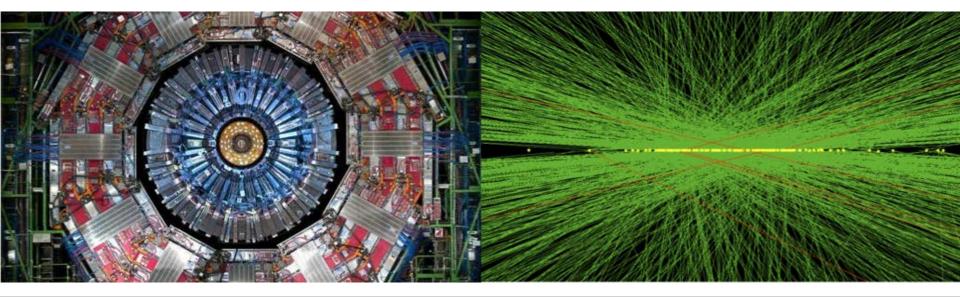


# **B08: MTD Cost and Schedule Overview** 402.8

Frank Chlebana, MTD Deputy L2 Manager Fermilab HL-LHC CMS CD-1 Review 23 October 2019





Frank Chlebana, Senior Scientist at Fermilab

- Serving as deputy L2 in US-MTD
- Experience in construction, commissioning, operations, and project planning while on CMS, CDF, and ZEUS

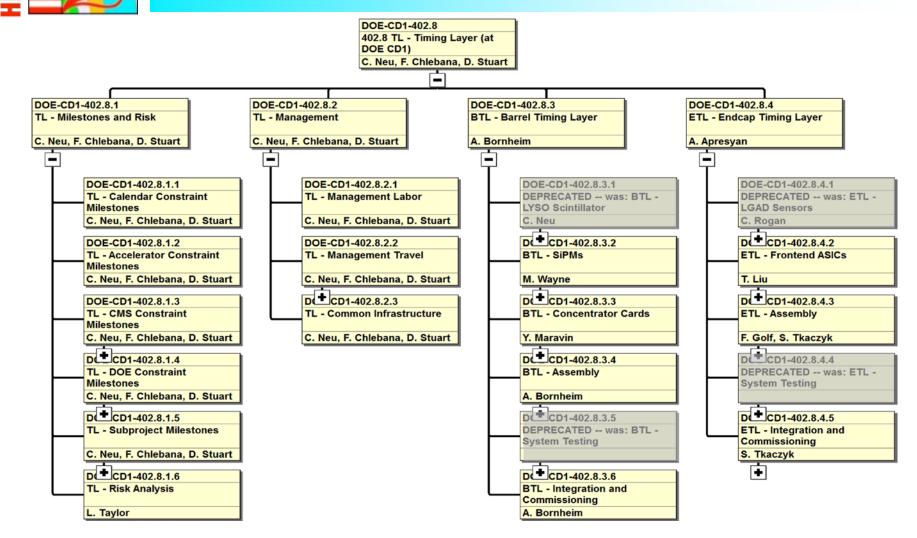
Deputy head of the Fermilab CMS Department Former deputy L2 for the HCAL phase 1 upgrades Former HGCal DPG co-convener Former HCAL DPG co-convener Former head of the DAQ group at CDF



## Schedule Development

- Costs
- Critical path
- Milestones
- Float
- Risks

## MTD Work Breakdown Structure



Deprecated WBS areas were included before scope optimization Removed LYSO and LGAD WBS elements  $\rightarrow$  moved LYSO contribution to "Common Infrastructure"

System testing focuses on US deliverables  $\rightarrow$  moved related activities to the associated assembly WBS

10/23/19

HL-LHC CMS CD-1 Review



MTD schedule has about ~1500 activities (including milestones)

A comprehensive set of tiered milestones allows us to monitor technical progress BTL ~60 milestones ETL ~90 milestones

Activity durations are **less than 3 months** to allow monitoring progress Some exceptions (Supervision activates treated as LOE activates, extended burn-in activities...)

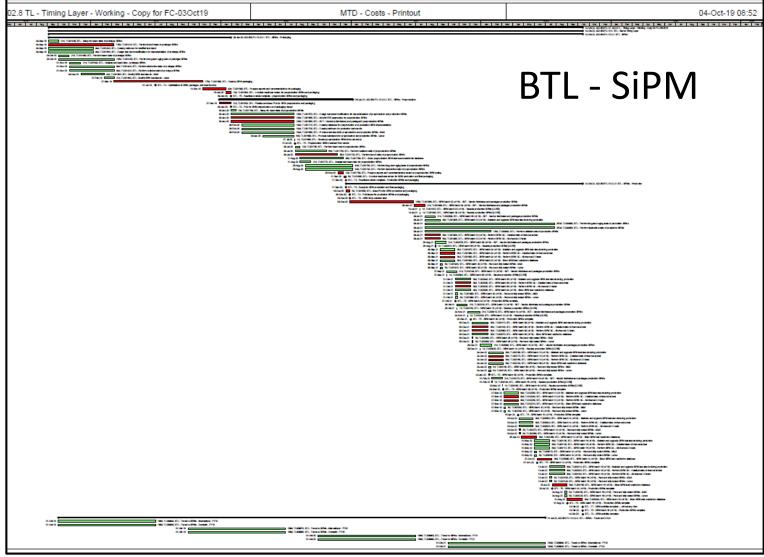
BTL and ETL production model updated to reflect the **design presented in the TDR** and taking **input from recent reviews**: CD-1 IPR (2018), Technical review (Nov 2018), OPSS cost and schedule review (Jan 2019), Director's Review (Mar 2019)

We are **directly involved** with developing the iMTD schedule and **fully synchronized** with iMTD planning *Adi Bornheim (BTL L3 manager) is the international BTL coordinator* 

