Sub-nanosecond timing and data acquisition endpoint for LHAASO project

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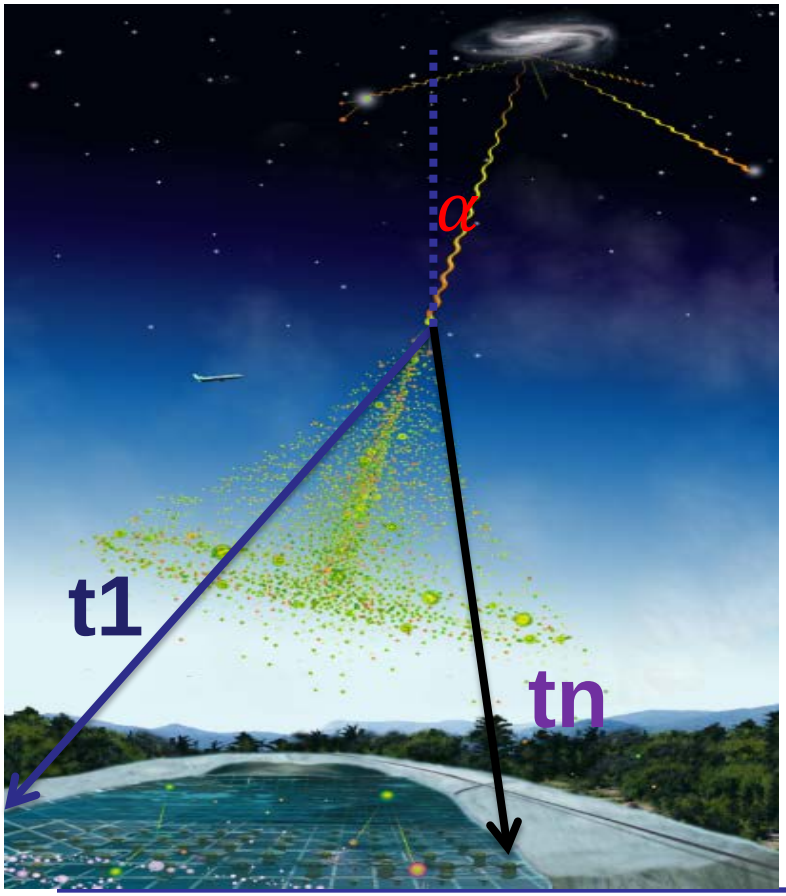
14th International Conference on Accelerator And Large Experimental Physics Control System
6-11st October 2013, San Francisco

Outline

Large High Altitude Air Shower Observatory (LHAASO)

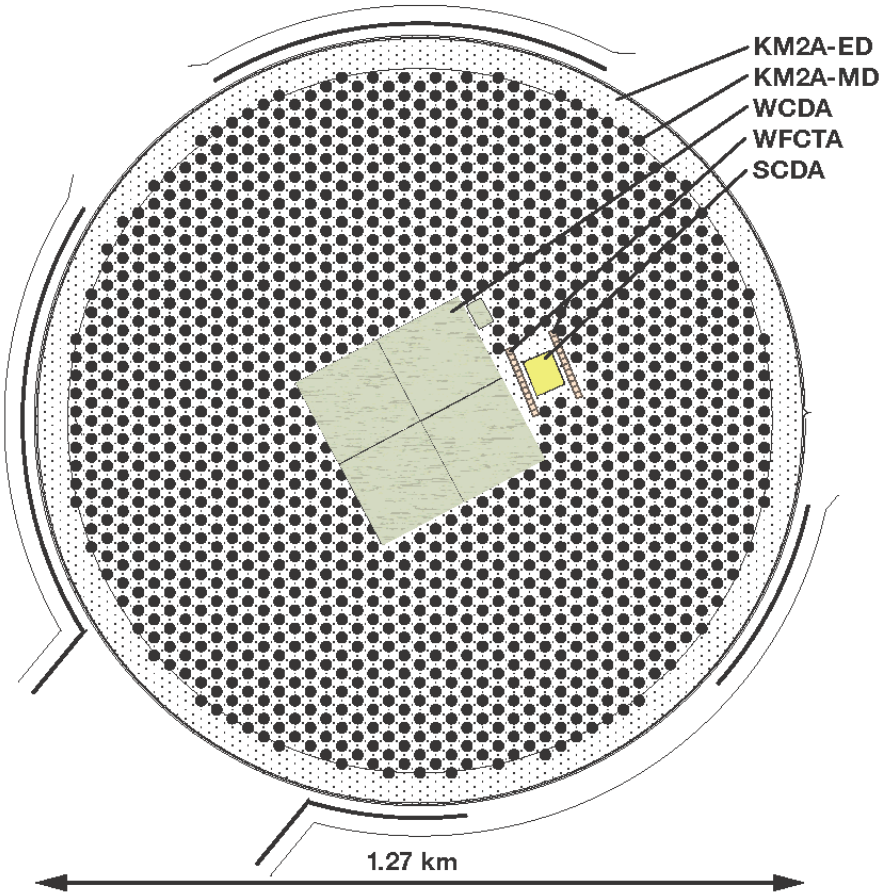
Goal : Tracing sources of galactic cosmic rays > 30 TeV



With angular resolution: < 0.5° !

Large High Altitude Air Shower Observatory (LHAASO)

4000m above sea level, Shangri-La, Yunnan, China



KM2A covering 1.2km^2
5632 electron detectors,
1221 muon detectors

WCDA four 150×150m^2 pools
3600 muon detectors under water

SCDA covering 5000m^2
452 shower core detectors

WFCTA 24 relocatable cherenkov telescopes

Tasks of LHAASO timing & DAQ network

Time-stamp Synchronization

Time stamps of 7344 nodes should be aligned <500ps (rms).

