Presentation 1: Summary of Preliminary Design Review

Presenter: Satoshi Yano

Presentation Summary

Satoshi Yano opened the TOF Mechanics Workfest by summarizing the outcome of the recent Preliminary Design Review (PDR). The presentation reviewed the major comments raised by the reviewers and outlined the tasks that need to be addressed before the next project milestone (CD-2). The primary objective of the Workfest is to identify high-priority issues, assign responsibilities, and coordinate the activities required to address the PDR recommendations.

Main Review Comments

Cooling

- Develop a realistic thermal model that includes the heat load from the FCFD ASIC.
- Validate the cooling concept through detailed thermal simulations.
- Evaluate temperature gradients along the staves and their impact on detector performance.

Material Budget

- Document the material budget for both the Barrel TOF and Forward TOF systems.
- Include support structures, cooling pipes, cables, flex circuits, and detector services in the material model.
- Evaluate the impact of detector material on physics performance and neighboring detector subsystems.

Detector Simulation

- Keep the simulation geometry synchronized with the latest

mechanical design.
- Perform detector simulations using realistic detector conditions.
- Quantify the effects of dead channels, inactive regions, and service materials on detector performance.

Assembly

- Develop standardized and reproducible assembly procedures.
- Define assembly workflows suitable for distributed production at multiple institutes.
- Improve documentation for assembly, integration, and installation procedures.

Quality Assurance / Quality Control (QA/QC)

- Clearly distinguish between Quality Assurance (QA) and Quality Control (QC).
- Define testing procedures for every production stage, including sensors, ASICs, FPCs, stavelets, and completed staves.
- Establish a common QA/QC workflow together with a centralized production database.

Discussion

This presentation served as an overview of the Preliminary Design Review and introduced the topics that would be discussed in greater detail during the subsequent Workfest presentations. **The participants recognized** that cooling, detector mechanics, simulation, FPC development, assembly, and QA/QC are strongly interconnected and must be developed in a coordinated manner across multiple working groups.

The discussion also emphasized that many of the PDR comments cannot be addressed independently, and that close collaboration between mechanics, electronics, detector simulation, and integration teams will be essential before the CD-2 review.

Key Points

- Address the PDR comments in a coordinated manner before CD-2.
- Give high priority to cooling development and thermal validation.
- Keep the detector simulation synchronized with the latest engineering design.
- Establish standardized QA/QC procedures throughout the production chain.
- Strengthen coordination among the mechanics, electronics, simulation, and assembly teams.

Action Items

- Update the cooling design and perform detailed thermal simulations.
- Refine the detector material budget using realistic engineering models.
- Synchronize the detector geometry with the simulation framework.
- Develop a detailed QA/QC workflow and establish a centralized production database.
- Finalize standardized assembly procedures for distributed production.
- Monitor progress on the PDR action items before the next design review.

Overall Significance

This presentation established the overall roadmap for the TOF Mechanics Workfest. Rather than introducing new technical developments, it summarized the reviewer feedback from the Preliminary Design Review and defined the priorities for the collaboration moving toward CD-2. The subsequent presentations on stavelet assembly, long FPC development, detector mechanics, and QA/QC each addressed specific topics identified during the review.

Presentation 2: BTOF Stavelet Assembly Plans

Presenter: Simone Mazza

Presentation Summary

Simone Mazza presented the current plan for the assembly of BTOF stavelets and the overall production workflow. The proposed strategy is based on a modular production model in which detector components are assembled at multiple institutes using common procedures and quality standards. The presentation covered the complete assembly sequence, quality assurance and quality control throughout the production process, and the logistics required for distributed detector construction.

The proposed workflow begins with sensor and ASIC preparation, followed by stavelet assembly, quality checks after each assembly stage, and final integration into complete staves before shipment to Brookhaven National Laboratory.

Main Discussion

Distributed Assembly and Production

- Multiple institutes are expected to participate in stavelet production and assembly.
- Standardized assembly procedures are essential to ensure consistent detector quality across all production sites.
- Distributed production was discussed as an effective strategy to increase production capacity while reducing the workload at individual institutes.

Assembly Workflow

- The assembly process should be divided into clearly defined stages, including sensor inspection, gluing, wire bonding, electrical testing, and final qualification.
- Quality checks should be performed after every major assembly step before proceeding to the next stage.
- Well-documented procedures will be necessary to ensure reproducibility among different production sites.

