B08: CE Path to CD-3a, CD-2

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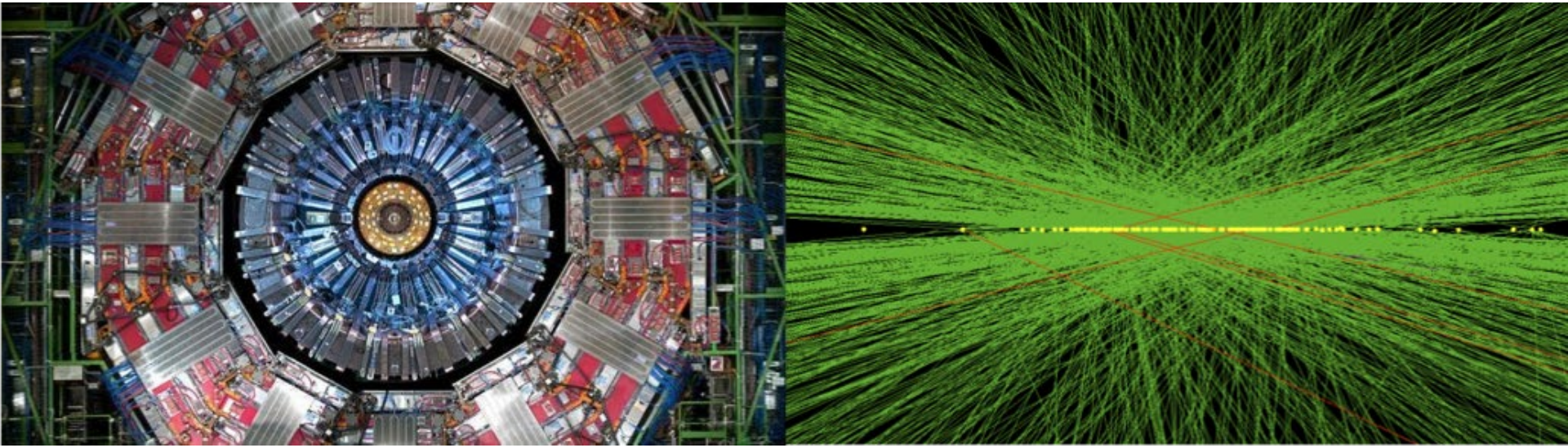
CD-1 Review

October 23, 2019



Prerequisites for Baseline

- Preliminary design
  - Resolve remaining technical questions
  - Definitive scope
  - High-quality, reliable cost and schedule estimate for performance baseline
  - Resource-loaded schedule suitable to measure Earned Value
- Implementation of Earned Value Monitoring System (EVMS)
  - Measure performance against fixed baseline
  - Formal change control
  - Analyze cost and schedule variance
  - Produce metrics for DOE's project reporting system (PARS-II)

402.4 Maturity

	L3s													
	Sensors		Modules		Cassettes		Scintillator		Electronics		AVE		BAC	
CE	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech
Conceptual Design	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Preliminary Design	100%	100%	100%	94%	88%	79%	95%	81%	100%	86%	97%	88%	96%	89%
Final Design	80%	90%	51%	22%	21%	14%	26%	18%	53%	19%	46%	33%	47%	34%
Detailed Design	0%	45%	0%	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%	10%
Construction Readiness	40%	50%	0%	0%	0%	0%	0%	0%	0%	0%	8%	10%	9%	11%

DESIGN PHASE	Maturity Categc	COMPLETION CRITERIA	Design Phase W
Preliminary Design	Management	Interfaces have been identified.	20%
Preliminary Design	Management	Value engineering performed.	10%
Preliminary Design	Management	Preliminary QA plan developed	20%
Preliminary Design	Management	Lessons learned from other experiments are incorporated into the design or planning as relevant.	10%
Preliminary Design	Management	Activity-based resource-loaded baseline cost and schedule fully developed, including a full contingency analysis.	30%
Preliminary Design	Management	Make/buy evaluation complete.	10%
Preliminary Design	Technical	Baseline design/methodolgy/architecture choice has been made.	20%
Preliminary Design	Technical	Preliminary design/methodology/architecture is sufficiently developed, incl. preliminary design drawings of major comp	20%
Preliminary Design	Technical	Technical Design Report completed.	20%
Preliminary Design	Technical	Component designs/methods at the 30% level of design completion.	40%

- Design maturity calculated based on a rubric which includes multiple aspects classified as “management” and “technical”
  - Includes a target level of technical design work completion, but this is only a portion of the overall maturity.
  - Technical design work completion is estimated by managers in consultation with engineers and represents a combination of outstanding design questions and remaining “drafting/implementation” phase of design

Detailed Design – Sensors

- Frame contract signed between CERN and HPK (August 2019)
  - Unit costs fixed in JPY
  - Delivery schedule understood and agreed
- Some details remain under discussion with the vendor
  - Procedures for sensor backside-protection
    - Affects details of sensor testing and could result in a small additional service charge from vendor for applying a protection layer at the vendor
  - Sensor design close to final
    - Improvements for streamlined QC implemented into final full-sensor designs (small details)
    - Multi-shape odd-sized wafer under advanced design
- QC center setup moving to completion
  - Will be ready to receive pre-series sensors in 2020
- CE will be ready for CD-3a (target: March 2020)