David Stuart (MTD Deputy L2 manager) is the international ETL coordinator

10/23/19





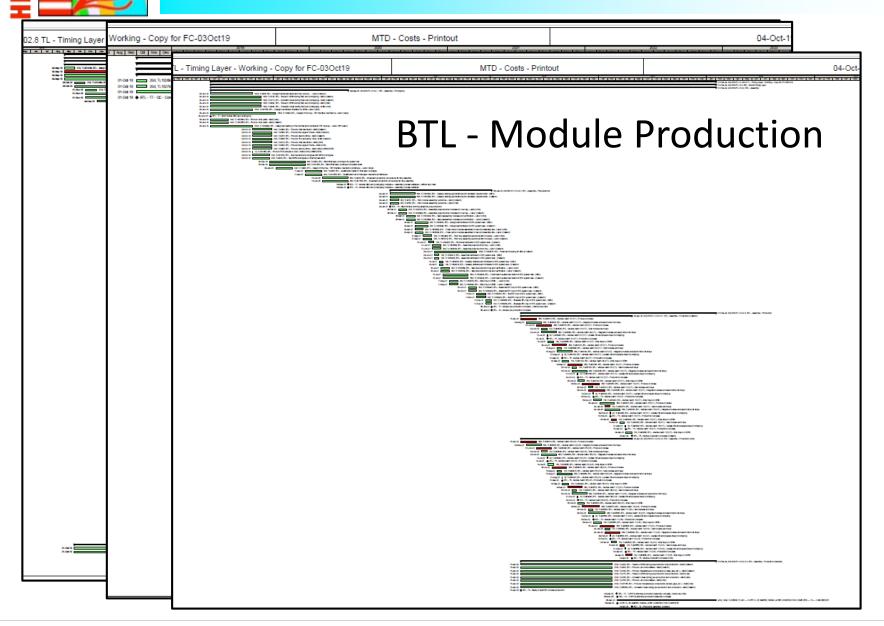


### BTL – Concentrator Card

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HL-LHC CMS CD-1 Review

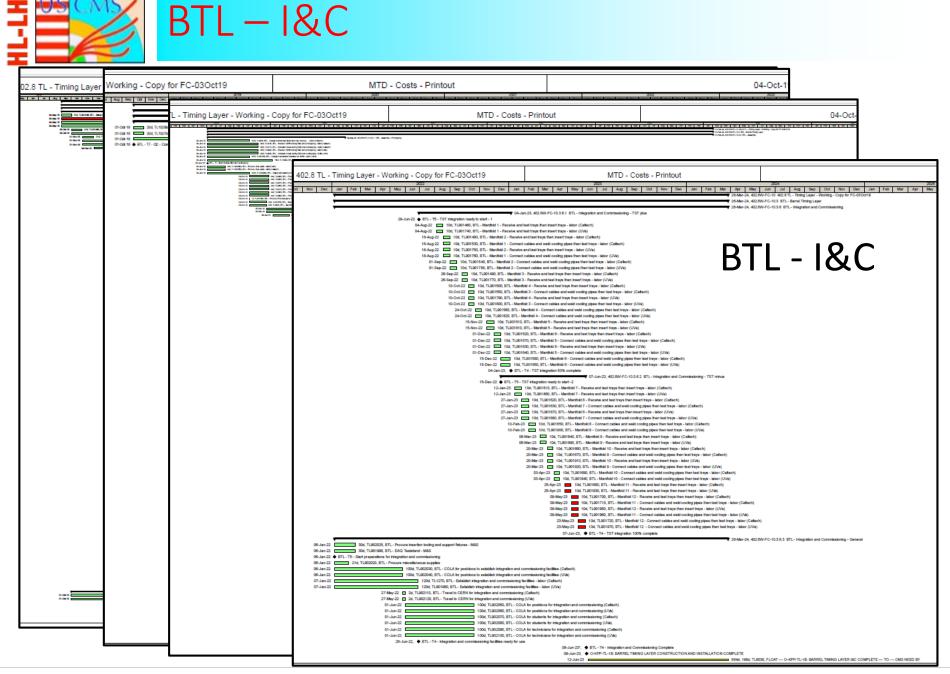
## **BTL – Module Production**



10/23/19

na HL-LHC CMS CD-1 Review

MTD - Cost and Schedule Overview



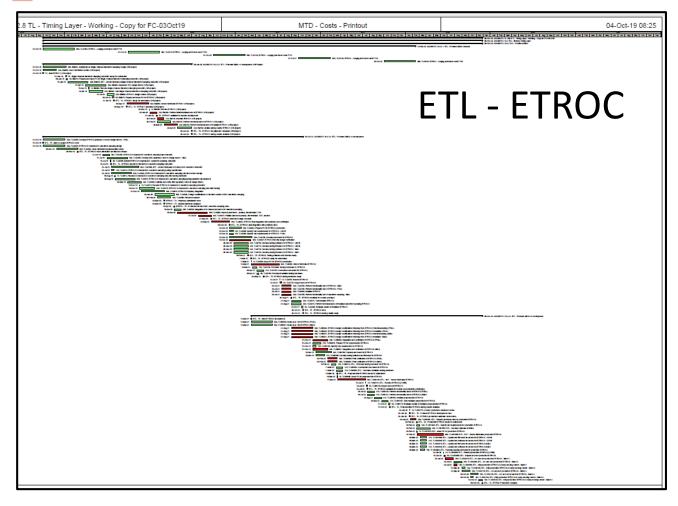
10/23/19

F. Chlebana

HL-LHC CMS CD-1 Review

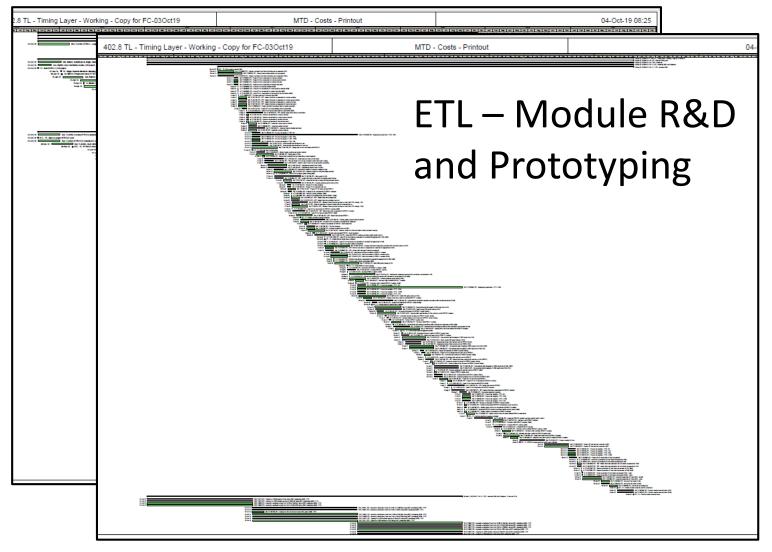
MTD - Cost and Schedule Overview



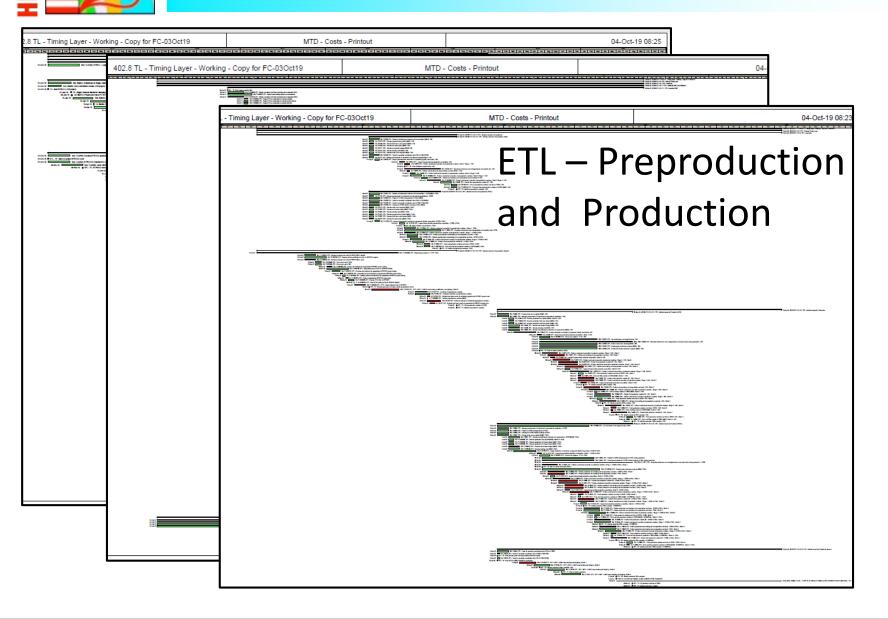




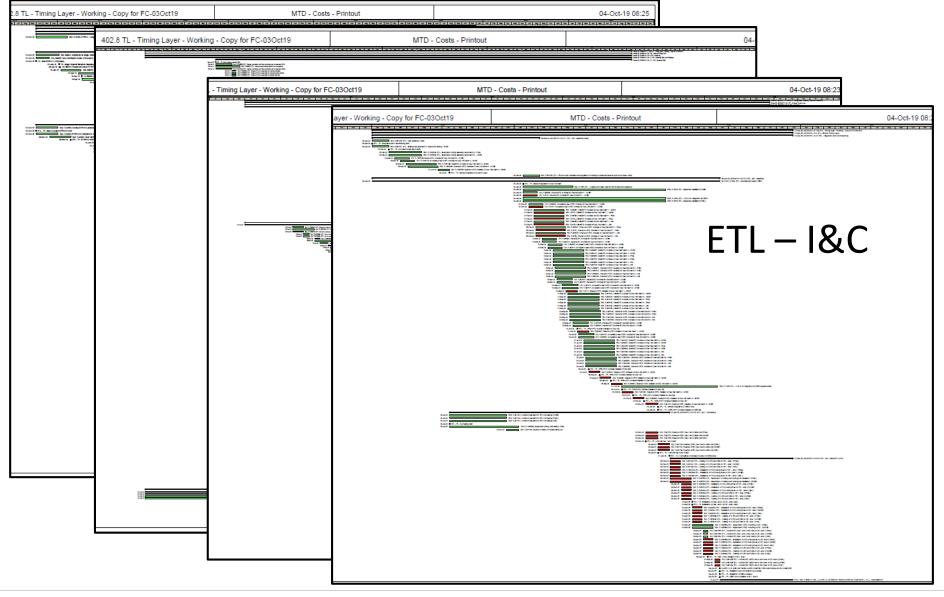
## **ETL - Module R&D and Prototyping**



## **ETL – Preproduction and Production**









## Basis of Estimate (BoE)

CMS-doc-13508

CMS-doc-13590

CMS-doc-13591

CMS-doc-13592

CMS-doc-13593

Basis of Estimates and supporting documentation are available in DocDB

Documentation includes a 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

L3 Parent:WBS : 402.8.3 BTL - Barrel Timing Layer (4)