Quality Assurance vs. Quality Control

- A detailed discussion was held on the distinction between Quality Assurance (QA) and Quality Control (QC).
- The participants emphasized that confirming a stavelet functions after assembly is **not sufficient** for comprehensive quality control.
- A complete QC program should include electrical characterization, environmental qualification, stress testing, and long-term reliability studies in addition to functional verification.

Role of Multiple Production Sites

- Several participants suggested distributing qualification activities among additional institutes.
- This approach would reduce the workload at individual laboratories while allowing more institutes to contribute meaningfully to detector production.
- Standardized procedures would ensure that measurements performed at different sites remain directly comparable.

Environmental and Reliability Testing

- Environmental qualification was identified as an essential component of the QC program.
- Proposed qualification tests include:
  - temperature- and humidity-controlled measurements,
  - thermal cycling,
  - long-term stress tests,
  - reliability evaluations under realistic operating conditions.

- Dedicated environmental chambers should be used whenever possible to standardize these tests across production sites.

Discussion

The discussion focused on how detector production can be successfully distributed among multiple institutes without compromising detector quality. The participants agreed that standardized assembly procedures and comprehensive QA/QC protocols will be essential for ensuring consistency throughout the production process.

Considerable attention was also given to expanding quality control beyond simple functional tests. In particular, environmental qualification and long-term reliability testing were recognized as important components of the production workflow.

Key Points

- Continue developing standardized assembly procedures suitable for distributed production.
- Clearly distinguish QA activities from QC activities throughout the production chain.
- Expand qualification beyond basic functionality tests to include comprehensive reliability evaluations.
- Encourage broader participation from collaborating institutes in qualification and testing activities.

Action Items

- Finalize the complete assembly workflow for stavelet production.
- Define mandatory QA/QC procedures for every stage of detector assembly.
- Prepare standardized qualification procedures that can be

implemented consistently across multiple institutes.
- Identify available facilities for environmental qualification and stress testing.
- Define the responsibilities of each institute within the distributed production framework.

Overall Significance

This presentation established the baseline strategy for large-scale production of the ePIC Barrel TOF stavelets. Rather than concentrating detector assembly at a single laboratory, the collaboration aims to distribute production across multiple institutes while maintaining common assembly procedures and QA/QC standards.

The discussion highlighted that successful distributed production depends not only on standardized assembly techniques but also on rigorous quality assurance, comprehensive quality control, and well-defined qualification procedures that ensure consistent detector performance across all production sites.

Presentation 3: Toward Long FPC

Presenter: Takashi Hachiya (RIKEN)

Presentation Summary

Takashi Hachiya presented the current status of the long Flexible Printed Circuit (FPC) development for the ePIC Barrel TOF detector. The presentation focused on the development of approximately 1.3-m-long FPCs capable of transmitting high-speed timing signals while minimizing the detector material budget. Prototype measurements, signal integrity studies, and the roadmap toward full-scale production were presented. Because the long FPC directly connects the front-end electronics to the backend readout system, its performance is critical to the overall performance and integration of the Barrel TOF detector.

Main Discussion

Signal Integrity

- Prototype measurements demonstrated promising signal transmission over the full FPC length.
- Further studies are required to evaluate signal attenuation, impedance matching, crosstalk, timing jitter, and clock distribution.
- Maintaining excellent timing performance over long transmission distances remains one of the primary design requirements.

Mechanical Reliability

- The mechanical robustness of the long FPC was discussed.
- Long-term reliability under repeated bending, installation, and detector operation must be evaluated.
- Connector reliability and mechanical stability during detector operation were also identified as important considerations.

Detector Integration

- The routing of the FPC must be coordinated with the mechanical support structure, cooling pipes, and detector services.
- Because the available service space inside the detector is limited, close collaboration between the electronics, mechanics, and integration teams will be required.
- The detector installation sequence should also be considered during the final FPC design.

Preparation for Mass Production

- The collaboration discussed preparations for large-scale production.
- Manufacturing procedures, acceptance criteria, QA/QC protocols, and production yield monitoring should all be

established before production begins.
- Production readiness should be demonstrated before entering the detector construction phase.

