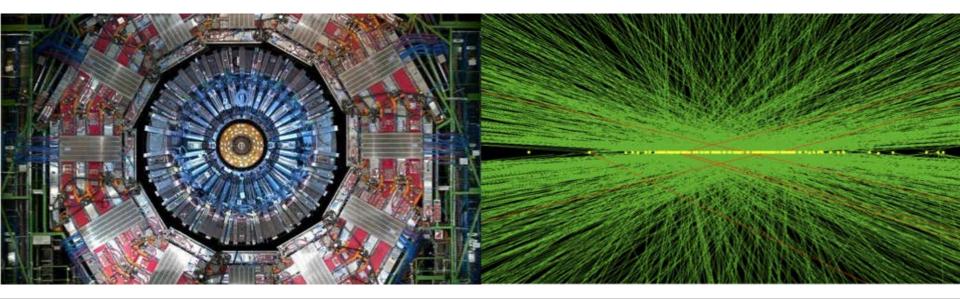


P05: MTD Cost, Schedule, Risk and Outcome of the OPSS Review

Frank Chlebana (Deputy L2 MTD Manager) Fermilab CD-1 Director's Review 19 March 2019





- Basis of estimate
- Schedule development
- Responses to the OPSS review
- Costs
- Milestones
- Synchronization with the international MTD schedule
- Risk
- Critical Path
- Float



Basis of Estimate (BoE)

Basis of Estimates and supporting documentation are available in DocDB

Detailed description of scope, vendor quotes, and a summary of how the costs and labor effort was determined

🗆 L3	Parent:WBS : 402.8.2 TL - Management (1)	
>	402.8.2 TL - Management	CMS-doc-13508
🗆 L3	Parent:WBS : 402.8.3 BTL - Barrel Timing Layer (6)	
1	402.8.3.1 BTL - LYSO Scintillator	CMS-doc-13589
>	402.8.3.2 BTL - SiPMs	CMS-doc-13590
>	402.8.3.3 BTL - Concentrator Cards	CMS-doc-13591
>	402.8.3.4 BTL - Assembly	CMS-doc-13592
>	402.8.3.5 BTL - System Testing	CMS-doc-13599
>	402.8.3.6 BTL - Integration and Commissioning	CMS-doc-13593
🗆 L3	Parent:WBS : 402.8.4 ETL - Endcap Timing Layer (5)	
1	402.8.4.1 ETL - LGAD Sensors	CMS-doc-13594
>	402.8.4.2 ETL - Frontend ASICs	CMS-doc-13595
>	402.8.4.3 ETL - Assembly	CMS-doc-13597
>	402.8.4.4 ETL - System Testing	CMS-doc-13737
>	402.8.4.5 ETL - Integration and Commissioning	CMS-doc-13598

Example of documentation for the BTL Concentrator Cards saved in DocDB

Files in Document:

- <u>BoE---402-8-3-3---BTL---Concentrator-Cards-6 (2).docx</u> (11.5 MB)
- Excel: M&S and Labor tables (BTL---Concentrator-Card---costestimate-V2.xlsx, 506.0 kB)

Other Files:

- <u>Activity list</u> (CC_ActivityList_v0 (3).docx, 20.3 kB)
- <u>M&S 2019 prototype BOM</u> (MS-1_CC_prototype_2019_BOM.pdf, 22.9 kB)
 <u>M85 CC production BOM</u>
- <u>M&S CC production BOM</u> (MS-15_CC_production_2021_BOM.pdf, 23.3 kB)
- <u>M&S CC prototype assembly</u> (MS-2_CC_prototype_2019_Assembly.pdf, 498.1 kB)
- M&S FEAST adapter PCB material (MS-6_FeastAdapter_2019_PCB.pdf, 86.0 kB)
 M&S FEAST adapter board BOM (MS-5_FeastAdapter_2019_BOM.pdf, 22.0 kB)
 M&S FEAST accomponent enotice
- <u>M&S FEAST component quotes</u> (MS-7_FeastAdapter_2019_components.pdf, 228.3 kB) M&S Feast adapter production BOM
- (MS-16_FeastAdapter_2021_BOM.pdf, 18.3 kB)
- <u>M&S Test Stand components quote</u> (MS-13_TestStand_components.pdf, 2.9 MB)
 <u>M&S Test stand BOM</u> (MS-12_TestStand_BOM.pdf, 46.5 kB)
- M&S Test stand quote for bare board (MS-11_TestStand_BareBoard.pdf, 84.6 kB)
- <u>M&S Vivado 1y license for test stand</u> (MS-14_TestStand_license.pdf, 104.0 kB)
 <u>M&S guote for FR4 halogen-free PCB material for CC card</u> (Med 102 poet)
- (MS-4_CC_PCB_quote.pdf, 80.8 kB)
 <u>M&S quotes for CC components, excluding lpGBT and VL+</u> (MS-3_CC_components_wo_lpGBT_and_VLplus.pdf, 785.1 kB)
- Quote for PCIe card for the test stand (MS-8_TestStand_PCIe.pdf, 257.1 kB) Outs for Stand for the test stand (MS-40_TestSt
- Quote for Stencil board for the test stand (MS-10_TestStand_Stencil.pdf, 216.1 kB)
- <u>Shipping rates</u> (MS-9_ShppingRates.pdf, 438.1 kB)

F. Chlebana

P05: Cost and Schedule

Fermilab Director's Review



All estimates for the major cost drivers are based on recent vendor quotes

LYSO: 14 vendors contacted, received quotes from 11 vendors (as of Nov 10, 2018) SiPM: Hamamatsu-SiPM (Feb 26, 2019) Concentrator Cards: Bill of material parts list, PCB production (Sep 10, 2018) BTL Assembly: Pick and place gantry and stencil printer (Aug 15, 2018)

LGAD: Shipping estimate (Sep, 2018), FBK-LGAD (Nov 10, 2018) ASIC: MWP, Fabrication, Estimates for Multi-project Wafer submission and maskset are based on contractual agreement between CERN and foundry (Sep 20, 2018) ETL Assembly: Service contract, misc parts, AIN quote (Jan 2019)

System testing: Estimates based on previous experience from the Phase 1 Tracker



Cost and schedule were reviewed during the Office of Project Support Service's (OPSS) Cost, Schedule, and Risk (CSR) review in Jan 2019

- Provided a detailed list of feedback (next slide)
- Clarify / improve BOE documentation
- Fix schedule logic (missing successors, predecessors)
- Add missing codes to P6
- Change generic university with institute specific codes
- Add correct MIE / OPC codes
- Establish critical path
- Long duration activities with Start-to-start logic (being worked on)

We have implemented updates to the schedule and have provided responses to most of the feedback



