B04 : BTL Assembly
402.8.3.4

Adi Bornheim
Caltech
HL-LHC CMS CD-1 Review
23 October 2019
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

- BTL Detector Design
- Tray and Sensor board Design
- Status of Prototyping
- BTL Integration
- Assembly model and part flow
- Milestones, schedule and cost
- ES&H
- QA/QC
- Summary
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 $\phi \times 2$ in $\eta$)
- 331k readout channels, 165k LYSO bars, organized in 6 Readout Units per tray.
- Tray: 250 x 18 x 2.5 cm, \(\sim 20\) kg
- TST: 5.3 m long, 2.4 m diameter
BTL tray design:

- Front End electronics, segmented into Readout Units
- Sensor layer, segmented into modules
- Cooling tray, providing mechanical support and houses CO₂ cooling pipes.
- US scope: Assembly of 60% of modules and trays.
BTL Sensor Modules

- **BTL Sensor Module**: 
  1. LYSO matrix + SiPM array: “Sensor”
  2. Connectivity to FE cards with flex cables or flex+mother board: “Sensor Board”
  3. Aluminum profiles providing mechanical and thermal contact to cooling tray.

- LYSO matrix and SiPM package delivered packaged from manufacturer.

- Module assembly:
  - Glue LYSO to SiPM
  - Plug sensor board into SiPM package connector
  - Mount module on tray with aluminum profiles.
BTL Tray Prototypes

Tray Mechanics Prototype

SiPM Mockup

Glass Mockup

TST Tray Support Prototype

TST Rails
Sensor Board Prototypes

Flex cable SiPM package with rigid interface board

Sensor Board
SiPM Mockup
Glass Mockup
Sensor Board Prototypes

Flexible Sensor Board

LYSO Matrix

Cooling Plate

Connector to SiPM
- **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.
BTL Construction model

- BTL segmented in small, relatively simply pieces: Cooling plate (IT), sensor modules (IT/US), ASIC boards (PT), CC card (US).
- Provides flexibility in production to mitigate schedule risks.
- Assuming three parallel tray integration centers, each capable of integrating one RU per day: 9 months.
- 2 assembly centers in the US (Caltech, UVA), 1 in Italy (Milano).
- All components get delivered to assembly centers: LYSO, SiPM, FE boards, cooling trays.
- LYSO to SiPM gluing as a separate step.
- Tray assembly in units of RUs.
- Pace: 1 RU per day per assembly center.
Tray mechanics and cooling:
- Several cooling plate prototypes have been built in Padova, technology and thermal performance being tested.
- Testing in FNAL with CO2 system being prepared, results expected within the next weeks.

Sensor boards:
- Design ongoing, initial prototypes used for test beam.
- Prototypes with final form factor and connectivity have been produced, tested.

Tray assembly:
- Detailed design of the tray assembly procedure ongoing
- Focus on fully exploiting possible outsourcing and usage of standard industry technology.
SiPM and LYSO prototypes being delivered, testing Q4 2019,
  - To be used in module prototypes in Q1/2020.

SiPM and LYSO preproduction in 2020
  - To be used for tray prototype, available in Q2/2020.

Tray prototype Q2/2020 to demonstrate EDR readiness.
  - Demonstrate system performance (mechanics, thermal, noise).
  - TOFHIR2 becoming available in Q1/2020, demonstrate DCR cancelation with irradiated modules.


Float towards “End of access to TST” : 8 months.
• Four major system tests scheduled to demonstrate performance throughout the project:
  • 03/2020: Prototype tray with RU prototype 1
  • 05/2020: Demonstrate DCR cancelation with Sensor Module prototype
  • 05/2021: Prototype tray with RU prototype version 2, TOFHIR version 2 with DCR cancelation.
  • 10/2022: Trial insertion of trays in TIF at CERN
  • At least 2 test beam campaigns per year.
Inputs to tray assembly come with well defined quality, largely from industry, reception testing by responsible institutes.

During assembly of the trays the following QC steps are followed:

- Mechanical verification of LYSO matrix dimensions.
- Functionality test of sensor board after LYSO matrix glues. Utilizing natural radioactivity of LYSO.
- Repeat test after boards are mounted on the tray, using the final FE electronics.
- Sample testing with cosmic test stand.

- Full tray cold test before shipping to CERN.
- Cold test at TIF with CO$_2$ before insertion into TST, global cold checkout jointly with TRK.
M&S cost:
- Some dedicated tooling, misc. supplies and test setups-
- Labor cost drivers:
  - Manual assembly of modules and trays, testing.
- Details are described in [cms-doc-13592](#)

### Cost Estimate for 402.8.3.4

#### Charge #3

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<tr>
<th>WBS - Name</th>
<th>BoE Ref</th>
<th>Name</th>
<th>Est. Type</th>
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<td>CMS-doc-13592-MS-101</td>
<td>Purchase misc components</td>
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10/23/2019  Adi Bornheim  HL-LHC CMS CD-1 Review  MTD - BTL Assembly
Assembly cost breakdown

402.8.3.4-TL-Base Budget Profile (DOE)-Resource Type
BAC = $1.29M (AY$)

Budget (AY$)

Thousands

$600

$500

$400

$300

$200

$100

$0

FY17 FY18 FY19 FY20 FY21 FY22 FY23 FY24 FY25 FY26 FY27

Assembly cost breakdown

402.8.3.4-TL-Estimate Uncertainty Breakdown-M&S (DOE)
BAC (M&S)=$0.36M (AY$)

Budgeted Cost - Material
Budgeted Cost - Labor

402.8.3.4-TL-Estimate Uncertainty Breakdown-Labor (DOE)
BAC (Labor Budget)=$0.94M (AY$)

10/23/2019

Adi Bornheim   HL-LHC CMS CD-1 Review   MTD - BTL Assembly
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 CO₂

- 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](#)
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`.

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<th>WBS</th>
<th>WBS Title</th>
<th>L2, L3, L4 Lead</th>
<th>QA/QC Activity Name</th>
<th>Responsible Institution</th>
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<tr>
<td>402.08.5.2</td>
<td>BTL: SIPMs</td>
<td>Chris Neu, Adi Bornheim, Mitch Wayne</td>
<td>Prototype/preproduction iterations. Production part QC.</td>
<td>University of Notre Dame / work to be performed in our SIPM lab at CERN</td>
<td>Yuri Musienko</td>
<td>MT-QA-001, MT-QC-001</td>
<td>Measurement and characterization of approximately 175,000 channels of data.</td>
<td>Development of test procedures, based on previous HCAL project. Setup test stand and test procedures using early prototype detector.</td>
<td>Validation of experimental functional ity. Verify each part with visual inspection for any defects.</td>
<td>[SPIPM spec dwg/doc number]</td>
<td>MTD-engr-001, 016, 032, 037</td>
<td>MTD-001, 026, 027</td>
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Sensor module and tray design well beyond the conceptual level.

US scope for the assembly well defined.

Assembly centers actively engaged in the R&D and prototyping.

Prototypes of all principal components of the detector (SiPMs, LYSO, FE boards, cooling tray) becoming available, on target to full system test in early 2020.