- QA compliance is the responsibility of each principal and institution, and encompasses all activities, including:
  - Design process and review; configuration management; QA and testing procedures; procurement.

Equity, Diversity & Inclusion

- The project remains abreast of all ED&I policies and procedures and is proactive in their implementation.
- These and related considerations are integrated into all aspects of its personnel management.
- This extends to new project hires, as well as appointments within the project organization as opportunities become available.
- ED&I practices and processes remain a priority for the project as the organization, staffing and character of the work evolve.

Path to CD-2/3 (1)

- Tasks on which we will be focusing to realize a CD-2/3 review in Q4 FY 2022 include:
  - Driving the International ATLAS designs & interfaces to fully construction-ready state, as defined by O413.3b.
    - Includes prototyping, pre-production.
  - Ensure that project plan is consistent with a performance baseline and DOE mission need.
  - Achieve appropriate CD/2-3 level of production/procurement readiness project-wide.
  - Finalize scope, schedule, critical path analysis, cost & contingency.
  - Ensure EVMS compliance and readiness.
  - Final ES&H plan in place, hazards documented and an integrated part of the project execution. QA/QC plan is documented and executable.
  - Ensure COVID estimates are current and integrated into the project plan.

Path to CD-2/3 (2)

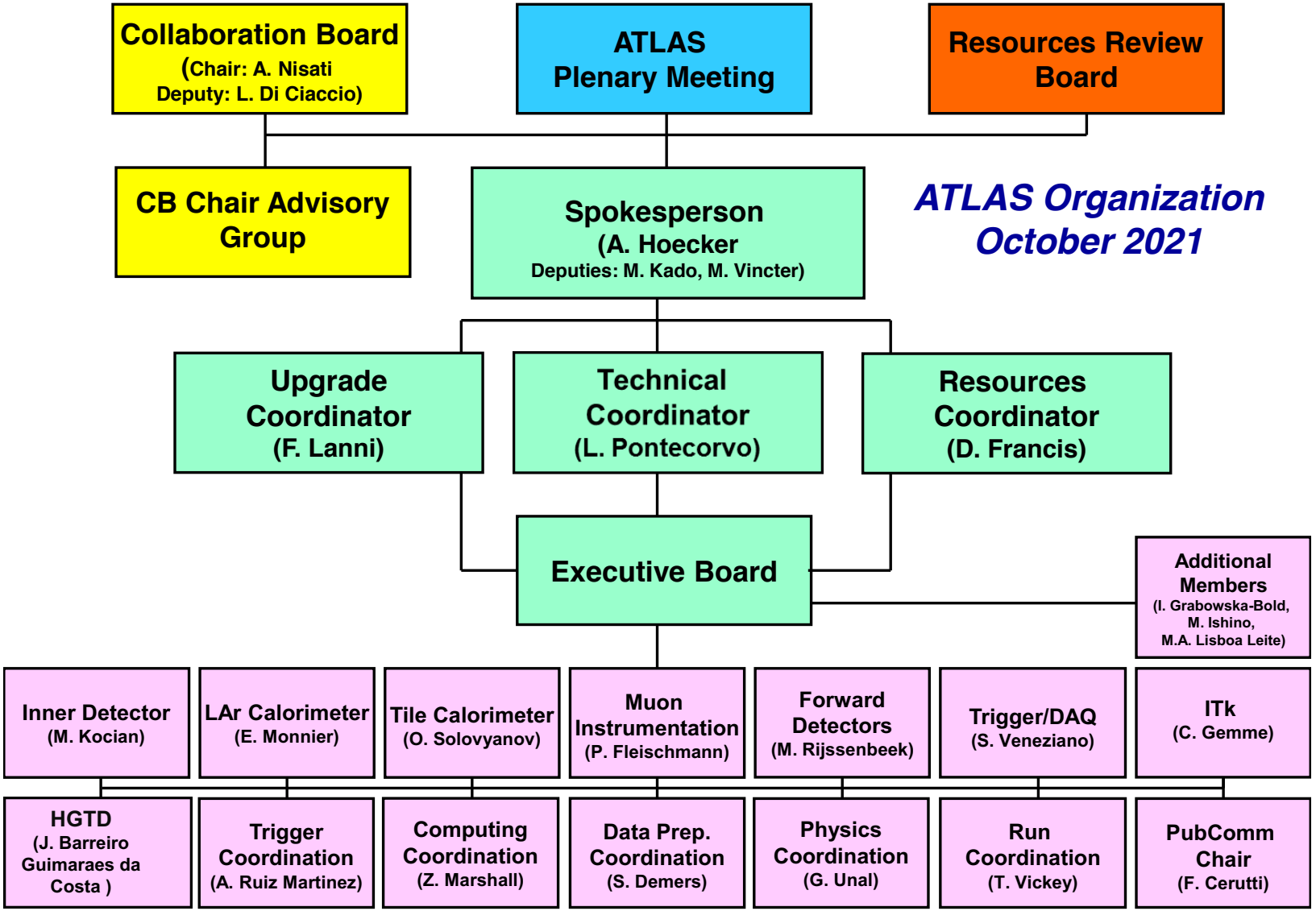
- Plan to CD-2/3 (cont'd):
  - Perform a Final Design Review and integrate panel recommendations.
  - Ensure necessary documentation and plans are complete and signed off on by relevant parties & stakeholders.
    - PEP, AS, Hazard Analysis, PMP, QA Plan, Value Management, Supply Chain Analysis, etc.
  - Ensure regulatory and coordination issues with stakeholders are in place and will support project execution.
  - Continue regular convening of IPT and other meetings, as needed.
  - Full and complete risk management plan, register and Monte Carlo and integration into the project plan.
  - KPPs and CD-4 that support project execution and contingencies.
  - A funding profile well-defined and agreed upon by all relevant parties that supports the project plan.
  - Appropriate level of project management and personnel staffing.