402.8.3.2 BTL - SiPMs 402.8.3.3 BTL - Concentrator Cards

402.8.3.4 BTL - Assembly

402.8.3.6 BTL - Integration and Commissioning

L3 Parent:WBS : 402.8.4 ETL - Endcap Timing Layer (3)

| 402.8.4.2 ETL - Frontend ASICs                | CMS-doc-13595 |
|---|---------------|
| 402.8.4.3 ETL - Assembly                      | CMS-doc-13597 |
| 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:

| <ul> <li><u>M&amp;S and Labor estimates excel spreadsheet</u> (BTL<br/>Concentrator-Cardcost-estimate-V9.1.xlsx, 503.0 kB)</li> <li><u>Main BoE file</u> (BoE402-8-3-3BTLConcentrator-Cards-<br/>11.pdf, 650.9 kB)</li> </ul> |
|---|
| Other Files:  |
| <ul> <li><u>Activity list</u> (CC_ActivityList_v0 (3).docx, 20.3 kB)</li> </ul>   |
| <ul> <li>BOE Source file (BoE402-8-3-3BTLConcentrator-</li> </ul>   |
| Cards-11.docx, 1.6 MB)  |
| <ul> <li><u>BOM</u> (Bill of Materials-CC_V1Quote Updated 6-14-2019 for</li> </ul>  |
| Yurii.xls, 42.5 kB)   |
| <ul> <li><u>GBT-SCA receipt (quote)</u> (GBT-SCAReceipt.pdf, 6.7 kB)</li> </ul>   |
| M&S Test Stand components quote   |
| (MS-13_TestStand_components.pdf, 2.9 MB)  |
| <u>PCB production quote</u> (Quote_278697.pdf, 200.9 kB)  |
| • <u>PCB quote</u> (103369-A.pdf, 71.7 kB)  |
| <u>Samtec board quote</u> (Samtec Quote 201906-11157.pdf, 49.0  |
| kB)   |
| <u>Spreadsheet to calculate costs for production</u> (MandS.xlsx,   |
| 17.0 kB)<br>- Test Stand BOM (MS 42, TestStand, BOM adf, 46 5 kB)   |
| Test Stand BOM (MS-12_TestStand_BOM.pdf, 46.5 kB)     Test Stand standing upte (MS 10, TestStand, Standing 1, 216.1   |
| <u>Test Stand stencil quote</u> (MS-10_TestStand_Stencil.pdf, 216.1   |
| <ul> <li>kB)</li> <li><u>Trenz Electronics board quote</u> (Trenz Electronics 88-3981</li> </ul>  |
| • <u>Thenz Electronics Doard Quote</u> (Thenz Electronics 86-3961<br>Order Confirmation.pdf, 91.8 kB)   |
| <u>Vivado license quote</u> (EF-VIVADO-DESIGN-FL Xilinx Inc   |
| Development Boards,pdf, 240.6 kB)   |
| XILINX KCU105 board quote (EK-U1-KCU105-G Xilinx Inc  |
| Development Boards, Kits,pdf, 851.3 kB)   |
|   |

• <u>lpGBT receipt (quote)</u> (lpGBTReceipt.pdf, 6.7 kB)



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

LYSO: Received quotes from multiple vendors (Nov 10, 2018) Non-binding RFQ issued in June 2019, average price was 6% lower Our contribution to the LYSO purchase is a fixed dollar amount

SiPM: Hamamatsu-SiPM (Apr 1, 2019) Concentrator Cards: Bill of material parts list (June 6, 2019), PCB production (Sep 12, 2019) BTL Assembly: Pick and place gantry and stencil printer (Aug 15, 2018)

ASIC: MPW, 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)



## Timing Layer Costs (Project Cost Book)

CMS-doc-13777

| WBS   | Direct M&S (\$) | Labor (Hours) | FTE   | Direct + Indirect + Esc.<br>(\$) | Estimate Uncertainty<br>(\$) | Total Cost (\$) |
|---|-----------------|---------------|-------|----------------------------------|------------------------------|-----------------|
| DOE-CD1-402.8 402.8 TL - Timing Layer (at DOE CD1)    | 6,845,630       | 156109        | 88.30 | 12,718,472                       | 3,230,993                    | 15,949,466      |
| DOE-CD1-402.8.2 TL - Management                       | 1,051,980       | 26520         | 15.00 | 1,245,677                        | 221,782                      | 1,467,459       |
| DOE-CD1-402.8.2.1 TL - Management Labor               | 0               | 26520         | 15.00 | 0                                | 0                            | 0               |
| DOE-CD1-402.8.2.2 TL - Management Travel              | 233,000         | 0             | 0.00  | 349,612                          | 27,526                       | 377,138         |
| DOE-CD1-402.8.2.3 TL - Common Infrastructure          | 818,980         | 0             | 0.00  | 896,064                          | 194,256                      | 1,090,321       |
| DOE-CD1-402.8.3 BTL - Barrel Timing Layer             | 2,832,903       | 47774         | 27.02 | 5,141,304                        | 1,263,514                    | 6,404,817       |
| DOE-CD1-402.8.3.2 BTL - SIPMs                         | 1,785,400       | 5384          | 3.05  | 2,474,076                        | 392,929                      | 2,867,005       |
| DOE-CD1-402.8.3.3 BTL - Concentrator Cards            | 559,143         | 4506          | 2.55  | 936,334                          | 194,269                      | 1,130,603       |
| DOE-CD1-402.8.3.4 BTL - Assembly                      | 290,360         | 27236         | 15.40 | 1,293,636                        | 553,215                      | 1,846,851       |
| DOE-CD1-402.8.3.6 BTL - Integration and Commissioning | 198,000         | 10648         | 6.02  | 437,258                          | 123,101                      | 560,359         |
| DOE-CD1-402.8.4 ETL - Endcap Timing Layer             | 2,960,747       | 81815         | 46.28 | 6,331,492                        | 1,745,697                    | 8,077,190       |
| DOE-CD1-402.8.4.2 ETL - Frontend ASICs                | 2,110,992       | 24495         | 13.85 | 4,186,640                        | 839,972                      | 5,026,613       |
| DOE-CD1-402.8.4.3 ETL - Assembly                      | 641,455         | 38348         | 21.69 | 1,754,080                        | 787,463                      | 2,541,542       |
| DOE-CD1-402.8.4.5 ETL - Integration and Commissioning | 208,300         | 18972         | 10.73 | 390,773                          | 118,262                      | 509,035         |

The MTD costs derived from the P6 schedule include institutional specific labor rates, overheads, escalation, and estimate uncertainty

