INO's RPC-DAQ module: Performance review and upgrade plans

M. N. Saraf[a,*], E.Yuvaraj[a,*], V. M. Datar[a], G.Majumder[a], Pathaleswar[a], Pethuraj[a,b], B.Satyanarayana[a], R.R.Shinde[a], D.Sil[a], S.Thoithoi[a], S.S.Upadhya[a]

(for the INO collaboration)

[a] Tata Institute of Fundamental Research, Mumbai - 400005, India.

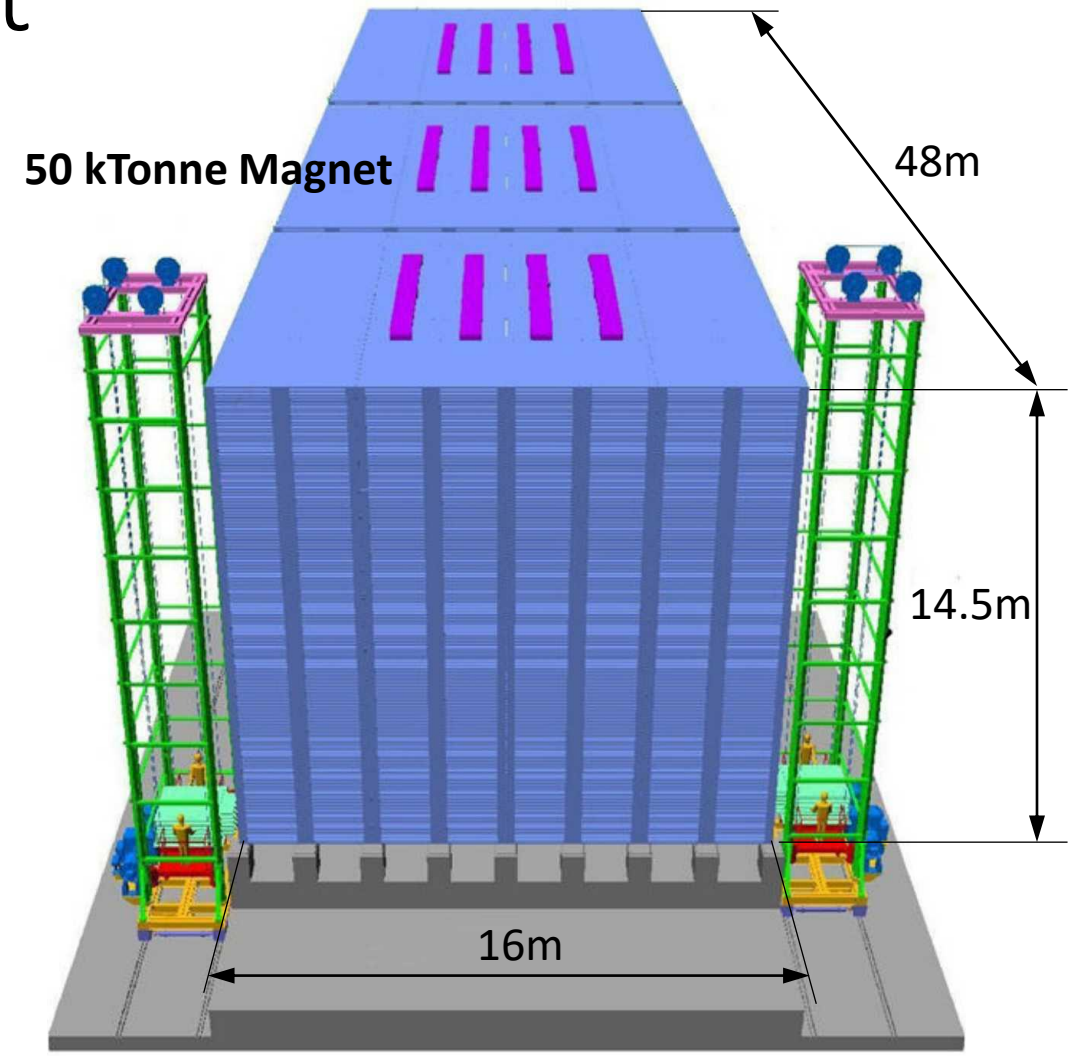
[b] Homi Bhabha National Institute, Mumbai - 400094, India.

Outline of the Talk

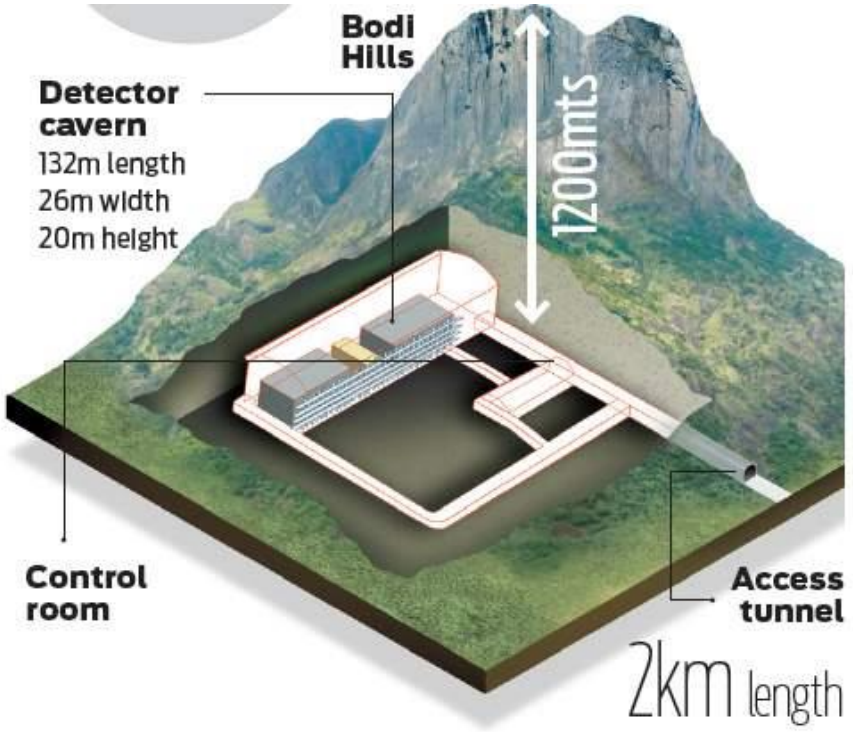
- INO ICAL Experiment
- Role of DAQ in ICAL
- The Overall DAQ Scheme
- Performance of the RPC-DAQ Module
- Upgrades Planned
- Summary

The INO ICAL Experiment

- ICAL is a magnetized Iron-Calorimeter which will be set up by the India based Neutrino Observatory (INO) collaboration to study neutrinos
- It will study atmospheric neutrinos to determine their mass hierarchy and other properties.
- It will use iron as its target mass and 28,800 glass Resistive Plate Chambers (RPCs) as the active detector element.



INO Site Location



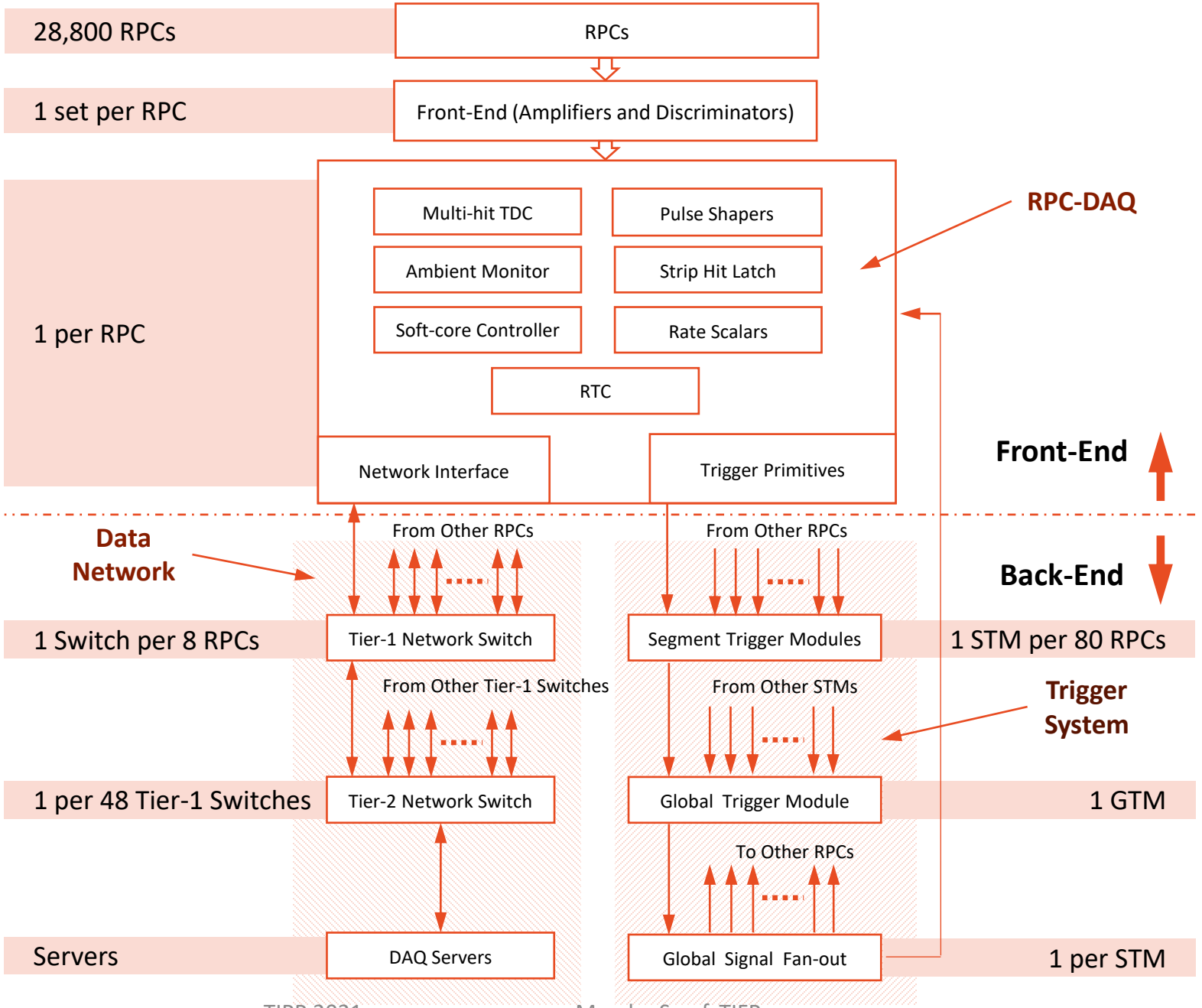
Role of DAQ in ICAL

- Identify physics events in the detector by forming a trigger
- Track the muons formed from the neutrino interaction with Iron by storing the detector state during the events
- Find directionality of muons through tracking and timing
- Slow Control and Monitoring
  - Monitor RPC health
    - RPC noise rate --> Background rate in each RPC strip
    - RPC chamber Current
  - High Voltage
  - Low Voltage
  - Ambient parameters, temperature, pressure and RH
- Carry out Calibrations
  - Pulse Amplitudes, Directly or via Time Over Threshold Measurement (TOT)
  - TDC Offsets

