



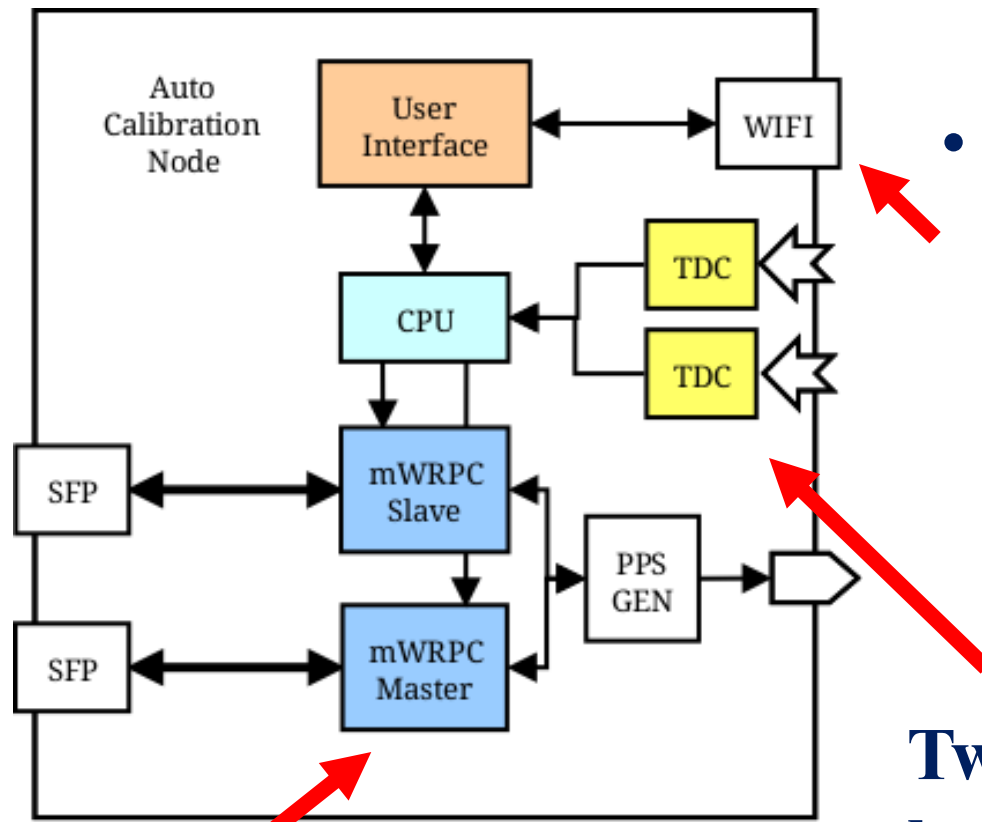
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# Portable Calibration Node for LHAASO-KM2A detector array

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## • Wi-Fi Interface

- Waterproof sealed case
- Convenience

## Two channel carry chain based TDC

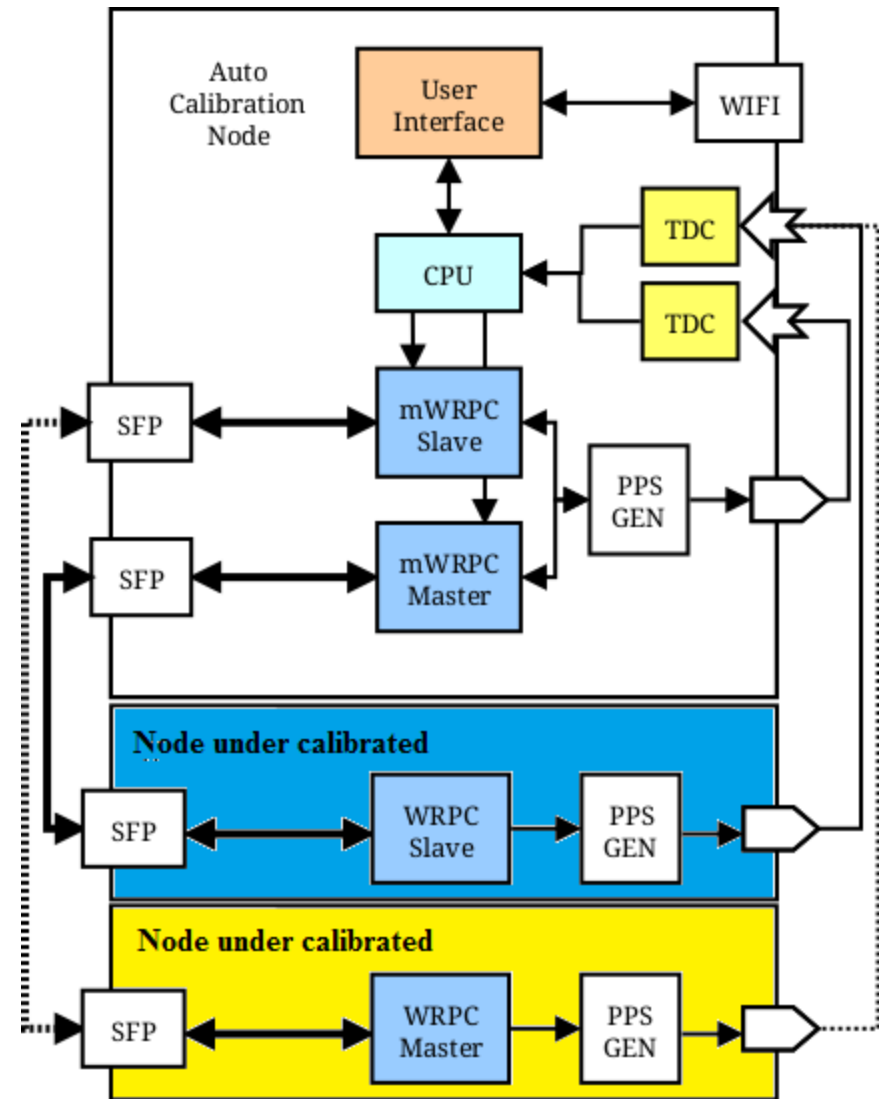
- Measure the skew of two input PPS signals