OPSS Review Feedback and Responses

						r	-				CMS-doc-13	277
			7) Are escalat	ion rates (M&S and lab	or) institied d	he hetromuse		E resources t				
\square	ote:		This project is	using two rate sets in				t the Hamama	"[Ref-4]_A	value based on a preliminary estimate by an enginee	r, physicist or a price of a similar	
			and is used to	generate immediate a		the material cost		nversion was		purchased for by another project. It will be updated		
	omments	port is she	(price/unit) ha			fied on the BOE	currency co	Inversion was		ith a vendor quote."		
	uchsia ii	from the	Cobra-genera	the estimate uncer		vhether the exch	The BOE d	The labor t	available w			
	ucnsia ii		current FY19	generated just for t	used.		THE DOL U	hours info i	The scope	Critical path		
			Assumptions	generated just for t			22) Are BC	hours.	and labor.	Completion milestones; are they tiered? C	an milestones be used to measure	schedule
		TL0018	needs to be u	Agree. We will revis	We have u	16) Have sche	Yes	nours.		float? Mandatory constrained milestones of		
		procure		ensure that the ove	the cost es	Some Fuse-ide	165		Residual te	path impossible.		i or enaca
		TL0010	Key Assumpt	new rules.		negative float).	23) Can the	We have a		patri impossible.		
- N	lote: This		Our choice of	new rules.	Fuse:		estimation		From Secti	For OD 4 million the school de must refler	the ended a street with the set	
	chedule r	Bill - to o		9) Are Fermilab lab	Schedule (Many of the sc	Yes	The estima	estimate fo	For CD-1 review, the schedule must reflec	t the project's critical path. There a	re issues
	he CMS-	replace	8) Are M&S in	MIE labor only use		addressed. Pri	103	therefore the	I would exp	with the critical path we viewed		
	ates, and		It is unclear w	MIE: only uncosted	13) Are ba	performed to fi	24) Are risl	on the BOB	However, [The Mandatory Start/Finish constra 		
12	2	TL0016	when needed	is assigned for 115	Yes.		We will rev	the correct	a price of a	2	emoved, in order to truly see the pro	oject's
	Section	What is	frequently. Th	is assigned for 115		17) Is full BoE	WC WIII ICV	and/or M&	detailed de	critical path		
~	fixed		been used wh	Fixed.	14) is the :	Full BOE scop	25) Are the	for project				
	Section	Does		TINGU.	There are	_	BOE?	several oth	The scope	These constraints are necessary beca	use they reflect the external commi	tment dates
	Section	There a	Recently-upd	OPC: There are tw	significant	Every resource	Yes		and labor.	from iCMS (e.g. delivery of ASICs)	needed by the US activities). We ca	annot
	formation	incomple	overhead (on	c. FNd. ELEC. TEC	2	(many to one r	100	We have re	Residual te	simply remove these constraints. A	and indeed, some of these deliverab	oles do
F	Y21 fix	Yes, we		resources.	We have r	1 hour (of labo	26) Is estin		Treated and the	have an influence on the US critica	I path.	
		problem	Many M&S ex	roodarood.	We have u	few exceptions	Yes	402.8.4.2 E	From Secti			
K	ey Assur	The sch	In such cases	Fixed.	such as m	management o		Total Labo	cost estima	Several activities have a high durat	tion. One we looked at was five mo	onths and
		scrubbe				Ongoing BTL S		Total Labo		another was nine months		
1) Are exte		We have scru	10) Are Institute lat	There are	whereas produ			procureme	 There are SS relationships with lag 	Justification for the lag is not con	tained in
E	xternal c	4) Are P		labor only use "CM	milestones	need to be EV		We have a	details fron	the Constraint/Lag Notes UDF	. equilibrium of the lag is not con	tamed in
0	ther tasks	There a	In the Cobra i	MIE and OPC task	by an SVT	they should ha			extrapolatio	 There is negative total float 		
		control a the P6 a	ESC_MS_FY			production, the		402.8.4.3 E		4. There is negative total loat		
	or comple	тпе Рба	file before inte	We have performed	Correct. TI	production, the		Labor hour	The scope	Ministry and shall be as head to as we	and the second second second second	
	ur RLS (Control		Resource Rates.	set of "tie-	The work asso	1	cells are to	and labor.	We have adjusted the schedule so we	no longer have negative float.	
	npact on	Control	Correct. More		iCMS mile	1 SiPM develo			There is so			
m	nilestones	CTC, C/	rollup to ensu	11) Are the P6 cod				The errant		We looked at the -10d TF activities		
		010, 0	TI 0040 -	See answer to #4.	Please cla	18) Are all M&		uploaded.	From M&S		activities, which precede pre-produc	
_) Does R	We have	TL9610 is an	Note: this is an exa					and \$24k fo		confidence that the end date is ach	
	eneral: It	Discuss	this may prov		There are	In some cases	BOE Com	In addition,		There are FLOAT activities in the s		
р	rofile can	for all fie	on overhead i	12) Is Estimate Cu	functionali				This has be	between milestones (such as KPP)) and CD-4. They are coded as LO	E activity
		for all fit	resource calc PO's which g	There doesn't seer	-	Resource desc	General co	The file wit	are consist	type; therefore, they do not show u	p on the critical path. They mask th	ne total
S	urprised	Cobra P	-	Estimate Currency	These are	on the Activity	The Resou	and the col		float		
_		laborato	exempt version of		float. They	· · · · · · · · · · · · · · · · · · ·	useful for t	in a differer	No total do			
	here is a		TL04235 is ar	This is indeed the o	always por	19) Are all cos	Consider u			We saved a copy of the Schedule Log (in t	the PARSII folder). In addition to th	le negative
n	o review	Estimate	assigned is "e	indicated in the Est	work and c	Yes. There ar	Historically	402.8.4.4 E	The tables	float, it shows issues with the following:		
- T	he CD-3	fully ent	invoices for m	accordingly.	15) Does F	Average Unive	sometimes	Although th	The tables	1. 136 activities with constraints		
	ne CD-3 nd ESAA		calculations a		There are	resources. Tot	phrase "co	document	Schedule	2. Missing Predecessors (44) and Su	ccessors (159)	
a	nu ESAA	5) Are e	resources.	Some tasks are co	Prototypin	the institution-	p	than half of			/	
I	L9610: N	Yes. M5	TL04045 is ar	coded. Exchange r	Frototyping	resources. Th	This is the	without the	The project	We have added many of the predeces	sors and successors and will contin	ue to work
	eviews.	EUF; L4	standard and	TL9610, coded for	Since the	soon as the pe	1110 10 1110	without the	schedule-d	on this.		
	wiews.	assigne		13589. The BOE id	Moreover		402.8.4.1 E	This has be	Ris			
R	ill - to che	can be u		assumptions.	which enal	We have repla	-102.0.4.1 0	This has be	Tas	Two milestone activities with invalid	d relationships (Finish Milestones w	with SS
L°	m - 10 618	L	1	TL004660 and d4	which cha	institute is kno		400.0.4.5			a relationarripa (i misri milestofies w	101 33
			L2 areas been in	TL001660, coded f				402.8.4.5 E		relationship with Predecessor)	ing. The majority and he FC antal	ionahin-
· · ·			no way to know	Material Cost of \$4		20) Are resourc	es in P6 trac	Some confu	ision on my pa	 There are too many SS and FF relationshi 		
		tell us ho	w/whether they?	attached, but it is fo	r several type	Yes		_		Also, when building a baseline plan, it is best t	to logically tie activities with a FS re	auonsnip
			l				l					

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P05: Cost and Schedule

Fermilab Director's Review

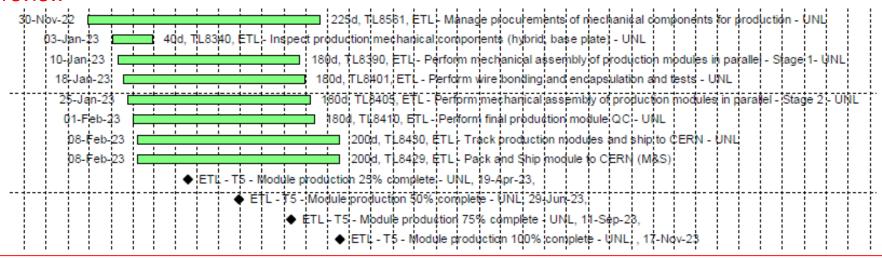


OPSS Review Follow Up

We will continue to improve the schedule between now and the CD-1 review

- Further develop the system testing plan
- Break up the long duration activities
- Remove SS and lags in the connection logic
- Refine the interface with international deliverables (bump bonding)
- Review activity sequencing to see if we can increase the float

Example of using long duration activities with start-to-start logic and a lag in the schedule to get the cost estimate \rightarrow *split into finer detailed activates to facilitate monitoring by the CD-1 review*



The MTD schedule is well advanced, provides a solid cost estimate, allows us to do a critical path analysis, and estimate the risk impact to the schedule

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P05: Cost and Schedule

Fermilab Director's Review



Timing Layer Costs (Project Cost Book)

CMS-doc-13777

WBS	Direct M&S (\$)	Labor (Hours)	FTE	Direct + Indirect + Esc. (\$)	Estimate Uncertainty (\$)	Total Cost (\$)
CD1-v2-DR-402.8 402.8 TL - Timing Layer	6,561,457	161764	91.50	11 ,3 64, 76 3	3,026,706	14,391,469
CD1-v2-DR-402.8.2 TL - Management	433,000	26520	15.00	568,714	144,562	713,276
CD1-v2-DR-402.8.2.1 TL - Management Labor	0	26520	15.00	0	0	0
CD1-v2-DR-402.8.2.2 TL - Management Travel	233,000	0	0.00	349,488	34,949	384,436
CD1-v2-DR-402.8.2.3 TL - Common Infrastructure	200,000	0	0.00	219,226	109,613	328,840
CD1-v2-DR-402.8.3 BTL - Barrel Timing Layer	3,352,236	49800	28.17	5,410,860	1,318,476	6,729,336
CD1-v2-DR-402.8.3.1 BTL - LYSO Scintillator	1,178,868	2946	1.67	1,301,006	191,882	1,492,888
CD1-v2-DR-402.8.3.2 BTL - SiPMs	1,135,400	5384	3.05	1,740,686	296,166	2,036,852
CD1-v2-DR-402.8.3.3 BTL - Concentrator Cards	492,896	5147	2.91	925,645	306,932	1,232,577
CD1-v2-DR-402.8.3.4 BTL - Assembly	343,120	19353	10.95	989,999	383,042	1,373,042
CD1-v2-DR-402.8.3.5 BTL - System Testing	78,952	6322	3.58	11 0, 401	49,734	160,135
CD1-v2-DR-402.8.3.6 BTL - Integration and Commissionin	123,000	10648	6.02	343,123	90,719	433,842
CD1-v2-DR-402.8.4 ETL - Endcap Timing Layer	2,776,221	85444	48.33	5,385,188	1,563,669	6,948,857
CD1-v2-DR-402.8.4.1 ETL - LGAD Sensors	0	3872	2.19	0	0	0
CD1-v2-DR-402.8.4.2 ETL - Frontend ASICs	1,922,500	22588	12.78	3,874,081	1,039,579	4,913,660
CD1-v2-DR-402.8.4.3 ETL - Assembly	680,860	30088	17.02	1,145,013	397,283	1,542,296
CD1-v2-DR-402.8.4.4 ETL - System Testing	79,561	6322	3.58	103,418	38,340	141,759
CD1-v2-DR-402.8.4.5 ETL - Integration and Commissionin	93,300	22574	12.77	262,676	88,467	351,143

The MTD costs derived from the P6 schedule include institutional specific labor rates, overheads, escalation, and estimate uncertainty and is within 14.39M\$

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P05: Cost and Schedule

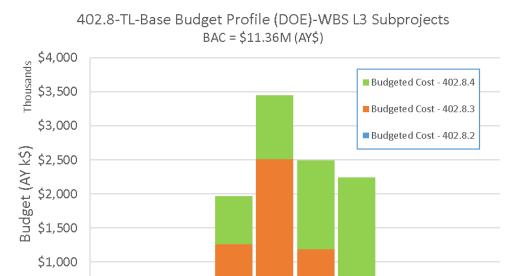
Fermilab Director's Review

19 March 2019



CMS-doc-13215

WBS	Direct M&S (\$)	Labor (Hours)	FTE	Direct + Indirect + Esc. (\$)	Estimate Uncertainty (\$)	Total Cost (\$)
CD1-v2-DR-402.8 402.8 TL - Timing Layer	6,561,457	161764	91.50	11,364,763	3,026,706	14,391,469
CD1-v2-DR-402.8.2 TL - Management	433,000	26520	15.00	568,714	144,562	713,276
CD1-v2-DR-402.8.3 BTL - Barrel Timing Layer	3,352,236	49800	28.17	5,410,860	1,318,47 <mark>6</mark>	6,729,336
CD1-v2-DR-402.8.4 ETL - Endcap Timing Layer	2,776,221	85444	48.33	5,385,188	1,563,669	6,948,857



