B01 : BTL Overview

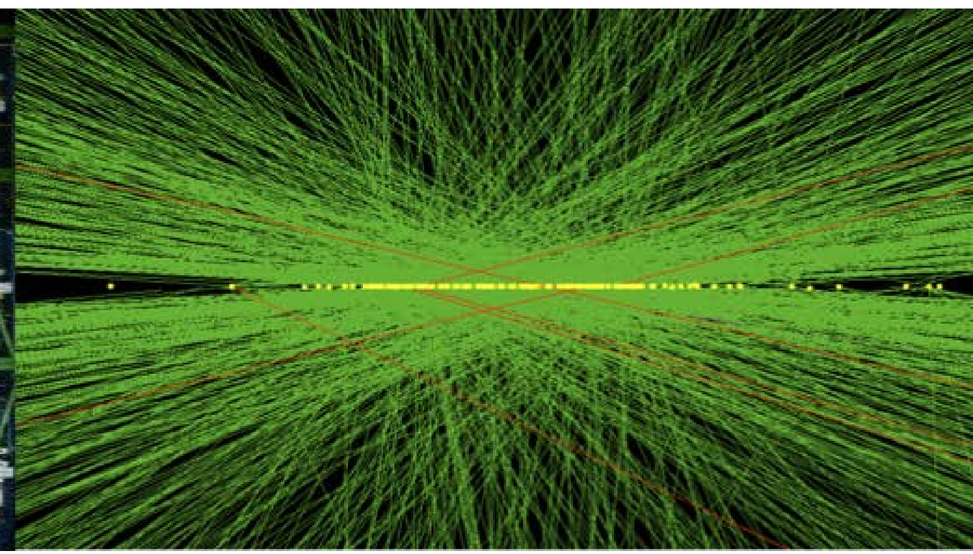
402.8.3

Adi Bornheim

Caltech

HL-LHC CMS CD-1 Review

23 October 2019



Charge #5

Brief Biographical Introduction

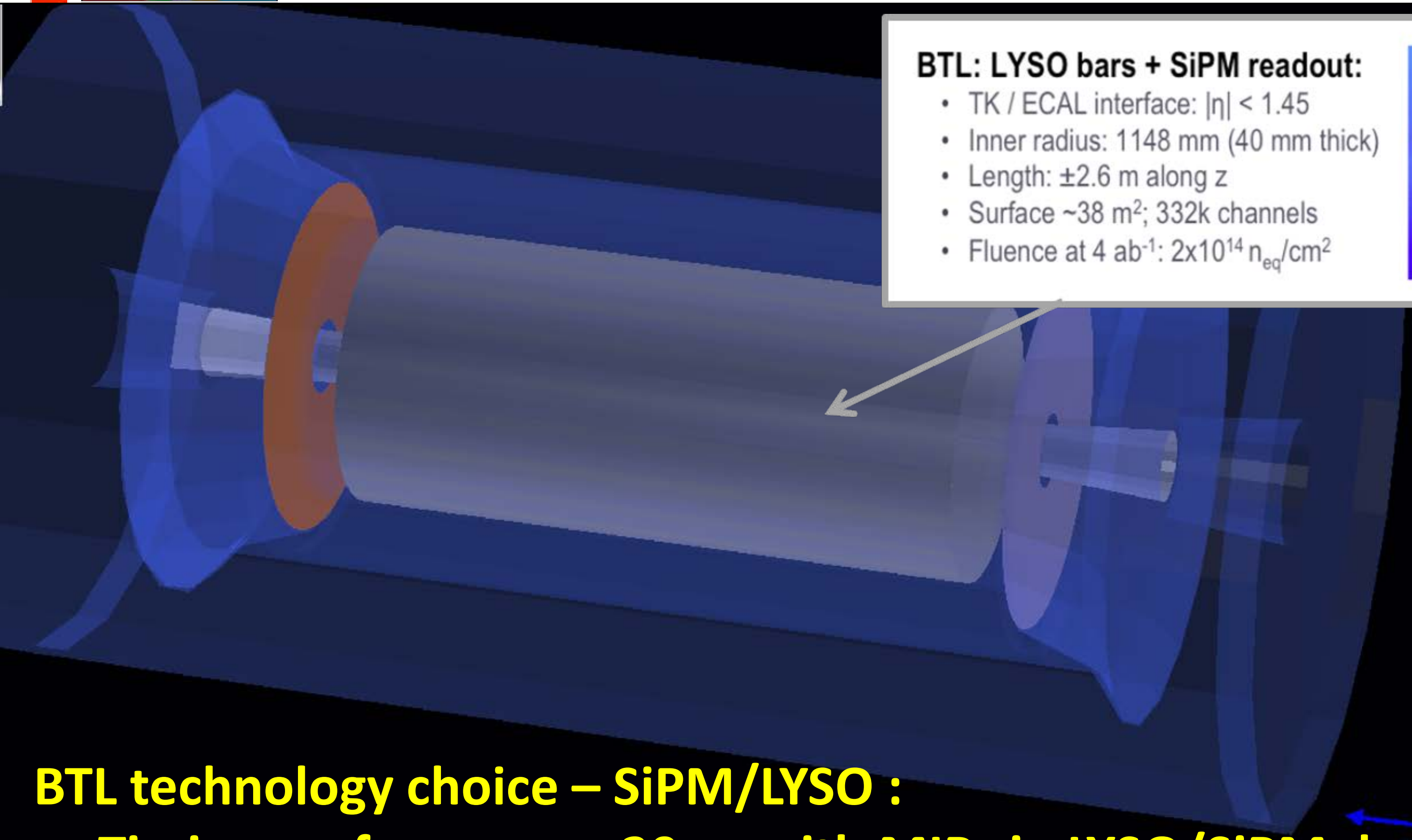
- Adi Bornheim, Caltech
- Roles in international MTD :
  - L3: BTL Technical Manager BTL
  - L4 : BTL Manager of Mechanics & Integration
- Roles in USCMS MTD :
  - L3 : BTL Manager
  - L4 : BTL Assembly, Integration and Commissioning
- Experience :
  - CMS since 2002
  - CMS ECAL R&D, installation, commissioning, operation, Higgs and SM physics
  - Precision timing detector R&D since 2012
  - Postdoc on CLEO, PhD on ZEUS/HERA

Outline

- Conceptual Design
- Scope and Deliverables for BTL (402.8.3)
- Cost and Schedule
- Contributing Institutions
- Resource Optimization
- ES&H
- QA/QC
- Summary

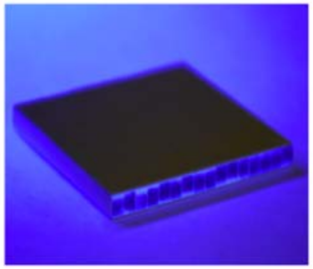
Conceptual Design, Scope and Deliverables

Introduction to BTL



BTL: LYSO bars + SiPM readout:

- TK / ECAL interface: |η| < 1.45
- Inner radius: 1148 mm (40 mm thick)
- Length: ±2.6 m along z
- Surface ~38 m^2; 332k channels
- Fluence at 4 ab^{-1}: $2x10^{14}$ n_{eq}/cm^2



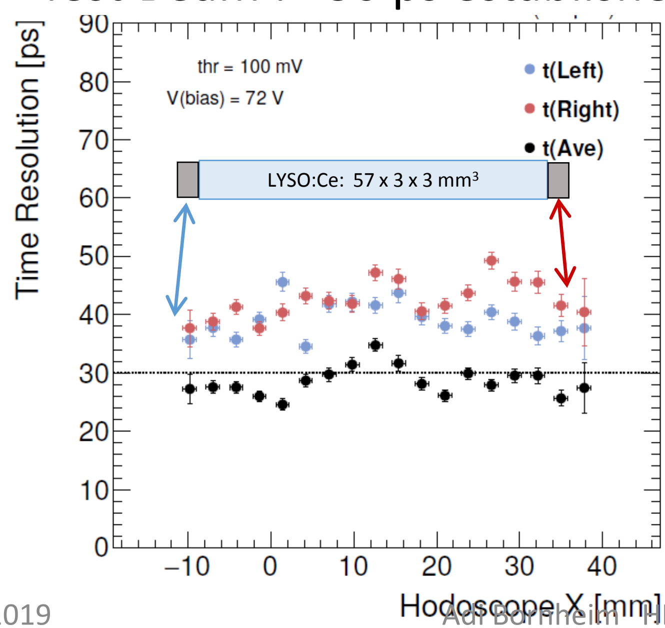
BTL technology choice – SiPM/LYSO :

- **Timing performance <30 ps with MIPs in LYSO/SiPM demonstrated.**
- **Radiation hardness established at the required level.**
- **Extensive experience with SiPM in CMS & LYSO in HEP & PET**
- **Cost effective mass market components**

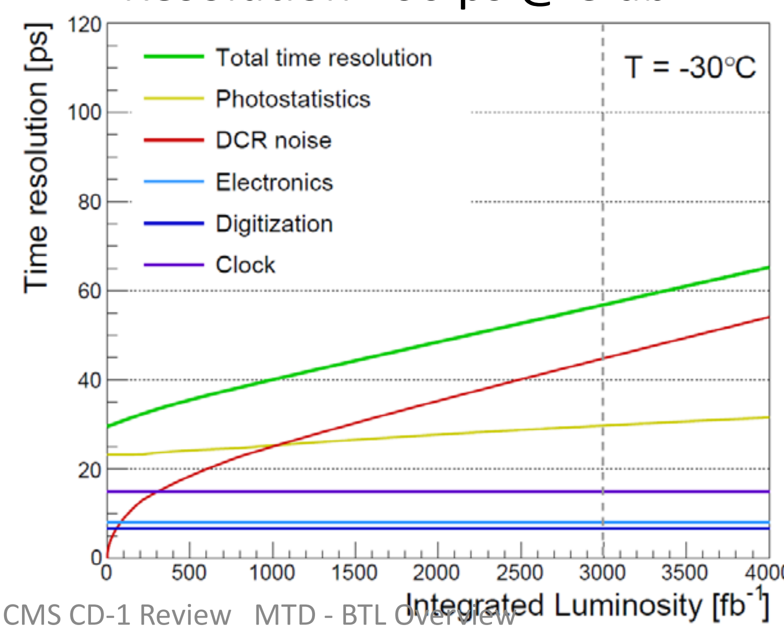
Design constraints & Performance

- Time resolution 30-40 ps at the start of HL-LHC, <60 ps up to 3000 fb^{-1}.
- Radiation levels for BTL at the end of HL-LHC :
  - Fluence 1.65 – 1.85 × 10^{14} n_{eq}/cm^2 , Dose : 16-20 kGy
- Maintenance free operation inside the tracker cold volume.
  - Requirement to run SiPMs at -30 C to limit dark count rate (DCR).
- Cover ~36 m^2 of area at the outer circumference of the CMS tracker.
- Design facilitating quick and efficient assembly and integration.

Test Beam : <30 ps established



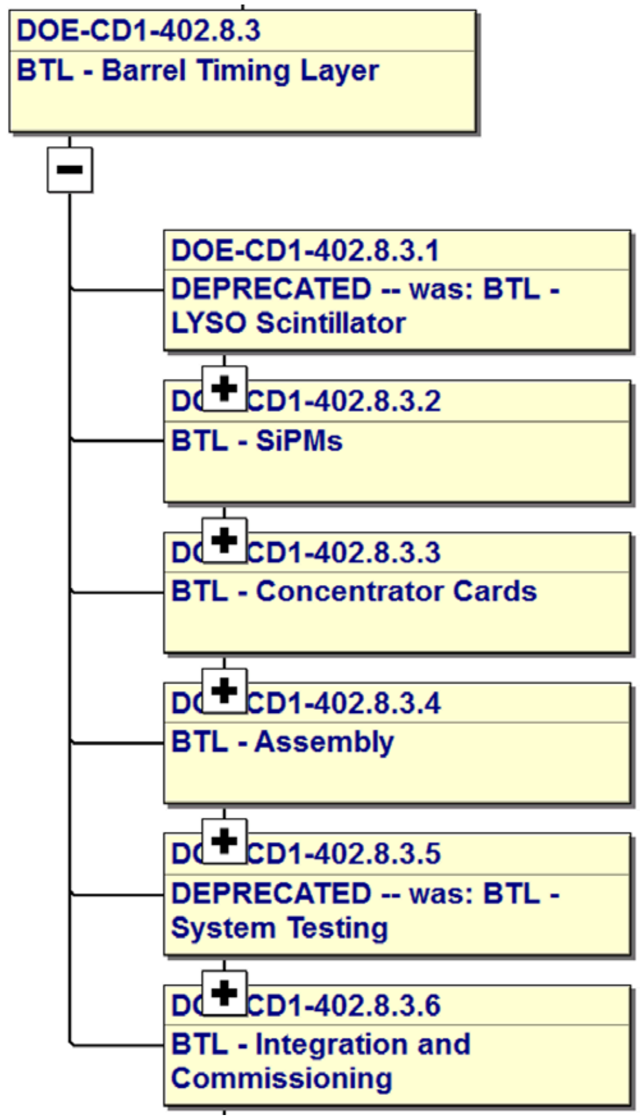
Resolution <60 ps @ 3 ab^{-1}



BTL (402.8.3) WBS Structure

Charge #4

- BTL project (402.8.3) subdivided into 6 tasks :
  - SiPM sensor (402.8.3.2)
    - Purchase and testing of part of the SiPMs
    - M. Wayne → separate talk
  - Concentrator Card (402.8.3.3)
    - Design and production of all CC
    - Y. Maravin → separate talk
  - Assembly (402.8.3.4)
    - Assembly of ~60% of the modules and the trays, delivery to CERN
    - A. Bornheim
  - Integration and Commissioning (402.8.3.6)
    - Participation in I&C activity at CERN, jointly with other BTL collaborators.
    - A. Bornheim



