TUPV013

BACKEND EVENT BUILDER SOFTWARE DESIGN FOR INO MINI-ICAL SYSTEM

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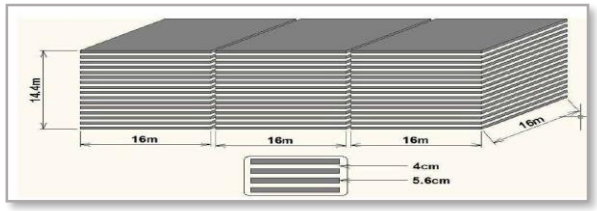
ICALEPCS 2021

a. Introduction

Mini-ICAL System

Planned main-ICAL System

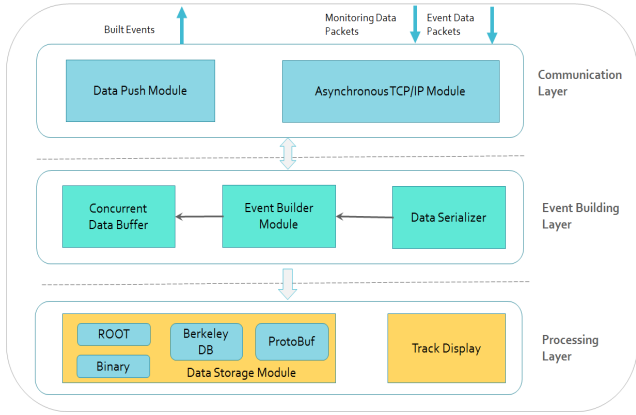


Objective

- Study atmospheric neutrinos
- Understanding the Engineering Issues in constructing main ICAL
- 85 ton Iron Calorimeter (ICAL)
- 20 Resistive Plate Chamber (RPC)
- Built at Inter Institutional Centre for High Energy Physics (IICHEP), Madurai
- Scaled down version of ICAL

b. Software Design

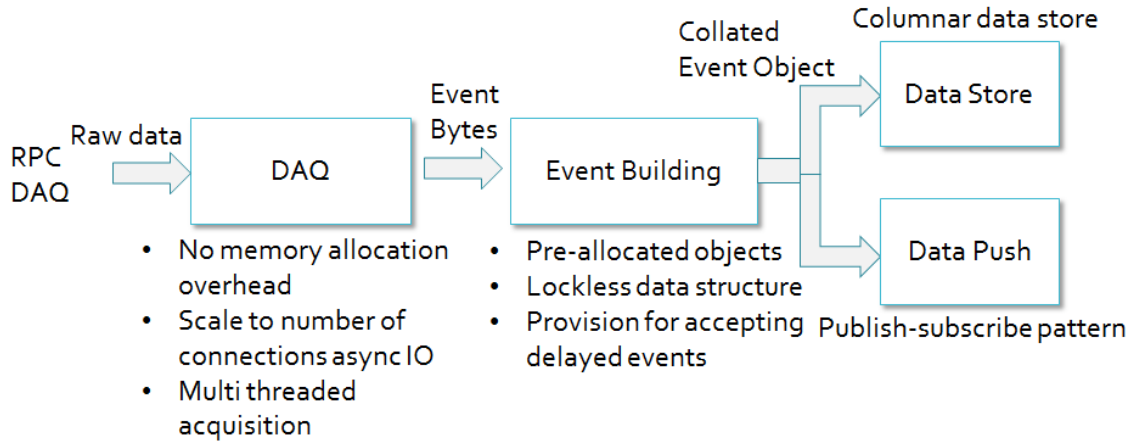
Software Architecture



Design Basis

- Data acquisition
- Event collation
- Local data archival
- Data pushing to remote consoles
- Scalability
- Performance
  - Low latency in overall event acquisition pipeline
- Loose coupling

c. Core Modules



System Max Throughput

System-RPCs	Max Throughput (MBps)
MiniICAL-20	3
E-ICAL-320	200
Main ICAL-28800	200

Test Results on 1Gbps link

Storage Type	Throughput
Binary Data	~90MBps
ROOT	~8MBps
BerkeleyDB	~90MBps

d. Conclusion

Conclusion:

- Software developed with scalability concern
- Async IO based data acquisition, lockless data structure for event building, High performance NoSQL Db can help to scale the software to E-ICAL and main-ICAL

a. Introduction

- The Indian-based Neutrino Observatory (INO) collaboration has proposed to build a 50 KT magnetized Iron Calorimeter (ICAL) detector to study atmospheric neutrinos.