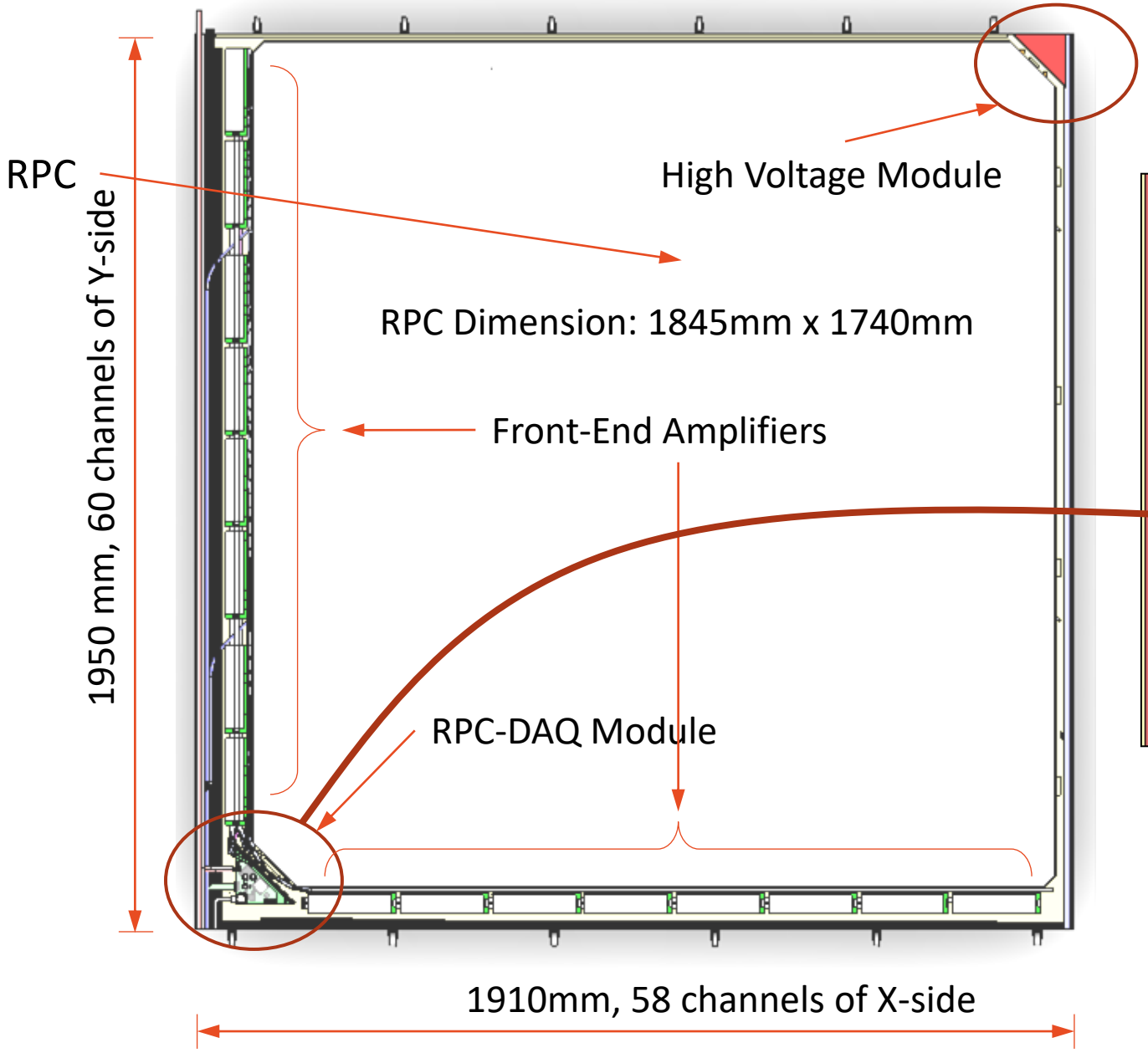
Functions of the RPC-DAQ Module

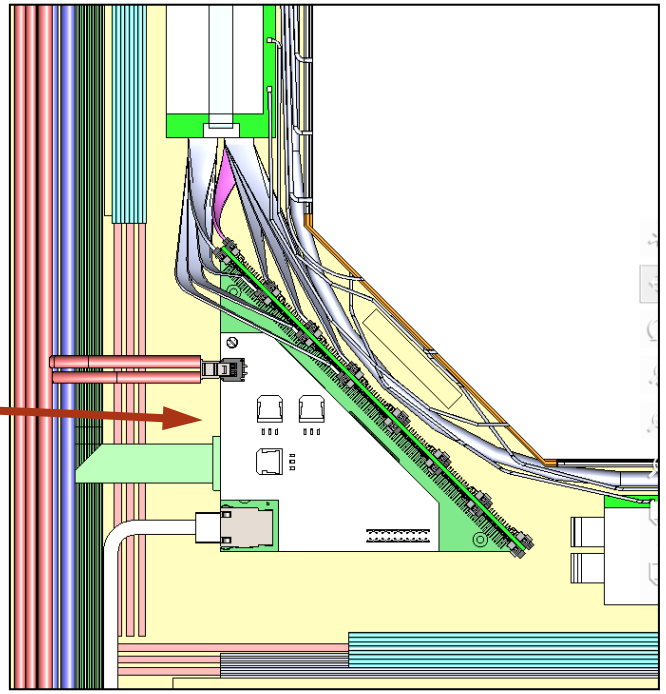
- The RPC-DAQ module is required to collect following information from the incoming RPC pulses.
  - Asynchronous event data on each trigger:
    - Strip hit data: event pattern across the 128 strips.
    - Timing data: relative arrival times of pulses (belonging to the same event) with respect to each other
    - Time Over Threshold Measurement, derived from TDC data
  - Periodic data:
    - Strip rates: Noise rate observed for each strip.
    - Ambient parameters: Temperature, Pressure and relative Humidity.
    - RPC Chamber Current from the local HV DC-DC (RPC Health).
    - RPC High Voltage, from the local HV DC-DC.
- Generate Trigger Primitives (1/2/3/4 Fold) for final trigger formation