Preliminary Design -- Modules

- Module assembly and design are well-understood from the initial testing cycles
  - High volume (55+) 6” module construction for testbeam
  - Low volume 8” module construction carried out so far
- Work remains to extend to odd-sized modules and to make the QC plans more-complete
  - Will be carried out as part of the ongoing major system prototype 1 cycle
  - Quotes for volume production also will be obtained as part of this cycle
- Ready for CD-2 in May 2020

Preliminary Design -- Cassettes

- Cooling plate design interface constraints (cooling pipe locations, support structure, shapes) established by CERN EDMS (Engineering Document Management System) documents
  - Design for cooling plate understood well from mockup campaign, prototype 1 design also complete
- Motherboard system is conceptually well-understood, but preliminary design is less-advanced
  - Division of functions (power distribution, DC/DC, data transfer, concentration) now well-understood, but a full design of a wagon/engine system has not been completed yet
  - A primary focus of major system prototype 1
- Cassette assembly procedure is advanced, but depends on motherboards for some details
  - Module-level assembly validated by mockup campaign
- Ready for CD-2 in August 2020

Preliminary Design -- Scintillator

- Conceptual design strongly-influenced by successful CALICE efforts, CMS modifications are limited
  - New SiPM+package – SiPM structure is validated by tests with commercial devices, custom package for high thermal conductivity and radiation tolerance will be validated in first half of 2020 (on order)
  - Differences in geometry – wrapping and assembly of tiles of various sizes. Assembly has been demonstrated at FNAL, wrapping optimizations underway at DESY and NIU. These are minor design optimizations.
- Electronics strategy and QC procedures will be validated by the major system prototype 1 which is underway
  - Tileboard-1 PCBs have been received at DESY, cables boards are at Minnesota, and wing-board work is underway at FSU
- Ready for CD-2 in May 2020
  - P6 milestone is early as it does not account for some delays to the tileboards

Preliminary Design -- Electronics

- Preliminary design requires 30% of design completion
  - ECON is currently considered at 20% of design completion
    - Inputs specified, receiver and alignment block complete, fast-control and slow-control initial implementations complete, algorithms at an advanced preliminary level
  - Path to surpassing 30% is clear: systematic plan to complete necessary blocks of ECON design
    - Expect to achieve at least 90% design completion by May 2020 for submission of ECON prototype
  - Power supply preliminary system design is also advancing to be ready for CD-2 approval
- Expect to be ready for CD-2 in May 2020

Scope, Cost and Schedule

- Scope defined in KPPs

WBS	Threshold KPP	Objective KPP
402.4	T-KPP-CE-1: CALORIMETER ENDCAP CONSTRUCTION	O-KPP-CE-1: CALORIMETER ENDCAP CONSTRUCTION AND INTEGRATION
Endcap Calorimeter	The project shall construct the silicon modules and scintillator modules for the hadron section of the endcap calorimeter, and integrate them onto cassettes. In addition, the project shall assemble the odd-sized modules for the electromagnetic calorimeter for delivery to collaborators, and design, produce, and test the data/trigger concentrator ASIC(s) required for the endcap calorimeter.	The project shall construct the silicon modules and scintillator modules for the hadron section of the endcap calorimeter, and integrate them onto cassettes. In addition, the project shall assemble the odd-sized modules for the electromagnetic calorimeter for delivery to collaborators, and design, produce, and test the data/trigger concentrator ASIC(s) required for the endcap calorimeter, and procure power supplies for the hadron section of the calorimeter. The fabrication shall include sufficient components for a testbeam calibration system.
	Calorimeter silicon and scintillator modules shall have sufficient granularity, noise level, and radiation tolerance to enable cell-by-cell calibration at the 5% level through the end of operation. The cassettes shall be demonstrated to operate standalone and delivered to CERN.	Calorimeter silicon and scintillator modules shall have sufficient granularity, noise level, and radiation tolerance to enable cell-by-cell calibration at the 5% level through the end of operation. The cassettes shall be demonstrated to operate standalone and delivered to CERN, where they shall be assembled, and integrated into the endcap calorimeter. The project shall additionally participate in the installation, testing and calibration of the detector.

- Estimates of Resources and Durations
  - Fundamental structure of sequenced activities is established
  - Major System Prototype 1 will validate these estimates
  - Vendor inquiries and MSP1 efforts will confirm costs and procurement processes

Cost – Basis of Estimate

- Project divided into 21 estimate documents
  - Maintain similarity in topics while parsing into finite number of digestible chunks
- Follows Project Office guidance via Key Assumptions Document
- Standard BOE format
  - Scope
  - Narrative for cost basis
    - May cite supplementary material in same or connected DocDB container
  - Summary Tables
    - M&S and Labor
    - Connected to costbook via“BoeRef”