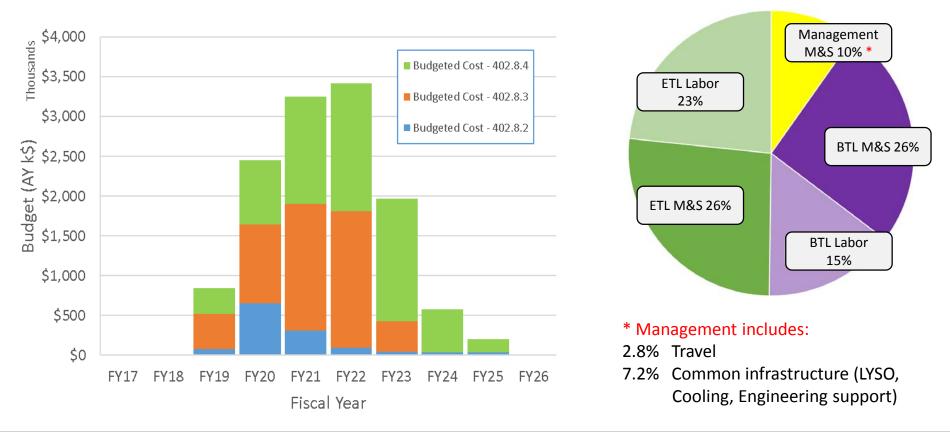
The MTD total project cost is: 15.95M\$ = 12.72 (BAC) + 3.23 (EU)



## Costs at Level 3

#### CMS-doc-13215

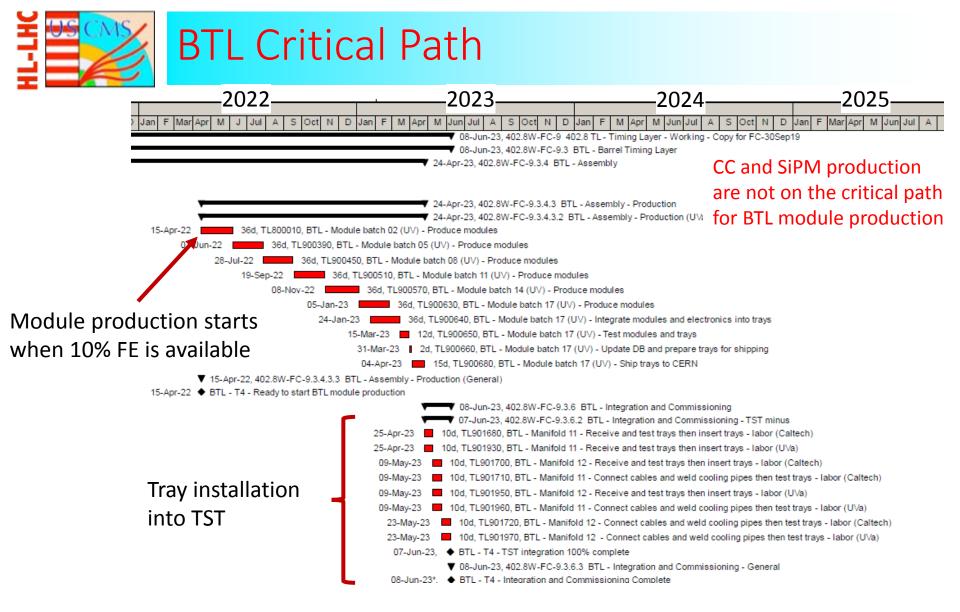
| WBS  | Direct M&S (\$) | Labor (Hours) | FTE   | Direct + Indirect + Esc.<br>(\$) | Estimate Uncertainty<br>(\$) | Total Cost (\$) |
|--|-----------------|---------------|-------|----------------------------------|------------------------------|-----------------|
| DOE-CD1-402.8 402.8 TL - Timing Layer (at DOE CD1) | 6,845,630       | 156109        | 88.30 | 12,718,472                       | 3,230,993                    | 15,949,466      |
| DOE-CD1-402.8.2 TL - Management                    | 1,051,980       | 26520         | 15.00 | 1,245,677                        | 221,782                      | 1,467,459       |
| DOE-CD1-402.8.3 BTL - Barrel Timing Layer          | 2,832,903       | 47774         | 27.02 | 5,141,304                        | 1,263,514                    | 6,404,817       |
| DOE-CD1-402.8.4 ETL - Endcap Timing Layer          | 2,960,747       | 81815         | 46.28 | 6,331,492                        | 1,745,697                    | 8,077,190       |





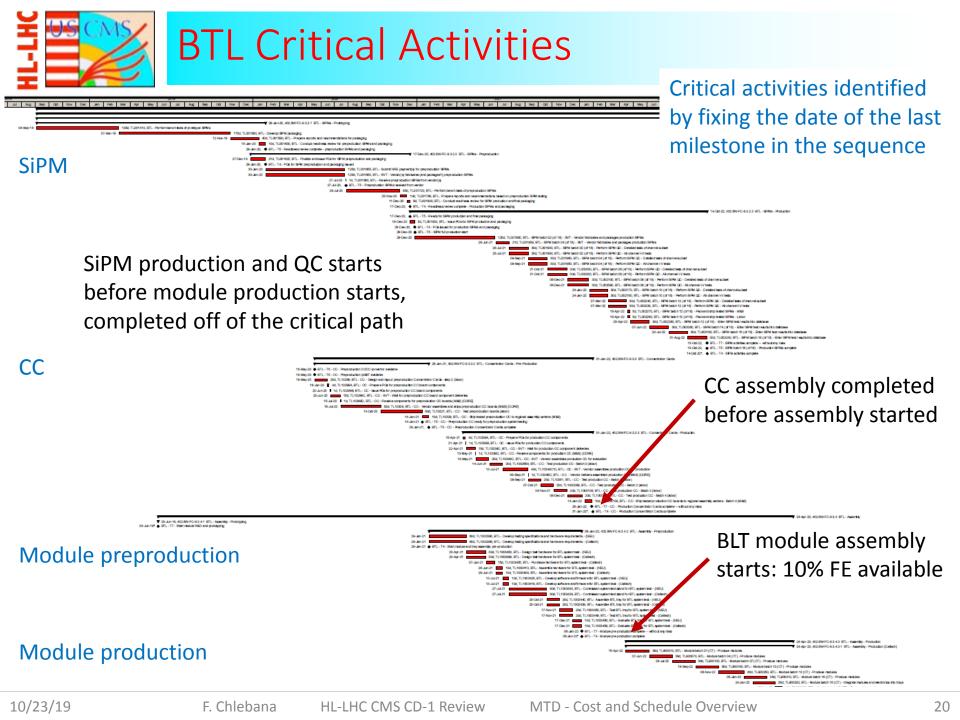
## **BTL Critical Path and Schedule Contingency**