BTL Layout

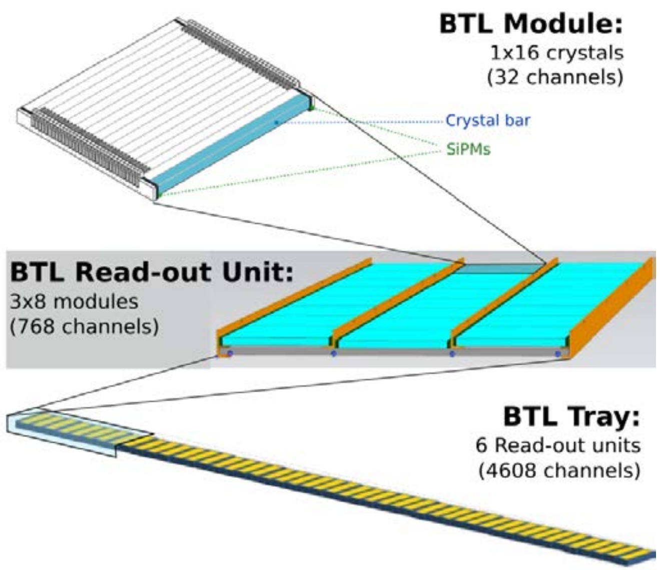
BTL will be attached to the inner wall of the Tracker Support Tube (TST).

Cold volume shared with Tracker (TRK).

BTL Segmentation :

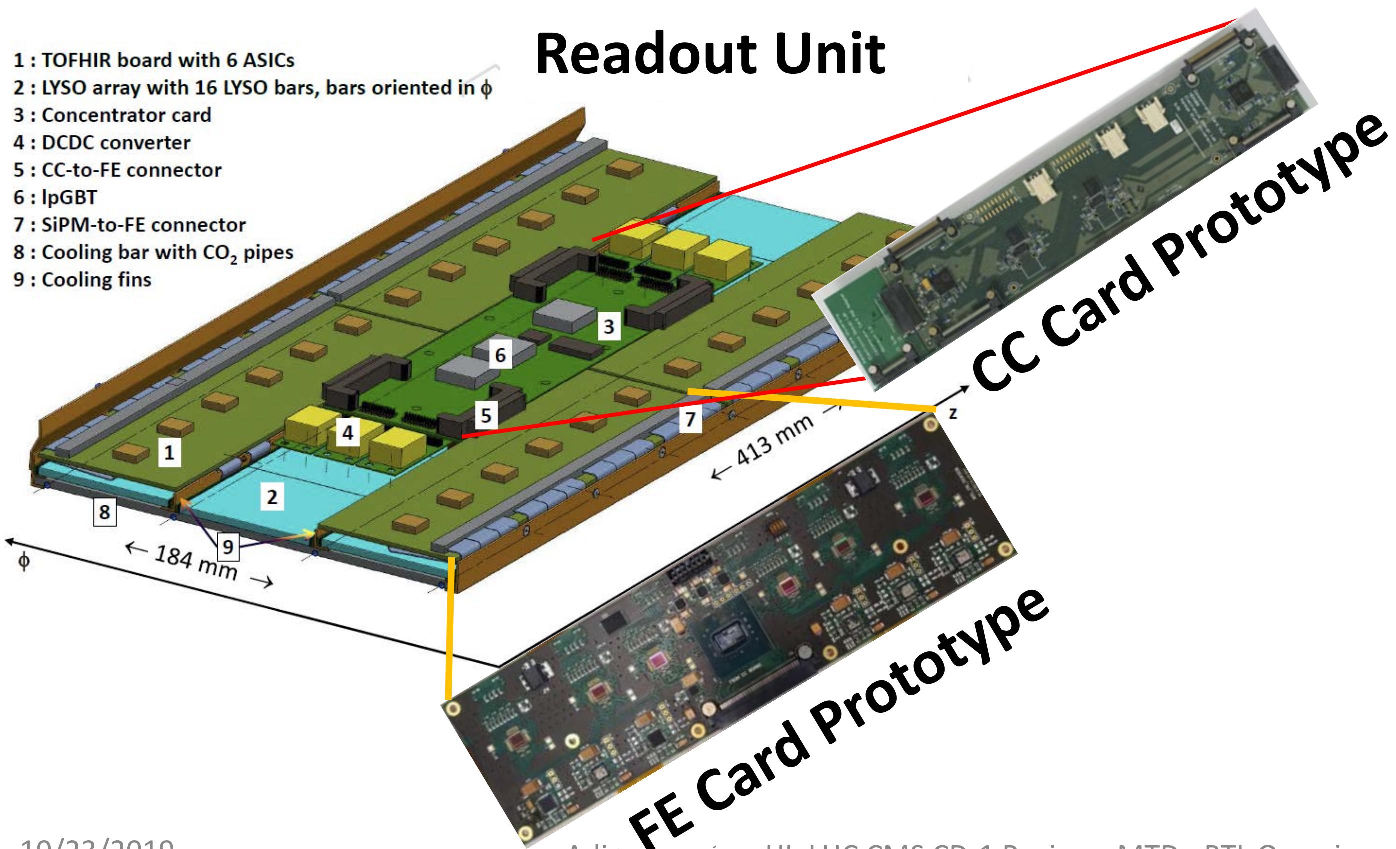
- 72 trays (36 in $\varphi \times 2$ in η)
- 331k readout channels, 165k LYSO bars, organized in 6 Readout Units per tray.
- Tray dimensions : 250 x 18 x 2.5 cm