Overall ICAL DAQ Scheme

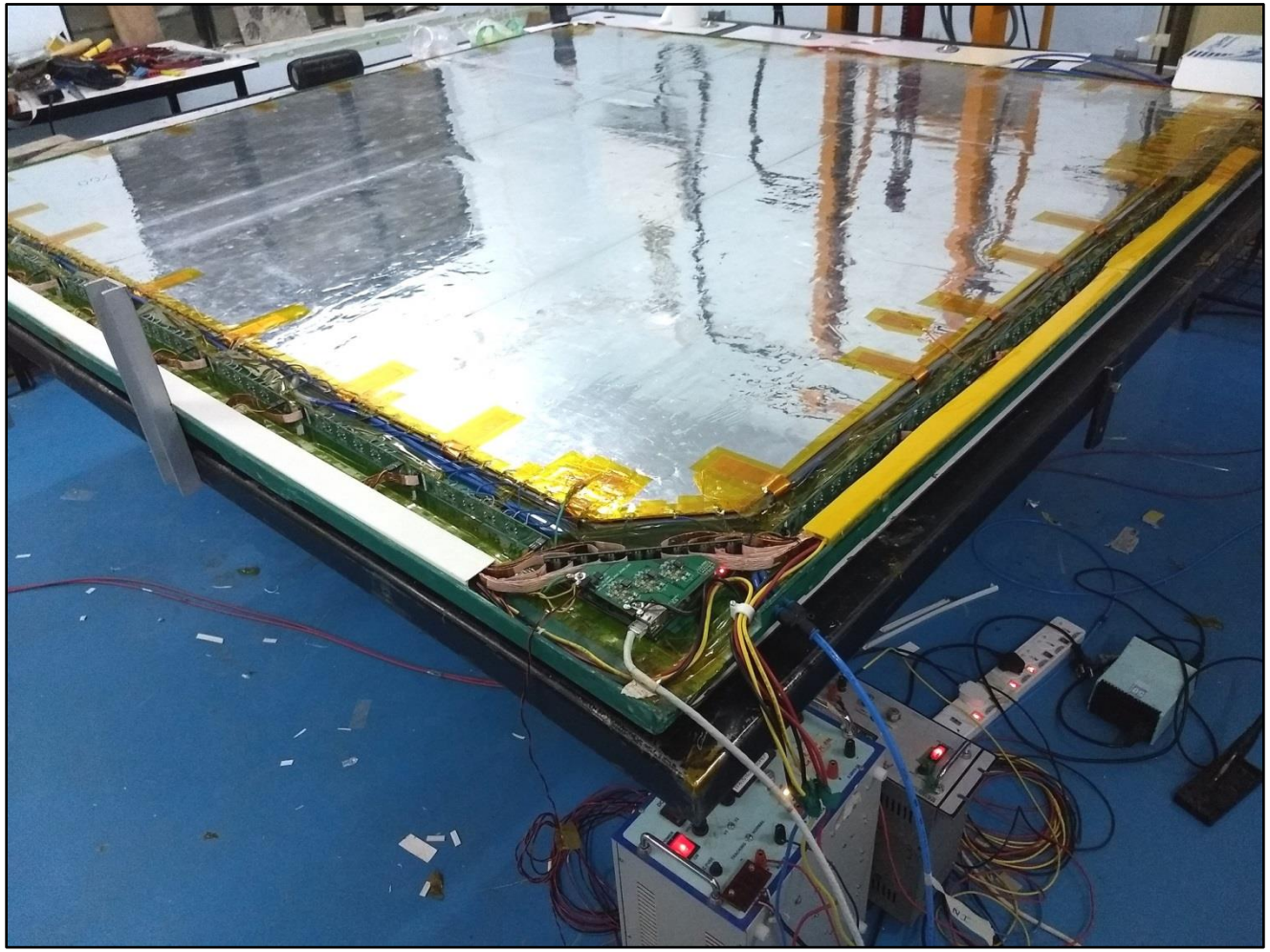


RPC-DAQ in the RPC Tray





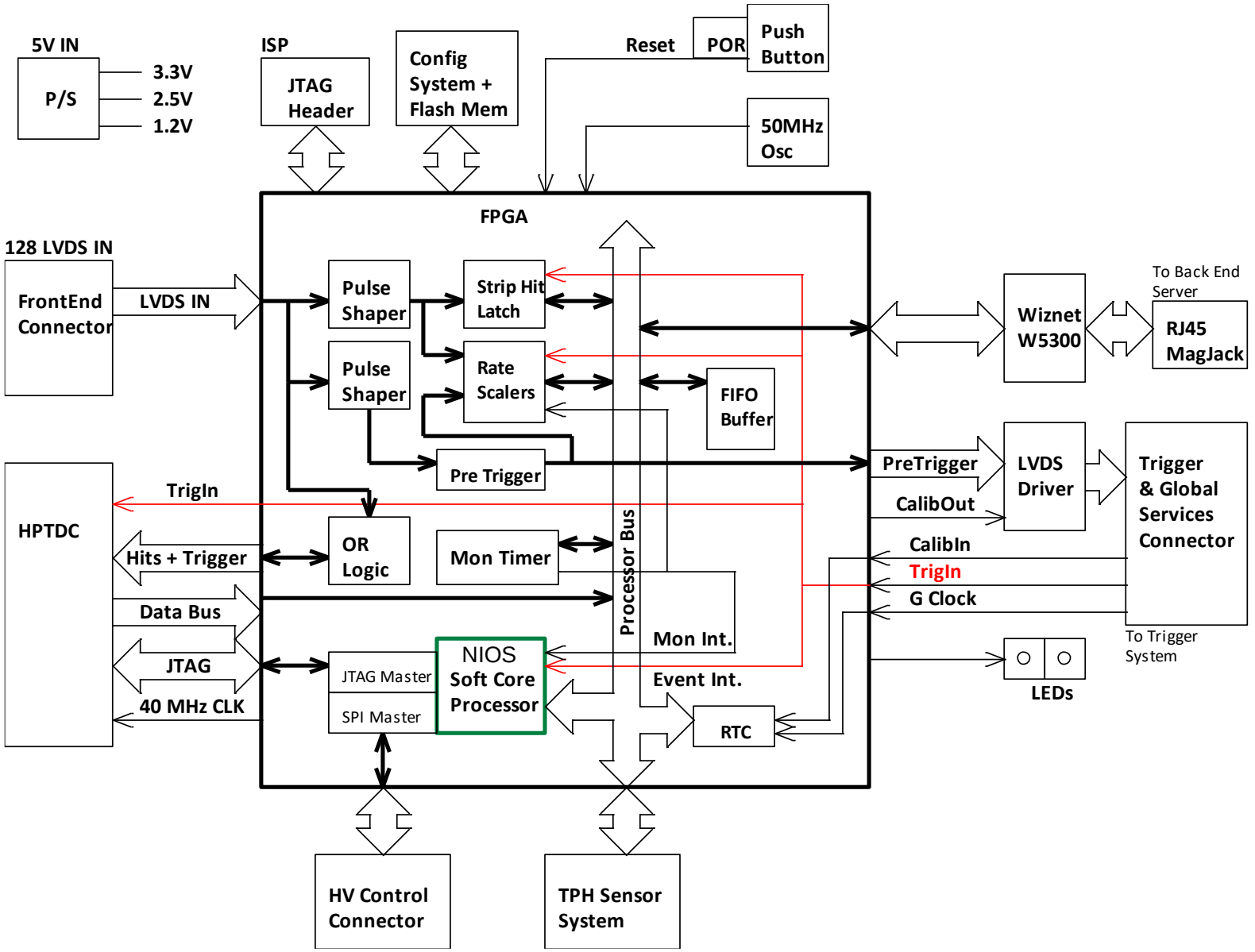
The RPC-DAQ in the RPC Tray



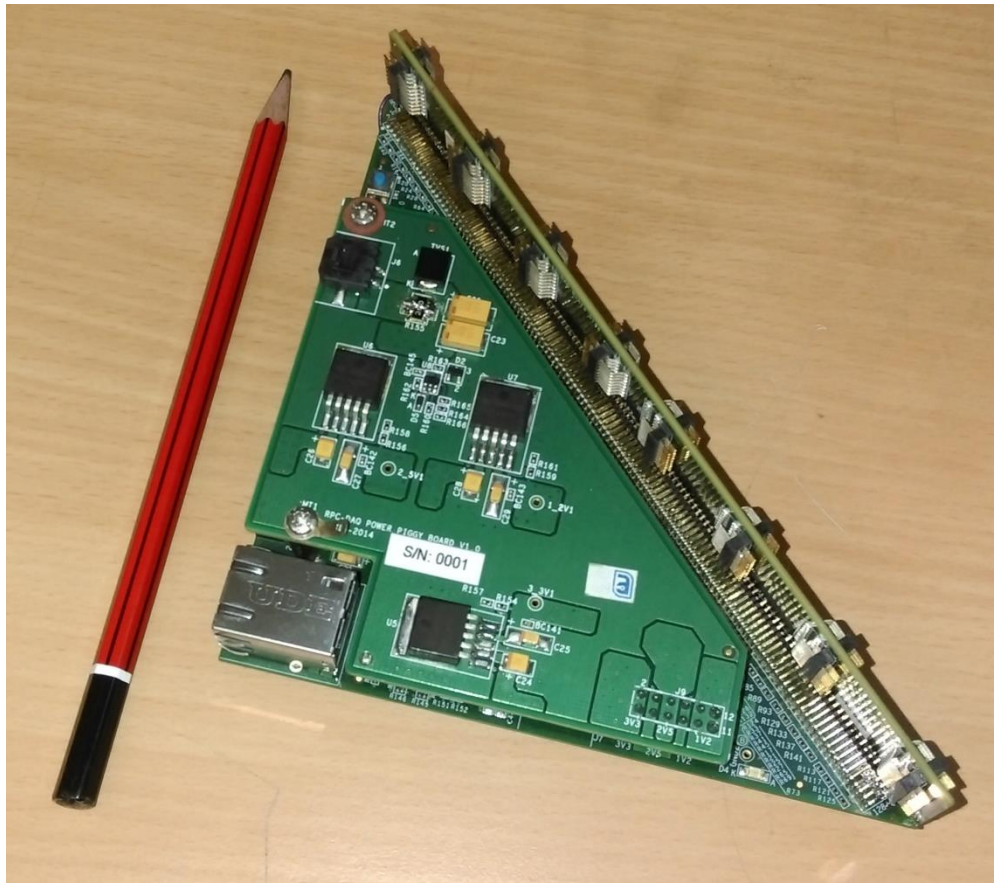
Design Considerations/Constraints

- Data rates, though very low for underground, but quite high for the surface detector
- Physical dimensions: In order to minimize the dead space, extremely small space has been allotted to the RPC-DAQ module
- Service life of the electronics is expected to be 15 years,
- Requirement of remote firmware upgradability