Closing Remarks

- A strong, committed and experienced U.S. ATLAS HL-LHC project team is in place and collaborating well together.
- We have defined an upgrade project that is well matched to the unique U.S. expertise and optimizes our contribution to a strong and cogent HL-LHC physics case.
- The project plan has been reconsidered bottom-up for this review and its trajectory is consistent with a mid-2022 baseline.
- COVID impacts are regularly being assessed and integrated.
- The updated DOE funding profile does not fully support the current technically-driven schedule.
- The project is prepared to adapt to the considerable global instabilities to the extent possible.
- Our close collaboration with both the agencies and International ATLAS are invaluable elements in the realization of our international commitments.

Backup Slides

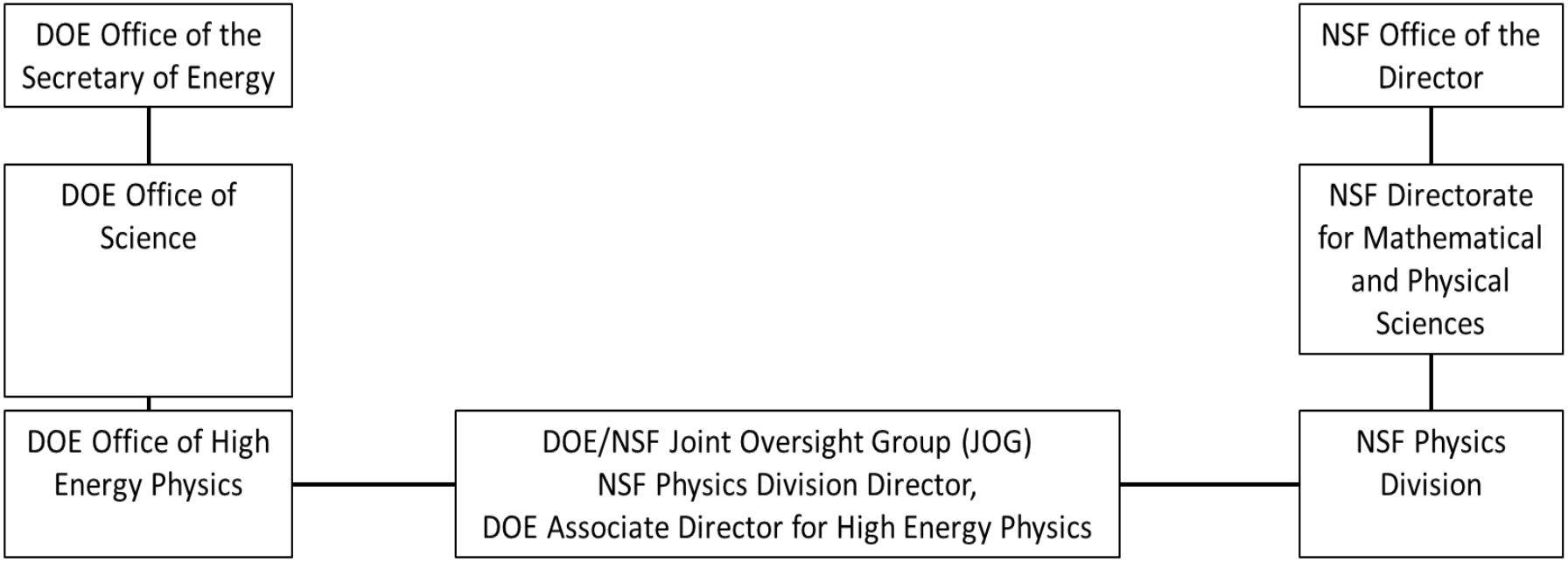
International ATLAS Organization



Technical Progress

- Good technical progress continues to be made, albeit in a manner limited by both domestic and international COVID-19 constraints.
  - Prototype module construction and loading of the pixel inner system.
  - Construction of carbon fiber silicon support shells.
  - Site qualification at the three silicon strip US production sites; submission of key strips ASICS (HCC*, AMAC*).
  - Selection and ongoing development of the U.S. version of the LAr preamp/shaper readout ASIC (ALFE2).
  - Completion of testing of the Global Common Module prototype for the ATLAS DAQ system.

Agency Oversight



The Joint Oversight Group (JOG) acts as the principal oversight body for the HL-LHC project.
It does not serve a line management function.
The project reports in line management to its corresponding sponsoring agency.

Overall HL-LHC Project Planning

- The US processes and requirements must dovetail with International ATLAS processes and decision making.
  - TDR schedule defines the U.S. deliverables – "project start."