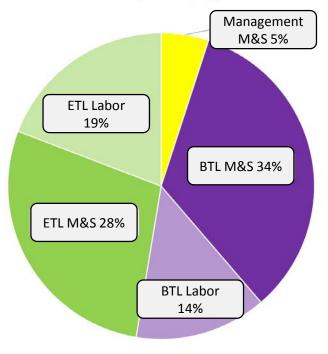
FY23

FY24

FY25

FY26

402.8-TL-WBS L3 Base Budget Breakdown (DOE) BAC= \$11.36M (AY\$)



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\$500

\$0

FY18

FY17

FY19

P05: Cost and Schedule

FY20

FY21

Fiscal Year

FY22

Fermilab Director's Review



Main M&S Cost Drivers (>500k\$)

Material	Obligation Date	Direct Cost (k\$)	Total Cost (k\$)	Approval Date
SiPM production	8/1/2020	950	1200	CD-3b (Apr 2020)
LYSO production	6/1/2020	1137	1421	CD-3b (Apr 2020)
ETROC preproduction	1/1/2022	728	939	CD-3 (Nov 2020)
ETROC production	7/1/2022	887	1166	CD-3 (Nov 2020)

Main cost drivers represent ~46% of the MTD M&S cost Estimate uncertainty of 15%

ETROC pricing is well-defined via the IMEC/CERN agreement.

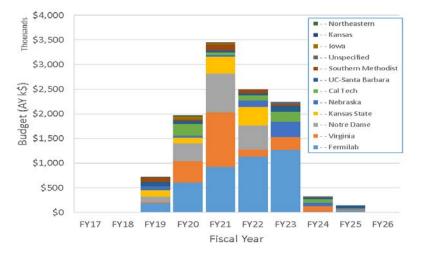
The LYSO pricing is based on the recent vendor quotes from 8 vendors, and our assumed cost is the mean of the responses from the vendors. LYSO is a commonly available commodity in the medical industry. We are not doing anything exotic in terms of its specification or preparation --hence our needs are similar to existing designs with little or no modifications.

SiPM pricing is based on a recent vendor quote from HPK. These SiPMs that were the subject of the vendor quote reflect a nearly-completed design and are similar to the design used for the HCAL upgrade, for which costs are documented.

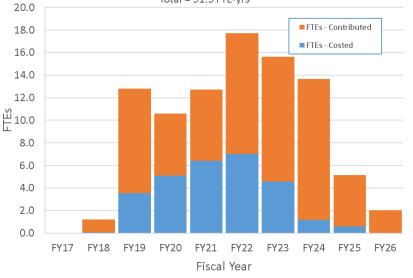


Timing Layer Labor

402.8-TL-Base Budget Profile (DOE)-Institutions BAC = \$11.36M (AY\$)



402.8-TL-Base Labor Profile (DOE)-Costed & Contributed Total = 91.5 FTE-yrs



The main labor cost is for the ASIC development

Contributed labor is mainly in the LYSO, LGAD, System testing, I&C, and the R&D phase of Assembly

The areas with technical deliverables, SiPM, CC, ASIC, are done with mostly costed labor

Assembly production is done with a combination of costed and contributed labor

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P05: Cost and Schedule

Fermilab Director's Review

19 March 2019



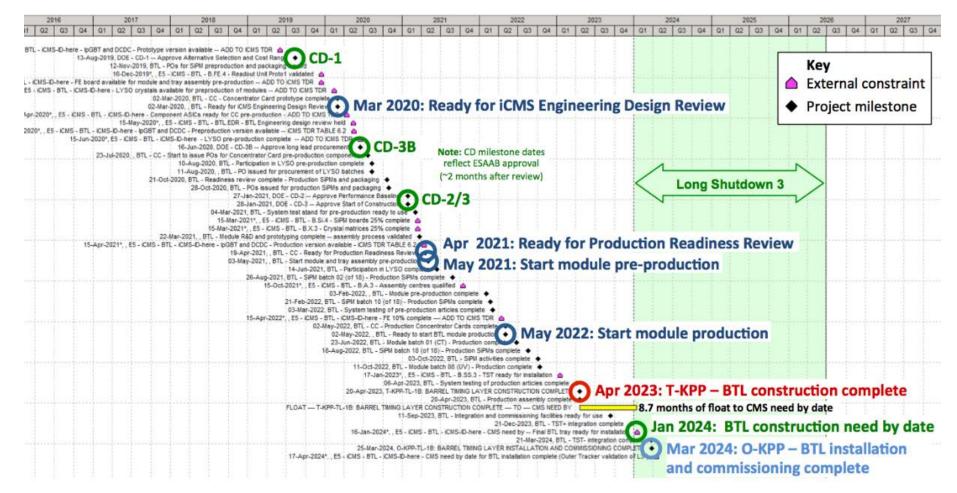
Leading Cost Drivers (M&S + Labor)

CMS Driver	Labor (FTE-yrs)	Labor (M\$)	M&S (M\$)	Labor + M&S (M\$)	Estimate Uncertaint (M\$)	y (M\$)
TL - ETL frontend ASIC development (v3) - M&S	0.0	0.0	1.9	1.9	0.3	2.2
TL - ETL frontend ASIC prototyping (v2) - Labor	7.7	1.2	0.0	1.2	0.5	1.7
TL - ETL module assembly	11.3	0.3	0.8	1.1	0.4	1.5
TL - BTL LYSO crystals [CORE]	0.0	0.0	1.2	1.2	0.2	1.4
TL - BTL assembly	10.8	0.6	0.4	1.0	0.4	1.4
TL - BTL SiPM production [CORE]	0.0	0.0	1.0	1.0	0.2	1.2
TL - BTL Concentrator Cards - production	1.6	0.2	0.5	0.7	0.2	0.9
TL - ETL frontend ASIC development (v3) - Labor	3.7	0.5	0.0	0.5	0.2	0.7
TL - BTL SiPM QC labor	3.0		402.8-TL	-Base Budget P	rofile (DOE)-Resou	rce Type
TL - BTL installation and commissioning	3.0	ے۔ 24 را	4,000	BAC = \$1	1.36 M (AY\$)	
TL - Management Travel and misc. support M&S	0.0		4,000		— P	dgeted Cost - Materia
TL - BTL Concentrator Cards - prototyping and preproduction	1.3		3,500			dgeted Cost - Materia
TL - ETL installation and commissioning	1.1		3,000			aBerea cost Eason
TL - ETL frontend ASIC prototyping (v2) - M&S	0.0					
TL - iCMS common infrastructure [CORE]	0.0		2,500			
TL - BTL system testing	0.1	— (4) \$2	2.000			
TL - ETL system testing	0.0	Budget (AY k\$)				
TL - BTL SiPM NRE and preproduction SiPMs [CORE]	0.0	д \$1	1,500			
TL - BTL SiPM prototyping and preproduction - misc.	0.0		1,000			
TL - BTL LYSO travel and COLA	0.0					
TL - BTL SiPM travel and shipping	0.0		\$500			
	1		\$0			

FY17 FY18 FY19 FY20 FY21 FY22 FY23 FY24 FY25 FY26 Fiscal Year



BTL Key Milestones



Threshold KPP: BTL module and tray construction is de-coupled from LHC schedule Participation in integration and commissioning with iCMS at CERN **Objective KPP:**