L3 Parent:WBS : 402.4.2 CE - Management (1)		
DOE	402.4.2 CE - Management	CMS-doc-12795
L3 Parent:WBS : 402.4.3 CE - Sensors (3)		
DOE	402.4.3.1 CE - Silicon Prototyping and Development	CMS-doc-13021
DOE	402.4.3.2 CE - Silicon Production	CMS-doc-13022
DOE	402.4.3.3 CE - Silicon Quality Control	CMS-doc-13762
L3 Parent:WBS : 402.4.4 CE - Modules (7)		
DOE	402.4.4.1.1 CE - Module Base Plates	CMS-doc-13023
DOE	402.4.4.1.2 CE - OBSOLETE WBS ELEMENT	
DOE	402.4.4.1.3 CE - Module Circuit Boards	CMS-doc-13026
DOE	402.4.4.2 CE - Module Factories	CMS-doc-13204
DOE	402.4.4.3 CE - Standard Module Assembly Site 1 (TTU)	CMS-doc-13031
DOE	402.4.4.4 CE - Standard Module Assembly Site 2 (CMU)	CMS-doc-13032
DOE	402.4.4.5 CE - Module Assembly at UCSB	CMS-doc-13033
L3 Parent:WBS : 402.4.5 CE - Cassettes (5)		
DOE	402.4.5.1.1 CE - Cassette Cooling Plates	CMS-doc-13034
DOE	402.4.5.1.2 CE - Silicon Module motherboards	CMS-doc-13035
DOE	402.4.5.1.3 CE - Cassette Interface and Cables	CMS-doc-13036
DOE	402.4.5.2 CE - Cassette Tooling and Test Stands	CMS-doc-13205
DOE	402.4.5.3 CE - Cassette Assembly and Shipping	CMS-doc-13206
L3 Parent:WBS : 402.4.6 CE - Scintillator Calorimetry (5)		
DOE	402.4.6.1 CE - Scintillator Development and Prototyping	CMS-doc-13141
DOE	402.4.6.2 CE - Scintillator Production	CMS-doc-13765
DOE	402.4.6.3 CE - SiPM Photodetectors	CMS-doc-13049
DOE	402.4.6.4 CE - Scintillator Tile Modules	CMS-doc-13766
DOE	402.4.6.5 CE - Scintillator Motherboards	CMS-doc-13308
L3 Parent:WBS : 402.4.7 CE - Electronics and Services (2)		
DOE	402.4.7.1 CE - Concentrator ASIC	CMS-doc-13051
DOE	402.4.7.2 CE - Power System	CMS-doc-13309

Example BOE Information Flow

My preferences Email notifications Limit my groups Logout

CMS Document 13049-v12

BoE for: 402.4.6.3 CE - SiPM Photodetectors

Document #: CMS-doc-13049-v12
Document type: Technical Data
Submitted by: Lucas Taylor
Updated by: Steven Christopher Nahn
Document Created: 03 Jun 2016, 15:09
Contents Revised: 19 Sep 2019, 22:27
Metadata Revised: 19 Sep 2019, 22:27

Update Document

Update Metadata

Abstract:
BoE for: 402.4.6.3 CE - SiPM Photodetectors

Files in Document:

- BoE (BoE---402-4-6-3---CE--SiPM_Photodetectors_09192019.pdf, 342.6 kB)

Other Files:

- BoE Source (BoE---402-4-6-3---CE--
- Quote for HE Phase 1 SiPMs (Quote 1300pcs 8CH MPPC array 20150513.pdf, 179.4 kB)
- Recent purchase of small-quantity SiPMs from Hamamatsu (SO-555582.pdf, 99.6 kB)

Get all files as tar.gz, zip.

Viewable by:

- CMSDocAdmin
- USCMS-MGMT
- USCMS-UP-REVIEWS
- USCMS-UP-TEAM
- USCMS-UP-PHASE2

Modifiable by:

- CMSDocAdmin
- USCMS-MGMT
- USCMS-UP-TEAM
- USCMS-UP-PHASE2

Quick Links:
Latest Version

Supporting Documentation

US CMS HL-LHC Upgrade Project **CMS-doc-13049**

Basis of Estimate

9.3. SiPM Production

The production of 142k SiPMs represents:

- 120k SiPMs, representing 50% of the total needed for the detector
- 10k SiPMs to build a test beam wedge
- 12k spares (10% of full production) for mechanical tests, electrical tests and destructive SiPM testing

The cost for the large-volume order is based on the cost for the HE SiPMs. These devices were purchased at a cost of $221 for an array of eight SiPMs, including the SiPMs themselves, the cost of putting the devices into a customer-supplied package, providing and mounting a glass window for the SiPM array, and carrying out tests both before and after the packaging. Each SiPM was prepared on a wafer of 3.3 x 3.3 mm (though the active area of each SiPM was round, the silicon surface was square). Extrapolating from the HE SiPM costs, we factor in a 20% discount due to the larger quantity being procured, and also because the testing requirements at the vendor will be less stringent than for HE. We arrive at an estimate of $4.66 per channel for a 2 mm² SiPM. For the 4 mm² SiPMs we simply scale the cost by area, giving an estimate of $9.31 per channel. The total cost estimate for production SiPMs is $720,000.

BoE

WBS - Name	BoE Ref	Name	Est. Type	Institute	Direct M&S
402.4.6.3 CE - SiPM Photodetectors	CMS-doc-13049-MS-01	SiPM prototyping costs	M5	ND	25,000
			M4	ND	80,000
			M1	ND	20,000
	CMS-doc-13049-MS-02	SiPM travel costs	M2	ND	15,000
			M1	ND	6,000
	CMS-doc-13049-MS-03	SiPM production	M4	ND	720,000
	CMS-doc-13049-MS-04	SiPM testing supplies	M5	ND	30,000
402.4.6.3 Total					**896,000**
Grand Total					**896,000**