  - CERN schedules define the delivery dates – "project completion."
- Start and end dates, fixed by international constraints, must be properly folded into the planning, while still allowing for the execution of a U.S.-style project (413.3b/MREFC).
  - The DOE and NSF approval gates require a certain level of design maturity; the TDRs must be completed "on time," but must also be ~ sufficiently detailed to meet the maturity standard required by the U.S. review processes.
- The joint U.S. ATLAS and U.S. CMS MREFC proposal has helped catalyze coordination between the two projects.

Groups, Contacts and Meetings (1)

- PM, PO personnel, L2 Managers and Deputies, and other U.S. project personnel continue to remain heavily engaged at CERN and with International ATLAS.
  - These include ongoing discussions about the evolving U.S. scope and involvement with the ATLAS Spokesperson, Upgrade and Technical Coordinators, Project Leaders, ATLAS Resource Coordinator, and others.
  - Frequent discussions with ATLAS management.
- The PO meets in the morning three times per week.
  - This is an extremely valuable time, during which we plan, compare notes, etc.
- Regular meetings between the PO and the Level 2 Managers and Deputies, and within the L2 systems, continue.
  - Weekly, or more frequently, as required.
- The PM meets weekly with ATLAS management.

Groups, Contacts and Meetings (2)

- The Integrated Project Team (IPT), mandated by the DOE order, has been expanded to include all HL-LHC stakeholders, and meets ~ bi-weekly.
  - BNL Federal Project Director, NSF Program Director, DOE Program Director, HL-LHC upper management, Phase I Project Manager, BNL Lab Management, DOE Site Office.
  - Covers both Phase I and HL-LHC, a very useful feature.
- Site visits to U.S. ATLAS HL-LHC institutes will resume once travel restrictions and COVID impacts ease.
  - These invariably prove to be of great value.