Current TST – HL-LHC upgrade very similar



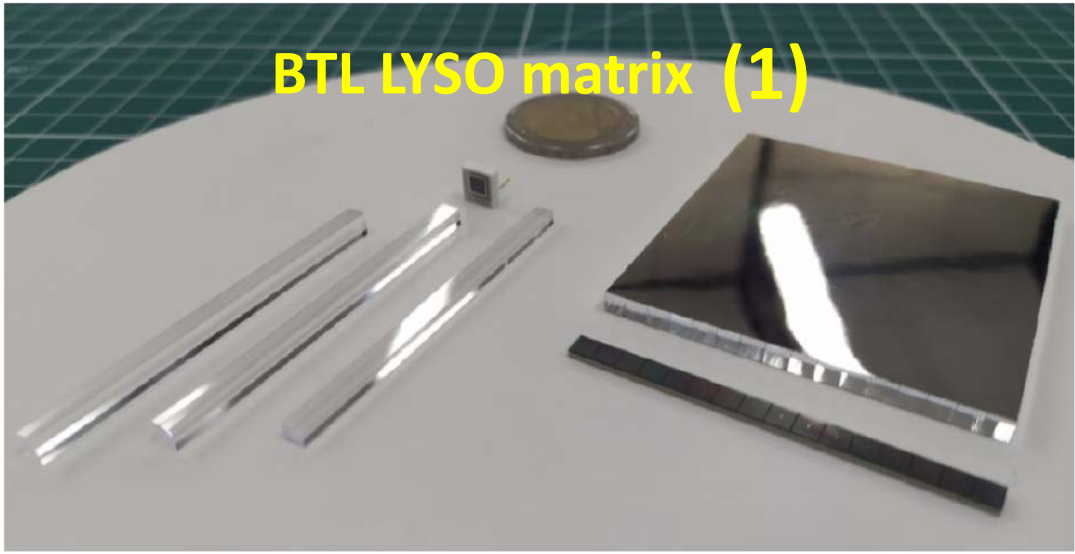
BTL tray

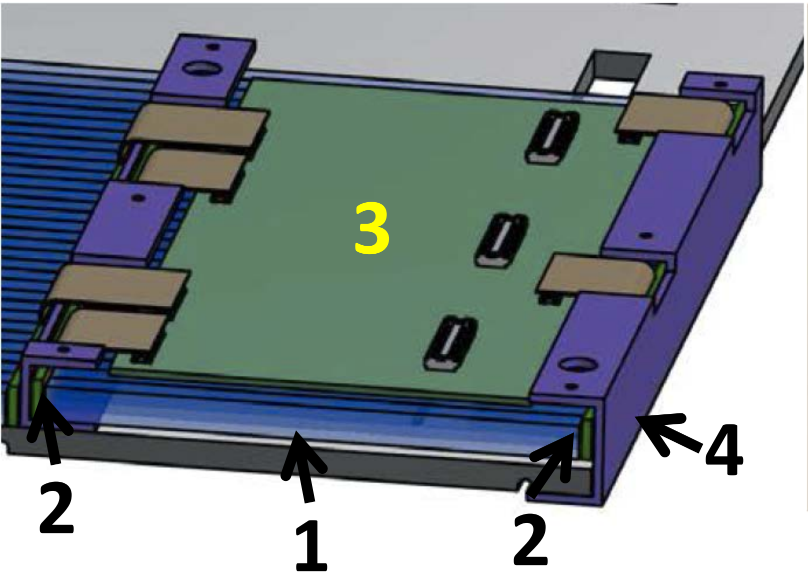
- BTL tray design :
  - Front End electronics, segmented into Readout Units
  - Sensor layer, segmented into modules
  - Cooling tray, providing mechanical support, CO_2 cooling pipes.

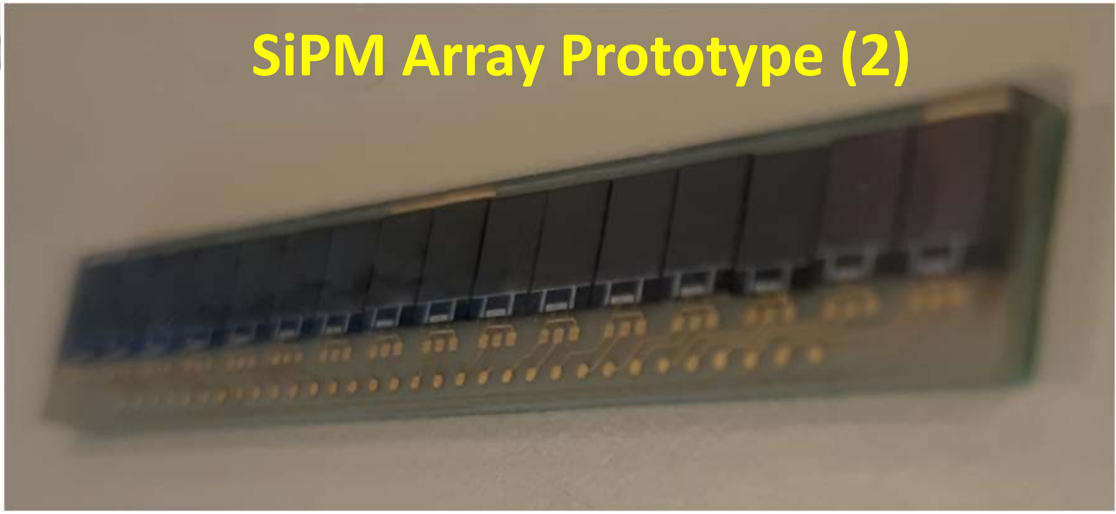


BTL Modules

- BTL module :
  1. LYSO matrix
  2. SiPM array
  3. Connectivity to FE cards
  4. Aluminum profiles providing mechanical and thermal contact to cooling tray.