F. Chlebana P05: Cost and Schedule

Fermilab Director's Review

19 March 2019

p. 13



ETL Key Milestones

2016	2017	2018	2019	2020	2021	2022	2023	2024 2025	2026 2027 2028
Q2 Q3 Q4	Q1 Q2 Q3	04 01 02 03	04 01 02 03	Q4 Q1 Q2 Q3 Q4	01 02 03 04	01 02 03 0	4 01 02 03 04	Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4	<u>01 02 03 04 01 02 03 04 01 02 03 04</u>
8, ETL - T4 - Prototyp IMS-D-here - IpGBT 14-Jun 13-Aug-2019, 1 - ICMS - ETL - ICMS 30-Sep-20	pe 1 ASIC ready for available for pre-p- 2019", E5 - ICMS DDE - CD-1 Appr 01-Oct 5-ID-here - DCDC ce 27-Jul-2020", E 20", E5 - ICMS - ETI 2021", E5 - ICMS - E	r aubmission - (Off proje roduction ADD TO ICM - ETL - E FL - ETROC V vove Atternative Selection -2019, ETL - 1 - ETROC V vove Atternative Selection -2019, ETL - 14 - Module minerative Selection -2019, ETL - 14 - 2000, ESL - ICMS-ID-here - IGGBT 14-Oct-2020 ⁺ , ESL - ICMS-ID-here - IGGBT 01-Jun-2021 ⁺ , ESL - ICMS-ID-here - DCD 01-Jun-2021 ⁺ , ESL - IC 021 ⁺ , ESL - ICMS - ETL - E 03-Sep- 25-Oct-2021 ⁺ , 14-Dec-2021 -14	ct) (1) IS TOR (2) IS TOR (2) IS TOR (2) IS TOR (2) IS TOR (2) assembly R&D do production – ADD TO IC 38 – Approve long lead p here – Service hybrid pro ETL – T4 – Prototype 2 rec available for production – S – ICHS – ETL – EFE 2 – E ETL – T4 – FTL – ICHS – D m-2021, DOE – CD-3 – Ap m-2021, DOE – CD-3 – Ap m-2021, DOE – CD-3 – Ap INS – ETL – ICHS – D here – S – ICHS – ETL – ICHS – D – TL – ICHS – D – TL – ICHS – D – Convertor available for CMS – ETL – ICHS – D – Here – 2021, ETL – ICHS – D – Here – 10-Jan – 2022; IFeb-2022*, ES – ICHS – ES – ICHS –	CD-1 MS TDR CD- rocurement CD totype available dy for submission - - ADD TO ICMS TDR	•3B Note: CD reflect (~2 mon CD-2/3 iDR	o milestone data ESAAB approval ths after review Jan 20	es I V)	Long Shutdown 3	Key ▲ External constraint ◆ Project milestone
			0	28-Jul-2022, ETL - T4 - Pr -Sep-2022, ETL - T4 - Syste 14-Oct-2022*, E5 - ICMS - E 22-Nov-2022 3-Jan-2023*, E5 - ICMS - ET 26-Jan-202 14-Jun-2023*, E	2, ETL - T4 - Module prot oduction ASIC ready for m testing of production a TL - E.FE.4 - ETROC read , ETL - T4 - Module integration 3, ETL - T4 - LGAD sens 10-Mar-2023, ETL - T4 - 5 - CM3 - ETL - E SI4 - 2 5 - CM3 - ETL - E SI4 - 2 5 - CM3 - ETL - E SI4 - 2 0. TKPP-TL - IE: ENDCAP TIMING LAVER CONSTR 14-Mar-2024*, E5 - CM3 03-May-2 16-Sep-2	otype done submission trickies completion dy for production and production completion ASIC Production completion ASIC Production completion ASIC Production Com Sensor production 50° for-2023, ETL - Module UCTION COMPLETE S - ETL - E SIS - Sensi 024, ETL - T4 - Module 204*, ES - CIMS - ETL -	te piete % complete and and a second TRUCTION COMPLET TO — CMS NEED BY to production 100% comp e integration on Dec 1 and = FA.7 - Module assembly	9.8 months of float Zdone + 100% complet Sep 2024: E	TL construction complete
					14-Mar-2025*, E	5 - ICMS - ETL - E.A.8 24-Mar-21 E5 - ICMS - ETL - E.A.9	I-Module integration 50% c 025, ETL - T4 - Module inte 02-May-2025, ETL - T4 9 - Module integration 1003 05-Dec	complete [Dees for first end) ▲ gration on Dee 3 and 4 done ◆ 4 Installation of Dees complete ◆ (icomplete [Dees for rescond end) ▲ 3025, ETL - T4 - ETL Commissioning complete • T4 - Installation and Commissioning complete • T4LLATION AND COMMISSIONING COMPLET • 01-Jul-2028', E5 - CMS - ETL - Commission	Dec 2025: O-KPP – ETL installation & commissioning

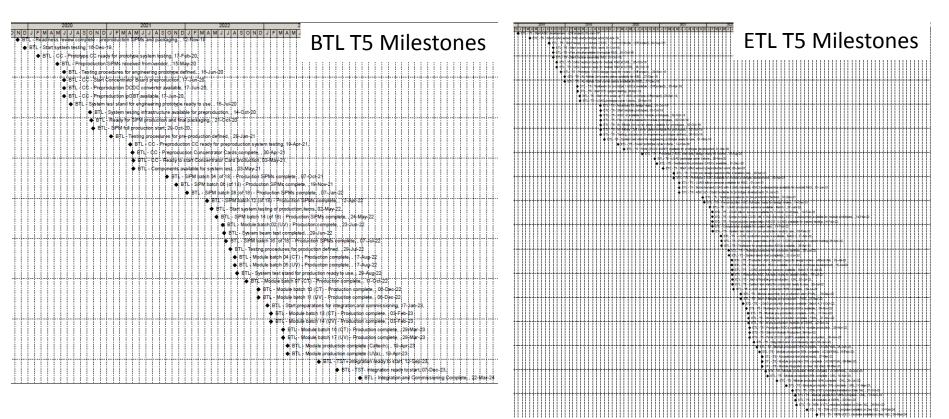
Threshold KPP:ETL construction is de-coupled from LHC scheduleObjective KPP:Participation in integration and commissioning with iCMS at CERN

F. Chlebana P05: Cost and Schedule Fermilab Director's Review 19 March 2019

p. 14

Milestones to Monitor Progress (Tier 5)

We have additional milestones throughout the MTD project to monitor technical progress, Tier 5 milestones are monitored by subproject manager



Complete list of milestones are listed in the Milestone Dictionary (CMS-doc-13321)

F. Chlebana

P05: Cost and Schedule

Fermilab Director's Review

19 March 2019



International milestones and need by dates are tabulated in the TDR and included in the US schedule logic to ensure we are aligned with the MTD schedule

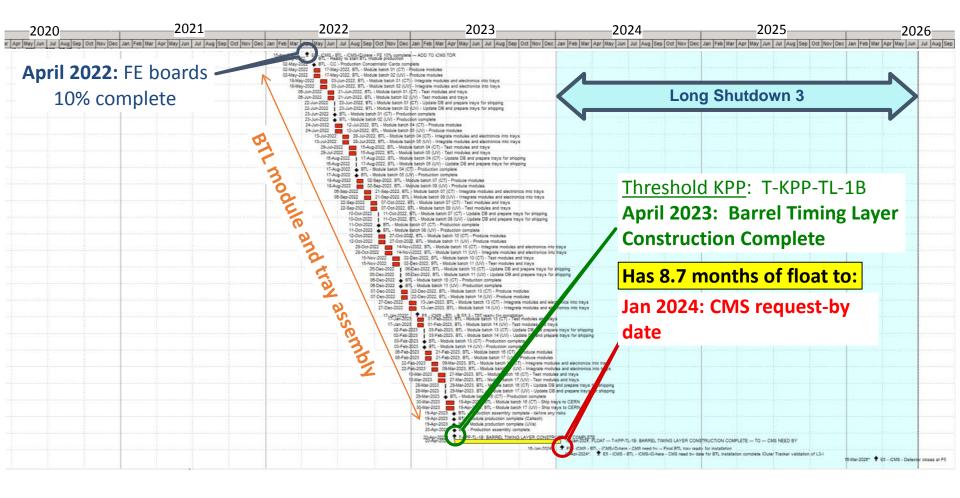
The US deliverables precede the CMS request-by-dates with sufficient float

We also have a watch list of external deliverables with people assigned to monitor progress *IpGBT, DC/DC converter, TOFHIR Expected delivery dates are included in the schedule and drive some activities*

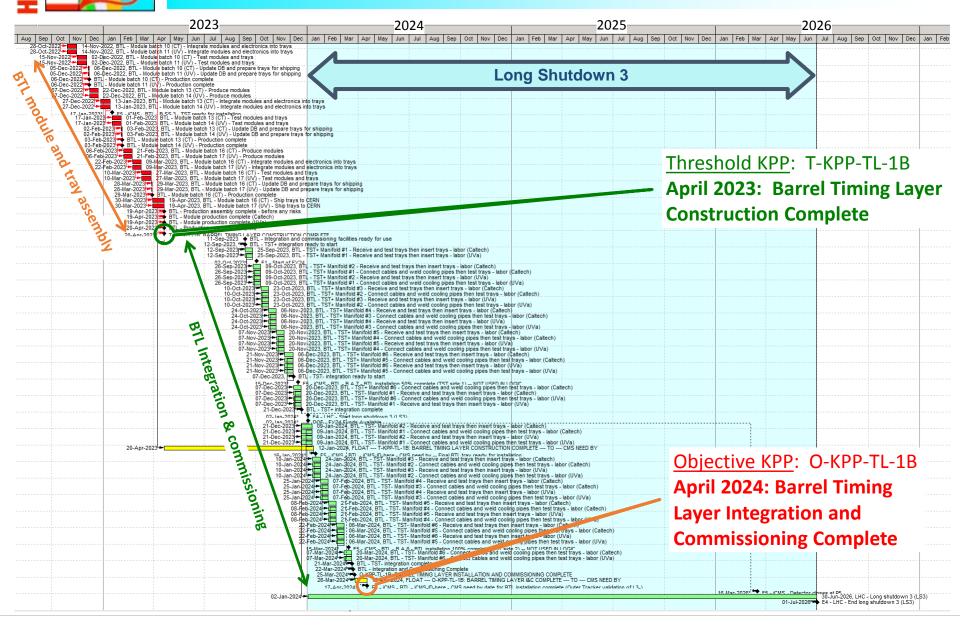
We are directly involved in developing the international MTD schedule and fully synchronized with international MTD planning