Principal PO Roles & Responsibilities (1)

- Project Manager
  - Management and oversight of project planning and execution ensuring it is executed safely, within cost and on schedule, point of contact to DOE and ATLAS management, manage central BNL PO, chair change control board
- Deputy Project Manager, Project Development
  - Management and oversight of development of project plan including RLS, risks and corresponding documentation, assist PM in project planning and execution
- Deputy Project Manager, Technical Integration
  - Management and oversight of technical planning, execution and integration of US-ATLAS deliverables, management of US ATLAS deliverables' integration in international ATLAS, technical point of contact to ATLAS
- NSF PI
  - Oversight of project planning and execution of NSF-specific scope, point of contact to NSF, manage and oversee the cooperative agreement and financial functions at Columbia, manage Columbia PO

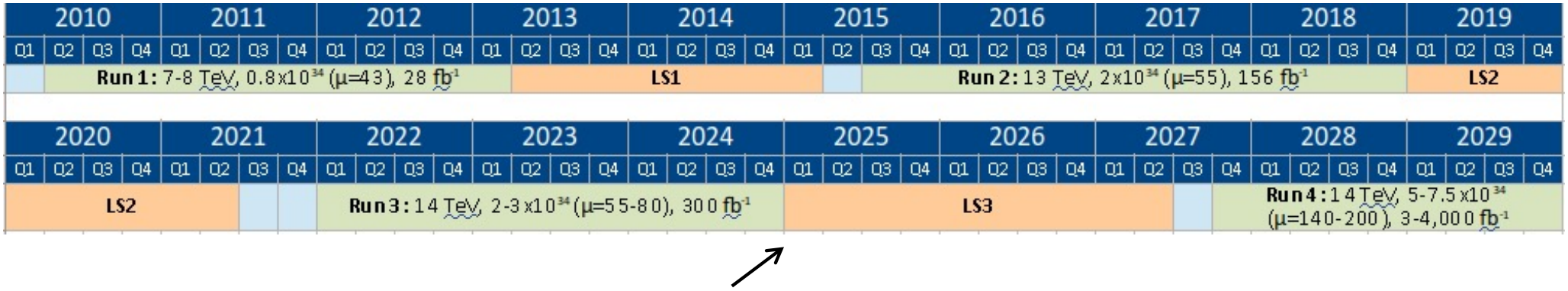
Principal PO Roles & Responsibilities (2)

- Assistant Project Manager, Project Finances and Controls
  - Coordinate project controls effort, ensure project's compliance with EVMS guidelines, DOE order 413.3B and NSF LFM
- Risk Manager
  - Manage and oversee implementation of project risk plan, manage variance reports and maintain risk register, perform risk analysis
- Level 2 Managers
  - Develop system's project plan and manage its execution, compile monthly status reports, develop and present BCPs, interface to corresponding ATLAS systems, compile and own risks
- Level 3 Managers/CAMs
  - Contribute to development of project baseline, manage execution of work, monitor institutional performance, analyze deviations from baseline and oversee corrective action plans, monitor and manage risks, identify and manage changes to baseline
- Institutional Contacts
  - Aid Level-3 managers in developing project plan, manage technical work, report on technical progress and costs, ensure adherence to ES&H policies

Integrating Past Experience

- The HL-LHC upgrades have been modeled on, and are heavily informed by, both the original ATLAS construction and Phase I experiences.
  - Long-standing, historical involvement with ATLAS designs, personnel & culture.
- Many project personnel have brought this experience to bear as they have shifted to HL-LHC.
  - Technical knowledge of, and familiarity with, the ATLAS detector.
  - Negotiating scope in the international context; navigating the CERN environment.
  - RLS, cost estimation, EVMS, reporting and variance tracking associated with modern project execution.
  - Project, technical and budget management.
- They recognize their role in training a new generation of scientists.
- The development of the HL-LHC project plan has benefitted greatly from this experience, as well as from a significant HL-LHC R&D effort.

Current LHC Schedule



- Long Shutdown 3 (LS3) – a 2.5-year shutdown and installation period beginning in Jan 2024 – is the overall milestone that drives the upgrade construction completion schedule.