Frequency distribution & phase locking

Distribute synchronous ADC clock with <100ps jitter.

Traceability & Real-time calibration

Timing delay compensation due to environmental perturbation in hardware in real time.

Synchronous & Trigger-less DAQ

High data throughput (26 Gbps) with minimum loss.

Reliability & maintainability

Automatic redundancy strategy to maximize reliability.

Manageability

Every FPGA register should be manageable on line.

Outline

1. Introduction LHAASO
2. **White Rabbit in LHAASO**
3. Timing & DAQ Endpoint
4. Summary

White Rabbit Project

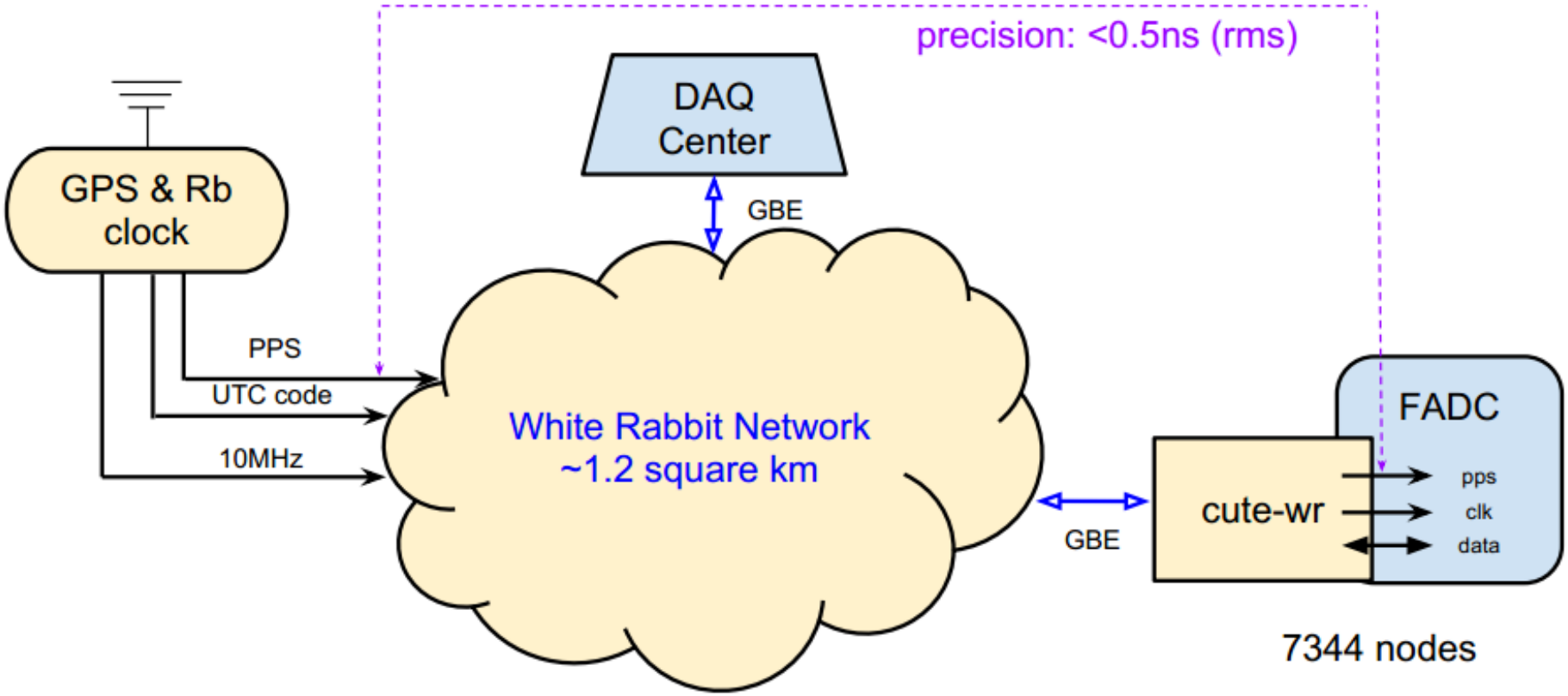
Ethernet based, sub-nanosecond time distribution network