| 2019 2020 202   | 120222023                           | 2024 2025  | 2026                                     | 2027                                  |                  |                       |   |
|---|-------------------------------------|--|--|---------------------------------------|------------------|-----------------------|---|
| 2017 2018 2019 2020 202<br>01 02 03 04 01 02 03 04 01 02 03 04 01 02 03 04 01 02 03 |                                     |  |  |                                       | 2028             | 2029 2030             |   |
| 27-Nov-2019* 2 DOE - CD-1 Alternative   |                                     |  | 11/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1 | 4 101 102 103 104 10                  |                  | 02 03 04 01 02 0      | 3   44   41   42   43   44   41   42   43   44   41   42   43   4 |
| 16-Dec-2019*, 🟅 CMS - BTL - FE board a  |                                     |  |  |                                       |                  |                       |   |
| 14-Feb-2020*, 📩 CMS - BTL - LYSO cn   |                                     |  |  |                                       |                  |                       |   |
| 15-Apr-2020*, 🛔 CMS - BTL - Comp  |                                     |  |  |                                       |                  |                       |   |
| 15-May-2020*, 🛔 CMS - BTL - BTL.  | EDR - BTL Engineering design rev    | ew held  |  |                                       |                  |                       | Critical path activity  |
| 15-May-2020* 🚼 DOE - CD-3A Lo   | ong lead procurements - Receive E   | SAAB approval  |  |                                       |                  |                       |   |
| 18-May-2020*, 👗 CMS - BTL - IpGB  | T and DCDC - Preproduction versi    | on available   |  |                                       |                  |                       | Schedule contingency  |
| 15-Jun-2020* 👗 CM <mark>S</mark> - BTL - LYS  | O pre-production complete           |  |  |                                       |                  | •                     | External milestone  |
| 30-Nov-2020* 📩 DOE - CD   | -2/3 Performance Baseline - Re      | eive ESAAB approval  |  |                                       |                  |                       |   |
| 15-Apr-2021*, 👗 CMS   | S - BTL - IpGBT and DCDC - Produced | ction version available                                      |  |                                       |                  |                       | (e.g. CMS need by date)   |
| Apr 2022: Ready to start PTI 15-Apr-  | 2022*CMS - BTL - B.FE.6 - FI        |  |  |                                       |                  |                       |   |
| Apr 2022: Ready to start BTL  |                                     | BTL module production  |  |                                       |                  |                       |   |
| module production   |                                     | (CT) - Produce modules                                       |  |                                       |                  |                       |   |
|   |                                     | 04 (CT) - Produce modules                                    |  |                                       |                  |                       |   |
|   |                                     | h 07 (CT) - Produce modules                                  |  |                                       |                  |                       |   |
|   |                                     | atch 10 (CT) - Produce module<br>batch 13 (CT) - Produce mod |  |                                       |                  |                       |   |
|   |                                     | e batch 13 (CT) - Integrate mo                               |  | etropice into trave                   |                  |                       |   |
|   |                                     | e batch 13 (CT) - Test module                                |  | cuonics into trays                    |                  |                       |   |
|   |                                     | e batch 13 (CT) - Update DB                                  | -  | trave for shinning                    |                  |                       |   |
|   |                                     | odule batch 13 (CT) - Product                                |  |                                       |                  |                       |   |
|   |                                     | ule batch 13 (CT) - Ship trays t                             |  |                                       |                  |                       |   |
| Timing Layer Threshold KPP:   |                                     | T-KPP (9 batches) production                                 |  | mblete - before any                   | risks            |                       |   |
|   |                                     | T-KPP (9 batches) production                                 |  | · · · · · · · · · · · · · · · · · · · |                  |                       |   |
| Mar 2023: BTL construction complete —   |                                     | 1B: BARREL TIMING LAYER                                      |  | 1                                     |                  |                       |   |
| (11.0 months float before CMS need by d   | ate)                                | FLOAT T-KPP-TL-1B: B   |  | NG LAYER CONST                        | FRUCTION COMP    | PLETE TO CMS          | S NEED BY   |
| (   |                                     | TL-1B: BARREL TIMING LAY                                     | ER CONSTR                                | RUCTION AND INS                       | TALLATION CON    | <b>IPLETE</b>         |   |
|   | ·                                   | FLOAT O-KPP-TL-1B  | BARREL TI                                | MING LAYER I&C                        | COMPLETE TO      | O CMS NEED BY         |   |
|   | 01-Feb-2024*                        | CMS - BTL - B.A.6 - Tray p                                   | oduction 100                             | 0% complete (inclue                   | ding iMTD schedu | le contingency as lag | <b>J</b> )  |
|   | 26-Mar-2024                         | 🗱 CMS - BTL - B.A.8.1 - TS                                   | T- end of acc                            | cess for BTL (CMS                     | need by date)    |                       |   |
|   | 17-Apr-20                           | 24 THRESHOLD KPP. (T-K                                       | P.PTL): TIMI                             |                                       |                  |                       |   |
|   |                                     | 4 <b>-</b>   |  |                                       |                  |                       | ONSTRUCTION COMPLETE TO CD-4                                      |
| Timing Lower Objective KDD  | : :                                 | 09-Jun-2025 😁 OBJE   | TIVE KPP (                               |                                       |                  |                       | ALLATION COMPLETE   |
| Timing Layer Objective KPP:   |                                     | A  |  |                                       |                  |                       | BJECTIVE KPP COMPLETE TO CD-4                                     |
| Jun 2023: BTL construction and installation   | on complete                         | Long Shutdowr  | 30.                                      | -Sep-2027*** DOI                      | E - CD-4 Projec  | t Completion - Recei  | ve approval   |
| Jun 2023. BTE COnstruction and Installation   | in complete                         | Long Chataowi  |  |                                       |                  | · · · · · ·           |   |
|   |                                     | N  | V  |                                       |                  |                       |   |

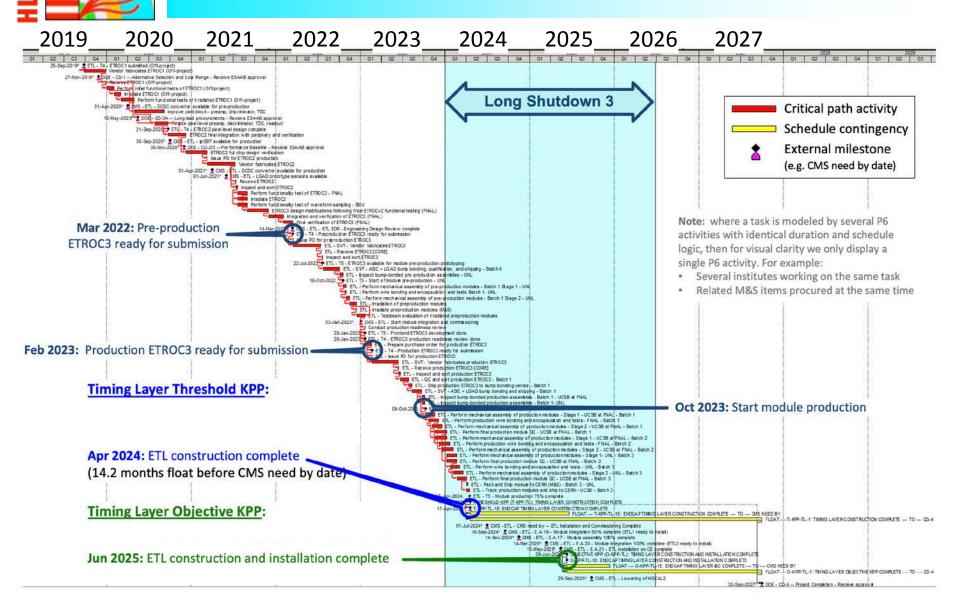


T-KPP (9/12 batches) production assembly complete (75%), 6-Mar-23 T4 Production assembly complete (100%), 24-Apr-23

HL-LHC CMS CD-1 Review



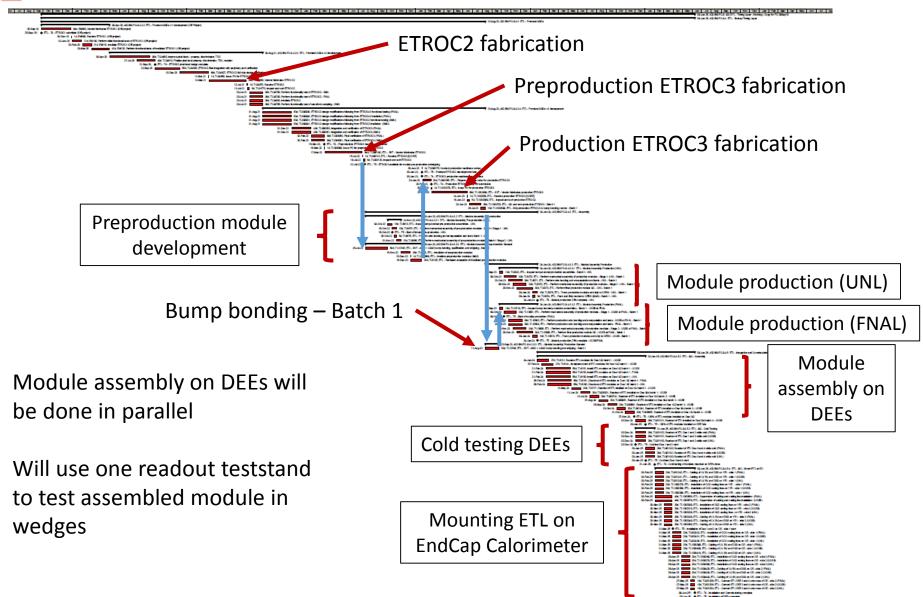
## ETL Critical Path and Schedule Contingency