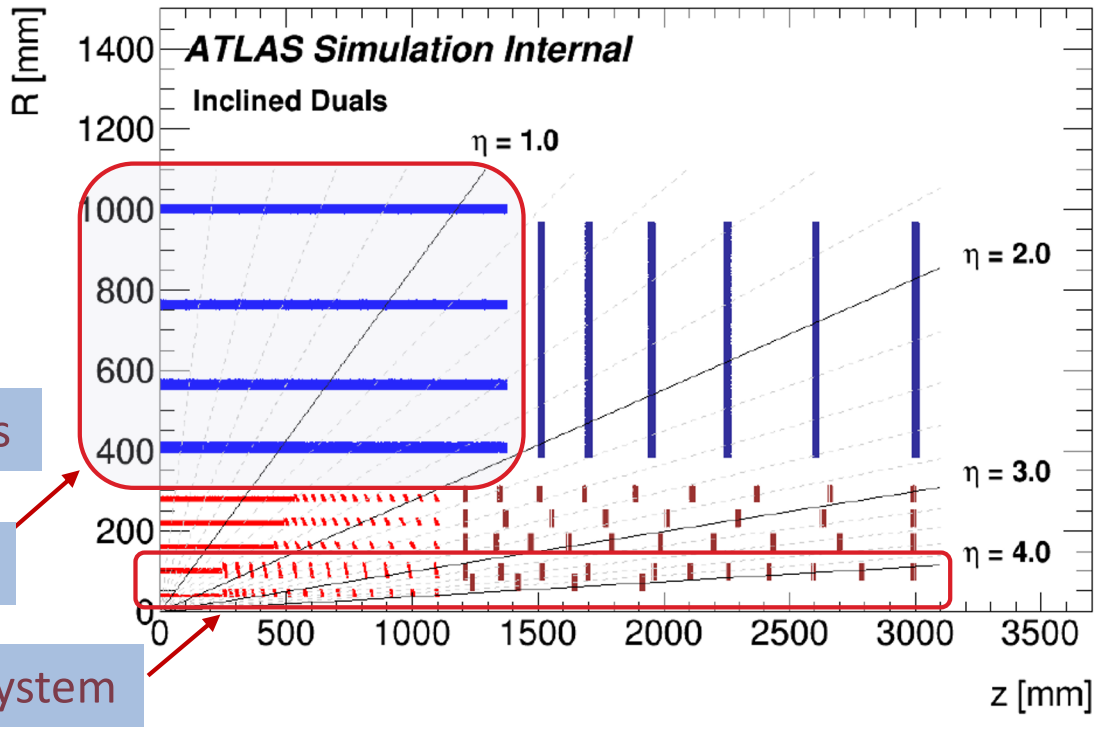
Run	Years	Energy (TeV)	Bunch Spacing (ns)	Peak Lumi (x 10^{34} $cm^{-2}s^{-1}$)	Peak Pileup (pp collisions/crossing)	Total Int. Lumi (fb^{-1})
1	2010-12	7,8	50	0.77	43	28
2	2015-18	13	25	2.1	55	156
3	2021-23	13-14	25	2-3	55-80	300
4	2026...	14	25	5-7.5	140-200	3-4,000

DOE Scope: WBS 6.1-6.3: Inner Tracker (ITk)

- Complete replacement of current Inner Detector with a new all-silicon Inner Tracker (ITK)
  - More radiation hard, many more readout channels.
  - Pixel and Strip detectors (coverage to |η|=4.0) + Global Mechanics
  - Current detector: pixels + strips + TRT (to |η|=2.5)

Silicon systems account for 80% of the DOE subsystem base cost.