J. Serrano, et al., *The White Rabbit Project*, ICALEPCS, 2009

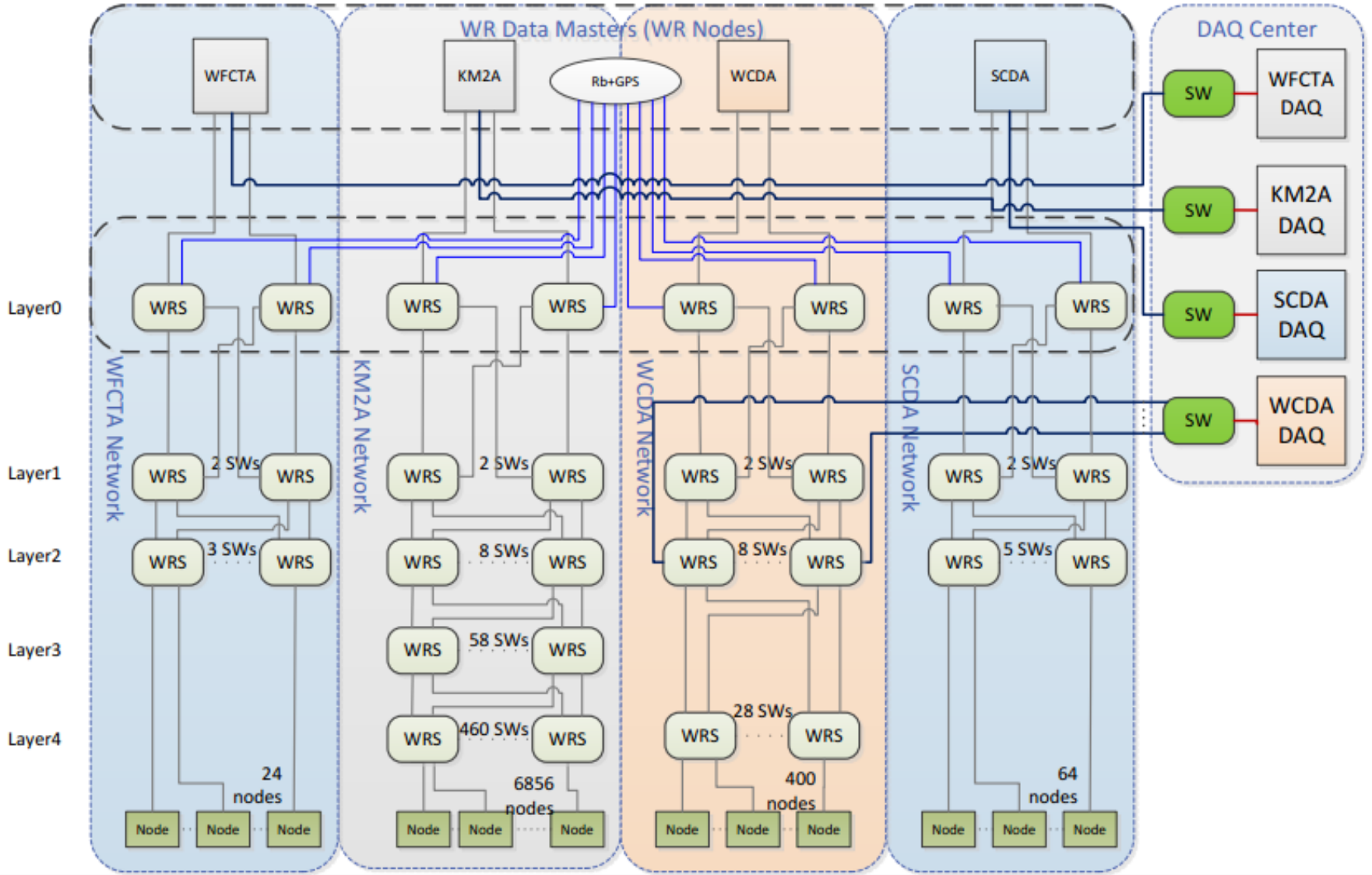
Packet based **frequency distribution** and **time synchronization**

- Sub-nanosecond synchronization
- Connecting thousands of nodes
- Typical distances of 10km between nodes
- Gigabit Ethernet-based data link
- Fully open hardware, firmware and software
- Multi-vendor commercially produced hardware

LHAASO WR network topology



LHAASO WR network topology



Q. Du, et al., Nuclear Instruments & Methods in Physics Research A (2013), http://dx.doi.org/10.1016/j.nima.2013.05.135

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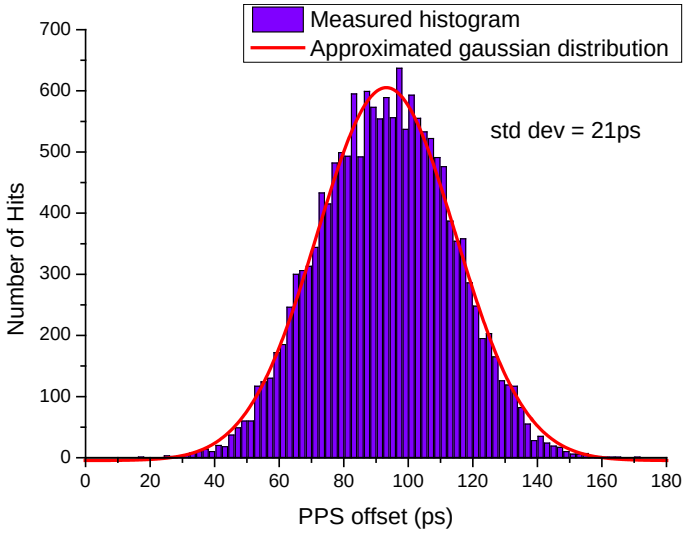
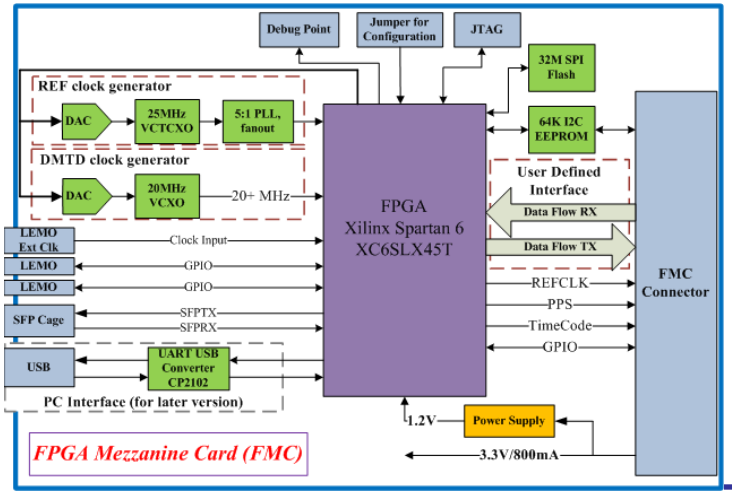
Compact Universal Timing Endpoint based on WR (CUTE-WR)