Cost Book

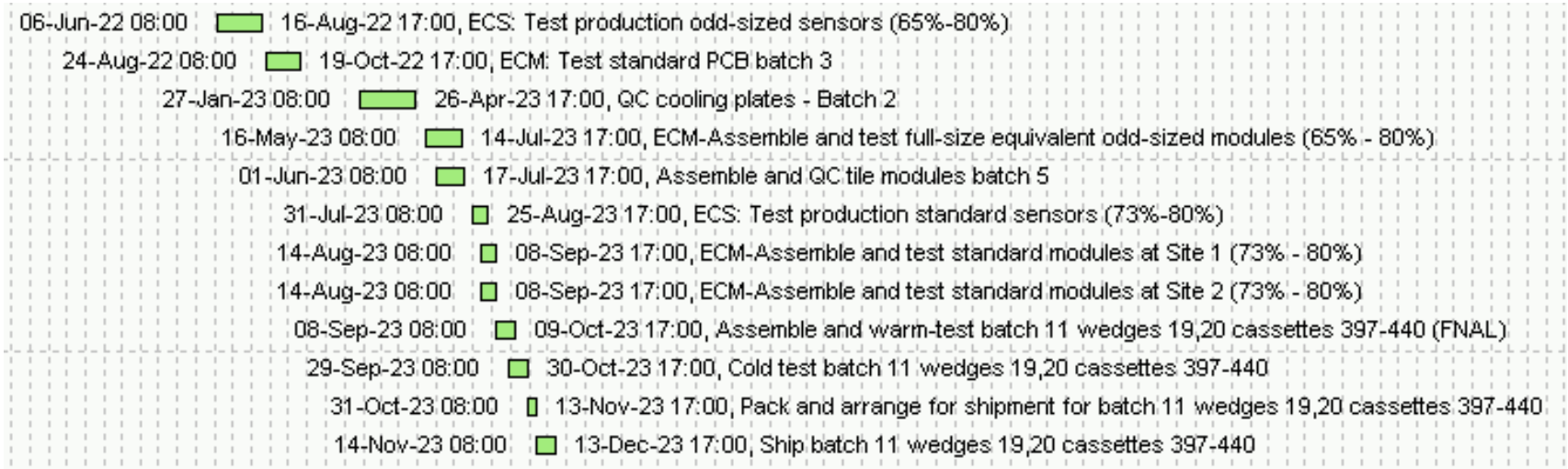
DOE-CD1-402.4.6.3 CE - SiPM Photodetectors				4854	896,000	1,564,589		398,521	1,963,110
Resource Type: Material				0	896,000	995,936		299,459	1,295,395
BoE Ref: CMS-doc-13049-MS-01				0	125,000	140,223		41,223	181,446
SC20040	ECB: Vendors deliver sample SiPM devices		with Base Year FY16	0	20,000	21,636	0%	0	21,636
SC20150	ECB: Vendor produces prototype S14160 de		with Base Year FY16	0	40,000	45,176	30%	13,553	58,729
SC20130	ECB: Materials costs for SiPM production test		with Base Year FY16	0	15,000	16,9[illegible]	50%	8,471	25,412
SC20200	ECB: Facility and fixture costs for irradiatation		with Base Year FY16	0	10,000	11,[illegible]94	50%	5,647	16,941
SC20140	ECB: Vendor B delivers prototype SiPM devices	ND	M&S Pass-Thru with Base Year FY16	0	40,000	4[illegible],176	30%	13,553	58,729
BoE Ref: CMS-doc-13049-MS-02				0	21,000	23,858		1,721	25,579
SC20070	ECB: Travel to coordinate with vendors to specify modified devices for er	ND	M&S Pass-Thru with Base Year FY16	0	6,000	6,644	0%	0	6,644
SC20210	ECB: Travel costs for irradiatation of prototype SiPMs at neutron and mixe	ND	M&S Pass-Thru with Base Year FY16	0	6,000	6,776	10%	678	7,454
SC20310	ECB: Travel costs for irradiation of production SiPMs - Batch 1	ND	M&S Pass-Thru with Base Year FY16	0	3,000	3,456	10%	346	3,802
SC20350	ECB: Travel costs for irradiation of production SiPMs - Batch 2	ND	M&S Pass-Thru with Base Year FY16	0	3,000	3,456	10%	346	3,802
SC20440	ECB: Travel costs for irradiation of production SiPMs - Batch 3	ND	M&S Pass-Thru with Base Year FY16	0	3,000	3,525	10%	353	3,878
BoE Ref: CMS-doc-13049-MS-03				0	720,000	797,064		239,119	1,036,183
SC20270	ECB: Vendors deliver production SiPM devices - Batch 1	ND	M&S Exempt with Base Year FY19	0	240,000	263,928	30%	79,178	343,106
SC20320	ECB: Vendors deliver production SiPM devices - Batch 2	ND	M&S Exempt with Base Year FY19	0	240,000	263,928	30%	79,178	343,106
SC20400	ECB: Vendors deliver production SiPM devices - Batch 3	ND	M&S Exempt with Base Year FY19	0	240,000	269,208	30%	80,762	349,970

Resource-Loaded Schedule (RLS)