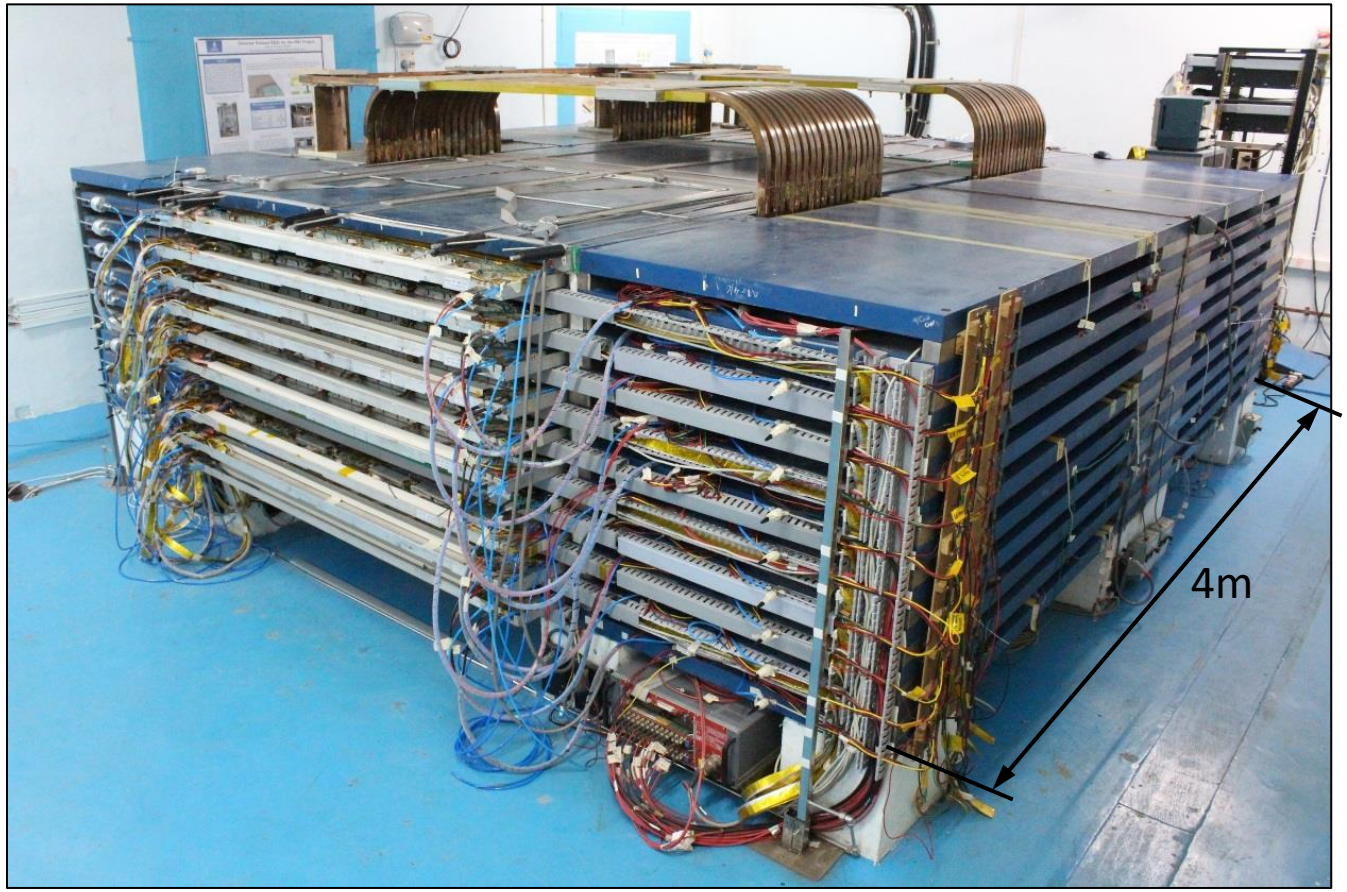
RPC-DAQ Block Diagram



The RPCDAQ Board



Mini-ICAL at Madurai

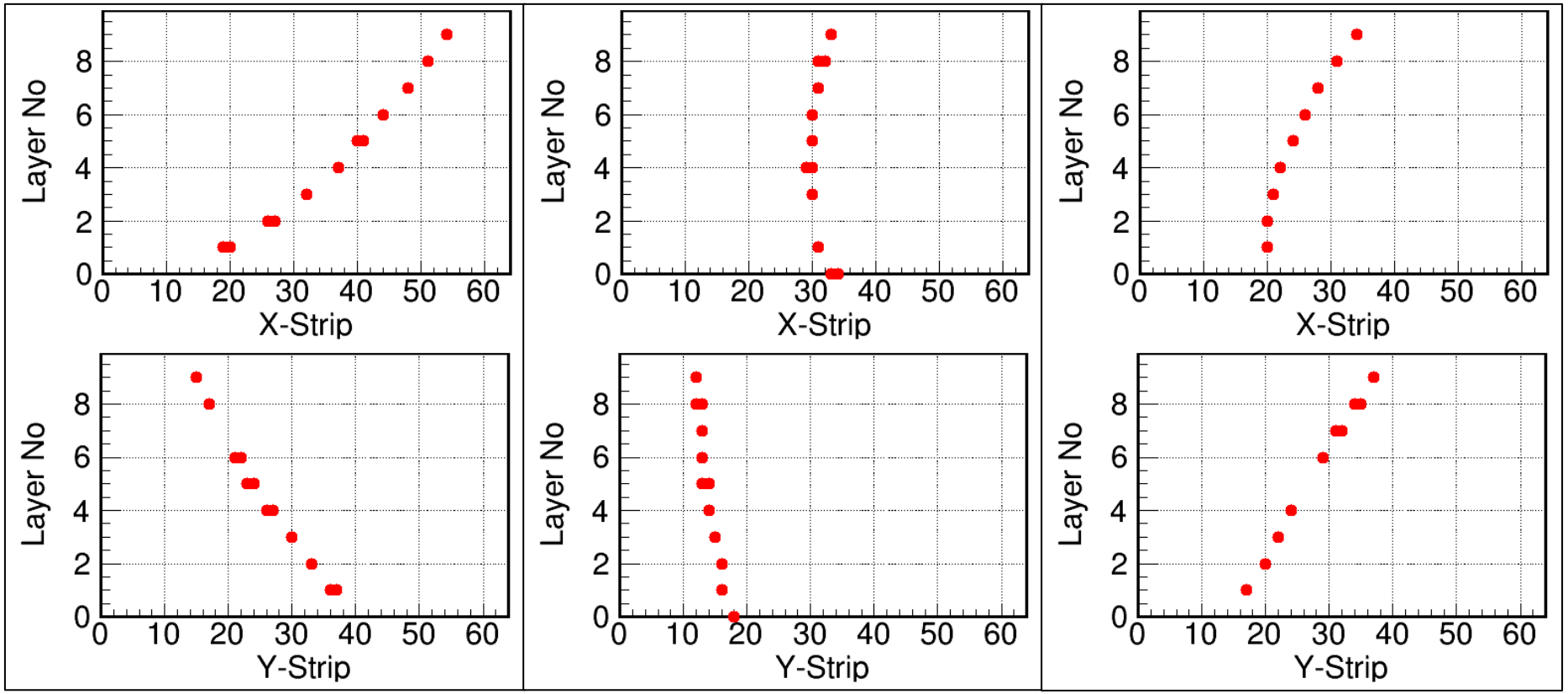


- 10 layers of RPCs interleaved in 11 layers of magnetized Iron
- Total 20 RPCs installed
- Complete set of ICAL electronics installed and commissioned

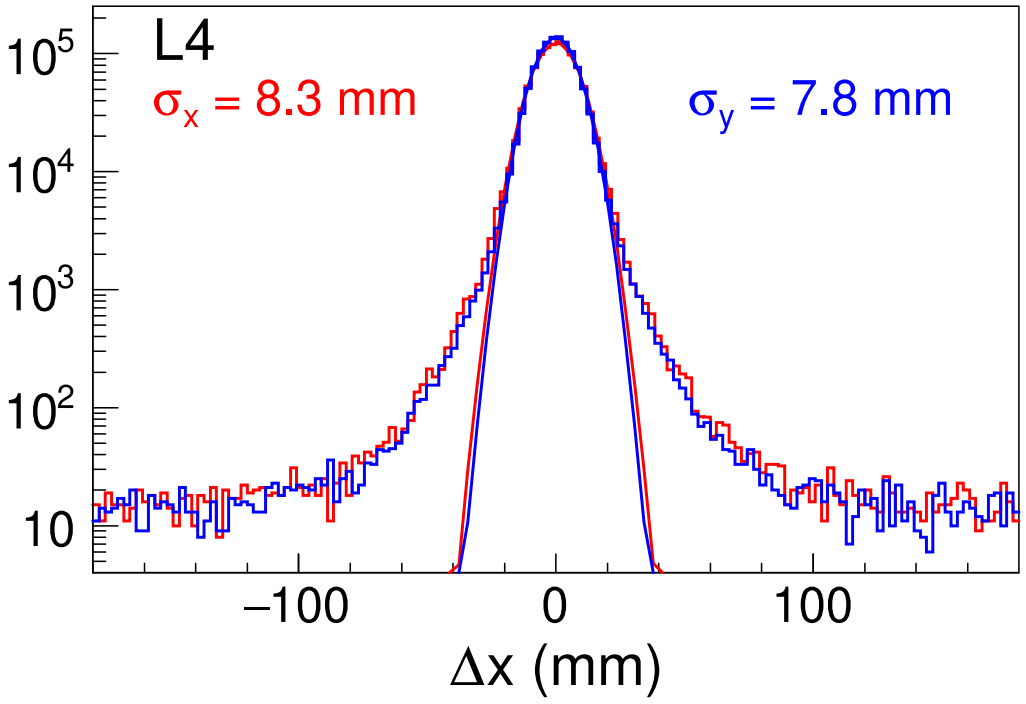
RPC-DAQ Performance at mini-ICAL

- RPCDAQs are working in the mini-ICAL since 2018
- Lot of data has been collected and analyzed
- Throughput – 8.5 kHz trigger rate