10/23/19

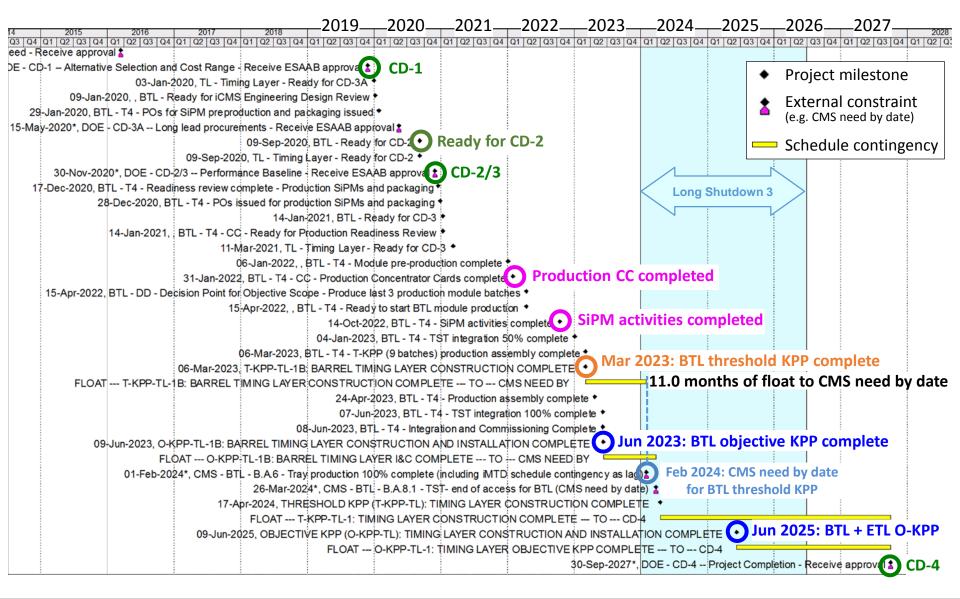
HL-LHC CMS CD-1 Review





### **BTL Key Milestones and Schedule Contingency**

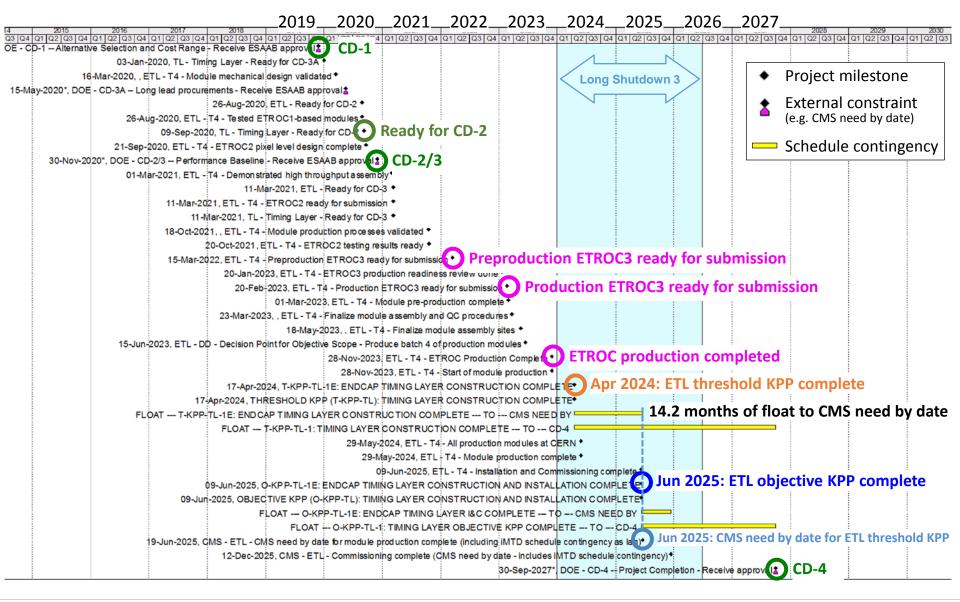




### ETL Key Milestones and Schedule Contingency



10/23/19





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

| Material            | Obligation<br>Date | Direct Cost<br>(k\$) | Direct+Esc<br>(k\$) | <b>Relevant Review</b> |
|---------------------|--------------------|----------------------|---------------------|------------------------|
| LYSO production     | June 2020          | 500                  | 523                 | CD-3a (May 2020)       |
| SiPM production     | Dec 2020           | 1600                 | 1765                | CD-2/3 (Nov 2020)      |
| ETROC preproduction | Mar 2022           | 728                  | 816                 | CD-2/3 (Nov 2020)      |
| ETROC production    | Feb 2023           | 887                  | 1014                | CD-2/3 (Nov 2020)      |

#### Main cost drivers represent ~54% of the MTD M&S cost

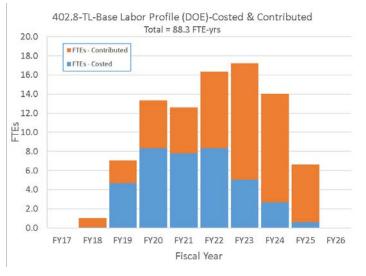
ETROC pricing is well-defined via the IMEC/CERN agreement.

The LYSO pricing is based on multiple vendor quotes and we contribute a fixed cost. 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 well documented.



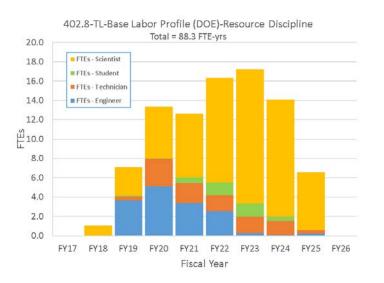
## **Timing Layer Labor**

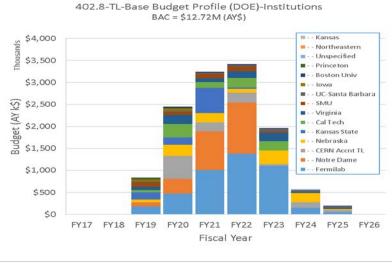


The areas with technical deliverables, SiPM, CC, ASIC, are done with mostly costed labor The main labor cost is associated with the ASIC development

Contributed labor is used during the R&D phase of module assembly, system testing, I&C