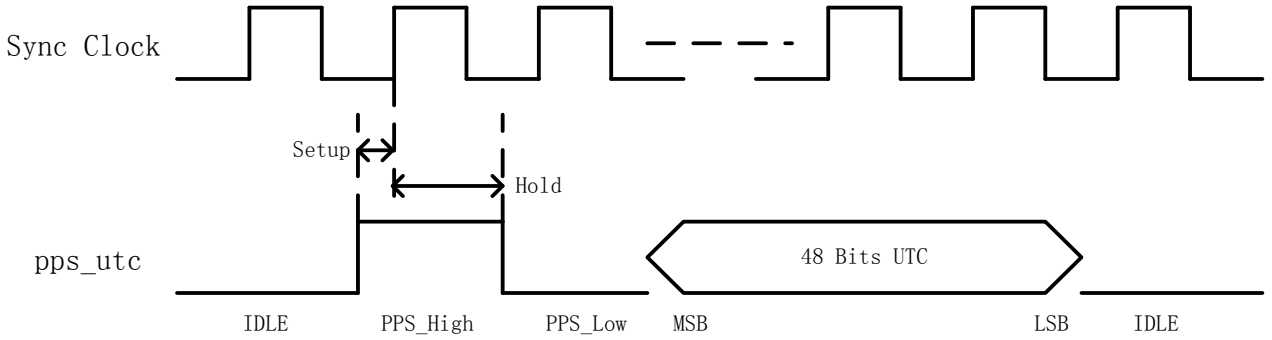


- **PPS Skew std dev ~ 21 ps**
- **Data throughput verified**

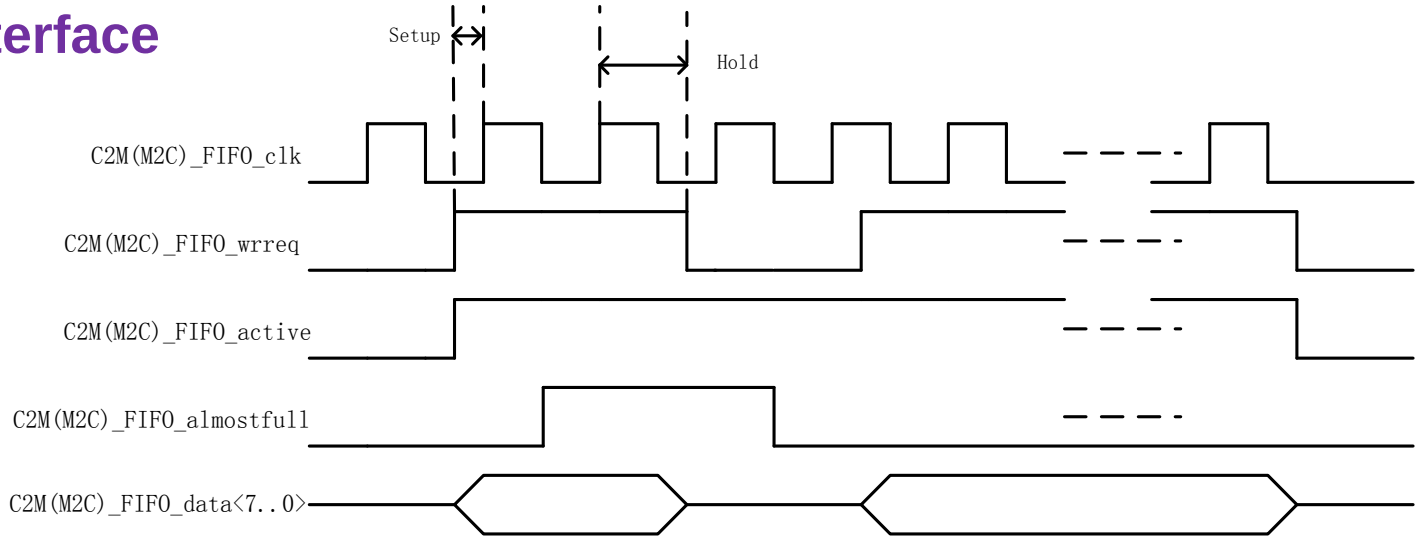
W. Pan, Q. Du, G. Gong, in Proceedings of IEEE Real Time Conference, Berkeley, CA, 2012
http://www.ohwr.org/projects/cute-wr/wiki