BTL Critical Path and Schedule Contingency



BTL Installation and Commissioning

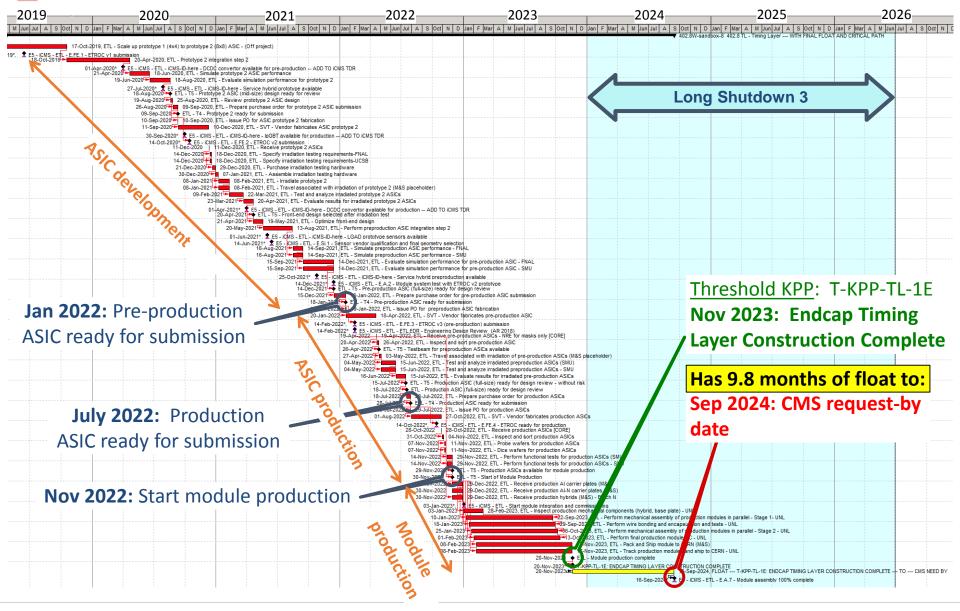


F. Chlebana P05: Cost and Schedule

Fermilab Director's Review

19 March 2019

ETL Critical Path and Schedule Contingency



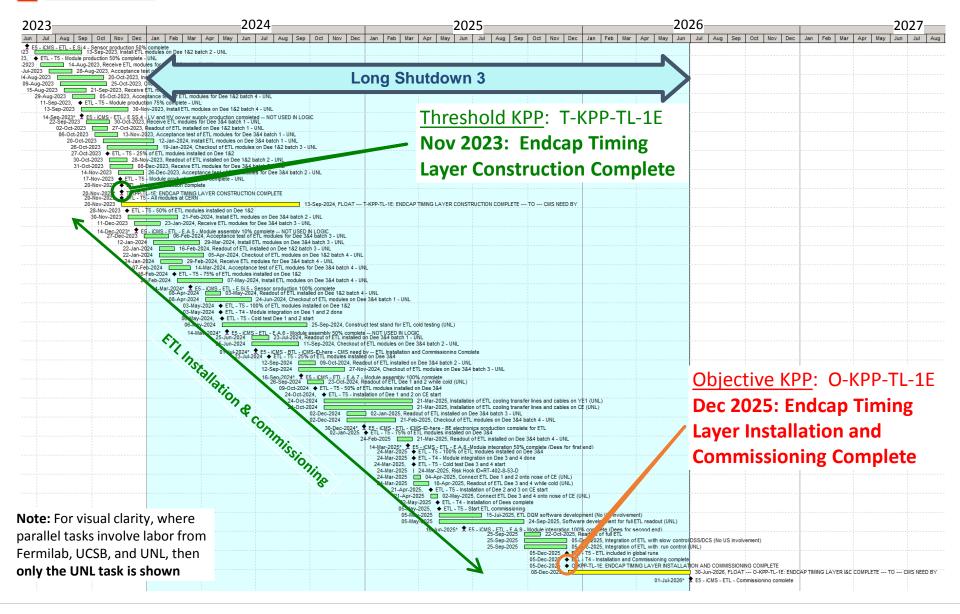
F. Chlebana P05: Cost and Schedule

Fermilab Director's Review

19 March 2019

p. 19

ETL Installation and Commissioning



F. Chlebana

P05: Cost and Schedule

Fermilab Director's Review

19 March 2019



P6 Schedule Adjustments for IPR

• We are following a staged approach for the schedule development:

- 1. US activities entered into P6 to produce our technically driven schedule. *DONE and frozen for this review*
- 2. International schedule formalized for the LHCC/UCG Step 2 approval. *Being done now*
- 3. Complete set of international project / external tie points entered into P6. *Many already implemented*
- 4. Recommendations from OPSS review and the DR implemented. *Majority of OPSS recommendations already in place*
- We've started to implement the following changes in the P6 sandbox
 - Implement bump bonding external tie point
 - Implement UNL external constraint and optimize UNL/FNAL workload sharing
- We expect to complete stages 3 and 4 listed above and freeze the schedule for the June 2019 IPR by end of April



BTL Risk Workshop: Nov 7, 2018: https://indico.fnal.gov/event/19025/ ETL Risk Workshop: Nov 8, 2018: https://indico.fnal.gov/event/19026/

Panel of external reviewers found that we have a comprehensive list of risks Provided feedback on: *consolidating risks, improving impact estimates, improving descriptive text, fixing missing risk register field entries*

Risk impact on the cost has been included in the total project cost Risks have now been included in the P6 schedule to get a better understanding of the schedule impact

A detailed description of the methodology used for the risk analysis can be found in CMS-DocDB-13481

	General Risks (3)							
	s Lab Activity : 40	2.8 TL - Timing Layer (general risks) (3)	Probability	Cost impact	Schedule impact	P*impact (k\$)		
2 (Medium)	RT-402-8-91-D	TL - Shortfall in Timing Layer scientific labor	30 %	0 0 421 k\$	0 months	42		
2 (Medium)	RT-402-8-90-D	TL - Key Timing Layer personnel need to be replaced	25 %	45 135 261 k\$	0 0 3 months	37		
2 (Medium)	RT-402-8-43-D	TL - System Testing - components late for system test	30 %	0 10 20 k\$	4 months	3		



BTL and ETL Risks

🖃 Risk Type	e : Threat (15)		Probability	Cost impact	Schedule impact	P*impact (k
2 (Medium)	RT-402-8-05-D	BTL - Change in interfaces of tray assembly components	20 %	150 250 350 k\$	3 months	50
2 (Medium)	RT-402-8-33-D	BTL - Difficulties procuring LYSO from international suppliers	10 %	200 450 700 k\$	3 6 9 months	45
2 (Medium)	RT-402-8-14-D	BTL - Problems with SiPM vendor	20 %	32 96 128 k\$	2 6 8 months	17
2 (Medium)	RT-402-8-30-D	BTL - Concentrator Card requires significant design changes	10 %	1 50 100 k\$	1 3 6 months	5
2 (Medium)	RT-402-8-07-D	BTL - Concentrator Card delay in external component deliveries	20 %	0 k\$	1 3 6 months	ο
1 (Low)	RT-402-8-15-D	BTL - Batch shipment of SiPMs lost in transport	5 %	224 k\$	1 months	11
1 (Low)	RT-402-8-35-D	BTL - Delays or damage of tray in transport to CERN	5 %	220 k\$	1 months	11
1 (Low)	RT-402-8-04-D	BTL - LYSO matrices not meeting specifications	10 %	100 k\$	1 2 3 months	10
1 (Low)	RT-402-8-36-D	BTL - Interface to iCMS changes	20 %	30 k\$	1 2 3 months	6
1 (Low)	RT-402-8-34-D	BTL - Delay in delivery of components from iCMS	20 %	10 20 30 k\$	1 2 3 months	4
1 (Low)	RT-402-8-08-D	BTL - Delay in cooling plate delivery	10 %	10 20 30 k\$	1 2 3 months	2
1 (Low)	RT-402-8-18-D	BTL - Concentrator card production & testing facility problem	20 %	10 k\$	0.5 1 2 months	2
1 (Low)	RT-402-8-42-D	BTL - Problems with module assembly site	10 %	10 20 30 k\$	1 2 3 months	2
1 (Low)	RT-402-8-16-D	BTL - Problems with SiPM QC test site	20 %	2 5 10 k\$	0.25 0.5 1 months	1
1 (Low)	RT-402-8-44-D	BTL - Concentrator Card batch shipment lost/damaged/delayed	5 %	0 3 9 k\$	0 0.5 1 months	0

WBS / Ops Lab Activity : 402.8.4 ETL - Endcap Timing Layer (12) ETL Risks (11) + Opportunity (1)

Risk Type	: Threat (11)					
3 (High)	RT-402-8-01-D	ETL - Additional FE ASIC prototype cycle is required	50 %	500 600 700 k\$	4 5 6 months	300
2 (Medium)	RT-402-8-03-D	ETL - FE ASIC does not meet specs - needs another pre-prod run	10 %	914 970 1026 k\$	6 7.5 9 months	97
2 (Medium)	RT-402-8-02-D	ETL - Problems with ETL module assembly facility	50 %	30 k\$	1 months	15
2 (Medium)	RT-402-8-10-D	ETL - Sensor quality problem during production	15 %	28 52 109 k\$	2 3 6 months	9
1 (Low)	RT-402-8-53-D	ETL - Integration facility at CERN runs out of components	25 %	21 k\$	3 months	5
1 (Low)	RT-402-8-48-D	ETL - Delay in delivery of parts from iCMS	20 %	10 20 30 k\$	1 months	4
1 (Low)	RT-402-8-31-D	ETL - Storage-related degradation of LGADs	10 %	18 k\$	3 months	2
1 (Low)	RT-402-8-52-D	ETL - Module Radiation Tolerance	10 %	15 k\$	1 months	2
1 (Low)	RT-402-8-49-D	ETL - Delays or damage in transport of ETL modules to CERN	5 %	10 k\$	1 months	1
1 (Low)	RT-402-8-50-D	ETL - Module assembly yield is low	10 %	0 5 15 k\$	0 0 1 months	1
1 (Low)	RT-402-8-51-D	ETL - Problem with AIN vendor	5 %	0 15 30 k\$	1 2 3 months	1
∃ Risk Type	: Opportunity (1)					
2 (Medium)	RO-402-8-01-D	ETL - Use AltiROC	10 %	-760 k\$	-8 months	-76