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





F. Chlebana

HL-LHC CMS CD-1 Review



| CMS Driver   | Labor        | Labor<br>BAC                  | M&S<br>BAC                                     | Total<br>BAC               |
|--|--------------|-------------------------------|--|----------------------------|
|  | (FTE-yrs)    | (M\$)                         | (M\$)  | (M\$)                      |
| TL - ETL ASIC Development                                      | 12.5         | 1.8                           | 1.3  | 3.2                        |
| TL - BTL Production SiPMS [CORE]                               | 0.0          | 0.0                           | 1.8  | 1.8                        |
| TL - ETL module assembly                                       | 15.4         | 1.0                           | 0.7  | 1.8                        |
| TL - BTL module assembly                                       | 15.1         | 0.9                           | 0.5  | 1.5                        |
| TL - ETL Production ASICs [CORE]                               | 0.0          | 0.0                           | 1.0  | 1.0                        |
| TL - Timing Layer installation and commissioning               | 6.5          | 0.3                           | 0.6  | 0.9                        |
| TL - BTL SiPM labor  | 3.0          | 402.8-TL-Base I               | Budget Profile (DOE)<br>BAC = \$12.72 M (AY\$) | -Resource Type             |
| TL - BTL LYSO crystals M&S [CORE]                              | 00 1         | \$4,000                       | BAC - \$12.72 IVI (AI\$)                       | Budgeted Cost - Material   |
| TL - BTL electronics - concentrator board [CORE]               | 0.0          | \$3,000                       |  | Budgeted Cost - Labor      |
| TL - BTL electronics - concentrator board                      | 2.5 (SX LAR) | \$2,500                       |  |                            |
| TL - Travel  | Budget 0.0   | \$2,500<br>\$2,000<br>\$1,500 |  |                            |
| TL - BTL iCMS common core infrastructure [CORE]                | 0.0          | \$1,000                       |  |                            |
| TL - ETL iCMS common core infrastructure [CORE]                | 0.0          | \$500                         |  |                            |
| * BAC = Budget at Completion (=direct + indirect + escalation) |              | FY17 FY18 F                   | Y19 FY20 FY21 FY2<br>Fiscal Yea                | 2 FY23 FY24 FY25 FY26<br>r |



Risks modelling is included in the P6 schedule and a risk analysis has been done to determine the cost and schedule impact

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

| BWBS / Ops Lab Activity : 402.8 TL - Timing Layer (general risks) (2)                       | General Risks (2)   |              |    |     |
|---|---------------------|--------------|----|-----|
| Bisk Rank : 2 (Medium) (1)  |                     |              |    |     |
| RT-402-8-91-D TL - Shortfall in Timing Layer scientific labor                               | 30 % 0 0 611 k\$    | 0 months     | 61 | 0.0 |
| ■ Risk Rank : 1 (Low) (1) RT-402-8-90-D TL - Key Timing Layer personnel need to be replaced | 25 % 45 135 261 k\$ | 0 0 3 months | 37 | 0.3 |



| RI-ID           | Title  | Probability     | Cost Impact     | Schedule Impact | P * Impact (k\$) | P * Impact (months) |
|-----------------|--|-----------------|-----------------|-----------------|------------------|---------------------|
| WBS / Ops Lal   | b Activity : 402.8 TL - Timing Layer (general risks) (2)       |                 |                 |                 |                  |                     |
| ■ WBS / Ops Lal | b Activity : 402.8.3 BTL - Barrel Timing Layer (14)            | <b>BTL Risk</b> | (14)            |                 |                  |                     |
| D Diek Deek - 0 |  |                 |                 |                 |                  |                     |
| Risk Rank : 3   |  | 50.0/           |                 | 1 0 0           | 50               | 17                  |
| RT-402-8-30-D   | BTL - Concentrator Card requires significant design changes    |                 | 40 135 175 k\$  | 1 3 6 months    | 58               | 1.7                 |
| RT-402-8-07-D   | BTL - Concentrator Card delay in external component deliveries | 50 %            | 50 k\$          | 3 6 9 months    | 25               | 3.0                 |
| Brisk Rank : 2  | (Medium) (4)   |                 |                 |                 |                  |                     |
| RT-402-8-05-D   | BTL - Change in interfaces of tray assembly components         | 20 %            | 150 250 350 k\$ | 3 months        | 50               | 0.6                 |
| RT-402-8-46-D   | BTL - Problems with sensor gluing facility                     | 50 %            | 90 k\$          | 1 2 3 months    | 45               | 1.0                 |
| RT-402-8-33-D   | BTL - Difficulties procuring LYSO from international suppliers | 10 %            | 100 250 400 k\$ | 3 6 9 months    | 25               | 0.6                 |
| RT-402-8-14-D   | BTL - Problems with SiPM vendor                                | 20 %            | 32 96 128 k\$   | 2 6 8 months    | 17               | 1.1                 |
| 🖃 Risk Rank : 1 | (Low) (B)  |                 |                 |                 |                  |                     |
| RT-402-8-15-D   | BTL - Batch shipment of SiPMs lost in transport                | 5 %             | 224 k\$         | 1 months        | 11               | 0.1                 |
| RT-402-8-35-D   | BTL - Delays or damage of tray in transport to CERN            | 5 %             | 220 k\$         | 1 months        | 11               | 0.1                 |
| RT-402-8-04-D   | BTL - LYSO matrices not meeting specifications                 | 10 %            | 100 k\$         | 1 2 3 months    | 10               | 0.2                 |
| RT-402-8-36-D   | BTL - Interface to iCMS changes                                | 20 %            | 30 k\$          | 1 2 3 months    | 6                | 0.4                 |
| RT-402-8-34-D   | BTL - Delay in delivery of components from iCMS                | 20 %            | 10 20 30 k\$    | 1 2 3 months    | 4                | 0.4                 |
| RT-402-8-18-D   | BTL - Concentrator card production & testing facility problem  | 20 %            | 10 k\$          | 0.5 1 2 months  | 2                | 0.2                 |
| RT-402-8-08-D   | BTL - Delay in cooling plate delivery                          | 10 %            | 10 20 30 k\$    | 1 2 3 months    | 2                | 0.2                 |
| RT-402-8-42-D   | BTL - Problems with module assembly site                       | 10 %            | 10 20 30 k\$    | 1 2 3 months    | 2                | 0.2                 |
|                 |  |                 |                 |                 |                  |                     |
| WBS / Ops Lal   | b Activity : 402.8.4 ETL - Endcap Timing Layer (10)            |                 |                 |                 |                  |                     |



| RI-ID           | Title  | Probability | Cost Impact      | Schedule Impact | P * Impact (k\$) | P * Impact (months) |
|-----------------|--|-------------|------------------|-----------------|------------------|---------------------|
| WBS / Ops Lai   | Activity : 402.8 TL - Timing Layer (general risks) (2)         |             |                  |                 |                  |                     |
| ⊞ WBS / Ops Lal | Activity : 402.8.3 BTL - Barrel Timing Layer (14)              |             |                  |                 |                  |                     |
| ■ WBS / Ops Lat | Activity : 402.8.4 ETL - Endcap Timing Layer (10)              | TL Risks    | (10)             |                 |                  |                     |
| Risk Rank : 3   | (High) (1)   |             |                  |                 |                  |                     |
| RT-402-8-01-D   | ETL - Additional FE ASIC prototype cycle is required           | 40 %        | 500 600 700 k\$  | 4 5 6 months    | 240              | 2.0                 |
| 🗉 Risk Rank : 2 | (Medium) (5)   |             |                  |                 |                  |                     |
| RT-402-8-03-D   | ETL - FE ASIC does not meet specs - needs another pre-prod run | 10 %        | 874 930 986 k\$  | 6 7.5 9 months  | 93               | 0.8                 |
| RT-402-8-55-D   | ETL - Schedule delay in submitting ETROC2                      | 30 %        | 55 110 165 k\$   | 2 4 6 months    | 33               | 1.2                 |
| RT-402-8-02-D   | ETL - ETL module facility unavailable                          | 50 %        | 20 k\$           | 2 months        | 10               | 1.0                 |
| RT-402-8-10-D   | ETL - Sensor quality problem during production                 | 15 %        | 28 52 109 k\$    | 2 3 6 months    | 9                | 0.6                 |
| RO-402-8-01-D   | ETL - Use AltiROC  | 10 %        | -720 k\$         | -8 months       | -72              | -0.8                |
| Risk Rank : 1   | (Low) (4)  |             |                  |                 |                  |                     |
| RT-402-8-54-D   | ETL - Schedule delay in submitting ETROC3                      | 20 %        | 27.5 55 82.5 k\$ | 1 2 3 months    | 11               | 0.4                 |
| RT-402-8-53-D   | ETL - Integration facility at CERN runs out of components      | 25 %        | 21 k\$           | 3 months        | 5                | 0.8                 |
| RT-402-8-31-D   | ETL - Storage-related degradation of LGADs                     | 10 %        | 18 k\$           | 3 months        | 2                | 0.3                 |
| RT-402-8-51-D   | ETL - Problem with vendor provision of module components       | 5 %         | 0 15 30 k\$      | 1 2 3 months    | 1                | 0.1                 |