FMC Connector on the CUTE-WR

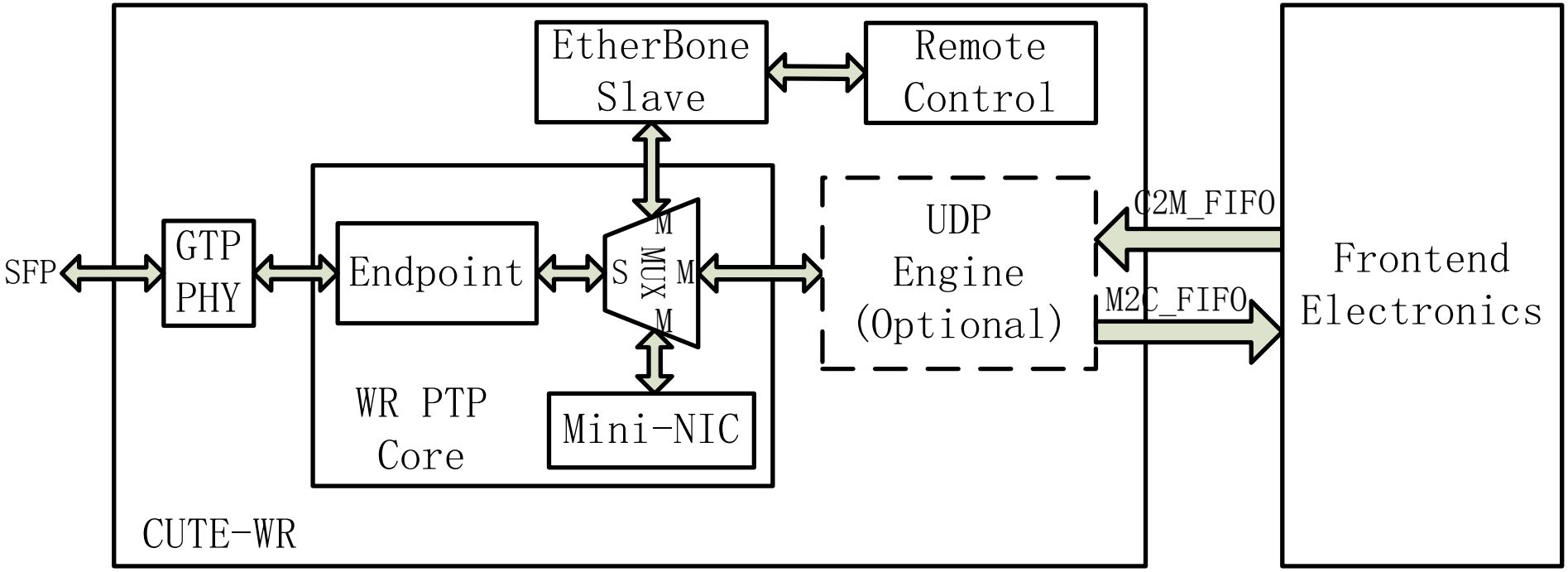
Timing interface



Data Interface

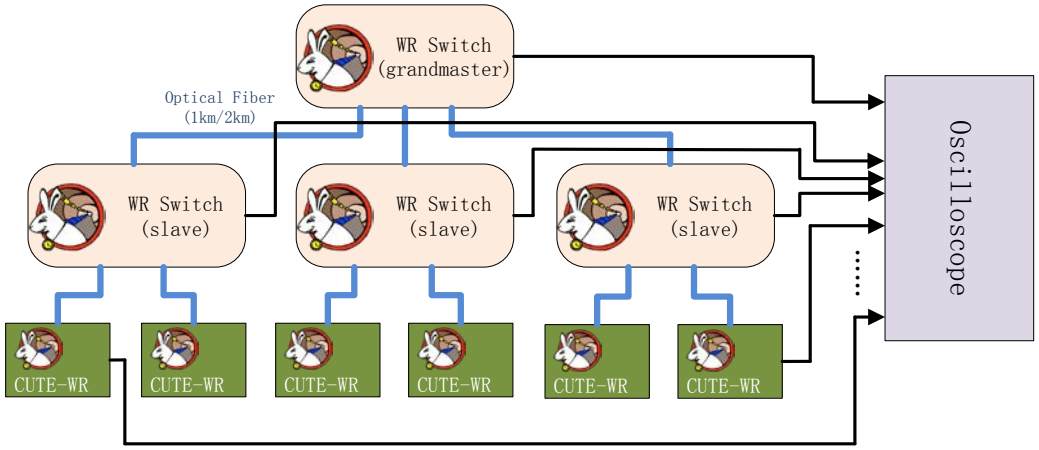


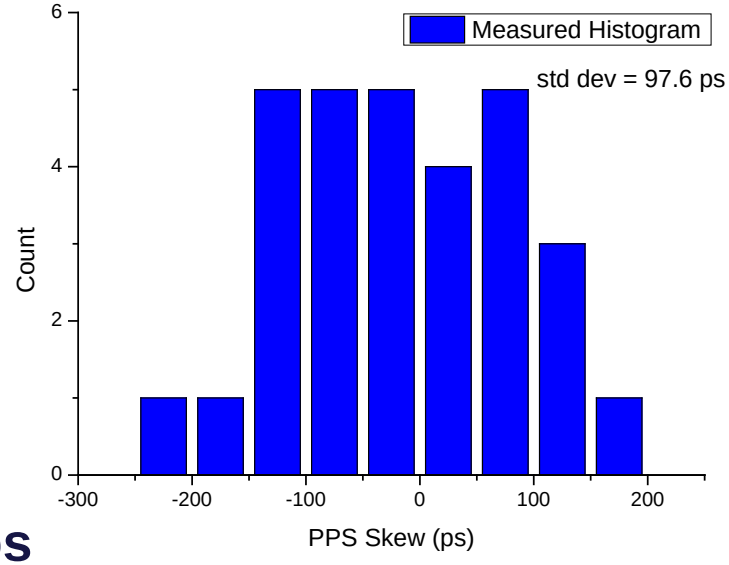
Data flow of the CUTE-WR



White Rabbit PTP Core: http://www.ohwr.org/projects/wr-cores/wiki/Wrpc_core
EtherBone Core : http://www.ohwr.org/projects/etherbone-core