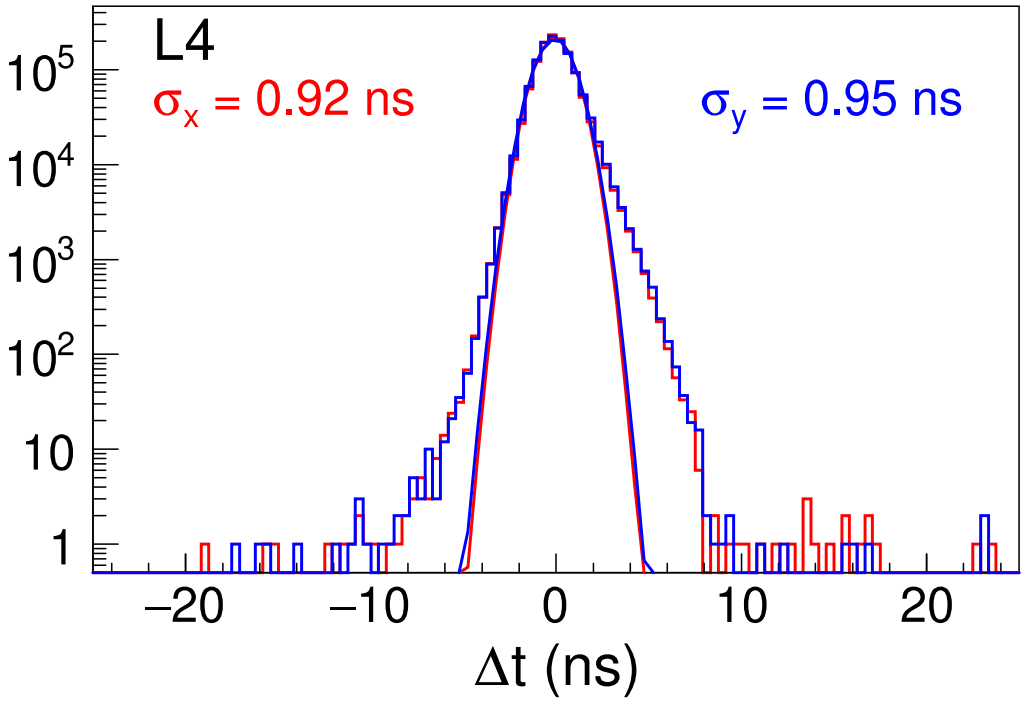
Performance: Bent Tracks with Magnet ON



Performance: Position & Time resolution

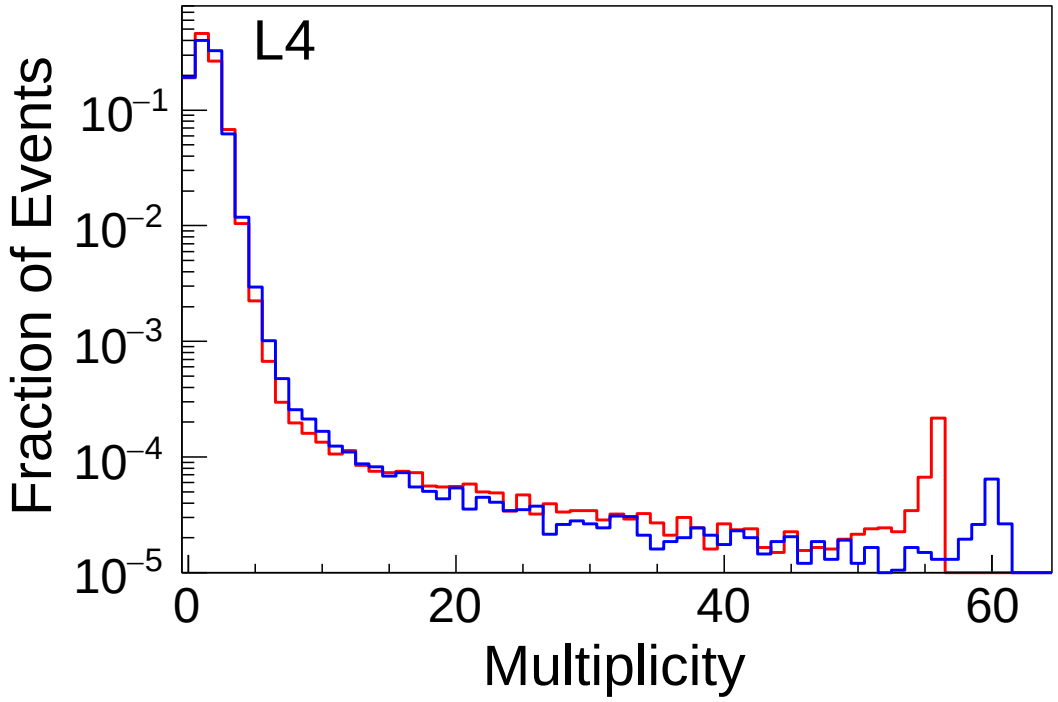


Position Resolution

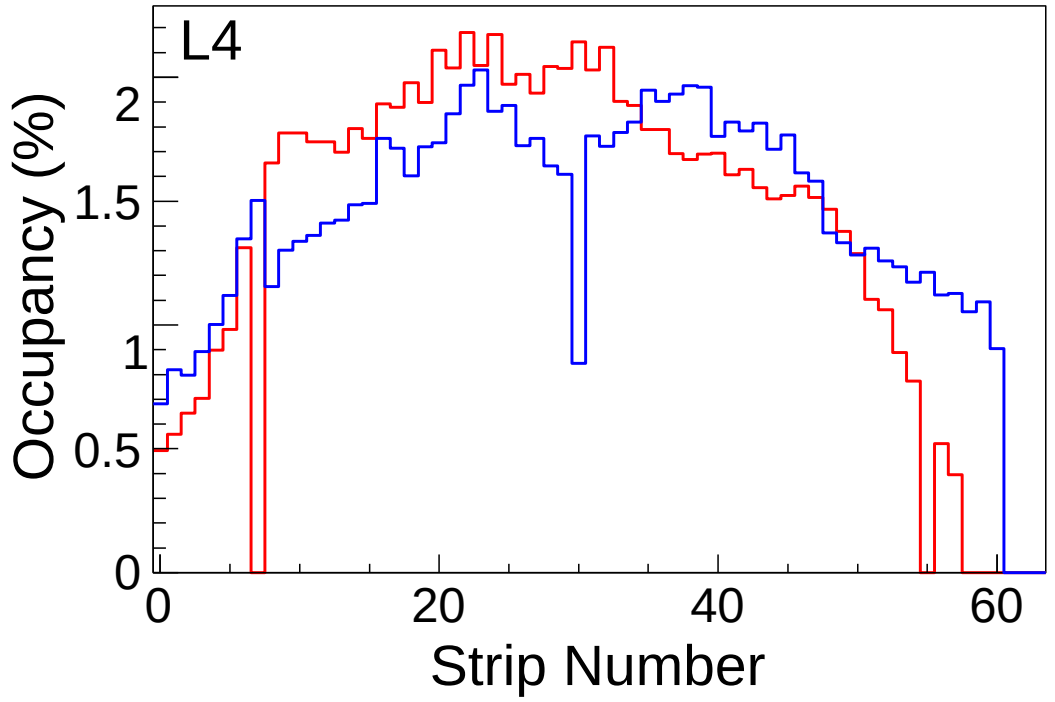


Time Resolution

Performance: RPC Strip Multiplicity & Occupancy

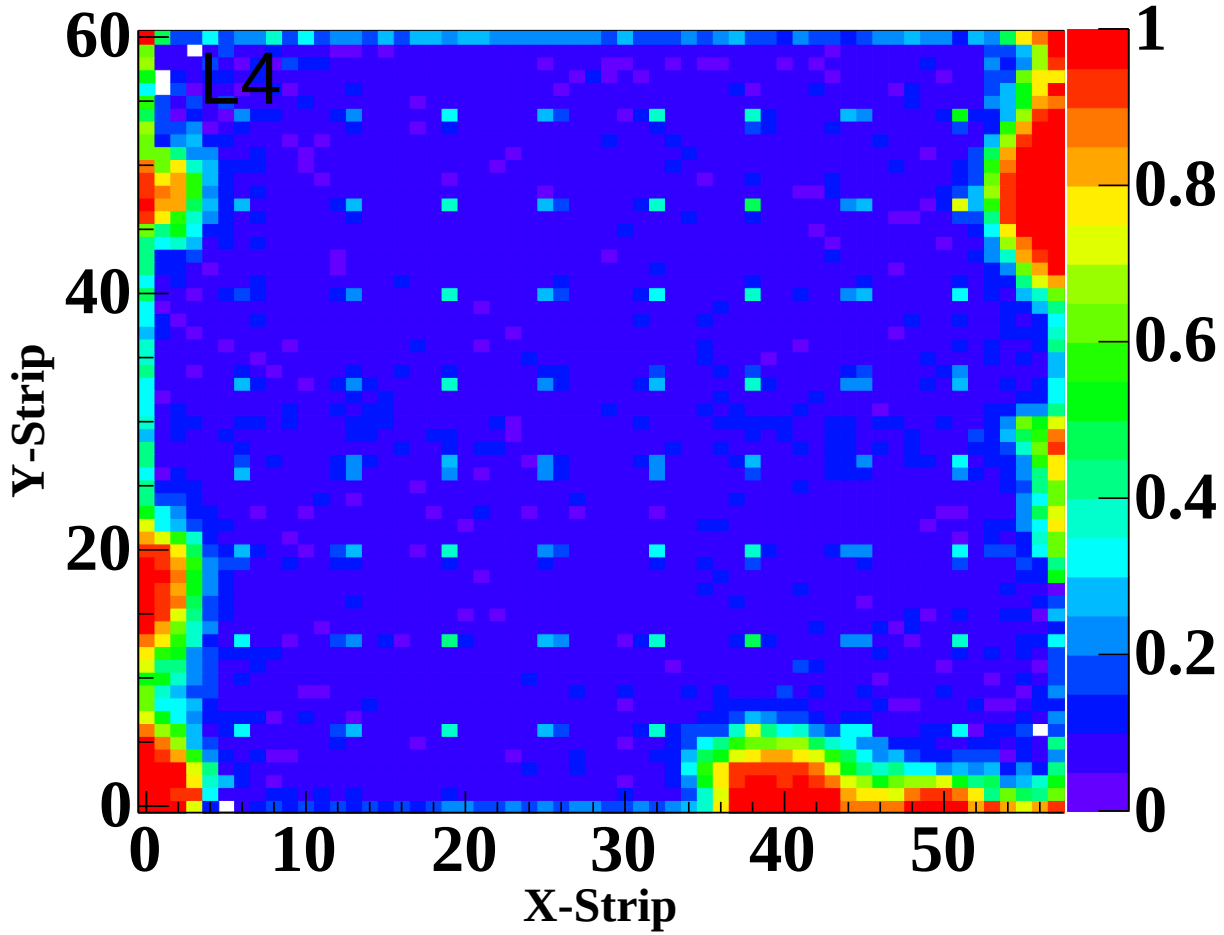


RPC Strip Multiplicity

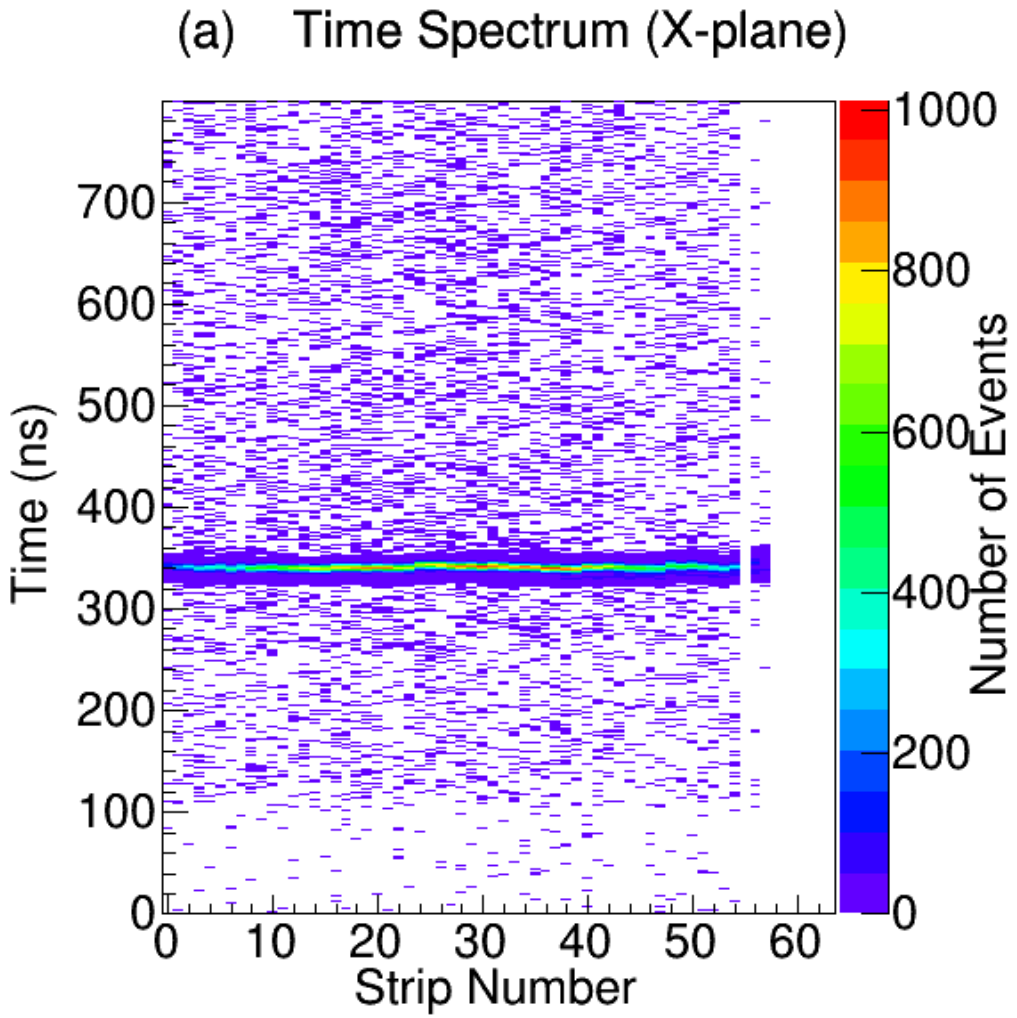


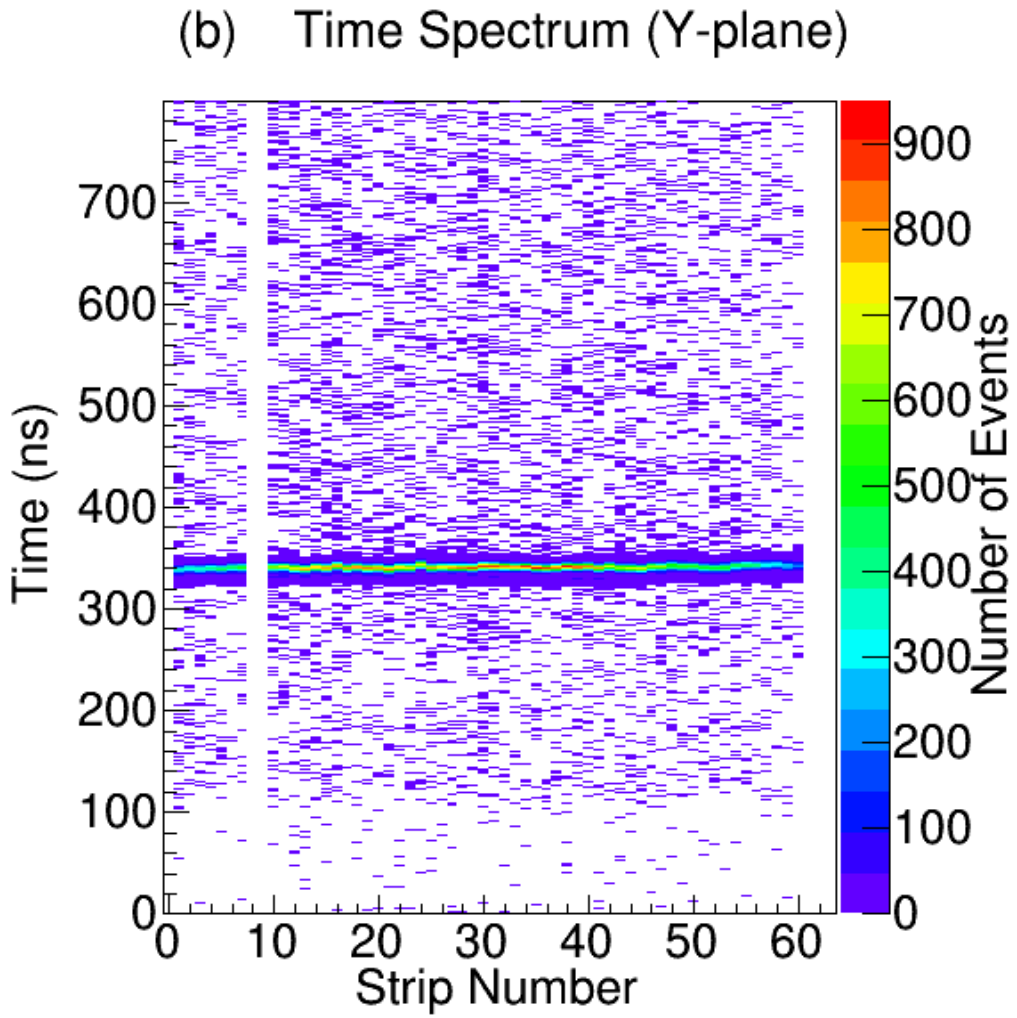
RPC Strip Occupancy