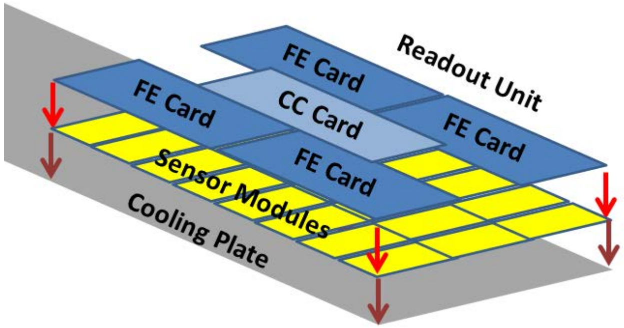




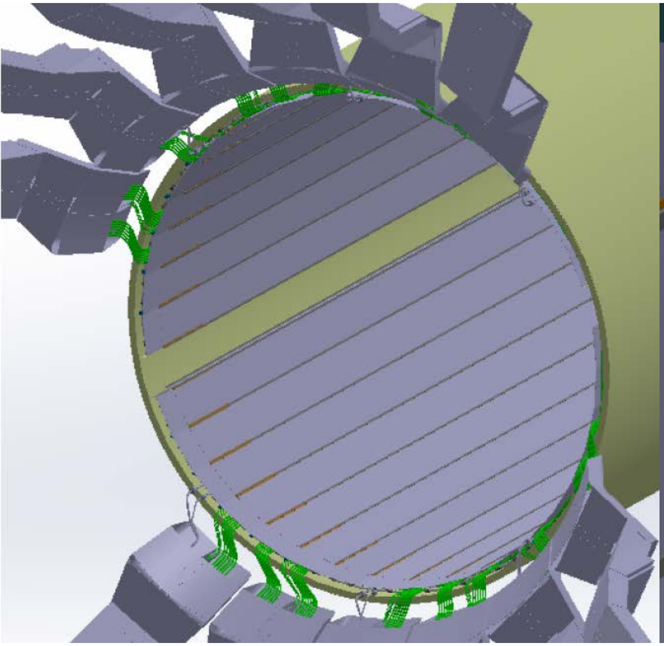


BTL Assembly, Integration & Commissioning

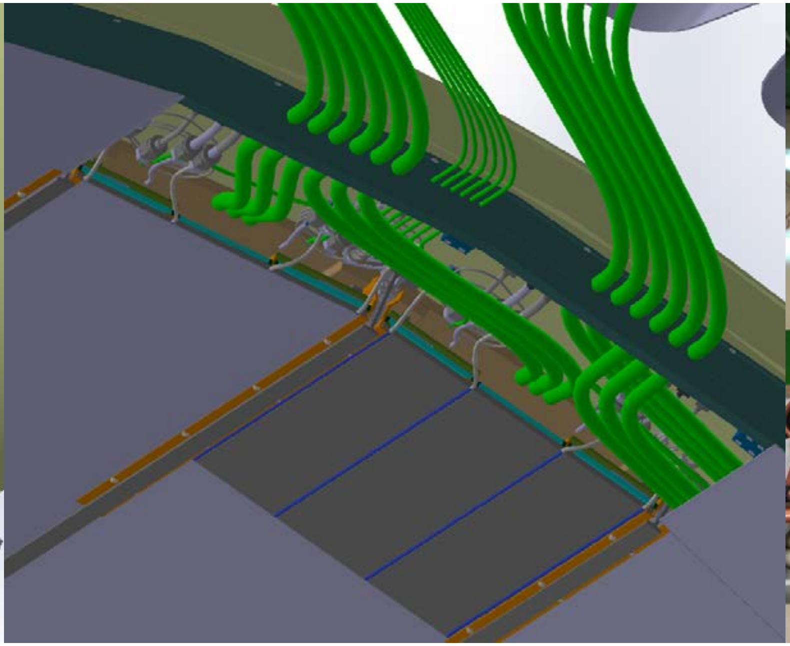
- Module and tray assembly :
  - Mating of LYSO and SiPM, connecting cables.
  - Mounting of modules and RU on cooling plate.
  - 2 assembly centers in the US
- Integration into the TST :
  - Trays sliding into support rails, connecting services.



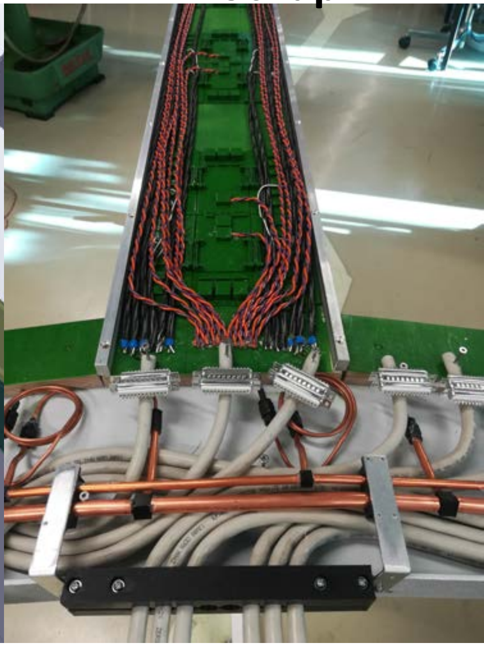
TST with BTL trays and services



BTL services channel



BTL services channel mockup



Charge #1, 2, 4

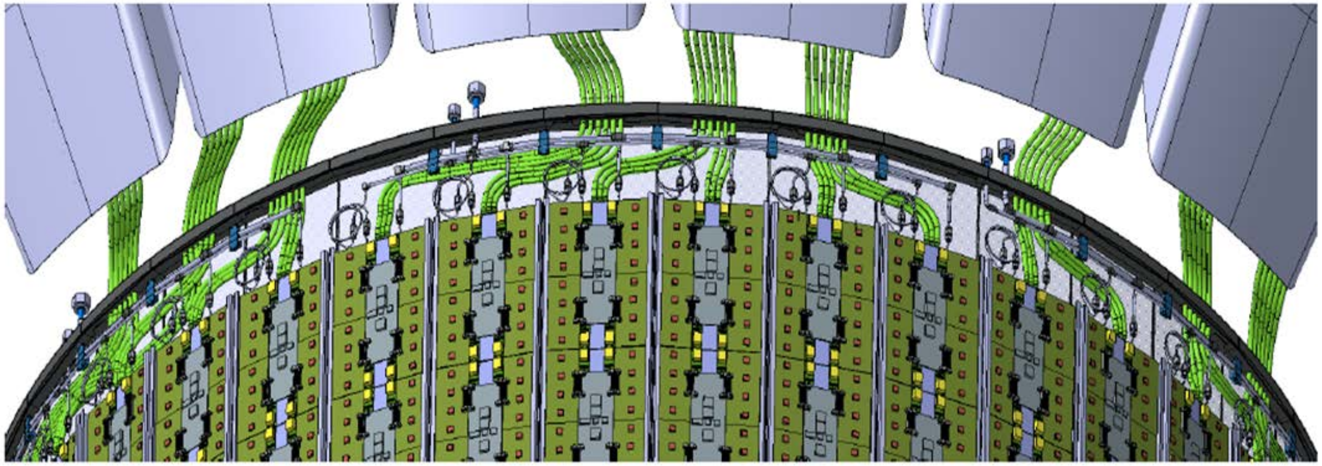
R&D achieved and remaining

- Sensor R&D concluding
  - Profiting from many years of R&D for HCAL
  - LYSO R&D now focused on producer choice and production details, selecting from commercially available solutions.
  - Gluing and wrapping of LYSO
  - SiPM : See presentation by M. Wayne
- Concentrator Card :
  - Prototyping ongoing, using common components from CMS
  - See presentation by Y. Maravin
- Assembly
  - Benefit from experience gained in existing detector projects : CMS ECAL, CMS HCAL, CALICE AHCAL.
  - Module and tray design now transitioning from conceptual to engineering design.
  - Industrialization options for module production being explored in detail.
- Installation and Commissioning
  - Joined project with Tracker, schedule and location (TIF) agreed.
  - Installation procedure to be worked out in detail.
- Remaining R&D focused on optimization and vendor choice.