Timing accuracy of different topology



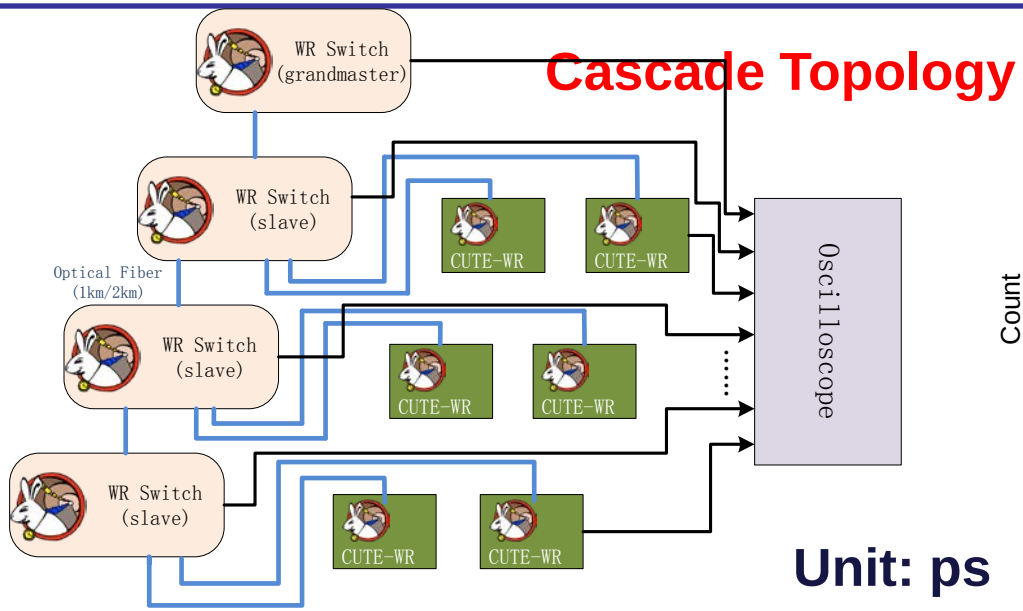


Unit: ps

Parallel Topology

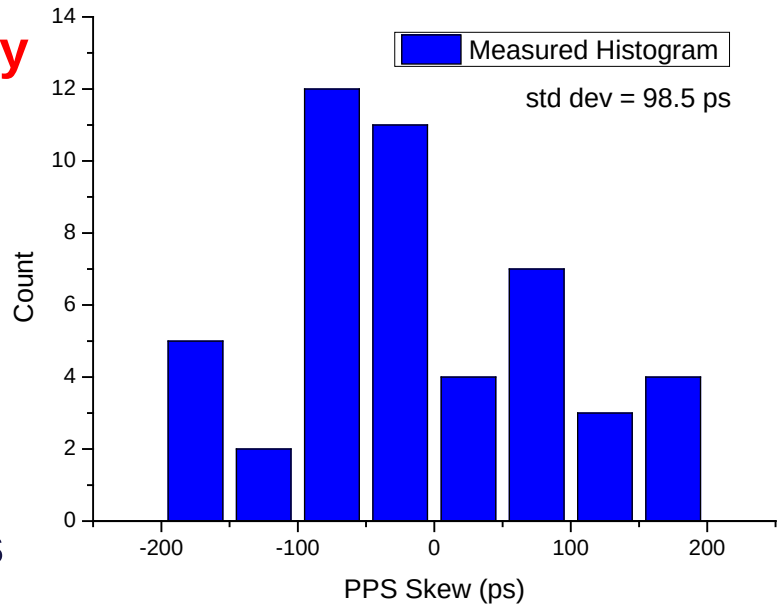
	1st run	2nd run	3rd run	4th run	5th run
CUTE-1	69.0	27.1	94.8	61.0	168.8
CUTE-2	62.6	82.0	101.4	145.6	124.1
CUTE-3	-51.5	-23.9	-3.90	-45.2	-104.4
CUTE-4	-93.6	-104.9	-208.2	-138.8	-190.7
CUTE-5	17.8	49.7	-37.4	-31.4	3.6
CUTE-6	-78.4	-59.6	-110.8	-105.1	-77.6