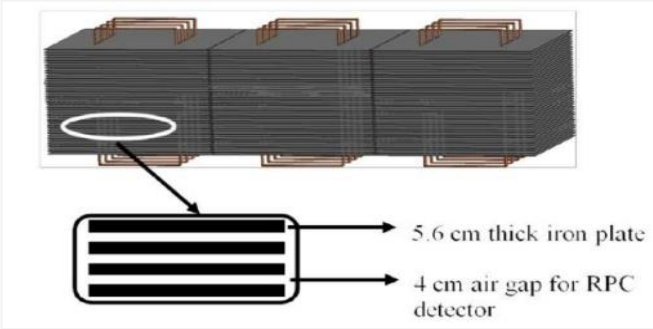


Fig. 50kt ICAL Layout

- The detector will look for muon neutrino induced charged current interactions using magnetized iron as the target mass and around 28,800 Resistive Plate Chambers (RPCs) as sensitive detector elements
- The mini-Iron Calorimeter (mini-ICAL) detector, a proto-type of the ICAL detector with 20 RPCs has been set up at the Inter Institutional Centre for High Energy Physics' (IICHEP), Madurai

- Atmospheric Neutrinos interact with the iron plates along its line of travel, producing charged muon particles, thus triggering events in several RPCs along its path. Orthogonal strip channels (X&Y) on RPCs pick up the charged particles.

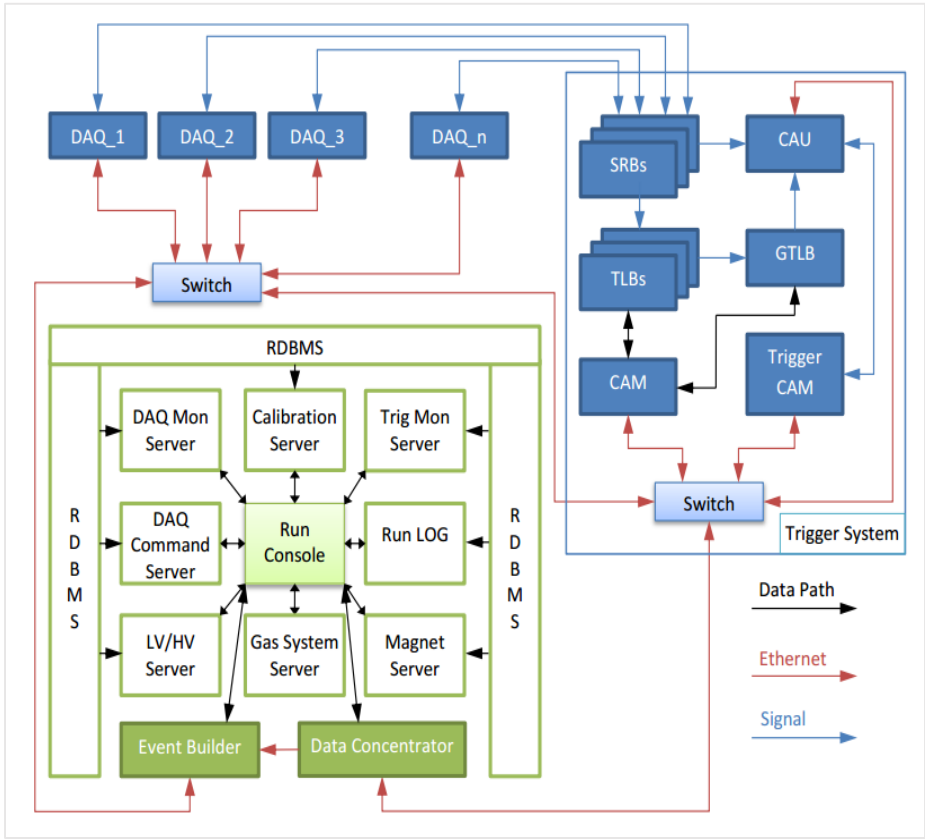


Fig. System Overview

- RPC DAQs
- Trigger System
- Backend system
- Magnet System
- Gas System
- LV/HV System