Performance: Efficiency (inefficiency plot)



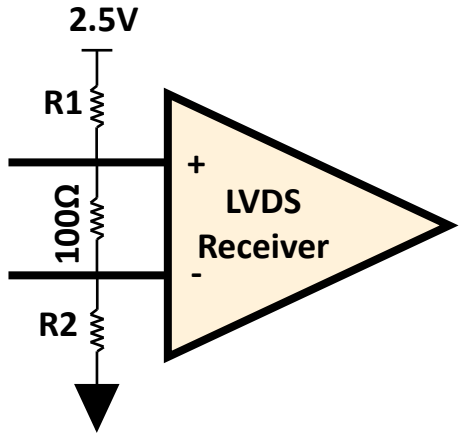
Performance: Timing Spectrum



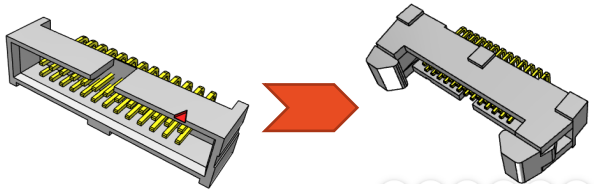


Upgrades

Upgrades Planned



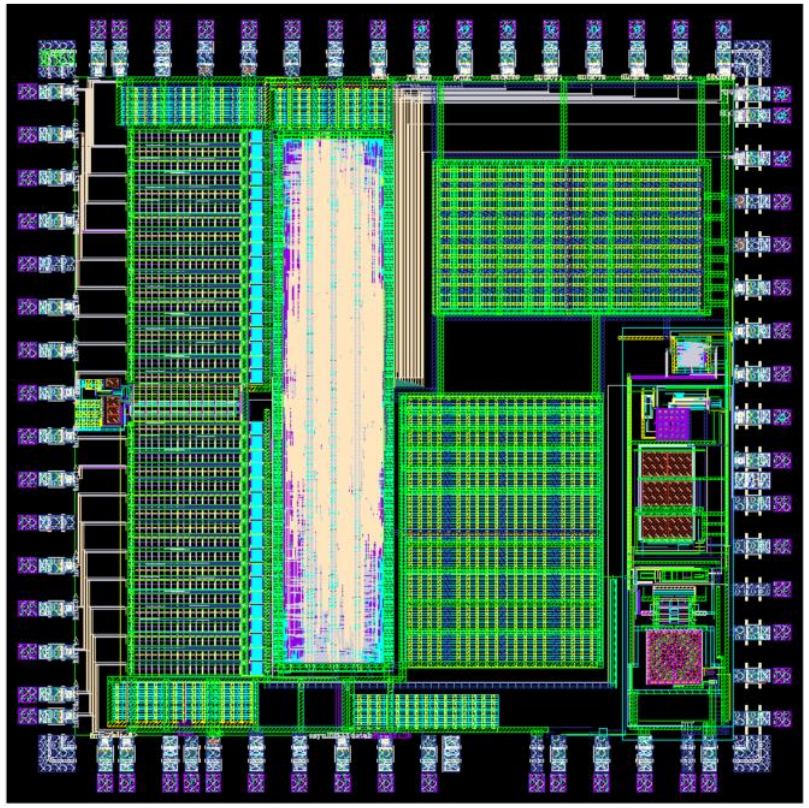
- External Fail Safe Bias Resistor network for LVDS inputs
- Connectors with Ejector latch/Strain Relief



- Migration to an integrated, digital ambient sensor - BME280
- Migrate from HPTDC to INO TDC, developed at IIT Madras, Chennai India