F. Chlebana

P05: Cost and Schedule

Fermilab Director's Review

19 March 2019



RT-402-8-01-D ETL - Additional FE ASIC prototype cycle is required

Risk Rank:	3 (High) Scores: Probability : 4 (H) ; Cost: 2 (M) Schedule: 2 (M))	Risk Status:	Open						
Summary:	This risk can have multiple causes.								
	1) If the necessary performance (precision vs power consumption) is not achieved during the last prototype cycle, an additional prototype cycle ma								
	be necessary causing a delay and incurring a cost increase. 2) ASIC specification has changed due to external reasons, such as lpGBT c	lock distribution doos no	at most specifications						
	2) Asic specification has changed due to external reasons, such as ipoble c	lock distribution does no	timeet specifications.						
Risk Type:	Threat	Owner:	Tiehui Liu						
WBS:	402.8.4 ETL - Endcap Timing Layer	Risk Area:	Technical Risk / Reliability or Performance						
Probability (P):	50%	Technical Impact:	0 (N) - negligible technical impact						
Cost Impact:	PDF = 3-point - triangular	Schedule Impact:	PDF = 3-point - triangular						
	Minimum = 500 k\$		Minimum = 4 months						
	Most likely = 600 k\$		Most likely = 5 months						
	Maximum = 700 k\$		Maximum = 6 months						
	Mean $= 600 \text{ k}$ \$		Mean = 5 months						
	P * <impact> = 300 k\$</impact>		P * <impact> = 2.5 months</impact>						
Basis of Estimate:	The cost for a MPW run is 400k, and we include 100-300k for additional en	ngineering.							
Cause or Trigger:	Prototype 2 does not meet requirements and we cannot include changes in the preproduction submission.	Impacted Activities:	Risk could delay completion of ASIC prototyping						
Start date:		End date:							
	1/Mar/2020	End date:	1/Jan/2022						
Risk Mitigations:	We have increased the effort for the design simulation and verification.								
Risk Responses:	We include an additional prototype cycle.								
More details:									



Timing Layer risks

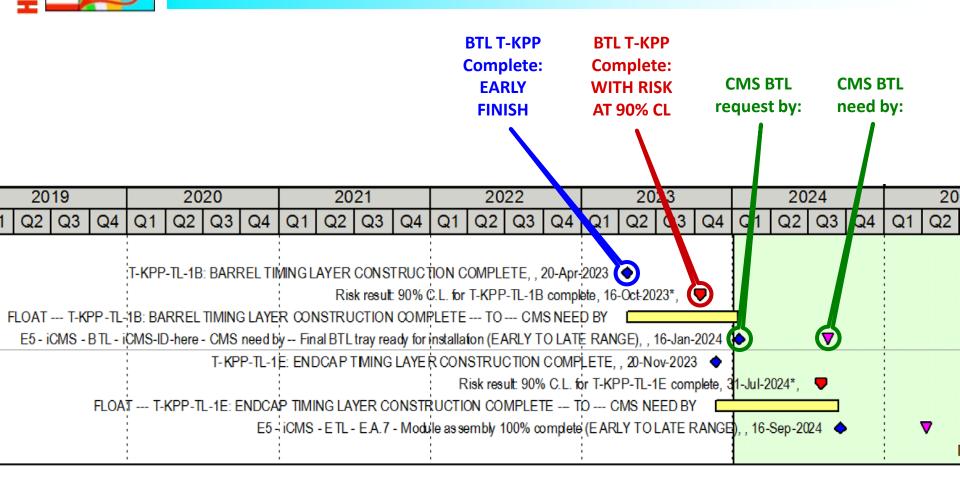
■ TL risk contingency ≈ \$1.27M = \$1.43M threats -\$0.16M opportunities

Risk Contingency (k\$)

= Total contingency at 90% C.L. shared amongst risks pro-rata with (Probability * Cost Impact)



Threshold KPPs – Schedule contingency



We have sufficient float in our schedule to accommodate the impact of our risks (at 90% CL)

F. Chlebana P05: Cost and Schedule Fermilab Director's Review 19 March



The US scope is well defined and we now have a detailed schedule in P6 that has well motivated cost and labor estimates that are documented in the BOEs

The detailed resource loaded schedule has been reviewed by OPSS in Jan/Feb 2019 and we have addressed most of the feedback

We are working closely with international MTD to ensure planning is synchronized and have sufficient milestones in the P6 schedule to monitor progress

Risks have been identified and reviewed and are now linked in the schedule allowing us to better estimate the schedule impact

Some adjustments to the schedule will be implemented prior to the IPR review, we do not expect they will have a significant impact on the cost and schedule

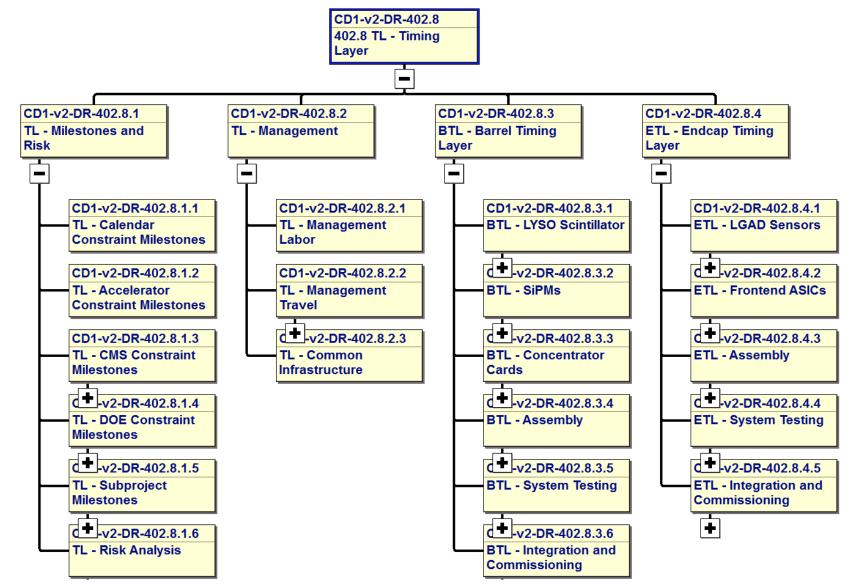
We have made significant progress with the MTD schedule allowing us to: develop an accurate cost estimate using recent vendor quotes and institution specific labor rates which includes cost escalation, determine the critical path, full MC risk analysis, and we are syncronizing with international MTD planning



Backup Slides



Work Breakdown Structure



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P05: Cost and Schedule

Fermilab Director's Review

19 March 2019



Barrel Timing Layer

WBS	Threshold KPP	Objective KPP
402.8	T-KPP-TL-1: BARREL TIMING LAYER CONSTRUCTION COMPLETE	O-KPP-TL-1: BARREL TIMING LAYER INSTALLATION AND COMMISSIONING COMPLETE
Timing Layer	The project will construct and qualify concentrator cards (CCs) and trays of modules+readout units (RUs) for the BTL.	The project will construct and qualify concentrator cards (CCs) and trays of modules+readout units (RUs) for the BTL.
	CC and module+RU performance will match the specification of production prototypes, whose sensor components and associated front-end readout electronics have been demonstrated in cosmic ray, source, and/or test beam exposures to be capable of measuring the arrival time of minimum-ionizing particles with a resolution of < 40ps at the start of the HL-LHC run. The specification further states that the time resolution will be < 60ps even after withstanding the radiation damage from fluences corresponding to an integrated 4000/fb of HL-LHC luminosity, as borne out in prototype testing of irradiated components.	CC and module+RU performance will match the specification of production prototypes, whose sensor components and associated front-end readout electronics have been demonstrated in cosmic ray, source, and/or test beam exposures to be capable of measuring the arrival time of minimum-ionizing particles with a resolution of < 40ps at the start of the HL-LHC run. The specification further states that the time resolution will be < 60ps even after withstanding the radiation damage from fluences corresponding to an integrated 4000/fb of HL-LHC luminosity, as borne out in prototype testing of irradiated components.
	The project shall deliver to CERN 100% of the CCs (476 which includes 10% spares) and approximately 60% of the total trays needed for the BTL.	The project shall deliver to CERN 100% of the CCs (476 which includes 10% spares) and approximately 60% of the total trays needed for the BTL.
		The project shall participate in the integration of the BTL trays into the MTD detector at CERN. The project shall additionally participate in the installation, testing and calibration of the detector.



Endcap Timing Layer

WBS	Threshold KPP	Objective KPP
402.8	T-KPP-TL-2: ENDCAP TIMING LAYER CONSTRUCTION COMPLETE	O-KPP-TL-2: ENDCAP TIMING LAYER INSTALLATION AND COMMISSIONING COMPLETE
Timing Layer	The project shall provide and qualify the front-end ASIC design for the ETL. The project shall construct and qualify modules for the ETL.	The project shall provide and qualify the front-end ASIC design for the ETL. The project shall construct and qualify modules for the ETL.
	The project shall deliver to CERN at least 50% of the ETL modules.	The project shall deliver to CERN at least 50% of the ETL modules.
	ASIC and module performance will match the specification of production prototypes, whose sensor components and associated front-end readout electronics have been demonstrated in cosmic ray, source, and/or test beam exposures to be capable of measuring the arrival time of minimum-ionizing particles with a resolution of < 40ps per track, for most tracks, at the start of the HL-LHC run. The specification further states that the time resolution will remain < 60ps even after withstanding the radiation damage from fluences corresponding to an integrated 4000/fb of HL- LHC luminosity, as borne out in prototype testing of irradiated components.	ASIC and module performance will match the specification of production prototypes, whose sensor components and associated front-end readout electronics have been demonstrated in cosmic ray, source, and/or test beam exposures to be capable of measuring the arrival time of minimum-ionizing particles with a resolution of < 40ps per track, for most tracks, at the start of the HL-LHC run. The specification further states that the time resolution will remain < 60ps even after withstanding the radiation damage from fluences corresponding to an integrated 4000/fb of HL- LHC luminosity, as borne out in prototype testing of irradiated components.
		The project shall participate in the integration of the ETL modules into the MTD detector at CERN. The project shall additionally participate in the installation, testing and calibration of the detector.