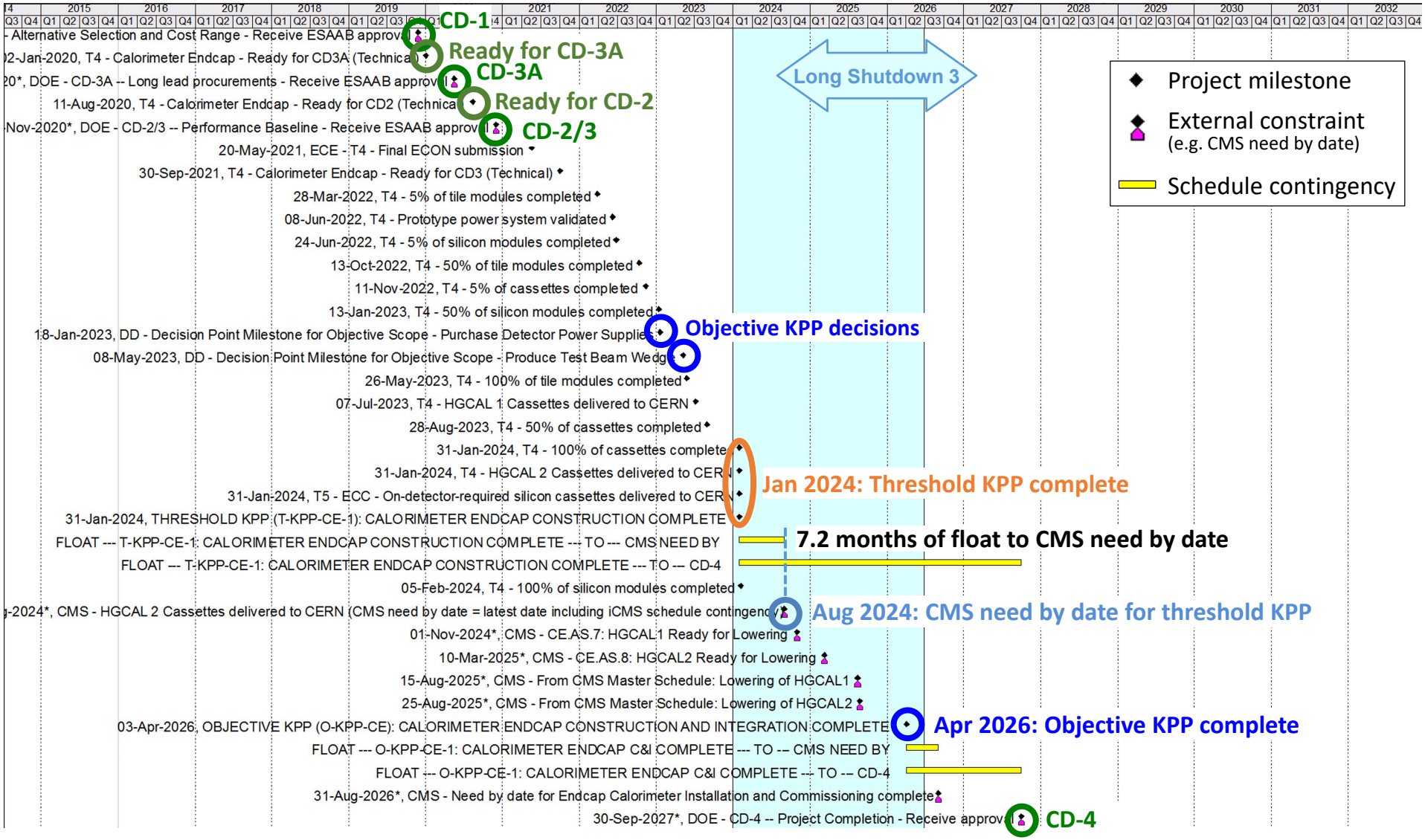
- Fully Resource-Loaded Schedule captures the CE project
  - Follows best practices of FNAL Office of Project Support Services
    - Vetted by other O413.3B projects: Mu2e, g-2, Phase 1, LBNF/DUNE, et al
  - Uses Industry-standard scheduling (Primavera, aka “P6”) and cost processing tools (Cobra)
    - Currently costs are calculated in P6 which facilitates development cycles and is accurate to better than 1%
  - Site-specific overhead, escalation computed by tools
    - M&S budgeted in direct dollars, resources which capture overheads at FNAL and Institutes
    - FNAL labor and Institute labor budgeted in hours, site-specific labor rates