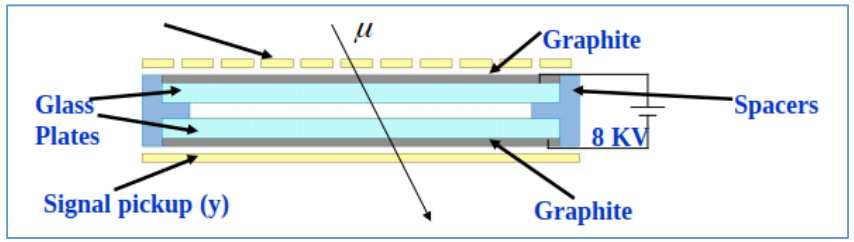


Fig. RPC Detector

b. Software Design

- The BDAQ system as shown in Fig comprises of several subsystems that are intended to acquire event data and monitor data from the RPC-DAQs. The scope of the poster presentation is limited to the development of Event Builder module

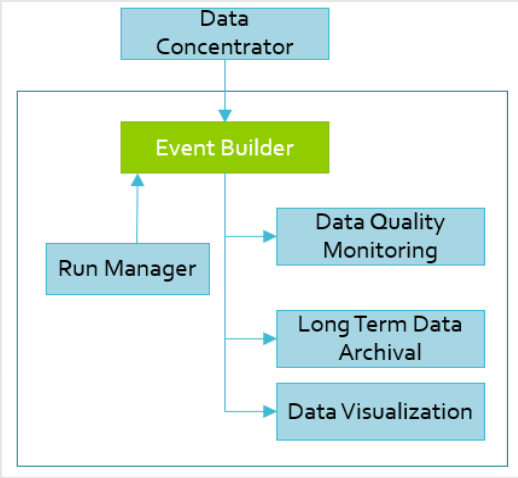


Fig. Back end Data Acquisition System

Event Builder: Design Basis

- Event data acquisition from Data Concentrator;
- Monitoring of data from RPC DAQs;
- Event Collation from the RPC event data;
- Local data archival in the selected data format;
- Pushing the collated event data to remote consoles;
- Online muon track visualization