Fermilab Director's Review



WBS	Direct M&S (\$)	Labor (Hours)	FTE	Direct + Indirect + Esc. (\$)	Estimate Uncertainty (\$)	Total Cost (\$)
CD1-v2-DR-402.8 402.8 TL - Timing Layer	6,561,457	161764	91.50	11 ,3 64, 76 3	3,026,706	14,391,469
CD1-v2-DR-402.8.2 TL - Management	433,000	26520	15.00	568,714	144,562	713,276
CD1-v2-DR-402.8.2.1 TL - Management Labor	0	26520	15.00	0	0	0
CD1-v2-DR-402.8.2.2 TL - Management Travel	233,000	0	0.00	349,488	34,949	384,436
CD1-v2-DR-402.8.2.3 TL - Common Infrastructure	200,000	0	0.00	219,226	109,613	328,840
CD1-v2-DR-402.8.3 BTL - Barrel Timing Layer	3,352,236	49800	28.17	5,410,860	1,318,476	6,729,336
CD1-v2-DR-402.8.3.1 BTL - LYSO Scintillator	1,178,868	2946	1.67	1,301,006	191,882	1,492,888
CD1-v2-DR-402.8.3.2 BTL - SiPMs	1,135,400	5384	3.05	1,740,686	296,166	2,036,852
CD1-v2-DR-402.8.3.3 BTL - Concentrator Cards	492,896	5147	2.91	925,645	306,932	1,232,577
CD1-v2-DR-402.8.3.4 BTL - Assembly	343,120	19353	10.95	989,999	383,042	1,373,042
CD1-v2-DR-402.8.3.5 BTL - System Testing	78,952	6322	3.58	11 0, 401	49,734	160,135
CD1-v2-DR-402.8.3.6 BTL - Integration and Commissionin	123,000	10648	6.02	343,123	90,719	433,842
CD1-v2-DR-402.8.4 ETL - Endcap Timing Layer	2,776,221	85444	48.33	5,385,188	1,563,669	6,948,857
CD1-v2-DR-402.8.4.1 ETL - LGAD Sensors	0	3872	2.19	0	0	0
CD1-v2-DR-402.8.4.2 ETL - Frontend ASICs	1,922,500	22588	12.78	3,874,081	1,039,579	4,913,660
CD1-v2-DR-402.8.4.3 ETL - Assembly	680,860	30088	17.02	1,145,013	397,283	1,542,296
CD1-v2-DR-402.8.4.4 ETL - System Testing	79,561	6322	3.58	103,418	38,340	141,759
CD1-v2-DR-402.8.4.5 ETL - Integration and Commissionin	93,300	22574	12.77	262,676	88,467	351,143

P05: Cost and Schedule

Fermilab Director's Review

19 March 2019 p. 32



Costs: Barrel Timing Layer

WBS	Direct M&S (\$)	Labor (Hours)	FTE	Direct + Indirect + Esc. (\$)	Estimate Uncertainty (\$)	Total Cost(\$)
CD1-v2-DR-402.8 402.8 TL - Timing Layer	6,561,457	161764	91.50	11,364,763	3,026,706	14,391,469
CD1-v2-DR-402.8.2 TL - Management	433,000	26520	15.00	568,714	144,562	713,276
CD1-v2-DR-402.8.3 BTL - Barrel Timing Layer	3,352,236	49800	28.17	5,410,860	1,318,476	6,729,336
CD1-v2-DR-402.8.3.1 BTL - LYSO Scintillator	1,178,868	2946	1.67	1,301,006	191,882	1,492,888
CD1-v2-DR-402.8.3.1.1 BTL - LYSO Scintillator - Technical participation	1,136,668	2946	1.67	1,235,626	185,344	1,420,970
CD1-v2-DR-402.8.3.1.2 BTL - LYSO Scintillator - Travel and COLA	42,200	0	0.00	65,380	6,538	71,918
CD1-v2-DR-402.8.3.2 BTL - SiPMs	1,135,400	5384	3.05	1,740,686	296,166	2,036,852
CD1-v2-DR-402.8.3.2.1 BTL - SiPMs - Prototyping	10,000	880	0.50	111,376	22,224	133,600
CD1-v2-DR-402.8.3.2.2 BTL - SiPMs - Preproduction	132,500	2020	1.14	335,945	73,827	409,773
CD1-v2-DR-402.8.3.2.3 BTL - SiPMs - Production	954,500	2484	1.40	1,241,126	194,891	1,436,017
CD1-v2-DR-402.8.3.2.4 BTL - SiPMs - Travel and COLA	38,400	0	0.00	52,238	5,224	57,462
CD1-v2-DR-402.8.3.3 BTL - Concentrator Cards	492,896	5147	2.91	925,645	306,932	1,232,577
CD1-v2-DR-402.8.3.3.1 BTL - Concentrator Cards - Prototyping	27,172	11 32	0.64	136,735	37,510	174,245
CD1-v2-DR-402.8.3.3.2 BTL - Concentrator Cards - Pre-Production	21,800	1141	0.65	127,466	60,841	188,307
CD1-v2-DR-402.8.3.3.3 BTL - Concentrator Cards - Production	443,924	2874	1.63	661,444	208,582	870,026
CD1-v2-DR-402.8.3.4 BTL - Assembly	343,120	19353	10.95	989,999	383,042	1,373,042
CD1-v2-DR-402.8.3.4.1 BTL - Assembly - Prototyping	242,920	4641	2.63	502,835	172,192	675,027
CD1-v2-DR-402.8.3.4.2 BTL - Assembly - Preproduction	0	888	0.50	30,958	15,479	46,437
CD1-v2-DR-402.8.3.4.3 BTL - Assembly - Production	100,200	13824	7.82	456,206	195,371	651,577
CD1-v2-DR-402.8.3.5 BTL - System Testing	78,952	6322	3.58	110,401	49,734	160,135
CD1-v2-DR-402.8.3.5.1 BTL - System Testing - Establish Infrastructure	60,103	1898	1.07	70,898	33,667	104,565
CD1-v2-DR-402.8.3.5.2 BTL - System Testing - Preproduction	9,448	1878	1.06	17,247	6,804	24,051
CD1-v2-DR-402.8.3.5.3 BTL - System Testing - Production	9,401	2546	1.44	22,256	9,264	31,520
CD1-v2-DR-402.8.3.6 BTL - Integration and Commissioning	123,000	10648	6.02	343,123	90,719	433,842
CD1-v2-DR-402.8.3.6.1 BTL - Integration and Commissioning - TST plus	0	4440	2.51	69,697	34,849	104,546
CD1-v2-DR-402.8.3.6.2 BTL - Integration and Commissioning - TST minus	0	4440	2.51	71,319	35,660	106,979
CD1-v2-DR-402.8.3.6.3 BTL - Integration and Commissioning - General	123,000	1768	1.00	202,107	20,211	222,317
CD1-v2-DR-402.8.4 ETL - Endcap Timing Layer	2,776,221	85444	48.33	5,385,188	1,563,669	6,948,857