Production Schedule

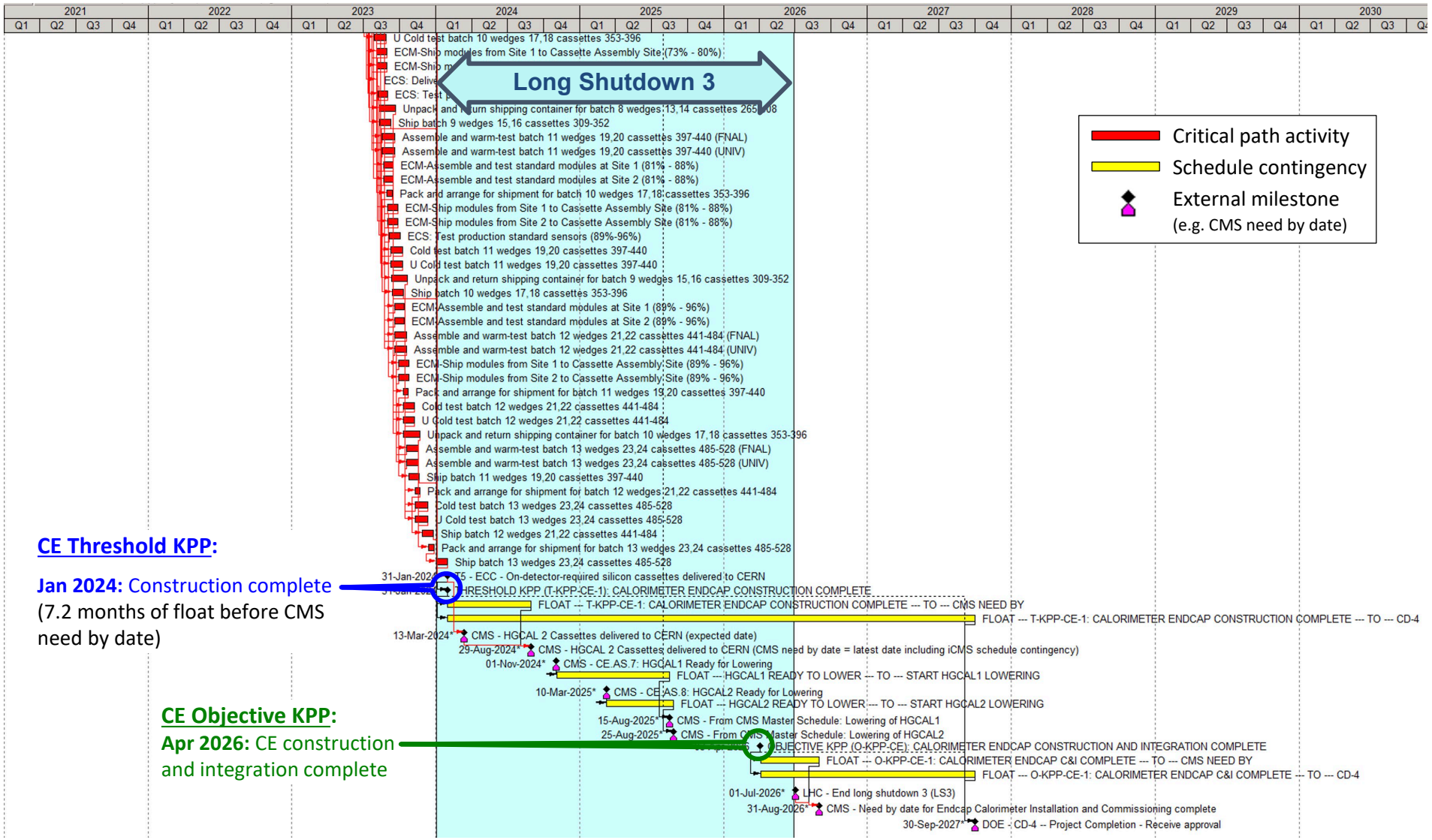
- Production flow scheduled into batches for each key input to the cassettes (full-size modules, odd-sized, scintillator), flowing down from key inputs (e.g. sensors)
  - Pipelined structure, allows study of and response to delays on any particular input branch
    - Some balance between granularity and maintainability – do not represent every variety of component in P6, will use appropriate daily tracking tools during production



Key milestones and schedule contingency



402.4 Critical Path and Float



CE Threshold KPP:

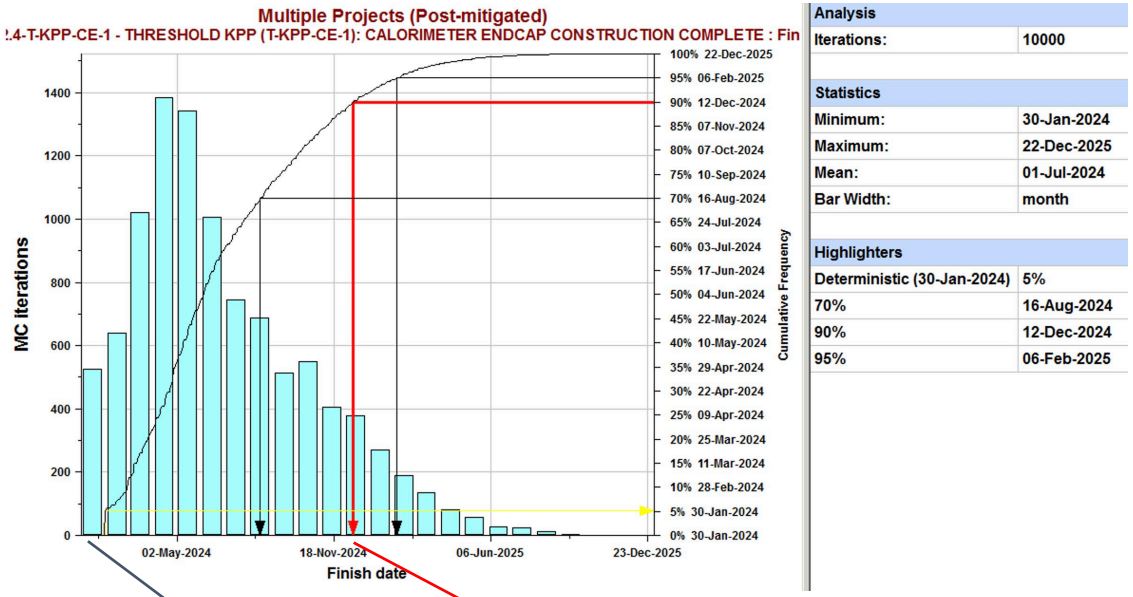
Jan 2024: Construction complete (7.2 months of float before CMS need by date)

CE Objective KPP:

Apr 2026: CE construction and integration complete

Schedule Contingency

- Risk MC aggregates delays stochastically in the full P6 schedule
- Risks will delay finish by < **10.4 months** at 90% confidence level
- Plan has **6.9 months** of float before the CMS need by date
- T-KPP will finish before the need by date at 73% confidence level
- Will revisit schedule risk when new LHC schedule is known