- All-new electronics & services
  - Significantly less material
  - Operation with new trigger architecture



6.3 Global Mechanics: support structures

6.2 Strips: Barrel staves + electronics

6.1 Pixels: Full Inner system

DOE Scope:
WBS 6.4: Liquid Argon Calorimeter (LAr)

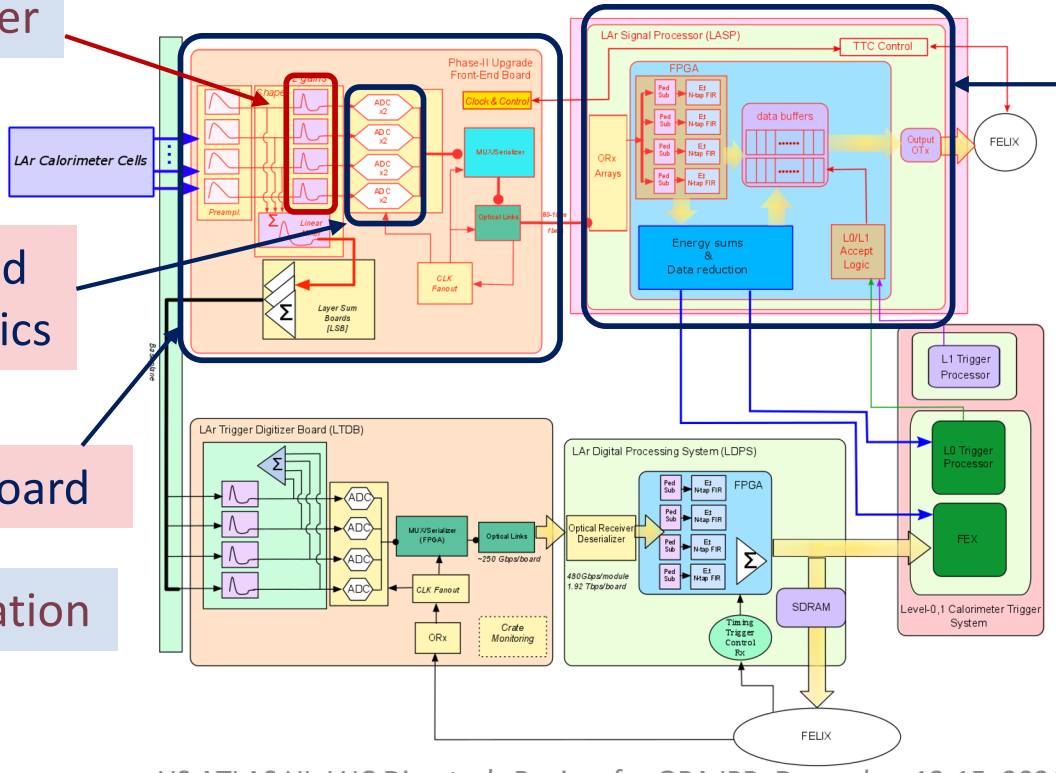
- Replacement of LAr electronics only – no detector changes
  - Readout all data from detector to Back End at 40 MHz bunch-crossing
    - Currently data stored in analog pipelines on Front Ends
  - Preamp-shaper with two 14-bit gains providing 12-bit precision at all times
    - Analog signals split off to L1 Trigger

