Portable Calibration Node for LHAASO-KM2A detector array

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Abstract: Aiming to high sensitivity and wide spectrum of cosmic ray detection, the 1km² complex array of Large High Altitude Air Shower Observatory (LHAASO-KM2A) project consists of over 7,000 detectors of different types. To precisely reconstruct the air shower events with high angular resolution, the timestamps of all detector electronics and digitizers should be aligned better than 500 ps RMS. White Rabbit network, a fully deterministic Ethernet based network with sub-nanosecond synchronization accuracy and picoseconds precision, is applied for the data and timing network. To guarantee the overall synchronization precision, each WR node should be calibrated individually. This paper talks about the auto-calibration procedure of all switches and nodes in the LHAASO-KM2A WR network using the portable calibration node. The usage of the portable calibration node is also discussed in deploying the detectors array and validating the synchronization performance of the WR network.

LHAASO-KM2A

Tracing galactic cosmic rays sources > 30 TeV
**With angular resolution < 0.5°**
KM2A sub-detector array:
- Covering 1.2km²
- 5632 electron detectors
- 1221 muon detectors
- Timestamps Synchronization < 500 ps (rms)
- Jitter of Synchronous ADC clock < 100 ps
- High data throughput (26 Gbps) with minimum loss
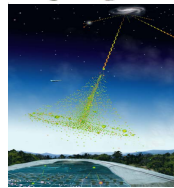
White Rabbit

Packet based frequency distribution and time synchronization
- Sub-nanosecond synchronization
- Connecting thousands of nodes
- Typical distances of 10 km between nodes
- Gigabit Ethernet-based data link
- Fully open hardware, firmware and software
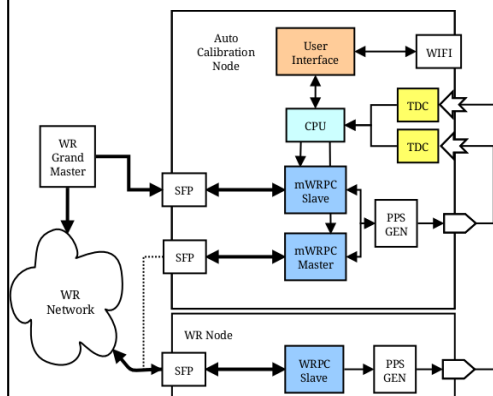- Multi-vendor commercially produced hardware
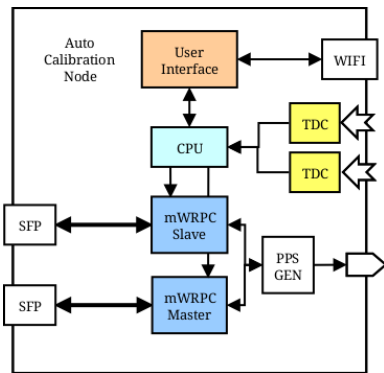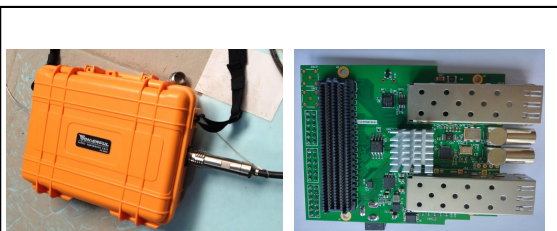
Portable Calibration Node (PCN)

- WRPC
  - White Rabbit PTP Core
  - Dual Ports
- Time to digital converter
  - Carry chain based
  - Two channel
  - Auto-calibration, reused with DMTD
  - 250MHz * 128 delay units
  - Effective Bin Width: 46 ps
  - RMS: 26.9 ps (preliminary)
- User Interface
  - Pmod wifi – External Device
  - Waterproof sealed case

PCN Usage

Auto calibration procedure
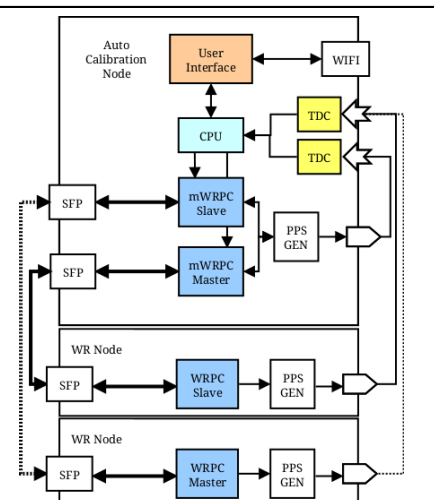- PCN works as the WR calibrator
- Reference fiber measurement
- PCN pre calibration
- Auto calibration of other WR device:
  - PPS skew measured by TDC
  - Hardware delays calculation
  - Update database through USB-UART or Etherbone interface
  - Synchronization accuracy verification
- Minimum human operation

WR Array deployment
- Normal function test, new WR devices connect to the PCN before joining the WR network
- Calibration accuracy verification

Synchronization accuracy validation
- PCN works as the mediator between the Grandmaster and other WR devices
- Online 7-24 1-PPS skew monitor
- Synchronization accuracy check periodically

Preliminary Test

Name	Run1/ps	Run2/ps	Mean
mean_os	133	157	145
std_osc	27	27	-
mean_tdc	479	-333	73
std_tdc	11	11	-
diff	-	-	**72**

1-PPS skew after auto calibration procedure