Discussion

The presentation demonstrated that the current long FPC prototype has achieved encouraging performance. However, the participants agreed that **electrical performance alone will not be sufficient** for the final detector design. Mechanical reliability, detector integration, production readiness, and long-term operational stability must all be demonstrated before the design can be finalized.

The discussion also emphasized that continued coordination between the electronics, mechanics, cooling, and integration teams will be essential to ensure that the FPC design remains compatible with the overall detector architecture.

Key Points

- Continue the development and evaluation of the long FPC prototype.
- Perform additional measurements of signal integrity using the latest prototype.
- Coordinate the FPC routing with the mechanics and detector integration teams.
- Develop QA/QC procedures and production acceptance criteria for the long FPC.
- Continue preparations for large-scale manufacturing.

Presentation 4: TOF Mechanics

Presenter: Andreas Jung

Presentation Summary

Andreas Jung reviewed the current baseline mechanical design of the ePIC Barrel TOF detector, including the overall support structure, stave layout, tray concept, material budget, cooling integration, and installation strategy. The presentation introduced the latest mechanical concepts developed following the Preliminary Design Review (PDR) and highlighted several open issues that require further study before the CD-2 review. Particular emphasis was placed on detector coverage, material budget, thermal performance, and maintaining consistency between the engineering design and detector simulation.

Main Discussion

Detector Coverage

- The collaboration discussed the definition of full detector coverage in both the azimuthal (ϕ) and longitudinal (z) directions.
- Andreas explained that the current three-layer stave arrangement restores full ϕ coverage without increasing the total number of staves.
- Questions were raised regarding detector acceptance near the forward edges, where a significant amount of service material is concentrated.
- The participants suggested evaluating whether complete sensor coverage is necessary in these high-material regions through dedicated physics simulations.

Mechanical Layout

- The updated mechanical concept consists of modular trays covering approximately 30° each, allowing independent installation and maintenance.
- The “super tray” concept, which integrates the TOF tray with neighboring detector components, remains the baseline mechanical design.
- Routing of cables, cooling pipes, and detector services within the limited available space was identified as one of the

primary integration challenges.

Material Budget

- An updated material budget evaluation based on the current engineering design was presented.
- The discussion covered contributions from cooling pipes, carbon-fiber supports, sensors, flexible circuits, and detector services.
- The participants noted that the current detector simulation may underestimate the amount of service material, particularly in the forward regions.
- It was emphasized that future detector simulations should be updated to reflect the latest engineering model.

Cooling and Thermal Performance

- The thermal design of the stave structure was discussed in detail.
- A proposal was presented to reduce the stave thickness near the service hybrid region by replacing part of the foam structure with a thinner carbon-fiber substrate.
- This approach could provide additional space for detector services while maintaining acceptable thermal performance.
- Additional thermal simulations will be required to validate the proposed design.

Simulation Consistency

- A major discussion focused on the discrepancy between the current detector simulation and the latest mechanical design.
- Andreas pointed out that the simulation still uses an older geometry based on tilted staves.
- The participants agreed that future simulation studies should be based on the latest detector geometry.
- Close collaboration between the mechanics and simulation teams will therefore remain essential before the CD-2 review.

Benchmark Physics Studies

- The collaboration discussed the need for representative

benchmark physics channels to evaluate the impact of mechanical design choices.
- Suggested benchmark channels included charm production and exclusive processes.
- Such studies will help quantify the effects of detector acceptance, material budget, and inactive regions on overall detector performance.

Discussion

The presentation generated extensive discussion regarding the strong coupling between detector mechanics, material budget, cooling, and detector simulation. The participants emphasized that future mechanical optimization should be guided not only by engineering considerations but also by realistic detector simulations and benchmark physics studies.

A recurring theme throughout the discussion was the importance of maintaining consistency between the engineering model and the simulation geometry. Without an up-to-date simulation, it will be difficult to reliably evaluate detector performance or assess the impact of future mechanical modifications.

Key Points

- Continue refining the mechanical design based on the latest detector requirements.
- Update the detector simulation using the current engineering geometry.
- Perform benchmark physics studies to evaluate detector acceptance and material effects.
- Continue optimization of the thermal design.
- Strengthen coordination among the mechanics, cooling, electronics, and simulation teams.