Charge #7

Interfaces

- Sensors :
  - Specs of LYSO and SiPMs, sensor boards, connectivity to FE
- Readout electronics :
  - Matching specs of CC and ASIC card, services, tray mechanics.
- Overall detector :
  - BTL resides in the same cold volume as TRK, radial space assignment to BTL signed off by TRK.
  - BTL shares service channel – cooling, power, data fibers - with the TRK. Preliminary design of all services exists.
- Documented in cms-doc-13536

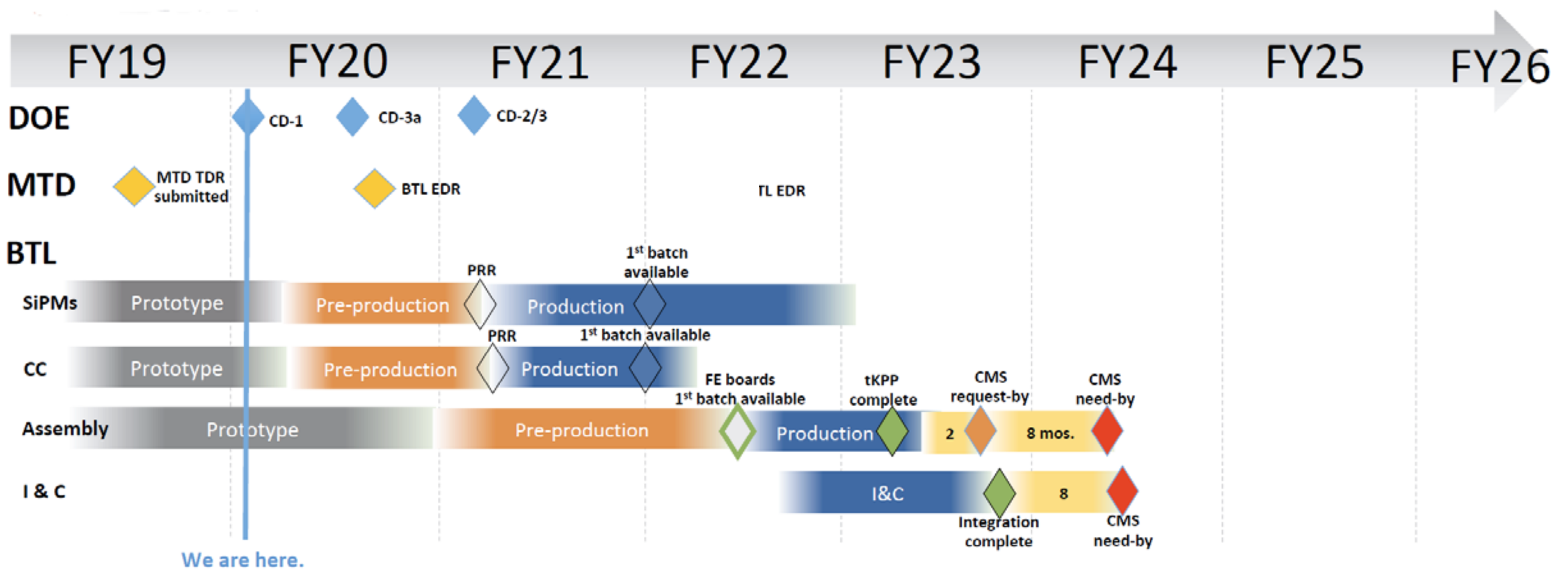


Schedule and Cost

Schedule Overview

Charge #3

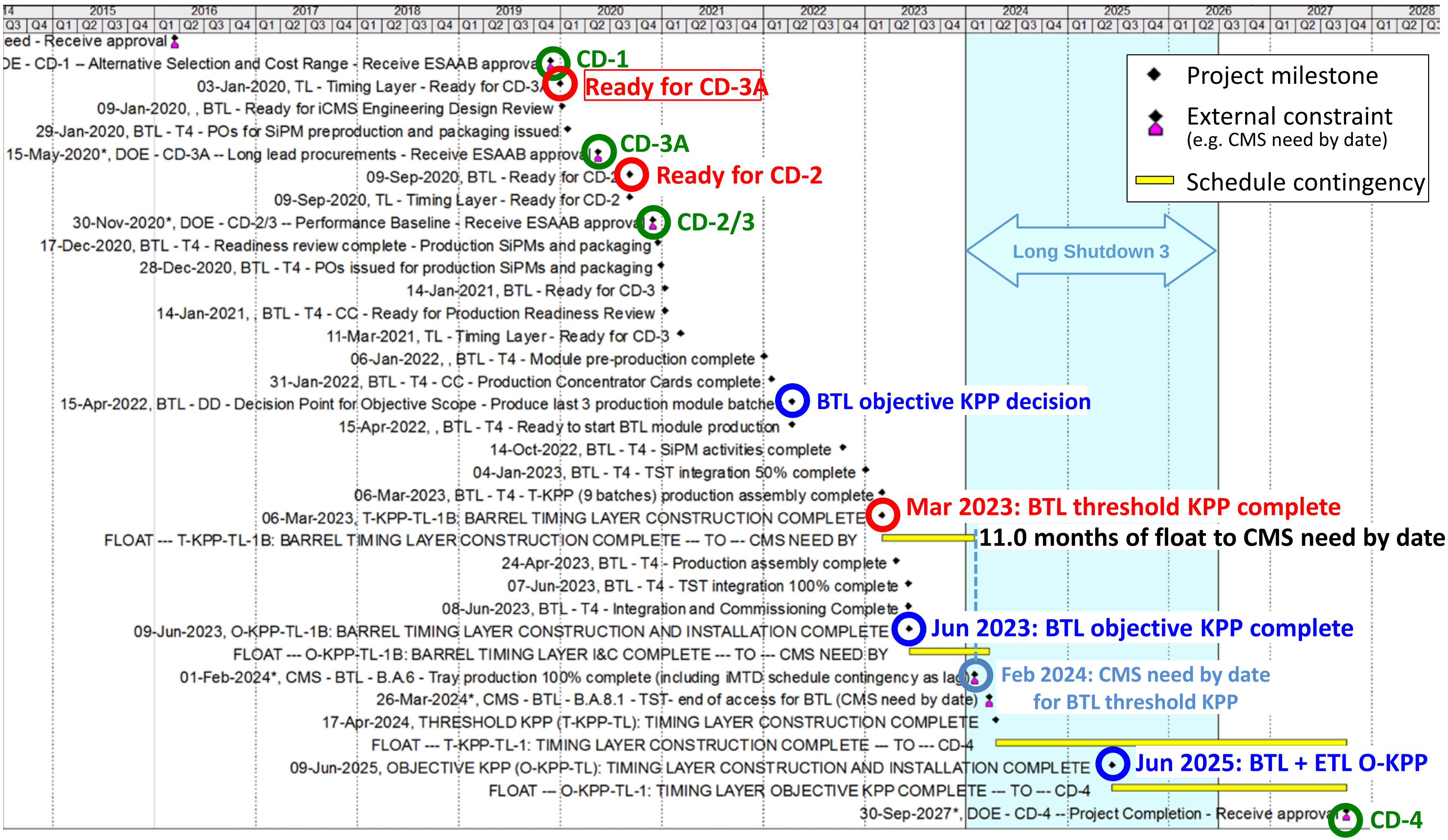
- BTL schedule constrained by Tracker integration
  - Flexibility by parallel work on both TST ends.
- Assembly and integration driven by FE boards (ASIC).
  - Assembly can be accelerated using teams working in parallel.
- Detailed schedule, resource loaded, available.
  - MTD approved by LHCC/UCG in September 2019