P05: Cost and Schedule

Fermilab Director's Review

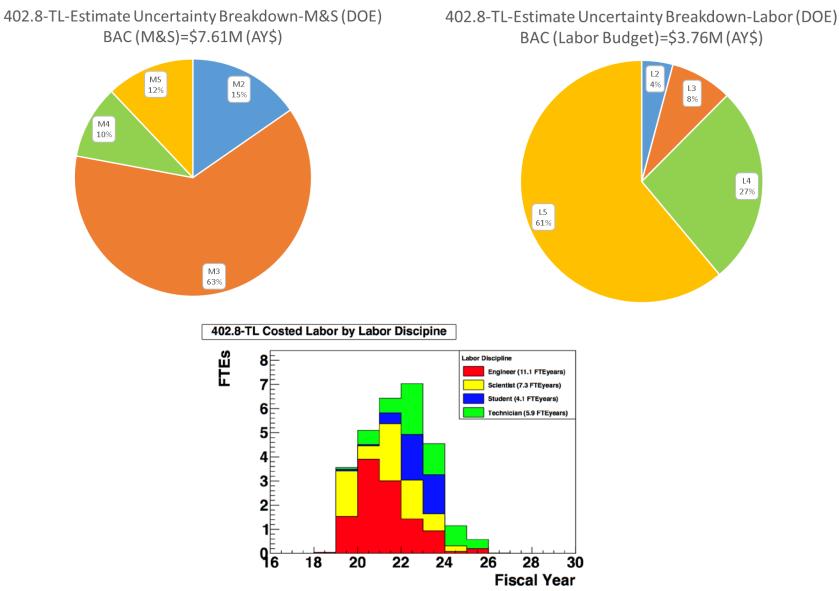
19 March 2019



Costs: Endcap Timing Layer

WBS	Direct M&S (\$)	Labor (Hours)	FTE	Direct + Indirect + Esc. (\$)	Estimate Uncertainty (\$)	Total Cost(\$)
CD1-v2-DR-402.8 402.8 TL - Timing Layer	6,561,457	161764	91.50	11,364,763	3,026,706	14,391,469
CD1-v2-DR-402.8.2 TL - Management	433,000	26520	15.00	568,714	144,562	713,276
CD1-v2-DR-402.8.3 BTL - Barrel Timing Layer	3,352,236	49800	28.17	5,410,860	1,318,476	6,729,336
CD1-v2-DR-402.8.4 ETL - Endcap Timing Layer	2,776,221	85444	48.33	5,385,188	1,563,669	6,948,857
CD1-v2-DR-402.8.4.1 ETL - LGAD Sensors	0	3872	2.19	0	0	0
CD1-v2-DR-402.8.4.1.1 ETL - LGAD Sensors - R&D and Prototypes	0	2400	1.36	0	0	0
CD1-v2-DR-402.8.4.1.2 ETL - LGAD Sensors - Pre-Production and Production	0	1472	0.83	0	0	0
CD1-v2-DR-402.8.4.2 ETL - Frontend ASICs	1,922,500	22588	12.78	3,874,081	1,039,579	4,913,660
CD1-v2-DR-402.8.4.2.3 ETL - Frontend ASICs v2 development	256,000	14634	8.28	1,474,236	556,360	2,030,596
CD1-v2-DR-402.8.4.2.4 ETL - Frontend ASICs v3 development	1,666,500	7954	4.50	2,399,845	483,219	2,883,064
CD1-v2-DR-402.8.4.3 ETL - Assembly	680,860	30088	17.02	1,145,013	397,283	1,542,296
CD1-v2-DR-402.8.4.3.1 ETL - Assembly R&D and Prototypes	268,660	19164	10.84	488,722	152,824	641,546
CD1-v2-DR-402.8.4.3.2 ETL - Module Assembly Pre-production	62,000	626	0.35	91,721	25,958	117,679
CD1-v2-DR-402.8.4.3.3 ETL - Module Assembly Production	350,200	10298	5.82	564,569	218,501	783,070
CD1-v2-DR-402.8.4.4 ETL - System Testing	79,561	6322	3.58	103,418	38,340	141,759
CD1-v2-DR-402.8.4.4.1 ETL - System Testing - Prototyping	60,448	1898	1.07	79,459	30,061	109,520
CD1-v2-DR-402.8.4.4.2 ETL - System Testing - Preproduction	9,584	1878	1.06	12,004	4,154	16,158
CD1-v2-DR-402.8.4.4.3 ETL - System Testing - Production	9,529	2546	1.44	11,955	4,125	16,080
CD1-v2-DR-402.8.4.5 ETL - Integration and Commissioning	93,300	22574	12.77	262,676	88,467	351,143
CD1-v2-DR-402.8.4.5.1 ETL - I &C - Assembly Setup	0	1768	1.00	0	0	0
CD1-v2-DR-402.8.4.5.2 ETL - I &C - Assembly	93,300	14434	8.16	164,318	39,288	203,606
CD1-v2-DR-402.8.4.5.3 ETL - I &C - Cold Testing	0	1888	1.07	20,355	10,178	30,533
CD1-v2-DR-402.8.4.5.4 ETL - I&C - Mount ETL on EC	0	948	0.54	78,003	39,001	11 7,004
CD1-v2-DR-402.8.4.5.5 ETL - I&C - Commissioning	0	3536	2.00	0	0	0





F. Chlebana

P05: Cost and Schedule

Fermilab Director's Review



Contributed Labor

WBS Area	Contributed FTE	Total FTE	Contributed / Total (%)
Management	15	15	100
BTL – LYSO	1.67	1.67	100
BTL – SiPM	0	3.05	0
BTL – CC	0	2.91	0
BTL – System Testing	3.47	3.58	97
BTL - Assembly	4.83	10.95	44
BLT - I&C	5.02	6.02	83
ETL – LGAD	2.19	2.19	100
ETL – ASIC	1.43	12.78	11
ETL – System Testing	3.58	3.58	100
ETL - Assembly	13.88	17.02	82
ETL- I&C	11.96	12.77	94
Total	63.03	91.52	69



High and medium-rank Timing Layer risks

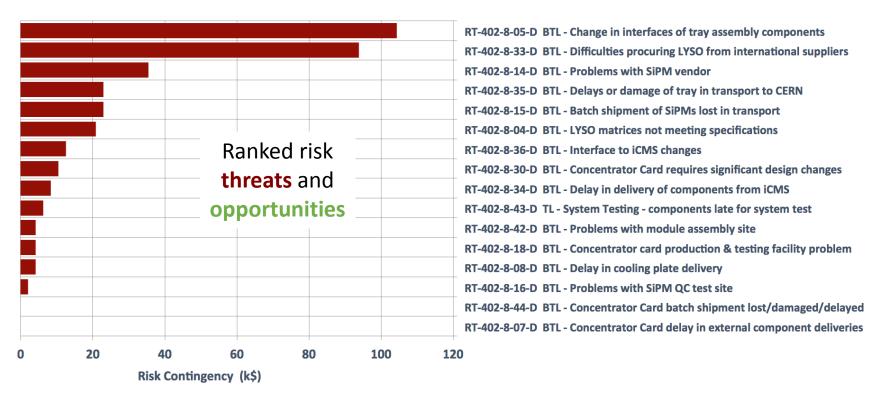
Risk Rank	RI-ID	Title	Probability	Schedule Impact	Cost Impact	P * Impact (k\$)			
Bisk Rank	∃ Risk Rank : 3 (High) (1)								
🖃 Risk Type	Risk Type : Threat (1)								
3 (High)	RT-402-8-01-D	ETL - Additional FE ASIC prototype cycle is required	50 %	4 5 6 months	500 600 700 k\$	300			
∃ Risk Rank	a : 2 (Medium) (12)								
🗆 Risk Type	e : Opportunity (1)								
2 (Medium)	RO-402-8-01-D	ETL - Use AltiROC	10 %	-8 months	-760 k\$	-76			
🖃 Risk Type	e : Threat (11)								
2 (Medium)	RT-402-8-03-D	ETL - FE ASIC does not meet specs - needs another pre-prod run	10 %	6 7.5 9 months	914 970 1026 k\$	97			
2 (Medium)	RT-402-8-05-D	BTL - Change in interfaces of tray assembly components	20 %	3 months	150 250 350 k\$	50			
2 (Medium)	RT-402-8-33-D	BTL - Difficulties procuring LYSO from international suppliers	10 %	3 6 9 months	200 450 700 k\$	45			
2 (Medium)	RT-402-8-91-D	TL - Shortfall in Timing Layer scientific labor	30 %	0 months	0 0 421 k\$	42			
2 (Medium)	RT-402-8-90-D	TL - Key Timing Layer personnel need to be replaced	25 %	0 0 3 months	45 135 261 k\$	37			
2 (Medium)	RT-402-8-14-D	BTL - Problems with SiPM vendor	20 %	2 6 8 months	32 96 128 k\$	17			
2 (Medium)	RT-402-8-02-D	ETL - Problems with ETL module assembly facility	50 %	1 months	30 k\$	15			
2 (Medium)	RT-402-8-10-D	ETL - Sensor quality problem during production	15 %	2 3 6 months	28 52 109 k\$	9			
2 (Medium)	RT-402-8-30-D	BTL - Concentrator Card requires significant design changes	10 %	1 3 6 months	1 50 100 k\$	5			
2 (Medium)	RT-402-8-43-D	TL - System Testing - components late for system test	30 %	4 months	0 10 20 k\$	3			
2 (Medium)	RT-402-8-07-D	BTL - Concentrator Card delay in external component deliveries	20 %	1 3 6 months	0 k\$	0			
🗄 Risk Rank	a : 1 (Low) (17)								



BTL risk contingency ≈ \$0.35

Risk Contingency (k\$)

= Total contingency at 90% C.L. shared amongst risks pro-rata with (Probability * Cost Impact)





Endcap Timing Layer risks

■ ETL risk contingency ≈ \$0.76M = \$0.92M threats -\$0.16M opportunities

Risk Contingency (k\$)

= Total contingency at 90% C.L. shared amongst risks pro-rata with (Probability * Cost Impact)



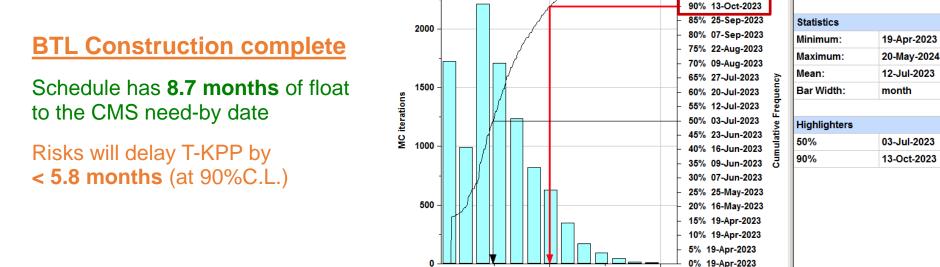


	Base cost	Risk contin	gency (90% CL)	
	(M\$)	(M\$)	(% of base)	
402.1 Project Management	18.13	5.65	31.2%	
402.2 Outer Tracker	42.03	1.06	2.5%	OT fraction ~6% for threats only (i.e. if without opportunities)
402.4 Calorimeter Endcap	39.90	1.93	4.8%	
402.6 Trigger and DAQ	Trigger and DAQ 8.92 0.74		8.3%	
402.8 Timing Layer	11.36	1.27 11.2%		
Total	120.34	10.64	8.8%	



Threshold KPP finish date at 90% C.L.

- MC models the stochastic schedule impacts of *all* risks
 - Project-wide risks and L2-specific technical risks (H/M/L rank)
 - Risk events are inserted into the P6 logic where they could occur
 Early finish 90% C.L.
 - Include correlations as neithed (ver.g.s) burn rate cost and risk delay)
 Analysis
 terrations: 10000



14-Oct-2023

Finish date

01-May-2024



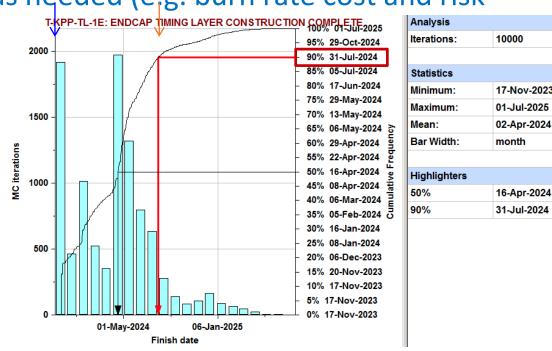
Threshold KPP finish date at 90% C.L.

- MC models the stochastic schedule impacts of *all* risks
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 - Risk events are inserted into the P6 logic where they could occur
 Early finish 90% C.L.
 - Include correlations as neighbor ded (verges) burn rate cost and risk delay)
 Analysis terations:

ETL Construction complete

Schedule has **9.8 months** of float to the CMS need-by date

Risks will delay T-KPP by < 8.3 months (at 90%C.L.)





US-MTD Schedule in P6