Action Items

- Update the detector geometry implemented in the simulation framework.
- Evaluate the physics impact of reduced detector coverage near the service regions.
- Refine the material budget using the latest engineering model.
- Perform detailed thermal simulations of the updated stave design.
- Continue development of the integrated tray and service routing concept.
- Coordinate future mechanical developments with the simulation and detector integration teams.

Overall Significance

This presentation **reviewed the current baseline mechanical design** of the ePIC Barrel TOF detector and identified the principal engineering challenges that remain before the CD-2 review. The discussion reinforced that detector mechanics, cooling, material budget, and detector simulation are tightly interconnected and must be developed together.

The collaboration recognized that future design decisions should be supported by realistic detector simulations and benchmark physics studies based on the latest engineering geometry, ensuring that both engineering optimization and physics performance are evaluated consistently.

Presentation 5: LGAD and ASIC QA/QC

Presenter: Jennifer Ott

Presentation Summary

Jennifer Ott presented the current Quality Assurance (QA) and Quality Control (QC) strategy for the LGAD sensors and readout ASICs of the ePIC TOF detector. The presentation outlined the production workflow from wafer fabrication through detector assembly and emphasized the importance of establishing standardized QA/QC procedures throughout the production chain. Plans for sensor characterization, ASIC testing, database management, and production traceability were also presented.

Main Discussion

Quality Assurance vs. Quality Control

- The distinction between Quality Assurance (QA) and Quality Control (QC) was discussed in detail.
- QA focuses on establishing standardized procedures that minimize the probability of defects during production.
- QC consists of inspections and measurements performed to verify that individual components satisfy the required specifications.
- The participants emphasized that both QA and QC are essential for reliable large-scale detector production.

Sensor QA/QC

- The proposed QA/QC workflow includes wafer-level testing, sensor acceptance tests, electrical characterization, and visual inspection.
- Electrical measurements, including IV and CV characterization, will be performed before sensor assembly.
- Additional inspections after assembly will be necessary to identify possible damage introduced during handling and integration.

ASIC QA/QC

- The presentation reviewed the testing strategy for the readout ASICs.

- Electrical functionality, calibration, and performance verification should be completed before sensor integration.
- Early identification of defective ASICs was recognized as an important step for improving production efficiency and avoiding unnecessary assembly work.

Production Database

- A centralized production database was proposed to record the complete history of every detector component.
- The database should include manufacturing information, QA/QC results, assembly history, detector configuration, and production status.
- Complete traceability throughout the detector lifetime was recognized as an important requirement for both production and future detector operation.

Coordination Across Institutes

- Because detector production will be distributed among multiple institutes, standardized QA/QC procedures are required.
- Common testing protocols and a unified database structure will ensure that measurements performed at different production sites remain directly comparable.
- Documentation and automation of QA/QC procedures should be established before production begins.

Discussion

The discussion emphasized that QA/QC should be considered an integral part of detector production rather than simply a final acceptance test. The participants recognized that standardized procedures, complete production traceability, and centralized data management will be essential for maintaining consistent detector quality across all production sites.

The discussion also highlighted that the QA/QC framework should be developed in parallel with detector construction so that production procedures, documentation, and database infrastructure are fully established before mass production begins.

Key Points

- Continue developing standardized QA/QC procedures for both LGAD sensors and readout ASICs.
- Establish a centralized production database for complete component tracking.
- Standardize QA/QC measurements across all participating institutes.
- Integrate QA/QC planning into the overall detector production schedule.
- Ensure complete production traceability throughout detector construction.

Action Items

- Finalize the QA/QC workflow for sensor and ASIC production.
- Define mandatory electrical and mechanical acceptance tests.
- Develop the centralized production database and component tracking system.
- Standardize testing procedures and documentation across all production sites.
- Coordinate QA/QC activities with the assembly and detector integration teams.

Overall Significance

This presentation established the foundation of the QA/QC strategy for the ePIC TOF detector. As detector production will be distributed across multiple institutes, rigorous QA/QC procedures and complete production traceability will be critical for ensuring consistent detector performance throughout the construction phase.

The proposed production database and standardized testing procedures **are expected to play a central role** in supporting reliable large-scale detector construction while providing complete traceability for every detector component.