Results of schedule risk MC

		Finish date (early)	CMS need by date	Float to CMS need by date (months)	Finish date (90% C.L.)	Delay due to risk (90% C.L.) (months)	Confidence level to finish before CMS need by date
T-KPP-CE	Calorimeter Endcap Construction Complete	31-Jan-2024	29-Aug-2024	6.9	12-Dec-2024	10.4	73%

Responsibility Assignment Matrix

- RLS fully factorized into Earned Value Monitoring Units
  - Control Accounts are the lowest level quantum for agency monitoring

402.4 CE - Calorimeter Endcap (at DOE CD1)	40,672,474
Akchurin, Nural	11,815,623
CE - Silicon Prototyping and Development	822,076
CE - Silicon Production	7,126,403
CE - Silicon Quality Control	444,553
CE - Module Components	2,051,899
CE - Standard Module Assembly Site 1	1,370,692
Paulini, Manfred	4,983,295
CE - Module Factories	1,358,597
CE - Standard Module Assembly Site 2	1,258,023
CE - Module Assembly at UCSB	2,366,675
Mans, Jeremiah	3,807,266
CE - Management	3,807,266
Kolberg, Ted	4,196,710
CE - Scintillator Calorimetry	4,196,710
Hirschauer, James	6,446,786
CE - Electronics and Services	6,446,786
Gecse, Zoltan	9,422,794
CE - Cassettes	9,422,794

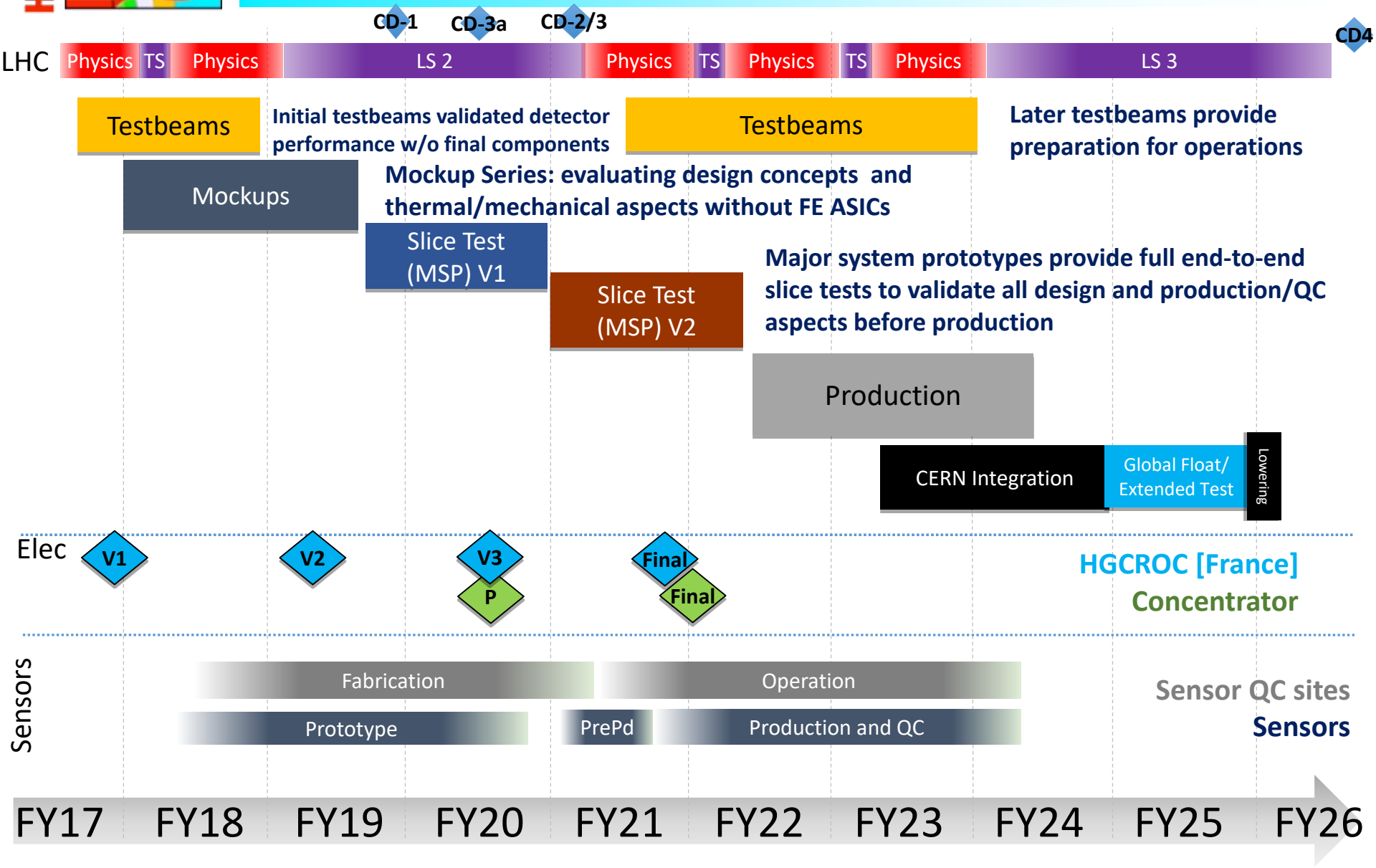
Statusing

- What is it?
  - Monthly collection of Work Performed
    - Objective measure based on pre-declared measurement technique (Performance Measurement Technique, “PMT”)
  - Monthly collection of Actual Cost
    - From FNAL fiscal system
- When does it start?
  - Required to demonstrate >3 months of EVMS reporting before CD-2
- Endcap Calorimeter carried out a practice statusing exercise between October 2018 and February 2019
  - Experience with the process while the schedule can still be modified
  - Project team gets familiar with the demanding EVMS cycle
  - Added benefit: Can relinquish contingency on completed activities
  - Project office resources were not sufficient to sustain monthly statusing while developing CD-1 documentation for all subprojects
- Plan is to resume monthly statusing following this review