Timing accuracy of different topology



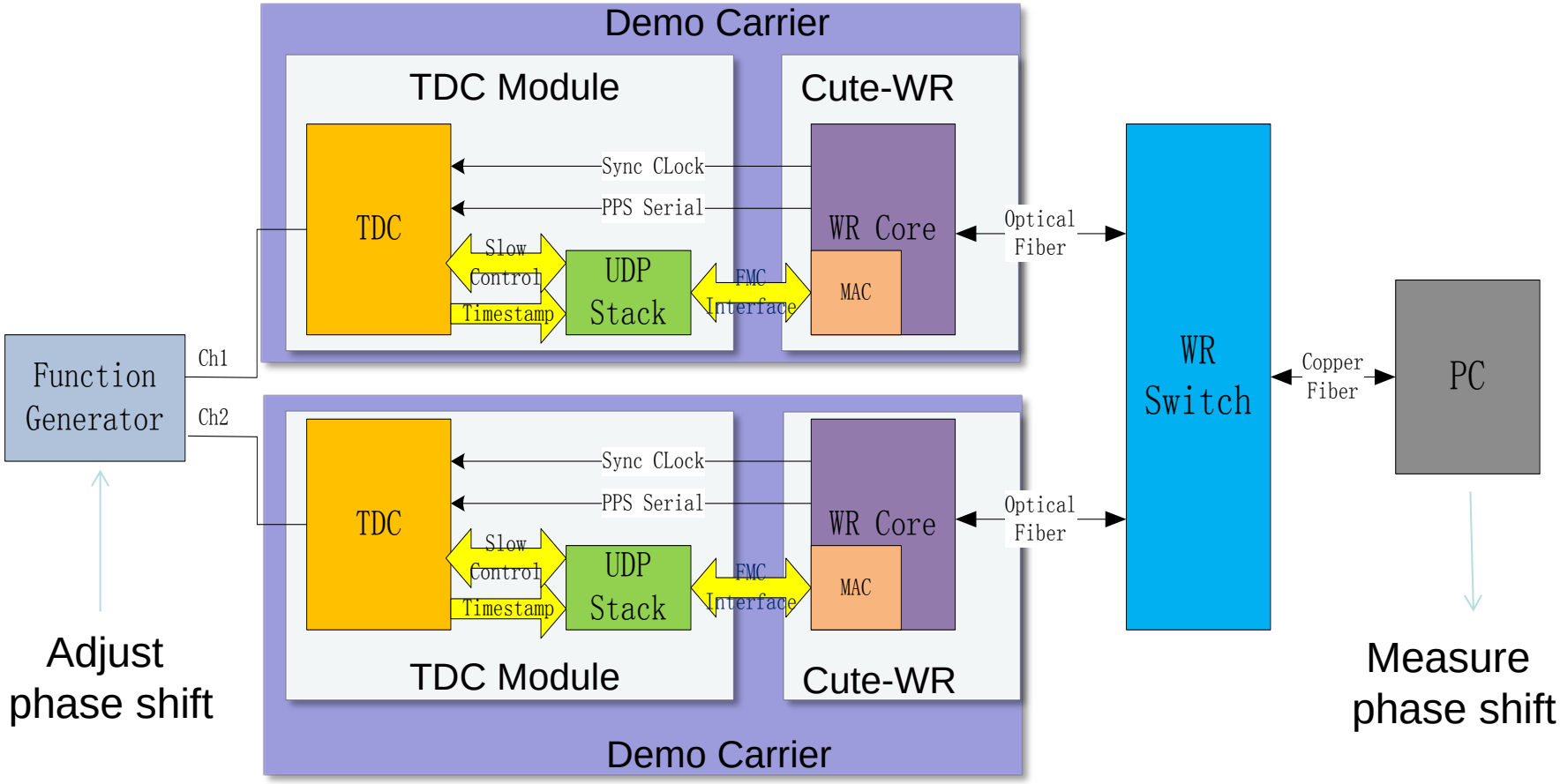
Cascade Topology

Unit: ps



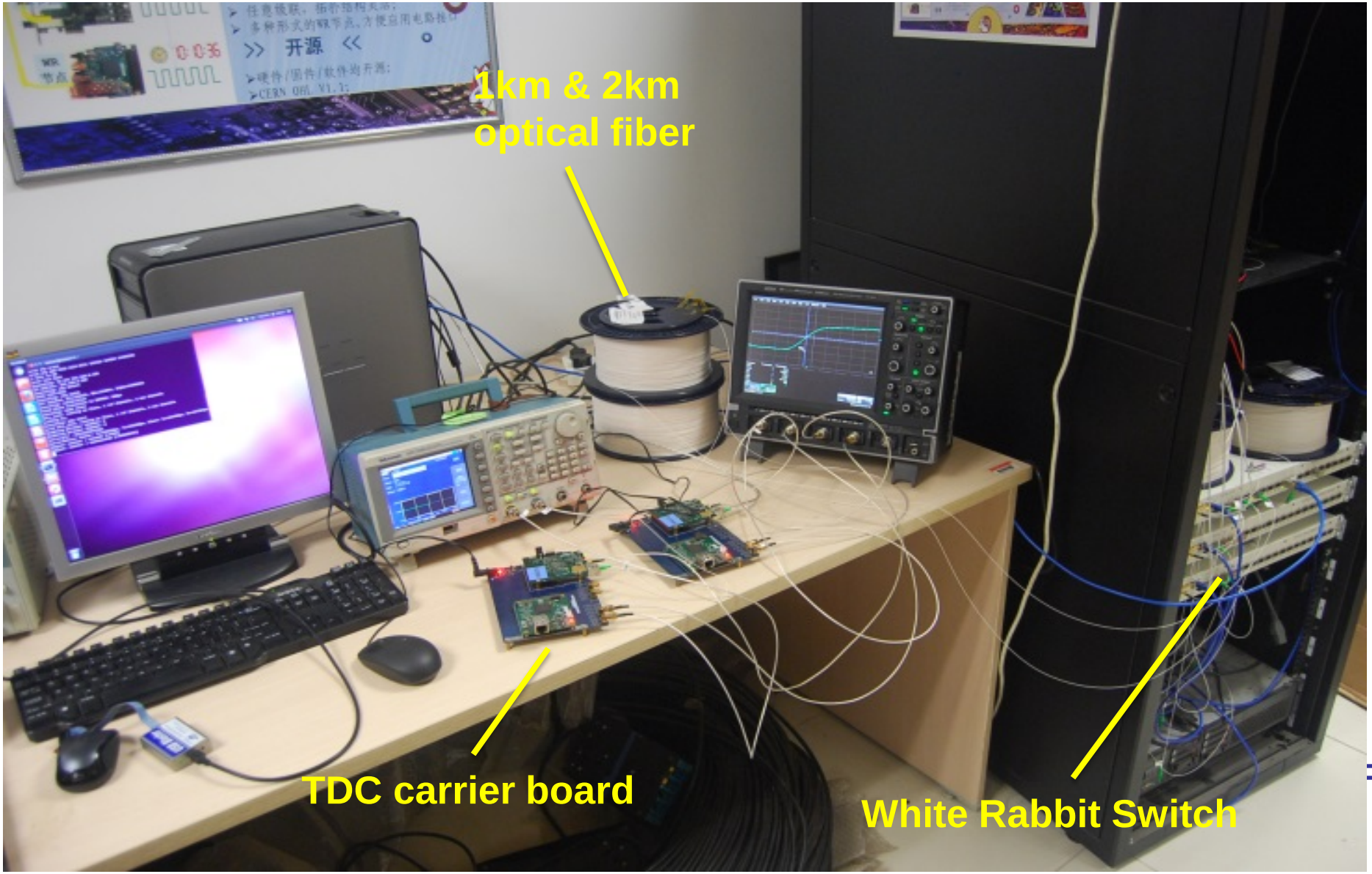
	1st run	2nd run	3rd run	4th run	5th run	6th run	7th run	8th run
CUTE-1	66.4	124.1	30.8	95.2	54.2	156.7	158.9	124.6
CUTE-2	-23.5	-111.9	-187.1	21.6	-146.5	-21.2	-19.0	-85.6
CUTE-3	-96.9	-17.2	-98.3	-34.2	-94.9	-62.3	-23.5	-68.8
CUTE-4	70.4	-96.3	-76.4	80.6	104.2	158.9	41.9	168.4
CUTE-5	-10.5	-92.8	-188.3	-3.2	-164.4	9.5	-82.1	-172.3
CUTE-6	-36.2	--94.7	-77.4	-18.0	-61.8	-25.2	-82.8	-151.5