## • Two reduced WRPC core

- Frequency distribution, Precision < 30 ps
- Timing synchronization, Accuracy < 500ps (goal)

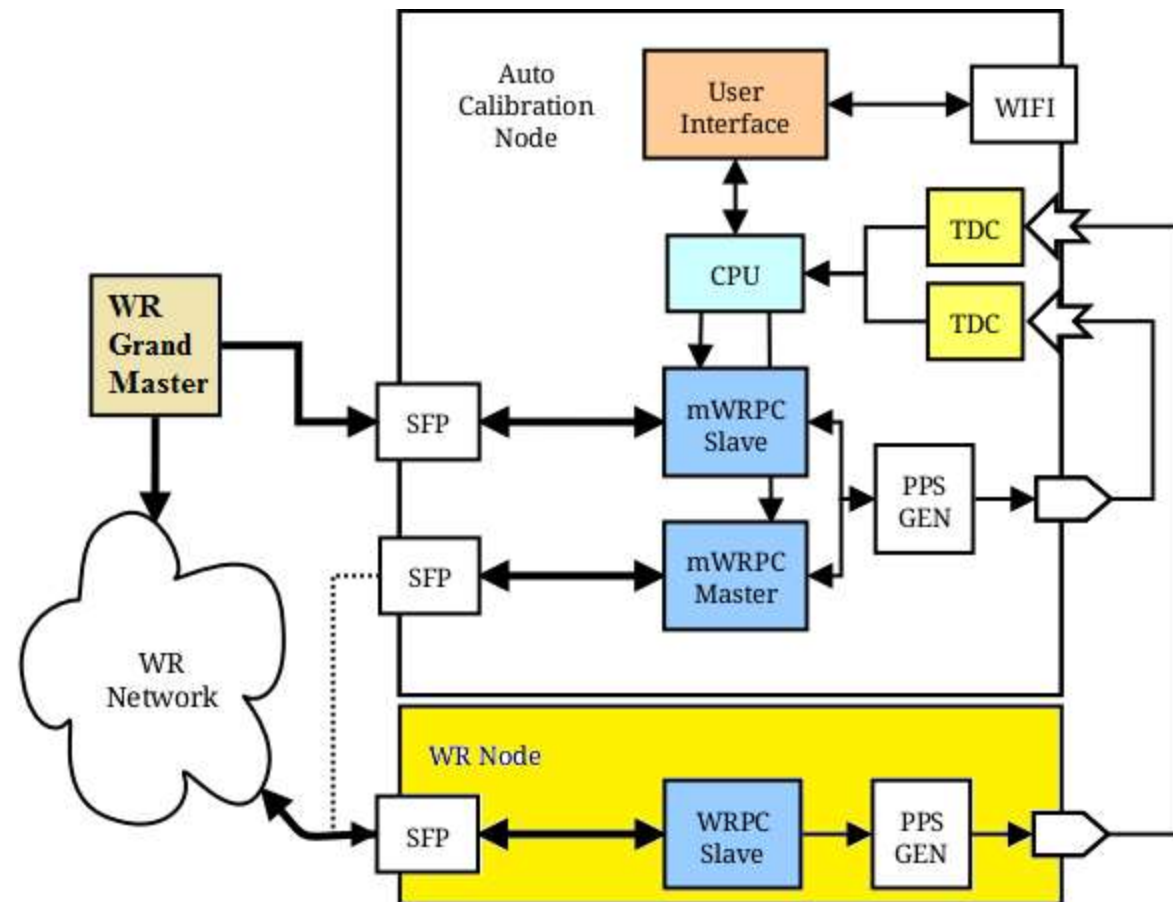
# WR Auto-Calibration Procedure

- Calibration accuracy  $< 200$  ps
- No oscilloscope
- Reduce manual involvement




# WR Array Deployment Synchronization Validation

- PCN Master does **pre-operation** check and fault detect
- PCN Slave connects with Grand-Master and works as the **mediator** between Grand-Master and Node



# Thank you! Grazie! 谢谢!



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## Portable Calibration Node for LHAASO-KM2A detector array

**Abstract:** Aiming to high sensitivity and wide spectrum of cosmic ray detection, the 1km<sup>2</sup> 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 > 30 TeV  
With angular resolution < 0.5°  
KM2A sub-detector array:

- Covering 1.2km<sup>2</sup>
- 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

### PCN Usage

**Auto calibration procedure**

- PCN works as the WR calibrator
- Reference fiber measurement
- PCN pee 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

### 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
  - Phnod wifi - External Device
  - Waterproof sealed case

### Preliminary Test

Name	Bin1/ps	Bin2/ps	Mean
mean_0s	133	157	145
std_0s	27	27	-
mean_tdc	479	-333	73
std_tdc	11	11	-
diff	-	-	22

1-PPS skew after auto calibration procedure