Milestones for 402.8.3

Charge #3

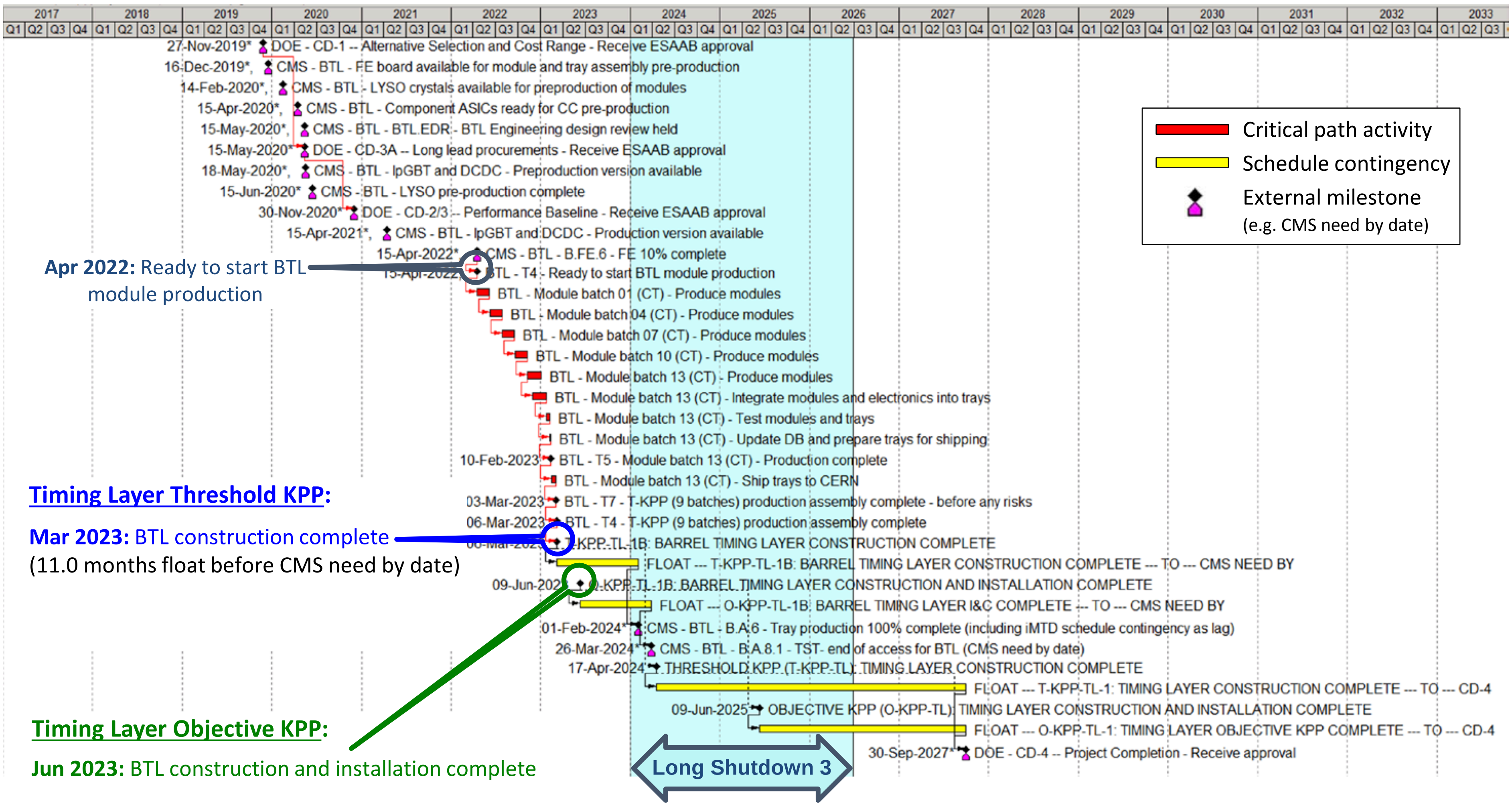
- Milestones defined and documented : [cms-doc-13321]
  - Finer grained milestones are listed in P6



Critical Path for 402.8.3

Charge #3

- Further details in F. Chlebana`s talk.



Apr 2022: Ready to start BTL module production

Timing Layer Threshold KPP:

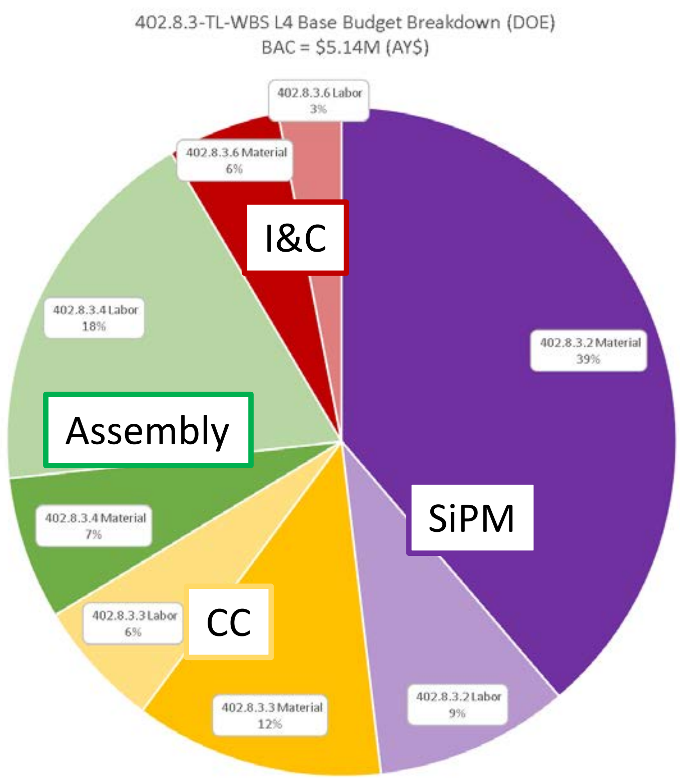
Mar 2023: BTL construction complete
(11.0 months float before CMS need by date)

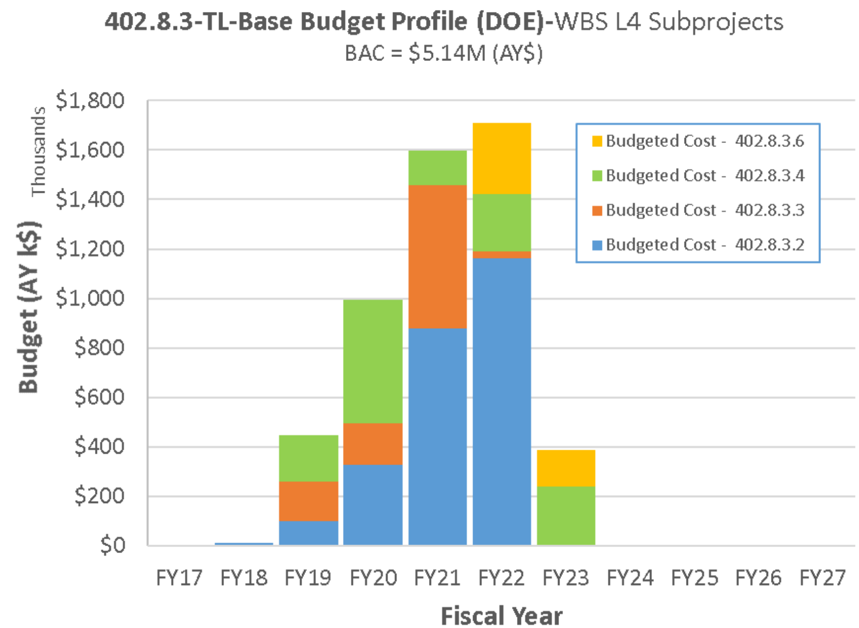
Timing Layer Objective KPP:

Jun 2023: BTL construction and installation complete

Cost Estimate for 402.8.3

- M&S cost drivers :
  - Purchase fraction of SiPM
- Labor cost drivers :
  - Module and tray assembly, CC card design and production





BTL Risks

Charge #3

- Project governed by Fermilab Risk Management plan.
- Risk workshop with external reviewers conducted.
- Dominated by changes to interfaces.
- Documented in cms-doc-13480

RI-ID	Title	Probability	Cost Impact	Schedule Impact	P * Impact (k$)	P * Impact (months)
WBS / Ops Lab Activity : **402.8 TL - Timing Layer (general risks)** (2)						
WBS / Ops Lab Activity : **402.8.3 BTL - Barrel Timing Layer** (14)						
Risk Rank : 3 (High) (2)						
RT-402-8-30-D	BTL - Concentrator Card requires significant design changes	50 %	40 -- 135 -- 175 k$	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
Risk 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) (8)						
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 Lab Activity : **402.8.4 ETL - Endcap Timing Layer** (10)						

Contributing Institutions and Resource Optimization

Charge #4

Contributing Institutions

- Main contributing institutions for the WBS 402.8.3 are Caltech, Iowa, Notre Dame, UVA, KSU, Princeton, FNAL, NEU.
- All have substantial experience in detector design, R&D, prototyping, construction and commissioning as well as in generic detector R&D.
- In CMS, experience in ECAL and HCAL
- Substantial experience with scintillating crystals, SiPMs and precision timing.

Resource Optimization

Charge #4

- We follow value engineering in organization of the project and optimal use of resources (cms-doc-13475).
- Participating institutions has very strong track record in the relevant technologies.
- Make maximal use of commercially available items for cost drivers (LYSO and SiPMs).
- Make maximal use of industrial processes and techniques for production and assembly.

Charge #6

ES&H

- All ES&H aspects of the HL LHC CMS Detector Upgrade Project will be handled in accordance with the Fermilab Integrated Safety Management approach, and the rules and procedures laid out in the Fermilab ES&H Manual (FESHM)
  - The current construction plan involves no materials of identified environmental risk : cooling plant is based on CO_2
- Detector will be operated in a refrigerated mode (-30°C), similar to TRK.
  - Standard operational procedures will be developed and documented to allow safe operation
- Handling of trays with a weight of 20 kg.
  - Proper handling procedures will be applied.
- Electrical hazards and discharges, voltages up to 100 V.
  - Standard operational procedures will be developed and documented to allow safe operation
- R&D and some production testing will involve the use of ionizing radiation and lasers.
  - These tests will be performed at commonly-used radiation and test beam facilities
- Documented in cms-doc-13394

Quality Assurance and Quality Control

- Following the strategy of maximal usage of commercial and industrial technologies, use respective standards for QA/QC.
- Extensive testing in prototyping, preproduction and production.
- Quality Assurance & Control plan documented in cms-doc-13093.

WBS	WBS Title	L2, L3, L4 Lead	QA/QC Activity Name	Responsible Institution	QA/QC Coordinator/ Contact	QA/QC Activity ID	Quality Control or Assurance Activity/ Parameter	Quality Assurance Activities	Quality Control Activities	Specification(s)	Requirement ID	Requirement Title
402.08.3.2	BTL: SiPMs	Chris Neu, Adi Bornheim, Mitch Wayne	Prototype/preproduction iterations. Production part QC.	University of Notre Dame / work to be performed in our SiPM lab at CERN	Yuri Musienko	MT-QA-001, MT-QC-001	Measurement and characterization of approximately 175,000 channels of SiPM	Development of test procedures, based on previous HCAL project. Setup test stands to measure	SiPM parameters measured in QA/QC will be verified in beam tests and radiation studies on	[SiPM spec dwg/doc number]	MTD-engr-001, 016, 032, 037	SiPM radiation hardness
402.8.3.3	BTL Concentrator Card	Chris Neu, Adi Bornheim, Yurii Maravin	Prototype testing and qualification. Production testing of all parts.	Kansas State University	Yuri Maravin	MT-QA-002, MT-QC-002	Power test and digital functionality	Development of test stands and test procedures using early prototype boards. Document	Verification of full electrical functionality. Verify each part with visual inspection for any	[Concentrator Card spec dwg/doc number]	MTD-engr-013, 026, 027	Electrical Hazards, BTL Concentrator Card performance; Backend Electronics
402.8.3.4	BTL Assembly	Chris Neu, Adi Bornheim, Adi Bornheim	Prototype qualification. Production inspection and testing	University of Virginia, Caltech	Adi Bornheim	MT-QA-003, MT-QC-003	Measurement of mechanical parameters. Measurement of performance	Development of test stands and test procedures using early prototype RUS and trays	Validation of electrical performance. Measurement of conformity to	[BTL Assembly dwg/doc number]	MTD-engr-002, 006, 007, 008, 009, 010, 011, 012, 014, 015, 030; 035, 036	Hit Multiplicity; Module Cooling; MTD thermal performance; MTD Magnetic Field
402.8.3.6	BTL: Integration and Commissioning	Chris Neu, Adi Bornheim, Adi Bornheim	Participate in installation and commissioning at CERN with international	University of Virginia, Caltech, Notre Dame, KSU / CERN	Adi Bornheim	MT-QA-004, MT-QC-004	Measurement of electronic performance and cooling and mechanical	Development of cooling system at TIF, test stands, and test procedures. Document tray test	Validation of full tray with background rate and cosmic ray based tests	[BTL System dwg/doc and installation procedures dwg/doc numbers]	MTD-engr-003, 004, 010, 011, 012, 014, 015	Impact on the OT and HGCal performance and design; Integration and accessiblity of

Summary

- Significant progress over the past year :
  - BTL design well advanced
  - SiPM and LYSO ready to move from R&D to preproduction
  - Close collaboration with Tracker on integration and technical coordination.
- Cost, schedule and risks well understood and documented
- Strong team of contributing institutions with significant experience of designing, building, and testing scintillator based detectors.
- Conceptual design is complete and well on the way to baselining.