A WR based distributed Time-to-Digital Converter (TDC) demo

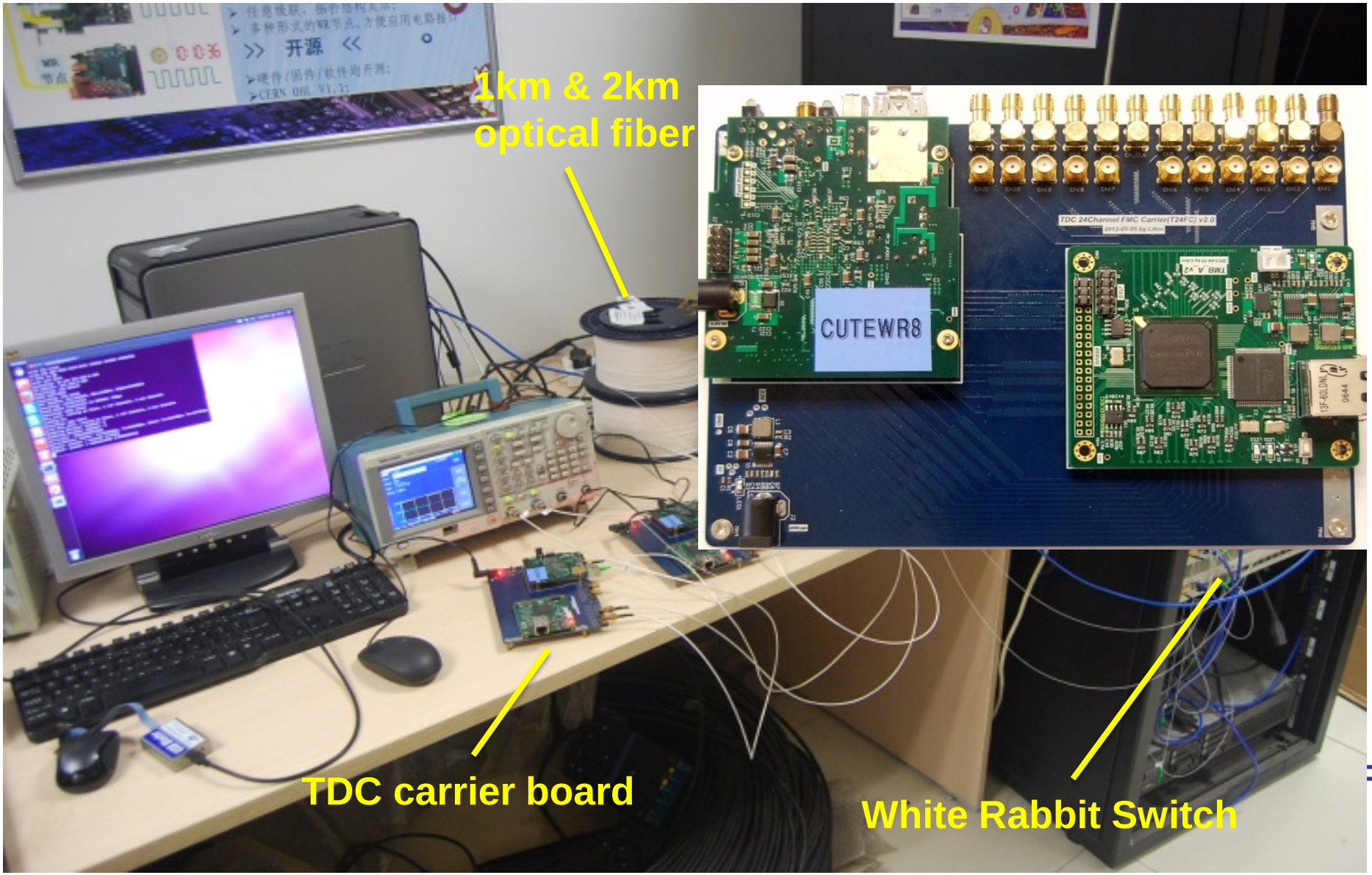


Video Available : http://v.youku.com/v_show/id_XNTc2MDc5ODA4.html

A WR based distributed TDC demo



A WR based distributed TDC demo



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Summary

- **LHAASO timing and DAQ network based on the White Rabbit technology is proposed.**
- **A compact WR endpoint (CUTE-WR) is designed, and the synchronization performance (precision and accuracy) has been evaluated.**
- **A prototype of WR based distributed time-to-digital converter (TDC) system is demonstrated.**

Thanks for your attention!

Timing Accuracy and Precision