Change in the Time to Digital Converter

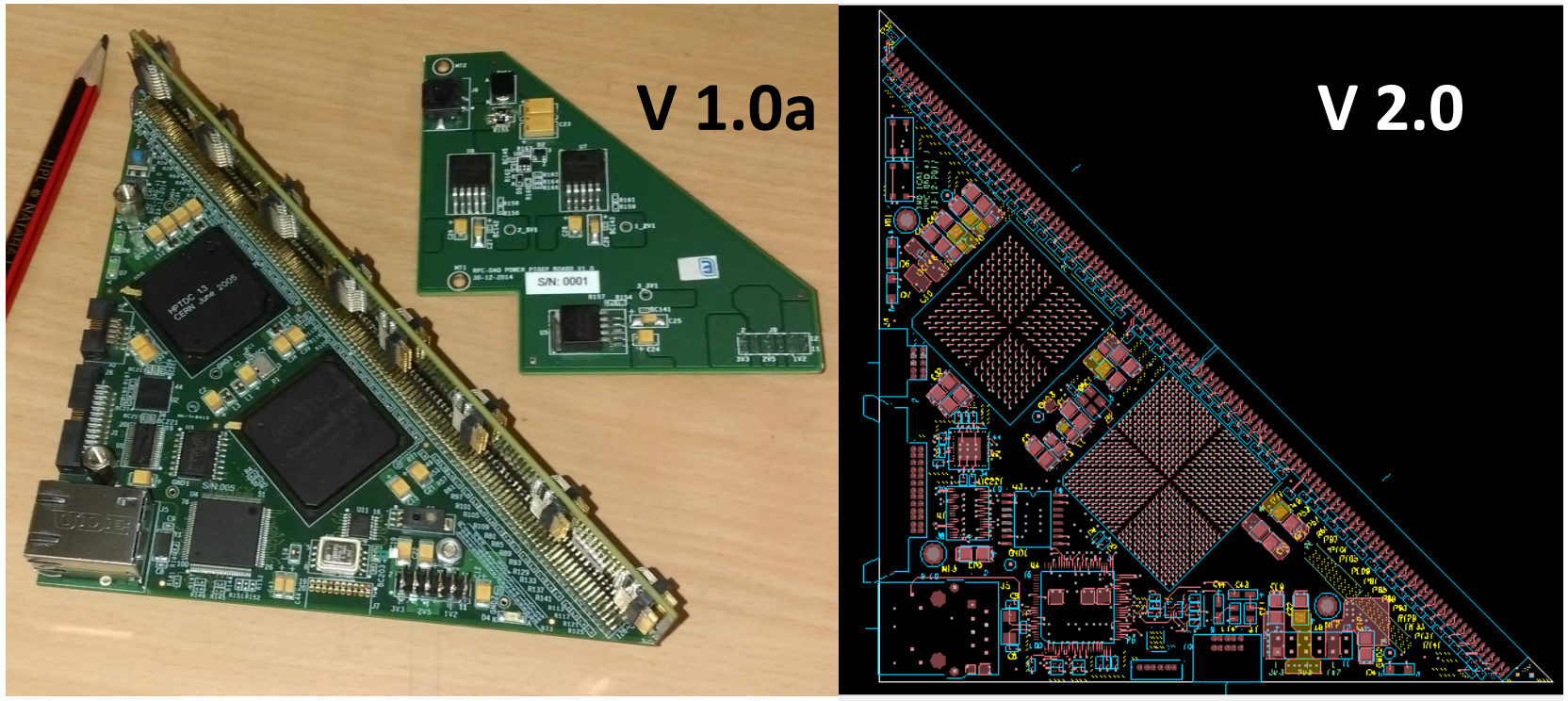
- The first version of DAQ used the HPTDC developed at CERN
- INO Collaboration has now indigenously developed a TDC chip at the IIT Madras.
- This will be incorporated in the next upgrade
  - 17 channels, 1 Trigger
  - Leading edge timestamp
    - Resolution: 125 ps
    - Dynamic Range: 65.5 µs



(a) TDC4 top-level layout

Poster 363 By Yuvaraj: Performance and Integration results of a high resolution Time to Digital Converter designed for INO ICAL Experiment

Old vs New



Summary

- The RPC-DAQ module has been successfully built and commissioned in the mini-ICAL
- Lot of data has been collected and insight gained
- Good performance of the DAQ has been recorded
- Some problems required module upgradation since firmware changes could not mitigate those
- We are already in the final stages of upgrades implementation.

THANK YOU FOR YOUR ATTENTION

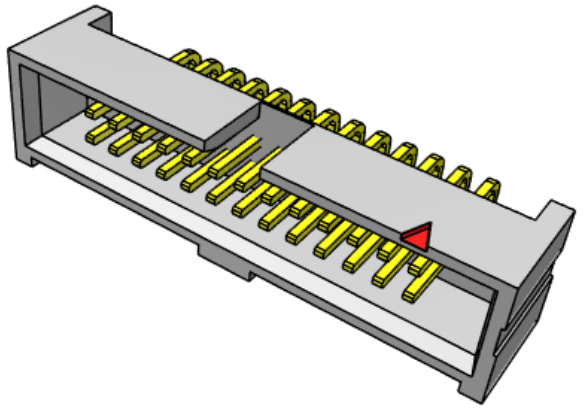
On behalf of INO Electronics Team

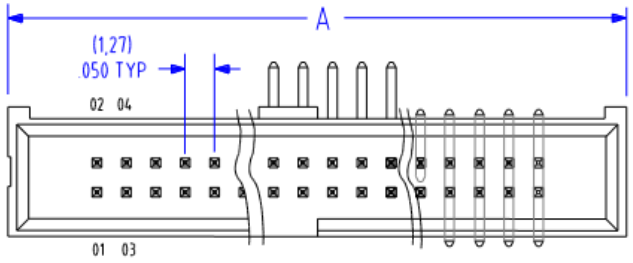
Visit us at www.ino.tifr.res.in

Global Services Connector Change with ejector/latches

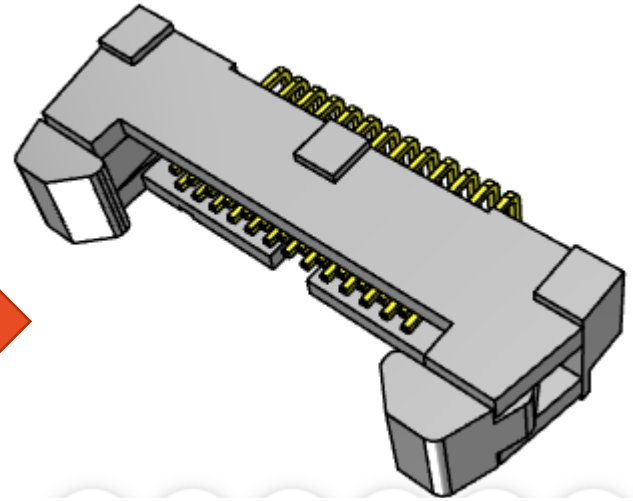
- Global signals like Trigger and Global Clock arrive on cable with miniature connector.
- Use of strain relief and ejector latches is very important for fixing and removing cables
- Hence this change

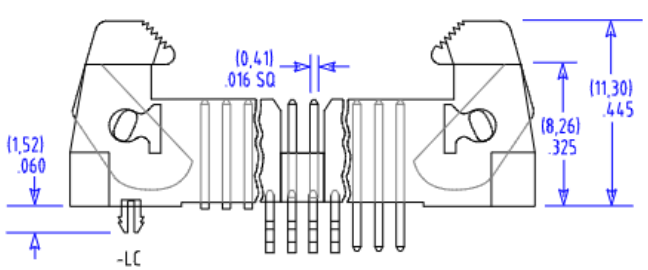
Samtec SHF-113-01-L-D-RA





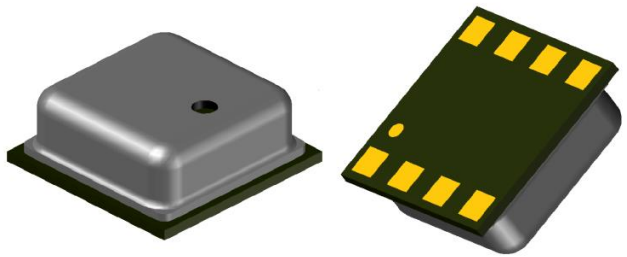
Samtec EHF-113-01-L-D-RA

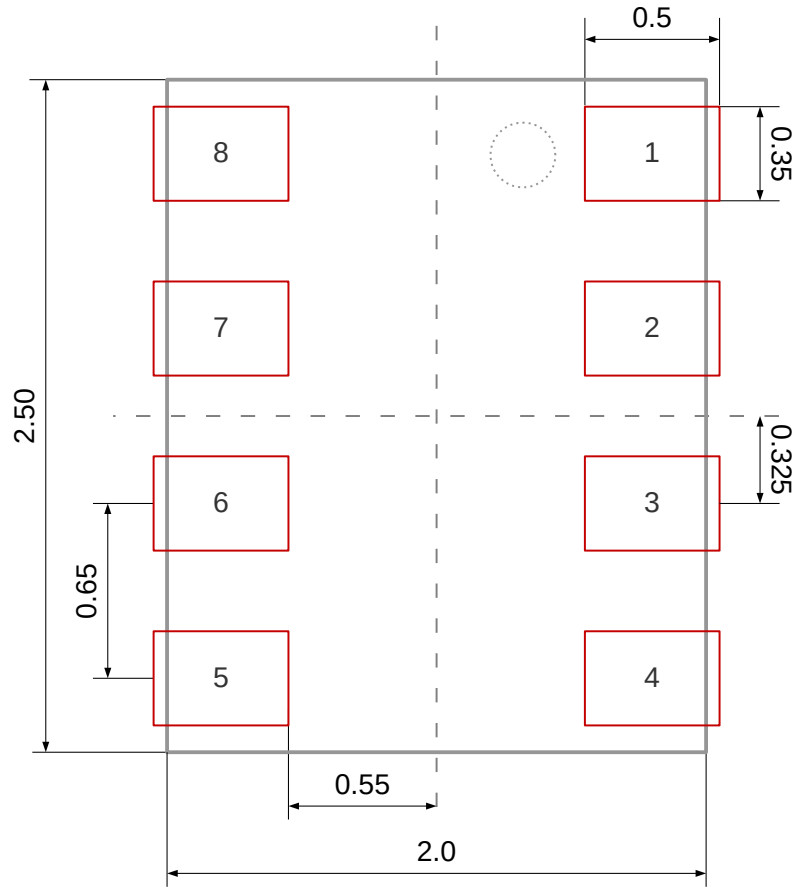




Upgradation of Temperature, Pressure and Humidity (TPH) Sensor

- Migration to newer, integrated digital TPH sensor.
- BME280 – Digital Humidity, Pressure and temperature Sensor
- Single component TPH, no external devices/ADC, micro miniature size





Event Acquisition Timing with hw write to wiz fifo

- One Data write from TDC to HW FIFO time = 100ns (approx.)
- One Data write from HW FIFO to WIZ FIFO = 100ns
- Total Event Collection Time (600 Bytes) = 30us (approx.)
- Total WIZ_FIFO write time (600 Bytes) = 35us
- EVENT push time from WiZ_FIFO to Network (600 Bytes) = 60us
- (This may increase if network is not free)
- HW_FIFO = 16kB
- WIZ_FIFO = 105kB
- Event Size FIFO= 2kB
- **Total Dead time = 125 µ s**
- Previous Dead time is with sw write to wiznet fifo: **281µs**