6.4.5: PA/Shaper

6.4.1: Front End Electronics

6.4.2: Front End Board

6.4.4: System Integration



6.4.3: Back End Electronics

Blue = DOE scope

Pink = NSF scope

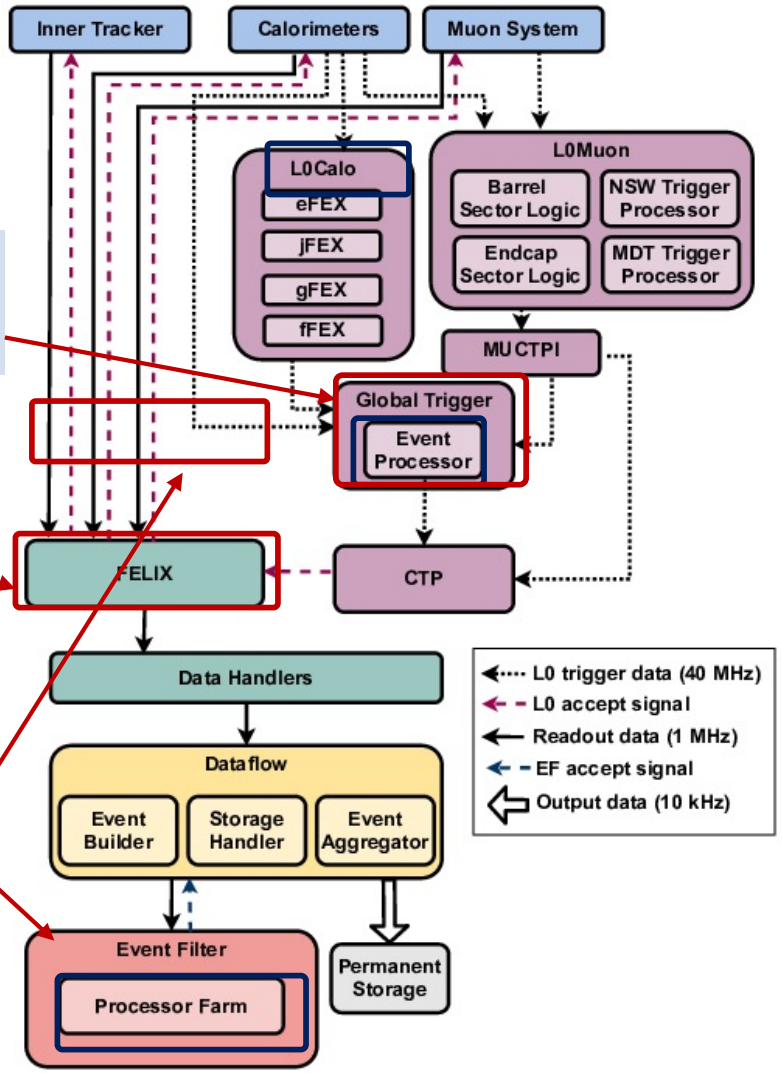
DOE Scope: WBS 6.7: Data Acquisition

- New Hardware-Level Trigger Architecture
  - Lowest level (L1→L0)
    - accept rate 100 kHz → 1 MHz
    - latency 2.5 → 10 µs
- FELIX readout system
- Significant changes to High Level Trigger (HLT)
  - Commodity-based track reconstruction (NSF scope)

6.7.1: Global Common Module

6.7.3: FELIX

6.7.4: Readout Interface Firmware



Project Planning

See talks from
G. Brooijmans, P. Novakova, C. Meyer

- The project scope is carefully crafted to adhere to the funding guidance.
  - Many factors are considered: physics goals, ATLAS needs, U.S. expertise and historical involvement, past institutional performance, developing our junior colleagues, etc.
- This scope provides the basis for the resource loaded schedule (RLS) in P6.
  - The RLS is quite mature for a project at this stage, consisting of 15,000 tasks, and has been extensively scrubbed and refined.
- P6 has been pushed through COBRA, the output of which is posted for this review.
  - BoEs, cost books, schedules, etc.
- The RLS contains all known dependencies.
- Task uncertainties, based on task maturity, and both global and sub-project risks, are fully integrated into the plan and simulated in the MC.
- Cost and schedule contingency is estimated via a Monte Carlo simulation.

Environment, Safety, & Health (2)

- All work on the Project will be planned in a manner that is ES&H compliant.
  - The principals will adhere to the work planning and review methods in place at each site or department where work is performed. Work at CERN will adhere to CERN protocols.
  - Planning is expected to include safety reviews, and work planning and permits.
  - Training needs will be identified; BNL training protocols are used if those at work location are not available or appropriate.
  - Institutional ES&H compliance is called out in all MoUs/SoWs.
- All documentation has been in place since CD-1.
  - Preliminary Hazard Analysis Report (PHAD), NEPA, ES&H Plan.
- ES&H will be regularly statused for compliance by the collaborating institutions, and periodic updates with the Liaison.

Quality Assurance & Control (2)

- QA compliance is the responsibility of each principal and institution, and encompasses all activities, including:
  - Design process and review; configuration management; QA and testing procedures; procurement.
- The current status of the Project's processes are described in the QA sheets, generated by deliverable; and the Configuration and Procurement Management Plans.
- QA and QC will be regularly statussed and evaluated for compliance.
  - PO, Change Control Board, Program Management Group.