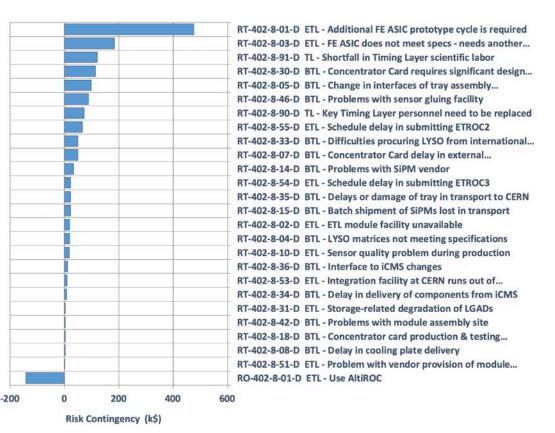
# MTD Risk Cost Impact

# Main risk changes in past 12 months are

- Detailed risk analysis of both BTL and ETL
- Careful alignment with iCMS (TDR) plans
- External risk reviews
- ASIC risks to cover realistic scenarios and submission delays



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



#### **MTD risk contingency** ≈ **\$1.95M** (15.3% of MTD BAC)

MTD risk contingency includes cost weighted fraction of project wide common risks (exchange rate, escalation, funding delay, import/export issues, OH, ES&H incident)



## Project Cost Risks

# Main risk changes in past 12 months are

- Reviewed and updated full spectrum of risks
- New: detailed risk analyses of BTL & ETL
- Re-aligned with the evolving iCMS plans
- Held external risk reviews
- Escalation, overheads, and exchange rate risks decreased (we have advanced by one year)

#### Risk Contingency (k\$)

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

|            | RU-402-1-01-D PM - Foreign exchange rates are uncertain (DO    |
|------------|--|
|            | RU-402-1-02-D PM - Future escalation rates are uncertain (DOR  |
|            | RU-402-2-01-D OT - Uncertain performance of Hybrids vendor     |
|            | RT-402-8-01-D ETL - Additional FE ASIC prototype cycle is      |
|            | RT-402-1-05-D PM - Significant funding delay during project    |
|            | RT-402-2-11-D OT - MaPSA bump bonding cost increases           |
|            | RT-402-4-18-D CE - Additional concentrator ASIC engineering    |
| Top 25     | RT-402-2-10-D OT - Vendor cannot perform MaPSA                 |
| nroject    | RT-402-4-22-D CE - Additional production acceleration required |
| project    | RT-402-6-03-D TD - I/O performance does not meet               |
| cost risks | RT-402-1-12-D PM - Major import or export issue (DOE)          |
|            | RT-402-2-91-D OT - Shortfall in Outer Tracker scientific labor |
|            | RT-402-4-91-D CE - Shortfall in Calorimeter Endcap scientific  |
|            | RT-402-4-04-D CE - Concentrator does not meet specifications   |
|            | RT-402-8-03-D ETL - FE ASIC does not meet specs - needs        |
|            | RT-402-4-01-D CE - Additional FE ASIC engineering run required |
|            | RT-402-2-09-D OT - MaPSA yield is lower than expected          |
|            | RT-402-2-90-D OT - Key Outer Tracker personnel need to be      |
|            | RT-402-4-90-D CE - Key Calorimeter Endcap personnel need to    |
|            | RT-402-6-06-D TD - Baseline FPGA does not satisfy              |
|            | RT-402-4-02-D CE - Infrastructure failure at module assembly   |
|            | RU-402-6-07-D_TD - DAO STMS I/O performance does not mee       |
|            | RT-402-8-91-D TL - Shortfall in Timing Laver scientific labor  |
|            | RT-402-8-30-D BTL - Concentrator Card requires significant     |
|            | RT-402-2-23-D OT - Vendor is unable to produce sensors to      |
|            | RT-402-8-05-D BTL - Change in interfaces of tray assembly      |
|            | RT-402-2-46-D OT - Problem with carbon foam vendor             |
|            | RT-402-2-01-D OT - Sensor quality problem during production    |
|            | RO-402-8-01-D ETL - Use AltiROC                                |
|            | RO-402-2-03-D OT - Module assembly can be automated            |

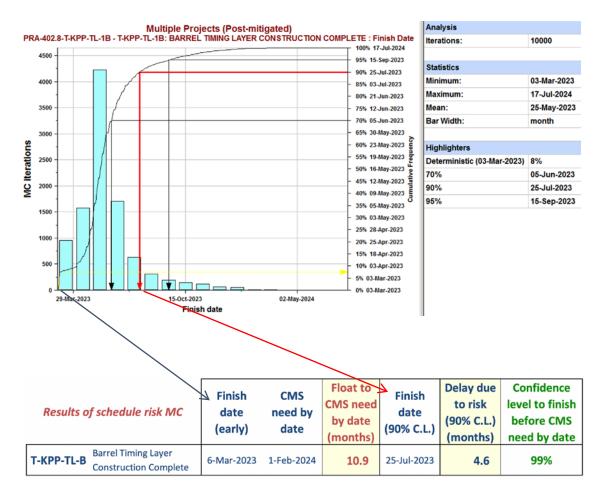
#### Risk Contingency (k\$)

#### **Project Risk-based contingency** ≈ **\$10.07M** (8.1% of BAC)



# **BTL Schedule Contingency**

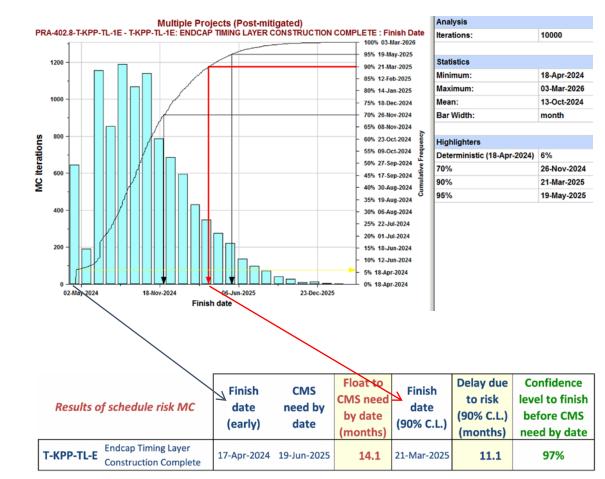
- Risk MC aggregates delays stochastically in the full P6 schedule
- Risks will delay finish by < 4.6 months at 90% confidence level
- Plan has 10.9 months of float before the CMS need by date
- T-KPP will finish before the need by date at 99% confidence level
- Will revisit schedule risk when new LHC schedule is known





# **ETL Schedule Contingency**

- Risk MC aggregates delays stochastically in the full P6 schedule
- Risks will delay finish by < 11.1 months at 90% confidence level
- Plan has 14.1 months of float before the CMS need by date
- T-KPP will finish before the need by date at 97% confidence level
- Will revisit schedule risk when new LHC schedule is known





The BTL and ETL design is mature and we have a well-developed schedule that reflects the design described in the MTD TDR and includes recommendations from the previous reviews

The detailed schedule in P6 has well motivated cost and labor estimates that are documented in the BOEs

Risks have been identified and reviewed and are linked in the schedule allowing us to model the cost and schedule impact

The MTD cost estimate and schedule is advanced, and we are well on the way to being prepared for CD-2