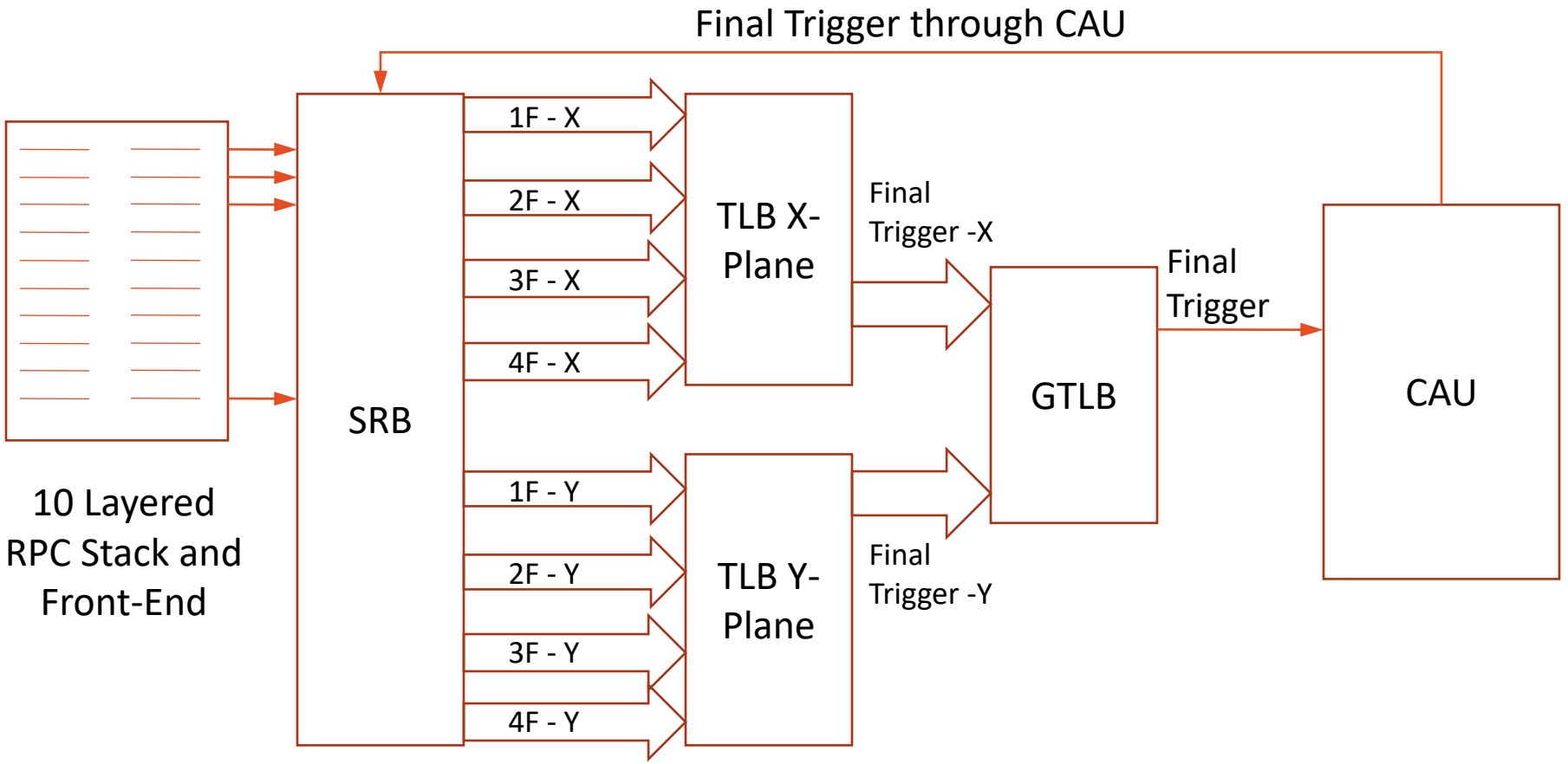
Results

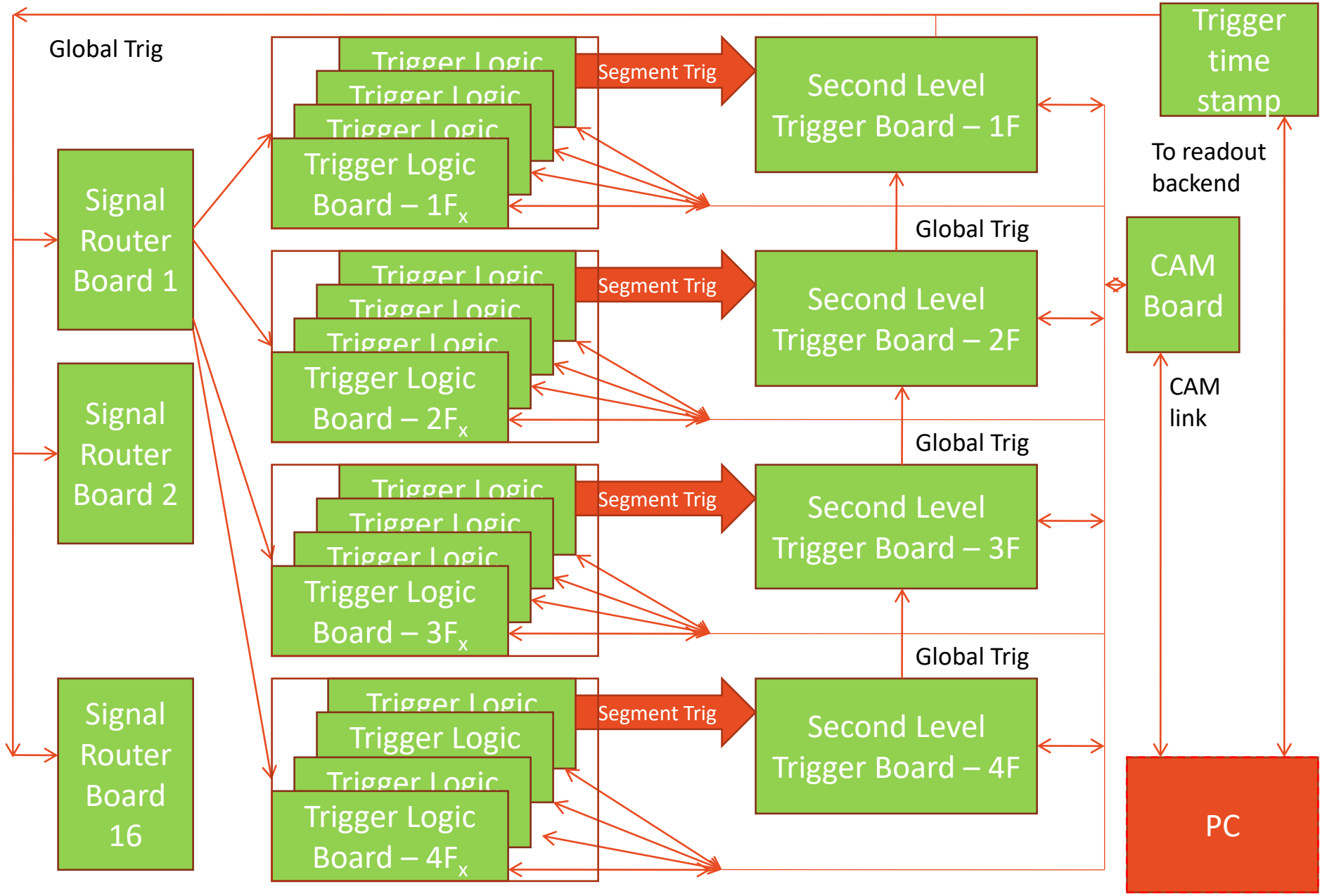
Event Data Processing Scheme Test with Measurement of event loss percentage at various rates(with Fixed & variable Event size (HW EVENT COLLECTION) (HW WIZNET ACCESS)

Random Triggers Mean Freq (kHz)	Event Triggers Sent (millions)	600 bytes		Random Data size (80-600 Bytes)	
		Events Rcvd	Loss (%)	Events Rcvd	Loss (%)
5	**3**	**2999957**	**0.0014**	**2999933**	**0.0022**
8	3	2998638	0.15	--	--
9	3	2999856	0.001	--	--
10.1	**3**	**2657432**	**11.5**	**2999595**	**0.013**

Periodic Triggers Frequency (kHz)	Event Triggers Sent (millions)	600 bytes per event		Random Data size (80-600 Bytes)	
		Events Rcvd	Loss (%)	Events Rcvd	Loss (%)
8	3	2999990	0.00033	2999009	0.0033
8.5	3	2998631	0.0456	2999983	0.00056
9	3	2805725	6.4	2999972	0.00093
10	3	2552219	14.9	2998859	0.0380

The Trigger System for mini-ICAL




Global Trig
Signal Router Board 1
Signal Router Board 2
Signal Router Board 16
Trigger Logic Board – 1F$_x$
Trigger Logic Board – 2F$_x$
Trigger Logic Board – 3F$_x$
Trigger Logic Board – 4F$_x$
Segment Trig
Segment Trig
Segment Trig
Segment Trig
Second Level Trigger Board – 1F
Second Level Trigger Board – 2F
Second Level Trigger Board – 3F
Second Level Trigger Board – 4F
Global Trig
Global Trig
Global Trig
Trigger time stamp
To readout backend
CAM Board
CAM link
PC

Parameter	ICAL	e-ICAL	m-ICAL
No. of modules	3	1	1
Module dimensions	16m × 16m × 14.5m	8m × 8m x 2m	4m × 4m x 1m
Detector dimensions	49m × 16m × 14.5m	8m × 8m x 2m	4m × 4m x 1m
No. of layers	150	20	10
Iron plate thickness	56 mm	56 mm	56 mm
Gap for RPC trays	40 mm	40 mm	45 mm
Magnetic field	1.3 Tesla	1.3Tesla	1.3Tesla
RPC dimensions	1,950mm × 1,910mm × 24mm	1,950mm × 1,910mm × 24mm	1,950mm × 1,910mm × 24mm
Readout strip pitch	30mm	30mm	30mm
No. of RPCs/Road/Layer	8	4	2
No. of Roads/Layer/Module	8	4	1
No. of RPC units/Layer	192	16	2
No. of RPC units	28,800 (107,266 m2)	320 (1,192 m2)	20 (74.5 m2)
No. of readout strips	36,86,400	40,960	2,560