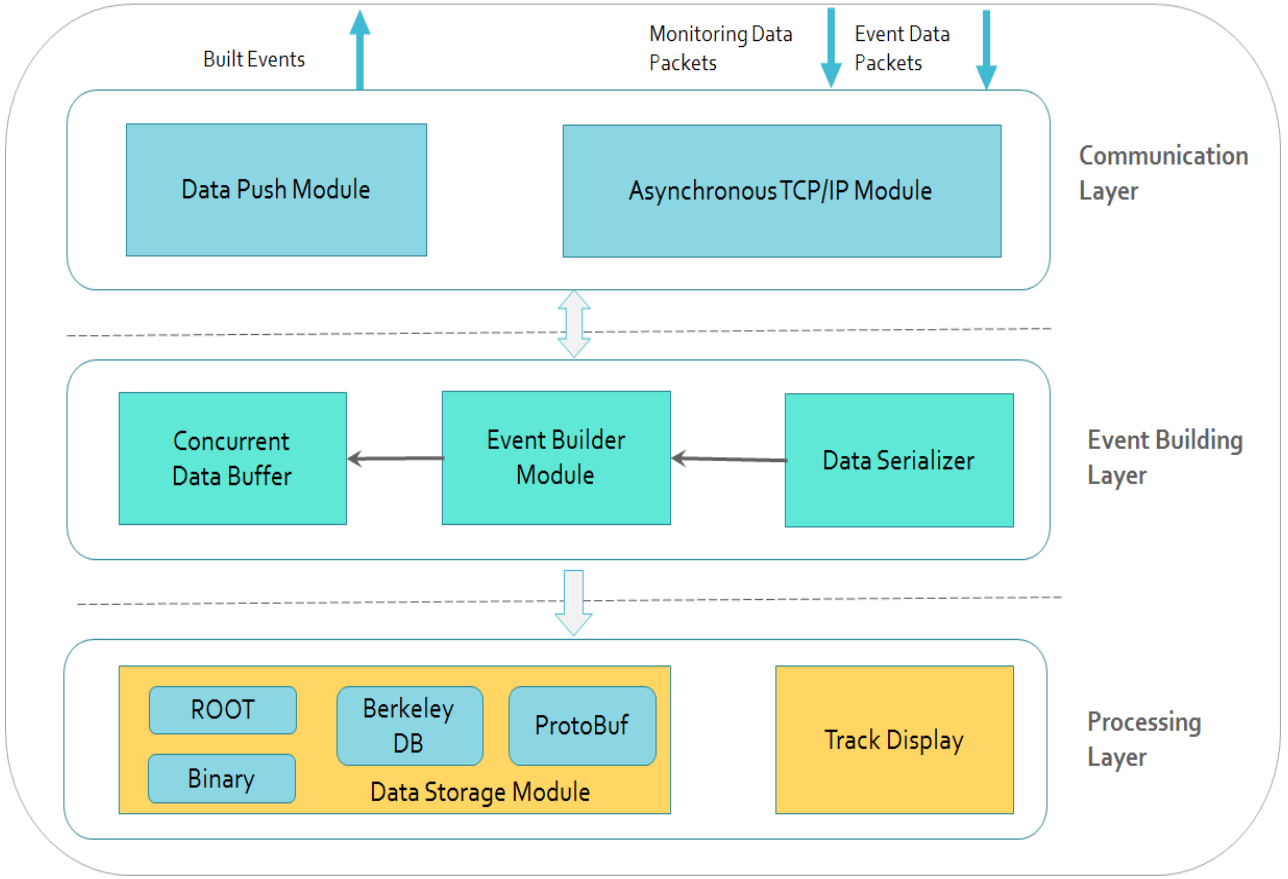


Fig. Software Architecture

c. Event Builder: Core Modules

- **Data acquisition:** Data acquisition provides high performance, catering to the system data throughput requirements. The module is optimized to eliminate any possible memory allocation overheads.
- **Event Building:** Event building algorithm is crucial part of the software. Event building module collates the complete event from out of order RPC data. The module design implements the necessary concurrency control mechanism to handle multi-threaded data acquisition.
- **Backend data store:** The collated event is processed by back end store, archiving the data locally. Data storage module write through-put should satisfy required system throughput, otherwise it would create back pressure in acquisition pipeline
- **Server push:** Server data push module publishes the data to the interested subscriber nodes like data quality monitor consoles and data visualization consoles

Event Building:

- Out of order individual RPC events are collated to form the complete event.
- Provision for accommodating the delayed events if any
- Collated events propagation to the event processor module is serialized based on the event number

Circular Ring Buffer:

- Lockless concurrent data structure based on LMAX disruptor pattern
- Event Collation without using locks
- Pre-Allocated Buffer and Reusable Event Objects

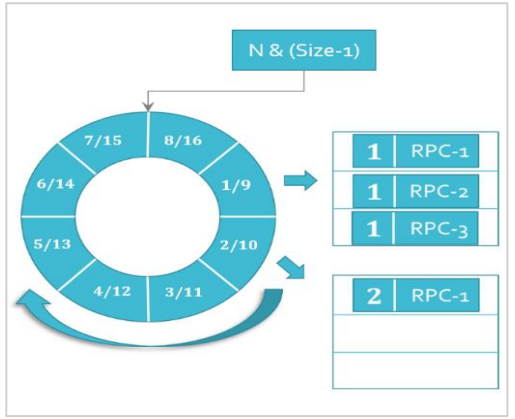


Fig. Ring Buffer for event building

Data Acquisition:

- State full TCP async Server
- Reusable *SocketAsyncEventArgs* and Buffer Manager
- Event driven message passing
- F# Async workflow
  - Succinct
  - Expressivity

Backend data store:

- Data Storage schemes
  - Binary Serialization
  - XML
  - Google ProtoBuf
  - **CERN ROOT Framework**
- ROOT has been used for event data archiving in mini-ICAL
- The main reason for choosing ROOT as a backend is its edge in analysis and visualization features

Server data push:

- There are other remote consoles that require the built events for track visualization and data quality monitoring.
- The server proactively pushes the data to the interested nodes without clients polling for the data
- Allows remote console implementation technology agnostic; browser based, web applications, desktop application or mobile application

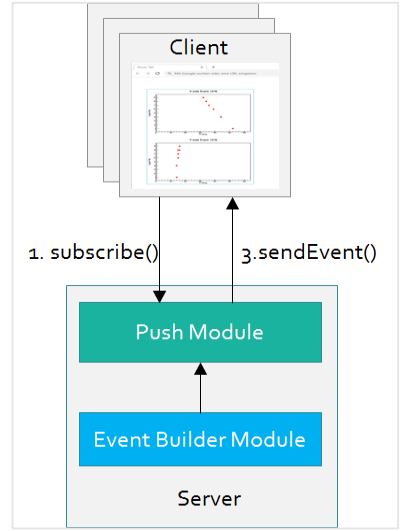


Fig. Server Push Module

d. Conclusion

Testing:

- The test setup consists of multiple Data Concentrator (DC) simulator clients sending data to EB server on 1 Gbps Ethernet link. It was observed binary data and BerkeleyDB write throughput was considerably better than ROOT.

Storage Type	Throughput
Binary Data	~90MBps
ROOT	~8MBps
BerkeleyDB	~90MBps

Fig. Performance

- With the designed ROOT TTree structure, the write speed observed was around 8MBps due to the write overheads (file meta data). With mini-ICAL, the maximum throughput requirement is around 3MBps.
- However, due to efficient columnar data access and data visualization, ROOT has been used for data archiving

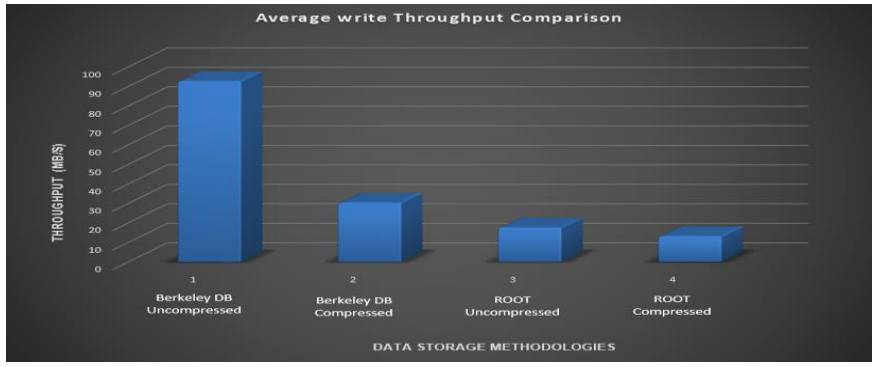


Fig. BerkelyDB vs ROOT write throughput

Installation:

- The software was installed at IICHEP, Madurai for mini-ICAL. It has been recording data since 2017.

Conclusion:

- The modules have been developed with scalability as design concern. Asynchronous IO based data acquisition module is scalable with the increasing the number of connections. Disruptor algorithm based event buffer provides lock-less data structure for event building. The optimized data structure can be scaled to work for E-ICAL by tuning the buffer parameters.

- Non-blocking multi-threaded networking and event building module has been tested up-to 90MBps on 1Giga bit Ethernet network. The required network throughput (200MBps for E-ICAL) can be achieved by upgrading the hardware resources (like 10 Giga bit network and SSD drives). For improving the data write speeds, multi-threaded file writing, multi-level data writing and high performance NoSQL databases like BerkeleyDB will be explored.