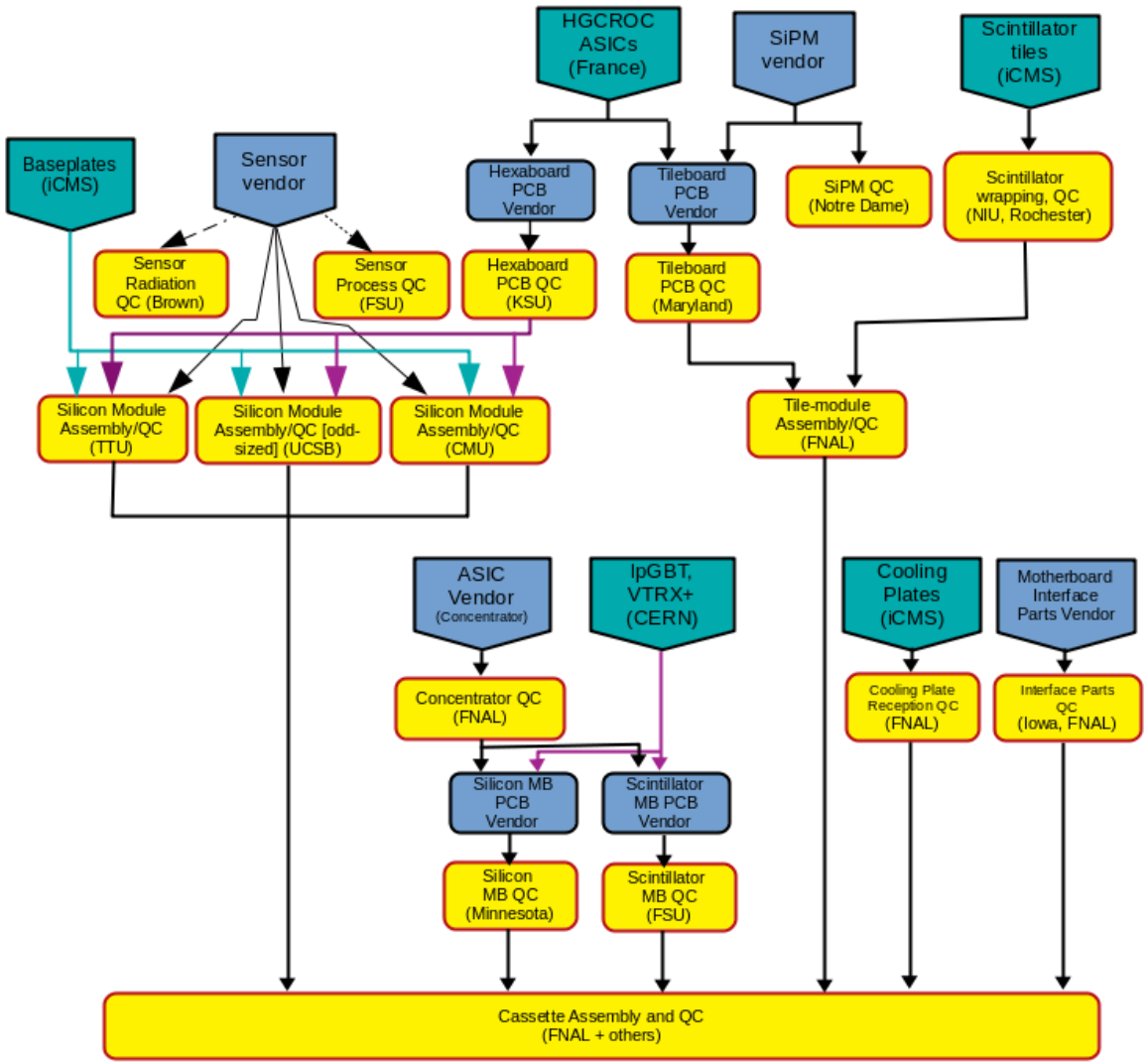
Summary

- Design Maturity
  - Preliminary design well-advanced, clear plan to be ready for CD-2
  - Design updates on track to be ready for CD-3a (long lead time procurements)
  - Further prototype cycles to validate detailed design
- Cost and Schedule
  - Structure is suitable for the deliverables of the project
  - BOE documentation is well-developed
  - Validate cost and schedule based on prototyping and vendor surveys
- Resource Loaded Schedule
  - Developed beyond requirements for CD-1
  - Suitable to support EVMS
  - Already conducted first statusing exercises
- Will be ready for targeted CD-2 review in November 2020

Cartoon Schedule



Workflow for the Project



- This chart, which is part of the project QA/QC documentation outlines the flow of the project through the construction phase and can be mapped directly onto the WBS structure